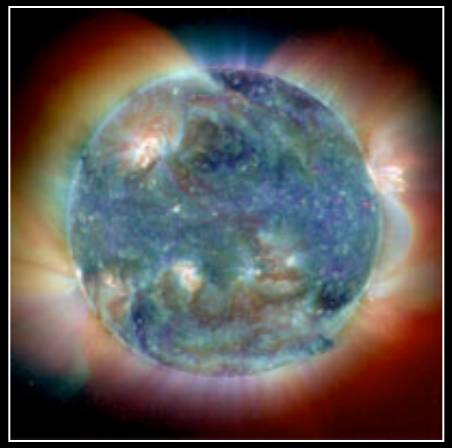
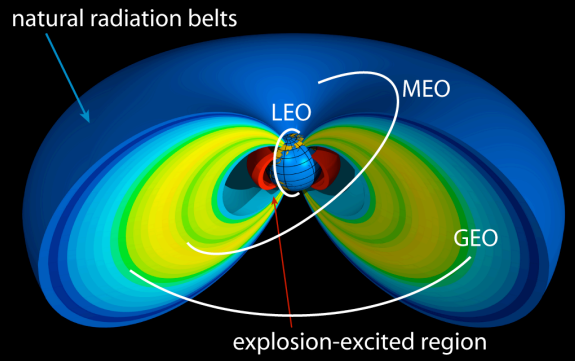
DREAM

The Dynamic Radiation Environment Assimilation Model

J. Koller
G.D. Reeves, R. L. Tokar, Y. Chen, M. G. Henderson, and R. H. W. Friedel





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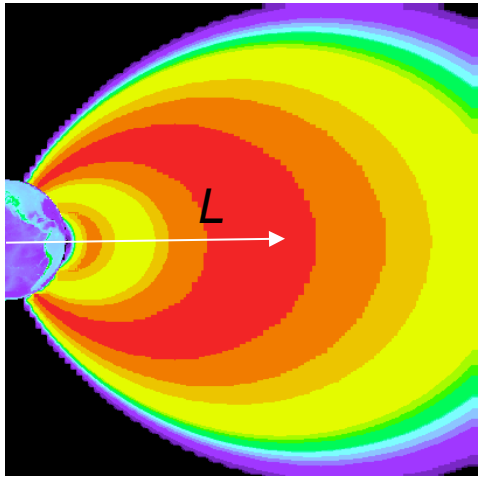
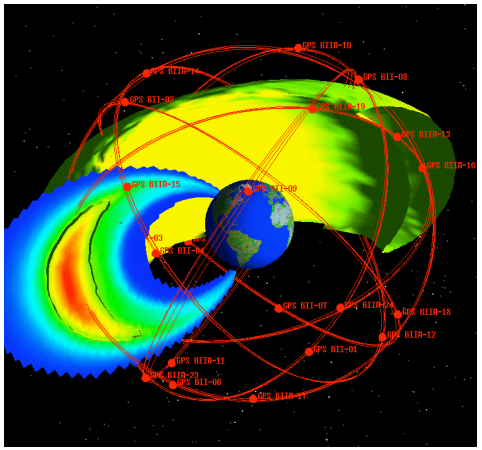
Radiation Belt Fluxes change dramatically but standard models are static or statistical

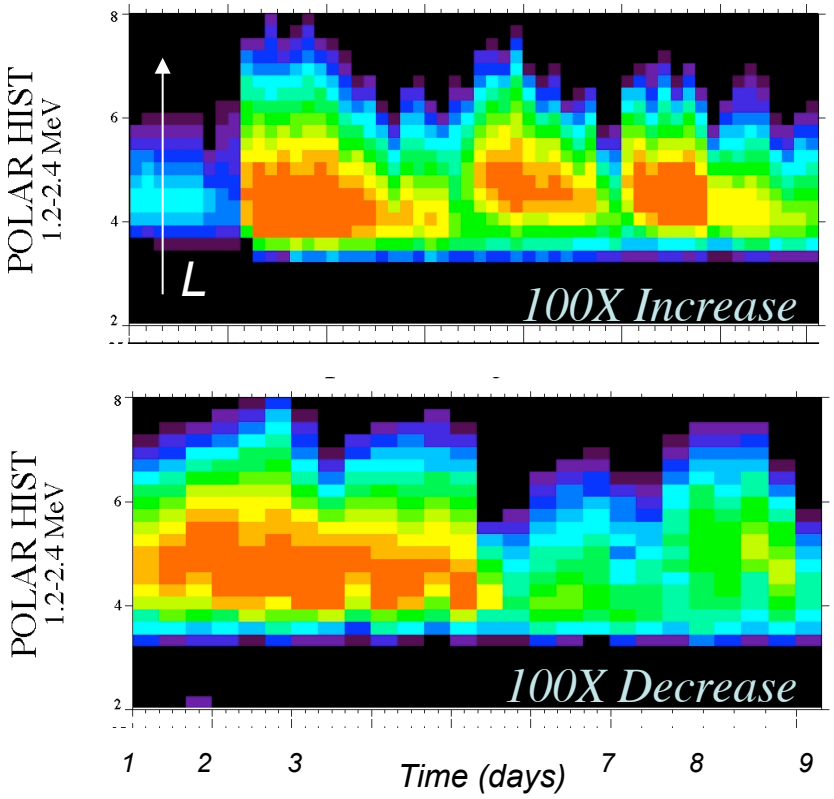
- *AE8 - static*



- *CRRES - statistical*

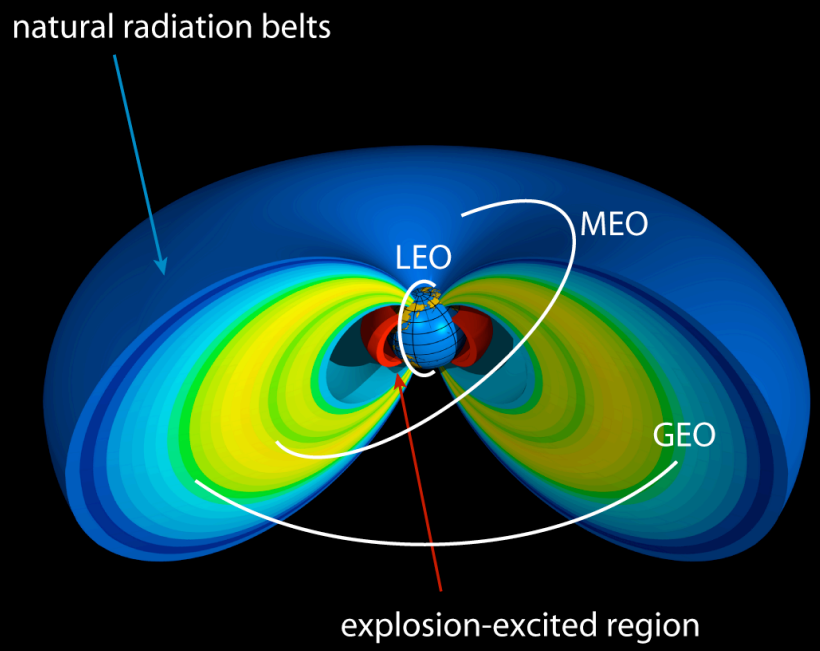


- *Observations - dynamic*



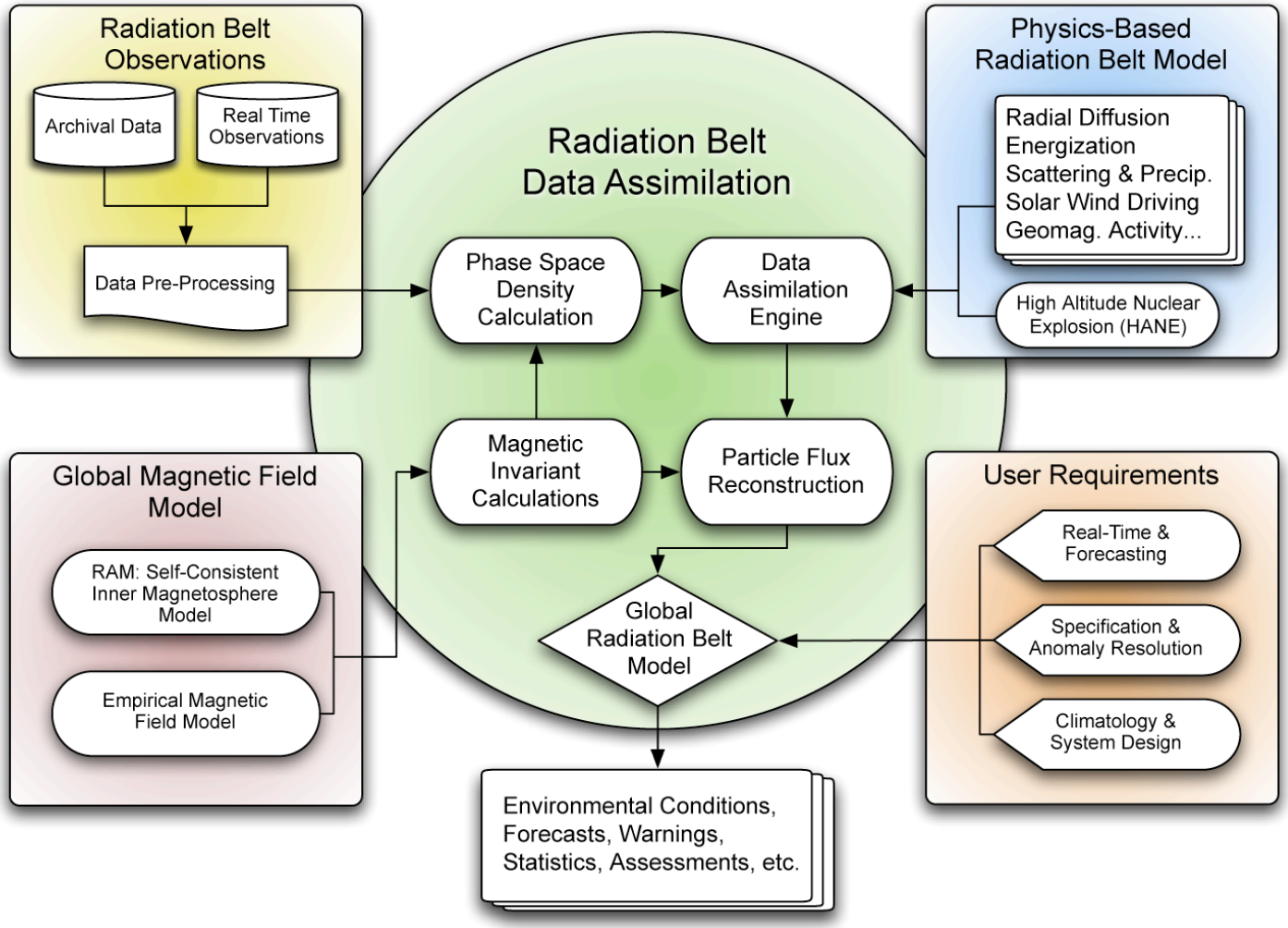
Intensities change by up to 1000x
Different changes at different energies
Different changes at different locations

