



Australian Government

Bureau of Meteorology

The Australian region space weather network

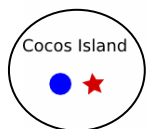
Marshall R, D. Neudegg, P. Wilkinson, J. Kennewell¹, G. Patterson, M. Terkildsen, G. Steward, M. Hyde, E. Smith, Z. Bouya, M. Francis, J. Caruana, B. Paterson, N. Prestage, M. Layoun, N. Bukilic, R. Jenssen, M. Parkinson, C. Thomson, C. Yuile

IPS Radio and Space Services
Bureau of Meteorology

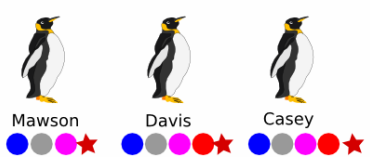
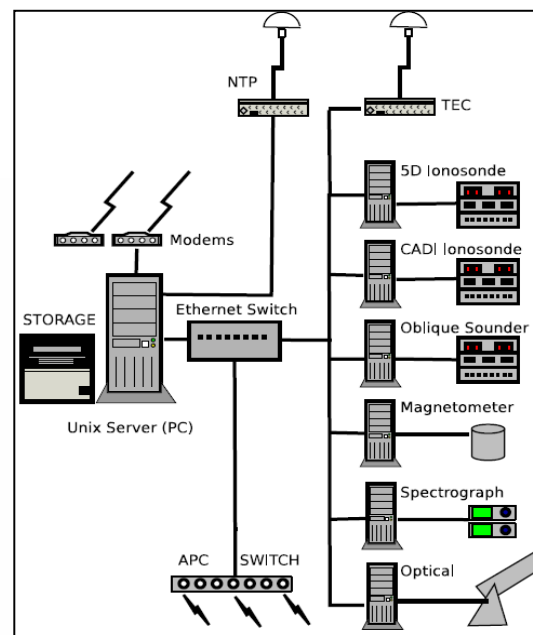
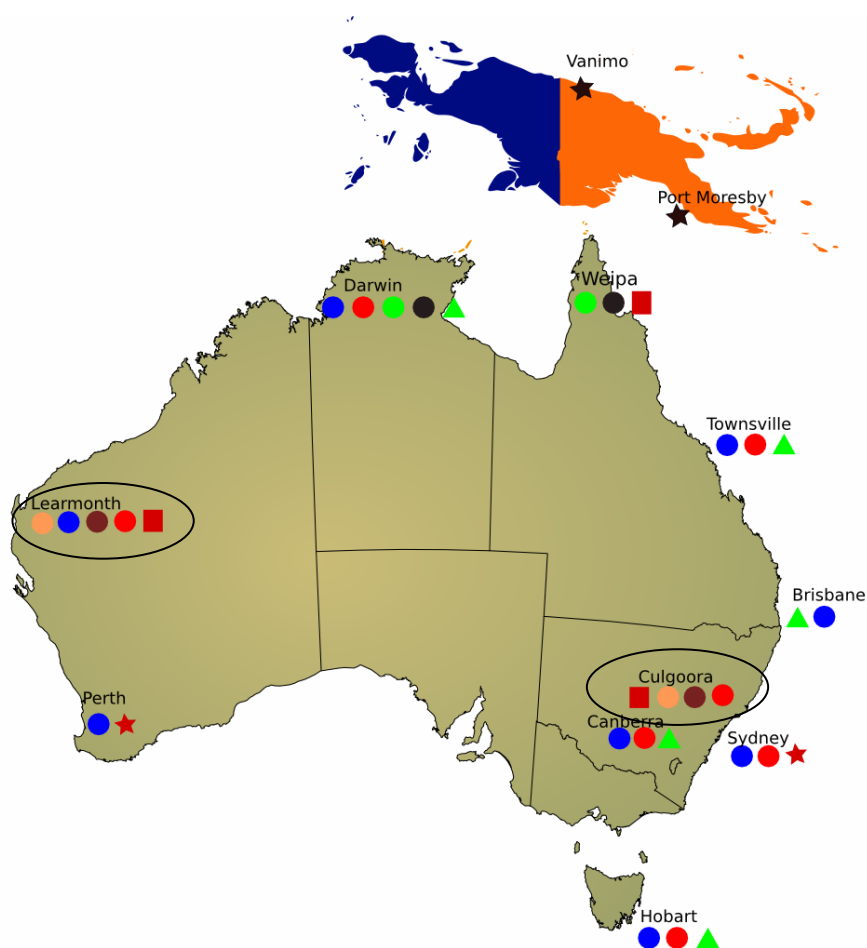
¹ Australian Space Academy



IPSNET - space weather sensor network



- Solar Observatory
- Ionosonde
- Magnetometer
- Riometer
- TEC
- Scintillation
- Pulsation
- Spectrograph
- Internet Access
- Dialup
- Direct link
- Station Closed





IPSNET covers 1/8th (12%) of Earth's surface

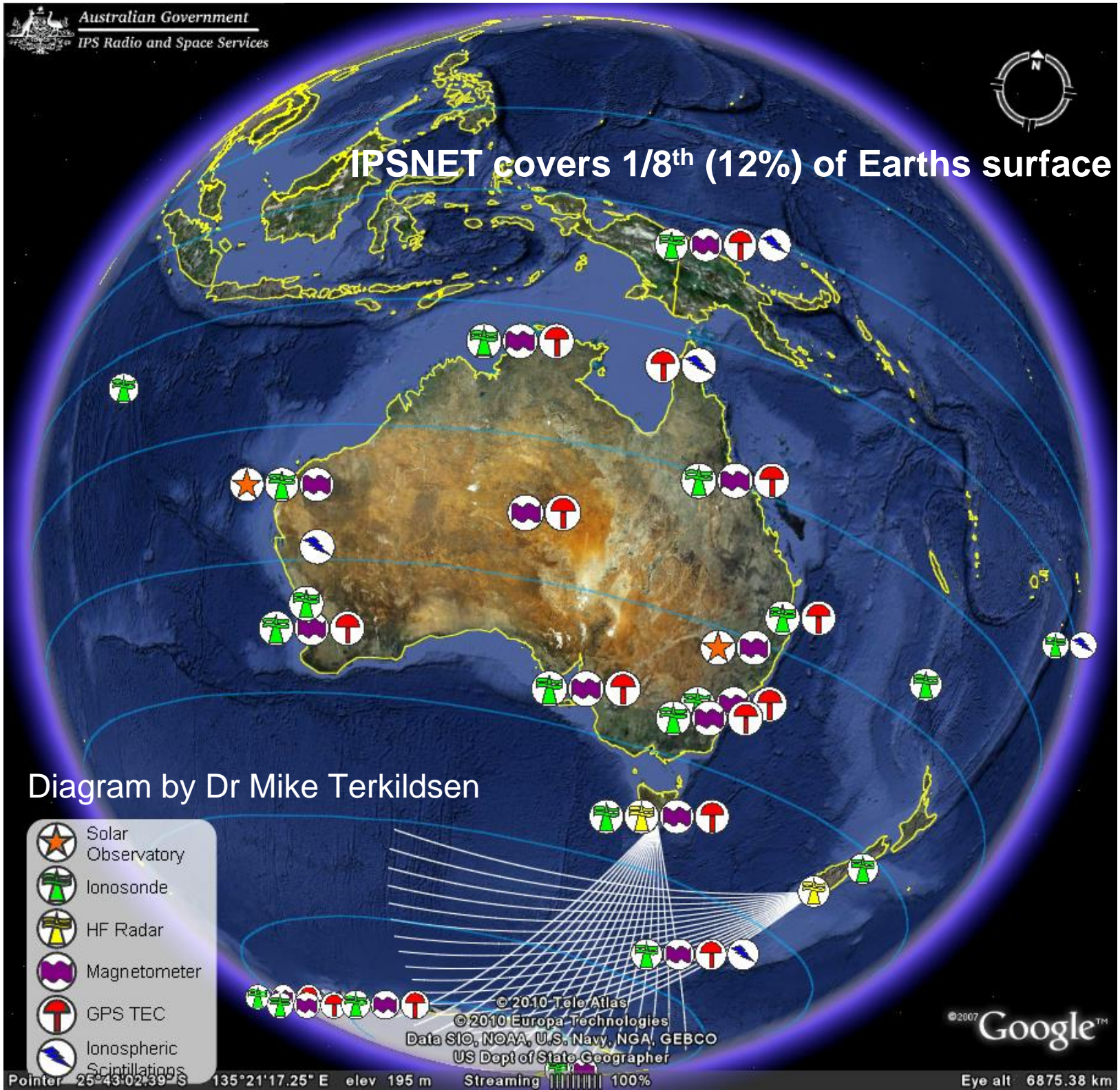


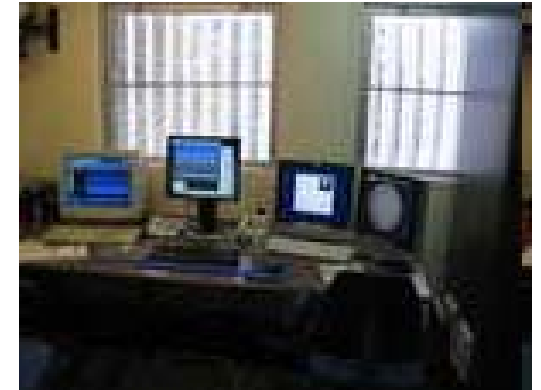
Diagram by Dr Mike Terkildsen

- Solar Observatory
- Ionosonde
- HF Radar
- Magnetometer
- GPS TEC
- Ionospheric Scintillations

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Data SIO, NOAA, U.S. Navy, NGA, GEBCO
US Dept of State Geographer

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Culgoora Solar Observatory

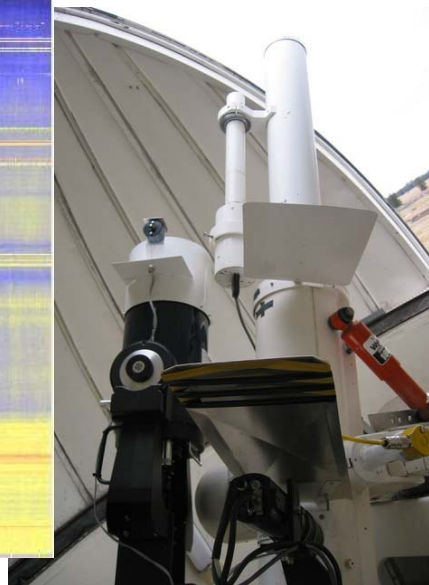
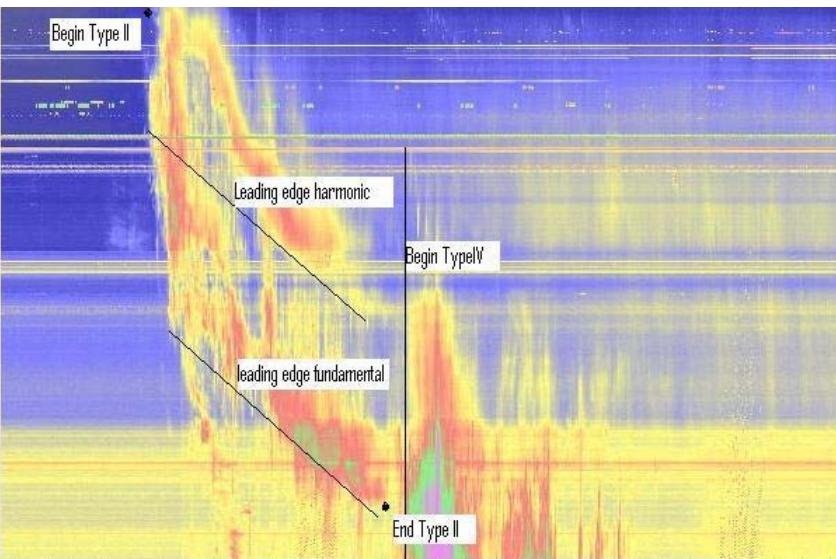
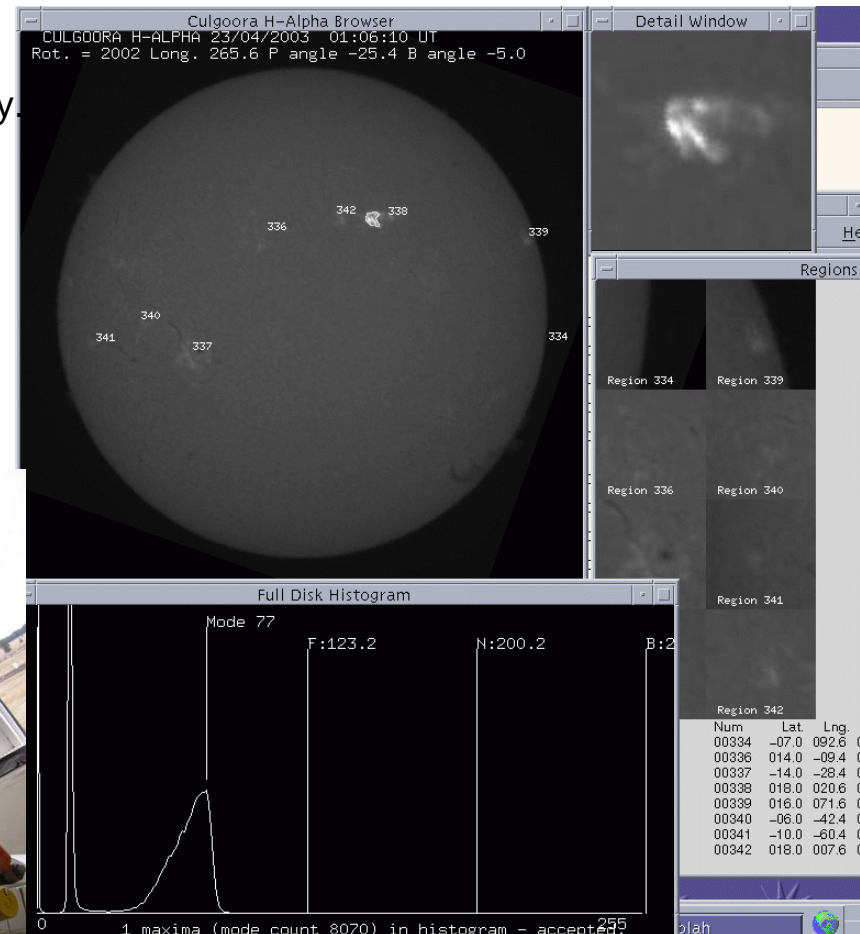


Culgoora

Radio quiet zone Next to Australia Telescope National Facility.
No transmissions allowed. Excellent radio reception site.

