A52B MCC: Level 2 Friday 1330h

Use of Inverse Modeling for Constraining Global Budgets of Atmospheric Trace Gases III Posters
(joint with B)

Presiding: **A M Michalak,** NOAA Climate Modeling and Diagnostics Laboratory**; W Peters,** NOAA Climate Modeling and Diagnostics Laboratory**; P P Tans,** NOAA Climate Modeling and Diagnostics Laboratory

A52B-0781 1330h POSTER

Can Satellite Measurements Represent Regional Scale CO_2 Variability?

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Due to their uniform spatial sampling and sheer data volume, CO_2 measurements from satellites have the potential to help identify sources and sinks at the regional scale. These satellite measurements can be used in inversion models to enhance our understanding of the carbon cycle; however, since inversion models use grid cells larger than the measurement footprint, it is essential that the measurements accurately represent the average concentration at the inversion model resolution. Using a five-day simulation of surface fluxes and atmospheric CO_2 concentration from the Regional Atmospheric Modeling System (RAMS) coupled to the Simple Biosphere Model (SiB2) centered around a tall tower validation site in Wisconsin, we investigated the representativeness of satellite measurements on the regional scale. Comparing the mean of 1-km-wide N-S swaths of simulated column mean CO_2 with the "true" domain-averaged column mean mixing ratio over the 38x38 km grid at 2 PM on each of the five days, we found 95% of the swaths had mean mixing ratios within 0.18 ppm of the true domain-averaged mixing ratio. A similar study on a larger 600x600 km domain with 16 km grid spacing yields 95% of the N-S swaths capture the domain average within 0.17 ppm. Although future work is necessary, these results indicate satellite measurements will be capable of representing regional scale CO_2 variations.

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A52B-0782 1330h POSTER

Differences Between Surface and Column CO_2 Variability and Implications for Carbon Cycle Research

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While diurnal, seasonal, and latitudinal aspects of CO_2 variability have been extensively explored near the surface, much less is known about the behavior of the CO_2 column integral. Understanding the modes of variability in column CO_2 is critical for the design and interpretation of new upward looking and satellite-based CO_2 spectrometers. We used a three dimensional atmospheric transport model to investigate key aspects of column CO_2, including the amplitude of the diurnal cycle and how it is related to surface fluxes, the amplitude and phase of the seasonal cycle, and the magnitude of the north-south hemispheric gradient. In our simulation, we found that column CO_2 had less variability than surface CO_2 on all scales. The annual mean column CO_2 north-south gradient and seasonal cycle amplitude were approximately one half of their surface counterparts and the column CO_2 diurnal amplitude rarely exceeded 1 ppm. A 1 Gt C yr^{-1} northern hemisphere carbon sink decreased the north-south column CO_2 gradient by $\sim$0.4 ppm.

A52B-0783 1330h POSTER

The Averaging Kernel of CO2 column measurements by the Orbiting Carbon Observatory (OCO), Its Use in Inverse Modeling, and Comparisons to AIRS, SCIAMACHY, and ground-based FTIR

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The sensitivity of a space-based CO2 measurement varies with height due to the physics of spectroscopy and radiative transfer interacting with atmospheric properties, and to instrument characteristics such as the spectral bandpass, resolution, and noise. Thus it is necessary to take the profile shape and variability with height into account in retrieving the column and in comparing it to other measurements for validation and to inverse models for studies of the CO2 budget. The variation of sensitivity with height is given by the averaging kernel. Errors in the CO2 column due to non-uniform sensitivity are referred to as smoothing error'. Here we examine the Orbiting Carbon Observatory (OCO) averaging kernel under various assumptions of aerosol optical depth, surface albedo, and solar zenith angle, and show how models can be made to mimic it, thus eliminating smoothing error from source/sink determinations. Next we compare the OCO averaging kernel to those of AIRS, SCIAMACHY, and the ground-based FTIR measurements to be used for validation. Then we assess the ability of the FTIR to copy the altitude sensitivity of the satellite instruments. Finally, we estimate the resulting smoothing error in comparing the measurements to true values and to each other.

