On the drivers of inter-annual and decadal rainfall variability in Queensland, Australia

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Objectives

(1) To identify the large-scale climate drivers of inter-annual and decadal rainfall variability in Queensland.
(2) To examine the temporal variability in the strengths of these drivers during the past 100 years.

1. Queensland's variable rainfall

Queensland has experienced considerable inter-annual and decadal rainfall variability since at least the early 1900s (Fig. 1). The inter-annual standard deviation is approximately 25% of the mean, higher than many other tropical regions (c.f., the Indian monsoon, with a standard deviation 10% of the mean).

The relationship between eastern Australian rainfall and the El Nino-Southern Oscillation (ENSO; e.g., Allan, 1988; Wang and Henson, 2007) is well-known, but ENSO explains only 25% of the variance in Queensland rainfall; far less is understood about the drivers of the other 75% of the variance.

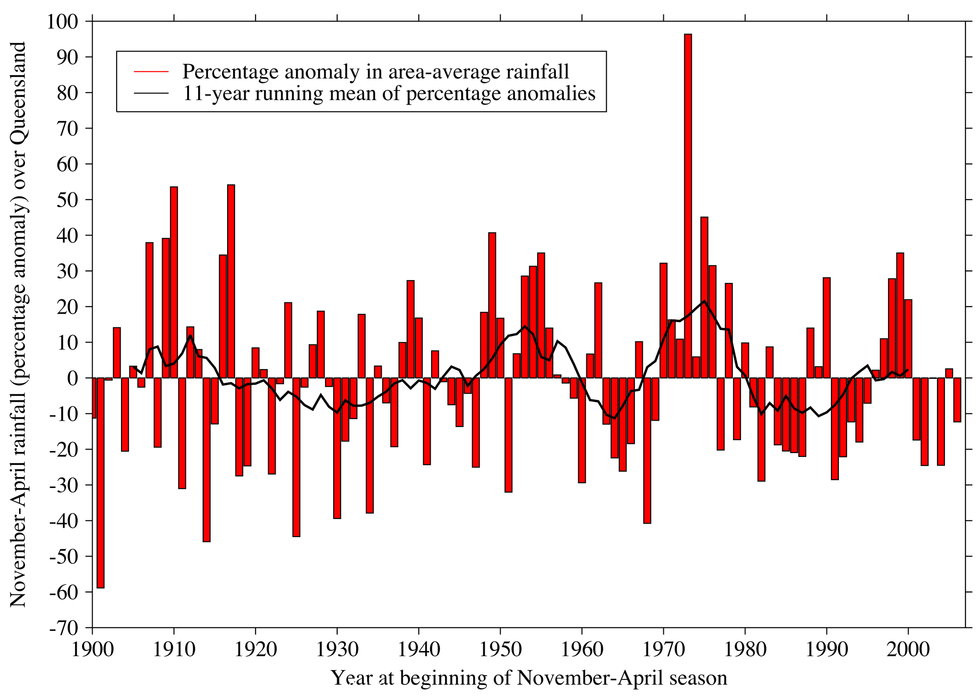


Figure 1: Wet season (November-April) rainfall in Queensland, expressed as a percentage anomaly from the long-term (1900-2008) mean.

Data taken from the SILO interpolated gauge dataset (section 2).

2. Data and methods

Empirical Orthogonal Teleconnection (EOT) analysis (Van den Dool et al., 2001; Smith et al., 2004) is applied to 1900-2008 seasonal-mean rainfall from the 25 km SILO interpolated gauge dataset. EOT analysis identifies patterns of variability based on correlations. The EOT 1 base point has the highest correlation with the Queensland-average rainfall; the spatial pattern is the correlation of every gridpoint with the central point. EOT 2 is computed similarly, after first removing EOT 1 from every point by linear regression. The first three EOTs in each season explain at least 55% of the variance and are analyzed here.

Linear regression on 20th Century Reanalysis (20CR; Compo et al., 2011) ensemble-mean fields determines the circulation patterns associated with each EOT.

3. ENSO-driven EOTs

The leading, state-wide EOTs in DJF (37.7% variance), JJA (45.1%) and SON (41.3%) are highly correlated with ENSO. In MAM, ENSO affects only tropical northern Queensland and is associated with EOT 3 (8.0%).

