# Climate driver impacts on global ocean surface wave variability and extremes

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Australian Government
Bureau of Meteorology

Earth Systems and Climate Change Hub

National Environmental Science Programme

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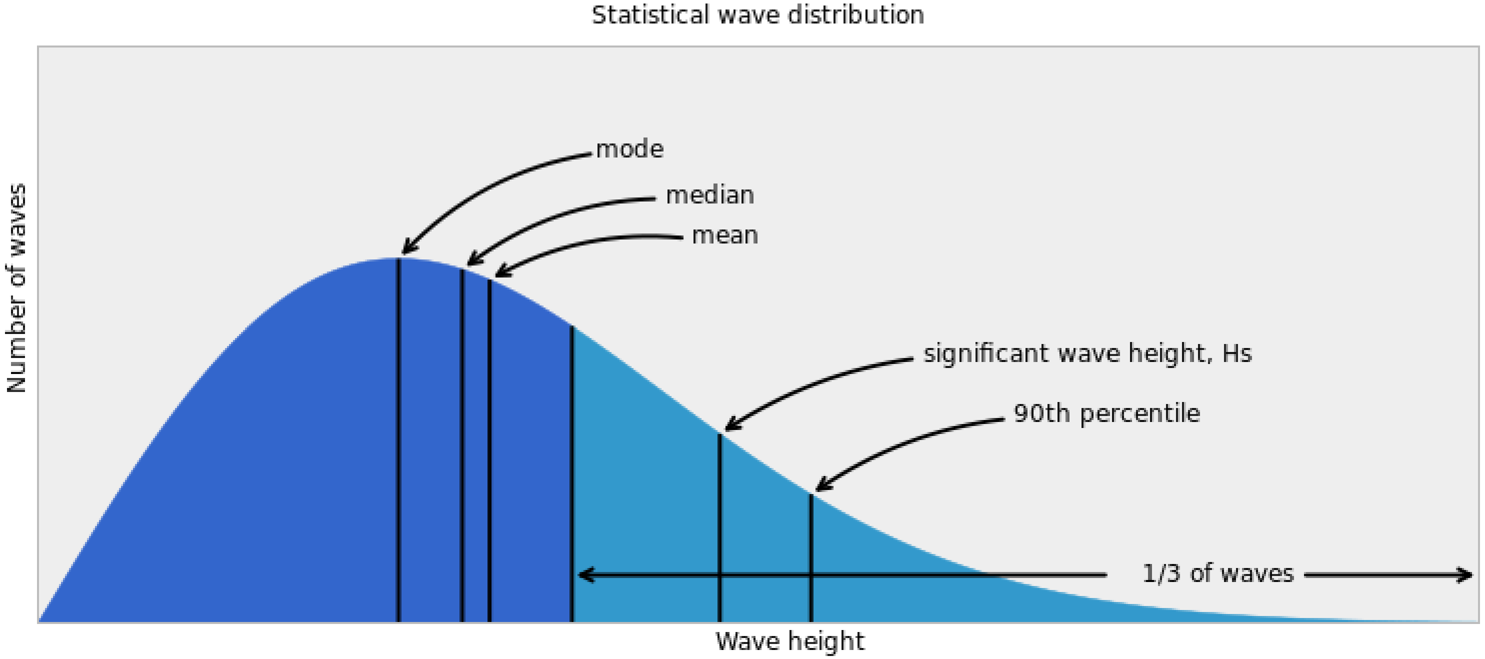
# Aims

**Key influences of subseasonal climate drivers on significant wave height ($H_s$) in the Southern Hemisphere**

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




**$H_s$: The average height (trough to crest) of the highest third of waves observed during a given period**

# The CAWCR wave hindcast

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

## CFSR winds

(Climate Forecast System Reanalysis)

- hourly surface winds & sea ice
- $0.3^{o}$ horizontal resolution
- unprecedented depiction of surface wind

⇒

## WAVEWATCH III™ model version 4.08

⇓

**CAWCR wave hindcast**
**Durrant et al. (2014)**

⇒

## Global wave data:

- significant wave height ($H_s$)
- 0.4° horizontal resolution
- hourly output, 1979-2009

# Subseasonal climate drivers

## Madden-Julian Oscillation

(Wheeler and Hendon 2004)

