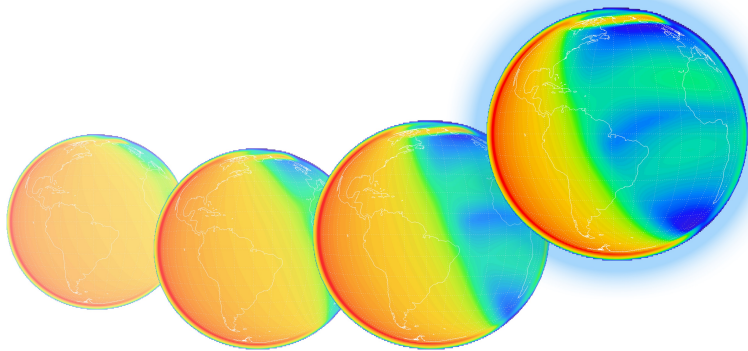


*Quan Gan and the GOLD team
LASP/CU Boulder*

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

Thanks to Richard Eastes, Alan Burns, Wenbin Wang, Liying Qian, Jia Yue, Jens Oberheide, Stan Solomon, and Bill McClintock for discussions.

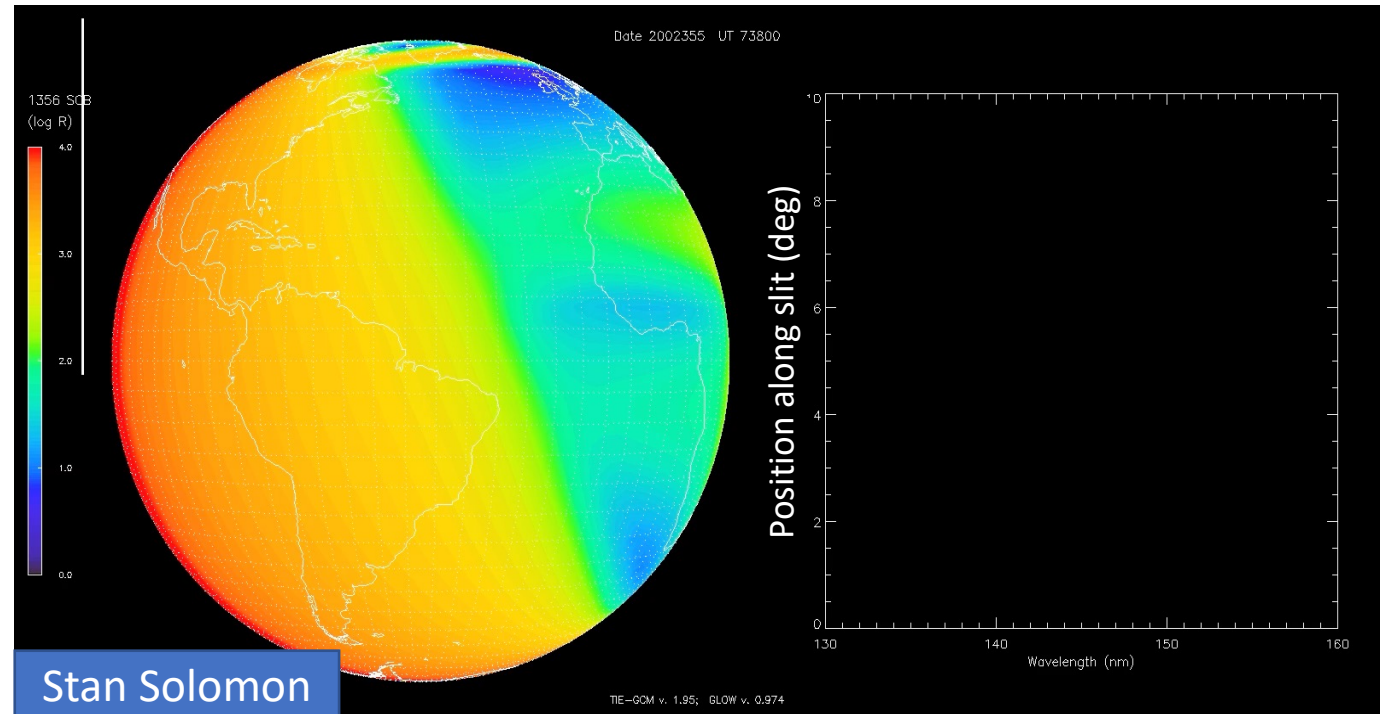
1. GOLD mission flies a far ultraviolet spectrograph built at LASP

