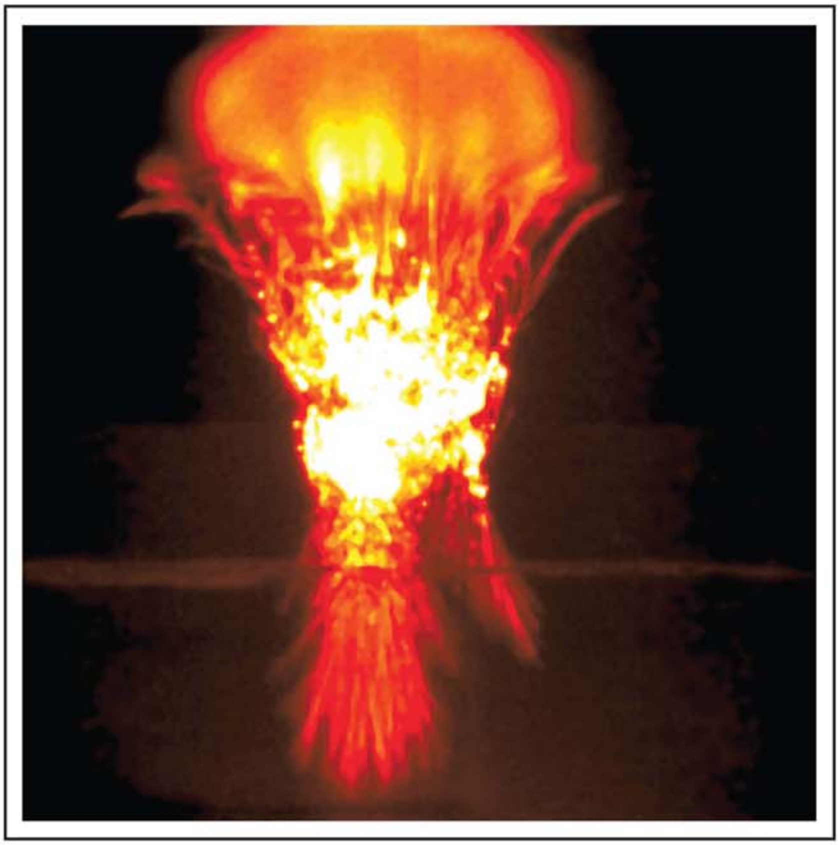
CHAPMAN
CONFERENCE



AGU CHAPMAN CONFERENCE ON THE EFFECTS OF THUNDERSTORMS AND LIGHTNING IN THE UPPER ATMOSPHERE

Penn State University
State College, PA, USA
10–14 May 2009

Chapman Conference on the Effects of Thunderstorms and Lightning in the Upper Atmosphere

Conveners

- **Davis D Sentman**, Geophysical Institute, University of Alaska Fairbanks (United States)
- **Victor P Pasko**, The Pennsylvania State University (United States)
- **Jeff S Morrill**, Naval Research Laboratory (United States)

Program Committee

- **Elisabeth Blanc**, CEA (France)
- **Steven Cummer**, Duke University (United States)
- **Martin Fullekrug**, Bath University (United Kingdom)
- **Umran Inan**, Stanford University (United States)
- **Elizabeth Kendall (nee Gerken)**, Stanford Research Institute (United States)
- **Walter Lyons**, FMA Research (United States)
- **Stephen Mende**, University of California, Berkeley (United States)
- **Gennady Milikh**, University of Maryland (United States)
- **Torsten Neubert**, Danish National Space Center (Denmark)
- **Colin Price**, Tel Aviv University (Israel)
- **Craig Rodger**, University of Otago (New Zealand)
- **Robert Roussel-Dupre**, Los Alamos National Laboratory (United States)
- **Fernanda São Sabbas**, Instituto Nacional de Pesquisas Espaciais (Brazil)
- **David Smith**, University of California, Santa Cruz (United States)
- **Han-Tzong Su**, National Cheng Kung University (Taiwan)
- **Yukihiro Takahashi**, Tohoku University (Japan)
- **Michael Taylor**, Utah State University (United States)
- **Earle Williams**, Massachusetts Institute of Technology (United States)

Cosponsors

- Air Force Office of Scientific Research
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Cover Image: A massive transient luminous event termed sprite observed at mesospheric altitudes above a lightning producing Nebraska thunderstorm. The image was obtained at 05:24:22.829 UT on 18 August 1999 with a digital, low-light-level, 1000 frame per second intensified CCD imager developed by the Geophysical Institute, University of Alaska Fairbanks, which was operated at the University of Wyoming Infrared Observatory (WIRO) at Jelm Mountain southwest of Laramie, Wyoming. The top of the diffuse, upper portion of the sprite is at about 90 km altitude, and the bottom of the lower tendrils is at about 50 km.

Credit: Stenbaek-Nielsen, H C, D R Moudry, E M Wescott, D D Sentman, and F T Sao Sabbas, Sprites and possible mesospheric effects, Geophysical Research Letters, Vol. 27, pp. 3829-3832, 2000

Meeting at a Glance

Sunday, 10 May

5:30 p.m. – 7:00 p.m.	Registration/Information Desk
5:30 p.m. – 7:00 p.m.	Welcome Reception

Monday, 11 May

7:00 a.m. – 6:30 p.m.	Registration/Information Desk
8:00 a.m. – 8:30 a.m.	Welcome/Opening Remarks
8:30 a.m. – 10:20 a.m.	Oral Presentations
10:20 a.m. – 10:50 a.m.	Refreshment Break
10:50 a.m. – 12:50 p.m.	Oral Presentations
12:50 p.m. – 2:20 p.m.	Lunch
2:20 p.m. – 3:35 p.m.	Oral Presentations
3:35 p.m. – 4:05 p.m.	Refreshment Break
4:05 p.m. – 5:00 p.m.	Oral Presentations
5:00 p.m. – 7:00 p.m.	Poster Session

Tuesday, 12 May

7:30 a.m. – 6:00 p.m.	Registration/Information Desk
8:00 a.m. – 8:05 a.m.	Morning Announcements
8:05 a.m. – 10:05 a.m.	Oral Presentations
10:05 a.m. – 10:35 a.m.	Refreshment Break
10:35 a.m. – 12:35 p.m.	Oral Presentations
12:35 p.m. – 2:05 p.m.	Lunch
2:05 p.m. – 3:00 p.m.	Oral Presentations
3:00 p.m. – 3:30 p.m.	Refreshment Break
3:30 p.m. – 4:25 p.m.	Oral Presentations
4:25 p.m. – 6:25 p.m.	Poster Session

Wednesday, 13 May

8:00 a.m. – 6:00 p.m.	Registration/Information Desk
8:00 a.m. – 8:05 a.m.	Morning Announcements
8:05 a.m. – 10:05 a.m.	Oral Presentations
10:05 a.m. – 10:35 a.m.	Refreshment Break
10:35 a.m. – 12:35 p.m.	Oral Presentations
12:35 p.m. – 2:05 p.m.	Lunch
2:05 p.m. – 3:10 p.m.	Oral Presentations
3:10 p.m. – 3:40 p.m.	Refreshment Break
3:40 p.m. – 4:40 p.m.	Oral Presentations
4:40 p.m. – 6:40 p.m.	Poster Session
7:30 p.m. – 10:00 p.m.	Conference Banquet

Thursday, 14 May

8:00 a.m. – 5:00 p.m.	Registration/Information Desk
8:00 a.m. – 8:05 a.m.	Morning Announcements
8:05 a.m. – 10:05 a.m.	Oral Presentations
10:05 a.m. – 10:35 a.m.	Refreshment Break
10:35 a.m. – 12:35 p.m.	Oral Presentations
12:35 p.m. – 2:05 p.m.	Lunch
2:05 p.m. – 3:20 p.m.	Oral Presentations
3:20 p.m. – 3:50 p.m.	Refreshment Break
3:50 p.m. – 4:50 p.m.	Oral Presentations
4:50 p.m. – 5:05 p.m.	Closing Remarks

Program Overview

Oral sessions are held in Room 207 and poster sessions are in Room 206. Refreshment Breaks and the Registration/Information Desk are in the Foyer outside of these meeting rooms.

An asterisk after an author's name denotes the first author is a student.

SUNDAY, 10 MAY

5:30 p.m. – 7:00 p.m. ♦ **Welcome Reception** ♦ Senate Lounge
All meeting attendees are invited to attend this kick-off event. Enjoy a relaxing evening with friends and colleagues. Complimentary hors d'oeuvres and drinks will be provided.

MONDAY, 11 MAY

7:00 a.m. – 8:00 a.m. ♦ **Breakfast**
Attendees are on their own for breakfast.

8:00 a.m. – 8:15 a.m. ♦ **Introductory Remarks** ♦ Convener: D D Sentman

8:15 a.m. – 8:30 a.m. ♦ **Welcome from Penn State University**
Remarks: W Kenneth Jenkins, Department Head of Electrical Engineering

Observations of Transient Luminous Events I ○ Chair: M Taylor

8:30 a.m. – 9:00 a.m. ♦ **D D Sentman** (Invited Review), *Effects of Thunderstorms and Lightning in the Upper Atmosphere: An Overview*

9:00 a.m. – 9:25 a.m. ♦ **A B Chen** (Invited), *Spatial and Interannual Variability of Transient Luminous Event and Intense Lightning by ISUAL Experiment*

9:25 a.m. – 9:40 a.m. ♦ **F Lefeuvre**, *TARANIS - Current Status of the Project*

9:40 a.m. – 10:05 a.m. ♦ **Y Yair** (Invited), *From the MEIDEX to the ILAN Winter Campaigns: Results From 6 Years of Sprite Research in Israel*

10:05 a.m. – 10:20 a.m. ♦ **S Soula**, *Characteristics and Conditions of Production of TLEs Observed Over a Maritime Storm*

10:20 a.m. – 10:50 a.m. ♦ **Refreshment Break** ♦ Refreshment Break Area

Observations of Transient Luminous Events II ○ Chair: F T São Sabbas

10:50 a.m. – 11:15 a.m. ♦ **H C Stenbaek-Nielsen** (Invited), *Sprite Initiation Altitude Measured by Triangulation*

11:15 a.m. – 11:30 a.m. ♦ **J Montanyà**, *High-Speed Intensified Video Recordings of Sprites and Elves Over the Western Mediterranean Sea During Winter Thunderstorms*

11:30 a.m. – 11:55 a.m. ♦ **C L Kuo** (Invited), *ISUAL Imager 427.8 nm Campaign for Transient Luminous Events*

11:55 a.m. – 12:10 p.m. ♦ **R T Newsome***, *Aggregate Study of Elves Using Ground-Based Array Photometry*

12:10 p.m. – 12:35 p.m. ♦ **T J Lang** (Invited), *Observations of Two Transient Luminous Event-Producing Mesoscale Convective Systems*

12:35 p.m. – 12:50 p.m. ♦ **Y Matsudo***, *Time Delays of Sprites Induced by Winter Lightning Flashes on the Japan Sea and in the Pacific Ocean*

12:50 p.m. – 2:20 p.m. ♦ **Lunch** ♦ The Gardens Restaurant
Lunch will be served until 2:00 p.m.

Observations of Transient Luminous Events III ○ Chair: A B Chen

2:20 p.m. – 2:45 p.m. ♦ **F T São Sabbas** (Invited), *Sprite Producing Systems: An Analysis of South American Cases Until Today*

2:45 p.m. – 3:10 p.m. ♦ **E Arnone** (Invited), *Satellite Observations of Middle Atmospheric NO2 and Ozone Above Thunderstorms*

3:10 p.m. – 3:35 p.m. ♦ **E Blanc** (Invited), *Gravity Waves Produced by Thunderstorms*

3:35 p.m. – 4:05 p.m. ♦ **Refreshment Break** ♦ Refreshment Break Area

4:05 p.m. – 4:30 p.m. ♦ **T Farges** (Invited), *Infrasound from Sprite Characteristics Deduced from Measurements Realized in 2003 and 2005*

4:30 p.m. – 4:45 p.m. ♦ **C L Siefring**, *Simultaneous Near-Infrared and Visible Observations of Sprites and Acoustic Gravity Waves During the EXL98 Campaign*

4:45 p.m. – 5:00 p.m. ♦ **P-D Pautet**, *Spatial Characteristics and Circular Symmetry Study of the Sprites Observed from Southern Brazil During the 2006 Sprites Balloon Campaign*

5:00 p.m. – 7:00 p.m. ♦ **Poster Session: Observations and Theory of Transient Luminous Events**
Take this opportunity to view posters and interact with colleagues. Beer and soft drinks will be provided.

TUESDAY, 12 MAY

7:00 a.m. – 8:00 a.m. ♦ **Breakfast**
Attendees are on their own for breakfast.

8:00 a.m. – 8:05 a.m. ♦ **Morning Announcements**

Theory of Transient Luminous Events I ○ Chair: M Fullekrug

8:05 a.m. – 8:45 a.m. ♦ **V P Pasko** (Invited Review), *Recent Advances in Theory of Transient Luminous Events*

8:45 a.m. – 9:10 a.m. ♦ **U Ebert** (Invited), *Streamer Discharges in Experiment and Theory: A Review of Recent Results*

9:10 a.m. – 9:35 a.m. ♦ **N Y Liu** (Invited), *Comparison of Streamer Modeling and High-Speed Video Observations of Sprites*

9:35 a.m. – 9:50 a.m. ♦ **M G McHarg**, *Streamer Splitting in Sprites*

9:50 a.m. – 10:05 a.m. ♦ **S Nijdam***, *3D Imaging of Interaction of Positive Streamers in Air*

10:05 a.m. – 10:35 a.m. ♦ **Refreshment Break** ♦ Refreshment Break Area

Theory of Transient Luminous Events II ○ Chair: T Neubert

10:35 a.m. – 11:00 a.m. ♦ **Yu Raizer** (Invited), *Streamer and Leader-like Processes in Upper Atmosphere: Models of Blue Jets and Red Sprites*

11:00 a.m. – 11:15 a.m. ♦ **M N Shneider**, *UV Flashes Caused by Gigantic Blue Jets*

11:15 a.m. – 11:40 a.m. ♦ **J Morrill** (Invited), *The Spectroscopy of Sprites and Related Phenomena*

11:40 a.m. – 12:05 p.m. ♦ **F J Gordillo-Vazquez** (Invited), *Influence of the Vibrational Temperature on the Sprite Induced Atmospheric Chemistry*

12:05 p.m. – 12:20 p.m. ♦ **S Celestin**, *Efficient Photoionization Models for Streamer Propagation: From Ground Pressure Discharges to Transient Luminous Events*

12:20 p.m. – 12:35 p.m. ♦ **C Li***, *3D Hybrid Simulation for Streamer and Sparks: Run-Away Electrons in Streamer Propagation*

12:35 p.m. – 2:05 p.m. ♦ **Lunch** ♦ Executive Conference Rooms
Lunch will be served until 2:00 p.m.

Theory of Transient Luminous Events III ○ Chair: Y Takahashi

2:05 p.m. – 2:30 p.m. ♦ **M J Rycroft** (Invited), *The Effects of Lightning and Sprites on the Ionospheric Potential Estimated Using an Equivalent Circuit Model*

2:30 p.m. – 2:45 p.m. ♦ **J A Riousset***, *Modeling of Thundercloud Screening Layers: Implications for Blue and Gigantic Jets*

2:45 p.m. – 3:00 p.m. ♦ **A Luque**, *The Sharp Transition Between Diffuse and Streamer Regions in Sprites*

3:00 p.m. – 3:30 p.m. ♦ **Refreshment Break** ♦ Refreshment Break Area

3:30 p.m. – 3:55 p.m. ♦ **Y Hiraki** (Invited), *Phase Transition Model of Sprite Halo*

3:55 p.m. – 4:10 p.m. ♦ **T-Y Huang**, *Observations of the Lightning-Induced Transient Emissions (LITEs) in the Mesospheric Airglow Layers*

4:10 p.m. – 4:25 p.m. ♦ **S Davydenko**, *Modeling Electromagnetic and Quasi-Stationary Electric Fields Following a Lightning Discharge*

4:25 p.m. – 6:25 p.m. ♦ **Poster Session: ELF/VLF Effects of Lightning and Transient Luminous Events**
Take this opportunity to view posters and interact with colleagues. Beer and soft drinks will be provided.

WEDNESDAY, 13 MAY

7:00 a.m. – 8:00 a.m. ♦ **Breakfast**
Attendees are on their own for breakfast.

8:00 a.m. – 8:05 a.m. ♦ **Morning Announcements**

ELF/VLF Effects of Lightning and Transient Luminous Events I ○ Chair: U Inan

8:05 a.m. – 8:45 a.m. ♦ **U S Inan** (Invited Review), *ELF/VLF Signatures of Lightning-ionosphere Interactions and Causative Discharges*

8:45 a.m. – 9:10 a.m. ♦ **T Neubert** (Invited), *The ASIM Mission for Studies of Severe Thunderstorms*

9:10 a.m. – 9:35 a.m. ♦ **S A Cummer** (Invited), *Currents, Charges, and Electromagnetic Fields Associated with TLE Initiation and Development*

9:35 a.m. – 9:50 a.m. ♦ **R A Marshall***, *Ionospheric Effects of Cloud-to-Ground and In-cloud Lightning Discharges*

9:50 a.m. – 10:05 a.m. ♦ **E Greenberg***, *ELF/VLF Signatures of Sprite-Producing Lightning Discharges Observed During the 2005 EuroSprite Campaign*

10:05 a.m. – 10:35 a.m. ♦ **Refreshment Break** ♦ Refreshment Break Area

ELF/VLF Effects of Lightning and Transient Luminous Events II ○ Chair: S Cummer

10:35 a.m. – 11:00 a.m. ♦ **C Haldoupis** (Invited), *EuroSprite Studies of Early VLF Perturbations Occurring in Relation with TLEs*

11:00 a.m. – 11:15 a.m. ♦ **M C Kelley**, *An Explanation for Parallel Electric Field Pulses Observed Over Thunderstorms*

11:15 a.m. – 11:40 a.m. ♦ **N G Lehtinen** (Invited), *Full-Wave Modelling of ELF/VLF Effects*

11:40 a.m. – 11:55 a.m. ♦ **J Li***, *Estimation of Charge Distribution in Sprites*

11:55 a.m. – 12:10 p.m. ♦ **X M Shao**, *Comparison of Terrestrial Gamma-ray Flashes and Los Alamos Sferic Array Lightning Measurement*

12:10 p.m. – 12:35 p.m. ♦ **M Sato** (Invited), *Global Sprite Occurrence Rates and Distributions Derived from ELF Measurements and Their Seasonal Variations*

12:35 p.m. – 2:05 p.m. ♦ **Lunch** ♦ Executive Conference Rooms
Lunch will be served until 2:00 p.m.

ELF/VLF Effects of Lightning and Transient Luminous Events III ○ Chair: Y Yair

2:05 p.m. – 2:20 p.m. ♦**S Kumar**, *Further Investigations on Subionospheric VLF Perturbations Observed at Suva, Fiji*

2:20 p.m. – 2:45 p.m. ♦ **O van der Velde** (Invited), *Temporal and Spatial Evolution of Intracloud Lightning Associated With Sprite-Producing Positive Cloud-to-Ground Flashes in Northeastern Spain*

2:45 p.m. – 3:10 p.m. ♦ **J N Thomas** (Invited), *In Situ Measurements of Electrodynamics Above Thunderstorms: Past Results and Future Directions*

3:10 p.m. – 3:40 p.m. ♦ **Refreshment Break** ♦ Refreshment Break Area

3:40 p.m. – 3:55 p.m. ♦ **C L Croskey**, *Conductivity Variations Above Thunderstorms During the ACES 2002 Campaign*

3:55 p.m. – 4:10 p.m. ♦ **T Suzuki**, *An Analysis of Sprite-Producing Thunderstorms During 2004/2005 Japanese Winter Sprite Campaign*

4:10 p.m. – 4:25 p.m. ♦ **E H Lay**, *Non-linear Retrieval of Ionospheric Electron Density Profiles Using FORTE Broadband Data*

4:25 p.m. – 4:40 p.m. ♦ **S I Klimov**, *Electromagnetic Parameters Study for Space Weather Research (Micro-satellite "Chibis-M")*

4:40 p.m. – 6:40 p.m. ♦ **Poster Session**: **Energetic Radiation From Lightning and Transient Gamma Ray Flashes**
Take this opportunity to view posters and interact with colleagues. Beer and soft drinks will be provided.

7:30 p.m. – 10:00 p.m. ♦ **Conference Banquet** ♦ Executive Conference Rooms
Guest Speaker: William Boeck, *Thinking Outside the Box: The Early Days of Sprite Research*

THURSDAY, 14 MAY

7:00 a.m. – 8:00 a.m. ♦ **Breakfast**
Attendees are on their own for breakfast.

8:00 a.m. – 8:05 a.m. ♦ **Morning Announcements**

Energetic Radiation From Lightning & Terrestrial Gamma Ray Flashes I ○ Chair: G Milikh

8:05 a.m. – 8:45 a.m. ♦ **G M Milikh** (Invited Review), *Runaway Breakdown and Electrical Discharges in Thunderstorms*

8:45 a.m. – 9:10 a.m. ♦ **E Williams** (Invited), *The Origin and Context of C.T.R. Wilson's Ideas on Electron Runaway in Thunderclouds*

9:10 a.m. – 9:35 a.m. ♦ **J R Dwyer** (Invited), *Relativistic Positron/X-ray Feedback and Thundercloud Electric Fields*

9:35 a.m. – 9:50 a.m. ♦ **J J Colman**, *Examining Distribution Functions in Thermal Runaway*

9:50 a.m. – 10:05 a.m. ♦ **O Chanrion**, *Production of Runaway Electrons in Conventional Electric Discharges*

10:05 a.m. – 10:35 a.m. ♦ **Refreshment Break** ♦ Refreshment Break Area

Energetic Radiation From Lightning & Terrestrial Gamma Ray Flashes II ○ Chair: E Williams

10:35 a.m. – 11:00 a.m. ♦ **G J Fishman** (Invited), *TGF Observations with the Gamma-ray Burst Monitor on the Fermi Observatory*

11:00 a.m. – 11:25 a.m. ♦ **N Ostgaard** (Invited), *Production Altitude, Initial Distributions and Time Delays for TGFs When Instrumental Deadtime Effects are Treated Properly*

11:25 a.m. – 11:50 a.m. ♦ **D M Smith** (Invited), *RHESSI Observations of Terrestrial Gamma-ray Flashes*

11:50 a.m. – 12:05 p.m. ♦ **H K Rassoul**, *Thunderstorm Characteristics of RHESSI Identified Terrestrial Gamma-ray Flashes*

12:05 p.m. – 12:20 p.m. ♦ **C V Nguyen***, *X-ray Burst in Long Discharges*

12:20 p.m. – 12:35 p.m. ♦ **B E Carlson***, *Simulations of Terrestrial Gamma-ray Flashes from Storm to Satellite*

12:35 p.m. – 2:05 p.m. ♦ **Lunch** ♦ Executive Conference Rooms
Lunch will be served until 2:00 p.m

Energetic Radiation From Lightning & Terrestrial Gamma Ray Flashes III ○ Chair: D Smith

2:05 p.m. – 2:30 p.m. ♦ **Y Takahashi** (Invited), *Observations of TLEs and TGFs by RISING Satellite*

2:30 p.m. – 2:55 p.m. ♦ **M Fullekrug** (Invited), *Runaway Breakdown in LF Radio*

2:55 p.m. – 3:20 p.m. ♦ **L P Babich** (Invited), *Localization of the Source of Atmospheric Neutron Flashes Detected in Thunderstorm Atmosphere*

3:20 p.m. – 3:50 p.m. ♦ **Refreshment Break** ♦ Refreshment Break Area

3:50 p.m. – 4:05 p.m. ♦ **B J Hazelton***, *Modeling RHESSI TGFs as a Distribution of Events with Non-vertical Beams at Various Altitudes*

4:05 p.m. – 4:20 p.m. ♦ **M Marisaldi**, *Observations of TGFs with AGILE*

4:20 p.m. – 4:35 p.m. ♦ **T Gjesteland**, *Analysis of BATSE TGFs Taking Deadtime Effects Into Account*

4:35 p.m. – 4:50 p.m. ♦ **M I Panasyuk**, *Transient Luminous Event Phenomena and Energetic Particles Impacting the Upper Atmosphere: Russian Space Experiment Programs*

4:50 p.m. – 5:05 p.m. ♦ **Closing Remarks** ♦ Convener: D D Sentman

Poster Sessions

In addition to the presenting author and abstract title, each listing begins with the poster number used during the poster sessions. An asterisk after an author's name denotes the first author is a student.

Presenters are required to be present at their posters on indicated days during the poster sessions.

Observations of Transient Luminous Events

Monday, 11 May; 5:00 p.m. – 7:00 p.m.

OTL-01 • **E Arnone**, *The Rate of Detection of Transient Luminous Events From Space*
OTL-02 • **M A Bailey***, *Investigating Halo Optical Signatures and Associated Lightning Parameters from a Large MCS Over Argentina*
OTL-03 • **J K Chou***, *Positive and Negative Gigantic Jets*
OTL-04 • **O G Gladysheva**, *Formation of Powerful Discharge in the Upper Atmosphere*
OTL-05 • **O G Gladysheva**, *Discharge in the Upper Atmosphere during the Tunguska Catastrophe*
OTL-06 • **T Kanmae***, *Observation of Rotational Temperature of the N2(B) in Sprite*
OTL-07 • **B A Khrenov**, *Program of Transient UV Event Research at Tatiana-2 Satellite*
OTL-08 • **Y S Lee***, *Summer High Latitude Mesospheric Observations of Apparent Supersonic Wind and O(1S) Emission Rate With the UARS/WINDII Instrument and the Association With Sprites, Meteors and Lightning*
OTL-09 • **L W Petersen***, *Comparison of Sprite-Halo Characteristics Imaged Over the USA and South America*
OTL-10 • **N N Solorzano**, *High-Energy Lightning Discharges in Intense Hurricanes*
OTL-11 • **M J Taylor**, *Airborne Image Measurements of Elves Over Southern Europe*
OTL-12 • **L Y Tsai***, *Blue Jets Over Tropical Cyclones*
OTL-13 • **Y Yair**, *The Spatial Organization of Column Sprite Elements Associated with Eastern Mediterranean Winter Thunderstorms*
OTL-14 • **K Yoshita***, *Development of Multi-Band Filter Photometer Onboard the TARANIS Satellite*

Theory of Transient Luminous Events

Monday, 11 May; 5:00 p.m. – 7:00 p.m.

TTL-01 • **Z Bonaventura**, *Similarity Properties of Discharges in Preheated Air at Ground Pressure and in Transient Luminous Events*
TTL-02 • **A Bourdon**, *Air Heating Associated with Ground Pressure Discharges and Transient Luminous Events*
TTL-03 • **S Davydenko**, *The Effect of Ionospheric Superrotation on the Atmosphric Electric Field*
TTL-04 • **A Y Kudryavtsev**, *Numerical Simulations of Volumetric Discharges Above Thunderclouds Correlated with Large Variations of Thundercloud Dipole Moment with Applications to Sprites*
TTL-05 • **N Y Liu**, *Comparison Between Sprite Streamer Modeling and ISUAL Multi-Wavelength Measurements*
TTL-06 • **H Peterson**, *NOx Production by Laboratory Simulated TLEs*
TTL-07 • **V Ratushna**, *Modelling Positive and Negative Streamers in Air: Propagation and Electrodynamic Interaction*
TTL-08 • **T Suzuki***, *Computer Simulations on the Sprite Initiation for Realistic Lightning Models with Higher Frequency Surges*
TTL-09 • **E Williams**, *The Sprite Lightning Polarity Paradox, Revisited*
TTL-10 • **G Wormeester***, *Propagation Mechanisms of Positive Streamers in Different Gases*

ELF/VLF Effects of Lightning and Transient Luminous Events

Tuesday, 12 May; 4:25 p.m. – 6:25 p.m.

EV-01 • **T Adachi**, *VHF Radar Echoes in the Lower Ionosphere Associated with Lightning Discharges*

EV-02 • **K A Franzen**, *Chasing Lightning, Sferics, Tweeks and Whistlers Observing Natural Radio Waves Using the INSPIRE Receiver*

EV-03 • **P Greninger***, *Impact of Sprites on VHF Propagation Through the D-region*

EV-04 • **M C Kelley**, *The Impact of Lightning on the Ionosphere*

EV-05 • **S I Klimov**, *Investigation of Atmospheric Lightning Discharges on the Micro-satellite "Chibis-M"*

EV-06 • **F Lefeuvre**, *Ground-based and Space-based Observations of ELF/VLF Waves Associated with TLEs*

EV-07 • **V Mushtak**, *On Requirements and Applications of Modeling Techniques in Inverse Problems at ELF*

EV-08 • **J Samuels**, *Applying Sum Absolute Difference (SAD) Algorithms to Lightning Geolocation*

EV-09 • **K Yamashita***, *Estimation of Net Current Due to Lightning Discharge in the Global Electric Circuit*

Energetic Radiation From Lightning and Terrestrial Gamma Ray Flashes

Wednesday, 13 May; 4:40 p.m. – 6:40 p.m.

ER-01 • **M A Alves**, *Observation of a Possible Neutron Burst Associated With a Lightning Discharge*

ER-02 • **P H Connell**, *The Diffuse Shape of Terrestrial Gamma Ray Flashes, as Seen by Imaging Instruments on the ISS and High Altitude Aircraft*

ER-03 • **E S Cramer***, *Primary Factors for Electron Relativistic Runaway Breakdown in Air*

ER-04 • **A Yu Drozdov***, *Experiment Based On Spacesuit "Orlan-M". Neutron Fluxes From Thunderstorm*

ER-05 • **B W Grefenstette***, *Characterizing the Intensities of Terrestrial Gamma-ray Flashes (TGFs) Observed by RHESSI*

ER-06 • **A V Grigoriev**, *Thunderstorm Neutrons at Altitudes up to 400 km: Theoretical Estimations and Numerical Simulation*

ER-07 • **H Kase***, *The Relationship Between the Terrestrial Gamma-ray Flashes Occurrence and the Charge Moment Change of Parent Lightning Discharge*

ER-08 • **A Y Kudryavtsev**, *Project of 3D Fluid Code Intended for Simulation of Thunderstorm Discharges Driven by Runaway Electrons Allowing for the Geomagnetic Field*

ER-09 • **Z Saleh***, *Statistical Study of X-ray Emission in Natural and Rocket-Triggered Lightning*

ER-10 • **M Schaal***, *Search for Ground-Level Terrestrial Gamma-ray Flashes Associated with Natural and Rocket-Triggered Lightning Using the Thunderstorm Energetic Radiation Array (TERA)*

Oral Presentation Abstracts

Abstracts are listed chronologically, according to the conference schedule.

Monday, 11 May 2009

Effects of Thunderstorms and Lightning in the Upper Atmosphere: An Overview

[*D D Sentman*] (Geophysical Institute and Dept. of Physics, University of Alaska, Fairbanks, AK 99775 USA; ph. +1-907-474-6442; dsentman@gi.alaska.edu)

The past twenty years have witnessed an explosion in the number of studies of previously unknown lightning-induced processes in the upper atmosphere that have significantly altered the traditional picture of the earth's electrical environment. Earlier balloon and rocket observations of electric fields and air conductivities above thunderstorms, and VLF observations of perturbations in the amplitudes and phases of the received signals from remote transmitters indicating lightning induced electron precipitation from the magnetosphere, had shown that thunderstorm electrical effects extended into the upper atmosphere, ionosphere and magnetosphere. There were, as well, observations of x-rays from in-cloud lightning that hinted at energetic electrical processes inside the thundercloud itself, and numerous anecdotal reports by pilots of mysterious flashes of light in the sky above thunderstorms. Overall, the picture of the global electrical environment was thought to be well understood, with the exception of a few unexplained anomalies.

This picture changed dramatically in 1989 with the accidental observation of what was interpreted to be a large electrical discharge extending upward from the top of a thunderstorm. The discharge appeared to extend to what was, at the time, an incredible altitude of ~34 km, well above the tops of thunderstorms. Researchers quickly discovered that there are actually several different types of discharges that, in their totality, span the full distance from the troposphere to the ionosphere at ~90 km altitude. They include red sprites, blue jets, elves, sprite haloes, and gigantic jets, collectively termed Transient Luminous Events (TLEs). Instead of being rare or exceptional events, as was initially thought, they turned out to be common occurrences above most vigorous thunderstorm systems, satellite observations revealing the global occurrence rate of all types of TLEs to be ~2x10^6/yr. Theorists have identified the underlying processes as manifestations of conventional electrical breakdown or electron impact-excited fluorescence in an altitude region that was previously thought to be electrodynamically simple. Only a few years after the 1989 discovery of TLEs, an equally unexpected discovery was made, that thunderstorms also produce transient flashes of gamma rays sufficiently intense to be observed from space. The underlying runaway process involves acceleration of electrons to relativistic energies in a strong thunderstorm electric

field, followed by bremsstrahlung radiation via collisions with the neutral atmosphere. In addition to these processes, more recent work has indicated that lighting may also produce local x-rays and photonuclear effects, as well as inducing chemical effects in the upper atmosphere.

