A21D MCC: Level 2 Tuesday 0830h

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

Presiding: **A Krueger,** University of Maryland Baltimore County**; R D McPeters,** NASA Goddard Space Flight Center

A21D-0992 0830h POSTER

TOMS Ozone Anomalies and Ozone Retrieval Errors Over Cloudy Areas

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This study characterizes TOMS Ozone Retrieval Errors (OREs) associated with incorrect Cloud-Top Pressures (CTPs) and with assuming opaque Lambertian clouds, investigates these errors' effects on tropospheric ozone derivation, and analyzes ozone anomalies over TOMS data. Large errors occurring in TOMS assumed CTPs and inaccurate CTP-caused OREs are most significantly from inappropriately added ozone below clouds. Because OREs are usually within the TOMS retrieval precision when Cloud Optical Depth (COD)>20, assuming Lambertian surface is good. Because of In-Cloud Ozone Absorption ENhancement (ICOAEN), assuming opaque clouds can introduce large positive OREs even for optically thick clouds. For a 2-12 km water cloud of COD 40 with 20.8 DU ozone inside the cloud, the ORE is 17.8 DU at nadir. The ICOAEN effect depends strongly on viewing geometry and inter-cloud ozone amount and distribution; it is typically 5-13 DU over the tropical Atlantic and Africa and 1-7 DU over the tropical Pacific for deep convective clouds. The negative errors from using the TOMS Partial Cloud Model (PCM) partly cancel other positive errors. At COD < 5, the TOMS algorithm retrieves approximately the correct total ozone because of compensating errors. With increasing COD up to 20-40, negative PCM effect decreases to almost zero, and the overall positive ORE increases and is dominated by ICOAEN effect. The ICOAEN effect can largely underestimate tropospheric ozone derived from cloudy/clear difference techniques. The convective cloud differential and cloud-clear pair methods use minimum ozone above clouds to cancel positive errors. A Positive or Negative Ozone Anomaly (POA/NOA) is defined to occur if the ozone/reflectivity correlation coefficient in a region is >0.5 or <-0.5. Average fractions of OA occurrence are 31.8% and 35.8% in Nimbus-7 and Earth-Probe TOMS data, respectively. Most tropical NOAs result from large cloud-height errors; corrections lead to 50-70% POAs in the tropics because of mainly the ICOAEN effect. POAs with fractions of 30-60% occur in marine stratocumulus regions west of South Africa and South America. OREs over clear and cloudy areas cause about half the ozone/reflectivity slope; greater ozone production from frequent low-altitude clouds and rich ozone precursors may cause the remainder. The knowledge of TOMS OREs has important implications for ozone/trace gas retrieval from other satellites.

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The Good, the Bad, and the Ugly: 25 Years of TOMS Optical Degradation

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The long-term stability of the TOMS data products (total ozone, aerosols, reflectivity, and UVB) is determined primarily by the accuracy of time-dependent sensor calibrations. These calibrations include variations in components such as electronics and spectral registration. But none has had a greater influence on product uncertainty than optical degradation. Radiometry in the TOMS wavelength range, from 309 nm to 380 nm, is particularly susceptible to contaminants and their subsequent photo-polymerization. Each of the 4 TOMS instruments has exhibited a unique set of degradation characteristics, which resulted in distinctly different challenges to maintaining calibration. The Nimbus 7 TOMS (1978-1993) flight calibration system was inadequate for maintaining long-term calibration, so alternate methods were employed. The Meteor-3 spacecraft of the second TOMS (1991-1994) had a precessing orbit that introduced periods of large calibration uncertainty. And the scan mirror on the Earth Probe TOMS (1996-present) has degraded as much as 80%, resulting in complex, spatially and spectrally dependent changes. We present here a summary of TOMS degradation characteristics and their effect on calibration uncertainties. We expect the resulting uncertainty of the ozone trend, as measured by TOMS, to be in the 2%-3% percent range for the preceding 25 years.

A21D-0994 0830h POSTER

A Comparison of TOMS Version 8 Total Column Ozone Data with Data from Groundstations

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The Nimbus-7 and Earth Probe Total Ozone Mapping Spectrometer (TOMS) data have been reprocessed with a new retrieval algorithm, (Version 8) and an updated calibration procedure. These data have been systematically compared to total ozone data from Brewer and Dobson spectrophotometers for 73 individual ground stations. The comparisons were made as a function of latitude, solar zenith angle, reflectivity and total ozone. Results show that the accuracy of the TOMS retrieval is much improved when aerosols are present in the atmosphere, when snow/ice and sea glint are present, and when ozone in the northern hemisphere is extremely low. TOMS overpass data are derived from the single TOMS best match measurement, almost always located within one degree of the ground station and usually made within an hour of local noon. The version 8 Earth Probe TOMS ozone values have decreased by an average of about 1% due to a much better understanding of the calibration of the instrument. The remaining differences between TOMS and ground stations suggest that there are still small errors in the TOMS retrievals. But if TOMS is used as a transfer standard to compare ground stations, the large station-to-station differences suggest the possibility of significant instrument errors at some ground stations.

