The trajectories were calculated using the FLEXTRA model v3.3 (*Stohl et al., 1999*). The most important factor determining the atmospheric concentrations besides the greenhouse gas emission strengths obviously is the atmospheric mixing layer height. This mixing height is determined in the model by following a critical Richardson number scheme. We used a long time series of 3 years of continuous high precision vertical concentration gradient measurements of CH_4 and N_2O at the tall tower of Cabauw in the center of the Netherlands to derive estimates of the West European spatial distribution of emissions of these gases and the corresponding trends. The forward and inverse calculations and the high resolution vertical concentration gradient data provide maps of both the local and more remote distribution of the sources. The inverse calculation uses the SVD matrix inversion technique to determine the best fitting solution to the overdetermined system that follows from the combination of the source receptor matrix derived from the trajectory model and the observed concentration data. The resulting best estimate for the emissions of CH_4 are for most parts of Western Europe in agreement with the current inventory data. The inherent uncertainty of the transport model and measurements and how these uncertainties translate into the uncertainty of the inverse calculated emissions is estimated by using a Monte Carlo error analysis technique. Other error estimations are determined from using ensemble trajectories with horizontal and vertical deviations. Several problems related to solving overdetermined problems still remain and options to overcome these will be discussed. **References**

Stohl, A., L. Haimberger, M.P. Scheele, and H. Wernli (1999): An intercomparison of results from three trajectory models. Meteorol. Applications 8, 127-135.

A51B-05 0900h INVITED

How Well Can We Constrain Regional CO2 Budgets Using Inverse Models?

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The atmospheric distribution of CO2 is the 4D response to surface CO2 sources and sinks (or forcing), and the (incomplete) mixing by the atmospheric circulation. Commonly used inversion techniques divide the total forcing spatially and temporally into regions and periods with unknown forcing strengths, and seek the optimal set of forcing strengths that best produces the observed response, in the context of an atmospheric circulation/ transport model. Because of the rapidity of CO2 mixing in the atmosphere, the sparsity of atmospheric observations, the heteorogeneity of the land surface, and high-frequency variability of surface fluxes, current inversion methods have yielded source strengths only for large spatial regions. In this paper, we review what we have learned about carbon sources and sink through inverse modeling, and explore how we could use satellite observations and ground-based ecological observations in inverse models for improving the resolution of CO2 sources and sinks.

A51B-06 0915h

Inverse Modeling of Carbon Monoxide Surface Sources Using MOPITT Satellite Data

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Carbon monoxide CO is a key component of the troposphere. It is the principal sink of hydroxyl radicals OH in the free troposphere (CO global mean lifetime is about 2 months) and thus it controls indirectly the lifetime of many other species, such as methane CH4. In the presence of nitrogen oxides, NOx ($> 10 - 15$ pptv), and sunlight, CO is a precursor of tropospheric ozone O3. The processes leading to the emission of CO are fairly well established. CO is a byproduct of fossil fuel use and incomplete biomass combustion. The incomplete oxidation of hydrocarbons also produces substantial amounts of CO. Uncertainties attached to CO sources are still high and, as a result, the comparison of model results and observations can show large discrepancies. These discrepancies are used to optimize the monthly sources of CO over large regions for the period April 2000 to March 2001.

A51B-07 0930h

Inverse Modeling of CO_2 Sources and Sinks Using Satellite Data: A Synthetic Inter-comparison of Measurement Techniques and Their Performance as a Function of Space and Time

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Several measurement concepts have been proposed for measuring CO_2 from space. Currently, the AQUA and ENVISAT satellites are in orbit and the possibility to retrieve CO_2 from their instruments (AIRS and SCIAMACHY) is being investigated. Measurements from satellites in combination with inverse modeling techniques might lead to significantly improved CO2 flux estimates. We conducted synthetic inverse modeling experiments to investigate the expected performance of several measurement techniques including those used in AIRS, SCIAMACHY and the planned OCO mission. Our inverse modeling set-up solves for fluxes on a global domain and at a relatively high resolution (8x10 degree). This allows us to study the performance of the instruments as a function of temporal and spatial scale. Our results show characteristic strengths and weaknesses of the techniques that were tested, emphasizing the importance of a high measurement sensitivity to CO_2 near the surface and global coverage. An analysis will be presented of the scales that are resolved by the satellite measurements and how they compare with the current surface networks. We will address the issue of instrument precision requirements, and suggest realistic scientific aims of instruments that are in flight at present. Finally, we'll give recommendation for future research and discuss potentially promising new instrument concepts.

