Microwave Limb Sounder Observations of Polar Middle Atmosphere: Decadal and Inter-annual Variability

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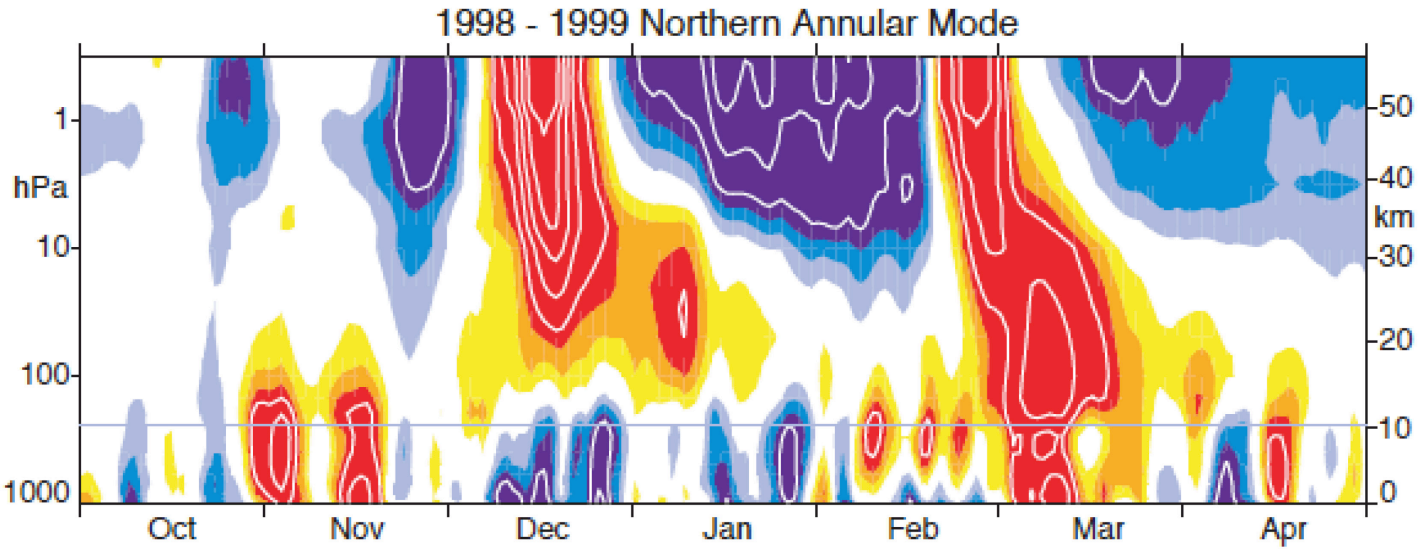
Motivation



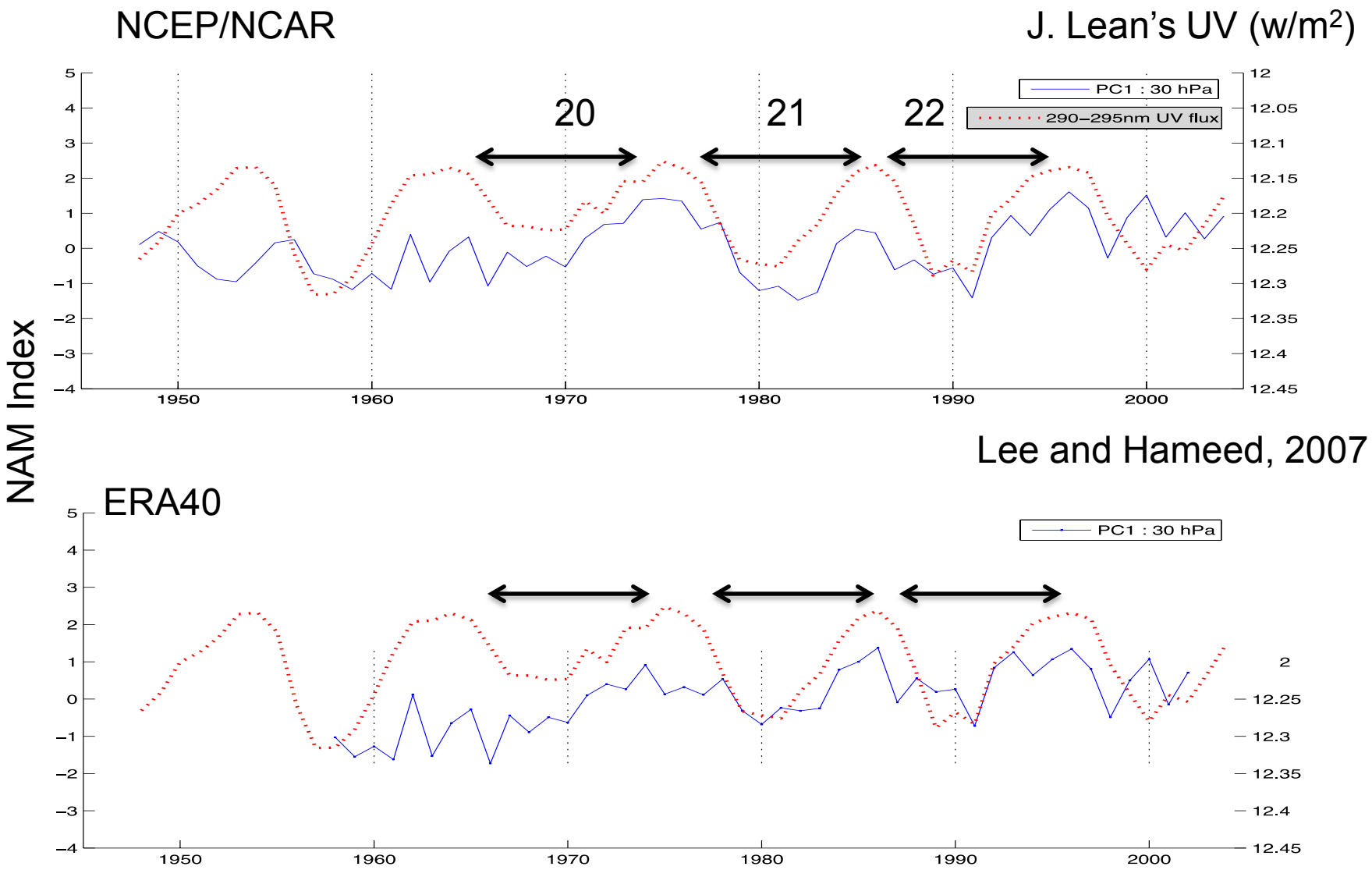
Baldwin and Dunkerton (2001)

- Why I care mode of variability?

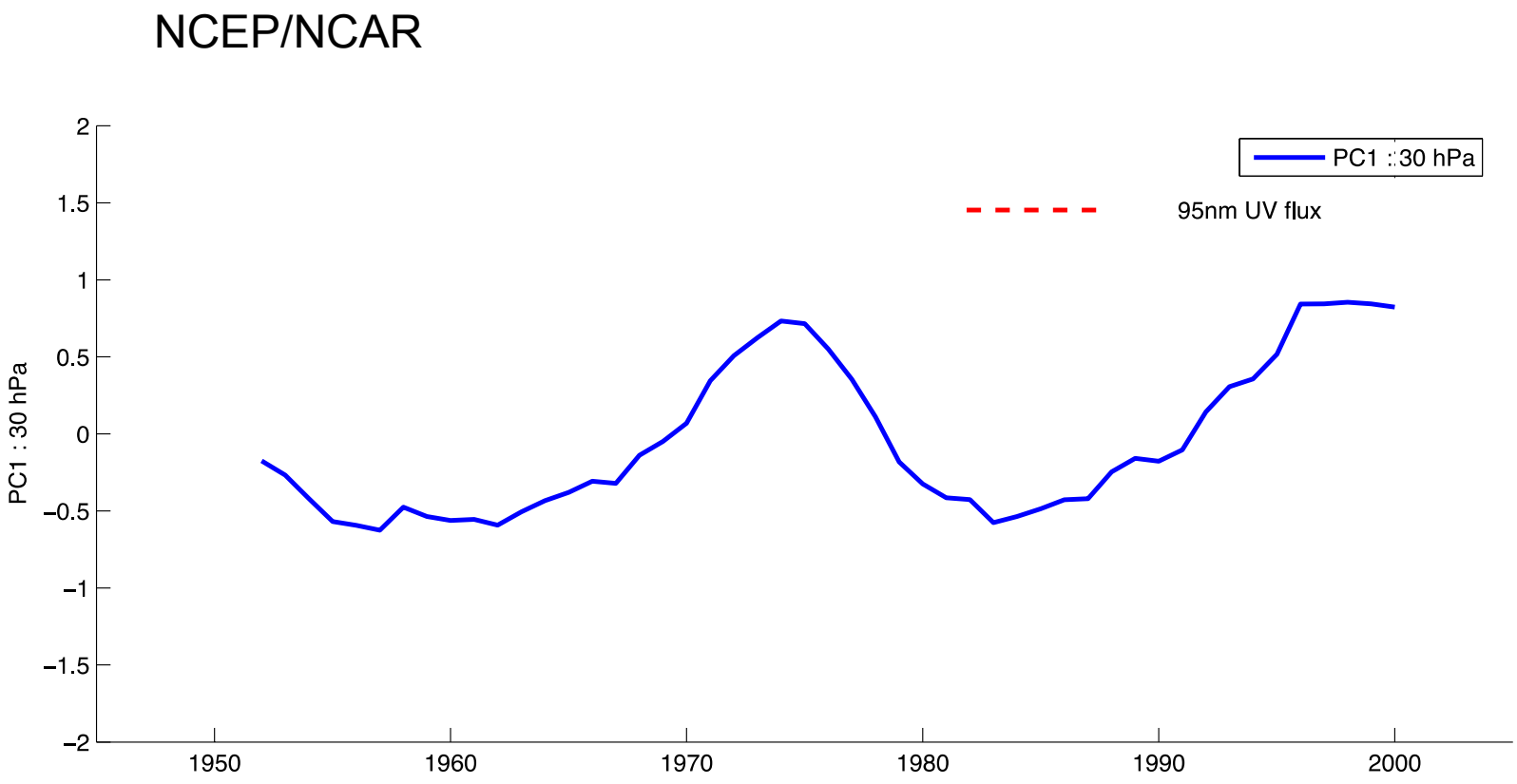
  - to diagnose the dynamics and transport

