Initial steps towards flash drought monitoring and prediction in Australia

Hanh Nguyen and **Matthew Wheeler**
Bureau of Meteorology, Melbourne, Australia

Jason Otkin
CIMSS, University of Wisconsin, Madison, Wisconsin

Roger Stone
University of Southern Queensland, Toowoomba, Australia

Australian Government
Bureau of Meteorology

Introduction

1. Part of the much larger *Northern Australia Climate Program* (NACP), with funding from the beef cattle industry.

2. Working on a milestone to monitor and predict "flash drought".

3. What is flash drought? Described to me as when a farmer suddenly finds themselves in drought, and this drought onset occurred more quickly than they had time to prepare, i.e., in a few weeks. They did not have time to do the things they normally do as a drought develops, such as sell stock, order hay, order water, or decide not to plant a crop.

Australian Government
Bureau of Meteorology

Part 1: Flash drought monitoring

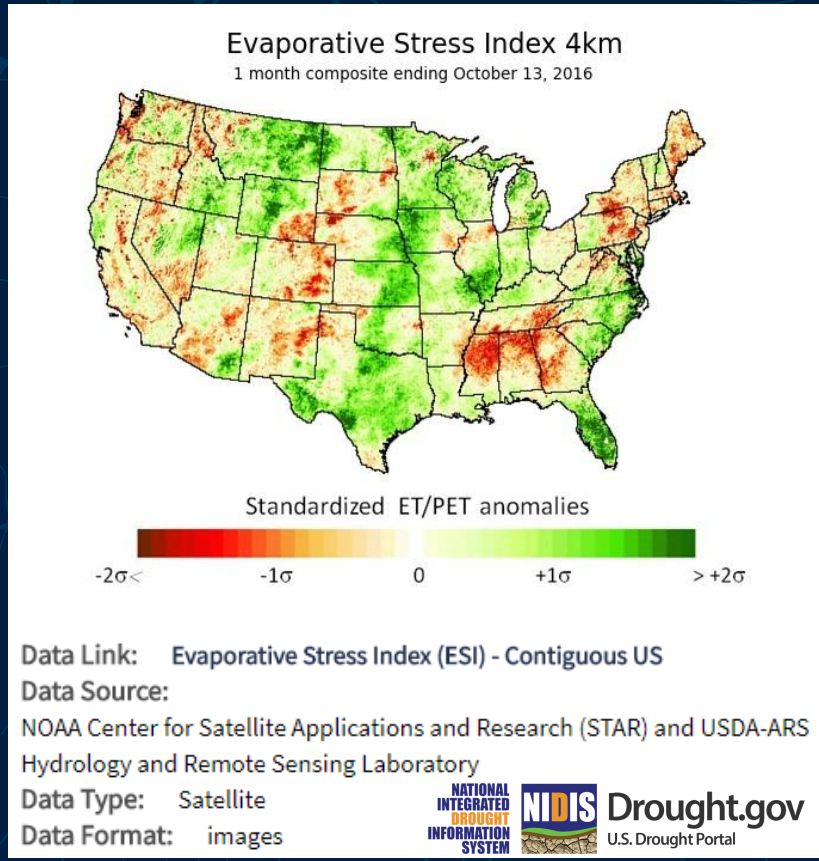
- Our literature review suggested that the *Evaporative Stress Index* (ESI) would be best for our purposes.
- ESI = Standardized anomaly of the ET/PET ratio Anderson et al. (JGR, 2007)

(ET = actual evapotranspiration; PET = potential evapotranspiration)

- During flash drought, rapid decreases in the ESI occur due to the combined effect of an increased evaporative demand (PET↑) and decreased availability of soil moisture (ET↓).
- Studies by Otkin et al. (2013, 2016), Anderson et al. (2016), and Chris Hain have shown the usefulness of the ESI for pre-warning of rapid changes in drought conditions (i.e. flash drought) as measured by the USDM and crop conditions.

