Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

AAS01-01 Room:301B Time:May 27 14:15-14:45

Lidar Measurements of Atmospheric Column CO2 from Regional to Global Scales

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Atmospheric CO2 is a critical forcing for the earth's climate and the knowledge on its distributions and variations influences predictions of the Earth's future climate. Large uncertainties in the predictions persist due to limited observations. This study uses the airborne Intensity-Modulated Continuous-Wave (IM-CW) lidar developed at NASA Langley Research Center to measure regional atmospheric CO2 spatiotemporal variations. Further lidar development and demonstration will provide the capability of global atmospheric CO2 estimations from space, which will significantly advances our knowledge on atmospheric CO2 and reduce the uncertainties in the predictions of future climate.

In this presentation, atmospheric CO2 column measurements from airborne flight campaigns and lidar system simulations for space missions will be discussed. Data analysis shows that airborne lidar CO2 column measurements over desert and vegetated surfaces agree well with in-situ measurements. A measurement precision of ˜0.3 ppmv for a 10-s average over these surfaces has also been achieved. Generally, airborne flight campaigns have demonstrated that the column CO2 measurements of the current IM-CW lidar systems meet the accuracy and precision requirements of atmospheric CO2 sciences. Furthermore, analyses of space CO2 measurements shows that the current IM-CW lidar technology and approach will enable space missions to achieve their science goals.

Keywords: atmospheric CO2, lidar measurements, regional, global

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Technical approaches for future active optical remote sensing

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Lidar is a unique active optical remote sensing technique, which can detect very small particles such as molecules, gas and particulate aerosols, clouds. Lidar can also measure range, wind speed, concentration of atmospheric constituents such as CO_2, water vapor and so on. Communication Research Laboratory (CRL: former institute of NICT) proposed development of the space-borne coherent DWL as a candidate of the earth observation missions on the International Space Station (ISS)-Japanese Experimental Module (JEM) in 1997, which was called JEM-CDL. NICT started studies on feasibility of JEM-CDL under the support of the Phase II studies of the Ground Research Announcement of the National Space Development Agency (former institute of JAXA). NICT studied 2-μm laser technologies for the JEM-CDL during 6 years from FY2000 to FY2005 and develop a 2-μm laser with a high pulse-energy of 460 mJ operating at 10 Hz. NICT developed a 2-μm conductively-cooled laser-diode-pumped single-frequency Q-switched solid-state laser as a second-generation laser system. NICT developed a ground-based 2-μm coherent differential absorption and Doppler wind lidar for CO_2 and wind measurements. DIfferential Absorption Lidar (DIAL) is more complicated than passive sensor, it has the potential advantage of measuring concentration of atmospheric constituents during nighttime. CO_2 sources and sinks are located near the earth's surface. Since 2-μm spectral region has sensitivity close to the surface higher than 1.6-μm spectral region, a 2-μm integrated path differential absorption (IPDA) lidar is one of the promising space-borne active optical remote sensors. The coherent Doppler Wind Lidar (DWL) is also a complicated system but can measure Doppler wind speed with a high accuracy during daytime as well as nighttime. Although space-borne passive sensor needs scattering objects (water vapor, cloud), coherent DWL can provide a wind profile even clear sky condition. A combination of CO_2 and wind measurements would facilitate better understandings of the carbon cycle on various temporal and spatial scales. Space-borne lidar can provide only profile data in a straight line. A synergy measurement of space-borne lidar and other technique would be important and valuable. NICT conducts studies on feasibility for a space-borne Doppler Wind lidar with JAXA, Tohoku University, the University of Tokyo, Meteorological Research Institute, and other institutes. NICT will start a new middle-term project in 2016. In this paper, we describe a future space-borne Doppler wind lidar and conceptual idea for carbon cycle lidar measurement.

Keywords: Active remote sennsing, Space-bonre, lidar, Wind, Greenhouse gas

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Atmospheric Gravity Waves: MST Radars and Sondes

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MST radars have proved to be extremely useful in monitoring atmospheric gravity waves and understanding their role in the middle and upper atmosphere dynamics. However, there are only a few such radars around the world, making routine monitoring of gravity waves in the global atmosphere impossible. Using sondes to extract wave information such as the momentum flux would help monitor and study gravity waves in the troposphere and the lower stratosphere, provided the method can be demonstrated to yield realistic results. As a sonde ascends, its vertical velocity is modulated by gravity waves so that, in principle, it should be possible to extract wave properties such as the energy density and momentum flux. However, the aerodynamics of the flow around the balloon complicates the sonde vertical motion. The Reynolds number of the flow is around the transitional value so that transition of the boundary layer on the forward hemisphere from laminar to turbulent can change the wake size and hence the drag in an unpredictable fashion, affecting the vertical velocity. We have modeled the behavior of the balloon assuming it to be elastic so that the sonde vertical velocity can be modeled and the transition from low drag to high drag assessed. The extensive sonde dataset collected during the 2005 CPEA II campaign at the Koto Tabang Equatorial Radar facility has been used to explore the technique. The vertical velocity fluctuations resulting from the model have been used to estimate atmospheric gravity wave properties at the radar site during the month-long campaign.

