2013 Workshop: Stratospheric Sudden Warmings

Long title
Coupling of the lower and upper atmosphere during Stratospheric Sudden Warmings
Conveners
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Description

In recent years observations as well as numerical models have shown that terrestrial weather can influence the upper atmosphere and ionosphere. Such influences are particularly well pronounced during extreme events such as Stratospheric Sudden Warmings (SSW) that are characterized by strong planetary wave activity in the winter polar region. Large amplitude planetary waves lead to rapid increases in polar stratospheric temperatures, and deceleration or reversals of the polar night jet. The polar vortex is distorted or split during SSWs and it can take several weeks to recover. Ionospheric signals of the SSW event are significant and comparable in size with the disturbances from geomagnetic storms. However, SSW events have the advantage that they can be predicted ahead of time because of the slow evolution compared to a geomagnetic storm. To predict the ionospheric variability we need to know how the stratospheric changes couple to the upper atmosphere and ionosphere. Recent studies have shown that SSW events are linked to changes in tidal and wave components, tropical stratospheric ozone, lunar gravitational tides, ionospheric electric fields, currents, temperatures, and electron densities. SSWs are also accompanied by reversals in mesospheric gravity wave forcing and secondary planetary wave generation and propagation into the mesosphere and lower thermosphere. We need to improve our understanding about the energy transfer from the lower to upper atmosphere, the latitudinal coupling during SSW periods, how the characteristics of SSW influences the ionospheric response, the role of gravity waves, and the relative importance of geospace variability during SSW events. One goal of this workshop is to bring together researchers from the troposphere-stratosphere-mesosphere-thermosphere-ionosphere communities to improve our understanding of the dynamic processes and the energy transfer resulting in the lower to upper atmosphere coupling. The workshop will encompass observational investigations and numerical model studies to encourage collaborations.

Agenda

10:00-10:20 Thomas Birner “How does polar winter stratospheric variability affect the troposphere?”

10:20-10:40 Richard Collins: "MTeX: The Mesosphere-Lower Thermosphere Turbulence Experiment" (pdf)

10:40-11:00 Valery Yudin “Wave dynamics during recent SSW events as recreated by WACCM-X/GEOS-5a: Arctic (2006-2013) and Antarctic (2002)” (pdf)

11:00-11:20 Tim Fuller-Rowell “What is it about the winds that changes the electrodynamics during the 2009 SSW?”

11:20-11:40 Nick Pedatella: "Simulations of the neutral dynamics during the 2009 SSW in different whole atmosphere models" (pdf)

11:40-12:00 Yosuke Yamazaki: "Response of the Ionospheric Current System to Stratospheric Sudden Warmings (SSWs)" (pdf)

1:30PM-3:30 PM (~13 min each)

1:30-1:43 Erdal Yigit "Propagation of small-scale gravity waves of lower atmospheric origin into the thermosphere during sudden stratospheric warmings" (pdf)

1:43-1:56 Chihoko Yamashita "Gravity Wave Variations during Elevated Stratopause Events using SABER Observations" (pdf)

1:56-2:09 Lynn Harvey & Jeff France "The zonally asymmetric elevated stratopause in WACCM and MLS" (pdf)

2:09-2:22 Brentha Thurairajah "Transport of Nitric Oxide during recent Arctic Winter using SOFIE Measurements" (pdf)

2:22-2:35 Amal Chandran "Inter-hemispheric coupling during SSW and their impacts on the Southern hemisphere PMCs"

2:35-2:48 Laura Holt et al. "Sudden stratospheric warming impact on energetic particle precipitation effects" abstract

2:48-3:01 Jia-Ting Lin et al. "Stratospheric Sudden Warming Effects on the Ionospheric Migrating Tides during 2008-2010 observed by FORMOSAT-3/COSMIC" (pdf)

3:01-3:14 Larisa Goncharenko et al. "Ionospheric disturbances during the sudden stratospheric warming of January 2013"

3:14-3:27 Maute: "Longitudinal TEC differences during the 2010 SSW period in the observations and the TIME-GCM" (pdf)