Evaporative Stress index (ESI)

- In the United States the publicly-available ESI data have been estimated from thermal band imagery from geostationary satellites.
- For this project we are estimating ESI from the *Australian Water Resources Assessment Landscape* (AWRA-L) model.
- Pro: We don't need to worry about cloud contamination.
- Con: We require accurate inputs of rainfall, temperature, solar radiation, and wind, into our water balance model.



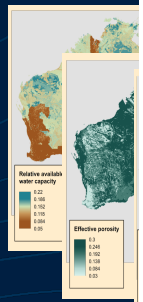
Australian Government
Bureau of Meteorology

AWRA-L - Operational continental landscape water balance model

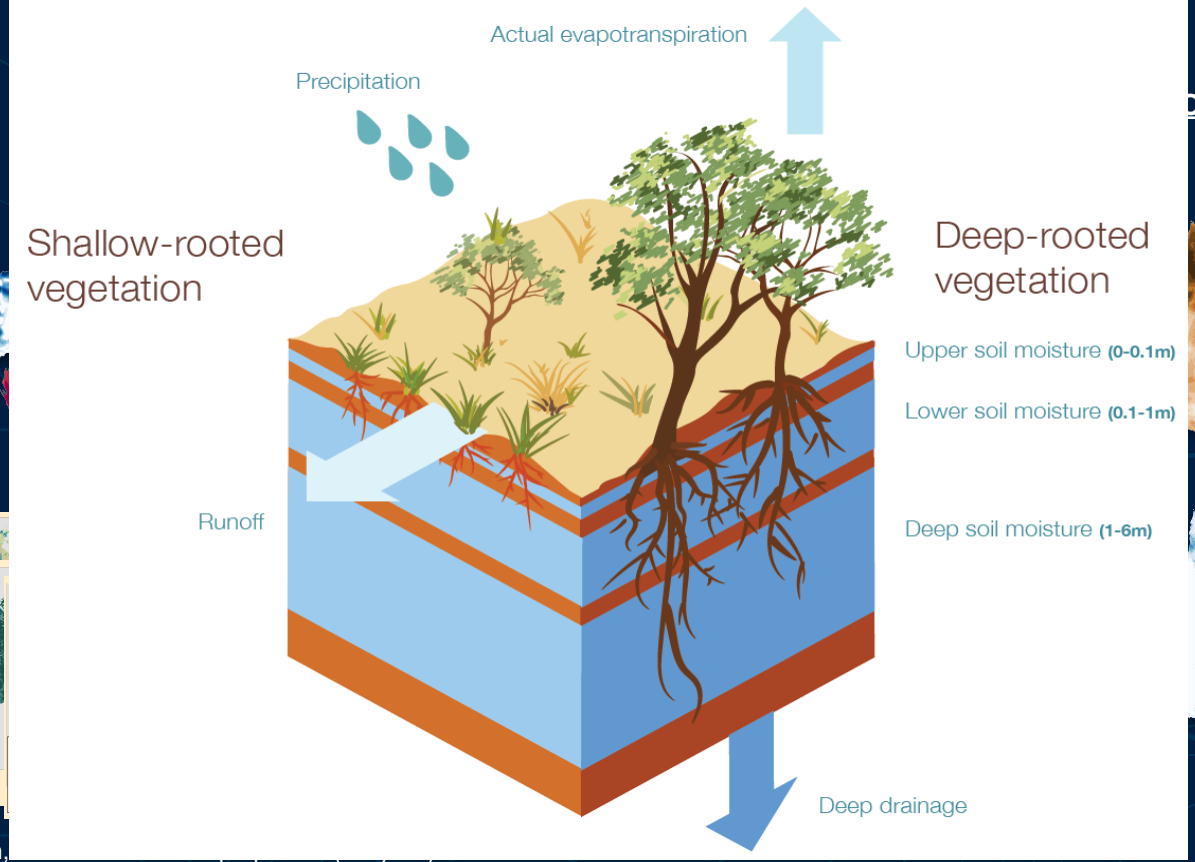
National, daily time-step, 5 km resolution

