Atmospheric Sciences

A11A MCC: 3018 Monday 0800h

A Quarter Century of Satellite Measurements by TOMS I *(joint with OS, SA, V)*

Presiding: **R S Stolarski,** NASA Goddard Space Flight Center**; J A Kaye,** NASA Headquarters

A11A-01 0800h

Contribution of TOMS to Earth Science- An Overview

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The TOMS instrument was launched on the Nimbus-7 satellite in Oct 1978 with the goal of understanding the meteorological influences on the ozone column. The nominal lifetime of the instrument was 1 year. However, in response to the concern over possible man-made influences on the ozone layer NASA continued to nurse the instrument for 13.5 years and launched a major program to produce accurate trend quality dataset of ozone. Despite severe optical degradation and other significant anomalies that developed in the instrument over its lifetime, the effort turned out to be a tremendous success. In 1984, TOMS took center stage as the primary provider of Antarctic ozone hole maps to the world community; it continues to play that role until today. An unexpected benefit of the close attention paid to improving the TOMS data quality was that several atmospheric constituents that interfere with ozone measurement were also identified and meticulously converted into long-term datasets of their own. These constituents include clouds, volcanic SO2, aerosols, and ocean phytoplankton. In addition, the high quality of the basic datasets made it possible to produce global maps of surface UV and tropospheric ozone. In most cases there are no other sources of these data sets. Advanced UV instruments currently under development in the US and Europe will continue to exploit the TOMS-developed techniques for several decades.

A11A-02 0815h INVITED

TOMS and the NASA Ozone Trends Panel

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In 1985, the measurements of total ozone over the Antarctic burst suddenly into the ongoing discussions of stratospheric ozone depletion and its possible causes in the spring (Halley Bay Dobson data) and the summer (Total Ozone Mapping Spectrometer, TOMS). These were quickly followed by three scientific expeditions to the Antarctic–from the surface at McMurdo in 1986 and 1987, and by air from Punta Arenas, Chile, in 1987. The NASA Ozone Trends Panel came into existence under the direction of NASA's Bob Watson in December of 1986, and made its conclusions public in March, 1988. The data from TOMS on total ozone, and from the SBUV instrument on vertical ozone distribution, were the primary cause for the formation of the Ozone Trends Panel. These results combined with those from the other expeditions all played very significant roles in the conclusions drawn by the Panel, and by the scientific community. The TOMS data over Antarctica have become the accepted world-wide symbol for stratospheric ozone depletion.

A11A-03 0840h

The State of Total Ozone Research Before TOMS

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The study of atmospheric ozone began in academic institutions in Europe in the late 19th and early 20th Centuries. G.M.B. Dobson soon determined the basic geographic and temporal variations of total ozone with a robust total ozone spectrophotometer. Sydney Chapman proposed a photochemical mechanism to explain the presence of ozone. Yet, even in the 1960's and 70's many uncertainties remained in the understanding of the ozone variations observed with ground, balloon, and rocket instruments. At that time the development of artificial satellites offered a new technology to observe the atmosphere and early survey experiments in the US and USSR showed the feasibility of ozone profile soundings. J.V. Dave and C. L. Mateer suggested in 1967 that total ozone might also be measured from space and proposed a dedicated ozone instrument for profile and total ozone. Donald Heath led the development of the Nimbus 4 Backscatter Ultraviolet (BUV) instrument that was produced by H. A. Roeder and colleagues at Beckman Instruments. Very high quality data proved the wisdom of a dedicated instrument. The credibility of the BUV total ozone data led to it's acceptance by the international ozone community as a data source comparable to the Dobson instrument. The nadir-staring BUV, however, added little to prior knowledge of total ozone due to high variability at mid-latitudes. This paper discusses the state of knowledge leading to the development of a satellite instrument to map the spatial and temporal variations of total ozone, the Total Ozone Mapping Spectrometer.

