Westward Large-Scale Dynamical Behavior of the Lower Thermosphere Simulated by WACCMX-SD

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Motivation

- Understand and quantify the role of travelling planetary-scale disturbances in the lower thermosphere.
- Use SD configuration to generate realistic lower atmospheric conditions.
- Execute simulations of different boreal winters to build an ensemble of dynamical conditions
- Illustrate how traveling, planetary-scale waves - ubiquitous during boreal winter - can affect tidal variability.

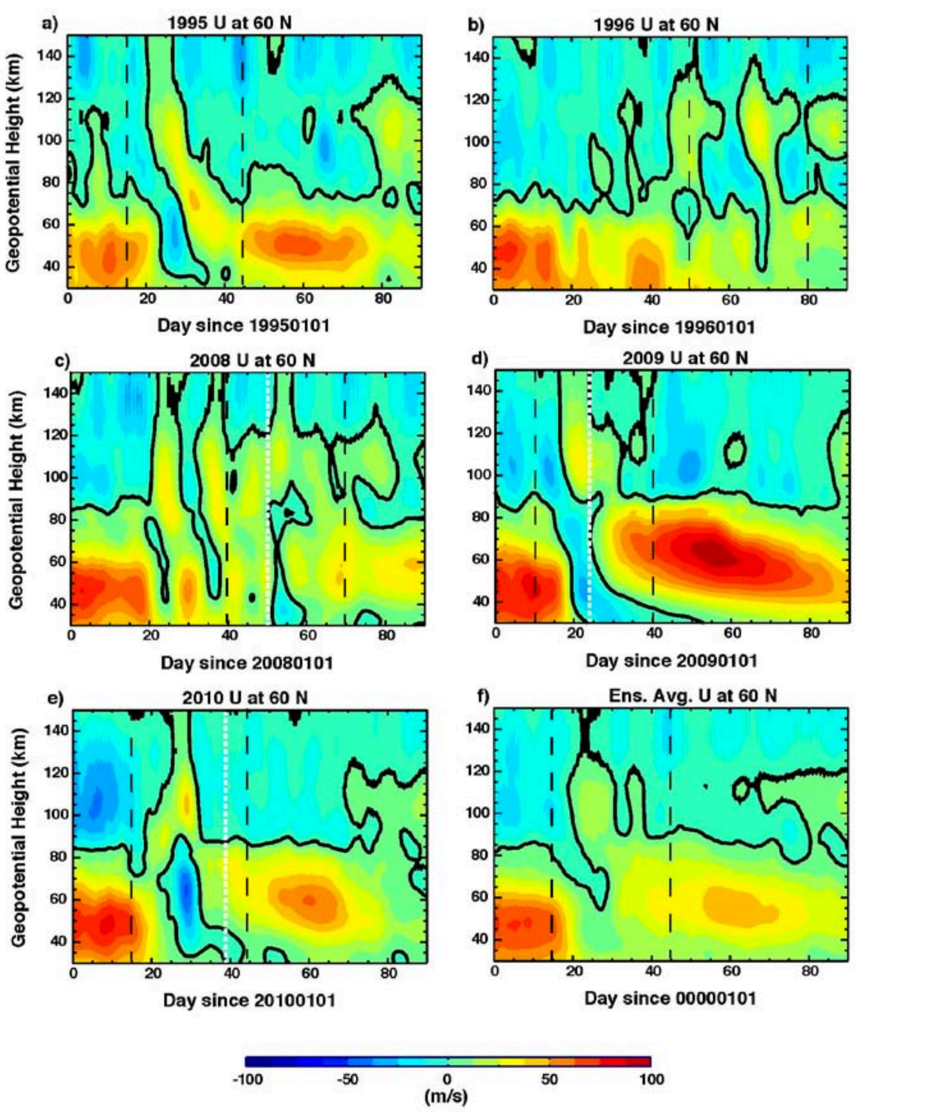
Simulations

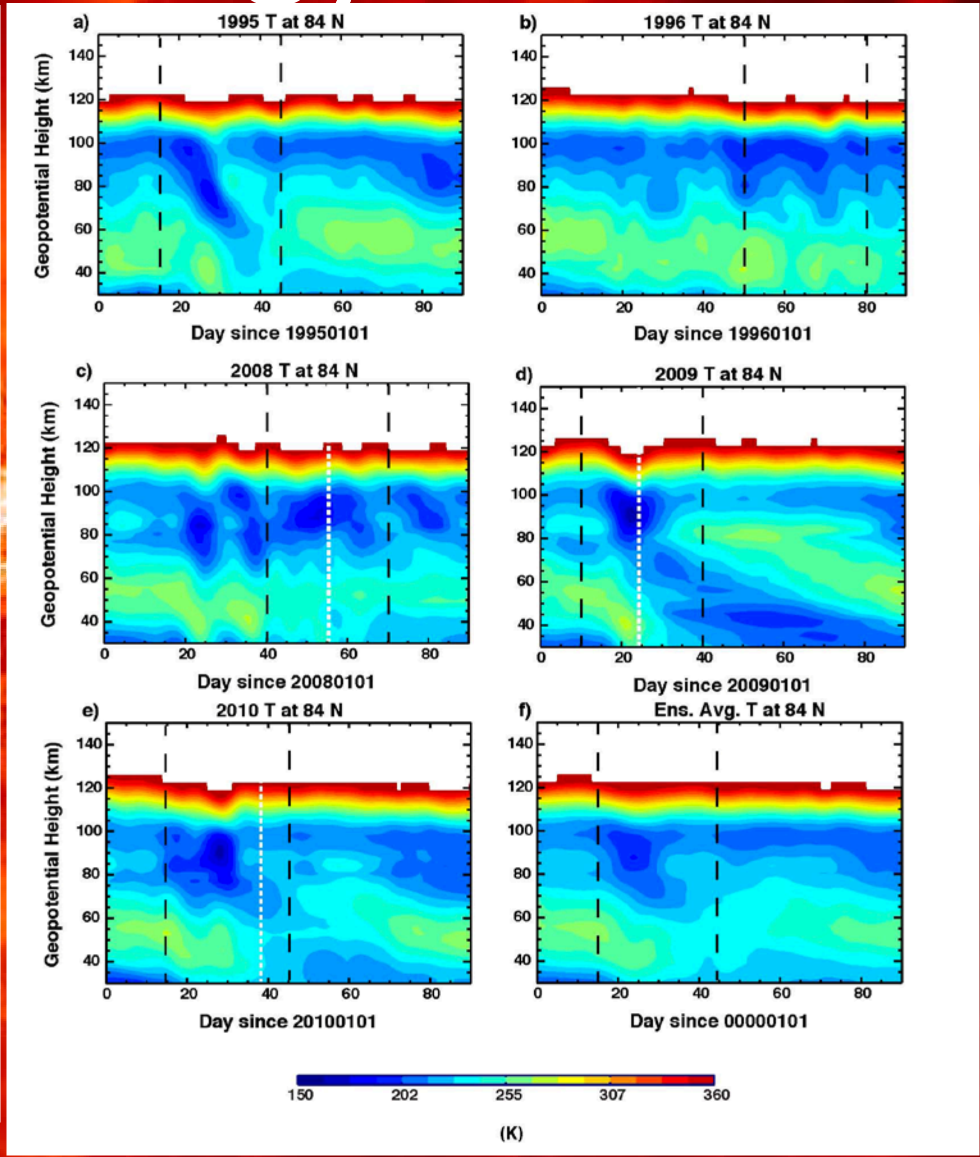
- Five boreal winters:
  - 1995: minor warming
  - 1996: no warming
  - 2008: wave-1 SSW
  - 2009: wave-2 SSW
  - 2010: wave-1 SSW
- These are all solar minimum winters
- SD configuration exploits Navy's and NASA's analysis (2008, 2009, 2010) or solely NASA's (1995 and 1996).

