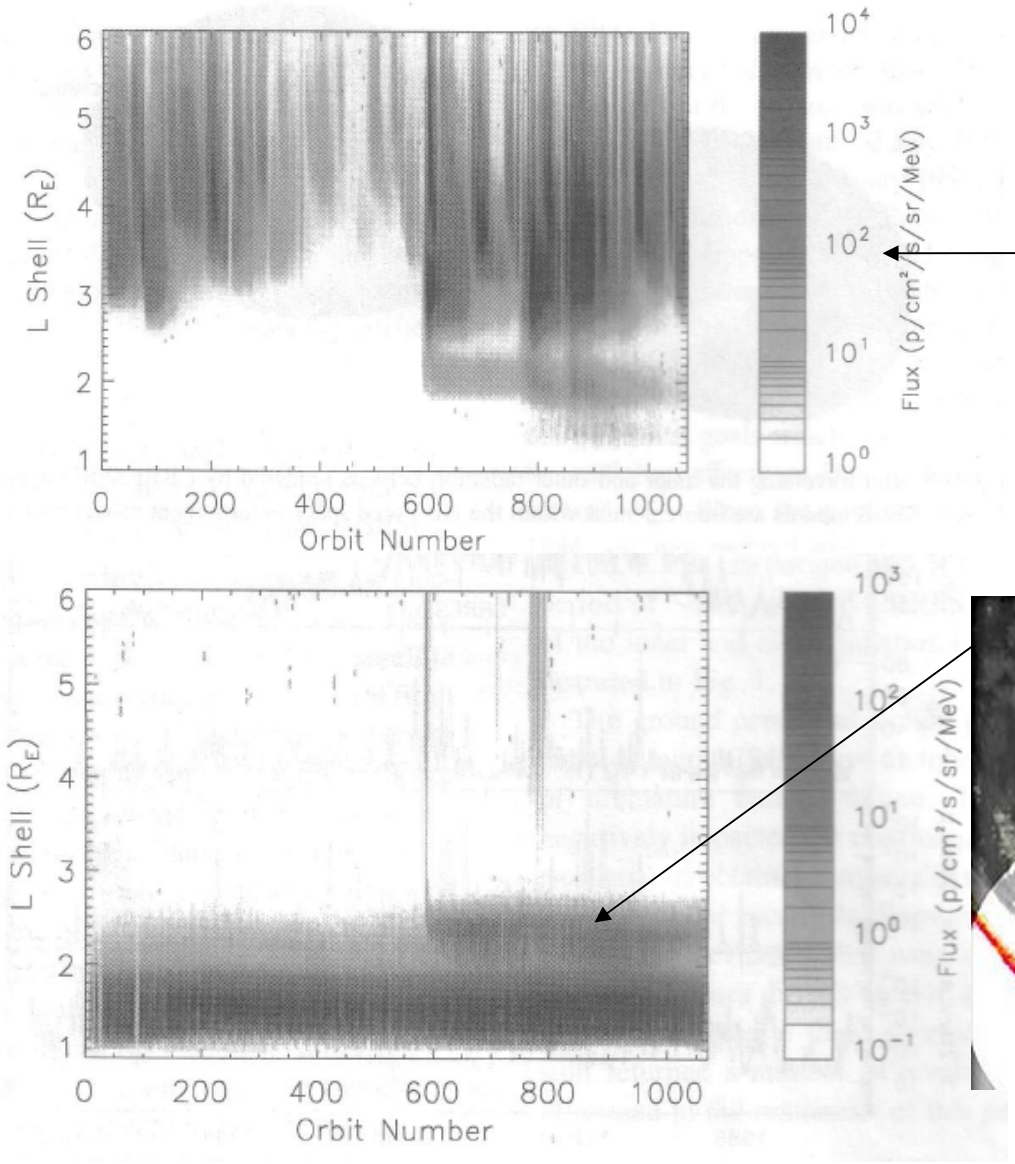
R. Marshall, M. Terkildsen, G. Steward, D. Neudegg, Z. Bouya

