Polar space weather studies: achievements and opportunities

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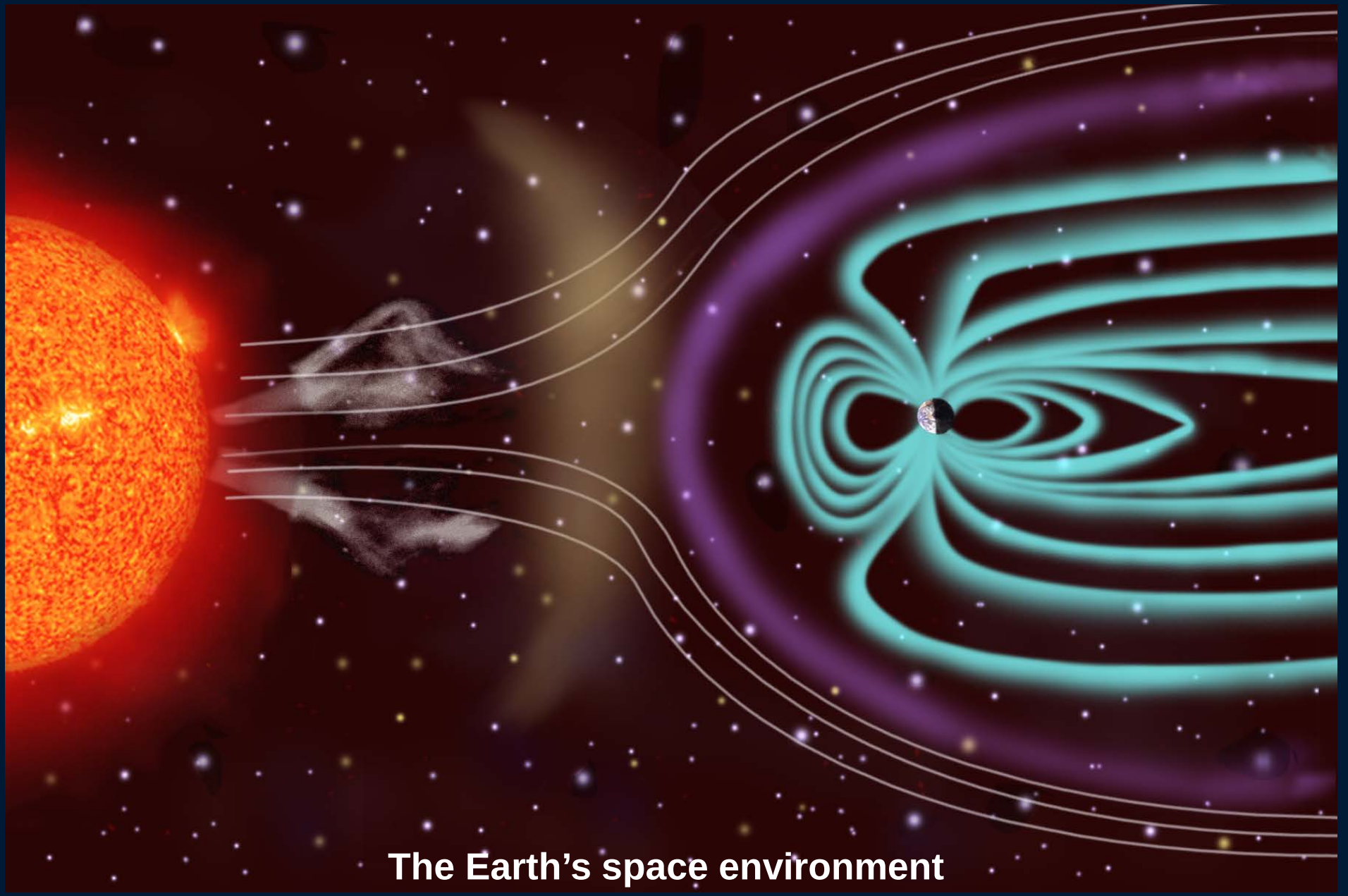
SANSA Space Science Directorate

SANSA Space Science Directorate in Hermanus.

Since June 2007 Regional ISES Space Weather Warning Center for Africa



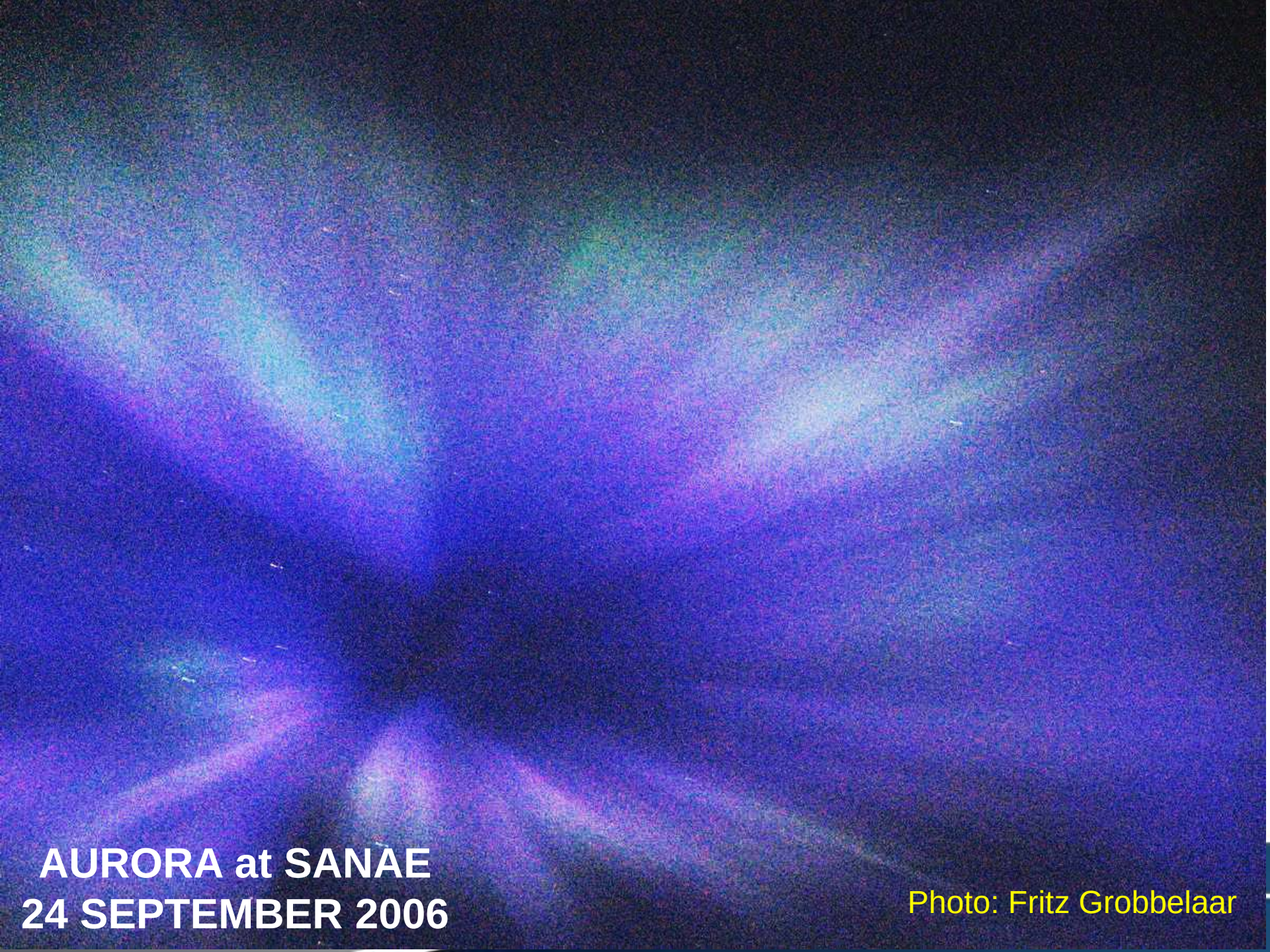
The Earth’s space environment

Schematic diagram of the sun, solar wind, and Earth’s magnetosphere.
This is the environment in which space weather is generated.

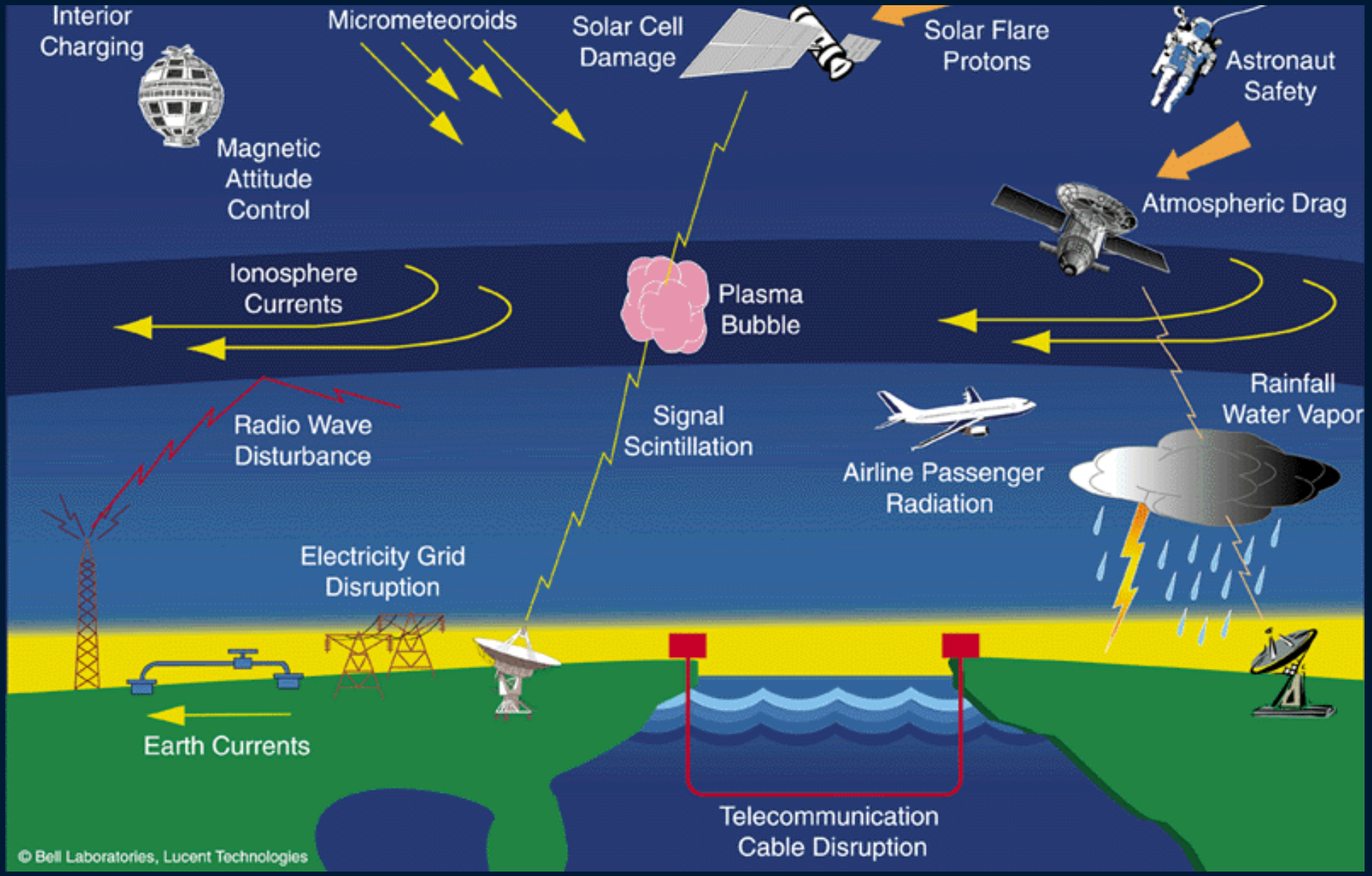
Photo: Fritz Grobbelaar **SANAE-IV Antarctica, May 2005**

