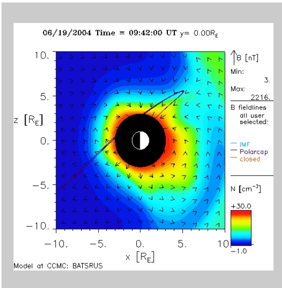

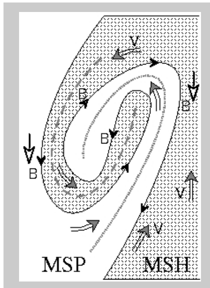

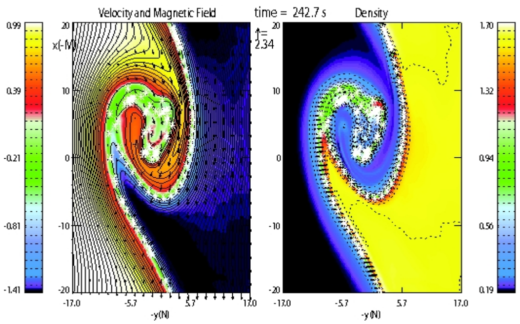

CCMC User Feedback:

Mapping of the Quasi-Periodic Oscillations at the Flank Magnetopause into the Ionosphere

Emily Dougal

Sandia National Laboratories

Albuquerque, NM

Sandia National Laboratories

Exceptional service in the national interest

Community Coordinated Modeling Center

CCMC Workshop 2014 – Annapolis, MD.

CCMC Student Research Contest Winner 2012

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NNSA National Nuclear Security Administration

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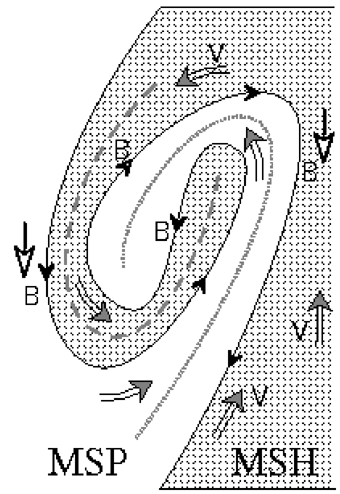
Motivation and Introduction

- Document ionospheric signatures of KHI occurring in the LLBL
  - Reverse engineer a method to observe KHI from more available ionospheric data (ground-based instruments, e.g.).
- Past publications have hinted on such signatures
  - Auroral bright spots (Lui 1989) and optical vortices (Farrugia et al. 1994)
  - Chain of traveling convection vortices with alternating rotational directions (McHenry et al. 1990)
  - Pc5 freq. range magnetic pulsations in magnetometer data (Ohtani et al. 1999)



Methodology

1. CCMC Global MHD Models – OpenGGCM and BATS-R-US
   - Map the effected field lines into the ionosphere and calculate travel times
2. Tsyganenko Magnetic Field Model (TS96) – 2001 update
   - To compare with global models
3. Run local 2D MHD simulations
   - Estimate ionospheric vortex size
4. Ionospheric Data for potential signatures
   - Auroral – Polar UVI and Image FUV
   - Radar – SuperDARN network
   - Magnetometer – SuperMAG network

Tsyganenko Magnetic Field Model

- Used external TS96 magnetic field model and internal IGRF 11.0
- Reversed typical TS96 technique to provide Space -> Earth field line mapping ability

Table 6. Comparison between the global MHD models and TS96 model ionospheric footprint location. 'N/A' refers to a footprint which yielded in one model, and was considered to be on an open field line in the other. The subindices refer to the mapped field line locations ending in the northern (N) or southern (S) pole.