Ionospheric Prediction Service (IPS)
Australian Bureau of Meteorology

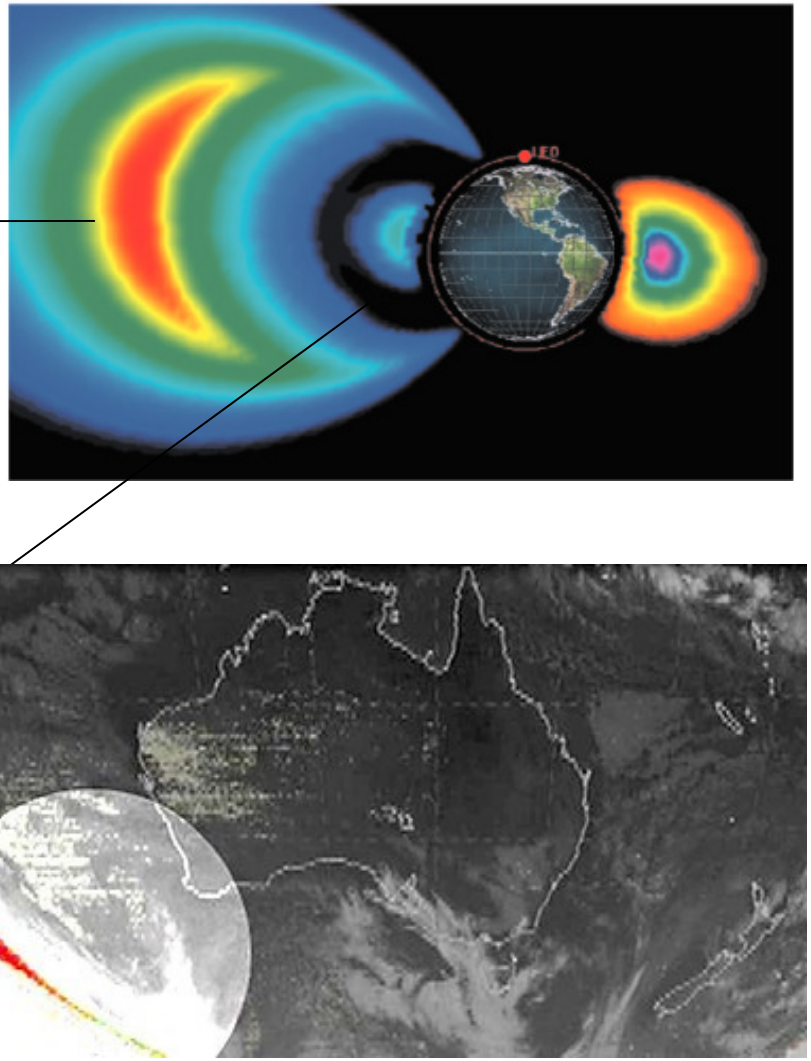
ESW Motivation

- 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



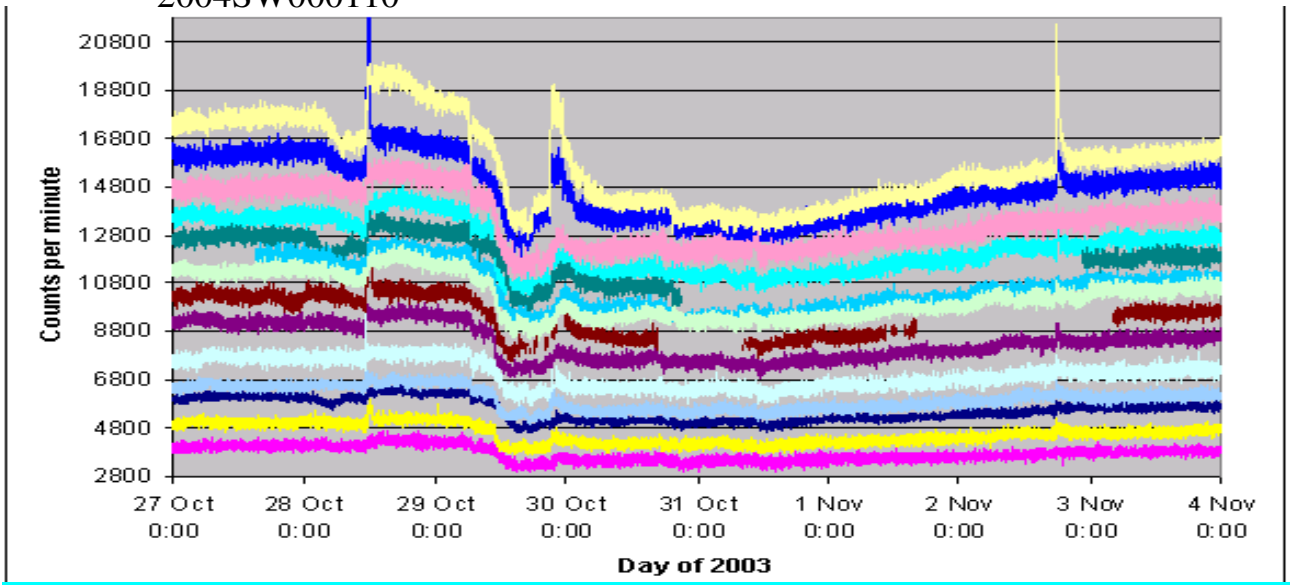
CRESS Electon and Proton Fluxes
(Brautigan, 2002)