Climatology

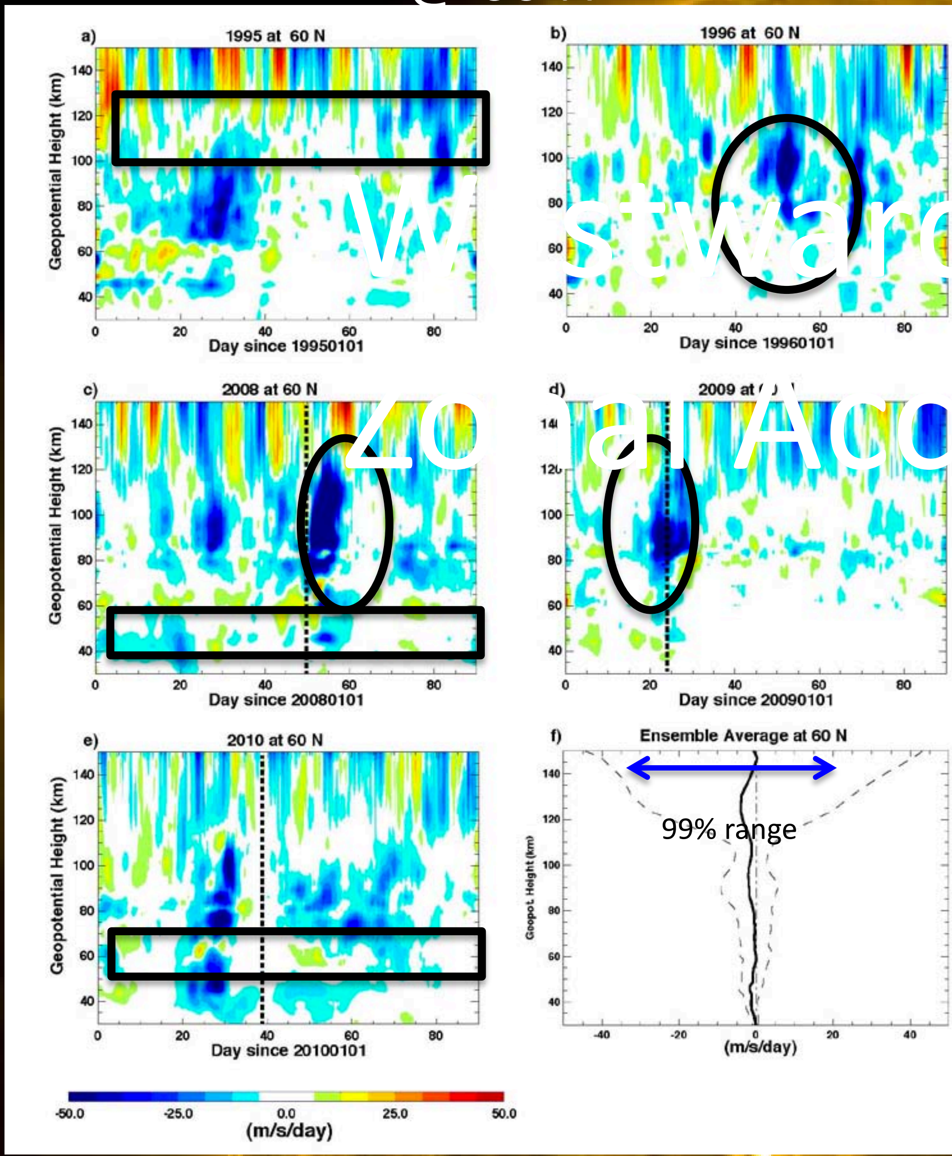
U at 60 N

T at 84 N

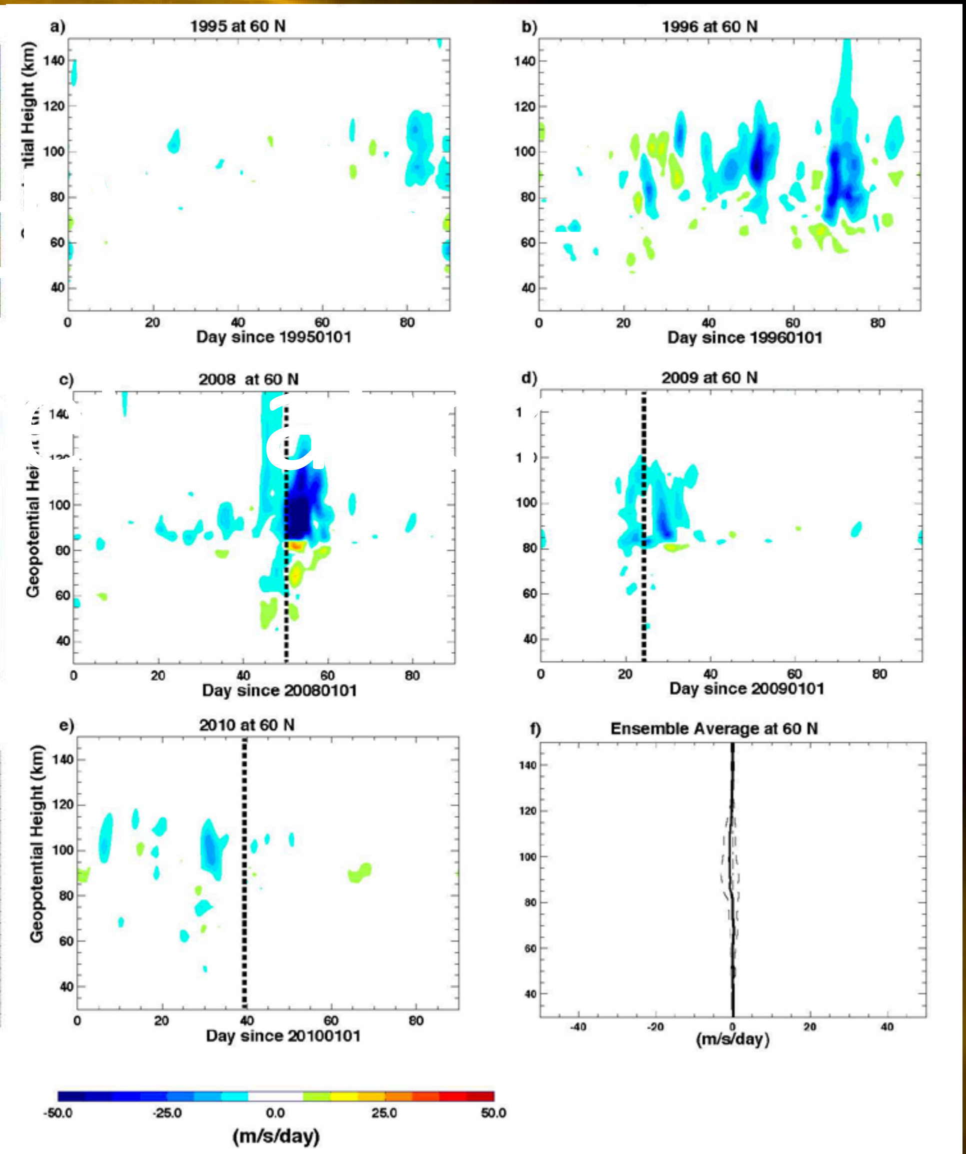




