Studying ‘cold pole’ problem in WACCM and comparisons to lidar temperature morphology

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Outline

- **What is Cold Pole Bias in Models**
  - Cold bias of southern winter stratosphere temperature in the polar region.
  - Winter polar vortex is too strong and breaks down too late.
  - Ozone recovery is too late.
  - Identified as an important model bias to be addressed in last WAWG meeting.
- **Possible causes of Cold Pole bias**
  - Lack of westward wave forcing in southern stratosphere (e.g. Austin et al., 2003).
- **Method to correct Cold Pole bias**
  - Add gravity waves in WACCM which will break in the stratosphere to compensate the missing forcing.
- **Simulation Results of WACCM**
  - Comparison with original gravity scheme using specified chemistry
  - Comparison with Lidar Observation
  - Comparison with ERA-40
  - Simulation results with interactive chemistry

Comparison of WACCM and Lidar temperature climatology at Rothera and South Pole

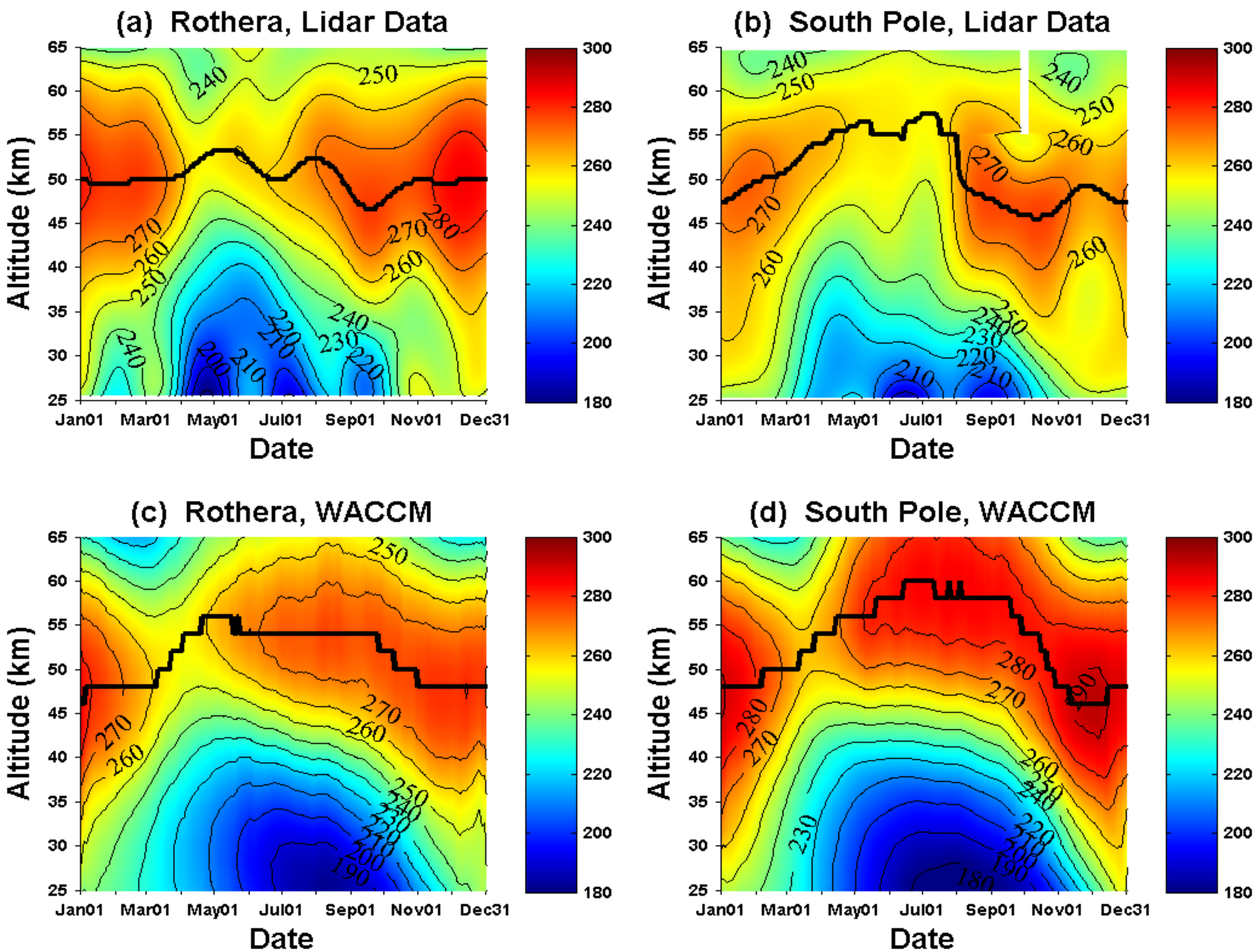


Figure: Temperature climatology at Rothera (67.5 S, 68 W) and South Pole from WACCM outputs and lidar observations. Stratopause are marked as solid black lines in each figure.

Temperature climatology difference

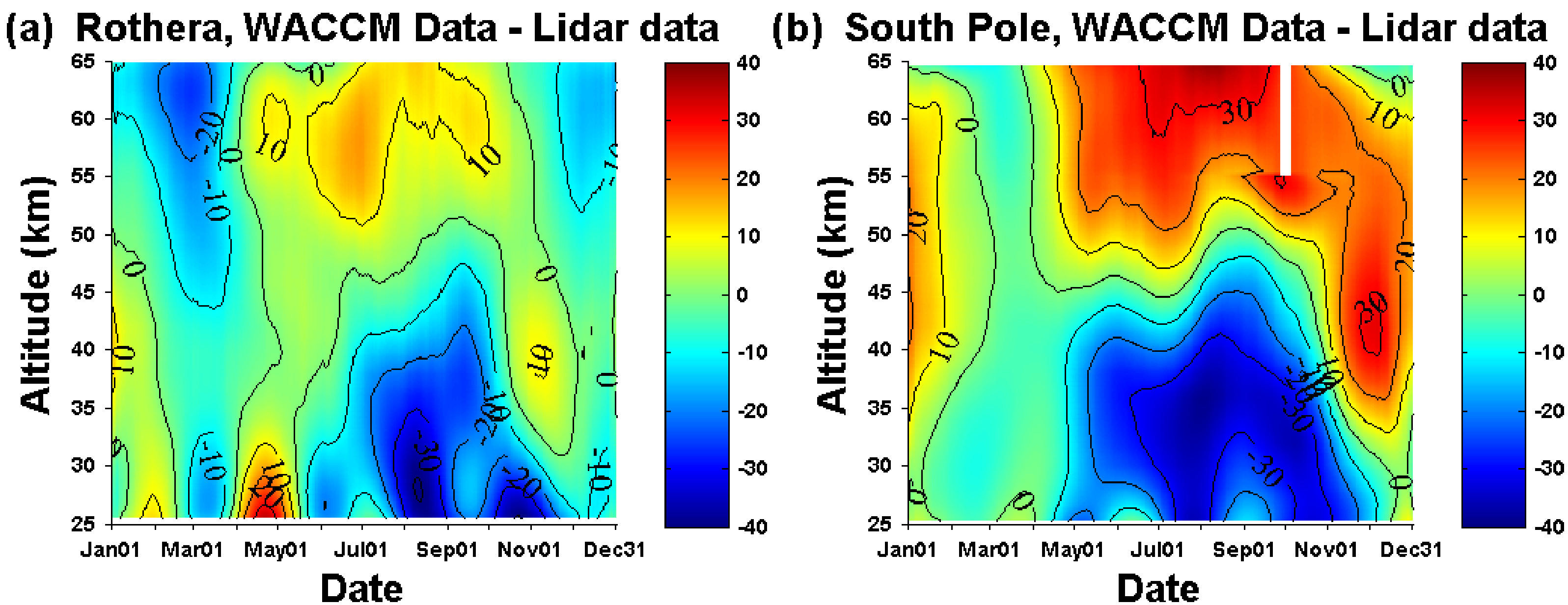


Figure: The upper two figures are temperature difference between lidar and WACCM at Rothera (upper left) and South Pole (upper right). The bottom two figures are temperature difference between South Pole and Rothera from lidar (bottom left) and WACCM (bottom right).