This talk will provide a broad overview of the subject matter of the Chapman Conference. It will briefly recount the key observations that have been made since 1989, indicate the context in which they were made and interpreted, and briefly discuss how they have extended the classical global electrical circuit picture to include fully kinetic descriptions of transient, non-LTE, energetic and chemical processes. Optical measurements will provide the focus for the talk, with supporting geophysical and laboratory observations included as needed. A few speculations are included about how this new understanding of the elements of the planetary electrical circuit could be applied to studies of similar classes of electrical processes in extraterrestrial environments.

Spatial and Interannual Variability of Transient Luminous Event and Intense Lightning by ISUAL Experiment

[*A B Chen*] (Institute of Space, Astrophysical and Plasma Sciences, National Cheng Kung University, Tainan, 70101, Taiwan; ph. 886-937099755; fax 886-62096035, alfred@phys.ncku.edu.tw); Han-Tzong Su (National Cheng Kung University, Physics Department, Tainan 70101, Taiwan; ph. 886-6-2757575; htsu@energy.phys.ncku.edu.tw); Rue-Ron Hsu (National Cheng Kung University, Physics Department, Tainan 70101, Taiwan; ph. 886-6-2757575; rrhsu@energy.phys.ncku.edu.tw); C. L. Kuo (Institute of Space Science, National Central University, Jhongli, Taiwan; ph. 886-3-4227151-65777; fax 886-6-2096035; clkuo@jupiter.ss.ncu.edu.tw); Y. J. Lee (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph: 886.6.2757575-65212, fax: 886.6.2096035, yjlee@phys.ncku.edu.tw); L. Y. Tsai (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. 886-6-2757575-65212; fax 886-6-2096035; esthertsay@gmail.com); J. K. Chou (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. 886-6-2757575-65212; fax 886-6-2096035; jkchou@phys.ncku.edu.tw); L. J. Lee (Department of

Physics, National Cheng Kung University, Tainan, Taiwan; ph. 886-6-2757575-65212; fax 886-6-2096035; c2493402@phys.ncku.edu.tw); S. C. Chang (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. 886-6-2757575-65212; fax 886-6-2096035; pollyce@phys.ncku.edu.tw); Stephen Mende (University of California at Berkeley, Space Sciences Laboratory, Berkeley, CA 94720, USA; ph: 510.642.0876; mende@ssl.berkeley.edu); Harald Frey (University of California at Berkeley, Space Sciences Laboratory, Berkeley, CA 94720, USA; ph. 510-643-3323; hfrey@ssl.berkeley.edu); Yukihiro Takahashi (Department of Geophysics, Tohoku University, Sendai, Japan; ph. 81-22-795-5775; fax 81-22-795-5775, yukihiro@pat.geophys.tohoku.ac.jp); Lou-Chuang Lee (National Central University, Institute of Space Science, Jhongli 32001, Taiwan; ph. 886-2-27377500; loulee@ncu.edu.tw)

Since the discovery of sprites in 1989, transient luminous events (TLEs; sprites, elves, halos, blue jets, and gigantic jets) were studied extensively by ground observations, remote radio measurements, as well as shuttle observations in the past decades. But the global distribution and seasonal variation of TLEs are still not well assessed due to limitations in previous space or ground observations. Imager of Sprites and Upper Atmospheric Lightnings (ISUAL), the scientific payload onboard FORMOSAT-2 satellite is the first space-borne instrument that dedicates to a long-term and global survey of TLEs. Between July 2004 and January 2009, ISUAL has recorded more than 10,000 TLEs and tens of thousands of intense lightning. The high cumulative TLE event number has allowed us to explore the temporal and regional variations and their relation to the climate variability. The statistic result shows that the seasonal variation of elves distribution closely follows both ITCZ (inter-tropical convergence zone) and the deep updraft regions in the low latitudes. These imply that the latitudinal atmospheric circulation maybe is the primary force driving the production of elves. The occurrence of sprite matches the distribution of lightning in low latitude regions and winter storm tracks in the winter middle latitude regions. Chen et al. [2008] noted that a strong dependency between the elves occurrence and the sea surface temperature; thus implying a strong coupling between ocean, atmosphere and ionosphere may exist, and the El Nino-South Oscillation (ENSO) should play an important role in the variability of TLEs. We also perform a cross comparison of the inter-annual variation of TLEs and the intense lightning with Southern Oscillation Index (SOI), climate variability and sea surface temperature change in a few regions. The result indicates that the variability of TLE and lightning activity are closely governed by the sea surface temperature and the meteorological dynamics in the troposphere.

TARANIS - Current Status of the Project

J-L Pinçon (LPC2E, CNRS-Orléans University, Orléans; France 45071; ph. 33 238-257-820; fax 33 238-631-234; jlpincon@cnrs-orleans.fr); [*F Lefeuvre*] (LPC2E, CNRS-Orléans University, Orléans; France 45071; ph. 33 238-255-284; fax 33 238-631-234; lefeuvre@cnrs-orleans.fr); Elisabeth Blanc (DAM Ile de France, CEA, Bruyères le Châtel; France 91297; ph. 33 169-264-996; fax 33 169-267-130; Elisabeth.BLANC@cea.fr)

TARANIS is a CNES micro-satellite project dedicated to the study of impulsive transfers of energy between the Earth atmosphere and the space environment. Such impulsive transfers of energy, pointed out by the observation at ground and on satellite (FORMOSAT 2) of Transient Luminous Events (TLEs) and the detection on satellites (CGRO, RHESSI) of Terrestrial Gamma ray Flashes (TGFs), are likely to occur in other environments. The TARANIS mission and instrumentation is presented. The way TARANIS may answer the numerous remaining questions about the physics of TLEs and TGFs is examined. The questions include: the characterization of the region sources of TLEs and TGFs, the environmental conditions (lightning activities, variations in the thermal plasma, occurrence of Extensive Atmospheric Showers, etc.), the identification and characterization of Lightning induced Electron precipitations (LEPs) and Runaway electron Beams (RBs), the generation mechanisms, and the effects of TLEs, TGFs, and RBs on the atmosphere and the radiation belts. It is shown that TARANIS has a sufficiently complete package of instrumentation to answer specific questions raised by the observations and the existing models.

From the MEIDEX to the ILAN Winter Campaigns: Results From 6 Years of Sprite Research in Israel

[*Yoav Yair*] (Department of Life and Natural Sciences, The Open University, Ra'anana 43107 Israel, ph. +972-9-7781341, fax +972-9-7780626, yoavya@openu.ac.il); Colin Price (Department of Geophysics and Planetary Sciences, Tel-Aviv University, Tel-Aviv, 69978 Israel, ph. +972-3-6408633, fax +972-3-6409282, cprice@flash.tau.ac.il); Peter Israelevich (Department of Geophysics and Planetary Sciences, Tel-Aviv University, Tel-Aviv, 69978 Israel, ph. +972-3-6408272, fax +972-3-6409282, peteri@post.tau.ac.il); Adam Devir (Institute for Advanced Research and Development, Yagur, Israel, ph. +972-4-8216402, iardad@iard.org.il); Eran Greenberg (Department of Geophysics and Planetary Sciences, Tel-Aviv University, Tel-Aviv, 69978 Israel, erangree@post.tau.ac.il); Michal Ganot (Department of Geophysics and Planetary Sciences, Tel-Aviv University, Tel-Aviv, 69978 Israel, michal.ganot@gmail.com); Roy Yaniv (Department of Geophysics and Planetary Sciences, Tel-Aviv University, Tel-Aviv, 69978 Israel, royya@012.net.il); Na'ama Reicher, Department of Geophysics and Planetary Sciences, Tel-Aviv University, Tel-Aviv, 69978 Israel, naama_reicher@walla.com); Elyakom Vadislavsky (Department of Atmospheric Sciences, The Hebrew University of Jerusalem, Jerusalem, 91904 Israel, elyakom.vadislavsky@mail.huji.ac.il); Carynelisa Erlick

(Department of Atmospheric Sciences, The Hebrew University of Jerusalem, Jerusalem, 91904 Israel, ph.+972-2-6584974, fax. +972-2-5662581, caryn@vms.huji.ac.il) and Daria Dubrovin (Department of Geophysics and Planetary Sciences, Tel-Aviv University, Tel-Aviv, 69978 Israel, dashafl@gmail.com)

We present results and progress in sprite research in Israel, commencing with observations conducted on-board the space shuttle Columbia during the Mediterranean Israeli Dust Experiment (2003, MEIDEX) and followed by subsequent ground-based observation campaigns of Eastern Mediterranean winter thunderstorms. From space, calibrated video images of nocturnal thunderstorms were obtained in 21 orbits (381 minutes) of which ~1/5 contained useful lightning data, over the Pacific Ocean, Australia, Central Africa and South America. In total we identified 10 Elves and 8 sprites. Sprites were detected between ~40-90 km above ground with brightness of 0.3-1.7 MR (in 665nm) and 1.4-1.7 MR (in 860nm). Elves were found near ~95 km mostly appearing as bright arcs (no central hole) suggesting a production by intra-cloud flashes. Synchronized with the optical observations, ELF and VLF data were recorded by stations in Israel, Japan, Antarctica, US and Hungary in order identify the parent lightning discharge. This international endeavor enabled triangulating the parent flash from distances of several thousand km.

The continuation of the MEIDEX into the ground-based ILAN campaigns (Imaging of Lightning And Nocturnal flashes) concentrated on optical and electromagnetic measurements of winter thunderstorms in the vicinity of Israel and the eastern coast of the Mediterranean Sea. Multiple sites were used, initially the Tel-Aviv University campus in Ramat-Aviv (20 MSL) and the Wise observatory in the Negev desert (900 MSL), later joined by the Hebrew University in Jerusalem (800 MSL). We report the results of 4 observation campaigns conducted during the 2005/6-2008/9 seasons. In over 60 different nights we detected >200 events at ranges of 150 to >500 km, mostly above the sea near Cyprus, Lebanon and Turkey. TLEs were found to be produced by lightning in active Cumulonimbus cells with a vertical dimension of 5-8 km and cloud top temperature ~-40°C, embedded in a larger matrix of stratiform precipitating cloudiness. Clear ELF transients were detected for ~90% of sprite-producing +CGs. Calculation of the charge moment change showed values of 1400±600 C•km. Within the accuracy of one video field (17 ms), it was found that the average time delay between the ELF transient of the parent +CG and its associated sprites was 76 ms (±34 ms), with some events delayed >120 ms from the parent lightning, much longer than values reported for summer sprites in the US (~10 ms). Furthermore, based on the ELF data, we find no early identifiable precursors to TLEs occurrence in the regional lightning activity and +CGs which had similar characteristics sometimes generated TLEs and at other times did not. The 3-D structure of columniform sprites was investigated with dual observations from two separate sites. We show that in this type of sprite the elements are arranged in a circular pattern, following the QE-field in the mesosphere. Theoretical studies of sprite occurrence in other planetary atmospheres where lightning had been observed show that sprites are possible in Venus, Jupiter and Saturn. We will report initial results from laboratory experiments of sprite streamers development in different gas mixtures, simulating the relevant planetary conditions.

Characteristics and Conditions of Production of TLEs Observed Over a Maritime Storm

[*S Soula*] (Université de Toulouse, UPS, LA (Laboratoire d'Aérologie), 14, avenue Édouard Belin - 31400 Toulouse, France; ph. 33-561-332774; fax 33-561-332790; sous@aero.obs-mip.fr); O van der Velde (Electrical Engineering Department, Technological University of Catalonia, 08222 Terrassa, Barcelona, Spain; oscar.van.der.velde@upc.edu); J Palmiéri (Université de Toulouse, UPS, LA (Laboratoire d'Aérologie), 14, avenue Édouard Belin - 31400 Toulouse, France; julien_palmieri@hotmail.fr); O Chanrion (Danish Technical University, Space Research Institute, Juliane Maries Vej 30, 2100 Copenhagen, Denmark; chanrion@space.dtu.dk); J Montanyà (Electrical Engineering Department, Technological University of Catalonia, 08222 Terrassa, Barcelona, Spain; ph. 0034-669-793-316; fax 0034-937-398-236; montanya@ee.upc.edu); F. Lefeuvre (CNRS/LPCE, 3A, Av de la Recherche Scientifique, 45071 Orléans cedex 02, France; ph. 33-0-2-38255284; fax 33-0-2-38631234; lefeuvre@cnrs-orleans.fr)

The coordinated European campaign of TLE observation in 2007 involved several cameras in southern France and northern Spain and lasted several months of summer, fall, and winter. Thanks to good conditions of observation at the camera locations and to several periods of long-duration storm activity, a large proportion of the TLEs (~90%) were observed from October to January over the Mediterranean Sea. Different types of TLEs (sprites, halos, elves) were produced by these maritime storms. The present study focused on one night of storm activity which was embedded in a long-duration period in Corsica area. The meteorological conditions generated a northerly flow of cold air over France. 30 TLEs, including 19 sprites, 6 elves (4 with a sprite), and 5 halos (4 with a sprite), were observed during the night of 15/16 November. For 26 of them, a positive "parent" lightning flash was detected and located, a large majority of which were produced in a region with low radar reflectivity values, typically lower than 45 dBZ. The peak current distribution of the 26 "parent" flashes clearly exhibits two groups, one with much lower values corresponding with the sprites alone (average value at 63.3 kA and maximum value at 124.8 kA) and one with larger values for the halos and the elves (average value at 272.3 kA and 350.6 kA, respectively, and maximum value at 311.9 kA and 383.6 kA, respectively). Most of TLEs (23) were gathered within three periods of production with the same chronology: the sprites alone were produced before and the halos and elves at the end of the periods. These periods were characterized by a low flash rate, a high positive flash proportion, and an increase of the cloud area with moderate radar reflectivity values (30-40 dBZ). The time delay was shorter in average for halos and elves. The TLEs were often associated with sequences of cloud-to-ground flashes which could spread out the whole stratiform region of the storm system. The analysis of the lightning activity of the storm shows two groups of flashes according to the time interval between two consecutive flashes. One sprite might have directly associated with intracloud lightning activity, according to ELF/VLF data. A large proportion of the TLEs (23) were detected by two cameras allowing their localization over the storm system.

Sprite Initiation Altitude Measured by Triangulation

[*H C Stenbaek-Nielsen*] (Geophysical Institute, University of Alaska Fairbanks, Fairbanks, AK 99775-7320; ph. 907-474-7282; fax 907-474-7290; hnielsen@gi.alaska.edu); R Haaland (Fort Lewis College, Durango, CO 81301; ph. 970-247-7514; haaland_r@fortlewis.edu); M G McHarg (US Air Force Academy, Colorado Springs, CO 80840; ph. 719-333-2460; fax: 719-333-3182; matthew.mcharg@usafa.edu); T Kanmae (Geophysical Institute, University of Alaska Fairbanks, Alaska, 99775; ph. 907-474-7578; fax: 907-474-7125; tkammae@gi.alaska.edu); B A Hensley (Fort Lewis College, Durango, CO 81301; ph. 970-247-7514; bahensley@fortlewis.edu)

High time resolution (10,000 frames per second) images of sprites combined with multi-station concurrent video recordings have provided data for triangulation of the altitude of the initial sprite onset as well as of the sprite location. The high-speed images were obtained from the Langmuir Laboratory, NM, during summer campaigns in 2007 and 2008, and the video observations were made from sites at Portales, NM, and Las Vegas, NM. The sprites are rarely over the causal lightning strike, but displaced horizontally by several 10s of km in agreement with earlier published triangulations. Sprites start with one or more downward propagating streamer heads, and the altitude of the onset, i.e. the altitude of the first detection of the initial downward streamer, vary from 66 km to 88 km. Further, the higher onset altitudes appear to be associated C-sprites and the lower with carrots. In the wake of the higher altitude streamer heads columnar luminosity is formed creating the C-sprite signature easily recognizable in video recordings. In many sprites there are also upward propagating streamers. When they occur, they occur later and their onset is from a lower altitude and from existing luminous sprite structures. The upward streamers form the diffuse higher altitude branches. With low altitude onset the upward streamers start not much lower than the initial downward streamers creating 'classical' carrot sprites. Many sprites are a mixture of C and carrot sprite characteristics; onset would be near 80 km and the initial temporal development would appear as a C-sprite, but later upward streamers, forming at altitudes near 70 km, will add carrot characteristics. The relative number of upward and downward streamers varies which, when combined with different onset altitudes, affects how the sprite will appear in a video frame; in effect, it leads to a 'sliding' scale from pure C-sprites to carrots.

High-Speed Intensified Video Recordings of Sprites and Elves Over the Western Mediterranean Sea During Winter Thunderstorms

[*J Montanyà*] (Electrical Engineering Department, Technological University of Catalonia, 08222 Terrassa, Barcelona, Spain; ph. 0034-669-793-316; fax 0034-937-398-236; montanya@ee.upc.edu); O van der Velde (Electrical Engineering Department, Technological University of Catalonia, 08222 Terrassa, Barcelona, Spain; oscar.van.der.velde@upc.edu); D Romero (Electrical Engineering Department, Technological University of Catalonia, 08222 Terrassa, Barcelona, Spain; romero@ee.upc.edu); S Soula (Université de Toulouse, UPS, CNRS, Laboratoire d'Aérologie, 14 avenue Edouard Belin, F-31400 Toulouse, France; serge.soula@aero.obs-mip.fr); N Pineda (Meteorological Service of Catalonia, Barcelona, Spain; e-mail: npineda@meteo.cat); V Reglero (University of Valencia, Valencia Spain; victor.reglero@uv.es)

High-speed video recordings of sprites and elves have been obtained for the first time over the northwestern Mediterranean Sea during winter 2008/2009. Observations were carried out with a Phantom 7.3 monochrome high speed camera attached to an image intensifier. Each frame was time stamped within 1 micro-second resolution provided by a GPS receiver. An additional CCD low light sensitive video camera was attached to the high speed camera in order to have simultaneous images. From three nights of observation during December 2008 and January 2009 a total of 14 sprites and 19 elves were recorded at frame rates from 6688 to 15037 fps. These observations revealed the high amount of elves produced by these storms and also some observations of sprites preceded by elves and haloes. We describe the thunderstorm activity on the Mediterranean related to the observations and presents the results of the analysis (time delay and currents) of the parent lightning associated to the observed TLEs. We summarize singularities of our high speed observations of TLEs and will focus on a particular case where a sprite tendril appears to rebounce from a previously formed column sprite.

ISUAL Imager 427.8 nm Campaign for Transient Luminous Events

[*C L Kuo*] (Institute of Space Science, National Central University, Jhongli, Taiwan; ph. 886-3-4227151; fax 886.3.4224394; clkuo@jupiter.ss.ncu.edu.tw); J K Chou

(Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. 886-6-2757575.65212; fax 886.6.2096035; jkchou@phys.ncku.edu.tw); Y J Lee (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. 886-6-2757575.65212; fax 886.6.2096035; yjlee@phys.ncku.edu.tw); S C Chang (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. 886-6-2757575-65212; fax 886.6.2096035; pollyce@phys.ncku.edu.tw); L J Lee (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. 886-6-2757575.65212; fax 886-6-2096035; c2493402@phys.ncku.edu.tw); L Y Tsai (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph 886-6-2757575-65212; fax 886.6.2096035; esthertsay@gmail.com); A B Chen (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. 886-6-2757575-65264; fax 886.6.2096035; alfred@phys.ncku.edu.tw); H T Su, (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. 886-6-2757575-65248; fax 886.6.2096035; htsu@phys.ncku.edu.tw); R R Hsu (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. 886-6-2757575-65242; fax 886.6.2096035; rrhsu@phys.ncku.edu.tw); H Frey (Space Sciences Lab, University of California, Berkeley, CA 94720-7450; ph. 510-643-7629; fax 510-643-7629; e-mail: hfrey@ssl.berkeley.edu); S Mende (Space Sciences Lab, University of California, Berkeley, CA 94720-7450; ph. 510-643-7629; fax: 510-643-7629; hfrey@ssl.berkeley.edu); Y Takahashi (Department of Geophysics, Tohoku University, Sendai, Miyagi 980-8578, Japan; ph. 81-0-22-795-5775; fax 81-0-22-795-5775; yukihiro@pat.geophys.tohoku.ac.jp); L C Lee (Institute of Space Science, National Central University, Jhongli, Taiwan; ph. 886-3-4227151-65777; fax 886-3-4224394; loulee@nsc.gov.tw)

During 2008 ISUAL 427.8 nm campaign, transient luminous events (TLEs), including sprites, elves and gigantic jets, were recorded by the ISUAL iCCD camera equipped with a 427.8 nm narrow band filter. This filter has a bandwidth of 4.6 nm and a center-wavelength of 428.7 nm. The emissions that fall into this bandpass include the dominant line from 1NN2+ (0, 1) and the weak N2 line 427.0 nm from 2PN2 (1, 5) [Armstrong et al., 1998]. The existence of 427.8 nm emission in TLEs provides a direct evidence for the generation of TLEs involving ionization processes. Analysis of the ISUAL recorded TLEs indicate there is a significant spatial variation in the ionization region in TLEs. In this presentation, we will present case studies on a sprite, an elve and a gigantic jet. For the sprite, only the lower altitude region at 35-65 km emits strong 427.8 nm emissions. The intensity ratio of ISUAL spectrophotometer (SP) channel 2 and 3 is ~10 for this sprite. This spectral ratio corresponds to a higher reduced E-field than those in the typical sprites as reported in Kuo et al. (2005). For the elve, the ISUAL Imager 427.8 nm had an edge-on view. The ionized region of the elve is ~300 km in diameter and has a thickness ~ 10 km. The gigantic jet (GJ) showed very low but discernible 427.8 nm emissions from the upper part of the fully-developed-jet. Besides, 427.8 emissions from the stem of the GJ that connects to the parent cloud last for more than 300 ms.

Aggregate Study of Elves Using Ground-Based Array Photometry

[*R T Newsome*] (Space, Telecommunications, and Radioscience Laboratory, Stanford University, Stanford, CA 94305; ph. 650-723-3789; fax 650-723-9251; rtnewsome@stanford.edu); U S Inan (Space, Telecommunications, and Radioscience Laboratory, Stanford University, Stanford, CA 94305; ph. 650-723-4994; fax 650-723-9251; inan@stanford.edu)

Photometric arrays have been a valuable tool in the study of transient luminous events (TLEs) from both the ground and from space. They offer very high temporal resolution and enough spatial resolution to discriminate the different kinds of TLEs from each other and from lightning flashes. Moreover, they can be operated in a free-running mode that does not require operator-triggering, allowing for higher rates of detection -- especially the detection of elves. Photometer arrays were instrumental in the early ground-based studies of elves and have been used in long-term studies of elves (and other TLEs) from satellites. Recently, a photometer array instrument called PIPER (Photometric Imaging of Precipitation of Electron Radiation) has been developed and deployed in ground-based TLE observation campaigns, and hundreds of elves (tens of elves from each storm) have been observed.

In this paper, we present an overview of the PIPER instrument and examples of recorded elves. We also present examples of elves occurring in doublets and triplets -- that is, in rapid (<20 ms) succession of each other -- and investigate why these events occur commonly for some types of storms and not at all for others. We then present a statistical summary of the body of PIPER elve recordings made to date This includes elve association with a variety of important lightning and storm parameters, as well as association with events recorded in VLF data.

Observations of Two Transient Luminous Event-Producing Mesoscale Convective Systems

[*T J Lang*] (Department of Atmospheric Science, Colorado State University, Fort Collins, CO 80523-1371; ph. 970-491-6944; fax 970-491-8449; tlang@atmos.colostate.edu); W A Lyons (FMA Research, Inc., Fort Collins, CO 80524; ph. 970-416-8851; walyons@frii.com); S A Rutledge (Department of Atmospheric Science, Colorado State University, Fort Collins, CO 80523-1371; ph. 970-491-8283; fax 970-491-8449; rutledge@atmos.colostate.edu); S A Cummer (Duke University, Durham, NC 27708; ph. 919-660-5256; cummer@ee.duke.edu); D R MacGorman (NOAA NSSL, Norman, OK; don.macgorman@noaa.gov)

We report combined radar and lightning observations of two mesoscale convective systems (MCSs) that produced multiple transient luminous events (TLEs) in central Oklahoma. The radars included multiple WSR-88D NEXRADs, and the lightning obervations included the National Lightning Detection Network, the Oklahoma Lightning Mapping Array (LMA), and estimates of charge moment change from the National Charge Moment Change Network. The first MCS, 20 June 2007, was an extremely large symmetric leading line/trailing stratiform MCS that produced nearly 300 TLEs during a 4-h observation period. TLE parent flashes, as mapped by the LMA, were split between initiating in the convective line and in the stratiform region. Those that initiated in the convective line did so at a higher altitude than those in the stratfiorm region, which tended to initiate near the melting level. TLE parents tapped upper-level positive charge near 8.4 km MSL on average during their TLE phase, no matter where they initiated. The second MCS, 9 May 2007, was an asymmetric MCS with a mesoscale convective vortex (MCV) on its northern end, which produced over 20 TLEs in a 2-h observation period. TLE-parent positive cloud-to-ground (CG) lightning flashes tended to strike within this MCV, which also contained disorganized embedded convection. Nearly all TLE parents initiated within convection, either in the MCV or in the main convective line to the south. Initiation altitude was critically dependent on the strength of the convection. TLE parents on average tapped positive charge near 6 km MSL during their TLE phase, which was much lower than 20 June. Also, TLE parents covered smaller areas than 20 June, implying they neutralized significantly less charge. This inference will be tested using total charge moment data. These apparent differences in charge moment change between the two storms may explain why 20 June was such a prolific producer of TLEs; in particular, it appears that classic symmetric MCSs, which detrain copious amounts of positive charge from the upper levels of their convective line, may be optimal TLE producers as they would maximize total charge moment change in their stratiform flashes.

Time Delays of Sprites Induced by Winter Lightning Flashes on the Japan Sea and in the Pacific Ocean

[*Y Matsudo*] (Department of Electronic Engineering, The University of Electro-Communications, 1-5-1 Chofu-gaoka, Chofu Tokyo, 182-8585, Japan; ph. +81-42-443-5168; fax +81-42-443-5168; endeavor@cj9.so-net.ne.jp); T Suzuki (Air Weather Group, Japan Air Self-Defense Force, Ministry of Defense, 2258 Koshizuno-cho, Sakaiminato Tottori, 684-0053, Japan; ph. +81-859-45-0211; rekonyanbb@yahoo.co.jp); K Michimoto (Air Weather Group, Japan Air Self-Defense Force, Ministry of Defense, 1-5-5 Sengen-cho, Fuchu Tokyo, 183-8521, Japan; michimot@nda.ac.jp); K Myokei (Department of Electronic Engineering, The University of Electro-Communications, 1-5-1 Chofu-gaoka, Chofu Tokyo, 182-8585, Japan; ph. +81-42-443-5168; fax +81-42-443-5168; meken103@zpost.plala.or.jp); K Kusunoki (Typhoon Research Department, Meteorological Research Institute, Japan); M Hayakawa (Department of Electronic Engineering, The University of Electro-Communications, 1-5-1 Chofu-gaoka, Chofu Tokyo, 182-8585, Japan; ph. +81-42-443-5168; fax +81-42-443-5168; hayakawa@whistler.ee.uec.ac.jp)

The measurement of unusual winter sprites in the Hokuriku area (Japan Sea side) was performed as a primary target of the 2006/2007 winter campaign by means of coordinated optical and extremely low frequency ELF/very high-frequency (VHF) electromagnetic observations. We have also added the same observations for the sprites in the Pacific Ocean, to be compared with the characteristics of Hokuriku sprites. The following results have emerged from this campaign: (i) the predominance of column sprites in winter has been confirmed not only for the Hokuriku area, but also in the Pacific Ocean (with the probability just above 60%), (ii) carrots are much more frequently observed in the Pacific Ocean (with a probability of ~ 28%) than in the Hokuriku area (~16%). (iii) a very unique property of Hokuriku sprites is the surprisingly long delay (average ~ 90 ms) of sprites from their parent lightning and the delays for carrots and columns show some significant difference (80 ms for columns and 100 ms for carrots) and (iv) while, the time delay of Pacific Ocean sprites is much shorter (~43 ms average) than that at Hokuriku. However, there is no remarkable difference in delay between carrots and columns. Finally, we discuss the importance of the time delay studies to understand sprite generations and their parent lightning discharges, because the difference of time delays on the Japan Sea side and in the Pacific Ocean are thought to be causally related to the parameters of parent thunderstorms.

Sprite Producing Systems: An Analysis of South American Cases Until Today

[*F T São Sabbas*] (Aeronomy Division, National Institute for Space Research–INPE, Sao Jose dos Campos, SP, Brazil, 12227-010; ph. +55-12-3945-7154; fax +55-12-3945-6990; saosabbas@dae.inpe.br); C A Morales Rodriguez (Institute of Astronomy, Geophysics and Atmospheric Sciences–IAG, University of Sao Paulo, Sao Paulo, SP, Brazil, 05508-090; ph.+55-11-30912711; fax +55-11-30914714; morales@model.iag.usp.br)

The intense lighting activity of South American thunderstorms results in a high probability of Transient Luminous Events (TLE) occurrence in this region of the globe. This characteristic has motivated the execution of 5 TLE observation campaigns in Brazil up to date. During the first campaign, in 2002/2003, 18 sprites were recorded above Minas Gerais State in two different nights; 11 sprites from 3 different storms above Goias and Mato Grosso States was the total recorded on a single night of the second campaign, in 2005. The third campaign, in 2006, had the impressive record of more than 600 TLEs from two thunderstorms over Argentina in different nights. In the year of 2007 we recorded 27 sprites from a single system above Uruguay, and last year, 2008, on the fifth campaign in Brazil, 13 TLEs were registered above one convective system over Rio Grande do Sul State. This paper will review the results of these campaigns, focusing on the characteristics of the 2005, 2006 and 2008 TLE generating convective systems. A cloud top temperature analysis based on GOES IR imagery was performed for all thunderstorms. It revealed a multi convective core structure that seamed to be an effective charge producer for one of the 2006 systems, explaining the high TLE rate (445 events) even with cloud tops ~20o C warmer than other South and North American TLE producing systems. The analysis showed weak convective activity for the three 2005 TLE producing storms, which could explain the low number of events recorded. The 2008 system is still under analysis which will take into account a detailed depiction of the 3-D rain structured as observed by Brazilian weather radar. As a consequence, we expect to investigate the relation between the convective activity and cloud electrification structure associated to the development of the TLEs.

Satellite Observations of Middle Atmospheric NO2 and Ozone Above Thunderstorms

[*E Arnone*] (Dept. of Physical and Inorganic Chemistry, University of Bologna, Viale Risorgimento 4, 40136 Bologna, Italy; ph. +39-051-2093709; fax +39-051-2093690; arnone@fci.unibo.it); A Kero (Sodankylä Geophysical Observatory, University of Oulu, Sodankylä, Finland; akero@sun3.oulu.fi); F Sao-Sabbas (Instituto Nacional de Pesquisas Espaciais-INPE, DAE/INPE; saosabbas@dae.inpe.br); M Carlotti (Dept. of Physical and Inorganic Chemistry, University of Bologna, Viale Risorgimento 4, 40136 Bologna, Italy; ph. +39-051-2093709; fax +39-051-2093690; carlotti@fci.unibo.it); B M Dinelli (Istituto di Scienza dell'Atmosfera e del Clima – CNR, Bologna, Italy; bm.dinelli@isac.cnr.it); Craig J Rodger (Department of Physics, University of Otago, Dunedin, New Zealand; crodger@physics.otago.ac.nz); C-F Enell (Sodankylä Geophysical Observatory, University of Oulu, Sodankylä, Finland; carl-fredrik.enell@sgo.fi); E Papandrea (Dept. of Physical and Inorganic Chemistry, University of Bologna, Viale Risorgimento 4, 40136 Bologna, Italy; ph. +39-051-2093709; fax +39-051-2093690; enzo@safire.fci.unibo.it); M Ridolfi (Dept. of Physical and Inorganic Chemistry, University of Bologna, Viale Risorgimento 4, 40136 Bologna, Italy; ph. +39-051-2093709; fax +39-051-2093690; marco.ridolfi@unibo.it); N F Arnold (Department of Physics and Astronomy, University of Leicester, Leicester, U.K.); E Turunen (Sodankylä Geophysical Observatory, University of Oulu, Sodankylä, Finland; esa@sgo.fi)

The chemical impact of sprites and other transient luminous events on middle atmospheric NO2 and ozone is investigated using satellite observations. Measurements from the MIPAS infra-red spectrometer onboard the ENVISAT satellite are used to seek changes in nighttime middle atmospheric NO2 and ozone that can be associated with thunderstorm activity. MIPAS measurements are retrieved with a tomographic 2-dimensional algorithm which accounts for atmospheric horizontal variability thus enhancing the sensitivity to weak changes. The original five-month dataset that led to the identification of a possible sprite-induced NO2 perturbation (Arnone et al., GRL, 35, L05807, 2008) is expanded doubling the number of measurements in the sample and reanalyzed with an improved algorithm. Intense thunderstorms are initially localised through the WWLLN lightning detection network in order to provide a statistically meaningful sample of MIPAS measurements in coincidence with high likelihood of sprite activity. Specific case studies are further discussed in conjuction with available sprite and thunderstorm measurements.

