Atmosphere-Ionosphere-Magnetosphere (AIM) Coupling Inferred from Lidar Observations and Modeling in Antarctica

*Xinzhao Chu[1], Jian Zhao[1], Zhibin Yu[1], Cao Chen[1], Xian Lu[2], Zhonghua Xu[3], Delores Knipp[1], Liam Kilcommons[1], Dongming Chang[1], Zhengyu Hua[1], Ian Geraghty[1]

1. University of Colorado Boulder, 2. Clemson University, 3. Virginia Polytechnic Institute and State University

Two stunning discoveries emerged from six years of lidar observations at Arrival Heights near McMurdo (77.8S, 166.7E), Antarctica are the thermospheric neutral Fe layers up to nearly 200 km and the persistent gravity waves all year round in the mesosphere and lower thermosphere (MLT). These discoveries provide unique opportunities to study the wave coupling from the lower atmosphere to the thermosphere and the plasma-neutral atmosphere coupling.

The discovery of thermospheric neutral Fe layers by lidar observations in Antarctica has opened a new door to explore the space-atmosphere interactions with ground-based instruments, especially in the least understood but crucially important altitude range of 100-200 km. These neutral metal layers provide excellent tracers for modern resonance lidars to measure the neutral wind and temperature directly, complementing the radar measurements of the ionosphere and the magnetometer measurements of the geomagnetic field. Even more exciting, the neutral metal layers in the thermosphere provide a natural laboratory to test our fundamental understandings of the atmosphere-ionosphere-magnetosphere (AIM) coupling and processes.

Lidar temperature and Fe density measurements have revealed persistent, dominant and large-amplitude gravity waves with non-tidal periods of ~3-10 h and vertical wavelength of ~20-30 km. There has not been any single lidar run that does not show the signature of this 3–10 h wave group during 5 years of lidar observations at McMurdo, and so far we have not seen any inactive wave gap epoch in observed temperature data. The mystery of persistent waves has sparked a wide range of speculation for their sources, e.g., secondary wave generation, or even resonance vibration of Ross ice shelf, etc.

In this paper we combine the lidar observations from the stratosphere and mesosphere to the thermosphere with the University of Colorado Thermosphere-Ionosphere Fe/Fe+ (TIFe) model to explore the possible wave sources and the connections between the TIFe layers and various atmospheric, ionospheric, magnetospheric and solar activities.

Keywords: Thermosphere-Ionosphere Fe and Fe+ Layers, Persistent gravity waves, Atmosphere-Ionosphere-Magnetosphere Coupling, Lidar Observations in Antarctica, Modeling, Wave sources

Inter-seasonal and interhemispheric coupling initiated by a major sudden stratospheric warming accompanied by an elevated stratopause event

*中島 駿[1]、佐藤 薫[1]
*Nakajima Shun[1], Kaoru Sato[1]

1. 東京大学　大学院理学系研究科　地球惑星科学専攻
1. Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo

The polar winter stratopause is formed and maintained by the meridional circulation which is driven by the gravity wave forcing in the mesosphere. During a major sudden stratospheric warming (SSW), the stratopause descends significantly. Occasionally, soon after a major SSW, the stratopause disappears and subsequently reforms at a significantly high altitude of about 80km. This phenomenon was recently discovered by satellite observations and is referred to as an elevated stratopause (ES) event. Meanwhile, recent studies discovered that the signal of the zonal mean temperature anomaly associated with an SSW propagates from one hemisphere to the other across the equator. For instance, observational studies showed that the northern polar stratospheric temperature and the southern polar mesospheric cloud occurrence correlate to each other. It is considered that this interhemispheric coupling (IHC) is induced by the modification of the meridional circulation in the middle atmosphere. Modeling studies have discussed the mechanisms of these two phenomena by a quantitative analysis, but their analysis is mainly based on the behavior of parameterized gravity waves at the present time. Moreover, observational studies of gravity waves from the perspective of the IHC have just begun. Therefore, much is unknown about these two phenomena. This study focuses on the IHC associated with the ES by using Microwave Limb Sounder satellite data in the time period from 2005-2016. It was shown that three ES events occurred in the northern hemisphere during almost the same calendar days for the analyzed time period. After about six months of these three ES events, the temperature maximum at the southern tropical region is intensified more strongly than in other years. An empirical orthogonal function (EOF) analysis is performed on half-monthly zonal-mean temperature anomaly data from January to August. As a result, a corresponding anomaly pattern is found as the first EOF mode. This result suggests the existence of the inter-seasonal IHC associated with the ES events. Furthermore, the ES events and the southern tropical temperature maximum are related to the time evolution of the polar night jet in the northern hemisphere and the easterly phase of the stratospheric semiannual oscillation in the equatorial region. In this presentation, we will discuss a plausible mechanism of the inter-seasonal IHC associated with the ES events based on the analysis of the wave properties by using the transformed Eulerian-mean equations.