Event	Δ MLAT$_N$	ΔMLT$_N$	ΔMLAT$_S$	ΔMLT$_S$
1	-9.8	-1.1	3.5	-3.1
2	N/A	N/A	N/A	N/A
3	-	-	10.1	-4.0
4	-16.7	3.0	N/A	N/A
5	-21.7	0.1	20.9	[illegible]
6	-20.7	0.3	21.1	-1.8
7	-9.8	1.8	-3.4	-6.4
8	-10.4	2.6	4.1	-0.4
9	N/A	N/A	-	-

Ionospheric Signature Results

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- Auroral Data
  - No data for our event dates.....
- SuperDARN Radar Network
  - Expected multiple traveling vortices of alternating rotation with sizes under 300 km
  - Observed few, single traveling vortices, had larger sizes than predicted
  - Low southern hemisphere coverage, highly dynamic region overall
- SuperMAG Magnetometer Network
  - Expected quasi-periodic oscillations of Pc5 freq. range in stations within the estimates location/area
  - Observed oscillations in ~50% of the stations, all within Pc5 freq. range

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Conclusion and Future Work

- We believe we were successful in our methodology….but
  - We want to be more confident in the accuracy of the ionospheric footprint
- Future work includes:

1. Using Themis data – previously used all Cluster data from 2001-2006
   - Can use more recent ionospheric instruments, better resolution
2. Understanding the field line mapping difference between TS96 and Global MHD models
   - TS96 used IGRF, Global MHD models did not
   - Resolution difference

CCMC User Feedback

- Global MHD models
  - Continuing to provide high resolution grids for possible KHI resolution/observation
  - Continuing to provide field line mapping ability in Global MHD codes
  - Including a coordinate system transformation would be helpful
- Tsyganenko Magnetic Field Model
  - Including both Earth -> Space and Space -> Earth field line mapping
  - Include ability to chose which additional models to couple with
- Providing online model capability tutorials
  - Voice-over presentations showing the user what each model can do post processing
  - Can be used for educations outreach, new users, summer schools, etc.

Current Work

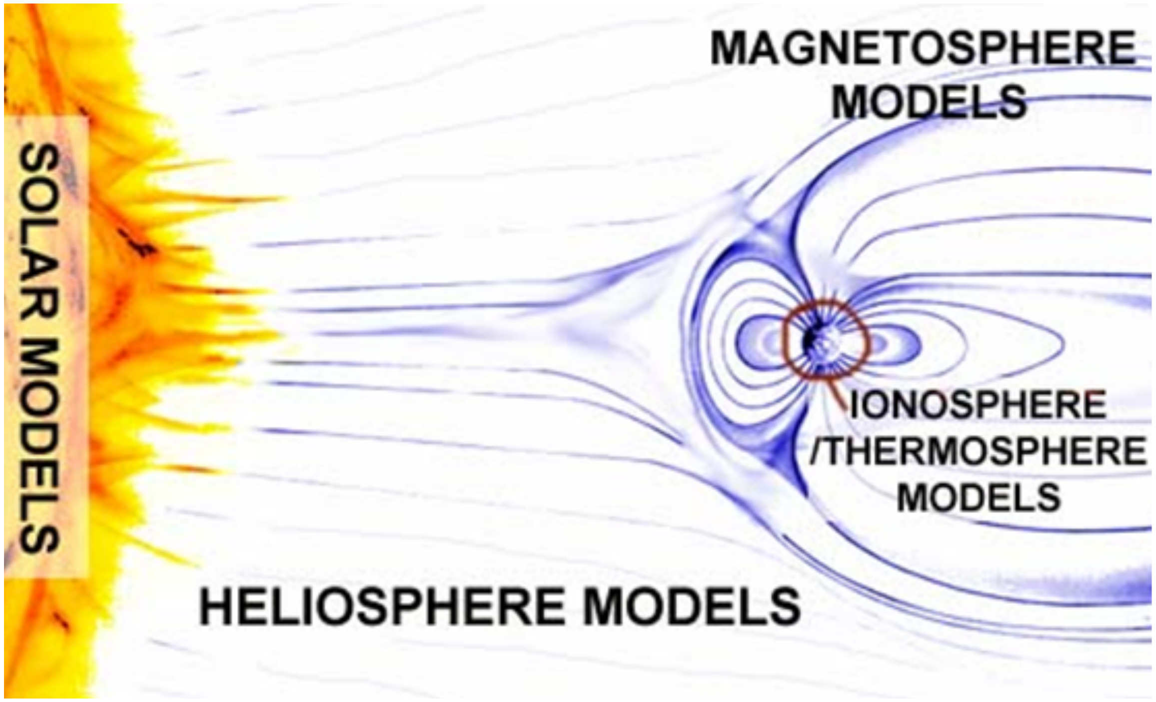
- Observing space weather effects on spacecraft instrument with Los Alamos Nat'l Lab
- Interested in Van Allen Belt locations in different conditions conditions
  - Will be choosing which Radiation Belt Models to estimate belt boundaries and growth
- Will be developing real-time weather monitoring for statistical detection impact
  - Looking at numerous agencies' now-casting capabilities

Thank you!