Gravity Waves Produced by Thunderstorms

[*E Blanc*] (CEA, DAM, DIF, F-91297 Arpajon, France; ph. 331-6926-4996; fax 331-6926-7130; elisabeth.blanc@wanadoo.fr); T Farges (CEA, DAM, DIF, F-91297 Arpajon, France; ph. 331-6926-5489; fax 331-6926-7130 ; thomas.farges@cea.fr); A Le Pichon; ph. 331-6926-7815; fax 331-6926-7130; alexis.le-pichon@cea.fr)

Thunderstorms are an important source of gravity waves at mid and low latitudes. Such waves affect a very large altitude range and were observed in the ionosphere by HF radars, in the mesosphere where they modulate the OH airglow, in the stratosphere by lidar and balloons and by microbarometers at ground. The source can be the convective cells, frontal systems or local heating in the thunderstorms areas. Infrasound produced by lightning and sprites are expected to have local or regional impact. At the contrary, gravity waves characterized by large wavelengths, reaching several tens to hundreds kilometres, could have a global influence. Gravity waves originating in the troposphere produce a forcing on the stratosphere and contribute to a general stratospheric circulation motion towards the polar regions where fluctuations move down with a possible effect on the troposphere. The presentation will review previous observations of the gravity waves in relation with thunderstorm activity. It will then present the analysis of gravity waves recently recorded by microbarometer stations in Europe. The possibility of global impact of atmospheric waves produced by thunderstorms will be discussed.

Infrasound from Sprite Characteristics Deduced from Measurements Realized in 2003 and 2005

[*T Farges*] (CEA, DAM, DIF, F-91297 Arpajon, France, thomas.farges@cea.fr)

The objective of this paper is to present the main characteristics of infrasound from sprites when the source is at short or long distance. Since the assumption by Liszka [2004] that infrasound have a specific signature in their spectrogram (a chirp, i.e. arrival of low frequencies before high frequencies) when a sprite occurs, several experiments have been organised to confirm that signature. During the Eurosprite 2003 campaign [Neubert et al., 2005], first correlations between camera observations and such kind of infrasound have been found [Farges et al., 2005]. In a study case, sprites were located 350 to 500 km away from the infrasound station. Using a ray-tracing model with a source at 60 km height, Farges et al. [2005] found a positive correlation between the calculated propagation time and the measured propagation time (which is the difference between the sprite time and the infrasound time of arrival). A near one-to-one correlation has been found. Only the small sprites, that are column sprites or single carrot sprites, are missed. Moreover, a clear relation between the duration of infrasound and the horizontal extent of the sprite has been found. The analysis of other thunderstorms of that campaign producing sprites shows that infrasound of sprite can be measured for events occurring up to 1000 km away from the infrasound station [Neubert et al., 2005]. Several infrasound with sprite signature have been detected during dawn or morning time (before or after sunrise, respectively) [Farges et al., 2005 ; Neubert et al., 2008]: this suggests that sprite detection could be available even if cameras are blind due to sky brightness (at dawn) or masking by cloud. About the specific signature (chirp in spectrogram), Farges et al. [2005] assume that it can be explained by the horizontal extent of a group of sprites because the wave coming from the nearest side of the group (relatively to the sensor) reflects at higher altitude (and is then more attenuated due to thermospheric acoustical filtering properties) than the wave generated from the farthest side. Recently, Pasko and Snively [2007] shows that the infrasound amplitude from 0.1 to few Pascal is in agreement with the heating of few degrees of a column which have sprite dimensions. Their modeling results demonstrate that the angle of arrival and the reflection at tropospheric altitudes significantly affect spectral properties of infrasound signals observed on the ground.

During the Eurosprite 2005 campaign [Neubert et al., 2008], a temporary station has been set up in the South-West of France where storms are frequent in summer. Measurements of infrasound from lightning and from sprites have been performed. For few thunderstorms, which occurred just over the station, interesting properties of infrasound from lightning have been described [Farges, 2008] such as the attenuation with distance and the frequency spectrum of infrasound from lightning. As in 2003, sprites have been observed with cameras at long distance from the station but also for the first time at less than 200 km. The analysis of far events improves our knowledge of the detection capacity of infrasound from sprite depending on the distance and the azimuth of sprites. Using events which occur close to the station, we look for the possibility to measureinfrasound from sprite in direct propagation from the source without refraction on thermosphere. We process infrasound data of the four sensors of the station to detect coherent waves and to calculate their apparent speed and arrival azimuth. We find that some infrasound events exhibit characteristics very different from infrasound from lightning. They last up to one minute (instead of few seconds for infrasound from lightning), their apparent speed is high (indicating a high altitude source) and varies very rapidly and the azimuth of arrival spreads on several ten degrees (indicating a large lateral extent). Assuming that these particular infrasound are due to sprite, we calculate the 3D location of the source of these infrasound. The wave characteristics (apparent speed, azimuth), the time and location of possible positive cloud-to-ground (+CG) parent lightning are used to initialize a ray-tracing calculation which takes into account the varying sound celerity with altitude. The results are close to that we know about sprite from optical measurements: large vertical extent (from 40 to 100 km altitude), large lateral extent (up to several ten of kilometres) and spatial shift (up to 100 km) in comparison to the location of the +CG parent lightning. These infrasound events are not correlated with observation of sprites in spite of three sprites recorded over this thundercloud. As the thunderstorm was close to the camera site, the camera field of view did not cover the entire thunderstorm zone and then the camera could miss sprites which can be at the origin of these infrasound events.

Simultaneous Near-Infrared and Visible Observations of Sprites and Acoustic Gravity Waves During the EXL98 Campaign

[*C L Siefring*] (Naval Research Laboratory, Plasma Physics Division, Washington, DC 20375-5346; ph. 202-404-4298; fax 202-767-0631; carl.siefring@nrl.navy.mil); J S Morrill (Naval Research Laboratory, Space Sciences Division, Washington, DC 20375-5346; ph. 202-404-7826; jeff.morrill@nrl.navy.mil); D D Sentmann (University of Alaska Fairbanks, Geophysical Institute, Fairbanks, AK 99775; ph. 907-474-6442; dsentman@gi.alaska.edu); M J Heavner (University of Alaska Southeast, Juneau, AK, 99801; ph. 907-796-6403; matt.heavner@uas.alaska.edu)

We present results of simultaneous Near-InfraRed (NIR) and visible sprite observations during the EXL98 (Energetics of Upper Atmospheric Excitation by Lightning 1998) airborne observing mission. These results were the first NIR observations of sprites and the first observations of correlations among nighttime hydroxyl (OH) airglow, gravity waves, and sprite locations. The EXL98 campaign fielded numerous cameras on a Gulfstream II jet aircraft. Of importance to this study are a NIR digital/video camera operating in the spectral range between 900 and 1700 nm and an intensified Dage-MTI VE-1000 B/W video camera operating in the visible range. The NIR camera was used to monitor OH nightglow and also to search for excitation of N2 First Positive emissions in the NIR by sprites. OH nightglow measure-ments are commonly used as a tracer of acoustic gravity waves and give indications of density structures in the neutral atmosphere. A possible correlation between neutral density variations and sprite initiation has been theoretically postulated for the classical breakdown mechanism of sprites. The Dage visible camera was the primary sprite observing instrument during the EXL98 mission. This imager also observed the hydroxyl nightglow at times, which fortunately allowed for correlated measurements between the acoustic gravity waves and the sprites with a single imager. On only one night of observations was a clear correlation observed between the OH nightglow and the sprites, with sprite tops appearing to align with the acoustic gravity wave troughs at 80-90 km altitude. Investigation shows that the most favorable viewing geometry for detecting such a correlation is at a distance of several hundred kilometers from the sprites.

A comparison of sprite visible and NIR emissions shows that the NIR is brightest in the central body of the sprites and weaker in the tops and tendril regions. Synthetic spectra indicate that the NIR portion of the N2 First Positive bands should be the brightest part of the spectrum. The shape of the emission spectrum in the NIR region has not been experimentally verified. These limitations indicate that estimates of the energy deposited into the Mesosphere, from the brightness of sprite emissions, will be very unreliable if extrapolating from only visible observations. We will discuss these observations and their implications.

Spatial Characteristics and Circular Symmetry Study of the Sprites Observed from Southern Brazil During the 2006 Sprites Balloon Campaign

[*P-D Pautet*] (CASS, Utah State University, Logan, UT 84322-4405; ph. 435-797-8128; fax 435-797-2992; dominiquepautet@gmail.com); M J Taylor (CASS, Utah State University, Logan, UT 84322-4405; ph. 435-797-3919, fax 435-797-2992, mike.taylor@usu.edu); M A Bailey (Trinity College, Hartford, CT 06106, ph. 860-297-5103; Matthew.Bailey@trincoll.edu); S A Cummer (Department of Electrical and Computer Engineering, Duke University, Durham, NC 27708, ph. 919-660-5256, fax 919-660-5293, cummer@ee.duke.edu); J N Thomas (Bard High School Early College, Elmhurst, NY 11373, ph. 206-947-2678, jnt@u.washington.edu); R H Holzworth (Earth and Space Sciences, University of Washington, Seattle, WA 98195-1310, ph. 206-685-7410, fax 206-685-3815, bobholz@washington.edu)

In February-March 2006, ground-based observations were conducted from the Southern Space Observatory (SSO) near Santa Maria, Brazil (29.4 S, 53.8 W) as part of a coordinated ground-based and balloon sprites campaign. Two large thunderstorms observed over north-eastern Argentina on February 22-23 and Paraguay on March 3-4 produced more than 580 TLEs. Coincident lightning data were provided by the World Wide Lightning Location Network (WWLLN) and associated charge moment changes were calculated using VLF data obtained by the Duke electromagnetic sensors also deployed at SSO.

This presentation focuses on the spatial characteristics of the sprites and their possible circular-shape arrangement. Previous studies (e.g., Adachi et al., 2004; Neubert et al., 2005; Vladislavsky et al., 2008; Yair et al., 2009) have suggested that the electromagnetic pulse (EMP) radiating from the parent +CG defines the area where the sprite streamers are seeded, which could lead to a circular symmetry in the sprite initiation. During our 2006 campaign a significant number (~50 events) of TLEs potentially exhibited this elliptical aspect. The length of the sprite columns, their top and bottom altitudes and the horizontal diameter of the sprite clusters are presented and compared with the parent lightning characteristics and the associated charge moment changes. These data provide new 3-dimensional perspective on the TLE development.

Tuesday, 12 May 2009

Recent Advances in Theory of Transient Luminous Events

[*V P Pasko*] (Department of Electrical Engineering, Communications and Space Sciences Laboratory (CSSL), The Pennsylvania State University, 211B Electrical Engineering East, University Park, PA 16802-2706, USA, ph. 814-865-3467, fax 814-865-7065, vpasko@psu.edu)

Transient luminous events are large-scale electrical discharges occurring at high altitude in the Earth's atmosphere, which are directly related to the electrical activity in underlying thunderstorms. Several different types of transient luminous events have been documented and classified. These include relatively slow-moving fountains of blue light, known as `blue jets', that emanate from the top of thunderclouds up to an altitude of 40 km; `sprites' that develop at the base of the ionosphere and move rapidly downwards at speeds up to 10,000 km/s; `elves', which are lightning induced flashes that can spread over 300 km laterally, and upward moving `gigantic jets', which establish a direct path of electrical contact between thundercloud tops and the lower ionosphere. The goal of this talk is to provide an overview of the recent modeling efforts directed on interpretation of observed features of different types of transient luminous events. Among topics covered in this talk, we will discuss a basic physical mechanism proposed for explanation of sprites, which is build on original ideas advanced many decades ago by the Nobel Prize winner C. T. R. Wilson. Similarity properties of electrical discharges as a function of gas pressure will be emphasized in the context of selected results from the recent laboratory and modeling studies of streamers, which are directly applicable for understanding of recent high spatial and temporal resolution imagery of sprites revealing many internal filamentary features with transverse spatial scales ranging from tens to a few hundreds of meters.

Streamer Discharges in Experiment and Theory: A Review of Recent Results

[*U Ebert*] (CWI Amsterdam, PO Box 94079, 1090GB Amsterdam, The Netherlands, ph. +31-20-592-4206, fax +31-20-5924199, ebert@cwi.nl)

The streamer process generically occurs in gases, liquids and solids; the emphasis of the talk is on positive and negative streamer discharges in ambient air, but includes remarks on streamers in “pure” molecular or noble gases like nitrogen or argon and on their density dependence. The streamer process can be divided into 1. inception, in the lab frequently close to needle or wire electrodes, 2. propagation, with a wide variation of diameters and velocities in the same medium, 3. branching, 4. repulsion or attraction of several streamers, and finally 5. extinction or approach to some electrodes. I will review the recent experimental characterization of these processes (nanosecond photography, stereo-photography, the role of the power supply, efficiency of ozone generation, experiments in gases of 1 p.p.m. purity), and I will review the state of theory, based on particle and fluid models and on the coupling of both. In particular, I will discuss microscopic mechanisms, discharge inception near a needle electrode, characterization of positive and negative streamers of different diameter in air, the high electron energies in the streamer head, the interaction of streamers with each other and with ceramic walls, and their electric current and charge content.

Comparison of Streamer Modeling and High-Speed Video Observations of Sprites

[*N Y Liu*] (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901, USA; ph. 321-674-7348; nliu@fit.edu); V P Pasko (Department of Electrical Engineering, The Pennsylvania State University, University Park, PA 16802, USA; ph. 814-865-3467; vpasko@psu.edu); H C Stenbaek-Nielsen (Geophysical Institute, University of Alaska, Fairbanks, Alaska, USA; ph. 907-474-7414; hnielsen@gi.alaska.edu); M G McHarg (Department of Physics, United States Air Force Academy, Colorado, USA; ph. 719-333-3510; Matthew.Mcharg@usafa.edu)

Filamentary streamers are basic components of sprite discharges in the Earth’s upper atmosphere [e.g., Gerken and Inan, JASTP, 65, 567, 2003]. High speed (>1000 fps) video observations of sprites have continuously provided more detailed information on their temporal development [e.g., Stanley et al., GRL, 26, 3201, 1999; Moudry et al., JASTP, 65, 509, 2003; McHarg et al., JGR, 107, 1364, 2002; Marshall and Inan, GRL, 32, L05804, 2005; Cummer et al., GRL, 33, L04104, 2006; McHarg et al., GRL, L06804, 2007; Stenbaek-Nielsen et al., GRL, L11105, 2007]. The video records at 10,000 fps obtained by McHarg et al. [2007] and Stenbaek-Nielsen et al. [2007] indicate that sprite streamers propagate with expansion, acceleration, and brightening. The increases in the speed, radius and brightness of sprite streamers during their propagation have been noted in previous modeling work [e.g., Liu and Pasko, JGR, 109, A04301, 2004; GRL, 32, L05104, 2005]. In this talk, we report the results from a comparison of streamer modeling and high-speed video observations. The acceleration computed from the modeling for applied electric fields close to the conventional breakdown threshold field is in a good agreement with the peak values observed experimentally. Both modeling and observations show that the brightness of a sprite streamer head increases exponentially with time and it can span more than 4 orders of magnitude in 1 ms. The exponential growth rate of the brightness depends on the magnitude of the applied electric field. This dependence leads to formulation of a method for remote sensing of the lightning induced electric field in the mesospheric and lower ionospheric regions of the atmosphere, which drives the sprite phenomenon. We also investigate the effects of different spatial and temporal resolutions of an observational system on the visual appearance of the captured sprite streamer. It is found that the large variation in brightness of sprites obtained in several previous studies can be directly attributed to different resolutions of used instruments.

Streamer Splitting in Sprites

[*Matthew G McHarg*] (The United States Air Force Academy, USAF Academy, CO, 80840); Hans Stenbaek-Nielsen (Geophysical Institute, University of Alaska, Fairbanks, AK); Takeshi Kanmae (Geophysical Institute, University of Alaska, Fairbanks, AK); Ryan Haaland (Fort Lewis College, Durango CO)

Branching; or splitting is a fundamental phenomenon in streamers. The time history of an individual streamer splitting in the laboratory is very challenging due to the extremely fast (ns) time scales involved. Recent observations of streamer tip splitting in sprites are possible due the reduced background pressure found at sprite altitudes. We report on high speed 10,000 frames per second with 50 micro second integration time observations of sprites were obtained on 23 June 2007 using a 300 mm lens on a Phantom 7 camera with a Video Scope HS 1845 HS image intensifier. The locations of the parent lightning strikes were located using the National Lightning Detection Network, and the range to the 75 km altitude point above the parent lightning strike determined. The resulting resolution was approximately 30m per pixel. Streamer tip divisions were seen at altitudes from 60 to 76 km altitude, effectively across the entire vertical field of view. We observe streamers splitting into smaller and smaller streamer tips once the splitting starts. We compare our observations to theoretical models of streamer tip splitting by Ebert et al. [Plasma Sources Sci. Technol. 15 (2006)] , and Liu and Pasko [J.G.R., 109, 2004].

3D Imaging of Interaction of Positive Streamers in Air

[*S Nijdam*] (Department of Applied Physics, Eindhoven University of Technology, PO Box 513, 5600 MB Eindhoven, The Netherlands; ph. +31-40-2474342; fax +31-40-2456050 s.nijdam@tue.nl); E M van Veldhuizen (Department of Applied Physics, Eindhoven University of Technology; e.m.v.veldhuizen@tue.nl); U Ebert (Department of Applied Physics, Eindhoven University of Technology and CWI, Centre for Mathematics and Informatics, PO Box 94079, NL-1090 GB Amsterdam, The Netherlands; ute.ebert@cwi.nl)

In pictures of streamer corona discharges or of sprite discharges, streamer channels often show branching. Besides branching, streamers of equal polarity sometimes seem to reconnect or merge. However, this could be due to the two-dimensional projection. Therefore we use stereography to investigate the full three-dimensional structure of such events. We analyze branching, the splitting of one streamer channel in two or more channels, reconnection, in which a late thin streamer reconnects to an earlier thick streamer channel, and merging, in which two simultaneously propagating streamer heads merge into one new streamer.

In our experiments branching is often observed. We have measured an average branching angle of about 43 degrees. We also find that reconnections as defined above occur frequently. Merging on the other hand was only observed at a pressure of 25 mbar and a tip separation of 2 mm, i.e., when the full width at half maximum of the streamer channel is more than 10 times as large as the tip separation. At higher pressures or with a wire anode, merging was not observed. It should be noted that some images of reconnection events exhibit striking similarities to movies of sprite discharges published by Cummer et al.

Streamer and Leader-like Processes in Upper Atmosphere: Models of Blue Jets and Red Sprites

Yu P Raizer (Institute for Problems in Mechanics, Russian Acad. Sci., 101 Vernadsky Str.119526 Moscow, Russia, raizer@ipmnet.ru); [*G M Milikh*] (Maryland University, milikh@gmail.com); M N Shneider (Princeton University, shneyder@princeton.edu)

The models of blue jets and red sprites based on the ideas about their streamer - leader nature are considered. Blue jet contains the bi-leader, whose top part is seen on photos as a “trunk of a tree”. The upward leader is capped by its streamer zone seen as the tall and narrow “branches” of “the tree”. The long upward streamers of blue jets can be sustained by the moderate cloud charge due to transfer of the high potential of the thundercloud edge by the upward leader tip. The streamer length is estimated along with the height from which the streamers can reach ionosphere. The propagation of a streamer is computed. It is shown that the critical external field ES required for an unlimited streamer growth satisfies the similarity law ES/N ~ const for a wide range of the molecular number density N. Red sprites are interpreted as the downward streamers. This idea and the simplified theory used for computations of the long streamers in the non-uniform atmosphere are confirmed by quantitative comparison of the results with the recent registrations of red sprites. The main unsolved problems in the field are discussed.

UV Flashes Caused by Gigantic Blue Jets

[*M N Shneider*] (Princeton University, MAE Department, Princeton, NJ, USA 08540; ph. 609-258-1022; shneyder@princeton.edu); G M Milikh (University of Maryland Department of Astronomy, College Park, MD, 20742, USA; ph. 301-405-1558; milikh@astro.umd.edu)

The micro satellite ‘Tatiana’ recently detected two scales of the UV flash duration: 1–4 ms and 10–64 ms [Panasyuk et al, 2005; Garipov et al., 2006]. In our opinion the first one corresponds to the lifetime of a long leader (prong) running towards the ionosphere, while the second corresponds to the lifetime of a slow moving leader or the streamer zone of a leader. In this paper we present a model of UV flashes due to a bunch of long streamers which form a leader (prong) of a Gigantic Blue Jet. Using our earlier model of upward propagation of a long streamer in the exponential atmosphere [Raizer et al., 2006,2007] we described the temporal evolution of the UV intensity generated by a bunch of such streamers in the given spectral range 300–400 nm and verified the model against the data obtained by the UV instrument on board the ‘Tatiana’ micro satellite [Milikh and Shneider, 2008]. The computed temporal behavior of UV flashes is in agreement with the observations. The total number of the radiated photons depends upon the conic angle on the GBJ and on the streamers packing factor. The better agreement for total number of the radiated photons reaches for the conic angles in the range 2.50 – 100 such as were observed in [Wescott et al., 2006] and for the packing factor of the order of 0.1.

The Spectroscopy of Sprites and Related Phenomena

[*Jeff Morrill*] (Naval Research Research Laboratory, Space Science Division, Washington DC 20375-5352, jeff.morrill@nrl.navy.mil)

As with many energetic phenomena in the terrestrial upper atmosphere there are distinct optical signatures which are governed by the energetic processes at play and the resident excited species involved. In atmospheric process like the aurora and airglow, the dominate role of N2 in the observed spectra is well know and understanding the details of the spectroscopy is necessary in order to derive information about these process. This is also the case with Sprites and other Transient Luminous Events (TLE). In addition to N2, other molecules, such as O2, OH, and NO, play a role in the production of the observed spectra and may contribute to emissions at lower levels or in spectral regions which have not yet been adequately observed.

In this presentation, the details of various N2 spectra will be discussed. This will including the formation of rovibronic bands, the estimation of rotational and kinetic temperatures, determination of electronic state vibrational distributions, and discussions of kinetic and chemical processes that affects populations of the rotational and vibrational energy level manifolds. Contributions to observed spectra by other molecules will also be addressed. Finally, possible future measurements and their implications will also be discussed.

Influence of the Vibrational Temperature on the Sprite Induced Atmospheric Chemistry

[*F J Gordillo-Vazquez*] (Solar System Department, Instituto de Astrofísica de Andalucía (IAA) CSIC, P.O. Box 3004, 18080 Granada, Spain; ph. +34-958-230-642; fax +34-958-81-45-30; vazquez@iaa.es)

Recent analysis of sprite spectra suggests the existence of N2 vibrational distributions similar to those observed in laboratory afterglow spectra. The latter seems to suggest that part of the sprite emissions might be originated from collisions of vibrationally excited N2 molecules and, consequently, non-negligible values of the vibrational temperature (Tv) might play a role in the activation of some reaction channels that would be negligible for hardly populated vibrational levels. Calculations will be presented on the impact of non-negligible Tv values on the transient electron distribution function (EDF) and on the glow and afterglow sprite chemistries for different values of the reduced electric field in the sprite streamer head and in afterglow.

Efficient Photoionization Models for Streamer Propagation: From Ground Pressure Discharges to Transient Luminous Events

[*S Celestin*] (Department of Electrical Engineering, Communications and Space Sciences Laboratory (CSSL), The Pennsylvania State University, 227 Electrical Engineering East, University Park, PA 16802-2706, USA, ph. 814-863-1780, fax 814-865-7065, sebastien.celestin@psu.edu); N Y Liu (Physics and Space Sciences, College of Science, Florida Institute of Technology, 150 West University Boulevard, Melbourne, FL 32901-6975, USA, ph. 321-674-7348, nliu@fit.edu); A Bourdon (Ecole Centrale Paris, EM2C laboratory, Grande voie des vignes, 92295 Chatenay-Malabry, France, ph. 1-41-13-10-46, fax 147028035, anne.bourdon@em2c.ecp.fr); V P Pasko (Department of Electrical Engineering, Communications and Space Sciences Laboratory (CSSL), The Pennsylvania State University, 211B Electrical Engineering East, University Park, PA 16802-2706, USA, ph. 814-865-3467, fax 814-865-7065, vpasko@psu.edu); P Segur (Université de Toulouse, LAPLACE, 118 route de Narbonne, 31062 Toulouse, France, ph. 5-61-55-64-99, pierre.segur@laplace.univ-tlse.fr); E Marode (École Supérieure d'électricité, LPGP, France, ph. 1-69-15-36-75, emmanuel.marode@u-psud.fr)

Streamers are present for a considerable range of spatial scales: from a few millimeters for laboratory microdischarges to several tens of kilometers in large-scale sprite discharges present in the mesosphere. Radiative processes play a significant role in the dynamics of streamers. Indeed, the photoionization greatly affects the propagation of the streamer. The photoionization process is manifested in the creation of photoelectrons by absorption of UV radiation emitted from the streamer head. The non-local aspect of this process makes it a difficult task to accurately quantify the effects of the photoionization on streamers. The widespread method in streamer simulation to compute the photoionization is based on the model proposed by Zheleznyak et al. [High Temp., 20, 357, 1982]. This model has been further justified by recent experimental work [Aints et al., Plasma Process. and Polym., 5, 672, 2008]. Direct use of this integral model requires a time consuming computation of global quadrature over the simulation domain. Several differential equation based approaches have been recently proposed in order to overcome this problem [Luque et al., Appl. Phys. Lett., 90, 081501, 2007; Ségur et al., Plasma Sources Sci. Technol., 15, 648, 2006; Bourdon et al., Plasma Sources Sci. Technol., 16, 656, 2007; Liu et al., Appl. Phys. Lett., 91, 211501, Liu et al., IEEE Trans. Plasma Sci., 36, 942, 2008]. In this paper we present a review of the existing photoionization models emphasizing the range of their applicability and their respective performances. We focus on two differential models. The first one is the three-exponential Helmholtz model, which provides an approximation of the integral Zheleznyak model by a set of three Helmholtz differential equations. We emphasize that the three equations are the minimum required for accurate solution of photoionization problems for the full range of validity of the original formulation by Zheleznyak et al. [1982] in the range $0.1 < pO2\ R < 150$ Torr cm, where pO2 is the partial pressure of molecular oxygen in air in units of Torr and R in cm is an effective geometrical size of the physical system of interest [Naidis, Plasma Sources Sci. Technol., 15, 253, 2006]. We note that this range of validity corresponds to 6.6 micrometers to 1 cm range at ground pressure, and 10 cm to 150 m at 70 km altitude where sprite streamers are typically initiated in the Earth's atmosphere. The second differential model we discuss is the three-group SP3 model, which is based on a physical approximation of the radiative transfer equation. We show that these differential photoionization models are efficient and readily usable even in complex electrostatic configurations. We demonstrate that the accuracy of the results and the ease of implementation of efficient boundary conditions based on radiative transfer theory represent advantages of the three-group SP3 model in comparison with other differential equation based models proposed to date.

3D Hybrid Simulation for Streamer and Sparks: Run-Away Electrons in Streamer Propagation

[*Chao Li*] (Center for Mathematics and Computer Science, 1090 GB Amsterdam, The Netherlands. ph. +31-(0)20-5924234; fax +31-(0)20-5924200; c.li@cwi.nl); Ute Ebert (Center for Mathematics and Computer Science, 1090 GB Amsterdam, The Netherlands; and Dept. Applied Physics, Eindhoven University of Technology, 5600 MB Eindhoven, The Netherlands. ph. +31-(0)20-5924206; fax +31-(0)20-5924200; Ute.Ebert@cwi.nl); W Hundsdorfer (Center for Mathematics and Computer Science, 1090 GB Amsterdam, The Netherlands. ph. +31-(0)20-5924211; fax +31-(0)20-5924200; Willem.Hundsdorfer@cwi.nl)

The streamer concept can be directly applied to sprites, and streamers also pave the way for the lightning discharge. Both fluid and particle models have been developed for streamer simulations. The particle model is suited to study physical phenomena related to the dynamics of individual electrons, such as the precise electron energy distribution, the generation of run-away electrons, the branching triggered by particle fluctuations, or streamer inception from few electrons. But it demands an enormous computational power and storage to simulate a full long streamer while so-called super-particle methods create numerical artifacts. Fluid models, on the other hand, approximate the electrons and ions as continuous densities. They are computationally efficient in regions with large particle densities like the interior of a streamer finger. To study the physics phenomena related with individual electron dynamics in an evolving streamer, a hybrid model that couples fluid and particle model in suitable regions, has been developed in a systematical way. We present the algorithms and the simulation results of the 3D hybrid model. The 3D hybrid model can simulate long streamers while following the real electron motion at the most active region of the streamer head. We also investigate the generation of run-away electrons and present how keV electrons are produced in a growing streamer.

The Effects of Lightning and Sprites on the Ionospheric Potential Estimated Using an Equivalent Circuit Model

[*M J Rycroft*] (CAESAR Consultancy, 35 Millington Road, Cambridge CB3 9HW, UK; ph. +44 1223 353839; fax +44 1223 303839; michaelrycroft@btinternet.com); A Odzimek (Department of Physics and Astronomy, University of Leicester, University Road, Leicester LE1 7RH, UK; ph. +44 116 2523548; fax +44 116 2523555; ao64@ion.le.ac.uk)

An equivalent circuit model of the global atmospheric electric circuit has been constructed using the PSpice electrical engineering software package. The circuit is driven by currents (~1 kA) above equatorial thunderstorms and electrified rain/shower clouds at middle latitudes. These currents raise the potential of the ionosphere (which is presumed to be an equipotential surface at 80 km altitude) to ~250 kV with respect to the Earth's surface. The analog circuit, composed of resistors and capacitors, is completed by currents flowing down through the fair weather atmosphere; in the presence of stratiform clouds there, charged layers are formed at their edges. The circuit is completed by currents flowing in the land/sea surface and up to the cloud systems. A model is used for the profile of atmospheric conductivity which varies by seven orders of magnitude from the surface up to the ionosphere. The effects of both negative and positive cloud-to-ground (CG) lightning discharges on the ionospheric potential have been estimated numerically. It is found that -CG lightning around the world contributes only ~7% to maintaining the high ionospheric potential, and that +CG discharges decrease that by ~5%. A typical +CG discharge from a model thundercloud, which has +26 C in a 1 km layer at a height of 5 km and a total charge moment (with its image in the ground) of 700 C.km, has a 30 kA return stroke current, and a significant (~2 kA) continuing current lasting for 90 ms. That discharge decreases the ionospheric potential by ~40 V, whereas the fifteen times more frequent -CG discharges each increase it by a tenth of that amount. Thus, the 0.7 +CG flashes per second globally are equivalent to an average downward current of ~50 A, the ~10 -CG flashes per second globally are equivalent to an upward current of ~70 A, and the net driving effect of lightning on the circuit is small (~2%). Such a +CG discharge also creates an electric field, which exceeds the breakdown field from the ionosphere at 80 km down to ~74 km, ~0.2 ms after the return stroke, so forming a sprite halo, and, some ms later, from ~67 km down to ~55 km at ~60 ms after the discharge, thereby forming a "carrot" sprite. It is estimated that the current flowing in the highly conducting sprite model reduces the ionospheric potential by an extra ~1 V. The ELF/VLF radio fields radiated by both the model lightning and the sprite currents are discussed. Finally, an estimate is made of the thundercloud charge moment for a +CG creating discharge which is necessary to exceed the threshold breakdown field, or the threshold field for negative or positive streamer creation, and therefore to contribute to

the fascinating structures of sprites observed in the mesosphere.