  - to see the stratosphere-troposphere, mesosphere-stratosphere couplings

Summer NAM at 30 hPa and UV

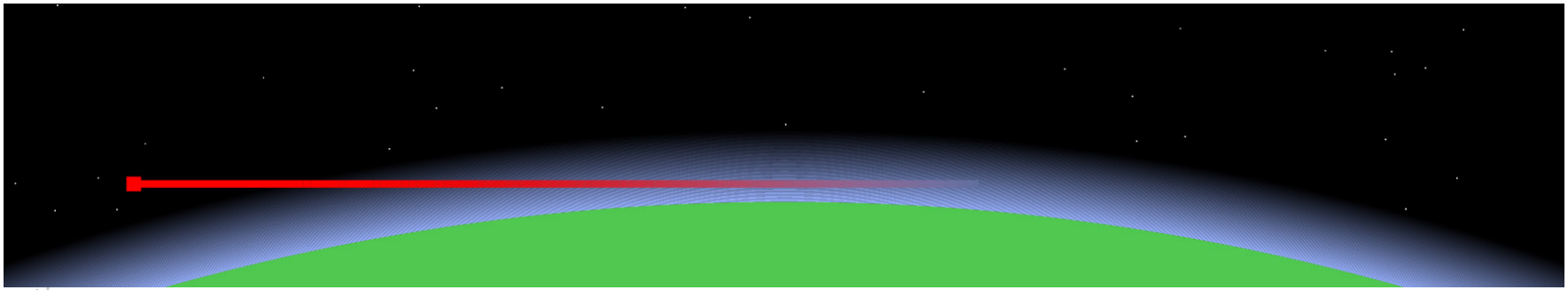


Summer NAM and UV

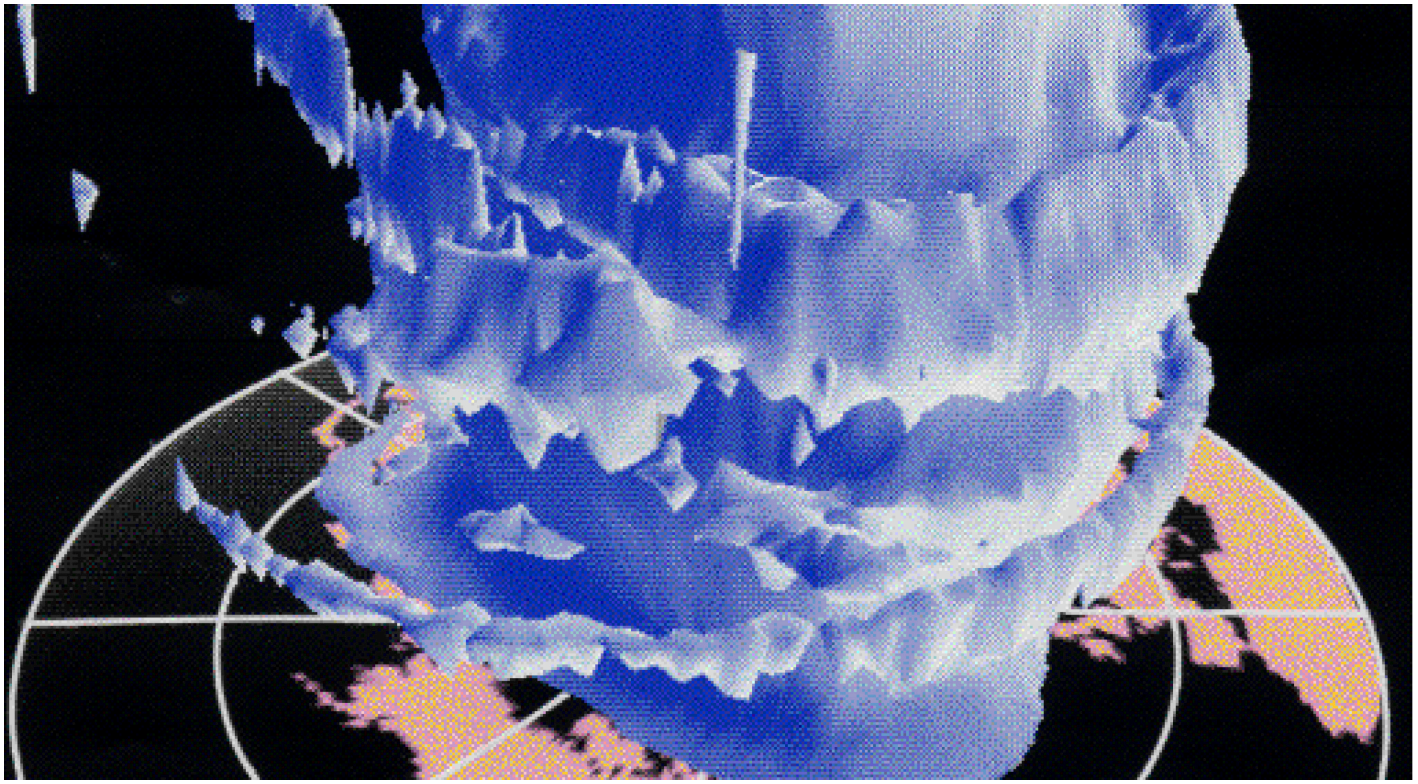


Microwave Limb Sounder (since 2004- on going)

- The MLS observe thermal microwave emission from rotational lines of atmospheric molecules
- Rather than looking straight down (nadir), MLS instruments scan up and down in the limb geometry (edge onto the atmosphere)
  - This gives good vertical resolution.
  - The longer path length compared to nadir viewing gives a stronger signal for trace species (H_2O, O_3, CO, OH, etc) and temperature.
  - Calibrations of MLS are less sensitive to solar variability than UV/VIS/IR instrument.
  - Microwave can measure the water vapor even in presence of the ice clouds and aerosols.