Summary

The morning session was attended by approximately 60 persons and consisted of invited contributions. Thomas Birner (CSU, Fort Collins) presented observations establishing the Stratosphere-Troposphere coupling. He highlighted that a series of proposed mechanism exist, but none is fully conclusive. He discussed how stratospheric circulation anomalies can penetrate downward into the troposphere and affect the tropopause height and temperature. Richard Collins (UoA, Fairbanks) introduced the Mesosphere-Lower Thermosphere Turbulence Experiment (MTeX) which will take place January 13-25, 2015. MTeX will measure turbulence associated with large scale planetary wave activity. Turbulence is important to understand and quantify since it determines the vertical transport between the thermosphere and mesosphere controlling the downward movement of ozone-active chemicals. Valery Yudin (NCAR, Boulder) presented simulations of recent SSW 2006-2013 periods with the Whole Atmosphere Community Climate Model (WACCM)/ Goddard Earth Observing System Model, Version 5 (GEOS-5) which is using a different gravity wave and eddy dissipation scheme (as compared to WACCM) leading to stronger tidal forcing, and resolves a known conservation of energy issue. Tim Fuller-Rowell (CIRES, CU Boulder) used the Whole Atmosphere Model (WAM) in combination with an ionosphere plasmasphere model (GIP or CTIPe) to study the 2009 SSW period with respect to ionospheric changes and the associated phase change in the semidiurnal tidal mode cause by the altered background atmosphere in WAM/CTIPe. Nick Pedatella (NCAR, Boulder) compared the GAIA, HAMMONIA, WACCM-X, and WAM numerical models for the 2009 SSW. Numerical models have significant differences due to the uncertainties in parameterizations, numerical methods, forcing, and comparison helps to understand the potential uncertainties. Yosuke Yamazaki (NCAR, Boulder) examined the ionospheric current system during SSW periods derived from ground magnetic perturbation using 50 years of data. SSW signals are present in the EEJ which are stronger during solar maximum than minimum, and correlated with the lunar time. The afternoon session consisted of contributed presentations, and was attended by approximately 50 persons. Erdal Yigit (UoC, Berkeley) addressed the question how gravity waves influence the thermosphere during SSW, and showed that SSW-induced gravity wave variations are an appreciable source of thermospheric variability, producing effects in the winter and summer hemisphere. Chihoko Yamashita (UoC, Berkeley) showed that using SABER data it is possible to study global patterns in gravity waves in the 30-100 km height regime, and the results suggest that the enhancement of the meridional propagation of gravity waves into the polar winter hemisphere is responsible for the elevated stratopause. Brentha Thurairajah (Virginia Tech) used 6 years of Solar Occultation For Ice Experiment (SOPHIE) observations to study nitric oxide (NO) during winter polar months. Strong NO descent which catalytically destroys ozone was observed by SOPHIE in 2009 and 2013. SOPHIE observations of ozone decreases at 65 km correlate well with the decent of NO. The SSW effect on inter-hemispheric coupling and polar mesospheric clouds (PMCs) was examined by Amal Chandran (UoA, Fairbanks) using WACCM. Laura Holt (CU, Boulder) discussed the SSW impact on energetic particle precipitation (EPP) which then can influence the production of NOx and HOx. There is either a direct influence on the stratosphere by production in the stratosphere or an indirect effect by the descent of EPP NOx and HOx from the mesosphere. SSWs that occur earlier in the winter result in larger indirect effects. Jia Lin (National Cheng Kung University, Taiwan) studied ionospheric migrating tides in FORMSAT-3/COSMIC observations between 2008 and 2010. He related the observed decreases in the diurnal, semidiurnal, and terdiurnal migrating components in NmF2 to the SSW peak in 2008, 2009 and 2010. Ionospheric data during the most recent SSW event in 2013 was presented by Larisa Goncharenko (MIT, Haystack). The 2009 SSW forcing was stronger than in 2013, and the 2009 warming occurred during low solar flux conditions, while during the 2013 SSW the solar flux reached a new maximum for the current cycle. Still, the ionospheric changes were as large as for the 2009 SSW, and the Jicamarca vertical drift observations showed similar local time behavior. Astrid Maute (NCAR, Boulder) studied the longitudinal differences in TEC response during the 2010 SSW period of observations and two TIME-GCM simulations (one forced by reanalysis data and tidal climatology, and the other used nudging of the background atmosphere with

WACCM/NOGAPS). Although the dynamics of the MLT region in the two simulations is very different, the ionospheric differences are not further diverging. The simulations could not reproduce the strong observed longitudinal TEC variation.