Phase 2

Phase 3

Phase 4

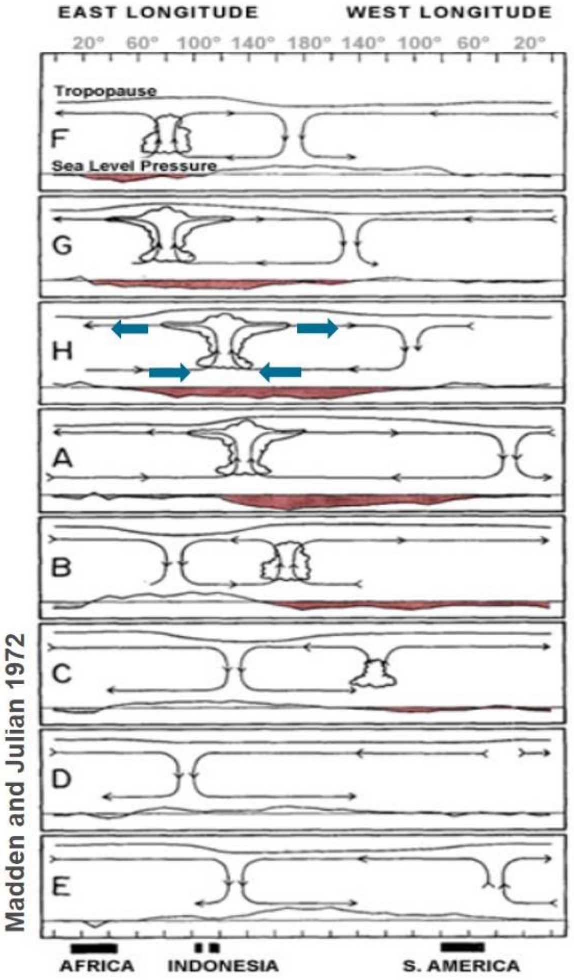
Phase 5

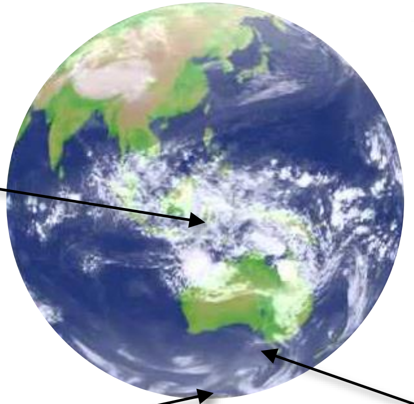
Phase 6

Phase 7

Phase 8

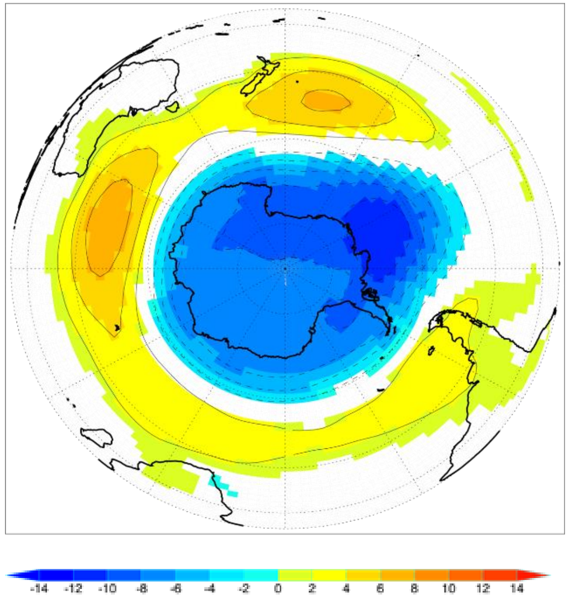
Phase 1



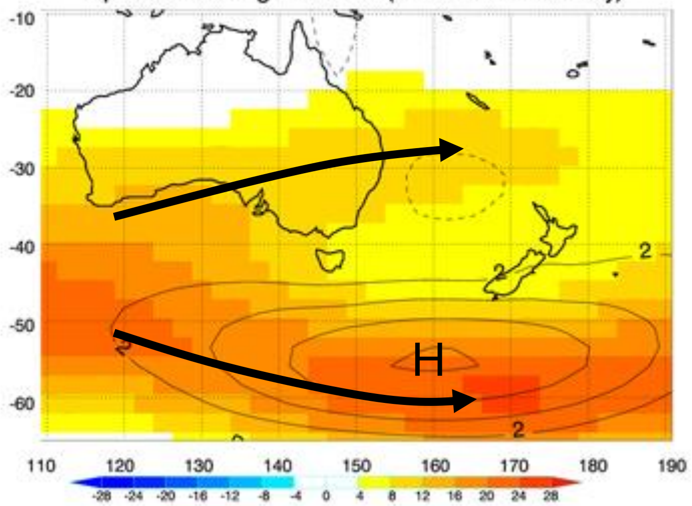
## Southern Annular Mode

MSLP (hPa), positive SAM, DJF

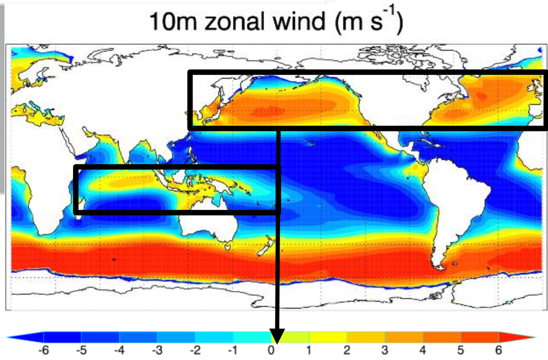



## Atmospheric split-flow blocking

Split-flow blocking in summer (December to February)



# $H_s$ varies with **MJO** zonal wind anomalies (Nov-Apr)




**Westerly mean state**

Rossby wave train anticyclone, **NAO+**

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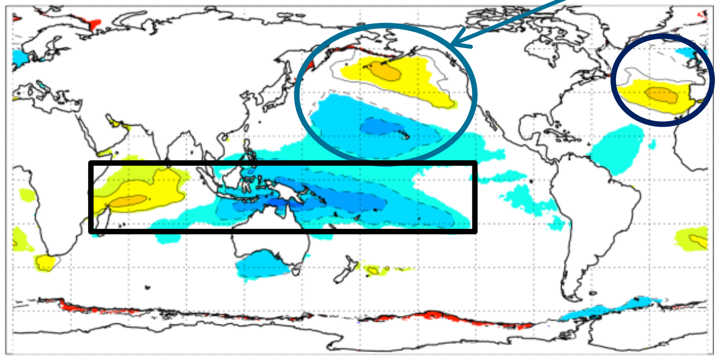
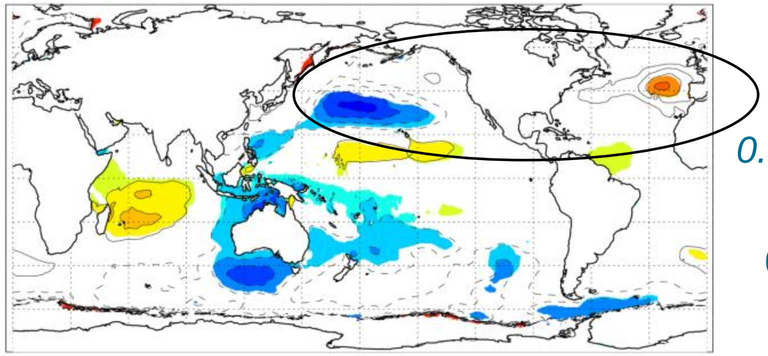
$H_s$

