The WINDMI Model at the CCMC

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Low-Dimensional dynamical system: WINDMI

$$L\frac{dI}{dt} = V_{\text{sw}}(t) - V + M\frac{dI_1}{dt} \quad (1)$$

$$C\frac{dV}{dt} = I - I_1 - I_{\text{ps}} - \Sigma V \quad (2)$$

$$\frac{3}{2}\frac{dp}{dt} = \frac{\Sigma V^2}{\Omega_{\text{cps}}} - u_0 p K_{\|}^{1/2}\Theta(u) - \frac{pVA_{\text{eff}}}{\Omega_{\text{cps}} B_{\text{tr}} L_y} - \frac{3p}{2\tau_E} \quad (3)$$

$$\frac{dK_{\|}}{dt} = I_{ps}V - \frac{K_{\|}}{\tau_{\|}} \quad (4)$$

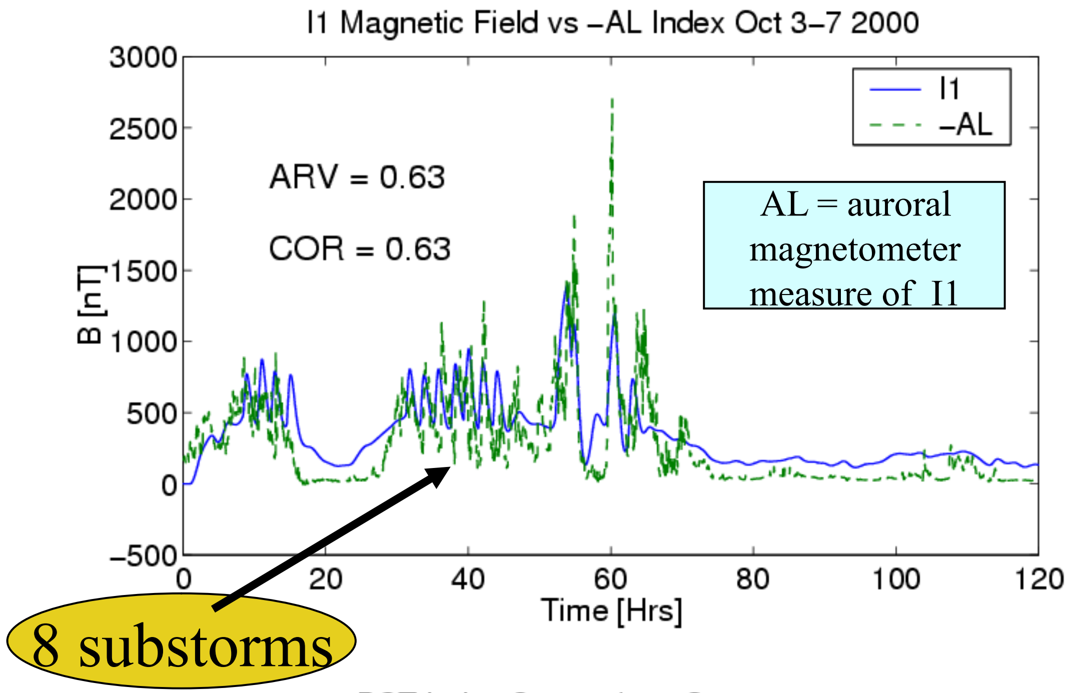
$$L_I\frac{dI_1}{dt} = V - V_I + M\frac{dI}{dt} \quad (5)$$

$$C_I\frac{dV_I}{dt} = I_1 - I_2 - \Sigma_I V_I \quad (6)$$

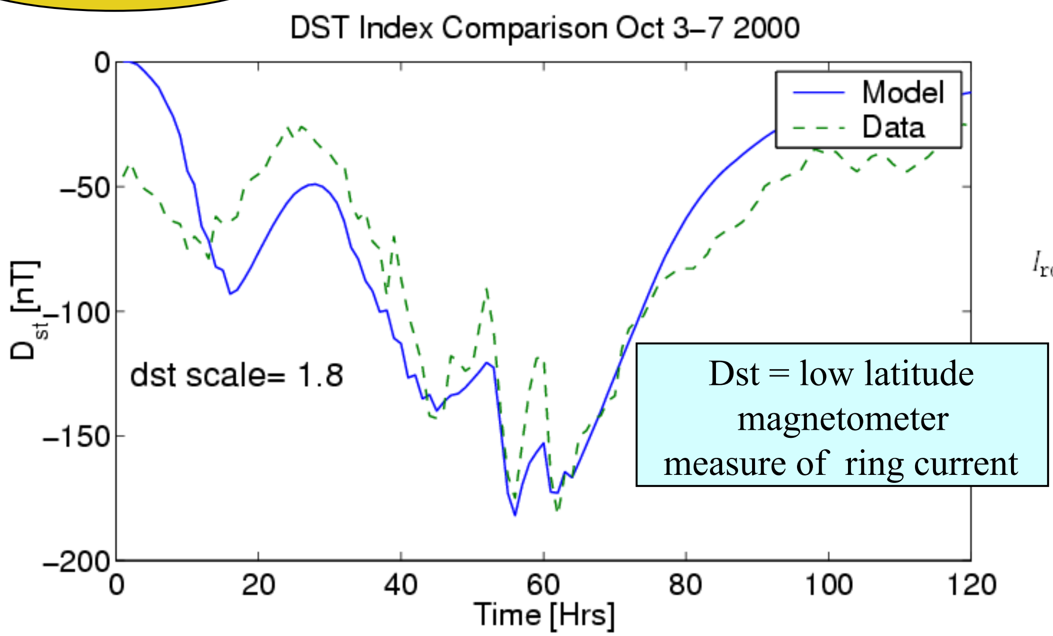
$$L_2\frac{dI_2}{dt} = V_I - (R_{\text{prc}} + R_{A2})I_2 \quad (7)$$

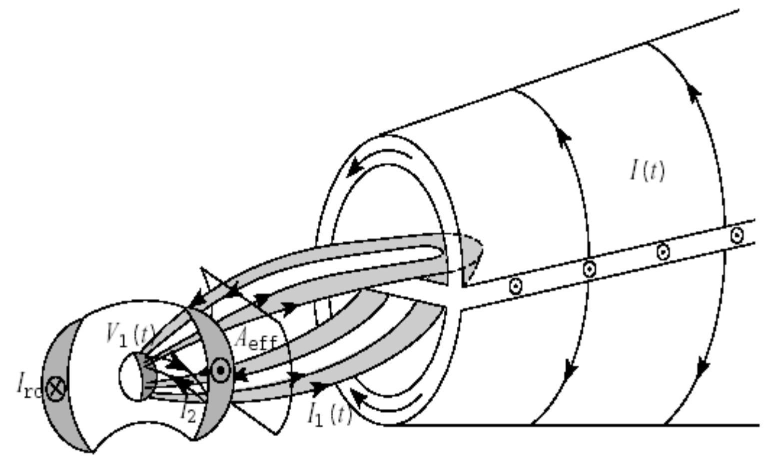
$$\frac{dW_{\text{rc}}}{dt} = R_{\text{prc}} I_2^2 + \frac{pVA_{\text{eff}}}{B_{\text{tr}} L_y} - \frac{W_{\text{rc}}}{\tau_{\text{rc}}} \quad (8)$$

Derived by projection of pde’s on to key basis functions: not simple dynamics.
attractors,bifurcations, chaos from strange attractors.
Limits to predictability of Weather systems



WINDMI-RC Simulation for 4-6 Oct 2000 GEM Storm



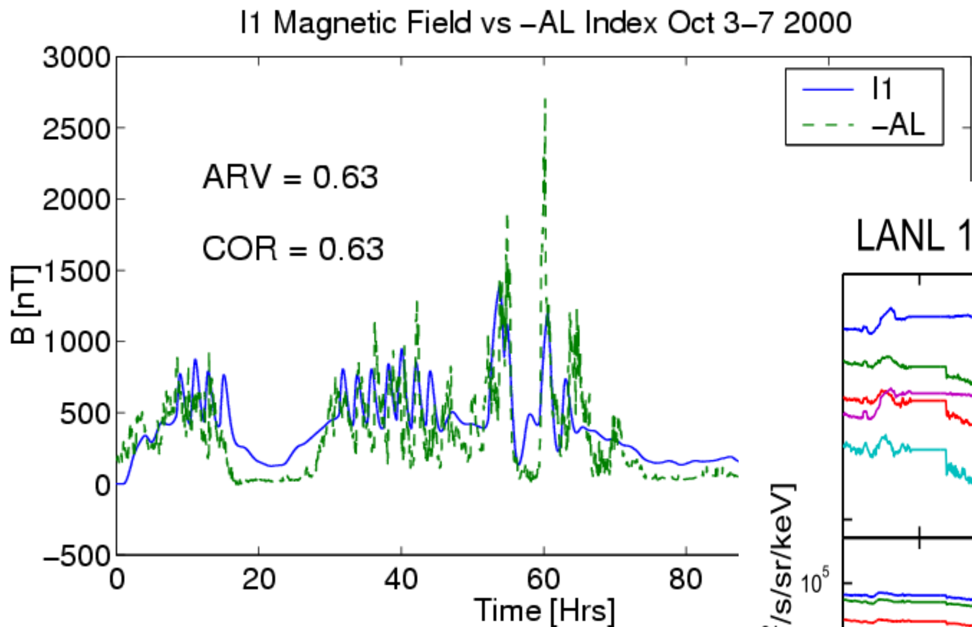


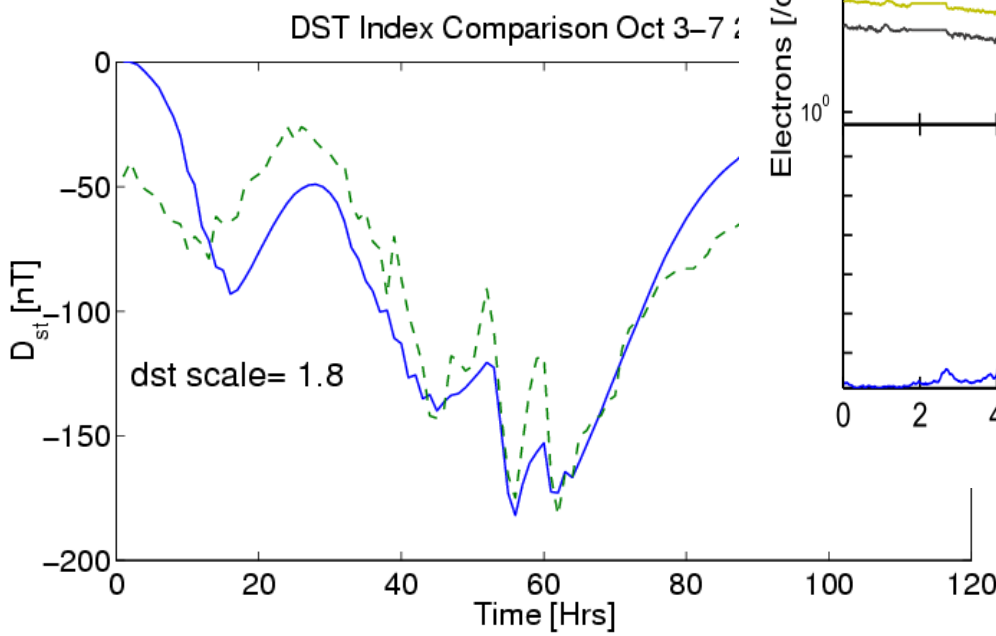
Spencer et al, Mays et al JGRs 2007, 2010, 2012, Patra 2011

