New findings of the response of thermospheric composition to low-moderate geomagnetic activity

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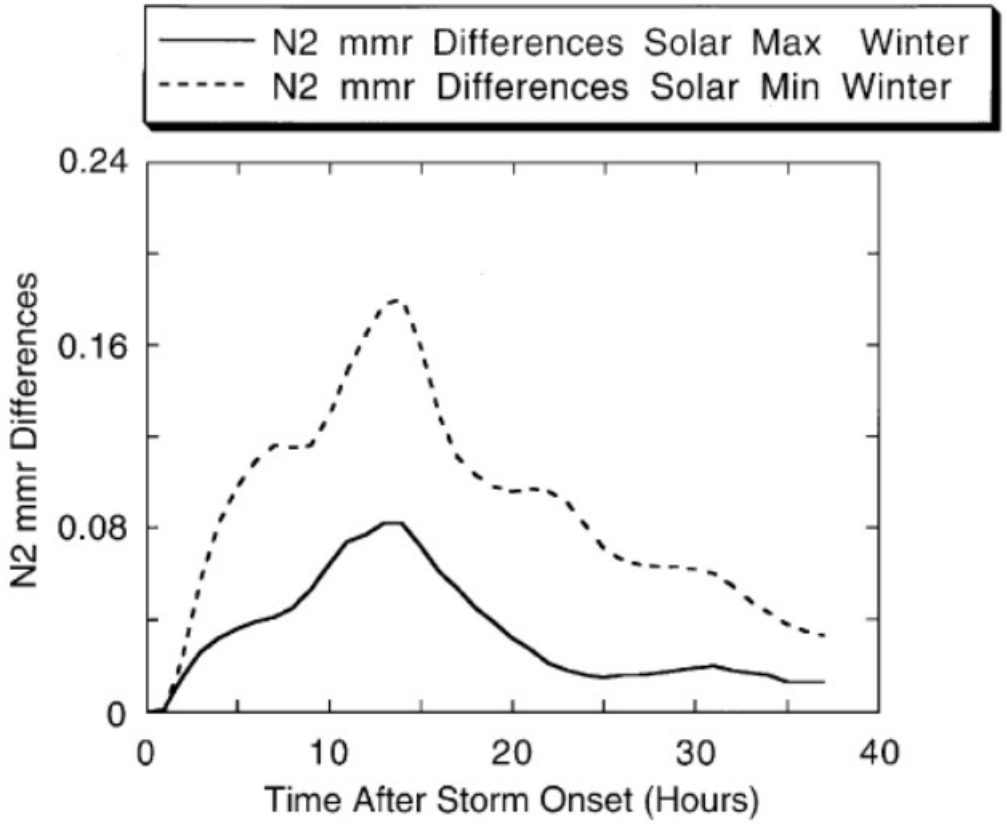
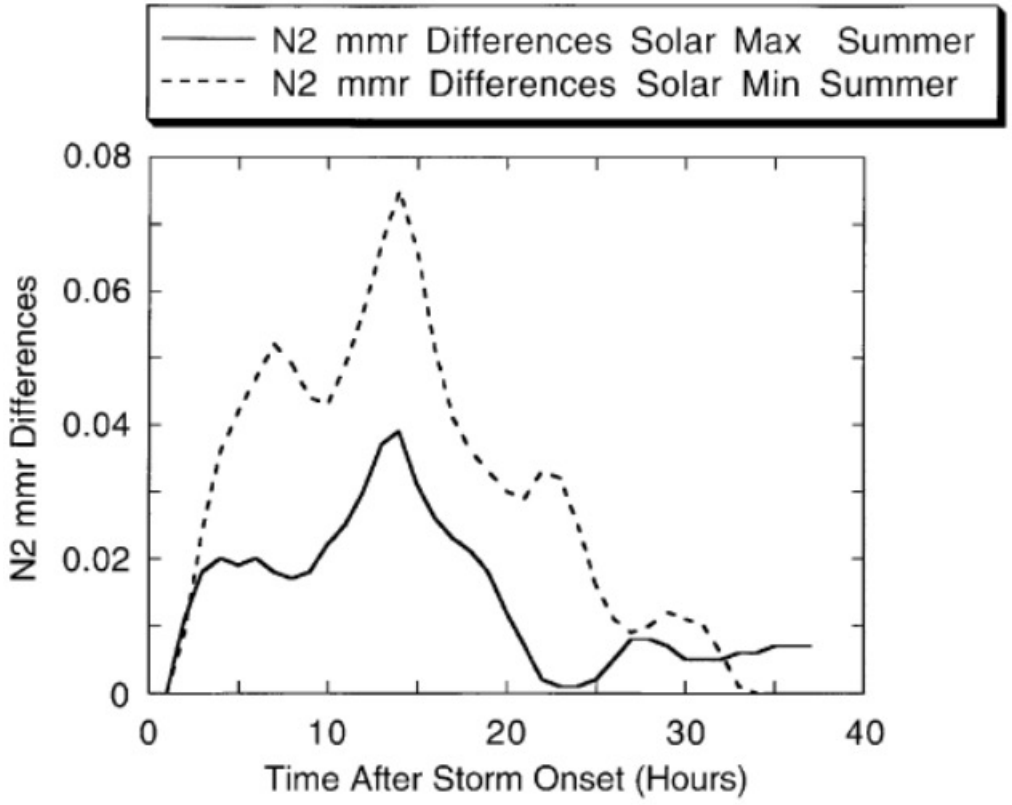
Motivation





