EOS Aura Science Team Meeting
Pasadena, CA, USA, October 1-5, 2007

ORALS

Tuesday, 2 October 2007

3:45 pm
Comparison of HIRDLS and COSMIC GPS radio occultation temperature profiles.

John Barnett (Oxford University, j.barnett1@physics.ox.ac.uk), J. C. Gille, C. Cavanagh, C. Craig, T. Eden, G. Francis, C. Halvorson, R. Khosravi, C. Hepplewhite, J. Smith

The FORMOSAT-3/COSMIC constellation of six satellites carrying GPS receivers launched in April 2006 provides a unique means to validate HIRDLS temperature profiles. They enable temperature up to the mid stratosphere to be retrieved from measurements of the phase delay as the COSMIC satellite-to-GPS transmitter path is occulted by the Earth's limb with a vertical resolution that should be even better than that of HIRDLS. With 1000-2000 such temperature profiles being measured per day at quasi random locations, it is possible to find sufficient very close coincidences with HIRDLS profiles, e.g. within 100 km and 500 seconds, to undertake cross-validation of the two systems, including of the fine vertical structure (which tends to vary on a short time scale). Comparisons will be shown using the standard publicly available COSMIC retrievals and the most recent (V20408) HIRDLS temperature retrievals.

4:00 pm
OMI HCHO, BrO, and OClO - Validation Status and Outlook

Thomas P. Kurosu (Harvard-Smithsonian Astrophysical Observatory, tkurosu@cfa.harvard.edu) and K. Chance

Pre-Collection 3 retrievals of minor trace gases from OMI measurements suffering from difficulties related to extreme striping in the data products that, in the case of HCHO and BrO, are playing a role in the current 35-40% underestimate of the derived columns compared to ground-based and other satellite observations. OMI OClO columns, on the other hand, are too high by about a factor of two when compared with SCIAMACHY observations. Presently, the retrieval algorithms for HCHO, BrO, and OClO are being adjusted for Collection 3 L1b data. Improved dark current correction in Collection 3 has lead to a reduction in across-track striping of the retrieved columns, and a reevaluation of the chosen fitting windows have brought the OMI products in closer agreement with ground-based and other satellite observations. We report on the current status of the OMI standard operational HCHO, BrO, and OClO data products and give an outlook on upcoming new data products, e.g., glyoxal (CHO-CHO), that are in line for being upgraded from science product to operational status.

4:15 pm
Observing the diurnal variation of NOx chemistry and emissions from space

Folkert Boersma (Harvard University; boersma@fas.harvard.edu), D. J. Jacob, H. J. Eskes, R. W. Pinder, and R. J. van der A

We will present a complete year (2006) of satellite measurements of tropospheric NO2 columns from OMI aboard Aura (13:30 local overpass time) and SCIAMACHY aboard Envisat (10:00 overpass). Comparing the OMI and SCIAMACHY measurements that have been retrieved by KNMI/BIRA with very similar algorithms, offers the opportunity to examine the consistency between the two instruments under tropospheric background conditions and the effect of different observing times. For most of the world, SCIAMACHY and OMI agree within their detection limits. Over the polluted regions in North America, Europe, and eastern Asia we find that SCIAMACHY observes up to 40% higher NO2 at 10:00 local time than OMI at 13:30. In contrast, SCIAMACHY observes up to 40% lower NO2 columns than OMI over biomass burning regions in the tropics. These differences are present in the retrieved slant columns, and are augmented in the fossil fuel regions, and dampened in the tropical biomass burning regions by the expected increase in air mass factor as the mixing depth rises from 10:00 to 13:30. Using a global 3-D chemical transport model (GEOS-Chem), we show that the 10:00-13:30 decrease in tropospheric NO2 column over fossil fuel source regions can be explained by photochemical loss, dampened by the diurnal cycle of anthropogenic emissions that has a broad daytime maximum. The observed 10:00-13:30 NO2 column increase from over tropical biomass burning regions points to a sharp midday peak in emissions, and is consistent with a diurnal cycle of emissions derived from geostationary satellite fire counts. We will discuss the results in the context of in-situ surface observations of NO2 in polluted regions, and time permitting, extend our analysis to also include a comparison between NO2 retrieved from OMI and GOME-2 in April 2007.

4:30 pm
The Atmospheric Chemistry Experiment (ACE): After Four Years In-orbit

Kaley Walker (Department of Physics, University of Toronto, kwalker@atmosp.physics.utoronto.ca), C. Boone, P. F. Bernath, C. Thomas McElroy, S. D. McLeod, and R. Hughes

On 13 August 2007, the Atmospheric Chemistry Experiment (ACE) completed its fourth year in-orbit. This Canadian-led scientific satellite carries two instruments. The Atmospheric Chemistry Experiment Fourier Transform Spectrometer (ACE-FTS) is a high-resolution (0.02 cm-1) FTS operating between 750 and 4400 cm-1. It also contains two filtered imagers (0.525 and 1.02 microns) to measure atmospheric extinction due to clouds and aerosols. The second instrument is a dual UV-visible-NIR spectrophotometer called ACE-MAESTRO (Measurements of Aerosol Extinction in the Stratosphere and Troposphere Retrieved by Occultation) which extends the ACE wavelength coverage to

the 280-1030 nm spectral region. The ACE-FTS and ACE-MAESTRO have been making solar occultation measurements for 3.5 years and over 16,000 have been recorded to date. From these measurements, altitude profiles of atmospheric trace gas species, temperature and pressure are obtained. The 650 km altitude, 74 degree circular orbit provides global measurement coverage with a focus on the Arctic and Antarctic regions. The primary goal of the ACE mission is to measure and to understand the chemical and dynamical processes that control the distribution of ozone in the upper troposphere and stratosphere, with a particular emphasis on the Arctic region. The instrument and mission status, current science results and validation program for the ACE mission will be reviewed in this paper.

4:45 pm
Intercomparison of Middle Atmospheric Water Vapor Measurements from EOS-MLS, HALOE, and WVMS

Gerald Nedoluha (Naval Research Laboratory, nedoluha@nrl.navy.mil), R. M. Gomez, B. C. Hicks, R. M. Bevilacqua, J. M. Russell III, B. J. Connor, and A. Lambert

We will compare water vapor measurements in the upper stratosphere and mesosphere from MLS, HALOE (from August 2004 through December 2005), and two ground-based WVMS systems at Network for the Detection of Atmospheric Composition Change (NDACC) sites at Mauna Loa, Hawaii (19.5N, 204.4E) and Lauder, New Zealand (45.0S, 169.7E). We will particularly emphasize the seasonal and interannual changes observed by the WVMS and MLS measurements in order to assess the relative stability of these measurements. With the available MLS v2.2 measurements we will be able to extend the previous WVMS-MLSv1.5 comparisons into the upper mesosphere. We will show how the incorporation of MLS temperature measurements in the WVMS water vapor retrievals can be used to improve the quality of the MLS-WVMS agreement.

5:00 pm
Polar winter balloon-borne observations for Aura Validation

Robert Stachnik (Jet Propulsion Laboratory, robert.a.stachnik@nasa.gov), K. Jucks, J. Margitan, B. Sen, B. J. Drouin, J. Landeros, R. Salawitch and T. Canty.

On 24 January 2007, a stratospheric balloon was successfully launched into the cold (minimum 187K at 21 hPa) polar winter vortex above Kiruna, Sweden (67N, 21E). Instrumental payload consisted of the CFA-SAO FIRS-2 far-infrared interferometer, the JPL SLS submillimeter-wave limb sounder and the JPL in situ ozone photometer. Profiles of several atmospheric gases were measured including O3, HCl, ClO, H2O, N2O, NO2, HNO3, OH, HF, HOCl, H2O2, HO2, ClNO3, HNO4, CFC12 and CFC11. We report these observed gas profiles, comparisons of these measurements to corresponding measurements from the Aura instruments and comparisons with photochemical model results.

5:15 pm
Nitric acid/ozone correlations as a tool for validating Aura MLS nitric acid retrievals in the upper troposphere and lower stratosphere

Peter Popp (NOAA Earth System Research Laboratory, peter.j.popp@noaa.gov),
T. P. Marcy, R. S. Gao, L. A. Watts, D. W. Fahey, E. C. Richard, S. J. Oltmans, M. L. Santee, B. Sen, and G. C. Toon

Nitric acid is a primary reservoir species for reactive nitrogen and is a key player in ozone chemistry in the upper troposphere and lower stratosphere (UT/LS). An extensive in situ dataset of nitric acid and ozone measurements has been collected in the UT/LS between the equator and northern hemisphere midlatitudes with NOAA instruments onboard the NASA WB-57F high altitude research aircraft. These data have been used to establish the robustness of nitric acid/ozone correlations in the lower stratosphere and the latitudinal variability in the correlation. The utility of this correlation is demonstrated by establishing vertical profiles of proxy nitric acid mixing ratios using ozone data from the NOAA GMD ozonesonde network. These profiles enhance the value of in situ nitric acid measurements in validating the Aura MLS instrument. Nitric acid to ozone correlations also provides a useful diagnostic for the redistribution of nitric acid in the UT/LS region by cloud sedimentation processes. The first in situ measurements of nitric acid in the tropical tropopause during Aura validation campaigns revealed extremely low nitric acid mixing ratios (< 100 ppt) in this region. High-resolution in situ datasets continue to reveal information about the small-scale variability of nitric acid in the UT/LS that may not be available from remote instruments with large sampling volumes.

