Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

AAS22-01 Room:201B Time:May 21 09:00-09:15

Overview of observational results from the Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES)

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The Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) was developed to be aboard the Japanese Experiment Module (JEM) on the International Space Station. It is a cooperative project of the Japan Aerospace Exploration Agency (JAXA) and the National Institute of Information and Communications Technology (NICT). The key concept of SMILES is its high-sensitivity measurement of minor species in the middle atmosphere by a receiver using superconductor-insulator-superconductor (SIS) mixers which are cooled to 4.5 K by a mechanical cryocooler. SMILES was successfully launched on September 11, 2009, and started atmospheric observations on October 12. Unfortunately, SMILES observations had been suspended since April 21, 2010 due to the failure of a critical component in the submillimeter local oscillator. Furthermore, the cooler stopped its operation due to the failure of the JEM thermal control system on June 5, 2010.

The mission objectives are as follows: i) To demonstrate a 4-K mechanical cooler and superconducting mixers in the environment of outer space for submillimeter limb-emission sounding in the frequency bands of 624.32-626.32 GHz and 649.12-650.32 GHz and ii) To measure atmospheric minor constituents in the middle atmosphere globally (O3, HCl, ClO, HO2, HOCl, BrO, O3 isotopes, HNO3, CH3CN, etc.) in order to get a better understanding of factors and processes controlling the stratospheric ozone amounts and those related to climate change. Though future states of the ozone layer have been investigated using coupled chemistry-climate model, there are still considerable uncertainties in factors affecting ozone levels, especially the bromine budget and inorganic chlorine chemistry. The SMILES mission can contribute to the detailed halogen chemistry by providing useful constraints for these issues. In this presentation, we will give a brief description of the SMILES observations, and on the basis of the version 2.1 level 2 data which is released to the public this spring, we will present some results that demonstrate SMILES abilities to observe the atmospheric minor constituents in the middle atmosphere.

Keywords: Middle Atmosphere, Ozone Chemistry, Atmospheric Dynamics, Satellite Measurement, International Space Station

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AAS22-02 Room:201B Time:May 21 09:15-09:30

Ozone distribution related to the QBO and the SAO — Observation by the SMILES and estimation by a nudging CTM

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An attempt is made to estimate dynamical and chemical effects on the variation of the ozone distribution in the equatorial stratosphere according to the phases of the QBO (quasi-biennial oscillation) and the SAO (semiannual oscillation). Both of the data from the observation by the SMILES and the data from the simulation by a nudging CTM based on the MIROC CCM are analyzed.

The distribution of ozone mixing ratio in the equatorial stratosphere has a maximum in the mid-stratosphere (about 30 km), and the value decreases with height in the upper stratosphere. The latitudinal distribution in the upper stratosphere basically shows a single-peak structure with a maximum around the equator, while sometimes exhibits a double-peak structure with two maxima according to the phases of the QBO and the SAO.

Such a double-peak structure, called as "rabbit ears" by Randel and Wu (1996), is clearly displayed in the daily mapped data from the SMILES observation. The SMILES observation also showed that the double-peak structure appears and disappears according to the phase of the SAO.

Furthermore in the present talk, a quantitative estimation will be made on contributions of both dynamical effects such as the advection and the chemical effects such as the production/destruction of ozone to form the double-peak structure.

Keywords: stratosphere, QBO, SAO, ozone, dynamics, chemistry

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AAS22-03 Room:201B Time:May 21 09:30-09:45

Diurnal ozone variations in the middle atmosphere as revealed with SMILES observations

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Diurnal ozone variations in the middle atmosphere are controlled by both photochemistry and dynamics. The global and quantitative understanding of diurnal ozone variations is crucial for trend analysis, intercomparison of different satellite observations made at different local times, validation of CCMs and so on. Previous studies mainly used in situ observations such as ozone lidars for detecting the diurnal variability; in contrast, global observations have been only possible by the two non-Sun-synchronous satellite observations, i.e., UARS/MLS and TIMED/SABER. However, the results from the two satellite observations are not consistent quantitatively at some altitude levels in the stratosphere. The Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) onboard the International Space Station is another non-Sun-synchronous satellite, which achieved global observations of minor constituents in the middle atmosphere with a very high accuracy during the period from October 2009 to April 2010. The purpose of this study is to obtain a global picture of diurnal ozone variations in the middle atmosphere, by using SMILES data as well as other satellite and CCM data sets.

We analyze ozone mixing ratio from four different observation/model data sets: (1) SMILES Version 2.0 data, (2) TIMED/SABER Version 1.07 data from the 9.6 micro-meter band, (3) SD-WACCM data, (4) CCSR/NIES Nudging CTM. These data are analyzed for the period of the SMIELS observations. For the non-Sun-synchronous SMILES (SABER) observations, 30 (60) days are needed to cover a whole diurnal cycle. In order to avoid sampling issues due to the background ozone changes, the 30-day (60-day) running mean has been subtracted from the original data for data (1, 3-4) (data (2)) in advance. Then, every 5 degrees in latitude and every ~3 km in altitude, the residuals from the running mean are binned and averaged in 1-hour local-time bins, which are considered as diurnal variations in this study.

Figure 1 shows vertical distributions of diurnal ozone variations averaged for 10S-10N, as derived from SMILES and SD-WACCM data. The diurnal variations shown here are the relative values to the daily-mean for the analysis period shown also in Figure 1. We discover that the results from the two data sets agree quite well. The results from SABER observations show a roughly similar phase pattern as in Figure 1 but with much larger amplitudes (approximately twice) at 30-50 km. These findings suggest that SMILES has allowed us to obtain the global picture of diurnal ozone variations for the first time. In other words, diurnal ozone variations in CCMs (e.g., SD-WACCM) have been validated for the first time. The observed results are summarized and interpreted as follows. At 20-30 km, the diurnal harmonic component is dominant with the amplitude of 2-3%. Its phase shows a downward progression with altitude. An analysis of dynamical fields (temperature and winds from MERRA) suggests that this diurnal component is mainly controlled by the vertical transport associated with diurnal tides. At 30-40 km, ozone minimizes after dawn and increases toward the maximum in the afternoon. The amplitude is 2-5%. The dawn minimum is caused by the depletion of odd oxygen associated with the NOx chemistry, while the afternoon maximum is caused by the production of odd oxygen through the photolysis of molecular oxygen as suggested by Pallister and Tuck (1983). At 40-50 km, we observe similar diurnal variations seen at 30-40 km and additional minimum of ~5% about at noon. This additional minimum is probably caused by the depletion of odd oxygen due to the HOx chemistry as also suggested by Pallister and Tuck (1983). Finally, above 50 km, the ozone shows a simple day/night contrast with an amplitude of ~100% at maximum. This is caused by the high [O]/[O3] ratio in the upper atmosphere; i.e., the odd oxygen resides as atomic oxygen so that ozone shows a strong depletion during the day.

Keywords: Middle atmosphere, diurnal ozone variations

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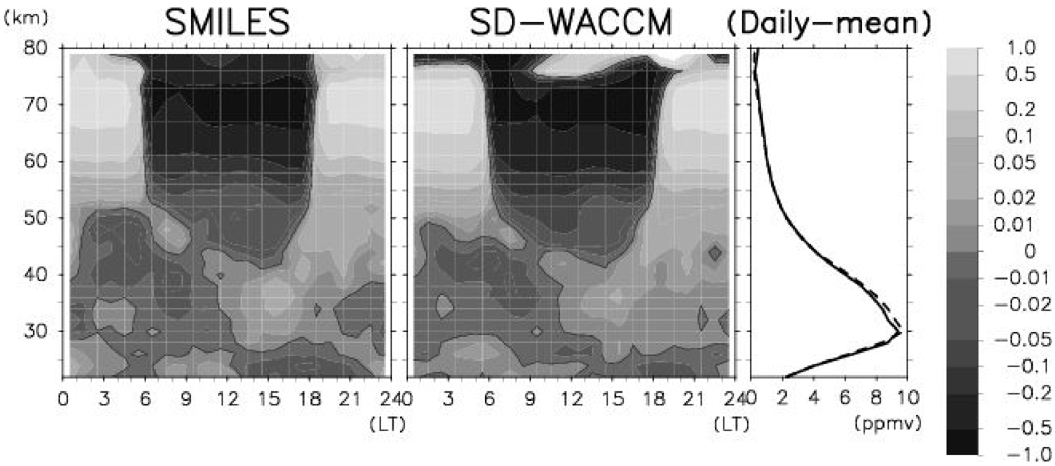

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AAS22-04 Room:201B Time:May 21 09:45-10:00

On the reaction ClO + HO2 –> HOCl + O2 based upon SMILES observation

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SMILES (Superconducting Submillimeter-Wave Limb Emission Sounder) is an instrument to measure global distribution of minor species in the middle atmosphere by limb observation. It was attached to the Japanese Experiment Module (JEM) on the International Space Station (ISS) and obtained a half year's worth of data between mid October, 2009 and mid April, 2010. SMILES has an advantage in low system noise realized by cooling the receiver to 4 degrees kelvin with a mechanical cooler, and it enables to measure distribution of trace gases such as O3, HCl, ClO, HO2 and HOCl with high sensitivity.

