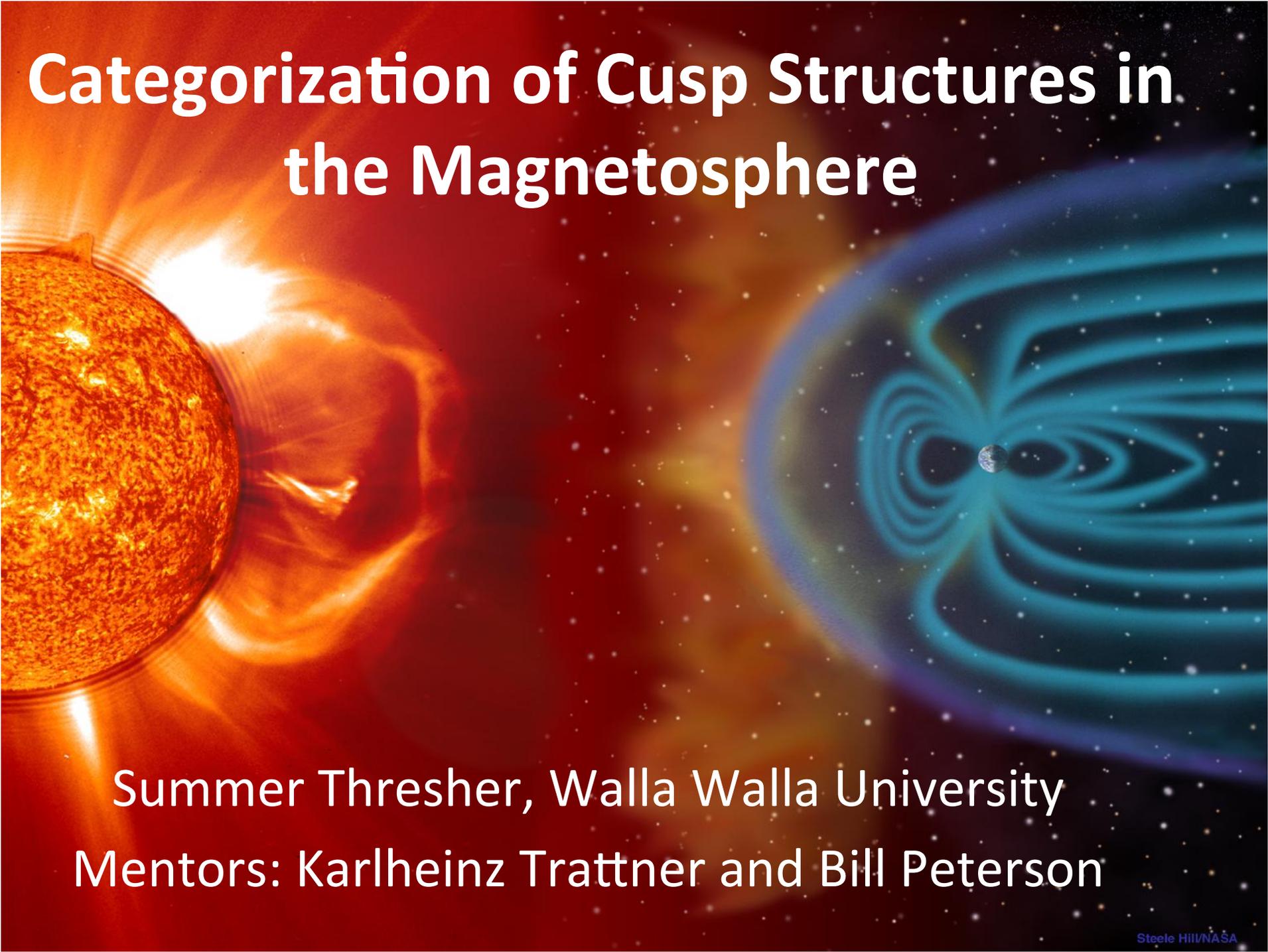


Categorization of Cusp Structures in the Magnetosphere



Summer Thresher, Walla Walla University
Mentors: Karlheinz Trattner and Bill Peterson

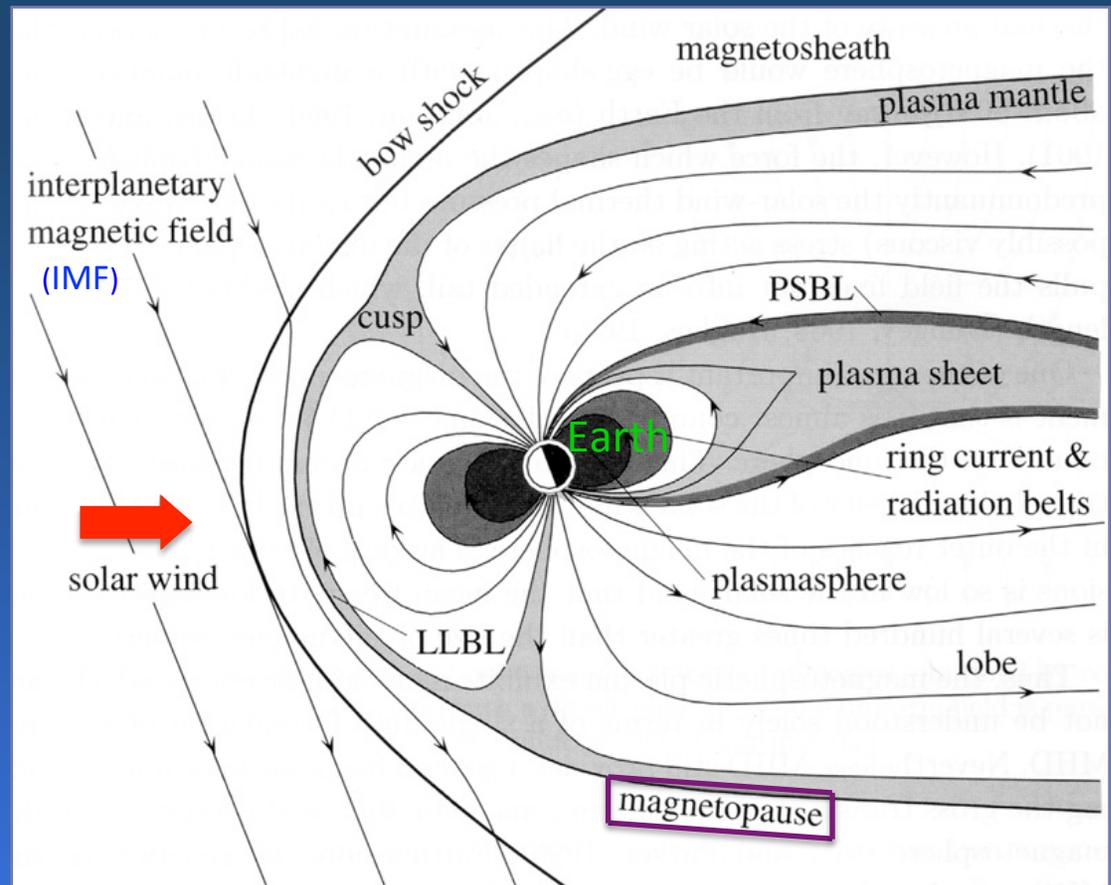
What is the Magnetopause?

Regions Magnetosphere

- Plasma Sheet
- Radiation Belts
- LLBL: Low Latitude Boundary Layer
- Cusp – Focus of magnetopause magnetic field lines
- Bow shock
- Solar Wind and IMF

