The Atmospheric Lunar Tide Simulated in the WACCM

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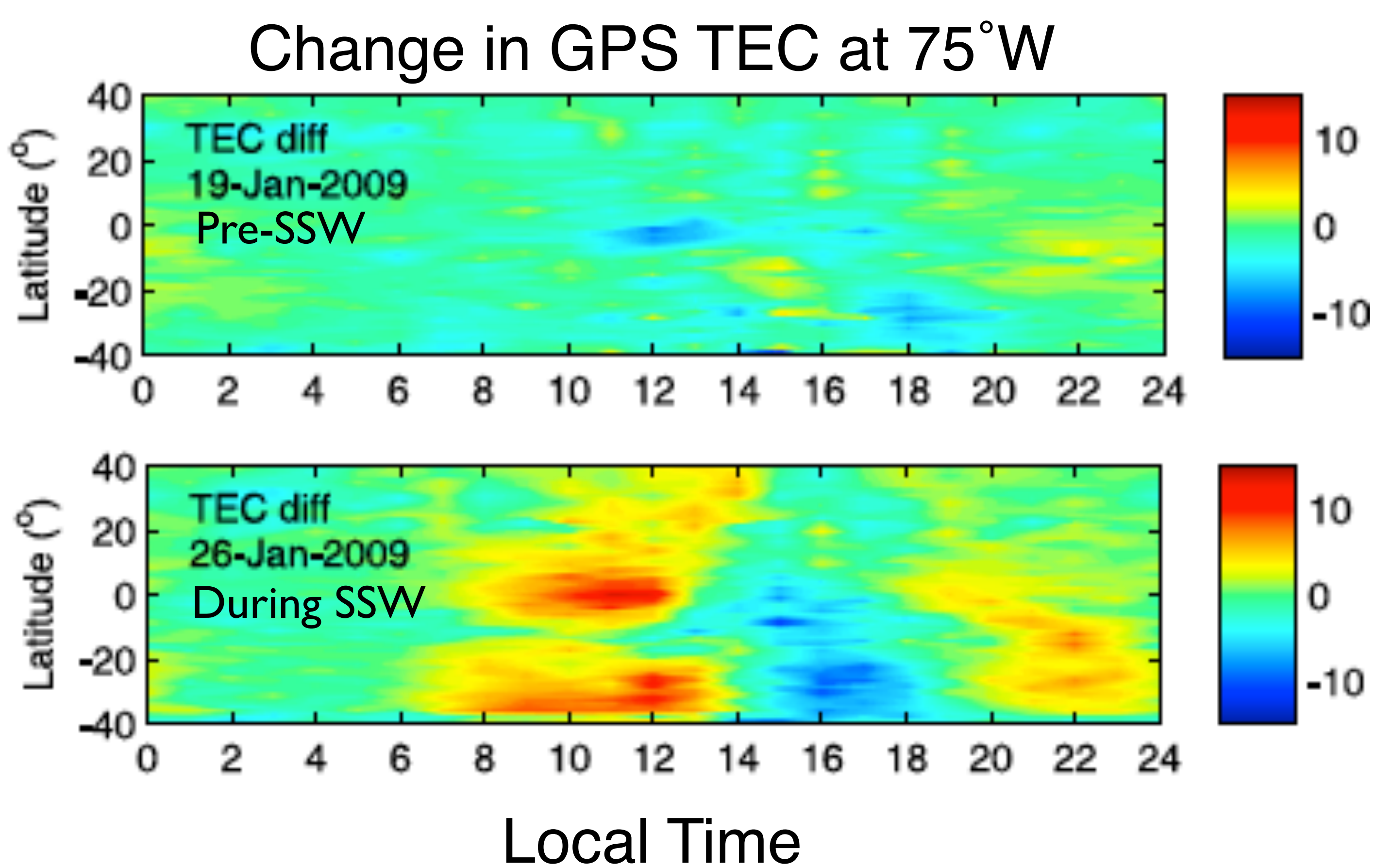
Whole Atmosphere Working Group Meeting

Motivation

- Several prior studies have demonstrated significant perturbations in the low-latitude ionosphere associated with sudden stratospheric warmings
- Multiple mechanisms have been proposed to explain the ionosphere response.

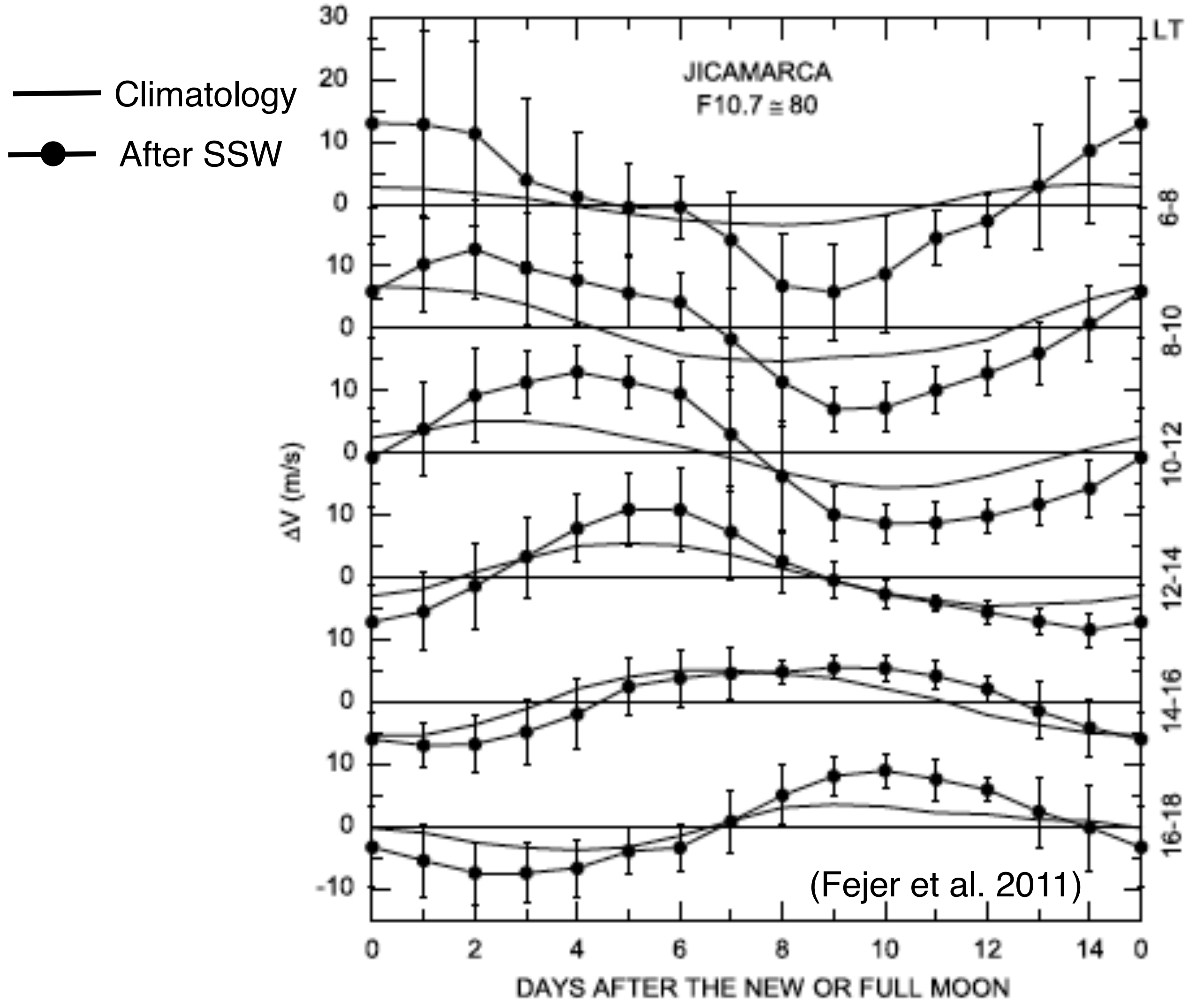


(Goncharenko et al. 2010)

