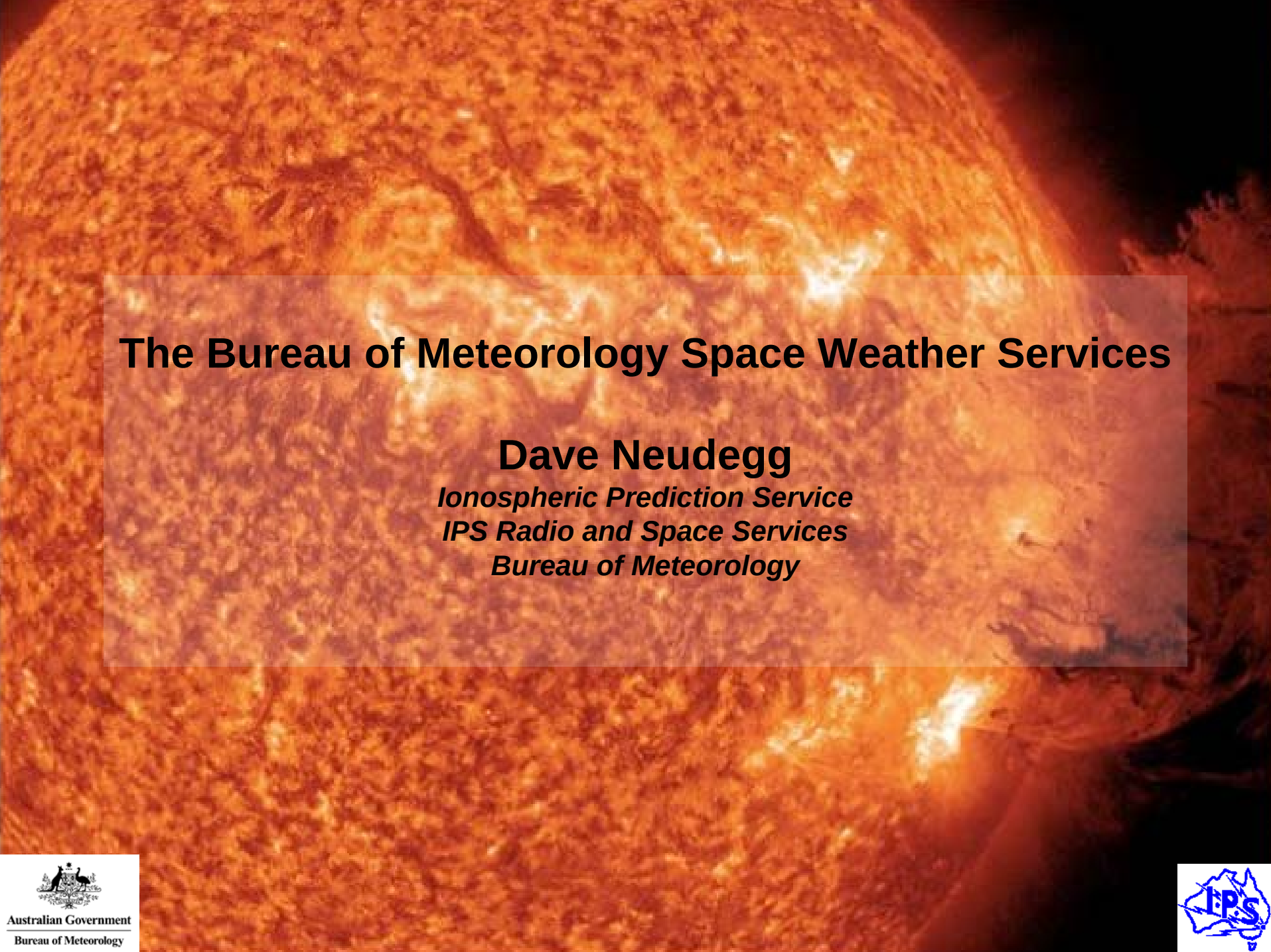


The Bureau of Meteorology Space Weather Services

Dave Neudegg

Ionospheric Prediction Service
IPS Radio and Space Services
Bureau of Meteorology

Australian Government
Bureau of Meteorology

What is “Space Weather”

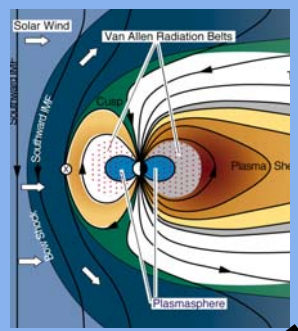
1. System planning with historical data
2. Real-time conditions

“Space Weather”

Geo-effective

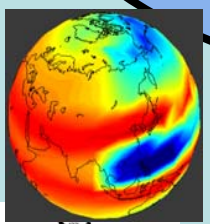
Space Physics

- Sun
- Heliosphere
- Solar wind – IMF
- Cosmic Rays
- Magnetosphere
- Ionosphere
- space debris
- Thermosphere



Technology

- Communications
- Navigation
- Energy transfer infrastructure
- Surveillance
- Aviation - biological



Systems affected that;

- Have a component in space above 100km
- Use radio communication through the ionised atmosphere
- Have a ground based component susceptible to magnetic or electric variations

Australian Government
Bureau of Meteorology

IPS

www.ips.gov.au/Space_Weather

IPS - Space Weather - Mozilla Firefox

File Edit View History Bookmarks To

http://www.ips.gov.au/Space_Weather

Yahoo! Mail (daveneud... Dave Anthony | Free M... Myspace Most Visited Customize Links Free Hotmail Windows Media Windows Australian Space Devel...

Australian Government
IPS Radio and Space Services

The Australian Space Weather Agency

Space Weather | Satellite | Geophysical | Solar | HF Systems | Products and Services | Educational | World Data Centre

Space Weather

Looking for something? Site Search

Home ▸ Space Weather

Sunday, Sep 25 2011 22:54 UT

Related Links
- SECCHI
- Solar Activity Prediction Centre
- Space Weather Resources
- South African Space Weather
- Spaceweather.com

Subscribe to IPS Reports & Alerts Sent to You by Email

Solar Conditions

Solar Wind Speed	X-Ray Flux	X-Ray Flares	Latest Culgoora Spectrograph	Latest Culgoora H-Alpha Image
	C3.3			

Geophysical Conditions

Geomagnetic Warning	GEOSTAT Alert	Geomagnetic Alert	Aurora Alert	K-Index	pc3-Index	AusDst-Index
Warning	4	No Alert	No Alert	1	1	> -20

HF Propagation Conditions

HF Comm. Warning	Current HF Fadeout	HF Fadeout Warning	Polar Cap Absorption
No Event	No Event	Warning	0.2dB AT 22:32 UT

Ionospheric Conditions

Australasia	World
	

TEC Conditions

Australasia	World
	

Note: Information on this page is updated frequently. To refresh the page, hold down the "SHIFT" key and click the "Refresh" or "Reload" button on your browser to refresh this page to obtain latest data.

▲ Top

Space Weather | Satellite | Geophysical | Solar | HF Systems | Products and Services | Educational | World Data Centre

IPS (Ionospheric Prediction Service) is a unit of the Bureau of Meteorology

Solar

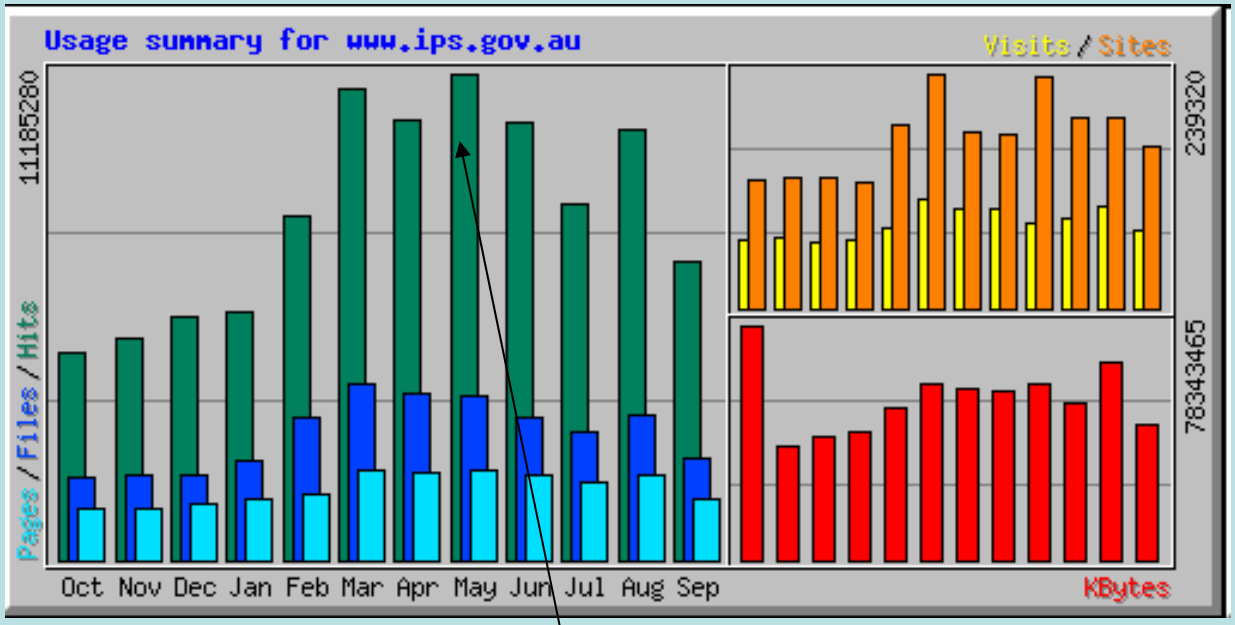
Geomagnetic

High-Frequency radio

Ionosphere

TEC-GPS

start Windows Task... IPS - Space W... Inbox - dave.... 3 Microsoft ... ASSC Canberr... Microsoft Pow... 9:31 AM

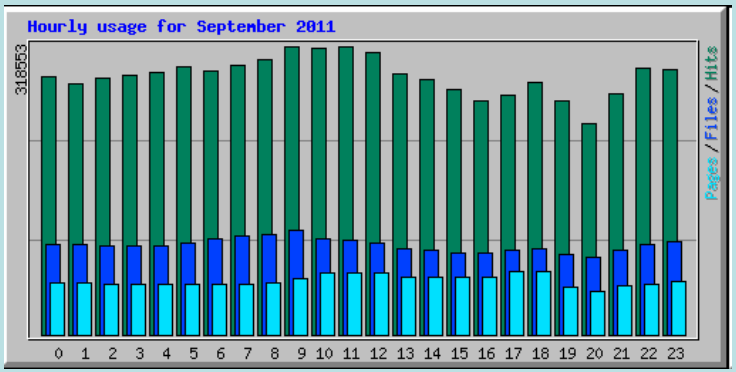


Monthly

Several million hits from hundreds of thousands of sites in tens of thousands of visits.

