Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

AAS020-01 Room:102 Time:May 22 10:45-11:00

An aim of this session and current status of SPARC

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The conveners will present an overview of this session and current status of SPARC and its related missions, such as a report of the SPARC SSG meeting held in February 2011, the JEM/SMILES mission, and the PANSY program.

Keywords: SPARC, stratosphere, climate

Japan Geoscience Union Meeting 2011
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AAS020-02 Room:102 Time:May 22 11:00-11:15

Future change in the quasi-biennial oscillation influence on the northern polar vortex simulated with an MRI chemistry

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The impact of climate change on the dynamics of the Holton-Tan (HT) relationship between the quasi-biennial oscillation (QBO) and the polar vortex is examined using a set of transient simulations from the Meteorological Research Institute chemistry climate model (MRI-CCM), focusing on the Northern Hemisphere extended winter (November-March). The set is an ensemble of three simulations extending from 1960 to 2100 under the REF2 scenario (i.e., reference simulations making future predictions) using model prescribed SSTs. The MRI-CCM, which includes the interaction between QBO dynamics and the ozone (i.e., heating) distribution, reproduces the QBO and the extratropical circulation. The climate change has resulted in the colder stratosphere with the decreases temperature of 6 K and a strengthening of the westerlies at high latitudes which peaks at ˜ 4 m s?1. In the ensemble averages, there is considerable multidecadal variability in the composite difference of zonal wind, a striking feature is found that the centers of positive anomalies tend to be higher as the time proceeds. This result indicates that the sensitive regions of the extratropical circulation influenced by the equatorial QBO in the future climate would be different from and higher than that of the past climate. The nature of these trends suggests that climate change is responsible. Further research is required to answer the questions as to and how a multi-decadal oscillation might modulate the QBO influence on the extratropical circulation.

Keywords: QBO, Polar vortex, Stratosphere, Holton-Tan, Future climate

Japan Geoscience Union Meeting 2011
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AAS020-03 Room:102 Time:May 22 11:15-11:30

The quasi-biennial oscillation in a global warming climate

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The effects of anticipated 21st century global climate change on the stratospheric quasi-biennial oscillation (QBO) has been studied using a high-resolution version of the MIROC atmospheric GCM. This version of the model is notable for being able to simulate a fairly realistic QBO for present day conditions including only explicitly-resolved nonstationary waves. We ran a long control integration of the model with observed climatological sea-surface temperatures (SSTs) appropriate for the late 20th century, and then another integration with increased atmospheric CO2 concentration and SSTs incremented by the projected 21st century warming in a multi-model ensemble of coupled ocean-atmosphere runs that were forced by the SRES A1B scenario of future atmospheric composition. In the experiment for late 21st century conditions the QBO period becomes longer and QBO amplitude weaker than in the late 20th century simulation. The downward penetration of the QBO into the lowermost stratosphere is also curtailed in the late 21st century run. These changes are driven by a significant (30-40 %) increase of the mean upwelling in the equatorial stratosphere, and the effect of this enhanced mean circulation overwhelms counteracting influences from strengthened wave fluxes in the warmer climate. The momentum fluxes associated with waves propagating upward into the equatorial stratosphere do strengthen overall by about 10-15% in the warm simulation, but the increases are almost entirely in zonal phase speed ranges which have little effect on the stratospheric QBO, but which would be expected to have important influences in the mesosphere and lower thermosphere.

Keywords: QBO, gravity wave, global warming

Japan Geoscience Union Meeting 2011
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AAS020-04 Room:102 Time:May 22 11:30-11:45

Global simulations of surface UV-B in a changing climate

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Results of comprehensive long-term simulations of the surface all-sky and clear-sky ultraviolet (UV) radiation through 1960-2100 are presented. A new earth system model, MIROC-ESM-CHEM is used for the simulations, which considers key processes changing the surface UV radiation, that is, atmospheric dynamics and chemistry affecting ozone in the stratosphere and troposphere, aerosols and clouds in the troposphere, and surface albedo changing with sea-ice and snow cover. In contrast to previous assessments considering only an effect of long-term change in the stratospheric ozone, simulated long-term behaviors of UV radiation are strongly affected by other processes. A choice of future socio-economic scenarios dramatically changes the resultant long-term behaviors of UV radiation.

Keywords: UV, ozone, earth system model, climate change

Japan Geoscience Union Meeting 2011
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AAS020-05 Room:102 Time:May 22 11:45-12:00

Wave Activity in the Tropical Tropopause Layer in Reanalysis and Chemistry Climate Model Data

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Sub-seasonal variability including equatorial waves significantly influence the dehydration and transport processes in the tropical tropopause layer (TTL). This study investigates the wave activity in the TTL in six reanalysis data sets (RAs; NCEP/NCAR, NCEP-DOE AMIP-II, ERA40, ERA-Interim, JRA25, and MERRA) and four chemistry climate models (CCMs; CCSRNIES, CMAM, MRI, and WACCM) using the zonal wavenumber-frequency spectral analysis method with equatorially symmetric-antisymmetric decomposition. Analysis is made for temperature and horizontal winds at 100 hPa in RAs and CCMs and for outgoing longwave radiation, which is a proxy for convective activity that generates tropopause-level disturbances, in satellite data and CCMs. Particular focus is placed on equatorial Kelvin waves, mixed Rossby-gravity waves, and symmetric eastward-moving intra-seasonal oscillations. It is found that the activities show significant difference among the RAs, ranging from ~0.5 to ~1.5 with respect to the RA average. Newer RAs tend to show greater activities. The activities in the CCMs are generally within the range of those in the RAs. It is concluded that the broad range of wave activity found in the different RAs decreases our confidence in their validity and in particular their value for validation of CCM performance in the TTL, thereby limiting our quantitative understanding of the dehydration and transport processes in the TTL.

