Australian Government
Bureau of Meteorology

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

Andrew Dowdy[1], Harvey Ye[1], Kevin Tory[1], David Jones[1], Alex Evans[1], Sally Lavender[2], Marcus Thatcher[2], Tony Rafter[2], Stacey Osbrough[2], Kevin Walsh[3], Leone Cavicchia[3], Jason Evans[4], Jennifer Catto[5]

Bureau of Meteorology[1], CSIRO[2], University of Melbourne[3], UNSW[4], Monash University[5]

AFAC 2017 - Research Forum

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**.

Australian Government
Bureau of Meteorology

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.

Australian Government
Bureau of Meteorology

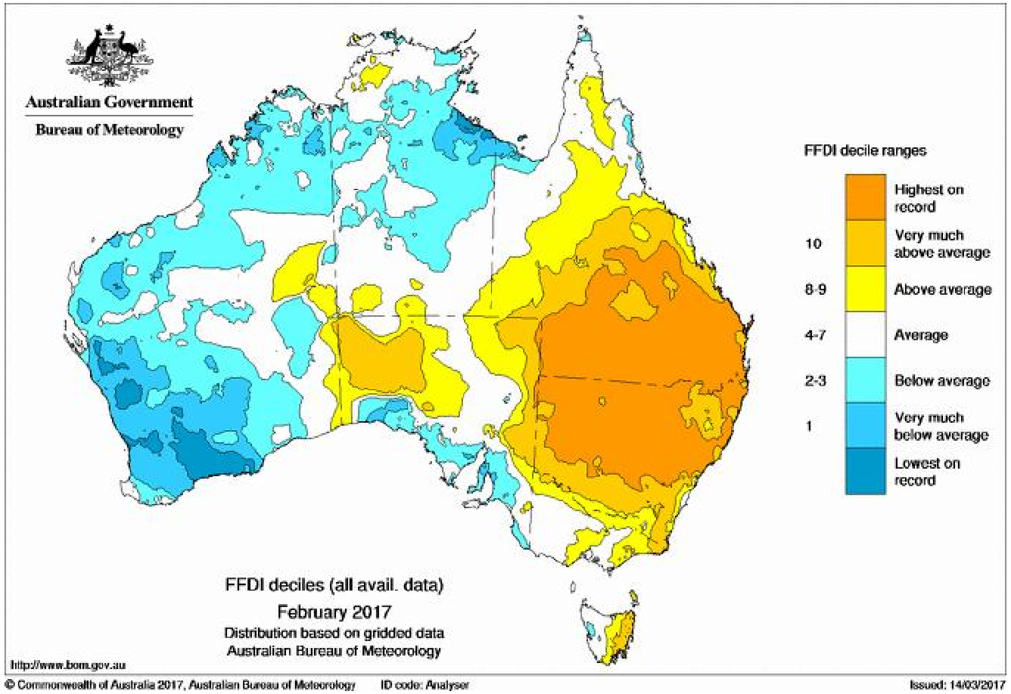
Bushfire research questions

- 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.

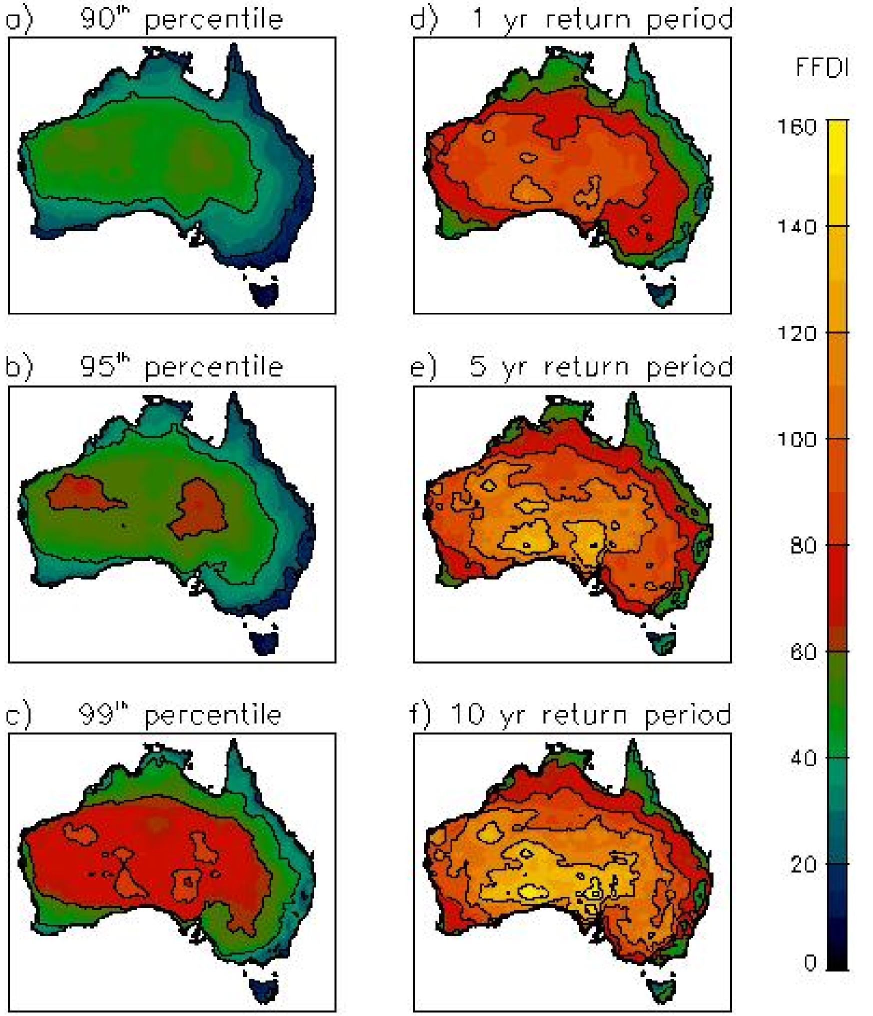
Designed for use with existing tools in BoM services



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.



