Atmospheric Sciences

A11A MC: Hall D Monday 0830h

Cloud Physics, Cloud Modeling, and Water Vapor

Presiding: **S Sherwood,** Yale University

A11A-0014 0830h POSTER

Polar Cloud Detection From MISRs Band-Differenced Angular Signatures

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Satellite-based cloud detection in polar regions has traditionally been extremely difficult owing to the similar spectral signatures of cloud and snow/ice. The Multi-angle Imaging SpectroRadiometer (MISR), onboard the EOS-Terra satellite, offers a new approach to cloud detection that uses a band-differenced angular signature (BDAS). The BDAS is the difference between MISRs 0.44 m and 0.865 m narrowband reflectance that is differenced between MISRs 70 degree and 60 degree cameras that view the forward scattered radiation. We will demonstrate for the first time using satellite data that the BDAS alone provides excellent cloud detection, especially in polar regions. A global 1.1 km resolution cloud mask using the BDAS approach from MISR will soon be released to the public.

A11A-0015 0830h POSTER

Regulation of Tropical Deep Convection by SST and Wind Speed

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In the tropics, temperatures follow a $\theta_e = 345$ K moist adiabat up to about 11.3 km. In order to participate in deep convection, an air parcel must have $\theta_e > 345$ K. We use the fraction of air parcels in the Convective Boundary Layer (CBL) whose θ_e exceeds 345 K as a proxy for deep convection. We show that this fraction is essentially zero for SSTs less than 26.5 °C, increases rapidly until 28 °C, and subsequently levels off. This is strongly analogous to the dependence of tropical deep convection on SST as inferred from the variation of Outgoing Longwave Radiation (OLR) with SST. For SSTs larger than 28 °C, the θ_e Probability Distribution Function (PDF) in the CBL appears to approach a form which is independent of SST. We use a simple model based on boundary-layer quasiequilibrium to show that, in this regime, the effect on the θ_e PDFs of increasing SST is offset by decreasing wind speeds.

A11A-0016 0830h POSTER

Increasing Trends in Cloud Reflectance and Planetary Albedo Over the Maritime Antarctic

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Recent analysis of fourteen years of Total Ozone Mapping Spectrometer (TOMS) UV-A reflectivity data, published by NASA Goddard Space Flight Center, has suggested that cloud reflectance may be increasing over large parts of the Southern Ocean. This potentially indicates an increase in cloud amount or cloud opacity, in response to a climate warming scenario. The TOMS program comprises a well-calibrated series of instruments that has provided useful information on top-of-atmosphere (TOA) reflectance since late 1978. The major limitation with analyzing TOMS data alone is that backscattered radiances at the conservative scattering UV-A wavelengths depend strongly on the albedo of the underlying sea ice as well as the clouds. The effects of sea ice and clouds cannot be separated, and trends in TOA reflectance as measured by TOMS by itself cannot be attributed unambiguously to purely atmospheric phenomena. In this work, we have combined TOMS data with Special Sensor Microwave Imager (SSM/I) passive microwave observations of sea ice concentration, to identify TOMS pixels in maritime Antarctic regions that lie over open ocean, and over various concentrations of sea ice. We have also extended the trend analysis to encompass two decades worth of TOMS data. As a whole, Antarctic sea ice concentration has been increasing slightly, although there is considerable variability in Antarctic sea ice trends (including changes in sign) with longitude. We find similar regional variability in TOMS reflectivity trends. There are some regions where upward trends in cloud reflectance can be separated from trends in sea ice, and in these regions the TOMS data may indicate a response to a changing atmosphere. These regions include parts of the Marie Byrd Land, Queen Maud Land, and American Highland sectors of the Southern Ocean. Regions where trends in TOMS reflectivity are zero or slightly negative include the Wilkes Land sector of the Southern Ocean, and the Weddell and Bellingshausen Seas. These results are discussed in terms of meteorological phenomena, changes in sea ice concentration, changes in sea ice reflectance, and the resulting changes to the shortwave and longwave radiation balance.

