

Climatological Modeling Using AMIE

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AMIE

- * AMIE is the Assimilative Mapping of Ionospheric Electrodynamics
- * AMIE uses data to morph geophysical patterns from a statistical background pattern to one that is more realistic.
 - * Ionospheric Potential is most common thing shown.
 - * Hall and Pedersen conductances
 - * Log(Electron Auroral Average Energy)
 - * Log(Electron Auroral Total Energy Flux)
 - * Obviously the Hall and Pedersen conductances are related to the electron average and total energy flux, but you CAN solve for them separately.

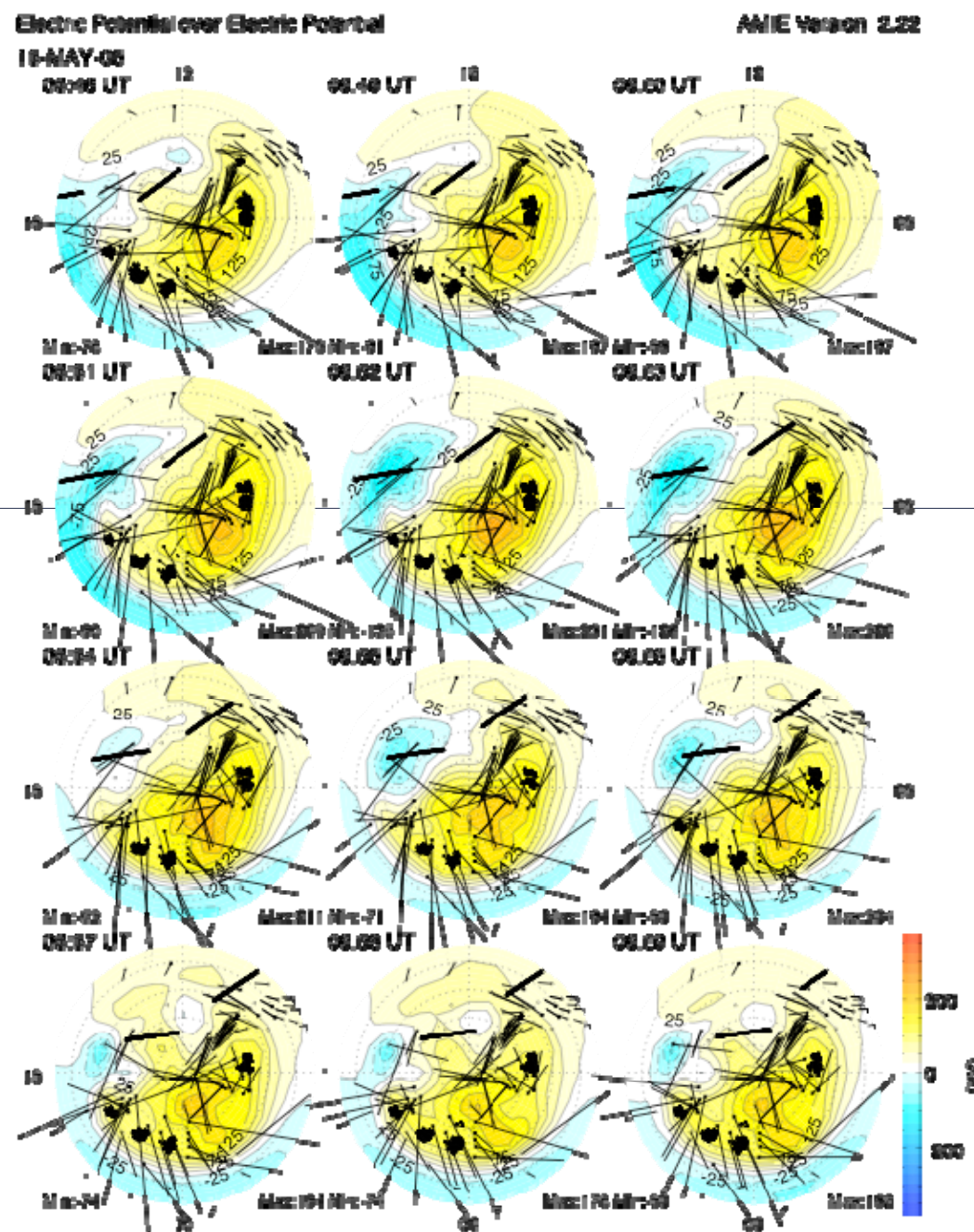


Data to Drive AMIE

- * Since AMIE can derive a lot of quantities, it can also be driven by a LOT of different data sets:
 - * SuperDARN radar (raw!) measurements of ion drifts.
 - * Incoherent Scatter Radar measurements of ion drifts and derived total conductances
 - * DMSP cross track (and along track) ion velocities
 - * DMSP magnetic perturbations
 - * Other satellite measurements of magnetic perturbations
 - * Auroral imagery from IMAGE and POLAR
 - * Average energy is tricky
 - * DMSP/NOAA particle precipitation measurements
 - * Ground-based magnetic perturbations

Example

Ground-based mags
SuperDARN radars
DMSP data





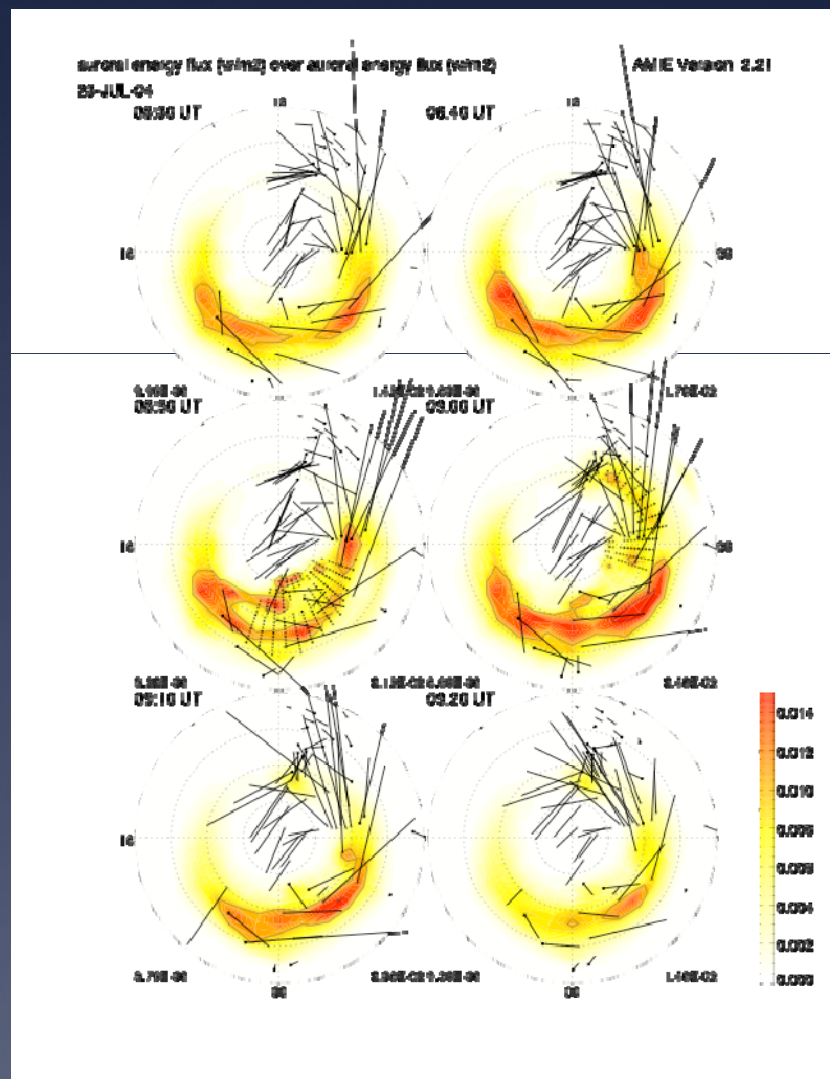
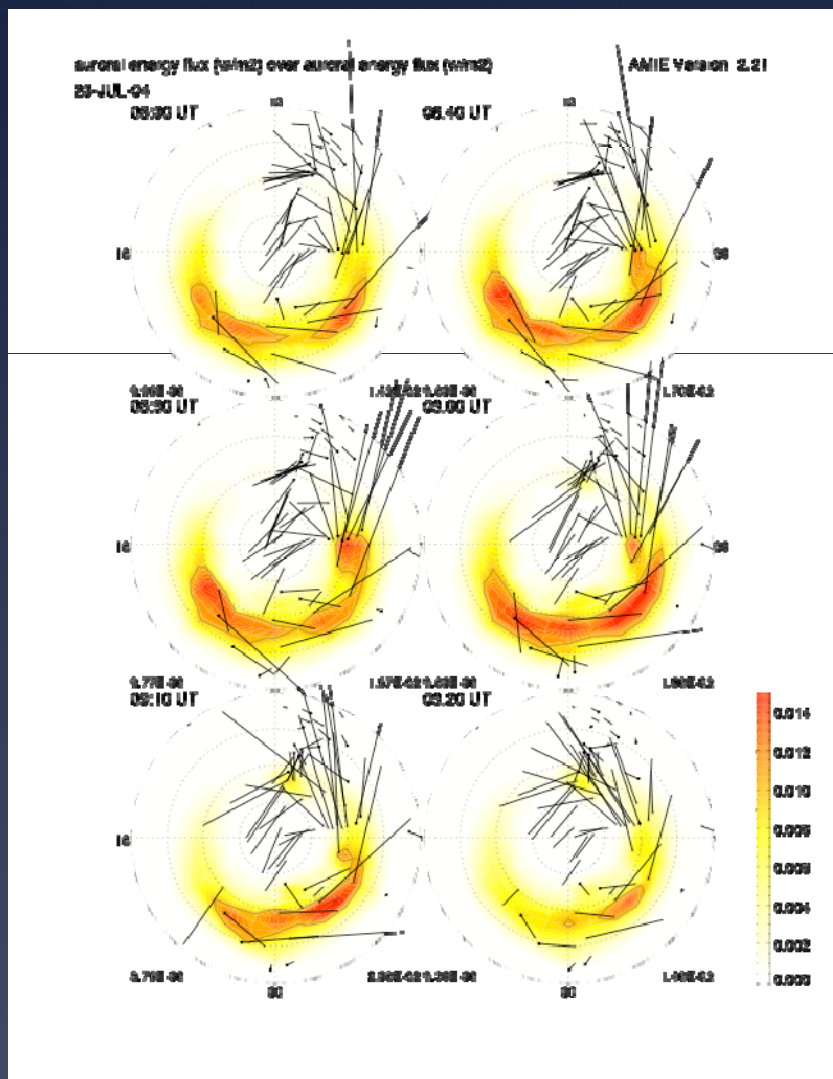
Data Caveats

- * All data has inherent limitations. Most data assimilation techniques can mitigate these limitations by the weighting that they put on the data sets.
 - * For example, if you trust radar data more than DMSP data, you can weigh the radar data more or give the DMSP data a larger error estimate (same effect).
- * Low altitude satellites go through the polar cap very fast, but they tend to have very good data.
 - * That means that the inversion is very accurate for the time that the satellite is going over the polar cap, but then it goes back to the “nominal” inversion.

Influence of low altitude satellite data

No GUVI

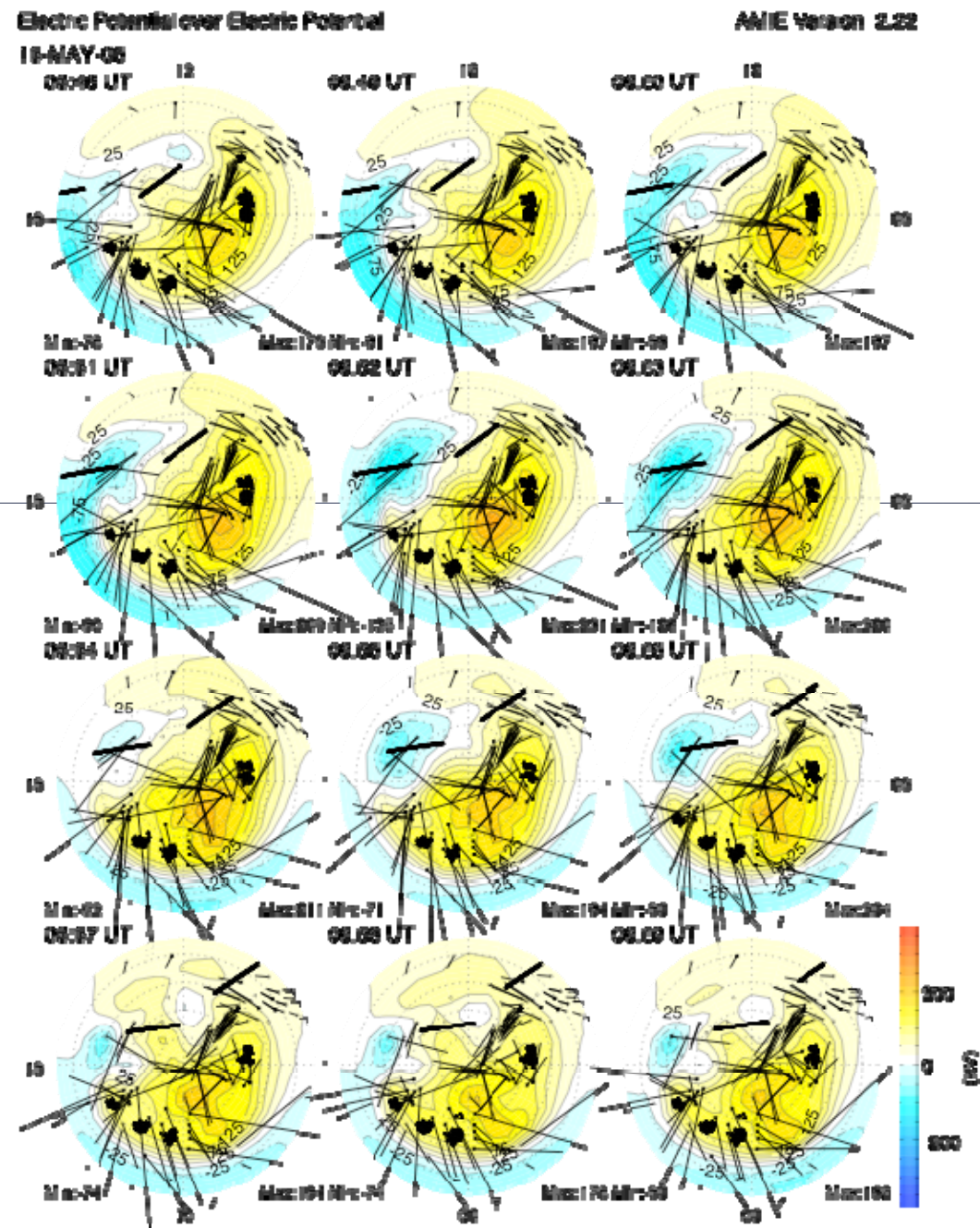
With GUVI



2nd Example

Same example as before!