It is a well-known fact that inorganic chlorine play an important role in the stratospheric chemistry. However, it is not fully understood quantitatively due to the limited precision of parameters such as the abundance of HCl, total abundance of inorganic chlorine, the ratio between HCl and other inorganic chlorine, the ratio between ClO and HOCl, and so on.

In this research, we estimated the reaction rate of ClO + HO2 –> HOCl + O2 with steady-state approximation. By using SMILES L2 ver.2.1 for the HOCl concentration and MODTRAN5 to calculate the photodissociation rate of HOCl, we obtained reaction rates similar to the JPL 2006 value at the altitude range of 30 - 40 km.

Keywords: stratosphere, inorganic chlorine

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AAS22-05 Room:201B Time:May 21 10:00-10:15

SMILES climatology and activity in SPARC DI

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The Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) on the Japanese Experiment Module (JEM) in the International Space Station (ISS) was successfully observed the altitude profiles of minor atmospheric compositions with new super-sensitive 4K heterodyne receiver system, which provide lower noise spectrum one order magnitude than Aura/MLS and Odin/SMR, from international space station (ISS) during 12 October 2009 and 21 April 2010. The atmospheric compositions SMILES observed were O3, H35Cl, H37Cl, ClO, HOCl, HO2, BrO, HNO3, CH3CN, Ozone isotopes, upper tropospheric humidity, ice cloud in the middle atmosphere. The wind velocities and temperature were also retrieved. ISS platform give us many unique observation characteristics, and one of them is a diurnal variation of the observation of atmospheric composition with non sun-synchronous orbit. SMILES is the co-development project between JAXA and NICT.

We would like to report a SMILES climatology for the diurnal variation for short-lived species in the stratosphere and mesosphere, and current status of our activity in SPARC data initiative. We used the SMILES L2 research product version 2.1.5 for the climatology. The status of the SMILES L2 research product version 2.1.5, including intensive error analysis, comparison/validation will be also present.

Keywords: SMILES, Sub-mm sounder, Stratosphere, Mesosphere, Atmospheric composition

AAS22-06 Room:201B Time:May 21 10:15-10:30

Gravitational Separation : A New Tracer of Stratospheric Circulation

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As a basic knowledge of the atmospheric science, it has been believed that the gravitational separation of the atmospheric components can be found in the atmosphere above the turbopause. Demolishing this scientific common sense, we have detected a significant gravitational separation of major atmospheric components in the stratosphere for the first time based on the high-precision measurements of the stable isotopic ratios of N2, O2 and Ar as well as the concentrations of O2 and Ar in the atmosphere. Observed relationships between them are identical to those expected from the gravitational separation, however, they are clearly different from those expected from the thermally-driven fractionation related to air-sampling procedures. From the comparison of stratospheric O2/N2 ratio with and without correction for the gravitational separation, it is indicated that the consideration of the gravitational separation is indispensable to derive reliable information from measured values of the concentration and the isotopic ratio of atmospheric components. It is also suggested that the simultaneous observation of the gravitational separation and the CO2 age in the stratosphere could provide useful information to clarify year-to-year variations of Brewer-Dobson circulation due to climate change associated with the global warming.

Keywords: gravitational separation in the stratosphere, a new tracer of stratospheric circulation, decrease of stratospheric O2 concentration, molecular diffusion by gravity and thermal effect

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AAS22-07 Room:201B Time:May 21 10:45-11:00

Stratospheric cooling and downward planetary-wave propagation in the lowermost stratosphere during the 2010-11 winter

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Dynamical cooling in the polar stratosphere is induced by weakening of E-P flux convergence (i.e. anomalous divergence) in the stratosphere. As the E-P flux convergence is mainly contributed to by upward planetary-wave (PW) propagation from the troposphere, the intensity of its propagation is well correlated with E-P flux convergence and the polar stratospheric temperature. Several studies (Orsolini et al. 2009, QJRMS; Nishii et al. 2010, GRL) pointed out a tropospheric blocking high over the western Pacific, whose circulation pattern has projection onto the Western Pacific (WP) teleconnection pattern, tend to weaken the upward PW propagation and to lower the polar stratospheric temperature. In this study, we investigate a possibility that downward PW propagation in the lowermost stratosphere also causes the E-P flux divergence in the polar stratosphere and leads to stratospheric cooling.

Based on prominent negative events of vertical 100-hPa E-P flux averaged over the mid- to high-latitudes in the northern hemisphere, we performed composite analyses for each term of a transformed Eulerian mean (TEM) equation. Downward E-P flux in the lowermost stratosphere and divergence of E-P flux in the stratosphere are observed around the reference date, which is followed by persistent cooling of the polar stratosphere more than two weeks. About one week before the reference date, enhanced upward E-P flux and its convergence lead to deceleration of upper stratospheric zonal wind. This deceleration results in weakening of vertical sheer of zonal wind at the level, which hints at a turning surface for vertically-propagating PWs there (Harnik 2009, JGR). Our results are mostly consistent with Harnik (2009, JGR) who showed that a short pulse of upward-propagating PW forms a turning surface in the upper stratosphere, where the PW is reflected back.

By taking above results into consideration, we analyzed the prolonged cold 2010-11 winter. We found that while three cooling events in December and January were accompanied by tropospheric WP pattern events, cooling in February was led by downward-propagating PW events. Cooling in March is accompanied both by WP and downward-propagating PW events.

Keywords: Polar vortex intensification, Western Pacific pattern, downward planetary wave propagation

AAS22-08 Room:201B Time:May 21 11:00-11:15

Coupling of atmospheric dynamics from the troposphere to the lower thermosphere - Analysis of GAIA data in 2009-Jan. SSW-

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In order to reveal mechanical interactions among dynamics in the troposphere, in the stratosphere, in the mesosphere, and in the lower thermosphere during the stratospheric sudden warming (SSW) in Jan. 2009, we analyze global atmospheric circulation and its disturbances appearing in the Ground-to-topside model of the Atmosphere and Ionosphere for Aeronomy (GAIA) data [Miyoshi et al., 2011]. We put the JMA/JRA data in the lower atmosphere part of GAIA. Finally, the GAIA data are interpreted by using results from a simplified transformed Euler equation.

It is concluded that the dynamical effects caused by the heating and disturbances in the SSW depend on latitudes. This dependence is derived mainly from latitudinal and meridional non-uniform structures of the m=2 planetary wave which propagates up to the lower mesosphere. It is also revealed that, during the 2009-Jan. event, a symmetric atmospheric circulation in the northern hemisphere appears first in the mesosphere and propagates down to the upper troposphere. The downward propagation of the circulation exhibits latitudinal variations in its structure.

The Arctic Oscillation (AO) is related to the SSW. As the present study manifested that the SSW is initiated in the mesosphere, the AO is controlled by the mesospheric dynamics. Because the AO is assumed to be related with the cold winter, it may be concluded that the mesospheric dynamics plays an important role in generating a cold winter.

Miyoshi, Y., H. Fujiwara, H. Jin, H. Shinagawa, H. Liu, and K. Terada (2011), Model study on the formation of the equatorial mass density anomaly in the thermosphere, J. Geophys. Res., 116, A05322, doi:10.1029/2010JA016315.

