

Climate driver impacts on global ocean surface waves



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Bureau of Meteorology



Aims

Focus on influence of the MJO and SAM on global ocean surface waves

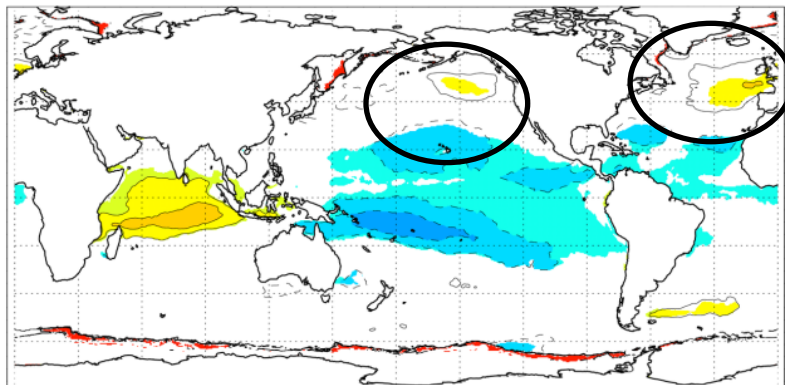
Wave field: significant wave height (H_s) is the most commonly observed wave variable

This varies with local variations in surface zonal wind

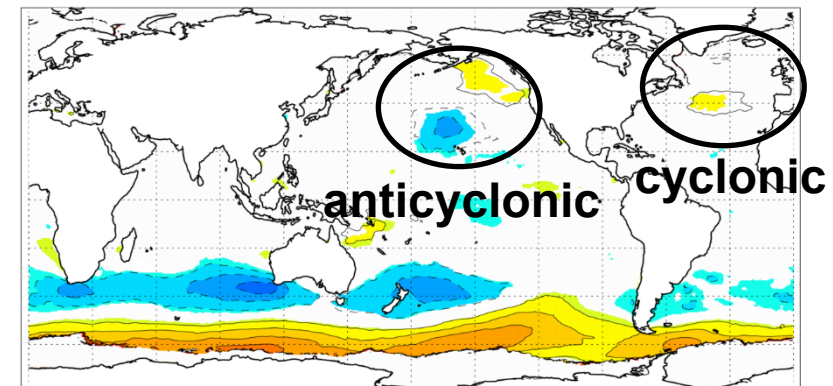
Potential for subseasonal predictive capability of ocean surface waves, to benefit coastal management

Zonal wind anomalies:

MJO phase 4 (Nov-Apr)



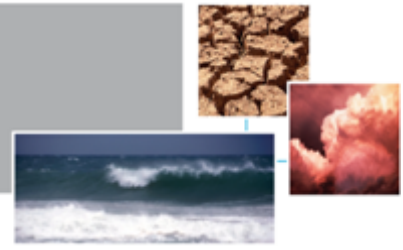
Positive SAM (DJF)



Resembles a Rossby wave train emanating out of the tropics...



The CAWCR wave hindcast



Hindcast output from surface wave model forced with high quality surface winds...

CFSR winds

(Climate Forecast System Reanalysis)



WAVEWATCH IIITM model version 4.08

- hourly surface winds & sea ice
- 0.3° horizontal resolution
- provides unprecedented depiction of global surface winds



CAWCR wave hindcast Durrant et al. (2014)

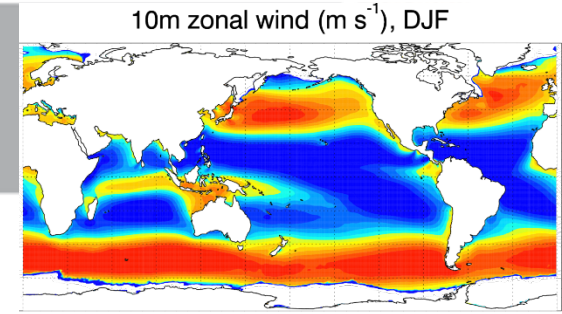


Global wave data:

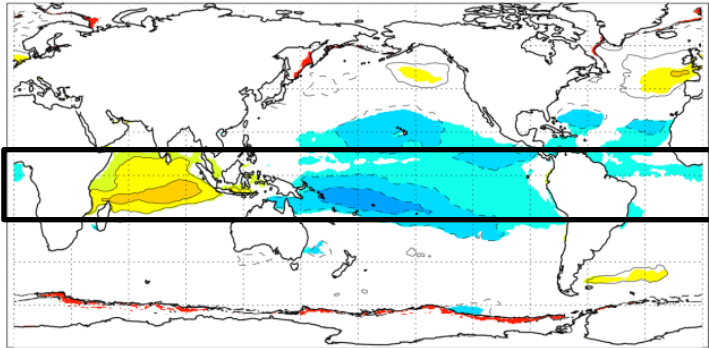
- significant wave height (H_s)
- peak period (T_p)
- wave energy flux ($C_g E$)
- 0.4° horizontal resolution
- hourly output, 1979-2009

MJO H_s anomalies

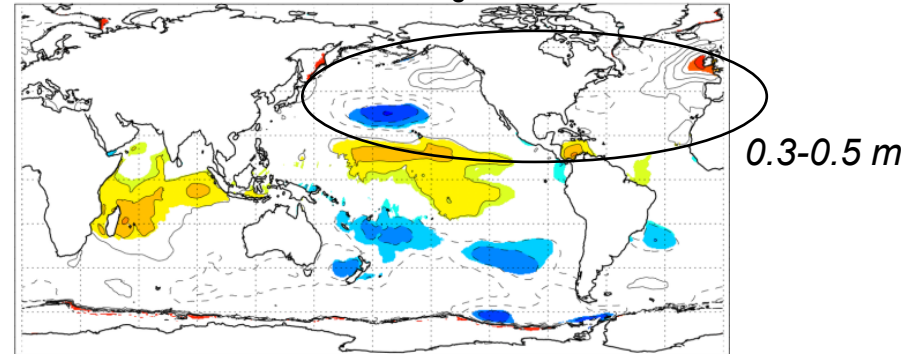
**Positive H_s where westerly anomalies act on a westerly mean state,
and easterly anomalies act on an easterly mean state**



