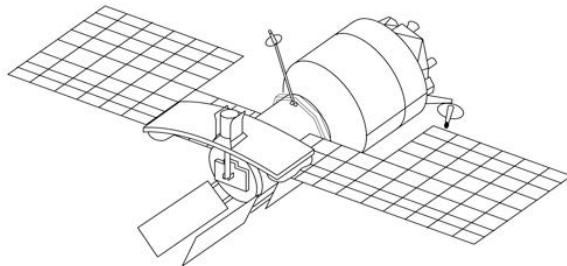




BE OND

Monitoring electromagnetic signals related to earthquakes with satellites and ground-based magnetometer arrays



Georgios Balasis
Senior Researcher
National Observatory of Athens



One Step BEYOND Workshop,
15/10/2015
ESA, Frascati



FP7-Regpot-2012-23-1

-
- The ENIGMA magnetometer array within the frame of BEYOND Center of Excellence
 - Electromagnetic (EM) signals related to earthquakes (EQs)
 - Satellite studies
 - Ground-based studies

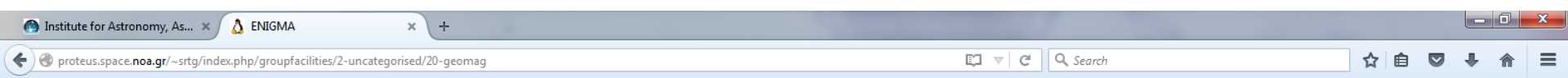
The HELLENIC GEOMAGNETIC ARRAY (ENIGMA)



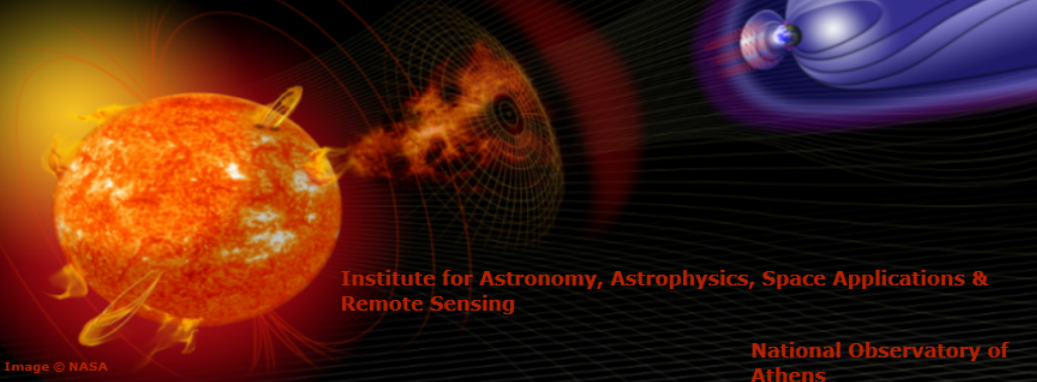
- The National Observatory of Athens (NOA) currently operates ENIGMA (HELLENIC GEOMAGNETIC ARRAY), an array of 3 ground-based magnetometer stations in the areas of Trikala (Klokotos), Attiki (Dionysos) and Lakonia (Velies).
- ENIGMA provides measurements for the study of geomagnetic pulsations, resulting from the solar wind-magnetosphere coupling.
- Ground-based magnetometers have proven to be the workhorse of magnetosphere-ionosphere coupling physics.

- Ground magnetometers enable effective remote sensing of geospace dynamics and therefore their importance in space weather monitoring and research is indisputable.
- *The ENIGMA network is used within BEYOND in an attempt to address the issue of earthquake predictability by studying electromagnetic signals attributed to the coupled lithosphere-atmosphere-ionosphere system as one of the most promising potential pre-seismic transients.*

The old ENIGMA website



Space Research & Technology Group



Institute for Astronomy, Astrophysics, Space Applications & Remote Sensing

National Observatory of Athens

- Home
- Members
- R&D Projects
- Publications
- Facilities
- Services
- News
- Public Outreach



ENIGMA

The Space Research and Technology Group operates the Hellenic GeoMagnetic Array (ENIGMA), an array of 3 ground-based magnetometer stations in the areas of Trikala (Klokotos), Attiki (Dionysos) and Lakonia (Velies) that provides measurements for the study of geomagnetic pulsations, resulting from the solar wind - magnetosphere coupling. ENIGMA is the first magnetometer station array that has ever operated in Greece and within a few years of operation has achieved to become a SuperMAG contributor.

SuperMAG is a worldwide collaboration of organizations and national agencies that currently operate more than 300 ground-based magnetometers. SuperMAG provides easy access to validated ground magnetic field perturbations in the same coordinate system, identical time resolution and with a common baseline removal approach. The purpose of SuperMAG it to help scientists, teachers, students and the general public have easy access to measurements of the Earth's magnetic field.

Ground-based magnetometers have proven to be the workhorse of magnetosphere-ionosphere coupling physics. Ground magnetometers enable effective remote sensing of geospace dynamics and therefore their importance in space weather monitoring and research is indisputable.

The Earth's Magnetic Field



The new ENIGMA website



A screenshot of a web browser displaying the ENIGMA website. The browser's address bar shows 'enigma.space.noa.gr'. The website has a dark blue header with the IAASARS logo and the text 'HellENic GeoMagnetic Array ENIGMA Space Research & Technology Group'. The main content area features a large image of the Earth's magnetic field with the text 'THE EARTH'S MAGNETIC FIELD' and a 'READ MORE' button. Below this is a 'WELCOME TO ENIGMA' section with a paragraph of text and an 'ABOUT US' button. The footer contains a copyright notice and a paragraph about ENIGMA's status as a SuperMAG contributor. The browser's taskbar at the bottom shows various icons and the system clock indicating 6:15 μμ on 13/10/2015.



