Investigation of CO_2 Variations From Multiple Satellite Retrievals & Model Simulations

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Overview

- Motivation
- Data
- Comparisons Between Satellite CO_2 with *In-situ* Observations
- Variability of CO_2
- Conclusions

Motivation

- Improve understanding of CO_2 variability and its effect on the global climate change using satellite data
- Investigate how natural variability influence the CO_2 distribution
- Improve CO_2 simulations from chemistry-transport models in the future

What do we learn from AIRS Mid-trop CO_2?

- Significant spatiotemporal variability in the AIRS CO_2, which is supported by the aircraft observations [*Chahine et al.*, GRL 2008].

- Intraseasonal Variations

  1. AIRS mid-tropospheric CO_2 are modulated by the Madden-Julian Oscillation [*Li et al.*, PNAS 2010].

  2. Semi-annual oscillation in the mid-tropospheric CO_2 [*Jiang et al.*, GBC 2012; *Ruzmaikin et al.*, JClimate 2012].

- Interannual Variations

  AIRS mid-tropospheric CO_2 can be modulated by the ENSO, Northern Annular Mode, and Tropospheric Biennial Oscillation [*Jiang et al.*, GRL 2010; Wang *et al.*, GRL 2011; *Jiang et al.*, JAS 2012].

Data

- **Satellite CO_2 Retrievals**

  1. Atmospheric Infrared Sounder (AIRS) V5 Mid-tropospheric CO_2 [Chahine *et al*., 2005; 2008]

     Period: Sep 2002 – Present; Sensitivity Peak: 500-300 hPa

  2. ACOS/Greenhouse gases Observing SATellite (GOSAT) V2.9 Column CO_2 [Crisp *et al*., 2012; Wunch *et al*., 2011; O'Dell *et al*., 2011]

     Period: Apr 2009 - Present

  3. Tropospheric Emission Spectrometer (TES) Mid-tropospheric CO_2 [Kulawik *et al*., 2012]

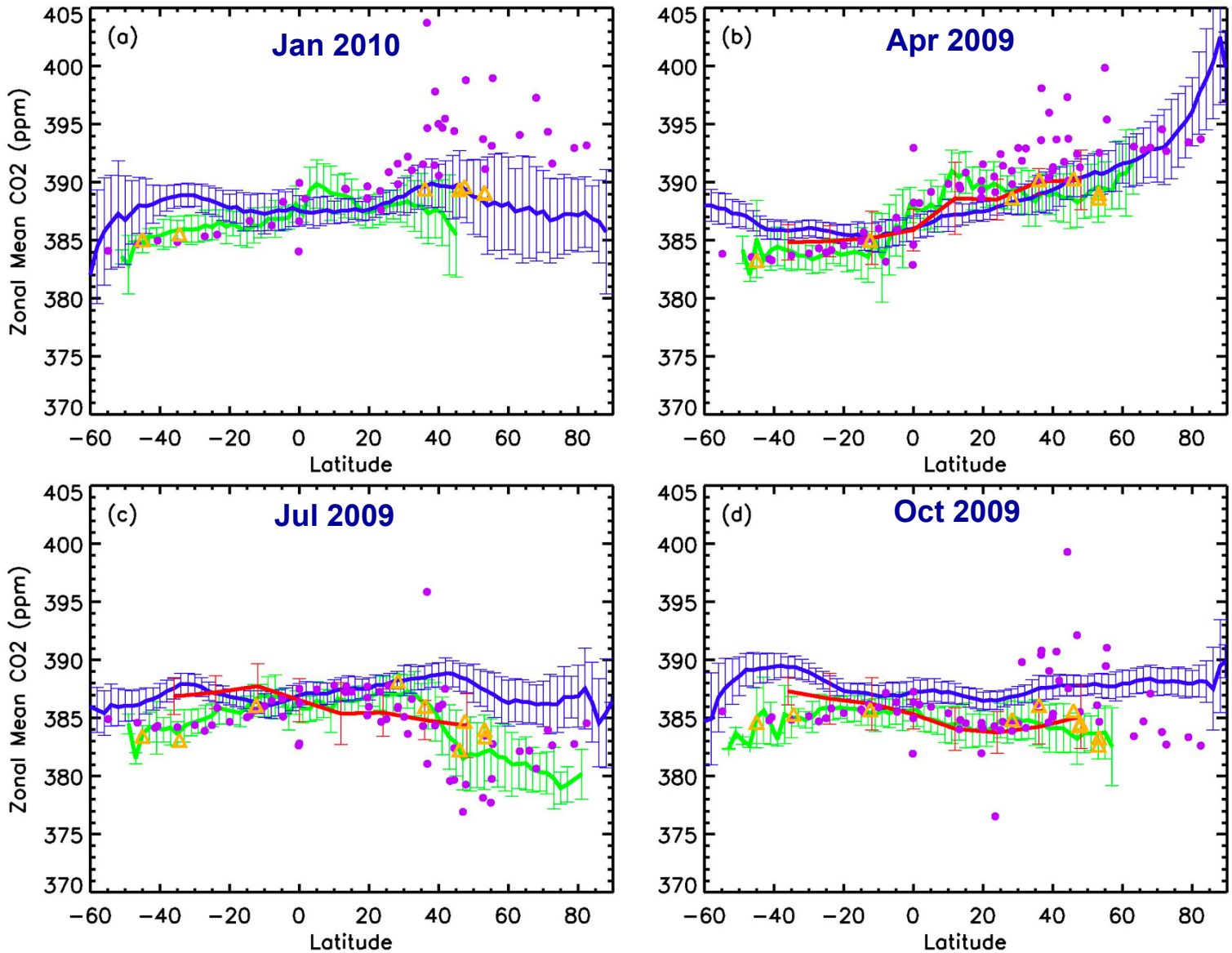
     Period: Jan 2006 – Present; Sensitivity Peak: 511 hPa

