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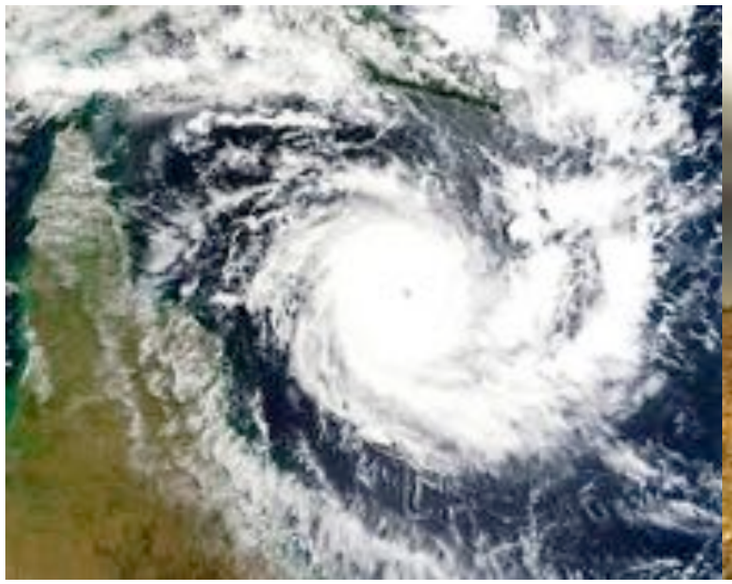
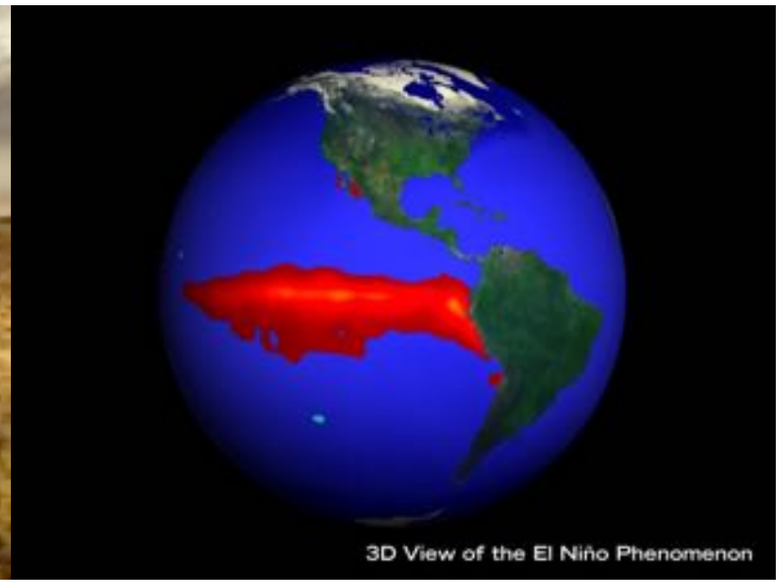
Using reanalysis to identify drivers of rainfall variability in Queensland, Australia





Nicholas Klingaman
National Centre for Atmospheric Science
and Walker Institute for Climate System Research
University of Reading

With thanks to: Steve Woolnough, Jozef Syktus,
Helen Fairweather, Ian Smith

University of Reading

Queensland Government

3rd ACRE Workshop
Friday 5 November 2010

Walker INSTITUTE

The Walker-QCCCE Collaboration

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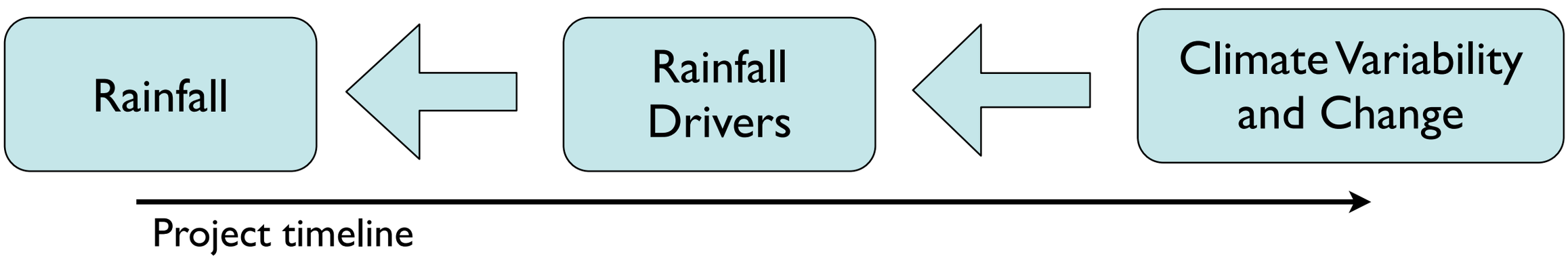
- A three-year project to ...
  - Investigate the key drivers of rainfall variability in Queensland
  - To assess the ability of high-resolution global climate models to simulate the observed variability and its drivers.
  - To reduce the uncertainties in predictions of changes in Queensland's rainfall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



Rainfall variability

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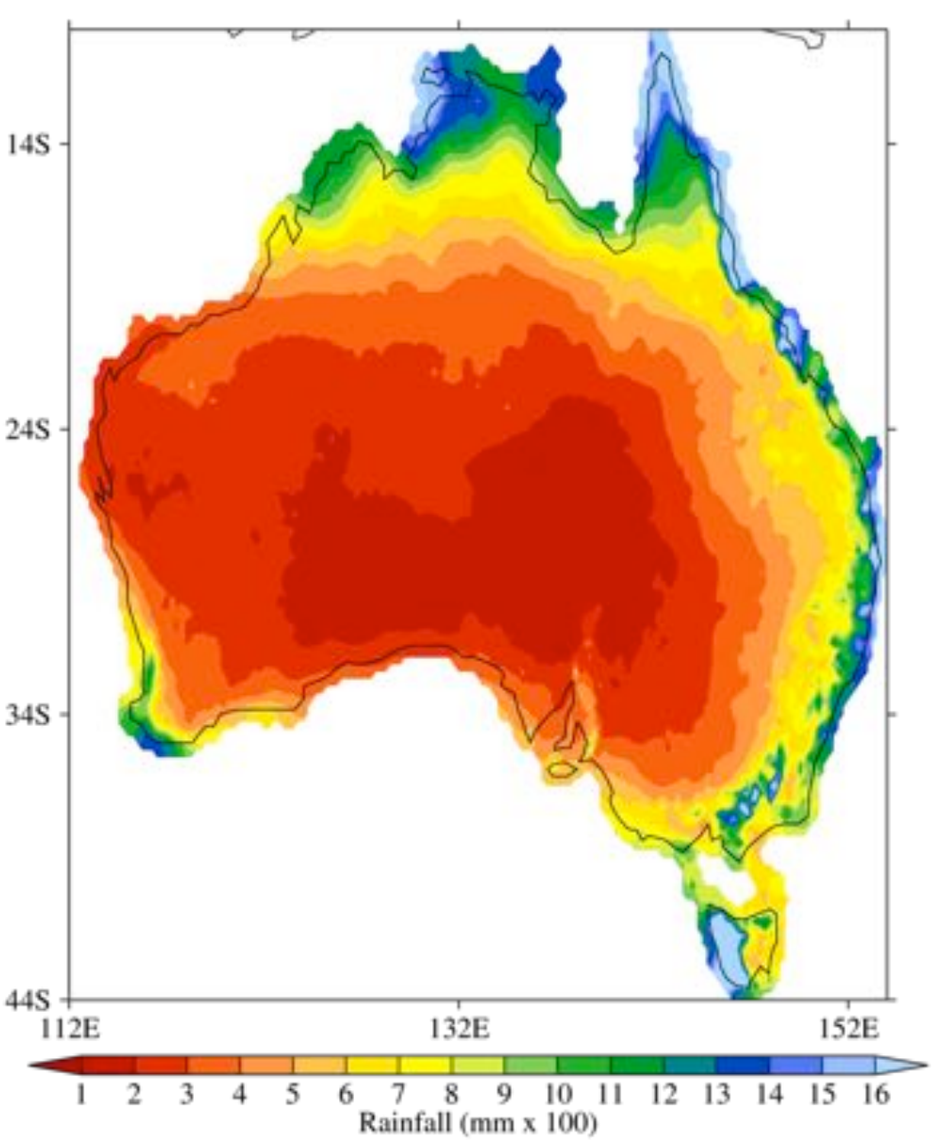
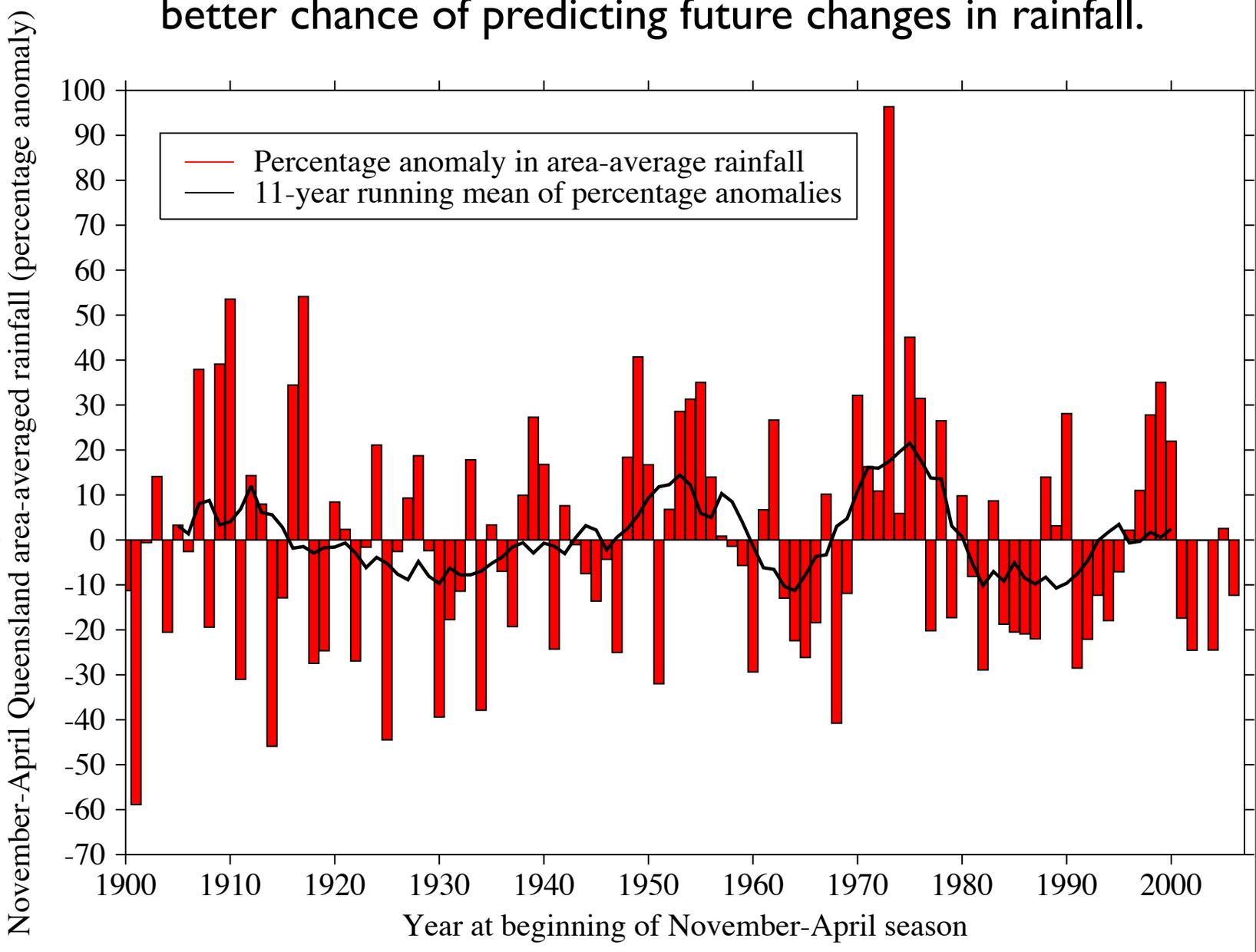


Queensland has experienced substantial inter-annual and decadal variability in its rainfall.

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

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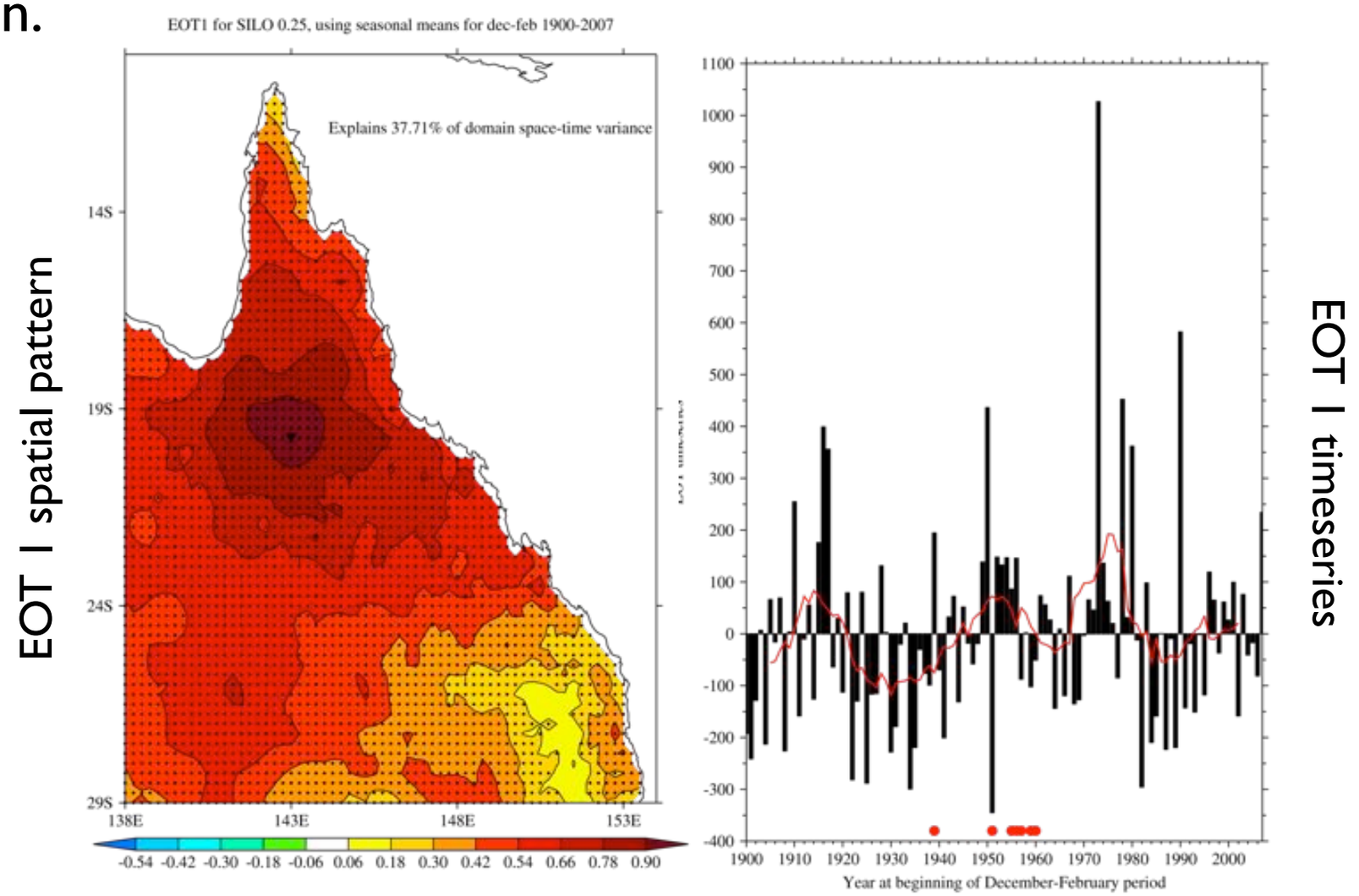
- EOTs identify patterns of rainfall variability that are linearly independent in time.
- The "central point" of the first EOT explains the most variance in the Queensland-mean rainfall.
- Prior to computing the second EOT, the first EOT is removed at all points via linear regression.
- EOTs computed for each three-month season, using 25 km interpolated gauge observations for 1900-2007.

