Off Equatorial Analysis of Several Commonly Used Magnetic Field Models

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Goals

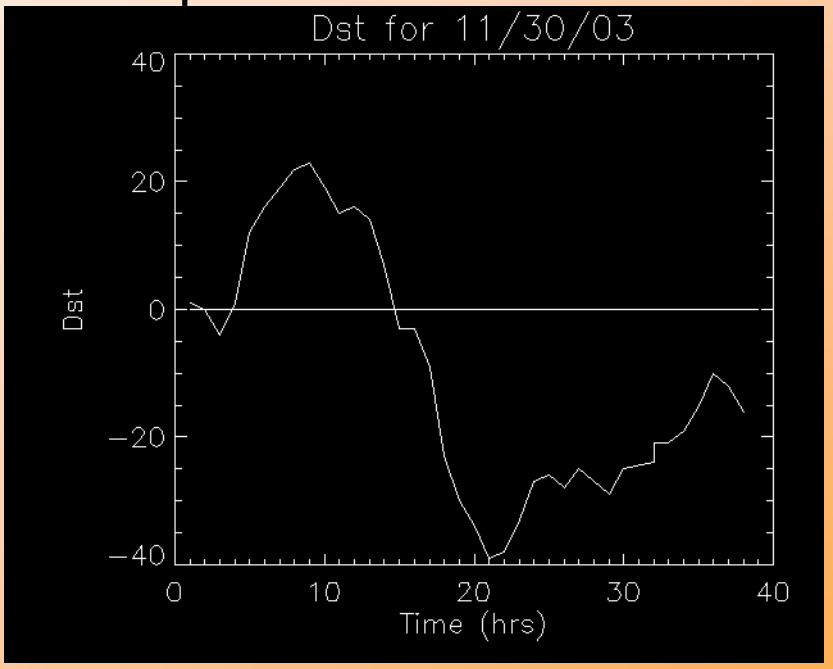
- Evaluate various external magnetic field models included in the ONERA-DESP code above and below the equatorial plane
- Recommend appropriate potential model validity situations

Methods

- Create visualization techniques to see off-equatorial performance of models
- Compare model outputs of |**B**| to satellite magnetometer measurements
- Bin comparison studies by Kp, Dst, and magnetic latitude

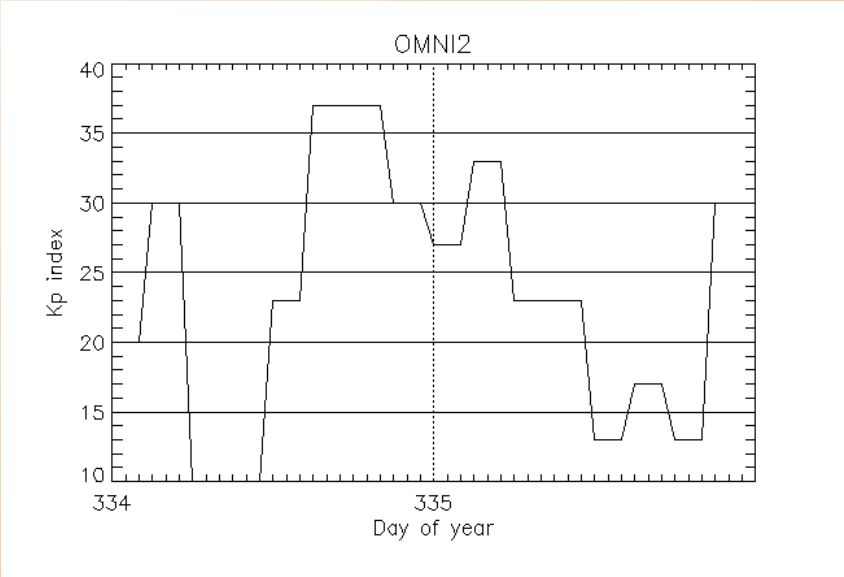
Some Definitions

- Dst = Geomagnetic Equatorial Index
  - "The Dst index represents the axially symmetric disturbance magnetic field at the dipole equator on the Earth's surface"
  - Define storm sub-phases



Some Definitions

- Kp = Geomagnetic activity index
  - … is a code that is related to the maximum fluctuations of horizontal components observed on a magnetometer relative to a quiet day, during a three-hour interval.
  - $0 \leq Kp \geq 9$



Why Does  Care ?