Wednesday, 3 October 2007

8:30 am
Validation of OMI Radiances in the Ultraviolet and Ozone Profiles with MLS Data

Xiong Liu (UMBC, xliu@umbc.edu), P. K. Bhartia, and K. Chance

Using zonal mean MLS data combined with climatological ozone profiles in the troposphere, we simulate normalized OMI radiances in the ultraviolet (270-355 nm) and compare simulations with observed OMI radiances in the tropics. The comparison discloses swath angle dependent biases (-2%-5%) in OMI radiances. We apply the swath angle dependent corrections to OMI UV-1 data (270-310 nm) and retrieve ozone profiles using the optimal estimation technique. The retrieved ozone profiles are validated against MLS data and OMI total ozone as a function of latitude during different time periods.

8:45 am
Comparison of NO2 in situ aircraft measurements with data from OMI

Eric Bucsela (UMBC/GEST/GSFC, bucsela@ix.netcom.com), A. E. Perring, R. C. Cohen, K. F. Boersma, E. A. Celarier, J. F. Gleason, M. O. Wenig, T. H. Bertram, P. J. Wooldrige, R. Dirksen, and J.P. Veefkind

We present an analysis of in situ NO2 measurements from aircraft experiments between summer 2004 and spring 2006. The data are from the INTEX-A, PAVE, and INTEX-B campaigns and constitute the most comprehensive set of tropospheric NO2 profiles to date. Profile shapes from INTEX-A and PAVE are found qualitatively similar to annual mean profiles from the GEOS-CHEM model. Using profiles from the INTEX-B campaign, we perform error-weighted linear regressions to compare OMI tropospheric NO2 columns with the integrated in situ columns. Results indicate that the OMI standard-product algorithm yields NO2 amounts lower than the in situ columns by a factor of 0.86(± 0.2). The correlation between the satellite and in situ data is good (r = 0.83). Using averaging kernels, the influence of the algorithm's a prior profiles on the satellite retrieval is explored. Results imply that air mass factors from the a priori profiles are, on average, larger than those from the measured profiles, but the differences are not significant.

9:00 am
Validation of MLS OH measurements with FTUVS total OH column measurements at Table Mountain, California

Shuhui Wang (Jet Propulsion Laboratory/Caltech, shuhui.wang@jpl.nasa.gov), S. Sander, H. M. Pickett, T. J. Pongetti, R. Cheung, Y. L. Yung, C. Shim, Q. Li, T. Canty, and R. J. Salawitch

As part of the Aura Validation Program, we have compared long-term ground-based measurements of the OH (hydroxyl radical) column abundance with OH profiles from the Microwave Limb Sounder (MLS). The column measurements were obtained using the Fourier Transform Ultraviolet Spectrometer (FTUVS) located at JPL's Table Mountain Facility (TMF) near Wrightwood, California. This is the first comparison of OH measurements from space- and ground-based instruments over seasonal and interannual time scales. The MLS OH densities over TMF are integrated vertically at altitudes with pressure of 21.5 hPa and below to derive partial OH column abundances for comparison with TMF OH column data. The missing OH in the lower stratosphere and the troposphere is estimated from GEOS-Chem monthly mean OH products, corrected for diurnal variation at Aura overpass times. Additional model calculations with hourly OH outputs during selected periods are also used in the analysis. Balloon and aircraft observations as well as the JPL 1-D photochemical model are employed to estimate the uncertainties in the extrapolated GEOS-Chem partial OH column. In general, the sum of the partial columns from MLS and GEOS-Chem agree with TMF total OH column abundance during 2004 – 2006, especially during summer and early fall when OH levels are high. In winter and early spring with low OH, the former is generally higher than the latter. The correlation of these two groups of data is studied based on least-square linear fits, seasonal T-tests, and contour mapping of the orthogonal chi square. Possible causes of the observed differences will be discussed.

9:15 AM
Direct sampling of tropospheric volcanic plumes in Ecuador and Colombia during TC4

Simon Carn (UMBC, scarn@umbc.edu), N. A. Krotkov, M. R. Schoeberl, P. Wennberg, J. E. Dibb, B. E. Anderson, G. Diskin, G. Sachse, S. A. Vay, K. Yang, A. J. Krueger, and S. Arellano

The NASA DC-8 aircraft intercepted tropospheric gas and aerosol plumes emanating from active volcanoes in Ecuador and Colombia during the Tropical Composition, Cloud and Climate Coupling (TC4) mission in July-August 2007. The emissions originated from Tungurahua volcano (Ecuador; alt. 5023 m), an open-vent system that has exhibited near-continuous unrest since 1999, and Nevado del Huila (Colombia; alt. 5365 m), a heavily glaciated volcano that reactivated in February 2007 after several centuries of dormancy. Elevated concentrations of SO2, sulfate and other species (CO, CO2) were measured by instrumentation aboard the aircraft in layers of probable volcanic origin at

altitudes of 3-6 km. Layers containing SO2 and sulfate detected at lower altitudes are assumed to originate from industrial pollution sources such as Guayaquil (southern Ecuador). In-situ sampling of volcanic plume constituents affords a rare opportunity to attempt validation of SO2 column amounts retrieved by the Ozone Monitoring Instrument (OMI) on the Aura satellite, and to investigate the chemistry of tropospheric volcanic plumes. We will report preliminary analysis of the data collected by the DC-8 and progress towards validation of correlative OMI SO2 measurements.

9:30 AM
Comparison of Airborne Sunphotometer and OMI Retrievals of Aerosol Optical Depth during MILAGRO/INTEX-B

John Livingston (SRI International/NASA Ames Research Center, jlivingston@mail.arc.nasa.gov), O. Torres, P. Russell, J. Redemann, R. Johnson, R. Bergstrom, B. Veihelmann, A. Smirnov, B. Holben, L. Remer, K. S. Schmidt, O. Coddington, and P. Pilewskie

In March 2006 the 14-channel Ames Airborne Tracking Sunphotometer (AATS) was operated on a Jetstream 31 (J31) aircraft based in Veracruz, Mexico during MILAGRO/INTEX-B (Megacity Initiative-Local And Global Research Observations / Phase B of the Intercontinental Chemical Transport Experiment). AATS measured total extinction aerosol optical depth (AOD) at 13 wavelengths (354-2139 nm) and water vapor column content in 13 flights that sampled clean and polluted airmasses over the Gulf of Mexico and Mexico City. Vertical differentiation of AOD and columnar water vapor data obtained during J31 vertical profiles yields vertical profiles of multiwavelength aerosol extinction and water vapor density, respectively. J31 flights were coordinated with overflights of several satellites, including Aqua, Aura, Terra, and Parasol, plus other aircraft, including the NASA DC-8 and King Air and the NCAR C-130. Data obtained by the Ozone Monitoring Instrument (OMI) aboard Aura are routinely inverted using two different inversion schemes, a near UV algorithm and a multiwavelength (MW) algorithm, to yield retrievals of AOD and absorption AOD (AAOD). We have identified four Aura overpasses for which OMI retrievals have been performed and AATS AOD spectra have been calculated at coincident or near-coincident times and locations. Three of these (March 3, 10 and 17) were over the Gulf of Mexico, and one (March 19) was over the Mexico City area. In this presentation we will compare the AATS and OMI AOD retrievals. For the 10 and 17 March comparisons, MODIS (aboard Aqua) AOD retrievals are available, and these agree well with the AATS AOD spectra. AOD values resulting from application of both the OMI UV and MW retrieval algorithms on 3, 10, and 17 March significantly overestimate the AATS and MODIS values. The suborbital data set for the 19 March comparison is particularly rich, including ground-based AERONET retrievals of aerosol properties from the T2 site NNE of Mexico City and the T0 site in the heart of the city, additional aerosol retrievals from radiometers on the J31, and lidar and in situ measurements from the DC-8. AERONET data at T0 yield AOD spectra that are consistent with AATS AOD spectra calculated

from measurements acquired ~450 m above the T0 site. OMI UV and MW AOD retrievals significantly exceed the AATS and AERONET values. However, when the comparison is performed in AAOD after conversion of AATS AOD to AAOD using realistic single scattering albedos obtained from other measurements during previous field campaigns, the OMI UV AAOD retrievals (which are less sensitive to surface albedo uncertainties than the OMI MW retrievals) agree well with the corresponding AATS values. We intend to examine possible reasons for these observed differences and explore plausible approaches to bring the retrievals into agreement. In particular we will explore using different assumptions about the nature of the absorbing particles.

9:45 am
Comparison of Aura HIRDLS and Envisat MIPAS Measurements - Case study.

Christopher Hepplewhite (University of Oxford, c.hepplewhite1@physics.ox.ac.uk), C. Waymark, J. Barnett, A. Dudhia, A. Waterfall, J. Gille, R. Khosravi, B. Nardi, D. Kinnison, et al.

The MIPAS instrument aboard the European Environmental Satellite (ENVISAT) provides an ideal data set against which to validate HIRDLS products. The ENVISAT orbit is sun-synchronous with mean local solar time 10:00 AM, with 98.5 deg inclination, the MIPAS instrument scans the limb of the atmosphere from about 5 to 150 km altitude with a 3km vertical X 30 km horizontal resolution. Standard geophysical products are available from ESA and also generated at Oxford University. A variety of different validation strategies are available, including comparison of radiant flux and of mixing ratios of gaseous species, using local and nearest coincident profiles or from long period zonal average analyses. In this paper a comparison is made with some of the product species selected from Temperature, H2O, O3, HNO3, CH4, N2O, NO2, N2O5 and ClONO2 for closest coincident profiles using the latest version 2.04.08 HIRDLS data.