A52B-0784 1330h POSTER

Modeling CO2 profiles for satellite validation

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The Orbiting Carbon Observatory (OCO) is a NASA satellite mission, scheduled for launch in 2007, that is intended to provide spatially dense measurements of the column-integrated CO2 mixing ratio. Like any such mission, OCO faces the problem of calibration and validation. In particular, both to allow the use of its data along with existing CO2 measurements for source-sink estimation and to avoid potential systematic errors in the satellite measurements, OCO data must be tied to the existing precise but sparse surface measurement network. This is difficult since we rarely if ever measure the same, column-integrated mixing ratio as OCO. A possible technique uses upward looking Fourier Transform Spectrometers to provide a ground-based measurement of the column-integrated mixing ratio. Now the problem shifts to the calibration and validation of these instruments. Aircraft profiling, in which discreet CO2 measurements are taken at a range of heights, provides one obvious link. However aircraft cannot fly to the top of the atmosphere and the question remains of how reliable a calibration can be provided by a profile to any given level. This poster investigates this problem by modelling the 3-dimensional CO2 field using climatological CO2 sources and an atmospheric transport model (The CSIRO Cubic Conformal Model) driven with observed meteorological forcing. We compare the modelled vertical profiles with those measured in several campaigns, most notably the decade-long series at Cape Grim, Tasmania. Next we consider the ability of a profile at various locations to represent the column-integrated mixing ratio. We consider variations both by season and location in order to suggest an optimal strategy for the use of aircraft profiles as a validation tool.

A52B-0785 1330h POSTER

Inversion of Column-CO_2 Observations from Space Using a High Resolution Inverse Model

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An inverse modelling approach is developed for surface source estimation of CO_2 fluxes at higher spatial resolution for large number of smaller source regions. The annual mean fluxes are retrieved for 432 source regions, each region's size of 10 x 15 degrees latitude-longitude, assuming availability of the CO_2 observations on the ground network and column abundance observed by satellite sensor. This inverse model is used to evaluate the utilities of columnar measurements of CO_2 in surface source estimations at regional scale. No prior flux pattern and correlation between regions is assumed. It can be concuded that the inverse model should utilize source regions that are small enough, approximately of the size of source footprints at surface measurement station, for a fair comparison of the satellite data utility against the ground-based observations. The columnar satellite CO_2 concentration measurements are effective in flux estimate uncertainty reductions if global coverage and total columns can be obtained with sufficient accuracy. The partial column measurements (above the PBL) and observations only over the ocean produce only minor contribution to constraining the inverse model estimates of terrestrial CO2 fluxes.

A52B-0786 1330h POSTER

Using Virtual Tall Tower [CO_2] Data in Inverse Models to Reduce Uncertainty in Global and Regional Estimates of Carbon Flux

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Previous studies in optimization of carbon observing networks considered any global grid cell as eligible for selection as a measurement site. In reality, measurement of mean CO_2 over highly variable terrestrial regions is very impractical and expensive. A global network of eddy covariance flux towers already exists where continuous measurements of CO_2 are taken, as well as measurements of sensible heat (H), latent heat (LE), and net ecosystem exchange (NEE). If the CO_2 measurements were calibrated, these surface layer values could be extrapolated to the mixed-layer using similarity theory providing a means to sample the continental mixed-layer for use in global inversions to further constrain the carbon budget. We show that with this method for estimating the mid-day continental boundary layer [CO_2] from calibrated [CO_2] and eddy covariance measurements at flux towers, a network of "virtual tall towers" can be readily implemented using existing infrastructure and minimal additional instrumentation. Using the TransCom3 experimental protocol, sites where high-frequency timeseries were saved from the forward runs of 12 transport models were used as eligible sites for possible global networks. The fluxes were optimized to fit the monthly mean of mid-day values by sub-sampling the global fields during the afternoon only, when this method works best. A genetic algorithm was used to determine which existing measurement sites should be grouped together in a network that can most reduce the root mean square uncertainty on estimates of carbon flux. The algorithm evolves the most "fit" population of flux tower sites by comparing and prioritizing them according to their performance in the inversions. A global and North American experiment were performed to determine which ten or five towers should be implemented first as virtual tall towers. In the global selection of ten towers, the algorithm selected four sites in North, Central, and South America in the strong flux areas of the tropics and eastern US. Two towers were selected in southern Europe, even though Europe has a dense network,