Leading EOT of December-February total rainfall for 1900-2007



Patterns of summer rainfall variability

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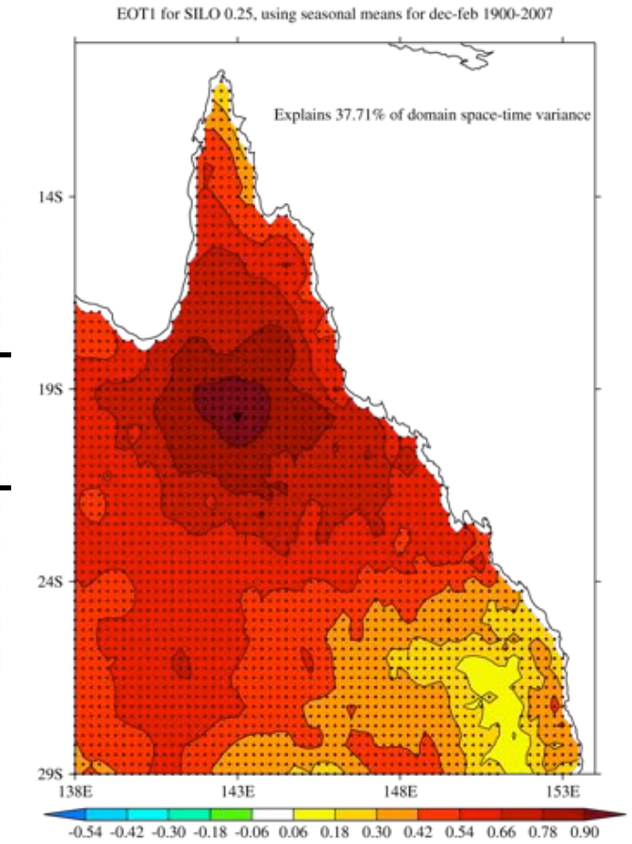
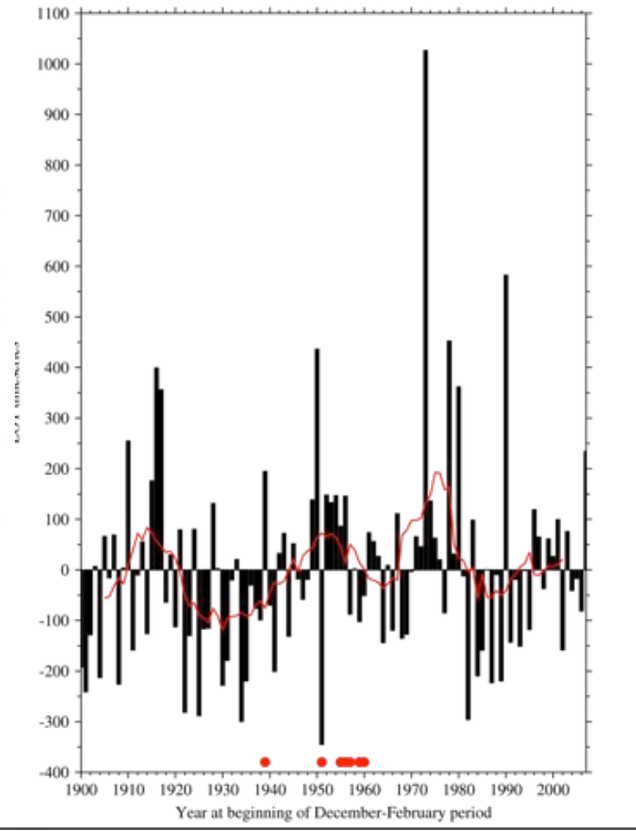
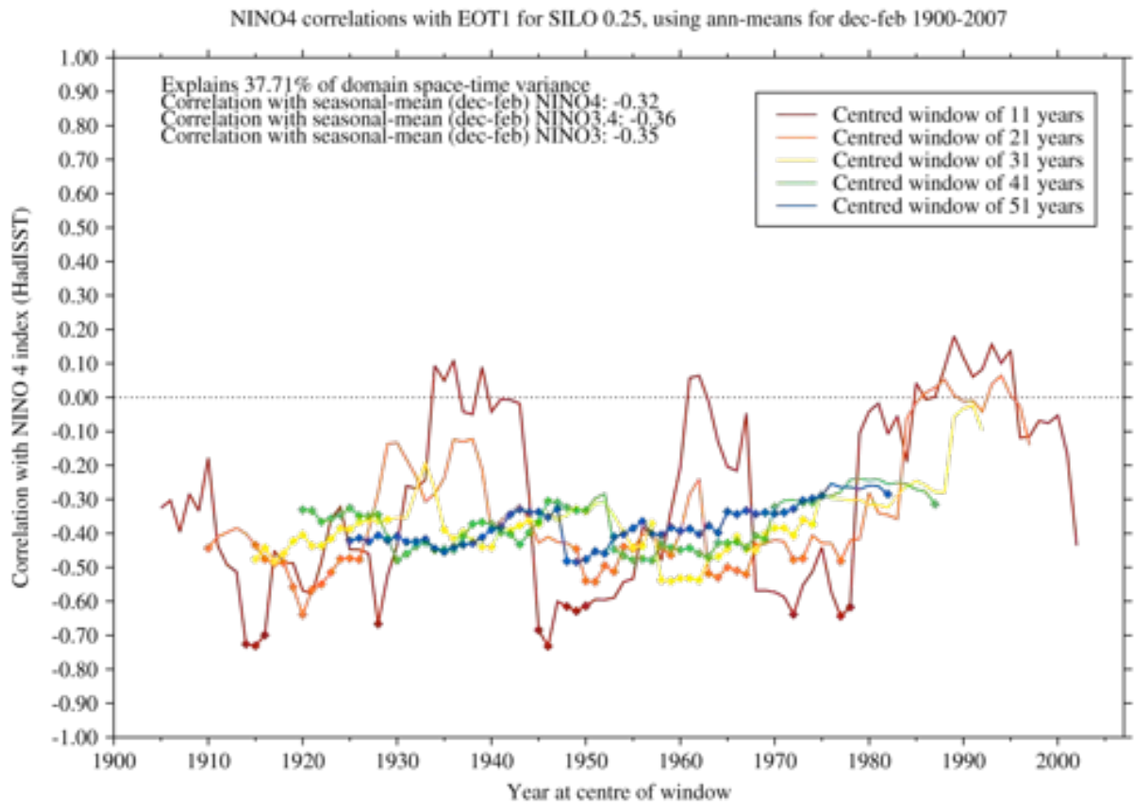
EOT 1 spatial pattern

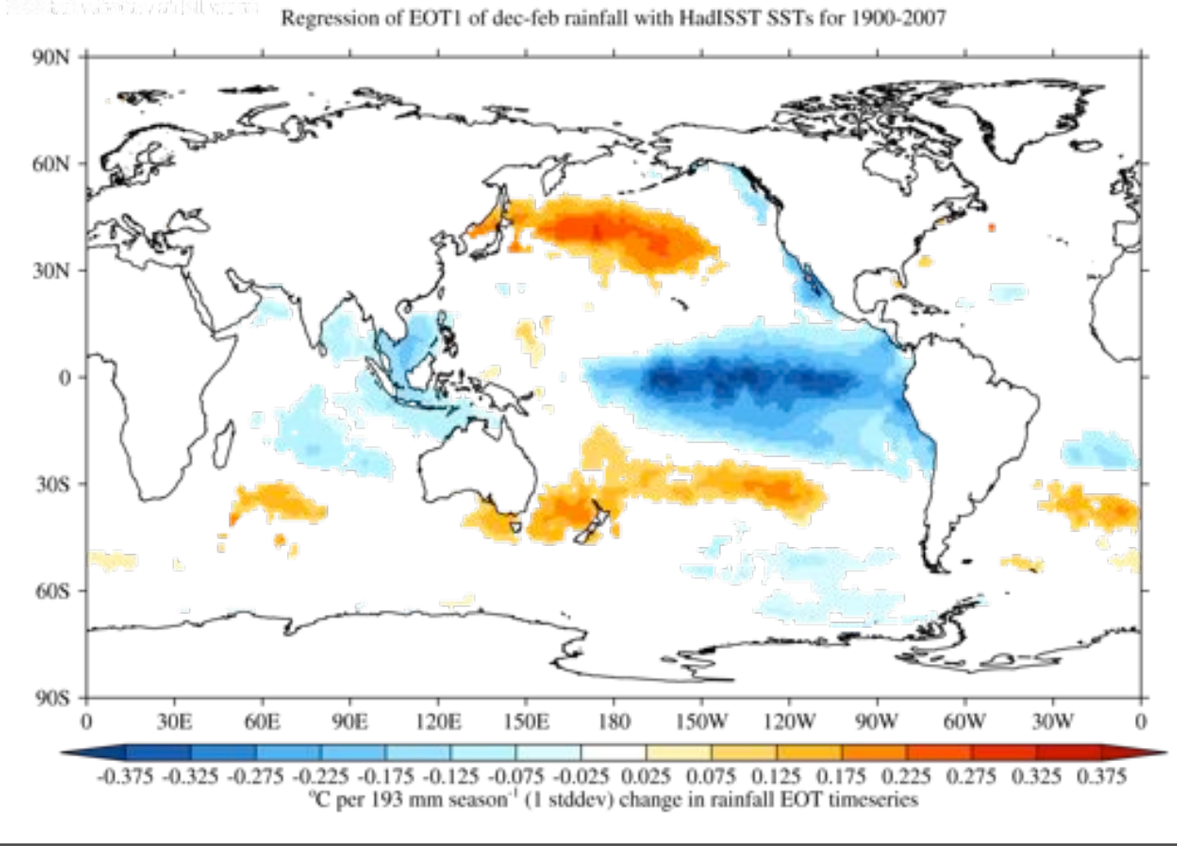


EOT 1 timeseries





EOT 1 correlations with Nino 4



Regression of HadISST onto EOT 1

Patterns of summer rainfall variability

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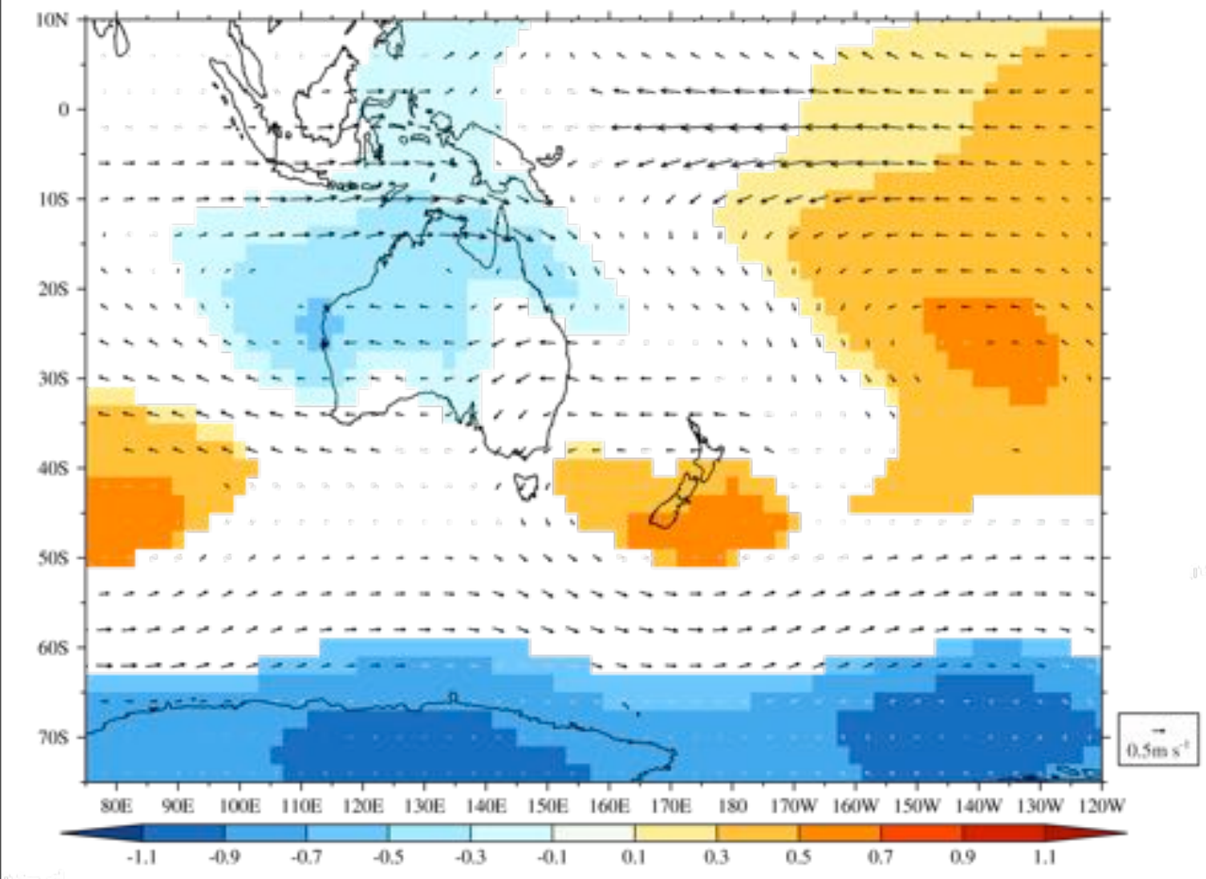
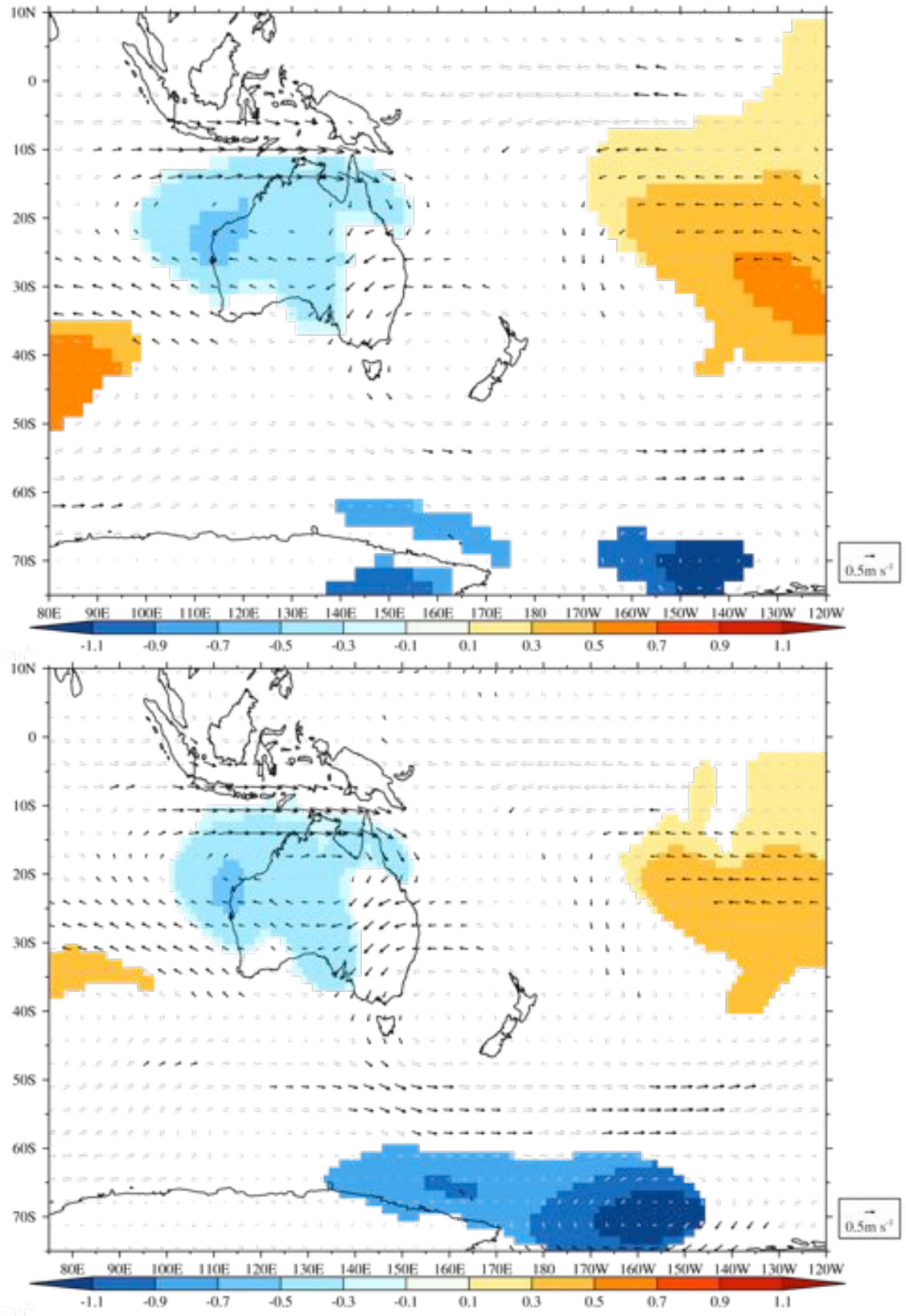
Twentieth Century Reanalysis
for 1900-2007