Solar radio and optical
Magnetometers (IPS & MAGDAS)
Oblique HF radio Rx from NZ and TVL

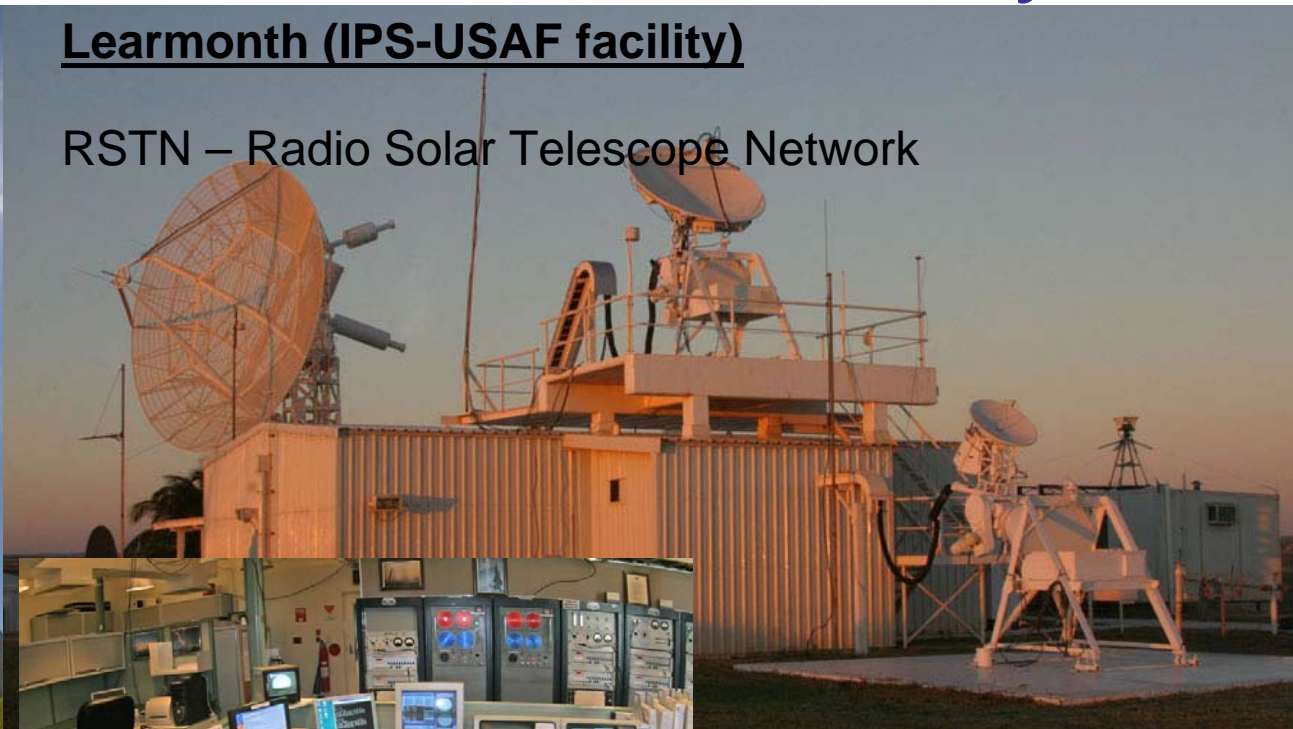
Spectrograph 18-1800MHz (A to D band)



Learmonth Solar Observatory

Learmonth (IPS-USAF facility)

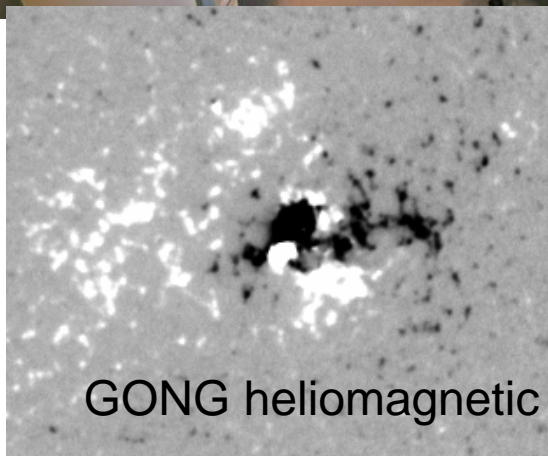
RSTN – Radio Solar Telescope Network



25 MHz to 15.4 GHz
3 parabolic antennae
8 fixed frequencies (245, 410, 610,
1415, 2695, 4995, 8800, 15400 MHz)

Solar Radio Spectrograph (designed by IPS) sweeps from 25 to 180 MHz – fed by semi-bicone (low band) and tracking log periodic (high band) antennae.

Operation from sunrise to sunset



IPSNET Observatories

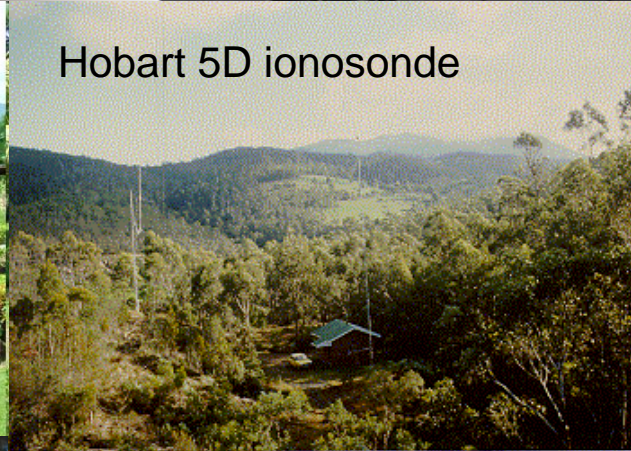
IPSNET sends data to the
Regional Warning Centre (RWC)
Australian Space Forecast Centre
(ASFC)



Vanimo 5D ionosonde
Papua New Guinea



Hobart 5D ionosonde



Canberra 5D ionosonde

Camden IPS magnetometer



Antarctic riometer for PCA



Vanimo scintillation monitor
Papua New Guinea

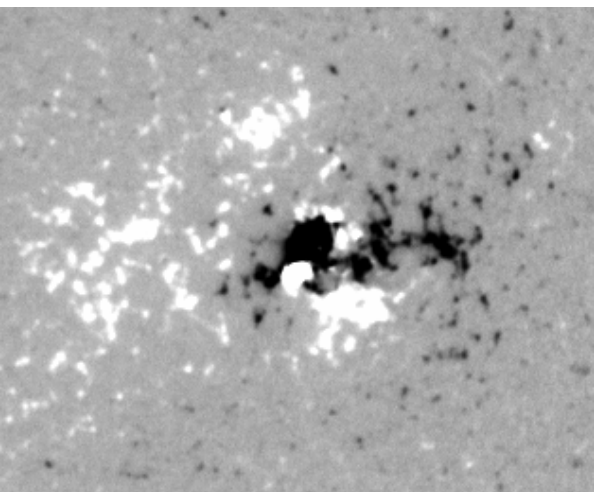
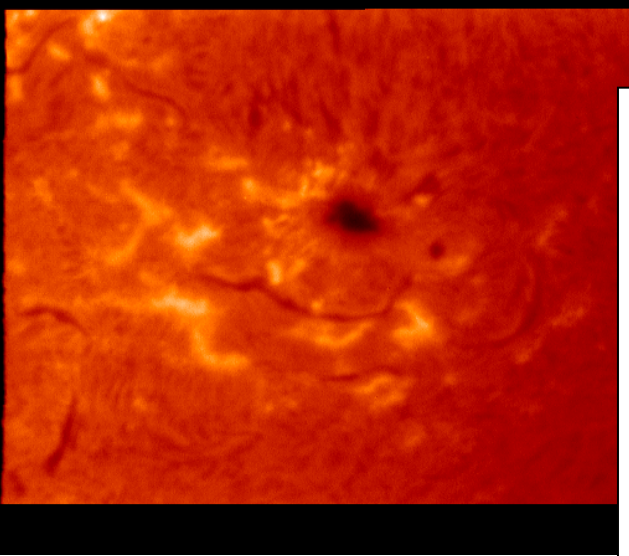


Flare Forecast

Theophrastus. Data and Forecast for 2230Z 4/ 8/2011.

<http://www.ips.gov.au/Solar/2/5>

Region Data			Forecast					
Region Number	McIntosh Class	Region Evolution	Delta Config.	Largest Flare	Probabilities			URSI Keyword
					C	M	X	
1260	Hsx	stable			20	0	0	QUIET
1261	Dai	decaying		M	80	15	2	ERUPTIVE
1263	Eki	stable			90	7	0	ERUPTIVE
1266	Bxo	stable			2	0	0	QUIET
C408	Axx	stable			2	0	0	QUIET
Full Disk Prediction is					98	21	2	

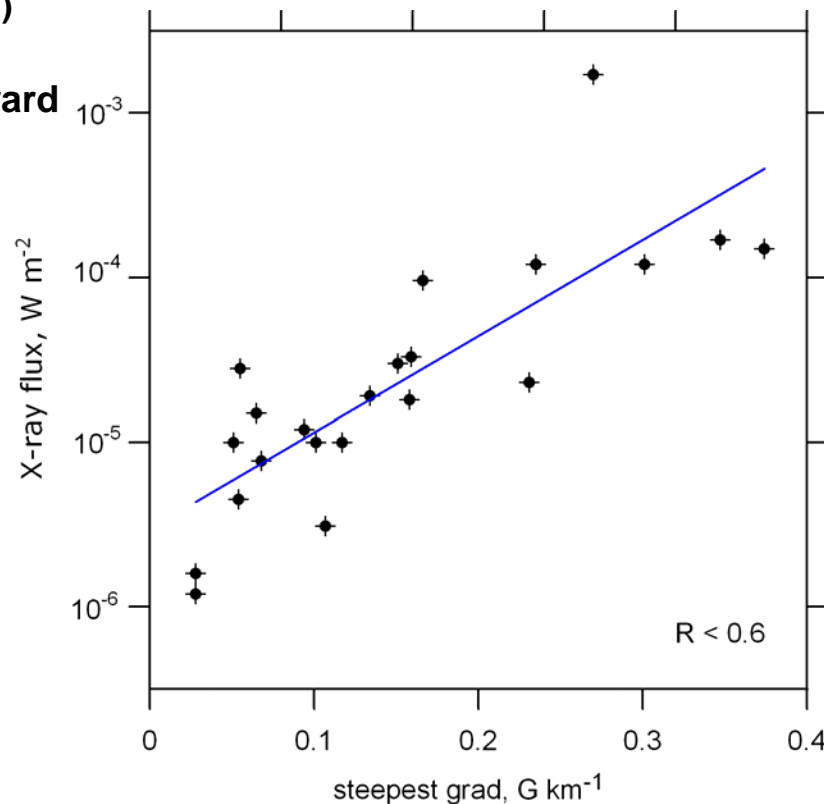
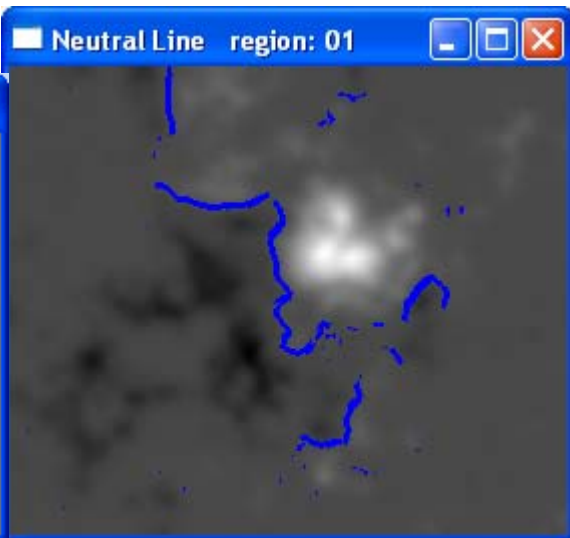
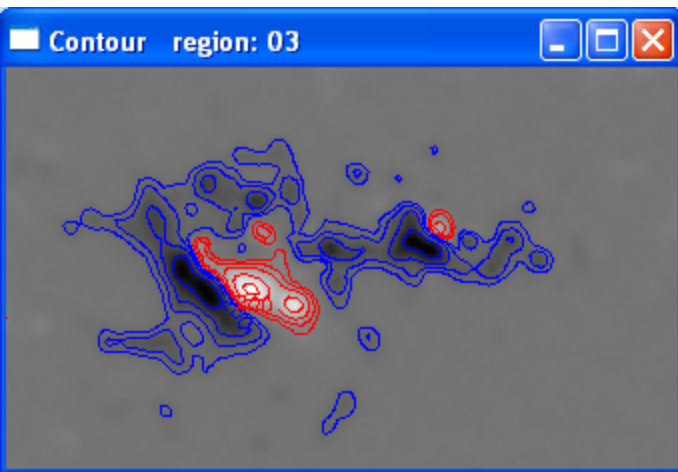


(McIntosh, P.S. 1990, Sol Phys., 125,251)