HellENic GeoMagnetic Array ENIGMA

Space Research & Technology Group

[HOME](#)

[ABOUT US](#)

[SCIENTIFIC INFO](#)

[ENIGMA STATIONS](#)

[ENIGMA DATA AND PRODUCTS](#)

[OUR TEAM](#)

THE EARTH'S MAGNETIC FIELD

[READ MORE](#)

© Copyright, ESA and AOES Medialab

WELCOME TO ENIGMA

The Space Research and Technology Group operates the HellENic GeoMagnetic Array (ENIGMA), an array of 3 ground-based magnetometer stations in the areas of Trikala (Klokotos), Attiki (Dionysos) and Lakonia (Velles) that provides measurements for the study of geomagnetic pulsations, resulting from the solar wind - magnetosphere coupling.

[ABOUT US](#)

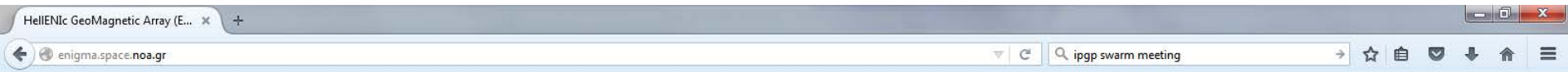
ENIGMA is the first magnetometer station array to operate in Greece, and within a few years of operation has achieved the status of a SuperMAG contributor. SuperMAG is a worldwide

A new geophysical service offered by



A screenshot of a web browser displaying the ENIGMA website. The browser's address bar shows "enigma.space.noa.gr". The website has a blue header with the IAASARS logo and the text "Hellenic GeoMagnetic Array ENIGMA" and "Space Research & Technology Group". A navigation menu on the left lists: HOME, ABOUT US, SCIENTIFIC INFO, ENIGMA STATIONS, ENIGMA DATA AND PRODUCTS, and OUR TEAM. The main content area features a satellite map of Greece with three magnetometer stations marked: Klokotos (Trikala), Dionysos (Attiki), and Velles (Lakonia). A "READ MORE" button is overlaid on the map. Below the map, the text "WELCOME TO ENIGMA" is displayed, followed by a paragraph: "The Space Research and Technology Group operates the Hellenic GeoMagnetic Array (ENIGMA), an array of 3 ground-based magnetometer stations in the areas of Trikala (Klokotos), Attiki (Dionysos) and Lakonia (Velles) that provides measurements for the study of geomagnetic pulsations, resulting from the solar wind - magnetosphere coupling." Below this text is a yellow button labeled "ABOUT US". At the bottom of the page, a small line of text reads: "ENIGMA is the first magnetometer station array to operate in Greece, and within a few years of operation has achieved the status of a SuperMAG contributor. SuperMAG is a worldwide". The Windows taskbar at the bottom shows the time as 6:17 μm on 13/10/2015.

A new geophysical service offered by



ENIGMA INSTRUMENTATION

- THL: GEOMAG-02 magnetotelluric station (GEOMAGNET, Ukraine)
- DION: GEOMAG-02M fluxgate magnetometer (GEOMAGNET, Ukraine)
- VLI: GEOMAG-02 magnetotelluric station (GEOMAGNET, Ukraine)
- 2 x Observatory variometer CTU-Vario (Czech Technical University in Prague)
- 1 x GSM-90F1 v7.0 Overhauser magnetometer (GEM Systems, Canada)
- Ag/AgCl electrodes (GFZ Potsdam, Germany)



IAASARS

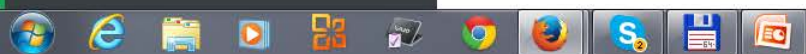
Hellenic GeoMagnetic Array

ENIGMA

Space Research & Technology Group

HOME

ABOUT US



A new geophysical service offered by



ENIGMA DATA AND PRODUCTS



IAASARS

Hellenic GeoMagnetic Array ENIGMA

Space Research & Technology Group

HOME

ABOUT US

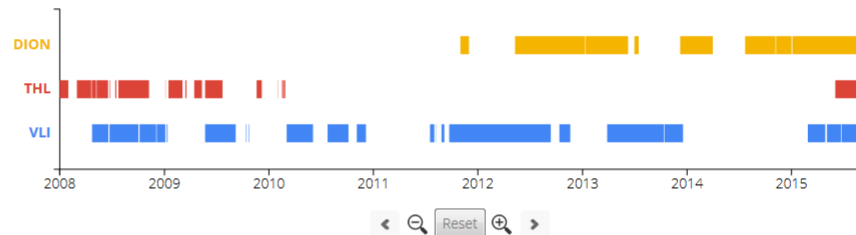
SCIENTIFIC INFO

ENIGMA STATIONS

ENIGMA DATA AND PRODUCTS

OUR TEAM

DATA COVERAGE ?



MAGNETOGRAMS

	Date ?	Station	Plot type ?	Variables ?
From:	2008 / Jan / 01 : 01 : 01	DION	Simple	<input type="checkbox"/> ΔBx <input type="checkbox"/> ΔBy <input type="checkbox"/> ΔBz
To:	2008 / Jan / 01 : 01 : 01			