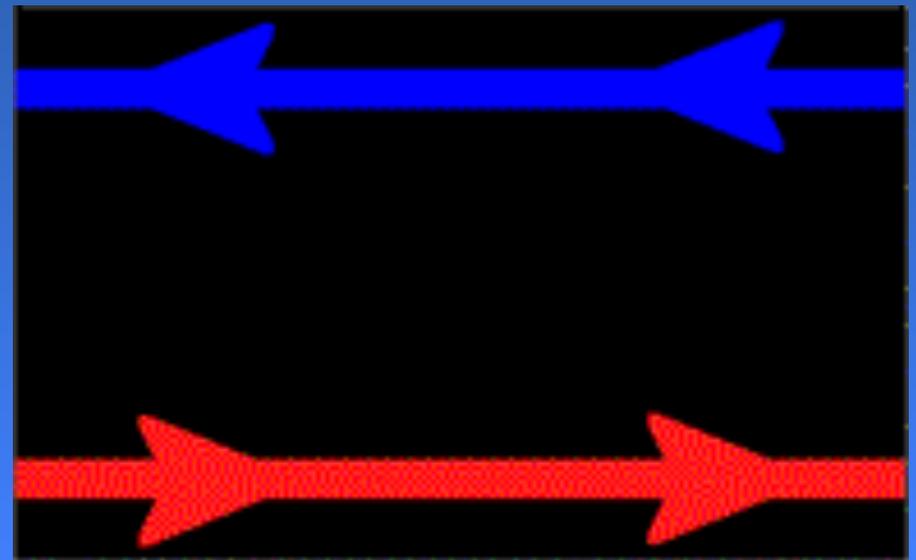
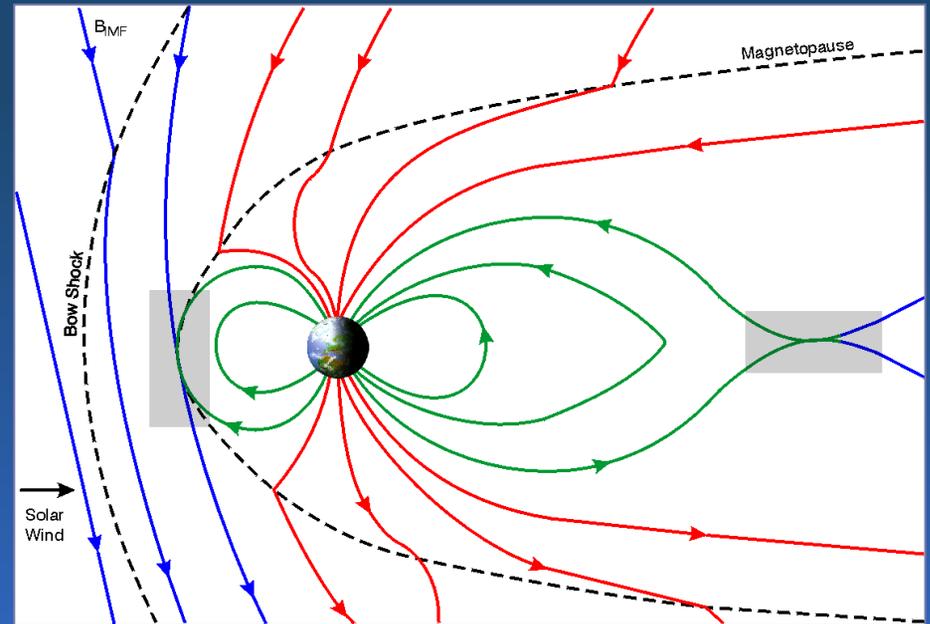
Magnetopause: the boundary between the solar wind and the geomagnetic field.

- Equilibrium surface between two regimes. The inside dominated by the Earth's magnetic field, the outside by solar wind plasma and magnetic field pressure.

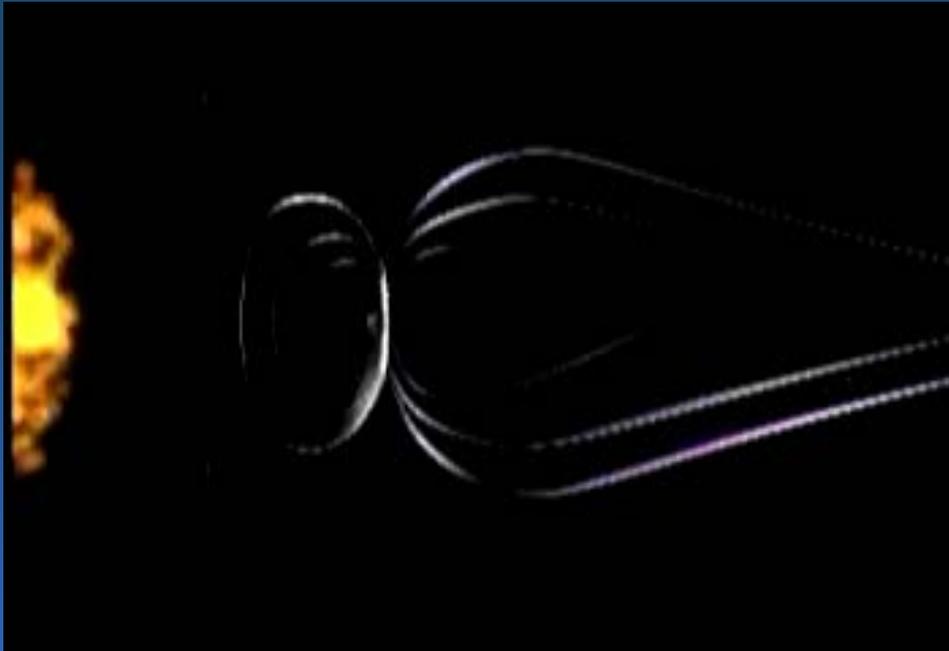


Magnetic Reconnection

- The interplanetary magnetic field (IMF) merges with the geomagnetic field lines at the magnetopause.
- This allows solar wind plasma into the Earth's magnetosphere, streaming into the cusps.
- Reconnection on the Dayside opens the magnetic field lines
- Reconnection on the nightside closes the field lines, injecting the ions and electrons into the ionosphere, creating the aurora.

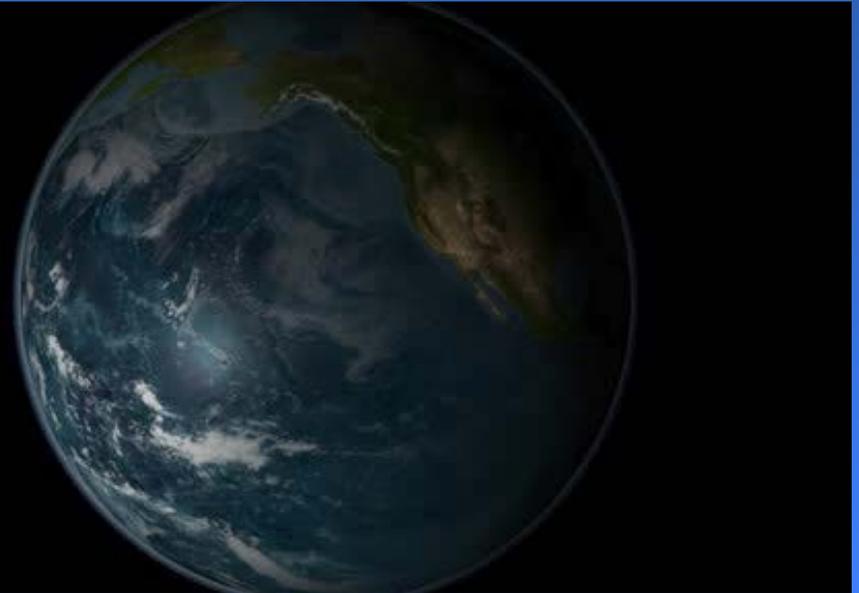


The Aurora



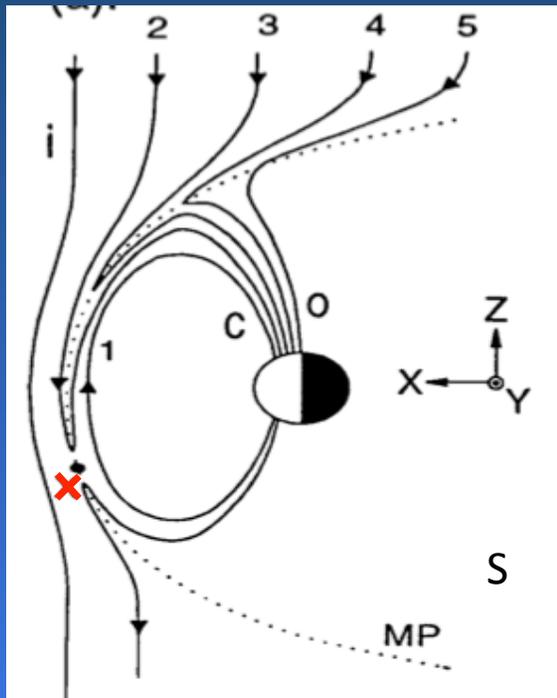
- IMF opens field lines
- Convected into the magnetic tail
- Nightside reconnection line (closes the field line)
- Field line retracts, plasma flows into the ionosphere
- Aurora created

- Coordinated campaign THEMIS satellites and All Sky Cameras
- Direct result of reconnection
- Dynamics of aurora indicate how dynamic reconnection is