DREAM: The Dynamic Radiation Environment Assimilation Model

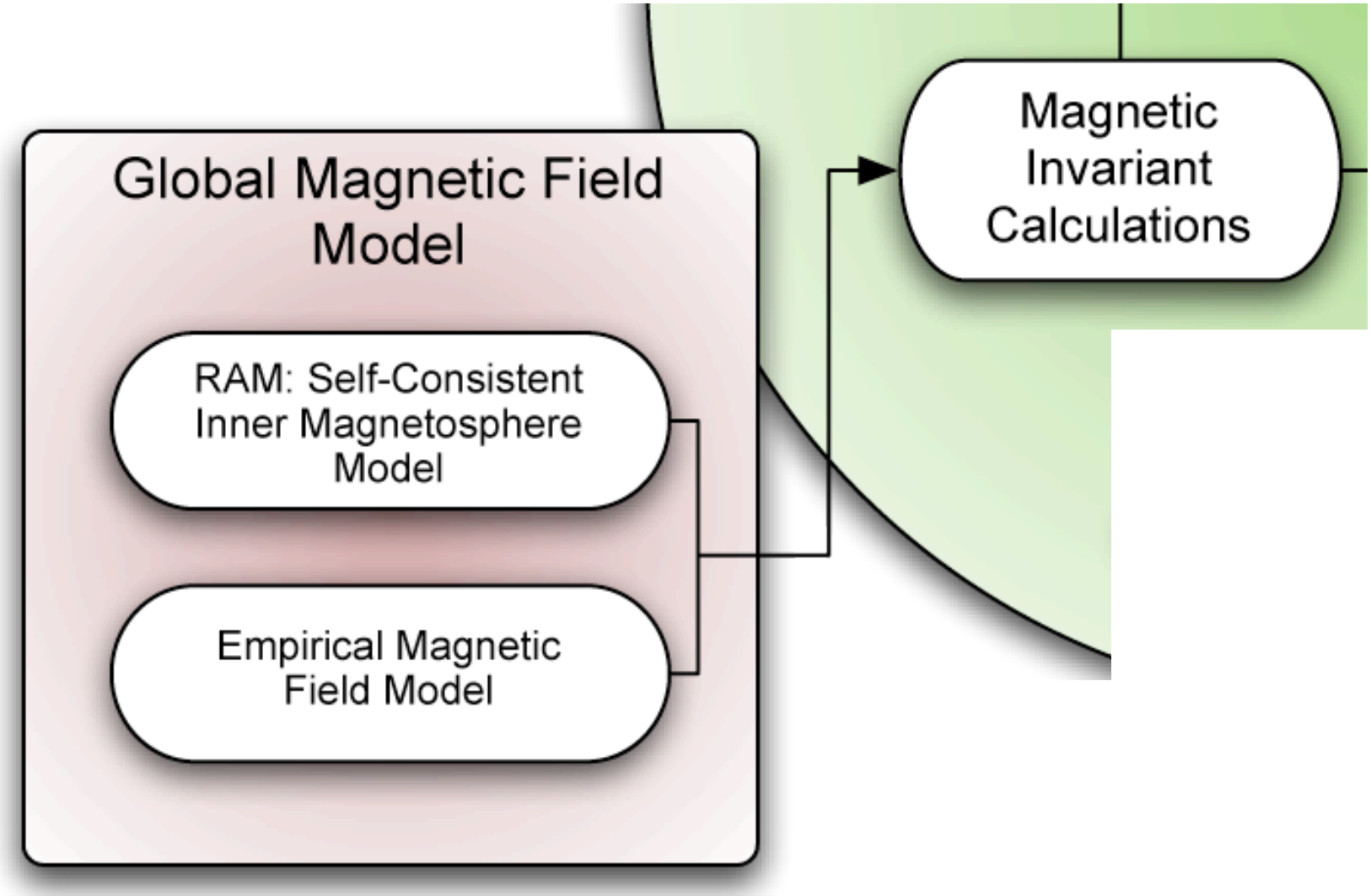


- Developed by LANL to quantify risks from natural and nuclear belts
- Uses Data Assimilation with GEO, GPS and other observations
- Couples ring current, magnetic field, and radiation belt models
- Goals: Specification, Prediction, Understanding

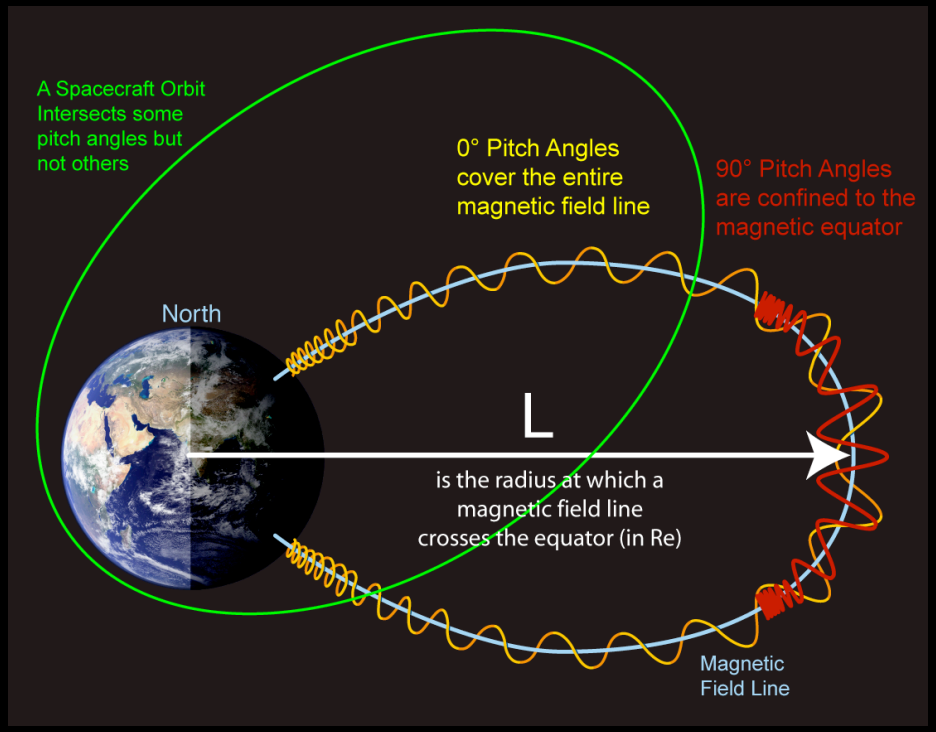
DREAM Computational Framework

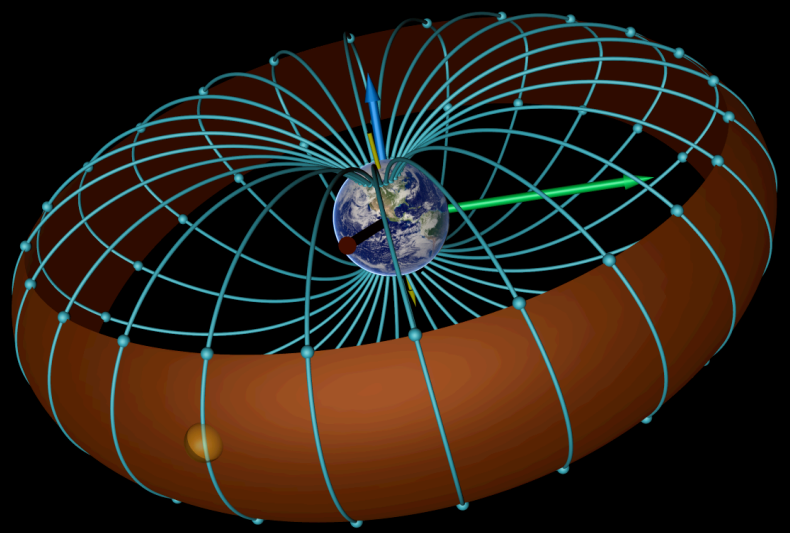


DREAM Computational Framework



The magnetic field defines particle motion

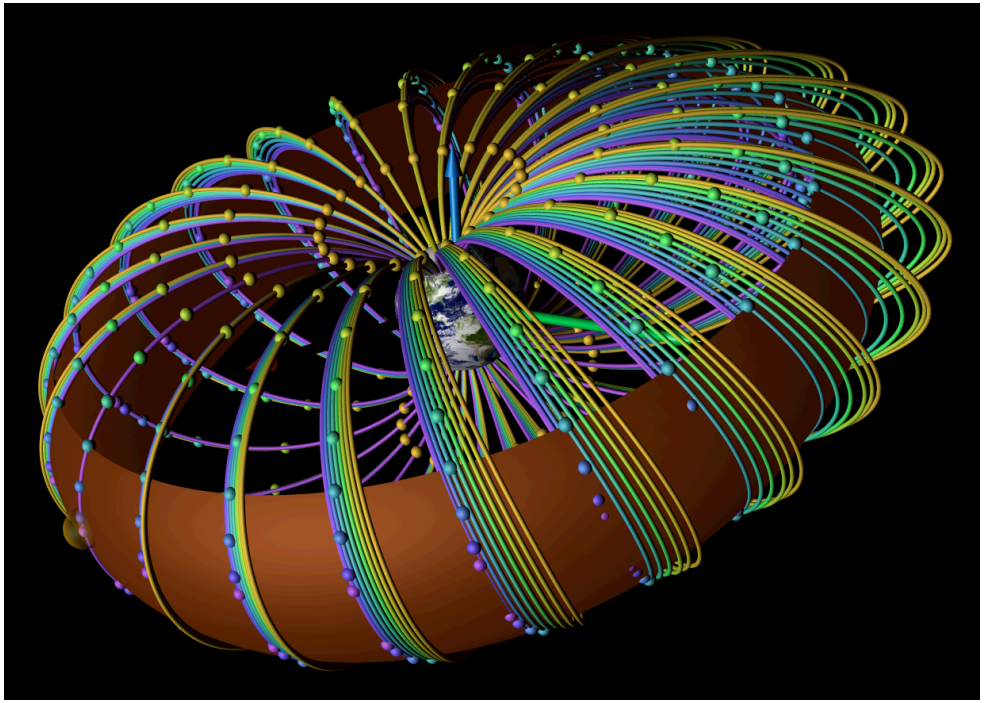




- Fastest (ms): gyration around the magnetic field
- Medium (sec): bounce along the magnetic field between the magnetic mirror points
- Slowest (min-hr): drift around the Earth along a “drift shell” or “L-shell”

Accurately calculating the third adiabatic invariant (L*) is a big part of DREAM

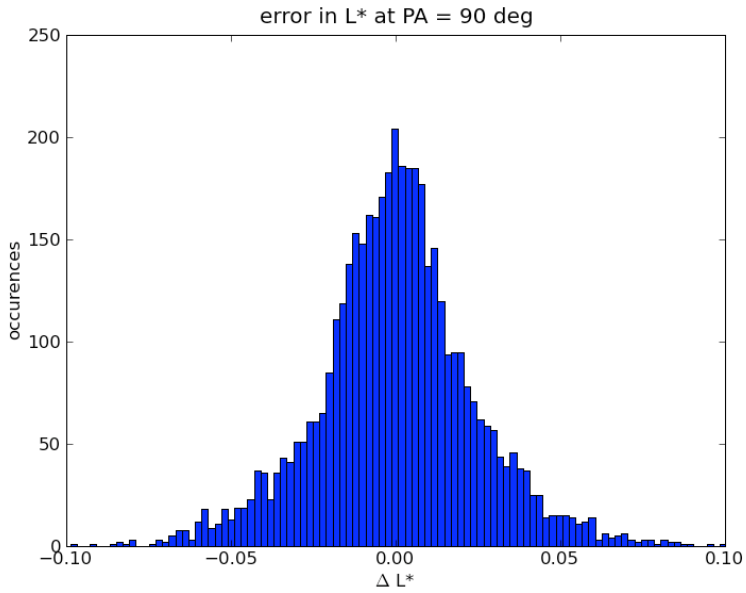
- In a dipole field L is independent of energy or pitch angle and is uniquely defined for a point in space
- In a real field L* does depend on energy and pitch angle and L* changes even for a fixed location



LANL* can calculate accurate drift shells six orders of magnitudes faster.

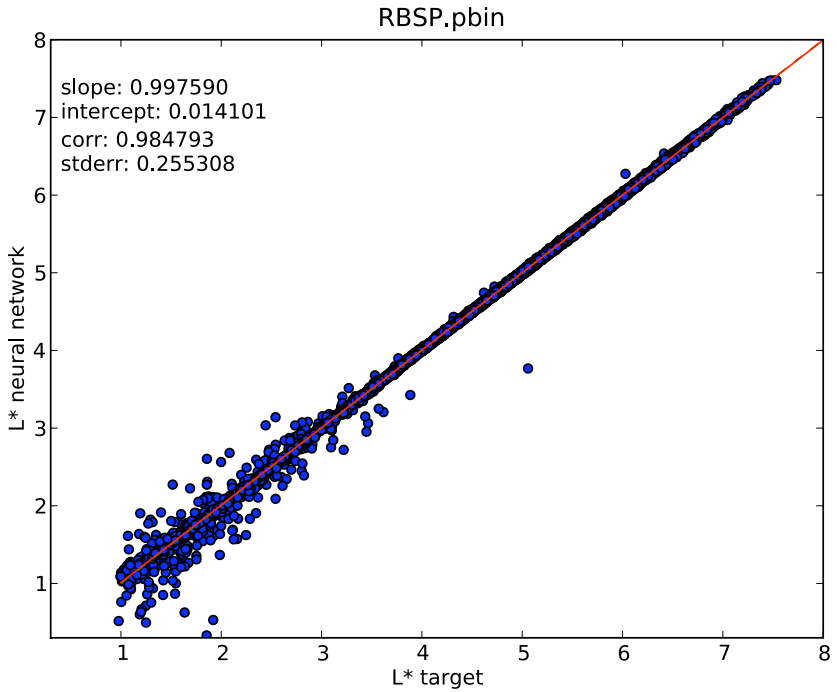
- based on a neural network technique replacing time-consuming drift shell integrations
- LANL* V2.0 based on Tsyganenko 2004 model
- trained on a whole solar cycle and larger spatial range 1.5 < Re < 10
- error less than 2%
- Project website: http://lanlstar.lanl.gov