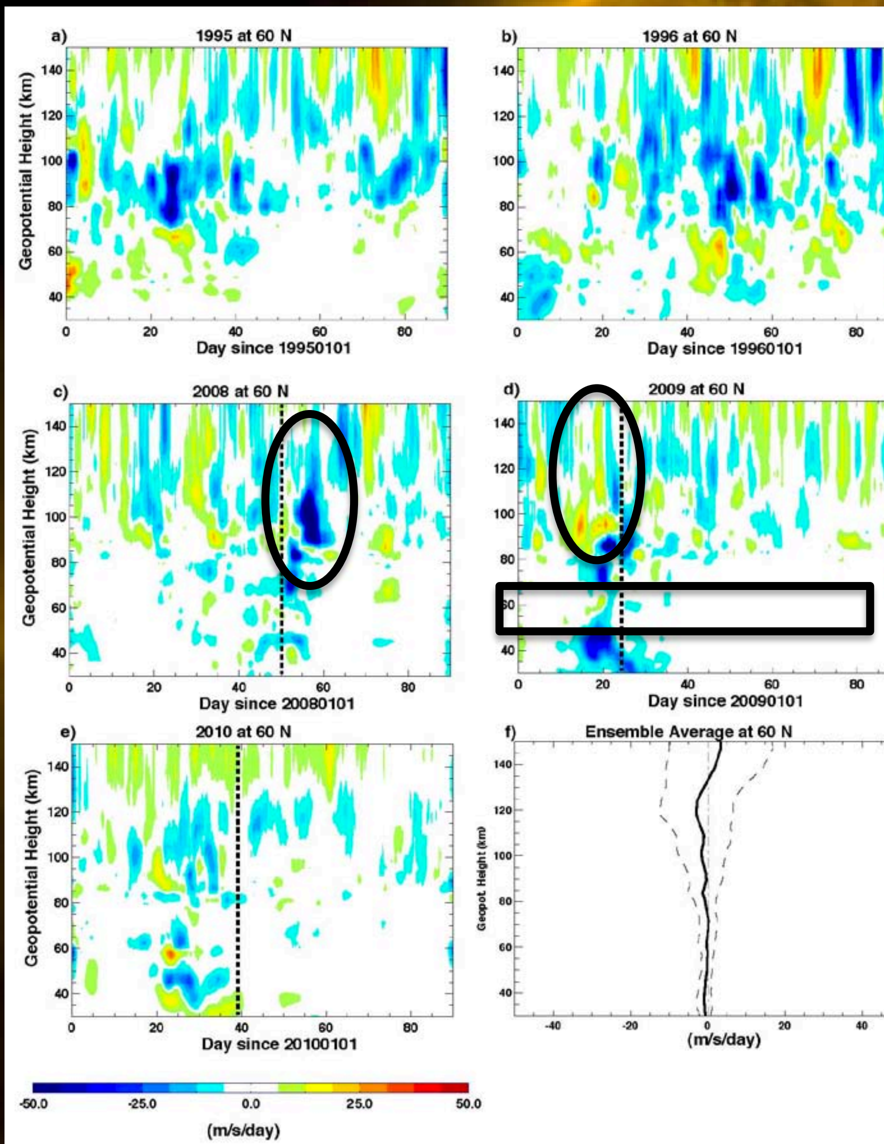
Westward wave-1
@ 60 N



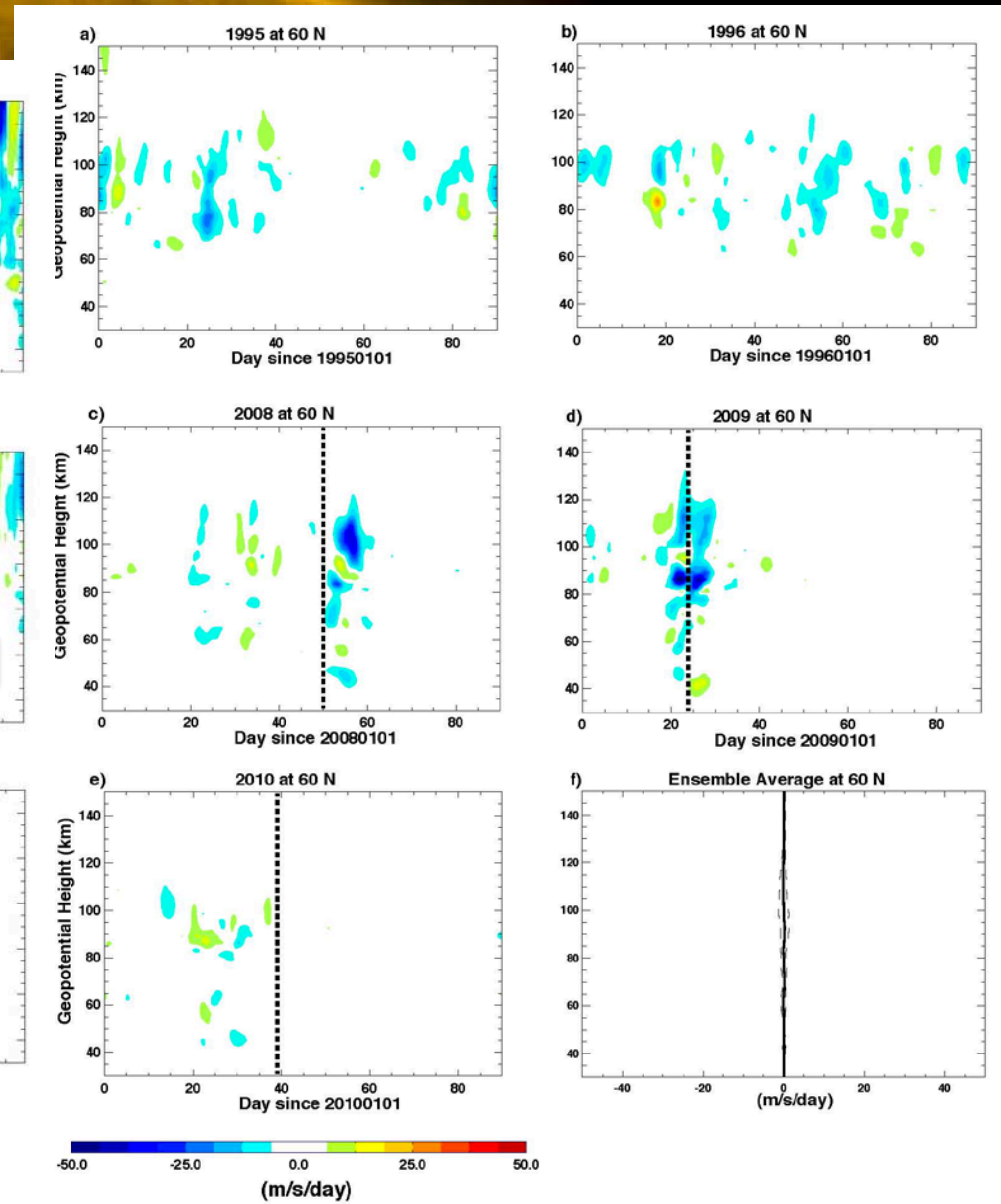
Westward wave-1 ; 0.1≤σ≤0.5 cpd
@ 60 N



