PLASMON: WP3: Data Model Comparison

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Outline

- Description of DGCPM
- Comparison with observations
  - LANL satellite observations
  - VLF Whistler observations
  - FLR FLIP/SAMBA observations
- Description of Data Assimilation
- Implementation
- LANL satellite assimilation
- Next Steps
  - Electric field
  - Particle Filter
  - Implementation
  - More observations

Description of the DGCPM

- Dynamic Global Core Plasma Model (e.g. Ober [1997])
- 2D, single species (discussion of adding multiple species)

$$\boldsymbol{F_n = -\frac{N B_i}{\tau}}$$

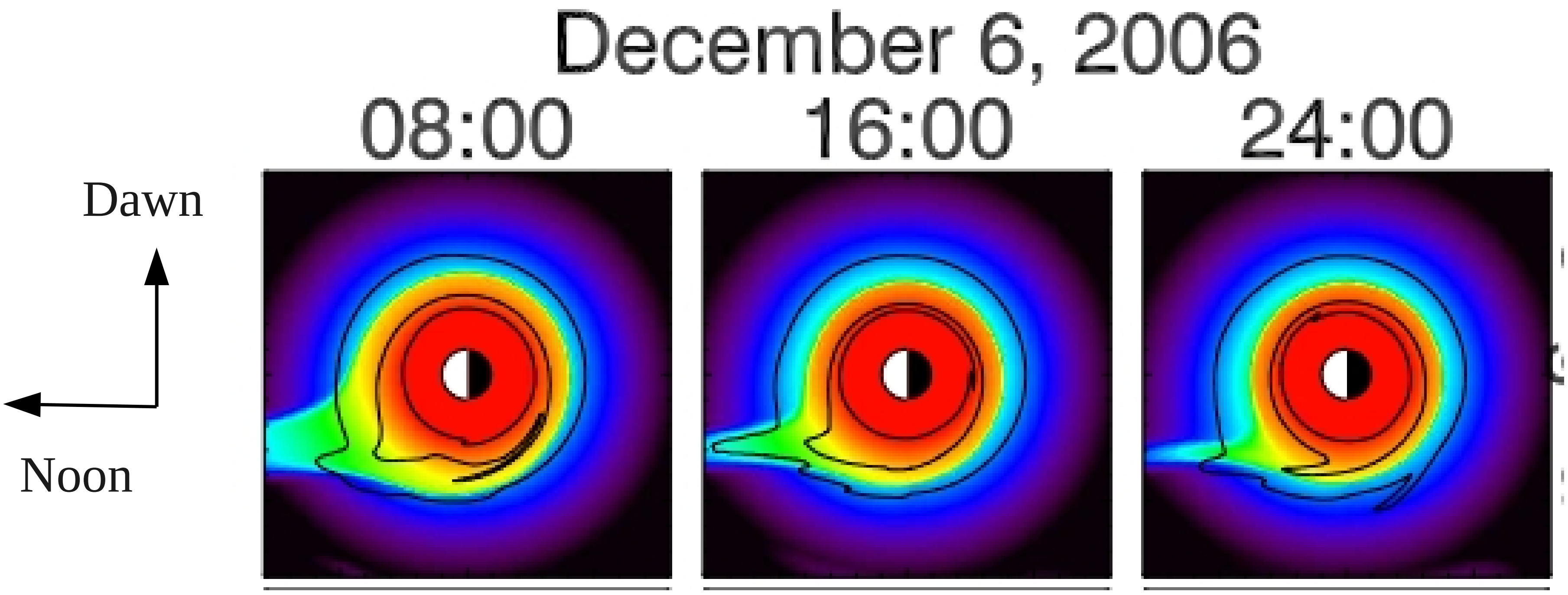
$$\boldsymbol{F_d = \frac{n_{\mathrm{sat}} - n}{n_{\mathrm{sat}}} F_{\mathrm{max}}}$$

$$\boldsymbol{\frac{D_\perp N}{Dt} = \frac{F_N + F_S}{B_i}}$$

$$\boldsymbol{\vec{E}\left(\vec{r}\right)}$$

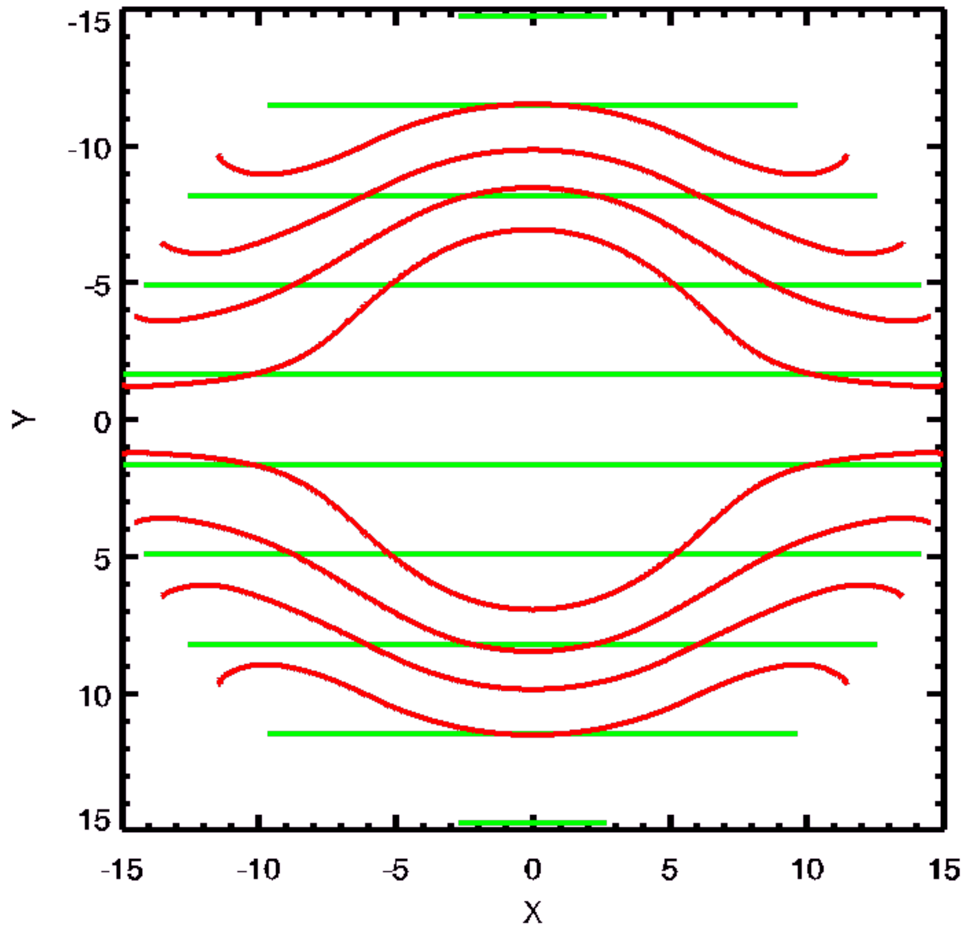
$$\boldsymbol{\vec{B}\left(\vec{r}\right)}$$

Example of a DGCPM run



Built-In Electric Field Models

Gallagher et al. (1995)

