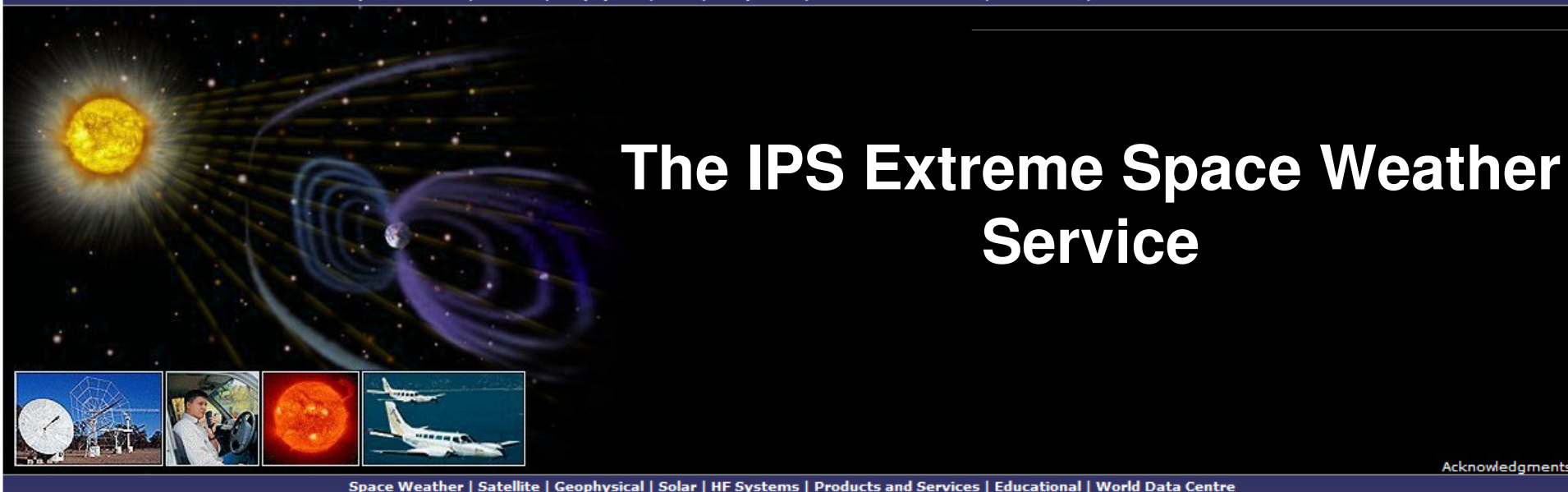




Australian Government
IPS Radio and Space Services

The Australian
Space Weather Agency

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



The IPS Extreme Space Weather Service

Acknowledgments

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

R. Marshall, M. Terkildsen, G. Steward, D. Neudegg, Z. Bouya

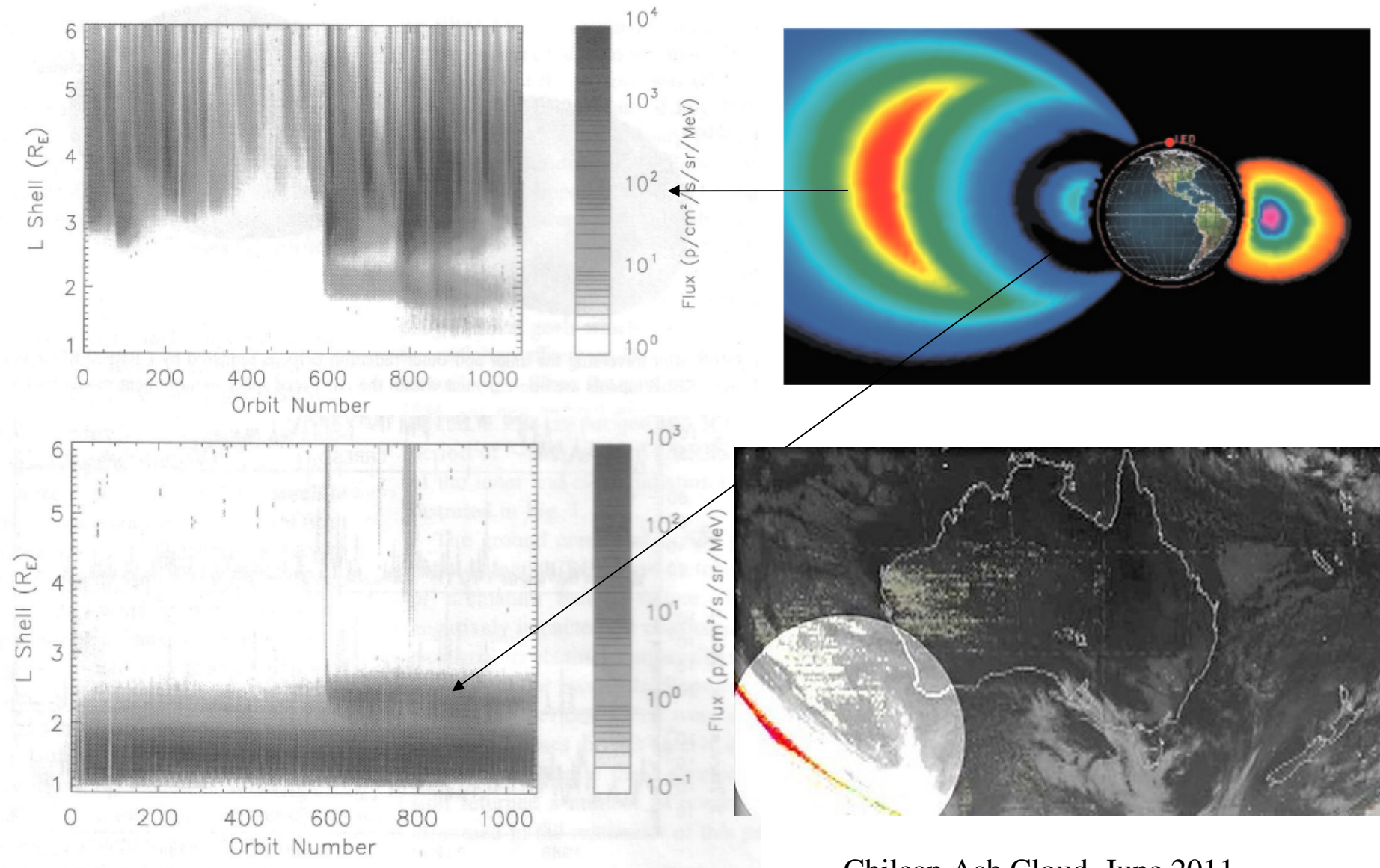
Ionospheric Prediction Service (IPS)
Australian Bureau of Meteorology

