Inter-hemispheric coupling in the atmosphere: Processes and consequences

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With
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Traditional picture of the atmosphere

A series of non-interacting layers

Uniform in latitude

Energy exchange:
  Radiation
  Latent heating (troposphere)
What is causing the summer cooling/winter warming?
Wave Breaking

- Waves propagate upward against wind, growing in amplitude to conserve energy.
- Become non-linear and overturn depositing energy and momentum locally.
- Large-scale Planetary waves (westward momentum) break in the Stratosphere.
- Small-scale Gravity waves (east or west momentum) break in the Mesosphere.
How our understanding has evolved
How our understanding has evolved

Waves: Primary way the atmosphere exchanges energy vertically

Atmospheric and Environmental Physics

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Planetary Waves
Gravity Waves
Zonal Winds
Circulation

Pole
Equator
Pole

Winter
Summer

Mesosphere
Stratosphere
Troposphere

Kilometers
90
80
70
60
50
40
30
20
10

Noctilucent
Gravity wave energy deposited here drives Pole-to-Pole circulation.

Convergent flow: Heating

Divergent Flow: Cooling

Waves: Primary way the atmosphere exchanges energy vertically.
How our understanding has evolved

Gravity wave energy deposited here drives Pole-to-Pole circulation

Waves: Primary way the atmosphere exchanges energy vertically

Convergent flow: Heating

Divergent Flow: Cooling

Planetary wave energy deposited here drives poleward flow

Zonal Winds

Equator

Gravity Waves

Planetary Waves

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Pole
What happens during a stratospheric warming event (SSW)?

• Planetary waves break in stratosphere and their westward momentum decelerates polar vortex
• Creates enhanced poleward flow in stratosphere from westward momentum and Coriolis force.
• Enhanced convergent flow creates a warm polar stratosphere
Zonal winds during strat-warm

4-day moving average zonal wind over Trondheim, Norway (2012-2013)
Shows wind reversal over the entire atmospheric column during SSW

Each new batch of waves must interact with wind regime created by previous batch
Gravity wave momentum flux

Wave forcing (dp/dz) helps to restore winter conditions

GW momentum from below reverses as stratospheric wind reverse

de Wit et al., GRL 41, 2014.
Vertical coupling driving interhemispheric effects

Remember temperature perturbations expected from the BKK-mechanism:

Established by Holton (1983)

Based on Körnich and Becker (2010)

Thermal wind/wave interactions suggested to extend effects to opposite hemisphere
Interhemispheric coupling during the 2013 major SSW

Remember temperature perturbations expected from the BKK-mechanism:

Place these on top of the MLS observed zonal mean temperature perturbations shortly after the onset of the 2013 major SSW
Global middle atmosphere temperature response during the 2013 major SSW

Place these on top of the MLS observed zonal mean temperature perturbations shortly after the onset of the 2013 major SSW:

SSW perturbations extend below 100 hPa in opposite hemisphere

Initial disturbance propagates to surface by modifying wave propagation (NH)

Daily surface temperature anomalies 1-60 days after stratospheric anomalies

Cold-air outbreak associated with tropospheric jetstreams moving southward

Winter Storm Severity Index for Weak (SSW) and Strong (No-SSW) conditions

Thompson et al. J. of climate, 2001
Initial disturbance propagates to ionosphere by modifying tidal-wave propagation

**Graph a:**
- Title: GPS TEC at 10LT (15UT), 75°W
- X-axis: Jan 01 to Feb 20
- Y-axis: Latitude (°)
- Legend: Total electron content at 10 LT, 75°W

**Graph b:**
- Title: GPS TEC at 16LT (21UT), 75°W
- X-axis: Jan 01 to Feb 20
- Y-axis: Latitude (°)
- Legend: Total electron content at 15 LT, 75°W

**Graph c:**
- Title: Stratospheric temperature and 30-yr average
- X-axis: Jan 01 to Feb 20
- Y-axis: T (K, 10hPa)
- Legend: 90°, 90°med

*Goncharenko et al., GRL 37, 2010*
Summary/conclusions

- Wave/wave and wave/mean-flow interactions couple the atmosphere vertically 100 hPa–300 km

- Resulting latitudinal temperature gradients can spread this effect to equatorial latitudes

- Observe effects of NH disturbance all the way to the opposite pole

- Mechanism for this SH coupling is yet to be confirmed by observation

Future collaboration with PANSY radar @ Syowa?
As always, more complicated than expected