Observing Tides in the Earth's Lower Thermosphere from a Geostationary Orbit: A Key Measurement for Understanding Thermosphere-Ionosphere Variability

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Abstract

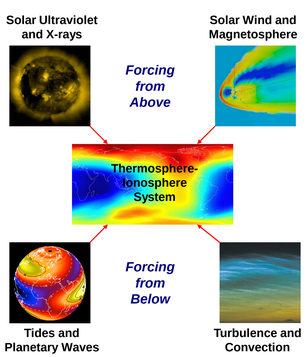
Tides in the Earth's upper atmosphere are thought to play an important role in the short term variability of the thermosphere-ionosphere (T-I) system, but current observations are insufficient for resolving critical questions about their influence. Recent work on the nighttime ionosphere suggests tides in the neutral atmosphere (thermosphere) play an important role in the ionospheric density variations seen during both day and night. However, the current observations are either synoptic (and limited to 24 hour time resolution), or localized (when they are available from ground based observatories). Observations of the spatial and temporal variations of tides throughout a day could revolutionize our understanding of tidal effects. Such observations are now possible. Full-disk, dayside measurements of tides in the lower thermosphere - a critical region where both the tides propagating up from lower altitudes and the solar driven diurnal tides play a significant role - are feasible from a geostationary orbit. The imager for the Global-scale Observations of the Limb and Disk (GOLD) mission, which will be proposed as a mission of opportunity to NASA's Explorers program, would make observations of the tides, as well as other phenomena in the Earth's thermosphere and ionosphere. Simulations of the daytime observations by GOLD show that realistic tides are readily observable. These simulations, based on TIEGCM model runs and temperature retrievals from simulated observations, indicate the GOLD mission can provide the data necessary to resolve critical questions about the influence of tides on the T-I system and to make revolutionary advances in our capabilities to model atmospheric tides.

GOAL: Understand the role of tidal forcing on global changes in the thermosphere and ionosphere

METHOD: Far Ultraviolet (FUV) images of the Earth from geostationary orbit to observe global-scale temporal and spatial changes in temperature, composition and density of the thermosphere and ionosphere

RESULT: Observations of neutral density tides in thermosphere to answer critical scientific questions about their influence on variability in the thermosphere-ionosphere system

I. The Thermosphere-Ionosphere System



- The thermosphere-ionosphere is driven by
  - solar and magnetospheric processes from above
  - tides and waves from below
- Observations suggest tidal dynamics may play an important role in modulating the system's response to solar and magnetospheric processes

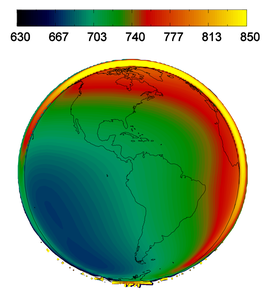
The thermosphere-ionosphere is a boundary between regions dominated by plasma and fluid processes

- This transition is common to planetary atmospheres
- Neutral and ion composition are strongly coupled
- Variations in either affect technological systems we depend on

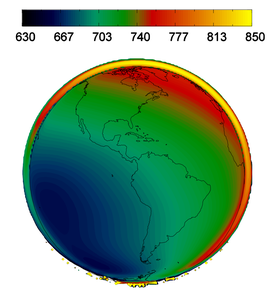
II. GOLD Mission

- GOLD would fly on a commercial communications satellite in geostationary orbit (first use of commercial, geostationary flight for NASA science instrument)
- Effects of tidal, solar and geomagnetic forcing can be followed, allowing effects of each to be isolated
- Orbit and operations provide continuous coverage over the Americas
- Repeated observations of same locations allows separation of changes in time and space
- Provides, for the first time, response of the thermosphere to tidal forcing across a hemisphere

III. Calculated Tidal Effects in Thermosphere



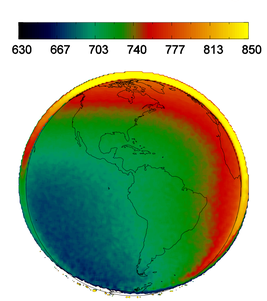
Temperatures Calculated using TIEGCM With Tides



Temperatures Calculated using TIEGCM Without Tides

- Temperatures and densities in the thermosphere are calculated using the TIEGCM model with and without tides from the GSWM model
- For lines-of-sight from geostationary orbit, temperatures and densities from the TIEGCM results are combined with emission profiles derived using AURIC to calculate the N_2 emission temperature observed
- Line-of-sight temperatures approximately represent the temperatures at 160 km and tides produce ~30 K perturbations in the calculated temperatures

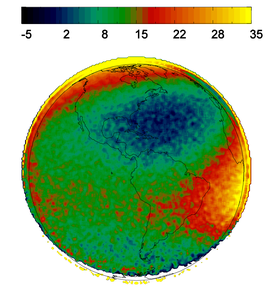
IV. Simulated Observation of Tidal Effects on Thermosphere by GOLD Imager



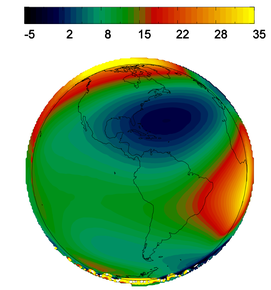
Temperatures Retrieved from Simulated Observations With Tides

- Observations are simulated by using temperature, brightness, and O_2 density profiles along lines-of-sight from geostationary orbit to produce synthetic LBH spectra
- The synthetic spectra are run through an instrument simulator to account for instrument sensitivity, instrumental lineshape, and statistical counting noise (instrument sensitivity is derated by factor of 2)
- The simulated spectra are then fit using a modified Levenberg-Marquardt scheme to perform Discrete Inverse Theory retrievals of the temperature.

V. Effects of Tides on Thermospheric Temperatures



Temperature Difference (Retrieved With – TIEGCM Without Tides)

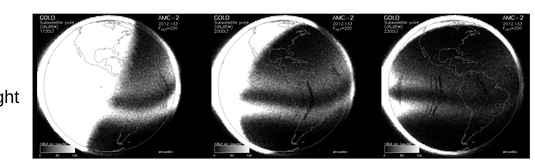


Temperature Difference (TIEGCM With – TIEGCM Without Tides)

- Temperature changes due to tides in the thermosphere are clearly distinguishable in the simulated and calculated images
- Amplitudes of tides at the altitudes GOLD would observe (near 160 km) are unknown, due to a lack of measurements
- At other altitudes the temperature changes calculated using the TIEGCM model are typically lower than is observed

VI. Effects of Tides on Equatorial Ionosphere at Night Could also be Observed

Imaging at 135.6 nm & Ionospheric bubbles at night (counts)



- Nighttime ionosphere is coupled with the thermosphere, which changes more slowly (the time constant is hours) than the ionosphere
- GOLD can continue observing same locations after sunset in order to determine the influence of dayside tides on the nighttime ionosphere

VII. Summary

GOLD provides new capabilities for understanding the thermosphere-ionosphere system.

- GOLD will provide unprecedented temperature measurements across the daytime disk
- GOLD will allow tracking of temporal and spatial changes across the disk during the day
- GOLD will provide almost continuous data across American sector from geostationary orbit
- GOLD mission will provide the global scale images of neutral temperatures and composition that are critical to advancing our understanding of the Thermosphere-Ionosphere system
- GOLD will provide the data necessary for understanding the role of tidal forcing on global changes in the thermosphere and ionosphere