Aura MLS observations of the polar middle atmosphere: Dynamics and transport of CO and H$_2$O

Jae N. Lee$^{1,2}$, Dong L. Wu$^1$, Gloria L. Manney$^{1,3}$, Michael J. Schwartz$^1$, Alyn Lambert$^1$, Nathaniel J. Livesey$^1$, Kenneth R. Minschwaner$^3$, Hugh C. Pumphrey$^4$, and William G. Read$^1$

1. Jet Propulsion Laboratory, Caltech, Pasadena, CA
2. NASA Postdoctoral Program Fellow
3. New Mexico Institute of Mining and Technology, Socorro, NM
4. University of Edinburgh, UK
Outline

• EOF analysis and annular modes
• NAM and SAM from MLS GPH, CO, and H$_2$O
• Vertical descent of NAM and SAM
• Perturbations at 50 km descend to the lowermost stratosphere;
• Tropospheric weather patterns follow;
• Surface pressure perturbation patterns are called the Arctic Oscillation (AO) pattern;
• Stratospheric events show impacts on location of storm tracks.
• MLS observations – up to 90km. EOF analysis from Nov. – March.
- Vertical and horizontal gradients of zonal mean CO and H2O structure.
- How does the polar descent shape up the tracer distribution?
- What is going to change during SSW? -> with strong perturbations.
If the tracer distribution has a meridional gradient that is not constant with height and time, and has a pronounced maximum somewhere, sometime, it may contain downward transport information.
EOF1 or NAM/SAM

GPH

(a) GPH (m): low index: 0.1 hPa
(b) GPH (m): high index: 0.1 hPa

CO

(d) CO (ppmv): low index: 0.1 hPa
(e) CO (ppmv): high index: 0.1 hPa

% of Variance

(c) NAM and SAM: variances (%)
(f) CNAM and CSAM: variances (%)
Low Index

EOF1 or NAM/SAM

High Index

% of Variance

(g) $\text{H}_2\text{O} \text{ (ppmv) low index: 0.1 hPa}$

(h) $\text{H}_2\text{O} \text{ (ppmv) high index: 0.1 hPa}$

(i) $\text{H}_2\text{O} \text{ (ppmv) low index: 10 hPa}$

(j) $\text{H}_2\text{O} \text{ (ppmv) high index: 10 hPa}$

(k) $\text{H}_2\text{O} \text{ (ppmv) low index: 56 hPa}$

(l) $\text{H}_2\text{O} \text{ (ppmv) high index: 56 hPa}$

(m) HNAM and HSAM: variances (%)
60°N-82°N

CO (log ppmv)

H2O (log ppmv)


Mesospheric CO NAM Index

- Mesosphere and stratosphere CNAM anti-correlated

- Planetary and Gravity wave coupling

- weak vortices in the stratosphere (low index)

→ Prevents gravity wave propagating upward

→ forming strong vortex in the mesosphere

→ Siskind et al. [2010]
Conclusion

• NAM/SAM (GPH) dominates the variance of polar winter in the broad range of altitude.
• MLS CO acts as a good tracer to polar atmospheric dynamics down to 30 km.
• More Rapid descent occurs in the upper mesosphere than in the stratosphere.
• Strong coupling is evident between middle and upper atmospheric CNAM, through interactions between planetary and gravity waves.
Acknowledgement

• All MLS team members
• Co-authors and reviewers
GPH

H₂O

0.1 hPa

10 hPa

30 hPa

CO

(a) SAM: 0.1 hPa: 88%
EOF2: 0.1 hPa: 2.5%
EOF3: 0.1 hPa: 1.6%

(b) CSAM: 0.1 hPa: 49%
EOF2: 0.1 hPa: 3.2%
EOF3: 0.1 hPa: 2.6%

(c) HSAM: 0.01 hPa: 57%
EOF2: 0.01 hPa: 4.6%
EOF3: 0.01 hPa: 2.7%

(d) HSAM: 4.64 hPa: 52%
EOF2: 4.64 hPa: 8.8%
EOF3: 4.64 hPa: 4.2%

(e) HSAM: 56.2 hPa: 49%
EOF2: 56.2 hPa: 6.4%
EOF3: 56.2 hPa: 5.9%

Jae N. Lee (JPL) / Aura 2010 Science Meeting
• 100-yr model runs and NCEP re-analysis reveal a strong leading EOF mode, the annual mode;

• Variations are forced by eddy fluxes in the troposphere;

• Stationary waves dominate the NH eddies;

• High-frequency transients dominate the SH eddies.

Jae N. Lee (JPL) / Aura 2010 Science Meeting
GPH

Strong SSW

(a) GPH : 2005

2006

2007

2008

2009

2010

Jae N. Lee (JPL) / Aura 2010 Science Meeting
Rosenfield et al. (1994)

- 1.3-2 km per month in the NH lower stratosphere
- 0.4-0.9 km per month in the SH lower stratosphere
- Descent rate increasing rapidly with height

Antarctic air parcel descent inside vortex

Modeled Antarctic air parcel descent inside vortex

Jae N. Lee (JPL) / Aura 2010 Science Meeting
• AO is often called Annular mode in the stratosphere.
• Annular mode and sea ice extent?
• Dynamical coupling between the troposphere and stratosphere?
• Impacts of global warming on AO?
• Regional extreme weather?

White England

MODIS image on Jan 7, 2010

Credit: National Snow and Ice Data Center