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



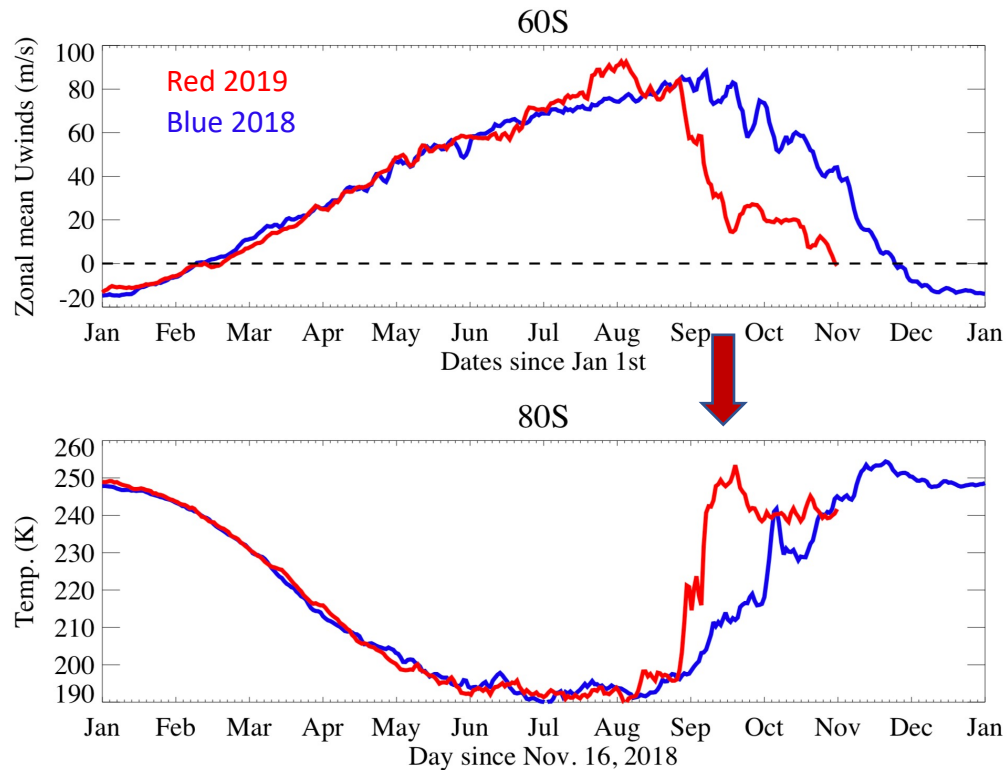
Disk Image

Detector Image

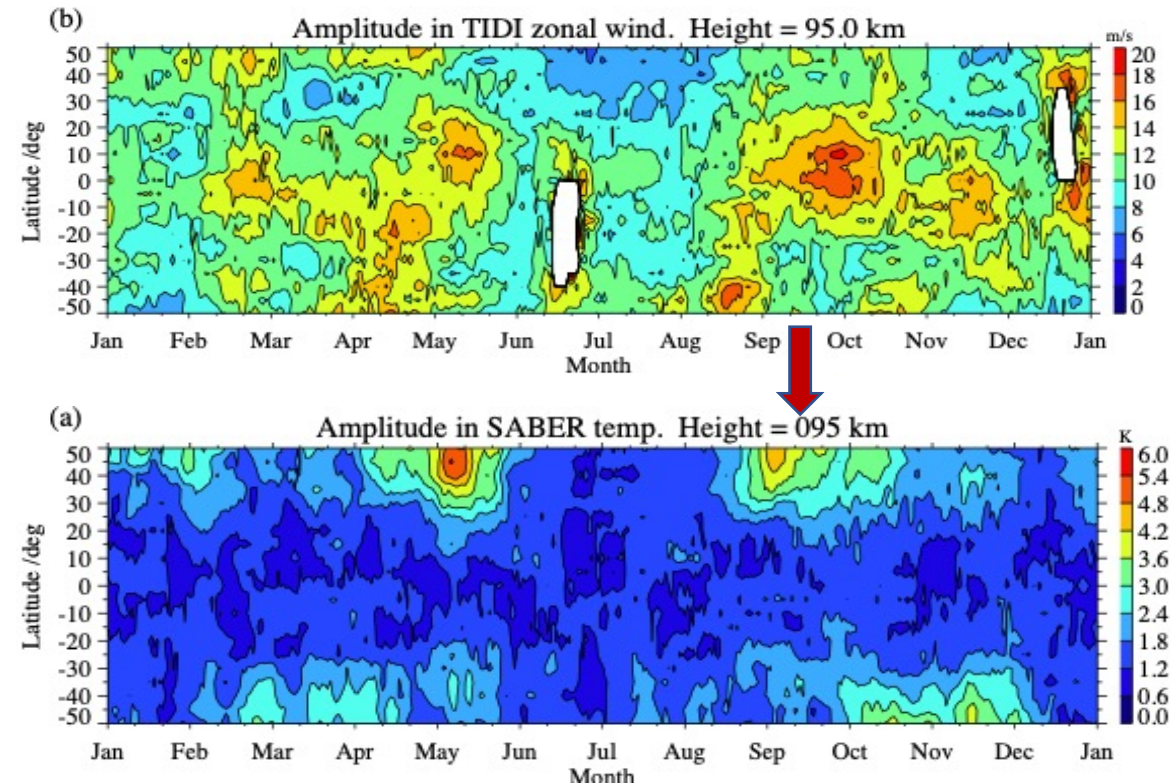
- Entrance slit of one (of two) channel is shown as white rectangle
- Slit step rate and position are commandable, can dwell on selected longitude range
- *Slit scans the disk back and forth with a 30-min cycle; but 15-mins if combine the two*
- **The 135.6 nm nightglow: the recombination of the F-region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

2. 2019 SSW event and Q6DWs

Zonal mean Uwinds and Temperature at 30 km and 60S



Climatological Q6DWs @ 95 km in TIDI and SABER



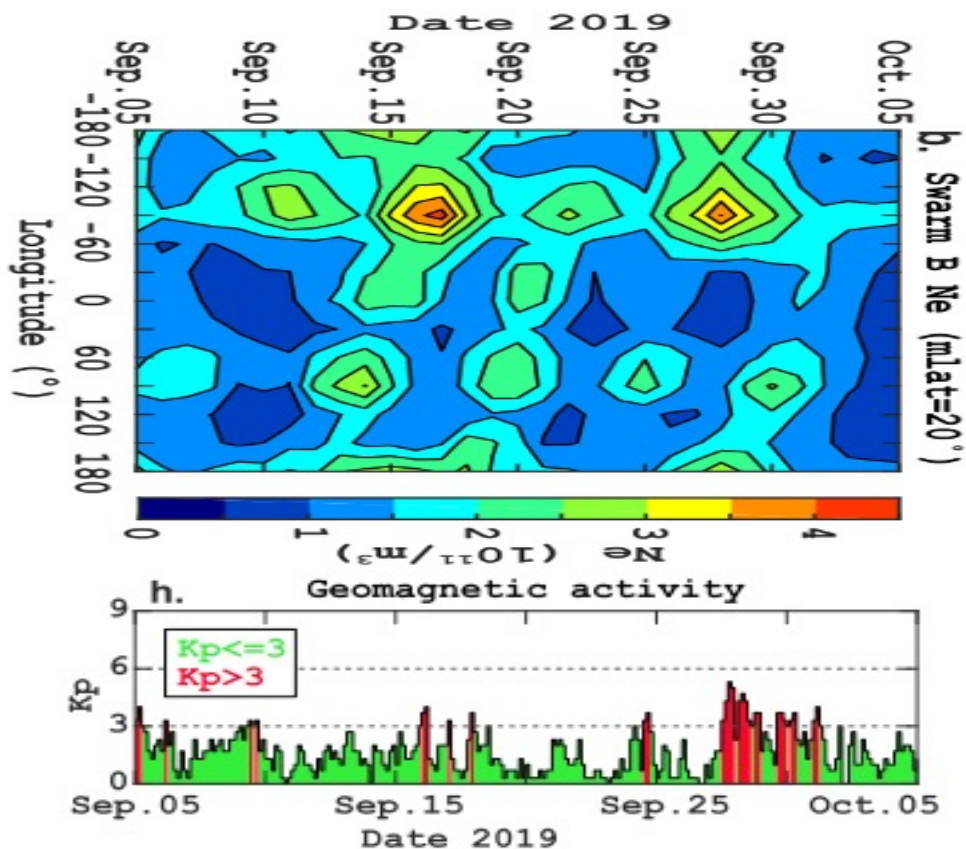
Gan et al. 2015

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

- Q6DWs are pronounced during equinoxes, $\sim 6\text{K}$ in temp. & $\sim 20\text{ m/s}$ 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.

