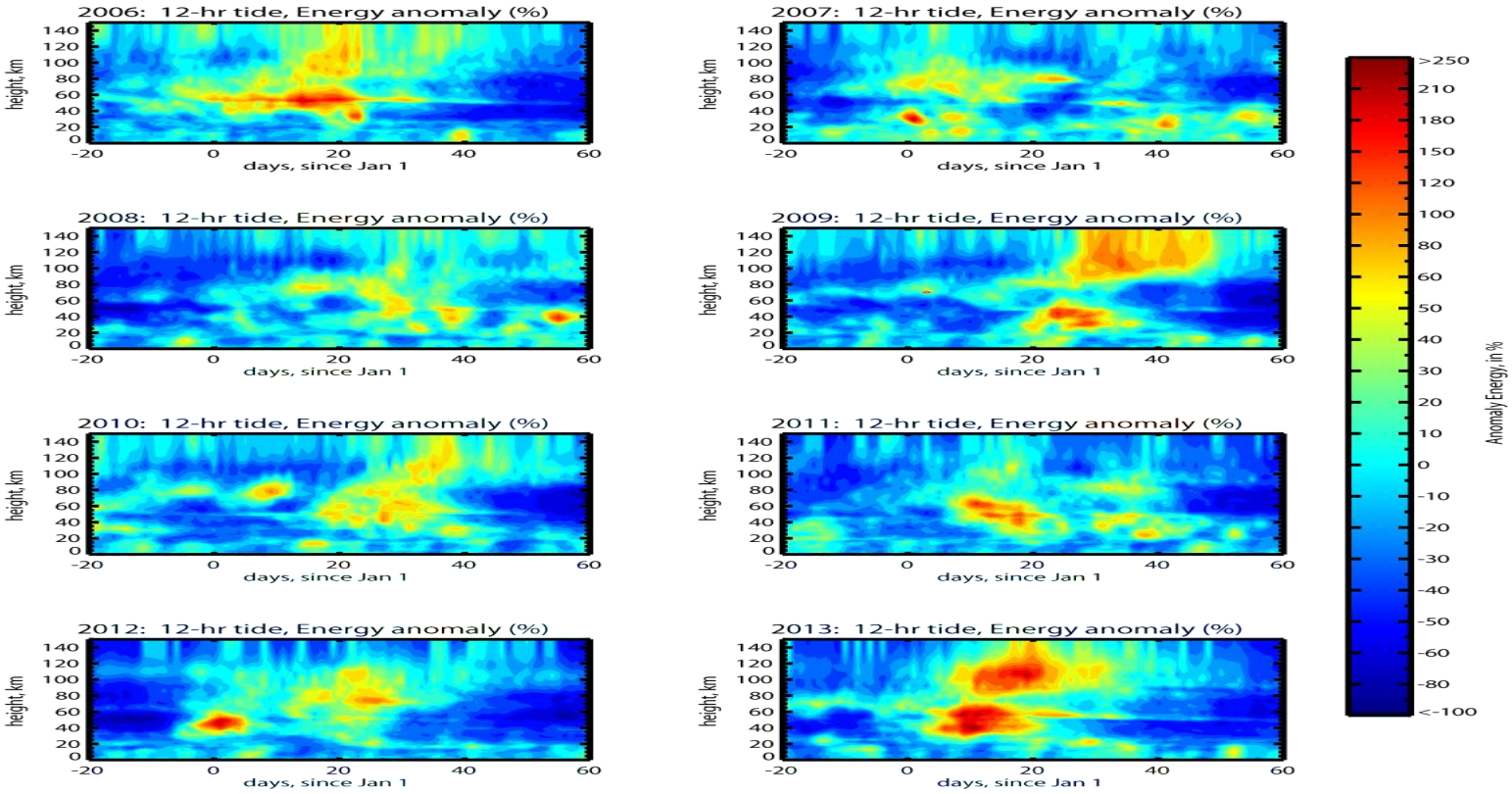
Wave dynamics during recent SSW events as recreated by WACCM-X/GEOS-5: Arctic (2006-2013) and Antarctic (2002)

V. A. Yudin, H.-L. Liu, L.P. Goncharenko and B.T. Foster

NCAR - MIT



Key elements for recreation of wave dynamics and ionosphere-atmosphere coupling during SSW in the Whole Atmosphere Community Climate Models (WACCM)

- **Zonal mean flow and Planetary Waves**

….. *Terrestrial weather from meteo-analyses (GEOS-5 and MERRA of GMAO at NASA/GSFC)*

- **Diurnal variations (tides):**

issue tidal amplitudes (quite weak in the MLT) due to "effective" eddy dissipation in WACCM

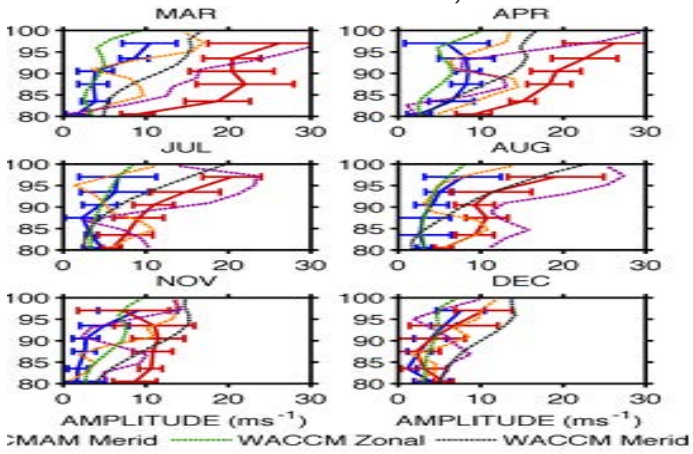
- **Accurate and "gentle" introduction of the Specified Meteorology in the LA**

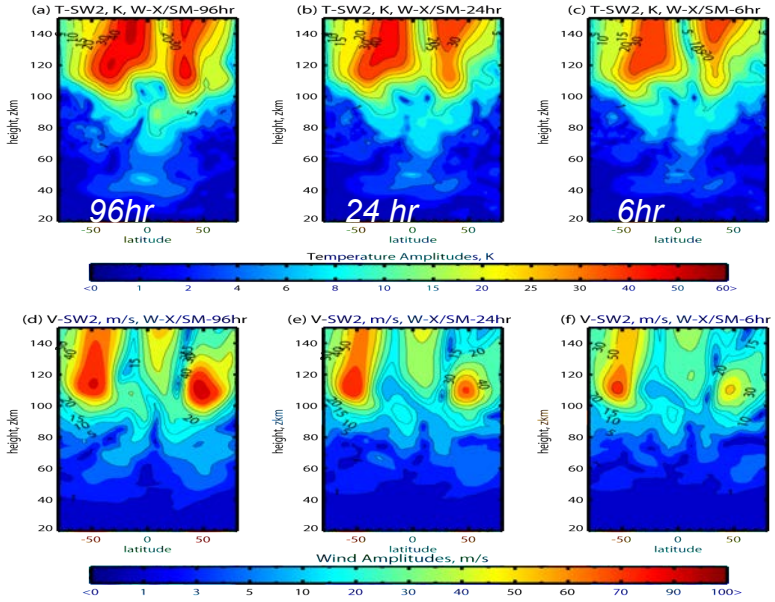
to preserve tides and transient PWs (48 hr)

- **Other model issues:**

conservation of energy in model "physics"… and updates of GW-MF closure

Davis et al. 2013, Ans. Isl. 8S





WACCM-X/GEOS-5, 116 level model with specified meteorology

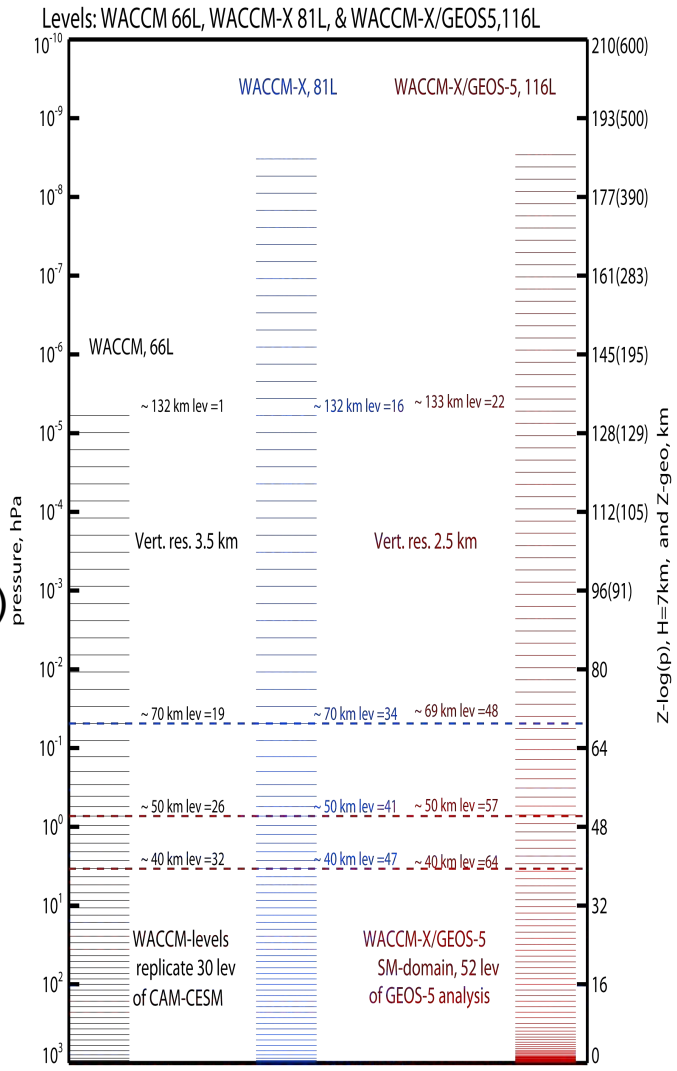
Specified Meteorology
Mean flow, O_3 and PWs

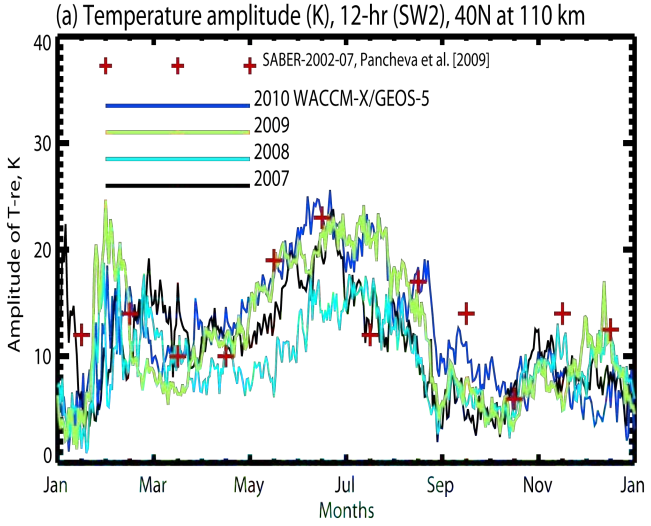
Tides that match data
(*annual cycles and QBO*)
due to updated GWPs

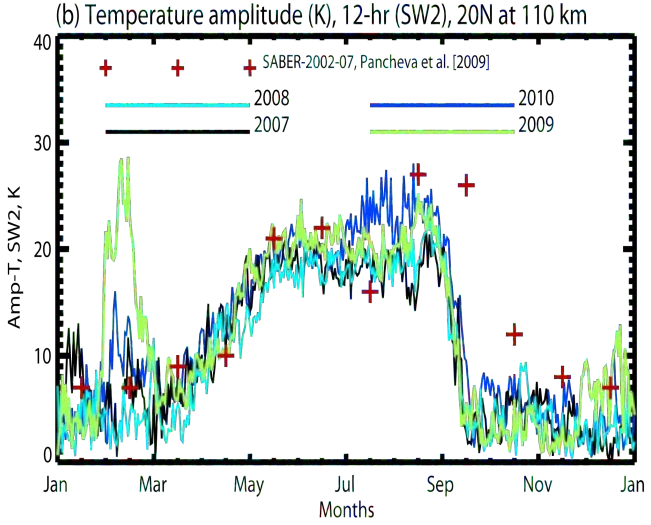
No reflection of waves
from top lid (~500km)

Enhanced vert. res-n

One-way coupling (hourly)
WACCM-X and TIME-GCM.