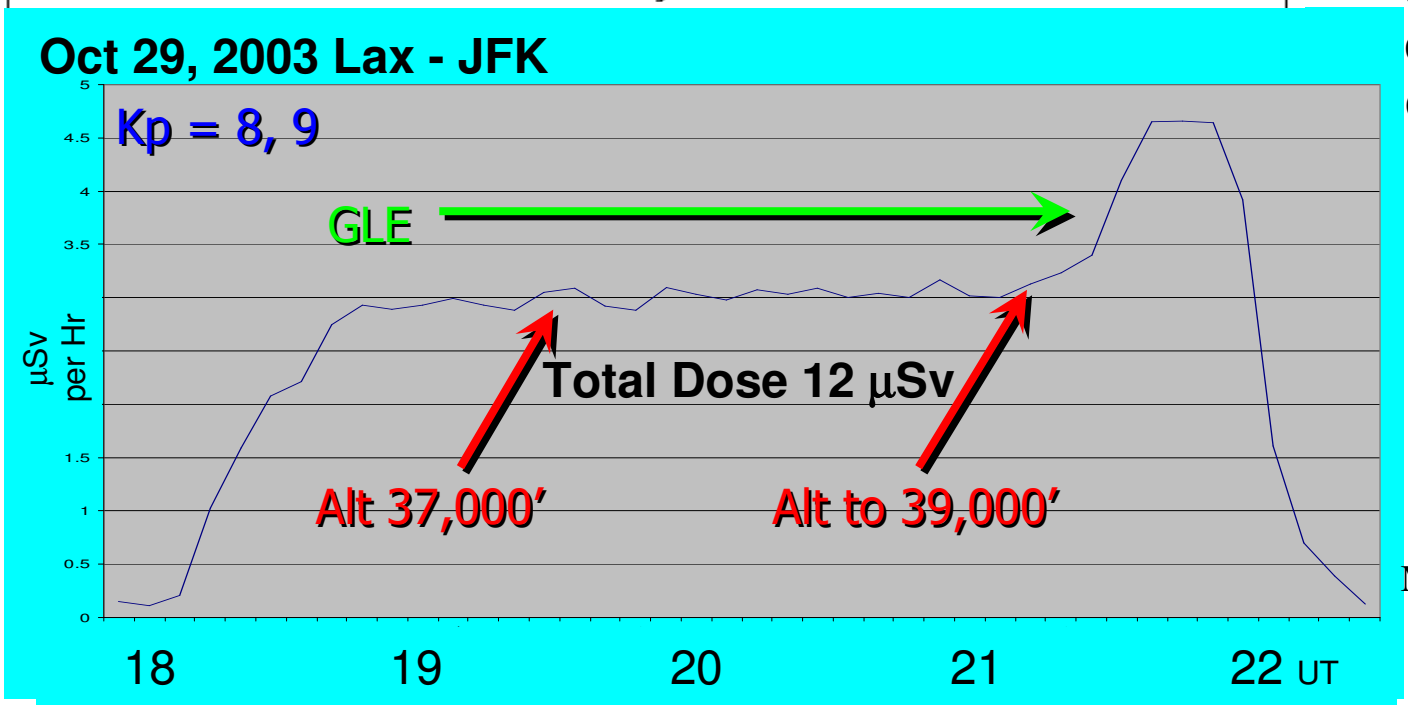


Chilean Ash Cloud, June 2011

Aviation

Getley et al., Space Weather, 2004SW000110



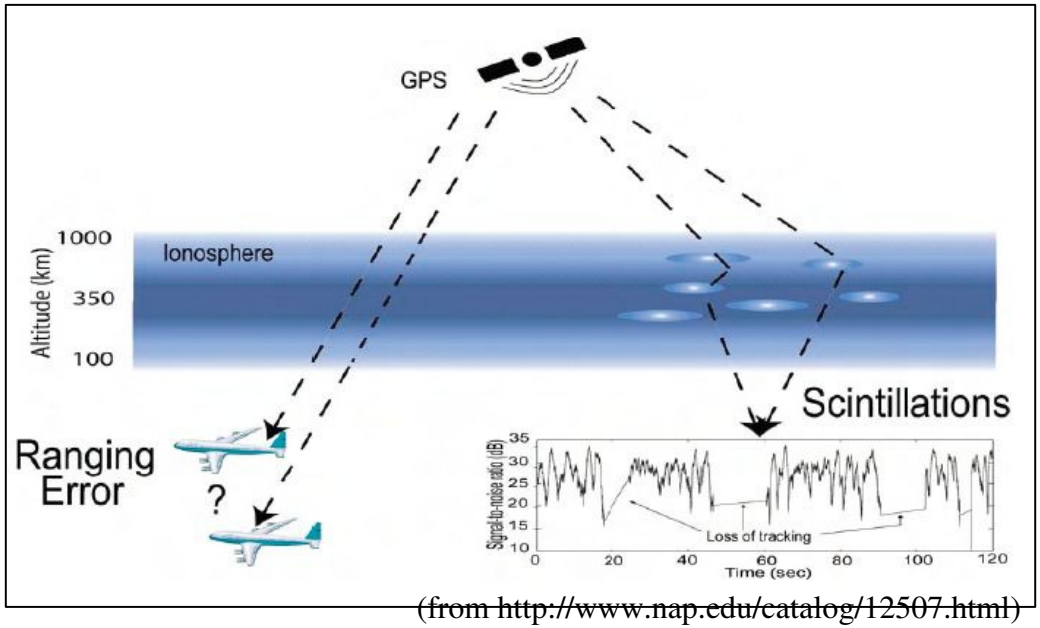


International guidelines:

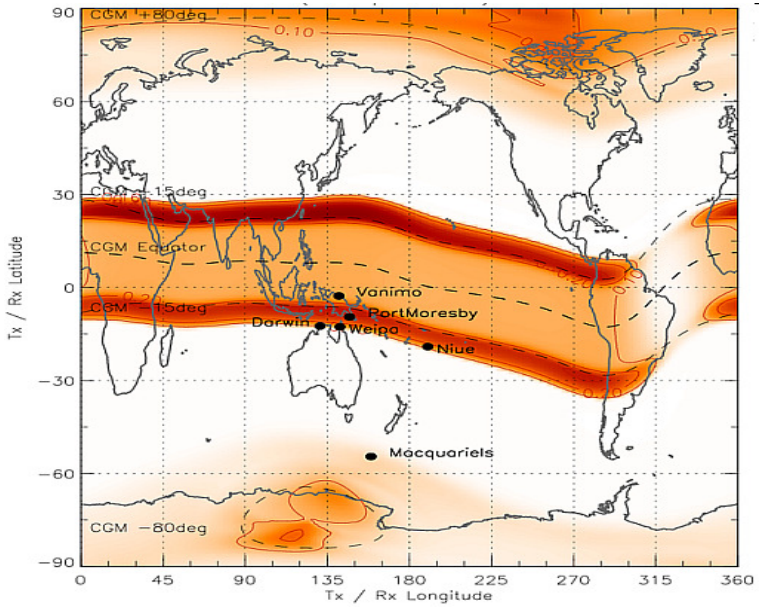
- 100 mSv/yr over 5 yrs
- < 50 mSv max any year
- < 1 mSv pregnant women
- Australian airline aircraft altered course during significant SPE event earlier this year

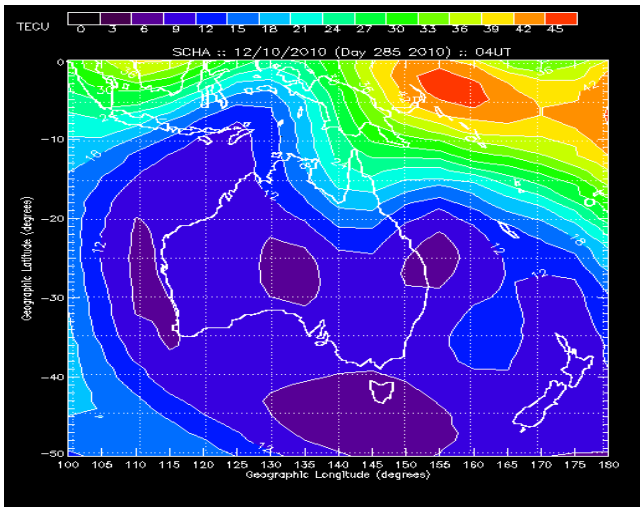
M. Duldig, adapted from Getley et al., Space Weather, 2004SW000110