A51B-08 0945h

Continental-scale partitioning of fire emissions during the 1997-2001 El Niño / La Niña period

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During the 1997-1998 El Niño event, the terrestrial biosphere experienced drought conditions that triggered widespread increases in fire activity. We combined satellite-based estimates of the timing and spatial distribution of fires, biogeochemical modeling, and an inverse analysis of atmospheric CO anomalies to evaluate the contribution of fire emissions from different continents to trace gas variability during this period. While anomalously high fire emissions from Southeast Asia accounted for 60% of the global fire emissions anomaly during the El Niño period, our analysis identified that significant, and previously underestimated, contributions from Central America (20%) northern boreal regions (10%), and South America (south of the equator; 10%) were also critically important in terms of explaining observed atmospheric trace gas anomalies. Globally, total carbon emissions from fires were 2 Pg C/yr higher in 1998 than in 2000, and accounted for 2/3 of the CO2 growth rate anomaly during late 1997 and early 1998.

A51C MCC: 3020 Friday 0800h

Deep Convective Transport *(joint with SA, AE)*

Presiding: **E Ray,** NOAA Aeronomy Laboratory**; J W Elkins,** NOAA Climate Monitoring and Diagnostics Laboratory

A51C-01 0800h

Evidence of Deep Convective Transport of Reactive Constituents to the Tropical Tropopause Layer Using Convective Influence Calculations

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Isentropic convective influence calculations are performed to identify upstream convective systems impacting air sampled just below the subtropical and tropical tropopause on a flight of the NASA WB-57F from Houston, Texas south to 5°N during the September 1999 airborne mission Atmospheric Chemistry of Combustion Effects Near the Tropopause (ACCENT). Interpretation of ensembles of in situ tracer measurements, in particular NO_y, O_3, and CH_3I, have indicated that much of the air sampled on this flight had been recently injected by deep convection, although from non-pristine marine boundary layers. In addition there were more limited stretches of the flight track with evidence of biomass burning and industrial sources. Consistent with this finding, convective influence calculations indicate that the great majority of the parcels along the flight track had been affected by deep convective events at some time in the seven days preceding the flight; the majority of these were oceanic systems. Under the anticyclonic upper tropospheric flow pattern prevailing north of $\sim 11^{\circ}$N, the marine convective influence came from systems in the Gulf of Mexico, around Cuba and over the waters east of the Bahamas. Influence from continental systems was sporadic except for one extended portion of the track with air that the calculations indicated had been injected by land-based systems over Guatemala within the previous 12-24 hours. South of $\sim 11^{\circ}$N, a group of systems east of the Lesser Antilles were major contributors of marine influence. However, as the aircraft approached its turnaround at 5°N, the calculations also show influence from land-based systems over Colombia, consistent with the tracer measurements. One important feature of the results is that the convective influence over the course of the 2600-km flight track is derived from a relatively small number of systems. This is a direct result of the minimal dispersion of the trajectories, particularly those emanating from the marine systems. This can be understand as a consequence of the weak shears in this anticyclonic, summer hemisphere circulation and suggests that, in the tropical troposphere layer at least, the tracer profiles of individual air masses are likely to persist far longer than in the dynamical rough and tumble near the jet streams and other more strongly sheared or vertically mixed environments.

