Using reanalysis to identify drivers of rainfall variability in Queensland, Australia

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• A three-year project to ...
  - Investigate the key drivers of rainfall variability in Queensland
  - To assess the ability of high-resolution global climate models to simulate the observed variability and its drivers.
  - To reduce the uncertainties in predictions of changes in Queensland’s rainfall with global climate change.

![Project timeline diagram]

- **Observed rainfall** (historical data)
- **Meteorological reanalyses** (best “predictions” of historical weather)
- **High-resolution climate models** (best predictions of the future climate)
Queensland has experienced substantial inter-annual and decadal variability in its rainfall.

If we can understand the causes of natural variability and how climate change will interact with that variability, we stand a better chance of predicting future changes in rainfall.
Empirical Orthogonal Teleconnections

- EOTs identify patterns of rainfall variability that are linearly independent in time.

- The “central point” of the first EOT explains the most variance in the Queensland-mean rainfall.

- Prior to computing the second EOT, the first EOT is removed at all points via linear regression.

- EOTs computed for each three-month season, using 25 km interpolated gauge observations for 1900-2007.
Patterns of summer rainfall variability

EOT 1 spatial pattern

EOT 1 timeseries

NIN4 correlations with EOT1 for SILO 0.25, using ann-means for dec-feb 1900-2007

Explains 37.71% of domain space-time variance
Correlation with seasonal-mean (dec-feb) NIN4: -0.32
Correlation with seasonal-mean (dec-feb) NINO3: 0.26
Correlation with seasonal-mean (dec-feb) NINO3: -0.35

Regression of HadISST onto EOT 1

Regression of HadSST onto EOT 1

EOT 1 correlations with Nino 4

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Patterns of summer rainfall variability

Twentieth Century Reanalysis for 1900-2007

Regression of EOT 1 onto seasonal-mean MSLP and 850 hPa winds

Enhanced monsoon circulation across all of Australia, associated with convergence in Maritime Continent and SOI.
Patterns of summer rainfall variability

After the leading pattern has been removed, the remaining EOTs describe patterns of regional rainfall variations in Queensland.
EOT 2 pattern of summer rainfall is associated with variability in tropical-cyclone tracks and genesis locations.

(Caution: Limited data period)
The third EOT pattern is associated with a local circulation regime of onshore winds and increased moisture flux to southeast Queensland.
Patterns of summer rainfall variability

EOT 3 timeseries
(Note: negative since 1970)

Regression of standard deviation in 2-10 day bandpass-filtered Twentieth Century Reanalysis MSLP onto EOT 3 timeseries

Pattern associated with increased synoptic activity over central and SE Queensland (reduced since 1970)
Patterns of autumn rainfall variability

EOT 1 spatial pattern

EOT 1 timeseries
(Note decline since mid-1970s)

Regression of HadISST SSTs onto EOT 1 timeseries

Leading pattern of March-May rainfall describes state-wide variations, but no connection to Pacific SST variability
Patterns of autumn rainfall variability

Regression of Twentieth Century Reanalysis MSLP and 850 hPa winds onto EOT 1 timeseries

Regression of standard deviation in 2-10 day bandpass-filtered Twentieth Century Reanalysis MSLP onto EOT 1 timeseries

Pattern corresponds to enhanced monsoon circulation across northern Australia and increased synoptic variability, suggesting a longer monsoon season.
Patterns of autumn rainfall variability

Second EOT for March-May describes variability in central and SE Queensland.

Timeseries displays decadal variability, confirmed by wavelet transform (next slide).
Patterns of autumn rainfall variability

Wavelet transform of March-May EOT 2 timeseries
Patterns of autumn rainfall variability

Regression of standard deviation in 2-10 day bandpass-filtered Twentieth Century Reanalysis MSLP onto EOT 2 timeseries

Pattern associated with synoptic variance over southeastern Australia, suggesting movement of cyclones from south to Queensland.
Patterns of autumn rainfall variability

ENS0 emerges as the third EOT for autumn, likely due to weak ENSO signals during this season.

For other three seasons, leading (state-wide) EOT is associated with ENSO and IPO.
Comparison of 20thC V2 (ensemble-mean) and SILO (on T62 grid) area-avg, seasonal total (nov-apr) rainfall for Queensland - 1891-2007

- SILO rainfall (on T62 grid)
- 20thC ens-mean rainfall
- Ratio of 20thC V2 ens-mean to SILO

Year at beginning of nov-apr seasonal-mean

Queensland area-averaged, seasonal-total (nov-apr) rainfall (mm/year)
Comparison of 20thC V2 and SILO (on T62 grid) area-averaged, seasonal-mean (nov-apr) rainfall for Queensland - 1891-2007

For La Nina years (Nino 4 < -0.2) - 38 years
20thC_rain = 0.65904 * SILO_rain + 54.29
Correlation = 0.745

For El Nino years (Nino 4 > 0.2) - 48 years
20thC_rain = 0.69357 * SILO_rain + 18.20
Correlation = 0.768

For neutral years (-0.2 <= Nino 4 <= 0.2) - 31 years
20thC_rain = 0.65740 * SILO_rain + 33.235
Correlation = 0.752

For all years - 117 years
20thC_rain = 0.70291 * SILO_rain + 18.25
Correlation = 0.806
The Twentieth Century Reanalysis reproduces the observed asymmetric ENSO-rainfall correlation, but the magnitude of the correlation with La Nina is weak.
Summary and conclusions

• The Twentieth Century Reanalysis is enabling investigations of inter-annual and decadal-variability in Queensland’s rainfall at the seasonal scale.

• Key advantages brought by the Twentieth Century Reanalysis
  - The ability to use the entire dataset of Australian rainfall, rather than being restricted to the second half of the 20th century.
  - The ability to sample several cycles of decadal and inter-decadal variability. Some EOTs are the same sign for most of the ERA-40 period!
  - Greater confidence that the EOT patterns accurately reflect variations in Queensland’s seasonal rainfall

• Conclusions from EOT analysis
  - In summer, Queensland’s rainfall is driven by a decadally varying monsoon circulation that is modulated by ENSO and the IPO.
  - Coastal circulations bring on-shore winds and rainfall to southern Queensland in summer. The frequency of these have decreased since the 1970s.
  - State-wide autumn rainfall is driven by the length of the monsoon season, which is un-related to Pacific SST variability.
  - Southern Queensland’s autumn rainfall is also influenced by mid-latitude cyclones. The associated EOT shows significant decadal variability.