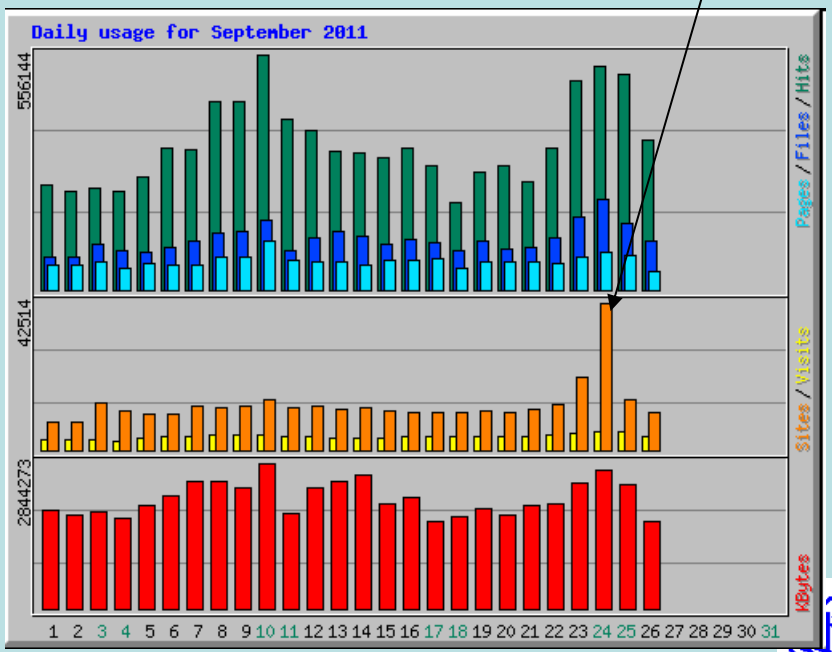
Generally follows solar activity

AR1302



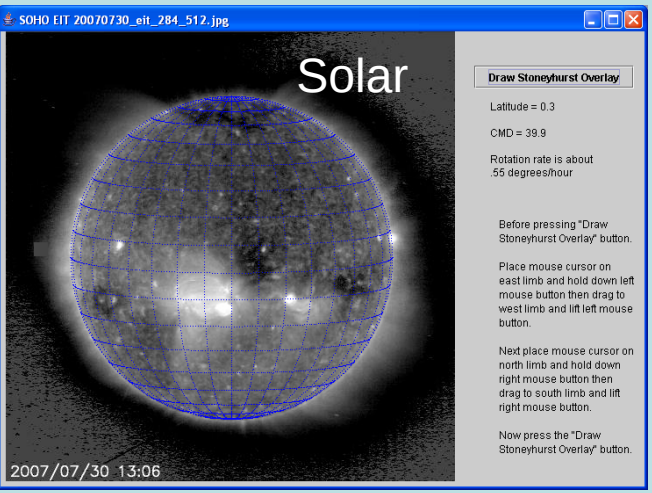
Hourly

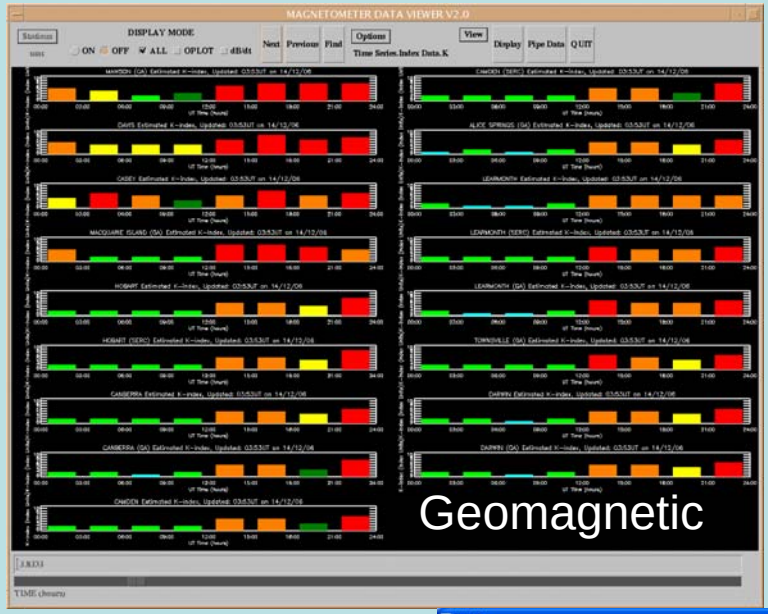
International visitors keep 24 hour variation less than if only national.

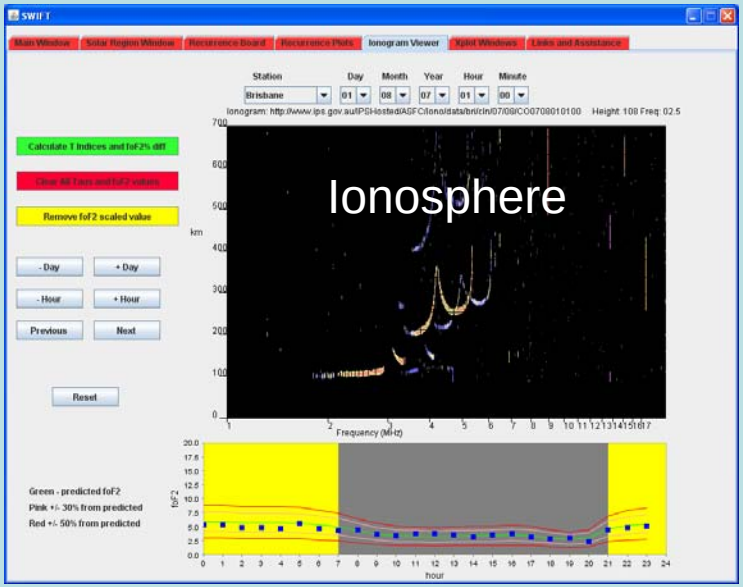


Australian Government
Bureau of Meteorology

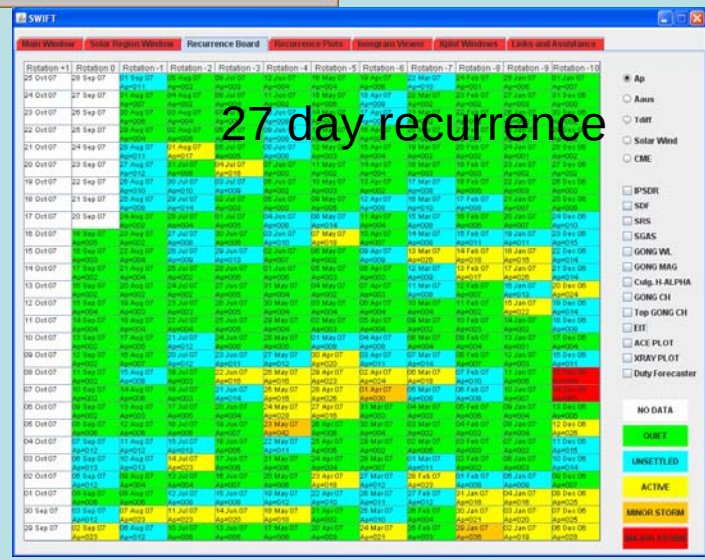
ASFC - Australian Space Forecast Centre







Software upgrade underway by
- Andrew Kelly
- Graham Steward
- Garth Paterson



Australian Government
Bureau of Meteorology

IPS

Customers

Type

- *HF radio users*
  - Communications
  - Surveillance :radar and direction finding
  - Broadcasting
  - Radio communications consultants
  - Sales/manufacturers
  - Amateurs
- *Geophysical and space*
  - Geophysical exploration
  - Power systems protection
  - Pipeline protection
  - Satellite data users (BoM/CSIRO) and operators
- Scientific research organisations
- Regulatory and strategic planning
-

Organisations

Commonwealth Govt -

- Defence - HFMOD
- Aviation - Airservices Australia
- Customs
- ACMA
- Radio Australia (ABC)
- Maritime (AMSA)
- BoM (maritime weather via HF radio)