2016年の準二年周期振動異常に伴う力学および微量大気成分変動

Dynamical and minor constituent changes related to the anomalous QBO appearance in 2016

*廣岡 俊彦[1]、加藤 諒一[2]、江口 菜穂[3]
*Toshihiko Hirooka[1], Ryoichi Kato[2], Nawo Eguchi[3]

1. 九州大学大学院理学研究院地球惑星科学部門、2. 九州大学大学院理学府地球惑星科学専攻、3. 九州大学応用力学研究所
1. Department of Earth and Planetary Sciences, Faculty of Science, Kyushu University, 2. Department of Earth and Planetary Sciences, Graduate School of Science, Kyushu University, 3. Research Institute for Applied Mechanics, Kyushu University

準二年周期振動（QBO）は、赤道域下部成層圏で観測される、平均約28か月周期で下方に伝播する東西風の振動である。2016年2月、QBOの東風シアーの下方伝播が20hPa付近で突然停止し、それより下方の西風領域中に東風が形成されるという、過去に例がない現象が生じた（Newman et al. 2016; Osprey et al. 2016）。しかしながら、この特異なQBO位相遷移の形成機構や、それに伴う子午面循環の変動については、未だ十分に調べられてはいない。そこで本研究では、長期再解析データJRA-55と、Aura MLS衛星観測に基づく、オゾン、塩化水素、一酸化二窒素などの大気微量成分の体積混合比データを用いて、QBO異常現象に関する詳細な解析を行った。その結果、この特異なQBO位相遷移に伴い、大気微量成分の分布にも特異な構造が見られた。これは、対応する赤道域気温場の変異に伴う子午面循環の変動により形成されたものだと考えられる。当日の発表では、特異なQBO位相遷移に対する、中緯度域からの力学的影響についても議論を行う。

キーワード：準二年周期振動、子午面循環、大気微量成分
Keywords: quasi-biennial oscillation, meridional circulation, minor constituents

Seasonal winter forecasts of the Northern stratosphere and troposphere: Results from JMA seasonal hindcast experiments

*田口 正和[1]
*Masakazu Taguchi[1]

1. 愛知教育大学
1. Aichi University of Education

Using seasonal hindcast (HC) experiments from 1979 to 2014 of the Japan Meteorological Agency, this study investigates seasonal forecasts in the stratosphere and troposphere for Northern winter. We focus on verifying the HC data initialized in late fall for the DJF mean NAM index using the ranked probability score as a verification measure.
Our verification shows that the HC data have a significant skill for the DJF mean NAM index only in the stratosphere. A further interesting feature is that the forecast skill depends on the phase of the QBO, with a higher skill during the QBO easterly phase in the equatorial lower stratosphere. Specifically, the HC data tend to well forecast the negative phase (weaker than normal polar vortex) of the NAM during the easterly phase, whereas they miss the positive phase of the NAM during some winters of the westerly phase.
The ranked probability score for the DJF mean NAM index tends to correlate, albeit weakly, between the stratosphere and troposphere from year to year. In some winters, the HC data are largely unsuccessful for both stratospheric and tropospheric NAM, whereas in other winters they have large errors only in the troposphere. The former case suggests a possibility that tropospheric NAM forecasts may be improved if poor stratospheric forecasts are improved in some winters.

キーワード：成層圏の季節予報、北半球環状モード、準二年周期振動
Keywords: Seasonal stratospheric forecasts , Northern Annular Mode , Quasi-Biennial Oscillation

Interhemispheric coupling of the atmosphere-ocean system and circulation in the response to greenhouse gas and aerosol radiative forcings

*V Ramaswamy[1]

1. NOAA/ Geophysical Fluid Dynamics Laboratory

Major changes have occurred in the radiative drive of the atmosphere and surface since preindustrial times owing to anthropogenic emissions, which includes well-mixed greenhouse gases and tropospheric aerosols. In particular, while the well-mixed greenhouse gases exert a forcing that is pervasive throughout the globe, the manmade aerosol forcing is predominantly in the Northern Hemisphere. This contrast is emblematic of a general climate science problem that seeks to understand the consequence due to an asymmetry in forcings between the Northern and Southern Hemispheres. How do the atmosphere-ocean system and interhemispheric circulation respond? Using the NOAA/GFDL global climate model and observations, we discuss how the hemispheric top-of-the-atmosphere and surface energy balance have evolved in the 20th Century under the action of the different forcings. The interhemispheric asymmetry in the forcings affects the coupling across the hemispheres, and this is discernible in the hydrologic cycle. There is a particularly interesting change in the tropical circulation yielding changes of opposite sign in the precipitation across the equator. We diagnose the physical factors that are responsible, including an accounting of the effects on the poleward transport of heat in the atmosphere and oceans in the two hemispheres. The asymmetric nature of the anthropogenic aerosol forcing and the resulting pattern of the climate response in the two hemispheres has a similarity to other climate forcing problems e.g., land surface changes induced in a hemisphere, presence of ice sheets in the Northern Hemisphere, stratospheric aerosols after a volcanic eruption.

