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

MIS26-01 Room:203 Time:May 23 13:45-14:00

Response of the north polar vortex and its evolution to solar activity using chemistry-climate model and reanalysis data

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Variations in solar ultra violet radiation, ozone, and temperature over the equatorial upper stratosphere caused by 11-year solar cycle have been observed (e.g., Lean et al., 1997; Gray et al., 2009). In the solar maximum, these variations were related to meridional gradient of the temperature and the strong polar vortex over the Northern Hemisphere extratropics in early winter (November-December) (e.g., Kodera and Kuroda, 2002). Kodera and Kuroda (2002) suggested that the strong polar vortex could influence the Brewer Dobson (BD) circulation, affecting distributions of equatorial ozone and temperature through ozone transport and adiabatic heating. Yamashita et al. (2010) investigated the difference between solar maximum and minimum from output of CCSR/NIES CCM, and they suggested that a simulation period of about 140 years might be sufficient for detecting the responses of the circulation around the polar vortex, equatorial ozone, and temperature.

The variation in the polar vortex is related to the equatorial quasi-biennial oscillation (QBO) as well as the 11-year solar cycle (e.g., Labitzke and van Loon, 1988). Holton and Tan (1980) showed that on average, the polar vortex is strong (weak) throughout the winter when the equatorial zonal wind at 50 hPa is westerly (easterly). Thus, we suppose that effects of the solar maximum and the westerly phase of the QBO create the strong polar vortex. In fact, the strong polar vortex was seen in early winter (e.g., Gray et al., 2004). In contrast, the polar vortex tended to be weak in westerly phase during the solar maximum in late winter (January-February) (e.g., Labitzke and van Loon, 1988). The reason for the different behavior between the early winter and late winter is still unclear. In addition, it is not well understood how mechanism for the influence of QBO on the polar region changes with the solar activity.

Yamashita et al. (2011) proposed a possible explanation that the difference of wave propagation and circulation in the upper/middle stratosphere as well as lower stratosphere between the easterly and westerly phases is related to the polar vortex.

In this study, we investigated the mechanism for the QBO and solar cycle influences on the polar vortex using CCSR/NIES CCM output and JRA-25 dataset, with a focus on detailed evolution of the influence throughout the winter. Note that we performed three transient runs from 1960 to 2006, and the output for 138 winters was analyzed in order to gain sufficient data for detecting the solar response.

Four composites were compiled on the basis of both 11-year solar cycle phase and QBO phase defined at 50 hPa. The composite analysis for CCM output and JRA-25 dataset suggested that the strong (weak) polar vortex and cold (warm) temperature were seen in the westerly (easterly) phase of the QBO during solar maximum (minimum) in the lower stratosphere over the polar region around December-January, indicating the suppression (enhancement) of upward wave propagation, wave dissipation and the BD circulation in the lower stratosphere. For these cases, the responses of the QBO and solar cycle were similar and reinforced each other around the polar vortex, indicating the strong/weak polar vortex. It moved poleward and downward with the seasonal march throughout the winter. These movements were related to weak polar vortex appeared in the upper stratosphere around February in the westerly phase/solar maximum, in agreement with previous foundation by Labitzke and van Loon (1988). In contrast, the response in the westerly (easterly) phase of the QBO was canceled by the opposite signs of response during the solar minimum (maximum).

These results suggest that the effects of solar cycle and QBO on the polar vortex are explained as the reinforcement and cancellation processes occurred between the solar activity and QBO influences in early winter. Later, these effects would change with the seasonal march associated with the wave-mean flow interaction.

Keywords: middle atmosphere, 11-year solar cycle, chemistry-climate model

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MIS26-02 Room:203 Time:May 23 14:00-14:15

How do environments affect the size of tropical cyclones?