State Govt

- Police, Emergency Services
- Educational
- Universities

Private

- Geophysical, Radio systems engineers and operators, amateurs

International Space Weather organisations

Data for the Services – Regional ground based sensor network

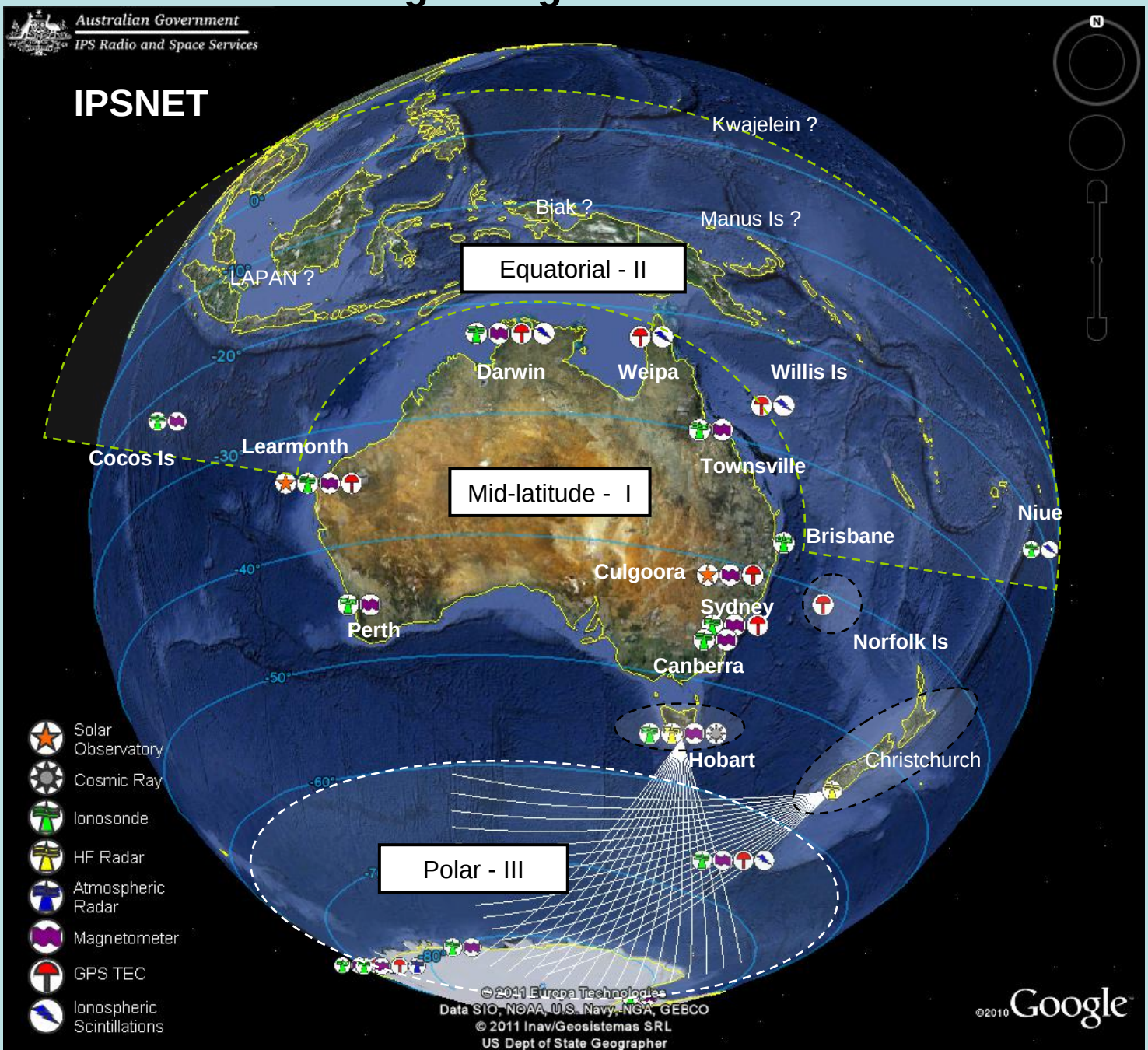
3rd party sensors

Magnetometers
- U. Newcastle
- SERC-MAGDAS
-Geoscience Aust

GPS
-Geoscience Aust

Solar
- USAF Learmonth

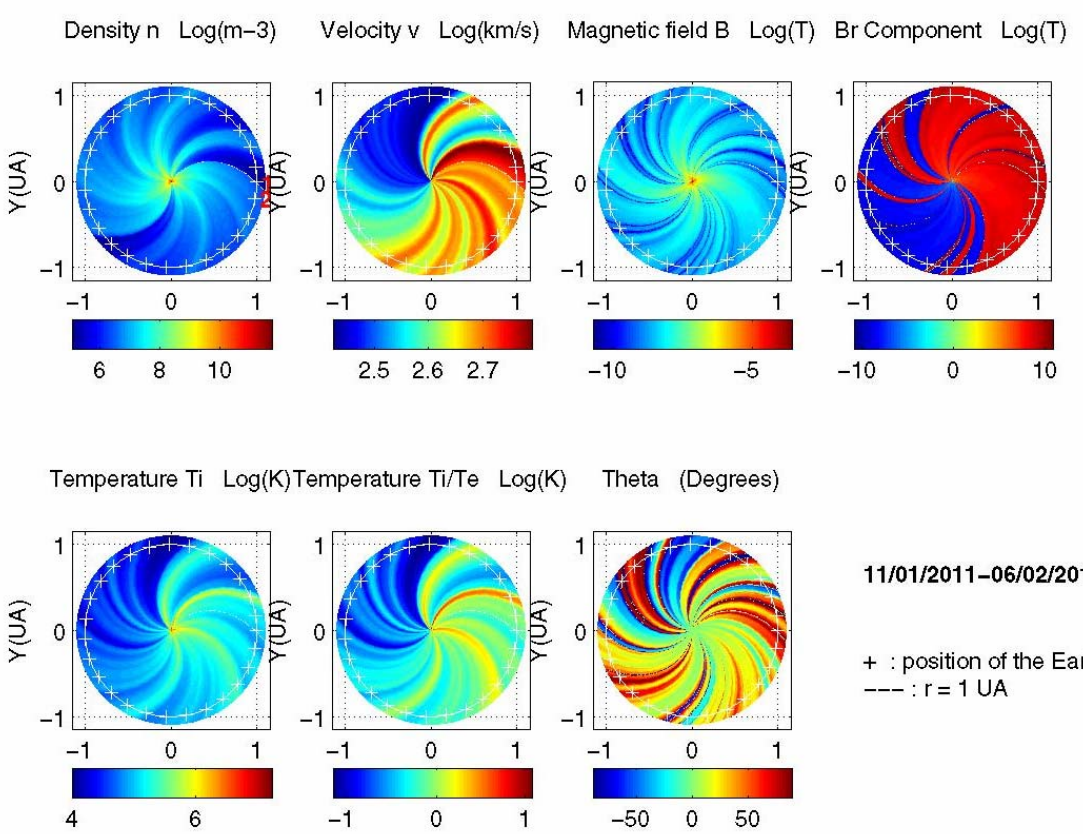
Antarctica
- AAD

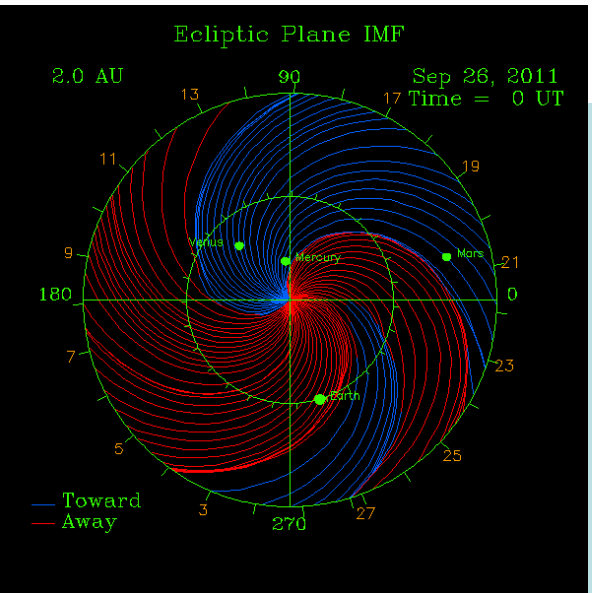


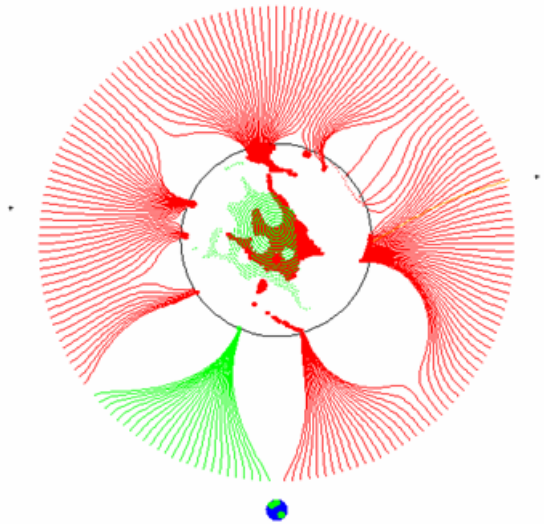
Aiming for more integration within BoM observation network

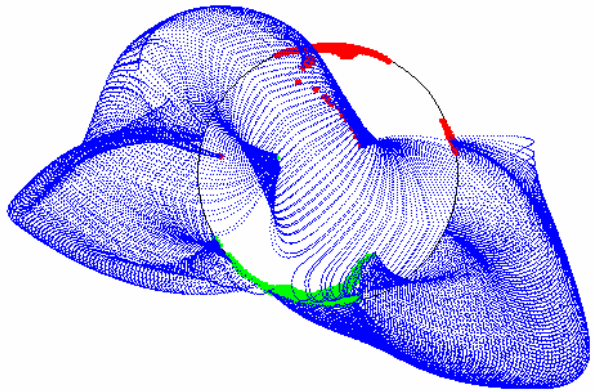
Australian Government
Bureau of Meteorology

Solar wind and Interplanetary Magnetic field (IMF)

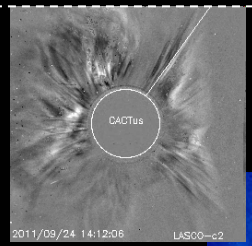




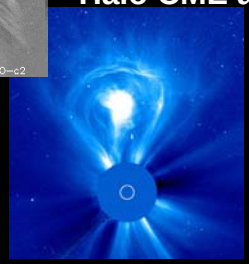


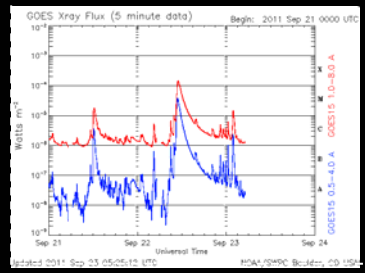


Measuring the wider environment - Space based sensor network



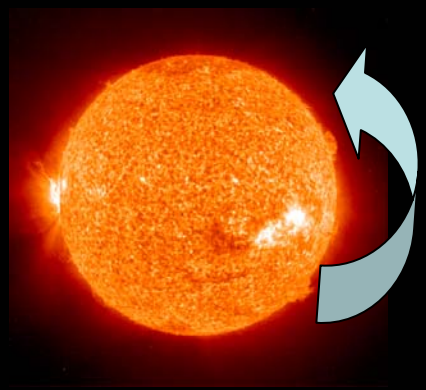
SOHO
– solar images
- Halo CME alerts



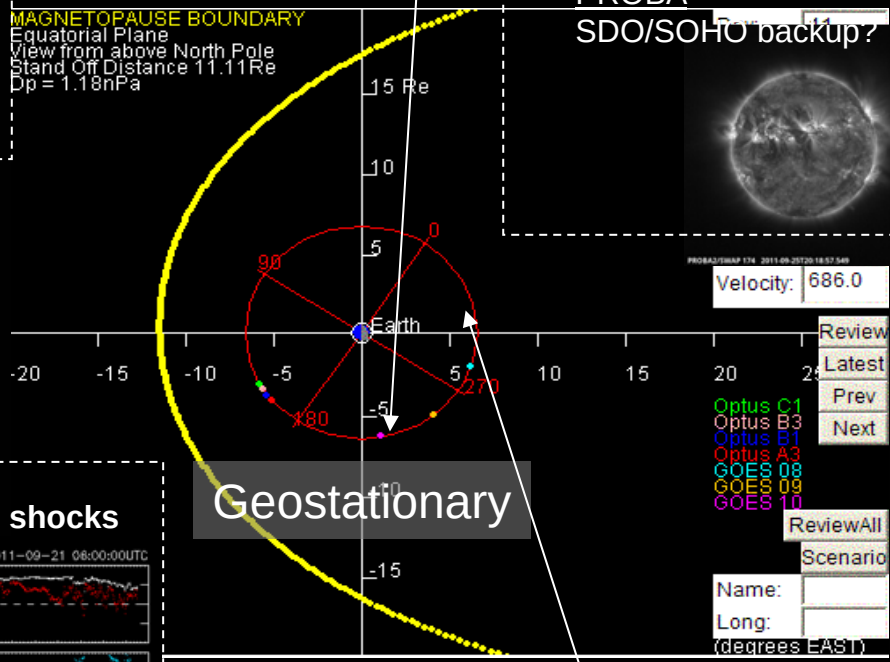


GOES
X-rays (SWF)
radiation for METSATS

STEREO-A
CME side view, in-situ Vsw



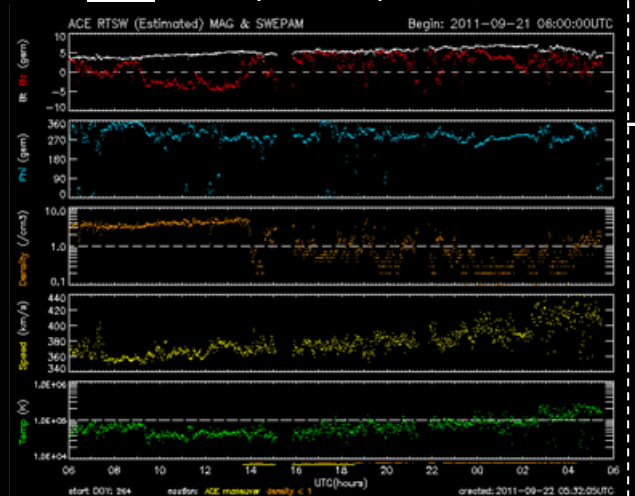
L1



PROBA
SDO/SOHO backup?

Geostationary

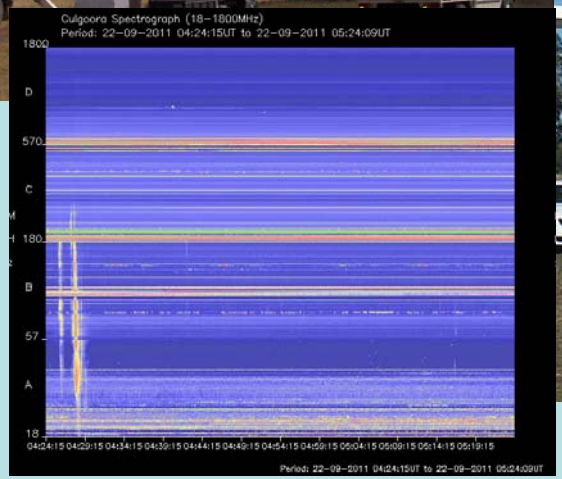
ACE – Vsw, IMF Bz, CME shocks



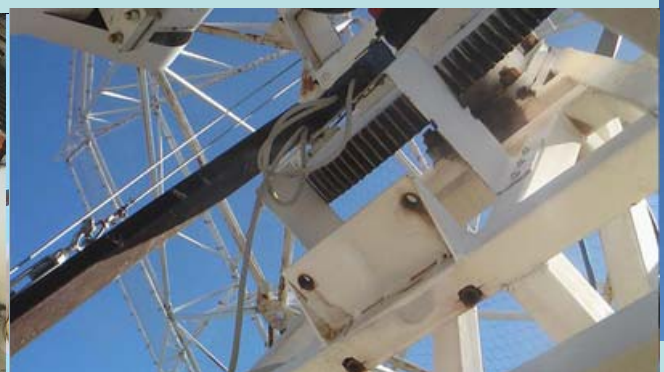
STEREO-B – upcoming ARs,
CME side view, in-situ Vsw

SDO (geosynch)
High res solar images

Australian Government
Bureau of Meteorology



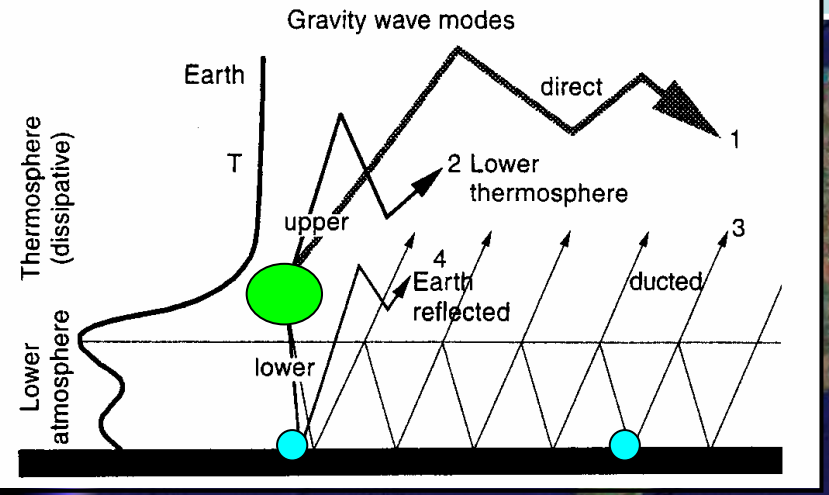
Culgoora Solar Radio Spectrograph upgrade (Nino Bukilic)



Short term ionospheric variability

Possible polar sources for atmospheric gravity waves and associated travelling ionospheric disturbances (TIDs)

Expect a combination of modes (1), (3) and possibly (4) at the observation radio reflection point.



Propagating AGW modes

Upper modes primarily affected by thermosphere
(1) direct wave observed far from thermospheric source
(2) direct wave seen near source

Lower modes primarily affected by lower atmosphere (troposphere/stratosphere/mesosphere). Modes occur for thermospheric source and lower atmosphere source such as a tropospheric cold front [T] or stratospheric jet stream.
(3) Wave ducted between surface and large temperature gradient at mesopause observed far from source
(4) Earth reflected wave close to source

[Neudegg et al, COSPAR 2010]

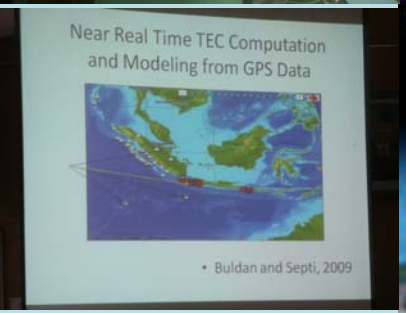
Sydney
observation radio reflection point
Irirangi
tropospheric cold front
(3) (4)
(1)
(3)
[T]
[P]
Macquarie Is
(Plasmapause)
(1)
(3)
(2)
(4)
Casey (polar cap)
[C] dayside
[S] nightside
Auroral oval
Davis (polar cusp)

Field-aligned-currents (FACs) at E-region (100km) altitudes may be strong thermospheric sources for upper modes,

[C] auroral zone R1 FAC near 14MLT, close to the dayside polar cusp, enhanced during merging of the geomagnetic field and IMF.
[S] Substorm current wedge FAC on the nightside auroral oval.
[P] FACs along the plasmapause

(Equatorial) Regional Engagement

AOSWA
Asia-Oceania Space Weather Alliance



RISH NiCT National Institute of Information and Communications Technology

Australian Government
IPS Radio and Space Services

LAPAN

2010 International Workshop on Space Weather in Indonesia

Theme:
Research Enhancement and System Establishment for Space Weather in Indonesia

Topics:
Plan and results of the research project on Space Weather
Promotion of Space Weather (study and operation)
International Network for Space Weather in Asia Oceania Region