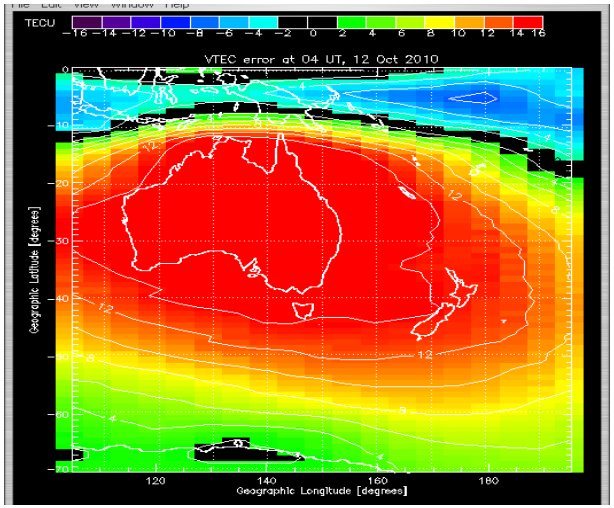
Low-End GPS Systems

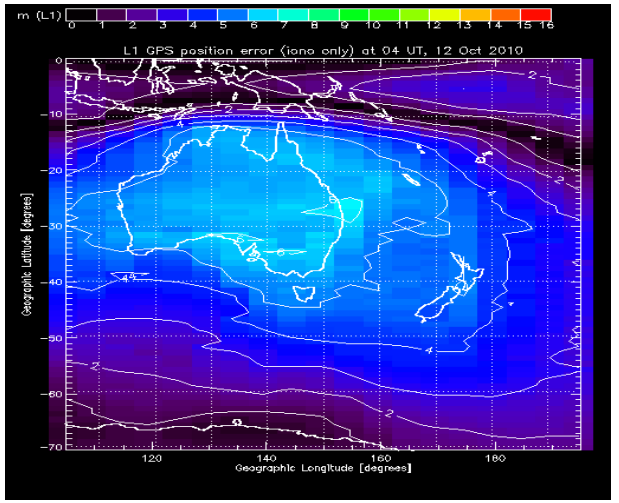


(from http://www.nap.edu/catalog/12507.html)



