

# Influence of the Madden-Julian Oscillation on marine heatwaves in the central Tropical Indian Ocean

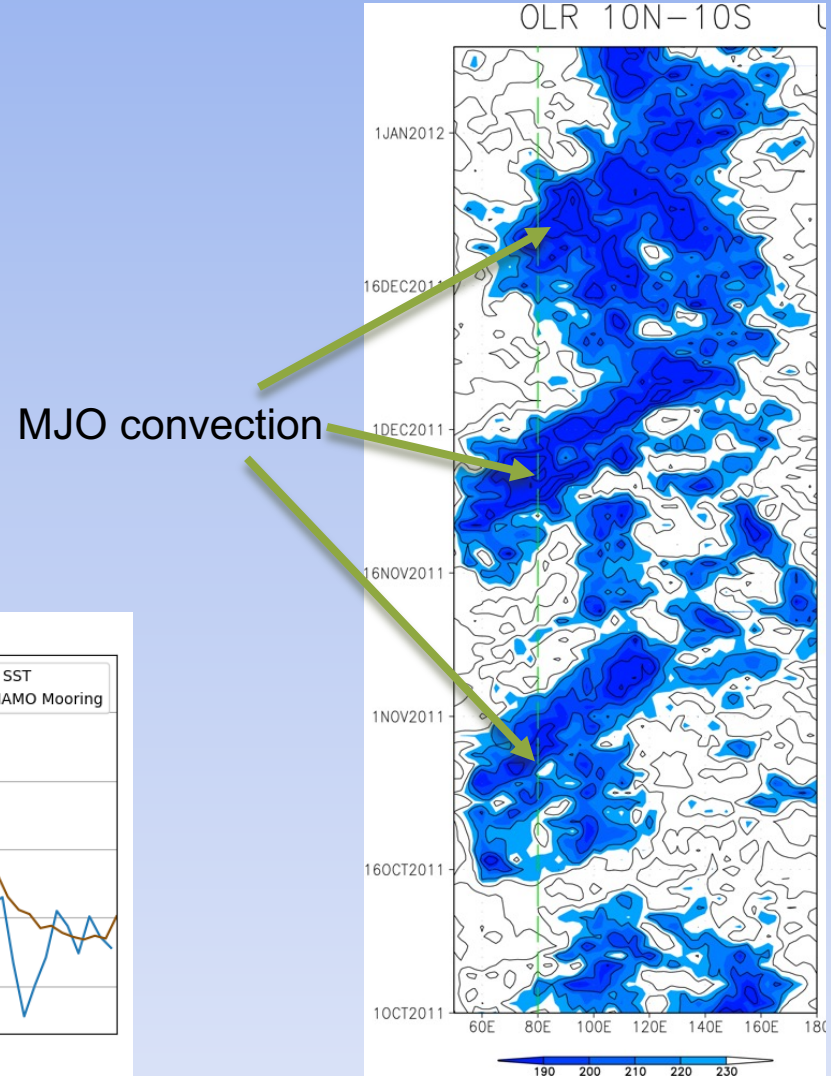
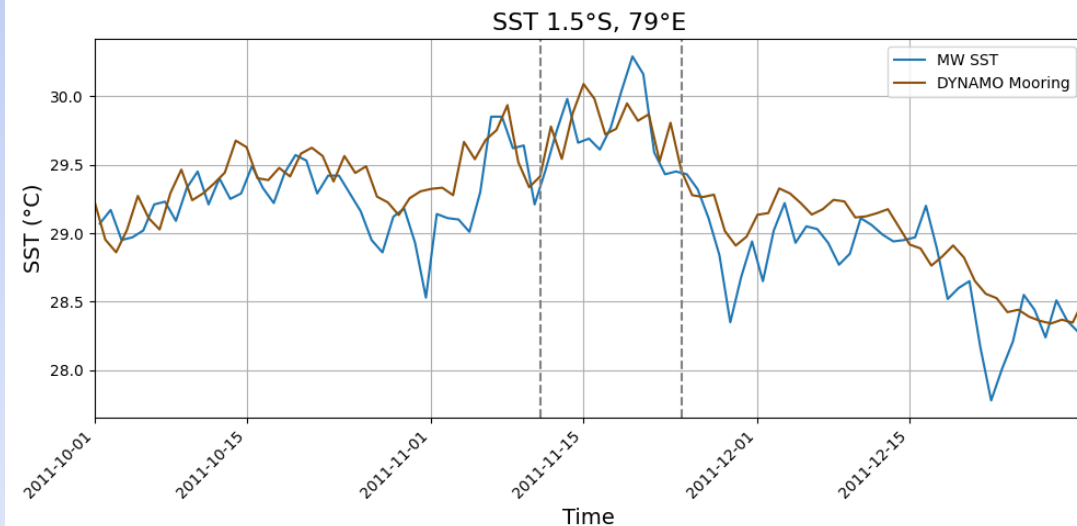
Toshi Shinoda<sup>1</sup>, Lillian Pedraza<sup>1</sup>, Weiqing Han<sup>2</sup>

