Using STORM to support short- term ionospheric forecasts

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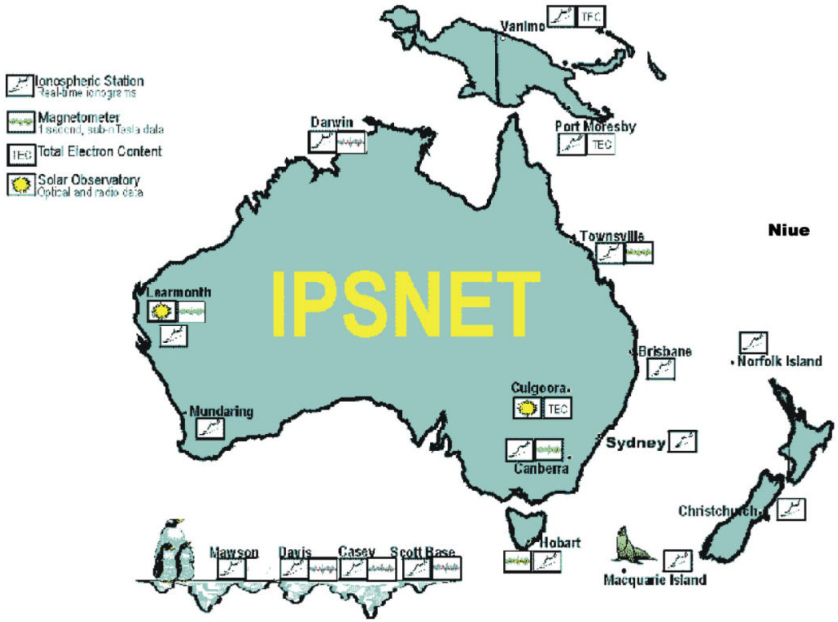
Abstract

- The International Reference Ionosphere, IRI2001, now contains a parameterised ionospheric storm model, called STORM. Using Ap indices, this predicts the nature of the global ionosphere by producing a latitudinal correction for peak electron-density F2-region maps. This paper explores the use of STORM to support ionospheric forecasts. To do this, a corrected global index of ionospheric activity is constructed using STORM and the results of using this index are compared with manual forecasts made locally. The utility of STORM is also explored for the Australian region to estimate whether it can be used to extend local regional ionospheric models.



The Problem – ionospheric support

- Dynamic ionospheric modelling efforts are possible,
  - and web-based near real-time ionospheric models are now available,
  - but there is still a demand for coarser ionospheric-based services, e.g., for HF communications.
- A typical HF support service
  - uses an empirical model of the ionosphere (e.g., ASAPS, IONCAP, IRI, REC533)
  - updated (monthly, daily, forecast) with an ionospheric index (e.g., IF2, effective R, T)
  - to offer a useful representation of the current and expected ionospheric conditions.

The Problem – an effective index

- Clearly, a single index is unsuitable to describe the global ionosphere,
  - irrespective of the details of the empirical model.
  - However, provided a suitable index forecast is made, it can provide an effective compromise;
    - index changes of 30 units and more are important.
  - As an example, the IPS T index is used in this paper.
- Two levels of forecast index are useful:
  - monthly forecasts, often a few months in advance
    - and based on solar cycle predictions.
  - daily forecasts, often for two to three days in advance
    - and based on current geophysical conditions and expectations.
- Making more effective daily ionospheric index forecasts is the subject of this paper.

The Problem – making forecasts

- Daily forecasts for the next three days are made in the Australian Space Weather Forecast Centre (ASWF) for:
  - the daily ionospheric T index
  - the daily Ap index , and other parameters.
- Daily (T_{DAY}) forecasts
  - use current geophysical observations and expectations,
  - T_{DAY+1} forecast is referenced to current daily index, T_{DAY}
  - T_{DAY+2} and T_{DAY+3} forecasts are more subjective;
    - success should depend mainly on geomagnetic storm timing and size.
  - Predictions for Ap available from the Space Environment Center (SEC) are also used.
- None of these forecasts shows great skill.

STORM: can it help?