Opening Speech :
Drs. Bambang S. Tejasukmana, Dipl.Ing
Deputy Chairman of LAPAN

Date and Venue
1 - 3 December 2010
Pusat Pemanfaatan Sains Antariksa LAPAN
Jl. Dr. Djundjunan No. 133, Bandung

Keynote Speech :
Prof. Dr. Mamoru Yamamoto, RISH Kyoto University Japan
Drs. Sri Kaloka Prabotosari, LAPAN
Dr. Takeshi Murata, NICT Japan

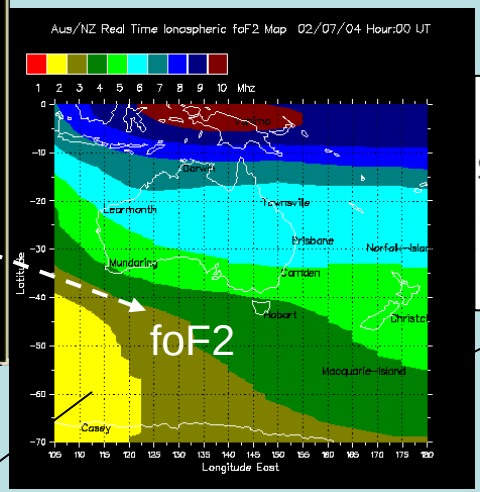
Invited Speech :
Dr. Dave Nuedegg, IPS Australia
Dr. Yuichi Otsuka, STEL Nagoya University
Directorate of Post and Telecommunication
Directorate of Air Transportation
Indonesia Satellite Association
BAKOSURTANAL

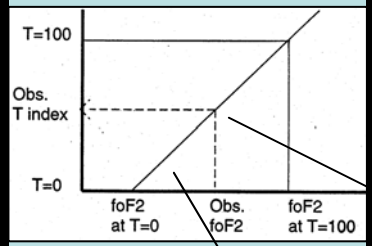
Further information contact :
timbul@bdg.lapan.go.id;timbulm@yahoo.com

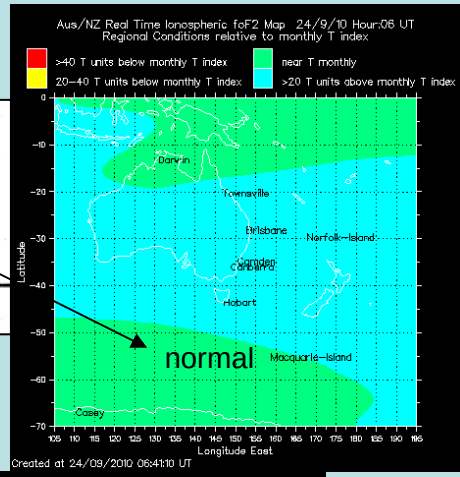
Australian Government
Bureau of Meteorology

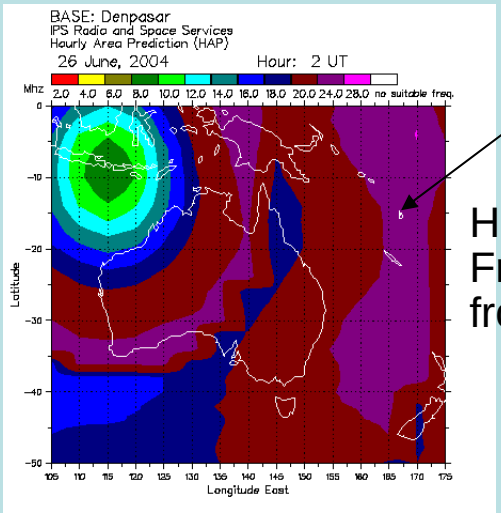
IPS

HF radio communications
‘bread and butter service’ since 1947

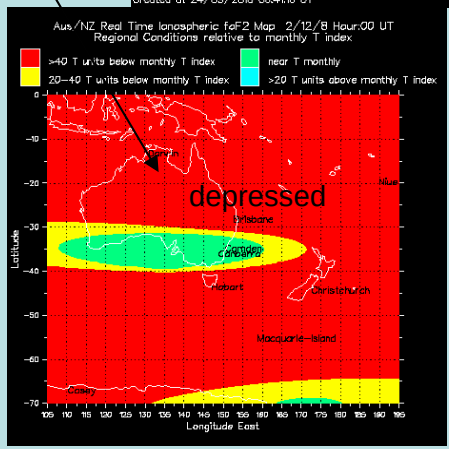








Hourly area prediction of max usable Frequencies (MUF) HF frequencies from a Tx site to broadcast area.



SUBJ: IPS HF RADIO COMMUNICATIONS WARNING 10/21 ISSUED AT 23/2354Z OCTOBER 2010 BY THE AUSTRALIAN SPACE FORECAST CENTRE. DEGRADED HF PROPAGATION CONDITIONS EXPECTED FOR 24 OCTOBER 2010
IF COMMS DIFFICULTIES EXPERIENCED TRY A LOWER FREQUENCY BAND

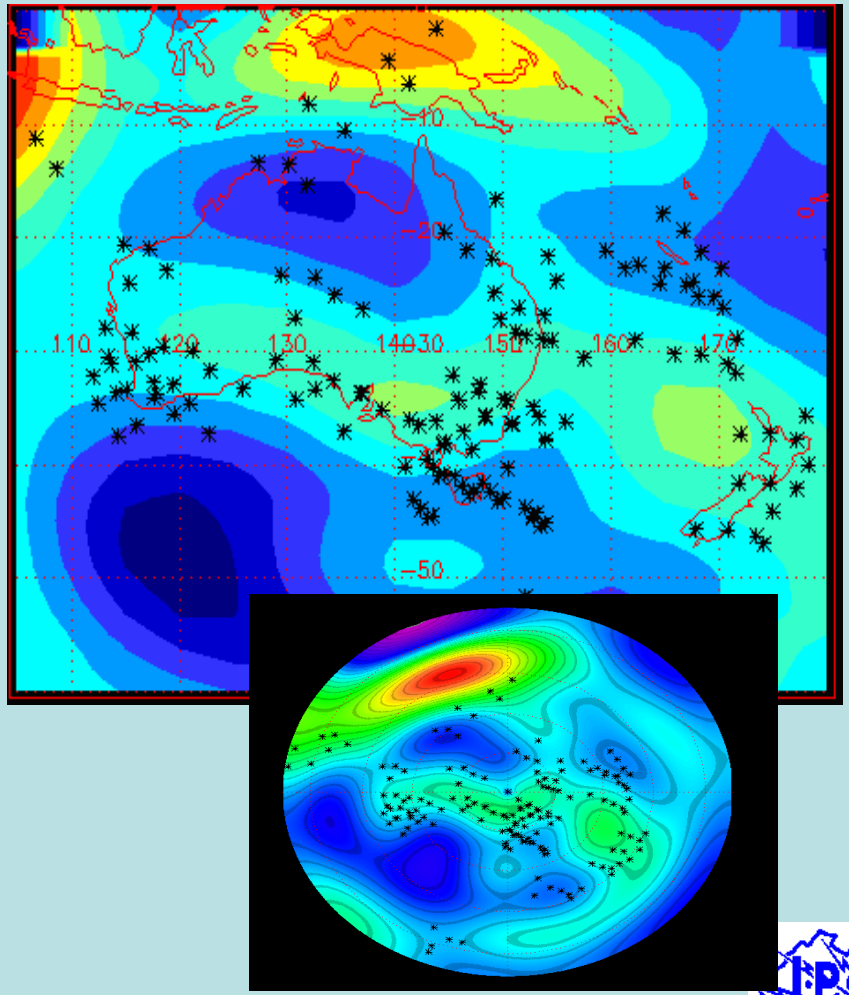
HF COMMUNICATIONS FORECAST (AUSTRALIAN/NEW ZEALAND REGION)
FREQUENCY BANDS

T-index	MUFs	2	4	6	8	12	16	22	26
-10	-22%	2	4	6	8	8	12	16	16

Australian Government
Bureau of Meteorology

Regional Ionospheric Modelling

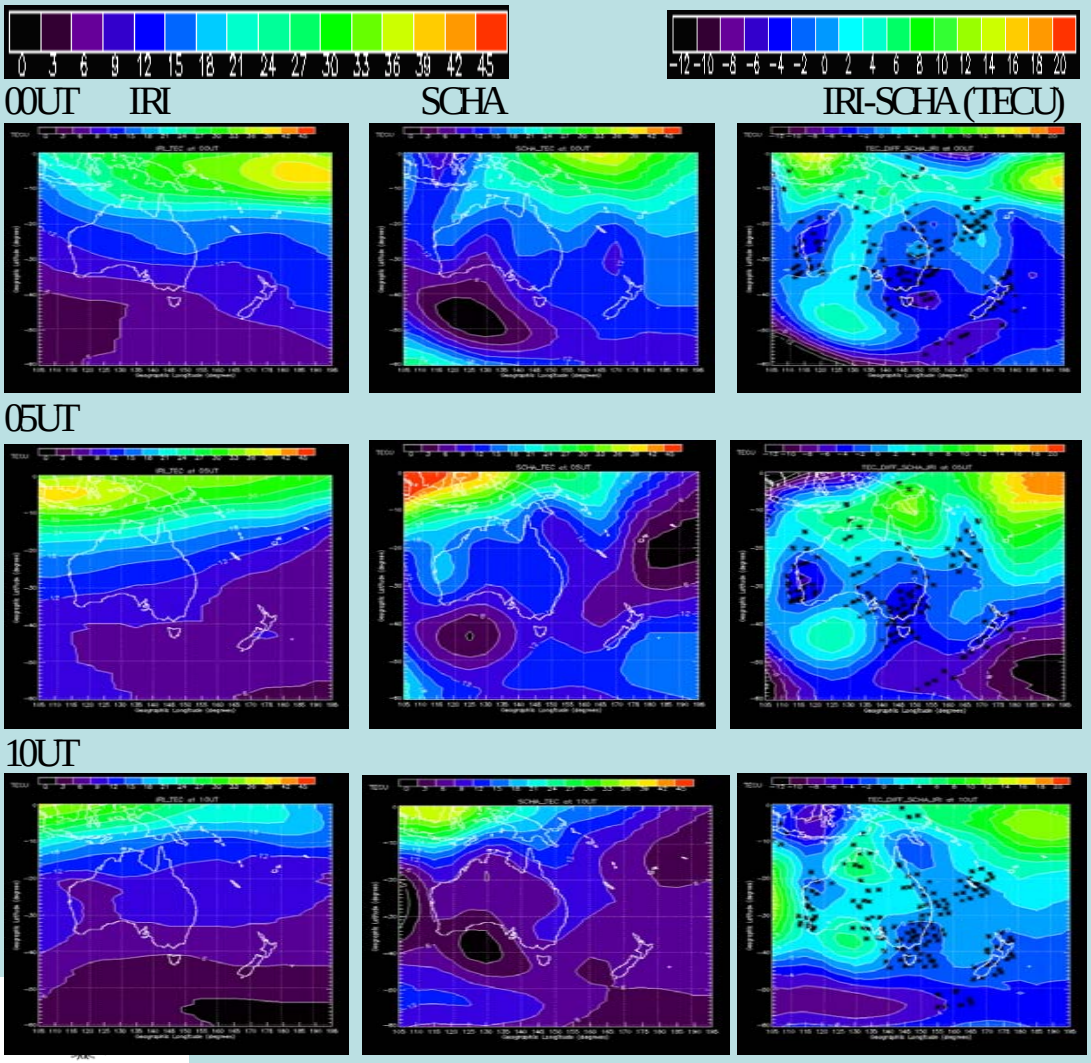
- GPS-derived real time ionospheric monitoring and modelling
- Total Electron Content (TEC) from 90km to GPS altitude (25,000km).
- Regional model, using Spherical Cap Harmonic Analysis (SCHA)
- Improved spatial resolution over ionosondes
- Forecast capability
- Data assimilation
- Conversion from TEC to foF2 for HF predictions very complex



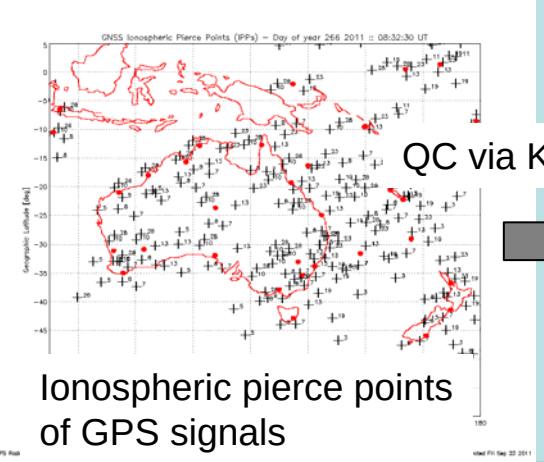
[Mike Terkildsen, Zahra Bouya, Matt Francis]

Regional ionospheric modelling :SCHA

$$VTEC(\theta_c,\lambda_c)=\sum_{k=0}^{K\max}\sum_{m=0}^{K}P^{m}_{nk(m)}(\cos\theta_c)\left[g^{m}_{k}\cos(m\lambda_c)\quad+h^{m}_{k}\sin(m\lambda_c)\right]$$

