Westward Traveling Planetary Wave Events in the Lower Thermosphere During Solar Minimum Conditions Simulated by SD-WACCM-X

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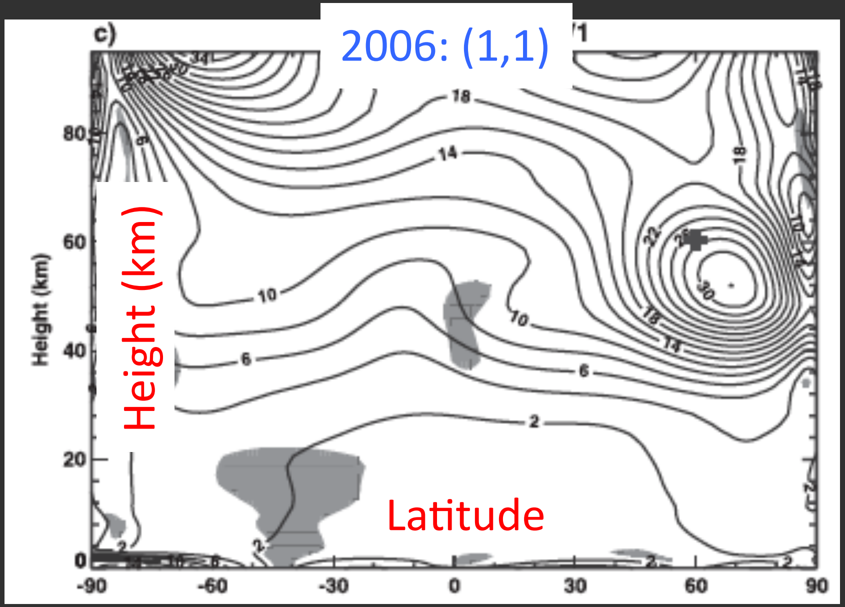
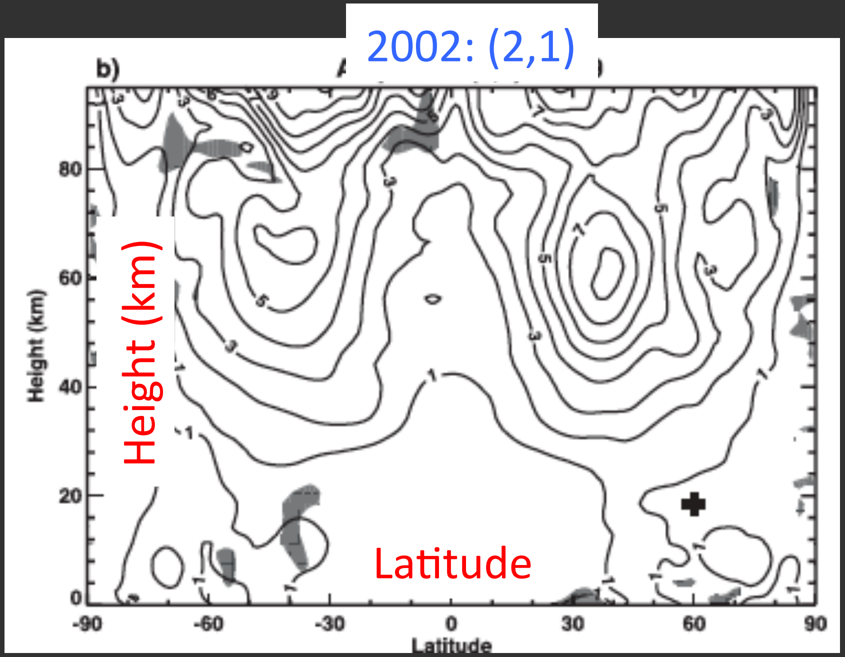
Motivation

Stratosphere ➔ Thermosphere/Ionosphere

- *Fraser* (1977) found evidence of concurrent 5-day variability in ionospheric scatter and lower stratospheric temperature during various seasons
- *Meyer* (1999) suggested that planetary-scale waves that survive dissipation may influence the ionosphere; their amplitude is strongly dependent on the GWD
- *Liu and Roble* (2002) showed that the wintertime variability associated with a SSW can reach into the thermosphere
- *Liu et al.* (2010) suggest that the presence of quasi-stationary PW in the thermosphere is necessary to couple the high latitudes with the tropical latitudes.

- Analysis of high altitude DAS (NOGAPS-ALPHA) have identified traveling (eastward propagating) planetary waves (TPWs) ➔ phase velocity << 0.
- TPWs may behave like normal modes, have very long vertical wavelength, and with sufficiently large phase velocity may survive dissipation to emerge with large amplitudes in the upper mesosphere and thermosphere