Rainfall, Temp

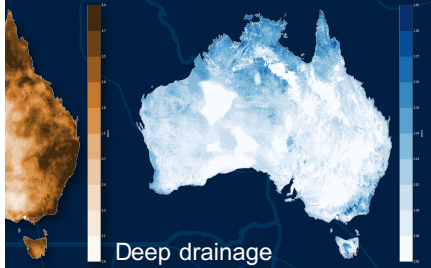
Solar radiation

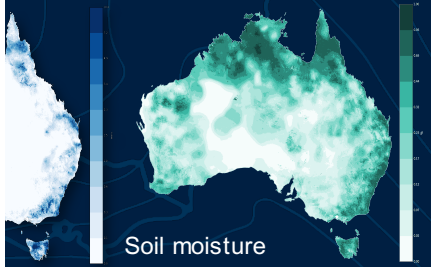


Terrain,



Outputs

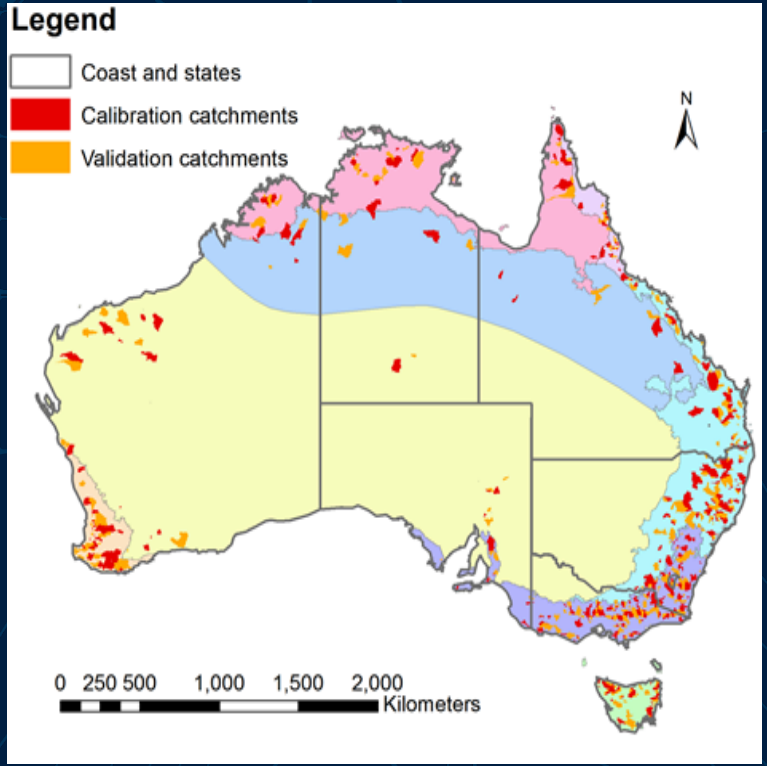




Australian Government
Bureau of Meteorology

AWRA-L details

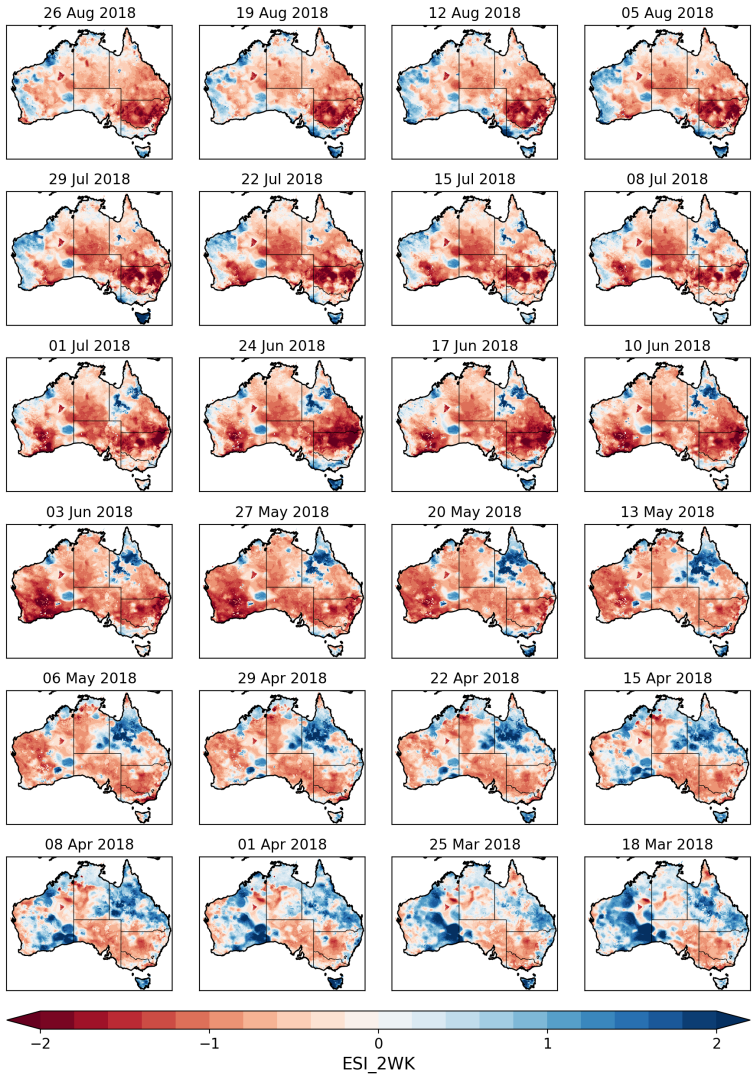
- Calibration performed using observations of streamflow and satellite observations of soil moisture and evapotranspiration, optimized for a correct water balance.
- Validation data also includes point measurements of soil moisture and evapotranspiration from flux towers.