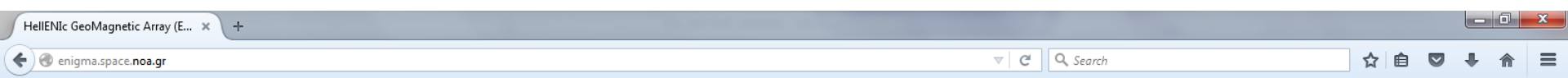
Search Last Daily Plot

DAILY WAVELET SPECTRA

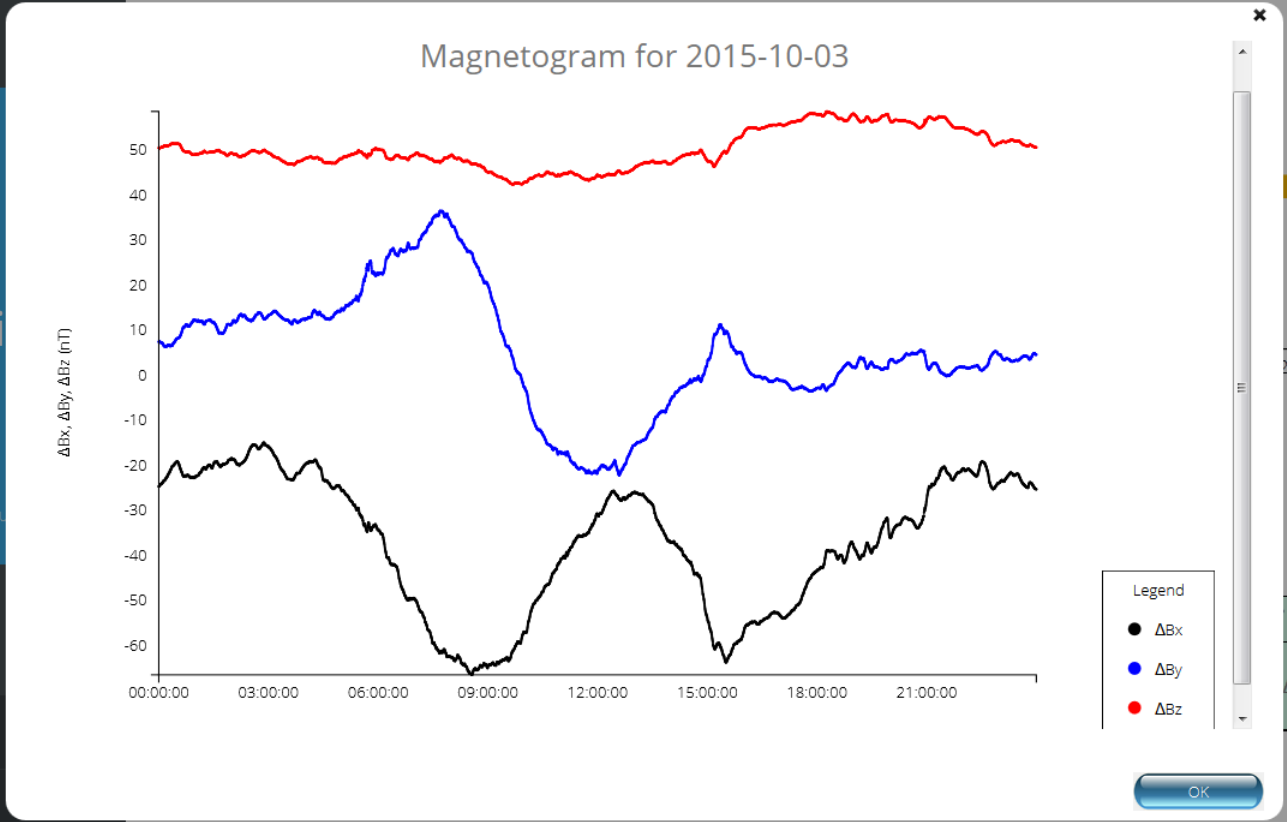
Date	Station	Bandwidth
2008 / Jan / 01 : 01 : 01	DION	Pc3

Search

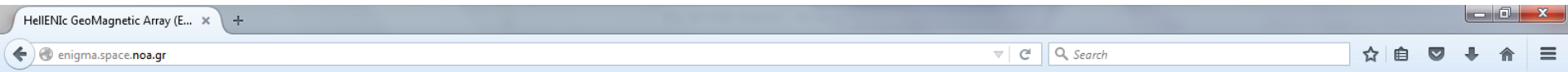
Geomagnetic data service offered by



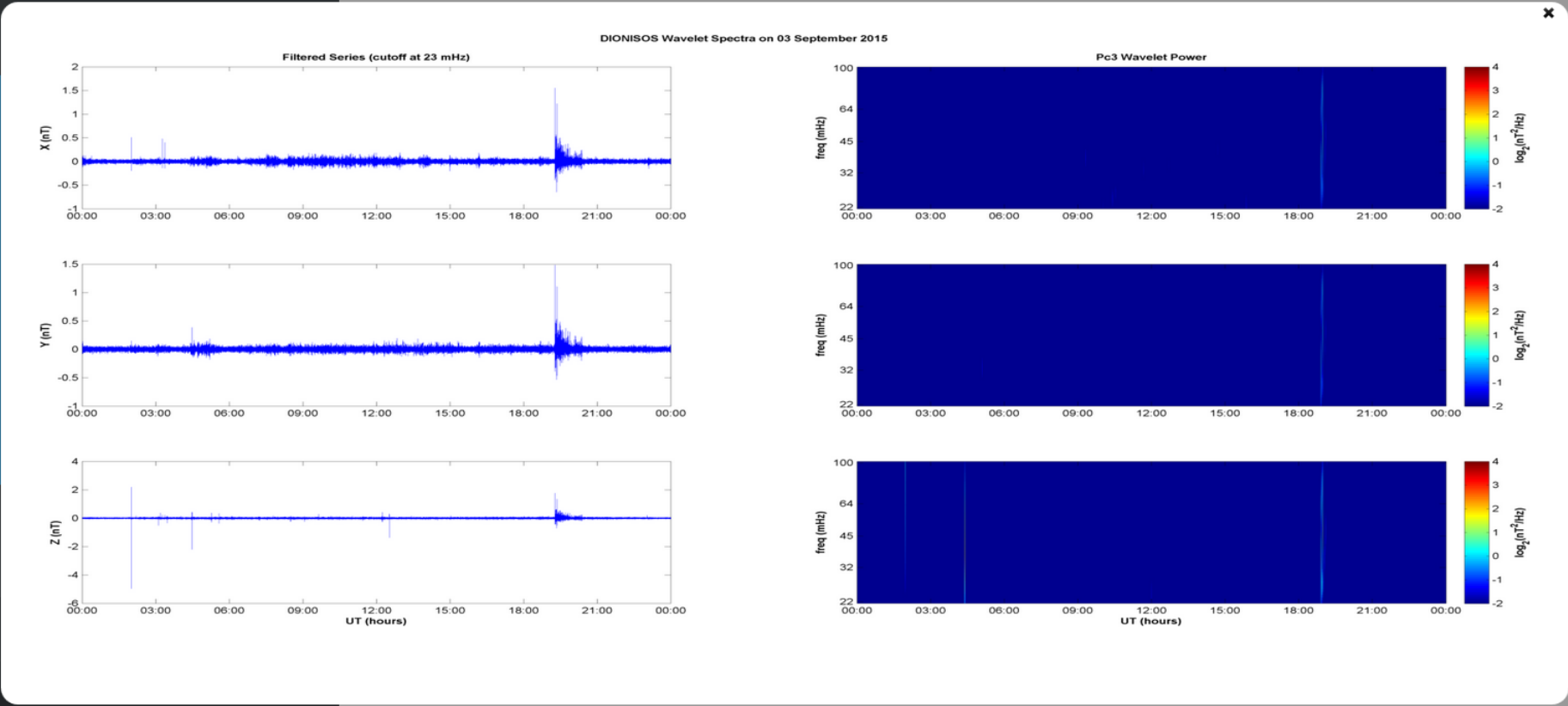
IAASARS
Hellenic GeoMagnetic Array
ENIGMA
Space Research & Technology Group