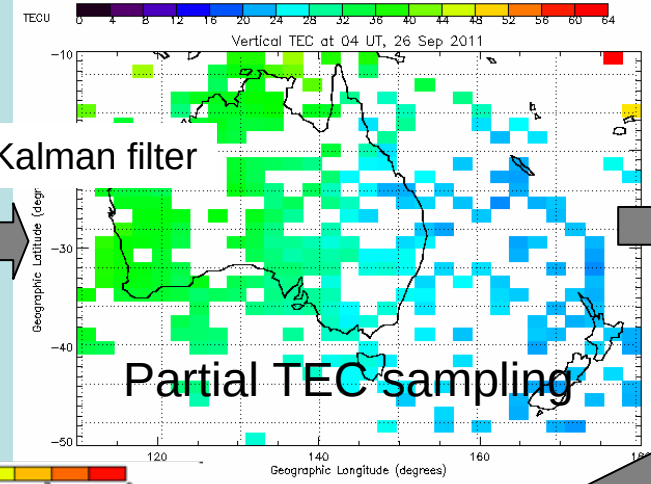


- Spherical Cap Harmonic Analysis (SCHA) for regional model of TEC
- High spatial resolution with less coefficients than global SHA
- Expansion stable over small regions, scalable
- SCHA gives more detail than simple interpolation (e.g. kriging)
- Combining SCHA with a model ionosphere gives even more detail

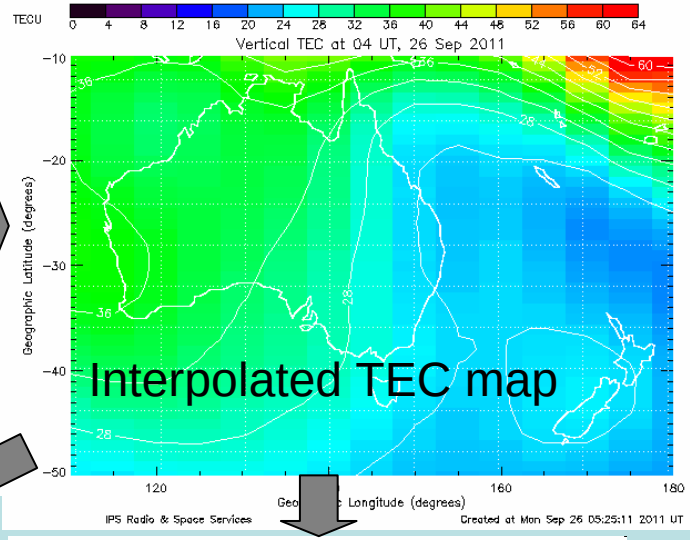


Ionospheric pierce points of GPS signals

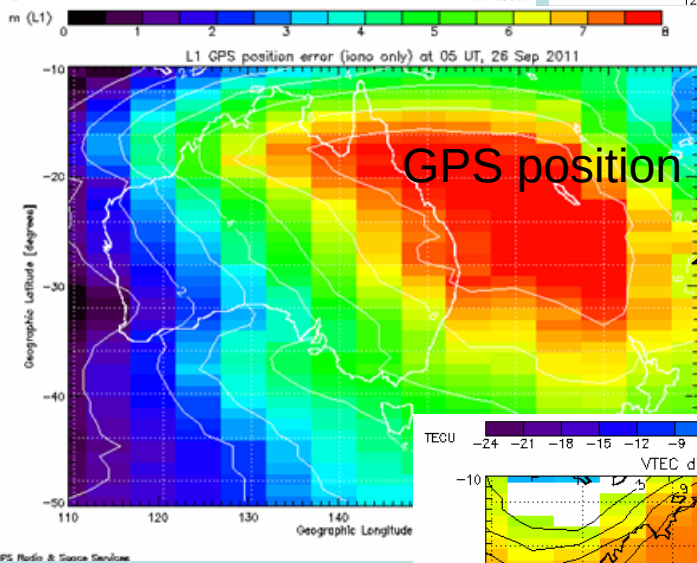
QC via Kalman filter



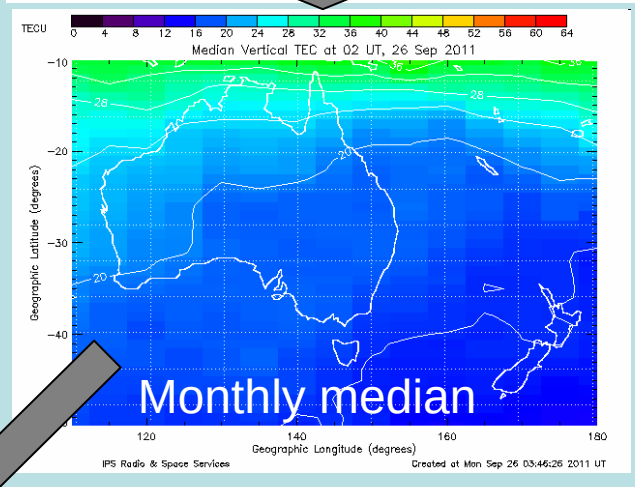
Partial TEC sampling



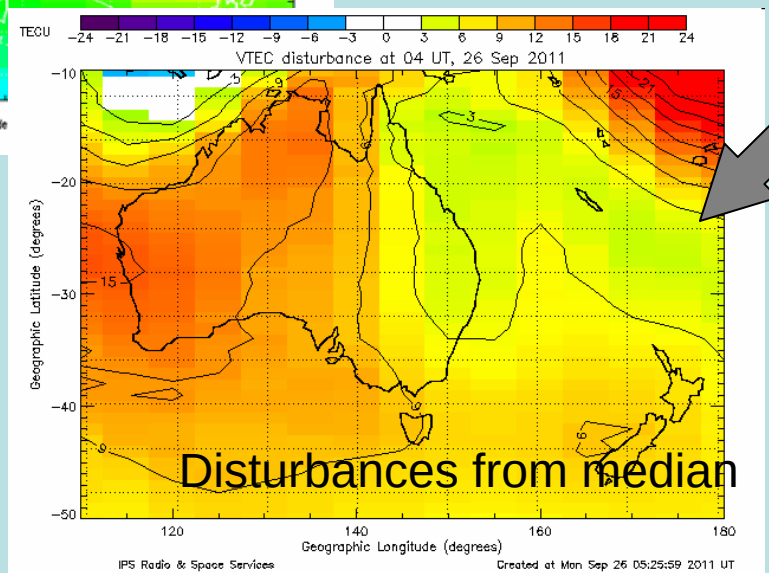
Interpolated TEC map



GPS position error



Monthly median



Disturbances from median

Total Electron Content (TEC) In the ionsophere

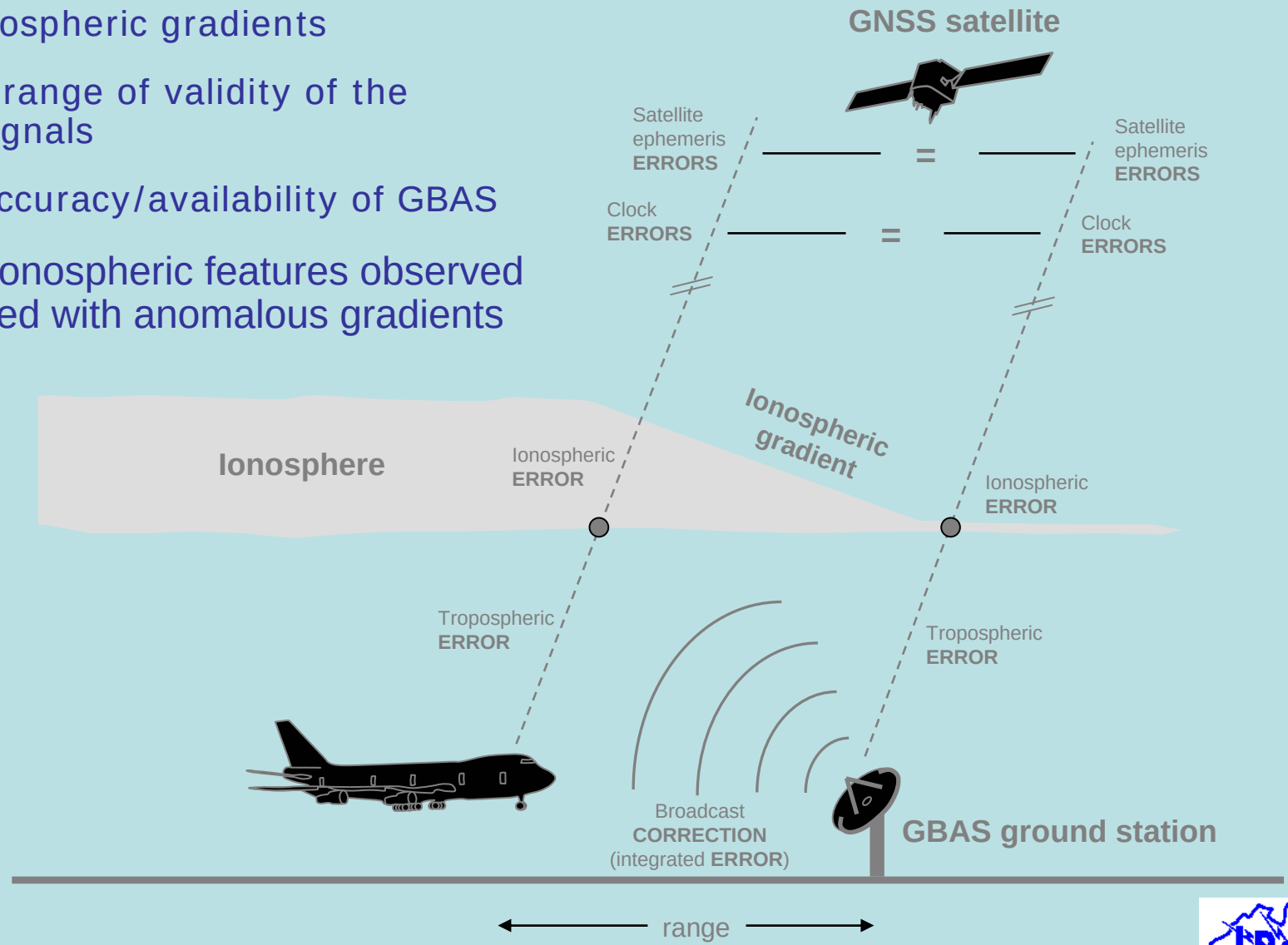
Australian Government
Bureau of Meteorology

Aviation GPS – GBAS – Ground Based Augmentation system

Spatial de-correlation of ionospheric error component

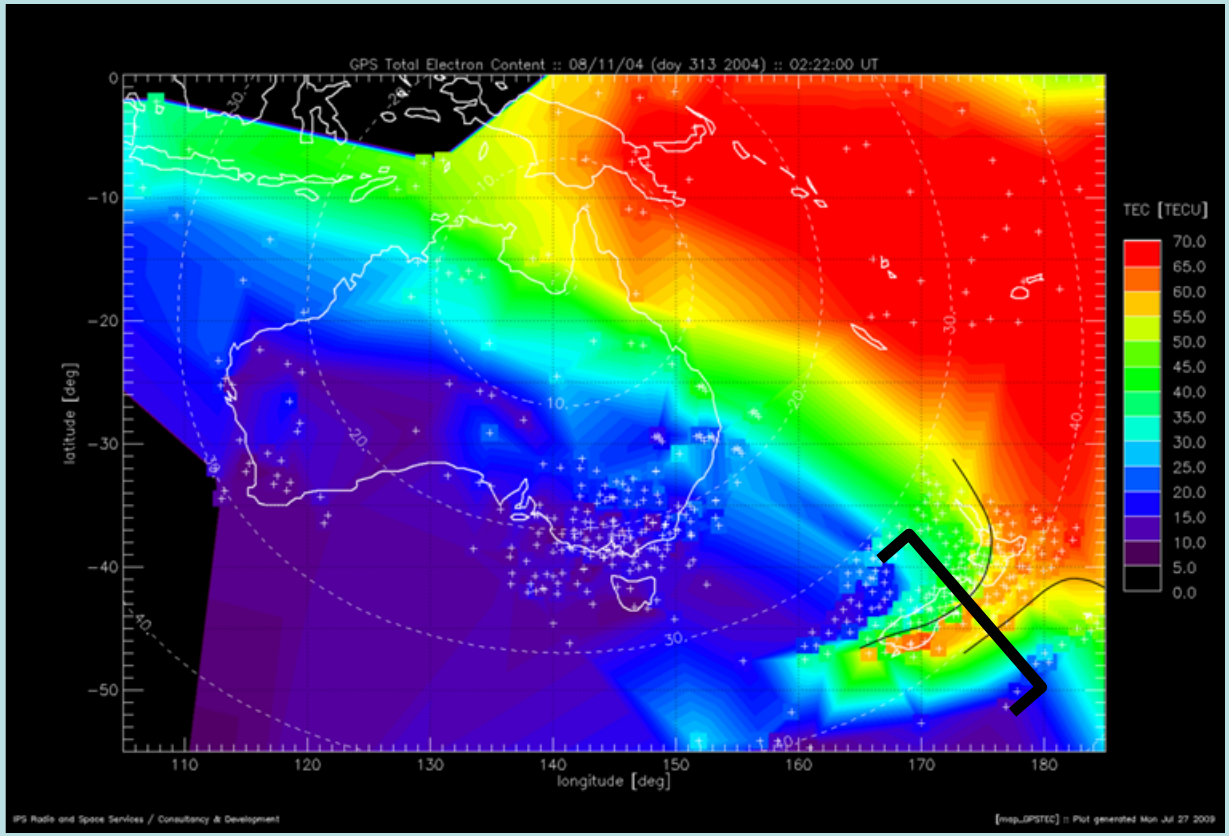
- Due to ionospheric gradients
- Limits the range of validity of the correction signals
- Reduces accuracy/availability of GBAS

