Deriving Nonmigrating Tides from GOLD Temperature and O/N_2 Measurements Using TIEGCM Tidal Phase Offsets

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ABSTRACT

Solar atmospheric tides are ubiquitous features in the variability of the thermosphere-ionosphere (T-I) system. Nonmigrating tides, those that do not propagate sun-synchronously, are a known coupling mechanism through which terrestrial weather transmits to the T-I. NASA's Global-scale Observations of the Limb and Disk (GOLD) instrument will soon reach geostationary orbit onboard the telecommunications satellite SES-14. GOLD will make novel measurements of temperature and the atomic oxygen to molecular nitrogen ratio (O/N_2) in the T-I over a roughly 140-degree longitude sector centered on Brazil. The two-channel far-ultraviolet imaging spectrograph of GOLD images the T-I on the dayside disk at half-hour time scales. Traditional tidal diagnostics require 24 hours of local time coverage and complete coverage in longitude, something GOLD alone cannot provide. TIEGCM modelling indicates that the respective DE3 and DE2 tidal oscillations in temperature and O/N_2 are out-of-phase in the single case at the equator and at 160 *km* altitude in September with quiet solar conditions. In this study we use knowledge of these phase offsets in a least-squares approach to derive the DE3 and DE2 tides from idealized GOLD temperature and O/N_2 measurements.

OBJECTIVES

1. Propose and test a method to observe nonmigrating tides from an observing platform in Earth geostationary orbit. Since observations from such a platform are not amenable to traditional tidal diagnostics, the method requires additional information.
2. Derive the relevant nonmigrating tidal amplitudes and phases using a least-squares approach that leverages temperature and O/N_2 observations and phase offsets from TIEGCM.

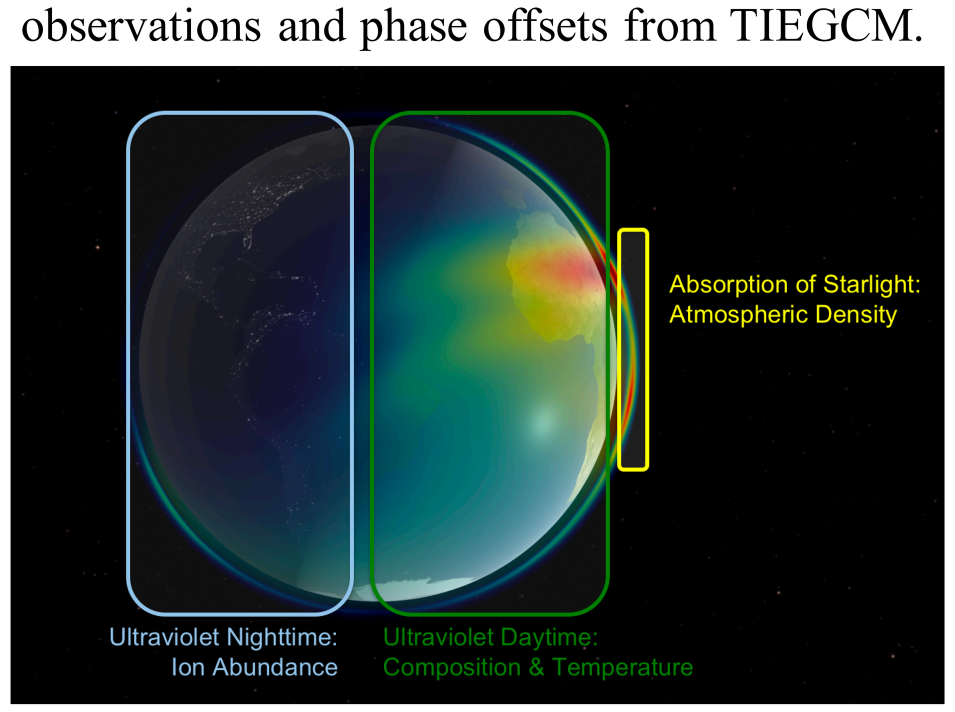

Figure 1. From geostationary orbit GOLD will remotely measure thermospheric composition and temperature, near 160 *km* altitude, and the nighttime evolution of the low-latitude ionosphere.

ACKNOWLEDGEMENT

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BACKGROUND

1. GOLD is an FUV imaging spectrograph (132 to 162 nm). See Figures 1 and 2.
2. DE3 and DE2 are believed to be the dominant nonmigrating tides at the altitude at which GOLD observes: DE2 during northern hemisphere winter, DE3 during rest of year.
3. Question: Why use phase offsets from TIEGCM rather than those from linear wave theory?