- ET is the modelled total evapotranspiration from vegetation, soil, and groundwater. The model does not currently include urban, irrigated, or open water landscapes.
- PET is calculated using the Penman formulation.
- Daily record from 1911-present. 1979-present for this study.
- Con: Currently uses climatological windspeeds only.



Australian Government
Bureau of Meteorology

ESI since March 2018

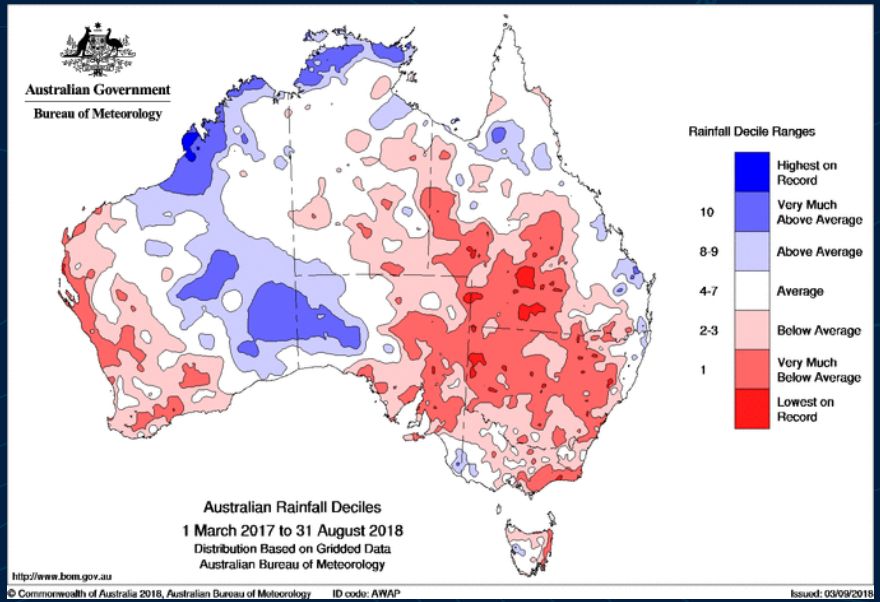
- Shown for a 2 week sliding window, ending on the indicated date.
- The strongly negative ESI values are coincident with areas that have been showing strong drought impacts on agriculture (and the attention from two prime ministers).