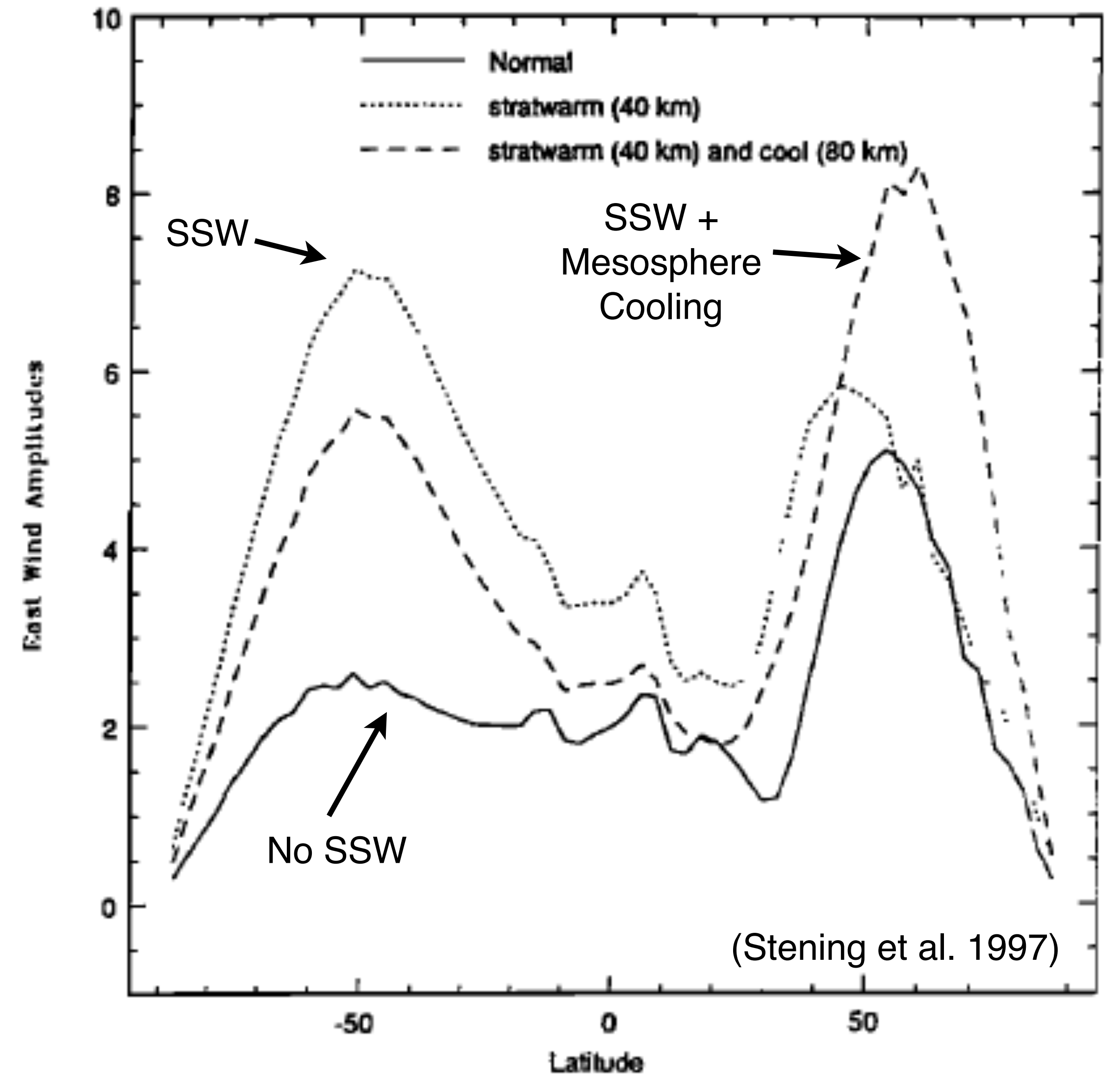
Motivation

Enhanced lunar tides in the MLT is among the proposed mechanisms for producing the ionosphere response to SSWs

Vertical Drift Velocity



GSWM M2 Lunar Tide in Zonal Wind at 90 km



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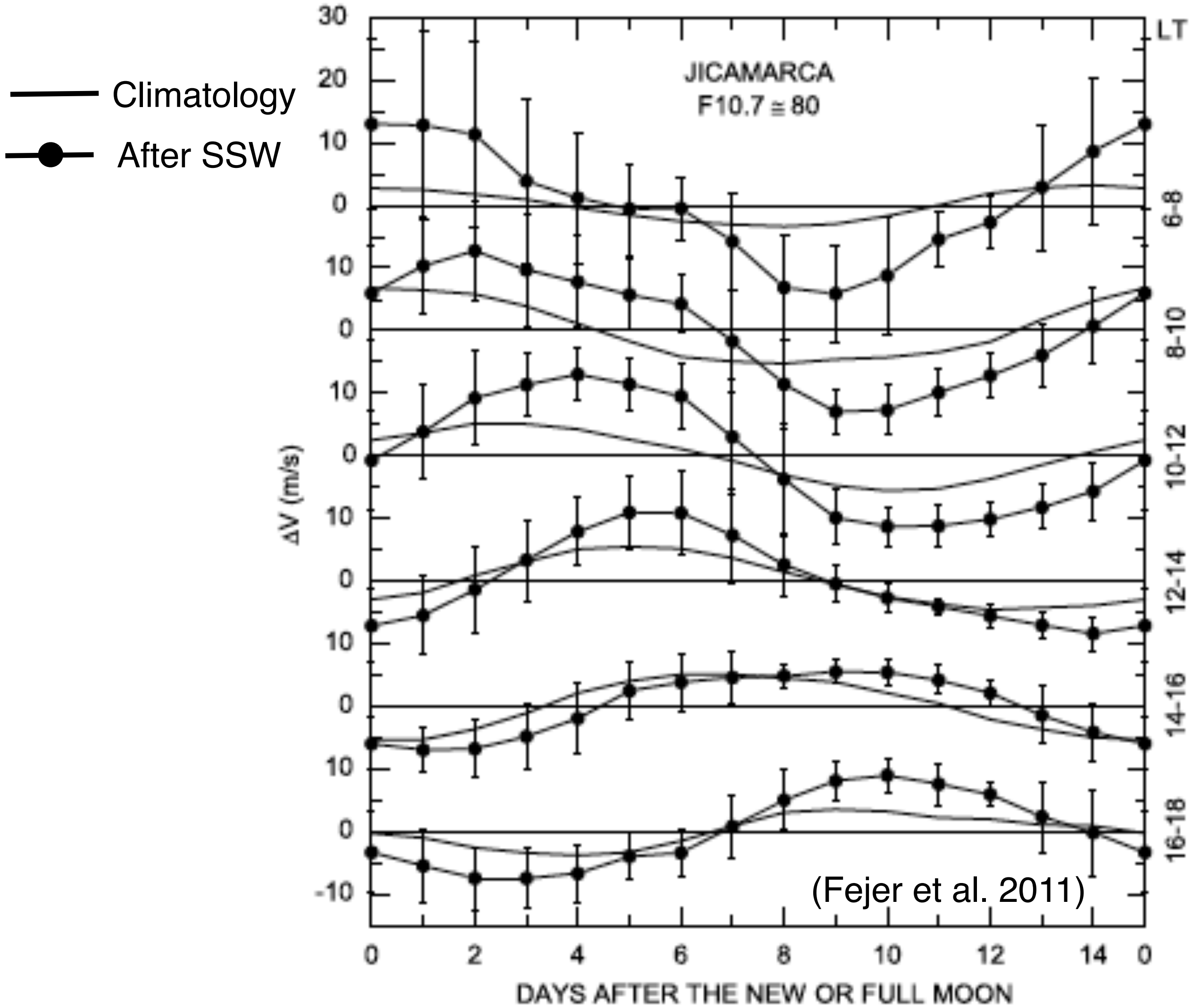

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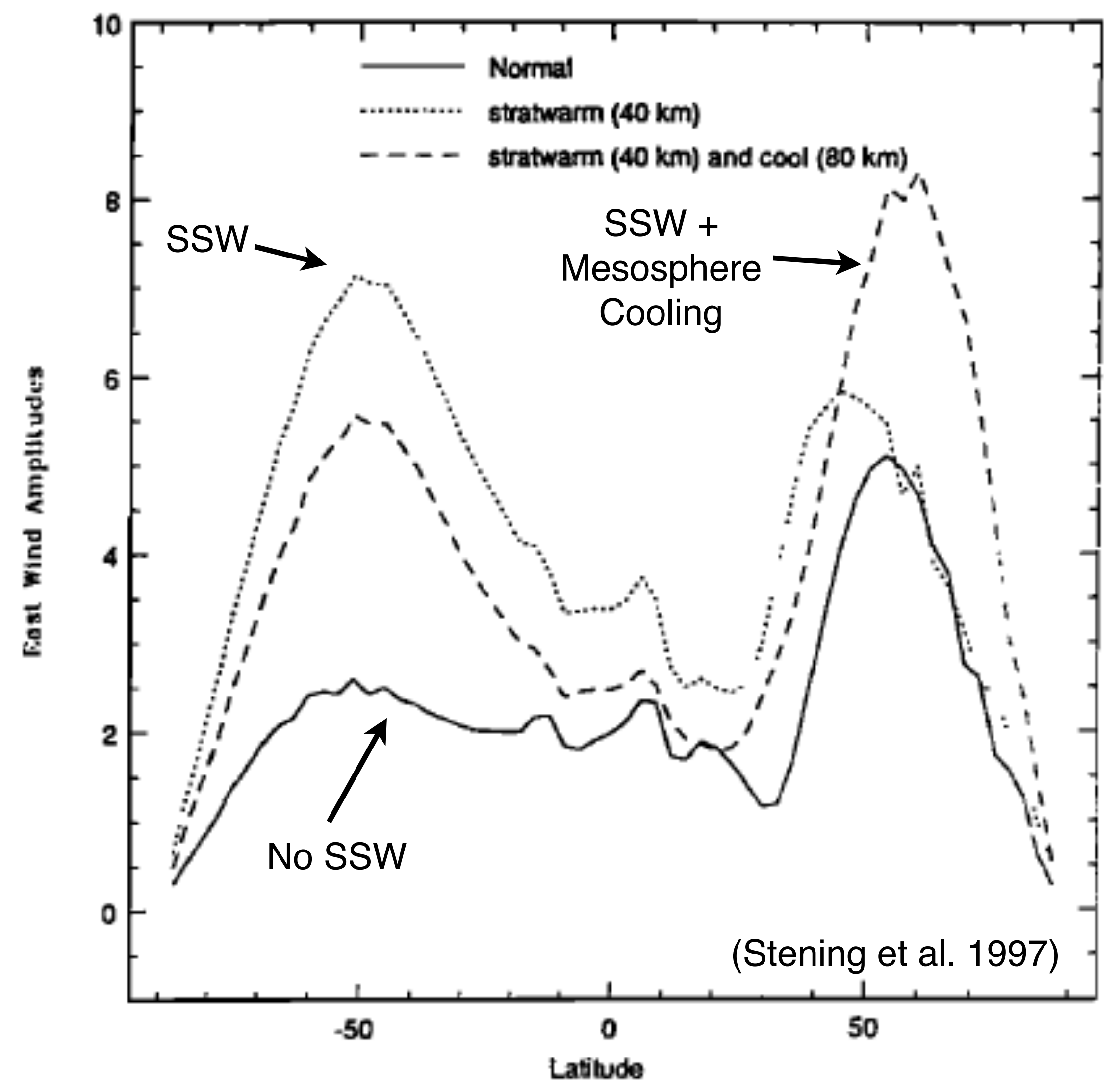