Answer: Because linear wave theory (Figure 2) has limitations in the upper atmosphere where nonlinear effects exist due to wave dissipation and molecular diffusion.

4. We derive TIEGCM tides from temperatures at the altitude of the peak of the LBH band emission profile as calculated by GLOW and O/N_2 as GUVI-style column densities.

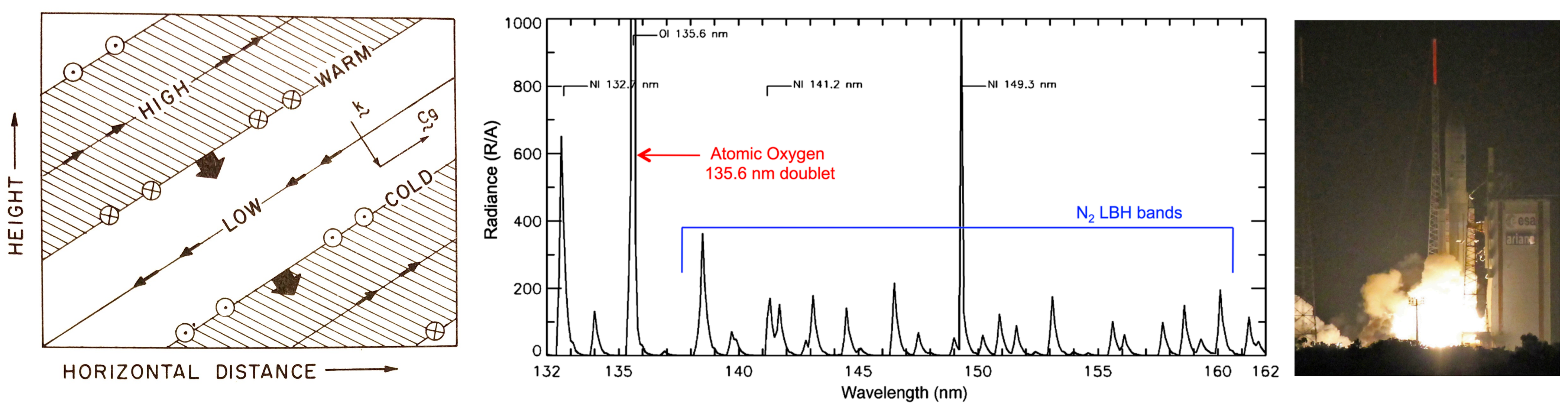
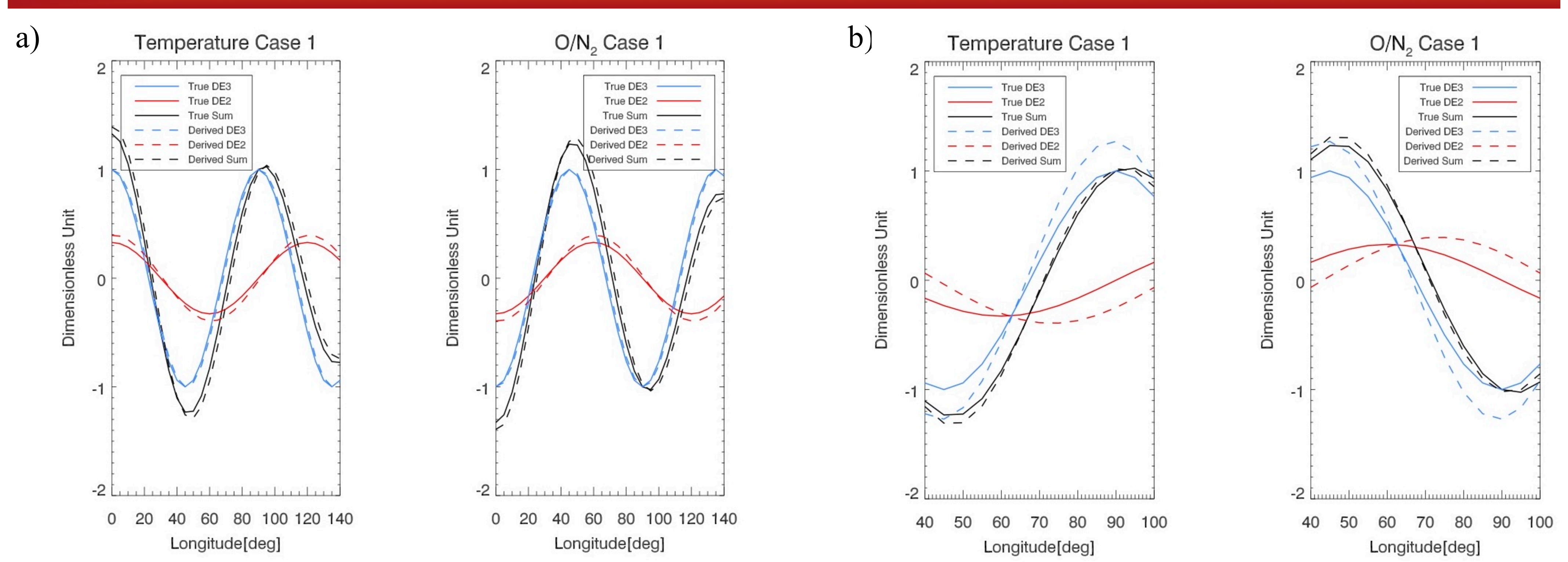