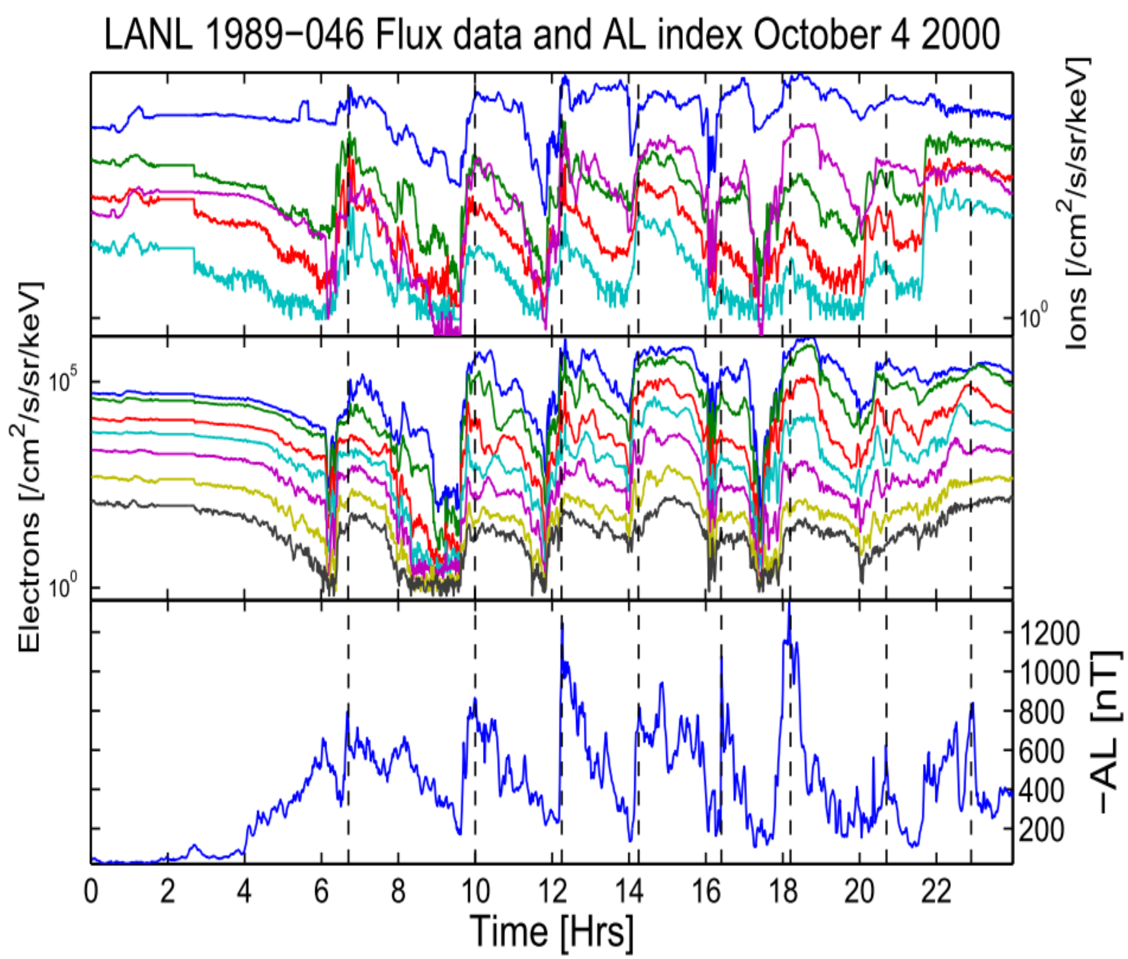
Events and Validation Publications

3–7 October 2000 AL and Dst for [Spencer-JGR-2007]
15–24 April 2002 with 8 substorms –Al >1000 [Mays]
August 2001 Dst tail current contribution [Spencer]
25 February 2008 isolated moderate substorm –Al=70[Patra]
4-8 Apr 2010 Dst – 80nT and –AL > 1300, 900
5-12 August 2011 Dst min. -113 nT AL min. -2000 nT
9-14 September 2011Dst min. -64 nT AL min. -1300 nT
17-19 September 2011Dst min. -58 nT AL min. -1200 nT
26-30 September 2011Dst min. -103 nT AL min. -1600 nT

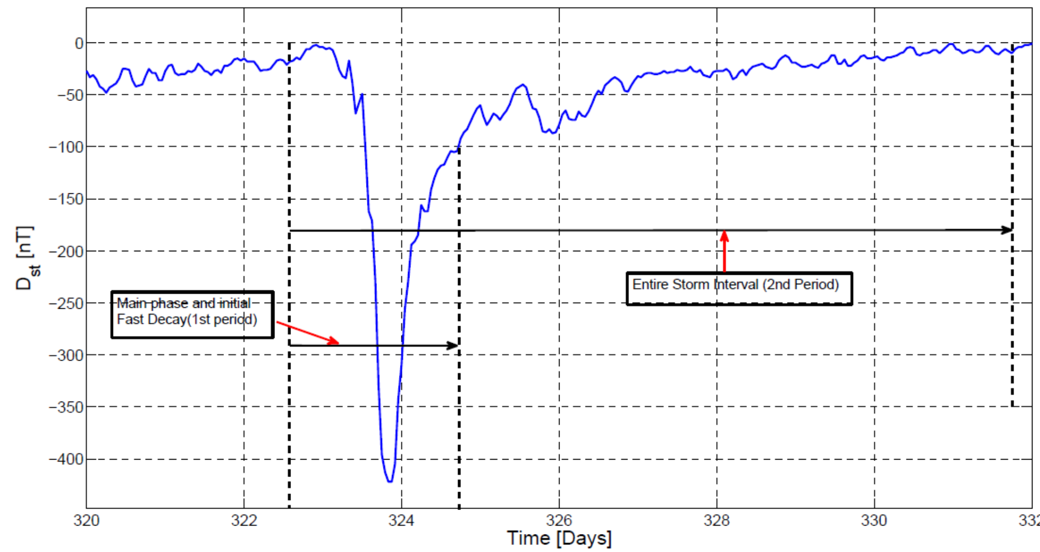
Publications:
Spencer et al. JGR 2007, 2010, 2011
Mays et al. Space Weather 2009
Patra et al. JGR 2011
Spencer et al JGR 2012


I1 Magnetic Field vs −AL Index Oct 3−7 2000
I1
−AL
ARV = 0.63
COR = 0.63
B [nT]
Time [Hrs]


DST Index Comparison Oct 3−7 2
dst scale= 1.8
D_st [nT]
Time [Hrs]


LANL 1989−046 Flux data and AL index October 4 2000
Ions [/cm^2/s/sr/keV]
Electrons [/cm^2/s/sr/keV]
−AL [nT]
Time [Hrs]

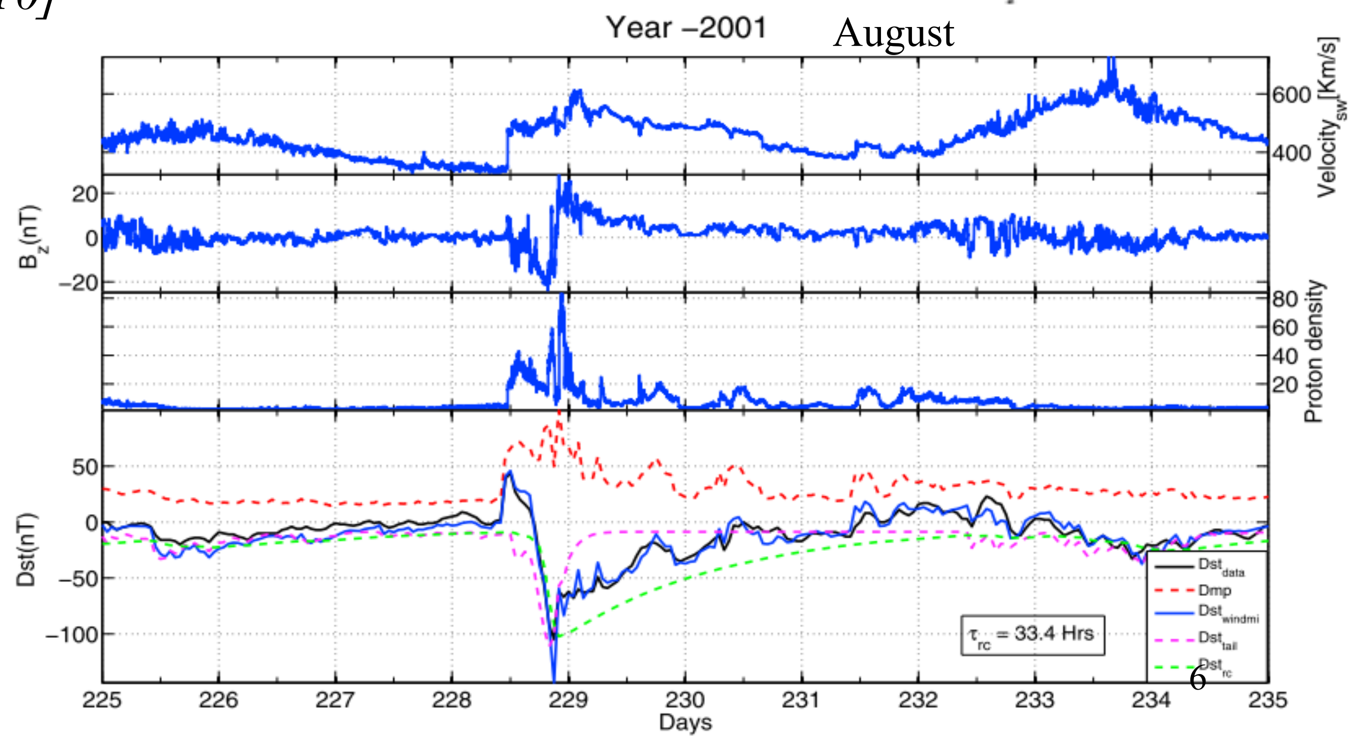
Typical two phase decay of a geomagnetic storm as indicated by the corresponding Dst Index.



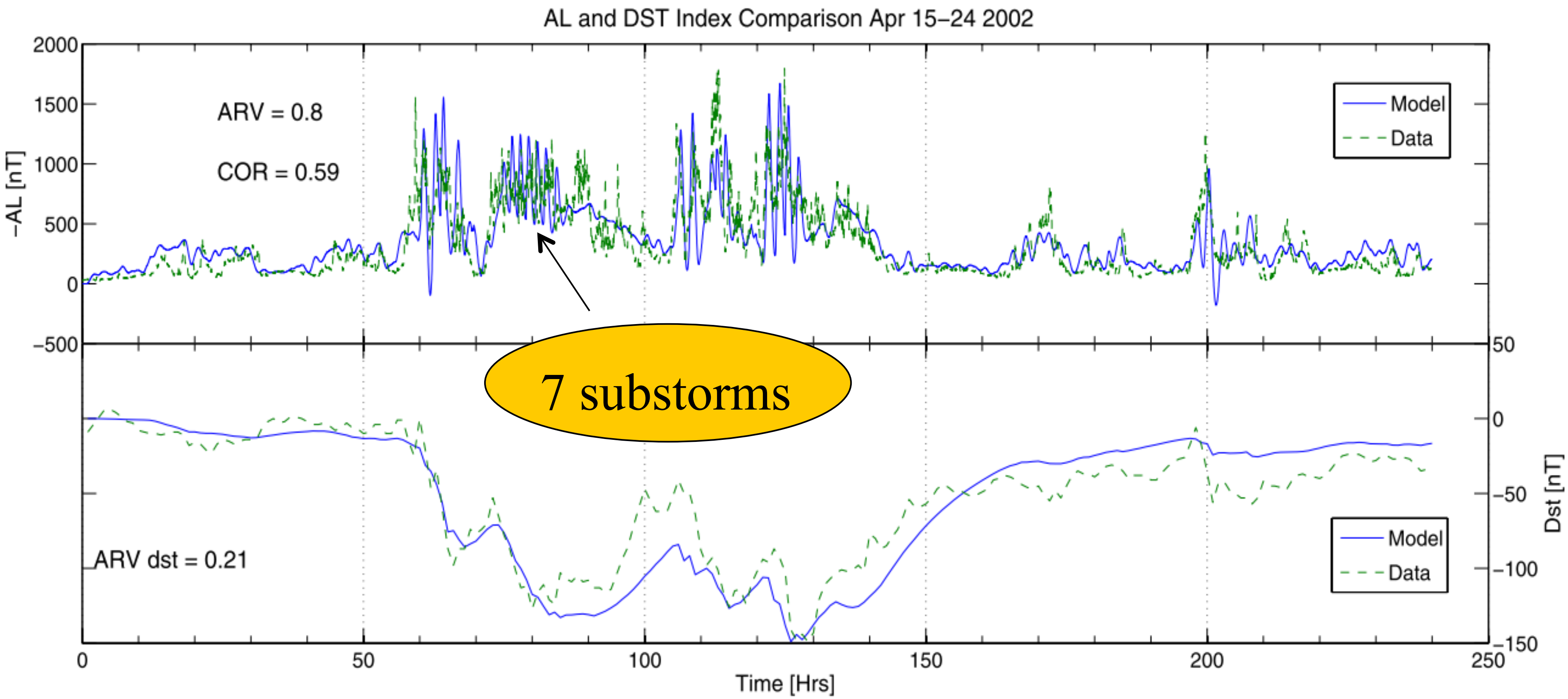
WINDMI Storms
[Spencer et al JGR 2010]

