Synthetic K_P Index From Global Magnetohydrodynamics

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ABSTRACT: **K_P is an important real-time indicator of geomagnetic activity as well as an important input for models that have forecasting potential. This paper describes a new, synthetic K_P index derived from the BATS-R-US global magnetohydrodynamic (MHD) model. It is obtained through virtual magnetometers that capture disturbances from global MHD currents, field-aligned currents mapped between the inner boundary of the MHD code and the ionosphere model, and Hall and Pedersen currents in the ionosphere. To validate the synthetic values, they are compared against observed K_P for several storm events. Agreement is varied but overall positive. Examples of how synthetic K_P and local-K values used in the derivation can be used to monitor local activity are also demonstrated.**

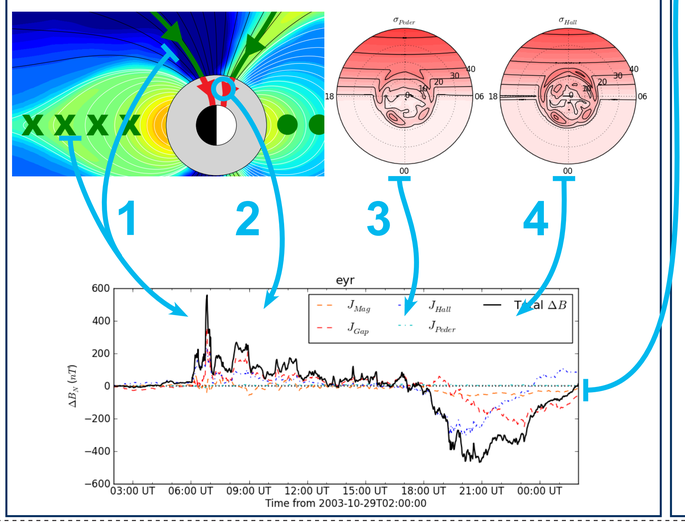
The Importance of K_P

K_P is the most established of all geomagnetic activity indexes. It is used as a quick-look indicator of geomagnetic activity and as inputs to many models, from simple empirical relations, such as the *Young et al. (J. Geophys. Res., 1982)* formulation for plasmasheet composition, to the more complicated Tsyganenko 1989 magnetic field model and many radiation belt codes that use the *Braughtigam and Albert (J. Geophys Res., 2000)* K_P-based radial diffusion coefficient. This reliance on K_P makes real time and forecasted K_P valuable to the space weather community.

Magnetohydrodynamic models, when coupled to ionospheric electrodynamic models, capture most of the currents that feed into magnetometer measurements and can potentially yield real time and predicted geomagnetic indexes. These values can be passed to other models to help produce self-consistent, whole magnetosphere models that benefit both research and space weather needs. This poster introduces *fa***K***e*$_P$, a synthetic K_P index produced by the BATS-R-US MHD code.

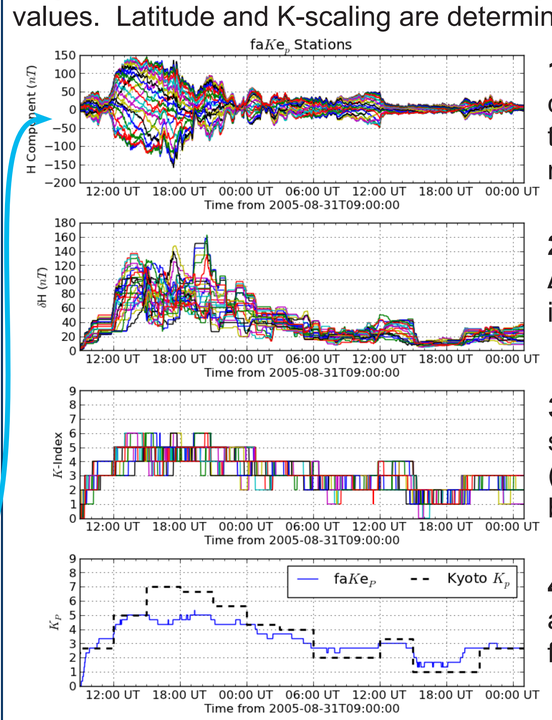
BATS-R-US Virtual Magnetometers

*fa***K***e*$_P$ begins with virtual magnetometers, a BATS-R-US product that combines (1) global magnetospheric currents, (2) gap-region currents inside of the MHD inner boundary, and (3) Hall and (4) Pedersen ionospheric currents to produce the total magnetic perturbation at any arbitrary location. Details and validation can be found in *Yu et al., J. Geophys. Research, 2010*.