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.

Twentieth Century Reanalysis
for 1958-2001



ERA-40
for 1958-2001

Patterns of summer rainfall variability

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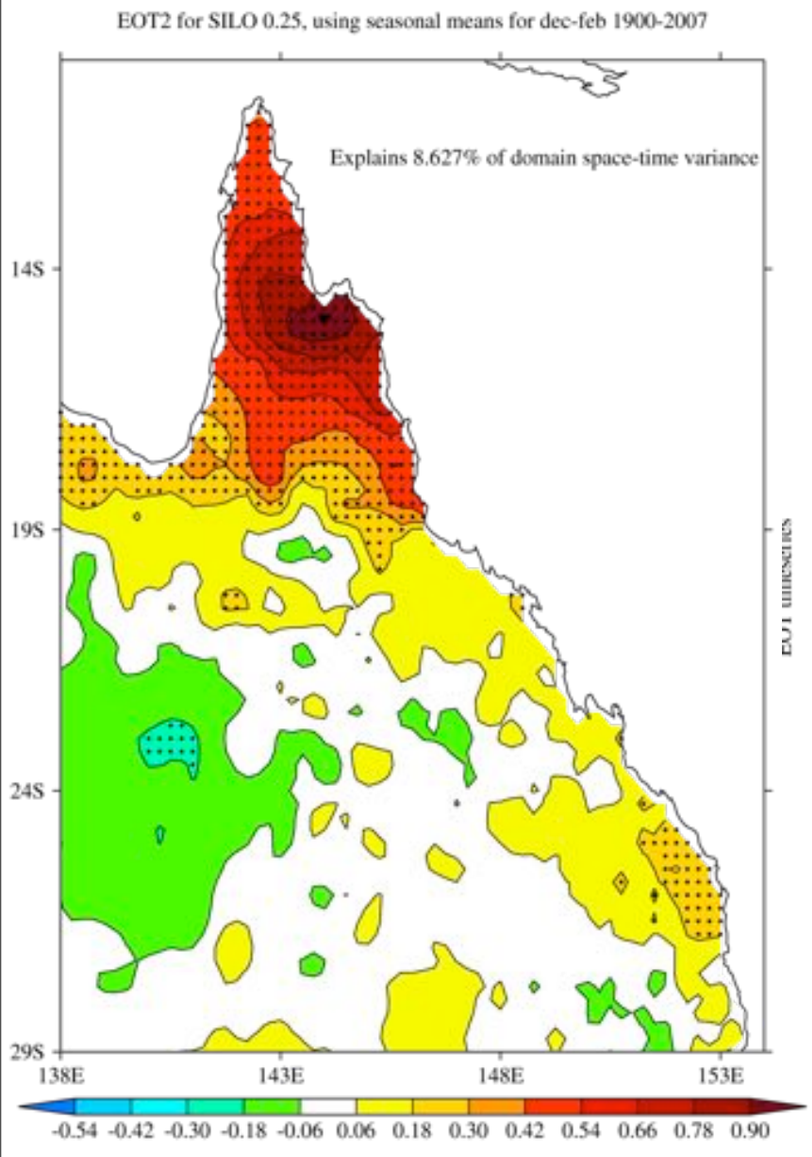
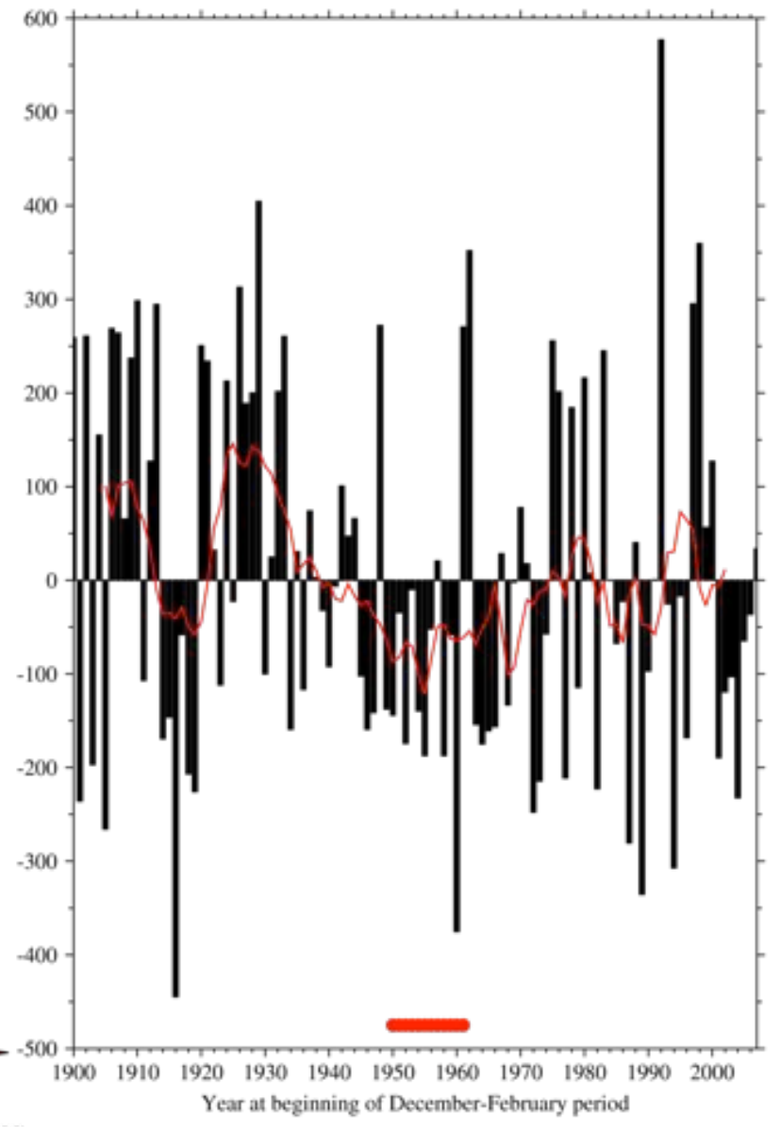
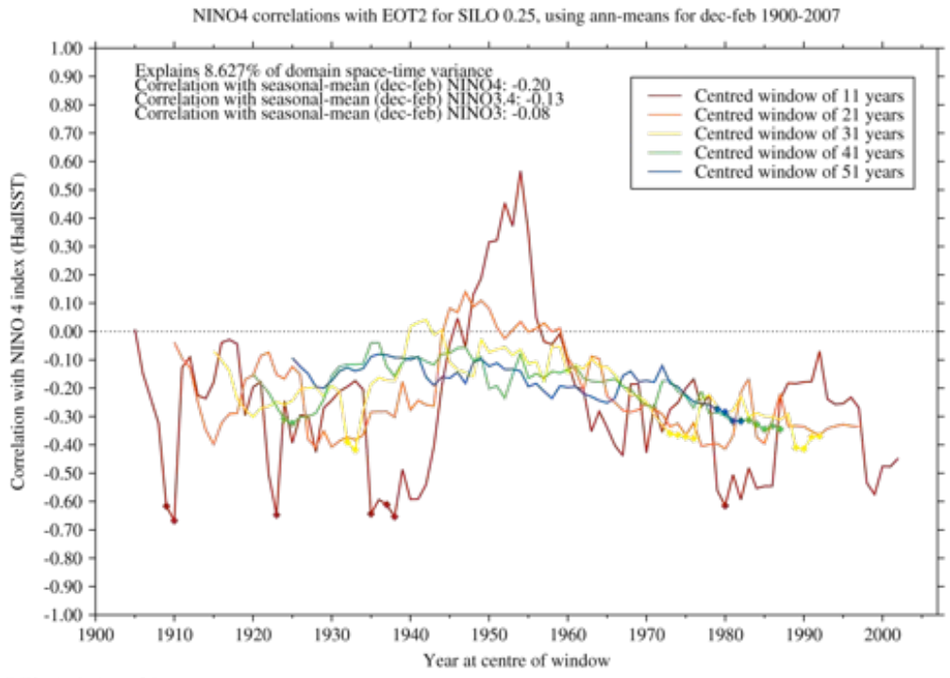
EOT 2 spatial pattern



EOT 2 timeseries



EOT 2 correlations with Nino 4 (no statistically significant correlations)



After the leading pattern has been removed, the remaining EOTs describe patterns of regional rainfall variations in Queensland.

Patterns of summer rainfall variability

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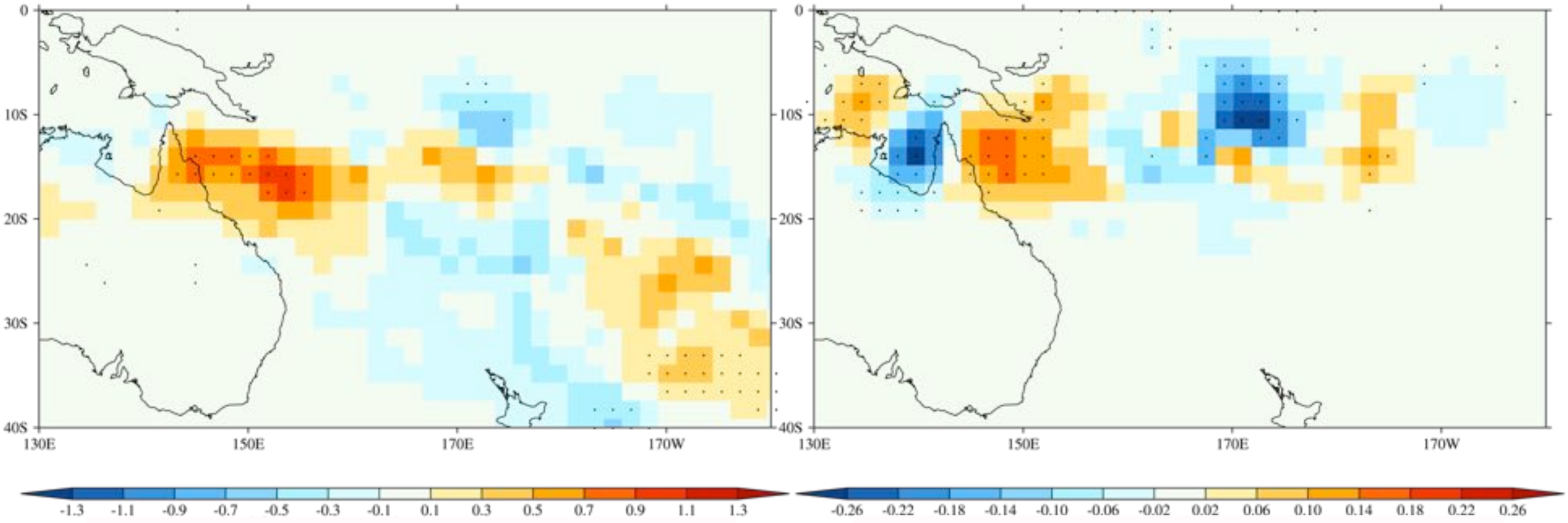
Regression of tropical cyclone track density (IBTrACS) onto EOT 2 (1978-2007)

Regression of tropical cyclone genesis density (IBTrACS) onto EOT 2 (1978-2007)



storms season^{-1} (10^6 km^2)$^{-1}$ per one stddev change in EOT timeseries

EOT 2 pattern of summer rainfall is associated with variability in tropical-cyclone tracks and genesis locations.

