**M-I Coupling Physics: Issues, Strategy, Progress**

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**Energization Regions**

- **Gap** exists between the upper boundary of TING (or TIEGCM) and the lower boundary of LFM.
- The gap is a primary site of plasma transport where electromagnetic power is converted into field-aligned electrons, ion outflows and heat.
- Modifications of the ionospheric conductivity by the electron precipitation is included in global MHD models via the "Knight relation"; crucial physics is missing:
  - Collisionless dissipation in the gap region;
  - Heat flux carried by upward accelerated electrons;
  - Conductivity depletion in downward current regions;
  - Ion parallel transport \( \rightarrow \) outflowing ions, esp. \( O^+ \).

**Conductivity Modifications**

- The mediating transport processes occur on spatial scales smaller than the grid sizes of the LFM and TING/TIEGCM global models.

**Issues**

- Reconciled \( E_\perp \) mapping and collisionless Joule dissipation with Knight relation in LFM.
- Developed and implemented empirical outflow model – \( O^+ \) flux indexed to EM power and electron precipitation flowing into gap from LFM (\( S_\perp \otimes F_\parallel \)).
- Initiated validation of LFM Poynting fluxes with global statistical results from DE, Astrid, Polar and 3rd/2nd/DARN events (Gagne thesis + student poster by Melanson).

**Strategy**

1. Current-voltage relation in regions of downward field-aligned current;
2. Ion transport in regions 1 and 3;

**EM Power In \( \rightarrow \) Ions Out**

- Collisionless Joule dissipation and electron energization in Alfvénic regions – mainly cusp and auroral BPS regions;
- Ion outflow model in the polar cap (polar wind).

**Priorities**

- Implement multifluid LFM (1)
- Implement CMW (2005) current-voltage relation in downward current regions
  - Include electron exodus from ionosphere \( \rightarrow \) conductivity depletion
  - Accommodate upward electron energy flux into LFM
  - Advance empirical outflow model

**Facts**

- Develop model for particle energization in Alfvénic regions (scale issues!)
- Need to explore frequency dependence of fluctuation spectrum at LFM inner boundary
- Parallel transport model for gap region (long term)

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**Global Effects of \( O^+ \) Outflow**

- Where does the mass go?

**Percent Change in Mass Density**

- 12:00 UT

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**Empirical “Causal” Relations**

**Alfvénic Electron Energization**

**Alfvénic Ion Energization**

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**Challenge:** Develop models for subgrid processes using dependent, large-scale variables available from the global models as causal drivers.