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CCMC's Experimental Real-time Runs: SWMF Geospace

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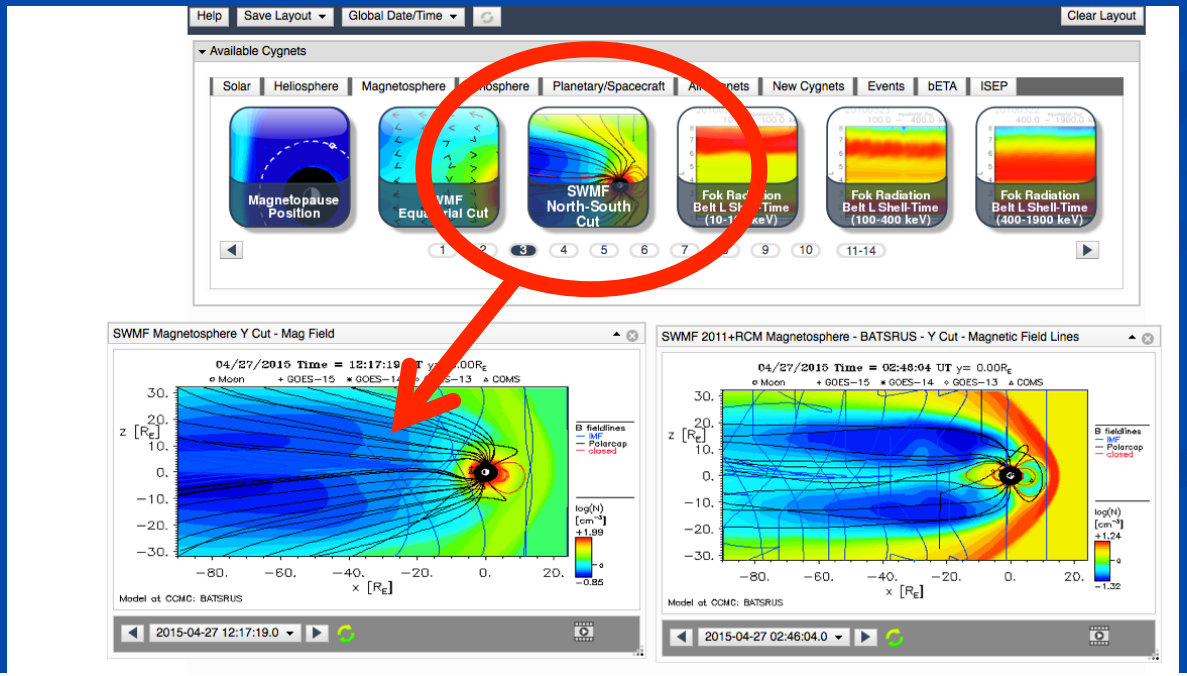
Real-time SWMF

- CCMC has been running a geospace configuration of SWMF in real time since 2007
  - Just the GM and IE physics modules
    - So, only BATS-R-US and the Ridley Ionosphere Model
    - Fairly low grid resolution (<1 M cells) for MHD code
- New version running since 2011
  - Three physics modules: GM, IE, and IM
  - So, now with the Rice Convection Model for near-Earth keV plasma solution
  - Better grid in MHD code and some other improvements
  - Consistently running since July 2015

