DREAM at LEO

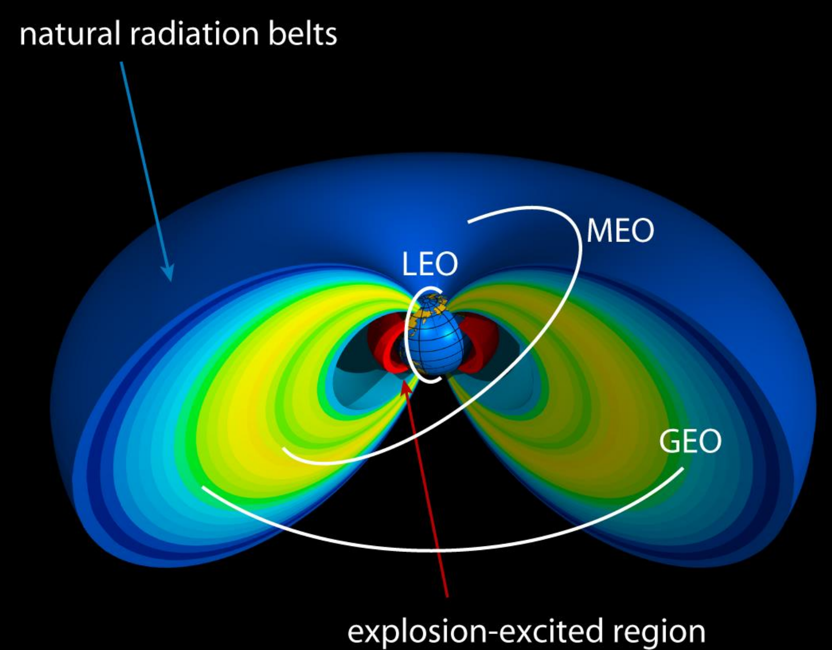
Low-Altitude Mapping of Ring Current and Radiation Belt Results

Geoff Reeves, Yue Chen, Vania Jordanova,

Sorin Zaharia, Mike Henderson, and Dan Welling.

Los Alamos
NATIONAL LABORATORY
EST. 1943

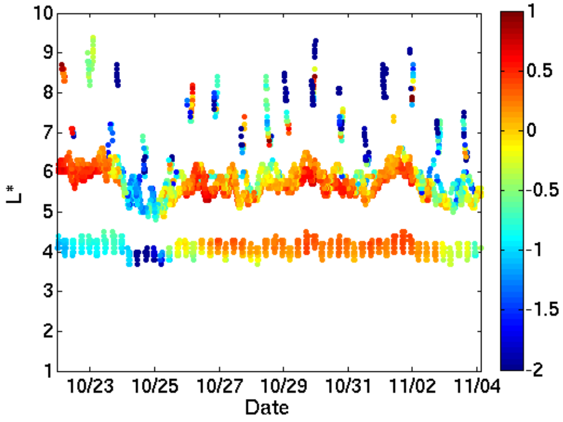
DREAM: The Dynamic Radiation Environment Assimilation Model



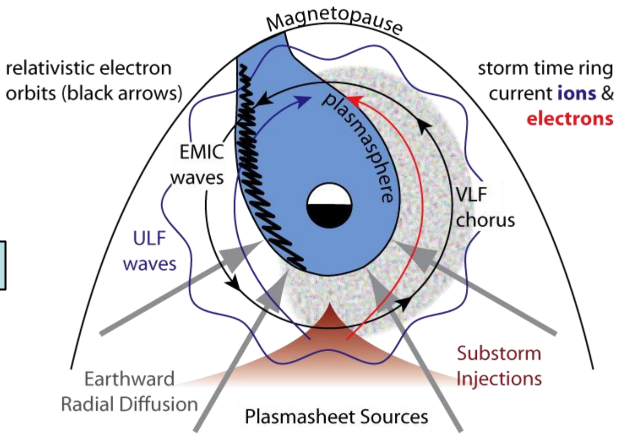
- Developed by LANL to quantify risks from natural and nuclear belts
- Uses Kalman Filter, satellite observations, and physics model
- Couples ring current, magnetic field, and radiation belt models
- Goals: Specification, Prediction, Understanding

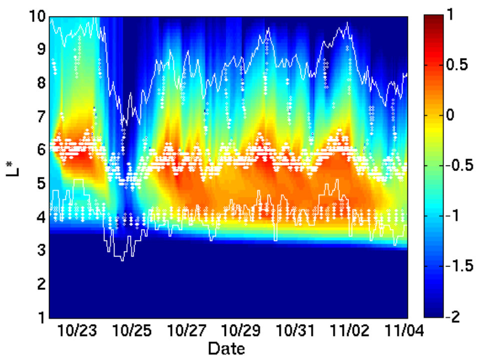
Why Data Assimilation?