Geomagnetic data service offered by



MAGNETOGRAMS



EM signals related to EQs: Proof of concept



2/16/2015

BBNET - Database of revised events



INSTITUTE OF GEODYNAMICS
NATIONAL OBSERVATORY OF ATHENS



Hellenic Seismic Network
HL

Home

Network Introduction

Seismicity

Automatic, Revised, Moment Tensors

Database

Search revised events

Noise Monitoring

Quality control

Networks

Real Time Plotting, Information

RSS

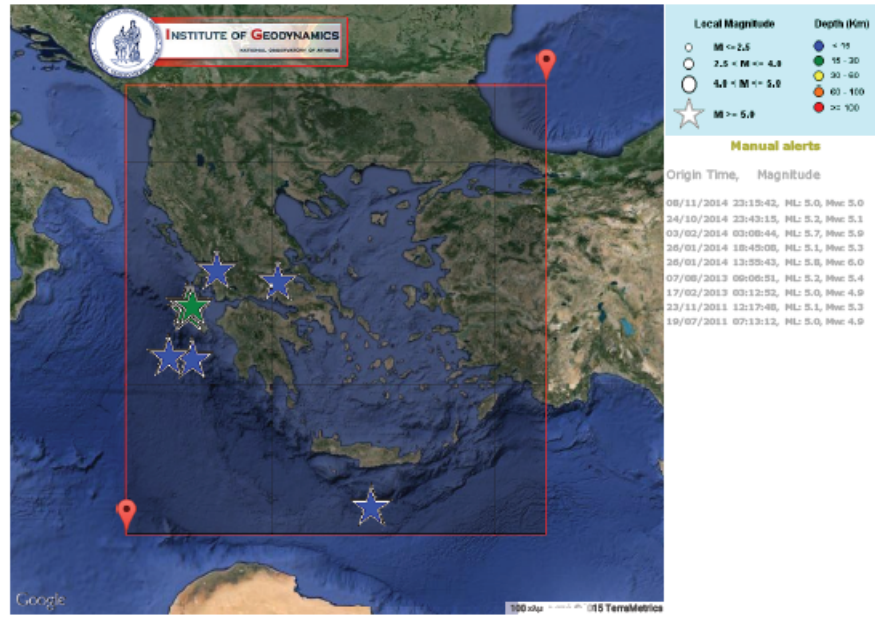
Automatic / Revised Alerts

Database of revised events

Google Maps API created by Athanasios Keskemper, migrated to v3 by Youth Reports

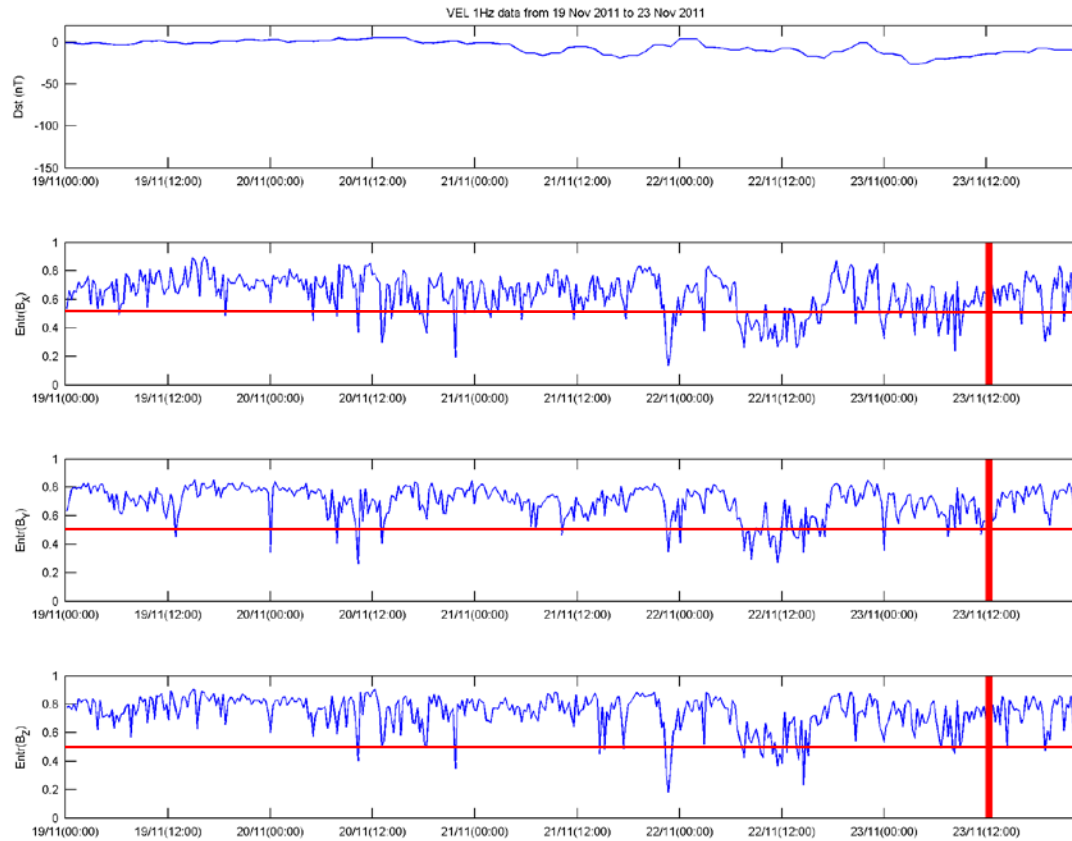
	Date	Latitude	Longitude	Depth (km)	Local magnitude	
FROM	2011 / Jan / 01 Cal	33.5110	18.8439	0	5	<input type="checkbox"/> Mw only
TO	2015 / Jan / 01 Cal	42.4428	29.4344	20	8	

