Space Environment Technologies

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Thermospheric Density Variations

EUV Solar and Geomagnetic Storm Modeling

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Density Variations at 400 km

Variations	Change	Frequency
Solar cycle	1600 %	11 years
Semiannual	125 %	12 months
Solar UV Rotation	250 %	27 days
Major Geomagnetic Storm	800 %	3 days
Diurnal effect	250 %	1 day

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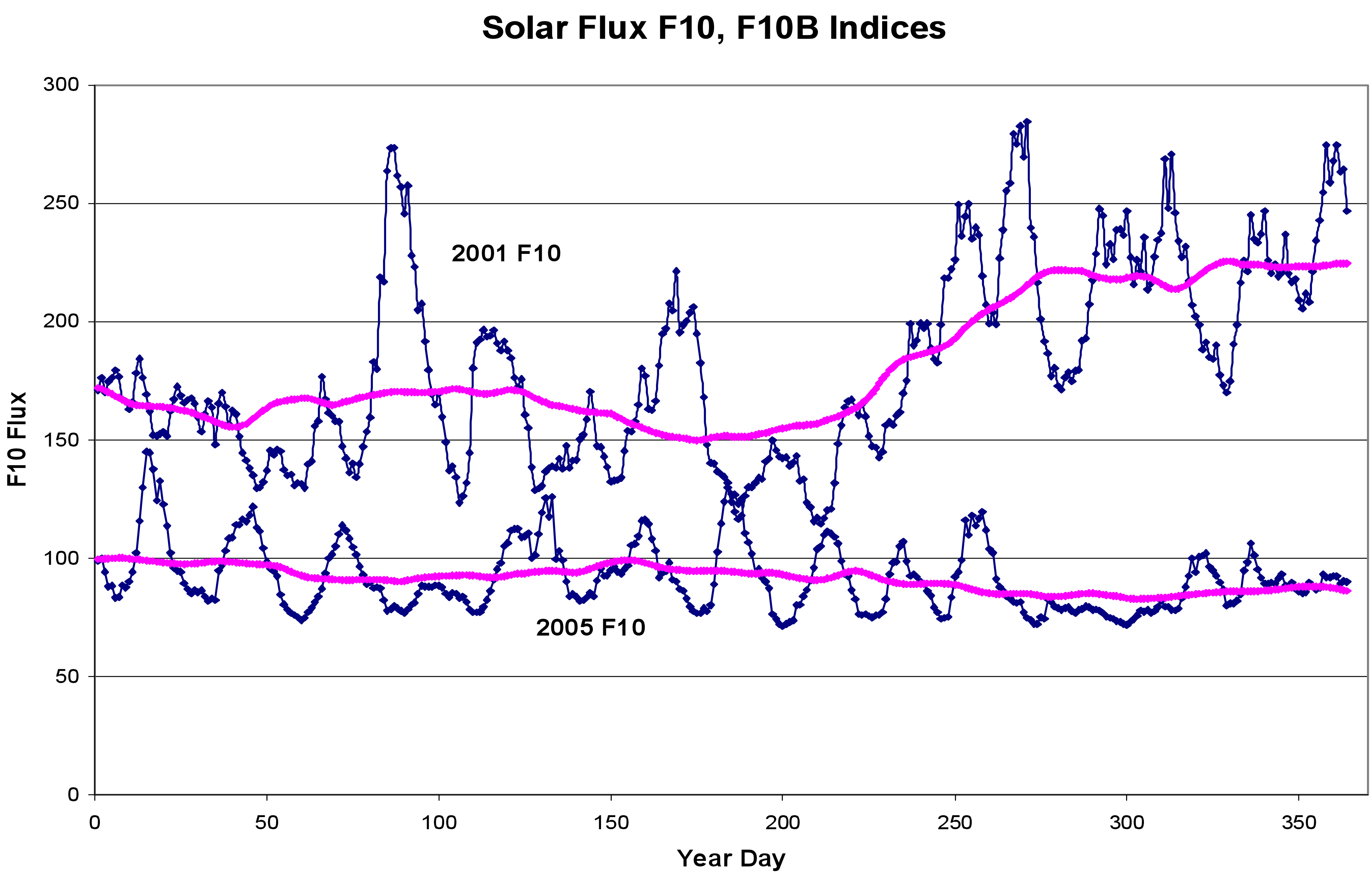
Solar EUV Rotation



