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Book of Abstracts

CENTRE NATIONAL D'ÉTUDES SPATIALES

14:00 Gen Inoue [Nagoya Univ] and Y Yasuoka

GOSAT: Greenhouse gases observation from space. Objectives, approach and status

The carbon cycle research program of Japan is composed of multi-disciplinary projects with multiple funding systems. Among them, GOSAT project is organized by Ministry of Environment, NIES and JAXA, and Science Team advises to them from the scientific point of view.
The final target of MOE is to identify the GHG emissions of each country, and to monitor the emission reduction activities. However, the precision of carbon budget estimated from the atmospheric GHG concentration is not so accurate even though the special resolution will be improved by high density observation network. Nevertheless, the satellite observation is recognized as an important approach to understand the carbon cycle more precisely, and project the future GHG change from the present inter-annual variability of it. Recent climate models include the feedback process of carbon cycle and more reliable model parameters are required.
GOSAT sensor, TANSO, is under the stage of pre-flight model development by JAXA, and the algorithm to retrieve the concentration from the spectra by NIES is in the stage to establish a routine analysis system. As a step of validation program, the field experiment in Australia was finished successfully, and similar spectra as GOSAT will do were obtained from a high altitude flying aircraft, 12,000m. As for the data user group, we expect the internationally coordinated group will be established sharing the satellite and in situ data and improving the methodology of inverse model and others.
Project is facing at several difficulties, both the development of sensor and the data analysis, but the target of launch in 2008 is still hold.

14:30 David Crisp [JPL]

The NASA Orbiting Carbon Observatory Mission: Objectives, approach, and status

The Orbiting Carbon Observatory (OCO) will make global, space-based measurements of atmospheric CO_2 with the precision, resolution, and coverage needed to characterize CO_2 sources and sinks on regional scales and quantify their variability over the year. This NASA mission will be launched from Vandenberg Air Force Base in December 2008. Its 98.8 minute, 705 km altitude, sun-synchronous (1:26 PM) orbit provides global coverage of the sunlit hemisphere with a 16-day ground track repeat cycle. The OCO instrument incorporates 3 bore sighted, high resolution grating spectrometers that will make coincident measurements of reflected sunlight in near-infrared CO_2 and molecular oxygen (O_2) bands. The weak CO_2 absorption band near 1.61 µm yields CO_2 column abundance estimates that are most sensitive to the CO_2 abundance near the surface, where most sources and sinks are located. The 0.765-µm O_2 A-band spectra constrain the total (dry-air) atmospheric mass, yielding clear-sky surface pressure estimates with accuracies near 1 mbar over most of the sunlit hemisphere. In regions with thin clouds and aerosols, these O_2 spectra will reduce uncertainties in the optical path lengths associated with multiple scattering. Spectra of the strong CO_2 band centered near 2.06-?m band will further constrain the aerosol optical properties at near-infrared wavelengths. OCO spectra will be analyzed to provide spatially resolved estimates of the column-averaged CO_2 dry air mole fraction, X_{CO2}. OCO collects 12 to 24 X_{CO2} soundings/second over the sunlit portion of the orbit, yielding 200 to 400 soundings per degree of latitude (7 to 14 million soundings every 16 days). At least 10% of these data are expected to be sufficiently cloud free to yield reliable X_{CO2} estimates. These measurements will be analyzed with source/sink inversion and data assimilation models to infer CO_2 surface fluxes. This presentation will summarize the objectives, approach, and status of the OCO mission.

15:00 Denis O'Brien and Thomas E. Taylor [CSU]

Cloud screening for OCO using neural networks and photon path length distributions

The current prototype for the OCO cloud screening algorithm uses a hierarchy of neural networks to estimate vertically integrated cloud water, cloud ice and the corresponding mean pressure levels from radiance spectra in the OCO bands. Training of the networks uses spectra simulated for approximately 10,000 profiles from an ECMWF data base of 60 layer atmospheres prepared by Chevallier. Principal component analysis suggests that there are approximately five degrees of freedom in the current set of synthetic measurements. Because a single network trained with the full range of cloudy atmospheres has limited skill when applied to optically thin clouds, the case of most interest to OCO, the screening algorithm uses a hierarchy of nested training sets with progressively less water and ice.

The second strand of the cloud screening algorithm derives an approximate representation of the probability distribution function (PDF) of photon path lengths from spectra in the OCO bands. Characteristics of the PDF, such as its modal value and width, are examined to see whether they can be used reliably to detect the presence of scattered radiance in an OCO sounding. Initial experiments with a data set of over 8000 cloudy profiles and spectra in micro-windows of the OCO bands suggest a relatively high level of skill. More rigorous tests, including the sensitivity of the detection to instrumental noise and offsets in the spectra, await spectra computed for the full OCO bands.

15:20 Hartmut Boesch [JPL, now at Leicester Univ] et al.

Global characterization of XCO_2 as observed by the OCO (Orbiting Carbon Observatory) instrument

The Orbiting Carbon Observatory (OCO) mission will make the first global, space-based measurements of atmospheric carbon dioxide (CO_2) with the precision, resolution, and coverage needed to characterize CO_2 sources and sinks on regional scales. During its 2-year mission, OCO will fly in a 1:26 PM sun-synchronous orbit with a 16-day ground-track repeat period, just ahead of the EOS Aqua platform. It will carry a single instrument that incorporates three bore-sighted, high-resolution spectrometers designed to measure reflected sunlight in the 0.76-micron O_2 A-band and in the CO_2 bands at 1.61 and 2.06 microns. Soundings recorded in these three bands will be used to retrieve the column-averaged CO_2 dry air mole fraction (X_{CO2}). Each sounding will be analyzed with an algorithm that incorporates an atmospheric radiative transfer model, an instrument simulator model, and an inverse method that adjusts the assumed atmospheric state to better match the measurements.

The goal of this study is to provide a global characterization of the OCO X_{CO2} retrievals that allows for verification and quantification of their precision, accuracy and sensitivity. Specifically, we have simulated and characterized OCO retrievals for the key parameters solar zenith angle, surface type, surface elevation and aerosol loading. This characterization scheme is then mapped to a global scale using global climatologies of aerosol and surface properties, together with the orbit geometry of OCO. In a final step, this OCO characterization scheme is used in a variational data assimilation framework to simulate the benefit of OCO observations for the inversion of carbon sources and sinks. These investigations will provide important feedback to help isolate areas where the retrieval must be improved and give guidance on the optimal observation and sounding selection strategy for OCO.

15:40 Takashi Hamazaki [JAXA]

Overview of GOSAT and TANSO

Japan Aerospace Exploration Agency (JAXA) is developing Greenhouse gases Observing Satellite (GOSAT). The mission objective of the GOSAT is to observe the global distribution of CO2 and CH4 and their changes from space. The accuracy of CO2 columnar density is expected between 1-4ppm. GOSAT has Thermal And Near infrared Sensor for carbon Observation (TANSO). The TANSO consists of Fourier Transform Spectrometer (TANSO-FTS) and Cloud and Aerosol Imager (TANSO-CAI). The TANSO-FTS is a Fourier transform spectrometer and covers wide range of spectrum including 0.75-14.3um in 0.2cm-1 spectrum resolution. The Signal to noise ratio is over 300 in each channel. The 0.76 µm band is used to observe O2 density and determine path length. The 1.6 and 2.0um bands are used to observe CO2 and CH4 density. The 5.5-14um band is used to observe CO2, CH4, water vapor, atmospheric temperature and pressure. Altitude distribution data for CO2 and CH4 is also available with this band. The number of total observation channel reaches up to 18,000. The TANSO-CAI is a push bloom scanner with 0.38um, 0.67um, 0.87um and 1.60um bands. Its IFOV is 0.5 to 1.5km and FOV is 1000km. The TANSO-CAI is used to compensate errors which are caused by the cloud and aerosol. The TANSO-FTS has fully redundant pointing mechanisms on-board. Two axes pointing mechanism allows GOSAT to observe any selected observation point on the earth surface. With zigzag observation sequence, 90 to 900km (180km nominal) mesh world-wide observation becomes possible. Over the ocean in day-time, operation mode is switched to the sun-glint points tracking mode. Sun-glint points tracking mode gives brighter sun reflection and consequently higher accuracy observation is expected.

The GOSAT is the joint endeavor with JAXA, Ministry of Environment (MOE) and National Institute for Environmental Studies (NIES). The GOSAT will be launched by the H-IIA launch vehicle in 2008.

16:30 Kei Shiomi et al [JAXA]

Calibration plan of GOSAT TANSO sensors

Greenhouse gases Observing SATellite (GOSAT) is aimed at observing the greenhouse gases, such as CO2 and CH4, from space. Thermal And Near infrared Sensor for carbon Observation (TANSO) is carried on the GOSAT satellite for measurement of greenhouse gases. TANSO is composed of 2 sensors, Fourier Transform Spectrometer (FTS) for measuring greenhouse gases absorption spectra, and Cloud and Aerosol Imager (CAI) for cloud detection and the correction of cirrus and aerosol interference within the FTS field of view. The FTS observes at wavelengths of shortwave infrared (SWIR) and thermal infrared (TIR) the common interferometer and fore optics. The interfered lights are divided into each band detector by dichroic mirrors.