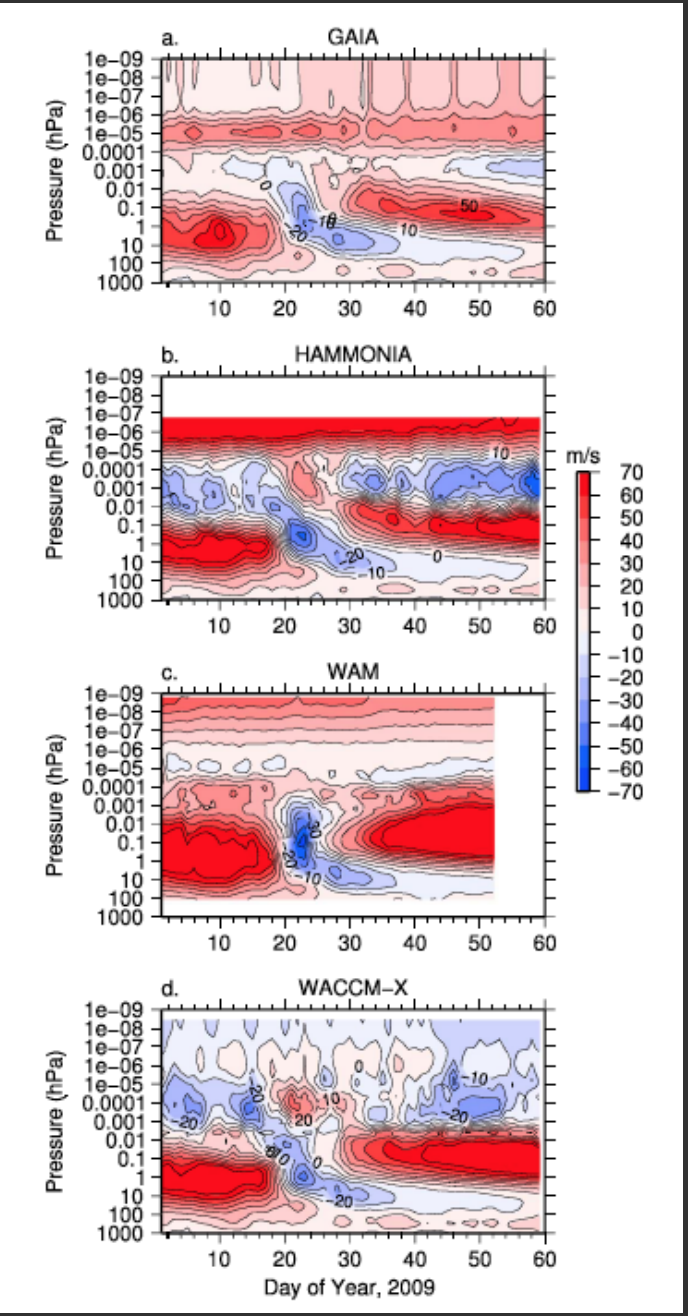




Sassi et al. (2012)

Gap

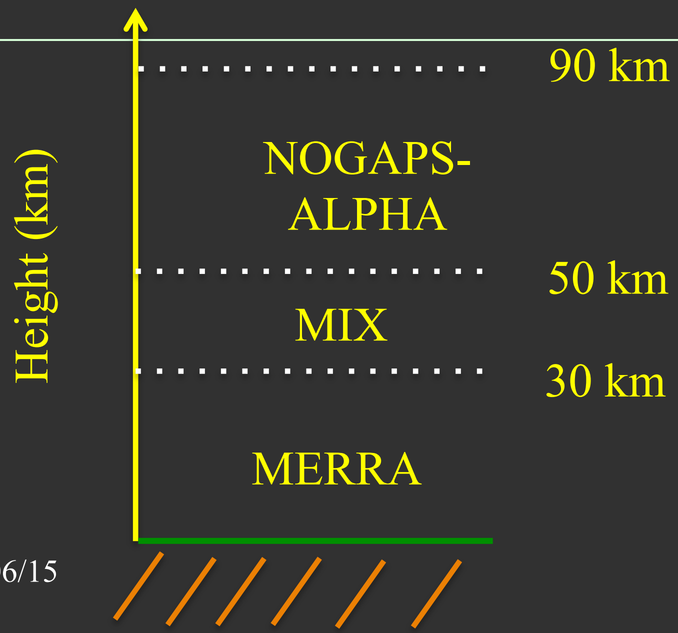
- There is no G2S forecast/analysis capability (yet) + obs are sparse and inhomogeneous
- Winds in the lower thermosphere are largely unknown & Models show a large variety of wind behavior in the thermosphere
- GCMs do not reproduce a specific event and there is large uncertainty related to gravity wave effects
- Intermediate Solution: Take a state-of-the-art GCM and nudge its meteorology toward hi-DAS