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Along-standing issue on how environments affect the size of tropical cyclones is studied through a series of numerical experiments using the cloud-resolving tropical cyclone model, TCM4, and the global cloud-system-resolving model, NICAM. To first order, the primary circulation of a tropical cyclone can be considered as a warm-cored, quasi-axisymmetric vortex in gradient wind and hydrostatic balance. As a tropical cyclone evolves slowly while its primary circulation remains in gradient wind and hydrostatic balance, the secondary circulation (radial and vertical circulation) can be considered as a result of the response to both diabatic heating and momentum forcing including surface friction. The secondary circulation transports high absolute angular momentum inward to spin up the tropical cyclone primary circulation. This spin-up process can be well described by the Sawyer-Eliassen equation following the classic work of Eliassen (1952).

The balanced contribution to the intensification of a tropical cyclone simulated in TCM4, in particular the size of the cyclonic circulation, is investigated by solving the Sawyer-Eliassen equation and by computing terms in the azimuthal-mean tangential wind tendency equation. Results demonstrate that the azimuthal-mean secondary circulation and the spin-up of the mid-tropospheric outer circulation in the simulated tropical cyclone are well captured by balance dynamics. The mid-tropospheric inflow develops in response to diabatic heating in mid-upper tropospheric stratiform (anvil) clouds outside the eyewall in active spiral rainbands and transports absolute angular momentum inward to spin up the outer circulation. Although the azimuthal-mean diabatic heating rate in the eyewall is the largest, its contribution to radial winds and thus the spin-up of outer core circulation in the mid-troposphere is rather weak. This is because the high inertial stability in the inner core region resists the radial inflow in the mid-troposphere, limiting the inward transport of absolute angular momentum. The result thus suggests that diabatic heating in mid-upper tropospheric stratiform clouds is the key to the continued growth of the storm scale circulation.

The 7-km run using NICAM successfully simulated tropical cyclones that formed in three months from 1June to 31August 2004. A multi-scale interaction between tropical cyclones and environment has been investigated. It is clear that the size of tropical cyclones was sensitive to the environmental relative humidity. In a relatively moist environment, the tropical cyclone developed considerable precipitation (and thus diabatic heating) outside the core accompanied by significant outward expansion of the wind field and increase in size of tropical cyclones.

Keywords: tropical cyclone size, multi-scale interactions, NICAM, TCM4

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MIS26-03 Room:203 Time:May 23 14:15-14:30

Meteorological influence of the solar wind ? Strong correlation of the temperature and the solar wind parameters at the

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Recent our findings strongly suggest that the solar wind affects the surface temperatures [1, 2]. The regions from the magnetosphere to the troposphere should participate to this phenomenon. In this presentation, we focus on the temperatures of the troposphere and the stratosphere.

Grid temperature data of the lower stratosphere and the troposphere (upper, middle and lower) were taken from the RSS satellite temperature data site. The data cover the period of 1979 to 2010. We mainly used Pa, rate of energy flow from the solar wind into the stratosphere, together with the aa index (a geomagnetic disturbance index). Years were classified into two groups using the wind phase of the QBO (easterly or westerly) at a suitable month. The Arctic Oscillation (AO) index was also considered because it gives correlation maps similar to those for the aa index (a geomagnetic disturbance index)[1].

Figure 1 shows examples of the correlation maps for the lower stratosphere and for the lower troposphere. Monthly temperatures and monthly Pa values for January were calculated for each year, and the correlation between their yearly variations was estimated.

When stratified using the QBO phase (easterly and westerly) at January, the correlation maps for the easterly and for those for the westerly were clearly different.

In Fig. 1, examples of correlation maps are shown. Specific procedures are as follows. Monthly values were obtained for the temperature, the aa index and Pa, and correlation was calculated using their time variations at each grid. The correlation maps largely depended on the QBO phase.

Figure 1a shows that the January lower stratosphere temperature positively correlates well with the January Pa at the Equatorial regions. The aa index gave similar results.

Figure 1b shows a correlation map for the lower troposphere. The spatial distribution is quite similar to that for the correlation map between the temperature and the AO index, where large correlation can be seen at, for instance, Europe and Siberia. The middle troposphere gave results similar to the lower troposphere.