URL: http://arcane.ucsd.edu

A11A-0017 0830h POSTER

Computation of Global Water Balance Components Using Observational and Model Data

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The aim of this research is to compute the global water balance components by using a combination of most recently available observational and model-generated data and compare our results with earlier studies. Wind velocity information from NCEP/NCAR Reanalysis II (in pressure coordinates; 1000, 925, 850, 700, 600, 500, 400, 300 mb), and atmospheric moisture from NASA Water Vapor Project (Nvap; same pressure levels as wind data) have been used to compute global fields of moisture flux divergence on a 2.5 degree by 2.5 degree lat/lon grid. These are combined with the latest available estimates of mean monthly precipitation from Global Precipitation Climatology Project (GPCP) and the atmospheric moisture tendency to estimate global evaporation as a residual. Ocean flux values will only be presented, however, because surface pressure over land areas is frequently less than 1000 mb on which moisture and wind information is reported.

It is observed that the magnitude of computed flux convergence is greater than the GPCP precipitation mainly near the Intertropical Convergence Zones (ITCZs). This results in negative values of computed evaporation given very small values of moisture tendency. When model (NCEP/NCAR Reanalysis II) precipitation is used instead of observed (GPCP) precipitation the extent of negative evaporation is greatly reduced suggesting that (as expected), model precipitation is more consistent with the model winds than it is with the GPCP precipitation. This suggests that mix of observations with model winds is not appropriate for water balance calculations. Additionally, substantial differences are observed between Nvap (mostly from observations) moisture and the model moisture fields. These differences are also partly responsible for the computed negative evaporation values.

Results will be presented comparing computation of water balance components using different vertical resolutions of the constituent data. Additionally, contribution of mean and eddie components of moisture flux divergence will be presented.

A11A-0018 0830h POSTER

Effects of Aerosols on Cloud Properties — Calculations With SensCAMP, A Rising Parcel Model With Parameter Sensitivity Analysis

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Ongoing efforts are being made to increase the fidelity of modeling the global spatial patterns and seasonal variations of direct and indirect aerosol radiative forcing. Our prior efforts have treated radiative spectral resolution, parameterization of aerosol optical properties as functions of local humidity and black carbon fraction, and parameterization of black carbon effects on cloud optical properties. Here, we use the SensCAMP rising parcel model to characterize cloud properties as functions of aerosol concentrations, composition, and size distribution. This forms a basis for parameterization of cloud optical properties as a function of aerosol properties within the context of IMPACT/CCM3, a coupled global chemistry/climate model.

The parcel equations, size-dependent condensation/evaporation equation, and auxiliary equations such as chemistry and coagulation are time-integrated using the SensIDA parallel, fully implicit, variable order and variable time-step differential algebraic equation (DAE) solver. SensIDA (and thus SensCAMP) includes the capability to simultaneously solve both the physics equations and the sensitivity of the solutions to selected model parameters.

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

URL: http://www.llnl.gov/CASC/nsde/sensitivity.html

A11A-0019 0830h POSTER

Using water vapor as a tracer of atmospheric circulation in a GCM

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The role of atmospheric circulation in determining humidity patterns has received considerable attention, in light of the importance of water vapor as a principal greenhouse gas and an amplifier of possible anthropogenic effects on climate. Addressing the maintenance of the free-tropospheric humidity distribution, and its covariation with temperature, investigators employ methods including (Reynolds) flux decomposition, Lagrangian trajectory calculation, and correlation with cloud indices.

An additional, complementary, approach is described: online simulation of atmospheric water age and its spatial pattern of surface origin, using the NASA Goddard Institute for Space Studies (NASA-GISS) GCM. A virtually ubiquitous surface source and short tropospheric lifetime render atmospheric water an informative tracer if "tagged" at the time and location of its surface input. The source determination resembles a trajectory calculation, but permits participation in cloud microphysical and transport processes.

The transport distance of water vapor, one measure of the influence of the general circulation upon humidity, is the primary context in which the model results are presented here. Factors such as synoptic vertical velocity statistics and the spatial coverage of deep convection strongly affect the nonlocality of moisture aloft. The relative contributions of distinct geographic regions (e.g. the ITCZ, storm tracks) to moistening of the upper troposphere are also examined.