Modeling of Thundercloud Screening Layers: Implications for Blue and Gigantic Jets

[*J A Riousset*] (Department of Electrical Engineering, Communications and Space Sciences Laboratory (CSSL), The Pennsylvania State University, 227 Electrical Engineering East, University Park, PA 16802; ph. 814-863-1780; fax 814-865-7065; riousset@psu.edu); V P Pasko (Department of Electrical Engineering, Communications and Space Sciences Laboratory (CSSL), The Pennsylvania State University, 211B Electrical Engineering East, University Park, PA 16802; ph. 814-865-3467; fax 814-865-7065; vpasko@psu.edu); P R Krehbiel, Physics Department, New Mexico Institute of Mining and Technology, Socorro, NM 87801; ph. 505-835-5215; fax 505-835-5707; krehbiel@ibis.nmt.edu); W Rison (Electrical Engineering Department, New Mexico Institute of Mining and Technology, Socorro, NM 87801; ph. 505-835-5486; fax 505-835-5332; rison@ee.nmt.edu); R J Thomas, Electrical Engineering Department, New Mexico Institute of Mining and Technology, Socorro, NM 87801; ph. 505-835-5683; fax 505-835-5332; thomas@nmt.edu); M A Stanley (114 Mesa Verde Road, Jemez Springs, NM 87025; sparky@mark-stanley.name)

Both normal and anomalous polarity thunderstorms occasionally produce upward propagating discharges called blue jets [Wescott et al., GRL, 22(10), 1995; Sentman and Wescott, Phys. Plasmas, 2(6), 1995; Boeck et al., JGR, 100, 1465, 1995] and gigantic jets [Pasko et al., Nature, 416, 152, 2002; Su et al., Nature, 423, 974, 2003; van der Velde et al., JGR, 112, D20104, 2007], depending on their polarity, their initiation location in the thundercloud and their termination altitude [Krehbiel et al., Nature Geoscience, 1(4), 233, 2008]. Such discharges are initiated by regular lightning leaders escaping the cloud near the top [Petrov and Petrova, Tech. Phys., 44, 472, 1999]. The recent work by Krehbiel et al. [2008] confirmed Petrov and Petrova's [1999] hypothesis and further demonstrated how charge imbalances could be responsible for the initiation and early stages of development of both blue and gigantic jets. Krehbiel et al. [2008] also identified three possible origins of these charge imbalances: occurrence of a cloud-to-cloud discharge, of an unbalancing intracloud discharge, and dissipation of charge due to the atmospheric conductivity. The first two hypotheses were supported by numerical simulations of the thundercloud and new Lightning Mapping Array observations, respectively. The last was suggested as early as the 1920's by C.T.R. Wilson [Phys. Trans. Roy. Soc. London A, 221, 73, 1921] and subsequently investigated in a later publication [Wilson, Proc. R. Soc. London Ser. A, 236, 297, 1956]. In this work, we present a two dimensional axisymmetric model of Maxwellian relaxation of the atmosphere and demonstrate how realistic conductivity profiles combined with experimentally substantiated thundercloud geometries lead to the formation of screening charges near the cloud boundaries, locally reducing the net charge content or forming extra charge layers, ultimately resulting in the initiation of blue and gigantic jets.

The Sharp Transition Between Diffuse and Streamer Regions in Sprites

[*A Luque*] (Centrum voor Wiskunde en Informatica (CWI), P.O. Box 94079, 1090 GB Amsterdam, The Netherlands; luque@cwi.nl); U Ebert (CWI and Dept. Appl. Physics, Eindhoven Univ. Techn., The Netherlands; ebert@cwi.nl)

The initiation of sprites after a lightning discharge is still an open problem. High-speed camera observations clearly indicate that sprite streamers always start propagating downward and only after several milliseconds upward-propagating streamers are observed. Often the streamers emerge from a visible, diffuse halo in the lower edge of the ionosphere; the transition from halo to streamer appears as a sudden transition, localized in a narrow range of about 1 km.

To explain this transition we used numerical simulations with adaptative refinement to capture the wide range of emerging spatial scales, and we introduced a realistic height dependent density profile for air and free electrons. We observe the sprite halo as a wide ionization wave; due to electron attachment the wave front becomes steeper until it collapses into thin, fast streamers. The emerging diameter and velocity of streamers are consistent with observations.

Phase Transition Model of Sprite Halo

[*Y Hiraki*] (Solar-Terrestrial Environment Laboratory, Nagoya University, Furocho, Chikusa-ku, Nagoya, Aichi 464-8601, Japan; ph. +81-52-788-6279; fax +81-52-747-6334; hiraki@stelab.nagoya-u.ac.jp)

Sprites are well known to exhibit various structures such as column, carrot, and tree-like ones. The diffuse emission in the upper part of sprites called halo is associated with electron impact excitation, while each filamentary channel is interpreted to be a streamer formed through an intense electron avalanche under the lightning-induced electric field. We have suggested that the amplitude of the electric field is most sensitive to charge moment and discharge timescale of causative lightning, and the criticalities of halo and streamer are determined by these parameters. We find that the observable halo emission is not expected when the ionospheric electron density decreases severely due to attachment process of non-thermal electrons; the critical discharge timescale is a few milliseconds. We suppose that the situation (no halo and halo) is quite similar to the phase transition, or the critical point, between vapor and liquid states. We perform to derive the order parameter and critical exponent characterizing the "halo" state based on the equilibrium statistical theory. We consider that this kind of formalism is useful in understanding the global distribution of transient luminous events. The phase transition between halo and streamer states is obvious but it is a difficult task to define the order parameter since the number of streamers depends on some ambient conditions. We further discuss a possible model of the transition between column and carrot states using lightning parameters.

Observations of the Lightning-Induced Transient Emissions (LITEs) in the Mesospheric Airglow Layers

[*T-Y Huang*] (Department of Physics, The Pennsylvania State University Lehigh Valley, Fogelsville, PA 18051; ph. 610-285-5100; fax 610-285-5220; tuh4@psu.edu); C Y Chiang (Department of Physics, National Cheng Kung University, Tainan 70148, Taiwan; ph. 886-6-275-7575; fax 886-6-2096035; johnson@plasma.pssc.ncku.edu.tw); A B Chen (Department of Physics, National Cheng Kung University, Tainan 70148, Taiwan; ph. 886-6-275-7575; fax 886-6-2096035; alfred@phys.ncku.edu.tw); H T Su (Department of Physics, National Cheng Kung University, Tainan 70148, Taiwan; ph. 886-6-275-7575; fax 886-6-2096035; htsu@phys.ncku.edu.tw); R R Hsu (Department of Physics, National Cheng Kung University, Tainan 70148, Taiwan; ph. 886-6-275-7575; fax 886-6-2096035; rrhsu@phys.ncku.edu.tw)

We will report observations of lightning-induced transient emissions (LITEs) in the mesospheric airglow layers, specifically the OH and the greenline airglow, observed from the Imager of Sprites and Upper Atmospheric Lightning (ISUAL) onboard the FORMOSAT-II satellite. Observations by the 630-nm narrow-band and the broadband filter show that LITEs occur more frequently in the OH airglow layer than below. It is also found that the observations of LITEs below the OH airglow layer by the narrow-band filter are rare. Observations with the 557.7-nm narrow-band filter are planned and will be analyzed. The observations of LITEs by the narrow-band filters (630 nm and 557.7 nm) will be the first of its kind in existence. The observations will no doubt provide some insight to what extent lightning affects the upper atmosphere.

Modeling Electromagnetic and Quasi-Stationary Electric Fields Following a Lightning Discharge

[*S Davydenko*] (Institute of Applied Physics RAS, 46 Ulyanova Str., Nizhny Novgorod, Russia; ph. +7-831-4164885; fax +7-831-4160616; davyd@appl.sci-nnov.ru); E Mareev, (Institute of Applied Physics RAS, 46 Ulyanova Str., Nizhny Novgorod, Russia; ph. +7-831-4164792; fax +7-831-4160616; mareev@appl.sci-nnov.ru); A Sergeev (Institute of Applied Physics RAS, 46 Ulyanova Str., Nizhny Novgorod, Russia; ph. +7-831-4164901; fax +7-831-4160616; sergeev@appl.sci-nnov.ru)

A numerical model of the electromagnetic field in the vicinity of an isolated thundercloud is developed. Both the quasi-static transient electric fields due to the Maxwell relaxation of the charge transferred during the lightning discharge and the corresponding electromagnetic pulse are calculated in the plane atmosphere using the FDTD method. The lightning flash is modeled as a distributed pulse currents producing dipole charge structure inside the thundercloud in the case of intracloud (IC) flash or monopole charge structure in the case of cloud to ground (CG) flash. A typical time profile of the lightning current is adopted in the model; the fine structure of the current like M-component and J- and K-processes is considered as well. Dependences of the relaxation time and electric charge transferred to the ionosphere on the flash type (IC or CG) and on the parameters of the model (the conductivity profiles inside and outside the thundercloud, its lateral scale, location and size of the charge regions) are considered. The net charge transfer to the upper atmospheric layers is estimated. A calculation of the electromagnetic field associated with a sprite in the framework of the model is discussed. Specific features of diagnostics of the discharge parameters using the observation of both the electromagnetic and quasi-stationary fields are discussed.

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ELF/VLF Signatures of Lightning-ionosphere Interactions and Causative Discharges

[*U S Inan*] (Space, Telecommunications and Radioscience (STAR) Laboratory, Stanford University, Stanford, CA 94305-9515; ph. 650-723-4994; fax 650-723-9251; inan@stanford.edu)

ELF/VLF observations have formed the corner stone of measurement and interpretation of effects of lightning discharges on the overlying upper atmospheric regions, as well as near-Earth space. ELF/VLF wave energy released by lightning discharges is often the agent of modification of the lower ionospheric medium that results in the conductivity and electron density changes and the optical emissions that constitute TLEs. In addition, the resultant ionospheric changes are best (and often uniquely) observable as perturbations of sub-ionospherically propagating VLF signals. In fact, some of the earliest evidence for direct disturbances of the lower ionosphere in association with lightning discharges were obtained in the for of such VLF perturbations. Measurement of the detailed ELF/VLF waveforms of parent lightning discharges that produce TLEs and TGFs have also been very fruitful, often revealing properties of such discharges that maximize ionospheric effects, such as generation intense Electromagnetic Pulses (EMPs) or removal of large quantities of charge. In this paper, we provide a review of the development of ELF/VLF

measurements, both from a historical point of view and from the point of view of their relationship to optical and other observations of ionospheric effects of lightning discharges.

The ASIM Mission for Studies of Severe Thunderstorms

[*T Neubert*] (National Space Institute, Technical University of Denmark, Juliane Maries Vej 30, 2100 Copenhagen O; ph. +45 3532-5731; fax +45 3536-2475; neubert@space.dtu.dk); Victor Reglero (University of Valencia, Spain); Nikolai Østgaard (University of Bergen, Norway); Elisabeth Blanc (Commissariat à l'Énergie Atomique, France)

The Atmosphere-Space Interactions Monitor (ASIM) is an instrument suite to be mounted on an external platform of the European Columbus module on the International Space Station. ASIM will study electric discharge processes of the stratosphere and mesosphere above severe thunderstorms. The instruments include a number of cameras and photometers simultaneously observing transient luminous events (TLEs) in different wavebands and an imaging instrument for detection of terrestrial gamma-ray flashes (TGFs). ASIM is a mission of the European Space Agency (ESA) recently approved for launch in 2013. The talk will present the mission and the preparations of the European science community for ASIM and for the French micro-satellite TARANIS (Tool for the Analysis of RAdiations from lightNIngs and Sprites) expected in operation during the same time frame.

Currents, Charges, and Electromagnetic Fields Associated with TLE Initiation and Development

[*S A Cummer*] (Department of Electrical and Computer Engineering, Duke University, Durham, NC 27708; ph. 919-660-5256; fax 919-660-5293; cummer@ee.duke.edu)

Understanding the quantitative characteristics of the lightning associated with mesospheric transient luminous events (TLEs) gives important insight into and bounds on the processes that drive these phenomena. We will begin with a review of past efforts to measure TLE-producing lightning using remotely measured low frequency electromagnetic fields and the implications of these measurements for theories of their initiation. We will then report our group's recent findings from the joint analysis of high-speed video observations of TLE and ground-level electromagnetic field measurements, which together provide a high time resolution view into the processes associated with TLE initiation and development. The background electric field in which sprites initiate is estimated from remote measurements of the driving lightning current and detailed modeling of the high altitude electromagnetic fields, enabling a comparison with theoretical predictions of the field required to initiate a sprite. This approach is applied to a wide variety of types of sprite including prompt, long delayed, and negative polarity in order to truly assess what specific lightning features are required to create a sprite and how this relates to our current understanding of streamer initiation and propagation.

Ionospheric Effects of Cloud-to-Ground and In-cloud Lightning Discharges

[*R A Marshall*] (STAR Laboratory, Stanford University, 350 Serra Mall, Stanford, CA 94305; ph. 650-725-7396; fax 650-723-9251; ram80@stanford.edu); U S Inan (STAR Laboratory, Stanford University, 350 Serra Mall, Stanford, CA 94305; ph. 650-723-4994; fax 650-723-9251; inan@stanford.edu)

Effects of cloud-to-ground lightning in the lower ionosphere include the optical phenomena known as sprites and elves, as well as heating and electron density perturbations measured via very-low-frequency radio waves. These effects have received a great amount of attention in the past two decades since their discoveries. In this work, we investigate in detail the effects of cloud-to-ground and in-cloud lightning on the lower ionosphere. We use a 3D time-domain model of the electromagnetic pulse due to vertical and horizontal lightning channels, including effects of the ground reflection, to show that a) the geometry of elves can be affected by the Earth's magnetic field, and b) realistic in-cloud lightning channels can produce observable optical emissions. With regards to a), we show that the measured asymmetry of an elve can be used to calibrate the causative lightning stroke, and the duration of optical emissions measured through photometry can yield information about the speed of the causative stroke. We further investigate how the ionospheric effects depend on the lightning channel parameters, such as altitude, orientation, and current pulse speed. We show that a series of horizontal pulses, as might be observed in a spider-lightning event, can produce an electron density perturbation that may be measurable by VLF techniques. These results further explain the recently-discovered "early/slow" VLF perturbation events, which build up over 1-2 seconds, similar to the duration of many spider lightning events. Results are shown in the context of realistic in-cloud discharge amplitudes, and in addition we present a method for calibration of in-cloud lightning bursts using VLF data. "Sferic Bursts" are intense bursts of noise-like VLF radiation that have been correlated with in-cloud lightning. By measuring the envelope amplitude of these bursts and comparing this amplitude to the cloud-to-ground sferic, we find the relative amplitude at the source for the in-cloud discharges, having taken into account the different propagation characteristics to the receiver. In this way the sources used in the EMP model fit within the parameters of measured sferic burst data.

ELF/VLF Signatures of Sprite-Producing Lightning Discharges Observed During the 2005 EuroSprite Campaign

[*Eran Greenberg*] (Department of Geophysics and Planetary Sciences, Tel-Aviv University, Tel-Aviv, 69978 Israel, erangree@post.tau.ac.il); Colin Price (Department of Geophysics and Planetary Sciences, Tel-Aviv University, Tel-Aviv, 69978 Israel, ph.+972-3-6408633, fax+972-3-6409282, price@flash.tau.ac.il); Yoav Yair (Department of Life and Natural Sciences, The Open University, Ra'anana 43107 Israel, ph. +972-9-7781341, fax +972-9-7780626, yoavya@openu.ac.il); Chrsitos Haldoupis (Department of Physics, University of Crete, Heraklion, Crete, Greece, chald@physics.uoc.gr); Olivier Chanrion (National Space Institute, Technical University of Denmark, Copenhagen, Denmark, chanrion@dsri.dk); Torsten Neubert (National Space Institute, Technical University of Denmark, Copenhagen, Denmark, neubert@spacecenter.dk)

During the summer of 2005, transient luminous events were optically imaged from the French Pyrénées as part of the EuroSprite campaign. Simultaneously, ELF (Extremely Low Frequency: 3-3000Hz) and broadband VLF (Very Low Frequency: 3-30 kHz) data were recorded continuously at two separate receivers in Israel, located about 3300 km from the area of the parent lightning discharges responsible for the generation of sprites. Additionally, narrowband VLF data were collected in Crete, at about 2300 km away from the region of sprites.

The motivation for the present study was to identify the signature of the sprite-producing lightning discharges in the ELF and VLF electromagnetic frequency bands, to qualify and compare their parameters, and to study the influence of the thunderstorm activated region on its overlaying ionosphere. For the 15 sprites analyzed, their causative +CG (positive cloud-to-ground) discharges had peak current intensities between +8 and +130 kA whereas their charge moment changes (CMC) ranged from 500 to 3500 C•km. Furthermore, the peak current reported by the Météorage lightning network are well correlated with the amplitudes of the VLF bursts, while showing poor correlation with the CMCs which were estimated using ELF methods.

Additionally, more than one +CG was associated with 6 of the sprites, implying that lightning discharges that produce sprites can sometimes have multiple ground connections separated in time and space. Finally, a significant number of events (33%) an ELF transient was not associated with sprite occurrence, suggesting that long continuing current of tens of msec may not always be a necessary condition for sprite production, a finding which influences the estimation of the global sprite rate based on Schumann Resonance (SR) measurements.

EuroSprite Studies of Early VLF Perturbations Occurring in Relation with TLEs

[*C Haldoupis*] (Department of Physics, University of Crete, Heraklion 71303, Crete, Greece; ph. 30-2810-394222; fax 30-2810-394201; chald@physics.uoc.gr); A Mika (ARGOSS B. V., Markenesse, The Netherlands; mika@argoss.nl)

A Stanford narrow-band VLF receiver has been in operation since 2003 in Crete, Greece (35.310 N; 25.080 E) in order to support the EuroSprite campaigns in southwest Europe run in the framework of a EU research training network project (http://www.dsri.dk/cal/). The Crete VLF station was capable of monitoring several transmitters, some of them chosen in order to provide VLF links that traverse subionospheric regions in the proximity of the areas viewed for transient luminous event detection by the EuroSprite cameras and lightning detection networks. This presentation summarizes several observational findings obtained over the recent years regarding Early VLF events of ionospheric perturbations that occur in relation with sprites. In particular we focus on: 1) the relationship between early VLF perturbations and sprites/elves, 2) a new subcategory of early VLF events, termed early/slow, characterized by long onset duration from 100 ms up to ~ 2 s, and 3) on modeling the early event recoveries in order to obtain estimates of sprite-related electron density increases in the upper D region of the ionosphere.

An Explanation for Parallel Electric Field Pulses Observed Over Thunderstorms

[*M C Kelley*] (School of Electrical and Computer Engineering, Cornell University, Ithaca, NY 14853; ph. 607-255-7425; fax 607-255-6236; mikek@ece.cornell.edu)

Every electric field instrument flown on sounding rockets over a thunderstorm has detected pulses of electric fields parallel to the earth's magnetic field associated with every strike. This paper describes the ionospheric signatures found during a flight from Wallops Island, VA on 2 September 1995. The electric field results in a drifting Maxwellian corresponding to energies up to 1 eV. The distribution function relaxes due to elastic and inelastic collisions, resulting in electron heating up to 4000 K to 5000 K and potentially observable redline emissions and enhanced ISR electron temperatures. The field strength scales with the current in cloud-to-ground strikes and falls off as 1/r with distance. Pulses of both polarities are found, although most electric fields are downward, parallel to the magnetic field. The pulse may be the reaction of ambient plasma to a current pulse carried at the whistler packet's highest group velocity. The charge source required to produce the electric field is very likely electrons of a few keV traveling at the packet velocity. We conjecture that the current source is the divergence of the current flowing at mesospheric heights, the phenomenon called an Elf. The whistler packet's effective radiated power is as high as 25 MW at ionospheric heights, comparable to some ionospheric heater transmissions. Comparing the Poynting flux in the whistler packet with the flux in the earth-ionosphere waveguide at the same distance, an attenuation of 10 db exists, nearly identical to the energy loss attenuation of the Siple transmitter's VLF signal when entering the ionosphere. Here we consider the first attempt to calculate the effects of lightning on the F2 region. Although pulsed electric fields parallel to the geomagnetic field have been observed by every rocket flight over active thunderstorms at thermospheric heights, their existence remains controversial. Studying the disturbance of ionospheric parameters induced by these electric fields facilitates verifying these fields from ground-based ionospheric observations. This study is also important for understanding the kinetics of ionospheric plasma disturbed by pulsed parallel electric fields. These fields can accelerate electrons from pulse to pulse. If the pause between flashes is longer than the electron neutral collision time, electrons are scattered by elastic collisions with neutrals and transformed into thermal electrons with a corresponding electron temperature enhancement. Inelastic collisions of electrons with neutrals will became more important with increased energy and, subsequently, the electron energy distribution (EED) can differ from a Maxwellian distribution. The vibrational excitation of molecular nitrogen is extremely important as a source of inelastic collisions for energy greater than or equal to 2 eV. This vibrational barrier can influence the EED. An electron kinetics model induced by pulsed parallel electric fields in ionospheric plasma is developed here. The accelerated and heated electrons can excite airglow in the F2 region. Excitation of red line emissions is most effective. Red line intensities during thunderstorms are predicted to be much higher than the background intensity. Our model also predicts a significant increase in electron temperature in the F2 region during a strong thunderstorm. Opportunities for observing the ionospheric effects of parallel electric fields induced by lightning are discussed.

Full-Wave Modelling of ELF/VLF Effects

[*N G Lehtinen*] (Department of Electrical Engineering, Stanford University, Stanford, CA 94305; ph. 650-725-6130; nleht@stanford.edu); U S Inan (Department of Electrical Engineering, Stanford University, Stanford, CA 94305; ph. 650-723-4994; inan@stanford.edu)

We use the recently developed full-wave method (FWM) to calculate electromagnetic fields in a horizontally-stratified ionosphere treated as a magnetized plasma. The source currents can have arbitrary vertical and horizontal distributions. The electromagnetic field is calculated both in the Earth-ionosphere waveguide (at arbitrary horizontal distance and direction) and in the ionosphere (as an upward propagating whistler mode wave). The FWM is applied to calculate both the radiation of ELF/VLF waves as well as the long-distance ELF/VLF propagation. Since the FWM is most suited to calculate radiation by harmonically-varying source currents, the transient sources are modelled through their frequency components. The long-distance ELF/VLF propagation is affected by the additional ionization created by the transient events, such as Giant Blue Jets, with the time evolution of electron and ion densities calculated with the use of the five-species ionosphere chemistry model.

Estimation of Charge Distribution in Sprites

[*J Li*] (Department of Electrical and Computer Engineering, Duke University, Box 90291, Durham, NC 27708; ph. 919-660-5232; jl108@ee.duke.edu); S Cummer (Department of Electrical and Computer Engineering, Duke University, Box 90291, Durham, NC 27708; ph. 919-6605256; cummer@ee.duke.edu)

Low frequency radio emission indicates that substantial electric current flows inside sprites. This charge motion, with unknown location and distribution, is related with the detail internal microphysics of sprite development that is connected to the effects sprites create in the mesosphere. Models developed based on electrical and chemical processes can predict the distribution of charges in sprites. However, it is hard to measure the electric fields and charge distribution inside sprites due to their small spatial scale, short temporal scale, and inaccessibility. In this work, we attempt to infer the charge distribution in sprites by combining measurements of lightning radiated magnetic fields, high speed sprite images recorded at 1,000 – 10,000 fps, and numerical simulations. A 2-D FDTD model is used to estimate the lightning-generated background electric fields in mesosphere through measurements of lighting source current waveform. Assuming sprite streamers propagate in the direction of local electric field, we combine this background electric field and streamer propagation direction measured from high speed images to estimate the total ambient electric field at streamer head locations, which is caused by both sprite-producing lightning and adjacent sprite streamers. The charge distribution in different sprite features can be inferred from this total electric field. We also compare this estimated charge distribution with model predicted values. Our result is a step toward constraining the detailed physical and chemical models that can predict the impact of sprites on the mesosphere.

Comparison of Terrestrial Gamma-ray Flashes and Los Alamos Sferic Array Lightning Measurement

[*Xuan-Min Shao*] (MS D436, Space and Remote Sensing, Los Alamos National Laboratory, NM 87545; ph. 505-665-3147; fax 505-664-0362; xshao@lanl.gov); Timothy Hamlin (MS D436, Space and Remote Sensing, Los Alamos National Laboratory, NM 87545; ph. 505-606-0252; fax 505-664-0362; thamlin@lanl.gov); Jeremiah Harlin (MS D436, Space and Remote Sensing, Los Alamos National Laboratory, NM 87545; ph. 505-665-8433; fax 505-664-0362; harlin@lanl.gov); David Smith (Department of Physics, University of California, 1156 High Street Santa Cruz, CA 95064; ph. 831-459-2183; fax 831-459-3043; dsmith@scipp.ucsc.edu)

During the time period from April 2004 to November 2007, Los Alamos Sferic Array (LASA) detected 15 lightning discharge events that were related to terrestrial gamma-ray flashes (TGFs) observed by the RHESSI satellite. Ten of the events were detected by three or more LASA stations and were geolocated with good accuracies. Based on the sferic waveforms, all TGF-related lightning events were found to be normal polarity intracloud discharges that effectively transported negative charge upward inside the cloud. The height for seven of the geolocated events was determined by using the ionosphere reflections of the original sferic signal, and was found mostly in the range of 11-14 km. For all the correlated TGF-sferic cases, TGFs appeared to be associated with precursor, small discharge events, possibly the runaway process that pre-conditioned for the subsequent “big” discharge events. For three classic, LASA detected narrow bipolar events (NBEs), TGFs preceded NBEs by a significant 2-3 ms. In one special case when TGF occurred near a LASA station, peak electric current were estimated for the correlated discharge, and was found at the level of a few hundred amperes.

Global Sprite Occurrence Rates and Distributions Derived from ELF Measurements and Their Seasonal Variations

[*M Sato*] (Department of Cosmosciences, Hokkaido University, Kita-10, Nishi-8, Kita-ku, Sapporo 060-0810, Japan; ph. +81-11-706-2763; fax +81-11-706-2760; msato@ep.sci.hokudai.ac.jp); Y Takahashi (Department of Geophysics, Tohoku University, Aoba, Aramaki, Sendai 980-8578, Japan; ph. +81-22-795-5775; fax +81-22-795-5775; spriteselves@gmail.com); K Yamashita (Department of Geophysics, Tohoku University, Aoba, Aramaki, Sendai 980-8578, Japan; ph. +81-22-795-6536; fax +81-22-795-5775; kozo@pat.geophys.tohoku.ac.jp); H Kase (Department of Geophysics, Tohoku University, Aoba, Aramaki, Sendai 980-8578, Japan; ph. +81-22-795-5776; fax +81-22-795-5775; kase@pat.geophys.tohoku.ac.jp)

In order to study the global sprite occurrence rates and distributions and their seasonal variations, we have analyzed the 1-100 Hz ELF magnetic field waveform data obtained at Syowa station in Antarctica (69.0S, 39.5E), Onagawa in Japan (38.4N, 141.5E), and Kiruna in Sweden (67.8N, 21.1E) for one-year period from September 2003 to August 2004. We have selected totally 1.7x10^5 events of transient Schumann resonance events from the ELF magnetic field waveform data whose amplitude exceeds 40 pT at all stations. Then, the locations of lightning discharges that generate transient Schumann resonance events are estimated by a triangulation method with an estimation error of 0.5 Mm. Using these lightning location data and a sprite occurrence probability derived from ELF and ISUAL measurements, we have estimated global sprite occurrence rates and distributions, and their seasonal variations. Recently, global sprite occurrence distributions derived from the ISUAL optical measurements are also reported. We will present the results of the ELF data analysis first, then we will discuss similarities and differences between the global sprite occurrence distributions derived from ELF data and ISUAL data in detail.

Further Investigations on Subionospheric VLF Perturbations Observed at Suva, Fiji

[*Sushil Kumar*] (School of Engineering and Physics, The University of the South Pacific, Suva, Fiji; ph. +679-3232144; +679-32321511; kumar_su@usp.ac.fj); Abhikesh Kumar (School of Engineering and Physics, The University of the South Pacific, Suva, Fiji; ph. +679-3232145; +679- 32321511; kumar_ab@usp.ac.fj)

This paper deals with early VLF perturbations observed on NWC, NPM, VTX3, and NLK transmitter signals received at Suva for period November 2006-February 2007, both during night and day times. Initial results on typical early/fast events at this station on the signals from NWC and NPM VLF transmitters during November 2006, have been published (Kumar et al. JGR, doi:10.1029/2007JA012734, 2008), which indicated that the early/fast events on both the signals could be observed due to narrow and wide angle scatterings. Particular emphasis is placed upon the percentages of early/fast events produced due to narrow and wide angle scatterings using longer duration (four months) narrow band data. The typical examples of early/slow events will also be presented. The properties and interpretation of these events are discussed in relation to the causative lighting discharges along the transmitter-receiver great circle paths detected by World Wide Lightning Location Network (WWLLN) and broadband data recorded at the site.

Temporal and Spatial Evolution of Intracloud Lightning Associated With Sprite-Producing Positive Cloud-to-Ground Flashes in Northeastern Spain

[*O van der Velde*] (Electrical Engineering Department, Technological University of Catalonia, 08222 Terrassa, Barcelona, Spain; oscar.van.der.velde@upc.edu); J Montanyà (Electrical Engineering Department, Technological University of Catalonia, 08222 Terrassa, Barcelona, Spain; ph. 0034-669-793-316; fax 0034-937-398-236; montanya@ee.upc.edu); S Soula (Université de Toulouse, UPS, CNRS, Laboratoire d'Aérologie, 14 avenue Edouard Belin, F-31400 Toulouse, France; serge.soula@aero.obs-mip.fr); N Pineda (Meteorological Service of Catalonia, Barcelona, Spain; npineda@meteo.cat); O Chanrion (Danish Technical

University, Space Research Institute, Juliane Maries Vej 30, 2100 Copenhagen, Denmark; chanrion@space.dtu.dk)

During the summer and autumn of 2008, multiple sprites have been recorded by low-light video cameras over northeastern Spain, within the range of a SAFIR lightning detection system. The 2007/2008 upgrade of this interferometric system allows better detection efficiency of sprite-related lightning processes and offers in the best cases reasonably detailed horizontal lightning patterns under the optically determined direction of sprites. Remarkable is that +CG flashes, detected by Météorage and LINET systems, are virtually always offset to the side of SAFIR-detected intracloud activity. The detected bursts of intracloud activity occurring between +CG and sprites exhibit speeds of around 10^7 m/s, corresponding with that of recoil leaders.

In Situ Measurements of Electrodynamics Above Thunderstorms: Past Results and Future Directions

[*J N Thomas*] (Physics Program, Bard High School Early College II, Elmhurst, NY, 11373; ph. 206-947-2678; jnt@u.washington.edu); R H Holzworth (Dept. of Earth and Space Sciences, University of Washington, Seattle, WA 98195-1310; bobholz@ess.washington.edu); M P McCarthy (Dept. of Earth and Space Sciences, University of Washington, Seattle, WA 98195-1310; mccarthy@ess.washington.edu)

Transient luminous events (TLES) above thunderstorms such as sprites, halos, and elves require large electric fields in the middle atmosphere. Since this region is below satellite altitudes, sounding rocket and high-altitude balloon campaigns are needed to measure electric fields there. We review results from past in situ campaigns, including rare examples of lightning-driven electric field changes obtained at 75-130 km altitude during a sounding rocket flight from Wallops Island, VA in 1995, and balloon measurements at 30-35 km altitude in the southeast of Brazil in 2002-03. We discuss how these in situ data, when combined with remote sensing data and numerical modeling, have helped to elucidate TLE mechanisms. Specifically, the Wallops Island rocket measurements disagree with the electromagnetic pulse mechanism for elves, while the Brazil balloon observations agree well with the quasi-static electric field mechanism for sprites. However, none of these past campaigns have successfully measured middle atmosphere electrodynamics during an optically confirmed TLE. Thus, we present some future strategies to accomplish in situ measurements of TLEs. This includes light-weight, high-altitude balloon platforms and new sounding rocket techniques.