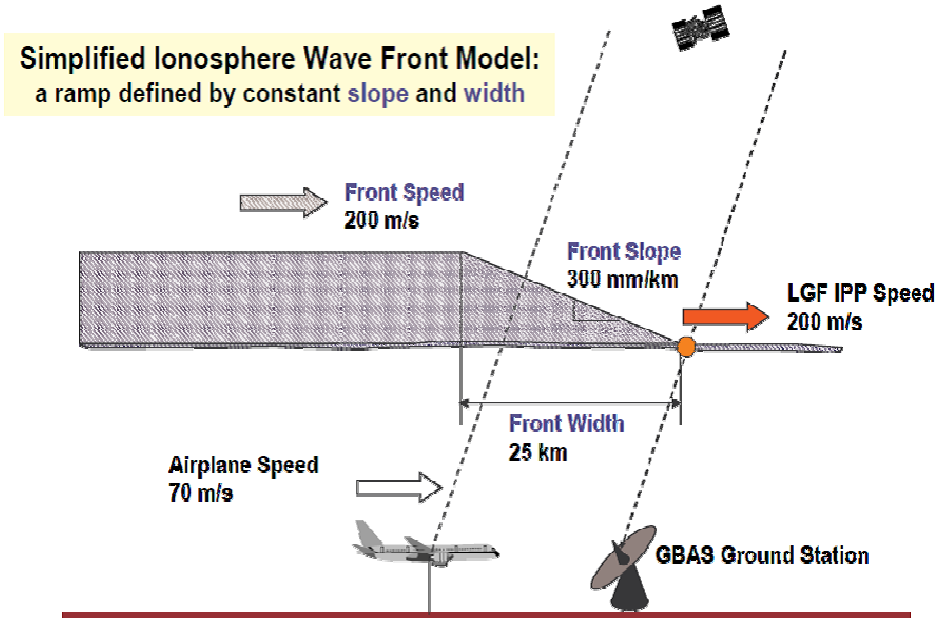




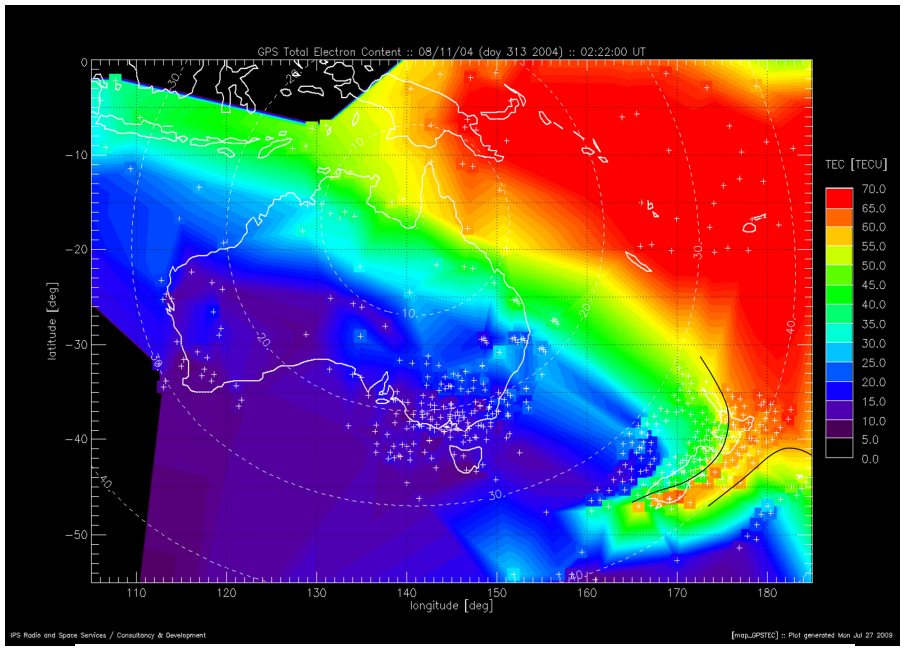


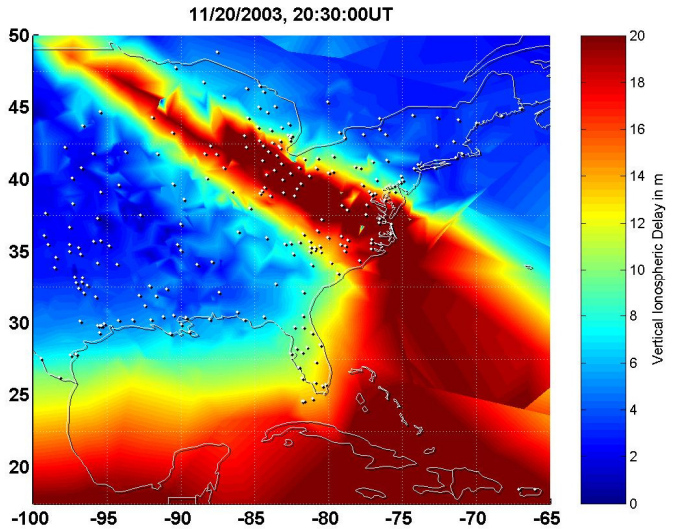
High-End GPS Systems

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



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

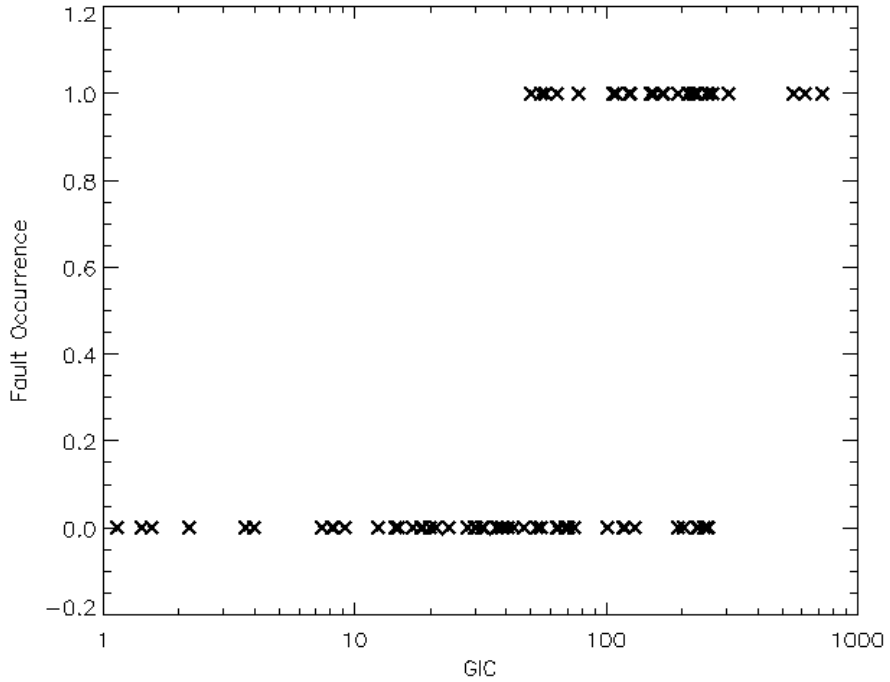


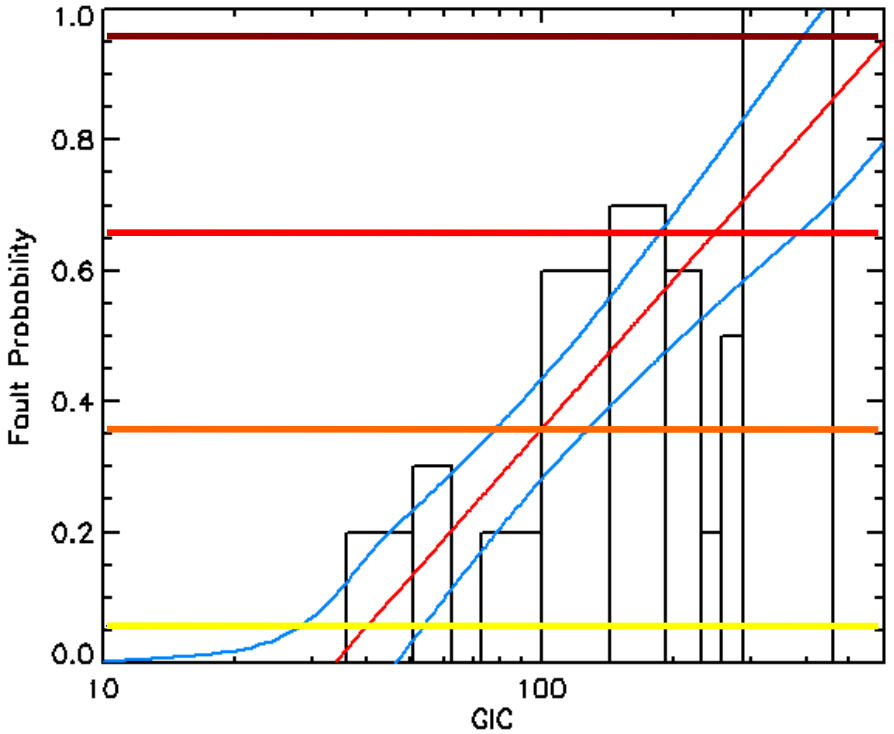


[from Ene et al (2005), Proceedings of ION 2005 National Technical Meeting]

Power Networks

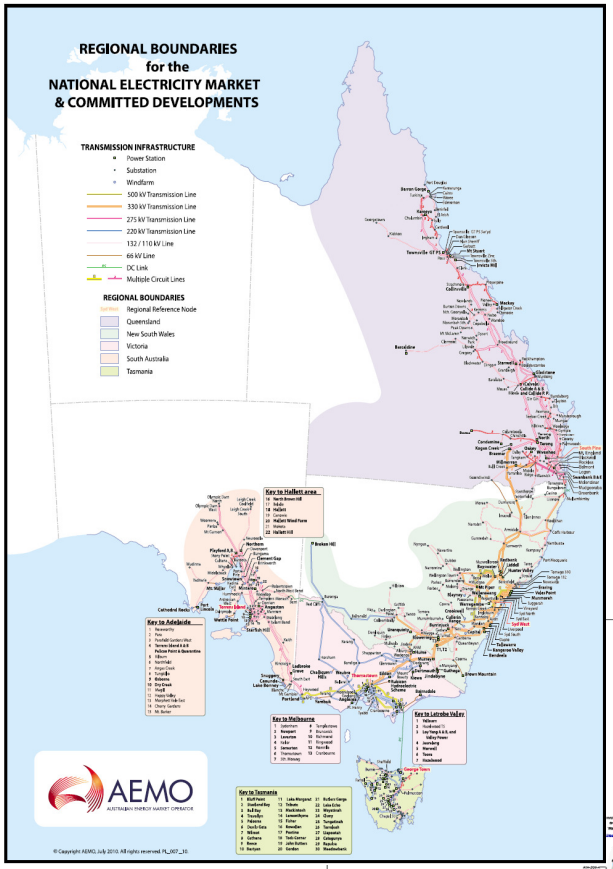
Threat Level Model from Global network observations