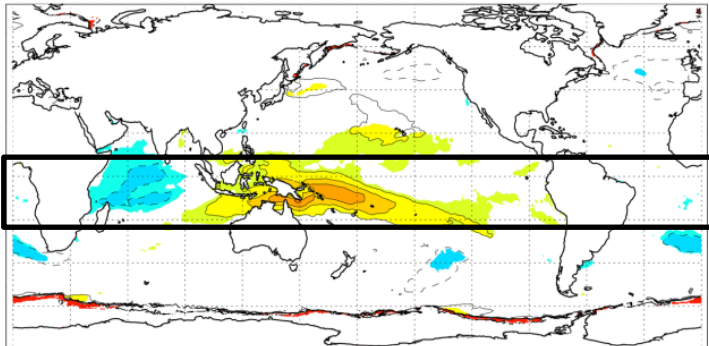
Phase 4 u_{10}



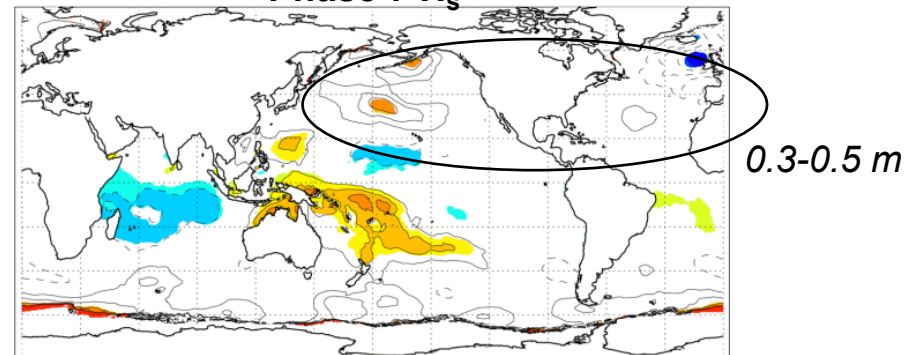
Phase 4 H_s



Phase 7 u_{10}



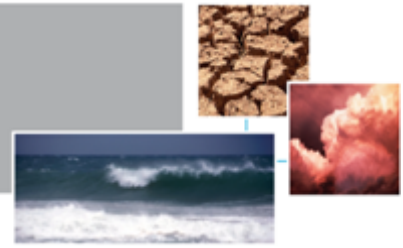
Phase 7 H_s



Negative H_s with easterly anomalies

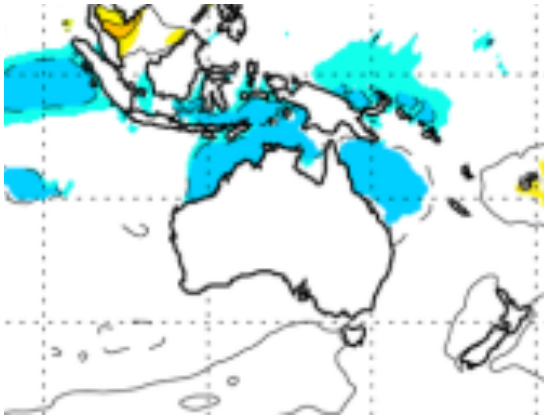


Australian coastal wave responses to the MJO: 0.4-0.5 m

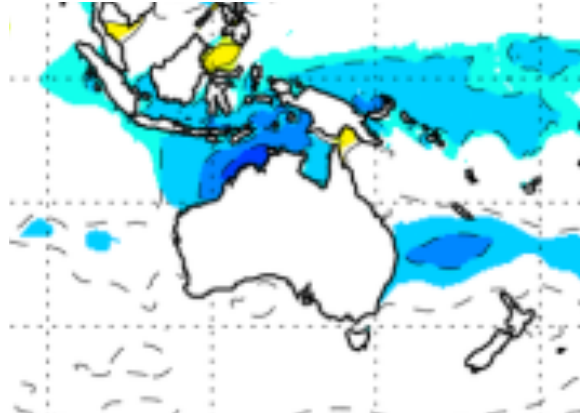


Pronounced wave height response along the NW Australian shelf

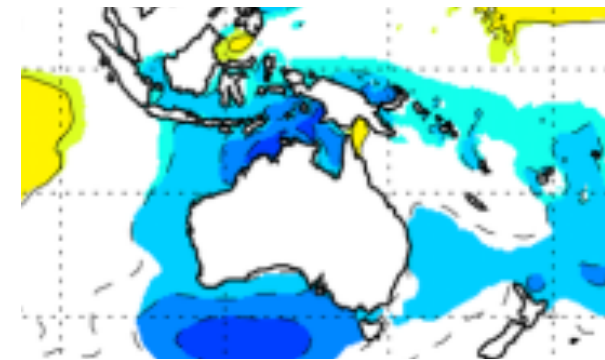
Phase 1



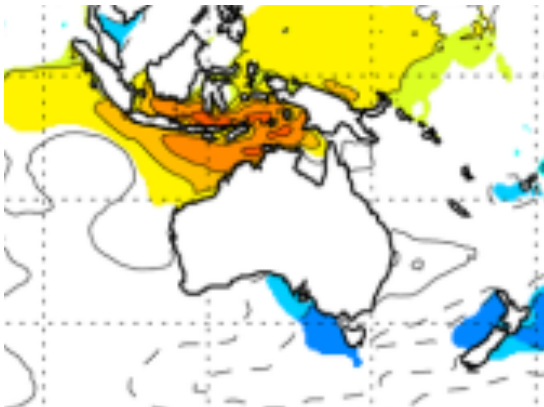
Phase 2



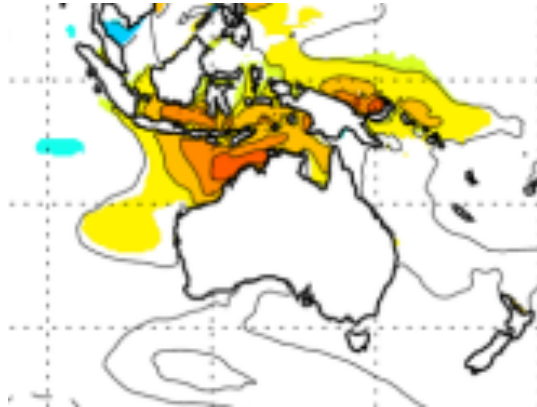
Phase 3



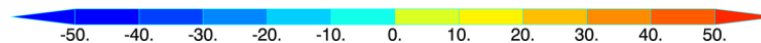
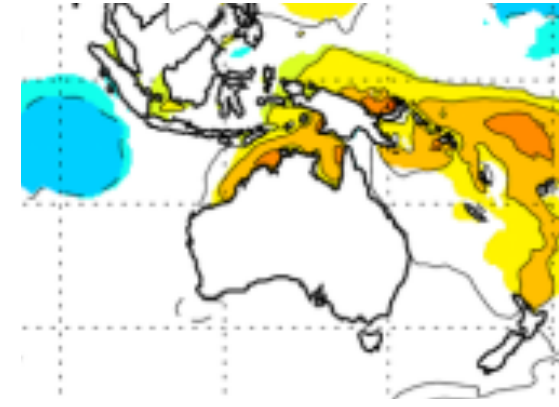
Phase 5