Photo: Andre Benade

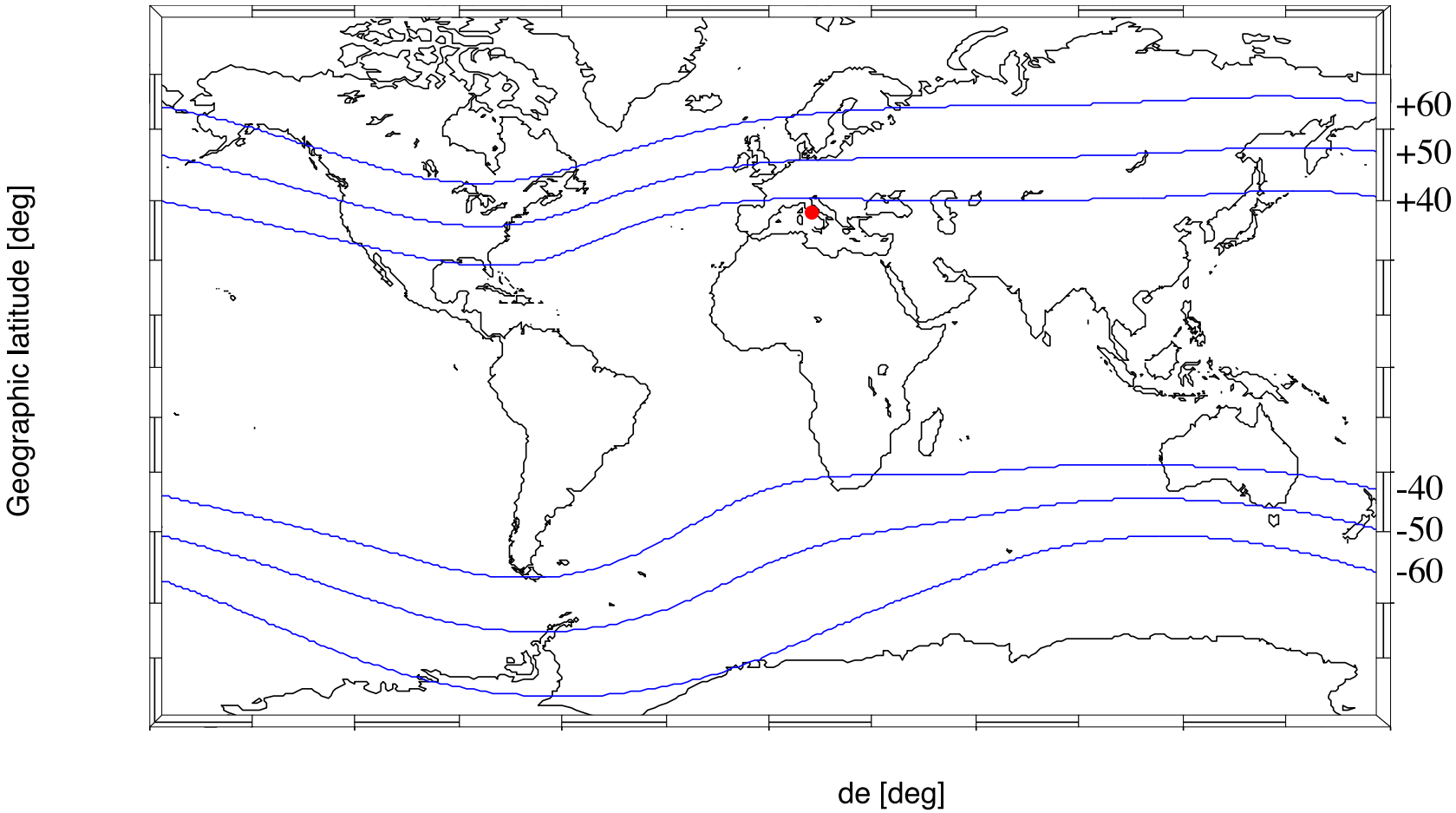
SANAE-IV Antarctica


AURORA at SANAE
24 SEPTEMBER 2006
Photo: Fritz Grobbelaar

Space Weather effects on technologies



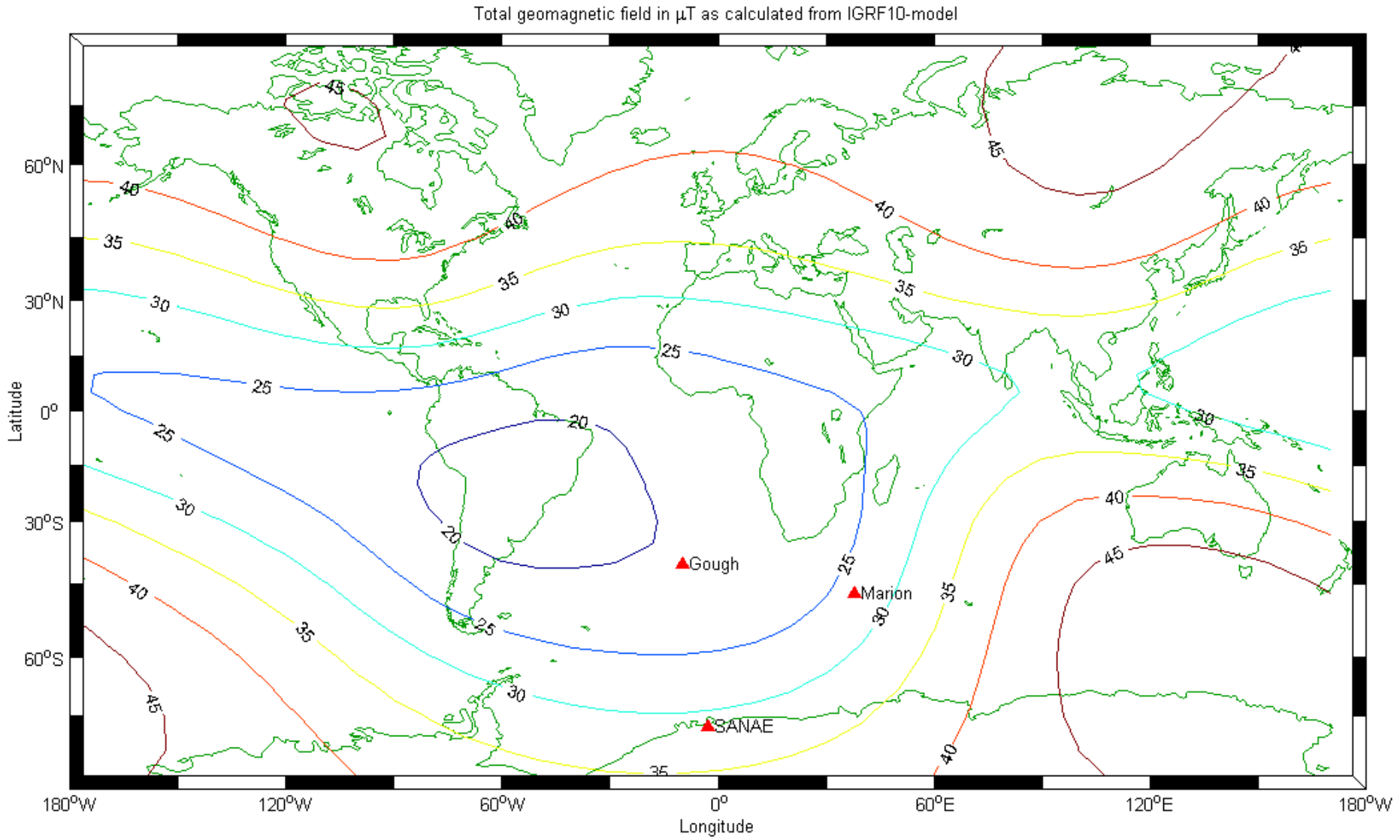
Geomagnetic mid-latitudes

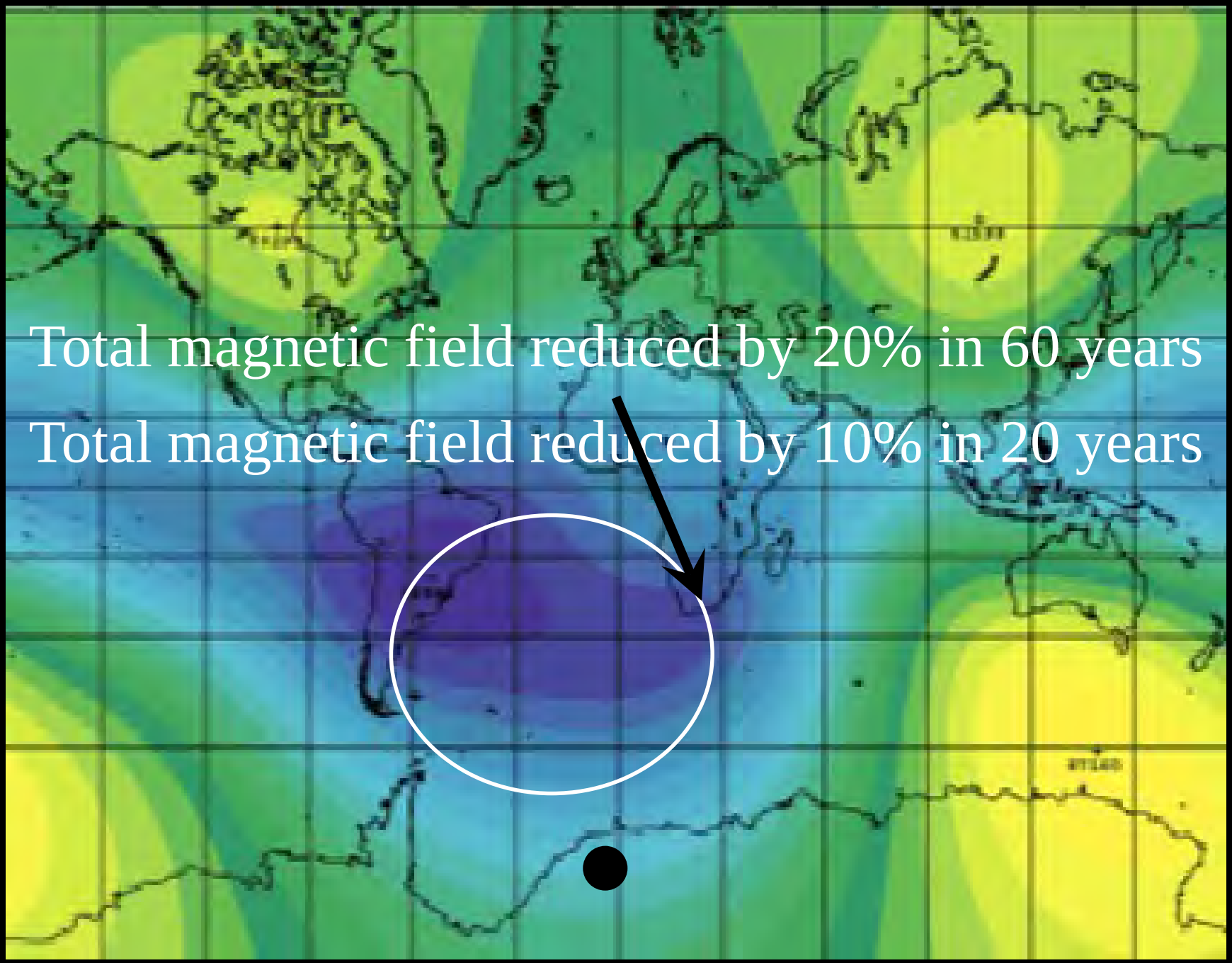


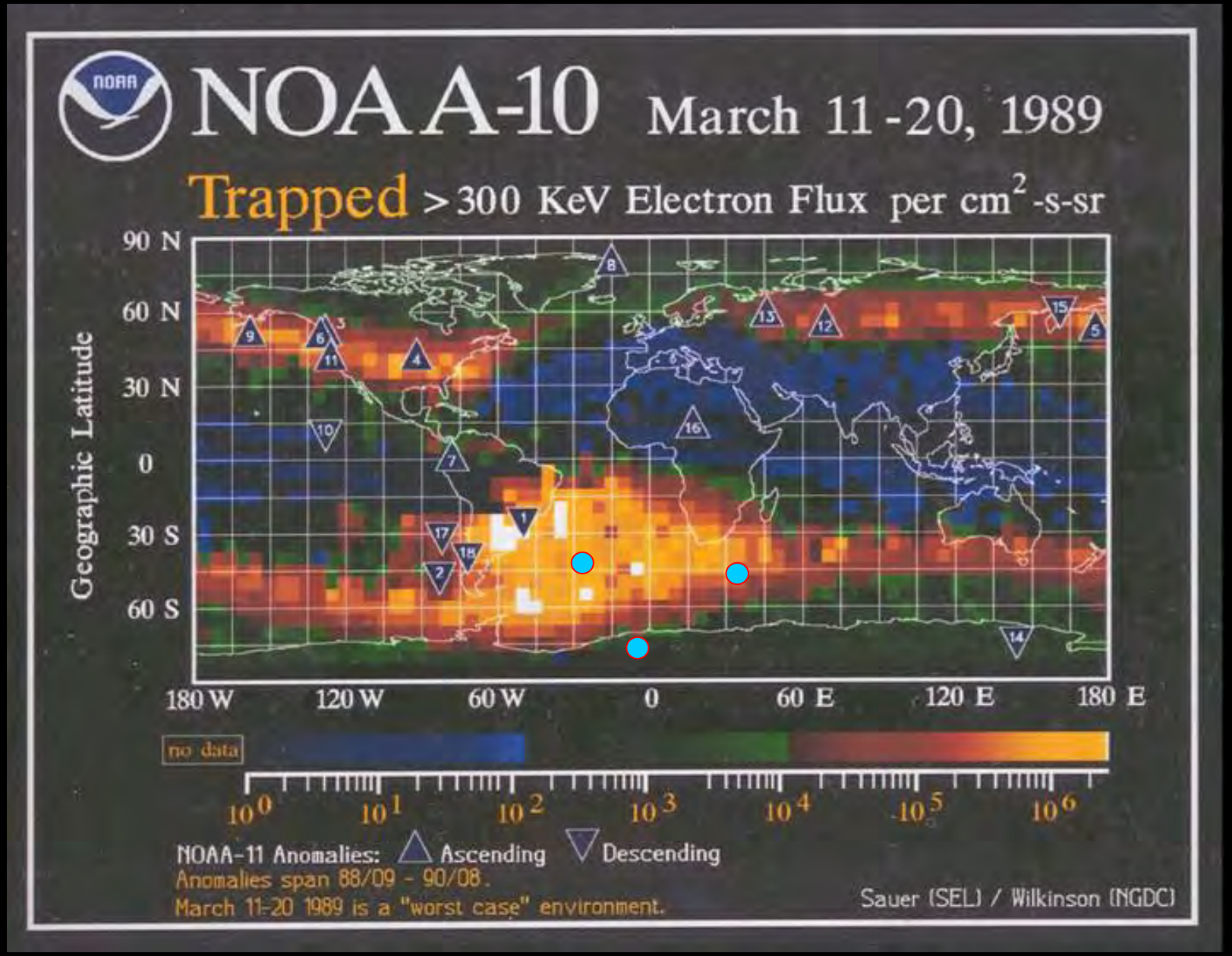
Space Weather generally has less impact in the geomagnetic mid-latitude regions than in the high latitude and low latitude regions. Space Weather can nevertheless cause the same kind of interruptions on radio communications and power systems as occurs in high latitudes.

SOUTH ATLANTIC MAGNETIC ANOMALY

Main Field Total Intensity F at ground level from IGRF10



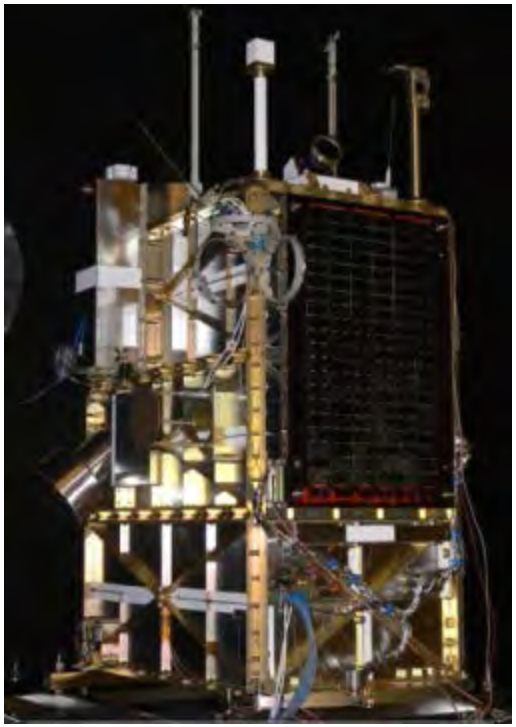

Total magnetic field reduced by 20% in 60 years
Total magnetic field reduced by 10% in 20 years

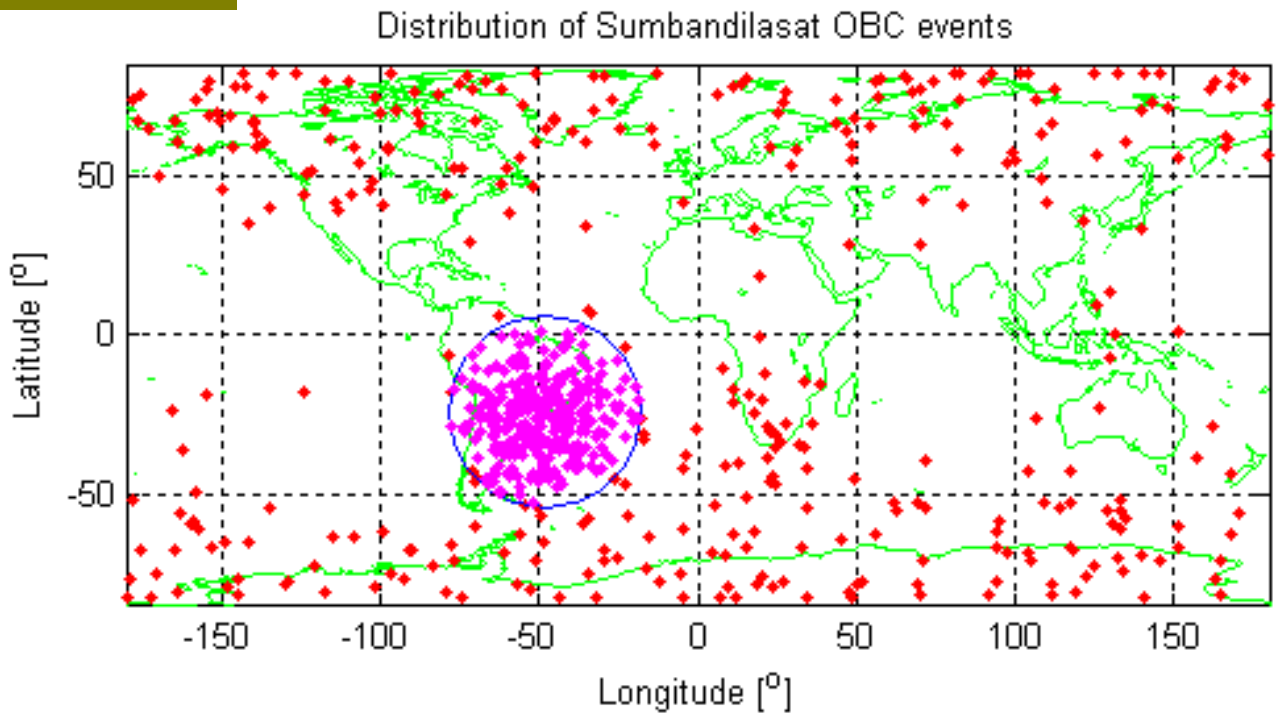


Flux of energetic electrons observed by a polar orbiting satellite 800 km above the Earth's surface during a large magnetic storm.

SAMA - On Board Computer (OBC) events

Sumbandilasat,
Launched: 17 Sep 2009
Failed: 13 August 2011





The circle encloses 46.5% of OBC events (resets) at 600 km.

