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Poster Abstracts

A Self-Updating Empirical Method to Define O₃-q Relationships, O₃ Profiles, and Tropospheric Ozone

Robert B. Chatfield, Robert Esswein, and the OMI, AIRS, MLS, and North American O₃-sonde network teams.

We describe a method of obtaining empirical information on ozone profiles from OMI total ozone column retrievals and AIRS retrievals of layer temperatures (not AIRS partial-column ozone). This study formalizes somewhat previous reports to the Aura Science Team of strong empirical relationships between ozone and temperature structure. We proceed from the long-known fact that ozone mixing ratio and potential temperature (q) of stratospheric air usefully conserved at a given latitude and vertical position. Usefully conserved means that there are enough samples of O₃ and temperature structure to capture temporal trends in the relationship by statistical methods over periods of weeks. A form of linear regression, additive-model regression, allows us to estimate with smooth functions the pattern of the O₃- q relationship. These functions are consistent with atmospheric dynamics, but variable enough to allow for (e.g.) chemical variation without the need to compute complex chemical kinetics and transport. Variance explained (R^2) for OMI total ozone column retrieved and reproduced from AIRS measurements ranges up to 0.92. The results are quite reproducible. We resolve this column variation into the implied vertical profiles of ozone in the atmosphere. Agreement of our techniques applied to the surface–200 hPa ozone partial column compares with the Schoeberl-Ziemke technique acceptably, $R^2 > 0.5$. Rough tropospheric ozone profiles and partial columns may be estimated and compared to the existing radiosonde record for North America in August 2007. The ozonesonde analysis also indicates two features. Estimation skill for ozone does not stop at the tropopause, but extends considerably down into the troposphere. Also, OMI appears to have the ability to inform us about ozone in the first kilometer or so, where theoretically rather few photons penetrate and physical retrieval sensitivity should be low. An analysis of the autocorrelation of ozone mixing ratios in the vertical, based on the sonde record, partially explains these surprising estimation features. We present autocorrelation functions for ozone by altitude and geographic location, and note the differences. (Note: there are also certain useful O₃- q relationships in the upper and middle troposphere.) These observations contribute independent information about lower tropospheric O₃ to UV, IR, and microwave techniques: if all information is used, we may get considerable ability to estimate lower-tropospheric ozone. We note the limitations of the technique (e.g., around upper-tropospheric fronts and stratospheric intrusions) and suggest that rather better estimates should be obtainable.

OMI Retrieval of Aerosol Absorption Using CALIOP Measurements

Zhong Chen and Omar Torres

Knowledge of the vertical distribution of aerosols in the atmosphere is important for the understanding of the atmospheric processes relating to the studies in climate and air pollution. The OMI derived aerosol properties such as aerosol optical depth and single scattering albedo are subject to uncertainties due to the assumed aerosol layer height. The CALIPSO satellite mission provides comprehensive observations of aerosol vertical distribution on a near global scale. We investigate OMI retrievals of the absorbing aerosol using CALIPSO height data. An integrated set of the merged data files was created. The merged product provides ability to map global vertical profiles of aerosols. The OMI retrieval of aerosol optical depth and single scattering albedo were constrained by CALIPSO 532 nm attenuated backscatter. The seasonal evolution of the aerosol vertical distribution is studied using measurements made in the period July, 2006 – December, 2008 with satellites and ground-based instruments. The comparative analysis shows the impact of using actually observed height information on the retrieved absorption properties. Our results show that the combination of CALIPSO data with aerosol properties derived from OMI leads to new insight into more accurate estimates of global aerosol, cloud and radiation data sets.

Comparison of OMI total column ozone from three retrieval algorithms (DEC 2004-DEC 2007)

E.W. Chiou and R.D. McPeters

NASA has initiated a program called Making Earth Data Records for Use in Research Environments (MEaSUREs), supporting several ongoing projects. Part of the efforts for one MEaSUREs project involved the retrieval of OMI ozone profiles using SBUV/2 Version-8 vertical profile algorithm. Total column ozone has been determined from these retrieved ozone profiles. We have conducted preliminary comparisons of total column ozone obtained from these results with OMTO3 version 8.5 and OMDOAO3 total column ozone products. These comparisons are unique in several aspects: (1) all three retrievals used the same OMI level-1 inputs; (2) only measurements from a single cross-track position are compared to avoid complication with cross-track dependency; (3) all of the samples are exactly matched, temporally, and in terms of measurement geometry. Comparisons of monthly zonal mean and monthly gridded total column ozone will be shown for the 3-year period DEC 2004-DEC 2007. The differences of the three pairs of products will also be analyzed to examine the dependency with total ozone, solar zenith angle, reflectivity and radiative cloud fraction. Our analysis indicate that in terms of monthly zonal mean, v8 profile total ozone agrees with OMTO3 to within 0.5%, 2%, and 1% for 30S-70S, 30S-30N, and 30N-70N respectively.

EOS MLS Production Version 3

David Cuddy, Paul Wagner, William Read, and Vincent Perun

In early August of 2009, Earth Observing System (EOS) Microwave Limb Sounder (MLS) began production with a newer version (Version 3) of Level 1 and Level 2 software. Over the next year, MLS intends to reprocess all of the mission data with these newer algorithms. Version 3 of MLS algorithms includes minor updates to Level 1 software; improvements in our Level 2 data products; and the addition of a new data product CH₃Cl. Updates to Level 1 include redefining the Galactic Core for the instrument field of view. Improvements in Level 2 include O₃ at higher vertical resolution with twice the resolution through the troposphere and a useful product at 260 hPa; H₂O with removal of a kink at 2.3 hPa; CO with a reduced high bias; ClO with a reduced negative bias; HCl with the removal of various kinks; and HCN with a useful range from 100hPa to 10 hPa. For every product we make it easier to exclude heights and geographic locations where the quality is known to be poor. Version 3 metadata employs eXtensible Markup Language (XML) format replacing the old Object Definition Language (ODL) format.

Clouds and water vapor in the northern hemisphere summertime stratosphere

Andrew E. Dessler

Cloud-top observations from the Calipso instrument are used to study the occurrence of clouds in the northern hemisphere (NH) summertime lower stratosphere. At low latitudes, clouds in the stratosphere tend to occur in regions of intense convection, while at high latitudes, there is little longitudinal preference for the clouds. Although there is some latitude and longitude variability, the 0.1% cloud-top occurrence contour tends to be found ~3 km or 40-50 K of potential temperature above the tropopause. Examining water vapor fields measured by the Microwave Limb Sounder, regions of enhanced cloud-top occurrence correlate well with regions of enhanced water vapor mixing ratio in the mid and high latitudes. At low latitudes, on the other hand, the correlation between cloud occurrence and water vapor is poorer. Regions of frequent cloud occurrence at low latitudes also tend to have high relative humidity, which inhibits evaporation of cloud ice there. Instead, the region of enhanced water vapor mixing ratio is offset to higher altitudes above the maximum in cloud occurrence, where the relative humidity is lower.