These observations clearly show that the energy (and/or particles) transferred from the solar wind affects the stratosphere and the troposphere. It is strongly suggested that the QBO plays an important role in this phenomenon.

[1] Kiminori Itoh, JpGU, 2008-2011
[2] Kiminori Itoh and Shinya Matsuo, JpGU, 2012

Keywords: Solar wind, Temperature, Troposphere, Stratosphere, QBO, Arctic Oscillation

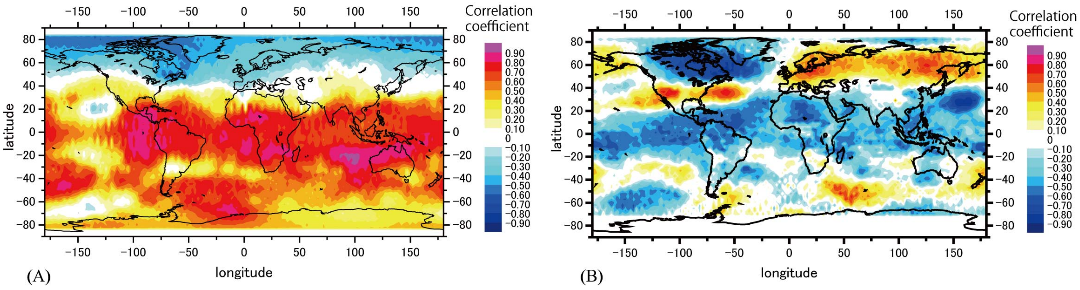

Fig.1. Correlation maps for the temperature and Pα (rate of energy flow from the solar wind into the magnetosphere) for the period of 1979-2010. A) For lower stratosphere, in January, and at QBO westerly phase. B) For lower troposphere, in January, and at QBO easterly phase.

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MIS26-04 Room:203 Time:May 23 14:30-14:45

The effects of sudden insolation change on the air temperature during a total solar eclipse over Dome Fuji, Antarctica

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The Moon cast a long shadow over Antarctica on 23 November 2003 in a total solar eclipse. The eclipse was observed at Dome Fuji Station, located at the highest point of East Dronning Maud Land, Antarctica, and lasted 1 h 41 min 37 s in a cloudless condition, during which the Sun was completely obscured for 1 min 43 s. This was the first total solar eclipse to be observed in the Antarctic ice sheet. During the eclipse at Dome Fuji, the air temperature at 1.5 m above the snow surface and the subsurface snow temperature decreased by 3.0 K and 1.8 K, respectively. Estimated surface snow temperatures decreased by 4.6 K. Atmospheric pressure and wind direction did not change, but the wind speed possibly decreased by 0.3 m/s with decreasing air temperature; natural variations in wind speed before and after the eclipse made it difficult to identify a true effect of the solar eclipse. Variations of energy components (net shortwave and longwave radiations, sensible and latent heat fluxes, and geothermal heat) during the eclipse were investigated. The total loss of global solar radiation during the eclipse was 0.60 MJ m-2, equaling 1.6% of the total daily global solar radiation. Regional effects of the eclipse due to a reduction of global solar radiation for air temperature and snow temperature ranged from 0.015 to 0.020 K (W m-2)-1. We additionally examined the relation between eclipse obscuration (the fraction of the Sun's surface area occulted by the Moon) and the reduction of global solar radiation from the first to second contacts. The eclipse was also observed from space by the Moderate Resolution Imaging Spectroradiometer (MODIS) sensors onboard NASA's Terra and Aqua satellites. The observational results of this study will contribute to detailed model calculations for clarifying the meteorological effects of eclipses.

Keywords: insolation change, air temperature change, total solar eclipse, Antarctic ice sheet, Dome Fuji

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MIS26-05 Room:203 Time:May 23 14:45-15:00

Estimation of solar ultraviolet radiation derived from analyses of solar imaging data

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We report the results on the estimation of long-term variations of solar UV/EUV radiations, which affect on the upper thermosphere, by using full-disk solar images. The SOHO/EIT has shown us full-disk features of the sun in EUVs over 15 years. Ground-based chromospheric observations also enable us to derive an indicator of solar UV emission. From these data, we try to derive the main features that affect on the upper thermosphere and to estimate the long-term UV/EUV variations.