**MJO ph 3**





*0.4-0.5 m*

**0.4-0.5 m**

Pos $H_s$ with westerly anoms
Neg $H_s$ with easterly anoms

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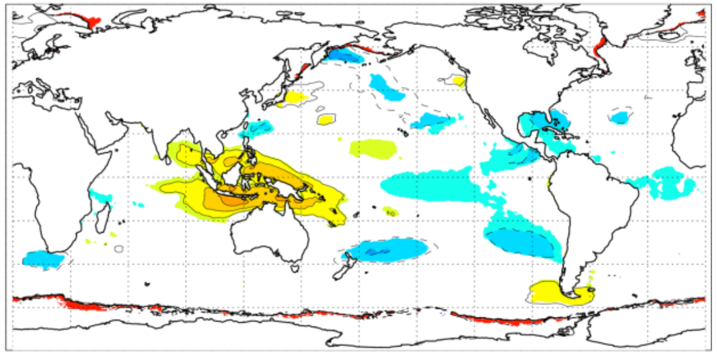
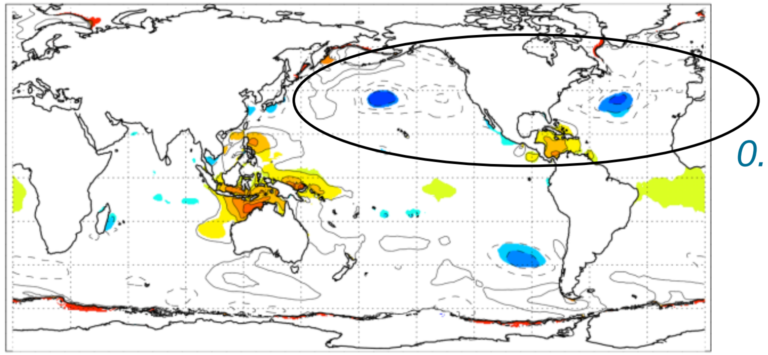
$H_s$

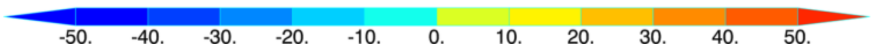
**MJO ph 6**



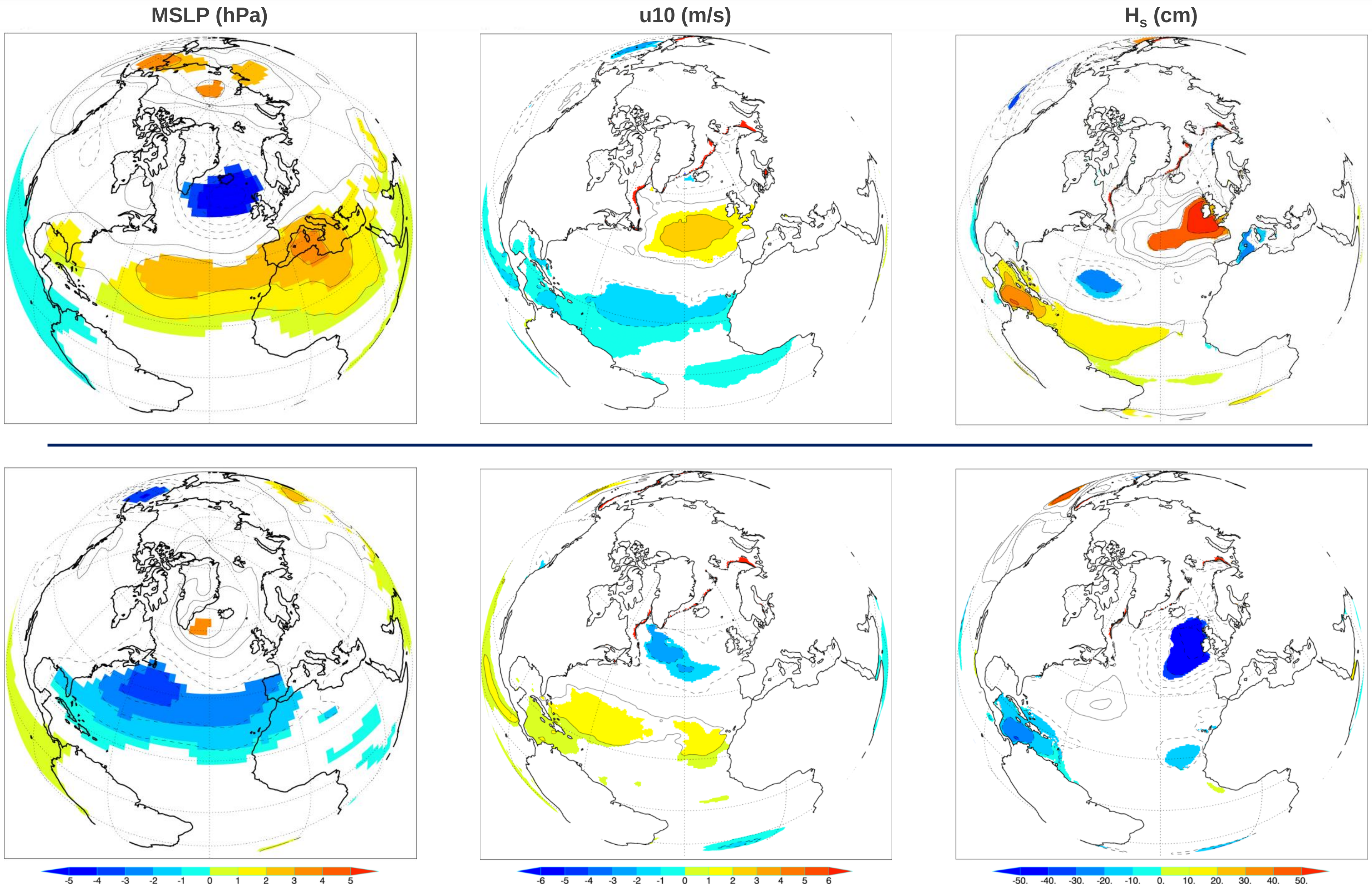


*0.3-0.4 m*

**0.4-0.5 m**

# MJO-NAO teleconnection (Nov-Apr)




**MJO ph 4 $^{+7\,d}$: NAO+**

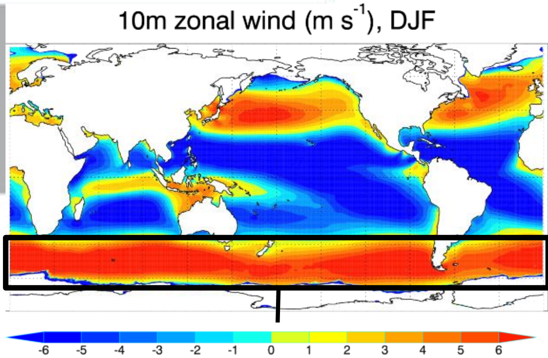
(~1 week after suppress. conv. in Central Pacific)