- ***In-situ*** **CO_2 Data**

  1. NOAA ESRL Cooperative Air Sampling Network Surface CO_2 [GLOBALVIEW-CO_2, 2010]

  2. TCCON Column CO_2 measured by Fourier Transform Spectrometer [Washenfelder *et al*., 2006; Macatangay *et al*., 2008]

Comparison Between Satellite CO_2 with *In-situ* Observations

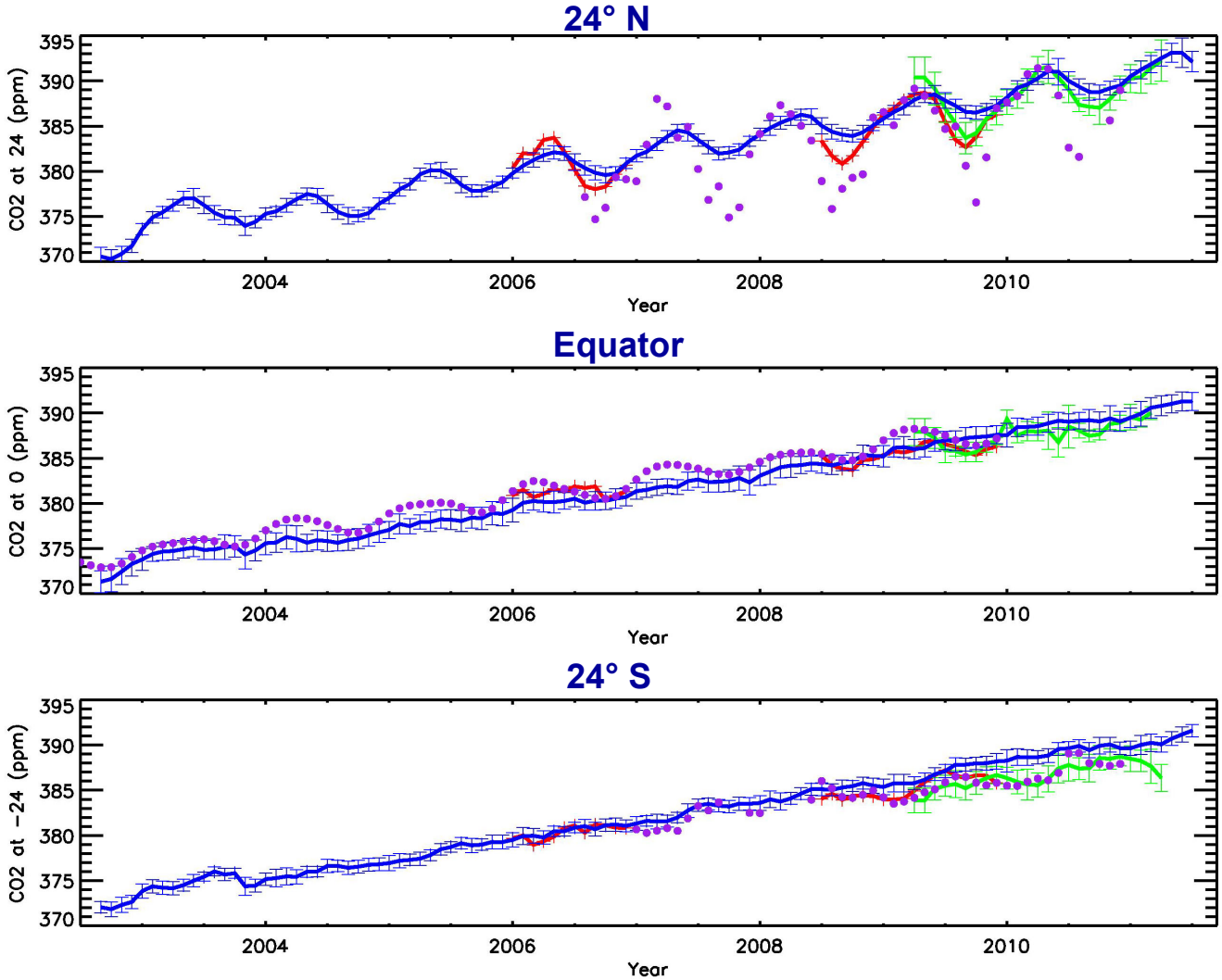


AIRS mid-tropospheric CO_2

GOSAT column CO_2; TES lower mid-tropospheric CO_2

NOAA ESRL Surface CO_2; TCCON column CO_2

Comparison Between Satellite CO_2 with *In-situ* Observations



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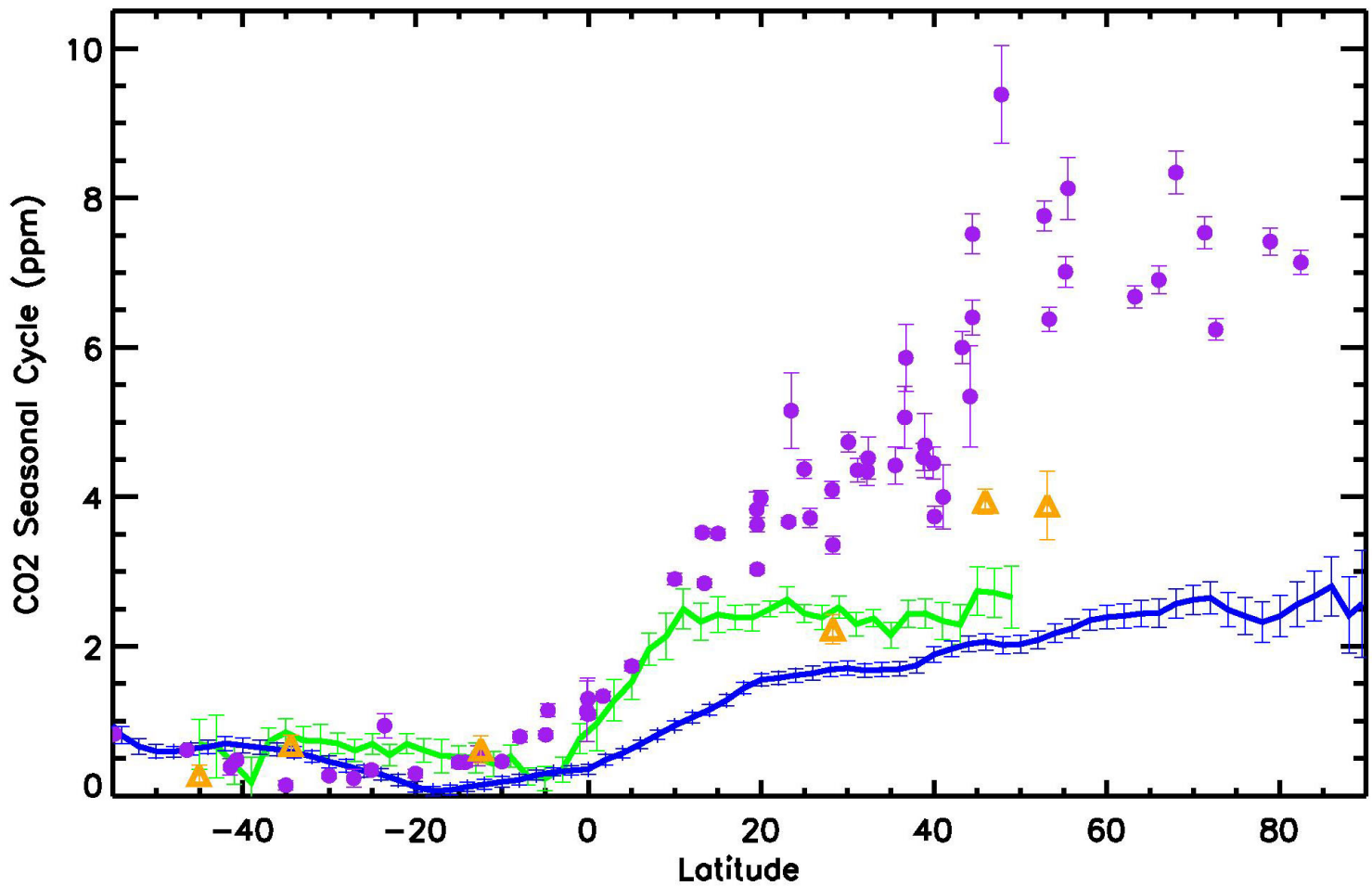
GOSAT column CO_2; TES lower mid-tropospheric CO_2