Analysis of OMI stratospheric NO₂ from DOMINO and the Standard Product

Ruud Dirksen, Folkert Boersma, and Dmitry Ionov □

We have studied the performance of the two operational NO₂ retrieval algorithms for OMI. Both algorithms, the standard product (SP, developed by GSFC) and the DOMINO (Dutch OMI NO₂, developed by KNMI) product, retrieve NO₂ vertical columns in the stratosphere and the troposphere. Although the algorithms start from the same DOAS fitted NO₂ total slant columns, they use different methods to separate the stratospheric column and to calculate the air mass factors (AMF) for converting slant columns into vertical columns. Accurate satellite observations of stratospheric NO₂ are important for two reasons: firstly, because it plays a significant role in the photochemistry of

stratospheric ozone and it is crucial to know whether there is a trend in stratospheric NO₂. Secondly, errors in the stratospheric column will lead to an over- or underestimation of the tropospheric column. Therefore we validate the stratospheric columns with ground-based observations. We used measurements from the SAOZ (Système d'Analyse par Observations Zénithales) system and from NDACC (Network for the detection of Atmospheric Composition Change), a network of stations that measure the overhead stratospheric NO₂ column (VCDstrat) at large solar zenith angles. The measurement sites range from the Arctic to the Antarctic and are predominantly situated at pristine locations, so that the observed columns are hardly affected by tropospheric contributions. Comparison of OMI overpass data with respect to SAOZ data for the year 2005 showed a slight overestimation of DOMINO stratospheric NO₂ columns (+0.6e14 molec/cm²) whereas the standard product underestimates the stratospheric column (-1.5e14 molec/cm²). Compared to the NDACC stations both DOMINO and SP underestimate (-2.2e14 and -3.8e+14 molec/cm²). The discrepancy between the comparisons with SAOZ and NDACC data is caused by differences in inferring the overhead column at the OMI overpass time from the sunrise/sunset measurements. To summarize, we find a systematic bias between DOMINO and SP VCDstrat, on average 1-2e14 molec/cm², which is most profound in the polar regions. Detailed analysis of the steps leading to the SP VCDstrat reveals that the differences between DOMINO and SP are attributable to how the background stratospheric field is determined and to the stratospheric AMF. The SP retrieves VCDstrat from a 2D wave fit to the observed NO₂ field whereas the DOMINO algorithm assimilates OMI data in a Chemistry Transport Model (CTM). Furthermore we show that DOMINO is capable at capturing small scale variations, such as sudden changes in the stratospheric NO₂ field associated with planetary wave activity.

Unprecedented Persistence of a Smoke Plume Monitored with AURA OMI Aerosol Index: The Black Saturday pyroCb of 7 February 2009

Mike Fromm and Omar Torres

On 7 February 2009 wild fires in Victoria Australia erupted into pyrocumulonimbus. The fire storm occurred in super extreme weather conditions, caused enormous death and destruction, and polluted the stratosphere in unprecedented measure. The AURA OMI aerosol index (AI), responsive to absorbing aerosol optical depth and altitude, took on values in the aftermath of the pyroCbs that unequivocally signaled a large stratospheric impact. Moreover, the plume was trackable via AI for more than three weeks as the plume was transported from near New Zealand, into subtropical latitudes and westward across Australia, the Indian Ocean, and to Africa. On another occasion after a Victoria pyroCb in December 2006, AI was perturbed for nearly two weeks as the stratospheric smoke completely circled the globe. Here we will detail both events. In particular we will show AI along with complementary data such as ACE Imager aerosol extinction profiles to characterize the historic smoke abundance and altitude responsible for the long-lasting AI signal.

The use of Aqua-MODIS derived Level 2 parameters to improve OMI aerosol retrievals □

Santiago Gassó, Omar Torres, Changwoo Ahn, and P.K. Bhartia

The MODIS detector onboard of Aqua has the capability to detect aerosol properties at high spatial resolution using visible to near-IR bands. The OMI detector on board of Aura also detects aerosols using UV bands at coarser spatial resolution. The Aura and Aqua platforms fly in formation a few minutes apart with respect to each other. As a first approximation, the closeness in time is short enough that it allows the use MODIS aerosol products in support of OMI aerosol retrievals. In fact, a retrieval method has been proposed that makes use of the aerosol optical depth retrievals of MODIS combined with OMI's sensitivity to aerosols to obtain an improved aerosol absorption optical depth (AAOT) over the ocean. This presentation will show the practical aspects of implementing and using MODIS information in support of OMI aerosol retrievals. Specifically, we will show the method applied to overlap the MODIS level2 pixels (~10x10km at nadir) with the OMAERUV product (~13x24km), show how the consolidation of MODIS retrievals into the OMI pixel is made, and illustrate case studies of combined MODIS-OMI retrievals of AAOT and aerosol height and respective comparisons with CALIPSO. In addition, an assessment of the aerosol type identification made by the OMAERUV algorithm will be made by comparing with aerosol size information from MODIS (fine mode fraction parameter).

Arctic chlorine activation and ozone depletion: Comparison of CLaMS simulations with satellite observations.

Jens-Uwe Grooß, Tobias Wegner, Rolf Müller, and Michelle L. Santee

The accurate simulation of Arctic stratospheric ozone depletion has been an issue for the last two decades. However, there are still notable quantitative discrepancies between the models and observations. We show results from the CLaMS 3D chemistry-transport model with the focus on chlorine activation in the polar vortex, the prerequisite for ozone depletion. As shown recently by Santee et al. (JGR, 2008) using AURA-MLS and ACE-FTS data, the extent of chlorine activation for the cold Arctic winter of 2004/2005 within the basic SLIMCAT model is overestimated with the likely consequence of too much simulated ozone depletion. In contrast, the CLaMS simulation for the same winter shows too little chlorine activation compared to observations, and therefore likely too little loss. The processes of heterogeneous chlorine activation depend very sensitive on temperature and are still not understood to all detail. In the CLaMS model, we have updated the parameterization of heterogeneous reactions on liquid aerosols from Carslaw et al. to that of Shi et al. (2001), with which chlorine activation on liquid aerosol becomes more efficient. HCl and ClO data from MLS as well as HCl and ClONO₂ data from ACE-FTS provide a good opportunity to check assumptions and parameterizations of the heterogeneous chlorine activation processes.

Ozone Profiles from the Ozone Monitoring Instrument: Recent Improvements in the Retrieval Algorithm

J. F. de Haan, J. P. Veefkind and P. F. Levelt

Recent improvements of the ozone profile retrieval algorithm for the ozone monitoring instrument OMI aboard the NASA EOS Aura platform are discussed. The ozone profile algorithm is based on the optimal estimation method where a-priori information is used as a side constraint for regularization purposes. The initial version of the algorithm showed large differences with ozone profiles retrieved from MLS measurements. After re-analyzing the assumptions used in the initial algorithm the following main improvements were made: (i) replacing the Fortuin/Kelder climatology by the McPeters/Labow climatology, (ii) fitting stray light, (iii) ignoring measurements close to the channel separation at 310 nm, and (iv) using wavelength dependent surface or cloud albedo. This resulted in a much better agreement with MLS profiles. The improvements will be discussed based on changes in the residues of the fit, simulation studies, and comparisons with MLS profiles.

Solar proton events and their effects on the middle atmosphere as observed by Aura-MLS

David Herceg, Manney, G., Minschwaner, K., and Santee, M.

Solar Proton Events (SPEs) can have a significant impact on ozone and other reactive species in the middle atmosphere. Decreases in ozone may be particularly large as a result of chemical loss from the nitrogen and hydrogen catalytic cycles. Focusing on two recent SPEs (15-23 January 2005 and 7-17 September 2005), we use measurements from EOS-Aura MLS to examine the effects of SPEs on the Northern hemisphere during the January event, and Southern hemisphere during the September event. We analyze the distribution and time evolution of O₃, HNO₃, and OH as observed by Aura-MLS.

