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The relationship between high-speed solar wind streams and ozone loss in the upper stratosphere and mesosphere

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Abstract

The solar wind is a stream of plasma released from the upper atmosphere of the Sun. The solar wind is divided into two components: slow and fast solar winds. The fast solar wind is thought to originate from coronal holes, which are funnel-like regions of open field lines in the Sun's magnetic field. The physical characteristics of fast solar wind are closely related to variations in space environments including the Earth's magnetosphere and the upper and lower atmospheres. Although its effects are not as strong as solar energetic particle events such as flare and CME, the high-speed solar wind stream more prevalently occurs and may affect the atmospheric chemistry. In this study, we analyzed the atmospheric density data for HO_2 and O_3 obtained by MLS onboard the AURA satellite according to solar wind speed measured by ACE satellite from 2005 to 2011 in order to study on the atmospheric effects of the high-speed solar wind streams. We report a preliminary result of this analysis.

Introduction

The increase in the speed of solar wind stream pumps energy into the magnetosphere, which can cause geomagnetic storms and energizes particles. It has been reported that the energetic particles driven by high speed solar wind stream (HSS) can have significant consequences in the chemistry of the mesosphere and stratosphere. As the energy of the particles increases they can penetrate down to lower atmosphere. But which range of electron energies is the most important for atmospheric chemistry remains a question of debate. Auroral electrons with the energy range of 100 eV < E < 30 keV can only penetrate as far as the lower thermosphere and therefore it requires downward transport of the produced NOx/HOx to affect the lower atmosphere.

A recent chemistry-climate model suggests that energetic particle precipitation can lead to annual ozone decreases of up to 30% in the polar stratosphere [Rozanov et al., 2005] leading to a cooling of up to 2 K in the polar middle stratosphere, together with detectable changes in temperature at the surface of the Earth.

➢ **Goals**

- Evaluate the atmospheric changes of HO_2 and O_3 densities during high speed solar wind streams.
- In addition, understand climate changes associated with energetic particle precipitations in the polar region by high speed solar wind streams.

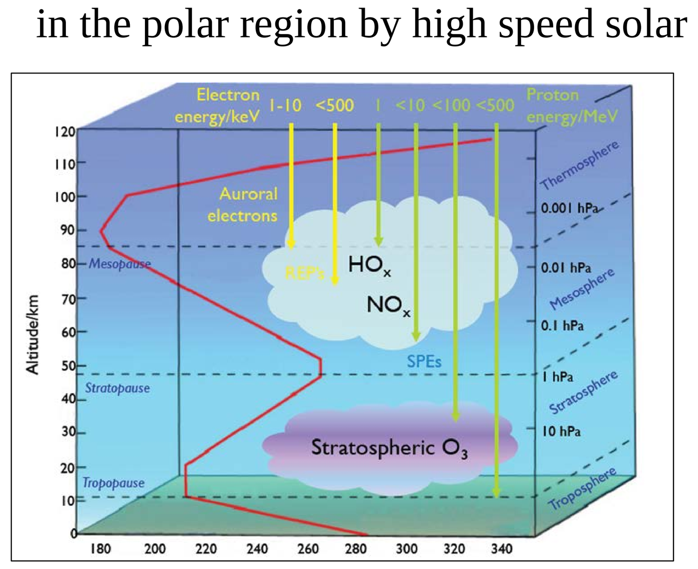

Fig. 1. Energetic particles from the Sun enter (precipitate into) the Earth's atmosphere. These precipitating particles are mostly electrons and protons. During large precipitation events, the particles can ionise and dissociate the neutral gases in significant amounts and disturb the chemical balance of the middle atmosphere. (figure by C. Rodger)

➢ **The differences between the atmospheric effects of SPEs and HSSs**

- Although relatively infrequent, Solar proton events(SPEs) can have a direct effect on chemical constituents in the polar middle atmosphere, especially HOx, NOy, and then ozone.
- High-speed solar wind streams more frequently occur than SPEs but, due to weaker energy of the particles, it requires the downward transport of resulting atmospheric components to have effects on the ozone density in the stratosphere.

Chemistry change

- Most important are changes to the budget of atmospheric nitric oxides (NOx = N, NO, NO_2) and to atmospheric reactive hydrogen oxides (HOx = H, OH, HO_2), which both contribute to ozone loss in the stratosphere and mesosphere.
- Protons and their associated secondary electrons produce odd hydrogen(HOx). The production of HOx takes place after the initial formation of ion-pairs and is the end result of complex ion chemistry. Odd nitrogen is produced when the energetic charged particles (protons and associated secondary electrons) collide with and dissociate N_2.