(Caution: Limited data period)

Patterns of summer rainfall variability

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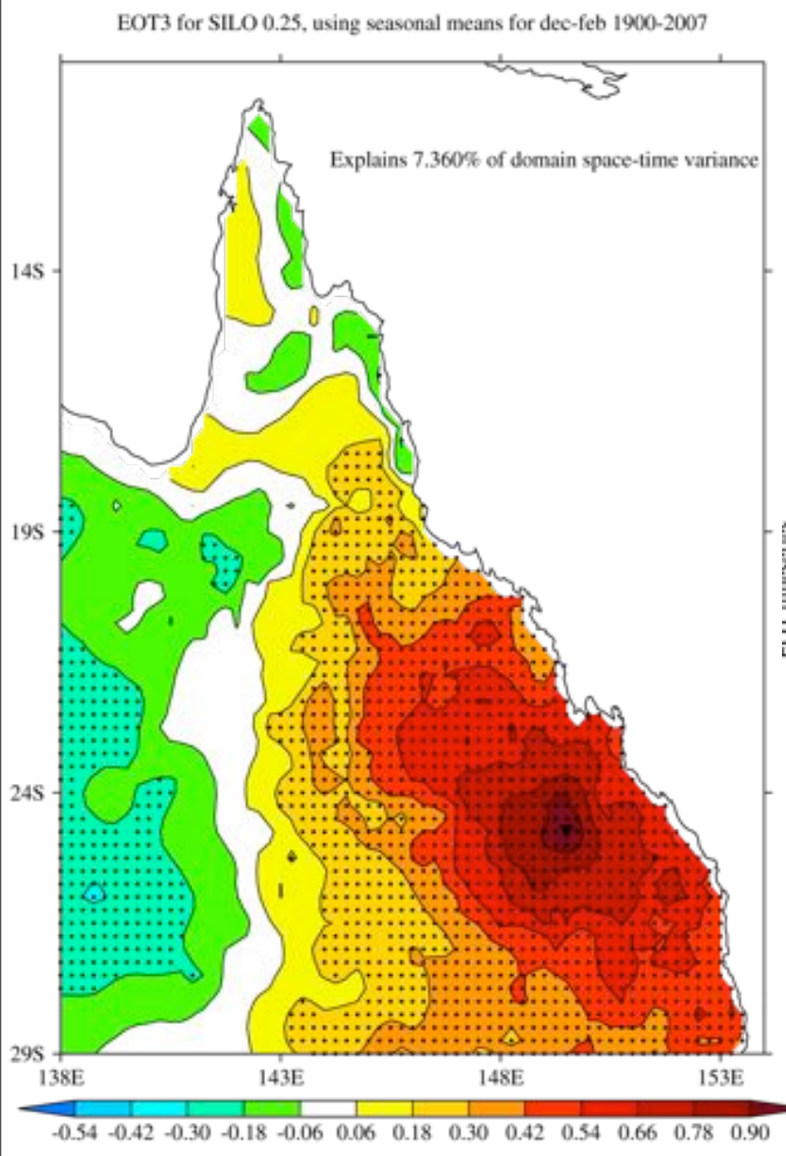
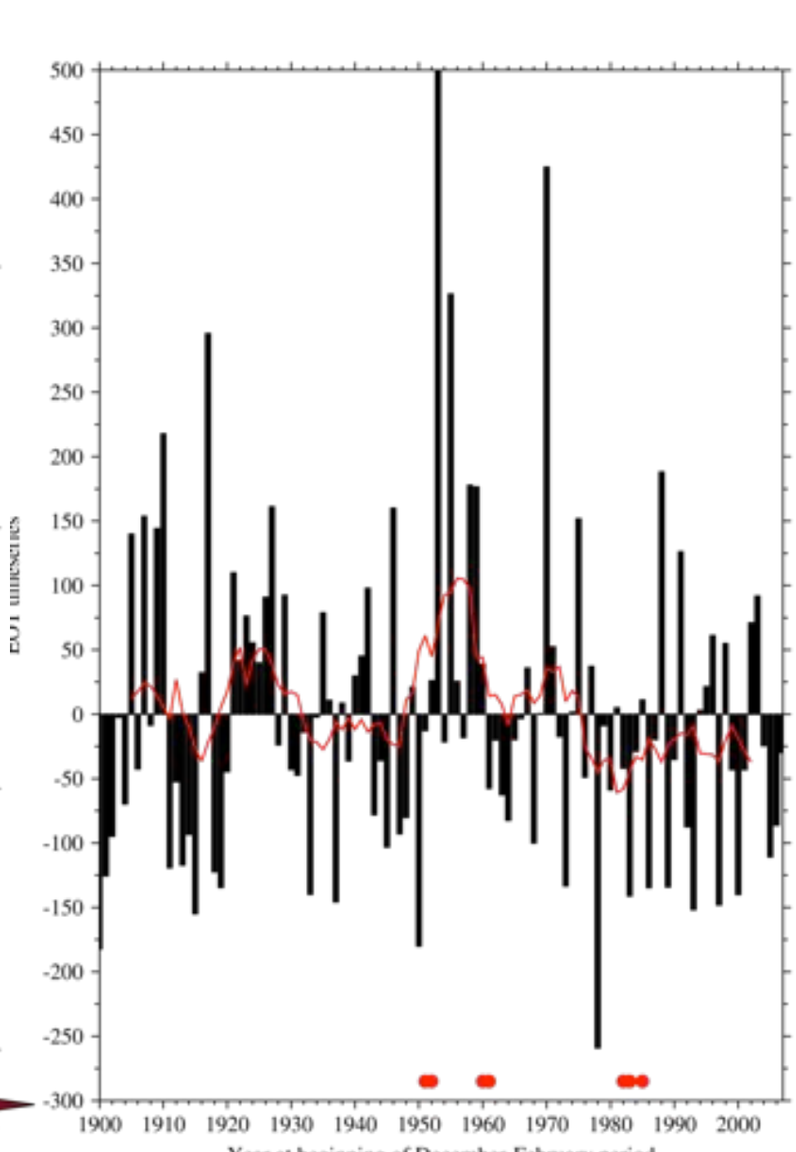
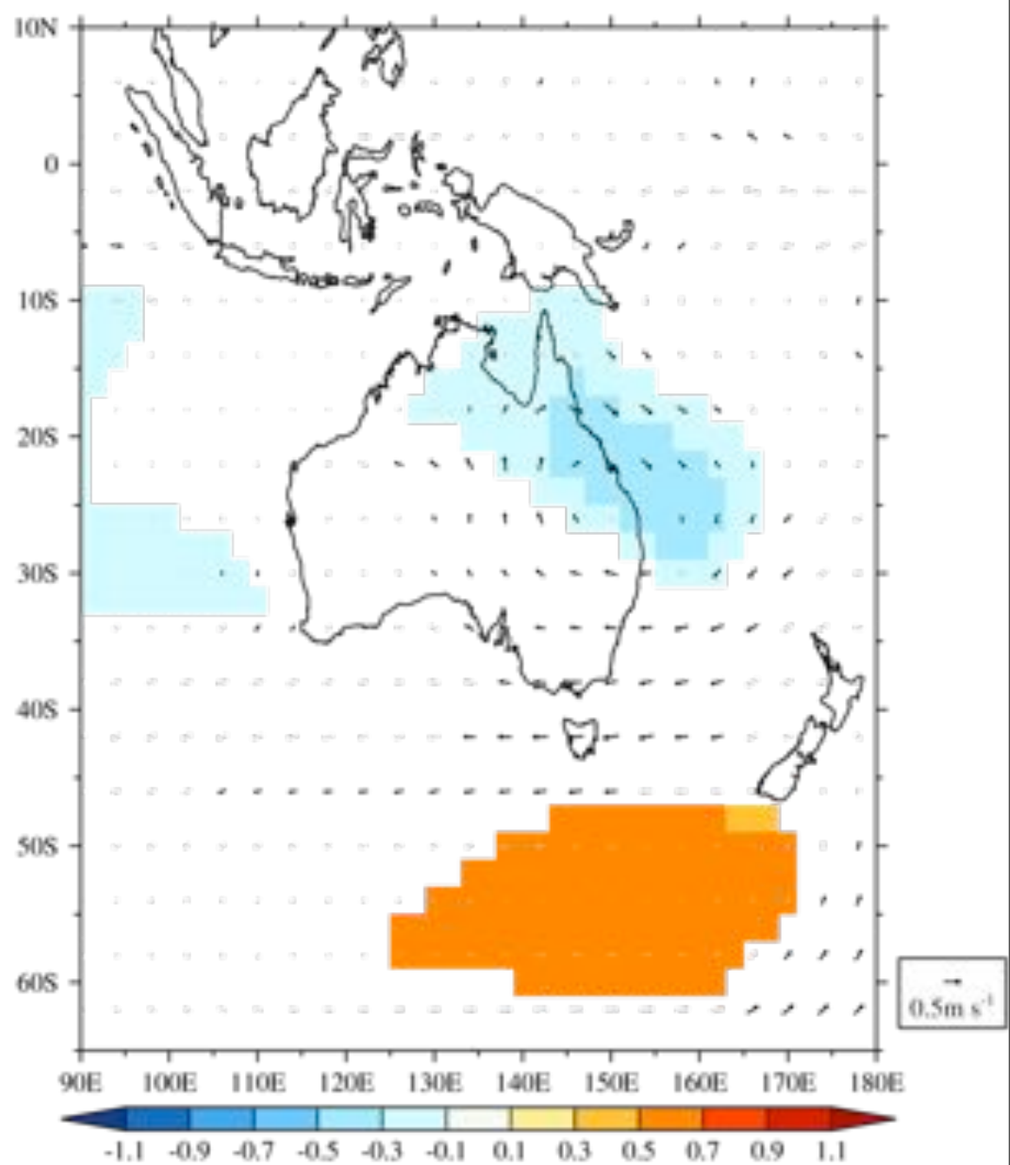
EOT 3 spatial pattern



EOT 3 timeseries
(Note: negative since 1970)



Regression of
Twentieth Century Reanalysis
MSLP and 850 hPa winds



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

National Centre for Atmospheric Science
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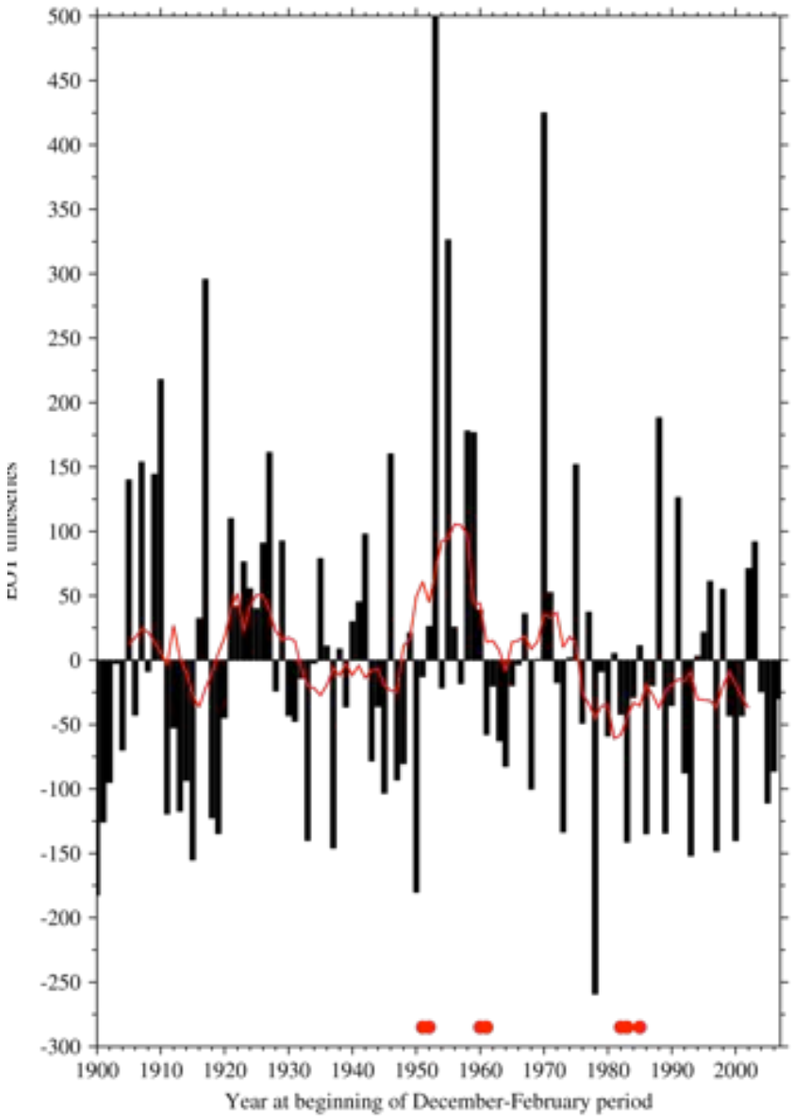
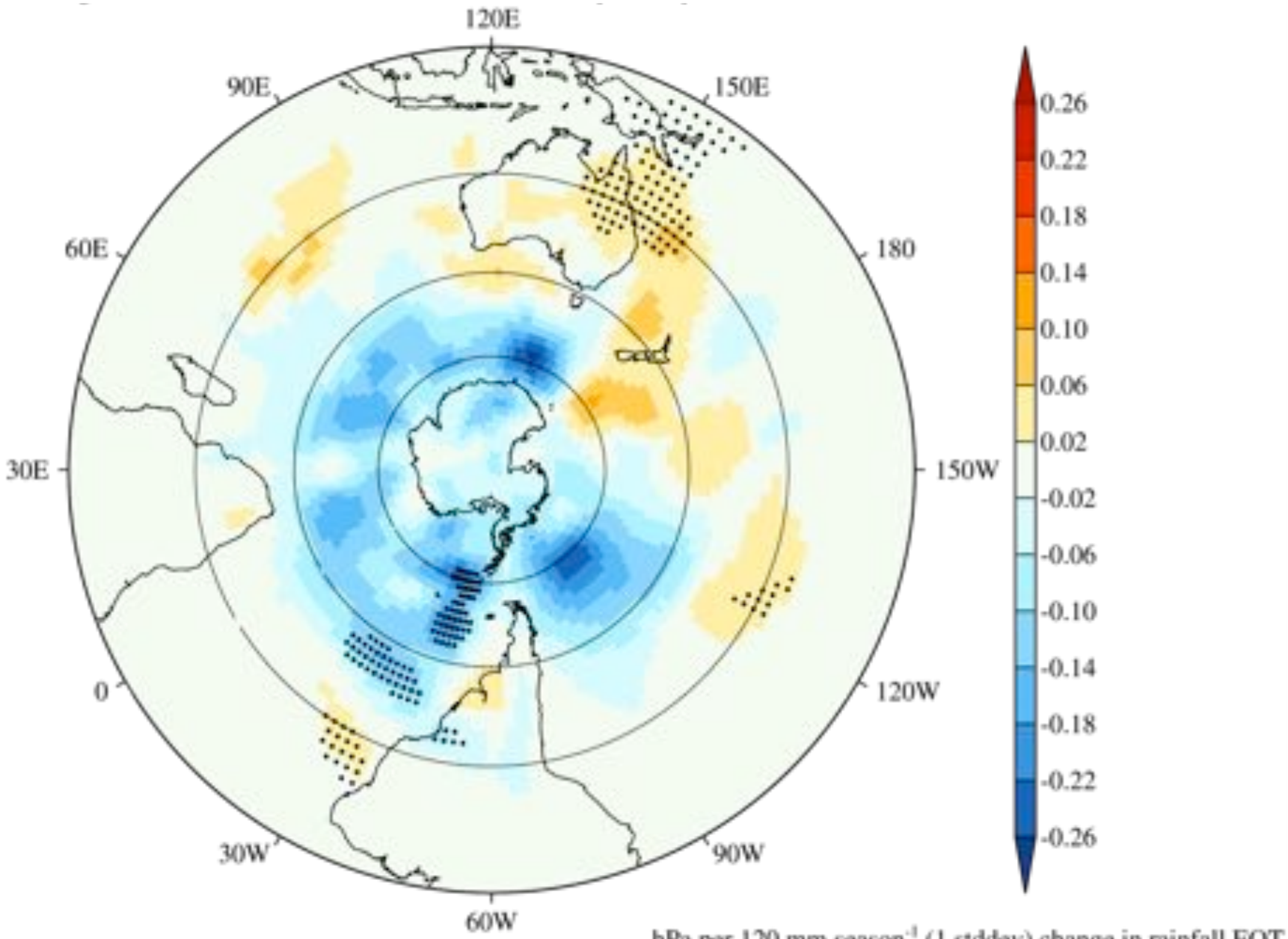
EOT 3 timeseries
(Note: negative since 1970)