Keywords: stratspheric sudden warming, mesosphere, troposphere, arctic oscillation, GAIA model

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AAS22-09 Room:201B Time:May 21 11:15-11:30

Predictability of the major stratospheric sudden warming in the Southern Hemisphere for September 2002

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A lot of attention has been drawn to dynamically coupled variability between the extratropical troposphere and stratosphere including stratospheric sudden warmings (SSWs) as an outstanding example. Existing studies have investigated such variability through diagnostic analyses of observational (reanalysis) and model simulation data as well as numerical experiments. Extensive studies using forecast data have been recently made in terms of predictability of SSWs. However, predictability of SSWs of a wavenumber 2 type (vortex split) has been relatively unexplored. This study seeks to investigate predictability of the major SSW in the Southern Hemisphere for September, 2002 using hindcast experiment data of one-month ensemble predictions conducted by Japan Meteorological Agency (JMA).

We use the JRA/JCDAS reanalysis data as a reference for the real world. We compare, to the reanalysis data, the JMA hindcast experiment data of one-month ensemble predictions. The experiment covers the period from 1979 to 2009. The predictions are initialized on the 10th, 20th, and last day of each month, with an ensemble size of 5. The polar night jet reverses its direction in late September of 2002, with an easterly wind peak on 9/27, accompanied by increased wave activity entering the stratosphere. We mainly focus on the predictions from (A) 8/31, (B) 9/10, and (C) 9/20 of 2002 to investigate these variations.

Our comparison between the reanalysis and prediction data shows the following features: Predictions initialized later forecast the wind variability better. The predictions of A and B do not at all show zonal wind reversals, whereas some of C do; The predictability of the zonal wind well corresponds to that of wave activity in the lower stratosphere. The predictions B underestimate the magnitude of the increased wave activity, whereas those C does the persistence; The predictability of the wave activity is further related to that of upper tropospheric anomalies. A blocking ridge over the South Atlantic, contributing to the increase in the wave activity, is likely the key for the above features.

We will also examine SSWs of the wave 2 type (2009 and 1989 cases) in the Northern Hemisphere.

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AAS22-10 Room:201B Time:May 21 11:30-11:45

On the dynamical responses in the middle atmosphere to ozone recovery and CO_2 increase

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Observational evidences have shown the stratospheric ozone decrease in the past decades. A preceding paper to the present study, Smith et al. [2010], examined the response of the mesospheric circulation and temperature to the past ozone loss using data from the Whole Atmosphere Community Climate Model (WACCM) developed by National Center for Atmospheric Research. They found a strong negative trend in the strength of the mesospheric residual flow driven by gravity waves in the Southern Hemisphere (SH) during early summer. The resultant temperature trend through the adiabatic process is positive in the polar mesosphere and negative in the polar lower thermosphere. The mechanism can be explained as follows: Ozone depletion leads a cooling trend in the lower stratosphere. The increase of positive temperature gradient is accompanied by westerly wind even in the early summer. The early summer westerly wind reduces the net eastward gravity wave drag in the mesosphere by wave filtering in the lower stratosphere. The residual flow from the summer to winter hemispheres is then weakened to modify the temperature responses around the polar mesopause.

On the other hand, many chemistry-climate models have simulated the disappearance of the ozone hole by the mid-21st century. One of the purposes of the present study is to investigate how the dynamical response changes in the ozone recovery period in the WACCM simulation for the 21st century. We have investigated linear trends of temperature, zonal wind, and residual circulation in the early SH summer in the period of 2005-2050 simulated by WACCM. Antarctic ozone recovery leads to temperature increase in early summer in the lower stratosphere which weakens westerly winds in the stratosphere. This mean zonal wind change modifies the filtering of gravity waves propagating into the mesosphere. The penetrating gravity waves accelerate the mesospheric equatorward flow which is followed by the accelerated upwelling below the mesopause in the southern polar region. These results support the mechanism of Smith et al. [2010].

In addition to ozone changes, the CO_2 emission scenarios are included in the WACCM simulation. The CO_2 variation also influences the background temperature fields by modification of radiation balance. We compared three simulations with different CO_2 scenarios to examine dynamical responses to them in the period of 2050-2100. An interesting feature appears around the winter stratopause. In the simulations, the winter polar stratosphere has warming trend against our intuition for CO_2 increase which has cooling effect on the stratosphere. The warming trend is caused by the acceleration trend of the Brewer-Dobson circulation due to the increasing trend of the amount of the E-P flux convergence in the upper stratosphere. At the same time, the westerly in the polar stratosphere is weaker in the future through the thermal wind balance. The wind profile filters the gravity wave propagation into the mesosphere. As a result of reduction of the net westward gravity wave drag, the mesospheric meridional circulation is decelerated. The winter polar mesospheric temperature then decreases by the decrease of adiabatic heating due to weakened downwelling. Combination of the cooling in the polar mesosphere and warming in the polar stratosphere lowers the stratopause height defined as the vertical temperature maximum.

Keywords: residual circulation, atmospheric waves, future prediction

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AAS22-11 Room:201B Time:May 21 11:45-12:00

Intercomparison of the stratospheric ozone data assimilation among three CTMs based on observation system experiments

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The impact of the model performance on the stratospheric ozone analysis is investigated using three different models with a common chemistry-meteorology coupling data assimilation framework. To develop a system for assimilation of meteorological field variables with ozone, we used a local ensemble transform Kalman filter (LETKF) with the CCSRNIES chemistry-climate model (CCM), the MRI CCM, and the CHASER chemical transport model (CTM). For the assimilation, we used ozone profiles provided by Aura/Microwave Limb Sounder (MLS) and total ozone provided by the Ozone Monitoring Instrument-Total Ozone Mapping Spectrometer (TOMS). We also used meteorological field variables of reanalysis data (JMA Climate Data Assimilation System), assimilated by LETKF or nudged, to drive the models. As a result, we found the effects of model bias in ozone on their assimilation performance as follows:

1. MLS assimilation

- The model-bias deteriorated the assimilation performance through the amplifying the growth of errors and preventing that of the ensemble spread. Both of these caused an underestimation of the forecast error covariance.

- An ozone bias causes a temperature bias through the radiation process. Therefore, in the stratosphere, reduction of the ozone bias by the assimilation of MLS ozone profiles greatly led to a reduction of temperature bias.

- In contrast, in the upper stratosphere and mesosphere, where the ozone concentration is mainly controlled chemically, the MLS assimilation did not work effectively. In this altitude range, the ozone spread rapidly converges to a photochemical equilibrium value. As a result, LETKF underestimated the forecast error of ozone because of the small ensemble spread relative to the observation error. In order to avoid the underestimation of forecast error, including some other chemical species into the assimilation will be needed to perturb the chemical equilibrium.

- In the troposphere, MLS ozone assimilation did not improve tropospheric ozone profiles because of the lack of data in the middle and lower troposphere and the large uncertainties of the data in the upper troposphere. The error in total ozone was not sufficiently reduced by the MLS data assimilation because of the uncorrected bias in tropospheric ozone. This is evident in the CCSRNIES model, which showed a large bias in ozone in the troposphere. Further, the MLS ozone assimilation for total ozone in CHASER was less effective than that in CCSRNIES and MRI, because in CHASER the ozone concentration above 70 hPa was fixed to the climatology.

2. OMI-TOMS assimilation

- Assimilation of OMI-TOMS total ozone data modified the ozone concentration profiles thorough the forecast error covariance, with the result that the modeled total ozone was close to the observation. In this study, we used a simplified method for vertical localization in which the localization distances were set to zero. It might be necessary to choose the localization distance more carefully to improve the assimilation performance. For example, applying a vertical localization using averaging kernel may be effective.

3. MLS and OMI-TOMS assimilation

- Assimilation of both MLS and OMI-TOMS data greatly reduced biases in the ozone profiles in both the stratosphere and the troposphere, resulting in a good assimilation performance for total ozone. Biases in total ozone were nearly zero, and the RMSE was smaller than the SCIAMACHY observation error in the NH and tropics. The biases between the CCSRNIES and MRI models showed little difference, although bias of CCSRNIES without assimilation was larger than that of MRI.

