Variations of stratospheric and tropospheric circulations related with ozone hole

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Due to anthropogenic emissions of ozone depleting substances, ozone hole has been developing in Antarctic stratosphere during the spring since about the 1980s. Ozone absorbs incoming solar radiation and heating the stratosphere. Hence the depletion of ozone over Antarctica leads to cooling of the polar stratosphere. As a result, polar vortex is strengthened from thermal wind equation. These variations related with ozone hole appear only in Antarctic stratosphere during the spring so that it was considered that the ozone depletion does not affect tropospheric climate. Since about the 2000s, however, it has become clear that the ozone hole is also associated with widespread changes in the Southern Hemisphere tropospheric circulation and surface climate. Previous research studies showed that the influences of the ozone hole go down from stratosphere and appear lower troposphere during the austral summer season. This tropospheric variation pattern resembles the most prominent pattern of large-scale Southern Hemisphere climate variability, the Southern Annular Mode. Hence the influence of the ozone hole has led to a range of Southern Hemisphere climate changes not only Antarctic stratosphere, but also over the Southern Hemisphere troposphere. However the mechanism of influence from the stratosphere to the troposphere is unclear. This study revealed how the stratospheric variation related with ozone hole affect the troposphere during austral summer season.

Previous study analyzed this mechanism using monthly or seasonal data; therefore, variations with timescale shorter than a month cannot be analyzed. For this reason, we used 10 days mean data in order to research the detail of the mechanism in the austral summer. As a result, we found out the variations of eastward wind are different among December, January and February. In December, most of eastward wind variations occur in the stratosphere and upper troposphere. In January, stratospheric variations disappear and only tropospheric variation can be found. In February, we could not find any significant variations both stratosphere and troposphere. We tried to find out the reason why these different variations appear using EP-Flux. As a result, we realized that, in December, wavenumber 1 propagating into the stratosphere has the most important role and that baroclinic instabilities with wavenumber 4 and 6 are important in January.

Furthermore we studied the influences of both global warming and ozone hole on Southern Hemisphere climate. We investigated in the Chemical Climate Model based on MIROC 3.2 using three scenarios, one is reference simulation, another is sensitivity simulation which is similar to reference simulation, but halogens fixed at 1960 levels throughout the simulation, and the last is sensitivity simulation which is also similar to reference simulation, but GHGs fixed at 1960 levels. Hence we can discuss two influences both global warming and ozone hole on Southern Hemisphere climate variations separately. As a result, we realized ozone hole has a role to maintain the signal at the lower troposphere in austral summer. On the other hand, global warming makes Brewer-Dobson circulation strong and the transportation of ozone to polar region is also enhanced. Because of ozone heating, global warming has a role to warm the polar atmosphere. Previous studies notice only the GHGs`s radiative cooling in the stratosphere but we suggested that the change of physical field is also important in the variation of Southern Hemisphere climate.

