Dynamics and variability of Saturn's equatorial thermosphere

I. Mueller-Wodarg[(1)], T. Koskinen[(2)], Z. Brown[(2)], L. Moore[(3)], J. Vriesema[(4)], A. Medvedev[(5)]

(1) Department of Physics, Imperial College London
(2) Lunar and Planetary Laboratory, Univ. of Arizona
(3) Center for Space Physics, Boston University
(4) University of Wisconsin Eau Claire
(5) Max Planck Institute for Solar System Research

Introduction

Grand Finale in-situ and remote observations by Cassini INMS and UVIS in 2017 (**1**, **2**) have revealed a highly variable low latitude thermosphere which hosts atmospheric waves. The discovery of azimuthal magnetic field at low latitudes imply electric currents associated with wind-driven electrodynamics (**3**,**4**), representing the first evidence of zonal winds in the equatorial thermosphere. Previously, such zonal winds had been observed in the troposphere & stratosphere.

Key Questions:

1. What are the characteristics and drivers of waves in Saturn's thermosphere?
2. What are the effects of the waves on the global circulation and energetics?
3. What are the characteristics and drivers of zonal winds at low latitudes?

The data

Pole to pole UV occultations by Cassini UVIS show the consistent presence of atmospheric waves (**Fig. 1**) with amplitudes weakly increasing with altitude. Spectral analysis reveals the simultaneous occurrence of 2 families of waves with vertical wavelengths of ~150 km and 250-400 km, roughly < 2 H, so most likely gravity waves. Amplitudes appear to peak at high midlatitudes (**Fig. 2**). Forthcoming analyses of these observed global waves will infer their momentum flux and wave drag to investigate their potential role in addressing the Saturn energy crisis (**2**).

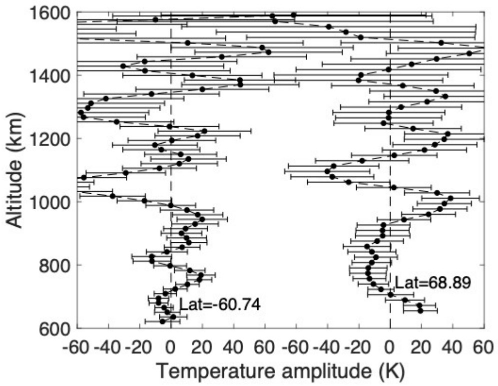

***Fig. 1:** Atmospheric temperature waves on Saturn derived from UVIS Grand Finale Occultations (1)*

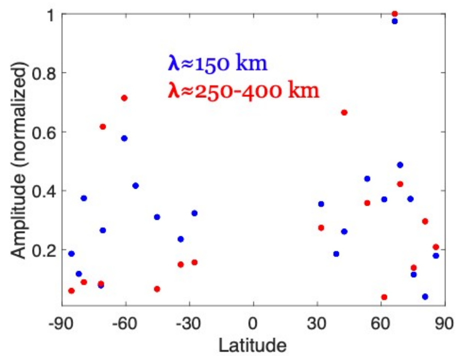

***Fig. 2:** Amplitudes of 2 families of waves with vertical wavelengths of ~150 km (blue) and 250-400 km (red)*

Model and simulations

We use the Saturn Thermosphere Ionosphere General Circulation Model (STIM GCM) to investigate the dynamics and wave propagation in Saturn's thermosphere. We investigate wave propagation by forcing its lower boundary (near 600 km altitude, 0.4 Pa) with waves extracted from a giant planet stratosphere GCM with a 6-day periodicity (**5**). These propagate vertically (**Fig. 3**) and show vertical characteristics similar to observations (**Fig. 4**). The wave dissipation in the thermosphere causes net zonal (eastward) acceleration, affecting the general circulation (**Fig. 5**). Upcoming model investigations will address the propagation of more families of gravity waves.

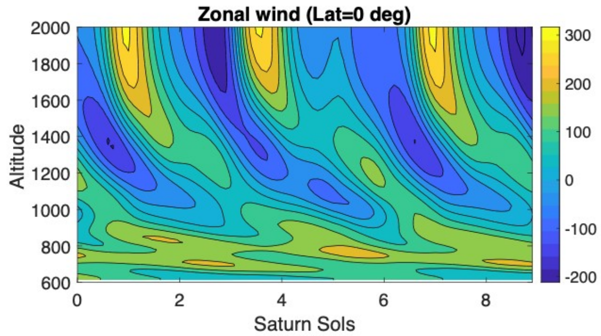

***Fig. 3:** Zonal winds from the STIM GCM forced by an equatorial 6-day wave which propagates vertically and interacts with the background atmosphere*

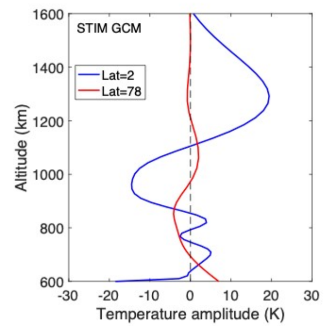

***Fig. 4:** Temperature wave in STIM GCM forced by an equatorial 6-day wave. A propagating wave is found at low latitude*

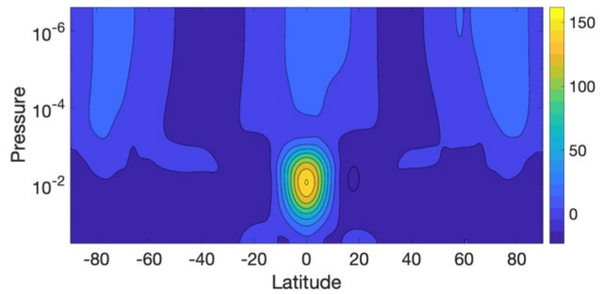

***Fig. 5:** Zonal winds (positive eastward) from STIM GCM as driven by dissipating equatorial 6-day waves.*

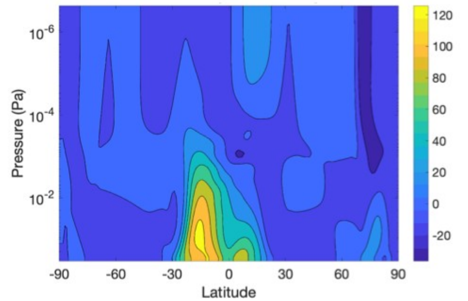

***Fig. 6:** Zonal winds from STIM GCM driven by lower boundary time-invariant jets.*

Zonal winds

Our simulations with STIM GCM illustrate that implementing a 6-day wave causes net eastward acceleration in the thermosphere near 1000 km (**Fig. 5**), potentially playing a key role in driving low latitude zonal jets. In contrast, implementing zonal winds alone near 600 km will result in their disappearance due to viscous drag near 1000 km (**Fig. 6**). Extending this idea, waves propagating vertically at other latitudes may equally play a crucial role shaping thermosphere global winds.

References

(1) Brown et al. (2020). Nature Astronomy
(2) Müller-Wodarg et al. (2019). GRL
(3) Vriesema et al. (2020). Icarus
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(5) Medvedev et al. (2013). Icarus