Keywords: stratospheric ozone, chemistry transport model, a local ensemble transform Kalman filter, data assimilation

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AAS22-12 Room:201B Time:May 21 12:00-12:15

Warming trends in the tropical tropopause layer estimated from GPS radio occultation in 2001-2010

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This study investigated the long term changes in the tropical tropopause layer (TTL) temperature using GPS radio occultation (RO) data form the German CHAMP satellite mission for the period May 2001-December 2007 and US?Taiwanese COSMIC six satellite mission for the period May 2006 - December 2010 in the latitude belt 15 S-15 N. Although continuous GPS RO data is only available for about 10 years, yet it has emerged as potential data to study the interannual changes of the TTL. The radiosonde data for period 1980-2010 in in the latitude belt 15S-15N is also used to compare the result. The TTL is the layer in the tropics between the level of main convective outflow level and the cold point tropopause (CPT), about 12-19 km. However, we use temperatures between altitudes 8-30 km which account both tropospheric (below the TTL) and stratospheric (above the TTL) processes besides TTL. The linear regression analysis was applied to the deseasonalized monthly mean temperature time series for each 1-km altitude bin for the periods 1980-2000 and 2001-2010 separately. The regression analysis included the components representing quasi-biennial oscillation (QBO), El Nino Sothern Oscillation (ENSO) and 11-year solar cycle for the period 2001-2010 as well as volcanic aerosols for the period 1980-2000. The analysis reveals dominance of the QBO (1-3 K/QBO index) in the upper part and above the TTL with maxima at the equator, particularly for the period during Northern Hemispheric (NH) autumn and winter during 2010-2010. The dominance of the ENSO is also seen within the TTL and below it (~ 0.5-1.0 K/ENSO index) with maxima at the equator, particularly during NH spring and summer during 2001-2010. Solar cycle effect was found to be negligible during 2001-2010.The troposphere below the TTL show warming trend (0.1-0.3 K/decade), while the TTL and above it shows cooling trend (0.2-1.2 K/decade) during 1980-2000. The TTL shows slow warming trend (0.5-1.0 K/decade) during 2001-2010 in contrast to period 1980-2000. The warming in the TTL could be possibly attributed due to increasing greenhouse gases.

Keywords: Tropical Tropopause Layer, GPS Radio Occultation, Temperature Trend, Global Warming

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AAS22-13 Room:201B Time:May 21 13:45-14:00

Relationship between relative humidity and cirrus clouds in the tropical tropopause layer over Indonesia

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The relationship between relative humidity and cirrus clouds in the tropical tropopause layer (TTL) is investigated using balloon-borne cryogenic frost-point hygrometers (CFH) and quasi-collocated measurements of space-borne Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) at two stations in Indonesia in January 2007 and 2008: Biak (1.17S, 136.06E) facing the western Pacific and Kototabang (0.20S, 100.32E) facing the eastern Indian Ocean. High supersaturations have been measured inside cirrus clouds. At Kototabang, thin layers of high supersaturation, up to ~160%, are often observed co-existing with cirrus clouds at altitudes of 15-18 km. At Biak, relative humidity over ice (RHi) inside the TTL cirrus is around 100% or less without large supersaturation layers, and most clouds are limited to altitudes below 16 km. Analysis of background meteorological fields and convective activity suggests that high supersaturations in cirrus clouds in this study are produced away from deep convective regions and where a well-developed transition layer exists between convective and highly stratified regions.

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(May 20-25 2012 at Makuhari, Chiba, Japan)

AAS22-14 Room:201B Time:May 21 14:00-14:15

On the turbulent mixing and ozone variations around the tropical tropopause associated with Kelvin waves

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We investigated the observed variations of ozone around the tropical tropopause in relation to large-scale waves both in the altitude and isentropic coordinates with ozonesondes provided by SHADOZ (Southern Hemisphere ADditional Ozonesondes) for period 1998-2009. Because ozone near this level can be used for the tracer of atmospheric motion, we regarded an ozone enhancement as the signal of a turbulent mixing. Global-model outputs (often $>$1.5 km) have difficulty analyzing the fine structure of ozone and temperature. Hence this study presents observed variations using ozonesondes ($<$0.2 km). Based on the signals of Kelvin waves (an eastward-traveling component of equatorial waves) which is filtered in the spectral-frequency domain using reanalysis data (ERA-Interim), we clarified the dependency of the observed profiles to phase evolution of the large-scale wave. In the phase-height cross sections or, in other words, the longitude-height cross sections for eastward-traveling Kelvin waves, the composite temperature and ozone profiles showed clear in-phase relationship. The phase line of temperature and ozone anomalies tilted eastward, indicating the undulation of isentropic surfaces associated with Kelvin waves. Finally, to avoid the influence of vertical advection accompanied by the waves, the ozone variation in the phase-isentrope cross sections were shown. The temperature anomalies still showed the phase progression associated with Kelvin waves. As for the ozone anomalies, however, the phase progression almost disappeared, but the enhancement of ozone was seen in the warm phase around 420 K level. Focusing on the positive ozone anomalies around 420 K level, the enhancement of ozone corresponded to the transition from warm to cold temperature anomalies. This suggests that the turbulent mixing may occur in the shear zone particularly for the warm anomaly. These observational results imply the connection between small-scale mixing and large-scale waves. May be there is the large shear zone near the maximum of temperature. Further research which is focused on the wave properties and the structure of temperature and wind is required.

Keywords: turbulence, equatorial wave, ozone

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AAS22-P01 Room:Convention Hall Time:May 21 17:00-18:30

SMILES L2 Product improvements in v2.X updates

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In this presentation, we will introduce about processing status of level 2 products of JEM/SMILES. Latest product v2.1 was already released for RA researchers), and it will be released to the general users in spring, 2012.

The SMILES (Superconducting Submillimeter-Wave Limb-Emission Sounder) has 4K-cooled superconducting mixers and had observed atmospheric spectra with high sensitivity for about half a year from Oct. 12, 2009. SMILES observes three submillimeter bands defined as band A, B, and C. Frequency coverages are 624.32-625.52 GHz, 625.12-626.32 GHz and 649.12-650.32 GHz, respectively. Standard L2 products are O_3, HCl, ClO, HNO_3, CH_3CN, HOCl, HO_2, BrO and O_3-isotioes (^{17}OOO, $O^{17}OO$, ^{18}OOO) in the stratosphere.

In Sep., 2010, version 2.0 products were released for RA researchers. Objective of v2.0 product is to reduce temperature bias. In the stratosphere, temperature of SMILES v1.3 is 2% higher than other satellite observation like as TIMED/SABER, AURA/MLS, and assimilated data like as GEOS-5. This is the largest issue in v1.X series since temperature is a basic parameter which characterizes the atmospheric structure. Temperature bias may suggest biases of other products.

The new products used latest L1B 007 which includes gain nonlinearity effect of receivers. The bias of temperature in upper stratosphere is successfully suppressed. In addition, we stopped temperature retrieval above 40km and refer MLS temperature product (v2.2) with applying migrating tidal model. HCl profiles in mesosphere became constant. This feature is suggested by Cl chemistry. V2.1 which was released in Jan. 2012 is miner update version for HOCl. HOCl lines are located near $O_{3\ (v1,3)}$ and ^{18}OOO. In this version, some parameters of these lines were changed and residual spectra were compressed. HOCl difference between SMILES and WACCM around 30km was suppressed.

Keywords: International Space Station, Kibo, O3, Data Processing, retrieval

Japan Geoscience Union Meeting 2012
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AAS22-P02 Room:Convention Hall Time:May 21 17:00-18:30

Validation of the SMILES Level 2 version 2.1 ozone data by using ozonesonde measurements

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Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) onboard International Space Station has provided global measurements of ozone (O3) profiles in the middle atmosphere from 12 October 2009 to 21 April 2010. We present validation studies of the SMILES version 2.1 ozone product in the altitude range from 16 km to 30 km using ozonesonde measurements.

A total of 225 ozonesonde profiles from 33 ozonesonde stations worldwide are compared with a total of 471 coincident SMILES ozone profiles. The agreement between the SMILES and the ozonesonde measurements is within 5% and better at higher latitudes in the altitude range from 26 km to 30 km.

Keywords: International Space Station, Kibo, SMILES, O3, ozone

Japan Geoscience Union Meeting 2012
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AAS22-P03 Room:Convention Hall Time:May 21 17:00-18:30

Validation of the SMILES Level 2 version 2.1 stratospheric ozone

IMAI, Koji[1*], SHIOTANI, Masato[5], SUZUKI, Makoto[2], MANAGO, Naohiro[2], SANO, Takuki[2], MITSUDA, Chihiro[3], NAITO, Yoko[4]

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Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) onboard International Space Station has provided global measurements of ozone (O3) profiles in the middle atmosphere from 12 October 2009 to 21 April 2010. We present validation studies of the SMILES version 2.1 ozone product in the stratosphere using other data sources: satellite data and chemical-climate models. The SMILES ozone data agree with most of other satellites data within 10- 15% at an altitude between 20 km and 50 km.