EXTRA SLIDES

Presentation Outline

- Research Intro
  - Motivation
  - Methodology
  - Results
- Conclusion and Future Work
- Current Work



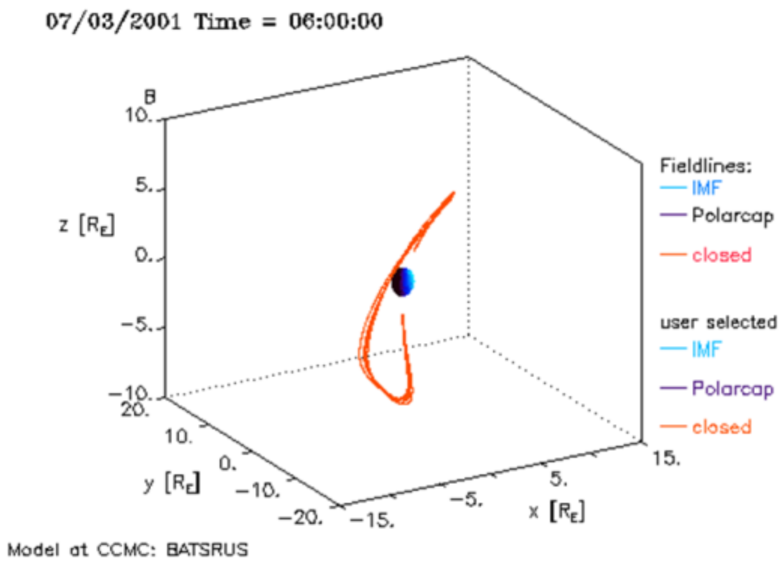
NASA: CCMC

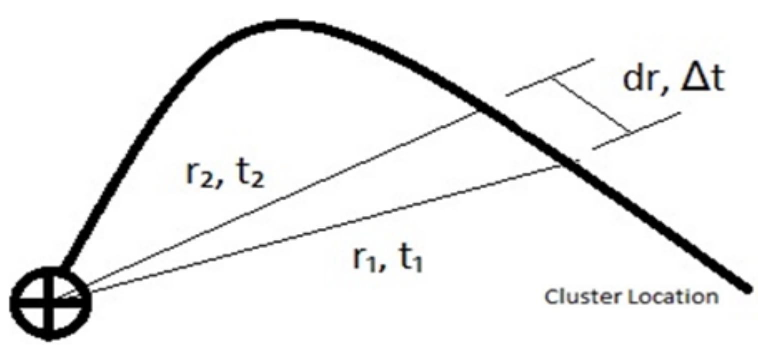
Ionospheric Data Availability

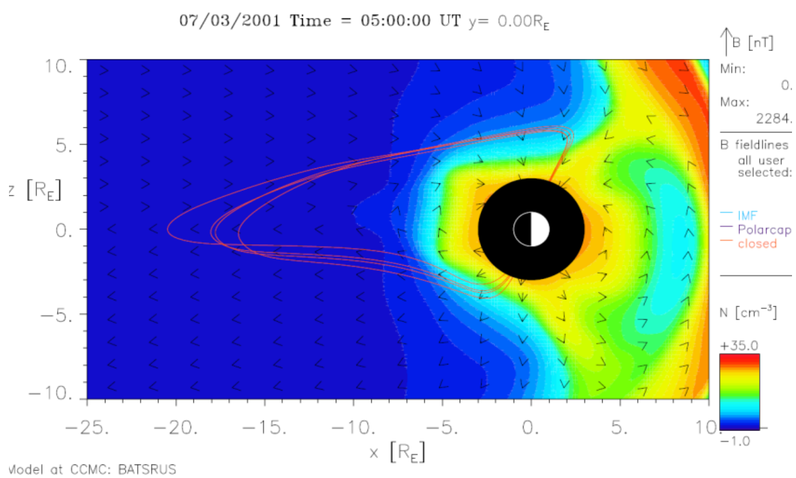
Instrument	Event								
	1	2	3	4	5	6	7	8	9
Polar UVI	Yes	No	No	No	No	No	No	-	
Image FUV	No	No	No	No	No	No	No	-	
SuperDARN - North	No	Yes	-	Yes	Yes	Yes	Yes	No	No
SuperDARN - South	Yes	No	No	No	Yes	Yes	Yes	No	No
SuperMAG - North	Yes	Yes	-	Yes	Yes	Yes	Yes	Yes	No
SuperMAG - South	No	No	Yes	No	Yes	Yes	Yes	Yes	No