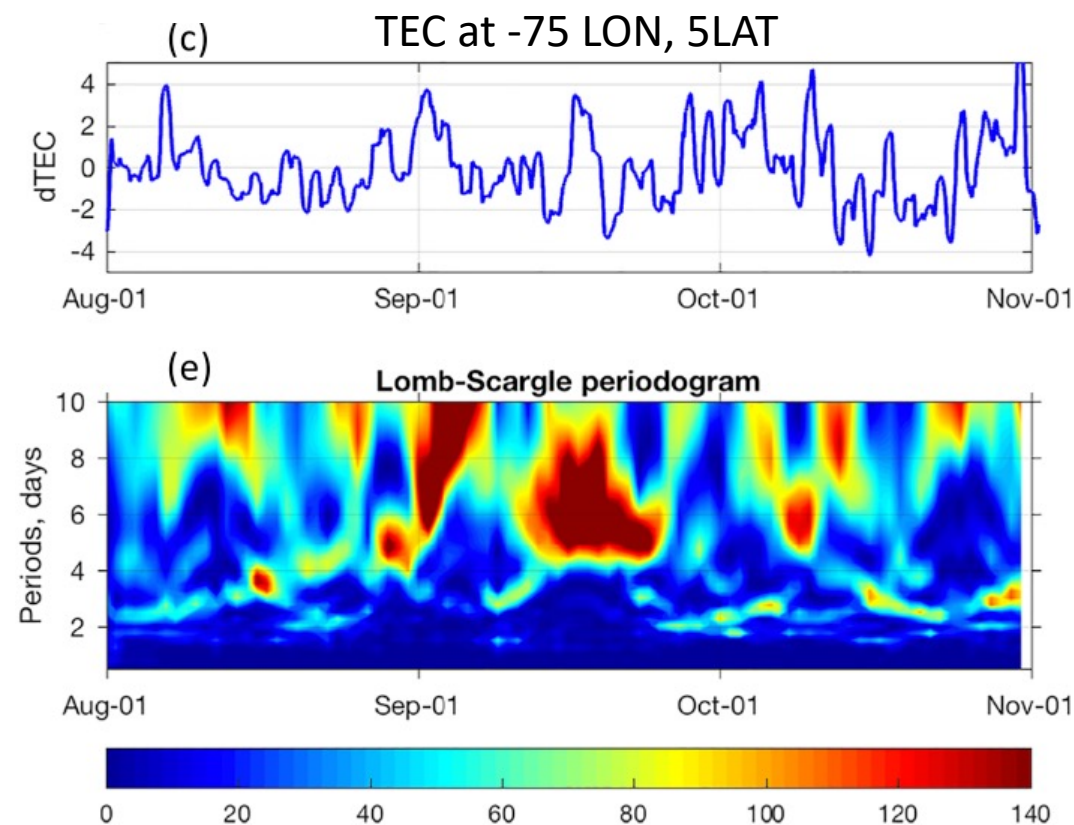
2. Observational evidence of the ionospheric 6-day periodicity