Keywords: International Space Station, Kibo, SMILES, O3, ozone

Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

AAS22-P04 Room:Convention Hall Time:May 21 17:00-18:30

Analysis of Arctic stratospheric minor gases related to ozone depletion observed with JEM/SMILES in 2009/2010

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The Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) is a sensor equipped in the Japanese Experiment Module "KIBO" on board the International Space Station (ISS), which has unprecedented high sensitivity with superconducting technology. SMILES had observed atmospheric minor constituents in the stratosphere and mesosphere from November 2009 to April 2010 with more than ten times the precision of other existing sensors. We analyzed SMILES L2 research products provided by the National Institute of Information and Communications Technology ("L2r") to discuss the relationship between temperature and stratospheric minor gases related to ozone depletion in the Arctic winter of 2009/2010.

Analysis of the SMILES L2r temperature data from 60 to 65^{o}N showed that the lowest temperatures occurred in a region centered at 30^{o}E at 24 km in January. The lowest temperature region shifted downward to 20 km in February. Here, we compared the SMILES L2r temperature data with the Goddard Earth Observing System Model Version 5 (GEOS-5) temperature data to assess the data quality of the L2r temperature product. Temperature data derived from Band B of SMILES had no distinct bias to the GEOS-5 temperature data, and those from Band A of SMILES were 5-10 times higher than the corresponding GEOS-5 temperature data.

Nitric acid concentrations were low in the lowest temperature region at 24 km in early and mid-January; in the same region, HCl concentrations decreased, ClO concentrations increased, and ozone concentrations slightly decreased. Similar feature was also seen at 20 km in late January and early February. These results suggest that Polar Stratospheric Clouds (PSCs) that were mainly composed of nitric acid were formed under cold conditions, and heterogeneous reactions on the surface of the PSCs particles occurred in these regions.

We calculated Nitric Acid Trihydrate (NAT) saturation temperature ("T_{NAT}") at each measurement location by using SMILES L2r nitric acid data. In the region where temperatures were lower than the calculated T_{NAT}, the amount of nitric acid was low, and the concentrations of HCl and ClO dramatically decreased and increased, respectively. However, changes in concentrations of nitric acic, HCl, and ClO were also seen in relatively warm region with temperatures higher than T_{NAT}; for more detailed analysis, we have to evaluate the quality of the L2r nitric acid data through comparisons with other independent data.

Keywords: stratospheirc minor gases, ozone depletion, remote sensing

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(May 20-25 2012 at Makuhari, Chiba, Japan)

AAS22-P05 Room:Convention Hall Time:May 21 17:00-18:30

Validation of stratospheric and mesospheric HCl (L2r product) measured by SMILES

YOKOYAMA, Kengo[1*], TAKESHI Manabe[1], YASUKO Kasai[2], HIDEO Sagawa[2], KODAI Suzuki[3]

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SMILES (Superconducting Submillimeter-Wave Limb-Emission Sounder) was attached to the ISS (Inter-national Space Station) / JEM (Japanese Experiment Module) to focus on molecules related to ozone destruction which includes hydrogen chloride (HCl). The period of observation covers October 2009 to April 2010. SMILES observes two HCl isotopes, H35Cl and H37Cl, in different SMILES frequency bands. The observation frequency of SMIELS includes three bands around 625 and 649 GHz (called Band A, Band B and Band C). H37Cl and H35Cl are observed in the Band A (624.32-625.62 GHz) and B (625.12-626.32 GHz) of the AOS (Acousto-Optic Spectrometer), respectively. The altitude distributions of the volume mixing ratio of HCl (called Level-2 product) are derived from the measured spectra separately for H37Cl and H35Cl.

HCl is estimated to comprise 95% of total stratospheric chlorine (Cl) and it is a reservoir molecule in the chlorine chemistry relating to the ozone depletion in the stratosphere. We can predict the future distribution of ozone as the results of researching the global distribution of halogen molecules including HCl.

Several instruments including Aura/MLS (Microwave Limb Sounder) and ACE/FTS (Fourier Transform Spectrometer) have observed the global distribution of HCl before SMILES observation. But these measurement results show a difference of 0.2 ppbv at about 53 km [S.A. Montzka et al 2011]. This research shows the comparison and validation between SMILES HCl (Level-2 Research product version 2.1.5) profiles and Aura/MLS and ACE/FTS. The L2r HCl profiles retrieved from the band A agreed with those from Aura/MLS at the altitudes from 25 km to 50 km , but the difference of the HCl profiles between L2r and Aura/MLS becomes larger at the altitude higher than 50 km. We confirmed the same tendency for the comparison between the L2r HCl profiles retrieved from the band B and Aura/MLS.

Keywords: HCl, SMILES

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AAS22-P06 Room:Convention Hall Time:May 21 17:00-18:30

HCl/Cly ratios of just before the breakup of the Antarctic vortex as observed by SMILES/MLS/ACE-FTS

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The International Space Station (ISS) / Japanese Exposure Module (JEM) borne instrument, the Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES), was successfully launched by the Japanese H-II Transfer Vehicle (HTV) on 11 September 2009 to measure chemical species in the stratosphere. We focus on inorganic chlorine species measured inside the Antarctic vortex in late spring when it is just before the breakup. At that time and location, the hydrogen chloride (HCl) is generally a main component of the total inorganic chlorine (Cly) in the lower stratosphere.

On 19-24 November 2009, SMILES measured southern latitudes up to 66 degrees. We will use the first public release of the dataset both for the operational and the research products. High HCl values up to 2.8 ppbv were observed near 460 K potential temperature levels (at altitude of 18 km). This characteristic agrees well with that observed in the past spring inside the Antarctic vortex. Comparisons with other satellite instruments, Microwave Limb Sounder (MLS) and Atmospheric Chemistry Experiment Fourier transform spectrometer (ACE-FTS), were also made at the same time and location. The results have shown the validity of the SMILES HCl data quantitatively. This also confirms the high HCl/Cly ratios inside the Antarctic vortex just before the breakup of the vortex. Then, such a feature in the recent past was examined using the MLS data between 2004 and 2011. It is found that this feature is rather regular in this late spring period in the Antarctic. Implication for this is to suggest that the future trend of Cly in the stratosphere can be deduced at this time and location by utilizing some aircraft or balloon measurements of HCl even below 20 km, as if no satellite measurement of HCl in the upper stratosphere in the future.

Keywords: stratosphere, antarctic, polar vortex, inorganic chlorine

AAS22-P07 Room:Convention Hall Time:May 21 17:00-18:30

Mesospheric O3 observed by ISS/JEM/SMILES

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The Superconducting Sub-millimeter Limb-emission Sounder (SMILES) onboard Japan Experiment Module (JEM) of the International Space Station (ISS) have observed atmospheric minor constituents related with ozone chemistry, such as O_3, HCl, ClO, HO_2, HOCl, BrO, with high sensitivity. Especially, O_3, HCl and ClO can be detected with altitude up to the mesosphere (around 80km). In comparison with the stratosphere, "in situ" photochemistry controls concentration of minor constituents, so that we can examine current understanding of whole atmospheric chemical reactions by the direct comparison with SMILES observational data and results from numerical model calculations. In this study, we report the characteristics of mesospheric ozone observed with SMILES, some results of comparative validation with past satellite data and numerical model calculations, and diurnal variation of mesospheric ozone.

In the atmospheric chemistry studies, numerical models calculation are the powerful tools for understanding of observation data and future forecasting, but we have to notice that the rates of chemical reactions which these models based on may have 30-50% of error, because these coefficients are extrapolated to stratosphere / mesosphere from the results from laboratory experiments. Therefore, the observation results of mesospheric minor constituents with 10-20% of error, such as SMILES data, can review the whole of past science of atmospheric chemistry with unprecedented accuracy.

Mesospheric ozone have been observed with ACE-FTS onboard Scisat-1, SABER onboard TIMED, and MLS onboard EOS-Aura. In this study, we have compared SMILES data with ACE-FTS and SABER (MLS data exists only for sunrise and sunset localtime, so they cannot be used for this comparison), as well as reproduction results of meteorological field from numerical model (SD-WACCM) calculation. As a result of this comparison, SMILES data relatively agreed with the results from SD-WACCM and 1.27micron-channel of SABER.

