

precipitation totals in this region show a smaller than observed interannual variability and a weak response to changes in SSTs. To understand the reasons behind the CCM3 misrepresentation of monsoonal processes in the NAMS region, we have chosen to examine model simulation during two extreme years: 1984 (wet) and 1993 (dry). These two years were selected according to observed precipitation totals in the northernmost portion, i.e. Arizona and New Mexico, of the NAMS region.

Ensemble AMIP-type simulations with CCM3 in its standard configuration (i.e., at T42 resolution and coupled to its standard land surface model; LSM) show only small differences in precipitation over the NAMS region between the two chosen extreme years. When CCM3 is coupled to BATS and integrated over several years with SSTs for the two contrasting years, the differences in summer precipitation remain much smaller than the observed differences. In a final experiment, CCM3 is coupled to the fine-mesh version of BATS (named HRBATS), which is described in Hahmann and Dickinson (2001). This model allows for explicit representation of sub-grid variations in vegetation and soils and the inclusion of fractional ocean areas. In these simulations, a very pronounced difference in precipitation, comparable to the observed precipitation differences, is seen between the two contrasting years. The possible physical mechanisms that might explain these differences are explored in this talk. Possible reasons include the presence of the waters of the Gulf of California, which might provide a moisture source, and the better representation of snow cover over the prior winter and spring seasons.

### A32C-03 1405h

#### Examinations of Linkages Between the Northwest Mexican Monsoon and Great Plains Precipitation

Stephen M Saleeby<sup>1</sup> (970-491-8424; smsaleeb@atmos.colostate.edu)

William R Cotton<sup>1</sup> (970-491-8593; cotton@atmos.colostate.edu)

<sup>1</sup>Colorado State University, Department of Atmospheric Science Colorado State University, Fort Collins, CO 80523, United States

The Regional Atmospheric Modeling System (RAMS) is being used to examine linkages between the Mexican monsoon and precipitation in the Great Plains region of the United States. Currently, available datasets have allowed for seasonal runs for July and August of the 1993 flood year in the midwest US and the 1997 El Niño year. There is also a plan to perform a full monsoon season simulation of the drought summer of 1988 once precipitation data becomes available. Preliminary results of this ongoing study are presented here.

The model configuration consists of a 120km resolution coarse grid that covers a region from west of Hawaii to Bermuda and from south of the equator up into Canada. Two 40km resolution nested grids exist, with one covering the western two-thirds of the United States and Mexico and the other covering the Pacific ITCZ. A 10km fine grid and 2.5km cloud resolving grid are spawned over the region of monsoon surges to explicitly resolve convection. The model is initialized with NCEP reanalysis data, surface obs, rawinsonde data, variable soil moisture, and weekly averaged SST's. RAMS is running with two-stream Harrington radiation, one moment microphysics, and Kuo cumulus parameterization.

The completed 1993 and 1997 seasonal simulations are now being examined and verified again NCEP reanalysis data and high resolution precipitation data. Initial model results look promising when verified against the NCEP upper level fields, such that the model is able to capture the large scale dynamics. For the duration of both seasonal runs, RAMS successfully simulates the mid and upper level geopotential heights, the temperature, and winds. The large scale 700mb and 500mb anti-cyclone over the US and Mexico is resolved, as well as the easterly flow over Mexico. Model fields are also being examined to isolate monsoon surge events which are characterized by increased precipitation over the Sierra Madres and a northward moisture surge into the northern extent of the Gulf of California and southern Arizona.

Within the coarse grids, the RAMS model has successfully resolved the low-level jet that persists in the Gulf of California and the local maximum in mixing ratio that persists over the gulf. It has also captured the upslope flow over the Sierra Madres that forces the moist air into the higher elevation to the east. This provides the necessary lifting and moisture for the development of intense convection and resulting large amounts of precipitation that occur along the Sierra Madre mountain range. Examination of model-predicted low-level moisture transport reveals that moisture advected from the Gulf of California is the primary monsoon moisture source, rather than the Gulf of Mexico. Time averages of moisture transport, mixing ratio, winds, and precipitation for July 1993 reveal the prominent diurnal cycle variations that exist due to radiative effects and land-sea interactions; the maximum in convection, precipitation rate, and moisture transport occurs around 00Z.

Seasonal accumulated precipitation amounts in the model are successful in predicting the placement of precipitation and relative amounts for most of the 40km continental grid, but there is an overestimation of precipitation along the northern Sierra Madre Occidental and an underestimation in the US mid-west. During the 1993 flood summer, much of the mid-west US precipitation fell in association with mesoscale convective systems; it is suspected that other cumulus parameterizations may provide better prediction of sub-grid scale convective precipitation.

URL: <http://hugo.atmos.colostate.edu/www/monsoon/monsoon.html>

### A32C-04 1420h

#### Stretched grid GCM simulations of the onset of the North American Monsoon

E. Hugo Berbery<sup>1</sup> (301 405 5351; berbery@atmos.umd.edu)

Michael Fox-Rabinovitz<sup>2</sup> (foxrab@atmos.umd.edu)

<sup>1</sup>E. Hugo Berbery, Department of Meteorology 3427 CSS Bldg University of Maryland, College Park, MD 20742, United States

<sup>2</sup>Michael Fox-Rabinovitz, ESSIC/Department of Meteorology University of Maryland, College Park, MD 20742, United States

Numerical experiments with a variable resolution general circulation model (GCM) are employed to investigate the mesoscale features of the circulations associated with the North American monsoon. The GEOS (Goddard Earth Observing System) stretched-grid (SG) GCM with enhanced resolution over the U.S. was run with two SG-configurations. The first configuration is obtained by redistribution of the grid points originally at a global uniform 2x2.5 degree grid, while the second one redistributes a 1x1 degree grid. The stretched grids have approximately 60 km and 40 km uniform resolution over the U.S., and immediate vicinity, for the model dynamics and orography, while physics is resolved at a 2x2.5 and 1x1 degree uniform global resolutions, respectively. Along with higher regional resolution, the 40km/1x1 grid has better resolved the land-sea differences.

Earlier research has shown that mesoscale components (not simulated by typical global models) are critical to resolve the monsoonal circulations over North America. Here, four subregions of interest were identified; they are the core monsoon region in Northwestern Mexico, the Arizona monsoon, the southern Great Plains and the northern Great Plains. The evolution of precipitation during the 1993 warm season for each region was analyzed and compared to high resolution rain gauge observations. The onset of precipitation over Arizona occurred about one month after the onset at the core monsoon region, although this may vary from season to season. The simulations also reproduce the decay of precipitation over the southern Great Plains that has been linked to the onset of the monsoon; over the northern Great Plains, where historical flood records were broken, heavy precipitation was also reproduced, both in intensity and frequency.