Keywords: Interhemispheric asymmetry in climate forcings, Interhemispheric coupling of circulation and climate change, Hemispheric poleward heat transport, Interhemispheric coupling of hydrologic cycle

Hydro-climatic variation in northwestern China and its teleconnection with the Pacific Ocean over the last millennium

*Harry F Lee[1]

1. The University of Hong Kong

Scientific studies that examine the long-term dynamics of drought over the northwestern (NW) China region have received special attention in recent years. However, these studies are often constrained by the availability of instrumental precipitation records. The present study seeks to address this issue. I based on historical drought/flood records to trace the geographic extent of drought anomalies as well as the intra-regional precipitation variability in NW China in AD580–2008, covering the periods with and without instrumental precipitation records. Moving correlation and wavelet analyses were applied to find their major determinants. Results show that El Niño Southern Oscillation (Indo-Pacific warm pool sea surface temperature) is the major multi-decadal to centennial (centennial to multi-centennial) determinant of the hydro-climatic variability in NW China. The associated mechanism is anchored with the change of Asian Summer Monsoonal precipitation, while it is driven by different factors at different time scales. The above findings are important for predicting the future impacts of, and developing proper counter-measures against, drought. Given that drought has been a limiting factor for the economy and society in NW China, this study is not only of academic interest but also of practical value.

Keywords: Asian Summer Monsoon, ENSO, Pacific Ocean, Hydro-climate, Northwestern China

Influences of tropical climate and weather on the variability of East Asian cold air outbreaks

*Muhammad Rais Abdillah[1], Yuki Kanno[1], Toshiki Iwasaki[1]

1. Department of Geophysics, Graduate School of Science, Tohoku University

A recent study proposed an analysis method for estimating polar cold air mass (CAM) flux from its generation to disappearance [1]. Below a designated threshold potential temperature 280 K, two climatological equatorward streams were identified during boreal winter: East Asian stream and North American stream. These streams indicate two major pathways of intermittent cold air outbreak (CAO) events. An East Asian CAO index (CAOI) was defined as a longitudinal integration of equatoward CAM flux over East Asian stream region (90˚-180˚E) at 45˚N [2]. This approach enables us to define a quantitative definition of East Asian CAO events. The CAO events often cause severe damages to human activities. It is characterized by strong equatorward wind and sudden drop of temperatures. CAOs are basically driven by extratropical internal dynamics. Nevertheless, its variation is also affected by remote forcing in the tropics. We present here the evidences of tropical impacts to the East Asian CAOs.

1) Interactions with El-Nino Southern Oscillation (ENSO)

Interannual variability of East Asian equatorward flow exhibits two major modes which are mentioned as western CAO and eastern CAO [3]. The western and eastern CAOs are closely associated with Siberian high and Aleutian low, respectively. In the tropics, their variations are affected by tropical climate anomalies associated with ENSO. The western and eastern CAOs are stronger than normal during La Nina and El Nino phases, respectively. The impacts of ENSO are delivered through Rossby wave trains triggered by convection anomalies over the Maritime Continent and central Pacific.

2) Interactions with Madden-Julian Oscillation (MJO)

We also investigated the interactions in intraseasonal time scale. Day-lagged regression analysis revealed that the intraseasonal western and eastern CAO events are preconditioned by large-scale tropical convection anomalies resembling particular phases of MJO. Western CAOs are triggered by MJO over the Maritime Continent, whereas eastern CAOs are triggered by MJO over the western Pacific. Observations and model experiments show the importance of Rossby wave trains in delivering the impact of MJO to the East Asian CAOs. Influence of MJO on the eastern CAO is relatively larger due to stronger Rossby wave trains induced by convection anomalies over the western Pacific and Indian Ocean.

Reference:

[1] Iwasaki et al., 2014: Isentropic Analysis of Polar Cold Airmass Streams in the Northern Hemispheric Winter. J. Atmos. Sci., 71, 2230–2243, doi:10.1175/JAS-D-13-058.1.

[2] Shoji et al., 2014: An isentropic analysis of the temporal evolution of East Asian cold air outbreaks. J. Clim., 27, 9337–9348, doi:10.1175/JCLI-D-14-00307.1.

[3] Abdillah et al., 2017: Tropical-extratropical interactions associated with East Asian cold air outbreaks. Part 1: Interannual variability. J. Clim., doi:10.1175/JCLI-D-16-0152.1.

[4] Abdillah et al., in prep.: Tropical-extratropical interactions associated with East Asian cold air outbreaks. Part 2: Intraseasonal variation.

Keywords: cold air outbreaks, ENSO, MJO, winter monsoon

Characteristic Features in the East-Asian Cold Anomalies in Winter of 2010/11, and its Relationship with Blocking

*Wookap Choi[1], Young-Ah Kim[1], Jiyeon Jung[1], Jong-Ghap Jhun[1]

1. Seoul National University

East Asia experienced extremely cold weather in January 2011, while the previous December and the following February had normal winter temperature. In this study NCEP/ NCAR reanalysis data are used to investigate the characteristic features observed in the meteorological fields during this winter period by focusing on the blocking phenomena formed at Northeastern Asia. In January the planetary-wave pattern was dominated by stationary-wave form in the mid-to-high latitude region, while transient waves were significant in the previous month. In the climatological-mean 500-hPa geopotential heights the wave numbers 1, 2, and 3 are dominant during the whole winter. In January 2011 the waves of number 1, 2, and 3 were dominant and stationary as in the climatological-mean field. In December 2010 and February 2011, however, the waves of number 4, 5, and 6 played a major role and show a transient pattern. In addition to the distinctive features in each month the planetary wave patterns were dependent on the latitude. The 2010/11 winter was divided into three periods P1, P2 (cold period), and P3 for the cold area (30-50N, 115-135E). During P1 and P3 temperature anomalies from the climatological mean were small with large standard deviation compared to those of P2, which had large negative anomaly and small standard deviation. The period P2 was dominated by blocking, which was determined by distributions of 500-hPa geopotential height and potential temperature on the 2 PVU surface. Correlation-coefficient analyses show that during P2 the temperature in the cold area is related with pressure of Northeastern Asia, while the temperature during P1 and P3 is related with pressure of Northwest of Korea. All the observations imply that, during the cold period P2, the temperature in the cold area was affected by blocking located in Northeastern Asia.