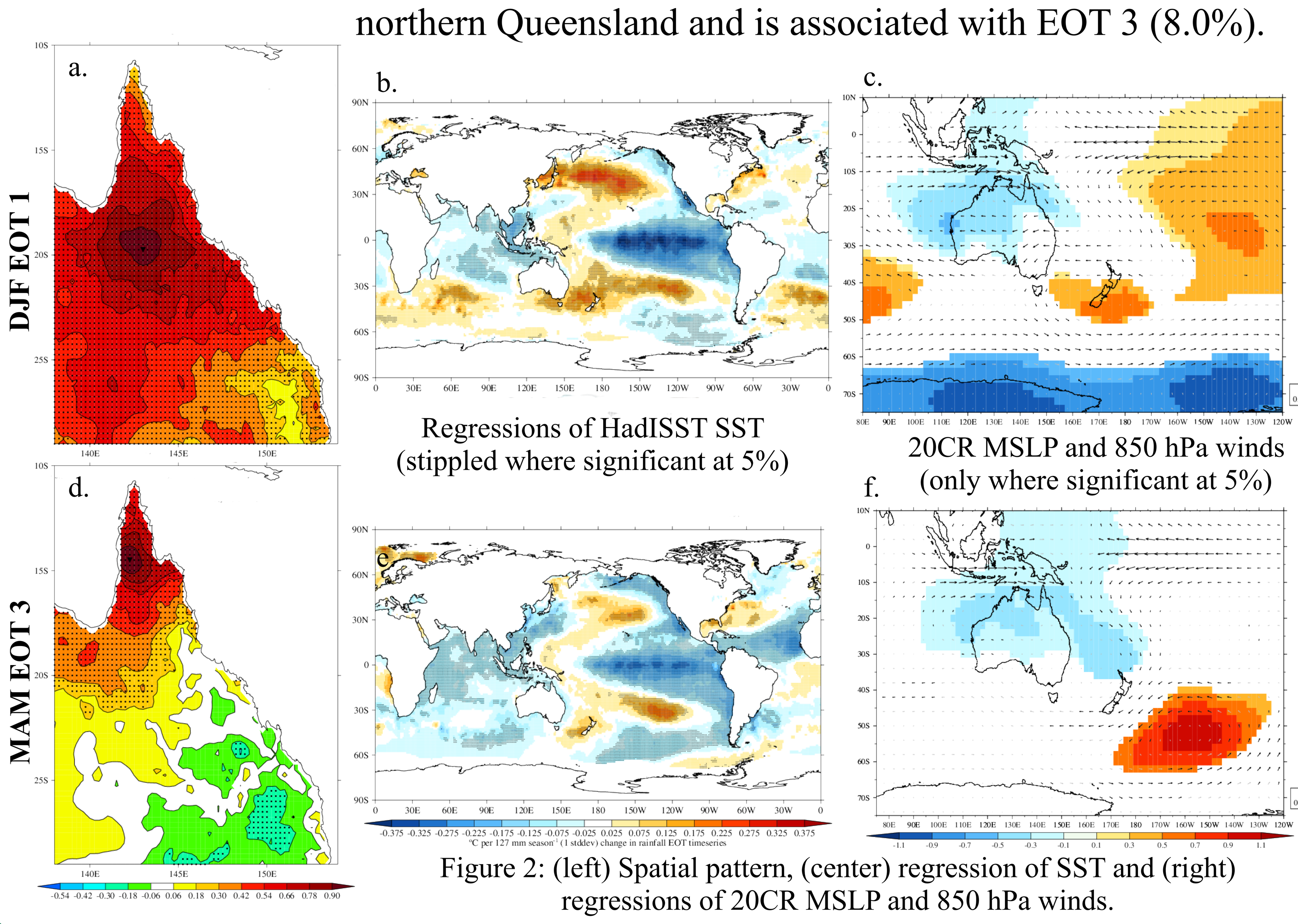