A21D-0995 0830h POSTER

Calibration of TOMS Radiances From Ground Observations

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Verification of a stratospheric ozone recovery remains a high priority for environmental research and policy definition. Models predict an ozone recovery at a much lower rate than the measured depletion rate observed to date. Therefore improved precision of the satellite and ground ozone observing systems are required over the long term to verify its recovery. We show that validation of radiances from the ground can be a very effective means for correcting long term drifts of backscatter type satellite measurements and can be used to cross calibrate all BUV instruments in orbit (TOMS, SBUV/2, GOME, SCIAMACHY, OMI, GOME-2, OMPS). This method bypasses the retrieval algorithms used to derive ozone products from both satellite and ground based measurements that are normally used to validate the satellite data. Radiance comparisons employ forward models, but they are inherently more accurate than the retrieval algorithms. This method employs very accurate comparisons between ground based zenith sky radiances and satellite nadir radiances and employs two well established capabilities at the Goddard Space Flight Center, 1) the SS-BUV calibration facilities and 2) the radiative transfer codes used for the TOMS and SBUV/2 algorithms and their subsequent refinements. The zenith sky observations are made by the SSBUV where its calibration is maintained to a high degree of accuracy and precision. Radiative transfer calculations show that ground based zenith sky and satellite nadir backscatter ultraviolet comparisons can be made very accurately under certain viewing conditions. Initial ground observations taken from Goddard Space Flight Center compared with radiative transfer calculations has indicated the feasibility of this method. The effect of aerosols and varying ozone amounts are considered in the model simulations and the theoretical comparisons. The radiative transfer simulations show that the ground and satellite radiance comparisons can be made with an uncertainty of less than 1% without the knowledge of the amount ozone viewed by either instrument on ground or in space. To demonstrate this technique, nadir radiances from Earth Probe TOMS were compared with zenith sky observations over Goddard Space Flight Center from 2001-2003 at three coincident wavelengths (312.5, 317.5 and 360 nm). These comparisons showed good agreement between EP-TOMS radiances corrected by the flight diffuser and by polar ice observations.

A21D-0996 0830h POSTER

Validation of TOMS Using SBUV and SBUV/2 Data Improved with In-flight Data Validation Methods and Version 8 Processing

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A continuous record of SBUV type measurements of global total ozone and its vertical distribution starts in November 1978 with the Nimbus-7. The SBUV/2 instruments on NOAA-11, NOAA-9 and the presently operating NOAA-16 complete this record to the present. Unfortunately, all these instruments had at least one problem with either albedo calibration, photomultiplier tube non-linearity, stray light and/or location error. In the past, certain limited corrections for albedo calibration drift and the PMT non-linearity have been implemented using internal data validation techniques. However, with the more precise and sophisticated new Version 8 processing to characterize the atmospheric radiances, these internal validation techniques have been further refined and expanded, in particular for radiances used to derive the vertical distribution (profile) of ozone. Total ozone derived from ozone profiles at high sun and low latitude conditions is considerably less sensitive to calibration drift than the TOMS derived total ozone. This occurs because the profile derived total ozone uses SBUV and SBUV/2 channels that are not available on the TOMS and have superior total ozone sensitivity. This SBUV derived total ozone is used to validate the long-term trend of Version 8 TOMS data.

A21D-0997 0830h POSTER

TOMS and Ground-based Measurements: Long-term Trends, Spatial Variability, Cloud Effects, and Data Quality.

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Ground-based measurements and TOMS measurements are mutually beneficial to each other. Ground-based measurements of UV radiation and total column ozone amounts are important for the validation of TOMS measurements. For example, it has been shown that TOMS measurements has a tendency to under-estimate ground UV exposure. Some of these effects can perhaps be ascribed to local cloud effects or choice of ozone profiles in the retrieval algorithm. More ground-based measurements are needed to establish the cause of these discrepancies. Recent technology advances have made ground-based measurements of UV doses and ozone column amounts with inexpensive multi-channel filter instruments not only possible, but also an attractive alternative to other more labor-intensive and weather dependent methods. Filter instruments can operate unattended for long periods of time, and it is possible to obtain accurate ozone column amounts even on cloudy days. We present results from extensive comparisons of the performance of several ground-based instruments (the NILU-UV and GUV filter instruments, as well as the Dobson and Brewer instruments) against the EP-TOMS instrument. The data used in the comparisons are from three different sites where we have had the opportunity to operate more than one type of UV instruments for extended periods of time. The sites include the University of Oslo, Norway, the NASA Goddard Space Flight Center facilities at Wallops Island, VA, and Greenbelt, MD and the University of Alaska, Fairbanks (during the TOMS3F campaign). Our results show that ozone column amounts obtained with current filter-type instruments are just as good as those obtained with the Dobson instrument, and might even out-perform the Dobson instrument on cloudy days. The TOMS measurements are shown to exhibit some more variability, but there is on average very good agreement with the ground- based measurements even for high solar zenith angles (SZA). Further more, our comparison shows that ozone column amounts are very insensitive to the choice of ozone profile for SZA $< 65^{\circ}$. We also show how the TOMS measurements can be used to detect drift in ground-based filter instruments over time.