Our objective is to use the WACCM to study the influence of SSWs on the lunar tide

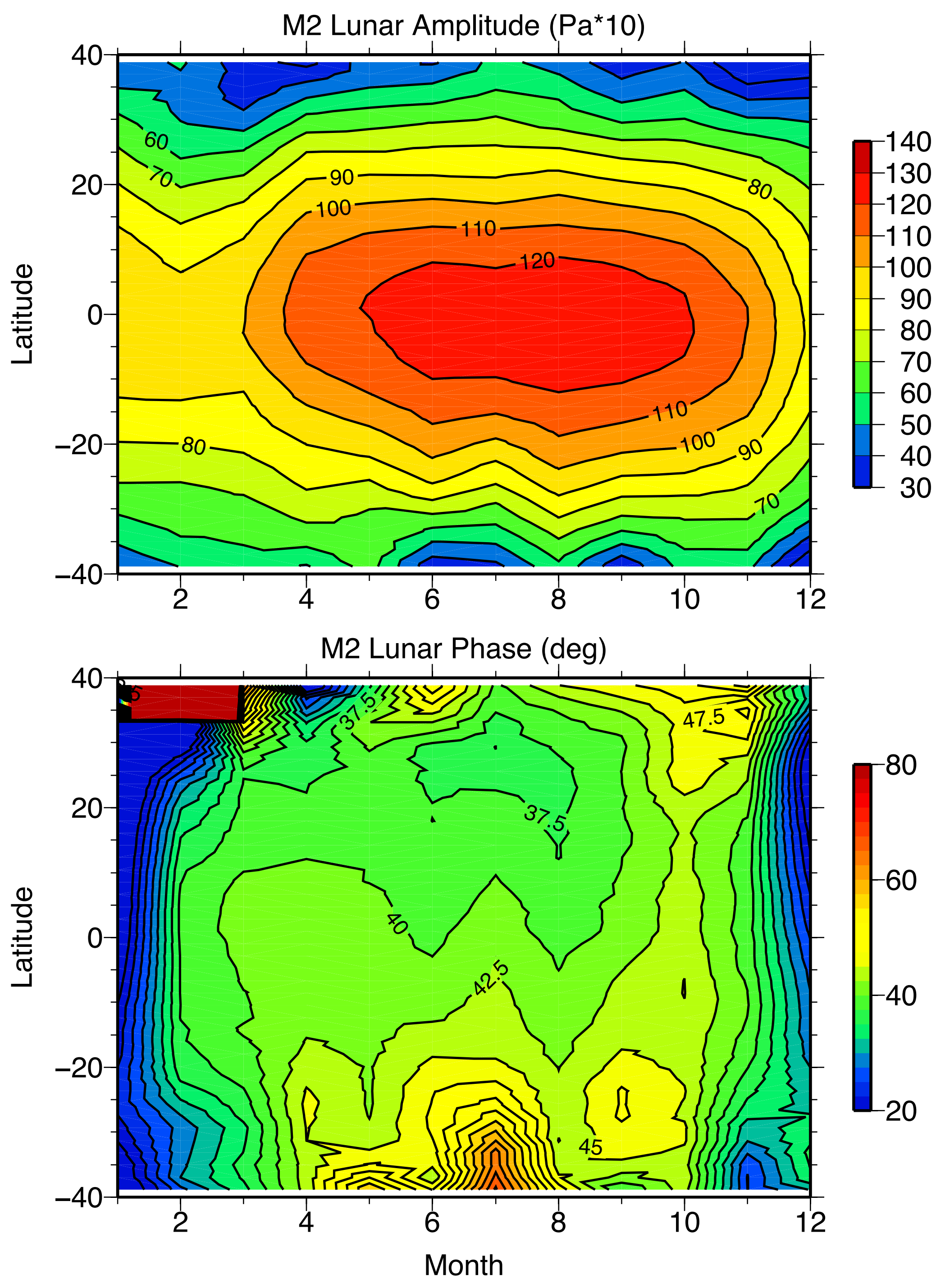
Methodology

- The lunar tide is added to the WACCM by including an additional forcing term in the zonal and meridional momentum equations
- Only the M2 (migrating semidiurnal) lunar tide is included since forcing from this term is known and it accounts for the majority of the lunar tide

$$\Omega_{M2} = -0.7933\ P_2^2(\Theta)$$

- We study both the lunar tide climatology and variability during SSWs
  - Climatology based on 10-year ensemble run
  - SSW variability based on 40-year ensemble of Northern Hemisphere winter simulations (~20 moderate to strong SSWs)

