Extreme weather: improved data products on bushfires, thunderstorms, tropical cyclones and east coast lows

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Overview

Natural disasters are commonly associated with extreme weather (particularly in Australia).

Significant knowledge gaps exist regarding some weather extremes.

The National Environmental Science Programme (NESP) has funded a project to research **TCs, east coast lows (ECLs), thunderstorms and bushfires**.
Project summary

Project is focused on Disaster Risk Reduction, through providing research products designed to meet user needs:

• Improved knowledge on bushfires, TCs, ECLs, thunderstorms and associated extremes (rainfall, wind, hail, lightning).

• New datasets and tools on extreme weather, in current and future climates.
Bushfire research questions

• What factors control fire weather variability over various time scales?

• Can we improve the prediction of these factors?

• What practical tools can build resilience to extreme fires?
**Database produced:** based on a long time period of gridded observations

- Daily FFDI (from 1950), KBDI (from 1911), with others intended (FWI, SDI, GFDI, C-Haines).
- Based on AWAP (0.05 degree grid), with NCEP reanalysis winds (bias corrected to BoM fire weather forecast winds).
- Broad-scale (temporal and spatial) guidance, complementary to other data.
- Automatic daily updates.

**Designed for use with existing tools in BoM services**
Fire weather extremes

How often do extremes occur at a given location?

- Some locations have FFDI > 100 more than once a decade.
- Some fire prone regions have relatively low values for extremes.
Long-term changes in extremes, based on days per season above 90th percentile FFDI.

**Partial derivatives:**

- **temperature** is primary cause of FFDI increase

\[
\left( \frac{\partial \text{FFDI}}{\partial T} \right)_{RH, DF} = 0.0338 \text{FFDI}
\]

\[
\frac{\partial \text{FFDI}}{\partial v} = 0.0234 \text{FFDI}
\]

\[
\left( \frac{\partial \text{FFDI}}{\partial RH} \right)_{T} = -0.0345 \text{FFDI}
\]

\[
\left( \frac{\partial \text{FFDI}}{\partial DF} \right)_{T} = 0.987 \frac{\text{FFDI}}{DF}
\]
Influence of ENSO

The El Niño/Southern Oscillation (ENSO) influences fire weather in Australia.

Significant correlations shown here between NINO3.4 index and FFDI at each grid point:

• more dangerous conditions during El Niño,
• however, depends on season and region.
Motivation: Drivers such as ENSO, as well as fuel moisture, provide predictive skill weeks to months ahead.

Proof of concept developed:

- FFDI grids throughout Australia based on ACCESS-S (11 member ensemble, Nov. 1 start dates, 1990-2012).
- Accurate predictions found at lead times from 1 week out to 4 months (based on above/below median FFDI).
- Intended to attract support for developing real-time capabilities.
ACCESS-S hindcasts of FFDI (black symbols) shown for one ensemble member during summer:

- Strong relationship to NINO3.4, and to AWAP-based FFDI dataset (orange symbols).

Accuracy of predictions are higher based on ensemble mean:

- 70-75% correct for southern or northern Australia in summer.
Modelling of future extremes

Currently examining daily FFDI from GCMs and downscaling (WRF and CCAM).

- Assessed against observations-based FFDI dataset for current climate.
- Next step is examining extremes in future climate simulations.

**Model assessment tool:** Mean number of days per month that the AWAP-based FFDI is above 90\textsuperscript{th} percentile (1950-2016).
Thunderstorms

- Currently examining thunderstorms and associated extremes: rainfall, winds, lightning (dry and wet), hail.

- Using station data, remote sensing (radar, satellite, lightning networks), reanalyses, GCMs and fine-scale downscaling.

- Developing improved knowledge and tools for current and future climate on thunderstorm hazards.
**New lightning climatology**

**Database of cloud-to-ground lightning**


- Time period over twice as long as previous best climatology.


- Range of applications (bushfire ignition, power distributors, insurance groups, emergency management).
**Pyrogenic lightning**

Black Saturday lightning (blue) and satellite hotspots (red), with the location of a pyrogenic lightning ignition (purple circle).