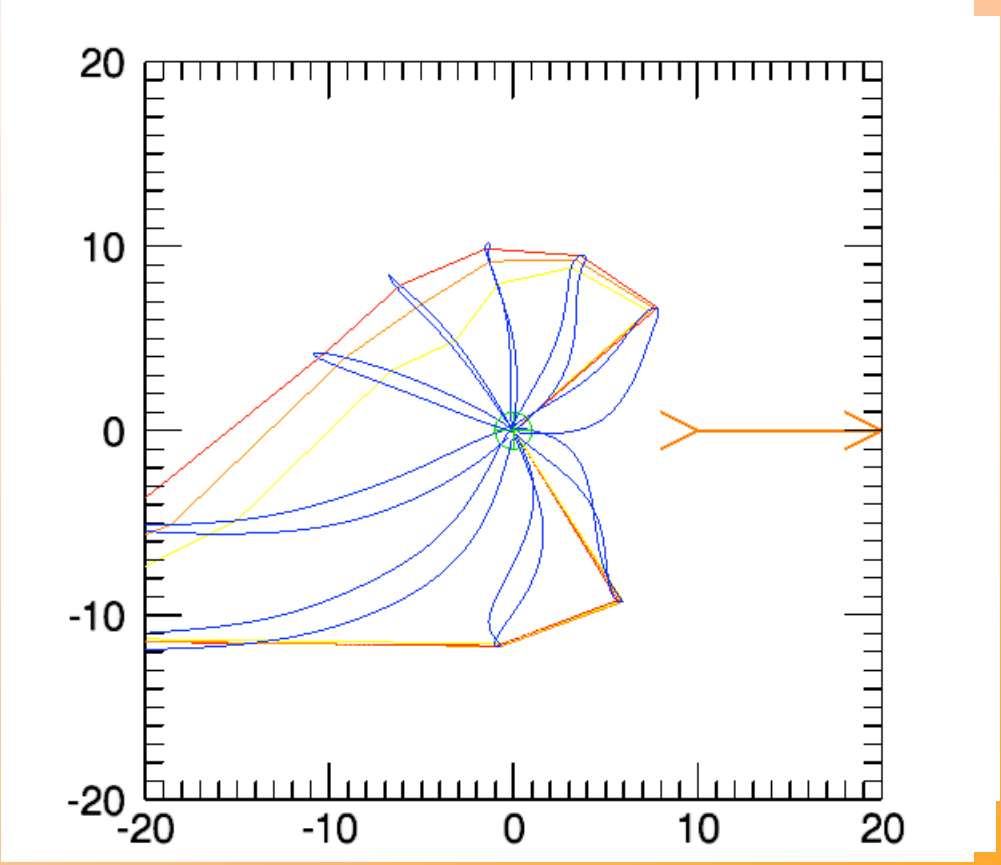
- Ultimately understanding how these models perform differently will help forecasting models.
- Scientific research is still performed with “outdated” models.
- Poor off equatorial performance of current models could help to spur the development of new ones.

Current Knowledge

- Equatorial performance on the noonside and midnightside is often poor (PE < .5) (anomalous B_z) [McCollough *et al* 2008].
- Tsyganenko '96 is popular but is significantly overstretched on the equatorial plane.
- Newer models are more complicated to implement.
- Models show decreased ***dawn*** and dusk performance at equator [Huang *et al* 2008].

Magnetic Field Models

- Olson & Pftizer “Dynamic” [1988]
  - Limited input range
  - Only basic physics