10:30 am
Balloon Borne Cryogenic Frostpoint Hygrometer Measurements in Support of Aura Water Vapor Validation

Holger Vömel (CIRES/U Colorado, Holger.Voemel@colorado.edu), J. E. Barnes, R. N. Forno, M. Fujiwara, F. Hasebe, S. Iwasaki, R.Kivi, N. Komala, E. Kyrö, T. Leblanc, B. Morel, S.-Y. Ogino, W. G. Read, S. C. Ryan, S. Saraspriya, H. Selkirk, M. Shiotani, J. Valverde Canossa, and D. N. Whiteman

Here we present an update on the extensive observations of stratospheric and upper tropospheric water vapor using the balloon borne Cryogenic Frostpoint Hygrometer (CFH) in support of the Aura Microwave Limb Sounder (MLS) satellite instrument. CFH soundings during TCSP, CR-AVE, TC4, WAVES, MOHAVE, SOWER, and at a number of other locations provide a sufficient number of AURA/MLS coincident observations, which allow a statistically significant validation of MLS version 2.2 retrieved water vapor

in the upper troposphere and lower stratosphere. In the stratosphere at pressures between 68 hPa and 21.5 hPa MLS v2.2 and CFH agree on average to within 2.7% ± 8.7%, which is comparable to version 1.5. In the vicinity of the tropical tropopause the average difference is -1.0% ± 9.7% and 3.6% ± 12.7% at 100 hPa and 82.5 hPa respectively. Despite the increase in vertical gridding compared to version 1.5, the variability of the difference using version 2.2 is smaller. The agreement between stratospheric observations by MLS version 2.2 and CFH is comparable to the agreement using MLS version 1.5. The variability in the difference between observations by MLS version 2.2 and CFH at tropospheric levels is significantly reduced, but a tropospheric dry bias and a reduced sensitivity remain in this version. In the validation data set a dry bias at 177.8 hPa of -24.1% ± 16.0% is statistically significant. We will also present an update on the intercomparison of various water vapor sensors in the upper troposphere and lower stratosphere.

10:45 am
North American Tropospheric Ozone Profiles from IONS (INTEX Ozonesonde Network Study, 2004, 2006): Aura Applications and Statistics for Pollution Comparisons

Anne M. Thompson (Penn State, anne@met.psu.edu), J. C. Witte, S. K. Miller, J. E. Yorks, K. M. Dougherty, S. J. Oltmans, O. R. Cooper, E. Joseph, J. T. Merrill, G. A. Morris, M. J. Newchurch, M. Dubey, F. J. Schmidlin, D. W. Tarasick, G. Forbes, B. Rappenglueck, B. Lefer, D. Baumgardner, R. B. Chatfield, R. B. Pierce, and M. R. Schoeberl

The recent deployment of strategically designed and launch-coordinated ozonesonde networks during Aura has transformed our capabilities for: [a] validation and intercomparison of satellite ozone products; [b] evaluation of models and assimilation mapping of global ozone; [c] sampling the UT/LS (upper troposphere-lower stratosphere) with consistent temporal and vertical resolution; [d] determination of dynamical and chemical processes affecting ozone throughout the troposphere. One example is the SHADOZ (Southern Hemisphere Additional Ozonesondes) tropical network <http://croc.gsfc.nasa.gov/shadoz>, operating since 1998 [Thompson et al., 2003]. The campaign-based IONS (INTEX [Intercontinental Transport Experiment] Ozonesonde Network Study) networks over North America in July-August 2004 and March-August 2006, <http://croc.gsfc.nasa.gov/ intexb/ions06.html>, targeted Aura validation. An overview of IONS-06 tropospheric ozone as applied to satellite, assimilation and models will be given. Selected discoveries from the 2004 and 2006 IONS soundings are described. IONS-04 provided ~300 O3 profiles from eleven North American sites and the R/V R H Brown in the Gulf of Maine. With July-August 2004 dominated by low-pressure conditions over northeastern North America (NENA), UT ozone consisted of approximately 25% stratospheric O3 [Thompson et al., 2007a,b] interleaved with O3 from aged or relatively fresh pollution and lightning [Cooper et al., 2006; Morris et al., 2006]. IONS-06 covered boreal spring and summer, with a greater range (the eleven 2004 sites plus a dozen in California, New Mexico, Mexico City, Barbados and southwestern

Canada). Tropospheric pollution statistics and contrasts in UT/LS O3 between 2004 and 2006 guide retrievals for various Aura retrievals. Both IONS periods displayed a persistent UT ozone maximum [Cooper et al., 2007] over the summertime south central US. March 2006 IONS sondes over Mexico manifested persistent UT/LS gravity wave influence and more sporadic pollution.

11:00 am
HIRDLS Observations of Strat-Trop Exchange in Thin Laminae in the Sub-Tropical Jet Region

John Gille (U. of Colorado and NCAR, gille@ucar.edu), V. Yudin, B. Nardi, T. Phillips, J. Barnett, R. Khosravi, C. Cavanaugh, C. Craig, T. Eden, D. Ellis, C. Halvorson, C. Hepplewhite, and D. Kinnison

HIRDLS data (version 2.04.08) show atmospheric structures in the mid-latitude UT/LS region in which thin layers of low-latitude air having a low ozone mixing ratio move pole-ward during northern hemisphere winter, and simultaneously layers of mid-latitude air with higher ozone amounts move equator-ward beneath them. This was observed during the time of a sudden stratospheric warming. Here we have extended this study to evaluate the frequency of such events as a function of time. We have particularly looked at the prevalence of these structures at the end of the northern hemisphere winter, when more frequent tropopause folds have been observed. Comparison to the overall dynamical situation shown by the GEOS-5.01 data reveals certain conditions in which these flows occur. Finally, the relationship of these structures to double tropopauses and the sub-tropical jet are examined.

11:15 am
Variations in Stratospheric Cly Between 1991 and the present

David Lary (UMBC/GEST NASA/GSFC, David.Lary@umbc.edu), A. Douglass, D. Waugh, R. Stolarski, P. Newman, and H. Mussa

A consistent time series of stratospheric inorganic chlorine Cly from 1991 to present is formed using space-borne observations together with neural networks. A neural network is first used to account for inter-instrument biases in HCl observations. A second neural network is used to learn the abundance of Cly as a function of HCl and methane, and to form a time series using available HCl and methane measurements. The estimates of Cly are broadly consistent with calculations based on tracer fractional releases and previous estimates of stratospheric age of air. These new estimates of Cly provide a critical test for current global models that predict significant differences in Cly and ozone recovery.

11:30 am
Studying the subvortex in the lowermost stratosphere using new trace gas measurements from Aura MLS

Michelle Santee (Jet Propulsion Laboratory, mls@mls.jpl.nasa.gov) and G. Manney

The Aura Microwave Limb Sounder (MLS) provides daily global profiles of several key species that are useful for studying the extratropical upper troposphere / lower stratosphere (UT/LS). In addition to CO, O3, and H2O, recently-released MLS version 2.2 (v2.2) data processing algorithms are now producing the first daily global measurements of HNO3 in the UT/LS. We will use v2.2 MLS data to explore chemical processing in and dispersal of chemically processed air from the "subvortex" (the portion of the polar vortex at levels where lower latitudes are in the troposphere) in the spring, including mixing in the lowermost stratosphere in the region between the subvortex and tropopause transport barriers, as well as possible transport of processed air into the troposphere. The seasonal evolution of and interannual and interhemispheric variability in trace gases in the lowermost stratosphere in MLS data will be described.

11:45 am
Stratospheric Ozone: Depletion and Recovery

Ross Salawitch (University of Maryland, rjs@atmos.umd.edu), E.-S. Yang, M. J. Newchurch, and D. M. Cunnold

We examine monthly mean time series of halogen and aerosol loading, ozone column, ozone profiles, temperature, and various chemical constituents measured by a suite of instruments onboard the UARS and Aura satellites. We will present quantitative analysis of the factors responsible for the recent rise in upper stratospheric and total column ozone in extra-polar regions, and for recent fluctuations in the depth of the Antarctic ozone hole. We will discuss the results of our model simulations and statistical analyses in the context of long-term depletion of the ozone layer and possible, recent "first stage of recovery" facilitated by the slight decline in stratospheric halogen loading.

1:45 pm
Temporal variability and wave activity from the tropical tropopause layer to 33 km: Radiosonde observations from Ticosonde/TC4, June-August 2007

Henry Selkirk (BAER Institute and NASA-Ames Research Center, hselkirk@mail.arc.nasa.gov), L. Pfister, H. Vömel, G. Peng, W. Stolz, V. Hernández and staff of the Instituto Meteorológico Nacional, W. Fernández, J. Amador, J. Andrés Diaz, K. Heinrich and students of the University of Costa Rica

During the recently-completed Ticosonde/TC4 radiosonde campaign at Juan Santamaria International Airport in Alajuela, Costa Rice [10.0°N, 84.2°W] Vaisala RS92 radiosondes

were launched twice daily at 00 and 12 UT from June 16 through 30 and then four times daily at 00, 06, 12 and 18 UT between July 1 and August 15. This was the fourth year of soundings during the Costa Rican wet season, and here we will compare this year's observations with those going back to 2004, with a particular focus on variability in the tropical tropopause layer. One notable feature of the observations in this campaign is the median altitude achieved by the soundings – nearly 33 km or ~8 hPa. This permits an examination of the time variability of the middle stratospheric easterly wind maximum which exceeded 50 m/s on numerous occasions. It also affords diagnosis of the fine structure of the wind and temperature profiles well into the middle stratosphere over the two-month period of observations. As in previous campaigns, there is a rich spectrum of high-amplitude wave features or laminations in the tropopause layer and into the lower stratosphere. We also observed on occasion significant wave-like features in the temperatures close to the middle stratospheric wind maximum.