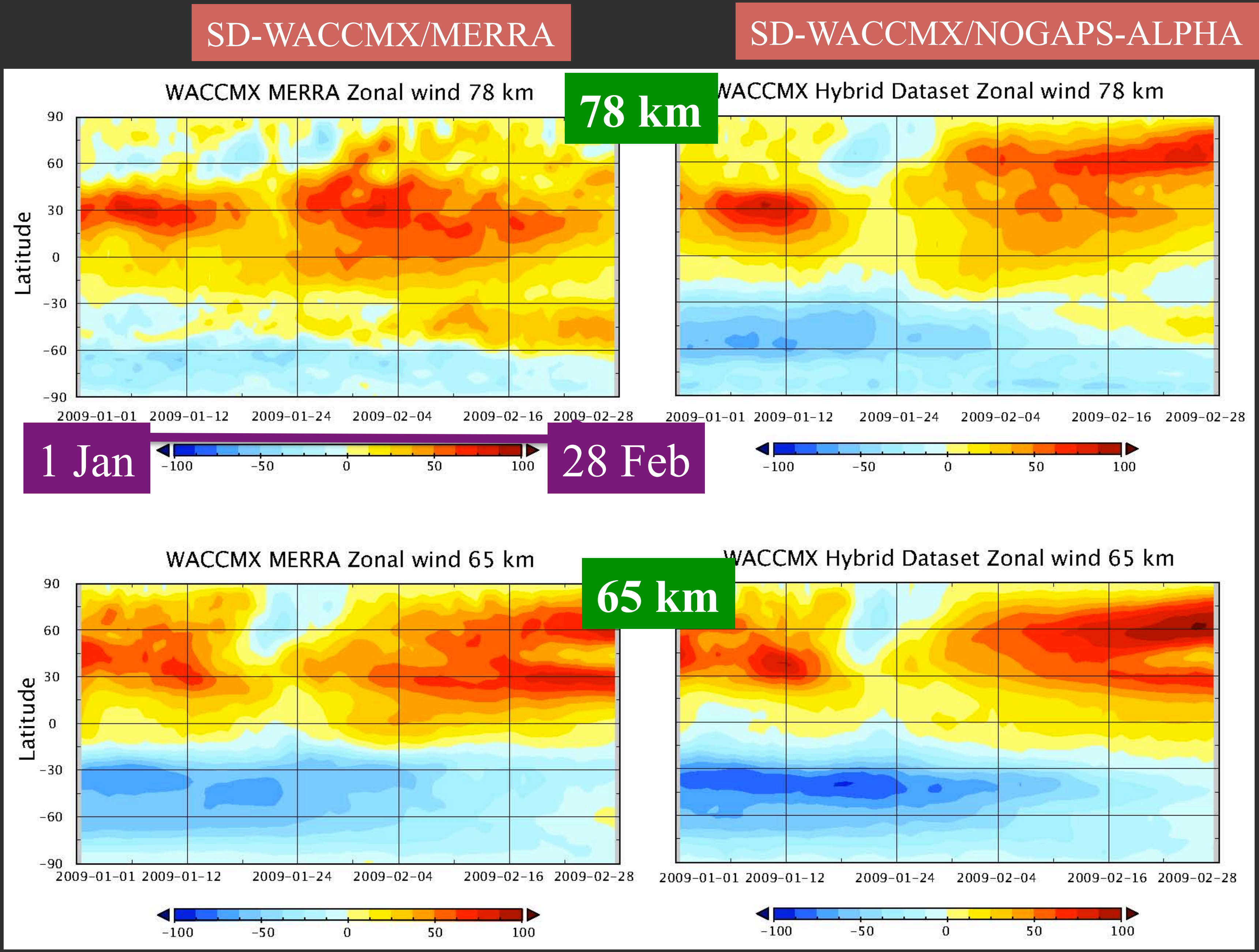


Pedatella et al. (2013)

SD-WACCMX

- WACCMX in SD configuration (lid at 3.3×10^{-9} hPa ~ 400 km); horizontal resolution 1.9° x 2.5° (lat x lon)
- Data analysis products are obtained merging NASA/MERRA and NRL/NOGAPS-ALPHA
- Focus period is January-February 2009.