New gravity wave scheme

$z_b \propto 2H \ln(2\pi/\lambda_h A)$ Gravity wave breaking level, Holton et al [1982]

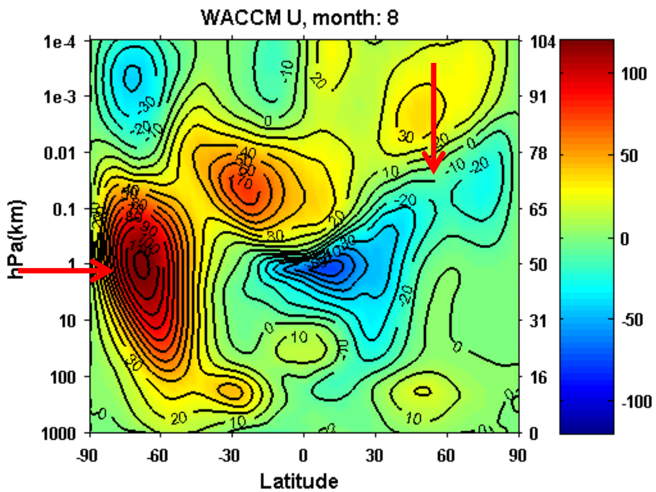
- Original Scheme: Mesoscale waves, horizontal wavelength 100 km, break in the mesosphere and lower-thermosphere (MLT)
- New Scheme: Horizontal wavelength 1000 km, break in the upper stratosphere or lower mesosphere

  case 1: Add the inertia gravity waves at Southern Hemisphere between 30 S and 90 S

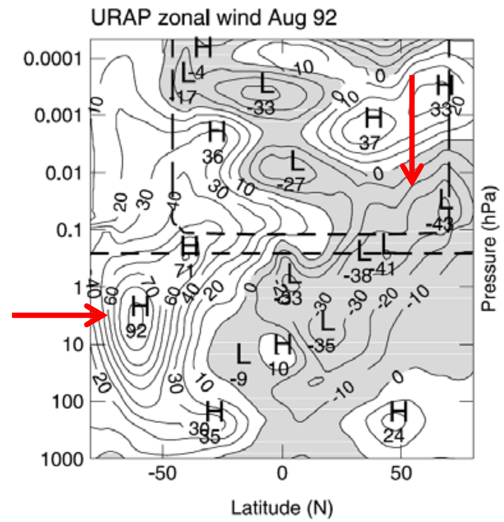
  case 2: Add the inertia gravity waves at Southern Hemisphere between 30 S and 90 S and Northern Hemisphere between 30 N and 90 N.
- This scheme has been used by Xianghui Xue and Hanli Liu to solve the QBO problems in WACCM [Xue et al., in press]

August. Zonal wind comparison of simulated results and observation

Original GW scheme

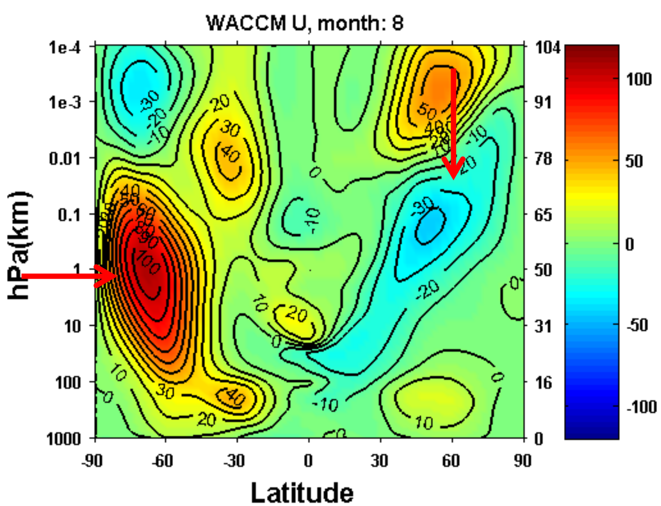


HRDI on UARS

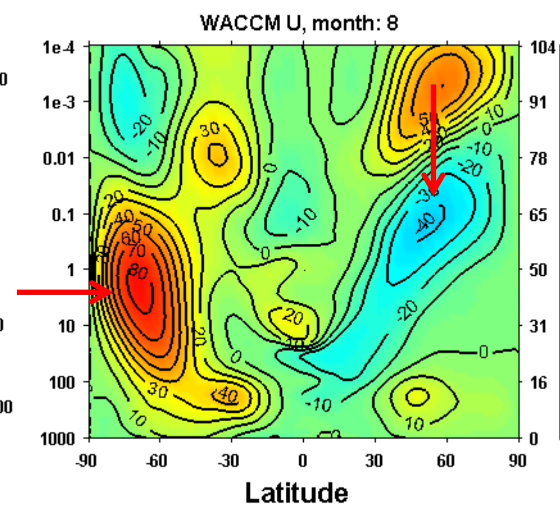


Swinbank and Ortland 2003

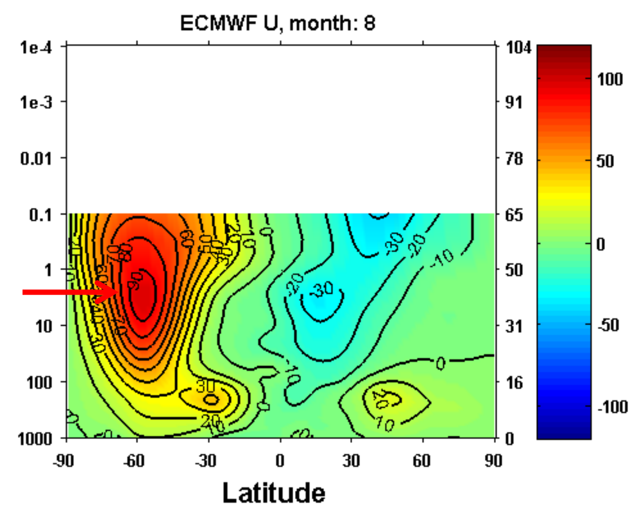
Add inertial GW at SH



Add inertial GW globally

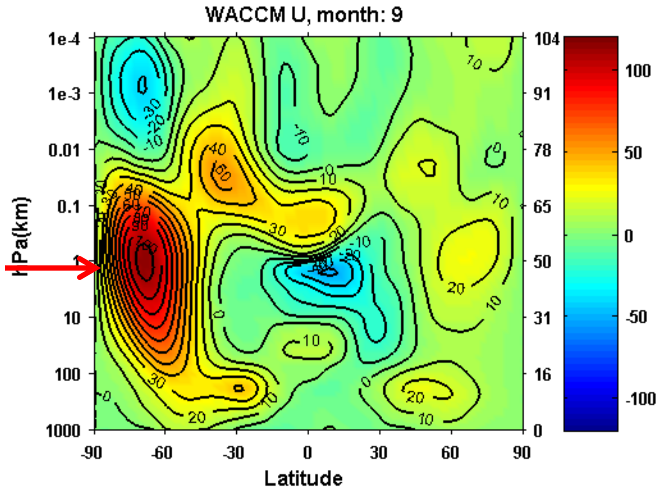


ERA-40

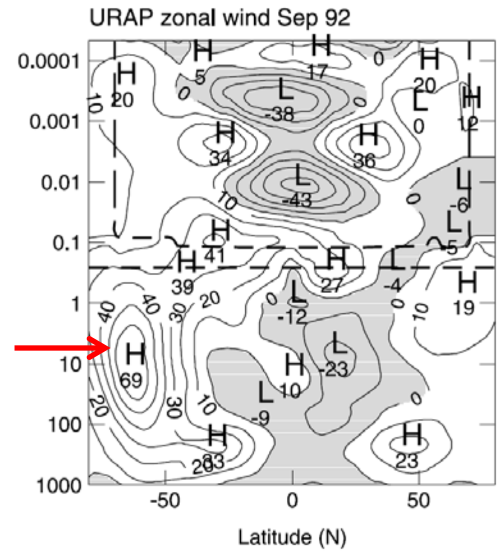


September. Zonal wind comparison of simulated results and observation

Original GW scheme



HRDI on UARS



Swinbank and Ortland 2003

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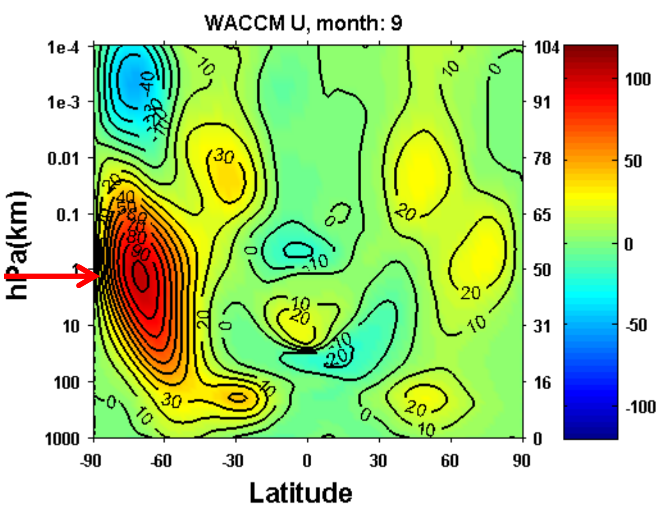
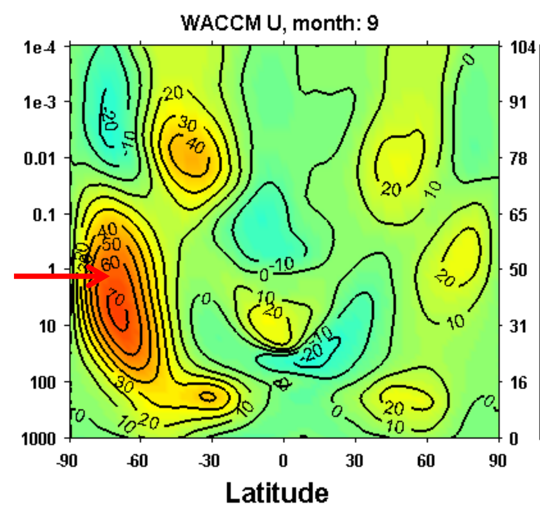