A21D-0998 0830h POSTER

Ozone Climatological Profiles for Version 8 TOMS and SBUV Retrievals

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A new altitude dependent ozone climatology has been produced for use with the latest Total Ozone Mapping Spectrometer (TOMS) and Solar Backscatter Ultraviolet (SBUV) retrieval algorithms. The climatology consists of monthly average profiles for ten degree latitude zones covering from 0 to 60 km. The climatology was formed by combining data from SAGE II (1988 to 2000) and MLS (1991-1999) with data from balloon sondes (1988-2002). Ozone below about 20 km is based on balloons sondes, while ozone above 30 km is based on satellite measurements. The profiles join smoothly between 20 and 30 km. The ozone climatology in the southern hemisphere and tropics has been greatly enhanced in recent years by the addition of balloon sonde stations under the SHADOZ (Southern Hemisphere Additional Ozonesondes) program. A major source of error in the TOMS and SBUV retrieval of total column ozone comes from their reduced sensitivity to ozone in the lower troposphere. An accurate climatology for the retrieval a priori is important for reducing this error on the average. The new climatology follows the seasonal behavior of tropospheric ozone and reflects its hemispheric asymmetry. Comparisons of TOMS version 8 ozone with ground stations show an improvement due in part to the new climatology.

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Accuracy and Precision in the 1998-2000 Southern Hemisphere Additional Ozonesondes (SHADOZ) Dataset in Light of the JOSIE-2000 Results

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A network of 12 southern hemisphere tropical and subtropical stations in the Southern Hemisphere ADditional OZonesondes (SHADOZ) project has provided over 2000 profiles of stratospheric and tropospheric ozone since 1998. Balloon-borne electrochemical concentration cell (ECC) ozonesondes are used with standard radiosondes for pressure, temperature and relative humidity measurements. The archived data are available at: http://croc.gsfc.nasa.gov/shadoz. In Thompson et al., [JGR, 108, D2: 8238, 2003] accuracies and imprecisions in the SHADOZ 1998-2000 dataset were examined using ground-based instruments and the TOMS total ozone measurement (version 7) as references. Small variations in ozonesonde technique introduced possible biases from station-to-station. SHADOZ total ozone column amounts are now compared to version 8 TOMS; discrepancies between the two datasets are reduced 2% on average. An evaluation of ozone variations among the stations is made using the results of a series of chamber simulations of ozone launches (JOSIE-2000, Juelich Ozonesonde Intercomparison Experiment) in which a standard reference ozone instrument was employed with the various sonde techniques used in SHADOZ. A number of variations in SHADOZ ozone data are explained when differences in solution strength, data processing and instrument type (manufacturer) are taken into account.

A21D-1000 0830h POSTER

Analysis of global trends and variability in ozone using a combined TOMS and GOME data base

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A global assimilated total column ozone data set has been created by combining total column ozone measurements from four TOMS experiments flown on the Nimbus 7, Meteor 3, Earth Probe and ADEOS satellites, together with the Global Ozone Monitoring Experiment (GOME) flown on ERS-2. Comparisons between TOMS data and measurements from the ground-based Dobson spectrophotometer network are used to remove offsets and drifts in the Nimbus 7 and Earth Probe satellite data. Statistical model fits to Nimbus 7 and Meteor 3 differences are then used to adjust the Meteor 3 TOMS data. Adjusted Earth Probe TOMS data are similarly used to correct ADEOS TOMS and GOME data. This data set was used in the most recent WMO/UNEP Scientific Assessment of Ozone Depletion (2002) and has recently been updated to the end of 2002, incorporating new (version 8) Nimbus 7 and Earth Probe TOMS data sets as well as the GOME assimilated ozone fields produced by KNMI in The Netherlands. Intercomparisons between these various data sets and the Dobson network will be presented. These data have been used as input to a linear least squares regression model incorporating terms for an offset, linear trend, and influence by the QBO, solar cycle and ENSO, as well as the El Chichon and Mt Pinatubo volcanic eruptions. Seasonal variability in each of these coefficients is expanded using Fourier components. This model has been applied to the assimilated total column ozone data set for a number of periods and trend results over different periods will be compared. The applicability of such statistical models for understanding long-term changes in ozone will be discussed. The data base has also been used to update indices of Antarctic ozone depletion such as the size of the Antarctic ozone hole, the ozone mass deficit within the Antarctic vortex, and annual minimum ozone values within the ozone hole. These will be presented for the entire period (1979 to 2002).

A21D-1001 0830h POSTER

Analysis and Validation of the Reprocessed NOAA-11 and NOAA-16 SBUV/2 Total and Profile Ozone Data Sets

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We have reprocessed the NOAA-11 (1989 - March 2001) and NOAA-16 (October 2000 - present) SBUV/2 total and profile ozone data using improved calibration and an improved algorithm. The SBUV/2 data record from NOAA-11 and -16 continues the Nimbus-7 SBUV data record that began in 1978. The newly developed Version 8 algorithm has latitudinally and seasonally varying ozone and temperature climatology, an improved forward model, corrections for aerosol contamination, an inverse model that uses measurements at ten wavelengths (273 - 331 nm). We determined the accuracy of the reprocessed total and profile ozone by performing external comparisons to ground-based and satellite-based observations. We validated the total ozone data sets by comparing them with ozone estimates from a network of Dobson spectrometers and ozone estimates from TOMS instruments during their overlap with the SBUV/2 instruments on NOAA-11 and NOAA-16. We validated the ozone profile data sets by comparing them with POAM-II retrievals during its overlap with NOAA-11 (1993-1994) and with POAM-III during its overlap with NOAA-11 (May 1998- March 2001) and with NOAA-16 (October 2000 - present). We will present analysis and validation of the newly reprocessed data sets with special emphasis on internal consistency and inter-instrument calibration, and discuss their applicability for ozone trend analysis.