Keywords: wave activity, tropical tropopause layer, reanalysis, chemistry climate model

Japan Geoscience Union Meeting 2011
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AAS020-06 Room:102 Time:May 22 12:00-12:15

Diurnal migrating tides in the troposphere to lower-mesosphere as deduced with TIMED/SABER data and six reanalysis data

Takatoshi Sakazaki[1*], Masatomo Fujiwara[1], Xiaoli Zhang[2], Maura Hagan[3], Jeffrey Forbes[2]

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It is important to study the tidal variability in the troposphere and stratosphere, since it has a great impact on the mesosphere and lower thermosphere (MLT region). However, there has not been a comprehensive study of tides in this altitude region. Here, we reveal the global structure and seasonal variation of diurnal migrating tides in the troposphere to lower-mesosphere, using TIMED/SABER satellite data and six reanalysis data sets (NCEP/CFSR, NASA/MERRA, ERA-Interim, JRA-25, NCEP1, NCEP2), as well as output data from Global Scale Wave Model (GSWM09).

It is shown that MERRA, ERA-Interim and CFSR perform best in reproducing the observed features in SABER as follows. The amplitude is basically the largest in the tropics for this altitude region, except for the maximum in midlatitudes in the upper stratosphere. The amplitude maximizes in winter and in summer over the tropics, while it maximizes at solstice in midlatitudes.

Using the classical Hough mode decomposition, it is confirmed that the propagating modes are mainly excited by the tropospheric heating, while the trapped modes are excited by the heating in the troposphere and upper stratosphere. Also, numerical experiments with a linear tidal model shows that the seasonal variation of background winds/temperatures (non-classical terms) shows a non-negligible contribution to that of tidal signatures.

Keywords: diurnal migrating tides, SABER, reanalysis, seasonal variation

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AAS020-07 Room:102 Time:May 22 12:15-12:30

Global characteristics of vertical wavenumber spectra based on a high-resolution climate model

Issei Takano[1], Kaoru Sato[1*], Shingo Watanabe[2], Yoshio Kawatani[2]

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It is well known by previous observational studies that, vertical wavenumber (m) spectra of horizontal wind and temperature fluctuations are proportional to m^{-t}, and t=3. The slope of spectra, t, is considered to be constant regardless of the season, geographical location and altitude range. Smith *et al*. derived the spectral amplitude theoretically assuming saturated gravity waves. Subsequent a lot of observational studies showed that this theory accords well with observations.

However, observations are usually made in limited geographical and vertical regions. First, there are many studies in the lower stratosphere, while there are a limited number of studies in mesosphere because observational data is insufficient at such high altitudes. Second, observational stations are not distributed uniformly. Thus, it is difficult to examine global characteristics of spectra only from observations. It is also shown in a few previous studies that slope and amplitude of the spectra slightly depend on the latitude. Furthermore, vertical wavenumber spectra of vertical velocity fluctuations have scarcely been examined so far because the observation of vertical velocity is very difficult. Thus, we examine global characteristic of vertical wavenumber spectra using data from a high-resolution general circulation model (GCM) which can resolve gravity waves explicitly without any gravity wave parameterizations. Seasonal and altitude dependence of the vertical wavenumber spectra is examined by analyzing data in two months of June and December in four height regions in the stratosphere and mesosphere.

First, vertical wavenumber spectra of GCM data (hereafter referred to as model spectra) compared with observed spectra, which are calculated using data from radiosonde observation campaign to scan the stratosphere meridionally over the middle Pacific in December 2001. It is shown that model and observational spectra accord well, assuring that the model data can be analyzed as a good surrogate of the real atmosphere. Characteristics of the model spectra are summarized as follows: Slopes of temperature spectra are generally close to t=3 but show significant dependence on the geographical location, season and altitude range. There are a maximum near the summer pole and weak maxima in the tropical region for the lower stratosphere. There are maxima at summer easterly and winter westerly jet regions in the lower mesosphere. Distributions of t values in December and June are almost symmetric about the equator. The characteristic vertical wavenumber of temperature spectra decrease with altitude, which is consistent with the theory by Smith *et al*. It is the theoretically expected that the relation between the spectral slopes for vertical wind (t_w) and temperature fluctuations (t_T) is $t_w=t_T+2$.However, the model spectra show that $t_w \geq t_T+2$ at most regions.

Second, several potential factors which control the shape of spectra are examined. There is positive correlation between the temperature variance and slope of temperature spectra in the upper stratosphere and lower mesosphere, which is consistent with the theory by Smith *et al*. However, the correlation in the lower stratosphere is low. The correlation between the spectral slope and the occurrence frequency of shear instability, which is one of the mechanisms for gravity wave saturation, is not high. These results suggest that the mechanism considered by Smith *et al*. do not act anywhere in the middle atmosphere. Instead, clear positive correlation is observed between the background horizontal wind speeds and the spectral slopes in particular in the lower mesosphere. A likely mechanism is that the intrinsic horizontal phase speeds of gravity waves become large in strong background wind conditions and hence the vertical wavenumbers become small following the dispersion relation.

Keywords: atmospheric gravity waves, vertical wavenumber spectra, high-resolution GCM

Japan Geoscience Union Meeting 2011
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AAS020-08 Room:102 Time:May 22 12:30-12:45

Atmospheric frequency spectra of short period fluctuations

Chikara Tsuchiya[1*], Kaoru Sato[1], Yoshio Kawatani[2], Shingo Watanabe[2]

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Accumulation of good quality data after the International Geophysical Year (1957-58) allows us to analyze statistical properties of meteorology in terms of wavenumber and/or frequency spectra. It is well known that in the free atmosphere, wavenumber (frequency) spectral shape is roughly proportional to a power of the wavenumber (frequency) (e.g. VanZandt 1982, Ecklund et al. 1985). This means that the spectra have a constant slope in the log-log plot. Recently, frequency spectra of surface meteorological parameters over a wide frequency range of 2 hours to 20 years in Japan and at Syowa Station in the Antarctic were examined. It was shown that frequency spectra have two different slopes with a transition frequency of several days (Sato and Hirasawa 2007; Tsuchiya et al. submitted). The spectral shape clearly varies as a function of latitude. Frequency spectra of the short period fluctuations of the surface pressure were examined using simulations with a global nonhydrostatic model (Nonhydrostatic Icosahedral Atmospheric Model, NICAM: Satoh et al. 2008). It was clear that spectral slopes are steeper than 3 at latitudes higher than about 30 degrees and are gentle at lower latitudes. In comparison with two simulations for different seasons, it was shown that the region with the gentle slope is extended into the summer hemisphere by about 10 degrees.