NOAA ESRL Surface CO_2

CO_2 Seasonal Cycle Amplitude



AIRS mid-tropospheric CO_2

GOSAT column CO_2; TES lower mid-tropospheric CO_2

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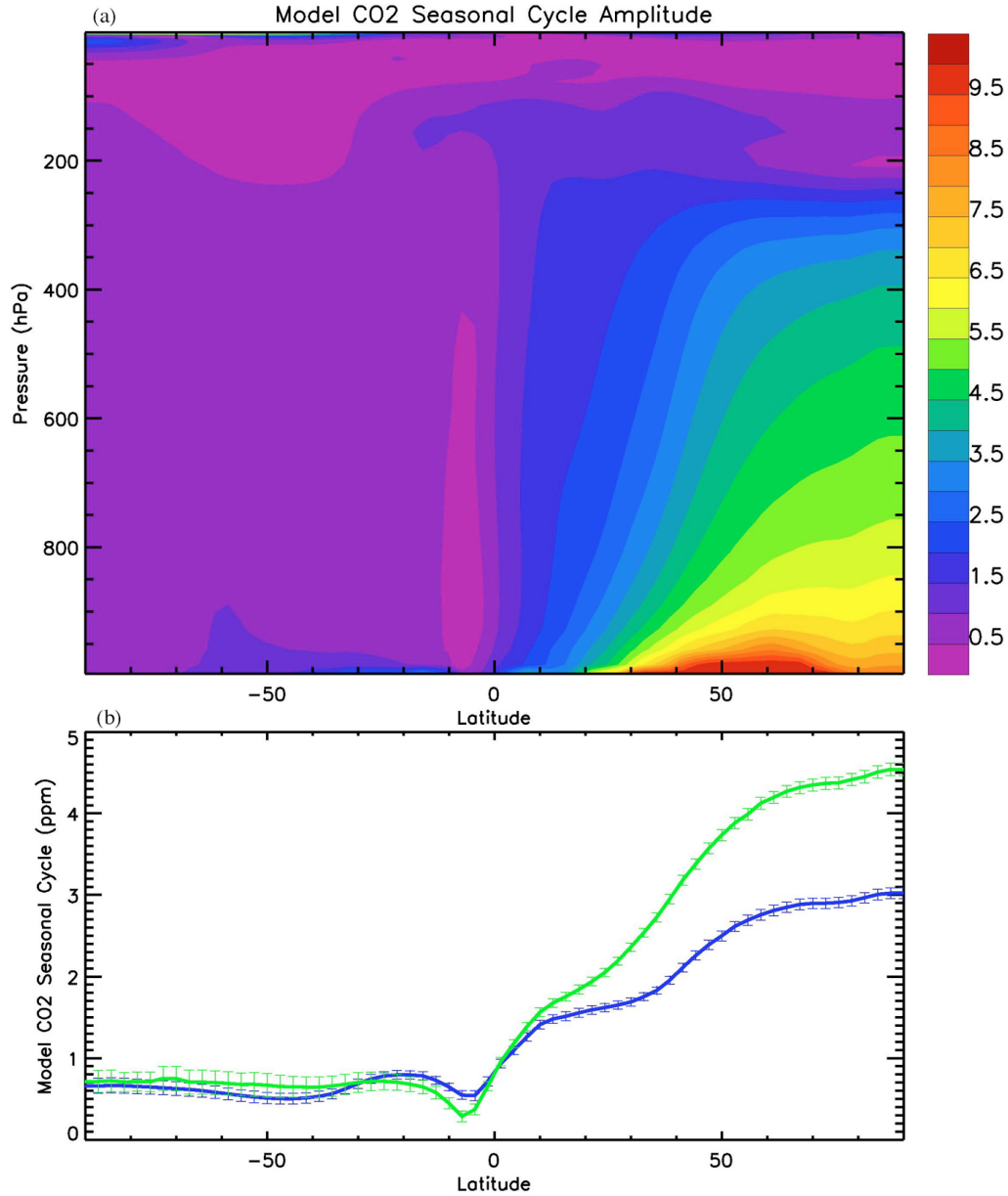
TCCON column CO_2

Model CO_2 Seasonal Cycle Amplitude



MOZART-2 CO_2 Convolved by AIRS Averaging Kernel

MOZART-2 CO_2 Convolved by GOSAT Averaging Kernel

Influence of Stratospheric Sudden Warming on AIRS CO_2

AIRS global mid-tropospheric CO_2 retrievals offer an unique opportunity to explore the influence of stratosphere on the troposphere in the polar region.

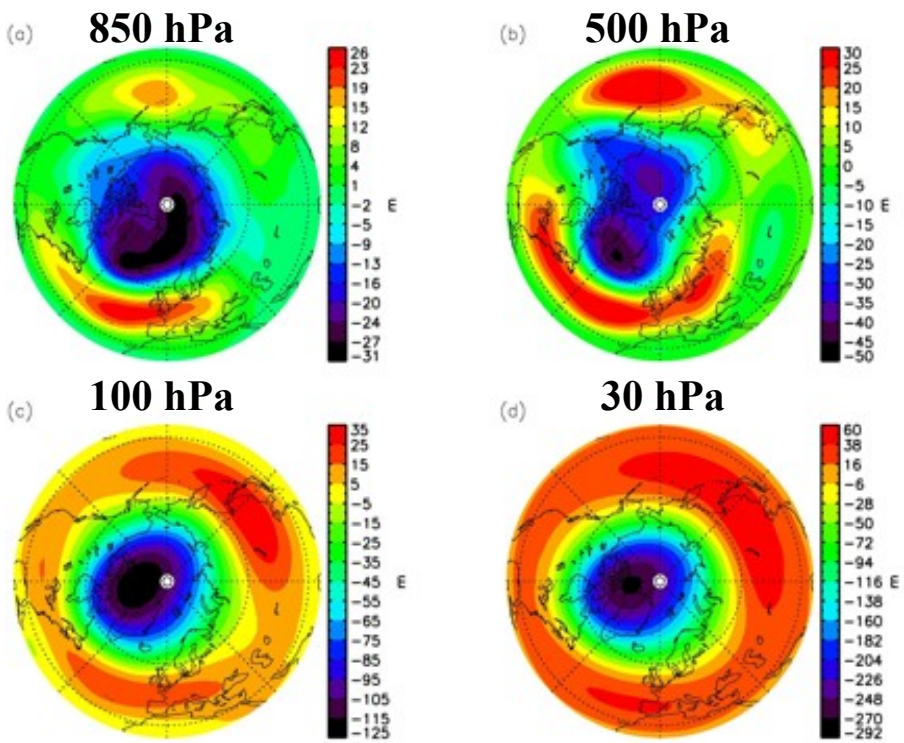
During the Stratospheric Sudden Warming (SSW), polar stratospheric temperature rises and the circum-polar flow reverses direction in a few days.