Add inertial GW globally



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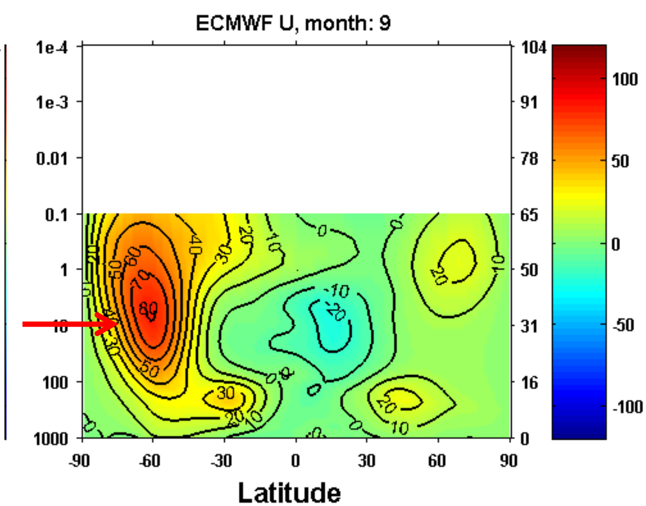
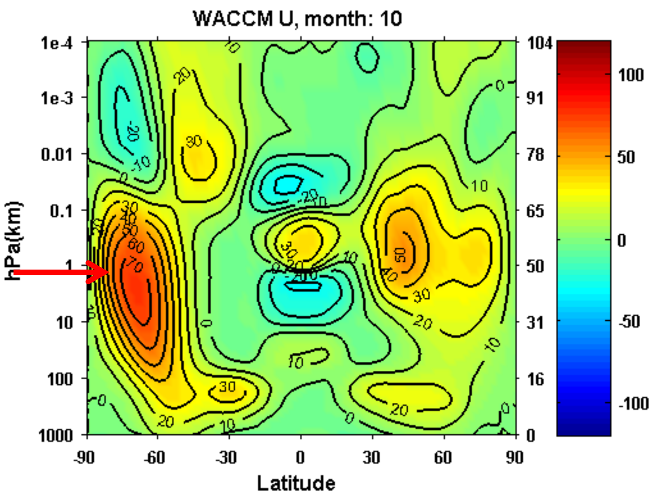
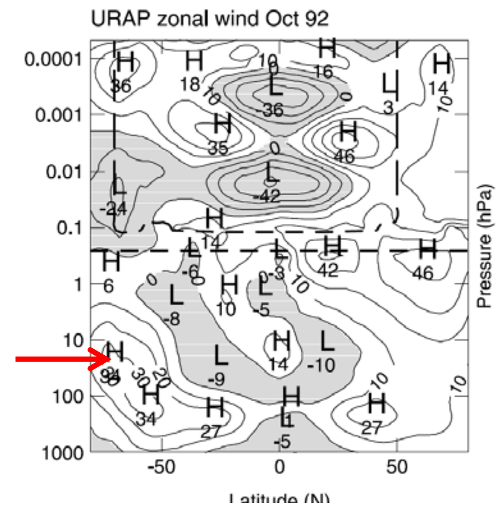


October. Zonal wind comparison of simulated results and observation

Original GW scheme



HRDI on UARS



Swinbank and Ortland 2003

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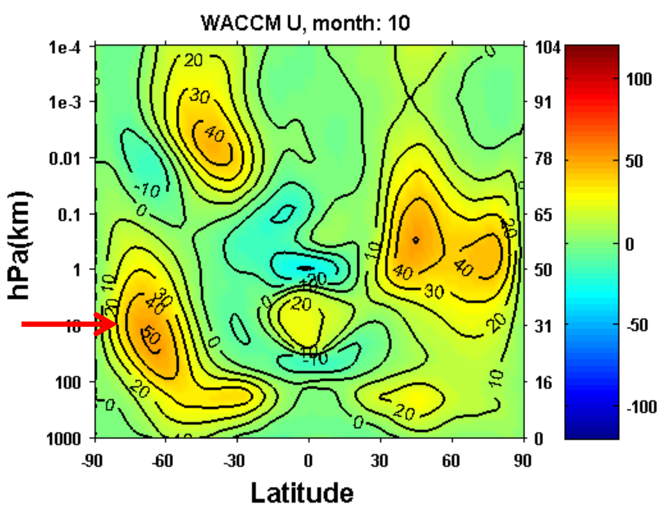
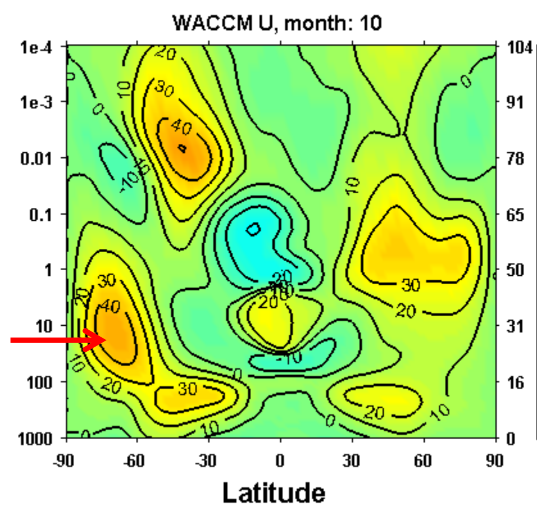
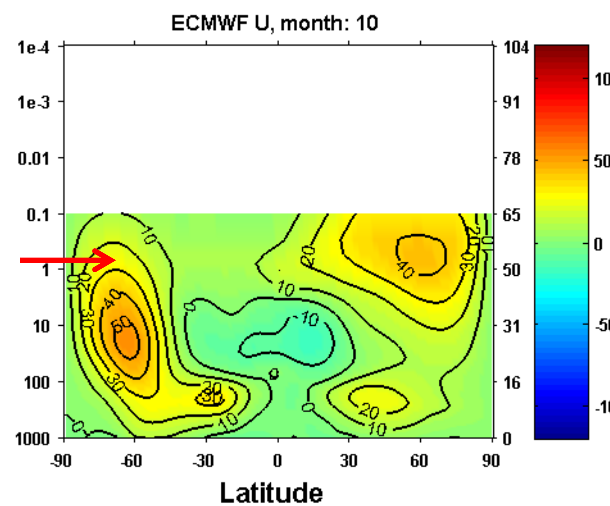