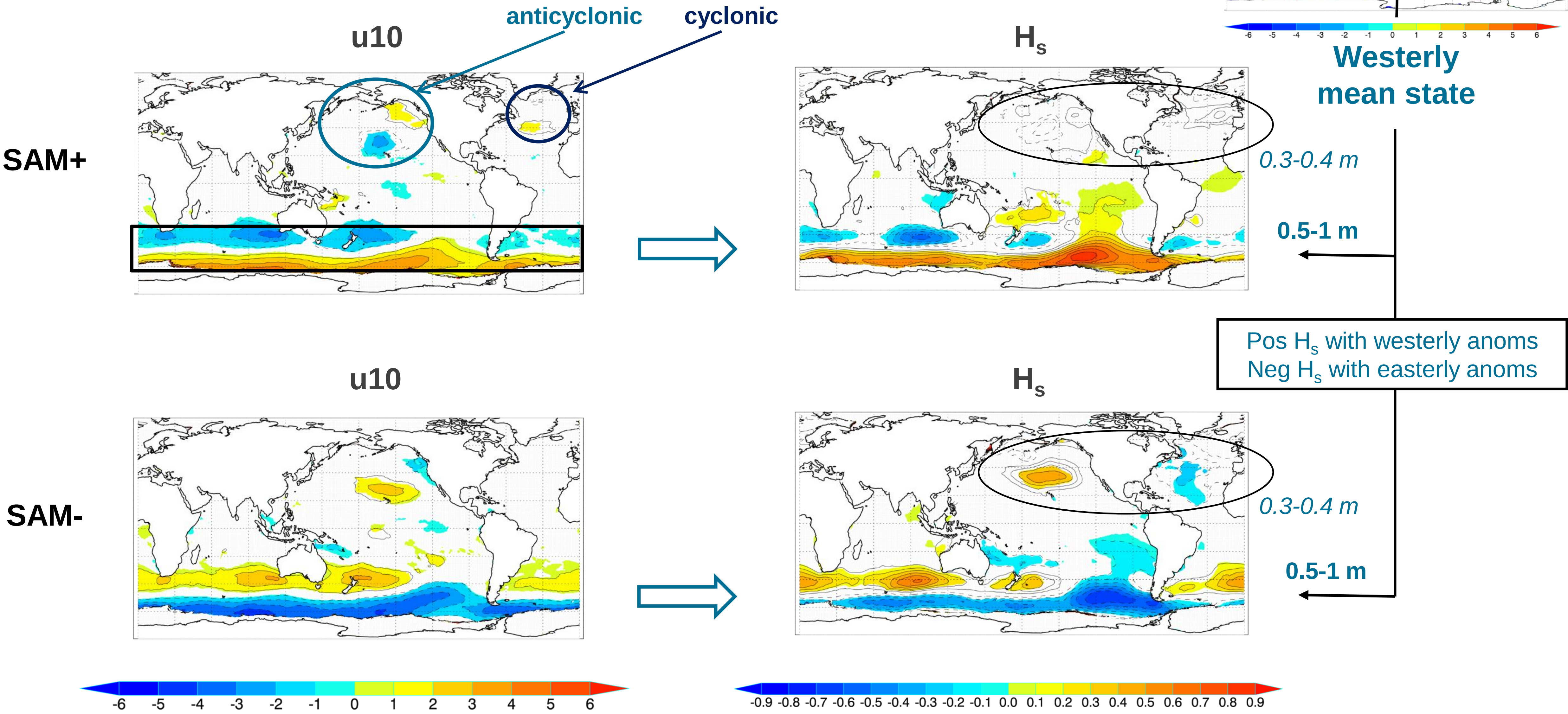
**I.e. Rossby wave train takes ~ 1 week to disperse from the tropics to the North Atlantic**

**MJO ph 7 $^{+7\,d}$: NAO-**

(~1 week after active conv. in Central Pacific)

# Largest $H_s$ anoms occur with strong **SAM** winds (DJF)

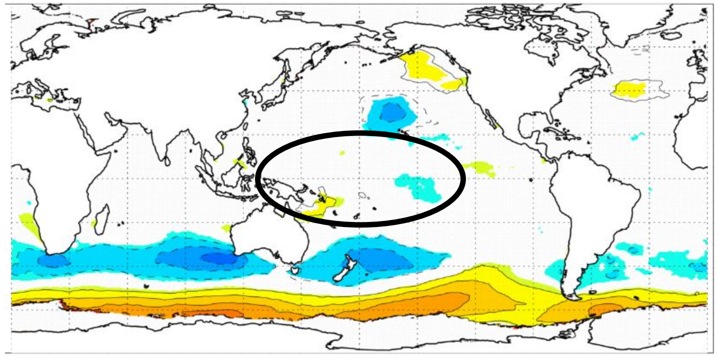


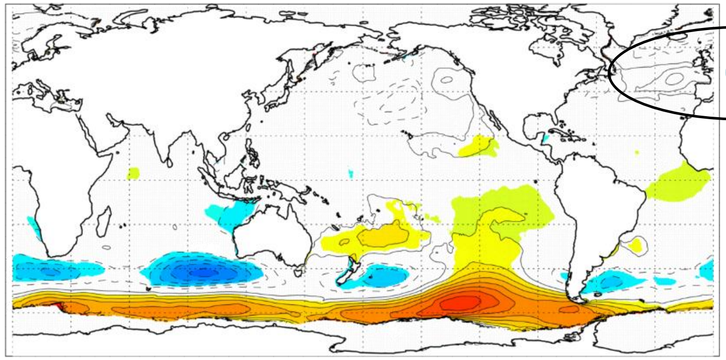
# ENSO weakens the **SAM** link to the NH (DJF)

