COMMUNITY WORKSHOP ON AIR QUALITY REMOTE SENSING FROM SPACE: DEFINING AN OPTIMUM OBSERVING STRATEGY

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Session 4: Future Mission Concepts and Observing Strategies
Co-chairs: ***John Burrows, Jack Fishman & Phil DeCola***

ORAL PRESENTATIONS

Burrows, U. Bremen, Germany

Atmospheric Pollution Measurements from Space: The GeoSCIA (Geostationary Scanning Imaging Absorption spectroMeter for Atmospheric ChartographY) and GeoTROPE (Geostationary Tropospheric Explorer)

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The amount and behaviour of tropospheric pollution is determined by the highly variable emissions of trace gases from the earth's surface, non linear photolytic and chemical cycling, and the dynamics of the troposphere. All of these processes have large intrinsic variability. Although measurements to the cloud top provide important information about the troposphere, measurement to the surface requires cloud free conditions. As a result of these considerations, high spatial and temporal sampling is required to make accurate and representative measurements of atmospheric pollution and its diurnal cycling. For passive remote sounding of the troposphere, as identified by the meteorological community several decades ago, the most practical approach is to make measurements from Geostationary orbit.

The first European proposal, GeoSCIA, to make measurements of atmospheric constituents at the required temporal and spatial scales, was developed in 1997 and 1998 and submitted to ESA. This resulted in industrial and scientific feasibility studies, supported nationally in Germany and the UK and by ESA. GeoSCIA is a passive remote sensing instrument measuring in the back solar scattered radiation in the ultraviolet, visible and near infrared spectral regions. It is a modular flexible concept building on the successful heritage of GOME and SCIAMACHY. GeoSCIA will provide measurements of its targeted trace gases, aerosol and cloud parameters at the required high spatial and temporal sampling to measure the diurnal

To meet the need to retrieve height resolved information about pollutants and optimise the target species and parameters, the GeoSCIA has been combined with GeoFIS (Geostationary Fourier Transform Imaging Spectrmeter) to become the GeoTROPE mission. This is currently under review by ESA as a demonstration scientific explorer mission. GeoTROPE meets the requirements of the IGOS-IGACO and the European GMES (Global Mearuements of Environment and Security) sentinel 4.This is planned to be an operational European contribution to GEOSS.

Eldering, Jet Propulsion Lab., USA

Air Quality Investigation Constellation

Annmarie Eldering

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As discussed in the NRC report, Global Air Quality, global population and urban population are increasing rapidly, and it is estimated that over a billion people are currently exposed to harmful air pollution (Schwele, 1995; Molina, 2004). Global measurements from the space shuttle, EOS Terra, EOS Aura, and other satellites have shown that air pollution is an international issue, with industrial and biomass burning emissions impacting both less developed nations as well as industrialized and rapidly growing developing countries (Akimoto, 2003).

With such large impacts to humans, it is imperative that we enable accurate prediction and control of global air pollution. This can be accomplished by a concerted program of emissions measurement, global air pollution measurement, and model development. Global chemical transport model development is hindered by the lack of observational data, especially vertically resolved chemical measurements. For the processes that happen in short timescales and are very responsive to sunlight, there are large diurnal cycles that must be sampled.

After discussing a careful development of measurement requirements, I will describe mission concepts that are responsive to these requirements. These mission concepts use a constellation approach with higher orbits. The new vantage point of this air pollution constellation mission will allow for multiple vertically resolved global measurements of air pollution each day. This information is essential for understanding the global context of air pollution - emissions, transformations, and concentrations of a suite of chemical species.

Herman, NASA Goddard Space Flight Center, USA

Advantages of Earth-Sun Observations from Lagrange 1

Jay R. Herman

NASA/Goddard Space Flight Center

Observing the Earth, solar wind, and the Sun from Lagrange-1 (L-1) affords us a unique view of the Earth’s whole atmosphere and its coupling to solar activity. The proposed JANUS L-1 observations can concurrently observe sources of upper atmospheric forcing from space weather phenomena and solar disk activity by including instrumentation for terrestrial atmospheric composition and airglow analysis, solar weather, and solar activity (soft x-rays and EUV, solar coronal flares, and mass ejections). The key to a possible L-1 mission is the careful selection of measurements and scientific objectives to target NASA's exploration goals, and advance our understanding of the Earth's total environment. Understanding the influence of the solar driver, and the coupling between the upper and lower atmosphere, is one of the most significant problems in Earth science. The JANUS mission will augment existing satellite and ground-based measurements and provide a unique measurement set enabled by the L-1 vantage point by providing a unique global mapping of synoptic atmospheric composition every 30 minutes over the Earth's sunlit disk (sunrise to sunset) with high spatial resolution (5 km at nadir). Measurements from L-1 can provide continuous tracking of anthropogenic and natural plumes (megacitiy pollution, trace gases, O3, SO2, NO2, dust storms, volcanoes, etc.) over scales extending from 5 km to the dimensions of the Earth. Beyond the Earth's troposphere and stratosphere, the unique JANUS suite of Sun and Earth measurements will enable continuous observation of the mesosphere and thermosphere extending to outer space, with vertical resolution in the stratosphere and ionosphere allowing exploration of the couplings between these domains.