Sparse and/or Heterogeneous Observations



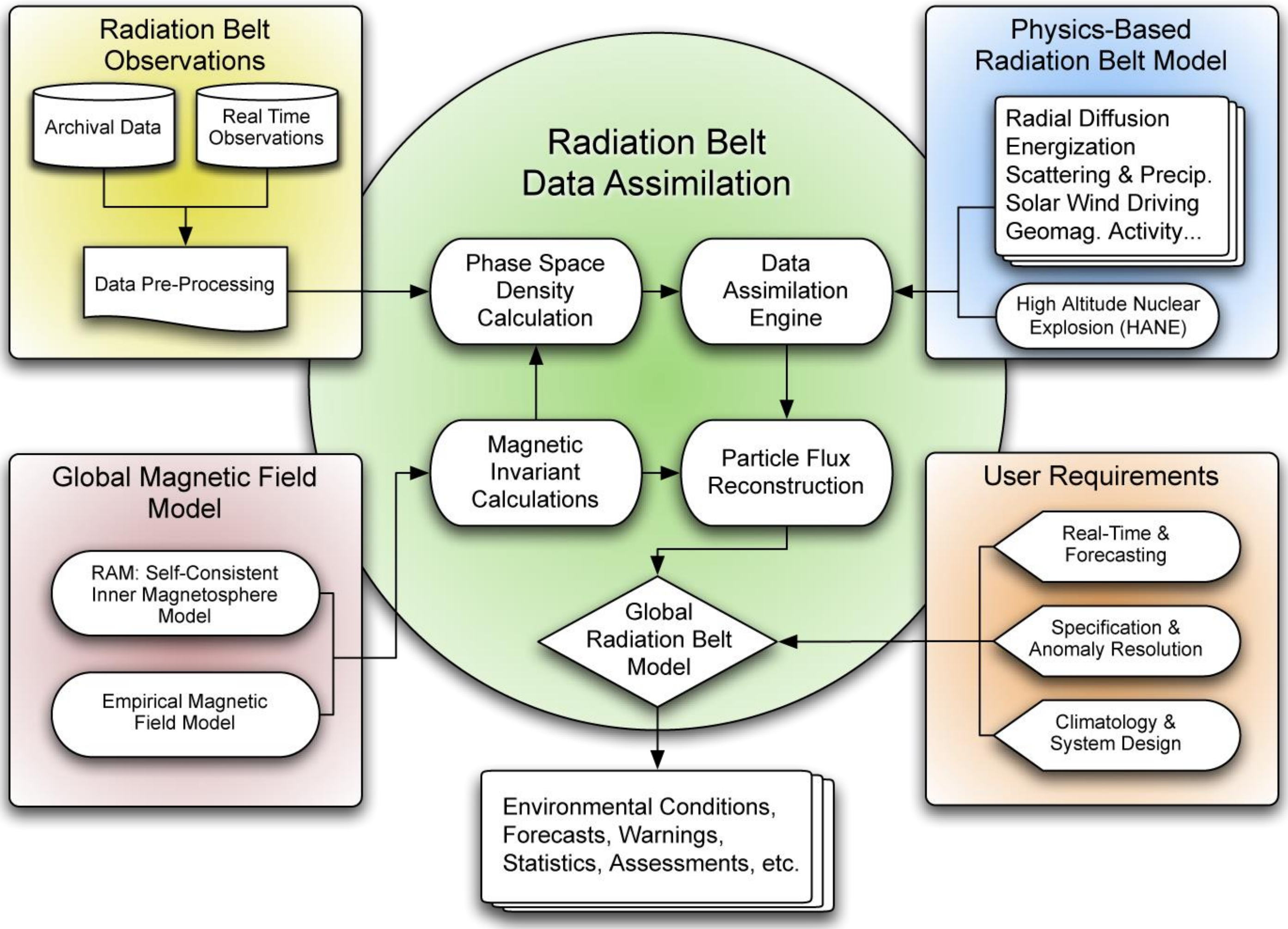
Complex Physical System



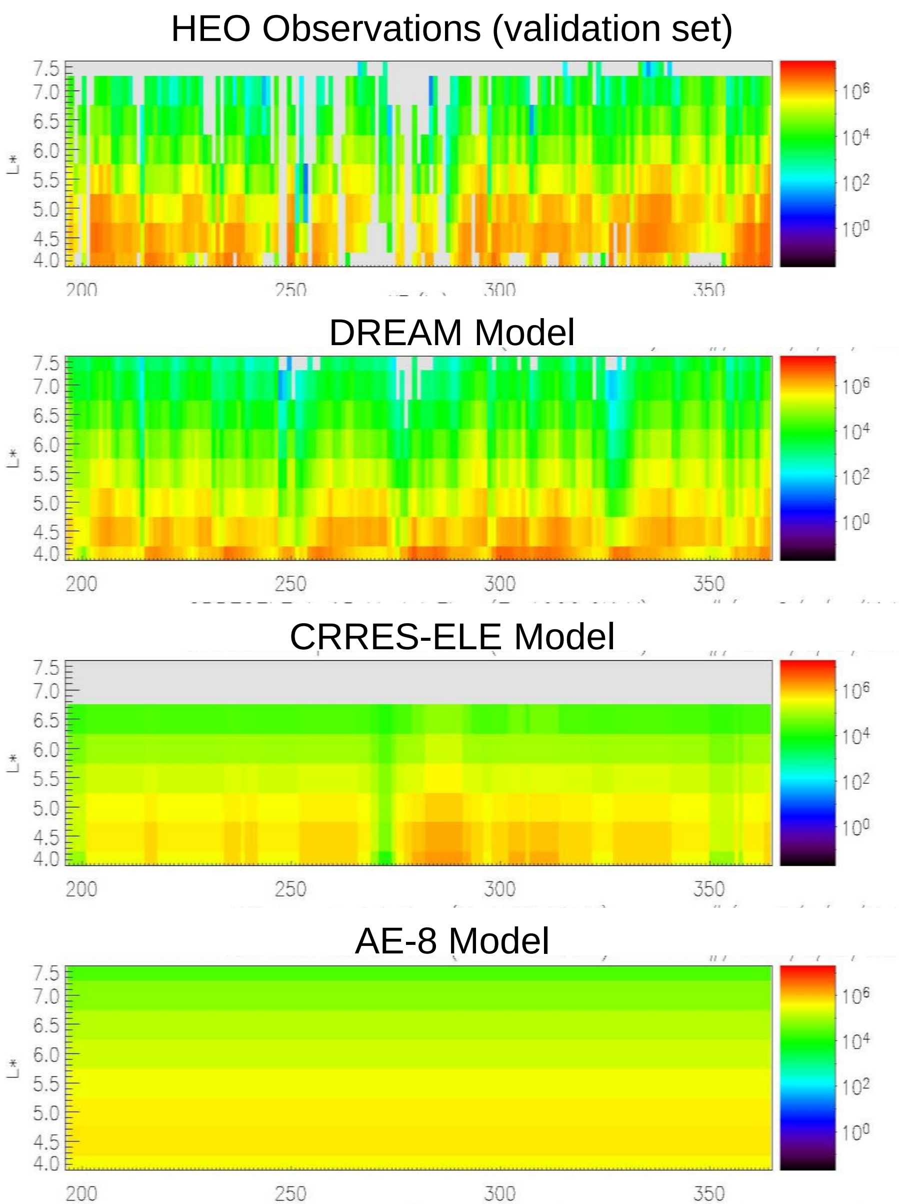


Global, Real-Time Data-Driven Solution

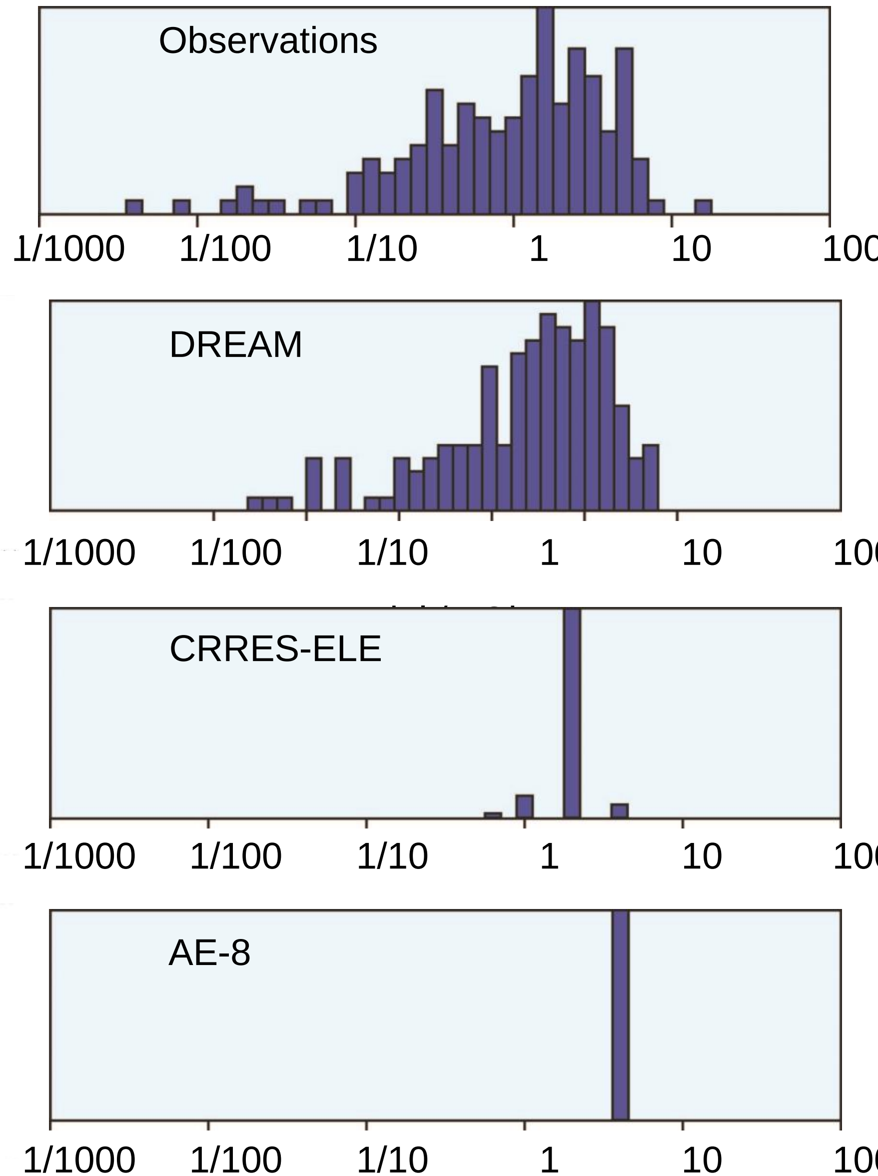
DREAM Computational Framework



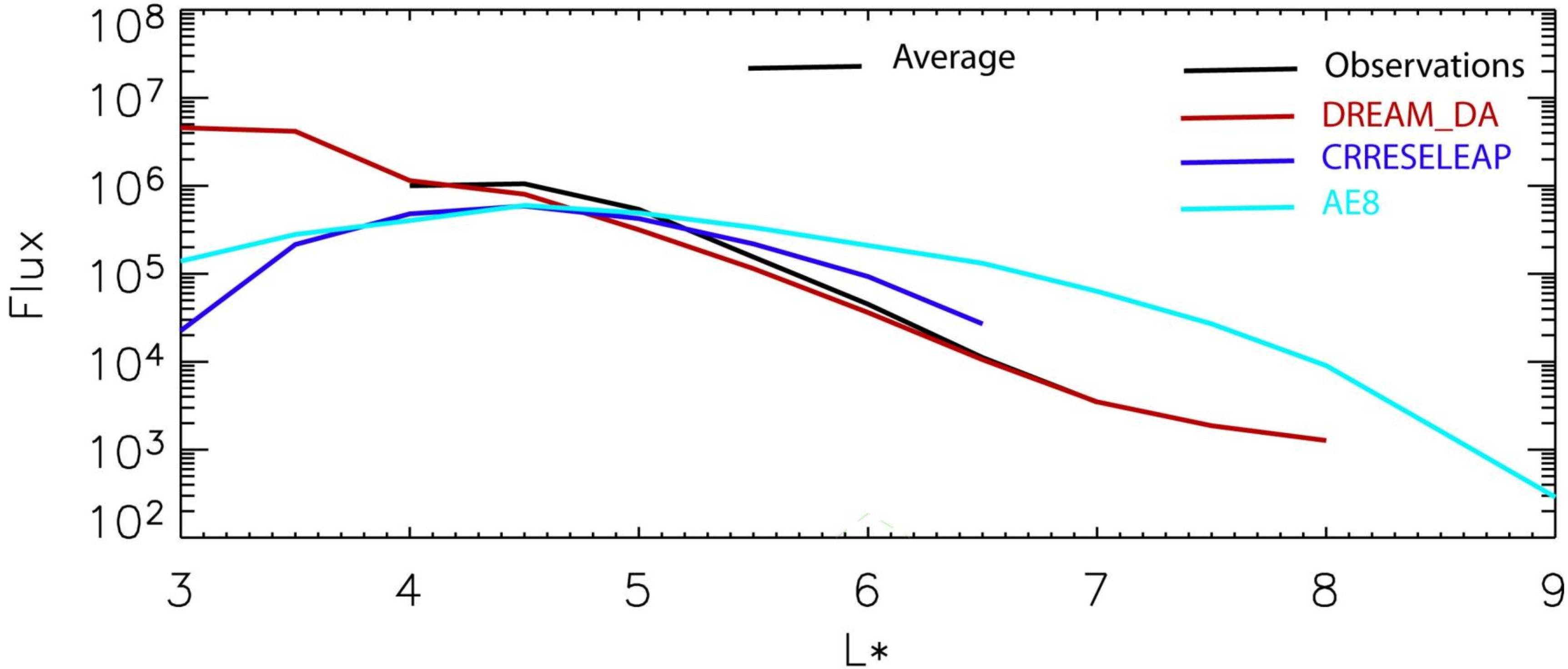
Flux vs L*, Time (1 MeV)