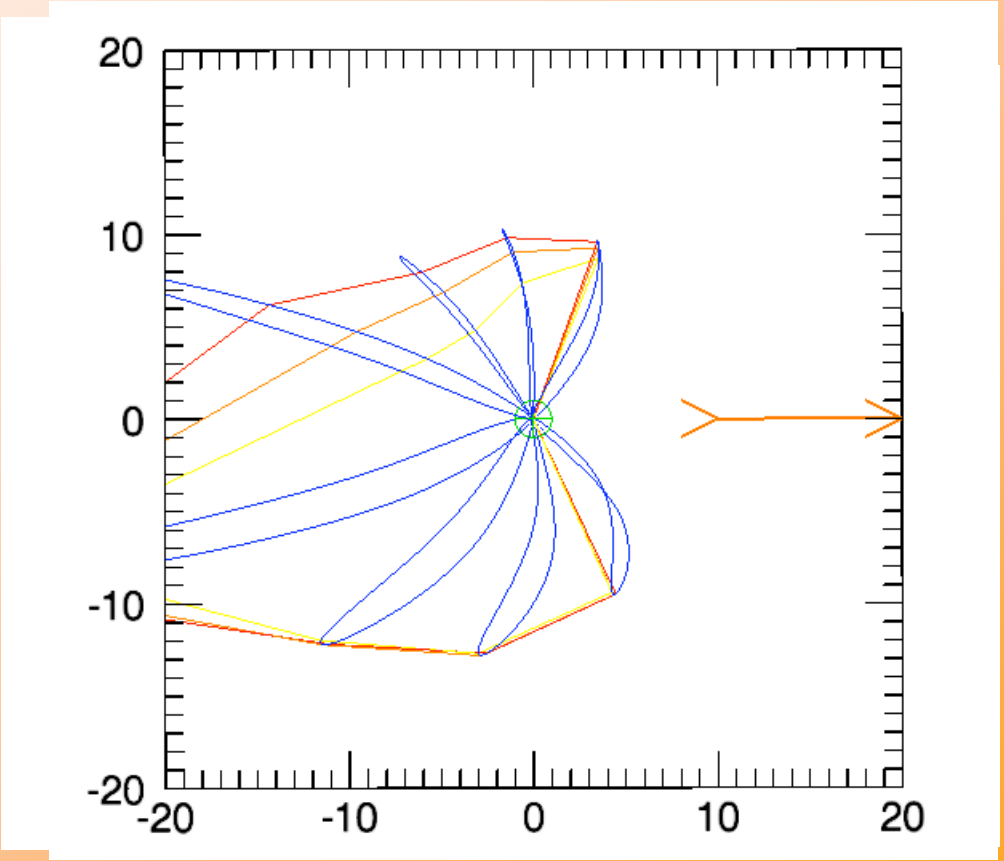


View: ⟶

Equatorial plane from above North Pole

Magnetic Field Models

- Tsyganenko ‘96
  - Still commonly used
    - Easy to implement
  - Equatorial field line over-stretching