Available at the CCMC

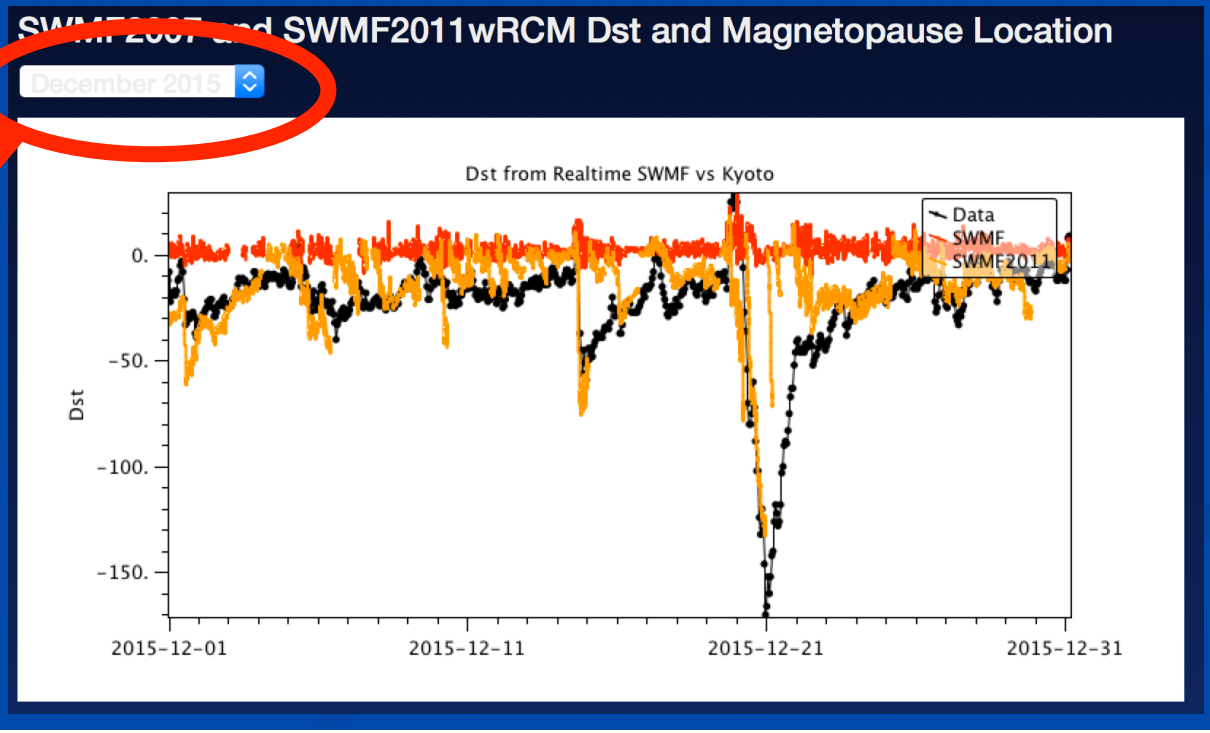
- The CCMC page for their experimental real-time runs:
  - http://ccmc.gsfc.nasa.gov/rt_simulations.php
- Within this page, there is a link for SWMF-Geospace
  - http://ccmc.gsfc.nasa.gov/cgi-bin/SWMFpred.cgi
- Also available at CCMC's iSWA site:
  - http://iswa.ccmc.gsfc.nasa.gov/
  - Many cygnets related to real-time simulations



Also available at U-M's CSEM Website

- Want to promote the existence of these experimental real-time results of SWMF
- Mirroring and analyzing the CCMC experimental real-time results
  - http://csem.engin.umich.edu/realtime/