2:00 pm
Impact of Recent Laboratory Measurements of the ClOOCl Absorption Cross Section On Our Understanding of Polar Ozone Chemistry

Tim Canty (University of Maryland, tcanty@atmos.umd.edu), M. Rex, R. Salawitch, R. Schofield, R. Stimpfle, F. Stroh, M. von Hobe, and D. Wilmouth

The photolysis of ClOOCl is crucial in determining the rate of polar ozone loss due to the ClO+ClO cycle. New laboratory measurements of the ClOOCl cross section suggest that its photolysis is about a factor of six slower than a value based on current recommendations. We show the incorporation of these new cross sections into a photochemical model leads to poor agreement with values of ClO and ClOOCl measured during the SOLVE and VINTERSOL campaigns. For both campaigns the model under-estimates measured ClO and over-estimates measured ClOOCl by amounts that are much larger than the measurement uncertainties. We also examine implications of the new ClOOCl cross section measurement on the chlorine budget, using observations of ClO and HCl from Aura MLS and ClNO3 from ACE. These comparisons indicate that a model using the new cross section, and no other changes, provides a poor description of the chlorine photochemistry. Such a simulation also results in much slower ozone loss rates compared to a model using standard chemistry. We use the various data sets to test a variety of processes that could be invoked to resolve these discrepancies. Implications of proposed new chemical mechanisms for ozone loss rates are also discussed.

2:15 pm
Tracer Correlations In the Tropopause Region Over the Pacific During INTEX-B: Statistical Comparisons of MLS and In Situ Tracer Measurement Distributions at 215 hPa

Melody Avery (NASA, melody.a.avery@nasa.gov), D. Fairlie, N. Livesey, G. Diskin, G. Sachse, M. Rano, and G. Lingenfelser

Exchange of trace gases and energy across the tropopause impacts composition and air quality in the troposphere, and pollution can ultimately impact the chemistry of the lowermost stratosphere. Accurate characterization of the magnitude and mechanisms of this exchange is fundamental to assessment of the impact of natural and anthropogenic changes to the atmosphere, and has been a central question in atmospheric science for more than fifty years. Further, the impact that greenhouse gases (like ozone) have on climate are the most uncertain near the tropopause (2007 IPCC report). However because it is a transition zone, the near-tropopause region is challenging to characterize accurately using available measurement or modeling techniques. Satellite observations provide continuous, global measurements, but are challenged to resolve the tropopause vertically. In contrast, high-resolution in situ data are severely limited spatially and temporally, since they represent a one-dimensional path through a four-dimensional sampling space, so it is difficult to build a representative ensemble of measurements for analysis and calculation of exchange budgets. We hypothesize that given a large enough ensemble of measurements, the satellite and in situ measurements ought to have similar statistical distributions if they are sampling the same dynamically distinct regions of the atmosphere. For this project we compare the statistical distributions of tracer correlation ratios measured by the MLS instrument at the 215 hPa retrieval level with DC-8 FASTOZ and DACOM measurements from the NASA DC-8. To increase the measurement ensemble size, and to reduce the likelihood of ambiguity in coincidence criteria, we compare distributions based on all the available data over the INTEX-B time period and over the geographical region that was sampled during the mission. So, the domain is April 17 – May 15 of 2006, 8-65 N, 180-265 E and from 170-250 hPa. The averaging length of the aircraft data is also varied to test the effect of horizontal resolution on lower stratospheric and pollution modes. Tracer correlations are sampled and compared, since the correlations are less sensitive than the individual species measurements to instrument noise and biases. The ozone – carbon monoxide system is studied intensively because there is a large amount of high-precision data available, and chemical lifetimes are much longer than mixing lifetimes for both species in the Upper Troposphere. The aircraft measurements may be able to provide an uncertainty or variance estimate that complements combined model and satellite strat-trop exchange calculations.

2:30 pm
Gravity Waves and Equatorial Waves Observed by HIRDLS

M. Joan Alexander (NWRA/CoRA, alexand@cora.nwra.com), A. Grimsdell, D. Ortland, J. Gille, C. Cavanaugh, M. Coffey, C. Craig, V. Dean, T. Eden, G. Francis, C. Halvorson, J. Hannigan, R. Khosravi, D. Kinnison, H. Lee, S. Massie, B. Nardi, J. Barnett, C. Hepplewhite, and A. Lambert

The High Resolution Dynamic Limb Sounder (HIRDLS) observes atmospheric temperature profiles at high horizontal and vertical resolution. We perform wavelet and Fourier analyses on HIRDLS measurements to derive global properties of atmospheric waves on a daily basis. Waves of all scales are collectively responsible for driving global-scale winds that affect weather and climate. Understanding these wind effects demands measures of wave momentum fluxes, which can be estimated from observations like HIRDLS with very high horizontal and vertical resolution. Using wavelet analysis we produce daily global maps of gravity wave momentum flux that identify the locations and sources of intermittent gravity wave events. The analysis identifies waves in adjacent HIRDLS temperature profiles, and estimates the temperature amplitude and horizontal and vertical wavelengths for each profile pair. From these results, global momentum fluxes are estimated, and individual wave events are examined in more detail. We also apply space-time Fourier analysis techniques developed for asynoptically sampled satellite observations to derive the properties of equatorial waves, and investigate their forcing by tropical convection. The results provide constraints for both resolved equatorial waves in data assimilation products like GEOS-5 and for parameterizations of unresolved gravity wave mean-flow forcing effects applied in most global models.

Thursday, 4 October 2007

8:30 am
TES Observations of Tropospheric Ozone as a Greenhouse Gas

Helen Worden (NCAR/JPL, HMW@ucar.edu), K. Bowman, J. Worden, and A. Eldering

We present satellite observations of the radiative forcing from tropospheric ozone, for cloud free ocean conditions. This analysis uses infrared (IR) radiance spectra, integrated over the 9.6 micron ozone band between 985 to 1080 cm-1, and ozone profile retrievals from the Tropospheric Emission Spectrometer (TES) on EOS-Aura. We examine the relationship between the outgoing longwave radiation (OLR) in the 9.6 micron band to upper tropospheric ozone and water vapor by separating the data into hemispherical and sea-surface temperature (SST) ranges. For 2006 data, we estimate an annual average radiative forcing for upper tropospheric ozone of 0.48 ± 0.13 W/m2 with a standard deviation of 0.24 W/m2 for the latitude range between 45°S to 45°N. This estimate includes natural and anthropogenic ozone sources and is higher than the 2007 IPCC average of 0.35 W/m2 for climate model estimates of anthropogenic tropospheric ozone forcing. We also observe that water vapor dominates the clear-sky ocean variability of the outgoing IR radiation in the 9.6 micron ozone band for SSTs higher than 299 K, consistent with the “super greenhouse effect”.

8:45 am
PDFs of Upper Tropospheric Humidity: Measurements and Theory.

Darryn Waugh (Johns Hopkins University, waugh@jhu.edu) J.-M. Ryoo, and T. Igusa

The Earth's climate is particularly sensitive to the water vapor content of the upper troposphere, and it is important to know the distributions of water vapor in this region as well the processes that determine these distributions. Here, we examine the probability distribution functions (PDFs) of Aura MLS measurements of upper tropospheric relative humidity (RH), for different regions and seasons. The PDFs from Aura MLS are also compared with those from Aqua AIRS and UARS MLS measurements, as well as with theoretical distributions. Several robust features are found in the observed PDFs. In particular, the observed PDFs from all three data-sets can be well fit by a generalized version of the Sherwood et al. (2006) theoretical model. There are consistent spatial variations in the key model parameter, which is ratio of drying and moistening times, that can be related to variations in the physical processes controlling the RH distributions.

9:00 am
The effects of convective ice lofting on H2O and HDO in the tropical tropopause layer (TTL)

Andrew Dessler (Texas A&M, adessler@tamu.edu), T. F. Hanisco, and S. Fueglistaler

We have derived a climatology of TTL-penetrating convective events from measurements of Ice-water content (IWC) from the Microwave Limb Sounder onboard NASA's Aura spacecraft. Using this climatology, we have added convective ice lofting to a Lagrangian trajectory model of TTL water vapor (H2O) and its stable isotopologue, HDO. The Lagrangian model has been previously shown to accurately simulate H2O in the TTL and lower stratosphere. We show here that the model without convective lofting does a poor job reproducing the observed HDO depletion (dD) in the TTL. When convective ice lofting to altitudes below the cold point (the point where air experiences its lowest H2O saturation mixing ratio) is added to the model, there is little change in H2O in the lower stratosphere, but a large change in dD throughout the TTL that brings the model into better agreement with measurements. Thus, convective ice lofting has the capacity to improve the model's dD simulation while not significantly degrading the agreement between simulated and measured H2O. Convective ice lofting to altitudes above the cold point, on the other hand, has a large effect on lower stratospheric H2O, suggesting that changes in convection reaching these altitudes could drive changes in lower stratospheric H2O. This suggests a mechanism by which lower stratospheric H2O trends may be at least partially decoupled from tropopause temperature trends. Such a disconnection was suggested by previous observations of simultaneously increasing stratospheric H2O and a cooling tropical tropopause.