After the SSW, the vortex area decreases and there is less mixing between the stratosphere and troposphere.

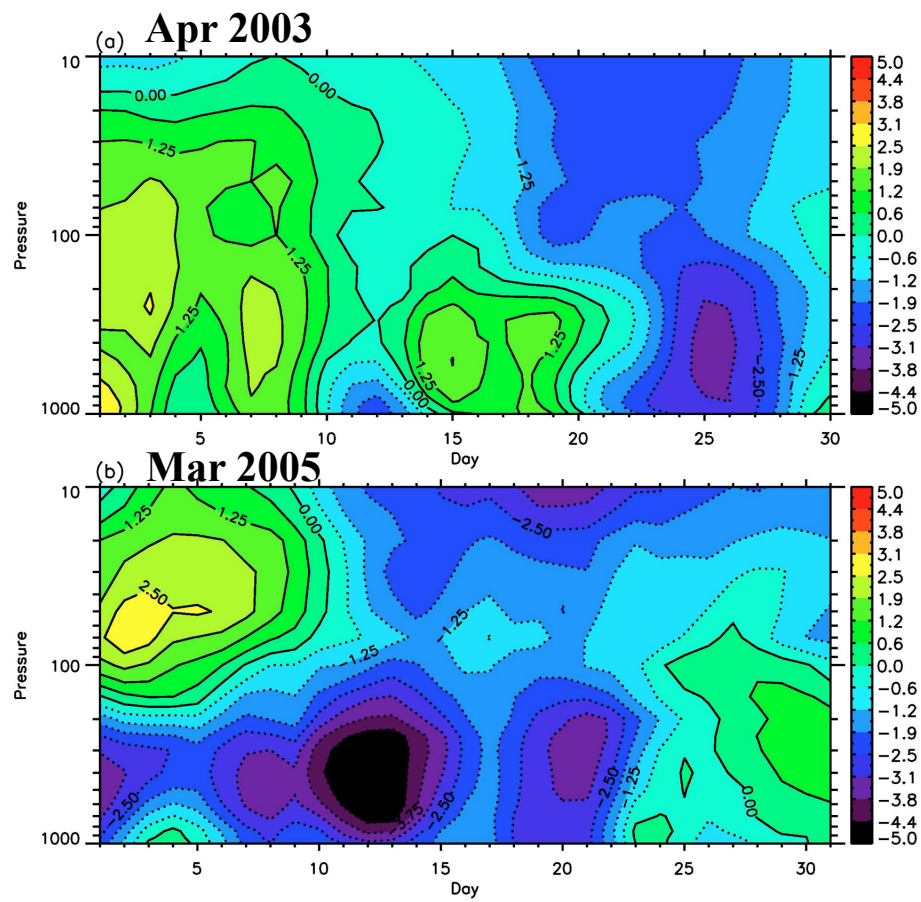
SSW has important influence on tracers.

Vertical Structure of the Northern Annular Mode

(Strength of Polar Vortex is Characterized by the NAM index)