to constrain the regions of North and South Africa. Two towers were selected in Thailand and two in Japan to constrain Temperate and Boreal Asia, respectively. In the North American experiment, the optimal network selected five sites located in North Carolina, Missouri, Illinois, Tennessee, and Maryland. Overall, the strategies of bracketing the main flux areas and making observations through a gradient of fluxes didn't work well in the TransCom3 inversions. The best virtual tall tower networks emphasized placement of measuring sites in and just downwind of strong fluxes.

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A52B-0787 1330h POSTER

On the CO2 Exchange Between the Atmosphere and the Biosphere: The Role of Synoptic and Mesoscale Processes

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Estimating global carbon fluxes by inverting atmospheric CO2 through the use of atmospheric transport models has shown the importance of the covariance between biospheric fluxes and atmospheric transport on the carbon budget. This covariance or coupling occurs on many time scales. This study examines the coupling of the biosphere and the atmosphere on the meso and synoptic scales using a coupled atmosphere-biosphere regional model covering Canada. The results are compared to surface and light aircraft measurement campaigns at two boreal forest sites in Canada (Fraserdale and BERMS). Associated with cold and warm frontal features, the model results showed that the biospheric fluxes are strongly coupled to the atmosphere through radiative forcing. The presence of cloud near frontal regions usually results in reduced photosynthetic uptake, producing CO2 concentration gradients across the frontal regions on the order of 10ppm. Away from the frontal region, the biosphere is coupled to the mesoscale variations in similar ways, resulting in mesoscale variations in CO2 concentrations of about 5ppm. The CO2 field is also coupled strongly to the atmospheric dynamics. In the presence of frontal circulation, the CO2 near the surface can be transported to the mid to upper troposphere. Mesoscale circulation also plays a significant part in transporting the CO2 from the planetary boundary layer (PBL) to the mid troposphere. In the absence of significant mesoscale or synoptic scale circulation, the CO2 in the PBL has minimal exchange with the free troposphere, leading to strong gradients across the top of the PBL. We speculate that the ubiquity of the common synoptic and mesoscale processes in the atmosphere may contribute significantly to the rectifier effect and hence CO2 inversion calculations.

A52B-0788 1330h POSTER

Application of Geostatistical Inverse Modeling to Gridscale Estimation of CO_2 Surface Fluxes

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A geostatistical inversion algorithm is applied to the recovery of CO_2 fluxes on a 3.75^o latitude by 5.0^o longitude scale. The geostatistical approach to inverse modeling is a Bayesian approach in which the prior probability density function is specified based on an assumed form for the spatial and/or temporal correlation of the function to be estimated. This differs from traditional Bayesian approaches to atmospheric inverse modeling, where the prior information is in the form of initial surface flux estimates for given regions or gridcells. In geostatistical inverse modeling, the degree to which values of an unknown function (in this case, surface fluxes) at two points are expected to be correlated is defined as a function of the separation distance in space or in time between these two points. The parameters describing this correlation, such as, for example, the variance of the process and its correlation length, are also estimated as part of the inversion. In addition, flux estimates are not subject to some of the limitations associated with traditional Bayesian inversions, such as potential biases created by the choice of prior fluxes and aggregation error resulting from the use of large regions with prescribed flux patterns. Results show that CO_2 surface flux variations can be recovered on a significantly smaller scale than that imposed by regional synthesis inversions, with posterior flux covariances indicating that these variations are well supported by the available observations.