Keywords: Cold anomaly, East-Asia winter temperature, blocking

EXTREME VARIATIONS IN THE POSITION OF INTERTROPICAL CONVERGENCE ZONE OVER THE SOUTHERN MARITIME CONTINENT

*Tercio Ambrizzi[1], Ana Carolina Vazques Freitas[2], Cristiano Prestelo Oliveira[3], Luis Aimola

1. USP University of Sao Paulo, 2. UNIFEI Federal University of Sao Paulo, 3. UFRN Federal University of Natal

This work investigates the extreme variations in the position of the Intertropical Convergence Zone (ITCZ) over the Southern Maritime Continent region in austral spring during the period 1979-2015. The extreme variations of the southern boundary of major tropical convection presents great correlations with a meridional Sea Surface Temperature (SST) gradient and Indian Ocean Dipole events.

Keywords: INTERTROPICAL CONVERGENCE ZONE, SOUTHERN MARITIME CONTINENT, EL NINO/SOUTHERN OSCILLATION

Variations of Mid-Oceanic Troughs and Associated Atmospheric Teleconnection Patterns: Roles of Tropical SST and Arctic Sea Ice

*Song Yang[1], Kaiqiang Deng[1], Mingfang Ting, Mengmeng Lu[1]

1. Sun Yat-sen University

The mid-Pacific trough (MPT), occurring in the upper troposphere during boreal summer, acts as an atmospheric bridge connecting the climate over Asia, the Pacific, and North America. The first (second) EOF mode of the MPT reflects a change in its intensity on the western (eastern) portion of the trough. Both modes are significantly correlated with the variability of tropical Pacific SST. Moreover, the first mode is affected by the Atlantic SST and the second mode is influenced by the Arctic sea ice near the Bering Strait.
A stronger MPT shown in the first mode is significantly linked to drier and warmer conditions in the Yangtze-River basin, southern Japan and northern U.S. and a wetter condition in South Asia and northern China, while a stronger MPT shown in the second mode is associated with drier and warmer southwestern U.S. The relationships between MPT and the climate over Asia (North America) are modulated by ENSO (Atlantic SST and Arctic sea ice). Moreover, the dominant modes of MPT are closely related to Pacific tropical cyclone (TC) genesis during summer. Overall, an intensified MPT corresponds to more TCs over the western North Pacific and less TCs over the eastern Pacific.
A nearly parallel analysis has also been applied to the variations of the mid-Atlantic trough and associated teleconnection.

Keywords: Mid-Pacific trough, Atmospheric teleconnection, Tropical SST and Arctic sea ice

North Atlantic origin of interdecadal variability of the Warm Arctic and Cold Eurasia pattern

*Mi-Kyung Sung[1], Seon-Hwa Kim[2], Baek-Min Kim[2]

1. Ewha Womans University, 2. Korea Polar Research Institute

The Warm Arctic and Cold Eurasia (WACE) pattern and its intimate relation to the Barents/Kara Seas (B/K Sea) ice loss have been recognized recently. In the present study, a long-term spatio-temporal variability of the WACE pattern and its origin were examined using Twentieth Century Reanalysis (20CR) dataset for the period of 1901-2013. Since a coupled interaction between Ural blocking and Siberian High (SH) is crucial for accompanying cold anomaly over Eurasia under warm Arctic condition, recent Arctic sea ice loss and concomitant increase of Ural blocking have been blamed as plausible causes of recurrent cold winters over Eurasia. However, interdecadal variation in horizontal structure of the WACE pattern since long before the recent Arctic warming as identified in this study implies a possible influence of natural variability in current arctic warming and resultant severe cold winters. We found a wave train whose phase variation affects the horizontal structure of the WACE pattern originates from the North Atlantic. It is suggested that a slow variation in climatological mean atmospheric circulation over the North Atlantic, i.e. growth of the continental trough and oceanic ridge, leads to changes in mean baroclinicity and storm track as well. The resultant alteration in transient eddy vorticity flux which acts as Rossby wave source influences preferable phase of the wave train and relevant downstream circulation over the B/K Sea region. We tested Rossby wave response to altered North Atlantic storm track due to interdacadal variation in background states via simple stationary wave model experiments forced by idealized transient eddy vorticity flux to support proposed mechanism.