Synthetic K_P Calculation

Calculation of *fa***K***e*$_P$ follows that of real K_P closely except for the placement of the virtual magnetometers and the choice of K-scaling factor to convert magnetic variations to local K-values. Latitude and K-scaling are determined through careful calibration and validation.



1) fa**K**e$_P$ virtual magnetometers are placed at a constant magnetic latitude at even local time intervals. This yields ΔB, the perturbation of the magnetic field in the H or northern direction.

2) δB is calculated by subtracting the minimum ΔB from the maximum over a three hour floating time window.

3) δB is converted to K-index using a specified scaling factor. No further processing is required (e.g. removal of seasonal dependences, etc.) because of the uniform station distribution.

4) K is converted to K_P (planetary) by merely averaging the whole-number K values to the familiar index that is quantized by thirds.

Calibration and Validation

*fa***K***e*$_P$ is first calibrated to determine the best latitude to place the virtual magnetometers and what K-scaling factor to use. These two values are key for ensuring good agreement with observations.

For calibration, 8 events are chosen to exercise the code during quiet, active, and very stormy conditions:

Date	Event Type	Min. Dst
Dec. 9th, 1996	CIR Event	-32
May 4th, 1998	Strong Storm Event	-205
July 15th, 2000	Bastille Day Storm	-198
August 31st, 2001	Pressure Induced Substorm	-40
April 17th, 2002	Strong Storm, Sawtooth Event	-127
October 29th, 2003	Halloween Storm	-353
November 20th, 2003	Super Storm	-422
September 2nd, 2004	Quite Period/Isolated Substorm	-23

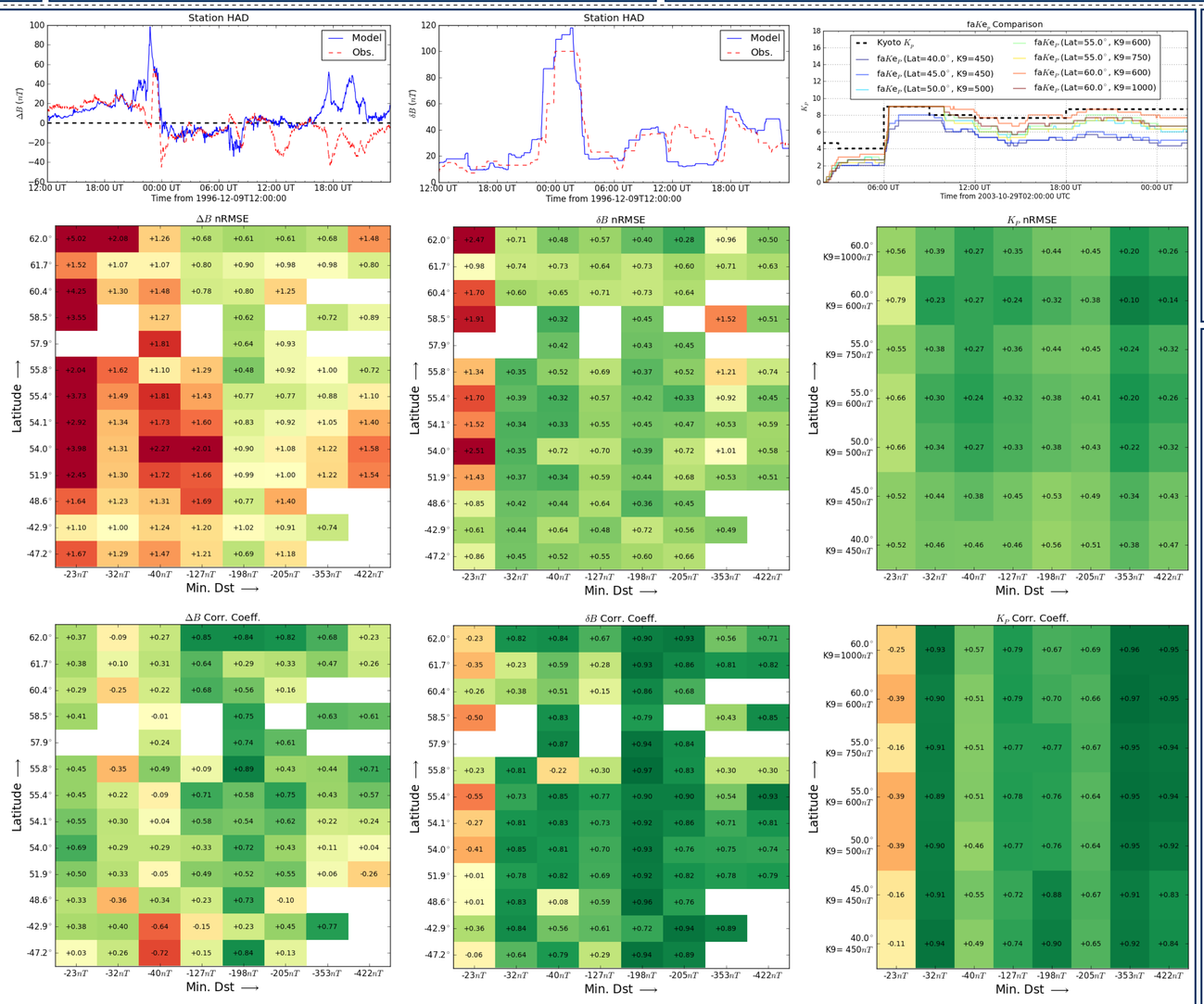
Two metrics are used to quantify the results: normalized root-mean-squared error (nRMSE, indicative of good agreement in magnitude) and Pearson's correlation coefficient (PCC, indicative of good agreement in dynamics).

