Observing geomagnetic storm effects in the Earth's lower thermosphere from geostationary orbit: A new view of thermosphere-ionosphere variability

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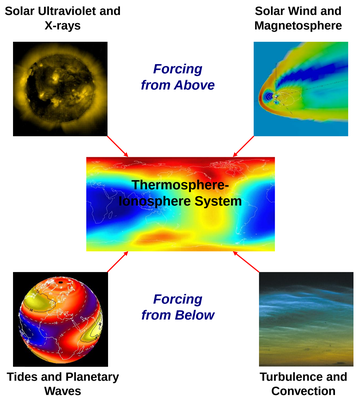
Abstract

The Global-scale Observations of the Limb and Disk (GOLD) mission of opportunity would fly an ultraviolet imaging spectrograph on a geostationary satellite to measure temperatures and composition in the daytime thermosphere. GOLD's unprecedented imaging capabilities provides simultaneous measurements of two critical state variables - neutral temperatures and composition (O/N_2 ratio) - in the Earth's lower thermosphere. The high (half-hour) cadence and global-scale coverage of GOLD's images will revolutionize our understanding of the global-scale response of the thermosphere, and ionosphere, to geomagnetic storms. These images will provide information that is essential to advancing our physical understanding of coupling between the space environment and the Earth's atmosphere and to developing an understanding of the Sun's effects on Earth. GOLD has been proposed as a mission of opportunity in response to the Explorers 2011 SALMON from NASA's Science Mission Directorate. GOLD's capability to provide real time data and knowledge gained from the observations will also advance space weather specification and forecasting capabilities.

I. The Thermosphere-Ionosphere System



- The Earth's thermosphere and ionosphere constitute a dynamic system that varies rapidly in response to energy inputs from above and from below
- How do the solar and magnetospheric processes interact with waves coming from below to produce the changes that are seen in the thermosphere?

OBJECTIVE OF MISSION: Determine how the thermosphere-ionosphere (T-I) system responds to forcing on a global-scale, which is essential to our physical understanding of coupling between the space environment and the Earth's atmosphere.

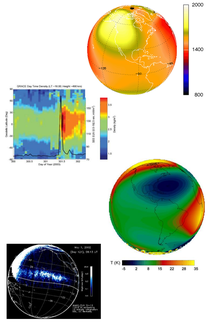
METHOD: Global-scale imaging of two critical state variables – thermospheric temperature and composition – on half-hour time scales. The mission will fly a Far Ultraviolet (FUV) imager in geostationary orbit to make the first, simultaneous images of both variables. Imaging provides both temporal and spatial changes in the temperature, composition and density of the thermosphere and ionosphere

RESULT: Break-through step in understanding the coupling between the space environment and the Earth's atmosphere.

II. GOLD Mission

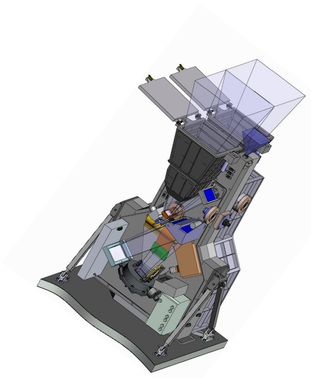
- GOLD to fly on a commercial communications satellite in geostationary orbit (pathfinder for use of geostationary communications satellites for other science missions)
- Orbit and operations provide continuous imaging of a hemisphere, first such continuous imaging of thermosphere-ionosphere system
- Imaging would provide Thermosphere-Ionosphere data necessary for full benefit of other NASA missions, such as the Solar Dynamics Observatory (SDO)

III. Addresses Four Primary Science Questions



1. How do geomagnetic storms alter the temperature and composition structure of the thermosphere?
2. What is the global-scale response of the thermosphere to solar extreme-ultraviolet variability?
3. How significant are the effects of atmospheric waves and tides propagating from below on the thermospheric temperature structure?
4. How does the structure of the equatorial ionosphere influence the formation and evolution of equatorial plasma density irregularities?

IV. GOLD Measures Composition and Temperature Simultaneously

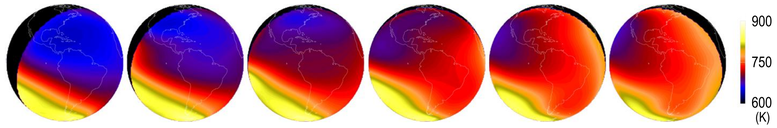


- Two, mirror-image channels and a single processor packaged in one housing
- Each channel operates independently in the nominal GOLD observing mode
  - full disk maps and limb scans with 30 minute cadence
  - Precision of ±55 K and ±10 K for cadences of 1 and 2 hours respectively
- A single channel can perform all measurements with reduced cadence or reduced spatial resolution

V. GOLD Observations of Geomagnetic Storm Effects

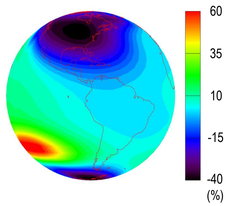
- Geomagnetic storms drive large changes in two important state variables - temperature and composition (O/N_2) - of the thermosphere
- Both state variables exhibit significantly different spatial and temporal changes
- Simultaneous, global-scale Images of both state variables at a high cadence will enable major advances in understanding the T-I response to storms
- GOLD mission will provide first such images of the temperature and composition
- Advances in understanding the T-I response and in measurements of the initial conditions - temperature, in addition to composition – will enable advances in forecasting of the thermosphere and ionosphere

Observations of Temperature



Thermospheric temperature (K) progression at one-hour intervals, during a geomagnetic storm, as sampled by GOLD from geostationary orbit. Based on TIEGCM model results. Temperatures, at an altitude of approximately 160 km, are obtained from N_2 LBH bands, with a precision of better than ±55 K at 1 hour cadence

Observations of Composition (O/N_2)



Differences in O/N_2 column density ratio between storm time and quiet time (in percent) from TIEGCM simulation. GOLD's measurements provide a precision of better than 5% at a 1 hour observing cadence

VI. Summary

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

- GOLD will provide simultaneous images of O/N_2 density ratio and unprecedented temperature measurements across the daytime disk
- GOLD will allow separation of temporal and spatial changes across the disk
- GOLD will fly on a commercial communications satellite in geostationary orbit
- Capability for continuous, real time data availability is inherent to the mission
- GOLD mission's observations of two critical state variables will advance our understanding the Thermosphere-Ionosphere
- GOLD will provide Thermosphere-Ionosphere data essential to obtaining full benefits of NASA solar missions such as Solar Dynamics Observatory (SDO)