Keywords: Solar Activity, Solar UV Radiation

Japan Geoscience Union Meeting 2012
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MIS26-06 Room:203 Time:May 23 15:30-15:45

Climatic cooling caused by a major weakening of the geomagnetic field

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The geomagnetic field's impact on climate through the modulation of cosmic ray (CR) flux is a long disputed problem. Its exact effects remain unknown. We carried out a paleoenvironmental analysis based on multiproxy records for five interglacials (marine oxygen isotope stages (MISs) 17, 19, 21, 25 and 31) between 0.7 to 1.1 Ma, and quantitatively evaluated the effect of the geomagnetic field on climate. Our samples come from a sediment core with an extremely high accumulation rate (ca. 50-70 cm/kyr) from Osaka Bay, Japan. The depositional environment of the bay has been strongly affected by glacio-eustatic sea-level changes, and the sediments clearly record the orbital cycles of environmental changes. In MIS 17, 21 and 25, the thermal maximum coincided with the sea-level highstand, as expected from Milankovitch theory. On the other hand, the thermal maxima of MIS 19 and 31 lagged the sea-level highstands by several thousand years. Additionally, cooling occurred at or near the sea-level highstand. The anomalous cooling cannot be caused by insolation changes. MIS 19 and 31 encompass the Matuyama-Brunhes (MB) and Lower Jaramillo (LJ) polarity reversals, respectively. Both cooling events coincided with the paleointensity low associated with the polarity reversals. The cooling interval occurred when the geomagnetic field intensity decreased to less than ca. 40% of present value, and the CR flux increased by more than 40%. The mean annual temperature estimated from pollen fossils using a modern analogue technique shows a cooling of ca. 1-4 degrees C. Despite their relatively low temporal resolution, a number of other paleoenvironmental records suggest a relatively cool climate before the MB and LJ boundaries in the low and middle latitudes. In contrast, ice core records from Antarctica shows no evidence of such a cooling event, and thus the magnetic field/CR effect on climate may not have occurred in polar regions. These results may indicate that the Earth's climate can be affected by the geomagnetic field.

Keywords: cooling, geomagnetic reversal, cosmic ray, paleoclimate, paleoceanography, paleomagnetism

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MIS26-07 Room:203 Time:May 23 15:45-16:00

Simulation study on bi-stability of cloud-rain system and cosmic ray influence on climate

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Although it has been pointed out many times that there is the correlation between solar activity, such as the Schwabe (11 year) cycle and the Maunder-type minima, and climate variability, the mechanism whereby the sun may affect climate is not yet well understood. Svensmark & Friis-Christensen (1997) proposed that galactic cosmic ray may control cloud through the ionization of atmosphere and the ion-induced nucleation. Recently, Kirkby et al. (2011) indicated in basis of experiments with artificial cosmic ray that the ion-induced nucleation is possible in the atmosphere if some conditions for chemical compounds and temperature are satisfied. However, although the experimental data show that the ion-induced nucleation rate for 1.7 nm diameter cluster J_1.7=10^-2 to 10^1cm^-3s^-1, it is not yet clear how this rate affects cloud and climate.

In this study, aiming at clarifying how the cloud-rain system depends on the change in the formation rate of cloud condensation nuclear, we have performed a systematic simulation study using super-droplet cloud model. The super-droplet cloud model is a novel computational technique to calculate the macro- and micro-physics of clouds (Shima, Kusano et al. 2009). We have implemented the super-droplet method on the cloud resolving model CReSS (Tsuboki & Sakakibara 2006), and developed an add-on function to create aerosols dynamically. Using it, we have surveyed the quasi-equilibrium state of cloud-rain system for different formation rate of 30 nm diameter aerosol J_30. The initial and boundary conditions are given by the data-set of RICO (Rain In Cumulus over the Ocean) project.