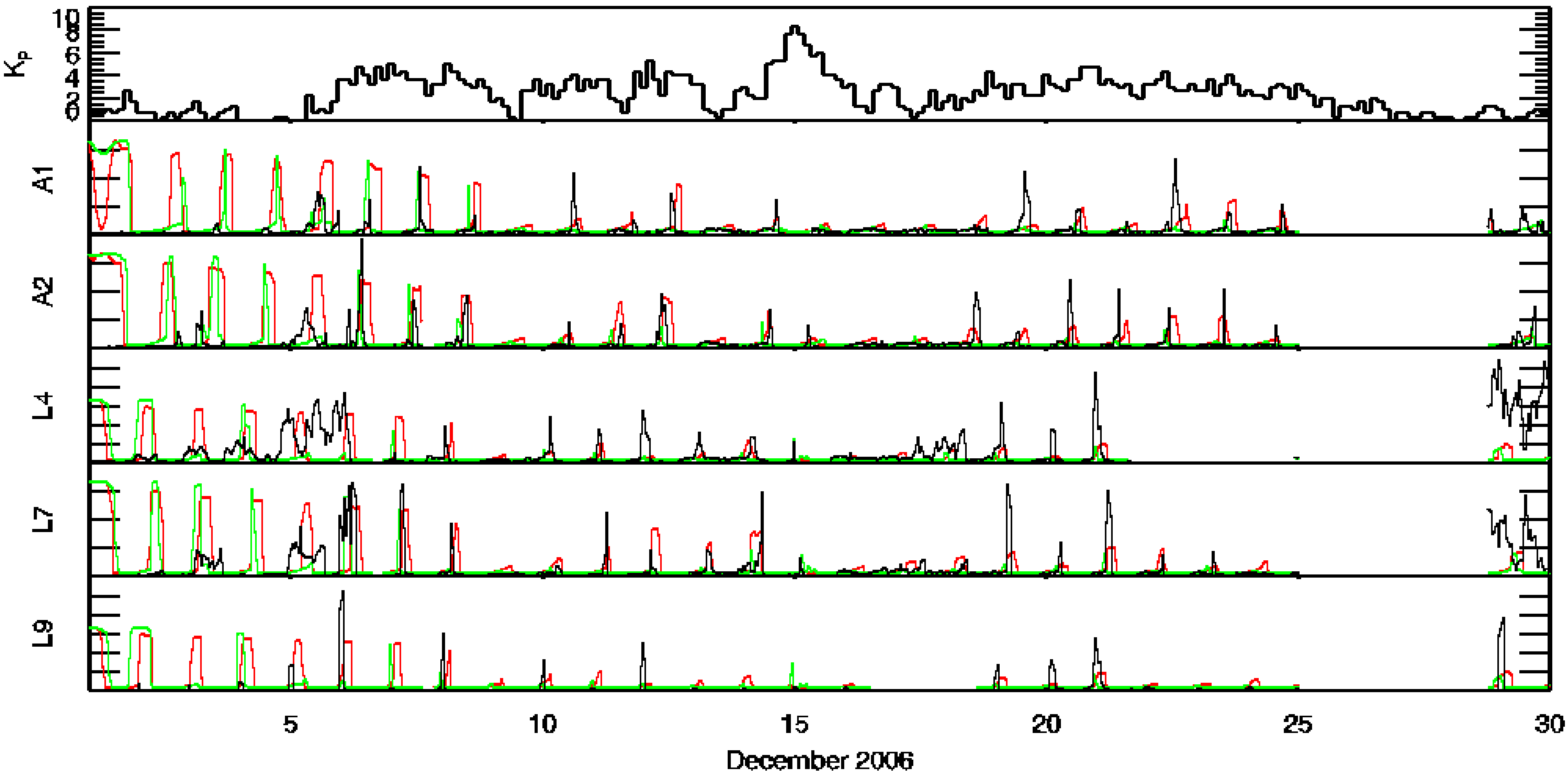


Other models to follow (see later)

Sojka et al. (1986)

Comparison with LANL Satellite observations

Gallagher et al. (1995)   Sojka et al. (1986)