View: ⟶

Equatorial plane from above North Pole

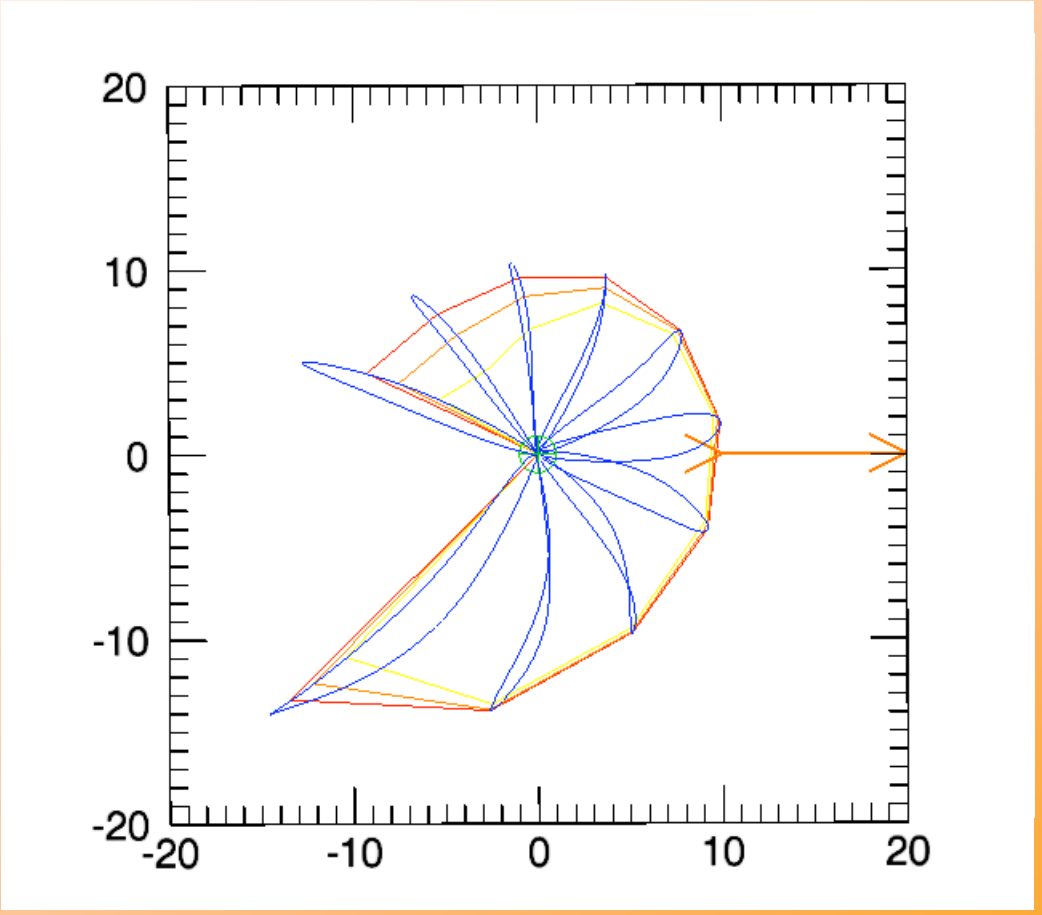
Magnetic Field Models

- Tsyganenko ‘01/“Storm”
  - Sibling models
  - “Storm” has no input constraints
  - First to allow for time dependence