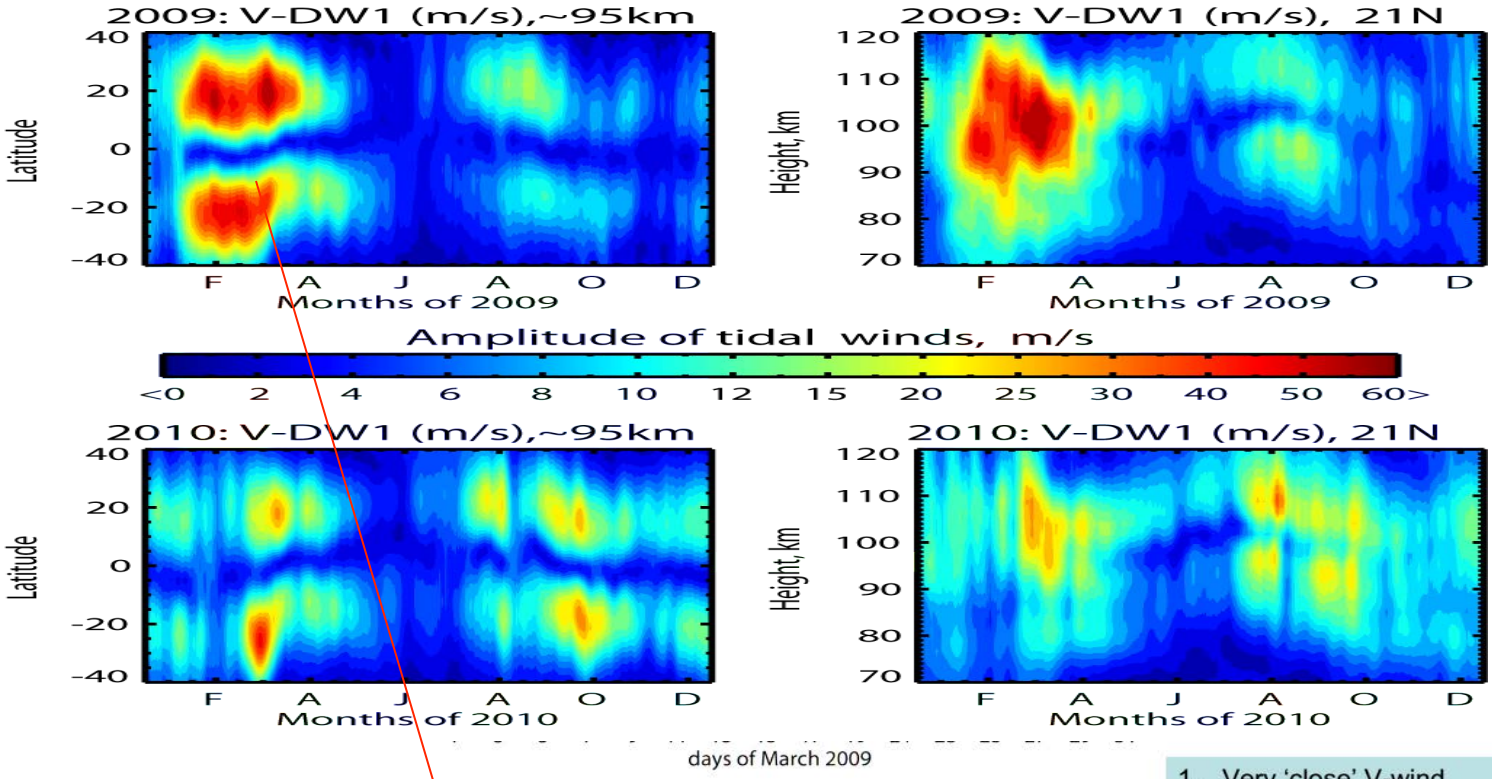


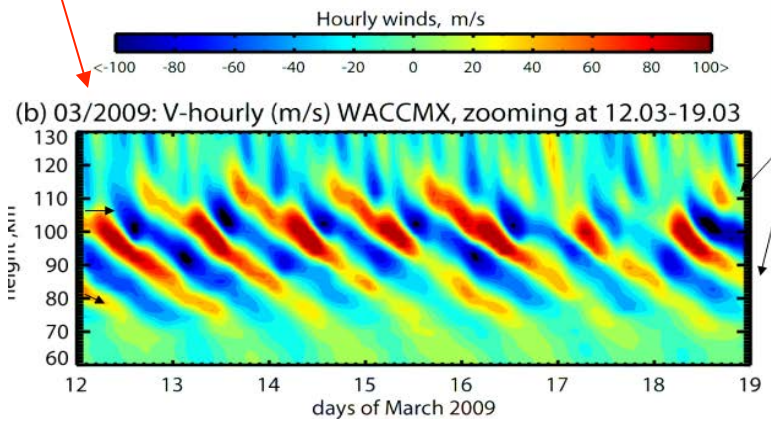


Updating GW schemes and physics => effects on tides along with terrestrial weather (QBO in DW1)

West-ly str-QBO

East-ly str-QBO





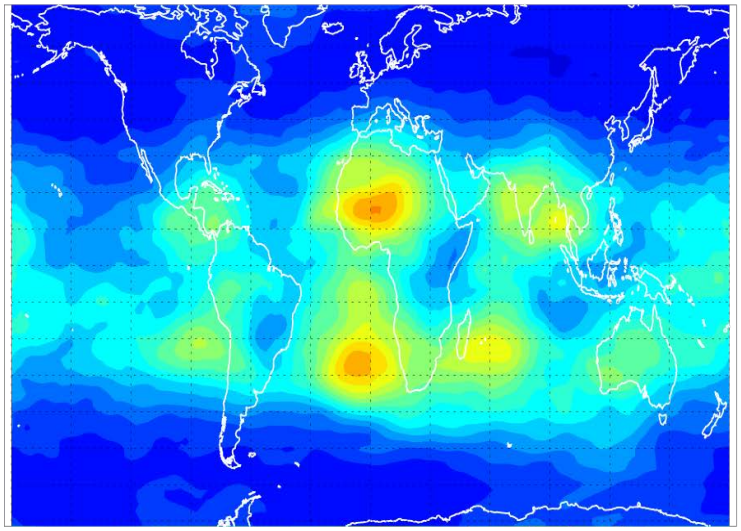
- ***New GW-MF closure***
- ***"Persistent" spectra of GWs no triggering***
- ***Eddy diffusion operator***
- ***Energy and momentum conservation***

1. Very 'close' V-wind variations to observed
2. Problems with equatiorial zonal mean U-winds
3. Average ~ 23-25 km VWL
4. Double peak amplitudes reminds HRDI/WINDII
5. 12-hr tide above110 km

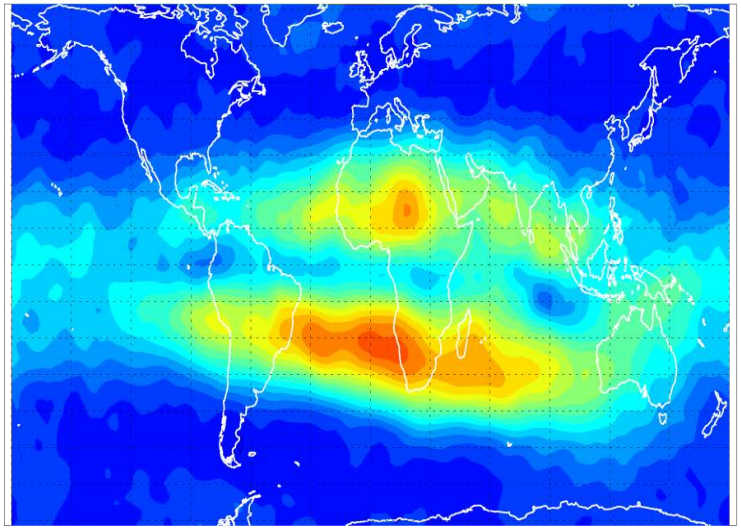
Ans. Island, 8°S

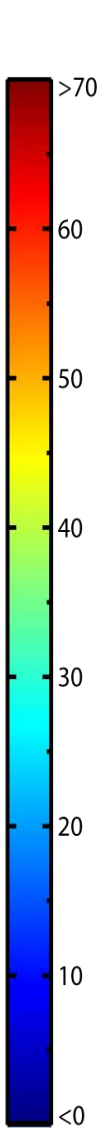
Local 100 m/s osc.

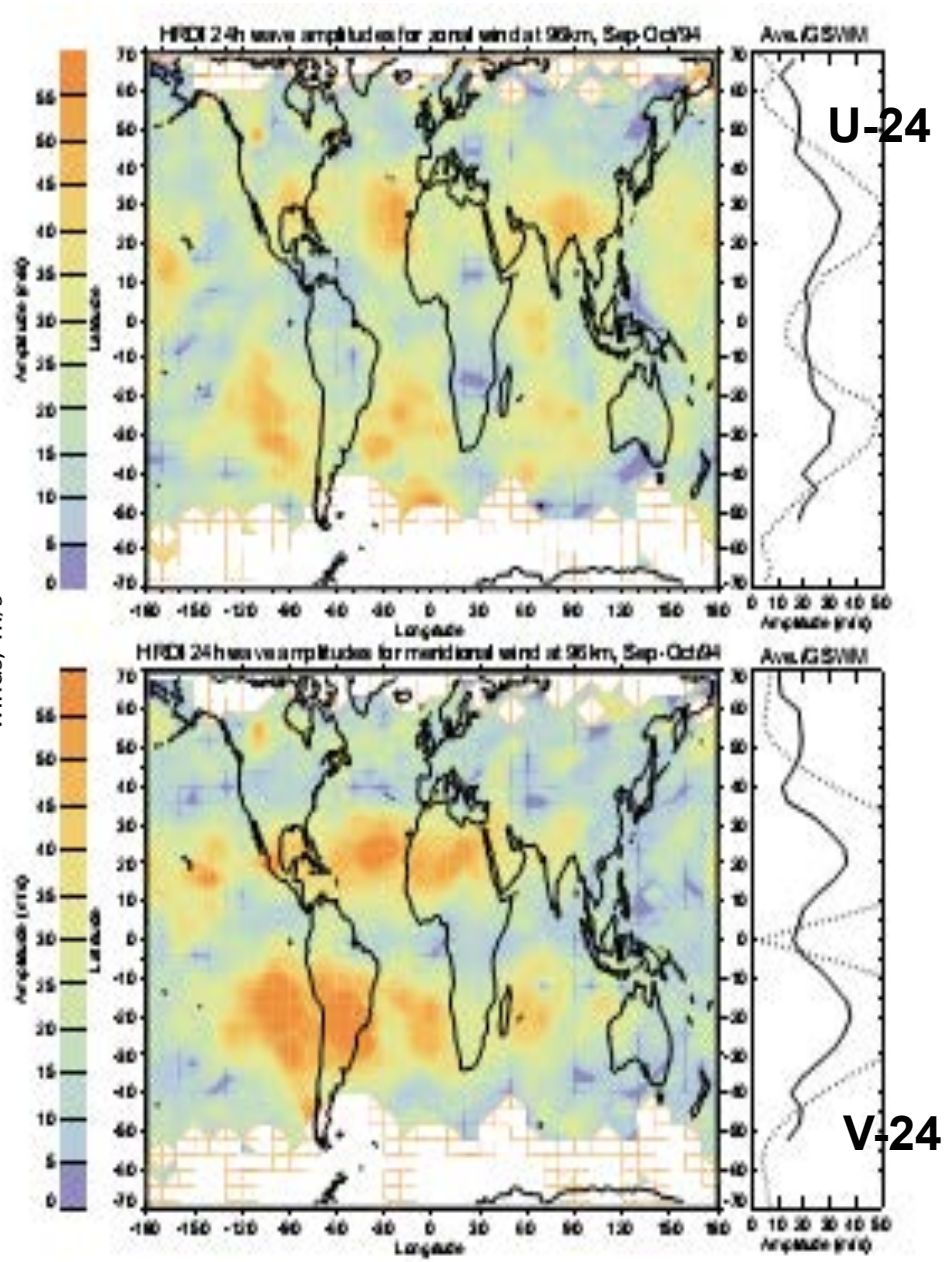
Sep-Oct 2007: Amplitudes of U-24hr, 96 km



Sep-Oct 2007: Amplitudes of V-24hr, 96 km





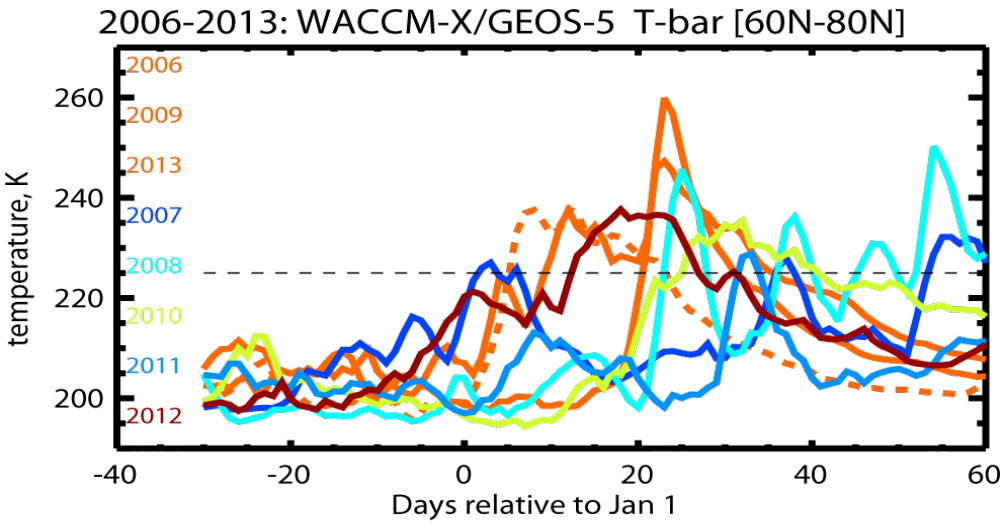


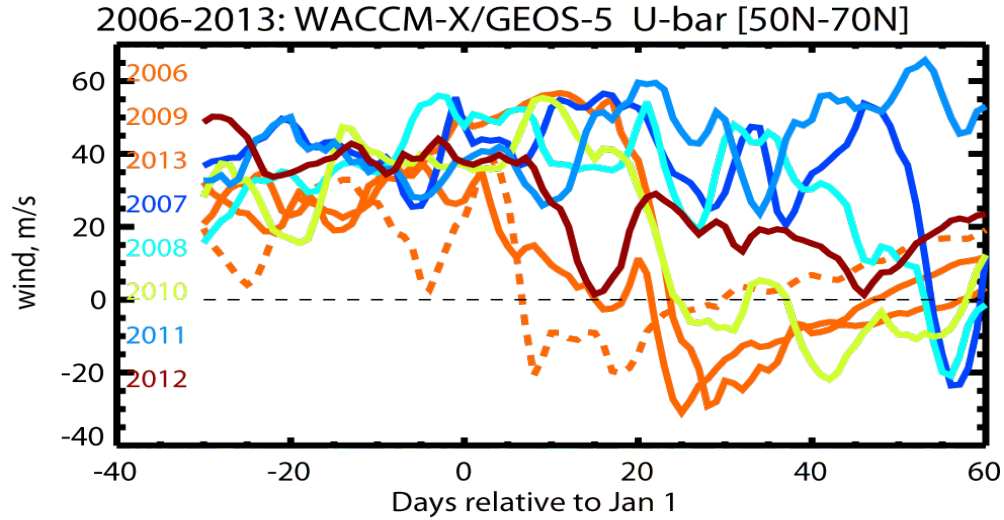
Migrating and non-migrating 24-hr modes, 96 km