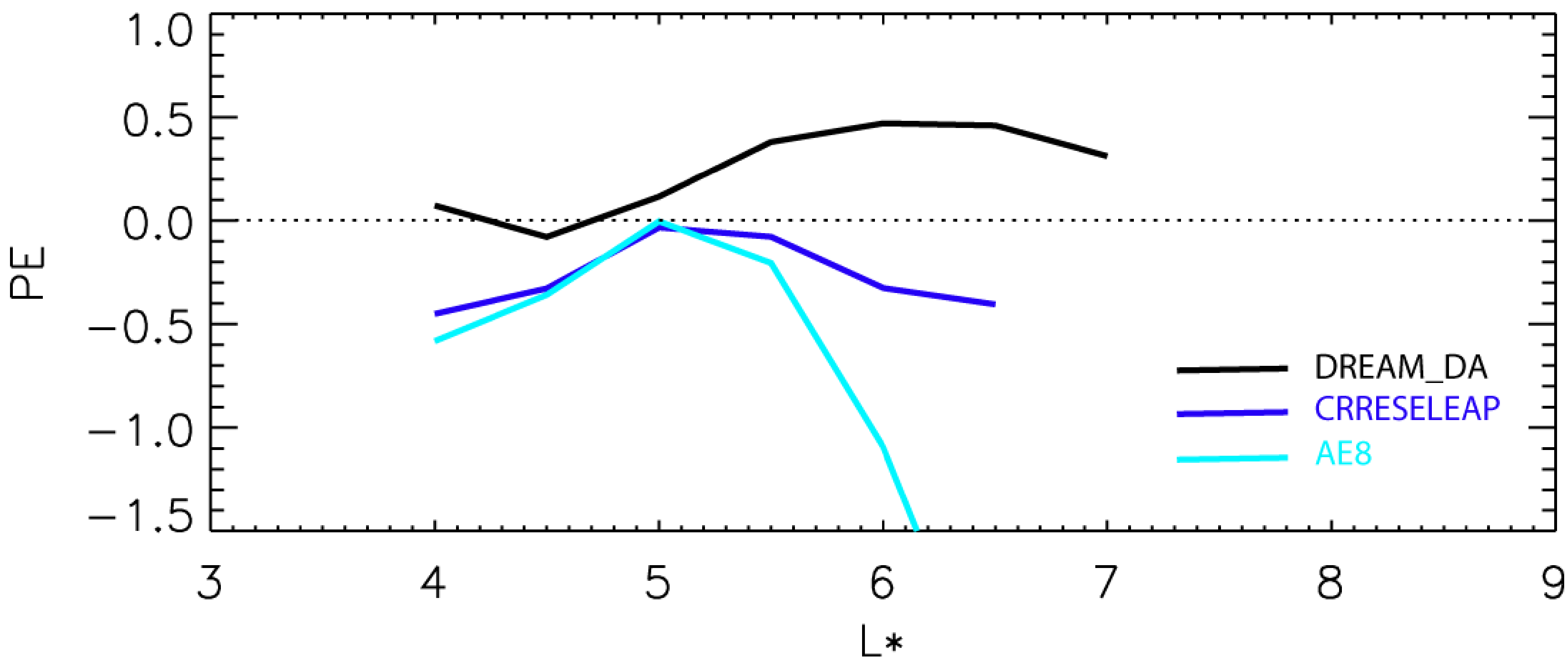
Distribution at L*=6



Validation 2:
Average Flux vs Altitude

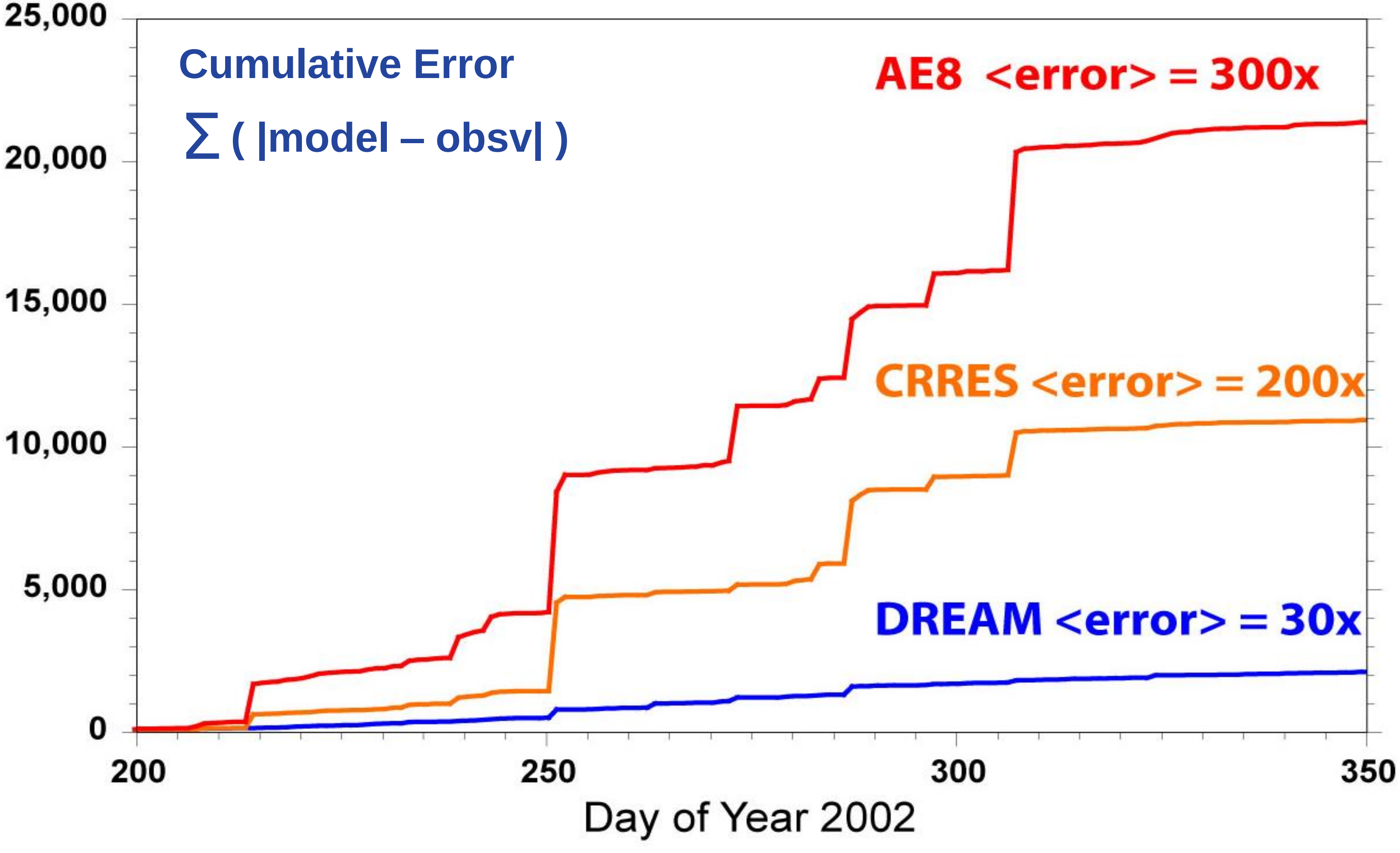


Validation 3: Prediction Efficiency testing variation around the mean



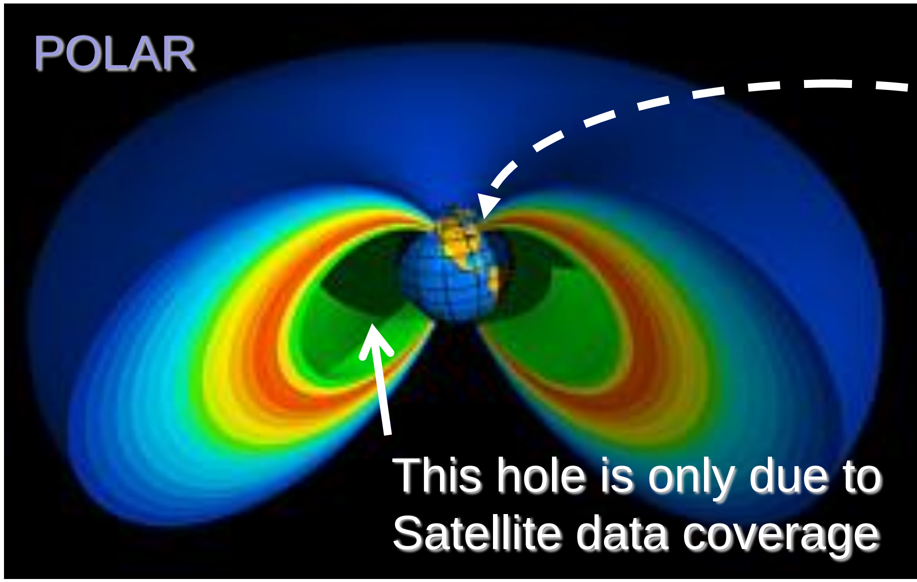
- $$PE = 1 - \frac{\Sigma\ (\text{model} - \text{obsv})^2}{\Sigma\ (\text{obsv} - \langle \text{obsv} \rangle)^2}$$

Validation 4: Average absolute error DREAM gives ~10x improvement

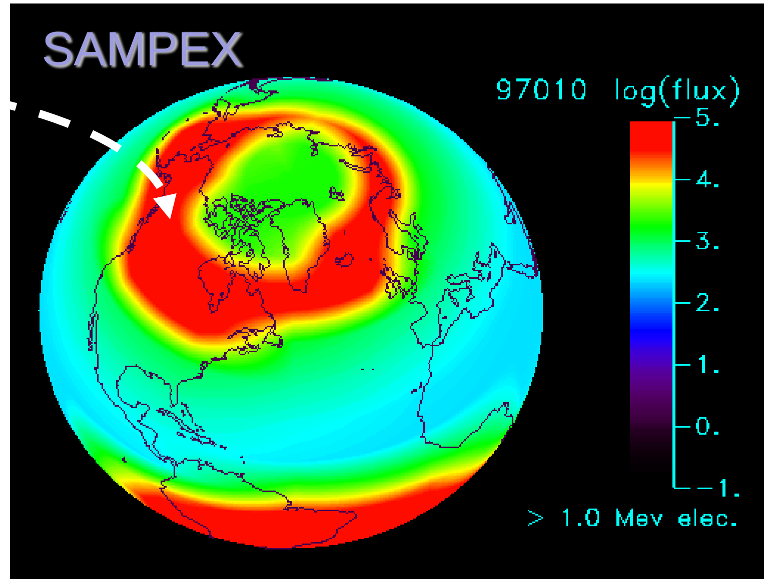


Connecting DREAM to LEO (and LEO to DREAM)