SWARM



Yamazaki et al. 2020

GPS-TEC

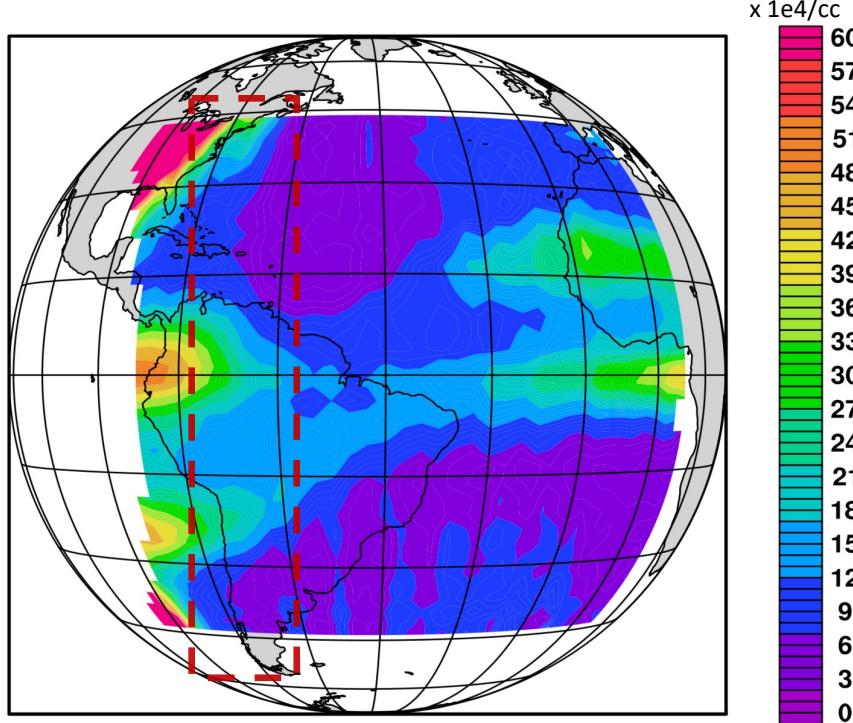


Goncharenko et al. 2020

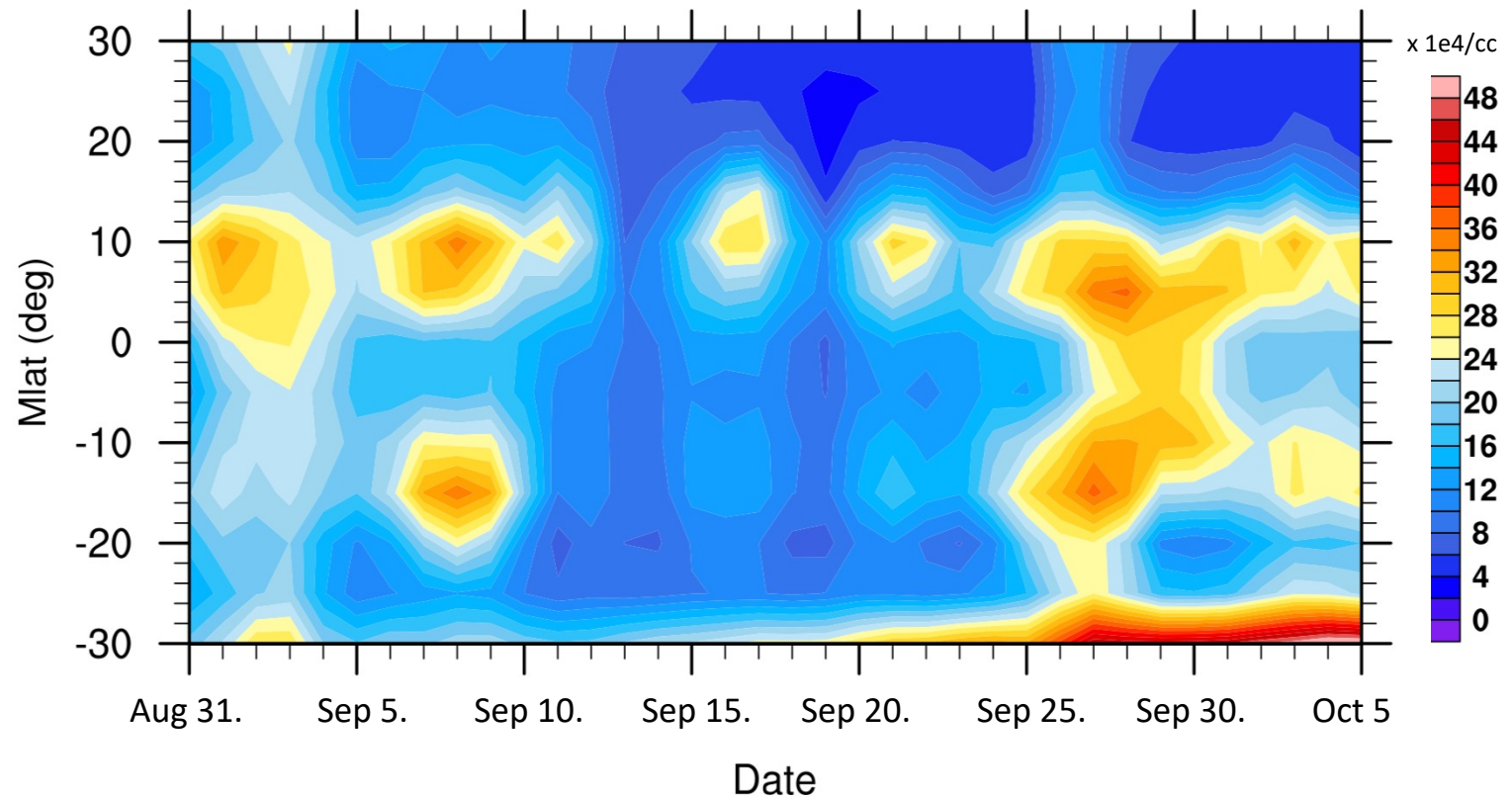
- Q1: Does the Q6DW-related periodicity manifest in the GOLD nighttime obs?**
Q2: If so, what is the underlying mechanism?

2. Quasi-6-day modulation of the nighttime Nmax in GOLD

Sept. monthly mean Nmax over 19 – 21 LT



GOLD Nmax day-to-day variation at 20 LT

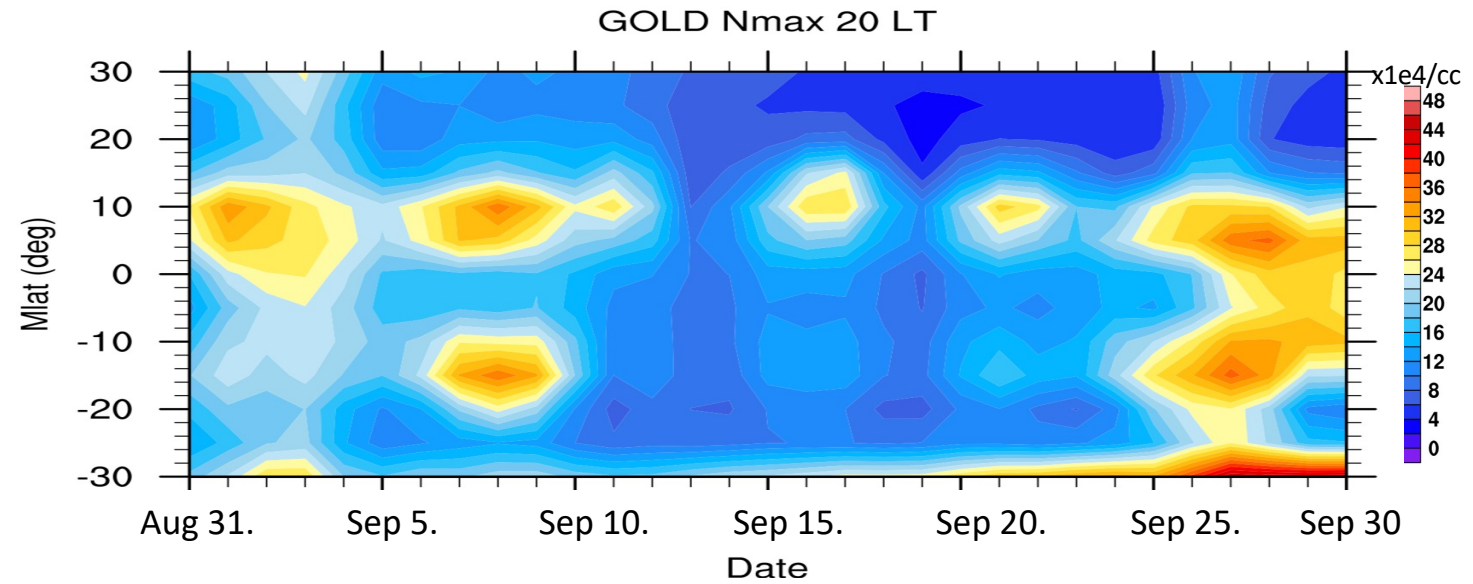


- Larger Nmax over South America and Africa.
- Nmax varies significantly from one day to the next; a 6-7-day periodicity in the EIA crest is seen.