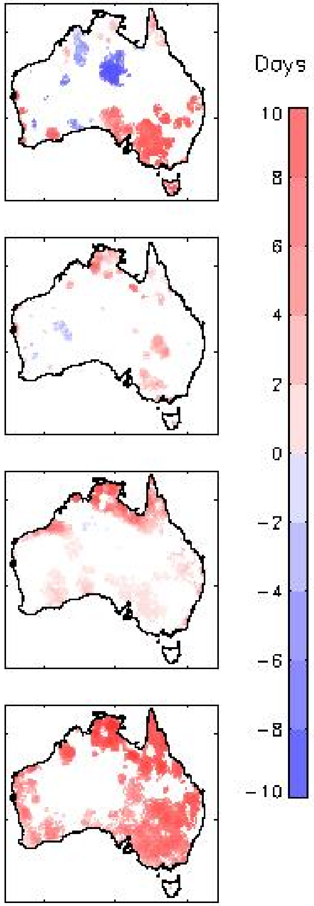
Long-term changes in extreme fire weather

Summer (Dec-Feb)

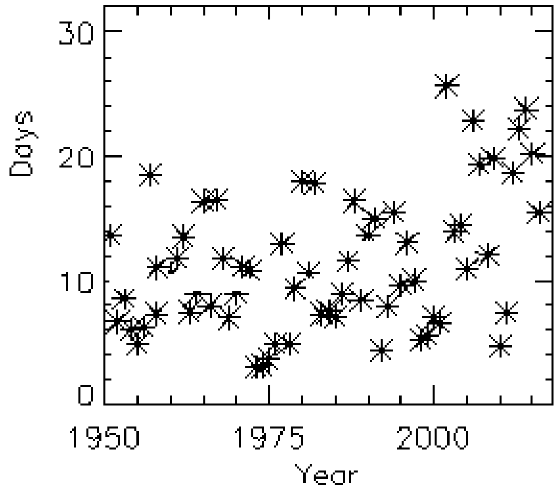
Autumn (Mar-May)

Winter (Jun-Aug)

Spring (Sep-Nov)



Long-term changes in extremes, based on days per season above 90th percentile FFDI.



Area-averaged mean for Southern Australia spring

Partial derivatives:

temperature is primary cause of FFDI increase

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

$$\frac{\partial FFDI}{\partial v} = 0.0234 FFDI$$

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

$$\left(\frac{\partial FFDI}{\partial DF}\right)_{T} = 0.987 \frac{FFDI}{DF}$$

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:

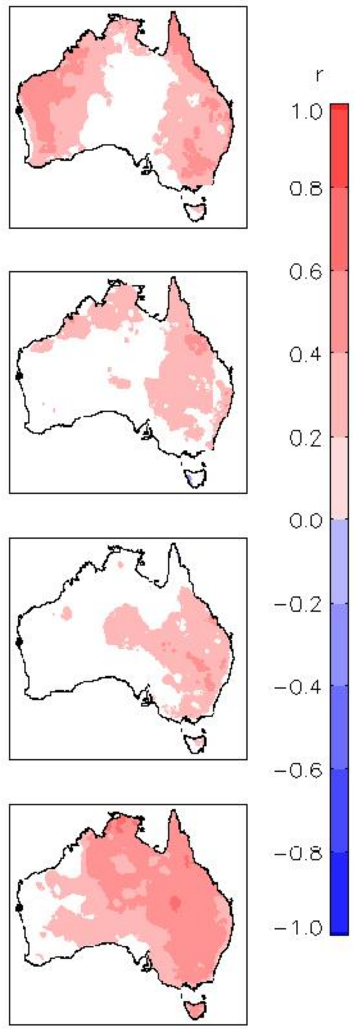
- more dangerous conditions during El Niño,
- **however**, depends on season and region.

Summer (Dec-Feb)

Autumn (Mar-May)

Winter (Jun-Aug)

Spring (Sep-Nov)



Australian Government
Bureau of Meteorology

Long-range prediction of fire weather

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.

Australian Government
Bureau of Meteorology

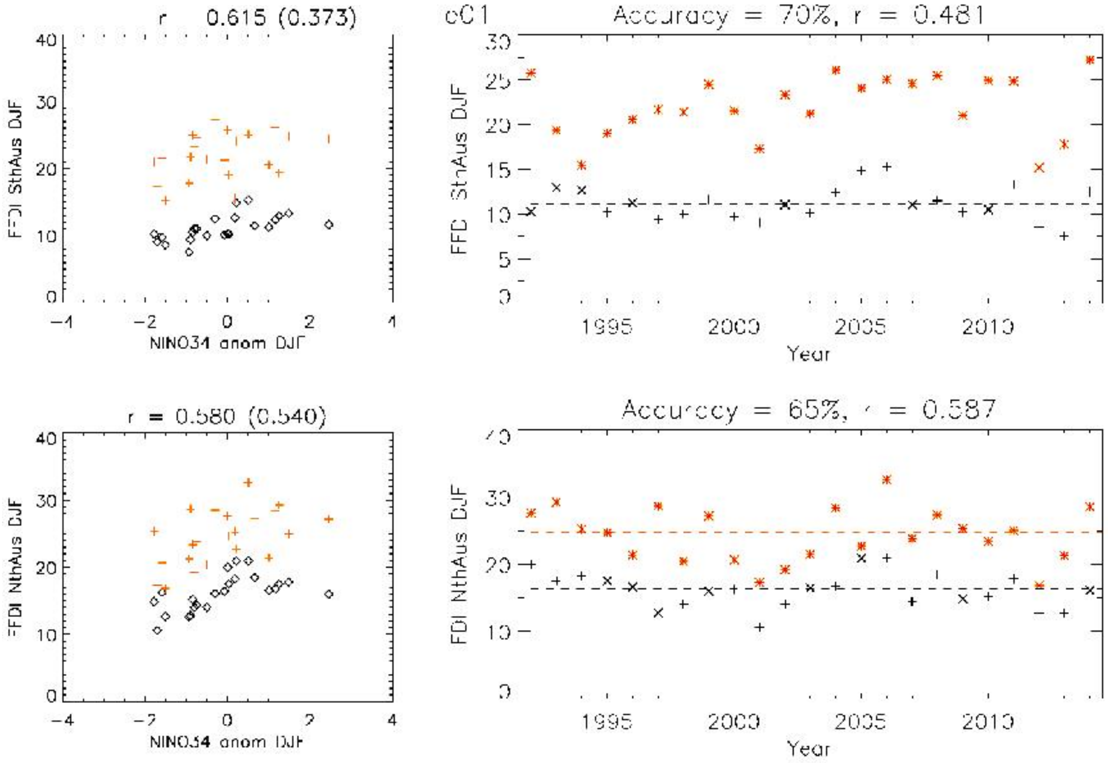
Long-range prediction of fire weather

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:

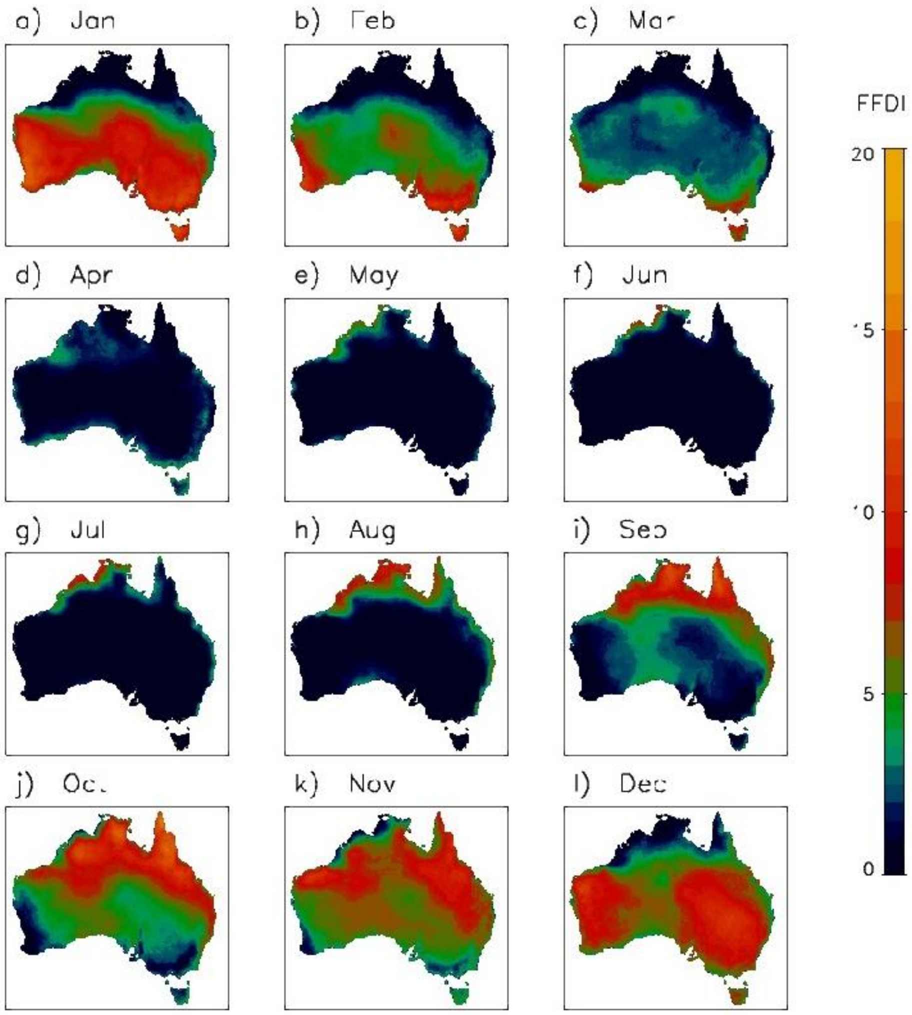
- 70-75% correct for southern or northern Australia in summer.



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 90th percentile (1950-2016).

Australian Government
Bureau of Meteorology

Thunderstorms

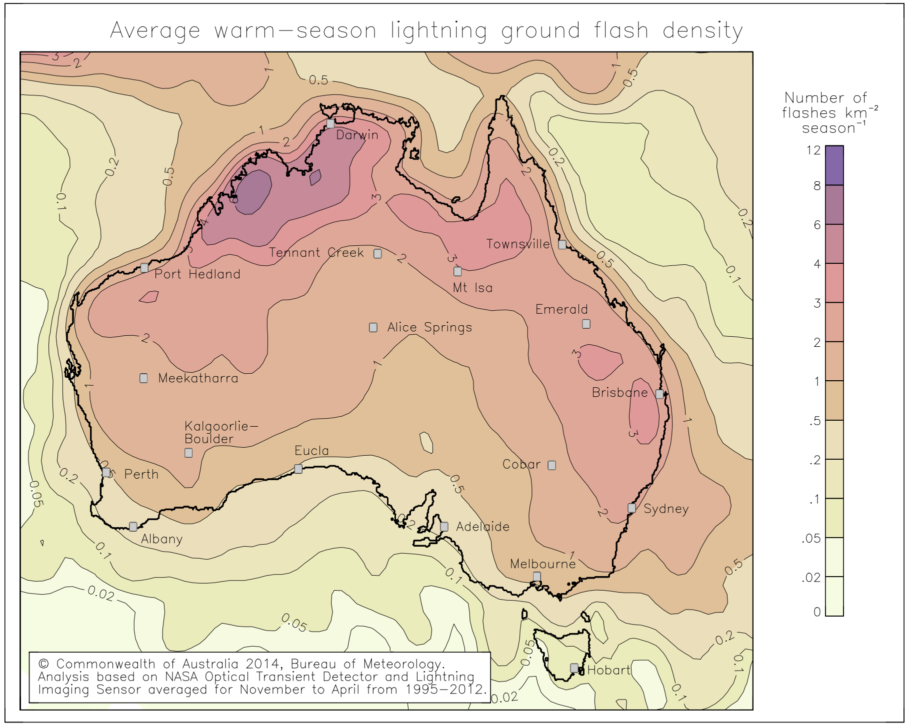
- Currently examining thunderstorms and associated extremes: rainfall, winds, lightning (dry and wet), hail.
- Using station data, remote sensing (radar, satellite, lightning networks), reanalyses, GCMs and fine-scale downscaling.
- Developing improved knowledge and tools for current and future climate on thunderstorm hazards.

Australian Government
Bureau of Meteorology

New lightning climatology

Database of cloud-to-ground lightning

- Available from http://www.bom.gov.au/jsp/ncc/climate_averages/thunder-lightning/index.jsp?maptype=otdg#maps
- Time period over twice as long as previous best climatology.
- For update to Australian/New Zealand Lightning Protection Standard AS/NZS-1768:2007.
- Range of applications (bushfire ignition, power distributors, insurance groups, emergency management).