Manson et al. 2005, HRDI-94
Sep-October 1994

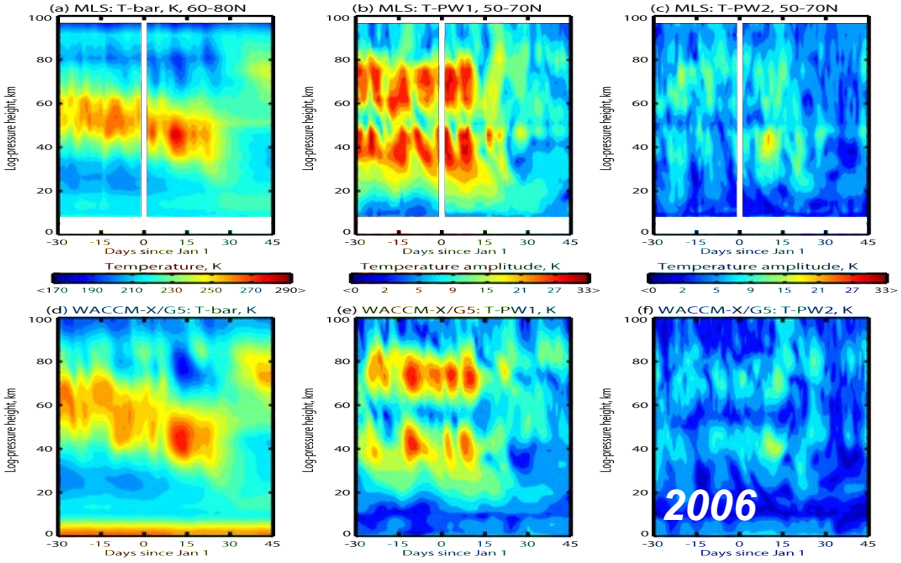
Next step: Model-data, model-model comparisons and evaluations during Arctic SSW events (2006-2013)

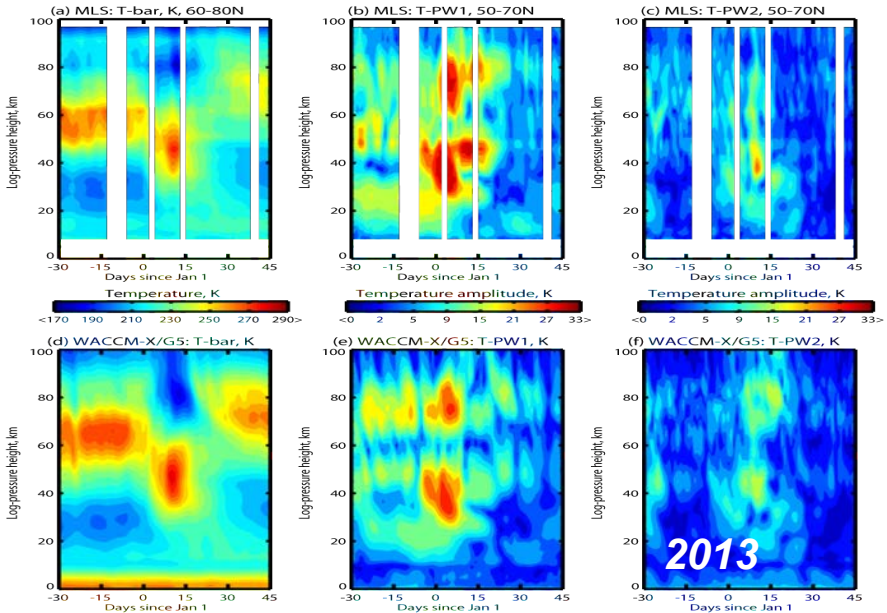
- **Transience of zonal means**
- **Transient PW structures**, QSPW and Q2DWs
- **Transient diurnal cycles**: day-to-day variability and changes of tides triggered by SSW.
- ***Local view***, like ground-based tidal signatures
- ***Spectral content*** of PWs and tides as global waves (s-ω)-spectra.



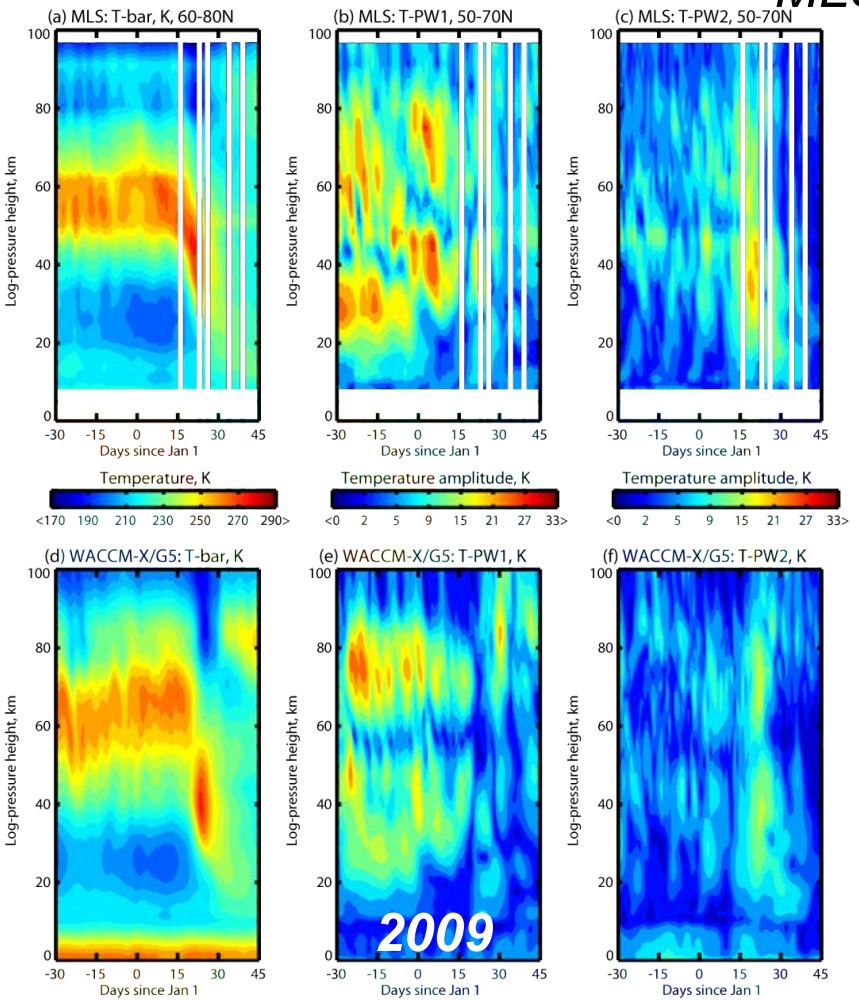


Major (2006, 2009, 2013) SSW: MLS (top) vs WACCM-X/GEOS-5





MLS

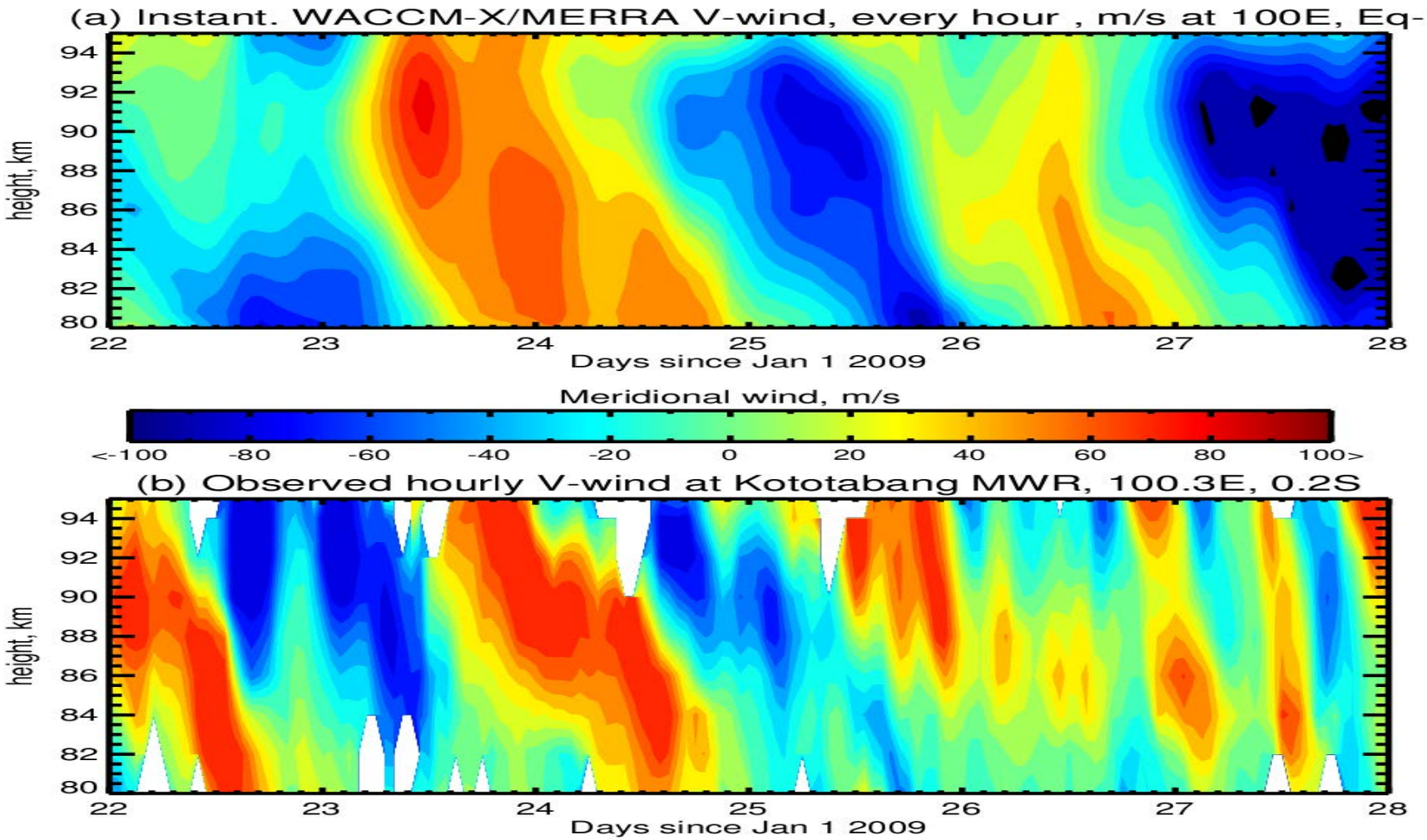


SSW ….2008/2009

WACCM-X/G5

MLS-T data are not analyzed in GEOS

Jan 22-28 of 2009: Hourly V-winds, WACCM-X/MERRA and MWR at Kototabang, quasi-2-day wave signatures at the equator