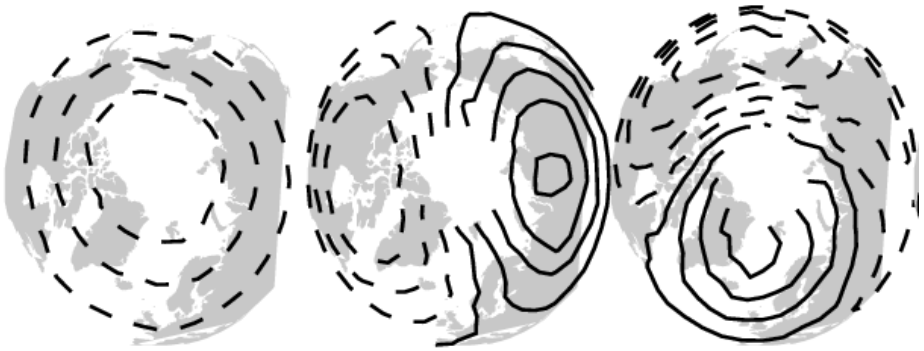
3-D visualization of polar vortex : GFDL model



Courtesy : Kevin Hamilton

The NAM patterns from the MLS (2005-2009)

MLS 0.002hPa



1hPa

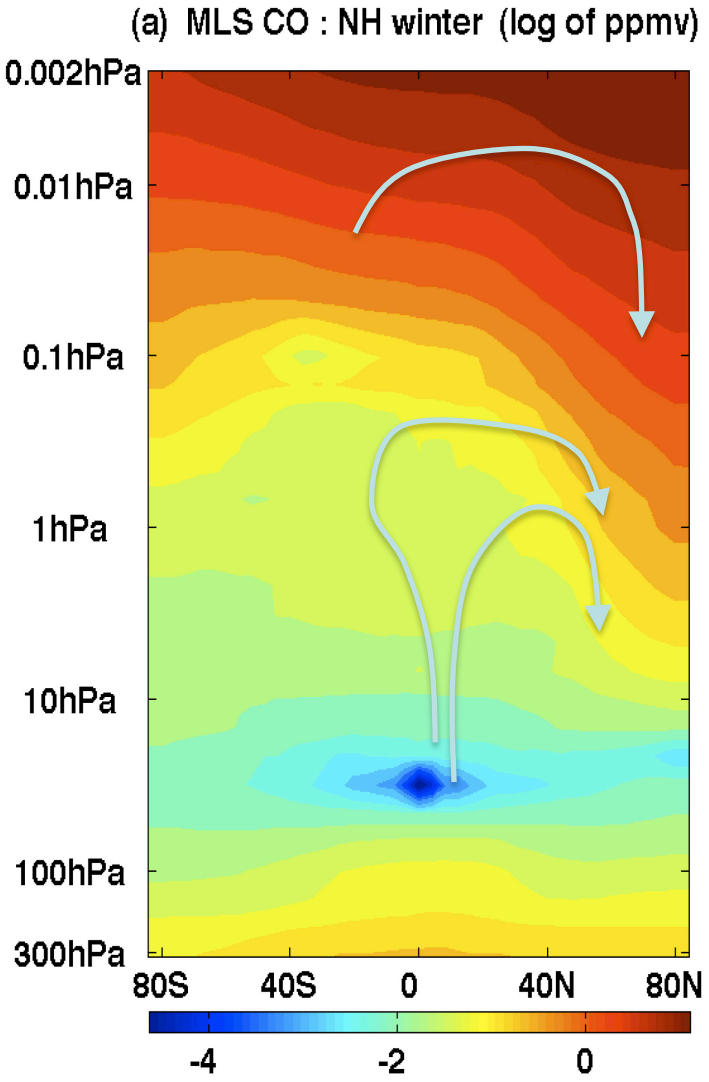
- NAM structure exists in the mesosphere.
- The NAM patterns derived from the MLS observations are consistent with those derived from long-term reanalysis below the middle stratosphere.

First annular mode : the same structure, with higher amplitudes at the pole

Second and third : orthogonal wave 1 patterns

Lee et al., GRL, 2009

Aura MLS CO : DJF



- Vertical and horizontal gradients of zonal mean CO

- How does the polar descent shape up the tracer distribution?

- What is going to change during SSW? -> with strong perturbations.

- Besides geopotential height, the mode was constructed with CO field.