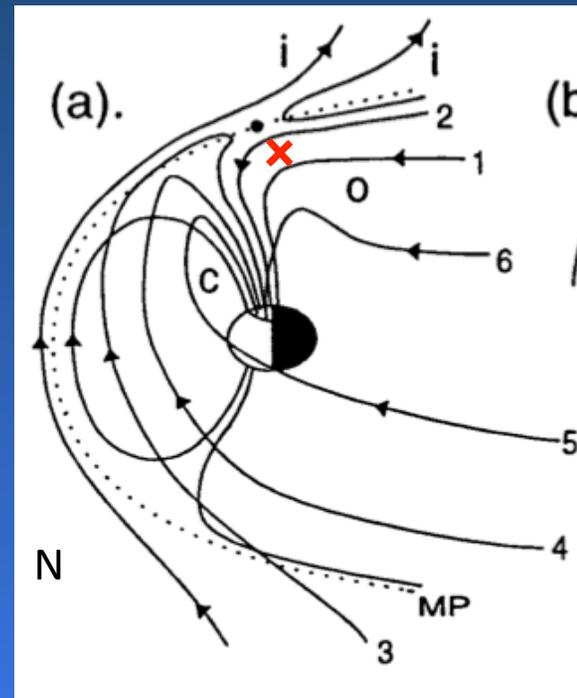


Reconnection Location

- Reconnection has been observed in two primary regions.
- Location is determined by the direction of the IMF



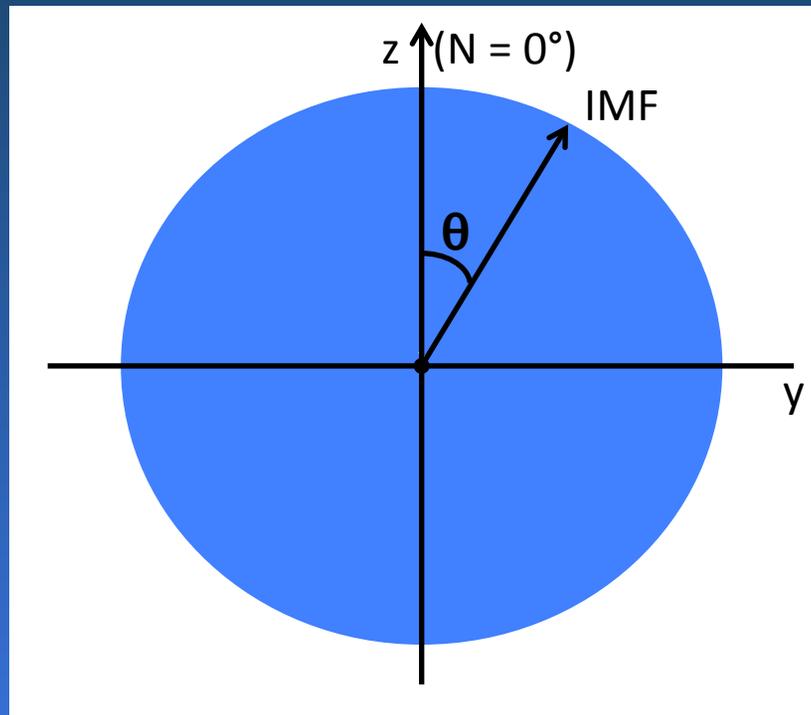
Southward IMF: Dayside - equatorial
IMF moves with the Solar Wind



Northward IMF: Poleward of the Cusp.
IMF moves against Solar Wind

IMF Clock Angle

The angle of the IMF in a coordinate system aligned to the dipole field of the Earth.



Importance:

- Parameter that organizes the information best, will be used for later tasks

Task I

Objectives:

- Use data from POLAR satellite, from March 1996 to December 1998.
- Categorize and organize cusp crossing data for specific cusp signatures and structures
- Combine cusp structures with solar wind data from the WIND spacecraft
- Locate any trends in the data and explain different features of reconnection

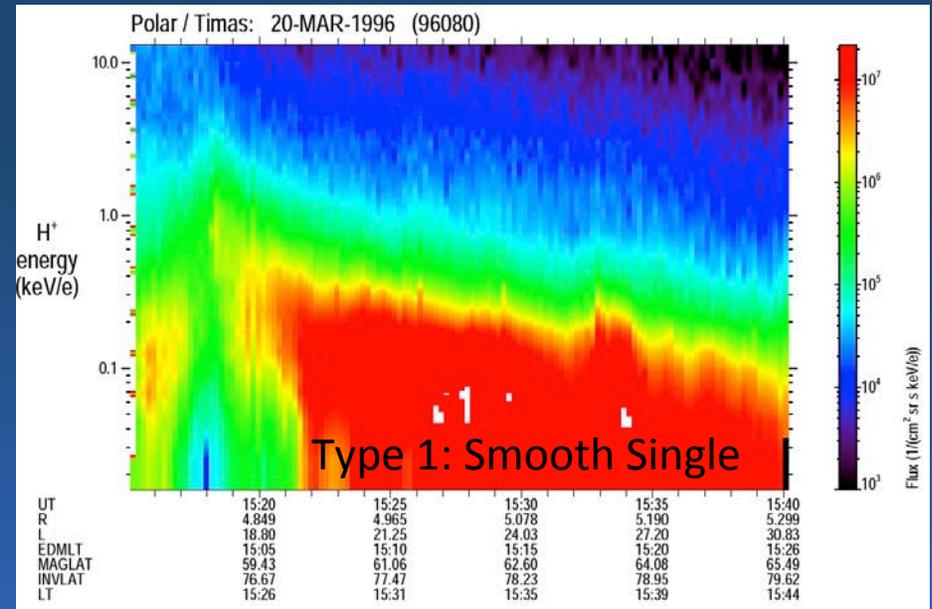
Task I

Types 1 & 2:

- Caused by Southward IMF
- Reconnection occurs on the Dayside
- Fast ions arrive first, slow ions later

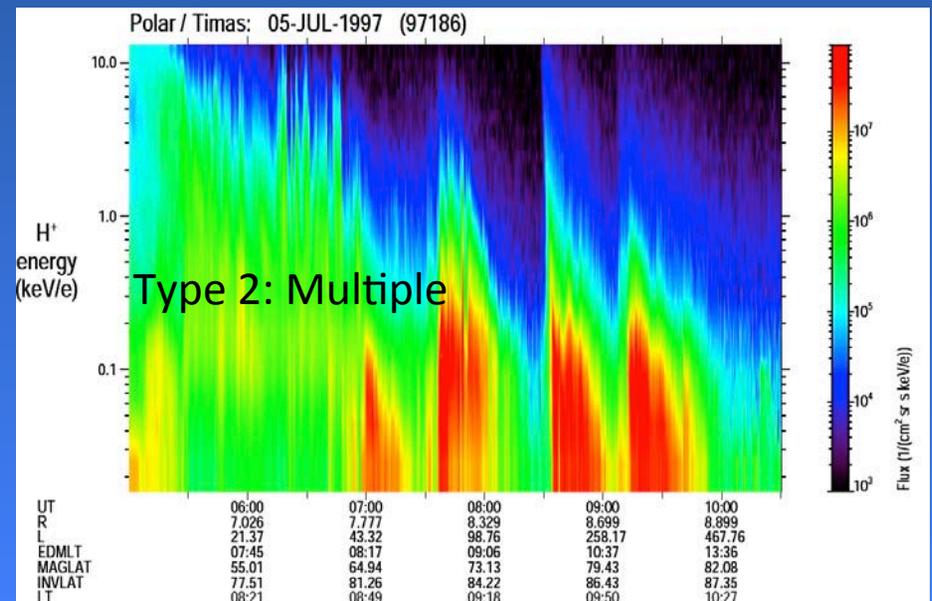
Criteria for Type 1: Single Smooth

- Smooth structure, no jagged peaks
- No more than one dispersion per plot



Criteria for Type 2: Multiple

- Contains the same smooth dispersion as Type 1
- Multiple dispersions per plot
- Dispersions separated by distinct spatial gap



Task I

Type 4:

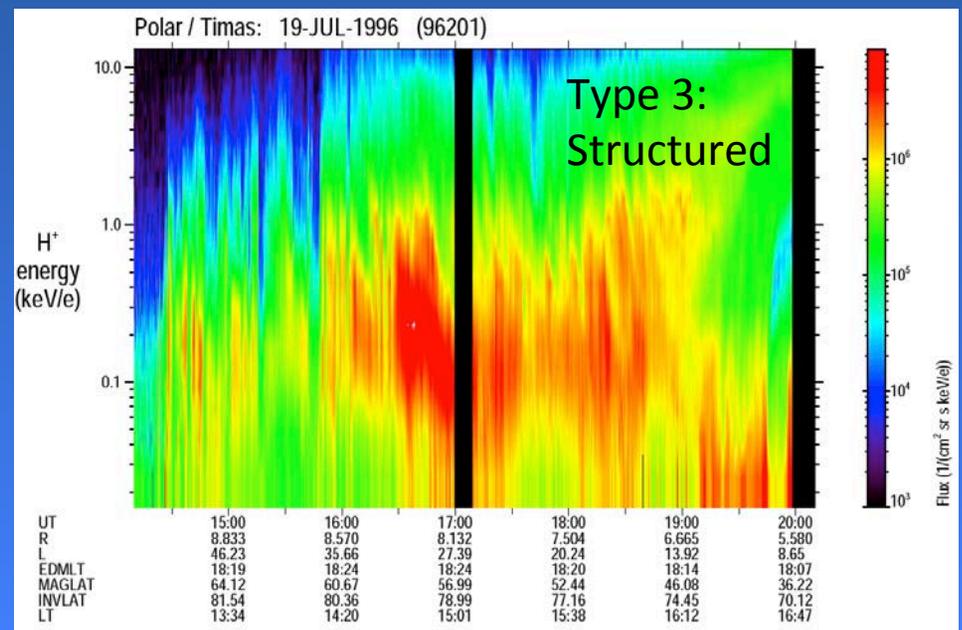
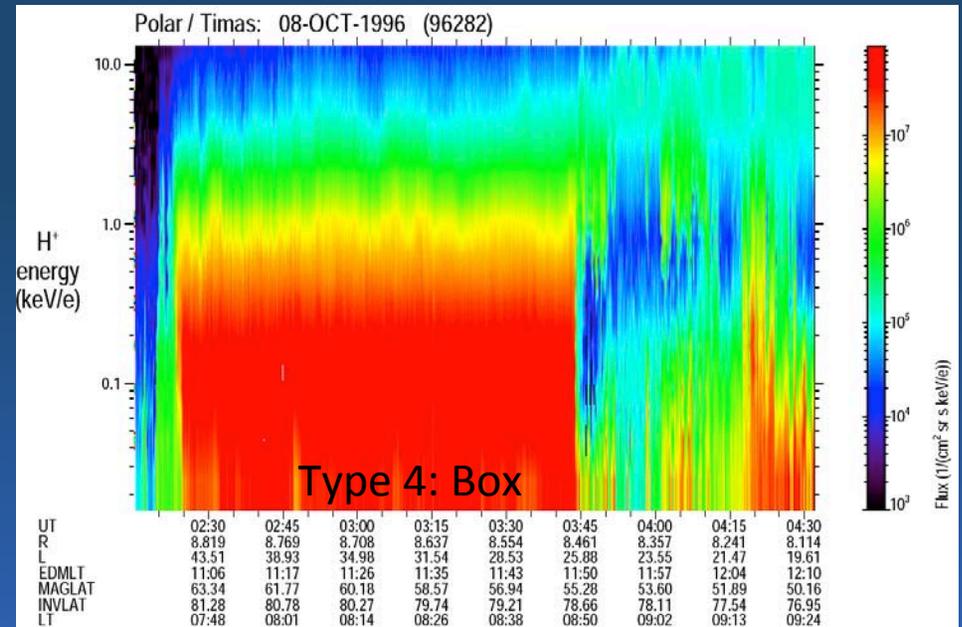
- Caused by Northward IMF
- Reconnection occurs poleward of the cusps
- Ions of all energies allowed, all are slowed to approximately same velocity

Criteria for Type 4: Box

- Flat top
- Straight sides

Criteria for Type 3: Structured

- “None of the above”
- Does not meet criteria for Types 1, 2 or 4.
- Can include pulsating reconnection lines, or characteristics of the others



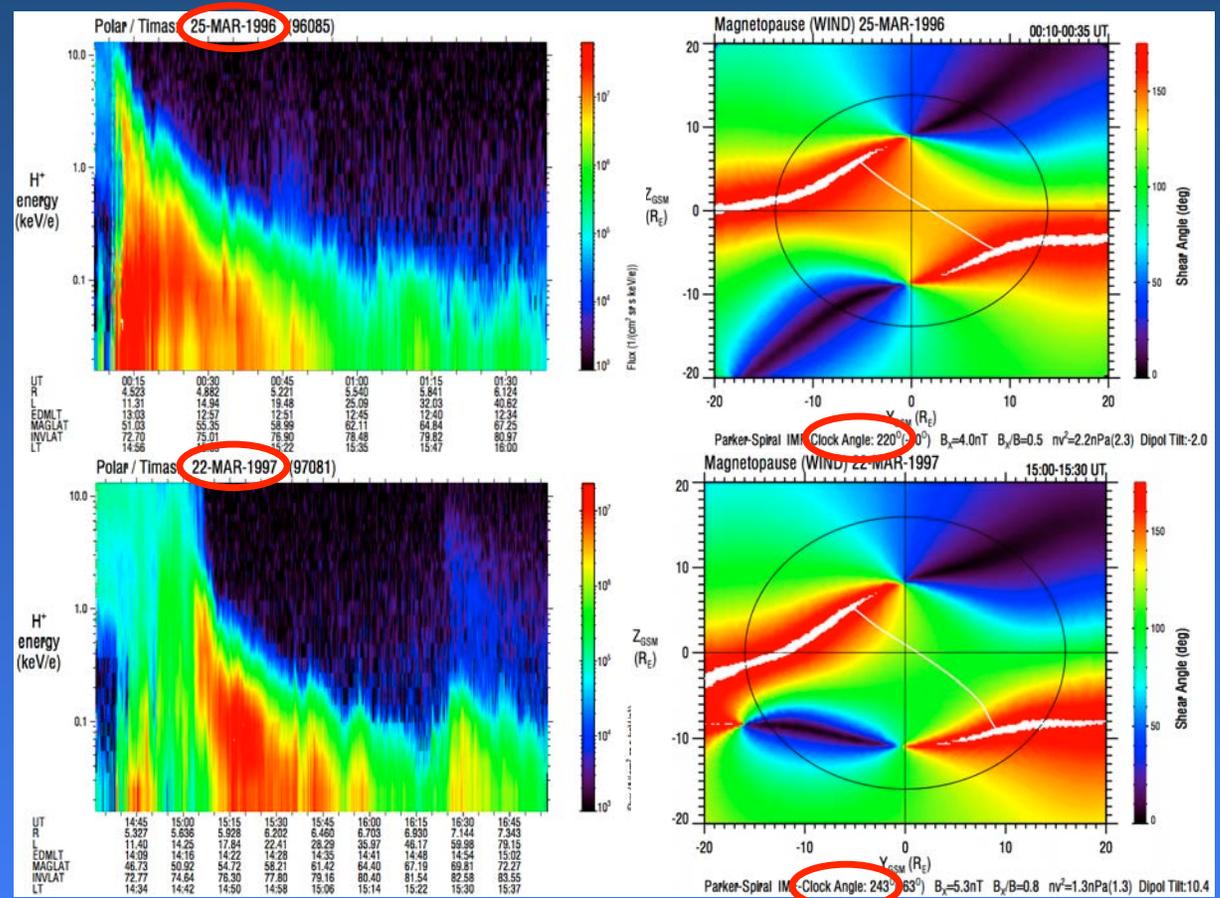
Task I

Errors and Difficulties

- Categorization subject to interpretation.
- Vast quantity of plots and information.

Results

- “Smooth Single” dispersions consistently possess clock angles between 220° and 270°
- Same dispersions also tend to occur around the Spring equinox (March 20th) of each year. WHY?!



Task II

Objectives:

- Use a selected list of MP Shear Angle Plots from WIND satellite (3/1996 – 12/1998)
- Clock angles between 55° and 95° , 265° and 305° : transition from S to N field
- Remove plots with $|B_x/B| > 0.7$
- Find the transition region when the Southward dispersion becomes the Northward box