5 observed ionospheric features observed are associated with anomalous gradients



Ionospheric plumes

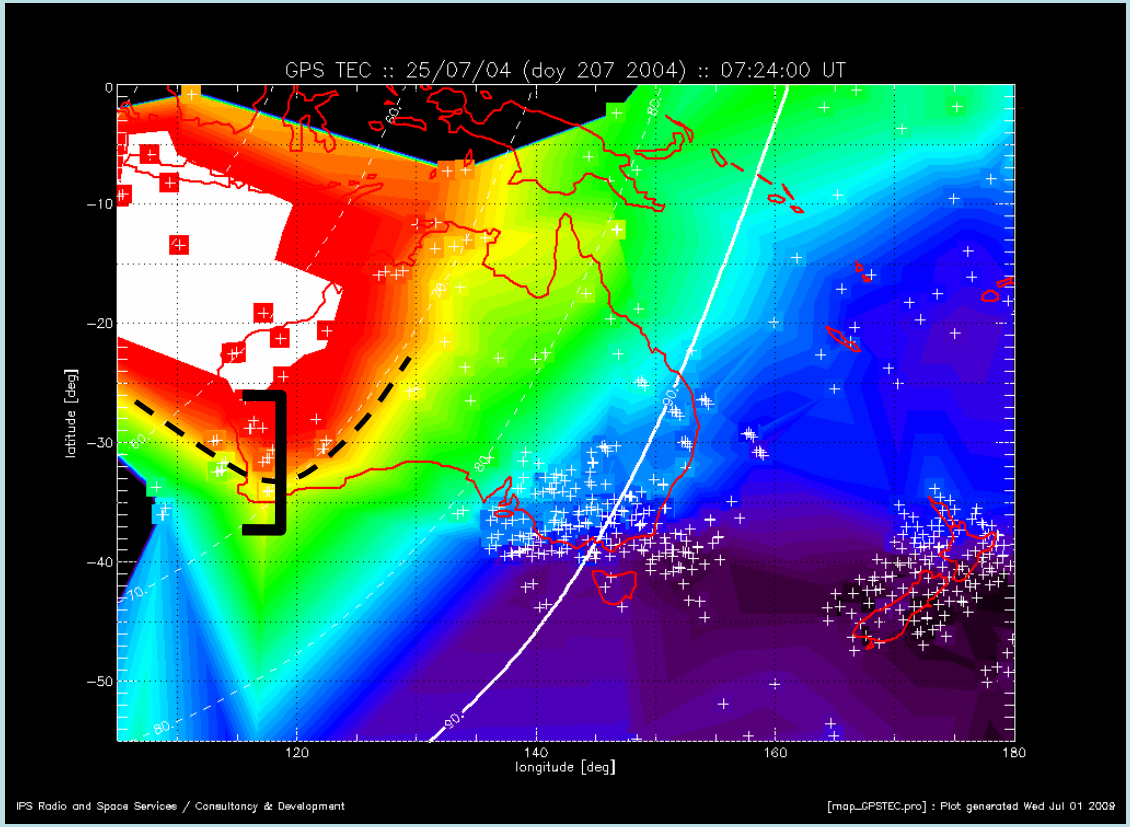
- Comparable to ionospheric 'plumes' observed over CONUS
- Generally smaller in magnitude (peak amplitude of ionospheric delay)
- Smaller ionospheric gradients
- Significant source of storm-time ionospheric variability



Aviation GPS – GBAS – Ground Based Augmentation system

Poleward expansion of equatorial anomaly

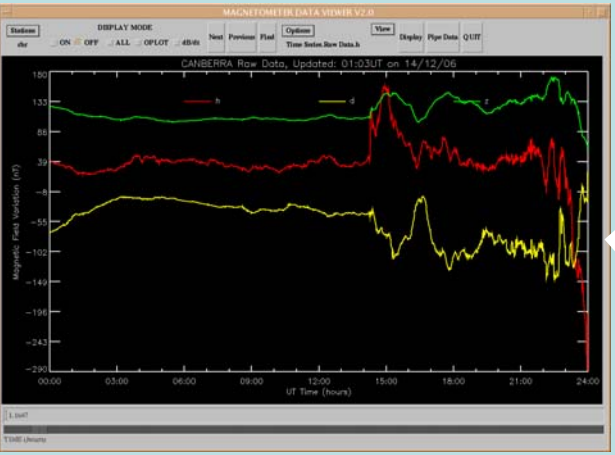
- Under super-fountain conditions, can reach well down into mid-latitudes
- Sharp boundaries, commonly found on poleward edge of fountain under storm conditions



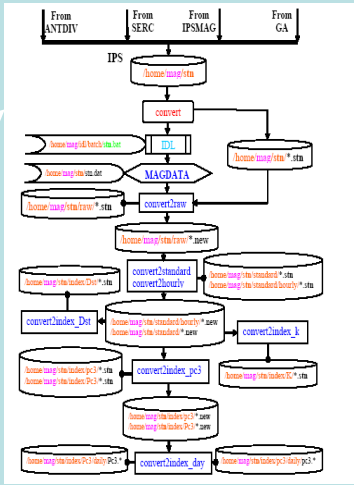
Australian Government
Bureau of Meteorology

Geomagnetic

[Richard Marshall]