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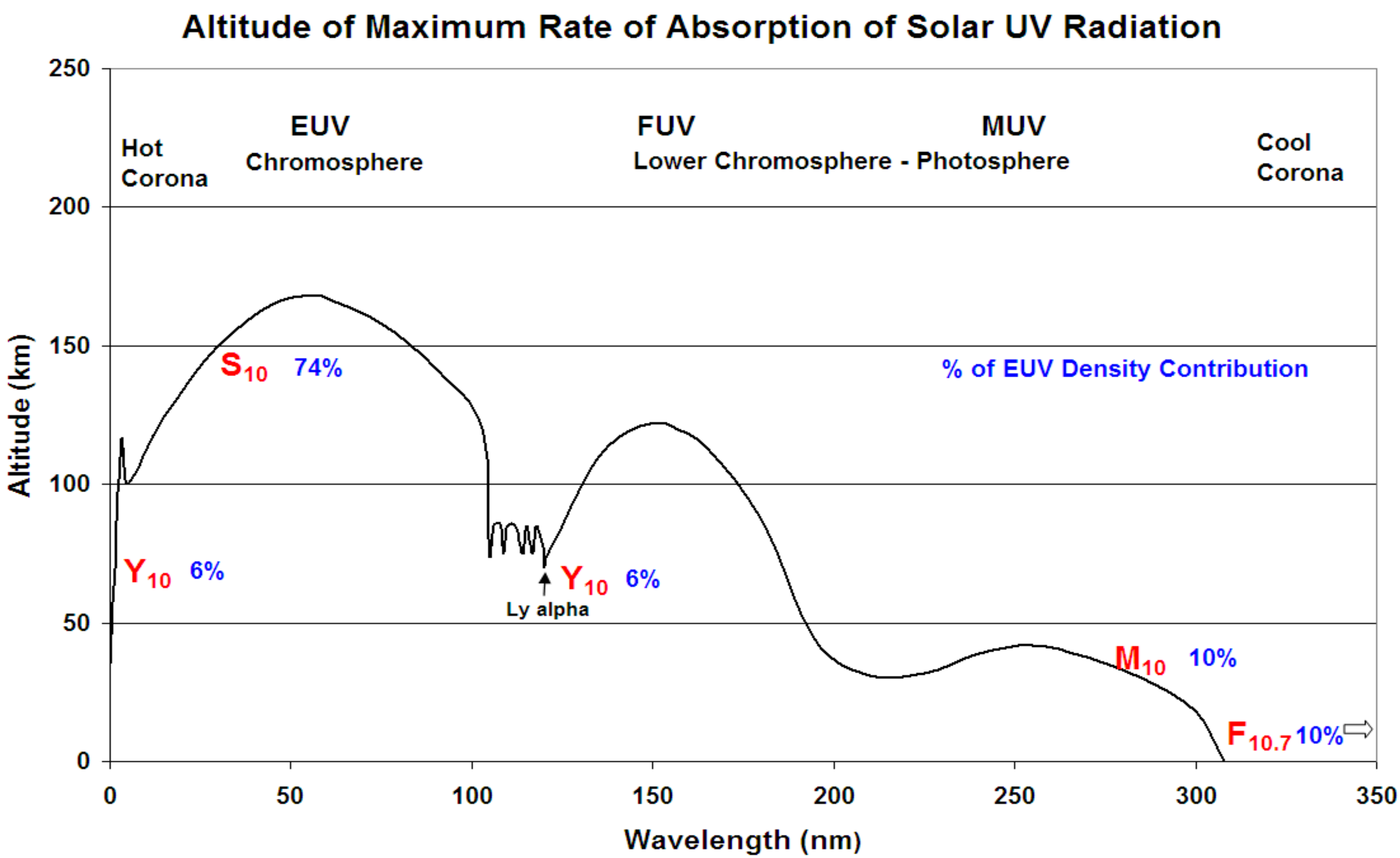
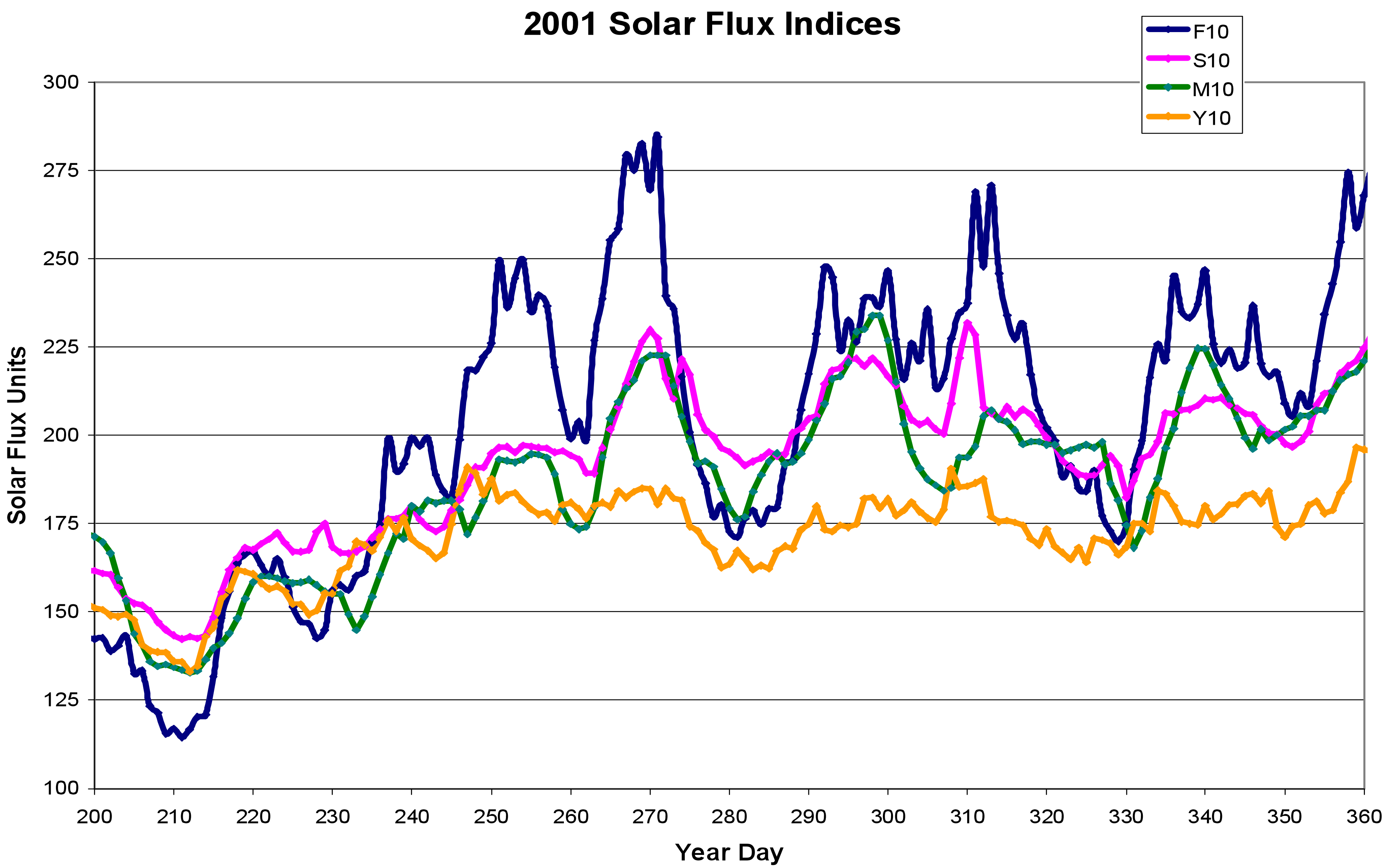
UV Absorption Regions