Processes contributing to the recent extreme ESI

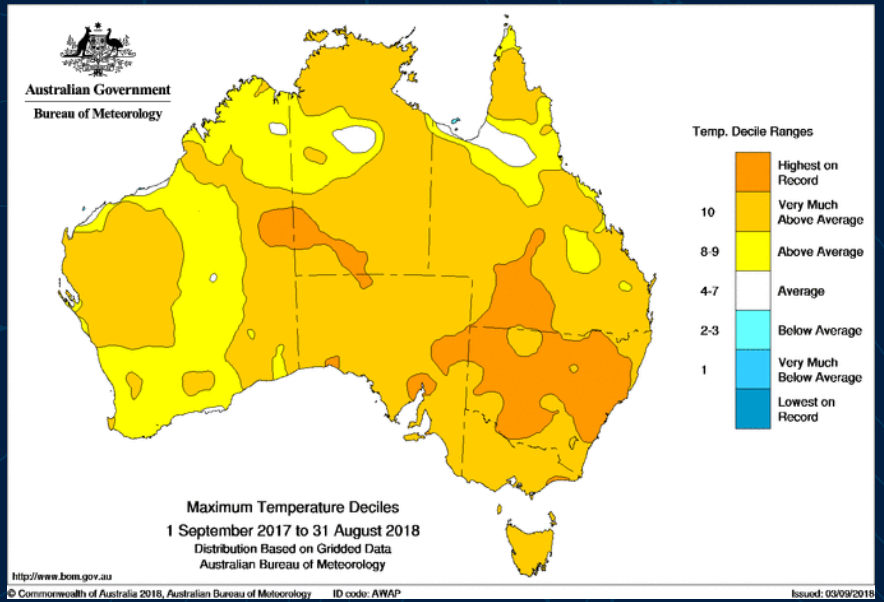
Rainfall has been very much below average for the last 18 months, but with only a few patches of lowest on record.

Records back to 1900



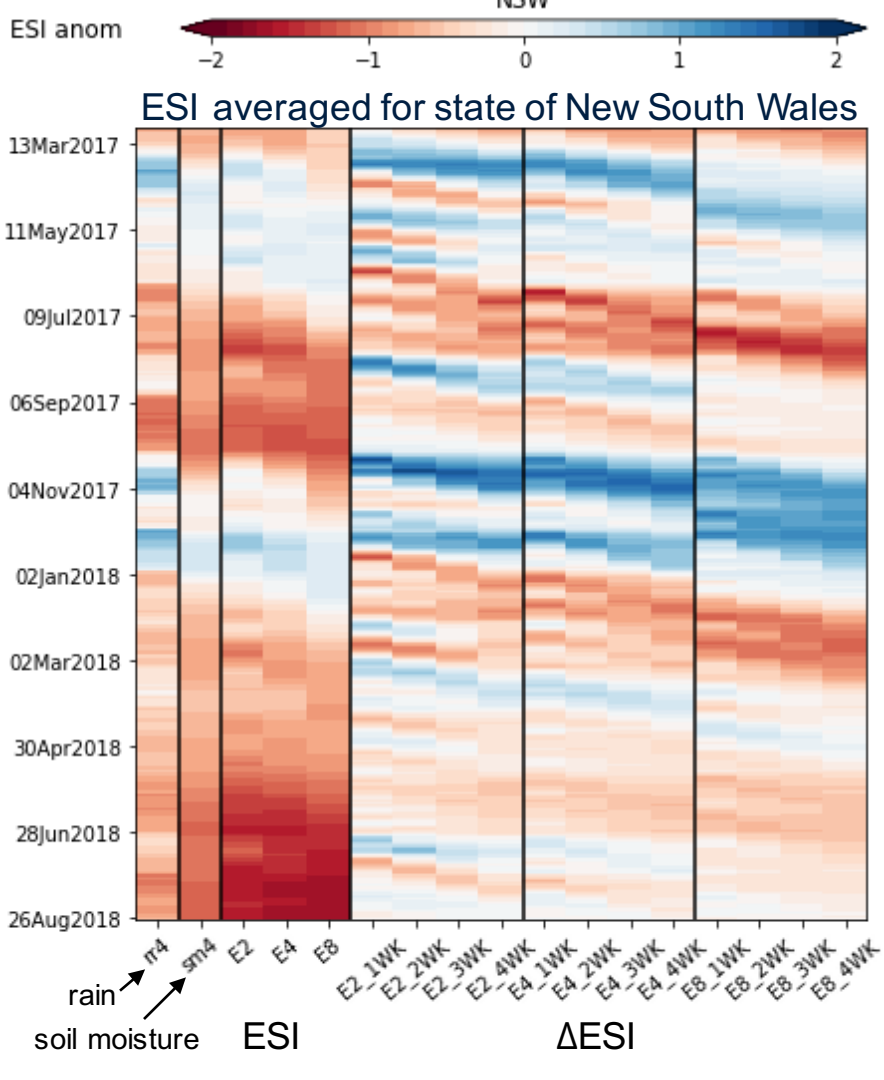
Maximum temperature has been highest on record for the last 12 months.