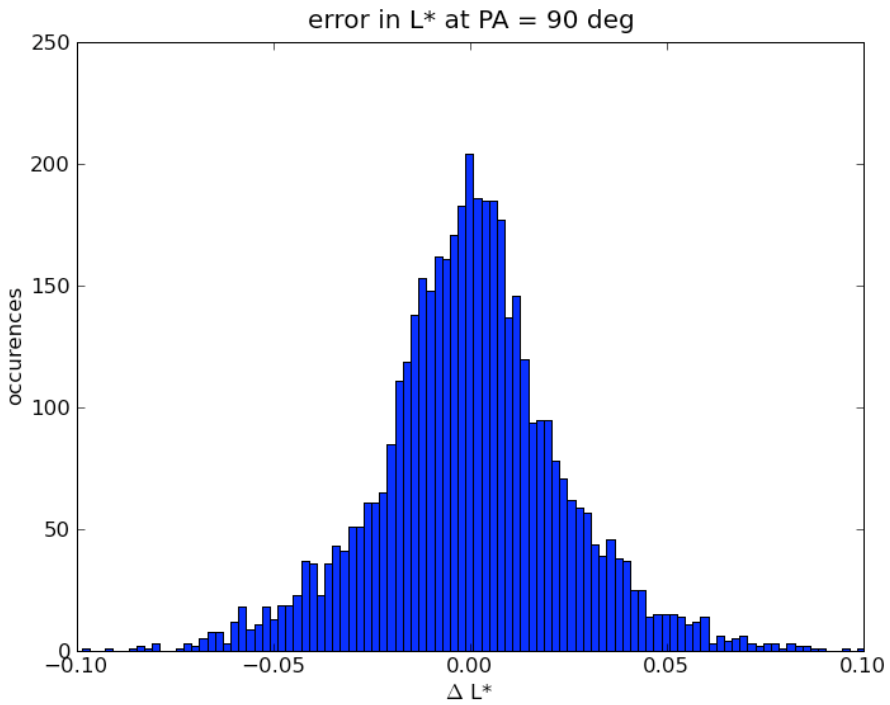
$$\mathbf{y} = \mathrm{f}^1\left(\mathbf{W}^1\,\mathrm{f}^0\left(\mathbf{W}^0\mathbf{x} + \mathbf{b}^0\right) + \mathbf{b}^1\right)$$



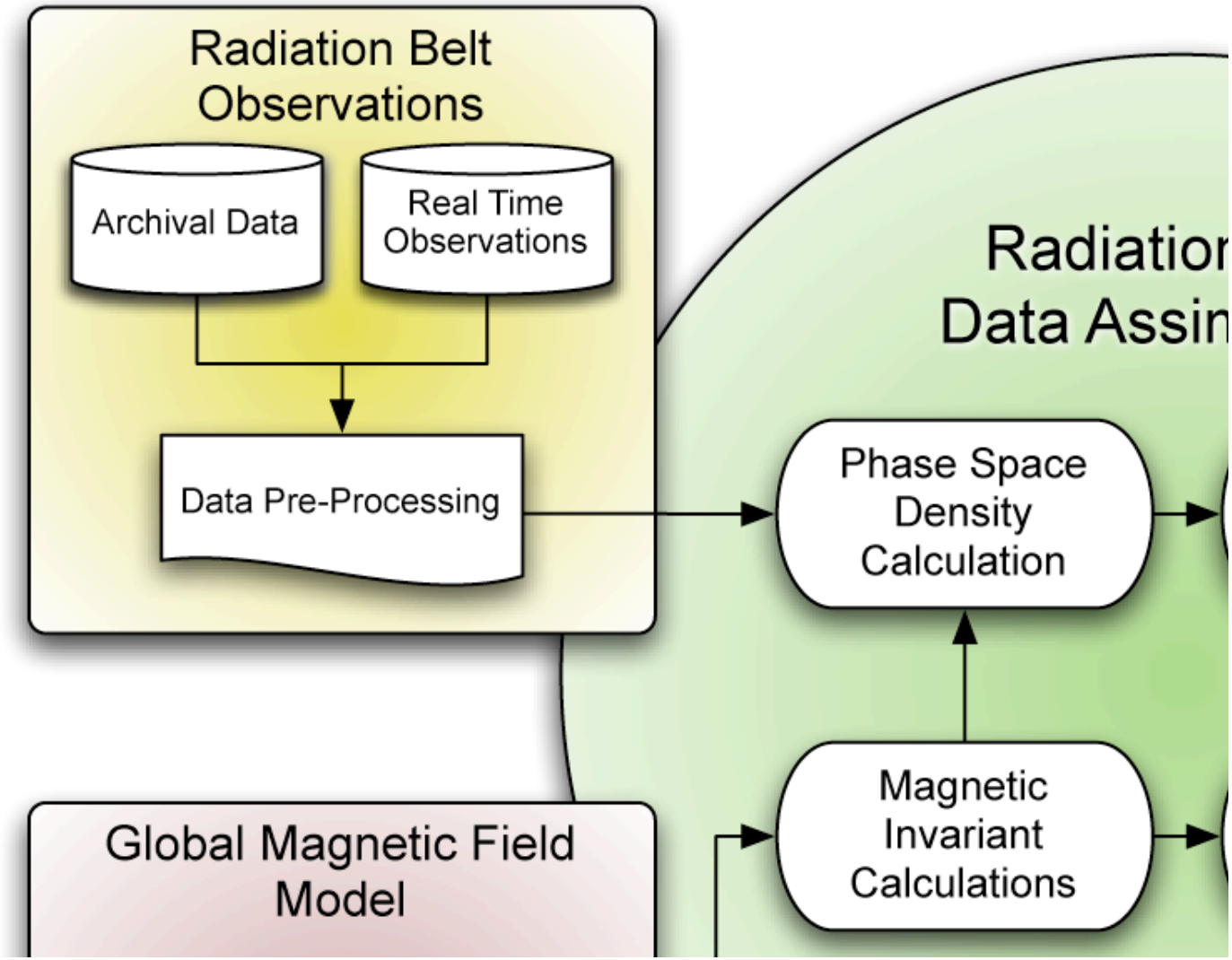
RBSP drift shells calculated in a few seconds for 5 min cadence

Model	time to calc. L* for RBSP
Tsyganenko and Sitnov [2005]	146 days
LANL V2*	12 secs





Observations + Magnetic Invariants => Phase Space Densities



Observations are in Flux
Physical equations use phase space density

Phase Space Density (PSD)

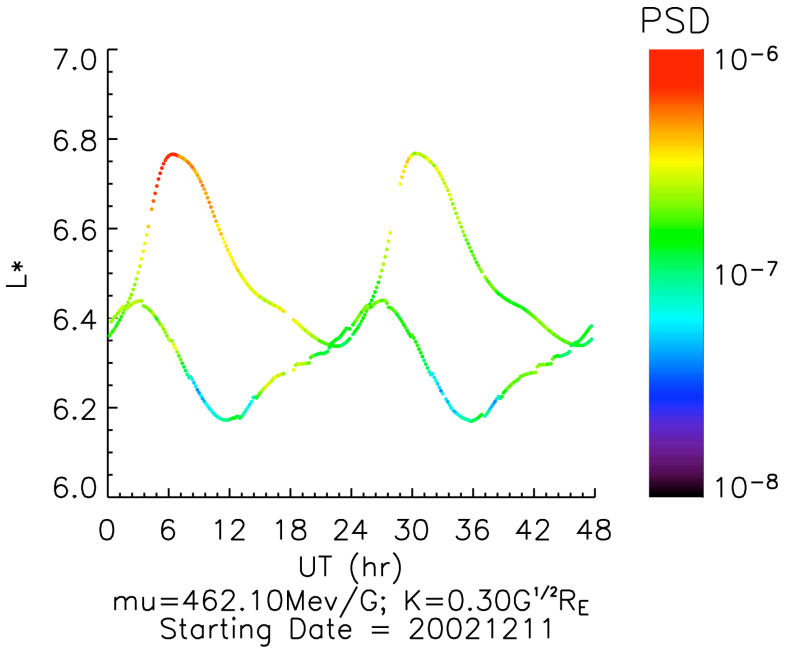
$$f = \frac{j}{p^2}$$

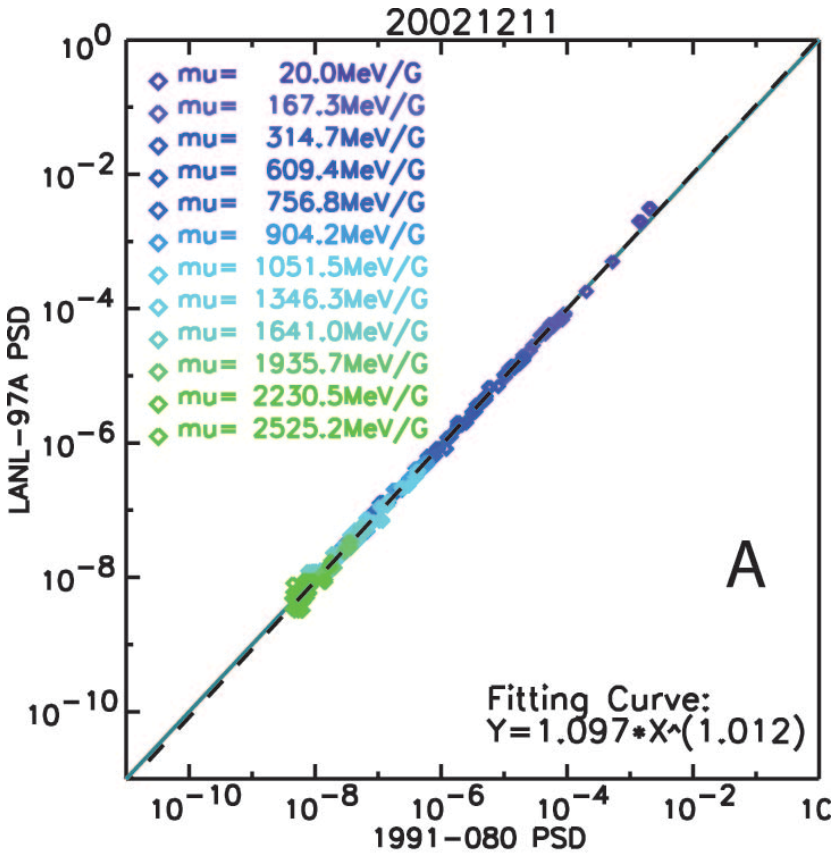
Equations of Motion
e.g. Radial Diffusion

$$\frac{\partial f}{\partial t} = L^2 \frac{\partial}{\partial L}\left(\frac{D_{LL}}{L^2}\frac{\partial f}{\partial L}\right)$$

- The conversion from flux (as a function of energy and location) to PSD (a a function of magnetic invariants) is a critical step in radiation belt modeling
- This conversion must also be reversed at the end to get predictions in physically-relevant quantities (e.g. dose)

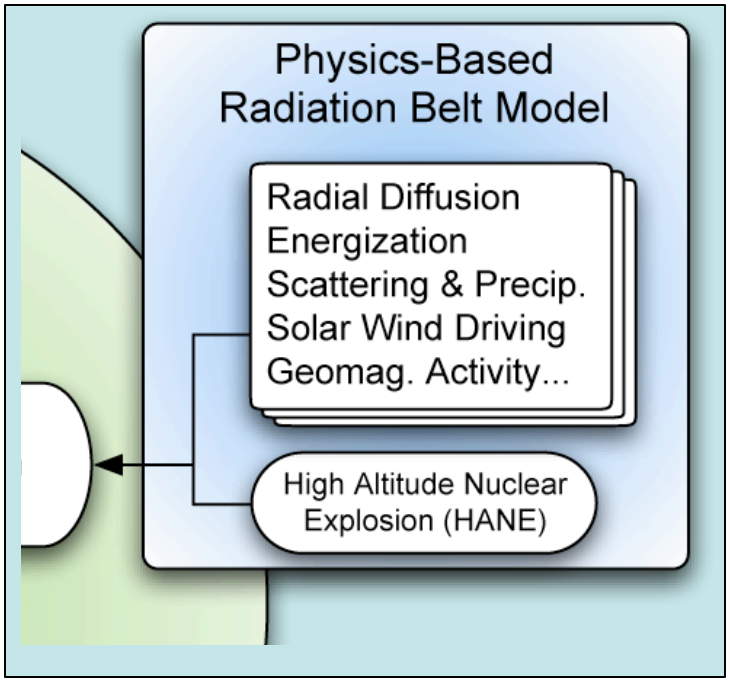
Pre-Processing data is a critical component. e.g. we also use PSD for calibration & validation

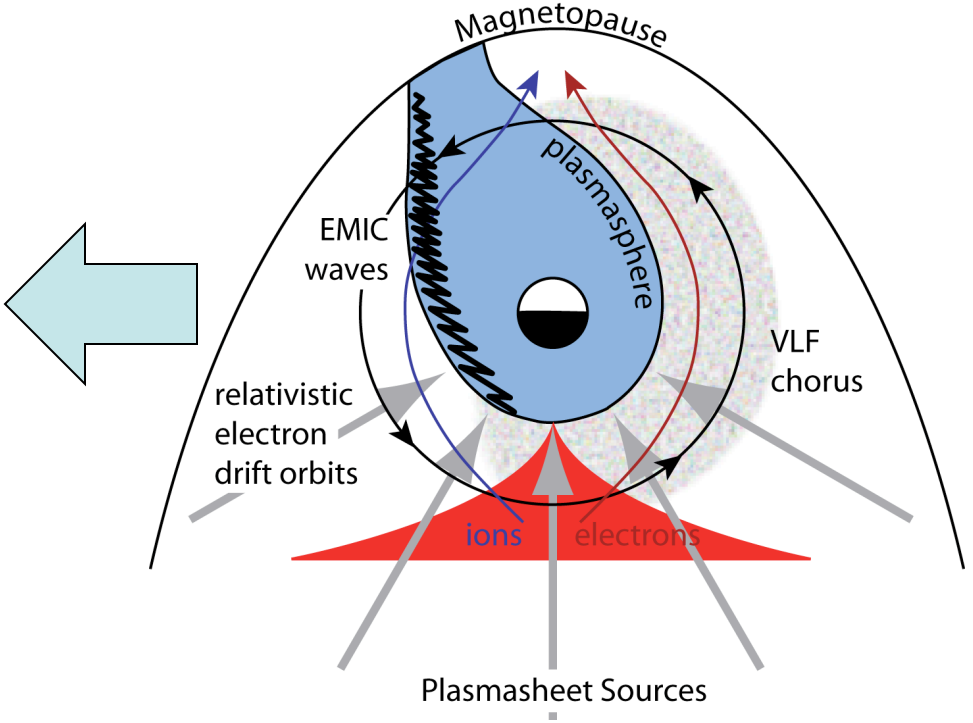




- "PSD Matching" tests both the intercalibration and the accuracy of the L* calculation