Characterization of OMI tropospheric NO₂ measurements in East Asia based on a robust validation comparison

Hitoshi Irie, Yugo Kanaya, Hisahiro Takashima, James F. Gleason, and Zifa Wang

In the period from June 2006 to December 2008, we measured the tropospheric nitrogen dioxide (NO₂) column by ground-based Multi-Axis Differential Absorption Spectroscopy (MAX-DOAS) at an urban site in China (Tai'an) and three sites in Japan, covering urban (Yokosuka), suburban (Tsukuba), and remote areas (Hedo). This robust dataset is used to characterize Ozone Monitoring Instrument (OMI) tropospheric NO₂ column data (the standard product, version 3). Correlations between MAX-DOAS and OMI data, both of which show very low NO₂ at Hedo and moderate/high levels at the other sites, have correlation coefficients (R²) as high as 0.64, indicating that relative changes in OMI NO₂ data are reliable. However, OMI data have a negative bias of 31% on average. Assuming that these results are valid for OMI data taken over China, we find an increasing trend in tropospheric column NO₂ at about 5% per year on average in the industrial areas of China (30°-40°N and 110°-123°E) over 2005-2008, but its spatial distribution is highly inhomogeneous.

Near-UV Remote Sensing of Spectral Aerosol Absorption using OMI Measurements

Hiren Jethva, Omar Torres, and P. K. Bhartia

We demonstrate the capabilities of the near-UV remote sensing of aerosol absorption properties, such as done by Aura/Ozone Measuring Instrument (OMI), of biomass burning aerosols over South America. Currently, OMI models biomass burning aerosols as “grey” aerosols (no spectral dependence in absorption) in the near-UV region. However, specific ground-based measurements [Krotkov et al. (2009); Hoffer et al. (2006); Kirchstetter et al. (2004)] reveal a strong spectral dependence in aerosol absorption in the UV region indicating possible role of organic carbon. As a result, the current OMI-derived aerosol optical depth (AOD) are over-estimated compared to that of ground-based Aerosol Robotic Network (AERONET). A new set of OMI aerosol retrieval with the assumption of wavelength-dependent absorption in the near-UV region provided much improved AOD. Also, the new retrieval of single-scattering albedo are consistent and in good agreement with the AERONET inversions within uncertainties of the two techniques (0.03). This study shows the potentiality of near-UV remote sensing of aerosols to quantify absorption and its spectral behavior, both are still poorly characterized in climate models.

Five-year Climatology of Upper Tropospheric Water Vapor and Cloud Ice from Aura MLS and GEOS-5 □

Jonathan Jiang, Hui Su, Steven Pawson, William Read, Michael Schwartz, Dong L. Wu, Alyn Lambert, Rayn Fuller, Jae Lee, Nathaniel Livesey, and Michelle Santee

This paper presents the climatologies of upper tropospheric (UT) water vapor and cloud ice water content (IWC) measured by Microwave Limb Sounder (MLS) during 2004-2009, and compares them with those derived from the NASA’s Goddard Earth Observing System, Version 5 (GEOS-5) data assimilation system. The UT water vapor and cloud ice are positively correlated at 215 to 147 hPa, but anti-correlated at 100 hPa. The high UT water vapor and cloud ice at 215 to 147 hPa are closely associated with deep convection. At 100 hPa, low water vapor mixing ratios are associated with low tropopause temperatures in regions of tropical deep convection. The transition from positive to negative correlation between H₂O and IWC occurs around 147 hPa. At 215 hPa, the MLS and GEOS-5 show good agreement. However, at 147 hPa, GEOS-5 significantly underestimates IWC and overestimates H₂O. Compared to MLS at 100 hPa, GEOS-5 produces lower IWC amount, lower H₂O in the tropics and higher H₂O in the extra-tropics. GEOS-5 also produces a relatively weaker inter-tropical convergence zone (ITCZ) in the UT H₂O and IWC fields, while a seasonally migrating band of equatorial deep convection is clearly evident in MLS UT H₂O and IWC. At 100 hPa, the seasonal cycle of MLS H₂O is largely controlled by temperature and exhibits a quasi-biennial oscillation. The vertical transport of the tropical mean H₂O seasonal cycle (the “tropical tape-recorder”) is evident from ~147 hPa to ~10 hPa in MLS but much weaker in GEOS-5, likely due to deficient stratospheric dynamics in GEOS-5. The inter-annual variation of IWC and H₂O in both MLS and GEOS-5 show clear imprints of the El Niño- Southern Oscillation (ENSO). The global regression MLS IWC and H₂O with Niño 3.4 sea surface temperature (SST) show a typical dipole pattern, with positive values in the Eastern Pacific and negative values in the Western Pacific at 215 to 147 hPa. At 100 hPa, associated with a wide-spread temperature response to ENSO is strong positive correlation of H₂O with Niño3.4 SST in the Indian Ocean and negative correlation in the eastern Pacific. Like MLS observations, GEOS-5 analysis captures the UT response to the ENSO event very well.

New Atmospheric Data Products in GIOVANNI

James Johnson, S. Ahmad, and G. Leptoukh

The Goddard Earth Sciences GIOVANNI online web data exploration and analysis tool is available for users to study regional and global atmospheric chemistry and dynamics phenomena. The most recent data versions from all of the Aura sensors (TES, OMI, MLS and HIRDLS) are now in GIOVANNI. The newest data added to GIOVANNI include Aura TES data, EPA AIRNOW PM_{2.5}, subsetted data from A-Train instruments along the CloudSat and CALIPSO track, GEOS-5 based MERRA (30 year model data), GOCART model, and Fire counts from MODIS. Hemispheric Transport of Air Pollution (HEMITAP) model data will be available soon. These compliment the existing atmospheric data in GIOVANNI including Aura OMI, MLS and HIRDLS, AIRS, MODIS, MISR, POLDER, TOMS and HALOE. Examples of using these data in GIOVANNI will be presented here. For more information, please go to <http://giovanni.gsfc.nasa.gov>.

Regional correlations between BC and CO from satellite remote sensing

Jhoon Kim, J. Mok, and J. Lee

Increases of CO, a very important gas in tropospheric chemistry, in atmosphere can reduce self-purification ability of atmosphere, thus modifies atmospheric chemical, physical, and climatological properties. Also, CO, gas due to long lifetime in the atmosphere, has similar source with BC (black carbon) including fuel combustion and biomass burning, but different sink mechanism. BC aerosol has been regarded as a potential factor causing global warming (IPCC, 2007). MODIS-OMI algorithm is used to classify aerosol types into four types – BC, soil dust, sulfate, and seasalt (cf. Jeong and Li, 2005; Kim *et al.*, 2007) using OMI's AI to determine radiative absorption of aerosol and MODIS's AE (Angstrom Exponent) to determine size of aerosol. Mean AOD of BC in North America, South America, Europe, North Africa, Southern Africa, Asia, and Australia is 0.25 ± 0.2 , 0.39 ± 0.2 , 0.25 ± 0.16 , 0.22 ± 0.11 , 0.28 ± 0.07 , 0.45 ± 0.23 , and 0.21 ± 0.11 , respectively. The major source regions of BC are Asia, South America and Southern Africa. With extensive dataset obtained, the MODIS-OMI algorithm and MOPITT allow us to investigate the correlation between BC and CO. The correlation between BC and CO is better than that between MODIS fine mode AOD and CO in most regions. For example, correlation (0.63) between CO and BC during total period in Europe are higher by four times than that (0.14) between CO and fine mode AOD. By comparing these results with MODIS fire counts, even enhanced correlations are found for CO with BC in the region of biomass burning and wild fires. Good correlation between CO and BC suggests possibilities that CO can be used as surrogates of BC and validate the classified BC aerosol from satellite remote sensing. In Southern Africa, however, the correlation between BC and CO becomes worse than that between fine mode AOD and CO. Wind fields, vegetative fuels, and distance from the source regions are suggested to explain the difference.