Burns et al., 2004

weaker background in solar minimum leads to a stronger response to geomagnetic forcing

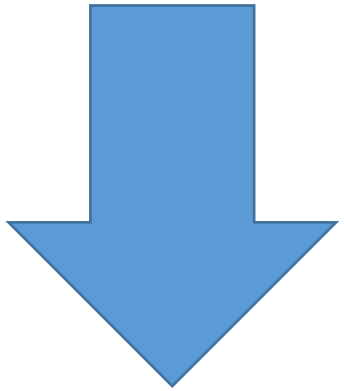
Question: does the neutral composition in the thermosphere also respond to weak geomagnetic activity (non-storm, Kp<=4) during solar minimum???

Global-scale Observation of Limb and Disk (GOLD) provides 2D images of $\sum O/N_2$ over a large area (70°S-70°N, 120°W-30°E) in the same time range (6:10-22:40 UT) everyday (More details in Eastes et al., 2017 and 2020)

Selection rules

Two consecutive quiet days, with AE disturbance less than 250 nT and daily average Kp<1

From the third day, there are some geomagnetic disturbances (AE<1000 nT), but they are weaker than a storm (Kp<5)



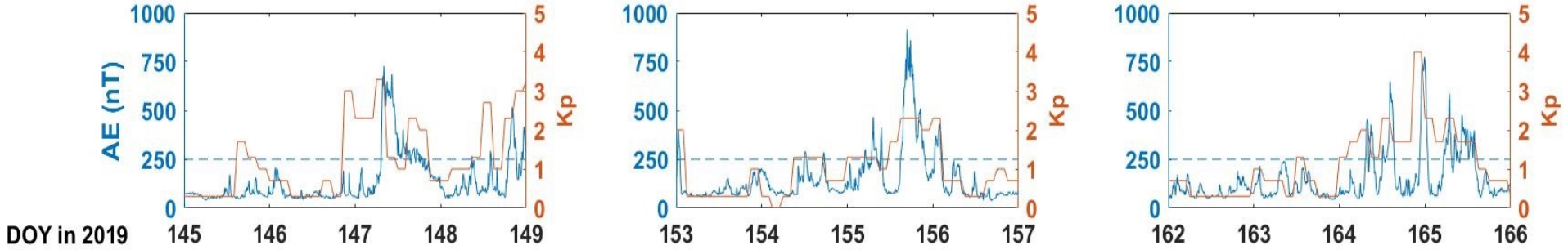
Calculate corresponding $\sum O/N_2$ percentage difference (PD) [(disturbed-quiet)/quiet].

