The SAMBA project

SAMBA-iMAGS meeting
Punta Arenas, Chile - Nov 3, 2013

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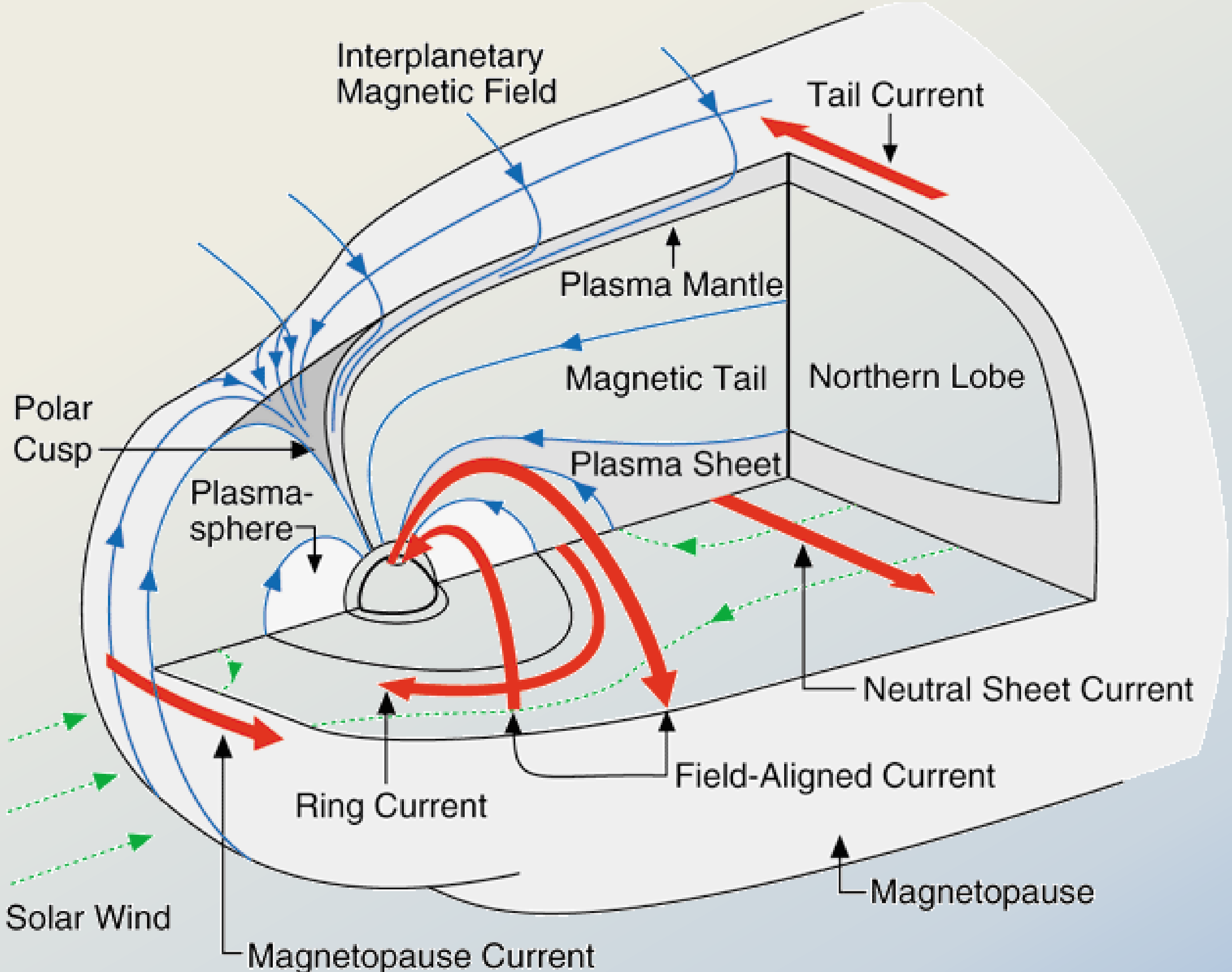
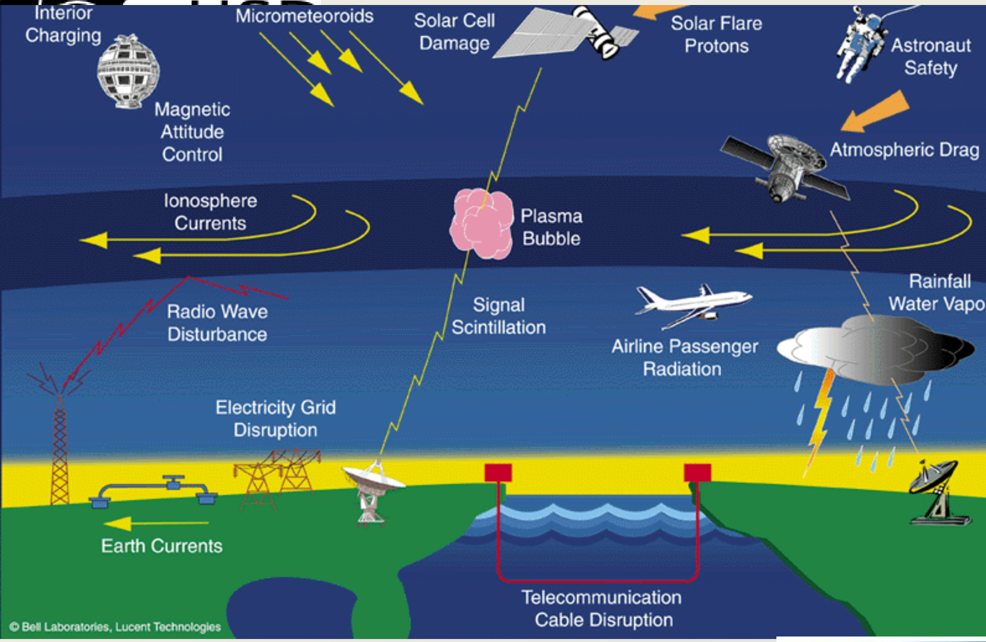
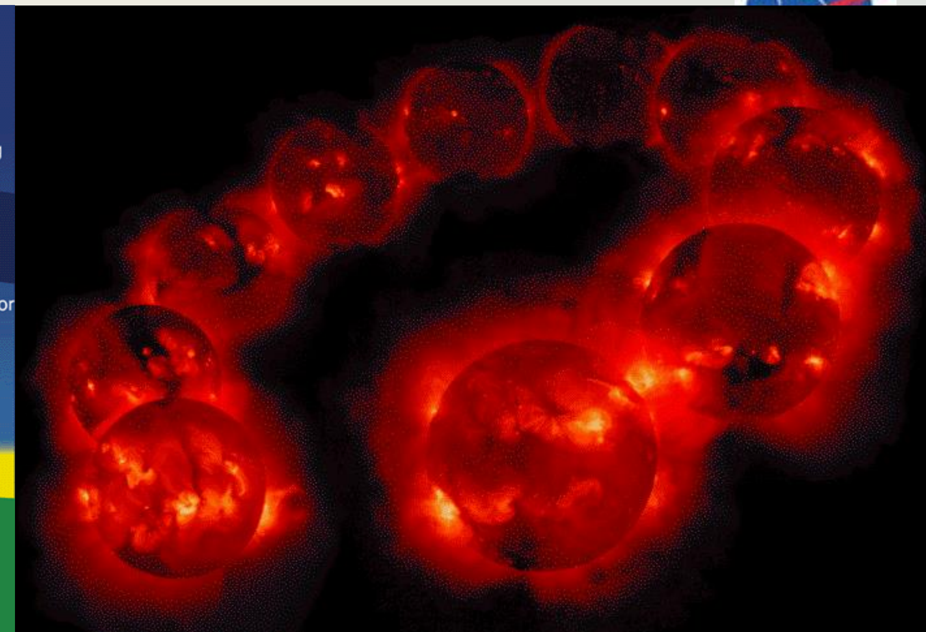
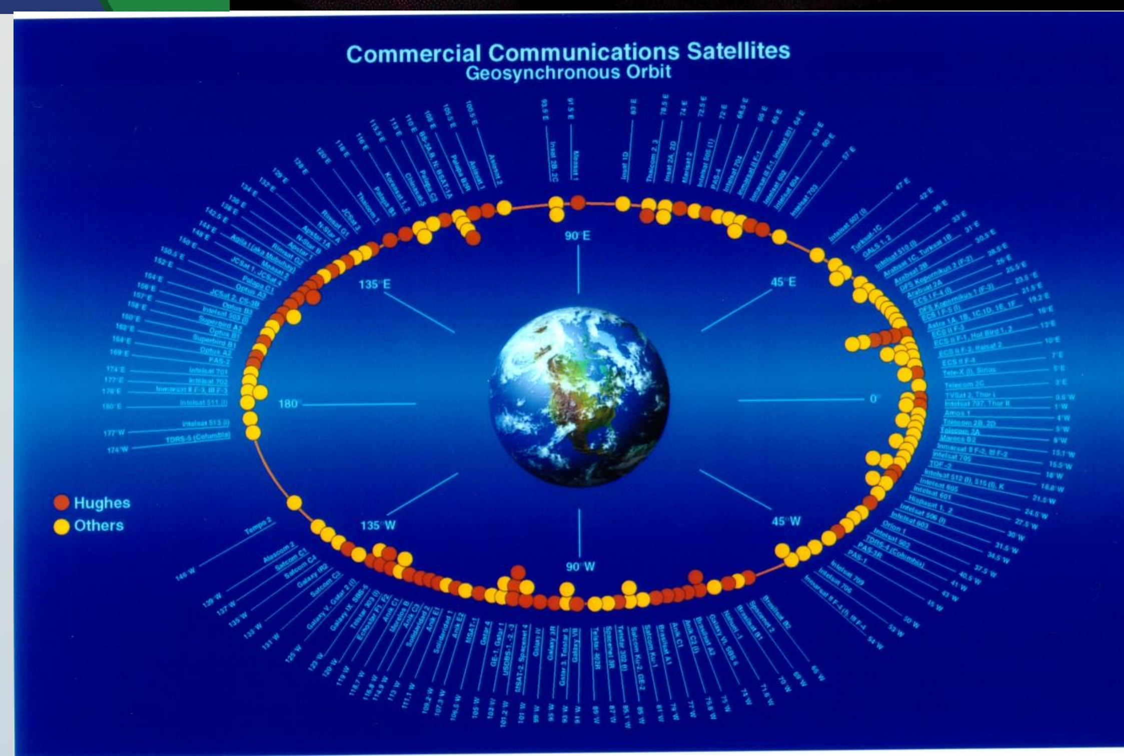
Geospace Science Laboratory


Interplanetary Magnetic Field
Tail Current
Plasma Mantle
Magnetic Tail
Northern Lobe
Polar Cusp
Plasma Sheet
Plasma-sphere
Neutral Sheet Current
Field-Aligned Current
Ring Current
Magnetopause
Solar Wind
Magnetopause Current







Space Weather impacts a range of technological systems.