A21D-1002 0830h POSTER

Contributions of the Ozone Processing Team, OPT, to the Measurement of Ozone and Other Parameters From the Total Ozone Measuring Spectrometer Instruments

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In 1976 NASA organized an Ozone Processing Team (OPT) to support the Science Team selected for the Solar Backscattered UltraViolet / Total Ozone Mapping Spectrometer (SBUV/TOMS) instrument to be flown on the Nimbus-7 spacecraft. For 28 years the OPT has continued to support the original TOMS and four following instruments. OPT's successor the OMI Science Support Team (OSST) is now providing similar assistance for the Science Team responsible for the OMI instrument to be launched on the AURA spacecraft next year. Our experience has shown that in addition to the scientists selected for an instrument an entire team including analysts, engineers, programmers and processing systems specialists is required to produce a consistent high quality long-term data set for general science use. This paper will discuss the scientific, engineering and processing contributions the OPT has made to the development of data sets from the TOMS instrument family. It will also provide scientists proposing for future instruments with some insight as to variety of talents and the magnitude of tasks that must be accomplished to support the production of similar climate data sets.

A21D-1003 0830h POSTER

Ozone Profile Comparisons From External Data Sources (Lidar, Sonde, and SAGE II) for Validating V8 SBUV Data

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Satellite measurements of ozone vertical profiles are critical for providing detection of changes in stratospheric ozone on a global scale. Recently, NASA Goddard Space Flight Center/Atmospheric Chemistry and Dynamics Branch has developed a new ozone profile algorithm (Version 8) for solar backscattered ultraviolet (SBUV) data with full multiple scattering, improved forward and inverse models, improved temperature and ozone climatology as well as better calibrations. These data (Nimbus 7, and NOAA's SBUV 2 series of NOAA-11, and NOAA-16) are compared with the external data from three Lidar (Mauna Loa, Table Mountain, Haute Provence), and six Sonde (Hohenpeissenburg, Payerne, Boulder, Wallops Island, Tateno, Hilo) stations and Stratospheric Aerosol and Gas Experiment II (SAGE II) for validating retrieved SBUV ozone profiles. This study shows how V8 SBUV data agree well with daily coincident external data, and also introduces a method to convert layer ozone differences into percent radiance differences for each SBUV wavelength using the Jacobian now included in each V8 SBUV data record.

A21D-1004 0830h POSTER

Ozone Trends from TOMS and SBUV data: Comparison to 3D Chemical-Transport Model Results

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We have updated our merged ozone data (MOD) set using the TOMS data from the new version 8 algorithm. We then analyzed these data for contributions from solar cycle, volcanoes, QBO, and halogens using a standard statistical time series model. We have recently completed a hindcast run of our 3D chemical-transport model for the same years. This model uses off-line winds from the finite-volume GCM, a full stratospheric photochemistry package, and time-varying forcing due to halogens, solar uv, and volcanic aerosols. We will report on a parallel analysis of these model results using the same statistical time series technique as used for the MOD data.

A21D-1005 0830h POSTER

A Madden-Julian Oscillation in Tropospheric Ozone

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This is the first study to indicate a Madden-Julian Oscillation (MJO) in tropospheric ozone. Tropospheric ozone is derived using differential measurements of total column ozone and stratospheric column ozone measured from total ozone mapping spectrometer (TOMS) and microwave limb sounder (MLS) instruments. Two broad regions of significant MJO signal are identified in the tropics, one in the western Pacific and the other in the eastern Pacific. Over both regions, MJO variations in tropospheric ozone represent 5-10 DU peak-to-peak anomalies. These variations are significant compared to mean background amounts of 20 DU or less over most of the tropical Pacific. MJO signals of this magnitude would need to be considered when investigating and interpreting particular pollution events since ozone is a precursor of the hydroxyl (OH) radical, the main oxidizing agent of pollutants in the lower atmosphere.

A21D-1006 0830h POSTER

Ozone, Aerosols and other Atmospheric Products from Version-8 TOMS Algorithm

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NASA has provided scientists with high resolution daily global maps of total column ozone obtained from a series of Total Ozone Mapping Spectrometer(TOMS) instruments flown on Nimbus-7 in 1978, Meteor-3 in 1991, the Advanced Earth Observing Satellite (ADEOS) and Earth Probe (EP) satellites in 1996. EP-TOMS (launched a few months prior to ADEOS-TOMS), is the currently operating TOMS instrument providing the ozone data continuity and key information on ozone trends. TOMS instruments have also been used for monitoring dust plumes, smoke from biomass burning, and ash and sulfur dioxide from volcanoes. The V8 TOMS algorithm is the most recent version of the buv (backscattered ultraviolet) radiance based total ozone retrieval algorithms. The TOMS algorithm has undergone more than two decades of progressive refinement. It enhances the previous version (V7) ozone retrievals by taking care of several small errors that were discovered by extensive error studies using radiative transfer models and by comparison with ground-based instruments. We estimate that the new TOMS algorithm is capable of producing total ozone with rms error of about 2 percent. This algorithm will also be used for retrieval of total column ozone from the buv measurements of Ozone Monitoring Instrument (OMI) to be flown on the Aura spacecraft (early 2004) that will provide continuity to the long time series of total column ozone retrieved using almost the same algorithm (to be consistent) for the study of ozone trend. The Goddard Earth Sciences Data Active Archive Center(GES DAAC) has been responsible for archiving the high quality ozone and other related products derived from the TOMS UV radiances and making it available to users. Additional products include effective Lambertian surface reflectivity, effective cloud fraction, a sun glint index, aerosol characteristics, an SO2 index, surface spectral UV and erythemal weighted irradiance. This presentation will provide some highlights of the standard products retrieved from the new V8 algorithm and examples of some new TOMS research products such as aerosol optical thickness and atmospheric single scattering albedo produced by the NASA/Goddard Ozone Processing Team (OPT). Information on data support and services provided by the GES DAAC Upper Atmosphere Data Support Team will also be presented.