Add inertial GW globally

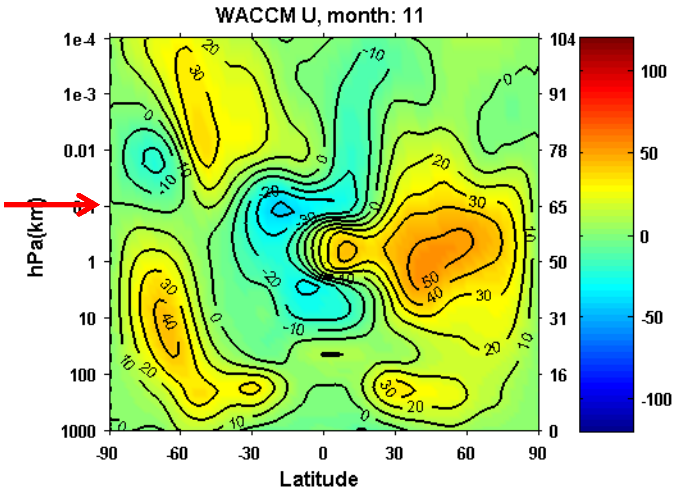


ERA-40

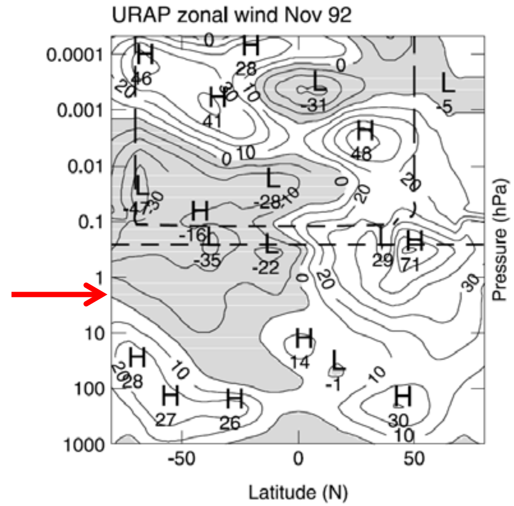


November. Zonal wind comparison of simulated results and observation

Original GW scheme

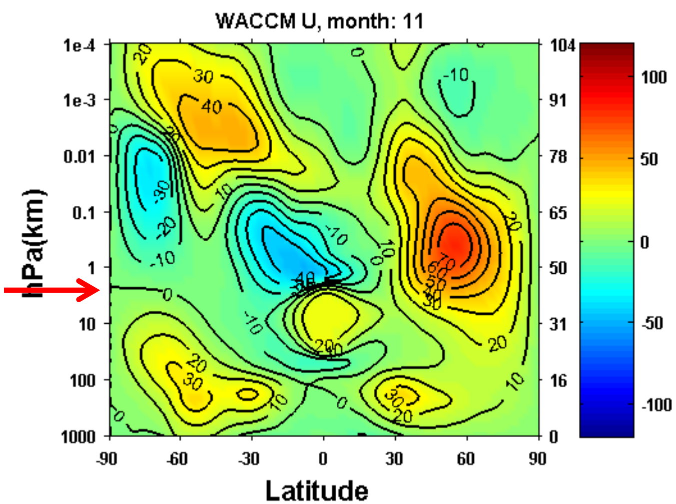


HRDI on UARS

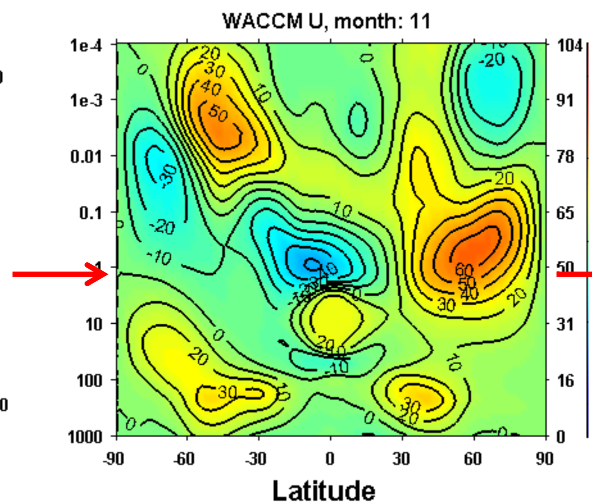


Swinbank and Ortland 2003

Add inertial GW at SH



Add inertial GW globally



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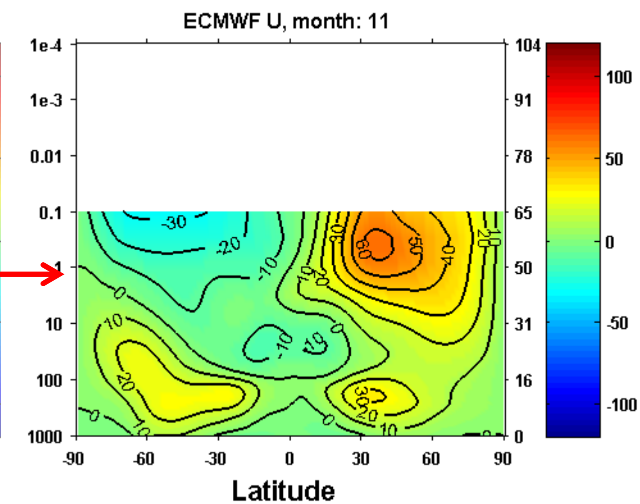
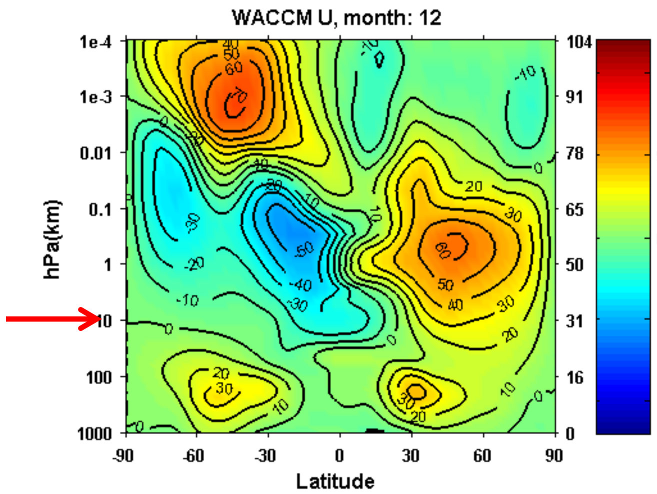
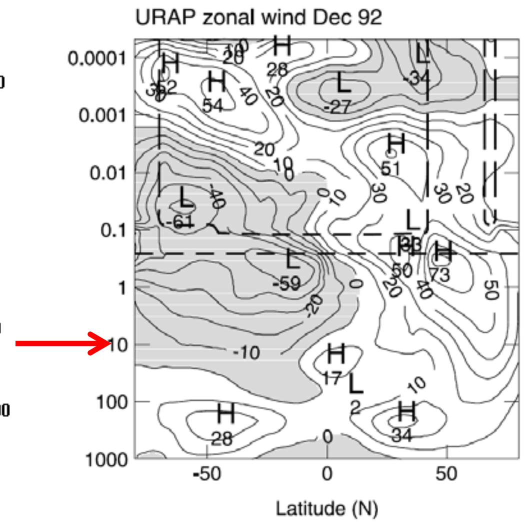


December. Zonal wind comparison of simulated results and observation

Original GW scheme

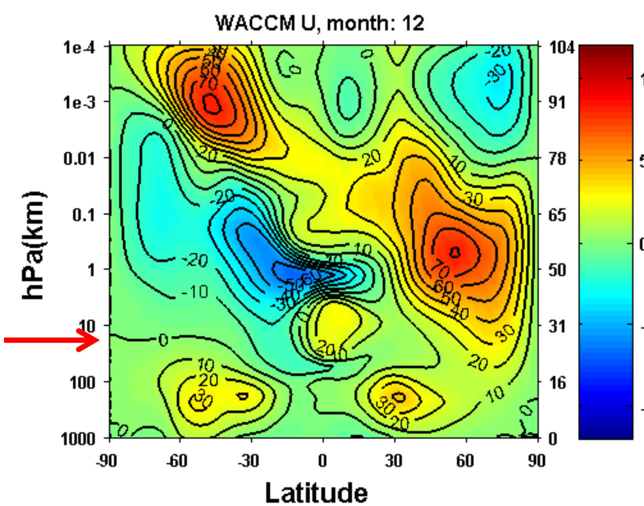


HRDI on UARS

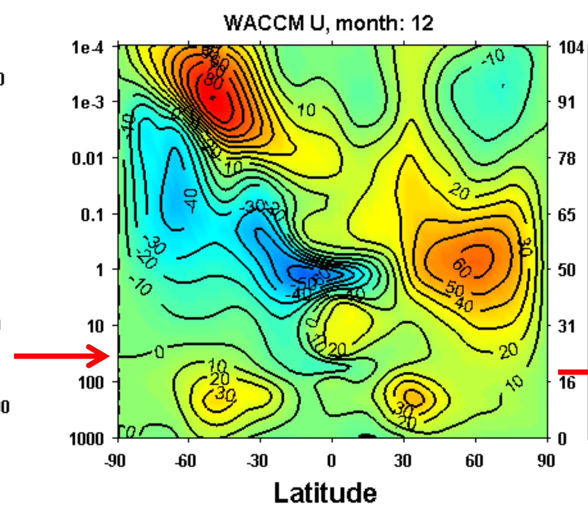


Swinbank and Ortland 2003

Add inertial GW at SH



Add inertial GW globally



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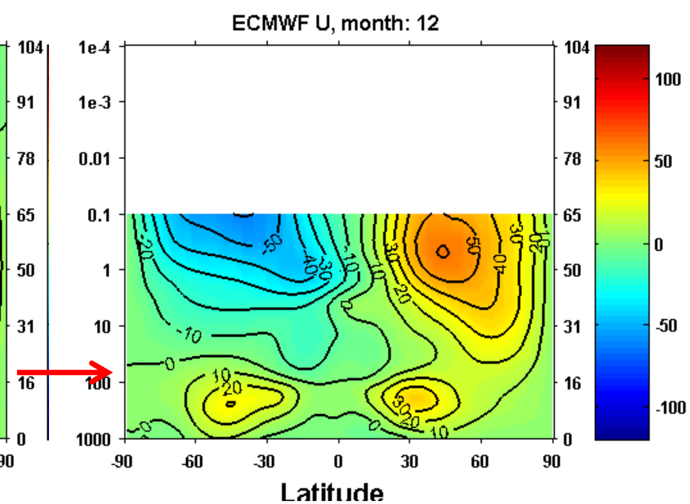