Waters, Jet Propulsion Lab., USA

Composition of the Atmosphere from Mid-Earth Orbit (CAMEO) observations for air quality studies

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CAMEO is a future atmospheric composition satellite mission concept to address air quality, climate change, general circulation model deficiencies, and ozone layer stability. It provides global coverage with a new and needed combination of temporal, vertical, and horizontal resolution – enabling measurements of fast processes (such as convection) from satellite. These processes have major influences on issues directly related to societal needs and benefits. CAMEO also continues certain long-term climate-quality data records needed for assessing global change and ozone recovery. It uses an easily-reached mid-Earth orbit (MEO, ~1000 to ~10,000 km height) and advanced versions of two instruments, both of which have proved highly successful on two or more previous satellite missions.

Eskes, KNMI Royal Netherlands Met. Inst., Netherlands

A mission for TRopospheric composition and Air Quality

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TRAQ (TRopospheric composition and Air Quality) is a mission proposed in ESA's 2005 EOEP call. The mission is a co-operation between The Netherlands and France, but scientists from many other countries are collaborators in this mission, including several US scientists. TRAQ is a mission focused on the troposphere in order to obtain a better understanding of air quality, sources and sinks of atmospheric constituents and global (climate) change. The science questions of TRAQ are:

- How fast is air quality changing on a global and regional scale ?
- What is the strength and distribution of the sources and sinks of trace gases and aerosols influencing air quality ?
- What is the role of tropospheric composition in global change ?

TRAQ aims at following tropospheric pollution during the day, while at the same time providing global-scale information on long-rang transport of pollutants, and a global survey of climate constituents and sources and sinks of tropospheric pollutants. To be able to obtain the time-resolution and coverage needed to address the science questions, TRAQ will fly in an optimized inclined LEO orbit, obtaining daily global coverage except for the poles and performing measurements up to 4 to 5 times per day at daytime over mid-latitudes.

To provide a full suit of tropospheric measurements, containing the most relevant key-tropospheric trace gases and aerosol parameters for pollution and climate change, a suite of 4 instruments was selected: an UV/VIS/NIR/possibly SWIR instrument TROPOMI, which is a follow-on instrument to OMI adding SWIR techniques from SCIAMACHY; SIFTI, an FTIR and possible SWIR instrument with strong heritage from IASI; CLIM, a cloud detector and OCAPI, an instrument with heritage from POLDER for a suite of aerosol parameters. The TROPOMI instrument will measure NO2, SO2, HCHO, CO, CH4 and O3 with improved accuracy over OMI and SCIAMACHY due to optimized surface albedo and cloud parameter detection, and the information on aerosols from OCAPI. The SIFTI instrument will add vertical profiles of O3 and CO in the free troposphere. By combining SIFTI with TROPOMI measurements the retrieval of tropospheric ozone and CO can be improved over existing techniques. The CLIM imager will provide subpixel information on clouds. It will be used by SIFTI to select cloud-free scenes. The OCAPI instrument will provide aerosol parameters, including aerosol optical thickness, aerosol type and aerosol size distribution.

In the presentation an overview of the mission will be presented focused on the science questions. A simulation of the orbit will be shown.

Fishman, NASA Langley Res. Center, USA

Challenges of Characterizing and Forecasting the Outbreak of Pollution Episodes: Defining Requirements for Spaceborne Air Quality Observations

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Measurements of CO, O3, NO2, and HCHO can currently be obtained from instruments on low-earth orbiting (LEO) satellites. As technology has advanced, the size of the footprints of these measurements has improved to the extent that the Ozone Monitoring Instrument (OMI), launched in 2004, can provide information with resolution as small as 12 km by 24 km. For air quality studies, however, the spatial and temporal resolution of the measurements must be greatly improved. In this study, we will demonstrate the type of measurements that would be available for the above chemical trace gases using instruments from a geostationary (GEO) platform, where spatial resolution on the order of 5 km2 and temporal resolution on the order of one hour should be attainable. As has been demonstrated previously, CO, NO2, and HCHO pollution "hotspots" should be readily identifiable since the total column measurements of these trace species is controlled by what is present in the planetary boundary layer. The O3 total column, on the other hand, is dominated by its stratospheric contribution. Using a global-scale chemical assimilation model and measurements from LEO instruments, we will present a technique that isolates pollution-generated ozone enhancements from total column measurements and thus identifiable from GEO-based instruments. The data products available from such a suite of measurements could then be used to improve model performance, evaluate air quality forecast products, and validate emission source estimates. We will also address the requirement of obtaining an accurate picture of the larger synoptic-scale environment so that the onset of widespread pollution episodes on both local and regional scales can be characterized and forecasted. Insight gleaned from previous case studies will be presented to illustrate the importance of resolving a spectrum of scales so that the chemistry and meteorological processes that result in the formation of widespread air pollution outbreaks can be better understood. Improved understanding of the synergistic aspect of the chemistry and dynamics on these differing spatial and temporal scales is critical for the successful development of a national air quality forecasting capability.