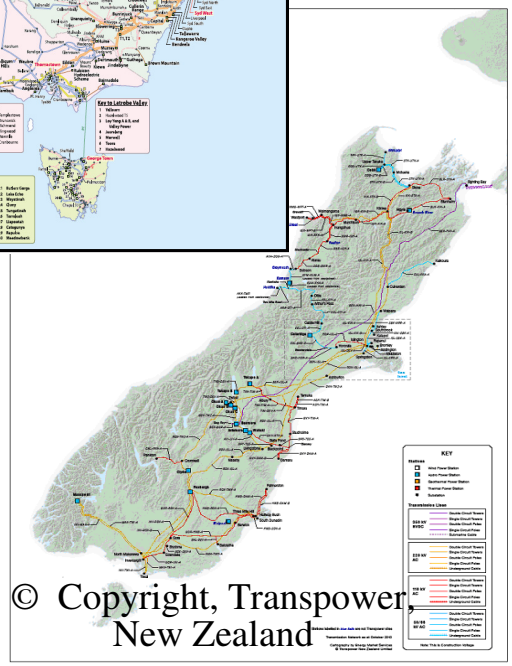


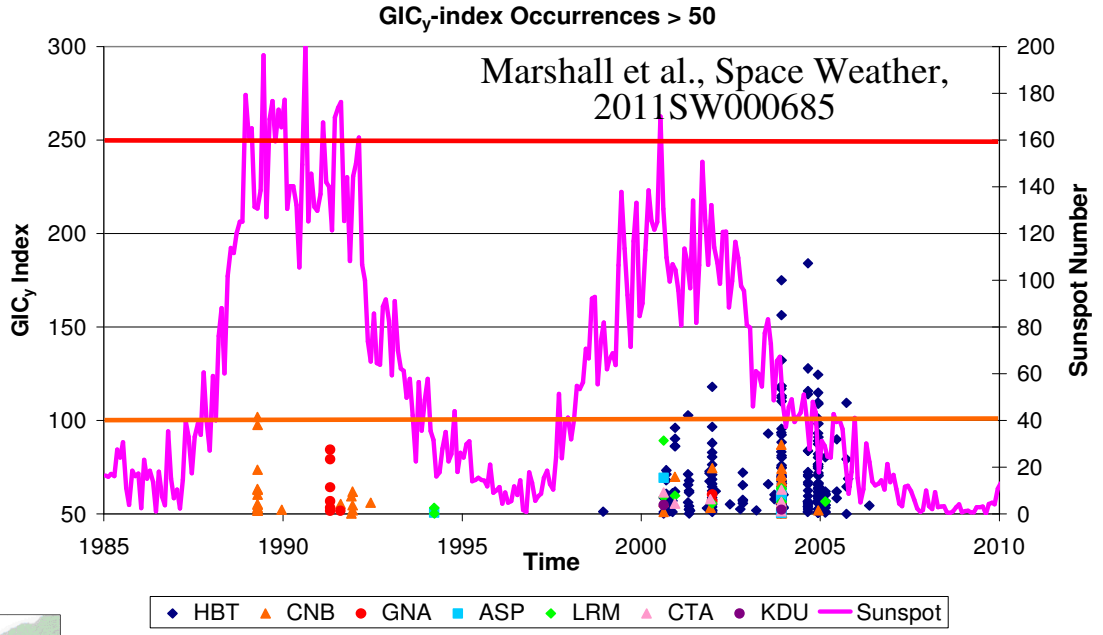


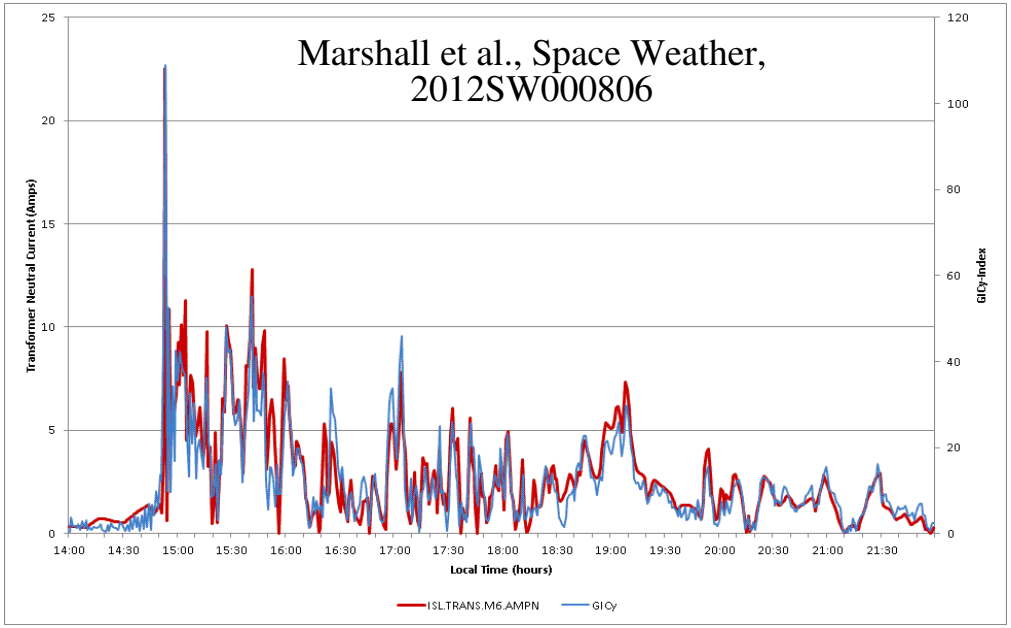
Marshall, Smith, Francis, Waters and Sciffer, Space Weather, 2011