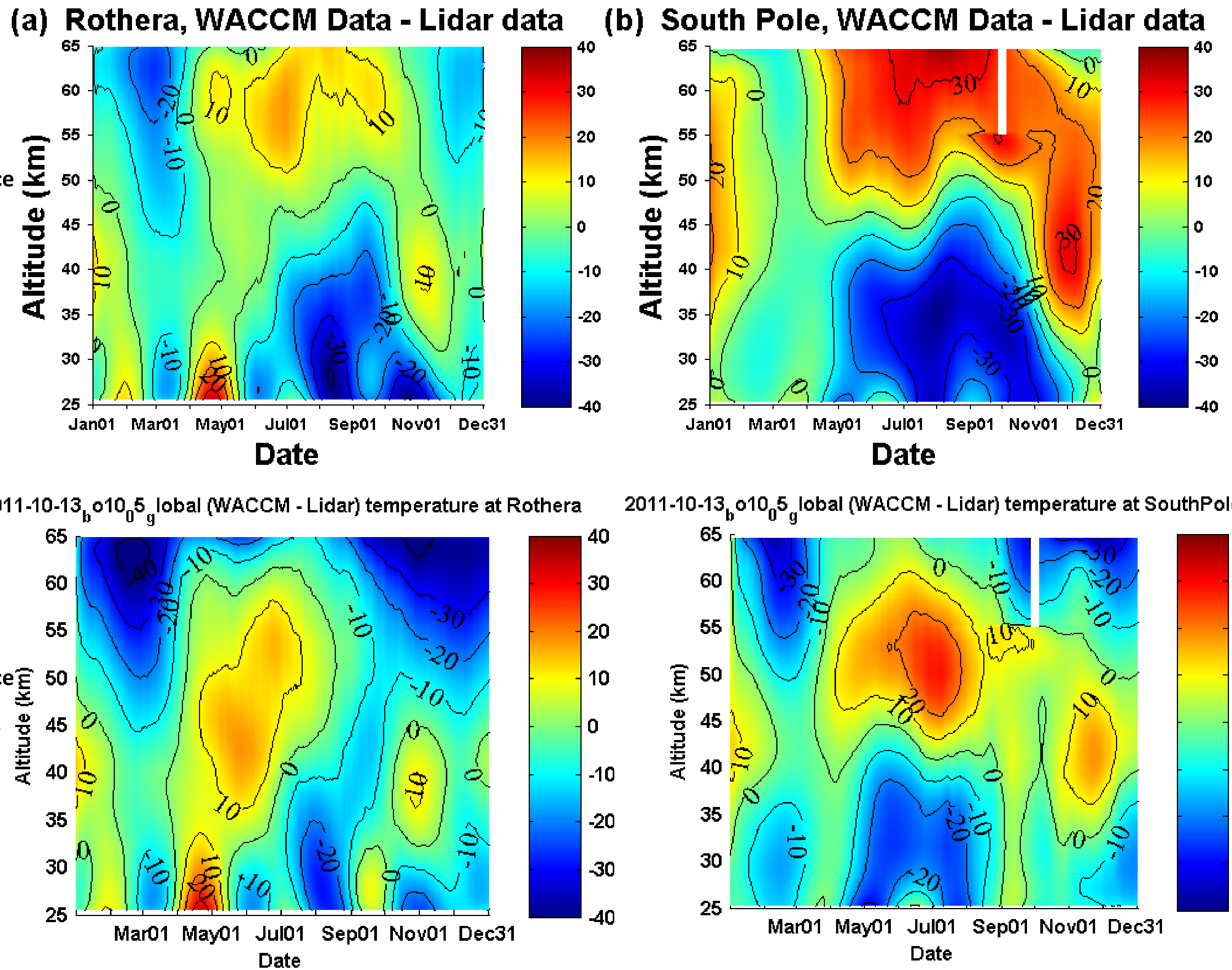
Temperature comparison of with lidar data using new GW scheme