Lee et al., 2011

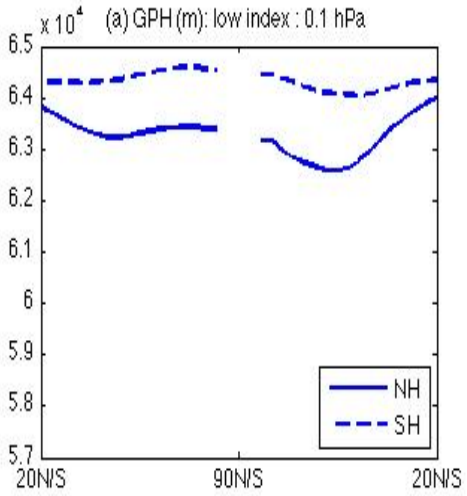
EOF1
or
NAM/SAM

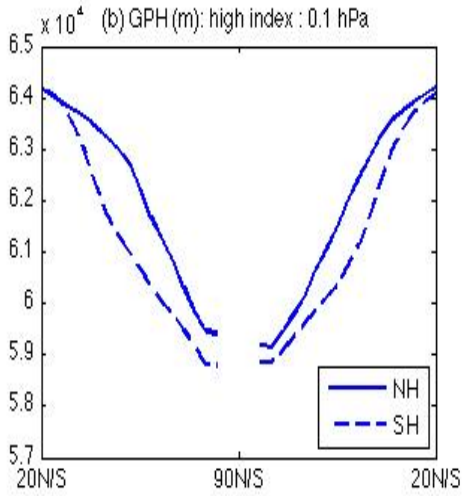
Low Index

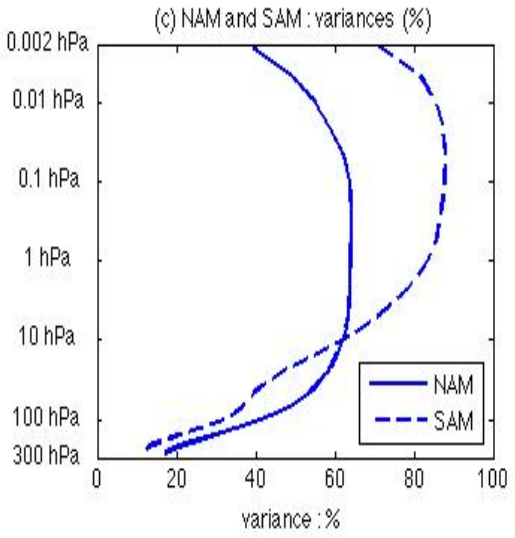
High Index

% of Variance

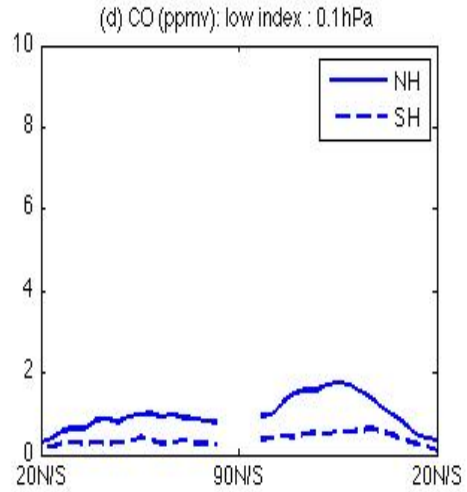
GPH

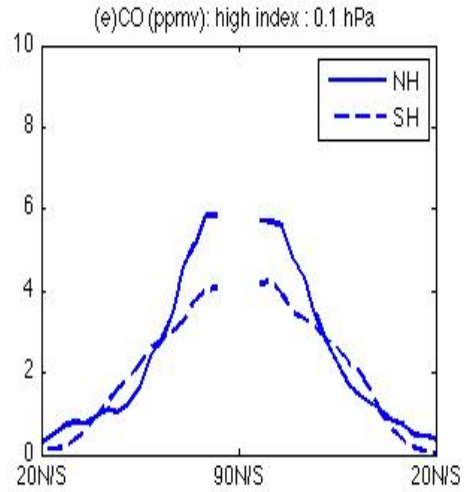


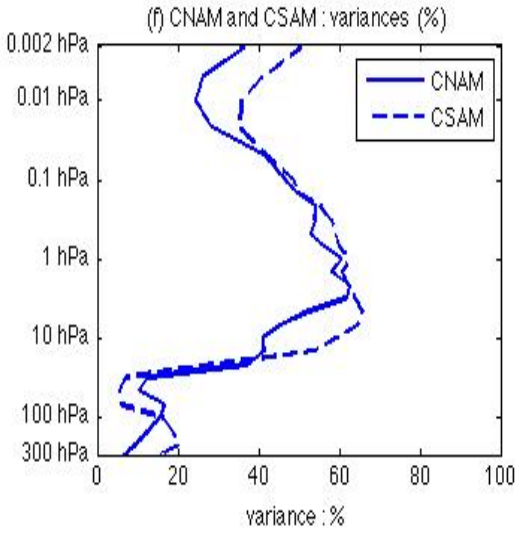


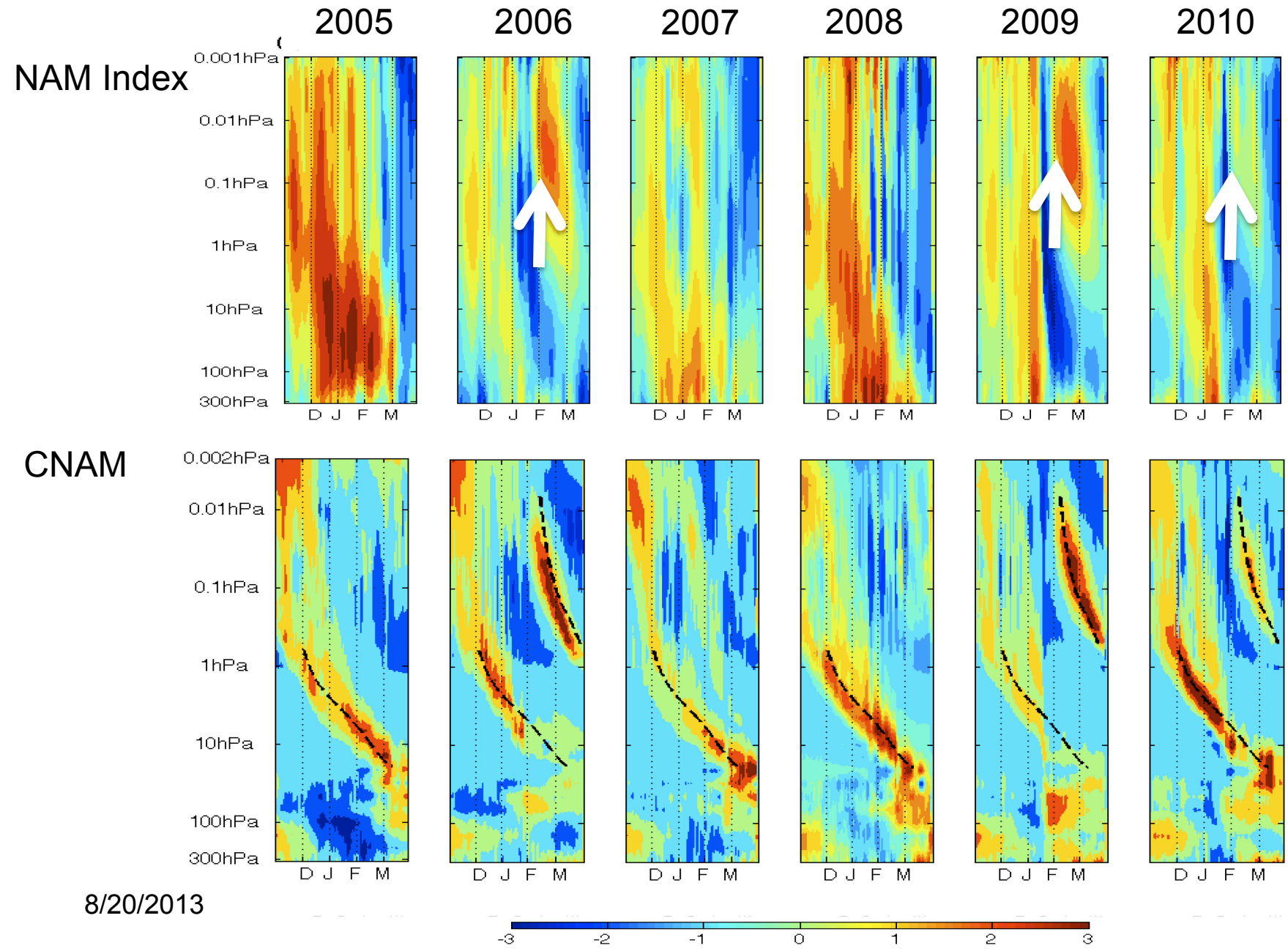


CO







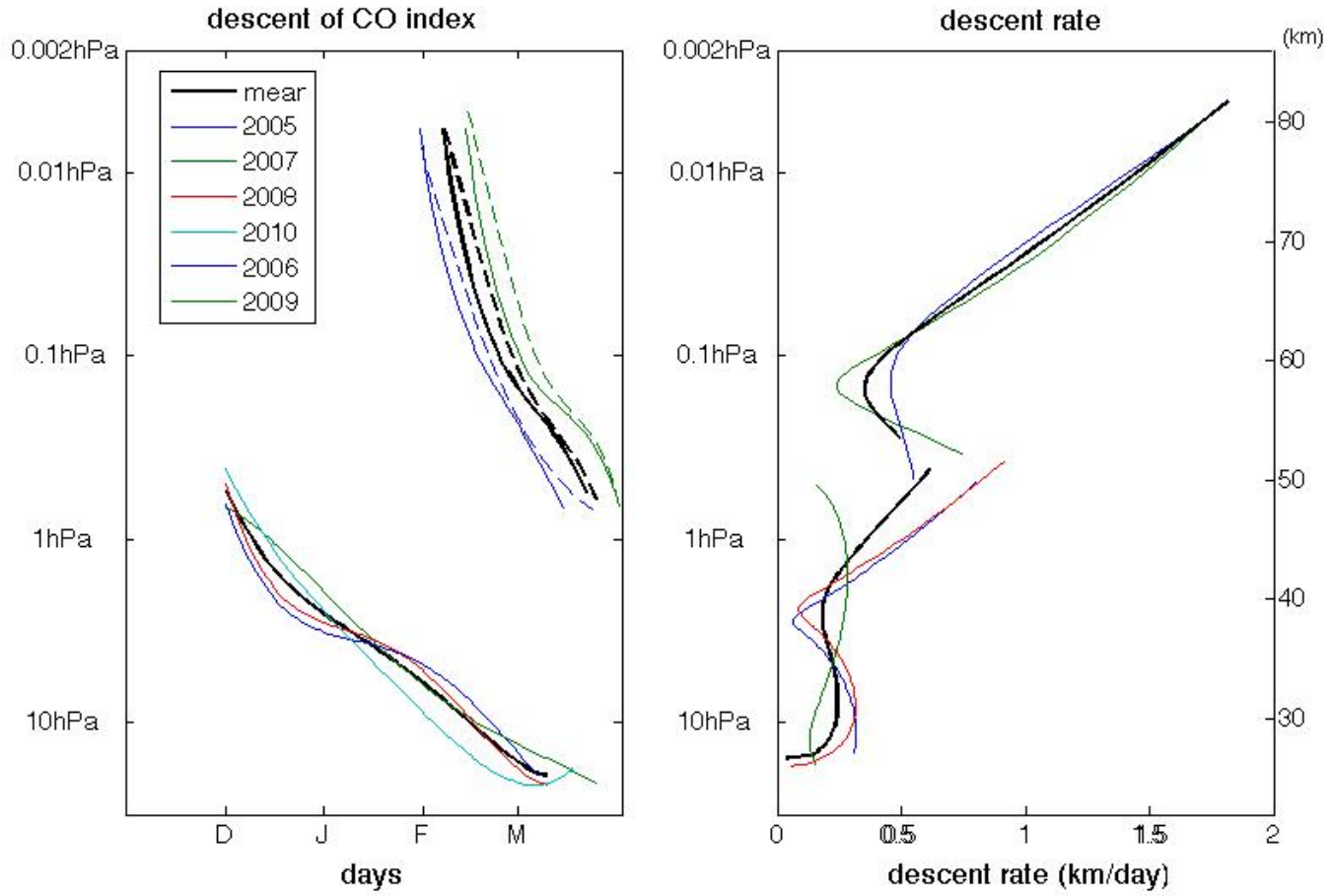

2005
2006
2007
2008
2009
2010
NAM Index
0.001hPa
0.01hPa
0.1hPa
1hPa
10hPa
100hPa
300hPa
D J F M
CNAM
0.002hPa
0.01hPa
0.1hPa
1hPa
10hPa
100hPa
300hPa
D J F M
-3
-2
-1
0
1
2
3

8/20/2013

60° N-82° N zonal mean CO

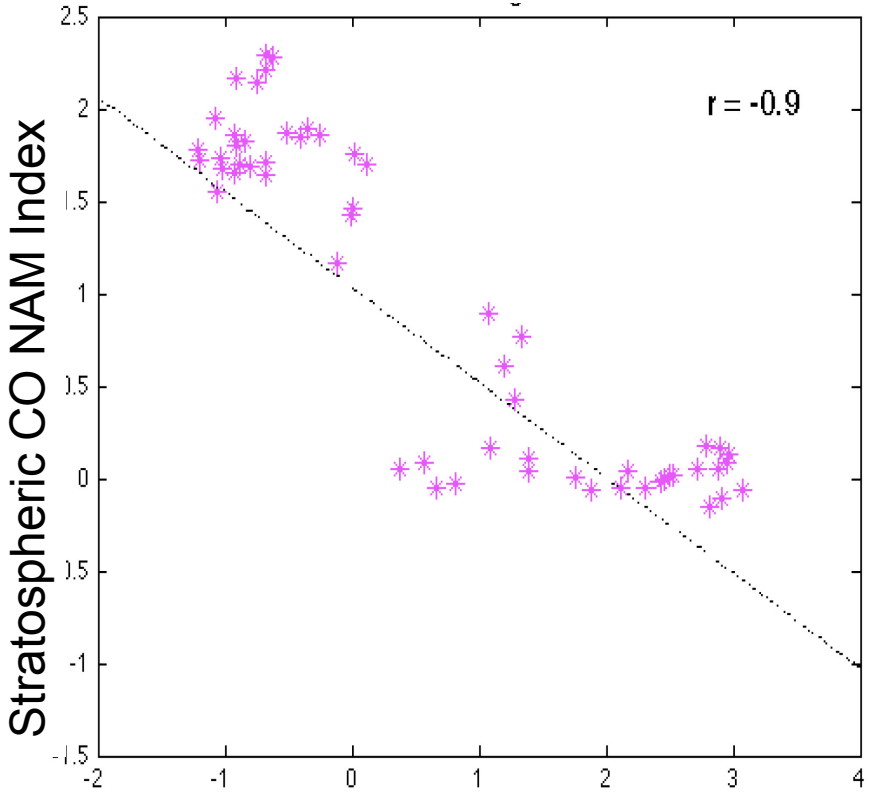
(log ppmv)