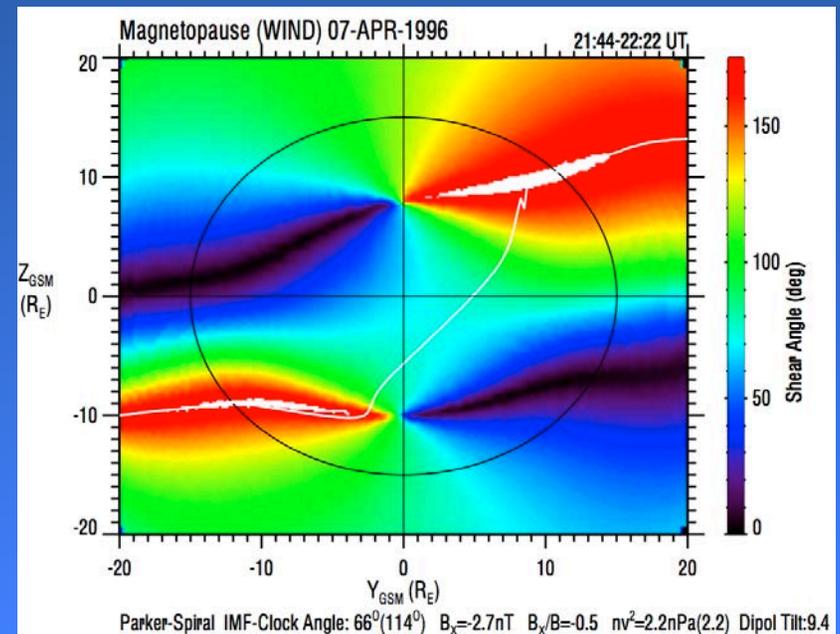
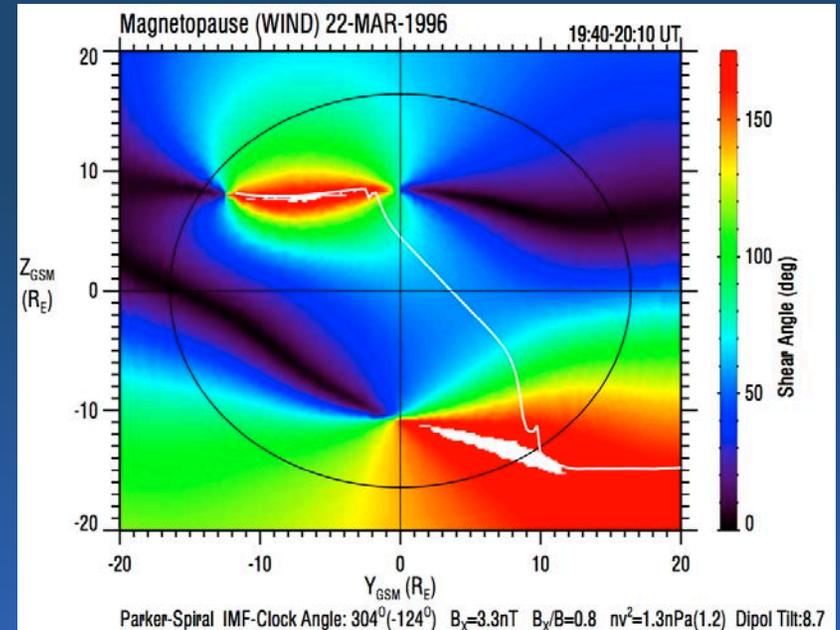
Task II

Plot Details:

- Northward shear angle plots
- IMF draped over the geomagnetic field, so you can see the angle between the field lines
- Clock angles between 55° and 95° , 265° and 305°
- Know South \rightarrow Dispersion, North \rightarrow Box
- Test tipping point as IMF moves from South to North

In the location model, B_x/B values greater than 0.7 become messy. Remove them by separating plots into two separate categories:

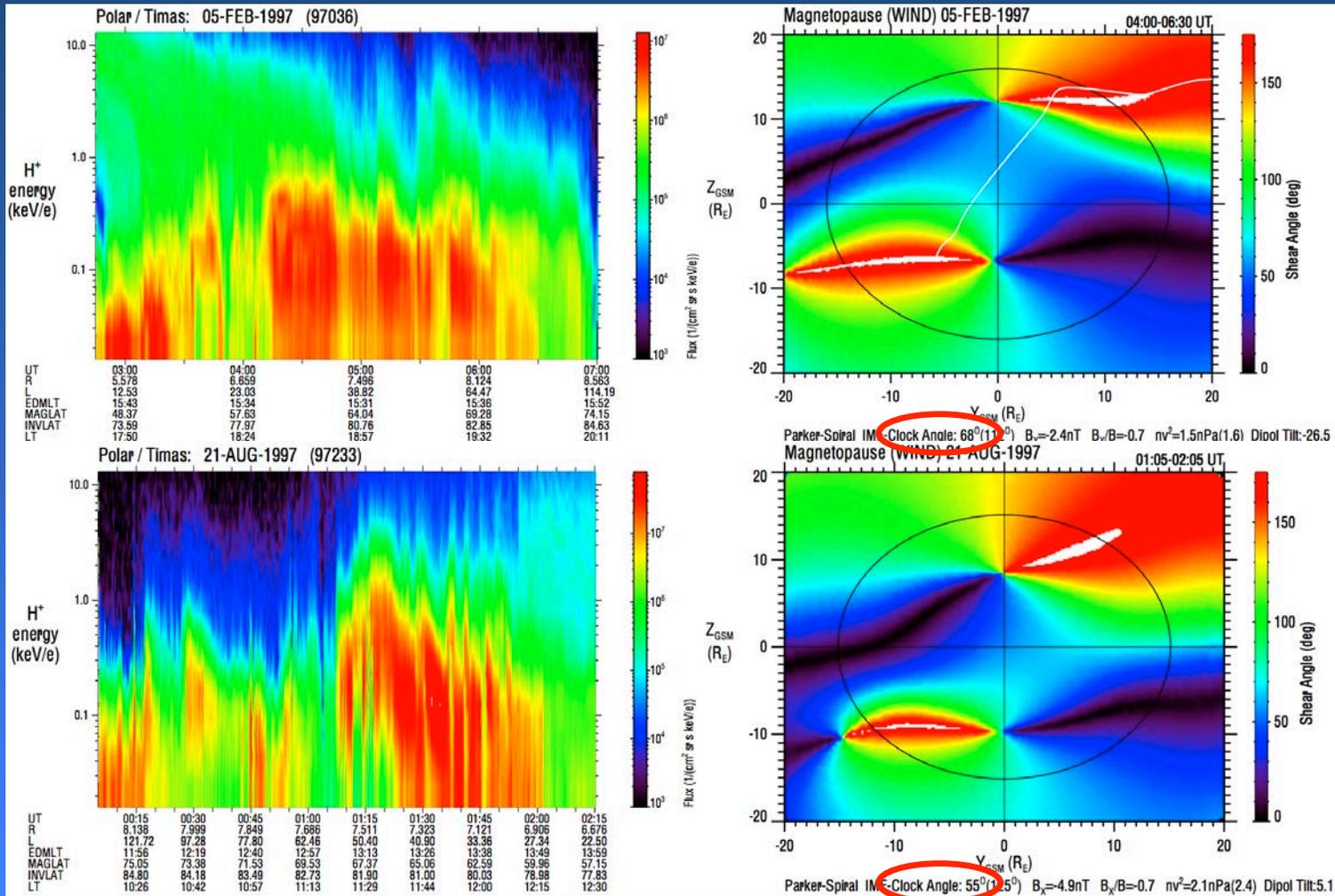
- Events $|B_x/B| \leq 0.7$
- Large IMF $|B_x/B| > 0.7$



Task II

Result:

Many of the plots with Northern IMF angles possessed characteristics of dayside reconnection (S) not poleward (N). No clear range where the transition occurs from Smooth to Box.



Task III

Objectives:

- Use POLAR color spectrograms (Task I plots) divided into 10 minute segments
- Locate plots with any high flux “overlap” – indicates multiple reconnection lines
- Combine plots with solar wind data to determine any trends