ICSU

INTERNATIONAL 2007 2008
POLAR YEAR

Polar Science with Global Impact

- IPY1 (1882-83)
- IPY2 (1932-33)
- IPY3 (1957-58)
- **IPY4 (2007-09)**

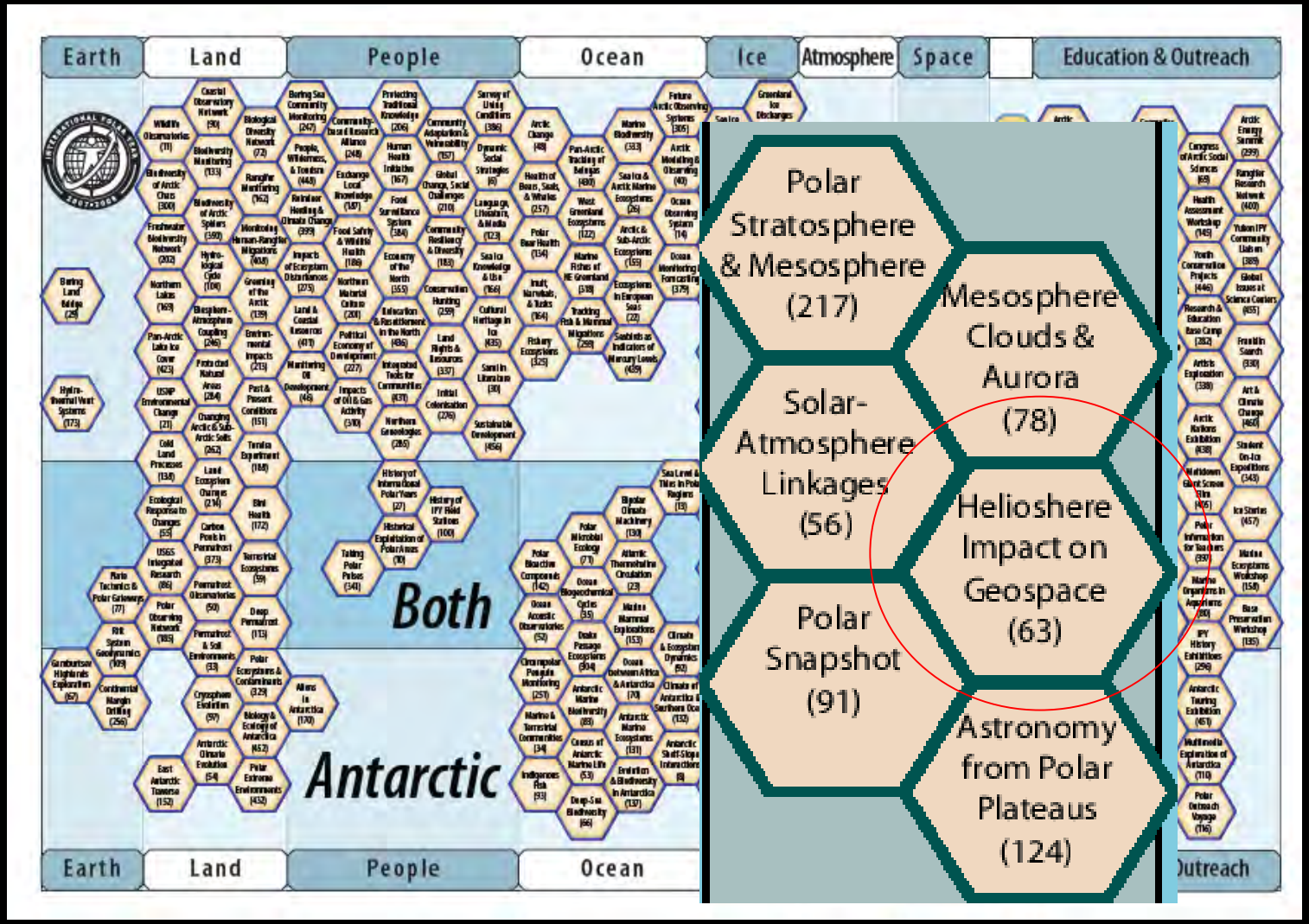
Opening Ceremony
1 March 2007
Palais de la découverte

ICSU INTERNATIONAL POLAR YEAR 2007/2008 PROJECT:

Polar Space Weather studies during IPY/IHY

Better understanding of the Space Weather and Geomagnetic Storm mechanisms will allow more effective prediction of storm intensity and better mitigation actions to be taken.

IPY4 (Participants in ICESTAR project 63)



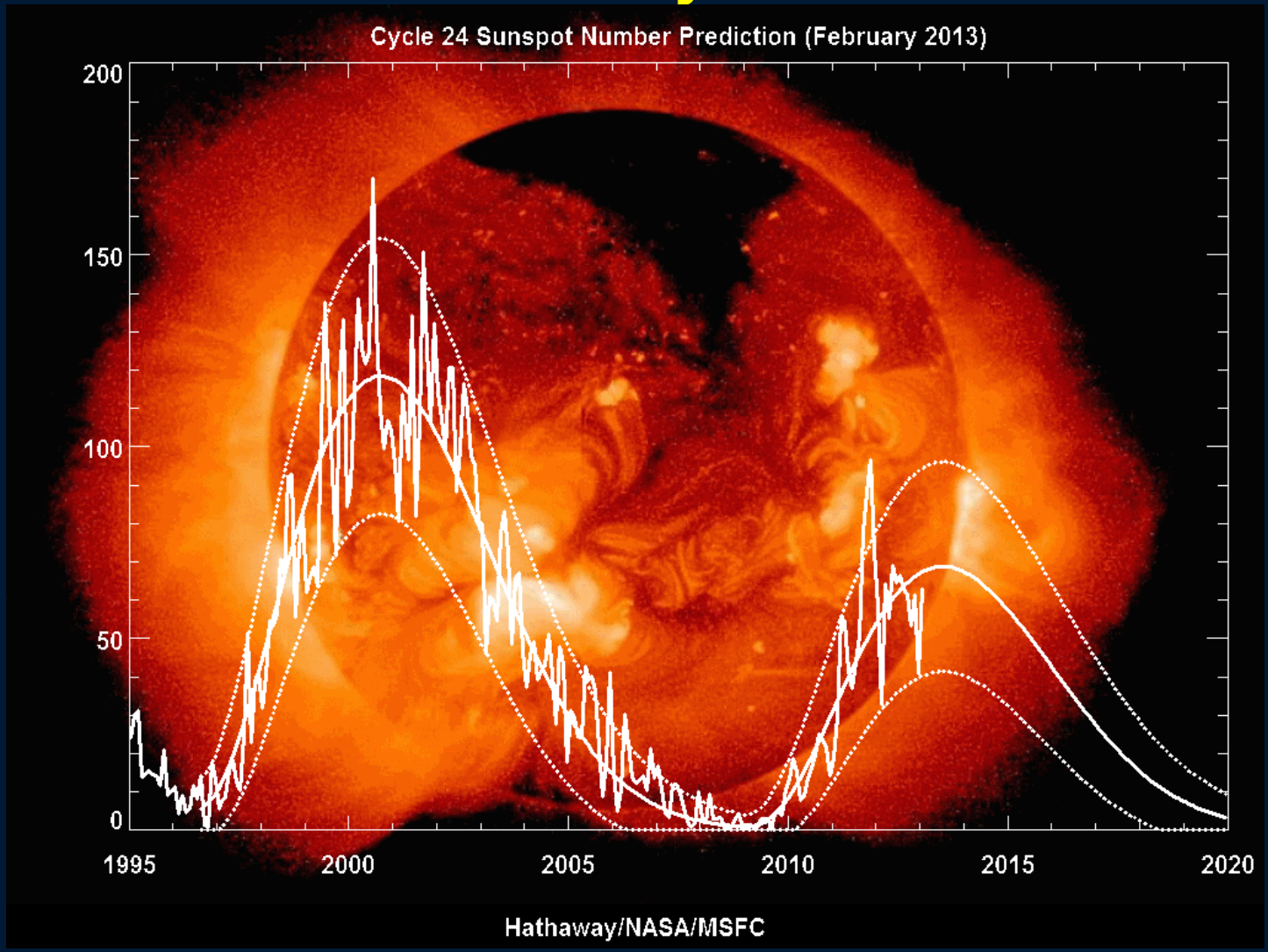
IPY Space Weather Objectives

The relationship between solar activity and subsequent processes in the solar wind and heliosphere, the magnetosphere, the ionosphere, and the neutral atmosphere is crucial to understand space weather and its impact on modern technology.

Space physics studies the very complicated system involving energetic particles, and high and low energy plasmas, strongly coupled to changing magnetic fields of the sun. To understand it, it is necessary to make observations on a global scale of a variety of phenomena, by different techniques, both in space and on the ground.

Because of the large inclination of the geomagnetic field at high latitudes, the high latitude Southern Oceans and Antarctic regions are particularly important for ground based observations.

Solar Cycle 24



The solar cycle is based on the number of sunspots. The number of sunspots increase and decrease over an 11 year cycle. The peak of the next solar cycle, cycle 24, is currently predicted to have a smoothed sunspot number maximum of about 69 and peak in June of 2013.

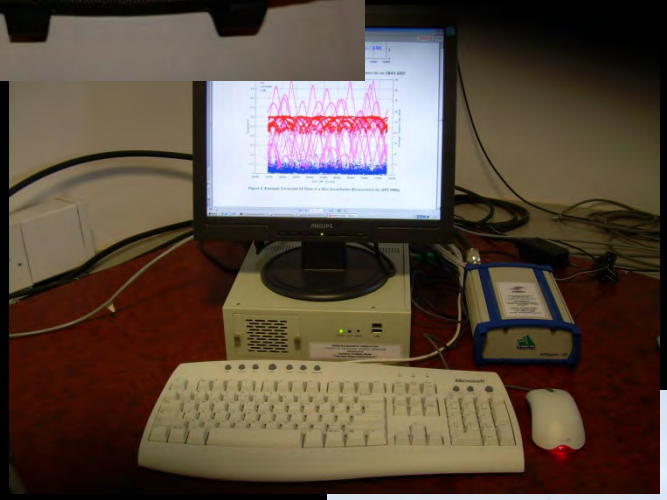
http://solarscience.msfc.nasa.gov/predict.shtml


Equator
S10°
Tropic of Capricorn
S30°
Hermanus
34.42° S, 19.22° E
E 10°
E 30°
Prime Meridian
W 10°
Gough Island
40.0° S, 10.0° W
E 50°
W 30°
E 70°
Marion Island
46.87° S, 37.86°E
S50°
E 90°
W 50°
E 110°
W 70°
SANAE IV
72.0° S, 2.5° W
Antarctic Circle
S70°
N
W
E
S
©2006 Google
Pointer 38°48'16.72" S 22°01'23.74" E
Streaming 100%
Eye alt 4676.73 mi

Physical Science Instrumentation at SANAE-IV

- HF radar
- Aurora cameras
- Radio Opacity meters
- Magnetometers
- VLF-receiver
- GPS receiver for ionospheric tomography
- GPS Scintillation receiver
- Neutron Monitors
- Seismometer
- Meteorology

New Instruments installed at SANAE in 2006-2008 for IPY Polar Space Weather Studies



- Overhauser magnetometer for total geomagnetic field measurements.

- GPS ionospheric scintillation monitor for ionospheric studies

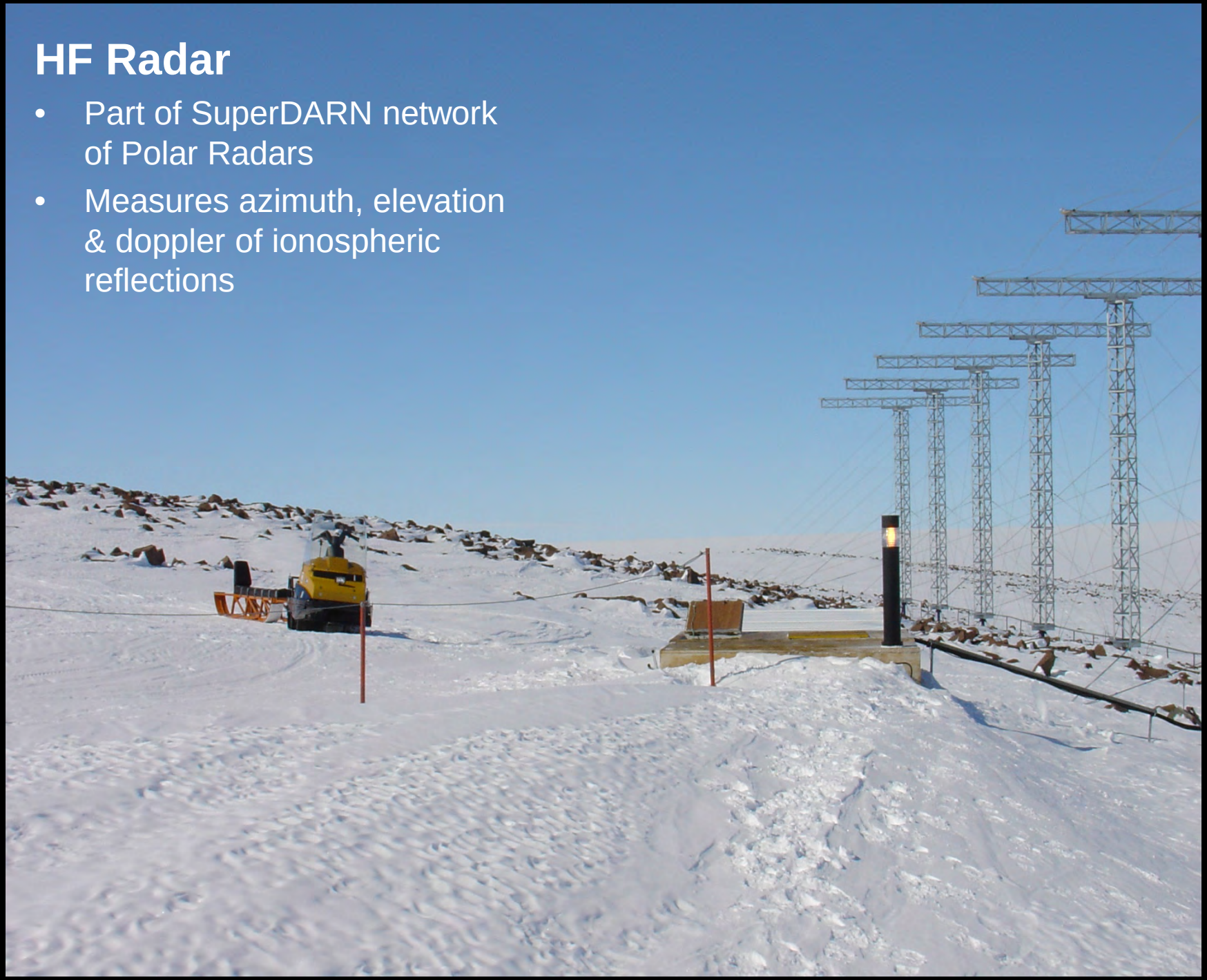
- DI Flux theodolite for absolute geomagnetic field measurements.

- FGE fluxgate magnetometer for continuous recording of vector geomagnetic field (2008).