Results also indicate that the two configurations adequately represent the main components of the monsoon and its onset, but the 40 km/1x1 version also resolves the low-level jet over the Gulf of California that develops in conjunction with the onset of precipitation over Arizona. On the other hand, this jet was not captured by the 60 km/2x2.5 version suggesting that both the dynamical forcing (including orography) and the physical forcing (including land/sea differences) need to be adequately resolved to reproduce the structure of the monsoon. It is suggested that 40 km/1x1 or finer resolutions are needed for efficient representation of mesoscales in SG-GCM simulations.

### A32C-05 1435h

#### SEASONALITY OF MODEL-BASED MOISTURE-FLUX QUANTITIES OVER THE NORTH AMERICAN MONSOON REGION

David A Salstein<sup>1</sup> (781-761-2288; salstein@aer.com)

Richard D Rosen<sup>1</sup> (781-761-2288; rdrosen@aer.com)

<sup>1</sup>Atmospheric and Environmental Research, Inc., 131 Hartwell Ave., Lexington, MA 02421

We examine differences among atmospheric general circulation models in their ability to reproduce the seasonal variation in the distribution of moisture and its fluxes over the continental United States, using results from the second Atmospheric Model Intercomparison Project. Currently output from 16 models is available from the AMIP-2 experiment, which covers the period 1979-1995. The model moisture flux divergence is calculated from the difference between evaporation and precipitation fields using the water balance equation, and it is compared against the vapor divergence in the NCEP-NCAR reanalysis. Water vapor fluxes from the reanalysis indeed reveal a distinct seasonal cycle, with

inflow from the Gulf of Mexico, becoming particularly strong in the summer. In fact, summer is the only season in which evaporation exceeds precipitation in the models over the conterminous US, leading to an overall moisture flux divergence. Focusing on the North American Monsoon Experiment domain 2, model and reanalysis results indicate a northward advance of moisture flux divergence from May to August, with a subsequent retreat southward by October. Model precipitation has a similar signature, though it fails to reach as northern a latitude as that of the reanalysis. Monthly anomalies in the time series of model-based moisture divergence over the NAME-2 region reveal some especially strong years, though not well correlated with the estimates from the reanalysis. We analyze in detail the Sud and Walker NASA/GSFC model to diagnose the capability of a GCM with sophisticated cloud and boundary-layer physics to produce this seasonal progression of the moisture flux divergence.

### A32C-06 1450h

#### Interannual Rainfall Variations in the North American Summer Monsoon Region

Qi Hu (402-472-6642; qhu2@unl.edu)

University of Nebraska-Lincoln, 237 L.W. Chase Hall, Lincoln, NE 68583-0728, United States

The following questions are addressed in this study using an array of data and statistical methods: 1) does the North American monsoon region have a single dominant monsoon system, 2) if it has more than one, what are they, and 3) what are major causes of interannual monsoon rainfall variations in these systems? Results showed two dominant summer monsoon systems in the region: one in south-central Mexico, south of 26°N latitude, and the other in the southwestern United States and northwestern Mexico. Monsoon rainfall variations in these regions are usually opposite to each other and have different causes. The interannual variations in monsoon rainfall in south-central Mexico were highly affected by interannual variations in the Intertropical Convergence Zone (ITCZ) in the eastern tropical PacificA northern (southern) position of the ITCZ, often related to cooler (warmer) than normal sea surface temperatures in the eastern tropical Pacific Ocean, corresponded to strong (weak) monsoon.

The land memory effect was evident in interannual variations of monsoon rainfall in the southwestern United States, showing by strong correlations of the summer rainfall variation vs. antecedent winter precipitation anomalies in the western United States. However, the effect was not robust but varied fairly regularly. It was strong from approximately 1920-1930 and disappeared from 1931-1960. It regained its strength from 1961-1990 but weakened again since 1990. The forcing of this variation was identified as a multidecadal variation in atmosphere circulations in the North Pacific-North American sector and the land memory effect is part of this variation. This multidecadal variation has to be included in prediction methods in order for them to correctly describe seasonal and interannual variations in summer rainfall in the North American monsoon region.

### A32D MC: 133 Wednesday 1330h

#### Advances in Aerosol Science and Technology II

Presiding: K D Perry, San Jose State University; L A Barrie, Pacific Northwest National Laboratory

### A32D-01 1330h

#### An Overview of the ACE-Asia Aerosol Characterization Experiment Intensive Observations During the Spring of 2001

Barry J Huebert (1-808-956-6896; huebert@soest.hawaii.edu)

University of Hawaii, Dept. of Oceanography, Honolulu, HI 96822, United States

The objectives of the ACE-Asia experiment are to 1) determine the physical, chemical, and radiative properties of the major aerosol types in the Eastern Asia and Northwest Pacific region and investigate the relationships among these properties, 2) quantify the interactions between aerosols and radiation in the Eastern Asia and Northwest Pacific region, and 3) quantify the physical and chemical processes controlling the evolution of the major aerosol types and their physical, chemical, and radiative properties. To achieve these objectives, scientists from 13 countries made intensive observations in the spring of 2001 using three ships,

three aircraft, and dozens of surface sites. The observations were directed using aerosol forecasts from three chemical transport models and real-time lidar data, and were often coordinated with satellite scenes to allow for column closure experiments and ground truth. Most platforms supported coordinated measurements of aerosol chemical and physical characteristics, optical properties, and radiation. The surface and ship sites did time series measurements and long-sampling-time observations, while the aircraft did vertical profiles and large-area spatial mapping for comparison with models. Numerous platform intercomparisons were done to help in harmonizing the many data streams.

The weather was very cooperative, providing us with two major dust storms (dust from one storm was transported to North America and the Atlantic Ocean), frequent regional dust layers, and pollution plumes. Among our many observations is that in the presence of dust, most of the soot and non-sea salt sulfate still reside in a submicron accumulation mode, even though the dust particles may be modified by coagulation with small amounts of soot and other pollutants.