A11A-0020 0830h POSTER

Role of Tropical Clouds in Surface and Atmospheric Energy Budget

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In this paper we present our diagnostic estimates of cloud radiative forcing (CRF) and clear-sky radiation budget at the surface and in the atmosphere based on satellite observed radiation budget at the top of the atmosphere (TOA) and empirical parameterizations derived from radiation models and field observations. Our analysis is restricted to the tropical Pacific. High clouds over the intertropical convergence zone (ITCZ), the south Pacific convergence zone (SPCZ) and the warm pool exert a positive CRF of about 70 W m-2 within the atmosphere and a negative CRF of about -70 W m-2 at the surface although with a negligible net CRF at the TOA. On the other hand, low clouds over the eastern sub-tropical Pacific and the equatorial cold tongue, exert a negative CRF of about -20 W m-2 at the surface as well as in the atmosphere. The spatial gradients of the clear-sky radiation budget at the surface and in the atmosphere are small. In particular, it is shown that the clear-sky radiative cooling in the atmosphere is larger over the ITCZ, the SPCZ and the warm pool, when compared with that over the subtropics and the cold tongue. Next, based on these diagnostic estimates and available surface turbulent heat flux data, we quantify the role of atmospheric CRF in the large-scale atmospheric moist static energy (MSE) transport. It is found that the atmospheric CRF provides the major energy source term for balancing the divergence of MSE transport (from the ITCZ, the SPCZ and the warm pool to the sub-tropics and the cold tongue) by the large-scale atmospheric circulation. On the other hand, the clear-sky radiative flux convergence and the surface turbulent heat fluxes have just the reverse spatial pattern and hence cannot satisfy the MSE transport requirements.

A11A-0021 0830h POSTER

Cloud Detection with MODIS: Regional and Global Applications

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NASA's TERRA spacecraft was successfully launched on 18 December 1999. Included in its suite of earth monitoring instruments is the MODerate Resolution Imaging Spectroradiomenter (MODIS), a 36 band high spatial resolution (250 m to 1 km) and broad spectral coverage (shortwave reflected solar through longwave emitted thermal) radiometer which allows unprecedented observations of the earth-atmosphere system.

Cloud masking from the MODIS observations are produced routinely and distributed to earth system scientists. The paper will present the latest updates to the MODIS cloud mask. Results of cloud detection for global and regional applications will be presented. The sensitivity of the cloud detection alogrithm to thresholds will be demonstrated. The detection of aerosols will also be demonstrated. Validation using other ground based, aircraft and orbiting instruments will be presented.

A11A-0022 0830h POSTER

NPOESS/VIIRS Cloud Mask Algorithm

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Identifying pixels as either cloudy or clear is an essential component of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Visible/Infrared Imager Radiometer Suite (VIIRS). The VIIRS Cloud Mask (VCM) technique incorporates a number of cloud detection tests that determine whether a pixel is obstructed by a cloud or cloud free. If a cloud is detected, the VCM indicates whether its phase is water, ice, or mixed. Additionally, the VCM specifies whether aerosols, fire, or shadows are detected within the pixel field of view. The VCM algorithm first determines a processing path for each pixel. The processing path indicates day or night, sun glint, land (desert or non-desert), water (inland or sea), coast (inland or sea), and snow/ice background. After the processing path is established, the VCM algorithm conducts a series of threshold and ratio tests using solar reflectance. The algorithm also involves threshold and difference tests using the thermal Brightness Temperatures (BT). The threshold values for the various tests are dependent upon the dominant regional classification, or surface type, of the pixel. The tests applied to generate the VCM have a heritage from the Advanced Very High Resolution Radiometer (AVHRR) and the Moderate Resolution Imaging Spectroradiometer (MODIS). Each test returns a clear or cloudy result with an associated confidence level. Analogous to the MODIS Cloud Mask, the VCM groups its cloud confidence tests into five categories. The minimum confidence from individual members represents the confidence for that group and the product of all the group confidences is used to determine the overall cloud confidence value. VIIRS cloud, aerosol, land, ocean, surface temperature, and snow/ice Environmental Data Records (EDRs) use the VCM as required input.

A11A-0023 0830h POSTER

Global Measurements of Water Vapor and High Clouds Using MODIS Near-IR Channels

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The Moderate Resolution Imaging Spectrometer (MODIS) on the Terra Spacecraft has been collecting scientific data since February of 2000. On the MODIS instrument, there are several channels located within the 0.94-micron water vapor band absorption region for remote sensing of water vapor. There is also a narrow channel centered at 1.375 micron for remote sensing of high clouds. Daily and seasonal variations of column atmospheric water vapor amounts have been observed reliably from MODIS data. Daily and seasonal variations of high clouds have also been observed. The results on global measurements of water vapor and high clouds using MODIS near-IR channels will be presented.