Australian/NZ Power Networks









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

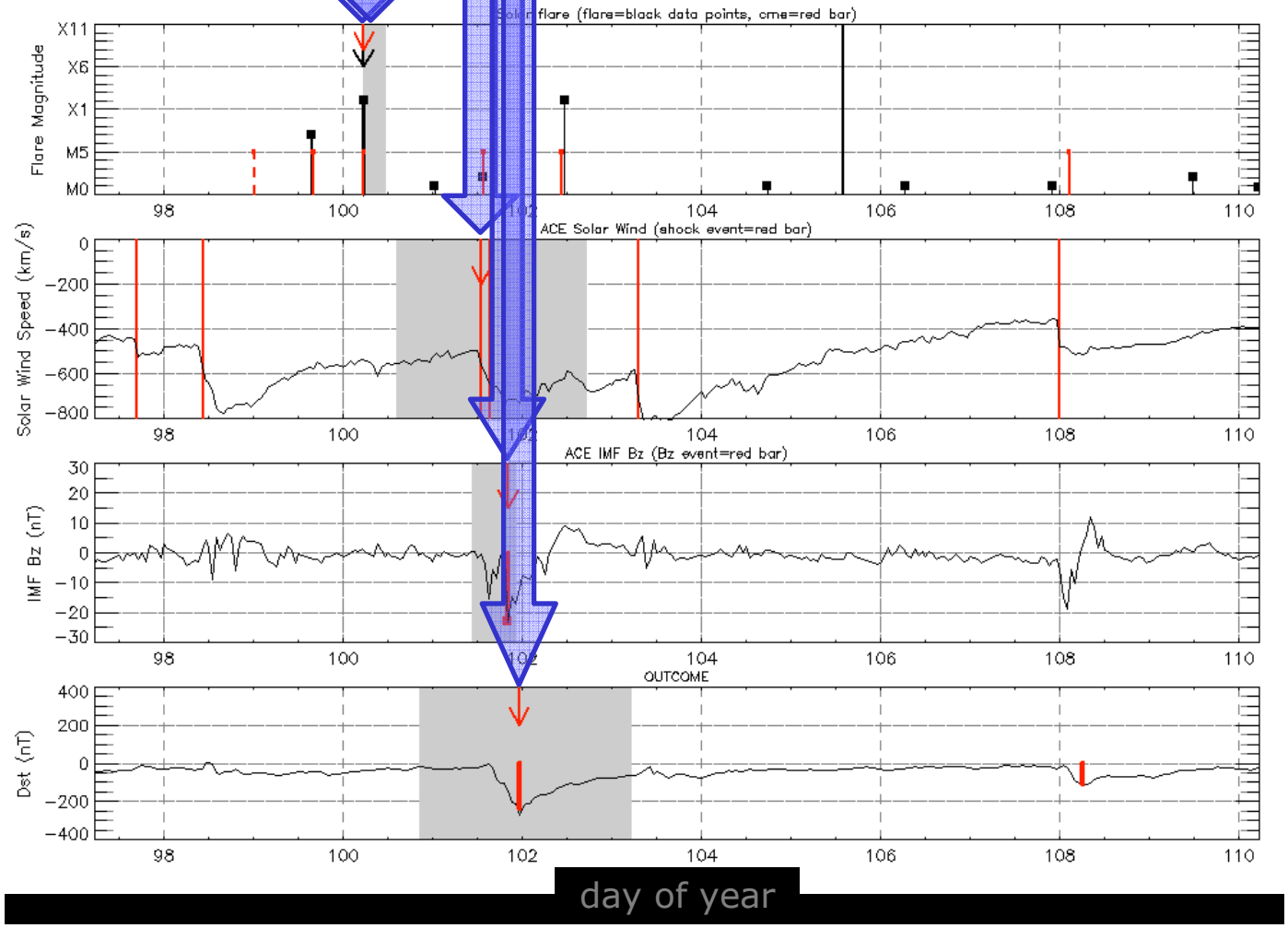
≥Associated solar disturbance event

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

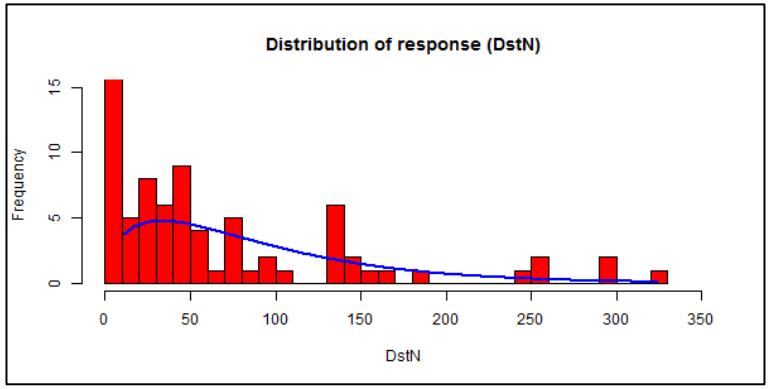
- IMF Bz
- Solar wind shock

ESW Model GLM

Generalised Linear Model

Response variable (what is being modelled)

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



Model (a GLM)

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

Training data (for fitting model coefficients)

15 years data (1996 – 2010)

Prediction (a binary output)

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

$x_{i1} \ldots x_{im}$ → Input variables

$a_0 \ldots a_m$ → Coefficients (to fit)

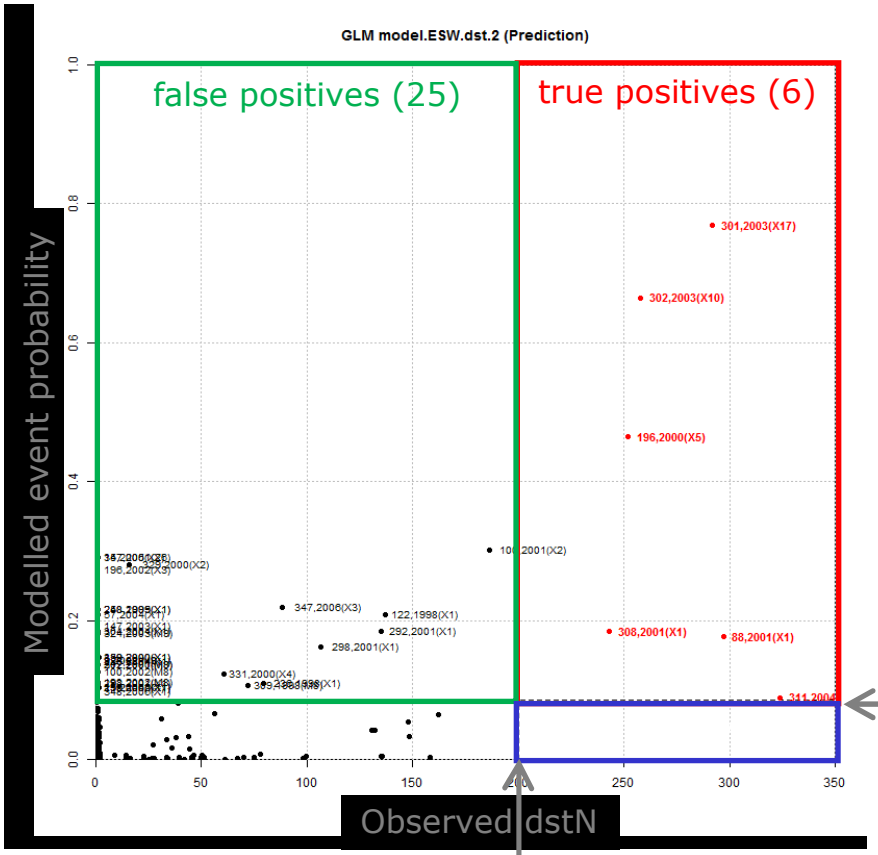
$p_i(y \mid \mu)$ → Response distribution

p_{thresh} → 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)