In this study, we analyzed frequency spectra with hourly data from simulations over 3 years by a gravity wave resolving Atmospheric Global Circulation Model (Watanabe et al. 2008). Spectral slopes of the sea level pressure fluctuations in the high frequency range (from (2 days)$^{-1}$ to (6 hours)$^{-1}$) is similar to these of NICAM data in terms of the latitudinal variation and seasonal dependence. The shape of the frequency spectra of the geopotential height, temperature, and wind speed fluctuations in the troposphere resemble those at the surface. The spectra in the stratosphere and mesosphere tend to have a constant slope, which is about 5/3, at frequencies higher than the inertial frequency, except for the temperature and wind speed spectra in the tropics and polar regions in the lower stratosphere.

Keywords: universal spectrum, mesosphere, stratosphere, troposphere

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AAS020-09 Room:102 Time:May 22 14:15-14:30

Ozone hole indices and wave activity in the Southern Hemisphere

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Relationships between the ozone hole indices and atmospheric wave activity in the Southern Hemisphere are examined. The data used for the analysis are TOMS, JRA25, and the output from the CCSR/NIES CCM for the future projection of ozone (the REF2 experiment) defined by CCMVal, that from REFB2 for CCMVal2, and that from a REFB2 run using a new CCM that was constructed based on a GCM for IPCC-AR4 (MIROC 3.2). Analysis was made for the period 1990-2009, when the Antarctic ozone loss developed and nearly reached the maximum. The result shows a similar relationship between the observation and the CCM; a positive correlation with statistical significance between annual minimum total ozone and September wave amplitude, and a negative correlation between annual maximum ozone hole area and September wave amplitude, which are expected by the assumption that a large wave activity brings more ozone, more heat, and more NOx from the mid-latitudes to the Antarctic region, thus reduces the ozone loss in the Antarctic in the year. However, a few exceptions were found. These exceptions are analyzed and discussed.

Keywords: ozone hole, wave activity, CCM, CCMVal, CCSR/NIES, future projection

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AAS020-10 Room:102 Time:May 22 14:30-14:45

A study of the relationship between polar stratospheric and upper tropospheric clouds

Masashi Kohma[1*], Kaoru Sato[1]

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Occurrence frequency of PSCs (Polar Stratospheric Clouds) is strongly affected by atmospheric waves (Kohma and Sato, 2011). The effects of planetary waves on PSCs around an altitude of 20 km are large, while synoptic-scale waves significantly affect PSCs around 12 km. On the other hand, there are several cases that PSCs at these different altitudes propagate eastward with almost the same velocity, which does not accord with the background zonal wind. This fact suggests that the atmospheric waves control the formation of PSCs in a wide altitude region simultaneously. However, the mechanism remains unclear.

So as to elucidate this mechanism, cloud observations by CALIPSO lidar and reanalysis (ERA-Interim) data are analyzed for the time period of the austral winter of 2008 and boreal winter of 2007/2008.

The effects of atmospheric waves are examined in terms of Ertel's potential vorticity (PV). It is shown that PSCs at 20 km are frequently observed over anticyclonic PV anomaly on the 300 K surface (~ tropopause height). This fact suggests that atmospheric waves near the tropopause may affect PSCs at 20 km remotely.

Recent studies (Wang et al., 2008, Adhikari et al., 2010) using CALIPSO observations indicated possible connection between PSCs and upper tropospheric clouds (~ 8 km). However, because of the existence of a weak minimum in the temperature profile around 25 km, the tropopause height tends to be wrongly estimated based on temperature or static stability. It is possible that the "upper tropospheric" clouds are clouds in the lowermost stratosphere. In this talk, the results of detailed analysis from this viewpoint using the tropopause heights defined based on Ertel's potential vorticity will be shown.

Keywords: polar stratospheric clouds, atmoshpheric waves

Japan Geoscience Union Meeting 2011
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AAS020-11 Room:102 Time:May 22 14:45-15:00

Geographical dependence observed in blocking high influence on the stratospheric variability

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Many previous studies have suggested the importance of blocking high (BH) development for the occurrence of stratospheric sudden warming (SSW), while there is a recent study that failed to identify their statistical linkage. Through composite analysis applied to high-amplitude anticyclonic anomaly events observed around every grid point over the extratropical Northern Hemisphere, the present study reveals distinct geographical dependence of BH influence on upward propagation of planetary waves (PWs) into the stratosphere. Tropospheric BHs that develop over the Euro-Atlantic sector tend to enhance upward PW propagation, leading to the warming in the polar stratosphere. In contrast, the upward PW propagation tends to be suppressed by BHs developing over the western Pacific and the Far East, resulting in the polar stratospheric cooling. This dependence is found to arise mainly from the sensitivity of the interference between the climatological PWs and upward-propagating Rossby wave packets emanating from BHs to their geographical locations. SSW tends to follow BH development over the climatological PW ridge over the Euro-Atlantic sector, whereas a polar stratospheric cooling event tends to be preceded by BH development over a climatological PW trough. Our results suggest that BHs that induce the stratospheric cooling can weaken statistical relationship between BHs and SSWs.

Keywords: blocking high, sudden stratospheric warming, planetary wave, interference

AAS020-12 Room:102 Time:May 22 15:00-15:15

The role of the gravity wave on the middle atmospheric circulation

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The roles of atmospheric gravity waves on both a formation of the mesospheric residual circulation and mechanisms of the maintaining and revolution of the upper flank of the polar night jet are investigated using gravity wave-resolved middle atmosphere general circulation model (GCM). The GCM has a T213 spectral horizontal resolution and 256 vertical levels with vertical intervals of 300 m. The model simulated explicitly resolved gravity waves generated by the spontaneous adjustment processes, convection, jets, topography, instability, and so on with no gravity wave parameterization.

The mesospheric residual circulation in terms of the stream function is examined by the downward control analysis. In the solstitial mesosphere, the residual circulation is one-celled, flowing from the summer hemisphere to the winter hemisphere, while the residual circulation consists of two cells of tropical upwelling and extratropical downwelling in the stratosphere. The downward control analysis reveals that the Rossby waves including the planetary scale waves and synoptic scale waves are the main driver of the stratospheric residual circulation. On the other hand, the gravity waves are the most important driver in the mesosphere and summer stratosphere. The gravity wave forcing in the mesosphere makes the meridional flow and associated upwelling in the summer hemispheric polar region and downwelling in the winter polar region, which leads to a local temperature maximum in the winter polar mesosphere at the height of 70 km by the strong adiabatic heating/cooling. The maximum descends in seasonal march and gets to the summer stratopause at the height of 50 km.