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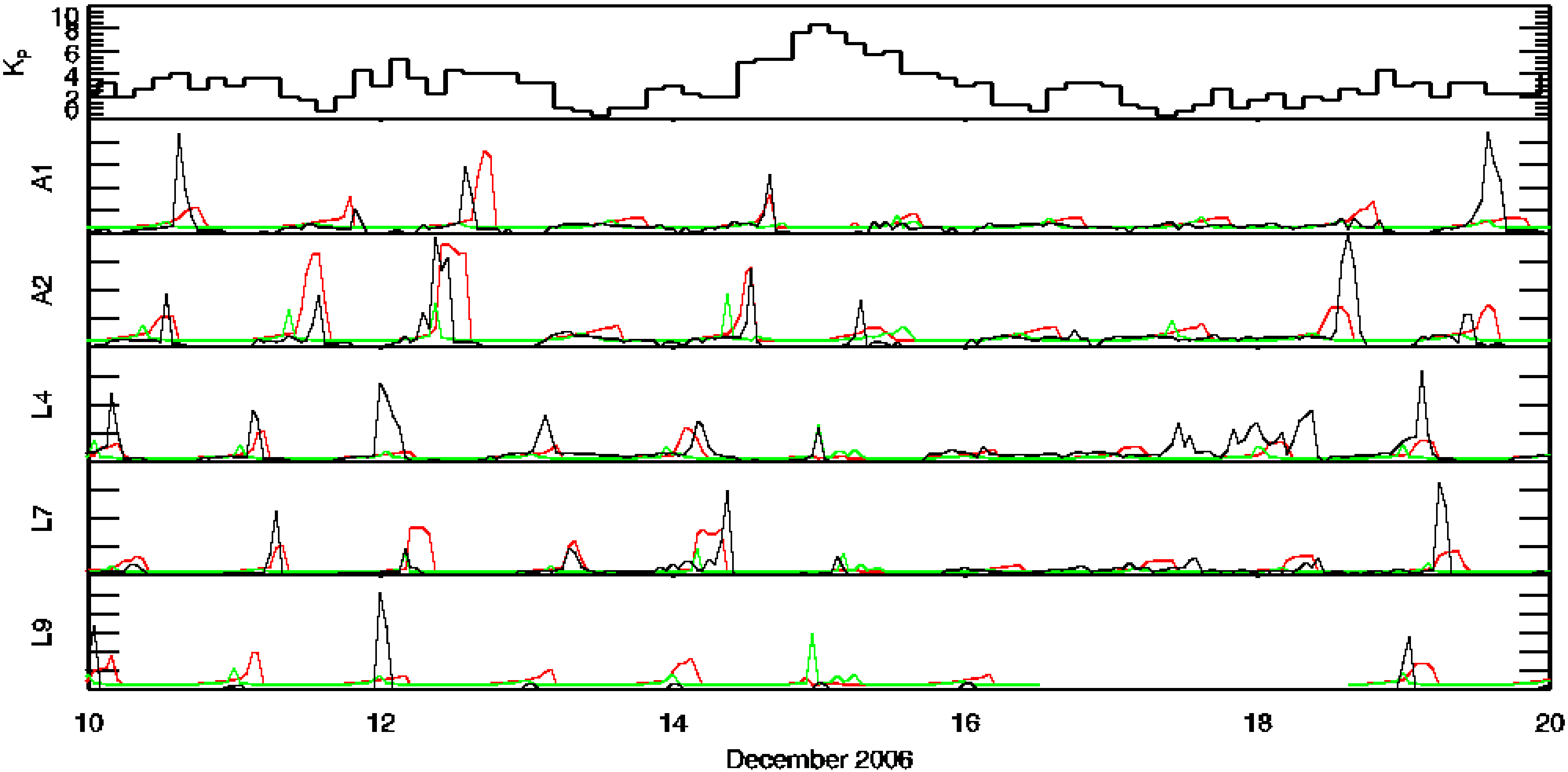
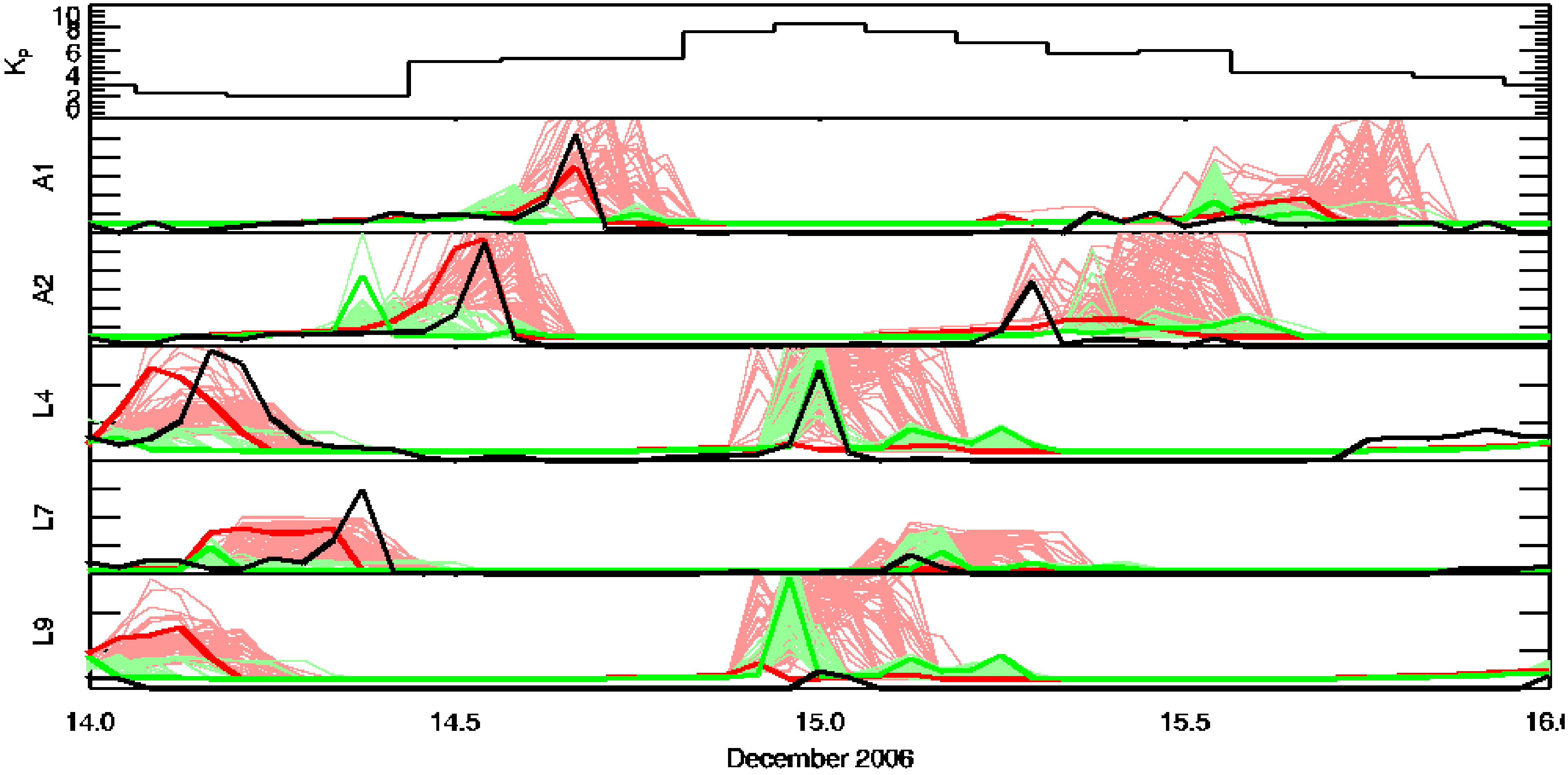


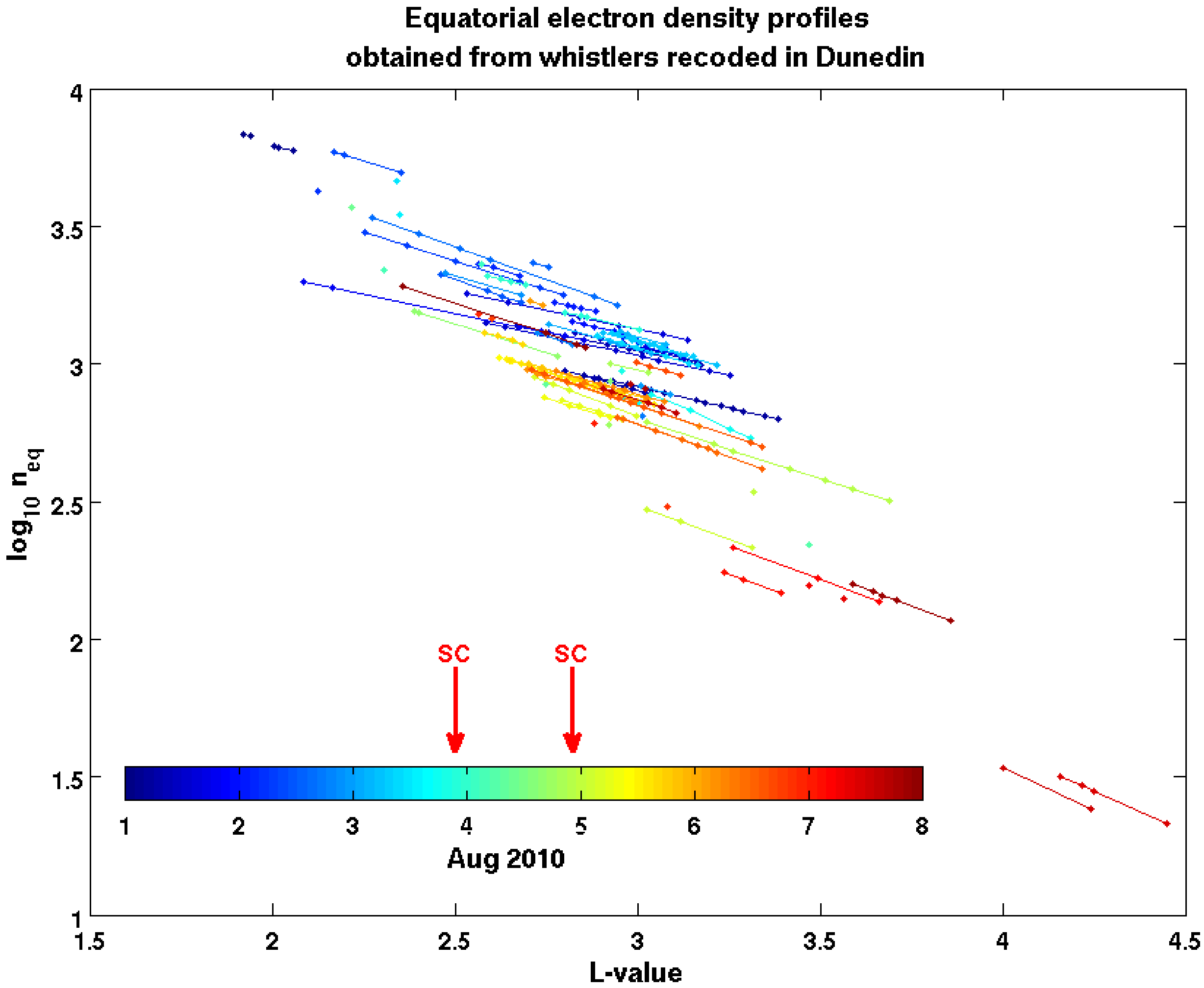
Comparison with LANL Satellite Observations – with Model Noise