Ozone and water vapor profiles by balloon and satellite borne instruments

Rigel Kivi, O. Aulamo, B. Bojkov, E. Brinksma, P. Heikkinen, E. Kyrö, H. Vömel

Ozonesonde measurements by ECC type of sondes from Sodankylä, northern Finland are compared to the space borne measurements by the instruments on board the Aura satellite (OMI, MLS, TES and HIRDLS). The Sodankylä site has hosted two major campaigns and has regular measurements of ozone by ground based instruments. The accurate water vapor observations have been made by research grade frost point hygrometer using cryogenic cooling and by Lyman-alpha hygrometer. These balloon measurements have been timed to the satellite measurements. Finally, we discuss the accuracy of water vapor measurements by the new versions of operational radiosonde RS92 and comparisons with the satellite borne measurements.

Trajectory modeling of Kasatochi eruption plume compared with OMI SO₂ observations

Nikolay Krotkov, M. Schoeberl, K. Yang, S. Carn, and G. Morris

OMI daily contiguous volcanic SO₂ data continue 25+ climatic records by its predecessors (Total Ozone mapping Spectrometers 1978-2005), but higher SO₂ sensitivity allows better measuring volcanic plume boundaries and tracking plumes for a longer time. In this presentation we combine OMI volcanic SO₂ data for the August 7, 2008 eruption of Kasatochi volcano (Aleutian Islands) with Goddard Trajectory Model to derive information on the altitude distribution of SO₂ and the emission time-series. Three major explosive eruptions occurred at Kasatochi volcano (52.18°N, 175.51°W) that injected SO₂ and ash directly into Arctic lower stratosphere between 35,000 – 45,000 feet. Initial OMI estimate of total SO₂ mass was on the order of 1.4 Tg, which characterizes Kasatochi eruption as largest since Pinatubo and Cerro Hudson eruptions in 1991. OMI SO₂ data on August 10 were used to initialize Goddard trajectory model to forecast of the SO₂ plume dispersion and to derive the SO₂ vertical profile. The trajectory model used the latest GEOS-5 assimilation. The results on inverse trajectory modeling of the OMI SO₂ data allow deriving information on the altitude distribution of SO₂ and the emission time-series. We analyze Kasatochi SO₂ plume dispersion during extended period following the eruption. Although the plume dispersed, the dispersal structure was quite filamentary and plume filaments were evident in the OMI data over three weeks later. The model predicted locations of the plume are compared with daily OMI SO₂ measurements and SO₂ heights are compared with CALIPSO lidar data. The dispersal of the plume is reasonably represented in the trajectory calculation with the largest dispersion occurring below 12 km. Integrating all daily OMI SO₂ observations and correcting for SO₂ plume heights we estimate total daily SO₂ mass loss due to chemical conversion to sulfate aerosols. Exponential decay rate of ~10 days was estimated from OMI data for SO₂ in the lower stratosphere. We also compared OMI data with the first in-situ SO₂ balloon launches during period 16-24 August 2008 from the Hokkaido University campus in Sapporo, Japan (43.070N, 141.350E). On August 22,

2008 the ascending data have shown elevated SO_2 from the surface to ~ 3 km, with a sharp SO_2 peak of >10 ppbv between 530 and 820m. Back trajectories for this case have shown the air masses over the previous 3 days arriving from the NNE, descending in altitude from ~ 1.5 to 0.5 and from ~ 4 to 1.5 km respectively as the air masses passed over the Sea of Okhotsk into Hokkaido. Additional back trajectory calculations indicate that this air mass originated in the upper troposphere near Mt. Kasatochi some 2 weeks earlier. Thus, the SO_2 signal seen in the sonde data are likely remnants of the Mt. Kasatochi or other unknown volcanic eruption. Of particular interest was the eruption of the Bezymianny volcano (55.98N, 160.58E) on 19 Aug. □

Synergy between Stratospheric-tropospheric Ozone: An EOF analysis

Ujjwal Kumar and Koen De Ridder

An empirical orthogonal function (EOF) analysis has been applied to the data sets of stratospheric column ozone (SCO) and tropospheric column ozone (TCO) over the period of Aug-1996 to Dec-2005. Both data sets are TOMS version (8) monthly mean column ozone in the tropics derived from the Convective Cloud Differential (CCD) method [J. R. Ziemke, S. Chandra, and P. K. Bhartia, *J. Geophys. Res.*, 101, 22115-22127, 1998]. The trend in TCO concentration is found to be of increasing in nature. This has been verified by carrying out a regression between time series of TCO concentration and time-indices. Out of 432 grid points, regression coefficients have been found to be positive at 394 grid-points confirming an overall increasing trend in TCO concentration. In case of regression between SCO concentration and time-indices, regression coefficients have been found to be negative at all latitudes sites (SCO is assumed to be independent of longitude) thus confirming an overall decrease in SCO at tropics. The time series of first EOF expansion coefficients (PC 1) of both SCO and TCO, that explains 71.3% and 49.7% of their respective total variances, are characterized by seasonal cycles. The phase of PC 1 of SCO (Fig 1) has been found to be in opposite of the phase of PC 1 of TCO (Fig 2). This relationship clearly implies that increase in tropospheric ozone leads to a decrease in the stratospheric ozone in the tropics and vice versa, i.e., a synergy between SCO and TCO.

OMI BrO, HCHO, and OCIO - Status, Issues, and Updates

Thomas P. Kurosu and Kelly Chance

We present the current status and known issues of the OMI operational data products for BrO, HCHO, and OCIO. All products are affected by the OMI instrument anomaly, which leads to some loss of data. A small noise increase in the data over time, possibly due to general instrument degradation (hot and dead pixels), can lead to degradation in temporal averages unless error-weighted averaging is employed. Finally, rebinned spatial zoom granules are currently not processed correctly. Updates for the next release of the data products will include weighting-function modified spectral fitting for BrO and, possibly, HCHO. It will also include improved flagging of pixels affected by the instrument anomaly.

Evaluation of SCIAMACHY CO total columns with MOPITT CO and FTIR measurements

A.T. Jos de Laat, A.M.S. Gloudemans, I. Aben and H. Schrijver

We present a detailed comparison of SCIAMACHY carbon monoxide (CO) total column measurements from the IMLM retrieval algorithm with MOPITT CO and FTIR measurements. The effect of instrument-noise errors, different sensitivities, collocations and clouds are quantified using model simulated CO profiles. When taking these effects into account, spatio-temporal variations of SCIAMACHY, MOPITT, and FTIR CO total columns are similar. Two important biases were identified. At Southern Hemispheric latitudes south of 30S IMLM underestimates CO total columns compared to model results. This may be caused by the empirical correction for the SCIAMACHY ice layer. On the other hand, MOPITT shows an overestimation at these latitudes compared to model results, which may be partly caused by too low emissions in de model and partly related to the MOPITT a priori. Secondly, in the transition from oceans to dry desert regions, MOPITT shows a rapid increase in the CO column which is not seen in SCIAMACHY CO and TM4 model results. The occurrence of this bias and the agreement between MOPITT and SCIAMACHY over the oceans suggests that this bias may be related to the thermal infrared emissivity of land dry surfaces, but this needs further confirmation. Validation of the IMLM CO total columns with in situ FTIR observations is complicated due to the limited spatial coverage of the FTIR stations, station sitting issues and the need to average multiple observations to reduce the SCIAMACHY instrument-noise errors. Nevertheless, when accounting for these

effects and carefully selecting FTIR stations suitable for validation, a number of findings from the SCIAMACHY-MOPITT comparison are confirmed: the existence of a Southern Hemisphere bias south of 45S, agreement between SCIAMACHY and FTIR observations elsewhere, the existence of useful information about CO over low ocean clouds and the ability of SCIAMACHY to probe deep into the troposphere at high northern latitudes, providing information not available from IR measurements.