URL: <http://saga.pmel.noaa.gov/aceasia/>

### A32D-02 1350h

#### Shipboard Measurements During ACE-Asia: an Overview

Timothy S. Bates<sup>1</sup> (206-526-6248; bates@pmel.noaa.gov)

Mitsuo Uematsu<sup>2</sup> (81-3-5351-6533; uematsu@ori.u-tokyo.ac.jp)

Kazuhiko Miura<sup>3</sup> (81-3-5228-8215; miura@rs.kagu.sut.ac.jp)

<sup>1</sup>NOAA/PMEL, 7600 Sand Point Way NE, Seattle, WA 98115, United States

<sup>2</sup>Ocean Research Institute University of Tokyo, 1-15-1 Minamidai Nakano-ku, Tokyo 164-8639, Japan

<sup>3</sup>Department of Physics Science University of Tokyo, 1-3 Kagurazaka Shinjuku-ku, Tokyo 162-8601, Japan

Shipboard measurements of aerosol properties and related parameters were conducted from the US NOAA R/V Ronald H. Brown and the Japanese R/V Mirai (MR01-K02) during the ACE-Asia Intensive Field Program (<http://saga.pmel.noaa.gov/aceasia/>). The R/V Brown cruise (14 March - 20 April 2001), with scientists from 22 research institutions, included measurements across the Pacific Ocean from Hawaii to Japan, in the East China Sea and in the Sea of Japan. Measurements were coordinated with the US NSF/NCAR C-130, US CIRPAS Twin Otter, and the Australian ARA King Air Aircraft, Terra and SeaWiFS satellite overpasses, and the ground station at Hachijo, Japan. Distinct aerosol and trace gas signatures were observed from the Miyakejima volcano, the deserts of China and Mongolia, the Chang Jiang Basin, the Korean Peninsula and the islands of Japan.

The R/V Mirai cruise (14 - 28 May 2001), with scientists from 10 research institutions, focused on the region east of Japan along 146.5 E from 30 N to 38 N. Enhanced concentrations of radon and super-micron aerosol were measured in a post-frontal air mass along the 146.5 E transect. Observations from a Kytoon and the NIES two-wavelength (1064 nm and 532 nm) dual-polarization lidar detected dust and sulfate aerosol plumes from the Asian continent. The vertical distribution patterns of the dust and sulfate aerosols qualitatively agreed with the model prediction by the Chemical Weather Forecasting System (CFORS).

URL: <http://saga.pmel.noaa.gov/aceasia/>

### A32D-03 1410h

#### ACE-Asia: Ground Stations Overview

R. Arimoto<sup>1</sup> (arimoto@cemrc.org); N. Sugimoto<sup>2</sup> (nsugimoto@nies.go.jp); A. Shimizu<sup>2</sup> (shimizu@nies.go.jp); JY. Kim<sup>3</sup> (jykim@metri.re.kr); SN. Oh<sup>3</sup> (snoh@metri.re.kr); CH. Kang<sup>4</sup> (changhee@cheju.cheju.ac.kr); Taiwan Asia Science Team<sup>5</sup> (shawliu@earth.sinica.edu.tw); T. Murayama<sup>6</sup> (murayama@ipc.tosho-u.ac.jp); Delta Group<sup>7</sup> (tachahill@ucdavis.edu); XY. Zhang<sup>8</sup> (xiaoye@loess.llqg.ac.cn); YJ. Kim<sup>9</sup>; VMAP Group<sup>10</sup>

<sup>1</sup>New Mexico State University, Carlsbad, NM, USA

<sup>2</sup>National Institute for Environmental Studies, Tsukuba, Japan

<sup>3</sup>Korea Meteorological Administration, Seoul, Korea

<sup>4</sup>Cheju National University, Cheju, Korea

<sup>5</sup>Various Universities and Institutes, Taiwan

<sup>6</sup>Tokyo University of Mercantile Marine, Tokyo, Japan

<sup>7</sup>University of California, Davis, CA

<sup>8</sup>Institute of Earth Environment, Xi'an, PR China

<sup>9</sup>Kwangju Institute of Science and Technology, Kwangju, Korea

<sup>10</sup>University of Tokyo, Japan

Observations of aerosol properties made at a network of ground stations were an integral part of ACE-Asia. During an intensive observation period (IOP, March - May 2001), high dust loadings were observed at many stations. At Zhenbeitai, China mass loadings well above average ( $260 \mu\text{g m}^{-3}$ ) were observed during eleven dust storms, and  $\sim 82\%$  of the total particle mass at the site could be attributed to Asian dust. Daily bulk dust concentrations at Kosan, Korea ranged from 130 to  $350 \mu\text{g m}^{-3}$  from April 10 - 13. Important sub-micron dust signatures were obtained during this storm, coincident with highly absorbing ultra-fine ( $< 0.24 \mu\text{m}$ ) soot and other anthropogenic materials.  $\text{PM}_{2.5}$  aerosol concentrations at Kosan varied from  $15.7$  to  $92.6 \mu\text{g m}^{-3}$  during the IOP. Comparisons with prior data show some evidence for a decrease in the relative amount of nitrate vs. sulfate. An Asian dust storm with peak  $\text{PM}_{10}$  concentrations of about  $200 \mu\text{g m}^{-3}$  was observed over Taiwan on April 12 - 13. While most of the  $\text{PM}_{10}$  was dust, significant levels (up to about 30%) of pollutants also were found. Analysis of this and previous events indicates that the concentrations of pollutants over Taiwan during Asian dust storms are controlled more by long-range transport than local sources. Measurements of aerosols and associated species on four Japanese islands showed clear intermittent transport of continental aerosols, especially at Rishiri. A Mie and Raman lidar system with auxiliary instruments, including a sun photometer, operated at Tokyo during the IOP; some of these data were used for C-130 flight planning. From combined Raman lidar observations of dust at Tokyo, a typical extinction-to-backscatter ratio was found to be  $\sim 40$  sr, ranging from 30 and 70 sr and tending to increase with Angstrom exponent. A lidar intercomparison with C-130 flight observations on April 23 showed widely distributed dust and non-dust aerosols up to 8 km. A multi-channel backscatter lidar system operating at Kosan showed a dust layer with scattering ratio of 13.3 at 5 - 6 km. The height-dependent correlation between the extinction coefficient and the depolarization ratio at Tokyo was consistent with measurements made from the C-130. Dual-polarization Mie-scattering lidars also operated at Beijing, Nagasaki, and Tsukuba during the IOP. Aerosol extinction coefficients were calculated up to 6 km from profiles on clear days. Dusts and other aerosols were distinguished based on depolarization ratios. At Beijing, dust was often detected near the surface, with the events often lasting for several days, sometimes reaching Nagasaki. Few surface dust events were observed at Tsukuba, but several were detected in the free troposphere ( $> 3$  km). Non-dust aerosols (inferred to be pollutants) were detected continuously at all sites. These particles were concentrated at lower altitudes (usually  $< 1$  km) than the dust, occasionally reaching 2 to 3 km.