Trapped Electron Observations



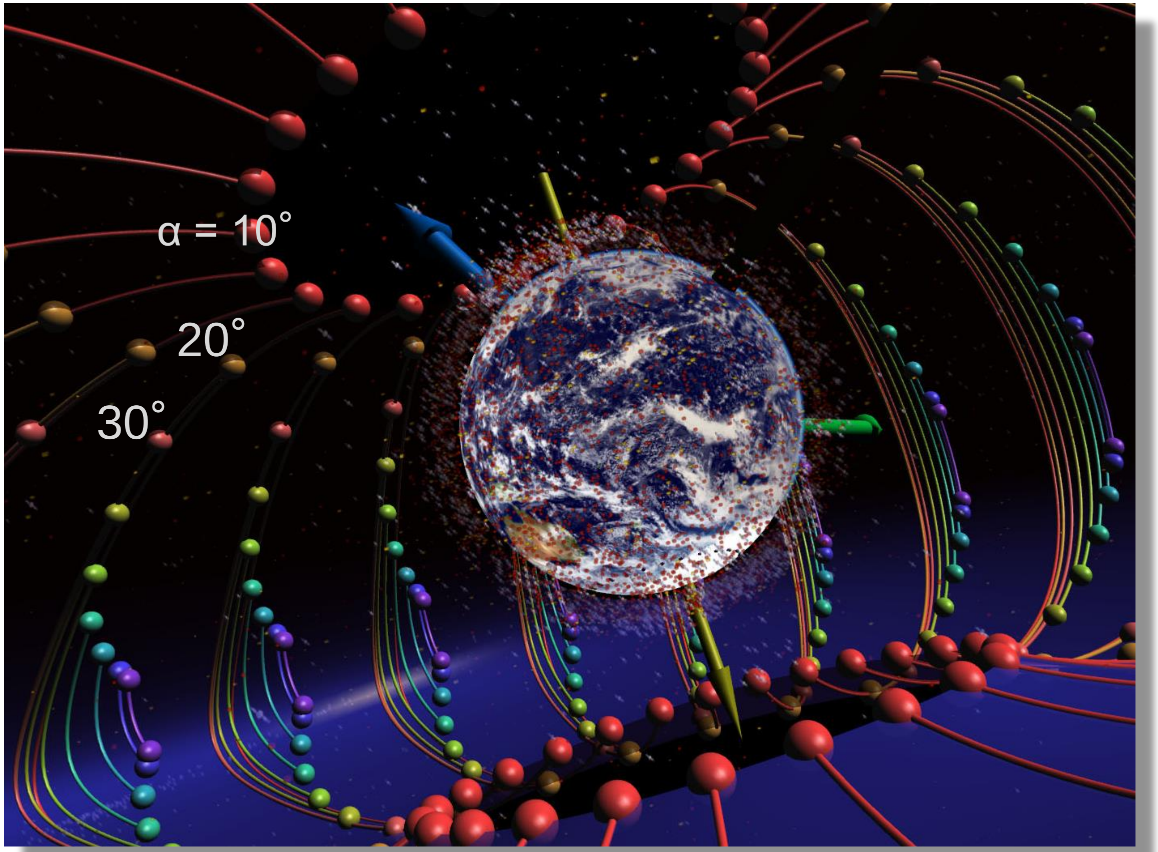
Precipitating Electron Observations at LEO



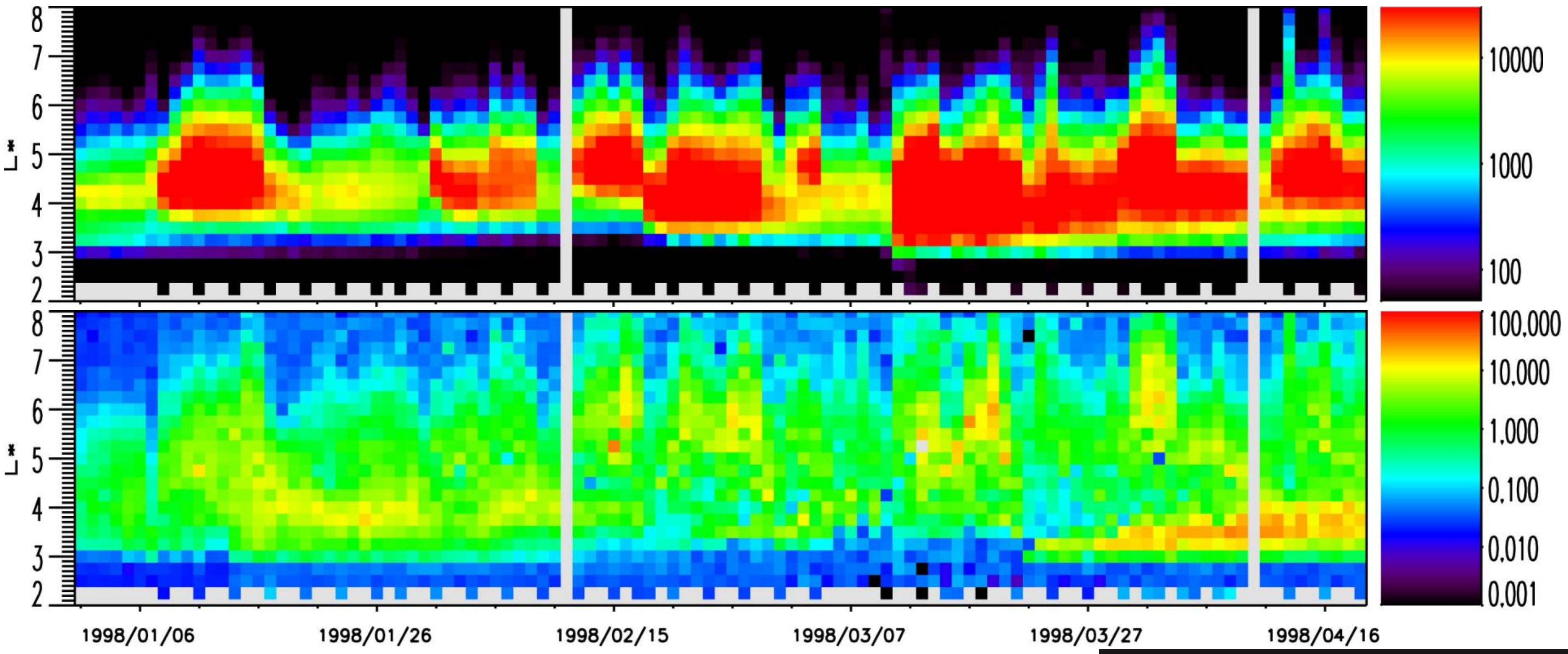
- LEO observations are critical: auroral, MeV electrons, MeV ions and NPOES instruments (post Nunn-McCurdy) are deficient
- LEO informs not only the local space weather conditions but also global models of surface charging, internal charging, dose, etc
- Extrapolating trapped particle models to LEO is challenging

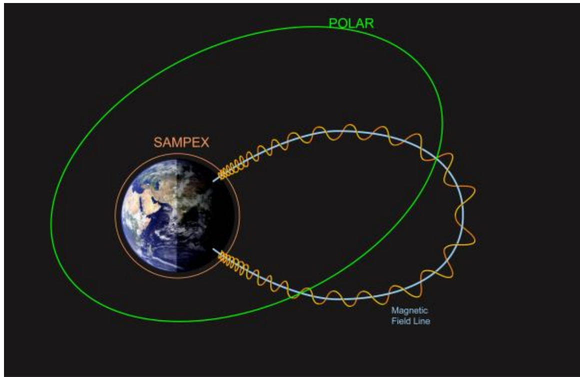
The Opportunities and Challenges of LEO

- LEO is heavily populated and an important region to predict
- LEO satellites provide global coverage at high cadence
- LEO measures ionospheric input
- But, only a small fraction of particles reach LEO
- Field asymmetries such as the SSA
- Time and activity-dependent precipitation