## SAM drives changes to the tropical atmospheric circulation independent of ENSO:

**u10 SAM+**



**$H_s$ SAM+**



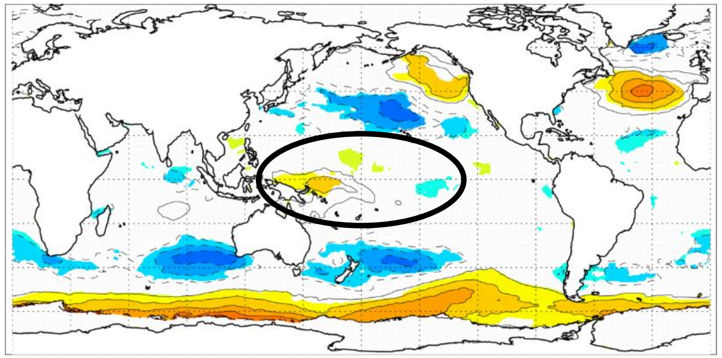
**ENSO included**

**0.4 m**

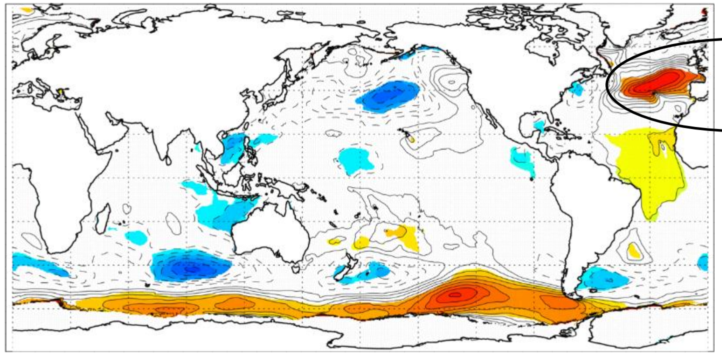
Enhanced divergence: teleconnection to extratropics (e.g. Hoskins and Karoly 1981).

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

**u10 SAM+**



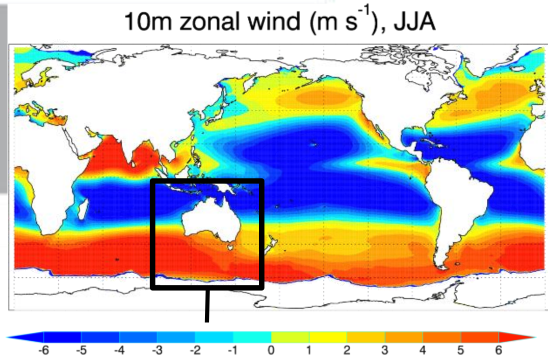
**$H_s$ SAM+**



**No ENSO**

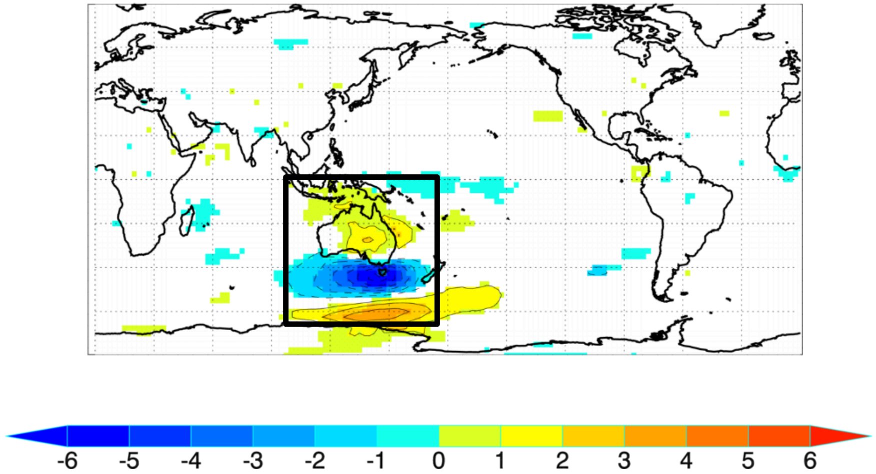
**0.8 m**


# $H_s$ varies with **blocking** zonal wind anomalies (JJA)

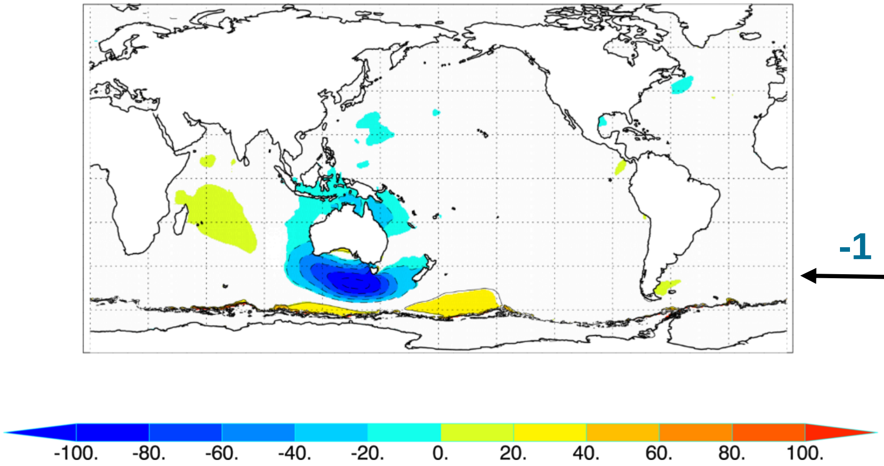



Neg $H_s$:
Westerly anoms in easterly state
Easterly anoms in westerly state

**u10**




**$H_s$**




**-1 m**

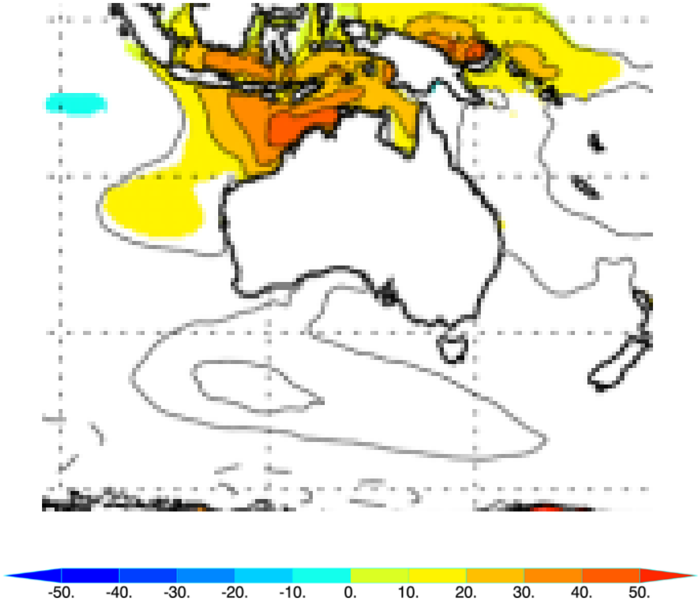
**Implications of calm wave conditions on the capacity of Australia's beaches to recover after winter storms?**