The workshop brought together researchers specialized in the different regions of the atmosphere relevant to Stratospheric Sudden Warmings. Having different perspectives and studying different aspects of the warming periods provided an enriching workshop atmosphere and fostered lively discussions and new ideas.

The workshop highlighted the following results and open research questions where progress should be made:

- Gravity schemes in numerical models have to be carefully checked to ensure realistic tidal variations and to maintain the conservation of energy. Several workshop presentations have identified gravity waves as a significant source of SSW variability in both hemispheres up to the thermosphere, and therefore highlighted its importance.
- There is a lack of gravity wave observations in the MLT region, and therefore the physical mechanism generating the elevated stratopause and the downward movement is not clear. Using SABER data it is possible to study global distributions of gravity waves in the 30-100 km height regime, and the results suggest that the enhancement of the meridional propagation of gravity waves into the polar winter hemisphere is responsible for the elevated stratopause.
- Results from different numerical models need to be compared, and differences should be used as a guide toward model improvement. Numerical models need to be continually validated with observations from the MLT and the ionosphere.
- Different numerical methods (e.g. nudging schemes, data assimilation, forcing at the lower boundary) in models leads to different results in the MLT and ionosphere. Future studies need to evaluate the numerical techniques to guide the community in the model usage.
- The local time behavior during SSW events of the equatorial vertical drift and the ionospheric responses was presented for several SSW periods using observations and simulations. The pre-noon increase in the vertical drift and the ionospheric response is associated with a phase shift in the semidiurnal tide. Possible reasons for the phase change could be the amplification of the lunar tide, changes in the ozone forcing, or in the tidal propagation and phase. More studies are needed to quantify the effects of different sources for different

SSW events.

- Several presentations pointed out the hemispheric differences during SSW periods in the stratosphere, MLT, and the ionosphere. The interhemispheric coupling in WACCM during a northern hemisphere SSW leads to a cooling of the southern hemisphere and a tendency for more PMCs. However, after the SSW the winter stratopause becomes cooler leading to a summer mesosphere warming and a decrease of PMCs. Further studies are needed to better understand the interhemispheric coupling, and extend the studies to the thermosphere and ionosphere.
- Using ground magnetic perturbations has the advantage that long data records exists. In the workshop is was shown that the equatorial electrojet (EEJ) response associated with SSWs has a strong correlation with lunar time, showing an increase of up to 300% in the lunar tide amplitude during SSW winters compared to non SSW winters. The EEJ response to SSWs is greater during high solar activity periods indicating that ionospheric SSW effects are important throughout the solar cycle. The global Sq current system responds to SSWs not only in the equatorial region but globally in the northern and southern hemispheres. Ionospheric currents and their associated magnetic perturbations should be more frequently used to quantify SSW effects in observations and numerical models.
- Not all SSW periods occur during geomagnetic quiet times (e.g., 2010, 2013), and separating geomagnetic activity signals from SSW signals remains a challenge. Numerical modeling can be used as one way of delineating the two effects.
- Recent results of the 2013 SSW period under medium/high solar flux condition have shown as large of an ionospheric effect as for the 2009 SSW which occurred during solar minimum conditions although the planetary wave forcing in 2009 was larger than in 2013. These results reveal that SSWs are an important source of ionospheric variability throughout the solar cycle. First results indicate that the ionosphere is electrodynamically coupled via a modified wind system to the lower atmosphere.
- During SSW periods the observed ionospheric signals exhibits a longitudinal dependence. Efforts should focus on understanding the ionospheric longitudinal variations attributed to SSWs, examining the corresponding longitudinal variations in the ionospheric electric fields, and evaluating the extent to which models reproduce the observed longitudinal variations during SSWs.