New Solar Indices



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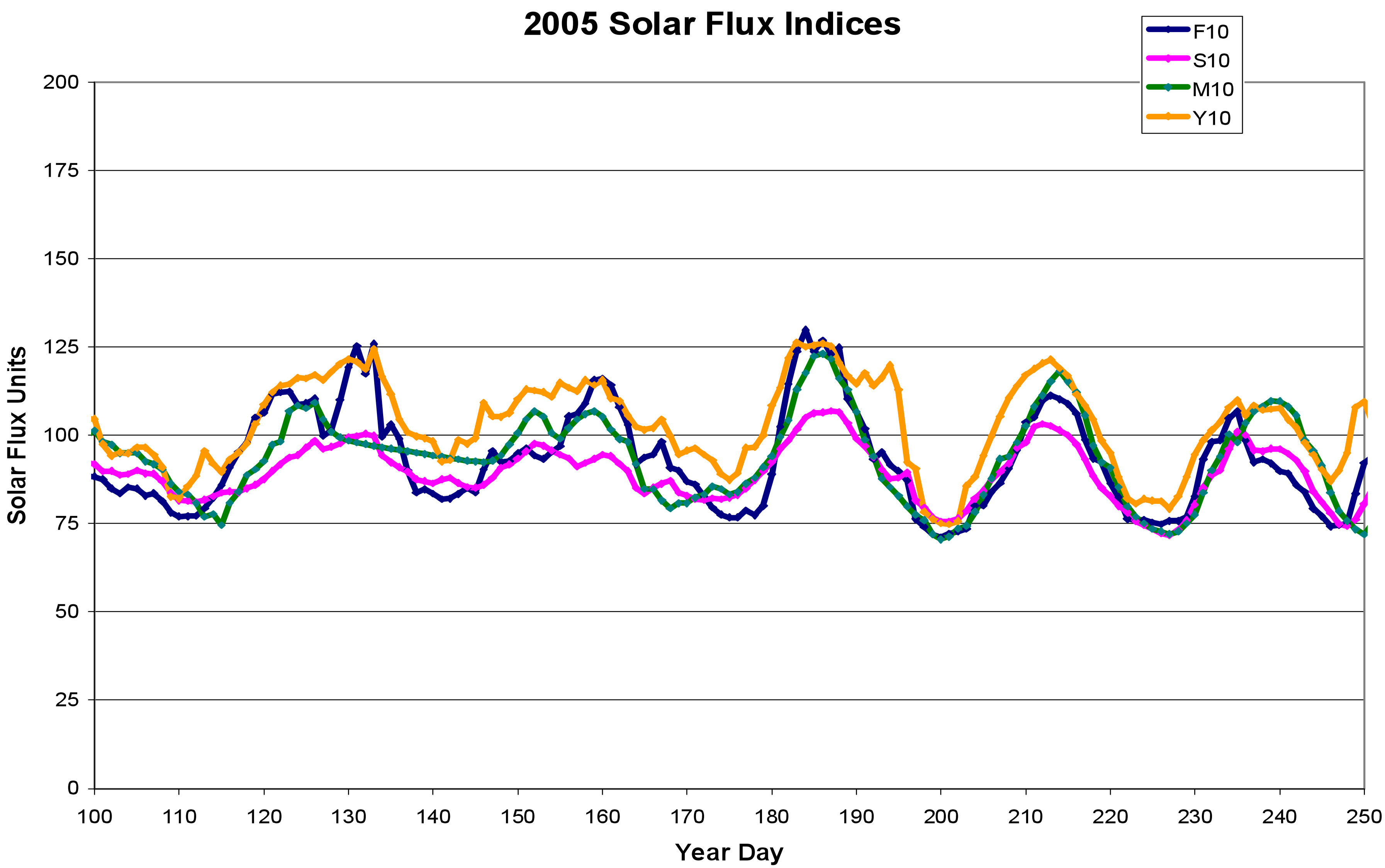
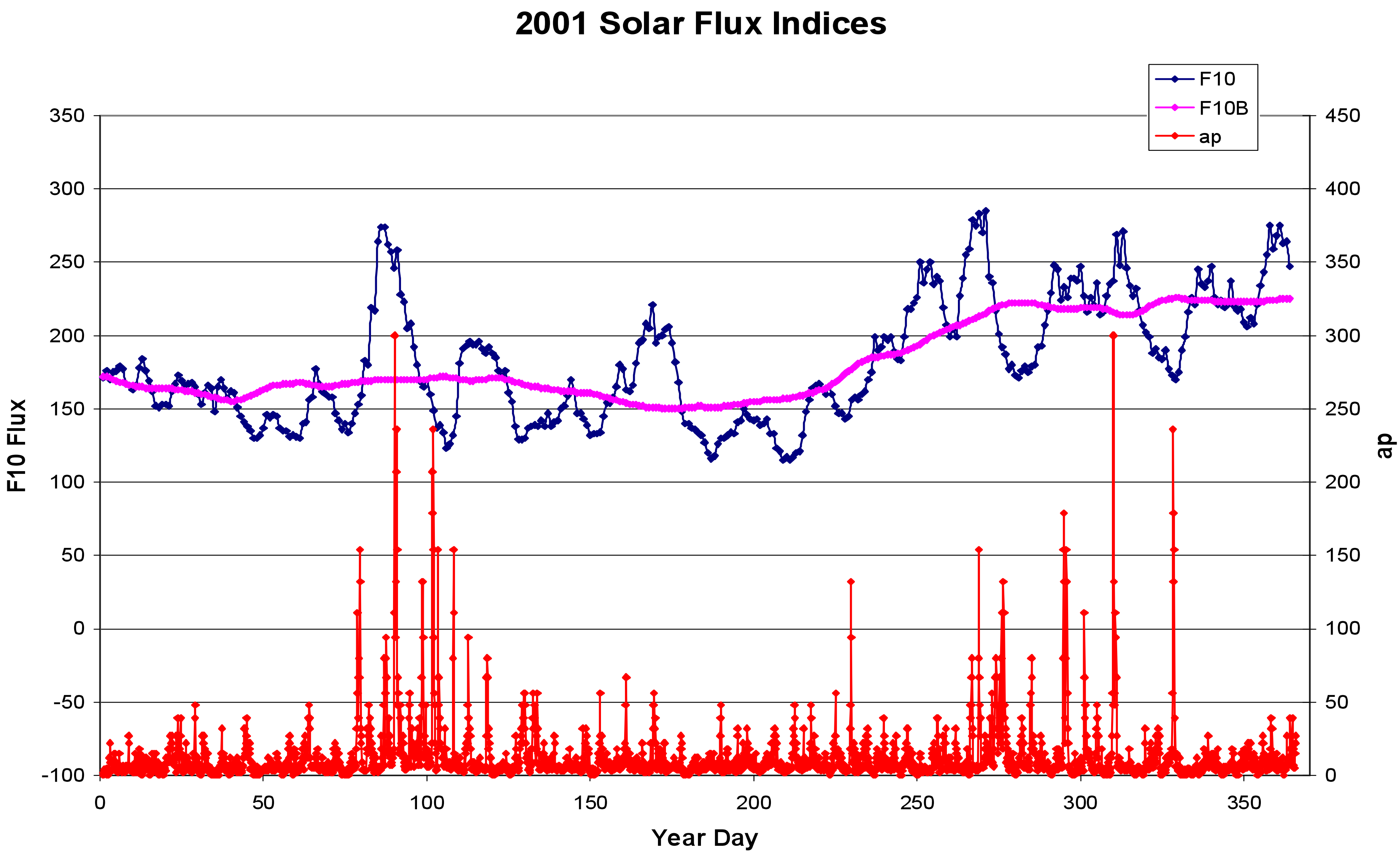
New Solar Indices