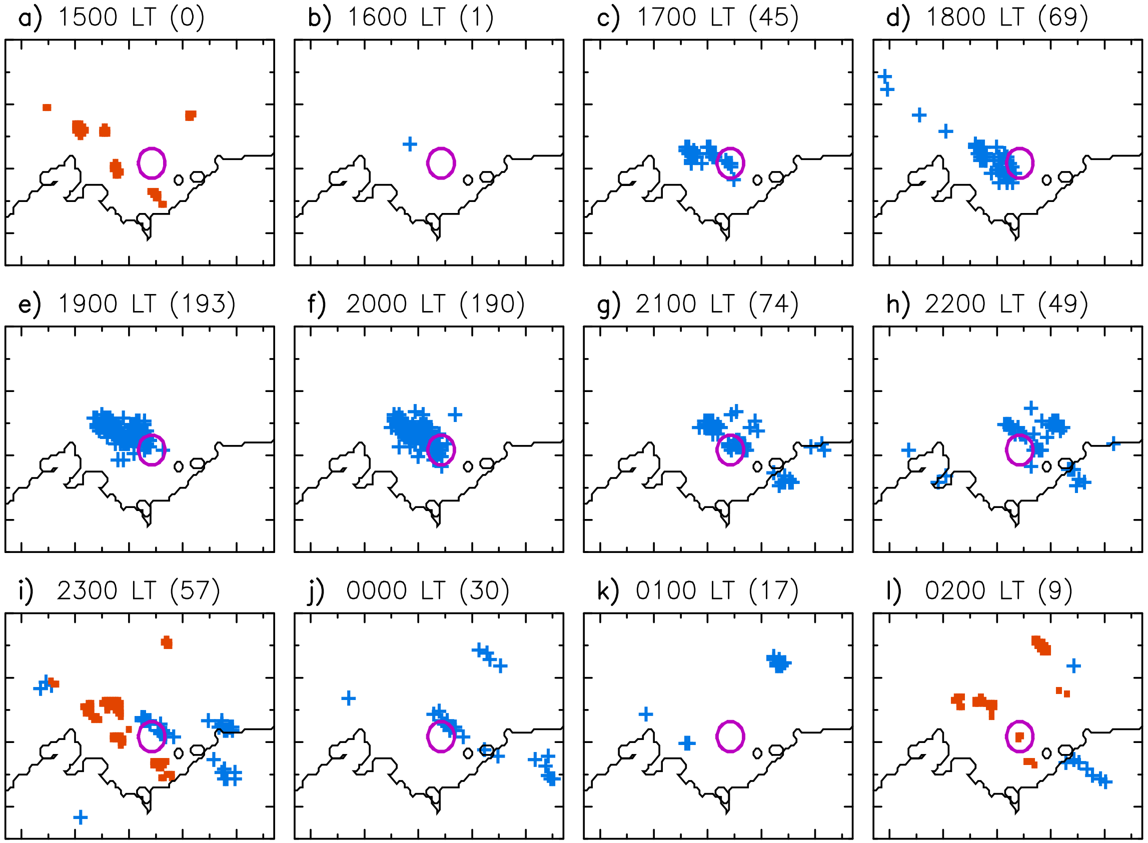
Pyrogenic lightning

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

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

Real-time guidance potential:

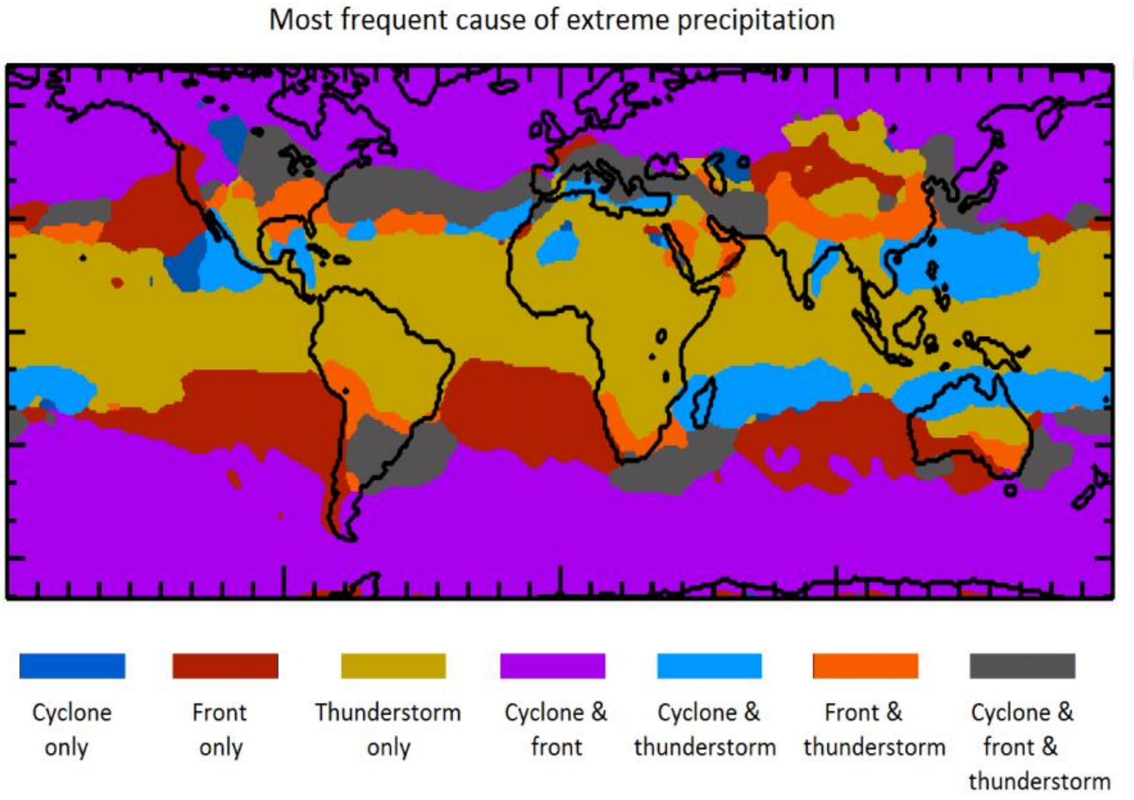
- First lightning stroke generated five hours after fire ignition (provides evidence of strong updrafts and deep convection)
- Atmosphere/fire feedback, including fire ignition from pyrogenic lightning: 100 km range
- Synoptic/mesoscale conditions are important for pyroCb (e.g. Beechworth fire ~midnight)



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 99th percentile threshold at individual ERA-Interim gridpoints, from 2005-2015.