www.ips.gov.au

ESW Motivation

- Growing awareness of impacts of space weather has lead to increased interest from critical infrastructure groups within Australia
- Australian Government TISN, includes Energy, Communications, and Transport Sector groups
- Energy sector includes power network asset owners and operators, gas pipeline owners and operators, mining companies
- Communications sector includes, Telstra, Optus, major TV broadcasters
- Transport sector includes major airlines (Qantas, Virgin), ASA, shipping and rail

Satellite Systems

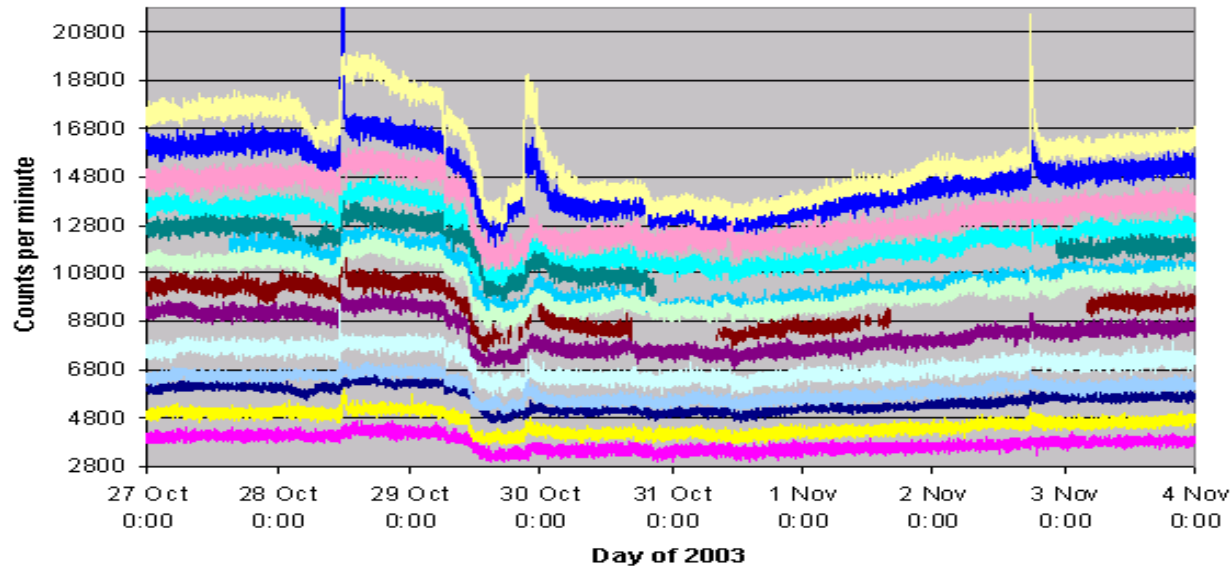


CRESS Electron and Proton Fluxes
(Brautigan, 2002)

Chilean Ash Cloud, June 2011

Aviation

Getley et al., Space Weather,
2004SW000110

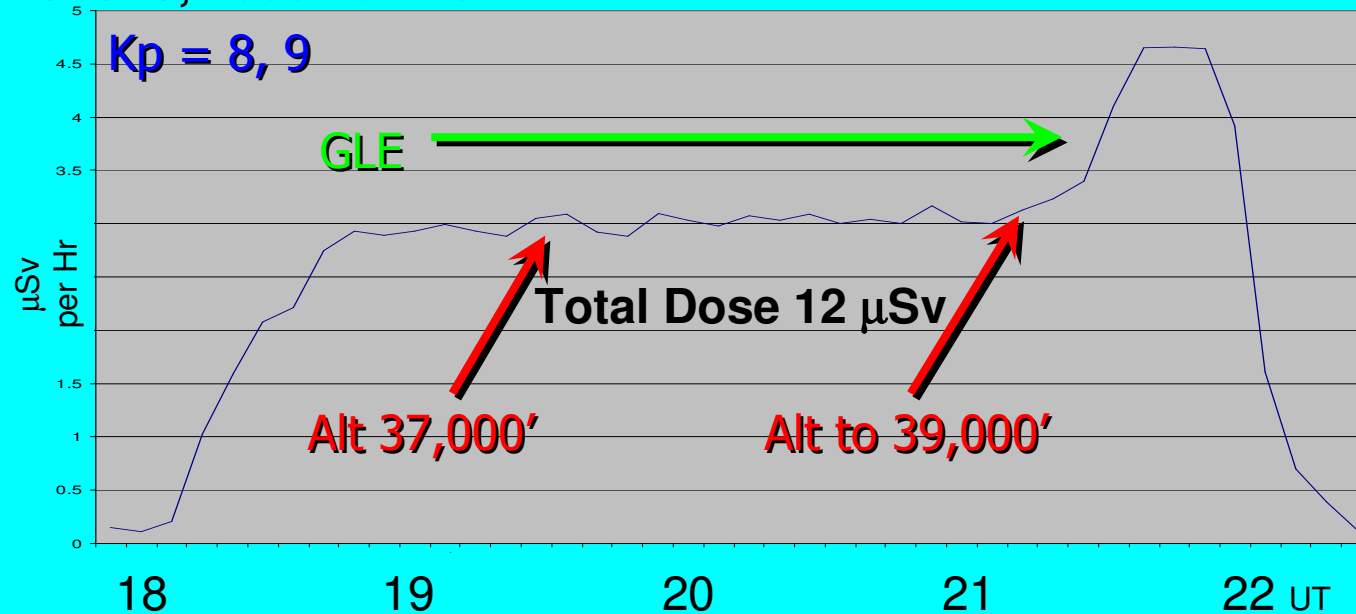


International guidelines:

- 100 mSv/yr over 5 yrs
- < 50 mSv max any year
- < 1 mSv pregnant women

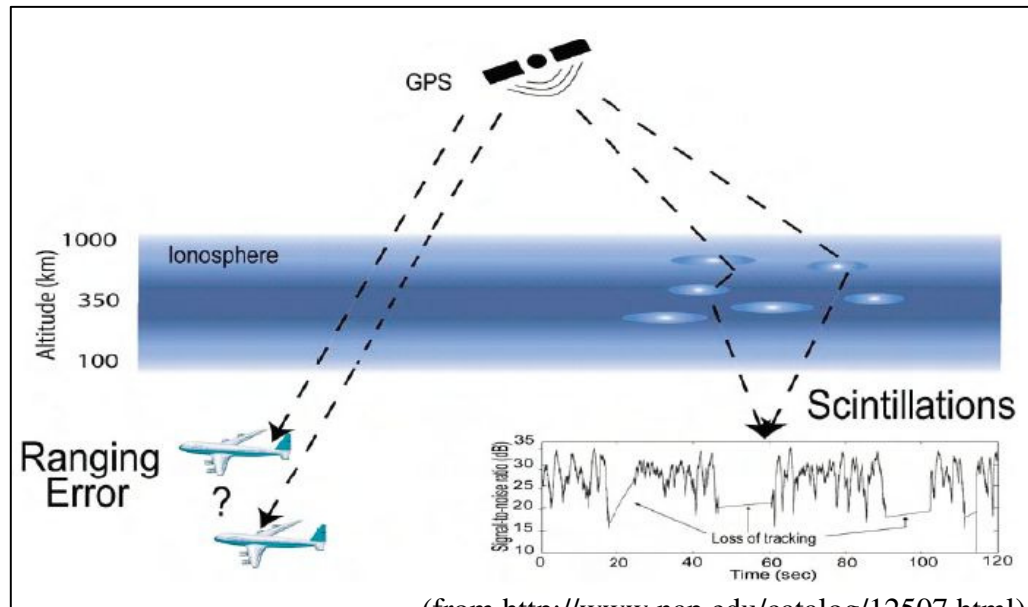
• Australian airline aircraft altered course during significant SPE event earlier this year

Oct 29, 2003 Lax - JFK

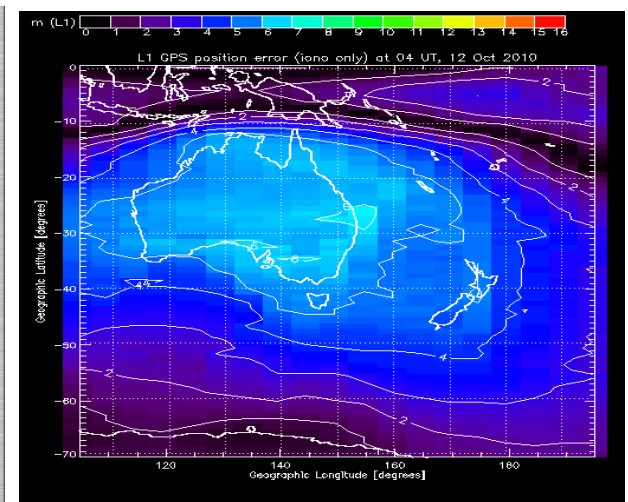
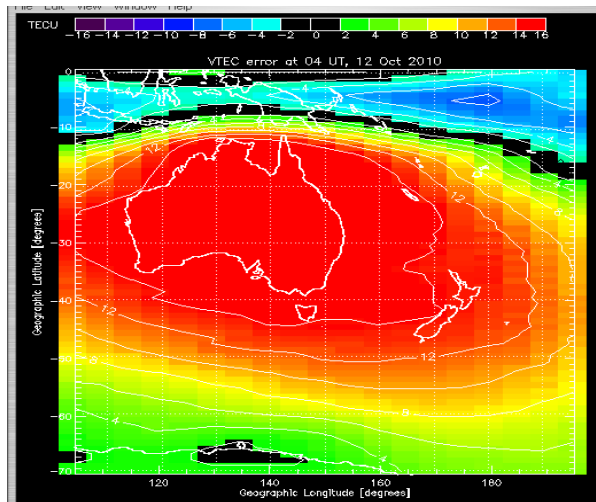
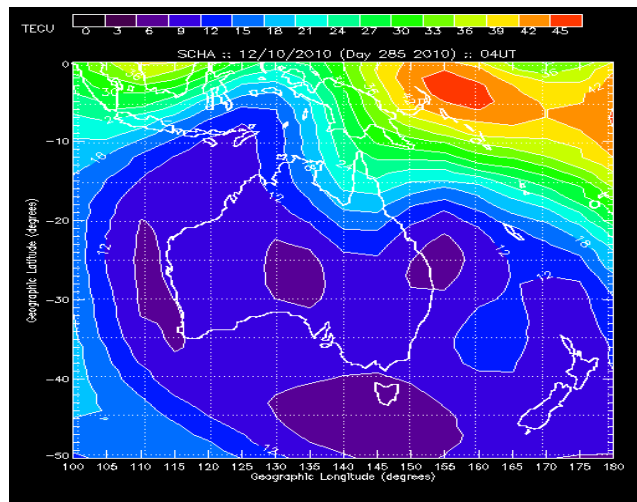
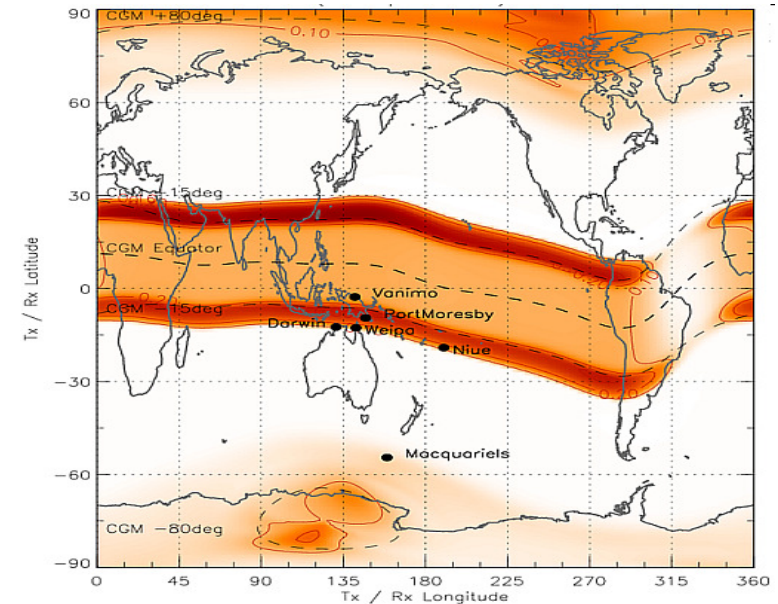