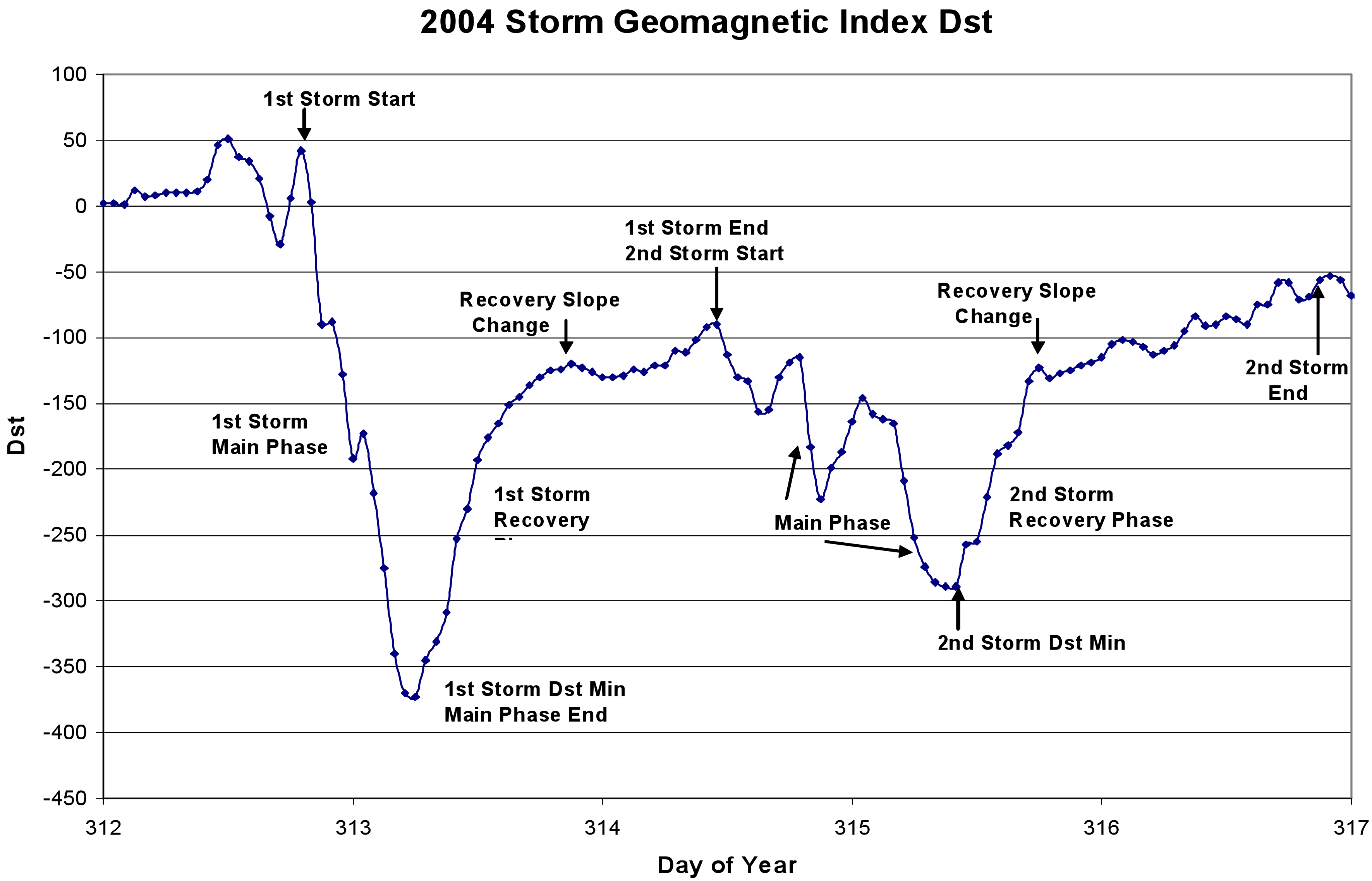
Storm Modeling



Geomagnetic Storm Modeling

- All previous empirical models use ap geomagnetic index for storm modeling
- The 3-hour ap is a measure of general magnetic activity over the Earth, and responds primarily to currents flowing in the ionosphere and only secondarily to magnetospheric variations
- The ap index is determined by observatories at high latitudes which can be blind to energy input during large storms (Huang and Burke, 2004)
- The Disturbance Storm Time (Dst) index is primarily used to indicate the strength of the storm-time ring current in the inner magnetosphere
- During the main phase of magnetic storms, the ring current becomes highly energized and produces a southward-directed magnetic field perturbation at low latitudes on the Earth's surface
- The Dst index is determined from hourly measurements of the magnetic field made at four points around the Earth's equator

Dst Storm Profile



Dst Equations

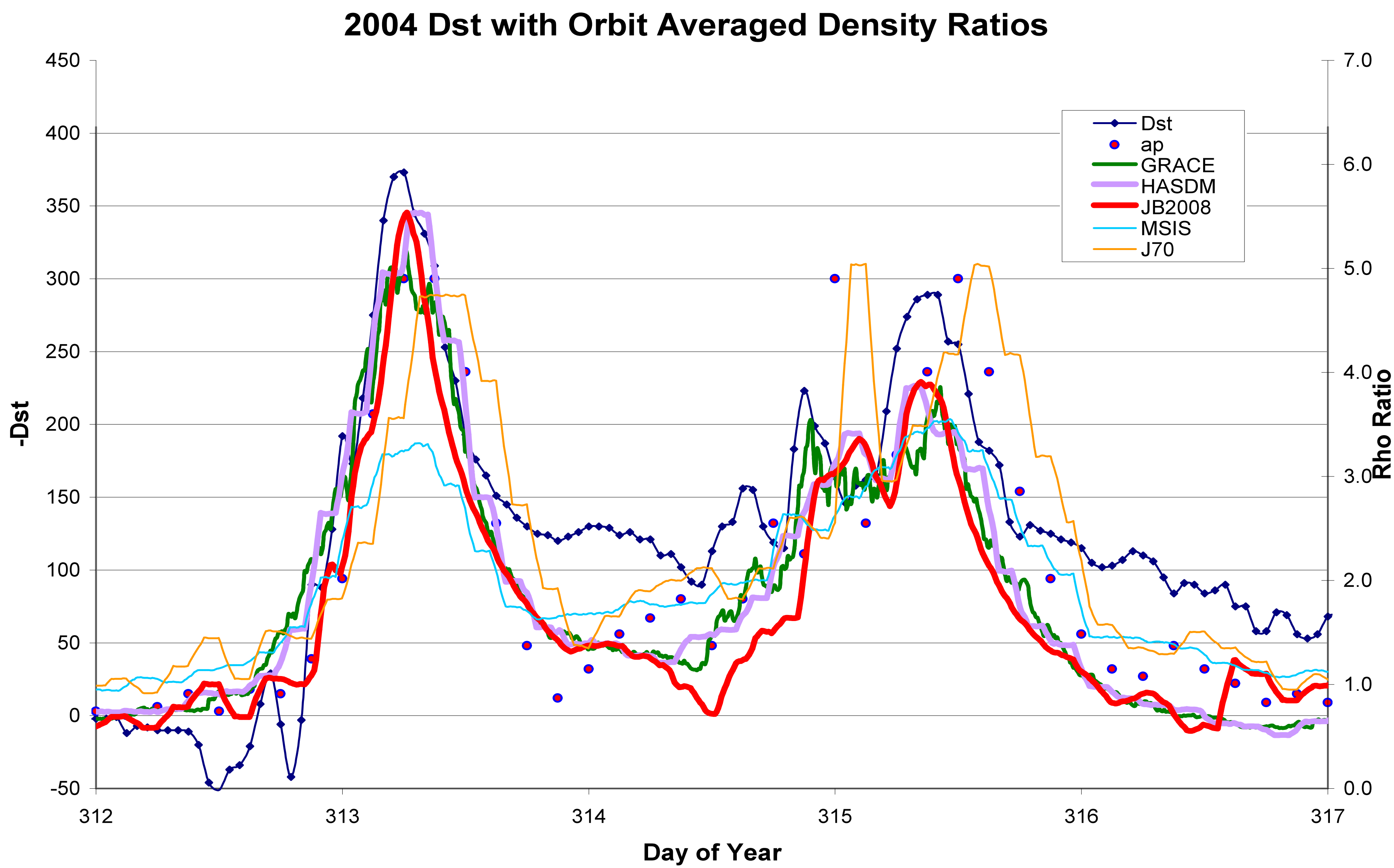
- The thermosphere acts during storm periods as a driven-but-dissipative system whose dynamics can be represented by a differential equation
- The driver is the magnetospheric electric field. Burke (2008) determined the relationship for the exospheric temperature responses as a function of Dst:

$$dTc_1 = (1 - \frac{1}{\tau_1})dTc_0 + S\left[Dst_1 - \left(1 - \frac{1}{\tau_2}\right)Dst_0\right]$$