**Magnetic gradient by Graham Steward
ASFC manager**

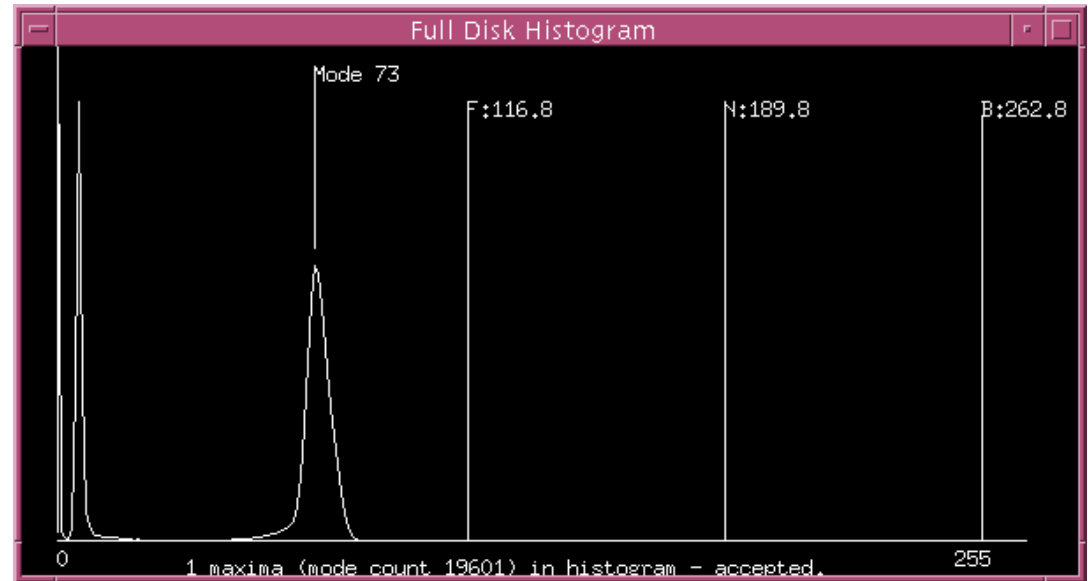
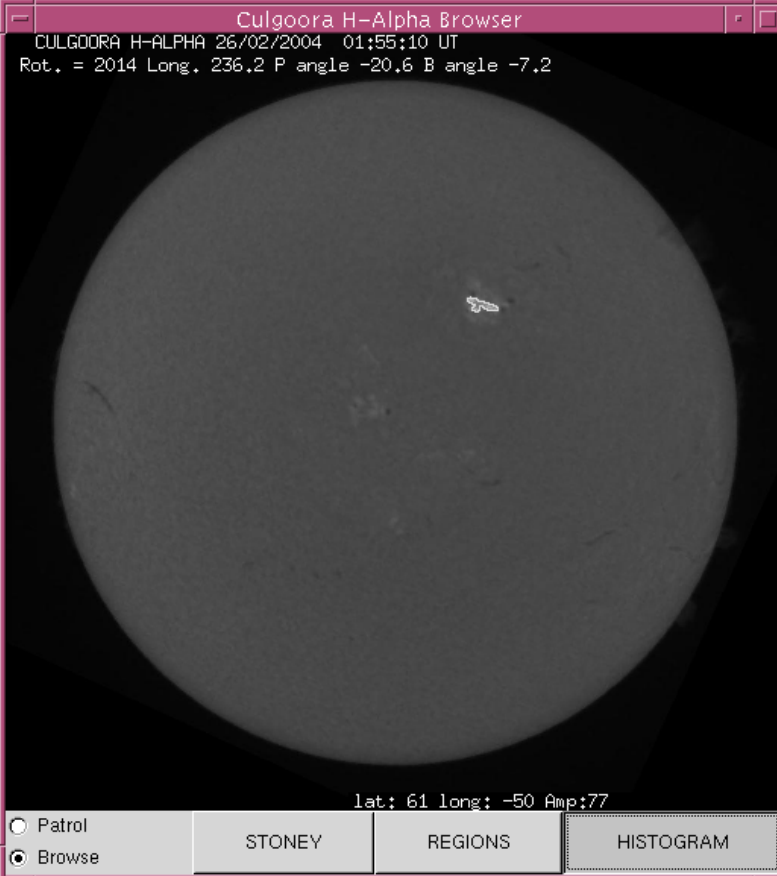
Max Gradient

- 0.025 - 0.09 – possible C-flares
- 0.09 - 0.25 – possible C and M-flares
- > 0.25 – possible C, M, and X-flares

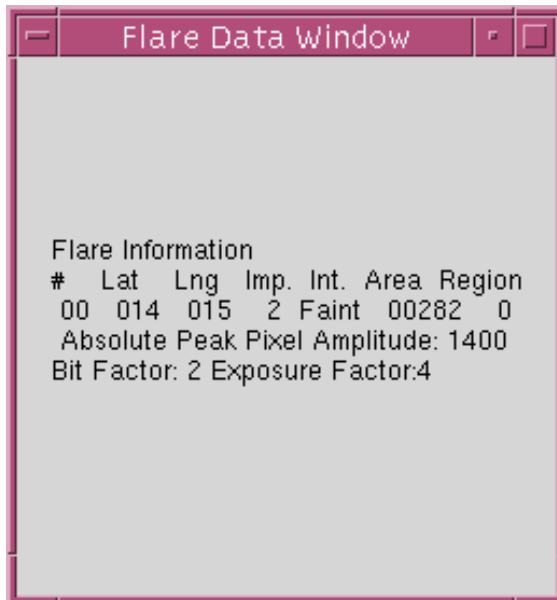


Steward et al. doi:10.1029/2011SW000703, in press.

Flare Alert



(G.Patterson)



IPS XRAY AND OPTICAL FLARE CORRELATION –PART D ISSUED AT 0245 UT on 26 Feb 2004 BY IPS RADIO AND SPACE SERVICES FROM THE AUSTRALIAN SPACE FORECAST CENTRE

Optical flares with maximum within 10 minutes of X-ray maximum are correlated.

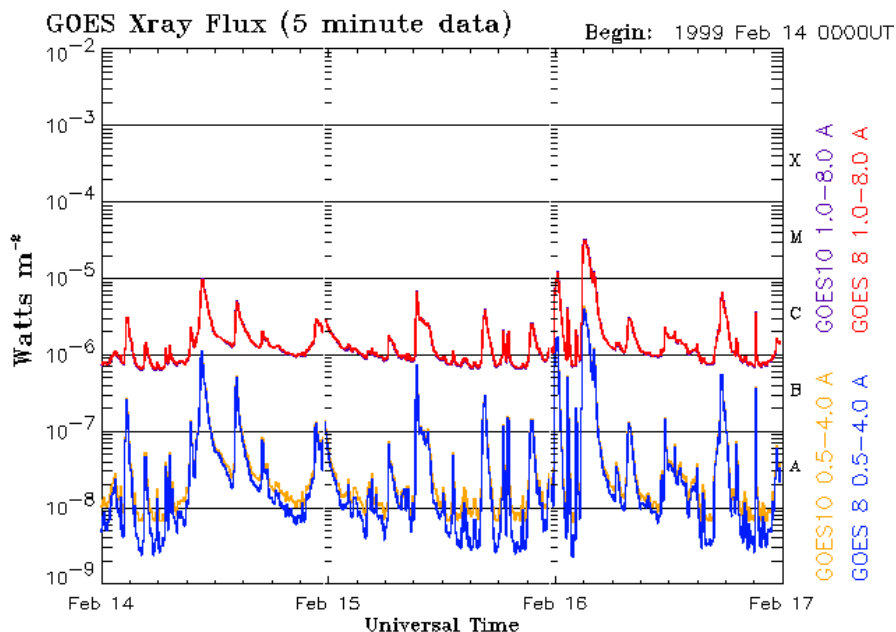
Approximate xray flare maximum 26 2 2004 0204 UT at Flux X1.1

Xray flare possibly optically correlated with the following H-alpha flare auto-detected at IPS Culgoora Solar Observatory:

Start date/time	Max date/time	End date/time
26 02 2004 01:55UT	26 02 2004 01:59UT	26 02 2004 02:41UT

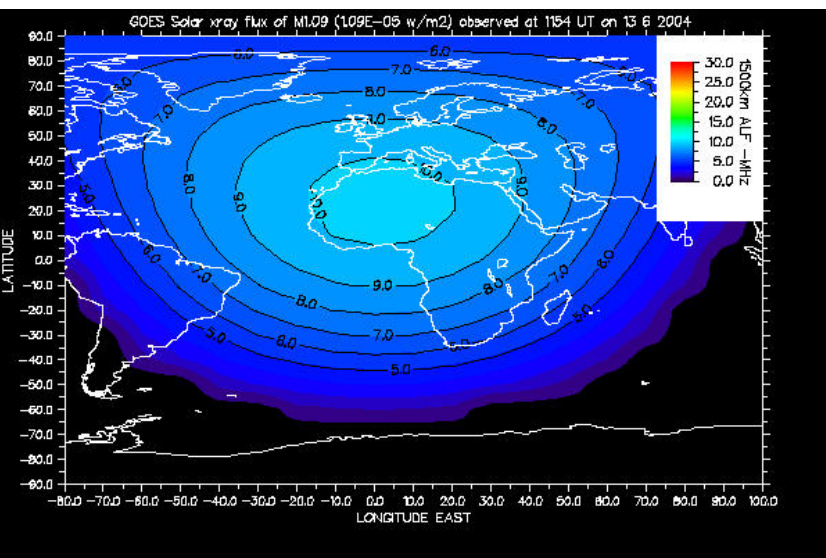
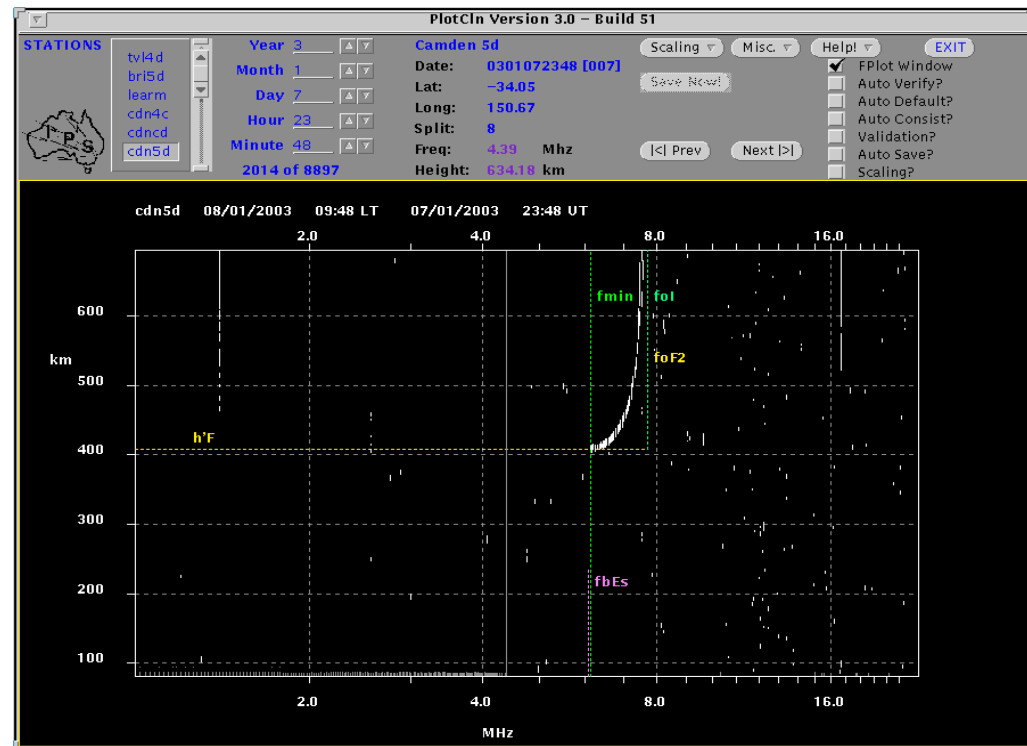
Lat	Long	Imp.	Bright.	Area	SEC	Region Num
014	014	2	Bright	00485		564

HF radio 'Short Wave Fadeout' (SWF) Alert



Updated 1999 Feb 16 23:59:10

NOAA/SEC Boulder, CO USA



IPS FADEOUT ALERT - PART A FOR HF FADEOUTS AFFECTING THE AUSTRALIAN REGION ISSUE TIME: Thu Feb 26 13:00:24 EST 2004

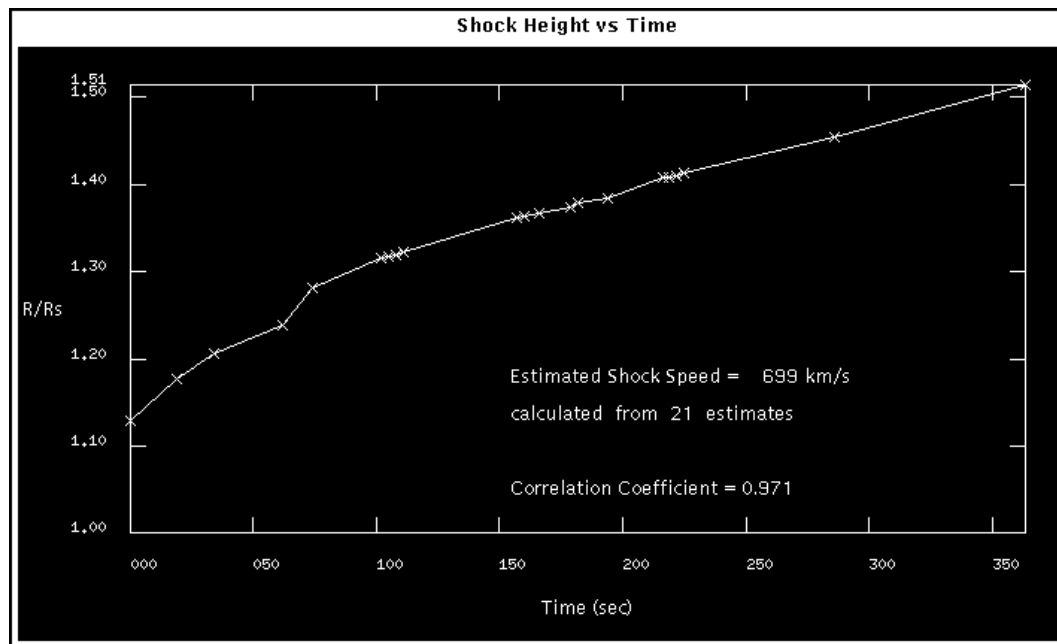
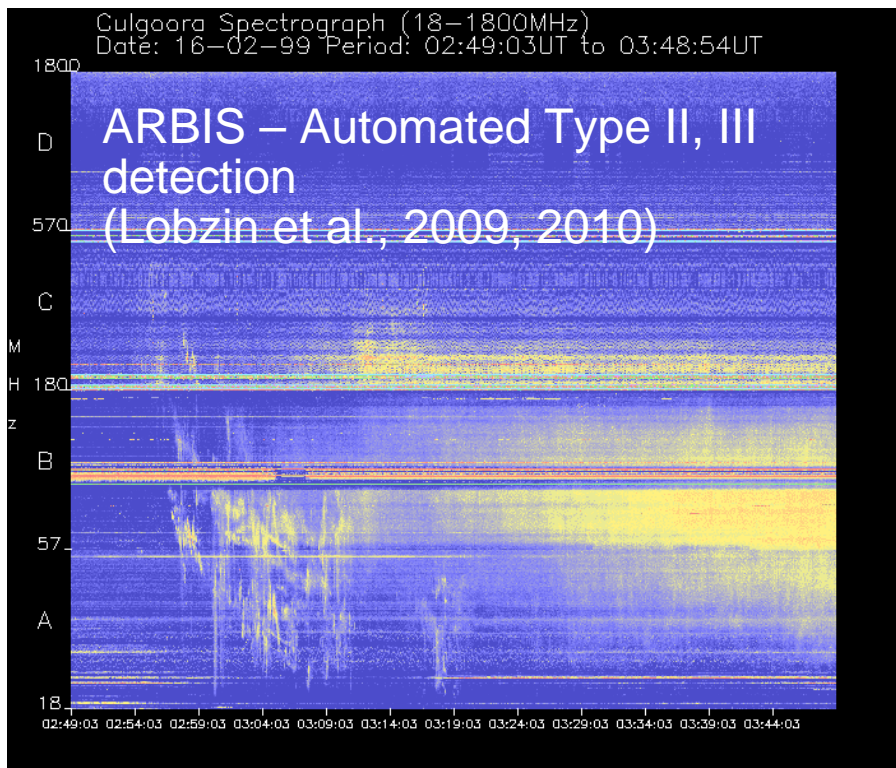
A HF FADEOUT IS NOW UNDERWAY IN PART OF THE AUSTRALIAN REGION. MORE DETAILS OF THE TIMING AND EXTENT OF THIS EVENT WILL BE ISSUED JUST AFTER IT ENDS.