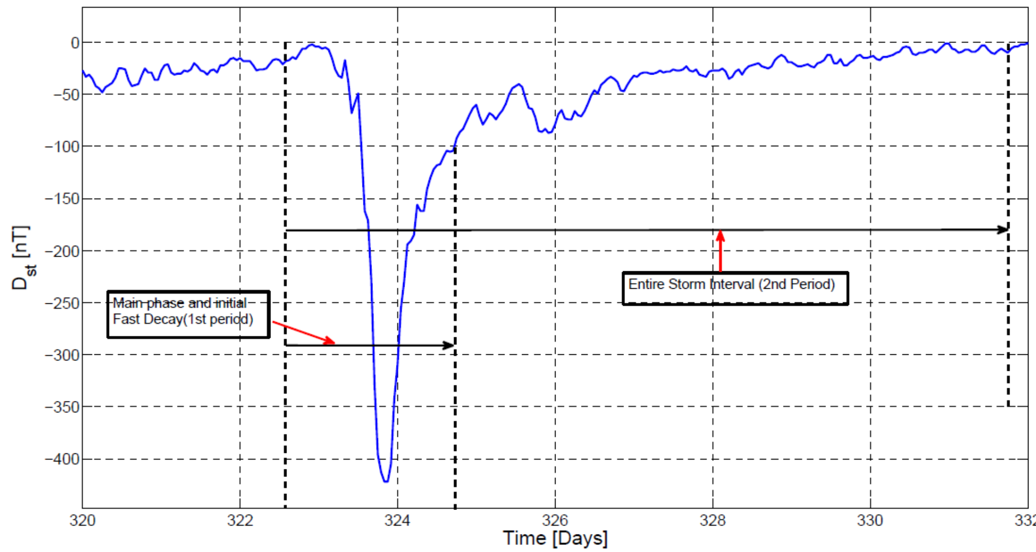
Windmi model calculation of Dst after including contributions from magnetospheric currents.

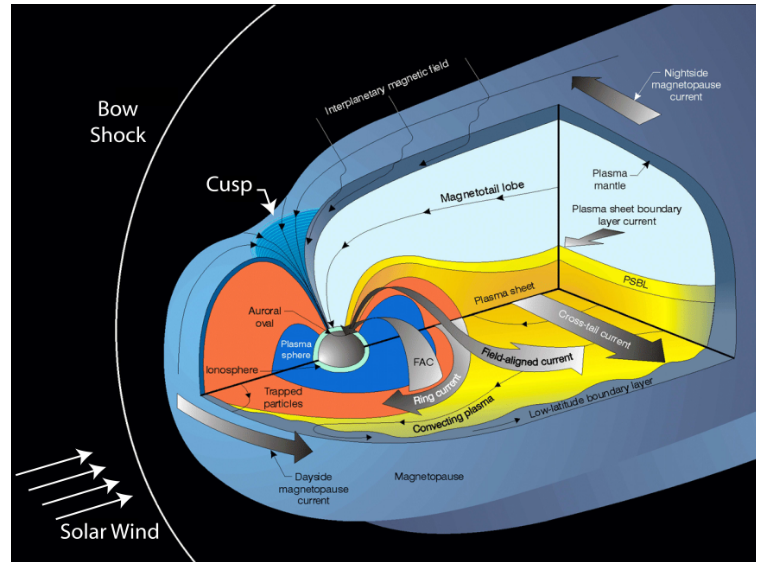
$$Dst_{windmi} = Dst_{rc} + Dst_{mp} + Dst_t$$



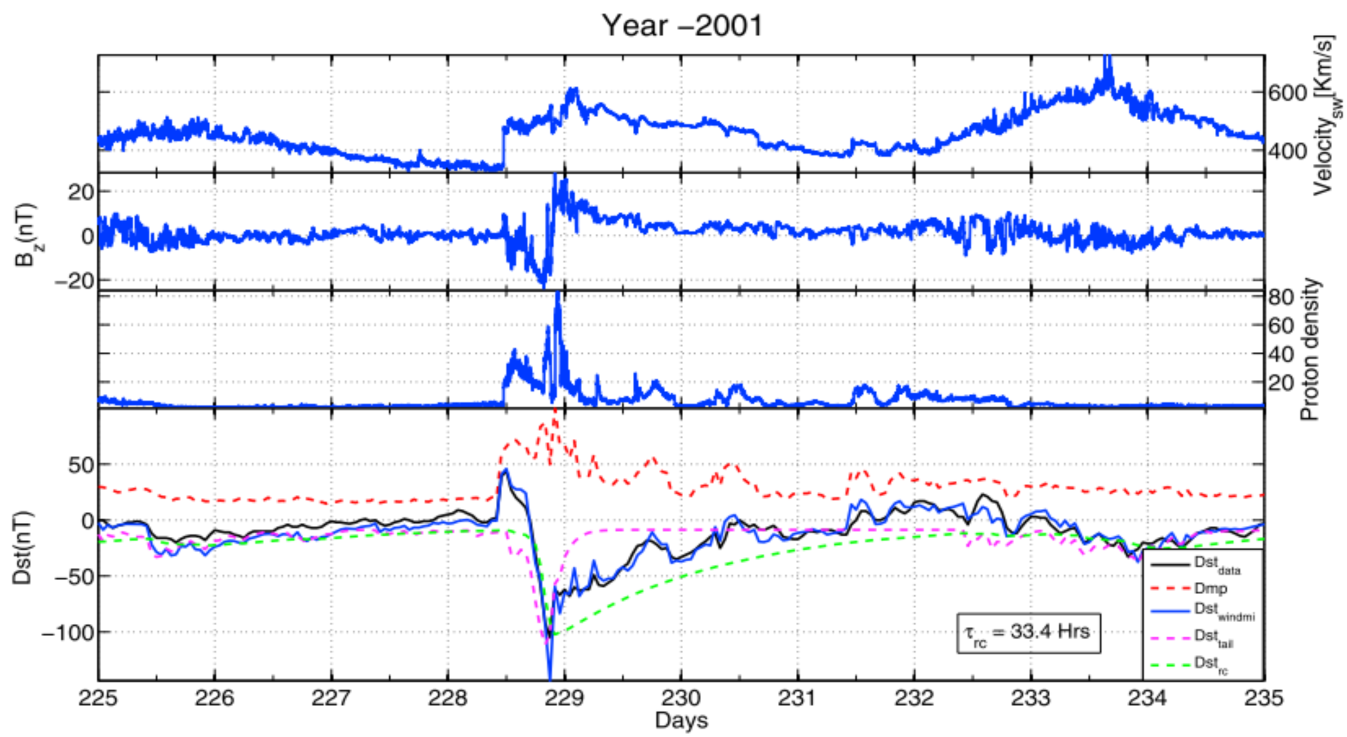
The 15–24 April 2002 prediction using VswN(Newell) with optimized parameters from equal weighting of AL and Dst.







$$Dst_{windmi} = Dst_{rc} + Dst_{mp} + Dst_t$$

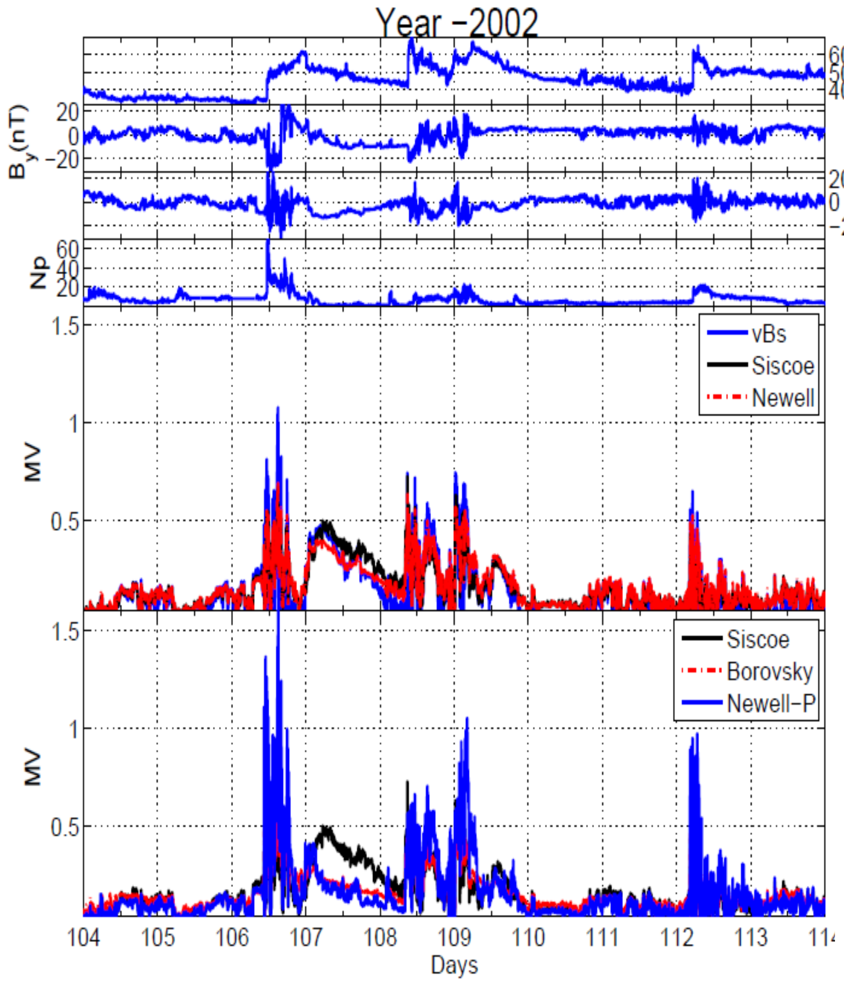


Top: Typical two phase decay of a geomagnetic storm as indicated by the corresponding Dst Index.