MWR-data from //database.rish.kyoto-u-ac.jp

Major SSW during last week of Jan 2009

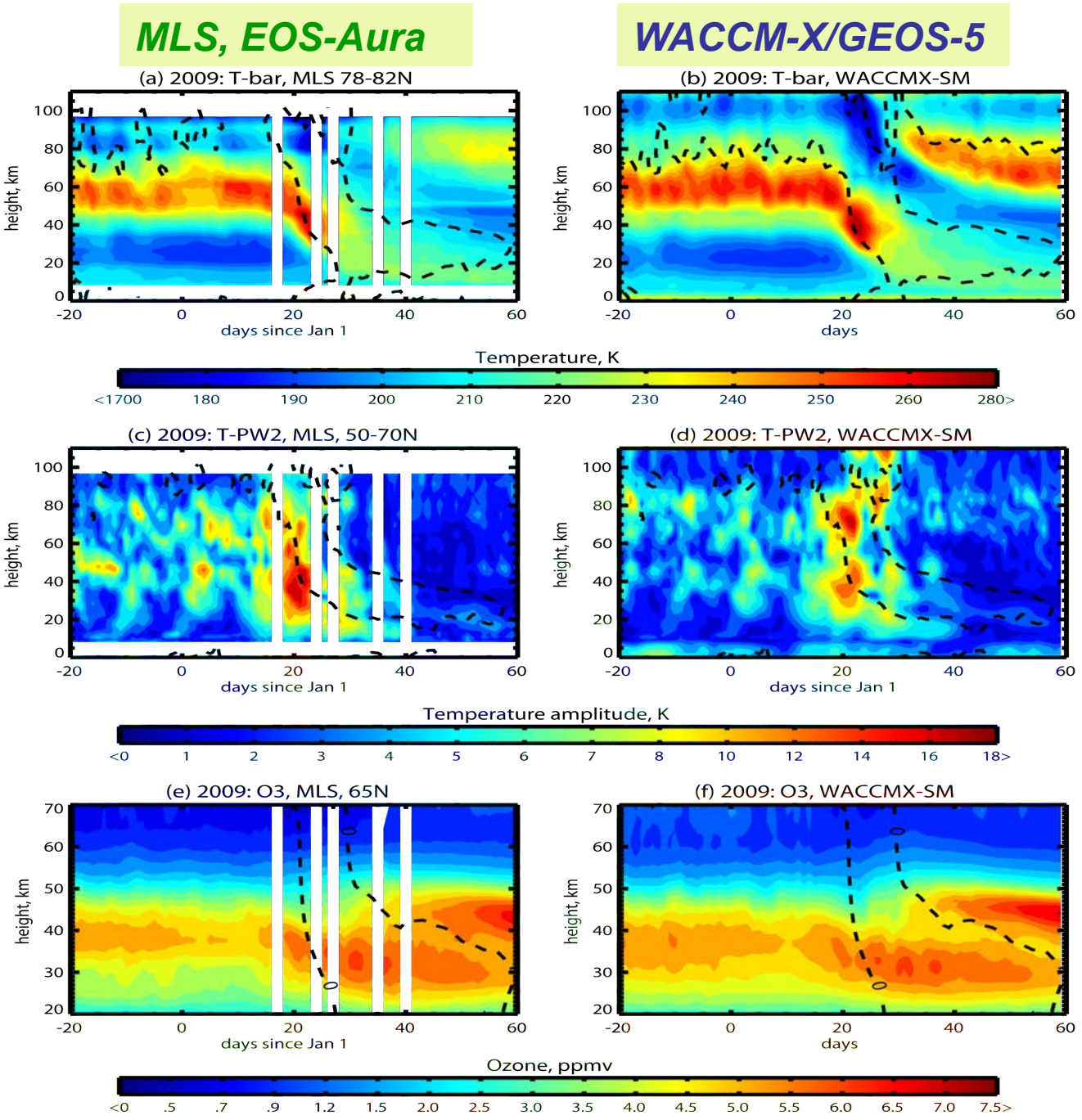
PW=2 breaking

WACCM-X/GEOS5

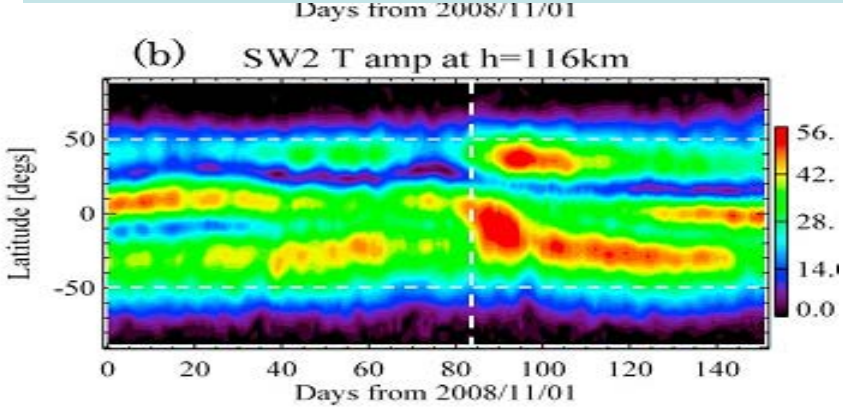
versus

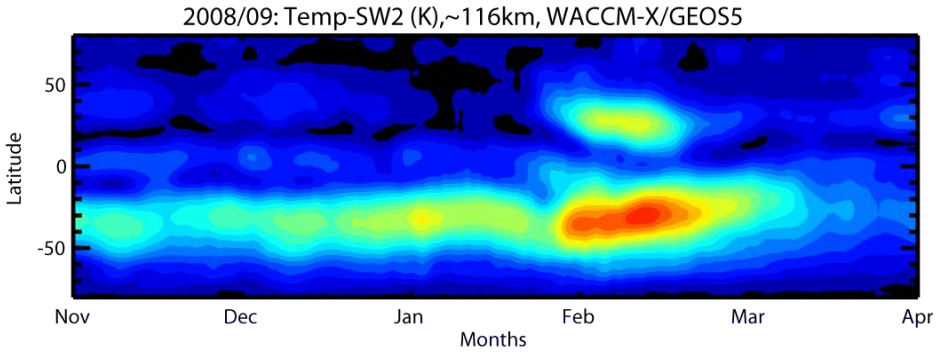
MLS on EOS Aura

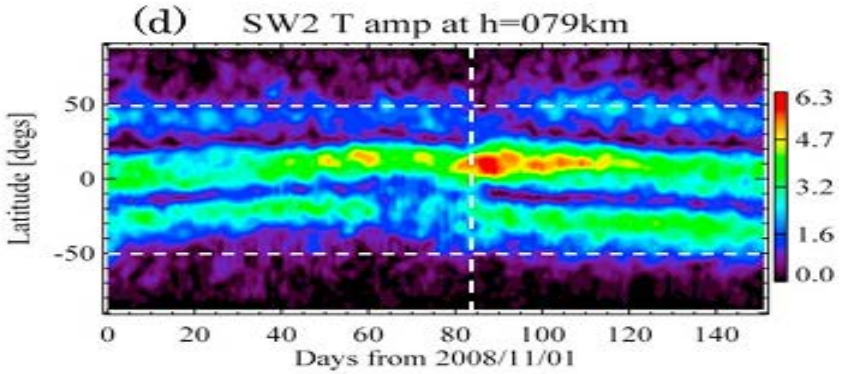
Ozone: MLS vs WACCM (tidal forcing)

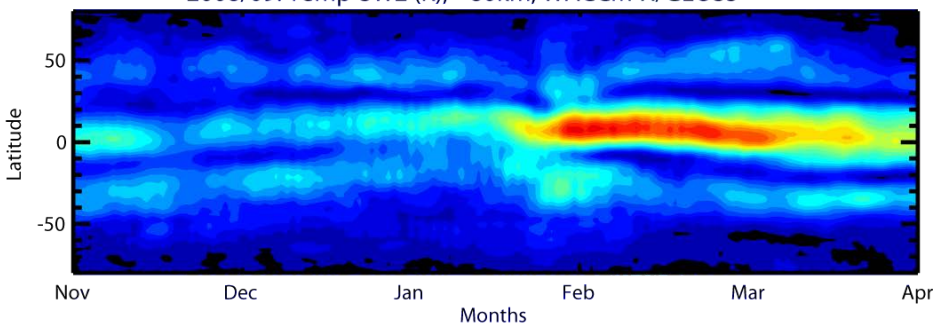


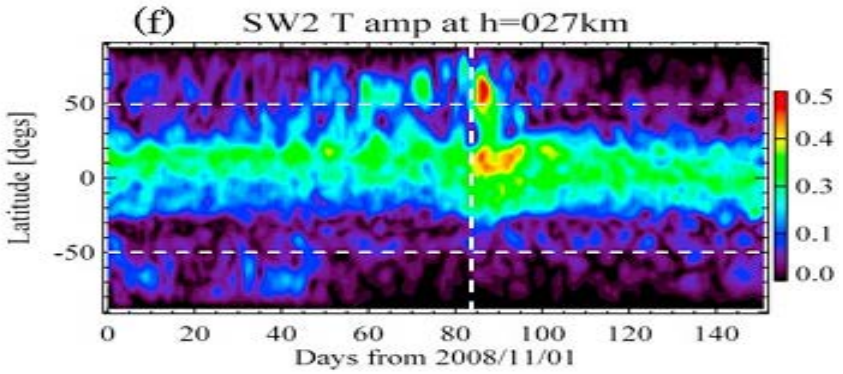
SSW of 2009, Model-model comparisons: GAIA/JRA-25 vs WACCM-X/GEOS-5

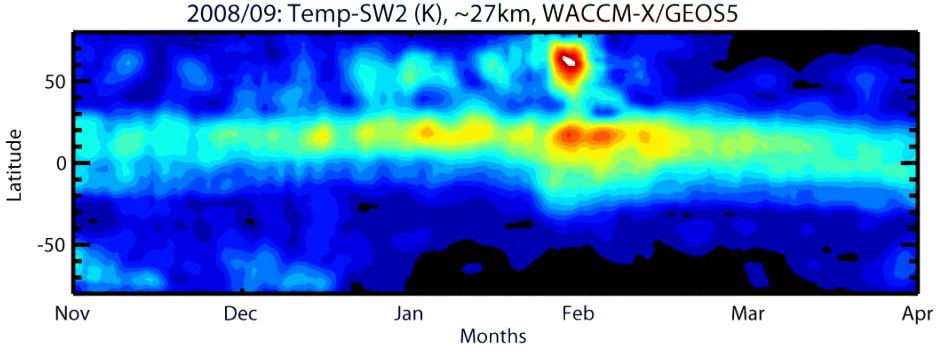


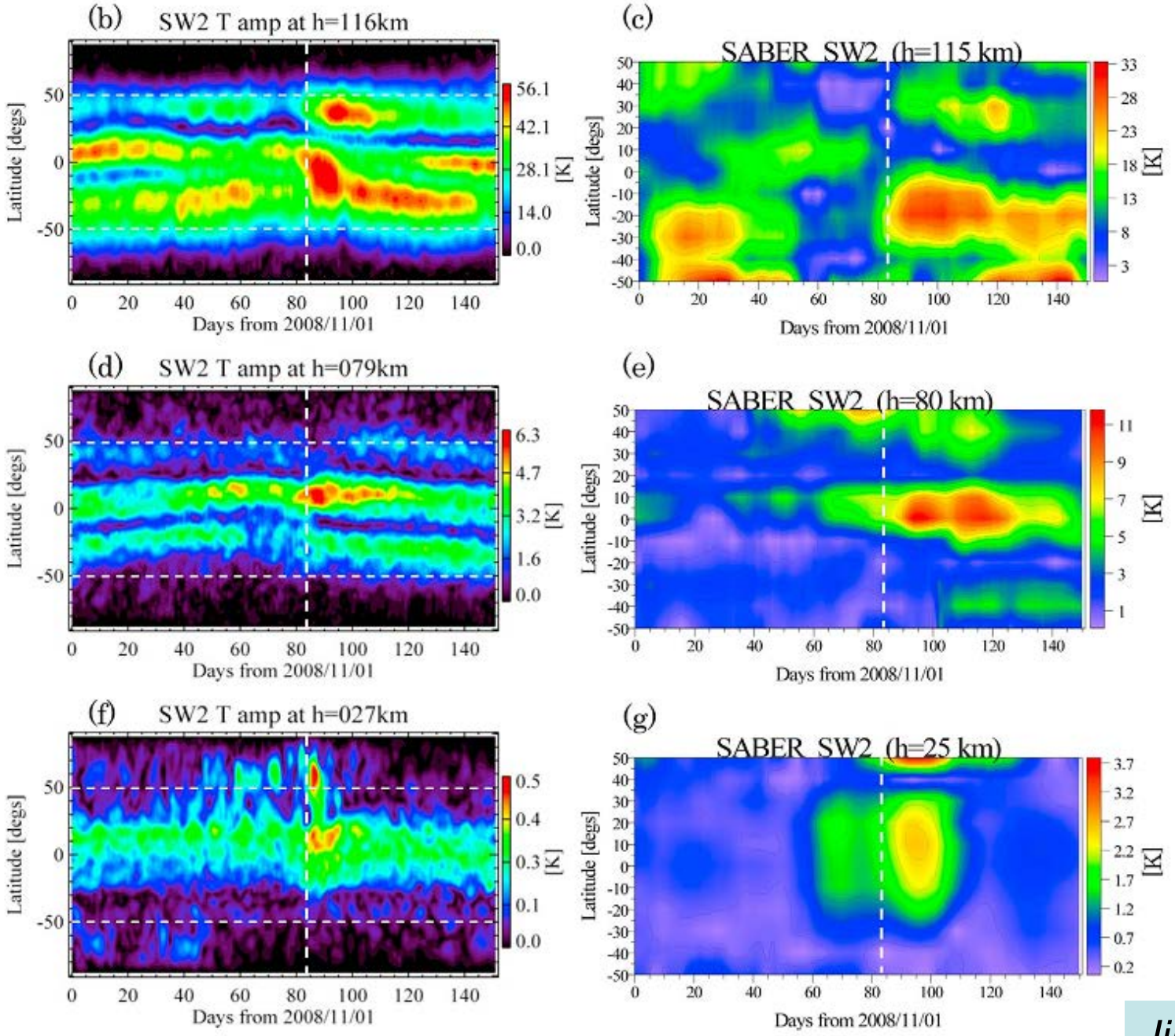












Color scales

56K vs 33K

SW2:

SABER

(60-day data collection)

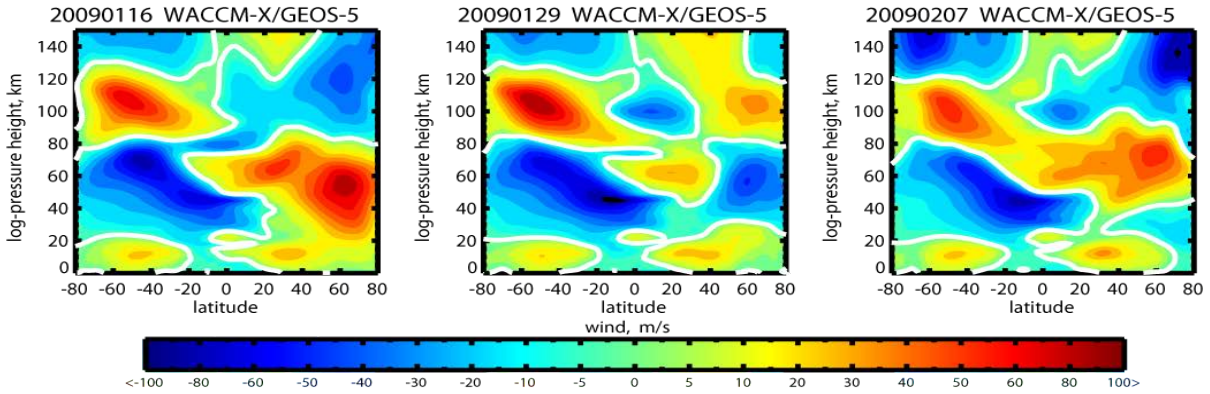
vs GAIA daily

Jin et al. 2012

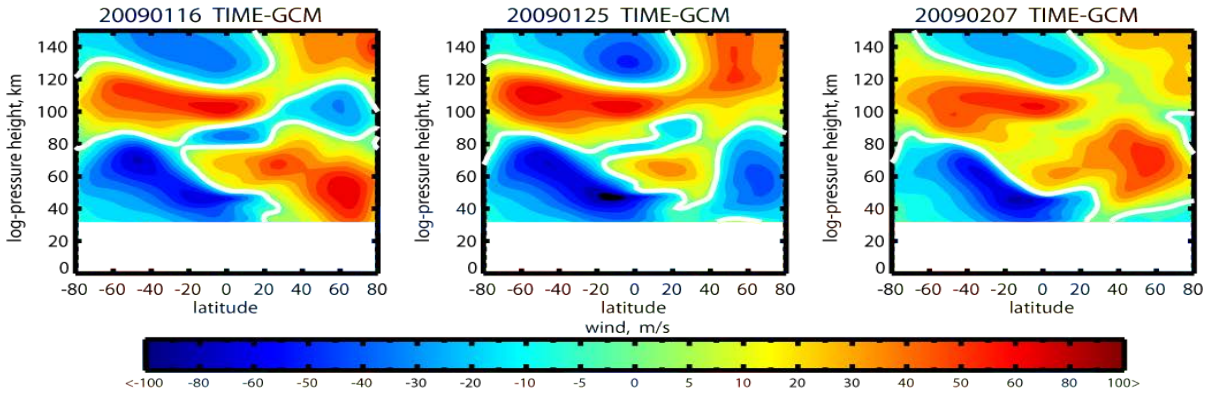
Figure 5. The same as Figure 4, but for semidiurnal migrating tide (SW2).