M. Duldig, adapted from Getley
et al., Space Weather,
2004SW000110

Low-End GPS Systems



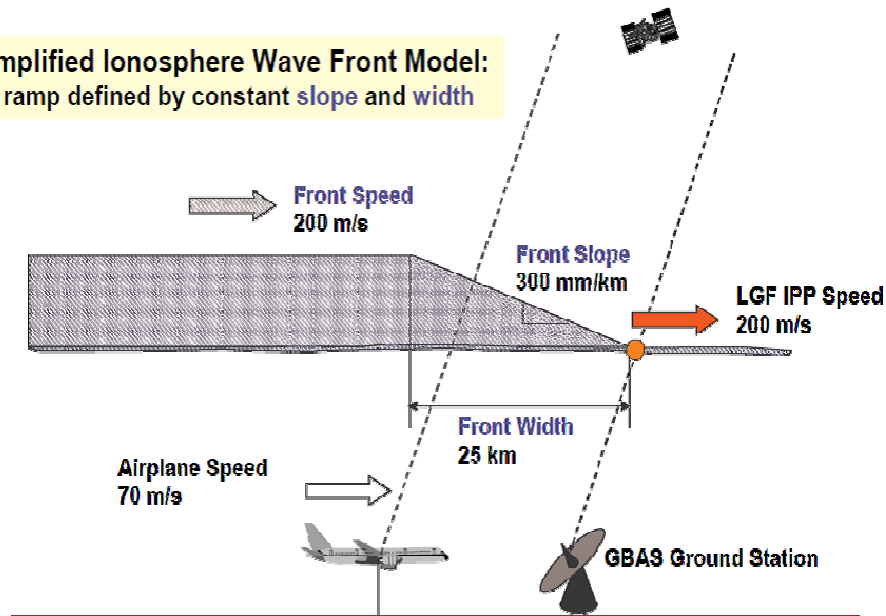
(from <http://www.nap.edu/catalog/12507.html>)



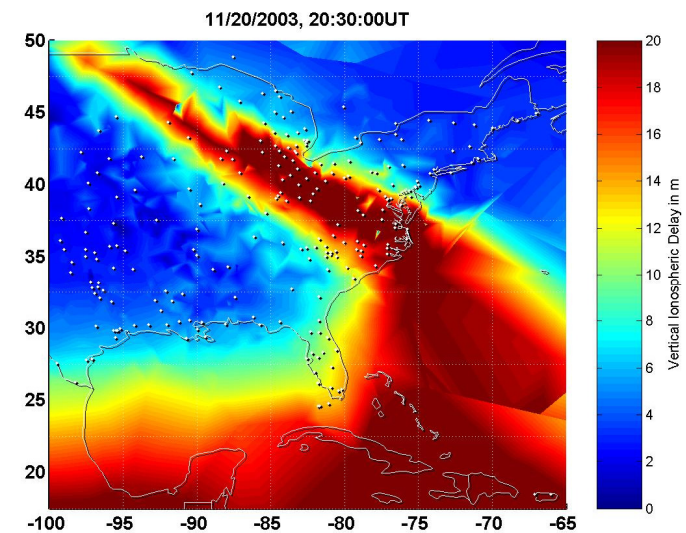
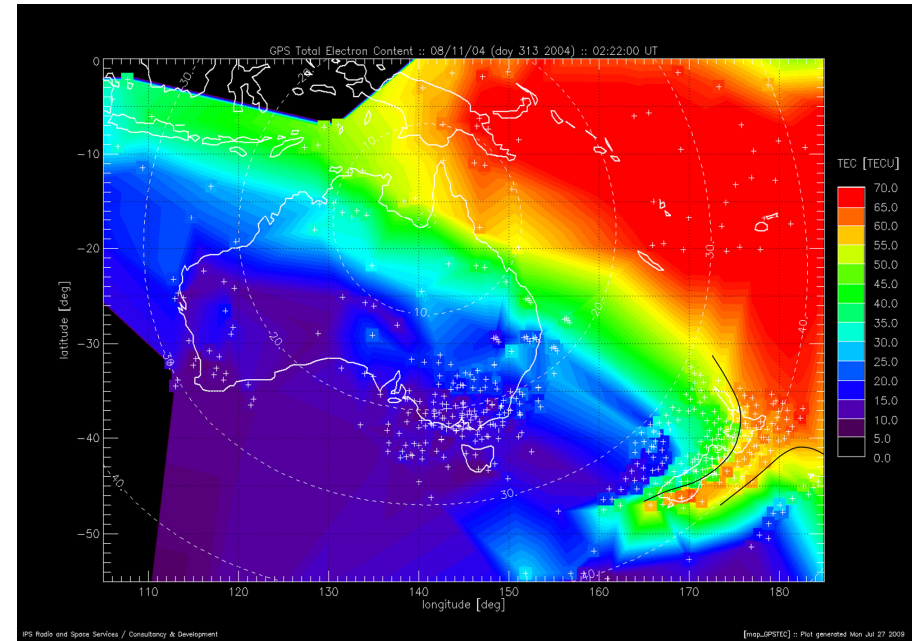
High-End GPS Systems