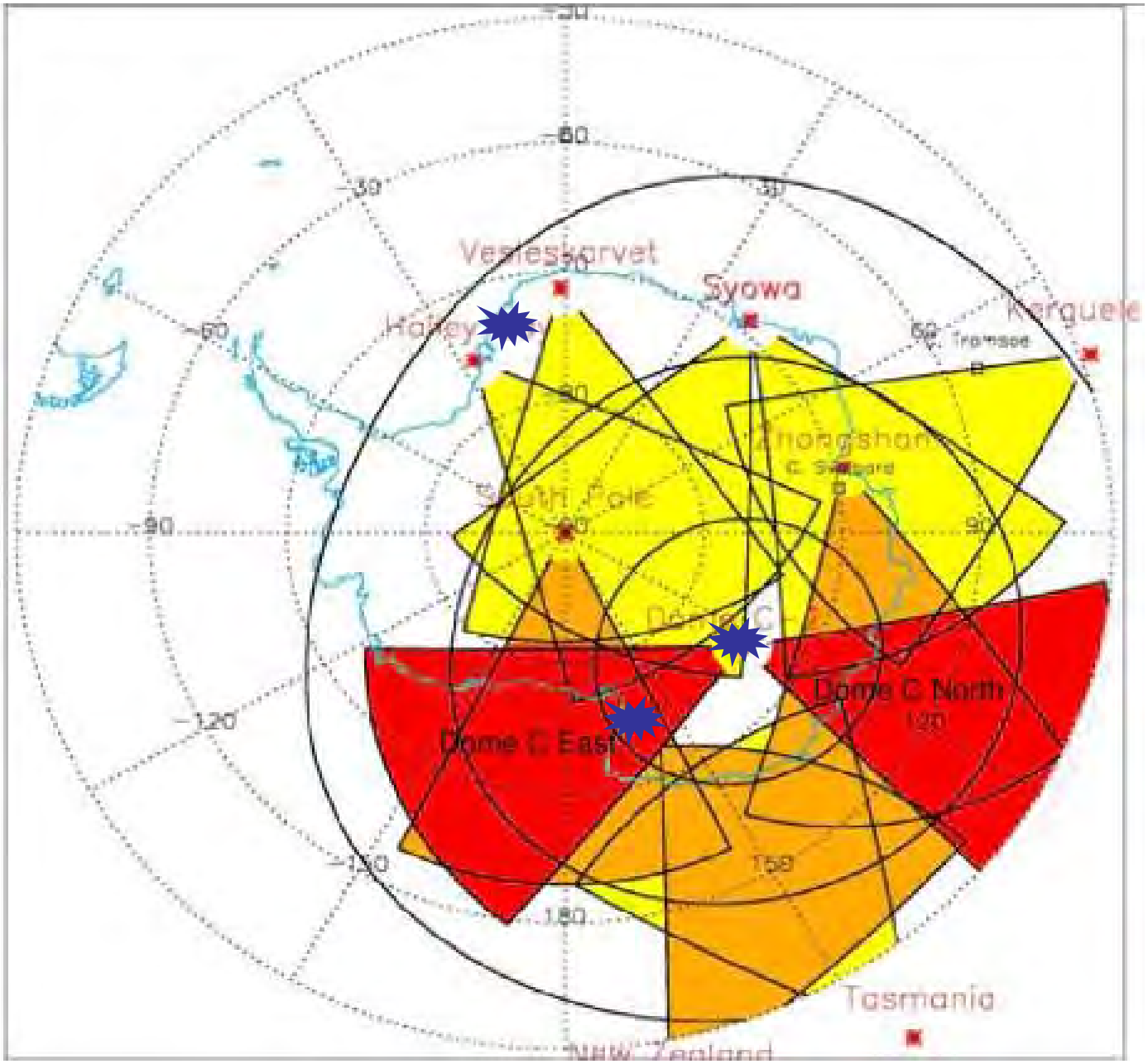
HF SuperDARN Radar

HF Radar

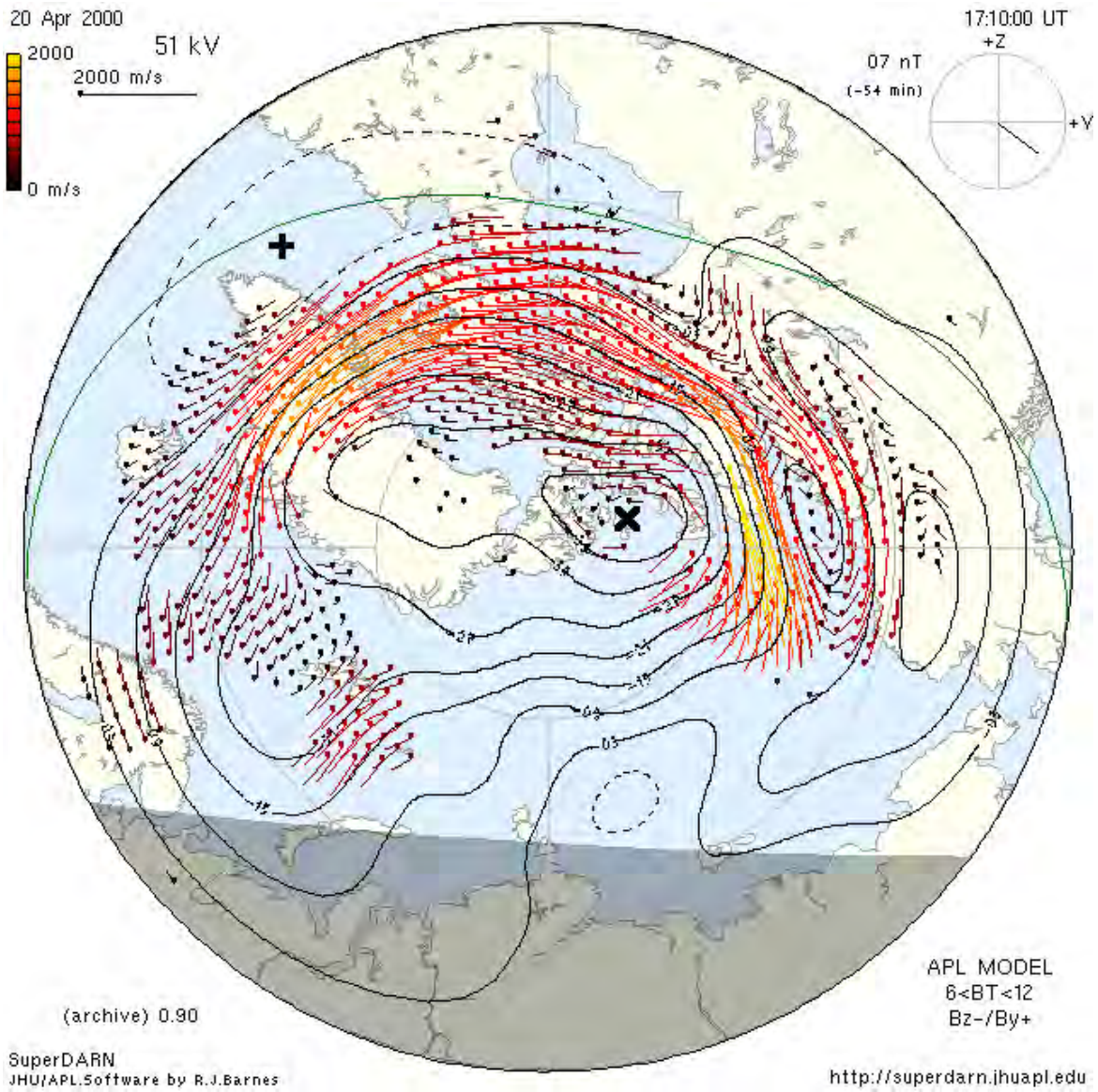
- Part of SuperDARN network of Polar Radars
- Measures azimuth, elevation & doppler of ionospheric reflections

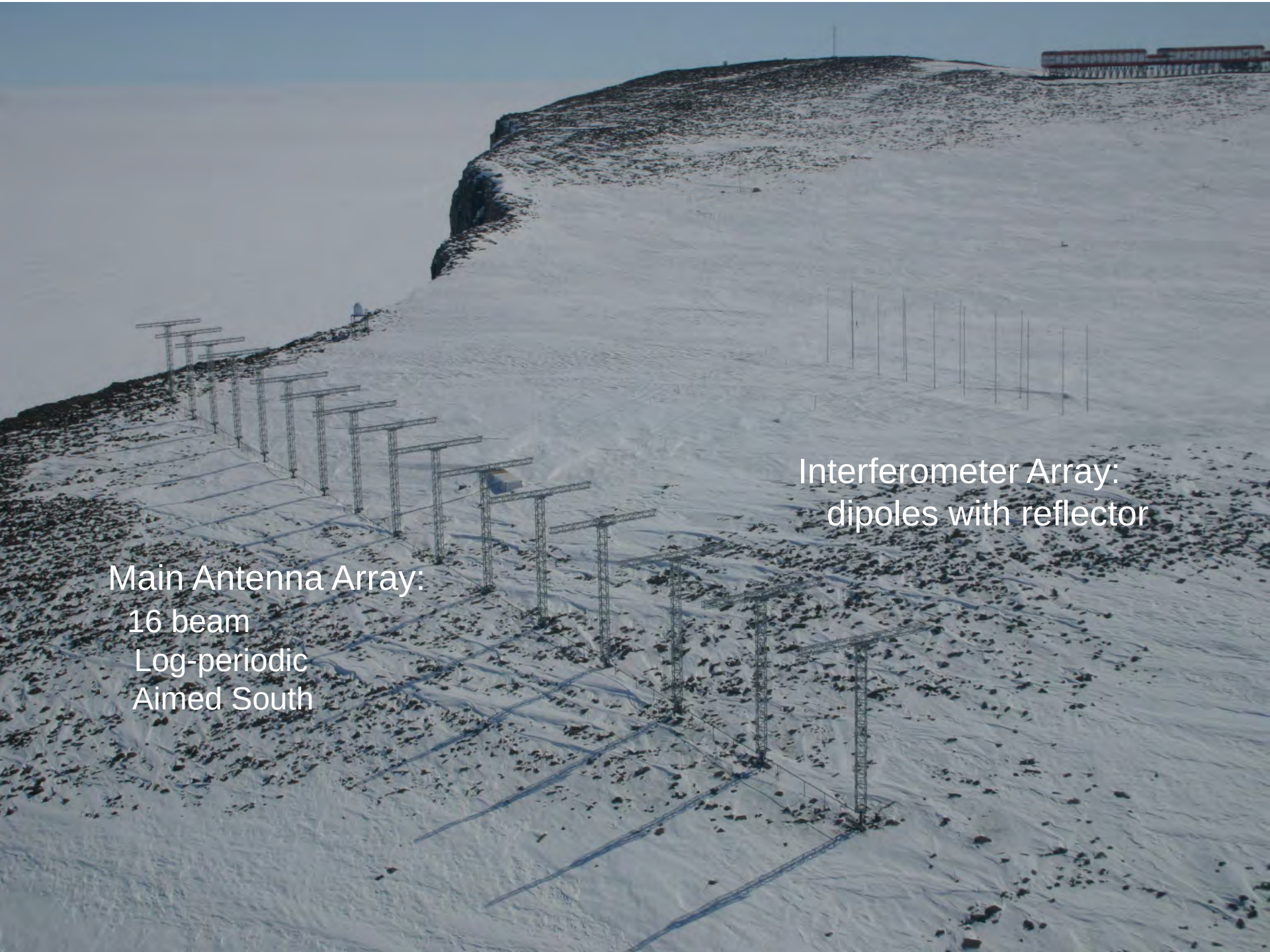


Overlapping fields of view of Antarctic HF Radars



Electron Convection Plot




Interferometer Array:
dipoles with reflector
Main Antenna Array:
16 beam
Log-periodic
Aimed South