Air flows avoiding the polar night jet core: The residual velocity is poleward and downward along the upper and poleward edge of the polar night jet and poleward and upward along the upper and equatorward edge of the jet in the mesosphere. This increases the temperature gradient so that the upper flank of polar night jet weakens and then its core descends, which can affect the change in the path of the residual velocity along the edge of the jet. These changes lead to feedback to the descent in the jet core.

The jet core descent also influences the time lag in appearance of peaks in the residual velocity because the residual velocity can be large above jet core. For example, in the southern hemisphere, a peak in the meridional velocity averaged in the height region of 70–80 km is located during June or July, although a peak in that averaged in 55–70 km appears during September.

On the other hand, the residual meridional velocity is small in the lower mesosphere and large and poleward in the middle mesosphere especially in the mid-latitudes. The residual vertical velocity is large and upward in the polar region of the middle mesosphere. As in the case of winter, the residual velocity seems to curve around the middle-mesospheric easterly jet core.

In the presentation, the role of gravity waves on changes in the structure of the polar night jet, easterly jet, the residual circulation, and the relation in them are explained in detail.

Keywords: middle atmosphere, residual circulation, gravity wave, polar night jet

Japan Geoscience Union Meeting 2011
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AAS020-13 Room:102 Time:May 22 15:15-15:30

A new estimation method of the momentum fluxes associated with gravity waves

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The momentum flux associated with gravity waves is an important quantity to evaluate their effects on global circulations. As the gravity waves have various sources, it is likely that multiple gravity waves propagating in different directions are usually superposed. In such situation, even if all physical quantities are available, it is difficult to estimate the total momentum flux of gravity waves (i.e., a sum of absolute values of momentum fluxes of respective waves).

In the present study, a new formula was derived to estimate the total momentum fluxes. This theoretical formula contains variances of three dimensional wind and temperature fluctuations and includes neither wavenumbers nor frequencies explicitly. This formula requires that wave fields are decomposed into monochromatic waves and momentum fluxes are overestimated whenever wave fields are not decomposed. Formulas to estimate intrinsic frequencies, horizontal and vertical wave numbers, absolute value of zonal and meridional components of total momentum fluxes are also derived. The momentum fluxes were estimated by applying this formula to a gravity-wave resolving general circulation model data. The model has T213 spectral horizontal resolution and 256 vertical levels extending from the surface to a height of 85 km with a uniform vertical spacing of 300 m in the middle atmosphere (Watanabe et al., JGR, 2008). As no gravity wave parameterization is used, all gravity waves in the model are spontaneously emitted from sources (convections, topographies, instabilities, jet imbalances, etc). Watanabe et al. showed that the model represents realistic general circulation and thermal structure in the middle atmosphere.

Disturbances whose horizontal wavenumbers are greater than 22 are defined as gravity waves. Estimation was made for the following 3 cases whose degree of monochromatic wave assumption at each grid is different. 1) The fluctuations are assumed to be due to a monochromatic gravity wave. 2) The fluctuations can be decomposed only by vertical wavenumbers. 3) The fluctuations can be decomposed by both vertical wavenumbers and frequencies. The differences between the resultant momentum fluxes from 1) and 2) are, though they reach nearly 40% in some region at the lower stratosphere, in the range of about 20% in most regions. The regions in which the difference between the resultant momentum fluxes are the regions in which those are relatively small. The resultant momentum fluxes from 2) and 3) are similar. This means that the resultant momentum fluxes from 2) and 3) can be regarded as true values. These results indicate that the total momentum fluxes can be estimated with about 20% error under the assumption 1).Under the assumption, three dimensional total momentum flux distribution can be obtained with use of time series variances, and three dimensional distributions of other properties (i.e. intrinsic frequencies, horizontal and vertical wave numbers, absolute value of zonal and meridional components of total momentum fluxes) can be also estimated.

Keywords: Gravity wave, High resolution GCM

Japan Geoscience Union Meeting 2011
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AAS020-14 Room:102 Time:May 22 15:30-15:45

Predictability of Northern winter stratospheric conditions using JMA one-month ensemble predictions for 2001/02-2009/10

Masakazu Taguchi[1*], Hitoshi Mukougawa[2], Toshihiko Hirooka[3], Shunsuke Noguchi[4], Shigeo Yoden[5]

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It has been widely accepted that the troposphere and stratosphere are dynamically coupled especially in the Northern Hemisphere during its winter. There is increasing interest in applying the dynamical coupling to predictability of tropospheric and stratospheric variations.

This study investigates predictability of Northern winter stratospheric conditions for 9 winters of 2001/02 to 2009/10. One-month ensemble predictions by JMA (Japan Meteorological Agency) are compared to JMA objective analysis data. The polar stratosphere is dynamically active for each mid-winter of this period, except for 2004/05, including occurrence of stratospheric sudden warmings (SSWs).

A survey comparison using daily temperatures at the North Pole, 10 hPa of all ensemble members vividly illustrates that the character of the predictions, as seen in PDFs of differences from the analyses, varies on intraseasonal and interannual scales. Such variations are apparent, for example, in looking at two SSW events occurring in January of 2008 and 2009 (Fig. 1). The ensemble forecasts relatively well capture the occurrence of the former SSW case with a lead time of about two weeks (Fig. 1a). On the other hand, the onset of the latter case is unpredictable by the majority of the forecasts with a two-week lead time (Fig. 1b).

A systematic assessment of the predictability is made using root mean square error of weekly-mean polar temperatures. Results show that the predictability is quite different according to the signs of anomalies of the analysis temperatures. When the anomalies are positive, i.e., the polar stratosphere is warmer than normal, the predictions tend to be much lower than the analyses. For the negative anomalies, the predictions are either higher or lower, with smaller errors in magnitude. Such asymmetry is a vital feature of stratospheric predictability reflecting the occurrence of SSWs, or displacement or splitting events of the polar vortex. In contrast, tropospheric predictability is symmetric about the signs of 500-hPa polar temperatures: the error becomes similarly large with increasing temperature anomalies with either sign.