A52B-0789 1330h POSTER

Towards Regional CO2 Flux Estimates for North America From Inverse Modeling

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The two-way nested TM5 transport model is used to estimate sources and sinks of CO2 on a regional scale over North America. This study uses a 80x80km grid scale over the US, a 250x150km grid over North America, and a 600x400km grid over the rest of the world. This setup balances the need for high spatial resolution, computational efficiency, and retaining information from remote areas. We focus on quantifying the model's seasonal and diurnal rectifier, the feasibility of solving for weekly grid-based CO2 fluxes, and the incorporation of vertical profiles from aircraft measurements in the inversion . The huge computational burden of this problem are tackled with the adjoint of the TM5 model, and a newly developed Kalman filter assimilation technique. The aim is to produce regional scale, weekly CO2 fluxes that are optimally consistent with the NOAA CMDL measurement, and can be used to answer both scientific and policy driven questions.

A52B-0790 1330h POSTER

An Adjoint-Based Analysis of the Sampling Footprints of Tall Tower, Aircraft and Potential Future Lidar Observations of CO2

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A detailed mechanistic understanding of the sources and sinks of CO2 will be required to reliably predict future CO2 levels and climate. A commonly used technique for deriving information about CO2 exchange with surface reservoirs is to solve an "inverse problem", where CO2 observations are used with an atmospheric transport model to find the optimal distribution of sources and sinks. Synthesis inversion methods are powerful tools for addressing this question, but the results are disturbingly sensitive to the details of the calculation. Studies done using different atmospheric transport models and combinations of surface station data have produced substantially different distributions of surface fluxes. Adjoint methods are now being developed that will more effectively incorporate diverse datasets in estimates of surface fluxes of CO2. In an adjoint framework, it will be possible to combine CO2 concentration data from longterm surface and aircraft monitoring stations with data from intensive field campaigns and with proposed future satellite observations. We have recently developed an adjoint for the GSFC 3-D Parameterized Chemistry and Transport Model (PCTM). Here, we will present results from a PCTM Adjoint study comparing the sampling footprints of tall tower, aircraft and potential future lidar observations of CO2. The vertical resolution and extent of the profiles and the observation frequency will be considered for several sites in North America.

A52B-0791 1330h POSTER

An Upward Revision of Current Estimates for the Atmospheric Lifetimes of Methane and Other Pollutants Removed by OH

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An inverse modeling study using observations of methyl chloroform (MCF) and the 3-D GEOS-CHEM chemical transport model with assimilated meteorology was conducted to estimate the global abundance of hydroxyl radical (OH). Our method differs from those of previous inversion studies in that we optimized both the emissions of MCF and the abundance of OH, we used winds specific to the analysis years, and we ran the model at a finer spatial resolution. Inversions were carried out for the years 1987-1993. High-frequency observations from the GAGE/AGAGE and CMDL networks were used in separate analyses. We inverted for MCF emissions from each of a number of regions. Different variations of the inversion optimizing global or hemispheric abundances of OH were implemented. We find that global emissions of MCF are about 10% lower than previous estimates for earlier years in the analysis period, before emissions declined precipitously in response to the phase-out of MCF production; our emissions estimates are more similar to previous estimates for later years. This result appears to be consistent with observations of MCF pollution plumes in the late 1990s, which suggest that the time lag between purchases and emissions of MCF may be longer than previously thought. Our estimate for the lifetime of MCF with respect to OH, 7.0-7.7 years, is 17%-35% longer than those of previous studies. The corresponding lifetime for methane is about 12 years, as compared to the 10.1 years estimated by a previous study. Photochemical calculations using recent versions of the GEOS-CHEM model also suggest a lower abundance of OH. Our results have important implications for the global warming potentials (GWPs) of methane and other greenhouse gases removed primarily by OH.

A52B-0792 1330h POSTER

Interannual variability in ocean and land CO_2 fluxes derived using Time Dependent Inverse model

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Using a Bayesian Time Dependent Inverse (TDI) model sources and sinks of CO_2 from 64 regions of the globe have been derived from the atmospheric data at about 100 stations. This inverse model version is primarily based on the TransCom-3 protocol for the distribution of monthly pulse functions of regional sources, and four background fluxes. The NIES/FRSGC global transport model has been run on the Earth Simulator