(Terkildsen, 2010, IPS-CR-09-01-P, April 2010)

Simplified Ionosphere Wave Front Model:
a ramp defined by constant **slope** and **width**



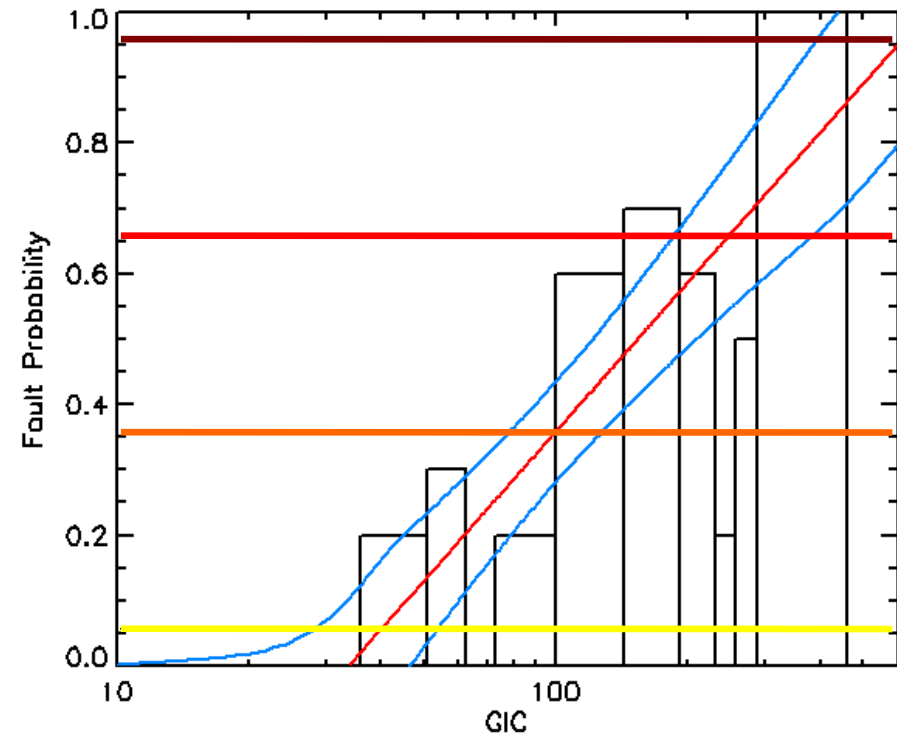
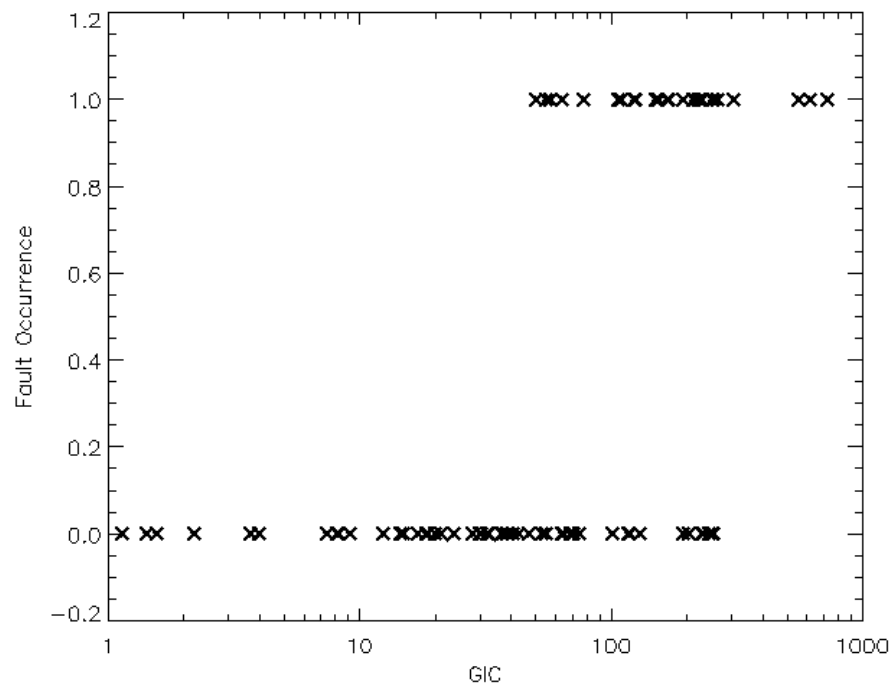
[from Pullen et al, 5th International GBAS Working Group Meeting (GWG/5), Nov 2006]



[from Ene et al (2005), Proceedings of ION 2005 National Technical Meeting]