Global MHD Models

- User defined flow lines
  - Input satellite location
  - Output north/south hemisphere footprint
- Provided magnetic field strength, density, etc. along flow lines
  - Could calculate Alfvén speed and travel time

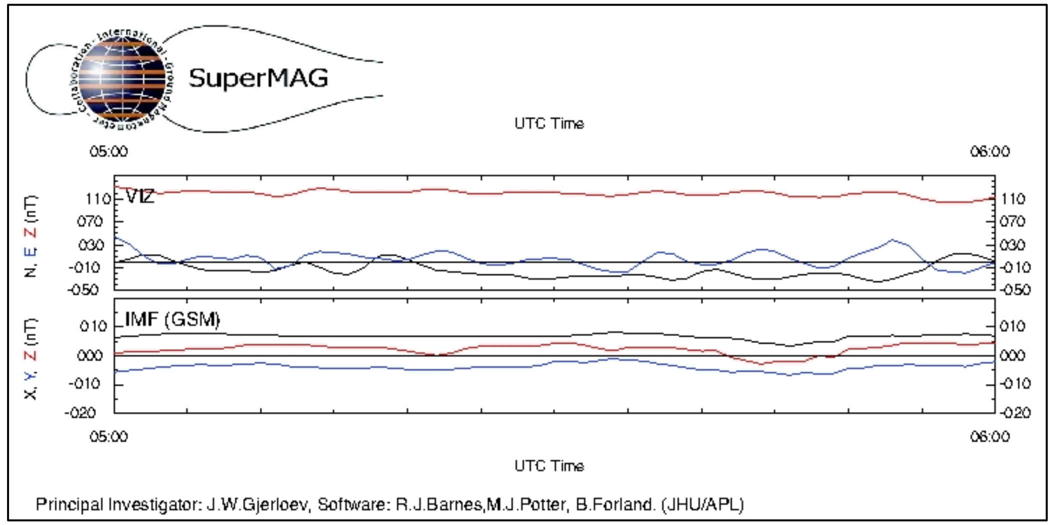






SuperMAG Magnetometer Network

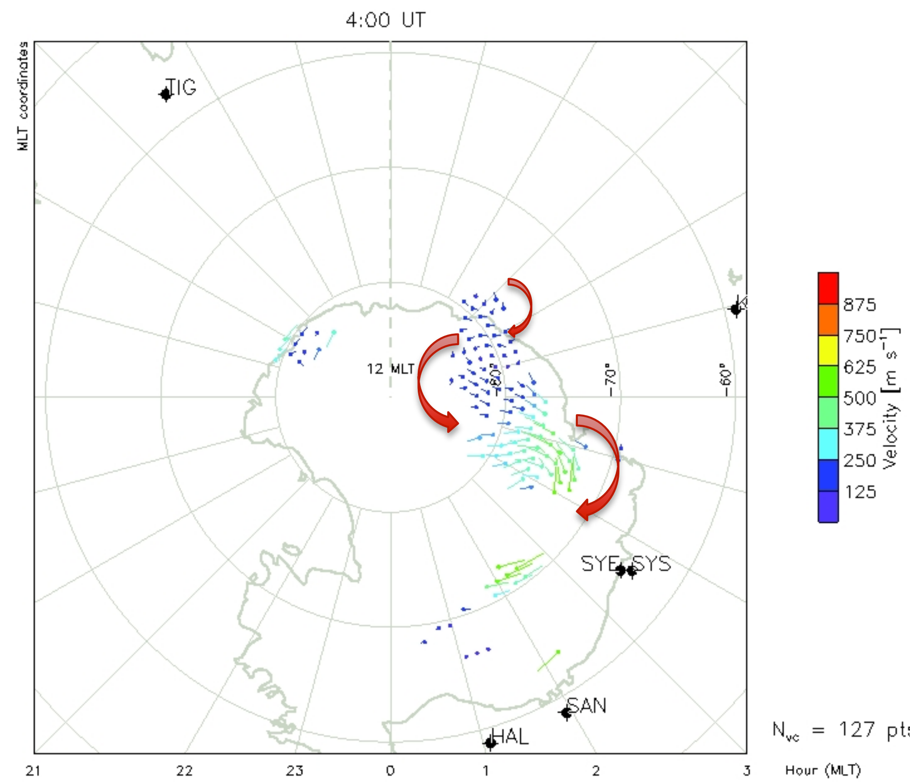
- Expected quasi-periodic oscillations of Pc5 freq. range
  - Only looked at data from stations located within the KHI's ionospheric footprint