Records back to 1910.



Flash drought as indicated by a rapid change in the ESI

- Following Otkin et al. (J. Hydrometeor, 2013) we examine ΔESI which is the standardized change in the ESI occurring over the change intervals of 1, 2, 3, and 4 weeks. Updated daily.
- Flash drought appears where there have been large negative ΔESI (i.e. a rapid decrease in the ESI) ending in a strongly negative state of the ESI (Otkin et al., BAMS, 2018)
- July 2017 and February 2018 appear to be flash drought events (in New South Wales) by this definition.
- We are currently working on a database of such flash drought events for studies of subseasonal-to-seasonal variability and trends.



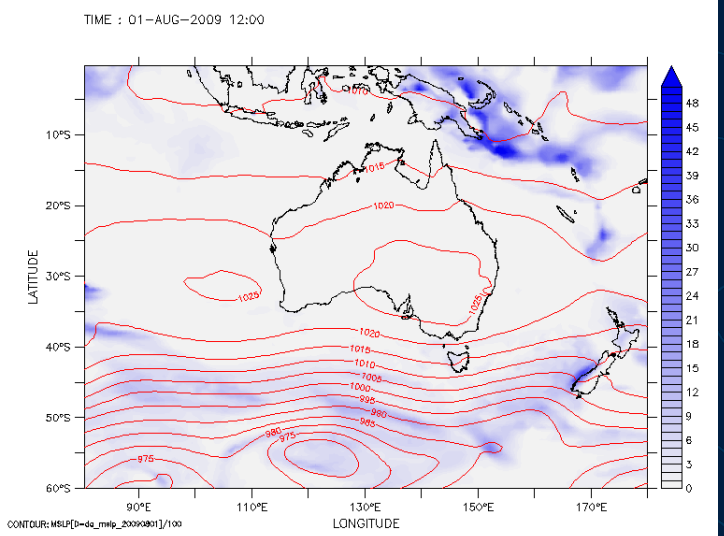
Part 2: Flash drought prediction

Bureau's coupled ocean-atmosphere prediction system, ACCESS-S1, based on UK Met Office GC2.