<sup>1</sup>Texas A&M University - Corpus Christi

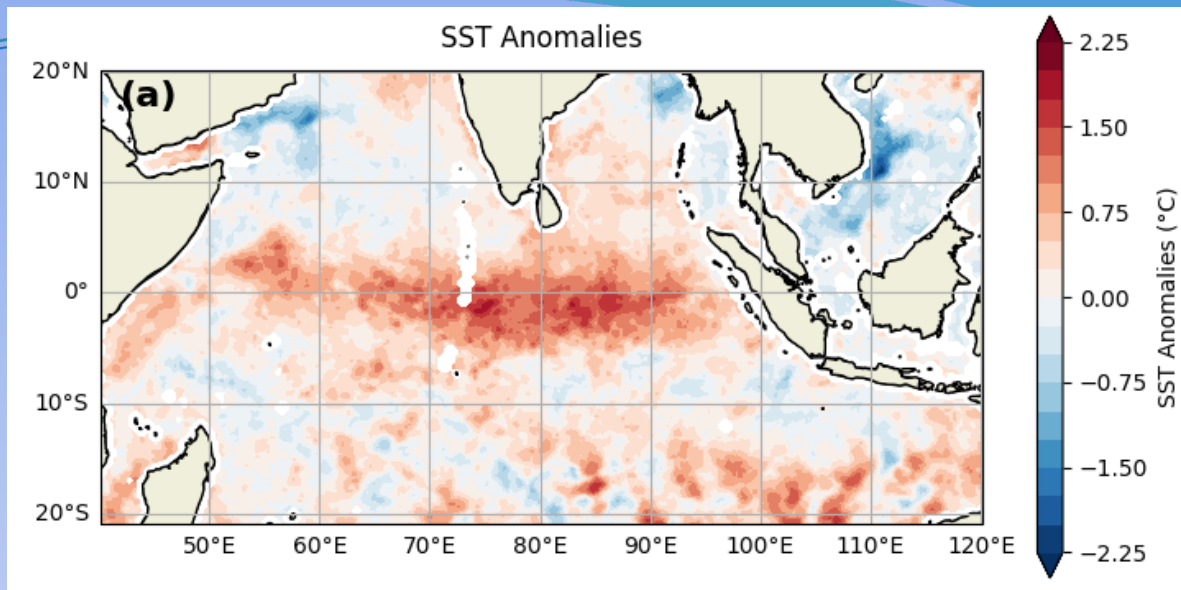
<sup>2</sup>University of Colorado

# Anomalous warming associated with the MJO during the DYNAMO field campaign

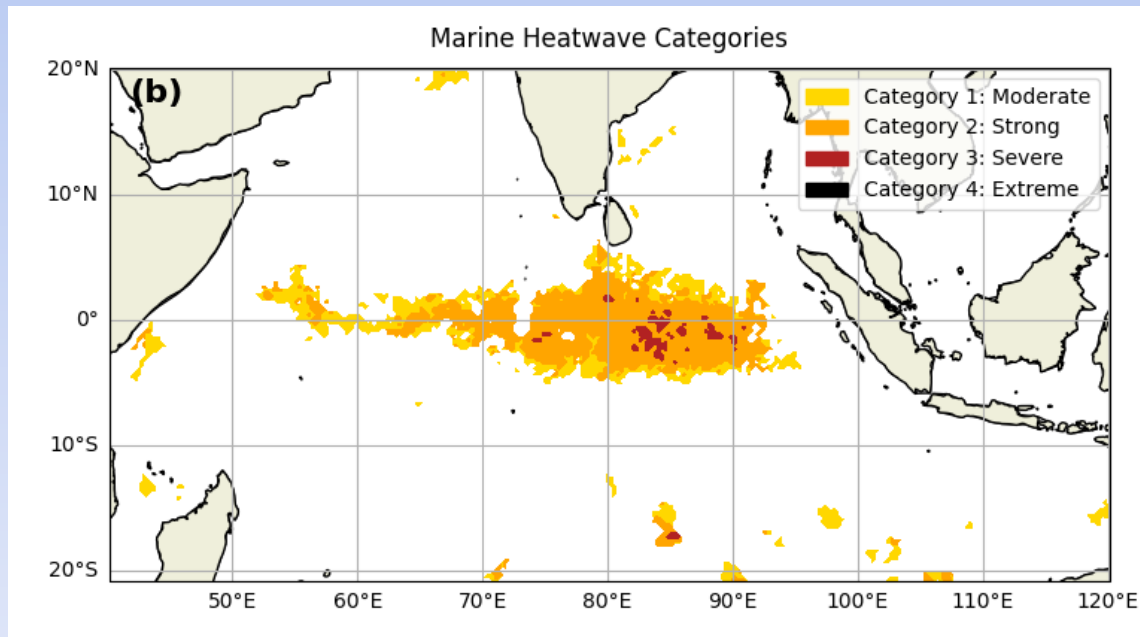
## DYNAMO Field Campaign



# SST anomalies in November 15, 2011



## Marine Heatwaves (SST exceeds 90<sup>th</sup> percentile; Hobday et al. 2016)



# Focus of this study

- Examine how the MJO modulates MHWs over the central tropical Indian Ocean
- Atmospheric and oceanic processes driving MHWs associated with the MJO