It is known that mesospheric ozone distribution has diurnal variation, such as time-variable characteristics after sunset, from numerical model calculations. Though the quality of past ground-based and space-borne observation data are not enough for discussing these diurnal variation. Thank to the unique orbital characteristics, diurnal variation can be plotted from about 45-day data of SMILES observation. The diurnal vatiation of mesospheric ozone will be discussed in combination with the mixing ratio of water vapor, so we also report these results.

Keywords: SMILES, Mesosphere, Atmospheric minor constituents, Ozone, Diurnal variation, Satellite observation

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AAS22-P08 Room:Convention Hall Time:May 21 17:00-18:30

Analysis on the seasonality of the QBO influence on the global circulation by making time-lagged composites

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1. Introduction

The QBO (quasi-biennial oscillation) is a phenomenum which is dominant in the equatorial storatosphere, and has influence on the extratropical circulation by modifiying meridional circulation and propagation of the planetary waves (Baldwin et al., 2001). In most of the previous works studying such influences of the QBO, composites for each month have been made according to the QBO phase in the ralevant month. In these cases, it is hard to make discussion about continuity of the features obtained for a sequential months. In the present study, therefore, we make time-lagged composite analysis in which the QBO phase in a fixed month is used to make composites for sequential months in order to investigate seasonality of the influence of the QBO on the global circulation.

The ERA40 data (1958-2002) are used in the analysis.

2. Time-lagged composite analysis

After Wallace et al. (1993), the phase of the QBO is defined with the phase angle of PC (principal conponent) 1 and PC 2 obtained from the EOF (empirical orthogonal function) analysis on the zonal wind in the equatorial lower stratosphere. The probability density function of the phase angles in June for 44 years shows bimodal structure: less frequent around -pi/2 and pi/2 and more frequent around 0 and pi. We fix a key month to June in defining two groups ”Westery” and ”Easterly”, and make composites for sequential months before and after the key month.

3. Results

In the present analysis, a composite obtained for six months before the key month is different from that obtained for six months after the key day, for example.

By extending the period of composite to several years before and after the key month, it is shown that descending of the easterly or westerly winds in the equatorial stratosphere as the QBO starts in a specified phase (in September-October or in December-January, respectively) of the SAO (semiannual oscillation) in the upper stratosphere. It is also shown that the descending speed of the easterly or westerly winds has semiannual variation (fast in May and October).

The composites of the EP (Eliassen-Palm) flux and the residual meridional circulation show variations which are well corresponding to the variation of the desceinding speed.

References

Wallace et al., 1993 : J.Atmos.Sci., 50, 1751-1762
Baldwin et al., 2001 : Rev.Geophys., 39, 179-229

Keywords: stratosphere, QBO, SAO, dynamics

Japan Geoscience Union Meeting 2012
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AAS22-P09 Room:Convention Hall Time:May 21 17:00-18:30

Observation of ClO at the lower stratosphere by JEM/SMILES

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In the chemistry of stratospheric, it is well known that the inorganic chlorine species such as ClO, HCl, HOCl, $ClONO_2$ and Cl-atom play major role. However, precision and/or accuracy of satellite observations for the inorganic chlorine species have been not sufficient for quantitative discussions of inorganic chlorine chemistry. In this paper, we report observed results of ClO in the lower stratosphere by using SMILES.

ISS/JEM/SMILES realized low-noise observation at the 650 GHz frequency region by using 4K-cooled superconducting SIS mixer. As a result, ClO was observed with high precision much better than previous observations (Aura/MLS and Odin/SMR).

Aura/MLS have been measuring ClO with a 0.1 ppbv precision at 25-50km altitude. Theoretical ClO precision of SMILES has been reported to be about 0.01 pptv at 30 km. This value can be verified from bin-width of histogram of nighttime ClO, since the ClO value during nighttime should be zero below 35km at the background atmosphere. We obtained actual bin-width, or ClO random error, to be 0.015 pptv, which is slightly larger than the theoretical value. It has been estimated that the additional random error might come from IFOV pointing error, temperature retrieval error, or baseline fitting error.

In tropical region (N10-S10), difference between day and night profiles was 79 pptv at 25 km. This result agreed quite well with reproductive calculated value (nearby 80 pptv) by using Chemical Transport Model (SD-WACCM). On the other hand, in middle latitude (N30-50) during Mar. 13-25, 2010, SMILES value were 71 pptv at 22km, and 35 pptv at 19 km. These value were significantly larger that reported as 10 pptv by airplane and balloon observation in 1986. SMILES mid-latitude value is about 3-7 times higher than the past observation, however, agrees with reproductive calculated value like as tropical region. These discrepancy in the mid-latitude between SMILES and past observation can be explained partly by the historical increase of total Clx from 2.4 pptv in 1968 to the present value, $>$3.0 ppbv.

Keywords: SMILES, International space station, ClO, stratosphere

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AAS22-P10 Room:Convention Hall Time:May 21 17:00-18:30

Chemistry within 2009/10 Arctic polar vortex observed by ISS/JEM/SMILES

SUZUKI, Makoto[1*], MANAGO, Naohiro[1], MITSUDA, Chihiro[2], IMAI, Koji[3], SANO, Takuki[1], AKIYOSHI, Hideharu[4], NAITO, Yoko[5], SHIOTANI, Masato[6], Douglas Kinnison[7]

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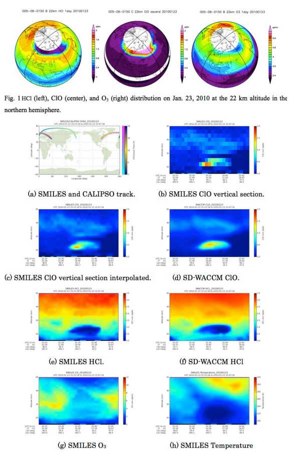
Superocnducting Submillimeter-Wave Limb-Emission Sounder (SMILES) is a 4K cooled limb sounding instrument in the 625-650 GHz frequency region, onboard International Space Station (ISS). SMILES was jointly developed by Japan Aerospace Exploration Agency (JAXA) and National Institute of Information and Communications Technology (NICT). SMILES operated from Oct. 12, 2009 to Apr. 23, 2010, when sub-mm local oscillator was suddenly terminated operation by failure. SMILES measured O3, H35Cl, H37Cl, ClO, HOCl, HO2, BrO, HNO3, CH3CN and O3 isotopes (17OOO, 18OOO, and O17OO). Precision (random error) of SMILES ClO product is about 0.01 ppb which is about 1/10 of Aura/MLS. SMILES measured 45 degree leftward from ISS forward direction, which gave latitudinal coverage of SMILES, 38S-65N.

It is well known that the chlorine chemistry (ClOx) becomes dominant when the heterogeneous processes occurred during the polar winter season. SMILES observed O3, HCl, and ClO during 2009/10 arctic winter season, as shown in Fig. 1. HCl is about 1.6 ppbt at outside polar vortex and it is almost entirely converted to the ClO (1.6 to 2.0 ppbt). O3 destruction has occurred as much as 20% (from 4 ppmv to 3.2 ppmv) after 3 weeks of heterogeneous chemical process.

Fig. 2 (a) shows trajectory of observation points of SMILES (large circles) from 15:23UT to 15:47 in Jan. 23, 2009, and CALIPSO observation points which passed north of Europe. Fig. 2(b) shows SMILES ClO vertical section. Figs. 2(c) and (d) shows horizontaly and vertically interpolated ClO of SMILES and SD-WACCM (specified dynamics-WACCM, reproduction run using GEOS-5 meteoroogical data), where slight difference is pbvious at the region observed in 15:38-15:40UTC at 20-22 km. Figs. 2 (e) and (f) shows those of HCl observed by SMILES and calculated by SD-WACCM, and HCl has been converted fully to the reactive inorganic species. Figs. 2 (g) and (h) show O3 and temperature observed by SMILES.



Japan Geoscience Union Meeting 2012
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AAS22-P11 Room:Convention Hall Time:May 21 17:00-18:30

Mesospheric HO2 and O3 Distribution in Tropical Region Measured by SMILES and Their Relation to Transient Luminous Event

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Based on the chemical simulation of the lightning-associated Transient Luminous Events (TLEs) such as sprites and elves, it is reported that the number density of NOx, HOx and O3 in the stratosphere and mesosphere can be drastically changed after the occurrence of TLEs. Though it is reported that the occurrence of TLEs mainly centers on the tropical region and that these TLEs may affect chemistry in the tropical stratosphere and mesosphere, no qualitative analysis has been performed so far. In order to identify the chemical impact of TLEs, we analyzed the O3 and HO2 data obtained by ISS/SMILES. Based on the initial analysis, we identified that the number density of HO2 increased over the tropical continents and that the number density is about 2 times bigger than that estimated by the three-dimensional photochemical model (SD-WACCM). At the presentation, we will show more detailed HO2, O3 distributions and time variations.