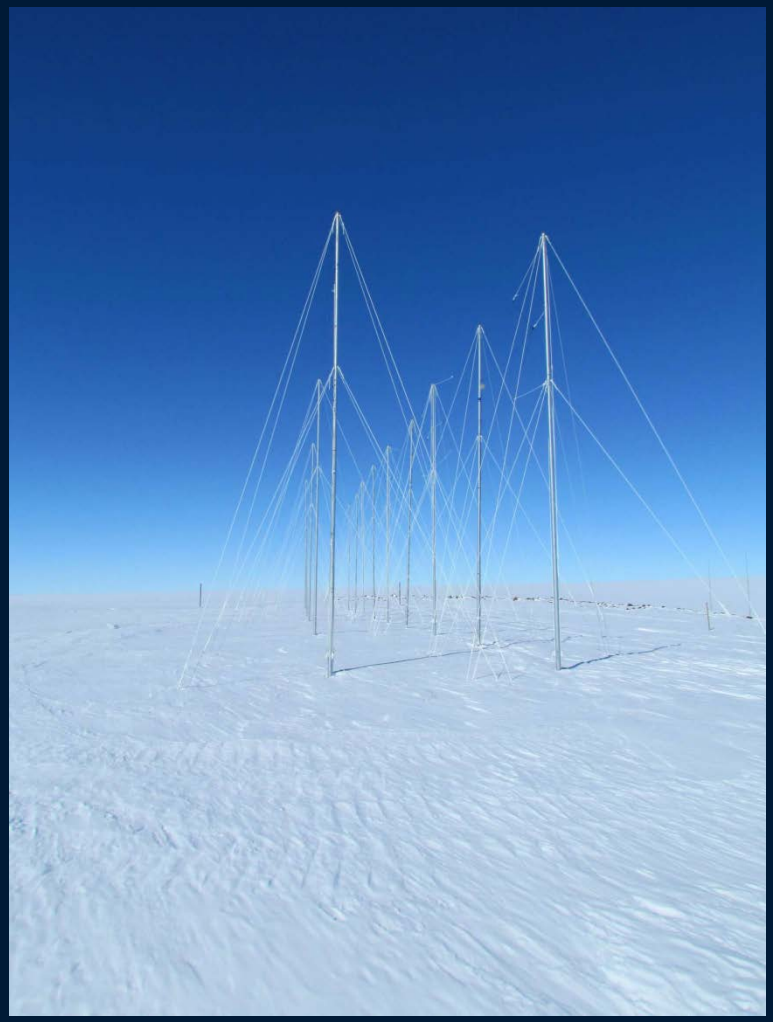
SuperDARN HF Radar Antenna damage

July 2008

New SuperDARN HF Radar Antenna

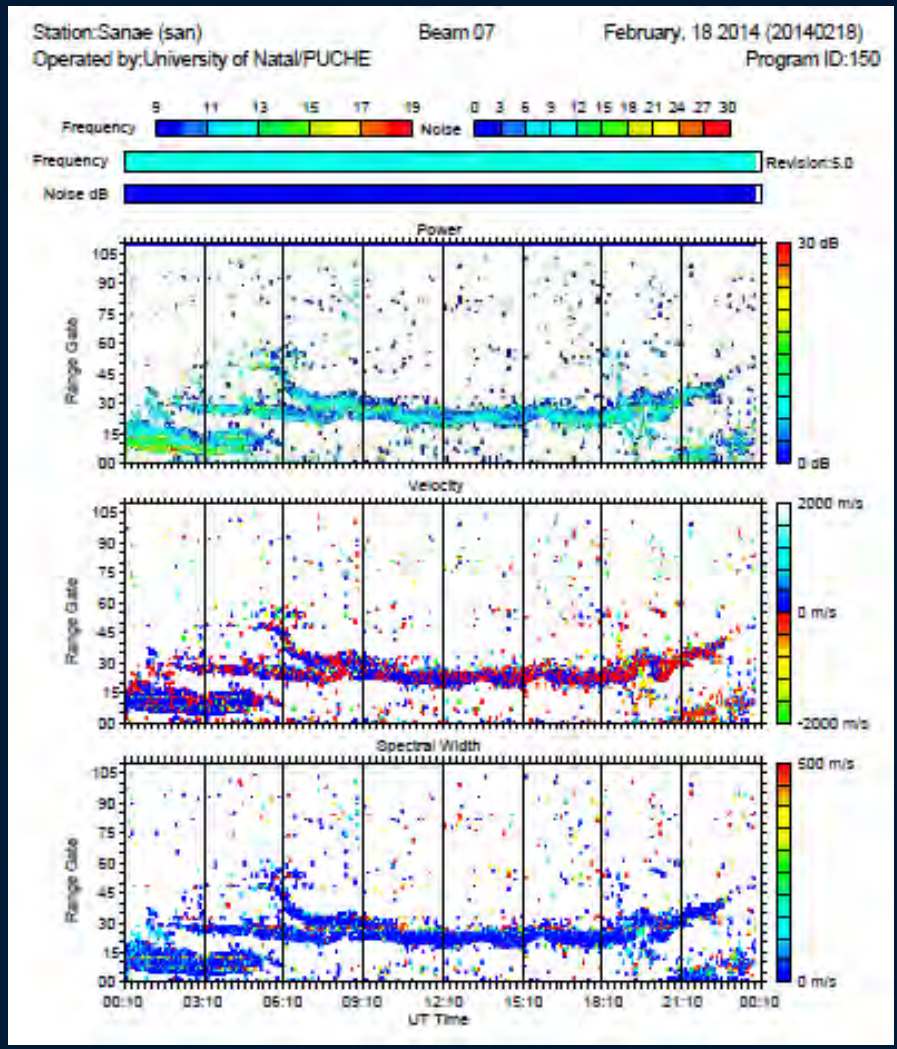
Installed in 2009-2010

HF Radar at SANAE-IV



. Main array Interferometer array

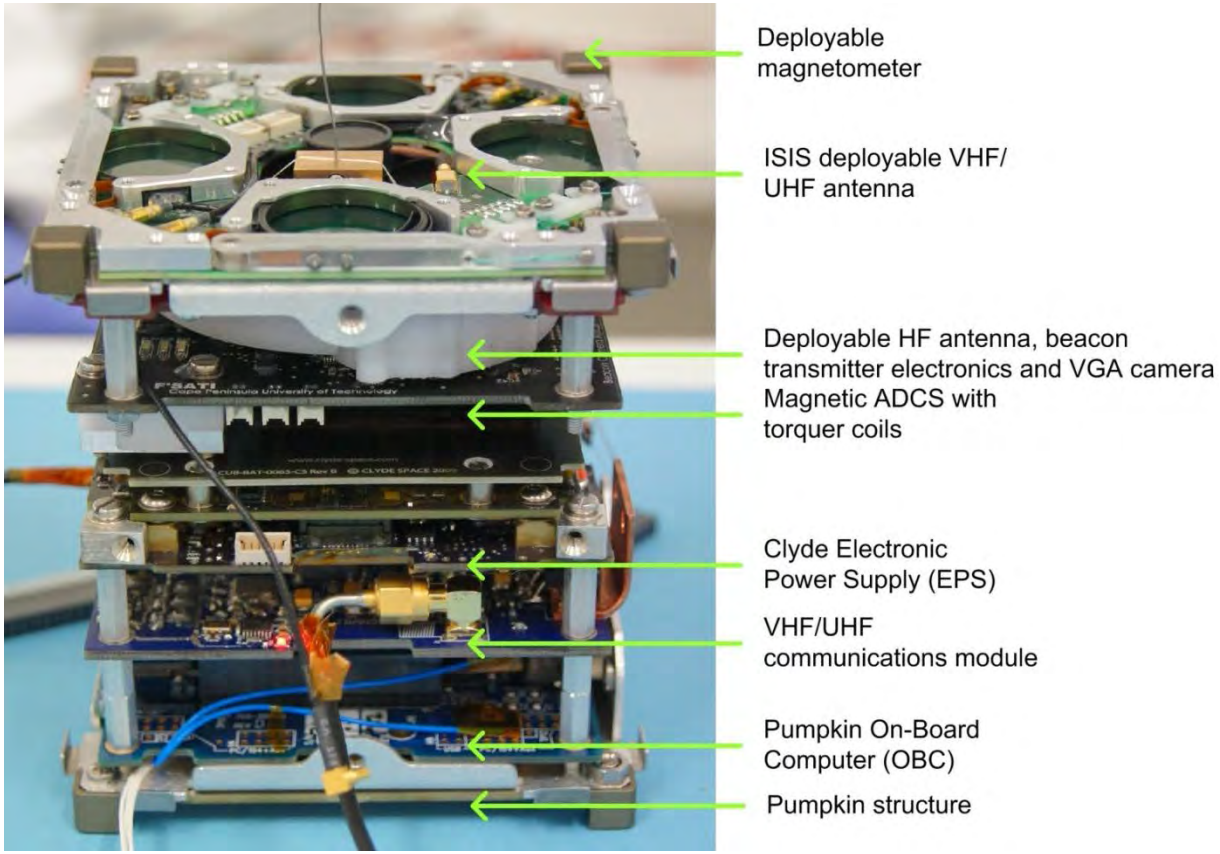
Digital upgrade of the SuperDARN HF Transceivers 2013



First data from the new digital radar 2014-02-18

HF Radar Calibration geometry

Nanosatellite Mission: ZACUBE-1



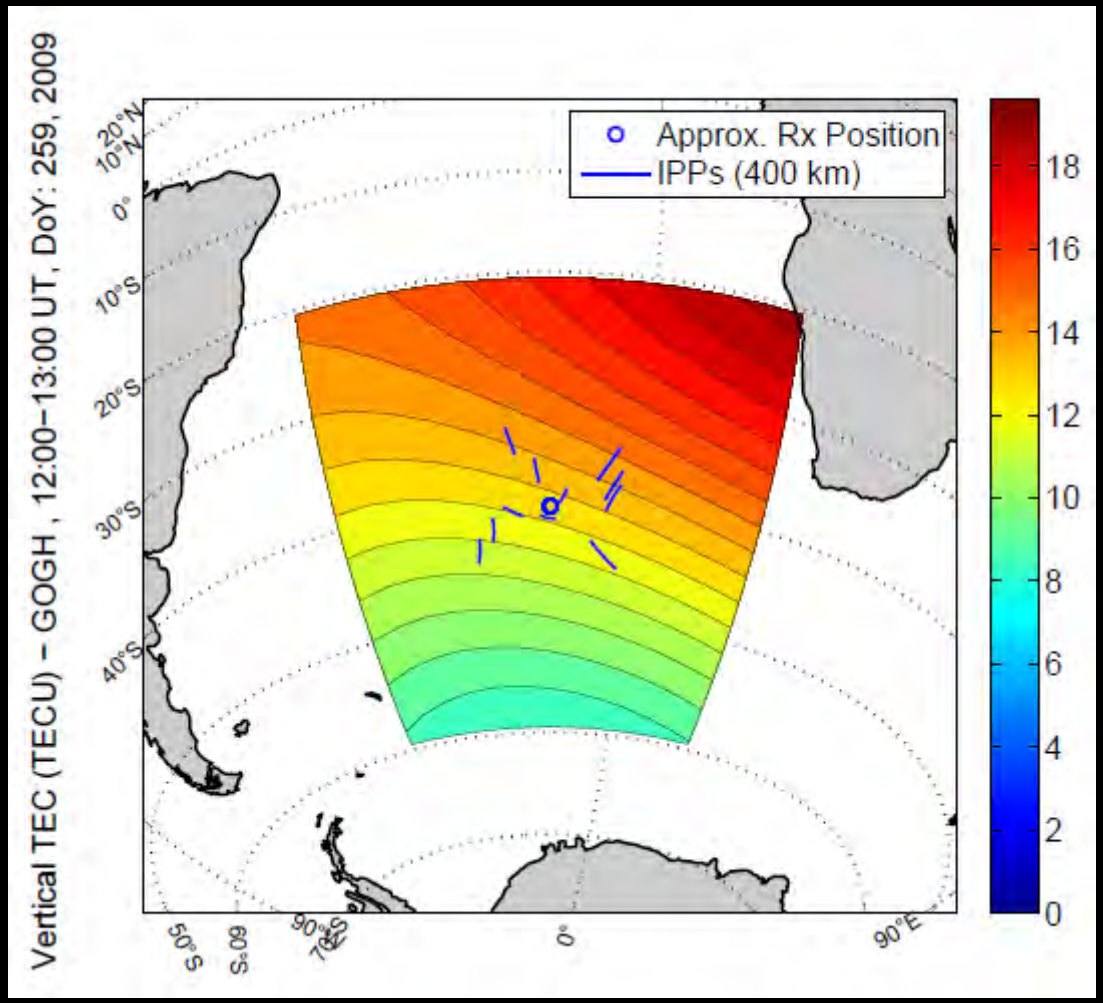
- Specifications
  - 10x10x10 cm, 1.3 kg
- Designed and built by postgrad students at Cape Peninsula University of Technology in partnership with SANSA and University of Stellenbosch
- Has an HF Beacon to calibrate the HF Radar (SuperDARN) at SANAE
- Launched by Russia 21 November 2013

Ionospheric Observations on the SA Agulhas

GPS Ionospheric observations on SA Agulhas

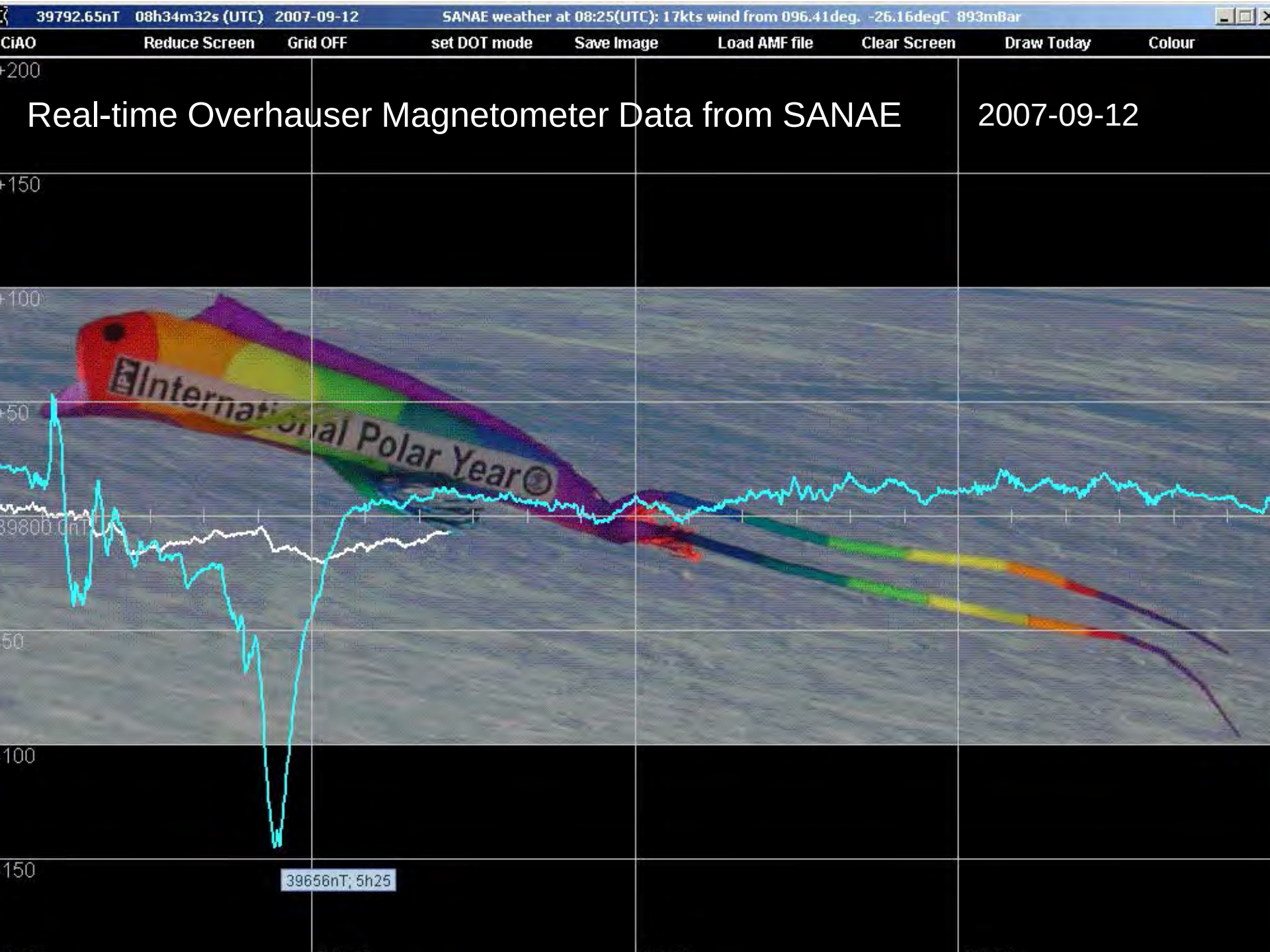

S. A. AGULHAS II

Ionospheric Total Electron Content Mapping using GPS data from the SA Agulhas

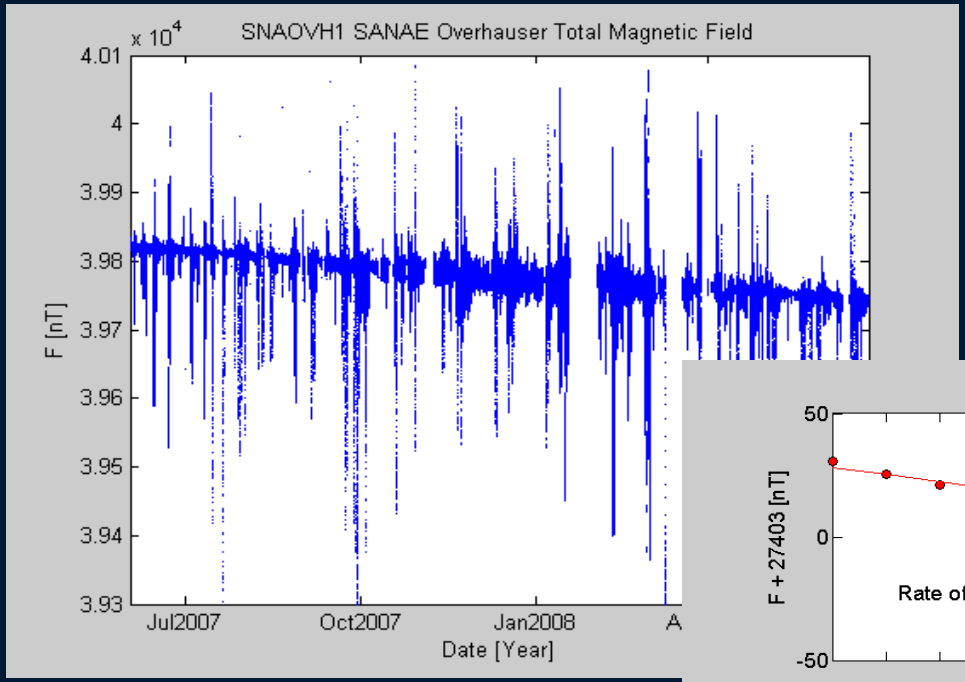


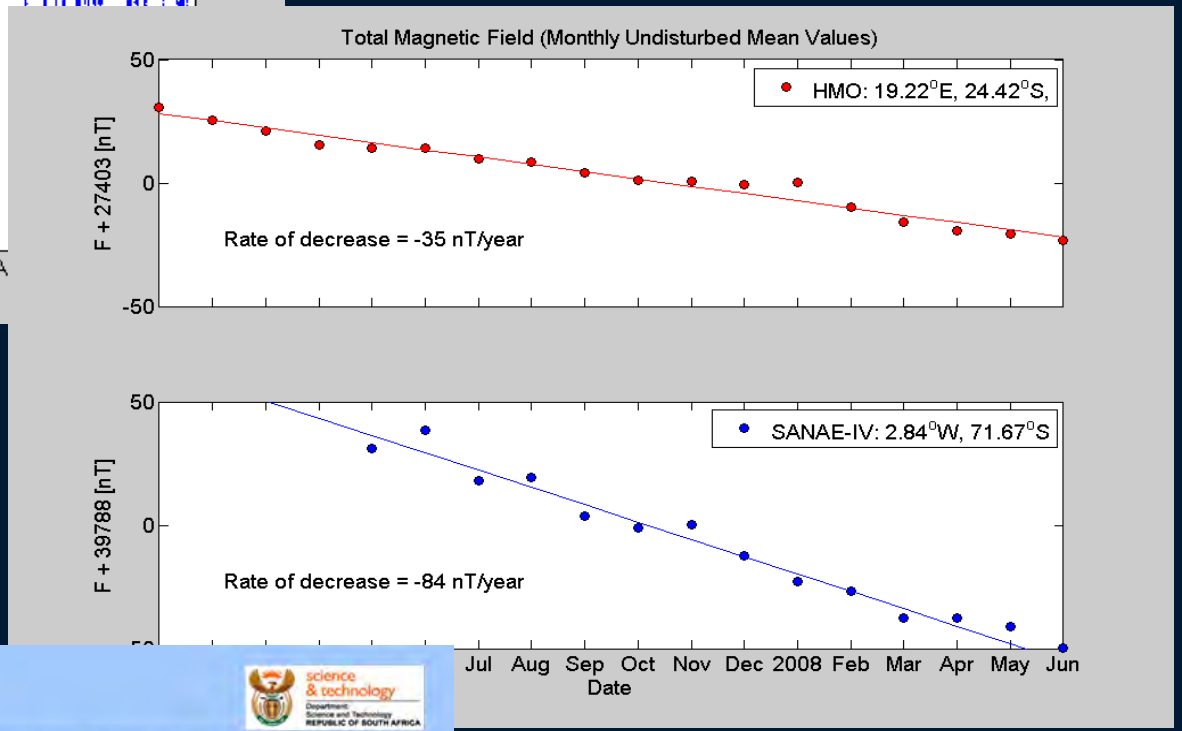
SJ Van der Merwe, CHARACTERISATION OF THE IONOSPHERE OVER THE SOUTH ATLANTIC ANOMALY BY USING A SHIP-BASED DUAL-FREQUENCY GPS RECEIVER, Meng Feb 2011

Magnetic field monitoring


39792.65nT 08h34m32s (UTC) 2007-09-12
SANAE weather at 08:25(UTC): 17kts wind from 096.41deg. -26.16degC 893mBar
CiAO
Reduce Screen
Grid OFF
set DOT mode
Save Image
Load AMF file
Clear Screen
Draw Today
Colour
+200
Real-time Overhauser Magnetometer Data from SANAE
2007-09-12
+150
+100
+50
39800.0nT
-50
-100
-150
39656nT; 5h25