Pattern associated with increased synoptic activity over central and SE Queensland (reduced since 1970)

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



Patterns of autumn rainfall variability

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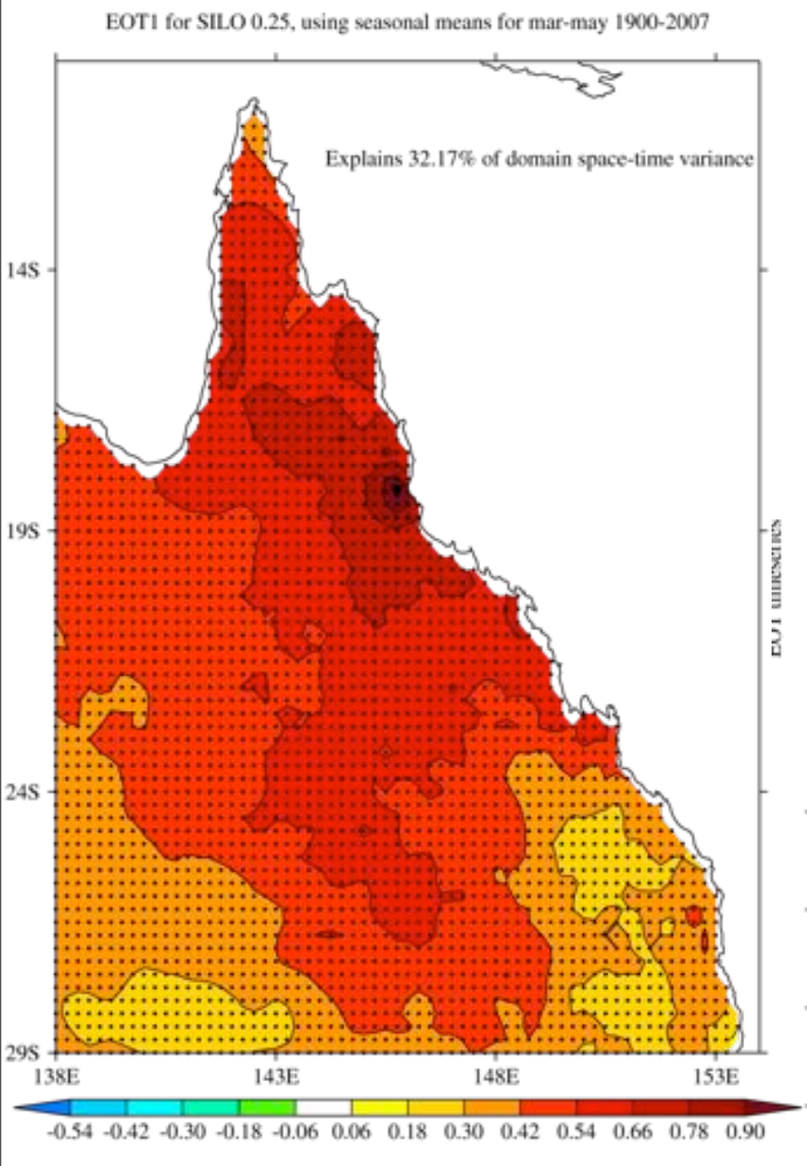
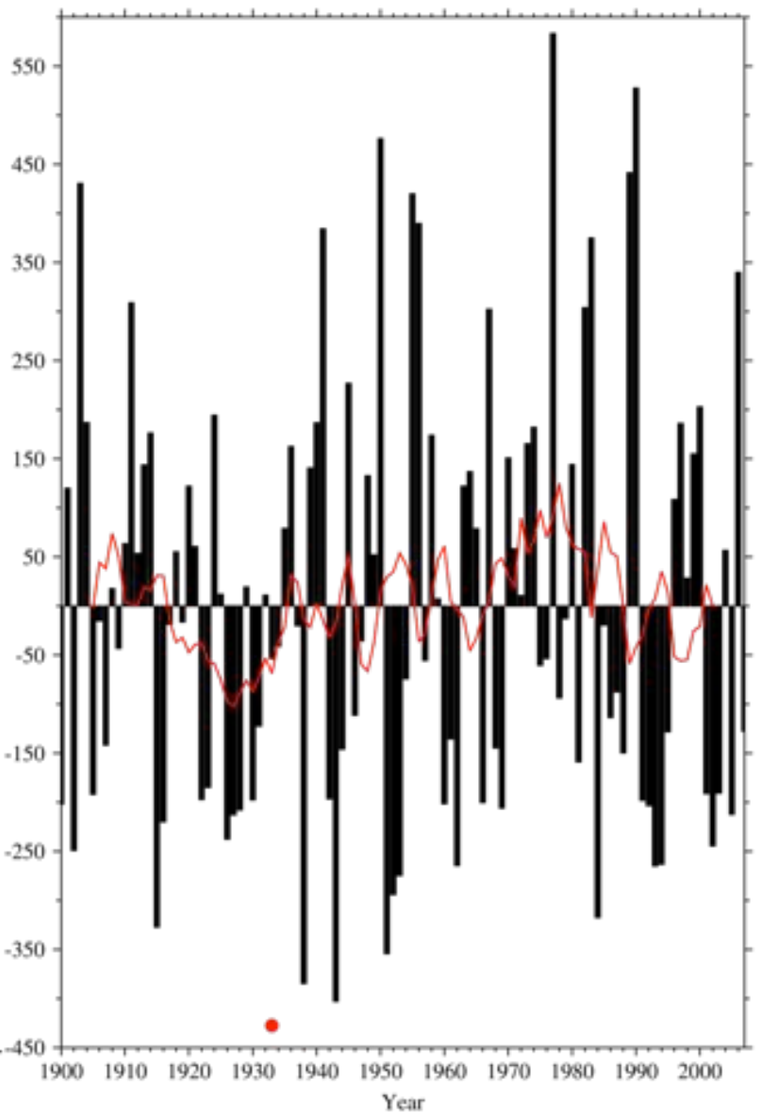
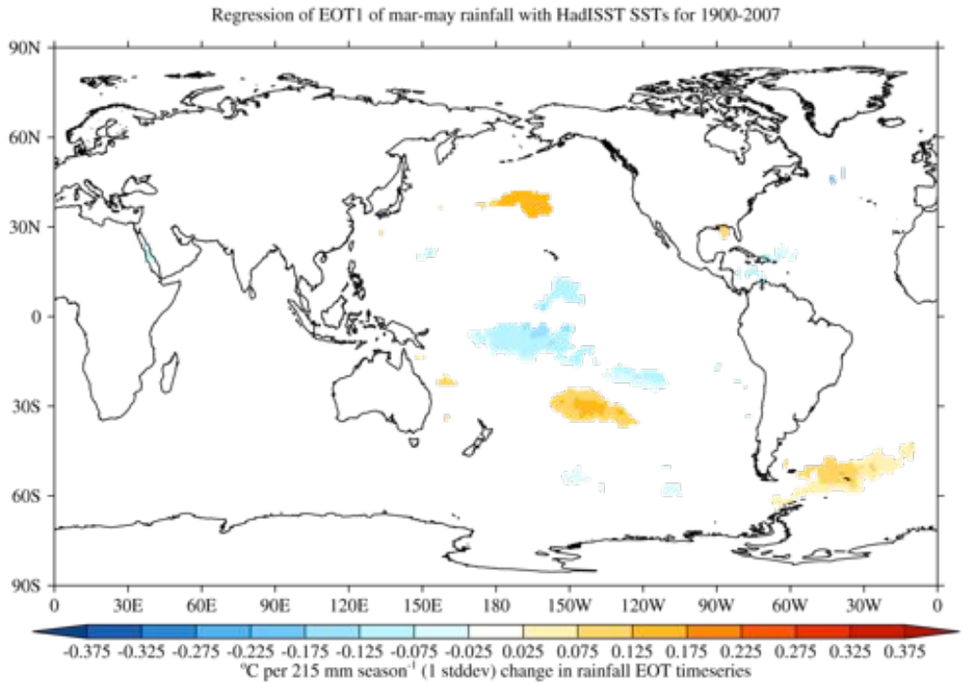
EOT 1 spatial pattern



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

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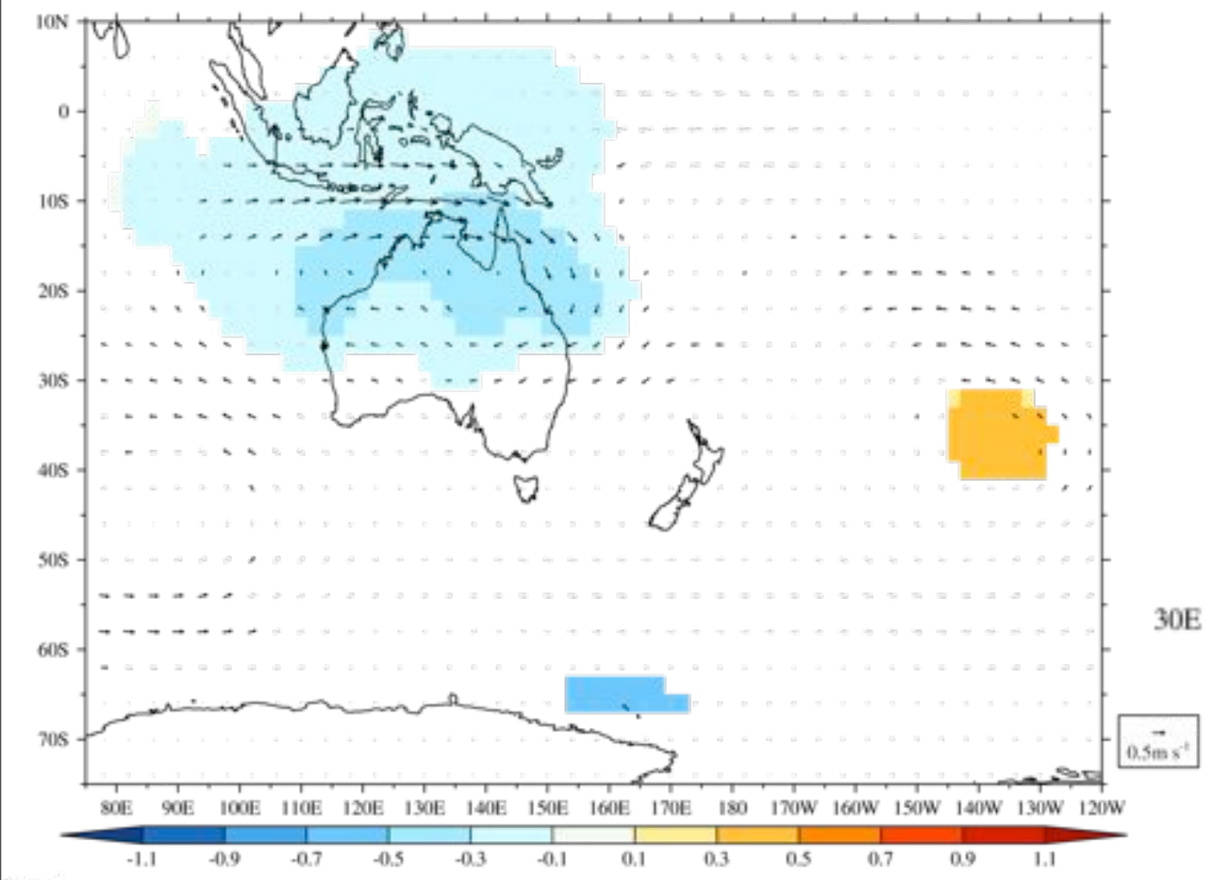
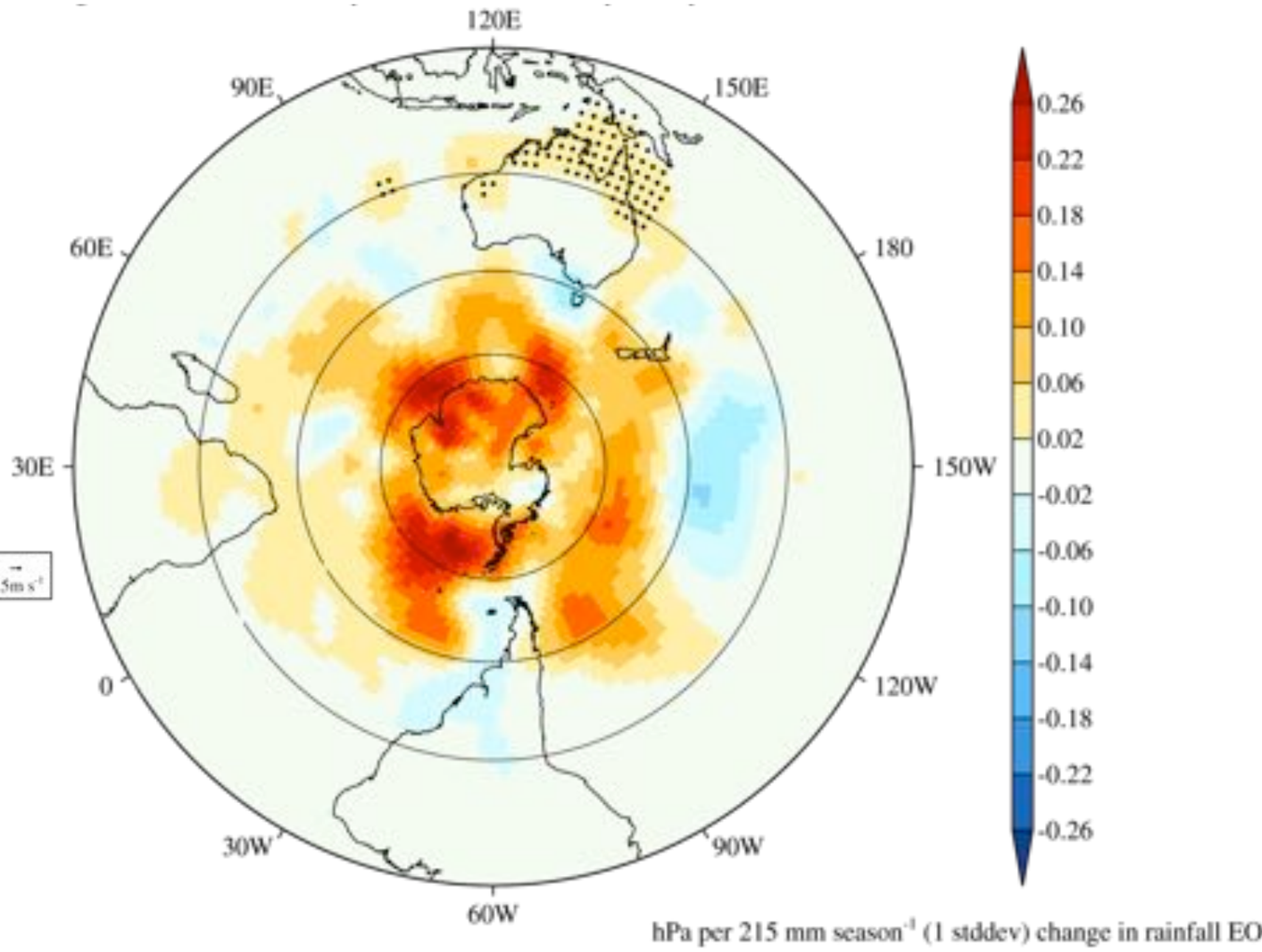
Regression of Twentieth Century Reanalysis MSLP and 850 hPa winds onto EOT 1 timeseries