Aura MLS Near Real Time (NRT) products - status update

Alyn Lambert, Lucien Froidevaux, Michael Schwartz, Nathaniel Livesey (presenting), Paul Wagner, and David Cuddy

The Aura Microwave Limb Sounder (MLS) Near Real Time (NRT) production system is reviewed. MLS NRT ozone and temperature products are routinely produced within ~3 hours of observation and made available to the operational and research atmospheric science communities. This poster describes the current NRT ozone and temperature products, and outlines plans for future improvements to these products. The possible inclusion of meteorological forecast information in the NRT system, for improved accuracy, will be discussed.

Indirect Validation of Tropospheric Nitrogen Dioxide Retrieved from the OMI Satellite Instrument: Insight into the Seasonal Variation of Nitrogen Oxides at Northern Midlatitudes

L. N. Lamsal, R. V. Martin, A. van Donkelaar, E. A. Celarier, F. K. Boersma, R. Dirksen, C. Luo, and Y. Wang,

We examine the seasonal variation in lower tropospheric nitrogen oxides ($\text{NO}_x = \text{NO} + \text{NO}_2$) at northern midlatitudes by interpreting tropospheric NO_2 columns observed from the OMI satellite instrument with surface NO_2 measurements (SEARCH and AQS) and current bottom-up NO_x emission inventories, using a global model of tropospheric chemistry (GEOS-Chem). The standard (SP) and DOMINO (DP) tropospheric NO_2 column products from OMI exhibit broadly similar spatial and seasonal variation, but differ substantially over continental source regions. Comparison of the two OMI tropospheric NO_2 products with in situ surface NO_2 concentrations and bottom up NO_x emissions over the southeast United States indicates higher annual mean NO_2 columns by 21–33% for DP and by 27–43% for SP. The bias versus SP columns is highly seasonal, 67–74% in summer compared with -6 to -1% in winter. Similar differences exist between top-down and bottom-up NO_x emission inventories over North America, Europe, and East Asia. The stratosphere troposphere separation and air mass factor largely explain the observed seasonal difference between the DP and SP. We develop a third product (DP GC) using averaging kernel information from the DP and NO_2 vertical profiles from GEOS-Chem. This product reduces to 5–21% the annual mean difference versus in situ and bottom-up emissions over the southeastern United States. We use the seasonal variation in the DP GC to estimate the seasonal lifetime of lower tropospheric NO_x against oxidation to HNO_3 over the eastern United States. The effective NO_x lifetime at OMI overpass time (early afternoon) ranges from 7.6 hours in summer to 17.8 hours in winter, consistent within 3 hours of the simulated lifetime. GEOS-Chem calculations reveal that the seasonal variation in OMI NO_2 columns largely reflects gas phase oxidation of NO_2 .

Retrieval of vertical columns of sulfur dioxide from SCIAMACHY and OMI: Air mass factor algorithm development, validation, and error analysis

Chulkyu Lee, Randall V. Martin, Aaron van Donkelaar, Gray O'Byrne, Nikolay Krotkov, Andreas Richter, L. Gregory Huey, and John S. Holloway

We develop an improved retrieval of sulfur dioxide (SO_2) vertical columns from two satellite instruments (SCIAMACHY and OMI) that measure ultraviolet solar backscatter. For each SCIAMACHY and OMI observation, a local air mass factor (AMF) algorithm converts line-of-sight “slant” columns to vertical columns using altitude-dependent scattering weights computed with a radiative transfer model (LIDORT), weighted by relative vertical SO_2 profile (shape factor) determined locally with a global atmospheric chemistry model (GEOS-Chem). The scattering weights account for viewing geometry, surface albedo, cloud scattering, absorption by ozone, and scattering and absorption by aerosols. Absorption of radiation by mineral dust can reduce seasonal mean instrument sensitivity by 50%. Mean SO_2 shape factors simulated with GEOS-Chem and used in the AMF calculation are highly consistent with airborne in situ measurements (INTEX-A and INTEX-B); differences would affect the retrieved SO_2 columns by 10%. The retrieved vertical columns are validated with coincident airborne in situ measurements (INTEX-A, INTEX-B, and a campaign over East China). The annual mean AMF errors are estimated to be 35-70% in polluted regions (e.g., East Asia and the eastern US) and less than 10% over clear ocean regions. The overall SO_2 error assessment is 45-80% for

yearly averages over polluted regions. Seasonal mean SO₂ columns retrieved from SCIAMACHY and OMI for 2006 are significantly spatially correlated with those from GEOS-Chem, in particular over the United States ($r = 0.85$ for SCIAMACHY and 0.82 for OMI). A sensitivity study confirms the sensitivity of SCIAMACHY and OMI to anthropogenic SO₂ emissions.

On the improvement of satellite retrievals of NO₂ using aerosol measurements

J. Leitão, A. Richter, A. Kokhanovsky, and J.P. Burrows

Global distribution of trace gases (such as O₃, NO₂, SO₂, etc) in the troposphere and identification of different emission sources can, nowadays, be determined from measurements of the backscattered solar radiation performed by various instruments operating from satellites such as GOME, GOME-2, SCIAMACHY and OMI. In the particular case of NO₂ the Differential Optical Absorption Spectroscopy (DOAS) method is used for retrieval of tropospheric columns in the wavelength window of 425-450nm. The tropospheric amount of NO₂ is obtained by subtracting the stratospheric contribution from the total slant column (SC). The vertical tropospheric column of NO₂ is then determined by dividing the SC by an airmass factor (AMF). These AMF are computed with a radiative transfer model, e.g. SCIATRAN, and are dependent on several factors, e.g. geometry and wavelength of measurement, vertical distribution of the species and many others. Here we focus on the impact of the aerosol characteristics, such as aerosol load and optical properties. The presence of aerosols in the atmosphere during the measurements of NO₂ (and other trace gases) can enhance the signal by means of multiple scattering within the aerosol layer or by an increase of the effective albedo when the NO₂ layer is above the aerosol. On the other hand, if the aerosol is above the trace gas the measured slant column can be decreased. Therefore, we consider that the improvement of the aerosol settings used for the calculation of AMF is a priority. This can be done via the application of independent satellite measurements (e.g., from MERIS or CALIPSO) and ground-based measurements (from AERONET or EARLINET stations) that provide AOD, aerosol vertical profile and aerosol physical properties. In this presentation we show how merging research efforts on aerosol and trace gas remote sensing is essential to achieve more accurate results. □

Tropical upper-tropospheric ozone variability as observed by the Aura Microwave Limb Sounder

Nathaniel Livesey, Michelle Santee, Lucien Froidevaux, William Read, Dong Wu, Jonathan Jiang, Alyn Lambert, and Jennifer Logan

We present a survey of five years of upper tropospheric ozone (O₃) observations from the Microwave Limb Sounder (MLS) on NASA's Aura spacecraft. Seasonal and interannual variability in different tropical regions will be quantified and contrasted. Relationships with concurrent MLS observations of upper tropospheric carbon monoxide (CO, indicating polluted air) and cloud ice (a marker of convective activity) will be discussed. MLS O₃ and CO observations in 'clear sky' and 'cloudy' conditions show significant differences in many regions and seasons, reflecting differences between freshly lofted and background upper tropospheric air. MLS observations are compared to selected observations from other platforms and instruments.