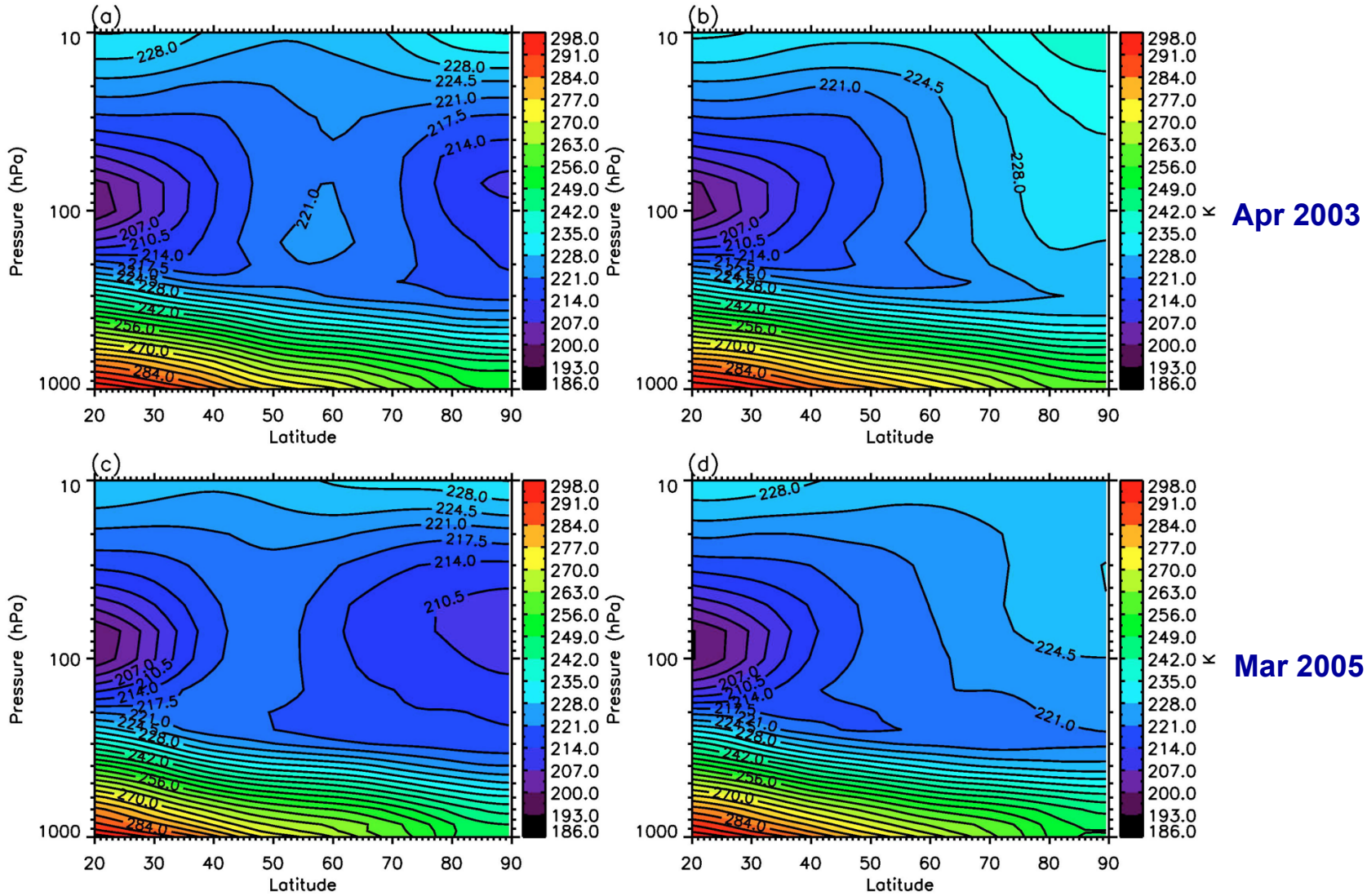


- Spatial patterns of leading mode of NCEP-2 geopotential height (GPH)



- Vertical structure of the Northern Annular Mode (NAM) index from the first mode of NCEP-2 GPH

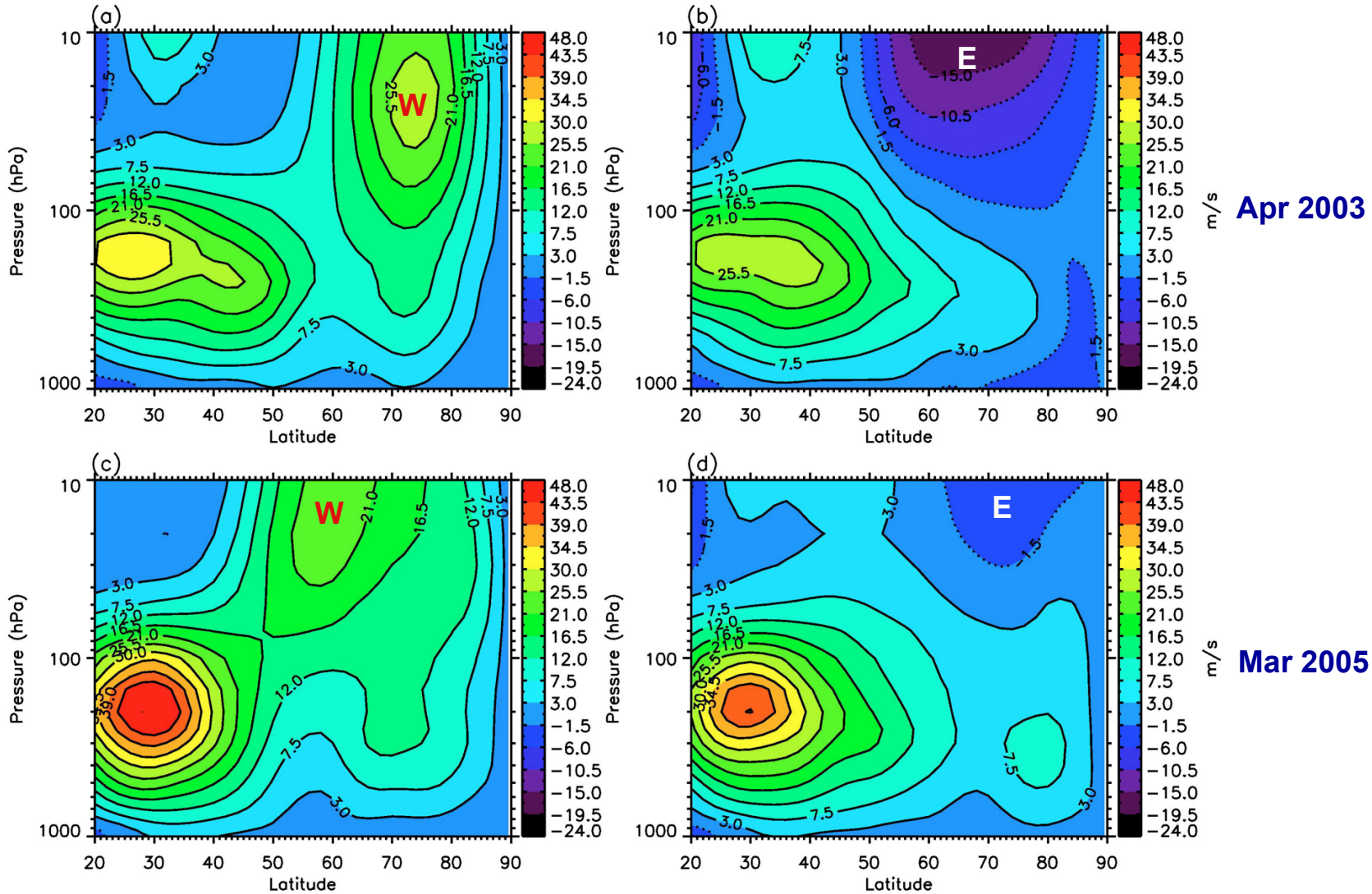
Temperature Before/After SSW



Before SSW **After SSW**

Polar stratospheric temperature increases by 15 K after the SSW.