Annual Variations in Surface Pressure



- Greatest amplitude around August

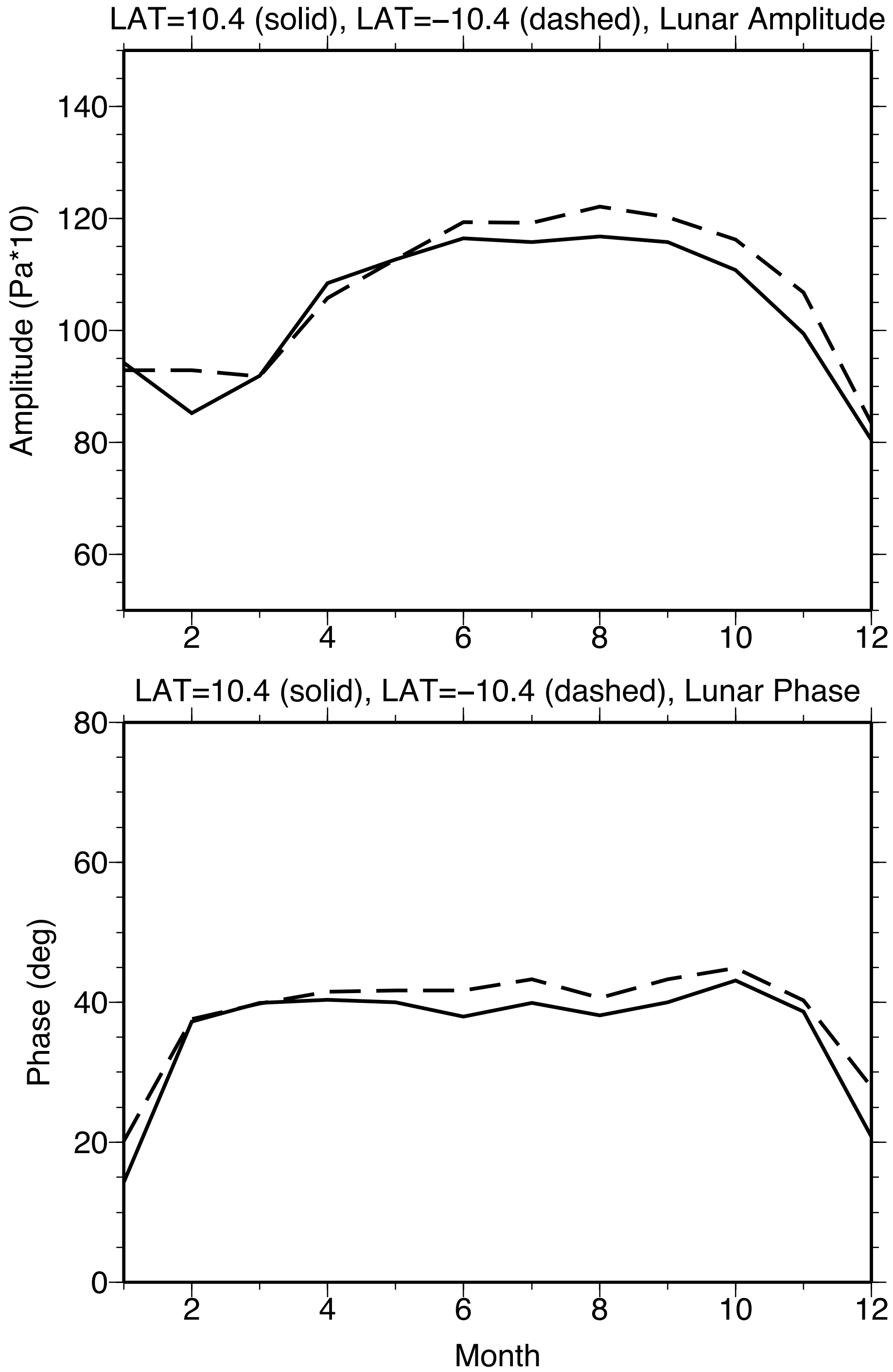
- Slightly larger in SH

- Large phase change during DJF

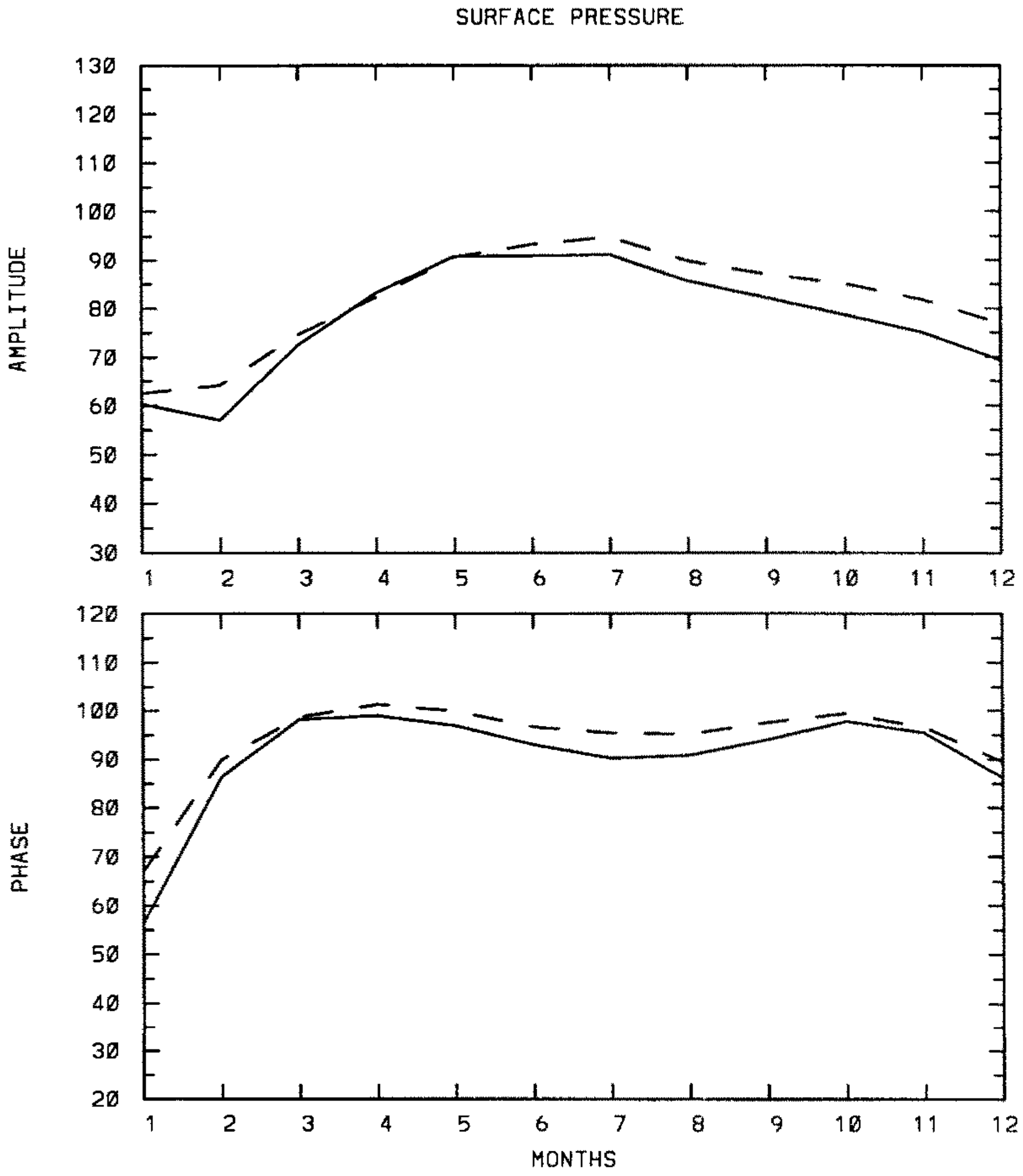
- Phase larger in SH

Surface Pressure Variations at ±10°

WACCM

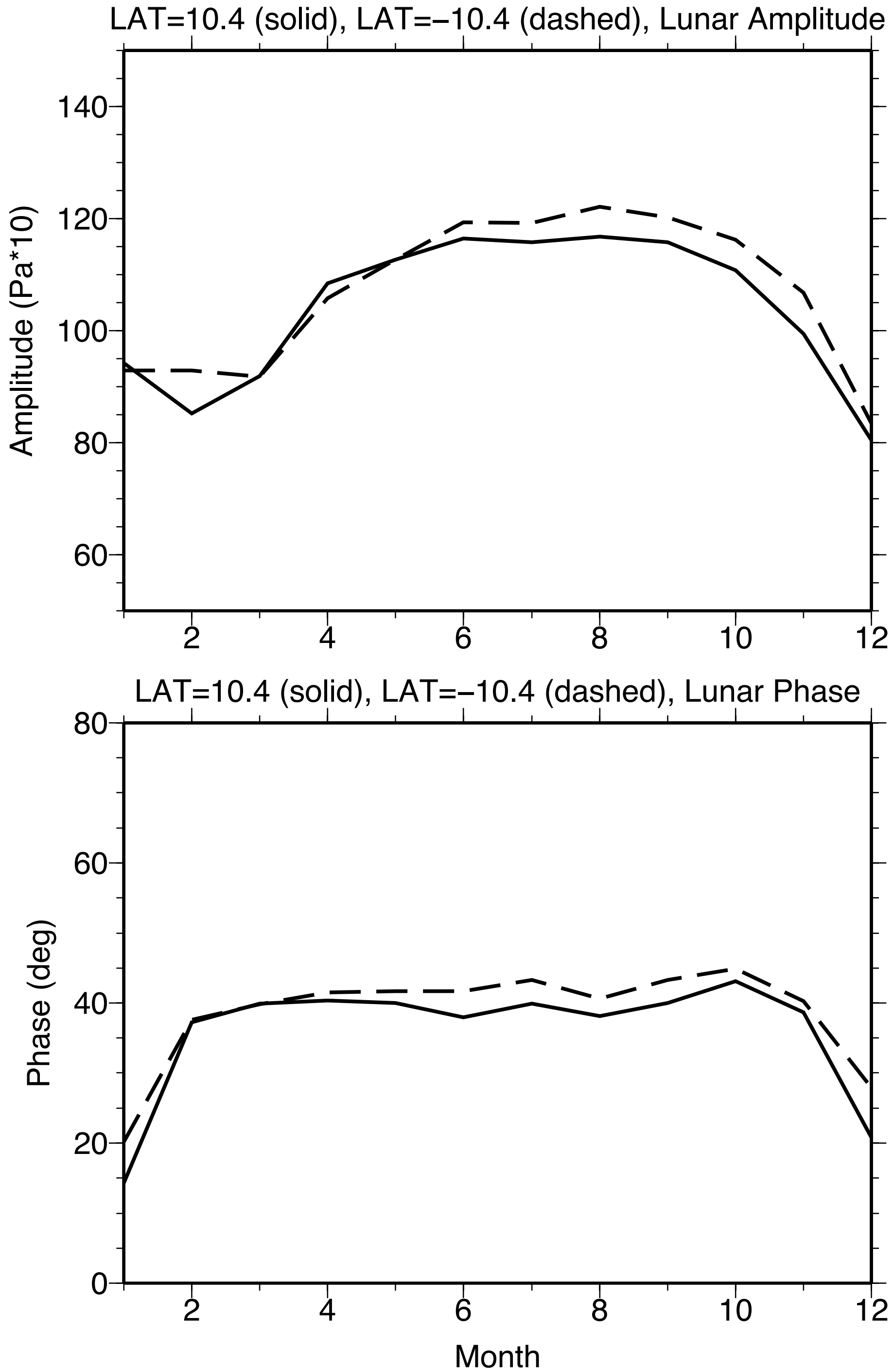