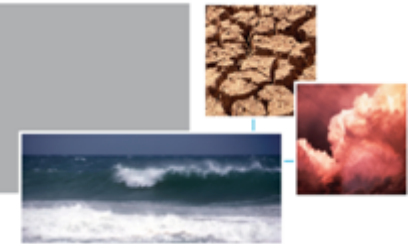
Phase 6



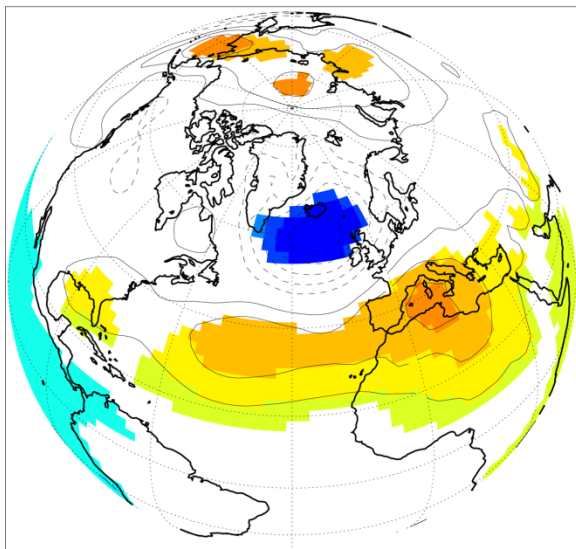
Phase 7



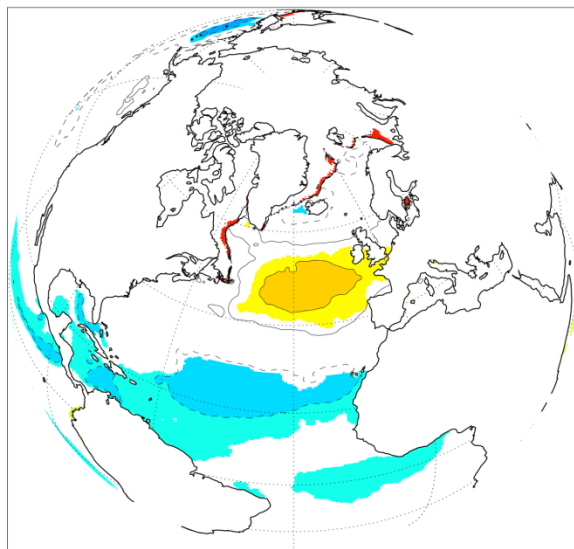
MJO-NAO teleconnection



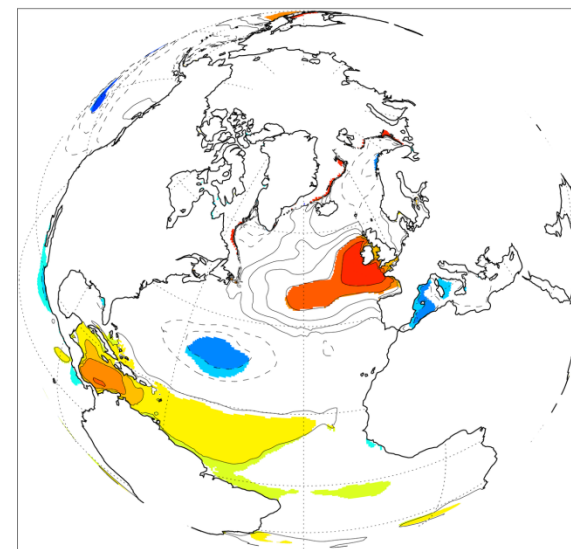
MSLP (hPa)



u10 (m/s)

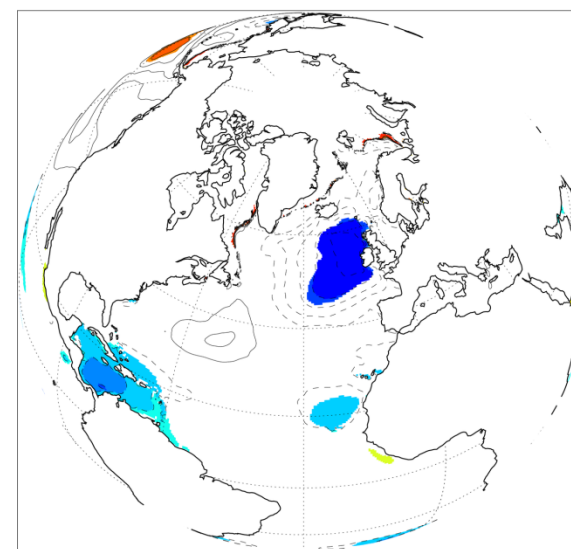
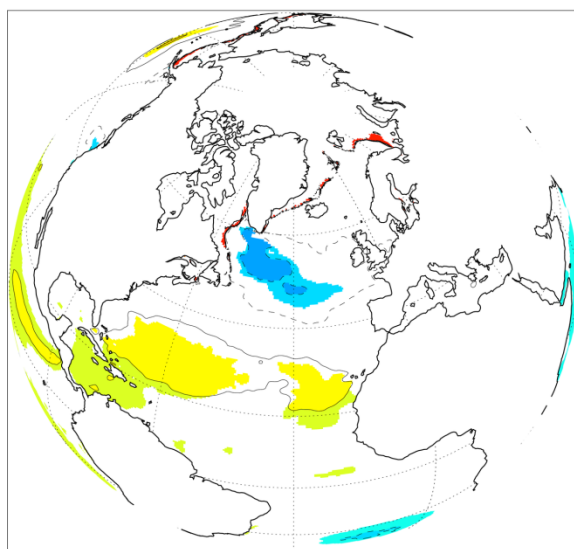
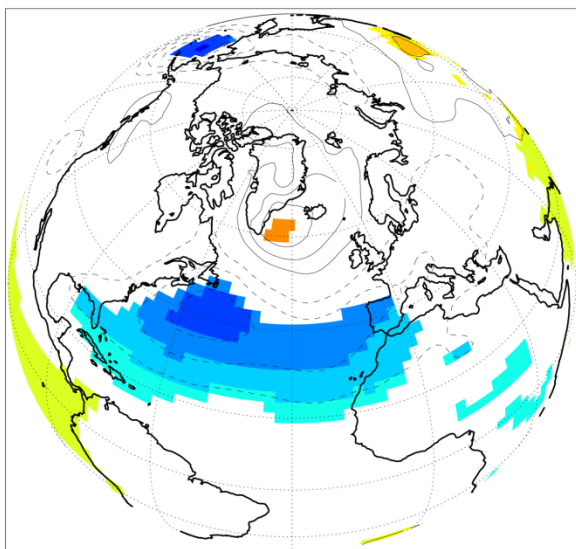