Figure 2. (left) Phase offsets between temperature, winds, and geopotential for intertio-gravity waves according to linear wave theory. Taken from Andrews (1987). (center) Daytime far-ultraviolet (FUV) model airglow spectrum at which GOLD observes. (right) Last January *Arianne 5* launched with GOLD onboard SES-14 as a hosted science payload.

RESULTS



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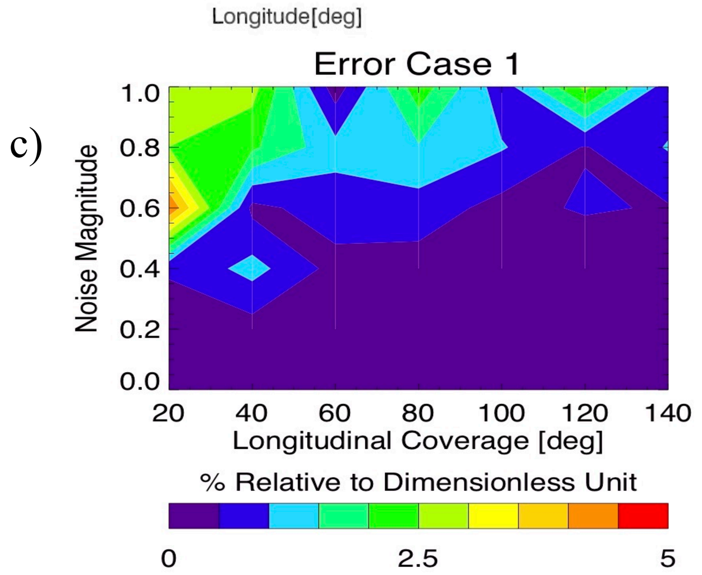

Case	Phase DE3 Temperature	Phase DE2 Temperature
1	0 degrees longitude	0 degrees longitude
2	0 degrees longitude	60 degrees longitude

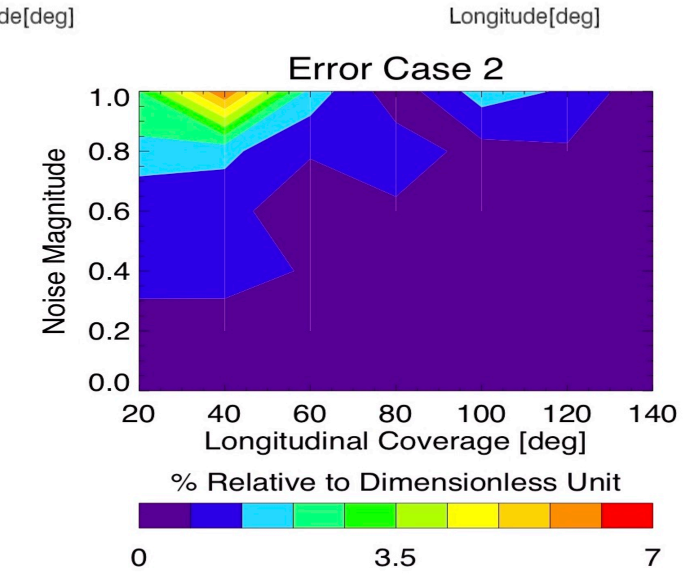

Figure 4. Line plots of the true input (solid) and derived output (dashed) T and O/N_2 longitudinal perturbations, in dimensionless units equal to DE3 amplitude, for cases of 140-deg longitudinal coverage (a) and 60-deg (b) with unit noise magnitude for Case 1 (see table). (c) Contour plots of the percent error relative to the dimensionless unit for our method run at different longitudinal coverages and noise magnitudes for different input phases of DE3 and DE2 T, i.e., Cases 1 & 2. Here T and O/N_2 phase offsets for DE3 and DE2 are respectively 45 and 60 degrees longitude (September solar quiet conditions at equator). The respective tidal amplitudes in T are taken to be equal to those in O/N_2.

