衛星ライダー観測データを用いた南半球における極成層圏雲と大気擾乱の関係の解析

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A study of modulation of polar stratospheric clouds by atmospheric waves in the Southern Hemisphere using CALIPSO lidar data

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Polar stratospheric clouds (PSCs) are the clouds that appear in the cold lower stratosphere in the polar regions and play a key role in the destruction of polar stratospheric ozone. Atmospheric waves including planetary, synoptic-scale and gravity waves modulate temperature fields and hence affect the PSC amounts as shown by previous studies. Thus, for better understanding of stratospheric ozone destruction, a comprehensive and quantitative analysis was made in this study on the relationship between atmospheric waves and PSCs. We used the PSC data from satellite lidar observations (CALIPSO), H_2O and HNO_3 data from a satellite microwave limb sounder (Aura MLS), reanalysis data (ERA Interim) and high-resolution dry temperature data from GPS radio occultation observations (COSMIC). The analysis was focused on the Southern Hemisphere.

The frequency of PSC occurrence at each location and time, hereafter referred to as the PSC frequency, was calculated as a proxy of the PSC amount from CALIPSO Level 2 data (Vertical Feature Mask data, simply showing the presence of cloud at the observation point). The polar-stereo map shows that the PSC frequency is not regionally uniform, and instead suggests strong influence of the atmospheric waves. High PSC frequency regions propagate eastward in the longitude-height section, which accords well with the timing and movement of negative temperature anomaly from the zonal mean. First the effects of planetary waves in the stratosphere and synoptic-scale waves in the upper troposphere are analyzed using potential vorticity (PV) on the isentropic surfaces of 650 K (a height of about 20 km) and 300 K (about 8 km) respectively. It is shown that low (cyclonic) PV anomaly is frequently associated with high PSC frequency at 650K, while high (anti-cyclonic) PV anomaly is sometimes accompanied with high PSC frequency. The opposite effects of the PV anomaly of the stratosphere and upper troposphere are explained by their vertical scales. The low PV anomaly in the stratosphere generally has long vertical scales and is associated with low temperature, while the high PV anomaly in the upper troposphere has very short vertical scales and hence negative temperature anomaly is formed in the lower stratosphere. The eastward propagation of PSC frequency observed in the longitude-time section is frequently followed by these low PV anomaly in the stratosphere and occasionally by high PV anomaly in the upper troposphere. To estimate the net effect of the planetary waves on the PSC frequency quantitatively, we compared two “PSC area” with and without planetary wave effects. The former is calculated as the area where the temperature is below the T_{STS} ($\equiv T_{NAT} - 3.5$) based on unfiltered H_2O and HNO_3 data, and the latter is calculated using temperature, H_2O and HNO_3 data from which the zonal wavenumber 1-3 components were extracted. As a result, it was shown that the PSC coverage ratio, defined as PSC area divided by the analyzed area, with the planetary waves is about 30% larger than that without planetary waves to the north of 70S and is about 40% smaller to the south of 70S in June and July. Similar analysis was made on the PSC area excluding synoptic-scale wave effects. It was shown that synoptic-scale wave decreases slightly PSC coverage ratio at an altitude of 20km.

Next, to examine the gravity wave effects on the PSC, we used GPS temperature data. The gravity wave potential energy is usually higher near the Antarctic Peninsula than in the other regions in June through September. However, the PSC frequency around the Antarctic Peninsula is higher than the other regions only in June and September, while the difference is small in July and August.