H_s (cm)

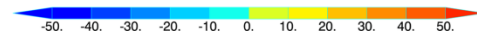


MJO ph 4 + 7 d: NAO+
(~1 week after suppress. conv. in
Central Pacific)

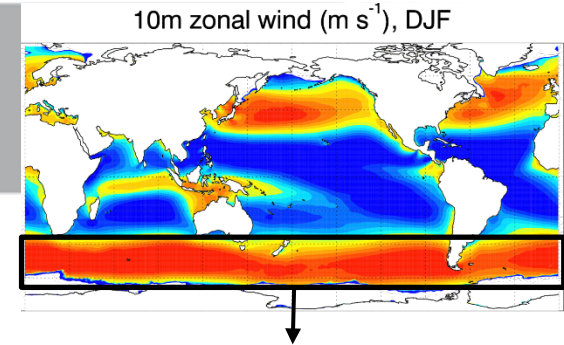
**I.e. Rossby wave train takes ~ 1
week to disperse from the
tropics to the North Atlantic**



MJO ph 7 + 7 d: NAO-
(~1 week after active conv. in
Central Pacific)

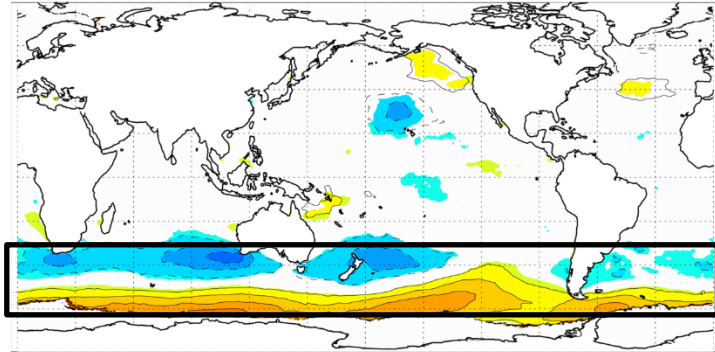


SAM H_s anomalies

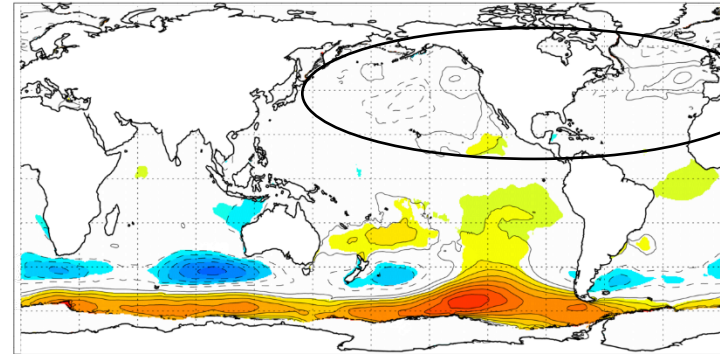


**Westerly
mean state**

10m zonal wind (m s^{-1}), positive SAM, DJF



Sig. wave height (m), positive SAM, DJF

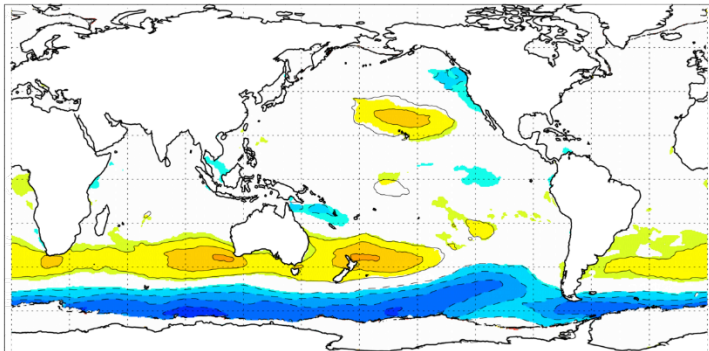


Positive H_s with westerly anomalies

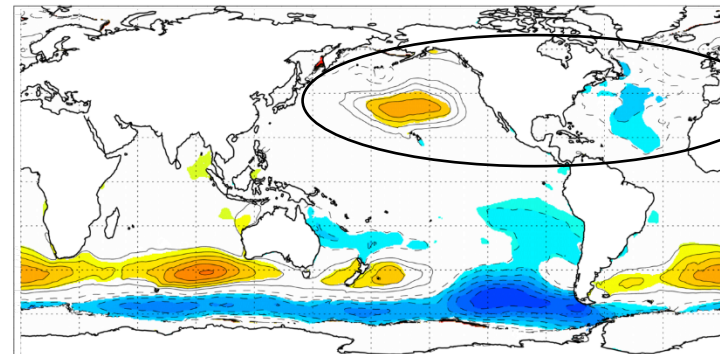
0.3-0.4 m

0.5-1 m

10m zonal wind (m s^{-1}), negative SAM, DJF



Sig. wave height (m), negative SAM, DJF



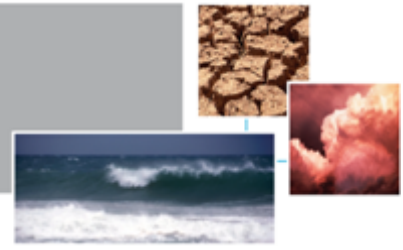
Negative H_s with easterly anomalies

0.3-0.4 m

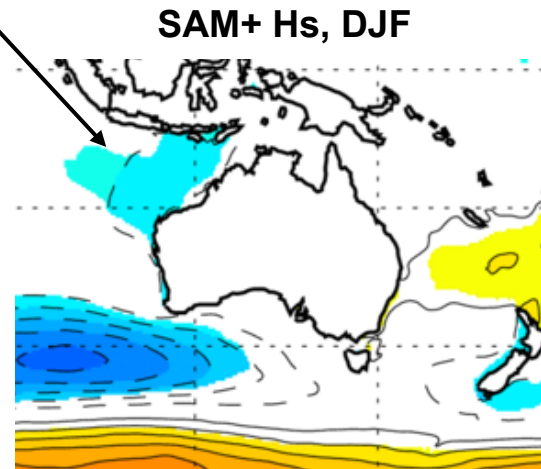
0.5-1 m



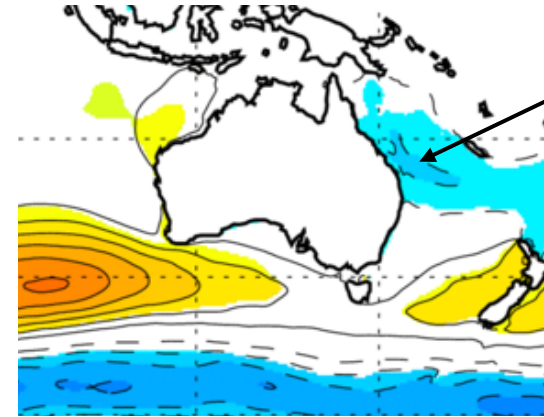
Australian coastal wave responses to the SAM: 0.1-0.3 m