Different types of magnetometers

USES OF MAGNETOMETERS

- Geophysical surveys
- Detection in archeological sites or shipwrecks
- Oil industry
- Medical applications
- Space applications

TYPES OF MAGNETOMETERS

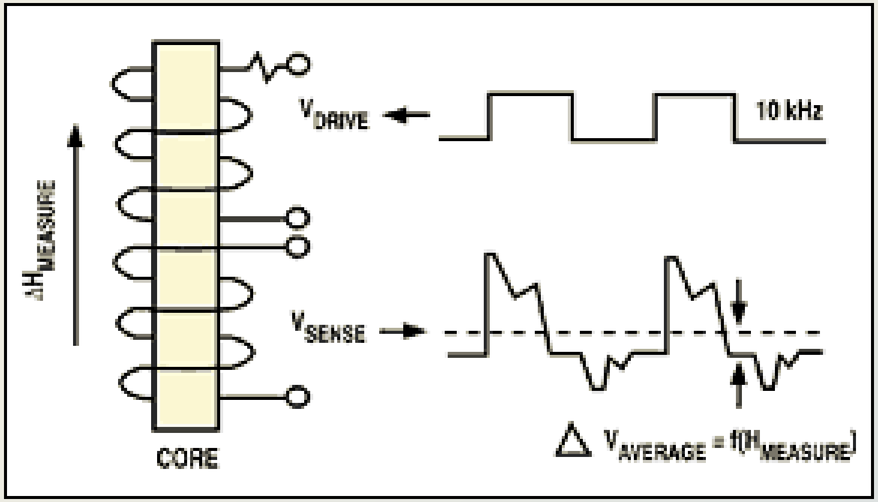
- Proton Precession (only magnitude)
- Magneto-optical (medical applications)
- SQUID (require very low temperature, most sensitive)

Geophysical applications require

- High dynamic range: 0-60000 nT
- Measurements in 3 directions
- Very high sensitivity, <1nT
- Fluxgate and search coil

Note: $1nT = 1\gamma = 10^{-5}$ G

The fluxgate magnetometer



Operation of the fluxgate

❖Driver and sense coils on ferromagnetic core

❖Drive signal drives core into saturation based on the core's hysterysis curve at a frequency much higher than the required sampling rate

❖Second harmonic of the transform of the sense coil signal is proportional to the external magnetic field

Typical properties of fluxgates for geophysical processes on the ground

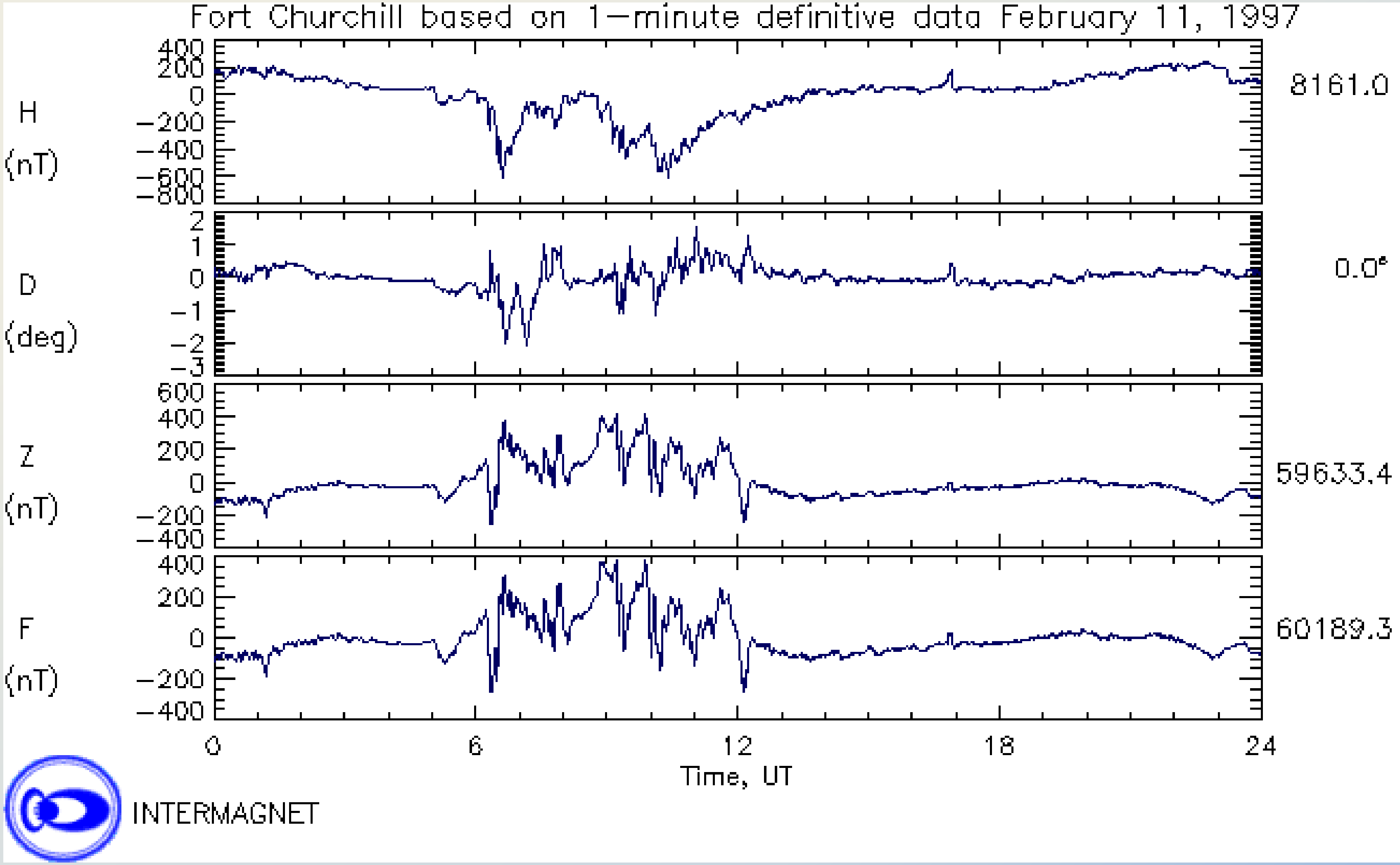
❖Sampling rate 1-2 Hz

❖Sensitivity 0.1 nT

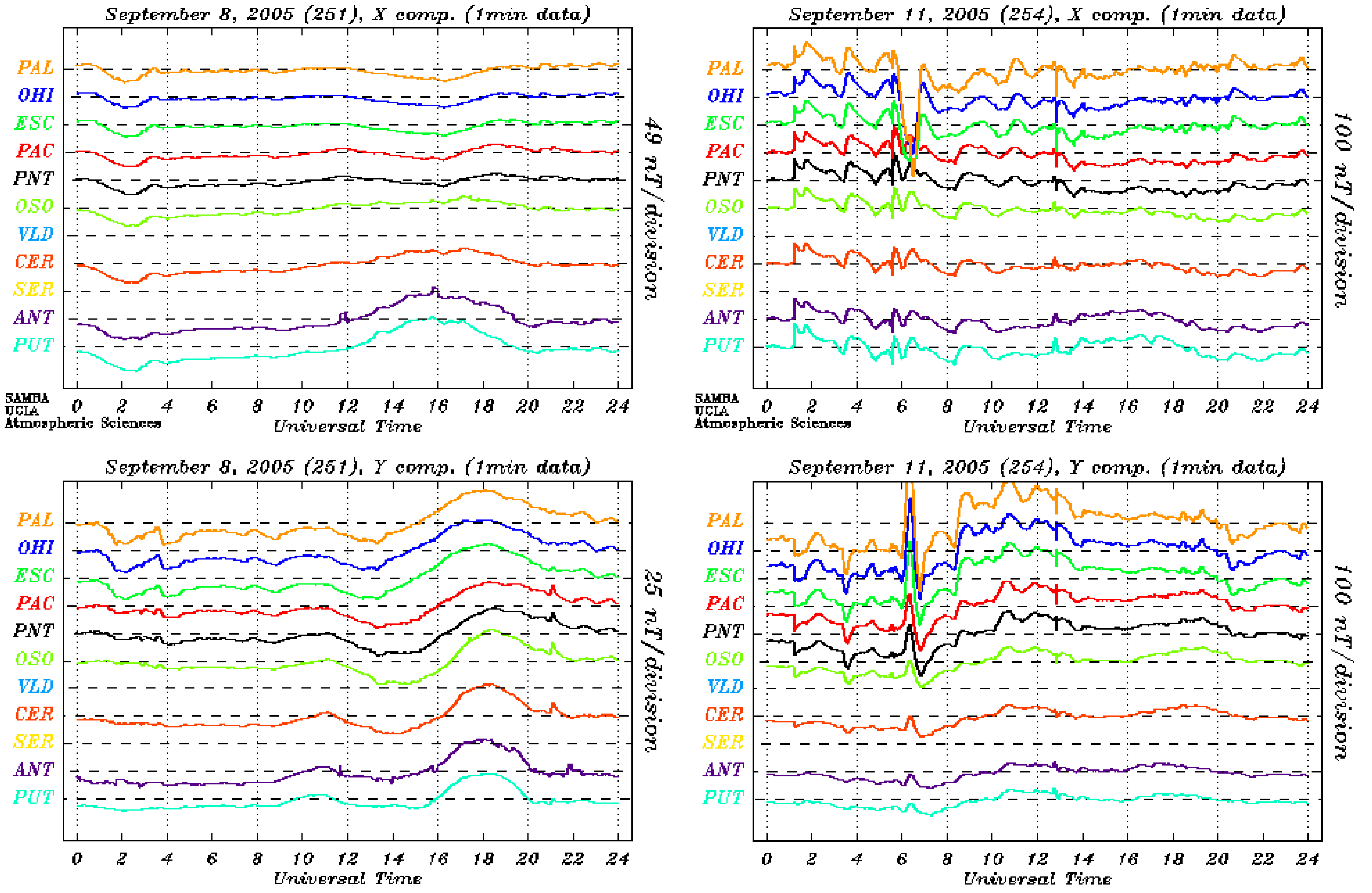
❖Can measure ULF waves only (these are the standard MHD modes up to the ion Cyclotron waves that basically represent the different scales of the magnetosphere).