Vial and Forbes (1994) Simulation

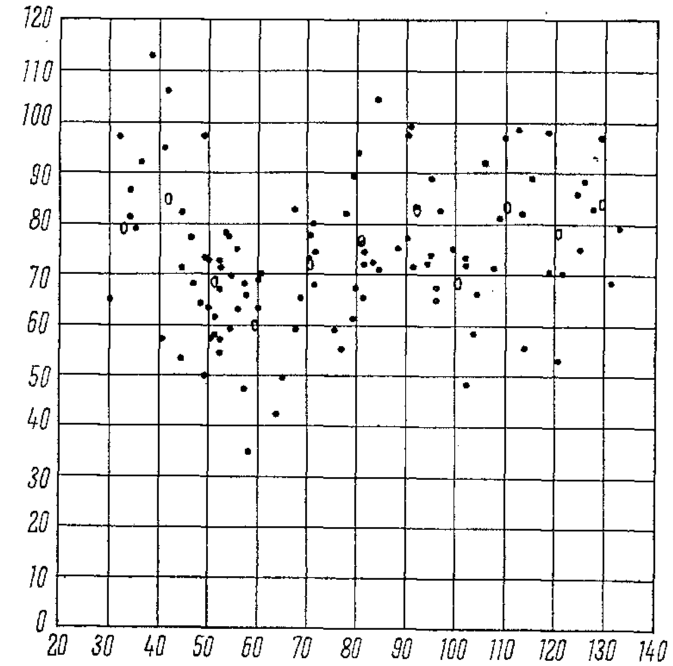


Surface Pressure Variations at ±10°

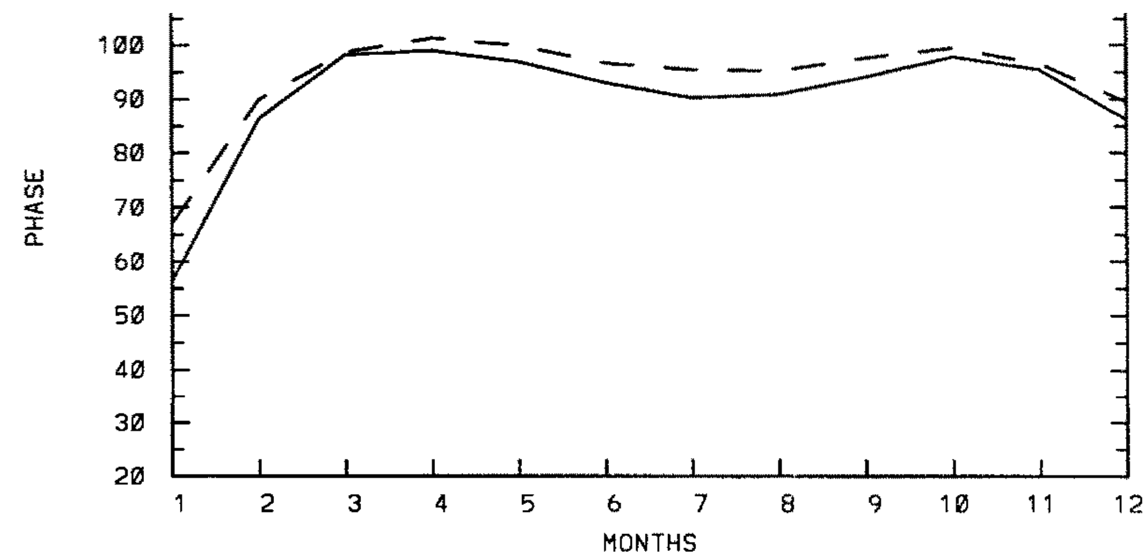
WACCM



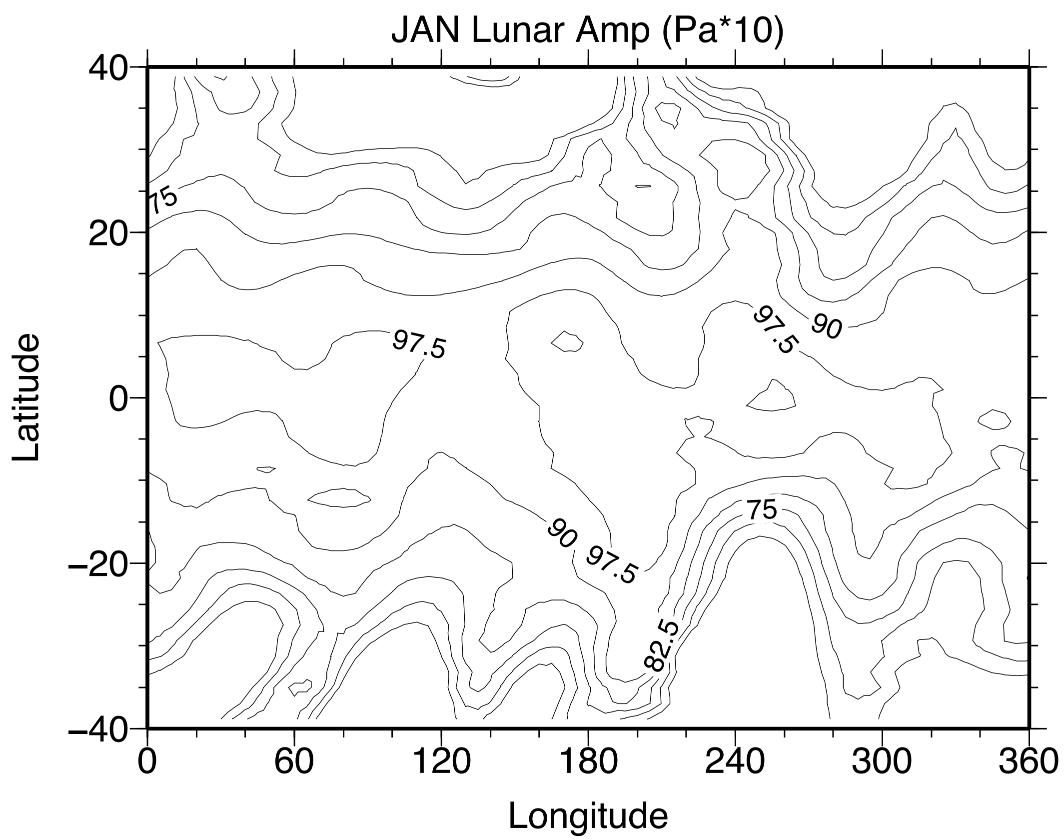
Annual Mean Phase

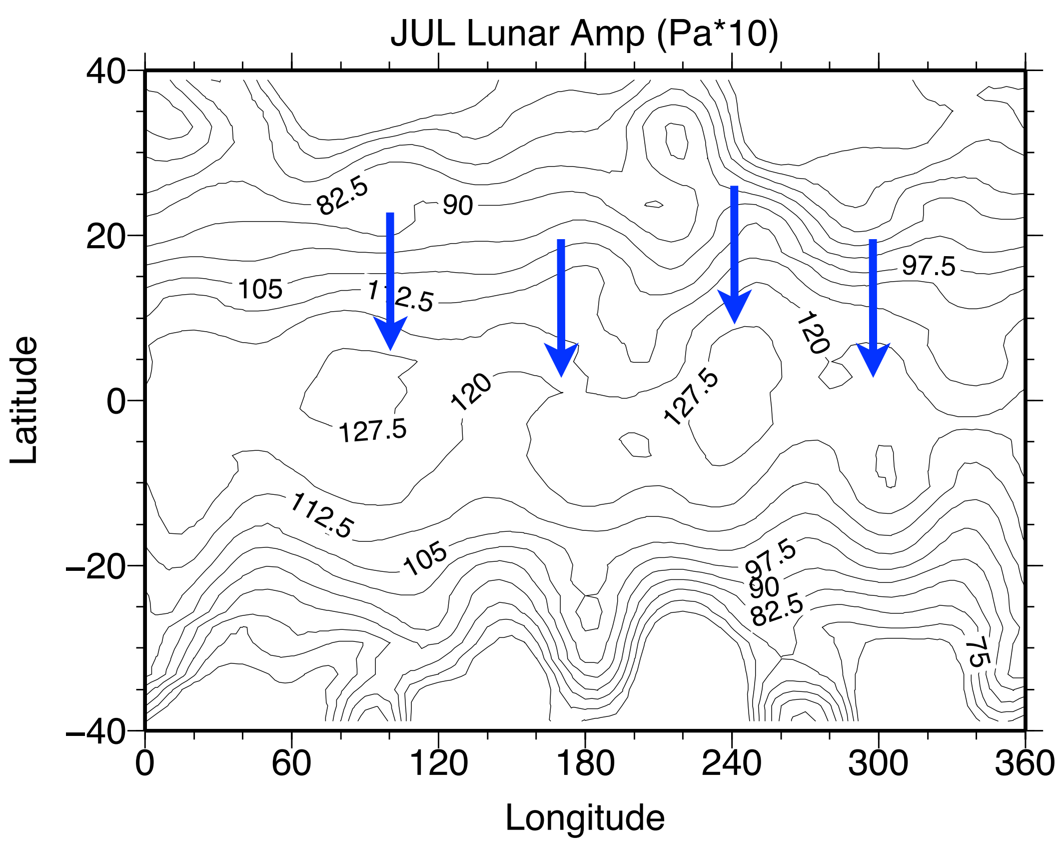


Colatitude (Haurwitz and Cowley, 1969)