The post-launch calibration will be implemented by several onboard calibrators and vicarious calibration methods. The vicarious calibration for radiance is studied by preparing the appropriate targets on the earth by using current satellite dataset, such as MODIS, which observes the equivalent wavelengths of the GOSAT observation band. The calibration sites can be used for the radiance comparison with the other satellite observation data. They should be selected in terms of homogeneity over 10km area, various radiance level and small BRDF. The spatial and time variations are investigated for estimation of registration error and accumulation of statistical dataset. As for SWIR targets, deserts, forests, and snowfield will be selected. As for TIR targets, sea surface temperature is well known by other sensor observations or reliable dataset.

This presentation shows the status of the post-launch calibration planning for GOSAT sensors.

16:50 Tatsuya Yokota et al. [NIES]

Data retrieval (Level 2) algorithms of the TANSO-FTS in SWIR bands and A pre-launch field experiment with GOSAT BBM-TOKYO in 2006

In the GOSAT project, one of the missions of National Institute for Environmental Studies is to develop data retrieval algorithms to estimate column densities (Level 2) of CO2 and CH4 from spectral (Level 1B) data of TANSO-FTS SWIR bands. TNASO-FTS measures ground reflected solar spectra with three spectral bands (0.76 µm, 1.6 µm, and 2.0µm bands). Two polarization signals are also measured in each band. The outline of the data retrieval flow is shown in this presentation. Two of the major error sources in the SWIR retrievals are cirrus and aerosols. We will summarize strategy to overcome these effects.

In December 2006, we have made field experiment with GOSAT BBM-TOKYO and in situ measurements at Mt. Tsukuba in Japan to check the retrieval algorithms. Retrieval results of CO2 column density from BBM data have agreed with in situ data in about 2% discrepancy, because it still remained uncertain situations (parameters). However, it was found that the results depend strongly on the CO2 spectral band to be used for retrievals. Tendency of the time variation of these data of column amounts well agreed with each other, and the retrieval algorithm worked well. Importance of line parameters has been demonstrated in this measurement and the retrievals. Summary of the Mt. Tsukuba field campaign will be shown.

17:10 Ryoichi Imasu et al. [CCSR]

Total performance of CO_2 observation by GOSAT FTS-TIR sensor

Greenhouse gases Observing SATellite (GOSAT) is a Japanese satellite joint mission of the Ministry of the Environment (MOE), the National Institute for Environment Studies (NIES), and the Japan Aerospace Exploration Agency (JAXA) aiming to observe CO_2 and CH_4 concentrations from space and advance the source/sing inversion analysis of these greenhouse gases.

The main sensor of GOSAT is a Fourier Transform Spectrometer (FTS) which covers wide spectral range of CO_2 absorption bands, 1.6µm and 2.0µm (SWIR), and 15µm (TIR:5.5-14µm). SWIR bands will be used to estimate columnar concentration of CO_2, and TIR band to retrieve the vertical profile of CO_2 concentration in the upper atmosphere above about 700hPa. CH_4 can be also measured by using both SWIR and TIR bands. Also installed on the satellite is an imaging sensor, Cloud and Aerosol Imager (CAI), which will be used to detect clouds and aerosols.

Center for Climate System Research (CCSR) has contracted with JAXA to develop algorithms for retrieving CO_2 and CH_4 concentrations from FTS-TIR data. In order to show the total performance of the observation by FTS-TIR sensor, we have developed an observation simulator based on the orbit calculation and CO_2 concentration data pre-calculated by a CO_2 transport model. This simulator is designed to be able to simulate various observational modes of the sensor including the sun-glitter mode and cross-tracking mode. Fractional cloud coverage and cloud optical properties in an instantaneous field of view (IFOV) are also simulated based on MODIS cloud data. At the present time we prepared MODIS data for a specific year of 2001. Based on the results from this simulator we present the total performance of FTS-TIR observation considering clear sky probability and temporal and spatial variation of CO_2 concentration.

17:30 Naoko Saitoh et al. [CCSR]

CO_2 and CH_4 concentrations retrieved from thermal infrared spectra of GOSAT/TANSO-FTS sensor

The Greenhouse gases Observing Satellite (GOSAT) has been developed by National Institute for Environmental Studies (NIES), Ministry of the Environment, and Japan Aerospace Exploration Agency (JAXA), and planed to be lunched in 2008 for global observation of CO_2 and CH_4 with high accuracy/precision. We assess the performance of the FTS sensor on board the GOSAT, Thermal And Near infrared Sensor for carbon Observation (TANSO), in retrieving CO_2 and CH_4 from spectra at around 15 µm (700-770 cm^{-1}) and 7.7 µm (1200-1400 cm^{-1}), respectively. Uncertainties in temperature produce significant errors in CO2 concentrations retrieved from the 15-µm band. The 7-µm spectral region contains absorption bands of H_2O and N_2O as well as that of CH_4. In this study, we applied Maximum a posteriori (MAP) method to pseudo-spectra with the spectral resolution (0.2 cm^{-1}) and the signal-to-noise ratio (around 300 at 280 K) of TANSO-TIR sensor, and evaluated CO_2 and CH_4 retrieval errors in various atmospheric conditions. The results showed that a random scatter of ±0.5 K in temperature caused more than 10 times larger discrepancy between retrieved CO_2 and true CO_2 concentrations than that without temperature error. Biases of 10% in H_2O and N_2O concentrations produced 3% and 2.5% biases in retrieved CH_4 concentrations, respectively. The random scatters of +/-0.5% led to 0.4% and 0.3% CH_4 random errors, respectively, regarded as a component of noise in measurement spectra. However, selecting channels appropriate for CO_2 and CH_4 retrievals on the basis of information contents of these gases computed following the Shannon's information theory [Shannon and Weaver, 1949] could greatly reduce both biases and random errors in retrieved concentrations compared to the errors in the case of all the channels used.

9:00 Edward V. Browell [NASA LaRC], Michael E. Dobbs, Berrien Moore

Airborne demonstration of a CW laser system for CO_2 column measurements

A unique, multi-frequency, single-beam, laser absorption spectroscopy (LAS) technique has been developed for space-based measurements of carbon dioxide (CO_2) in the troposphere. A prototype of the space-based system has been developed by ITT, and it has been flight tested in a coordinated series of experiments over the last two years. The LAS system utilizes a low power, modulated continuous wave (CW) telecom laser system at 1.57 ?m with matching detection system to achieve high signal-to-noise ratios (SNRs) of the on-line-to-off-line ratio for differential CO_2 column optical depth measurements. The LAS is operated at various wavelengths across a CO_2 absorption line to optimize the sensitivity for CO_2 detection in the low to mid troposphere. Prior to flight testing, the LAS was tested extensively in the laboratory and in horizontal ground testing over ranges of 0.5 to 2 km, and SNRs in excess of 1000 were obtained. For flight testing, the LAS system was mounted in the Flight International L-25 Lear Jet along with a high-precision in situ CO_2 instrument for "ground-truth" measurements.

Three flight test campaigns have been conducted: 21-25 May 2005 over the Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) Central Facility (CF) site; 26-29 June 2006 over land and Lake Michigan near Alpena, Michigan; and 21-24 October 2006 over land and Atlantic Ocean near Portsmouth, New Hampshire. In addition, a fourth flight test campaign is tentatively scheduled for May 2007 near Newport News, Virginia. All of these campaigns have provided vital information on how to optimize the operation of the LAS in the Lear Jet and in making high precision CO_2 measurements over widely varying surface and cloud albedo conditions. The modeled radiometric performance of the LAS instrument was found to compare well with observed in-flight measurements. High quality remote and in situ CO_2 measurements were obtained in all of these campaigns, and the LAS CO_2 measurements were found to be within 6% of the in situ modeled optical depths. Details of these flight test campaigns will be presented in this paper, and future activities supporting the development of a space-based CO_2 LAS system will be discussed.

9:25 Charles E. Miller [JPL, CalTech] et al.

New spectroscopic parameters for satellite remote sensing of atmospheric CO_2 with sub-1% accuracy

Remote sensing of the column averaged CO_2 dry air mole fraction (X_{CO2}) from space with 1 ppm precision (~0.3%) is an imposing measurement challenge and places stringent requirements on the spectroscopic reference standards used to simulate the atmospheric radiance spectra. The spectroscopic parameters must correctly reproduce the line positions, intensities, and pressure-induced line shape changes for the strong $^{16}O^{12}C^{16}O$ absorption features used to retrieve X_{CO2} as well as the weaker, interfering absorptions due to hot bands and less abundant isotopologues (e.g. $^{16}O^{13}C^{16}O$). Furthermore, the absolute accuracy of the intensities and line shapes should be established to better than 1.0% and the relative accuracies of all different vibrational bands used to retrieve X_{CO2} must be consistent to ensure that the space-based remote sensing data are bias-free. We report new high accuracy measurements of intensities for 125 near infrared CO_2 vibrational bands (~10,000 rovibrational transitions). A Voigt line shape analysis yielded self- and air-broadening coefficients for the stronger bands. The new spectroscopic parameters have a sub 1.0% absolute accuracy, although there are still systematic residuals observed in the differences between experimental and simulated spectra. A constrained multispectrum fit employing a speed dependent Voigt profile and the off-diagonal relaxation matrix elements (RME) formulation for line mixing reduced the systematic fitting residuals an additional 30 – 50% for the 30012 ? 00001 band at 6348 $cm^{?1}$. Similar results have been observed for the 30013 ? 00001 band near 6220 $cm^{?1}$. We conclude that X_{CO2} retrieval algorithms for satellite data will require line mixing and non-Voigt line shape formulations to achieve 1 ppm precision.