Gallagher et al. (1995) Sojka et al. (1986)



VLF Whistler Observations from Dunedin, NZ

- August 2010 storm



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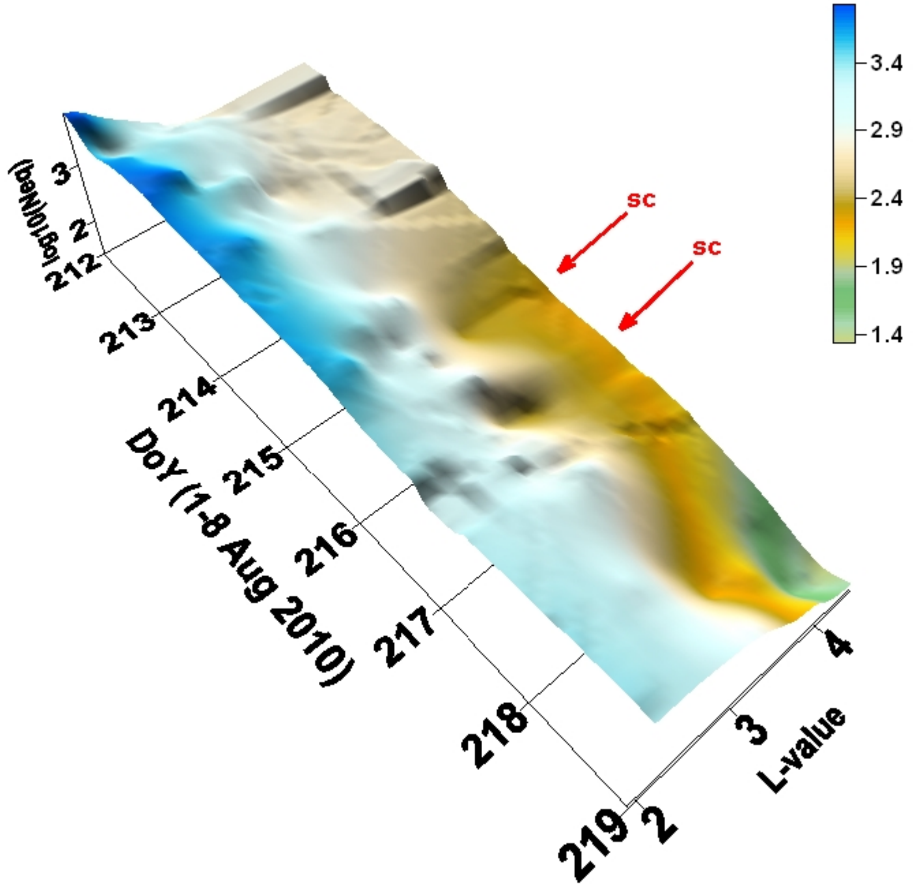
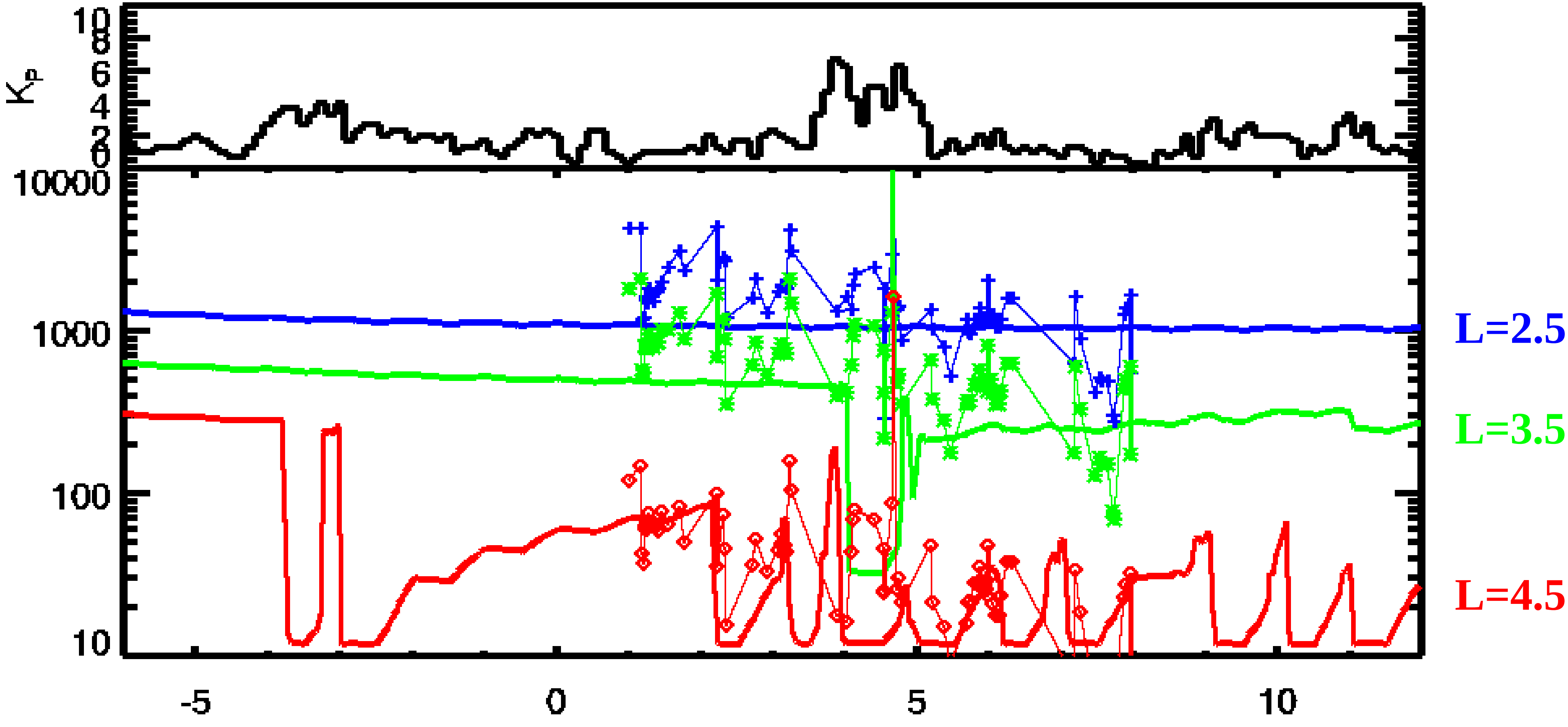