Brune, Pennsylvania State University, USA

Measurement requirements for geostationary observations of pollutants with the NASA GSFC GeoChem instrument

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Geostationary satellite measurements of tropospheric pollutants will revolutionize the understanding of and predictive capability for air quality for local to continental scales. Current polar orbiting satellites have demonstrated the value of satellite measurements of a subset of atmospheric constituents – ozone, carbon monoxide, nitrogen dioxide, formaldehyde, and aerosols - for understanding pollutant source emissions and monitoring long-range pollutant transport. Geostationary satellite measurements complement these polar orbiting measurements in three ways: by resolving the fundamental diurnal nature of pollutant emission and formation; by measuring on horizontal spatial scales appropriate for the size of concentrated emission sources and the evolving non-linear chemistry; and by measuring these same atmospheric constituents. Such high temporal and spatial resolution of geostationary satellite measurements is quite compatible with emerging mesoscale models, which have horizontal resolution approaching a kilometer. Much of the power of geostationary satellite measurements will derive from the combination of these atmospheric constituent observations with high-resolution models and information from the next generation of weather satellites.

In our presentation, we will examine the measurement requirements, in terms of spatial and temporal resolution and atmospheric constituents, that are needed to understand and predict air quality from space-based measurements. We will show the design of a ultraviolet-to-visible spectrograph that meets these measurement requirements.

Diner, Jet Propulsion Lab., USA

The Aerosol Global Interactions Satellite (AEGIS) concept: Science objectives, mission design considerations, and applications to air quality

David J. Diner
Jet Propulsion Laboratory, California

Fine airborne particles are implicated in adverse impacts on human respiratory health, yet in situ measurements are lacking over much of the globe. Recognizing the need for future measurement advances, a mission concept—the Aerosol Global Interactions Satellite (AEGIS)—consisting of a multiangle spectropolarimetric imager (MSPI) and a high spectral resolution lidar (HSRL) was submitted to the 2005 NAS Decadal Survey. With the goal of measuring the 3-D distribution of aerosol abundances, sizes, shapes, and absorption on a global basis, AEGIS objectives include understanding the impact of natural and anthropogenic processes on trends in particulate pollution near the surface.

The MSPI instrument provides a synergistic combination of UV-SWIR, multiangle, and polarimetric imaging to obtain column-averaged aerosol properties plus stereoscopic layer-top heights for spatially distinct aerosol plumes. HSRL measurements provide vertical profiles of aerosol backscatter and extinction for dispersed aerosol layers plus vertically resolved estimates of microphysical properties. For surface air quality monitoring, the MSPI-HSRL combination offers a direct approach for column-to-surface scaling, with the potential to account for variability in the vertical distribution of aerosol type. High spatial resolution and frequent global coverage are necessary for integrating the satellite data with in situ and suborbital measurements of aerosol physical and chemical composition, and with transport models.

Besides air quality, AEGIS objectives include exploring cause-and-effect relationships between cloud properties, precipitation, and aerosol amount and type. This implies the need for passive/active cloud scanners and profilers on the same platform or in formation flight. Careful consideration of orbit parameters and payload choices is needed to balance particulate air quality requirements with complementary science goals.

Ferrare, NASA Langley Res. Center, USA

Future Spaceborne Aerosol and Ozone Lidars for Air Quality Applications

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Spaceborne lidars offer significant advantages over passive optical sensors for providing detailed information on the vertical distribution of aerosols and trace gases relevant to air quality applications. This vertical information is crucial for understanding transport and chemistry in the troposphere and for constraining models for improved air quality forecasting. The backscatter lidar technique employed on ICESAT and CALIPSO provide global information on the vertical distribution of aerosol backscatter and estimates of aerosol extinction. The High Spectral Resolution Lidar (HSRL) technique can provide a more direct measure of aerosol extinction; this technique, when applied at multiple wavelengths and coupled with advanced retrieval algorithms, shows promise for measuring the vertical distribution of aerosol macrophysical and microphysical properties, including concentration and size. The DIfferential Absorption Lidar (DIAL) technique, which has been used for decades in atmospheric chemistry studies of ozone and aerosols from aircraft, has the potential for providing global distributions of ozone with a vertical resolution in the troposphere that is a significant improvement over what can be done currently with passive instruments. This talk will discuss some of the capabilities and limitations of current and potential future spaceborne lidar instruments, their application to air quality prediction and monitoring, and synergies with complementary passive optical instruments (e.g., a multiangle spectropolarimetric imager such as the JPL MSPI instrument and passive instruments such as TES and OMI).

van Weele, KNMI Royal Netherlands Met. Inst., Netherlands

Definition of Operational Atmospheric Chemistry Monitoring Missions: Final Results of the ESA CAPACITY Study (2003-2005)

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It is urgent to set up an operational monitoring system that can meet Air Quality user requirements. Stringent requirements on temporal resolution and horizontal spatial resolution can not be met with the missions that are planned for the next decade (2010-2020). A combination of satellites is needed, either in a combination of a mission in low-earth orbit and a mission in geostationary orbit, or by multiple satellites in low-inclination orbit.