to distribute the monthly and yearly tracer pulse functions at 15 sigma vertical layers and $2.5^0 \times 2.5^0$ horizontal resolution. The model transport is driven by 6-hourly interannually varying meteorological fields from the NCEP/NCAR reanalysis dataset. The target period of our study is set to January 1988 to December 2001. Overall the estimated fluxes are in fairly good agreement with previous estimates (direct and inverse) at both regional and global scales. The average flux rates for the global land and ocean regions are estimated to be -0.8±1.2 (1σ), and -1.9±0.8 Pg C/yr, respectively for the period of our study (excluding the 1997/1998 El Niño period). Since the oceanic CO_2 fluxes are relatively undisturbed by the human influences, regional anomalies are closely linked with the major modes of climate variabilities. A detailed correlation study indicates that the flux anomalies have mode of variabilities that are distinct from region to region; e.g., the flux anomalies in northern most Pacific Ocean is linked to the PDO, the anomalous component of Eastern Pacific and Southern Ocean fluxes covary with ENSO/SOI, while the Northern Ocean flux anomalies are controlled by the NAO/AO variability. Details of the land and ocean region fluxes will be presented in the meeting.

A52B-0793 1330h POSTER

Meridional Gradients in Atmospheric O_2 and CO_2.

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Measurements of atmospheric O_2 and CO_2 can be combined to create a "tracer" referred to as Atmospheric Potential Oxygen (APO) [Stephens et al. 1998]. APO is unaltered by terrestrial photosynthesis and respiration, and influenced only slightly by fossil fuel combustion. Consequently, measurements of APO have the potential to provide unique constraints on models of oceanic circulation and biology, atmospheric circulation and air-sea gas exchange. We present here the first long-term measurements of atmospheric oxygen from the equatorial region, building upon the initial measurements of Stephens [1999]. When combined with our extra-tropical observations, we find that the meridional gradient in APO exhibits the gross features we expect from the combined influences of ocean processes, fossil fuel combustion and atmospheric transport: an interhemispheric gradient that changes sign seasonally. We then use these data to examine the equatorial "bulge" in APO predicted by ocean models [Stephens et al, 1998, Gruber et al. 2001]. This bulge in APO (high values of APO, relative to the extratropical regions) results from large fluxes of both O_2 and CO_2 from the ocean to the atmosphere due to equatorial upwelling.

A52B-0794 1330h POSTER

Is the Global Atmospheric Methane Budget at Steady-State?

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The atmospheric CH_4 abundance began increasing near the start of the industrial revolution, and this increase continued through the 20th century. But during the past 4 years (1999 to 2002), the global abundance of atmospheric CH_4, as determined from an extensive network of air sampling sites, has been approximately constant at 1751 ppb. If it is assumed that the CH_4 lifetime has been constant over this 4-year period, then the global CH_4 budget has been at steady state. Although the growth rate of CH_4 decreased from about 15 ppb yr^{-1} in the early 1980s to a few ppb yr^{-1} in the late 1990s, it seems unlikely that the global CH_4 budget could have already reached steady-state without a reduction in emissions. Our measurements support such a reduction; we have observed a significant decrease in the difference between polar northern and polar southern zonal averages of CH_4 from 1991 to 1992. Using a 3-D transport model, we show that this change is consistent with a decrease in CH_4 emissions of ∼10 Tg from north of 50°N in the early-1990s, which may have accelerated the global CH_4 budget towards steady state. Based on current knowledge of the global CH_4 budget and how it has changed with time, it is not possible to tell if the atmospheric CH_4 burden has peaked, or if we are only observing a persistent, but temporary pause in its increase.

A52B-0795 1330h POSTER

Estimation of Atmospheric Methane Surface Fluxes Using a Global 3-D Chemical Transport Model