Coupling WACCM-X/MERRA and TIME-GCM and checking vs NRL NOGAPS-ALPHA (Jan-Feb, 2009)

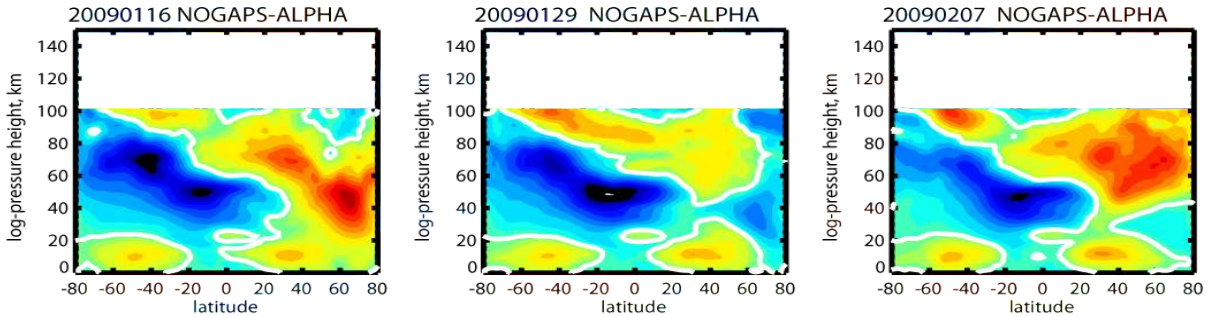
Zona flowJan-Feb 2009:
WACCMX-GEOS5;



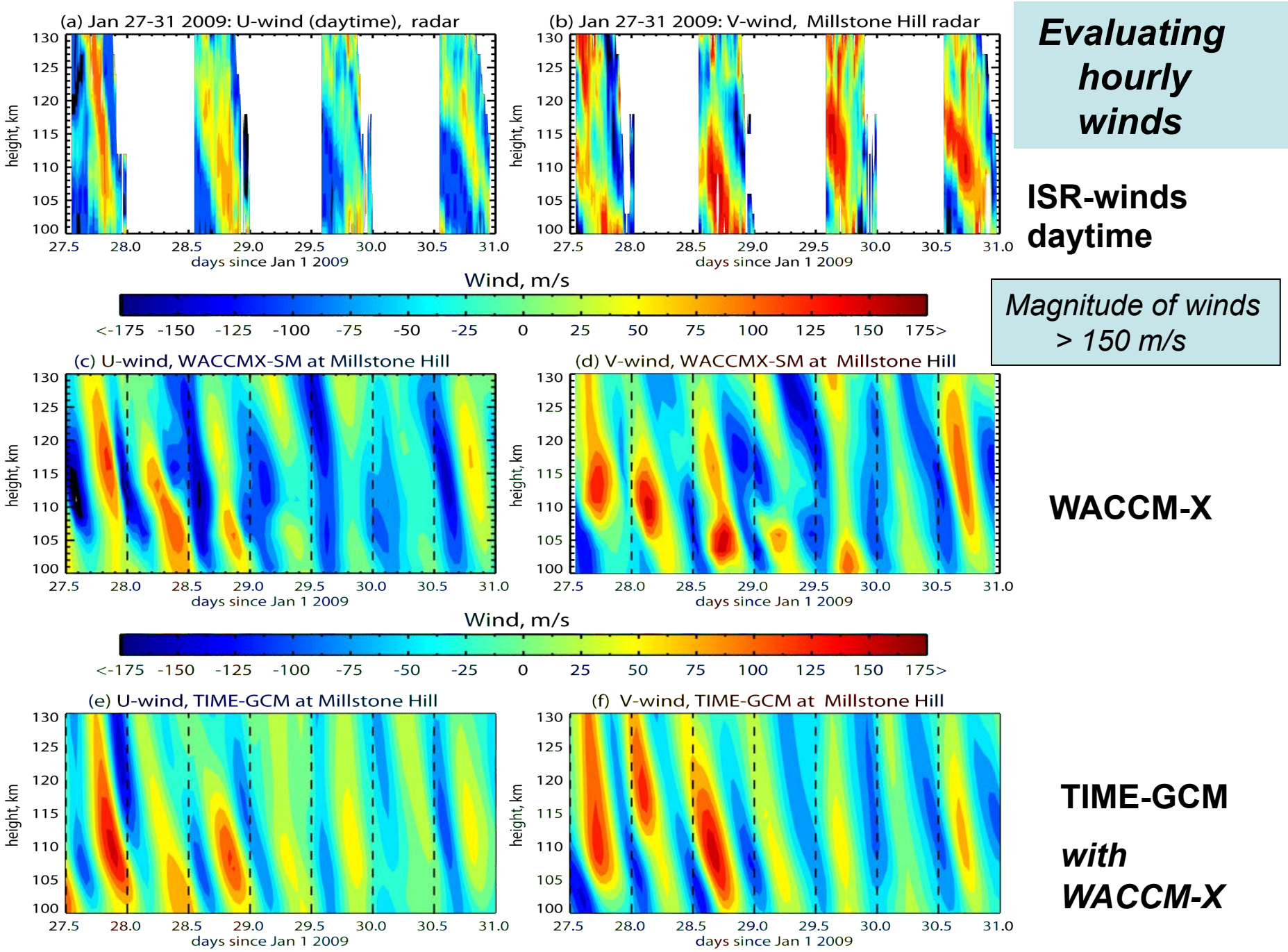
TIME-GCM/WACCM-X



NRL NOGAPS-Alpha



- *Liu et al. (2013)*
- *Yudin et al. (2013)*



Evaluating hourly winds

ISR-winds daytime

Magnitude of winds > 150 m/s

WACCM-X

TIME-GCM

with WACCM-X

SSW effects on the diurnal cycles: tides and TEC perturbations

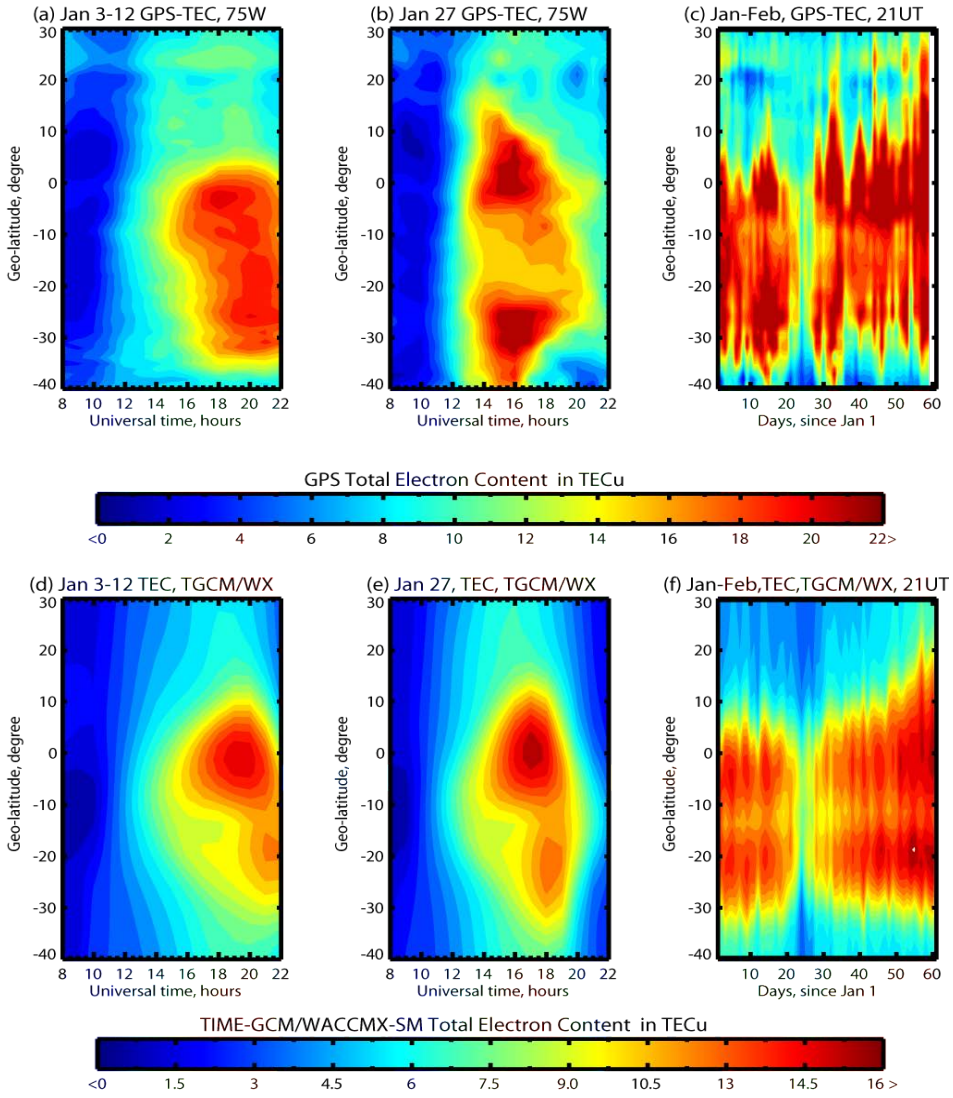
- WACCM-X/G5 and TIME-GCM:

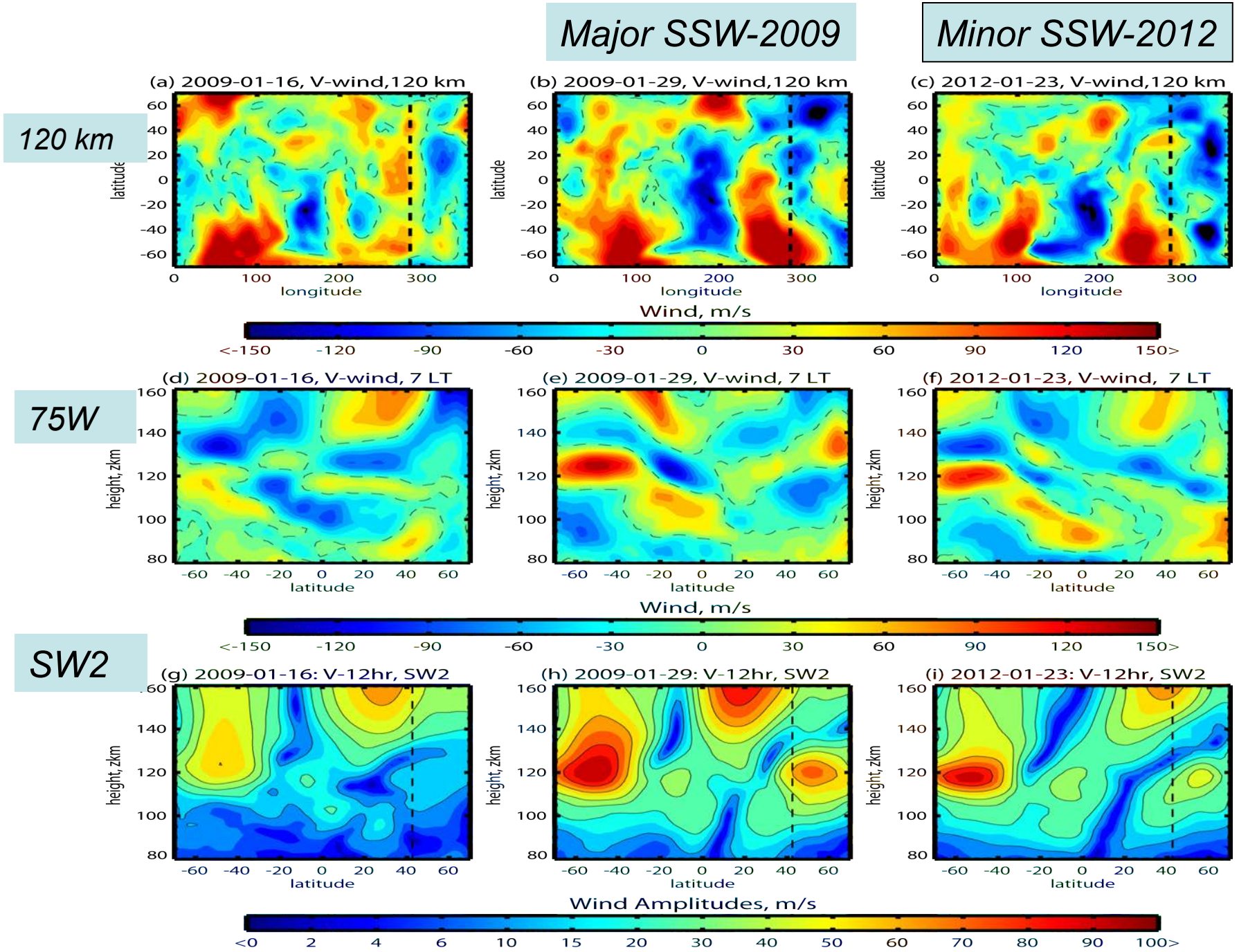
  Arctic: *2006,2009,2012*

  Antarctic: *2002*

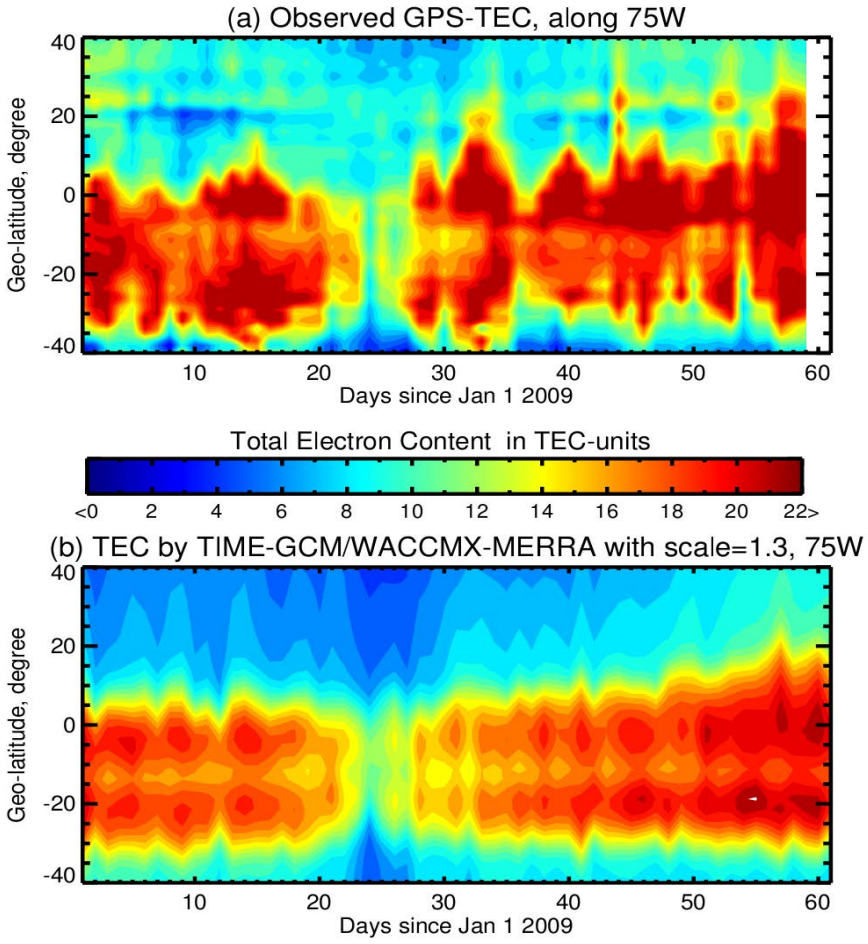
- **Key feature**: *amplification of 12-hr tide, after isolation of PW-activity and separation of MA from troposphere*.

- **Striking effects on the ionosphere, Jan 2009**…
  Can TIME-GCM driven by WACCM-X-G5 can match it ?

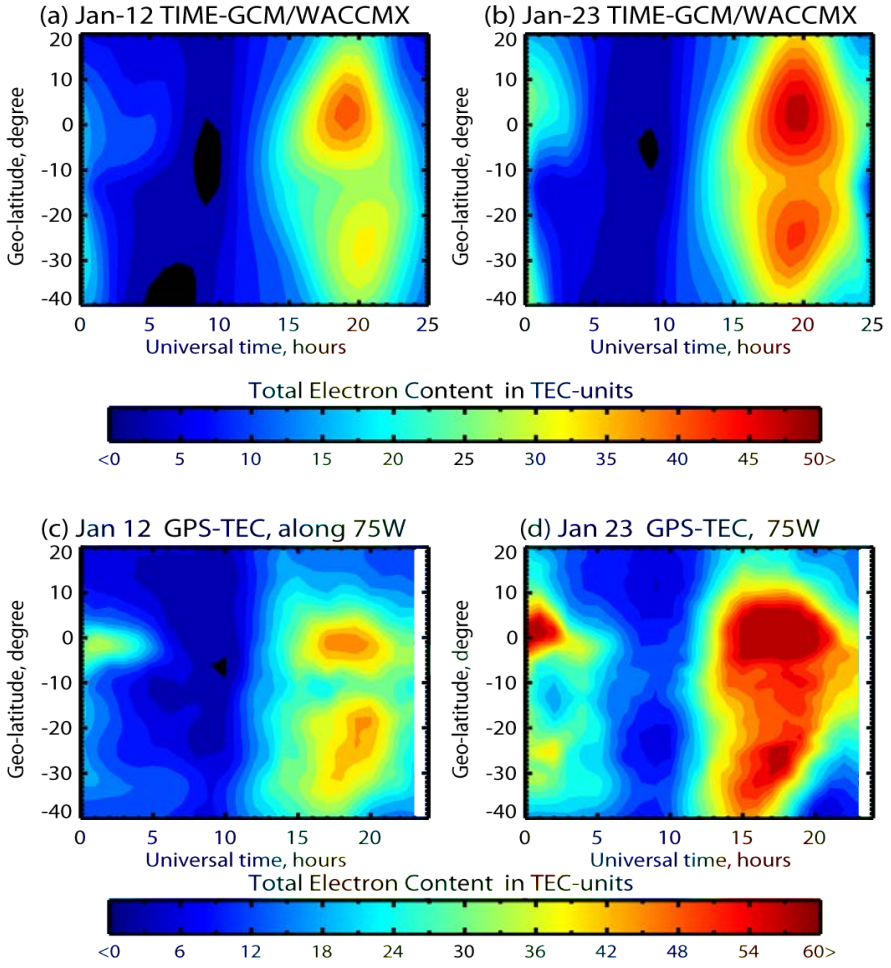



Major SSW-2009
Minor SSW-2012
120 km
75W
SW2
(a) 2009-01-16, V-wind,120 km
(b) 2009-01-29, V-wind,120 km
(c) 2012-01-23, V-wind,120 km
latitude
longitude
Wind, m/s
<-150 -120 -90 -60 -30 0 30 60 90 120 150>
(d) 2009-01-16, V-wind, 7 LT
(e) 2009-01-29, V-wind, 7 LT
(f) 2012-01-23, V-wind, 7 LT
height, zkm
latitude
Wind, m/s
<-150 -120 -90 -60 -30 0 30 60 90 120 150>
(g) 2009-01-16: V-12hr, SW2
(h) 2009-01-29: V-12hr, SW2
(i) 2012-01-23: V-12hr, SW2
height, zkm
latitude
Wind Amplitudes, m/s
<0 2 4 6 10 15 20 30 40 50 60 70 80 90 100>

Evaluation of TEC variations in TIME-GCM with WACCM-X/MERRA neutral atmosphere below mesopause

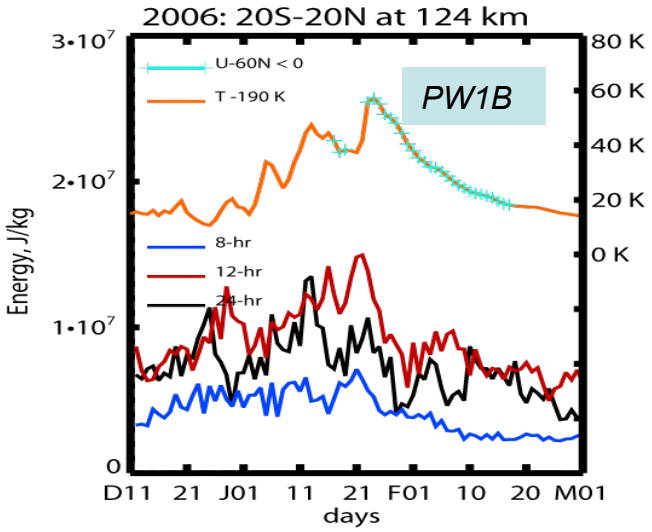


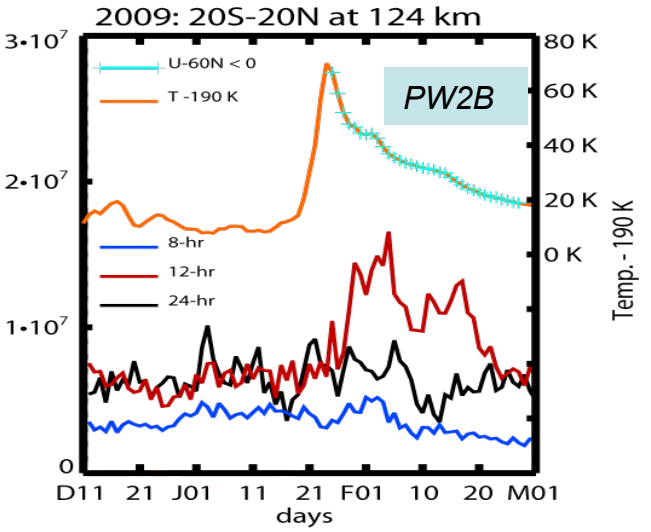
SSW Jan 2009, solar-min

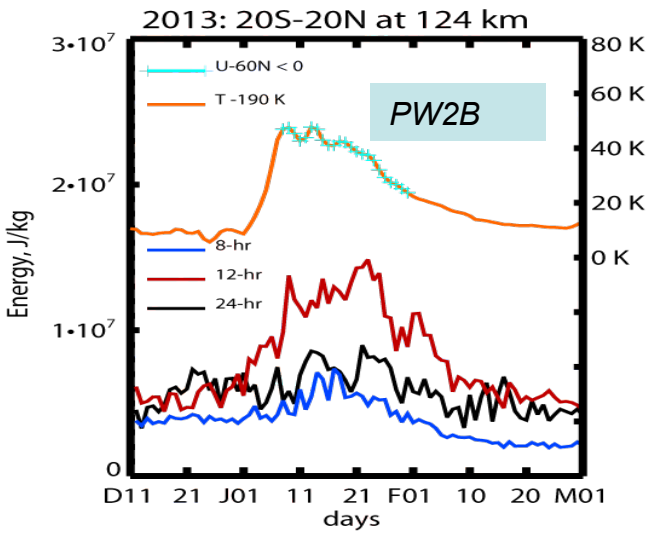


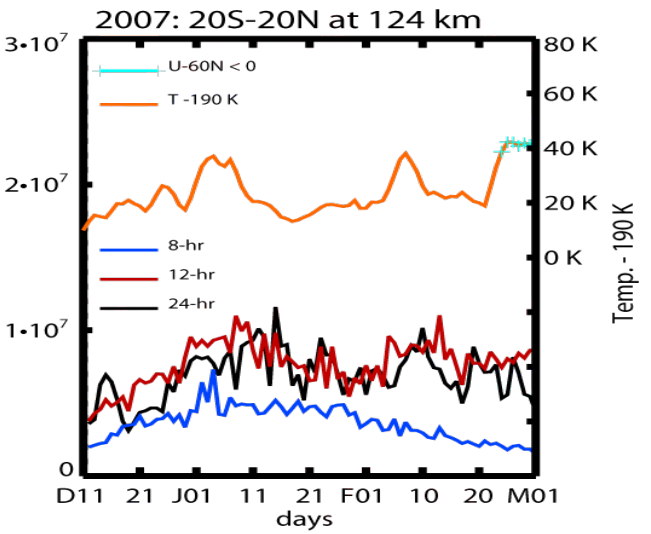
SSW Jan 2012: before (left) and during SSW + geo-storm (right)

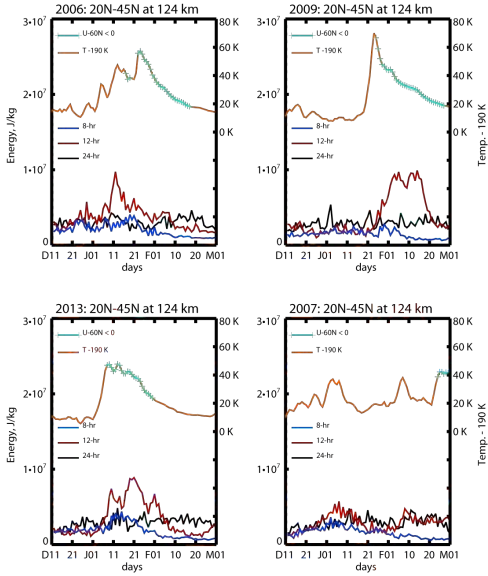
Evolution of tidal energies (24-hr, 12-hr and 8-hr) at ~124 km in the equatorial region: 2006, 2009, 2013 (major SSW) and 2007