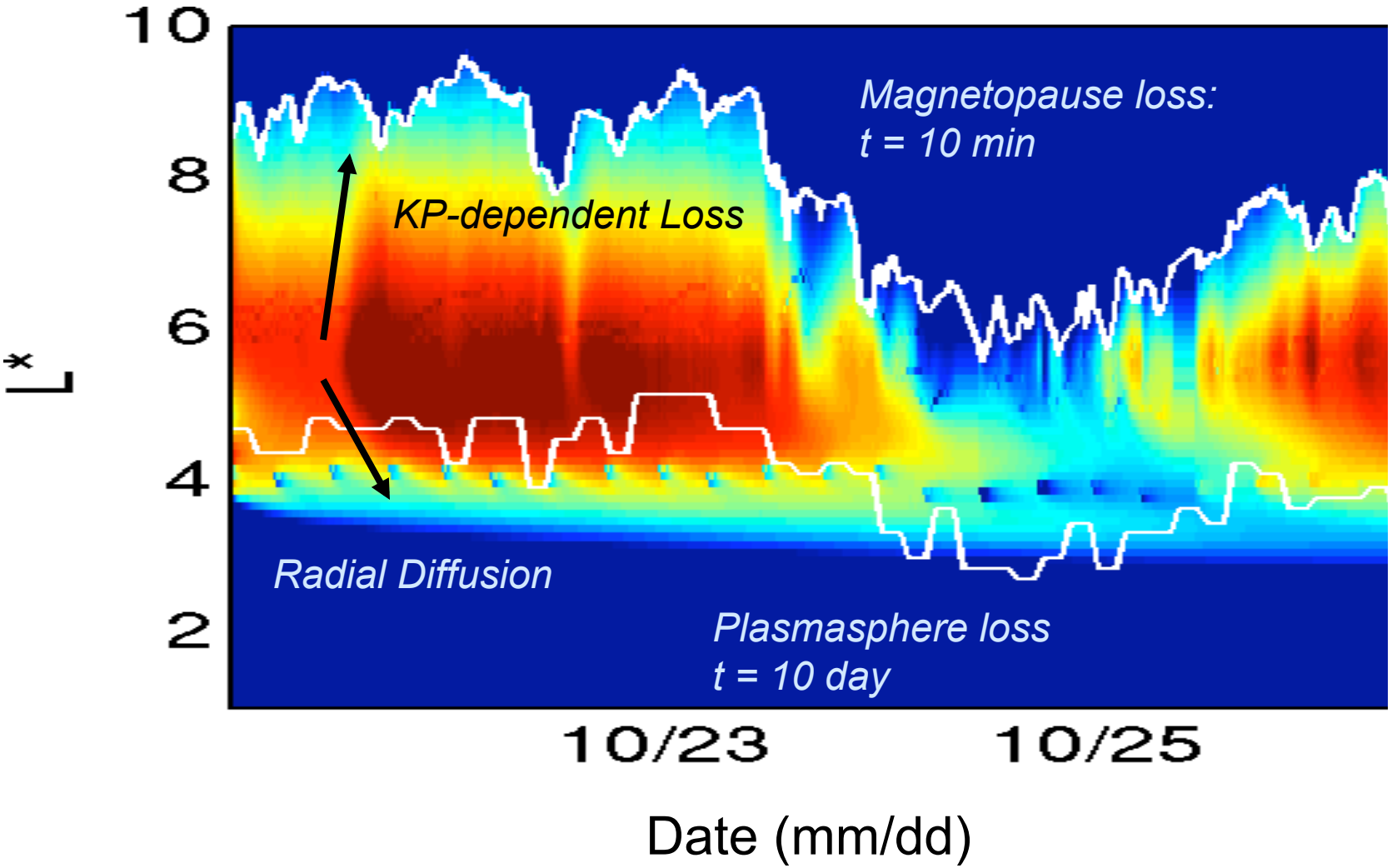
DREAM Computational Framework
Physics Models



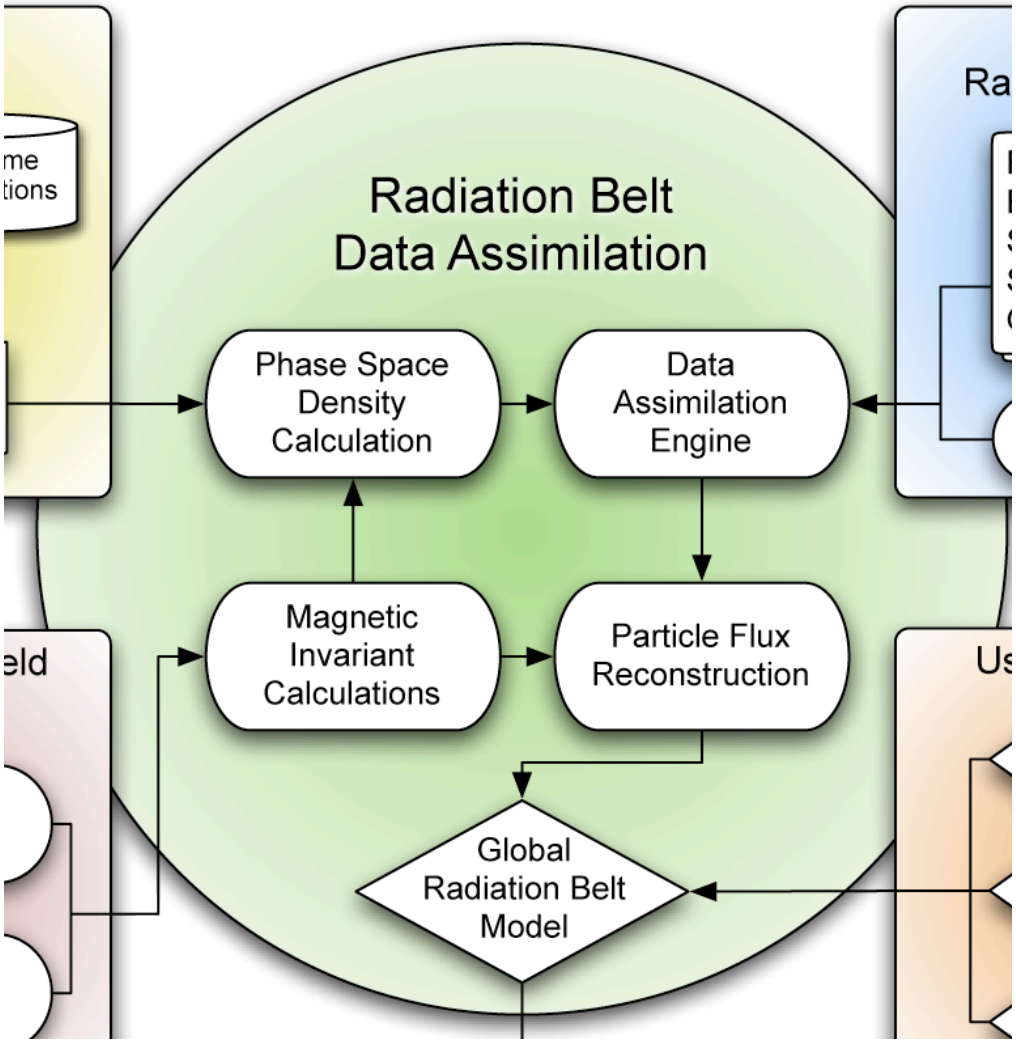


- DREAM can use physics models with various levels of physical and computational complexity
- But, physics models alone can not yet make accurate predictions

Phase Space Density as a function of L* and Time

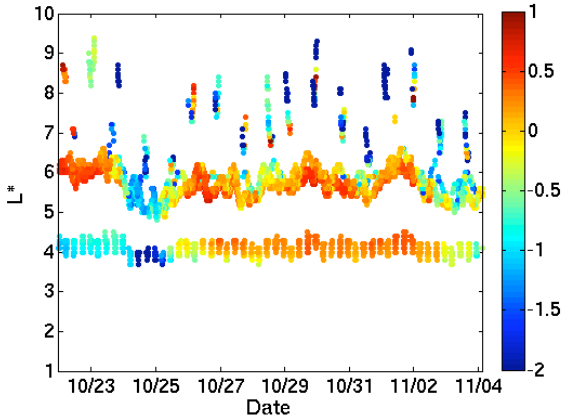


DREAM Computational Framework
Data Assimilation

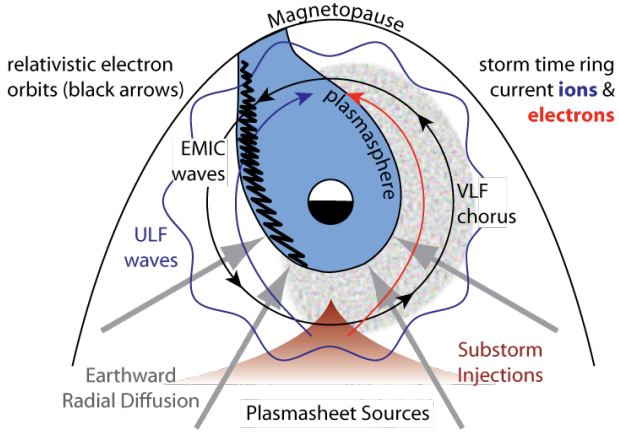


Data Assimilation turns sparse observations into global, data-driven solutions

Sparse and/or Heterogeneous Observations



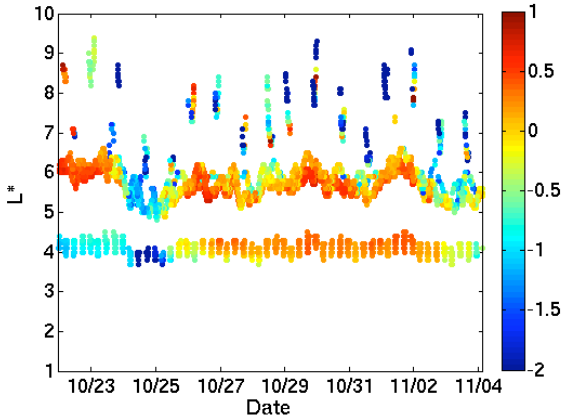
Complex Physical System



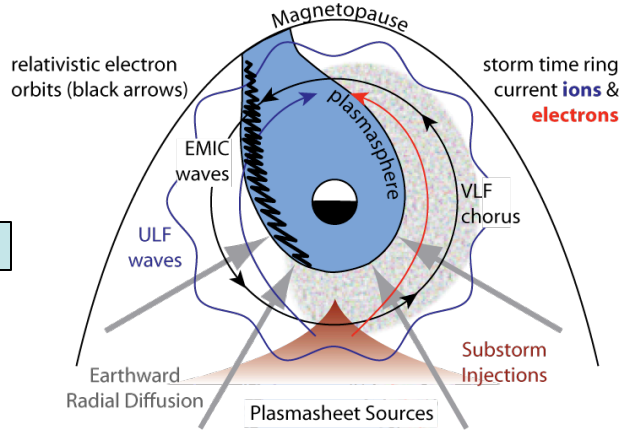
- Data Assimilation methods such as Kalman Filtering are techniques to combine physical models with sparse or conflicting data to produce optimized global solutions. The assimilation, or ‘reanalysis’, gives information not present in the model or measurements alone

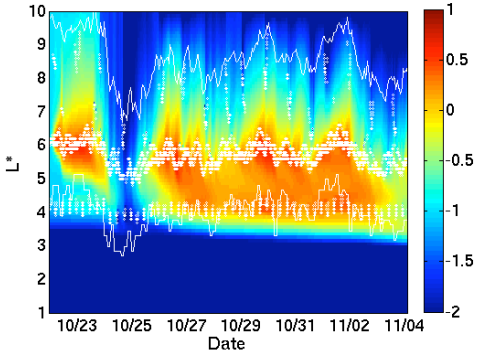
Data Assimilation turns sparse observations into global, data-driven solutions