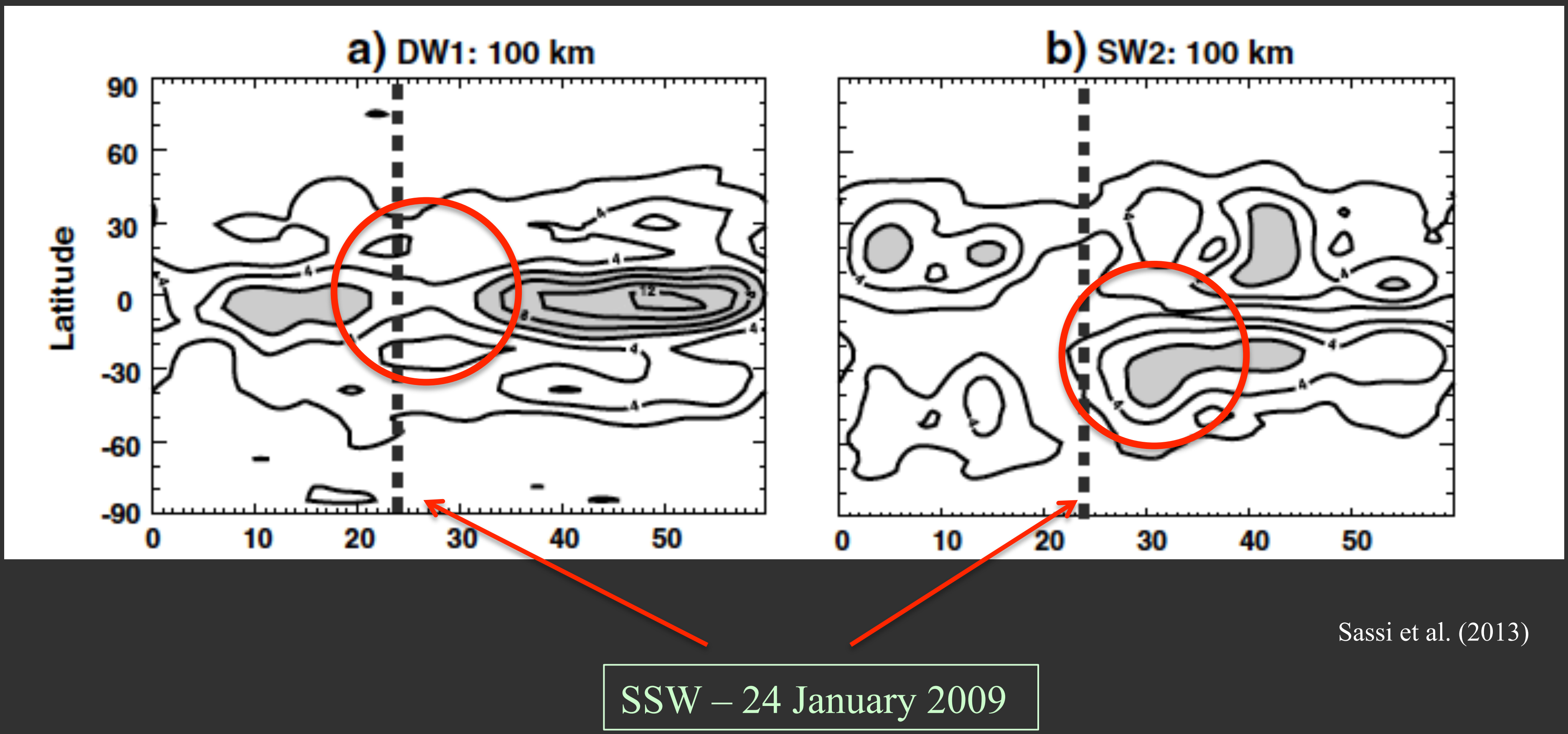




Sassi et al. (2013)

SSW 2009

Migrating Tides



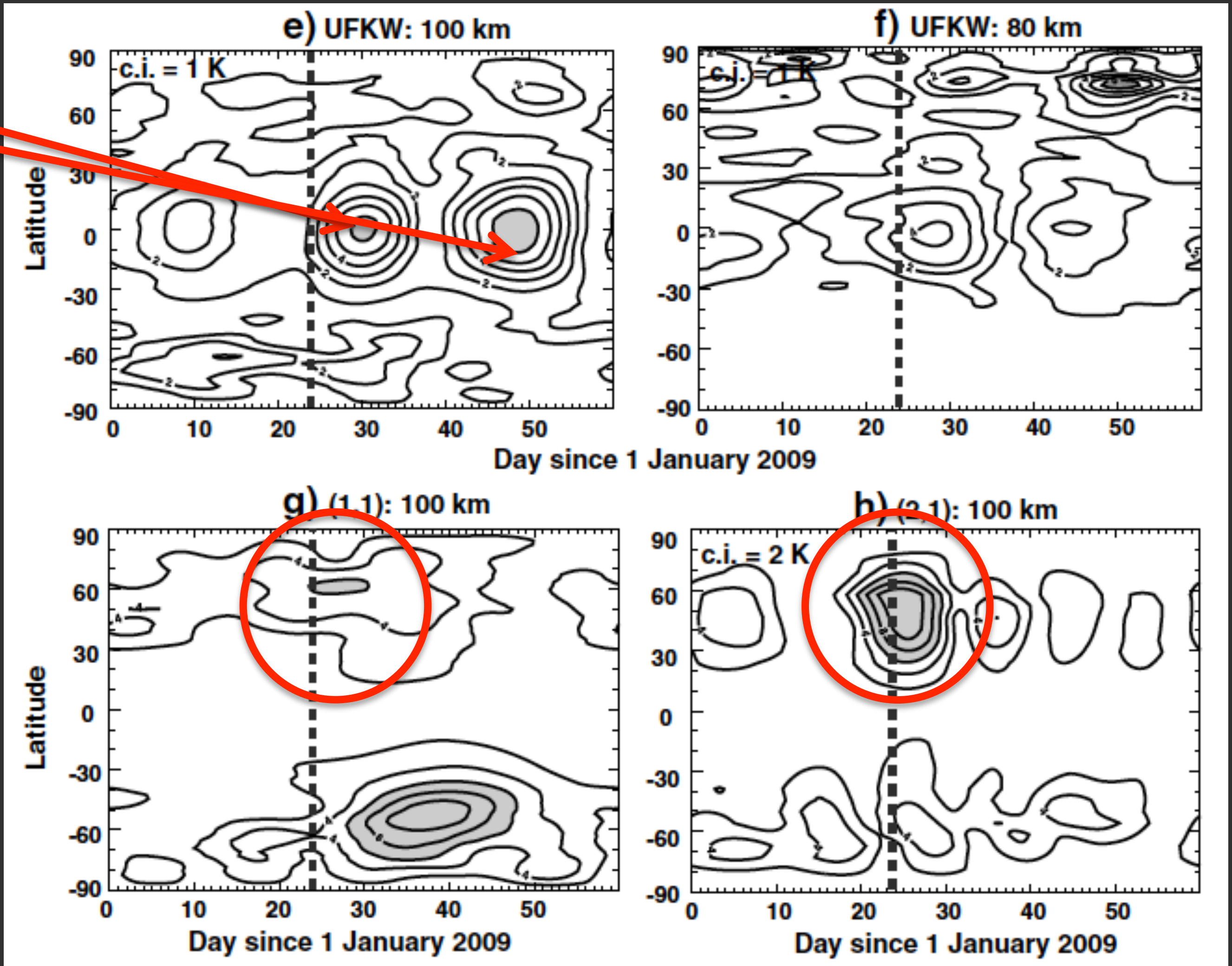
Sassi et al. (2013)