### A32D-04 1425h

#### Overview of Aircraft Operations during ACE-Asia

John H. Seinfeld<sup>1</sup> (626-395-4635; seinfeld@caltech.edu)

Barry Huebert<sup>2</sup> (808-956-6896; huebert@soest.hawaii.edu)

<sup>1</sup>California Institute of Technology, California Institute of Technology 210-41, Pasadena, CA 91125, United States

<sup>2</sup>Univ. of Hawaii, Dept. of Oceanography Univ. of Hawaii, Honolulu, HI 96822, United States

The NSF/NCAR C-130 flew 19 flights out of Iwakuni, Japan between March 31 and May 4, 2001, and data were collected on 7 ferry flights crossing the Pacific. Many of the instruments derived their air from low-turbulence inlets, which enabled studies of super-micron particles vs altitude. Several flights sampled two heavy dust outbreaks, where the aerosol mass concentration exceeded  $1000 \text{ g/m}^3$ . Size-dependent chemical measurements indicated that this dust did not dramatically change the sulfate size distribution (by causing  $\text{SO}_2$  to convert to sulfate on its alkaline surfaces), since the vast majority of the sulfate was still in a sub-micron accumulation mode. Similarly, while the scattering in dust was dominated by large particles, the particle absorption was almost exclusively submicron. We found extensive layering, with as many as 6 distinct dust layers (and clean layers between them) in one profile to 6 km.

During ACE-Asia research missions were also conducted using a modified De Havilland DHC-6 Twin Otter aircraft operated by the California Institute of Technology and the Center for Interdisciplinary Remotely Piloted Aircraft studies (CIRPAS). A total of 19 research flights were conducted between March 31 and May 1, 2001 from the base of operations at the MCAS Iwakuni, Japan. The sampling area included portions of the Sea of Japan south and east of the Korean Peninsula, the East China Sea between China, Japan and

Korea, and the Philippine Sea south of Japan. Collected aerosols were analyzed to determine their chemical composition and physical properties such as size distribution, hygroscopic growth, light scattering and absorption properties. Simultaneous radiative measurements were also made using the 14-channel Ames Airborne Tracking Sunphotometer (AATS-14), which measured solar beam transmission at 14 wavelengths (353-1558 nm), yielding aerosol optical depth (AOD) spectra and column water vapor (CWV). Vertical differentiation in profiles yielded aerosol extinction and water vapor concentration. The wavelength dependence of AOD and extinction indicates that supermicron dust was often a major component of the aerosol. Frequently this dust-containing aerosol extended to high altitudes.

### A32D-05 1440h

#### Overview of ACE-Asia Spring 2001 Investigations on Aerosol Radiative Effects and Related Aerosol Properties

P. B. Russell<sup>1</sup> (prussell@mail.arc.nasa.gov); F. P. J. Valero<sup>2</sup>; P. J. Flatau<sup>2</sup>; M. Bergin<sup>3</sup>; B. Holben<sup>4</sup>; T. Nakajima<sup>5</sup>; P. Pilewskie<sup>1</sup>; R. W. Bergstrom<sup>6</sup>

<sup>1</sup>NASA, Ames Research Center, Moffett Field, CA 94035, United States

<sup>2</sup>Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA 92093, United States

<sup>3</sup>Georgia Institute of Technology, 200 Bobby Dodd Way, Atlanta, GA 30332, United States

<sup>4</sup>NASA, GSFC, Greenbelt, MD 20771, United States

<sup>5</sup>University of Tokyo, 4-6-1 Komaba, Meguro-Ku, Tokyo 153, Japan

<sup>6</sup>BAERI, NASA Ames, Moffett Field, CA 94035-1000, United States

A primary ACE-Asia objective was to quantify the interactions between aerosols and radiation in the Asia-Pacific region. Toward this end, radiometric and related aerosol measurements were made from ocean, land, air and space platforms. Models that predict aerosol fields guided the measurements and are helping integrate and interpret results. Companion overviews survey these measurement and modeling components. Here we illustrate how these components were combined to determine aerosol radiative impacts and their relation to aerosol properties.

Because clouds can obscure or change aerosol direct radiative effects, aircraft and ship sorties to measure these effects depended on predicting and finding cloud-free areas and times with interesting aerosols present. Pre-experiment satellite cloud climatologies, pre-flight aerosol and cloud forecasts, and in-flight guidance from satellite imagery all helped achieve this. Assessments of aerosol regional radiative impacts benefit from the spatiotemporal coverage of satellites, provided satellite-retrieved aerosol properties are accurate. Therefore, ACE-Asia included satellite retrieval tests, as part of many comparisons to judge the consistency (closure) among diverse measurements.

Early results include:

- Solar spectrally resolved and broadband irradiances and optical depth measurements from the C-130 aircraft and at Kosan, Korea yielded aerosol radiative forcing efficiencies, permitting comparisons between efficiencies of ACE-Asia and INDOEX aerosols, and between dust and "pollution" aerosols. Detailed results will be presented in separate papers.
- Based on measurements of wavelength dependent aerosol optical depth (AOD) and single scattering albedo the estimated 24-h average aerosol radiative forcing efficiency at the surface for photosynthetically active radiation (400 - 700 nm) in Yulin, China is  $\sim -30 \text{ W m}^{-2}$  per AOD(500 nm).
- The R/V Brown cruise from Honolulu to Sea of Japan sampled an AOD gradient, with AOD(500 nm) extremes from 0.1 to 1.1. On the Honolulu-Hachijo transit AOD(500 nm) averaged 0.2, including increases to 0.4 after storms, suggesting the strong impact of wind-generated seasalt. The AOD maximum, found in the Sea of Japan, was influenced by dust and anthropogenic sources.
- In Beijing, single scattering albedo retrieved from AERONET sun-sky radiometry yielded midvisible SSA=0.88 with strong wavelength dependence, suggesting a significant black carbon component. SSA during dust episodes was  $\sim 0.90$  and variable but wavelength neutral reflecting the presence of urban haze with dust. Downwind at Anmyon Island SSA was higher,  $\sim 0.94$ , but wavelength neutral for dust events and spectrally dependent during non dust periods.