View: ⟶

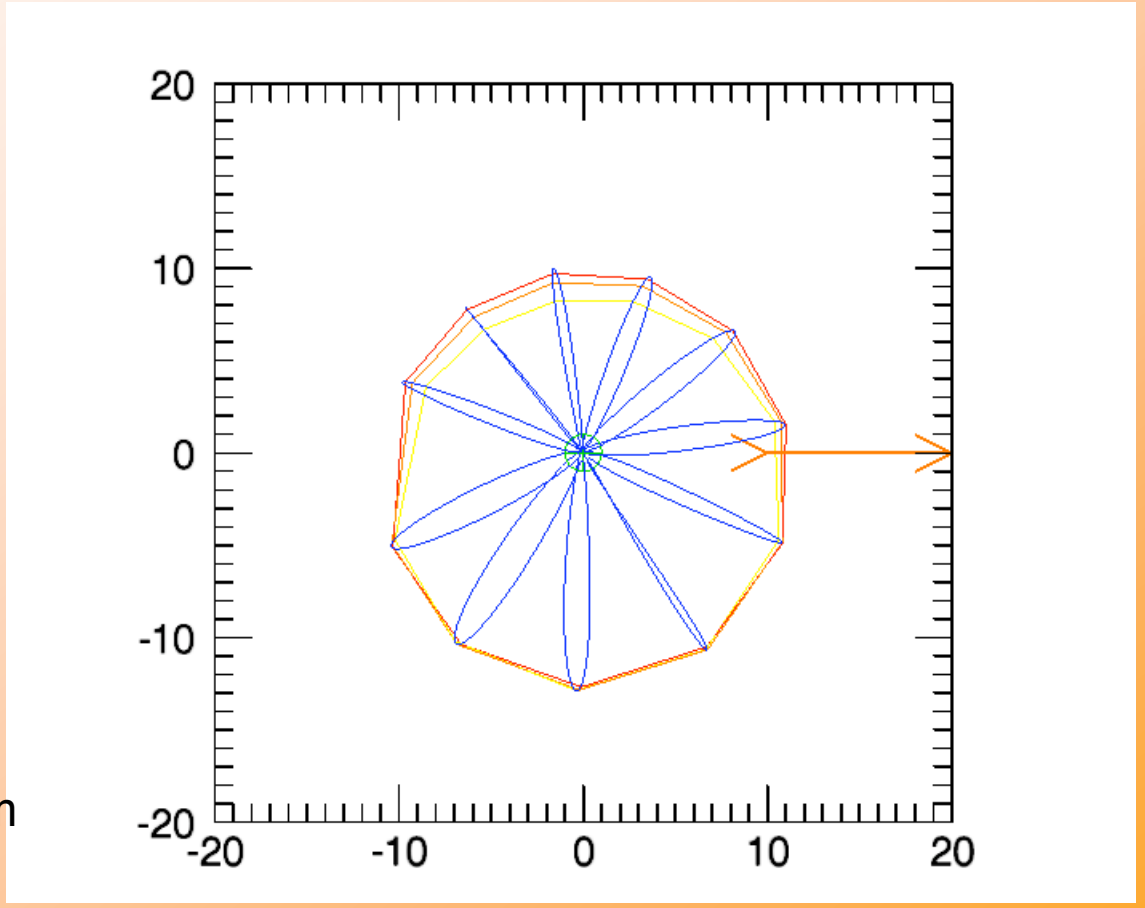
Equatorial plane from dawn side

North Pole



Magnetic Field Models

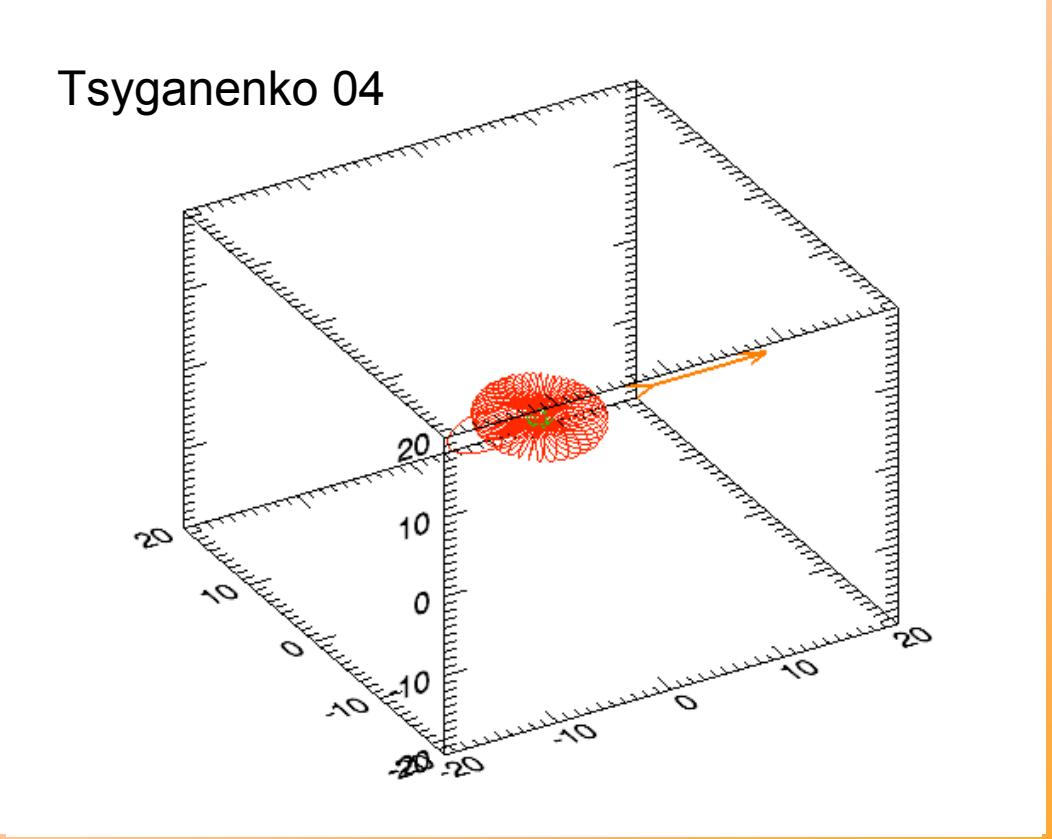
- Tsyganenko ‘04
  - Newest model available
  - Increased time dependence
  - Recently touted as providing the best results at the Equator