Zonal Wind Before/After SSW

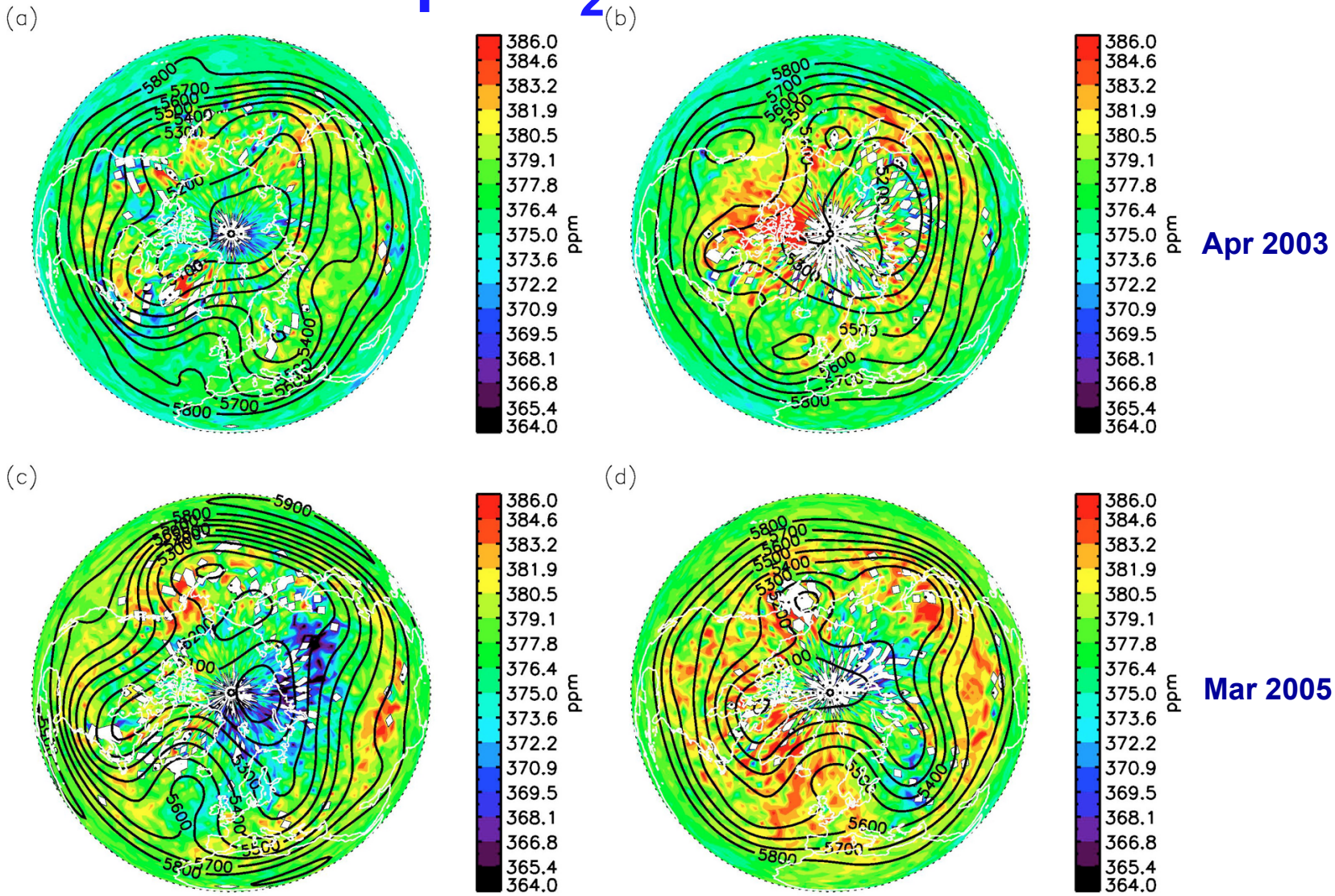


Before SSW

After SSW

Polar zonal winds switch from westerly to easterly after the SSW.