-CO NAM index line follows the maximum anomaly CO descent.


descent of CO index
0.002hPa
0.01hPa
0.1hPa
1hPa
10hPa
mear
2005
2007
2008
2010
2006
2009
D
J
F
M
days
descent rate
(km)
80
70
60
50
40
30
0
0.5
1
1.5
2
descent rate (km/day)

Planetary and Gravity Wave Coupling

CO NAM Index during 1 – 10 March



- Mesosphere and stratosphere CNAM anti- correlated

- Planetary and Gravity wave coupling

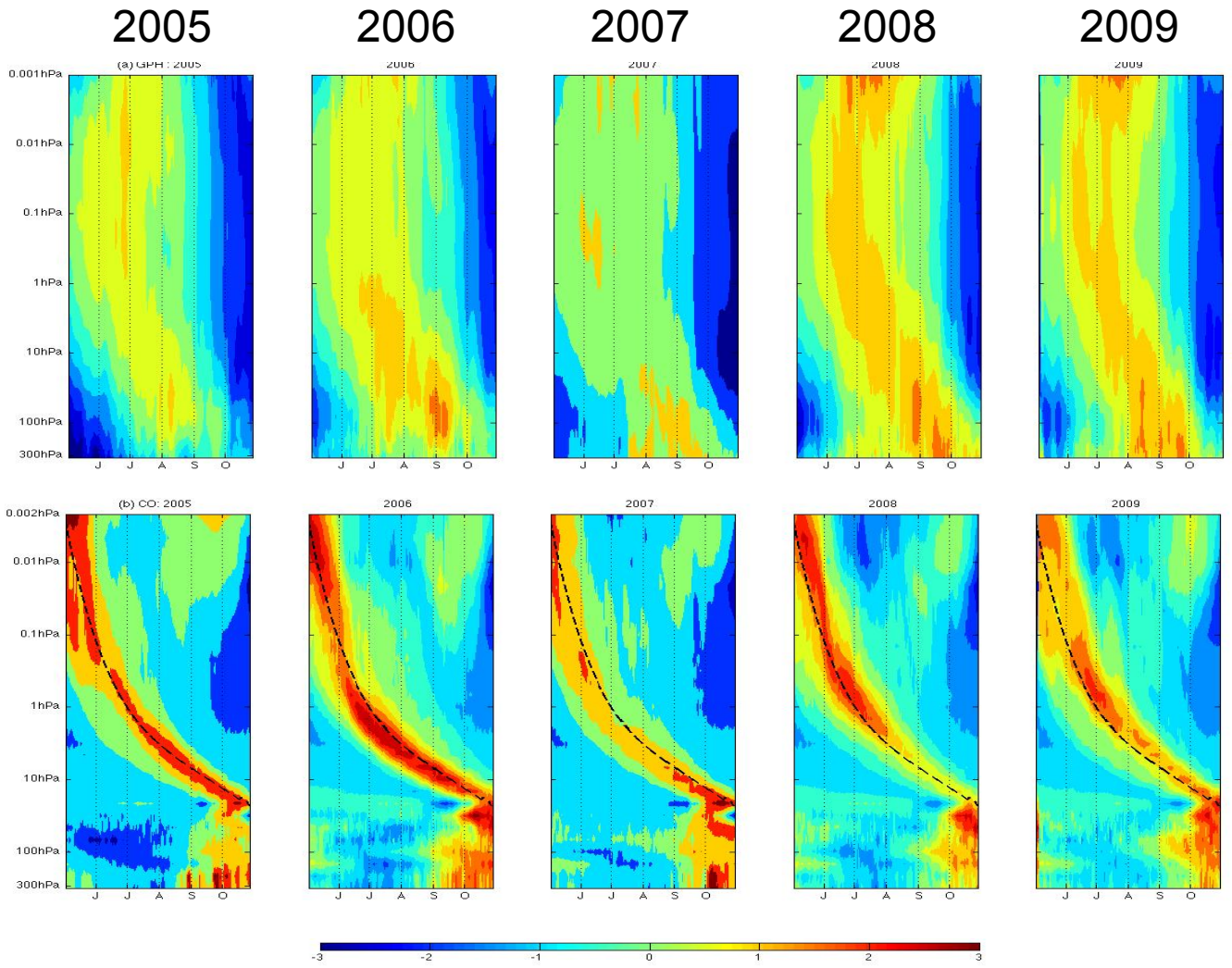
-weak vortices in the stratosphere (low index)

→ Prevents gravity wave propagating upward

→ forming strong vortex in the mesosphere

→ Siskind et al. [2010]