9:15 am
Results from Aura MLS and the in situ hygrometers during the Costa Rica AVE campaign on the annual cycles of tropical UTLS H2O and CO.

William Read (Jet Propulsion Laboratory, bill@mls.jpl.nasa.gov), A. Lambert, H. Su, J. H. Jiang, D. L. Wu, and N. J. Livesey

The MLS instrument on board the Aura satellite launched on 15 July 2004 is providing daily near H2O and CO profile data in the upper troposphere and lower stratosphere (UTLS). H2O measurements from the 2006 Costa Rica AVE campaign and the cryogenic frost point hygrometer are compared to MLS. Tropical tape recorder signatures are present in both CO and H2O. The H2O tape recorder signature is the imprint of the annual cycle in the tropical tropopause temperature. The CO tape recorder is the imprint of biomass burning events brought up to the UTLS by tropical deep convection. The CO and H2O measurements can be used to understand the roles of convection and in situ

freeze-drying processes in the tropical tropopause layer. The MLS CO and H2O from MLS and the in situ hygrometers are compared to results from a convective cold trap model.

9:30 am
Optical effects of clouds on trace gas absorption

Joanna Joiner (NASA/GSFC, Joanna.Joiner@nasa.gov), A., P. K. Bhartia, R. Spurr, and P. Levelt

Clouds may be considered a nuisance for some remote sensing applications. However, in the visible (VIS) and ultraviolet (UV), their effects can be accounted for to first order with relatively simple models. Therefore, information about trace gases can be accurately retrieved in their presence. For example, the so-called cloud-slicing method has been used to derive tropospheric ozone mixing ratios from both the Total Ozone Mapping Spectrometer (TOMS) and OMI. Such approaches are relatively new and can be improved upon by more fully utilizing the information contained in OMI spectral measurements. These techniques are based on the concepts of optical cloud pressure and fraction. Optical cloud pressures can be derived using scattered sunlight from the near infrared to the ultraviolet. Two approaches have been implemented with OMI. These are based on 1) rotational-Raman scattering in the UV, and 2) O2-O2 absorption in the visible. The oxygen A-band approach has been used with GOME and SCIAMACHY and will be used on the Orbiting Carbon Observatory (OCO). Many studies have shown significant differences between these cloud pressures and those derived from the thermal IR. It was hypothesized that these differences were due in part to inadequate cloud models and/or radiative transfer. In the past year, Cloudsat has provided new insights into these differences. We now understand that optical (UV/VIS) approaches provide different pieces of information from those based on thermal IR measurements; Infrared retrievals are sensitive primarily to the physical cloud-top pressure. Based on Cloudsat/MODIS observations, we show how the optical techniques respond to various complex cloud scenarios, such as multiple cloud decks and deep convective clouds. We also show why optical cloud pressures and fractions are important for trace-gas retrievals that use similar spectral regions.

9:45 am
Global Distribution of Absorbing Aerosols as seen by OMI

Omar Torres (JCET, University of Maryland, Baltimore County, torres@qhearts.gsfc.nasa.gov), P. K. Bhartia, and C. Ahn

The capability of observing absorbing aerosols on a global basis is a unique advantage of the OMI sensor. Traditional space-borne measurements in the visible and near IR are sensitive to aerosol scattering effects but largely insensitive to particle absorption. Because the OMI aerosol detection technique takes advantage of radiative transfer

properties unique to the near UV region, OMI aerosol observations are a very important contribution towards the quantification of the role of aerosol absorption in the global radiative energy balance. In this presentation we will discuss the three-year record of OMI aerosol absorption observations in terms of the Aerosol Index as well as aerosol absorption optical depth, and single scattering albedo. We will discuss the observed annual cycle of the occurrence of absorbing aerosols. We will also illustrate the occurrence of special aerosol events captured by OMI during the first three years of operation of this AURA sensor.

10:30 am
HIRDLS Observations of Subvisible Cirrus

Steven Massie (NCAR, massie@ucar.edu), J. Gille, J. Barnett, R. Koshravi, and C. Craig

HIRDLS radiance and preliminary extinction profiles are analyzed to locate cirrus layers in the upper troposphere. The cirrus layers are of interest because they are associated with microphysical processes that dehydrate the upper troposphere / lower stratosphere. We use HIRDLS observations to calculate the seasonal variations and latitude-longitude distributions of the cirrus layers. The HIRDLS observations are compared to those determined from analyses of CALIPSO lidar observations. Both experiments indicate that cirrus layers are most prevalent in the winter season (December – February) away from the Maritime continent.

10:45 am
Aerosol Properties from OMI Measurements: Potential of the Multi-wavelength Algorithm

Ben Veihelmann (KNMI, veihelma@knmi.nl), J. P. Veefkind, R. Braak, P. F. Levelt, and J. F. de Haan Royal

The Ozone Monitoring Instrument (OMI) is an imaging UV-VIS solar backscatter spectrometer providing global coverage with high spatial resolution (13 km x 24 km at nadir). It is a Dutch-Finnish instrument onboard the NASA satellite EOS-Aura which has been launched in July 2004. In this contribution we discuss the potential of OMI measurements for characterizing atmospheric aerosol using the multi-wavelength algorithm. We focus on ongoing and future studies using OMI data alone as well as OMI data in combination with models or other satellite data.

11:00 am
Evaluation of the global hydrologic cycle with HDO measurements from TES

David Noone (University of Colorado, dcn@colorado.edu), D. Brown, J. Worden, and K. Bowman

While much is known about the global hydrologic cycle, there remains much uncertainty which ultimately confounds global prediction of water resource availability and climate. Since the isotopic composition of atmospheric water vapor gives insight into the processes controlling the atmospheric hydrologic cycle, water isotope measurements provide a unique opportunity to quantify the movement of water in the climate system and evaluate the importance of mechanisms responsible. We use estimates of the HDO to H2O ratio from the Tropospheric Emission Spectrometer on Aura to characterize the difference between the hydrologic regimes over tropical continents. Specifically we examine the Amazon, Northern Australia and the South East Asian Monsoon region. While these areas are climatically similar in a number of respects, they show remarkable differences in the balance between the supply of water by advection, local surface exchange and condensation. The role of convection is found to act both as a strong water source, through the influence of detrainment in the mid-troposphere, and as a sink, due to the importance of condensation. At each location, analysis of the TES HDO data show that the balance of local versus remote sources is different from season to season, and within each season, which is due in part to change in the hydrologic state upstream. At local scales, transpiration and exchange with surface waters and the evaporation of falling rain is found to be important. In the case of the dry seasons, large-scale subsidence is highlighted in seasonal differences and is particularly pronounced over Northern Australia and in the region of the topographic forcing of Tibet in the Southeast Asian Monsoon region. The linkage to large-scale subsidence is particularly important since it in part controls the humidity of the subtropics, which in turn is an important control on the radiative cooling of the planet. To this end, the isotopic measurements allow the details of transport of atmospheric constituents to provide a better understanding of the processes which control climate.

11:15 am
The effect of convection on the composition of the upper tropical troposphere as seen by MLS

Leonhard Pfister (NASA/Ames Research Center, lpfister@mail.arc.nasa.gov)

The composition of the upper tropical troposphere (UTT) contributes to global change through the impact of ozone and water vapor on outgoing longwave radiation. Convective injection and mixing is a primary contributor to UTT composition, yet fundamental parameters, such as convective turnover time, are poorly known. Global dynamical models have substantial difficulty in simulating convection. This, along with

the (until recently) lack of observational constraints on UTT composition, means that we lack a quantitative understanding of the effect of convection on this important region. Observations of CO, ozone, and water vapor made by the Microwave Limb Sounder aboard NASA's Aura satellite remedy the lack of observational constraints. This paper compares 147 mb MLS CO and water vapor measurements with distributions of convective influence as calculated using meteorological satellite imagery. The approach is to calculate clusters of back trajectories from the air volumes measured by MLS and monitor their intersection with regions of cold cloud tops as determined by the imagery. CO is then evaluated by mixing MLS observations and model-predicted boundary layer values at the location and time of the convection. Water is determined by simply saturating the convectively influenced parcels. Initial comparisons focus on the following questions: (1) How good are the convective influence calculations in comparison with the data, and what is the sensitivity to various parameters (e.g. clear sky heating rates, proportion of boundary layer air in a convective anvil)?; (2) How recently has a typical air parcel in the tropical 147 mb region been affected by convection?; and (3) Which convective systems in which regions are most important in driving the 147 mb CO and water vapor distributions? Preliminary results indicate rapid (order of 1 week or less) times to most recent convection at 147 mb, with a very strong correspondence between convective influence and CO. This correspondence occurs even if low level CO values are not substantially enhanced by pollution or biomass burning.

11:30 am
Near-real time OMI NO2 and the assimilation of satellite data with regional-scale air quality models for the Netherlands and Europe

Henk Eskes (KNMI, eskes@knmi.nl), R. Dirksen, P. Veefkind, R. van der A, S. Jongen, and P. Levelt

OMI is providing a unique data set on tropospheric NO2 with it's small ground pixels and daily coverage. In Europe there are several initiatives to use the OMI NO2 for model validation and for data assimilation. In our contribution we will describe the first results of these activities. The “regional air quality” subproject of the European GEMS project (coordinated by ECMWF) is developing an ensemble forecast of air quality in Europe. This ensemble is based on the forecasts of 11 regional scale air pollution models. Data assimilation approaches are being developed within GEMS to exploit the available surface and satellite measurements. The Dutch “SmogProg” project is developing an air quality analysis and forecasting system. One central focus of this project is the assimilation of OMI NO2 measurements.