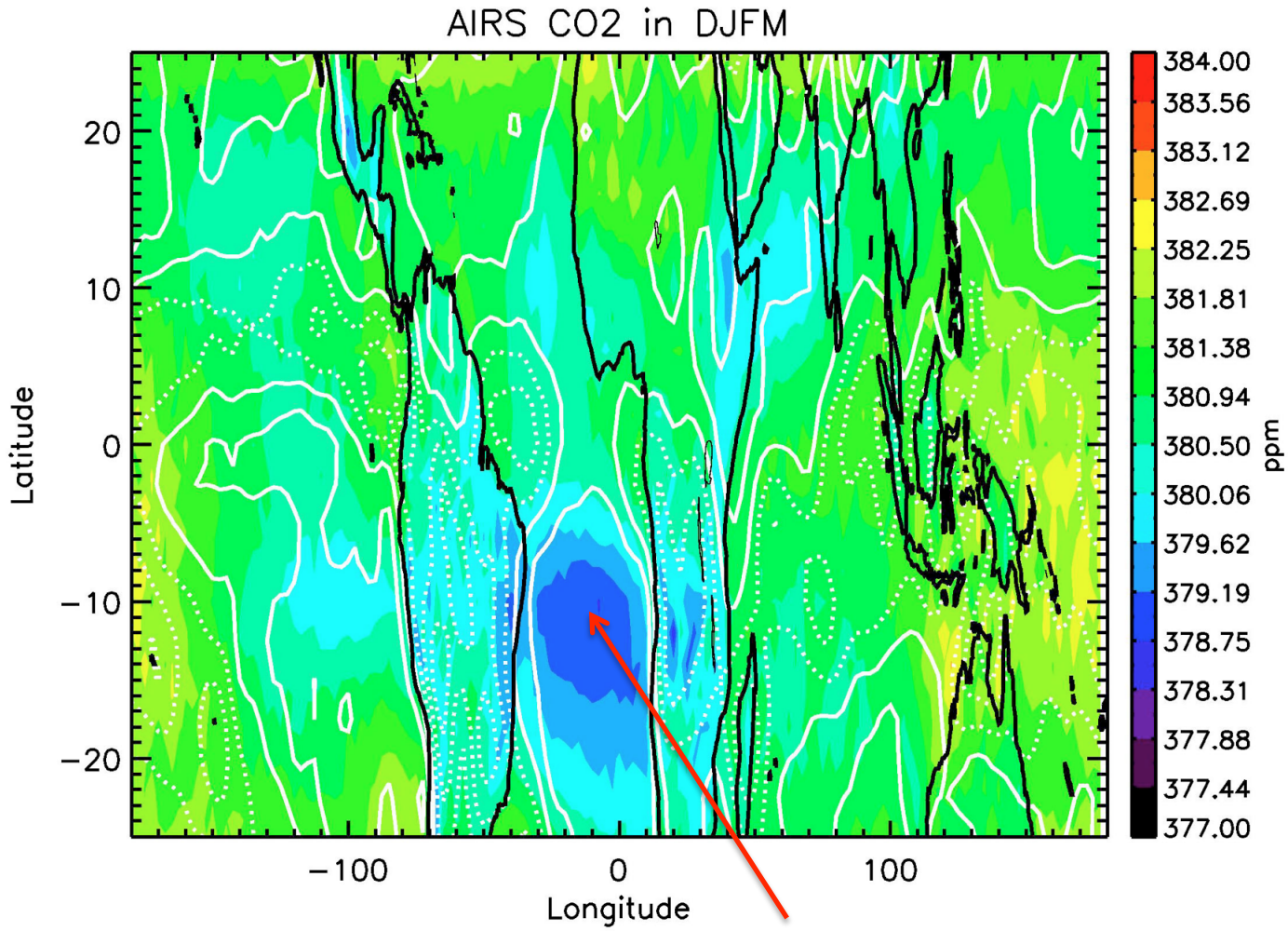
AIRS Mid-trop CO_2 Before/After SSW



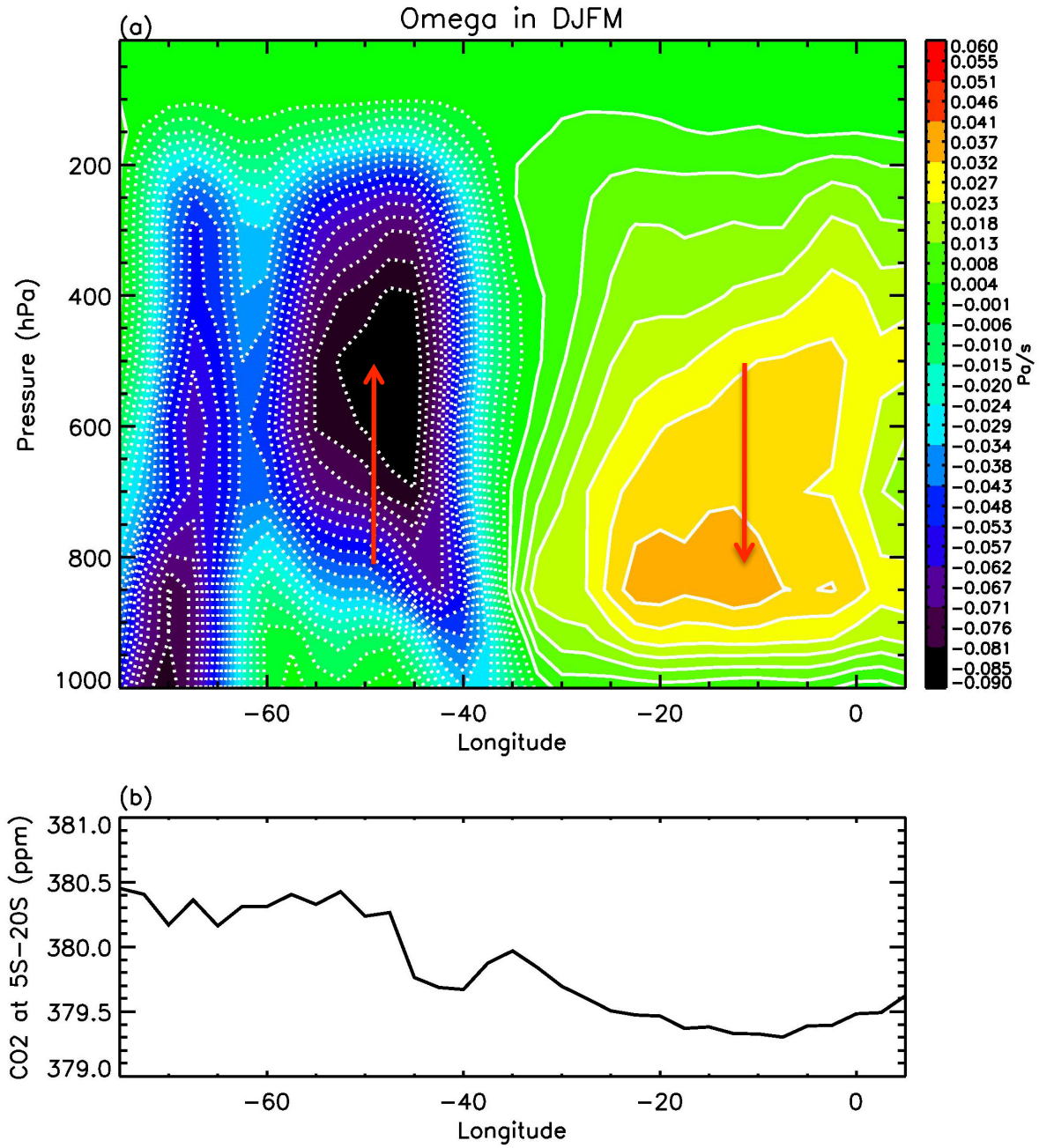
Before SSW **After SSW**

Polar CO_2 increases ~3 ppm within a few days after the SSW.

AIRS CO_2 in DJFM Averaged from 2003 to 2010



Solid White Contours: Sinking Air; Dotted White Contours: Rising Air


(a)
Omega in DJFM
Pressure (hPa)
200
400
600
800
1000
−60
−40
−20
0
Longitude
0.060
0.055
0.051
0.046
0.041
0.037
0.032
0.027
0.023
0.018
0.013
0.008
0.004
−0.001
−0.006
−0.010
−0.015
−0.020
−0.024
−0.029
−0.034
−0.038
−0.043
−0.048
−0.053
−0.057
−0.062
−0.067
−0.071
−0.076
−0.081
−0.085
−0.090
Pa/s
(b)
CO2 at 5S−20S (ppm)
381.0
380.5
380.0
379.5
379.0
−60
−40
−20
0
Longitude

Conclusions

- Zonal averaged CO_2 for three satellite data sets (AIRS, GOSAT, and TES) are consistent with the surface and TCCON column CO_2 data. CO_2 seasonal cycle amplitudes decrease with altitudes.

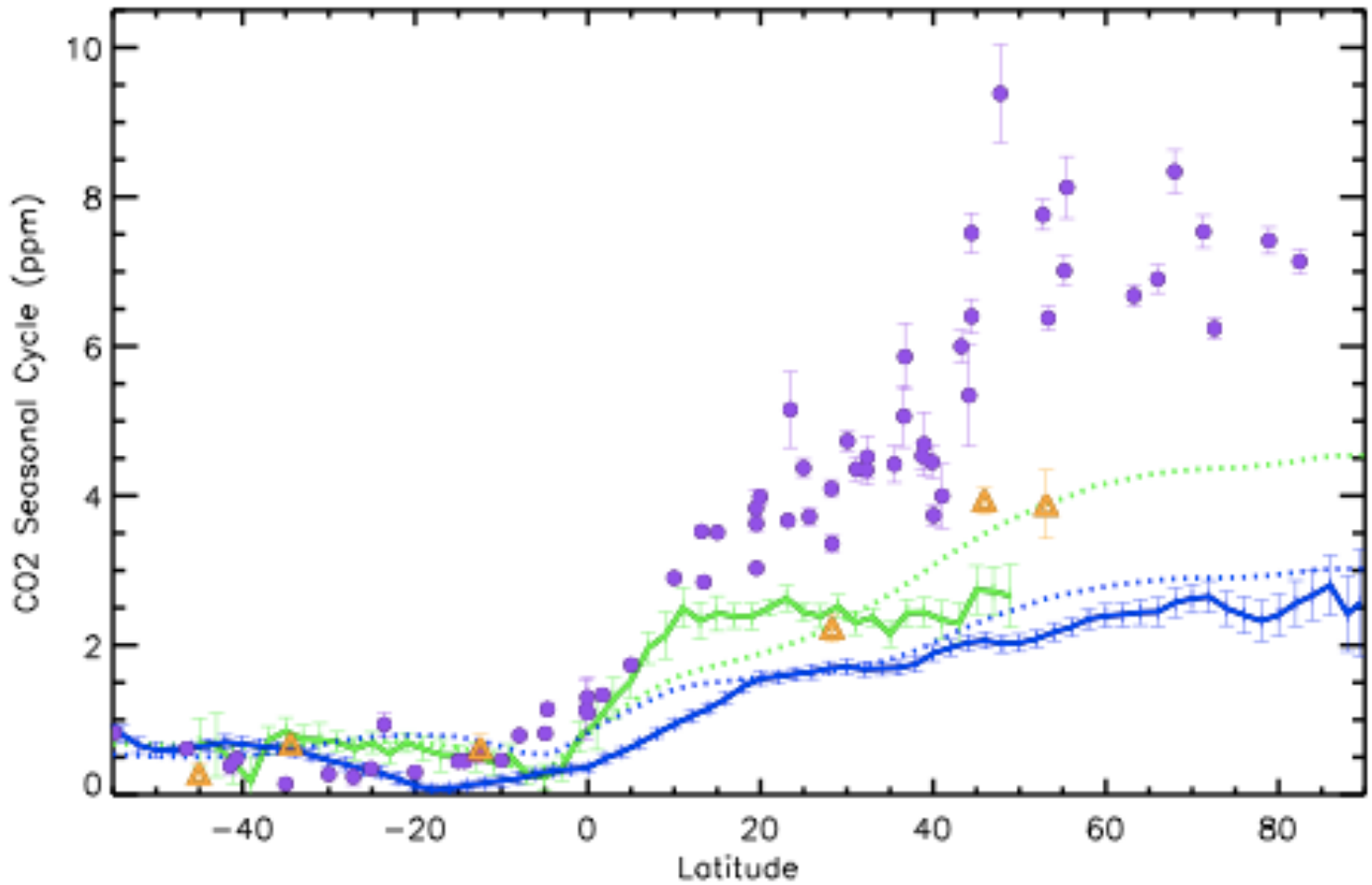
- During the Stratospheric Sudden Warming (SSW) event, the polar temperature increases and polar winds switch from westerly to easterly. Polar mid-tropospheric CO_2 concentrations increase after the SSW.