Choose a month

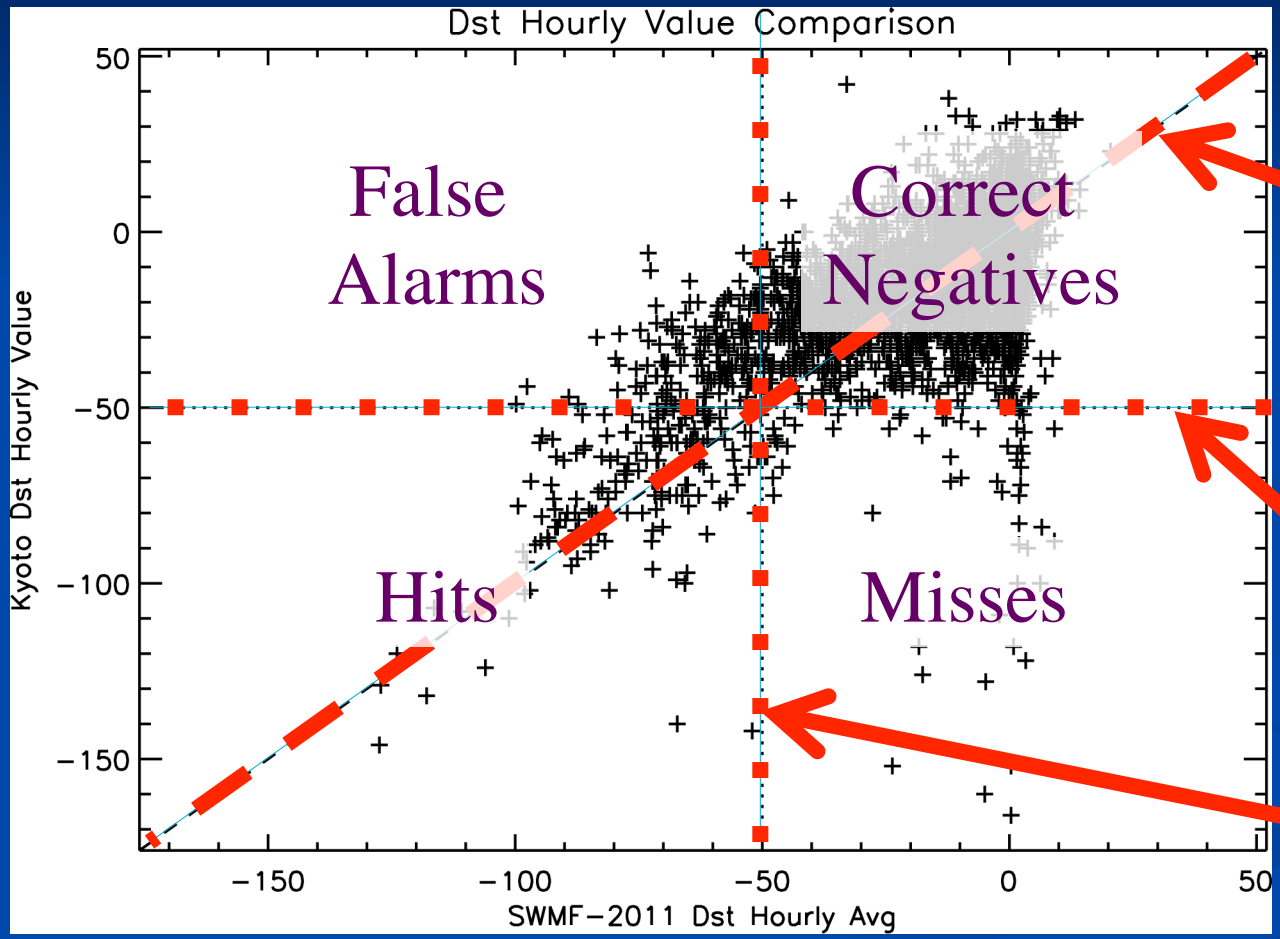


Analyzing the SWMF-Geospace results

- For July-Dec 2015, assess the hourly Dst
  - Nearly 4000 hours of values
  - Compare against the real-time Kyoto Dst values
- Calculate some statistics
  - Correlation coefficient, RMSE, prediction efficiency
- Set up contingency tables
  - Binary yes-no decisions of whether either value surpassed a defined "critical threshold" (- 50 nT)
  - Great for determining if model can accurately predict the "big events"

Kyoto and SWMF Dst Values

- Everything distilled to a single scatter plot



Kyoto Dst (nT)

SWMF Dst (nT)

Unity slope line

Kyoto Dst -50 nT threshold

SWMF Dst -50 nT threshold

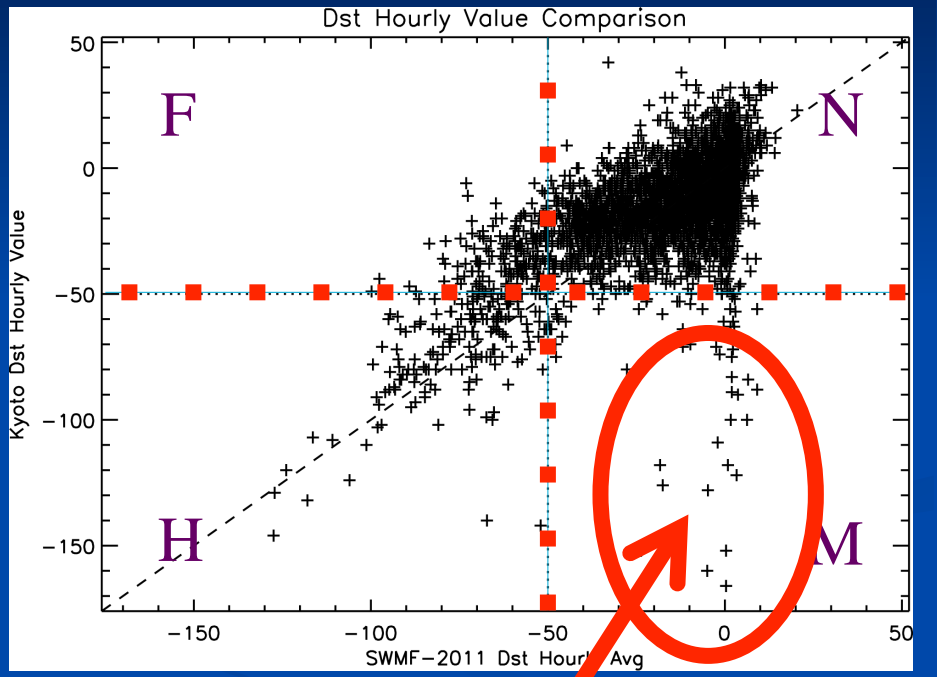
The Statistics

- The peak values
  - Max and min of hourly SWMF Dst: +20 and -127 nT
  - Max and min of real-time Kyoto Dst: +42 and -166 nT
- Correlation coefficient: R = 0.62
  - Very good
- Root mean square error: RMSE = 18.3 nT
  - Okay…
- Prediction efficiency: PE = 0.22
  - Not high, but at least it is positive