Comparison with VLF Whistler Observations

I had to divide VLF densities at L=4.5 by 10 in order to get agreement



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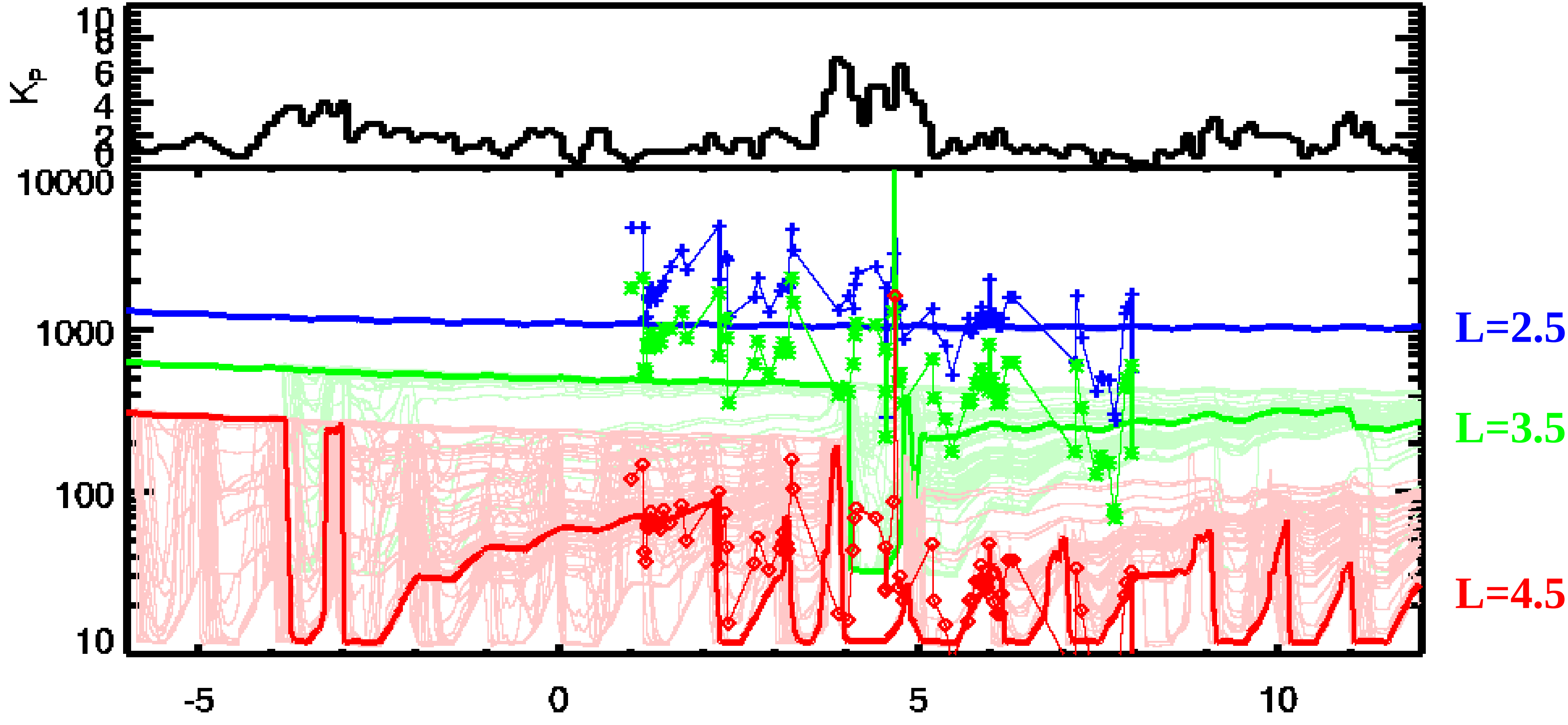
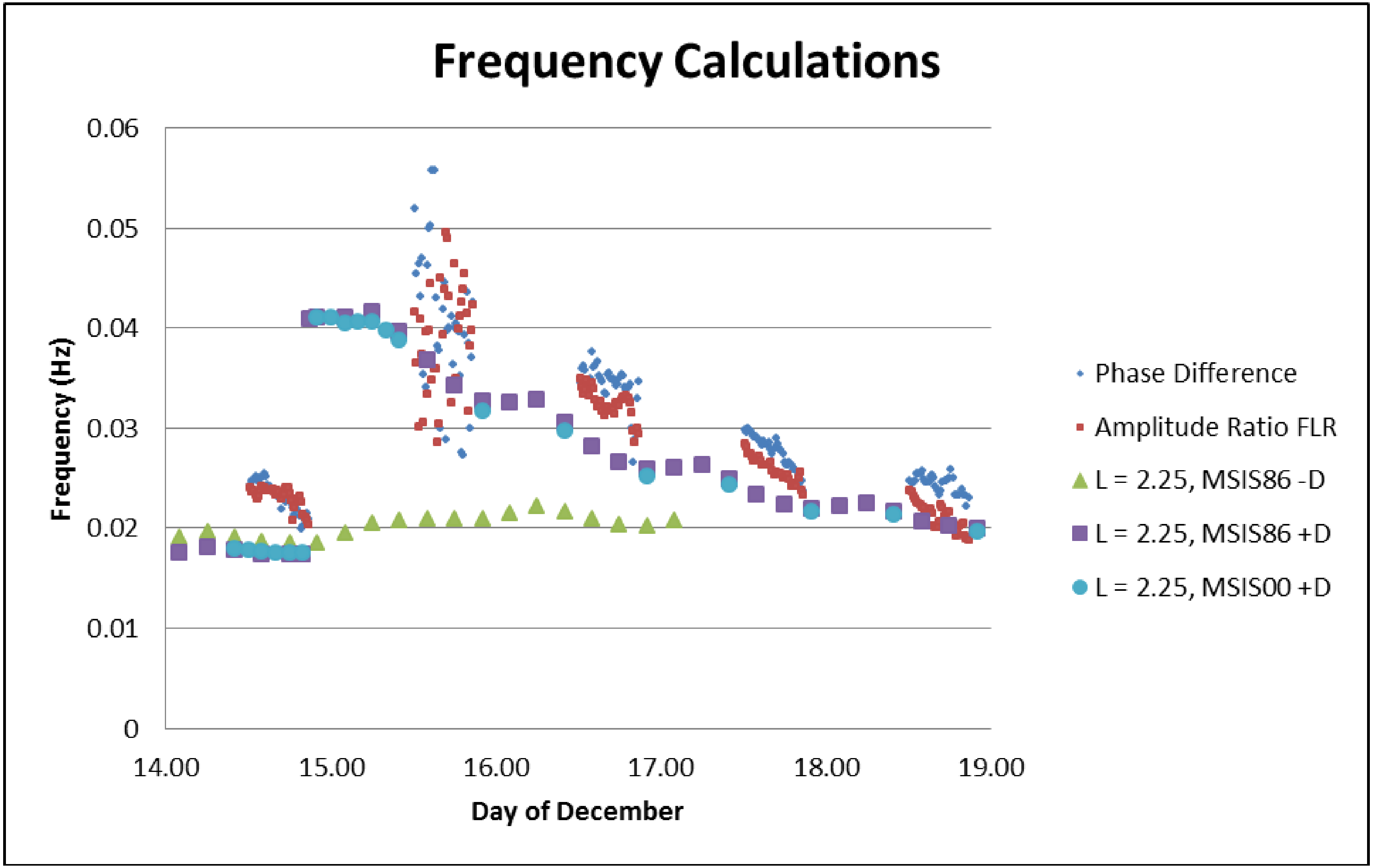