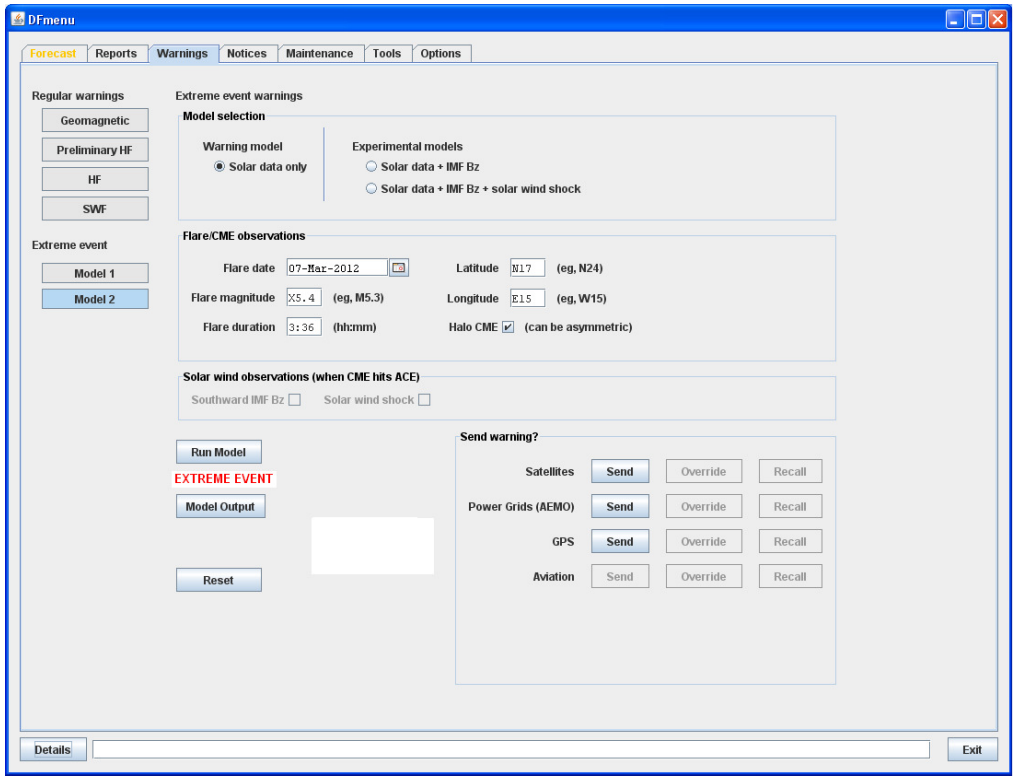
true positives	6
false positives	25
false negatives	0
total events	644

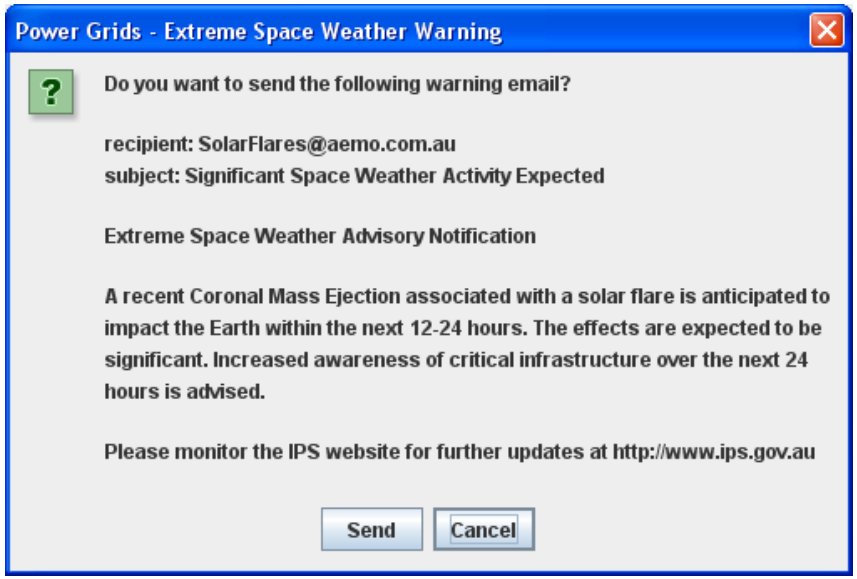
Probability threshold
(to determine binary outcome)

ESW event threshold (dst < -250)

ESW Model Implementation

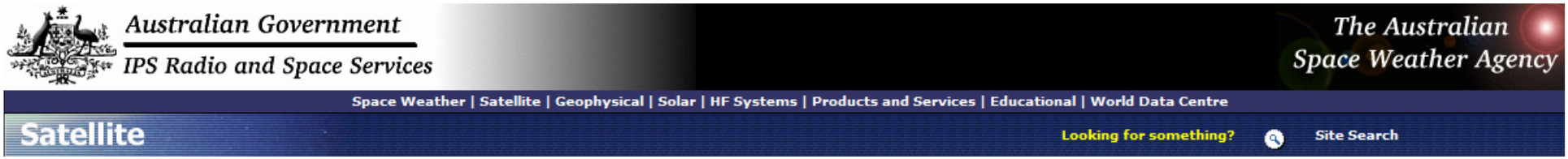
- Operational GUI in ASFC
- Uses Dst-based ESW models as a back-end, proving both binary and probabilistic forecasts for ESW
- Accepts a range of covariates for added flexibility
- Simple text warning message





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



Thank you.

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