- The STORM model (a subroutine distributed with the IRI) provides a correction for the effects of ionospheric storms based on past 3-hourly a_p observations.
  - Ref: E. A. Arujo-Pradere, T. J. Fuller-Rowell, and M. V. Codrescu "STORM: An empirical storm-time ionospheric correction model 1. Model description" Radio Science **37**, 1070, doi:10.1029/2001RS002467, 2002. (and other references cited in this paper).
- How can STORM assist forecasters?
  - It provides estimates of geomagnetic storm effects (or lack of effect) on the ionosphere.
  - It may assist in making consistent magnetic and ionospheric forecasts.
  - It may encourage forecasters by providing estimates of storm timing and magnitude
    - possibly helping reduce the inevitable lag in forecasts
    - and conservative estimates of storm magnitude.

STORM - method

$F_{L1} = a_L T_1 + b_L$

F_{L1} is the undisturbed foF_2 at location L for undisturbed, or baseline index T_1 at time 1.

(a_L, b_L) define the ionospheric model at location L.

$F_{LS} = S_0 F_{L1}$

$F_{LS} = S_0 a_L T_1 + S_0 b_L$

If a storm occurs at time 1, then a correction, S_0, from STORM, is made to the undisturbed foF2.

$F_{LS} = a_L T_{SL} + b_L$

This is equivalent to applying a new index T_{SL} to the model.

$T_{SL} = S_0 T_1 + (b_L/a_L)(S_0 - 1)$

Using this expression, the storm affected index can be calculated at location, L.