## Data

- CCMP (3.1) and ERA5 surface winds
- MW OI SST (2000-2022)
- OAFlux (Yu et al. 2008)
  - Latent heat flux
  - Sensible heat flux
- Shortwave and longwave radiation (CERES)
- High resolution ocean reanalysis (HYCOM)

# Methods

## MHW detection (Hobday et al. 2016)

Periods when daily SST were above the seasonally varying 90th percentile (threshold) for at least five consecutive days.

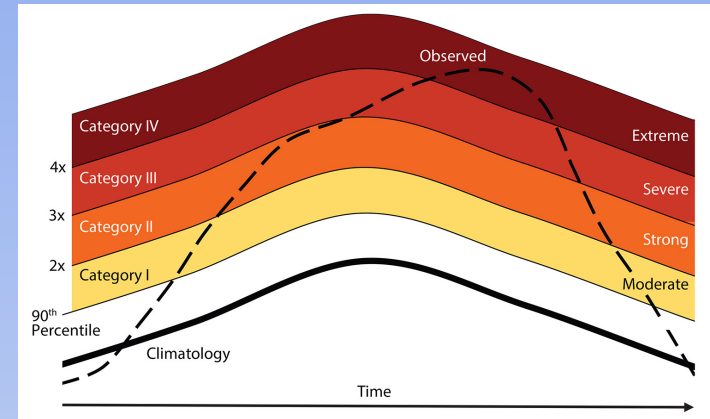
11-day window centered on the date across all years within the climatology period

Strong ENSO/IOD periods (2015/16) were excluded to isolate the MJO influence.

