Observations of pole-to-pole, stratosphere-to-ionosphere connection

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Coupling from above:
Solar, magnetospheric and geomagnetic processes

Traditional school of thought:
Solar + magnetospheric drivers are dominant
Primary example: Geomagnetic storm

New school of thought:
Lower atmosphere drivers can be dominant
Primary example: Sudden stratospheric warming

Coupling from below:
Gravity waves (GW), tides, planetary waves (PW)

• Geomagnetic storms and sudden stratospheric warmings are two extremes
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Primary example:
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“We have reached a paradigm shift, where any self-respecting space weather model of the upper atmosphere now needs to have some representation of the lower atmosphere” – Jackson et al., Space Weather, Oct 2019
Special case: sudden stratospheric warming

- Large disruption of the polar vortex
- Largest known meteorological disturbance
- Rapid increase in temperature in the high-latitude stratosphere (25K+); from winter-time to summer-time
- Accompanied by a change in the zonal mean wind
- **Anomalies last for a long time in the stratosphere (2 weeks +)**
- SSW events occur 1-3 times per winter

**“Normal” polar vortex is small, round, centered on the North Pole**

**Disturbed vortex is broken into 2 cells**

**Disturbed vortex is broken into 4 cells**
Early 2014 North American cold wave

- Record (or near record) temperatures:
  - -37°F in Babbit, Minnesota
  - -9°F in Marstons Mills, MA
  - 21°F in Huston, 31°F in Tampa, FL
- 49 record lows for the day across the country on January 7
- Heavy snowfall or rainfall + strong winds
- 23.8 inches of snow in Boxford, MA
- $5 billion in damage, 21 fatalities

Ongoing blizzard across Ohio River Valley and Northeastern US as cold air from Canada moves across warm air from the Gulf of Mexico. A GOES-13 image on January 2, 2014

Ice formations on the Schuylkill River in Philadelphia
... and in Massachusetts ...

...we should have fixed the snowblower...

This is me

This is my mailbox
Ionospheric response to sudden stratospheric warming: plasma motion and dramatic TEC changes

• Upward drift in the morning, downward in the afternoon – enhanced 12-hr tide
• Related increase and decrease in electron density
• Reviews Chau et al., 2012; Goncharenko et al., 2019

Entire daytime low to mid-latitude ionosphere is affected during stratoswarming; Total Electron Content change 50-150%

Results included in the space physics textbook in 2015
Variety of effects during SSW: from Arctic stratosphere to mesosphere over Antarctica

From Pedatella et al., 2018
AGU EOS
Variety of effects during SSW: from Arctic stratosphere to mesosphere over Antarctica and ionosphere

From Pedatella et al., 2018
AGU EOS
Interhemispheric coupling (IHC) between winter stratosphere and summer mesosphere is an established phenomenon (Becker and Schmitz, 2003; Becker and Fritts, 2006; Tan et al., 2012).

- Aura MLS temperature increase and CIPS PMC frequency drop shows SH mesospheric warming during SSW 2013.

See also de Wit, 2015.
Southern Hemisphere anomalies in TEC

- Large positive TEC anomaly appears in the 40-70oS
- Extends to high latitudes in the Southern Hemisphere and modifies Weddell Sea anomaly
- TEC model for 75°W is developed from 15+ years of TEC data (Goncharenko et al., 2018)
Increase in TEC during SSW in the morning to afternoon sector and around local midnight.

TEC control day
Jan 15, 2012
F10.7=133, Ap=4

TEC During SSW
Jan 16, 2013
F10.7=137, Ap=5
Anomalous variations in NmF2 observed at both locations

Increase in daytime NmF2 by a factor of ~2 at 51°S, Port Stanley and 65°S, Vernadsky
Summary

- Persistent mesospheric anomalies over Antarctica in January 2013 are an example of interhemispheric coupling.
- Mesospheric anomalies are observed with two independent datasets, Aura MLS and CSIPS on AIM.
- Ionospheric anomalies are observed with two independent techniques, GNSS TEC and ionosondes.
- Increase in TEC/NmF2 by a factor of ~2.
- The results provide strong observational evidence that Arctic SSW events generate truly global disturbances that reach high latitudes and altitudes of the opposite hemisphere.
- These observations show for the first time that interhemispheric coupling extends all the way to the thermosphere and ionosphere.