Studies of Stratopause Structure, Evolution and Transport from Satellite Data and New Assimilation Products

Gloria L. Manney, M.J. Schwartz, K. Krüger, S. Pawson, N. McKee, S. Polavarapu, S. Ren, K. Hoppel, K. Minschwaner, and E.E. Remsberg

Recent daily global temperature datasets extending through the mesosphere from the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument launched 2001 and the Aura Microwave Limb Sounder (MLS) launched in 2004 are the first datasets that allow comprehensive evaluation of the performance of models and data assimilation systems (DAS) in the upper stratosphere through the lower mesosphere. Operational analyses from European Center for Medium-Range Weather Forecasting (ECMWF) and NASA's Global Modeling and Assimilation Office (GMAO) show serious deficiencies in reproducing extreme events such as the prolonged stratospheric sudden warmings in January 2006 and January 2009; they also show substantial biases in global stratopause structure and evolution under more typical conditions. New research assimilation products show promise in improving the representation of the stratopause with higher model tops, more sophisticated gravity-wave drag parameterizations, and/or assimilation of MLS and SABER data. We show stratopause structure and evolution in a NOGAPS-ALPHA (NRL's high-altitude DAS) runs that assimilate MLS temperatures. The interannual and interhemispheric variability of stratopause evolution and its representation in data assimilation systems is explored, focusing in particular on the over

four-year IPY run of the Canadian Middle Atmosphere Model DAS (CMAM-DAS). CMAM-DAS also includes online trace gas transport, and we use MLS data to evaluate transport processes in CMAM-DAS in the stratosphere through the lower mesosphere.

Ozone Profile Validation Results from the SAUNA Campaign

Richard McPeters, B. Bojkov, T. McGee, L. Flynn, and R. Kivi

The Sodankyla Total Column Ozone Intercomparison (SAUNA) was held in Sodankyla, Finland in March-April 2006 and February-March 2007 in support of Aura validation. Results showed that the ozone profiles from the satellite instruments (MLS on Aura and SBUV/2 on NOAA 16 and 17) generally agreed with profiles from the ground-based instruments (lidar and sondes) within 10%. Large gradients in ozone at high latitudes is the most significant source of variation when profile measurements are compared. For the purpose of validation both spatial and temporal variations must be taken into account. The largest differences were seen in the profile below 25 km, consistent with our conclusion that spatial variability in the lower stratosphere and upper troposphere is the most significant source of disagreement in these comparisons. The total column ozone comparison shows that SBUV/2 and OMI agree well with the double Brewer instruments provided the scenes are carefully matched.

Sensitivity studies to determine the effect of rotational Raman scattering on ozone profile retrieval from backscattered UV measurements

Joke Meijer, J.F. de Haan, and P.F. Levelt

Ozone profile retrieval from backscattered UV measurements has gradually developed since SBUV retrievals. Currently we try to improve the ozone profile algorithm used for the Ozone Monitoring Instrument (OMI) on board of Aura. In particular, our aim is to improve the retrieval of tropospheric ozone. At the quadrennial ozone symposium in 2004 it was shown that advanced treatment of rotational Raman scattering is required if the differential optical absorption spectroscopy is used to determine the total ozone column. Therefore we are investigating whether we need rotational Raman scattering in the forward model used for the ozone profile retrieval and whether including rotational Raman scattering improves the information content on tropospheric ozone. We expect to gain more information on tropospheric ozone because rotational Raman scattering increases with multiple scattering and is therefore more sensitive to the lower parts of the atmosphere than the elastic scattering. For this purpose we use wavelengths from 270 up to 330 nm to sample both the troposphere and the stratosphere. We have created an accurate forward model that accounts for polarization effects (through look-up tables) and rotational Raman scattering. The current OMI ozone algorithm uses an approximation for rotational Raman scattering. With our forward model we can assess the accuracy of this approximation. We will present results of this assessment. In addition we hope to present the initial results of a sensitivity study that includes the full diagnostic information provided by the optimal estimation method.

10-min Variations in PBL/FT Ozone from DIAL Measurement in Huntsville

Mike Newchurch, Shi Kuang, and John Burris

The tropospheric ozone Differential Absorption Lidar (DIAL), developed jointly by University of Alabama in Huntsville and NASA/GSFC, measures ozone profiles from 0.3 to ~8 km at 10-minute intervals with a vertical resolution less than 750 m. These time-series observations show a wide variety of evolving conditions including growing and diminishing, rising and sinking ozone layers that are sometimes associated with aerosol or water-vapor layers. Trajectory analyses indicate some cases of very sharp shear layers with very different sources and effects from widely disparate directions. Nighttime residual ozone layers and morning entrainment processes are also evident in these observations. This lidar characterizes the atmospheric variations of ozone and aerosol fields that must be observed by the GEO-CAPE instrument suite for air-quality science and forecasting.

Application of OMI Ozone Profiles in CMAQ

Mike Newchurch, L. Wang, A. Biazar, M. Khan, X. Liu, D. Byun, and B. Pierce

Using OMI ozone profiles as the boundary conditions for CMAQ calculations significantly improves the agreement of the model with ozonesonde observations during IONS06. This improvement results from both representing the free-tropospheric ozone amounts more accurately and also from representing recirculating air masses more accurately. A simultaneous assessment of the OMI ozone profiles directly with the sondes indicates agreement to better than 10% throughout the free troposphere with 10-20% differences in the PBL.

Influence of Lightning NO_x on Upper Tropospheric Ozone Concentration

Mike Newchurch, UAH, Huntsville, AL; and L. Wang, A. Biazar, and W. Koshak □

Lightning is a particularly significant NO_x source (LNO_x) in the middle and upper troposphere where NO_x is long-lived, typically at more dilute concentrations, and consequently more efficient at producing ozone than in the boundary layer where the majority of NO_x is emitted. Currently, the CMAQ model does not count for NO_x emission from lightning. However, it's important to quantify the effect of LNO_x on tropospheric ozone concentration in order to make our model simulation more realistic, particularly in regions/periods with frequent lightning events. In this study, we will apply the National Lightning Detection Network (NLDN) lightning data as an extra NO_x emission sources to the CMAQ model, and then to quantify the contributions of LNO_x to tropospheric ozone. These quantitative values will be useful for parameterization in future modeling studies.

Surface reflectivity from OMI using MODIS to eliminate clouds: Effects of snow on UV-Vis trace gas retrievals

G. O'Byrne, R. V. Martin, A. van Donkelaar, J. Joiner, and E. A. Celarier

Satellite retrievals of tropospheric composition from measurements of solar backscatter require accurate information about surface reflectivity. We use clear-sky data from the OMI satellite instrument to determine global surface reflectivity under both snow-covered and snow-free conditions. Clear-sky scenes are determined using cloud and aerosol data from the MODIS/Aqua satellite instrument that flies 12 minutes ahead of OMI/Aura. The result is a database of OMI-observed Lambertian equivalent reflectivity (LER) that does not rely on statistical methods to eliminate cloud and aerosol contamination. We apply this database to evaluate previous climatologies of surface reflectivity. Except for regions of seasonal snow cover, agreement is best with a climatology from OMI which selects the surface reflectivity from a histogram of observed LER (mean difference 0.0002; standard deviation 0.011). Three other climatologies from TOMS, GOME and OMI which select the minimum observed LER as the surface reflectivity are less consistent with our cloud- and aerosol-filtered dataset (mean difference -0.008, 0.012, -0.002; standard deviation 0.022, 0.026, 0.033). Snow increases UV-Vis instrument sensitivity to trace gases in the lower troposphere. However all four existing LER climatologies poorly represent seasonal snow. Surface reflectivity over snow-covered lands depends strongly on the vegetation type covering the surface. The monthly variation of snow-covered reflectivity varies by less than 0.1 in fall and winter. Applying our snow-covered surface reflectivity database to OMI NO₂ retrievals could change the retrieved wintertime NO₂ column by up to 100% over large regions.

Quantifying the impact of BOREal forest fires on Tropospheric oxidants over the Atlantic using Aircraft and Satellites: An overview of the BORTAS project.