# Australian coastal wave responses

## $H_s$ anomalies up to 0.6 m:

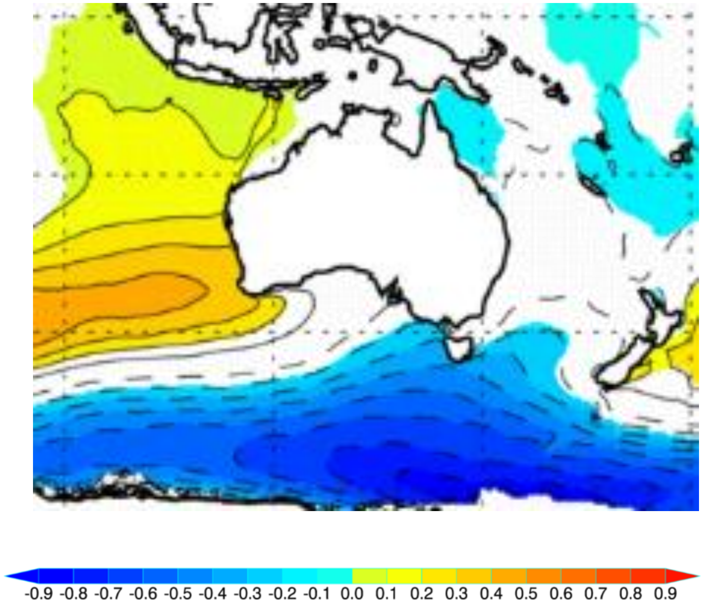
**Madden-Julian Oscillation**

*Example: $H_s$ for MJO phase 6, Nov-Apr*



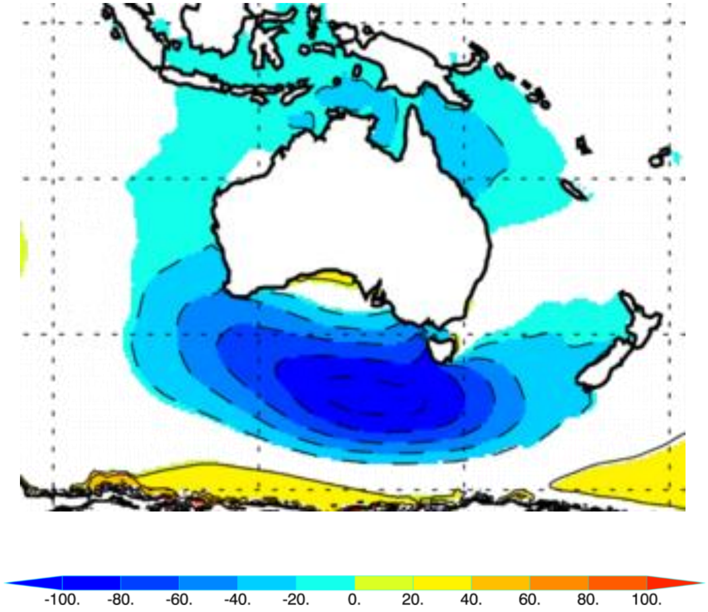

**Southern Annular Mode**

*Example: $H_s$ for negative SAM phase, Jun-Aug*

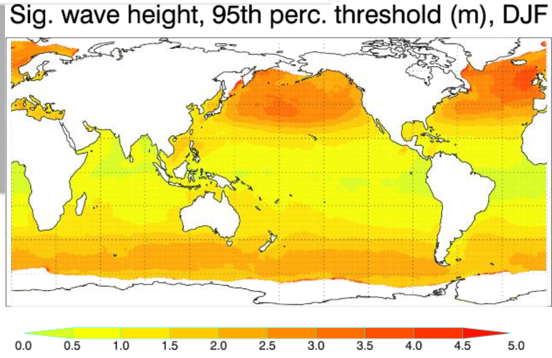



**Split-flow blocking**

*Example: $H_s$ for split-flow blocking, Jun-Aug*



# Impact on high wave conditions (above $95^{th}$ %)




## Up to three times the normal likelihood of high wave conditions:

**Madden-Julian Oscillation**

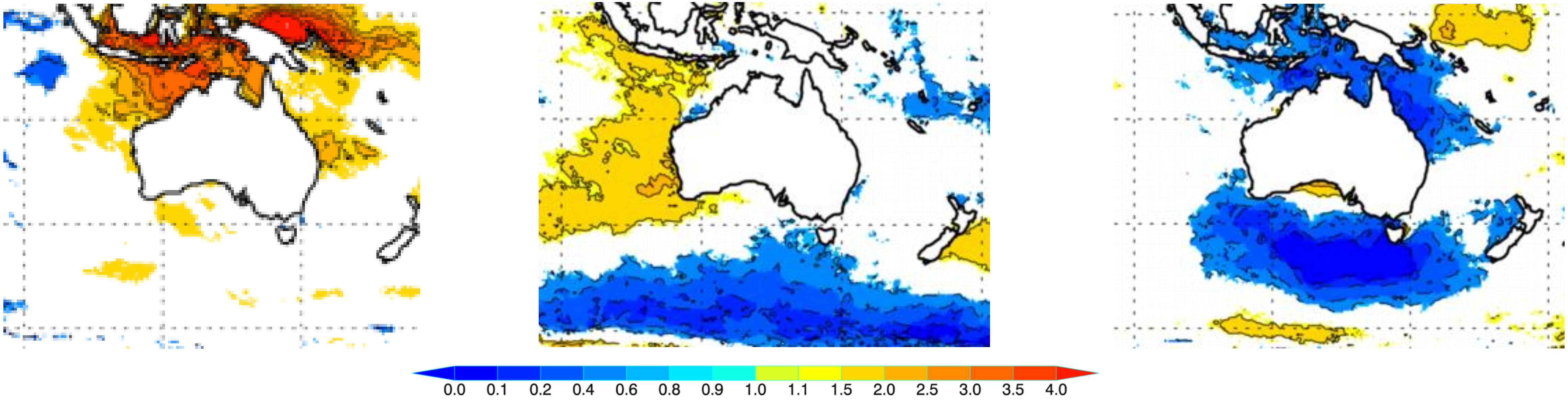
*Example: $H_s$ for MJO phase 6, Nov-Apr*