Sparse and/or Heterogeneous Observations



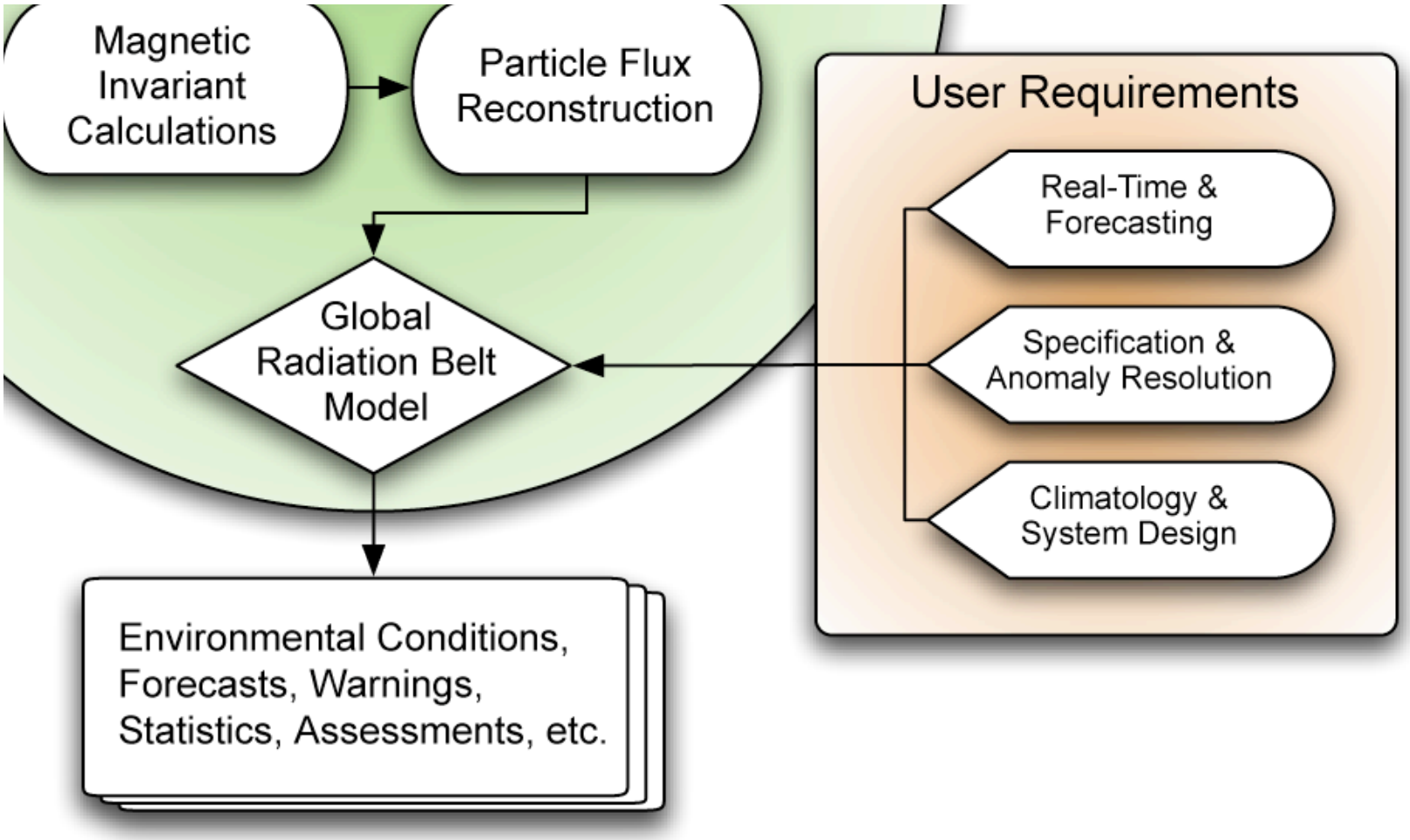
Complex Physical System





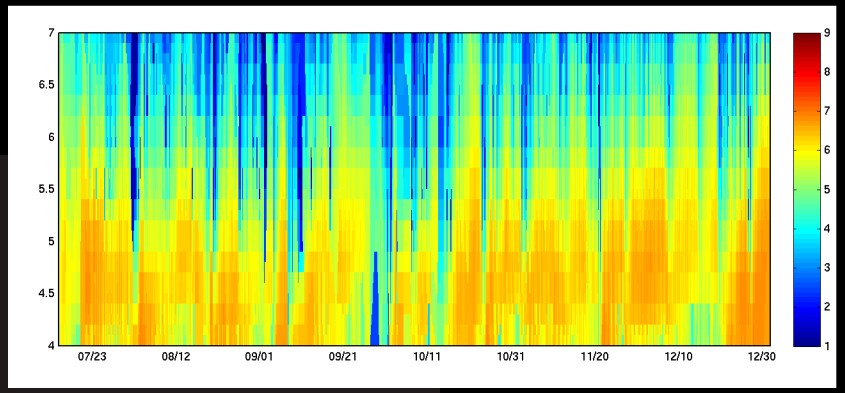
Global, Real-Time Data-Driven Solution

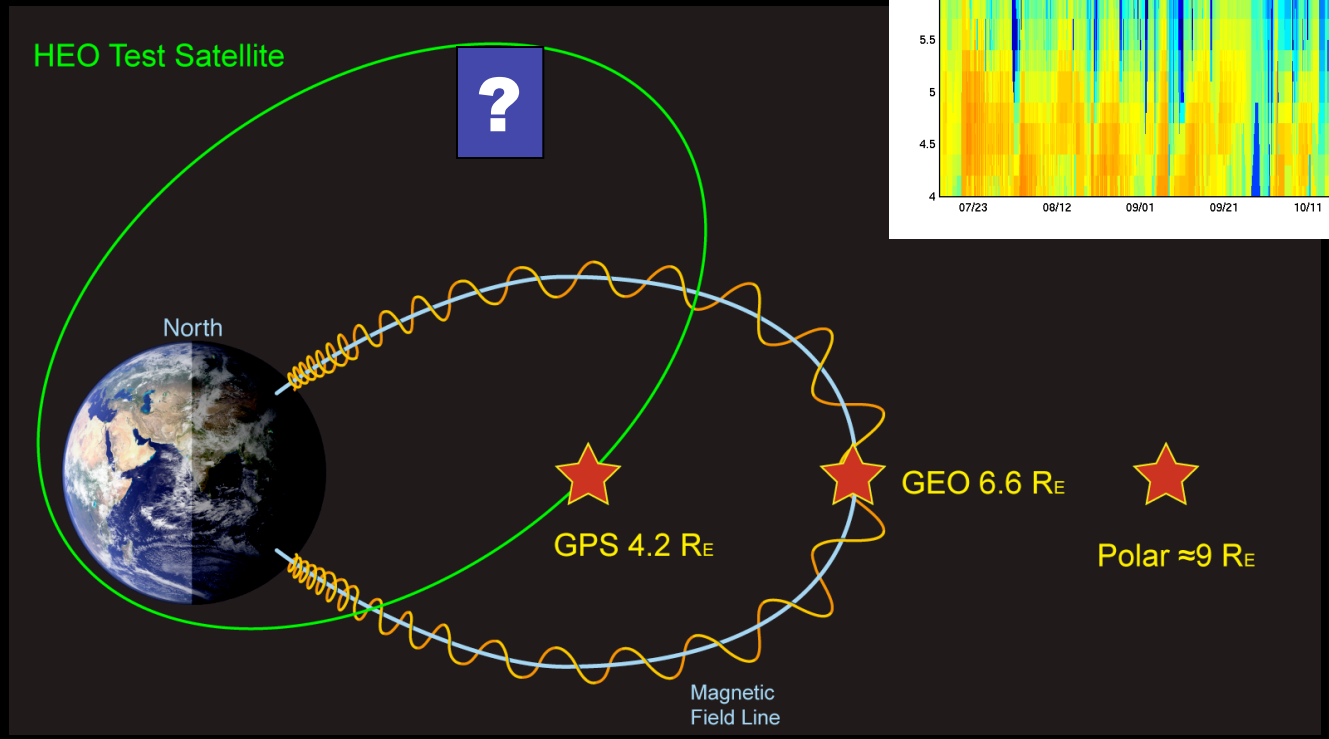
DREAM Computational Framework Validation and Applications