A11A-0024 0830h POSTER

NPOESS/VIIRS Cloud Module: An Overview of the Science and Software

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Cloud parameters are an important subset of the output products from the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Visible/Infrared Imager Radiometer Suite (VIIRS) sensor. The following cloud Environmental Data Records (EDRs) are produced in sequence: cloud optical thickness and cloud effective particle size, cloud top temperature, height, and pressure, cloud cover and corresponding cloud layers, and cloud base height. This paper discusses the scientific algorithms and expected performance for each cloud product. An overview of the Cloud Module interface to the VIIRS Cloud Mask and the remainder of the VIIRS system is presented. Software units within the Cloud Module are addressed including inputs, processing, and outputs. Special emphasis is placed on discussion of new products and enhancements over existing cloud retrieval capabilities from heritage sensors.

A11A-0025 0830h POSTER

Algorithm Development and Sensitivity Study on the Retrieval of Cloud Optical Thickness and Effective Particle Size for NPOESS/VIIRS

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This paper describes the algorithm development and sensitivity study on the retrieval of cloud optical thickness and effective particle size for the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Visible/Infrared Imager Radiometer Suite (VIIRS). Overall retrieval processing begins with the identification of cloud-contaminated pixels and their associated phase via the VIIRS cloud mask and cloud phase programs. The solar two-channel correlation and the infrared (IR) cirrus techniques are used to infer the cloud optical thickness and effective particle size based on the theory and parameterizations of radiative transfer and cloud microphysics. VIIRS measurements are simulated using the University of California, Los Angeles (UCLA) line-by-line equivalent radiative transfer model to generate radiance/reflectance tables for various combinations of cloud optical thickness, effective particle size, and scene parameters. Signal-to-noise ratio tests and the error budget studies are carried out using input radiance perturbations based on design noise models and typical uncertainties in atmospheric and surface parameters. The methodologies and results of algorithm sensitivity studies are presented along with discussions on relevant practical considerations.

A11A-0026 0830h POSTER

Toward Closing the Water Cycle over the ARM/CART Region: Implementation of Stable Water Isotope Physics in MM5

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To date, atmospheric water isotope modeling has been performed on a global scale. The development of a stable water isotope scheme in a mesoscale model will lead to a simulated spatial distribution that will improve our understanding of present day climate variability, as well as historical climate patterns. The purpose of this study was to add water isotope tracers to the regional atmospheric model MM5 (NCAR's Mesoscale Model 5) in order to link existing global and basin-scale isotope models, and to work toward an improved knowledge of the water budget over the ARM site.

In order to include isotopic processes in MM5, eight new prognostic variables were added to the model's dynamical core. These are the isotopic mixing ratios for water vapor, cloud liquid water, cloud ice, and rain for the stable isotopes O18 and deuterium. The isotopes are treated in a manner similar to the natural water vapor, cloud liquid water, etc. in terms of diffusion, advection, nudging, and filtering. Isotope fractionation and diffusion are handled using the approach of Gedzelman and Arnold (1994). Processes treated in this model are fractionation during deposition of water vapor onto cloud ice and condensation of water vapor onto cloud water, and also diffusive exchange of isotopes between vapor and falling rain drops. The bulk flux model of Hoffman et al. (1998) is used here as a first order approximation for isotopic evaporative processes.

For the runs to be discussed here, lateral boundary conditions were generated by the Melbourne University General Circulation Model. This GCM runs at a resolution of R21, and predicts values of the O18 and deuterium mixing ratios at each grid point. Results of preliminary model runs will be discussed.

A11A-0027 0830h POSTER

Quantitative Precipitation Sensitivity in Simulated Deep Convective Storms due to Variations in the Particle Density and Size Distribution for the "Large Ice" Category

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This work reports on the sensitivity of quantitative precipitation produced by deep convective thunderstorms to the ice phase microphysical parameterization using a three-dimensional, non-hydrostatic cloud model. The model utilizes the traditional Lin *et al.* (1983) microphysics scheme, which includes prognostic equations for water vapor, two categories of liquid water (cloud water and rain) and three categories of frozen water (cloud ice, snow, and "large ice").