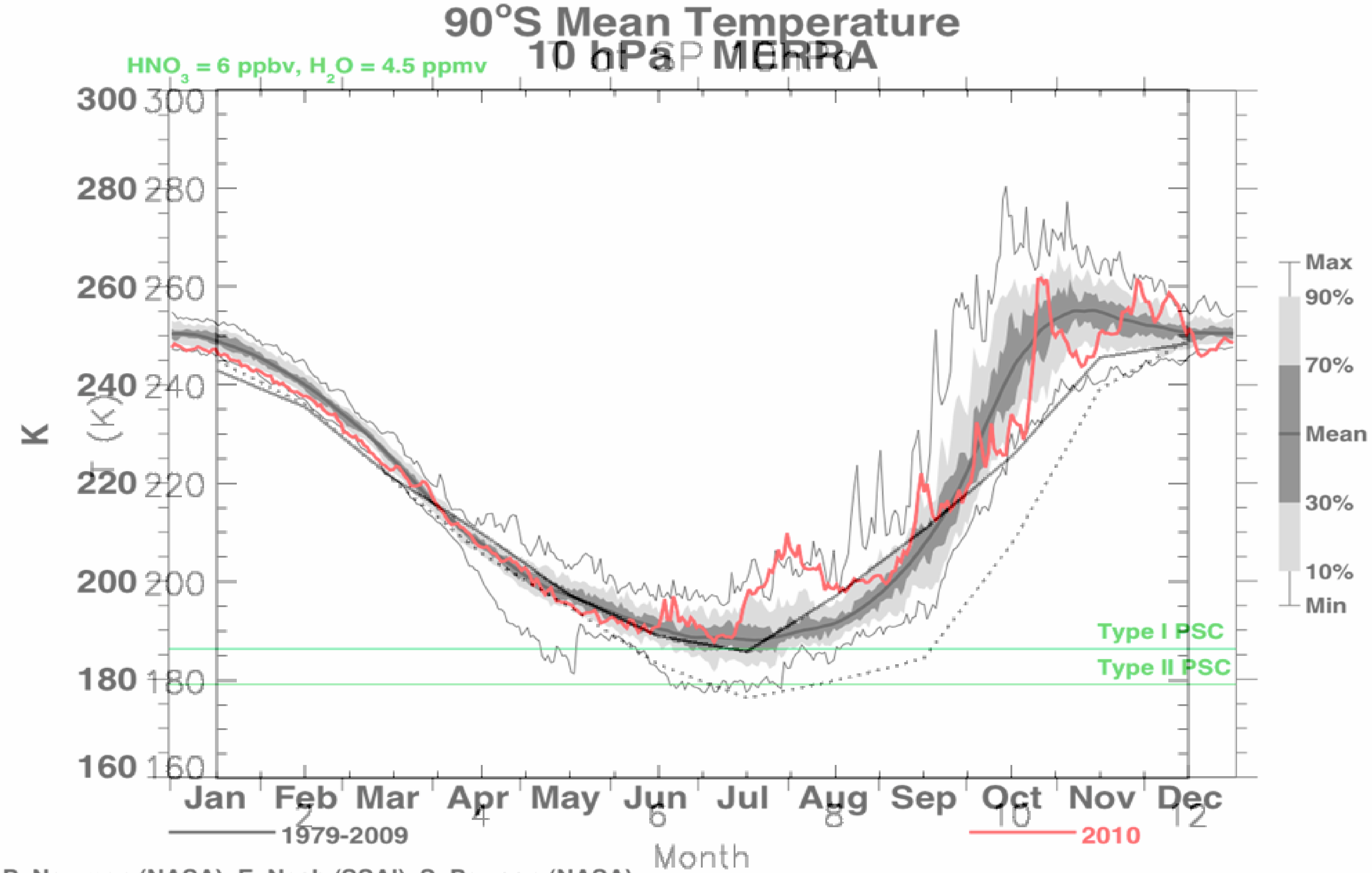
Temp difference

Original GW scheme

Temp difference

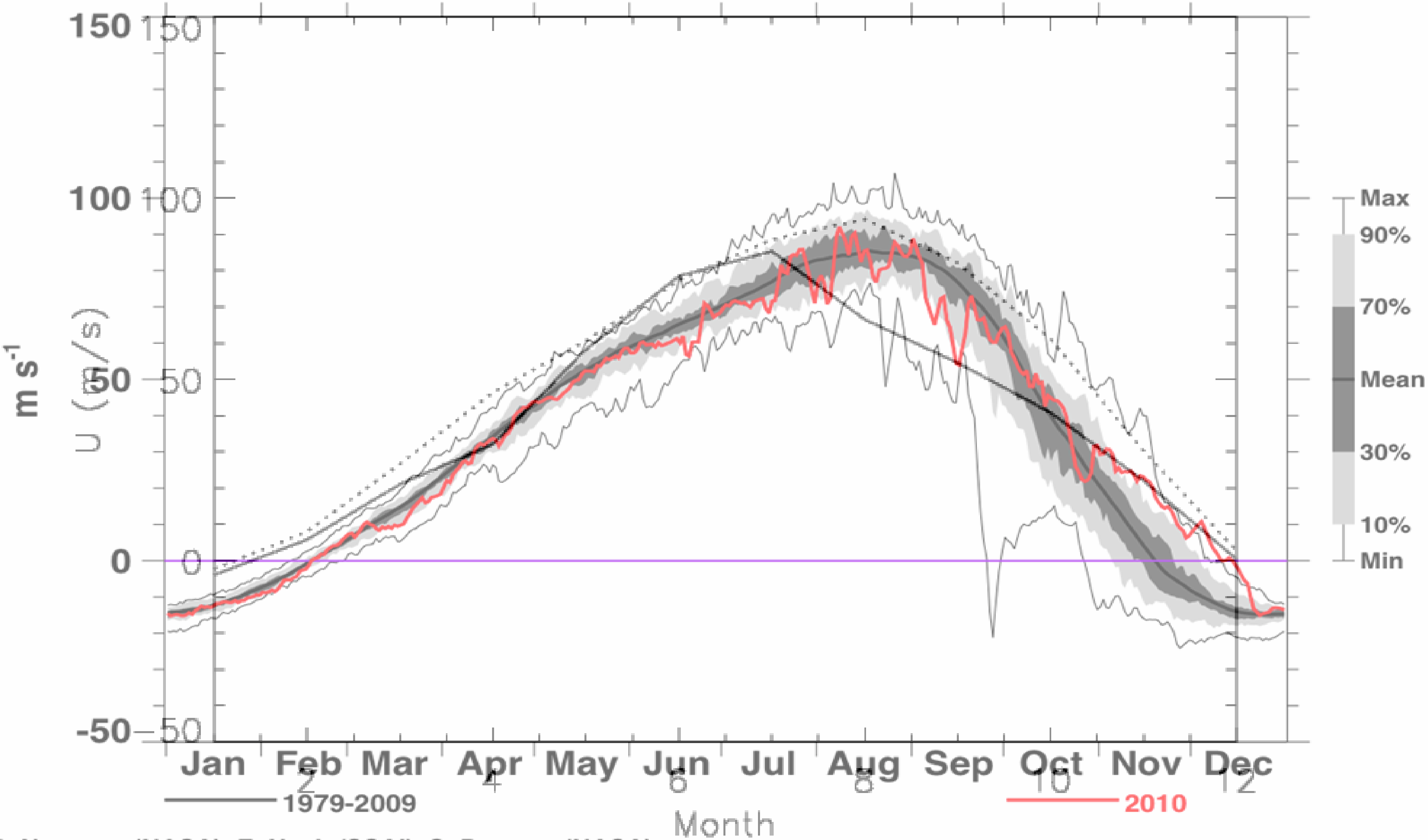
New GW scheme





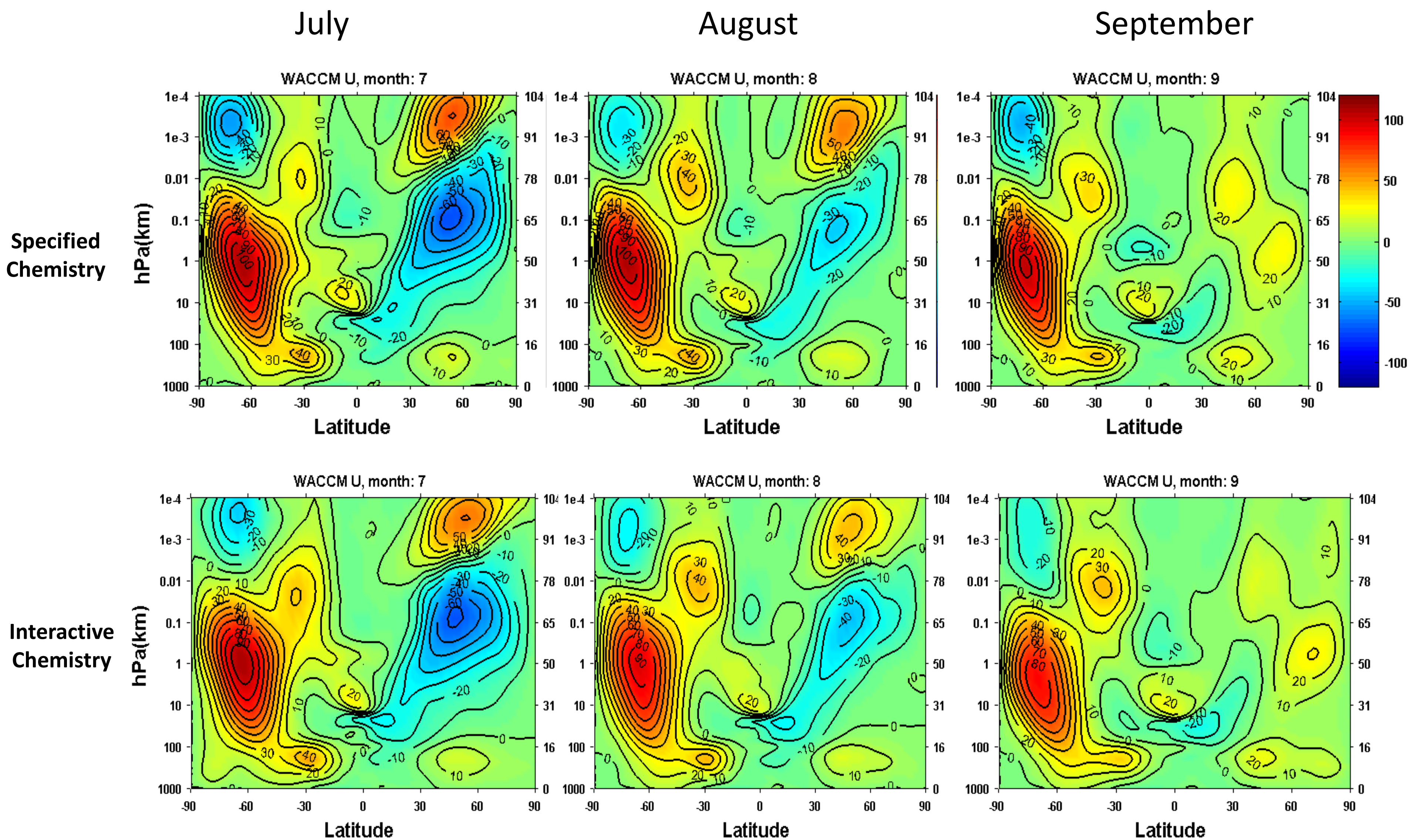
90°S Mean Temperature
10 hPa MERRA
HNO3 = 6 ppbv, H2O = 4.5 ppmv
K
300
280
260
240
220
200
180
160
Max
90%
70%
Mean
30%
10%
Min
Type I PSC
Type II PSC
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1979-2009
2010
Month

