Macroscopic Effects of Microscopic Ionospheric Turbulence

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Farley-Buneman (two-stream) instability affects ionospheric conductance globally via two mechanisms:

1. Anomalous electron heating (AEH) — (rough estimates):
   - Threshold electric field \( E_{th} \sim 20 \text{mV/m} \)
   - \( T_e \) increases \( T_e \sim E/E_{th} \)
   - Recombination rate decreases \( \alpha_{e,i} \sim 1/T_e \)
   - Plasma density increases \( n \sim 1/\sqrt{\alpha_{e,i}} \)
   - Conductivity increases \( \Sigma_P, \Sigma_H \sim n \sim \sqrt{E/E_{th}} \)

2. Nonlinear DC current (NC, e.g., Oppenheim 1997)
Two-stream instability: Global effects

Conductance multipliers (theory + PIC simulations)

Height-integrated

Pedersen

Hall

Dimant&Oppenheim [2011b]
First test: Halloween storm 2013

Effect of including the conductance multipliers in a global MHD model: Used simplified multipliers and only AEH effect

Merkin et al. [2005]
Include LFM-RCM coupling

And more accurate conductance model (FB=AEH+NC)

Bz=-30 nT driving
Test LFM-RCM simulation: constant IMF $B_z=-30$ nT

No corrections

Turbulent corrections

- Pedersen conductance enhanced where $E$ is strong
- $E$ and $\Phi$ significantly reduced
- Unlike uncoupled LFM, strongest effect in electrojet
Real storm-time simulation

Figure 1. Solar wind and IMF conditions during the 17 March 2013 geomagnetic storm event. Panel a) shows the number density, b) the $V_X$ in GSM coordinates. The IMF GSM $Y$ and $Z$ values are plotted in panels c) and d) respectively.
Real storm-time simulation

Figure 3. Comparison of the CPCP, FAC, and DST time series for the storm event for the Northern hemisphere. Panel a at the top shows the CPCP in kV. The middle panel (b) has the integrated FAC. Panel c at the bottom has the DST index. In each panel the LFM-RCM results are shown with the green line, the AEH results with the purple line. In the bottom panel the DST obtained from CDAWeb is plotted in blue.

Wiltberger et al., in preparation, [2016]
Real storm-time simulation

Comparisons of Ionospheric Parameters
2013-03-17 10:00:00
Real storm-time simulation

- Strong agreement on dusk side.
- Dawn side problematic: electron drifts? precipitation in R2 area?

*Vertical lines mark equator ward edge of electron precipitation in simulation and data
Real storm-time simulation

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Comparison of RBSP-A Magnetometer

AEH: more stretched tail

Wiltberger et al., in preparation, [2016]
Real storm-time simulation
Pressure in meridional plane

- It’s not this different all the time
- AEH has stronger pressure peak = more stretched tail?
- Peak pressure ~100 nPa. RBSP 15 nPa (Gkioulidou et al., 2015) but above equator.
- More stretched tail — better agreement with RBSP? Hypothesis — needs verification

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Figure credit: G. Stephens

Wiltberger et al., in preparation, [2016]
• Ionospheric micro-scale turbulence has significant macro-scale effects on the magnetosphere-ionosphere system.

• Reduces the strength of convection in the magnetosphere, leads to better agreement with ionospheric data.

• Important non-linear feedback loop: ionospheric turbulence leads (at times) to stronger ring current pressure peak, more stretched tail.