Case 1

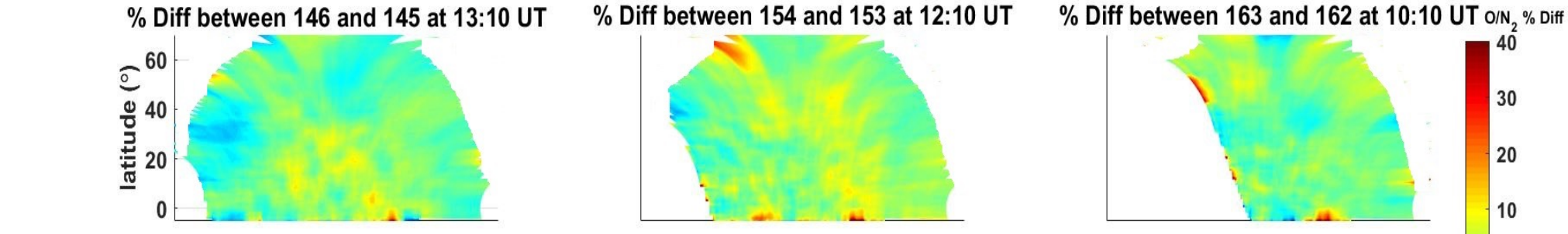
Case 2

Case 3

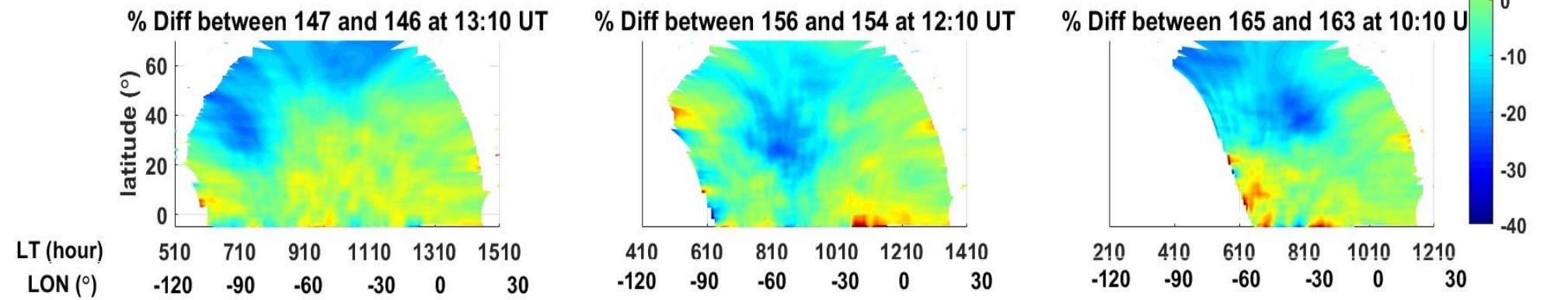
AE and Kp