Long term geomagnetic field changes at SANAE-IV





HMO NRF science & technology

MULTI-INSTRUMENT GEOSPACE OBSERVATION AND MODELING IN ANTARCTICA IN SUPPORT OF ICESTAR/IPY

P.J. Cilliers, B.D.L. Opperman, P. Kotzé, S. Malinga,
Hermanus Magnetic Observatory, Hermanus, South Africa,
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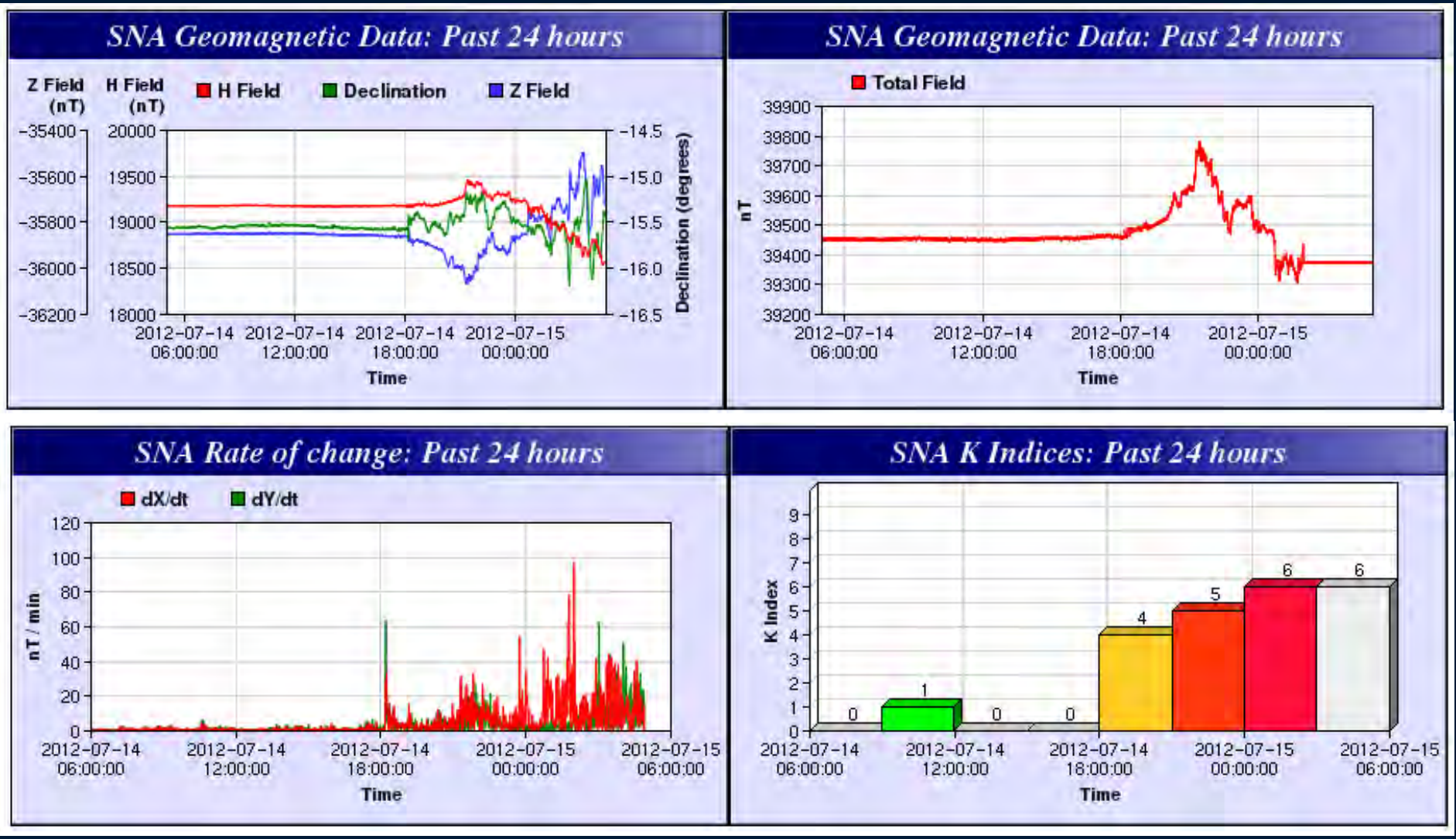
Geomagnetic field changes at SANAE-IV, 14 July 2012

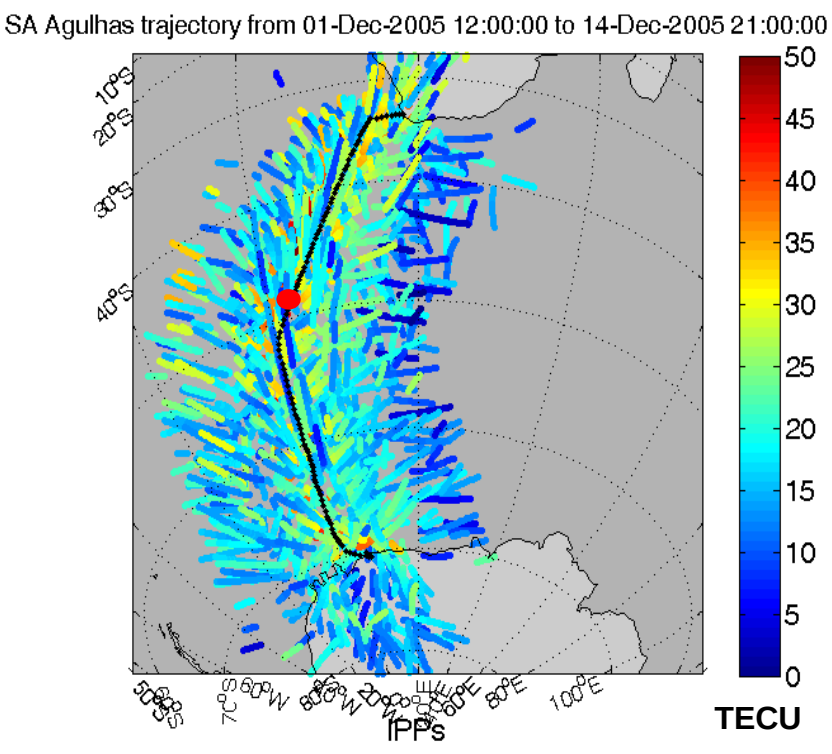


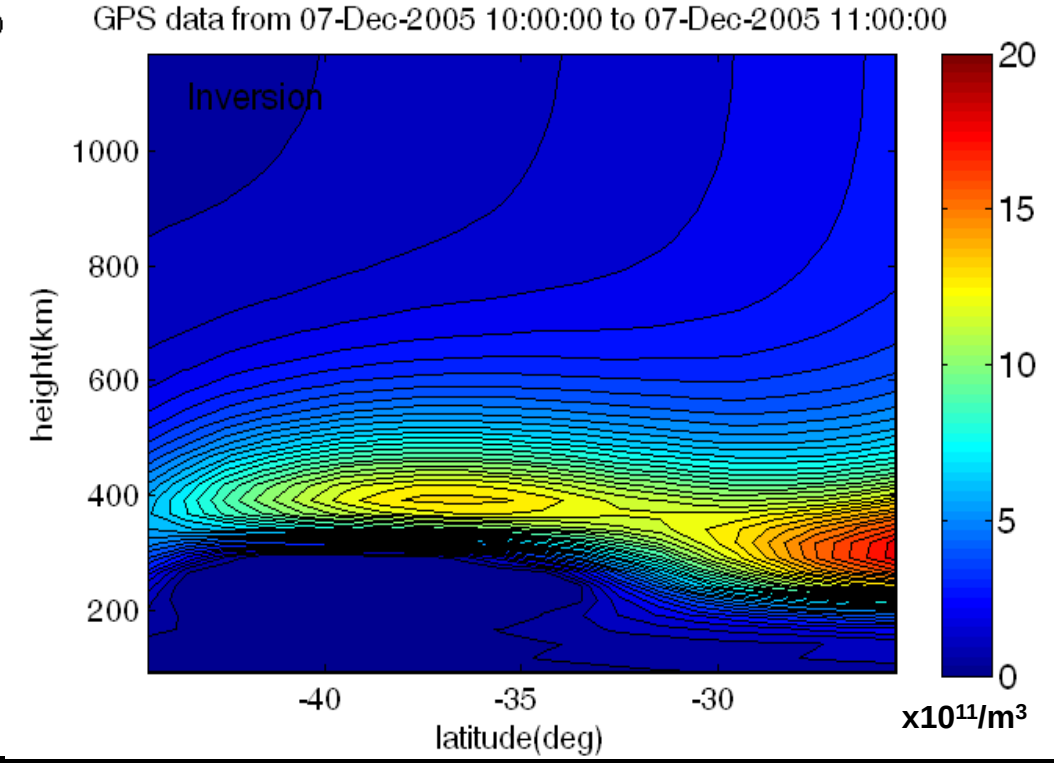
Magnetic field variation at SANAE-IV on 14 July 2012

Ionospheric effects

XXXII SCAR OPEN SCIENCE CONFERENCE
13-25 July 2012, Portland, USA

GPS tomography Cape Town to SANAE IV
1-14 December 2005





Ionospheric Pierce Points (IPPs) at hourly intervals for all satellite ray paths observed along the route of the SA Agulhas on its first trip to Antarctica during which measurements were made of the ionosphere over the South Atlantic Ocean using a GPS dual frequency receiver. The colours indicate bias-corrected VTEC at the IPPs.

Electron density distribution (x10^{11} /m^3) along longitude =0º at 10:00 UT. Derived by ionospheric tomography using MIDAS from measurements made during the trip of the SA Agulhas to Antarctica on day 7 of the trip. The location of the ship at the time is shown by the red dot on the trajectory. Note the interesting high latitude structure resolved by the inversion.

3D Advanced Ionospheric

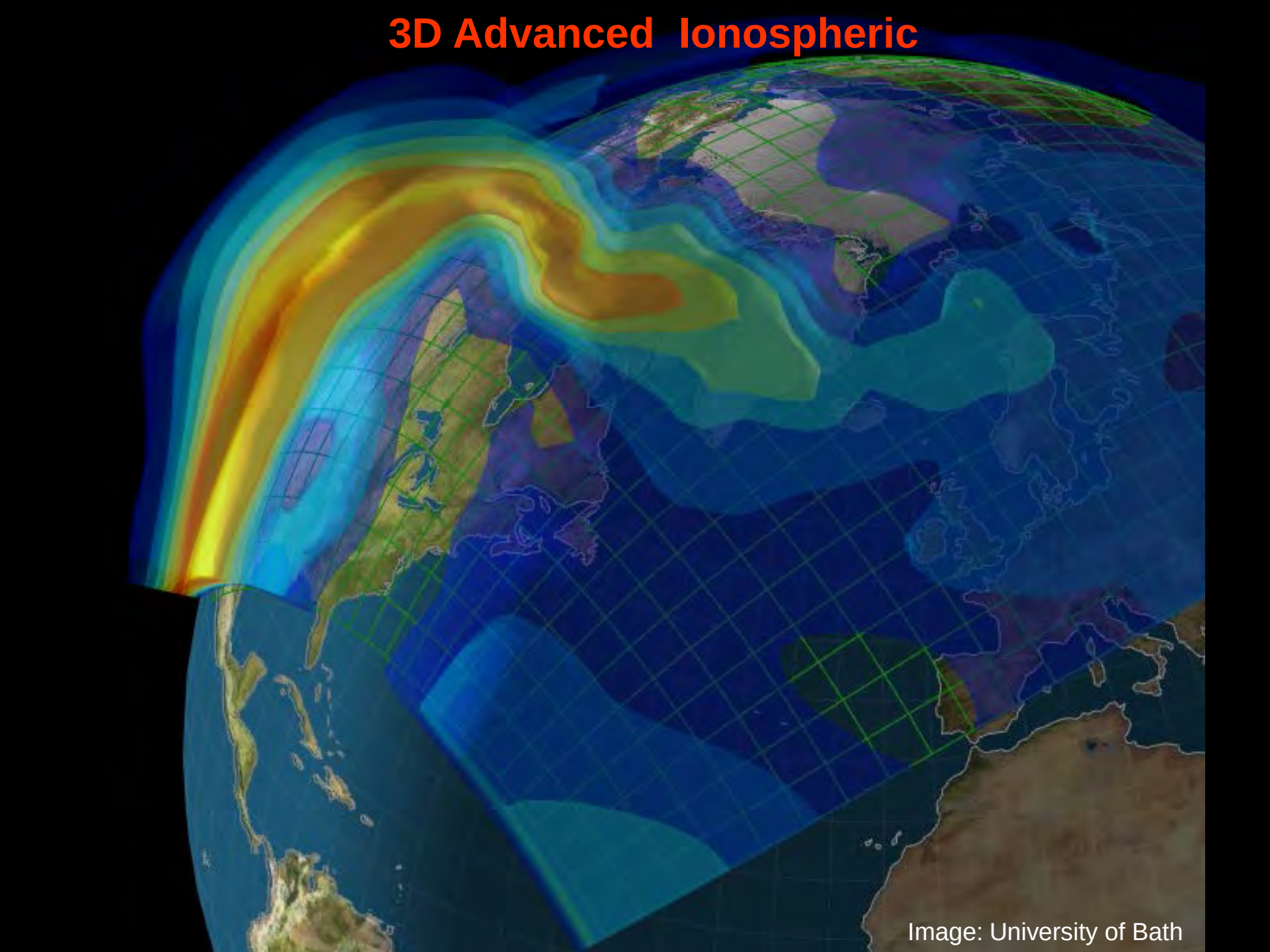
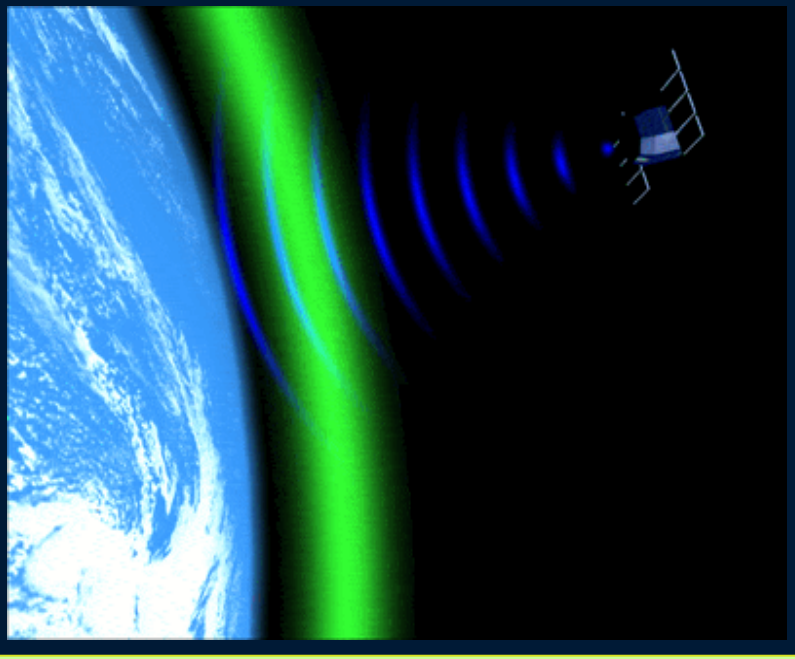


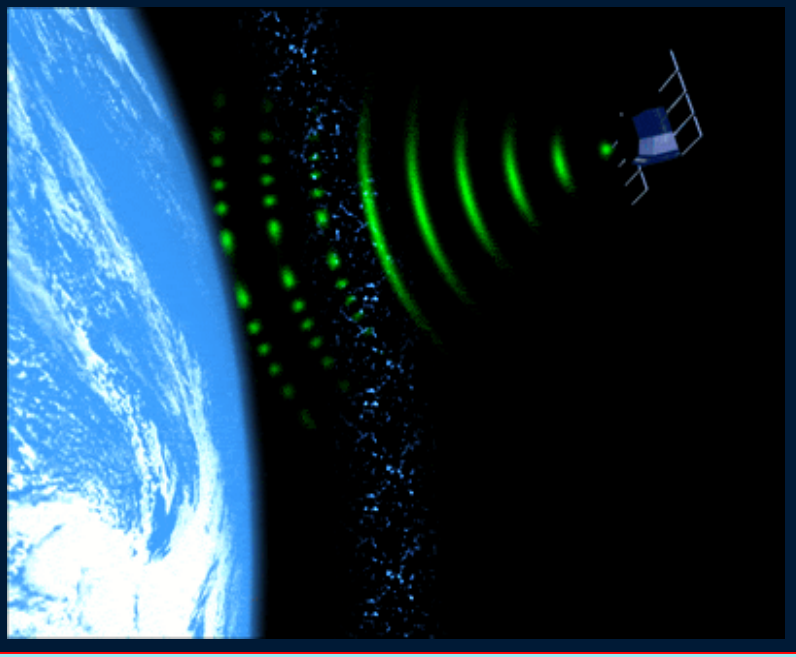
Image: University of Bath

Ionospheric effects on GPS



Delay

Ionization perturbs the signal propagation speed. Error proportional to total electron content: tens of metres error at solar maximum.