Follow the progress of this event on the IPS Web site

<http://www.ips.gov.au> Click "Space Weather" Click "X-Ray Flux"

**Australian Space Forecast Centre IPS Radio and Space Services
 (61)(2)9213 8010 (phone) (61)(2)9213 8061 (fax) asfc@ips.gov.au**

Coronal Mass Ejection (CME) Warning



PLAIN PRESTO CULGOORA 03/0131UT NOV 2003

SOLAR RADIO EVENT 1: DRIFTING: 200 - 30 MHZ

START TIME: 0124 UT

END TIME: 0129 UT

SPECTRAL TYPE: TYPE II BURST

IMPORTANCE: STRONG

FUNDAMENTAL AND HARMONIC VISIBLE

ESTIMATED SHOCK SPEED 699 KM/S

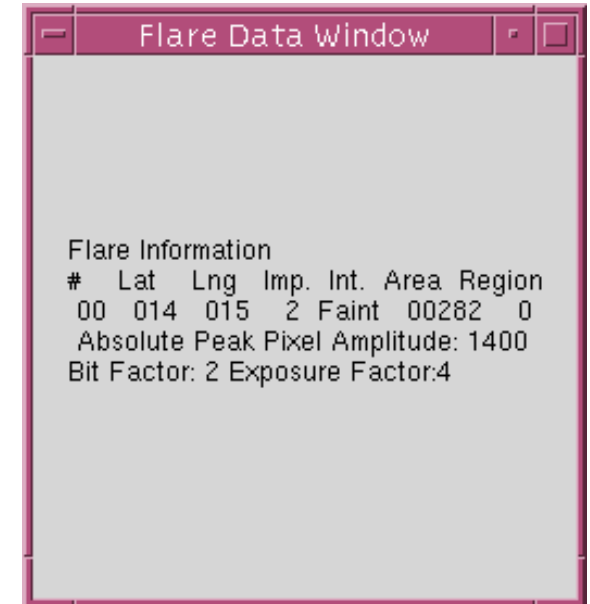
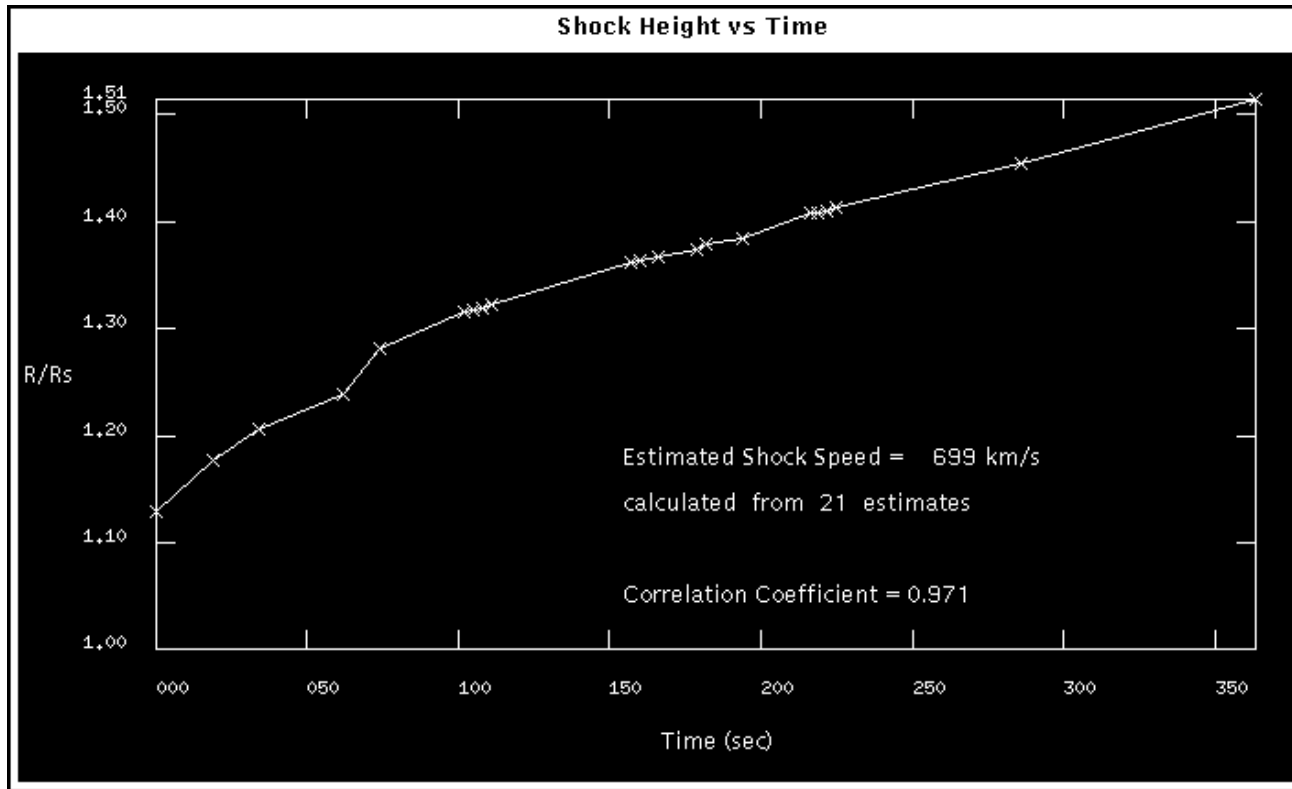
FLARE OBSERVED IN REGION 10488 SHORTWAVE

FADEOUT OBSERVED

Shock Details

```
#####
Type II Radio Burst Type
Fundamental
#   Time   Freq   Ne    Height
   sec   MHz   Rsun
0    0    159   2.820  1.13
1    19    133   1.964  1.18
2    34    120   1.604  1.21
3    62    108   1.298  1.24
4    74    94    0.993  1.28
5   102    85    0.811  1.32
6   105    85    0.801  1.32
7   108    85    0.797  1.32
8   111    84    0.778  1.32
9   157    75    0.626  1.36
10  160    74    0.618  1.36
11  166    74    0.610  1.37
12  179    72    0.586  1.37
13  182    72    0.574  1.38
14  194    71    0.554  1.38
#####
```

Geomagnetic Storm Warning



**SUBJ: IPS GEOMAGNETIC DISTURBANCE WARNING 02/46
ISSUED AT 23/0107Z DECEMBER 2002 BY THE AUSTRALIAN
SPACE FORECAST CENTRE.**

**INCREASED GEOMAGNETIC ACTIVITY EXPECTED DUE TO
CORONAL MASS EJECTION FROM 23-24 DECEMBER 2002**

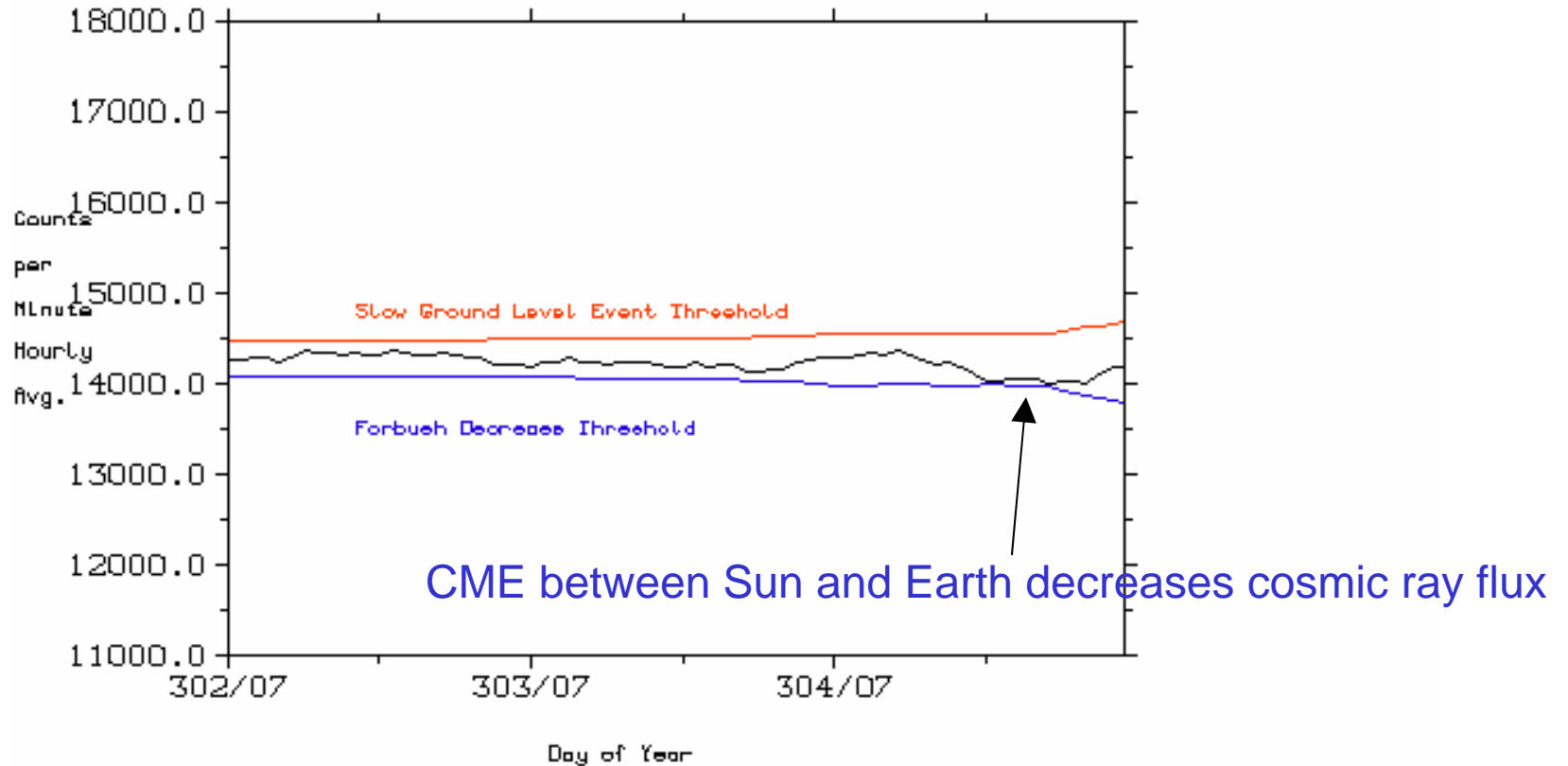
GEOMAGNETIC ACTIVITY FORECAST

23 Dec: Active to minor storm periods.

24 Dec: Active

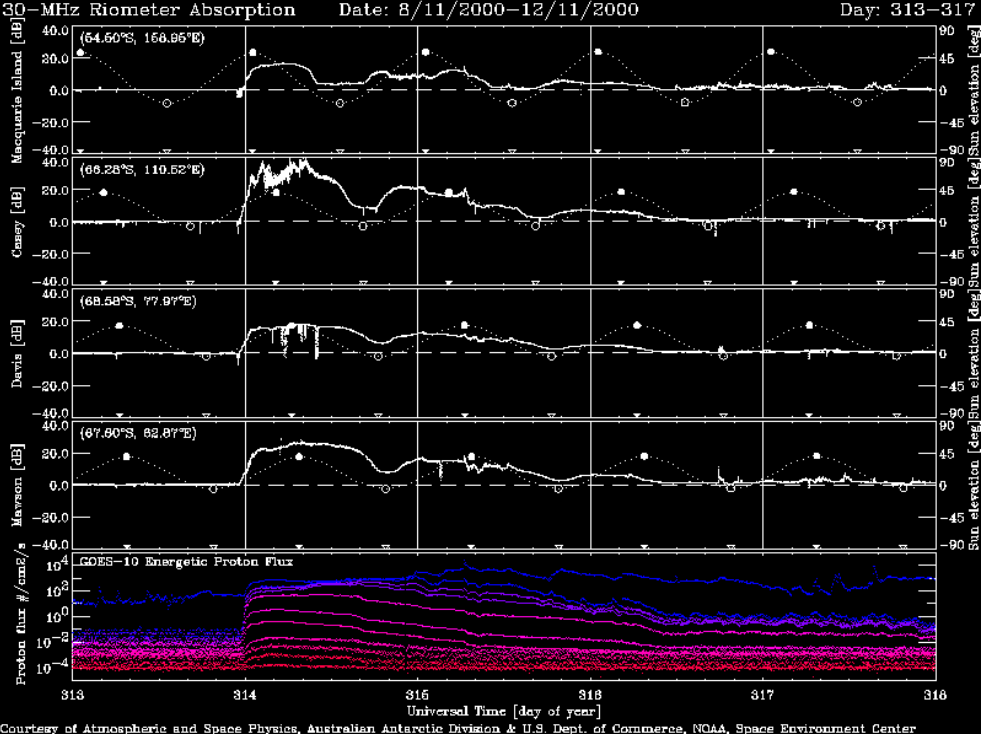
CME Alert

RAA/IPS Mawson Cosmic Ray Data 2010/302 0700 to 2010/305 0600 UT



Last updated 01 Nov 2010 07:30 UT

Forbush Decrease Observed (3%) at MAW 05/04/2010 DOY: 95 Hour: 17UT
Forbush Decrease Observed (3%) at MAW 04/08/2010 DOY: 216 Hour: 04UT