As the results of simulations for J_30 from 10^-6 to 10^0 cm^-3s^-1, we find that the cloud water path remains about 5 gm^-2 when J_30 is smaller than 10^-3cm^-3s^-1, but it quickly increases to 20 gm^-2 for J_30=10^-2cm^-3s^-1 and it keeps the value for higher J_30. On the other hand, the rain water path is about 6 gm^-2 for J_30 smaller than 10^-3cm^-3s^-1, but it drastically decreases to smaller than 1 gm^-2 for J_30 larger than 10^-3cm^-3s^-1. These results suggest that the cloud-rain system has the two different equilibrium states which are controlled by the formation rate of aerosols. Although the quantitative relation between the cosmic ray induced nucleation and the bifurcation of cloud-rain system is still unclear, our results implies how susceptible is the cloud-rain system on the nucleation rate.

Keywords: cloud, aerosol, space climate, cosmic ray, super-droplet, simulation

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MIS26-08 Room:203 Time:May 23 16:00-16:15

Climate change induced by changes in cloud droplet radius

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It has been pointed out that the colder climate during the Mounder Minimum was associated with the smaller number of sunspots. When the number of sunspots is low,the solar activity is also low although the total solar irradiance hardly decreases. The intesity of galactic cosmic ray into the terrestrial atmosphere increases when the solar activity is low. While it is not understood clearly, yet, the cosmic ray intensity may change the number of cloud condensation nuclei and the cloud droplets' radii.

We have conducted a set of numerical experiments with a three-dimensional coupled atmosphere-ocean general circulation model and a vertically one-dimensional radiative-convective equilibrium model with different cloud droplet sizes. When the droplet size is decreased (increased), climate becomes colder (warmer) according to our experiments.

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MIS26-09 Room:203 Time:May 23 16:15-16:30

An isotopic view on ionising radiation as a source of sulphuric acid

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Sulphuric acid is an important factor in aerosol nucleation and growth. It has been shown that ions enhance the formation of sulphuric acid aerosols, but the exact mechanism remains undetermined. Furthermore some studies have found a deficiency in the sulphuric acid budget, suggesting a missing source. In this study the production of sulphuric acid from SO2 through a number of different pathways is investigated. The production methods are standard gas phase oxidation by OH radicals produced by ozone photolysis by UV light, liquid phase oxidation by ozone, and gas phase oxidation initiated by gamma rays. The distributions of stable sulphur isotopes in the products and substrate were measured using isotope ratio mass spectrometry. All methods produced sulphate enriched in 34S and we find a

34S value of 8.7 permil for the OH reaction. Only UV light (Hg emission at 253.65 nm) produced a clear nonmass-dependent excess of 33S of around 0.3 permil. The pattern of isotopic enrichment produced by gamma rays is similar,but not equal, to that produced by aqueous oxidation of SO2 by ozone. This, combined with the relative yields of the experiments, suggests a mechanism in which ionising radiation may lead to hydrated ion clusters that serve as nanoreactors for S(IV) to S(VI) conversion.

Keywords: Cosmic ray, Sulphuric acid, Stable isotope

MIS26-10 Room:203 Time:May 23 16:30-16:45

Possible influence of 27 day cosmic-ray variations on tropical cloud activity

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Galactic cosmic rays (GCRs) are one of the possible mediators of Sun-climate connection; however, the detailed mechanism of their influence has not been solved. In order to trace the influence of cosmic rays on climate system, we analyzed the daily data of outgoing long-wave radiation (OLR) for AD1979-2004 and the data obtained from International Satellite Cloud Climatology Project (ISCCP), and compared them with neutron monitor data obtained at Oulu University. We find that high altitude cloud around the tropical regions shows a similar time profile with the variations of cosmic rays at around the time scale of solar rotations. At this time scale, the depletions of cosmic rays occur associated with solar flares and current sheet passages.

Keywords: solar rotation, cosmic rays, tropical cloud activity