METHODOLOGY

1. Consider the following thought experiment: If the set of GOLD temperature and O/N_2 observations consists only of idealized DE3 and DE2 tidal perturbations plus random noise, can we tell the tides apart? Consider data at only a single latitude and local solar time such that the data varies only longitudinally in GOLD's approximately 140-degrees FOV at the equator.
2. Use the TIEGCM derived phase offsets between temperature and O/N_2 of the respective DE3 and DE2 tidal components as proxies to those from linear wave theory. See Figure 3.
3. Define solution space of possible DE3 and DE2 tidal amplitudes and phases in temperature. The space of possible DE3 and DE2 tidal amplitudes and phases in O/N_2 follows directly from the TIEGCM-derived phase offsets and the polarization relations between temperature and O/N_2 tidal components.
4. Using a least-squares approach that takes into account the TIEGCM phase offsets and polarization relations, determine the set of DE3 and DE2 tidal amplitudes and phases in temperature that best fits the observations.
5. Vary the noise magnitude and/or narrow the longitudinal coverage to test the robustness of the method.

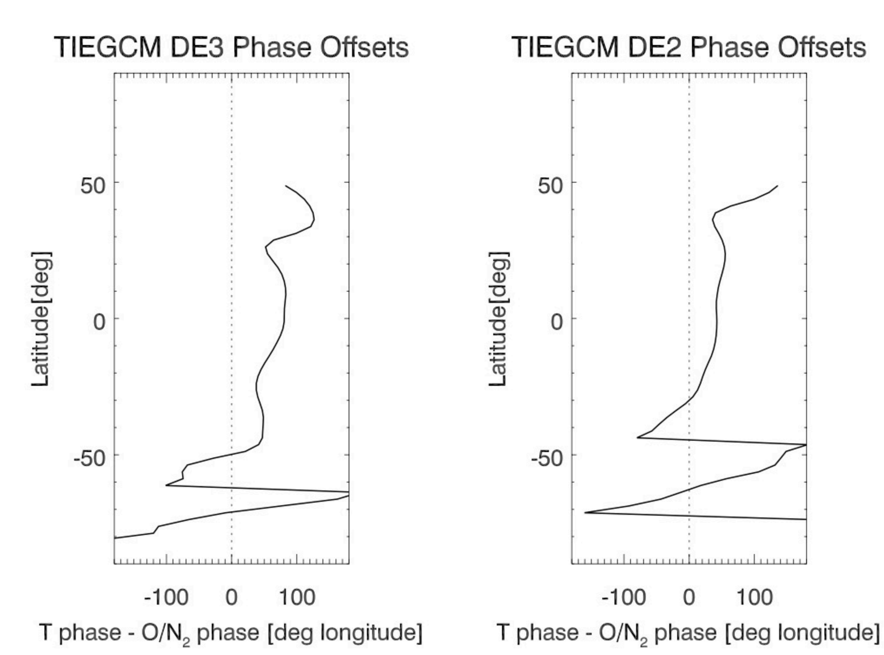

Figure 3. Expected tidal phase offsets between T and O/N_2 for DE3 and DE2 respectively in GOLD data derived from TIEGCM interfaced with the GLOW model. February solar quiet conditions. We propose to diagnose nonmigrating tides in GOLD data by using these phase offsets as functions of latitude, time-of-year, and solar conditions.

CONCLUSIONS

1. The proposed method works reasonably well for idealized cases with errors less than 10 percent relative to the dimensionless unit equal to the DE3 amplitude (See Figure 4c). Thus, our method should be able to observe nonmigrating tides in the forthcoming GOLD data.
3. The accuracy of the method depends on: (1) geophysical and instrument-related noise (examined here), (2) longitudinal coverage (examined here), and (3) whether the phase offsets returned by TIEGCM match those in the real-time atmosphere observed by GOLD (still an open question since TIEGCM is forced at the lower boundary by GSWM which does not include small-scale waves or sources of day-to-day tidal variability).
4. Future work is to test method on simulated TIEGCM temperature and O/N_2 sampled in GOLD's observational geometry.
5. When applied to real data, results can be used to validate thermospheric nonmigrating tides in TIEGCM.

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