Keywords: Warm Arctic and Cold Eurasia pattern, North Atlantic , Ural blocking

Snow variation modes in the Northern Hemisphere related to the Arctic and Antarctic Oscillations

*Liang Zhao[1,2], Ziniu Xiao[1]

1. LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences, 2. National Climate Center, China Meteorological Administration

The atmosphere lacks the mechanisms to generate predictable variations beyond synoptic time scales (Lorenz 1963), so for climate prediction, it is very important to study patterns of variation in atmospheric forcings. El Nino as a variation mode of the tropical ocean water has become an important factor in prediction that significantly influences the atmosphere (Kim et al. 2012). Snow over land is another important lower boundary forcing source and another form of water that directly and persistently influences the atmosphere and soil on multi-time scales. Thus, snow has also been investigated during recent decades as another potential source of predictability. It is still unclear whether a stable snow–atmosphere coupled mode exists in the extratropics, like the sea-atmosphere coupled ENSO mode in the tropics. Our study analyzes the major modes of winter snow over the Northern Hemisphere, quantitatively evaluates the stability of coupling relationships between the snow modes and the winter atmospheric Arctic Oscillation (AO), the Antarctic Oscillation (AAO) and the Siberian High over the period 1872–2010, and discusses their possible relationships for different seasons.
Results show that the first mode of the winter snow cover fraction and the winter AO together constitute a stable snow–atmosphere coupled mode, the SNAO. The coupled mode is stronger during recent decades than before. The snow anomaly over Europe is one key factor of the SNAO mode due to the high stability there, and the polar vortex anomaly in the atmosphere is its other key factor. The continuity of signals in the SNAO between autumn and winter is weaker than that between winter and spring. The second winter snow mode is generally stably correlated with the winter AAO and was more stable before the 1970s. The AAO signal with boreal snow has a strong continuity in seasonal transition. Generally, through these coupled modes, snow and atmosphere can interact in the same season or between different seasons: autumn snow can influence the winter atmosphere; the winter atmosphere can influence spring snow.

Keywords: Snow, Arctic Oscillation, Antarctic Oscillation

Modulation of Stratospheric Sudden Warming characteristics by sea-ice reduction in the Barents-Kara Sea

*星 一平[1]、浮田 甚郎[1]、本田 明治[1]、中村 哲[2]、山崎 孝治[2]
*Kazuhira Hoshi[1], Jinro Ukita[1], Meiji Honda[1], Tetsu Nakamura[2], Koji Yamazaki[2]

1. 新潟大学、2. 北海道大学
1. Niigata University, 2. Hokkaido University

There has been much discussion on climatological impacts of the Arctic sea ice reduction through stratosphere-troposphere coupling, in particular those from Barents-Kara sea ice anomalies. Both observational and modeling studies indicate that this stratospheric pathway became more apparent after 2000. This was concurrent with a period of frequent stratospheric sudden warming (SSW) occurrence. Here we postulate that the Arctic sea-ice reduction modulates temporal and spatial characteristics of the atmospheric conditions leading to and during SSWs. To test this we compare respective tropospheric conditions between the light and heavy Barents-Kara sea ice years based on the Japanese 55-year reanalysis data for the period of 1979-2015.

First, we identify SSW events based on the daily Northern Annular Mode index, the leading principal component time series of geopotential height at 10 hPa northward 20˚N, for the winter (December-February) period. Using early-winter (December) Barents-Kara sea-ice criterions, those SSW events are classified into 14 low sea ice and 23 high sea ice SSW events. For the low sea ice case, the tropospheric precursor (-10 days to the starting date of SSW) is characterized by a wave pattern over Eurasia (anticyclonic anomalies over the central Eurasia and cyclonic anomalies over the eastern Eurasia), which resembles a spatial pattern of the stationary Rossby wave response to the sea ice reduction in the Barents-Kara Sea. This anomalous wave pattern is in phase with the climatological wavenumber-2 structure. At the lower stratospheric level, wavenumber-2 contribution to the vertical Eliassen-Palm (E-P) flux component is larger than the wavenumber-1 contribution. After the SSW, the negative phase of the Arctic Oscillation and Eurasian cooling appear at the surface level due to downward propagation of the signals.

In contrast, SSWs in the high sea ice years are marked with more dominant contribution from the wavenumber-1 component to the vertical E-P flux, which is related to the enhanced climatological trough over the Pacific and the ridge over Europe at the upper tropospheric level. Downward propagation of the stratospheric signals to the troposphere and the negative phase of the surface AO pattern are much less pronounced. Based on the above analysis, we conclude that the Barents-Kara sea ice reduction modulates SSWs in such a way that upward planetary wave propagation with the wavenumber-2 structure is enhanced by the stationary Rossby wave response of the sea ice reduction.

キーワード：成層圏突然昇温、北極海氷減少、成層圏対流圏結合
Keywords: SSW, Arctic sea ice loss, stratosphere-troposphere coupling