- Satellite retrievals show major aerosol features moving from Asia over the Pacific; however, determining seasonal-average aerosol effects is hampered by sampling frequency and large-scale cloud systems that obscure key parts of aerosol patterns. Preliminary calculations using satellite-retrieved AOD fields and initial ACE-Asia aerosol properties (including sulfates, soot, and dust) yield clear-sky aerosol radiative effects in the seasonal-average ACE-Asia plume exceeding those of manmade greenhouse gases. Quantifying all-sky direct aerosol radiative effects is complicated by the need to define the height of absorbing aerosols with respect to cloud decks.

URL: <http://geo.arc.nasa.gov/sgg/ACE-Asia/>

#### A32D-06 1455h

### Transport of Aerosols From Asia and Their Radiative Effects Over the Western Pacific: A 3-D Model Study for ACE-Asia Experiment During Spring 2001

Mian Chin<sup>1</sup> (301-614-6007;

chin@rondo.gsfc.nasa.gov); Paul Ginoux<sup>1</sup> (301-614-6035; ginoux@rondo.gsfc.nasa.gov); Piotr Flatau<sup>2</sup>, Tad Anderson<sup>3</sup>, Sarah Masonis<sup>3</sup>, Philip Russell<sup>4</sup>, Beat Schmid<sup>4</sup>, John Livingston<sup>4</sup>, Jens Redemann<sup>4</sup>, Ralph Kahn<sup>5</sup>, Omar Torres<sup>6</sup>, Christina Hsu<sup>6</sup>

<sup>1</sup>Georgia Tech/NASA GSFC, NASA Goddard Space Flight Center, Code 916, Greenbelt, MD 20771, United States

<sup>2</sup>Scripps Institution of Oceanography, Center for Atmospheric Sciences, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA 92093, United States

<sup>3</sup>University of Washington, Dept. of Atmospheric Science, University of Washington, Seattle, WA 98195, United States

<sup>4</sup>NASA Ames Research Center, NASA Ames Research Center, Moffett Field, CA 94035, United States

<sup>5</sup>Jet Propulsion Laboratory, Jet Propulsion Laboratory, MS 169/237 4800 Oak Grove Dr., Pasadena, CA 91109, United States

<sup>6</sup>University of Maryland at Baltimore County, NASA Goddard Space Flight Center, Code 916, Greenbelt, MD 20771, United States

The Aerosol Characterization Experiment-Asia (ACE-Asia) took place in Spring 2001 in the East Asia-West Pacific Ocean. During the ACE-Asia intensive field operation period, high concentrations of dust and anthropogenic aerosols were observed over the Yellow Sea and the Sea of Japan, which were transported out from the Asian continent, with the plume often extending to 6-8 km altitude. The multi-component aerosols originated from Asia are expected to exert a significant radiative forcing over the Pacific region. We present here results from the Georgia Tech/Goddard Global Ozone Chemistry Aerosol Radiation and Transport (GOCART) model of aerosol transport and radiative forcing in the context of ACE-Asia. The model calculated aerosol concentrations, extinctions, optical thickness, size distributions, and vertical profiles are compared with the aircraft and ship measurements, and the distributions of aerosols are compared with satellite data. The model will be used to understand the origins of the aerosols observed in ACE-Asia, estimate the contributions from anthropogenic and natural aerosols to the total aerosol optical thickness, investigate the effects of humidification and clouds on aerosol properties, and assess the radiative forcing of Asian aerosols over the Pacific region and in the northern hemisphere.

#### A32D-07 1530h

### Aerosol Optical Properties and Chemical Composition Measured on the Ronald H. Brown During ACE-Asia

Patricia K Quinn<sup>1</sup> (206-526-6892; quinn@pmel.noaa.gov)

Timothy S Bates<sup>1</sup> (206-526-6248; bates@pmel.noaa.gov)

Theresa L Miller<sup>1</sup> (206-526-6220; tmiller@pmel.noaa.gov)

Derek Coffman<sup>1</sup> (206-526-6574; derek@pmel.noaa.gov)

<sup>1</sup>NOAA PMEL, 7600 Sand Point Way NE, Seattle, WA 98115, United States

Measurements of aerosol chemical, physical, and optical properties were made onboard the NOAA R/V

Ronald H. Brown during the ACE-Asia Intensive Field Program to characterize Asian aerosol as it was transported across the Pacific Ocean. The ship traveled across the Pacific from Hawaii to Japan and into the East China Sea and the Sea of Japan. Trajectories indicate that remote marine air masses were sampled on the transit to Japan. In the ACE-Asia study region air masses from Japan, China, Mongolia, and the Korea Peninsula were sampled. A variety of aerosol types were encountered including those of marine, volcanic, crustal, and industrial origin.

Presented here, for the different air masses encountered, are aerosol optical properties (scattering and absorption coefficients, single scattering albedo, Angstrom Exponent, and aerosol optical depth) and chemical composition (major ions, total organic and black carbon, and trace elements). Scattering by sub-micron aerosol (55 % RH and 550 nm) was less than 20 1/Mm during the transit from Hawaii to Japan. In continental air masses, values ranged from 60 to 320 1/Mm with the highest submicron scattering coefficients occurring during prefrontal conditions with a low marine boundary layer height and trajectories from Japan. For the continental air masses, the ratio of scattering by submicron to sub-10 micron aerosol during polluted conditions averaged 0.8 and during a dust event 0.41. Aerosol optical depth (500 nm) ranged from 0.08 during the Pacific transit to 1.3 in the prefrontal conditions described above. Optical depths during dust events ranged from 0.2 to 0.6.

Submicron non-sea salt (nss) sulfate concentrations ranged from 0.5  $\mu\text{g}/\text{m}^{-3}$  during the Pacific transit to near 30  $\mu\text{g}/\text{m}^{-3}$  during the prefrontal conditions described above. Black carbon to total carbon mass ratios in air masses from Asia averaged 0.18 with highest values (0.32) corresponding to trajectories crossing the Yangtze River valley.