The Contingency Table

- Set the cutoff = - 50 nT
  - For Kyoto and SWMF

Contingency Table	$Dst_M < X_M$	$Dst_M > X_M$
$Dst_K > X_K$	F = 179	N = 3574
$Dst_K < X_K$	H = 172	M = 66



POD = 0.72 R = 0.62
POFD = 0.048 PE = 0.22
HSS = 0.55 RMSE = 18.3

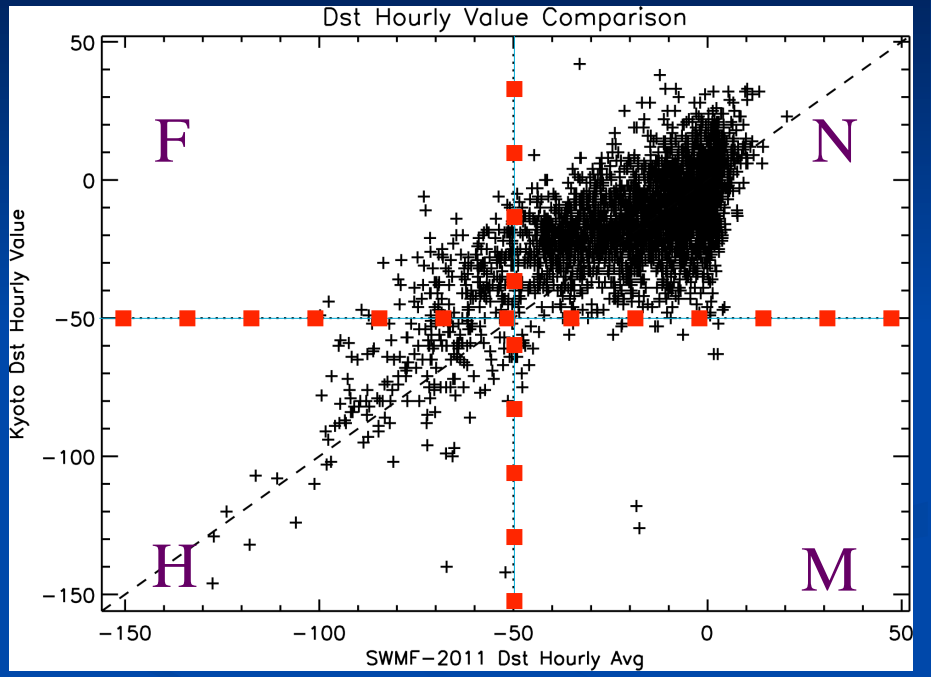
These are from restarts, which happens regularly

Can we eliminate them?

Filtering out SWMF restarts

- Same -50 nT cutoffs
- Removed values within 3 h of an SWMF restart

Contingency Table	$Dst_M < X_M$	$Dst_M > X_M$
$Dst_K > X_K$	F = 179	N = 3277
$Dst_K < X_K$	H = 172	M = 30



POD = 0.85 R = 0.71

POFD = 0.051 PE = 0.35

HSS = 0.59 RMSE = 16.0

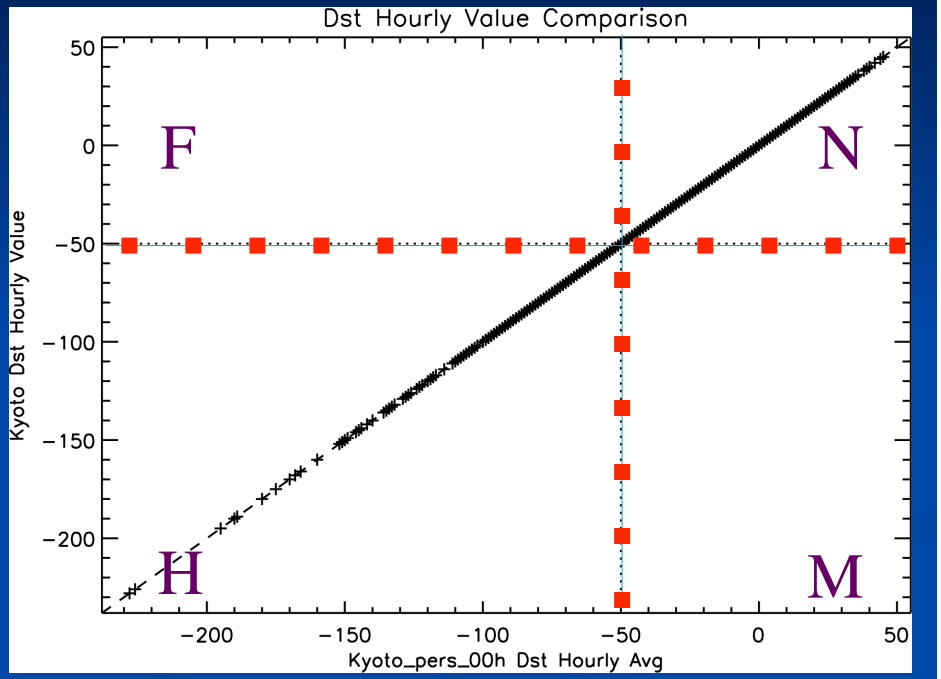
These values got better. Good!