Climate protocol monitoring can efficiently be integrated in an Air Quality combined mission. For NWP and other climate applications and for the monitoring and assessment of the ozone layer it is recommended to also have an operational limb component. Total ozone monitoring is guaranteed by MetOp/NPOESS.

Future extensions of the integrated operational system for the global monitoring of atmospheric composition have been investigated by a large European consortium in an ESA commissioned 18-month study named CAPACITY (2003-2005). Focus was given to applications in air quality forecasting, ozone/UV forecasting, air quality monitoring and assessment, protocol monitoring (e.g. Montreal, Kyoto) and assessments of climate change and ozone layer recovery. Geophysical data (Level-2) and instrument requirements (Level 1) have been derived for each of the envisioned applications. The final report is available from http://www.knmi.nl/capacity. Operational monitoring of atmospheric composition is called for within, e.g., GMES (Global Monitoring of Environment and Security), the European contribution to the international Global Earth Observation System of Systems GEOSS.

Tjemkes, EUMETSAT, Germany

The METEOSAT Third Generation UVS Mission

Stephen Tjemkes, Rolf Stuhlmann, Antonio Rodriguez (EUMETSAT), Donny Aminou, Jean-Loup Bezy and Paolo Bensi (ESA)

During an oral presentation we would like to present the user and instrument requirements for the METEOSAT Third Generation (MTG) UVS. This instrument is currently being studied in the frame of the MTG System Architecture Studies at pre-phase A level conducted by ESA, as part of the suite of instruments for the future meteorological satellite system in geostationary orbit. The observations by the UVS instrument could be used to monitor key atmospheric constituents, like ozone, SO2 and aerosol properties (both columnar and vertical resolved) in support of atmospheric chemistry and air quality operational applications. Data and services from MTG should be made available in the period from 2015 - 2030.

POSTER PRESENTATIONS

Chatfield, NASA Ames Res. Center, USA

Synthesizing IR and UV Remote Sensing for Forecasting Air Pollution

RB Chatfield (NASA/Ames), JB Kumer, AR Roche, J Mergenthaler (LMATC), F Binkowski (UNC), and S McKeen (NOAA-CIRES)

Infrared-based remote sensing can contribute strongly to our national and international efforts to forecast near-surface pollutant ozone. We describe the use of new IR technology, a simple and robust suite of Grating Mapping Spectrometer (GMS) instruments, in predicting the creation of broad regional patterns of ozone and also fine respirable particles. GMS technology, which we are developing in an Instrument

Incubator Program, can make relevant height-resolved measurements of tropospheric ozone. Measurements made a few times a day globally may be superior to geostationary measurements that miss important source regions.

(1) Ozone measurement quality similar to Aura-TES can be expected, but retrievable in broad swaths which sample the whole globe twice daily for each instrument deployed. (2) LEO or MEO measurements of CO globally, including distant boreal regions, allow for forecasting of forest-fire effects on air quality, which proved once again in the ICARTT sampling intensive of 2004 to be significant for regional Eastern US pollution ozone. (3) Measurements of HCHO allow a quantification of the intensity of organic oxidation regionally; HCHO has proved to be highly correlated with both ozone production; we will show that, surprisingly, it is even more strongly correlated with fine submicron aerosol; this aerosol occasions increasing concern for morbidity and mortality in the United States, but has proven difficult to sense remotely.

The combination of IR with UV techniques for O3 and HCHO promises improvements in skill not obtainable from one technique alone. Difficulties associated with the verticality of instrument response and of cross-sensitivities tend to be different for remote sensing using the two wavelength regions. We may expect that the prediction of pollutant ozone will benefit from the cross-validation of different instruments, as it has already profited from the cross-validation of multiple forecast models. The most pernicious errors of each technique will avoided.

Eskes, KNMI Royal Netherlands Met. Inst., Netherlands

TROPOMI and TROPI: UV/VIS/NIR/SWIR instruments

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TROPOMI (Tropospheric OMI instrument) is a four-channel UV-VIS-NIR-SWIR non-scanning nadir viewing imaging spectrometer that combines a wide swath (114°) with high spatial resolution (10 × 10 km2) . The instrument heritage consists of GOME on ERS-2, SCIAMACHY on Envisat and, especially, OMI on EOS-Aura [Levelt et al., IEEE Trans. Geo. Rem. Sens. Aura Special Issues, 2005]. TROPOMI has even smaller ground pixels than OMI-Aura but still exceeds OMI's S/N performance. These improvements optimize the possibility to retrieve tropospheric trace gases.