#### A32D-08 1545h

### Dust Characteristics over the North Pacific Observed with Shipboard Sampling During ACE-Asia

Yuan Gao<sup>1</sup> (1-609-258-0625; yuangao@splash.princeton.edu)

James R. Anderson<sup>2</sup> (1-480-965-7139; janderson@asu.edu)

Xin Hua<sup>3</sup> (1-480-727-7138; huaxin@asu.edu)

Monica D. Rivera<sup>4</sup> (1-609-258-6670; mrivera@princeton.edu)

<sup>1</sup>Princeton University, Program in Atmospheric and Oceanic Sciences, Princeton, NJ 08544-0710, United States

<sup>2</sup>Arizona State University, Program in Environmental Fluid Dynamics, Tempe, AZ 85287, United States

<sup>3</sup>Arizona State University, Department of Geological Sciences, Tempe, AZ 85287, United States

<sup>4</sup>Princeton University, Department of Civil and Environmental Engineering, Princeton, NJ 08544, United States

Aerosol sampling was conducted aboard the NOAA R/V Ronald H. Brown between Hawaii (20°N, 156°W) and Hachijo (33°N, 137°E) as part of the Asian Pacific Regional Aerosol Characterization Experiment (ACE-Asia) during March and April 2001. Aerosol samples collected with a streaker sampler were selected from 10 locations along 32°N between 140°E and 170°W on the path of Asian dust transport in the spring. A total of 12,427 particles were examined by individual-particle analysis to characterize dust properties. Here we report the results on the concentrations, chemical composition, shape, and size-distributions of dust particles in the marine boundary layer over this part of the global ocean. The non-spherical nature along with heterogeneous characteristics in dust particles will be highlighted. We will also discuss the potential application of these findings on dust to radiative transfer calculations and oceanic biogeochemical cycles.

#### A32D-09 1600h

### Spectral Radiative Forcing of the ACE-Asia Aerosol Observed During the NOAA Ship R. H. Brown Cruise

Andrew M Vogelmann<sup>1</sup> (858-534-6472;

avogelmann@ucsd.edu); Piotr J Flatau<sup>1,2</sup>

(pflatau@ucsd.edu); Jim Jafolla<sup>3</sup>

(jjafolla@surfaceoptics.com); Krzysztof

Markowicz<sup>4</sup> (kmark@meteo.igf.fuw.edu.pl); Peter J

Minnett<sup>5</sup> (pminnett@mombin.rsl.rsmas.miami.edu);

Malgorzata Szczodrak<sup>5</sup>

(goshka@rsmas.miami.edu)

<sup>1</sup>Center for Atmospheric Sciences Scripps Institution of Oceanography, 9500 Gilman Dr 0221, La Jolla, CA 92093-0221, United States

<sup>2</sup>Naval Research Laboratory, 7 Grace Hopper Avenue, Monterey, CA, United States

<sup>3</sup>Surface Optics Corporation, 115555 Rancho Bernardo Dr, San Diego, CA, United States

<sup>4</sup>Institute of Geophysics Warsaw University, Krakowskie Przedmiecie 26/28, Warsaw, Poland

<sup>5</sup>RSMAS/MPO University of Miami, 4600 Rickenbacker Causeway, Miami, FL, United States

We use radiometric observations made from the NOAA Ship R. H. Brown during ACE-Asia to determine the impact of the aerosols on the infrared radiative forcing, and how it relates to the solar forcing. Measurements of aerosol optical depth, column ozone, and the atmospheric temperature/water vapor structure are used to diagnose the aerosol radiative signature observed for the cruise from Hawaii to the Sea of Japan. Comparisons are made of the high-resolution spectral measurements made by the Marine-Atmospheric Emitted Radiance Interferometer (M-AERI) and line-by-line calculations by the Line-By-Line Radiative Transfer Model (LBLRTM). Samples of the dust from the region are analyzed to determine its infrared complex refractive index. These data are used in calculations by the Discrete-Dipole Approximation (DDA) to determine the effect of nonsphericity on the aerosol scattering properties. The overall aim of these research thrusts is to develop a consistent, integrated picture of the aerosol radiative forcing across the visible and infrared portions of the spectra. This will improve our understanding of both the role of aerosols in the climate system, and how they influence satellite remote sensing of surface signatures.

#### A32D-10 1615h

### ACE-Asia: Size/Time/Compositionally Resolved Aerosols During ACE-Asia Using Continuously Sampling DRUM Technology and Synchrotron-XRF Analysis

Thomas A Cahill<sup>1</sup> (530 752-4674; tacahill@ucdavis.edu)

Steven S Cliff<sup>1</sup> (530 754-8943; ssliff@ucdavis.edu)

Michael Jimenez-Cruz<sup>1</sup> (530 752-3177; cruz@crocker.ucdavis.edu)

Kevin D Perry<sup>2</sup> (408 924 5188; perry@metsun1.sjsu.edu)

<sup>1</sup>DELTA Group, Department of Applied Science University of California One Shields Avenue, Davis, CA 95616, United States

<sup>2</sup>Department of Meteorology, San Jose State University, San Jose, CA 95412, United States

The adaptation of focused beam technology to continuously sampling drum impactors (DRUMs) has allowed for an unprecedented number of size/time/compositional analyses of aerosols during the Spring, 2001 ACE-Asia study and a summer follow-on. While continuously sampling and sizing inertial drum impactors have been available for aerosol monitoring and research for the past 30 years, cost and sensitivity considerations have generally limited their use, even in research studies. These constraints have been greatly relaxed by our application of synchrotron X-ray fluorescence (S-XRF) analysis for elemental analysis of aerosols, both increasing sensitivity and decreasing cost. The intense polarized x-ray beams of the Lawrence Berkeley National Laboratory's Advanced Light Source (ALS) allows us to eliminate 99% of all the background normally present in x-ray analysis while matching the x-ray beam spot to the 0.2 mm "footprint" of our DRUM impactors. This combination allows non-destructive analyses of elements from sodium to uranium (with some minor elements masked by interferences) with a time resolution set during analysis, not during sampling. The DELTA Group and its many collaborators executed a 21 site network of continuously sampling 3 and 8 stage DRUM impactors for the 6 weeks of ACE-Asia. Fewer than 5% of the potential 80,000 samples were lost due to sampling problems. During S-XRF analysis, a nominal time resolution of 6 hrs was chosen, with 2 hrs available as needed during aerosol episodes. The 168 mm drum strips were mounted in frames and exposed to the "white" polarized x-ray beam of ALS Beam Line 10.3.1 for 30 seconds, yielding quantitative elemental determinations from sodium through molybdenum plus heavy elements, certified by 80 analytical standards and NIST SRMs. Minimum detectable limits ranged from 0.1 ng/m<sup>3</sup> for sulfur to 0.005 ng/m<sup>3</sup> for transition metals such as zinc, allowing scores of positive elemental determinations in each spectrum. During ACE-Asia, we sampled 2 major and several minor dust incursions into the Pacific Ocean, across Japan, Alaska, Hawaii, and to the west coast of the United States, where the Asian aerosols often dominated local aerosols. These events were typically associated with sub-micron soils, fine metals, and highly absorbing particles especially in the ultra-fine (Dp less than 0.24 micrometer) mode. Early results show a great deal of

size structure versus time in the largely anthropogenic transition and heavy metals, which when combined with trajectory analysis should clarify the sources of the highly absorbing fine aerosols so characteristic of the orient. The aerosol data will be evaluated for optical impacts and compared to co-located optical instrumentation.

