

Lunar Tide Effects on the 2013 Sudden Stratospheric Warming (SSW)

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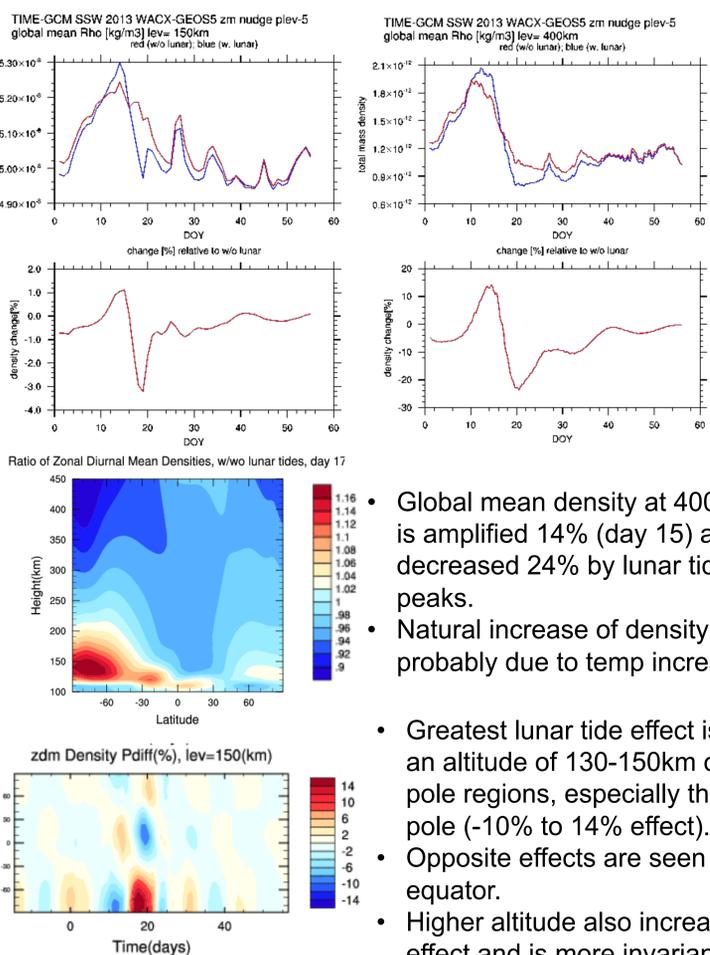
Method

TIME-GCM, a numerical model that models the middle and upper atmosphere, was used to simulate atmospheric conditions during the Sudden Stratospheric Warming of January 2013. TIME-GCM is forced by WACM-GEOS5, taking into account tide propagation, and it successfully reproduces the SSW event. The model was run for two situations: one with forcing that includes the lunar tide, and one that omits it. By comparing the two simulations, the lunar tide effects on neutral air density, temperature, and wind were quantified in the middle and upper atmosphere.

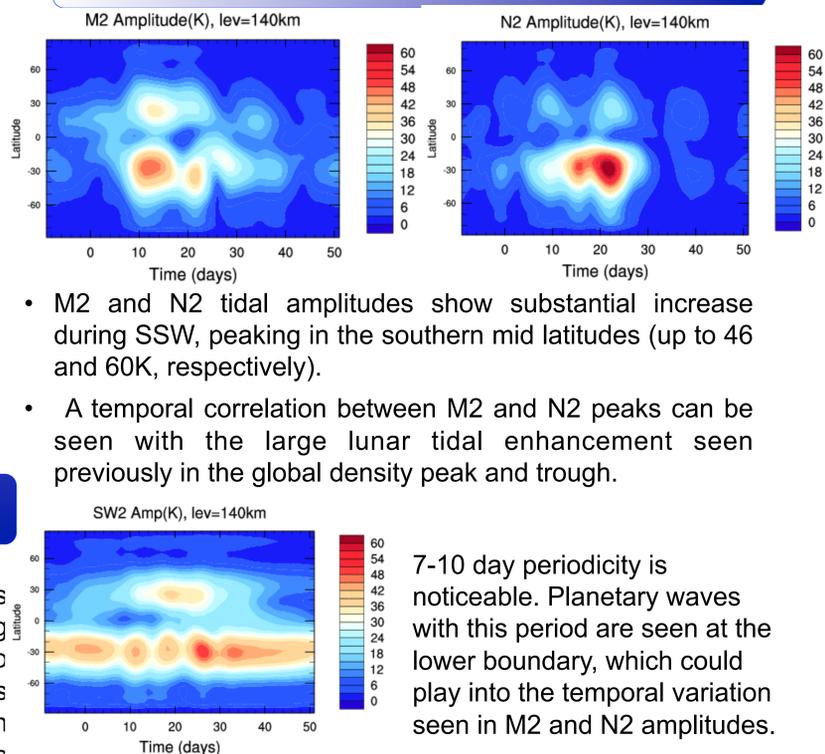
Why It's Important

The lunar tide always has a slight effect on Earth's atmosphere, but during Sudden Stratospheric Warming (SSW), these slight effects are greatly amplified due to resonance.¹ The lunar tide alters many atmospheric conditions globally during SSW, however a large effect was seen on neutral density (15-25% change due to lunar tide which is surprisingly large) in the upper atmosphere, so this was the point of focus. Many satellites orbit at 400km, so atmospheric conditions at that height are important to understand to effects of things like drag (most notably for neutral air density).