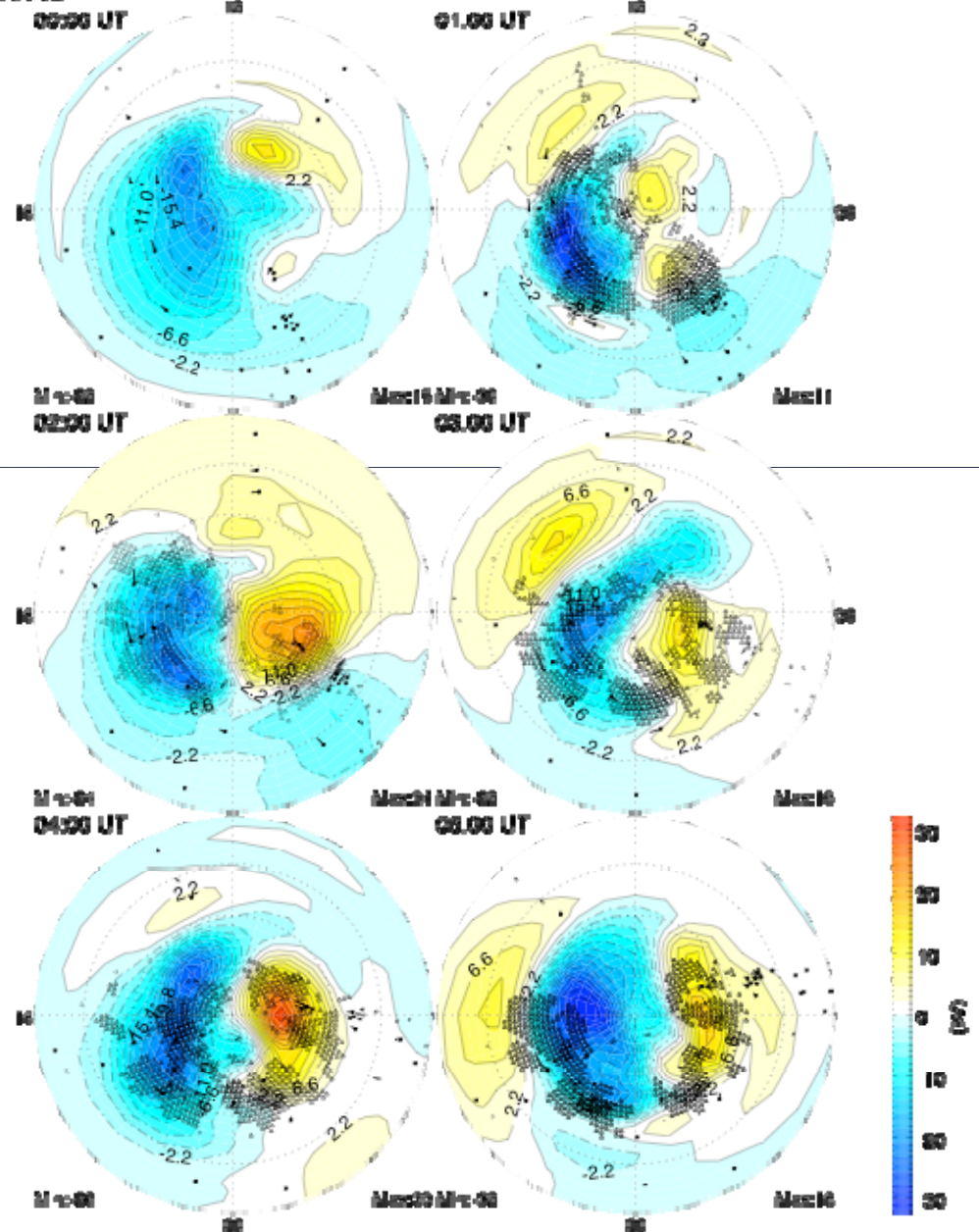
Notice how potential changes around DMSP flight path!!



SuperDARN

electric potential over electric potential
01-JAN-02

AME Version 2.22





Ground-based Magnetometers

- * As you can see, there are good things and bad things about EVERY data set.
- * Ground-based magnetometers need the ionospheric conductance to really specify the ionospheric potential.
 - * The Hall conductance, really.
- * The conductance is hard to specify accurately.
- * Also, ground-based magnetometers are integral devices, so, in theory, the resolution is about 110 km maximum (1 degree)
 - * AMIE is run at 2 degrees latitudinal resolution most of the time, so this isn't really an issue too much...
- * The big advantage with the magnetometers is that they don't change from moment to moment – so there is CONSISTENCY!
 - * And you want consistency when doing some physics.
 - * Other times, a more accurate solution trumps the more consistent patterns. Depends!



History 101

- * Art Richmond (NCAR/HAO) basically made the AMIE technique in the late 1980s.
- * People like Delores Knipp, Barbara Emery and Gang Lu did work on AMIE to make it so it could use data sets such as ground-based and satellite-based magnetometers and DMSP cross track ion velocity and precipitation data.
- * When I started work at HAO in 1996 as a grad student (holy crap – that was a long time ago!), the magnetometer processing took weeks to do.
 - * Modify a fortran-77 file to add the day and file name and station information
 - * Recompile
 - * Run
 - * Repeat over and over and over and over and over and over.....



History 102

- * I take my hat off (if I were wearing a hat...) to Barbara and Gang and Delores
 - * Some of the ground-based magnetometers that they used were not even files – they were plots printed out on big sheets of paper
 - * You had to use a special machine to trace them and get the data
 - * During a storm you couldn't tell which component was which
 - * Barbara showed me how to do this one time and I didn't even try because it looked like such a pain in the ...
 - * So, don't try to do events before about 1990 if you want Russian magnetometer data!



History 103

- * My contribution to AMIE at that point was to optimize the magnetometer processing.
- * I, in essence, threw away all of the fortran codes and rewrote a significant amount of processing codes in IDL and c.
 - * Funny story there – ask me how I finished my thesis using the 7 minute IDL demo because HAO didn't support Linux machines and refused to give me a license file... Ha! Ha!
- * I basically simplified all of the steps so you didn't have to change the code and recompile anymore.
- * This sped up the time to do an AMIE inversion from a couple of months of prep time to less than a week.



A week?

- * Yes, a week.
- * There are a lot of data sets that go into an AMIE run:
 - * CANOPUS data
 - * MACCS data
 - * USGS data
 - * IMAGE data
 - * Greenland data
 - * 210mm data
 - * Etc.
- * Each has a different format and a different temporal cadence. So each type had to be dealt with individually.
- * Beg borrow and steal the data...



History, cont.

- * After my defense, I went to work at Southwest Research Institute with Geoff Crowley
- * I continued to work on AMIE, and did a couple of things:
 - * Continued to optimize the data processing for AMIE input
 - * Made scripts that would make the input file (painful!)
 - * Parallelized the run using Perl with help from Thomas Immel
- * After these changes, I realized that we could actually run AMIE in real time, so we started rtAMIE.
 - * Download and process all data in real time
 - * Run AMIE every 10 minutes predicting the next 60 minutes.
- * Most AMIE runs from Crowley et al., are using this version of AMIE, in which much of the data processing and scripting was done during this time.



More and More History

- * When I moved to UM, I did a couple of things with AMIE
 - * Moved rtAMIE to NOAA (it ran from something like 1999-2005, and then we just stopped, since no one was interested...)
 - * I completely rewrote AMIE, except for the core solver which was written by Art.
 - * The input files are MUCH cleaner and easier to use
 - * Output files are much more condensed and easier to use
 - * Allowed AMIE to read in non-processed SuperDARN and DMSP data
 - * Fully parallelized it using MPI
 - * Again rewrote much of the data processing routines to improve them for automation.



Enter Eric!

- * About this time Eric Kihn was thinking about creating a “space weather reanalysis” project
 - * Run models for a solar cycle so investigators could look at any type of condition they want.
 - * Funded by DoD.
- * I agreed to run AMIE for a solar cycle.
- * I was really, really stupid to agree to this.
- * But, eventually everything turned out great. It worked exactly as he originally envisioned it!
 - * Thanks Eric – you are a visionary!



Space Weather Reanalysis Project

- * Originally wanted to run AMIE, GITM (global ionosphere thermosphere model), and SIMM (simple magnetosphere model) from about 1990 to 2004.
 - * Drive GITM and SIMM using AMIE output
 - * Didn't exactly complete the GITM runs
 - * Not sure about SIMM
- * With AMIE runs, we wanted the most consistent runs possible, which meant using ground-based magnetometers
 - * Still a major problem, since many chains came on-line in the 1990s
 - * So very different magnetometer coverage between 1990 and 2002 or 2003 (the best coverage years)
 - * Also, wanted Southern Hemisphere AMIE patterns
 - * Very few magnetometers in Southern hemisphere, especially at high latitudes where it counts!



More problems

- * Many of the students may not know this, but IMF data was hard to come by before the launch of WIND, so before 1994 or so, the background patterns in AMIE varied dramatically depending on IMF or no IMF input.
 - * IMP-8! Yeah!
- * Not all data available over the WWW
 - * The 2003 CANOPUS magnetometer data came on 36 CDs!
 - * Many data sets you basically have to know someone to get the data!
 - * Thanks Bob Clauer for working with the Danish Meteorological Institute to get Greenland data!
 - * I literally walked into Volodya Papitashvili's and stole a few Intermagnet CDs. I returned them. Eventually.
 - * Beg, borrow, and steal!



Think about this

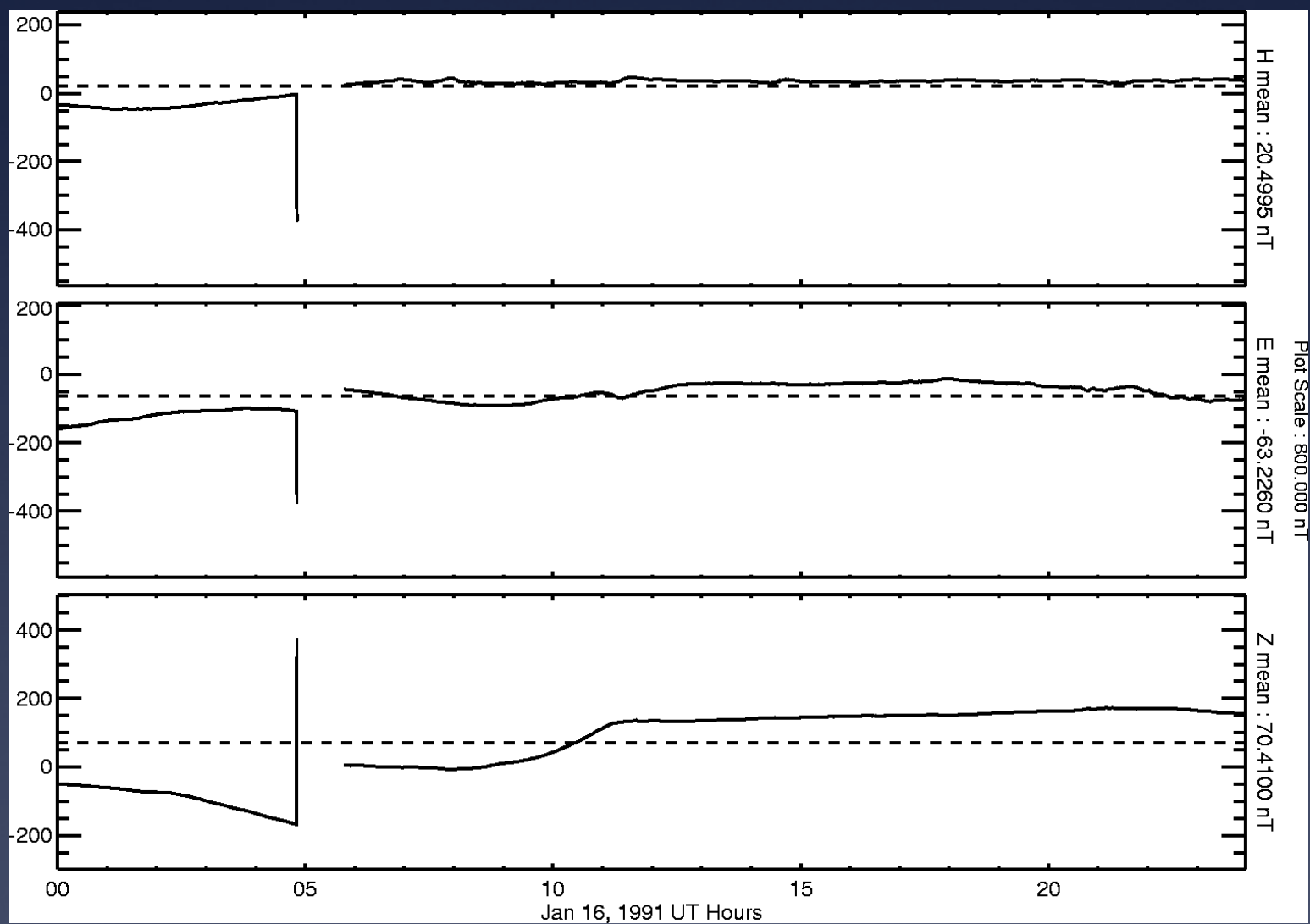
- * I wanted to run AMIE from 1990-2004.
- * With about 150 ground-based magnetometer stations.
- * 365 days a year.
- * That is 54,750 magnetometer data files to deal with per year.
- * Or 821,250 files for the 15 years. (plus leap files)
- * And I am not really an organized person.
- * That was bad. I became more organized.