Polar Cap Absorption (PCA) Alert for HF radio

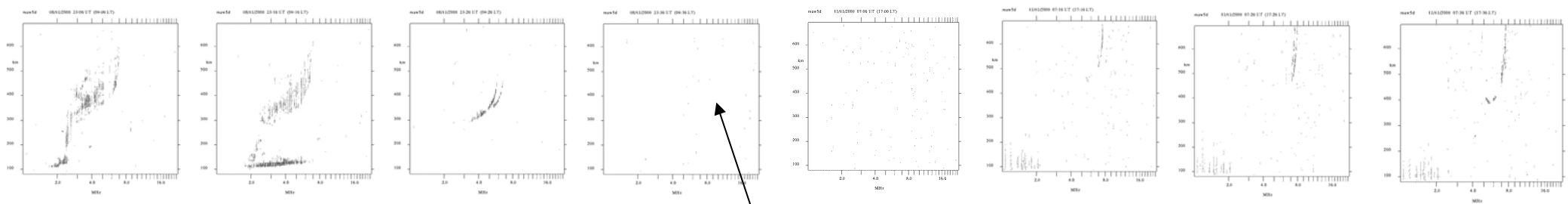
$$A(\text{dB}) = 10 \log_{10} (A_{\text{qdc}} / A_{\text{day}})$$



Ionospheric D-region absorption
of 30MHz background radiation



“quiet day curve”



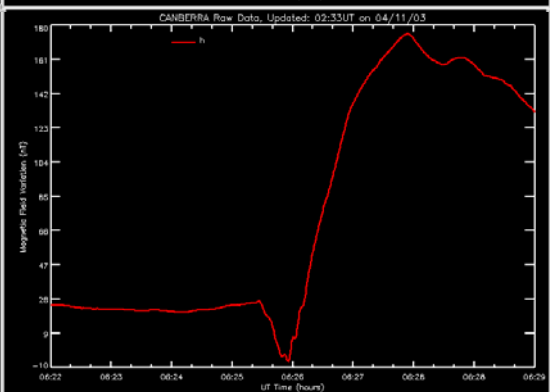
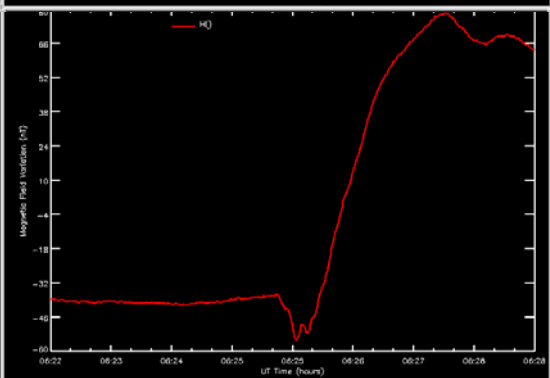
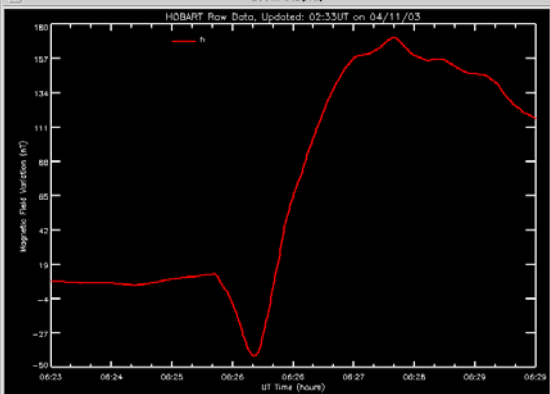
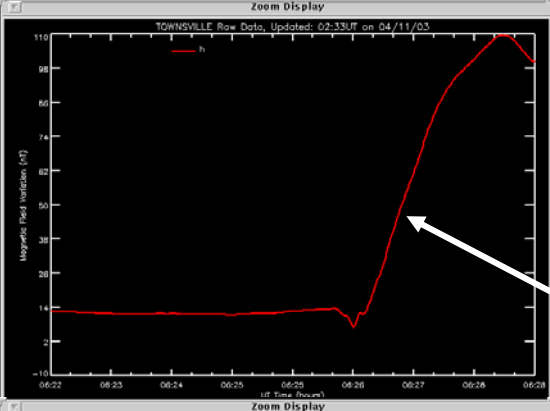
Ionograms completely absorbed

10Mev Proton/PCA Event Began 31 05 2003 0505UT and is in progress

Casey 30Mhz Riometer Data at time of Issue: Casey 1.9 dB

Geomagnetic Storm Sudden commencement (SSC) and Sudden Impulse (SI) Alert

Simultaneous (global) response on magnetograms

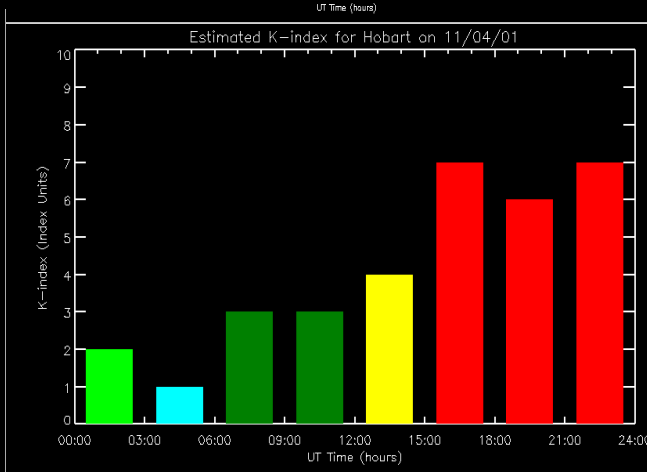
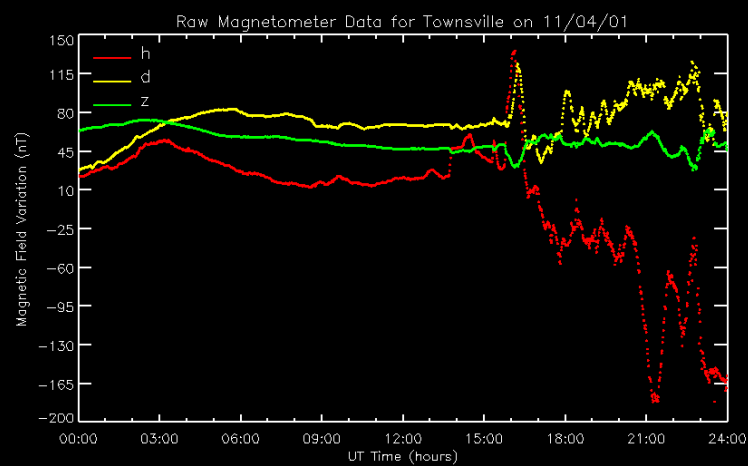
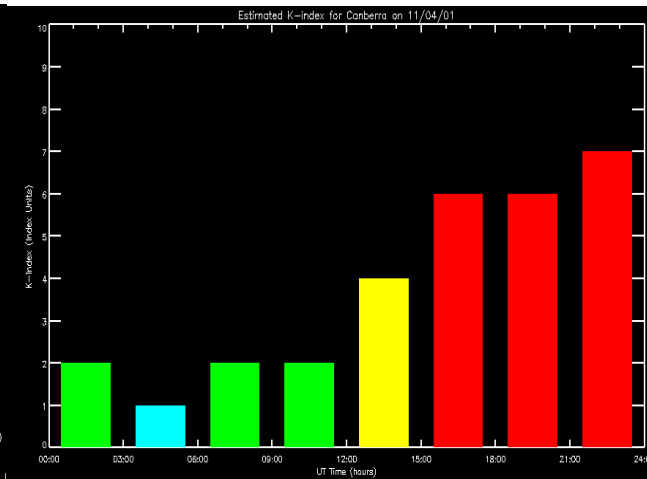
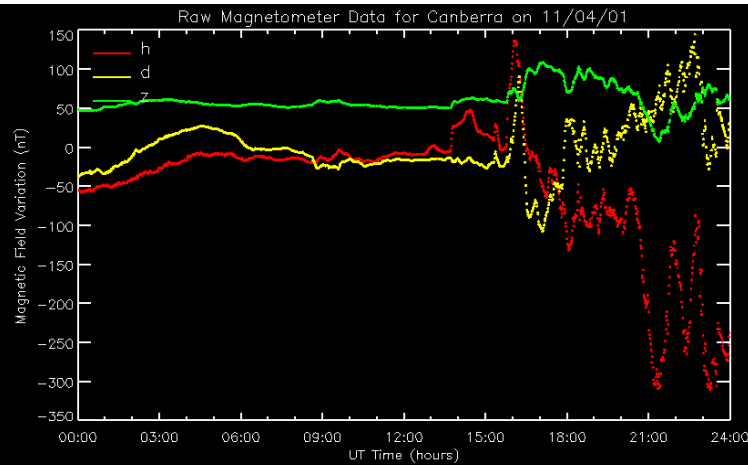


**MODERATE SUDDEN IMPULSE DETECTED (87nT)
IN IPS MAG DATA 04 11 03 0626UT**

Mean Mag Parameters Pre/Post Impulse:

Stn	Unit	Pre Impulse	Post Impulse	Change
hbt	nT	15.0	118.9	103.9
cbr	nT	29.1	131.7	102.5
tvl	nT	17.0	69.6	52.6
lem	nT	43.2	130.4	87.2
clg	nT	-34.4	54.7	89.1

Geomagnetic Storm Alert



Estimated Indices 05 Jun :

Darwin	2222	1222
Townsville	1222	2222
Learmonth	1212	2332
Culgoora	2211	2222
Canberra	-311	2223
Hobart	1211	2222

Australian Region 2212 2222

SUBJ: IPS GEOMAGNETIC DISTURBANCE ALERT

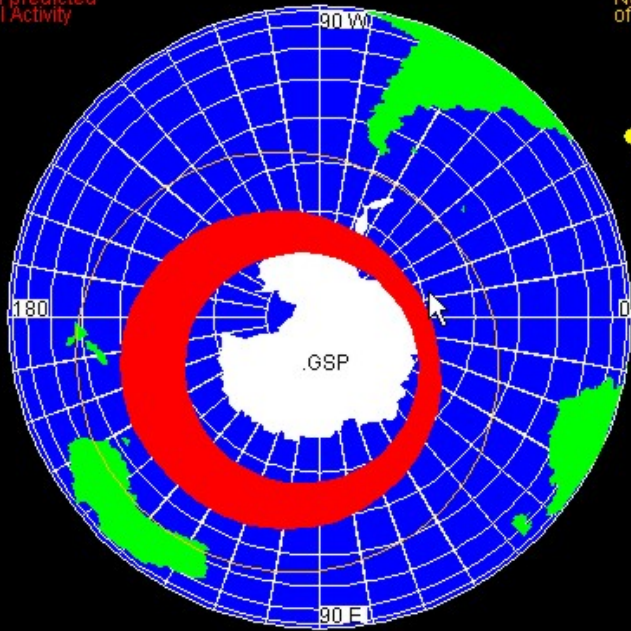
ISSUED AT 1716 UT ON 11 APR 2001 BY IPS RADIO AND SPACE SERVICES FROM THE AUSTRALIAN SPACE FORECAST CENTRE

**SEVERE GEOMAGNETIC DISTURBANCE IN PROGRESS (K OF 7 REACHED)
PRELIMINARY AUSTRALIAN REGION K INDICES FOR 11 04 01: 2122 47--**

SOUTHERN TERRESTRIAL HEMISPHERE

Area of predicted Auroral Activity

Predicted Northern Limit of Auroral Visibility

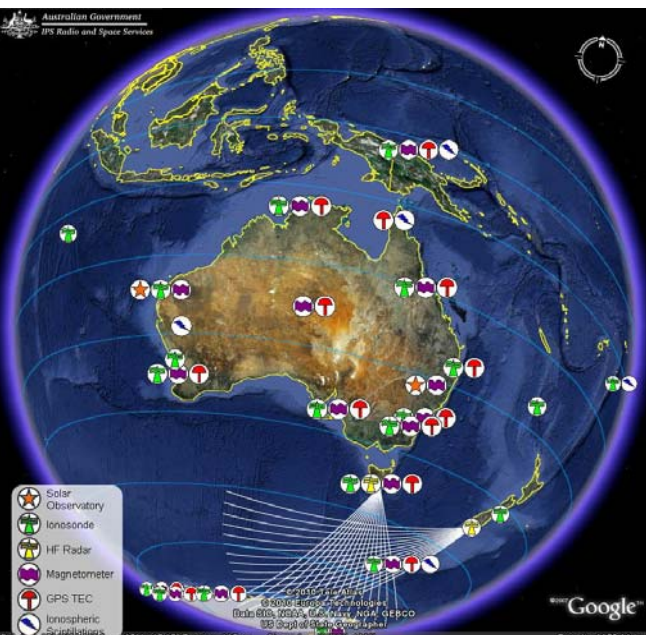


GSP - GEOMAGNETIC SOUTH POLE

Aurora Alert



Photo courtesy of Dallas & Beth Stott, Blackmans Bay Tasmania

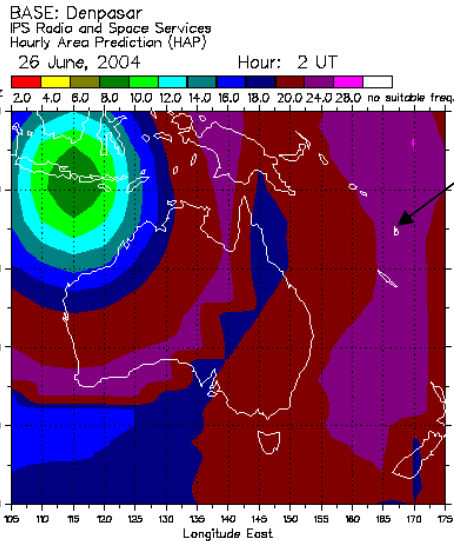
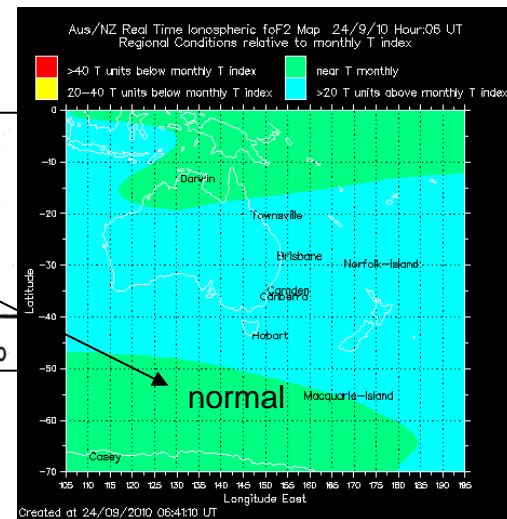
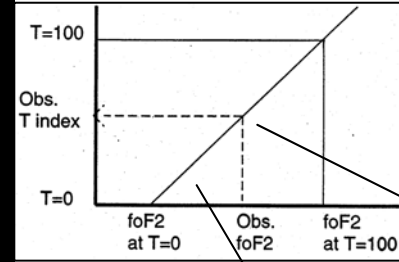
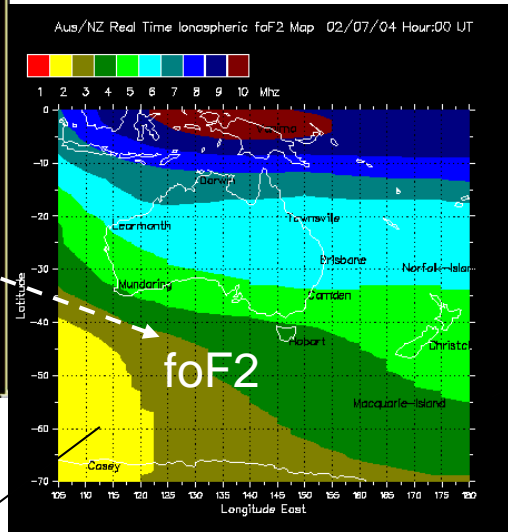
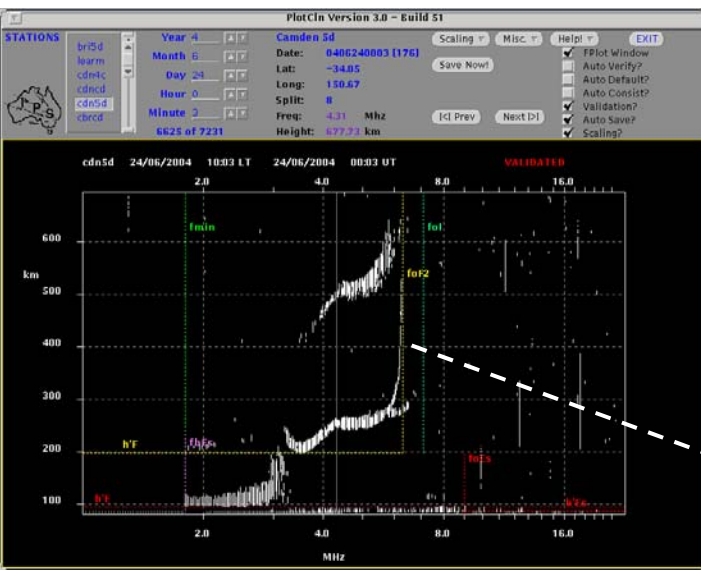