SAM Index



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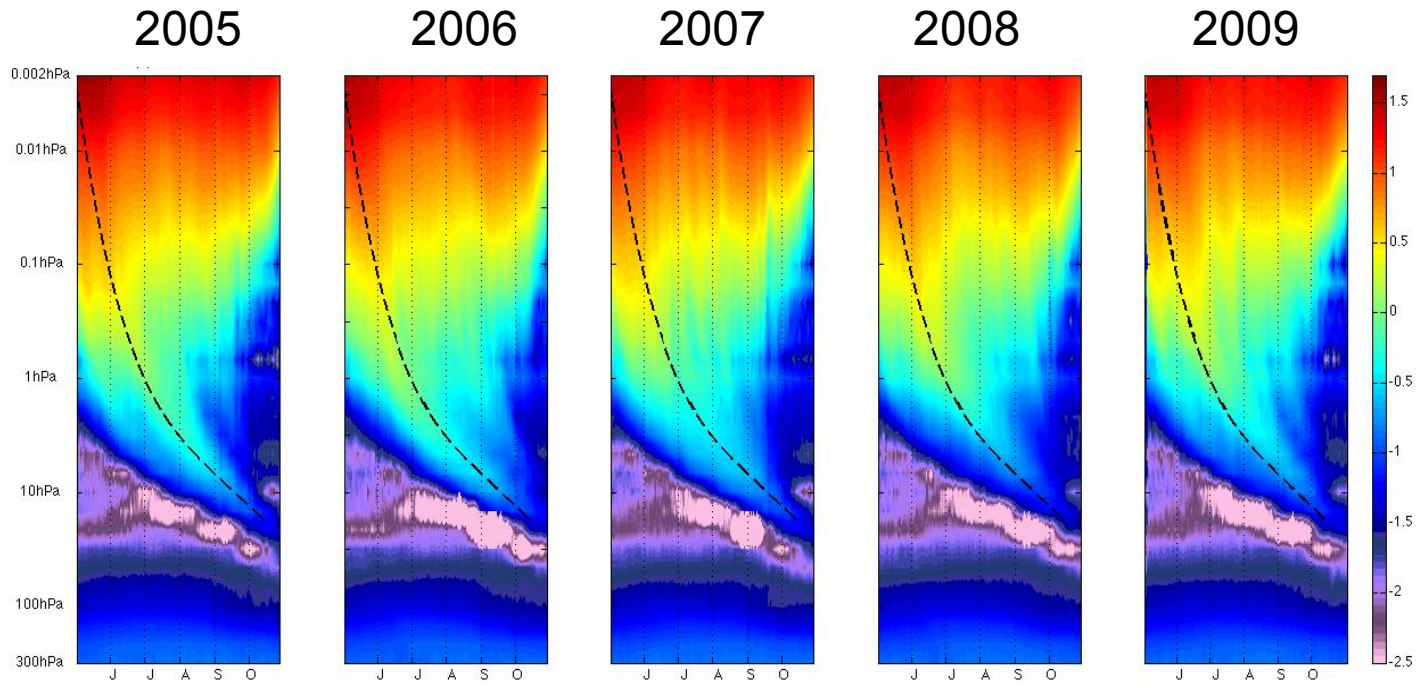
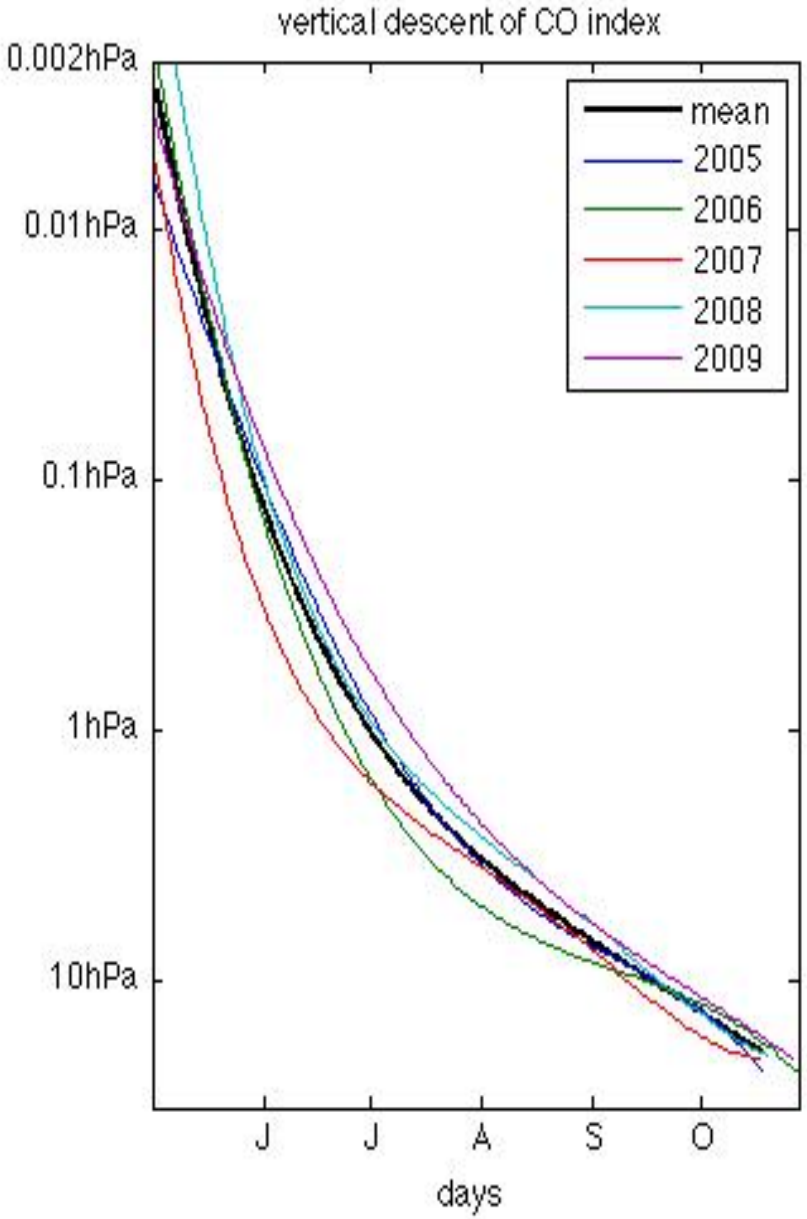
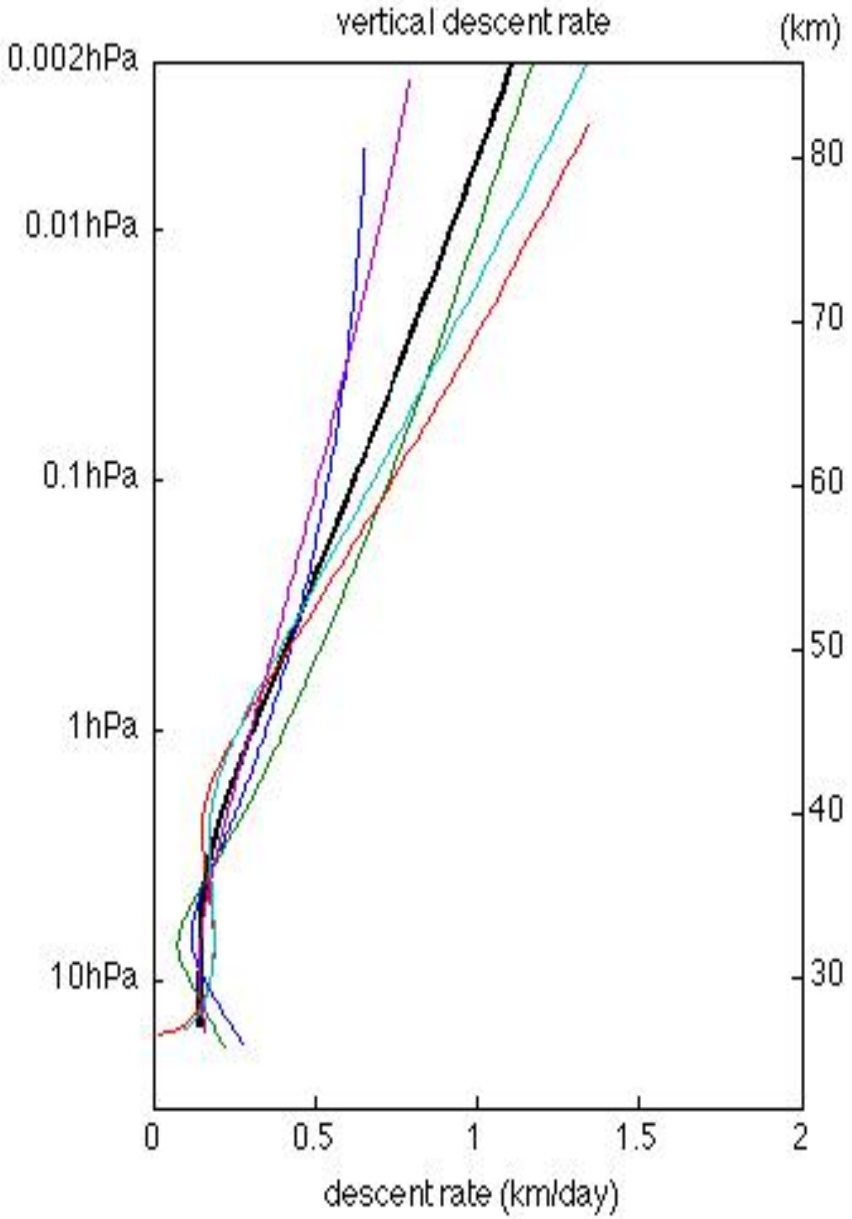
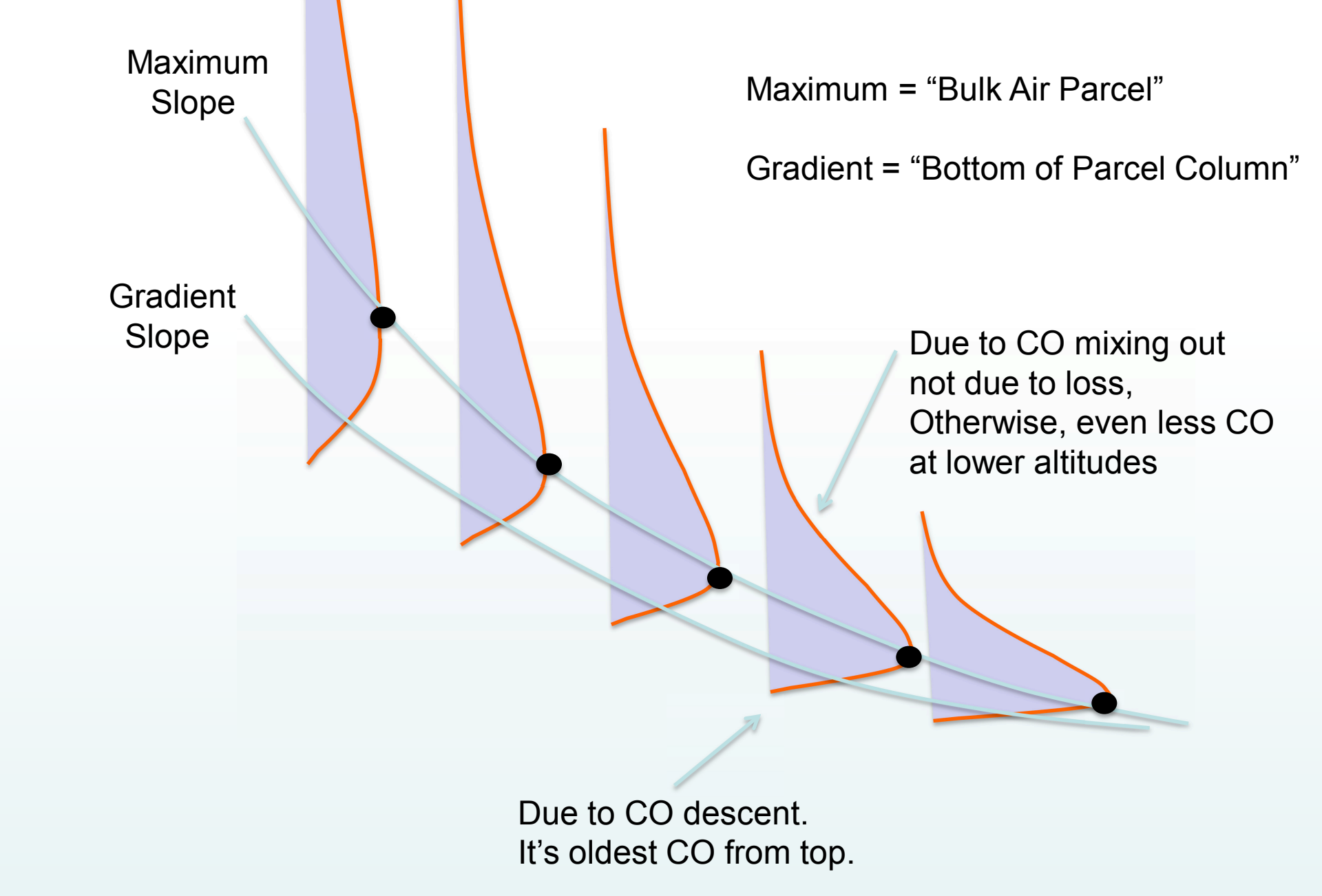
SORCE 2011, Sedona, Arizona