In SON and DJF, wave height anomalies along the NW shelf

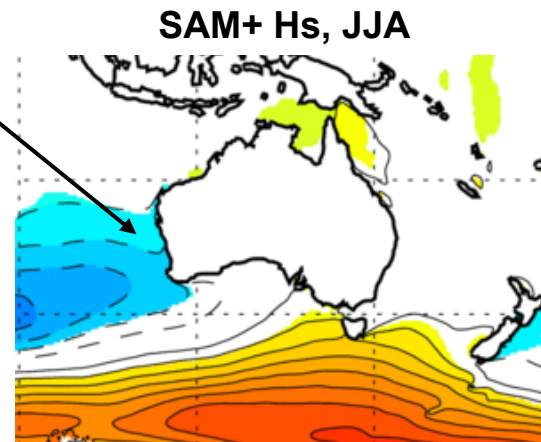


SAM- Hs, DJF

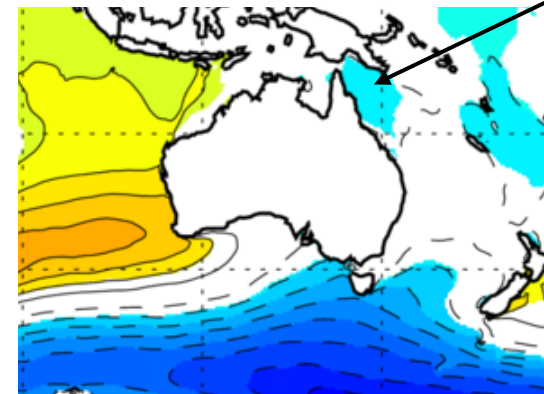


In DJF, wave height anomalies along the east coast

In all seasons, wave height anomalies off the SW Aus coast (Leeuwin Current)



SAM- Hs, JJA



In JJA, wave height anomalies on the northeast coast

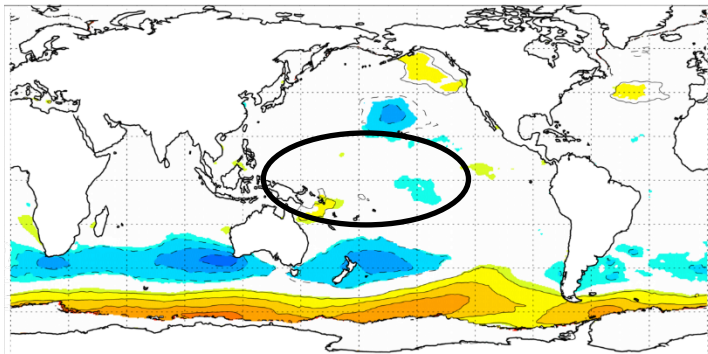


ENSO weakens the SAM link to the Northern Hemisphere

SAM is significantly anticorrelated with ENSO in DJF

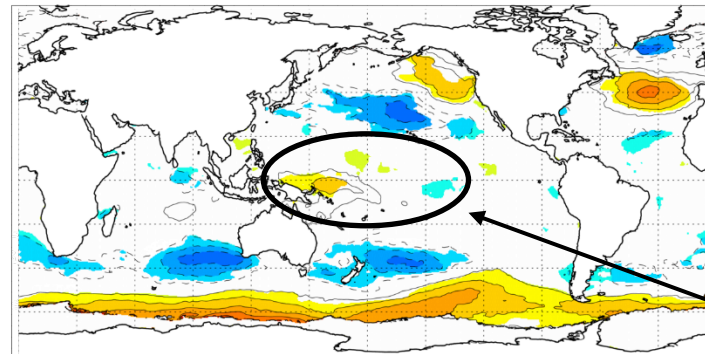
ENSO included

10m zonal wind (m s^{-1}), positive SAM, DJF



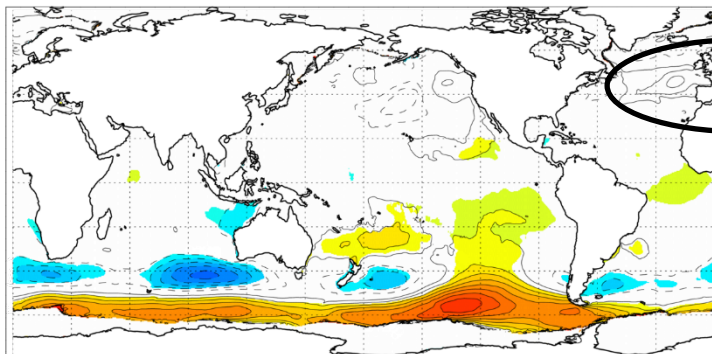
No ENSO

10m zonal wind (m s^{-1}), positive SAM, DJF

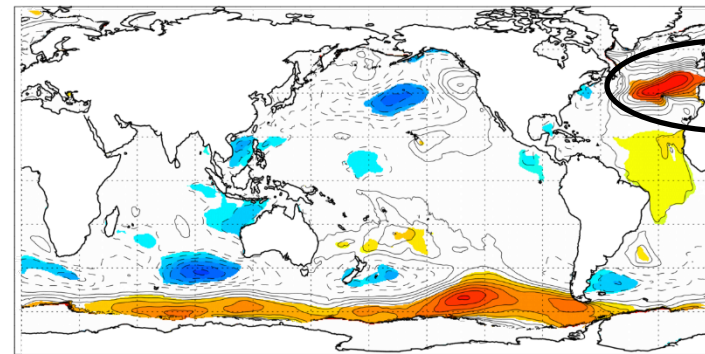


Intensification of the Northern Hemisphere signal, particularly over the North Atlantic (0.8 m, cf. 0.4 m)