❖In space fluxgates can measure much higher frequencies because the amplitude of waves is much larger there and the background field is much smaller.

Fluxgate data from auroral latitudes during active times



Fluxgate data from SAMBA during quiet and storm time



SAMBA

South American Meridional B-field Array

- Eftyhia Zesta (PI) – NASA, Goddard Space Flight Center
  - ezesta@atmos.ucla.edu; Eftyhia.Zesta@nasa.gov
  - http://samba.atmos.ucla.edu
- 11 magnetometers (1-sec sampling) along the coast of Chile and in Antarctica. 1 remote system with 10-sec sampling in Antarctica.
- 4 magnetometers installed April 2002, 4 magnetometers on May 2003, 2 magnetometers on January 2004, 1 mag on April 2005 and the last one on Nov 2005.

Map of SAMBA magnetometers

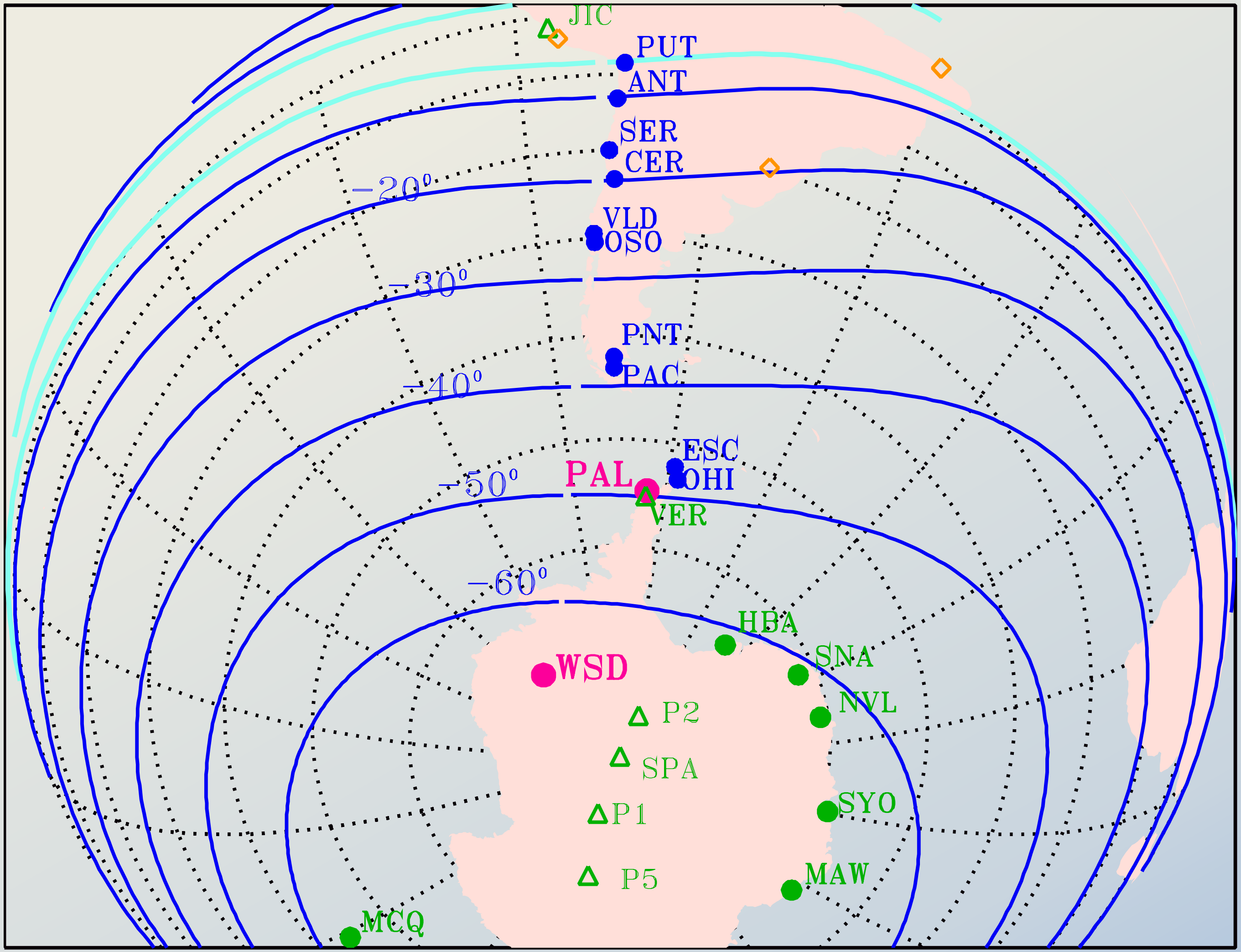
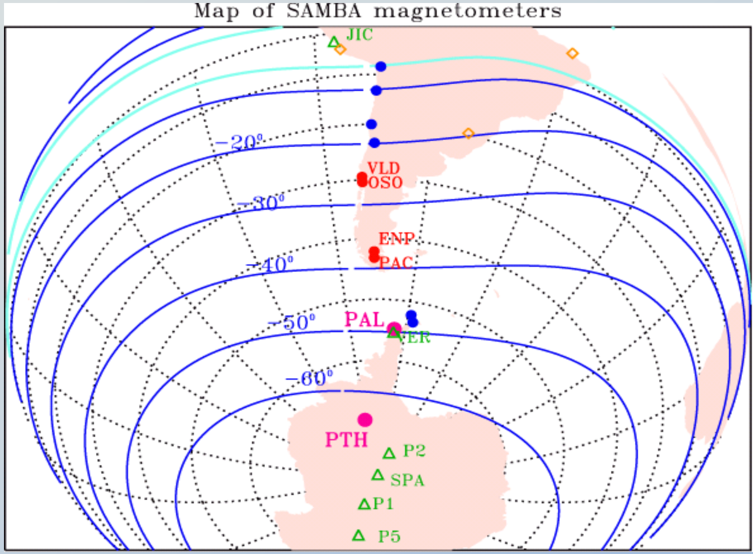


Table 1: SAMBA (A Chilean-American magnetometer chain) and the conjugate **MEASURE** stations

•Station Name	Station Code	Geographic Latitude	Geographic Longitude	CGM Latitude	CGM Longitude	UT of noon MLT	L-value
Putre	PUT	-18.33	-69.5	-5.50	1.44	16:30	1.01 **May 2003**
Antofagasta	ANT	-23.39	-70.24	-10.31	0.72	16:26	1.03 **May 2003**
La Serena	SER	-30.0	-71.13	-16.55	0.17	16:28	1.09 **May 2003**
Los Cerrillos	CER	-33.45	-70.6	-19.80	0.75	16:26	1.13 **May 2003**
Valdivia	VLD	-39.48	-73.14	-25.58	359.60	16:32	1.23 **Apr 2002**
Osorno	OSO	-40.34	-73.09	-26.39	359.73	16:32	1.25 **Apr 2002**
St. Gregorio	ENP	-52.13	-70.9	-37.58	1.59	16:22	1.59 **Apr 2002**
Magallanes	PAC	-53.2	-70.9	-38.27	2.87	16:22	1.63 **Apr 2002**
Escudero	ESC	-62.18	-58.92	-47.17	11.45	15:48	2.18 **Jan 2004**
O'Higgins	OHI	-63.32	-57.9	-48.8	12.43	15:45	2.28 **Jan 2004**
Palmer	PAL	-64.77	-64.05	-49.74	9.20	16:00	2.39 **(Apr 2005)**
Vernadsky	VER	-65.25	-64.27	-50.19	9.19	16:00	2.44 (Ukranian)
WAIS-D	WSD	-79.47	-112.86	-66.99	355.43	17:08	**6.54 (Dec 2005)**
MEASURE CONJUGATE STATIONS							
APL, MD	APL	39.17	-76.88	50.01	358.65	17:02	2.42
Fredricksburg, VA	FRD	38.20	-77.40	49.11	357.82	17.05	2.33
Boone, NC	DSO	36.22	-81.68	47.55	351.54	17:26	2.23
Aiken, SC	USC	34.00	-81.00	45.37	352.34	17:23	2.06
Jacksonville, FL	JAX	30.33	-81.66	41.79	351.16	17:26	1.83
Melbourne, FL	FIT	28.07	-80.63	39.57	352.39	17:21	1.71

SAMBA Attributes and Science Objectives

- SAMBA conjugate to MEASURE
- Equatorial to Mid-Latitude
- Paired Stations for ULF Resonance studies
- Mass density determination
- ULF wave propagation
- Effective cusp to cusp chain
- 12 hrs of MLT from 210-chain
- Chilean-US Collaboration