Interannual variability of the predictability is also found by comparing weeks when the analysis temperature anomalies are highest or lowest in each year. In particular, the warmest weeks in 2008/09 and 2002/03, which are closely related to the occurrence of SSWs, are the most difficult cases to predict (See Fig. 1b). The case-to-case variability is most notable for the lead time of 2 and 3 weeks. Such variability is smaller for the coldest conditions. Dynamical origins for such variations of the predictability will be studied with wave activity driving the stratospheric circulation.

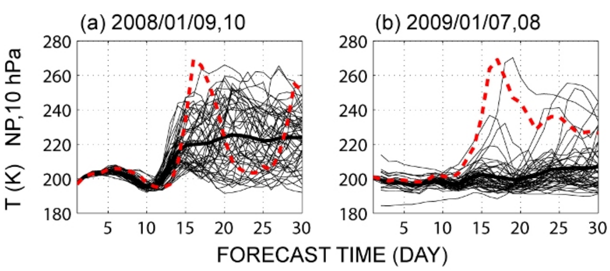

Figure 1: Daily time series of temperature at NP, 10 hPa: red boken line is for GANAL, and thin black lines for ensemble forecasts. Thick black lines denote the ensemble means. Panal (a) is for initial dates of January 9 and 10 of 2008, and (b) for those of January 7 and 8 of 2009.

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

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AAS020-15 Room:102 Time:May 22 15:45-16:00

Westerly acceleration during the recovery of the stratospheric sudden warming in the high-resolution AGCM

Yoshihiro Tomikawa[1*], Shingo Watanabe[2], Yoshio Kawatani[2], Kazuyuki Miyazaki[2], Masaaki Takahashi[3], Kaoru Sato[4]

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Stratospheric sudden warmings (SSWs) have occurred almost every year in the 2000s. The SSWs in Jan. 2004, Jan. 2006, and Jan. 2009 showed a common feature that the stratopause and the polar-night jet were reformed at an altitude of about 80km after the SSWs. While the polar stratosphere is supposed to be warmed by the meridional circulation driven by the momentum deposit due to planetary waves, it is not clear how the subsequent warming and westerly acceleration around 80km is caused.

In the T213L256 CCSR/NIES/FRCGC AGCM which was integrated over three years, the SSW similar to that mentioned above has occurred. Relative contributions of meridional circulation and different kinds of waves to the westerly acceleration after the SSW were investigated using a momentum budget analysis based on the transformed Eulerian-mean equations. It showed that, while the planetary waves with zonal wavenumber 1-3 mostly contributed to the momentum budget during the SSW, the momentum advection due to the meridional circulation played a primary role in the westerly acceleration above 50km after the SSW.

Keywords: stratospheric sudden warming, planetary wave, meridional circulation

Japan Geoscience Union Meeting 2011
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AAS020-16 Room:102 Time:May 22 16:00-16:15

Development of a Next Generation System for Monitoring the Atmospheric Environment and Estimating the Emission Inventory

Toshiki Iwasaki[1*]

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It is a great concern that human activity seriously affects the atmospheric environment. The anthropogenic and natural emissions, and distributions of ozone must be accurately estimated from advanced observations.

We are developing the data assimilation system of atmospheric minor constituents, such as carbon dioxide, aerosol and ozone, for monitoring the atmospheric environment and estimating the emission inventory. The data assimilation system incorporates an ensemble Kalman filter, because it can be set up without considering the forward model including complicated chemical reactions and atmospheric transports. Observation data of minor constituents are assimilated into a coupled model of chemical transport and general circulation (CTM-GCM). The model is driven by the objective analyses of meteorological parameters.

A prototype was set up and optimized individually for carbon dioxide, aerosol and ozone. An observational system simulation experiment (OSSE) on carbon dioxide was performed to evaluate contributions of the surface, airborne and the GOSAT observations. CARIPSO aerosol observations were successfully assimilated for the first time and shown to greatly improve Asian dust (Kosa) predictions. Data assimilation parameters for ozone and related species were carefully optimized considering complicated chemical reactions through an OSSE. Now, our efforts are shifted to assimilation experiment of real data.

Keywords: Data assimilation, Minor constituent, Carbon dioxide, Aerosol, Ozone

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AAS020-17 Room:102 Time:May 22 16:30-16:45

Middle atmospheric chemistry and dynamics: results from the SMILES mission

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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. SMILES was successfully launched by the H-IIB rocket with the H-II Transfer Vehicle on September 11, 2009, was attached to JEM on September 25, and started atmospheric observations on October 12. Unfortunately, SMILES observations have been suspended since April 21, 2010 due to the failure of a critical component in the submillimeter local oscillator. However, high-sensitivity measurements of minor species had been performed by a receiver using superconductor- insulator- superconductor (SIS) mixers, cooled to 4.5 K by a compact mechanical cryocooler. Thus global and vertical distributions of about ten atmospheric minor constituents related to the ozone chemistry are derived. 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 and ii) To measure atmospheric minor constituents in the middle atmosphere globally in order to gain a better understanding of factors and processes controlling the stratospheric ozone amounts and those related to climate change. In this talk, an overview of the SMILES measurements will be introduced with some observational results in association with middle atmospheric chemistry and dynamics. These results 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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AAS020-18 Room:102 Time:May 22 16:45-17:00

Middle atmospheric winds observation from JEM/SMILES

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Middle atmospheric winds have been retrieved from the JEM/SMILES measurements. The winds, observed in the line of sight direction, are retrieved from the frequency shift of the intense and spectrally resolved atmospheric lines from O_3 and HCl. Currently, data are available between 35 to 80 km but theoretical estimations indicate a sensitivity down to 20 km.

We will introduce the retrieval strategy and show comparisons of the measurements with data from meteorological analysis. Improvements of the retrieval algorithms will be discussed.