Sig. wave height (m), positive SAM, DJF



Sig. wave height (m), positive SAM, DJF

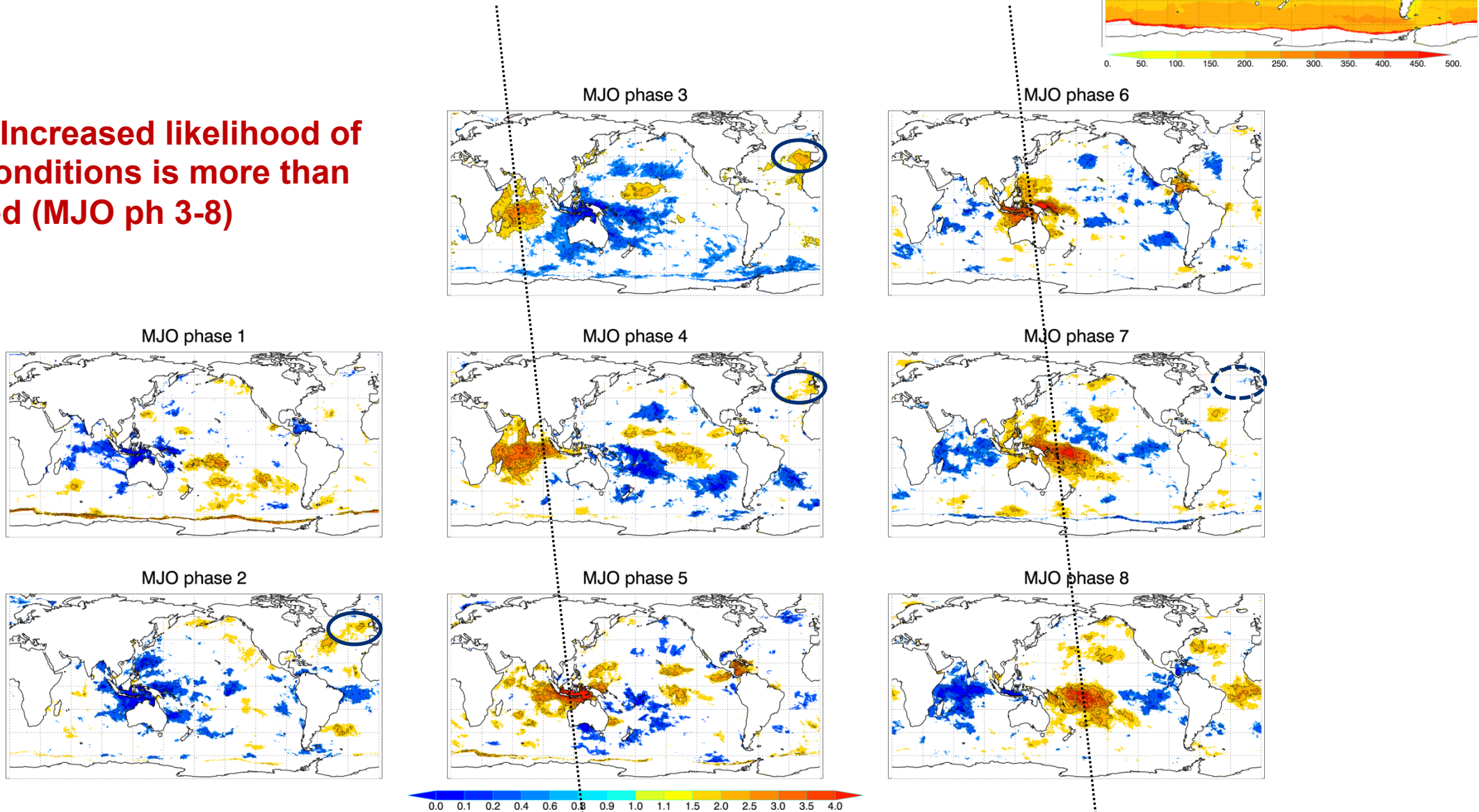


Enhanced divergence: teleconnection to extratropics (e.g. Hoskins and Karoly 1981).

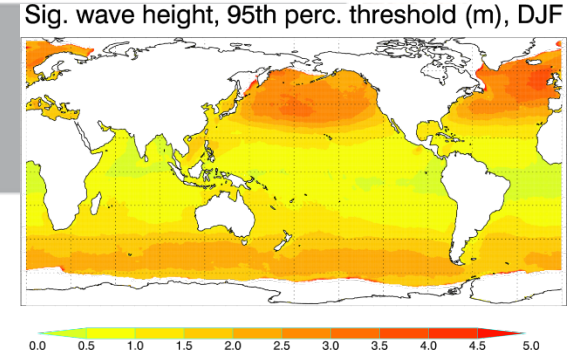
SAM drives changes to the tropical atmospheric circulation independent of ENSO

MJO impact on high wave conditions (above 95th %)

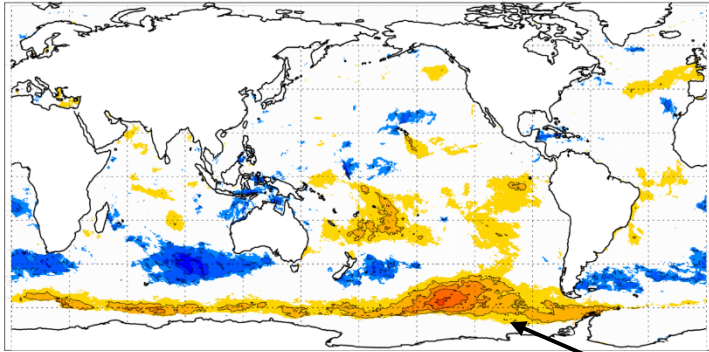
Indo Pacific: Increased likelihood of high wave conditions is more than tripled (MJO ph 3-8)



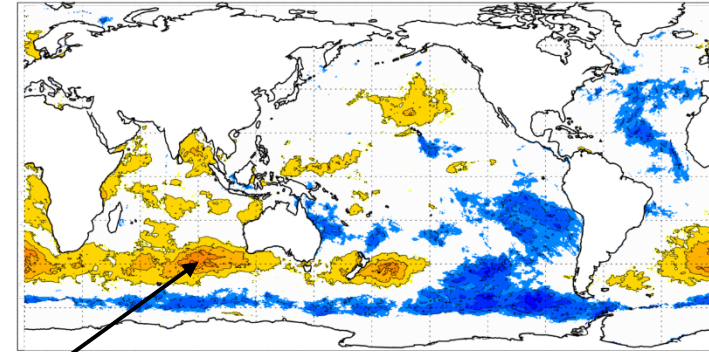
SAM impact on high wave conditions (above 95th %)



SWH above 95th percentile, positive SAM, DJF



SWH above 95th percentile, negative SAM, DJF

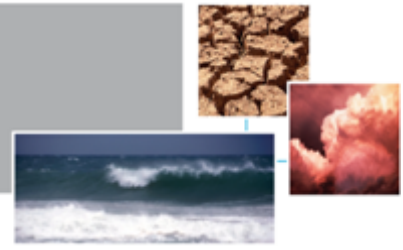


Up to three times the normal likelihood of high wave conditions

Implications for trends in wave conditions, considering the positive trend in the SAM over recent decades



Take-home points

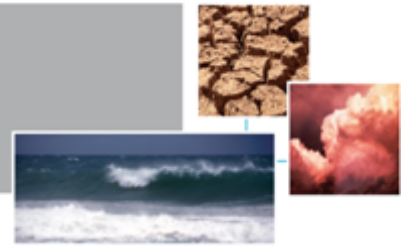


Understanding driver impacts can help underpin development of subseasonal predictive capability of global ocean surface waves (including for the Northern Hemisphere during austral summer)

Practical benefits of this understanding include anticipating wave-induced coastal inundation and long-term management of coasts.