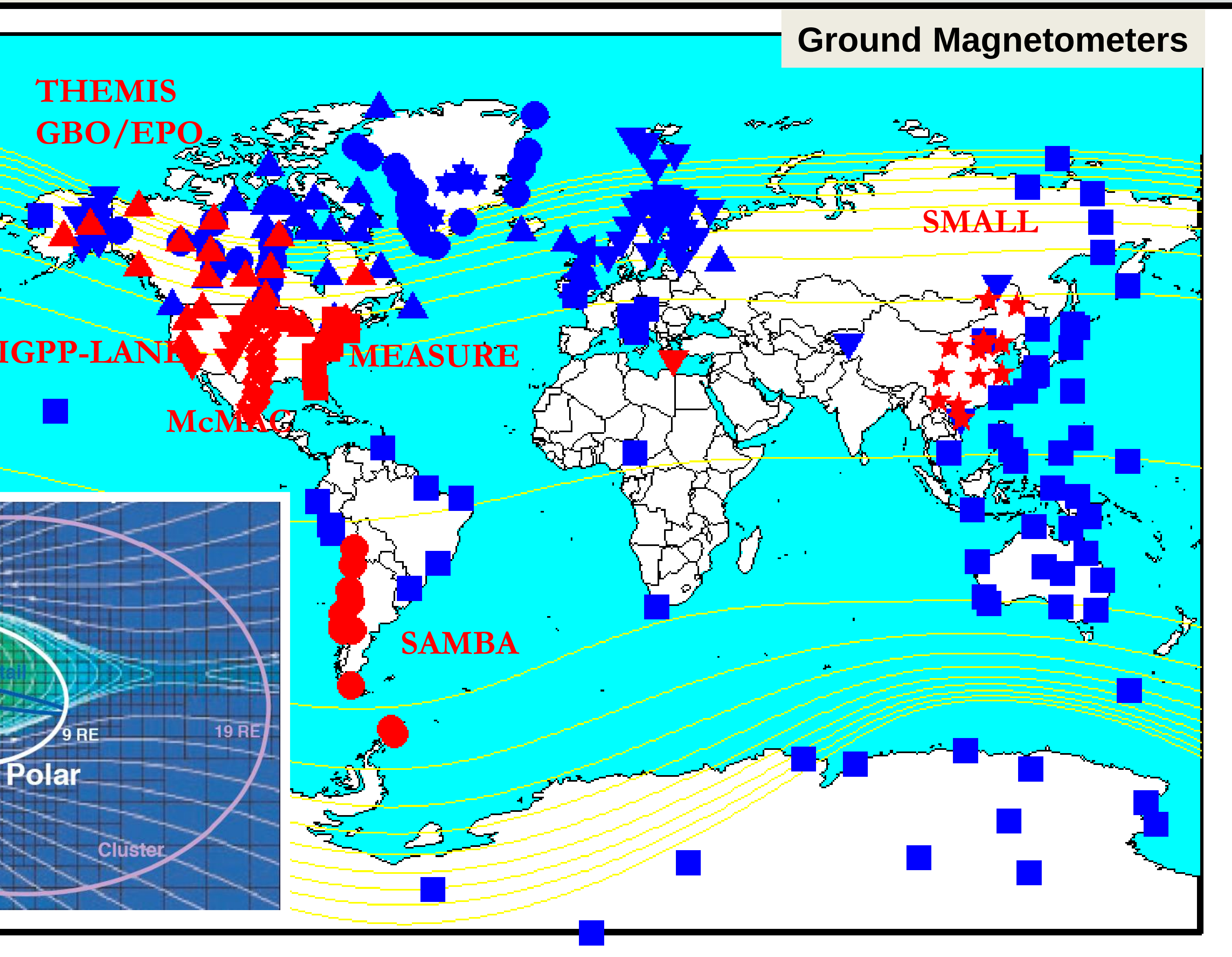


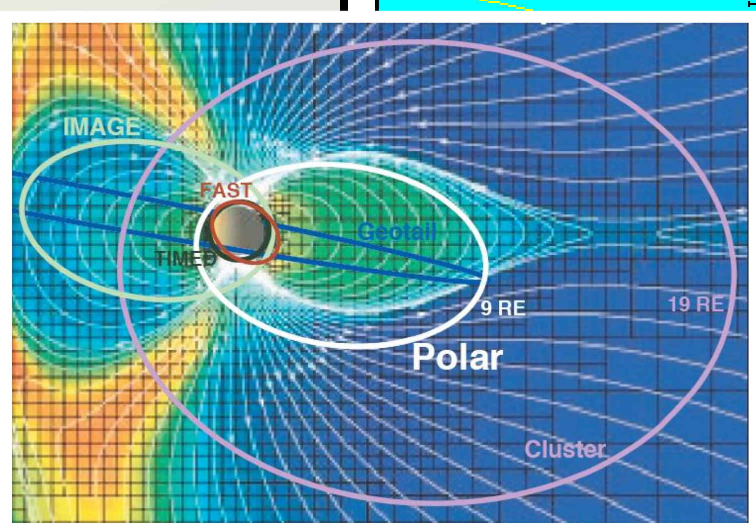
Magnetometers over the world courtesy of Peter Chi

Station Count:

Total: 250

- **CPMN: 54 (second)**
- **UCLA-built ( ) ♦ 65 (largest)**





The present SAMBA team

US SAMBA team:
Eftyhia Zesta (NASA)
M. Moldwin (U. of Michigan)
Th. Boudouridis (Space Science Inst)
Endawoke Yizengaw (Boston College)
Bob Strangeway and Kathryn Rowe (UCLA)

CHILE SAMBA team:

- Marina Stepanova, science lead of Chilean team and general manager
- PUT, CER: Prof Enrique Cordaro
- ANT: Jorge Araya
- SER: Prof. Pedro Vega, and Julio Marin
- VLD: Christian Lazo
- OSO: Prof David Martinez
- PAC, PNT: Prof Ricardo Monreal, and Cecilia Llop
- ESC, OHI: INACH

Science Output of SAMBA

So far SAMBA has

- Supported 4 senior and mid-career researchers
- Graduated 1 PhD student in the US and 2 MS student in Chile and 2 MS students in US (NMT)
- Currently supports with collaboration 1 PhD student in Greece
- Supported 2 Chilean students that are now doing their PhD in UCLA
- Produced 12 peer-reviewed publications, 3 more currently submitted, and over 50 conference presentations
- We are ripe for more dense future output

Students/postdocs

PhD thesis: Yong Shi (UCLA, 2008)
MS thesis: Nick (NMT, 2011), Victor Pinto (U de Chile, 2011), Jared Duffy (NMT, 2013), Juilio Marin (U de la Serena, 2013)
Postdocs: Yong Shi (UCLA, UNM), Pablo Moya (NASA-GSFC)

History of the project and its people

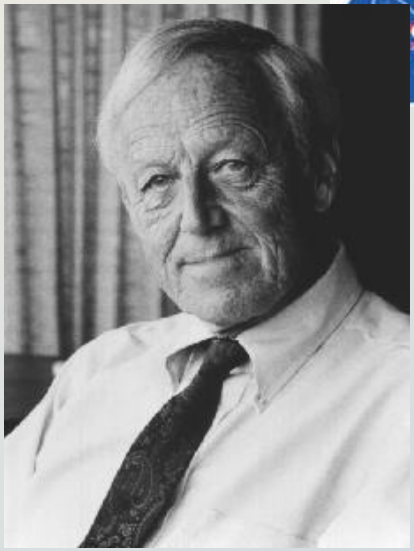
- What have been the lessons and key issues
  - Good local support is even more important than the “right location”
  - Cables get cut, instruments get hit by lightning, computers die, UPS’s burn, people leave and live, dust covers and kills electronics, water damages sensors, and much much more. It is a constant effort to keep things running
- What has helped
  - Can’t stress enough the good local support
  - Continuous funding
  - Good engineers/students/postdocs to constantly monitor the stations
  - Good engineering support and the funding to access it
  - Good data analysis tools
  - Wide data sharing with the community
- What we will need in the future
  - New phase of funding, strengthened collaborations and agreements, wider data distributions

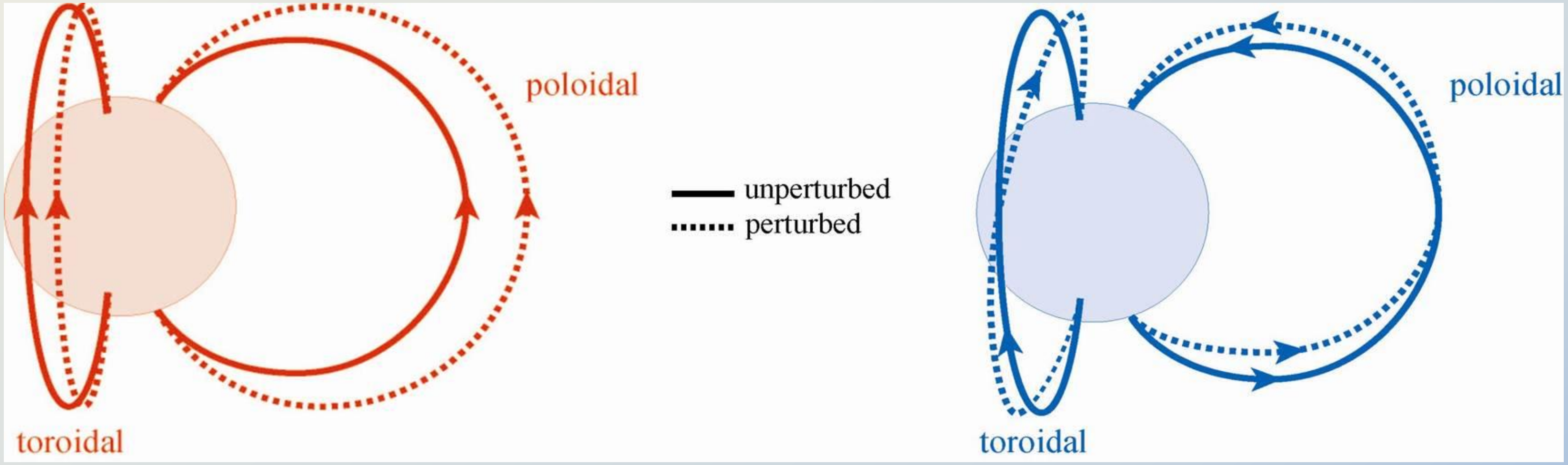
ULF waves

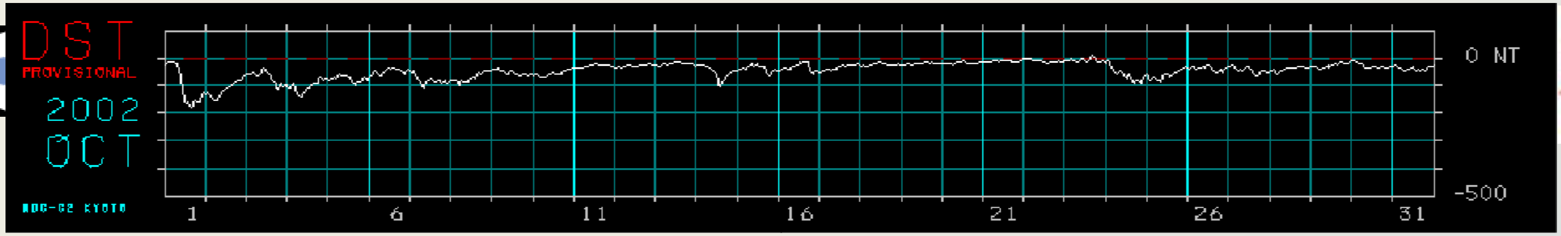
- Hydromagnetic waves of the cold-plasma magnetosphere. Frequency range 1mHz – 1 Hz (17min-1sec).
- Fast mode and shear mode
- Lowest range are the lowest f waves supported by magnetospheric cavity. Highest range from ion gyrofrequencies.
- Large amplitudes, seen in ground magnetometers. Thus have been studied for over 140 years [Steward, 1861]. Observations lead to suggestion of electric currents flowing in the upper atmosphere.
- ULF waves allow the remote monitoring of magnetospheric properties (i.e. density structure).
- ULF wave source: SW, MP, Sheath, BS
- **Fast mode couples with shear mode to create FLRs. For FLRs frequency increases with decreasing latitude and phase reverses across the resonance.**