Conductivity Variations Above Thunderstorms During the ACES 2002 Campaign

[*C L Croskey*] (Department of Electrical Engineering, The Pennsylvania State University, University Park, PA 16802; ph. 814-865-2357; fax 814-863-8457; ccroskey@psu.edu); J D Mitchell (Department of Electrical Engineering, The Pennsylvania State University, University Park, PA 16802; ph. 814-865-2359; fax 814-863-8457; jmitchell@psu.edu); R J Blakeslee (NASA MSFC, National Space Science and Technology Center, 320 Sparkman Dr., Huntsville, AL 35805; ph. 256-961-7962; fax 256-961-7979; rich.blakeslee@nasa.gov); D M Mach (ESSC, The University of Alabama in Huntsville, Huntsville, AL 35899; ph. 256-961-7830; fax 256-961-7979; dmach@nasa.gov); D E Buechler, (NSSTC, The University of Alabama in Huntsville, Huntsville, AL 35899; ph. 256-961-7827; fax 256-961-7979; Dennis.E.Buechler@nasa.gov); R A Goldberg (NASA GSFC, Laboratory for Space Weather, Greenbelt, MD 20771; ph. 301-286-8603; fax 301-286-1648; Richard.A.Goldberg@nasa.gov); W M Farrell (NASA GSFC, Planetary Magnetospheres Laboratory, Code 695, Greenbelt, MD 20771; ph. 301-286-4446; fax 301-286-1683; William.M.Farrell@nasa.gov)

The flights of the NASA ACES (Altus Cumulus and Electrification Study) mission in August 2002 were remotely guided to pass nearby and also overhead several active thunderstorm cells in the southern Florida region. The UAV (Uninhabited Aerial Vehicle) carried instrumentation for observation of both static and dynamic electric fields, the dynamic magnetic fields, and the optical flashes produced by local thunderstorm activity. In addition, a Gerdien condenser instrument mounted beneath the aircraft measured the polar components of electrical conductivity at the ~15 km observation altitude. Ground-support data were provided by the National Weather Service WSR88D (Nexrad) radars located in Key West and Miami, Florida, and by the National Lightning Detection Network (US NLDN). Previous work of the ACES team has shown that if standard model conductivity values are assumed, the upwardly coupled radiated power from a thunderstorm is on the order of ten times larger than the conducted power. In this study we evaluate the connections between the apparent variations in observed electrical conductivity and the relative position of the aircraft to the thunderstorm, as determined by the Nexrad and NLDN data. Such conductivity variations could affect the coupling of energy to the mesosphere.

An Analysis of Sprite-Producing Thunderstorms During 2004/2005 Japanese Winter Sprite Campaign

[*T Suzuki*] (Air Weather Group, Japan Air Self-Defense Force, Ministry of Defense, 2258 Koshizuno-cho, Sakaiminato Tottori, 684-0053, Japan; ph. +81-859-45-0211 ext.285; rekonyanbb@yahoo.co.jp); Y Matsudo (Department of Electronic Engineering, University of

Electro-Communications, 1-5-1 Chofu Tokyo, 182-8585, Japan; ph. +81-42-443-5159; fax +81-42-443-5168; matsudo@whistler.ee.uec.ac.jp); M Hayakawa(Department of Electronic Engineering, University of Electro-Communications, 1-5-1 Chofu Tokyo, 182-8585, Japan; ph. +81-42-443-5159; fax +81-42-443-5168; hayakawa@whistler.ee.uec.ac.jp); K Michimoto(Air Weather Group, Japan Air Self-Defense Force, 1-5-5, Fuchu, Tokyo, 183-8521, Japan; ph. +81-859-45-0211 ext.285; michimoto45@ybb.ne.jp)

A sprite campaign was conducted in the Hokuriku area of Japan during a winter of 2004/2005. Radar, VHF lightning mapping system (SAFIR), field mill network, and ELF observation system were operated during this campaign. The analysis of integrated observations with these various instruments is presented on meteorological and electrical characteristics of parent thunderstorms and lightning discharges of winter sprites. 23 sprite events were captured during the 2004/2005-winter sprite campaign, and 13 of 23 events were observed by all of our instruments. Further we succeeded in triangulation of the sprite position by two CCD cameras only for 4 cases of 13 events. Three of four events had simple column shapes, but another includes simple column and non-column shape. The sprite parent thunderstorms have an area from 100 to 8500 km2 in extent and their echo top altitude were between 3 and 5 km (AGL). Eleven from these thirteen events exhibit long linear lightning channels more than 10 km in extent in the thunderstorms. These thunderstorms have a large stratiform precipitation region embedding in the small convective core or/and large stratiform cloud shield. The lightning channels associated with sprites are found to have developed in the stratiform region, which shows that a large amount of positive charge was removed from the large stratiform region in the thunderstorms. From an analysis of field mill data, we found that some of these thunderstorms would have a large stratiform precipitation region or cloud with inverted or simple mono polar electrical structure. On the other hand, small thunderstorms have an ordinary dipole electrical structure (upper positive and lower negative). The lightning channel seems to have developed only in the convective core. Therefore, the special events were generated by the removal of upper positive charge in the small thunderstorms. This fact shows that some winter small thunderstorms can generate large positive charge associated with sprites.

Non-linear Retrieval of Ionospheric Electron Density Profiles Using FORTE Broadband Data

[*E H Lay*] (Los Alamos National Laboratory, ISR-2, MS D436, Los Alamos, NM 87545; ph. 505-665-6312, fax 505-664-0362, elay@lanl.gov); S Close (Los Alamos National Laboratory, ISR-2, MS D436, Los Alamos, NM 87545; ph. 505-667-8793, fax 505-664-0362, sigrid@lanl.gov); G Bust (ASTRA, San Antonio, TX 78249; ph. 210-877-915, gbust@astraspace.net); A R Jacobson (University of Washington, Dept. of ESS, Seattle, WA 98195; ph. 360-734-5019, abramj@u.washington.edu)

We present results from a non-linear ionospheric removal algorithm applied to FORTE satellite-detected broadband signals. For these signals, the FORTE satellite detects frequency versus time in the 15 to 88-MHz frequency range. In this study, the received-FORTE data originates from two sources: the Los Alamos Portable Pulser (LAPP) and lightning strokes. We use these data in non-linear inversion algorithms to retrieve the electron density profile along the transmitter-receiver path. Non-linear inversion of these 2D data sets is motivated by the goal of being able to estimate the 2D (altitude versus horizontal satellite trajectory) electron density field directly from the FORTE data.

We present preliminary results for two separate non-linear techniques. The first technique uses the Appleton-Hartree equation to fit the dispersion of the signal by using a Downhill-Simplex minimization routine, and, thus, retrieves the electron density profile along the path. For this technique, we verify the fitted output parameters for FORTE signals detected from sources with known locations (LAPP pulses and located lightning strokes). We then use this non-linear ionospheric retrieval algorithm to determine electron density profiles in disturbed ionospheric regions. The second technique makes use of the ionospheric imaging algorithm Ionospheric Data Assimilation Four-Dimensional (IDA4D). IDA4D ingests a wide variety of data sets, both linearly and non-linearly-related to electron density, and applies the principles of data assimilation to retrieve the 4D global electron density field. IDA4D will use a 3D ray-trace forward model and apply iterative non-linear techniques upon the FORTE broadband data. IDA4D will be run in a mode in which the primary data set is FORTE, and also in a mode in which all available data sets, including FORTE, are ingested.

Electromagnetic Parameters Study for Space Weather Research (Micro-satellite “Chibis-M”)

[*S I Klimov*], L M Zelenyi, D I Novikov (Space Research Institute of RAS; Profsoyuznaya 84/32, 117997 GSP-7 Moscow, Russia; ph. +7-495-333-1100; fax +7-495-333-1248; sklimov@iki.rssi.ru); L Bodnar (BL-Electronics; Solymar, Hungary; ph./fax: + 36-309-193-171; bodnarl@bl-electronics.hu); Cs Ferencz, J Lichtenberger (Space Research Group of Eötvös University, Budapest, Hungary; spacerg@sas.elte.hu); V E Korepanov, A Marusenkov (Lviv Centre of Institute of Space Research; Naukova str., 5a, 79000 Lviv, Ukraine; ph./fax: +38-032-263-9163; vakor@isr.lviv.ua)

Plasma-wave experiment onboard the micro-satellite “Chibis-M” is aimed at the solution of fundamental problem - a study of the plasma - wave interrelations, connected with the manifestation of solar - magnetosphere - ionosphere - atmosphere interactions in the ionosphere and the space weather parameters

formation. Specific fundamental problem is the search for universal laws governing transformation and dissipation of plasma - wave energy in the magnetosphere - ionosphere system. The solution of this problem is supposed to achieve using the coordinated research procedure:

1. Study in situ of the fluctuations of electrical and magnetic fields, the parameters of thermal and epithermal plasma in the ionosphere near F layer during different solar and geomagnetic conditions.
2. Study of the geomagnetic and geophysical parameters on the ground-based observatories with the time scales from 10-1 to 10-3 s.
3. Study of the interrelation of electromagnetic phenomena (spectra of ULF/VLF- waves) in different regions of near-Earth space by means of the comparative analysis of the wave measurements carried out simultaneously at different spacecrafts and ground-based geophysical stations.

The principal uniting item of this study is the micro-satellite "Chibis-M" which is now under design in IKI. It will carry a scientific payload allowing simultaneous measuring of all necessary parameters in the frequency band from DC to ULF. Also the payload includes an advanced intelligent onboard data processor allowing both the automated event detection and onboard analysis with the reprogrammable by commends processing algorithm. The total mass of "Chibis-M" micro-satellite including hardware, service systems and scientific instruments is below 40 kg. The launch date and the beginning of the described experimental study are planned for the beginning of 2010. Discussion of the methodical questions of atmospheric lightning discharges study was carried out within the framework ISSI Team: CARNES (Coupling of Atmosphere Regions with Near-Earth Space)

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Runaway Breakdown and Electrical Discharges in Thunderstorms

[*G Milikh*] (University of Maryland, College Park, MD, milikh@astro.umd.edu); R Roussel-Dupré (SciTech Solutions, LLC, 14 Blue Jay Drive, Santa Fe, NM, 87506, 505-471-2101, bobrdnm@comcast.net)

The precise role played by runaway breakdown (RB) in the initiation and development of lightning discharges remains a fundamental research topic under intense investigation. This presentation seeks to set the stage for follow on, more detailed discussions of RB and its various manifestations. In a historical context conventional air breakdown dominated our understanding and interpretation of electrical discharges for a century or more despite the prescient ideas of CTR Wilson [circa 1925-1950] regarding the potential role of energetic particles in the electrical environment of thunderstorms. The notion of thermal runaway was discussed independently in the 1950s and 1960s in the context of fusion plasmas. In the last decade the basic mechanism of RB that involves an avalanche of runaway electrons was introduced as a potential explanation for the persistent measurements of X-rays in association with lightning. Today, the question of how lightning is initiated and subsequently evolves in the thunderstorm environment rests in part on a more fundamental understanding of RB and cosmic rays and the potential coupling to thermal runaway (as a seed to RB) and conventional breakdown (as a source of thermal runaways). In this talk we describe the basic mechanism of RB and the conditions required to initiate an observable avalanche. Feedback processes that fundamentally enhance RB are discussed, as are both conventional breakdown and thermal runaway. Observations that provide clear evidence for the presence of energetic particles in thunderstorms/lightning include gamma ray and X-ray flux intensifications over thunderstorms, gamma ray and X-ray bursts in conjunction with stepped-leaders, terrestrial gamma ray flashes, and neutron production by lightning. Intense radio impulses termed narrow bipolar pulses (or NBPs) provide indirect evidence for RB particularly when measured in association with cosmic ray showers. Our present understanding of these phenomena and their enduring enigmatic character are touched upon briefly.

The Origin and Context of C.T.R. Wilson’s Ideas on Electron Runaway in Thunderclouds

[*E R Williams*] (Parsons Laboratory, MIT, Cambridge, MA 02139 ph. 781-981-3744; fax 781-981-0632; earlew@ll.mit.edu)

Research work by the Scottish physicist C.T.R. Wilson has had a profound and sustained influence on the field of atmospheric electricity. Pioneering contributions, all relevant to this Chapman Conference, include (1) the ground-based analysis of the electrostatic structure of thunderclouds and the use of vertical charge moments, (2) the formulation of the key hypothesis for the maintenance of the global electrical circuit, (3) the prediction of dielectric breakdown in the mesosphere by energetic lightning flashes now recognized as sprites, and most important in the context of this paper (4) the prediction that thunderclouds produce gamma radiation by a process of electron runaway. Very early in his career, Wilson constructed an expansion cloud chamber with initial intention of duplicating the glory phenomenon he had frequently observed from the summit of Ben Nevis. The early cloud chamber work demonstrated that charged particles (small ions) would induce nucleation of water droplets at large super-saturation. Wilson then left the cloud chamber work for an extended period (1915-1921) to study thunderstorms and their electric fields. Following this new exposure, he returned to more quantitative work with the cloud chamber (work for which A.H. Compton and Wilson shared the 1927 Nobel Prize in Physics) in which the tracks of high energy beta particles were studied, including the departures from straight line paths due to collisions. It was at this stage of his career (1924) that he published his ideas on runaway electrons and the possibility that gamma radiation might be produced by the thundercloud.

This paper will examine the ~50 research notebooks of Wilson for further insights on the development of his ideas on the topic of energetic particles, including the years following the 1924 paper when he contrived experimental methods aimed at documenting high energy radiation from lightning discharges.

Relativistic Positron/X-ray Feedback and Thundercloud Electric Fields

[*J R Dwyer*] (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901; ph. 321-674-7208; fax 321-674-7482; jdwyer@fit.edu)

Relativistic positron/x-ray feedback occurs when runaway positrons and/or Compton scattered x-rays propagate to the beginning of a runaway electron avalanche region and generate additional runaway electron avalanches. In such cases, the production of runaway electrons becomes self-sustaining, without the need for external energetic seed electrons from cosmic-rays. The fluxes of runaway electrons plus x-rays and gamma-rays that result from this mechanism can be very large and may provide an explanation for Terrestrial Gamma-ray Flashes (TGFs). In addition, the increased conductivity due to the large amount of ionization provides a powerful discharge mechanism that affects the large-scale electric field inside thunderclouds. In this presentation, the role that the relativistic feedback mechanism plays in gamma-ray production and in determining thundercloud electric fields will be discussed, and calculations based upon Monte Carlo simulations will be presented.

Examining Distribution Functions in Thermal Runaway

[*J J Colman*] (Los Alamos National Laboratory, Group EES-16, Mail Stop D401, Los Alamos, NM 87545; ph. 505-667-3409; fax 505-665-3415; jonah@lanl.gov); R A Roussel-Dupré (SciTech Solutions, LLC, 14 Blue Jay Drive, Santa FE, NM 87506; bobrdnm@comcast.net); L A Triplett (Los Alamos National Laboratory, Group EES-16, Mail Stop F665, Los Alamos, NM 87545; ph. 505-665-3328; fax 505-665-3687; ltriplett@lanl.gov)

Detailed Boltzmann kinetic calculations of the electron distribution functions resulting from Thermal Runaway in a constant electric field and in the absence of a magnetic field will be presented. Thermal Runaway is considered to occur when a thermal electron is accelerated above the 100 eV peak in the dynamical friction force in air and becomes a runaway electron. Note that the critical field for Thermal Runaway is well above that for conventional breakdown, so these processes occur together. We will investigate the role of Runaway Breakdown in situations where Thermal Runaway, as well as conventional breakdown, is occurring. The electric field strengths studied span the range from the threshold for Runaway Breakdown in air (213 kV/m at sea level) through conventional breakdown (~2-3 MV/m at sea level) and exceeding the Thermal Runaway threshold (~ 20-30 MV/m at sea level). Electronic excitation, ionization, and attachment rates will all be investigated as well as optical emissions.

Production of Runaway Electrons in Conventional Electric Discharges

[*O Chanrion*] (National Space Institute, Technical University of Denmark, Copenhagen, Denmark; ph. +45 3532 5781; fax. +45 3536 2475; chanrion@space.dtu.dk); T Neubert (National Space Institute, Technical University of Denmark, Copenhagen, Denmark; ph. +45 3532 5731; fax. +45 3536 2475; neubert@space.dtu.dk)

Bursts of X- and Gamma -rays from the atmosphere above thunderstorms has been recently discovered. The bursts of radiation are thought to be generated by bremsstrahlung from energetic electrons accelerated in electric discharges of the thunderstorm. It has raised new questions relating to the electric discharge. To study the production of such high energy electrons in conventional (thermal) discharges a Particle In Cell plus Monte Carlo Collision with neutral atoms (PIC-MCC) code is used. A 2D cylindrical version of the code allows simulating streamer discharges until a time when the first runaway electrons appear. High energy electrons are seen to create ionization trails of ionization ahead of the streamer which stimulate its branching. In order to improve the precision of the number of runaway electron inside the streamer tip, a 1D version of the code with improved particle resolution in the high energy range is used. It allows calculating the probability for electrons to have energies above the runaway threshold. It is found that the probability of generating runaway electrons is significant even for modest field in the streamer tip.

TGF Observations with the Gamma-ray Burst Monitor on the Fermi Observatory

[*G J Fishman*] (Space Science Department, NASA-Marshall Space Flight Center, Huntsville, AL 35812; ph. 256-961-7691; fax 256-961-7215; fishman@msfc.nasa.gov)

Terrestrial Gamma-ray Flashes (TGFs) have now been detected with four different orbiting spacecraft. The latest observations are being made with the scintillation detectors of Gamma-ray Burst Monitor (GBM) on the Fermi Gamma-ray Space Telescope Observatory (Fermi). Although this experiment was designed and optimized for the observation of cosmic gamma-ray bursts (GRBs), it has unprecedented capabilities for TGF observations, surpassing those of the experiment that discovered TGFs, the BATSE experiment on the Compton Gamma-ray Observatory.

Launched in June 2008 from the Kennedy Space Center, the Fermi-GBM has been detecting about one TGF every four weeks. The thick bismuth germinate (BGO) scintillation detectors of the GBM have now observed photon energies from TGFs at energies up to ~40 MeV. Individual photons are detected with an absolute timing accuracy of 2 microsec. Unlike the BATSE instrument, the GBM data system allows higher counting rates to be recorded and deadtime characteristics are well-known and correctable; thus the saturation effects seen with BATSE are avoided. TGF pulses as narrow as ~0.1ms have been observed with the GBM. Like BATSE (and unlike RHESSI) an on-board trigger is required to detect TGFs. The minimum time window for this trigger is 16ms. A trigger window this wide greatly reduces the number of detected TGFs, since they most often have a much shorter duration than this window, thus reducing the signal-to-background. New on-board trigger algorithms based on detected photon energies are about to be implemented; this should increase the number of TGF triggers. High-energy spectra from TGFs observed with Fermi-GBM will be described.

Production Altitude, Initial Distributions and Time Delays for TGFs When Instrumental Deadtime Effects are Treated Properly

[*N Ostgaard*] (University of Bergen, Allegt 55, N-5007 Bergen, Norway, ph: +4755582794); T Gjesteland (University of Bergen, Norway); P H Connell (University of Valencia, Spain); J Stadsnes (University of Bergen, Norway)

By combining modeling of X-ray propagation through the atmosphere we (Østgaard et al., 2008) analyzed 21 TGF measured by BATSE and concluded: 1) Observed time delays can be explained qualitatively by Compton scattering effects of the Xrays as they propagate through the atmosphere. 2) BATSE TGFs are most likely produced at 10-20 km, but a significant number can be produced at higher altitudes; 30-40 km. 3) The initial X-ray distribution (at the production altitude) is most likely beamed. Both the time delays and the fact that a softening of observed spectra for larger zenith angles support this conclusion.

Since then it has been shown that the BATSE instrument suffered from a significant dead time problem (Grefenstette et al., 2008), i.e., that the electronics of BATSE were not fast enough to process all the pulses from the detector. As many studies based on BATSE measurements, including ours, might be affected by this, we have found a method to identify the TGFs measured by BATSE where the count rates and spectra can be corrected corrected for this effect. We have repeated the analysis and will compare these with our initial results from 2008. We require that the modeled solutions must reproduce both the measured spectrum and time delays.

RHESSI Observations of Terrestrial Gamma-ray Flashes

[*D M Smith*] (Santa Cruz Institute for Particle Physics and Physics Department, University of California, Santa Cruz, 1156 High St., Santa Cruz, CA 95064, USA; ph. 831-459-2183; fax 831-459-5777; dsmith@scipp.ucsc.edu); B J Hazelton and B W Grefenstette (Santa Cruz Institute for Particle Physics and Physics Department, University of California, Santa Cruz); J R Dwyer (Department of Physics and Space Sciences, Florida Institute of Technology); R H Holzworth (Department of Earth and Space Science, University of Washington); and E H Lay (Los Alamos National Laboratory)

The Reuven Ramaty High-energy Solar Spectroscopic Imager (RHESSI) satellite has been in orbit since February, 2002. Since that time, it has detected over 800 terrestrial gamma-ray flashes, providing the largest statistical database for characterizing these events. I will summarize what RHESSI observations have taught us about TGFs since we first found them in the data in 2004. I will emphasize the statistical properties of the RHESSI TGF data set (spectral, temporal, and geographical) by itself and in comparison with lightning as represented by sferics detected by the World-Wide Lightning Location Network (WWLLN).

Thunderstorm Characteristics of RHESSI Identified Terrestrial Gamma-ray Flashes

M E Splitt (Department of Marine and Environmental Systems, Florida Institute of Technology, Melbourne, FL 32901; ph. 321-394-2160; msplitt@fit.edu); S M Lazarus (Department of Marine and Environmental Systems, Florida Institute of Technology, Melbourne, FL 32901; ph. 321-394-2160; slazarus@fit.edu); D Barnes (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901; ph. 321-868-1783; daniel.e.barnes-1@usa-spaceops.com); J R Dwyer (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901; ph. 321-674-7208; fax 321-674-7482; jdwyer@fit.edu); D M Smith(Physics Department and Santa Cruz Institute for Particle Physics, Santa Cruz, CA 95064; ph. 831-459-3032; dsmith@scipp.ucsc.edu); B Hazelton (Physics Department and Santa Cruz Institute for Particle Physics, Santa Cruz, CA 95064; ph. 831-459-3242; bhazelto@physics.ucsc.edu); B Grefenstette (Physics Department and Santa Cruz Institute for Particle Physics, Santa Cruz, CA 95064; ph. 831- 459-3242; bwgref@gmail.com); [*H K Rassoul*] (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901; ph. 321-674-8778; fax 321-674-8864; rassoul@fit.edu)

Recent RHESSI observations suggest that thunderstorms may be the source of terrestrial gamma-ray flashes (TGFs). However, precisely where a TGF occurs within or above the thunderclouds is not known. Furthermore, it is not understood what conditions result in the production of TGFs. In this presentation, we investigate the properties of the thunderstorms that likely produced the TGF. Specifically, RHESSI-identified TGFs that are associated with localized sets of WWLLN lightning flashes are used to isolate specific convective systems within the larger RHESSI footprint. Cloud top thunderstorm characteristics associated with TGFs are examined using an array of satellite platforms. When available, geostationary satellites (e.g. GOES) and TRMM data are used to retrieve cloud top temperature and height estimates of these thunderstorms along with cloud liquid and ice content profiles from the TRMM platform. Additionally, thunderstorms that did not produce observable TGFs (i.e. the null event set) are identified with the aid of the TRMM LIS sensor and are then compared with TGF producing systems.

X-ray Burst in Long Discharges

[*C V Nguyen*] (Department of Electrical Engineering, Group EPS, Eindhoven University of Technology P.O. Box 513, 5600 MB Eindhoven, The Netherlands, ph. +31-40-247-3973, fax +31-40-245-0735, c.v.nguyen@tue.nl); A.P.J. van Deursen (Department of Electrical Engineering, Group EPS, Eindhoven University of Technology P.O. Box 513, 5600 MB Eindhoven, The Netherlands, ph. +31-40-247-4434, fax +31-40-245-0735, a.p.j.v.deursen@tue.nl)

A lightning surge generator generates a high-voltage surge with a 1.2µs rise time. The generator fed a point-plate electrode at 0.5 to 2m gap distances. Various scintillator detectors with different response times recorded multiple bursts of hard radiation in nearly all surges. The bursts were detected over the time span between approximately half of the maximum surge voltage and full gap breakdown. Analyses of the data showed a correlation between the stepping process of the leader development and the onset of the X-ray burst.

A more controlled study into the onset of the X-ray bursts with a pulsed streamer corona source was done. Streamer corona is produced in a wire-plate corona reactor open to ambient air. The width of the driving voltage pulse is less than 2.5 times the primary streamer transit time. Due to these conditions no total spark discharge occurred between the wire and the plate during the plasma discharge. Time resolve measurements showed that X-ray emission occurred only during the early stage of the streamer development, more precisely at the onset of the primary streamer. No X-ray was detected during or after the secondary streamer development. The total X-ray energies detected per voltage pulse ranges from 10 to 42keV.

Simulations of Terrestrial Gamma-ray Flashes from Storm to Satellite

[*B E Carlson*] (Department of Physics, Stanford University, Stanford, CA 94305; ph. 650-723-3789; brantc@stanford.edu); N G Lehtinen (Department of Electrical Engineering, Stanford University, Stanford, CA 94305; ph. 650-723-3582; nleht@stanford.edu); U S Inan (Department of Electrical Engineering, Stanford University, Stanford, CA 94305; ph. 650-723-4994; inan@stanford.edu)

Terrestrial gamma-ray flashes are brief intense bursts of energetic photons observed by satellites in close coincidence with detectable lightning discharge. Despite many theories and deep analysis of nearly all available data, the underlying mechanism whereby lightning discharge occurs coincident with satellite observation of extremely energetic photons is unknown. We present here an integrated model of all aspects of TGF physics from storm to satellite. The model uses parametrized thunderstorm charge and electric field structure to drive analytical and numerical models of the relevant aspects of energetic electron physics and lightning discharge. The static, quasi-static, and dynamic electric fields involved are used to drive analytical and Monte Carlo models of relativistic electron mechanics. Feedback effects of the relativistic electrons on the electrical structure of the storm are included when necessary. The energetic photons produced are tracked throughout their atmospheric interactions and those photons and electrons that escape the atmosphere are compared with satellite observations of TGFs. The implications for existing theories of TGF production will be discussed.

Observations of TLEs and TGFs by RISING Satellite

[*Y Takahashi*] (Department of Geophysics Tohoku University, Aramaki, Aoba-ku, Sendai, Miyagi 980-8578; ph. +81-22-795-5775; fax +81-22-795-5775; yukihiro@pat.geophys.tohoku.ac.jp); SPRITE-SAT project team

RISING satellite,the project name SPRITE-SAT, was successfully launched by HIIA rocket form Tanegashima, Japan on 23 Jan and inserted into the geosynchronous (01-13h meridian) low altitude (665km) orbit. It was developed and fabricated in-house by Tohoku University team with supports by some universities and institutes. The total weight of the satellite is about 50 kg, including 5 kg science mission payloads. There are two scientific objectives in this micro-satellite mission: the first is to identify the generation mechanisms of sprites by investigating their horizontal structures, and the second is to identify the generation mechanisms of TGFs by investigating their location of parent lightning discharge. Lightning and Sprite Imagers (LSI-1 and 2) are CMOS cameras with apixcel format of 512 x 512 , which is directed nadir to take images of the horizontal distribution of sprite elements and area of lightning flash. In order to image lightning emissions, we put a broadband filter in the band of 740 and 830 nm on LSI-1. We install a rather narrow band- pass filter centered at 762 nm on LIS-2. The optics and the detector array altogether yield an effective field of view (FOV) of 27 deg, giving the pixel resolution of less than 620 m from the altitude of 660 km. Wide Field CCD imager (WFC) is a CCD camera with 659 x 494 pixels and the pixel size of 7.4 um, which will image lightning discharge flashes associated with TGF events. WFC is looking at nadir direction and is equipped fish-eye lens to cover the whole visible disk of the earth. The outputs of all cameras are digitized by 10 bit A/D conversion. In order to detect TGFs, terrestrial gamma-ray counter (TGC) which consists of CsI scintillator is installed at the bottom of the spacecraft. TGC can detect gamma-rays with discrete levels of 150, 450, 1000, 2800 keV with a time resolution of 250us. This satellite also has a VLF antenna provided by Stanford University, which receives VLF radiations from lightning discharges at sampling rate of 100kHz. The observation strategy and the latest results will be introduced.

Runaway Breakdown in LF Radio

[*M Fullekrug*] (University of Bath, Centre for Space, Atmospheric and Oceanic Science, Department of Electronic and Electrical Engineering, Bath BA2 7AY, UK; ph. +44 1225 386053; fax +44 1225 386305; eesmf@bath.ac.uk)

Runaway breakdown in the Earth's atmosphere can result in a broadband electromagnetic signal in ULF/ELF/VLF/LF/MF radio. Model calculations and electromagnetic observations are used to estimate the electric field strength that would be observed at large distances on the ground and at satellite heights. Particular attention is given to the transionospheric attenuation of the electromagnetic signal. It is found that that ground based electromagnetic recordings would measure spectral intensities on the order of mV/m/Hz, while at satellite heights of 700 km, the observed spectral intensities would be on the order of uV/m/Hz. The maximum intensity will be observed in direction of the geomagnetic field line.

Localization of the Source of Atmospheric Neutron Flashes Detected in Thunderstorm Atmosphere

[*L P Babich*]; E I Bochkov; I M Kutsyk (Russian Federal Nuclear Center – VNIIEF, Mir av., 37, Sarov, 607188, RF; ph. +7-83130-44598; +7-83130-40425; fax +7-83130-45738; babich@elph.vniief.ru)

For interpreting results of on-ground observations of the neutron flux increases correlated with lightning discharges, Monte Carlo simulations were executed of generation and transport in the atmosphere of the neutrons generated by photonuclear reactions. Vast (of 1 km) source of primary γ-rays was assumed. The universal bremsstrahlung spectrum of relativistic runaway electron avalanche was used for the source. Calculations were executed for the downward γ-ray flux. This implicitly assumes descending electron avalanches. A dependence of the neutron fluence at the altitude Z_{det} above the sea level, at which the detectors were located, was investigated on the altitude of the neutron source location Z_{cl}, the source size, and γ-ray flux angular aperture. The fluence calculated for Z_{det} = 3 km [*Shah et. al.* (1985), Letters to Nature, 313, 773-775] and Z_{cl} = 8-12 km is close to the observational data of Shah et. al. This may indicate that the neutron flashes detected in thunderstorm atmosphere, originated from (γ,n) reactions of the high-energy bremsstrahlung of descending relativistic runaway electron avalanches. For Z_{cl} = 5 km the fluence calculated at $Z_{det} \approx 0$ km is sufficiently large to account for the events of neutron flux increases observed at the sea level [*Shyam and Kaushik (*1999), *JGR*, 104, 6867-6869; *Kujevskii* (2004) Bulletin of the Moscow University, Ser. 3, Physics. Astronomy, 14-16; *Martin* (2009), University of Taubate, UNITAU, Brazil. Private communication]. It is not clear, however, if vast and intensive γ-ray source with photon energies above the (γ,n) threshold (10.5 MeV) could be produced by thunderstorms at so small altitudes.

Modeling RHESSI TGFs as a Distribution of Events with Non-vertical Beams at Various Altitudes

[*B J Hazelton*] (Department of Physics and Santa Cruz Institute for Particle Physics, University of California, Santa Cruz, CA, 95064; ph. 831-459-3242; fax 831-459-5777, bhazelto@physics.ucsc.edu); D M Smith (Department of Physics and Santa Cruz Institute for Particle Physics, University of California, Santa Cruz, CA, 95064; ph. 831-459-2183; fax: 831-459-5777; dsmith@scipp.ucsc.edu); B W Grefenstette (Department of Physics and Santa Cruz Institute for Particle Physics, University of California, Santa Cruz, CA, 95064; ph. 831-459-3242, fax 831-459-5777, bwgref@scipp.ucsc.edu); J R Dwyer (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901; ph. 321-674-7208; jdwyer@fit.edu); E H Lay (Los Alamos National Laboratory, ISR-2 MS D436, Los Alamos, NM 87545; ph 505-665-6312; elay@lanl.gov); R H Holzworth (Department of Earth and Space Science, University of Washington, Seattle, WA, 98195, ph. 206-685-7410; fax: 206-685-3815; bobholz@ess.washington.edu)

The spectrum of RHESSI TGFs has been shown to be consistent with models of relativistic runaway breakdown (Dwyer & Smith, 2005). But the small number of photons detected for each event (< 30 on average) means that many events must be combined together to generate a spectrum to compare with models. Recent work has shown, however, that all RHESSI TGFs do not have the same intrinsic spectrum (Grefenstette et al., 2009, in press) and that TGFs detected close to their source have a different spectrum than TGFs detected at a larger distance (Hazelton et al., 2009). Work on TGFs detected by BATSE also suggests that TGFs are likely to be produced at a range of altitudes (Ostgaard et al., 2008). In addition, the orientation of the electric field that generates the runaway breakdown with respect to the vertical is likely to be different for different TGFs. All this means that a combined spectrum of many RHESSI TGFs needs to be modeled using a distribution of events at different locations with different luminosities, altitudes and tilt angles.

We present such a model developed from Monte Carlo simulations of relativistic runaway breakdown and the subsequent propagation through the atmosphere for many different altitudes and source/satellite geometries. These simulations include the effects of the deadtime that we now know to be present in RHESSI TGFs and the selection effects of the RHESSI trigger algorithm.