Well, POFD up, but low.

How does SWMF do v. Kyoto persistence?

- Test of the calculations:
  - No time shift.
- As expected!

Contingency Table	$Dst_M < X_M$	$Dst_M > X_M$
$Dst_K > X_K$	F = 0	N = 8458
$Dst_K < X_K$	H = 554	M = 0



POD = 1.00 R = 1.0

POFD = 0.00 PE = 1.0

HSS = 1.00 RMSE = 0.0

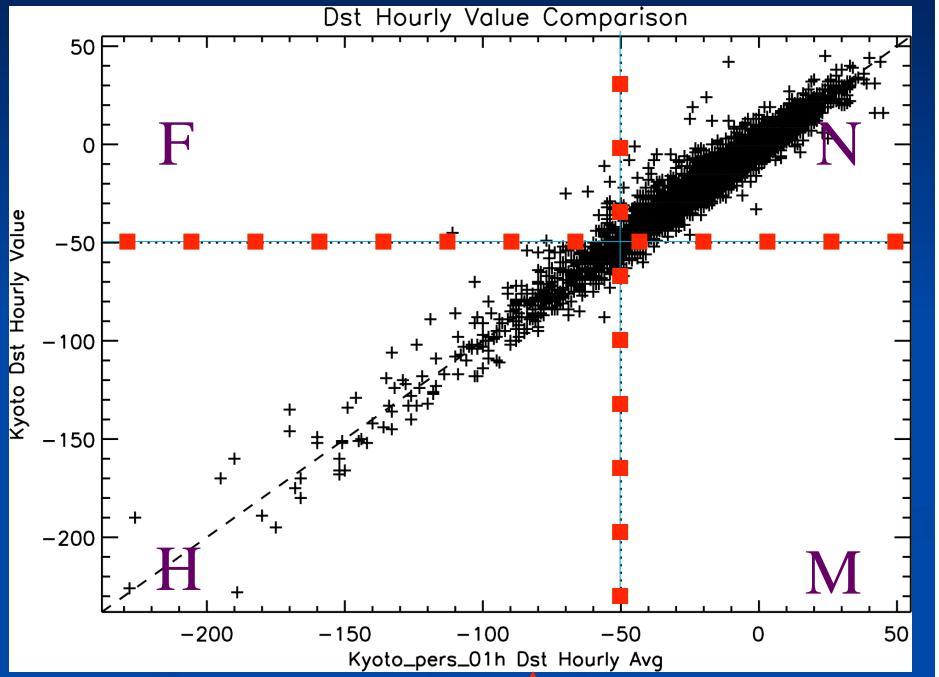
For the entire year of 2015, not just the 2nd half.

More Kyoto persistence: 1 h shift

- Values are still really good.

Contingency Table	$Dst_M < X_M$	$Dst_M > X_M$
$Dst_K > X_K$	F = 59	N = 8398
$Dst_K < X_K$	H = 495	M = 59