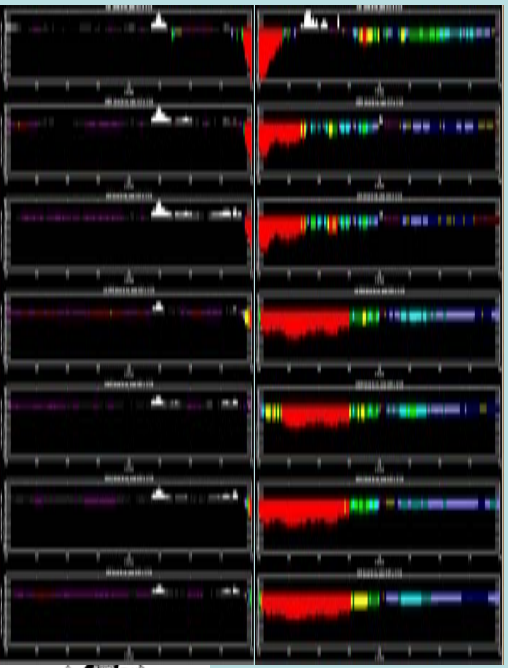


Raw data

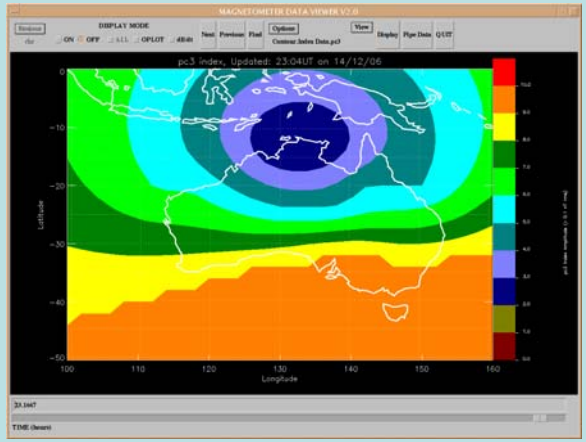


processing

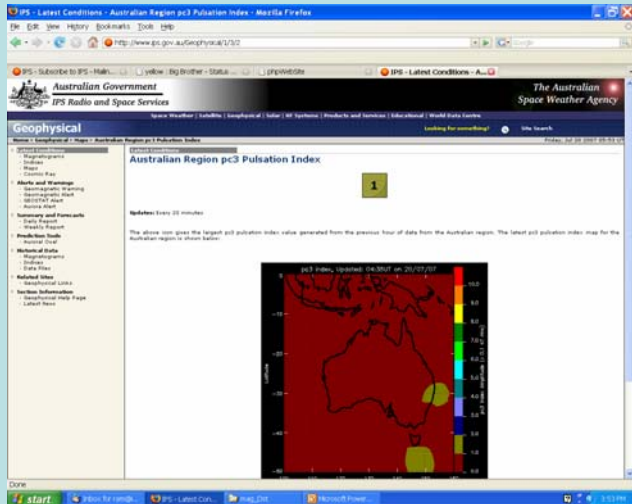
Indices – K, A, pc3



Dst storm index

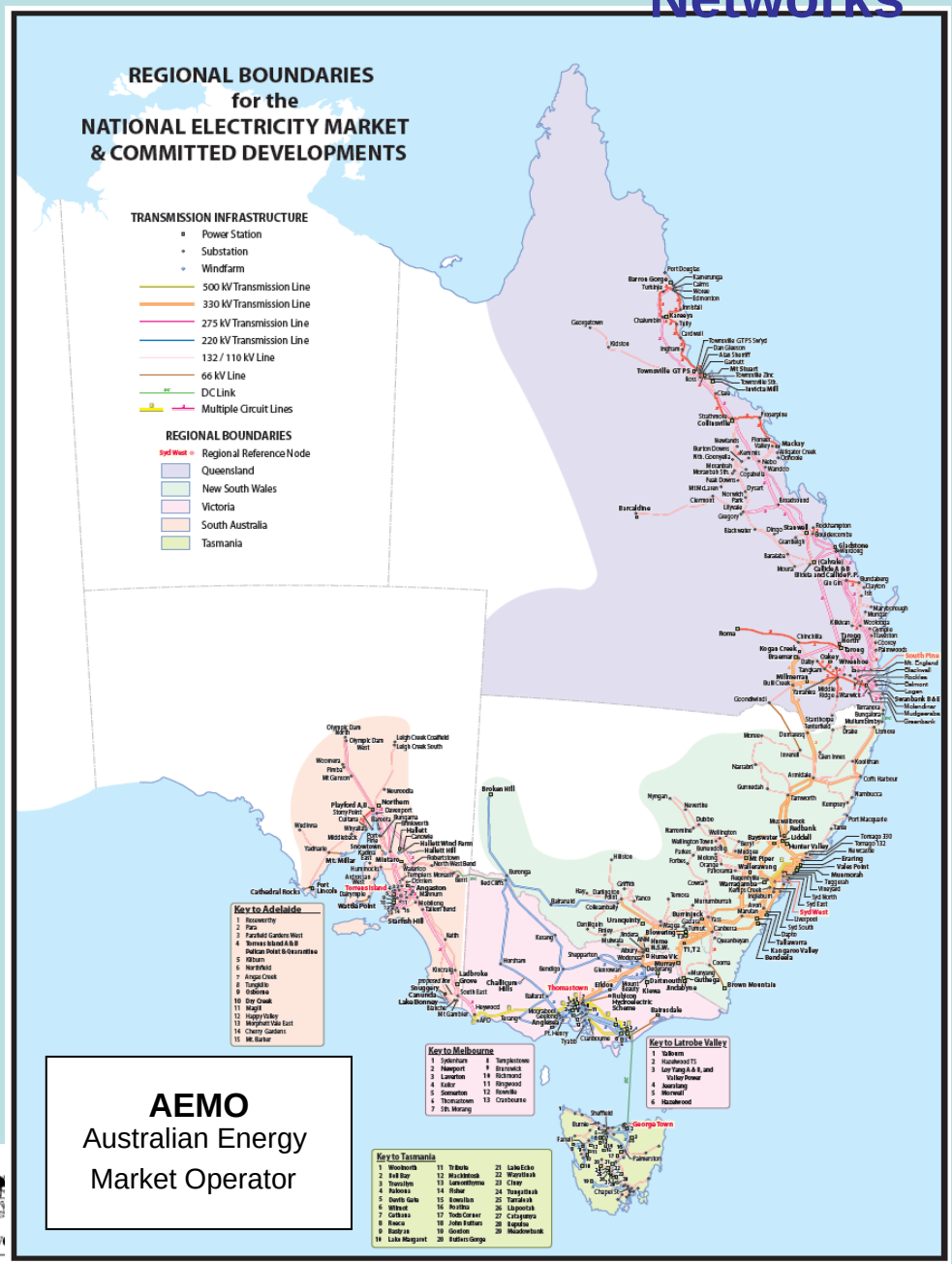


Maps of K, pc3



Australian Government
Bureau of Meteorology

Geomagnetically Induced Currents (GICs) in Power Networks



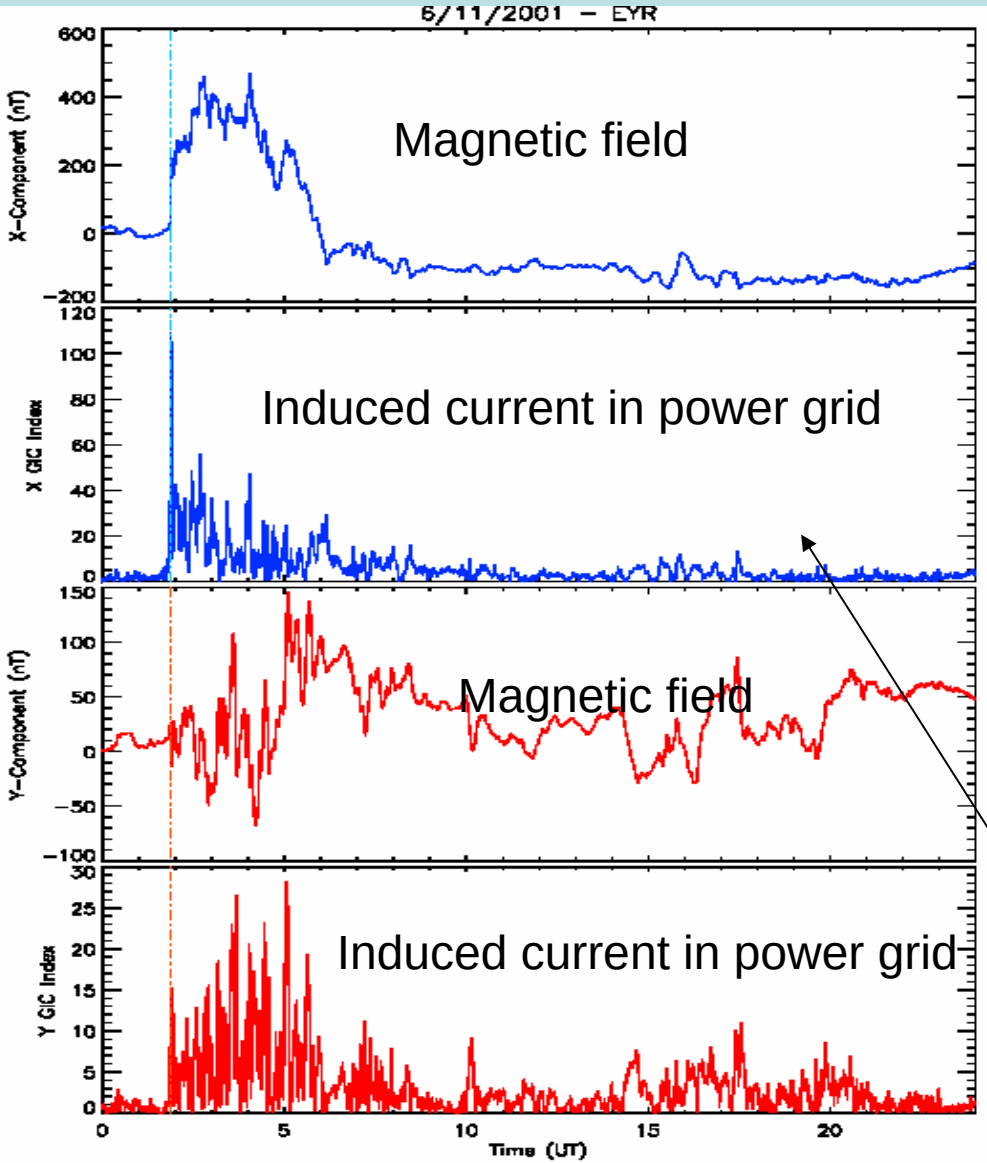
Increased national connectivity driven by

- **Market Competition**
- **Robustness to demand**

BUT longer power lines means increased susceptibility to Space weather

Australian Government
Bureau of Meteorology

GICs in Power Networks

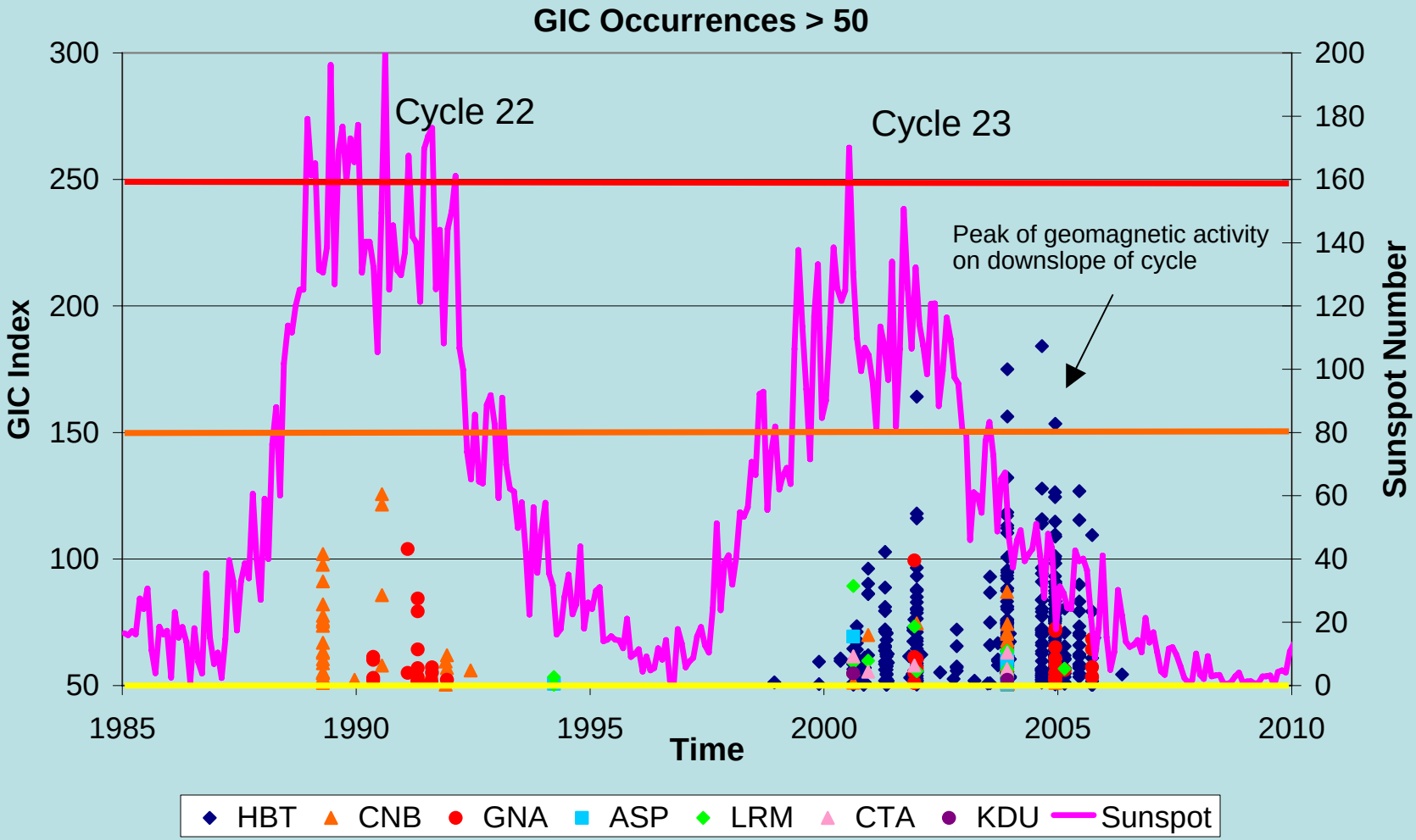


Transformer burnout occurred in
Canada (Hydro-Quebec 1989)
South Africa
New Zealand 2001

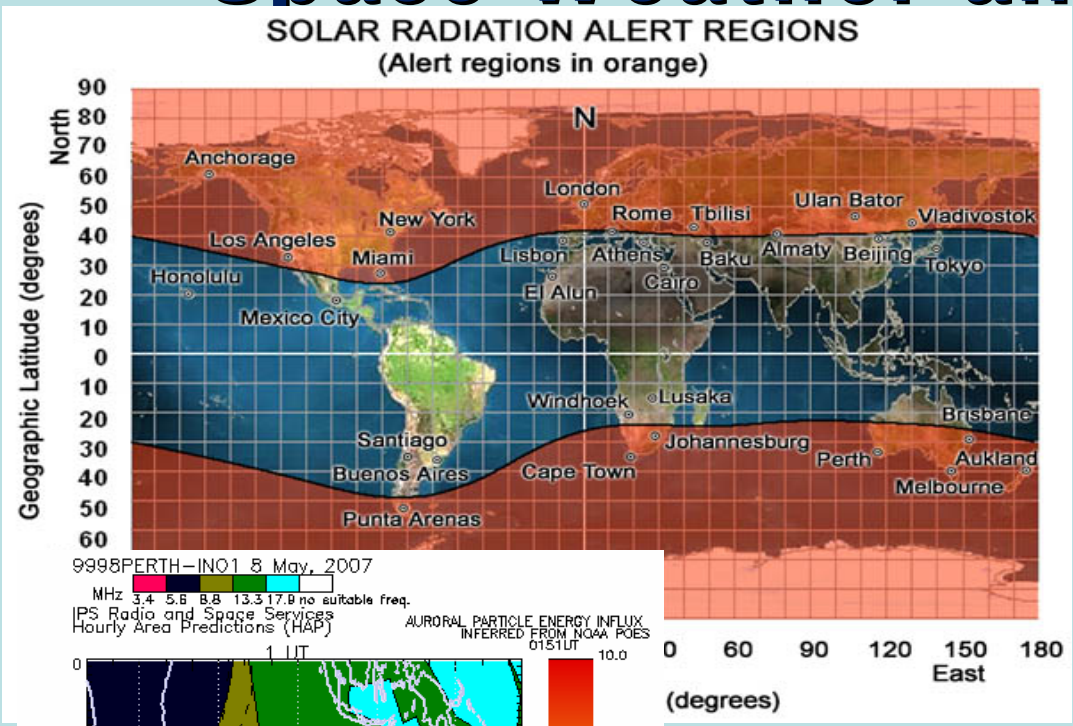
- **New Zealand Previously considered safe due to mid-latitude location**
- **Prior to 2001 no GIC related faults recorded**
- **Fault attributed to premature ageing**
- **Analogous situation between NZ south Island and Tasmania**

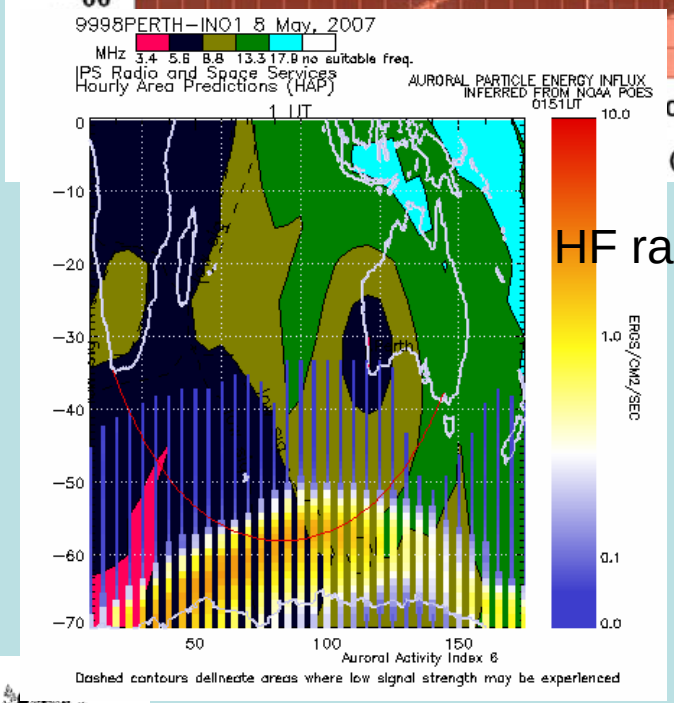
GICs in Power Networks

[Richard Marshall, Liz Smith]

