Variability in the thermosphere and ionosphere during small geomagnetic disturbances in April 2002

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ISRs, Ne on April 15-16, 2002

Unusually low Ne on April 16, 2002
Millstone Hill digisonde, April 2002

Ionosondes:
This is a global effect, observed from 40°E to 270°E at latitudes > 35-40°N
ISRs, Ne on April 15-16, 2002

Millstone Hill, 43°N 289°E

- Ne decrease on April 16 is comparable to the decrease during April 17 storm
- Occurs throughout the whole day
- Reduction in Ne at all altitudes
- Accompanied by increase in Ti

Kharkiv, 47°N, 50°E

March 15-17, 2004
GPS TEC

- Over 900 receivers
- $3^\circ \times 3^\circ$ lat/long bins
- 20 min intervals
- Error is 3-5 TEC units
- No interpolation over areas without data
GUVI O/N2

Global view of O/N2 column density

Different UT time for different passes

Crosses equator close to local noon
April 15, 2002

GPS: Decrease in TEC

April 16, 2002

GUVI: Decrease in O/N2
• Reductions in both TEC and O/N2 by 30-50% in coincident regions

• Decrease in TEC is caused by decrease in O/N2

• Reductions extend 150° in longitude from 60°E to 270°E

• Reductions penetrate to 35-40°N

• Reductions restricted to higher latitudes in Southern Hemisphere

• Increase in O/N2 at some longitudes outside of this region
Model successfully predicts reductions in both TEC and O/N2, but in a smaller longitudinal area.

Depletions in TEC and O/N2 penetrate to middle latitudes.

The magnitude of simulated reductions is smaller compared to observations.
Features of the phenomena

Long-lasting decrease in the daytime Ne caused by O/N2 reduction
Observed globally
Penetrates to middle latitudes
Penetrates to lower latitude in summer hemisphere
Successfully simulated by a model driven with realistic high-latitude energy input

Typical signature of geomagnetic storm

Variations in thermospheric and ionospheric parameters at midlatitudes depend on high-latitude energy input and effective transport of disturbances to lower latitudes
Case 2: April 26-28, 2002

Large reduction in NmF2 at Millstone Hill

Max $K_p = 4+$

Min $SYM-H = -48$
April 26-28, 2002

Reduction in TEC and O/N2 in the same area

Region with depletions extended from 330°E to 120°E

Disturbances penetrate to 5-10°N at 300°E, to 45-55°N at other longitudes

March 15-17, 2004
Discussion

- Players:
  - Total energy input (AE, HP)
  - Transport

- Wind drivers:
  - Day-to-night circulation
  - Pressure gradients
  - Ion-neutral coupling
    - Primary mechanism (Burns et al., 1991)
Discussion (cont.)

What affects winds through ion drag:

- Solar activity
  - Killeen et al., 1995 – FPI data
- Season
- By component of IMF
  - By > 0, Bz < 0 – larger dusk cell
  - By < 0, Bz < 0 – larger dawn cell
    - Killeen et al., 1995 – FPI data
    - Immel et al., 1997, Strickland et al., 2001 – DE-1 data
IMF components

April 14-16, 2002

By > 0 for many hours; By >= 5 nT

April 26-28, 2002
90°E  
By < 0  

315°E  
By > 0
Questions to ask

- Other cases
- By magnitude and sign
- Positive effects (increase in O/N2,Ne)
- Propagation in longitude and latitude
- By negative – effects in the evening sector?
- Effects in the Southern Hemisphere
- More insights into origins of ionospheric variability
Summary

• Two case studies of small geomagnetic disturbances (Kp = 3-, Kp=4+).

• Decrease in O/N2 (GUVI) and Ne (ISRs, GPS, ionosondes) in the coincident area by 30-50%.

• Reductions in O/N2 ratio and Ne penetrate to the latitude of 35-40°N for weaker disturbance (case 1), and to the latitude of ~5-10°N for stronger disturbance (case 2).

• Similar variations are also predicted by the TIMEGCM/ASPEN model in both O/N2 ratio and Ne, though the magnitude of the variations in the model is smaller.

• We suggest that strong and positive By component of IMF plays important role in delivering high-latitude thermospheric disturbances to lower latitudes close to local midnight.