SUBJ: IPS AURORA ALERT ISSUED AT 1818 UT on 31 Mar 2001 BY IPS RADIO AND SPACE SERVICES FROM THE AUSTRALIAN SPACE FORECAST CENTRE

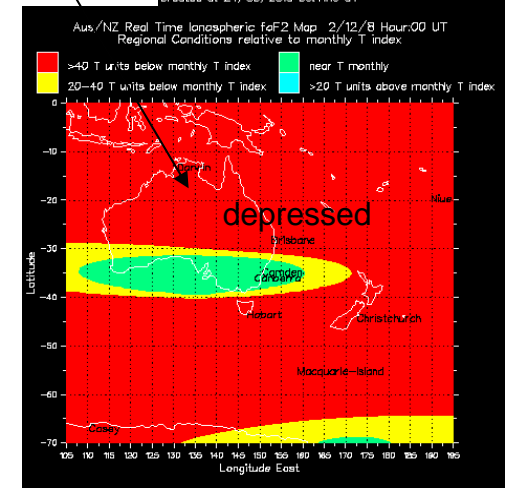
SEVERE GEOMAGNETIC STORM IN PROGRESS.

AURORA MAY BE OBSERVED DURING LOCAL NIGHT TIME HOURS IN GOOD OBSERVING CONDITIONS AT REGIONS AS FAR EQUATORWARD AS MIDDLE LATITUDES.

HF COMMS Warning



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



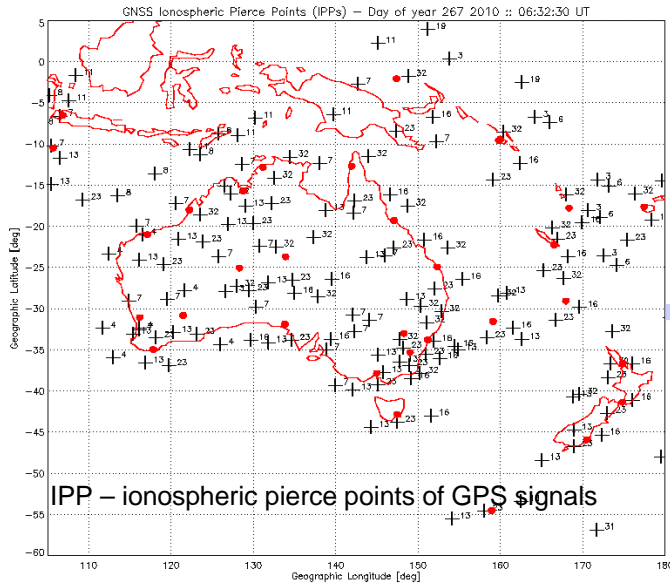
SUBJ: IPS HF RADIO COMMUNICATIONS WARNING 10/21 ISSUED AT 23/2354Z OCTOBER 2010 BY THE AUSTRALIAN SPACE FORECAST CENTRE. DEGRADED HF PROPAGATION CONDITIONS EXPECTED FOR 24 OCTOBER 2010 IF COMMS DIFFICULTIES EXPERIENCED TRY A LOWER FREQUENCY BAND

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

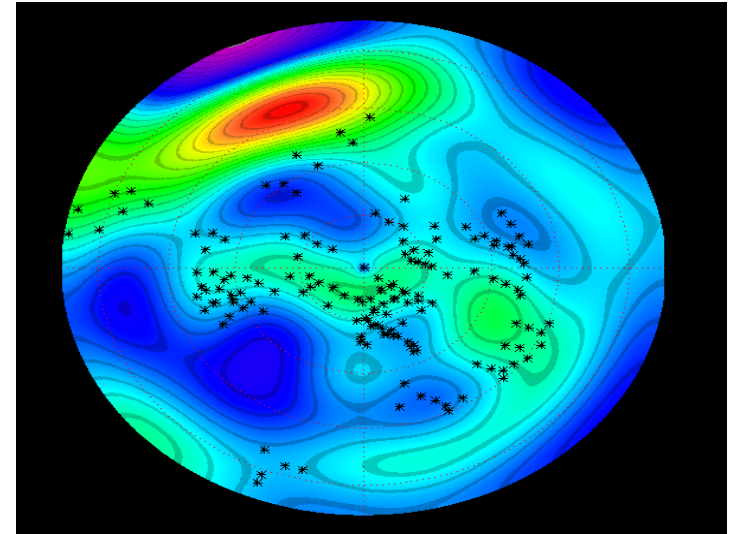
T-index	MUFs	2	4	6	8	12	16	22	26
-10	-22%	2	4	6	8	8	12	16	16

Total electron content (TEC) Ionospheric Model

<http://www.ips.gov.au/Satellite>



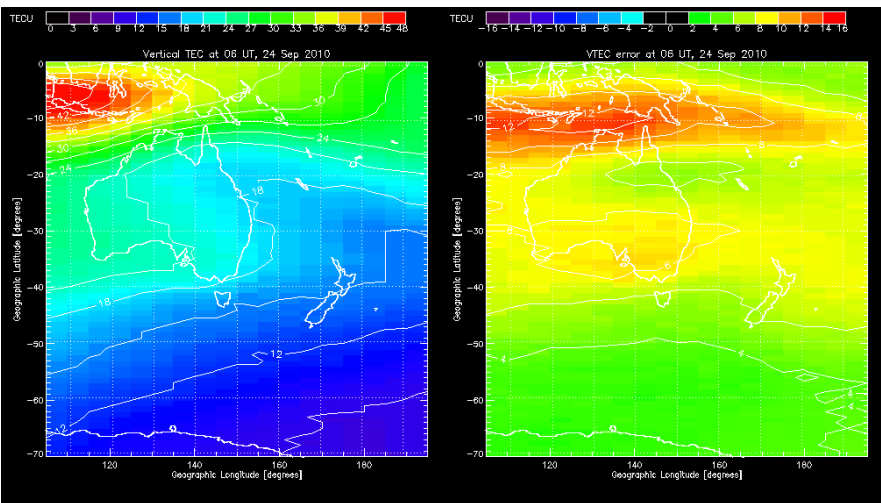
Input data QC
Kalman filtering



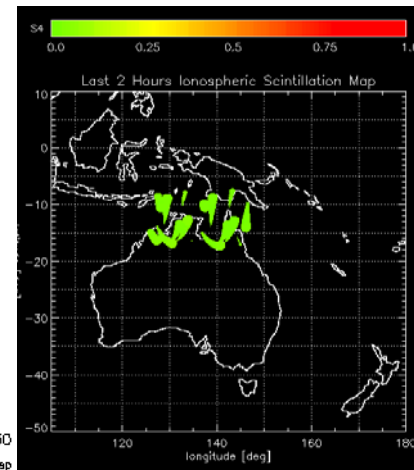
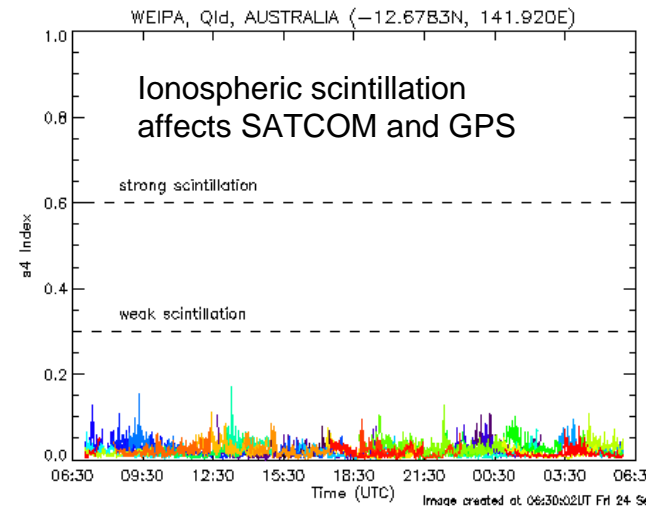
(M.Terkildsen, Z.Bouya and M.Francis)

SCHA – spherical cap harmonic analysis of TEC
Legendre polynomial basis functions

$$TEC(\vartheta, \varphi) = \sum_{k=0}^{K \max} \sum_{m=0}^k P_{nk(m)}^m(\cos(\vartheta)) [g_k^m \cos(m\varphi) + h_k^m \sin(m\varphi)]$$



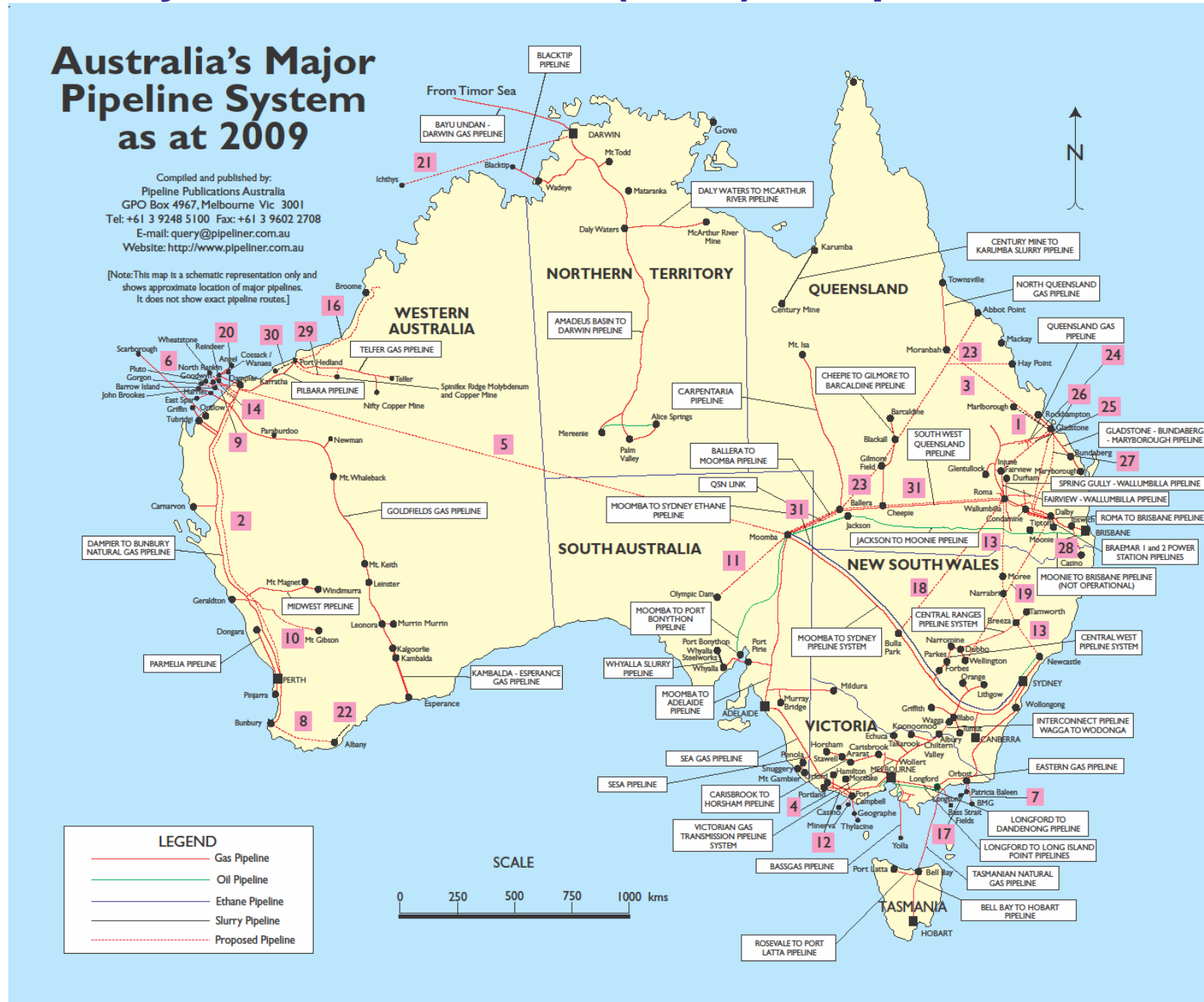
Plasmasphere model
Klobuchar model



Geomagnetically Induced Currents (GICs) in Pipelines

Enhanced corrosion from GICs flowing in pipelines.