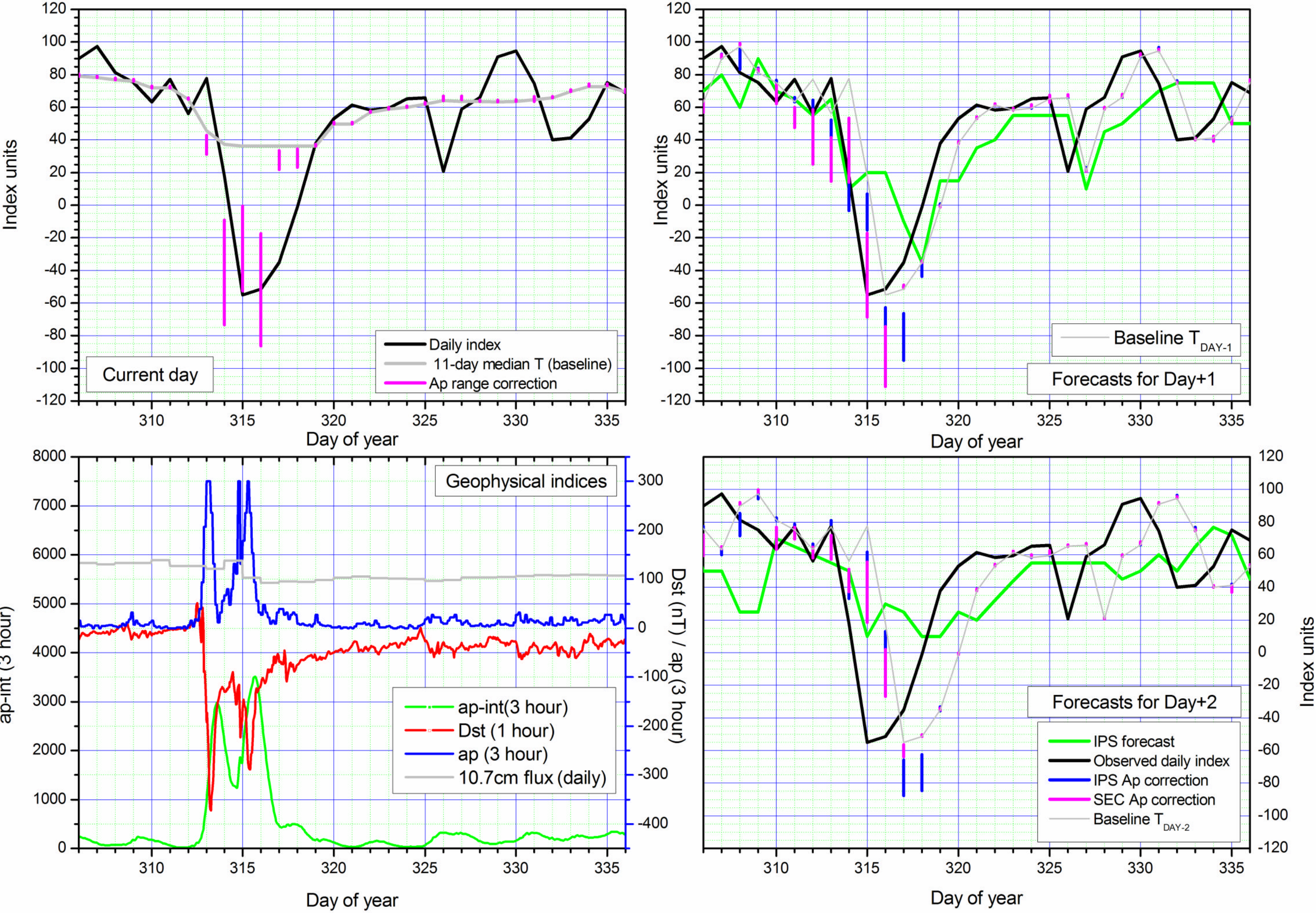
$T_{STORM} = S\ T_{SL}$

Summing over all such indices gives the storm index, T_{STORM}.

STORM - implementation

- Estimating the undisturbed, or baseline index (T_1)
  - Forecasters use current T_{DAY} as guidance and reference.
  - The undisturbed ionosphere (baseline) used were:
    - Current day (the perfect forecast): the 11-day median T index
    - Forecasts: T_{DAY} (time-shifted in figures).
- Observed and forecast ap, provide T_1 corrections.
  - The STORM correction is used to estimate adjusted indices (T_{SL}) at contributing ionosonde stations in the Australian region,
  - the range of T_{SL} given by the 10% and 90% percentiles, for both IPS (blue) and SEC (magenta) Ap forecasts provide an indication of the likely ionospheric storm effects.
- These can be compared with the observed daily T index.