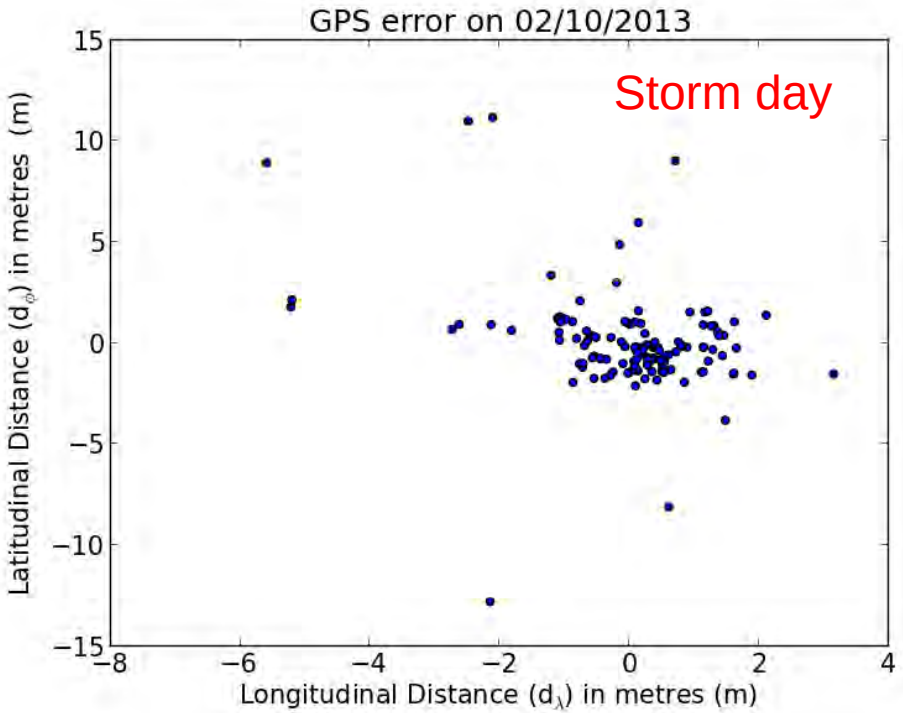
Scintillation

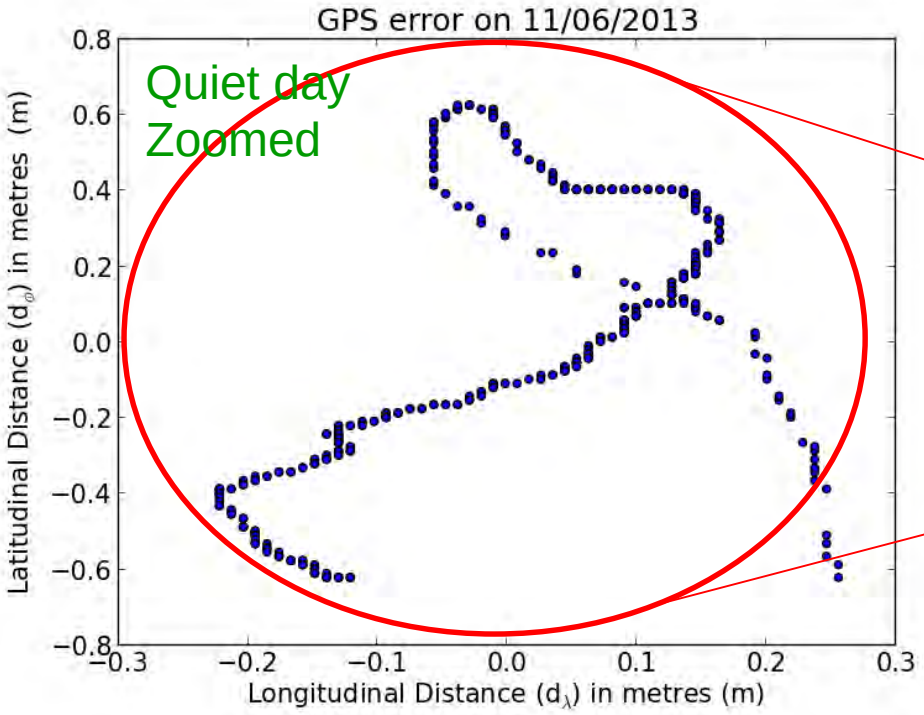
Fluctuations in ionization density causes rapid changes in the intensity and phase of L-band radio waves. Decreases GPS accuracy.

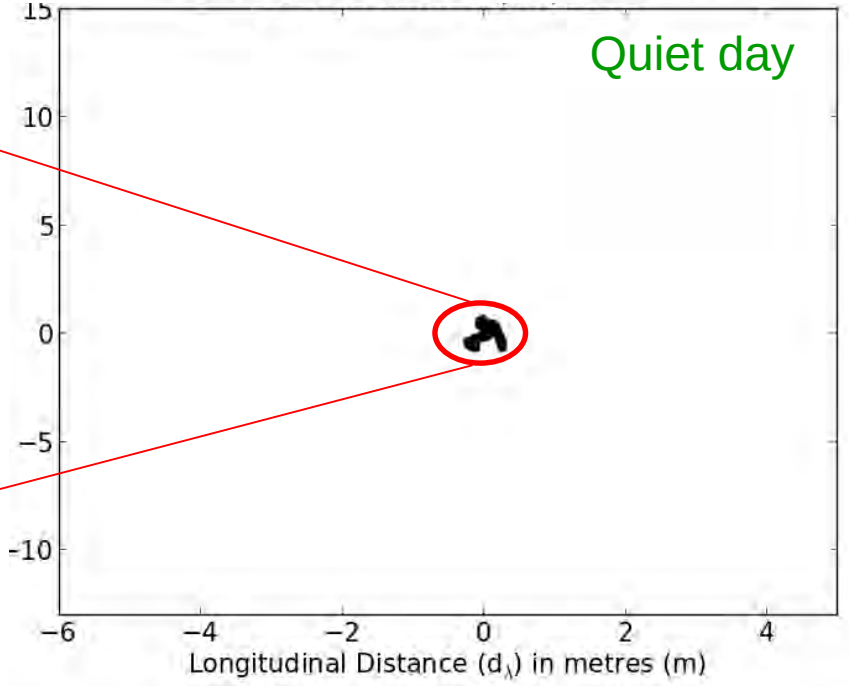
Images: Credit Bath University

GPS errors due to ionospheric scintillation

Single frequency handheld GPS receiver





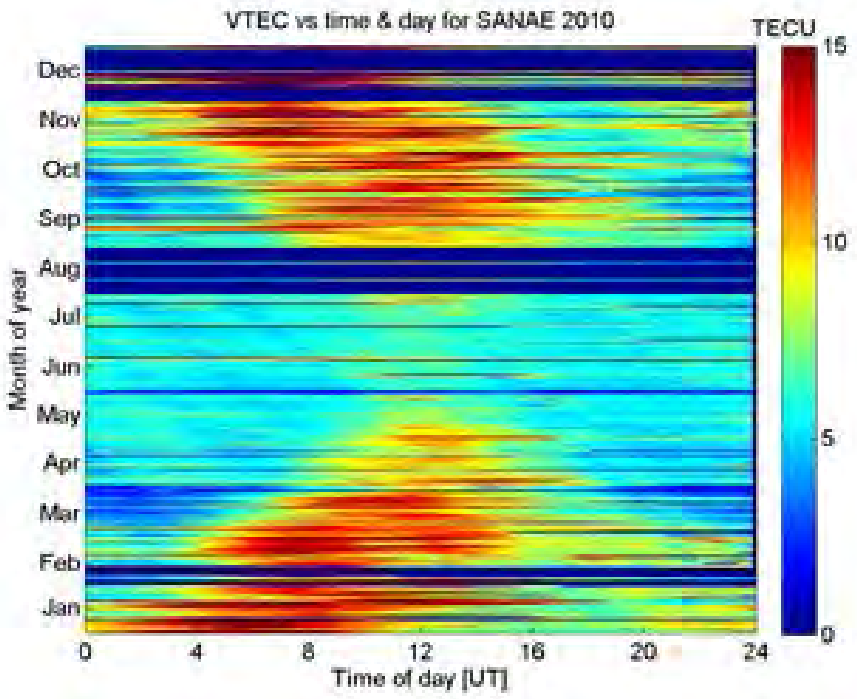


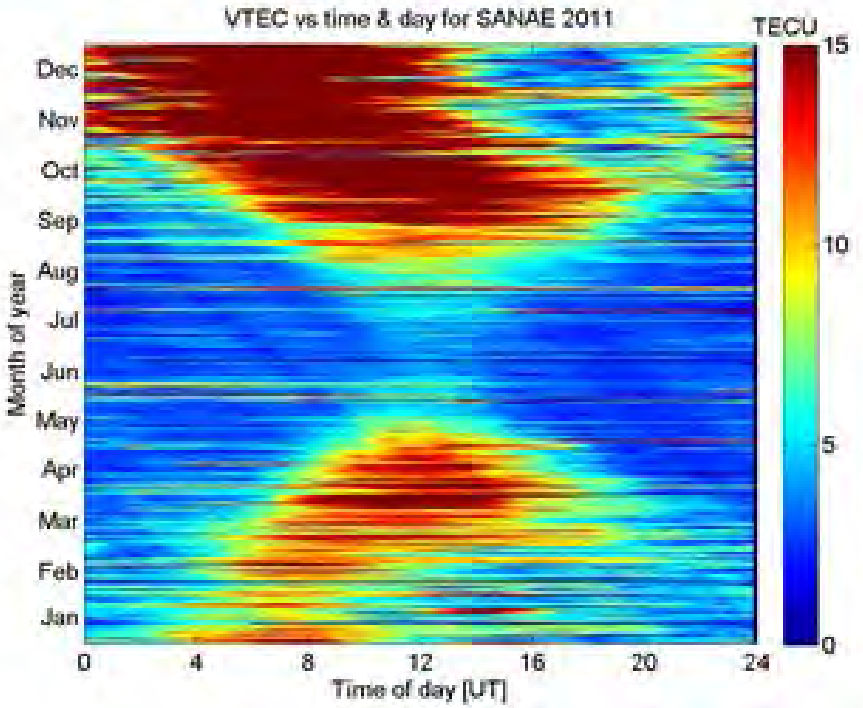
Ionospheric Scintillation Receivers

- These instruments are of the same kind as those deployed by University of New Brunswick, INGV, University of Bath, and others in both the Northern and Southern high latitudes.
- All the GISTMS managed by SANSA use SCINDA software to sample and store the 50 Hz data, derive 1-minute means and upload daily parameter summaries to SANSA.

Ionospheric Scintillation Monitoring

Results: Diurnal, seasonal & solar cycle variation in TEC





Contributions to ionospheric TEC and GPS phase scintillation climatology at Southern high latitudes and in Antarctica by new instruments deployed during IPY

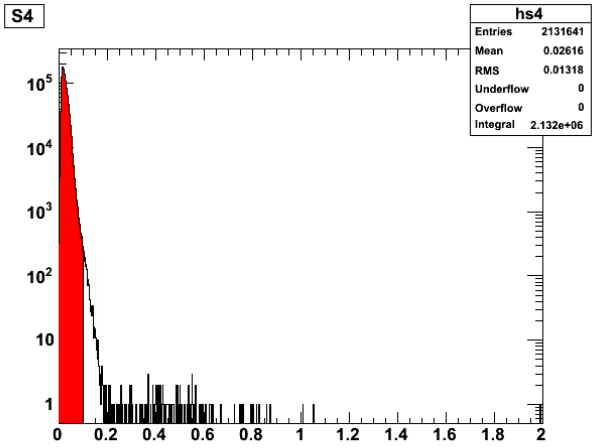
P.J. Cilliers[1], C.M. Ngwira[1], P. Prikryl[2], L. Alfonsi[3], C.N. Mitchell[4]

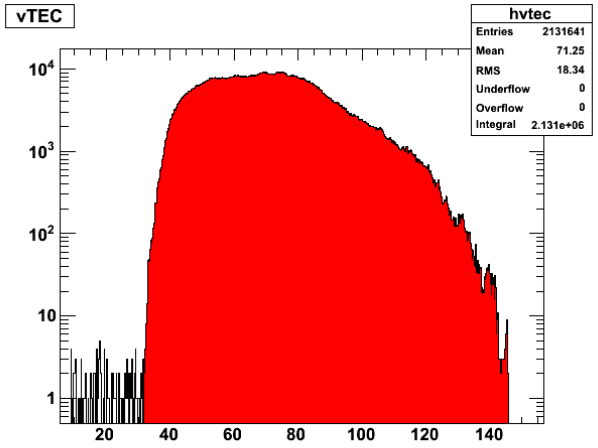
[1] South African National Space Agency, Hermanus, South Africa; [3] Istituto Nazionale di Geofisica e Vulcanologia(INGV), Rome, Italy;
[2] Communications Research Centre, Ottawa, ON, Canada; [4] Department of Electronic and Electrical Engineering, University of Bath, UK

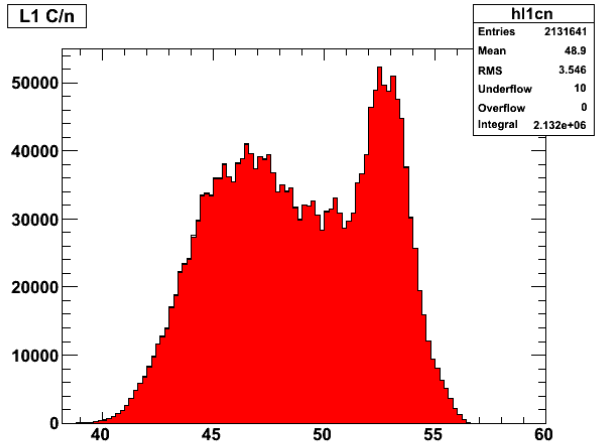
E-mail: pjcilliers@sansa.org.za

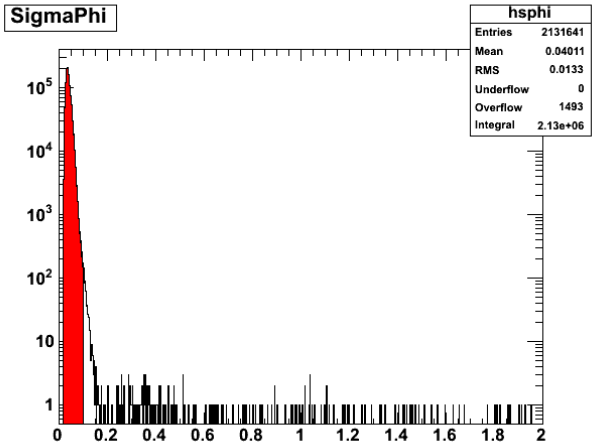
Cilliers et al, IPY2012 Oslo

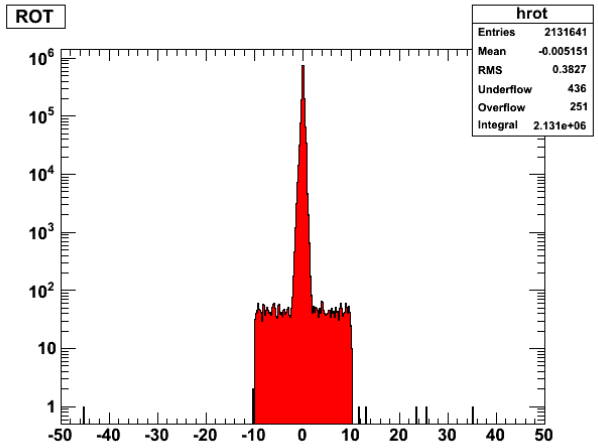
Gough Island Ionospheric Scintillation Statistics for 2011