9:50 William S. Heaps [NASA GSFC]

Fabry-Perot based radiometers for precise measurement of greenhouse gases

Differential radiometers based upon the Fabry-Perot interferometer have been developed and demonstrated that exhibit very great sensitivity to changes in the atmospheric column of carbon dioxide, oxygen, and water vapor. These instruments employ a solid Fabry-Perot etalon that is tuned to the proper wavelength by changing the temperature. By choosing the thickness of the etalon its multiple pass bands can be made to align with regularly space absorption features of the molecule under investigation. Use of multiple absorption features improves the optical throughput of the instrument and improves the stability of the instrument response with respect to environmental changes. Efforts are underway at Goddard to extend this technique to the carbon 13 isotope of carbon dioxide and to methane. These instruments are intrinsically rugged and can be made rather small and inexpensively. They therefore hold promise for widespread use in ground based networks for calibration of satellite instruments such as OCO and GOSAT. Results will be presented for ground based and airborne operations for these systems. The effects of atmospheric scattering, pointing errors, pressure broadening and temperature effects will be discussed with regard to achieving precision better than .5% required for validation of carbon dioxide column measured from space. Designs permitting the extension of the technique to an even larger number of atmospheric species will be discussed along with theoretical analysis of potential system performance.

10:10 Antoine Lacan [CNES /LSCE] et al.

Study of a new kind of static Fourier Transform Spectrometer for CO_2 concentration monitoring

CNES has developed and patented a new kind of Fourier Transform Spectrometer which offers promising prospects for the definition of payloads for micro-satellite platforms. Thanks to a Static configuration the mass and the volume of the spectrometer are reduced and consequently the overall cost. Such a spectrometer could be well adapted to a multi-satellite mission for a long term monitoring.

A Fourier Transform Spectrometer records an interferogram which is the Fourier Transform of the spectrum of the incoming light. The key of this Static concept is the combination of a narrow band filter and stepped mirrors. The narrow filter limits the spectral measurement window and thus decreases the sampling frequency of the interferogram. The stepped mirrors provide all the path differences (all the samples) simultaneously. The measurement is consequently obtained spatially by imaging the stepped mirrors on a CCD detector rather than temporally by moving a mirror.

To validate this concept for gas monitoring applications, an on ground breadboard has been built to measure CO2 concentration on the total atmospheric column. The principle of measurement is the Differential Optical Absorption Spectroscopy. The light source is the sun and the CO2 concentration is deduced from the depth of the CO2 absorption lines in the spectra.

Up to now the spectrometer has been characterised and modified into an operational configuration. Now the measurements are made on a 22.5 cm^{-1} (5.6 nm) wide window centred at 6357 cm^{-1} (1573 nm). The expected resolution is around 0.15 cm^{-1} with a sampling period of 0.075 cm^{-1}. The objectives in SNR are 200 for the spectra and 3000 for the interferograms. A year long measurement campaign is about to begin. The goal is to retrieve the annual carbon cycle.

We are beginning to obtain encouraging results when measuring atmospheric spectra. These results will be presented and the quality of the measurement will be discussed particularly thanks to comparisons with the a priori. If the progress of the work is sufficient some results of inversion of spectra will be presented.

10:30 Michel Ramonet et al. [LSCE]

Ground, airborne and remotely-sensed greenhouse gases measurements at LSCE

11:10 ⇒ 13:00 Poster Session

13:00 ⇒ 14:00 On site lunch

14:00 Michael Buchwitz [IUP, Bremen Univ]

Three years of carbon dioxide, methane and carbon monoxide retrieved from SCIAMACHY/ENVISAT nadir observations

We present three years of global data of the greenhouse gases carbon dioxide (CO_2) and methane (CH_4) and of the related tracer and air pollutant carbon monoxide (CO). These data products are retrieved from SCIAMACHY near-infrared nadir satellite observations using the latest versions of the scientific retrieval algorithm WFM-DOAS (version 1.0 for CO_2 and CH_4, version 0.6 for CO). For the greenhouse gases CO_2 and CH_4 the main data products are column-averaged CO2 dry air mole fractions needed for inverse modelling to get information on their sources and sinks. The time period covers the first three years of ENVISAT (2003-2005). The satellite CO_2 data set is compared with ground based Fourier Transform Spectroscopy (FTS) measurements and results from NOAA's global CarbonTracker assimilation system. The satellite CH_4 data set is compared with FTS and with the TM5/JRC model optimally adjusted to highly precise surface observations. The satellite CO data set is compared with FTS and with the operational CO column data product of MOPITT. First attempts are currently being made by NASA to assimilate the SCIAMACHY CO columns and the status of this activity will be briefly presented.

14:30 Michael Barkley, Alan Hewitt and Paul Monks [Leicester Univ]

Measuring atmospheric CO_2 from space using full spectral initiation (FSI) WFM-DOAS

Satellite measurements of atmospheric CO_2 concentrations are a rapidly emerging area of scientific research which can help reduce the uncertainties in the global carbon cycle fluxes and may provide insight into surface sources and sinks. One of the new CO_2 measurement techniques is a retrieval algorithm called Weighting Function Modified Differential Optical Absorption Spectroscopy (WFM-DOAS), (Buchwitz et al., J. Geophys. Res., 2000). This algorithm is designed to measure the total columns of CO_2 (and other greenhouse gases) through the application to spectral measurements in the near–infrared (NIR), made by the SCIAMACHY instrument on-board the ENVISAT satellite. The algorithm itself is based on fitting the logarithm of a model reference spectrum and its derivatives to the logarithm of the ratio of a measured nadir radiance and solar irradiance spectrum. A detailed error assessment of this technique has been conducted and it has been found necessary to include suitable a priori information within the retrieval in order to minimize the errors on the retrieved CO_2 columns. Hence, we introduce a new CO_2 retrieval algorithm called Full Spectral Initiation (FSI) WFM-DOAS which generates a reference spectrum for each individual SCIAMACHY observation using the known properties of the atmosphere and surface the time of the measurement. Initial retrievals over Siberia and North America, for the years 2003 and 2004, show that the measured CO_2 columns are not biased from the input a priori data and that whilst the monthly averaged CO_2 distributions contain a high degree of variability, they also contain significant spatial features which correlate well with land vegetation type. Comparisons to both ground-based Fourier Transform Infrared (FTIR) measurements and to the output from a global chemistry-transport model are also demonstrated. Strong similarities between the CO_2 anomalies measured by SCIAMACHY and ground-based surface flask/tower sites are additionally shown.

14:50 Christian Frankenberg [NISR] et al.

Satellite chartography of atmospheric methane from SCIAMACHY onboard ENVISAT

SCIAMACHY onboard ENVISAT enables the retrieval of atmospheric methane with high sensitivity towards the ground. Methane is the second most important greenhouse gas. However, the partitioning of global methane sources is still highly uncertain.
Further, a newly discovered additional source, viz. direct plant emissions, requires other sources to be reassessed.
SCIAMACHY from its vantage point in space now offers the possibility of sensing methane globally. However, high accuracy is needed in order to employ the retrievals in source inversion models. This work shows latest methane results from SCIAMACHY using a revised retrieval setup that includes ECMWF pressure and temperature profiles as well as the gtopo30 surface elevation database as prior input. Further, several parameters influencing retrieval accuracy, such as spectroscopic uncertainties in methane transitions are discussed in detail.

15:10 Cathy Clerbaux [SA/IPSL and Univ Libre de Bruxelle] et al.

Overview of initial results for trace gas measurements from the IASI / MetOp mission

MetOp, the first European meteorological platform on a polar orbit was launched on October 19, 2006. The platform carries a series of instruments, including IASI, the Infrared Atmospheric Sounding Interferometer designed and built by the French spatial agency CNES. IASI consists of a Fourier transform spectrometer, which measures radiance spectra of the Earth-atmosphere system between 645 and 2760 cm^{-1} in the thermal infrared, at a spectral resolution of 0.5 cm^{-1} (apodised). The nadir-looking geometry of IASI, combined with an across-track scanning mode reaching 48° on both sides, allows global coverage to be achieved in twelve hours.
This work surveys the first results acquired by analyses of IASI spectra, using retrieval tools dedicated both to operational and scientific processing. We show that the extended spectral coverage of IASI provides unique information on the concentration distribution of numerous tropospheric species, impacting on climate (H_2O, CO_2, N_2O, CH_4, CFCs) or on chemistry (O_3, CO, HNO_3). For most of these gases we demonstrate that vertical profiling is possible.
The emphasis of this work is put on preliminary analyses of O_3, CO, CH_4 and possibly HNO_3 distributions on local to global scales, acquired during the first months of IASI operation. The results, which are firstly compared to operational level 2 data provided by EUMETSAT, are discussed with respect to pollution sources and transport in the troposphere. The attractive possibility to combine the data products of IASI and GOME-2, flying together on MetOp, in order to improve our understanding of tropospheric processes is put in perspective.