$OH+O_3 \rightarrow HO_2+O_2$	and $H+O_3 \rightarrow OH+O_2$	$NO+O_3 \rightarrow NO_2+O_2$
followed by $HO_2+O \rightarrow OH + O_2$	followed by $OH+O \rightarrow H+O_2$	followed by $NO_2+O \rightarrow NO+O_2$
Net: $O+O_3 \rightarrow O_2+O_2$	Net: $O+O_3 \rightarrow O_2+O_2$.	Net: $O+O_3 \rightarrow O_2+O_2$.

HSS events and analysis

- Using the measurements of solar wind speed by Advanced Composition Explorer(ACE) satellite and a total of 51 HSS events are identified from 2005 to 2011.
- A well-defined high speed solar wind stream was based on the following requirements:
  - Solar wind speed greater than 500km/s
  - Continues for more than 3days after HSS onset
- For the 51 events, the changes of atmospheric densities of HO_2 and O_3 are investigated in the northern and southern polar regions (60° - 82.5° latitude) during HSS events. The densities are measured by Microwave Limb Sounder(MLS) onboard the AURA satellite. performed the difference between "with HSSs" and "without HSSs".

Example

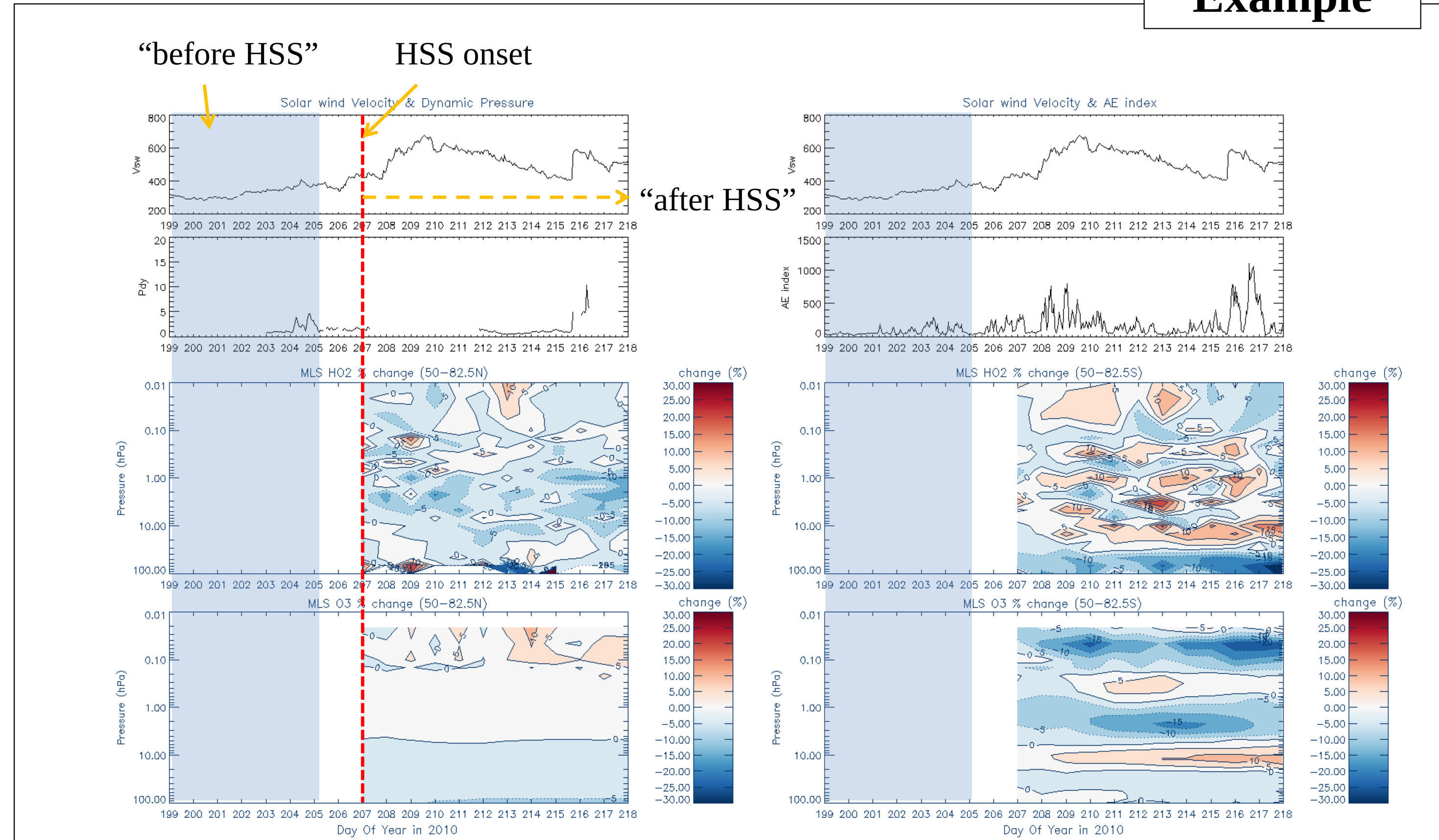

Fig. 2. A example of HSS events and the resulting changes of HO_2 and O_3 densities on July 27, 2010. The right panels show the density changes after HSS onset.