These climate drivers may have a significant influence on shoreline position/stability, particularly in the context of projected future sea-level rise.

Key questions

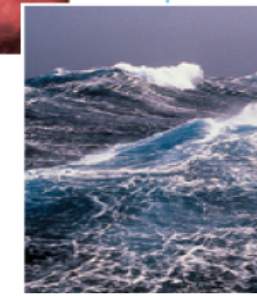


How these driver-induced wave variations translate to predictability of global ocean surface waves on subseasonal and longer timescales

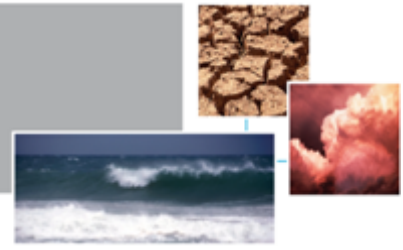
Better understanding / elucidating the ENSO-independent SAM-driven changes to the tropical atmospheric circulation and their impact on climate extremes

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Thank you



Wave fields



H_s : most commonly observed wave variable

T_p : indicates the source of waves. Short periods for locally generated and longer periods for distally generated swell.

$C_g E$: indicates the potential force of the waves on coastal or offshore infrastructure

$C_g E$ depends on H_s and the period T :

$$C_g E = \rho \cdot g^2 \cdot H_s^2 \cdot T / 64\pi$$

(ρ is the water density and g is the gravitational acceleration)

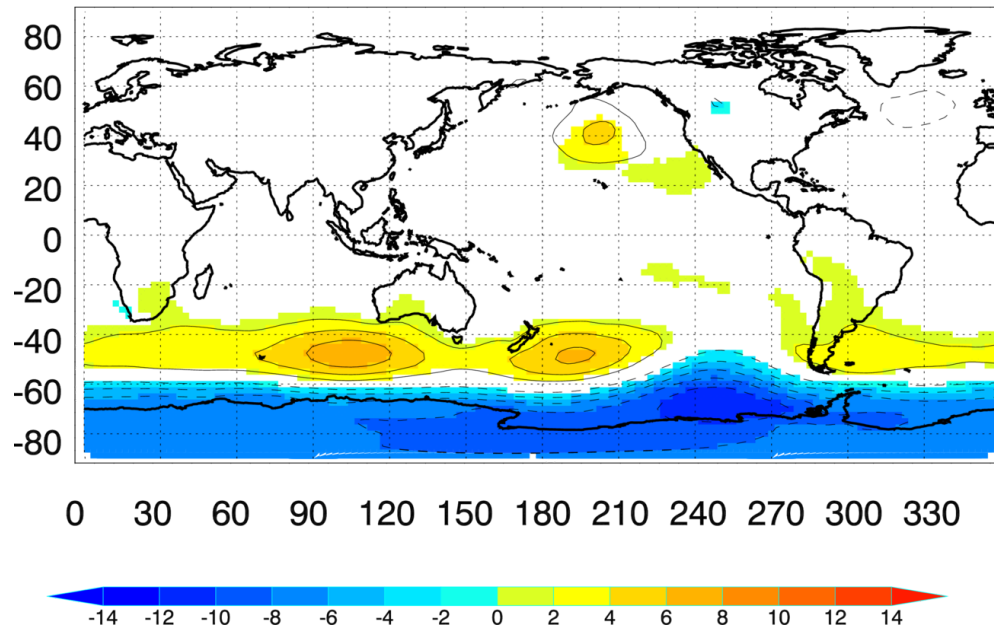
(we express $C_g E$ as a vector quantity to resolve the directional response by using peak wave direction)

ENSO weakens the SAM link to the Northern Hemisphere

SAM is significantly anticorrelated with ENSO in DJF

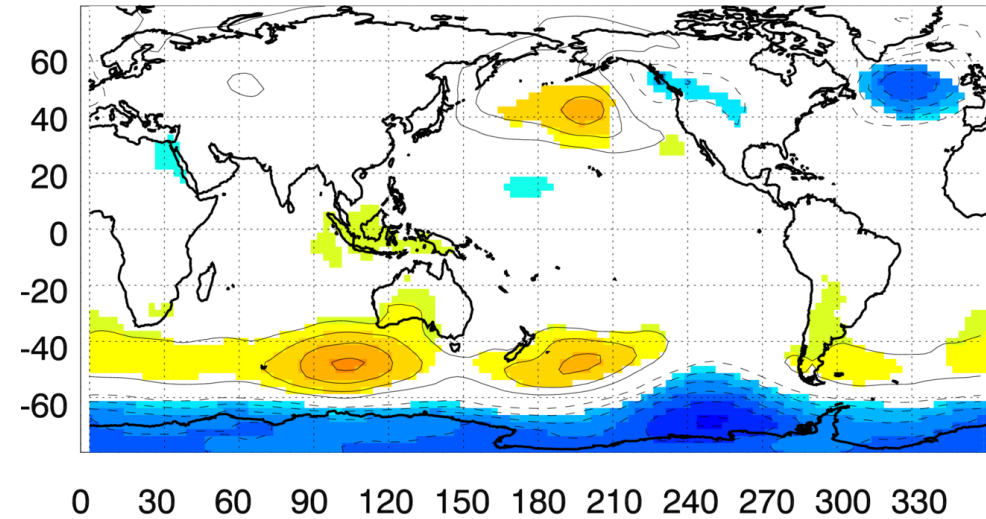
ENSO included

MSLP (hPa), positive SAM, DJF



No ENSO

MSLP (hPa), positive SAM, DJF



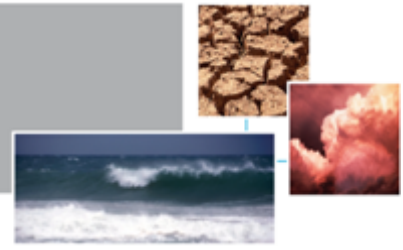
Aims

Focus on influence of key climate drivers on wave field and swell in the Southern Hemisphere

Wave fields: significant wave height (H_s), peak wave period (T_p) and zonal wave energy flux ($C_g E$)