TROPOMI is part of the TRAQ payload, a mission proposed in response to ESA's EOEP call. The TRAQ mission will fly in a non-sun synchronous drifting orbit at about 720 km altitude providing nearly global coverage.. TROPOMI measures in the UV-visible wavelength region (270-490 nm), in an additional channel (NIR) in the 710-775 nm range and has a shortwave infrared channel (SWIR) near 2.3 μm. The wide swath angle, in combination with the drifting orbit, allows measuring a location up to 4 times a day at

1.5-hour intervals. The spectral resolution is about 0.45 nm for UV-VIS-NIR and 0.25 nm for SWIR. The instrument will carry on-board calibration sources like LEDs and a white light source. Radiometric calibration will be maintained via solar irradiance measurements using various diffusers. Innovative aspects include the use of improved detectors in order to improve the radiation hardness and the spatial sampling capabilities. Column densities of trace gases (NO2, O3, SO2 and HCHO) will be derived using primarily the Differential Optical Absorption Spectroscopy (DOAS) method. The NIR channel serves to obtain information on clouds and the aerosol height distribution that is needed for tropospheric retrievals. A trade-off study will be conducted whether the SWIR channel, included to determine column densities of CO and CH4, will be incorporated in TROPOMI or in the Fourier Transform Spectrometer SIFTIon TRAQ.

The TROPI instrument is similar to the complete TROPOMI instrument (UV-VIS-NIR-SWIR) and is proposed in the CAMEO initiative, as described for the U.S. NRC Decadal Study on Earth Science and Applications from Space. CAMEO also uses a non-synchronous orbit, but at a higher altitude (around 1500 km). Pixel sizes and swath width will increase accordingly.

In the paper several aspects of the instruments will be discussed and first estimates of the uncertainties of the trace gases will be given for nominal and minimum radiance scenarios.

Fishman, NASA Langley Res. Center, USA

Earth's First Time-Resolved Mapping of Air Pollution from Space

Jack Fishman, Doreen Neil, James Crawford, R. Bradley Pierce (NASA), David Edwards (NCAR); Kelly Chance, Thomas Kurosu (Harvard-Smithsonian Center for Astrophysics); W. Paul Menzel (NOAA); Gary Foley, Rich Scheffe (US EPA)

We describe a near term mission, GeoTRACE (Geostationary Observatory for Tropospheric Air Chemistry), that powerfully addresses Earth science and applications from space. Geostationary orbit uniquely provides continuous access to the wide temporal and spatial variability of atmospheric composition and observes the continental distribution of air pollution, cloud formation and dispersion, and diurnal changes to Earth's lower atmosphere. A tropospheric chemistry mission from geostationary orbit also meets needs of public health and policy applications related to assessing and managing national air quality, determining the impact of daily human activity on both chemical weather and climate, and assessing policy implications of international transport of air pollution.

The required observations use well-understood measurements and well-validated retrieval techniques already employed in space, and advance these techniques to geostationary orbit, in order to capture hourly around-the-clock (IR) and dawn-to-dusk (UV-visible) observations. Time-resolved observations from geostationary orbit provide the temporal and spatial measurement sampling required to match the anticipated tropospheric chemistry model resolutions of the near future. These models support the air quality research, forecasting, and assessment mandates of NASA, NOAA, and EPA. Time-resolved observations will complete the network of surface-based, process study, and existing global (though non-synoptic) observations for air quality applications, and make such data useful in predictive models.

The unique observing capabilities from geostationary orbit that have been traditionally used for water vapor and cloud observations are particularly important for chemical weather (air quality). Chemical weather evolves on time scales that are similar to traditional weather due to the strong influences of transport and precipitation processes on atmospheric composition. However, chemical weather has the additional complexities of highly heterogeneous precursor and primary emissions and strong diurnal variations in production, loss, and transformation rates of the pollutants ozone and aerosol. Anthropogenic emissions have strong diurnal variations associated with urban commute cycles, while biogenic emissions are dependent on diurnal variations in leaf temperature and photosynthetically active radiation. Measurements from geostationary orbit can observe these processes over the continental domain with the required temporal sampling.

Time-resolved measurements are particularly important for linking regional air quality with global chemical composition. Long-range transport is most efficient in the free troposphere due to the strong winds within the sub-tropical and polar jet streams. This free tropospheric transport is coupled to the continental boundary through diurnal growth and decay of the continental boundary layer, deep convective exchange, and moist ascent within synoptic storms. These coupling processes occur on synoptic and sub-synoptic time-scales and must be observed from geostationary orbit since they are severely aliased by polar orbiting platforms. The time resolved trace chemical measurements would provide new insight into the role of deep convection in venting boundary layer emissions into the free troposphere, allow assessment of the role of low-level transport of residual pollution layers within the nocturnal jet in the evolution of regional pollution events, identify the synoptic transport of continental emissions into the global environment, and allow us to test our nascent predictive tools for national and international policy.