URL: http://daac.gsfc.nasa.gov

A21D-1007 0830h POSTER

Applications of TOMS Aerosol Data in Climate Forcing Studies

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Measurements from the TOMS series of instruments not only provided the foundation for the study of the effects of ozone depletion on climate, but they have also provided a way to look at the climatic effects of aerosol. By combining measurements of the TOMS aerosol data with measurements of shortwave and longwave radiation from ERBE and CERES, we investigated the effects aerosols have on the Earth's radiation budget over both land and ocean. Specifically, we found that Saharan and Asian dust provided a cooling effect at the top of atmosphere over ocean. However, the radiative effect of mineral dust is more complicated over land and the sign of the forcing depends on the dust sources and the reflectance of the underlying surface. As opposed to dust, we found that smoke aerosols always excert a cooling effect of radiation at the top of the atmosperhere over both land and ocean. We then extended our studies by combining TOMS aerosol index and CERES radiation data with reflectivity measurements from either TOMS or SeaWiFS to determine how smoke aerosols modify radiative forcing in the presence of clouds. We found that the presence of smoke aerosols, when mixed with clouds or on top of the clouds, strongly modified the radiative energy balance in the atmosphere-cloud system. In this poster we will present the techniques we developed, details on our results, and plans for future studies.

A21D-1008 0830h POSTER

Direct Modelling of Sea Salt Aerosol Flux from Ocean Surface Stress with Model Comparison to Satellite Data

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Our previous work modelling the surface flux of sea salt aerosol has relied on the 10 meter wind speed to calculate the flux. However, the 10 meter wind speed does not contain all the relevant information to calculate the surface flux. Therefore, we have developed a flux scheme based on the surface stress, which contains information on ocean surface roughness length and boundary layer stability. We model the generation, transport, and removal of the sea salt aerosol using CARMA, a 3D synoptic scale model. We drive our model with archived meteorological data from MATCH to simulate real events, and we compare our model results to land-based observations from AERONET and satellite-based observations from TOMS.

A21D-1009 0830h POSTER

Ocean Color and Evidence of Chlorophyll Signature in the TOMS Minimum Reflectivity Data

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Analysis of the TOMS minimum reflectivity data for 380 nm channel (R380) show regions of high reflectivity values (7 to 8%) over Sargasso Sea in the Northern Atlantic, anti-cyclonic region in the Southern Atlantic, and a large part of the ocean in the Southern Pacific, and low values (5 to 6 %) over the rest of the open ocean. Through radiative transfer simulations we show that these features are highly correlated with the distribution of chlorophyll in the ocean. Theoretical minimum reflectivity values derived with the help of CZCS chlorophyll concentration data as input into a vector ocean-atmosphere radiative transfer code developed by Ahmad and Fraser show very good agreement with TOMS minimum reflectivity data for the winter season of year 1980. For the summer season of year 1980, good qualitative agreement is observed in the equatorial and northern hemisphere but not as good in the southern hemisphere. Also, for cloud-free conditions, we find a very strong correlation between R340 minus R380 values and the chlorophyll concentration in the ocean. Results on the possible effects of absorbing and non-absorbing aerosols on the TOMS minimum reflectivity will also be presented. The results also imply that ocean color will affect the aerosol retrieval over oceans unless corrected.

A21D-1010 0830h POSTER

The Ozone Mapping and Profiler Suite: Extending the BUV Technique to Meet Future Ozone Measurement Requirements

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Measurements from the original TOMS and SBUV instruments onboard the Nimbus-7 spacecraft form one of the cornerstones of satellite-based studies of long-term ozone trends. These sensors established the use of the backscattered ultraviolet (BUV) technique, along with calibration techniques based on the measurement of solar flux, to determine and monitor total column and profile ozone amounts on a global, daily basis. They also provided the foundation for the design and development of the Meteor-3, ADEOS, and Earth Probe TOMS sensors and NOAA's successful SBUV/2 series of ozone sensors, whose total column and profile ozone measurements continue through today to extend the set of ozone measurements begun by Nimbus-7. The Ozone Mapping and Profiler Suite (OMPS) is a new generation of hyperspectral BUV sensors that are currently in development for the National Polar-orbiting Operational Environmental Satellite System (NPOESS). These sensors, whose first launch will be onboard the NPOESS Preparatory Project (NPP) satellite in 2006, are designed to continue this long-term data set with better accuracy, precision, and other requirements than any of the total column and profile ozone retrieval systems currently in orbit. In developing the OMPS suite to meet the NPOESS requirements, we systematically analyzed the performance of current BUV systems. We determined that the TOMS sensor and algorithm provided a strong starting point for the development of the OMPS total column ozone retrieval system and we identified areas where design improvements in both would lead to the performance necessary to meet the NPOESS requirements. Since we also determined that an SBUV-type nadir-looking sensor would not meet the NPOESS profile ozone requirements, the OMPS system includes both a nadir profiling sensor to provide measurements that directly link to the SBUV and SBUV/2 heritage dataset and a sensor-algorithm system that uses the limb-scattered BUV/Visible technique pioneered by SOLSE/LORE, OSIRIS, and SCIAMACHY to provide ozone profile measurements within the NPOESS-required accuracy and precision. In this presentation we will provide an overview of the OMPS sensors and algorithms, both in terms of their links to the past and improvements designed to meet the performance requirements of the future.