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Accurate determination of atmospheric methane surface fluxes is an important and challenging problem in global biogeochemical cycles. We use inverse modeling to estimate annual, seasonal, and interannual CH_4 fluxes between 1996 and 2001. The fluxes include 7 time-varying seasonal (3 wetland, rice, and 3 biomass burning) and 3 steady aseasonal (animals/waste, coal, and gas) global processes. To simulate atmospheric methane, we use the 3-D chemical transport model MATCH driven by NCEP reanalyzed observed winds at a resolution of T42 (∼$2.8^\circ \times 2.8^\circ$) in the horizontal and 28 levels (1000 - 3 mb) in the vertical. By combining existing datasets of individual processes, we construct a reference emissions field that represents our prior guess of the total CH_4 surface flux. For the methane sink, we use a prescribed, annually-repeating OH field scaled to fit methyl chloroform observations. MATCH is used to produce both the reference run from the reference emissions, and the time-dependent sensitivities that relate individual emission processes to observations. The observational data include CH_4 time-series from ∼15 high-frequency (in-situ) and ∼50 low-frequency (flask) observing sites. Most of the high-frequency data, at a time resolution of 40-60 minutes, have not previously been used in global scale inversions. In the inversion, the high-frequency data generally have greater weight than the weekly flask data because they better define the observational monthly means. The Kalman Filter is used as the optimal inversion technique to solve for emissions between 1996-2001. At each step in the inversion, new monthly observations are utilized and new emissions estimates are produced. The optimized emissions represent deviations from the reference emissions that lead to a better fit to the observations. The seasonal processes are optimized for each month, and contain the methane seasonality and interannual variability. The aseasonal processes, which are less variable, are solved as constant emissions over the entire time period. The Kalman Filter also produces emission uncertainties which quantify the ability of the observing network to constrain different processes. The sensitivity of the inversion to different observing sites and model sampling strategies is also tested. In general, the inversion reduces coal and gas emissions, and increases rice and biomass burning emissions relative to the reference case. Increases in both tropical and northern wetland emissions are found to have dominated the strong atmospheric methane increase in 1998. Northern wetlands are the best constrained processes, while tropical regions are poorly constrained and will require additional observations in the future for significant uncertainty reduction. The results of this study also suggest that interannual varying transport like NCEP and high-frequency measurements should be used when solving for methane emissions at monthly time resolution. Better estimates of global OH fluctuations are also necessary to fully describe the interannual behavior of methane observations.

A52B-0796 1330h POSTER

Constraints on Asian and European Sources of Methane from CH4 - C2H6 - CO Correlations in Asian Outflow

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Aircraft observations in Asian outflow from the TRACE-P aircraft mission (March-April 2001) show persistently strong CH_4/C_2H_6 correlations with uniform slope (r2=0.8-0.95, slope=45-59 mol/mol for individual flights) and more variable CH_4/CO correlations (r2=0.6-0.88, slope=0.4-1.2 mol/mol). We apply a global 3-D simulation of the CH_4-C_2H_6-CO system, including consistent representations of sources and sinks for all three species, to interpret these correlations and the CH_4 concentration enhancements observed in TRACE-P toward improved estimates of Asian and European CH_4 sources. We use as a priori a state-of-the-science global CH_4 inventory constrained with NOAA/CMDL observations [J.S. Wang et al., J. Geophys. Res. 2003]. This inventory is found to overestimate CH_4 concentration enhancements in the Asian outflow while giving an unbiased simulation of CH_4-C_2H_6-CO correlations. Matching the TRACE-P observations in subtropical outflow requires a 70% decrease in seasonal Southeast Asian biomass burning emissions for CH_4, C_2H_6 and CO, implying a general overestimate of biomass burned. Matching the observations in the Asian outflow north of 30°N can be achieved by using the Streets et al. [J. Geophys. Res., 2003] inventory for anthropogenic Asian emissions and by reducing the European and Russian sources by 25%. The former change increases the CH_4/C_2H_6 and CH_4/CO slopes, while the latter decreases the slopes, and the combination of the two changes maintains the unbiased simulation of the observed slopes. The resulting simulation also provides a good match to the observed CH_4 background and to the NOAA/CMDL data.

A52B-0797 1330h POSTER

Exploiting observed CO:CO_2 correlations in Asian outflow to invert simultaneously for emissions of CO and CO_2

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Observed correlations between trace gases provide additional constraints to chemical inverse problems but have been largely unexploited. We use correlations between CO and CO_2 in Asian outflow from the NASA TRACE-P aircraft campaign, together with the GEOS-CHEM global 3-D model driven by time-dependent emission inventories for these gases, to invert simultaneously for the emissions of CO and CO_2 using a maximum likelihood technique. We show that these CO:CO_2 correlations help to distinguish emissions from different countries in eastern Asia, and also to provide valuable information about source type attribution, that would otherwise be impossible using only one of these gases.