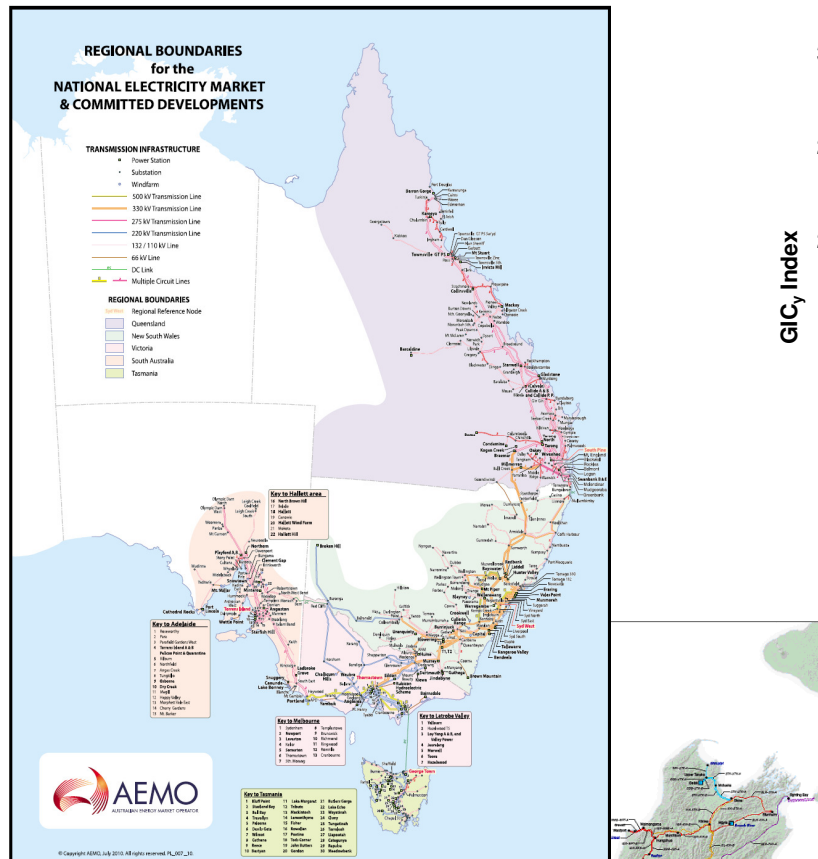
Power Networks

Threat Level Model from Global network observations

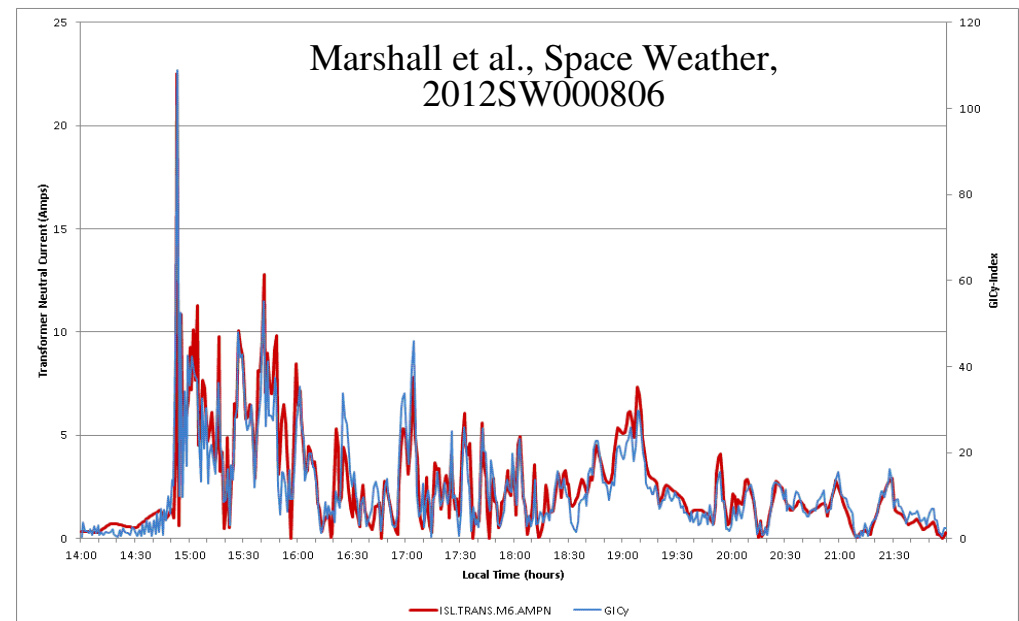
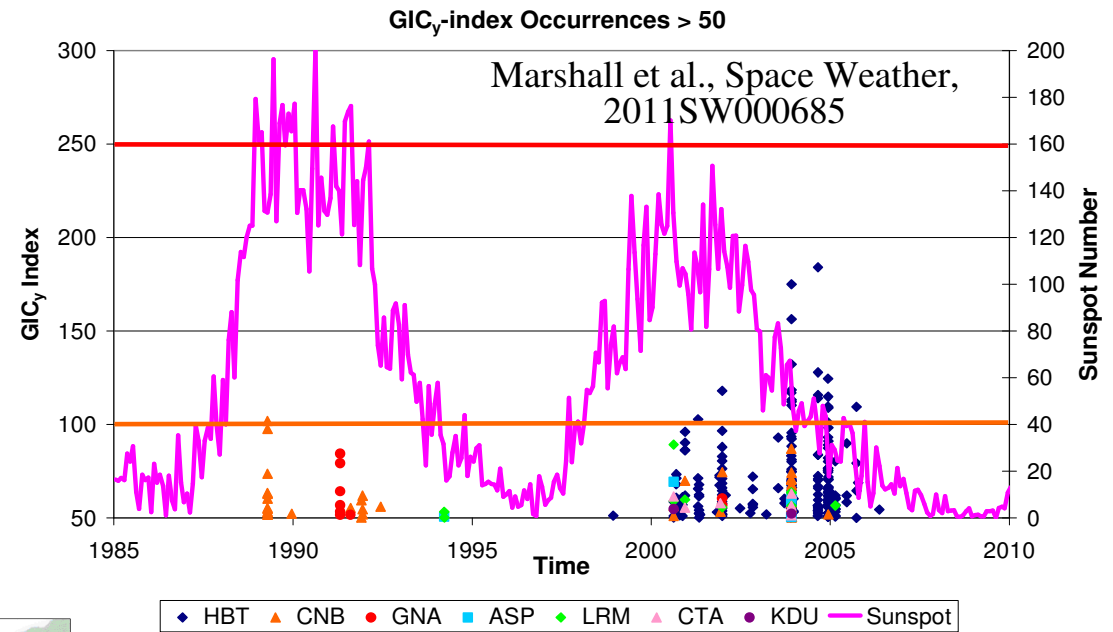
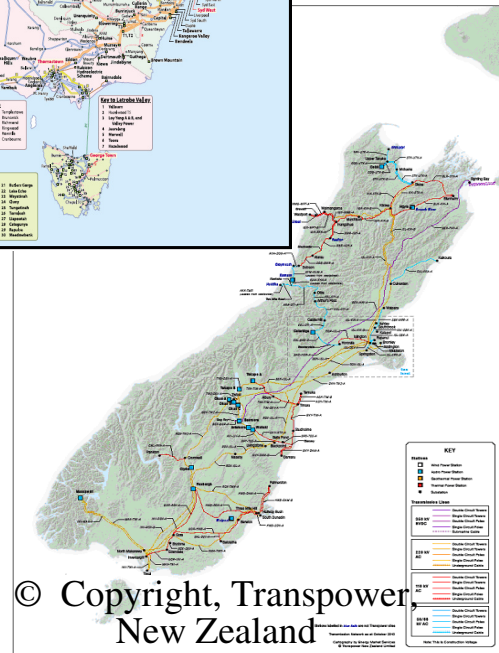