Real-time guidance potential:

- First lightning stroke generated five hours after fire ignition (provides evidence of strong updrafts and deep convection)
- Atmosphere/fire feedback, including fire ignition from pyrogenic lightning: 100 km range
- Synoptic/mesoscale conditions are important for pyroCb (e.g. Beechworth fire ~midnight)

Ref.: Dowdy et al., 2017: Pyrocumulonimbus lightning and fire ignition on Black Saturday in southeast Australia. J GR-A.
**Multi-hazards**

**Concurrent storms:**

- Thunderstorms based on lightning observations (WWLLN).
- Cyclones based on closed contours of MSLP for ERA-Interim reanalysis, supplemented with IBTrACS.
- Fronts based on a thermal front parameter for ERA-Interim reanalysis.
- Extreme weather (precipitation, wind speed, wave height, …) based on 99\textsuperscript{th} percentile threshold at individual ERA-Interim gridpoints, from 2005-2015.

East Coast Lows

Some recent results:

• Fewer ECLs due to global warming (based on GCMs and downscaling)

• ECLs found to be dominant cause of large waves in eastern Australia (from buoy obs), rather than TCs or remote swell.

• However, storms that do occur could become stronger and rising seas could increase impacts.

Current research focus:

• Better understanding of energetics, including hybrid characteristics, and associated hazards.

ECL energetics

- Different ECL events can have different characteristics.
- Aim to classify ECLs based on formation and intensification mechanisms.
- Focus on storm structure (Hart phase space) and energetics (Lorenz parameters).
- Method tested on Pasha Bulker (June 2007) and Duck (March 2001) events.
Tropical cyclones

- Currently examining TCs based on observations, reanalyses, GCMs and fine-resolution downscaling.

- Developing improved knowledge and tools for current and future climate on TCs and associated hazards (extreme rain and wind).

- Examining influence of modes of variability (e.g. ENSO, MJO), decadal variability, climate change, and tropical expansion.
Long-term changes in TCs

Difficult to determine whether past changes have exceeded natural variability:

• limited period of high quality data
• temporal variability in TC activity

Can some of this variability be accounted for, resulting in an improved ability to examine changes?
25% of TC variability can be related to NINO3.4, and 17% can be related to SOI. This variability, $V$, is represented here as:

$$V_{\text{NIN}} = -2.15 \times \text{NINO3.4} - 0.1$$

$$V_{\text{SOI}} = 0.13 \times \text{SOI} + 0.1$$

Data:
- July-Sep. averages of SOI and NINO3.4
- TC occurrence (from BoM) in Australian region (90-160E), < 995 hPa (to avoid weak systems), 1982/83 to 2012/13.
Downward trend

After accounting for ENSO, trend significance increases from a confidence level of 87% to

- 93% based on NINO3.4
- 98% based on SOI

Stability of TC/ENSO relationship

- NINO3.4 accounts for 49% of TC variability in the first half of the study period, but only 9% in the second half.

- SOI accounts for 36% of TC variability in the first half of the study period, but only 9% in the second half.
Pacific Decadal Oscillation

Mostly positive in 1\textsuperscript{st} half of study period (upper panel) and negative in 2\textsuperscript{nd} half (lower panel):

- More TCs in 1\textsuperscript{st} half of study period, however, TC\#s show little relationship to PDO, suggesting downward trend not likely due to PDO.

- Only $\sim\frac{1}{2}$ PDO cycle, so little confidence in modulating effect on ENSO/TC relationship (e.g., stronger ENSO influence in +ve PDO).
Tropical expansion

TC latitude (IBTrACS) vs. boundary of tropics (based on tropopause height: May-Oct in NH, Nov-Apr in SH) 1979-2009.

Poleward migration of the location of tropical cyclone maximum intensity is plausibly linked to tropical expansion [Kossin et al., 2014: Nature]
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Australian region, $r = 0.35$
NESP project on extremes, has similar amounts of activity on

**TCs, Thunderstorms, Bushfires, East Coast Lows**

Please contact me for further details, including for linking this research with services.

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