2. GOLD vs. SABER: Correlation of Nmax 6-day periodicity and mesospheric 6-day wave

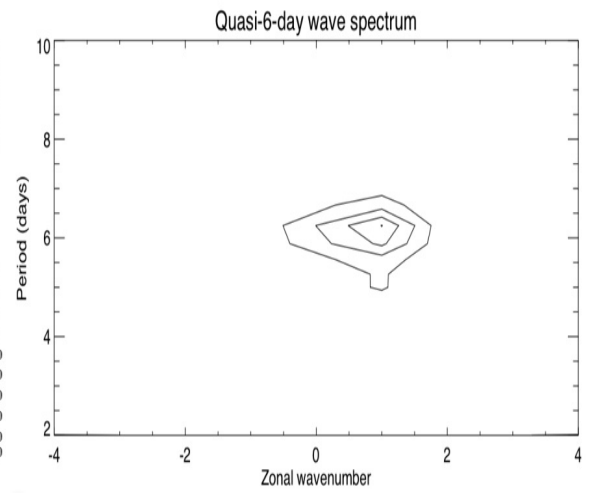
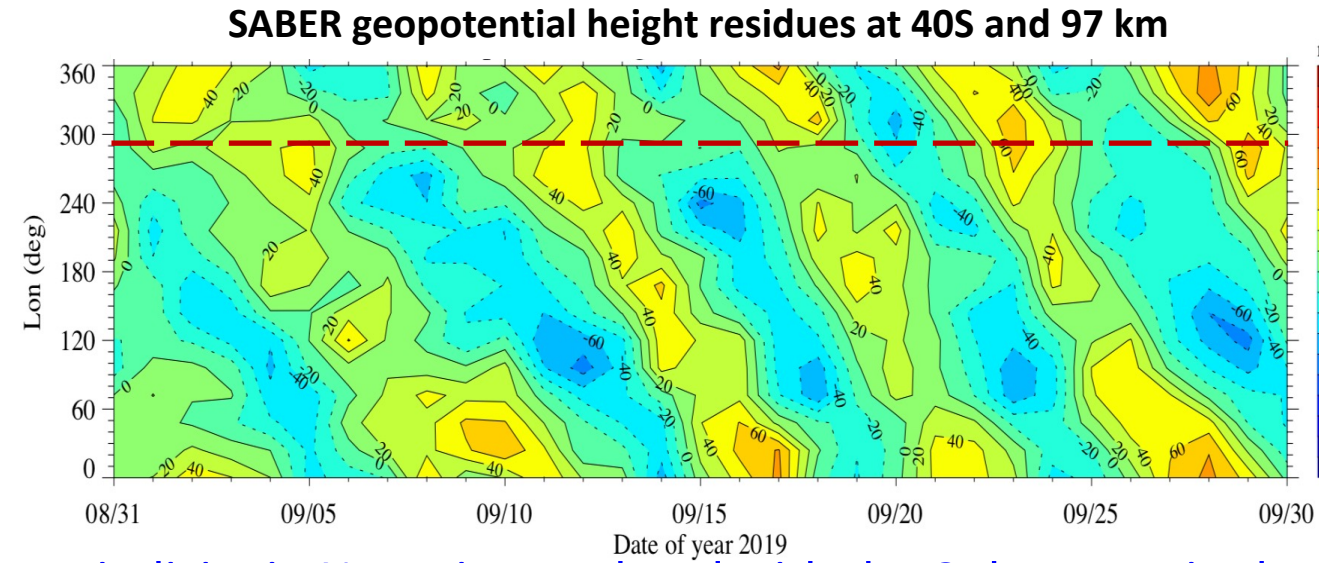
GOLD

- 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



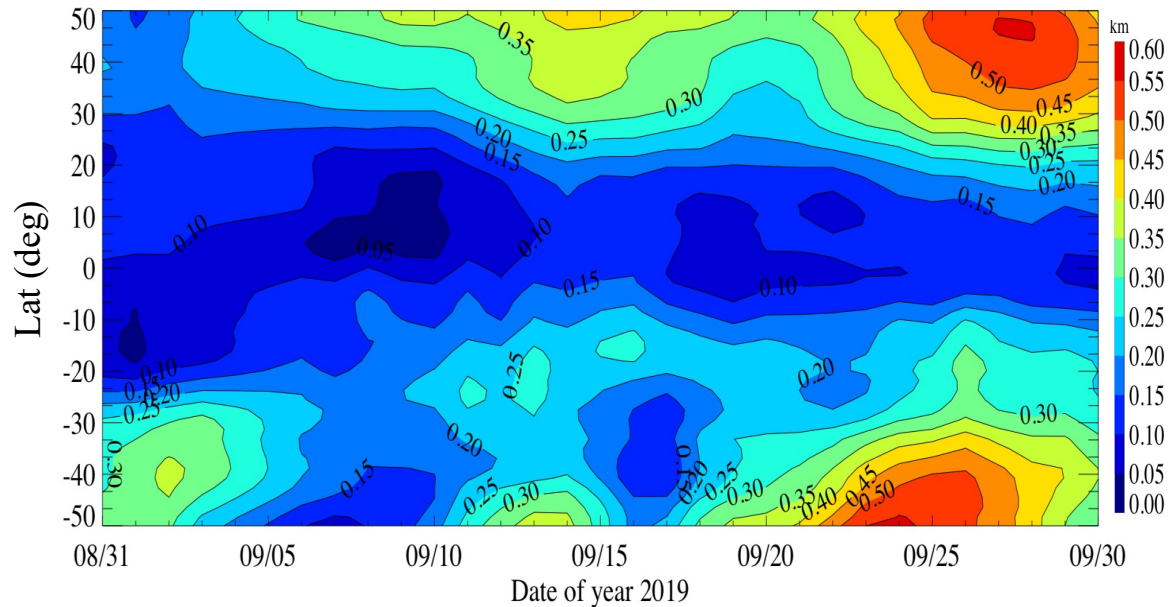
- A 6-7-day periodicity in Nmax is correlated with the 6-day wave in the mesosphere.

2. TIEGCM + WACCM-X simulations

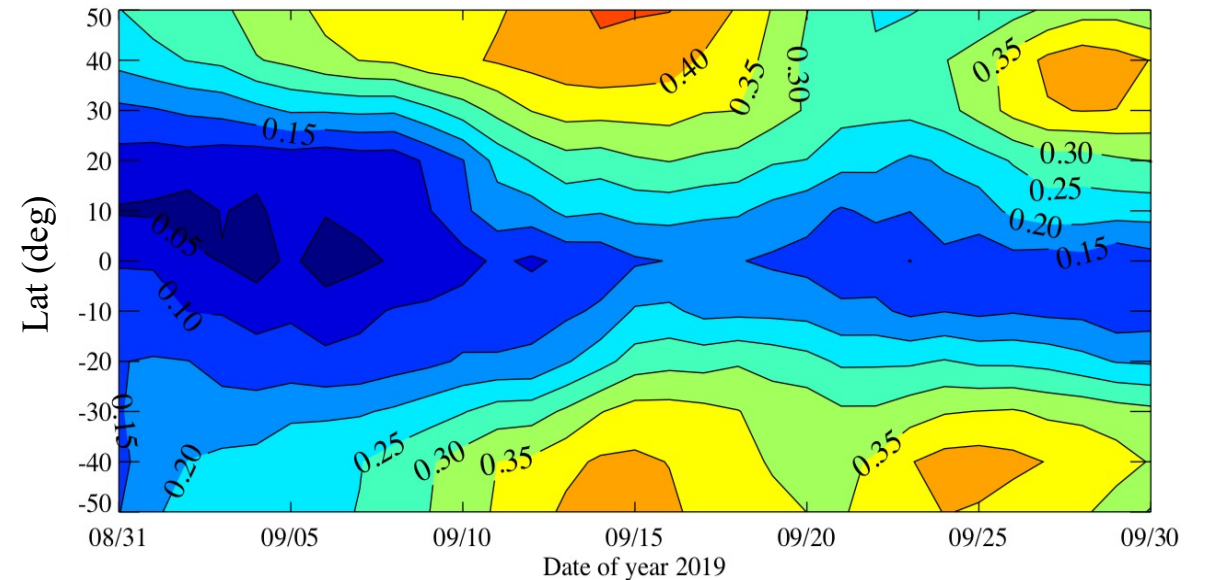
TIEGCM:

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

Q6DW in WACCM-X GPH at 97 km



Q6DW in SABER GPH at 97 km

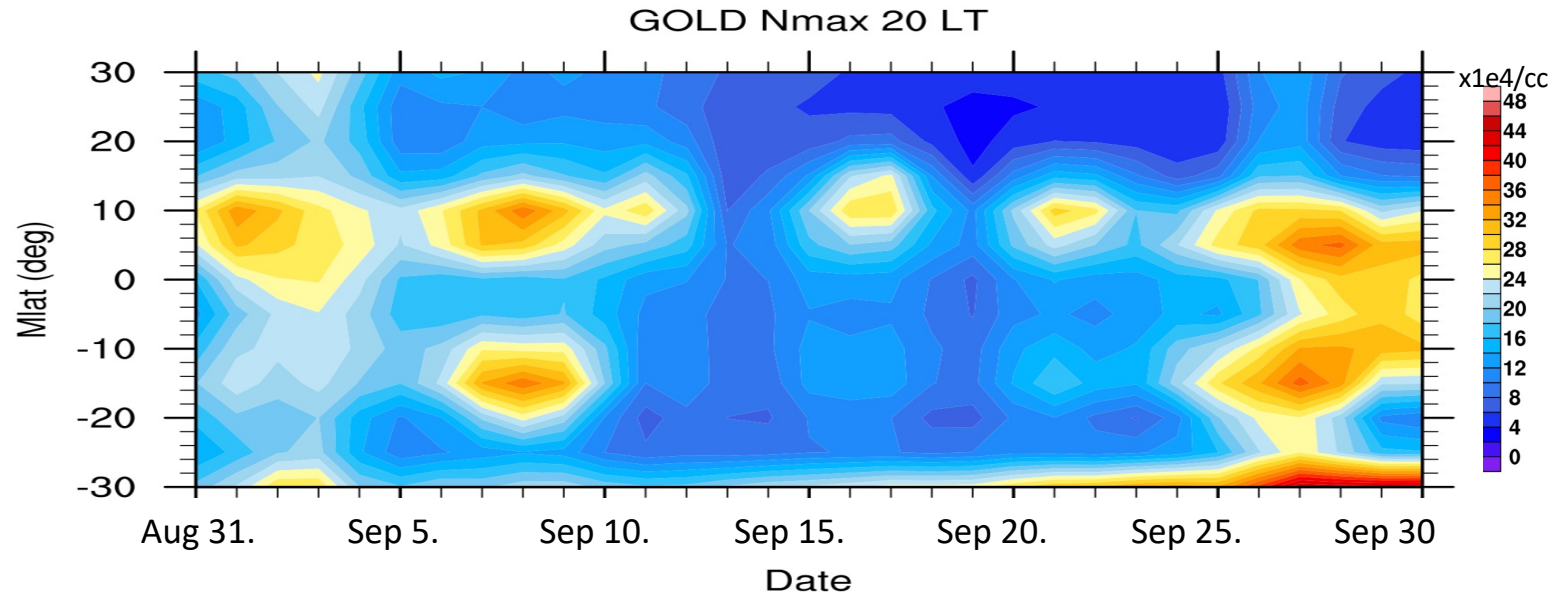


- The Q6DW is well reproduced in the SD-WACCM-X run.
- Enable us to prescribe the TIEGCM LB using the WACCM-X output.

2. GOLD vs. TIEGCM: 6-day periodicity in the nighttime F-region

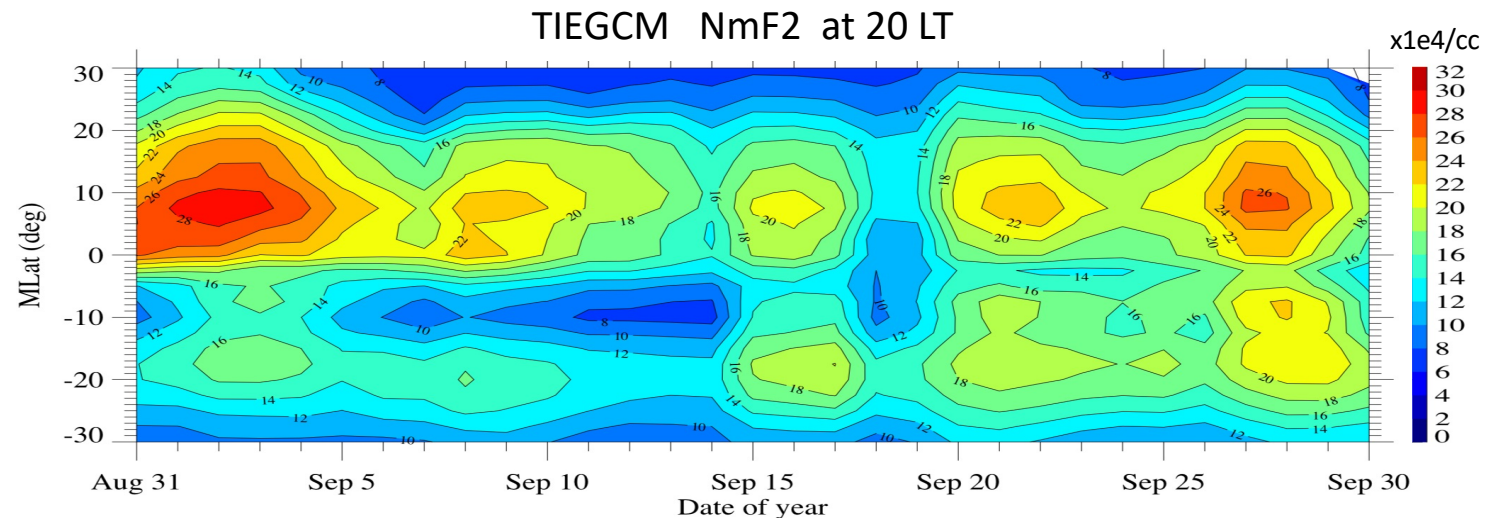
GOLD

- Average over the South America
- 20 LT



TIEGCM:

- LB forced by SDWACCM-X output
- Assuming quiet time condition ($K_p = 0.3$; $F_{10.7} = 70$ sfu)
- Outputs sampled by the GOLD FoV



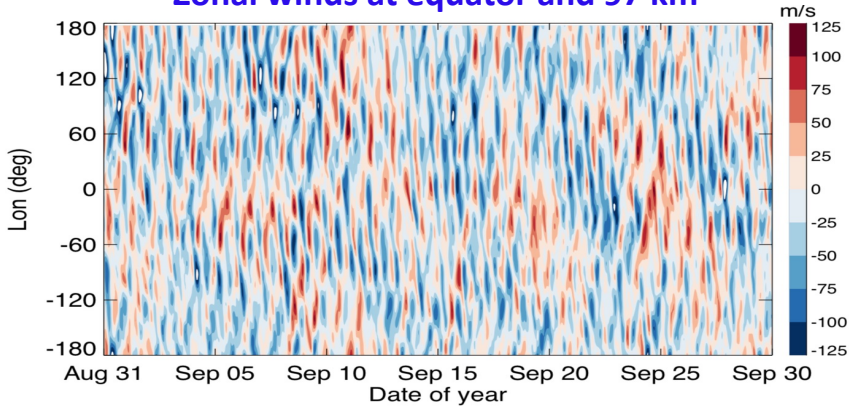
- Day-to-day variation compares well; slightly Larger Nmax in observations.
- Sims. suggest that the periodicity in obs. is driven primarily by waves.

2. The role of the Q6DW in transmitting the 6-day periodicity

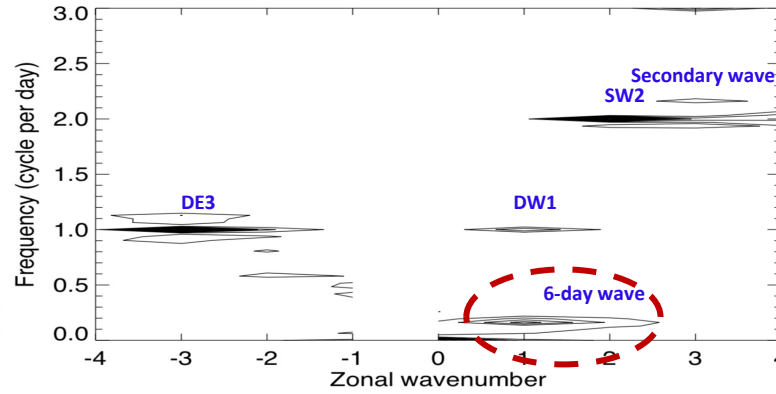
Case 1: zonally diurnal mean + tides + 2-7-day PWs