DELTA - Detection and Evaluation of Long-range Transport of Aerosols

### A32D-11 1630h

#### Mixing States of East Asian Aerosols During the Spring 2001 ACE-Asia Intensive

James R Anderson<sup>1</sup> (480-965-7139; janderson@asu.edu)

Hua Xin<sup>1</sup> (huaxin@asu.edu)

<sup>1</sup>Environmental Fluid Dynamics Program, Arizona State University, Tempe, AZ 85287-6106, United States

Aerosols originating in China and Korea and transported to the East during the Spring 2001 dust season have been analyzed using manual and automated scanning electron microscopy to determine compositions, sizes, shapes and states of mixing. Samples discussed were collected from the NCAR C-130 aircraft, the NOAA R/V Ronald H. Brown and two ground sites on Cheju Island. Depending upon distance of transport, altitude and air mass history, the aerosols are varying mixtures of mineral dust, marine particles, and primary and secondary anthropogenic particles. Degree of reaction or aggregation of mineral dust and marine particles with secondary sulfate and nitrate are highly variable. Although these samples all have many different individual particle types present, and are therefore strongly externally mixed, the range of internal mixing states exhibited between particles of different origins is extreme.

Mixtures of mineral dust and anthropogenic combustion products (both from coal and biomass) sampled at low altitude tend to exhibit a high degree of internal mixing. Many higher altitude samples (2500 m and higher) have lower proportions of anthropogenic particles and show less internal mixing between the two categories. A common feature in the lower altitude samples is the internal mixture of mineral particles and elemental carbon in the form of soot, thus significantly altering the optical properties of the mineral dust.

### A32D-12 1645h

#### Measurements of Aerosol Optical Properties From South Korea During ACE-Asia

Anne Jefferson<sup>1,2</sup> (303-497-6493; anne.jefferson@noaa.gov)

Patrick J. Sheridan<sup>1</sup> (303-497-6672; psheridan@cmdl.noaa.gov)

John A. Ogren<sup>1</sup> (303-497-6210; john.a.ogren@noaa.gov)

<sup>1</sup>Climate Monitoring and Diagnostics Lab National Oceanic and Atmospheric Association, 325 Broadway, Boulder, CO 80305-3328, United States

<sup>2</sup>Cooperative Institute for Research in Environmental Sciences, University of Colorado, Campus Box 216, Boulder, CO 80309-0216, United States

Measurements of the aerosol scattering coefficient as a function of wavelength, aerosol size, and relative humidity were taken along with those of the aerosol absorption coefficient at a ground based site on Cheju Island, South Korea. The aerosol scattering coefficient was highly variable during the campaign ranging between 20 and 250 Mm<sup>-1</sup>. Spring in Korea is known as the dust season when southeasterly winds bring dust to the region from the Gobi Desert. Two such events were apparent in April. On these days over 60% of the aerosol scattering was in the super micron size mode as indicated by the low values of F<sub>bsp</sub>, the ratio of the sub micron aerosol to sub 10 micron aerosol scattering coefficients. The aerosol single scattering albedo, the fraction of aerosol scattering to that of the total extinction, during the dust events declined slightly to 0.93 for super micron aerosol and as low as 0.63 for sub micron aerosol. Most of the aerosol absorption during the campaign was in the sub micron mode aerosol. The aerosol hygroscopic growth, a measure of the increase in scattering due to aerosol water uptake, was relatively high during the dust events ranging from 1.5 to 2.5. The low single scattering albedo and high hygroscopic growth factor indicate the aerosol at the site was composed of not only dust but also likely had absorbing elemental and organic carbon and hygroscopic species such as sulfate, oxidized organics and sea salt.

URL: <http://www.cmdl.noaa.gov/aero>

### A32E MC: 123 Wednesday 1520h

#### Chemical and Dynamical Data Assimilation I

*Presiding:* W Lahoz, University of Reading; R Swinbank, Met Office

### A32E-01 1520h

#### Featured Presentation: Recent Developments in the Theory of Data Assimilation

Olivier Talagrand (talagran@ravel.ens.fr)

Ecole Normale Supérieure, Laboratoire de Météorologie Dynamique, Paris, France

There is no abstract available for this presentation.

### A32E-02 1540h INVITED

#### Constituent Data Assimilation: Challenges and Limitations

Richard B Rood<sup>1</sup> (301-614-6155;

rrood@dao.gsfc.nasa.gov); Ivanka Stajner<sup>1</sup>

(301-614-6177; istajner@dao.gsfc.nasa.gov);

Nathan Winslow<sup>1</sup> (301-614-6207;

nwinslow@dao.gsfc.nasa.gov); Anne R Douglass<sup>1</sup>

(301-614-6028;

douglass@persephone.gsfc.nasa.gov); Steven

Pawson<sup>1</sup> (301-614-6159;

spawson@dao.gsfc.nasa.gov); Susan Strahan<sup>1</sup>

(301-614-5995; sstrahan@dao.gsfc.nasa.gov)

<sup>1</sup>NASA/Goddard, Laboratory for Atmospheres, Greenbelt, MD 20771, United States

The assimilation of observations of atmospheric constituents naturally divides into two major pieces. The first is the assimilation of trace gases whose variability is related to atmospheric motions. The second is the assimilation of trace gases which are sharply influenced by chemical exchange between different constituents. In order to advance beyond the initial successes of explorative investigation of assimilation techniques, tremendous challenges must be met to improve the geophysical integrity of assimilated data products.