Keywords: lightning, sprite, HO2, O3, SMILES

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AAS22-P12 Room:Convention Hall Time:May 21 17:00-18:30

Sudden Stratospheric Warming event and its impact on mesospheric compositions in 2009-2010 Arctic Winter by JEM/SMILES

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The final target of this research is to find out the potential response of the atmospheric compositions affected by Sudden Stratospheric Warming (SSW) in the upper stratosphere and mesosphere. A SSW is a dramatic middle atmosphere event where the polar vortex of westerly (eastward) winds in the winter hemisphere abruptly (i.e. over the course of a few days) slows down (Minor warming) or even reverses direction (Major warming). During such events, the polar stratosphere exhibits a warming of tens of degrees over a few days and polar mesospheric cooling has also been observed during SSWs. Over the past decades, satellite instruments have observed the impact of SSW events on minor constituents like carbon monoxide (CO), ozone (O3), nitrous oxide (N2O) and water vapor (HO2). It is now clear that SSWs are dynamical disturbances affecting the entire middle and upper atmosphere, in addition to perturbing the tropospheric circulation (Kvissel, O.-K., et al., 2011).

We investigated the impact of SSW in the strato/mesosphere using newly obtained data with SMILES (Superconducting sub-Millimeter Limb Emission Sounder). SMILES is a highly sensitive radiometer with a few to several tens percent of precision from upper troposphere to the mesosphere. SMILES was developed by the Japanese Aerospace eXploration Agency (JAXA) and the National Institute of Communications and Technology (NICT) located at the Japanese Experiment Module (JEM) on board the International Space Station (ISS). From October 2009 to April 2010, SMILES has successfully measured the vertical distributions and the diurnal variations of various atmospheric species in the latitude range of 38S to 65N.

The analysis of temperature and ozone for the SSW during 1st January - 31 March 2010 was performed. Ozone increasing from January to March in the stratosphere has been confirmed. In the mesosphere, the diurnal variation structure of ozone was illustrated due to the variation in SMILES solar zenith angle. Night time ozone enhancement in the mesosphere has already been approved during this period, with respect to the temperature. SMILES observation approved the occurrence of SSW event in the end of January 2010 and the end of March 2010. SMILES observation of latitudinal, diurnal and seasonal variation of ozone in the mesosphere will be investigated in detail with the focus on discovering the impact of SSW on the mesospheric temperature and minor constituents such as O3, HCl and HO2.

Keywords: sudden stratospheric warming, SMILES, atmospheric compositions, ozone, mesosphere, diurnal variation

AAS22-P13 Room:Convention Hall Time:May 21 17:00-18:30

Predictability variations in a stratosphere-troposphere coupled system associated with winter polar vortex conditions

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Predictabilities of sudden stratospheric warming (SSW) events have been examined by the use of operational ensemble one-month forecast data produced by the Japan Meteorological Agency (JMA) (e.g., Mukougawa et al. 2005; Hirooka et al. 2007). However, they are case studies limited to a few SSW events.

In this study, intraseasonal and interannual variations in predictability of temperature inside the polar vortex in the northern hemispheric winter are investigated for seven winters of 2001/02 to 2007/8 by the use of the JMA forecast data. The ensemble one-month forecast is performed every Wednesday and Thursday from a control initial condition and several couples of perturbed conditions with both signs. In total, 26 or 50 ensemble members are taken for a week with a time-lagged (one-day) ensemble technique. The seven-winter period includes four SSW events and some minor ones.

Several measures on the predictability of the ensemble forecasts are introduced to study the predictability variations associated with dynamical conditions of the polar vortex, which are related to SSW events or vortex intensification events. Predictability limit is defined using the root mean square error as the time when it first surpasses one half of the climatological standard deviation in winter for a statistical analysis of its seasonal variation. On average, the predictability limit in the stratosphere is longer (about 10 days) than that in the troposphere (about 5 days). Its seasonal variation is large in the middle stratosphere; relatively long in early and late winter, whereas relatively short in midwinter.

The occurrence of some SSW events is well predicted by a large part of the ensemble members with a lead time of one week or so, whereas that in some other cases is more difficult to predict. We also have some examples of the predictions of an SSW event but no realization in the real atmosphere: the real world is in the other tail of the probability distribution of the ensemble forecasts of an SSW event. The occurrence or non-occurrence of such extreme events is discussed with probability distribution functions that have large non-Gaussian nature.

Keywords: stratospheric circulation, predictability, sudden warming, ensemble one-month prediction

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Evaluation of the molecular diffusion process in the stratosphere

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It has been shown that the gravitational separation effect can be detected in the stratosphere from nitrogen, oxygen, and argon isotopic ratios and Ar/N2 ratio observed by balloon experiments. The gravitational separation has a possibility to be a new tracer of stratospheric circulation. In this study, theoretical model simulations are performed to validate an existence of the gravitational separation in stratosphere, as well as to evaluate the magnitude of isotopic discrimination of the atmospheric major components driven by molecular diffusion including the thermal diffusion. 2-D model of the middle atmosphere, SOCRATES, used in this study has a high altitude domain up to 120 km and includes molecular diffusion process above the mesosphere. In an original setting of SOCRATES, the thermal diffusion is calculated only for hydrogen atom in the mesosphere. We expanded a model domain affected by the molecular diffusion process to the stratosphere, and calculated the ratio of 32O2 and 34O2 concentrations. The molecular diffusion flux is calculated by applying a theory in Banks and Kockarts (1973). Thermal diffusion factor for the mixture of 32O2 and 34O2 is assumed to be 0.01 by considering the value previously reported in Grew and Ibbs (1952). We repeated model simulations with and without ordinary molecular diffusion and/or thermal diffusion, and compared the distributions of oxygen isotopic ratios. As a result, it is concluded that the magnitude of gravitational separation in stratosphere will be significant enough to be detected by the isotopic measurements. However, simulated magnitudes of the gravitation separation are considerably smaller than observed values. Possible effects of the thermal diffusion on isotopic ratio will be also discussed.

Keywords: stratosphere, molecular diffusion

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Ozone variations over the northern subtropical region revealed by ozonesonde observations in Hanoi

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We have conducted continuous monthly ozonesonde observations and campaign intensive observations with a few-day interval every winter at Hanoi (21N, 106E), Vietnam since September 2004. By using the obtained data, seasonal and subseasonal variations in ozone mixing ratio (OMR) are investigated and the cause of the variations are discussed. A relative standard deviation (RSD), which is defined as a standard deviation divided by the mean value, is employed to evaluate the amplitude of variation in order to eliminate the rapid increase of the mean OMR with height.

In the lower and middle stratosphere (above about 20 km height), a clear seasonal variation is found with larger values in spring and summer and with smaller values in winter which is consistent with the well-known features of seasonal variation shown by previous studies.

A seasonal cycle with a winter minimum and a spring-summer maximum is also found in the UTLS region (10–20 km) with the larger RSD of 20-30%. Backward trajectory analysis shows that the winter minimum is due to the low OMR air mass transport form the tropical troposphere. This feature is commonly seen through the UTLS region in winter. On the other hand, the variation from spring to summer seem different between above and below the tropopause level at around 17 km. Below the tropopause level (upper troposphere around 14 km), the OMR peaks in late spring (May). This peak is consistent with the air mass transport from the mid-latitude stratosphere to the deep troposphere due to tropopause foldings. Above the tropopause level (lower stratosphere around 18 km), the OMR peaks in summer (July to August). This peak seems to be caused directly by the anti-cyclonic circulation associated with the Tibetan High, which is different from the upper tropospheric increase due to the tropopause folding. In mid-summer, the well-developed tongue-shape structure with high OMR air masses moves over Hanoi. As a result, the maximum OMR is considered to appear at around 18 km height in summer over Hanoi.

In the lower troposphere, the OMR has a clear maximum in March to April at about 3 km height. The maximum seems to propagate downward from 3 km height to the surface ozone maximum in May. The relation with surface ozone enhancement due to biomass burning is suggested, although the feature with downward propagation is inconsistent with the surface source. A tropopause folding is another candidate for producing the spring ozone maximum at 3 km.