Storms were simulated in a thermodynamically unstable environment with a half-circle wind hodograph capable of supporting rotating supercell thunderstorms. Seven inverse-exponential size distributions, based upon *in situ* observations reported in the literature, were tested by varying the slope intercept parameters and particle densities for the "large ice" (graupel/hail) category. The first regime is characterized by a distribution of graupel particles that are most numerous at the smallest sizes resulting in the slowest net fall velocities. The slope intercept in that case is 4 x 10^7 m^{-4} with a graupel ice particle density of 400 kg m^{-3}. The last regime is characterized by a distribution of hail particles that are most numerous at the larger sizes resulting in the fastest net fall velocities. The slope intercept in that case is 4 x 10^3 m^{-4} with a hail ice particle density of 900 kg m^{-3}. Five other regimes with intermediate size distributions and net fall velocities for the "large ice" category fill the parameter space.

A smaller slope intercept and a larger ice particle density results in storms associated with greater net precipitation at the ground. For example, the net precipitation mass at the ground after 2 hours for the first regime was about half that of the last regime (38 Tg versus 80 Tg) given storms with similar updraft intensity and rotation at midlevels. This result has important implications for storm scale predictability using cloud-resolving models.

URL: http://mrd3.nssl.ucar.edu/~gilmore/www/AGU.html

A11A-0028 0830h POSTER

Comparison of Cloud Fractions and Cloud Properties Retrieved Over the North Slope of Alaska.

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In the Arctic there is a large seasonal variability in cloud cover, cloud base height, and cloud liquid water content. We have retrieved cloud properties above the Atmospheric Radiation Measurement Program Site in Barrow using a suite of different instruments and retrieval techniques. Daily and monthly averages of the cloud properties are compared over a full annual cycle using data from LIDAR, Whole Sky Imager, Cloud Radar, Micro Wave Radiometer, and Broadband Radiometer instruments. The cloud properties retrieved from the ground-based instruments are compared with cloud properties derived from AVHRR data. Instruments and retrieval algorithms are usually developed for mid-latitudes and will often fail under the extremes experienced during the arctic winter, which makes it important to verify their performance under these conditions. Accurate parameterization of cloud properties in the Arctic is instrumental for improving the performance of climate models at high latitudes. Currently data from ISCCP does not agree well neither with ground based measurements nor satellite data derived using algorithms developed for use at high latitudes.

A11A-0029 0830h POSTER

Validation of Top-of-Atmosphere Radiative Fluxes Using Multiangle Measurements from the Clouds and the Earth's Radiant Energy System (CERES) Satellite Instrument

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Nine months of measurements from the Clouds and the Earth's Radiant Energy System (CERES) instrument aboard the Tropical Rainfall Measuring Mission (TRMM) satellite are used to assess uncertainties in shortwave (SW), longwave (LW) and window (WN) top-of-atmosphere (TOA) radiative flux estimates based on recently developed CERES Angular Distribution Models (ADMs).

CERES has the unique capability of being able to acquire measurements over a region in either a crosstrack, alongtrack or rotating azimuth plane (RAP) scan mode. CERES's multiangle sampling capability is exploited to determine errors in instantaneous and regional mean TOA fluxes over the tropics. Results are compared with those obtained from the CERES ERBE-Like product, which uses algorithms from the Earth Radiation Budget Experiment (ERBE) applied to the same CERES data.

Instantaneous fluxes from the new CERES ADMs for days when CERES samples radiances in the alongtrack scan mode show a factor of 4 improvement in consistency with angle compared to CERES ERBE-Like fluxes. Similarly, mean albedos based on the new CERES ADMs show very little dependence on viewing geometry, whereas ERBE-like albedos show a 10% (relative) increase with viewing zenith angle. Regional mean flux errors from all nine months of CERES/TRMM are generally less than 0.5 W m-2 (1 sigma), a 40% improvement over CERES ERBE-Like. Flux uncertainties are also examined as a function of cloud and clear sky properties inferred using measurements from the Visible Infrared Radiometer (VIRS), which flies alongside CERES on the TRMM spacecraft.

A11A-0030 0830h POSTER

The Multi-spectral NPOESS/VIIRS Cloud Thermodynamic Phase Algorithm

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The successful demonstration of the Moderate Resolution Imaging Spectroradiometer (MODIS) cloud phase algorithm opens the door for the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Visible/Infrared Imager Radiometer Suite (VIIRS) to determine cloud phase operationally. VIIRS will be built to meet the Integrated Program Office (IPO) operational imagery requirements. VIIRS multi-spectral measurements, encompassing visible, near infrared and longwave infrared, can provide significant spatial and spectral information allowing inference on the existence of cloud and its thermodynamic phase. This paper describes the operational algorithm that uses VIIRS spectral measurements to retrieve cloud phase (ice, water, or mixed) at the single pixel resolution. Similar to MODIS, VIIRS will use a tri-spectral thermal infrared algorithm augmented by visible and near infrared spectral information. A cloud phase confidence indexing system, defining unique VIIRS cloud phase information for various applications, is also presented. Some simulation test results are shown demonstrating the utility of this multi-spectral algorithm.