Westward wave-2 @ 60 N



Westward wave-2 ; 0.1≤σ≤0.5 cpd @ 60 N

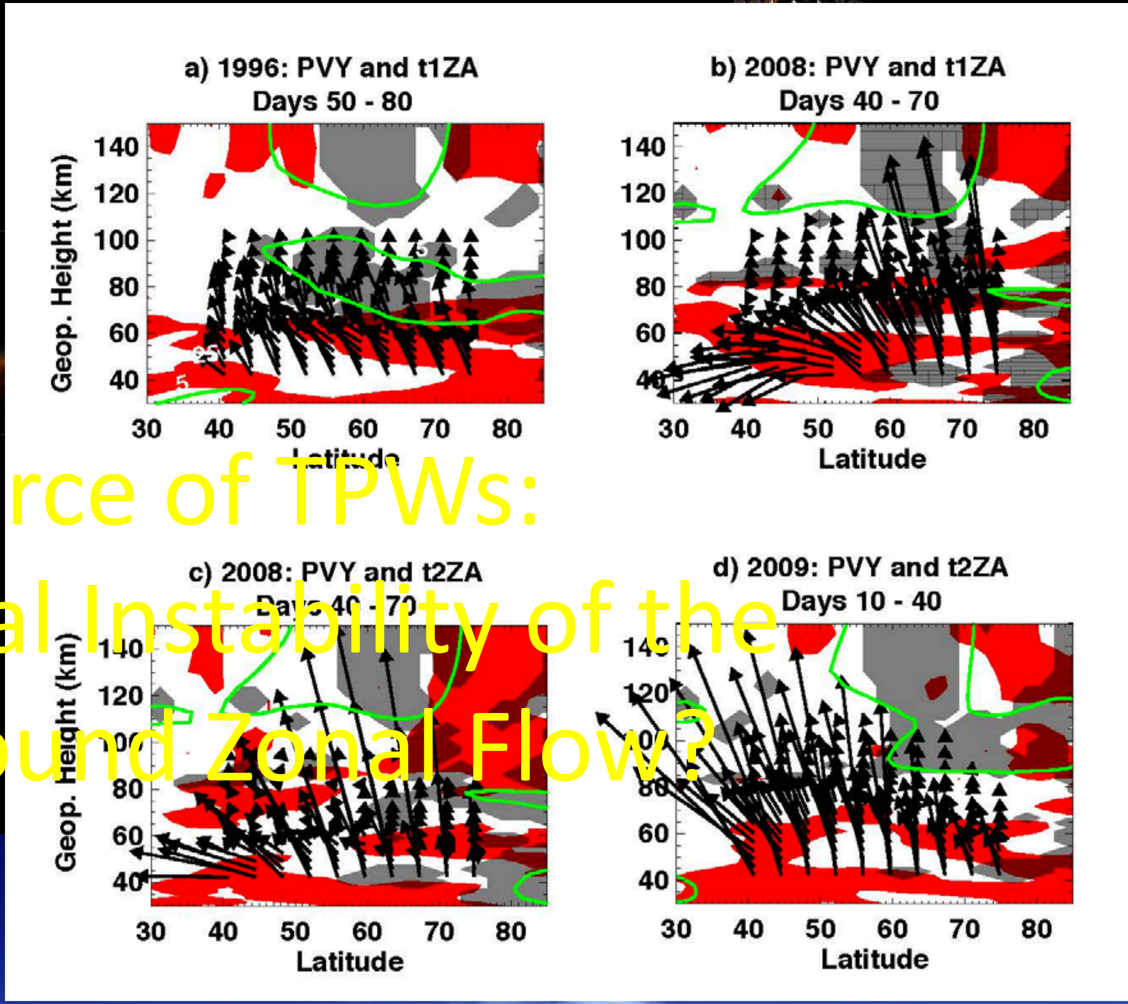


Arrows: $(F^{(y)}, F^{(z)})$