60° S-82° S zonal mean CO




vertical descent of CO index
0.002hPa
0.01hPa
0.1hPa
1hPa
10hPa
mean
2005
2006
2007
2008
2009
J
J
A
S
O
days


vertical descent rate
(km)
0.002hPa
0.01hPa
0.1hPa
1hPa
10hPa
80
70
60
50
40
30
0
0.5
1
1.5
2
descent rate (km/day)


Maximum
Slope
Gradient
Slope
Maximum = “Bulk Air Parcel”
Gradient = “Bottom of Parcel Column”
Due to CO mixing out
not due to loss,
Otherwise, even less CO
at lower altitudes
Due to CO descent.
It’s oldest CO from top.
Time

Conclusions

- Strong coupling in the middle atmosphere
- Descent is fast (~1km/day) in the upper level (~80km) and slows down to ~0.2km/day at 30km
- Inter-annual variability in NH and SH

Descent means?

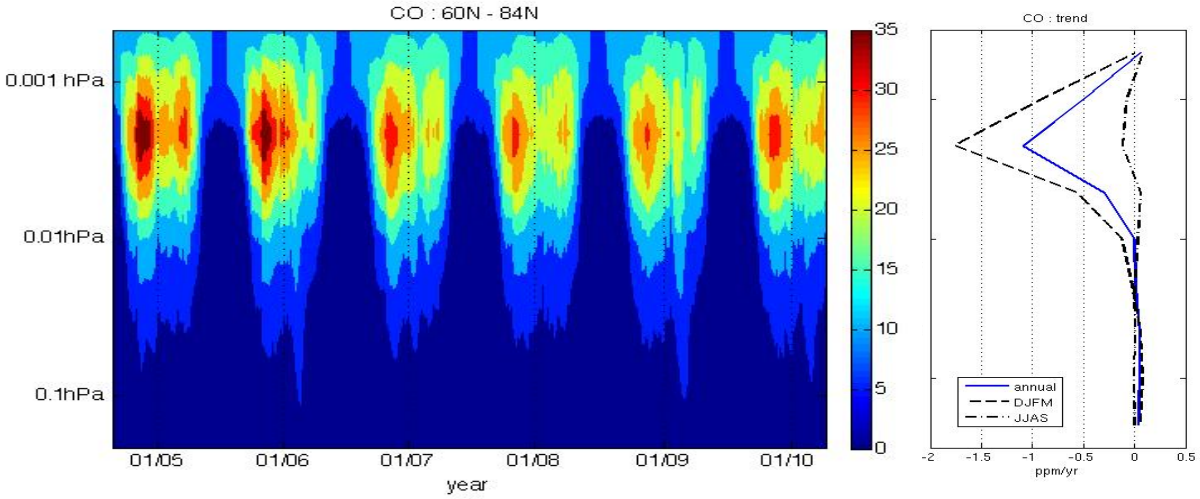
- Whole vortex descent?
- Constant mixing ratio gradient?
- Occurs at the center of air mass? Or at the bottom?
- Slope of the descent at the bottom of air mass is slower than that from the center of air mass.

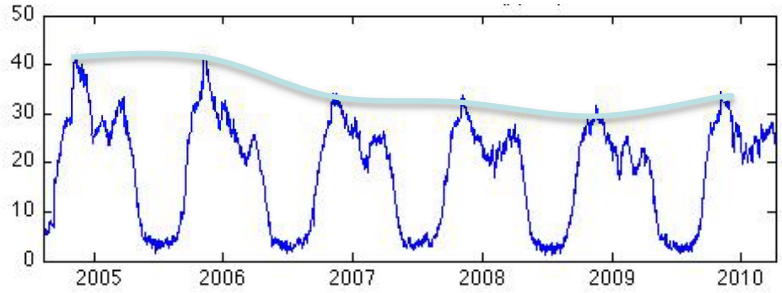
Future Plans

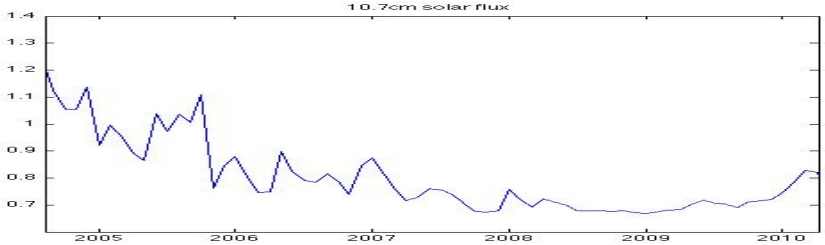
- Observational evidences of the solar signal in the middle and upper atmosphere
- Application of new remote sensing data to decadal variability
  - MLS and MEaSUREs, Korean GEMS in conjunction with SORCE SIM
  - Stratosphere-troposphere coupling

Zonal mean CO

High Lat (60N-84N)







— — - DJF

------ JJA

——— Annual mean

- CO decrease over 5 years during the winter (1.5ppmv/yr)