- Low concentrations of CO_2 are seen over the Southern Atlantic Ocean, which might be related to the sinking branch in the Atlantic Walker Circulation.

References:
Chahine et al., GRL, doi:2008GL035022, 2008.
Jiang et al., GRL, doi:2010GL042823, 2010.
Li et al., PNAS, doi:10.1073/pnas.1008222107, 2010.
Wang et al., GRL, doi:10.1029/2011GL049288, 2011.
Ruzmaikin et al., JCLI, doi:JCLI-D-11-00223.1, 2012.
Jiang et al., JAS, doi:JAS-D-11-0282.1, 2012.
Jiang et al., GBC, doi:10.1029/2011GB004118, 2012.

Thank you!

CO_2 Seasonal Cycle Amplitude



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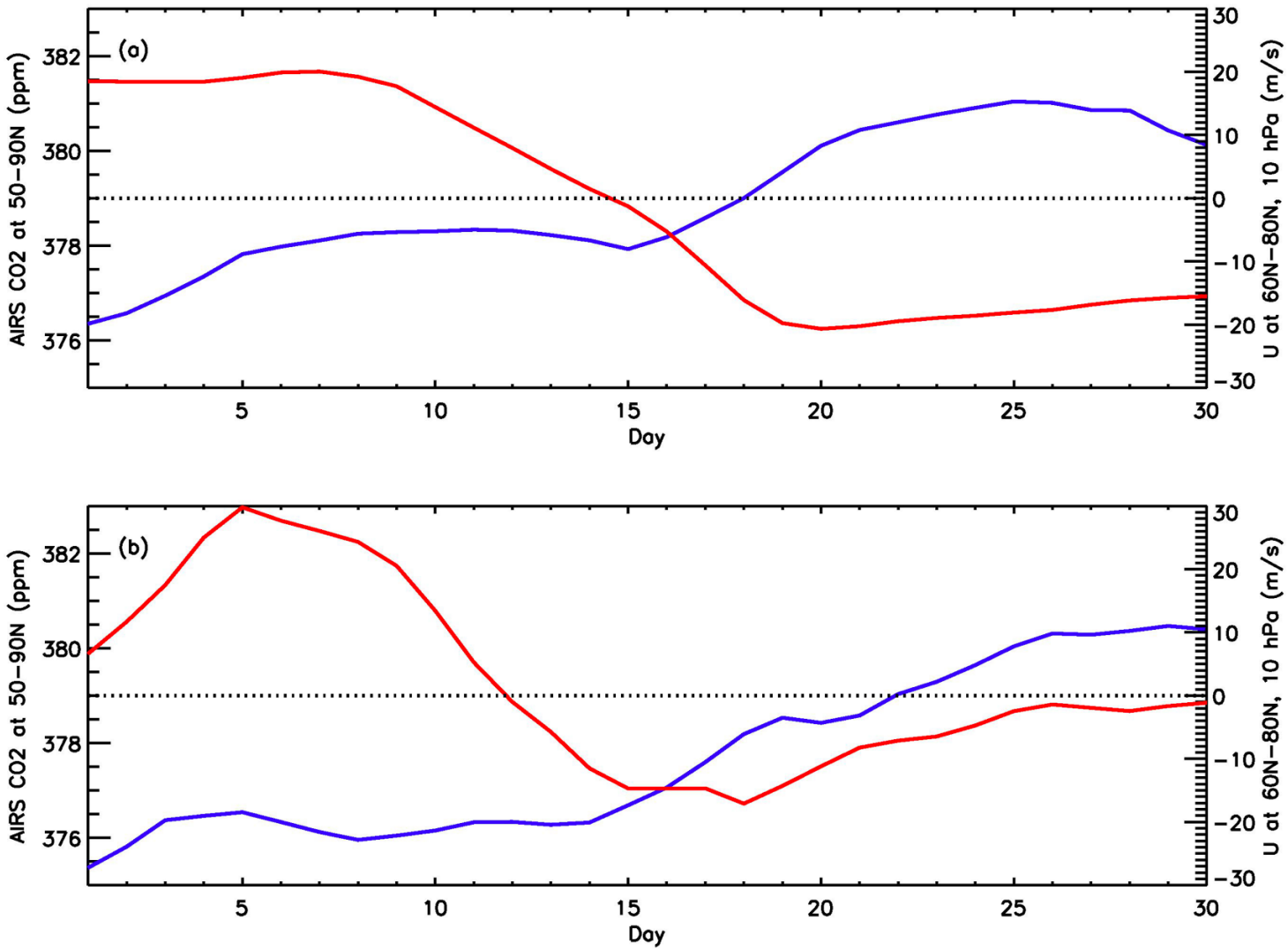
(a)
AIRS CO2 at 50–90N (ppm)
U at 60N–80N, 10 hPa (m/s)
Day
(b)
AIRS CO2 at 50–90N (ppm)
U at 60N–80N, 10 hPa (m/s)
Day