View: → Equatorial plane from above North Pole

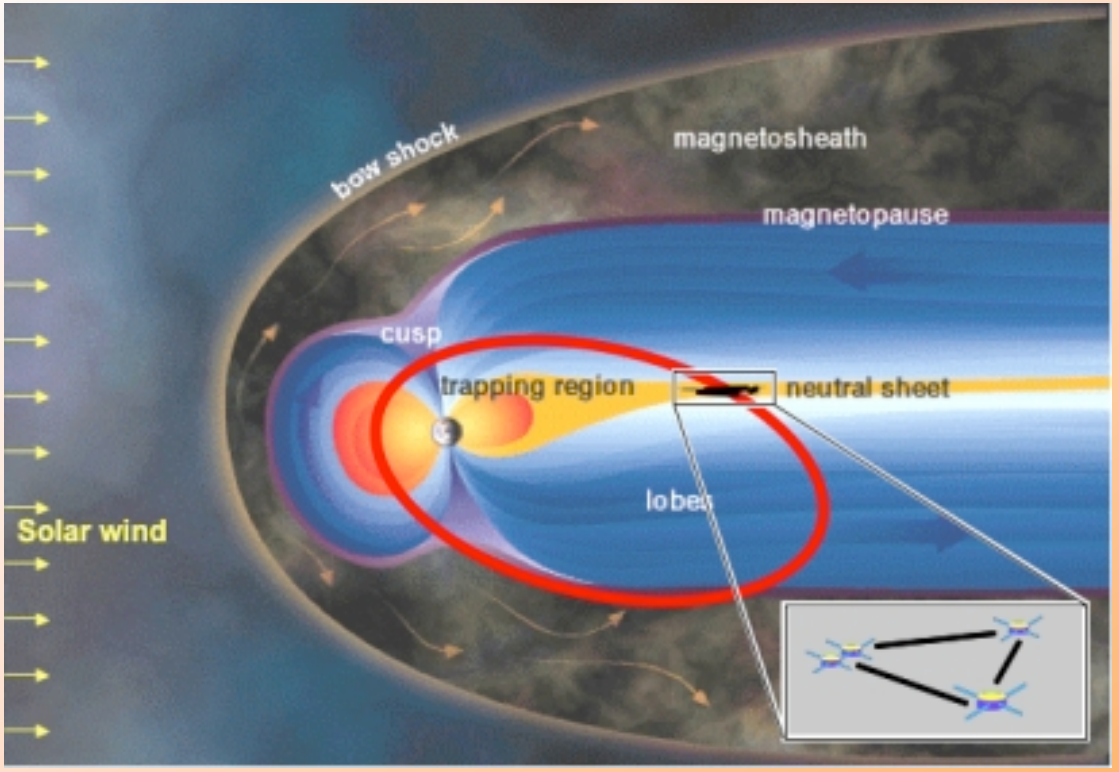
Drift Shells

- Shapes are similar between models
- Magnitudes are variable
- Results confirm equatorial findings



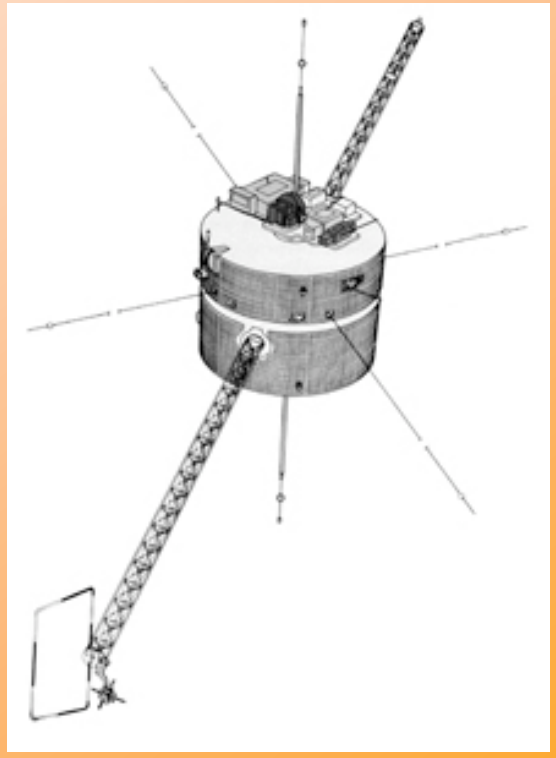
Satellite Verification of model output |**B**| Field