$$nRMSE = \sqrt{\frac{\Sigma(x_i - y_i)^2}{\Sigma x_i^2}} \begin{cases} > 1 & \text{Poor prediction} \\ = 1 & \text{Near data avg.} \\ < 1 & \text{Good prediction} \end{cases}$$

$$PCC = \frac{\Sigma(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\Sigma(x_i - \bar{x})^2}\sqrt{\Sigma(y_i - \bar{y})^2}} \begin{cases} = 1 & \text{Perfect correlation} \\ = 0 & \text{No correlation whatsoever} \\ = -1 & \text{Results anti-correlated} \end{cases}$$

Calibration takes place using observations from the 13 K_P stations. Both ΔB and δB values are tested to get thorough, high time resolution results.

Finally, *fa***K***e*$_P$ resulting from several different latitudes and K-scaling factors is compared against data to determine the best combination. All scaling factors are taken from official K_P stations.



ΔB values are plagued by regions of poor performance; magnitudes are particularly hard to capture. Higher latitudes perform the best.

δB performs far better; the model captures general dynamics very well. Quiet time remains troublesome but overall correlation is excellent.

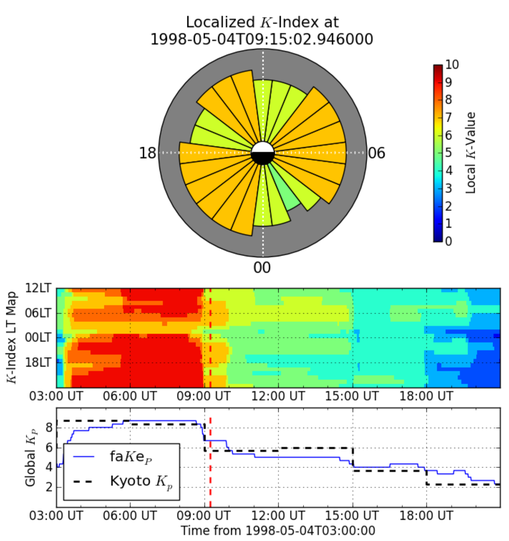
δB results translate to excellent *fa***K***e*$_P$ metrics with high latitudes and strong storms performing the best. K-scaling from the Uppsala station yields the best results.

Summary and Future Work

*fa***K***e*$_P$ is the first MHD-based synthetic K_P system. It has been calibrated to find the best combination of latitude and K-scaling factor. Comparisons against observed K_P are excellent. Future work will expand the number validation events as well as test the impact of including coupled ring current models on the calibration and overall results.

Operational Applications

*fa***K***e*$_P$ results can be presented as localized, real-time indicators of space weather activity. The system is ready to be used with BATS-R-US simulations.



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