**Southern Annular Mode**

*Example: $H_s$ for negative SAM phase, Jun-Aug*

**Split-flow blocking**

*Example: $H_s$ for split-flow blocking, Jun-Aug*




## Implications for trends in wave conditions

e.g. projected wintertime decrease in blocking and summertime increases in blocking and SAM

# Take-home points

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

The MJO, SAM and blocking may be valuable sources of subseasonal predictability of surface wave variability and extremes, with predictability of 4 weeks for the MJO and 2 weeks for the SAM & blocking

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Thank you

# AMOS2020 – Fremantle WA

## 10 – 14 February

## 01. Impact of wind driven sea and swell waves
## 41. Ocean extremes and their impacts
## 05. General Oceanography

# 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.**

**$C_gE$: indicates the potential force of the waves on coastal or offshore infrastructure**

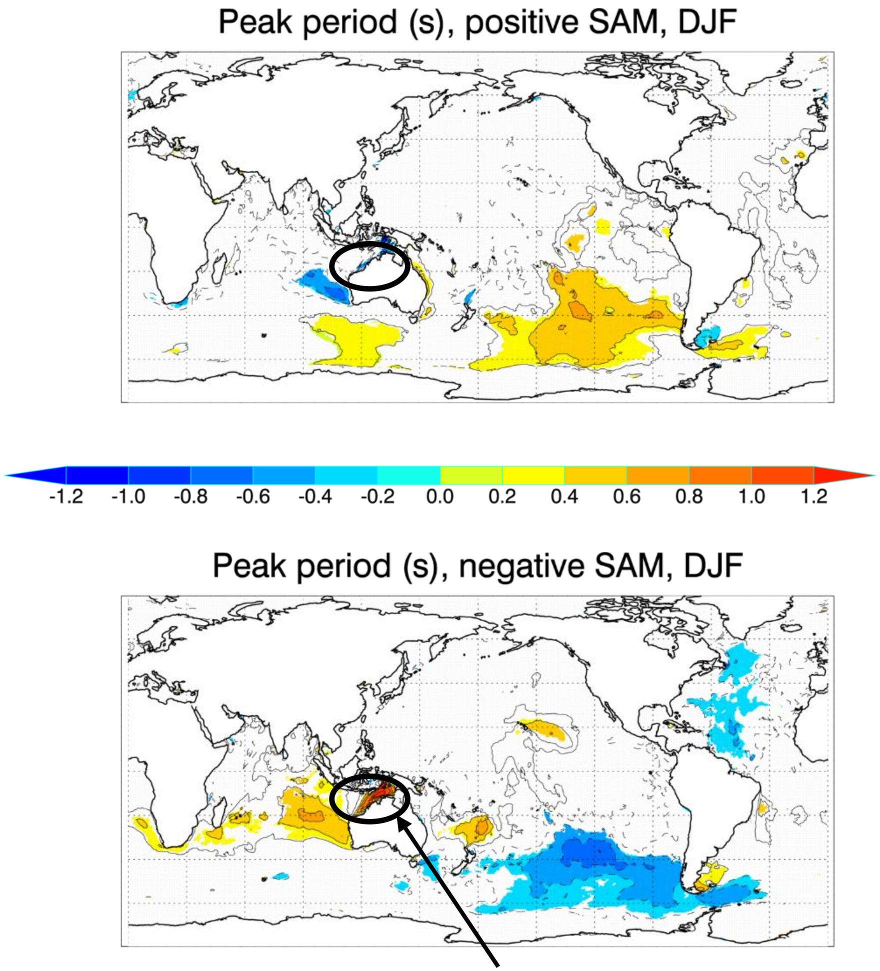
**$C_gE$ depends on $H_s$ and the period T:**

$$C_gE = \rho . g^2 . H_s^2 . T / 64\pi$$

($\rho$ is the water density and $g$ is the gravitational acceleration)

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

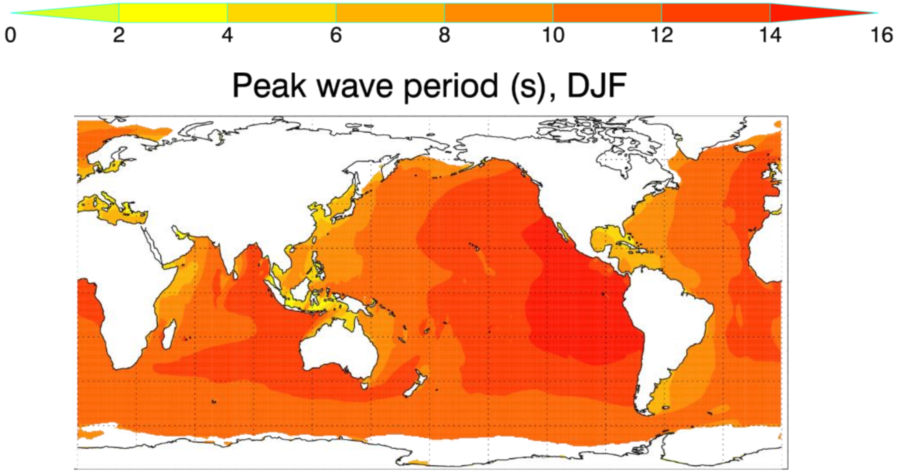
# Waves primarily generated by ocean swell