Density



Lunar Tides

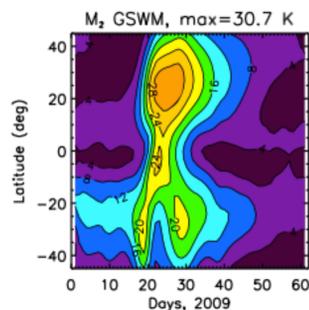


- M2 and N2 tidal amplitudes show substantial increase during SSW, peaking in the southern mid latitudes (up to 46 and 60K, respectively).
- A temporal correlation between M2 and N2 peaks can be seen with the large lunar tidal enhancement seen previously in the global density peak and trough.

Comparisons

Decent agreement is seen between TIME-GCM data and observed SABER data.

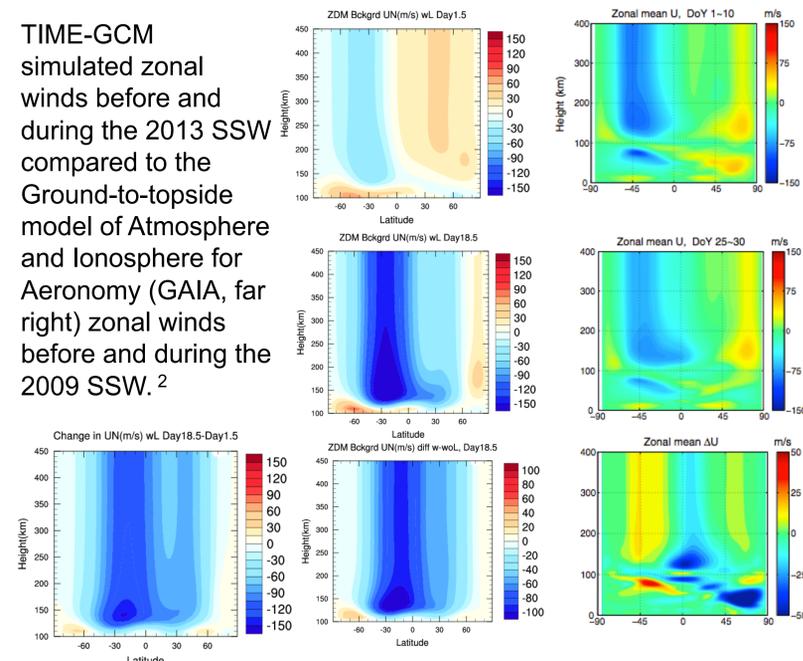
- Similar magnitudes
 - Similar latitudinal and temporal trends
- Max M2 amplitudes:
- TIME-GCM: 15K
 - SABER-M2: 28K
- Difference could be due to TIME-GCM background and processing.



GSWM shows larger amplitudes in the northern hemisphere compared to the southern which might be due to the different background in the two different SSW events.¹

Effect on Zonal Mean Zonal Wind

TIME-GCM simulated zonal winds before and during the 2013 SSW compared to the Ground-to-topside model of Atmosphere and Ionosphere for Aeronomy (GAIA, far right) zonal winds before and during the 2009 SSW.²



- Strong lunar enhancements seen on zonal wind especially in southern hemisphere where the zonal wind in the upper atmosphere was enhanced by up to 100m/s westward due the lunar tide. Potentially, M2 and N2 dissipation might have dumped energy and westward momentum into the atmosphere.
- In contrast, GAIA sees opposite change in zonal wind during SSW compared to TIME-GCM. Again, this could be caused by fact that they are different SSW events.

Conclusions/Future Research

Important conclusions

- The model can be used because with lunar tides it compares favorably with observation (and other models). Thus one can use it study the lunar tide effects by differencing a simulation with the lunar tide and one without.
- Density was affected by upwards of 20% due to lunar tides at an altitude of 400km, and up to 14% at 150km near the poles (surprisingly large effects).

Further Research:

- The mechanisms for the enhancements observed during SSW are still unknown. Density variation could be due to background wind circulation, tide dissipation, composition mixing, etc.
- How do the lunar tides propagate and why is there a stronger response is seen in the southern hemisphere? Forcing at the lower boundary is symmetric over the equator, so probably some background is causing change as waves propagate upwards.

References:

- ¹Forbes, J. M., and Zhang, X. (2012), Lunar tide amplification during the January 2009 stratosphere warming event: Observations and theory, *Journal of Geophysical Research*, 117, A12312.
- ²Liu, H. et al. (2014), Thermal and dynamical changes of the zonal mean state of the thermosphere during the 2009 SSW: GAIA simulations, *Journal of Geophysical Research: Space Physics*, JA020222.