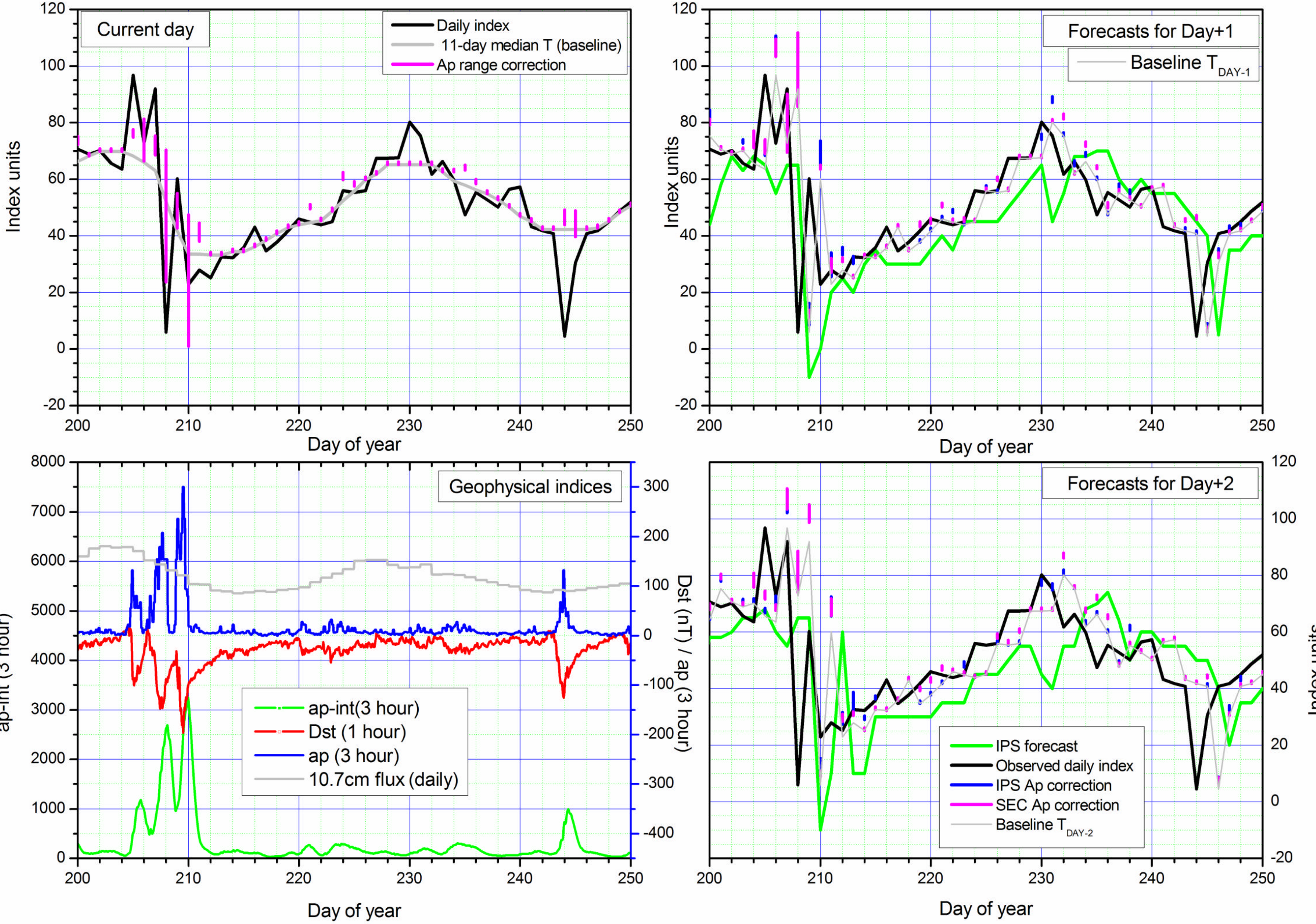
Example: 1 - 30 November 2004



Example – November (Summer)

- Current day – the perfect forecast :
  - undisturbed (baseline) index is the centred 11-day median,
  - the a_p range is derived using observed 3-hourly a_p.
  - Disturbance (days 313 – 319)
    - the initial magnitude is over-estimated,
    - short-term a_p structure (314) not seen in T_{DAY},
    - the disturbance recovery (day 316) is too rapid.
  - STORM offers no assistance tracking later large fluctuations in T_{DAY}.
- Forecasts for T_{DAY+1}: (T_{SL} range bars show IPS and SEC Ap forecasts).
  - STORM forecasts give useful guidance on the ionospheric effects,
  - the disturbance duration is over-estimated.
    - and best forecast (fortuitously?) lies between STORM and IPS forecasts.
- Forecasts for T_{DAY+2} :
  - STORM still offers useful confirmation of the IPS forecasts
    - although the disturbance magnitude and duration are over-estimated,
    - a direct consequence of modelling forecasts using T_{DAY}.
- STORM offers useful <u>subjective</u> guidance for forecasters

Example: 18 July - 6 September 2004



Example – July / August (Winter)

- Current day :
  - the T_{DAY} roughly tracks the changes in 10.7 cm flux
    - modified by storm depressions, near days 205 and 245.
  - for the disturbance days: 204 - 211
    - STORM T-ranges agree well with small structure in T_{DAY}
  - disturbance days: 243 - 246
    - STORM predicts an enhancement rather than a depression
    - which was found to be a common failure during winter.
- Forecasts for T_{DAY+1} :
  - T_{DAY} fluctuations, together with STORM enhancements, lead to less helpful forecasts than during summer,
    - more structure in 3-hourly a_p may be valuable here, although challenging for forecasters to supply.
    - However, since IPS forecasts lag T_{DAY}, STORM still offers guidance.
- Forecasts for T_{DAY+2} : gives similar results.
- During winter, STORM tends to predict enhancements too often
  - which could be misleading for forecasters.

Discussion

- The examples shown are typical;
  - STORM is most valuable during large disturbances,
  - and is more useful in summer than winter.
- These examples highlight:
  - Strengths: timing and magnitude of disturbances during summer
  - Weaknesses: enhancements in winter
  - STORM, used cautiously, can assist forecasters.
    - Note: the simple forecasting environment modelled here is likely to under-estimate the contribution STORM can make.
- Future work
  - Apply STORM directly to station observations.
  - Investigate the T_{DAY} fluctuations further.
  - Investigate use with empirical real-time maps.
    - Note: the current indices need to be refined before it is worth applying more interesting forecasting techniques.