$T_p$ increases towards the eastern Pacific

$T_p$ varies in phase with $H_s$

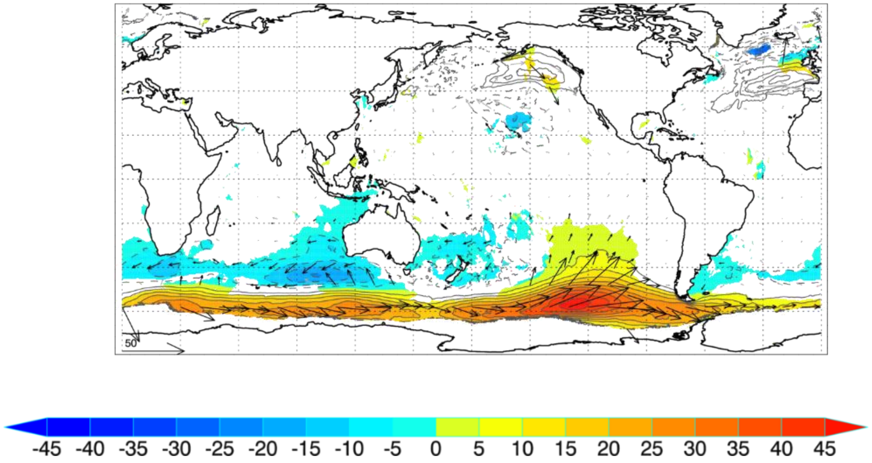
Large $T_p$ anomalies relate to the large breadth of (annular) zonal winds



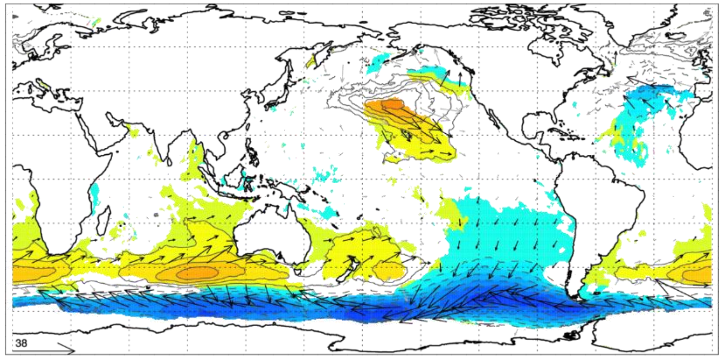

$T_p$ anomaly of 2s (50% of climatology). The swell observed here is impacted by wave energy rotation…

# Rotation in direction of the wave energy flux

Wave energy flux (kW m$^{-1}$), positive SAM, DJF




Wave energy flux (kW m$^{-1}$), negative SAM, DJF

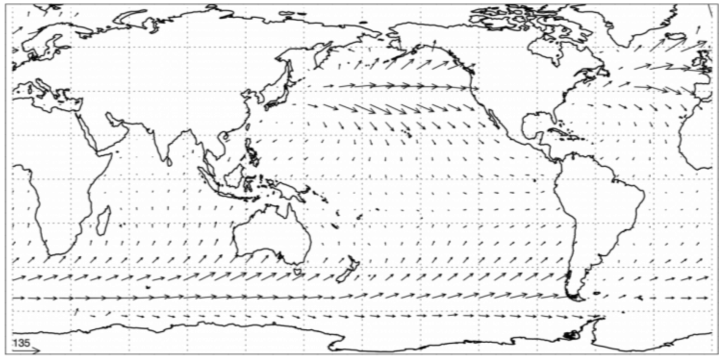



**Positive $C_gE$ indicates wave energy from west**

**Negative $C_gE$ indicates wave energy from east**

**Indicate changes in magnitude and direction**

Wave energy flux (kW m$^{-1}$), DJF



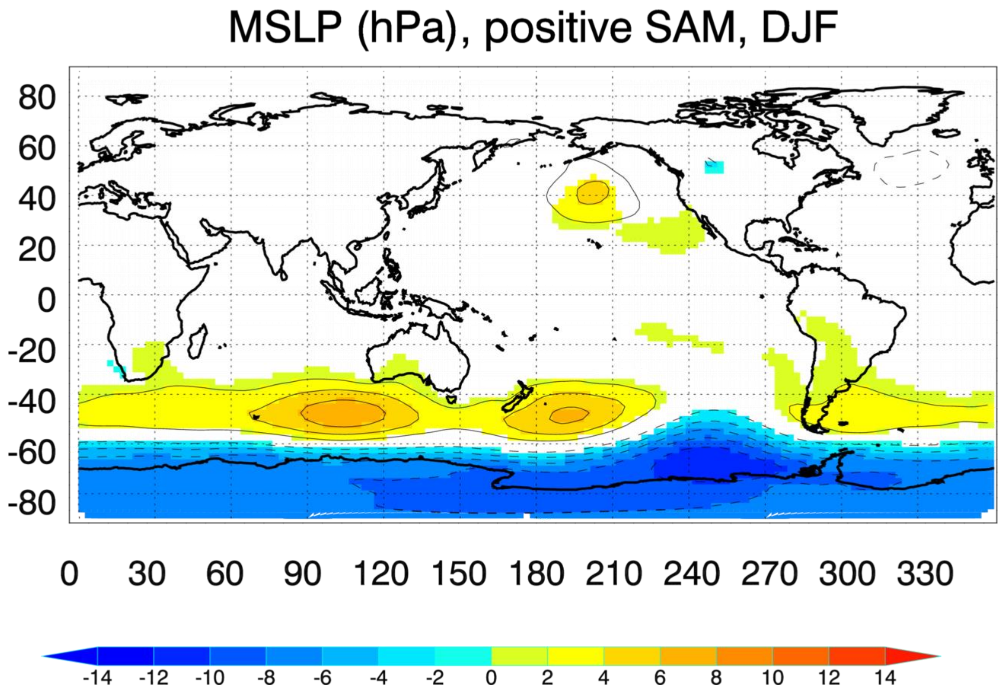

*Swell propagates along great circle paths*

*Westerly anomalies generally represent clockwise rotation*

# ENSO weakens the SAM link to the Northern Hemisphere

## SAM is significantly anticorrelated with ENSO in DJF

**ENSO included**




**No ENSO**