ULF or Alfven Waves

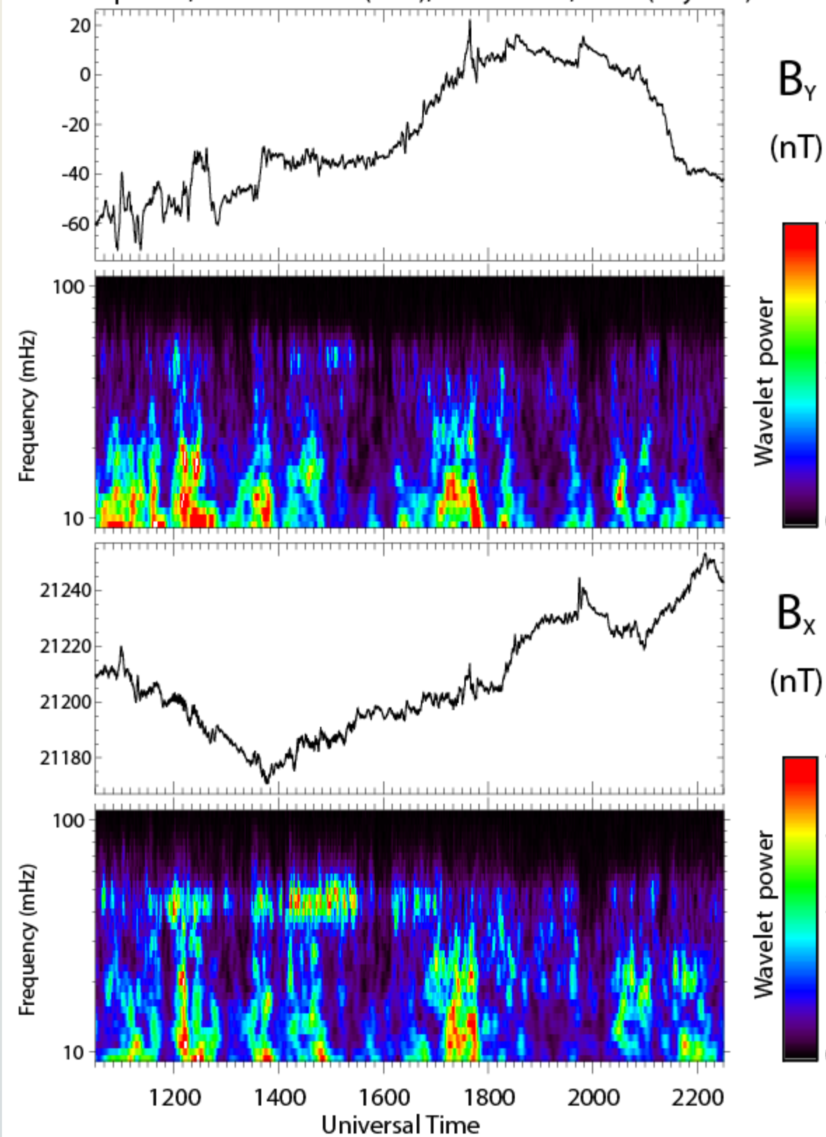
- $V_A = B/(\mu_o\rho)^{1/2}$
- PC 3/4 waves (7 - 100 mHz or 10-150 s)
- Field-line standing wave period
  - $T = (2/n) \int ds/V_A$ [Dungey, 1954]



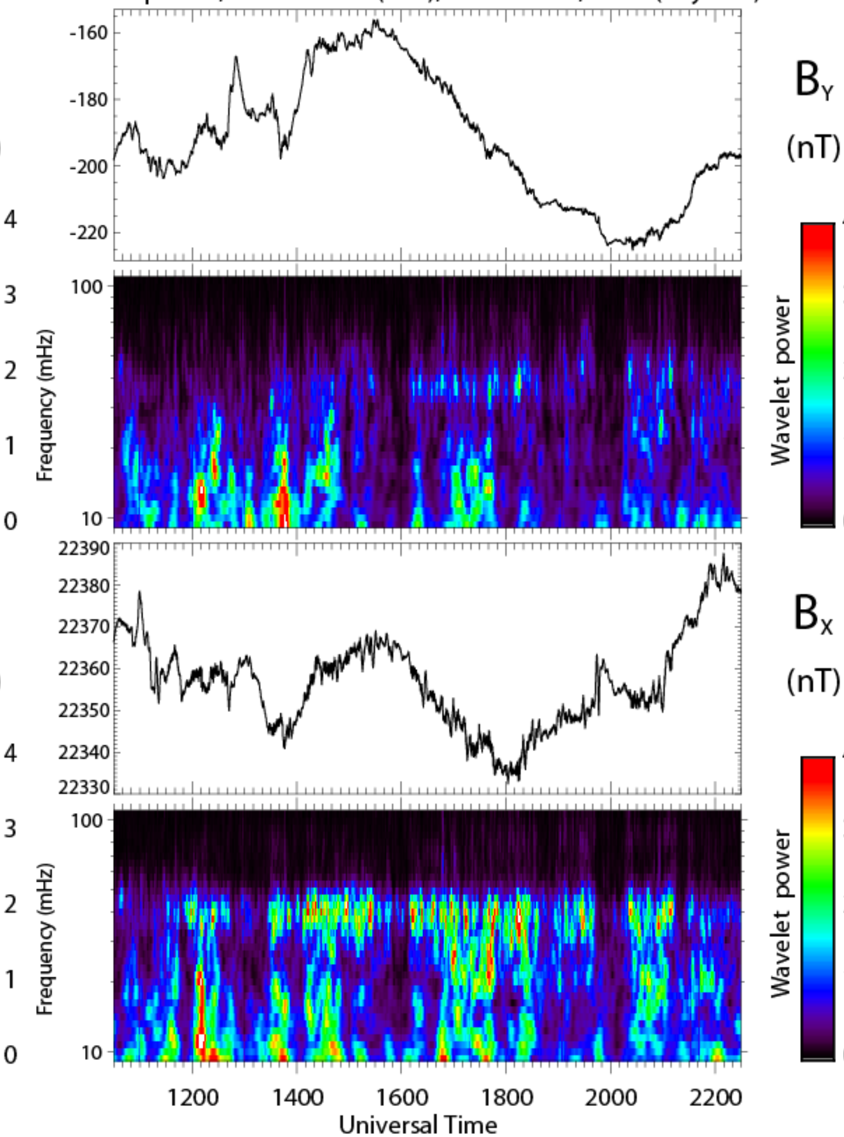




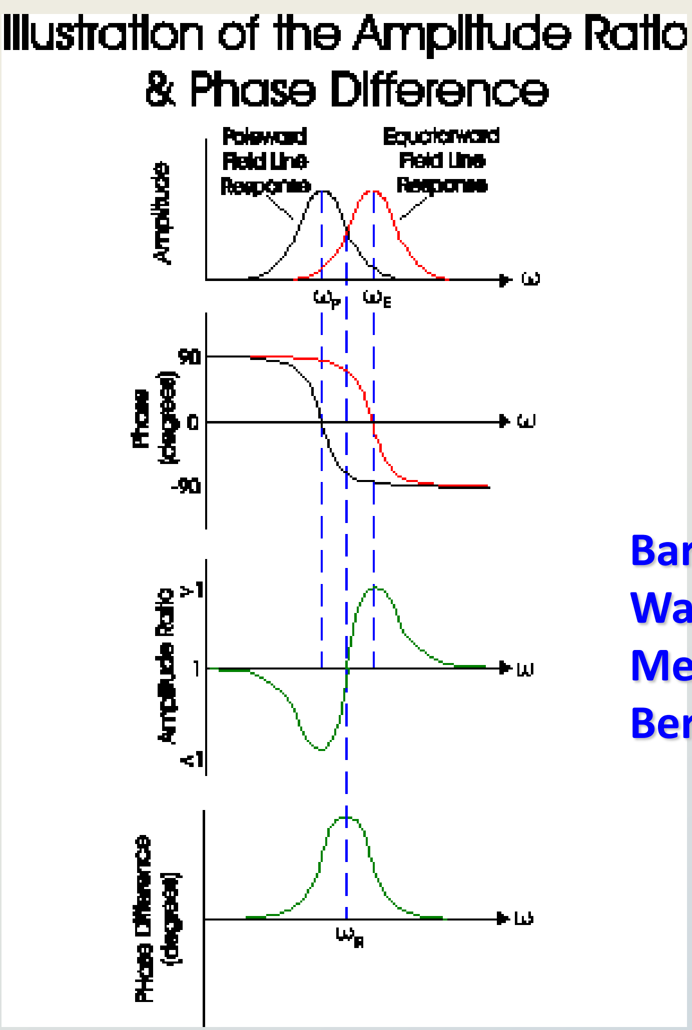
Wavelet spectra, Punta Arenas (PAC), October 25, 2002 (day 298)



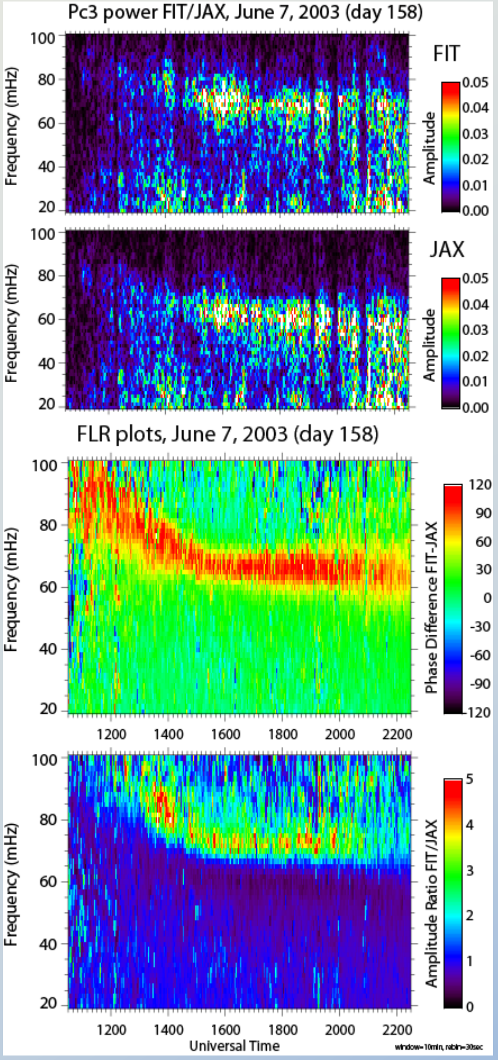
Wavelet spectra, Jacksonville (JAX), October 25, 2002 (day 298)