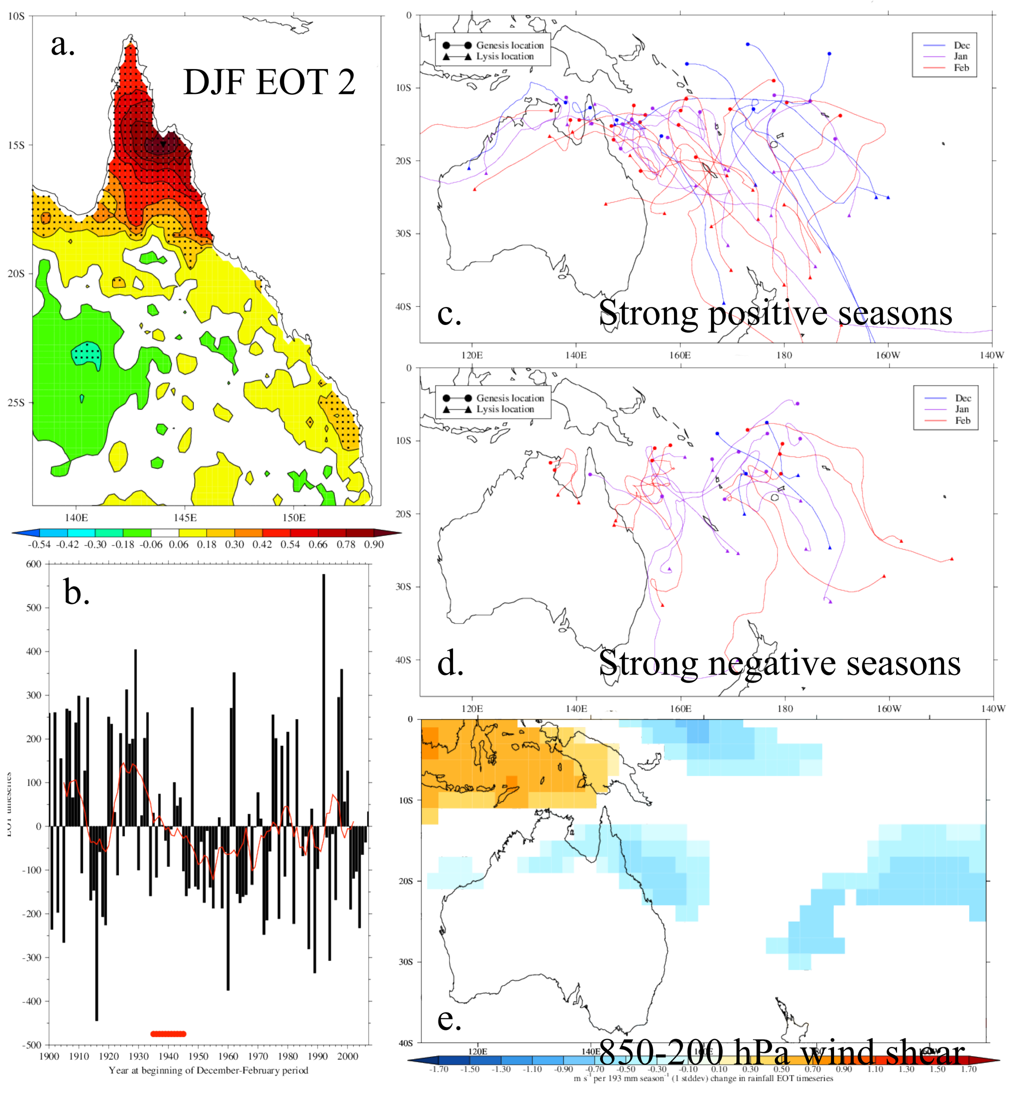