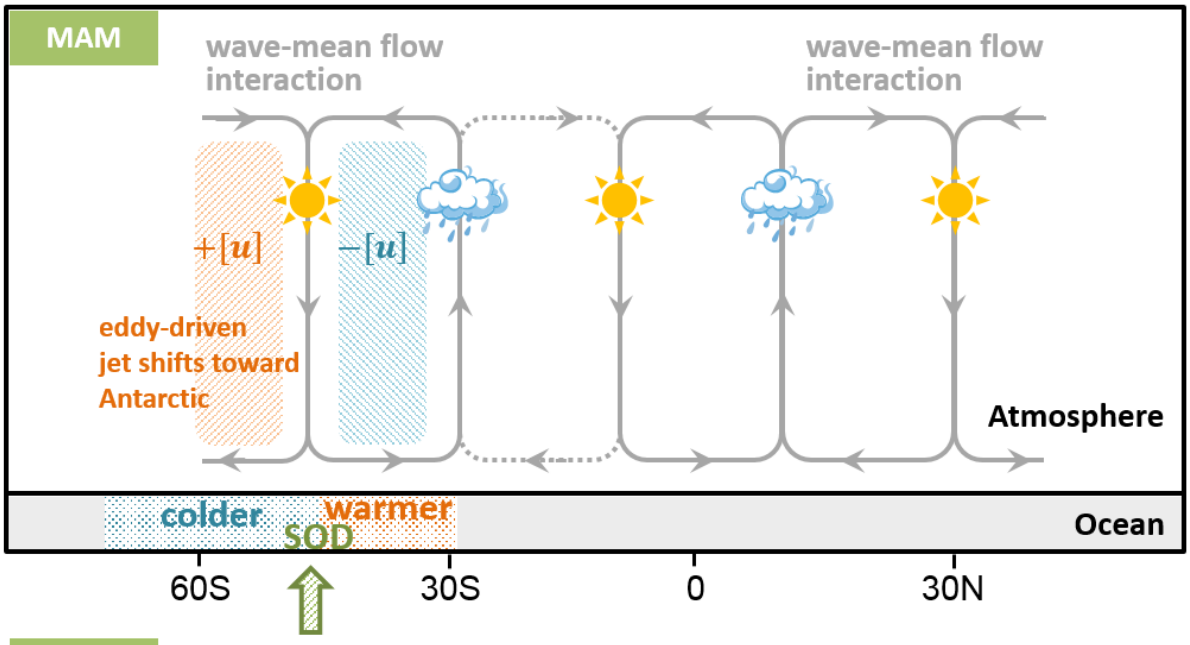
Cross-Seasonal Influence of the December–February Southern Hemisphere Annular Mode on March–May Meridional Circulation and Precipitation

*Fei Zheng[1], Jianping Li[2], Lei Wang[3], Fei Xie[2], Xiaofeng Li[1]

1. State Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics, Institute of Atmospheric Physics, Chinese Academy of Sciences, 2. College of Global Change and Earth System Science, Beijing Normal University, and Joint Center for Global Change Studies, 3. Key Laboratory of Research on Marine Hazards Forecasting, National Marine Environmental Forecasting Center

New evidence suggests that interannual variability in zonal-mean meridional circulation and precipitation can be partially attributed to the Southern Hemisphere annular mode (SAM), the dominant mode of climate variability in the Southern Hemisphere (SH) extratropics. A cross-seasonal correlation exists between the December–February (DJF) SAM and March–May (MAM) zonal-mean meridional circulation and precipitation. This correlation is not confined to the SH: it also extends to the Northern Hemisphere (NH) subtropics. When the preceding DJF SAM is positive, counterclockwise, and clockwise meridional cells, accompanied by less and more precipitation, occur alternately between the SH middle latitudes and NH subtropics in MAM. In particular, less precipitation occurs in the SH middle latitudes, the SH tropics, and the NH subtropics, but more precipitation occurs in the SH subtropics and the NH tropics. A framework is built to explain the cross-seasonal impact of SAM-related SST anomalies. Evidence indicates that the DJF SAM tends to lead to dipolelike SST anomalies in the SH extratropics, which are referred to in this study as the SH ocean dipole (SOD). The DJF SOD can persist until the following MAM when it begins to modulate MAM meridional circulation and large-scale precipitation. Atmospheric general circulation model simulations further verify that MAM meridional circulation between the SH middle latitudes and the northern subtropics responds to the MAM SOD.

Keywords: Southern Hemisphere Annular Mode, Southern Ocean Dipole, zonal-mean precipitation



SAM-related **SOD** persists from DJF to the following MAM

南極対流圏・下部成層圏重力波に関するPANSYレーダーを用いた観測的研究

A study of gravity waves in the Antarctic troposphere and lower stratosphere observed by the PANSY radar

*南原 優一[1]、佐藤 薫[1]、堤 雅基[2]、佐藤 亨[3]
*Yuichi Minamihara[1], Kaoru Sato[1], Masaki Tsutsumi[2], Toru Sato[3]

1. 東京大学　大学院理学系研究科　地球惑星科学専攻、2. 国立極地研究所、3. 京都大学　情報学研究科　通信情報システム専攻
1. Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, 2. National Institute of Polar Research, 3. Department of Communications and Computer Engineering, Graduate School of Informatics, Kyoto University

Gravity waves (GWs), which are mainly generated in the troposphere, propagate into the middle atmosphere, and deposit the momentum in the mean field through dissipation and breaking processes. Since GWs have temporally and spatially small scales, observations of GWs are quite limited especially in the polar region due to harsh environment there. The purpose of this study is to conduct a statistical analysis of the GWs in the Antarctic troposphere and lower stratosphere based on continuous observation data over a year from October 2015 to September 2016 by the full system of the PANSY radar, the first Antarctic Mesosphere-Stratosphere-Troposphere (MST) radar, installed at Syowa Station (69.0S, 39.6E). Note that continuous observations over such a long duration are unprecedented as observations by high-power MST radars at any location.