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

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



Patterns of autumn rainfall variability

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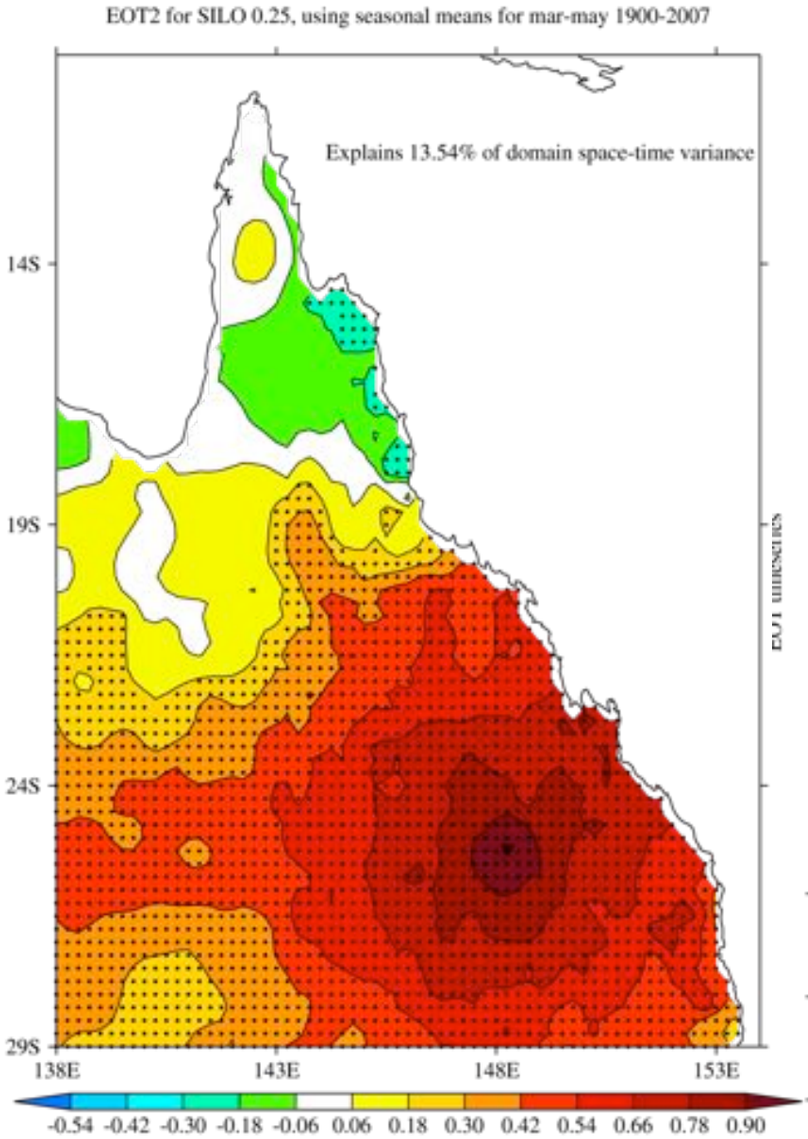
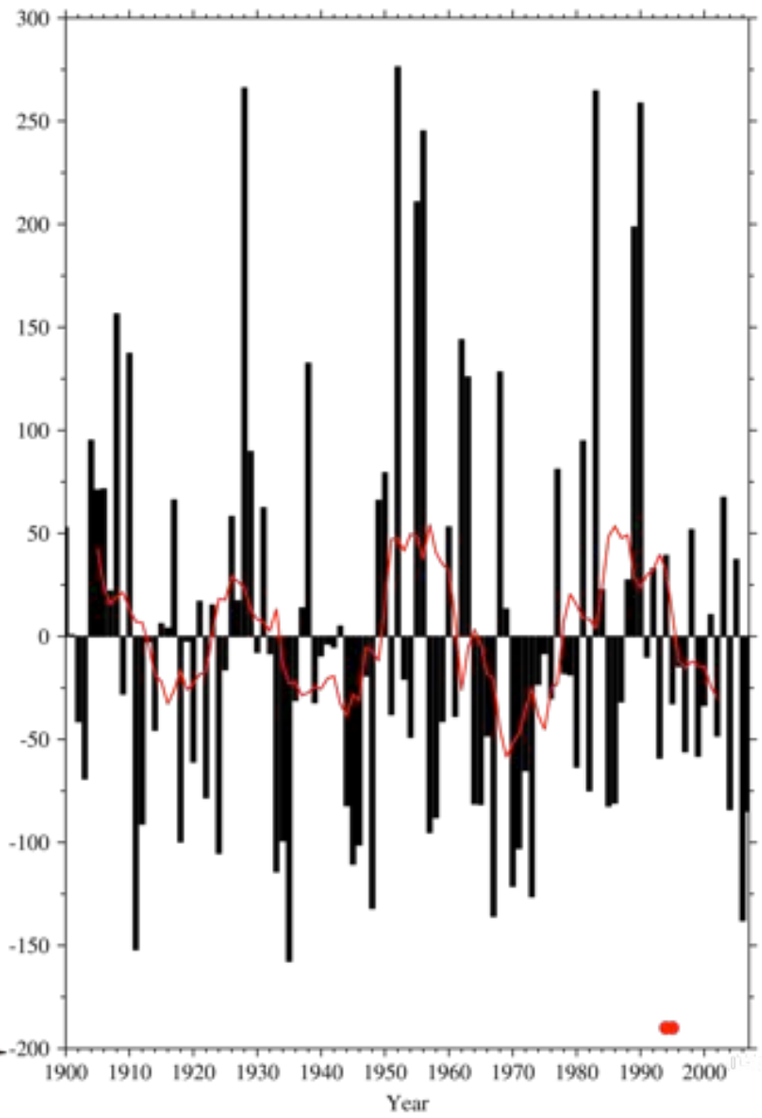
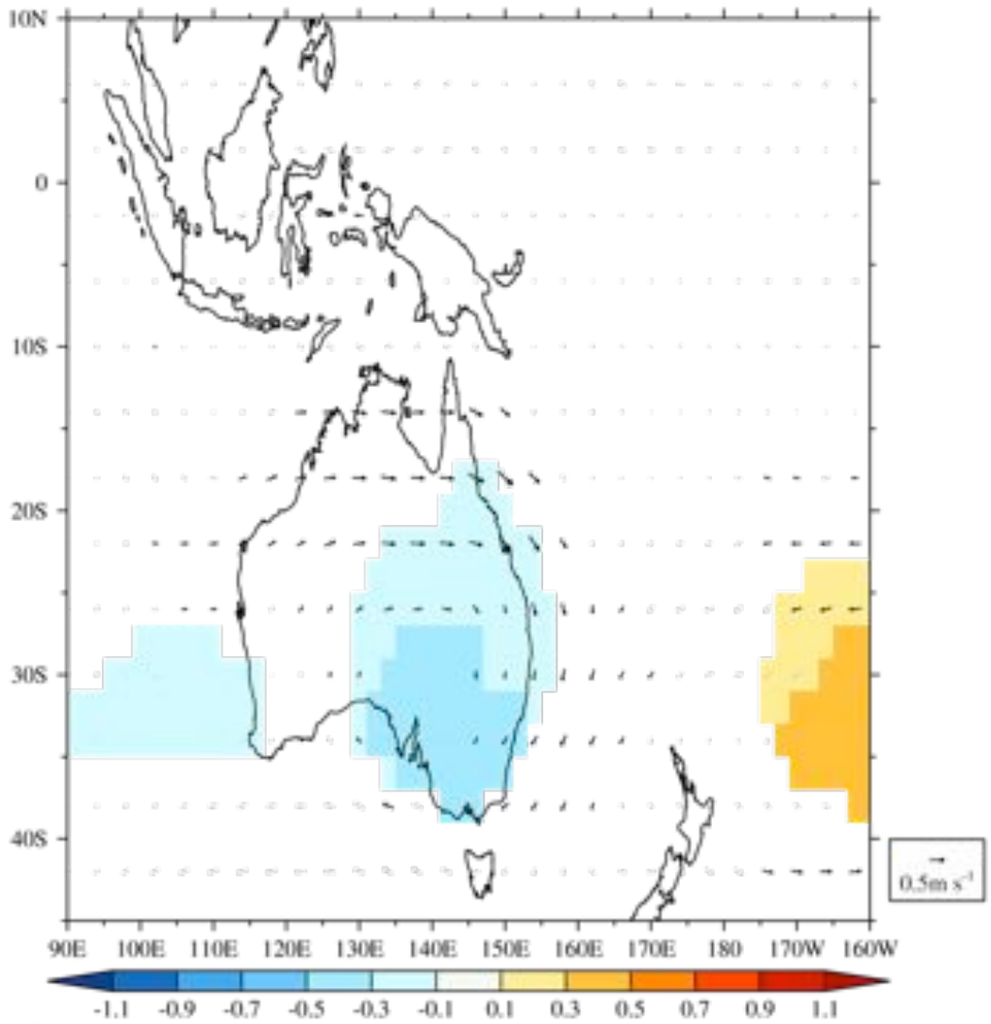
EOT 2 spatial pattern



EOT 2 timeseries



Regression of Twentieth Century Reanalysis MSLP and 850 hPa winds



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

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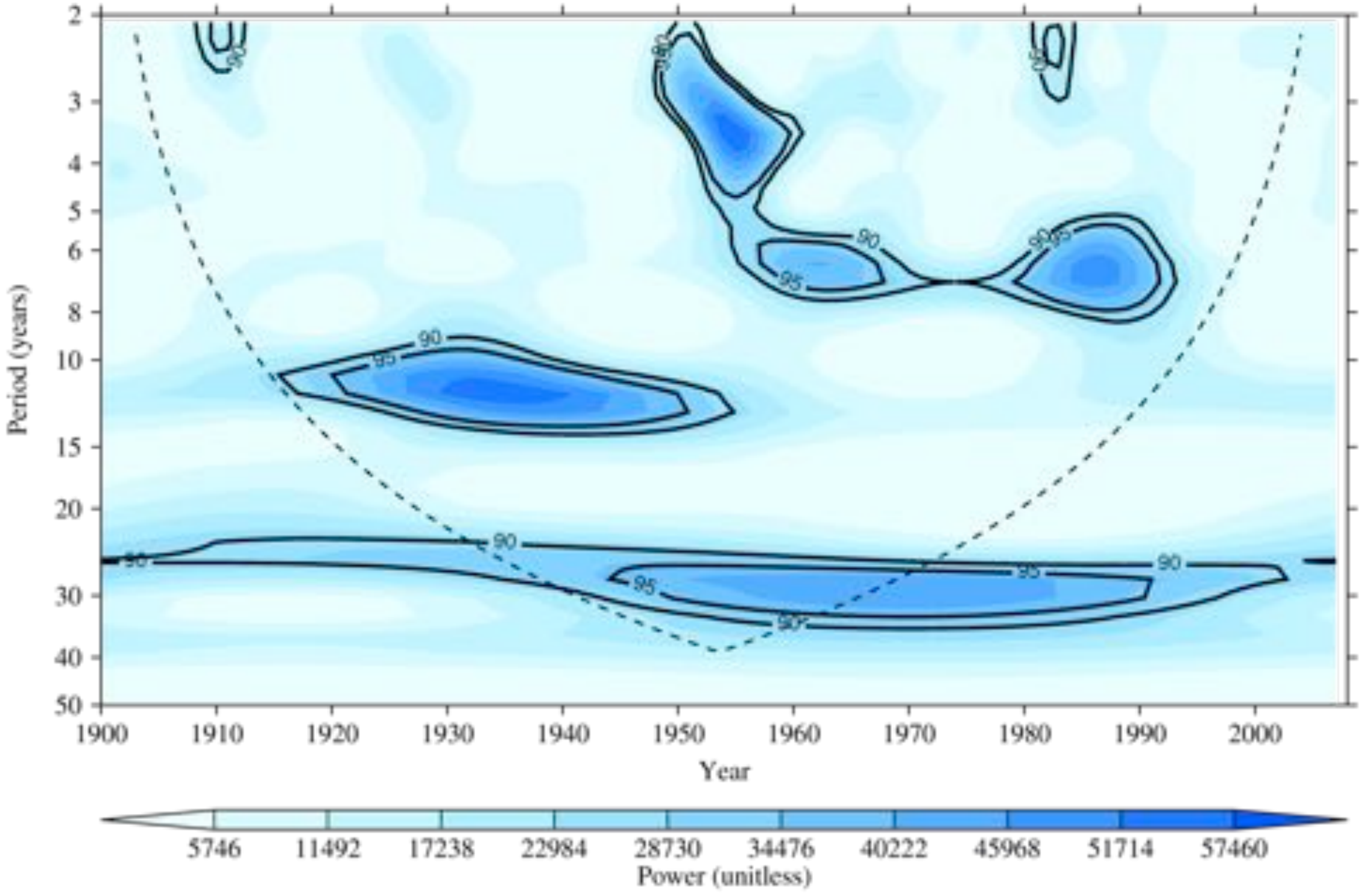
Wavelet transform of March-May EOT 2 timeseries