- The above equation must be integrated from storm beginning throughout the entire storm period in-order to compute ΔTc at every point during the storm
- The above equation was optimized to fit the CHAMP and GRACE accelerometer density data, along with HASDM global densities. The resulting main phase equation, with variable slope S, is shown below
- Additional optimized equations were also developed for use during the Dst recovery phase period

$$dTc_1 = 0.846\ dTc_0 + S\left[Dst_1 - 0.870\ Dst_0\right]$$

2004 Major Storm



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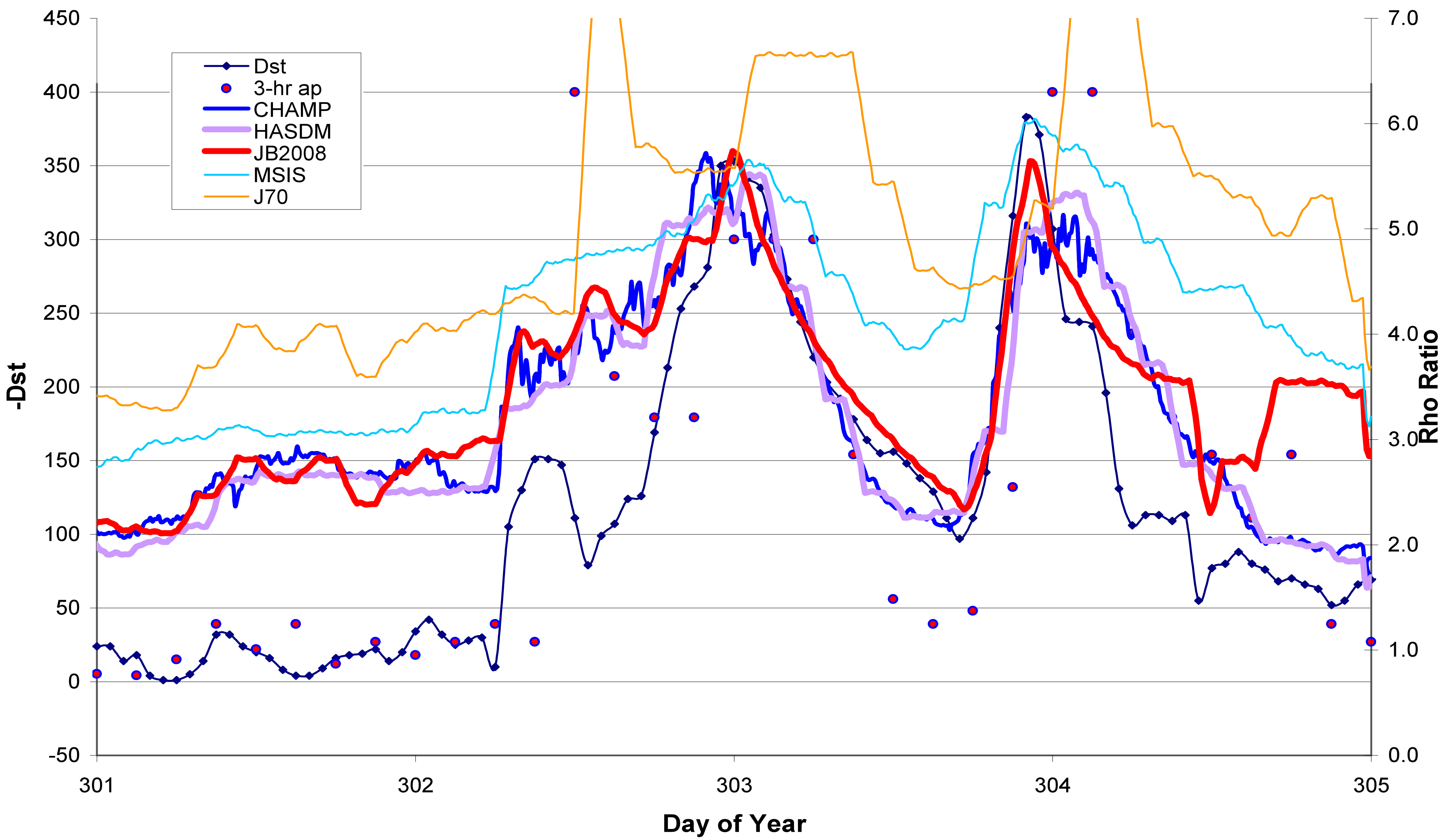
2003 Major Storm

2003 Dst with Orbit Averaged Density Ratios



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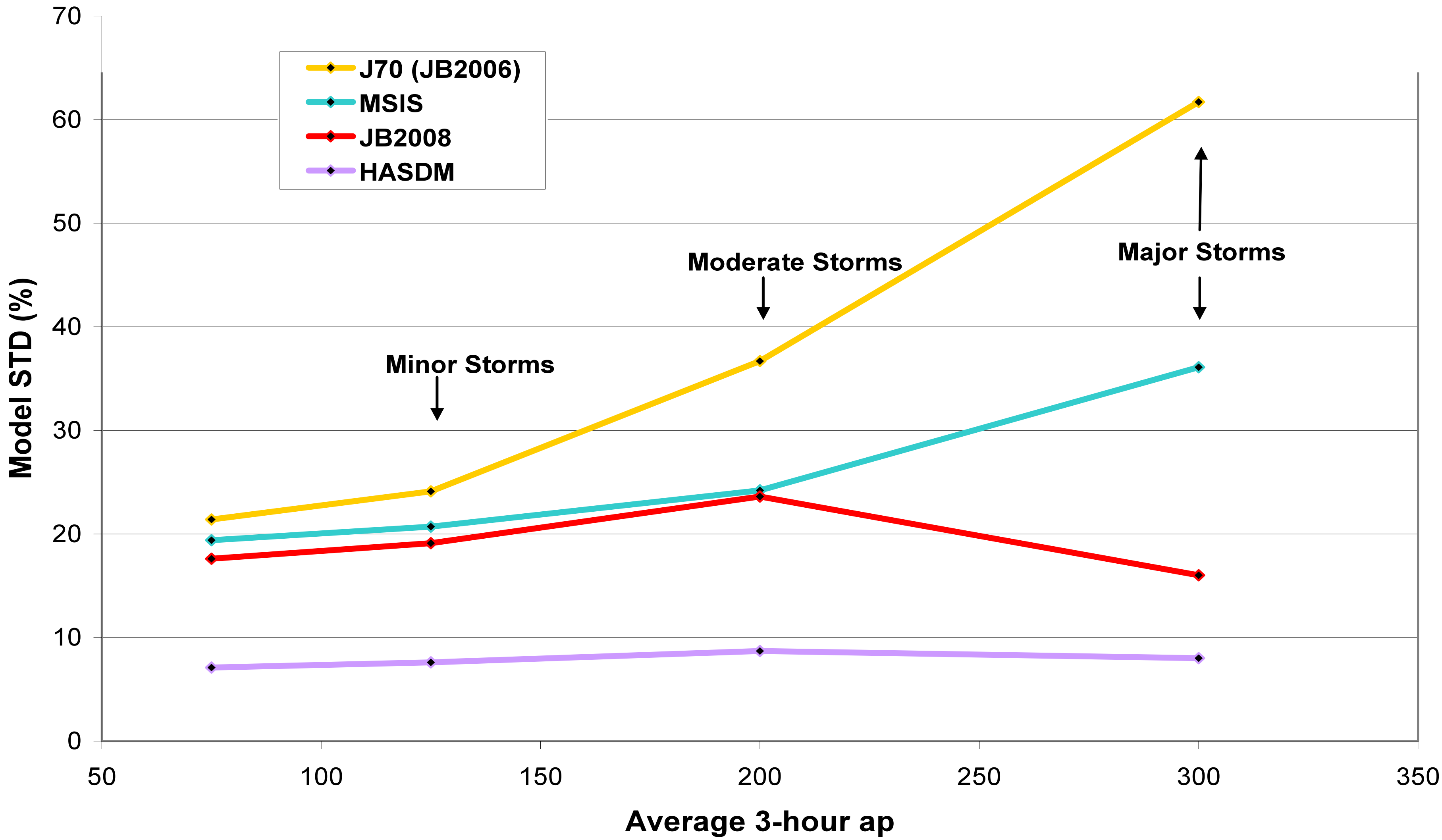
Density Model Accuracies