Proper validation of sonde-extracted gravity wave properties requires comparison with another independent, reliable and simultaneous set of measurements. MST radars, being the gold standard for gravity wave studies, provide such an opportunity. At the NARL MST radar facility in Gadanki, India, there exist radar data obtained during some sonde launches. We have used these data to compare wave properties extracted from sondes with those extracted from radar horizontal and vertical wind velocity measurements. We find the sonde provides results consistent with radar measurements, thus providing more confidence in the utility of the technique for studying gravity waves in the global stratosphere. We will present results of these comparisons and discuss their potential utility and some unresolved issues.

Keywords: MST radar, Radiosonde, Atmospheric gravity waves

AAS01-04 Room:301B Time:May 27 15:30-15:45

Changes of Arctic Clouds and Its Implications

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There has been studies (e.g., Schweiger, 2004) suggest significant increase of Arctic clouds during the last three decades, especially in the western Arctic region. Such studies are based on passive remote sensing that are not highly reliable due to the lack of contrasts in temperature and reflectance between clouds and snow/ice surfaces. Changes in the Arctic clouds can be evaluated more accurately using the space-based lidar measurements from CALIPSO during the last nine years since CALIPSO can provide much more accurate detection and classification of both water and ice clouds in the Arctic.

Time series of Arctic cloud properties (e.g., cloud fraction, cloud thermodynamic phase, water cloud depolarization ratio and droplet number concentration) from CALIPSO data are analyzed in this study. This study reveals the changes in both cloud fraction and cloud microphysical properties during the last nine years when CALIPSO data are available. We will evaluate the changes in Arctic cloud fraction and cloud microphysical properties, their seasonal and spatial characteristics and the potential impact on the energy budget and the climate of the Arctic.

Keywords: lidar, arctic, clouds

AAS01-05 Room:301B Time:May 27 16:15-16:45

Ice cloud analysis using Himawari-8 data

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The Himawari-8 satellite was launched in October 2014 and carries the Advanced Himawari Imager (AHI) that has 16 spectral bands in visible to thermal infrared spectra. Spatial resolution and observation frequency have been significantly improved. Nine bands are in the thermal infrared at 6?13.5 micron wavelengths. This study aims at obtaining optical and microphysical properties of ice cloud, and we are developing a cloud analysis system that uses the thermal infrared bands of the AHI. Our group has been studied ice cloud properties by using three bands of 8.5-, 11- and 12-micron of MODIS onboard the Aqua satellite (Iwabuchi et al., 2014). The cloud top temperature was obtained from the MODIS operational product and used as a priori for inversion. To extend the retrieval method to the AHI, we have modified the method to use multiple bands including the CO2 and water vapor absorption bands.

First we have developed a forward model that computes brightness temperatures and its partial derivatives with respect to several variables. The input data are atmospheric temperature and humidity profile and surface properties. The radiative transfer calculation is made at only a single wavelength band for each sensor band, using the correlated-k distribution (CKD) method (Sekiguchi & Nakajima, 2008) with several quadrature points. Optical properties of water droplets are computed by the Lorenz-Mie theory, and those of ice particles are obtained from a database made by Yang et al. (2013). Ice cloud habit models include hexagonal column and plate, and the General Habit Mix (GHM) model (Cole et al., 2013) with different degrees of surface roughness. Double-layer clouds are modeled, and radiative transfer is solved by the two-stream approximation. Brightness temperature biases due to model approximation are removed by empirical formulae.

Absorption by ice particles is stronger at wavelengths longer than 10 micron. As suggested by prior studies, a combination of multiple bands in the window region of 8?13 micron wavelengths allows inferring effective particle size of ice cloud. Ice particle habits do not significantly affect the brightness temperatures, but water phase (liquid/ice) is moderately important to spectral differences in brightness temperatures. Measurements are sensitive to ice cloud with cloud optical thickness of 0.05?12 and effective particle radius of 2?100 micron. Top pressure of lower cloud in multi-layer cloud column can be retrieved if the upper cloud optical thickness is less than about 5.

Background surface and atmospheric data needed for the cloud analysis are interpolated spatially and temporally from MODIS products and MERRA reanalysis. The optimal estimation method (Rodgers, 2000) is used to infer cloud properties including cloud water path, effective particle radius, cloud-top pressure, and background surface temperature in single-layer cloud cases. Top-pressure of lower cloud is inferred in multi-layer cloud cases, instead of background surface temperature. Measurement?model biases due to errors in atmospheric data and model approximations and assumptions are evaluated by comparing to simulated and measured brightness temperatures. The biases are removed, and remaining errors are evaluated for use in the optimal estimation. Initial test analysis will be presented in the presentation.