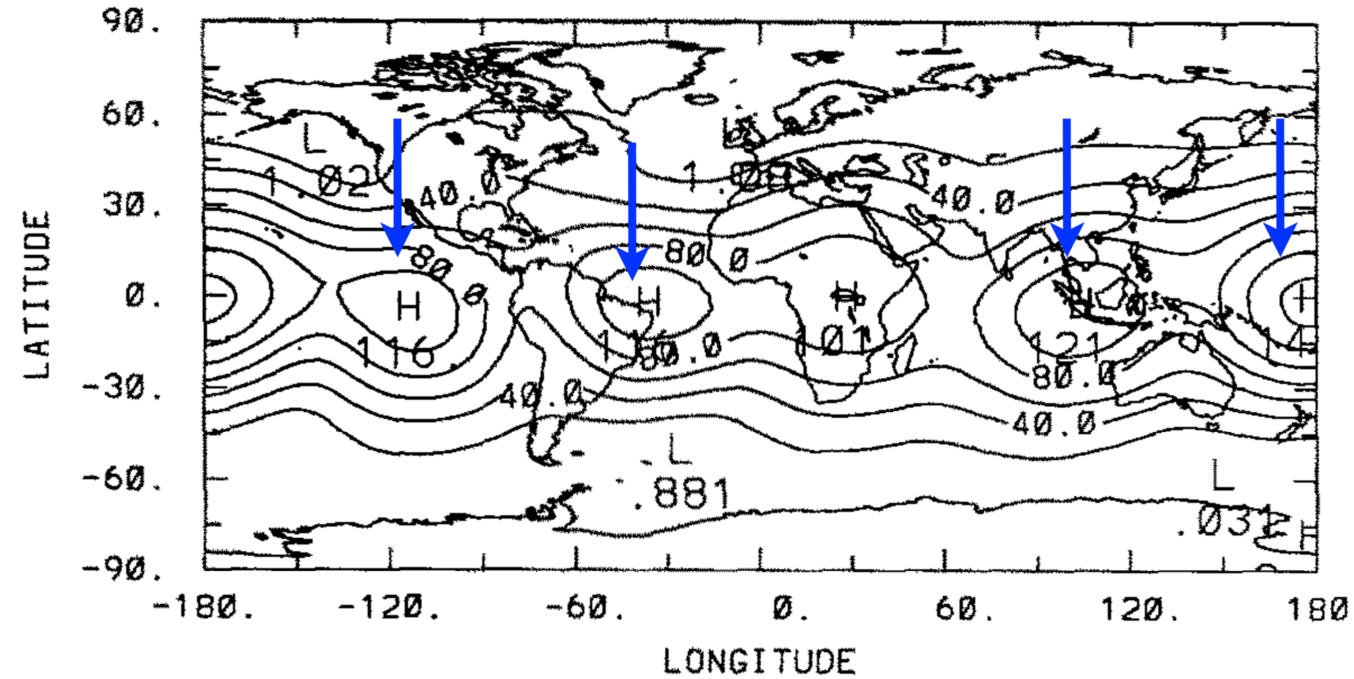


Longitude Variability in Surface Pressure



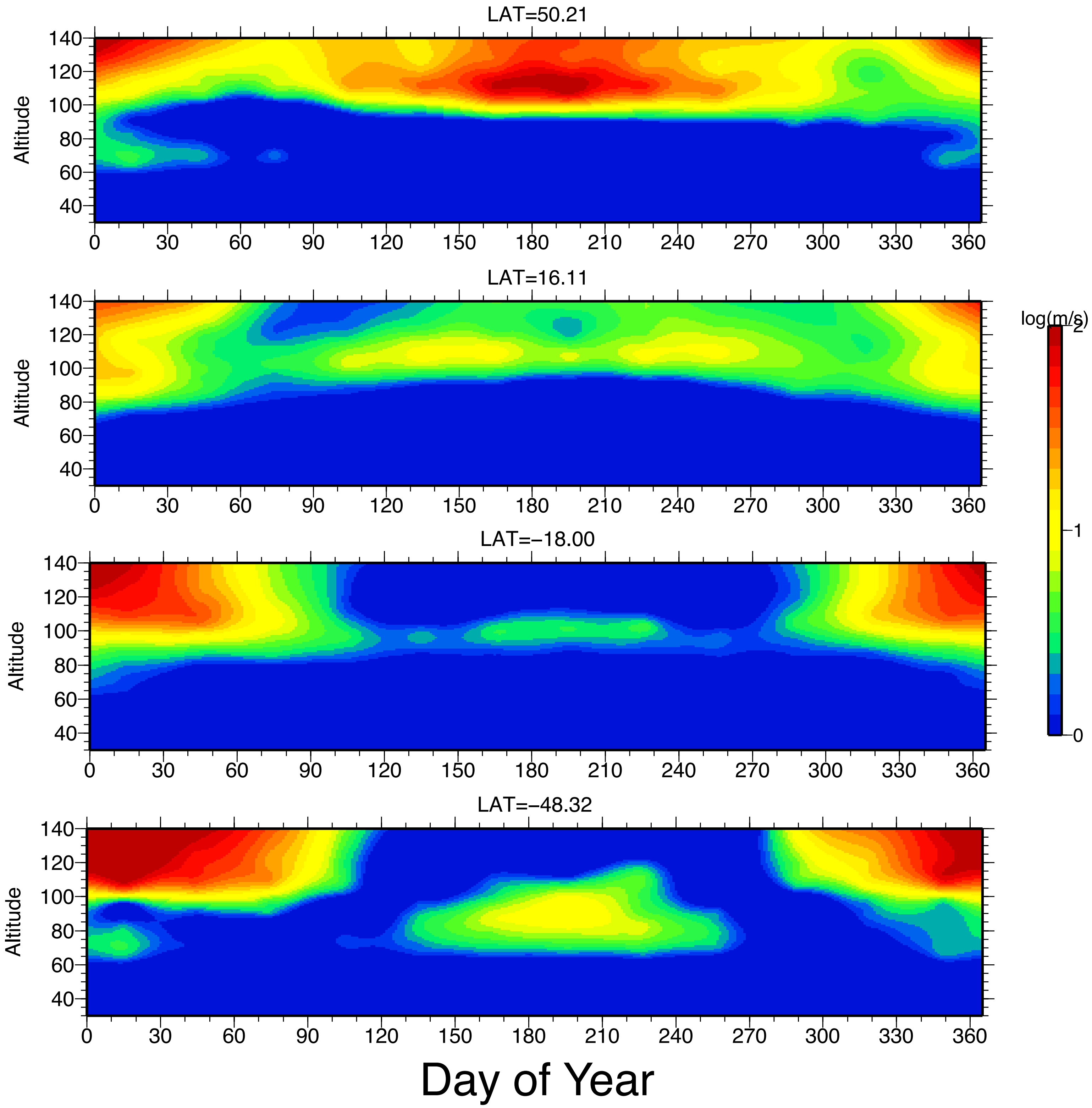


Vial and Forbes (1994) Simulation (July)