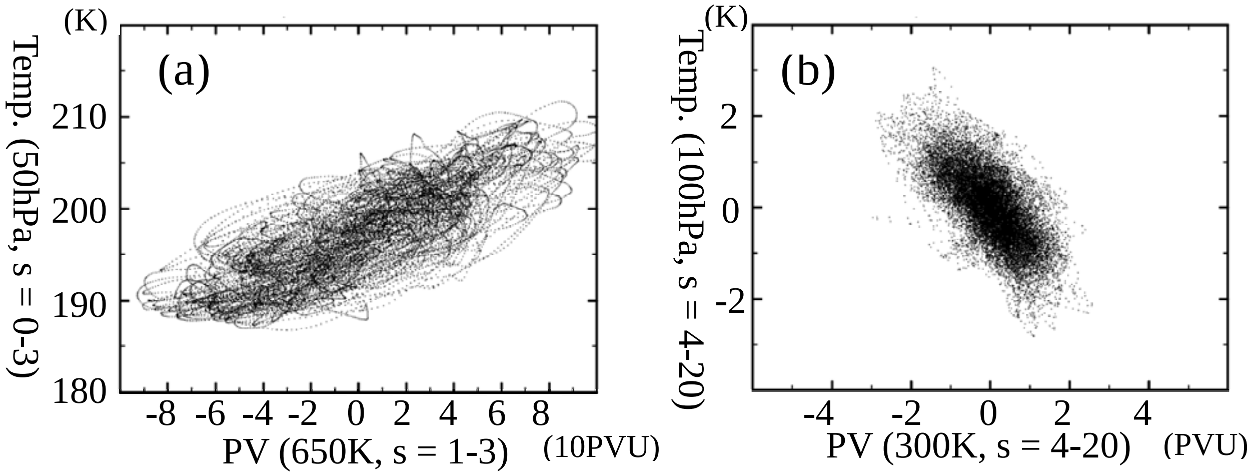

Fig.1 (a) Scatter diagram of potential vorticity on the 650K isentropic surface from which the zonal wavenumber larger than 4 are extracted and temperature at 50hPa from which the zonal wavenumber larger than 4 are extracted for 65-70S in June. (b) Scatter diagram of potential vorticity on the 300K isentropic surface from which the zonal wavenumber 0-3 are extracted and temperature at 100hPa from which the zonal wavenumber 0-3 are extracted for 65-70S in June.

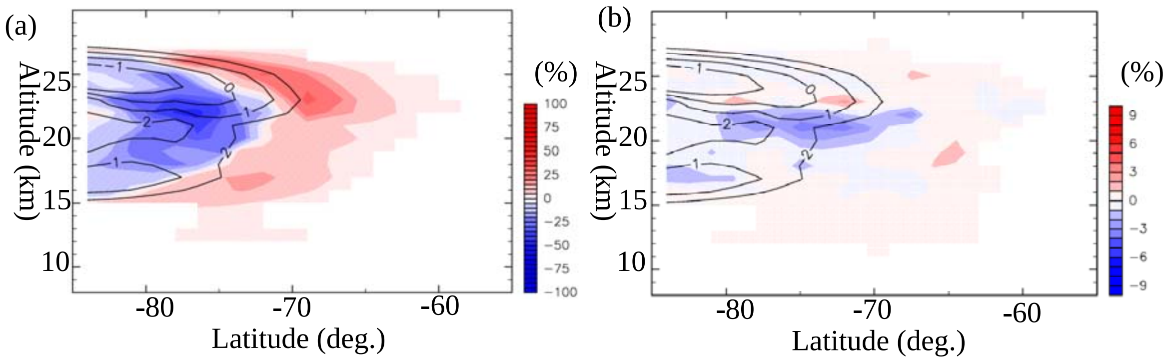

Fig.2 (a) A latitude-altitude cross-section of the difference between PSC coverage ratio with the planetary waves and without planetary waves. Solid thick contours indicate T-TSTS. (b) The same as (a) but for the difference between PSC coverage with synoptic-scale waves and without synoptic-scale waves.

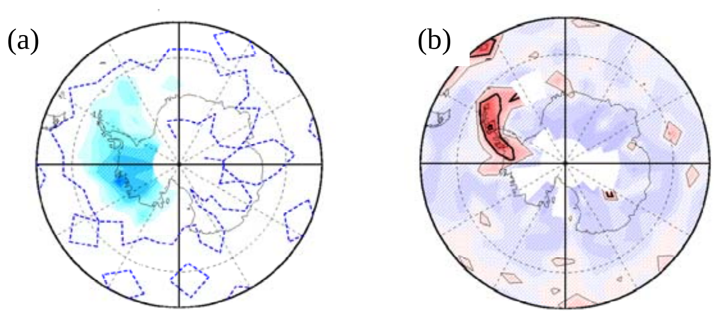

Fig.3 Polar-stereo maps of (a) the PSC occurrence calculated using CALIPSO data and (b) potential energy of the gravity waves calculaged using COSMIC RO temperature around an altitude of 20km in 11-15 August 2007.