11:45 am
Global Ozone Determined from Assimilation of OMI and MLS Retrievals

Steven Pawson (NASA/GSFC, Steven.Pawson-1@nasa.gov), I. Stajner, K. Wargan, and M. Sienkiewicz

This paper will discuss aspects of the time-dependent, three-dimensional, global ozone distribution deduced from EOS-Aura observations. Ozone concentrations produced by assimilating OMI total columns and MLS profiles into global atmospheric models will be discussed. Our previous work has examined ozone assimilated into the GEOS-4 system, in which ozone is treated separately from the meteorological fields (winds, temperature, moisture and surface pressure). Ongoing efforts involve coupling MLS and OMI ozone into GEOS-5, where it is assimilated alongside the traditional meteorological variables. In GEOS-5, ozone impacts the meteorological analyses (and forecasts) through its impacts on infrared radiances as well as through its impact on radiative heating rates in the general circulation model. This study will discuss the quality of the ozone analyses in the UTLS, comparing the GEOS-4 and GEOS-5 analyses. If results are available, it will examine impacts of a "fast retrieval" of MLS ozone compared to the standard products, which forms part of a feasibility study for a near-real-time product. Finally, impacts of Aura ozone on the performance of GEOS-5 will be examined: while there is apparently little improvement in five-day forecast skill in the middle troposphere, there are impacts on the structure of the UTLS region that will be discussed.

12:00 pm
Assessment of GEOS-Chem and GFDL AM2 models with assimilated TES observations: Implications for North American tropospheric ozone

Kevin Bowman (Jet Propulsion Laboratory, Kevin.W.Bowman@jpl.nasa.gov), M. Parrington, D. Jones, L. Horowitz and A. M. Thompson

TES observations of ozone and CO are assimilated into the GFDL AM2 and GEOS-Chem chemistry and transport models from July 1st to August 31st, 2006 based on a sub-optimal Kalman filter. Comparisons of assimilated ozone fields with the IONS ozone sondes taken over the same period show reductions in the mean bias with AM2 and GEOS-Chem to 10% and 5% respectively in the mid-troposphere. Moreover, mean differences between AM2 and GEOS-Chem ozone are reduced to less than a 1 ppb. The residual differences between the IONS dataset and the models are used to assess the variability of ozone in North America and have the potential to improve our understanding of the dominant processes controlling that variability.

1:30 pm
An overview of trace gas retrievals from AIRS

Fredrick W. Irion (Jet Propulsion Laboratory/CalTech, bill.irion@jpl.nasa.gov), M. Chahine, G. Osterman, W. McMillan and C. Barnet

The Atmospheric Infrared Sounder (AIRS) currently on the EOS-Aqua platform globally retrieves profile information of several trace and minor gases from nadir viewing of IR emittance. We present results on ozone, carbon monoxide, methane and carbon dioxide and compare our results with near coincident measurements from the Tropospheric Emission Spectrometer.

1:45 pm
Towards understanding the impact of TTL cirrus clouds on troposphere-to-stratosphere transport

Hui Su (Jet Propulsion Laboratory, hui.su@jpl.nasa.gov), Xi. Huang, J. Jiang, and K. R. Minschwaner

Although it is well accepted that air enters stratosphere through the tropical tropopause by large-scale upwelling, the detailed mechanisms of troposphere-to-stratosphere transport (TST) remain unclear. Recently, Corti et al. postulated that the radiative heating effect of cirrus clouds in the tropical tropopause layer (TTL) can be an important factor in affecting the rate of TST. Their results were confined to a one-dimensional view which may arguably apply to only tropical-mean conditions. To examine the validity of this postulation in the real atmosphere, we use new observations of TTL cirrus acquired from Aura MLS and CALIPSO, along with trajectory analyses, to examine the impact of cirrus on TST when horizontal displacements of air parcels and spatial and temporal variations of cirrus distributions are taken into account. The trajectories of air parcels are sorted according to the cirrus cloud occurrence frequency and a set of cloud-influenced TST pathways will be identified. Our preliminary analysis shows that the radiative heating associated with cirrus can contribute to a faster ascent of air from the troposphere to stratosphere, and that the spatial and temporal variations of cirrus impacts are significant.

2:00 pm
A-Train Tropospheric Chemistry Observations on 30 August 2006 over the 2006 TexAQS/GoMACCS Study Area

Wallace McMillan (UMBC, mcmillan@umbc.edu), G. Osterman, K. Evans, R. Hoff, F. W. Irion, N. Livesay, K. Pickering, L. Sparling, D. Wicks, and L. Yurganov

During the 2006 Texas Air Quality Study (TexAQS)/Gulf of Mexico Atmospheric Composition and Climate Study (GoMACCS), AIRS and TES Science Team members provided flight planning support for NASA and NOAA aircraft, large scale context for

NOAA, EPA, and State of Texas surface measurements, and contributions to post-mission modeling analyses and the Rapid Science Synthesis (RSS) Report. We present results from our ongoing integrated analysis using a number of A-Train observations to investigate tropospheric chemistry and dynamics over the 2006 TexAQS/GoMACCS study area (Texas, surrounding states, the Gulf of Mexico, and bordering countries). Focusing on one pollution event over Houston, Texas on August 30-Sept 1, AIRS and TES retrievals of tropospheric CO indicate distant biomass burning contributed to poor air quality in Houston. Closer examination of AIRS and TES tropospheric ozone retrievals reveals additional features due to surface pollution, lightning, and stratospheric intrusions. As part of the integrated analysis, AIRS' wide swath provides context for TES' higher vertical resolution retrievals of CO and O3. Integrating MODIS, OMI, MLS, CALIPSO observations and in situ measurements into our analysis yields a more complete and complementary view of tropospheric processes.

2:15 pm
Convective transport of surface pollution: New observations from the "A-Train" satellites

Jonathan Jiang (Jet Propulsion Laboratory, jonathan@mls2004.jpl.nasa.gov), H. Su, M. Schoeberl, S. Massie, R. Fuller, P. Colarco and N. Livesey

Global cloud, aerosol, and CO observations from CloudSat, Calipso, Aura MLS, and other "A-Train" satellites are explored to investigate how boundary layer pollution is transported vertically and globally in the upper troposphere, and how they may affect global air quality and climate. Two methods are applied: "track approach" and "gridded approach". In the track approach, we analyze the data along the A-Train tracks to study near-simultaneous measurements of clouds and pollutants (CO and aerosol). It provides information about convection and how they connect upper tropospheric pollutants to surface emission sources. In the gridded approach, we focus on studying the bulk properties of convection and pollution averaged over certain space and time, and compare the observations with model climatology. This approach can be used to identify different regimes for upper troposphere CO/aerosol variations and factors that control them. It can also used to evaluate the model performance.

2:45 pm
Ground-level nitrogen dioxide concentrations inferred from OMI

Randell Martin (Dalhousie University, randall.martin@dal.ca), L. N. Lamsal, M. Steinbacher, E. A. Celarier, E. Bucsela, E. J. Dunlea, and J. Pinto

We infer ground-level nitrogen dioxide (NO2) concentrations from OMI tropospheric NO2 columns by applying local scaling factors from a global three-dimensional model (GEOS-Chem). The OMI-derived surface NO2 mixing ratios are compared with in situ surface NO2 measurements from the U.S. Environmental Protection Agency's Air Quality System (AQS) and Environment Canada's National Air Pollution Surveillance

(NAPS) network for 2005. The ground-based NO2 measurements use a molybdenum converter that has significant interference from other reactive nitrogen species (e.g. nitric acid, peroxyacetyl nitrate, alkyl nitrates). Laboratory and field measurements of specifically NO2 and of reactive nitrogen are used to develop and test a correction algorithm for the interference. The overall agreement between the OMI-derived surface NO2 and the corrected in situ measurements is within 21–48%. A larger difference in winter/fall than in spring/summer may indicate a seasonal bias in the OMI NO2 retrieval. The correlation between OMI and the ground-based measurements is significant (correlation coefficient up to 0.8) with a tendency for higher correlation in polluted areas. The satellite derived data base of ground-level NO2 concentration should be valuable to epidemiological studies and the development of air quality control strategies.

3:30 pm
Recent increases in Asian emissions and consequences for transpacific ozone pollution in the United States: Aura and INTEX-B observations

Lin Zhang (Harvard University, linzhang@fas.harvard.edu), D. J. Jacob, the TES Science Team and the INTEX-B Team

We examine ozone production in transpacific transport of Asian pollution and its impact on surface ozone air quality in the United States, with aircraft, satellite and surface observations in April-May 2006 from the INTEX-B campaign. The observations are interpreted with a global three-dimensional chemical transport model (GEOS-Chem). We estimate anthropogenic NOx emissions over eastern Asia using tropospheric NO2 column observations from OMI for April-May 2006. We find a factor of two increase compared with the bottom-up 2000 Asian NOx emissions. Observations from Mount Bachelor Observatory (MBO) suggest three major events of pollution transport during INTEX-B. One of them was sampled by INTEX-B as well as TES and AIRS satellite instruments. GEOS-Chem captures the transpacific event and TES observed O3-CO correlations. We characterize the relative importance of direct transport of Asian ozone and continuous ozone production during transpacific transport. We also address the impact of increasing Asian anthropogenic NOx emissions on surface ozone air quality over the United States.