Mark Parrington, P. I. Palmer, S. Matthesen, P. F. Bernath, J. D. Lee, A. C. Lewis, and A. Rickard

BORTAS is a 3-year multi-national project, led by the University of Edinburgh, aimed at quantifying the connections between the composition and the distribution of pollutant outflow from boreal forest fires, ozone production and loss within that outflow, and the resulting perturbation to oxidant chemistry in the troposphere. A central feature of BORTAS is an aircraft measurement campaign, focused over the Northwest boundary of the North Atlantic during July 2010, which will sample biomass burning outflow from boreal North America. These aircraft measurements will be used, in conjunction with data from satellite instruments (including TES and OMI), ozonesondes, and the GEOS-Chem chemical transport model, to detect, validate and quantify the impact of boreal biomass burning on global tropospheric composition. We present an overview of the BORTAS project along with preliminary results from an analysis of the summers of 2006, 2007 and 2008.

Evaluation of Upper Stratospheric and Mesospheric Structure in the CMAM and ECMWF data assimilation systems using MLS Geopotential Height

Michael J. Schwartz, J.N. Lee, G.L. Manney, D.L. Wu, S. Polavarapu, and K. Krüger

Analysis of the geopotential height (GPH) product from the Microwave Limb Sounder (MLS) on the Aura satellite provides means of studying the dynamical structure of the atmosphere from the upper troposphere into the mesosphere. Recent work with this product has shown that the northern annular mode (NAM) extends into the mesosphere, and that significant NAM perturbations associated with sudden stratospheric warmings (SSW) propagate downward from the mesosphere. Here, we compare representations of middle atmospheric structure in the European Center for Medium range Weather Forecasting (ECMWF) data assimilation system (DAS) and in the Canadian Middle Atmosphere Model (CMAM-DAS) with the MLS analysis. Of particular interest is the impact on the CMAM analysis of its higher model top ($>0.001\text{hPa}$ vs 0.01hPa) and more-sophisticated gravity-wave (GW) representation.

Measurements of stratospheric gases by a balloon-borne SIS submillimeterwave heterodyne radiometer for Aura Validation

Robert Stachnik, G. Toon, J. Margitan, J. Blavier and B. Drouin

ClO, HO₂ and BrO are among the key trace gases in the photochemistry of stratospheric ozone. Observed spectra and composition profiles of ClO, HO₂, BrO, O₃, HCl and other gases were obtained from recent stratospheric balloon flights of the JPL Submillimeterwave Limb Sounder (SLS) instrument. The SLS is a submillimeterwave heterodyne radiometer that measures thermal emission spectra at 600~GHz to 700~GHz by means of a superconductor-insulator-superconductor (SIS) mixer and tunable local oscillator. Data presented are from a polar winter flight conducted from Kiruna, Sweden (68N) in January 2007 and a mid-latitude flight from Ft. Sumner, NM (34N). The Kiruna flight was a joint flight with the CFA FIRS-2 far-infrared emission FTS and the JPL UV photometer measuring O₃ in situ. The Ft. Sumner payload included these instruments and the JPL MkIV solar occultation FTIR. We compare these measured profiles with corresponding observations by satellite, specifically the Microwave Limb Sounder on Aura and the ACE-FTS, and with those of the other instruments in the balloon payload. Observed diurnal variation of HO₂ from the mid-latitude flight and the ClO abundance observed in the winter polar vortex were analyzed using photochemical models. We discuss implications of these results in the context of Aura validation and the chemistry of chlorine-catalyzed polar O₃ depletion.

Transport Behavior of GEOS4-DAS and GEOS5-DAS in the GMI CTM

Susan A. Strahan, Jose M. Rodriguez, and Stephen Steenrod

The Global Modeling Initiative CTM has carried out calculations of the composition of the troposphere and stratosphere for the AURA period, using meteorological fields from the GEOS-4 product of Goddard's Global Modeling and Assimilation Office (GMAO). These calculations have been used by scientists to analyze AURA data, and are still available. The GMAO is in the process of releasing a 30-year analysis utilizing the GEOS-5 system. Among other differences, the GEOS-5 fields are produced at a resolution of $1/2 \times 2/3^\circ$, with 72 levels from 1000 to 0.01 hPa. (For comparison, the GEOS-4 fields had a resolution of $1 \times 1.25^\circ$, with 55 levels from the ground to 0.01 hPa). The physics and assimilation system of the GEOS-5 system is also quite different from GEOS-4. Since the emphasis of the 30-year MERRA analysis is on the tropospheric hydrological cycle, it is important that these meteorological fields be evaluated in the stratosphere. We present preliminary evaluations for the mean and modal age of air in the GMI-CTM using GEOS-5 fields, comparing to both GEOS-4 GMI CTM results and age data derived from observations of CO₂ and SF₆. Meteorological fields for both GEOS-4 and GEOS-5 have been degraded to a resolution of $2 \times 2.5^\circ$ for use in the CTM. We find that, in general, GEOS-5 age of air is older than that calculated using GEOS-4 meteorological fields by as much as 2 years in the upper stratosphere. The mean and modal ages in the tropics are also older than those derived from observations, which imply differences in tropical ascent rates and in isolation of the tropical pipe. Comparisons are also shown with O₃ and N₂O from MLS. Although there is very little difference between both systems in the lower/middle stratosphere, above 10 hPa GEOS-5 results for N₂O are better than those of GEOS-4, presumably because of the higher vertical resolution used in the GEOS-5 CTM. Continuing evaluation the GEOS-5 simulation will determine the relative strengths and weaknesses of these two systems. GEOS-5 GMI simulation results for the AURA period will soon be available, complementing the analysis of AURA data and GEOS-4 CTM results.

Looking for signs of stratospheric folds in the four Aura ozone measurements

Qi Tang and Michael Prather

We have completed high-resolution CTM simulations of stratospheric and tropospheric ozone for the early Aura period and identified the locations of significant strat-trop folding (STE) that are associated with the net flux of ozone into the troposphere. We archive the $1^\circ \times 1^\circ \times 40$ levels of simulated ozone, then follow the Aura track and timing of the individual measurements from MLS, HIRDLS, TES, and OMI, and attempt to simulate the retrieved ozone from each instrument, noting specifically the horizontal and vertical ozone structures in the region of each observation. We find some successes and some failures using the recommended approaches for comparing higher resolution data with the instrument retrievals. One particular problem is the use of the least-squares approach to the profiles. Also, if we process the TES simulations with the a priori and sensitivity functions then we lose most STE events. We select 600+ ozone sonde observations over the year from regions where STE events are predicted in the model. These provide a reasonable validation of model's simulation of folds. The 40-level ECMWF met fields (even at 1×1) have clear problems with the stratospheric circulation as noted at T42 resolution (Hsu et al., JGR, 2009). Some of these biases can be filtered out, but others provide excess variability in the tropics. We expect these to be resolved with the 60-level fields now being developed at University of Oslo.

Validation of Aura MLS by the JPL MkIV Interferometer

Geoffrey Toon, Jean-Francois Blavier, Armin Kleinboehl, Voltaire Velazco, and the MLS Team

The JPL MkIV interferometer performed balloon flights from Ft. Sumner, NM, in September 2004, 2005, & 2007, during which it obtained solar occultation spectra covering the 10-40 km altitude range. Retrieved vmr profiles of H₂O, O₃, N₂O, CO, HCN, HNO₃, HCl, HOCl, have been compared with selected co-located measurements by the MLS instrument on board the Aura satellite. Agreement is generally good (within 10%) for HCl, O₃, N₂O, and H₂O, but less good for the other gases (i.e. CO, HCN, HNO₃, HOCl). which will be discussed on an individual basis. We will also show some of the longer term trends inferred from the MkIV balloon profile data.