Ref.: Dowdy and Catto, 2017: *Sci. Rep.*

East Coast Lows

Some recent results:

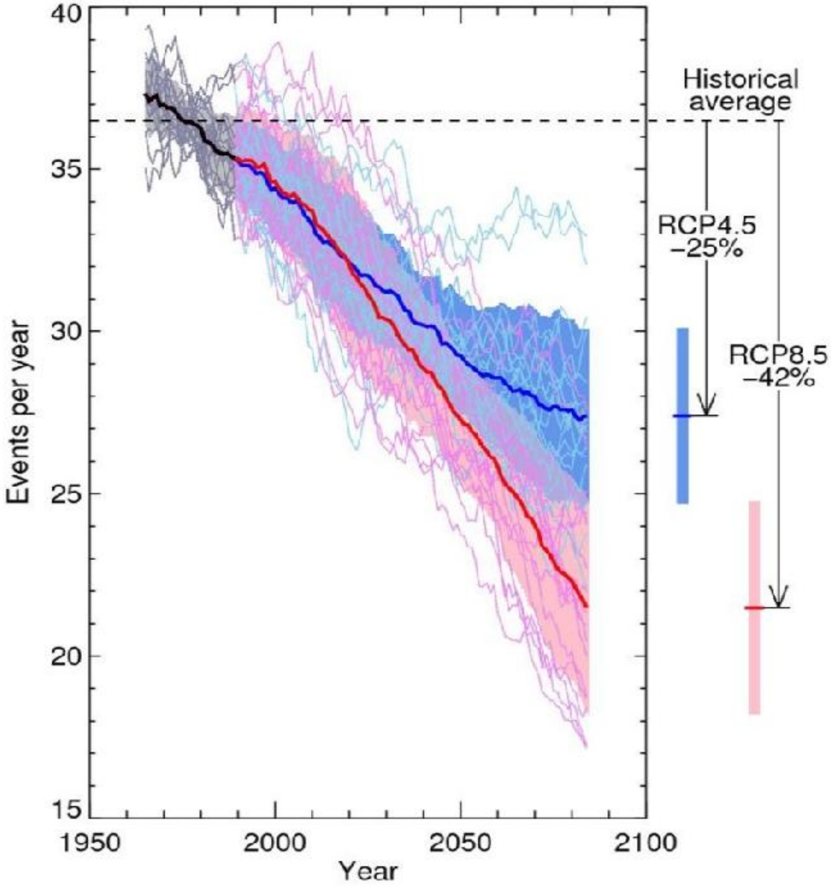
- Fewer ECLs due to global warming (based on GCMs and downscaling)

- 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:

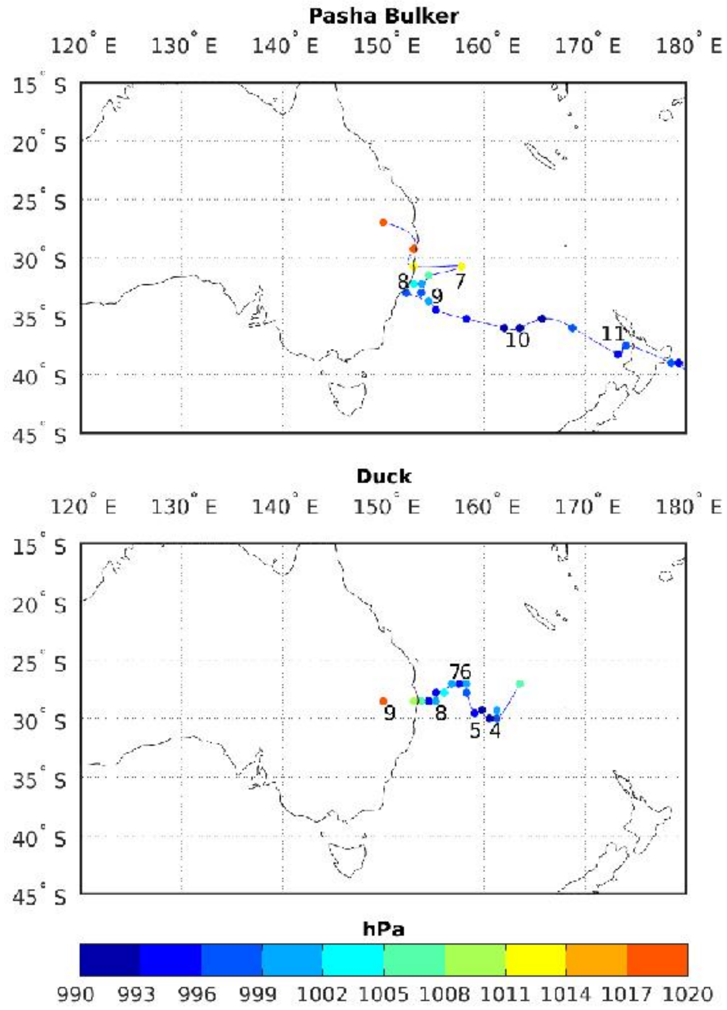
- Better understanding of energetics, including hybrid characteristics, and associated hazards.



Ref.: Dowdy et al. (2014) *Nature Climate Change.*

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?

ENSO/TC relationship

25% of TC variability can be related to NINO3.4, and 17% can be related to SOI.