Search

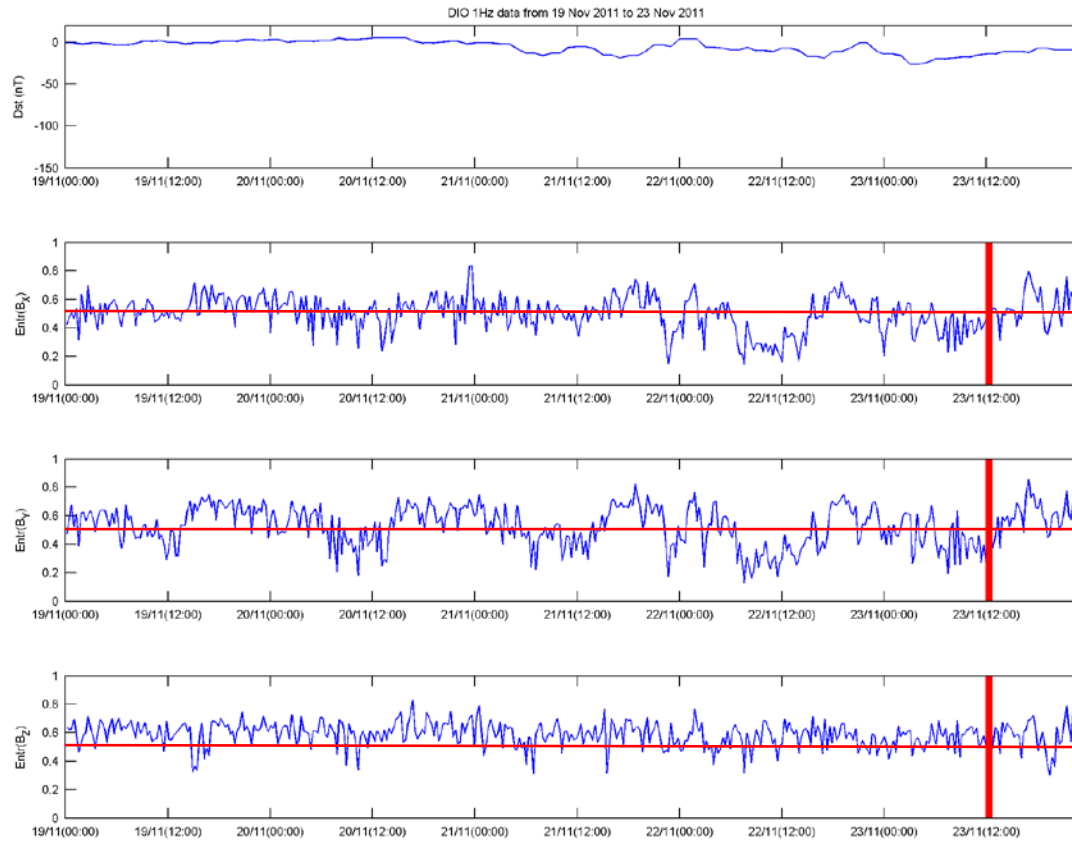


#	Event-Code	Origin Time (GMT)	Latitude (°N)	Longitude (°N)	Depth (km)	Magnitude	
1	evman141108231542	2014-11-08 23:15:42	38.0998	20.4400	18.4	5.0	
2	evman141024234315	2014-10-24 23:43:15	38.9172	21.1458	12.5	5.2	!
3	evman140203030844	2014-02-03 03:08:44	38.2462	20.3958	11.3	5.7	!
		2014-01-26					