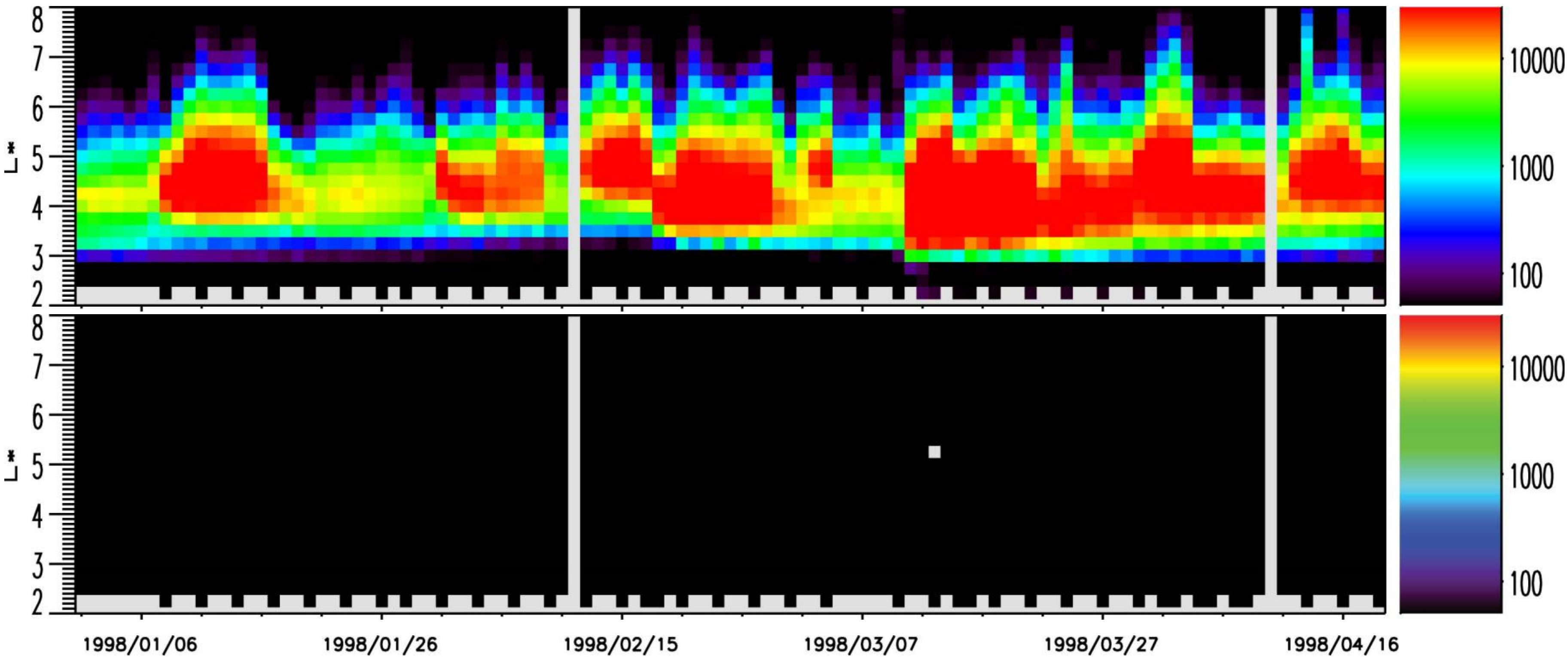


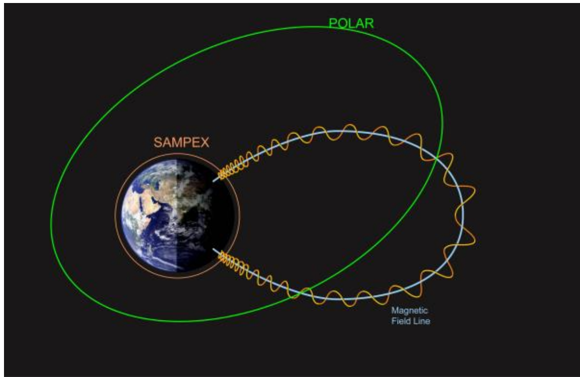
POLAR and SAMPEX: 2 MeV electron flux



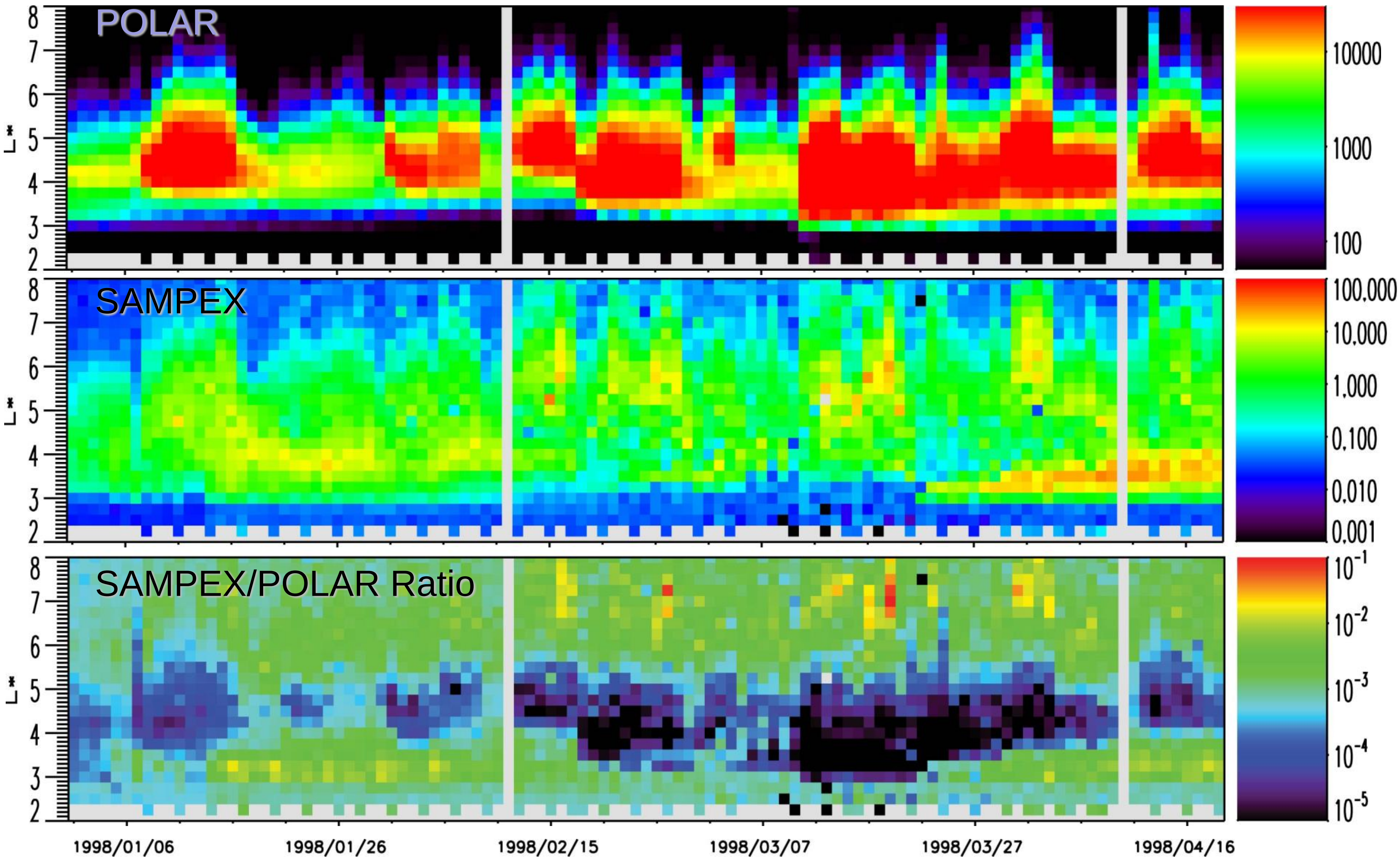


POLAR and SAMPEX on the same scale

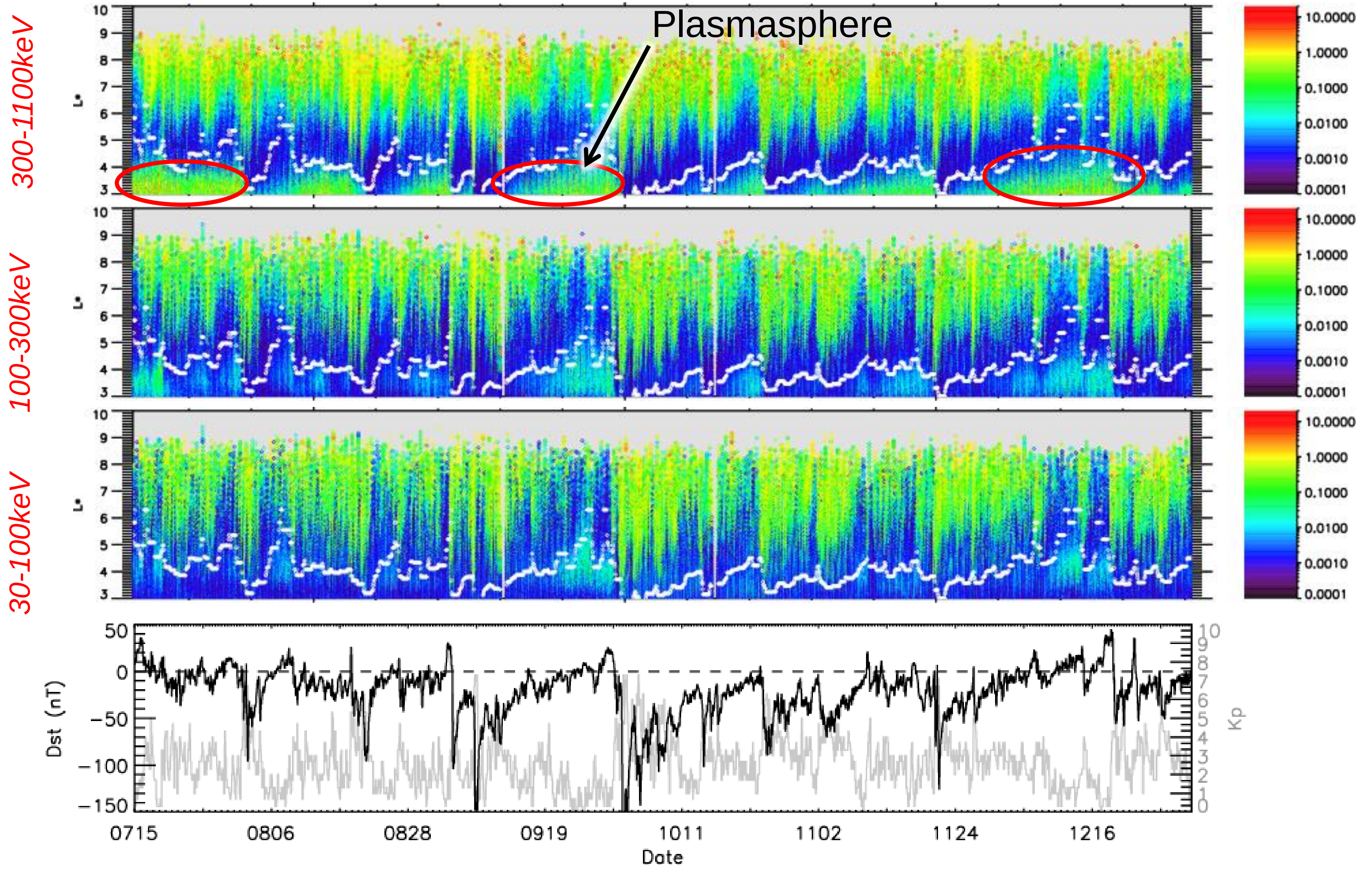




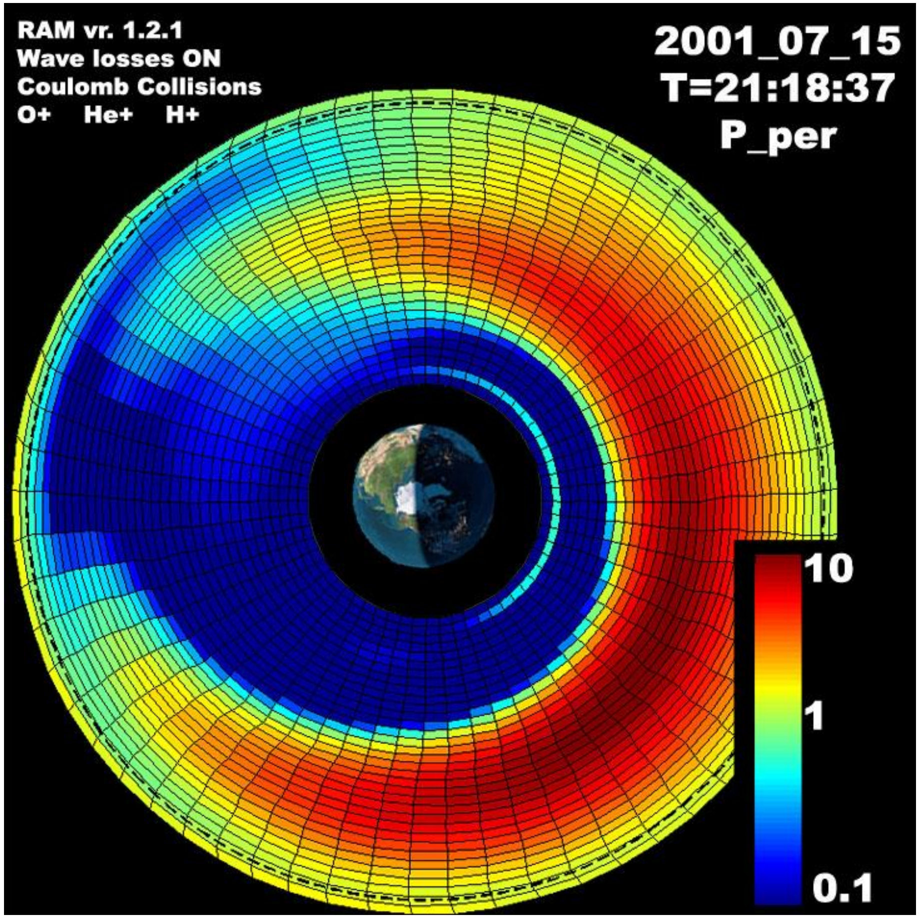
The flux ratio varies from 0.1 to 10^{-5} with Time, L, Activity