Observations of TGFs with AGILE

[*M Marisaldi*] on behalf of the AGILE team (INAF-IASF Bologna, Via Gobetti 101, I-40129 Bologna, Italy; ph. +39 051 6398740; fax +39 051 6398723; marisaldi@iasfbo.inaf.it)

We report the detection of terrestrial gamma-ray flashes (TGFs) with the mini-calorimeter (MCAL) instrument on-board the AGILE satellite. After the onset of the on-board trigger logic on time scales of 16ms and shorter, several events at millisecond time scale have been triggered on-board. A careful analysis allowed us to extract a population of events with characteristics compatible with those of TGFs previously reported by other spacecrafts. Between June 18th 2008 and January 31st 2009 we selected 38 events showing millisecond time scale, large hardness ratio and a geographical distribution peaked over Africa and south-east Asia. We computed the cumulative spectrum for the whole data set, showing a significant emission up to tens of MeV.

Analysis of BATSE TGFs Taking Deadtime Effects Into Account

[*T Gjesteland*] (University of Bergen, Dept. of Physics and Technology, Bergen, Norway; ph. +47-5558-9406; thomas.gjesteland@uib.no); N Ostgaard (University of Bergen, Dept. of Physics and Technology, Bergen, Norway) ; P H Connell (University of Valencia, Spain); J Stadsnes (University of Bergen, Dept. of Physics and Technology, Bergen, Norway)

Due to the very high intensity at the peak of Terrestrial Gamma ray Flashes (TGF), measurements done by the Burst And Transient Source Experiment (BATSE) suffer from deadtime losses. The electronics can not read out the pulses created in the detector fast enough and will therefore loose a significant amount of counts. These losses will influence the spectral and temporal properties of the TGF and it's intensity. This study shows a method to find TGFs where the detector is not totally paralyzed, and the deadtime losses can be corrected for. By using this method we have reanalyzed a subset of TGFs with the corrected count rates to find solutions for production altitude which are consistent with both the observed spectra and time delays. The photon flux that reaches satellite altitudes is also calculated based on the corrected BATSE TGFs.

Transient Luminous Event Phenomena and Energetic Particles Impacting the Upper Atmosphere: Russian Space Experiment Programs

[*M I Panasyuk*] (D V Skobeltsyn Institute of Nuclear Physics, M V Lomonosov Moscow State University, Moscow, 119992, Russia; ph. 07-495-939-1818; fax 07-495-939-0896; panasyuk@sinp.msu.ru); V V Bogomolov (D V Skobeltsyn Institute of Nuclear Physics, M V Lomonosov Moscow State University, Moscow, 119992, Russia) G K Garipov (ibid); Yu I Denisov (ibid); B A Khrenov (ibid); P A Klimov (ibid); L L Lazutin (ibid); S I Svertilov (ibid); N N Vedenkin(ibid); I V Yashin (ibid); S I Klimov (Space Research Institute of Russian Academy of Science, Moscow, Russia), L M Zeleny (Space Research Institute of Russian Academy of Science, Moscow, Russia); V S Makhmutov (Lebedev Physical Institute of Russian Academy of Science, Moscow, Russia); Yu I Stozkov (ibid); N S Svirzhevsky (ibid), V V Klimenko (ibid), E A Mareev (Institute of Applied Physics of Russian Academy of Science, N. Novgorod, Russia); Y V Shlyugaev (Institute of Applied Physics of Russian Academy of Science, N. Novgorod, Russia); V E Korepanov (Institute of Space Research of Ukrainian Academy of Science and National Space Agency, Kiev, Ukraine); I H Park (Research Center of MEMS Space Telescope, Ewha Womans University, Seoul, Korea); H I Salazar (University of Puebla (BUAP), Puebla, Mexico); H Rothkaehl (Space Research Centrum of Poland Academy of Science, Warsaw, Poland)

In Russia several space missions are now planned to study transient luminous events in the atmosphere and high energy charged particles at satellite altitudes. The experimental goal is to investigate the origin of the high energy electrons and gamma-ray quanta for specific transient luminous events (TLEs) and their role in the ionosphere-magnetosphere system. Simultaneous measurements of electrons at the orbit of the satellite and TLE atmospheric radiation in many wavelength bands will be performed in 3 missions: Tatiana-2, Chibis and RELEC. In the TUS mission UV transient event detection will be accompanied by measurements of the weak UV emission from the “seed” electrons of extensive air showers of extreme high primary energies.

Poster Presentation Abstracts

Abstracts are listed alphabetically, by the last name of the presenting author.

Observations of Transient Luminous Events

11 May; 5:00 p.m. – 7:00 p.m.

The Rate of Detection of Transient Luminous Events From Space

[*E Arnone*] (Department of Physical and Inorganic Chemistry, University of Bologna, Viale Risorgimento 4, 40136 Bologna, Italy; ph. +39-051-2093709; fax +39-051-2093690; arnone@fci.unibo.it); M Ignaccolo (Department of Physics, Duke University, Duke Free Electron Laser Laboratory PO Box 90319 (mail), Durham, NC 27708, United States; mi8@phy.duke.edu)

We estimate the probability of detecting transient luminous events (TLEs) from different spaceborne observation systems. As the number of spaceborne missions involving TLE measurements increases, it is important to correctly understanding the representativity of the detections compared to the natural rate of TLE occurrence, and learn how to maximize the detection rate. The detection probability estimates are based on the planetary rate of sprites by Ignaccolo et al. (GRL, 33, L11808, 2006) updated with recent observations. The sensitivity to the adopted assumptions is discussed. Advantages and disadvantages of spaceborne observations compared to equivalent ground-based observations are analyzed in terms of achievable detection rates and meaningfulness of the detected samples.In particular, estimates are calculated for the probability of detecting milliseconds long TLEs within the field of view of spectrometers such as MIPAS or SCIAMACHY onboard the ENVISAT satellite, and that of detecting expected long lasting chemical changes caused by the TLE occurrence.

Investigating Halo Optical Signatures and Associated Lightning Parameters from a Large MCS Over Argentina

[*M A Bailey*] (Trinity College, Hartford, CT 06106; ph. 860-297-5103; fax 860-987-6239; Matthew.Bailey@trincoll.edu); [P-D Pautet] (CASS, Utah State University, Logan, UT 84322-4405; ph. 435-797-8128; fax 435-797-2992; dominiquepautet@gmail.com); M J Taylor (CASS, Utah State University, Logan, UT 84322-4405; ph. 435-797-3919; fax 435-797-2992; mike.taylor@usu.edu); S A Cummer (Department of Electrical and Computer Engineering, Duke University, Durham, NC 27708; ph. 919-660-5256; fax 919-660-5293; cummer@ee.duke.edu); J N Thomas (Bard High School Early College, Elmhurst, NY 11373, ph. 206-947-2678; jnt@u.washington.edu); R H Holzworth (Earth and Space Sciences, University of Washington, Seattle, WA 98195-1310; ph. 206-685-7410; fax 206-685-3815; bobholz@washington.edu)

During a large Mesoscale Convective System (MCS) over Argentina in February, 2006, over 440 transient luminous events (TLEs) were imaged as part of a coordinated measurements campaign from Santa Maria, Brazil (29.4 S, 53.8 W). The optical observations were made using two intensified CCD cameras arranged to view the low elevation sky with overlapping fields of view. This paper focuses on the optical characteristics of well over 150 sprite halo events and their associated polarity and charge moments as determined by an ELF-VLF lightning sensor also deployed at the SSO. Halos are associated with lightning strokes that exhibit prompt charge moment changes, and are formed at altitudes near 80 km, where molecular nitrogen is easily excited to produce the N2 first positive band emissions. Although halos have been associated with both negative and positive lightning strokes, recent satellite measurements suggest that they are mainly associated with negative cloud-to-ground (CG) discharges. The halos that we imaged over Argentina were overwhelmingly associated with positive CGs, although several halos and sprite-halos apparently triggered by negative lightning were also imaged. This presentation will discuss the halo properties, including measurements of their relative brightness, and compare them with their associated impulsive charge moments.

Positive and Negative Gigantic Jets

[*J K Chou*] (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. +886-6-2757575-65212; fax +886-6-2096035; jkchou@phys.ncku.edu.tw); C L Kuo (Institude of Space Science, National Central University, Jhongli, Taiwan; ph. +886-3-4227151-65777; fax +886-3-4224394; clkuo@jupiter.ss.ncu.edu.tw); L Y Tsai (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. +886-6-2757575-65212; fax +886-6-2096035; esthertsay@gmail.com); S C Chang (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. +886-6-2757575-65212; fax +886-6-2096035; pollyce@phys.ncku.edu.tw); L J Lee (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. +886-6-2757575-65212; fax +886-6-2096035; c2493402@phys.ncku.edu.tw); Y J Lee (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. +886-6-2757575-65212; fax +886-6-2096035; yjlee@phys.ncku.edu.tw); A B Chen (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. +886-6-2757575-65264; fax +886-6-2096035; alfred@phys.ncku.edu.tw); H T Su (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. +886-6-2757575-65248;

fax +886-6-2096035; htsu@phys.ncku.edu.tw); R R Hsu (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. +886-6-2757575-65242; fax +886-6-2096035; rrhsu@phys.ncku.edu.tw); H Frey (Space Sciences Laboratory, University of California at Berkeley, USA; ph. 510-643-3323; fax 510-643-2624; hfrey@ssl.berkeley.edu); S Mende (Space Sciences Laboratory, University of California at Berkeley, USA; ph. 510-642-0876; fax 510-643-2624; mende@ssl.berkeley.edu); Y Takahashi (Department of Geophysics, Tohoku University, Japan; ph. +81-22-217-5775; fax +81-22-217- 5775; yukihiro@pat.geophys.tohoku.ac.jp); L C Lee (Institute of Space Science, National Central University, Jhongli, Taiwan; ph. +886-3-4227151-65777; fax +886-3-4224394; loulee@nsc.gov.tw)

From analyzing the ISUAL recorded gigantic jets (GJs), we found that there are two different types of GJs. The first type (type-I) is similar to those reported in the ground observations [Pasko, et al., 2002; Su, et al. 2003]. These GJs start from the cloud top and propagate upward. After the GJ completes the discharge channel that connects the cloud top and ionosphere, it follows by the trailing jet. The data from ISUAL Imager, spectrophotometers (SP), and array photometers (AP) all indicate that the cloud radiate continuous luminance during the trailing-jet stage. The second type of GJs (type-II) begins as a blue luminous event (BLE) that slowly propagates upward and then develops into a gigantic jet. There is no trailing-jet for this type of GJs. We also found that BLEs occurred frequently at the same region before and after the type-II GJs. The ISUAL data shows that type-II GJs are dimmer and their S/N ratio are lower comparing with those for the type-I GJs. During fully-developed stage, type-I GJs averagely are 4.76 times brighter than the type-II.

We propose that these two types of GJs have different discharge polarities. The associated ELF sferics for the ground observed GJs indicates that the type-I GJs are negative cloud-to-ionosphere discharges (-CIs). Since the preceding BLEs cause the leakage of charges and energy in the parent cloud, Type-II GJs are dimmer than the Type-I. Type II GJs are probably comprised of positive streamers (+CIs), similar to those in blue jets [Pasko, 1996].

Formation of Powerful Discharge in the Upper Atmosphere

[*O G Gladysheva*] (Departmant of Astrophysics, Ioffe Physical-Technical Institute, Politeknicheskaya 26, St.Petersburg 194021 Russia; ph. +7-909-593-31-71; fax +7-812-297-10-17; Olga.Gladysheva@mail.ioffe.ru)

The process of explosive destruction of a comet at a height of 7÷10 km over the earth surface was examined. It was shown that during a long fragmentation of a space body two clouds (plains) with unlike charges are formed. One of them consists of positively charged, crushing under heating fragments of the comet body. These fragments are carried to the earth surface by gravitation. The other plain consists of negatively charged aerosol particles (the final stage of crushing of the comet's fragments) which are lifted up by powerful convection currents. Lightnings that take place between these two plains lead to ignition of comet gases evolved during the heating of fragments, subsequent warming-up of the comet's fragments, intensification of their crushing and increasing of convection streams. As a result, we deal with increasing of magnitude of charges in the clouds. When the positive charge carried by larger fragments of the body flows down to the earth the negative uncompensated charge remains over the earth surface. This causes an abrupt increasing of field strength in the upper atmosphere and leads to powerful discharge. During to the Tunguska catastrophe the energy-release of the discharge exceeded 10^{10} J.

Discharge in the Upper Atmosphere during the Tunguska Catastrophe

[*O G Gladysheva*] (Departmant of Astrophysics, Ioffe Physical-Technical Institute, Politeknicheskaya 26, St.Petersburg 194021 Russia; ph. +7-909-593-31-71; fax +7-812-297-10-17; Olga.Gladysheva@mail.ioffe.ru)

On the sunny morning of the Tunguska catastrophe dozens of eye-witnesses from distances of 60÷500 km observed fiery columns ~ 80 km in height which had risen over the place where the space body had disappeared from the scene. Description of those fiery columns resembles the one of a very large lightning. It was found that the point of the explosion which had caused trees to fall down on a considerable territory during the Tunguska catastrophe and the center in which radiation energy had been liberated differ in area and time. The conclusion was made that we deal with two interdependent but different phenomena. The explosive destruction of the Tunguska body over the epicenter zone had taken place considerably before the liberation of radiation energy. The process of the explosive destruction of the space body lasted approximately 2 minutes and was so powerful that it was fixed by some observatories. The source of radiation was engaged in ~ 70 seconds after the beginning of explosive destruction of the space body over the epicenter. The supposition was made that a discharge had served the source of light energy in the Tunguska catastrophe. The eye-witnesses' observations and burns of plants in the epicenter allow to conclude that duration of the discharge was several seconds. Size of the area with lightning destructions of trees in the epicenter of the catastrophe allows to estimate magnitude of the charge, which flowed down from the atmosphere to the ground, as $10^5 \div 10^7$ C. Analysis of remnant magnetization of rock in the epicenter of the Tunguska catastrophe showed that we deal with currents of ~ 10^7 ampere.

Observation of Rotational Temperature of the N2(B) in Sprite

[*T Kanmae*] (Geophysical Institute, University of Alaska Fairbanks, AK 99775-7320; ph. 907-474-7578; fax 907-474-7125; tkammae@gi.alaska.edu); H C Stenbaek-Nielsen (Geophysical Institute, University of Alaska Fairbanks, AK 99775-7320; ph. 907-474-5667; fax 907-474-7125; hnielsen@gi.alaska.edu); M G McHarg (Space Physics and Atmospheric Research Center, US Air Force Academy, CO 80840; ph. 719-333-2460; fax 719-333-3182; matthew.mcharg@usafa.edu)

Sprite spectra were recorded by an imaging spectrograph from the Langmuir Laboratory near Soccoro, NM, in July 2005. Spatially resolved spectra with moderate spectral and temporal resolution of 3 nm and 3 ms respectively allow better evaluation of rotational temperature as well as vibrational distribution in the upper state of the N2 1PG band system. Since rotational relaxation is at most 10 times slower than the rate of translational relaxation, equilibrium between the rotational and kinetic temperature is reached within the 3 ms exposure assuming a neutral collision frequency at 80 km of order 105 Hz. Thus the observed rotational temperature would be a proxy for the kinetic temperature. Spectra from six different sprites were analyzed and the rotational temperatures associated with the N2 1PG band emission were estimated to be <400 K. The observed rotational temperatures are consistent with previous spectral observations using video frame rates (30 fps). No significant difference in the rotational temperature between the upper and the lower portions of sprites was found. Some sprite spectra were recorded in successive frames, but no temporal variation in the rotational temperature was found indicating that sprites are not energetic to heat ambient air enough to thermally excite vibrational energy levels.

Program of Transient UV Event Research at Tatiana-2 Satellite

[*B A Khrenov*] (D V Skobeltsyn Institute of Nuclear Physics, M V Lomonosov Moscow State University, Moscow, 119992, Russia; ph. 07-495-939-5734; fax 07-495-939-1158; bkhrenov@yandex.ru); A V Dmitriev (D V Skobeltsyn Institute of Nuclear Physics, M V Lomonosov Moscow State University, Moscow, 119992, Russia); G K Garipov (D V Skobeltsyn Institute of) Nuclear Physics, M V Lomonosov Moscow State University, Moscow, 119992, Russia); B A Khrenov (ibid); P A Klimov (ibid); L L Lazutin (ibid); I N Myagkova (ibid); A N Petrov (ibid); V L Petrov (ibid); M I Panasyuk (ibid); V I Tulupov (ibid), V M Shahparonov(ibid), A V Shirokov (ibid), N N Vedenkin (ibid), I V Yashin (ibid); J A Jeon (Research Center of MEMS Space Telescope, Ewha Womans University, Seoul, Korea); S M Jeong (Research Center of MEMS Space Telescope, Ewha Womans University, Seoul, Korea); A Jung (ibid); J E Kim (ibid); W S Kim (ibid); J Lee (ibid); H Y Lee (ibid); G W Na(ibid); S W Nam (ibid); S J Oh (ibid); I H Park(ibid); J H Park (ibid); J Y Jin (Department of Electrical Engineering, Seoul National University, Seoul, Korea); M Kim (Department of Electrical Engineering, Seoul National University, Seoul, Korea); Y K Kim (ibid); B W Yoo (ibid); Y-S Park (Department of Astronomy, Seoul National University, Seoul, Korea); H J Yoo (Department of Astronomy, Seoul National University, Seoul, Korea); C H Lee (Department of Physics, Pusan National University, Pusan, Korea); H I Salazar (University of Puebla (BUAP), Puebla, Mexico); O B Martinez (University of Puebla (BUAP), Puebla, Mexico); E L Ponce (ibid); J P Cotsomi (ibid)

In a new Tatiana-2 mission the measurement of temporal (millisecond scale) images of near UV flashes from the Earth atmosphere in nadir direction, their emission spectrum and simultaneous measurement of temporal variation of electron flux at the satellite orbit are planned. Aims of these measurements is to continue research of bright UV flashes, started in the Tatiana-1 mission (“Universitetsky-Tatiana” satellite), to continue research of global distribution of UV flashes, their rate over oceans and continents and to look for possible correlation between UV flashes from the atmosphere and variations of electron flux in the atmosphere-magnetosphere system.

Summer High Latitude Mesospheric Observations of Apparent Supersonic Wind and O(1S) Emission Rate With the UARS/WINDII Instrument and the Association With Sprites, Meteors and Lightning

[*Y S Lee*] (Department of Space Science, York University, Toronto, ON, M3J1P3, Canada; ph. 416-736-2100 x77702; fax 416-736-5817; yslee@yorku.ca); G G Shepherd (CRESS, York University, Toronto, ON, M3J1P3, Canada; ph. 416-736-2100 x33221; fax 416-736-5626; gordon@yorku.ca)

Apparent supersonic winds (SWs) (Mach number <5) with enhanced O(1S) emission rate (100-200 kR limb viewed) are observed at 72-82km altitudes with over 40% occurrence rate above 65°N during summer daytime by the Wind Imaging Interferometer (WINDII) onboard UARS satellite.

The O(1S) emission rate is identified as produced by accelerated electrons in a strong electric field. Theory suggests that an electric field of 25-146 V/m is required to generate a supersonic wind of 825 m/s forced by ion-neutral collisions at 75-85 km, along with apparent PMC peak altitudes in background profiles, below which large phase-shifted interferograms are observed to occur.

Coincidences in space and time between SW profiles and the space-based lightning detection observed at a wavelength of 777.4 nm were found in a limited number of cases, for which the lightning detection has the highest occurrence frequency (2-3.5%) and optical energy (1 J/m^2/sr/µm) in high latitude summer.

In addition, three sets of coincidences between lightning detection and the OH(8-3) P1(3) emission rate enhancement were found at low latitude in summer, which is identified as a sprite signature.

The electric field is thus proposed as originating from daytime sprites at high latitude in summer. Confirmation of the existence of daytime sprites at high latitude is provided through the observation of ``chirps'' in infrasound emissions [Liszka and Enell, 2007]. Sprites may also be triggered by meteors and so frequently occur in the absence of lightning [Liszka and Enell, 2007]. In summary, this study suggests for the first time that during high latitude summer daytime sprites with an optical radiation comparative with lightning are associated with observations of a supersonic wind of enhanced O(1S) emission rate.

Comparison of Sprite-Halo Characteristics Imaged Over the USA and South America

[*L W Petersen*] (CASS, Utah State University, Logan, UT 84322-4405; ph. 435-797-3519; fax 435-797-2992; lance.petersen@aggiemail.usu.edu); M J Taylor (CASS, Utah State University, Logan, UT 84322-4405; ph. 435-797-3919; fax 435-797-2992; mike.taylor@usu.edu); M A Bailey (Trinity College, Hartford, CT 06106, ph. 860-297-5103, Matthew.Bailey@trincoll.edu); J Hayes (CASS, Utah State University, Logan, UT 84322-4405; ph. 435-797-3519; fax 435-797-2992; jesse.hayes@aggiemail.usu.edu); P-D Pautet (CASS, Utah State University, Logan, UT 84322-4405; ph. 435-797-8128; fax 435-797-2992; dominiquepautet@gmail.com); S A Cummer (Department of Electrical and Computer Engineering, Duke University, Durham, NC 27708, ph. 919-660-5256, fax 919-660-5293, cummer@ee.duke.edu)

Sprites and Halos are prominent members of an extraordinary family of Transient Luminous Events (TLE's)_that have been discovered over the past 20 years. Halos are short-lived (few millisecond) diffuse optical emissions that appear as horizontal bright disks suspended briefly above distant thunderstorms. They frequently (but not always) precede the formation of a vertically structured sprite. Although easy to capture using intensified video cameras operating at standard rates (30 frames per second), reports of halos are relatively few and indicate a limited height range centered around approximately 80 km with optical diameters up to about 100 km. Unlike sprite events, which occur almost exclusively in association with large positive cloud-to-ground lightning discharges, halos have recently been observed from satellite in association with both positive and negative discharges. This poster presents an initial comparison of the optical and electrical properties (where known) of a large number of halos and sprite-halos imaged over the U.S. Great Plains and over Northern Argentina in South America. Our goal is to improve current knowledge of their characteristics and variability.

High-Energy Lightning Discharges in Intense Hurricanes

[*N N Solorzano*] (Physics Program, Bard High School Early College II, Elmhurst, NY, 11373; ph. 206-947-1520; nataliansolo@gmail.com); J N Thomas (Physics Program, Bard High School Early College II, Elmhurst, NY, 11373; ph. 206-947-2678; jnt@u.washington.edu); S A Cummer (Dept. of Electrical and Computer Engineering, Duke University, Durham, NC, cummer@ee.duke.edu); R H Holzworth (Dept. of Earth and Space Sciences, University of Washington, Seattle, WA 98195-1310; bobholz@ess.washington.edu)

We examine cloud-to-ground lightning in the inner core of intense hurricanes, with the specific objective of analyzing their potentiality to produce transient luminous events. The motivation for this study comes from our observations of high peak currents and large charge moment changes in numerous discharges located in the inner core region, which is defined as within 100 km from the storm center. In a broader context, we analyze the energetics of lightning during hurricane intensification or weakening processes, since previous works report episodic eyewall lightning outbreaks before or during hurricane intensity variation. In our prior investigations, these outbreaks are observed in the majority of storms of category 3 or greater on the Saffir- Simpson Hurricane Scale.

The World Wide Lightning Location Network (WWLLN), the only real-time network that covers the entire globe, is used to analyze the lightning activity during the lifespan of hurricanes. The polarity and energetics of these discharges is calculated using data from a broadband ELF/VLF sensor system operated by Duke University.

Our preliminary results show a predominance of positive polarity during landfall events. In the 2005 hurricanes Rita and Katrina, hundreds of discharges were potential generators of elves, with peak currents above 50 kA. In the same storms, tens of discharges had charge moment changes above the typical threshold necessary for sprite production. In short, these results indicate that the investigated hurricanes could be important drivers of transient luminous events that electromagnetically couple the lower and the middle atmosphere.

Airborne Image Measurements of Elves Over Southern Europe

M J Taylor (CASS, Utah State University, Logan, UT 84322-4405; ph. 435-797-3919; fax 435-797-2992; mike.taylor@usu.edu); [*P-D Pautet*] (CASS, Utah State University, Logan, UT 84322-4405; ph. 435-797-8128; fax 435-797-2992; dominiquepautet@gmail.com); L C Gardner (CASS, Utah State University, Logan, UT 84322-4405; ph. 435-797-8231; fax 435-797-2992; larry.gardner@usu.edu);C Price (Department of Geophysics and Planetary Sciences, Tel Aviv University, Israel, ph. +972-3-6406029, fax +972-3-6409282, cprice@flash.tau.ac.il); S Abe (Department of Earth and Planetary Science, Faculty of Science, Kobe University, Kobe, Japan, ph. +81-78-803-6566, fax +81-78-803-6483, avell@kobe-u.ac.jp); H Yano (Institute of Space and Astronautical Science/ Japan Aerospace Exploration Agency, Japan, ph. +81-42-759-8197, fax +81-42-759-8457, yano@isas.jaxa.jp); P Jenniskens (SETI Institute, Mountain View, CA 94043 ; ph. 650-810-0216 ; fax 650-962-9419; pjenniskens@mail.arc.nasa.gov)

Elves appear as rapidly expanding horizontal disks of light at the base of the night-time ionosphere due to the absorption of electromagnetic pulse (EMP) energy generated by powerful cloud-to-ground (CG) lightning discharges (with peak currents typically >80 kA). They were first postulated in 1993 to explain unusual transient limb “brightenings” observed at mesospheric airglow heights (~90 km) from the Space Shuttle, and subsequently were measured using ground-based high-speed mapping array photometers (Fukunishi et al., 1996). Elves occur within a few hundred μs of the parent lightning discharge, well ahead of the onset of sprite emissions. Modeling and recent satellite measurements have shown that they can attain a diameter of a few to several hundred kilometers and usually exhibit a characteristic “donut shape” with a dark central hole (for a near vertical CG). To date, most elve studies have been performed using specialized narrow-field photometer arrays (e.g. Barrington-Leigh et al., 2001) that are capable of measuring their temporal evolution during their very short lifetimes (<0.5 ms), but not their integrated two-dimensional structure.

Here we report an exceptional set of airborne measurements of elves (and sprites) imaged over southern Europe using intensified video cameras operating at standard video frame rates (30 fps). The serendipitous observations were made during the NASA Leonid-MAC Airborne Campaign on the night of 17/18 November, 1999 over a period of ~1 hour close to the peak of the Leonids meteor storm. These observations predate more recent satellite studies, and provide important new information on the occurrence, scale-sizes, polarity and association of 18 distinct elves with two isolated, early winter-time storms over the Dalmatian coast.

Blue Jets Over Tropical Cyclones

[*L Y Tsai*] (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. +886-6-2757575-65212; fax +886-6-2096035; esthertsay@gmail.com); S M Huang (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. +886-6-2757575-65276; fax +886-6-2096035; simonh@phys.ncku.edu.tw); Alfred Chen (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. +886-6-2757575-65264; fax +886-6-2096035; alfred@phys.ncku.edu.tw); L J Lee (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. +886-6-2757575-65212; fax +886-6-2096035; c2493402@phys.ncku.edu.tw); S C Chang (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. +886-6-2757575-65212; fax +886-6-2096035; pollyce@phys.ncku.edu.tw); J K Chou (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. +886-6-2757575-65212; fax +886-6-2096035; jkchou@phys.ncku.edu.tw); C M Chen (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. +886-6-2757575-65276; fax +886-6-2096035; airosprey@phys.ncku.edu.tw); H T Su (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. +886-6-2757575-65248; fax +886-6-2096035; htsu@phys.ncku.edu.tw); R R Hsu (Department of Physics, National Cheng Kung University, Tainan, Taiwan; ph. +886-6-2757575-65242; fax +886-6-2096035; rrhsu@phys.ncku.edu.tw); C L Kuo (Institude of Space Science, National Central University, Jhongli, Taiwan; ph. +886-3-4227151-65777; fax +886-6-2096035; clkuo@jupiter.ss.ncu.edu.tw); C C Wu (Department of Atmospheric Sciences, National Taiwan University, Taipei, Taiwan; ph. +886-2-23632303; fax +886-2-23632303; cwu@typhoon.as.ntu.edu.tw); P S Lin (Department of Atmospheric Sciences, National Taiwan University, Taipei, Taiwan; ph. +886-2-33663916; fax +886-2-23633642; polin@ntu.edu.tw); Robert Holzworth (Department of Earth and Space Sciences, and Physics, University of Washington, Seattle, USA; ph. +1-202-685-7410; fax +1-202-685-3815; bobholz@washington.edu); Harald U Frey (Space Sciences Lab, University of California, Berkeley, USA; ph. +1-510-643-3323; fax +1-510-643-2624; e-mail: hfrey@ssl.berkeley.edu); Stephen B. Mende (Space Sciences Lab, University of California, Berkeley, USA; ph. +1-510-642-0876; fax +1-510-643-2624; mende@ssl.berkeley.edu); Yukihiro Takahashi (Department of Geophysics, Tohoku University, Sendai, Japan; ph. +81-22-795-5775; fax +81-22-795-5775; yukihiro@pat.geophys.tohoku.ac.jp); L C Lee (Institude of Space Science, National Central University, Jhongli, Taiwan; ph. +886-3-4227151-65777; fax +886-6-2096035; loulee@nsc.gov.tw)

The ISUAL observation indicates that tropical cyclones seem preferentially harboring blue jets. Of the 996 blue jets registered by ISUAL between 1 January 2005 and 1 October 2008, 84% of them were found to occur in succession. Furthermore, of the blue jets occurred in succession, more than 30% of them were associated with tropical clones. For case studies, we present cyclone systems in two regions: the West Pacific near Taiwan and the Australia region, owing to the interesting geographic comparison, the availability of the meteorological data, and the usually high blue jet occurrence rate. We utilize data from the Lulin magnetic-ELF system, WWLLN and ISUAL imager to look for the possible causes behind the usual high concentration of blue jets near the tropical cyclones. The most interesting case maybe is Typhoon Fungwong (July 27, 2008), which features rapid and successive interactions between blue jets (positive streamers) and two types of lightning (intra-cloud and negative cloud-to-ground ones). Current evidence indicates that both ICs and wind shear could produce charge imbalance which favor the occurrence of blue jets.

The Spatial Organization of Column Sprite Elements Associated with Eastern Mediterranean Winter Thunderstorms

[*Yoav Yair*] (Department of Life and Natural Sciences, The Open University, Ra'anana 43107 Israel, ph. +972-9-7781341, fax +972-9-7780626, yoavya@openu.ac.il); Elyakom Vadislavsky (Department of Atmospheric Sciences, The Hebrew University of Jerusalem, Jerusalem, 91904 Israel, elyakom.vadislavsky@mail.huji.ac.il); Carynelisa Erlick (Department of Atmospheric Sciences, The Hebrew University of Jerusalem, Jerusalem, 91904 Israel, ph. +972-2-6584974, fax +972-2-5662581, caryn@vms.huji.ac.il); Colin Price (Department of Geophysics and Planetary Sciences, Tel-Aviv University, Tel-Aviv, 69978 Israel, ph. +972-3-6408633, fax +972-3-6409282, cprice@flash.tau.ac.il); Roy Yaniv (Department of Geophysics and Planetary Sciences, Tel-Aviv University, Tel-Aviv, 69978 Israel, royya@012.net.il); Eran Greenberg (Department of Geophysics and Planetary Sciences, Tel-Aviv University, Tel-Aviv, 69978 Israel, erangree@post.tau.ac.il) and Na'ama Reicher, Department of Geophysics and Planetary Sciences, Tel-Aviv University, Tel-Aviv, 69978 Israel, naama_reicher@walla.com)

We report observations of sprites during the winter of 2007-8 optical ground-based campaign in Israel. Transient luminous events (TLEs) above winter thunderstorms approaching Israel and the eastern coastline of the Mediterranean Sea were observed from two sites simultaneously. The sites were the Hebrew University in Jerusalem (800 MSL) and either the Tel-Aviv University campus in Ramat Aviv (20 MSL) or the Wise observatory in the Negev desert (900 MSL). Based on several events we show that the elements of columniform sprites are organized in spaced intervals on the circumference of a circle centered directly above, or with some offset to, the vertical direction above the parent lightning. In two-dimensional images, most of the cases show columns to be arranged in highly eccentric elliptical forms or in straight rows. This effect is caused by the angle of observation to the sprite which distorts the circular arrangements. The analysis of the optical images provided the geometrical dimensions of the columns and their spatial organization. We used a 3D numerical model of the quasi-electrostatic field between the thundercloud and the ionosphere to show that with reasonable assumptions on the location and magnitude of the cloud charge center, constrained by ELF evaluation of the Charge Moment Change in the parent flash and meteorological information on cloud dimensions in Mediterranean winter thunderstorms, the observed diameter of the columns arrangement closely matches the field line contour of the critical electrical breakdown at the sprite altitude.