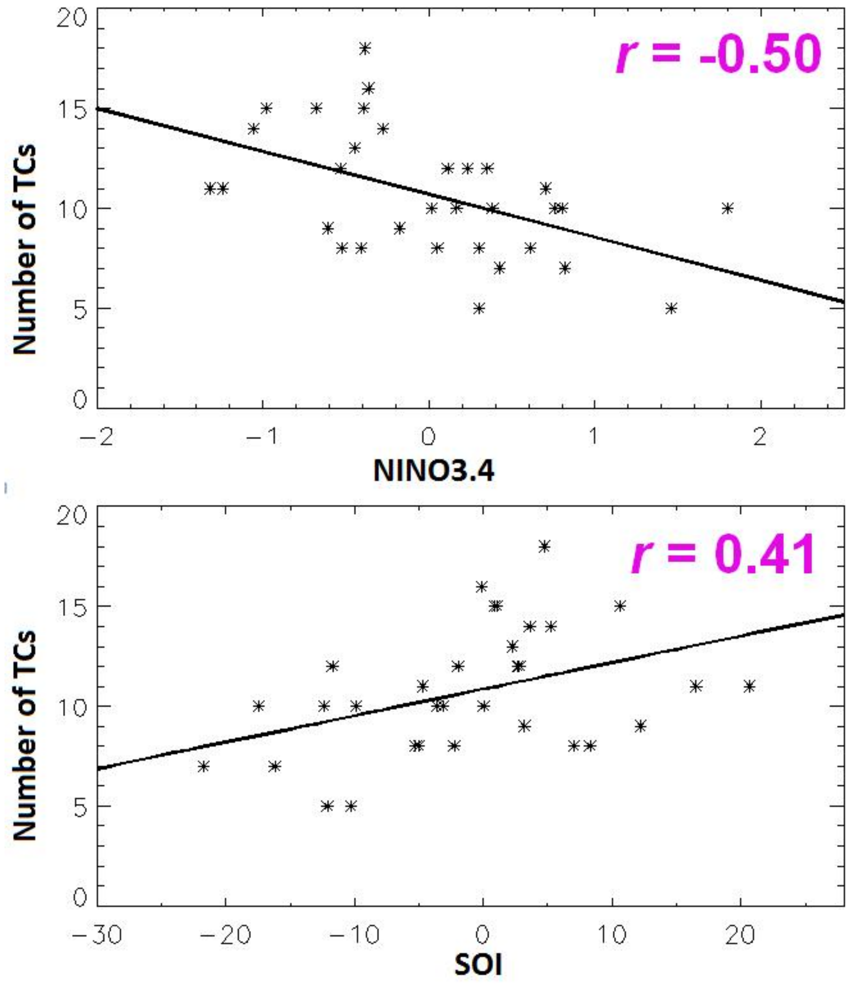
This variability, *V*, is represented here as:

$$v_{NIN} = -2.15 * NINO3.4 - 0.1$$

$$v_{SOI} = 0.13 * SOI + 0.1$$

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.