Figure 2: (left) Spatial pattern, (center) regression of SST and (right) regressions of 20CR MSLP and 850 hPa winds.

Conclusions

(1) State-wide variations: ENSO is the leading driver in DJF, JJA and SON; in MAM, locally driven variations in the late-season monsoon dominate.
(2) Cape York and SE Queensland emerge as regions of coherent rainfall variability. Cape York summer rainfall is associated with tropical-cyclone activity; SE Queensland rainfall is driven by onshore winds and coastal cyclones.

4. Tropical cyclones

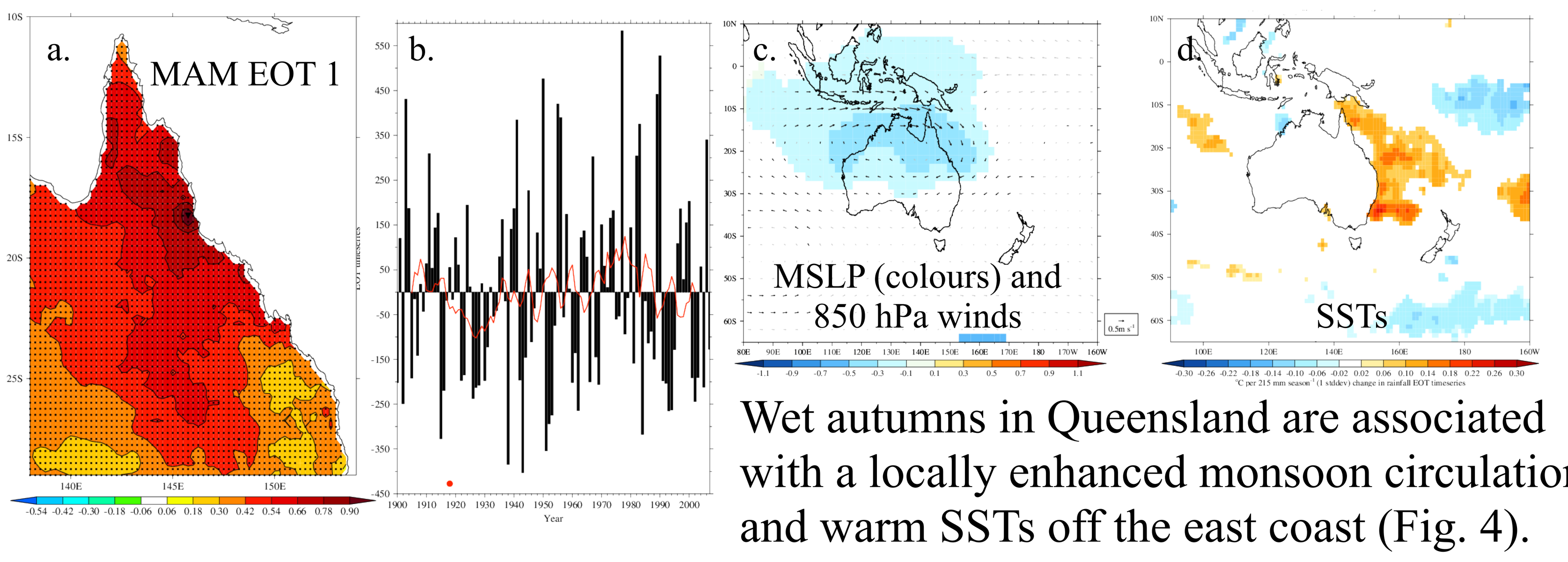


DJF EOT 2 (8.6%; Fig. 3a) explains the most variance in Cape York, northern Queensland. The timeseries (Fig. 3b) has little correlation with ENSO.

Composites of seasons above (Fig. 3c) and below (Fig. 3d) one standard deviation show a strong association with tropical cyclone tracks in the Coral Sea. Wet summers are associated with greater cyclone activity, supported by lower vertical shear (Fig. 3e).

Figure 3: The (a) spatial pattern and (b) timeseries of DJF EOT 2. Composites of IBTrACS cyclone tracks in seasons (c) above and (d) below one standard deviation (1979-2008 only). (e) Regressions on 20CR vertical shear (only where significant at 5%).

5. The leading, state-wide autumn EOT



Wet autumns in Queensland are associated with a locally enhanced monsoon circulation and warm SSTs off the east coast (Fig. 4).

Figure 4: The (a) spatial pattern and (b) timeseries of MAM EOT 1. Regressions on (c) 20CR MSLP and 850 hPa winds and (d) HadISST SSTs. Regressions are shown only where significant at 5%.

6. Onshore winds in the southeast

Rainfall variability in the southeast in DJF (Fig. 5a-d), MAM (not shown) and JJA (Fig. 5e-h) is associated with blocking and onshore winds. These EOTs show significant decadal variability, but are not correlated with ENSO or decadal Pacific SST variability.