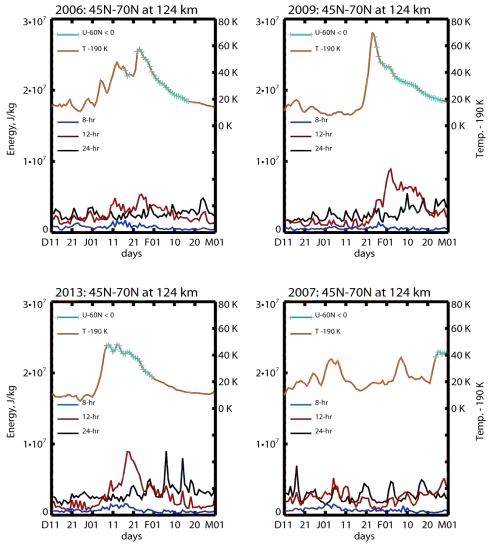


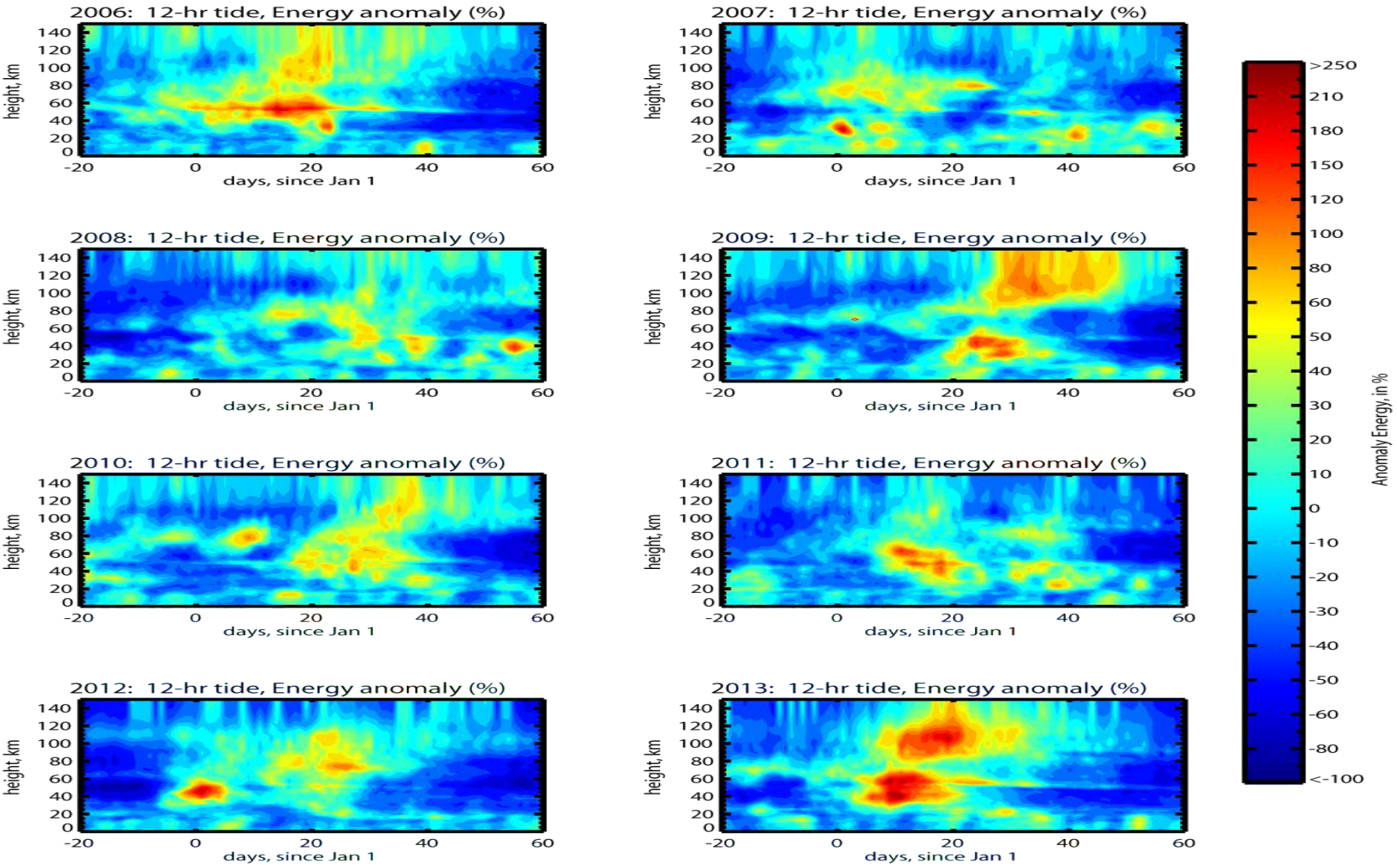












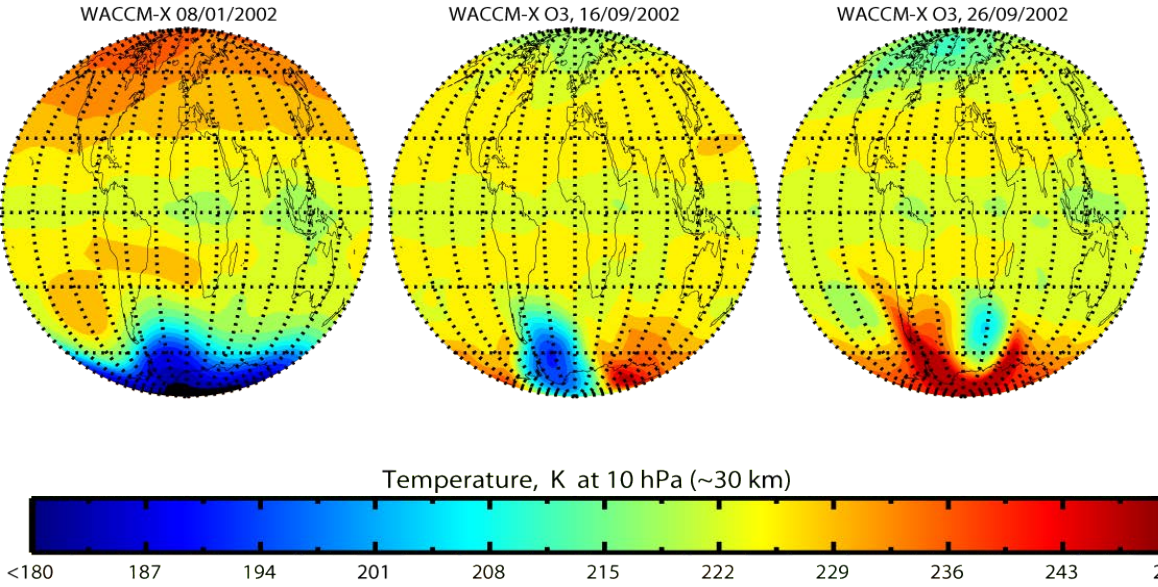
Anomalies (%) of 12-hr tide energy (global) during SSW

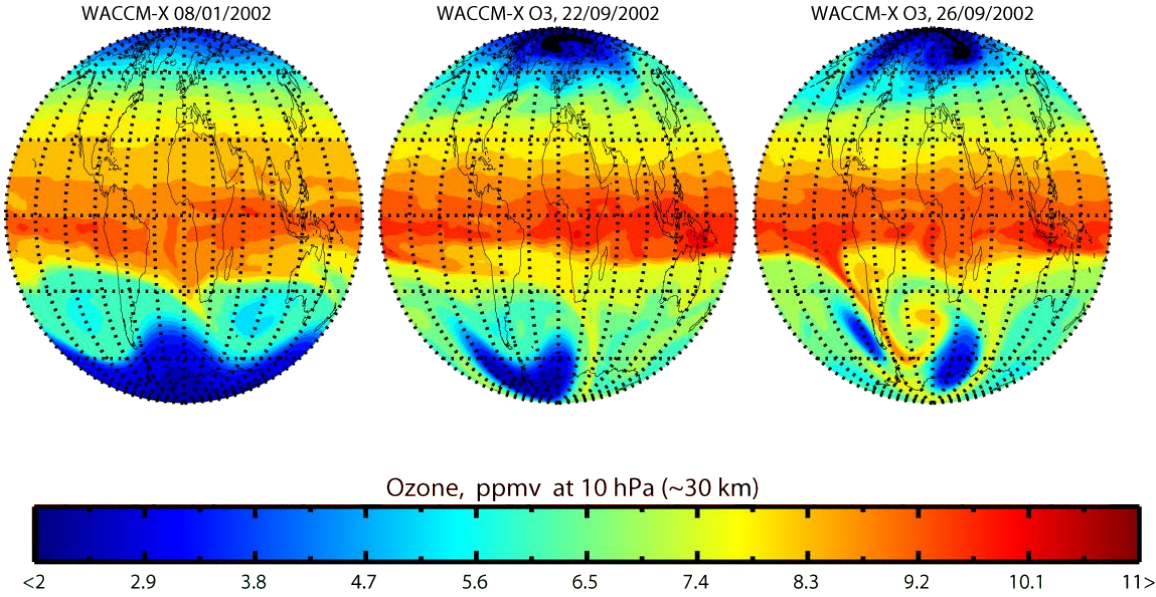
Anomalies represent deviations of the global total tidal energies from the wintertime averaged values (2005-2013)

ARCTIC SSW

2006-2013

Antarctic SSW-2002, Sep 17-26





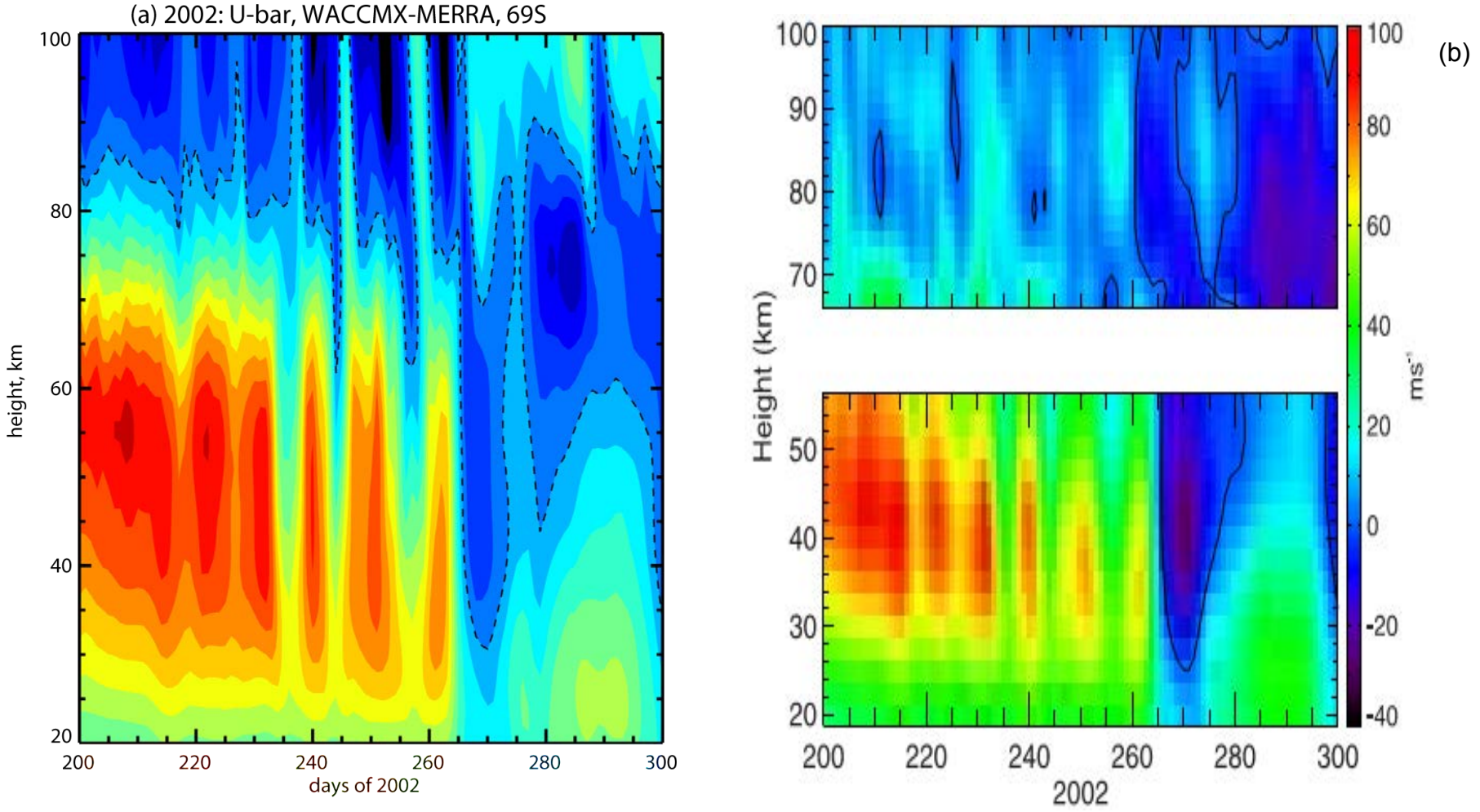


Figure. July-Oct 2002: Daily mean zonal wind variations at 69°S as (a) simulated by WACCM-X and (b) observed by MF radars (80-100km) and UKMO analyses (20-60 km) from Dowdy et al. (2007) with mid-September Antarctic stratospheric warming event (days 265-275).