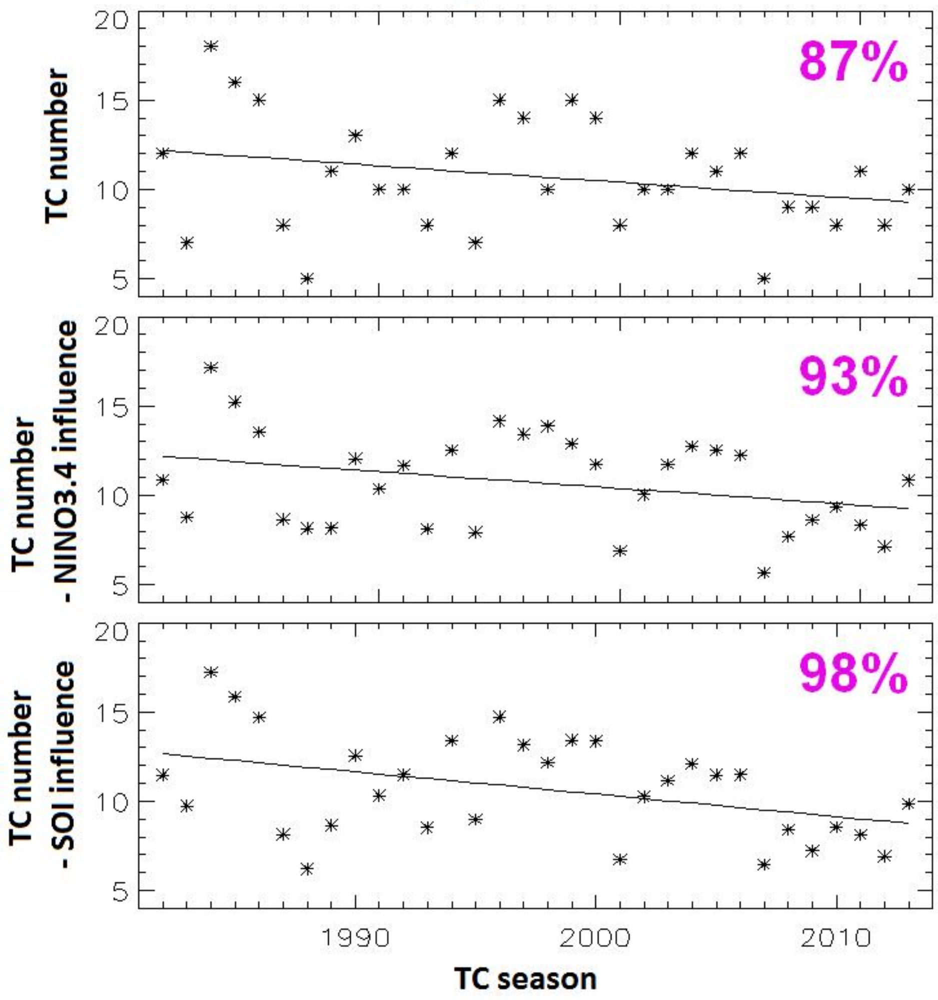


Downward trend

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

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

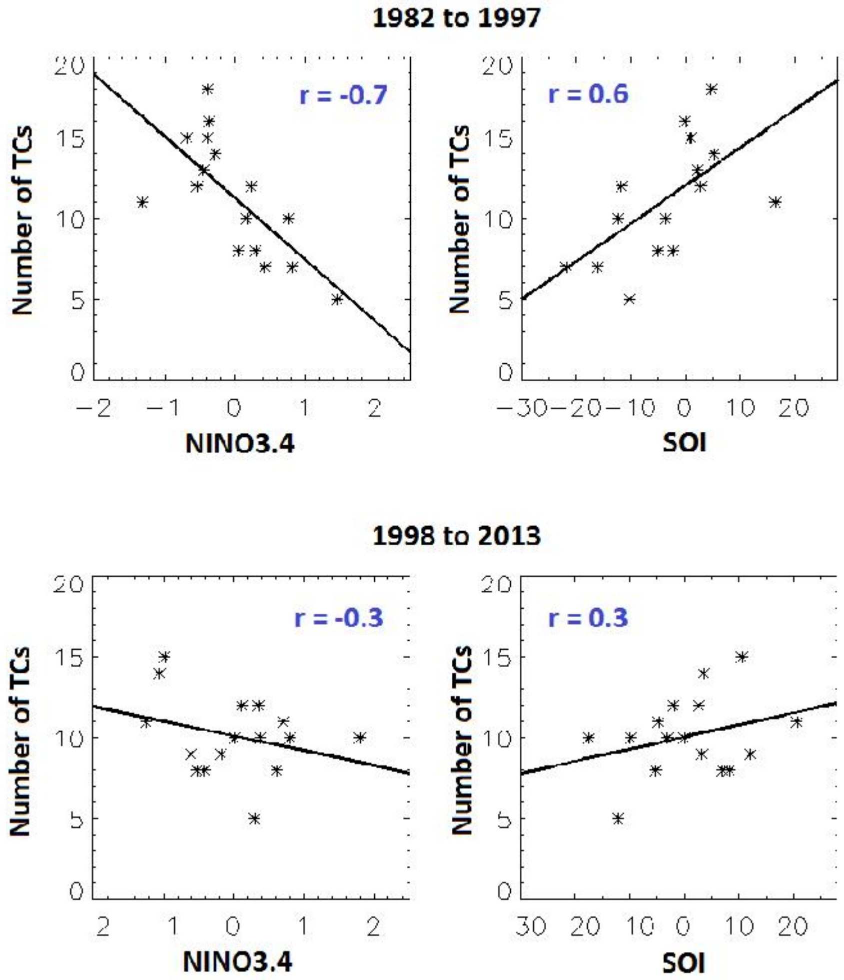
Ref.: Dowdy, 2014: *Atmospheric Science Letters*.



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.

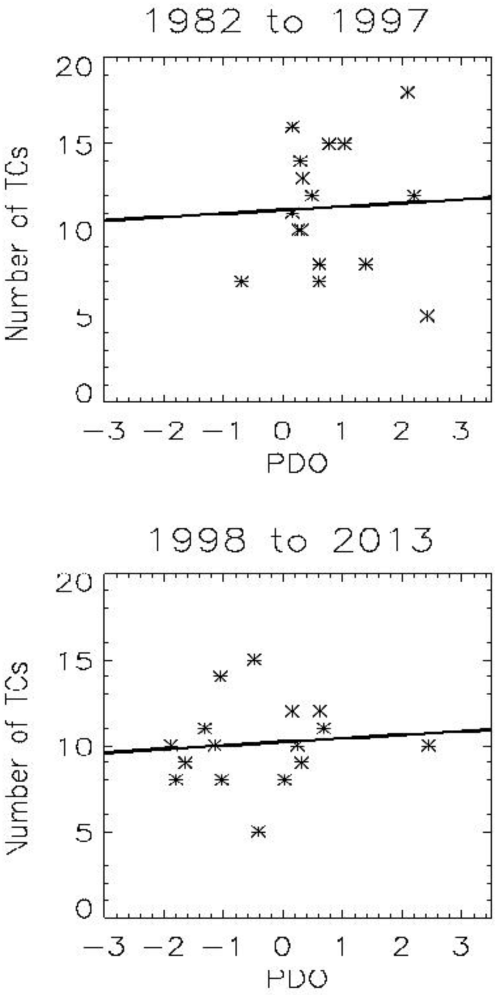


Pacific Decadal Oscillation

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

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

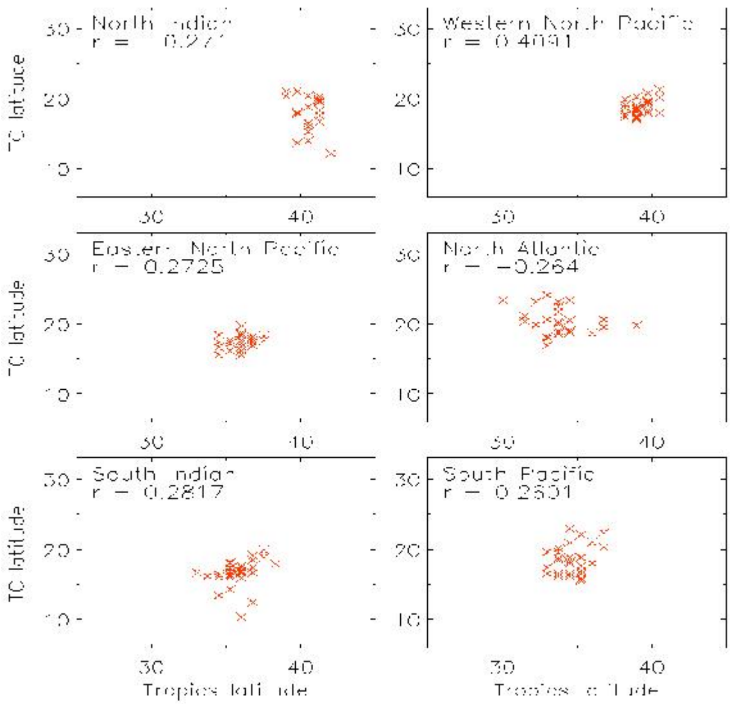
- Only ~½ PDO cycle, so **little confidence in** modulating effect on ENSO/TC relationship (e.g., **stronger ENSO influence in +ve PDO**).



