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

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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

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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:

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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

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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

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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

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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

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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

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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

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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.

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

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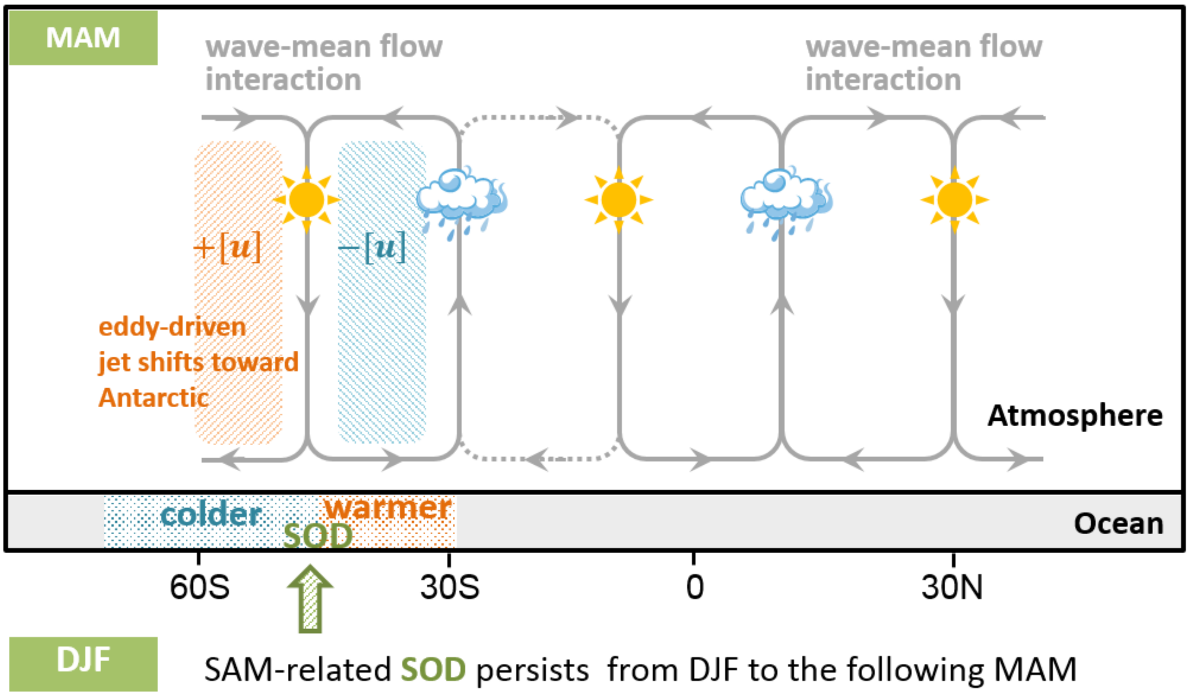
New evidence suggests that interannual variability in zonal-mean meridional circulation and precipitation can be partially attributed to the Southern Hemisphere annular mode (SAM), the dominant mode of climate variability in the Southern Hemisphere (SH) extratropics. A cross-seasonal correlation exists 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


MAM
wave-mean flow interaction
wave-mean flow interaction
+[u]
−[u]
eddy-driven jet shifts toward Antarctic
Atmosphere
colder
warmer
SOD
Ocean
60S
30S
0
30N
DJF
SAM-related SOD persists from DJF to the following MAM

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

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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.

Keywords: Gravity waves, Polar atmosphere, MST/IS radar

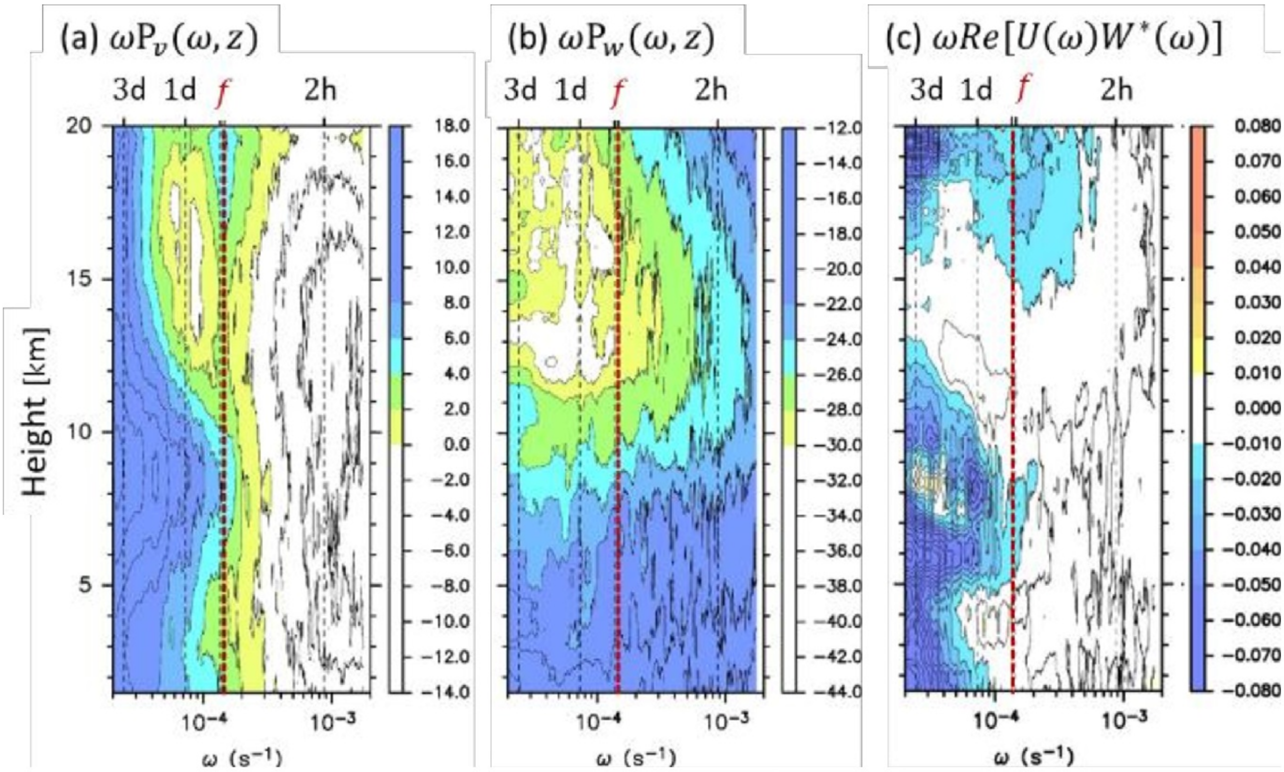

Figure 1. Frequency power spectra of (a) zonal ($\omega P_u(\omega)$) and (b) vertical wind fluctuations ($\omega P_w(\omega)$) and (c) the zonal momentum flux spectra ($\omega Re[U(\omega)W^*(\omega)]$) in the energy content form as a function of height in the frequency range of $2\pi/(3\,\mathrm{d})$-$2\pi/(1\,\mathrm{h})$.

Vertical and meridional extent of effects of energetic particle precipitation

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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

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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