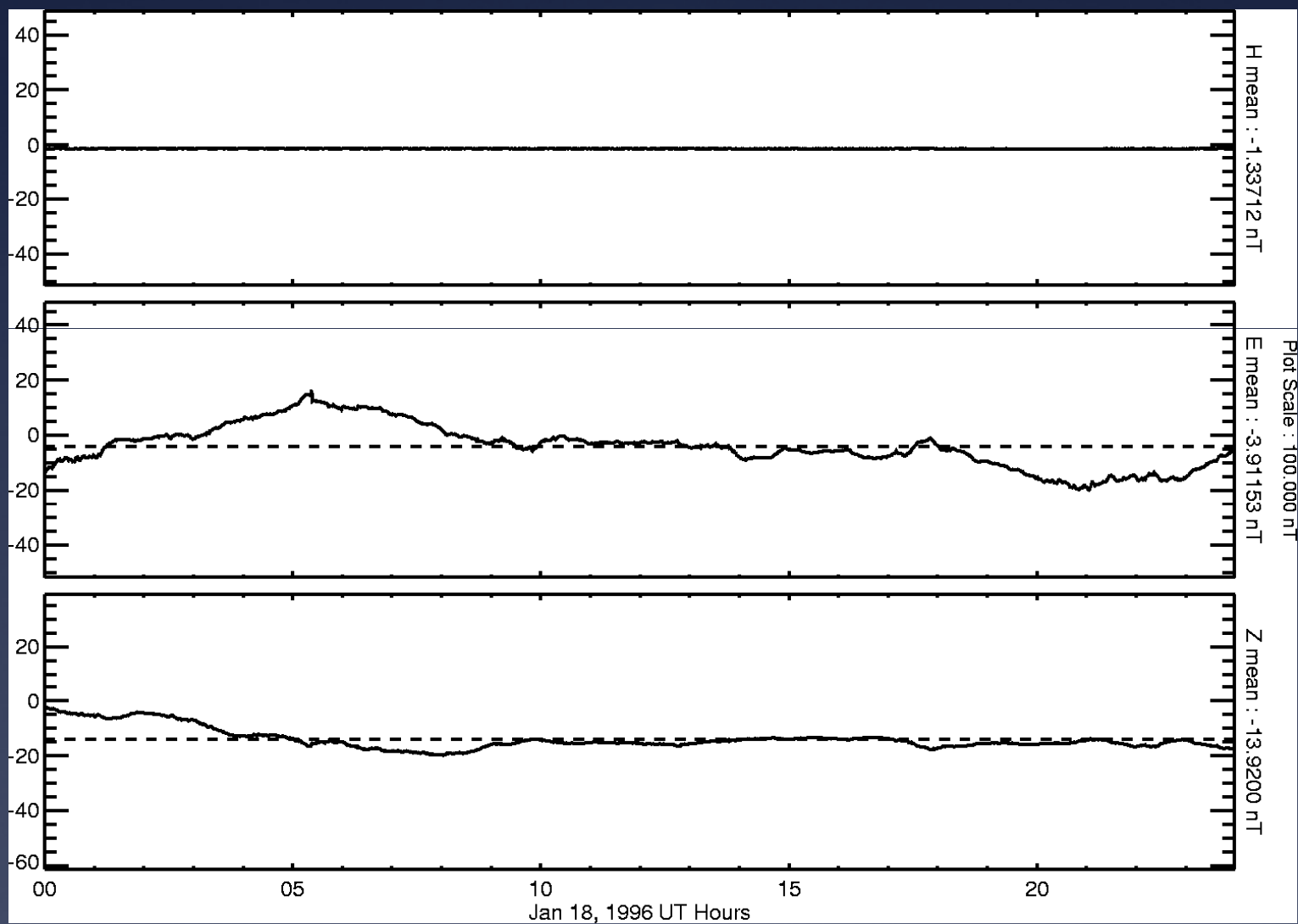
Processing and Processing and Processing

- * So, let's say you have 820,000 files you want to process....
- * You have to build scripts and more scripts.
- * You quickly realize that doing anything by hand is too painful to imagine.
- * Everything was automated:
 - * Convert all files to flatfiles (just a consistent data type)
 - * Despike all files the same way
 - * Average all files the same way
 - * Automatically remove quiet days
 - * Can't really do this the "old school" way, which is basically by hand.
 - * Plot everything on month long plots to visually check
 - * Enter mind numbing hours of visual inspections
 - * If anything looks bad on the data, remove the day – do not "repair" the bad data or try to fix the problem – chuck it.

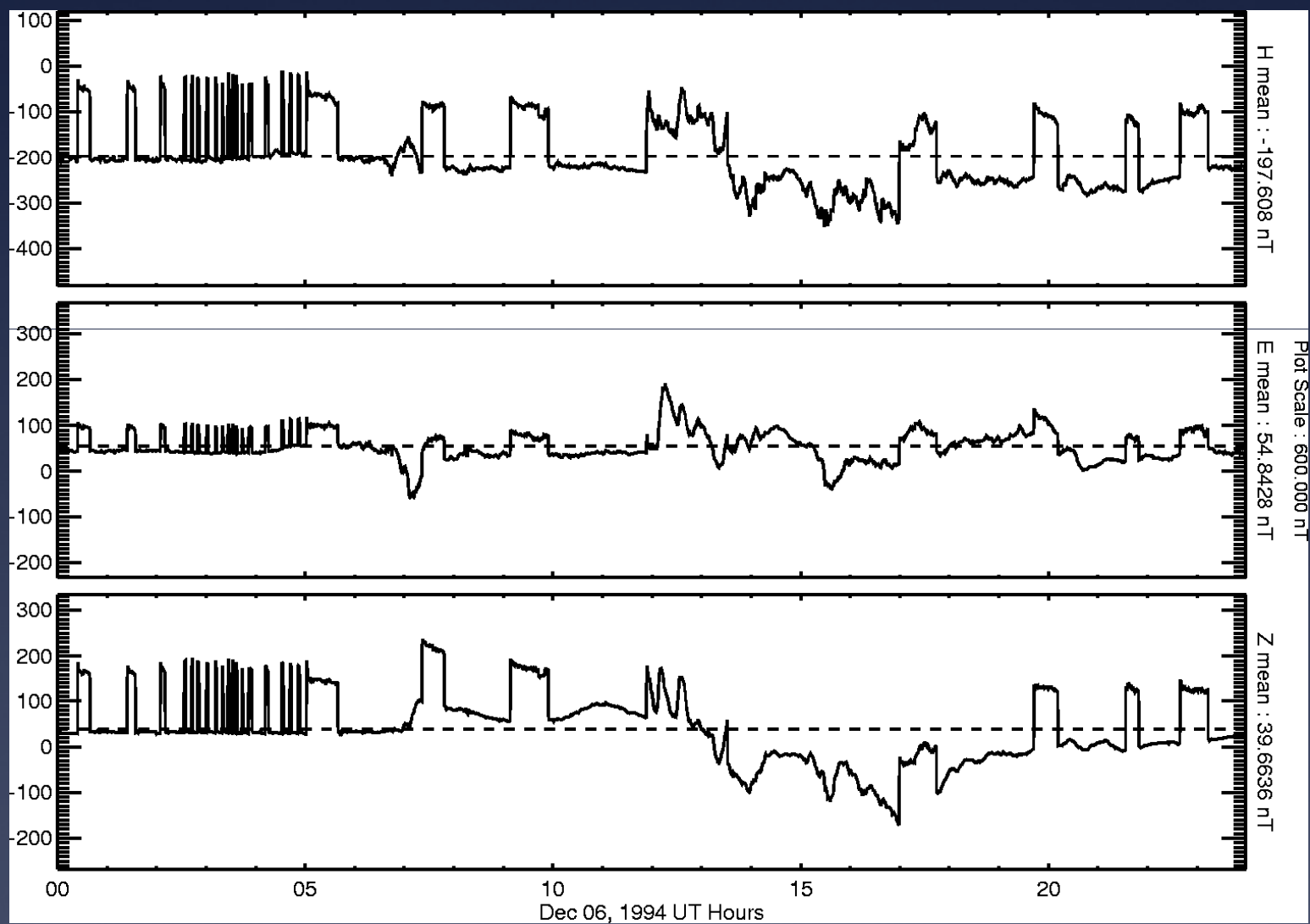
Bad data!



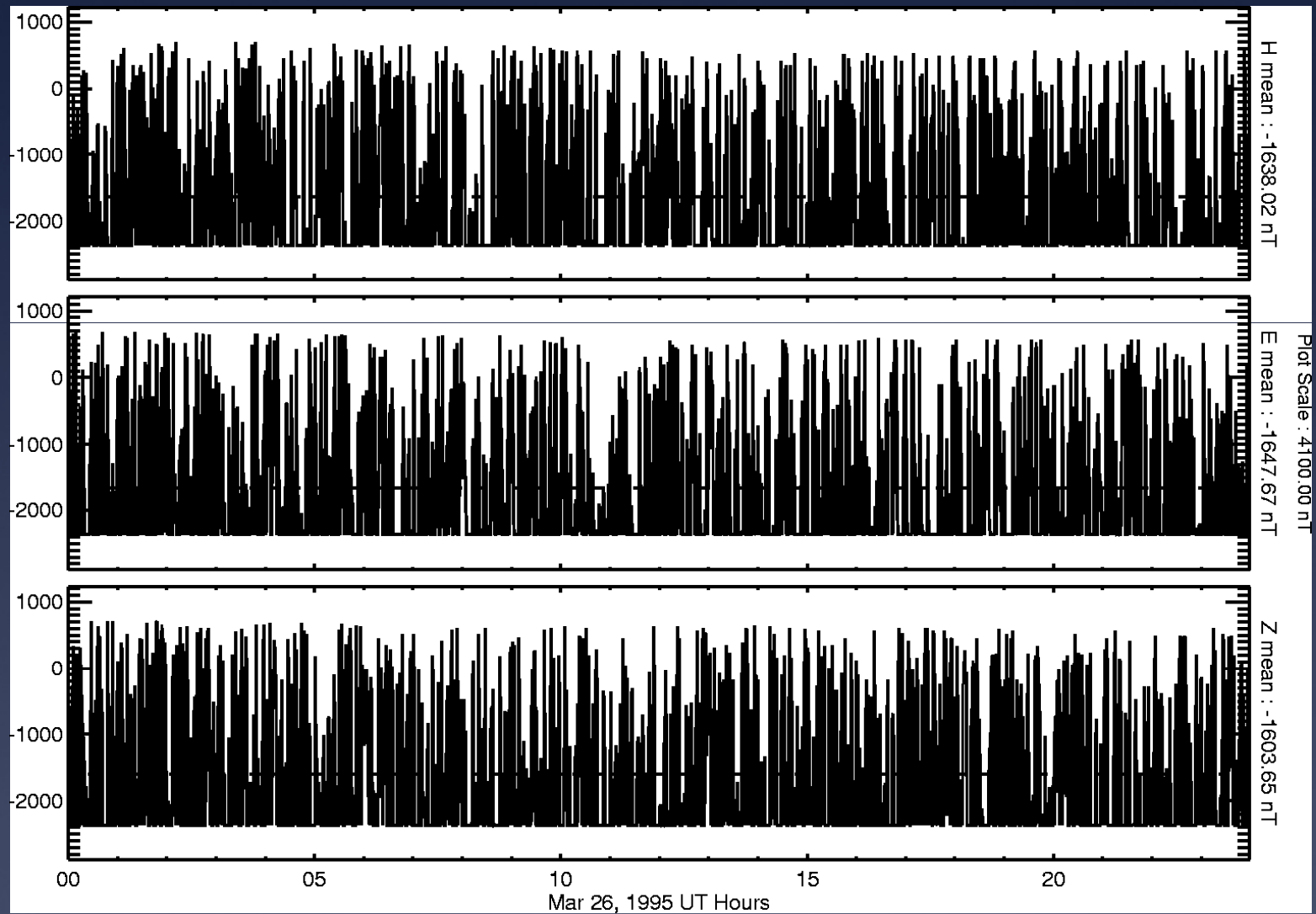
Bad Data!