Prediction of flux in different satellite orbits

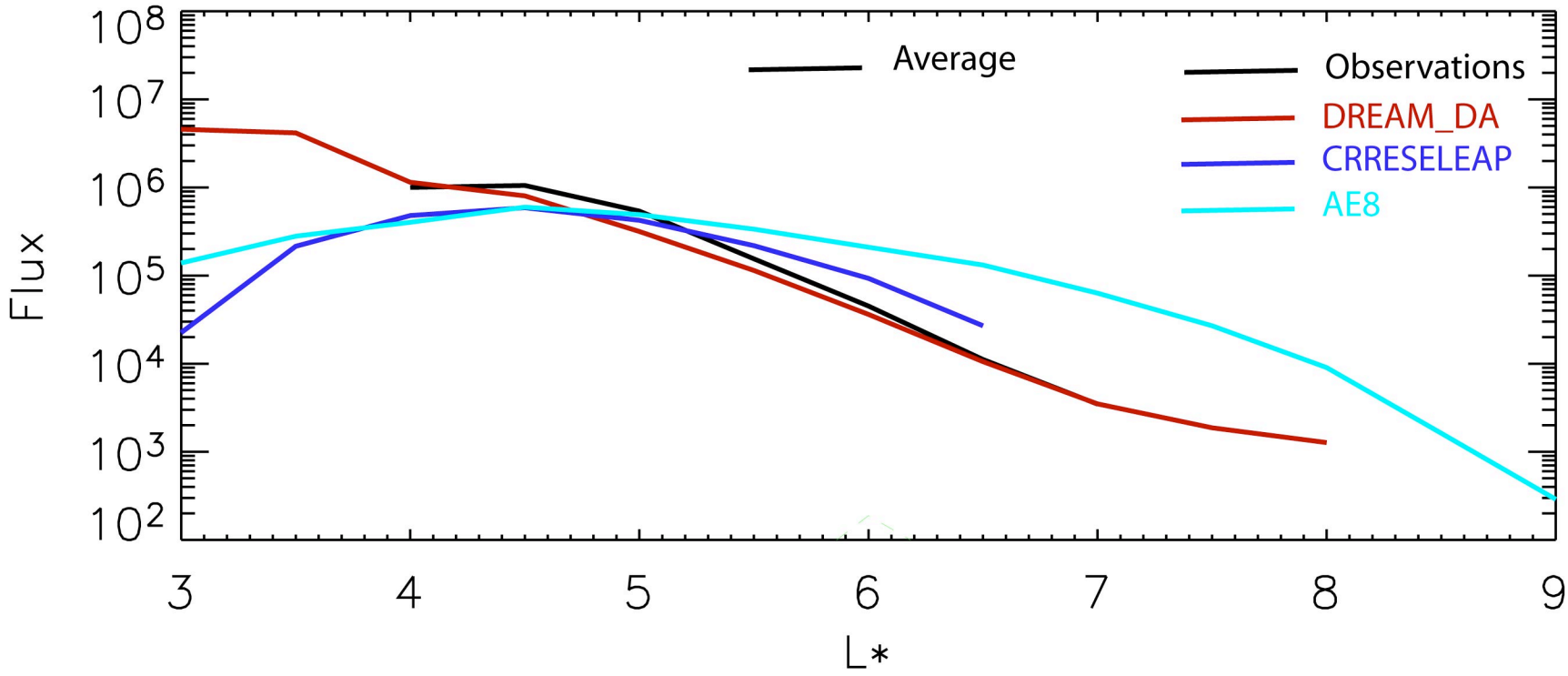
~ 1 MeV electron flux at HEO-3



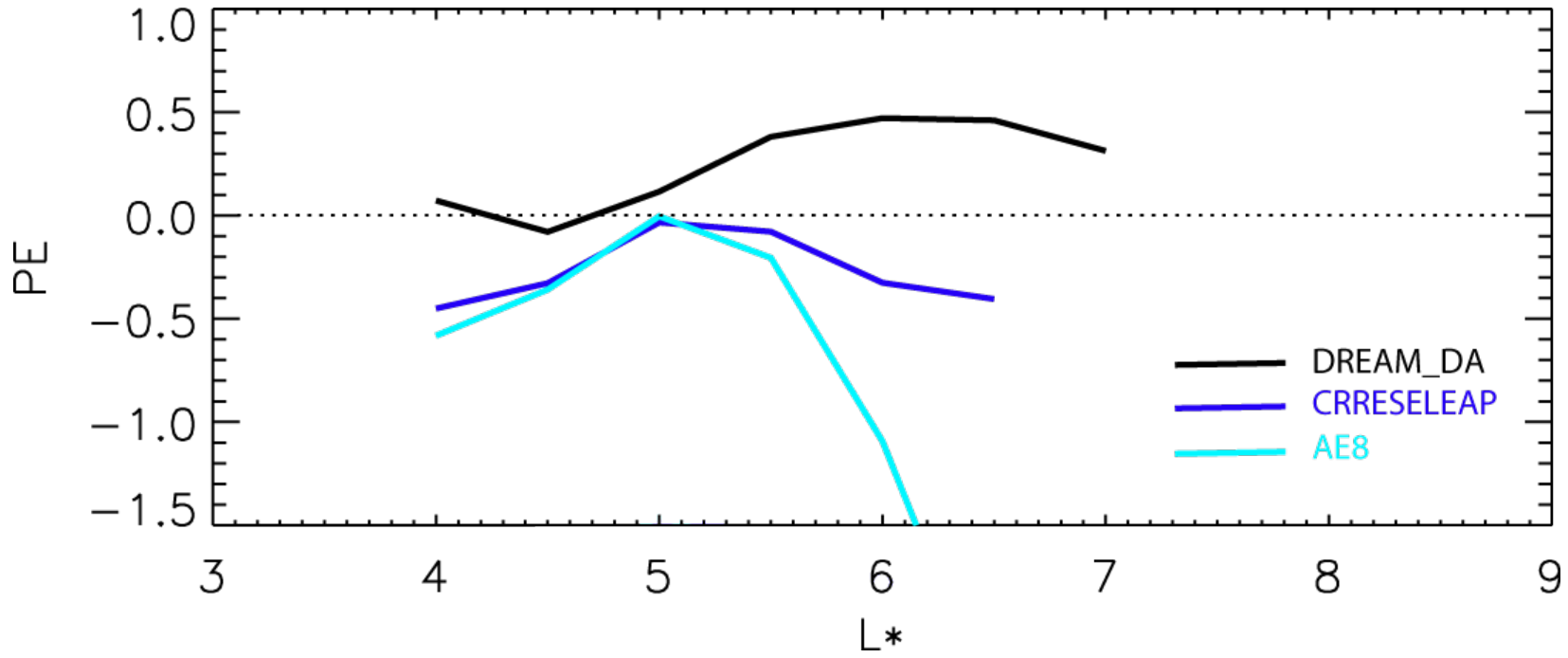


HEO is a different orbit and is not used as input to DREAM

Validation 1:
Average Flux vs Altitude

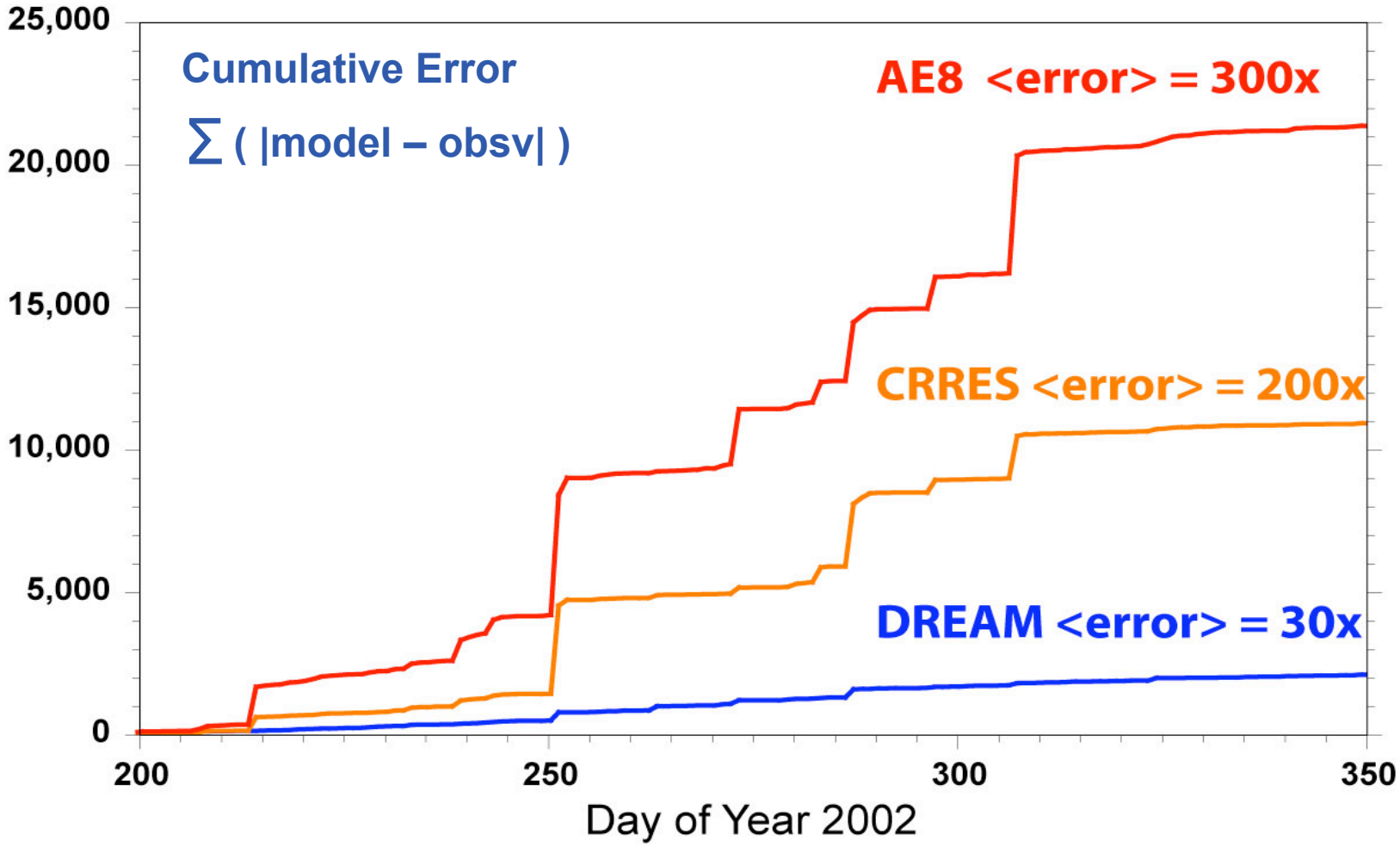


Validation 2: Prediction Efficiency testing variation around the mean

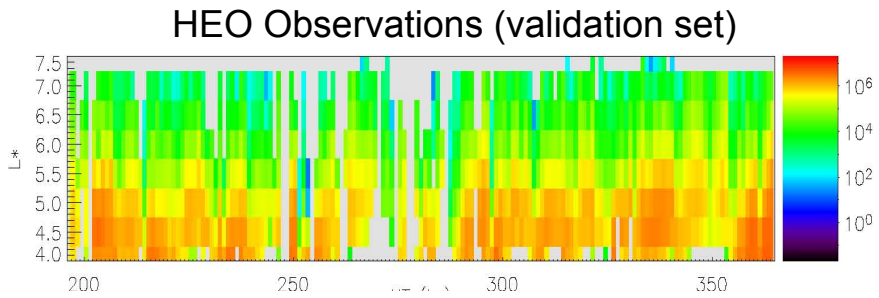


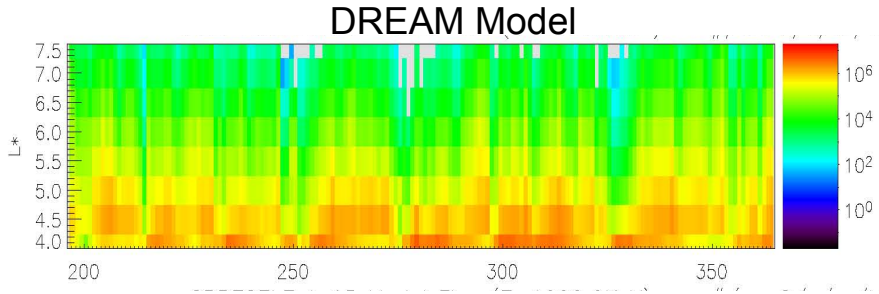
$$PE = 1 - \frac{\Sigma\ (\text{model} - \text{obsv})^2}{\Sigma\ (\text{obsv} - \langle \text{obsv} \rangle)^2}$$

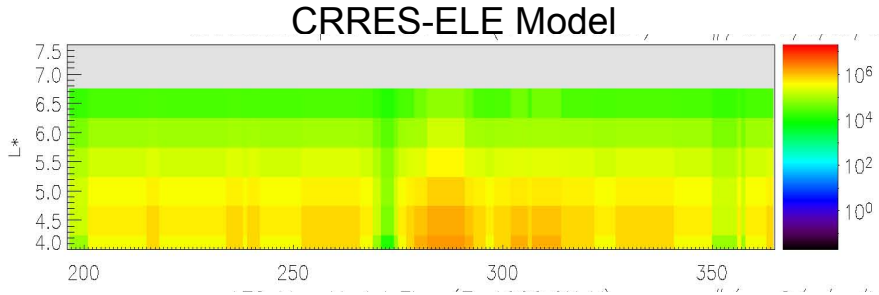
Validation 3: Average absolute error
DREAM gives ~10x improvement

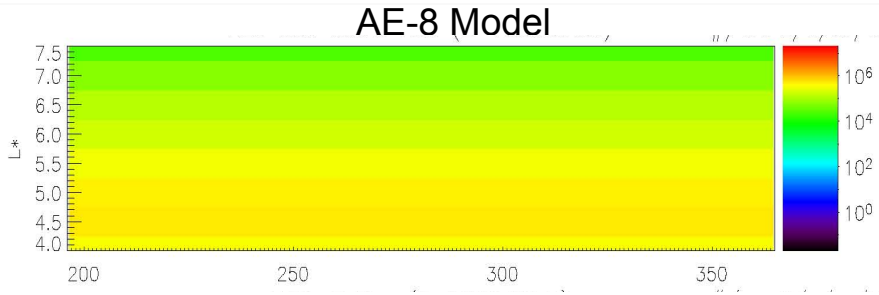


Flux vs L*, Time (1 MeV)