What does OMI see over snow and ice? A study of clouds and ozone

Alexander Vasilkov, Joanna Joiner, Pawan K. Bhartia, and David Haffner

Due to their high albedos, snow and ice provide excellent conditions for passive remote sensing by satellite-based solar backscatter measurements. However, these observations can be complicated by clouds, especially at high solar zenith angles. In this work, we examine how clouds over snow and ice affect ozone absorption and how these effects may be accounted for in retrieval algorithms. Over snow and ice, the OMI Raman cloud pressure algorithm derives an effective scene pressure assuming a Lambertian surface. When this scene pressure differs appreciably from the climatological surface pressure, the difference is likely caused by a cloud of moderate to high optical thickness. We have used a pressure difference of 100 hPa as a crude threshold for the detection of clouds that provide significant shielding of tropospheric ozone absorption. The MODIS CO₂ slicing algorithm provides a good estimate of the cloud top pressure for high clouds. Using a combination of OMI and MODIS, we may therefore distinguish between optically thick and thin clouds over snow ice. To evaluate this approach, we have performed a number of radiative transfer simulations under various observing conditions. We find that the sensitivity of ozone absorption to clouds varies significantly with the viewing geometry as well as the surface albedo. We also evaluate our results using estimates of cloud vertical extinction profiles from CloudSat and MODIS. Currently, the OMI-TOMS total ozone algorithm assumes no clouds over snow and ice. This assumption can lead to an underestimate of the total column ozone over snow and ice when clouds are present because ozone beneath the clouds is not accounted for. Use of the OMI effective cloud pressures should reduce this type of error and result in a more homogeneous spatial distribution of the retrieved column ozone over snow and ice. We will evaluate OMI-TOMS total column ozone retrievals over snow and ice using the effective scene pressures derived in the OMI Raman cloud algorithm.

TROPOMI Overview

Robert Voors, Johan de Vries, Agnes Mika, Gerard Otter, Nick van der Valk, Ilse Aben, Ruud Hoogeveen, Annemieke Gloudemans, Marcel Dobber, Pepijn Veeffkind, and Pieter Levelt

The Tropospheric Monitoring Instrument (TROPOMI) is currently planned for launch on ESA's Sentinel 5 precursor satellite in the time frame of 2014. TROPOMI is an ultraviolet-to-SWIR wavelengths imaging spectrograph that uses two-dimensional detectors to register both the spectrum and the swath perpendicular to the flight direction. The swath is about 110 degrees wide to allow daily global coverage from the polar orbit of the Sentinel 5 precursor satellite. The instrument follows the heritage of SCIAMACHY (ENVISAT, launch 2002) and OMI (AURA, launch 2004), but it has been improved in several ways: the ground resolution is down to 7 x 7 km², the instrument is fit for low albedo scenes and the wavelength bands are optimized using the SCIAMACHY and OMI heritages to have the best trace gas products. The first two improvements basically mean that the instrument aperture is much larger for TROPOMI and, related to this, the reading of the detectors needs to be much faster. The selected wavelength bands for TROPOMI are UV1 (270-310 nm), UV2 (310 - 370 nm), VIS (370 - 500 nm), NIR (675 - 775 nm) and SWIR (2305 - 2385 nm). The first three bands are very similar to the OMI bands, the NIR has been added to improve on clouds and air mass corrections and the SWIR allows measuring CH₄ and CO. The paper discusses the development status on several topics, such as detector selection and polarization scrambler performance simulations using the TIDE grid based level 2 scene simulator.

Satellite air quality monitoring before, during and after the Beijing 2008 Olympics and Paralympics

Jacque C. Witte, M.R. Schoeberl, N. Krotkov, K. Pickering, D. Streets, J. Gleason, and J. Gille

In 2001, Beijing, China was awarded the hosting rights to the 2008 Olympic/Paralympic Games. Since then, the government has gradually implemented pollution emission control strategies to improve Beijing's air quality in preparation for both games. Long-term industrial and short-term vehicle emission controls have also been enforced upwind of Beijing's neighboring provinces to the south and west. This region is characterized by numerous heavy-polluting industries whose emissions are typically transported towards Beijing, significantly impacting the city's air quality. We examine the efficacy of these emission control measures on tropospheric NO₂, SO₂, and CO using satellite data from Aura's Ozone Monitoring Instrument (OMI) and Terra's Measurements Of Pollution In The Troposphere (MOPITT) from 2004 to the present. During both games, held in August and September 2008, OMI and MOPITT measured significant decreases in all three tracer gases compared to the past three years: NO₂ (-43%), SO₂ (-13%), and CO (-12%). This decrease in CO and SO₂ over northeastern China continues through 2009, reflecting the longer-term nature of emission controls on heavily polluting industries. The global recession is also a likely contributor, as factories have shut down or slowed production due to the decrease in demand for manufactured goods. The tropospheric NO₂ column over Beijing returned to typical monthly mean values when controls on vehicle emissions were lifted by the end of September 2008. However, we observe a slight NO₂ decrease at the beginning of 2009 relative to 2008 suggesting a decrease in the contribution of industrial emissions of NO_x to the overall NO₂ column.

HIRDLS Analyses of Planetary Wave Filtering of the Gravity Wave Spectrum

Corwin Wright, Scott Osprey, John Barnett, and John Gille

Inertia-gravity waves propagating vertically through the atmosphere are believed to interact with larger-scale planetary waves, leading to filtering effects altering their magnitude and distribution. In this poster, HIRDLS analyses of gravity wave temperature perturbations and momentum fluxes are analyzed and compared to Rossby-wave distributions, to investigate for measurable effects of this filtering.

Evaluating model predictions and ozone analyses using the vertical resolution of Aura limb constituent data

Valery A. Yudin, J.C. Gille, D. E. Kinnison, S. Tilmes, B. Nardi and S. Karol

The paper presents the evaluation of simulated ozone, CFC and N₂O vertical structures using the HIRDLS and MLS constituent data. The retrieved tropical multi-year ozone anomalies are compared with the chemistry-climate (WACCM) and chemistry-transport model (WACCM-GEOS5) simulations and analyzed ozone products constrained by SBUV/2 and GOME-2 observations. In the extra-tropical UTLS the monthly frequency of simulated ozone laminas

(thin layers with the negative ozone gradients) are evaluated for three years (2005-2007) of HIRDLS observations. The similar annual cycles of lamina frequencies are reproduced by models and HIRDLS data in the mid-latitudes of the lower stratosphere. The analyzed ozone products tend to substantially underestimate the ozone lamina frequency. The monthly zonal mean CFC (HIRDLS) and N₂O (MLS) distributions are used to evaluate the CTM transport, including year-to-year variations introduced by QBO dynamics.

Aerosol properties from OMI using cloud and aerosol information from MODIS

D. C. Stein Zweers, J. P. Veefkind, B. Veihelmann, and P. F. Levelt

Aerosol retrieval from OMI measurements is difficult as there are more unknowns than degrees of freedom of signal. Cloud contamination is a primary source of error and must be considered. It is addressed in this study by performing OMI aerosol retrieval based on a modified multi-wavelength OMAERO algorithm product where measurements of OMI are evaluated using MODIS aerosol optical thickness and cloud data. The MODIS information is based on pixels smaller than OMI and is re-gridded to OMI pixel size for evaluation. The OMI measurements are a valuable source for information on aerosol absorption, due to enhanced multiple scattering in the UV. As such, the OMI aerosol information is complementary to MODIS aerosol products which are not measured in the UV. Results are presented based on aerosol optical thickness constrained by MODIS data where the remaining aerosol parameters, including choice of aerosol models are determined based on OMI measurements.