Orbit Averaged Model Density Errors

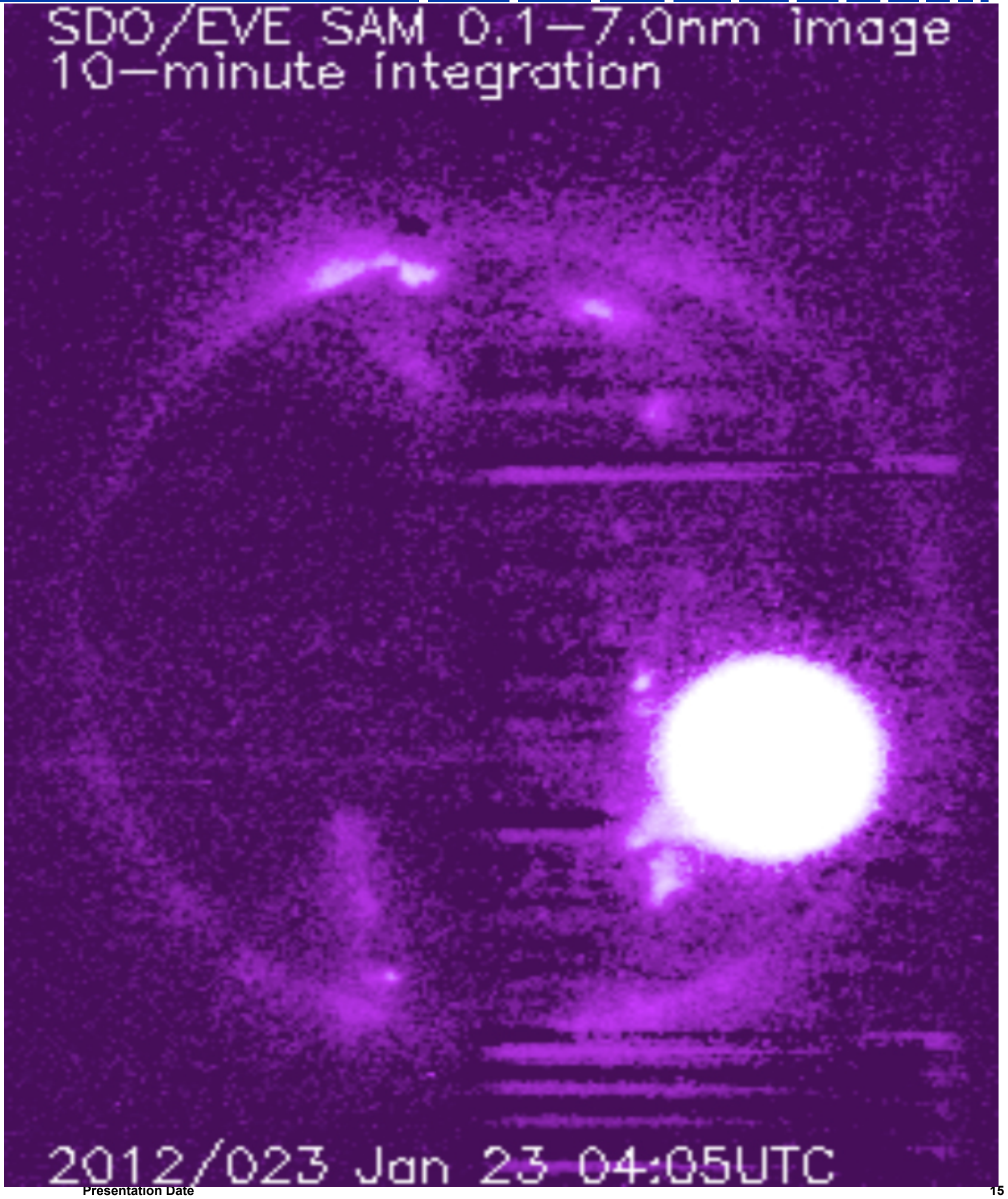


Anemomilos Dst Prediction Model

- Operational, event-driven Dst forecasting requires:
  - **Flare magnitude** – proxy for ejected mass
  - **Integrated flare irradiance** – used for speed computation
  - **Flare event location** – earthward storm effectiveness
- GOES hourly X-ray Xhf index used for **flare magnitude** and **integrated flare irradiance** (0.1–0.8 nm X-rays with background removed)
- NOAA and SDO SAM **flare event locations** are used
  - optical flare observed in H-alpha
  - SXI X-ray flare from GOES Solar X-ray Imager (SXI)
  - X-ray event from SWPC's Primary or Secondary GOES spacecraft
- Standard Dst storm profile assumed