A51C-02 0820h

Observations of deep convective transport of reactive constituents to the tropical and mid-latitude tropopause region

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Measurements of ozone, reactive carbon and nitrogen, and other trace constituents from flights of the NASA WB-57 aircraft in the upper troposphere and lower stratosphere reveal that convection in the tropics can present a complex mix of surface emitted constituents right up to the altitude of the lapse rate tropopause. Trace gas measurements indicate that surface emissions from biomass burning, industrial combustion and processing, and marine biogenic sources were present in the upper troposphere during most research flights during the ACCENT mission during September, 1999. At latitudes over the southern US, the strongest detrainment, in terms of constituent mixing ratios, occurred in the potential temperature range of 340-350o K or approximately over the altitude range of 9-11 km, but weaker detrainment signals were also seen up to near the tropopause. There was no evidence of convective detrainment directly into the lower stratosphere from these flights.

A51C-03 0840h

CARIBIC Observations of Non-Methane Hydrocarbons (NMHCs) in the UT/LS: Biomass Burning in the Tropics and Anthropogenic Pollution in the Extra-Tropics

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CARIBIC (Civil Aircraft for the Regular Investigation of the atmosphere Based on an Instrumented Container) used a Boeing 767 on intercontinental flights to measure trace gases and aerosols between November 1997 and April 2002. From April 2004 onwards, a new Lufthansa Airbus A340-600 with a new inlet system and measurement container with 16 experiments will become operational. Here we discuss the results for NMHCs for a flight from the Maldives to Germany, June 2000. Twelve air samples of 350 L were collected and analyzed in the laboratory for NMHCs, halocarbons, CH_4, CO, N_2O, SF_6, and isotopic compositions in CO and CO_2. In the upper troposphere (UT) of the tropics, the concentrations of saturated NMHCs ($C2 - C6$) were significantly lower and less variable than in the extra-tropics, likely due to enhanced photooxidation in summer. A good correlation between long-lived NMHCs and CO, and their emission ratios imply that the air masses come from biomass burning regions. By contrast, the concentrations of all saturated NMHCs in the extra-tropics were greatly augmented. In particular, very high concentrations of several short-lived NMHCs, i.e., *n*-pentane, *i*-pentane, *n*-hexane, were observed near or even in the lowermost stratosphere (LS). Tight anti-correlations between CO and O_3, the enhancement of ultra-fine particles, and the calculated backward trajectories indicate the occurrence of deep convection of highly polluted air from southern Europe into the lowermost stratosphere. The CARIBIC findings show a direct (fast) injection of polluted air to be a significant source of NMHCs observed in the lowermost stratosphere in the extra-tropics.

URL: http://www.caribic-atmospheric.com

A51C-04 0900h

Preferred Pathways of Tropical Troposphere-to-Stratosphere Transport

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From an analysis of trajectory calculations in the tropical tropopause layer (TTL) based on ECMWF analysis data, we infer typical pathways of tropical troposphere-to-stratosphere transport (TST) for January/February and July/August 2001. It is shown that TST does not occur zonally uniform, but that preferred pathways exist. In particular, the Western Pacific region shows three features which render this region of particular importance for TST. First, its unprecedented convective mass flux into the TTL accounts for about 80% of TST. Second, its tropopause temperatures are lowest, and third, the upper level circulation of the Asian-Australian monsoon ensures that about 70% of TST is transported through this particularly cold region, such that the amount of water entering the stratosphere is found to be largely controlled by these temperatures. In addition to the upper-level circulation of the Asian-Australian Monsoon, the equatorial Easterly Jet and the northern Subtropical Jet are of importance for TST, transporting air from convective outflow over the Western Pacific to the Indian Ocean and Africa, or eastward to South America and Africa, respectively. During ascent in the TTL, air parcels typically travel 5'000-10'000 kilometers in the horizontal before they enter the stratosphere. While we cannot exaplain stratospheric water trends from the analysis of one year, it is conceivable that even minor changes in the pathway of tropical TST could account for changes in stratospheric water.