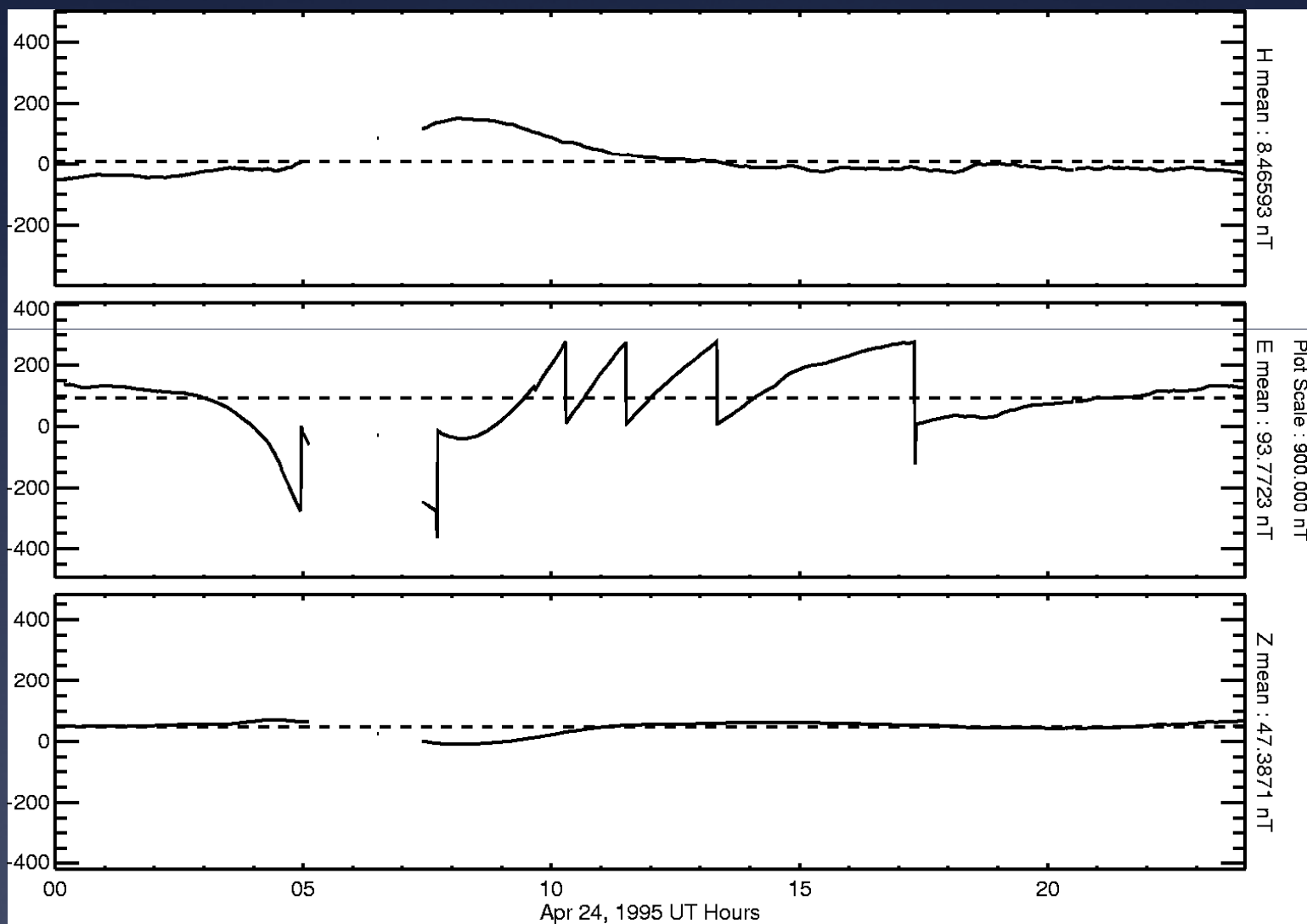
Bad Data!



What?



I don't understand this





Bad data

- * I have to say that there were thousands of bad magnetometer days.
- * Hardest problems to deal with are baseline shifts in the middle of a day and spikes that are large, but smaller than the normal min and max variation in a day.
- * And garbage. It is difficult to weed out the absolute garbage.



Input files

- * Magnetometer files are 90% of issue
 - * It should be noted again that all magnetometer data files from different chains have DIFFERENT formats, so I wrote about 50 different magnetometer readers.
 - * And then, to piss me off (I am sure), the data providers would change formats from year to year.
- * IMF files
 - * Mostly a nonissue until a day popped up when (for example) WIND was inside the magnetosphere and the “IMF” went up to something like $B_z +9000$ nT and the solar wind velocity went to 0.
 - * Have to hand deal with all days in which IMF does not exist past the launch of WIND. Before this, we ran with a K_p driven pattern for times when IMP-8 was in the magnetosphere.
- * All “hand dealing” means lots of time spent just to get a couple days of runs.



- * You still aren't finished!
- * We discovered very early on that AMIE could blow up (spectacularly!) producing cross polar cap potentials of may 1000s of kV.
- * The typical way to handle this is to figure out the time, then figure out which data point is giving you the problem, then rerun it. In other words, by hand! No!





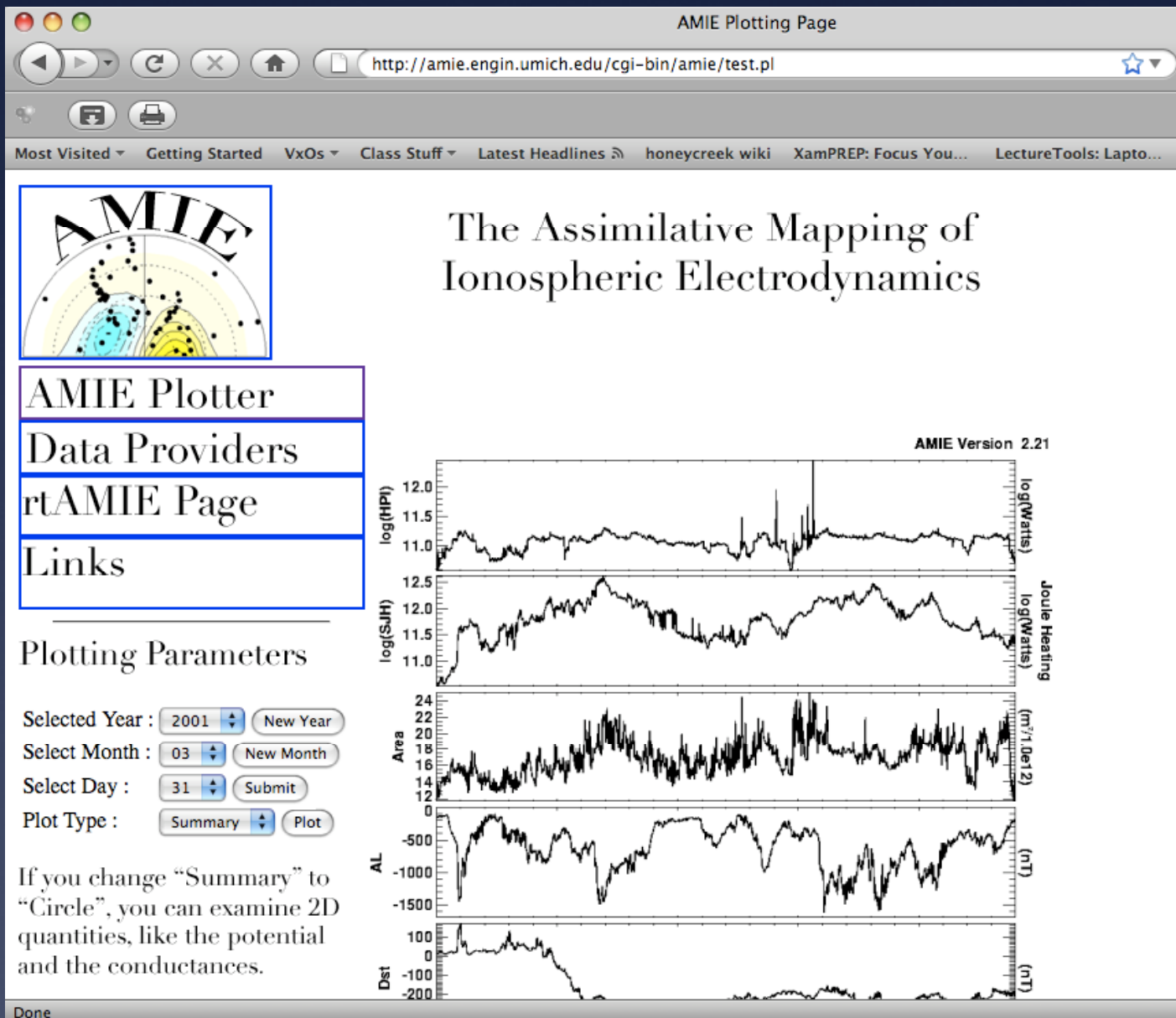
Back to the drawing board...

- * AMIE has the ability to state an error estimate on the predicted values at the input locations.
- * So, you can compare the input data with the output data and see if it is uncertain to a large degree.
- * You can then throw away all of the “bad” data and try again.
- * Repeat this a couple of times until the error is minimized, and you have an “optimal” solution.
- * In other words, rewrite the core section of AMIE to deal with bad data with no human interaction.
- * This reduced blowups by a significant degree.



Finished now?

- * Yes!
- * We finished the run from 1990-2003. Eric has hired someone to learn how to do this and he has run 2004-2006.
- * Most data available over the WWW.

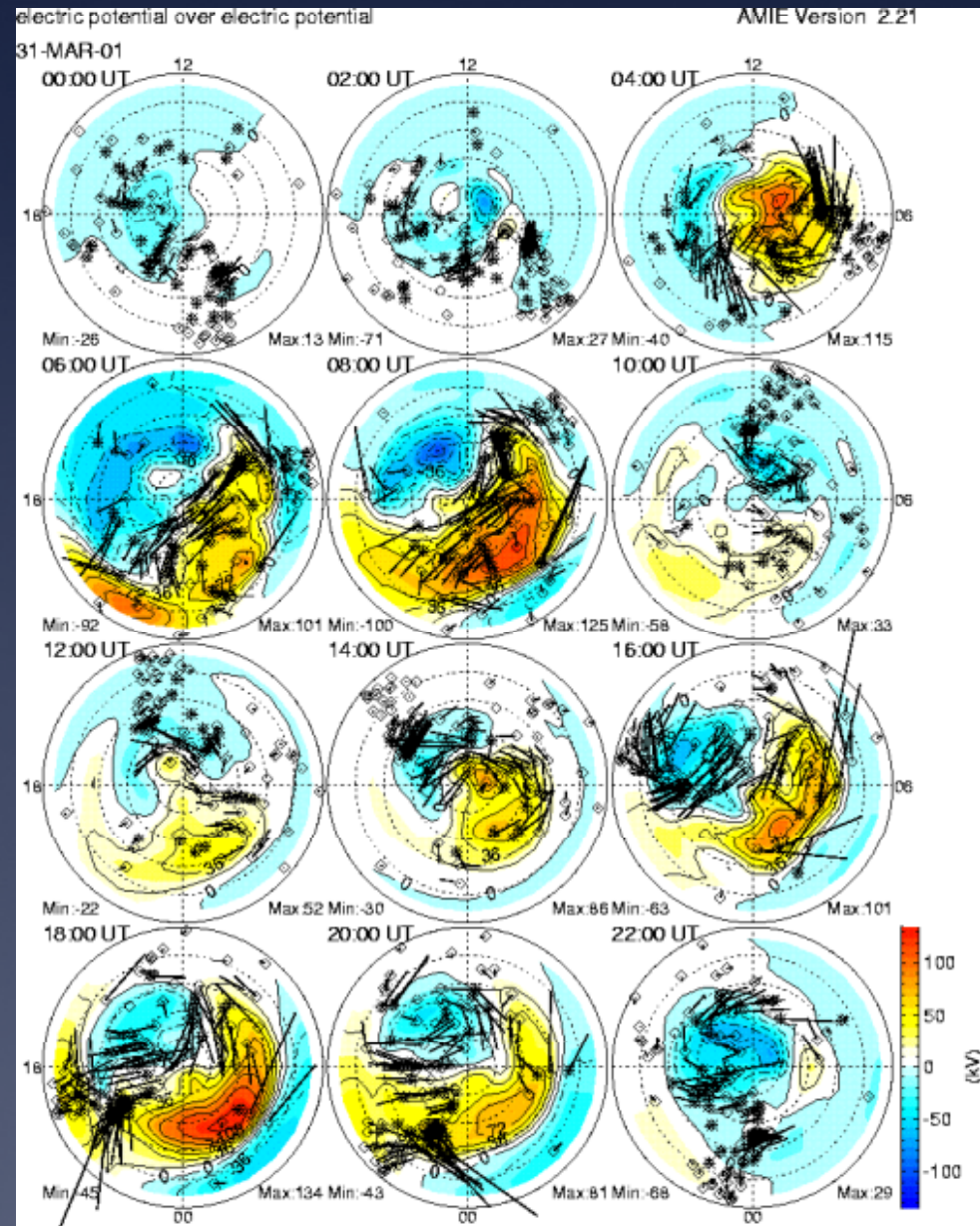


Plots available on the web

Can choose:
 Potential
 Field-Aligned Currents
 Horizontal Currents
 Electric Fields
 Conductances
 Precipitation
 Joule Heating

Can select time interval
 Always gives 12 plots

A little slow, since it is
 running on an old mac...





Super Secret Data!

- * <http://amie.engin.umich.edu/~amie/data/potentials/>
 - * Gives potential data as ascii files for years of these runs
- * <http://amie.engin.umich.edu/~amie/data/indices/>
 - * Gives summaries of the data, like CPCP, Dst, AE, etc
- * Feel free to download whatever you want and use it!