Patterns of autumn rainfall variability

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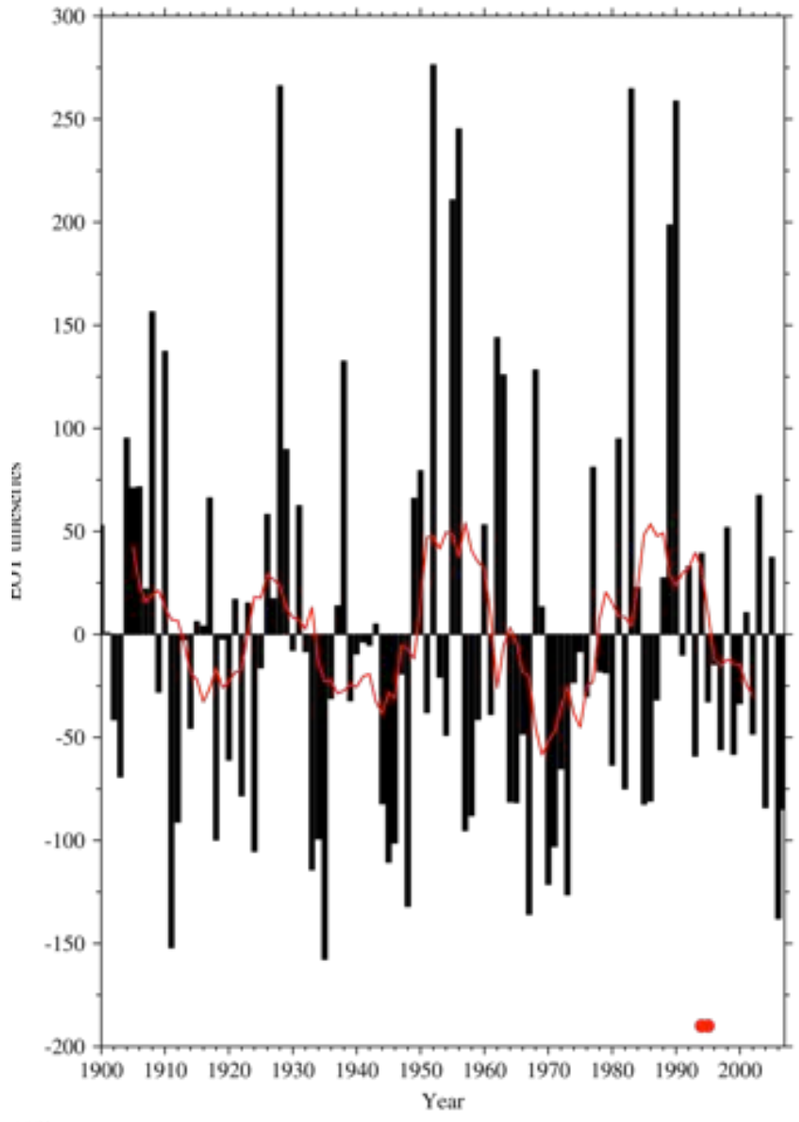
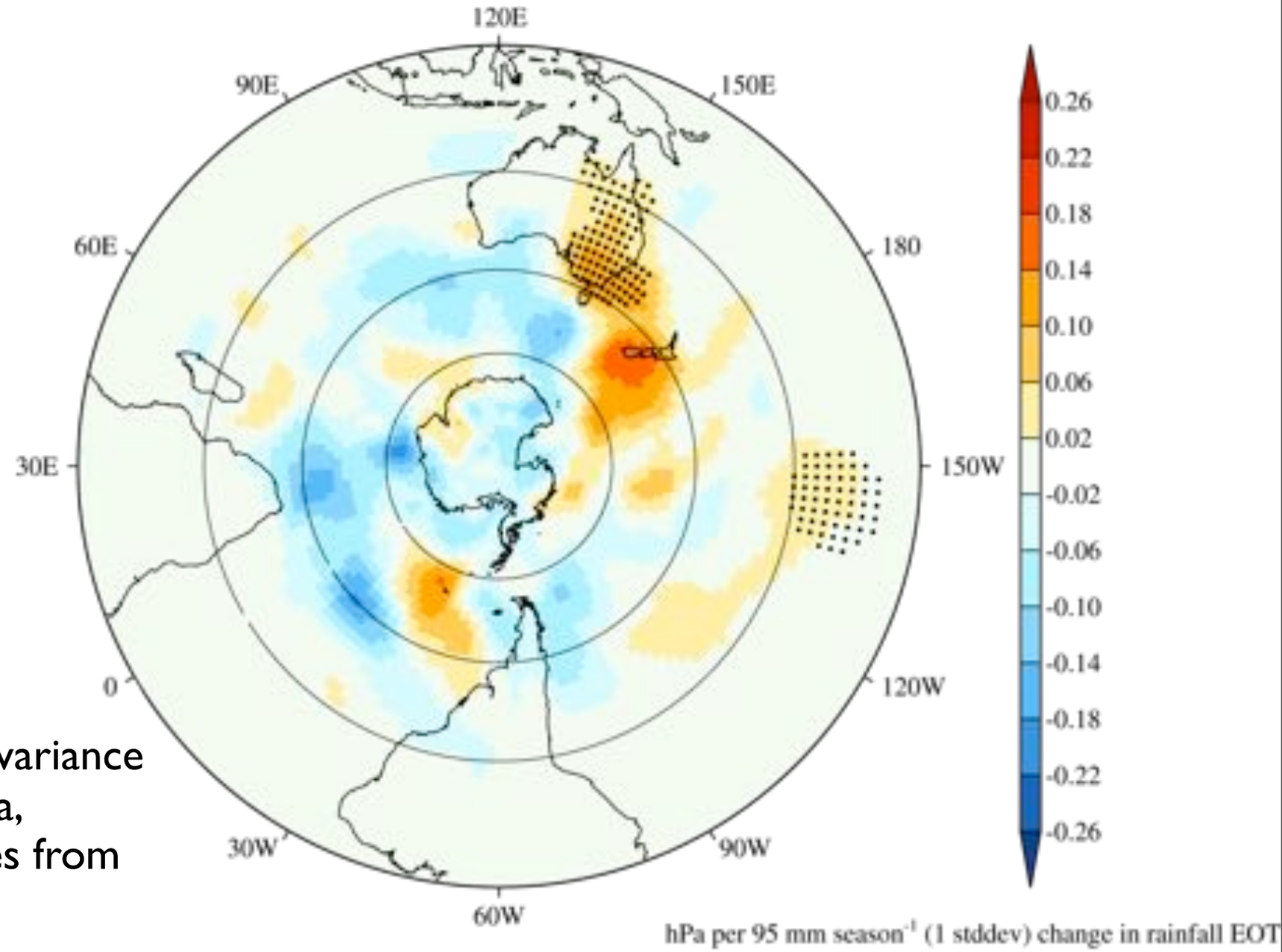
EOT 2 timeseries



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

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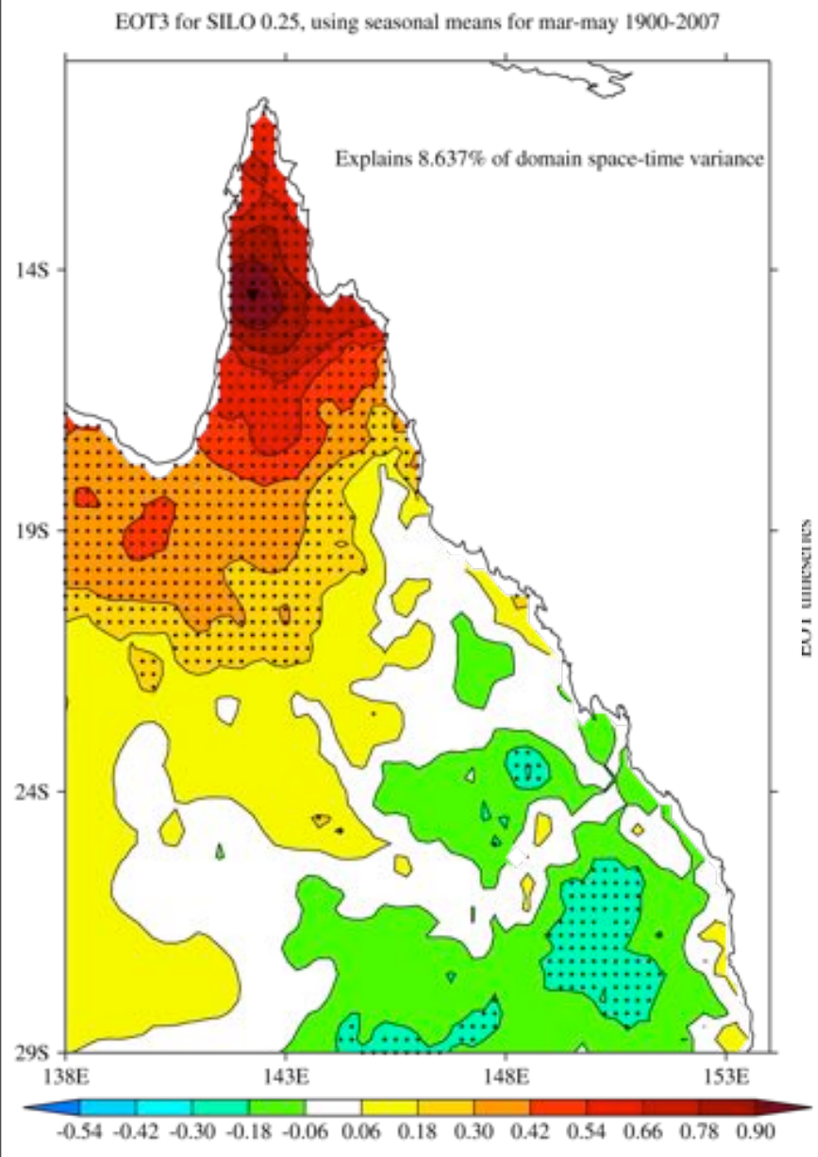
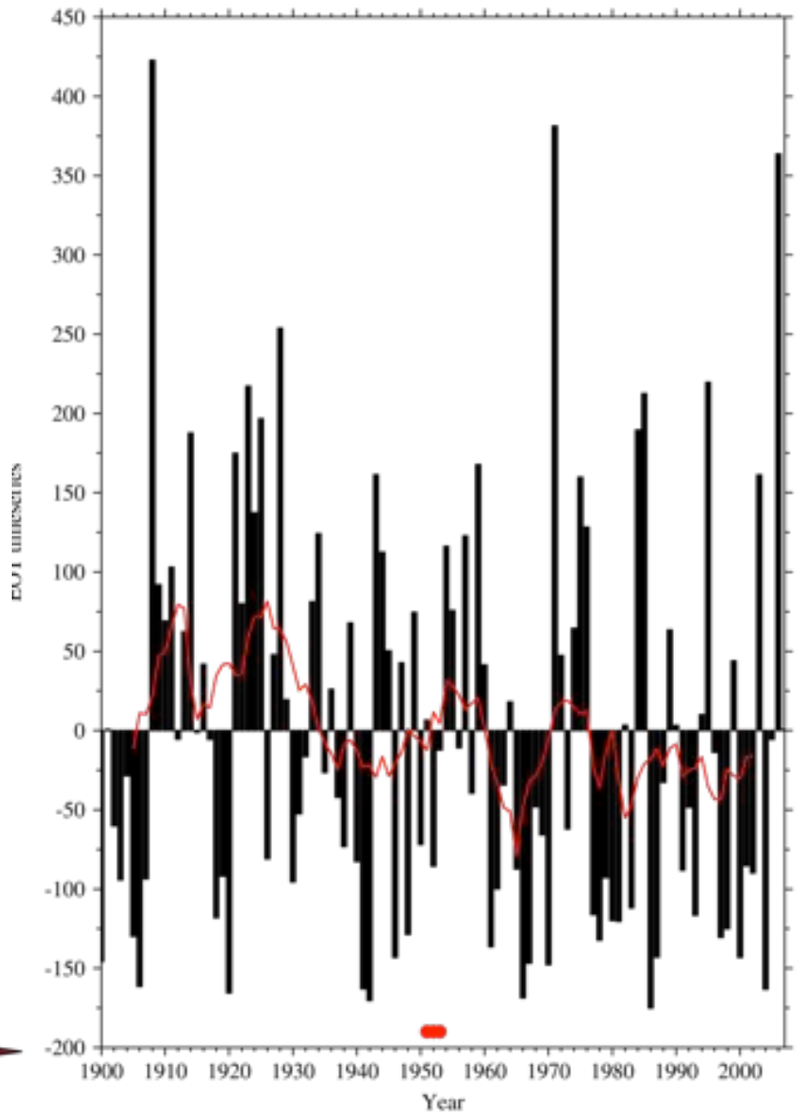
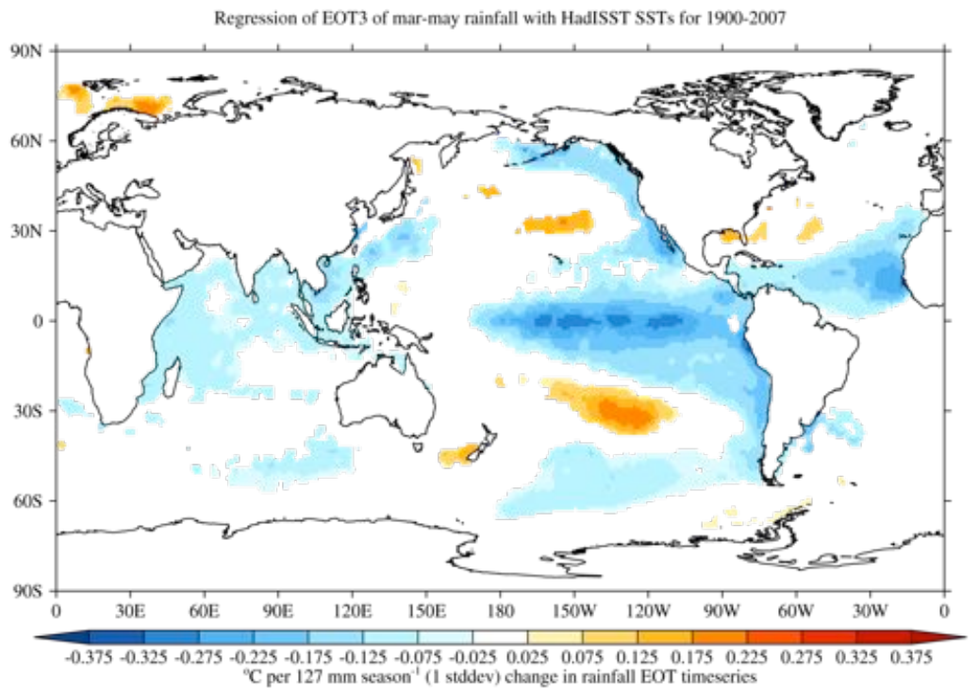
EOT 3 spatial pattern



EOT 3 timeseries



Regression of HadISST SSTs onto EOT 3 timeseries



ENSO 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.