15:30 Pascal Prunet et al. [Noveltis]

Potential of CO2 retrieval from IASI

The potential of CO_2 retrieval from IASI data is assessed, through the qualitative and quantitative analysis of two questions: expected accuracy of the CO_2 atmospheric concentration from the IASI infrared high resolution spectrum; impact of a specific cloud decontamination processing on the usefulness of the IASI CO_2 product.
A signal processing is developed to efficiently exploit the CO_2 information of the IASI spectrum, through Discrete Fourier Transform (DFT) filtering. Information content analyses and inversion experiments on simulated and real data are performed to assess the expected precision of retrieved CO_2 concentration. This analysis shows that one can retrieve the mean atmospheric CO_2 concentration from a single IASI spectrum with a precision better than 2 ppmv, i.e., better than 1 %. The possibility to derive CO_2 profile information (about 3 pieces of information) is also suggested. An algorithm including the DFT filtering is developed to derive an optimal CO_2 product from IASI measurement.
A processing chain for the infrared sounding measurements above heterogeneous scenes was developed for IASI. It uses the information provided by a co-registered imager for characterizing the sounder sub-pixel information in terms of homogeneous radiative surfaces, and for extracting the sounder spectrum component associated with each homogeneous surface. Such a processing is required for any exploitation of non-homogeneous pixel measurements. Tests on partly-cloudy simulated data suggest that the global percentage of IASI measurements exploitable for CO_2 inversion should be increased by a factor of 3.
The CO_2 retrieval algorithm, combined with the IASI processing for cloud decontamination, will be applied on representative sets of IASI data, in order to assess the possible contribution of IASI for the estimation of CO_2 surface sources and sinks.

16:20 Cyril Crevoisier et al. [LMD/IPSL]

Mid-to-upper tropospheric CO_2 atmospheric content from hyperspectral infrared sounders: 4 years from Aqua/AIRS and initial results for MetOp/IASI

Since the launch of NASA/Aqua on May 2002, four years of observation from the high spectral resolution infrared sounder AIRS and the microwave sounder AMSU have been interpreted in terms of an integrated content of tropospheric carbon dioxide (CO_2). Use has been made of a non-linear inference scheme based on neural networks. Except for a short period from October 2003 to April 2004, during which AIRS observations have been affected by instrumental problem following a strong solar eruption, the retrieved CO_2 seasonal cycle is in good agreement with in-situ observations made in the troposphere by commercial aircrafts and gives access to the increasing trend and amplitude of the seasonal cycle of CO_2 over a long time period.
Following the launch of the hyper-spectral infrared sounder IASI on board ESA/MetOp on October 2006, a set of IASI channels presenting optimum characteristics for CO_2 estimation has been selected, based on a systematic sensitivity study of the observations to CO_2, temperature, and other absorbers. Tests performed with simulated observations show that the use of these IASI channels in the retrieval procedure should significantly improve tropospheric CO_2 monitoring from space.

16:40 James R. Drummond [Dalhousie University] et al.

Measurements Of Pollution In The Troposphere (MOPITT) – Seven years of global carbon monoxide measurements

MOPITT was launched on the Terra satellite in December 1999 and has been gathering data for over 7 years on carbon monoxide concentrations in the lower atmosphere. These data have provided input for a wealth of scientific studies on the global, regional and local scale, including biomass burning and intercontinental transport. Although limited in their vertical resolution, they have also been used in studies of frontal systems and venting over mountainous regions.
With a long time series of consistent data available, it is now possible to look at longer term activities in the atmosphere on annual and biennial timescales, such those associated with El Niño. The biennial burning cycle in the South Asian region being one example.
This talk will give a brief overview of the MOPITT operating methodology and review some of the most recent results relevant to the study of greenhouse gases in the atmosphere.
The MOPITT activities are supported by the Canadian Space Agency in Canada and by NASA in the US.

17:00 Alain Chédin [LMD/IPSL] et al.

A quantitative link between CO_2 emissions from tropical vegetation fires and the daily tropospheric excess (DTE) of CO_2 seen by NOAA-10 (1987-1991)

Monthly mean mid-tropospheric CO_2 columns over the tropics are retrieved from evening and morning observations of NOAA-10 (1987-1991). We find that the difference between these two columns ("Daily Tropospheric Excess", DTE) increases up to 3 ppm over regions affected by fires. At regional scale over Africa, America, and Australia, the variations of the DTE are very similar to those of independently derived biomass burning CO_2 emissions. A strong correlation (R2~ 0.8) is found between regional mean DTE and fire CO_2 emissions values from the Global Fire Emissions Data base (GFEDv2) even though the two products span over periods ten years apart from each other. The DTE distribution over Africa indicates that the southern hemisphere experiences 20% more fire activity during El Niño conditions than during La Niña conditions and the reverse for the northern hemisphere. Such an African dipole of ENSO-related fire variability is comparable to changes analyzed from GFEDv2 CO_2 emission maps. The physical mechanism linking DTE with emissions is not fully elucidated. Hot convective fire plumes injecting CO_2 into the troposphere during the afternoon peak of fire activity, seen by the satellite at 1930 LT, and then being dispersed by large scale atmospheric transport, before the next satellite pass at 0730 LT, could explain the tight observed relationship between DTE and CO_2 emissions. We conclude that DTE data can be very useful to quantitatively reconstruct fire emission patterns before the ATSR and MODIS era when better quality fire count and burned area data became available.

17:20 Moustafa Chahine [JPL]

AIRS CO2 in the Upper Troposphere

Atmospheric Infrared Sounder (AIRS) retrieved CO2 and O3 by Vanishing Partial Derivative (VPD) method in the upper troposphere have been validated with the aircraft and ozonesonde data in Jan, Apr, Jul, and Oct 2003. The retrieved CO2 and O3 have the correct latitudinal distributions, which are also simulated correctly by the two-dimensional (2-D) and three-dimensional (3-D) chemistry and transport models (CTMs). After the stratospheric major final warming, the retrieved CO2 increases and retrieved O3 decrease in the upper troposphere. These results are consistent with the CO2 aircraft data and ozonesonde data. The spatial patterns of retrieved CO2 and O3 are consistent with the large-scale circulations. The seasonal cycle of retrieved CO2 matches that from aircraft data. The 3-D CTMs seem to underestimate the seasonal cycle amplitude of CO2 in the upper troposphere. Sensitivity studies reveal that the convection mass flux is very crucial for the correct simulation of upper tropospheric CO2.

12:30 ⇒ 14:00 On site lunch and poster session

14:00 James B. Abshire [NASA GSFC] et al.

Laser sounder for global measurement of CO2 concentrations in the troposphere from space

Measurements of tropospheric CO2 abundance with global-coverage, a few hundred km spatial and monthly temporal resolution are needed to quantify processes that regulate CO2 storage by the land and oceans. The Orbiting Carbon Observatory (OCO) is the first space mission focused on atmospheric CO_2 for measuring total column CO_2 and O_2 by detecting the spectral absorption in reflected sunlight. The OCO mission is an essential step, and will yield important new information about atmospheric CO_2 distributions. However there are unavoidable limitations imposed by its measurement approach. These include best accuracy only during daytime at moderate to high sun angles, interference by cloud and aerosol scattering, and limited signal from CO_2 variability in the lower tropospheric CO_2 column.

We have been developing a new laser-based technique for the remote measurement of the tropospheric CO_2 concentrations from orbit. Our initial goal is to demonstrate a lidar technique and instrument technology that will permit measurements of the CO_2 column abundance in the lower troposphere from aircraft. Our final goal is to develop a space instrument and mission approach for active measurements of the CO_2 mixing ratio at the 1-2 ppmv level. Our technique is much less sensitive to cloud and atmospheric scattering conditions and would allow continuous measurements of CO_2 mixing ratio in the lower troposphere from orbit over land and ocean surfaces during day and night.

Our approach is to use the 1570nm CO_2 band and a 3-channel laser absorption spectrometer (ie lidar used an altimeter mode), which continuously measures at nadir from a near polar circular orbit. The approach directs the narrow co-aligned laser beams from the instrument's lasers toward nadir, and measures the energy of the laser echoes reflected from land and water surfaces. It uses several tunable fiber laser transmitters which allowing measurement of the extinction from a single selected CO_2 absorption line in the 1570 nm band. This band is free from interference from other gases and has temperature insensitive absorption lines. During the measurement the lasers are tuned on- and off- a selected CO_2 line near 1572 nm and a selected O_2 line near 768 nm in the Oxygen A band at kHz rates. The lasers use tunable diode seed lasers followed by fiber amplifiers, and have spectral widths much narrower than the gas absorption lines. The receiver uses a 1-m diameter telescope and photon counting detectors and measures the background light and energies of the laser echoes from the surface. The extinction and column densities for the CO_2 and O_2 gases are estimated from the ratio of the on and off line surface echo via the differential optical absorption technique.