A21D-1011 0830h POSTER

The Role of TOMS in Understanding the Fates of Volcanic Emissions

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The Total Ozone Mapping Spectrometer (TOMS) has observed over 100 eruption s during the past 25 years, from both explosive and effusive sources. The four TOMS instruments (Nimbus-7, Meteor, ADEOS, and Earth Probe) have gen erated an unprecedented archive of eruption data and allowed us to look at processes, in addition to describing individual events. The TOMS sensors are less affected by atmospheric water vapor and optical thickness than i nfrared techniques, and thus are able to return information on the cloud f rom it's early, most concentrated form, to dilute cloudmasses several days later. From the many observations and advances generated from TOMS data, here we document those which pertain to the first few days following emis sion into the atmosphere. Following discrete eruption events, we have observed that the mass of retr ieved SO2 often increases for 1-2 days, independent of any volcanic contri bution. Combining TOMS with other sensor data suggests that significant S O2 is sequestered by ice in the rising plume. Ablation of the ice slowly re-releases SO2, which results in the apparent increase. After 2-3 days, this process appears to be largely complete, and SO2 removal then follows an exponential decay rate. TOMS-derived removal rates of SO2 have ranged from approximately 25 days (e-folding time) for Pinatubo-sized eruptions, to less than one day for smaller or tropospheric eruptions. Within the sa me eruption this rate may vary, as SO2 removal is strongly affected by ads orption onto co-existing ash and ice particles. The removal processes can also be linked to an eruption height threshold, separating eruptions whic h are emplaced above the tropopause and produce potentially long-lasting a tmospheric impacts from those which are rapidly removed from the atmospher e. We have also observed that many eruptions produce a vertical separatio n of gas-rich and ash-rich phases. However, other events have produced no separation, suggesting that the separation may be linked to the eruption dynamics or an early, gas-enriched pulse rather than a post-eruption, grav itational process.

A21D-1012 0830h POSTER

Total Ozone Mapping Spectrometer Data Processed With a New Algorithm

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The Total Ozone Mapping Spectrometer (TOMS) series comprises four instruments providing a total of 25 years of daily global stratospheric ozone data over the sunlit portion of the Earth. A new retrieval algorithm has been developed for TOMS and applied to the Nimbus 7 and Earth Probe TOMS Data Sets. The algorithm and the data have been designated Version 8. The algorithm is based on differential absorption across a pair of wavelength channels chosen close together to minimize the impact of wavelength dependent forward modeling errors. Version 8 enhancements include correction for the presence of tropospheric aerosols and sun glint from water surfaces, a better treatment of variability due to tropospheric ozone and temperature dependence, and an improved forward model, particularly in regions of persistent snow and ice. Among other things, the Version 8 enhancements have reduced latitudinal dependence seen previously in TOMS - Dobson comparisons, predominantly in the Southern Hemisphere's summer, when the tropospheric ozone, temperature, and snow/ice corrections are additive. The basic components of the algorithm and its impact on derived total ozone will be discussed.

A21D-1013 0830h POSTER

Effects of the Pinatubo Aerosols on South Hemisphere High Latitude Ozone Measured with TOMS/NASA and Analyzed with Artificial Neural Networks

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We present a detailed analysis of the total ozone column losses in the Southern Hemisphere high latitudinal band (55°S-60°S) after Mount Pinatubo eruption in June 1991, based on measurements of TOMS/Nimbus7 satellite instrument up to April 1993. Different artificial neural networks (ANNs) were trained to predict the expected unperturbed ozone values in the June 1991-April 1993 period. The predictions of the best performing ANN are then compared with the observed values in this period in order to determine the net Pinatubo effect. This comparison reveals a positive anomaly of (5+-3) % observed in 1991 late spring and 1992 summer and disappears in early 1992 autumn. After this, an ozone loss appears in Southern Hemisphere winter and spring 1992, reaching a maximum of (-12+-3) % on September, that is followed by a steady recovering to unperturbed values on late 1992. The characterized anomalies can be attributed to sulfate aerosol generated by the Pinatubo eruption, as they agreed with the aerosol surface area density measured by the SAGE II satellite in the latitude and period studied in the present work. The predictions of ANNs are in quite good agreement with those of an interactive 2-D radiative-dynamical-chemical model.