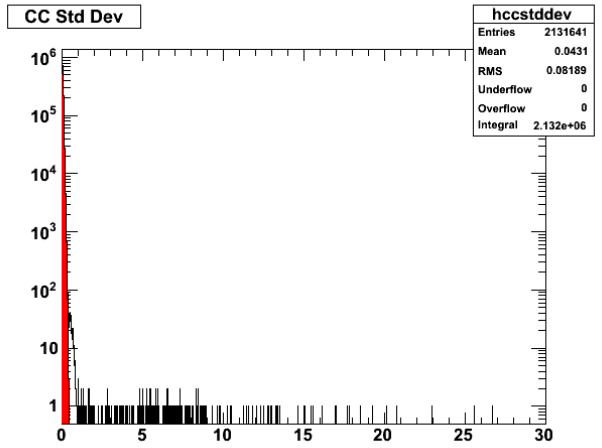






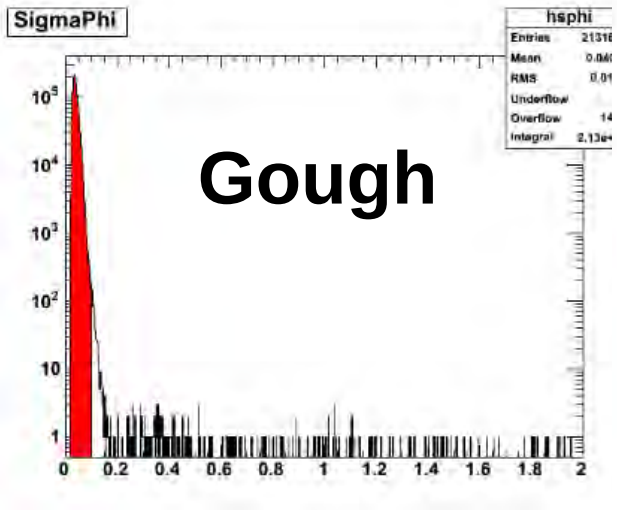


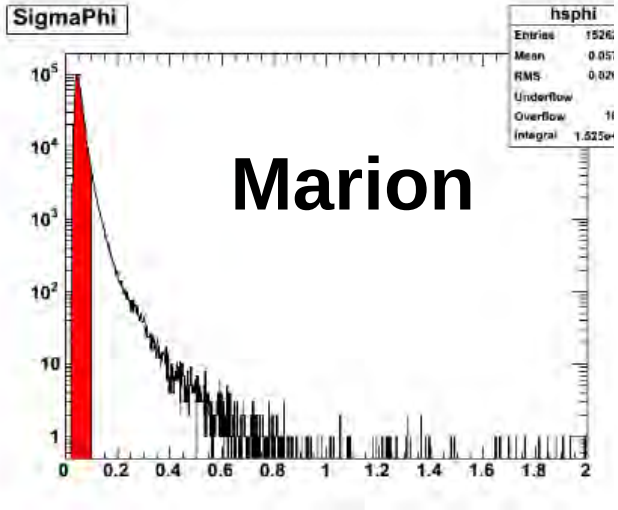


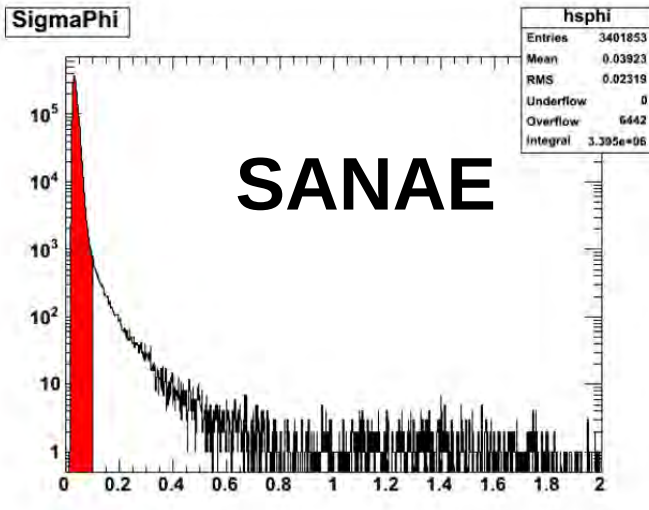


Spogli et al, SCAR OPEN SCIENCE CONFERENCE (13-25 July 2012, Portland, USA)

Ionospheric Scintillation Statistics from GBSC, 2011



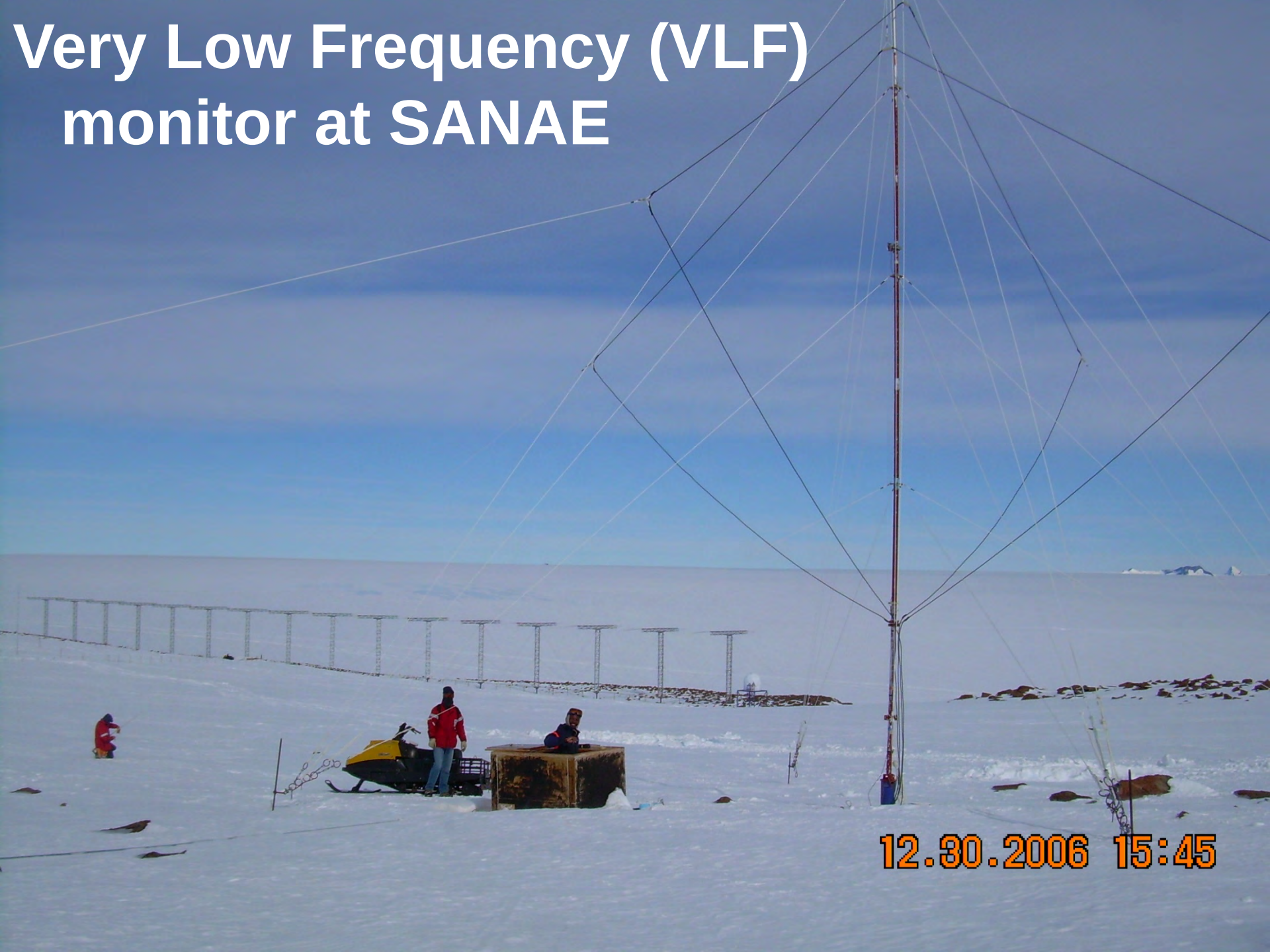




Black is the distribution obtained from all data with elev>20° ,
Red is from data with both S4<0.1 and σ_Φ<0.1, i.e. due to non-scintillating signals.

Spogli et al, SCAR OPEN SCIENCE CONFERENCE
(13-25 July 2012, Portland, USA)

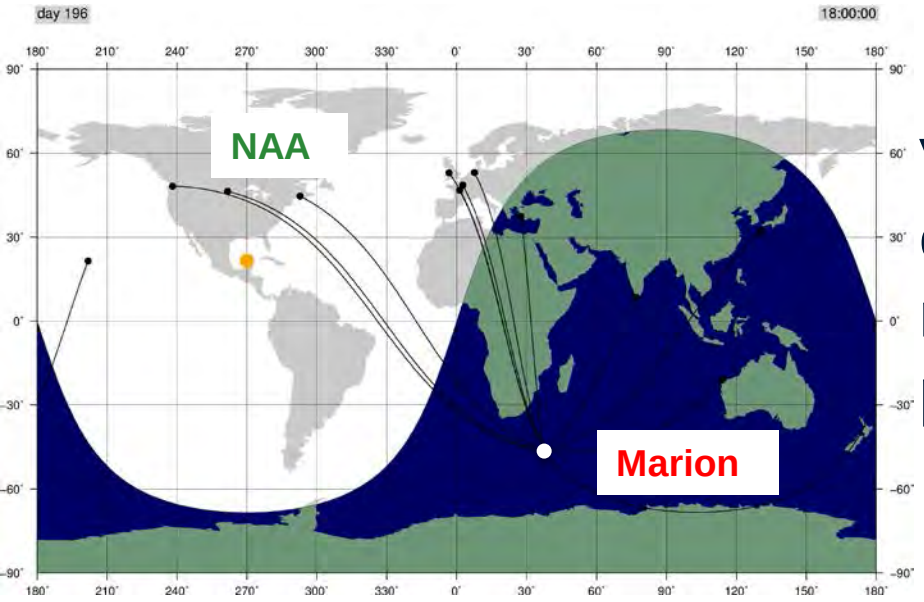
Very Low Frequency (VLF) monitor at SANAE



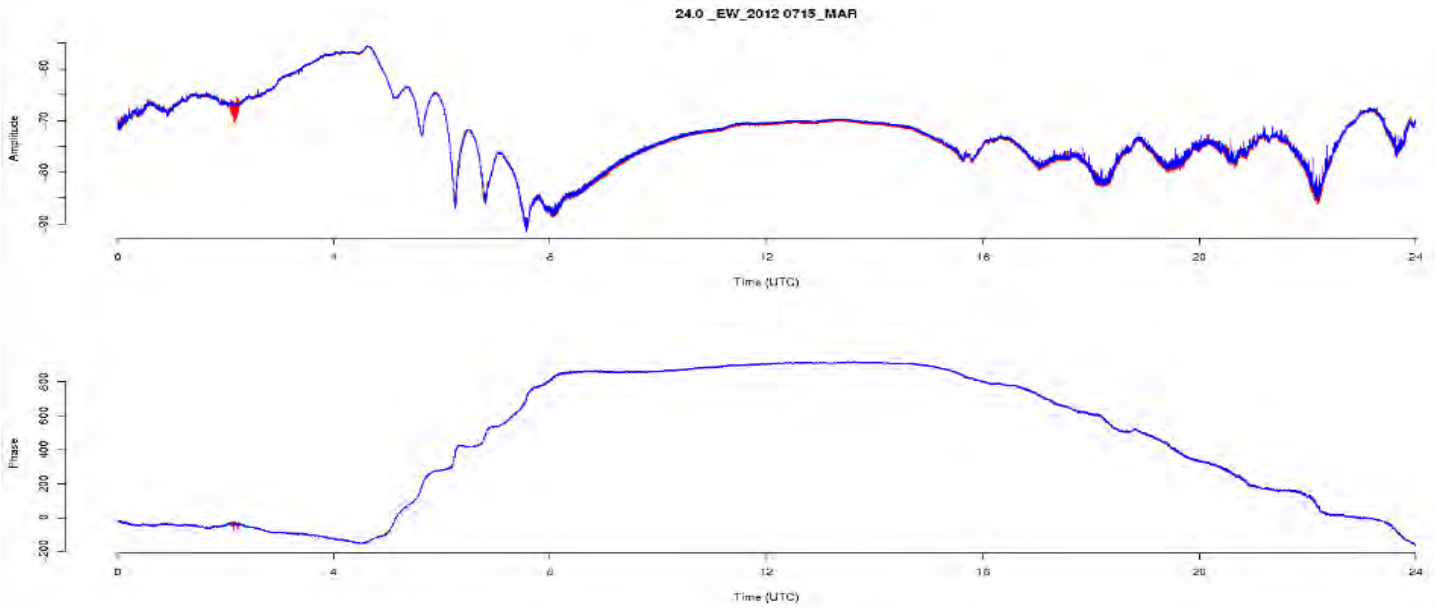
Repairs on very Low Frequency (VLF) monitor at SANAE

Low Frequency (VLF) monitor on Marion Island

VLF



VLF can provide evidence of enhanced precipitation on the narrowband VLF paths that passes through the SAMA from NAA to Marion.



Research Aims

To conduct continued analysis of the ionospheric scintillation data from the SANAP observatories to enhance the understanding of the causes and consequences of high latitude ionospheric scintillation and their link to other space weather phenomena i.e.

1. How severe is the disruption of GPS positioning, radio-astronomy and radio-communications due to ionospheric scintillations in the Southern mid- and high latitudes.
2. What are the mechanisms of ionospheric dynamics that are responsible for the formation of the structures that cause ionospheric scintillations?,
3. How frequently do mid- and high latitude ionospheric scintillations occur?
4. With which space weather related magnetospheric and geomagnetic events are ionospheric scintillations correlated?
5. Which scintillations are associated with travelling wave disturbances in the ionosphere as identified with ionospheric tomography and ionosonde measurements such as Spread F?
6. Which scintillations are associated with events of energetic particle precipitation?

International Collaborations

The GPS and GPS ionospheric scintillation data recorded on the SA Agulhas, at SANAE-IV, Marion and Gough Islands through the SANAP project (“Polar Space Weather studies during IPY 2007-2009) has since 2006 been making contributions to a number of international collaborations on the study of ionospheric effects of space weather. Specifically,

* UAMPY (Upper Atmosphere Monitoring for Polar Year 2007-2008)

* ICESTAR/IHY (Inter Hemispheric Conjugacy Effects in Solar Terrestrial and Aeronomy Research)(http://www.siena.edu/physics/icestar/)

* POLENET (Polar Earth Observation Network) (http://www.polenet.org/support/countries/index.php)

- GWSWF (GPS for Weather and Space Weather Forecast, SCAR Action Group) (http://www.gwswf.scar.org/modena_download.html)
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  * FP7 project proposal 2009 (“Space Weather Ionospheric and irregularities propagation Model (SWIM)”) initiated by the Instituto Nazionalae di. Geofisica e Vulcanologia in which South Africa would have been a key

International Collaborations

- * FP7 project proposal 2009 (“Space Weather Ionospheric and irregularities propagation Model (SWIM)”) initiated by the Instituto Nazionalae di. Geofisica e Vulcanologia in which South Africa would have been a key partner. It was highly rated, updated and resubmitted in 2013
- * RSA-Argentina Bilateral Research Agreement 2010 (“Ionospheric Investigations across the South Atlantic Anomaly”)
- * RSA-UK Research exchange between SANSA and the Univerisity of Bath on Ionospheric Tomography using GPS (MIDAS) and on the development of GPS Scintillation models.
- * SANSA-University of Bath agreement on the provision of real-time ionospheric scintillation data for the development of global ionospheric scintillation models (http://www.bath.ac.uk/elec-eng/invert/iono/scintillation.html).

Acknowledgements

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DEA
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International collaborators

Thank you for your attention

SANSA – in service of humanity