Our technique rapidly alternates between several on-line wavelengths set to the sides of the selected gas absorption lines. It exploits the atmospheric pressure broadening of the lines to weight the measurement sensitivity to the atmospheric column below 5 km. This maximizes sensitivity to CO_2 in the boundary layer, where variations caused by surface sources and sinks are largest. Simultaneous measurements of O_2 column will use an identical approach with an O_2 line. The laser frequencies are tunable and have narrow (MHz) line widths. In combination with sensitive photon counting detectors these enables much higher spectral resolution and precision than is possible with passive spectrometers. Laser backscatter profiles are also measured, which permits identifying measurements made to cloud tops and through aerosol layers. The measurement approach using lasers in common-nadir-zenith path allows retrieving CO_2 column mixing ratios in the lower troposphere irrespective of sun angle. Pulsed laser signals, time gated receiver and a narrow receiver field-of-view are used to isolate the surface laser echo signals and to exclude photons scattered from clouds and aerosols. Nonetheless, the optical absorption change due to a change of a few ppm CO_2 is small, <1%, which makes achieving the needed measurement sensitivities and stabilities quite challenging. Measurement SNRs and stabilities of >600:1 are needed to estimate CO2 mixing ratio at the 1-2 ppm level.

We have calculated characteristics of the technique, and have demonstrated aspects of the laser, detector and receiver approaches in the laboratory. We have also measured O2 in an absorption cell, and made CO2 measurements over a 400 m long (one way) horizontal path using a sensor breadboard. We will describe these and more details of our approach in the paper.

14:20 Pierre H. Flamant [LMD/IPSL]

Atmospheric CO2 measurements by Lidar: an itinerary from ground to space

Carbon dioxide and other greenhouse gases are currently measured by in situ techniques with high accuracy but at some dedicated locations while the remote sensing techniques are considered today as a serious candidate to provide an Earth continuous global coverage. It turns out that the mission requirements are very stringent in terms of accuracy and sampling in order to be fully useful for assessments of sinks and sources and future trends. Accordingly, two CO2 dedicated passive remote sensor missions are under development in the USA and Japan namely OCO and GOSAT, respectively, to be launched in 2009. These initiatives are certainly taken as demonstrative and as a first step toward a comprehensive observation system to be implemented in the future. Along the same line, the Lidar technique is now considered for CO2 measurements after successful implementation in space as demonstrated by CALIPSO launched in April 2006. At present, few groups around the world are conducting innovative Lidar instrument developments and field experiments to demonstrate the capability of the Differential Absorption Lidar technique for accurate atmospheric CO2 measurements. In parallel, the strong environmental and societal issues led the European Space Agency to launch two feasibility studies finalized in 2005, and further selection in 2006 of A-SCOPE a proposal submitted in response to a call for the next earth explorer mission. The purpose of this talk is twofold: 1) to report on the on-going works conducted at LMD/IPSL using a breadboard CO2 DIAL and the most recent proposals to develop airborne or advanced ground-based DIAL, 2) to present the findings of the two studies conducted for ESA by IPSL and DLR and on going activities conducted in the framework of the A-SCOPE Assessment Mission Group.

14:40 Michael Dobbs [ITT] et al.

Narrow band modulated CW laser system for CO_2 column measurements

A unique, multi-frequency, single-beam, laser absorption spectroscopy (LAS) instrument has been developed for space-based measurements of carbon dioxide (CO_2) in the troposphere. The system developed by ITT Space Systems utilizes high Technology Readiness Level (TRL), low-power narrow-band modulated-continuous wave (CW) telecom components in the 1.57 μm region, with large area, high quantum efficiency, high gain and no excess noise detector and narrow-band demodulation system to achieve high signal-to-noise ratios (SNRs) of the on-line-to-off-line ratio for differential CO_2 column optical depth measurements. A prototype instrument and matching high-fidelity, physics-based performance model has been constructed and validated through several years of ground, field and airborne testing. This paper will discuss the performance and mission level advantages of the ITT developed laser absorption spectroscopy system (LAS) relative to other systems under consideration for space-based measurements of carbon dioxide (CO_2) in the troposphere.

15:00 Frédéric Chevallier et al. [LSCE/IPSL]

Inferring surface fluxes of greenhouse gases from satellite observations: method and application to OCO and IASI

Inferring surface fluxes from the atmospheric concentrations that they influence is a powerful but challenging idea. On the positive side, Bayes' theorem provides a rigorous statistical framework for such an inverse problem. Moreover, the variational formulation of Bayes' theorem, borrowed from numerical weather prediction, makes it possible to handle huge volumes of data. On the negative side, atmospheric dispersion is not a reversible process and taking it into account implies imperfect chemical-transport models. Further, Bayesian analysis involves assigning proper statistical error distributions to all the components of the inference system: the chemical-transport model outputs, the observations and the prior information. Yet, the availability of a wealth of satellite information about the atmospheric composition has motivated an increasing effort in this direction over the last decade.

This paper presents the variational inversion system that has been developed at LSCE to estimate the surface fluxes of CO2, CO, CH4 and aerosols from satellite measurements. The assignment of the error statistics in input to the system and different strategies to estimate those of the output fluxes will be discussed. Applications to OCO (for CO2) and IASI (for CH4 and CO) will illustrate the presentation.

15:20 Scott Denning, Kathy Corbin, and Nick Parazoo [Dpt Atmos Sciences, CSU]

Assessing sampling and representation errors in assimilation of satellite CO_2 retrievals

Retrieval of the mean dry mole faction of atmospheric CO_2 (X_{CO2}) from spectra measured by dedicated spaceborne instruments will be made a few times each month over a given location and will only represent clear atmosphere columns. Variations in atmospheric CO_2 on synoptic time scales may lead to temporal sampling errors in transport inversions, especially if they covary strongly with cloud cover. To assess the potential magnitude of these errors, we investigated sources of synoptic variability and its relationship to clouds using continuous tower observations, a coupled cloud-resolving model, and a global chemical transport model.

An observational assessment of systematic differences between mid-day CO_2 on clearsky vs all days used multiyear timeseries of continuous data from the WLEF-TV tower and Harvard Forest in the USA, and Flona Tapajos, Brazil. The WLEF site is a temperate forest in a remote rural area, and Harvard Forest is located in a region with strong anthropogenic emissions. Flona Tapajos is a very remote equatorial forest reserve. We found systematic differences of 1 to 3 ppm in measured mid-day CO_2, with lower values on sunny days than average. At the temperate sites, the differences are greatest in winter and are not attributable to anomalous surface fluxes. The tropical site showed the biggest differences in the rainy season, with very little sampling error in the dry season.

We performed cloud-resolving simulations of two cases using the SiB-RAMS coupled ecosystem-atmosphere model, one during summer at the temperate WLEF site and one during the dry season at the tropical Tapajos site. Simulated X_{CO2} was sampled on 1-km-wide swaths in clear columns only as if nadir sampling from space, and compared to a (100-km) mean which represents the grid column of a global CTM such as might be used in a transport inversion. In both cases, this “local” clearsky sampling error was found to be much smaller than the likely instrument retrieval error. At the temperate site, temporal sampling errors in representing time means from individual swaths were comparable to likely retrieval errors because of systematic X_{CO2} anomalies associated with fronts that were masked by clouds. In the tropics, these temporal sampling errors were much smaller.

The magnitude and seasonal variation of clearsky sampling errors at the three towers were reproduced well using the global PCTM. Global simulations of monthly mean X_{CO2} were compared to the means of samples taken only under clearsky conditions to assess spatial and seasonal patterns of these errors. Clearsky temporal sampling errors were found to be greatest over land, and were dominated by positive errors over the midlatitudes (especially Asia) in summer and negative errors over the tropics (especially South America) during the rainy season. These errors often exceeded 1 ppm, and must be addressed in a data assimilation system by correct simulation of synoptic variations in X_{CO2} associated with cloud systems.

16:10 Shamil Maksyutov [NIES] et al.

Towards development of the operational system for GOSAT CO_2 data use in the inverse model of the atmospheric CO_2 transport

A large volume of the atmospheric CO2 data will be produced by the planned GOSAT mission. We are preparing an inverse modeling system in order to use the data for estimating of the surface CO2 fluxes. The inverse modeling system prototype is based on monthly time resolution regional CO2 inversion, currently operating with 66 regions globally. Regular operation of the inverse model system components is planned, which is a proper way to increase the spatial resolution of both the inverse model and transport model. In particular, atmospheric transport calculations require a lot of computational time on supercomputers, and are most efficient way is to execute it operationally in a manner adopted by forecast centers. At present we conduct research on optimal design of the inverse modeling system. We use the data from regional CO_2 observing networks to test the impact of the high volume observational data. The fine grid-based inversion study is used to estimate the optimal resolution of the inverse model. For European network the optimal resolution appears to be in order of several hundred km, and temporal resolution around 2 weeks. To reduce biases in inverse model, we make effort to reduce biases and uncertainties in the seasonal and spatial patterns of the terrestrial and oceanic fluxes, as well as in the atmospheric transport. For example, optimization of the forward model of the surface CO2 fluxes at monthly time resolution was completed with the use of atmospheric CO2 observations in Northern hemisphere, leading to reduced misfit in most observation sites.

16:30 Peter J. Rayner [LSCE/IPSL] et al.

On the use of active remote sensing of atmospheric CO2 in source-sink estimation

We use a 4-dimensional variational technique (4dVar) to explore the constraint of surface sources and sinks afforded by active remote sensing of atmospheric CO2. The variational method uses the statistically consistent randomisation approach described in Chevallier et al. (2007). The required inputs for the calculation are a priori uncertainties on fluxes, a transport model (including its adjoint) and the space-time distribution and uncertainty of measurements. The first two are equivalent to Chevallier et al. (2007) allowing direct comparisons with the results of that paper for OCO. The data distribution and uncertainty are taken from simulation of the ACCLAIM instrument. We used several configurations of measurement, differing mainly in their vertical weighting function and uncertainty. We find that the greater coverage of the active measurements cf OCO leads to a stronger constraint on sources and sinks. Furthermore, the trade-off of higher errors against weighting functions favouring the lower atmosphere comes out as a net gain, that is it is worth focusing the measurements on the lower atmosphere even at the cost of higher data uncertainty.