Flaud, CNRS/U. Paris, France

The Geostationary Imaging Fourier Spectrometer (GeoFIS): Scientific Requirements and Specifications

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The GeoFIS experiment, a component of the GeoTROPE-R (The Geostationary Tropospheric Pollution Explorer Regional) mission which also includes a UV-Vis spectrometer (GeoSCIA), aims at measuring tropospheric trace gas distributions over Europe at the appropriate spatial and temporal resolutions to monitor air quality and tropospheric photochemistry at the regional and continental scales. The GeoFIS instrument will operate in the mid-infrared region and can therefore observe the troposphere during day and night. In this talk, the scientific approach to derive the instrument and platform specifications is presented. In order to assess the impact of the satellite data on the forecasting capabilities of numerical models for air quality at the regional scale, a modified version of the CHIMERE model was used. The derived specifications are discussed and the feasibility of the GeoFIS project based on available components and technologies is addressed.

Hasekamp, SRON Netherlands Inst. for Space Research, Netherlands

An Optimized Instrument Concept for Measuring Tropospheric Ozone and Aerosols from Space

Otto Hasekamp and Jochen Landgraf
SRON, Netherlands Institute for Space Research

Tropospheric ozone and aerosols are two key species in the field of air quality monitoring. In this contribution we will propose one measurement concept that allows a highly accurate retrieval of both species. The proposed measurement concept is based on multiple-viewing-angle measurements of intensity and polarization in the ultraviolet, visible, and near infrared part of the electromagnetic spectrum. The measurements in the ultraviolet will be used for the retrieval of tropospheric ozone. Here, both the use of polarization measurement as well as the use of multiple viewing angles significantly increases the sensitivity to tropospheric ozone compared to instruments that measure only the radiance in one viewing direction. Also for the retrieval of all relevant aerosol properties over land it is essential to use this type of measurements, over an extended spectral range. Using a retrieval algorithm that fully exploits the capabilities of the proposed measurement concept, we performed several sensitivity studies corresponding to different instrument setups. In this contribution we will present the effect of different instrument characteristics (e.g. spectral range and -resolution, number of viewing angles) on the information content, resulting in a measurement specification that is optimal for the retrieval of both tropospheric ozone and aerosols. The information content of the proposed measurement concept will be compared to other concepts that are commonly used for the retrieval of tropospheric ozone and aerosols.

Ho, Nat. Center for Atmospheric Res., USA

Improvements of the Retrievals of Carbon Monoxide in the Planetary Boundary Layer using Combined Infrared and Solar Measurements : A Simulation Study

Shu-peng Ben Ho
NCAR ACD

Tropospheric carbon monoxide (CO) is produced primarily from anthropogenic emissions related to incomplete combustion, and makes an excellent indicator of poor air quality and a tracer of pollution transport. It is also one of the few tropospheric species that can be detected from space at the present time. Retrievals of CO from the Measurement Of Pollution In The Troposphere (MOPITT) instrument aboard the low Earth orbit (LEO) EOS-Terra satellite launched in December of 1999 now provide the first global record of the recent inter-annual variability of this important pollutant.

However, due to instrument noise issue, only infrared measurements are used for MOPITT CO retrievals. Because of the lack of CO information in the lower atmosphere, the retrieved CO results in the planetary boundary layer (PBL) from MOPITT measurements are mainly from the background a priori CO profile. The accurate description of CO concentration in the PBL is still not available. In this study, we present a simulation study that combines both infrared and solar measurements from an MOPITT-like instrument to improve the CO retrievals in the PBL. The defined solar channel is used together with infrared channels for an optimal retrieval strategy to provide independent sensitivity to CO vertical profiles in both the PBL and free troposphere. The cases of strong CO emission due to wild fire over CA and city scale CO pollution near Boston are simulated. The retrieval results using the optimal retrieval strategy are presented.

Kondragunta, NOAA/NESDIS, USA

Air Quality Products from NOAA's GOES-R Advanced Baseline Imager (ABI) and Hyperspectral Environmental Sounder (HES)

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The Advanced Baseline Imager (ABI), Hyperspectral Environmental Suite (HES), Coastal Waters Imgaer (CWI), and Lightning Mapping Imager (LMI) instruments on the next generation Geostationary Environmental Operational Satellite (GOES)-R are going to provide unprecedented information on air quality. Plans are currently underway to develop various air quality products (aerosol optical depth, particle size, aerosol type, carbon monoxide, methane, sulfur dioxide, ozone, sulfur dioxide, fires, trace gas and aerosol emissions, and potentially nitrogen dioxide) over the Americas at temporal resolution ranging from five to 60 minutes. These products are expected to become operational after the launch of GOES-R in 2013. We will describe the ongoing algorithm and product development work and discuss potential applications of these products.