Before SSW

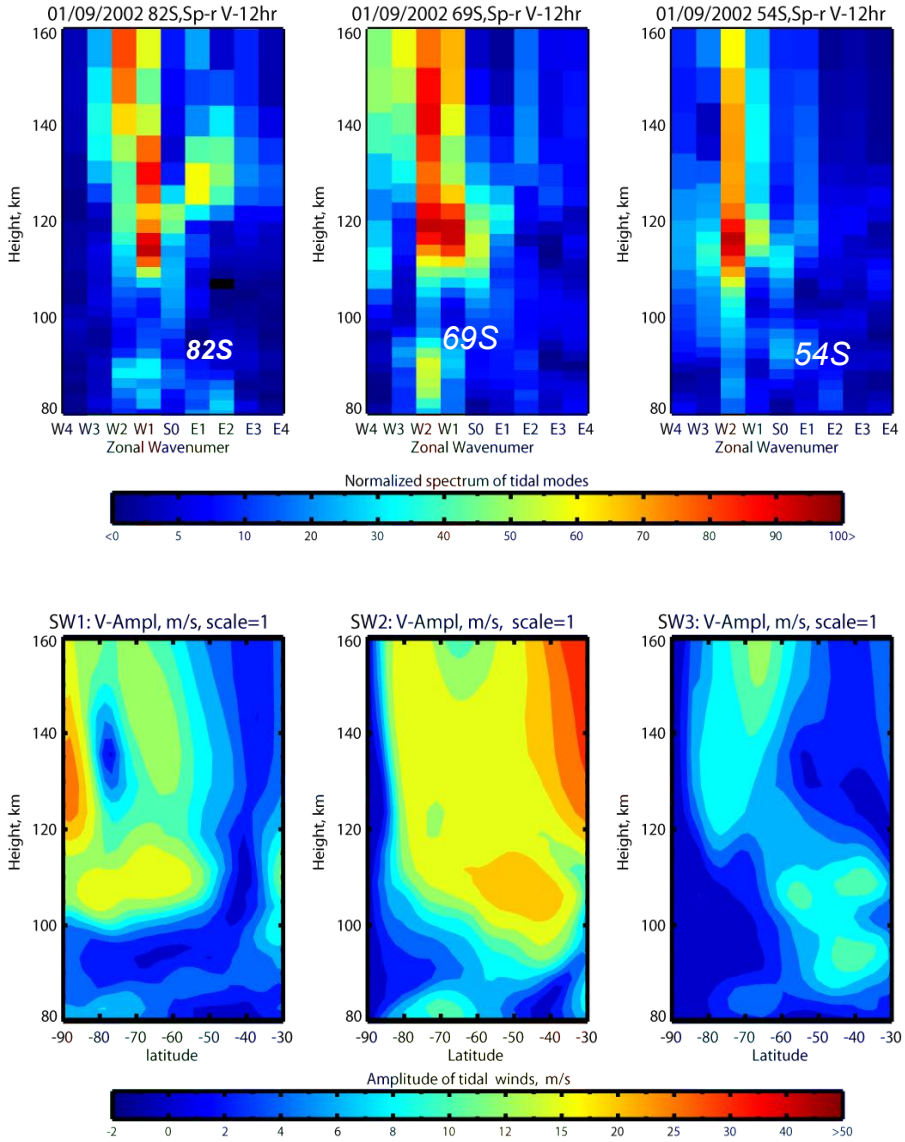


Fig 4: 01/09/2009, Top row: Spectra of 12-hr tide at 82°S, 69°S and 54°S; Bottom row height-latitude structure of 12-hr meridional wind amplitudes for SW1, SW2 and SW3 before sudden warming event.

During SSW

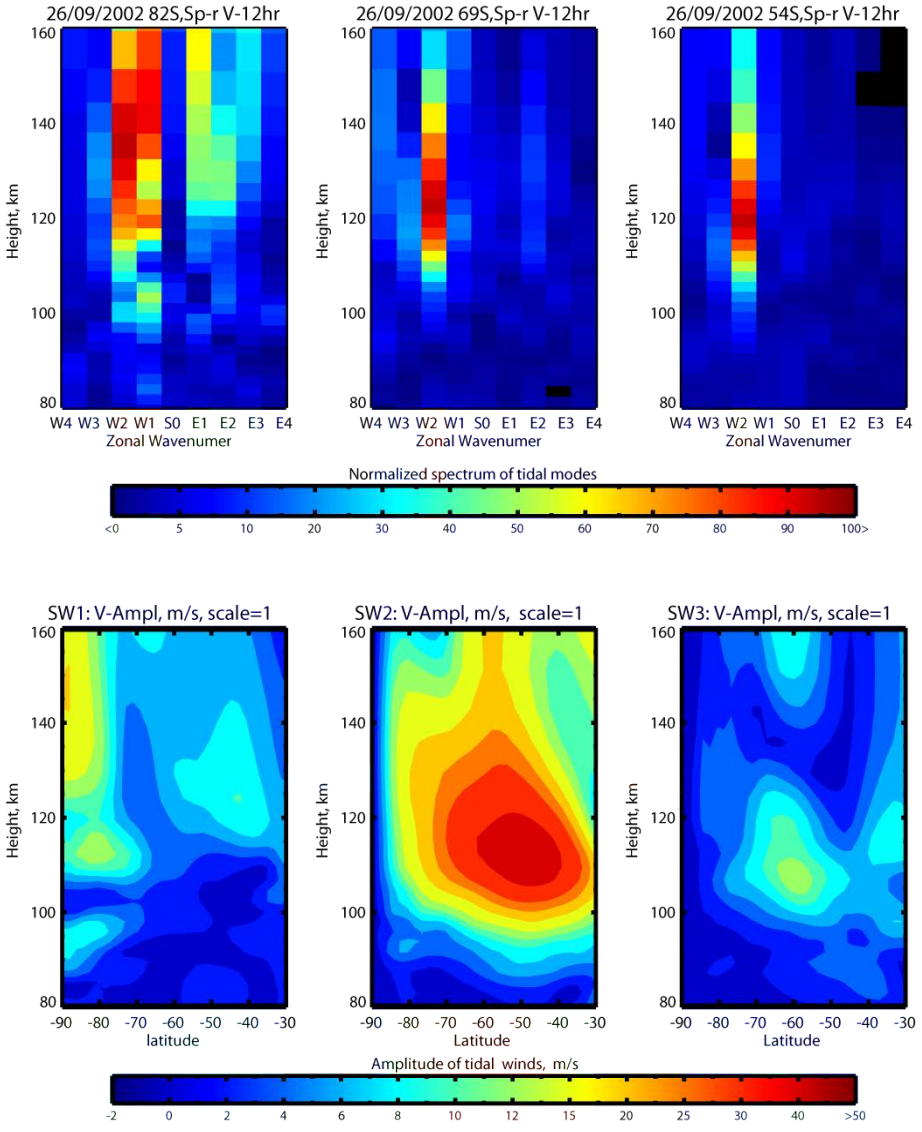


Fig 5: 26/09/2009, Top row: Spectra of 12-hr tide at 82oS, 69oS and 54oS; Bottom row height-latitude structure of 12-hr meridional wind amplitudes for SW1, SW2 and SW3 after sudden warming event.

Summary

- **WACCM-X/GEOS-5 with updated physics**

(GW, energy conservation, eddy diffusion)

SSW runs: *Arctic: SSW (2005/06-2013)*
Antarctic: SSW (2002)

Diagnostics:

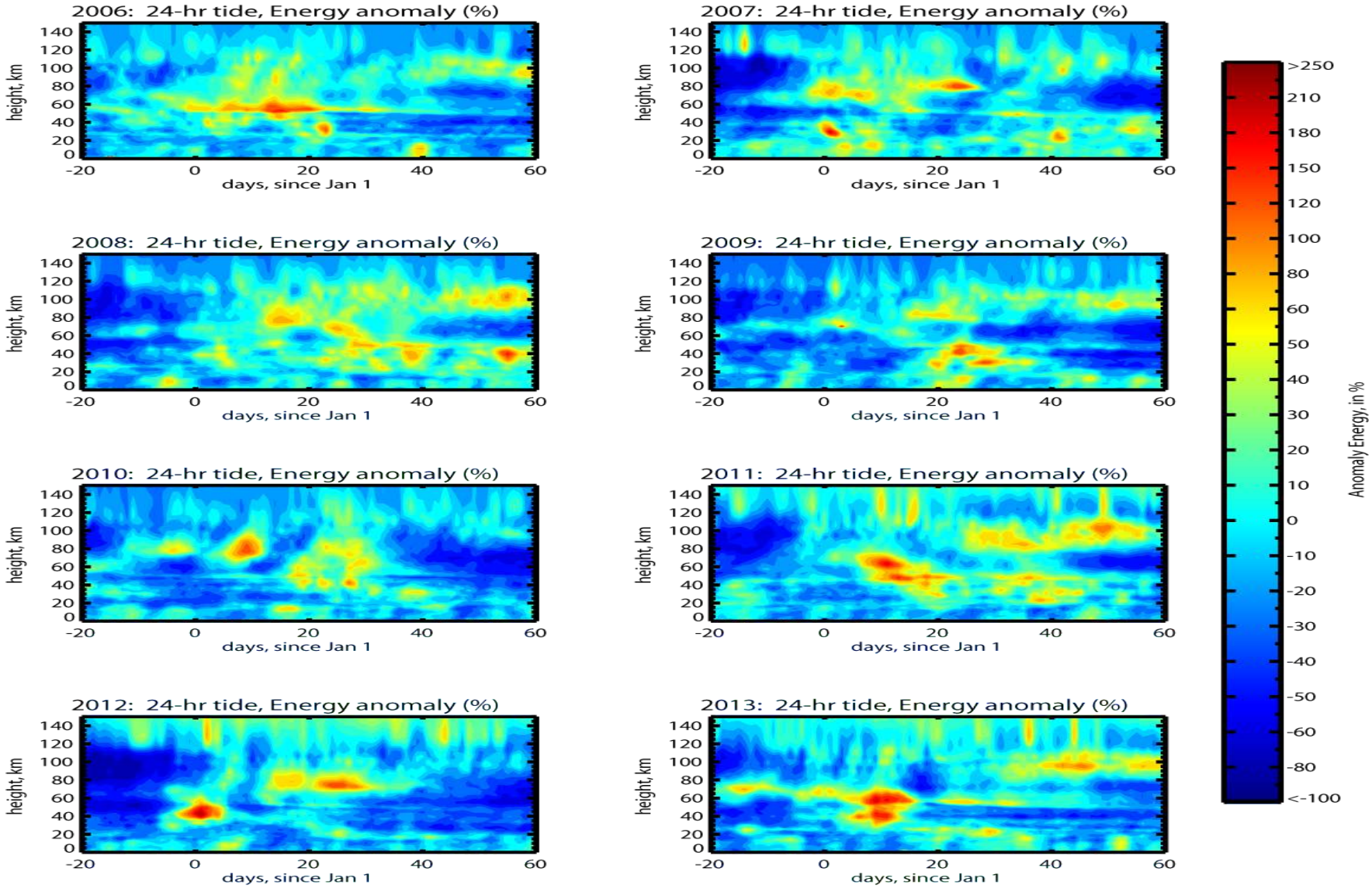
(1)Tidal diagnostics from s=-3,-2,-1,0, 1,2,3
for 24-hr, 12-hr, 8-hr oscillations
(2) Complete diagnostics for QSPW and transient PWs

Comparisons:

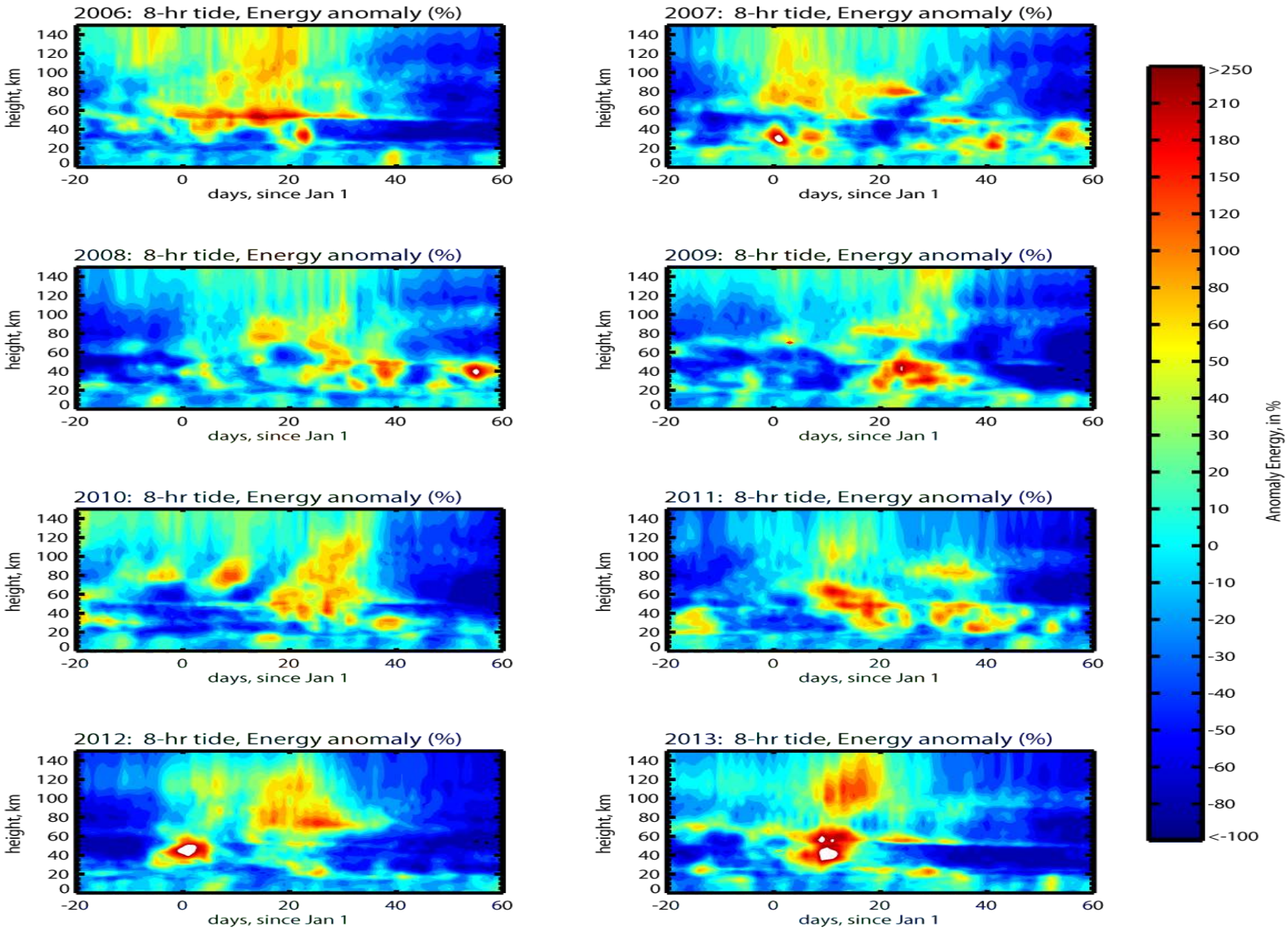
First outlook on SW2: GAIA/JRA-25 vs WACCM-X/GEOS-5

I-A Coupling: TIME-GCM and WACCM-X/GEOS-5

Support future campaign, OSSE for satellite missions and Data Assimilation studies, including ozone, temp-re and winds.



Anomalies of total energies of 24-hr oscillations: 2005/2006 …2012/2013



Anomalies for 8-hr tide