60°S Zonal Mean Zonal Wind
10 hPa MERRA



P. Newman (NASA), E. Nash (SSAI), S. Pawson (NASA)

Zonal wind, specified chemistry and interactive chemistry

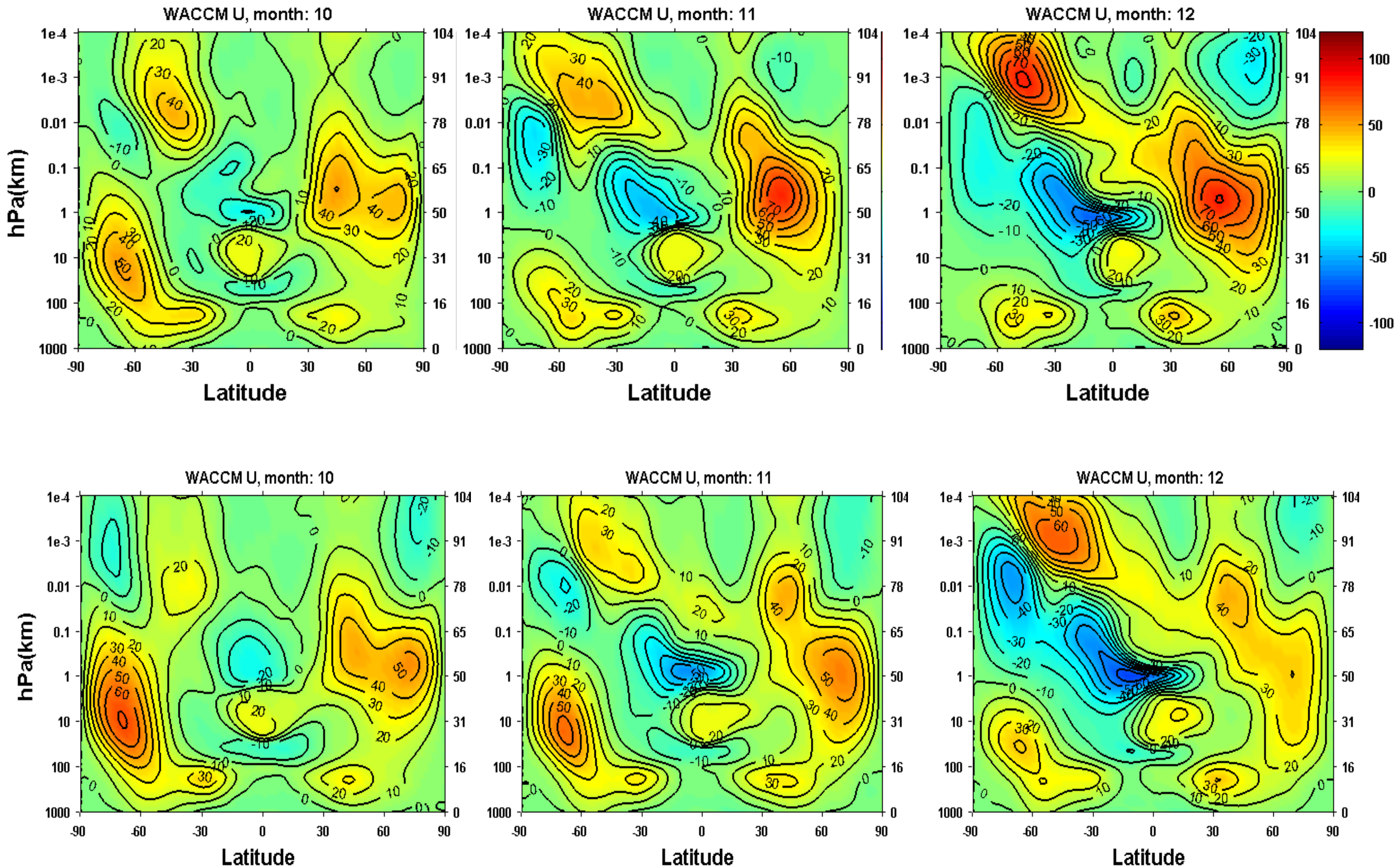


Zonal wind, specified chemistry and interactive chemistry

October | November | December

Specified Chemistry

Interactive Chemistry



Conclusions

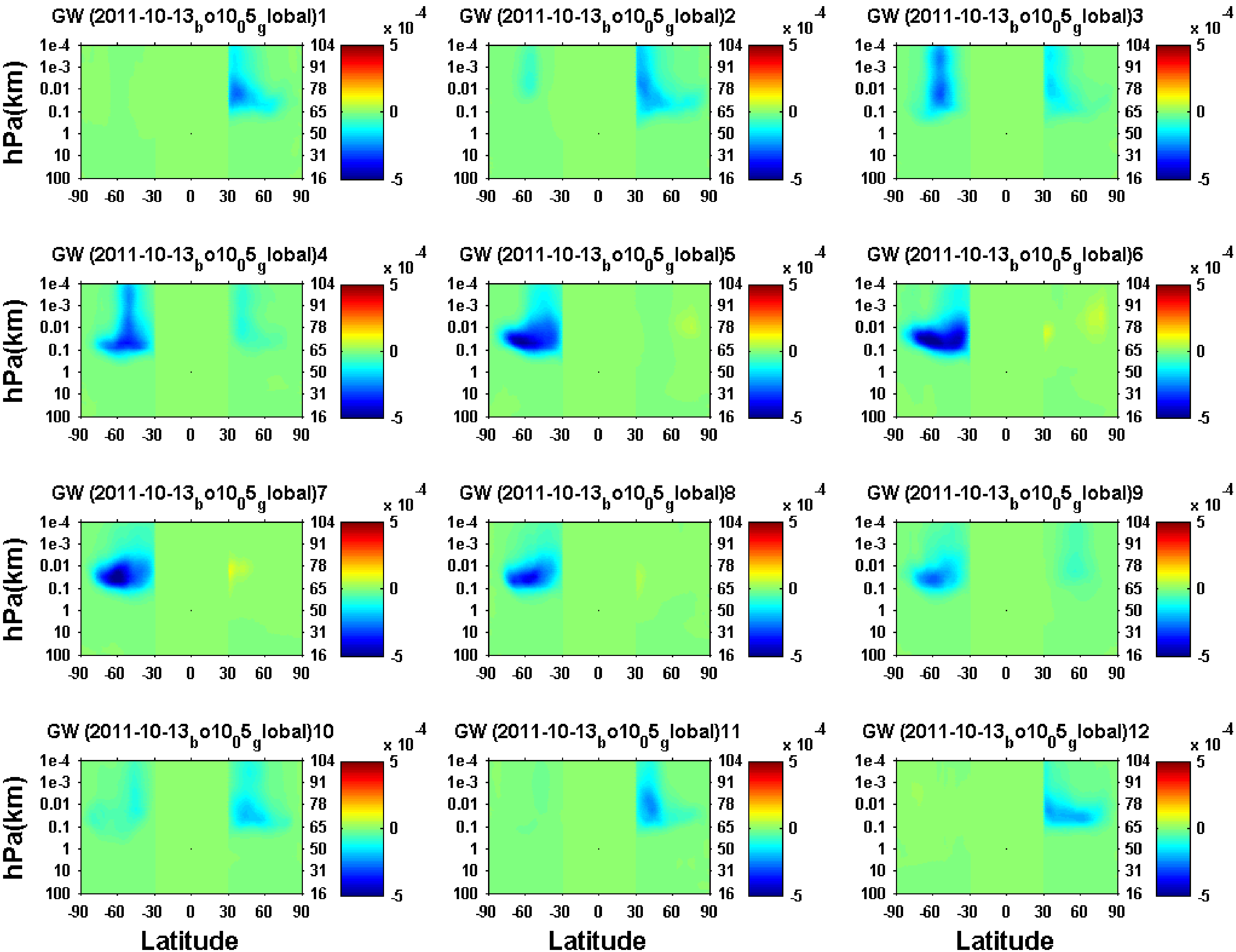
Using new gravity wave scheme:

- Zonal mean wind speed:

  Winter: Reduced zonal mean speed.

  Summer: Tropopause wind reversal altitude is decreased, closer to ERA-40.
- Comparing with ERA-40, the zonal wind difference between WACCM simulation and ERA-40 is reduced
- Winter temperatures in the stratosphere are warmer and in the lower mesosphere are colder in new scheme, so the cold & warm biases are reduced, closer to lidar observations.
- Spring time polar vortex recovery happens earlier (now in October, rather than November)
- This study demonstrate that the inertial gravity wave breaking plays an important role in the stratosphere and mesosphere dynamics.