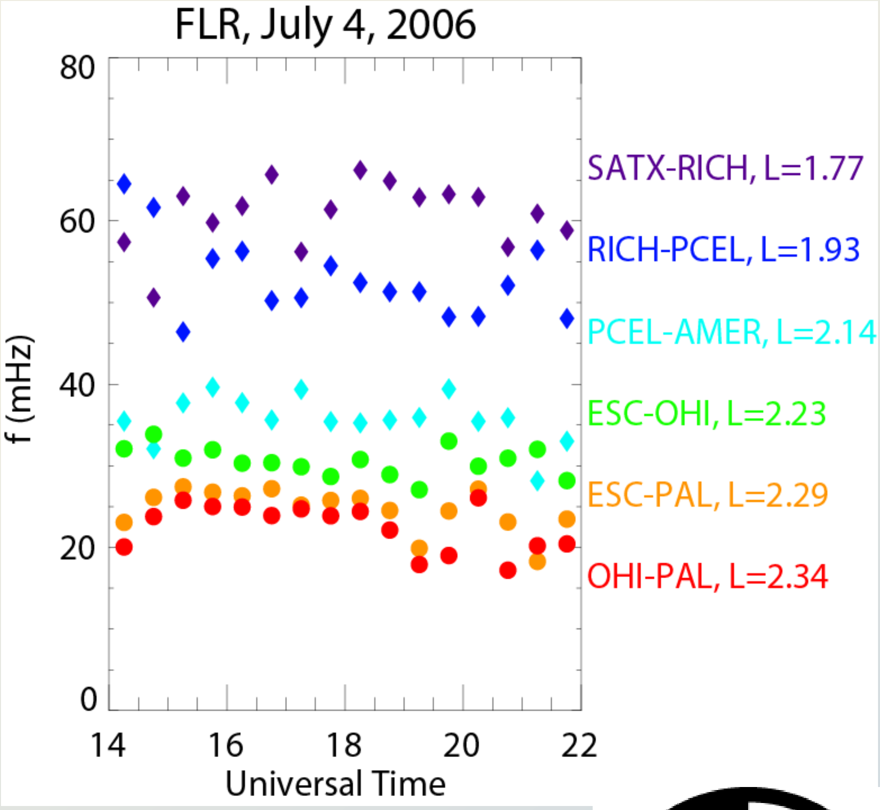
FLR determination for closely spaced pair of stations FIT-JAX

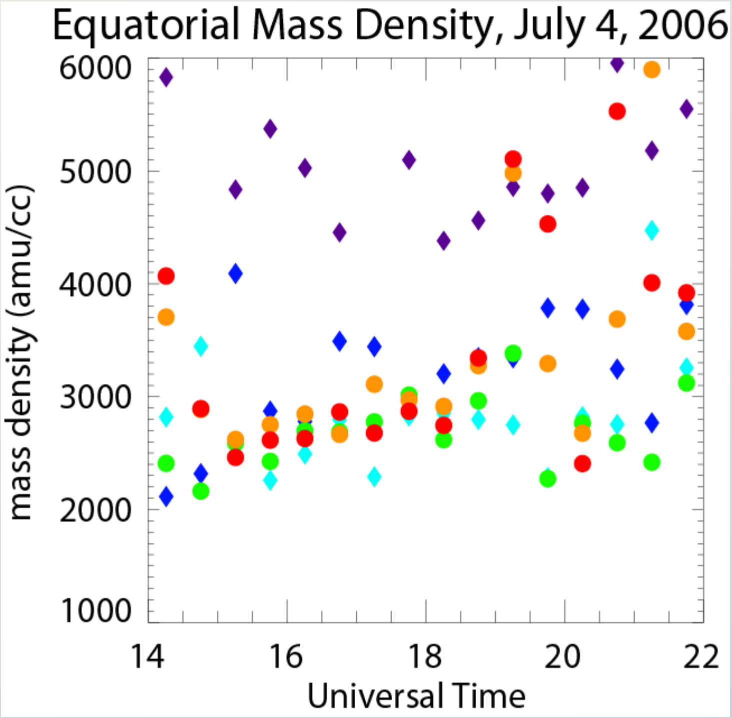


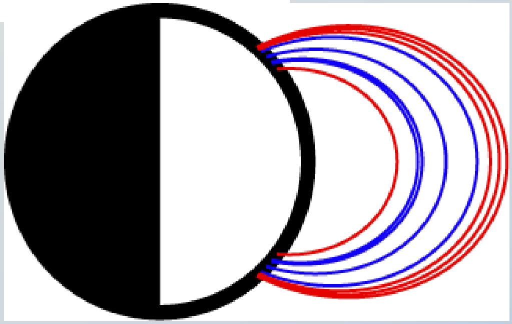
Baranksy et al. [1985]
Waters et al. [1991]
Menk et al. [1999]
Berube et al. [2003]



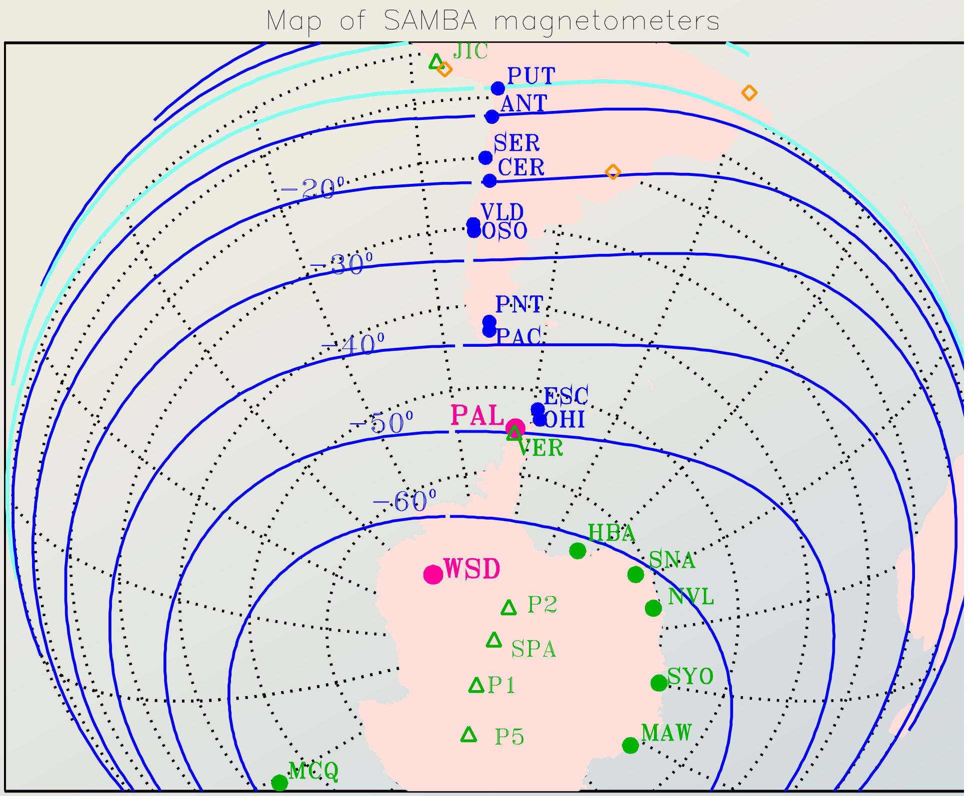
FLR inversion to get equatorial mass density
July 4, 2006 event