Keywords: SMILES, Stratosphere, Wind, Remote sensing

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AAS020-19 Room:102 Time:May 22 17:00-17:15

SMILES observation on global distribution of minor constituents and the QBO

Yoko Naito[1*], Noriyuki Nishi[1], Eriko NISHIMOTO[2], Makoto Suzuki[3], Chihiro Mitsuda[4], Chikako Takahashi[4], Koji Imai[5], Naohiro Manago[3], Hiroo Hayashi[2], Takuki Sano[3], Masato Shiotani[2]

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The Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) is an instrument designed to make observation of the global 3-dimensional distribution of the minor constituents in the middle atmosphere, such as O3 and some species related to ozone depletion (HCl, ClO, and so on). It was attached to the Japanese Experiment Module (JEM) on the International Space Station (ISS) and have made observation for the period over half a year since October 12, 2009. Three spectral ranges of submillimeter-wave limb-emission are measured by the SMILES: band A (624.32 - 625.52 GHz), band B (625.12 - 626.32 GHz), or band C (649.12 - 650.32 GHz).

The present study investigates how the global distribution of minor constituents such as ozone observed by the SMILES is related to the phase of the quasi-biennial oscillation (QBO).

During the period of the SMILES observation, easterly wind have stayed around 20-hPa level in the equatorial stratosphere, and westerly shear above the easterly wind have changed its strength according to the phase of the semi-annual oscillation (SAO). The variation in latitude-altitude distribution of minor constituents observed by the SMILES corresponds to such variation in background wind field. In October 2009 or April 2010, isolines of the distribution of minor constituents was bending downward over the equator in association with meridional circulation accompanied with the westerly shear. It resulted in clear double-peaked structure with two peaks in latitude (as for ozone, the structure called "rabbit-ears" by Randel and Wu (1996)). January 2010, on the other hand, the double-peaked structure was absent corresponding to weaker westerly shear over the easterly wind. The SMILES observation displays the double-peaked structure even in daily-mapped data without monthly averaging. Such variation in the double-peaked structure was observed also in other minor species such as HCl and CH3CN.

Keywords: Atmospheric minor constituents, Atmospheric dynamics, Stratosphere, Quasi-Biennial Oscillation

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AAS020-20 Room:102 Time:May 22 17:15-17:30

ClO observation by 4K cooled submm limb sounder ISS/JEM/SMILES

Makoto Suzuki[1*], Chihiro Mitsuda[2], Chikako Takahashi[2], Takuki Sano[1], Koji Imai[3], Hiroo Hayashi[4], Eriko NISHIMOTO[4], Yoko Naito[4], Masato Shiotani[4]

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The Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) is one of the first instruments to use 4K mechanical cooler in space. It was successfully launched and attached to the Japanese Experiment Module (JEM) on the International Space Station (ISS) on September 25, 2009. It has been making atmospheric observations since October 12, 2009 with the 4-K cooled superconducting mixers for submillimeter limb-emission sounding in the frequency bands of 624.32-626.32 GHz and 649.12-650.32 GHz. Unfortunately, SMILES observations have been suspended since April 21, 2010 due to the failure of a critical component. On the basis of the observed spectra, the data processing has been retrieving vertical profiles for the atmospheric minor constituents and trace free radicals in the middle atmosphere, such as O3 with isotopes, HCl, ClO, HO2, BrO, and HNO3.

SMILES observed ClO several times higher sensitivity compared to previous satellite programs, Aura/MLS and Odin/SMR. Validation of SMILES ClO has been carried out with Aura/MLS data, and it agreed within error bars of Aura/MLS (since MLS has lower sensitivity and larger error bar). SMLES ClO in nighttime showed small bias and histogram showed gaussian shape, and it looks SMILES ClO value is reasonable at low altitude region down to 22 km altitude. Diurnal variation of ClO was obrtained from 30-45 days dataset. ClO and ClO-OCl equilibrium is observed within arctic polar vortex in January 2009.

Keywords: submm, ClO, stratosphere, ISS, Limb Observation

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AAS020-21 Room:102 Time:May 22 17:30-17:45

On the maintenance of high HCl/Cly ratio in the late spring of the antarctic vortex as measured by SMILES

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We will perform a study on time evolution of partitioning in the total inorganic chlorine (Cly) species in the late period of the seasonal ozone hole. The evolutions of HCl and ClONO2, which are the main reservoirs of Cly, reveal year to year differences and even some discrepancy between measurement and model (Santee et al., 2008). To understand the chemical processes of Cly species quantitatively in this period, we will utilize stratospheric observations from satellites by the SMILES, MLS, and ACE-FTS instruments as well as a photo-chemical box modelling.

The SMILES observations (65N to 38S) have started on October 12, 2009 and ceased on April 21, 2010, with sporadic measurements in the high latitudes in the Southern Hemisphere (38N to 65S). In this study, we focus on measurements between 19 and 24 November, when SMILES looked up to 66S, and examine what processes affect the determination of the Cly partitioning by utilizing the model calculations. The measured HCl and ClO volume mixing ratios (vmr) were, respectively, around 3.0 and zero ppbv at the altitude of 19 km (490 K potential temperature) inside the vortex. This agrees well with those obtained by the MLS measurements in the same period and latitude. Further, the ACE-FTS measurements were also conducted at latitudes between 66 and 69S in the same period, and the HCl and ClONO2 vmr were 3.0 and 0.2-0.3 ppbv, respectively. These results strongly support that a high ($>$ 0.9) HCl/Cly ratio has maintained in this period in the antarctic vortex at a 490 K level.

Generally, the production of HCl is proportional to CH4 and inversely to the square of O3. The other terms involving reactions between ClOx and HOx are also important, but not yet fully understood so far (Wilmouth et al., 2006). To reproduce the high HCl/Cly ratio by the model, we perform sensitivity tests with changing O3 vmr, rate constants for ClOx and HOx reactions, and the surface albedo on a representative 30 days air-parcel trajectory (between Oct. 25 and Nov. 24) inside the vortex. We will discuss impact of such changes on the maintenance of HCl vmr in the course of the trajectory. Preliminary results suggest that a possible mixing with a vortex boundary air, where O3 vmr is higher than that inside the vortex, is also contribute to this trajectory. A further discussion will be made at the presentation.