A11A-04 0855h

The Solar Cycle Variation of Total Ozone in the TOMS Record: Role of Extratropical Wave Forcing

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The merged global satellite total ozone record is characterized by a decadal variation at low latitudes that is approximately in phase with the 11-year solar cycle. Analyses of ozone profile data (SBUV and SAGE) demonstrate that most of the column ozone solar cycle variation occurs in the lower stratosphere (85% below the 16 hPa level). Further evidence for a significant solar cycle variation in the lower stratosphere is obtained from analyses of NCEP 50 hPa temperature data, which also show a decadal variation in phase with the column ozone variation. One source of long-term variability in the tropics and subtropics is extratropical wave forcing, which is an important driver of the Brewer-Dobson circulation. To investigate possible long-term variability of extratropical wave forcing, daily and monthly mean meridional eddy heat fluxes have been calculated at a series of lower-stratospheric pressure levels over a 24-year period using NCEP reanalysis data. A decadal variation of the low-pass filtered extratropical eddy heat flux is present in the NH at pressure levels ranging from 100 hPa to 20 hPa. A similar, but less regular, decadal variation of the eddy heat flux is present in the SH. When this eddy heat flux record is used together with a simplified model based on the ozone continuity equation, it is found that a decadal variation of column ozone in the tropics can be simulated that is in phase with the observed variation (Hood and Soukharev, J. Atmos. Sci., in press). These results suggest that solar UV induced changes in the wave forcing may be mainly responsible for the solar cycle variation of total ozone. We are currently improving the model to account for seasonal differences in sensitivity of tropical total ozone to extratropical wave forcing. Results of the revised model simulations will be presented.

A11A-05 0910h INVITED

Tropospheric Ozone from TOMS: Providing the First Depictions of the Extent of Global Pollution

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The Total Ozone Mapping Spectrometer (TOMS) was first launched more than a quarter century ago to determine the global distribution of total ozone, a quantity that is dominated by the ozone distribution in the stratosphere. On average, approximately 90 percent of the total ozone column resides in the stratosphere, which is an order of magnitude greater than what is present in the troposphere. However, because of the care taken to ensure the instrument's precision and accuracy, the use of TOMS data has also provided the atmospheric chemistry community an excellent understanding of the distribution of tropospheric ozone. This paper will focus on the history of the development of the use of TOMS to provide meaningful tropospheric ozone measurements. The first papers to suggest the use of TOMS for tropospheric studies were published in the mid-1980s. Subsequently, the research over the past decade has been the development of a variety of methods to separate the tropospheric component from the total ozone column as cleanly and as accurately as possible. Using these various techniques, there have been a number of studies that have identified pollution plumes from tropical biomass burning and, more recently, pollution episodes at northern temperate latitudes during the summer. The synergistic use of TOMS with other trace gas species observed from space (e.g., CO, NO2, and aerosols) has provided a unique perspective into global-scale tropospheric chemical processes. Other new developments include the use of TOMS with cloud and reflectivity measurements to provide a profiling capability in the upper troposphere. The methodologies developed for TOMS have provided the foundation for deriving tropospheric information for ozone and other species from instruments such as GOME, SCIAMACHY, and OMI.

A11A-06 0930h

Elevated Tropospheric Ozone Over the Atlantic and Pacific Oceans in Northern Midlatitudes

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Tropospheric column ozone (TCO) is derived from differential measurements of TOMS total column ozone and Microwave Limb Sounder stratospheric column ozone. It is shown that TCO during summer months over the Atlantic and Pacific Oceans in northern midlatitudes is about the same (50 to 60 Dobson Units) as over the continents of North America, Europe, and Asia, where surface emissions of nitrogen oxides from industrial sources, biomass and biofuel burning and biogenic emissions are significantly larger. This nearly uniform zonal variation in TCO is modulated by surface topography of the Rocky and Himalayan mountains, and Tibetan plateau where TCO is reduced by 20 to 30 Dobson Units. The zonal variation in TCO is well simulated by a global chemical transport model called MOZART-2 (Model of Ozone and Related Chemical Tracers, version 2). The model results are analyzed to delineate the relative importance of various processes contributing to observed zonal characteristics of TCO.