Indices

Mozilla Firefox

http://amie.engin.umich.edu/~amie/data/indices/2000/b20000103_sum

Most Visited ▾ Getting Started VxOs ▾ Class Stuff ▾ Latest Headlines ▾ honeycreek wiki XamPREP: Focus You... LectureTools: Lapto... Schedule of Classes

yyyy	mm	dd	hh	mm	ss	CPCP	Ae	Au	Al	Bx	By	Bz	Vsw	Comp Det	Comp HPI	Comp SJH	A (m ²)
2000	1	3	0	0	0	7.09e+01	3.16e+02	1.02e+02	-2.14e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-4.05e+00	3.10e+10	6.44e+10	1.58e+1
2000	1	3	0	1	0	7.06e+01	3.12e+02	9.20e+01	-2.20e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-4.13e+00	2.68e+10	6.26e+10	1.42e+1
2000	1	3	0	2	0	6.90e+01	3.25e+02	9.70e+01	-2.28e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-4.47e+00	3.20e+10	6.10e+10	1.59e+1
2000	1	3	0	3	0	6.84e+01	3.15e+02	9.20e+01	-2.23e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-4.48e+00	3.05e+10	5.89e+10	1.50e+1
2000	1	3	0	4	0	6.08e+01	3.17e+02	9.40e+01	-2.23e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-4.51e+00	3.16e+10	6.08e+10	1.48e+1
2000	1	3	0	5	0	5.72e+01	3.05e+02	9.00e+01	-2.15e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-4.74e+00	3.00e+10	5.58e+10	1.41e+1
2000	1	3	0	6	0	6.08e+01	2.95e+02	8.20e+01	-2.13e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-4.57e+00	3.03e+10	5.73e+10	1.36e+1
2000	1	3	0	7	0	6.58e+01	2.80e+02	7.90e+01	-2.01e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-4.81e+00	2.67e+10	4.96e+10	1.39e+1
2000	1	3	0	8	0	7.05e+01	3.04e+02	1.03e+02	-2.01e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-5.14e+00	2.81e+10	5.75e+10	1.36e+1
2000	1	3	0	9	0	7.14e+01	3.12e+02	1.09e+02	-2.03e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-4.83e+00	2.82e+10	5.59e+10	1.39e+1
2000	1	3	0	10	0	7.10e+01	2.97e+02	8.70e+01	-2.10e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-4.99e+00	2.68e+10	5.48e+10	1.36e+1
2000	1	3	0	11	0	7.02e+01	3.21e+02	1.02e+02	-2.19e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-4.83e+00	2.44e+10	5.22e+10	1.37e+1
2000	1	3	0	12	0	6.90e+01	3.18e+02	9.80e+01	-2.20e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-5.13e+00	2.37e+10	5.06e+10	1.37e+1
2000	1	3	0	13	0	7.05e+01	3.10e+02	8.20e+01	-2.28e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-5.13e+00	2.42e+10	4.97e+10	1.34e+1
2000	1	3	0	14	0	6.86e+01	3.40e+02	9.20e+01	-2.48e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-5.34e+00	2.56e+10	5.09e+10	1.34e+1
2000	1	3	0	15	0	6.59e+01	3.16e+02	8.00e+01	-2.36e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-5.72e+00	2.45e+10	4.79e+10	1.30e+1
2000	1	3	0	16	0	6.55e+01	3.27e+02	8.30e+01	-2.44e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-5.86e+00	2.48e+10	4.63e+10	1.32e+1
2000	1	3	0	17	0	6.48e+01	3.17e+02	7.80e+01	-2.39e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-6.02e+00	2.35e+10	4.48e+10	1.31e+1
2000	1	3	0	18	0	5.78e+01	2.97e+02	6.40e+01	-2.33e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-6.11e+00	2.70e+10	4.07e+10	1.39e+1
2000	1	3	0	19	0	5.73e+01	2.90e+02	6.50e+01	-2.25e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-6.45e+00	2.70e+10	4.05e+10	1.21e+1
2000	1	3	0	20	0	5.77e+01	2.90e+02	6.80e+01	-2.22e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-6.44e+00	2.62e+10	3.94e+10	1.21e+1
2000	1	3	0	21	0	6.04e+01	3.11e+02	8.80e+01	-2.23e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-6.51e+00	2.63e+10	4.06e+10	1.25e+1
2000	1	3	0	22	0	5.86e+01	3.15e+02	9.50e+01	-2.20e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-6.35e+00	3.24e+10	3.89e+10	1.57e+1
2000	1	3	0	23	0	5.67e+01	3.13e+02	8.50e+01	-2.28e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-6.34e+00	3.27e+10	3.80e+10	1.55e+1
2000	1	3	0	24	0	5.58e+01	3.10e+02	7.40e+01	-2.36e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-6.50e+00	3.36e+10	3.73e+10	1.47e+1
2000	1	3	0	25	0	5.67e+01	3.16e+02	7.20e+01	-2.44e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-6.62e+00	3.45e+10	3.82e+10	1.49e+1
2000	1	3	0	26	0	5.59e+01	3.21e+02	7.70e+01	-2.44e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-6.75e+00	3.62e+10	3.90e+10	1.58e+1
2000	1	3	0	27	0	5.78e+01	3.46e+02	8.40e+01	-2.62e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-6.97e+00	3.57e+10	3.86e+10	1.56e+1
2000	1	3	0	28	0	5.06e+01	3.35e+02	6.80e+01	-2.67e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-7.44e+00	4.69e+10	3.72e+10	1.73e+1
2000	1	3	0	29	0	4.94e+01	3.34e+02	5.70e+01	-2.77e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-8.08e+00	4.68e+10	3.78e+10	1.80e+1
2000	1	3	0	30	0	5.03e+01	3.42e+02	6.70e+01	-2.75e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-8.21e+00	4.78e+10	3.81e+10	1.74e+1
2000	1	3	0	31	0	4.98e+01	3.35e+02	7.00e+01	-2.65e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-8.22e+00	4.86e+10	3.74e+10	1.75e+1
2000	1	3	0	32	0	4.80e+01	3.29e+02	6.40e+01	-2.65e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-8.08e+00	4.99e+10	3.87e+10	1.79e+1
2000	1	3	0	33	0	4.96e+01	3.54e+02	6.50e+01	-2.89e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-8.13e+00	5.11e+10	4.01e+10	1.81e+1
2000	1	3	0	34	0	5.42e+01	3.95e+02	8.20e+01	-3.13e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-8.39e+00	4.88e+10	4.14e+10	1.83e+1
2000	1	3	0	35	0	5.66e+01	4.20e+02	9.70e+01	-3.23e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-8.27e+00	5.07e+10	4.76e+10	1.80e+1
2000	1	3	0	36	0	5.80e+01	4.35e+02	9.60e+01	-3.39e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-8.23e+00	5.03e+10	5.18e+10	1.92e+1
2000	1	3	0	37	0	5.69e+01	4.47e+02	8.50e+01	-3.62e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-8.21e+00	5.23e+10	5.42e+10	1.79e+1
2000	1	3	0	38	0	5.50e+01	4.75e+02	8.50e+01	-3.90e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-8.51e+00	7.16e+10	5.77e+10	1.88e+1
2000	1	3	0	39	0	5.48e+01	5.05e+02	9.00e+01	-4.15e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-8.77e+00	7.19e+10	6.11e+10	1.89e+1
2000	1	3	0	40	0	5.56e+01	5.11e+02	9.40e+01	-4.17e+02	4.17e-01	3.13e+00	-3.86e+00	6.72e+02	-8.82e+00	6.87e+10	5.84e+10	1.93e+1

Done



Potentials

16.00
17.00
18.00
19.00
20.00
21.00
22.00
23.00
24.00

#FORMAT
(25f8.2)

#TIME
2001 1 6 0 0 0

#DATA

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-4.56	-4.51	-4.50	-4.53	-4.59	-4.65	-4.70	-4.70	-4.64	-4.49	-4.25	-3.95	-3.63	-3.37	-3.23	-3.25
-2.86	-2.52	-2.42	-2.50	-2.67	-2.85	-3.02	-3.15	-3.16	-2.96	-2.51	-1.84	-1.09	-0.50	-0.26	-0.48
-1.08	-0.19	0.19	0.15	-0.08	-0.31	-0.47	-0.50	-0.33	0.09	0.73	1.43	1.99	2.19	1.91	1.14
-0.14	1.51	2.55	2.83	2.56	2.16	2.04	2.41	3.29	4.38	5.21	5.33	4.53	2.95	1.03	-0.65
0.60	2.91	5.02	5.93	5.36	4.29	3.93	4.80	6.62	8.48	9.28	8.29	5.35	1.03	-3.30	-6.16
2.08	4.85	8.28	9.81	8.40	6.00	5.00	6.10	8.46	10.50	10.82	8.74	4.15	-2.33	-8.77	-12.79
3.62	6.93	11.60	13.40	10.68	6.70	4.95	5.94	8.10	9.52	9.06	6.55	1.90	-4.81	-11.87	-16.57
3.55	7.59	12.97	14.50	10.70	5.81	3.72	4.42	5.85	6.29	5.28	3.23	0.06	-4.87	-10.69	-15.14
1.81	6.19	11.12	11.95	8.06	3.66	1.93	2.35	2.97	2.71	1.71	0.67	-0.51	-2.82	-6.29	-9.53
0.25	3.84	7.06	7.04	4.19	1.46	0.52	0.72	0.80	0.41	-0.09	-0.17	0.06	-0.24	-1.52	-3.23
0.15	2.00	3.06	2.45	1.11	0.18	-0.09	-0.10	-0.20	-0.29	-0.17	0.29	0.96	1.38	1.23	0.61
0.91	1.08	0.62	-0.06	-0.20	-0.07	-0.15	-0.37	-0.47	-0.16	0.41	0.98	1.40	1.60	1.57	1.38
1.39	0.63	-0.32	-0.72	-0.27	0.14	-0.00	-0.40	-0.51	-0.03	0.64	1.09	1.17	0.99	0.77	0.62
1.35	0.31	-0.68	-0.80	-0.17	0.30	0.20	-0.24	-0.45	-0.14	0.33	0.59	0.56	0.37	0.19	0.09
1.18	-0.01	-1.08	-1.10	-0.39	0.25	0.41	0.09	-0.25	-0.25	-0.11	-0.01	0.03	0.09	0.20	0.22
0.98	-0.31	-1.47	-1.44	-0.64	0.18	0.55	0.35	0.01	-0.16	-0.23	-0.23	-0.15	0.06	0.31	0.39
0.67	-0.52	-1.53	-1.38	-0.58	0.18	0.49	0.32	0.09	0.00	-0.01	-0.03	-0.03	0.02	0.09	0.08
0.35	-0.58	-1.30	-1.04	-0.37	0.13	0.21	-0.02	-0.12	-0.00	0.17	0.23	0.11	-0.11	-0.33	-0.52
0.23	-0.54	-1.07	-0.85	-0.37	-0.09	-0.17	-0.43	-0.47	-0.24	0.05	0.18	0.06	-0.24	-0.58	-0.84
0.30	-0.48	-1.03	-0.94	-0.57	-0.34	-0.39	-0.59	-0.64	-0.47	-0.22	-0.08	-0.11	-0.28	-0.50	-0.68
0.34	-0.46	-1.05	-1.04	-0.68	-0.38	-0.31	-0.42	-0.50	-0.45	-0.34	-0.26	-0.24	-0.26	-0.31	-0.39
0.30	-0.45	-0.99	-0.97	-0.60	-0.24	-0.08	-0.13	-0.21	-0.25	-0.25	-0.25	-0.25	-0.24	-0.24	-0.28
0.24	-0.42	-0.87	-0.85	-0.52	-0.16	0.02	0.00	-0.08	-0.14	-0.18	-0.21	-0.23	-0.24	-0.24	-0.27

#TIME

Stopped



Publications

Saturation of the polar cap potential: Inference from Alfvén wing arguments

- Kivelson and Ridley (JGR)

- Technique: Large-scale ionospheric conductance estimated from combined satellite and ground-based electromagnetic data

- Green et al. (JGR)

- A statistical comparison of the AMIE derived and DMSP-SSIES observed high-latitude ionospheric electric field.

- Kihn et al. (JGR)

- High-Latitude Joule Heating Response to IMF Inputs

- McHarg et al. (JGR)

- A statistical analysis of the AMIE auroral specification.

- Kihn and Ridley (JGR)

- Stormtime particle energization with high temporal resolution AMIE potentials

- Liemohn et al. (JGR)

- A.D. DeJong, A.J. Ridley, and C.R. Clauer, Balanced reconnection intervals: Four case studies, *Annales Geophysicae*, 26, 3897-3912, 2008.

- 36
- A. Boudouridis, E. Zesta, L.R. Lyons, P.C. Anderson, and A.J. Ridley, Temporal evolution of the transpolar potential after a sharp enhancement in solar wind dynamic pressure, *Geophys. Res. Lett.*, 35, L02101, doi:10.1029/2007GL031766, 2008



More Publications

1. Polar cap index comparisons with AMIE cross polar cap potential, electric field, and polar cap area
 - Ridley and Kihn (GRL)
2. Magnetospheric convection electric field dynamics and stormtime particle energization: case study of the magnetic storm of 4 May 1998
 - Khazanov et al. (AG)
3. A new formulation for the ionospheric cross polar cap potential including saturation effects
 - Ridley (AG)
4. Statistical analysis of ionospheric potential patterns for isolated substorms and sawtooth events
 - Cai et al. (AG)
5. Comparison of satellite ion drift velocities with AMIE deduced convection patterns
 - Bekerat et al. (JASTP)
- Should note that we have many other publications using the magnetometer data that was used for the AMIE runs...



Results

- * There have been five papers that have just focused on the validation of AMIE patterns
- * For the potential, the papers clearly show that AMIE with ground-based magnetometers is MUCH better than using an empirical model.
 - * This is statistical – years of data compared
- * We have found that AMIE potentials have a seasonal dependency that is not present in the PCI index, indicating that there may be a problem in the seasonally specified conductance.
- * We also found that the AMIE derived conductances are only slightly better than the empirical models
 - * Much better when real conductance data is used!

Validation Plot

Bekerat et al. 2005,
JASTP

Showed that AMIE
was much better
than statistical
models

But still not perfect...