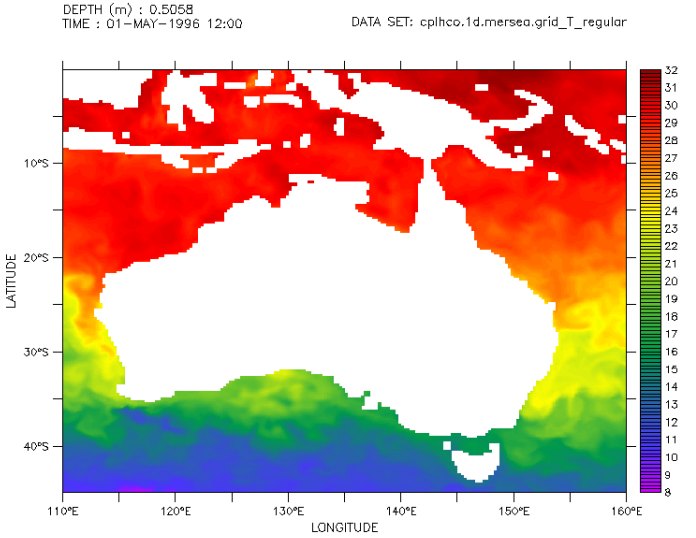
Atmosphere has 60km horizontal resolution (N216) with 85 vertical levels.

Ocean has 25km horizontal resolution with 75 vertical levels.

A comprehensive set of hindcasts (23 years, 11 members, 4 times per month) and real-time forecasts (33 members per day).



Evolution of atmosphere and ocean over the Australian region from a single ACCESS-S ensemble member forecast



Australian Government
Bureau of Meteorology

Computing ESI with ACCESS-S1 output

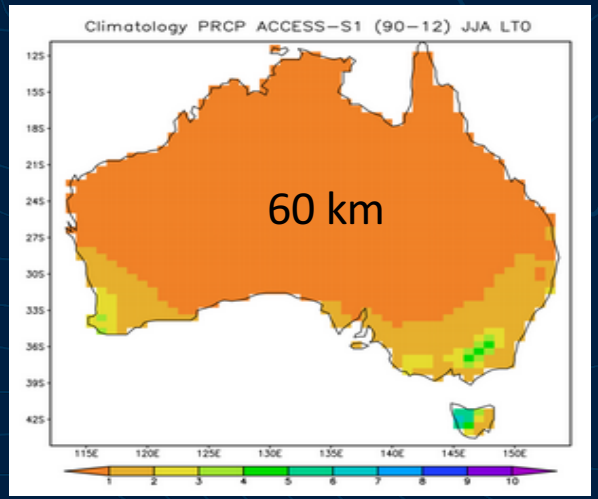
Two methods to test:

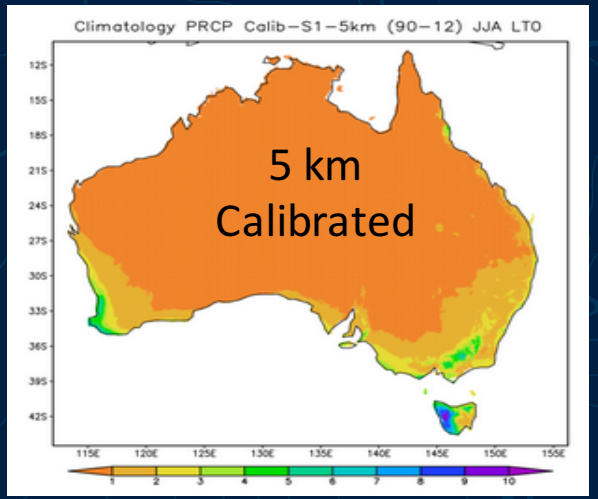
1. Use ACCESS-S1 output of ET and compute PET with the Penman equation.

2. Drive AWRA-L with ACCESS-S1 outputs of rainfall, temperature, solar radiation, wind, and then use AWRA-L to compute the forecast ET and PET.

ACCESS-S1 model output is already being calibrated to a 5km grid.

Generating a 5km forecast database over Australia using a quantile-quantile matching calibration technique





Being generated every day in real-time

Thankyou and questions

Matthew.Wheeler@bom.gov.au
Hanh.Nguyen@bom.gov.au
jasono@ssec.wisc.edu
Roger.Stone@usq.edu.au

Australian Government
Bureau of Meteorology

WISCONSIN
UNIVERSITY OF WISCONSIN-MADISON

UNIVERSITY OF SOUTHERN QUEENSLAND