Red shade: EPD(0.1 cpd ≤σ≤0.5 cpd) ≥ 0

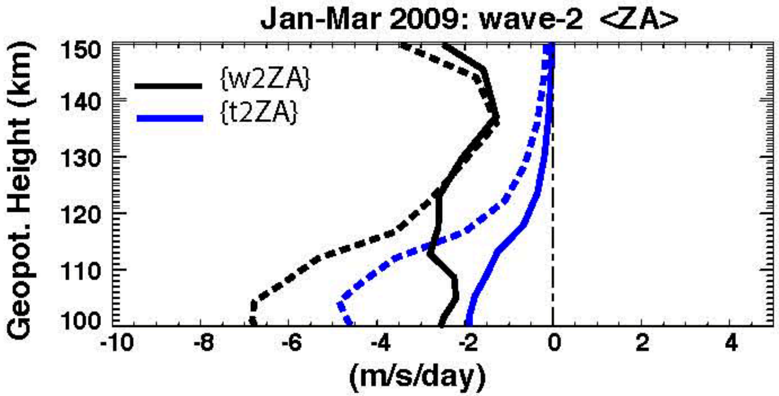
Gray shade: $(PV)_y \leq 0$

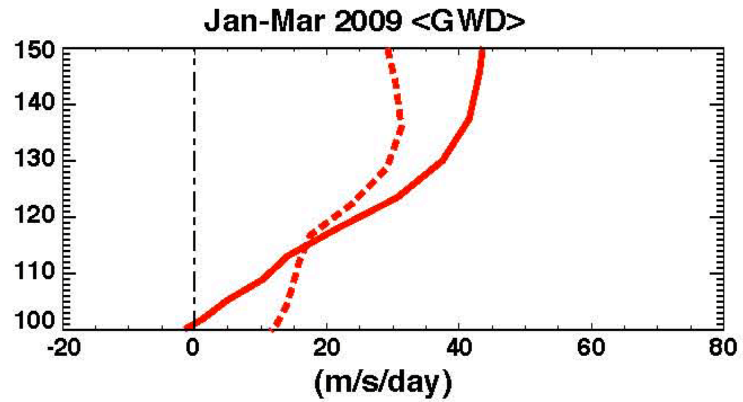