SSW 2009

Other Modes

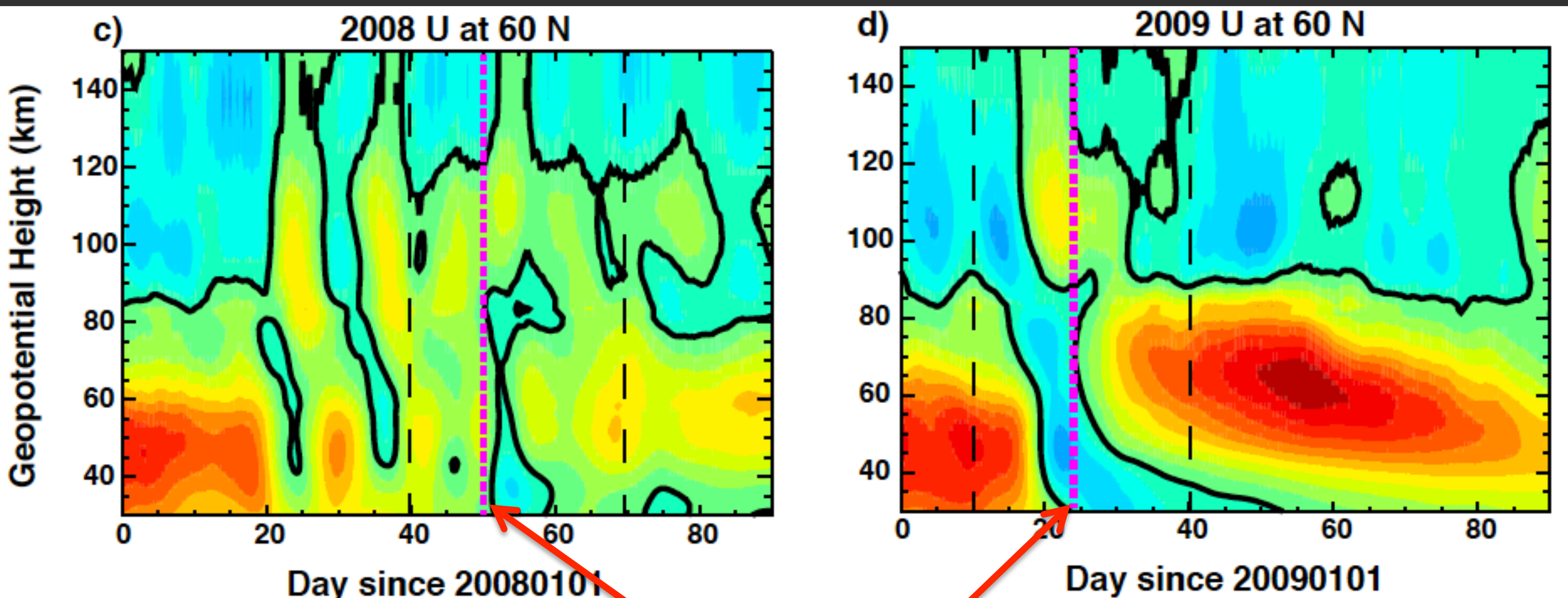
Ultra-fast Kelvin wave
🡐 Tropical convection

(1,1) & (2,1): 5-day period normal modes



SSW 2008 vs. 2009:

Zonal Wind at 60 N



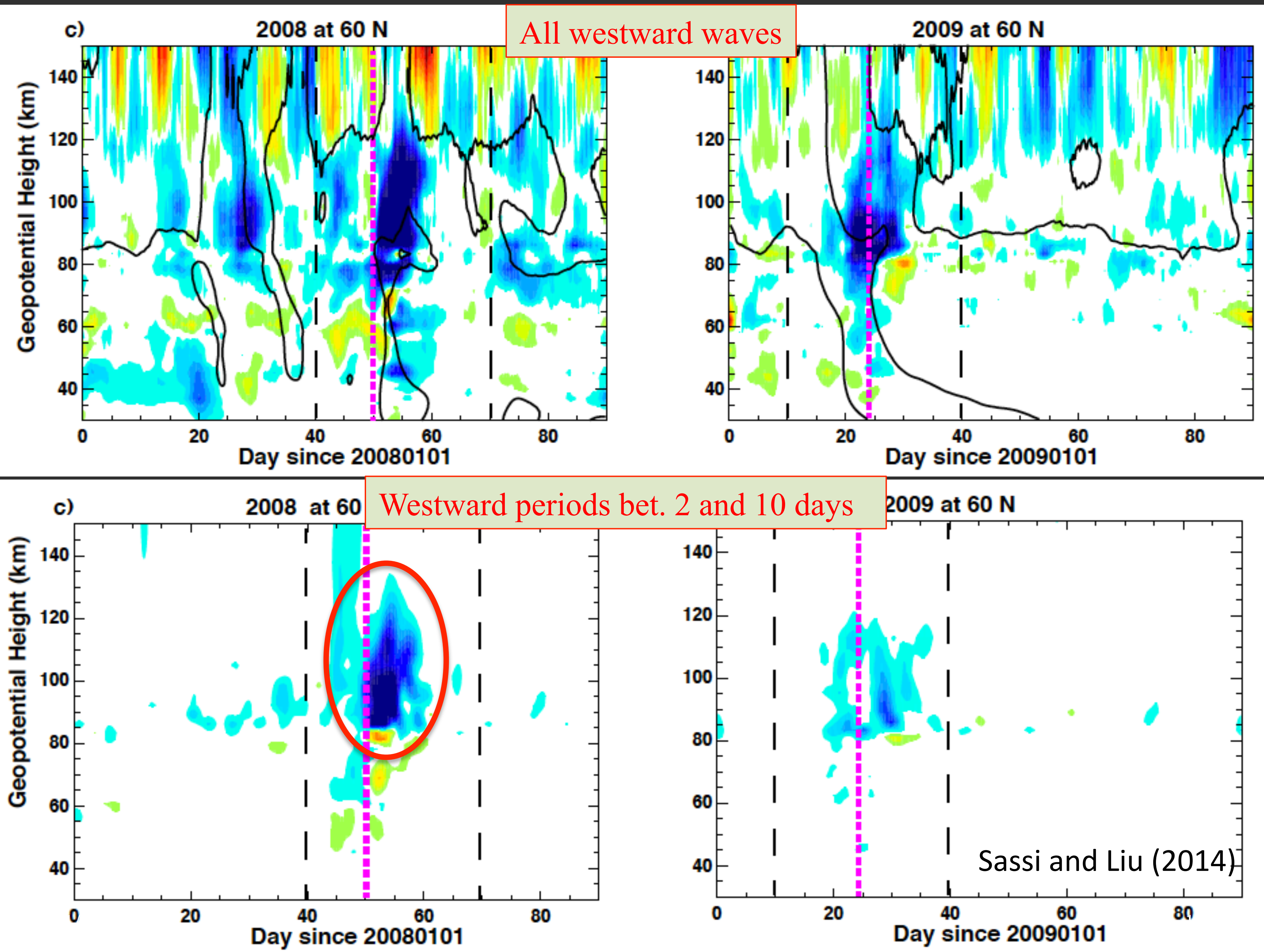
Sassi and Liu (2014)

2008 SSW 2009

SSW 2008 vs. 2009

U-tendency:

wave-1 / westward propagating waves

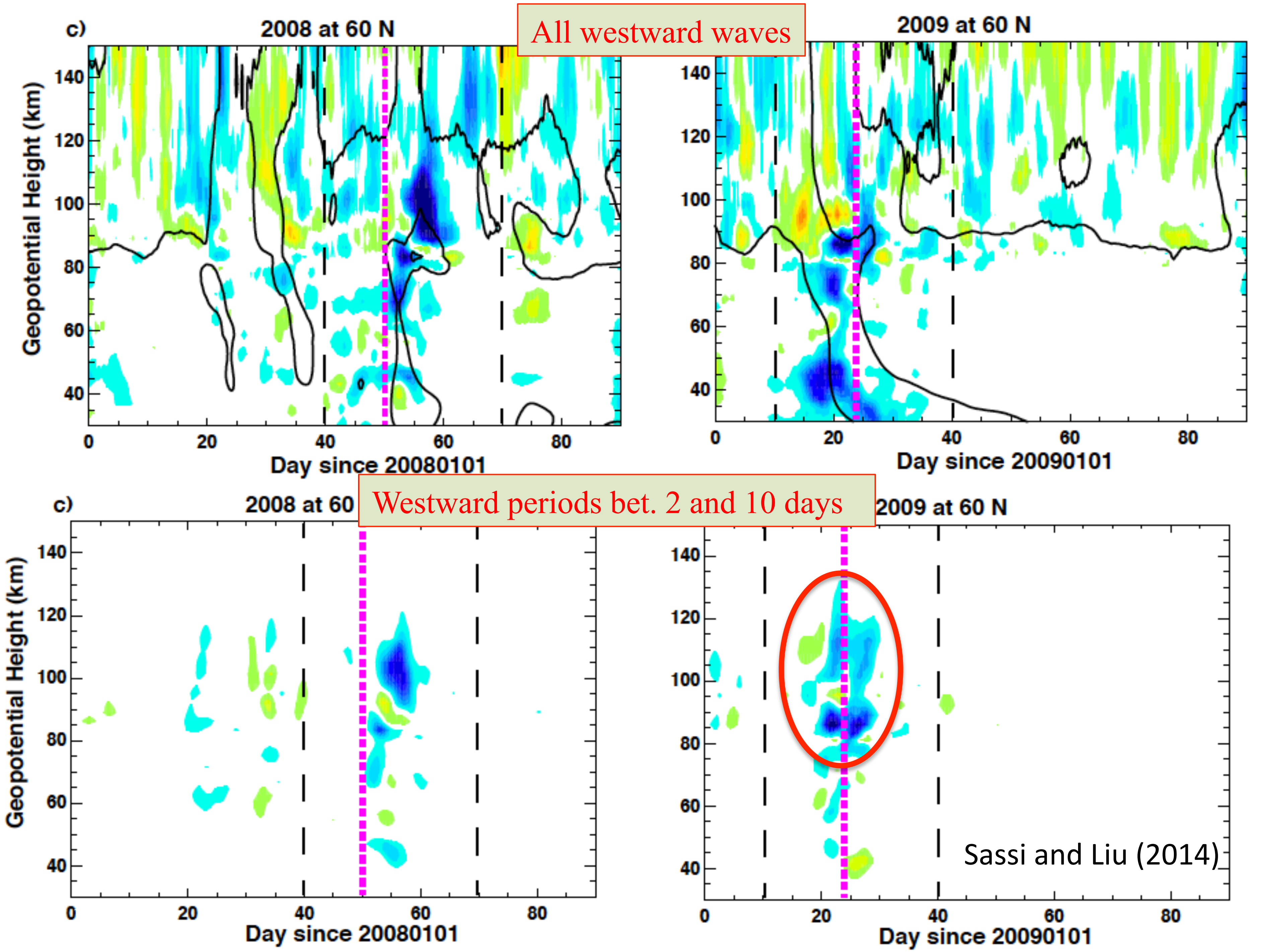


All westward waves
c)
2008 at 60 N
2009 at 60 N
Geopotential Height (km)
Day since 20080101
Day since 20090101
Westward periods bet. 2 and 10 days
c)
2008 at 60
2009 at 60 N
Geopotential Height (km)
Day since 20080101
Day since 20090101
Sassi and Liu (2014)

SSW 2008 vs. 2009

U-tendency:

wave-2 / westward propagating waves

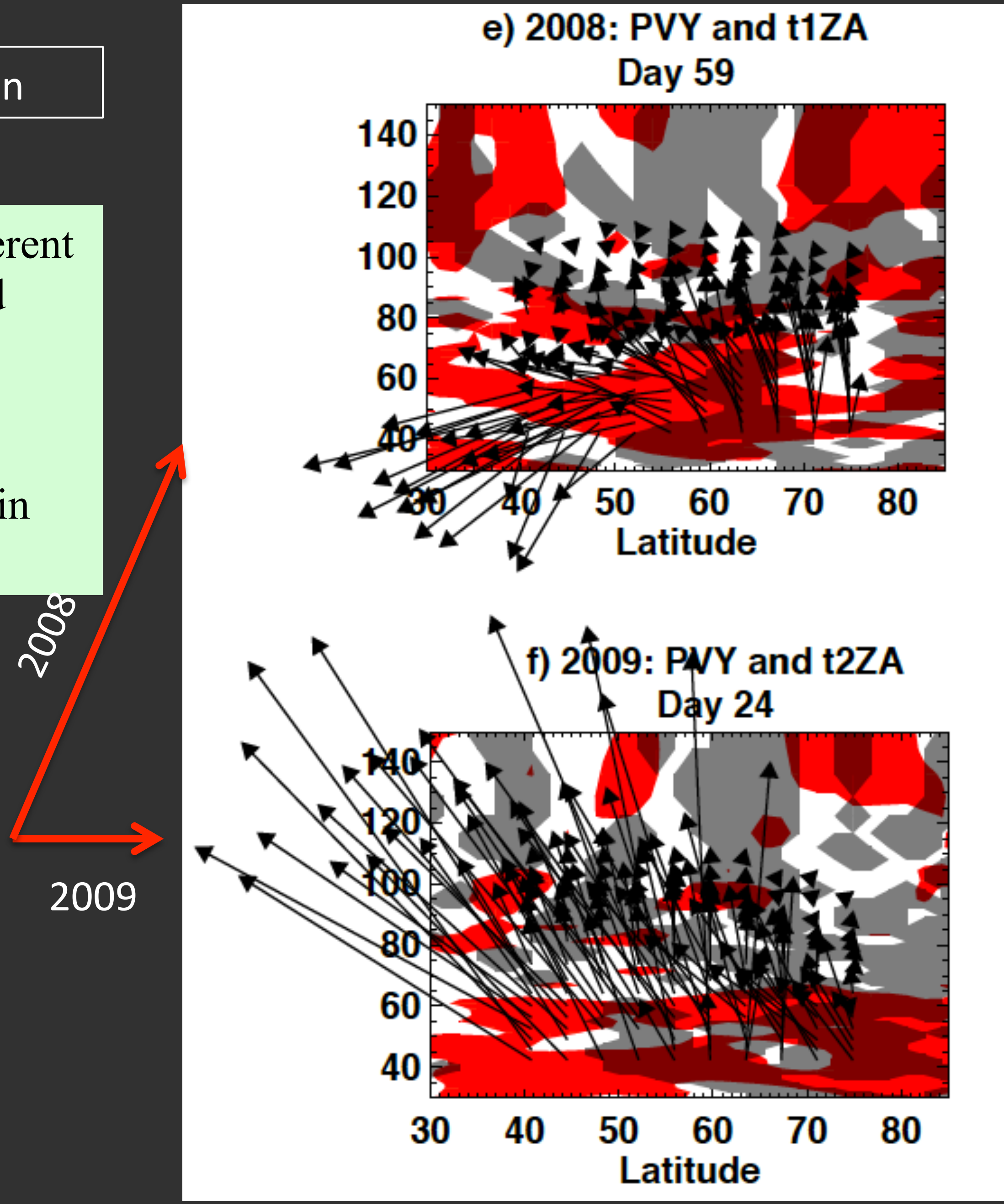


All westward waves
c)
2008 at 60 N
2009 at 60 N
Geopotential Height (km)
Day since 20080101
Day since 20090101
Westward periods bet. 2 and 10 days
c)
2008 at 60
2009 at 60 N
Geopotential Height (km)
Day since 20080101
Day since 20090101
Sassi and Liu (2014)