16:50 Marko Scholze [QUEST, Univ. Bristol]

Carbon Cycle Data Assimilation System: A potential framework for assimilating remotely sensed CO2 data

The quantification of CO2 exchange fluxes and their uncertainties between the terrestrial biosphere and the atmosphere and predicting the evolution of these fluxes into the future is of major importance. It requires the use of process-based models in a way that makes best use of the existing and upcoming global observational networks, which is best tackled by the technique of data assimilation. The Carbon Cycle Data Assimilation System is built around the Biosphere Energy Transfer HYdrology Scheme (BETHY) model, coupled to the atmospheric transport model TM2. First, it uses remotely sensed vegetation activity data to constrain the phenology and hydrology part of the model. In a second stage, it uses about two decades of observations of the atmospheric carbon dioxide concentration from a global network to constrain 57 process parameters via an adjoint approach. The model's Hessian matrix of second derivatives serves to derive uncertainty estimates for the optimised process parameters that are consistent with the assumed uncertainties in the observations and the model. This presentation highlights the latest results from the Carbon Cycle Data Assimilation System and presents a roadmap for assimilating remotely sensed CO2 data in CCDAS.

17:10 Jan Folle Meirink [IMAU] et al.

Application of 4DVAR for inverse modelling of atmospheric CH_4

We present a novel 4DVAR system based on the atmospheric transport model TM5 for inverse modelling of atmospheric CH_4. The main advantage of the new system is that it allows optimizing the emissions of individual model grid cells, compared to optimization of larger geographical regions in classical synthesis inversions. At the same time very large observational data sets can be used, such as high frequency in situ measurements and global satellite data (e.g. from SCIAMACHY).

We present the results of global inversions and coupled global-regional inversions, exploiting the zooming capability of the TM5 model, and using both surface and SCIAMACHY measurements. It is shown that the SCIAMACHY observations are biased compared to the model with only surface observations assimilated. Our strategy to correct for these biases will be outlined. Finally, estimates are given of the uncertainty reduction in emissions due to the observations.

P1 Carol J. Bruegge et al. [JPL & CalTech]

Preflight calibration plans for the Orbital Carbon Observatory

The Orbital Carbon Observatory (OCO) instrument will provide retrievals of carbon dioxide, averaged over the atmospheric column. Currently the instrument is undergoing assembly and preparing for preflight characterization. Test plans include verification of the instrument design specifications, radiometric and spectral calibration, and illumination of the instrument via a heliostat. The latter observations will conduct sunlight onto the instrument while in a thermal vacuum environment. These data will be used to exercise the CO2 retrieval algorithm, and provide preflight data products. The observations will be validated using co-located in-situ instruments. This presentation will describe these test plans and data simulations.

P2 David Crisp [JPL & CalTech]

The Spatial Sampling Approach for Orbiting Carbon Observatory Measurements: Implications for CO_2 Assimilation and Source/Sink Inversion Models

The primary objective of the Orbiting Carbon Observatory (OCO) is to make global, space-based, measurements of atmospheric CO_2 with the accuracy, coverage, and resolution needed to quantify surface sources and sinks. To achieve this goal, OCO data must be assimilated accurately into global source/sink inversion models. There are several aspects of the OCO data acquisition strategy that pose challenges to this effort. For example, OCO will continuously acquire 12 to 24 bore-sighted CO_2/O_2 soundings per second while moving along the sunlit portion of its orbit. Each sounding will be analyzed with a remote sensing retrieval algorithm to yield a surface-weighted estimate of the column-averaged CO_2 dry air mole fraction, X_{CO2}. This produces 200 to 400 X_{CO2} samples per degree of latitude within a narrow (<10.4km) swath along the orbit track, but the separation between this track and the one from the next orbit is almost 24.7? of longitude. In addition, while the surface footprint of each sounding is relatively small (1.29 km by 2.25 km at nadir), the effective atmospheric footprint can be substantially larger, since it includes the path of the incoming solar beam between the top of the atmosphere and the surface, and the outgoing reflected beam between the surface and the spacecraft. At high latitudes, where the solar zenith angles are large, these paths can extend the spatial sampling well beyond the extent of the surface footprint. For example, if the vertical weighting function confines the measurement to the troposphere (<15 km), the horizontal distance between the beam entry point at the tropopause and the center of a nadir surface footprint increases from 6.7 km at the sub-solar latitude to 150.6 km at a solar zenith angle of 85?. How can these aspects of the OCO sampling be introduced into source/sink models without introducing biases in X_{CO2}?

P3 Akihiko Kuze and GOSAT Project Team [JAXA]

Performance and Ground Test results of TANSO on GOSAT

The Greenhouse gases Observing SATellite (GOSAT) is a satellite to monitor the carbon dioxide (CO_2) and the methane (CH_4) globally from orbit. The Thermal And Near infrared Sensor for carbon Observation Fourier-Transform Spectrometer (TANSO-FTS) detects the Short wave infrared (SWIR) reflected on the earth's surface as well as the thermal infrared (TIR) radiated from the ground and the atmosphere. It is capable of detecting wide spectral coverage, specifically, three narrow bands (0.76, 1.6, and 2 micron) and a wide band (5.5-14.3 micron) with 0.2 cm^{-1} spectral resolution. From these spectral data, major GHGs such as CO_2, CH_4, and ozone (O_3) are observed. Column density of CO_2 is mainly retrieved from 1.6 micron region absorption lines, of which intensities are less temperature dependent and not interfered by other molecules. Oxygen (O_2) A band absorption at 0.76 micron are used to estimate the effective optical path length. The polarization of the scene flux is also acquired by measuring P and S polarization, simultaneously. ? The other instrument on GOSAT is TANSO Cloud and Aerosol Imager (TANSO-CAI) to detect and correct the cloud and aerosol interference. ?It is a radiometer of ultraviolet (UV), visible, and SWIR with continuous spatial coverage, wider field of view, and higher spatial resolution.

JAXA had developed the bread board model (BBM) of TANSO-FTS three years ago and with National Institute for Environmental Studies (NIES) the feasibility to retrieve the CO_2 and CH_4 column density using this model is demonstrated.

The engineering models of TANSO-FTS and CAI have been manufactured, integrated and tested. The summary of the performance test methods and results (signal to noise ratio, instrument line shape function, polarization sensitivity etc.) will be presented. The proto-flight models are also being manufactured and integrated. Before launch, radiometric inter-comparison with Orbiting Carbon Observatory (OCO) is planned by NASA and JAXA.

P4 Tsuneo Matsunaga et al. [NIES]

Data screening in FTS Level 2 processing at NIES GOSAT DHF

Although several tens of thousands of FTS spectra will be received from GOSAT per day, the accuracy of retrieved column densities of GHGs(greenhouse gases) will be significantly deteriorated in case of spectra which are contaminated by clouds and thick aerosol.

In addition, as the current estimate of the computation time necessary for the retrieval process of a single FTS SWIR spectrum at planned NIES GOSAT DHF(Data Handling Facility) is much longer than the time of a single FTS data acquisition, the number of FTS spectra which are inputted to the GHGs retrieval process should

be reduced to 10% or less of the total number of acquired FTS spectra.
Therefore, in FTS Level 2 processing at NIES GOSAT DHF, FTS Level 1B products, which are "Top of the Atmosphere" radiance spectra, will be screened prior to GHGs retrieval process. In this screening, cloud information both from Cloud and Aerosol Imager's Cloud Mask products and FTS TIR Level 1B products will be used.
In this presentation, after requirements for FTS data screening are summarized, the basic ideas and the implemenation plan of the screening procedures will be discussed.

P5 Sergey Oshchepkov et al. [NIES]

Aerosol and cloud correction for the GOSAT data processing with respect to CO_2 retrievals

This paper concerns development of the retrieval algorithms for the processing of the Greenhouse gases Observing SATellite (GOSAT) data. GOSAT is scheduled to be launched in 2008 to monitor column amounts of CO_2 and CH_4. A nadir-looking Fourier-Transform Spectrometer (FTS) of Short Wavelength Infrared (SWIR, 1.6 µm and 2 µm) and 0.76 µm oxygen A-band regions will be mounted on GOSAT.
Accurate retrievals of CO_2 and CH_4 column density require clouds and aerosols correction. A traditional way of this correction is to involve cloud and aerosol optical or/and microphysical parameters in the retrieval scheme. However, such simultaneous retrievals could run into problems because the amount of information contained in the spectral bands outlined above is rather limited with respect to simultaneous estimation of cloud and aerosol properties.
In this paper, we describe an original methodology that permits correction of the net effect of cirrus cloud on nadir radiance spectra without retrieving its microphysical and optical parameters. This approach is based on the optimal estimation technique for gas amount retrievals in 1.58 µm CO_2 band. Aerosol and cloud correction was performed on the basis of the equivalence theorem with further parameterization of photon path-length probability density function (PPDF). In this paper, we focus on the retrieval of the PPDF parameters from water vapor saturated area of the CO_2 2.0 µm spectral band.
Application of the proposed approach was shown to provide reasonable accuracy (within 1%) of CO_2 column density retrievals in the presence of cirrus clouds with optical thickness up to 0.5 for the wide range of observation conditions. The proposed algorithm offers one of the candidates for the GOSAT operational data processing.

