GOLD Observations of nighttime ionospheric responses to planetary waves from the lower atmosphere

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Outline:

• GOLD mission and imaging
• Quasi-6-day wave coupling during 2019 Sep SSW
• Other PW-related periodicity in the GOLD data
• Conclusions

2021 CEDAR Early Career Highlight

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1. GOLD mission flies a far ultraviolet spectrograph built at LASP

**NASA Mission of Opportunity, Imaging I-T System from GEO**

- **Host Mission**
  - SES-14, in geostationary orbit at 47.5° west (over mouth of the Amazon River)

- **GOLD Instrument**
  - Two identical, independent imaging spectrographs covering 134-162 nm

- **Measurements**
  - Earth’s disk
    - *Nighttime: peak density in ionosphere*
    - *Daytime: O/N₂ (density ratio) and temperature in lower thermosphere*
  - Earth’s limb
    - *Exospheric temperature and O₂ density profile*

[Eastes et al., 2019, 2020]

**Image cube simulation**

- Entrance slit of one (of two) channel is shown as white rectangle
- Slit step rate and position are commandable, can dwell on selected longitude range
- *Slit scans the disk back and forth with a 30-min cycle; but 15-mins if combine the two*
- *The 135.6 nm nightglow: the recombination of the F-region ionosphere*
2. 2019 SSW event and Q6DWs

Q6DWs are pronounced during equinoxes, ~ 6K in temp. & ~ 20 m/s in zonal winds in the mesopause region.

Q6DWs are greater during 2019 SSW than the average in Sept. (Yamazaki et al., 2020).

Sep 2019 SSW - a good opportunity to study the 6-day wave coupling in the atmosphere-ionosphere system.

- Zonal mean Uwinds and Temperature at 30 km and 60S
- Climatological Q6DWs @ 95 km in TIDI and SABER

Antarctic SSW (Sept. 2019)
Second time in the history record

Gan et al. 2015
2. Observational evidence of the ionospheric 6-day periodicity

Q1: Does the Q6DW-related periodicity manifest in the GOLD nighttime obs?
Q2: If so, what is the underlying mechanism?
2. Quasi-6-day modulation of the nighttime Nmax in GOLD

- Larger Nmax over South America and Africa.
- Nmax varies significantly from one day to the next; a 6-7-day periodicity in the EIA crest is seen.
2. **GOLD vs. SABER**: Correlation of Nmax 6-day periodicity and mesospheric 6-day wave

**GOLD**
- Average over the South America
- 20 LT

**SABER**
- Geopotential heights at 40S and 97 km
- Prevalent 6-day propagating pattern
- Measure for equatorial 6-day wave in zonal winds

- A 6-7-day periodicity in Nmax is correlated with the 6-day wave in the mesosphere.
TIEGCM:

- LB forced by the WACCM-X output
- \( K_p = 0.3, F_{10.7} = 70 \) sfu; (assuming quiet time condition)

The Q6DW is well reproduced in the SD-WACCM-X run.

Enable us to prescribe the TIEGCM LB using the WACCM-X output.
2. **GOLD vs. TIEGCM: 6-day periodicity in the nighttime F-region**

**GOLD**
- Average over the South America
- 20 LT

**TIEGCM:**
- LB forced by SDWACCM-X output
- Assuming quiet time condition (Kp = 0.3; F10.7 = 70 sfu)
- Outputs sampled by the GOLD FoV

- Day-to-day variation compares well; slightly Larger Nmax in observations.
- Sims. suggest that the periodicity in obs. is driven primarily by waves.
2. The role of the Q6DW in transmitting the 6-day periodicity

Case 1: zonally diurnal mean + tides + 2-7-day PWs
Case 2: zonally diurnal mean + tides

- 6-day periodicity appears in the ionosphere, with and without the 6-day waves forcing at the lower boundary.
- Implies that the periodicity is not only driven by the 6-day wave, but also by the modulation of tides.
Other PW effects on the ionosphere seen by GOLD
Example of 16-day wave in 2018
Oscillating pattern in the Mlat versus time brightness at 20 degree magnetic longitude

EOF2: (21%): the 16-day periodicity in the F-region ionosphere coincides with the quasi-16-day wave in the mesosphere.

3. F-region quasi-16-day periodicity vs. Mesospheric quasi-16-day waves

GOLD Nmax

16-day oscillations in the GOLD Nmax

16-day wave in the SABER temperature

- Oscillating pattern in the Mlat versus time brightness at 20 degree magnetic longitude
- EOF2: (21%): the 16-day periodicity in the F-region ionosphere coincides with the quasi-16-day wave in the mesosphere.

Gan et al [2020 JGR]
4. Conclusions

- GOLD observations reveal a strong 6-7-day periodicity in the nighttime EIA regions during the 2019 Sep SSW event – a rare case of Antarctic SSW.

- Close correlation with the mesospheric 6-day wave indicates that the 6-day variation in Nmax is primarily driven by lower atmosphere forcing.

- TIEGCM+WACCM-X simulations suggest that the 6-7-day periodicity in the ionosphere is not directly driven by the quasi-6-day wave, but rather by the modulation of upward propagating tides by the 6-day wave.

- GOLD also observed a 16-day variation in the nighttime ionosphere, which was correlated with the lower atmosphere source during the NH winter.