A52B-0798 1330h POSTER

Asian emissions of CO: constraints from aircraft and Chinese station data

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Previous inversion studies indicate that Chinese anthropogenic emissions of CO are underestimated by current reporting. A 1(degree) x 1(degree) nested-grid capability has been implemented in the GEOS-CHEM global 3-D model of atmospheric chemistry and applied to Asia to better resolve the geographic distribution of CO sources. CO observations from (a) the TRACE-P aircraft mission over northwestern Pacific, and (b) two Chinese ground stations (in Hong Kong and Lin An) during spring 2001 are used in conjunction with an optimal estimation inverse model to improve estimates of Asian emissions of CO. A priori emissions are based on a detailed bottom-up inventory for the observation period. Error budgets for the ground-based and aircraft data are quantified separately. The inversion study indicates a 70% increase in anthropogenic CO emissions from eastern China (east of 110E, and south of 40N), distributed heterogeneously with the largest adjustments required in the south. A posteriori estimates of emissions from biomass burning in Southeast Asia are much lower than a priori values, consistent with conclusions reached in other TRACE-P studies. Integrating data from the ground-based stations with the aircraft results allows for better resolution of CO sources from three sub-regions in eastern China.

A52B-0799 1330h POSTER

Integrating MOPITT and Aircraft Observations to Estimate Asian CO Emission Sources

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Satellite and aircraft observations of trace species provide independent top-down constraints on emissions. The integration of these data sets in a formal inverse model framework requires careful characterization of their error covariances. Daily MOPITT satellite observations and CO data from the TRACE-P aircraft mission over the NW Pacific are applied here to the regional estimation of emissions from Asia for the spring of 2001. We use the GEOS-CHEM global 3-D model of atmospheric chemistry as the forward model. A priori estimates of Asian emissions are based on state-of-the-science gridded inventories for the observation period, including daily satellite fire count data to constrain biomass burning emissions. The derived a posteriori emissions are consistent with the observations, a priori constraints and their respective errors. We account for the model transport error using an innovative approach based on paired forecasts as well as differences between observations and forecasts. This method accounts for the daily spatial correlations of the errors. We examine the sensitivity of the a posteriori source estimates to the structure of the error covariance as well as the complementarity of the satellite and aircraft observations towards constraining the detailed structure of Asian CO sources.

A52C MCC: Level 2 Friday 1330h

Chemistry and Composition of the Troposphere II Posters *(joint with B, GC)*

Presiding: **A H Goldstein,** University of California**; P Novelli,** NOAA Climate Modeling and Diagnostics Laboratory

A52C-0800 1330h POSTER

Comparison of Measured and Modeled Ozone Profiles Above McMurdo Station, Antarctica, During August-October, 1992-2000

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Measurements are needed to understand the present state of the atmosphere while models are required to test our quantitative understanding of complex processes and for future predictions. These models must be validated and tested by detailed comparison with observations. Here, we compare more than 9 years of balloon-borne ozonesonde profile observations at 78°S with calculations from the SLIMCAT 3-dimensional chemical transport model (CTM). The CTM is forced by ECMWF meteorological analyses and has a detailed stratospheric chemistry scheme. Here the model is run on 18 isentropic levels with a horizontal resolution of 7.5°. While SLIMCAT performs well in reproducing total column ozone values as well as the general trends of spring-season ozone depletion in both the Northern and Southern hemispheres, a detailed comparison with austral polar measurements has not been completed. Here, at the vertical resolution of SLIMCAT, we compare modeled and measured ozone mixing ratios (OMR) between 12 and 30km (potential temperatures of ∼330-1000K) over McMurdo Station, Antarctica from 1992 to 2000 in the period of late August to late October. A one-to-one comparison of OMR at the SLIMCAT levels covered by the measurements gives a linear relationship where SLIMCAT OMR = 0.82(Measured OMR)+ 0.54 with R^2 = 0.83. A slope <1 and positive y-intercept correspond to an overestimation of OMR by SLIMCAT, especially in the region of most active ozone destruction (∼12-20km). The overestimation by SLIMCAT is more evident after mid-September of each year during the period of high ozone depletion. The percent differences between the model and measurements through the austral spring seasons range from -50 to 450% in the active region, and are between -50 and 50% above this region (∼20-30km). Some of this discrepancy is related to the extent of ClO activation in SLIMCAT. Preliminary analyses suggest that SLIMCAT is underestimating ClO and thereby overestimating ozone at the altitudes of greatest ozone loss.