FLIP/SAMBA Comparisons

J. Duffy (2011)



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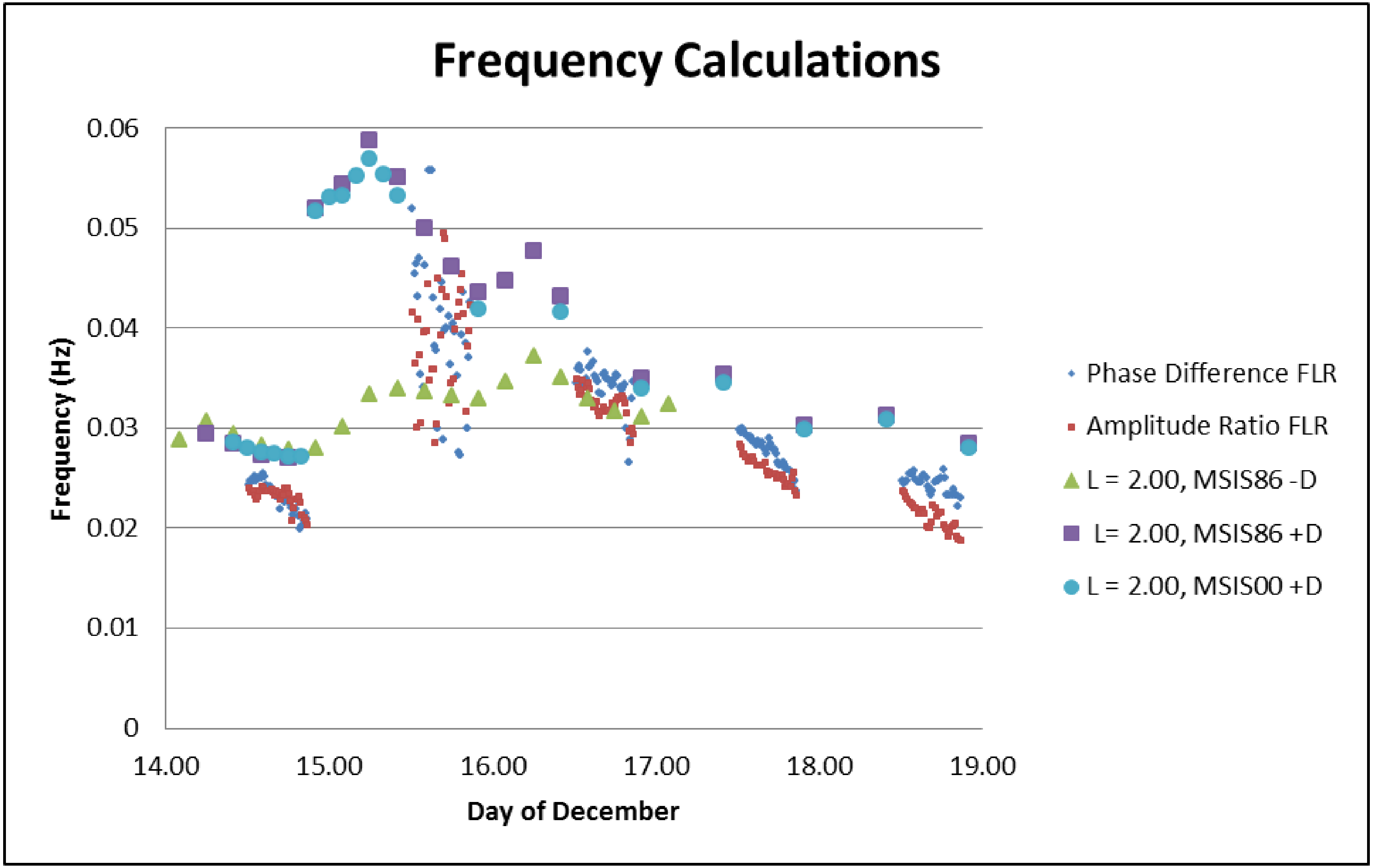


Description of the Data Assimilation

- For the time being we use the Ensemble Kalman Filter
- Model ensemble:

$$\boldsymbol{A} = \begin{bmatrix} \psi_{11} & \psi_{12} & \cdots & \psi_{1N} \\ \psi_{21} & \psi_{22} & & \psi_{2N} \\ \vdots & & \ddots & \vdots \\ \psi_{m1} & \psi_{m2} & \cdots & \psi_{mN} \end{bmatrix}$$

- Analysis: $\boldsymbol{A}_{\text{posterior}} = \boldsymbol{A}_{\text{prior}} \times \boldsymbol{X}$
- (computing X requires, a series of matrix operations including SVD, multiplications, and additions)
- Typical:

$$\boldsymbol{A} : \boldsymbol{m} \times \boldsymbol{N} = \mathbf{40000} \times \mathbf{100} = \mathbf{4} \times \mathbf{10^6}$$

$$\boldsymbol{X} : \boldsymbol{N} \times \boldsymbol{N} = \mathbf{100^2} = \mathbf{10^4}$$

Model Noise

- For now the model noise is entirely in the electric field
  - In the future it could be in refilling/loss rates also
- q contains as many parameters as are needed
- In the two built-in models q is just the value of the KP parameter of those models
- A third model I have been working with has two parameters – but no results included here
- Augmented state:

$$\boldsymbol{\psi^* = \begin{bmatrix} q \\ \psi_1 \\ \psi_2 \\ \vdots \\ \psi_m \end{bmatrix}}$$