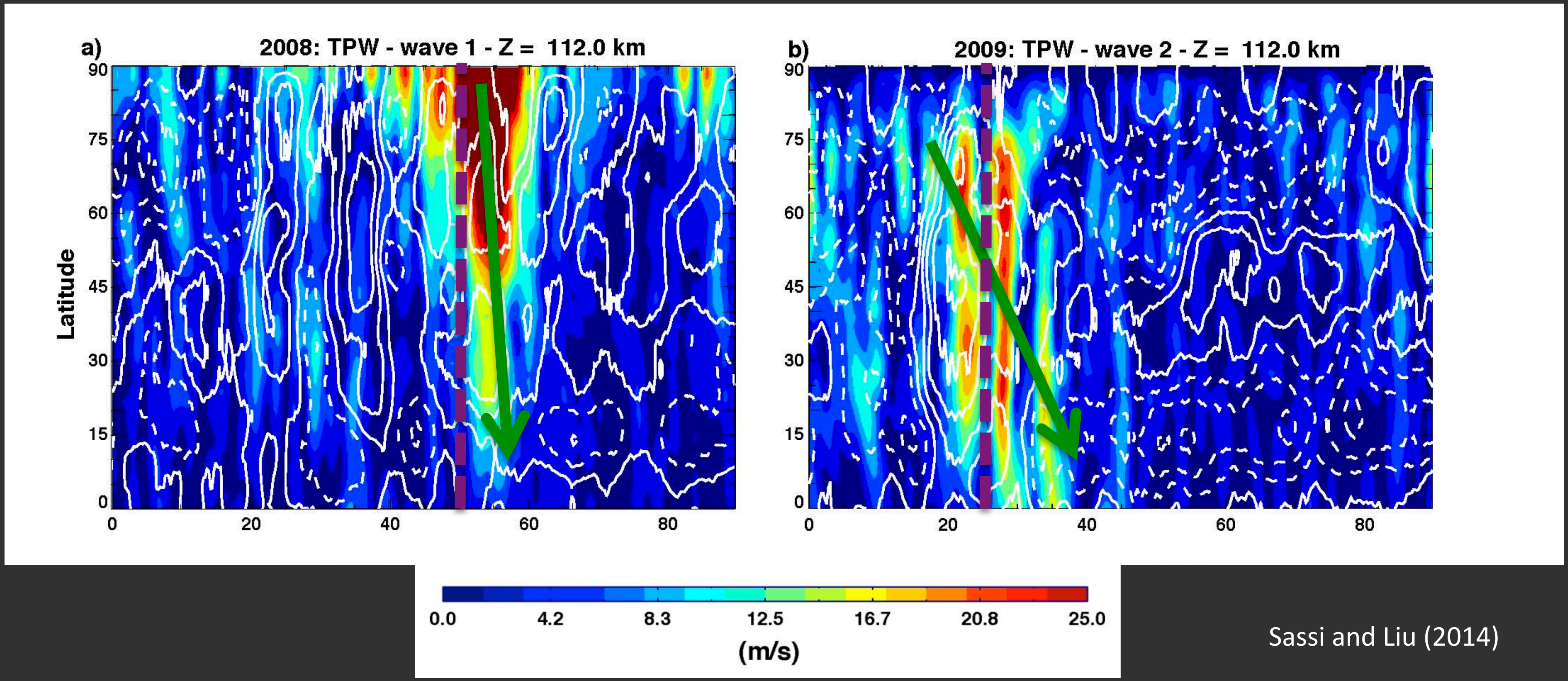
Source of TPWs and propagation

- Two distinct winters with two different SSWs show U-tendency associated with TPWs at wave-1 and wave-2 extending in the thermosphere
- TPWs are generated by
- TPWs can propagate equatorward in the lower thermosphere

Arrows: $\mathbf{F}=(F^{(y)},F^{(z)})$
Red shades: $U_t < 0$ (wave-1 in 2008 / wave-2 in 2009)
Gray shades: $PV_y < 0$



Coupling between high and low latitudes



Sassi and Liu (2014)

@ 112 km

Color shade: RMS amplitude of v-wind between 0.1≤σ ≤ 0.5 cpd westward

White contours: U

Closing Thoughts

- High-altitude atmospheric specifications are critical to understand dynamical coupling in the whole atmosphere
  - A G2S capability is inconceivable without hi-alt data.
  - Hi-alt data are critical to predict the meteorology of the lower thermosphere
- Coupling between the thermosphere and the ionosphere may rely on the presence of traveling ($c<0$) planetary-scale waves during boreal winter.
- The physical mechanisms underlying this coupling and their dependence on varying solar and atmospheric conditions needs more studies.

Acknowledgments

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