Case 2: zonally diurnal mean + tides

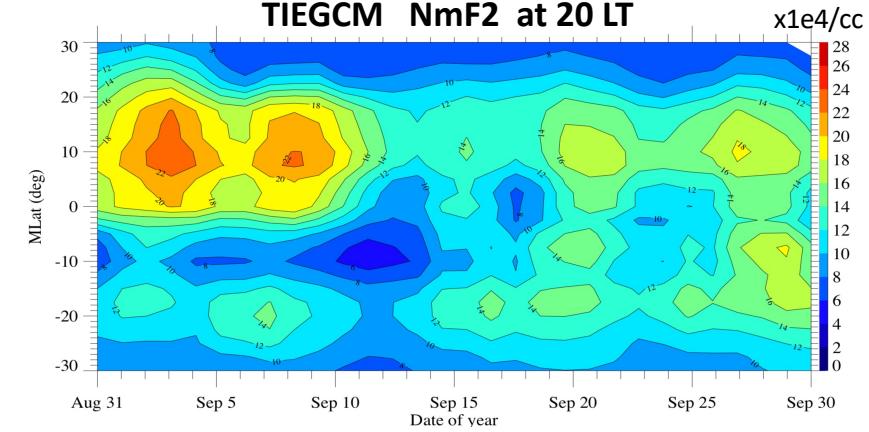
Zonal winds at equator and 97 km



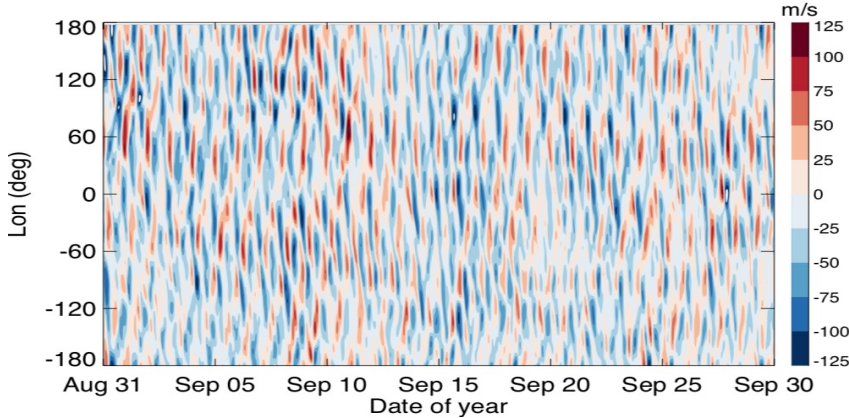
Frequency- wavenumber Spectra



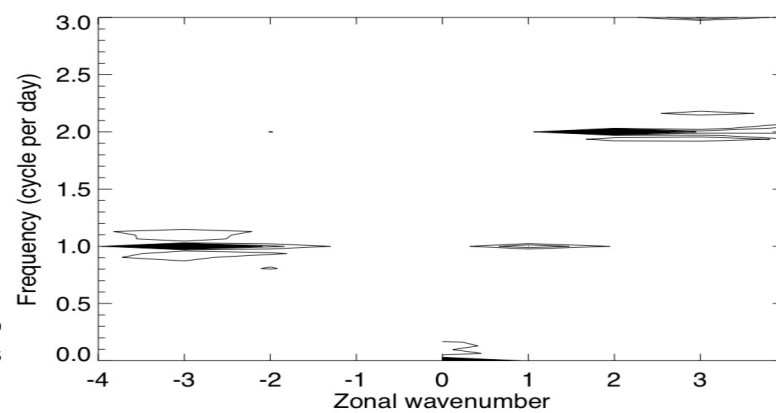
TIEGCM NmF2 at 20 LT



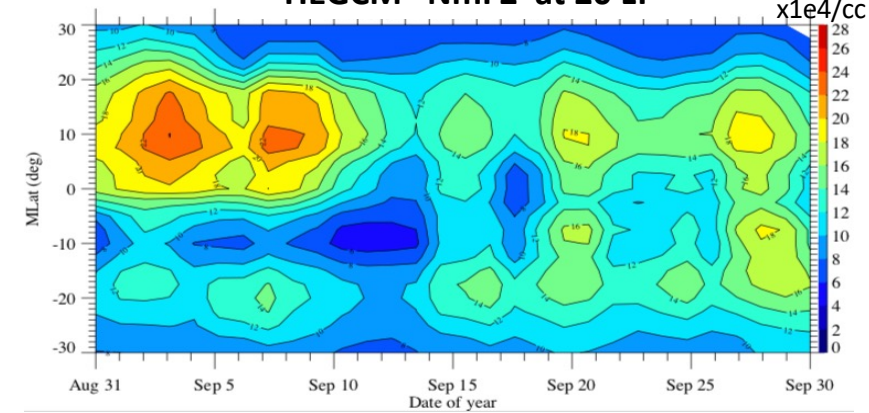
Zonal winds at equator and 97 km



Frequency- wavenumber Spectra



TIEGCM NmF2 at 20 LT

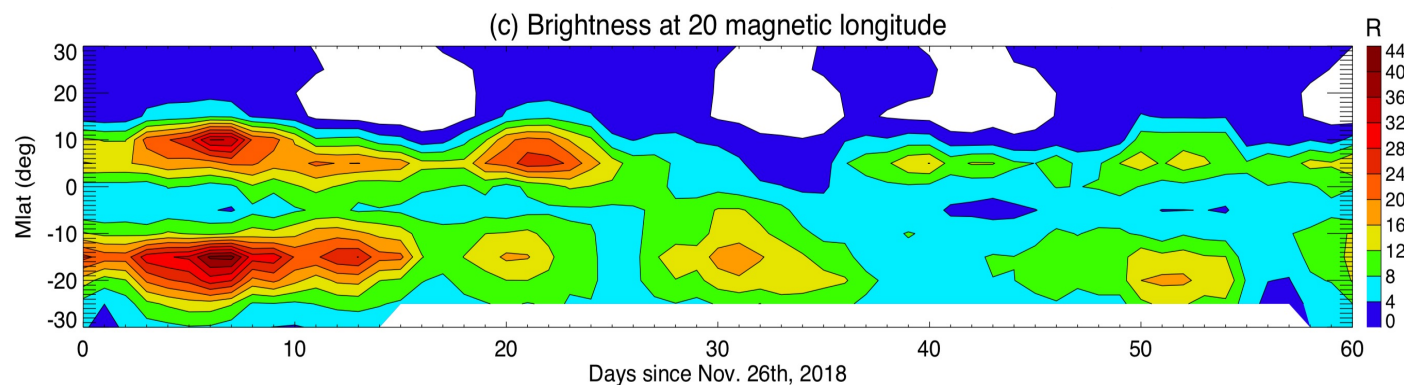


- 6-day periodicity appears in the ionosphere, with and without the 6-day waves forcing at the lower boundary.
- Implies that the periodicity is not only driven by the 6-day wave, but also by the modulation of tides.

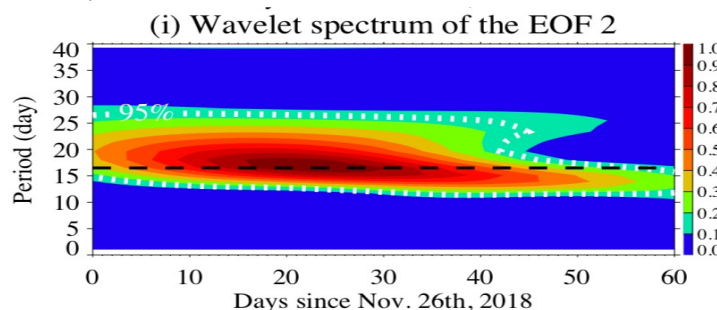
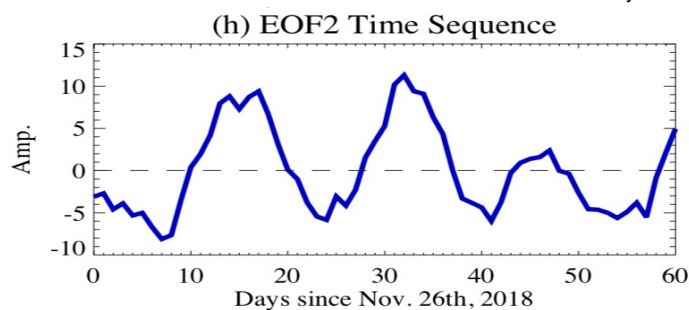
Other PW effects on the ionosphere seen by GOLD
Example of 16-day wave in 2018

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

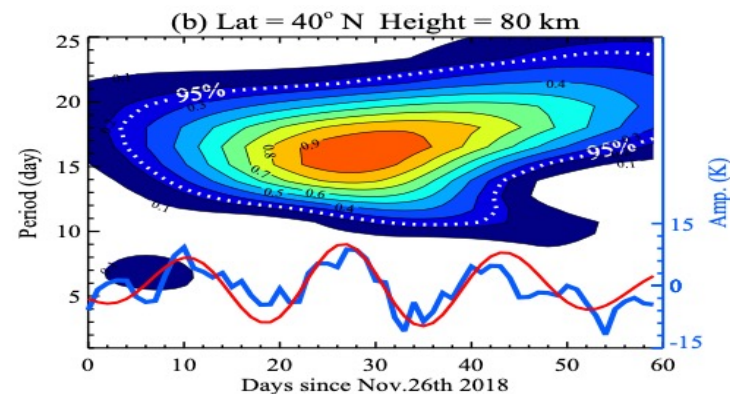
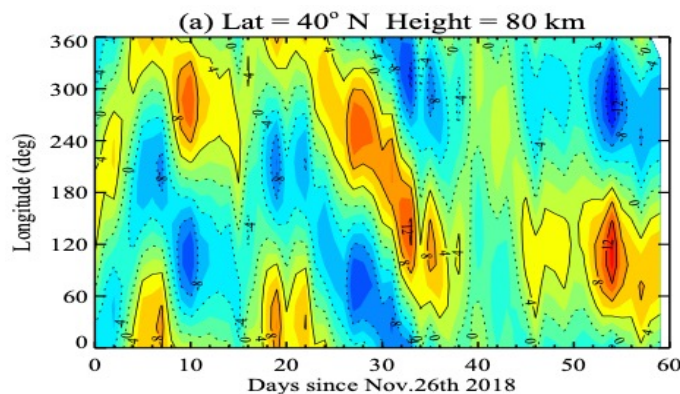
GOLD Nmax



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.

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.