POD = 0.89 R = 0.98
POFD = 0.007 PE = 0.95
HSS = 0.89 RMSE = 4.9



Kyoto values from 1 h prior to y-axis values

More Kyoto persistence: 2 h shift

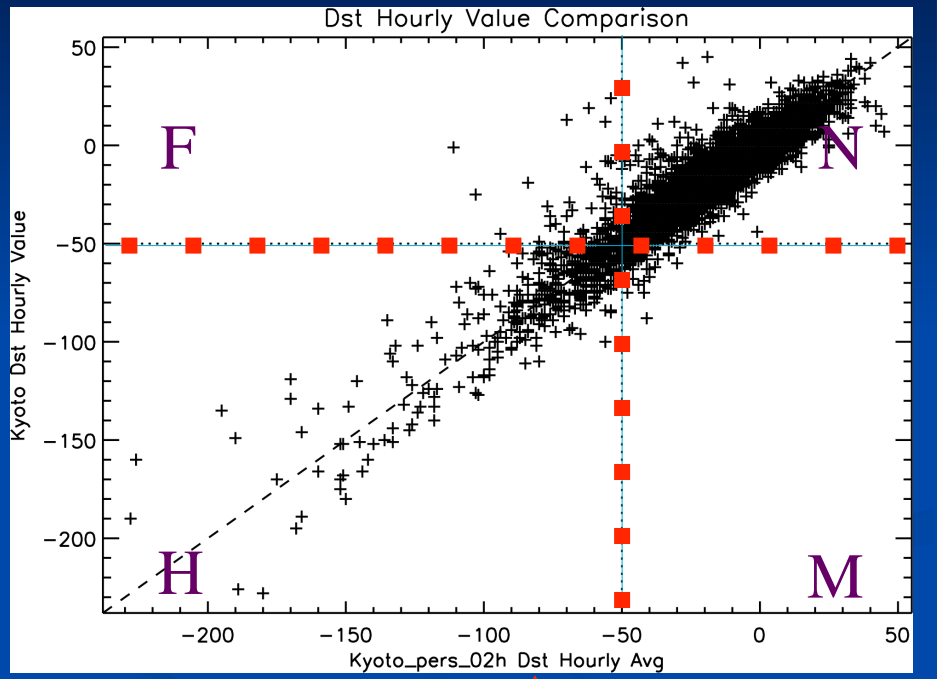
- Still good, but not quite
  - POD and POFD are worse than SWMF!

Contingency Table	$Dst_M < X_M$	$Dst_M > X_M$
$Dst_K > X_K$	F = 98	N = 8358
$Dst_K < X_K$	H = 456	M = 98

POD = 0.82 R = 0.93

POFD = 0.012 PE = 0.87

HSS = 0.81 RMSE = 8.1



From 2 h prior to y-axis values

More Kyoto persistence: 24 h shift

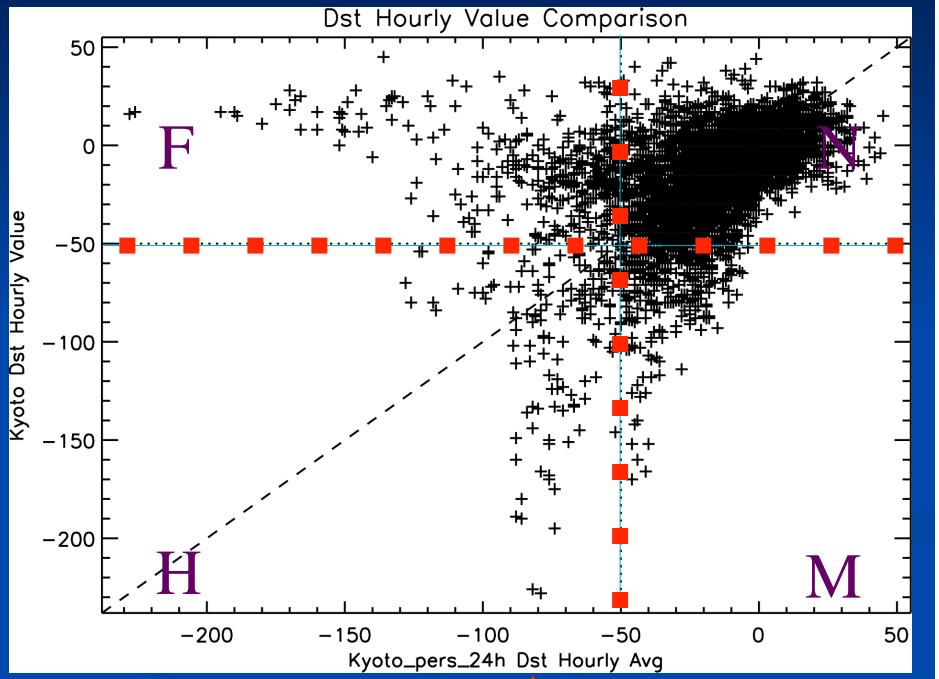
- *All* values are *worse* than CCMC's real-time SWMF-geospace

Contingency Table	$Dst_M < X_M$	$Dst_M > X_M$
$Dst_K > X_K$	F = 398	N = 8036
$Dst_K < X_K$	H = 156	M = 398