- All observed oscillations were within the Pc5 range
  - For some events, majority of stations within estimated KHI area did not observe any oscillations
- Expected dominating freq. on the ground to be within 0.3 mHz of MSP freq.
  - Using PSD analysis, half of stations which detected oscillations observed this

SuperDARN Radar Network

- Expected multiple traveling vortices of alternating rotation with sizes under 300 km
- Observed few vortices
  - Most were over 800 km
  - Most had a single vortex
  - Half were within estimated location
    - 3 were within TS range
    - 2 were within MHD range
- Difficult to conclude
  - Southern hemisphere had VERY LOW coverage
  - Background convection interference



SuperDARN Results

Event	Hemisphere	Location	Speed [km/s]	Size [km]	Type
1	South	In TS96 limit	400	1,000	1
2	North	Outside limit	300	1,100	2
4	North	Outside limit	300	1,200	1
5	North	Outside limit	400	1,800	2
	South	In TS96 limit	300	1,200	1
6	North	-	-	-	-
	South	-	-	-	-
7	North	Outside limit	250	600-900	2, 3
	South	In TS96 limit	300	-	1
		In MHD limit	400	800	2
		In MHD limit	400	500-800	2, 3

SuperMAG Results

Event	Station (Total)	ΔB_N, ΔB_E, ΔB_Z [nT]	Period [m]
1	VIZ (1)	15, 25, 5	7
3*	- (1)	-	-
2	- (4)	-	-
4	IGC (15)	0, 10, 0	7
	IQA	0, 15, 3	7
	PGC	3, 10, 0	6 - 7
5	ATU (13)	0, 5, 5	5 - 7
	GHB	15, 0, 5	6 - 8
	KUV	3, 3, 0	6 - 7
	NAQ	5, 3, 5	6
	SKT	20, 0, 7	6 - 7
	STF	20, 10, 7	6 - 7
5*	MAW (1)	0, 10, 0	7 - 10
6	- (1)	-	-
6*	B15 (5)	0, 13, 0	4 - 5
7	CCS (1)	0, 10, 10	7
7*	MAW (1)	3, 5, 2	6
8	- (6)	-	-
8*	- (1)	-	-