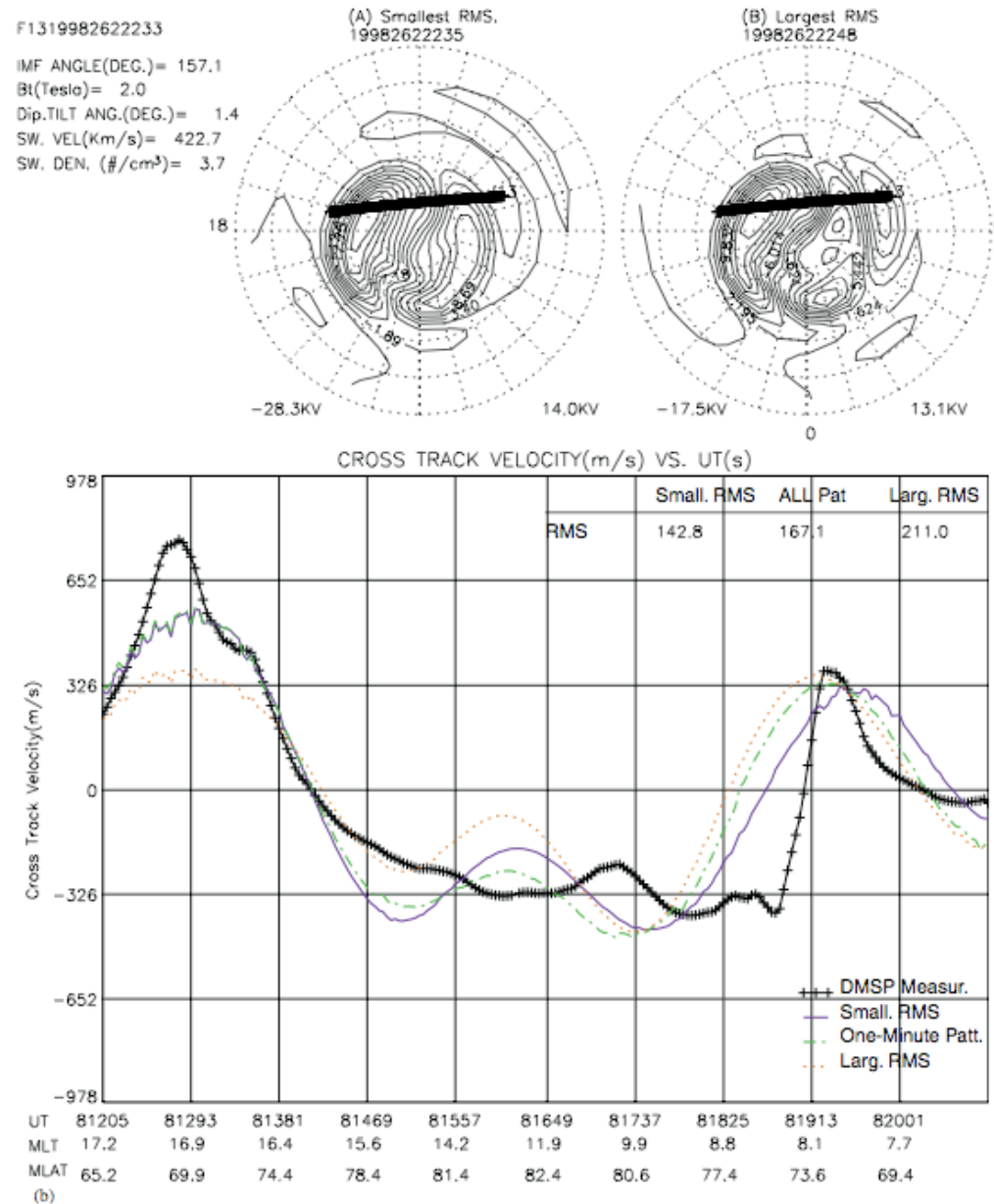
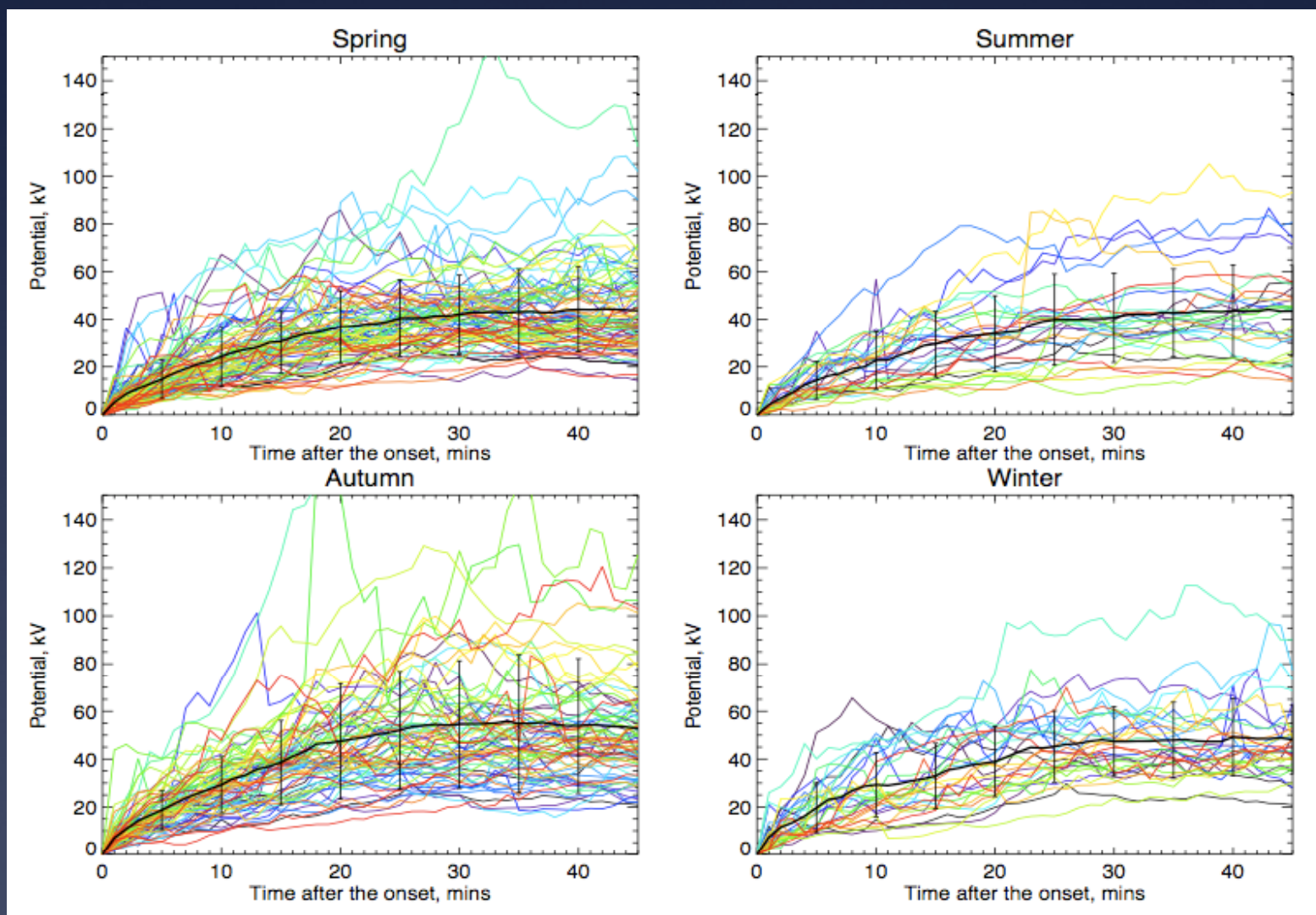


Fig. 4. (Continued)

Science

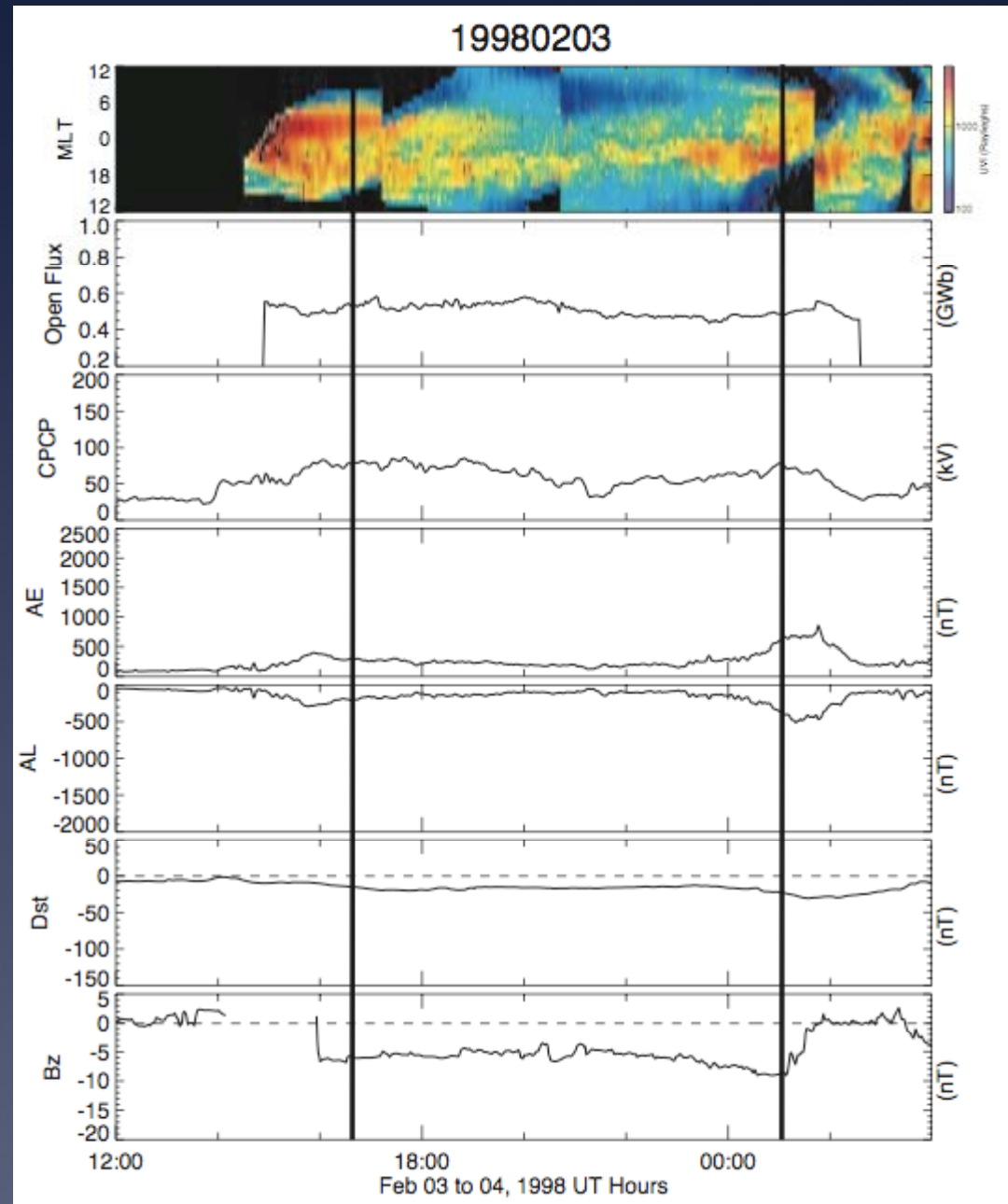
X. Cai et al., Ann. Geo.