POD = 0.28 R = 0.45

POFD = 0.047 PE = - 0.10

HSS = 0.23 RMSE = 23.4

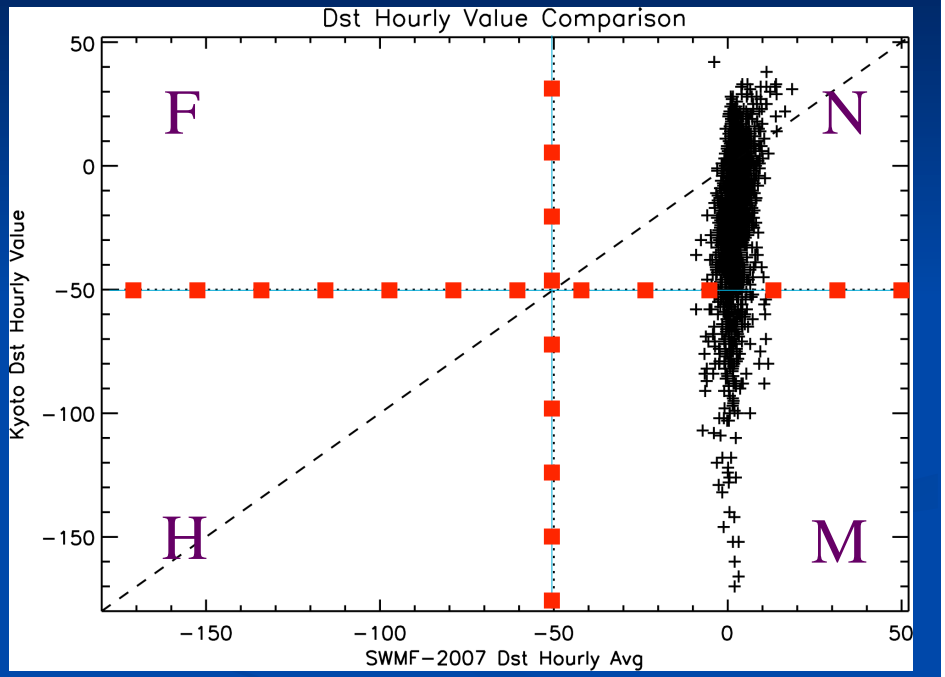


Taken exactly one day prior to y-axis values

What about that other SWMF run?

- The one without an inner mag drift physics model included

Contingency Table	$Dst_M < X_M$	$Dst_M > X_M$
$Dst_K > X_K$	F = 0	N = 3891
$Dst_K < X_K$	H = 0	M = 266



POD = 0.00 R = 0.33
POFD = 0.00 PE = - 0.71
HSS = 0.00 RMSE = 27.9

Not a single hit or false alarm.
The code never got a Dst less than -50 nT

Summary

- Experimental real-time simulations of SWMF-geospace exist at CCMC
  - Lots of plots available for quick-look perusal at the CCMC main page and via their iSWA tool
    - http://ccmc.gsfc.nasa.gov/cgi-bin/SWMFpred.cgi
    - http://iswa.ccmc.gsfc.nasa.gov/
  - Also available at our website:
    - http://csem.engin.umich.edu/realtime/
- Analysis of Dst values
  - SWMF-Geospace does quite well
  - Need an inner magnetosphere model to get storms

Acknowledgments

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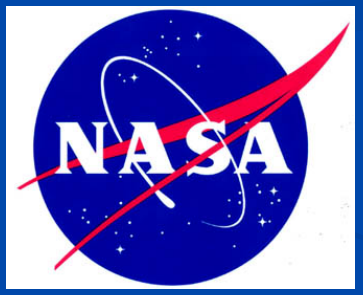


The contingency table

- Four-part table of integer values
- The quadrants have names:
  - **Hits:** both model and data are in the state
  - **Misses:** data in state but not the model
  - **False alarms:** model in state but data not in state
  - **Correct negatives:** both data and model not in state

Contingency Table	Model in the state	Model not in state
Data not in state	False Alarms (F)	Correct Negatives (N)
Data in state	Hits (H)	Misses (M)

Derivative Values From the Table

- Probability of Detection and Hit Rate:
  - Range from 0 to 1
  - Want these high

$$POD = \frac{H}{H+M} \qquad HR = \frac{H}{H+M+F}$$

- Probability of False Detection (False Alarm Rate):
  - Ranges from 0 to 1
  - Want it low