Cluster



http://clusterlaunch.esa.int/science-e/www/object/index.cfm?fobjectid=41122

Polar



http://pwg.gsfc.nasa.gov/polar/

Prediction Efficiency

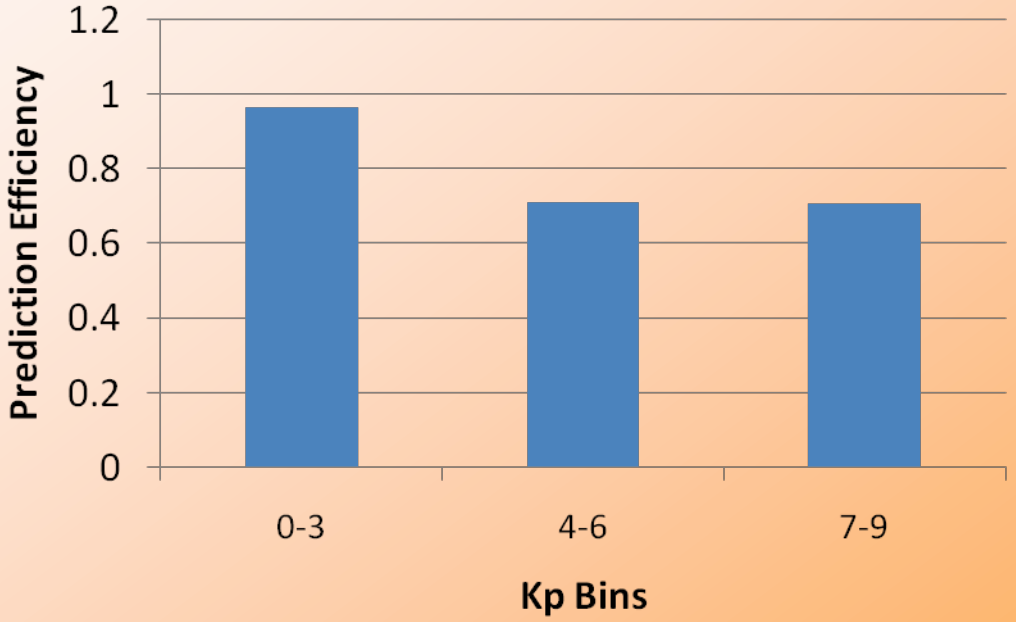
$$PE = 1 - \frac{e_{rms}^2}{\sigma_x^2}$$

Measures how much variation in the data can be explained by the model.

$$e_{rms} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\hat{x}_i - x_i)^2}$$

Kp Bins

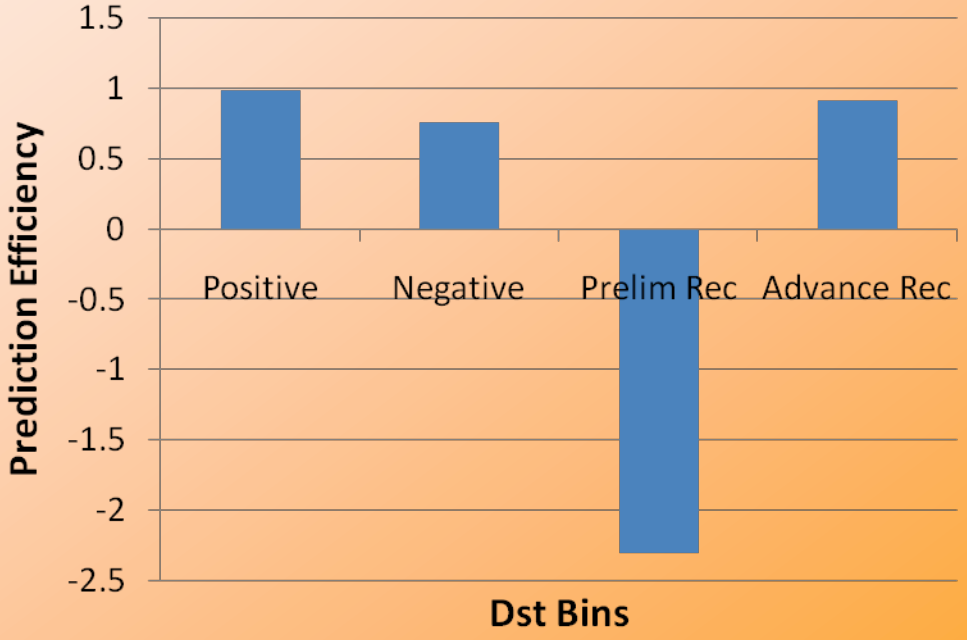
- Divided into…
  - Low (0 < kp < 3)
  - Medium (4 < kp < 6)
  - High (7 < Kp < 9)