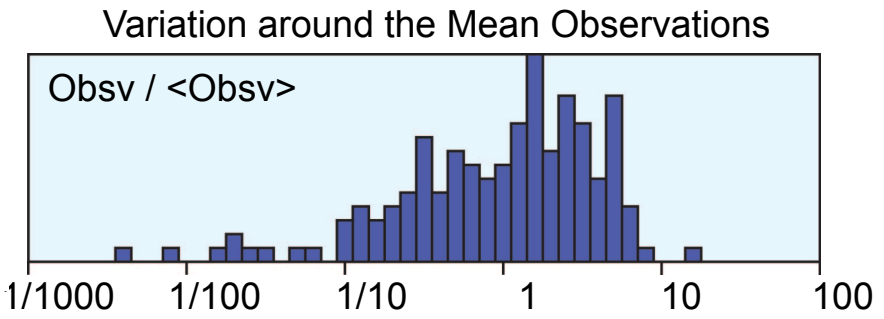


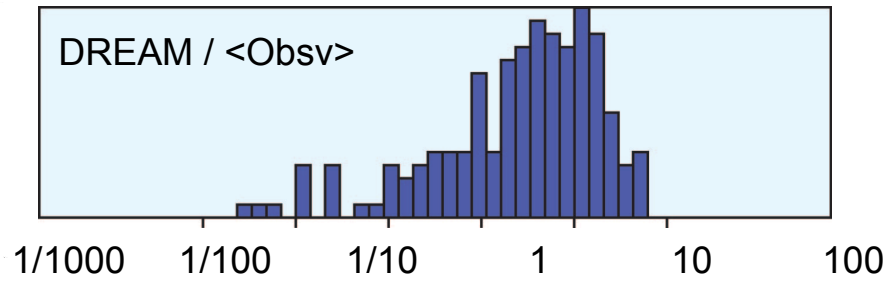


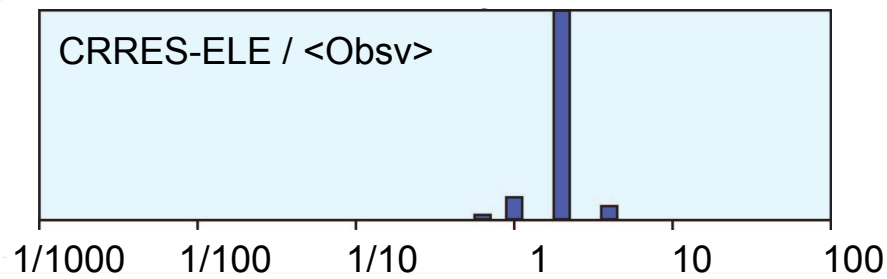


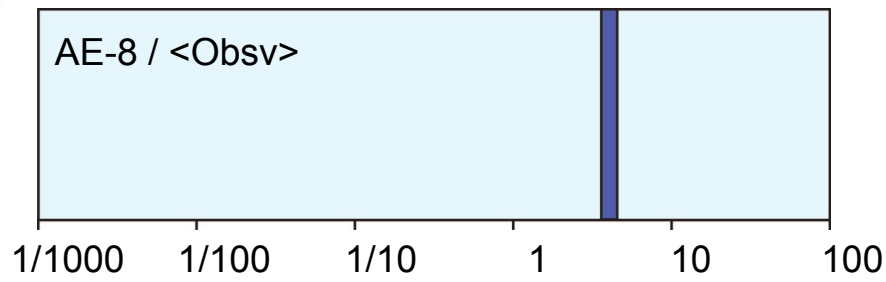


Distribution at L*=6



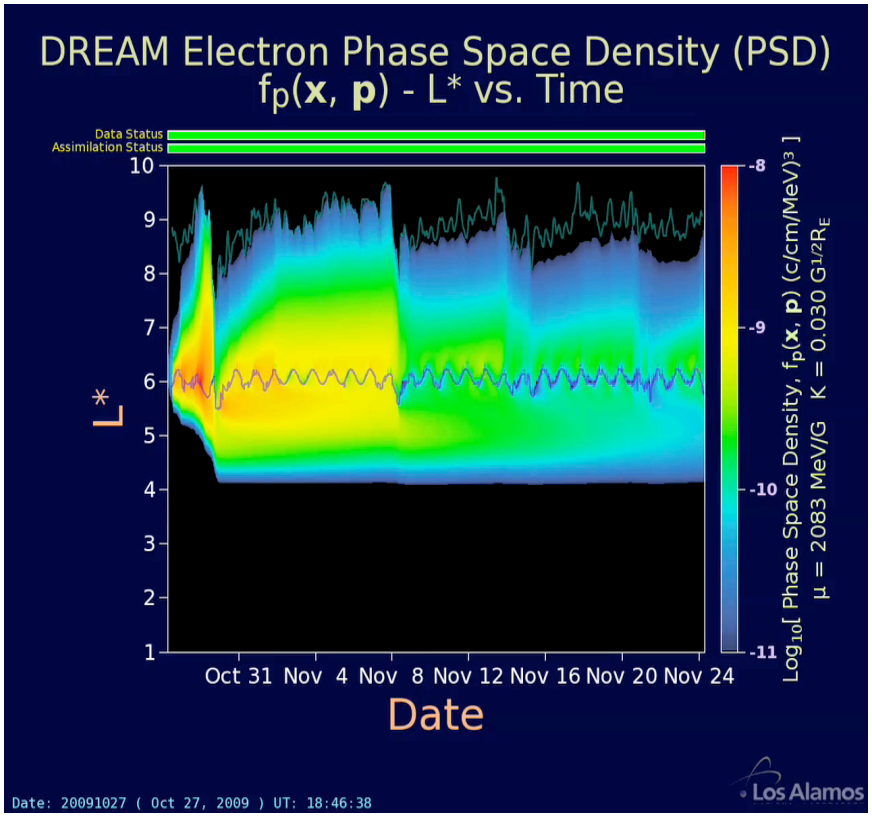




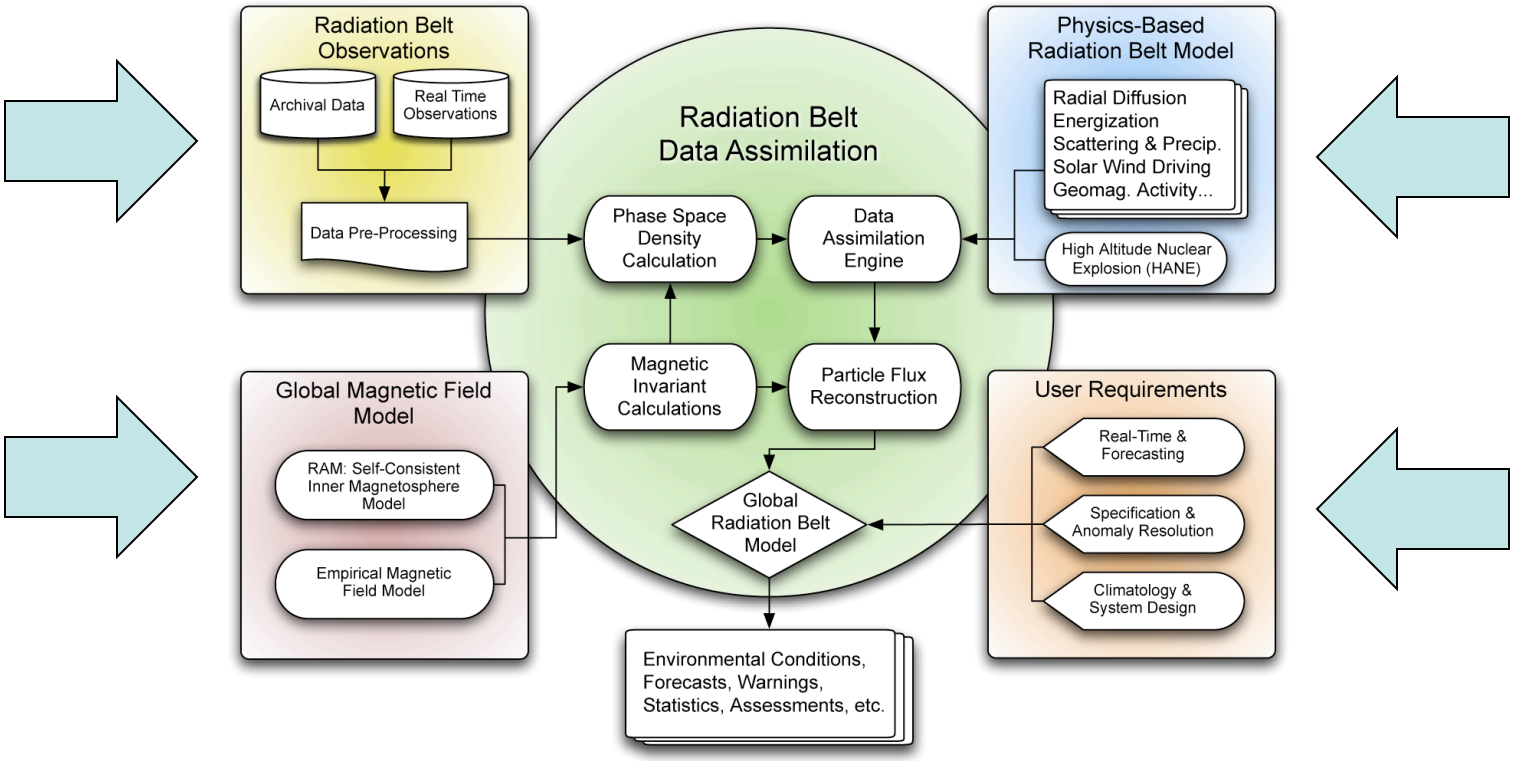


DREAM – Research to Operations (R2O)

- Alpha version recently installed for testing at AFRL R2O center in Albuquerque: SWFL
- Real-time single GOES satellite input
- It's platform independent and will run on a desktop computer
- A demo mode runs with time speeded up
- The same tool allows users to look back at archived assimilations
- Forecasts can be produced using the nowcast + a physics model

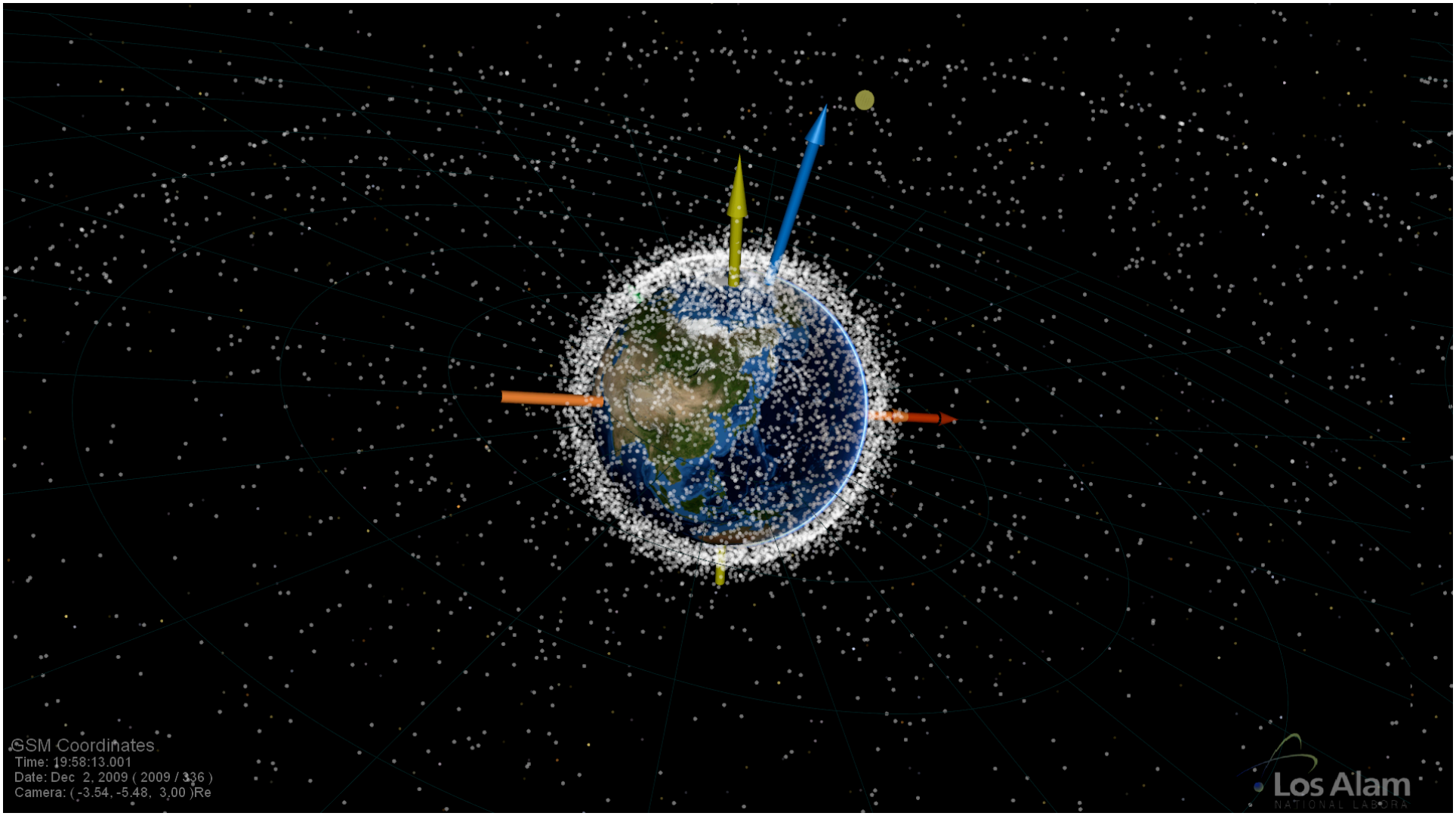


New and Future work



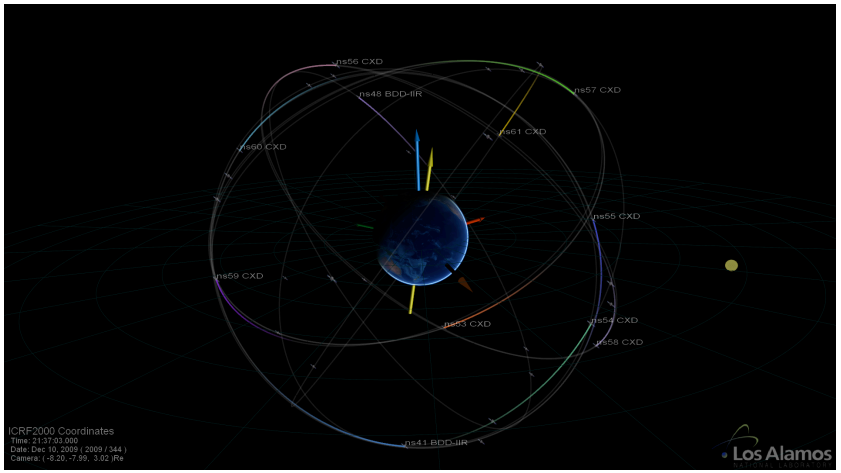
We are currently working on next-generation capabilities in all of the major components of DREAM