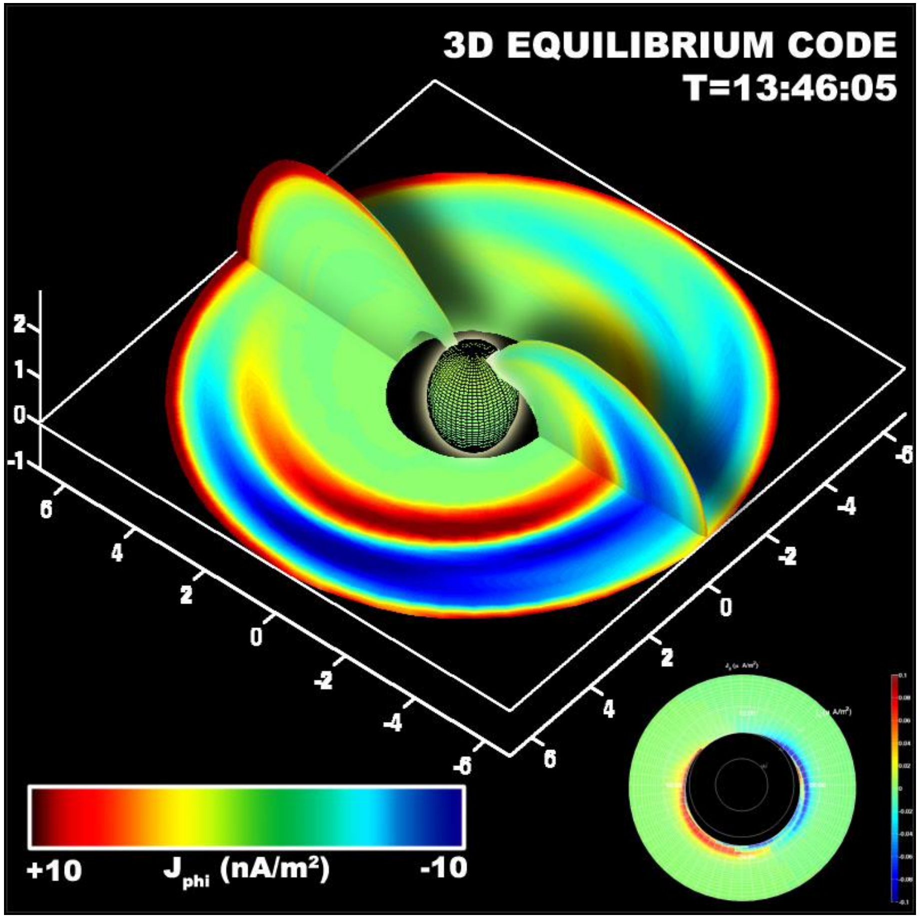
POES: Ratio of precipitating/trapped flux can be better understood in physical context



The RAM-SCB provide further information on coupling of trapped fluxes to LEO & the ionosphere



Perpendicular Pressure



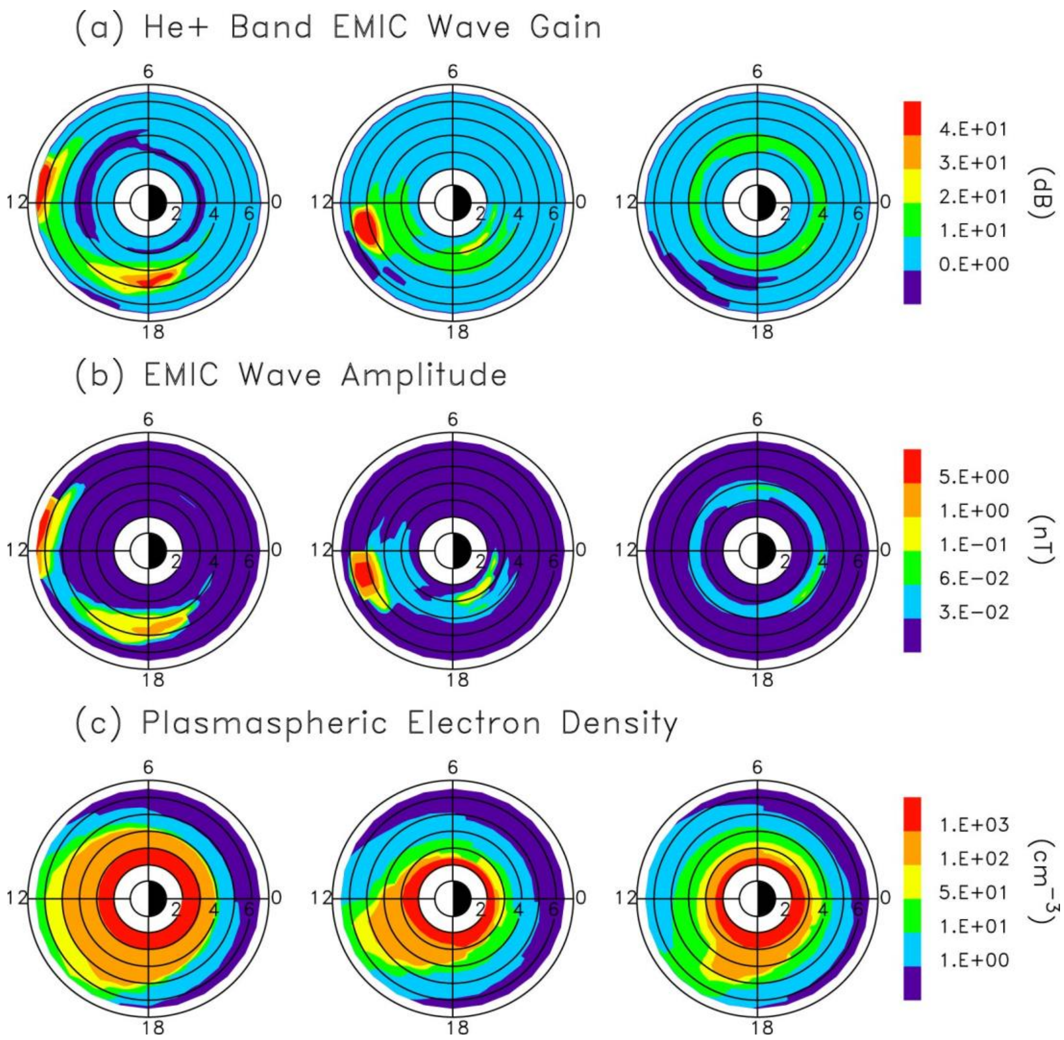
Azimuthal Current Density

RAM-SCB calculates EMIC & Whistler wave growth, amplitude, & wave-particle interactions