A21D-1014 0830h POSTER

Tropical tropospheric ozone morphology and seasonality seen in satellite, model, and in-situ measurements: No paradox in North Africa

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An important issue in satellite remote sensing techniques for retrieving tropical tropospheric ozone is to understand the cause of the disparity between ozone derived from satellite residual-based methods and the precursor distributions seen in both the fire-count distribution and the Measurements Of Pollution In The Troposphere (MOPITT) CO distributions in boreal winter and spring. This disparity has sometimes been termed the Northern Atlantic Paradox. We have employed an approach to probe the paradox problem with a new retrieval algorithm, the Scan Angle Method (SAM). This algorithm takes advantage of the difference in the Total Ozone Mapping Spectrometer (TOMS) retrieval information between nadir and high viewing angles. The averaging kernel for this difference exhibits a broad maximum centered at 5 km in the troposphere and thereby can be used as a surrogate of tropospheric ozone information. We have investigated the seasonality of satellite-derived products of fire counts and MOPITT CO concentration, TOMS Aerosol Index, ozone from GEOS-CHEM model and the Convective Cloud Differential (CCD) method along with the Tropospheric Ozone Index (TOI) from the SAM. In meridional distribution, all products except the CCD clearly reveal the seasonal oscillation between the maximum over northern tropical Africa in boreal winter and over southern tropical Africa in boreal summer. The CCD products always show the ozone maximum over the southern Atlantic off the coast of southwest Africa. Investigation of in-situ measurements from the Measurement of Ozone and Water Vapor by Airbus In-Service Aircraft (MOZAIC) campaign also reveals the ozone maximum in boreal summer and the minimum in boreal winter at three locations over the northern tropics; Abidjan (5aN, 4aW), Madras (13aN, 80aE), and Bangkok (14aN, 101aE). The seasonality of the SAM and the model ozone are in accordance with the MOZAIC measurements, but the CCD ozone is about six months out of phase.

A21D-1015 0830h POSTER

QBO and QBO-annual Beat Signals in the Tropical Total Column Ozone Simulated by a Two-dimensional Chemistry and Transport Model

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The NCEP/NCAR Reanalysis II 4-times daily spectral coefficients are used to calculate the monthly mean meridional circulations from 1979 to 2000 to drive the Caltech/JPL two-dimensional (2-D) chemistry and

transport model. The first two empirical orthogonal functions (EOFs) of the stratospheric stream function capture 88% of the total variance. The first EOF captures over 70% of the variance and is related to the quasi-biennial oscillation (QBO) and QBO-annual beat signal in the meridional circulation. The 2-D model provides realistic simulations of the seasonal and interannual variability of ozone in the tropics. The equatorial ozone anomaly from the 2-D model is close to that derived from TOMS/SBUV merged total ozone data sets. The phase and amplitude of the QBO signal are well captured by the model. The QBO-annual beat signal found in the simulated ozone agrees well with that in the TOMS/SBUV merged total ozone data sets.

A21E MCC: Level 2 Tuesday 0830h

Chemistry and Physics of Clouds and Aerosols Posters *(joint with SA, AE, GC)*

Presiding: **G L Kok,** Droplet Measurement Technologies**; L M Avallone,** Laboratory for Atmospheric and Space Physics, University of Colorado

A21E-1016 0830h POSTER

Orographic Influences on the Annual Cycle of Namibian Stratocumulus Clouds

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The impact of African orography on the annual cycle of stratocumulus incidence off the coast of Namibia is examined. To this end, we perform two experiments with the UCLA atmospheric general circulation model (AGCM). Since the UCLA AGCM produces a very realistic annual cycle and geographical distribution of marine stratocumulus clouds, it is well suited for this task. In one experiment, No-Orography, orographic surface heights are set to sea level over the African continent, while the other experiment, Control, features realistic orography everywhere. After the initial adjustment, Control and No-Orography are run for 20 and 3 years, respectively, and their climatological monthly means are examined. Compared to No-Orography, Control shows a significant increase in stratocumulus cloud incidence over the Namibian stratus region (defined here as the area 0°E to 10°E, 20°S to 10°S). Differences elsewhere are found to be small. Computing the area average of stratocumulus incidence over the Namibian stratus region, we find that the difference between Control and No-Orography is significant from July through November, with the maximum occurring in August, where the incidence in Control is about 40% higher than in No-Orography. Analysis of the bulk static stability (defined here as the potential temperature at 700 hPa minus the potential temperature at 1000 hPa) for the same region reveals that an increased static stability in Control occurs during the same months as the increase in stratocumulus incidence. This is consistent with the notion that static stability is favorable to the maintenance of stratocumulus clouds. The difference in static stability is mainly due to an increase in the potential temperature at 700 hPa in Control (since sea surface temperatures are prescribed in the model, the potential temperature at 1000 hPa can only vary to a small extent between the two experiments). An analysis of the terms in the thermodynamic energy equation for the region shows that horizontal advection is the dominant factor contributing to the greater heating at 700 hPa in Control. Comparing the 700 hPa wind and temperature fields between the two experiments, it is evident that orography acts to break up zonal symmetry over the southern part of the African continent and to the west of it. In accordance with linear barotropic theory, anticyclonic circulation is found over southwest Africa. This anticyclonic circulation advects warm air poleward toward the Namibian stratocumulus region. The same result is obtained from an analysis of the stationary eddies. It is concluded that African orography interacts with the mean flow to generate an increased bulk static stability off the Namibian coast, which is conducive to the maintenance of stratocumulus clouds.

A21E-1017 0830h POSTER

Is it Correct to Keep the Super-Saturation Constant in a Time Step?

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Air super-saturation controls nucleation and growth of cloud particles and therefore determines the formation of rain. Models, which calculate cloud microphysics, have to correctly determine super-saturation.

This study analyses the methods used to calculate the mean super-saturation and the time dependent super-saturation. The analytical method is the first method that has been studied and is hereby presented. The present work was motivated by the following questions: Is it correct to keep the super-saturation constant in simulations for an entire time step? How to find the equilibrium super-saturation? What is the temporal variability of super-saturation in the clouds? How to determine the super-saturation integral for a time step of the simulation?