Client for Service Oriented Architecture for SSA applications



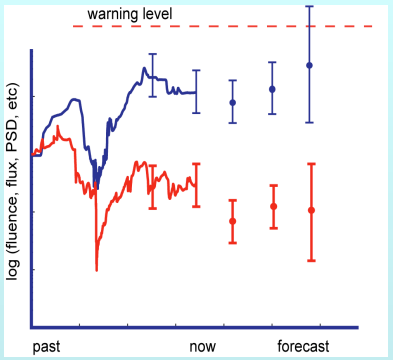
Space Environment SOA

User Interface/Client
LANL 3D
Visualization Tool



Nominal

Data Service

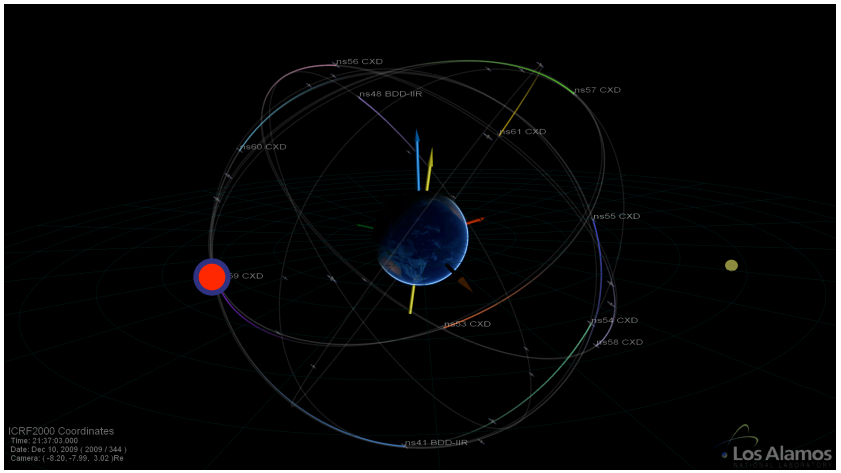


predictions as service

Spacecraft Orbits

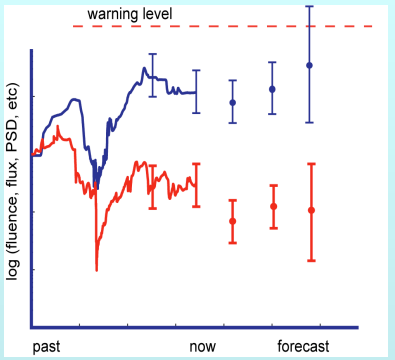
Space Environment SOA

User Interface/Client
LANL 3D
Visualization Tool



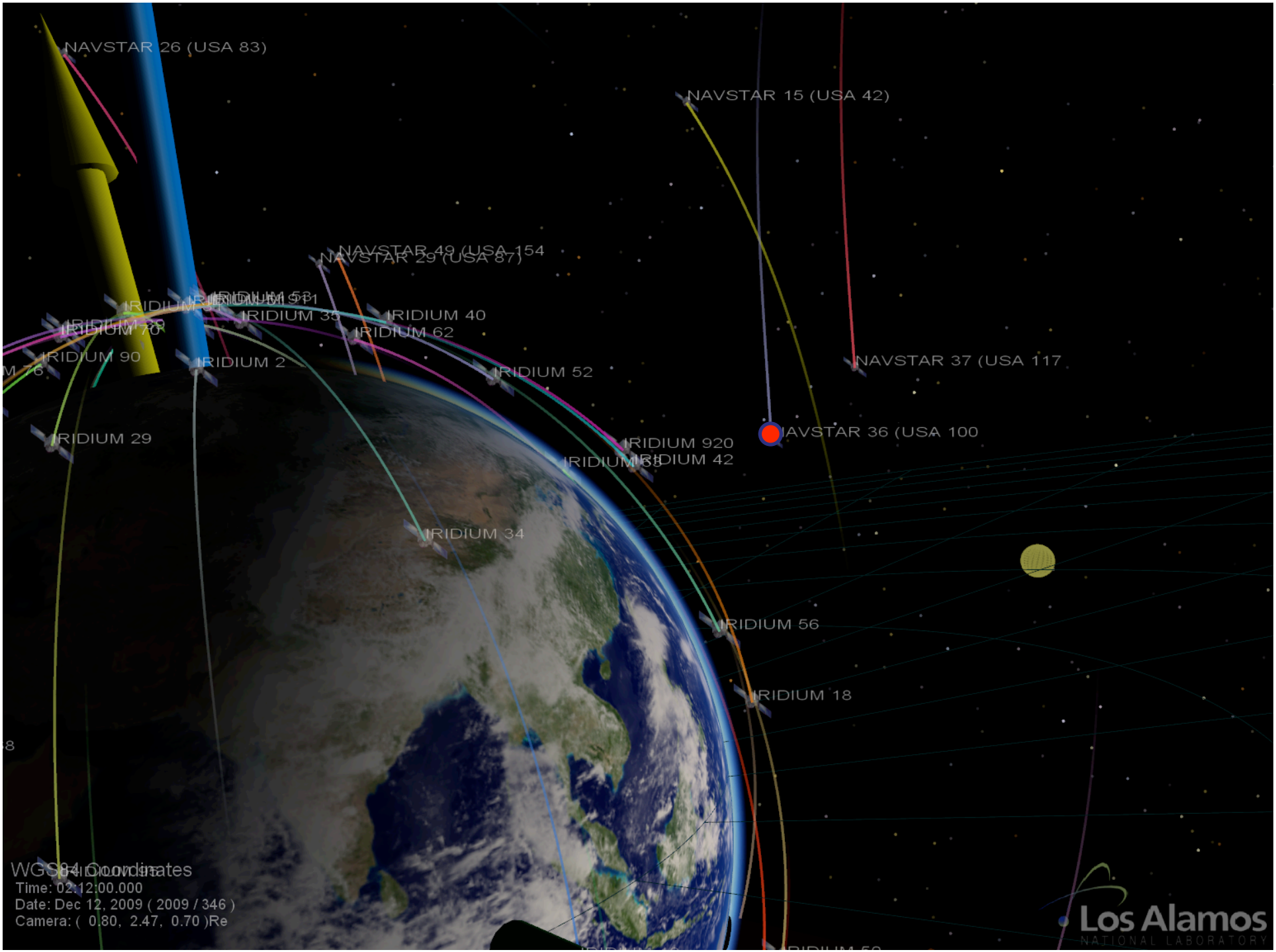
Extreme

Data Service



predictions as service

Spacecraft Orbits


NAVSTAR 26 (USA 83)
NAVSTAR 15 (USA 42)
NAVSTAR 49 (USA 154
NAVSTAR 29 (USA 87)
IRIDIUM 35
IRIDIUM 40
IRIDIUM 62
IRIDIUM 90
IRIDIUM 2
IRIDIUM 52
NAVSTAR 37 (USA 117
IRIDIUM 29
NAVSTAR 36 (USA 100
IRIDIUM 920
IRIDIUM 42
IRIDIUM 34
IRIDIUM 56
IRIDIUM 18
WGS84 Coordinates
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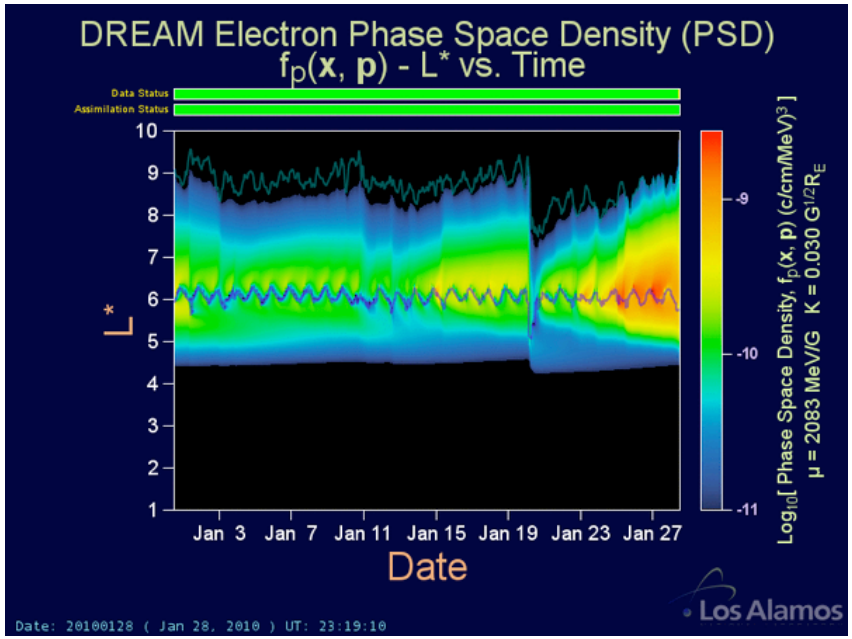
Other projects feeding into DREAM

- Spacepy: a library written in Python, C, C++, F90 including
  - CDF support
  - LANL*
  - RB modeling
  - V&V algorithms
  - Data Assimilation
  + Launch at GEM 2010
  + http://spacepy.lanl.gov
- DREAM website with real-time nowcast:

http://dream.lanl.gov



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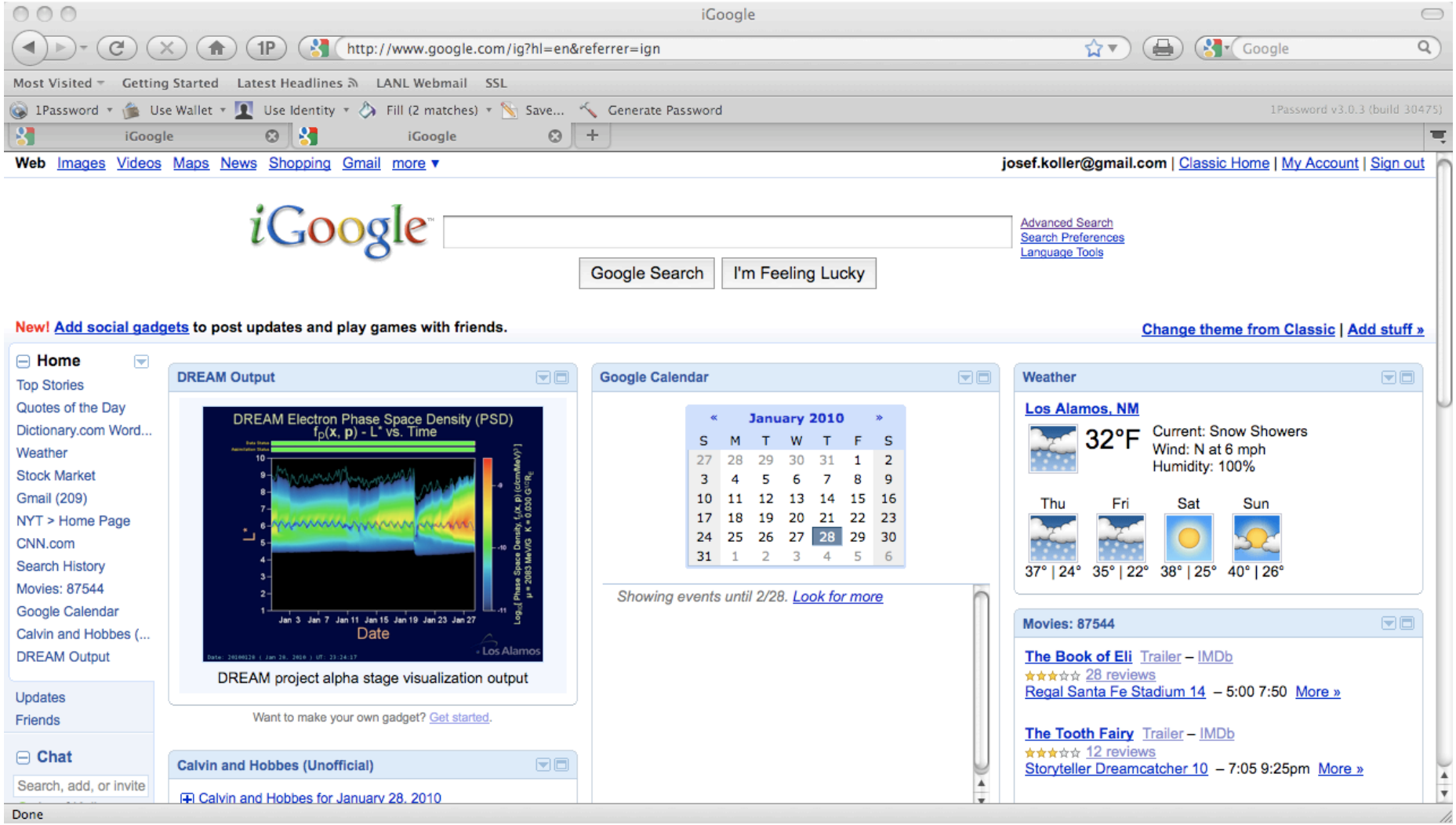
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http://www.google.com/ig?hl=en&referrer=ign
Most Visited
Getting Started
Latest Headlines
LANL Webmail
SSL
1Password
Use Wallet
Use Identity
Fill (2 matches)
Save...
Generate Password
Web Images Videos Maps News Shopping Gmail more
josef.koller@gmail.com | Classic Home | My Account | Sign out
iGoogle
Advanced Search
Search Preferences
Language Tools
Google Search
I'm Feeling Lucky
New! Add social gadgets to post updates and play games with friends.
Change theme from Classic | Add stuff »
Home
Top Stories
Quotes of the Day
Dictionary.com Word...
Weather
Stock Market
Gmail (209)
NYT > Home Page
CNN.com
Search History
Movies: 87544
Google Calendar
Calvin and Hobbes (...
DREAM Output
Updates
Friends
Chat
Search, add, or invite
DREAM Output
DREAM Electron Phase Space Density (PSD)
Date
Los Alamos
DREAM project alpha stage visualization output
Want to make your own gadget? Get started.
Calvin and Hobbes (Unofficial)
Calvin and Hobbes for January 28, 2010
Google Calendar
January 2010
S M T W T F S
27 28 29 30 31 1 2
3 4 5 6 7 8 9
10 11 12 13 14 15 16
17 18 19 20 21 22 23
24 25 26 27 28 29 30
31 1 2 3 4 5 6
Showing events until 2/28. Look for more
Weather
Los Alamos, NM
32°F
Current: Snow Showers
Wind: N at 6 mph
Humidity: 100%
Thu Fri Sat Sun
37° | 24° 35° | 22° 38° | 25° 40° | 26°
Movies: 87544
The Book of Eli Trailer – IMDb
28 reviews
Regal Santa Fe Stadium 14 – 5:00 7:50 More »
The Tooth Fairy Trailer – IMDb
12 reviews
Storyteller Dreamcatcher 10 – 7:05 9:25pm More »
Done

Other on-going and future work

- Full integration of RAM-SCB, DREAM assimilation, and global MHD models
- Extending the methods that we've demonstrated to other parts of the space environment such as the surface charging environment and global electric field
- New physics models for acceleration, scattering, and loss
- Development of AE9 and a standard solar-cycle model as a baseline for forecasts and satellite design
  - Ongoing LANL/AFRL/NRO/Aerospace collaboration
- Visualization tools for SSA demonstrations