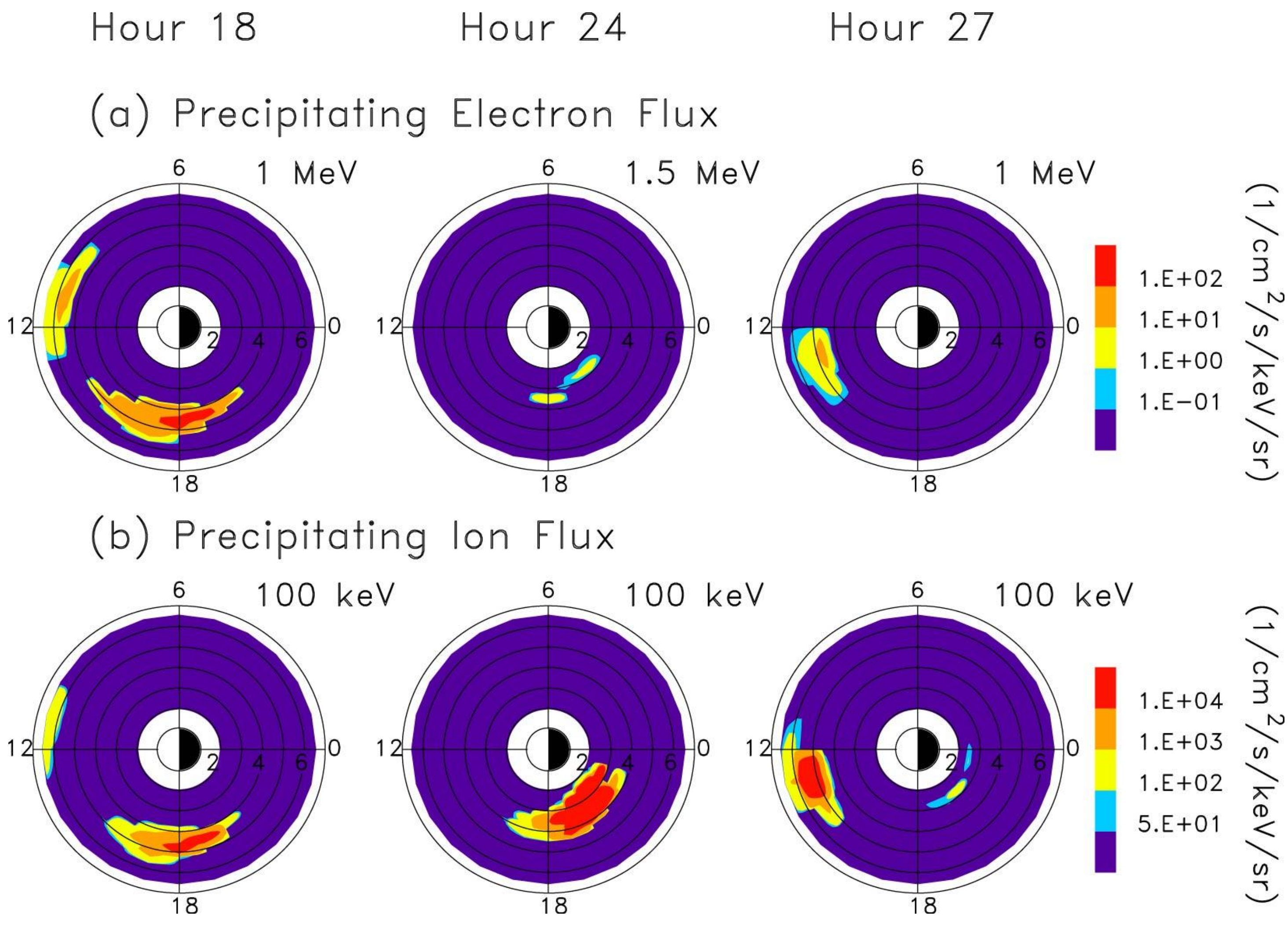
EMIC
Wave Gain

EMIC
Wave Amplitude

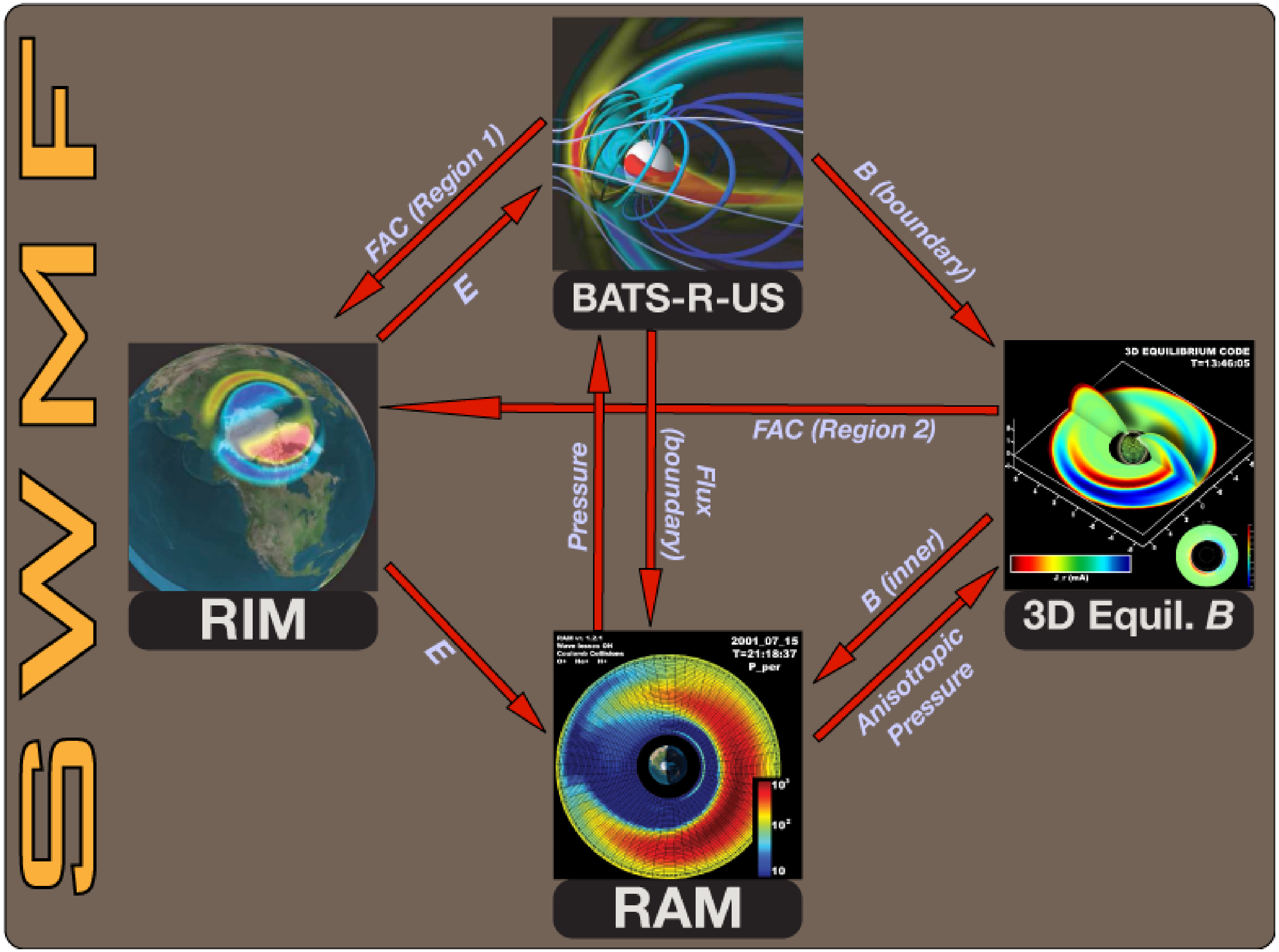
Plasmaspheric
Electron Density



Precipitating 1 MeV electron and 100 keV ion fluxes as a function of L, LT, and time