A11A-0031 0830h POSTER

Atmospheric Dynamical Responses to Solar Wind Variations on the Day-to-Day Timescale

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In the early 1970s it was shown by John Wilcox and associates and verified by Colin Hines that the strength of winter storms across the northern hemisphere decreases at times of solar wind 'sector boundary' crossings. These are now known as heliospheric current sheet (HCS) crossings, and correspond to the extension of the coronal streamer belt passing over the Earth, with reductions in solar wind velocity by about 10%. The strength of winter storms is objectively evaluated by the vorticity area index (VAI) calculated from gridded geopotential height data sets. It was shown by Tinsley, Hoeksema, Baker and Kirkland in the mid-1990s that this VAI response (the Wilcox effect) tracks the decrease in MeV electron flux precipitating from the magnetosphere, with a lag of less than a day. The MeV electron flux is strongly correlated with solar wind velocity, and together with its associated X-ray Bremsstrahlung modulates the stratospheric vertical column resistance. For winters when the column resistance is unusually high because of a high mixing ratio of H2SO4 from volcanic eruptions, the ionosphere-earth current density Jz is modulated by these stratospheric resistance variations.

The winter storm response can be understood in terms of a general theory (Tinsley, Space Sci. Rev., 94, 231-258, 2000), and it involves changes in cloud microphysics and precipitation from the storm systems at mid-high geomagnetic latitudes, due to electroscavenging by cloud droplets. The electroscavenging rate tracks the Jz changes. There is a similar effect from reductions in tropospheric resistance associated with changes in cosmic ray flux during magnetic storms, first noticed in the 1960s by Walter Orr Roberts and associates. The Roberts and Wilcox effects are part of a more general influence of solar activity affecting Jz and clouds, which is part of an even more general influence of electroscavenging on clouds. The precipitation changes associated with cosmic ray and Jz changes have been evaluated by Kniveton and Todd (GRL 28, 1527-1530 and 3279). In winter storms the VAI response arises from a redistribution of vorticity within the storm because of diabatic heating changes. The storm vorticity changes have longer term dynamical and climatic consequences.

URL: http://www.utdallas.edu/dept/physics/Faculty/tinsley/tinsley.htm

A11A-0032 0830h POSTER

Laboratory Studies of Ice Particle Nucleation and Habit Formation Under Cirrus Cloud Conditions

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Ice particle structure and ice particle shape, particularly at cirrus altitudes, strongly influences the earth's climate via scattering of solar incoming radiation, absorption and re-emission of terrestrial outgoing infrared radiation, cloud chemistry and uptake of gaseous species and precipitation development. The most commonly observed ice crystals found in recent field observations of ice clouds have habits quite different and with much more irregular and complex shapes than the reported primary habits of ice. The cause of this irregularity is an area of active study with possible processes being nucleation and polycrystallinity. Yet to date few studies of ice crystal growth and sublimation

and habit evolution have been done under cirrus conditions without the possible effects of substrates.

We have developed a low-temperature electrodynamic balance with a central thermal diffusion chamber, which provides a range of humidity control similar to cirrus cloud conditions. Experiments have been done looking at the shape and structure of ice particles grown from frozen droplets for a temperature range from -5 to -40 C and for an increase in particle mass of about 10x. Similar to results found in recent laboratory experiments, we find plate-like and nearly isometric compact particle aspect ratios predominate over the full temperature range. We observe a weak dependence of crystal morphology on growth rate with crystals grown slowly adopting isometric habits, while faster grown crystals often result in habits containing thin side-planes. From analysis of the growth patterns, we observe a morphological transition from which we infer a lower limit for the critical supersaturation for layer nucleation. In general we find that defect nucleated growth predominates at lower growth rates and layer nucleation becomes increasingly important with increasing growth rate. Preliminary results also indicate no effect of nucleation mode (homogeneous versus heterogeneous freezing of the initial droplet) on ice particle habit although particles nucleated and grown at the lowest temperatures tend to be more polycrystalline.