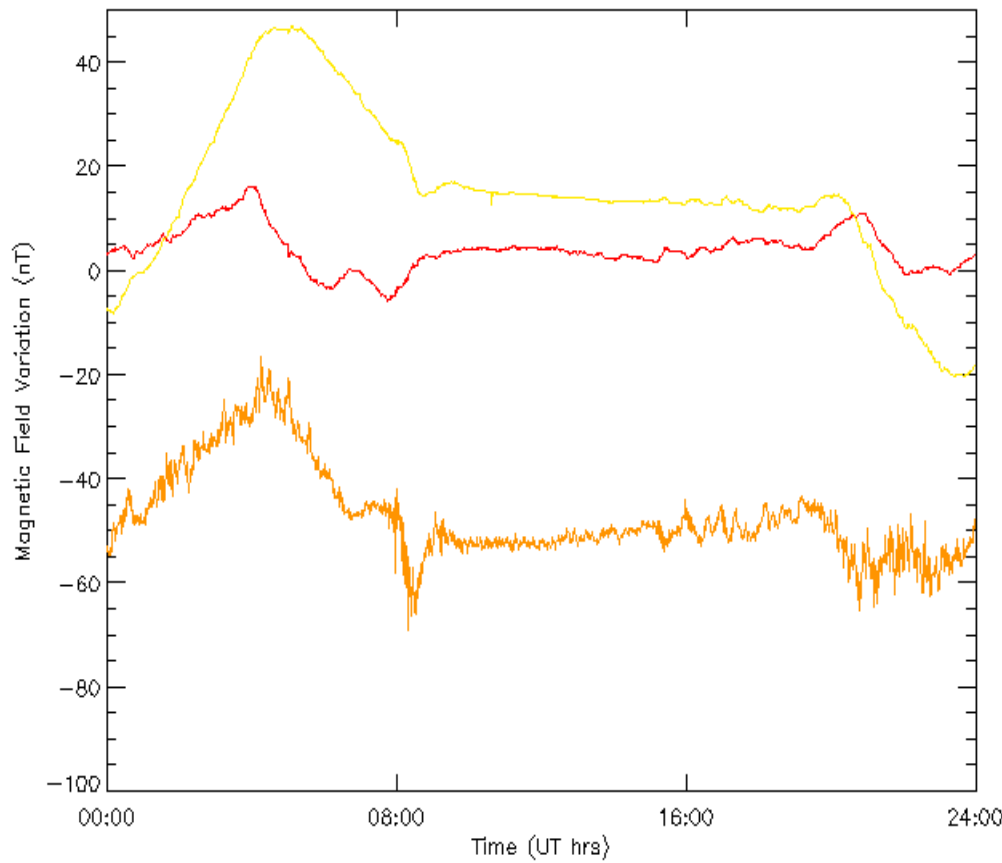
Can help to plan where to place current reversal devices



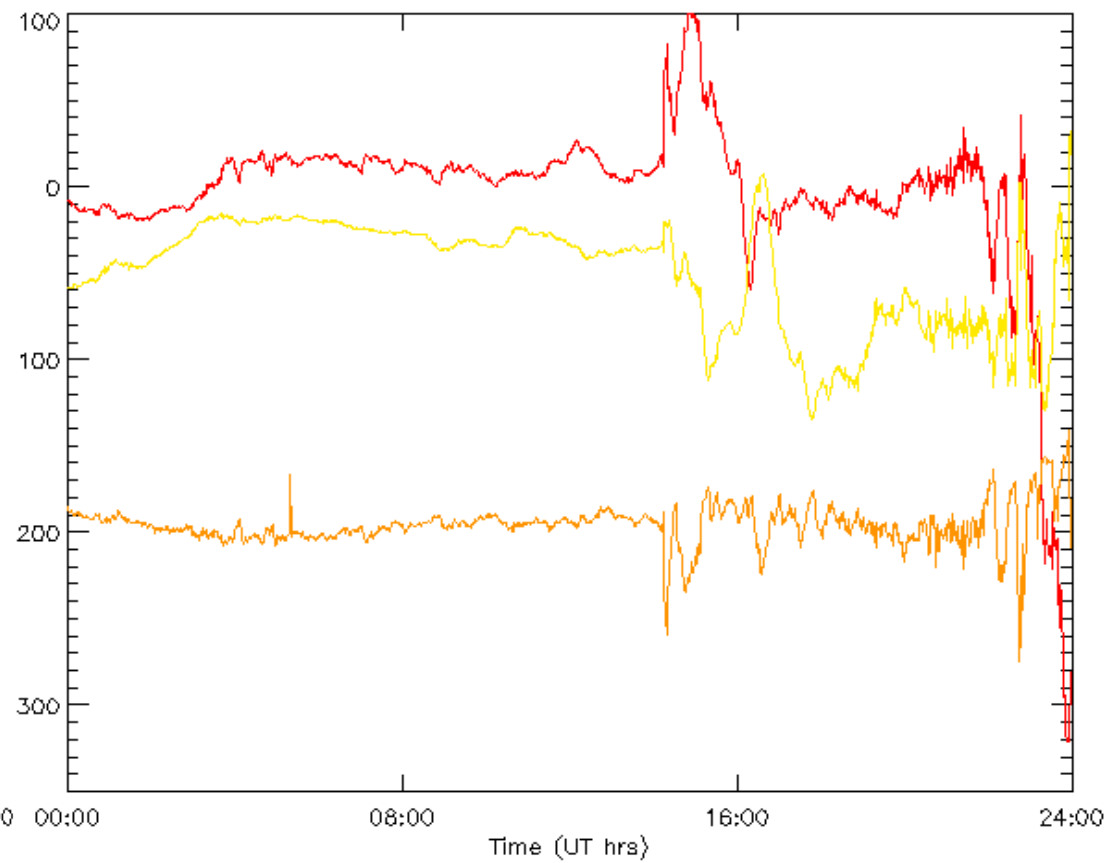
Map compiled and published by Great Southern Press. All copyright remains with Great Southern Press (www.pipeliner.com.au).

GICs in Pipelines

Geomagnetic Quiet Day

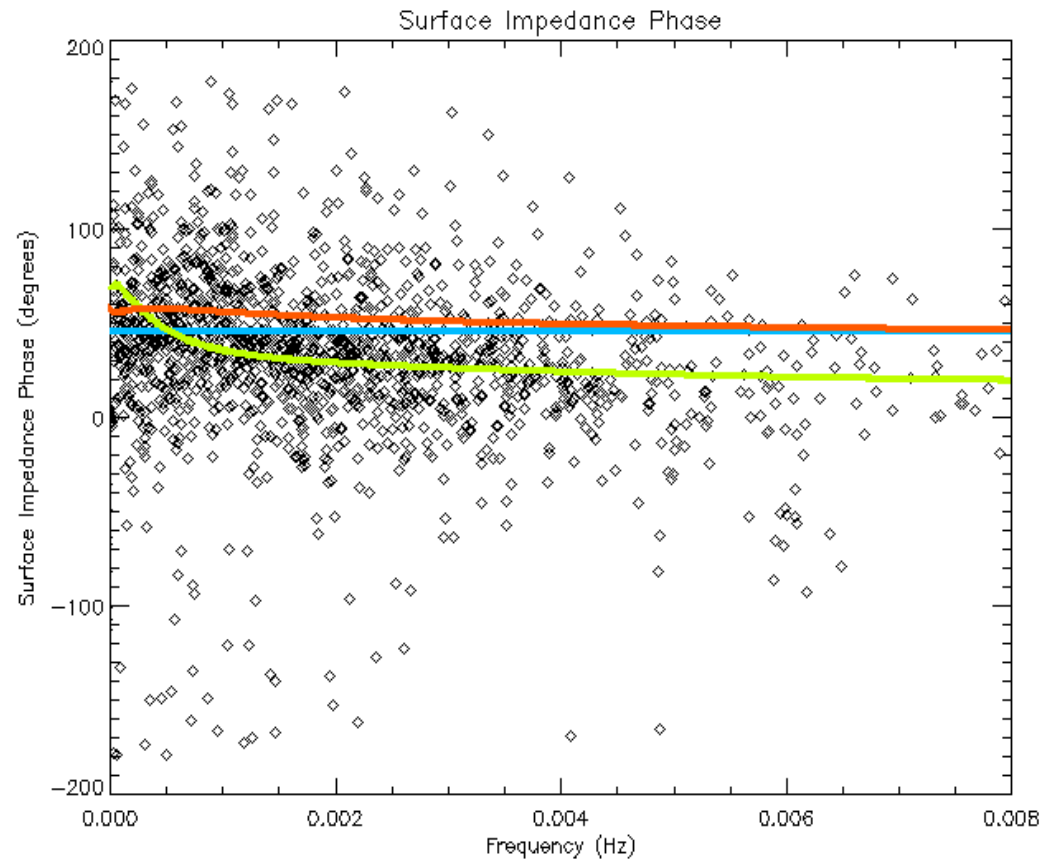
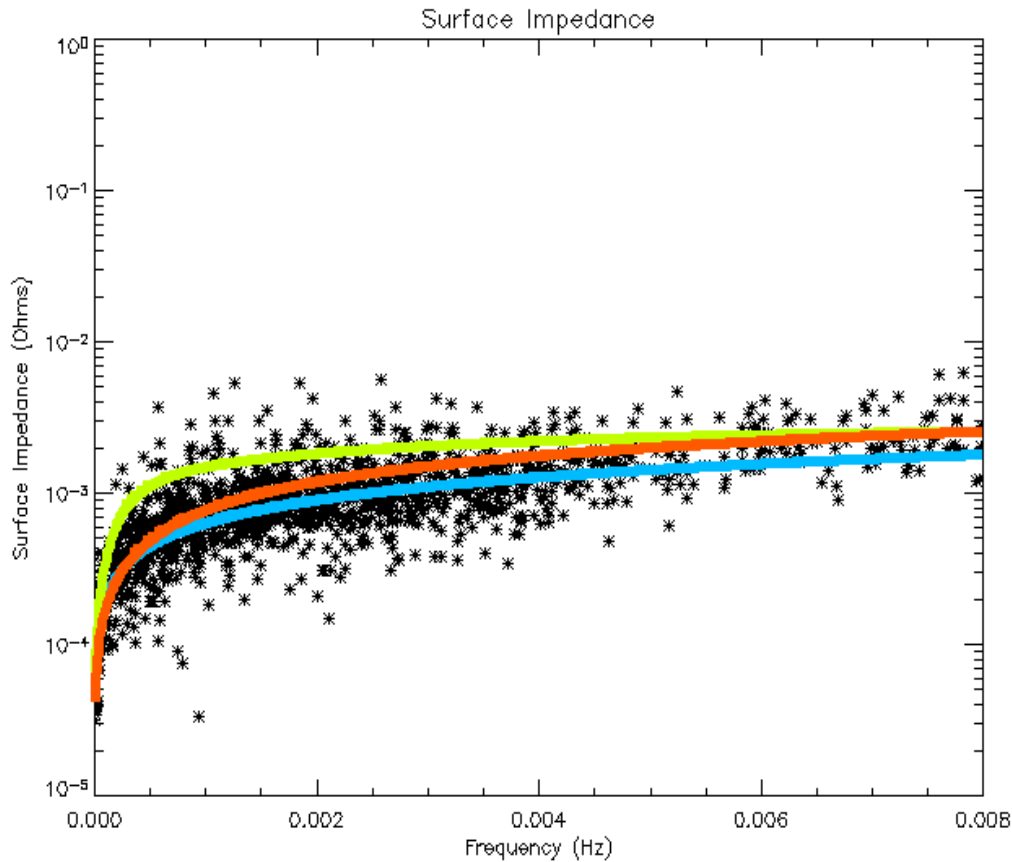


Geomagnetic Storm



GICs in Pipelines

Spectral Analysis: B vs PSP

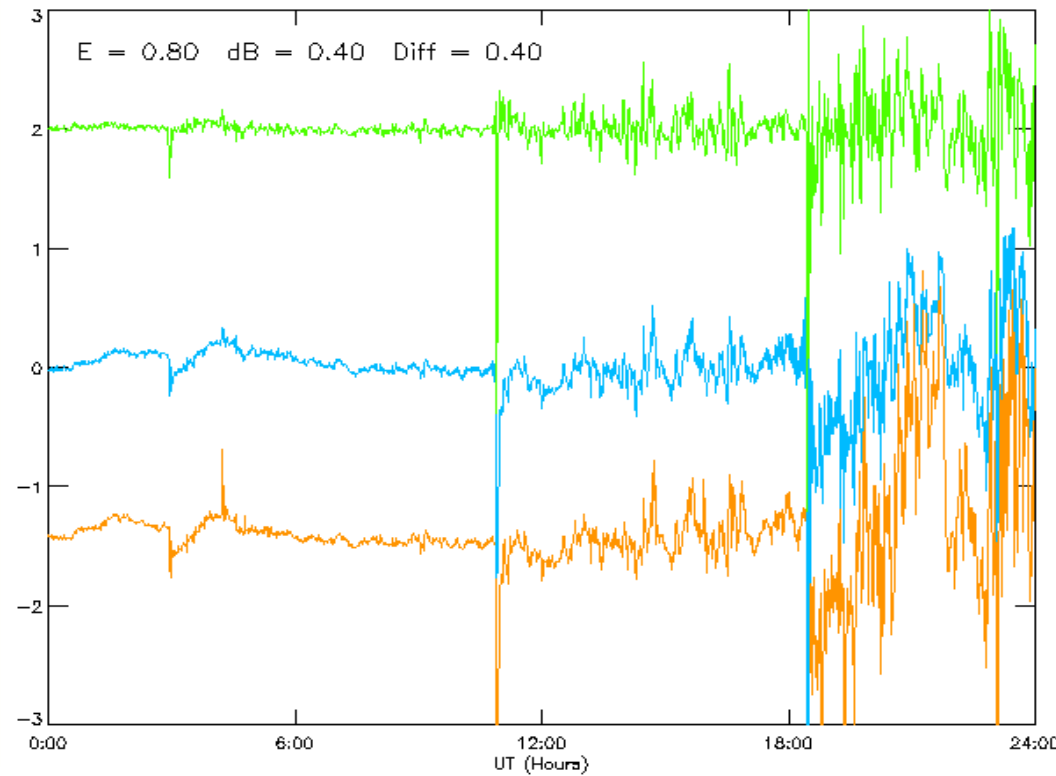
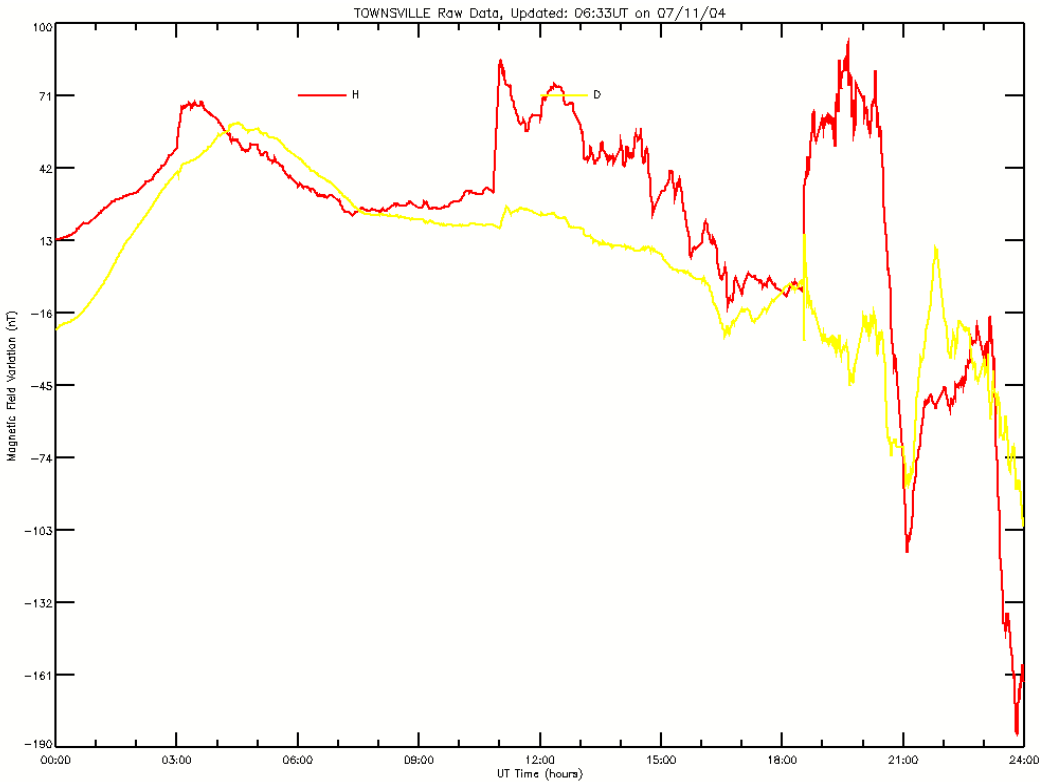