$$POFD = \frac{F}{F+N}$$

- Heidke Skill Score:
  - Max is 1
  - = 0 is = random
  - < 0 is...well...bad

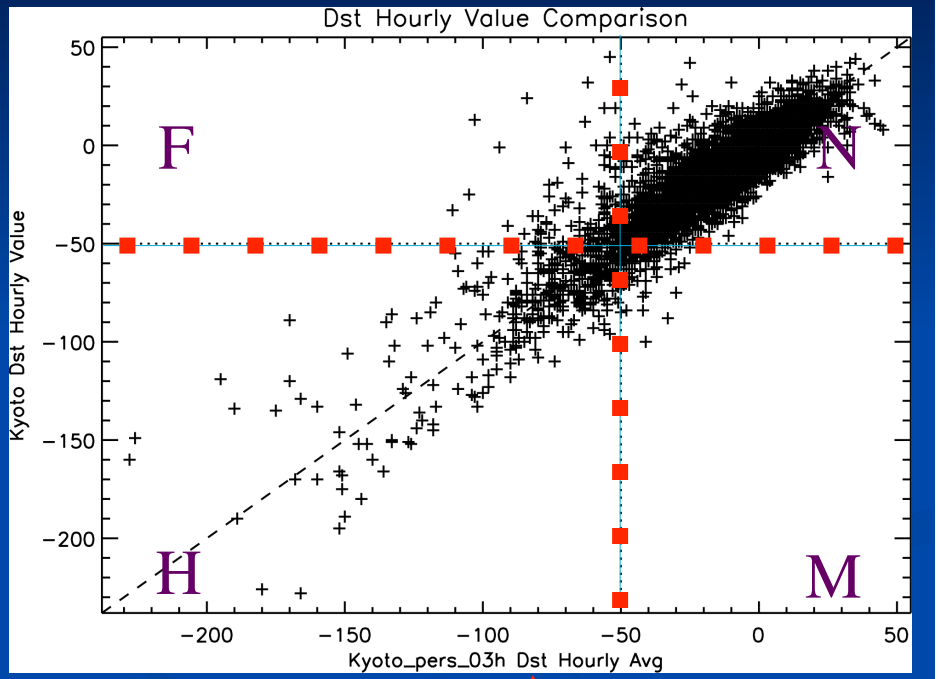
$$HSS = \frac{2\left[\left(H \cdot N\right) - \left(M \cdot F\right)\right]}{\left(H+M\right)\left(M+N\right) + \left(H+F\right)\left(F+N\right)}$$

More Kyoto persistence: 3 h shift

- Getting closer to SWMF values

Contingency Table	$Dst_M < X_M$	$Dst_M > X_M$
$Dst_K > X_K$	F = 129	N = 8326
$Dst_K < X_K$	H = 425	M = 129

POD = 0.77 R = 0.90
POFD = 0.015 PE = 0.79
HSS = 0.75 RMSE = 10.1



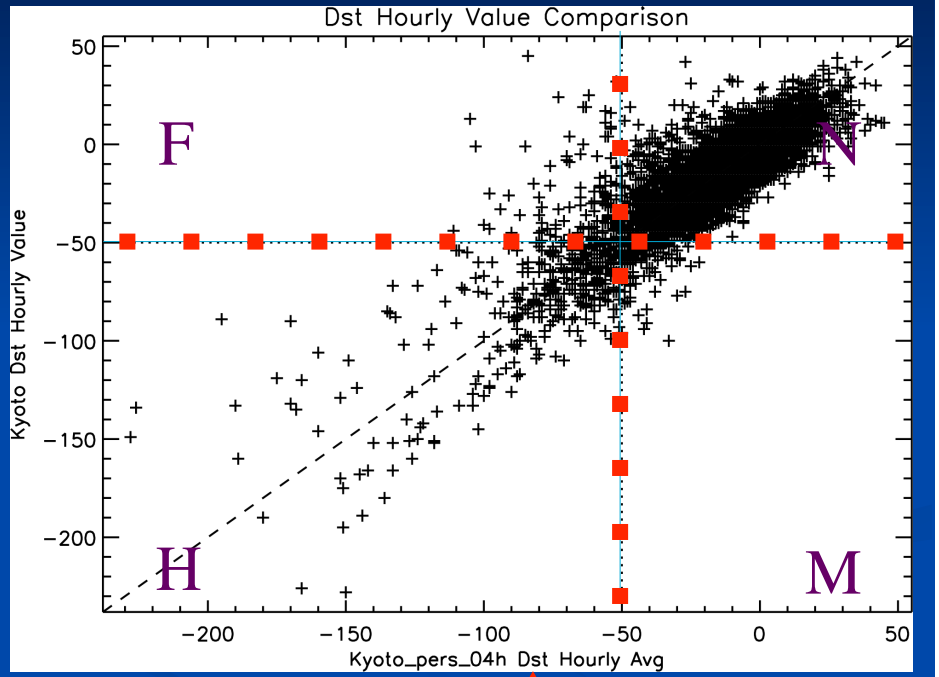
From 3 h prior to y-axis values

More Kyoto persistence: 4 h shift

- Still better, but even closer, to SWMF values

Contingency Table	$Dst_M < X_M$	$Dst_M > X_M$
$Dst_K > X_K$	F = 153	N = 8301
$Dst_K < X_K$	H = 401	M = 153

POD = 0.72 R = 0.86
POFD = 0.018 PE = 0.72
HSS = 0.71 RMSE = 11.7



Kyoto values from 4 h prior to y-axis values