Marshall, Smith, Francis, Waters and Sciffer, Space Weather, 2011

Australian/NZ Power Networks



© Copyright, Transpower,
New Zealand



Extreme Space Weather (ESW) Model

- Most space weather impacts in Australian region associated with extreme events
- Generalised Linear Model (GLM) techniques
- Event-based analysis
- Requirements:

LATENCY

- ‘Long range’ warning (> 12 hours) ☐ Based on solar data only
- ‘Short range’ alert (~ 1 hour) ☐ Based on solar data + ACE

ACCURACY

- Long range: Optimise to minimise missed events
- Short range: Optimise for forecast accuracy

SIMPLICITY

- Design for active use in space weather forecast environment

ESW Model Events

Event- based analysis

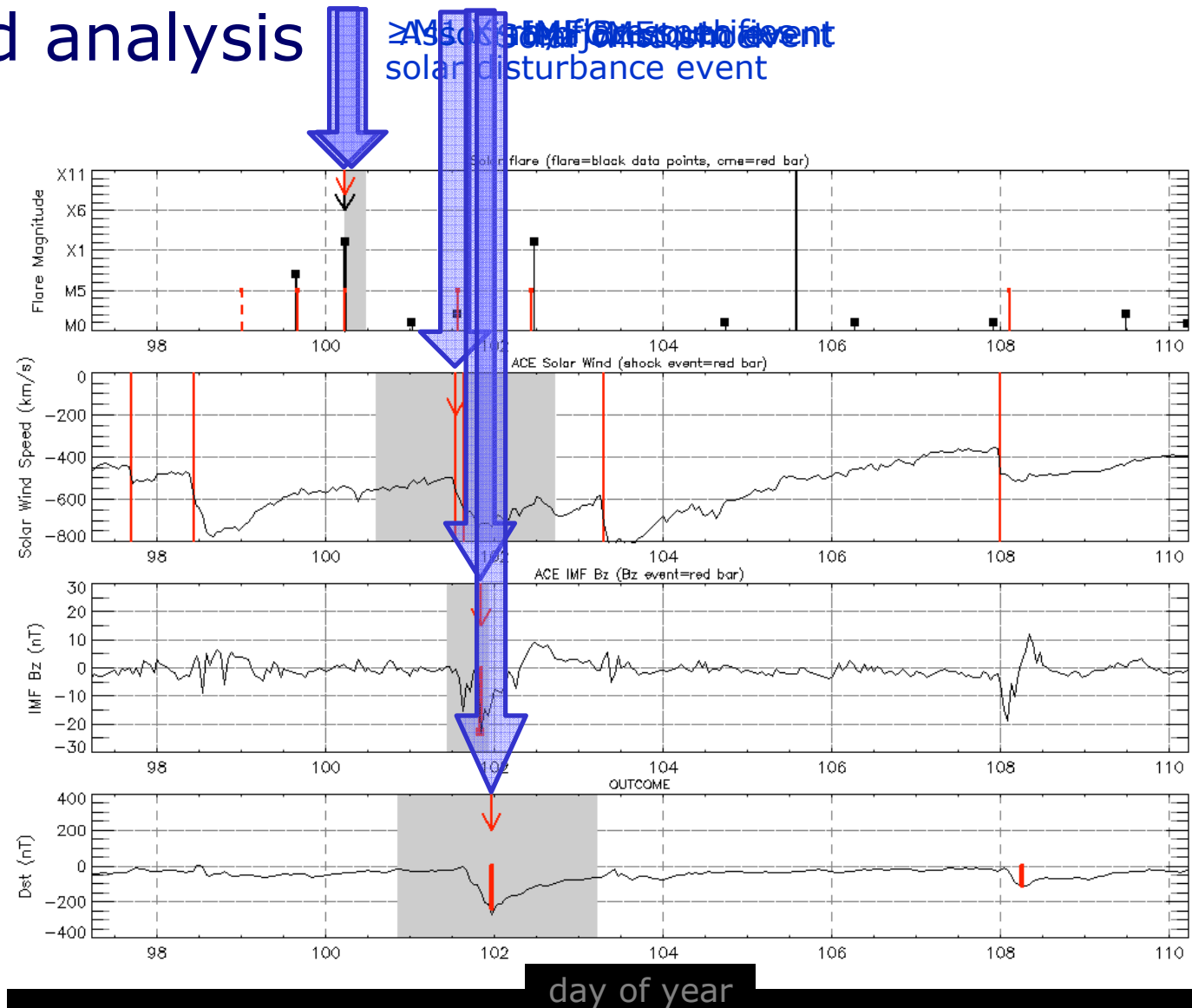
≥ 450 km/s IMF On South event
solar disturbance event