A51C-05 0915h

Characteristics of Convective Cloud Systems Over Costa Rica, Darwin and Guam for CRYSTAL

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Three possible sites have been chosen for the next phase IOP of CRYSTAL. In order to facilitate the site selection, convective life cycle statistics have been derived for each location. Frequent isolated convective systems would be ideal to monitor the transition of convective anvils into upper tropospheric cirrus. Full-scale convection is difficult to monitor with aircraft given the turbulence and its effect on landing. Conversely, long periods with little convective activity would limit the effectiveness of the field campaign. For this study, the GOES-8 4km IR hourly images over Costa Rica during July of 2002, and GMS-5 5km IR hourly images for Guam during July of 2002 and Darwin during January of 2002 were used. For each site large and small domains were determined to depict the conditions of the ground sites and aircraft flight ranges and are further subdivided into land and ocean regions. IR thresholds were used to estimate convective and anvil areal coverage. The areal coverages were also used to determine the diurnal cycle amplitude and Fourier analysis to determine the diurnal cycle consistency. For each site, isolated discernable anvils were visually inspected in order to record the convective diameter and anvil length for each IR image from the onset of convection to dissipation. Convective and anvil duration frequencies were computed and compared with previous CRYSTAL-FACE results. Also comparisons of convective diameters and anvil lengths will be presented. Results indicate that Darwin and Guam have the greatest areal coverage of convective systems and the Florida domain has the smallest. Darwin has the greatest diurnal convective cycle and matches that of Florida. The convective and anvil durations for all three sites are similar, but limited by the hourly and spatial resolution of the IR images, since the tracking of anvil dissipation is difficult. In any case anvils persist longer than those of CRYSTAL-FACE and cover greater areas.

A51C-06 0930h

Tropical deep convection observed by TRMM satellite

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Incomplete knowledge of cloud radiative properties of tropical deep convective clouds (DCC) and their responses to sea surface temperature (SST) variations causes large uncertainties in climate change predictions of general circulation models. This study uses more accurate and complete TRMM satellite datasets to answer some related fundamental questions. The measurements from multiple instruments on board TRMM satellite are collocated into an integrated data set, that is, this study combines the DCC data of CERES shortwave (SW) and longwave (LW) measurements, CERES cloud properties obtained from narrowband VIRS visible and infrared measurements, and TMI microwave retrievals of precipitation, water cloud properties, boundary layer moisture, and sea surface evaporation. Additionally, the variations of these DCC properties with SST, wind fields, and other environmental conditions are investigated. The study finds that most DCCs have effective radii less than 400km with some systems larger than 800km. DCC occurrences generally increase with SST, especially when SST reaches about 301K. For the warmest SST (> about 304K) DCC frequencies drop significantly due to a smaller total area having that high SST. Less favorable boundary conditions for convergence may be another reason. Although DCC rain rates increase with SST, the change of DCC size is not significant. Large-scale dynamics also play important roles.

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A51C-07 0945h

Interaction Between Troposphere And Lower Stratosphere Associated With The Passage Of A Tropical Cyclone Over India

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Changes in the characteristics of the troposphere and lower stratosphere associated with the passage of a tropical cyclone has been studied using MST radar observations at Gadanki (13.5^0N, 79.2^0E), India. A tropical cyclone formed as a low pressure on 14th October 2001 in the west central Bay of Bengal developed into a deep depression by 15th October morning. This system intensified into a cyclonic storm on the same day evening, crossed over Gadanki on 16th October morning. In addition to the regular daily MST radar observations at 0930 hrs, special observations of 1-hour interval for 32 hours and 4-minute interval continuous observation during the time of cyclone over the station have been utilized for the study. The horizontal wind velocity components show considerable changes in the upper troposphere and lower stratosphere during the passage of the cyclonic storm, whereas the vertical wind show significant changes at 10 - 12 km level. The upper troposphere experiences strong northeasterly wind components during the passage of the cyclonic storm over the station. In lower levels, the magnitude of the wind speed is quite low, but the wind direction changes from northeasterly to southwesterly. After the passage of the cyclonic storm upper tropospheric wind speed reduces considerably, whereas the mid-tropospheric wind speed increases. In order to understand the dynamical interaction between the troposphere and lower stratosphere associated with the passage of the cyclonic storm, the zonal and meridional momentum flux transport in the vertical has been carried out. Considerable changes in the flux transport is noted in the upper troposphere and lower stratosphere.