Keywords: JEM, SMILES, ozone, chlorine species

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AAS020-22 Room:102 Time:May 22 17:45-18:00

Latest Updates of JEM/SMILES L2 Products

Chihiro Mitsuda[1*], Makoto Suzuki[2], Naohiro Manago[2], Yoshitaka Iwata[2], Yoko Naito[3], Chikako Takahashi[1], Koji Imai[4], Eriko NISHIMOTO[5], Hiroo Hayashi[5], Masato Shiotani[5], Masahiro Takayanagi[2], Takuki Sano[2], Hirotomo Taniguchi[1]

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The Superconducting Submillimeter-wave Limb-Emission Sounder (SMILES) on International Space Station (ISS), which was planned by JAXA and NICT, had observed minor species in stratosphere and mesosphere from 2009/10/12 to 2010/04/21. The 4K-cooled Superconductor-Insulator-Superconductor mixers enabled the sensitive observation. Standard L2 Products are O3, HCl, ClO, HNO3, CH3CN, HOCl, HO2, BrO, and O3-isotopes. The diurnal variations of ClO, BrO, HO2 and mesospheric O3 are observed since the ISS orbit is sun-asynchronous.

SMILES L2 Products operated by ISAS/JAXA have been released every six months. In this presentation, we introduce the latest product v1.3, which is released in this March, and next update plans.

Japan Geoscience Union Meeting 2011
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AAS020-23 Room:102 Time:May 22 18:00-18:15

Improvement of inversion algorithm for SMILES Level2 data processing

Naohiro Manago[1*], Makoto Suzuki[1], Takuki Sano[1], Masato Shiotani[2], Michio Yamada[3], Shin-ichi Takehiro[3], Chihiro Mitsuda[4], Yoshitaka Iwata[4], Chikako Takahashi[4], Koji Imai[5]

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SMILES (Superconducting Submillimeter-Wave Limb Emission Sounder) is an instrument to measure 3-dimensional global distribution of trace gases etc. between the upper troposphere and the lower mesosphere by limb observation. SMILES 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 has an ability to measure distribution of trace gases such as ozone, hydrogen chloride, chlorine monoxide, etc. with the best accuracy ever.

In the Level2 (L2) data processing of SMILES, already-calibrated observed spectra obtained by the Level1B (L1B) data processing are compared with calculated spectra obtained by forward calculation based on an atmospheric radiative transfer model and an instrumental model. Then the model parameters (altitude profiles of trace gases etc.) are determined by matching the calculated spectra with the observed spectra. When solving this inverse problem, it is possible that we cannot get a unique answer because the number of independent conditional equations is not sufficient to determine all of the unknown parameters (ill-posed problem). Also, the retrieved profile may exhibit oscillating behavior because of the random noise in the observed spectra. A lot of techniques have been developed for such problems by many researchers, and in the SMILES L2 data processing we now use the Levenberg-Marquardt Method (LMM), i.e., the Optimal Estimation Method (OEM) with a damping factor. In this research, we compare inversion analysis methods such as OEM, Tikhonov Regularization (TR), Maximum Entropy Method (MEM), and investigate reliable methods suitable for the SMILES L2 data processing.

Keywords: satellite observation, inversion problem, regularization, smoothing

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AAS020-24 Room:102 Time:May 22 18:15-18:30

Validation of the SMILES Level2 ozone data by using ozonesonde measurements

Koji Imai[1*], Masatomo Fujiwara[2], Makoto Suzuki[3], Naohiro Manago[3], Takuki Sano[3], Masato Shiotani[4], Chihiro Mitsuda[5], Chikako Takahashi[5]

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To demonstrate the high sensitivity of 4-K cooled sub-mm limb sounders and to monitor global distributions of the stratospheric trace gases, the Japan Aerospace eXploration Agency (JAXA) launched the Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) instrument to the International Space Station (ISS) in 2009 using the H-II Transfer Vehicle (HTV). SMILES has been transferred to normal operation phase on 6th November, 2009. Currently, level 2 (L2) data products of the SMILES measurements has been evaluated.

Here we show the early validation results of the SMILES L2 ozone measurements using worldwide ozonesonde sounding net work data (SOWER, SHADOZ, WOUDC). SMILES L2 ozone data in the lower stratosphere are validated using near-coincident ozone measurements by analysing volume mixing ratio profiles. The average values of the mean relative differences are consistent within the margin of error.

Keywords: SMILES, ozonesonde

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AAS020-P01 Room:Convention Hall Time:May 23 16:15-18:45

Phase speed and period of equatorial Kelvin waves around the tropopause

Noriyuki Nishi[1*], Junko Suzuki[2], Atsushi Hamada[3], Masato Shiotani[4]

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We investigated period and phase speed of equatorial Kelvin waves around the tropopause. Typical cases of Kelvin waves with extremely large amplitude have different speed and period from those which are detected as a spectral peak in widely-used (e.g. Suzuki and Shiotani 2008, JGR) k-omega spectral diagram; in these cases, the period of the wave is longer (10-30 days) and speed is smaller (around 15 m/s) than those in spectral diagrams (5-10 days and 20-30 m/s).

We analyzed zonal wind at 100 hPa in re-analysis data made by European Centre for Medium-range Weather Forecast (ERA-40, 1979-2001). We can explain the difference in period by plotting the power value above the background value, instead of the significance defined by the ratio of power to the background. Peak of wave energy was found to be located in the lower frequency range than that of the significance. However, this alteration still does not account for the difference in phase speed. We traced zonal propagation of every Kelvin-wave case by using the method of Suzuki et al. (2010, JGR) and calculated the speed of waves. The average of speed is around 12-16 m/s at all longitude. The number of cases with the speed of larger than 20m/s, which corresponds to the spectral peak in a diagram, is very small.

We examined relationship between faster waves and slower waves. We found that slower waves (<20m/s) have shorter zonal wavelength, which results in a sharp shape in a zonal direction, and that they are rather confined in zonally smaller packet than faster waves (>20m/s). Therefore, they can be well traced regardless of their rather smaller power in climatological spectral diagram. In longitude-time section, both modes are seen to propagate rather independently and to be superposed almost linearly. On the other hand, Suzuki et al. (2010) has shown that both speeds are observed in a lifecycle of each wave case: slower waves initially coupled with convective activity at 200 hPa have faster speed in the eastern longitude after losing coupling several days later. The faster waves propagate further eastward and upward, and then re-couple with convection at 100 hPa and have smaller speed again. Our results indicate that, when investigating the mechanism of propagation and amplification of Kelvin waves, the relationship between two kinds of waves with different speed should be carefully examined.