Thanks


GW (2011-10-13$_b$o10$_0$5$_g$lobal)1
GW (2011-10-13$_b$o10$_0$5$_g$lobal)2
GW (2011-10-13$_b$o10$_0$5$_g$lobal)3
GW (2011-10-13$_b$o10$_0$5$_g$lobal)4
GW (2011-10-13$_b$o10$_0$5$_g$lobal)5
GW (2011-10-13$_b$o10$_0$5$_g$lobal)6
GW (2011-10-13$_b$o10$_0$5$_g$lobal)7
GW (2011-10-13$_b$o10$_0$5$_g$lobal)8
GW (2011-10-13$_b$o10$_0$5$_g$lobal)9
GW (2011-10-13$_b$o10$_0$5$_g$lobal)10
GW (2011-10-13$_b$o10$_0$5$_g$lobal)11
GW (2011-10-13$_b$o10$_0$5$_g$lobal)12
hPa(km)
1e-4
1e-3
0.01
0.1
1
10
100
104
91
78
65
50
31
16
-90
-60
-30
0
30
60
90
Latitude
$\times 10^{-4}$
5
0
-5

Background of Cold Pole

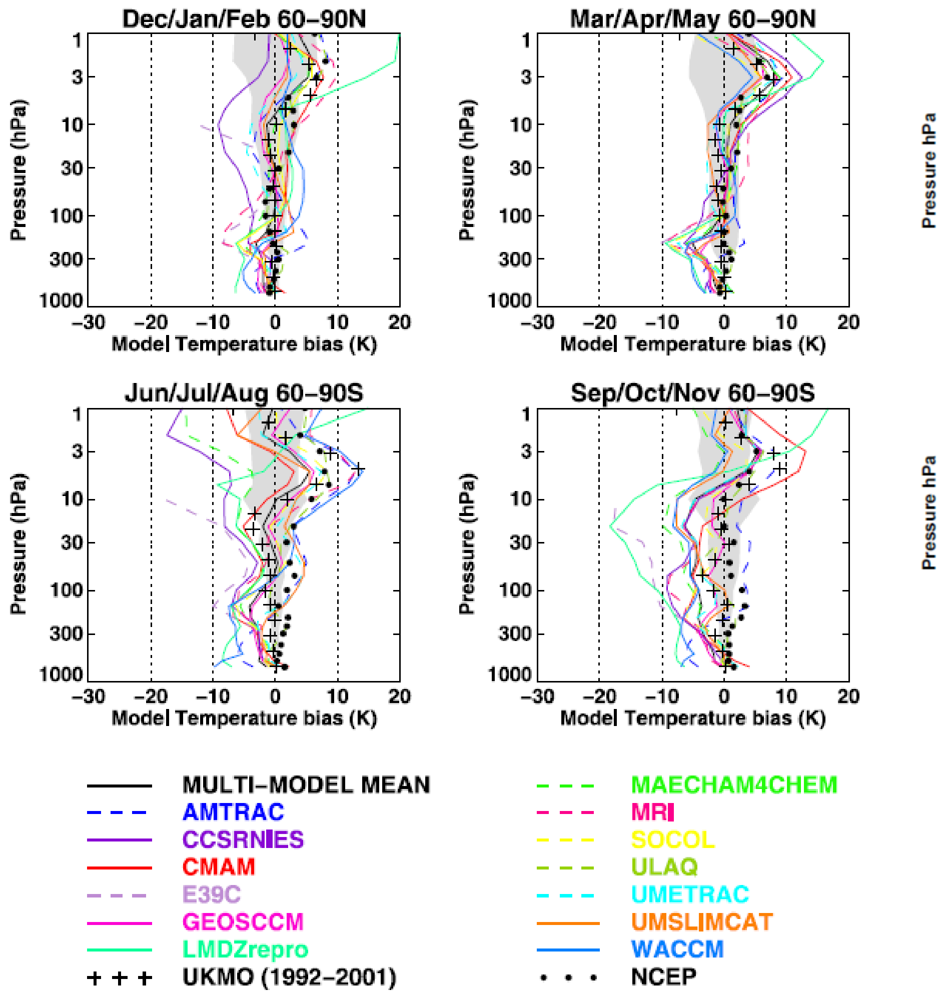
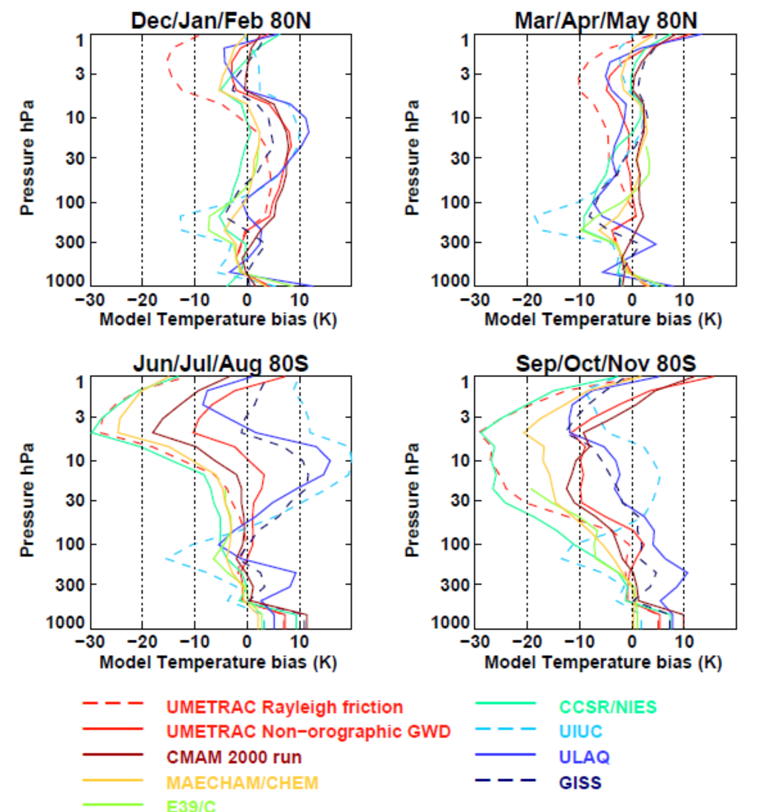


Figure 1. Climatological mean temperature biases for (top) 60–90°N and (bottom) 60–90°S for the (left) winter and (right) spring seasons. The climatological means for the CCMs and NCEP data from 1980 to 1999 and for UKMO from 1992 to 2001 are included. Biases are calculated relative to ERA-40 reanalyses. The grey area shows ERA-40 plus and minus 1 standard deviation (σ) about the climatological mean.

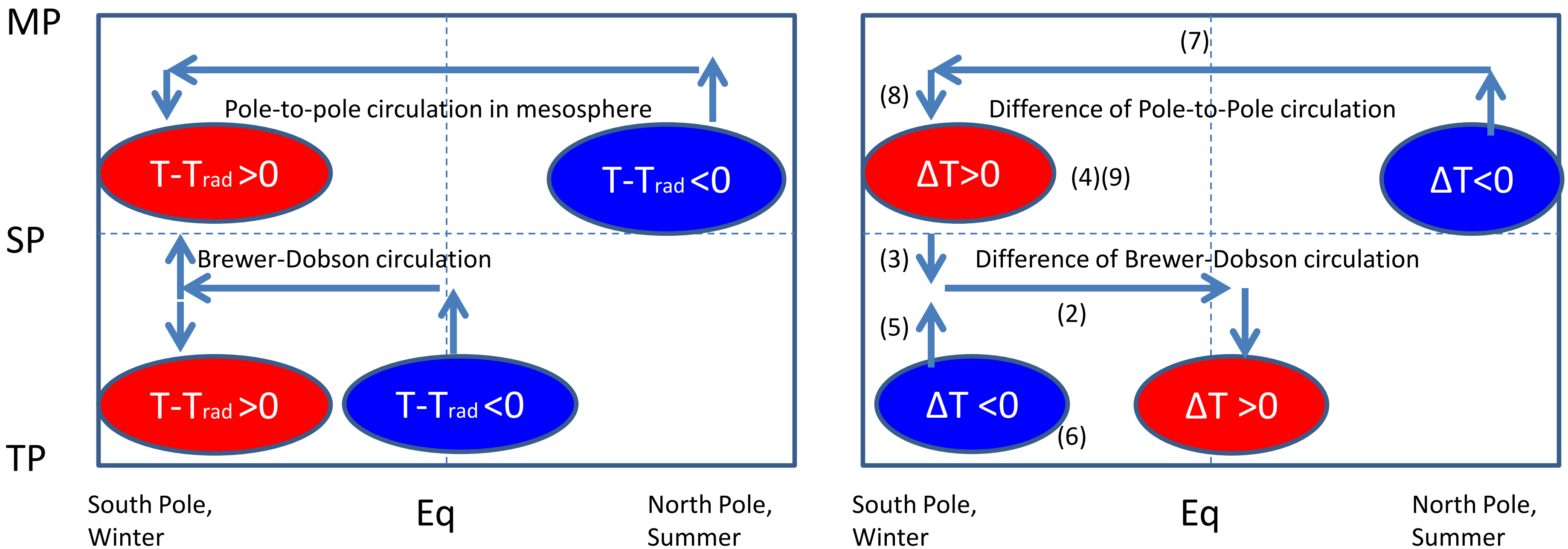
Eyring et al., 2006



Temperature biases at 80 N and 80 S for the winter and spring seasons, as a function of pressure. To determine the bias, a climatology determined from 10 years of UKMO data assimilation temperatures was subtracted from the model

Austin et al., 2003

Possible mechanisms of Cold Pole



Atmosphere circulation and adiabatic heating/cooling

Difference of circulation and adiabatic heating/cooling between model and observation