A11A-07 0945h

Signatures of stratospheric intrusions in TOMS swath data

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TOMS swath data of total column ozone, TRACE-P observations, and high resolution CTM 4-D data are used to identify signatures of stratospheric intrusions into the troposphere over Pacific areas during March 2001. The events with significant total ozone anomalies are singled out for detailed analysis and compared with chemical transport simulations. FRSGC/UCI CTM driven by the T63L40 ECMWF forecast meteorology (190 km horizontal, 600 m vertical) developed at U.

Oslo is used to further reconstruct the 3-D intrusions in terms of isentropic potential vorticity and ozone distributions. In addition to intrusion events due to mid-latitude cyclogenesis, intrusion events due to stationary Rossby waves propagating into westerly ducts in the tropics are also investigated. A quantitative relationship between TOMS column filaments and the stratospheric influx of ozone is sought.

A11B MCC: 3016 Monday 0800h

Tropical Cirrus Anvils: Properties and Processes I *(joint with SA, AE)*

Presiding: **E Jensen,** NASA Ames Research Center**; D E Anderson,** NASA Headquarters

A11B-01 0800h

Tropical Anvil Cirrus Microphysics

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This study synthesizes data collected during a number of field campaigns by in-situ aircraft to characterize the microphysical properties of tropical, convectively-generated cirrus. The field campaigns include the Tropical Rain Measuring Mission KWAJEX campaign near Kwajalein, M. I., KAMP (the Keys Area Microphysics Project) and the Cirrus Regional Study of Tropical Anvils and Cirrus Layers (CRYSTAL) Florida Area Cirrus Experiment (FACE), both over southern Florida, and CAMEX-4 (the fourth convection and moisture experiment), studying hurricanes off the east coast of Florida. The measurements include particle size distribution and particle shape information, direct measurements of the condensed water content (CRYSTAL-FACE), and radar imagery. We examine the temperature dependence and vertical variability of the ice water content (IWC), extinction, and effective radii, and deduce the ensemble-mean ice particle densities. Data obtained in quiescent regions outside of convection are compared to observations within convective cells. The relationship between the properties of the particle size distributions and proximity to convection are examined. The IWCs show a strong temperature dependence and dependence on distance below cloud top. The IWCs are larger in the convective regions than in the quiescent regions, and the particle size distributions are markedly broader. Ensemble-mean ice particle densities are a strong function of the breadth of the particle size distributions.

A11B-02 0815h

Small, Highly Reflective Ice Crystals in CRYSTAL-FACE Anvil Cirrus

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Aircraft measurements, obtained during CRYSTAL-FACE using new instruments, indicate that ice crystals within cirrus anvils have smaller sizes and are more reflective than is assumed in most current climate models. Cloud mass, scattering cross section and number concentration were highly correlated within any given temperature range. Consequently, values of effective radius r_e were primarily a function of temperature, increasingly exponentially from approximately 5 μm at -75 $^{\circ}$C to 30 μm at freezing. Values of the asymmetry parameter g were 0.75$\pm$0.01 between freezing and -55 $^{\circ}$C. For a given model prediction of cloud mass, these results suggest low-latitude cirrus anvils should have greatly higher values of cloud albedo and emissivity than is usually assumed in climate model representations of these clouds.

URL: http://www.met.utah.edu/tgarrett/Publications/Icescattering/GRL2003.pdf

A11B-03 0830h

Summer African Dust and Florida Thunder Storms: Are CRYSTAL-FACE Anvils Typical of the Subtropics?