3:45 pm
Analysis of TES Observations from the 2006 TexAQS/GoMACCS Campaign

Gregory Osterman (Jet Propulsion Laboratory, Gregory.Osterman@jpl.nasa.gov), K. Bowman, B. Pierce, J. Al-Saadi, W. McMillan, B. Irion

Analysis of measurements made by TES during the Texas Air Quality Study 2006 will be shown. The TES results are used in conjunction with Lagrangian trajectory model results from the RAQMS group to show the processing history of air parcels observed by TES. We will focus on an August 23 measurement showing enhanced ozone both in the lower and upper troposphere over Texas. Model analysis suggests the lower tropospheric ozone

had been processed in the boundary layer days earlier. The analysis will highlight the ability of TES to provide information on concentrations of ozone above the boundary layer and provide context to the study of the transport of pollution in Texas. Carbon monoxide data from AIRS and TES and RAQMS model results will be used to provide further insight on the August 23 case.

4:00 pm
Elevated tropical tropospheric ozone and CO during the 2006 El Niño from TES observations and GEOS-Chem simulations

Ray Nassar (Harvard University, ray@io.harvard.edu), J. A. Logan, L. Zhang, I. A. Megretskaia, and the TES Team

Changes in atmospheric convection as a result of the moderate El Niño in 2006 resulted in changes in tropical trace gas mixing ratios measured by TES. We investigate the mechanisms for these changes through simulations using the chemical transport model GEOS-Chem, comparing 2006 TES data with 2005 (a neutral year with respect to Pacific sea surface temperatures in the region defining El Niño or La Niña). The most prominent tropospheric changes during 2006 in both TES and GEOS-Chem data were elevated levels of ozone and CO over Indonesia and the eastern Indian Ocean. In autumn 2006, ozone and CO exceeded the previous year's values by more than 30 ppb and 80 ppb, respectively. The elevated ozone and CO can be traced to increased biomass burning in Indonesia during the dry El Niño conditions, but the magnitude of the anomaly can only be adequately modeled by satisfactorily accounting for factors such as transport, convection, fire emissions and lightning NOx. Overall, GEOS-Chem does a reasonable job of simulating the major ozone and CO features and interannual anomalies in the TES measurements. To further understand the importance of the factors contributing to elevated ozone, we focus in particular on testing the sensitivity of the ozone anomaly to changes in fire emissions and lightning NOx.

4:15 pm
Interpreting Aura MLS observations of hydrogen cyanide using a chemistry transport model

Qian Li (School of GeoSciences, University of Edinburgh, Q.Li@ed.ac.uk), P. Palmer, and H. Pumphrey

We use the GEOS-Chem global 3-D CTM to interpret the atmospheric distributions of hydrogen cyanide (HCN) observed by the Aura MLS instrument. The main sources of HCN are from the burning of biofuel and biomass while the main sink is uptake by oceans, resulting in a tropospheric lifetime of 5 months. This lifetime is long enough to allow the signals from surface sources and sinks to be observed in the tropical upper troposphere and lower stratosphere (UTLS). A recent study by Pumphrey et al. has reported a 2-year cycle in elevated HCN concentrations observed by Aura MLS in the

UTLS, which they attribute to South-east Asian biomass burning. However, GEOS-Chem shows a strong annual cycle in elevated HCN concentrations in the tropical upper troposphere. In this study, we present results from model experiments that investigate the origin of the discrepancy between the model and observed HCN atmospheric distributions in the tropical UTLS.

4:30 pm
The effects of the 2006 El Niño on tropospheric composition as revealed by data from the Tropospheric Emission Spectrometer (TES)

Jennifer Logan (Harvard University, jlogan@seas.harvard.edu), I. Megretskaia, R. Nassar, L. T. Murray, L. Zhang, K. W. Bowman, H. M. Worden, and M. Luo

Observations from the Tropospheric Emission Spectrometer show large differences in tropospheric CO, ozone, and water vapor over Indonesia and the eastern Indian Ocean in October-December 2006 relative to 2005. In 2006, ozone was higher by 15-30 ppb (30-75%) while CO was higher by >80 ppb in October and November, and by ~25 ppb in December. These differences were caused by high fire emissions from Indonesia in 2006, associated the lowest rainfall since 1997, and by dynamical differences induced by the moderate El Niño. The persistence of the ozone difference into December is consistent with higher NOx emissions from lightning in 2006 compared to 2005, as indicated by data from the Lightning Imaging Sensor. Data from OMI and SCIAMACHY also show enhanced tropospheric NOx from the fires in 2006. The ozone anomaly in 2006, while substantial, was not quite high as that during the major El Nino in late 1997. By contrast, TES data show that CO and ozone were much less enhanced in 2004, during the weak El Nino; there was higher rainfall during the dry season in 2004 compared to that in 2006, and consequently biomass burning emissions were much smaller. MOPITT data show that CO over Indonesia in October-November of 2006 was the highest since observations began in 2000, and MODIS data show the highest aerosol optical depth.

4:45 pm
On inferring urban and agricultural NOx emissions from space

Ronald Cohen (UC Berkeley, rccohen@berkeley.edu) and T. H. Bertram

Analyses have yet to tap the full potential of the high space and time resolution of SCIAMACHY, OMI or GOME-II data. Using examples from OMI and SCIAMACHY we describe observations of agricultural NOx emissions with time resolution of individual rain driven pulses. We use the daily coverage of OMI to describe day-of-week patterns in urban plumes that show both the well known decrease in weekend emissions but also a memory effect such that Monday, a weekday followed by a weekend is different than Wednesday, a weekday followed by a weekday.

5:00 pm
TES and OMI observations to study chemical evolution of Siberian Boreal fire plumes

Sunita Verma (Jet Propulsion Laboratory/CalTech, spayra@jpl.nasa.gov), J. Worden, B. Pierce, D. Jones, J. Al-Saadi, K. Bowman and TES Team

Boreal fires play an important role in the magnitude and inter-annual variability of tropospheric ozone in the Northern Hemisphere. The formation, chemical evolution, and transport of ozone from fire plumes has been widely studied however these processes are still not well understood. The July 2006 Siberian forest fire presents a unique event for studying the chemical evolution of boreal fires from space-based observing platforms as the plume stretched across Eastern Europe, Russia, and the Pacific. We examine the chemical evolution of this plume using co-located ozone and CO profiles as measured by the Tropospheric Emission Spectrometer (TES) as well as NOx and Aerosol amounts as measured by the Ozone Monitoring Instrument (OMI). Both instruments are on the Earth Observing System (EOS) Aura platform. Back trajectories from observations of enhanced CO are used to mark the plume from this fire and also provide an estimate of the temporal displacement from the fire source. We find significant production of ozone in the presence of optically thick aerosol amounts indicating that optically thick aerosols strongly mitigate photochemical ozone production. At high latitudes (larger then 70 degrees North) there is little observed ozone despite significant CO concentrations ranging between 120 and 300 PPB. This decreased correlation of ozone enhancement with CO enhancement suggests mixing of the plume with background air in conjunction with a drop in photochemical ozone production.

Friday, 5 October 2007

8:15 am
Improved temporal constraints on and vertical injections of biomass burning emissions: Implications on global aerosol simulation

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Biomass burning from wild fires is a major source of air pollutants including aerosols and some other climate forcing agents. Biomass burning emissions are typically prescribed on a monthly base in most global chemistry and transport models (CTMs). We investigated the sensitivity of global aerosol transport and distribution to the diurnal cycle, synoptic variability, and vertical injection height of biomass burning emissions. Global simulations of aerosols were conducted using the GEOS-Chem global 3-D chemistry and transport model for summer 2004, with the aforementioned constraints imposed on the 8-day Global Fire Emissions Database (GFED v2). The diurnal cycle was determined using active fire data. The synoptic variability, which depends on temperature, relative humidity, and wind speed, was derived from a fire model. The injection height was derived from MISR smoke plume stereoheights. Model results, with monthly or 8-day (with or without the additional constraints) biomass burning emissions, were compared with aerosol optical depths (AOD) from MISR/MODIS/OMI and the AERONET network, and (mass) concentrations from the IMPROVE network and the INTEX-NA aircraft campaign. Using 8-day instead of monthly biomass burning emissions significantly improves the comparison of mass concentrations of BC, OC, and sulfate with observations. The inclusion of diurnal cycle, synoptic variability, and vertical injection height in the 8-day biomass burning emission inventory lead to more efficient transport of aerosols out of the boundary layer, resulting in lower aerosol loadings over the biomass burning source regions and higher loadings downwind, compared with simulations with monthly inventory. The inclusion of the additional constraints also reduces the discrepancies, both in magnitude and daily variability, between observed and simulated aerosol optical depths (AODs), especially downwind of the biomass burning source regions.