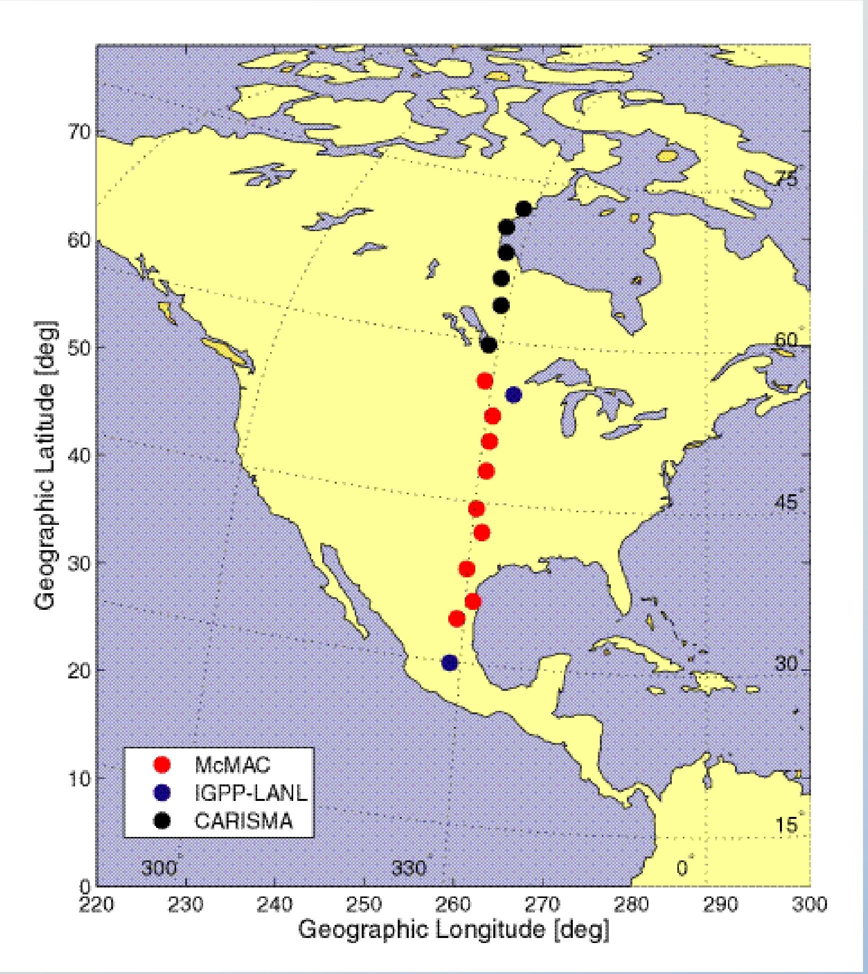




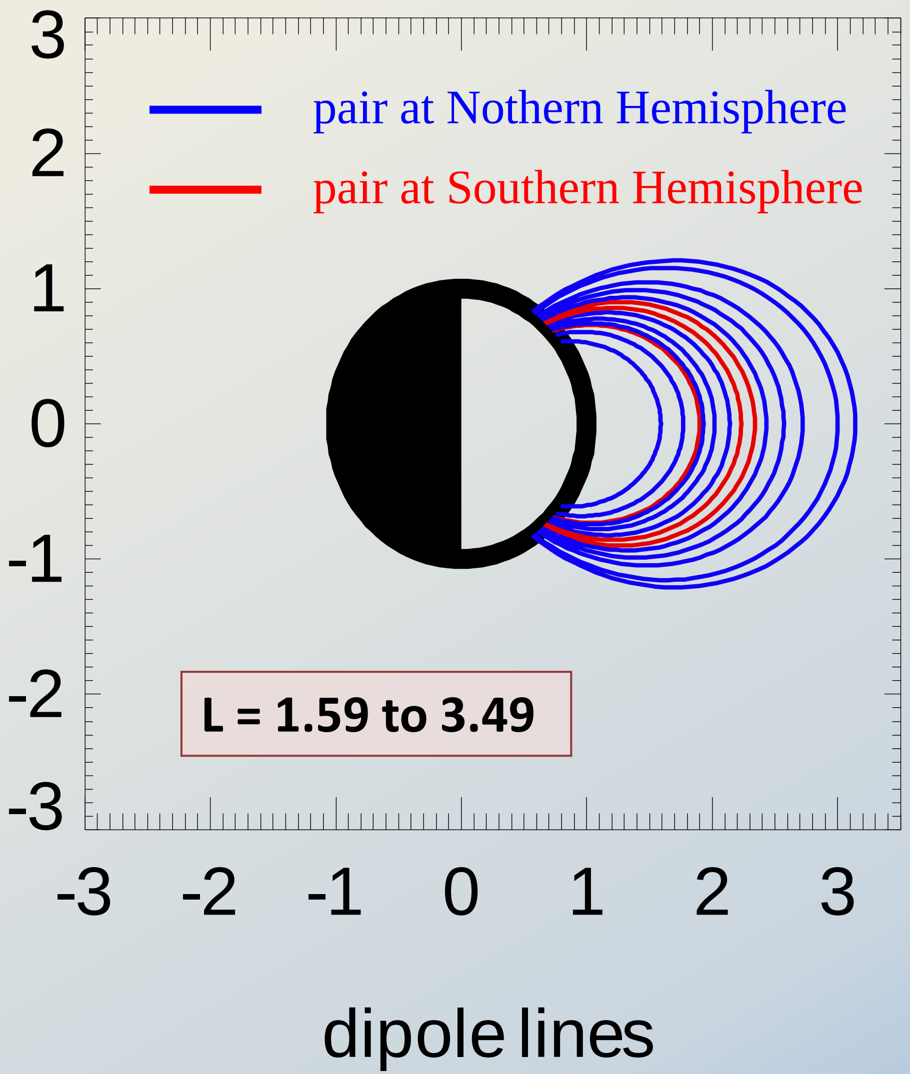


SAMBA and McMAC chains



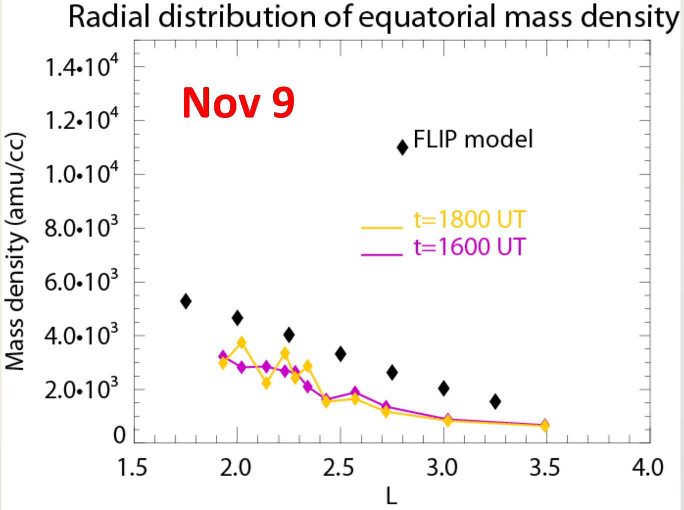


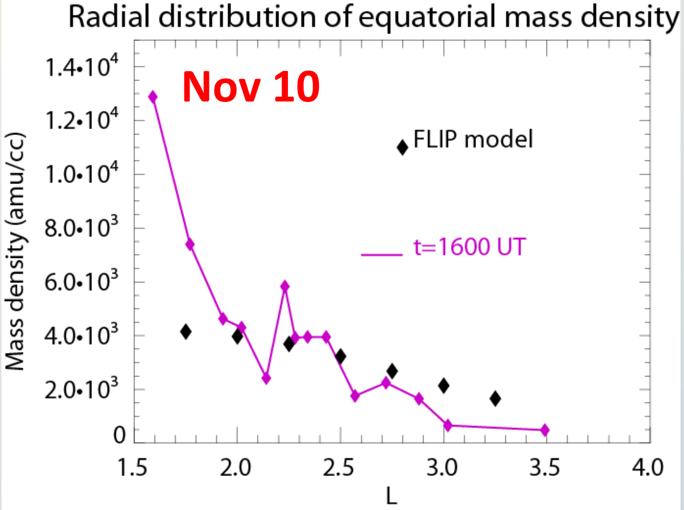
Radial mass density distribution using 13 pairs of stations

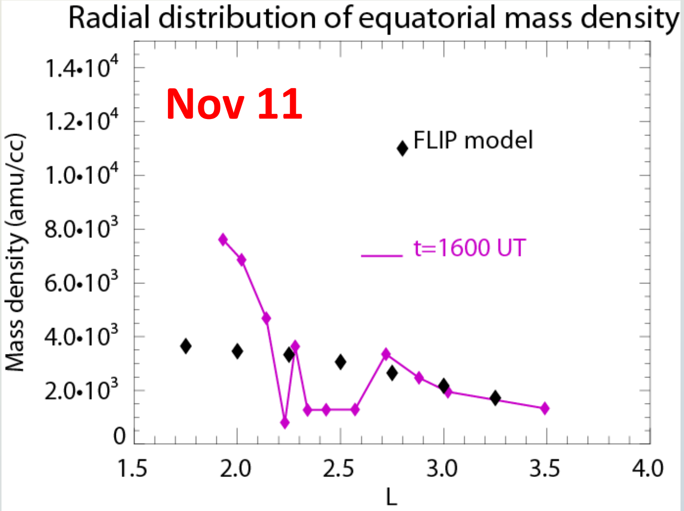


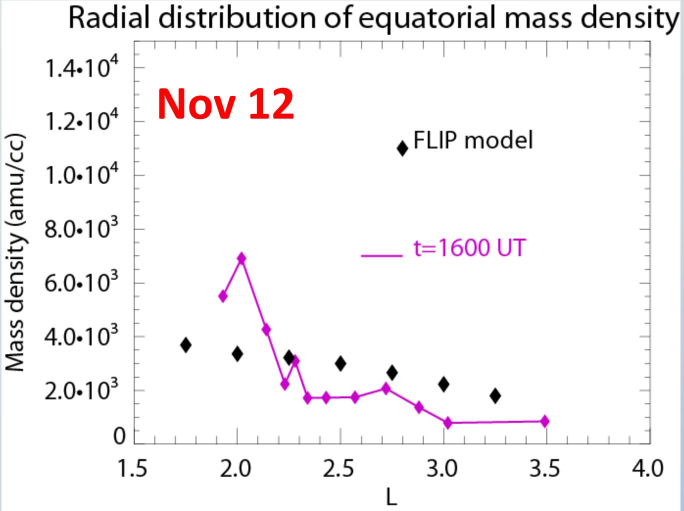
The Nov 9-12 weak storm

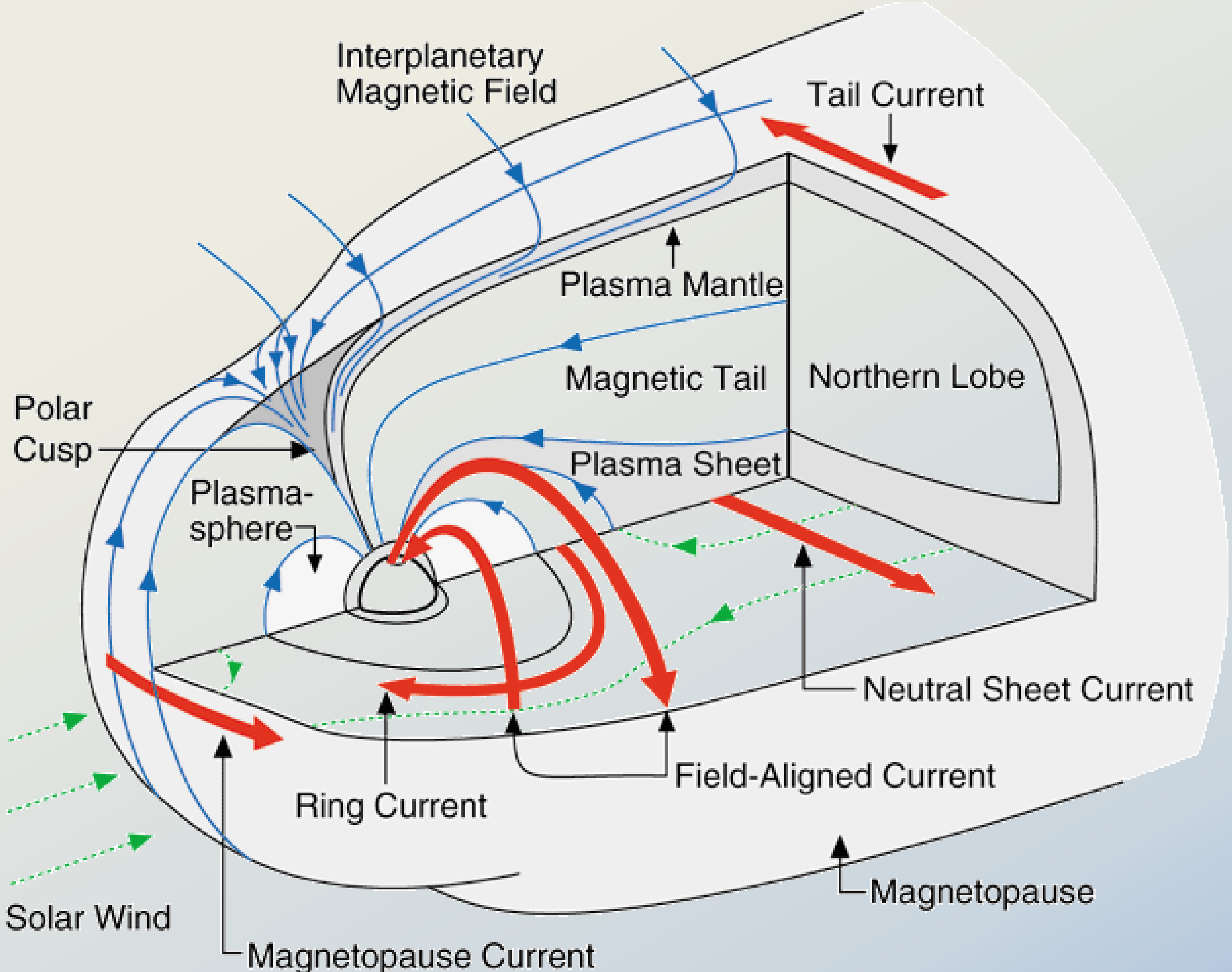
Comparisons of FLR inversion mass densities with the FLIP model