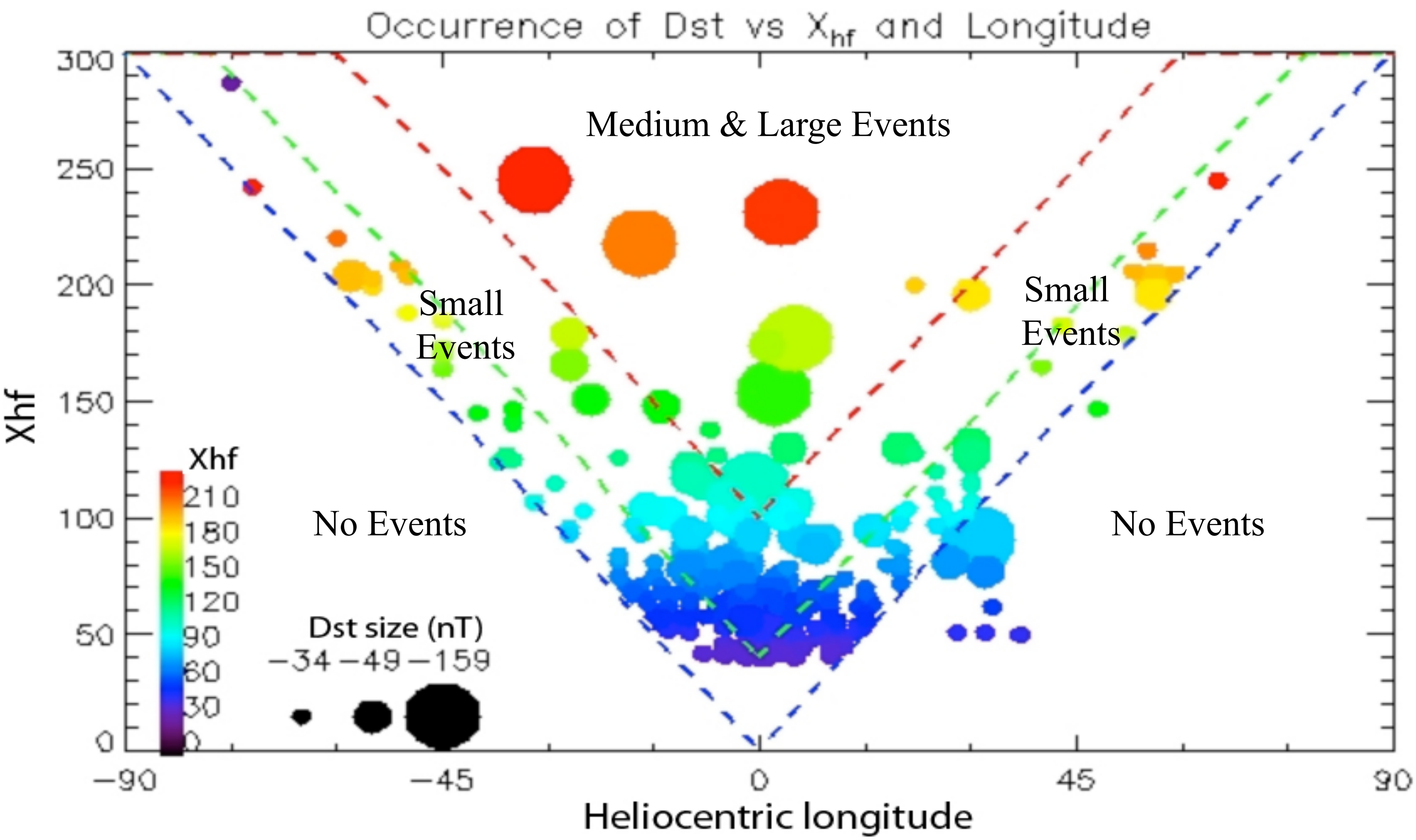
Flare Event Location Analysis

SDO EVE SAM detector with centroid of flare location



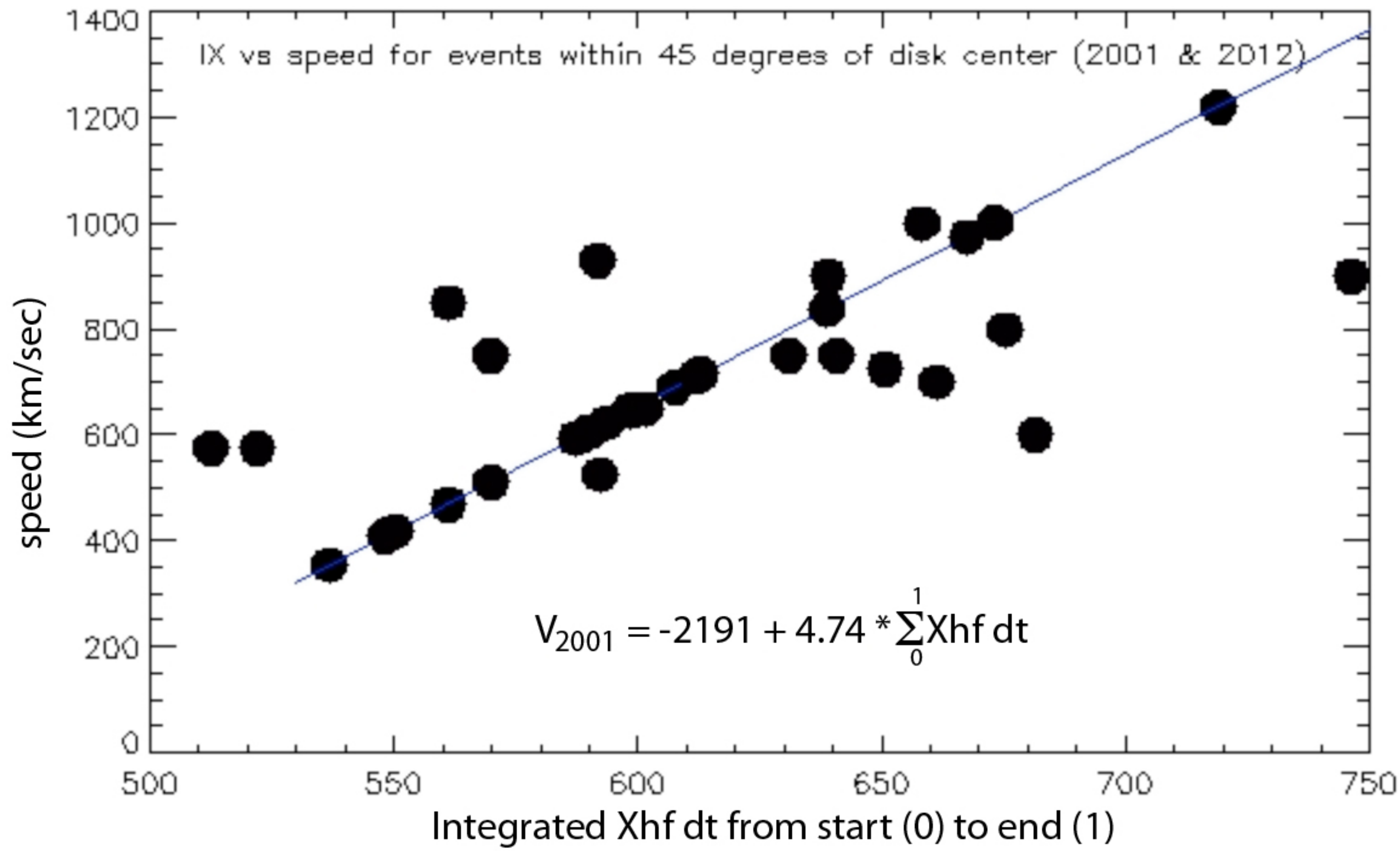
Dst Magnitude Analysis

Anemomilos Dst size vs. flare size and location



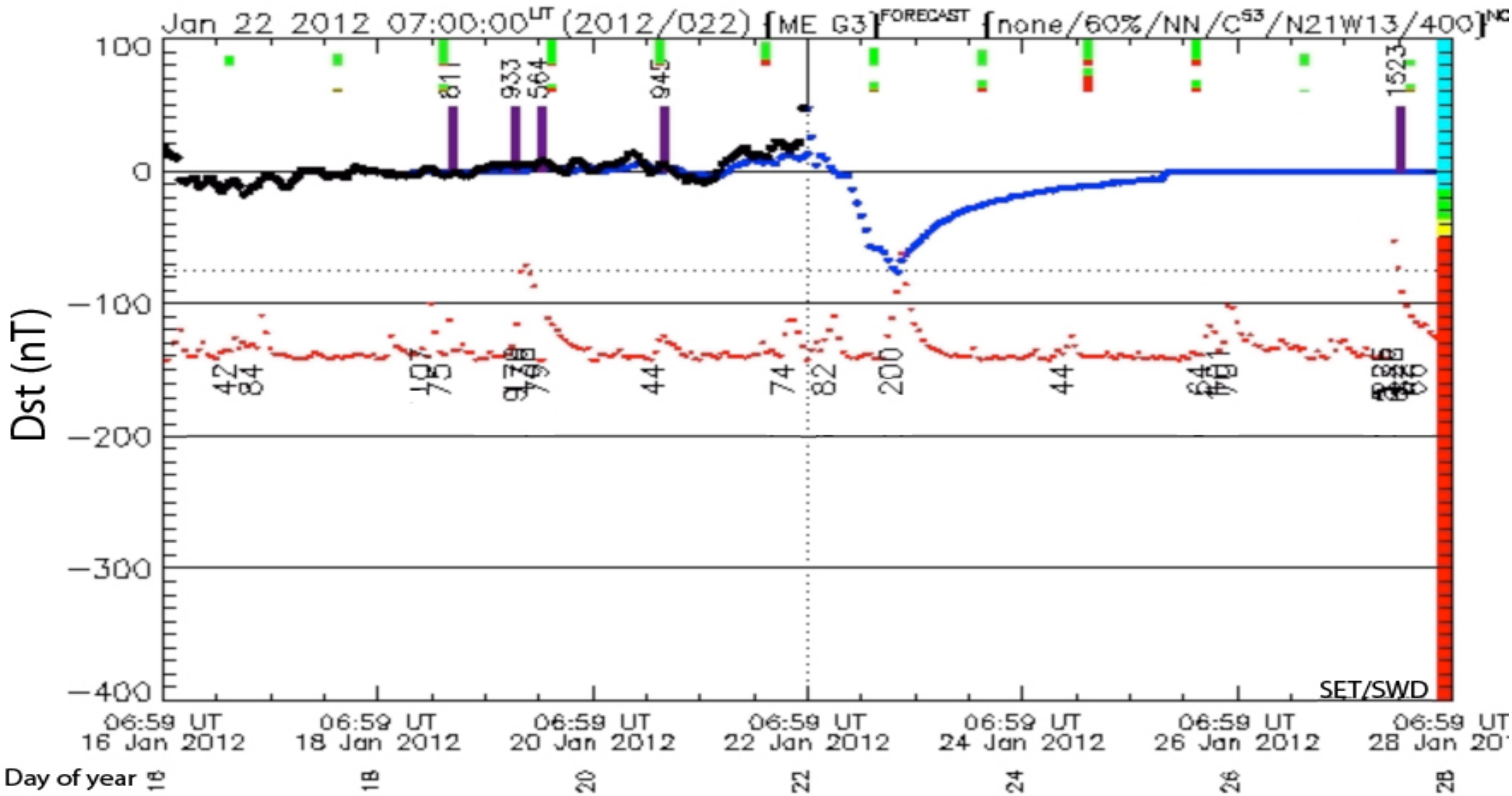
Dst Velocity Analysis

Anemomilos flare velocity function from integrated Xhf



Dst Storm Example

Anemomilos Dst prediction of start