A52C-0801 1330h POSTER

NAO signature in tropospheric ozone: data and model analysis

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This study focuses on the NAO signature in the interannual variability of tropospheric ozone, with an emphasis on spring ozone in the northern latitudes of the American and European continents. The analysis is performed on ozonesonde data. It is shown that the variability in NAO significantly modulates the tropospheric ozone with a correlation of ?0.57 in the lower troposphere over North America. Finally, using model results, it is shown that the NAO signal is global in nature.

A52C-0802 1330h POSTER

The Solar Cycle Variation of Ozone and Other Chemical Species in the Stratosphere Simulated With a 3-D Chemistry-Climate Model

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Photochemical reactions in the atmosphere are induced by ultraviolet (UV) radiation from the sun. Radiation from the sun shows an 11-year oscillation, in which total irradiance changes are relatively small. But more than 10 % irradiance changes occur in ultraviolet (UV) radiation. The photochemical reactions, therefore, are influenced by the solar cycle variation. The response of the stratospheric ozone particularly could have an impact on Earth's climate. We have analyzed the results of a three-dimensional chemistry-climate model of the Meteorological Research Institute (MRI) in order to evaluate the sensitivity of ozone and other chemical species in the stratosphere to the solar cycle variation. The dynamical module of the model is based on an atmospheric general circulation model (AGCM), which is developed by MRI and the Japan Meteorological Agency (JMA). The chemical module includes 49 chemical species, 34 photolysis reactions, 79 gas phase reactions, 5 heterogeneous reactions on polar stratospheric clouds (PSCs), and 2 heterogeneous reactions on sulfate aerosols. Chemical species are transported with semi-Lagrangian scheme.

A52C-0803 1330h POSTER

Effect of the Horizontal Resolution of General Circulation Model on the Ozone Distribution Simulated by Chemical Transport Model

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Effect of the horizontal resolution of winds and temperature used in the transport of chemical species are investigated with a 3-D chemical transport model of Meteorological Research Institute, MJ98-CTM. The vertical resolution is fixed to be 45 layers extending from the surface to 0.01 hPa (about 80 km), while the horizontal resolution of GCM module is varied. Control run uses T21 resolution both for GCM and CTM modules, and experiment run uses T42 resolution for GCM module. T21 and T42 resolutions correspond to 300 km and 600 km grid sizes, respectively. GCM module is a full primitive spectral model, which includes major physical processes. CTM module treats 34 long-lived species including 7 families, and 15 short-lived species with 79 gas phase reactions, 34 photochemical reactions and 9 heterogeneous reactions on polar stratospheric clouds and sulfate aerosols. Transport scheme is a flux form semi-Lagrangian type in the vertical and, at once, a simple semi-Lagrangian type in the horizontal with cubic interpolation. Greenhouse gases are not treated interactively, i.e., CTM-simulated ozone, methane and nitrous oxide are not used in the radiation scheme in GCM module. Climatological values of sea surface temperature and greenhouse gases for GCM module are used and so do those of tropospheric-origin species for CTM module. Time integration is made for five years and the control run of T21-GCM coupled with T21-CTM (T21-T21) and the experiment run (T42-T21) are compared for the simulated fields of chemical species, focusing on ozone. Since the increase in GCM horizontal resolution does not necessarily improve simulated fields of winds and temperature, similar experiment is also made with the nudging force toward observed winds and temperature.

A52C-0804 1330h POSTER

Trajectory Assisted Analysis of Long-Term Ozonesonde Data Over N. America: A Comparison With Europe and East Asia

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