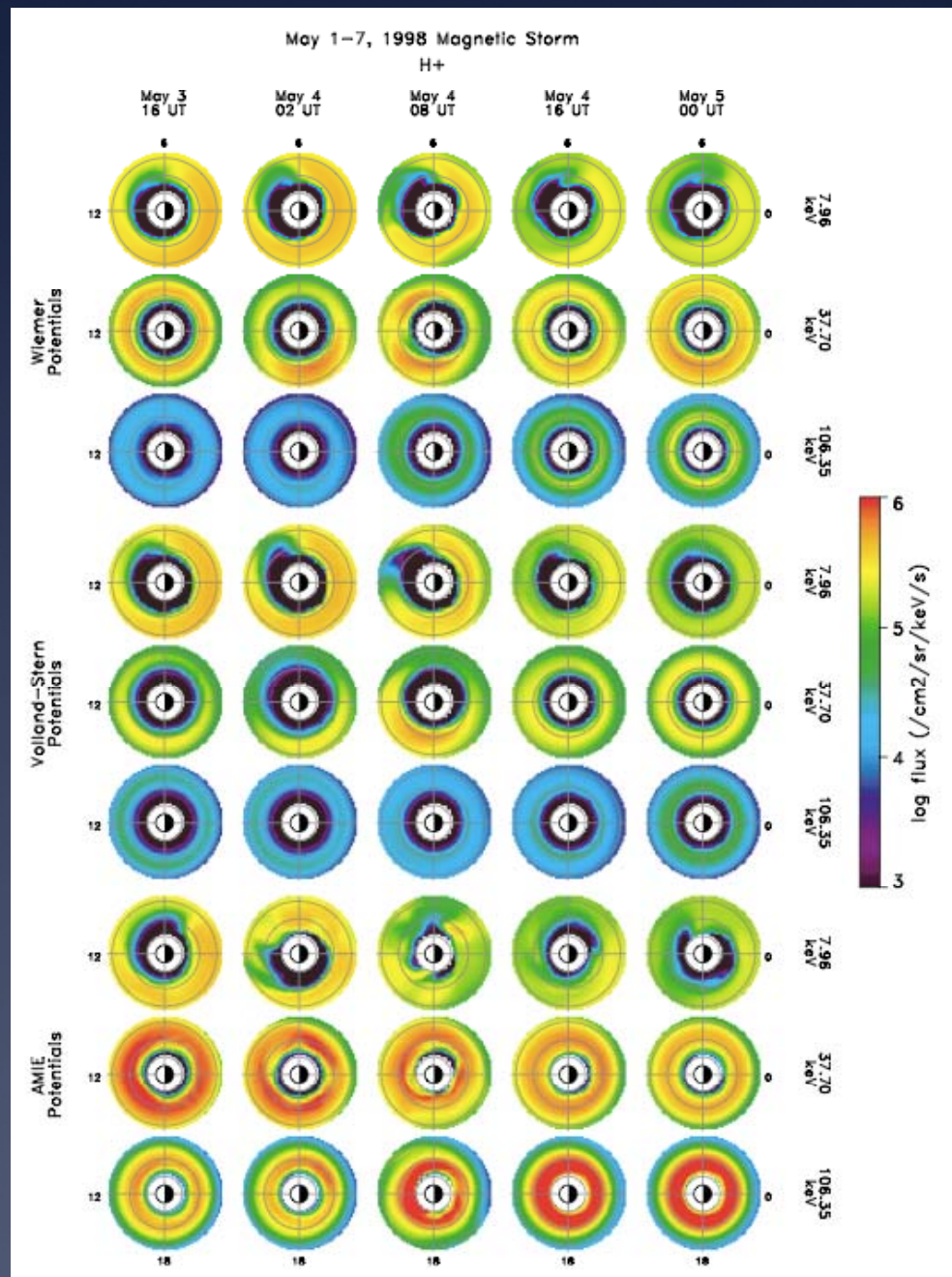
Science

DeJong et al. (AG)
examined Steady
magnetospheric
convection (BRI) time
periods



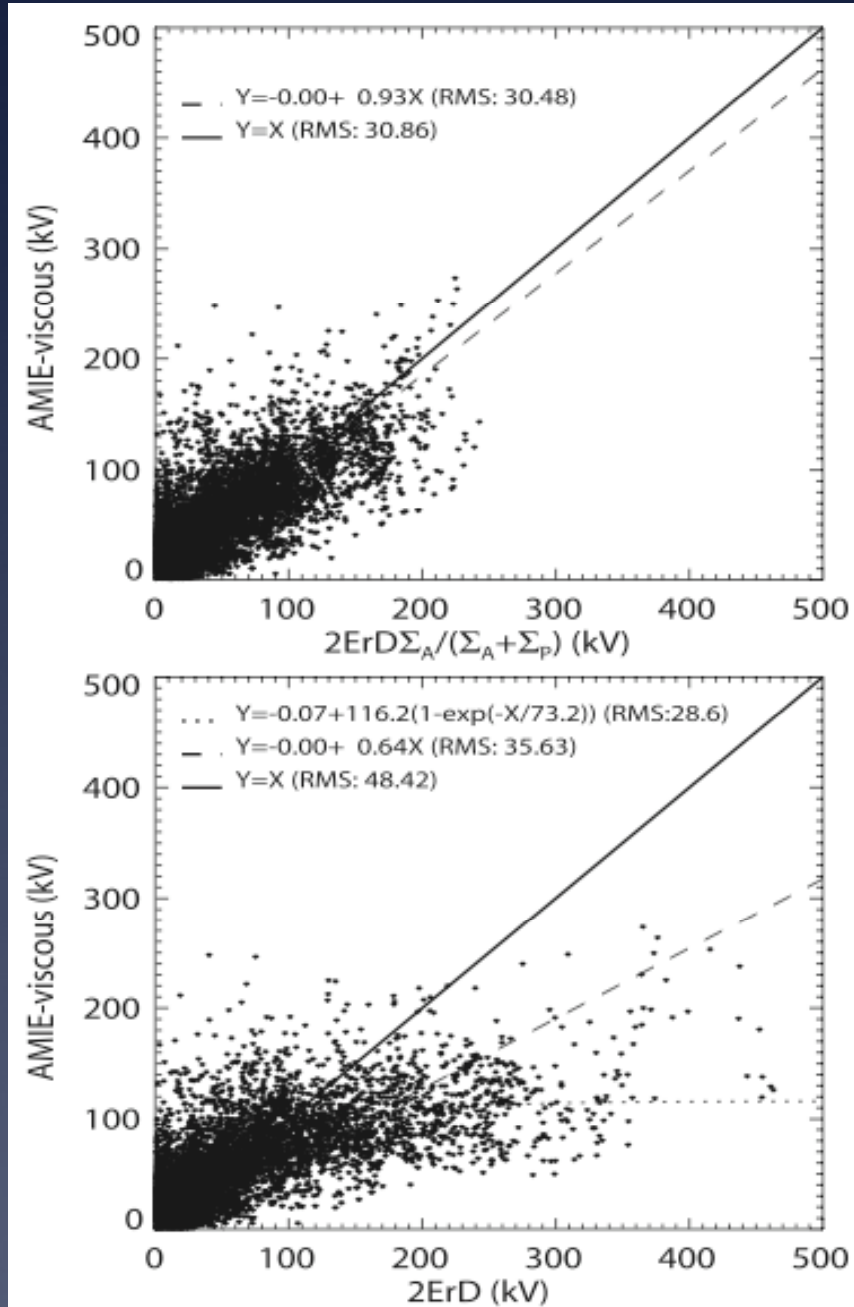
Science

Khazanov et al., AG



Science

Kivelson and Ridley, JGR



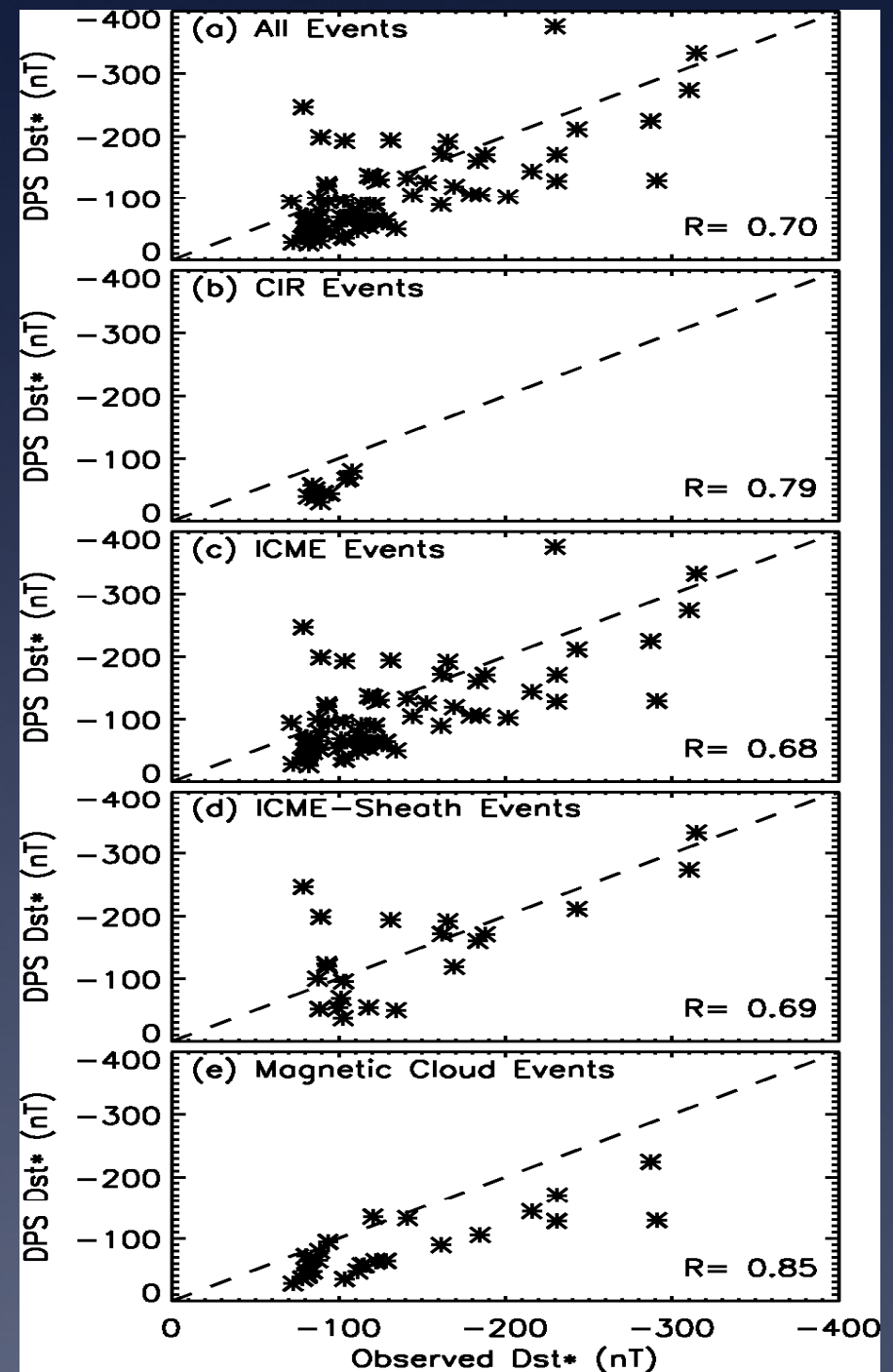


Other Efforts

- * Mike Liemohn has run 90 storms using HEIDI.
 - * Run first with simple electric field model (Volland-Stern)
 - * Get some physics out of these simulations and learn a lot
 - * Run with model complex electric field models to determine, statistically, what effect the effect the E-field has on the results
 - * Can then run with more complicated magnetic field and see what effect this has on the results
 - * Idea is to be quite methodical and do statistics

Example

- * Break down all events into what type of driver controlled them
- * Look for systematic errors
- * Magnetic clouds are almost always under estimated
- * Sheath Events are better modeled





Other Efforts

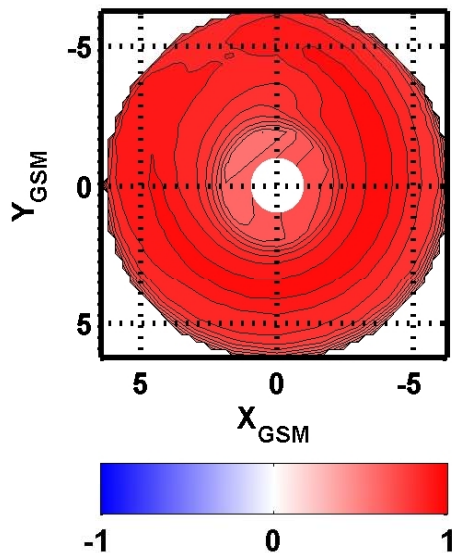
- * Paul O'Brien and Timothy Guild want predict things
- * Utilize Principle Component Analysis to do this
- * From my understanding, this PCA determines how patterns react to given inputs
- * With enough data, you can more completely determine how the ionospheric potential or ring current or radiation belt is controlled by inputs, like IMF, solar wind density, etc.



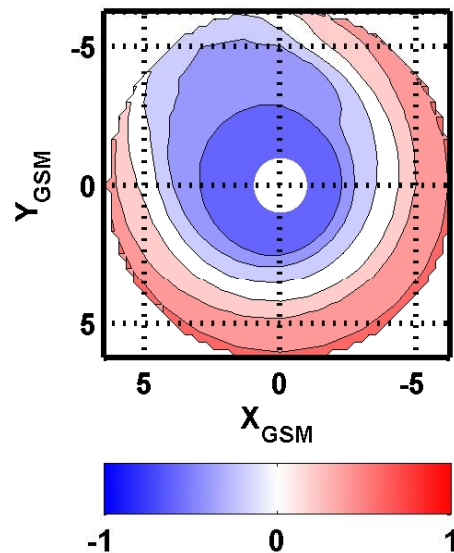
PCA of the HEIDI ring current simulation

- * First 3 principal components of the H⁺ perpendicular pressure from the HEIDI model (formerly known as the Michigan RAM model) shown next.
 - * Static dipole field, shielded Volland-Stern electric field driven by K_p, nightside boundary provided by LANL MPA observations.
- * PCs computed from only the large 6-12-2005 storm ($Dst_{min} = -105$ nT), classified as a magnetic cloud event.
- * Top row are the 1st, 2nd, and 3rd principal components.
 - * Spatial patterns of the “normal modes of variation”.
- * Bottom row shows the time-series of the model projected into these three principal components in blue – response compared to Dst and ASYM-H (black).
- * PC#1 contains 76% of the model variance throughout this storm, PC#2 contains 15%, PC#3 contains 3%.

