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

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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

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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

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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

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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

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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