Twentieth Century Reanalysis rainfall

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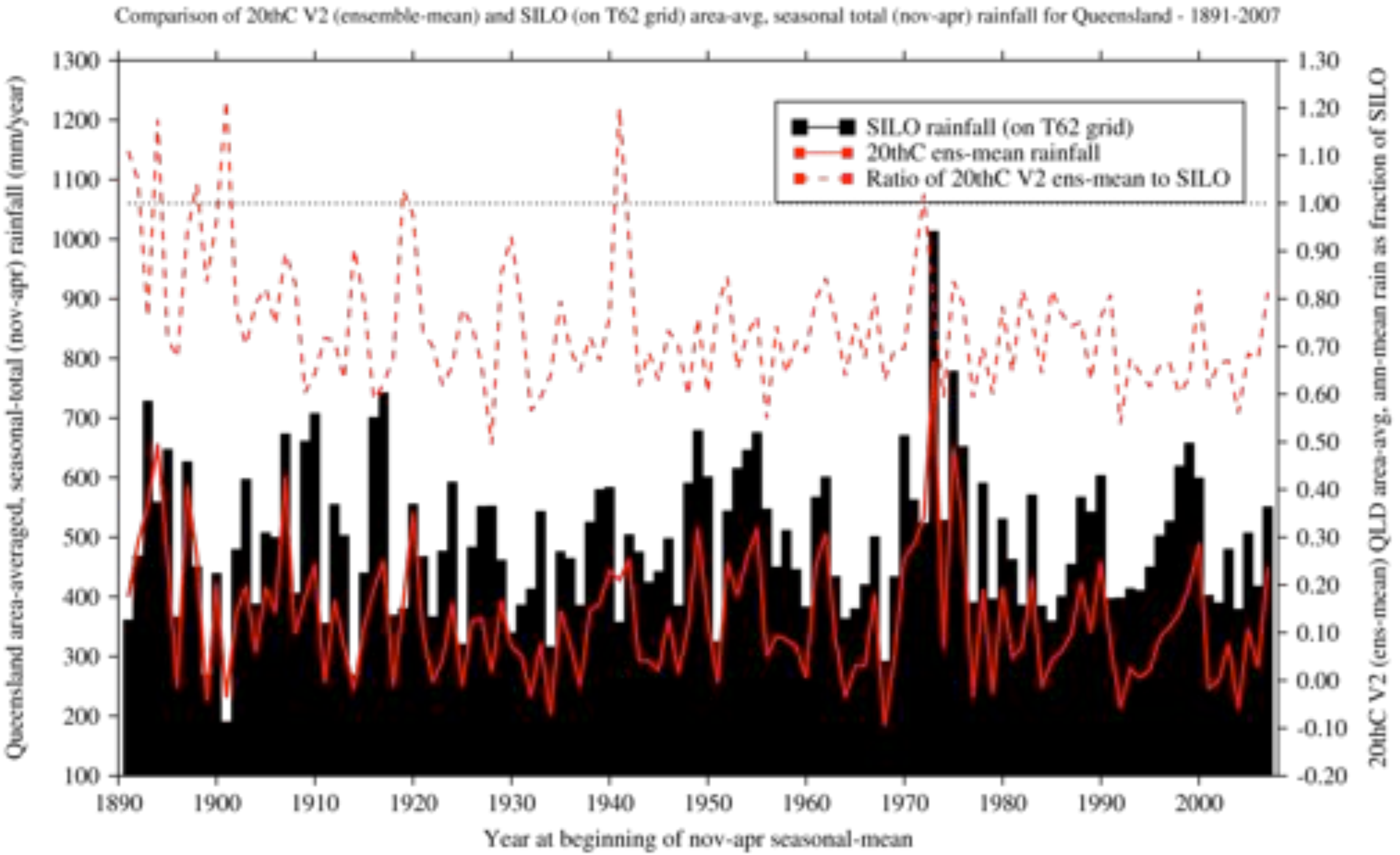

Twentieth Century Reanalysis rainfall

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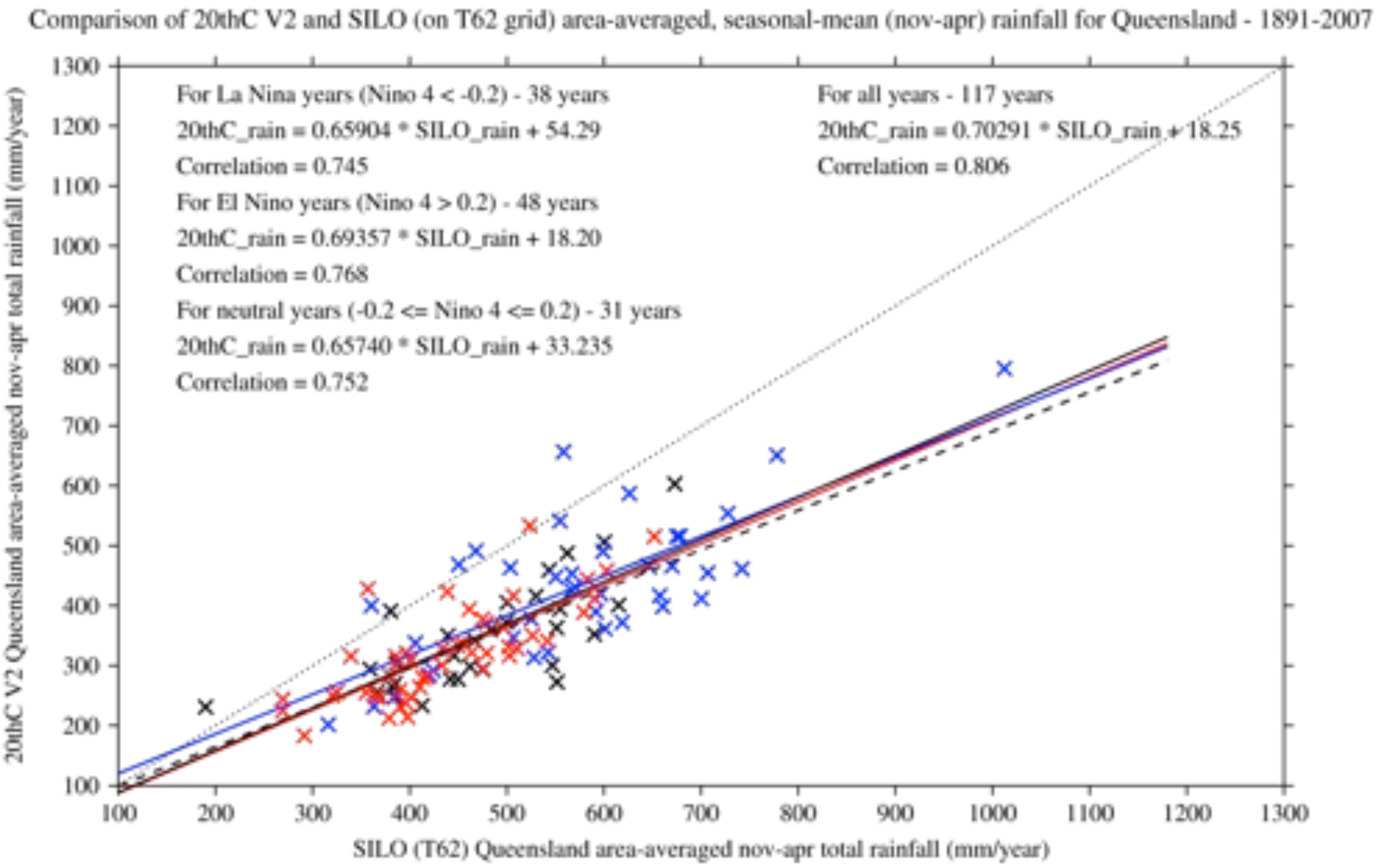

Twentieth Century Reanalysis rainfall

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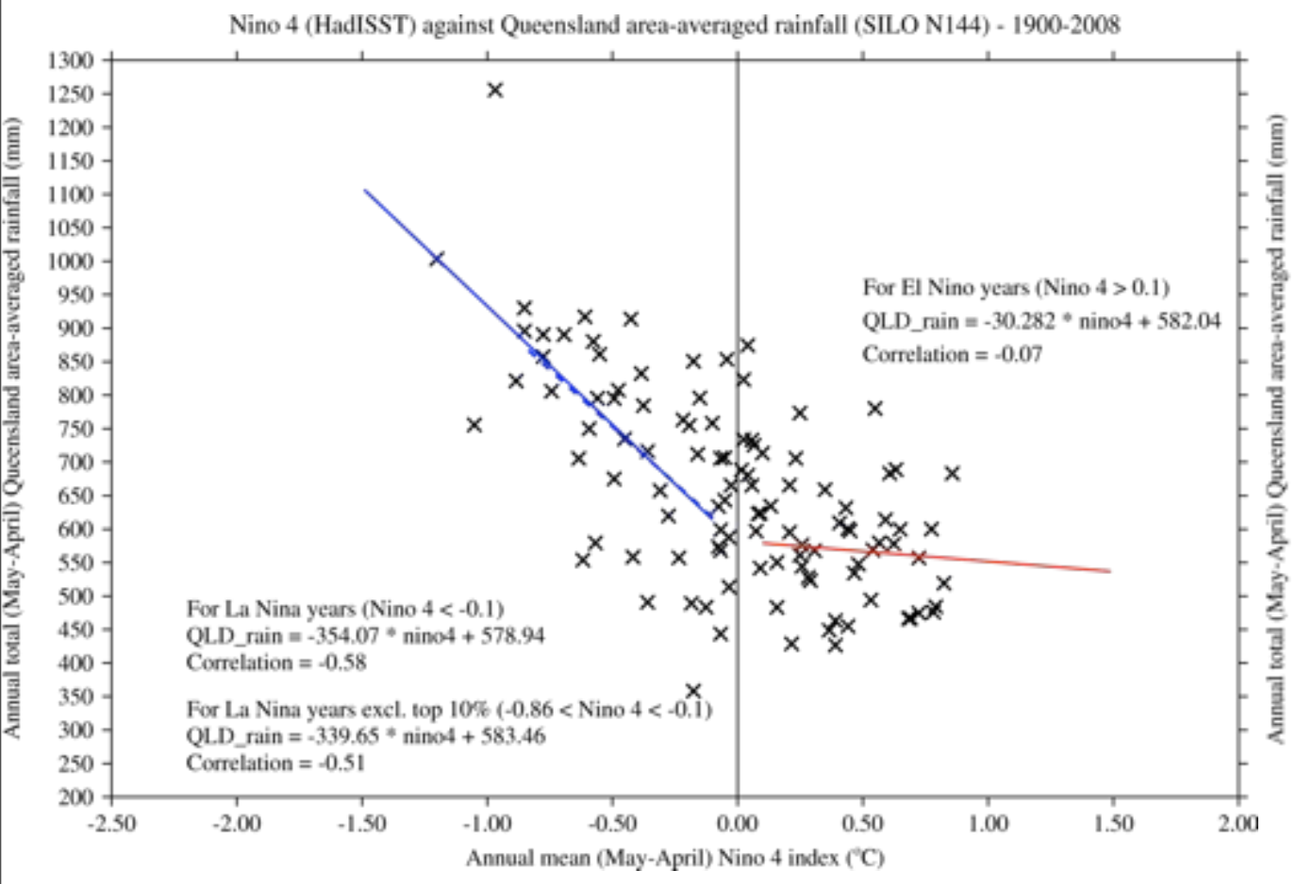
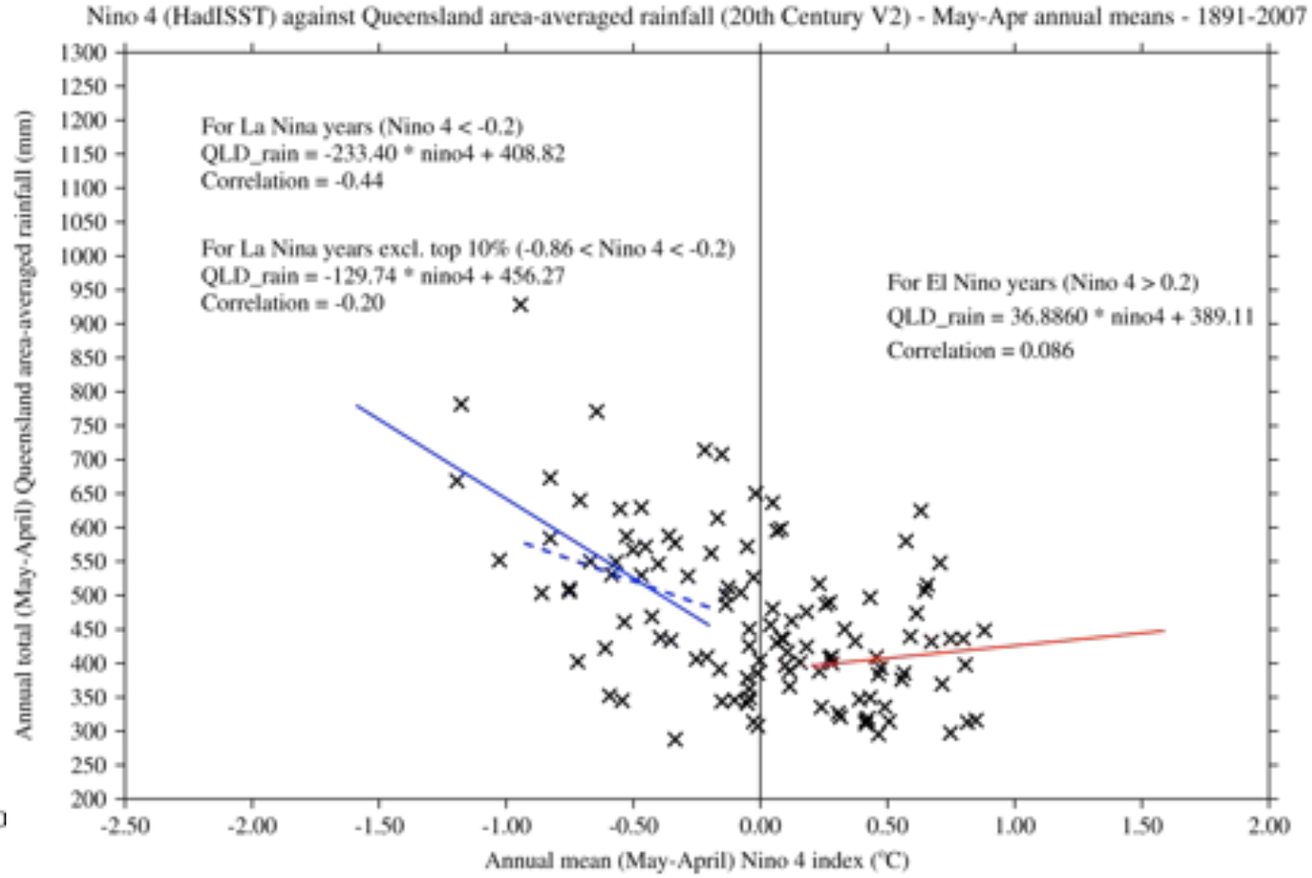
Scatterplots of Nino 4 SST anomalies (HadISST)
and Queensland annual-total (May-April) rainfall

Observations



Twentieth Century Reanalysis



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

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- 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.