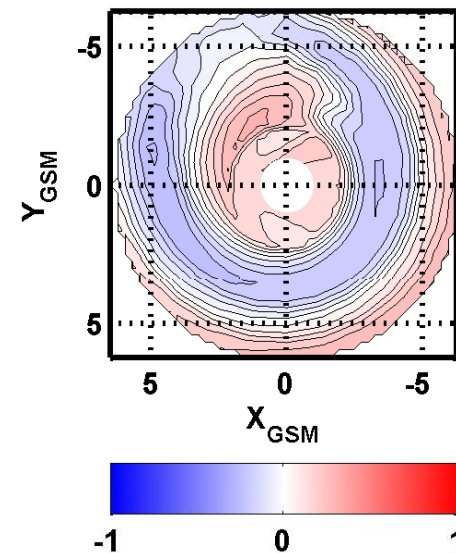
PC 1, 75.5%



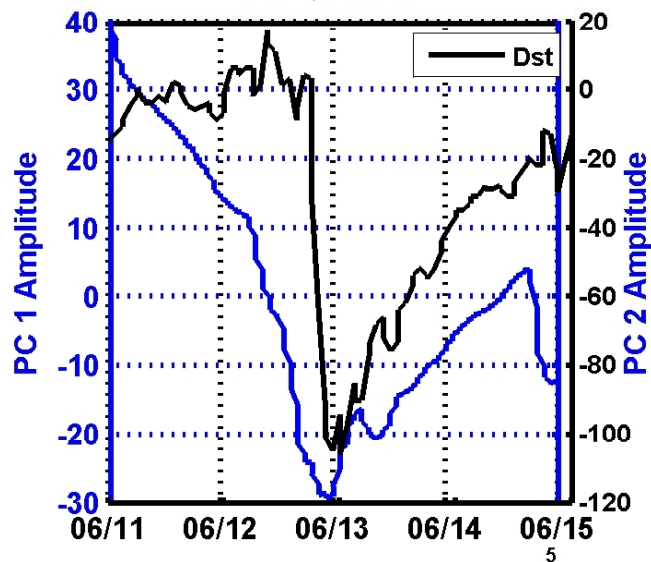
PC 2, 14.8%



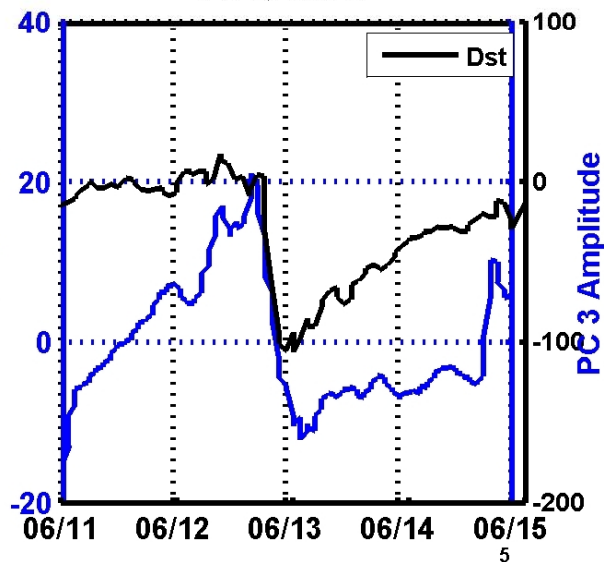
PC 3, 2.7%



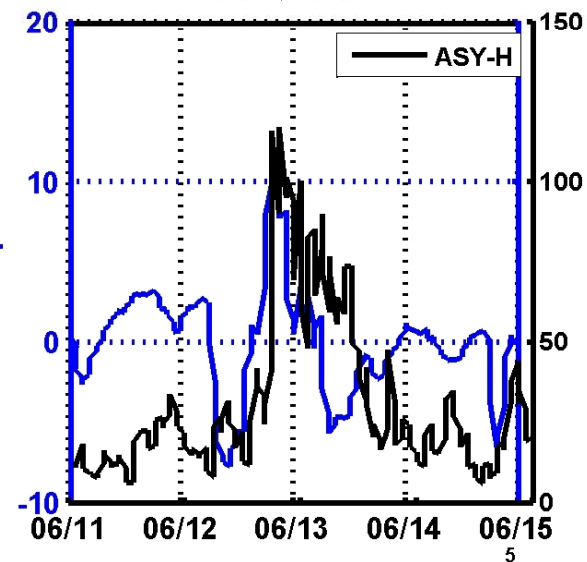
PC 1, 75.5%



PC 2, 14.8%



PC 3, 2.7%



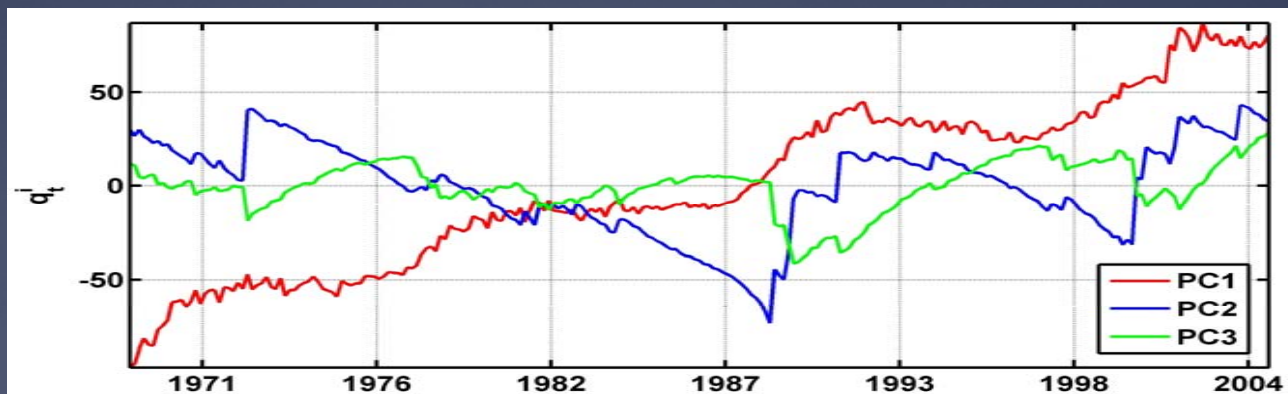
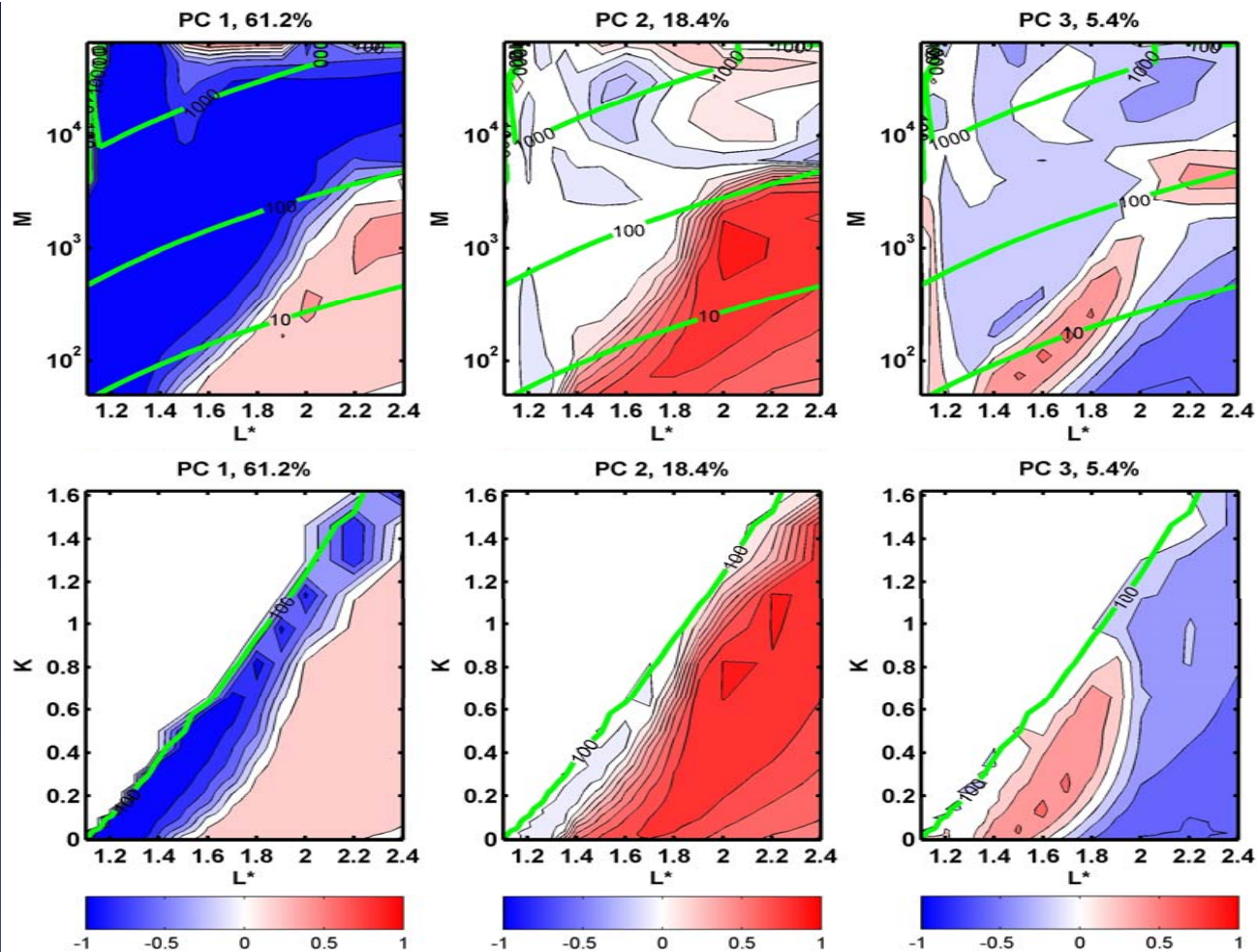


PCA of the Selesnick et al., Inner Zone Model (SI_ZM)

- * First 3 principal components of the SI_ZM model trapped proton intensity shown next.
 - * Time-dependent physics-based model computes the proton intensity of trapped protons as a function of time and the three adiabatic invariants (M, K, and L) from ~10 MeV to ~4 GeV and from $1.1 < L < 2.4$.
 - * Sources: CRAND, solar protons, radial diffusion
 - * Losses: ionization energy loss, free electron energy loss, adiabatic energy change, radial diffusion
- * Calculate PC from SI_ZM inner belt simulation from 1969-2005.
- * PC#1 contains 61% of the model variance throughout this interval, PC#2 contains 18%, PC#3 contains 5%.



- PC maps vs L^* and M ($\sim$ energy)
- Green contours in energy (MeV)
- PC maps vs K ($\sim$ bounce distance along field line) and L^*
- Green contour of 100 km altitude.
- Project model intensities into the first 3 PCs
- PC1 has a solar-cycle modulation.
- PC2 impulsive, coincident with SPEs
- PC3?



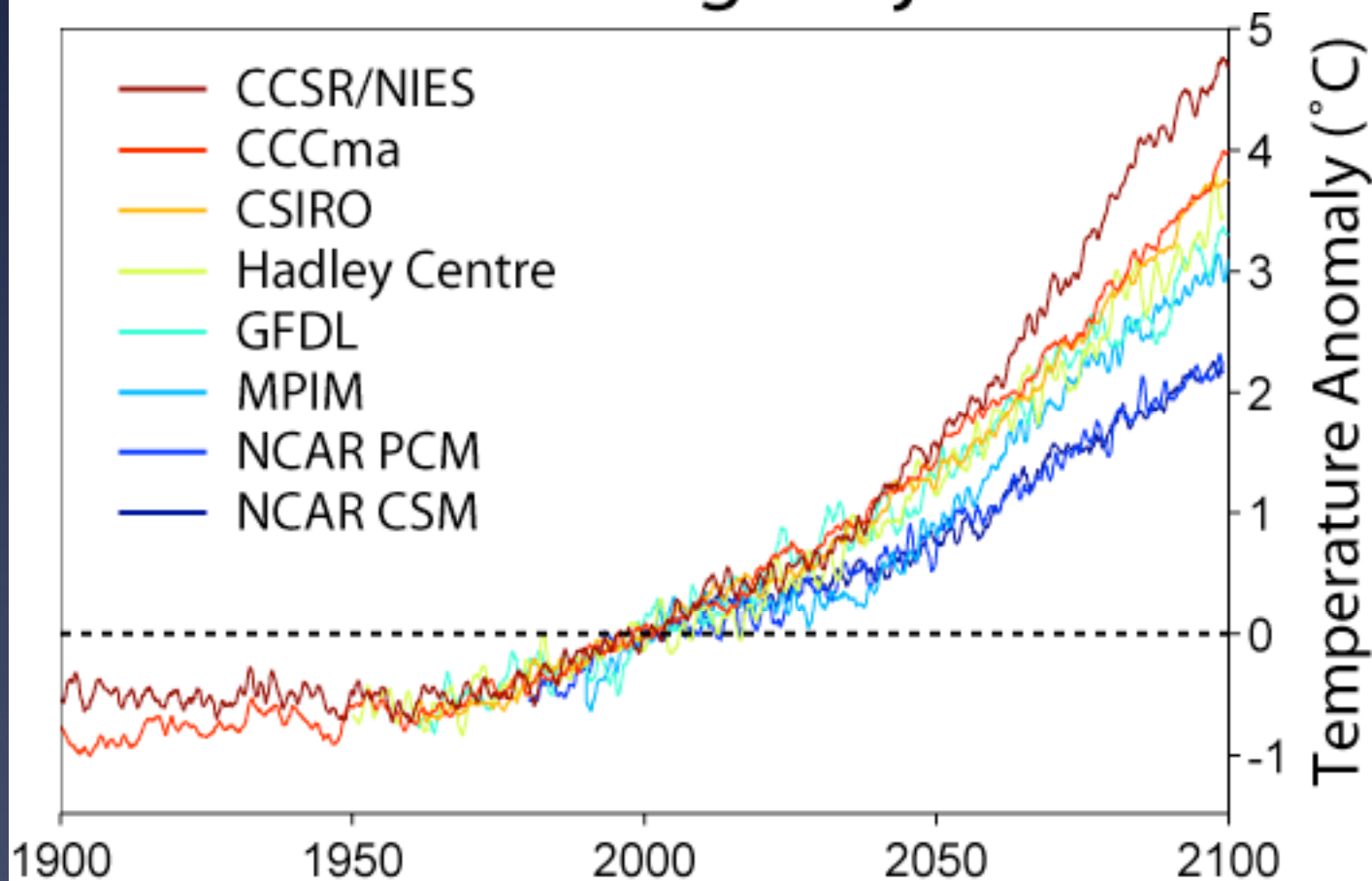


Climate Modeling

- * Climate modelers do this type of reanalysis all of the time.
- * They plan the runs for years. Figure out what physics they need to include for the latest, greatest simulations.
- * Test and test and test.
- * Then prepare data for previous climatology to be used in data assimilation.
- * Run models from 50 years in the past to 100 years into the future.
 - * Takes hundreds of thousands of CPU hours.
- * All public sees is...

All that work...

Global Warming Projections





Summary

- * AMIE is a powerful data assimilation tool to examine the ionospheric electrodynamics.
- * AMIE used to be quite painful to run. But now it is “easy”.
 - * So easy, you can run in real time with scripts.
- * AMIE was run for 1990-2006 at a 1-minute time cadence
 - * About 9 Million patterns for Northern Hemisphere only!
 - * Utilized ground-based magnetometers
- * This data has been used to do science!
 - * Can do individual event studies
 - * Can do statistical studies
- * These types of projects really can enable a huge range of science to be conducted!



Questions?