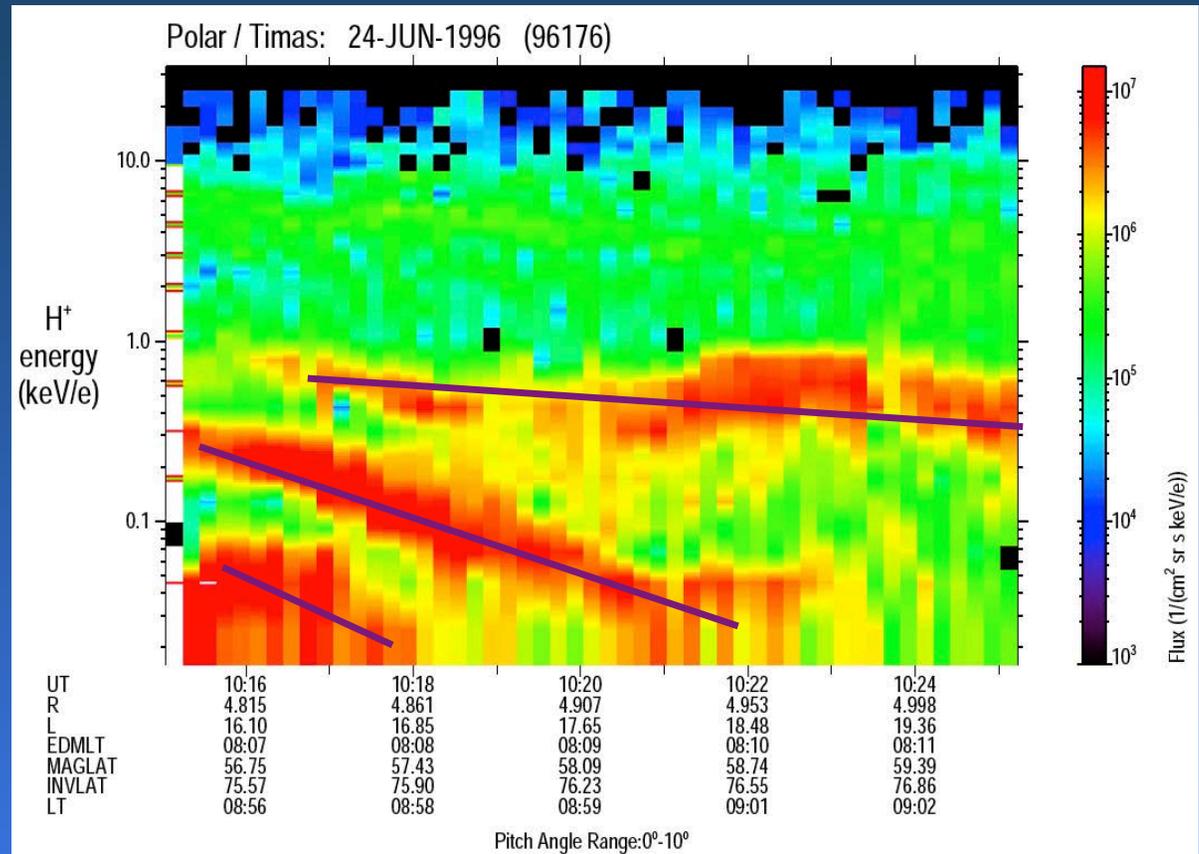
Task III

“Overlap Criteria”

- Red areas (high flux) horizontally overlap other areas of red
- “Cords” of flux form distinct lines – do not cross each other
- Different entry points of plasma along the MP

Results and Future Work:

- Approximately 9.8% of the 10-minute plots contain overlap, or 24.5% of the total events – lower than expected.
- Calculate entry points and see how they line up



Task IV

Objectives:

- Use data sets from Double Star satellites, which crossed the MP at a reconnection lines
- Using IDL program, created by my mentor, generate plots for ACE and WIND satellites.
- Compare prediction models with the actual observed locations of reconnection.

```

Terminal — ssh — 82x28
Last login: Wed Jul 23 16:47:18 on ttys000
[macd79:~] suth6004% ssh -Y suth6004@willow
suth6004@willow's password:
Warning: No xauth data; using fake authentication data for X11 forwarding.
Last login: Wed Jul 23 2014 15:05:40 -0700 from macd79.lasp.color
Sun Microsystems Inc. SunOS 5.9 Generic May 2002
No mail.
Sun Microsystems Inc. SunOS 5.9 Generic May 2002
tcsh: using dumb terminal settings.
Willow %scplot
/spg/kjt/student/UNIX/mission/sciplot/idl_program
Willow %idl
IDL Version 7.1.1, Solaris (sunos sparc m64). (c) 2009, ITT Visual Information Sol
utions
Installation number: 100-550.
Licensed for use by: University of Colorado

IDL> science_plot
% Compiled module: SCIENCE_PLOT.
SOFTWARE DIRECTORY: /spg/kjt/student/UNIX/mission/sciplot
EXPERIMENT SETUP FILE DIRECTORY: /spg/kjt/student/UNIX/mission/sciplot/exp_files
% X windows protocol error: BadWindow (invalid Window parameter).
% X windows protocol error: BadWindow (invalid Window parameter).
% X windows protocol error: BadWindow (invalid Window parameter).
% Compiled module: CW_BGROUP.
% Compiled module: XMANAGER.

```

The Science Plots window shows a menu with 'Load Exp.' highlighted in yellow. Below it, the 'Load Experiment' dialog box is open, with 'untitled' in the 'Select Experiment File' field and a 'Browse' button.

The 'Please Select a File for Reading' dialog shows a directory path: /spg/kjt/student/UNIX/mission/sciplot/exp_files/. The file list includes wind_mp_shear_angle2.exp, wind_sw.exp, wind_sw_convected.exp, wind_sw_convected_bs.exp, wind_sw_convected_bs2.exp, and wind_sw_convected_sp.exp. The file 'wind_sw_convected_sp.exp' is highlighted in yellow.

The Science Plots window menu is shown again, with 'Input Date' highlighted in yellow.

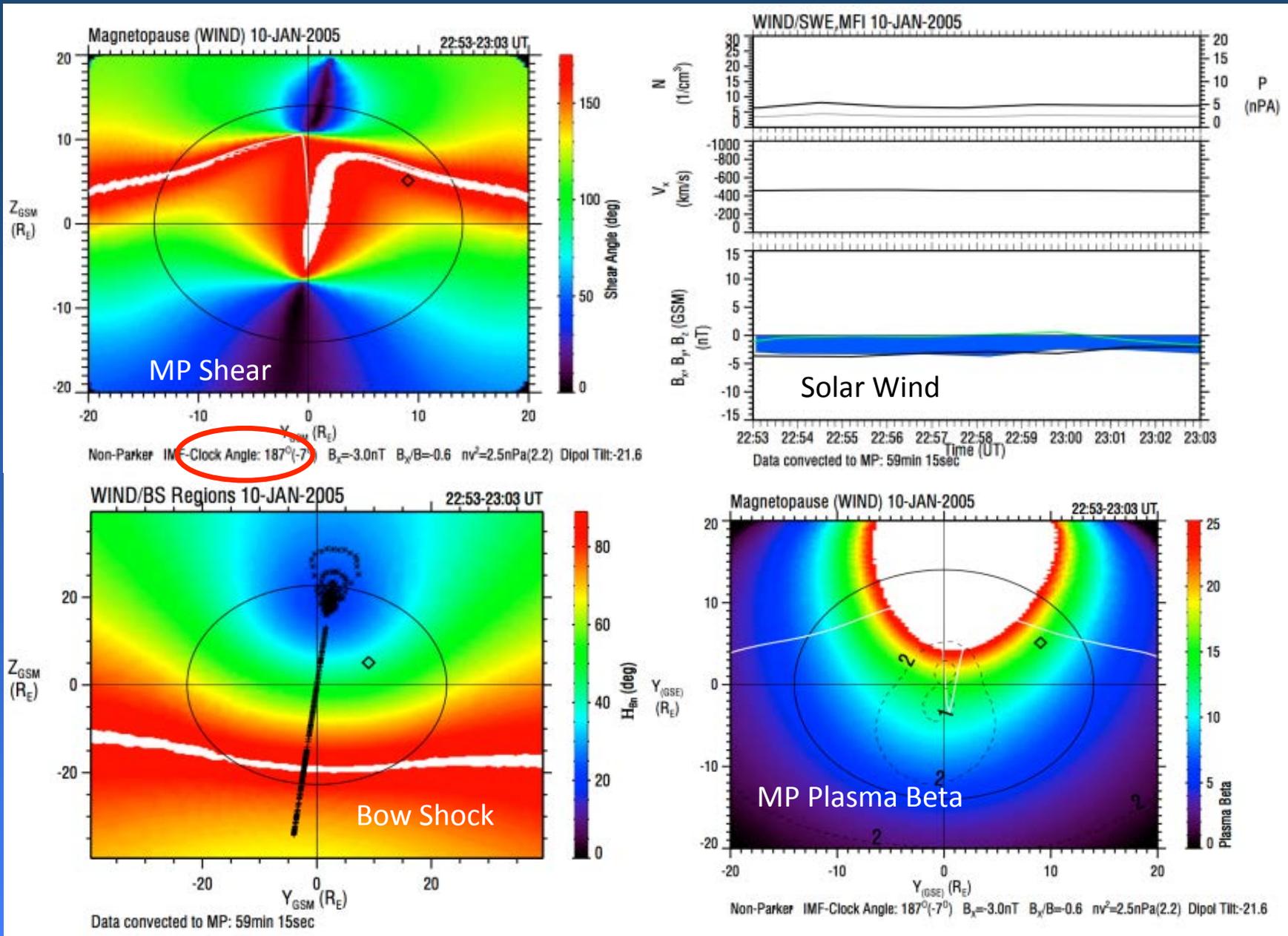
The 'Input Window' dialog is open, showing start and stop time settings. The start time is Year: 2004, Month: 4, Day: 03, Hour: 10, Minutes: 4, 2. The stop time is Year: 2004, Month: 4, Day: 03, Hour: 10, Minutes: 5, 2. There are 'Use Date to search Files' and 'Remember Input Date' checkboxes.

The 'Layout' dialog is open, showing plot type 'Color Spectrogram', values divided by 1.00000, and satellite position settings: X: -3.32, Y: -1.89. There are buttons for 'Write/Add to List', 'Write Shear Line', and 'Copy Values'.