Kumer, Lockheed Martin Adv. Tech. Center, USA

Tropospheric infrared mapping spectrometers (TIMS) for Air Quality measurements

JB Kumer, AE Roche and JL mergenthaler (LMATC), and Robert Chatfield (ARC)

We have been awarded a NASA Instrument Incubator Program (IIP) to develop grating mapping spectrometers (GMS) with very high spectral resolution, very low noise, and very wide field of view. These also would be very compact facilitating deployment in either a leo or geo application. The measurement set could be very comprehensive, addressing air quality, carbon species and climate change, or subsets of these. For this presentation we'll focus on the potential application of these GMS to provide an air quality subset of primary measurements consisting of CO partial columns, (vertical information), ozone partial columns and HCHO column. The measured spectra provide opportunity to retrieve secondary products including columns of CH_4, N_2O and CO_2, and improved retrieval of near surface H_2O. The CH_4 and CO_2 columns ratio can be used to retrieve vertically averaged tropospheric CH_4 mixing ratio. Spectral measurements would be acquired with several spectrometers. For the species as cited above these would include solar reflected spectra near 2.33 and 2.08 µm, and emissive spectra near 4.68 µm. Additional, optimal O3 information could be obtained by adding another emissive region near 9.52 µm. For this application we'll discuss spectral regions, spectral resolution and noise for potential geo and leo applications. For these applications we'll describe the temporal and areal coverages and footprint sizes. We'll present retrieval results predicted by a linear error analysis for these applications. We'll present results from an in house lab demonstration GMS that is a predecessor to the IIP design.

Livesey, Jet Propulsion Lab., USA

Composition of the Atmosphere from Mid-Earth Orbit (CAMEO) observations for air quality studies

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CAMEO is a future atmospheric composition satellite mission concept to address air quality, climate change, general circulation model deficiencies, and ozone layer stability. It provides global coverage with a new and needed combination of temporal, vertical, and horizontal resolution - enabling measurements of fast processes (such as convection) from satellite. These processes have major influences on issues directly related to societal needs and benefits. CAMEO also continues certain long-term climate-quality data records needed for assessing global change and ozone recovery. It uses an easily-reached mid-Earth orbit (MEO, ~1000 to ~10,000 km height) and advanced versions of two instruments, both of which have proved highly successful on two or more previous satellite missions. This poster provides additional information on the scientific case for CAMEO, along with further details of the CAMEO concept not discussed the in presentation during the oral session.

Livesey, Jet Propulsion Lab., USA

The Scanning Microwave Limb Sounder Instrument component of the Composition of the Atmosphere from Mid-Earth Orbit (CAMEO) mission concept.

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A new class of high temporal and spatial resolution measurements is needed to quantify the role of critical 'fast processes' (such as convection) in air quality, climate change and weather/climate forecast accuracy. In addition, continued observations of stratospheric

composition are needed for ongoing studies of ozone layer stability. The Scanning Microwave Limb Sounder (SMLS) measures the abundance of key chemical species, humidity and cloud ice content in the upper troposphere and stratosphere with high spatial resolution and ~2 hour temporal resolution. SMLS has heritage from the Aura and UARS Microwave Limb Sounder instruments, with a new azimuth scanning capability (enabled by flight qualified 4K coolers allowing the use of more sensitive superconducting microwave receivers). The combination of this scanning capability with the higher 'Mid-earth' orbit envisioned in the 'Composition of the Atmosphere from Mid-Earth Orbit' (CAMEO) concept provides the improvements in horizontal and temporal resolution and coverage needed for study of fast processes. This poster describes the SMLS measurement capabilities and instrument design. Examples are also given of scientific questions SMLS observations will help to address.

Osowski Neil, NASA Langley Res. Center, USA

Compact Imaging Spectroradiometer (CISR): Tropospheric carbon monoxide measurements from geostationary orbit

Doreen Osowski Neil (NASA) , Larry L. Gordley, Benjamin T. Marshall (GATS Inc.), David P. Edwards (NCAR)

Remote sensing of atmospheric trace gases from geostationary orbit offers unique scientific value and unique measurement interpretation advantages. This poster describes a proposed measurement method and analysis strategy for inferring CO concentration in two layers in the troposphere. Gas filter correlation radiometry is very well suited for remote sensing using regional images from geostationary orbit. Strengths of the gas correlation technique include measurement efficiency, effective high spectral resolution, excellent spectral calibration, manageable data rate, and simultaneous measurements over the full spectral bandpass.