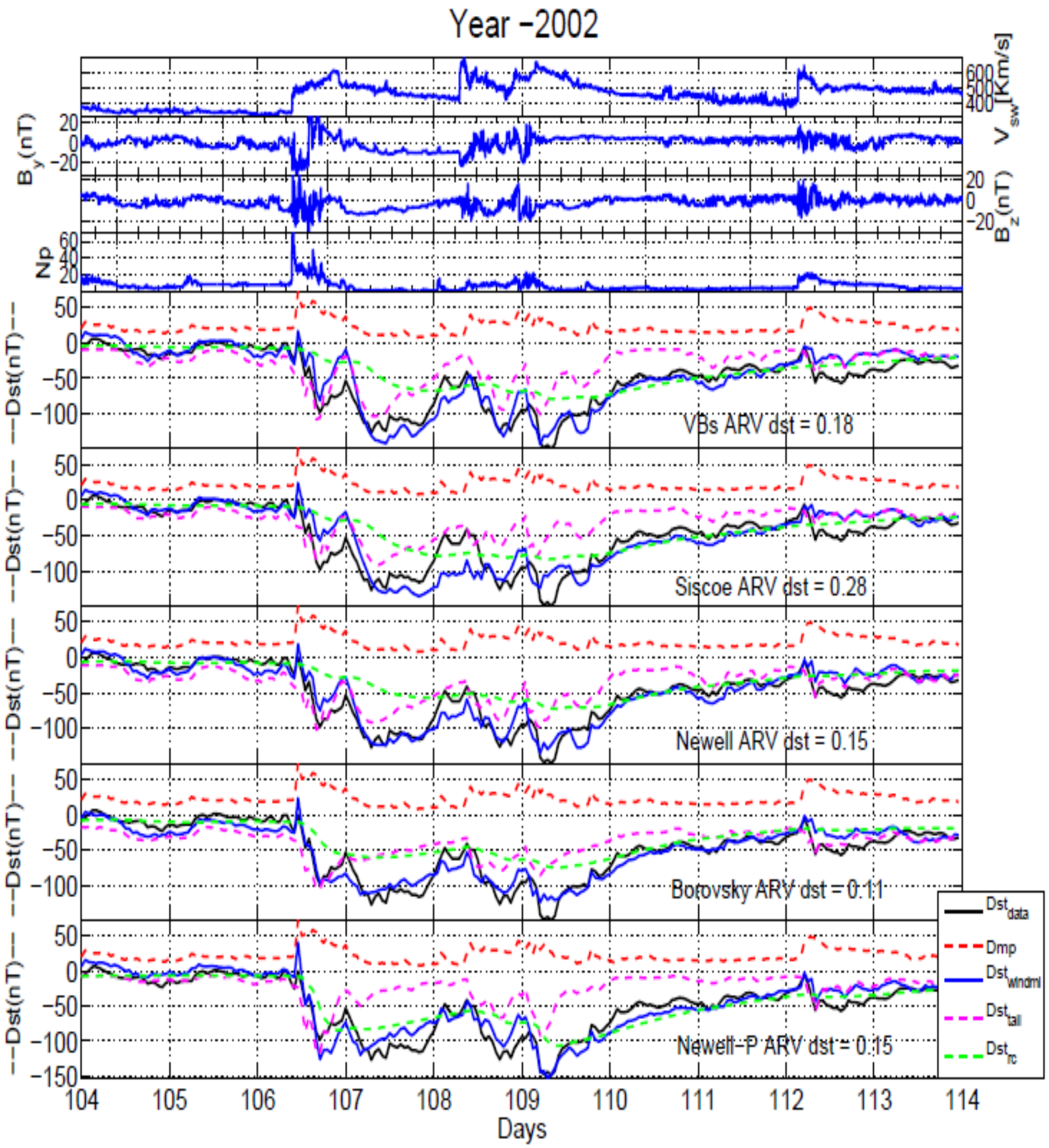
Top Right: Magnetospheric currents

Right: Windmi model estimation of Dst after including contributions from magnetospheric currents.

Generalized to include spectrum of SW Couplers



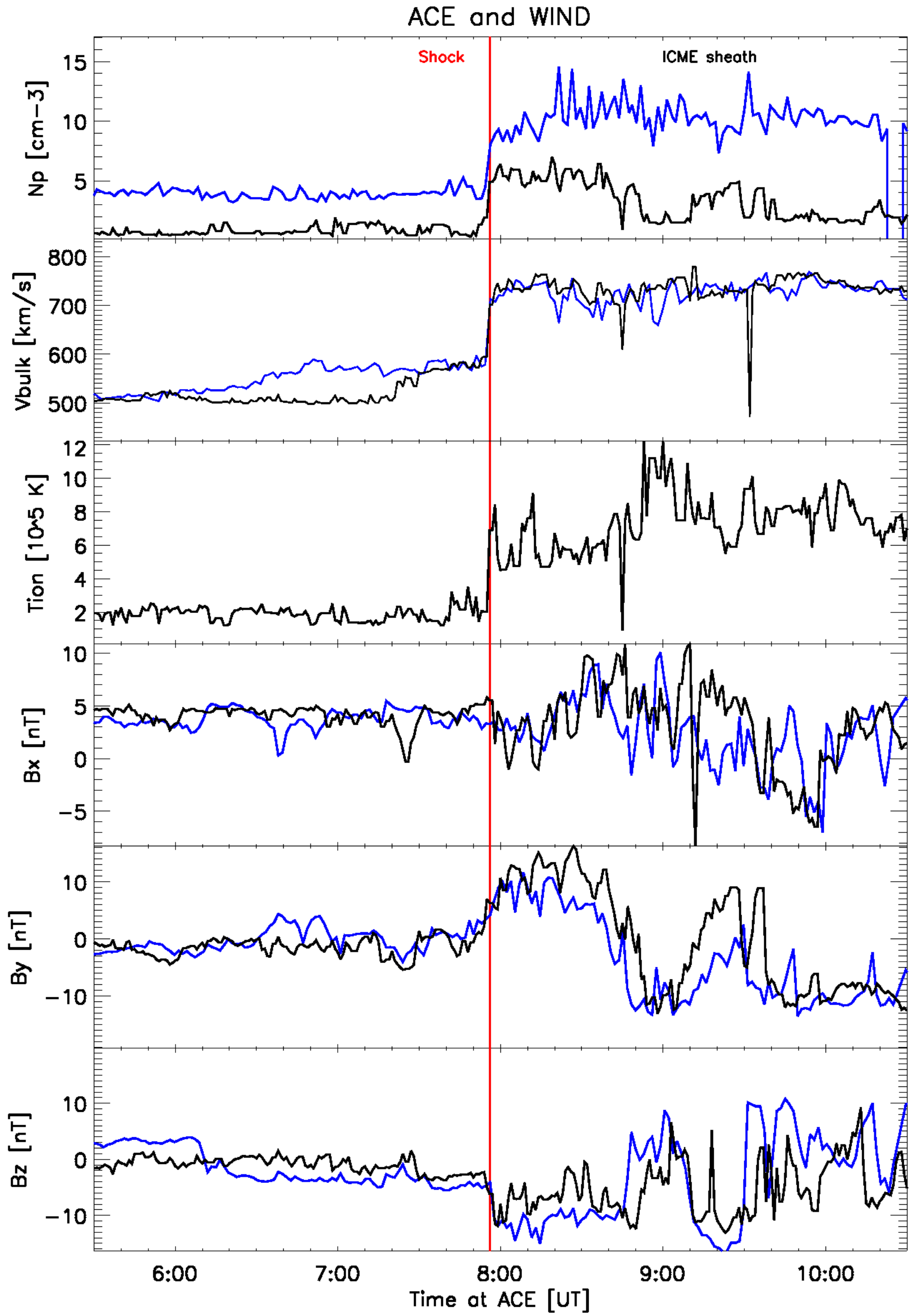
Top: Different coupling functions for a category II storm.

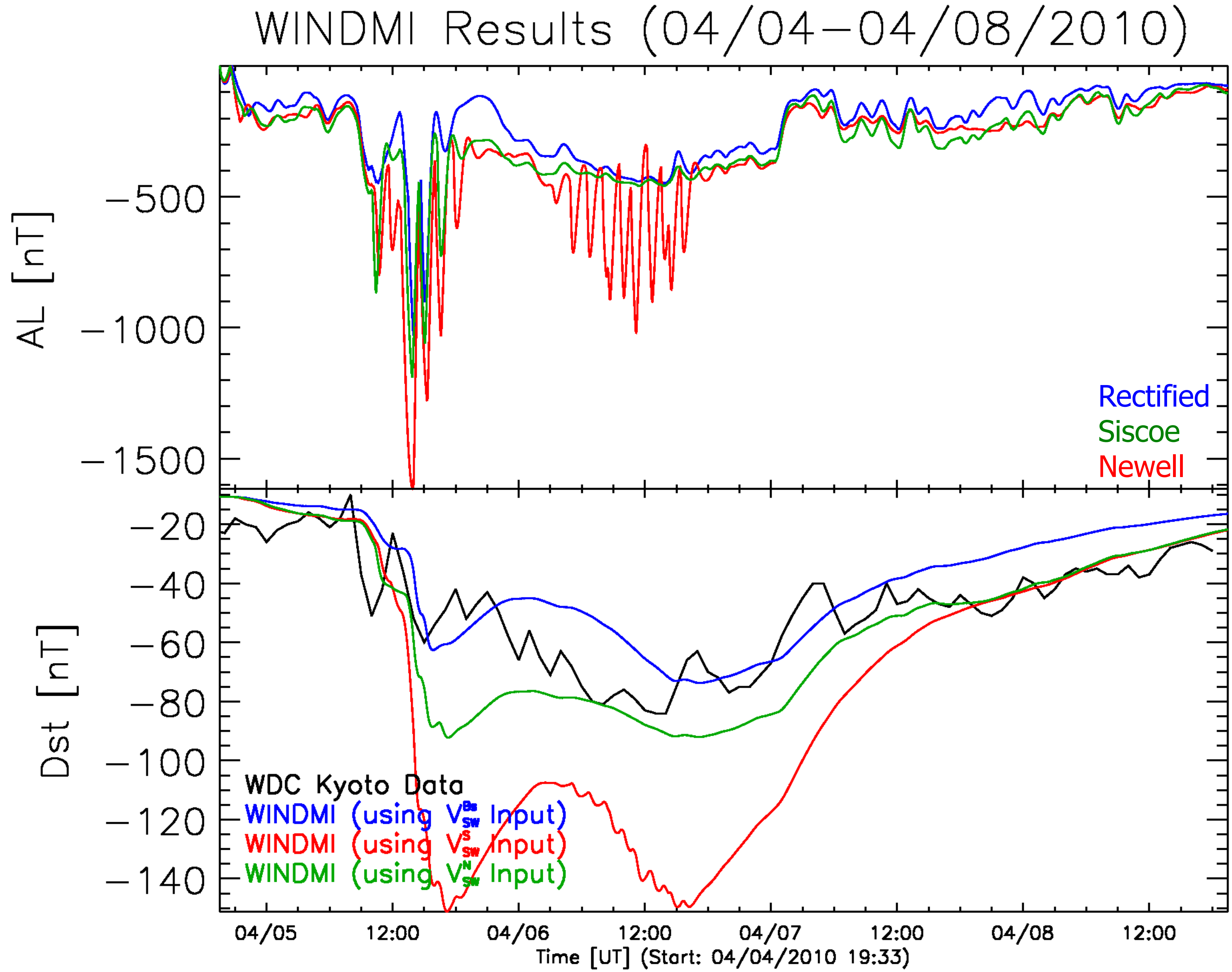


Right: Contributions from different magnetospheric currents to the Dst index using various coupling functions. Notice the different relative contributions from the tail and ring currents.

04 April 2010

Real-time ACE and WIND solar wind data comparison.