Input data from both files, "33" and "110" as shown below.

Day	Time_Jet	X_GSM	Y_GSM	Z_GSM	NorthSouth
20040225	11634 03:13	9.21	-3.43	-3.32	2
20040226	20081 05:34	8.21	-4.08	-2.86	2
20040304	8014 02:13	7.93	-4.33	-3.93	2
20040307	52407 14:33	9.75	-5.30	-3.34	2
20040308	15470 04:17	10.30	.53	-1.33	2
20040311	56035 15:33	9.33	.46	-1.14	2
20040314	34557 09:35	7.89	-6.51	-3.05	2
20040315	53250 14:47	9.49	-6.28	-3.86	2
20040316	68382 18:59	9.69	-5.55	-5.05	2
20040317	9902 02:45	12.00	-3.27	-3.84	2
20040318	84390 23:36	7.52	-5.54	-5.41	2
20040319	48291 13:24	10.70	-2.17	-2.09	2
20040320	4660 01:17	5.63	-5.57	-4.86	2
20040320	67192 18:39	9.31	-.65	-1.65	2
20040326	35363 09:49	10.38	-3.31	-2.23	2
20040412	1548 00:25	5.61	-8.21	-6.72	2
20040415	39465 10:57	5.17	-10.34	-3.54	2
20040415	04862 23:34	8.29	-4.22	-3.77	2
20040430	54411 15:06	6.35	-10.54	-3.95	1(triangle)
20040430	78059 21:40	6.42	-4.58	-3.22	2

Plots Generated



Alfven Mach Number:

- Based on Alfven velocity – a characteristic velocity in the plasma
- If the solar wind streaming around the MP becomes super-alfvenic reconnection location becomes unstable.
- $MA \# > 1$

Generate and record values.

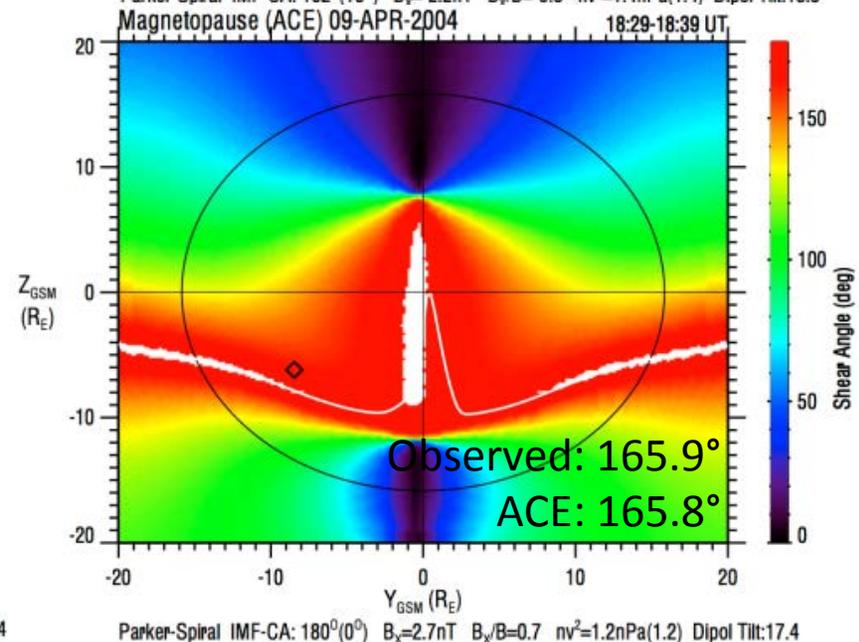
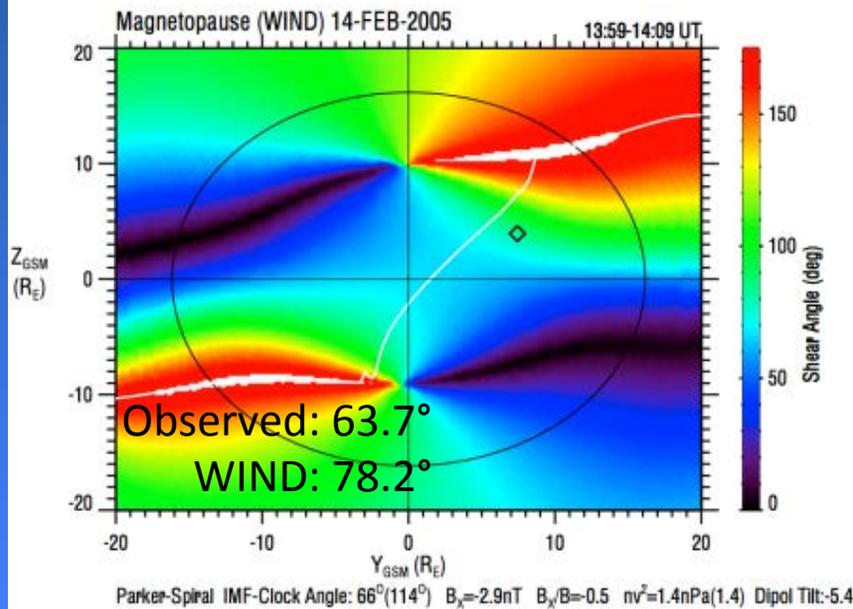
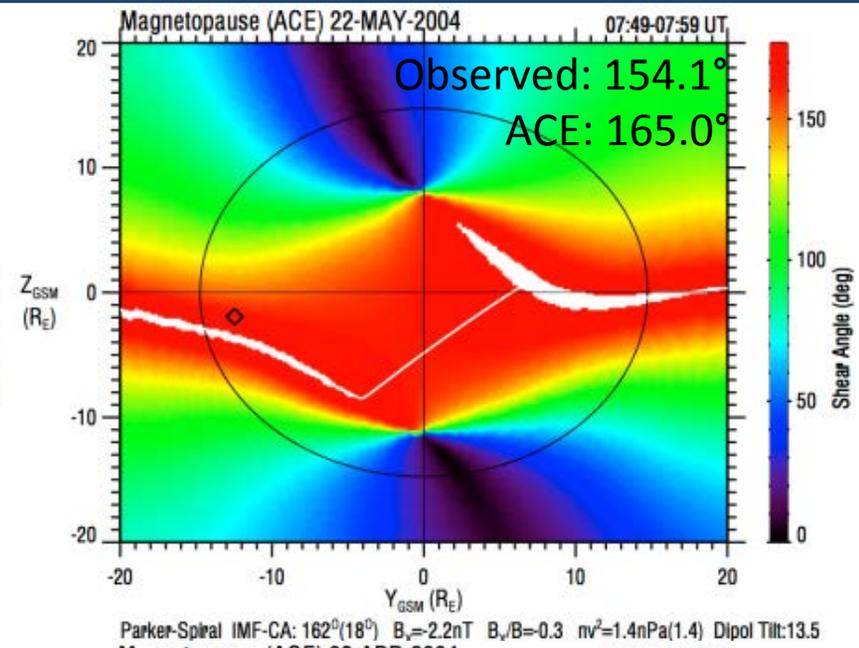
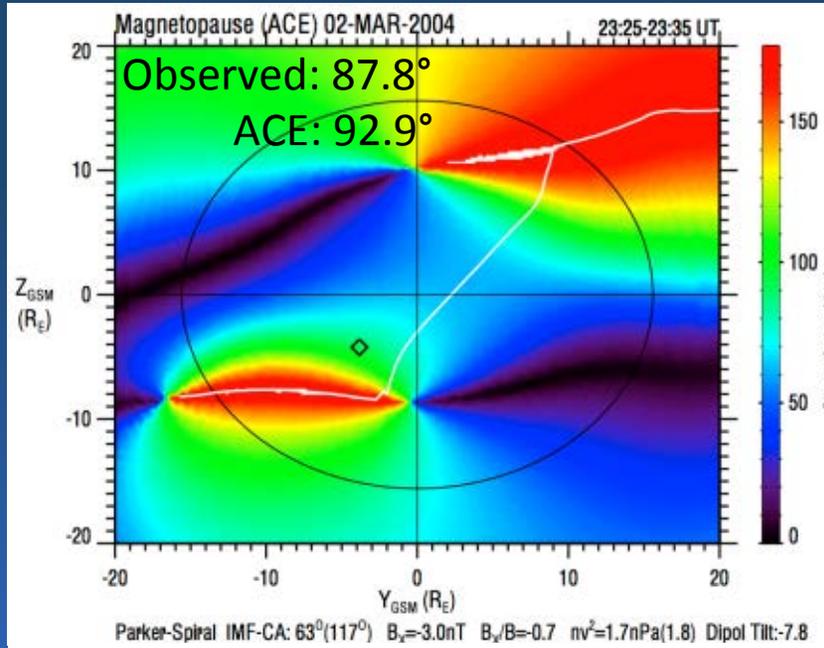
```

Science Plots
-----
Create Exp. Load Exp. Edit Exp. Save Exp.
-----
Input Date Read Data Select Layout Re-Draw Plot/Print Exit
-----
MAP ARRAY: NEW DIMENSIONS      150      300
MAP ARRAY: Original ARRAY      150      150
CONTURE PLOT - OVERLAY - NOTE the map array funktion has been
disabled for this option

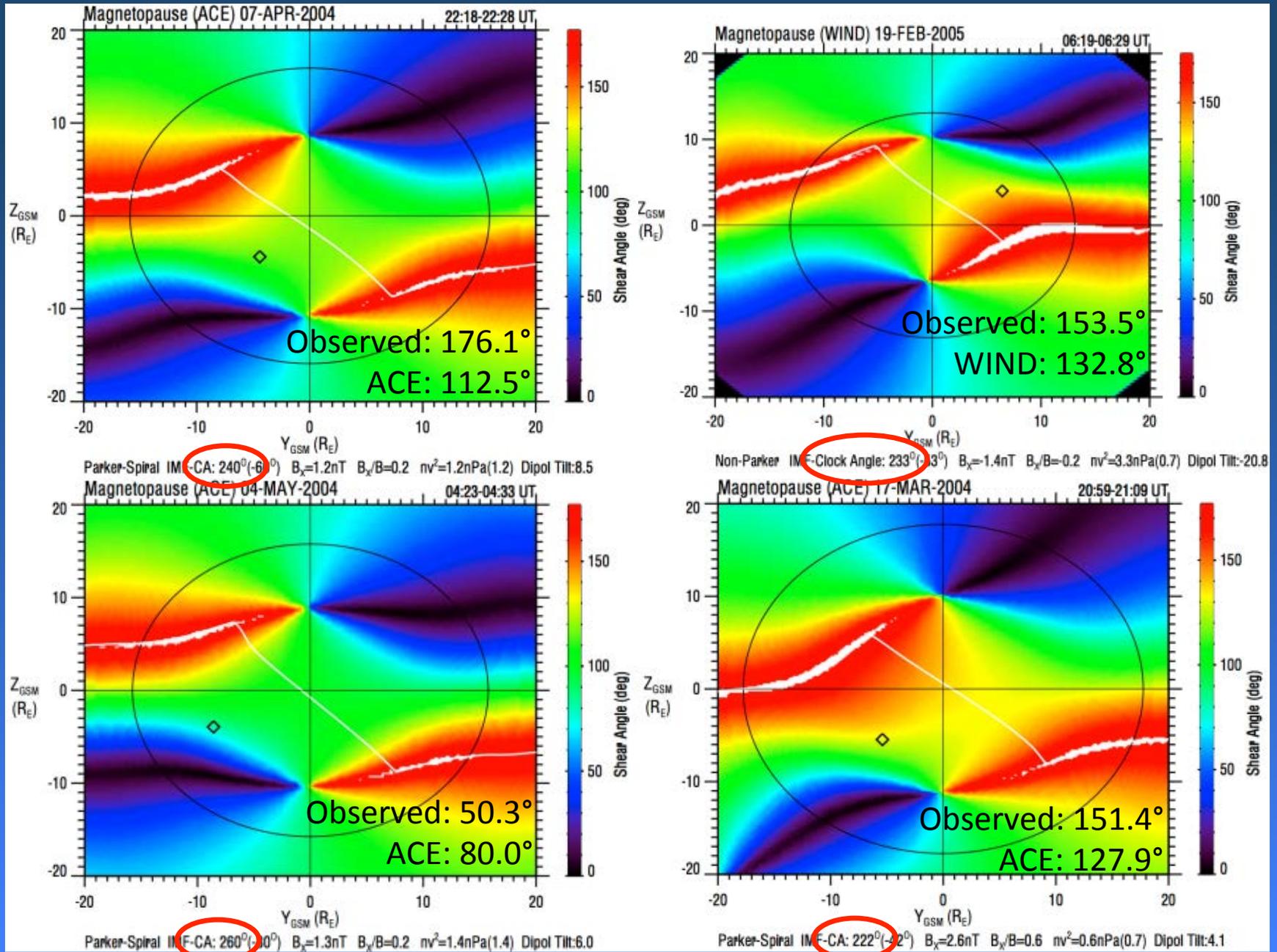
#####
#####
SHEAR ANGLE - PLASMA BETA - ALFVEN MACH NUMBER AT SATELLITE
POSITION
20040403 1042 Shear_angle_at_MP = 43.8
20040403 1042 Beta_at_MP = 1.9
20040403 1042 Alfven_MAch_at_MP = 0.5
    
```