A11A-0033 0830h POSTER

Aerosols and Ice Particle Size in Tropical Cumulonimbus

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Reduction of cloud particle size by aerosol-induced nucleation is widely suspected but hard to prove definitively due to the possible confounding of aerosol and meteorological influences on cloud development. This effect may be important for climate change since many aerosols are anthropogenic. Here statistical analysis is applied to a long dataset of cumulonimbus clouds, a type where aerosol impacts have not yet been studied empirically, to differentiate between aerosol and meteorological impacts. A retrieval of ice crystal size near the tops of active deep convective clouds (Cb) throughout the Tropics over a 12-year period is presented based on radiances from the 3.7-μm channel of the AVHRR. Effective diameters are 10-20% smaller over land than ocean. Downwind of continents, crystals are smallest when low-level, offshore transport is strongest. Other regional, seasonal, interannual and long-term variations are also found. These are compared with variations of TOMS retrieved tropospheric aerosol and with variations of convective intensity and amount in an effort to identify potential causes by statistical association. Evidence is found to support reduction of ice sizes by both aerosol increases and convective intensity increases, but no relationship is found with convective rate of occurrence. Aerosols appear to be the main influence on seasonal and longer times scales, with a ~20% decrease in Cb crystal effective diameter per unit increase in TOMS aerosol index in regions of biomass burning that is consistent among all robust aerosol variations. Based on the locations of lowest and greatest sensitivity of to aerosol, open biomass burning appears to be more important than urban sources of aerosol in influencing Cb microphysics. Soil dust may also be important.

A11B MC: 133 Monday 0830h

Current Understanding of Tropospheric Aerosol: Advances in Laboratory and Field Measurements I

Presiding: **V H Grassian,** University of Iowa**; J Jayne,** Aerodyne Research Inc

A11B-01 0830h

Long-Term Record of nss-Sulfate and Nitrate in Asian Aerosols on Midway Island, 1981-2000: Evidence of Increased Anthropogenic Emissions from Asia

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Increasing anthropogenic emissions from Asia, especially from regions undergoing rapid industrial development, have raised interest in the outflow of chemically and radiatively important gases and aerosols. Various studies have shown that every spring large quantities of mineral dust and pollution aerosol are carried eastward out of Asia and transported over a broad region of the North Pacific. Here we present the results of a long-term aerosol study on Midway Island in the central Pacific (28°13N, 177°22W) in the central North Pacific where sampling began in 1981 and continued through the 1990s. Filters were analyzed for species that have both anthropogenic and natural sources: non-sea-salt (nss) $SO_4^=$, NO_3, methanesulfonate (MSA), mineral dust and sea salt. Natural (DMS-derived) $SO_4^=$ (nat-$SO_4^=$) is estimated on the basis of the MSA concentration and subtracted from total $SO_4^=$ to yield an estimate of anthropogenic $SO_4^=$ (anth-$SO_4^=$). Monthly means show that anth-$SO_4^=$ increases strongly in March (0.52 μg m^{-3}) along with mineral dust and peaks in April (0.59 μg m^{-3}). In spring, 50% of the nss-$SO_4^=$ in the boundary layer at Midway is from "anthropogenic" sources; on an annual basis, about 40%. Anth-NO_3^- also reaches a maximum in spring when it accounts for about half the total NO_3^-.

To elucidate long-term trends we estimated the mean spring-time anth-$SO_4^=$ and anth-NO_3^- concentrations on a year-to-year basis. Both show an increasing trend, almost doubling from the early 1980's to the mid-1990's. The general rate of increase in anth-$SO_4^=$ aerosol at Midway matches estimates of the rate of increase of SO_x emissions in China. There are no long term data on NO_x emissions in Asia but recent trends suggest they are increasing at a rate comparable to that of SO_2.

Finally we point out that our data suggest that anth-$SO_4^=$ and anth-NO_3^- at Midway have decreased since the mid 1990's. A downward trend in anth-$SO_4^=$ concentrations would be consistent with recent estimates which show that SO_2 emissions from China in the middle 1990's have flattened and begun to decline. Thus the quantities of SO_2 and associated pollutants emitted from Asian sources over the longer term may be less than that projected in many emission scenarios. Taken as a whole, the Midway data show that Asian emissions have had a great impact on aerosols over a large area of the central North Pacific and that this impact has changed markedly and rapidly over the past two decades. The assessment of the future climate effects of Asian aerosols over the Pacific will be challenging because of the complex composition of the windborne particles and their rapidly changing concentrations.