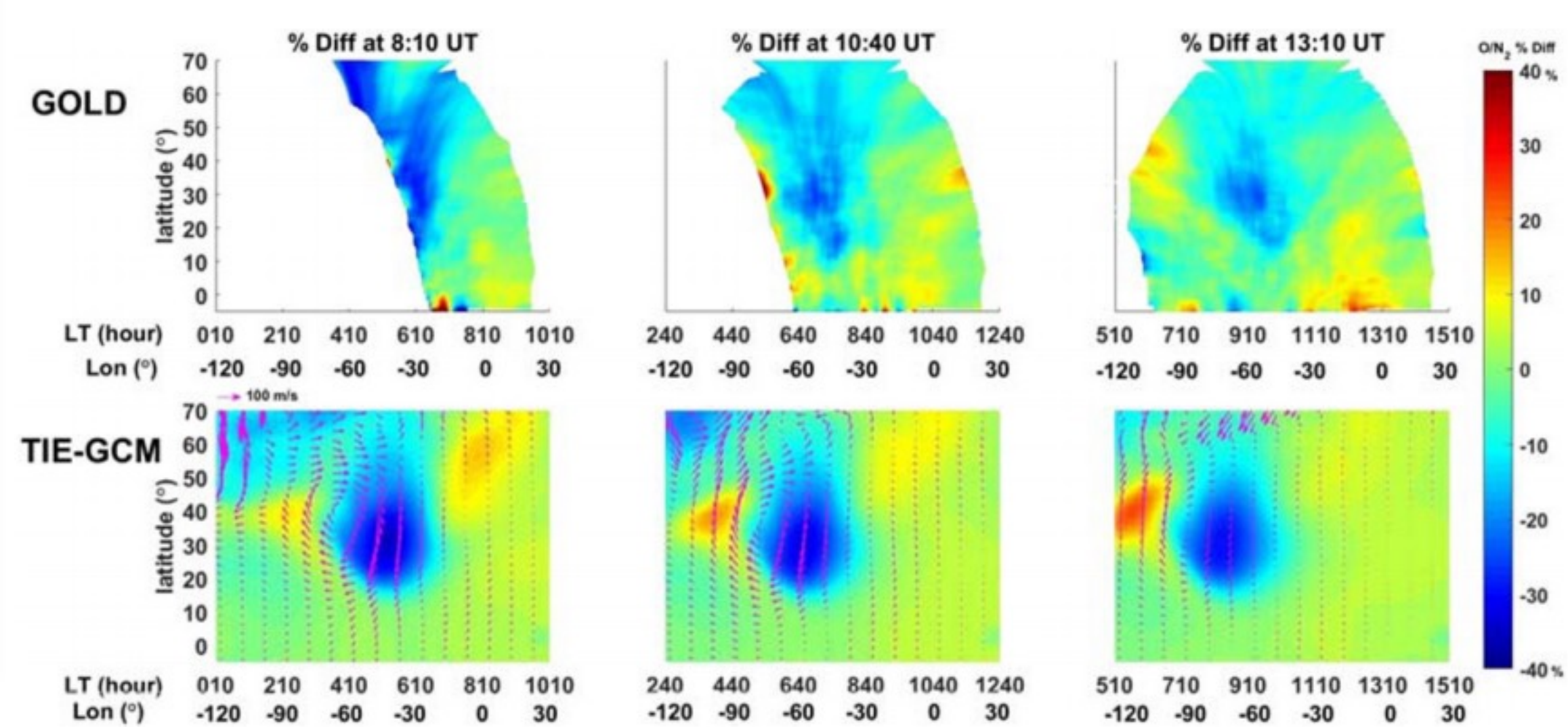
% Diff between 2 quiet days



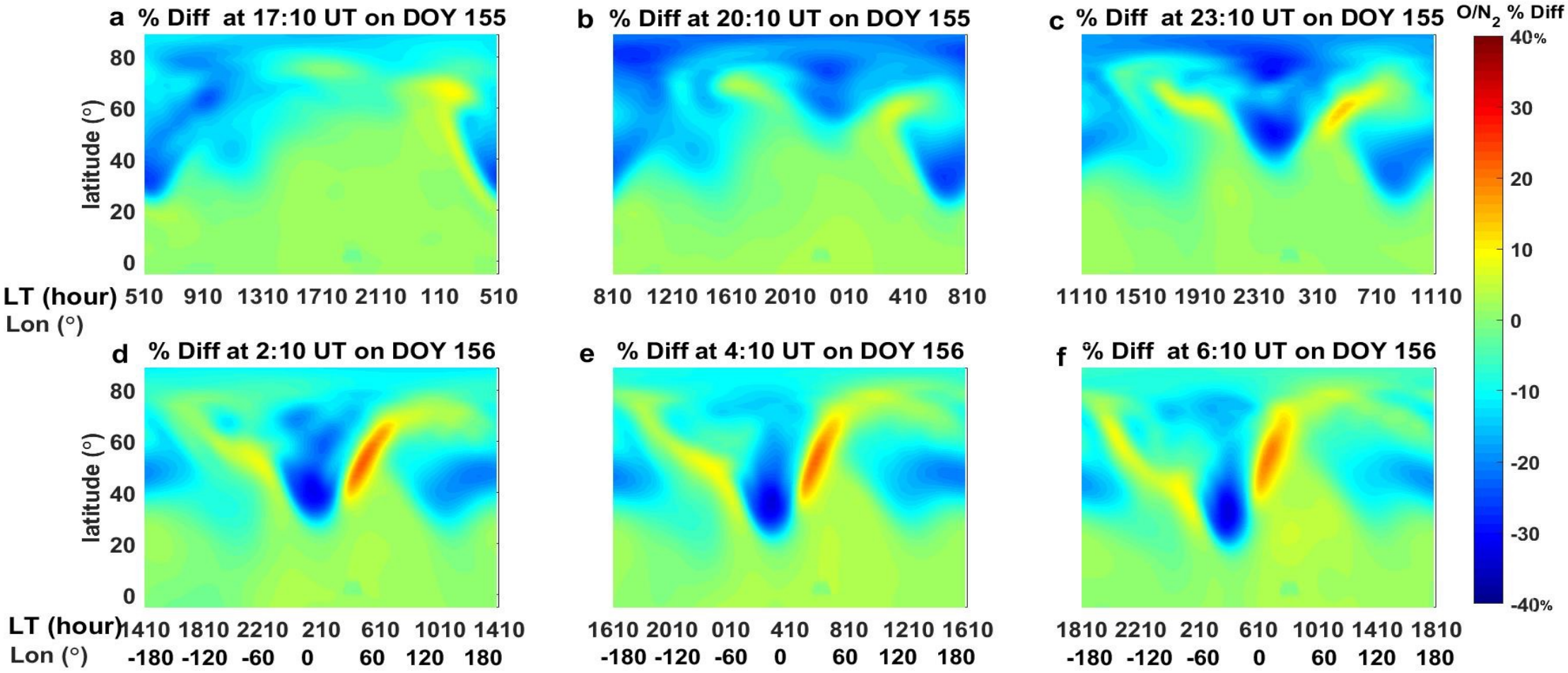
% Diff between disturbed and quiet days



Data-Model comparison for case 2



Temporal evolution of disturbed $\sum O/N_2$ in case 2 (similar to process described in Prolss, 1980)