WINDMI Results (04/04–04/08/2010)
AL [nT]
−500
−1000
−1500
Rectified
Siscoe
Newell
Dst [nT]
−20
−40
−60
−80
−100
−120
−140
WDC Kyoto Data
WINDMI (using V_{sw}^{Bs} Input)
WINDMI (using V_{sw}^{S} Input)
WINDMI (using V_{sw}^{N} Input)
04/05
12:00
04/06
12:00
04/07
12:00
04/08
12:00
Time [UT] (Start: 04/04/2010 19:33)

The Newell function performs best in predicting the AL; The Rectified function performs best in predicting the Dst

Feb. 2006 - Aug. 2008 Selected Events, Mean ARV		
Input	**Mean AL ARV**	**Mean Dst ARV**
Rectified V_{sw}^{Bs}	**0.38 ± 0.21**	**0.37 ± 0.27**
Siscoe V_{sw}^{S}	**0.41 ± 0.16**	**0.42 ± 0.23**
Newell V_{sw}^{N}	**0.33 ± 0.17**	**0.54 ± 0.39**

Feb. 2006 - Aug. 2008 Selected Events, Mean COR			
Input	**Mean AL COR**	**Mean AL Direct COR**	**Mean Dst COR**
Rectified V_{sw}^{Bs}	**0.62 ± 0.13**	**0.40 ± 0.20**	**0.80 ± 0.12**
Siscoe V_{sw}^{S}	**0.52 ± 0.15**	**0.37 ± 0.18**	**0.77 ± 0.13**
Newell V_{sw}^{N}	**0.64 ± 0.12**	**0.42 ± 0.18**	**0.79 ± 0.14**

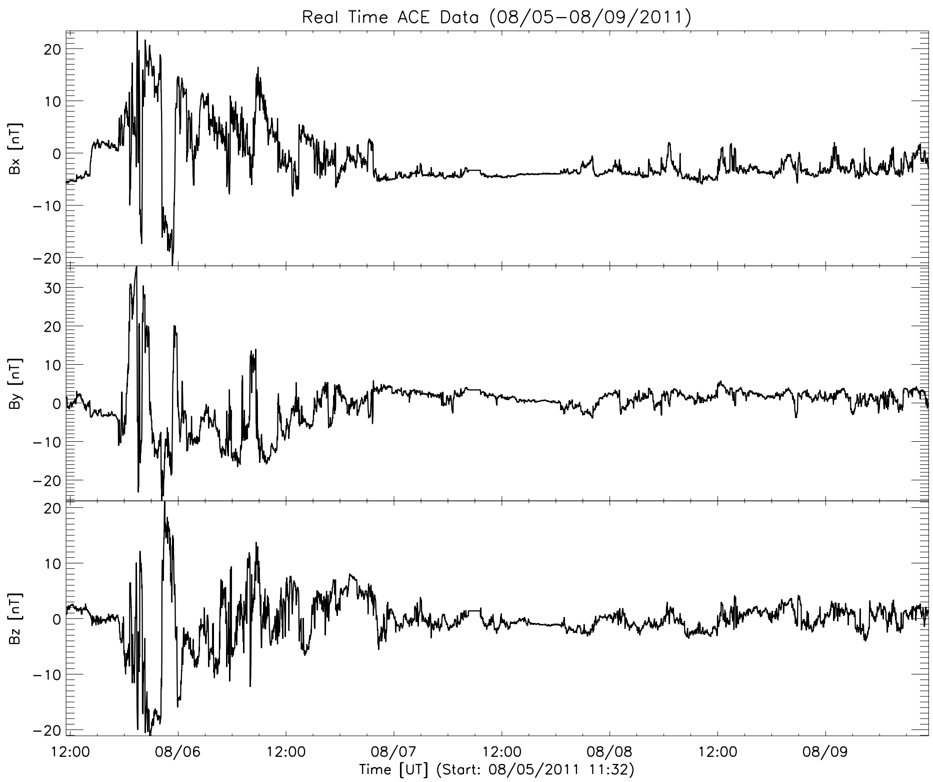
Validation statistics for more recent events during solar minimum are in progress.

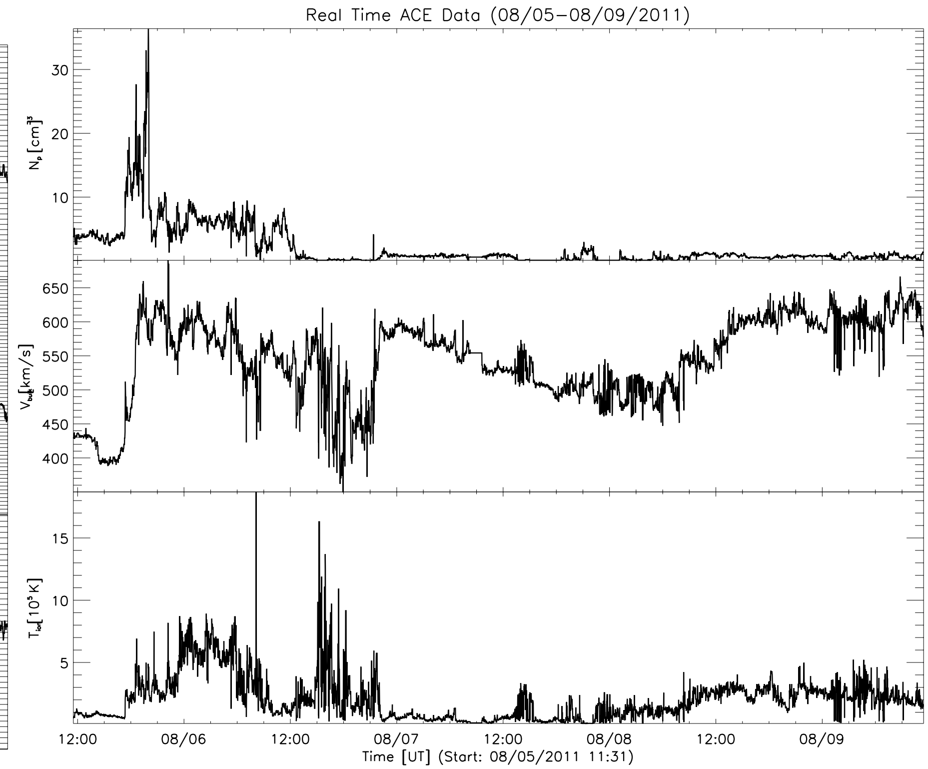
(Mays et al, Space Weather, 2009)

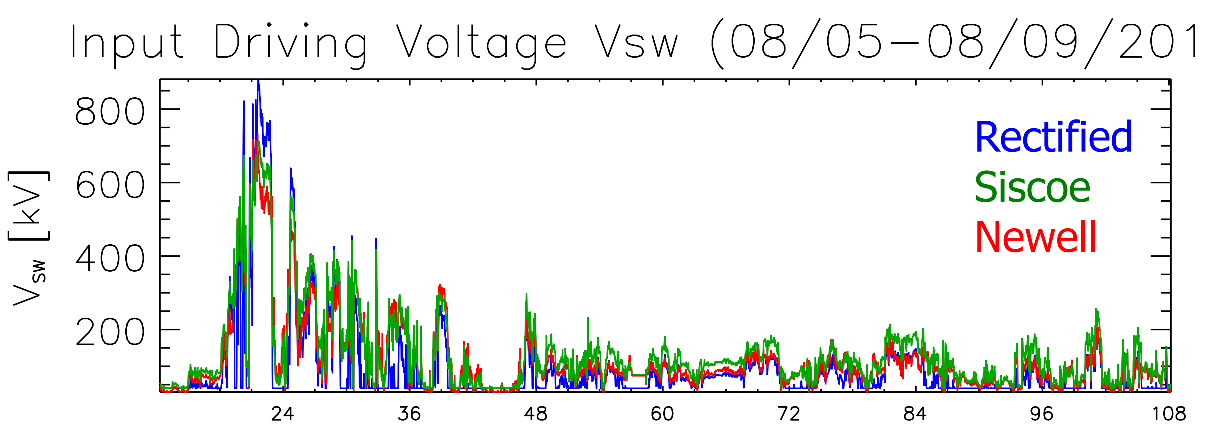
Some Examples of Recently Captured Storms

5-12 August 2011 Dst min. -113 nT AL min. -2000 nT
9-14 September 2011 Dst min. -64 nT AL min. -1300 nT
17-19 September 2011 Dst min. -58 nT AL min. -1200 nT
26-30 September 2011 Dst min. -103 nT AL min. -1600 nT

5-12 August 2011 Dst min -113 nT, AL min -2000 nT





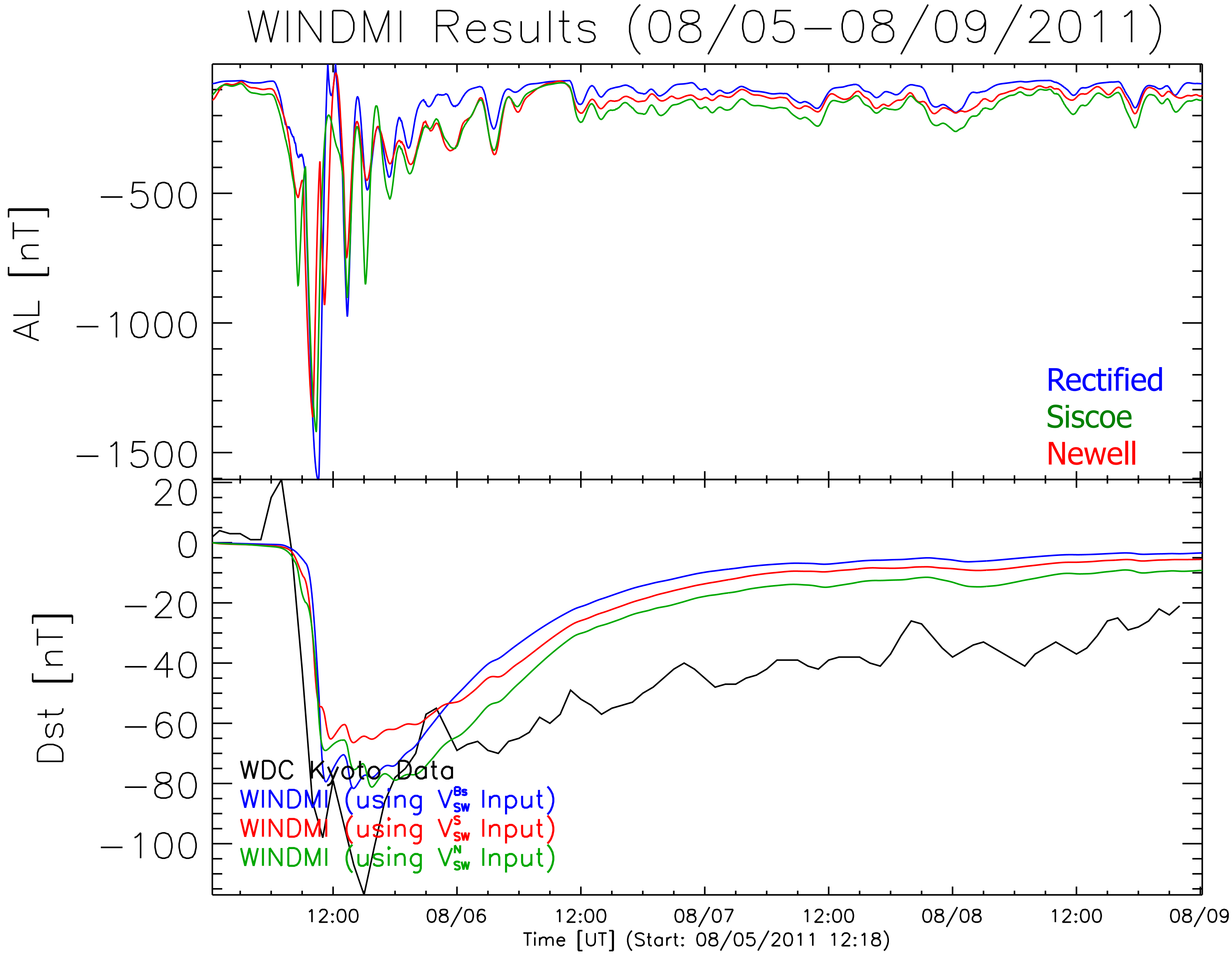


From AR1261
M6.0 flare peak 2011-08-03 13:48 UT
M9.3 flare peak 2011-08-04 03:57 UT