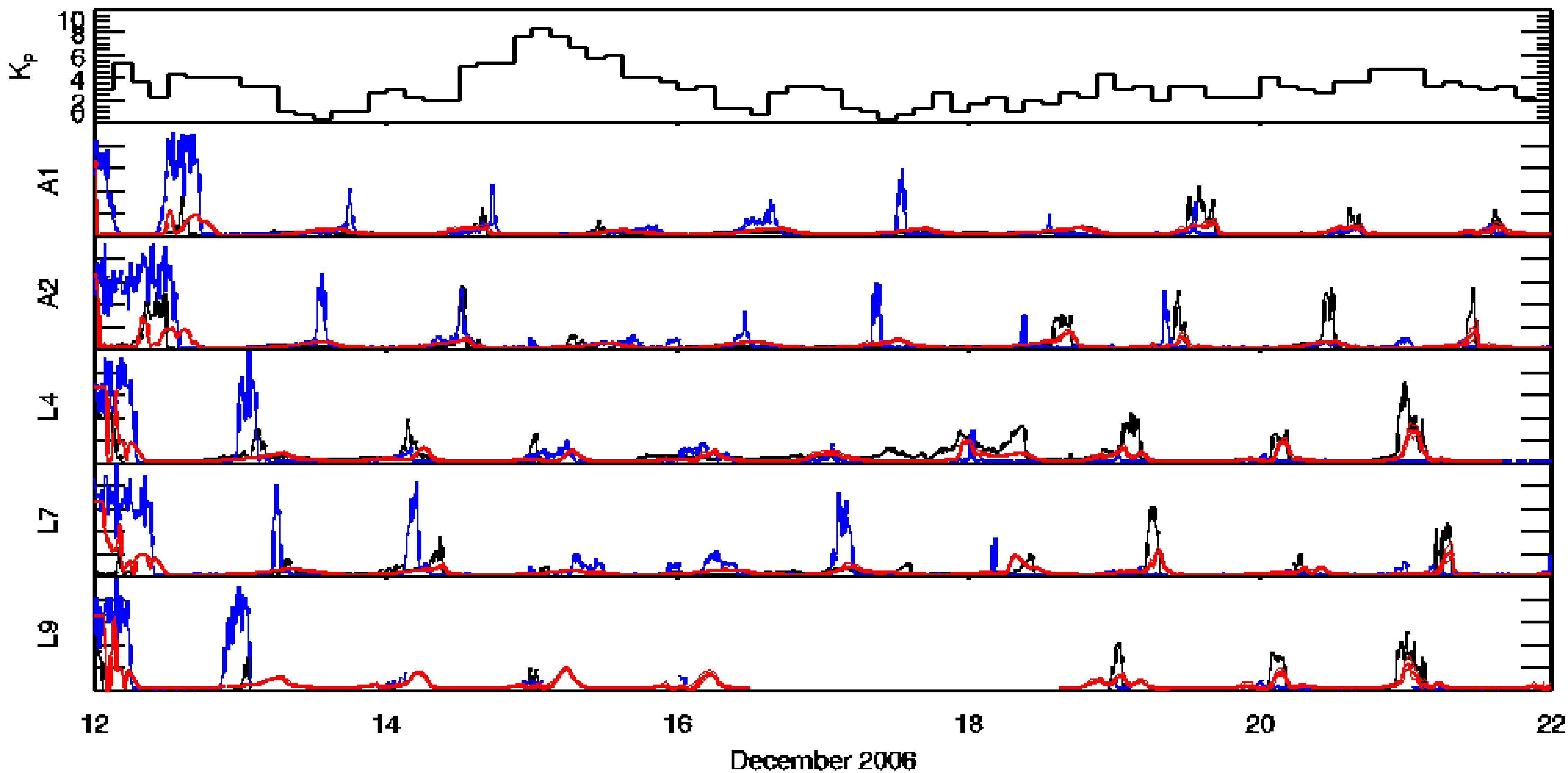
$$\boldsymbol{q_k = \alpha q_{k-1} + \sqrt{1-\alpha}\, w_k}$$

Implementation

- Homemade code
  - C++
  - MPI – use to parallelize the problem across multiple CPUs on multiple computers on a network.
  - ScaLaPACK – a parallel linear algebra/matrix library which uses MPI
    - I wrote a C++ class which encapsulates the Fortran interface

LANL Satellite In-Situ Assimilation

Can we drive the model with the simple parametrized electric field (Sojka, 1986) and improve the agreement with LANL in-situ observations?



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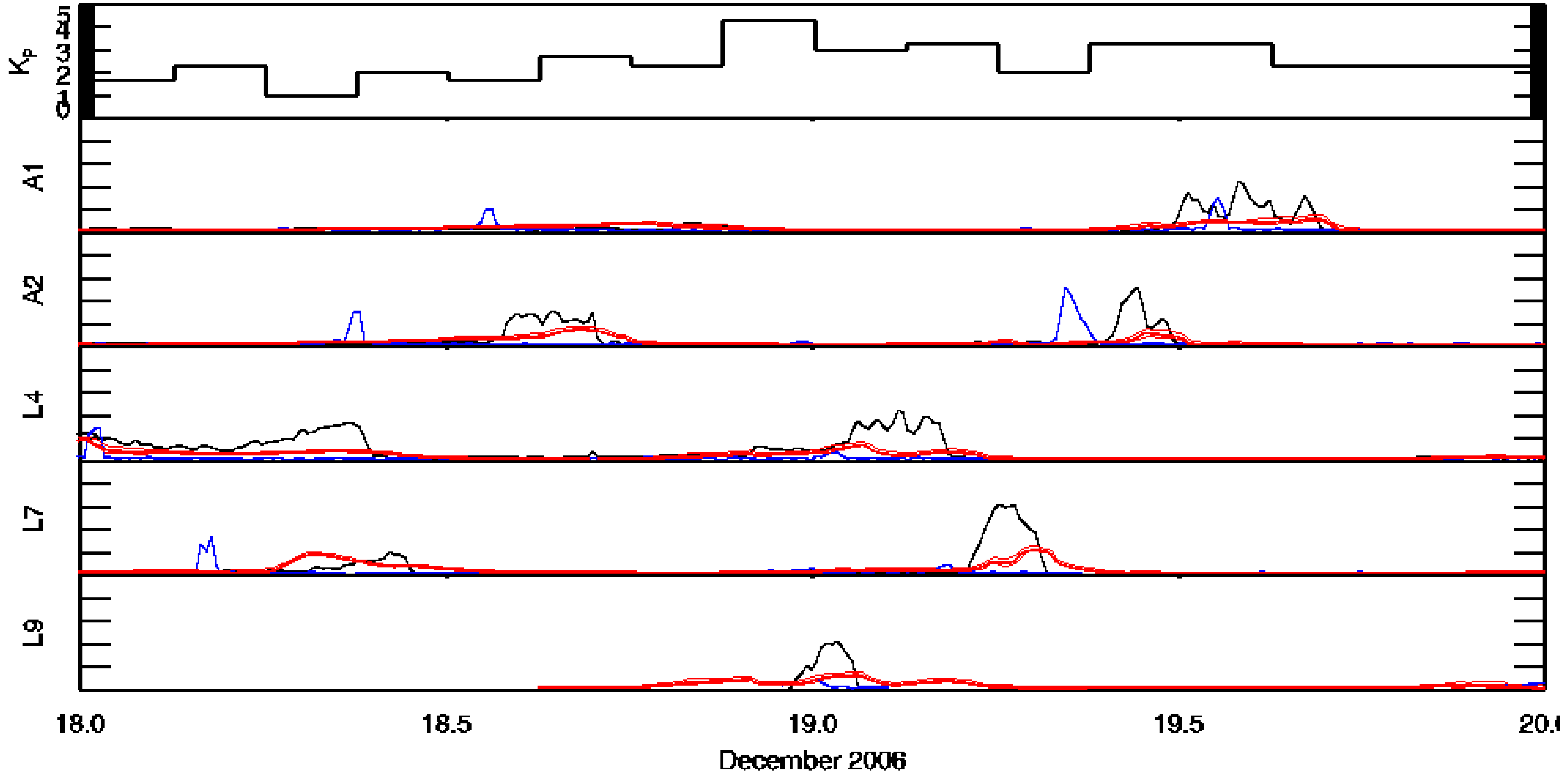