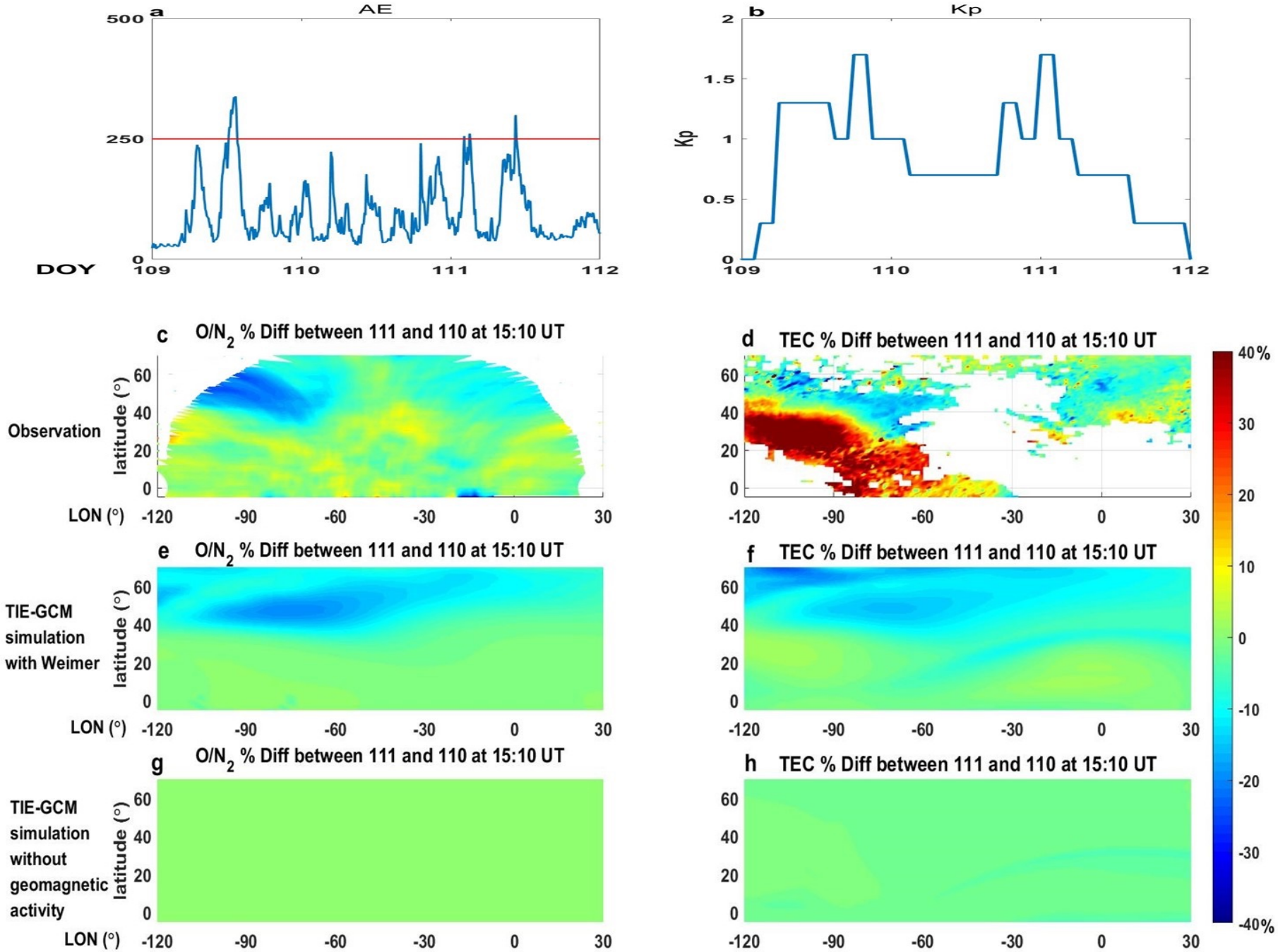
See more details in Cai et al., 2020 GRL