8:30 am
OMI Tropospheric NO2 from Lightning in Observed Convective Events

Kenneth Pickering (NASA/GSFC, Kenneth.E.Pickering@nasa.gov), E. Bucsela, T. Kucsera, L. Pan, C. Davis, J. Gleason, and P. Levelt

Lightning is responsible for an estimated 10-20% of total NOx emissions, and is one of the most prominent sources in the upper troposphere. In this study, we present evidence of lightning-generated NO2 (LNO2) using data from the Ozone Monitoring Instrument (OMI), which has observed tropospheric NO2 since its launch in 2004. Although LNO2

has been also reported in previous satellite studies from the Global Ozone Monitoring Experiment (GOME) and SCIAMACHY, OMI is better suited for such measurements by virtue of its higher spatial resolution and daily global coverage. We will present data clearly showing the LNO2 signal in the OMI tropospheric NO2 product on two days over and downwind of specific convective systems in the US Midwest. Gridded monthly mean tropospheric NO2 data (screened to exclude > 30% cloud cover) are subtracted from the daily gridded data to obtain the presumed LNO2 signal. Observed cloud-to-ground (CG) lightning flashes from the National Lightning Detection Network (NLDN) were counted along middle and upper tropospheric back trajectories that were run from the regions containing the LNO2 signal. A vertically-weighted average number of upwind CG flashes was obtained using a profile of LNOx mass obtained from a series of midlatitude cloud-resolved storm chemistry simulations. The number of CG flashes was scaled up to total flashes (intracloud (IC) flashes plus CG) using a climatological IC/CG ratio. The number of moles of LNOx in the region considered was estimated by assuming that LNO2 is 30% of LNOx. This value was divided by the number of upwind flashes to obtain an average estimate of the number of moles produced per flash. Results yield values in the range obtained through other estimation techniques (e.g., aircraft measurements, models). Estimates are also made for individual 1o x 1o grid cells to examine the variability of the LNOx production. We are also conducting a similar analysis over northern Australia during the SCOUT-O3/ACTIVE field campaigns in November and December 2005, in which we will compare the OMI LNOx signals with aircraft observations from the storm anvils.

8:45 am
Understanding Synoptic Controls on North American Pollutant Export using TES Observations

Jennifer Hegarty (University of New Hamphire, jhegarty@ccrc.sr.unh.edu), H. Mao, and R. Talbot

The role of synoptic-scale atmospheric circulations in the export and intercontinental transport of air pollutants from North America was investigated using observations from the Tropospheric Emission Spectrometer (TES). The predominant circulation patterns influencing eastern North America during each season were identified using a correlation-based classification scheme with multiple-year analysis data from the National Centers for Environmental Prediction (NCEP). Approximately 70 % of the days during 2005 and 2006 had circulation patterns that could be classified as one of the common seasonal patterns. The corresponding spatial distributions of tropospheric O3 and CO measured by TES were used to identify the primary pollutant transport mechanisms. The results indicate that enhancements in lower free tropospheric O3 and CO over the North Atlantic appeared to be associated with synoptic-scale shortwave troughs crossing the east coast of the United States.

9:00 am
Observations of The Middle East Ozone "Maximum"

John Worden (Jet Propulsion Laboratory/Caltech, john.r.worden@jpl.nasa.gov), D. Jones, J. Liu, K. Bowman, S. Kulawik, M. Parrington, L. Jourdain, S. Verma, A. Eldering, G. Osterman, M. Luo, B. Fisher, H. Worden, and R. Beer.

The GEOS-CHEM model predicts that ozone amounts in the upper troposphere during the summer is highest over the middle east relative to the rest of the globe. Consequently this feature is important to understand both from a climate perspective, because upper tropospheric ozone is a green-house-gas, and as a pollution reservoir, because these enhanced ozone concentrations can be re-circulated to other locations. The presence of this ozone "maximum" was proposed by Li et al (2003) to be due to a summertime anti-cyclone, centered over the middle east, which gathers pollution from Europe and East Asia along with lightning from the Indian Monsoon. Subsidence in this region is also thought to play a role. We characterize the ozone and carbon monoxide concentrations over this region as examined by TES. Peak ozone values of 95 PPB are observed over Northeast Africa with ozone amounts of 80 – 90 PPB observed over adjacent regions and 40 PPB over the central pacific at similar longitudes. We show these differences are statistically significant. Observations of similarly enhanced ozone amounts south of Russia and Eastern China are also observed, indicating that the middle east ozone maximum is not a "global" maximum.

9:15 am
Spatial distribution of isoprene emissions from North America derived from formaldehyde column measurements by the OMI satellite sensor

Dylan Millet (Harvard University, millet@eps.harvard.edu), D. J. Jacob, K. Folkert Boersma, T.-M. Fu, T. P. Kurosu, K. Chance, C. L. Heald, and A. Guenther

Space-borne formaldehyde (HCHO) column measurements from the Ozone Monitoring Instrument (OMI), with 13 x 24 km2 nadir footprint and daily global coverage, provide new constraints on the spatial distribution of biogenic isoprene emission from North America. OMI HCHO columns for June-August 2006 are consistent with measurements from the earlier GOME satellite sensor (1996-2001) but OMI is 10-20% lower. The spatial distribution of OMI HCHO columns follows that of isoprene emission; anthropogenic hydrocarbon emissions are undetectable except in Houston. We develop updated relationships between HCHO columns and isoprene emission from a chemical transport model (GEOS-Chem), and use these to infer top-down constraints on isoprene emissions from the OMI data. We compare the OMI-derived emissions to a state-of science bottom-up isoprene emission inventory (MEGAN) driven by two land cover databases, and use the results to optimize the MEGAN emission factors (EFs) for broadleaf trees (the main isoprene source). The OMI-derived isoprene emissions in North America (June-August 2006) with 1deg x 1deg resolution are spatially consistent with

MEGAN (R2 = 0.48-0.68) but are lower (by 4-25% on average). MEGAN overestimates emissions in the Ozarks and the Upper South. A better fit to OMI (R2 = 0.73) is obtained in MEGAN by using a uniform isoprene EF from broadleaf trees rather than variable EFs. Thus MEGAN may overestimate emissions in areas where it specifies particularly high EFs. Within-canopy isoprene oxidation may also lead to significant differences between the effective isoprene emission to the atmosphere seen by OMI and the actual isoprene emission determined by MEGAN.

9:30 am
Constraints on the lightning NOx emissions over the USA using TES, NLDN, IONS data and the GEOS-Chem model

Line Jourdain (Jet Propulsion Laboratory, line.jourdain@jpl.nasa.gov), S. Kulawik, H. Worden, K. Pickering, B. Fisher, D. Rider, A. Thompson and the TES team

The knowledge of the strength and distribution of the lightning source of NOx is required to understand NOx and ozone distributions in the upper troposphere and the oxidizing capacity of the atmosphere. It is also critical to assess the present and future impact of anthropogenic sources on upper tropospheric ozone as well as possible feedback between lightning and climate change. In this study, we use the data from the Tropospheric Emission Spectrometer (TES) in conjunction with the lightning flashes observed by the National Lightning Detection Network (NLDN) to better quantify the lightning NOx source over the US as well as its impact on the upper tropospheric ozone. First, TES ozone profiles are compared to the ozonesonde measurements from the IONS (INTEX Ozonesonde Network Study) 2006 campaign to provide validation specific to the North American summer conditions. Then, the lightning influence on the air parcels sampled by TES is investigated by computing forward trajectories initialized at the times and locations of each cloud-to-ground flash observed by the lightning detection networks. Several cases are identified where distinct enhanced ozone layers observed by TES could be related back to lightning events. For these cases, we exploit the differences between the ozone measured by TES and simulated by GEOS-Chem to improve the lightning NOx parameterization in the model.

9:45 am
A Satellite Perspective on the Interhemispheric Transport of Pollution

Chenxia Cai (Jet Propulsion Laboratory, Chenxia.Cai@jpl.nasa.gov), Q. Li, N. Livesey and J. Waters

Interhemispheric transport (IHT), which occurs predominantly in the tropical upper troposphere, is of great interest as it results exchanges of energy, water vapor, and air pollutants including many climate forcing agents between the hemispheres. We investigated the IHT of pollution as indicated by carbon monoxide (CO), a tracer of combustion pollution, by analyzing satellite observations of CO from EOS-MLS and

MOPITT in conjunction with results from the GEOS-Chem global 3-D chemistry and transport model. Multi-year CO observations from EOS-MLS (2004-2006) and MOPITT (2000-2006), along with GEOS-Chem model results for 2005 were analyzed to characterize the spatiotemporal variability of IHT. Upper tropospheric CO fluxes calculated from MLS (147 hPa) and MOPITT (150 hPa) CO concentrations and NCEP reanalysis wind fields exhibit strong longitudinal and seasonal variations which are consistent with the GEOS-Chem model results. In northern summer, the strong southward CO flux over the Indian Ocean is associated with the Asian monsoon circulation. In northern winter-spring, the southward CO flux over the Eastern Pacific is attributed to transport in the so-called "westerly ducts". GEOS-Chem tagged CO simulations (i.e., tracking CO emitted from different geographic regions) show that the IHT of CO over the Indian Ocean in summer are mainly from Asian fossil fuel, biomass burning, and biofuel sources. Over the Eastern Pacific in winter-spring, Asian fossil fuel and biofuel burning and African biomass burning are the major contributors to the IHT of CO. IHT of CO over the Indian Ocean shows distinct interannual variability and is positively correlated with precipitation in that region, indicating the modulating effect of Asian monsoon. Although previous studies have shown that La Nina conditions favor IHT over the Eastern Pacific while El Nino conditions usually suppress it, our analysis shows that El Nino conditions could also enhance the "westerly ducts" and thus IHT during winter over that region.

10:00 am
Analysis of OMI Tropospheric NO2 data for Northwestern Europe

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In Northwestern Europe the predominant source for NO2 in the boundary is the combustion of fossil fuels. NO2 is a pollutant by itself, but also plays an important role in the formation of tropospheric ozone and as a precursor for nitrate aerosol particles. By combining a full year of OMI data, a high resolution (0.03x 0.03 degrees) dataset of tropospheric NO2 has been produced. Analyses of this dataset will be presented, including the following aspects:
- the unprecedented spatial resolution of the yearly averaged data;
- the expected detection limit for OMI and related instruments;
- the weekly cycle and its relation to traffic intensity;
- the relation between the satellite data and ground based measurements.