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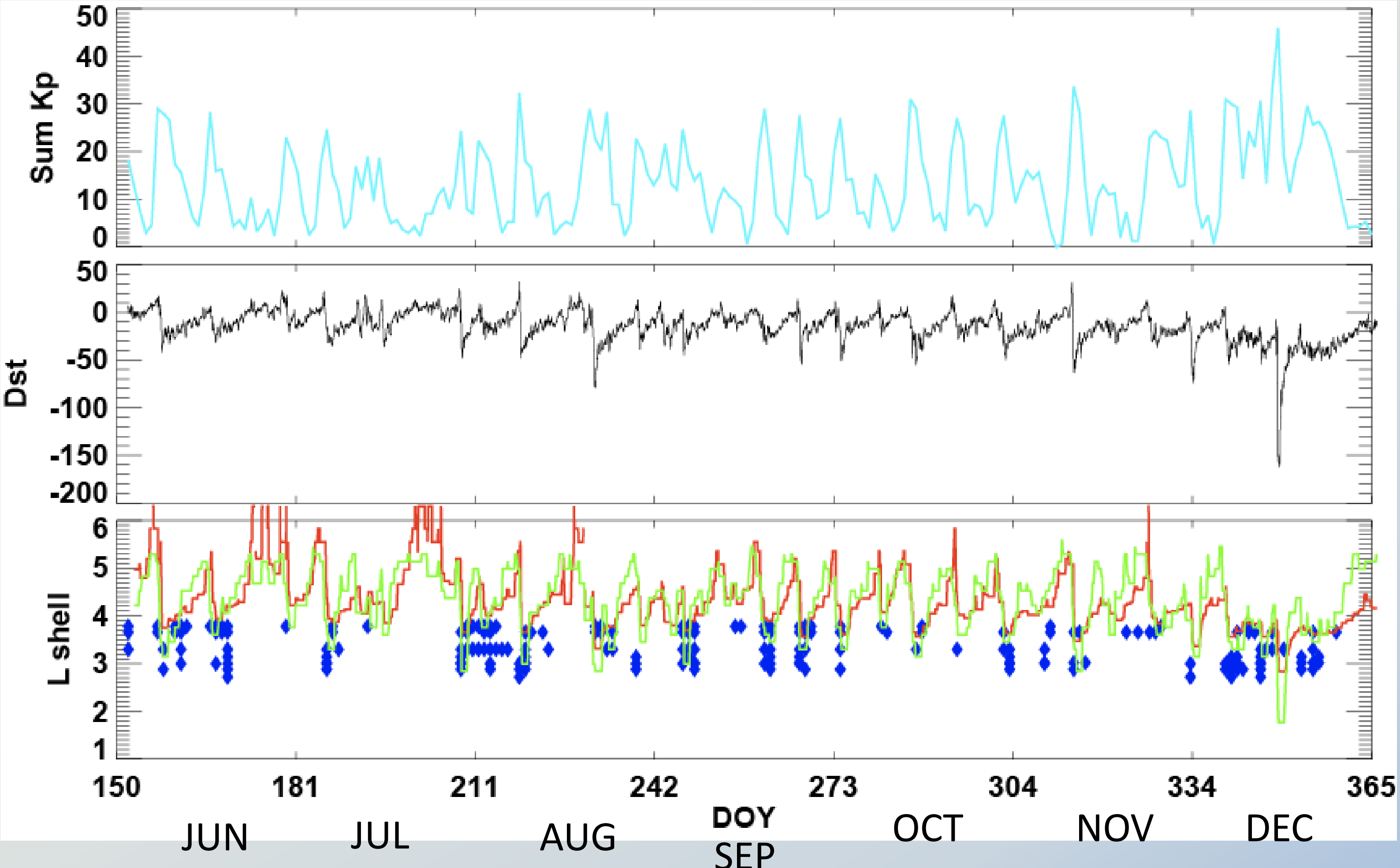
Occurrence of reverse Phase Difference and correlation with models: Jun-Dec 2006



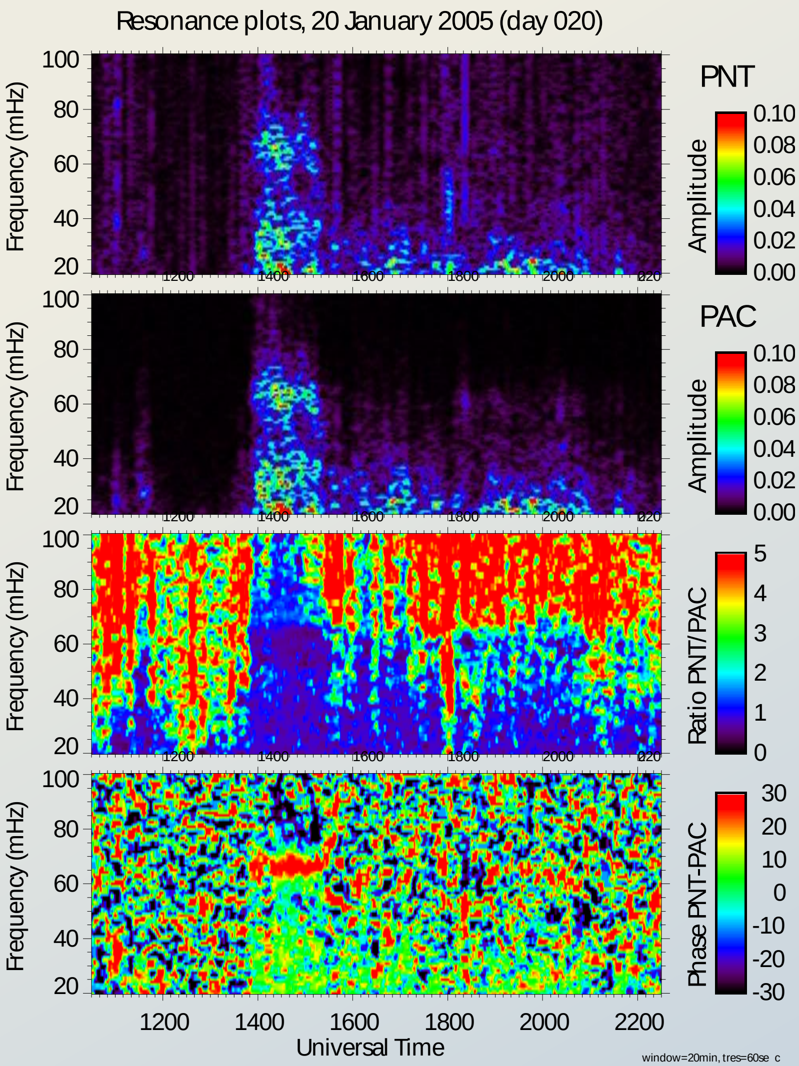
Carpenter and Anderson [1992] , Kp

O'Brien and Moldwin [2003], Dst

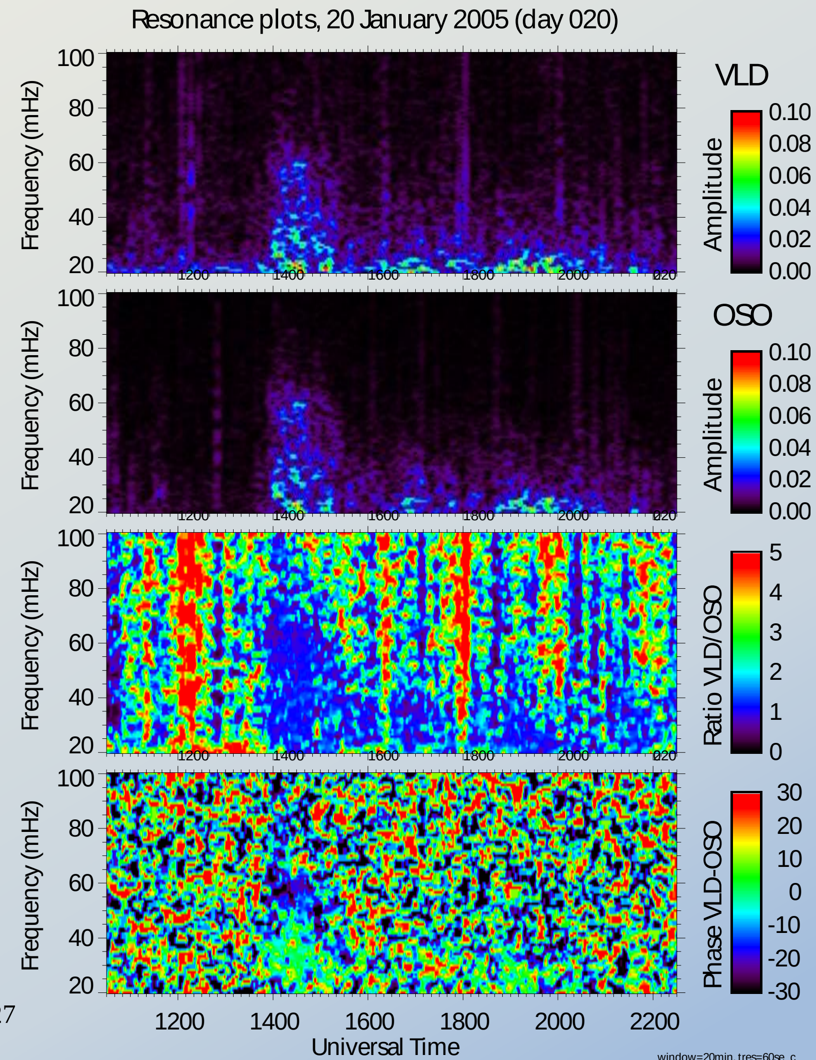
Reverse PD from ground mags

Lowest L detected FLRs

PNT-PAC L=1.67



VLD-OSO L=1.24



Annual FLR occurrence in SH