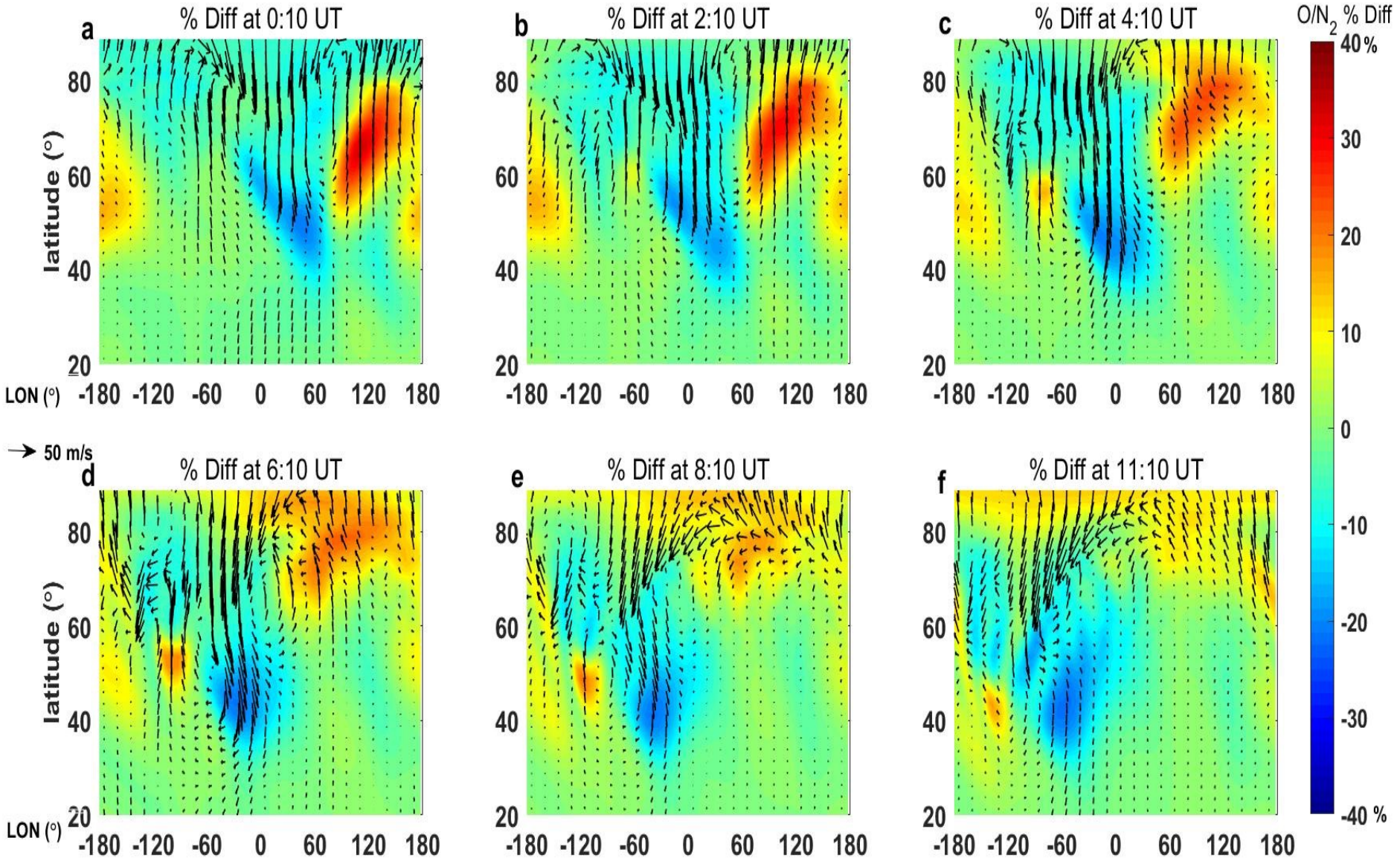
The above work from Cai et al., 2020 (GRL) raises another question

What happens during geomagnetically quiet time (Kp<2): are there still composition and ionospheric density disturbances?

Now we make the rules stricter by setting AE<250 nT for the whole day, and Kp<2 (quiet (Q) conditions), to see what happen to $\sum O/N_2$ and TEC,

We pick the case where **three quite days** satisfy quiet conditions, and then calculate the % Diff between third and second days. The first quiet day is not used so that the possible influence of previous geomagnetic activity can be avoided.


a
AE
500
250
0
DOY
109
110
111
112
b
Kp
2
1.5
1
0.5
0
Kp
109
110
111
112
c
O/N2 % Diff between 111 and 110 at 15:10 UT
Observation
latitude (°)
60
40
20
0
LON (°)
-120
-90
-60
-30
0
30
d
TEC % Diff between 111 and 110 at 15:10 UT
e
O/N2 % Diff between 111 and 110 at 15:10 UT
TIE-GCM simulation with Weimer
f
TEC % Diff between 111 and 110 at 15:10 UT
g
O/N2 % Diff between 111 and 110 at 15:10 UT
TIE-GCM simulation without geomagnetic activity
h
TEC % Diff between 111 and 110 at 15:10 UT
40%
30
20
10
0
-10
-20
-30
-40%



See more details in Cai et al., 2021 GRL

Summary

1 Weak geomagnetic activity (2<Kp<=4) can generate strong daytime responses in the thermospheric ∑O/N2 (~ -30% and up to 12-hour) at mid and low latitudes during solar minimum.

2 During some geomagnetically quiet periods (Kp<2), GOLD observed similar strong localized daytime $\sum O/N_2$ variations (sustained ~10 hours) at mid-latitudes

3 Ionospheric TEC depletions are also seen in the region of $\sum O/N_2$ depletion

4 Model simulations are consistent with observations and demonstrate that the observed $\sum O/N_2$ depletions are caused by geomagnetic activity

Reference

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