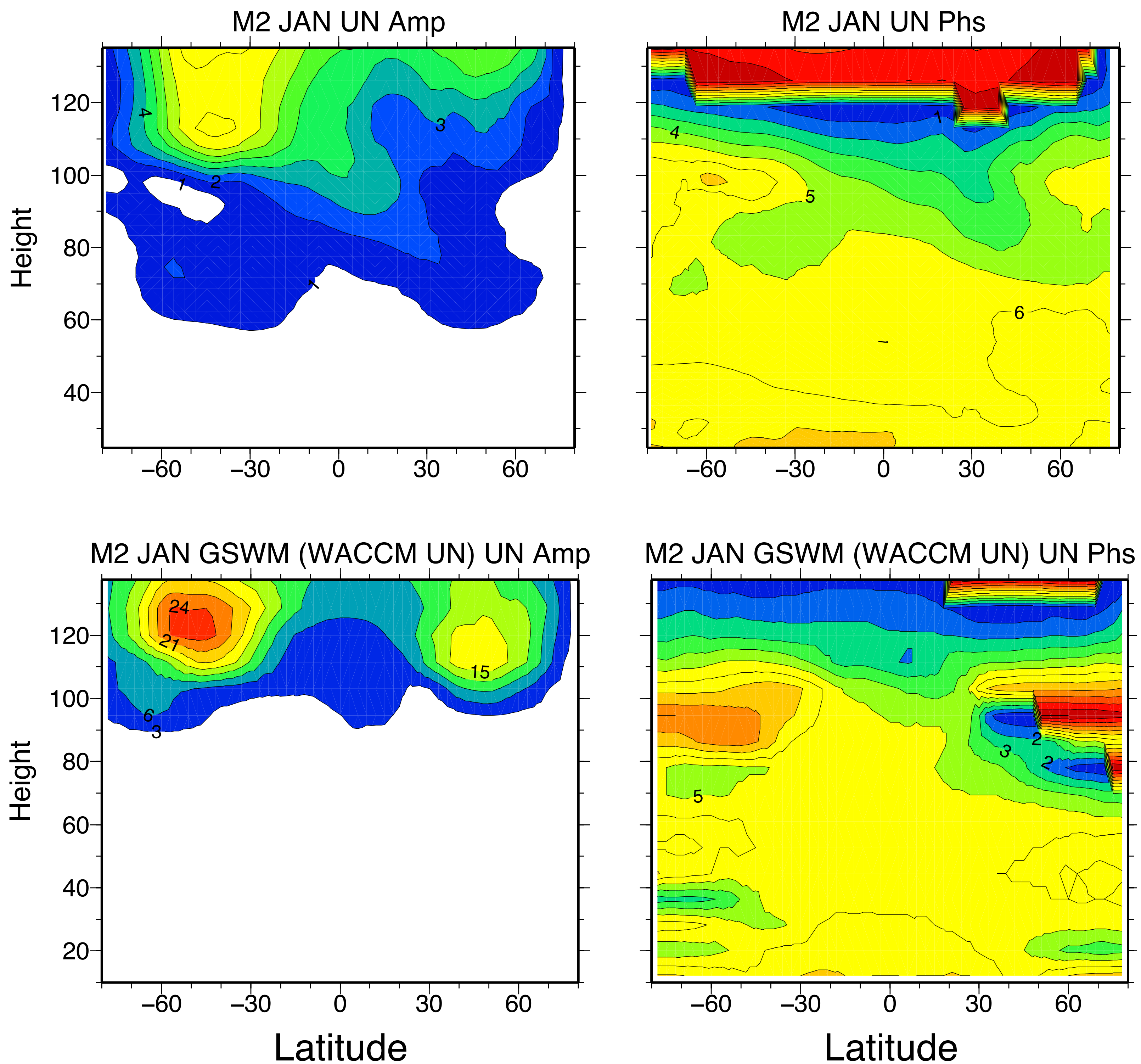


Note that Vial and Forbes use more realistic tidal forcing

Annual Variations in the MLT

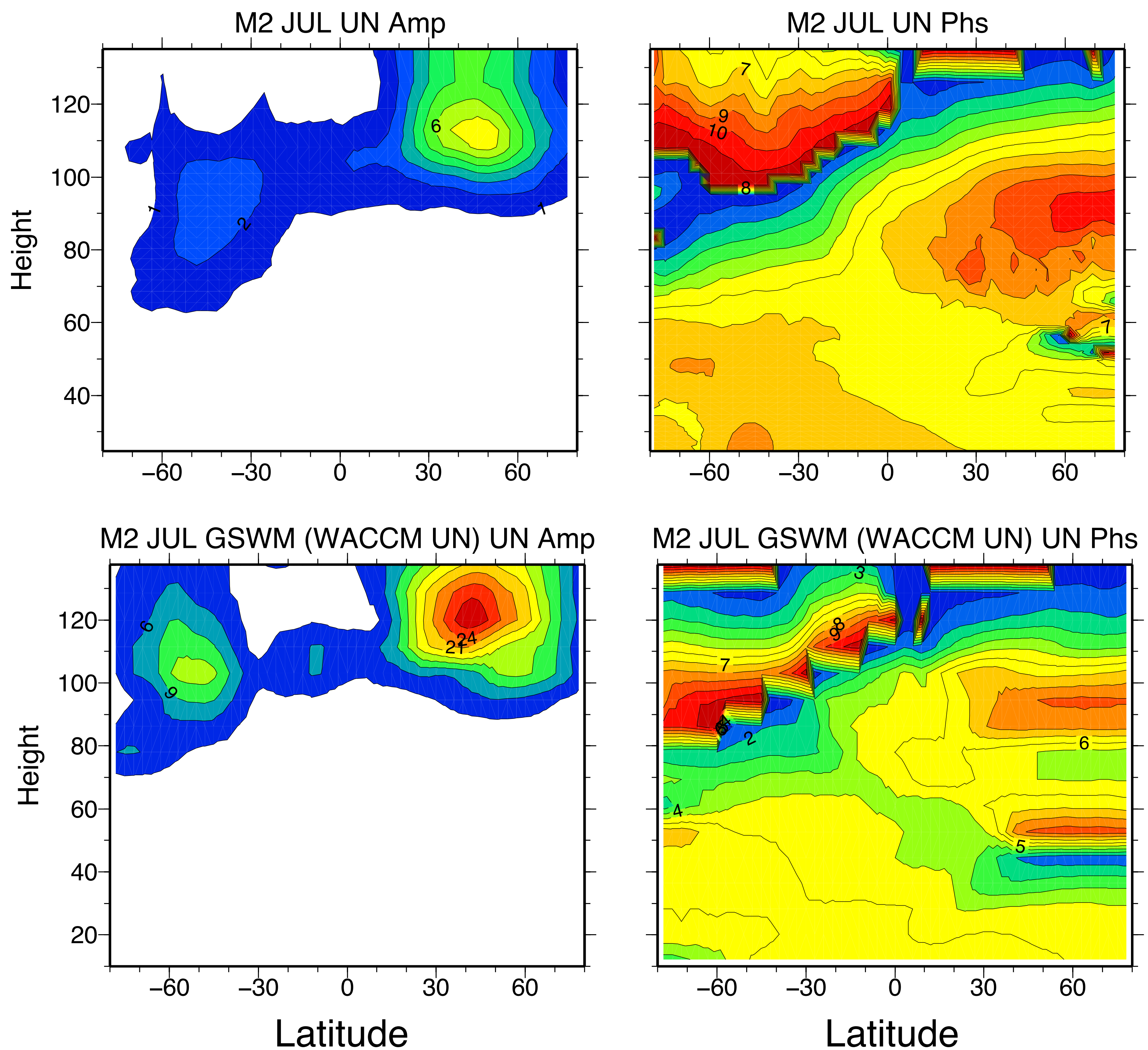


Comparison with GSWM (Jan.)



Similar agreement for VN, TN

Comparison with GSWM (July)



Similar agreement for VN, TN

Variability During SSWs

- Simulated 40 Northern Hemisphere winters with WACCM
- To study SSW induced variability the background tidal climatology is removed to prevent seasonal changes from influencing the results
- Calculate the average tidal change between day of peak warming and 10 days post warming
  - Include all warmings where $T(90^\circ N) > T(60^\circ N) + 20K$ at 10hPa

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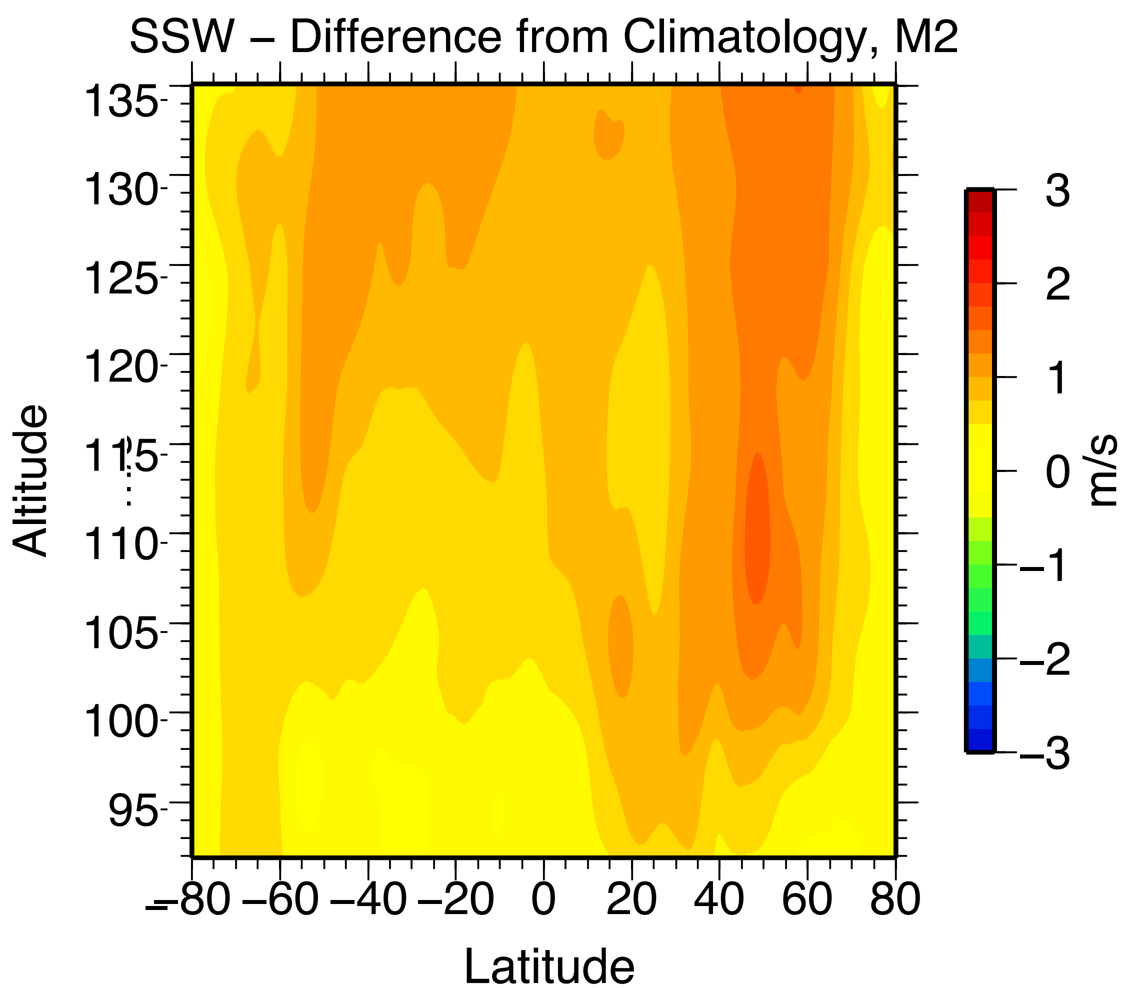
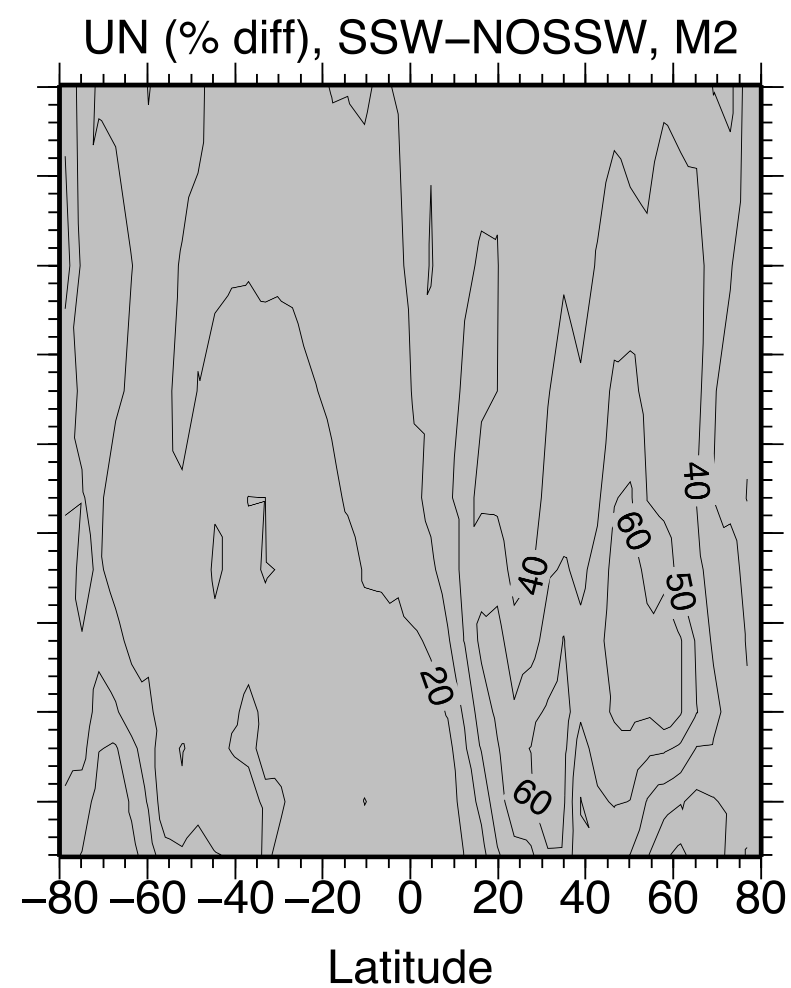
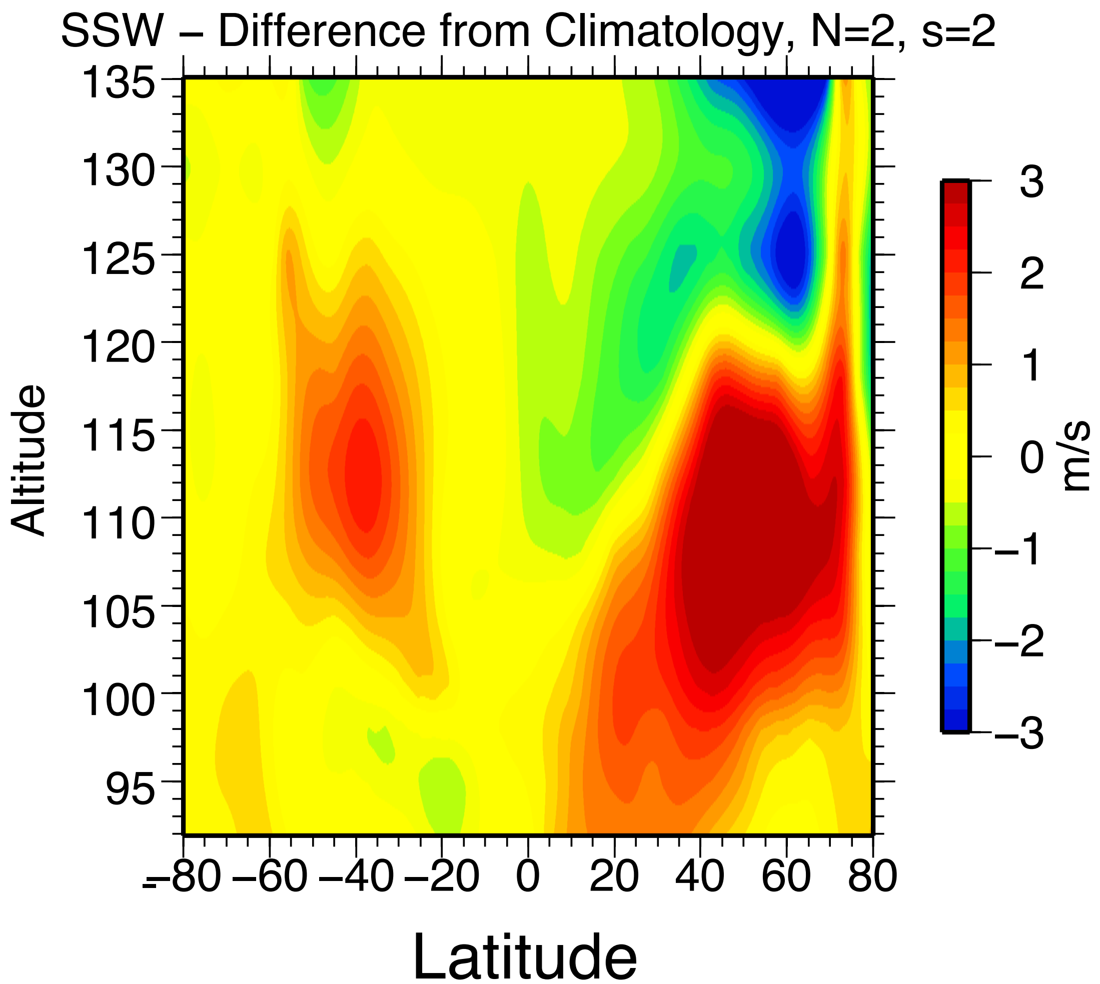
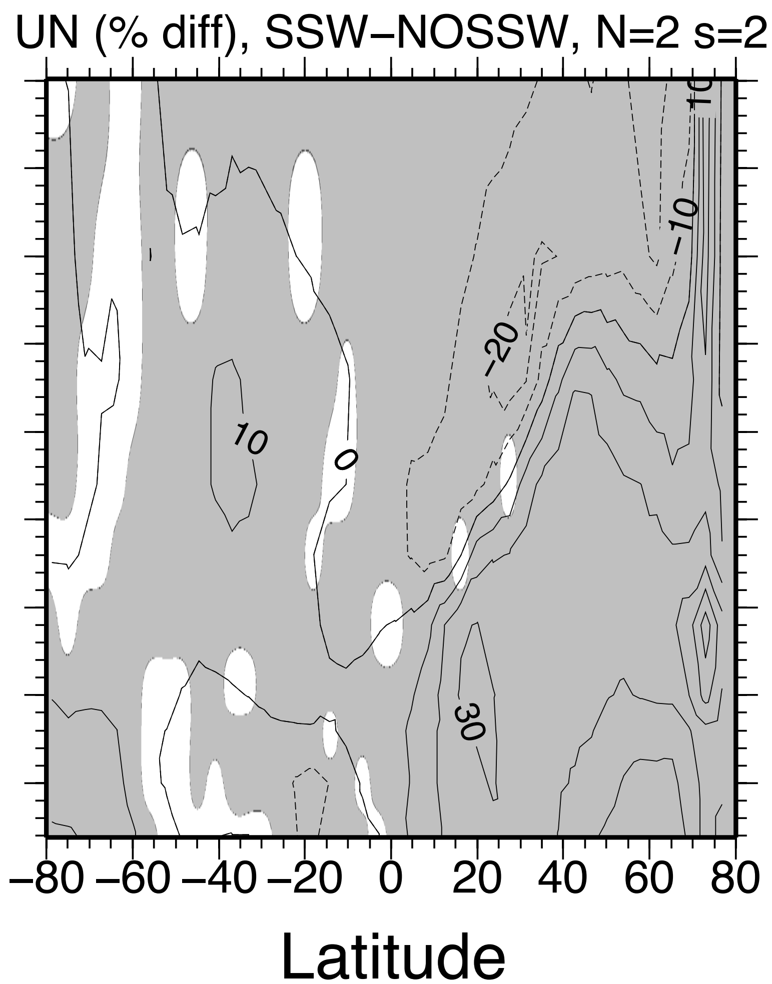