Development of Multi-Band Filter Photometer Onboard the TARANIS Satellite

[*K Yoshita*] (Department of Cosmosciences, Hokkaido University, Kita-10, Nishi-8, Kita-ku, Sapporo 060-0810, Japan; ph. +81-11-706-2763; fax +81-11-706-4688; yoshita@ep.sci.hokudai.ac.jp); M Sato (Department of Cosmosciences, Hokkaido University, Kita-10, Nishi-8, Kita-ku, Sapporo 060-0810, Japan; ph. +81-11-706-2763; fax +81-11-706-2760; msato@ep.sci.hokudai.ac.jp); M Suzuki (ISAS/JAXA, 3-1-1 Yoshinodai, Sagamihara 229-8510, Japan; ph. +81-42-759-8575; m-suzuki@isas.jaxa.jp); Y Takahashi (Department of Geophysics, Tohoku University, Aoba, Aramaki, Sendai 980-8578, Japan; ph. +81-22-795-5775; fax +81-22-795-5775; spriteselves@gmail.com); T Farges (Commissariat Energie Atomique, Bruyeres-le-Chatel, France; thomas.farges@cea.fr); E Blanc(Commissariat Energie Atomique Bruyeres-le-Chatel, France; Elisabeth.BLANC@cea.fr)

TARANIS (Tool for the Analysis of RAdiations from lightNIngs and Sprites) is a French micro-satellite mission and will be launched in 2012 in order to investigate transient luminous events (TLEs), terrestrial gamma-ray flashes (TGFs) and lightning discharges. TLEs, such as sprites, elves and blue jets, are lightning-associated transient optical flashes occurring above thunderclouds. Though the quasi-electrostatic field model (QE model) is a most reliable generation mechanism of sprites, it is suggested that recent observational results may not be explained by the model perfectly. Recent satellite observations of TGFs revealed that the occurrence distributions of TGFs are strongly correlated with those of lightning discharges. However, the relationships between the TGF occurrences, TLE occurrences, and micro processes of their parent lightning discharges are still not clear. Then, TARANIS satellite will find hints to solve them. We are developing a multi-band filter photometer that is one of the optical instruments onboard the TARANIS satellite. The photometer consists of four channels (150-280nm, 337+/5nm, 762.5+/-5nm, 600-900nm) to measure the absolute optical intensity of lightning discharges and TLEs. We have fabricated a breadboard model (BBM) of the photometer and have carried out calibration experiments. Based on these tests, we determine the specification of the engineering model (EM) of the photometer. We will present calibration results of BBM and introduce the EM specification of the photometers in detail.

Theory of Transient Luminous Events

11 May; 5:00 p.m. – 7:00 p.m.

Similarity Properties of Discharges in Preheated Air at Ground Pressure and in Transient Luminous Events

[*Zdenek Bonaventura*] (Ecole Centrale Paris, EM2C laboratory, Grande voie des vignes, 92295 Chatenay-Malabry, France, ph. 33-1-41-13-10-57, fax 33-1-47-02-80-35, zdenek.bonaventura@em2c.ecp.fr); Anne Bourdon (Ecole Centrale Paris, EM2C laboratory, Grande voie des vignes, 92295 Chatenay-Malabry, France, ph. 33-1-41-13-10-46, fax 33-1-47-02-80-35, anne.bourdon@em2c.ecp.fr); Sebastien Celestin (Department of Electrical Engineering, Communications and Space Sciences Laboratory (CSSL), The Pennsylvania State University, 227 Electrical Engineering East, University Park, PA 16802-2706, ph. 814-863-1780, fax 814-865-7065, sebastien.celestin@psu.edu); Ningyu Liu (Physics and Space Sciences, College of Science, Florida Institute of Technology, 150 West University Boulevard, Melbourne, FL 32901-6975, ph. 321-674-7348, nliu@fit.edu; Victor Pasko (Department of Electrical Engineering, Communications and Space Sciences Laboratory (CSSL), The Pennsylvania State University, 211B Electrical Engineering East, University Park, PA 16802-2706, ph. 814-865-3467, fax 814-865-7065, vpasko@psu.edu)

Plasma discharges at atmospheric pressure have received renewed attention in recent years in regards of their ability to enhance the reactivity of a variety of flows for applications ranging from surface treatment to the crucial issue of lean flame stabilization and ignition for aeronautical or automotive engines. Among the different types of discharges at atmospheric pressure, ultrashort (nanosecond) repetitively pulsed discharges are particularly promising. Experimentally, synergy effects between successive pulses to create active species (e.g. atomic oxygen) in the reacting flow have been observed. To better understand the diffuse and filamentary regimes of these transient discharges, we have carried out a numerical study of the discharge structure in preheated air. In this work, first, we compare the calculated optical emissions from these discharges with experimental results and with pressure scaled optical emissions from high altitude discharges. Second, we carry out a parametric study on the influence of the change of voltage, gas temperature, radius of curvature of electrodes on the discharge regimes to derive similarity properties of these discharges. Special emphasis is placed on documentation of the effects of changes in ambient air temperature on discharge morphology and optical emissions for pressures ranging from ground pressure to the very low (by a factor of 10000) pressures at altitudes of transient luminous events.

Air Heating Associated with Ground Pressure Discharges and Transient Luminous Events

[*Anne Bourdon*] (Ecole Centrale Paris, EM2C Laboratory, Grande Voie des Vignes, 92295 Chatenay-Malabry, France; ph. 33-1-41-13-10-46; fax 33-1-47-02-80-35; anne.bourdon@em2c.ecp.fr); Victor Pasko (Department of Electrical Engineering, Communications and Space Sciences Laboratory (CSSL), The Pennsylvania State University, 211B Electrical Engineering East, University Park, PA 16802-2706; ph. 814-865-3467; fax 814-865-7065; vpasko@psu.edu)

The visual appearance of a subset of recently observed transient luminous events in the middle atmosphere, which originate from thundercloud tops indicate that these events may be related to conventional lightning leader processes and therefore are associated with significant heating of the air in the regions of atmosphere through which they propagate. In parallel, in recent laboratory experiments on transient nanosecond pulsed discharges in preheated air, a discharge regime with significant gas heating has been observed. In this work, we have developed a zero-dimensional model with a detailed kinetic mechanism for air to investigate effective time scales of air heating associated with streamer discharges at ground pressure and at high altitudes. In particular, we discuss scaling properties of physical processes involved in the air heating in streamer channels as a function of air pressure and gas density.

The Effect of Ionospheric Superrotation on the Atmosphric Electric Field

[*S Davydenko*] (Institute of Applied Physics RAS, 46 Ulyanova Str., Nizhny Novgorod, Russia; ph. +7-831-4164885; fax +7-831-4160616; davyd@appl.sci-nnov.ru)

An exact solution for the electric field and current in the vicinity of the rotating magnetized planet surrounded by the non-rigidly rotating plasma envelope is obtained. The case of the arbitrary radial profile of the envelope angular velocity is considered. Obtained solution is used to determine the electric field in the lower atmosphere (due to the planetary electric generator effect) in the case of a superrotation of the ionospheric layer which means the forward flow of the ionospheric layer as compared to the Earth's rotation; modern estimates of the relative angular velocity of this flow vary form 0.02 to 2. The ranges of the superrotating layer parameters (its thickness, conductivity, angular velocity) are determined when the radial electric field at the Earth surface is determined either by the relative motion of the magnetospheric plasma or by the ionospheric flows. The induced electric field near the Earth surface is about the ratio of the unipolar potential and the scale height of the atmosphere and can be as large as tens kilovolts per meter. An exact estimate of the superrotation effect on the atmospheric electric field is impeded by the absence of reliable data on both the thickness and angular velocity of the ionospheric layer. Nevertheless, the results show that a presence of the superrotating

ionospheric layer always decrease the atmospheric electric field induced by the magnetospheric plasma motion up to reverse of the polarity of the electric field. For example, if the thickness of the ionospheric layer is about 1000 km, the field in the lower atmosphere decreases up to 81% of the undisturbed value under the relative velocity of the ionospheric flow 0.02 and up to 63% under the relative velocity of the ionospheric flow 2. The further development of the model is discussed.

Numerical Simulations of Volumetric Discharges Above Thunderclouds Correlated with Large Variations of Thundercloud Dipole Moment with Applications to Sprites

L P Babich; A Y Kudryavtsev; I M Kutsyk (Russian Federal Nuclear Center – VNIIEF, Mir av., 37, Sarov, 607188, RF; ph. +7-83130-65092; fax +7-83130-45738; kay@sar.ru; babich@elph.vniief.ru)

2D numerical simulations were carried of volumetric discharges above thunderclouds with large charges located in the troposphere. The obtained results prove conclusions of analyzes published by Cummer and Lyons [JGR 110 A04304, doi:10.1029/2004JA010812, 2005] according to which Sprites are correlated with large thundercloud charge moment variations caused by lightning.

Comparison Between Sprite Streamer Modeling and ISUAL Multi-Wavelength Measurements

[*N Y Liu*] (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901, USA; ph. 321-674-7348; nliu@fit.edu); V P Pasko (Department of Electrical Engineering, The Pennsylvania State University, University Park, PA 16802, USA; ph. 814-865-3467; vpasko@psu.edu); H U Frey (University of California at Berkeley, Space Sciences Laboratory, Berkeley, CA 94720, USA; ph. 510-643-3323; hfrey@ssl.berkeley.edu), S B Mende (University of California at Berkeley, Space Sciences Laboratory, Berkeley, CA 94720, USA; ph. 510-642-0876; mende@ssl.berkeley.edu), A B Chen (National Cheng Kung University, Physics Department, Tainan 70101, Taiwan; ph. 886-6-2757575; alfred@phys.ncku.edu.tw), H T Su (National Cheng Kung University, Physics Department, Tainan 70101, Taiwan; ph. 886-6-2757575; htsu@energy.phys.ncku.edu.tw), R R Hsu (National Cheng Kung University, Physics Department, Tainan 70101, Taiwan; ph. 886-6-2757575; rrhsu@energy.phys.ncku.edu.tw), L C Lee (National Central University, Institute of Space Science, Jhongli 32001, Taiwan; ph. 886-2-27377500; loulee@ncu.edu.tw)

Streamer discharge theory has been successfully applied to explain the filamentary structures observed in sprites [e.g., Pasko et al., GRL, 25, 2123, 1998; Stanley et al., GRL, 26, 3201, 1999; Gerken et al., GRL, 27, 2637, 2000]. Modeling results on positive and negative sprite streamers under the influence of external electric fields of various strength have been reported in [Liu and Pasko, JGR, 109, A04301, 2004; Liu and Pasko, GRL, 32, L05104, 2006; Liu et al., GRL, 33, L01101, 2006; Liu and Pasko, GRL, 34, L16103, 2007]. The ISUAL instruments on the FORMOSAT-2 satellite [Chern et al., JASTP, 65, 647, 2003] provide multiwavelength observations of transient luminous events (TLEs) from space. The ISUAL data provide important new knowledge about TLEs, including the information on the energetics of electrons and the driving field in sprites [e.g., Kuo et al., GRL, 32, L19103, 2005; Liu et al., 2006; Adachi et al., GRL, 33, L17803, 2006], and the detailed morphologies of elves and their ionization effects on the lower ionosphere [e.g., Mende et al., JGR, 110, A11312, 2005; Kuo et al., JGR, 112, A11312, 2007]. For the work reported by Liu et al. [2006], we conducted a single case study by comparing modeling results of a positive streamer with ISUAL spectrophotometric data of a sprite event. In this talk, we report our comparison results of additional case studies. The results indicate that the ratios of different emissions obtained from the streamer model and from ISUAL observations are in agreement with streamers developing in electric fields with magnitudes close to the conventional breakdown threshold field. The results support the sprite theory proposed by Pasko et al. [JGR, 102, 4529, 1997] that sprites are caused by conventional breakdown of air when the lightning field in the upper atmosphere exceeds the local breakdown threshold. The results are also in agreement with a recent study comparing the video observations of sprites and the lightning fields computed using the realistic current moment measurements of the causative lightning discharges [Hu et al., JGR, 112, D13115, 2007].

NOx Production by Laboratory Simulated TLEs

[*H Peterson*] (NASA-Marshall Space Flight Center 320 Sparkman Drive Huntsville, AL 35805; ph. 256-961-7634; fax 256-961-7979; peter188@unr.nevada.edu); M Bailey (Desert Research Institute 2215 Raggio Parkway Reno, NV 89512; bailey@dri.edu); J Hallett (Desert Research Institute 2215 Raggio Parkway Reno, NV 89512; hallett@dri.edu); W Beasley (University of Oklahoma School of Meteorology120 David L Boren Blvd Suite 5900 Norman, OK 73072; whb@ou.edu)

This research examines nitrogen oxides (NOx) produced in the middle atmosphere by transient luminous events (TLEs), which are transported to the polar stratosphere via the global meridional circulation and downward diffusion. A pressure-controlled discharge chamber was used to simulate middle atmosphere pressures, while a power supply and in-chamber electrodes were used to simulate TLEs in the pressure controlled environment. Chemiluminescence NOx analyzers were used to sample NOx produced by the chamber discharges. Total NOx production for each discharge as well as NOx per ampere of current and NOx per Joule (J) of discharge energy were calculated. Absolute NOx production was greatest for discharge environments with upper tropospheric pressures (100-380 torr), while NOx/J was greatest for discharge environments with stratospheric pressures (around 10 torr). The different production efficiencies in NOx/J as a function of pressure pointed to three different production regimes, each with its own reaction mechanisms: one for tropospheric pressures, one for stratospheric pressures, and one for upper stratospheric to mesospheric pressures (no greater than 1 torr). Using NOx per cubic meter and per J, global annual average sprite NOx production was determined to be between 2.6x1030 and 1.4x1031 molecules per year.

Modelling Positive and Negative Streamers in Air: Propagation and Electrodynamic Interaction

[*Valeria Ratushna*] (Center for Mathematics and Computer Science, P.O. Box 94079, 1090 GB Amsterdam, The Netherlands, ph. +31-(0)20-5924208, fax +31-(0)20-5924200, V.Ratushna@cwi.nl); Alejandro Luque (Center for Mathematics and Computer Science, P.O. Box 94079, 1090 GB Amsterdam, The Netherlands, ph. +31-(0)20-5924208; fax +31-(0)20-5924200, A.Luque@cwi.nl); Ute Ebert (Center for Mathematics and Computer Science, P.O. Box 94079, 1090 GB Amsterdam, The Netherlands, and also in Dept. Applied Physics, Eindhoven University of Technology, 5600 MB Eindhoven, The Netherlands, ph. +31-(0)20-5924206, fax +31-(0)20-5924200, Ute.Ebert@cwi.nl)

Streamers are growing filaments of plasma governed by localized space charge regions. We simulate streamers in air at standard temperature and pressure emerging from a needle electrode and propagating towards a planar electrode. In a search for a reduced electrodynamic model, we characterize the streamer evolution by its length, velocity, head radius, head charge and maximal field enhancement. We find that the velocity of positive streamers is determined mainly by their radius, in quantitative agreement with recent experimental results by Briels et al. As electron drift defocuses the negative streamer, positive streamers frequently are faster than negative ones, both in experiments and in our simulations.

We also consider arrays of interacting positive streamers. Closely packed streamers are slower, thinner and have higher field enhancement than streamers with weak interactions. Furthermore, we calculate the current induced in the external circuit by the streamers.

Computer Simulations on the Sprite Initiation for Realistic Lightning Models with Higher Frequency Surges

T Asano (Department of Electronic Engineering, The University of Electro-Communications, 1-5-1 Chofu-gaoka, Chofu Tokyo, 182-8585, Japan; ph. +81-42-443-5168; fax +81-42-443-5168; qpxgh556@ybb.ne.jp); [*T Suzuki*] (Air Weather Group, Japan Air Self-Defense Force, Ministry of Defense, 2258 Koshizuno-cho, Sakaiminato Tottori, 684-0053, Japan; ph. +81-859-45-0211; rekonyanbb@yahoo.co.jp); Y Hiraki (Nagoya University, The Solar-Terrestrial Environment Laboratory, Nagoya, Japan, Furo-cho, Chikusa-ku,Nagoya 464-8601, Japan; hiraki@stelab.nagoya-u.ac.jp; E Mareev (Institute of Applied Physics, Russian Academy of Science, Nizhny Novogorod, Russia; M G Cho (Kyushu Institute of Technology, Kita-Kyushu, Japan; M. Hayakawa (Department of Electronic Engineering, The University of Electro-Communications, 1-5-1 Chofu-gaoka, Chofu Tokyo, 182-8585, Japan; ph. +81-42-443-5168; fax +81-42-443-5168; hayakawa@whistler.ee.uec.ac.jp)

Computer simulations on transient luminous emissions in the mesosphere/lower ionosphere have been performed for realistic lightning modelings with M components (fast-varying current surge superimposed on the lightning continuing current). The algorithm used here is EM (electromagnetic) code, which enables us to estimate self-consistently the reduced electron field, electron density, conductivity and luminosity as a function of space and time by solving the Maxwell's equations. It is found that the M components with small amplitude, but with fast-varying EM effect, can initiate or enhance the sprites. Drastic changes in transient luminous emissions are noticed with higher occurrence frequency, shorter repotition period etc of those M components. These computational results are used to provide some useful hints on the unsolved problems of sprites/halos, including polarity asymmetry, long-delay characteristics and morphological characteristics of sprites.

The Sprite Lightning Polarity Paradox, Revisited

[*E R Williams*] (Parsons Laboratory, MIT, Cambridge, MA 02139 ph. 781-981-3744; fax 781-981-0632; earlew@ll.mit.edu; E Downes (Parsons Laboratory, MIT, Cambridge, MA 02139; ph. 781-981-3744; fax 413-789-1256; edown@mit.edu; C-L Kuo (Dept. of Physics, National Cheng Kung University, Tainan, Taiwan); Cheng-Ling Kuo (johnny@phys.ncku.edu.tw); A B Chen (Dept. of Physics, National Cheng Kung University, Tainan, Taiwan, alfred@phys.ncku.edu.tw); R-R Hsu (Dept. of Physics, National Cheng Kung University, Tainan, Taiwan, rrhsu@phys.ncku.edu.tw); H-T Su (Dept. of Physics, National Cheng Kung University, Tainan, Taiwan, htsu@phys.ncku.edu.tw); J Bor (Geodetic and Geophysical Research Institute, Hungarian Academy of Sciences, Sopron, Hungary, jbor@ggki.hu); G Satori (Geodetic and Geophysical Research Institute, Hungarian Academy of Sciences, Sopron, Hungary, gsatori@ggki.hu); W Lyons (FMA Research, Inc., Ft. Collins, CO, walyons@frii.com); R Boldi (University of Alabama, Huntsville, AL, boldi@ix.netcom.com)

New developments in both observation and theory have shed new light on a paradox discussed earlier by Williams (2001) and Williams et al (2007): namely, the numbers of sprites initiated by positive polarity ground flashes exceed those by negative polarity lightning by about a factor of 1000 to 1 in the available observations at the time (primarily ground-based video camera observations), in comparison with the polarity-independent theory for sprite initiation by dielectric breakdown originating with C.T.R. Wilson (1925). In contrast, global ELF observations (Williams et al., 2007) show that >10% of all supercritical charge moments (by region and globally) are of negative polarity. New observations with a limb-viewing satellite (ISUAL) and new theory (Hiraki and Fukunishi, 2006) highlight the role of the halo, a TLE not involving dielectric breakdown but still exhibiting respectable brightness (>100 kR), as a resolution to the polarity paradox. Recent studies by Bering et al., (2004) in balloon-based observations over land, and by Frey et al. (2007) and Adachi et al (2008) in USUAL satellite observations, find a great predominance of negative polarity lightning- producing halos, primarily over the ocean. In the present study, ELF measurements of halo-parent lightning from the Nagycenk Observatory in Hungary identify 100 'negative' halos and 23 'positive' ISUAL halos, with a predominance of negative polarity even over land (24 of 33 events). Both observations and theory support the idea that the polarity asymmetry of TLEs (sprite/positive CG and halo/negative CG) is caused by a distinct polarity asymmetry in lightning behavior (Williams, 2006), with negative CGs with large peak current (~100 kA) showing short (<3 ms) or negligible continuing current (Saba et al., 2006) and with positive CGs showing smaller peak current but prevalent longer and more intense continuing current. Earlier ELF observations of current moment spectra showed primarily white spectra for negative lightning and 'red' spectra for positive lightning. The more impulsive negative CGs with supercritical charge moments are evidently able to accelerate ambient electrons at higher altitude (where they are substantially more prevalent) to induce impact excitation over a broad region and thereby produce a halo (Hiraki and Fukunishi, 2006; Adachi et al., 2008), without ionized sprites. Returning to the ELF-measured bipolar distributions of lightning charge moment for Rhode Island (Williams et al., 2007), if charge moment thresholds for 'negative' halo and 'positive' sprite are equal (1000 C-km), we expect 16% of electrostatically-induced TLEs (sprites and halos) will be halos, in the case of Africa. If the charge moment threshold for the halo is half that for the sprite (500 C-km), we expect 47% of all TLEs to be halos. ISUAL observations (Hsu et al., 2009) show that the halo/(halo + sprite) ratio over land to be 31%, a value which is bracketed by the two estimates above. A similar consideration of statistics for the Atlantic Ocean shows halo ratios (in the same sequence as that considered above) of 26%, 85% and 58 %, again showing the first two estimates bracketing the third (ISUAL) measurement. The satellite-measured occurrence frequency of halos is therefore in reasonable agreement with the bipolar distribution of measured charge moments, for both land and ocean.

Propagation Mechanisms of Positive Streamers in Different Gases

[*G Wormeester*] (Center for Mathematics and Computer Science, 1090 GB Amsterdam, The Netherlands. ph. +31-(0)20-5924208; fax +31-(0)20-5924200; G.Wormeester@cwi.nl); Sergey Pancheshnyi (Laboratoire Plasma et Conversion d'Energie, University Paul Sabatier, 118 Route de Narbonne, 31062 Toulouse cedex 4, France. Ph. +33-(0)561556499; fax +33-(0)561556332; sergey.pancheshnyi@laplace.univ-tlse.fr); Alejandro Luque (Center for Mathematics and Computer Science, 1090 GB Amsterdam, The Netherlands. ph. +31-(0)20-5924208; fax +31-(0)20-5924200; A.Luque@cwi.nl); Ute Ebert (Center for Mathematics and Computer Science, 1090 GB Amsterdam, The Netherlands; and also in Dept. Applied Physics, Eindhoven University of Technology, 5600 MB Eindhoven, The Netherlands. ph. +31-(0)20-5924206; fax +31-(0)20-5924200; Ute.Ebert@cwi.nl); W. Hundsdorfer (Center for Mathematics and Computer Science, 1090 GB Amsterdam, The Netherlands. ph. +31-(0)20-5924211; fax +31-(0)20-5924200; Willem.Hundsdorfer@cwi.nl)

Though positive streamers propagate against the electron drift direction and need a source of electrons in front of the streamer head, they typically appear easier than negative ones. Using numerical simulations with adaptive grid refinement, we investigate and compare two mechanisms for propagation of positive streamers: photoionization or field detachment of electrons from background ionization. We investigate different gases and the effect of the level background ionization on the propagation velocity, radius of the streamer head and strength of the electric field enhancement due to the space charge layer.

ELF/VLF Effects of Lightning and Transient Luminous Events

Tuesday, 12 May; 4:25 p.m. – 6:25 p.m.

VHF Radar Echoes in the Lower Ionosphere Associated with Lightning Discharges

[*T Adachi*] (STAR Laboratory, EE Department, Stanford University, 350 Serra Mall, Stanford, CA 94305-9515, United States; ph. 650-723-7712; fax 650-723-9251; tadachi@rish.kyoto-u.ac.jp); M Yamamoto (RISH, Kyoto University, Gokasho, Uji, Kyoto 611-0011, Japan; ph. +81-774-38-3814; fax +81-774-31-8463; yamamoto@rish.kyoto-u.ac.jp); U S Inan (STAR Laboratory, EE Department, Stanford University, 350 Serra Mall, Stanford, CA 94305-9515, United States; ph. 650-723-4994; fax 650-723-9251; inan@stanford.edu); Y

Otsuka(STEL, Furocho, Chikusa, Nagoya 464-8601, Japan; ph. +81-533-89-5168; fax +81-533-89-1539; otsuka@stelab.nagoya-u.ac.jp); Y Takahashi (Department of Geophysics, Tohoku University, Aramaki, Aoba, Sendai, Miyagi, 980-8578, Japan; ph. +81-22-795-5775; fax +81-22-795-5775; yukihiro@pat.geophys.tohoku.ac.jp)

It is well-known that D-region ionosphere is sometimes perturbed by lightning discharges. So far, their spatio-temporal characteristics have primarily been observed by means of VLF remote sensing. Although VHF radar observation of the lower ionosphere would provide further critical information to clarify the underlying physical processes, such attempts have not yet been extensively carried out. In the present study, we report the evidence of ionospheric radar echoes that were clearly associated with the occurrence of lightning. On the night of 23 August 2008, MU radar (Middle and Upper atmospheric radar), which is a VHF (46.5 MHz) active phased-array radar located at Shigaraki (34.85 N, 136.10 E), observed the ionosphere by using four beams that point to the north, east, south and west with a zenith angle of 30 degrees. The west beam observed the ionosphere just above a thunderstorm system that was developed 60-80 km away of the MU radar. A VLF electric-field sensor installed on the roof of a building of Kyoto University (34.90 N, 135.80 E) simultaneously observed lightning atmospherics radiated from the same thunderstorm system. During the period from 13:20 to 13:25 (UT), we found seven lightning atmospherics in VLF data. Four out of seven events were found in the concurrent MU data to have corresponding radar echoes at heights of ~108 km with an intensity of up to 10 dB. Since we found no corresponding radar echoes in the beams other than the west beam that observed above the thunderstorm, we conclude that the radar echoes were produced by lightning discharges. In this presentation, we discuss the detailed properties of lightning-associated echoes and their possible generation processes.

Chasing Lightning, Sferics, Tweeks and Whistlers Observing Natural Radio Waves Using the INSPIRE Receiver

[*K A Franzen*] (The INSPIRE Project, Inc. 518 Sixth Street SE, Washington, DC 20003; ph. 202-547-1364; fax 202-547-6937; president@theINSPIREproject.org); P A Webb (Space Weather Laboratory Heliophysics Science Division Code 674, NASA Goddard Space Flight Center Greenbelt, Maryland 20771; ph. 301-286-6172; fax 301- 286-1648; Phillip.A.Webb@nasa.gov); L N Garcia (Heliospheric Physics Laboratory, Heliophysics Science Division Code 672, NASA Goddard Space Flight Center, Greenbelt, Maryland 20771; ph. 301-286-9486; fax 301-286-1771; Leonard.N.Garcia@nasa.gov)

We all know what lightning looks like during a thunderstorm, but the visible flash we see is only part of the story. This is because lightning also generates light with other frequencies that we cannot perceive with our eyes, but which are just as real as visible light. Unlike the visible light from lightning, these other frequencies can carry the lightning's energy hundreds or thousands of miles across the surface of the Earth in the form of "tweeks" and "sferics." Some of this energy can even travel tens of thousands of kilometers into space before returning to the Earth as "whistlers." The INSPIRE Project, Inc is a non-profit scientific and educational corporation whose beginning mission was to bring the excitement of observing these very low frequency (VLF) natural radio wave emissions from lightning to students and participants. Since 1989, INSPIRE has provided specially designed radio receiver kits to over 2,600 individuals around the world to make observations of signals in the VLF frequency range. Many of these participants are using the VLF data they collect in very creative projects that include fiction, music and art exhibitions.

With the INSPIRE receivers the VLF emissions can be simply detected, amplified and turned into sounds that we can hear, with each emission producing a distinctive sound. In 2006 INSPIRE was re-branded and its mission has expanded to developing new partnerships with multiple science projects. Links to magnetospheric physics, astronomy, and meteorology are being identified. This presentation will introduce the INSPIRE project, display the INSPIRE receiver kits, show examples of the types of VLF emissions that can be collected and provide information on scholarship programs being offered.

Impact of Sprites on VHF Propagation Through the D-region

[*Paul Greninger*] (Physics Department, University of New Mexico, Albuquerque, NM, 87131; ph. 505-661-4628; fax 505-664-0362; paulg@lanl.gov); Christopher Jeffery (Space & Remote Sensing Sciences, Los Alamos National Laboratory, Los Alamos, NM, 87545; ph. 505-665-9169; fax 505-664-0362; cjeffery@lanl.gov); Patrick Colestock (Space & Remote Sensing Sciences, Los Alamos National Laboratory, Los Alamos, NM, 87545; ph. 505-665-3565; fax 505-664-0362;colestoc@lanl.gov); Sigrid Close (Space & Remote Sensing Sciences, Los Alamos National Laboratory, Los Alamos, NM, 87545; ph. 505-667-8793; fax 505-664-0362; sigrid@lanl.gov)

Recent investigations of elves, red sprites and blue jets-optical emissions that occur above lightning storms-have shown that the near-storm ionospheric D-region is strongly perturbed by quasi-electrostatic thundercloud fields and vertically propagating EMP. This disturbance, particularly as revealed by sprites, may have important implications for VHF propagation through the ionosphere. Sprites form in dense clusters above thunderclouds and have a narrow columniform structure with a horizontal extent that is 100 m or less. Although the optical emission from sprites lasts only a few tens of

milliseconds, the associated ionospheric electron density perturbations last several minutes, as revealed by the scattering of VLF radiation (so called "VLF sprites"). Studies of VLF sprites indicate ionization levels of 105 electrons per cc or more with a fine-scale structure on ~10 m scales [Rodger, J. Atmos. Solar-Terr. Phys., 2003]. Such small scale variability has the potential to scatter and disperse 30-100 MHz VHF transmission through the ionosphere.
Using a fractal model of thunderstorm intracloud "spider lightning" by Valdivia et al. [RS, 1998], we investigate the impact of lightning EMP on VHF propogation through the D-region. Our study builds on the large body of pioneering work on sprite modeling by Valdivia et al., Pasko et al., and others. We focus, however, on electron density variability at scales less than 25 m, which has the greatest potential to impact VHF communication and transmission. Preliminary results from this effort will be detailed and discussed in our poster presentation.

The Impact of Lightning on the Ionosphere

[*M C Kelley*] (School of Electrical and Computer Engineering, Cornell University, Ithaca, NY 14853; ph. 607-255-7425; fax 607-255-6236; mikek@ece.cornell.edu); J J Makela (Department of Electrical and Computer Engineering, University of Illinois at Urbana-Champaign, Urbana, Illinois 61801; ph. 217-265-9470; fax 217-333-4303; jmakela@illinois.edu); G Crowley (Astra, San Antonio, TX 78249; ph. 210-834-3475; gcrowley@astraspace.net)

A variety of observations from the ground, radar, rockets, and satellites indicate that the electromagnetic pulse (EMP) from lightning creates new plasma in the ionosphere. Much of this evidence is circumstantial, however. For example, there is exactly one measurement of energetic (1 keV) electrons accelerated by lightning]. The purpose of this talk is to describe a dedicated multi-institutional attack on this problem. A theatre approach will be taken, instrumenting the New Mexico area centered on the Institute of Mining & Technology's Langmuir Laboratory for Atmospheric Research and the Los Alamos National Laboratory. The possibility exists that a Cubesat mission may be involved.