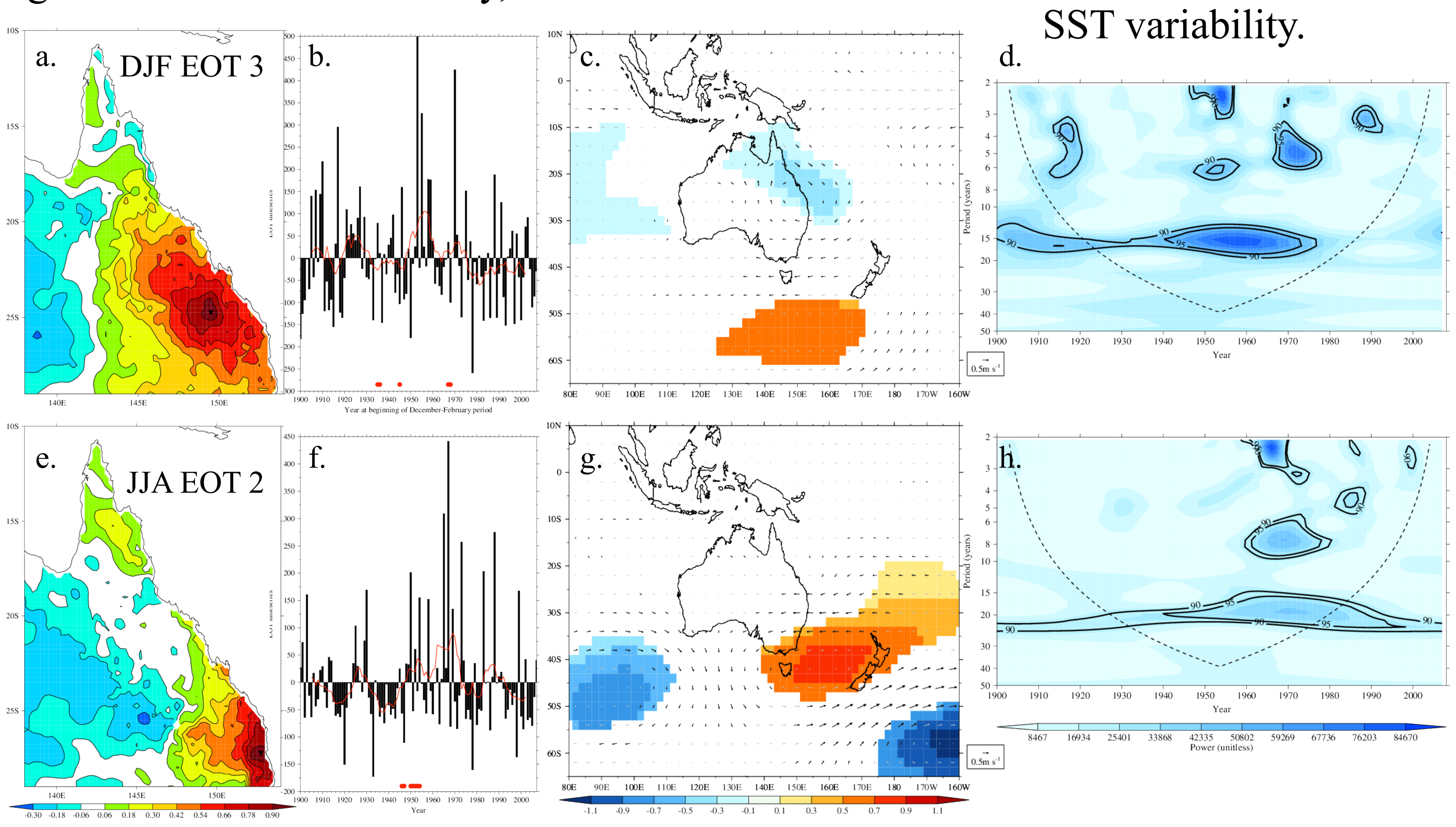


Figure 5: The (a,e) spatial patterns, (b,f) timeseries, (c,g) regressions of 20CR MSLP and 850 hPa winds and (d,h) wavelet transforms with a Morlet mother wavelet for (a-d) DJF EOT 3 (7%) and (e-h) JJA EOT 2 (14%).

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