GIC- Index: $Z(f) = \sqrt{\frac{f}{f_N}} e^{i\frac{\pi}{4}}$

[Marshall et al., 2010]

GICs in Pipelines

GIC Index: 7th November 2004



Red – H north-south component

Yellow – D east-west component

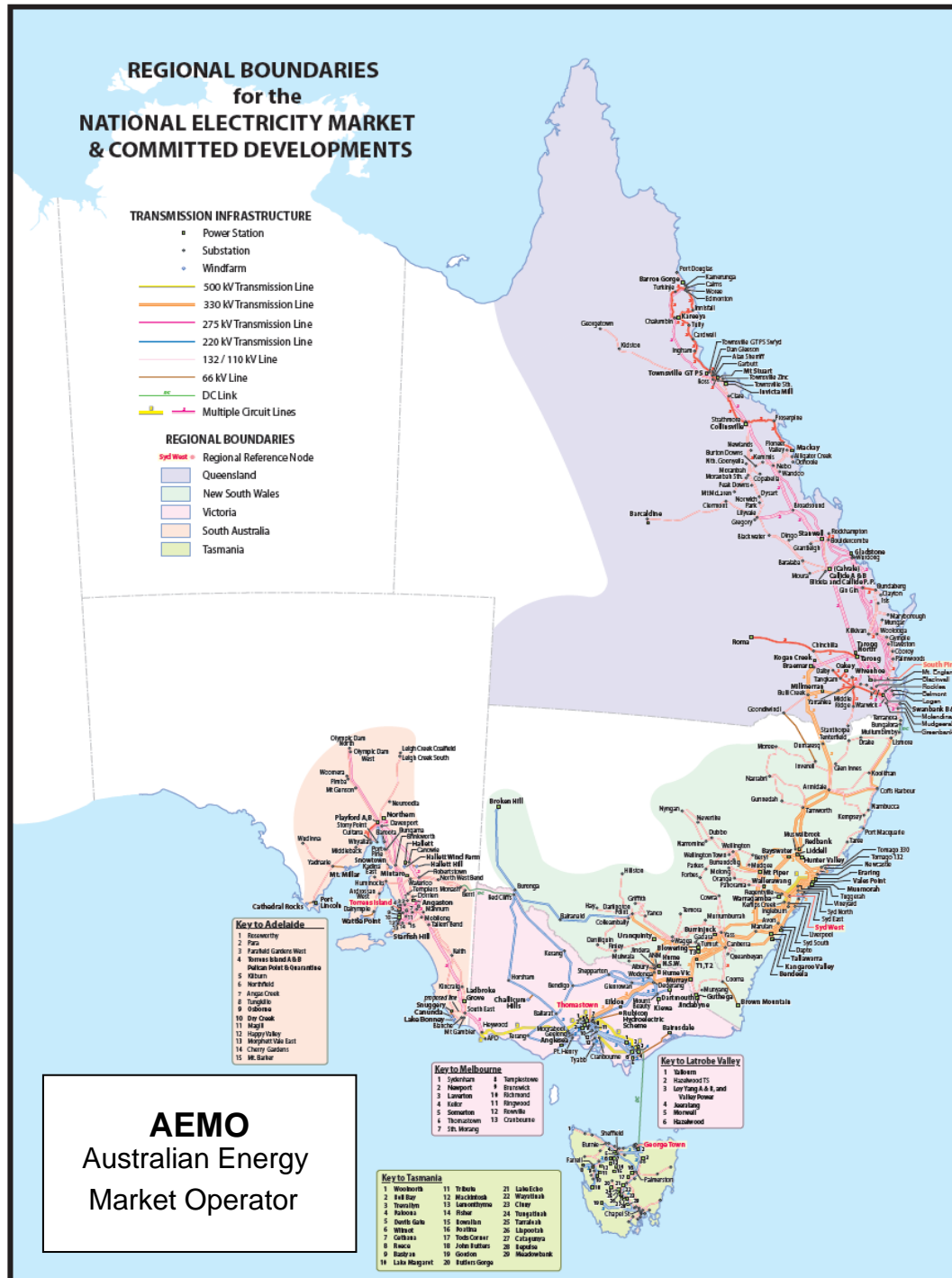
Green – dB/dt

Blue – GIC-index

Orange – PSP

= pipe to soil potential

Geomagnetically Induced Currents (GICs) in Power Networks

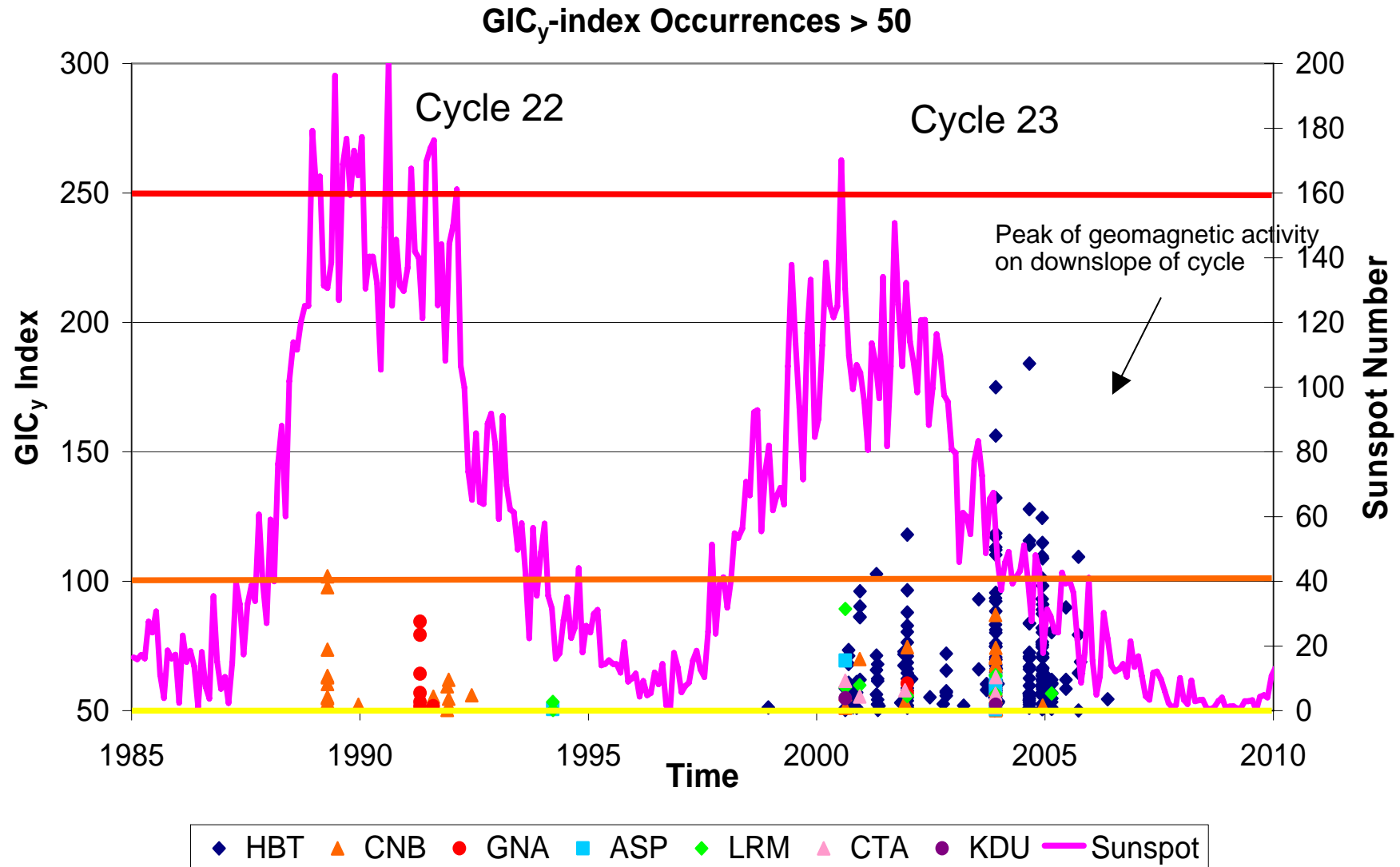


Increased Connectivity eg., high voltage DC link to Tasmania driven by

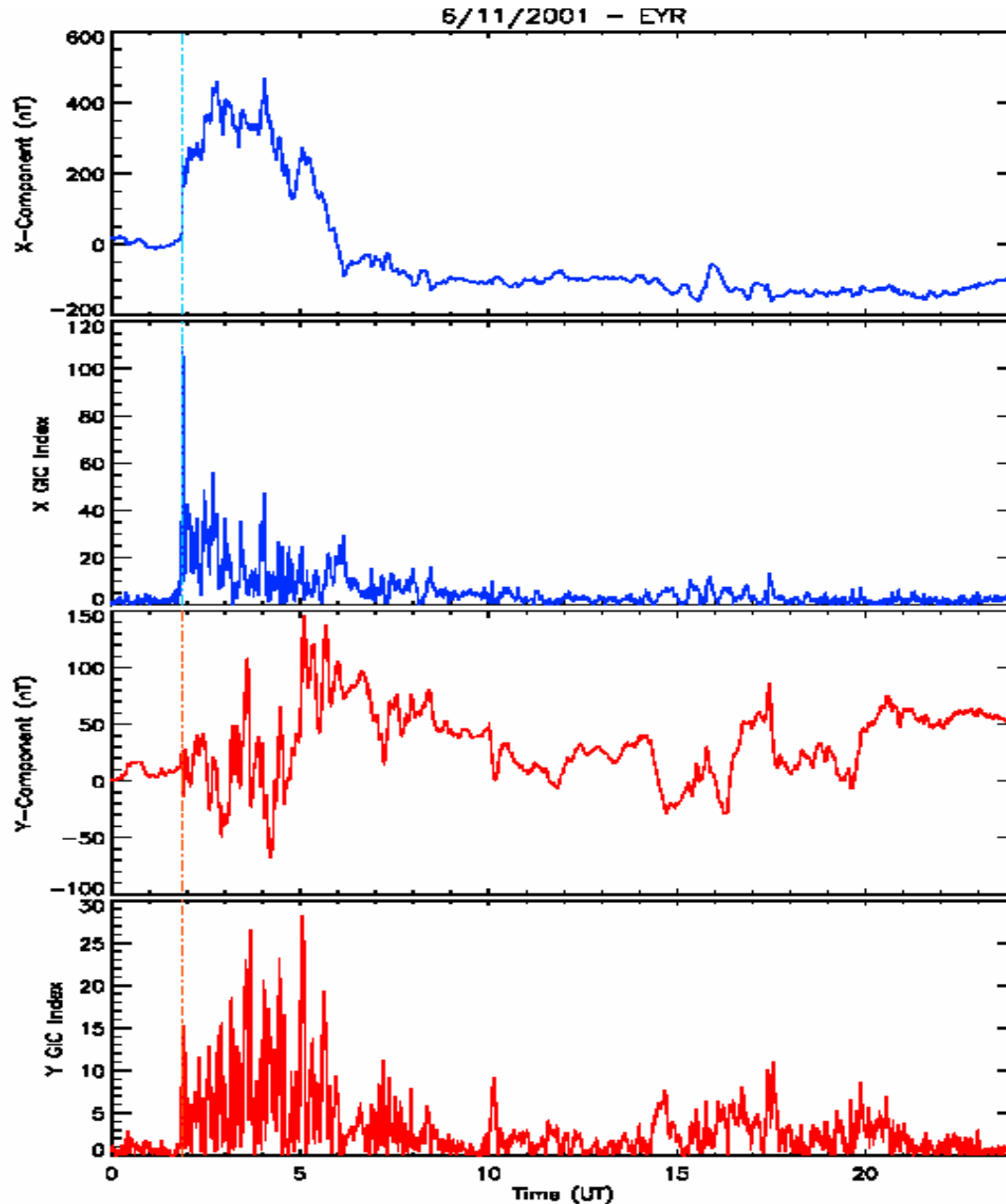
- Market Competition
- Robustness to demand

BUT longer power lines means increased susceptibility to Space weather

GICs in Power Networks



GICs in Power Networks



- 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

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Geophysical Conditions

Geomagnetic Warning

Warning

K-Index

5

pc3 Index

4

GEOSTAT Alert

0

Geomagnetic Alert

Alert

Aurora Alert

No Alert

HF Propagation Conditions

HF Comm. Warning

Warning

Current HF Fadeout

No Event

HF Fadeout Warning

Warning

Polar Cap Absorption

2.5dB
AT
08:11 UT

Ionospheric Conditions

Australasia



North America



Europe



TEC Conditions

Australasia



North America



Europe



World



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