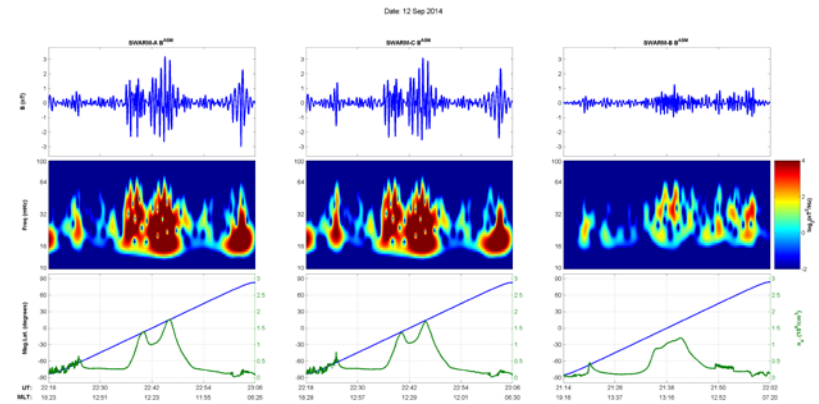
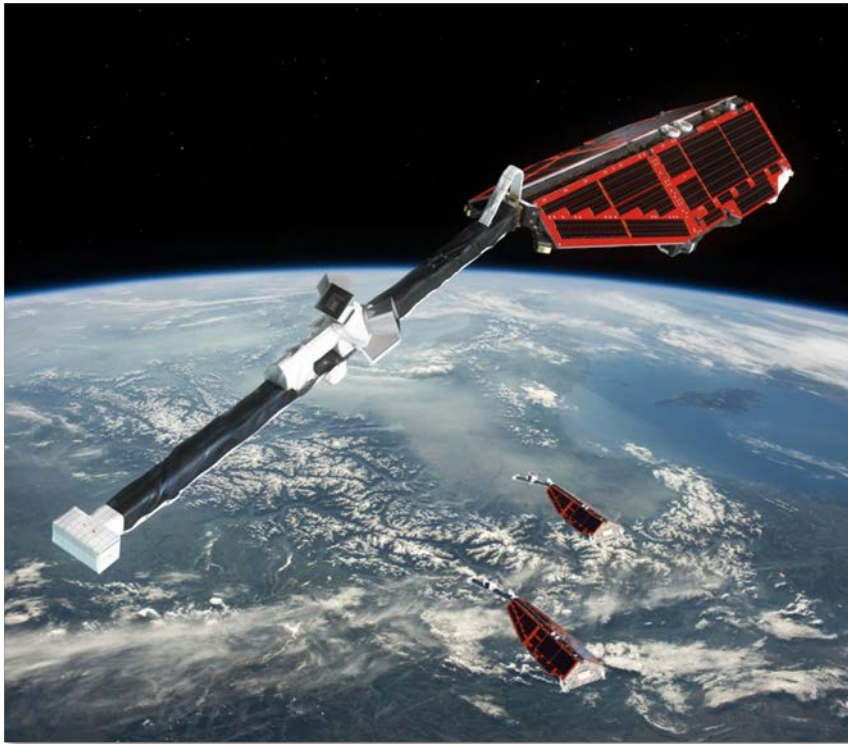
Entropy analysis of Velies data around 23/11/2011 M5 EQ



Entropy analysis of Dionysos data around 23/11/2011 M5 EQ



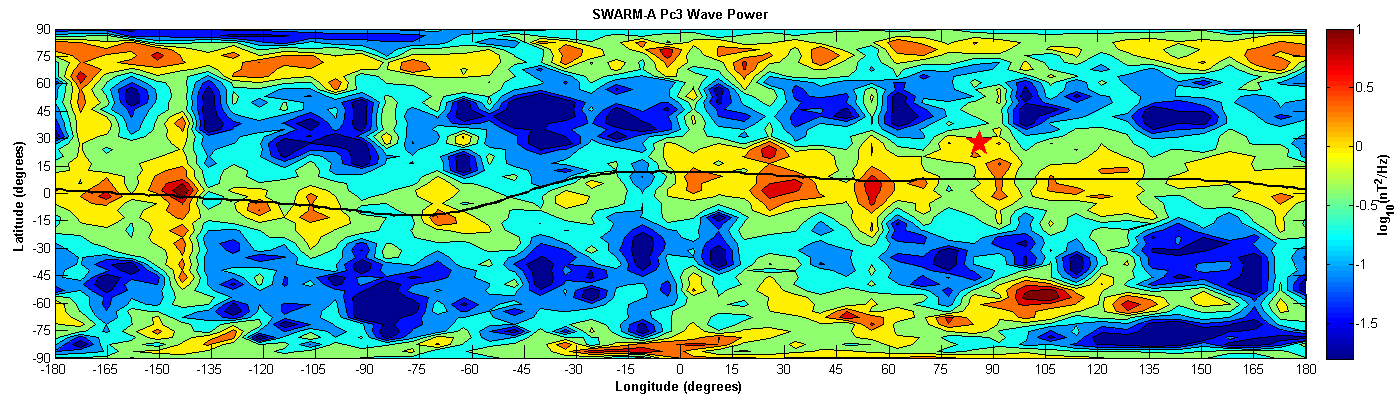
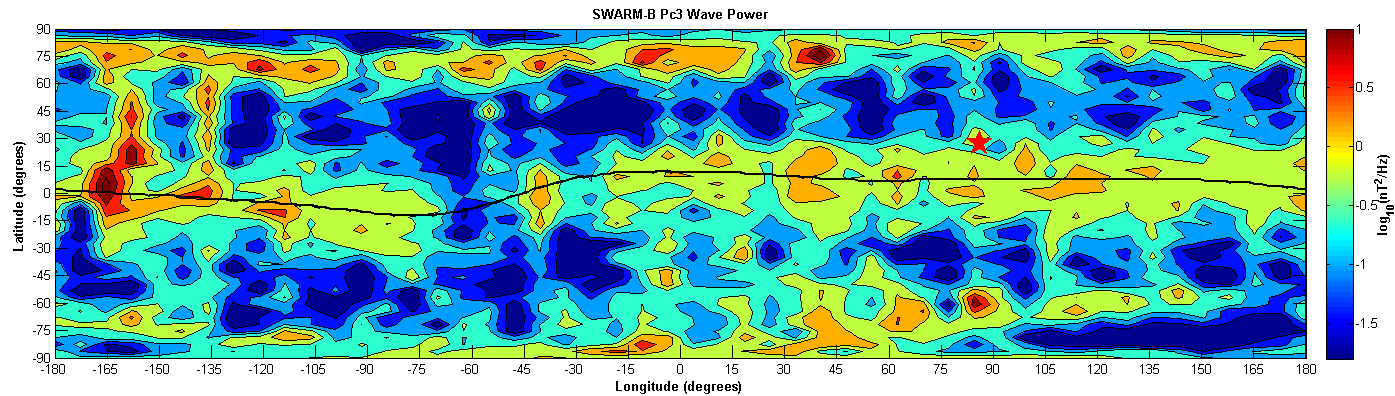
ULF wave power features in the topside ionosphere revealed by Swarm observations



- Balasis, G., C. Papadimitriou, I. A. Daglis, and V. Pilipenko (2015), *Geophys. Res. Lett.*, 42, 6922–6930, doi:10.1002/2015GL065424.