- Lowest bin shows highest prediction efficiency.
- Overall: Tsyganenko ‘04 has highest PE.
- High Kp: Tsyganenko ‘01/“Storm” has best PE.

Dst Bins (Storm Phases)

- Divided into: Positive, Negative, Preliminary Recovery, and Advanced Recovery phases.
- Best during Positive and Advanced Recovery
- Overall poor early recovery phase results
- Tsyganenko ‘04 has best prelim recovery PE probably due to time dependence.

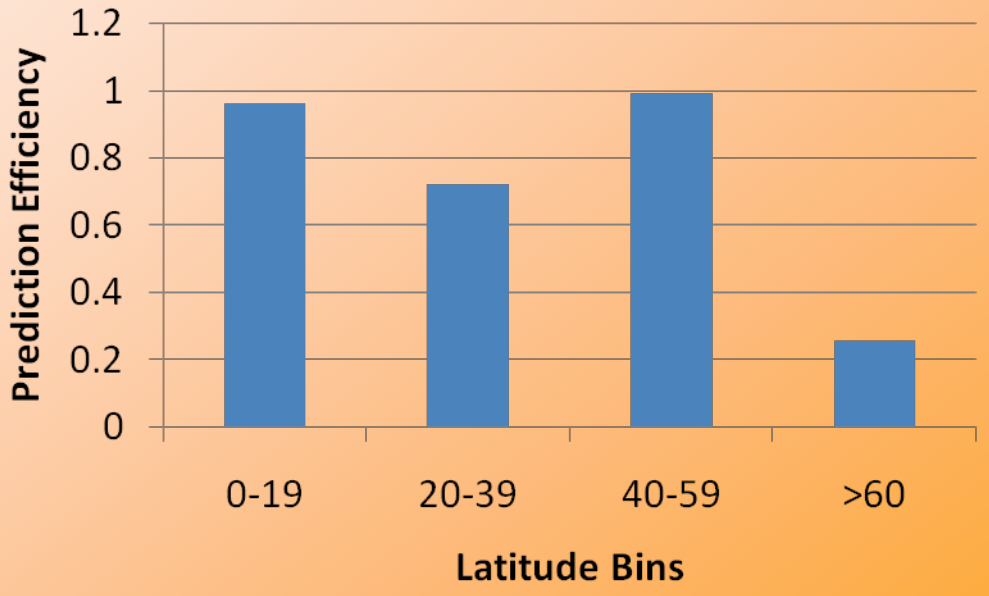


Magnetic Latitude

- Divided into: 0°-19°, 20°-39°, 40°-59°, >60°.

- 0°-19° and 40°-59° latitude bins show best performance.

- >60° bin shows lowest predictive power.



Magnetic Latitude Con't

- All three Tsyganenko model perform decently in lowest latitudes. Olson & Pftizer is weakest.
- As latitude increases…
  - Newer models retain robust performance.
  - Older models drop off in performance.
- At highest latitudes, Tsyganenko '01 is best.

Conclusions

Overall

- Models perform best in low geomag activity.
- Storm time model performance is best during positive and advanced recovery phases of storms.
- Many of the problems shown in equatorial studies are manifest at higher L values.
- Drift shells are very similar among models.

Conclusions Con't

Models

- Overall, Tsyganenko '04 shows best performance statistics.
- During extremely high Kp and at high geomag latitudes, Tsyganenko '01 provides best performance.
- Tsyganenko '96 and Olson & Pfitzer "dynamic" show worst performance.

Future Work (for the fall)

- Continue to expand the number of data points for better statistics
- Submit for Fall AGU conference
- Write it up and send if off to *Space Weather*

Wall of Shame