Removal of excess water vapor so that there is no super-saturation at the end of each time step of the model usually gives an over-estimation of the latent heat exchanged with the system during phase changes. The energy balance is not the only one affected by saturation. The activation of condensation nuclei and ice nuclei is very sensitive to the value of super-saturation in clouds.

To introduce the temporal variation of saturation into the models is, therefore, necessary. In the work presented two different cases arise: the time step is smaller than the saturation relaxation time and the time step is larger than the saturation relaxation time.

The solution of the differential equations of saturation for warm and cold clouds should be calculated from the integral of saturation in the case where the time step is smaller than the saturation relaxation time. In the case where the time step is longer than the relaxation time, the model should calculate the equilibrium saturation.

In order to confirm our assumption, we present some results obtained with the Cloud Resolving Model using the integral of the saturation ratio versus the results given by the same model which cuts the saturation at 100% at the end of which time step.

A21E-1018 0830h POSTER

A Study of the Spatial and Vertical Structure of Modeled Hydrometeor Profiles: Insights for weather prediction modeling and precipitation retrieval from remote sensors

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Weather models predict precipitation reaching the ground as the vertical flux of hydrometeors from the cloud (evaporation effects are also considered). Looking at the entire profile of hydrometeors throughout the cloud, rather than precipitation on the ground, may provide important insight into the strengths and weaknesses of the microphysical models used in weather prediction. Also, certain algorithms for precipitation retrieval from passive microwave sensors, e.g., as part of the Tropical Rainfall Measuring Mission (TRMM), heavily rely on the ability of Cloud Resolving Models (CRMs) to produce realistic profiles of hydrometeor size, shape, and concentration throughout the cloud. In this study, the Advanced Regional Predictions System (ARPS) was used to simulate a severe thunderstorm in Ft. Worth, Texas on March 28, 2000. This case study was run with other research objectives in mind, including assessing the effect of a data assimilation cycle using sophisticated WSR-88D radar data analysis on the ability of the ARPS model to predict a real life weather event. A previous study concluded that the model did a good job of producing the major features of the storm; this research aims at evaluating the ability of the model to reproduce realistic hydrometeor profiles for the storm. Since observations of 3D hydrometeor fields are not available for this storm, predicted radar reflectivity from the model is compared to WSR-88D Level II reflectivity. Although additional uncertainties are introduced in the reflectivity calculation, this gives an indirect method for assessing hydrometeor profiles. Mean profiles and probability distributions of reflectivity at all altitudes have been created to compare modeled versus observed fields. Initial comparisons reveal that, at a given precipitation rate, the spatial statistics of modeled reflectivity (estimated from the modeled 3D hydrometeors fields in the atmosphere) are significantly different than the statistics of observed radar echoes. This discrepancy may be the result of limitations in CRMs to produce the correct composition of hydrometeors in the cloud even if they predict the correct precipitation on the ground. However, part of the error is probably due to limitations in the estimate of reflectivity from hydrometeor fields, pointing out that caution must be exercised when model-estimated reflectivity fields are compared to observed fields. Investigations are underway to narrow in on possible causes of the lack of agreement. Future research using detailed hydrometeor observations, e.g., from polarimetric radar, is needed to further quantify the degree to which CRMs can produce realistic 3D hydrometeor fields. The results of such a study may be utilized to arrive at a calibration for model reflectivity based on observations - a calibration that may be used in precipitation retrieval algorithms.

A21E-1019 0830h POSTER

Critical Supersaturation for Ice Crystal Growth: Laboratory Measurements and Atmospheric Modeling Implications

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An improved understanding of ice crystal growth, particularly at low temperatures, is much in demand for the advancement of numerical modeling of atmospheric processes. Cirrus models must contend with the complexity of ice crystals growing in cold temperatures, low pressures, low supersaturations, and with multiple nucleation mechanisms. Recent observations have allowed increasingly realistic parameterizations of cirrus ice crystal microphysics, but these observations need to be supplemented by a fundamental understanding of growth processes affecting low-temperature crystals. Several experimental studies have demonstrated that certain ice crystals require a minimum "critical" supersaturation before exhibiting detectable growth. These crystals are presumed to be essentially defect-free, preventing vicinal hillock growth at the site of crystal dislocations. In the case of crystal growth by spiral dislocation, advancement of faces begins as soon as supersaturation is present. The finding of conditional critical supersaturations have analogies in other materials (metals, semiconductors, potassium dihydrogen phosphate) and are thermodynamically predicted given a two-dimensional nucleation growth mechanism. Previous measurements have determined the critical supersaturation for ice as a function of temperature and crystallographic face from 0 to −15°C with extrapolation to −30°C. For both basal and prism faces, critical supersaturation is seen to increase with decreasing temperature, suggesting that low-temperature, low-supersaturation processes are most likely to be affected by this critical contingency. We present laboratory results to verify and extend prior critical supersaturation measurements using a novel approach for supersaturation generation, control, and measurement. The crystals are grown on the tip of a fine glass fiber (∼10 microns in diameter) under varying conditions of temperature, pressure, and saturation. Supersaturation is generated when a pre-saturated airflow passes over a coil of ice warmed by electrical resistance upstream from the growing crystal. Supersaturation is determined by a system of differential thermocouples calibrated to sulfuric acid drop size measurements. Measurements follow those made in earlier studies, but also extend to temperatures of −45°C, mimicking conditions found in some high altitude clouds.