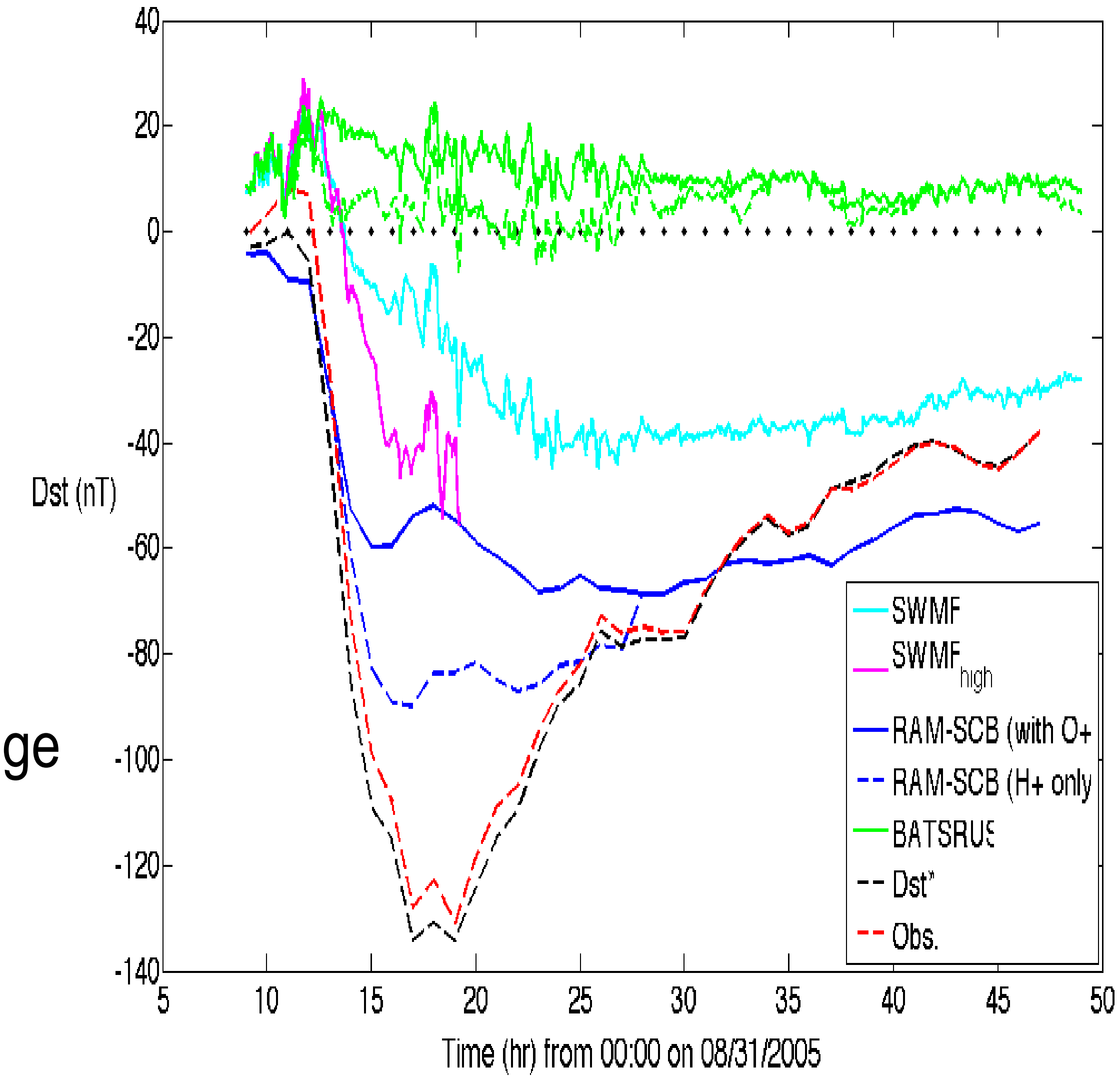
RAM-SCB and the SW Modeling Framework



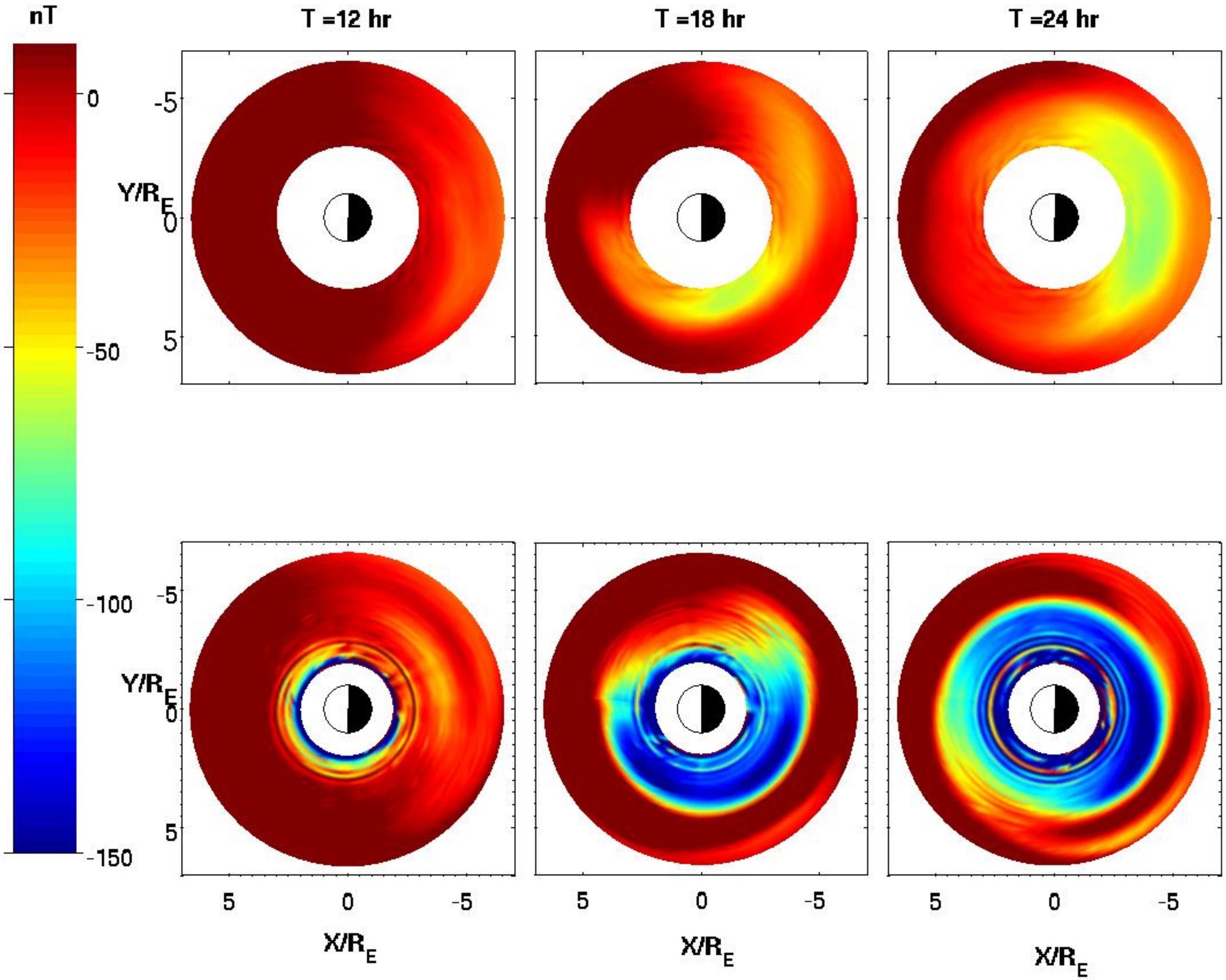
1-way coupling has been demonstrated
2-way is in development

Realistic calculation of ring current is the first step for calculation of Region 2 currents

- BATSRUS ~ zero Dst
- RAM-SCB - stronger RC than SWMF (BATSRUS+RCM)
- Including O+ implies fewer ions and weaker Dst
- E-field very strong in recovery phase– will change with shielding
- Tail current (> 6.6 R_E) not included (~ 30% of Dst?)



RAM-SCB equatorial B field is much lower and has more structure than SWMF

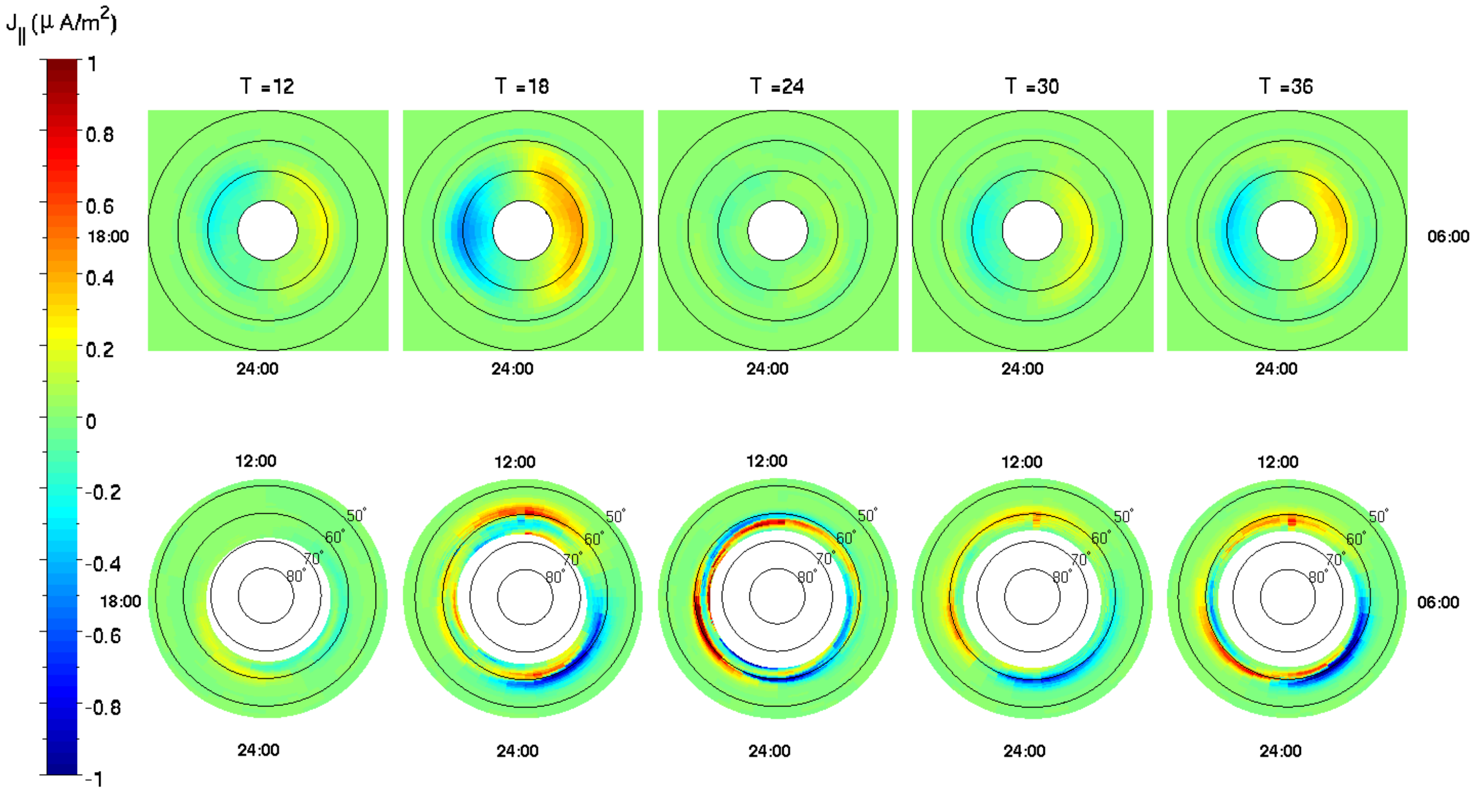


SWMF

RAM-SCB

Artifacts at L<3.5 are due to imperfect model grid matching

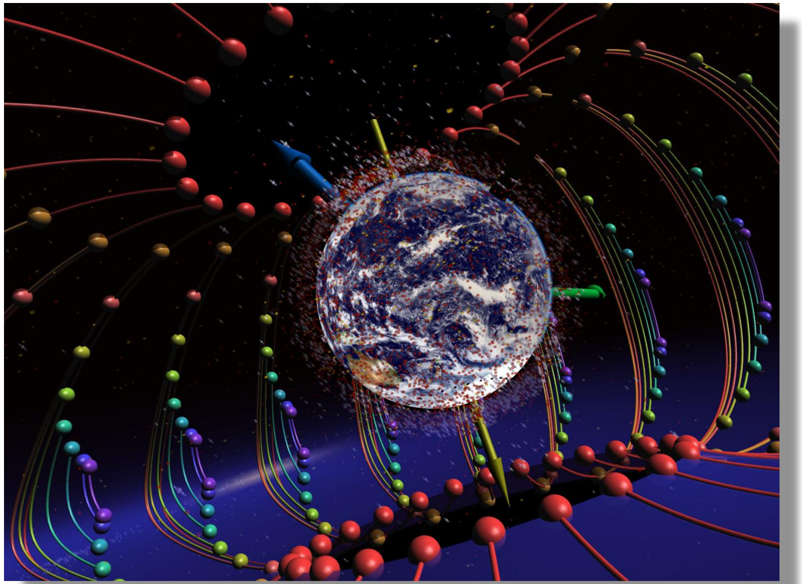
Realistic calculation of ring current pressures and B produce very realistic R2 currents



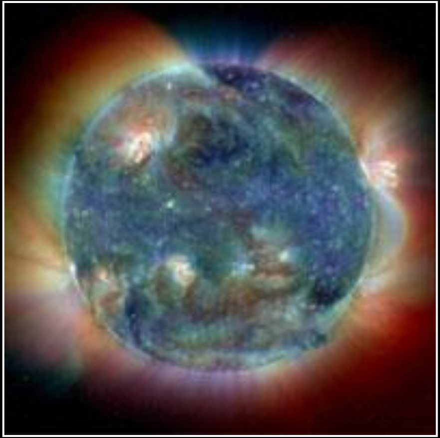
- *3D equilibrium code calculates currents from pressure gradients and force-balanced B-field*
- *much sharper resolution (field line inter-distance increases toward Earth)*
- *SWMF – R-1 currents; very small R-2 currents no shielding*
- *RAM-SCB: R-2 currents at lower latitudes; some R-1 currents higher*

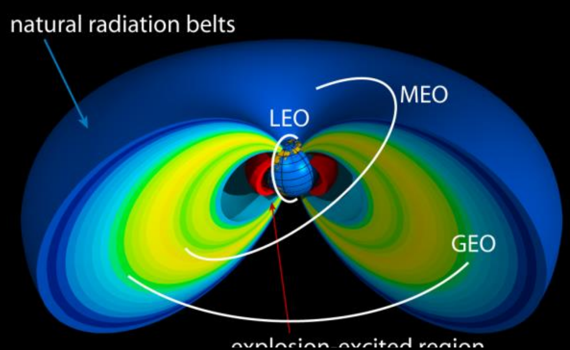
DREAM at LEO : Conclusions

- Extrapolating global radiation belt models to LEO is complex
- Assimilating LEO fluxes into a global model could produce large (>10^3) errors if not done properly
- "Properly" means considering dependence on energy, local time, geomagnetic activity, magnetospheric regions…
- Local pitch angle information hugely helps understand different behavior in trapped, bounce-loss, & drift-loss cones
- LEO measurements (if any) help more than just LEO satellites



DREAM





Los Alamos
NATIONAL LABORATORY
EST. 1943