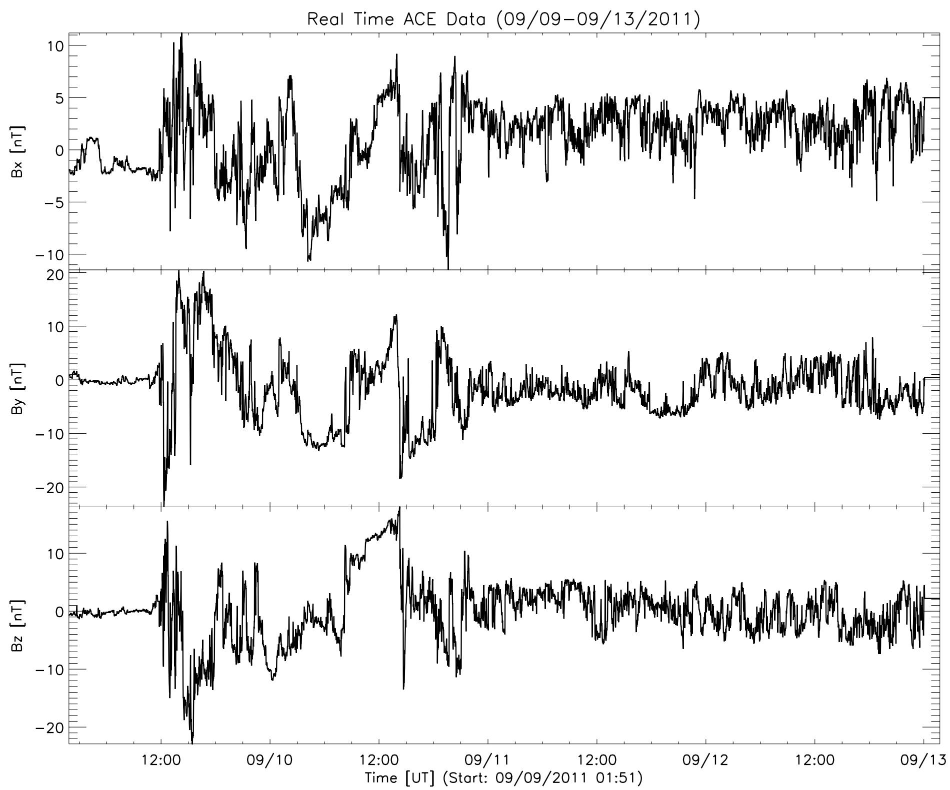
Two CMEs merged at ACE, initiated at
2011-08-03 13:55UT (~1350km/s)
2011-08-04 04:10UT (~1950 km/s)

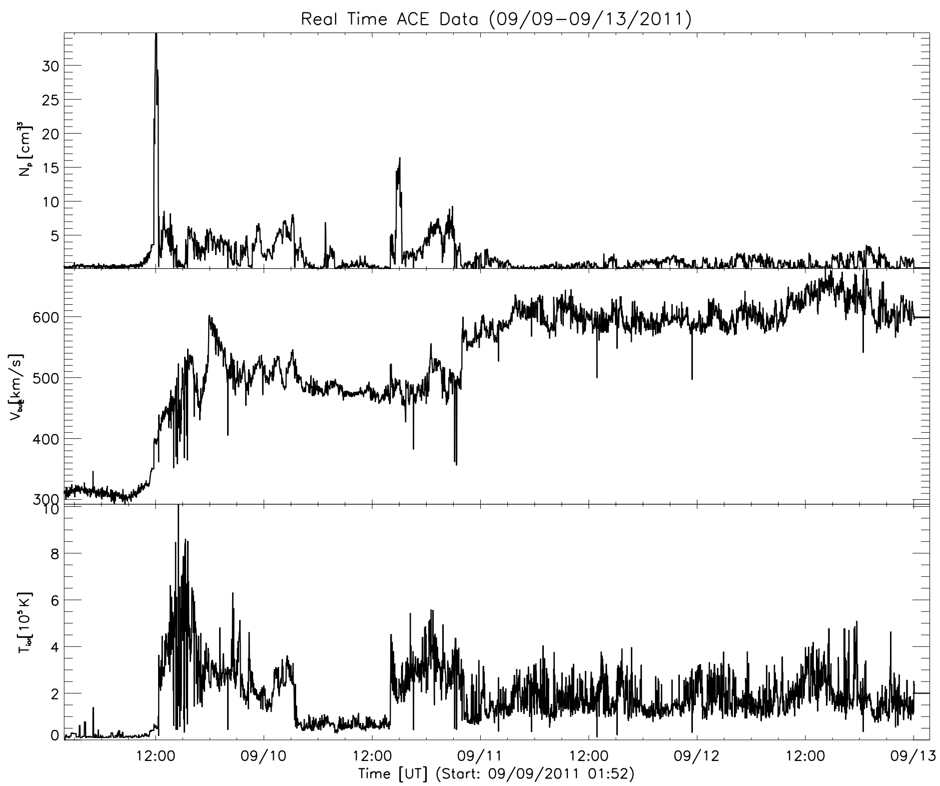
ACE shock at 2011-08-05 17:20 UT
Dst min. -113 nT on 6 Aug

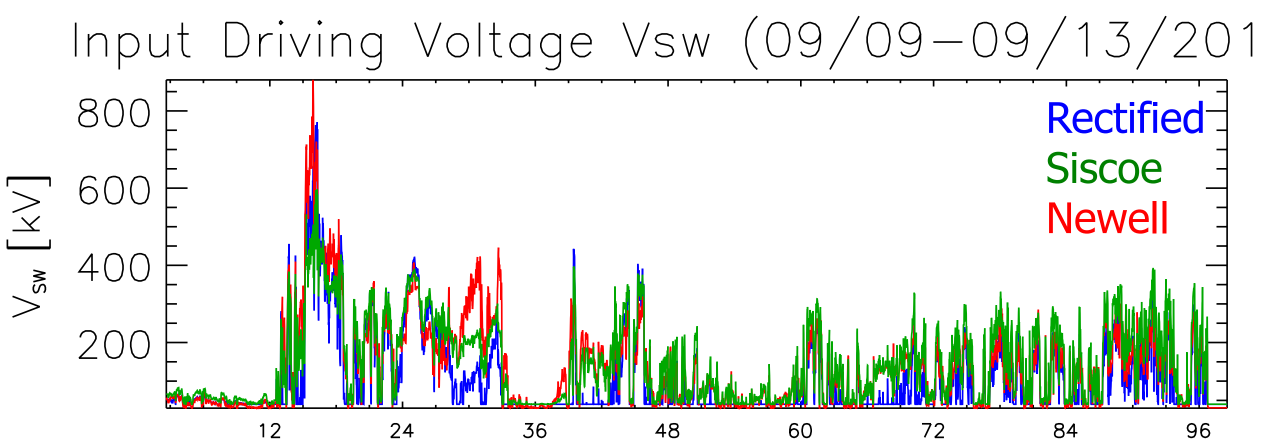
5-12 August 2011 Dst min -113 nT, AL min -2000 nT



9-14 September 2011 Dst min. -64 nT, AL min. -1300 nT







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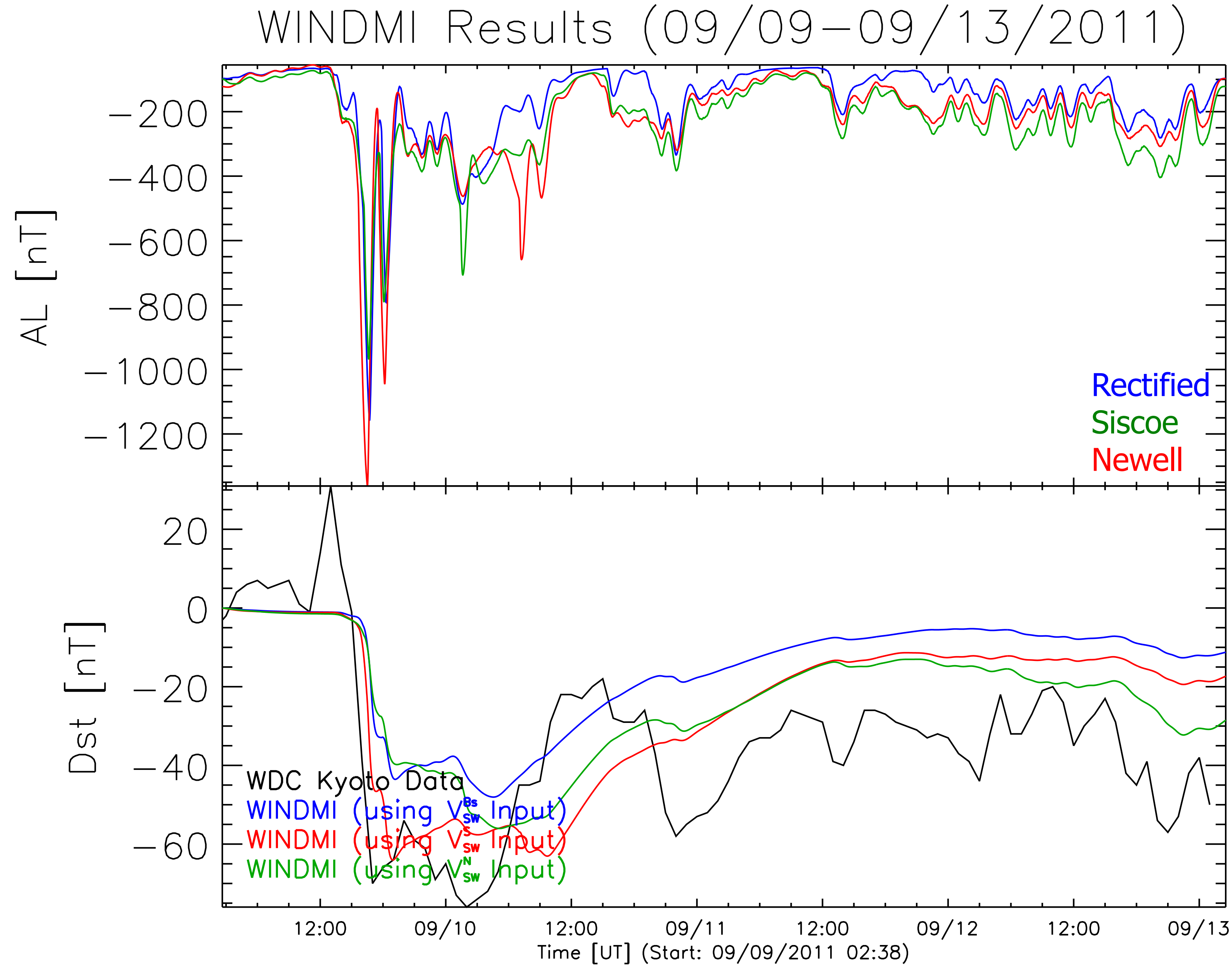
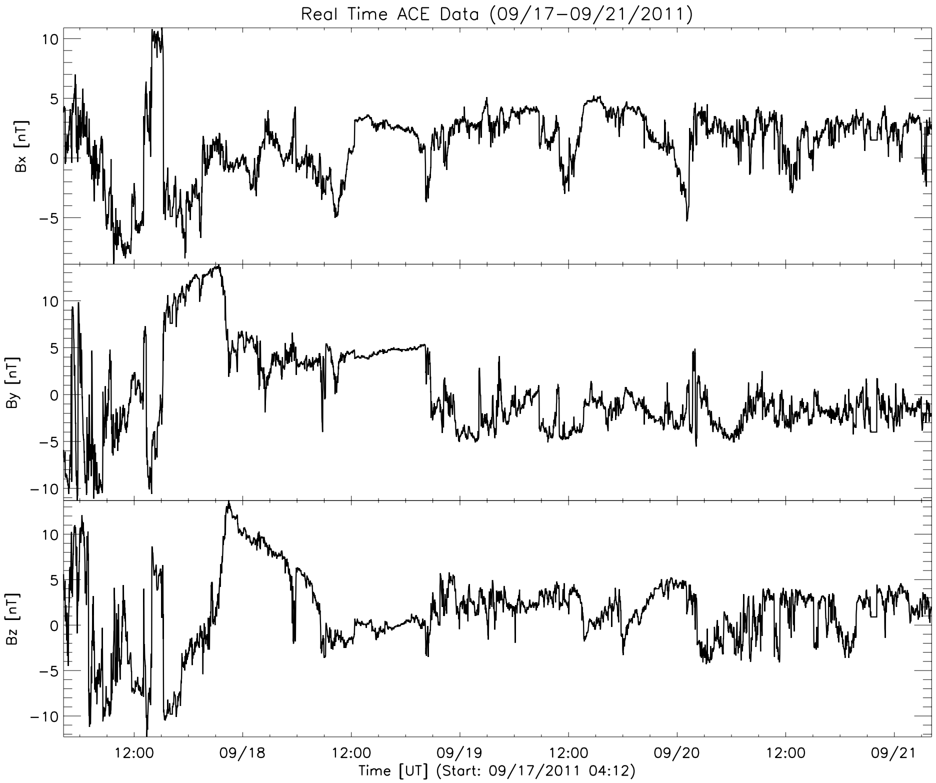
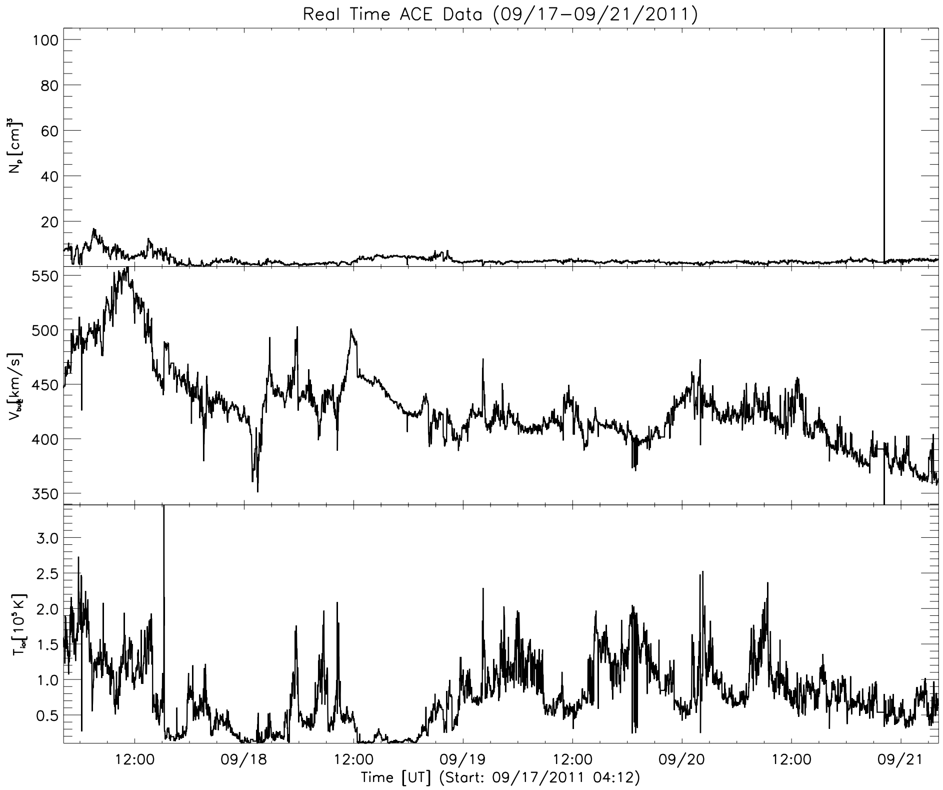
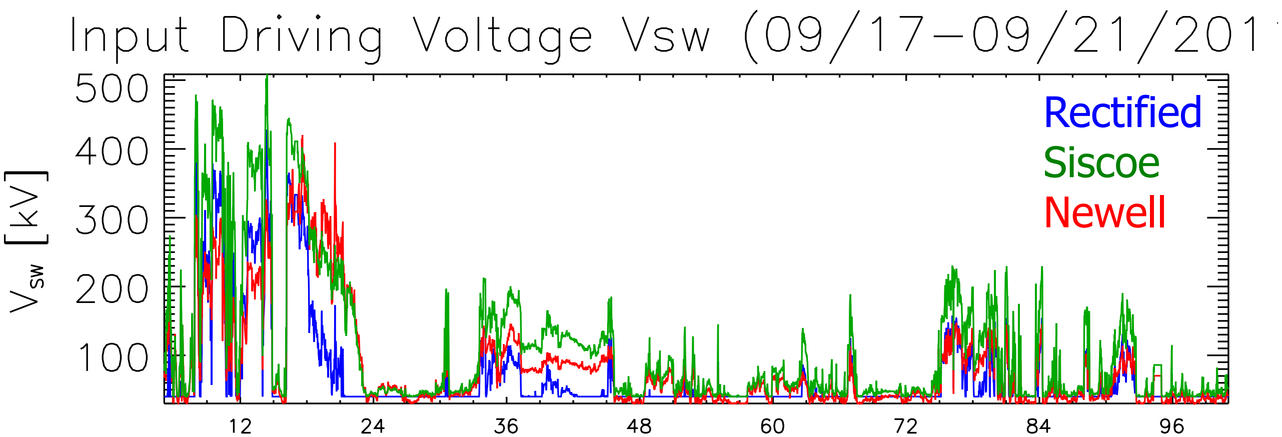