PSD Results

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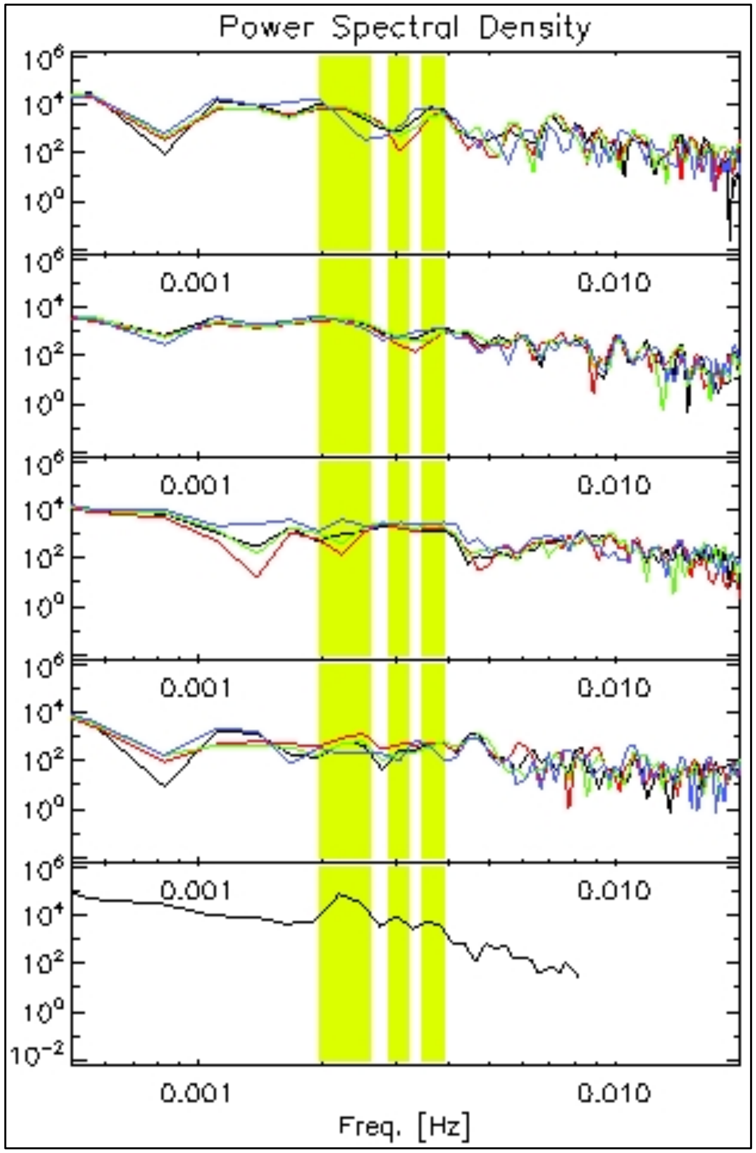

Event	Instrument	Dominating Freq. [mHz]
1	Cluster	3.1, 3.6
	VIZ	2.2, 2.5, 3.0, 3.6, 3.8
4	Cluster	4.2, 5.0, 6.7, 9.2
	IGC	3.2, 5.6, 7.9
	IQA	3.2, 5.6, 7.9
	PGC	3.2, 5.6, 7.9
5	Cluster	2.8, 5.0, 5.7
	MAW	2.0
	SKT	2.7, 4.7
	STF	2.7, 4.7
	ATU	2.7, 6.0
	GHB	2.0, 2.7, 4.7
	KUV	2.0, 2.7, 5.3
	NAQ	2.7, 3.3, 5.3
6	Cluster	4.1, 7.4
	B15	4.0, 6.3
7	Cluster	4.1, 4.9, 5.7
	CCS	2.4
	MAW	3.2, 5.6

Local MHD Analysis

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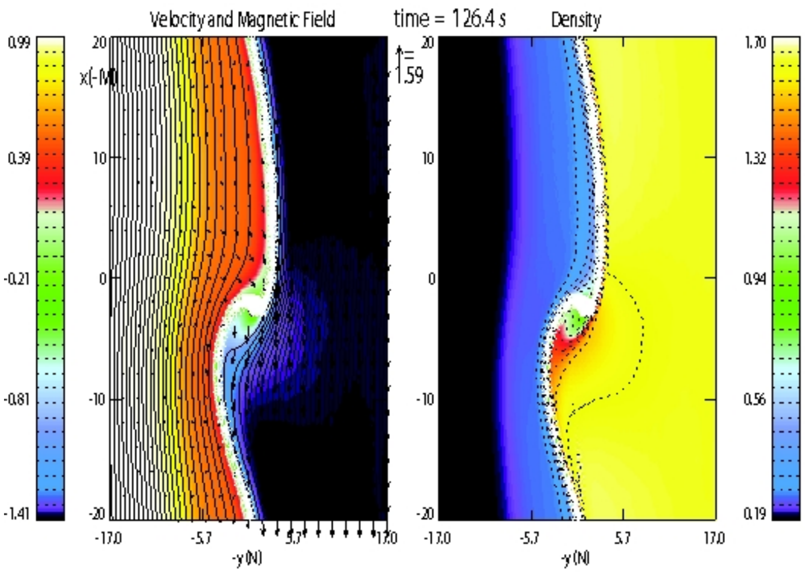