P6 Hiroshi Watanabe et al. [NIES]

Development of GOSAT Data Handling Facility (GOSAT DHF) at National Institute for Environmental Studies (NIES), Japan and planned GOSAT Data Products

GOSAT Project is a joint project of MOE (Ministry of Environment), JAXA (Japan Aerospace Exploration Agency) and NIES. Data acquired by TANSO-FTS (Fourier Transform Spectrometer) and TANSO-CAI (Cloud and Aerosol Imager) on GOSAT will be collected at Tsukuba Space Center @ JAXA. The level 1A/1B data of FTS and the level 1A of CAI will be processed at JAXA and will be transferred to GOSAT DHF for further processing. The processed data including those from JAXA will be archived and become available to all scientific users on non-discriminatory basis through the data search system of GOSAT DHF after the Initial Checkout phase. The GOSAT standard data products will be Level 1A/1B of FTS (Interferogram / Spectra) and L1A/L1B of CAI (raw data in “scene” and corrected data in “frame”), L2 of FTS (column concentration in “scene,” related data with location) and L2 of CAI (albedo and indeces derived from it). L3 data will be “world map column concentration” of Green House gases averaged in time and space. L4 data will be world source/sink model and re-calculated forward model. Major data flow will be also described. The Critical Design Review will be completed in early July of 2007 to prepare the scheduled launch of GOSAT in August 2008.

P7 Tomoaki Tanaka [NIES] et al.

Aircraft observation of solar scattered light spectra from land surface. Validation experiment of GOSAT No.1

The simulation experiment of GOSAT observation was conducted by use of high altitude flying aircraft (Egrett) equipped with a FTS. Thus obtained data is very useful to validate the algorithm to retrieve the CO2 and CH4 concentration from solar scattered light on land surface in advance to the launch of GOSAT.
The FTS spectrometer called as TSUKUBA similar to TANSO-FTS on GOSAT was developed by JAXA-BOMEM. It is designed to fly at high altitude on an aircraft in low temperature and pressure environment. In order to fix the viewing point of TSUKUBA during an interferogram acquisition, an image motion compensator was developed by NIES/AES Co.
This combined system was installed in the pod of G520T Egrett, ARA Co., and several flights over Adelaide have been conducted in March-April, 2007. The spectral resolution of TAUKUBA is 0.2cm-1, and it has three detectors covering 0.76, 1.6, and 2.0 µm bands. The differences from GOSAT TANSO-FTS are (1) one interferogram / 1 sec (4 sec), (2) no thermal infrared channel, (3) no polarization measurement.
The results of flight measurement over land in clear sky condition and partial cloud conditions, changing the altitude up to 12,000 m are discussed.

P8 Ryu Saito [NIES] et al.

Comparison between in-situ aircraft observation and direct solar spectral observation. Validation experiment of GOSAT No.2

The most reliable validation of GOSAT data is to compare then with the column integration of the direct sampling analysis data at different altitude; in situ observation on aircraft or balloon. GOSAT is going to use the in situ observation data of passenger planes of JAL (T.Machida et al), the precision of which data is excellent and the observation is very frequent, but the area where the vertical concentration profile is obtained is only over the airport. So, it is important to develop the method to observe the height distribution to compare with COSAT data at any place and time. A simple NDIR CO2 sensor may be possible to be launched on a balloon with a data down-link system (CO2 sonde) in the 1 ppm precision.
Another approach is the direct solar spectral observation. This observation has several advantages; good SNR, much less disturbances by cloud and aerosol, and time series of data. OCO is planning to use high resolution FTS, but it requires a large infrastructure and logistics, including data transfer. So, we decided to use Fabry-Perot Etalon in place of FTS. The comparison between in situ and FPE observation is discussed.

P9 Jouni Pulliainen, et al. [FMI]

Ground-based observations from Sodankylä-Pallas satellite CAL-VAL site for aiding space-borne greenhouse gas monitoring

Near-future satellite remote sensing instruments, such as Orbiting Carbon Observatory (OCO) of NASA, are able to provide data applicable for the mapping of CO_2, but only if their observations can be combined and calibrated with ground-based observations using advanced methods. The sparseness of ground observation network measuring CO_2 flows is a major problem at the high northern latitudes, which emphasizes the significance of using Earth Observation (EO) data. Moreover, as the carbon cycle north of the latitude of 50º is constrained rather by temperature than precipitation (soil moisture), dedicated carbon monitoring methodologies have to be developed for these regions. Such missions as OCO are able to provide information on the column of CO_2, if disturbing effects of spatial and temporal surface reflectance variations can be eliminated in the data retrieval algorithms. The Sodankylä-Pallas test site located in northen Finland is a potential candidate for investigating these aspect as extensive reference data, including detailed land cover information, are available from the region.

The Sodankylä-Pallas site belongs to the Global Atmosphere Watch (GAW) network. It provides unique ground-based CO_2 and other trace gas time-series observations as well as aerosol information on the surface and column concentrations to be applied for algorithm development and verification. The area is presently developed as a comprehensive surface satellite calibration and validation site. The Sodankylä-Pallas infrastructure consists of two nodes. The Arctic Research Centre of FMI is in Sodankylä which is in the middle of northern boreal vegetation zone. Pallas is close to tree limit area to the northwest. At Pallas, greenhouse gas concentrations according to GAW standards are measured on a treeless arctic mountain top site. The surrounding landscape, consisting of mosaic of spruce and pine forests and wetlands, acts as sources and sinks of carbon dioxide and methane. At Sodankylä, for example upper-air and spectral radiation measurements are routinely conducted. Sodankylä has also a micrometeorological flux site above a Scots pine forest. The Sodankylä-Pallas flux sites cover the three most common land-use classes in Finnish Lapland providing CO_2 source and sink estimates of natural surfaces. The data is used to study spring recovery, growing season CO_2 uptake and respiration, winter respiration and annual carbon balances of these ecosystems.

The essential factors contributing to carbon cycle also include the length of the growing season in boreal forests. This issue can be indirectly monitored by coarse spatial resolution microwave radiometers. The present microwave instruments include the AMSR-E multi-channel microwave radiometer of NASA. It is able to provide information on on-set of spring snow melt, which is a relevant factor concerning the monitoring of carbon balance. The results obtained for the mapping of snow melt in northern Eurasia, as well as the comparison of these results with Sodankylä-Pallas CO_2 flux observations are demonstrated.

P10 Dietrich G. Feist et al. [MPI-BGC]

Ground based FTIR system for high-accuracy measurements of atmospheric CO_2 and CH_4

Our knowledge of the global carbon cycle has several uncertainties that make it difficult to correctly model sources and sinks of important atmospheric greenhouse gases like carbon dioxide and methane. One such uncertainty is the role of plants in the global methane cycle. Recent studies suggest that living plants could actually be net producers of CH4. These results are backed by first methane measurements from SCIAMACHY on Envisat. These show enhanced methane especially over the tropical rain forests when compared with modeled global methane distributions. However, the retrieval of methane from SCIAMACHY and other future satellite instruments is difficult and has to make several assumptions, for example about the vertical carbon dioxide distribution. These assumptions and the resulting retrievals need to be validated.

However, groundbased measurements of the column atmospheric methane and carbon dioxide distribution that the satellite sees are very sparse - especially with the required high accuracy and especially in tropical regions. Ground-based FTIR instruments can provide the necessary accuracy but need to be able to also observe the total column of oxygen in order to relate the methane and carbon dioxide column measurements to the total air mass. The Max-Planck-Institute for Biogeochemistry in Jena, Germany, has recently bought such an FTIR instrument and is currently preparing it for employment in the tropics. The excat location will be determined by summer 2007. The instrument will be able to observe the temporal variation of methane and carbon dioxide and these results will be interpreted with the help of global source and sink models and possibly talltower measurements at the site. Like a satellite instrument it will observe the total column of these trace gases and possibly provide some altitude information. It will therefore provide an ideal reference and validation site for future SCIAMACHY and OCO measurements of carbon dioxide and methane in the very active tropical region.

P1 Ilse Aben [SRON] et al.

SCIAMACHY CO measurements, validation, and interpretation of southern hemisphere biomass burning observations

The SCIAMACHY satellite instrument was launched in 2002 on-board of ENVISAT and currently provides 4 years of global carbon monoxide (CO) data. Contrary to the thermal infrared measurements of CO, such as those by MOPITT, SCIAMACHY CO near-infra red measurements are sensitive down to the Earth's surface where most of the CO sources are located. Unfortunately we have had some instrumental complications with the channel measuring CO, but these are now well understood and corrected for. Validation of the measurements is on-going and some important progress will be presented using an atmospheric chemistry transport model for statistical comparison. This comparison allowed for an evaluation of the SCIAMACHY CO observations as a function of many relevant parameters such as instrument measurement noise, SZA, surface albedo, geolocation etc. It further showed that SCIAMACHY CO data contains useful information for science.
If time allows, a case study will be presented showing CO pollution over Australia during its biomass burning season coming in fact from biomass burning emissions in South America. In fact we can show that the interannual variation of excess CO over Australia is caused by interannual variation in biomass burning CO emissions in South America.