Results

Average changes of HO_2 and O_3 densities in summer and winter

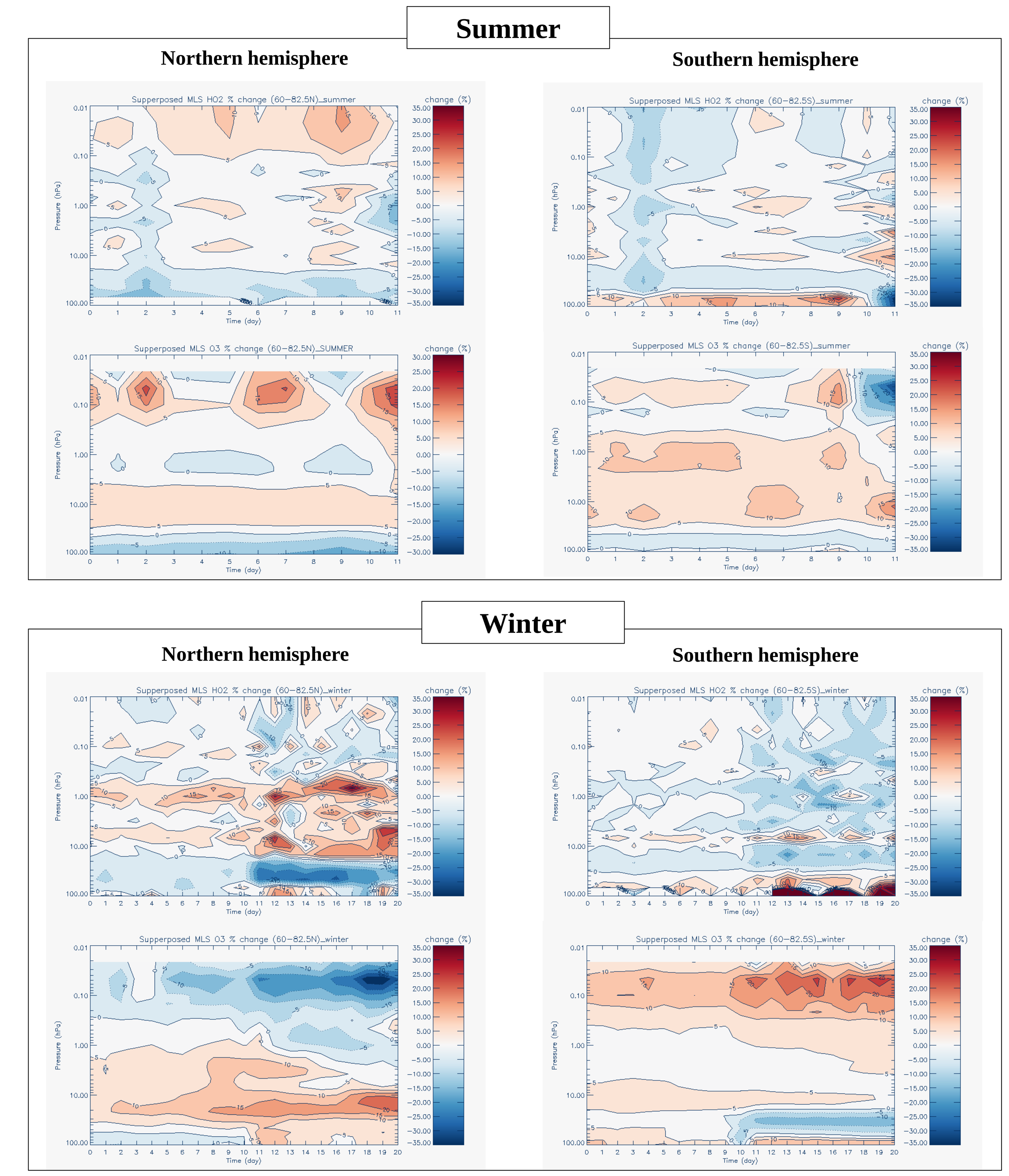

Fig. 3. The average changes of depending on the season at stratosphere and mesosphere as shown northern hemisphere and southern hemisphere.

- We focus on the winter hemisphere since the energetic-particle-induced atmospheric components are lived long during night and can descend to the middle atmosphere to affect ozone density.
- The result showed that a significant ozone depletion was found in the northern winter while the opposite occurred in the southern winter.
- However, it was hard to see any correlation between the changes of HOx and O_3 densities.

Future Work

- Density changes of NOx during HSSs will be further investigated in addition to HOx density changes.

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