Keywords: Kelvin wave, equatorial wave

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AAS020-P02 Room:Convention Hall Time:May 23 16:15-18:45

Simulations of 21st century climate using a chemistry-climate model: Comparison with fixed-halogen and -climate runs

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Future changes in wave forcing and transport characteristics of the middle atmosphere are examined using multidecadal simulations carried out with a chemistry-climate model (CCM) developed at the Meteorological Research Institute (MRI-CCM). First, we conducted a control experiment through the 21st century under the forcing prescribed according to the CCM Validation Activity (CCMVal-2) for SPARC REF2 scenario, in which both the greenhouse gas (GHG) and ozone depleting substance (ODS) forcings vary transiently in time. In the control experiment, subtropical wave forcing strengthens in the lower stratosphere especially in both summer hemispheres. However, wave forcing over the Antarctic is decreased in spring and summer as a result of an earlier breakdown of the polar vortex in the future period. Next, we conducted two sensitivity experiments in which either GHGs or ODSs are held fixed at 1960 levels, while the other forcing varies transiently as in the control experiment. Comparing the two sensitivity experiments with the control experiment, the relative impacts of the ODS and GHG forcings on the climate of the middle atmosphere are evaluated through 21st century.

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AAS020-P03 Room:Convention Hall Time:May 23 16:15-18:45

Early validation of the SMILES level 2 products

Koji Imai[1*], Makoto Suzuki[2], Naohiro Manago[2], Takuki Sano[2], Masato Shiotani[3], Hiroo Hayashi[3], Eriko NISHIMOTO[3], Yoko Naito[4], Chihiro Mitsuda[5], Chikako Takahashi[5]

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To demonstrate the high sensitivity of 4-K cooled sub-mm limb sounders and to monitor global distributions of the stratospheric trace gases, the Japan Aerospace eXploration Agency (JAXA) launched the Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES) instrument to the International Space Station (ISS) in 2009 using the H-II Transfer Vehicle (HTV). SMILES has been transferred to normal operation phase on 6th November, 2009. Currently, level 2 products of the SMILES measurements has been evaluated.

Here we compare the latest data of SMILES with coincident observations from the other satellite-borne instruments (ACE-FTS, Aura/MLS, Odin/SMR and SCIAMACHY), by analysing volume mixing ratio profiles. The average values of the mean relative differences are consistent within the margin of error.

Keywords: SMILES

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Development of semi centimeter-wave atmosphere observation system for stratospheric water vapor distribution

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For better understandings of the mechanism of long-term changes of the stratospheric water vapor distribution and the relation with the global warming, it is important to monitor variations of the stratospheric water vapor continuously. Observations of the stratospheric water vapor are mainly made with a technique of UV and infrared spectroscopy. These can be observed only in daytime because these require the sunlight. On the other hand, an observation of the stratospheric water vapor with a microwave spectroscopy technique can be made in daytime and nighttime, because they observe an emission spectrum of the water vapor at 22 GHz band and do not require any light sources. In addition, a microwave observation is expected to be obtained an accurate dataset, because the atmospheric attenuation in this region is relatively smaller than that in the UV and infrared region. However, at present, ground-based microwave observations of the stratospheric water vapor are carried out only in 5 sites in the world because there are difficulties of the size of the instrument and lack of sensitivity of the receiver system. To improve these situations, we have newly developed a microwave observation system for the stratospheric water vapor which is equipped with low noise detector consisting of microwave MMIC amplifiers and a cooling system. The size of this instrument is expected to be much reduced than any other ones. In this presentation, we show hardware features, results of evaluation of the system as well as measurement results of the stratospheric water vapor.

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Feasibility Study on Observation of Water Vapor between Upper Troposphere and Lower Stratosphere using DIAL on JEM

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The need to improve the description of the global water vapour distribution extends to the upper troposphere and lower stratosphere. This is needed to improve our understanding of stratosphere/troposphere exchanges. Feedback processes linking the various components need to be better understood to realistically simulate, for instance, the level of increase of water vapour in a global warming scenario. For both the climate and numerical weather prediction communities, the specific need for improved vertical coverage and quality of water vapour observations is particularly evident. We propose on observation of water vapor between upper troposphere and lower stratosphere using DIAL on standard payload of JEM exposed facility.

Keywords: water vapor, upper troposphere, lower stratosphere, lidar, JEM

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AAS020-P06 Room:Convention Hall Time:May 23 16:15-18:45

Emission location dependent ozone depletion potentials for very short-lived halogenated species

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We present trajectory-based estimates of Ozone Depletion Potentials (ODPs) for very short-lived halogenated source gases as a function of surface emission location. The ODPs are determined by the fraction of source gas and its degradation products which reach the stratosphere, depending primarily on tropospheric transport and chemistry, and the effect of the resulting reactive halogen in the stratosphere, which is determined by stratospheric transport and chemistry, in particular by stratospheric residence time. Reflecting the different timescales and physico-chemical processes in the troposphere and stratosphere, the estimates are based on calculation of separate ensembles of trajectories for the troposphere and stratosphere. A methodology is described by which information from the two ensembles can be combined to give the ODPs.

The ODP estimates for a species with a fixed 20 d lifetime, representing a compound like n-propyl bromide, are presented as an example. The estimated ODPs show strong geographical and seasonal variation, particularly within the tropics. The values of the ODPs are sensitive to the inclusion of a convective parametrization in the trajectory calculations, but the relative spatial and seasonal variation is not. The results imply that ODPs are largest for emissions from South and South-East Asia during Northern Hemisphere summer and from the Western Pacific during Northern Hemisphere winter. Large ODPs are also estimated for emissions throughout the tropics with non-negligible values also extending into northern mid-latitudes, particularly in the summer. These first estimates, whilst made under some simplifying assumptions, show larger ODPs for certain emission regions, particularly South Asia in NH Summer, than have typically been reported by previous studies for emissions distributed over land in within broad latitudinal bands.

Keywords: ozone, troposphere-stratosphere-transport, short lived species, boundary layer emissions