Unlike previous gas filer correlation radiometer systems, the design presented here enables simultaneous analysis for surface temperature, surface emissivity, atmospheric water vapor, atmospheric temperature gradient, and cloud contamination. The concurrent determination of these quantities is essential for accurate CO retrievals under clear-sky conditions for a variety of atmospheric states and surface properties at the time and space scales featured by the measurements.

The poster discusses the measurement requirements, modeled performance, calibration approach, and measurement enhancements due to the geostationary nature of the observations. We suggest the utility of such measurements to identify source regions and long range transport, and to provide context for more localized measurement and modeling studies. This work is a summary of CO measurement capability proposed for GeoTRACE (Geostationary Observatory for Tropospheric Air Chemistry).

Phulpin, CNES, France

Low troposphere monitoring with TRAQ (TRopospheric composition and Air Quality) mission

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TRAQ (TRopospheric composition and Air Quality) is a mission devoted to air pollution monitoring which has been proposed to ESA's 2005 EOEP call (Levelt et al). For this project CNES contributed through technical studies to design a system and instruments meeting the requirements given by expert scientists. This presentation will describe SIFTI (standing for Static Infrared Fourier Transform Interferometer), which allows to measure atmospheric spectral radiances at very high resolution in small windows. It was possible through simulations permitted to define the optimal spectral range and resolution in the infrared to obtain accurate information on O3 and CO in the troposphere. Moreover, it is expected from simulations that a combination of these data with measurements in the UV or in the SWIR will lead to improved columns of respectively O3 and CO. Because of its concept, SIFTI can only provide information sampled on one pixel of 10 km in a grid of 50 by 50 km with a footprint diameter at nadir. For cloud-free or homogeneous pixels itt is proposed to associate an embedded high resolution two-channel imager, CLIM (CLoud IMager).

To detect and quantify small particles, one of the most efficient means apart from lidar is a multichannel multidirectional and polarized imager as demonstrated by POLDER or Parasol. So, an advanced POLDER imager is proposed as a synergistic instrument for aerosols.

Finally, the payload should be completed by the UV-visible spectrometer TROPOMI a successor of OMI to be developed by the Netherlands.

The requirement for trace species and aerosols to have information with a high repeat cycle can be satisfied with a constellation of LEO satellites. CNES proposed a dedicated orbit allowing maximizing the number of observations at mid-latitude, with a revisit time of 99 minutes.

Pickering, NASA Goddard Space Flight Center, USA

Air Quality Science and Regulatory Efforts Require Geostationary Satellite Measurements

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Air quality scientists and regulatory agencies would benefit from the high spatial and temporal resolution trace gas and aerosol data that could be provided by instruments on a geostationary platform. More detailed time-resolved data from a geostationary platform could be used in tracking regional transport and in evaluating mesoscale air quality model performance in terms of photochemical evolution throughout the day. The diurnal cycle of photochemical pollutants is currently missing from the data provided by the current generation of atmospheric chemistry satellites which provide only one measurement per day. Often peak surface ozone mixing ratios are reached much earlier in the day during major regional pollution episodes than during local episodes due to downward mixing of ozone that had been transported above the boundary layer overnight. The regional air quality models often do not simulate this downward mixing well enough and underestimate surface ozone in regional episodes. Having high time-resolution geostationary data will make it possible to determine the magnitude of this lower-and mid-tropospheric transport that contributes to peak eight-hour average ozone and 24-hour average PM2.5 concentrations. We will show ozone and PM2.5 episodes from the CMAQ model and suggest ways in which geostationary satellite data would improve air quality forecasting. Current regulatory modeling is typically being performed at 12 km horizontal resolution. State and regional air quality regulators in regions with complex topography and/or land-sea breezes are anxious to move to 4-km or finer resolution simulations. Geostationary data at these or finer resolutions will be useful in evaluating such models.

Turquety, Service d'Aeronomie, France

Ozone and CO observation from future Eumetsat missions: IASI-METOP and IRS-MTG

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In the recent years, several satellite missions measuring the thermal infrared radiation in a nadir viewing geometry from low orbiting satellites (IMG, MOPITT, AIRS, TES) have demonstrated the capabilities of such measurement technique for global monitoring of atmospheric composition. Combining high spectral resolution with improved spatial and temporal coverage for more accurate view of regional and local pollution will be the major objective of future missions.

The capabilities offered by IASI-METOP and MTG-IRS for CO and O3 monitoring, in terms of accuracy, and vertical/horizontal/temporal sounding ability will be presented.

The Infrared Atmospheric Sounding Interferometer (IASI) is a nadir viewing FTS recording high resolution IR spectra with a daily global coverage and a 25 km horizontal sampling. IASI is an instrument mounted on the European Polar System METOP satellite. The first METOP satellite will be launched in 2006.

The Meteosat Third Generation InfraRed Sounder (MTG-IRS) is currently being studied as part of a suite of instruments for the future European meteorological satellites in geostationary orbit. MTG data is expected to be available 2015 - 2030.