P2 Paul Palmer [Univ. Edimburgh] et al.

Interpreting variability of CO_2 column observations from SCIAMACHY using a global 3-D chemistry transport model

We use the GEOS-Chem model of atmospheric chemistry and transport, driven by terrestrial biosphere fluxes from the CASA model, to interpret the observed variability in CO2 columns retrieved from SCIAMACHY NIR spectra using the FSI-WFM-DOAS algorithm. Individual model tracers represent partial contributions to total column CO2 from surface sources and sinks over different geographical regions, allowing us to estimate the sensitivity of observed CO2 variability to surface fluxes. We will present an analysis of SCIAMACHY CO2 data over North America for two successive years to investigate the magnitude of seasonal and year-to-year variations in observed columns.

P3 Thierry Phulpin [CNES]

Presentation of IASI

MetOp-A, the first of the European Polar meteorological satellite series, was launched on October 19, 2006. The platform embarks a suite of instruments, among them IASI, the Infrared Atmospheric Sounding Interferometer designed and developed by the French spatial agency CNES in cooperation with EUMETSAT. IASI consists of a Fourier transform spectrometer, which measures radiance spectra of the Earth-atmosphere system between 645 and 2760 cm-1 in the thermal infrared, at a spectral resolution of 0.5 cm-1 (apodized) and an embedded single channel imager with a 850 m resolution. The nadir-looking geometry of IASI, combined with an across-track scanning mode reaching 48° on both sides, allows global coverage to be achieved in twelve hours.
Scientific studies performed in the preparatory program in the framework of the IASI Sounding Science working Group (ISSWG) showed that thanks to its extended spectral coverage and spectral resolution, IASI will provide unique information on the concentration distribution of numerous tropospheric species, impacting on climate (H2O, CO2, N2O, CH4, CFCs) or on chemistry (O3, CO, HNO3). For most of these gases we demonstrate that vertical profiling is possible.
During the Calibration/validation period of 8 months after launch, a lot of work has been done at CNES, EUMETSAT or by scientific partners to evaluate the IASI performances. The in-flight performances are very close to those measured during pre-flight on ground calibration of the instrument. The absolute calibration, checked with balloon data or airborne instruments data is within 0.5 K.
Now data have been operationally delivered by EUMETSAT since end of May 2007.

P4 Ray Nassar [Harvard University] and the TES team

Greenhouse gas measurements from the Tropospheric Emission Spectrometer (TES)

The Tropospheric Emission Spectrometer (TES) is a Fourier transform spectrometer on the Aura satellite. TES measures infrared emission of Earth's atmosphere with the primary objective of studying the global distribution of tropospheric ozone along with its chemical sources and sinks. Many of the chemical species measured by TES including O_3, H_2O, CH_4 and CO are greenhouse gases, some of which contribute significantly to the radiative forcing of the troposphere. The current state of TES measurements of each of these species will be discussed, with a particular emphasis on O_3 and CH_4, as well as an outline of some future work utilizing TES measurements for studies related to climate change.

P5 Valery A. Yudin et al. [NCAR]

Estimation of carbon monoxide from space: Retrievals, data analysis and inverse estimations

Paper outlines the current stage of monitoring CO from space by MOPITT, TES, and AIRS instruments. We discuss challenges in providing integrated estimations of the global CO state and corresponding CO emissions by data assimilation and inverse methods that employ the reported multi-instrumental CO retrievals simultaneously. The limits of averaging kernels methodology for characterization of retrieved CO profiles are examined as a part of these challenges. These limits are related to arbitrary choice of the background CO (profiles and errors) in the retrieval algorithms, nonlinearity of CO weighting functions, and rank-deficiency of employed retrieval schemes. The radiance data assimilation schemes in the comprehensive chemistry-transport models present the possible way to address these challenges in the estimation of CO from the space. We present a prototype of assimilation of clear-sky MOPITT radiances in the MOZART CTM using the family of scale-consistent estimation schemes with ensemble-based description of CO uncertainties. Based on these radiance data analysis studies this study outlines possible benchmarks for evaluation of retrieved CO profiles and inverse algorithms employing the in situ data and/or ensemble-based CO model predictions.

P6 Gerhard Ehret et al. [Institut für Physik der Atmosphäre, DLR]

Active remote sensing of the greenhouse gases CO_2, CH_4, and N_2O from space-borne platform by integrated path Differential Absorption Lidar: A sensitivity analysis

Lidar (Light Detection and Ranging) is regarded as an innovative component of the global observing system offering the possibility to directly sample the concentration of atmospheric trace gases with unprecedented accuracy. In this paper we report on Integrated Path Differential Absorption (IPDA) lidar which is regarded as a potential observational method for monitoring of the greenhouse gases carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) from space-borne platform. From comprehensive performance simulations it was found that instruments of moderate size in terms of telescope aperture (~ 1m) and laser average power (~ 1W) tend to have a low random error. The wavelength selection in the vicinity of the absorption lines is critical as it controls the height region of highest sensitivity as well as the temperature cross-sensitivity. Other sources of systematic errors can be kept to a minimum by using a narrow-band laser transmitter and a spectral filter in the receiver channel. Coherent detection instruments are less attractive as they are handicapped by speckle noise. Direct detection instruments perform better at shorter wavelengths (< 2 µm). Finally, the added value of an instrument which is potentially suited for the measurement of CO2 columns with high precision and low systematic error is highlighted at the end of our presentation.

P7 Susan A. Kooi [Science Systems and Applications and NASA LaRC]

Characterization of error sources for airborne and space-based CO_2 DIAL Measurements

Although CO_2 is widely recognized as a major contributor to global climate change, it is not easy to measure because the variations above background levels are very small. This makes it extremely difficult to detect temporal and spatial trends, and yet that is what is needed on a global scale to gain a better understanding of the sources and sinks regulating the amount of CO_2 in the atmosphere. Global column CO_2 measurements from a space-based DIAL instrument have been proposed as a way to address this need. A measurement precision of about 1 part per million by volume (ppmv) or about 0.3% has been indicated as the requirement for such an instrument to measure CO_2 sources and sinks. The DIAL measurement of CO_2 is sensitive to many potential errors including: the knowledge of CO_2 line parameters (line strength, half width, and pressure shift); knowledge of DIAL laser wavelengths; knowledge of water vapor in determining dry air density; and knowledge of temperature in determining CO_2 absorption cross sections. Since the CO_2 absorption line parameters are experimentally determinable, we did not include them in our analysis. This analysis does address the CO_2 DIAL measurement errors associated with uncertainties in the knowledge of DIAL laser wavelengths, water vapor profiles, and temperature profiles. These error sources are evaluated over a range of nominal laser wavelengths for a selected CO_2 absorption line by calculating mixing ratio errors using the modeled CO_2 optical depth variations.

This paper discussed the background for the modeling of CO_2 column measurements from airborne and space-based platforms and the sensitivity of those measurements to errors in the knowledge of laser wavelengths, atmospheric water vapor, and atmospheric temperature. These results will be used to help estimate the error budget for high sensitivity DIAL column measurements from aircraft and space and to help optimize the various trade-offs associated with the development of such a system.

P8 Claire Carouge [LSCE] et al.

Regional inversion of daily mean CO2 measurements over Western Siberia: pseudo-data experiment.

The number of continuous CO_2 measurement stations has increased recently resulting in relatively dense regional observation networks. Such networks increase our knowledge of local synoptic variations of CO_2 concentrations. The National Institute for Environmental Studies (NIES) has developed a network of five continuous measurement towers in Western Siberia. These towers are located in relatively close proximity, covering 786,000 km^2, and allow for the study of CO_2 fluxes at regional scale through inverse modeling.

We describe an inversion model already developed and tested over Europe by Peylin et al. (2005) applied to Western Siberia. In this model, a Bayesian synthesis inverse scheme is used to infer daily CO_2 fluxes over Western Siberia at a spatial resolution of 50x50 km^2 from daily mean CO_2 concentrations. We use the global transport model LMDZt with a nested grid over Western Siberia. With this transport model choice, the influence functions of CO_2 fluxes from all over the world on the observation stations can be simulated. Issues of assuming boundary conditions outside Western Siberia, common to mesoscale transport models, are avoided. With this inversion setup, we optimise approximately 1,800,000 fluxes with 1,825 individual measurements. It is therefore impractical to calculate influence functions at the stations by direct transport as this requires one tracer per daily flux. Instead, we use the so-called retro-transport methodology. Hourdin et al. (2006) shows an equivalent result to the adjoint transport is obtained by running transport model backward in time. With this method, the influence functions are calculated by only one retro-tracer per measurement.

We present initial results from studies using pseudo-data. These data were simulated by forward atmospheric transport of daily CO_2 fluxes from the biogeochemical model ORCHIDEE for the year 2005. These initial results indicate in which areas the best retrieved fluxes are obtained with the assumption of perfect atmospheric transport. We focus our analysis on the error reduction on fluxes by inversion. The results show a strong seasonality with a higher reduction in winter than in summer. We also provide an analysis of the spatial and temporal resolution at which fluxes can be reliably retrieved.