A subject of special interest is ozone near the tropopause. At the tropopause the information from both the observations and the model simulation becomes most uncertain. However a number of important geophysical parameters, e.g. stratosphere-troposphere exchange and tropospheric ozone, require the assimilation to have high accuracy at the tropopause. This talk will review the current status of the quality of assimilated data products near the tropopause, what must be done to improve the assimilation near the tropopause, and the intrinsic limitations that will require additional sources of information in order for the field to advance.

### A32E-03 1600h INVITED

#### 4D Variational Chemical Data Assimilation of CRISTA I and MLS stratospheric observations

Dominic Fonteyn (32-2-3730382;

D.Fonteyn@oma.be)

BIRA-IASB, Ringlaan 3, Brussel B-1180, Belgium

Although global data assimilation has been run operationally by NWP centres for more than two decades, global data assimilation of chemical species with a model taking into account all relevant chemical interactions has started the last five years. The main objective of chemical data assimilation is the production of a model consistent picture of the chemical composition distribution based on the synoptic observations of some chemical species. Since our assimilation system is based on an Eulerian 4D-Var scheme, the 3D chemical transport model and its adjoint will be discussed. The results of two case studies will be shown and used to illustrate the characteristics of the assimilation results. The assimilation of the CRISTA I observations (O<sub>3</sub>, HNO<sub>3</sub>, ClONO<sub>2</sub>, N<sub>2</sub>O<sub>5</sub>, N<sub>2</sub>O, CH<sub>4</sub>, CFC-11 (November 5-11, 1994) highlights the fundamentals of the 4D-Var method. The second case study, the assimilation of MLS O<sub>3</sub>, HNO<sub>3</sub> and ClO for the period December, 1995 until March, 1996 represents a longer period during which Polar Stratospheric Clouds and subsequently ClO activation was present. During this period a non-standard chemical regime was active. These results will be used to present the statistics of the assimilation. Furthermore, since the Polar Stratospheric Cloud particles are interactively calculated in the model, the chlorine activation and resulting ozone loss will be discussed.

### A32E-04 1620h INVITED

#### Assimilation of GOME ozone data in chemistry-transport model

Hennie Kelder<sup>1</sup> (+31-30-2206472; kelder@knmi.nl)

Ghada El Serafy<sup>1</sup> (elserafy@knmi.nl)

Henk Eskes<sup>1</sup> (eskes@knmi.nl)

Ronald van der A<sup>1</sup> (avander@knmi.nl)

Pieter Valks<sup>1</sup> (valks@knmi.nl)

<sup>1</sup>KNMI, P.O.Box 201, De Bilt 3730 AE, Netherlands

In this presentation we will give an overview of GOME ozone data assimilation activities at the KNMI. Topics to be discussed are:

The assimilation software TM3-DAM provides operational global ozone maps and five-day ozone (and UV) forecasts, based on GOME total ozone measurements. The chemistry-transport model used is driven by the new 60 layer ECMWF model analyses and forecasts, with a well resolved stratosphere and a top level in the mesosphere. Parameterised chemistry schemes have been included for stratospheric gas phase and heterogeneous chemistry.

Ozone profiles derived from the GOME nadir observations are assimilated using a fast simplified Kalman filter approach. The data assimilation software provides near real time assimilated ozone fields. The assimilation approach and validation results will be presented.

GOA is a Fifth Framework EU project that has started in 2001 and is co-ordinated by the KNMI. The aims of GOA are: a) To generate and distribute a five year data set of assimilated fields of ozone and NO<sub>2</sub> based on GOME observations. b) To compare this data set to independent observations obtained during measurement campaigns and from monitoring networks. c) To confront this data set with output from global chemistry-transport models (CTM's) to improve their modelling capability.

### A32E-05 1640h INVITED

#### MOPITT CO MEASUREMENTS: ASSIMILATION AND INVERSE MODELING

Boris Khattatov<sup>1</sup> (boris@ucar.edu); Jean-Francois

Lamarque<sup>1</sup> (lamar@ucar.edu); Gabrielle Petron<sup>1</sup>

(gap@ucar.edu); Valery Yudin<sup>1</sup>

(vyudin@ucar.edu); John Gille<sup>1</sup> (gille@ucar.edu);

David Edwards<sup>1</sup> (edwards@ucar.edu); Lawrence

Lyjak<sup>1</sup> (vl@ucar.edu); Daniel Ziskin<sup>1</sup>

(ziskin@ucar.edu); Gene Francis<sup>1</sup>

(gfrancis@ucar.edu); Merritt Deeter<sup>1</sup>

(mnd@ucar.edu); Guy Brasseur<sup>3</sup>

(brasseur@mpi.ge); Jim Drummond<sup>2</sup>

(jim@atmos.physics.utoronto.ca); Phil Rasch<sup>1</sup>,

Louisa Emmons<sup>1</sup>; Doug Kinnison<sup>1</sup>; Stacy

Waters<sup>1</sup>; Claire Granier<sup>1</sup>; Didier Hauglustaine<sup>1</sup>

<sup>1</sup>NCAR, PO Box 3000, Boulder, CO 80305, United States

<sup>2</sup>University of Toronto, 60 St. George Street, Toronto M5S 1A7, Canada

<sup>3</sup>Max Planck Research Institute, Bundesstr. 55, Hamburg, Germany

The MOPITT (Measurements Of Pollution In The Troposphere) instrument on board the NASA Terra satellite has been taking measurements of tropospheric carbon monoxide since March of 2000. MOPITT along-track observations are irregular in both time and space and they contain gaps while it is highly desirable to have data presented on a uniform, space (latitude, longitude, and height) and time grid. In addition, MOPITT averaging kernels are fairly wide, meaning that an observation is actually a weighted mean taken over a portion of the true, unknown CO profile.

Data assimilation allows one to overcome some of these limitations and to map MOPITT measurements onto regular time-space grid. In addition, it opens possibilities for expanding our understanding of atmospheric chemistry and dynamics via systematic comparisons of model and observations. In this talk we present results of assimilation of MOPITT measurements of carbon monoxide in the global chemistry transport model MOZART 2.

MOPITT measurements provide a unique opportunity to better understand surface sources and sinks of carbon monoxide. Such task, however, is made difficult due to chemical interactions of carbon monoxide with OH and other atmospheric chemicals. These interactions make the relationship between local concentrations of CO and its surface emissions non-linear. We review challenges arising in inverse modeling of emissions of chemically active gases and present some results of our work on inversion of surface sources of CO from MOPITT data.