Investigation of Atmospheric Lightning Discharges on the Micro-satellite "Chibis-M"

[*S I Klimov*] (Space Research Institute of RAS; Profsoyuznaya 84/32, 117997 GSP-7 Moscow, Russia; ph. +7-495-333-1100; fax +7-495-333-1248; sklimov@iki.rssi.ru); G K Garipov (Institute of Nuclear Physics, Moscow Sate University; Leninskie gory, b. 1, s. 2; 119992 Moscow, Russia; ph. +7-495-939-4496; fax +7-495-939-1246; ggkmsu@yandex.ru); V M Gotlib (Space Research Institute of RAS; Profsoyuznaya 84/32, 117997 GSP-7 Moscow, Russia; ph. +7-495-333-2177; fax +7-495-333-1248; gotlib@mx.iki.rssi.ru); A V Gurevich (P.N.Lebedev Physical Institute of RAS, Leninskyi prospect 53, 119991 Moscow, Russia; ph. +7-499-132-6414; fax +7-499-135-8533; alex@lpi.ru); M O Ptitsyn (P.N.Lebedev Physical Institute of RAS, Leninskyi prospect 53, 119991 Moscow, Russia; ph. +7-499-132-6050; fax +7-499-135-8533; ptitsyn@lpi.ru); V G Rodin (Space Research Institute of RAS; Profsoyuznaya 84/32; 117997 GSP-7 Moscow, Russia; ph. +7-495-333-4333; fax +7-495-333-1248; Natalia@iki.rssi.ru); S I Svertilov (Institute of Nuclear Physics, Moscow State University, Leninskie gory, b. 1, s. 2; 119992 Moscow, Russia; ph. +7-495-939-4496; fax +7-495-939-1246; sis@coronas.ru); L M Zelenyi (Space Research Institute of RAS; Profsoyuznaya 84/32; 117997 GSP-7 Moscow, Russia; ph. +7-495-333-2588; fax +7-495-333-3311; lzelenyi@iki.rssi.ru)

At present micro-satellite sufficiently widely are used in the practice, including for warning and liquidation of extraordinary situations. In this case in practice is used the relatively narrow range of the electromagnetic radiations of the visible region - visible light.

Using a large experience of basic space research, Space Research Institute (IKI) of RAS in last 2 years studies the scientific programs with the use of micro-satellite, oriented to the study of infrared, ultraviolet - UV and X -ray ranges not only for basic space research, but also oriented to the tasks the study of some aspects of extraordinary situations.

A number of the physical phenomena in the atmosphere, which fundamentally changed our idea about the lightning discharges, are discovered in recent years. IKI with participation of SINP, FIAN, LC SRI NANU-NKAU (Lviv, Ukraine) and Etvos University (Budapest, Hungary) is developed the model composition of complexes of scientific instruments (12.5 kg):
-X-ray - gamma detector (range of X-ray and gamma emission - 50-500 keV),
-UV detector (range UV - emission - 300-450 nm),
-radiofrequency analyzer (20 - 50 MHz).
-camera of optical range (spatial resolution 300 m).
-plasma-wave complex (0.1-40 kHz).

Micro-satellite "Chibis-M" now designed in IKI. Total mass "Chibis-M" with support systems, construction and scientific instruments - 40 kg.

The scientifically- educational program, begun on the micro-satellite of "Kolibri -2000", it will be continued to "Chibis-M".

Discussion of the methodical questions of atmospheric lightning discharges study was carried out within the framework ISSI Team: CARNES (Coupling of Atmosphere Regions with Near-Earth Space)

Ground-based and Space-based Observations of ELF/VLF Waves Associated with TLEs

[*F Lefeuvre*] (Laboratoire de Physique et Chimie de l'Environnement et de l'espace, CNRS –University of Orleans, CNRS/LPCE 45071 Orleans cedex 2 France; ph. 33238255284; fax 33238631234; lefeuvre@cnrs-orleans.fr); R. Marshall (Space, Telecommunications, and Radioscience Laboratory, Electrical Engineering Department, Stanford University, Stanford, California, USA); J.L. Pincon (Laboratoire de Physique et Chimie de l'Environnement et de l'espace, CNRS –University of Orleans, CNRS/LPCE 45071 Orleans cedex 2 France); U.S. Inan (Space, Telecommunications, and Radioscience Laboratory, Electrical Engineering Department, Stanford University, Stanford, California, USA); J.A. Sauvaud (Centre d'Etude Spatiale des Rayonnements, CNRS, Toulouse, France), M. Parrot (Laboratoire de Physique et Chimie de l'Environnement et de l'espace, CNRS–University of Orleans, CNRS/LPCE 45071 Orleans cedex 2 France)

Recordings of satellite ELF/VLF waveform data associated with TLE observations are reported from the Summer 2005 campaign coordinated by Stanford University and LPCE. TLEs are optically observed from the US Langmuir Laboratory, while ELF/VLF waveform data are simultaneously recorded on-board the CNES microsatellite DEMETER and on the ground at Langmuir. Analyses of ELF/VLF measurements associated with sprite events observed on July 28 2005 and August 3 2005 are presented. Propagation characteristics at the entry points of the ionosphere are discussed. The main results concern: (i) the identification from a low Earth orbit satellite of the 0+ whistler signatures of the TLE causative lightning, (ii) the identification of the propagation characteristics of proton whistlers triggered by the 0+ whistlers of the causative lightning, and the potential use of those characteristics to identify longitudinal or quasi-longitudinal 0+ whistlers, (iii) the use of geographical display of average powers received by DEMETER electric antennas over ground-based VLF transmitters to evaluate VLF transmission cones (iv) demonstration of an optimum transfer of energy from the atmosphere to the ionosphere for waves with wave normals anti-parallel to the Earth magnetic field direction at the altitude of the X= f_pe ^2 /f2 =1 plasma cut-off, with f_pe the local plasma frequency.

On Requirements and Applications of Modeling Techniques in Inverse Problems at ELF

[*V Mushtak*] (Parsons Laboratory, MIT, Cambridge, MA 02139; ph. 781-981-3744; fax 781-981-0632; vadimcm@gmail.com; E R Williams (Parsons Laboratory, MIT, Cambridge, MA 02139; ph. 781-981-3744; fax 413-789-1256; earlew@ll.mit.edu)

In the half century of ELF research, numerous ideas, methods, and models have been suggested, discussed, developed, used, tested – and, finally, accepted or rejected. These approaches have prevailingly targeted direct propagation problems - computations of electromagnetic fields generated by the given (modeled) source(s) within the Earth-ionosphere cavity with the given (modeled) electrodynamic properties. Having provided an invaluable physical insight into and understanding of the ELF propagation process and accompanying phenomena, the direct techniques have often not been assessed from the point of view of their applicability to solving inverse problems – estimating the properties of source(s) and/or propagation media from experimental observations. Due to the general nature of such tasks, the requirements for an inverse technique are: the presence of an accurate forward model for the task at hand; the possibility of exploiting the forward model as an efficient algorithm to be used in repeated computations (sensitivity matrices, iterative procedures, etc.); a possibility of effective parameterization of the problem (description of the sought-for properties via a reasonably limited number of parameters) with a proper choice for the form of observational results - specific sets of field components presented in the time or frequency domains, full spectra or the variables of their approximations (for instance, Lorentzian-fitted ones), etc. Applications of these principles are illustrated for several inverse ELF tasks: locating the source for a transient signal on the basis of an accurate model of propagation parameters; vice versa, specifying the model of propagation parameters from spectra of a transient signal generated by an independently located source; monitoring the temporal-spatial dynamics of the integrated vertical charge moment change of the global lightning "chimneys" from background Schumann resonance observations; estimating the day-to-night change in the ionospheric characteristic altitude using a proper ratio of background magnetic components. As for the propagation theory, the two-dimensional telegraph equation method (Kirillov [2002]) based on the ideas of Madden and Thompson [1965] and Greifinger and Greifinger [1978] is used in two different realizations (dependent on the task): as an analytical algorithm with a step-like day/night boundary, and as a numerical algorithm with a realistic "smooth" day-to-night transition. The limits of applicability of the azimuthally symmetrical day/night model of the Earth-ionosphere cavity are discussed and illustrated by comparison with observations.

References

Greifinger, C., and Ph. Greifinger (1978). Radio Science, 13 (831-837).

Kirillov, V.V. (2002). Radiophysics and Quantum Electronics, 45 (929-941).

Madden, T., and W. Thompson (1965). Reviews of Geophysics, 3 (211-254).

Applying Sum Absolute Difference (SAD) Algorithms to Lightning Geolocation

[*J Samuels*] (Remote EMI Mapping Program, Soneticom, Inc, West Melbourne, FL 32904; ph. 321-733-0400, x420; fax 321-733-1841; jsamuels@soneticom.com); J French (Remote EMI Mapping Program, Soneticom, Inc, West Melbourne, FL 32904; ph. 321-733-0400, x456; fax 321-733-1841; jfrench@soneticom.com)

Approaches to locating a lightning strike on the surface of the earth have been refined and commercialized over the past few decades. Cloud-to-ground lightning strikes emit radio frequencies (RF) in the Very High Frequency (VHF) region (30-300MHz) of the RF spectrum and those emissions are routinely geolocated to accuracies of approximately 1km using Time of Arrival (TOA) and Interferometric techniques.

Little advancement toward the precise geolocation of cloud-to-ground lightning to accuracies much less than 1km has been accomplished over the past few years. This presentation describes an expanded Time Difference of Arrival (TDOA) system that uses a set of networked ground sensors (which can be expanded to include space-based sensors) to determine a more precise, 2D (in the case of just ground sensors) or 3D (if a space-based sensor is employed), geolocation of VHF emissions from cloud-to-ground lightning strikes (or higher altitude VHF emissions such as Trans-Ionospheric Pulse Pairs (TIPP), etc.).

This work, which expands TDOA by using the Sum Absolute Difference (SAD) method of estimating the time difference between two signals, has proven very promising when applied to ultrasound data and to RF emissions other than lightning. The SAD approach allows data to be combined from a sensor array in a two dimensional or three dimensional grid. Each test point in the grid is the amount of RF energy that was emitted from that point. Using this imaging technique in 2D or 3D, the path of the VHF emissions from a lightning strike can be determined to a high degree of accuracy at the surface of the earth or at high altitudes.

Estimation of Net Current Due to Lightning Discharge in the Global Electric Circuit

[*Kozo Yamashita*] (Dept.Geophysics, Graduate School of Science Tohoku University, 6-3 Aza-aoba, Aramaki, Aoba-ku Sendai, Miyagi 980-8578, Japan; ph.+81-(0)22-795-5775; fax +81-(0)22-795-5775; kozo@pat.geophys.tohoku.ac.jp); Mitsuteru Sato (Planetary Physics Laboratory, Department of Cosmosciences, Hokkaido University, ph. 011-706-2763; fax 011-706-2760; msato@ep.sci.hokudai.ac.jp); Hiromi Kase (Dept.Geophysics, Graduate School of Science Tohoku University, 6-3 Aza-aoba, Aramaki, Aoba-ku Sendai, Miyagi 980-8578, Japan; ph.+81-(0)22-795-5775; fax +81-(0)22-795-5775; kase@pat.geophys.tohoku.ac.jp); Yukihiro Takahashi (Dept.Geophysics, Graduate School of Science Tohoku University, 6-3 Aza-aoba, Aramaki, Aoba-ku Sendai, Miyagi 980-8578, Japan; ph.+81-(0)22-795-5775; fax +81-(0)22-795-5775; kozo@pat.geophys.tohoku.ac.jp)

Recent study for the global electric circuit (GEC) has rapidly made progress. It is mainly caused by the advancement of research for global lightning activities in the lower atmosphere and for Transient Luminous Events (TLEs), such as sprites, in the mesosphere.

The goal of our study is to develop the new GEC model which take into account the electrical connection between the lower atmosphere and ionosphere. As a first step for a new model, we derive the global distribution of vertical charge transportation by big lightning discharge.

We made use of the ELF electromagnetic wave measurement network with 4 sites in the world constructed and maintained by Tohoku University, which records the magnetic waveform in the frequency range of 1-100 Hz.. We calculated the positions and electrical properties (charge moment change and polarity) for 295,653 events observed in the period from January 1, 2004 to December 31, 2004.

This result enable us to discuss the net-current caused by lightning discharge with a charge moment of larger than 718 C km. Upward and downward currents are estimated to be 0.98A and 1.24A on the globe, respectively. This value is about 0.1 percent of the total global lightning discharge current estimated by previous studies. Also the polarity of the net current of the present analysis is opposite to the result of previous studies. These facts imply that most of the currents are carried by smaller events. It is also found that the net current by lightning discharge have regional variations, namely, upward currents are dominant in continents while downward currents maritime area.

Energetic Radiation From Lightning and Terrestrial Gamma Ray Flashes

Wednesday, 13 May; 4:40 p.m. – 6:40 p.m.

Observation of a Possible Neutron Burst Associated With a Lightning Discharge

I M Martin (Physics Department, Instituto Tecnologico da Aeronautica and Universidade de Taubate, Sao Jose dos Campos, SP, 12228-900, Brazil; ph. +55-12-9153 7676; martin@ita.br); [*M A Alves*] (Physics Department, Instituto Tecnologico da Aeronautica, Sao Jose dos Campos, SP, 12228-900, Brazil; ph. +55-12-39221287; mauro@sepn.org)

During routine measurements of background count rate of low-energy neutrons in the city of Sao Jose dos

Campos, Brazil (610 m; 23° 12′ 17″ S, 45° 51′ 29″ W) using a standard He-3 detector tube (area, 70 cm^2; pressure, 3800 Torr; operating voltage plateau, 1200 to 1500 V; Ludlum, USA) we observed a sudden and sharp increase in the neutron count. The measured neutron backg round count rate for this detector tube at this location is about 0.7+0.1 neutrons/minute. During a lightning storm and at the moment of a lightning discharge that occurred in the vicinity of the tube detector (< 0.5 km), the neutron count rate increased to about 690 neutrons/minute within less than one minute. Since sources of spurious signals, such as malfunctioning equipment and electrical transients, have been eliminated we are led to conclude that we possibly recorded a burst of neutrons associated with a lightning discharge.

The Diffuse Shape of Terrestrial Gamma Ray Flashes, as Seen by Imaging Instruments on the ISS and High Altitude Aircraft

[*P H Connell*] (Image Processing Laboratory, University of Valencia, 46071 Valencia, Spain; phone: +34-963543611; fax: +34-963543261; Paul.Connell@uv.es)

The hope of imaging TGFs for location purposes with the MXGS spectrometer/imager on board the ASIM mission to the ISS has raised the question of whether a TGF has a substantial diffuse character or is effectively a point source. To answer this Monte Carlo simulations have been made of TGF photon transport for various spatial and spectral models of TGF photon beams traversing the upper atmosphere to the ISS. The escaping photons are input to imaging, spectral and light curve analysis procedures to determine the TGF shape observed in orbit as a function of the TGF zenith angle from the observer and its relationship to spectral variations and photon time delays at low energies, as apparently seen in the analysis of BATSE observation data. The results show TGF shapes expected from flight and orbital observations and the constraints this will put upon the angular location resolution to be expected from coded-mask and wide-angle imaging instruments.

Primary Factors for Electron Relativistic Runaway Breakdown in Air

[*E S Cramer*] (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901; ph. 646-239-4266; eric.s.cramer@gmail.com); J R Dwyer (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901; ph. 321-674-7208; jdwyer@fit.edu); Hamid K. Rassoul (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901; ph. 321-674-8778; fax 321-674-8864); rassoul@fit.edu; Ziad Saleh (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901; ph. 321-674-7122; ziad.saleh@gmail.com

One of the great mysteries in the atmospheric sciences is the source of Terrestrial Gamma-Ray Flashes (TGF's). TGF's are short bursts of gamma-rays, observed by satellites in low Earth orbit, that come from the atmosphere with energies extending up to several tens of Mev. In order to develop a theory of the source mechanism for Terrestrial Gamma-Ray Flashes, a Monte Carlo simulation is used to model specific runaway breakdown processes. Runaway breakdown is initiated when an electron is struck by a cosmic ray, in which the electron's energy gained from the electric field exceeds the losses from collisions with air. In turn, this allows the electron to accelerate to relativistic speeds, and gain energy extending to the Mev range. Recent theoretical models have helped us depict both the energy spectrum of the runaway avalanche electrons, as well as their scattering angle dependence. Primary factors such as avalanche length and average energy were calculated using electric field strengths ranging from 300 to 2500 kV/m. 0Using avalanche lengths ranging from 7 to 10 times the e-folding value, we were also able to calculate the fluence of electrons per scattering angle. Comparisons have also been made with previous work in which the characteristic time scale of the avalanche length was computed as a function of the overvoltage.

Experiment Based On Spacesuit "Orlan-M". Neutron Fluxes From Thunderstorm

[*A Yu Drozdov*] (Faculty of Physics, M.V.Lomonosov Moscow State University, Leninskie Gory, 1(2), Moscow 119991, Russia, ph. +7-495-939-5088, fax +7-495-939-0896, aleksandr.drozdov@gmail.com); A M Amelushkin (Lomonosov Moscow State University Skobeltsyn Institute of Nuclear Physics, Leninskie gory, 1(2), Moscow 119991, Russia, ph. +7-495-939-5088, fax +7-495-939-0896, amelyushkin@srd.sinp.msu.ru); L S Bratolyubova-Tsulukidze (Lomonosov Moscow State University Skobeltsyn Institute of Nuclear Physics, Leninskie gory, 1(2), Moscow 119991, Russia, ph. +7-495-939-5088, fax +7-495-939-0896, lbc@srd.sinp.msu.ru); A V Grigoriev (Lomonosov Moscow State University Skobeltsyn Institute of Nuclear Physics, Leninskie gory, 1(2), Moscow 119991, Russia, ph. +7-495-939-1617, fax +7-495-939-0896, ax.grigoriev@mail.ru); O R Grigoryan (Lomonosov Moscow State University Skobeltsyn Institute of Nuclear Physics, Leninskie gory, 1(2), Moscow 119991, Russia, ph. +7-495-939-5061, fax: +7-495-939-0896, orgri@srd.sinp.msu.ru); D I Iudin (Radiophysical Research Institute, Nizhny Novgorod, Bolschaya Pecherskaya St., 25/13a, Russia 603195, ph. +7-831-432-3327, fax +7-831-236-0299, di_iudin@nirfi.sci-nnov.ru); E A Mareev (Institute of Applied Physics of the Russian Academy of Sciences, Nizhny Novgorod, Ul'yanov St., 42, Russia 603195, ph. +7-831-416-4792, fax +7-831-416-4792, mareev@appl.sci-nnov.ru); O Yu Nechaev (Lomonosov Moscow State University Skobeltsyn Institute of Nuclear Physics, Leninskie gory, 1(2), Moscow 119991, Russia, ph. +7-495-939-5088, fax

+7-495-939-0896); V L Petrov (Lomonosov Moscow State University Skobeltsyn Institute of Nuclear Physics, Leninskie gory, 1(2), Moscow 119991, Russia, ph. +7-495-939-5088, fax +7-495-939-0896, vas@srd.sinp.msu.ru)

The first experimental evidence that neutrons are generated in lightning discharge was found by Indian scientists in 1979. One probable mechanism of a neutron generation is deuteron-deuteron fusion. Another probable mechanism is generation during thunderstorms in photo-nuclear reactions by gamma rays produced by runaway electrons. Such neutrons can be detected in top of the atmosphere by equipment onboard space satellite. In this work presented experiments that were carried out onboard the space station "MIR" ("Rabina", 1991) and during the "Kolibri-2000" microsatellite flight (2002), which obtained data on neutron fluxes in the range from thermal energies (0.025 eV) up to ~1 eV. The experiments revealed neutron background count growth as well as separate bursts in the region of the geomagnetic equator. The main feature was existence of sharp longitudinal dependence in the flux distribution. It was shown that the location of that events corresponded to near-equatorial thunderstorm systems in Asian, Pacific and African areas. But that was not the case for the American area. For the estimation of the observable neutron flux on the orbital altitudes we propose a model of numerical calculation of the neutron transport in the atmosphere by the cellular automation method. That method make possible to connect theoretical estimations with the count rate of real experimental counter taking to account the geometry, position and other attributes of the detectors. Also, presented is the space experiment "Scafandr" which is launched in 2009 and which is based on the free-falling spacesuit "Orlan-M". The equipment onboard spacesuit will allow registration of neutrons with different energies. Small satellites are hard in orientation, so the detection system was selected with criteria of orientation-independence. Previous spacesuit called "Ivan Ivanovich" was launched from International Space Station in 2006. Its lifetime at orbit was about 6 months. Now it is planned that the spacesuit will function while falling from altitude of 370…400 km down to atmosphere altitudes – this is a characteristic feature of new experiment. This will allow us to receive altitudinal distribution of neutron fluxes. The experiment is put forward to prove the idea that thunderstorms could be an origin of neutron bursts and in the case of positive answer its results will help to determinate the correct theory of neutron generation in thunderstorms.

Characterizing the Intensities of Terrestrial Gamma-ray Flashes (TGFs) Observed by RHESSI

[*B W Grefenstette*], D M Smith, B J Hazelton (Physics Department and Santa Cruz Institute for Particle Physics, Santa Cruz, CA 95064; ph. 650-387-3951; bwgref@scipp.ucsc.edu); J R Dwyer (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL, 32901; jdwyer@fit.edu).

Terrestrial gamma-ray flashes (TGFs) are short bursts of energetic radiation associated with lightning strikes. These flashes of x-rays and gamma-rays have been observed by the Large Area Detectors (LADs) of the Burst and Transient Source Experiment (BATSE) on the Compton Gamma Ray Observatory (CGRO) and by the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) satellite among other satellites. A detailed spectroscopic analysis of the RHESSI data has indicated that the TGFs originate from deep in the atmosphere, near the tops of thunderstorms. Such a deep source results in significant losses of x-rays and gamma-rays as they propagate through the air from the source region to space. However, we have recently shown that, during their peak emission, TGFs can still cause a high enough count rate such that the readout electronics of both the BATSE LADs and the RHESSI detectors become saturated. This instrumental deadtime has been shown to be important in understanding the temporal analysis, spectroscopy, and overall intensity of the TGFs. We present the analysis of the RHESSI peak emission and compare it with times when the RHESSI detectors are known to be counting at their peak throughput. We also present a possible constraint on the peak brightness of TGFs by comparing count rates in the front and rear segments of the RHESSI detectors.

Thunderstorm Neutrons at Altitudes up to 400 km: Theoretical Estimations and Numerical Simulation

[*A V Grigoriev*] (Lomonosov Moscow State University Skobeltsyn Institute of Nuclear Physics, Leninskie gory, 1(2), Moscow 119991, Russia, ph. +7-495-939-1617, fax: +7-495-939-0896, ax.grigoriev@mail.ru); O R Grigoryan (Lomonosov Moscow State University Skobeltsyn Institute of Nuclear Physics, Leninskie gory, 1(2), Moscow 119991, Russia, ph. +7-495-939-5061, fax: +7-495-939-0896, orgri@srd.sinp.msu.ru); A Yu Drozdov (Faculty of Physics, M.V.Lomonosov Moscow State University, Leninskie Gory, 1(2), Moscow 119991, Russia, ph. +7-495-939-5088, fax: +7-495-939-0896, aleksandr.drozdov@gmail.com); D I Iudin (Radiophysical Research Institute, Nizhny Novgorod, Bolschaya Pecherskaya St., 25/13a, Russia 603195, ph. +7-831-432-3327, fax: +7-831-236-0299, di_iudin@nirfi.sci-nnov.ru); E A Mareev (Institute of Applied Physics of the Russian Academy of Sciences, Nizhny Novgorod, Ul'yanov St., 42, Russia 603195, ph. +7-831-416-4792, fax: +7-831-416-4792, mareev@appl.sci-nnov.ru), D D Pastushenkov (Lomonosov Moscow State University Skobeltsyn Institute of Nuclear Physics, Leninskie gory, 1(2), Moscow 119991, Russia, ph. +7-495-939-5061, fax: +7-495-939-0896)

In this work we perform the theoretical analysis of direct passage of neutrons in the atmosphere from altitude of about 5 km up to several hundred kilometers. We presume that these neutrons are generated during thunderstorm lightning discharges in what favour there is some experimental evidence. There are two main mechanisms of the neutrons generation in thunderstorm lightnings appeared in the literature: directly in the lightning discharge and owing to the production of the so called runaway electrons. Both of them are discussed in the present work. For the qualitative analysis we considered the process of neutrons propagation in the atmosphere as consisting of two stages: initial neutron deceleration to thermal energies and further diffusion. Absorption of neutrons was neglected. Also, in modeling of the atmospheric matter only nitrogen and oxygen were considered as the main atmospheric components. With these conditions and taking into account the plurality of lightning discharges in the typical thunderstorm, it is shown that the estimated flux well corresponds to known experimental results. For more rigorous picture of the neutrons propagation, capable for description of the slowing down, thermalization and diffusion processes, one has to perform numerical calculation and for this we propose computer simulation scheme based on the cellular automation method. The corresponding preliminary analysis of the neutrons passage confirms the estimation mentioned above and provides prediction for the neutron density distribution depending on altitude. On the basis of our results we discuss some characteristic features of the observed neutron flux. Among them is the observed difference of neutron fluxes over African and American thunderstorm activity regions. Also, we discuss how altitude and spectrum of the neutron source can affect the picture of neutrons propagation, in connection with the two different mechanisms of neutron generation. The obtained results are to be tested by the "Radioskaf" experiment based on the scientific device called "RAZREZ". One of the experiment objectives is detection of neutrons with different energies at altitudes of 200-400 km aiming to reveal the nature and characteristics of the neutron radiation source.

The Relationship Between the Terrestrial Gamma-ray Flashes Occurrence and the Charge Moment Change of Parent Lightning Discharge

[*H Kase*] (Department of Geophysics, Tohoku University, Sendai, Aobaku; ph. 81-022-795-5776; fax 81-022-795-5775; kase@pat.geophys.tohoku.ac.jp); Y Takahashi (Department of Geophysics, Tohoku University, Sendai, Aobaku; ph. 81-022-795-5775; fax 81-022-795-5775; spriteselves@gmail.com); T Uno (Department of Geophysics, Tohoku University, Sendai, Aobaku; ph. 81-022-795-5776; fax 81-022-795-5775; uno@pat.geophys.tohoku.ac.jp); A Yoshida (Department of Geophysics, Tohoku University, Sendai, Aobaku; ph. 81-022-795-5776; fax 81-022-795-5775; akihiro@pat.geophys.tohoku.ac.jp); K Yamashita (Department of Geophysics, Tohoku University, Sendai, Aobaku; ph. 81-022-795-5776; fax 81-022-795-5775; kozo@pat.geophys.tohoku.ac.jp); M Sato (Department of Cosmosciences, Hokkaido University, Sappro, kitaku; msato@ep.sci.hokudai.ac.jp)

Terrestrial Gamma-ray Flashes (TGFs) are gamma-ray emission phenomena associated with lightning discharge. TGFs have a duration time of a few msec and an energy range of a few 10 keV-20 MeV. RHESSI satellite observed over 170 TGFs per year from 2002 to 2005. The orbit of RHESSI is circular with an inclination of 38 degrees at an altitude of 600 km. So far the characteristics of lightning associated with TGFs have been investigated. However, the relationship between the TGF occurrence and the charge moment change (CMC) of parent lightning discharge has not been examined in global scale.

Tohoku University has been measuring ELF magnetic field in the frequency range of 1-100 Hz at 4 sites located globally. From these data, we can estimate the CMC, location, and polarity of lightning around the world. We estimated occurrence frequency of lightning as a function of CMC. We derived the CMC of lightning discharge generating TGFs from the ELF waveforms and the timings of TGFs listed by RHESSI observation. 174 TGF events were observed by RHESSI in 2004. We analyzed 141 events whose ELF data at 3 stations are available. We estimated lightning location based on the time of arrival method. Detection Limit of the CMC with global uniformity was 187 C-km.

We analyzed 141 events observed in 2004 and identified 7 TGFs with ELF sferics. We consider the other 134 TGF events are related to smaller lightning discharge whose CMC are less than the detection limit of 187 C-km. We derived the occurrence probability of TGFs based on the occurrence frequency of lightning discharge as a function of CMC. Relative occurrence probabilities of TGFs in the ranges of 0-200 C-km, 200-400 C-km and 400-600 C-km to that occurrence number of lightning are 0.27 +/- 0.023 %, 1.28 +/- 0.52 % and 1.53 +/- 1.53 %, respectively, assuming the emission cone angle of gamma-ray as 15 deg. Occurrence probabilities of TGFs for positive flashes are 5.4 +/- 0.47 %, 25.6 +/- 10.5 %, and 30.7 +/- 30.7 %, respectively. that's not to say that the occurrence probability of TGFs is higher for lightning with smaller CMC.

Project of 3D Fluid Code Intended for Simulation of Thunderstorm Discharges Driven by Runaway Electrons Allowing for the Geomagnetic Field

[*A Y Kudryavtsev*] (Russian Federal Nuclear Center – VNIIEF, Mir av., 37, Sarov, 607188, RF; ph. +7-83130-65092; fax +7-83130-45738; kay@sar.ru; babich@elph.vniief.ru)

3D numerical code intended for simulating thunderstorm discharges driven by runaway electrons and their emissions is planned to be developed. The code is the improvement of already available 2D fluid code allowing for selfconsistent electric field. The new code will include the external magnetic (geomagnetic) field. The inclusion of parallel computations will make the new code efficient and time saving. The code could be used for simulating different laboratory discharges. It may be commercially attractive.

Statistical Study of X-ray Emission in Natural and Rocket-Triggered Lightning

[*Z Saleh*] (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901; ph. 321-684-0180; ziad.saleh@gmail.com); J Dwyer (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901; ph. 321-674-7208; fax 321-674-7482; jdwyer@fit.edu); H Rassoul (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901; ph. 321-674-8778; fax 321-674-8864; rassoul@fit.edu); M Schaal (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901; ph. 701-740-9620; mschaal2008@fit.edu); E Cramer (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901; ph. (646) 239-4266; ecramer2008@fit.edu); M Uman (Department of Electrical and Computer Engineering, University of Florida, Gainesville, FL 32611: ph. 352-392-4038; fax 352-392-8671; uman@ece.ufl.edu); J Howard (Department of Electrical and Computer Engineering, University of Florida, Gainesville, FL 32611: ph. 386-496-8325; ironjoe@ufl.edu); D Hill (Department of Electrical and Computer Engineering, University of Florida, Gainesville, FL 32611: ph. 904-708-0689; gators15@ufl.edu); C Biagi (Department of Electrical and Computer Engineering, University of Florida, Gainesville, FL 32611: ph. 352-514-8430; biagi@ufl.edu)

Ground based observations from the Thunderstorm Energetic Radiation Array (TERA) at the International Center for Lightning Research and Testing (ICLRT) at Camp Blanding, FL, have shown a considerable amount of x-ray emission during lightning discharges. These emissions are found to be spatially and temporally associated with both the stepped leader of natural lightning and the dart leader from rocket triggered lightning. Furthermore, these x-rays are emitted in discrete bursts at the same time and location as the dE/dt pulse radiation. Using data obtained from 2005-2008, which include several natural flashes and rocket-triggered events, we will look into statistical correlation between the intensity of x-ray bursts and other simultaneous measurements including the electric current, magnetic field, electric field and its derivative. We shall also discuss any trends or statistical variations between the intensity of x-ray emission from consecutive return strokes within the same flash. Finally, a comparison between x-ray emission from natural and triggered-lightning will be discussed.

Search for Ground-Level Terrestrial Gamma-ray Flashes Associated with Natural and Rocket-Triggered Lightning Using the Thunderstorm Energetic Radiation Array (TERA)

[*M Schaal*] (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901; ph. 701-740-9620; mschaal2008@fit.edu) JR Dwyer (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901; ph. 321-674-7208; fax 321-674-7482; jdwyer@fit.edu) Z Saleh (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901; ph. 321-684-0180; ziad.saleh@gmail.com) H Rassoul (Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901; ph. 321-674-8778; fax 321-674-8864; rassoul@fit.edu); MA Uman (Department of Electrical and Computer Engineering, University of Florida, Gainesville, FL 32611: ph. 352-392-4038; fax 352-392-8671; uman@ece.ufl.edu); J Hill (Department of Electrical and Computer Engineering, University of Florida, Gainesville, FL 32611: ph. 904-708-0689; gators15@ufl.edu); C Biagi (Department of Electrical and Computer Engineering, University of Florida, Gainesville, FL 32611: ph. 352-514-8130; biagi@ufl.edu); D Jordan (Department of Electrical and Computer Engineering, University of Florida, Gainesville, FL 32611: ph. 352-392-4933; jordan@ece.ufl.edu)

Terrestrial Gamma-ray Flashes (TGFs) are intense bursts of gamma-rays first observed from space using the BATSE instrument onboard the Compton Gamma Ray Observatory. Recent measurements from the RHESSI spacecraft, along with modeling, show that these flashes most likely originate from altitudes between 15 and 21 km, making it difficult to detect such events on the ground due to atmospheric attenuation. However, in 2004, Dwyer et al. reported a gamma-ray burst at ground level during the initial stage of a rocket-triggered lightning that had a similar energy spectrum and time duration to TGFs. These results suggest that the processes that produce TGFs may also occur at lower altitudes within thunderclouds, making it possible to observe such events on the ground. Using ground based observation over the past four years from the Thunderstorm Energetic Radiation Array (TERA) at the International Center for Lightning Research and Testing (ICLRT) at Camp Blanding, FL; we have searched for TGF-like gamma-ray events associated with both natural and rocket-triggered lightning. In this presentation, we shall report preliminary results of this data analysis along with modeling of the gamma-ray emission from thunderclouds and propagation to the ground.

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