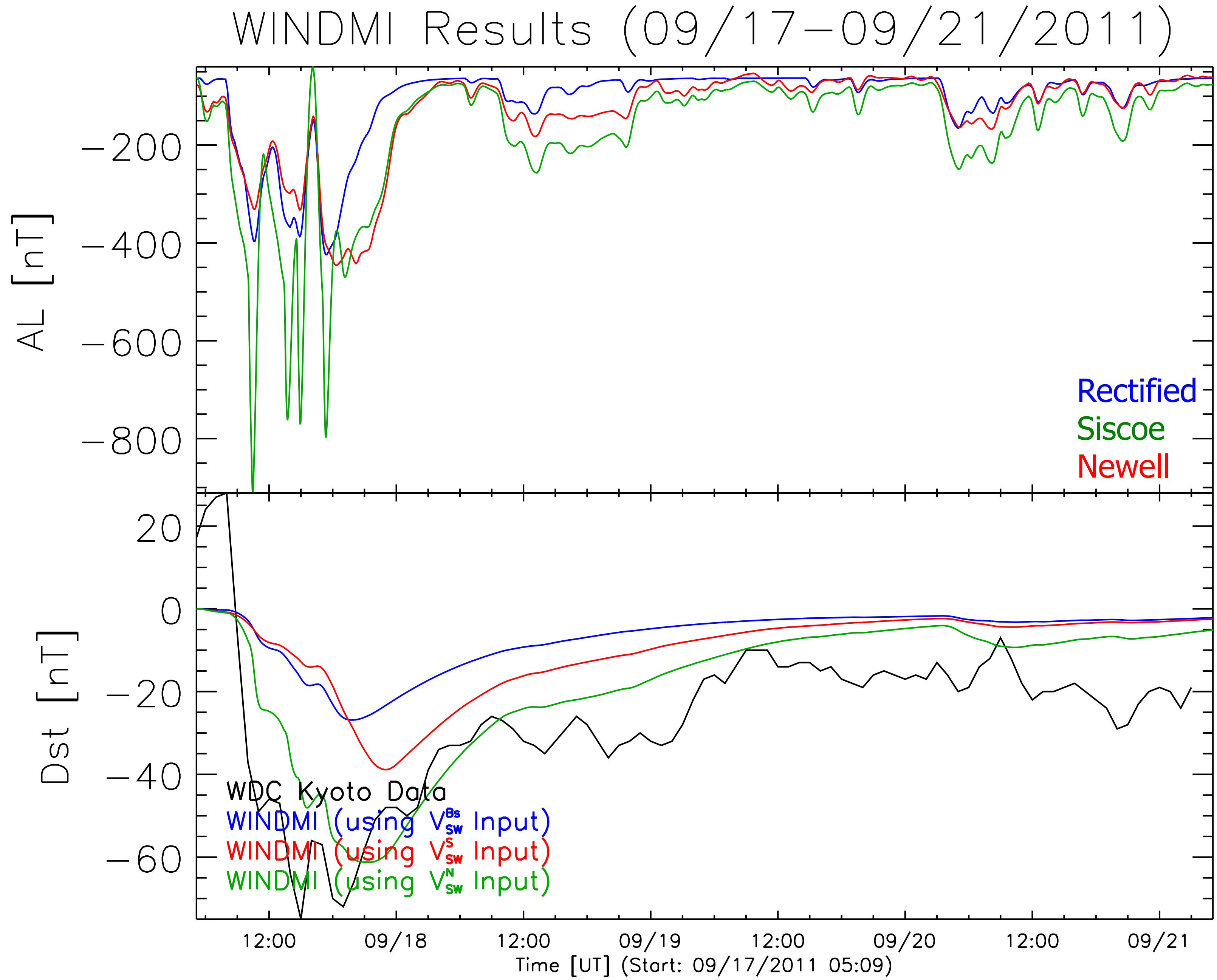
17-19 September 2011 Dst min. -58 nT, AL min. -1200 nT