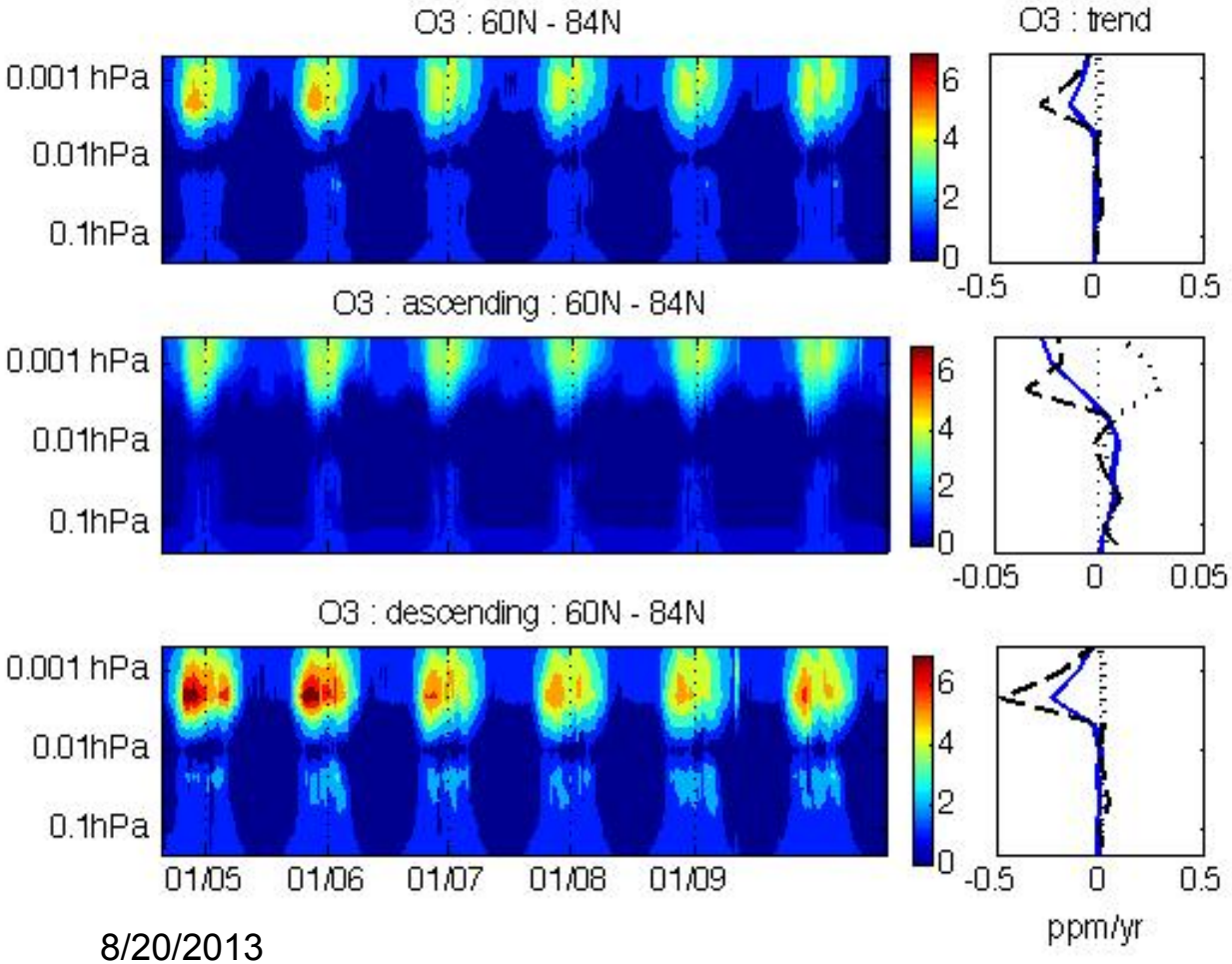
$CO_2 + hv \longrightarrow CO + O$

SORCE 2011, Sedona, Arizona

Zonal mean O_3

High Lat (60N-84N) in ppmv

DJF
JJA
Annual mean



- Decreasing trend since 2004 in the upper mesosphere (0.2ppmv/yr)

← day time

← night time

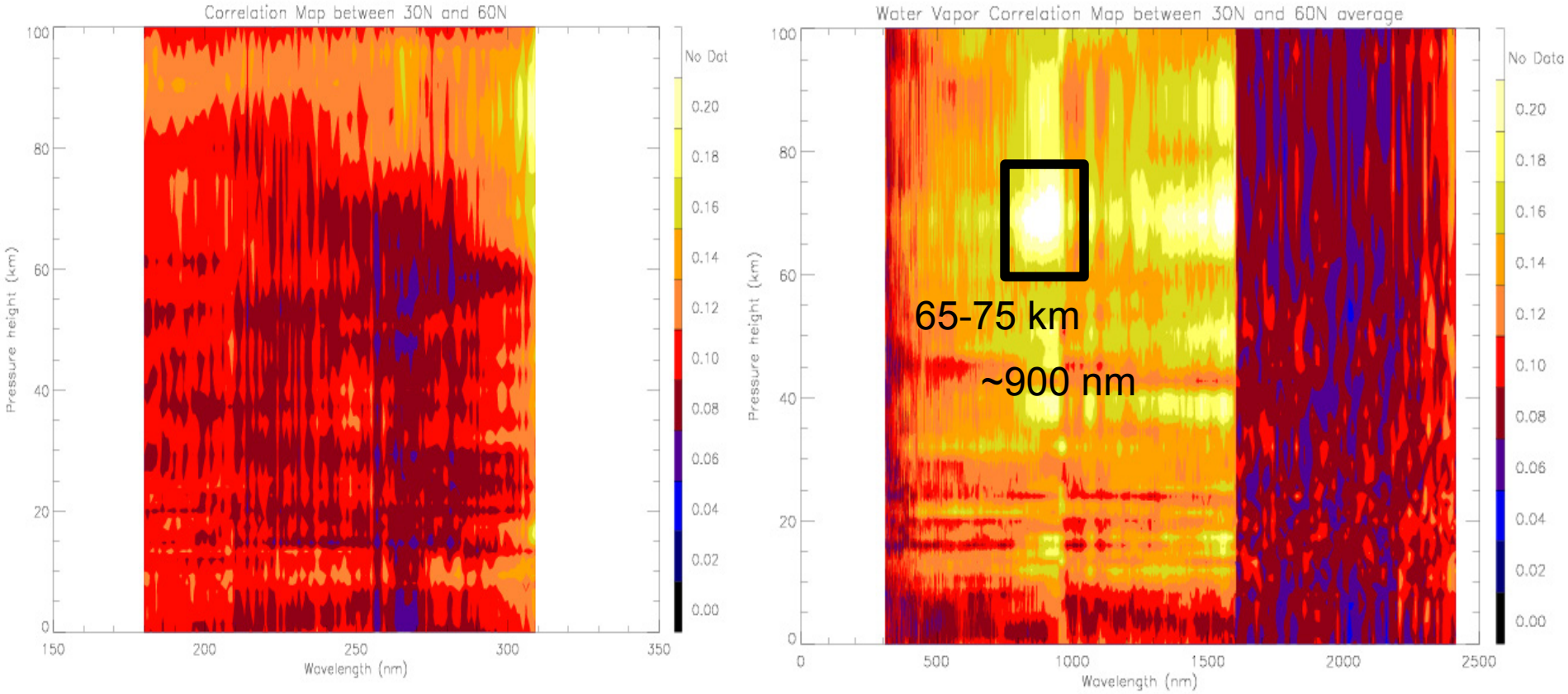
8/20/2013

SORCE 2011, Sedona, Arizona

Water Vapor : Correlation with spectral solar irradiance

30N-60N H_2O and SOLSTICE
180-310 nm

30N-60N H_2O and SIM
310-2413 nm



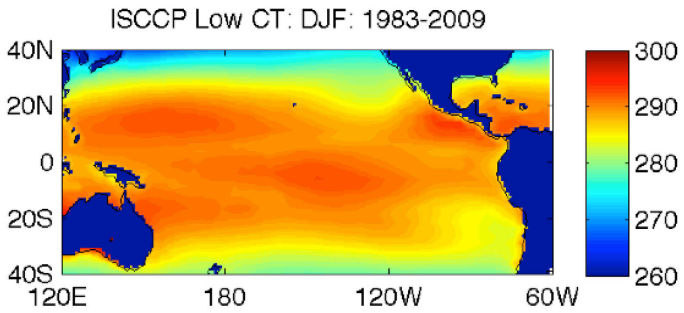
Courtesy : Greg Simonian

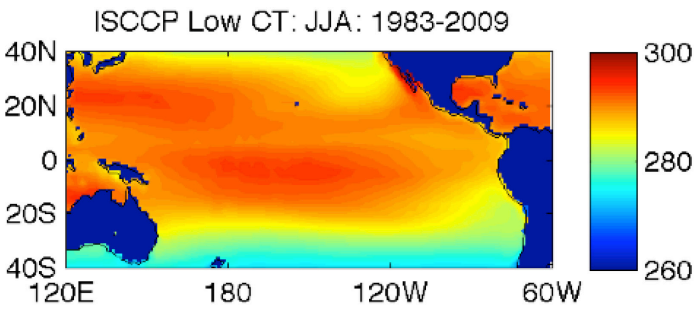
Solar impact on cloud variability?
ISCCP Low Cloud Top Temperature (1983-2009)

DJF

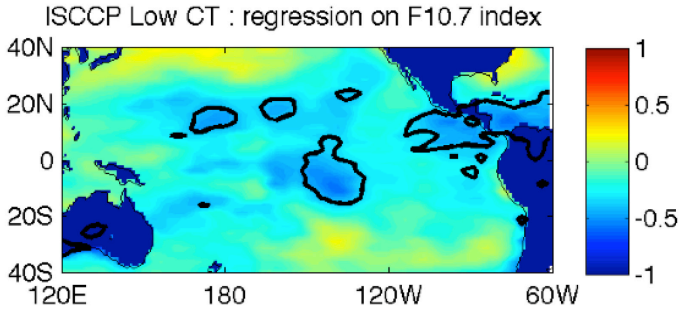
JJA

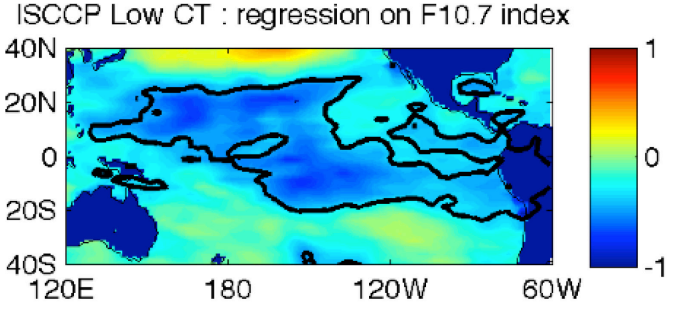
mean





Regression on Solar F10.7 index





Regression on Nino 3.4 index