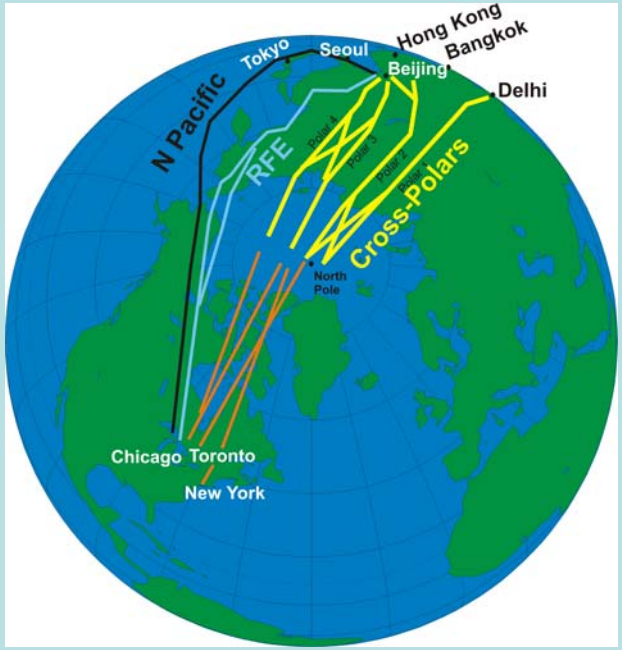


Space Weather and Aviation

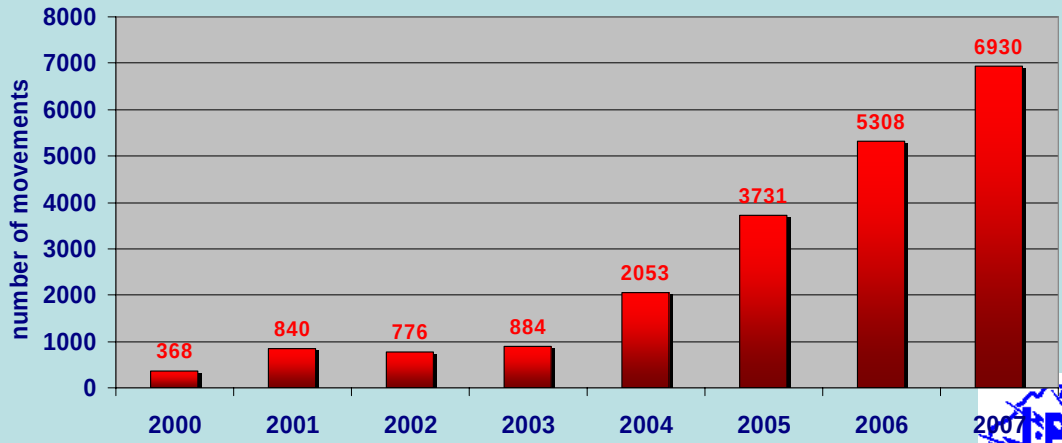




HF radio



Crosspolar Traffic Levels from 2000 through 2007

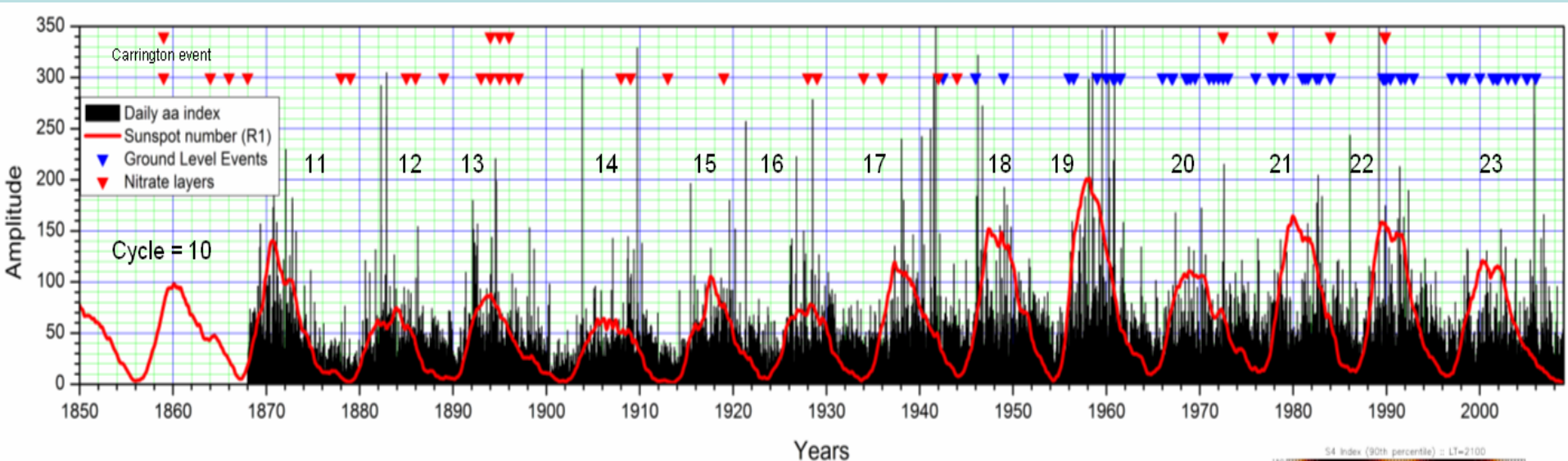


Australian Government
Bureau of Meteorology

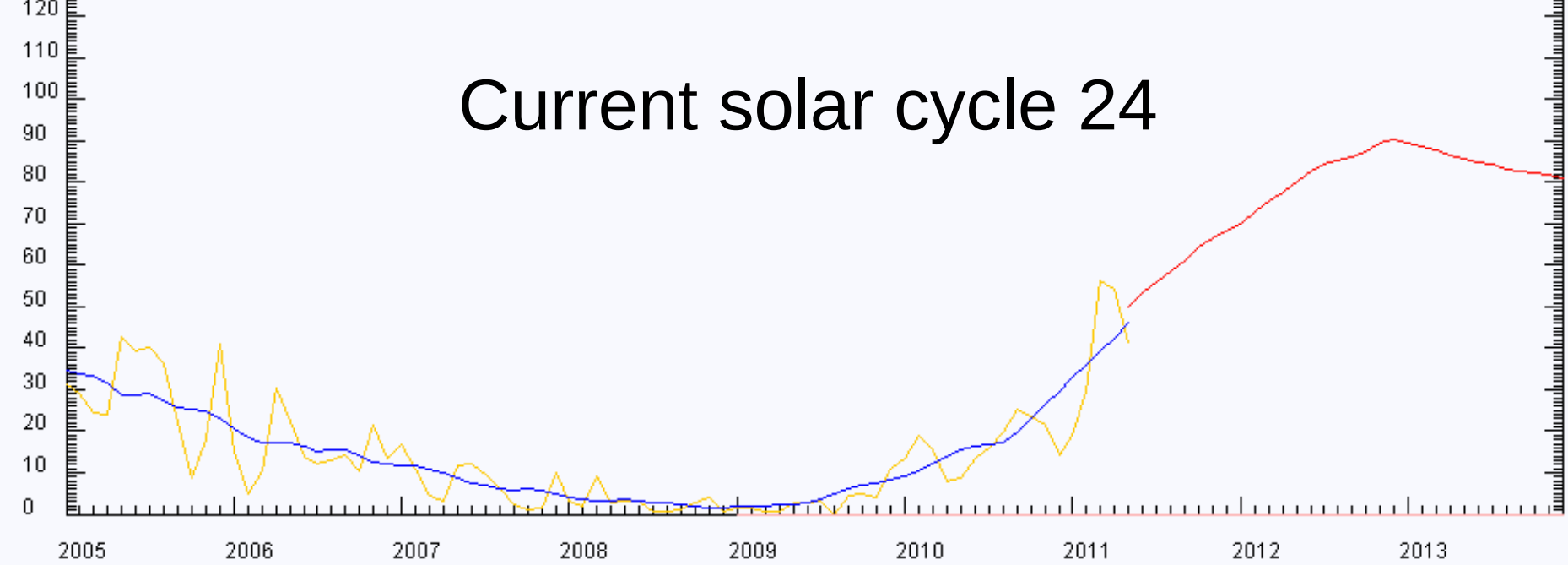
IPS

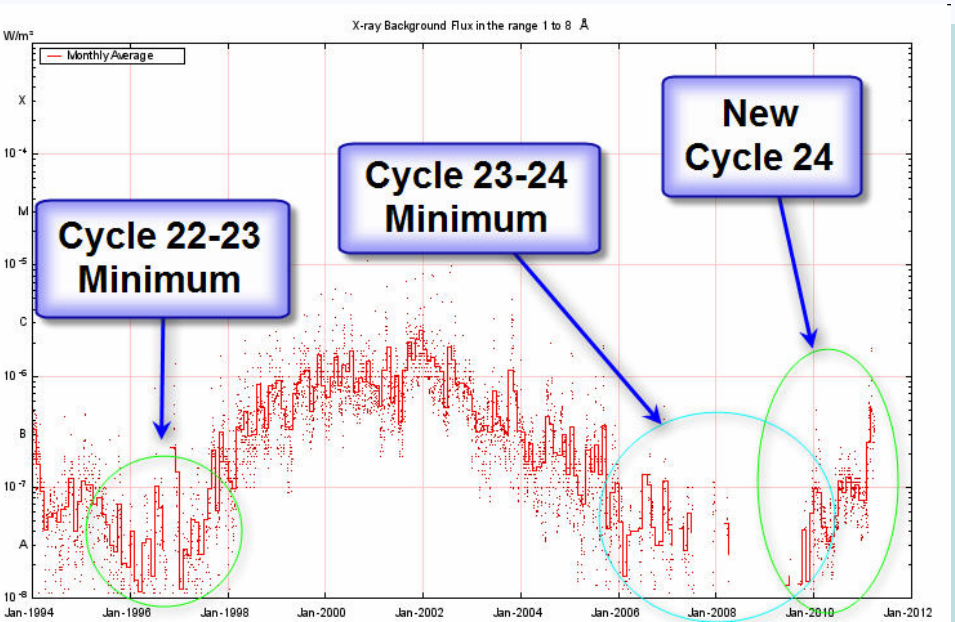
Current solar cycle 24

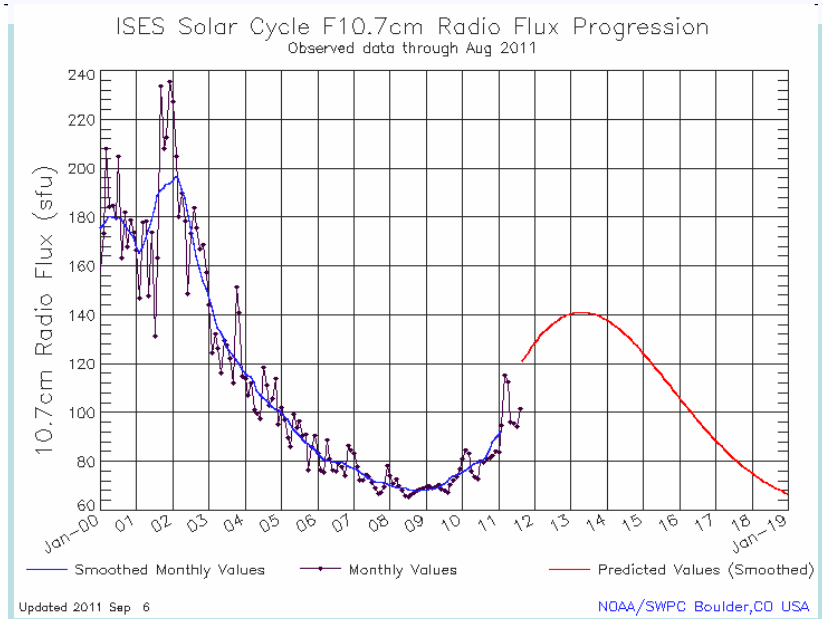
- Fairly low max (Jan 2013) – predict sunspot number = 90
- What it means
  - Low solar radiation fluxes (R12, X-ray)
  - Low solar particle fluxes (probably; lack of Solar Proton Events (SEP) ?)
  - High cosmic ray fluxes as low IMF does not divert them as much
  - Fewer geomagnetic storms



Current solar cycle 24







Australian Government
Bureau of Meteorology

What lower solar activity does

Region	Likely characteristics for low solar cycle (R12 < 50)	Issues
Sun	Fewer active regions, Low number of sunspots, generally less activity Lower fluxes (10.7cm and all wavelengths) Fewer flares	Normal coronal hole activity? But possibly more solar particle events (SEP)? Ice-core studies suggest several large SEP events (including Carrington event) occurred near 1900.
Solar wind	Less disturbed Fewer shocks Fewer ICME Less turbulent environment?	Solar wind less disturbed, Well-established, high speed solar winds Same high speed solar winds Better connectivity to Earth?
Cosmic Ray	Increased galactic fluxes Decreased solar cosmic ray particle fluxes	**Bad news for astronauts** Maybe deep space issues, Heliopause moves closer to sun?
Magnetosphere	Fewer substorms?	Aurora generally near auroral oval; **better for aviation** Few killer electron events; **better for satellites**
Geomagnetic field	Lower ionospheric conductivities Still potential for extreme geomagnetic events	Smaller magnetic activity effects **Major storms (1 or 2 per solar cycle) probability probably unchanged**
Neutral atmosphere (thermosphere)	Less heating of upper atmosphere	Less satellite drag **More benign environment for LEO** **Less debris removal**
Ionosphere	Less ionisation of upper atmosphere	Smaller HF bandwidth is more vulnerable to storms and fadeouts; **Bad for HF** Bottom-side ionosphere more structured (F1 always present); **bad for HF** Less scintillation at low latitudes; Less problems with trans-ionospheric propagation - **better for SATCOM; GPS**