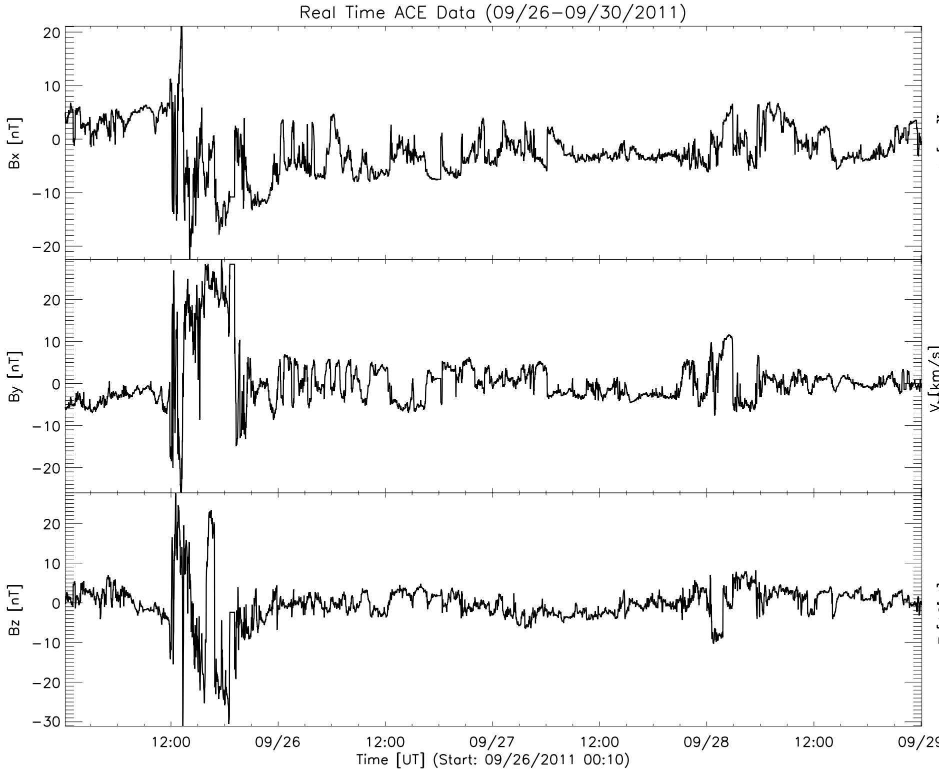


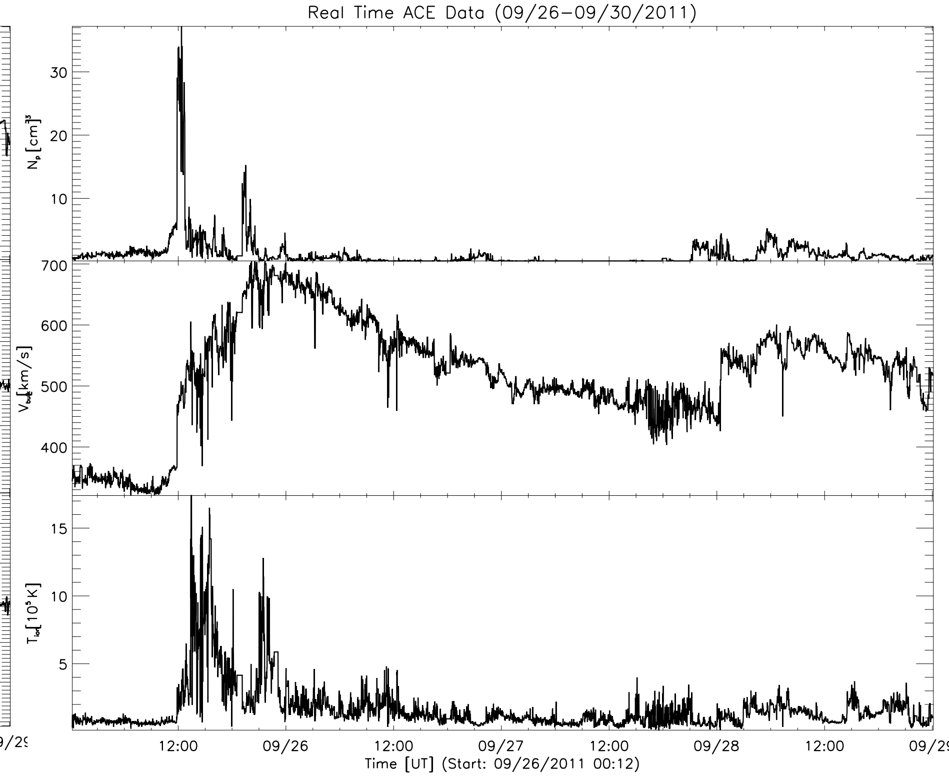


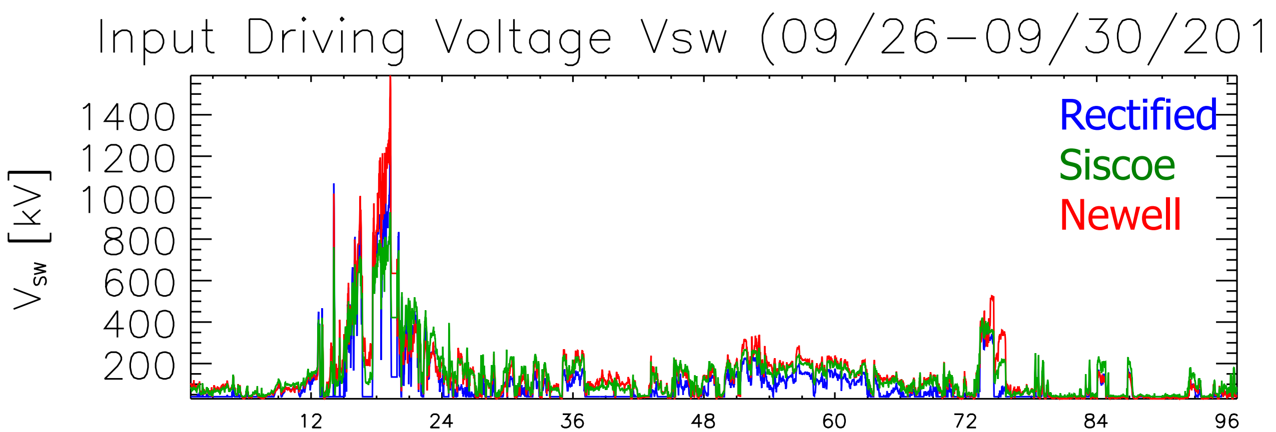
17-19 September 2011 Dst min. -58 nT, AL min. -1200 nT



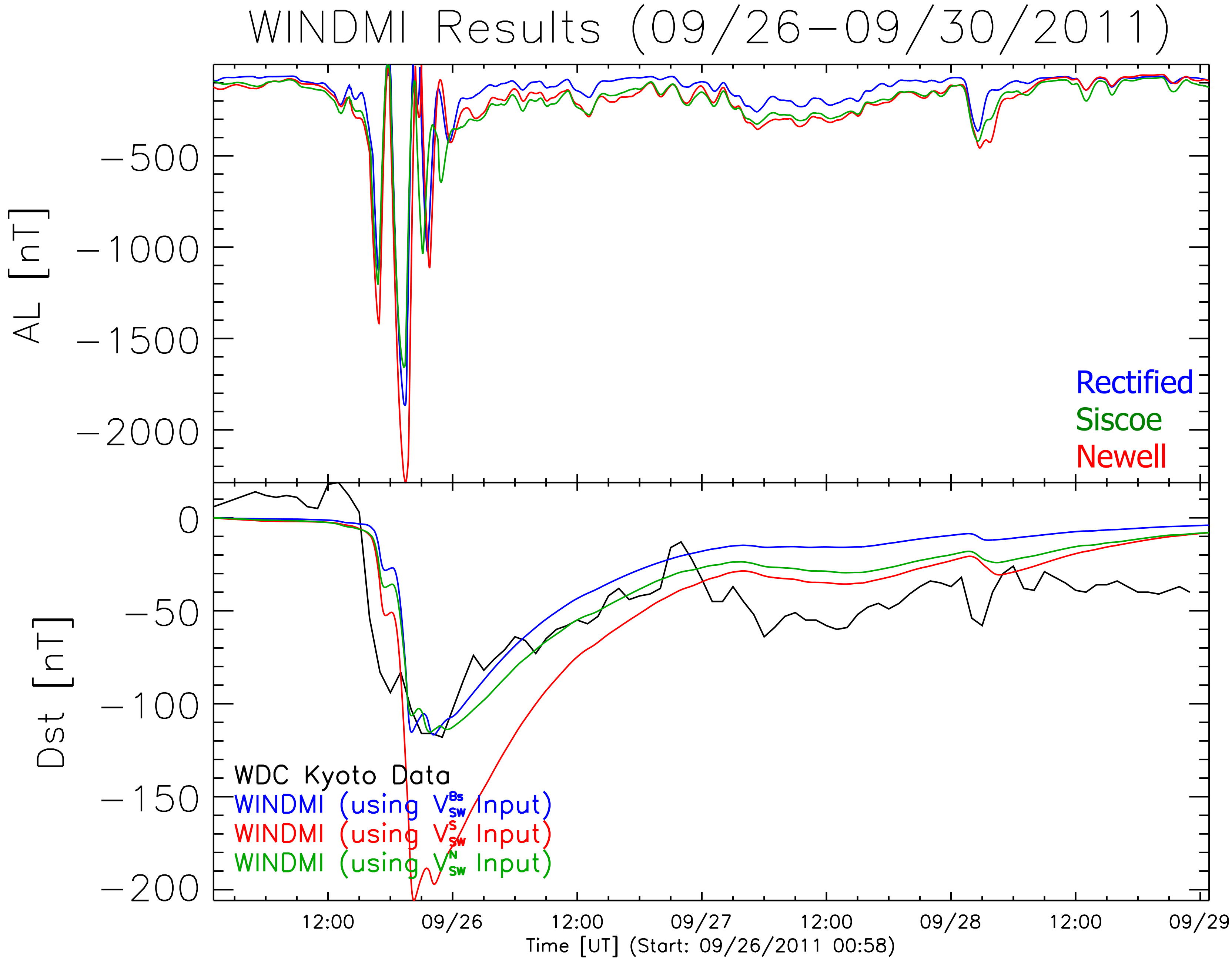
26-30 September 2011 Dst min. -103 nT, AL min. -1600 nT



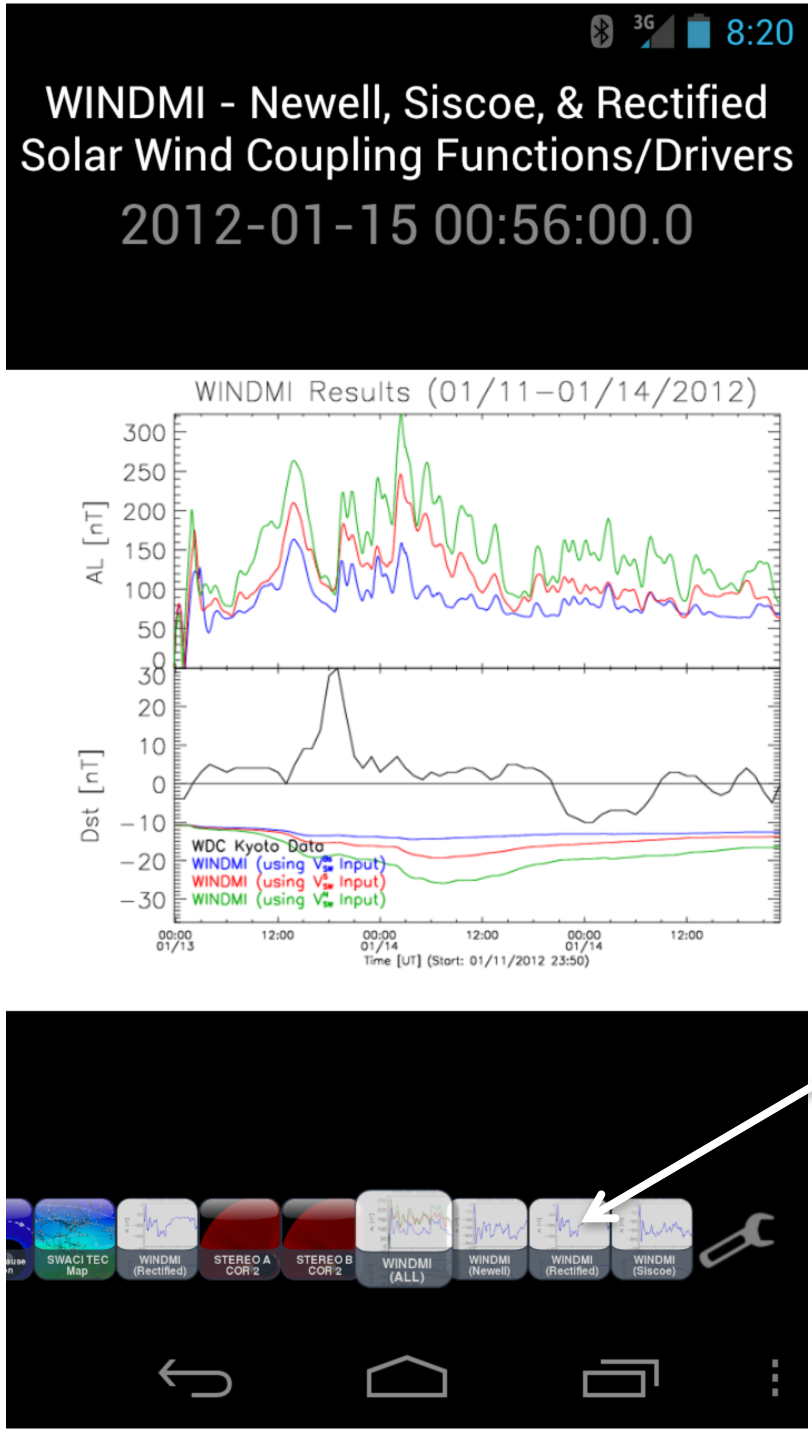




26-30 September 2011 Dst min. -103 nT, AL min. -1600 nT



Screen Shot from Smart-Phone 11-14 Jan 2012



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Look at Cygnets for WINDMI

Conclusions: WINDMI

- WINDMI is a fast, reliable tool for real-time forecasting of Space Weather: Storms and Substorms
- Download runs at CCMC.gsfc.nasa.gov under tab “Instant Runs” and as APP [iTunes NASA Space Weather].
- Algorithms for the sum of the contributions multiple current loops +ring current yield 3 phases of

  Dst (t) for large storms. Validation pubs in JGR.
- Auroal magnetic index AL(t) reproduces historical substorm data with low Average Rel Variance. (isolated substorms and substorms-within-storms)
- Support of L. Rasttaeller and CCMC team make it work!