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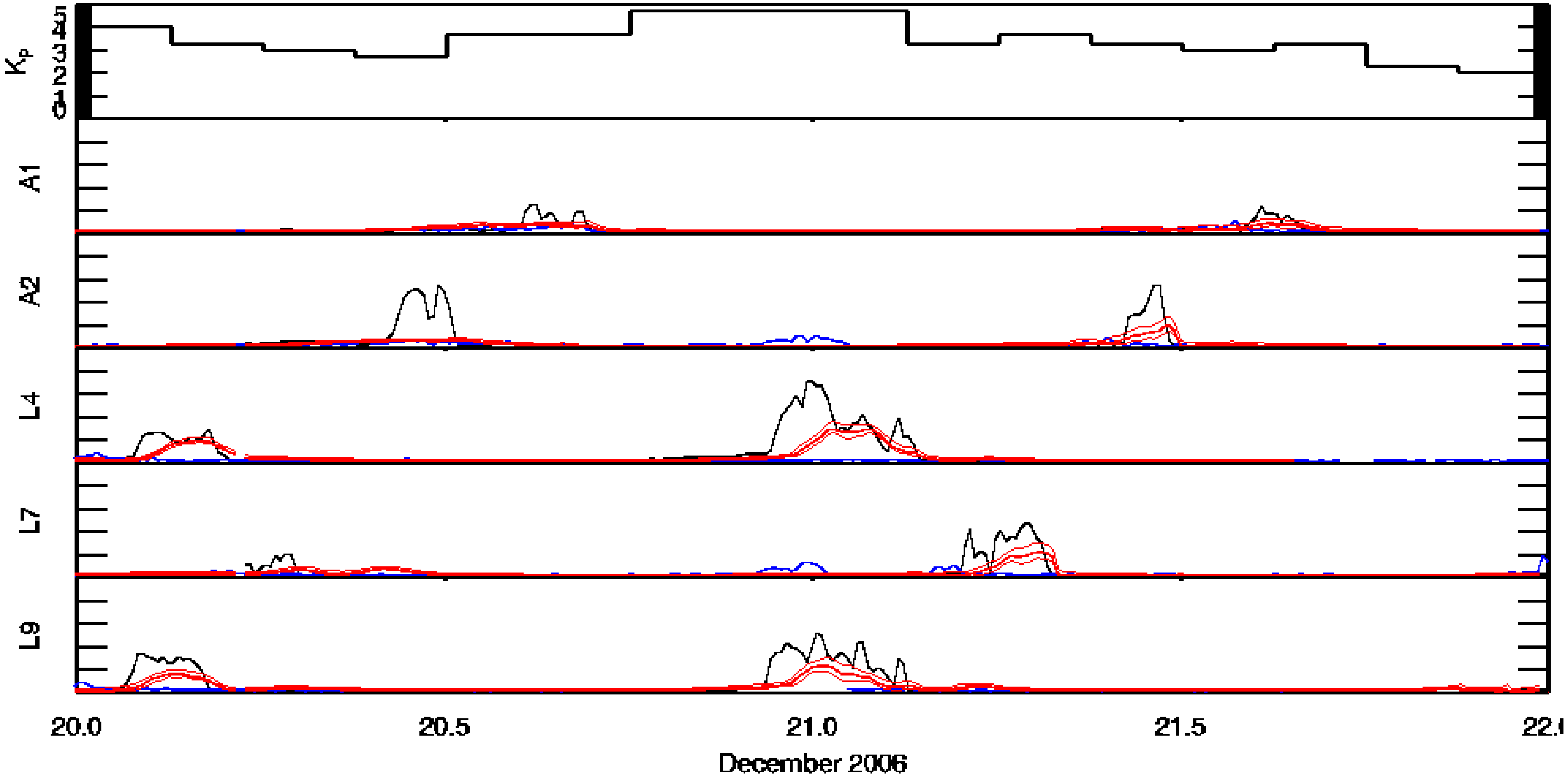
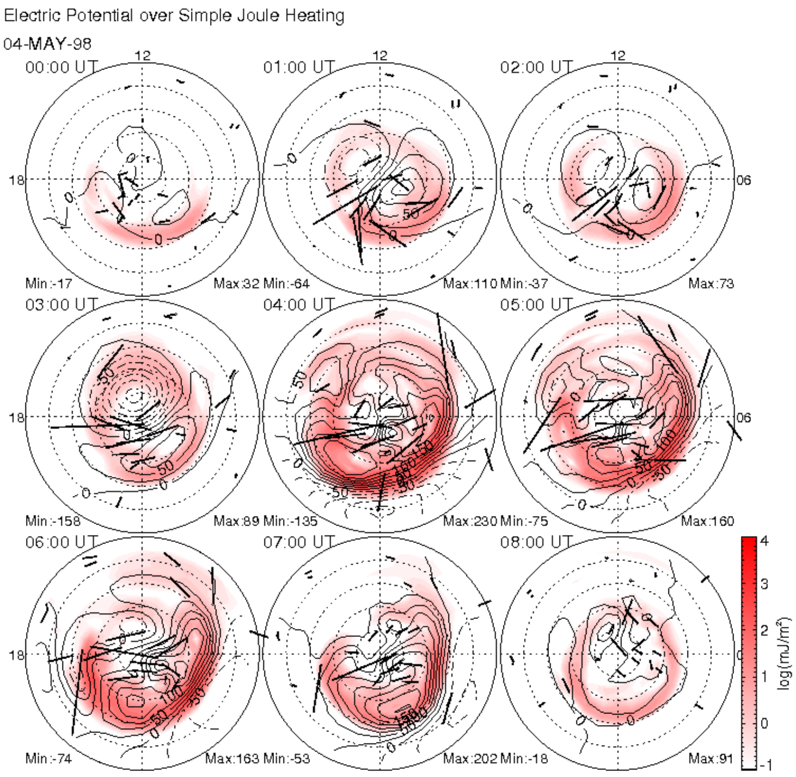
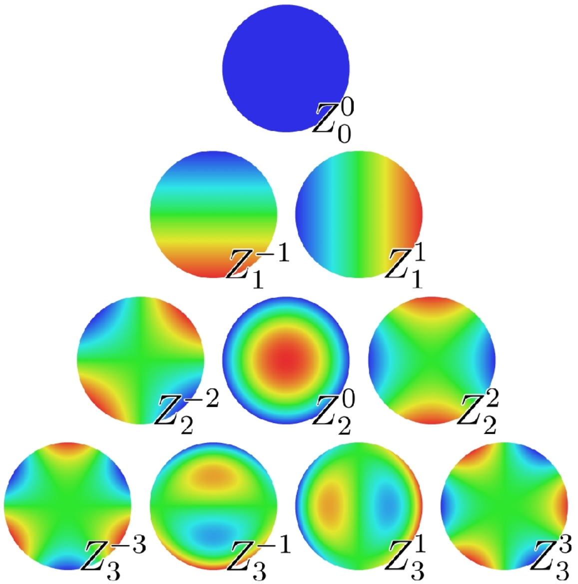


Next Step: the Electric Field

- AMIE electric potential as base – with noise to modify it
- Zernike polynomials alone of with another model





Next Step: Particle Filter

- The Kalman Filter assumes linearity which is not fulfilled
  - Linear combinations can lead to un-physical states, including negative density
- We will also implement a Particle Filter and make comparisons
  - Can (probably) be implemented in the same code base

Next Step: Implementation

- Computing on a GPGPU
- More sophisticated models with more observations require more computation
- Instead of using remote super-computers we are beginning to use Graphics Processors
- Well-suited for grid-based processing like the DGCPM and many other models

Workstation: 16 CPUs, 12 GB RAM, $4000, 20 GFlops

Tesla C2070: 480 multiprocessors, 6 GB RAM, $2000, 1000 GFlops

Next Step: More Observations

- LANL In-situ
- AWDANet number density
- EMMA VLF mass density
- SAMBA VLF mass density
- Which leads to the next session.....

Conclusions

- Enough similarities between model and data that it is encouraging
- Some calibration will be needed and feedback should be provided, especially to VLF reduction
- Assimilation works well so far with only a few LANL in-situ observations