Flares / CMEs

solar wind
(shocks)

IMF
(Bz events)

Dst
(storm events)



ESW Model Parameters

Model covariates (the 'input data')

X-RAY FLARE

Solar flare magnitude

Solar flare duration

LOCATION OF SOLAR ACTIVE REGION

Latitude of solar active region

Longitude of solar active region

CME CHARACTERISTICS

Presence of Halo CME (CME width)

CME speed

SOLAR CYCLE

– Solar Cycle Phase

SOLAR WIND / IMF

– IMF Bz

– Solar wind shock

ESW Model GLM

Generalised Linear Model

Response variable (what is being modelled)

$$dstN = \begin{cases} 0 & Dst \geq -50 \\ |Dst + 49| & \text{else} \end{cases}$$

Model (a GLM)

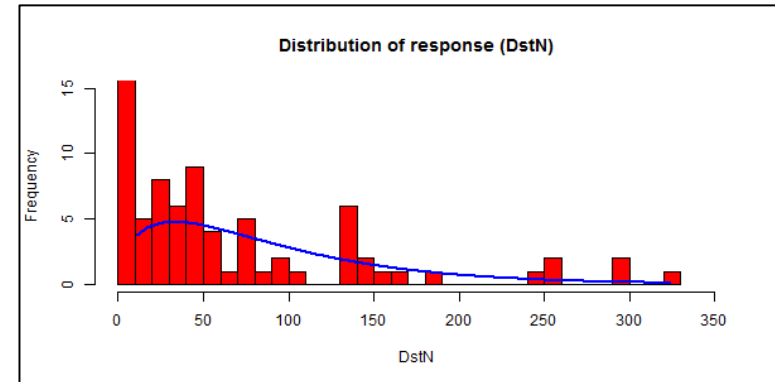
$$\ln(\mu_i) = \alpha_0 + \alpha_1 x_{i1} + \alpha_2 x_{i2} + \dots + \alpha_m x_{im}$$

Training data (for fitting model coefficients)

15 years data (1996 – 2010)

Prediction (a binary output)

$$y_i = \begin{cases} 0, & p_i(y | \mu) < p_{thresh} \\ 1, & p_i(y | \mu) \geq p_{thresh} \end{cases}$$



$x_{i1} \dots x_{im} \rightarrow$ Input variables

$a_0 \dots a_m \rightarrow$ Coefficients (to fit)

$p_i(y | \mu) \rightarrow$ Response distribution

$p_{thresh} \rightarrow$ Threshold on event probability used to produce binary prediction (ESW event/no-event). Optimised for required model performance.

ESW Model Validation

Model validation: Solar data only

Optimising for no missed events (false negatives = 0)



Leave-One-Out Cross Validation (LOOCV)

true positives	6
false positives	25
false negatives	0
total events	644

ESW Model Implementation

- Operational GUI in ASFC
- Uses Dst-based ESW models as a back-end, providing both binary and probabilistic forecasts for ESW
- Accepts a range of covariates for added flexibility
- Simple text warning message

Power Grids - Extreme Space Weather Warning

 Do you want to send the following warning email?

recipient: SolarFlares@aemo.com.au
subject: Significant Space Weather Activity Expected

Extreme Space Weather Advisory Notification

A recent Coronal Mass Ejection associated with a solar flare is anticipated to impact the Earth within the next 12-24 hours. The effects are expected to be significant. Increased awareness of critical infrastructure over the next 24 hours is advised.

Please monitor the IPS website for further updates at <http://www.ips.gov.au>

DFmenu

Forecast Reports Warnings Notices Maintenance Tools Options

Regular warnings

Geomagnetic
Preliminary HF
HF
SWF

Extreme event

Model 1
Model 2

Extreme event warnings

Model selection

Warning model
☒ Solar data only

Experimental models
☐ Solar data + IMF Bz
☐ Solar data + IMF Bz + solar wind shock

Flare/CME observations

Flare date: 07-Mar-2012
Latitude: N17 (eg, N24)
Flare magnitude: X5.4 (eg, M5.3)
Longitude: E15 (eg, W15)
Flare duration: 3:36 (hh:mm)
Halo CME: ☒ (can be asymmetric)

Solar wind observations (when CME hits ACE)

Southward IMF Bz: ☐ Solar wind shock: ☐

EXTREME EVENT

Send warning?

Satellites:
Power Grids (AEMO):
GPS:
Aviation:

Future Developments

- ACE solar wind parameters
- CME symmetry parameter / CME “mass”
- Active region magnetic characteristics (proxy for IMF Bz events?)
- CME travel time (flare-shock interval) to replace CME plane-of-sky speed (a poor proxy for true CME speed)
- Type II / Type IV radio bursts
- Direct modelling of ESW parameters as response
 - GIC index
 - Ionospheric gradient index



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Thank you.

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