Day	Time_Jet	X_GSM	Y_GSM	Z_GSM	NorthSouth	Shear	ACE Shear	ACE Beta	ACE Mach	WIND Shear	WIND Beta	WIND Mach
20040225	11634 03:13	9.21	-3.43	-3.32	2	142.8337000	134.0	3.6	0.7	-	-	-
20040226	20081 05:34	8.21	-4.08	-2.86	2	106.5435000	-	-	-	-	-	-
20040304	8014 02:13	7.93	-4.33	-3.93	2	59.7847800	94.4	4.9	1.0	85.6	5.2	0.9
20040307	52407 14:33	9.75	-5.30	-3.34	2	141.9577000	-	-	-	-	-	-
20040308	15470 04:17	10.30	.53	-1.33	2	77.3073100	-	-	-	-	-	-
20040311	56035 15:33	9.33	.46	-1.14	2	58.8694600	88.5	3.6	1.0	85.8	2.3	1.0
20040314	34557 09:35	7.89	-6.51	-3.05	2	122.4166000	135.0	2.8	1.2	143.6	5.9	1.7
20040315	53250 14:47	9.49	-6.28	-3.86	2	154.3589000	115.6	3.2	0.8	105.0	3.5	0.9
20040316	68382 18:59	9.69	-5.55	-5.05	2	104.8367000	-	-	-	97.8	3.0	1.1
20040317	9902 02:45	12.00	-3.27	-3.84	2	64.3751000	56.9	2.2	1.4	109.8	7.4	0.9
20040318	84390 23:36	7.52	-5.54	-5.41	2	120.0563000	124.8	2.2	0.8	99.3	3.1	0.9
20040319	48291 13:24	10.70	-2.17	-2.09	2	80.3519000	-	-	-	-	-	-
20040320	4660 01:17	5.63	-5.57	-4.86	2	66.3074600	106.9	2.1	0.7	92.2	6.2	1.2
20040320	67192 18:39	9.31	-.65	-1.65	2	137.6008000	161.0	5.2	0.7	168.9	4.7	0.2
20040326	35363 09:49	10.38	-3.31	-2.23	2	45.6587100	69.2	1.4	0.4	81.0	1.6	0.6
20040412	1548 00:25	5.61	-8.21	-6.72	2	144.5996000	157.5	1.9	1.7	-	-	-
20040415	39465 10:57	5.17	-10.34	-3.54	2	117.6141000	120.7	12.1	2.7	-	-	-
20040415	84862 23:34	8.29	-4.22	-3.77	2	103.5420000	170.5	4.9	1.4	-	-	-
20040430	54411 15:06	6.35	-10.54	-3.95	1(triangle)	51.5091100	148.6	1.0	1.6	110.9	3.6	2.0
20040430	78059 21:40	6.42	-4.58	-3.22	2	171.0556000	175.4	2.9	1.4	167.5	3.5	1.2
20040502	84282 23:26	6.27	8.62	6.00	2	146.0068000	124.0	2.0	2.2	100.2	2.8	1.5

Examples: Good Plots



Examples: Anomalies



Task IV

Errors and Difficulties:

- Forgetting to “print” plots
- Not changing satellite position after every plot

Results:

- Most plots agreed with the model’s prediction
- Anomalies in the plots had the same angles as the smooth plots in Task I (220° to 270°). (We don’t get it...)

Future Work

Last Week:

- Fix some errors that still exist in Task IV
- Tackle a new task laid out by my mentor

Distant Future Work:

- Look more closely at all the data to determine trends
- Continue to test and fix the prediction model

Acknowledgements

- NSF and the CU-Boulder REU Program
- Erin Wood and Marty Snow
- Mentors: Karlheinz Trattner and Bill Peterson
- LASP Community

References:

Trattner, K. J., S. M. Petrinec, S. A. Fuselier, N. Omid, and D. G., Sibeck (2012), *Evidence of multiple reconnection lines at the magnetopause from cusp observations*, J. Geophys. Res., 117, A01213, doi:10.1029/2011JA017080.

Questions?