Green line: U = 0



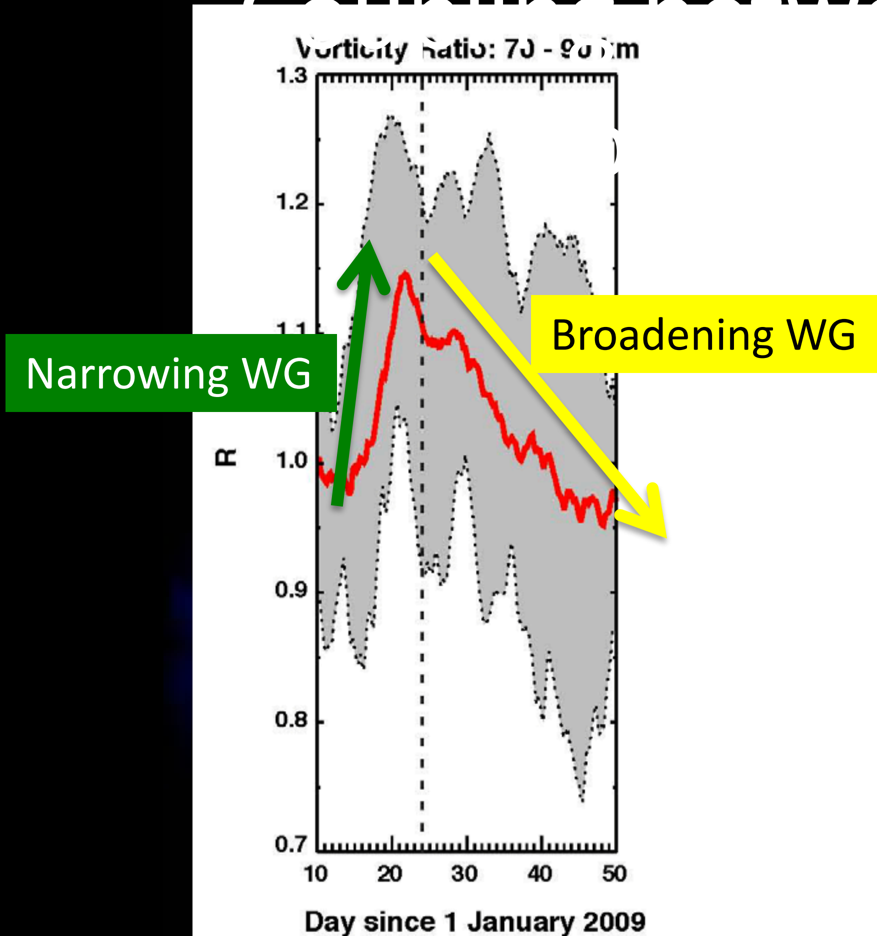
Source of TPWs: Dynamical Instability of the Background Zonal Flow?