Keywords: Himawari-8, ice cloud

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Computation of surface irradiances using satellite observations

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Understanding the surface radiation budget is important for several reasons. At the global and large temporal scales, it should balance with the sum of surface latent and sensible heat fluxes and ocean heating. At regional scales, it is an indispensable boundary condition for ocean or snow models or any other models that need energy input to the surface. NASA's Clouds and the Earth's Radiant Energy System (CERES) project provides surface irradiance data products for a range of temporal and spatial scales computed using a radiative transfer model initialized using satellite-derived cloud and aerosol properties. Other inputs to the radiative transfer model include temperature and humidity profiles from NASA Global Modeling and Assimilation Office's (GMAO) reanalysis. The CERES team uses more than 80 surface observation sites located over land and ocean to evaluate computed irradiances. When computed monthly 1degree by 1 degree gridded mean downward irradiances are compared with 10 years of observed irradiances, the bias averaged over all land and ocean sites are, respectively, -1.7 Wm^{-2} and 4.7 Wm^{-2} for shortwave and -1.0 Wm^{-2} and -2.0 Wm^{-2} for longwave. The shortwave agreement is significantly better than other satellite-based surface irradiance products. One of reasons for the better agreement is careful treatment of diurnal cycle of clouds by merging 3-hourly geostationary satellite-derived cloud properties. In addition, computed surface irradiance variability shows a remarkable agreement with observed variability. However, these data sets have their shortcomings. The uncertainty in nighttime surface longwave irradiance over polar regions is larger than that of other regions primarily due to the difficulty of cloud detection and large uncertainties in skin temperature and near-surface temperature and humidity. The large uncertainty in polar region surface irradiances hampers, for example, investigation of surface radiation budget changes in response to changes in sea ice extent. In this presentation, we present an evaluation of the current CERES products and discuss ways these products can be improved in the future.

Keywords: surface radiation budget, climate data record

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Distributional correspondence of 94-GHz radar reflectivity with the variation in water cloud properties

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This paper studied the behavior of 94-GHz radar reflectivity (Ze) with variation in the properties of low-level water clouds, such as the effective droplet radius (re), geometrical thickness (Dcld), and liquid water path (LWP), over the northwest Pacific and China. The changes in the distribution of maxZe (the largest Ze within a cloud layer) were examined in terms of variation in the cloud parameters such as small, mid and large categories. While maxZe had monomodal distributions regarding variation in re and Dcld, that appeared bimodal in the small category of LWP. It was confirmed that the small category of LWP contained both non-precipitating clouds in the incipient stage and raining clouds in the dissipating stage. Next, optically-measured particle size was combined with LWP derived from the microwave measurement to classify the precipitation type. Applying maxZe and Dcld to the analysis of classified precipitation types corroborated the importance of Dcld for examining the occurrence of precipitation. Finally, the position of maxZe relative to the cloud top was investigated using a measure of the probability of precipitation (POP) according to variation in re. The results showed that the Pacific and China had 'bow' and 'funnel' shapes, respectively. The emergence of these shapes according to the variation in re was interpreted as the enhancement of Ze due to droplet collisional growth and the attenuation of Ze by the presence of large particles. Furthermore, a detailed analysis of smaller particles ($<$10 micron in radius) reinforced the idea of rapid, efficient particle growth in the lower part of the cloud.

Keywords: CloudSat, Radar reflectivity, cloud physics, aerosol, precipitation

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Detecting Super-thin Clouds with Polarized Sunlight

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Super-thin clouds exist globally but are extremely difficult to be detected by satellite instruments. These clouds can tremendously impact the remote sensing of aerosols, surface temperature, and atmospheric composition gases. They are also very important for climate modeling. In this presentation, a novel method for detecting cloud particles in the atmosphere with measuring the polarized sunlight from the Earth-atmosphere system (Sun et al., 2014) is reviewed. Preliminary modeling results suggest that this method can be used to detect super-thin cirrus clouds having an optical depth of only about 0.06 and super-thin liquid water clouds having an optical depth of only about 0.01. Such clouds are too thin to be sensed using any current passive satellite instruments. This method has potential to become an innovative satellite mission of NASA to advance Earth observation from space and improve scientific understanding of all clouds and cloud-aerosol interactions.

Reference

Wenbo Sun, Gorden Videen, and Michael I. Mishchenko: Detecting super-thin clouds with polarized sunlight. Geophy. Res. Lett. 41, doi: 10.1002/2013GL058840 (2014).

Keywords: Remote Sensing, Super-thin clouds, polarized sunlight, angle of linear polarization of light