Australian Government
Bureau of Meteorology

Tropical expansion

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

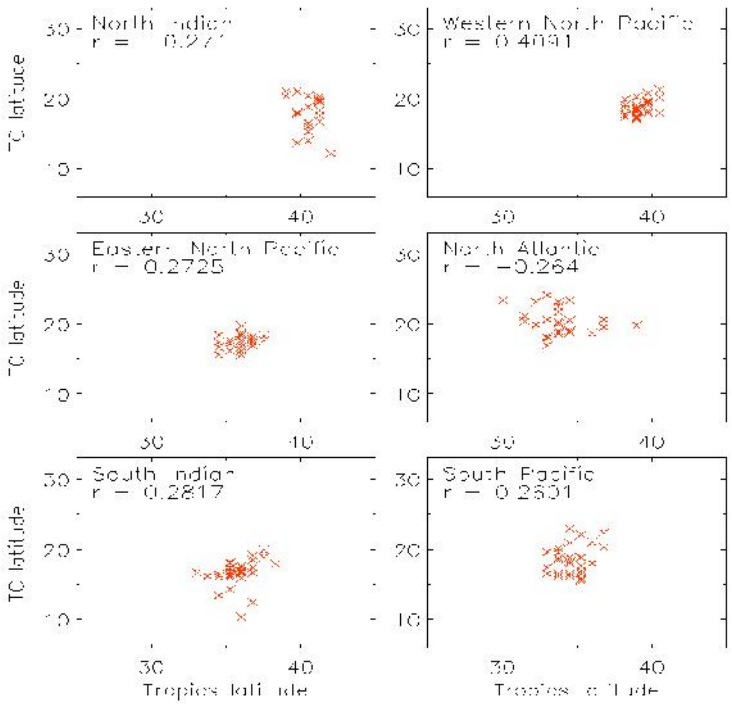


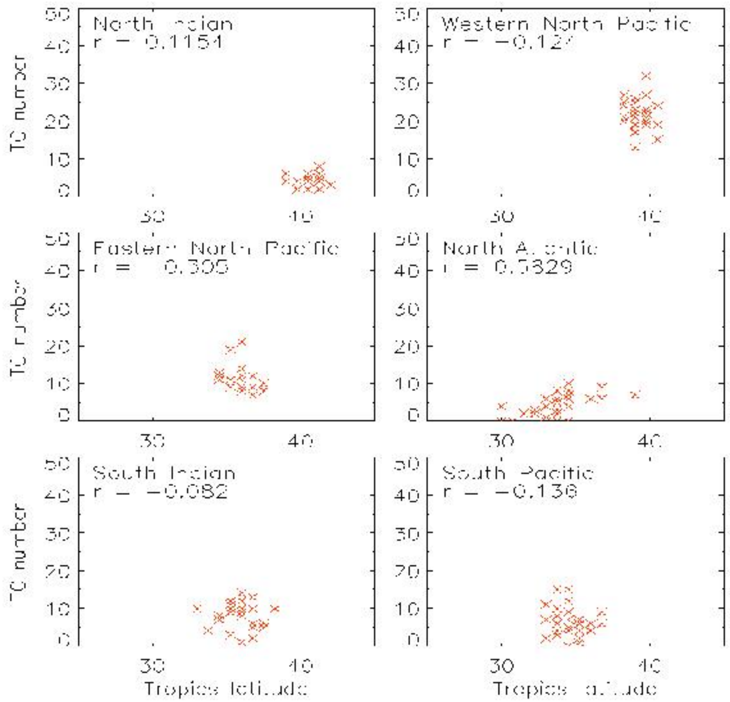
Poleward migration of the location of tropical cyclone maximum intensity is plausibly linked to tropical expansion [Kossin et al., 2014: *Nature*]

Tropical expansion

Australian Government
Bureau of Meteorology

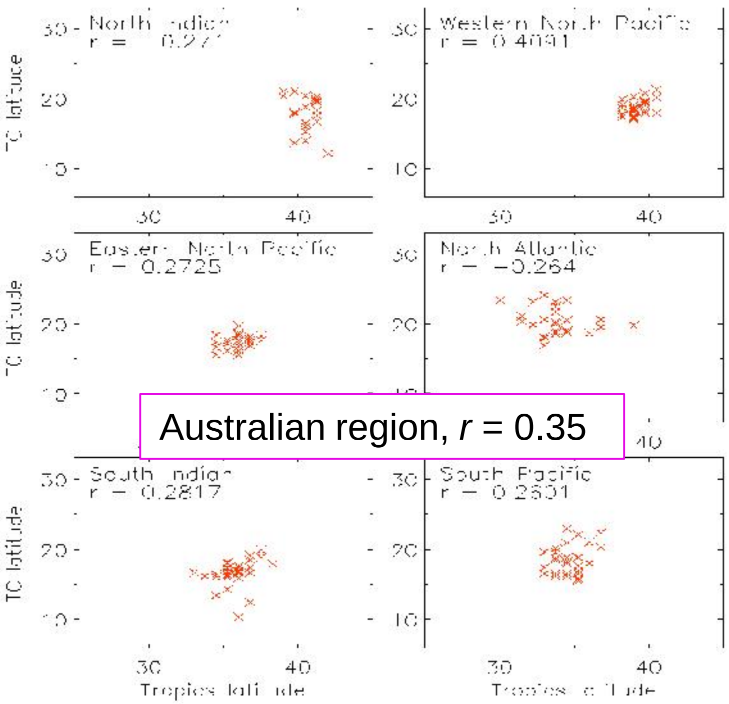
TC latitude (IBTrACS) vs. boundary of tropics (based on tropopause height: May-Oct in NH, Nov-Apr in SH) 1979-2009.

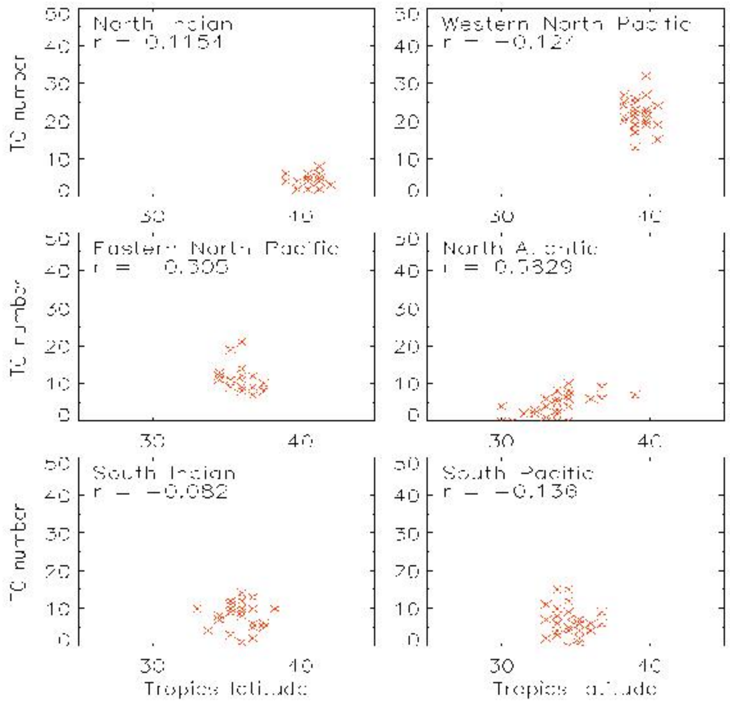




Tropical expansion

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





Thank You

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.

Dr Andrew J. Dowdy

Bureau of Meteorology

p: +613 9669 4722

e: andrew.dowdy@bom.gov.au