Thermospheric Impacts





Coupling between high and ...tudes



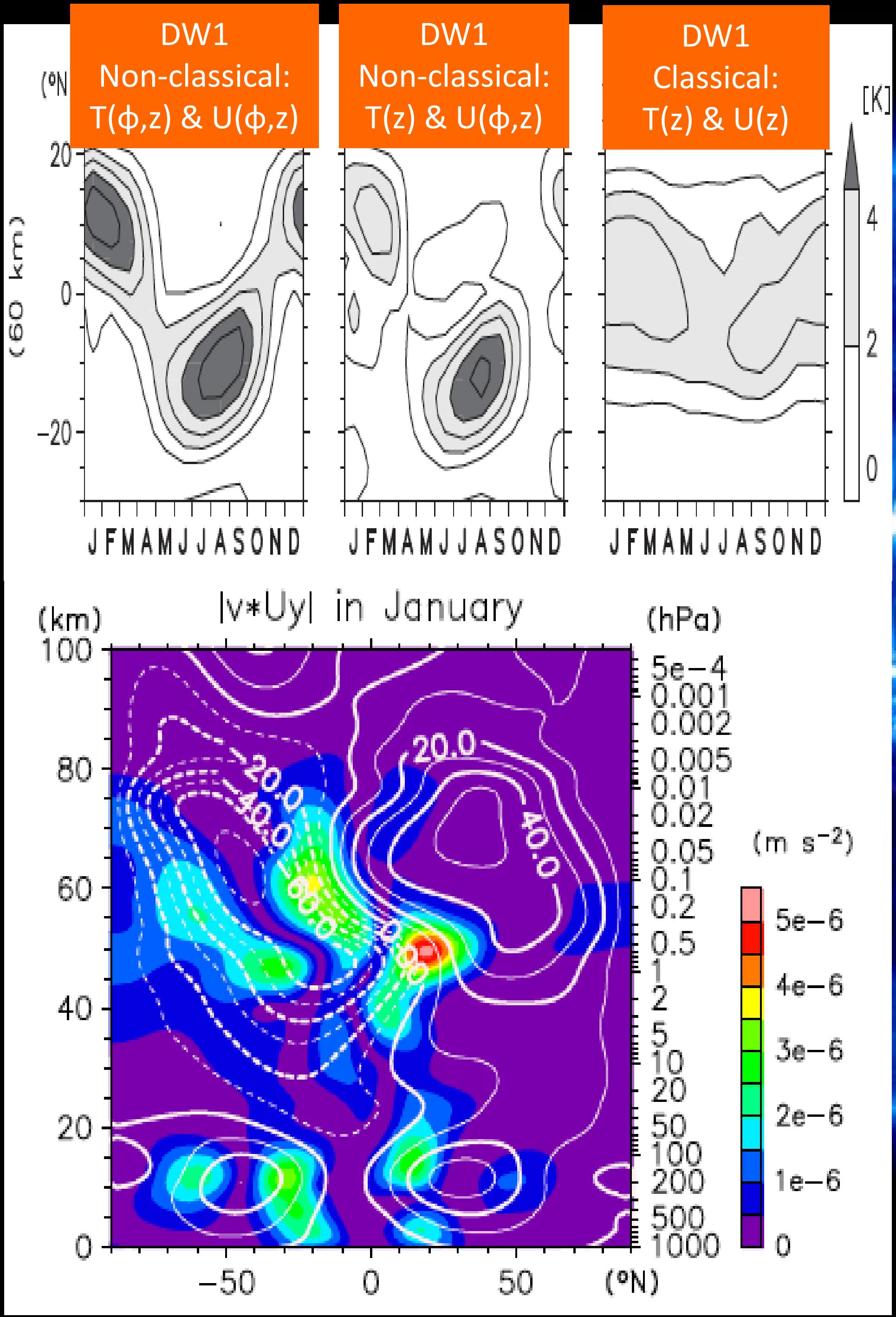
- *McLandress* (2002) suggests that the background zonal wind can change the vorticity in the tropics narrowing or broadening the wave guide for tropically trapped tides, and this mechanism can explain the intra-seasonal change of tidal amplitude.
- *Sassi et al.* (2013) show that a SD-WACCM-X simulation reproduces the same mechanism on shorter time scales and is reflected in consistent changes of the tidal amplitudes.