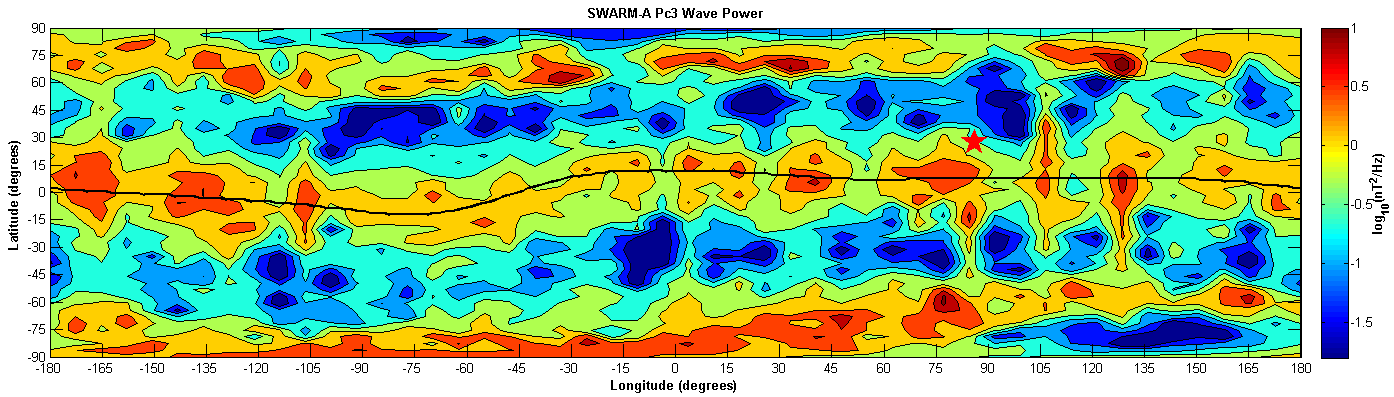
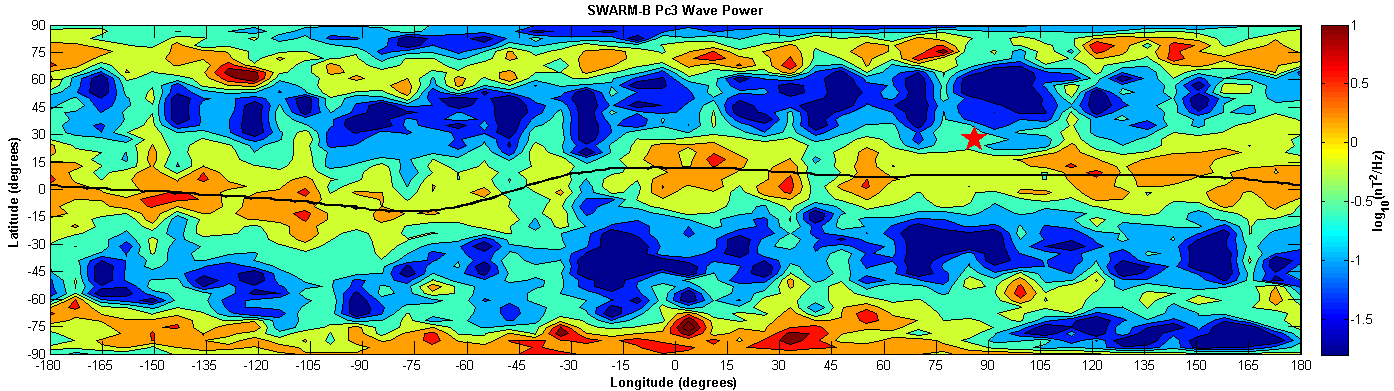
Copyright / ESA and AOES Medialab

SWARM Pc3: Apr 1st – June 15th 2014

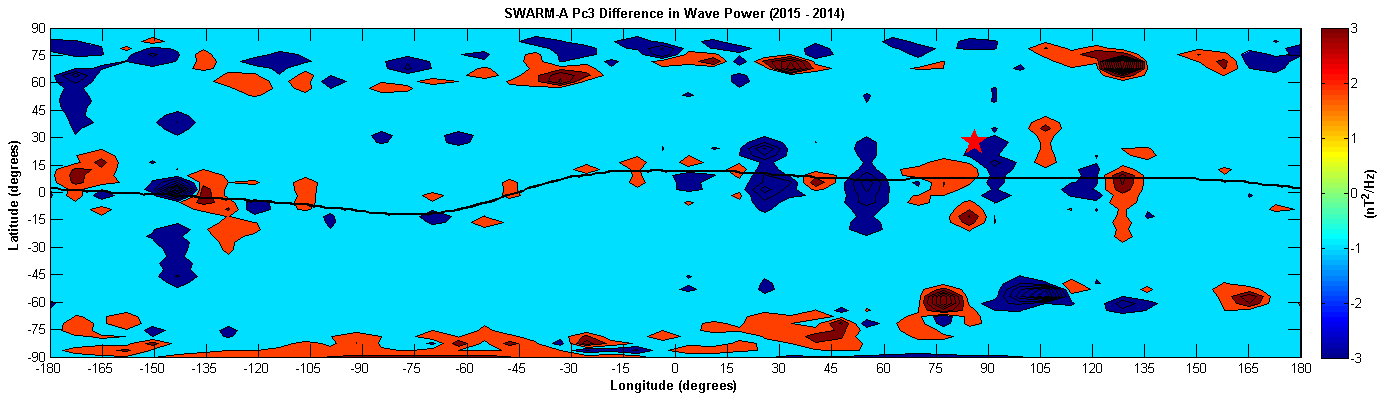
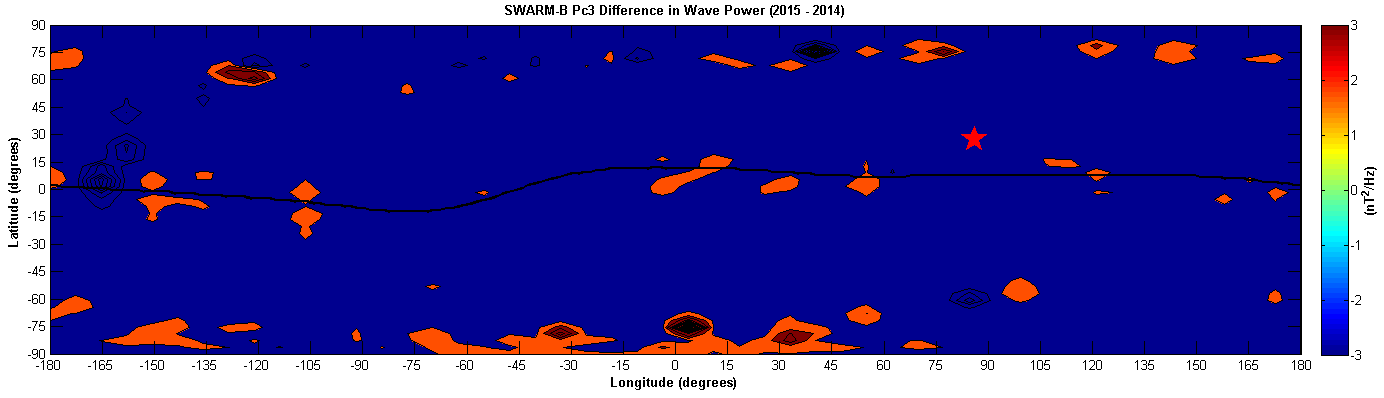