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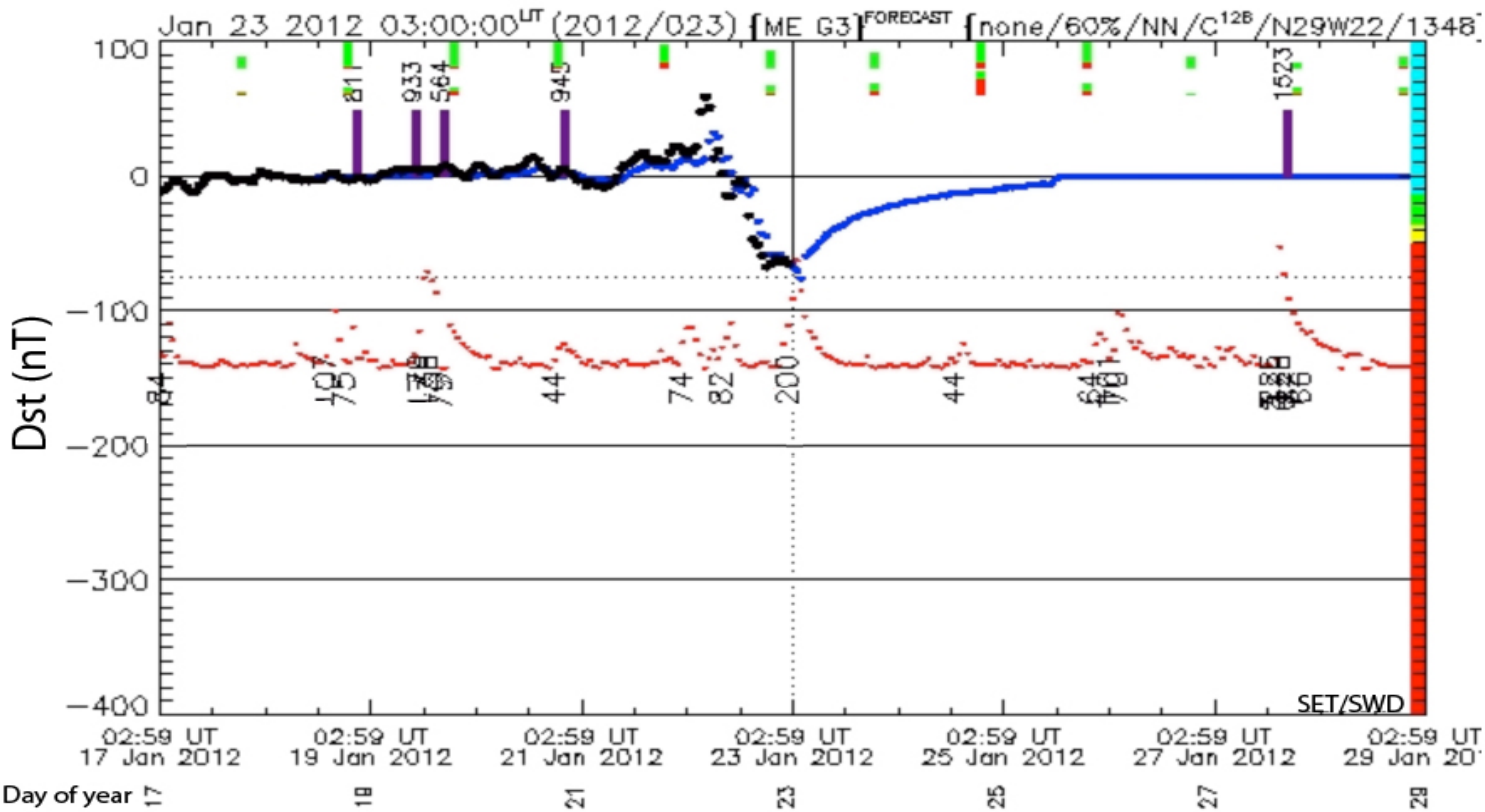
Dst Storm Example

Anemomilos Dst prediction of event peak



Conclusion

- Operational satellite position predictions greatly improved through:
  - JB2008 atmospheric model implementation
  - HASDM global density corrections
  - Use of new UV solar indices
  - Dst geomagnetic storm modeling
  - Dst storm prediction Anemomilos modeling