Subseasonal variations in OMR show large amplitude in the UTLS region (around 15 km) and in the boundary layer (below 1 km) with the RSD of larger than 40¥%, which is comparable to that of mean seasonal variation of OMR. It is shown that the OMR variations in the UTLS region during the every winter campaigns have a negative correlation with the meridional wind. This relation indicates that the low OMR observed at Hanoi has been transported from the equatorial region, which is confirmed by backward trajectory analyses. This result supports the interpretation that the OMR winter minimum in UTLS is caused by the low OMR air mass transport from the equatorial region where the mean ozone concentration is low.

The mean OMR values during the winter campaigns suggest an existence of significant year-to-year variability in OMR at Hanoi. In January 2006, the convective center accompanied by the anti-cyclonic circulation as Rossby response moved westward due to the La Nina condition, which result in the more frequent arrival of low OMR air masses transported from the equatorial region to Hanoi. There is a possibility that a similar large-scale circulation change associated with the ENSO variation can strongly affect the ozone and other quantities over Hanoi.

Keywords: ozone, Stratosphere troposphere exchange, Indochina Peninsula, tropopause folding, Rossby wave breaking, biomass burning

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Analysis of an Extratropical Cyclone and Tropopause Inversion Layer using a Meso-scale Model

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Tropopause Inversion Layer (TIL) is a persistent layer with high static stability (Birner, 2002). Formation mechanisms of the TIL are not well understood, though mechanisms which may contribute the formation have been proposed, such as a dynamical mechanism due to local vertical convergence associated with a synoptic vortex (Wirth, 2003) and a radiative forcing mechanism due to heating by ozone and cooling by water vapor (Randel et al., 2007). Most of the studies so far used some idealized simulations and numerical experiments with realistic conditions have not been conducted yet.

We perform numerical experiments on a life cycle of an observed extratropical cyclone with Non-Hydrostatic Model (NHM) of Japan Meteorological Agency (JMA), which is originally used for operational numerical weather predictions. The model we modified has 200 layers in the vertical from the surface to 25 km in altitude, and the horizontal domain is 4140 km x 4000 km around Japan with a horizontal resolution of 20 km. The time integration period is 72 hours from 19th to 22nd in February, 2009, during which a typical event of explosive cyclogenesis was observed. For the initial and boundary conditions, we use NCEP/FNL data.

The TIL obtained in the control run has similar characteristics as observation, including dependence on local relative vorticity (Birner et al., 2002): stronger TIL in negative vorticity areas and weaker TIL in positive vorticity areas. But the dependence is clear only at the developing and mature stages of the cyclone, which suggests that the evolution of the cyclone plays an important role in the formation of the TIL. In the model, stronger TIL tends to appear in the areas where stronger gravity waves exist. To see the effects of gravity waves on the TIL, vertical convergence at the tropopause is analyzed. The histograms of maximum buoyancy frequency square within the TIL ($N^2{}_{max}$) show that the regions of vertical convergence show higher $N^2{}_{max}$, whereas those of vertical divergence show lower $N^2{}_{max}$. This tendency is clearer in the regions of negative relative vorticities at the tropopause. By taking account of the fact that the gravity wave activities associated with the cyclone and the jet streak seems to be enhanced during the developing and mature stages of the cyclone, the vertical convergence by gravity waves associated with synoptic weather systems can be a key in the formation of the negative correlation between the strength of the TIL and the local relative vorticity at the tropopause.

In experimental runs, water vapor is removed above 300 hPa level (EXP300) and 500 hPa level (EXP500) in the initial conditions in order to investigate the temperature response to the radiative forcing by water vapor perturbations around the tropopause. The explosive development of the extratropical cyclone is not different from the control run very much, but the TIL becomes stronger in EXP300 and weaker in EXP500. The vertical profiles of static stability in EXP300 become sharper due to the shaper vertical water vapor profile with sudden decrease of water vapor just below the tropopause (that is, 300 hPa level in EXP300). Quantitative analyses on the formation of the TIL are performed in detail to see the relative importance of dynamical and radiative forcing mechanisms.

Keywords: tropopause inversion layer, extratropical cyclone, gravity wave

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Chemical Reactions in the Stratosphere Induced by Transient Astronomical Ionizing Events

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Issues on terrestrial consequences of astronomical ionizing events (such as solar energetic particle events or supernovae) have motivated researchers both in astronomy and aeronomy. We focus especially on the influences of such events on the concentration change of nitric oxides (NOx) and ozone in the stratosphere, and start to do a new simulation study at the frontier of atmospheric chemistry, chemical physics, astronomy, and climate-change research. In this research area, Thomas et al. recently performed a two-dimensional photochemical transport model calculation and reported that gamma-ray bursts could induce ozone depletion (at most 20 - 30 % depletion) in the stratosphere [1,2]. In their photochemical model, they did not explicitly consider intermediate ions to avoid heavy calculations of the ion-molecule reactions. Instead, they used reported parameters of initial nitric oxide (NOx) increase per ion pairs generated by the irradiation.

In our approach, first we directly solve differential equations of ion-molecule reactions and analyze the influence of each reaction on the concentration change of NOx species. After we find adequate values of NOx concentration change we use them as input parameters for large-scale simulation. In the future we plan to realize a three-dimensional large-scale simulation with a chemistry climate model that is more advanced than the simulation by Thomas et al. For the first step of our study, we build a zero-dimensional model where the geographical height (altitude) is the only parameter (so-called BOX model).

Due to solar energetic particle events, showers of photons (X ray and gamma ray) and high energy (>100 MeV) particles (protons, neutrons) come down to the atmosphere, and due to near-earth supernovae, showers of photons (X ray and gamma ray whose energy are less than about 1 MeV) come. These high-energy particles/photons ionize and dissociate N_2 and O_2 in the stratosphere. On this radiolytic processes of N_2 and O_2, we used the G values of radiolysis [3] to obtain the yield of product ions (N^+, O^+, $N_2{}^+$, $O_2{}^+$, e^-) and radicals (N(^{4}S) , N(^{2}D), N(^{2}P), O(^{3}P), O(^{1}D)). G value is the number of product atoms or molecules per 100eV energy absorbed by the reactant system. We can roughly say that the product species generated by radiolysis of light atoms are defined only by the absorbed energy, which allow us to use G values. With this treatment we can estimate rate constants without considering the details of initial multi-step scattering processes. The ions and radicals generated by the radiolytic process react and form positive and negative ions for example, NO^+, $O_4{}^+$,O^-, and $O_2{}^-$. We include more than 100 chemical reactions (including ozone-destroying NOx, HOx, and halogens) at this stage and used the software for complex chemical kinetics, FACSIMILE (mcpa corp.)

In the present study, we assumed large solar-proton events (for example, see [4]) as input irradiation of the astronomical events, and represented the temporal variation of the irradiation with a step-function as Thomas et al. did in their calculations. We set the values of the fluence and duration at $1.0*10^9$ cm^{-2} and 24 hours, respectively. We did calculations with parameters (temperature and initial concentrations of chemical species) corresponding to altitudes between upper (50 km) and lower (25 km) stratosphere.

We discuss NOx concentration change and primary reaction paths, and their altitude dependence.

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Keywords: Solar energetic particle events, Supernovae, Ozone depletion

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A proposal of the SPARC Reanalysis/Analysis Intercomparison Project (S-RIP)

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Available global reanalysis data sets (8 currently) will be investigated for the major middle atmospheric diagnostics under the collaboration between the SPARC community and the reanalysis centers. The purposes of this project are to have a good communication platform between the SPARC community and the reanalysis centers, to understand the current reanalysis products, and to contribute to future reanalysis improvements in the middle atmosphere region. The project will have three major components: (1) the management team which deals with the overall coordination including the SPARC-reanalysis center connection, (2) the scientific working group which suggests the diagnostics covered and has the responsibility for editing and writing the final report, and (3) all SPARC-related researchers who make the data analysis, write journal papers, and contribute to the final report. The project will hold two or three dedicated workshops, where analysis results are discussed among the SPARC community and the reanalysis centers, and produce the final report as a SPARC report, which reviews the then past and near-future publications. The project duration is expected to be 3-5 years for the first phase. This project will be officially proposed at the SPARC SSG meeting in February 2012.