“Swarm & Nepal EQ” in collaboration with the group of A. De Santis (INGV),
PI of ESA SAFE project

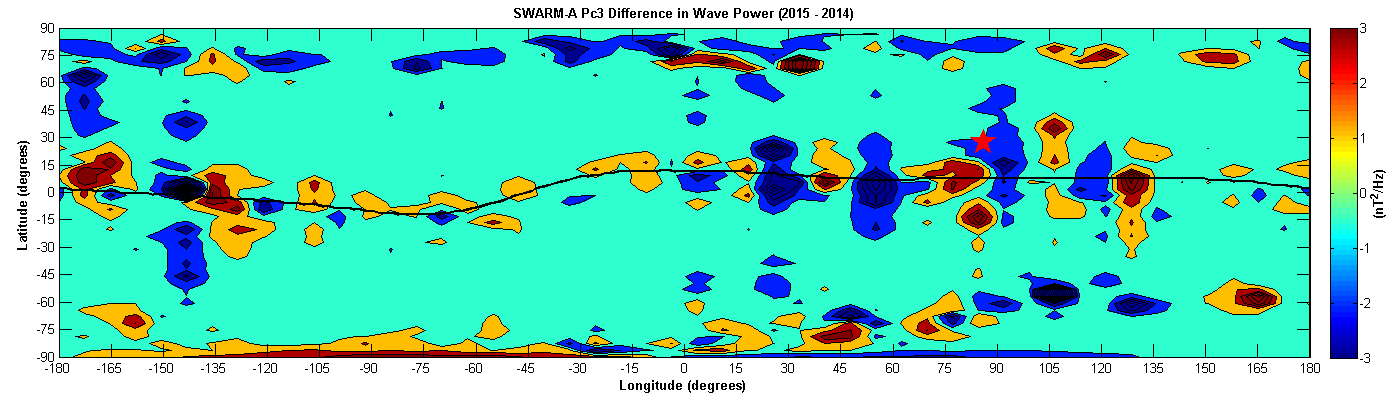
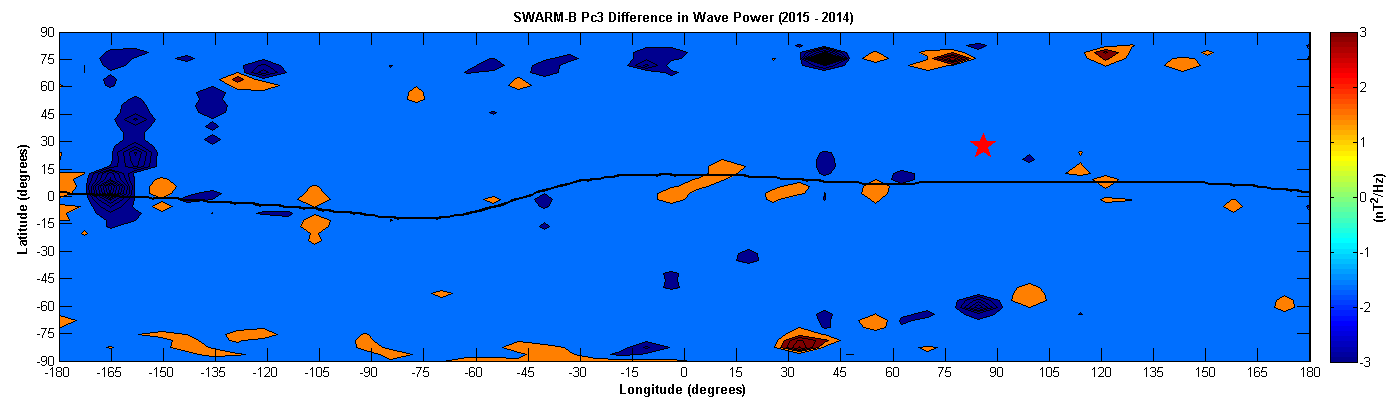
SWARM Pc3: Apr 1st – June 15th 2015



SWARM Pc3: Difference 2015 – 2014



SWARM Pc3: Difference 2015 – 2014 (Waves)



SWARM Pc3: Difference 2015 – 2014 (Instab.)