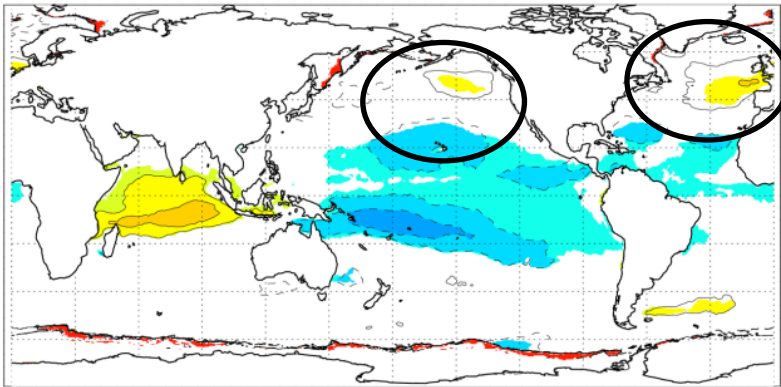
These vary with local variations in surface zonal wind

Potential for subseasonal predictive capability of ocean surface waves, to benefit coastal management

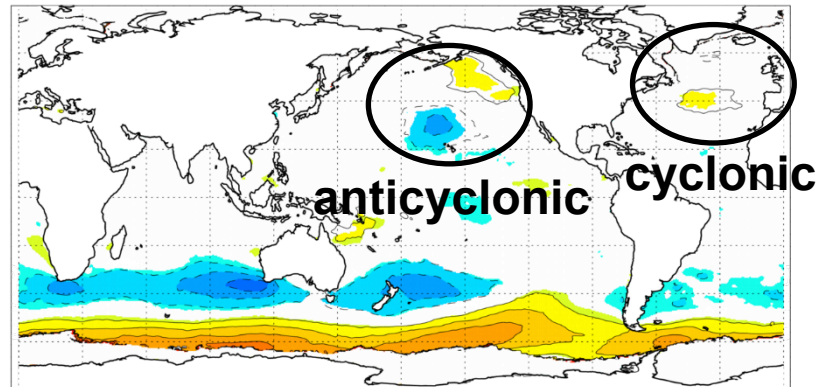


DJF zonal wind anomalies:

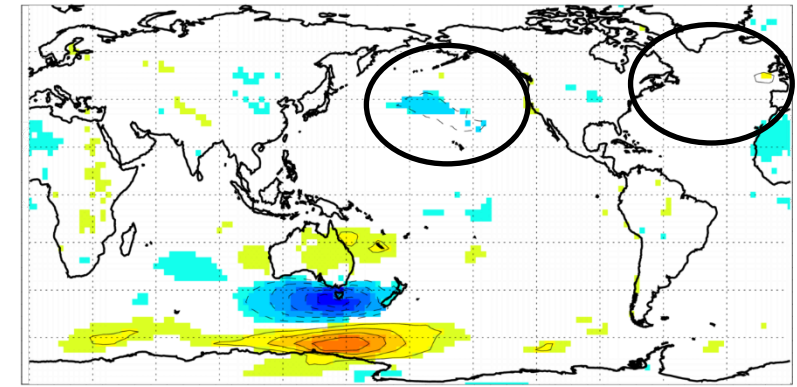
MJO phase 4



positive SAM



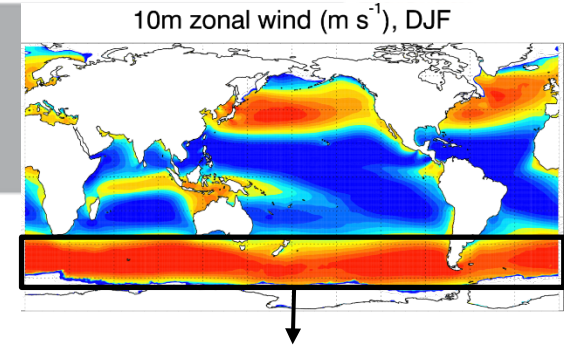
split-flow blocking



Resembles a Rossby wave train emanating out of the tropics...

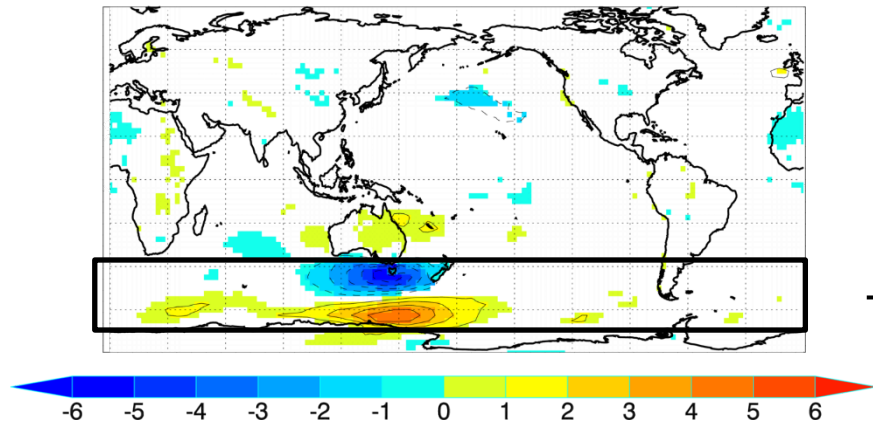


Split-flow blocking H_s anomalies

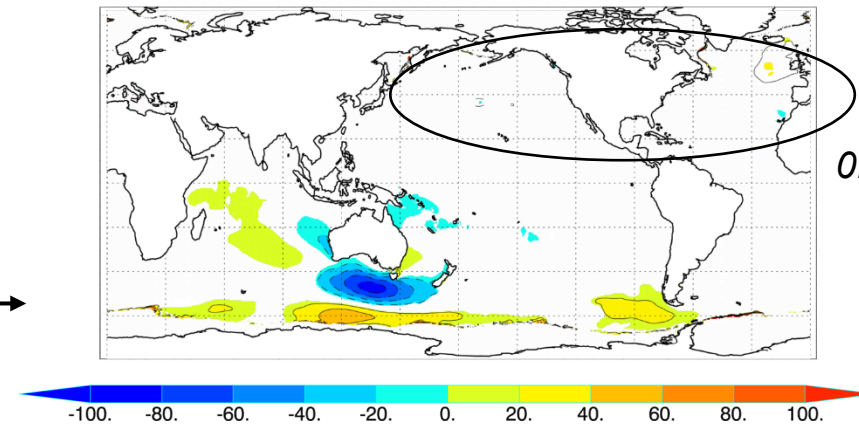


**Westerly
mean state**

10m zonal wind (m s^{-1}), DJF



Sig. wave height (cm), DJF



0.2 m

0.4-0.8 m