$$R = (f - Uy) / f \; ; \; Uy = (Uy)_0 + \partial Uy$$

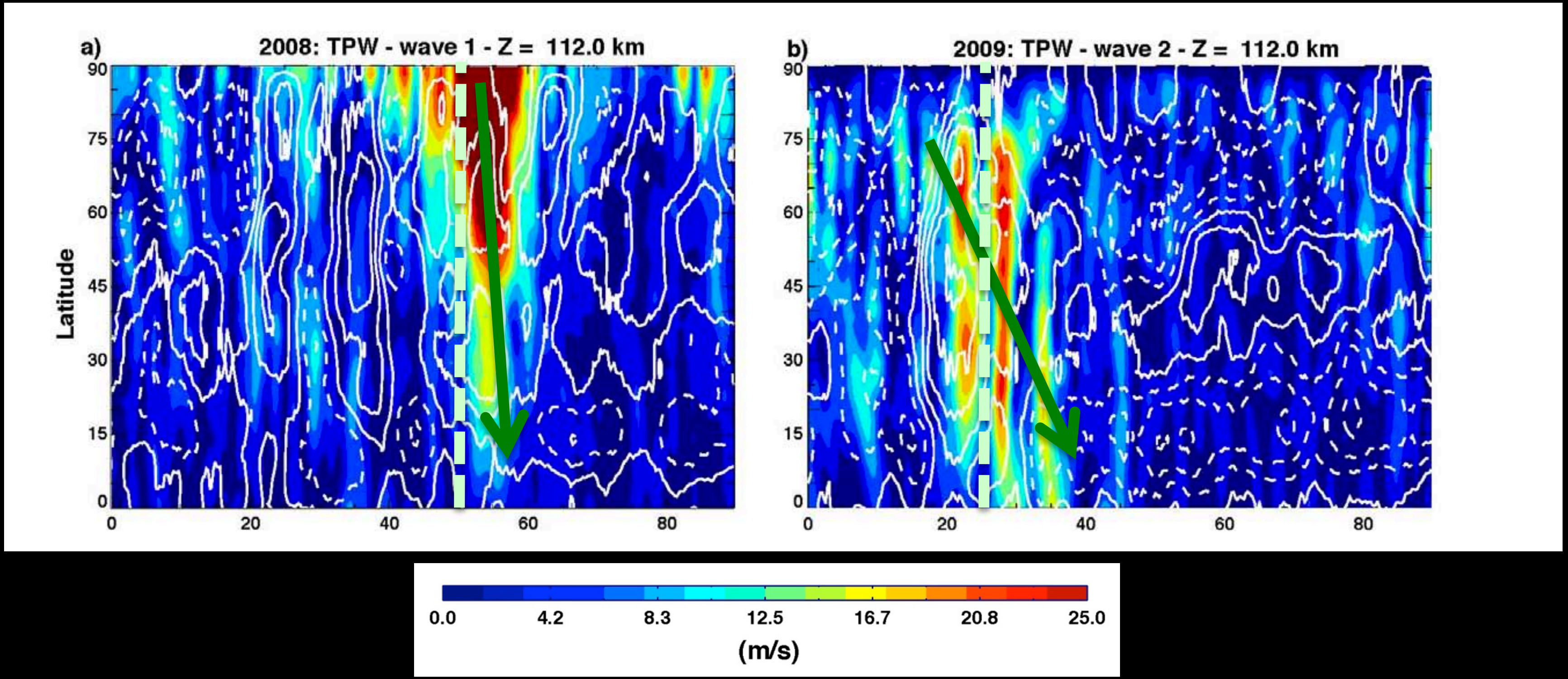
$\partial Uy = 0 \rightarrow R_0$

$\partial Uy > 0 \rightarrow R < R_0$; R decreases $\rightarrow$ *slower rotation / broad waveguide*

$\partial Uy < 0 \rightarrow R > R_0$; R increases $\rightarrow$ *faster rotation / narrow waveguide*



- *Sakazaki et al.* (2013) use a perturbation technique to find the solution to the horizontal structure tidal equation in the presence of a non-uniform (non-classical) background state: they show that non-uniform winds account for the difference from the classical solution.
- A term proportional to the wind shear behaves as a mechanical source of momentum in the upper atmosphere and modifies the seasonal evolution of the classical (1,2) Hough mode.



Color shade: RMS amplitude of v-wind between $0.1 \leq \sigma \leq 0.5$ cpd westward

White contours: U

Conclusions

- TPWs emerge in the thermosphere from the upper mesosphere; their zonal acceleration can be prominent both at times of SSWs or during dynamically quiet times.
- The direct impact of TPWs to the momentum budget of the thermosphere is secondary compared to the parameterized GWD.
- Instability of the background flow as a source of TPWs remains uncertain, at least in a time-mean sense during the most disturbed periods.
- TWPs are associated with propagation of wave activity from mid-latitudes toward the tropics. Following *Sakazaki et al.* (2013) and *Sassi et al.* (2013), the associated perturbation of the zonal flow are ***qualitatively*** consistent with tidal variability.
- It remains to be explained exactly how TPWs interact with the tropical circulation, especially which mechanisms is more important to modify the tidal amplitudes: mechanical forcing (*Sakazaki*) or width of the waveguide (*McLandress*).

Acknowledgements:

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THANK YOU!