The frequency power spectra of horizontal wind fluctuations ($\omega P_u(\omega)$ and $\omega P_v(\omega)$) have an isolated peak around inertial frequency (f) in the lower stratosphere (Figure 1a). For $\omega Pw(\omega)$, high frequency components are dominant and an isolated peak is not seen (Figure 1b). The zonal momentum flux spectra ($\omega Re[U(\omega)W^*(\omega)]$) are strongly negative around (Figure 1c). It is considered that the waves having a quasi-inertial frequency observed by the PANSY radar are likely such inertia-GWs as reported by Sato et al. (1999).

Vertical fluxes of horizontal momentum are estimated using a dual-beam method proposed by Vincent and Reid (1983). It is seen that negative is dominant in the stratosphere. On the other hand, does not show systematic features. , and variances of the horizontal wind fluctuations are relatively large in the lower stratosphere compared with those in the troposphere. In contrast, variances of vertical wind fluctuations are large in the lower troposphere and weak in the stratosphere. In the lower troposphere, large momentum fluxes and horizontal wind fluctuation variances are sporadically seen for all seasons. Furthermore, strong sporadic features from the surface to the lower stratosphere are seen in all components several times a year.

Next, a statistical analysis is performed focusing on the GWs with a quasi-inertial frequency (QIGWs) that are dominant in the lower stratosphere. We extract the fluctuations with period from 6 h to 24 h and vertical wavelength shorter than 5 km as the QIGWs. Furthermore, a two-dimensional Fourier series expansion method is used so as to separately analyze the QIGW with upward and downward phase velocities. A hodograph analysis is performed for the respective QIGW components at each time and height.

QIGWs with upward group velocity are dominant in the lower troposphere and in the lowermost stratosphere, whereas a considerable proportion of QIGWs propagating energy downward in the upper troposphere in all seasons, and in the stratosphere above the height of 15 km in winter. These results

suggest that there are QIGW sources on the ground surface and around the tropopause in all seasons, and in the stratosphere and/or above in winter.
It is also shown that vertical and horizontal wavelengths and intrinsic frequency have large vertical dependences and do not largely depend on the season and the vertical energy propagation direction.
A statistics of the intrinsic and ground-based phase velocity of QIGWs are also examined. It is interesting that most are about 0 ms^{-1} for the QIGWs propagating energy upward while a significant proportion of QIGWs propagate energy downward have large pointing to the east in the lower stratosphere. These results support the inference that most QIGWs with upward group velocity are likely waves that were orographically-forced near the ground surface and that QIGWs propagating energy downward are originated from sources moving eastward in the stratosphere and/or above. A likely candidate of such GW sources is the polar night jet blowing eastward in the winter stratosphere.

キーワード：大気重力波、極域気象、大型大気レーダー
Keywords: Gravity waves, Polar atmosphere, MST/IS radar