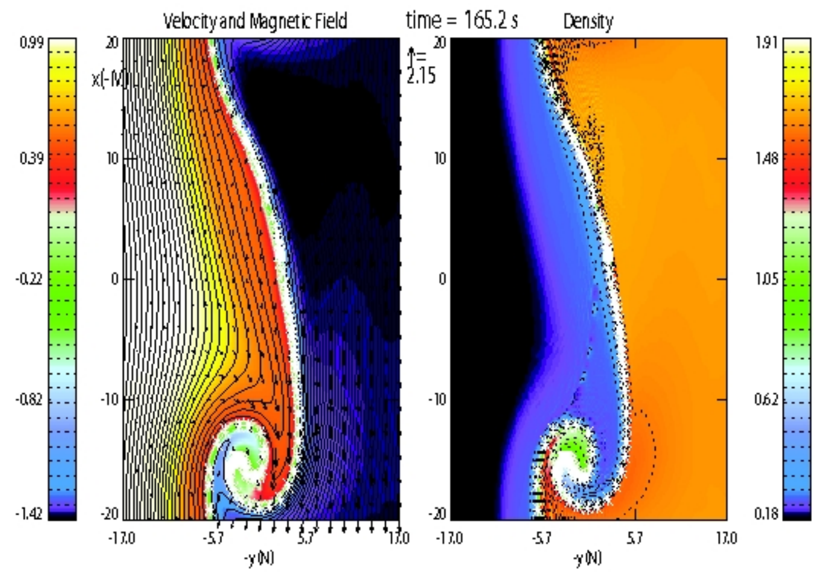

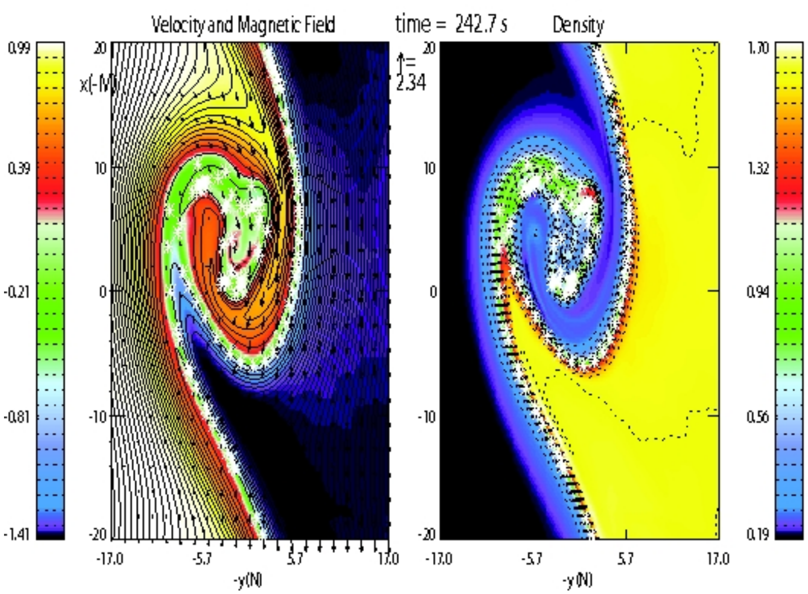

- Left Panel: Velocity color bar and magnetic field vector
- Right Panel: Density color bar
- Asterisks: fluid plasma elements integrated along the initial boundary
- Measured vortex when fluid elements made a full rotation

Calculating Vortex Dimensions

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- For each simulation, the simulation box size was adjusted to $\lambda = V_{PH}T$
  - Where T is the observed KH frequency, typically between 1 – 3 minutes
  - The spacecraft separation was not comparable to the KH wavelength, therefore we estimated the phase speed using two different methods:

1. $V_{PH} \approx 0.5\ V_{MSH}$
2. $V_{PH} = V_{HT}$