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The Florida peninsula can be viewed as an outdoor laboratory for the study of the indirect effects of aerosols on the properties of deep convective clouds, and the possible subsequent impact on precipitation. Depending on the seasonal weather patters affecting the area, sources of aerosols can be continental, smoke-produced, oceanic, and, as long known, of Saharan Desert origin. During the recent CRYSTAL-FACE field campaign, a variety of in situ and remote sensing evidence shows that after transport across the mid-Atlantic Ocean, episodes of African dust were widespread in the region. This is a well-known summertime phenomenon. In one study using aircraft ice nuclei (IN) data and ground-based polarization lidar measurements, the dust was observed to induce the glaciation of a slightly (about -5.0 to -8.0 degrees C) supercooled altocumulus cloud. Extrapolating the finding that African dust particles are especially active IN, it follows that the ingestion of boundary-layer Saharan aerosol could have a strong potential for modifying the microphysical content, dynamics and precipitation of summer thunderstorms in southern Florida. In the current study, we will attempt to identify connections between the characteristics of the intensively-studied thunderstorms and the nature of the dominant aerosols involved in cloud particle formation. As a first step, the near-continuous data record from the Micropulse Lidar, supplemented by Polarization Diversity Lidar data, will be used to monitor aerosol conditions. Backtrack and satellite analyzes, along with the University of Miami surface aerosol sampling record, will identify their source and likely cloud particle forming characteristics. The final stage of this research will search for correlations in in situ-derived cloud microphysical properties such as ice crystal concentration and type. If such connections are found, it must be recognized that the CRYSTAL-FACE dataset may not be representative of subtropical thunderstorms and the anvils derived from them.

A11B-04 0845h

CRYSTAL-FACE Convective Drafts

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Dual-Doppler data from 4 different days of the CRYSTAL-FACE experiment were analyzed. These days represented three different regime types - maritime convection, typical Florida peninsula convection, and peninsula convection influenced by Saharan dust. These days exhibited differences in convective organization, ranging from mostly short-lived cells embedded in larger convective clusters to larger more coherent, longer-lasting mesoscale organization. We will present and contrast draft (up and down) statistics for all days. Mass and water fluxes were calculated for all cases.

A11B-05 0900h

In Situ Measurements of Microphysical and Radiative Properties of Cirrus and Anvil Clouds

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In situ microphysical and radiative properties of mid-latitude cirrus, anvil and tropical anvil clouds, based on research flights conducted with the SPEC Learjet, the NASA WB-57 and DC-8, and the University of North Dakota Citation research aircraft, are presented. The measurements were collected in Colorado, Utah, Oklahoma, Florida and Kwajalein. All of the research aircraft were equipped with a standard complement of microphysical sensors and optical probes, plus a cloud particle imager (CPI), which produces high-definition (2.3 micron pixel) digital images of ice particles. The CPI data provide improved measurements of particle shape and size, facilitating better calculations of radiative properties of cirrus and anvil clouds. Based on the measurements, average mid-latitude cirrus, and mid-latitude and tropical cirrus microphysical properties of particle size distribution, crystal habit, ice water content, extinction coefficient, effective radius and optical depth are derived. The data show a distinct difference between particle characteristics in mid-latitude cirrus and anvil clouds. In cirrus, the predominate crystal type (weighted by area or mass) is the bullet rosette, a polycrystalline structure typical of crystal formation at temperatures colder than -30 C. Conversely, although anvils occur at temperatures similar to cirrus, bullet rosettes are very rare in anvils. Instead crystal types in anvils are typical of those formed at temperatures warmer than - 30 C. There is also a notable difference in microphysical and radiative characteristics between mid-latitude, Florida, and tropical (Kwajalein) anvils. Tropical anvils are comprised mainly of single crystals, mostly irregular blocky-shapes. In mid-latitude and Florida anvils, there are more aggregates and often chains of small particles that may be formed as a result of the higher electric fields in continental clouds. The impact of crystal type on calculations of radiative transfer are also considered.

URL: http://www.specinc.com

A11B-06 0915h

The Microphysical and Radiative Evolution of a Cirrus Anvil During CRYSTAL-FACE

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