A11B-02 0845h

Saharan Dust: Particle Size Distributions and Light Absorption From Measurements During PRIDE and AEROCE

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During July 2000, the Office of Naval Reseach and NASA co-sponsored the Puerto Rican Dust Experiment (PRIDE) to assess the physical and optical properties of Saharan dust over the western Atlantic. Numerous aerosol characterization instruments were deployed on Isla Cabras (18.21 N, 65.60 W) in the Roosevelt Roads Naval Station at the eastern end of Puerto Rico. As part of AEROCE (Atmosphere/Ocean Chemistry Experiment), we had previously made similar measurements over the eastern Atlantic at Izana, Tenerife, Canary Islands (28.30 N, 16.48 W). Instrumentation included a TSI APS33 aerodynamic particle sizer, a Ruprecht and Patashnick Tapered Element Oscillating Microbalance (TEOM), and a Radiance Research particle soot absorption photometer (PSAP). At the same locations, daily, high-volume, bulk aerosol samples were collected and analyzed for mineral dust, sea-salt, nitrate, sulfate, and ammonium and for aerosol light absorption (every 10 nm from 300 to 1100 nm via total diffuse reflectance measurements). With the concurrent aerosol chemistry, variations in the in-situ aerosol physical and optical properties can be linked to variations in the concentrations of particles from specific sources. High concentrations of Saharan dust were present at Izana during the last half of July 1995. The APS data at Izana are almost exclusively from dust as there is no sea-salt at this free troposphere site. We used the measured particle size distributions for high dust periods from this campaign to establish an average dust size distribution. Because of the nearly zero correlation between sea-salt and dust, the APS size distributions during PRIDE could be reasonably well resolved between these two components. In contrast to the situation at Izana, there were virtually no particles larger than 10 um geometric diameter at Puerto Rico. Progressively lesser fractions of particles were lost between the eastern and western Atlantic as the particle size decreased. With the natural variability of the dust size distribution and the uncertainties associated with the sample analyses, we could not positively identify any significant differences between the size distributions at Izana and those at Puerto Rico for particle sizes less than about 6 or 7 um. Our measured dust size distributions at both locations show a broad peak that is flat topped from 3.5 to 8.5 um diameter. dV/dlogD decreases sharply above this range, but with a much gentler slope toward smaller particles. This size distribution is consistent with the TEOM total mass concentrations at both Puerto Rico and Izana. Mie estimates of the Saharan dust absorbance based on our measured size distributions and a previously reported dust refractive index yield a dust light absorption efficiency of 0.08 to 0.09 m2/g at 565 nm. Comparable Saharan dust specific absorbances at 565 nm were obtained from the diffuse reflectance technique for samples collected at Izana and Puerto Rico as well as at Barbados and Miami. Notably, the specific absorbance for dust derived from the PSAP measurements during PRIDE were more than a factor of two lower. In contrast, our previous results have shown that the PSAP and diffuse reflectance techniques yield nearly identical results for absorbing aerosols that are dominated by black, submicron particles, i.e. soot.

A11B-03 0900h INVITED

Spatial and Temporal Variability of Transformations Occurring on Particles During INDOEX and ACE-Asia

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This presentation will focus on the aerosols observed during two major field campaigns, INDOEX and ACE-Asia. In both studies, an aerosol time-of-flight mass spectrometer (ATOFMS) was used to make continuous measurements of the size and chemical composition of individual particles while traveling into different regions on board the NOAA Research Vessel Ronald H. Brown. A central theme in both of these campaigns involved the investigation of the chemistry of aerosols with a goal of understanding their role in global climate change. This presentation will focus on the temporal and spatial variability of individual particles in different regions and the major changes observed during these studies. Specifically, the chemical transformations occurring on various types of dust and sea salt will be described, detailing the resulting chemical associations between various particle types and secondary species such as nitrate, sulfate, and carbon. High temporal resolution particle measurements will be compared with simultaneous measurements of gas phase species and correlated with trajectory data.

A11B-04 0930h

Chemical Analysis of Individual Aerosols Particles by Electron Energy-Loss Spectroscopy (EELS)

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We use electron energy-loss spectroscopy (EELS) with a transmission electron microscope (TEM) to obtain chemical and bonding information on individual aerosol particles. EELS is ideally suited to this task because of its high spatial resolution and sensitivity to