Variability During SSWs

Also changes in migrating solar semidiurnal tide





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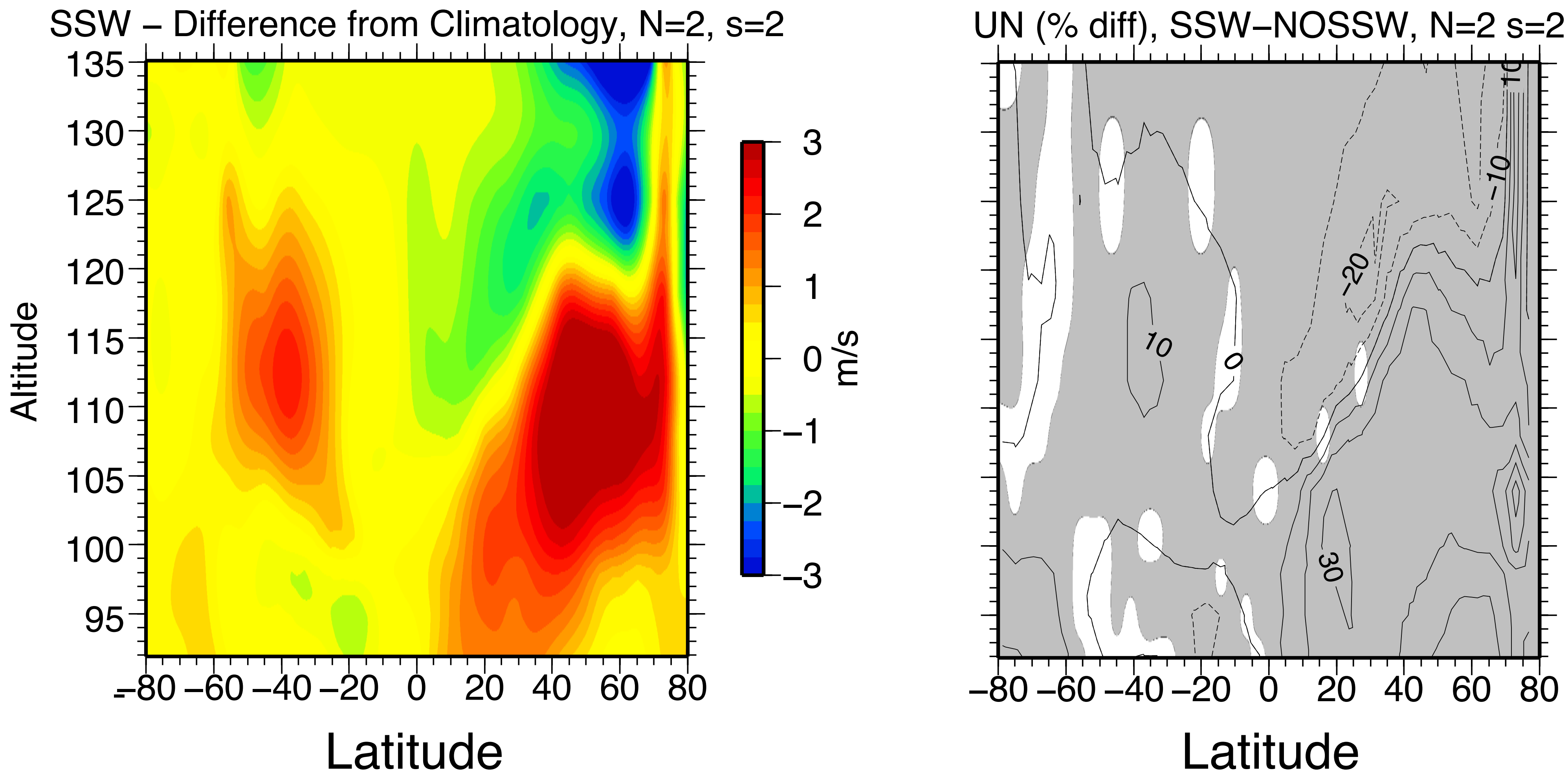

How do these influence the ionosphere?

Summary and Conclusions

- A simplified lunar tidal forcing has been added to the WACCM
- The WACCM climatology of the lunar tide is generally consistent with prior observations and modeling results
- The average tidal response in the MLT due to SSWs has been investigated based on an ensemble of 40 winters
    - Statistically significant changes in the M2 lunar tide of ~50-60% are observed
    - Changes in other tides also occur, most notably the migrating solar semidiurnal tide
- Work is currently underway to use WACCMX fields to drive an ionosphere model to understand the relative importance of different tides on generating the observed ionosphere response to SSWs.