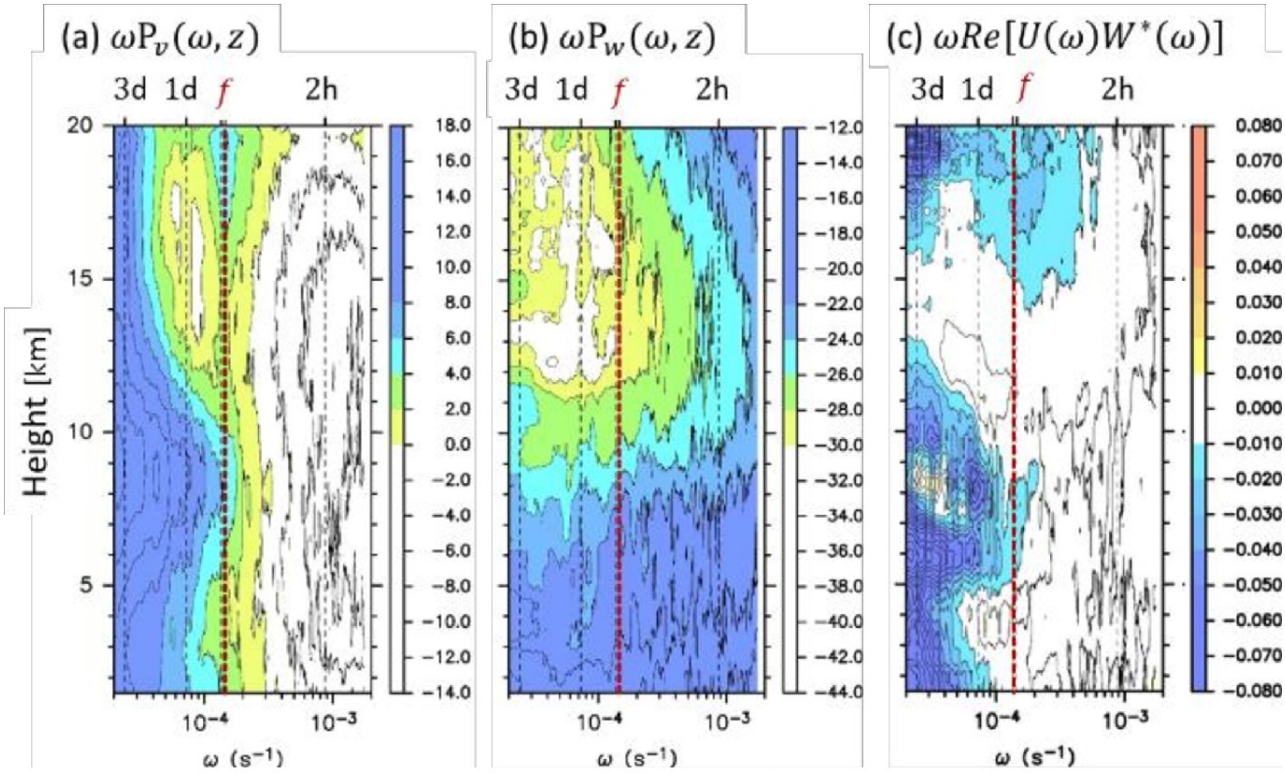


Figure 1. Frequency power spectra of (a) zonal ($\omega P_u(\omega)$) and (b) vertical wind fluctuations ($\omega P_w(\omega)$) and (c) the zonal momentum flux spectra ($\omega \mathrm{Re}[U(\omega)W^*(\omega)]$) in the energy content form as a function of height in the frequency range of $2\pi/(3\,\mathrm{d})$-$2\pi/(1\,\mathrm{h})$.

Vertical and meridional extent of effects of energetic particle precipitation

*冨川 喜弘[1]
*Yoshihiro Tomikawa[1]

1. 国立極地研究所
1. National Institute of Polar Research

This study extracts effects of energetic particle precipitation (EPP) on the middle atmosphere in the southern hemisphere from the latest reanalysis datasets using multiple regression analysis and composite analysis. Statistically significant temperature anomalies in the winter polar upper stratosphere and lower mesosphere are found, but a simple dynamical signature explaining the anomalies is not evident. On the other hand, it is found that a negative temperature anomaly extending from the polar lower mesosphere to the midlatitude upper stratosphere in July is driven by anomalous Eliassen-Pam flux divergence in the midlatitude lower mesosphere. Vertical and meridional extent of the EPP effects will be discussed in my presentation.

Solar wind influence on tropospheric weather through atmospheric vertical coupling

*Paul Prikryl[1,2], Takumi Tsukijihara[3], Koki Iwao[4], Donald B Muldrew[5], Robert Bruntz[6], Vojto Rušin[7], Milan Rybanský[8], Maroš Turna[9], Pavel Štastný[9], Vladimír Pastircák[9]

1. Physics Department, University of New Brunswick, Fredericton, NB, Canada, 2. Geomagnetic Laboratory, Natural Resources Canada, Ottawa, ON, Canada, 3. Department of Earth and Planetary Sciences, Kyushu University, Fukuoka, Japan, 4. National College of Technology, Kumamoto College, Yatsushiro, Japan, 5. Emeritus, Communications Research Centre, Ottawa, ON, Canada, 6. Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA, 7. Astronomical Institute, Slovak Academy of Sciences, Tatranská Lomnica, Slovakia, 8. Slovak Central Observatory, Hurbanovo, Slovakia, 9. Slovak Hydrometeorological Institute, Bratislava, Slovak Republic

A link between solar wind magnetic sector boundary structure and mid-latitude upper tropospheric vorticity discovered in the 1970s (Wilcox et al., Science, 180, 185-186, 1973) was later confirmed and physical mechanisms proposed (Tinsley et al., J. Geophys. Res., 106(D23), 1994; Prikryl et al., Ann. Geophys., 27, 1-57, 2009). To further emphasize their importance we investigate the occurrence of mid-latitude severe weather in the context of solar wind coupling to the magnetosphere-ionosphere-atmosphere (MIA) system. It is observed that significant snowstorms, windstorms and heavy rain, particularly if caused by low pressure systems in winter, tend to follow arrivals of high-speed solar wind. Previously published statistical evidence that explosive extratropical cyclones in the northern hemisphere tend to occur after arrivals of high-speed solar wind streams from coronal holes (Prikryl et al., J. Atmos. Sol.-Terr. Phys., 149, 219–231, 2016) is corroborated for the southern hemisphere. The leading edge of high-speed solar wind streams is a locus of large-amplitude magneto-hydrodynamic waves that modulate Joule heating and/or Lorentz forcing of the high-latitude lower thermosphere generating medium-scale atmospheric gravity waves that propagate upward and downward through the atmosphere. Simulations of gravity wave propagation in a model atmosphere using the Transfer Function Model (Mayr et al., Space Sci. Rev., 54, 297–375, 1990) show that propagating waves originating in the thermosphere can excite a spectrum of gravity waves in the lower atmosphere. In spite of significantly reduced amplitudes but subject to amplification upon reflection in the upper troposphere, these gravity waves can provide a lift of unstable air to release instabilities in the troposphere thus initiating convection to form cloud/precipitation bands. It is primarily the energy provided by release of latent heat that leads to intensification of storms. These results indicate that vertical coupling in the atmosphere exerts downward control from solar wind to the lower atmospheric levels influencing tropospheric weather development.

Keywords: Atmospheric gravity wave, Severe weather, Extratropical cyclone, High-speed solar wind, Co-rotating interaction region, Solar wind coupling to the magnetosphere-ionosphere-atmosphere