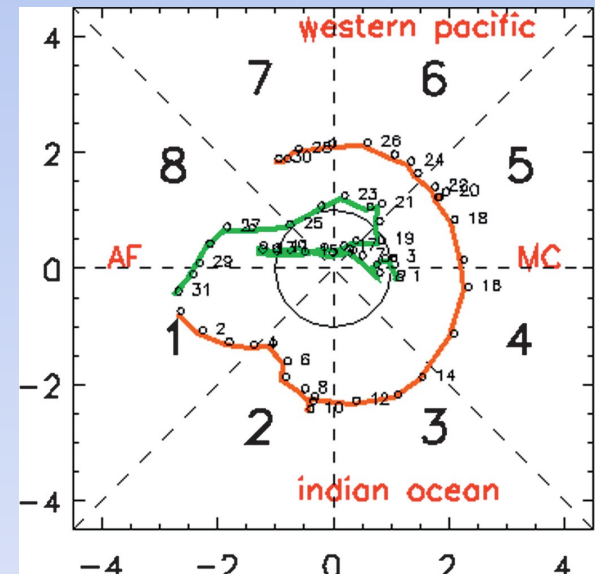
## MJO identification and composite

The Real-time Multivariate MJO (RMM) index (Wheeler and Hendon 2004)

Two principal components, RMM1 and RMM2, are calculated from the EOF analysis of winds and OLR.



*Hobday et al. (2018)*



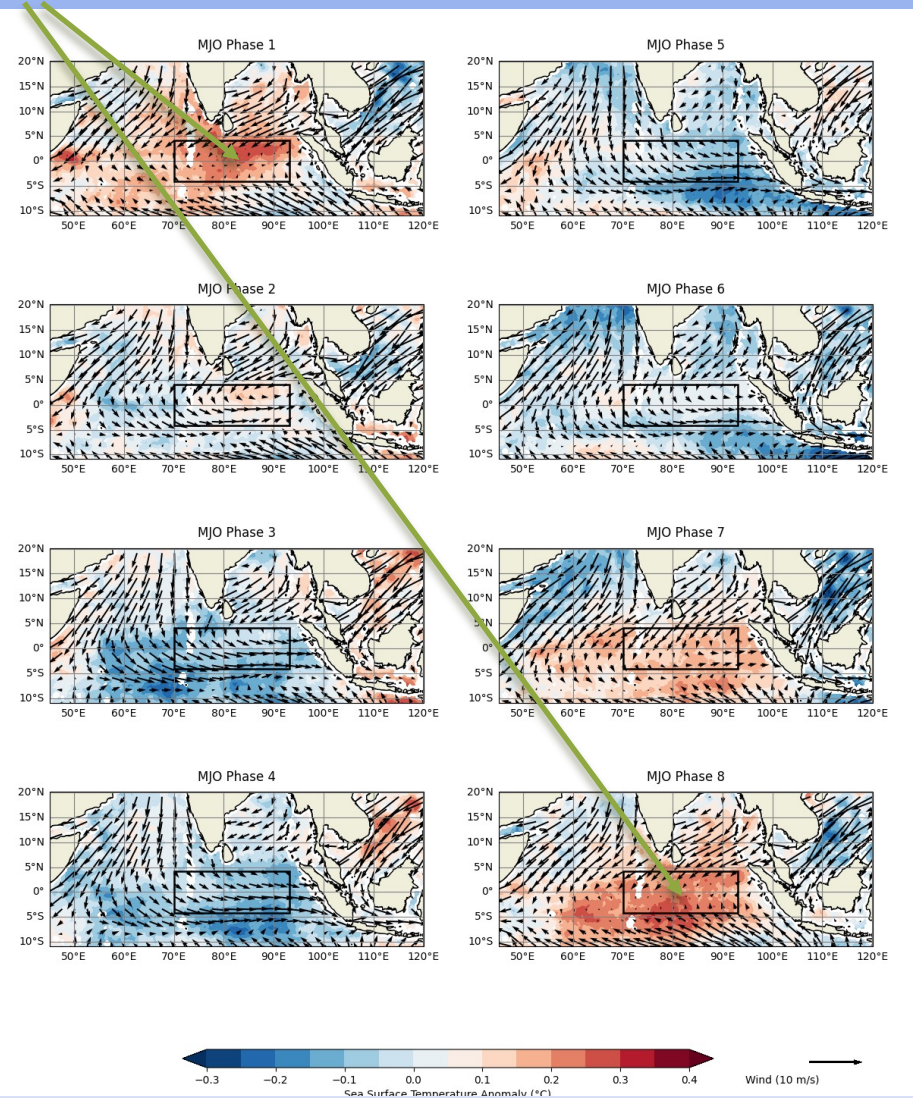
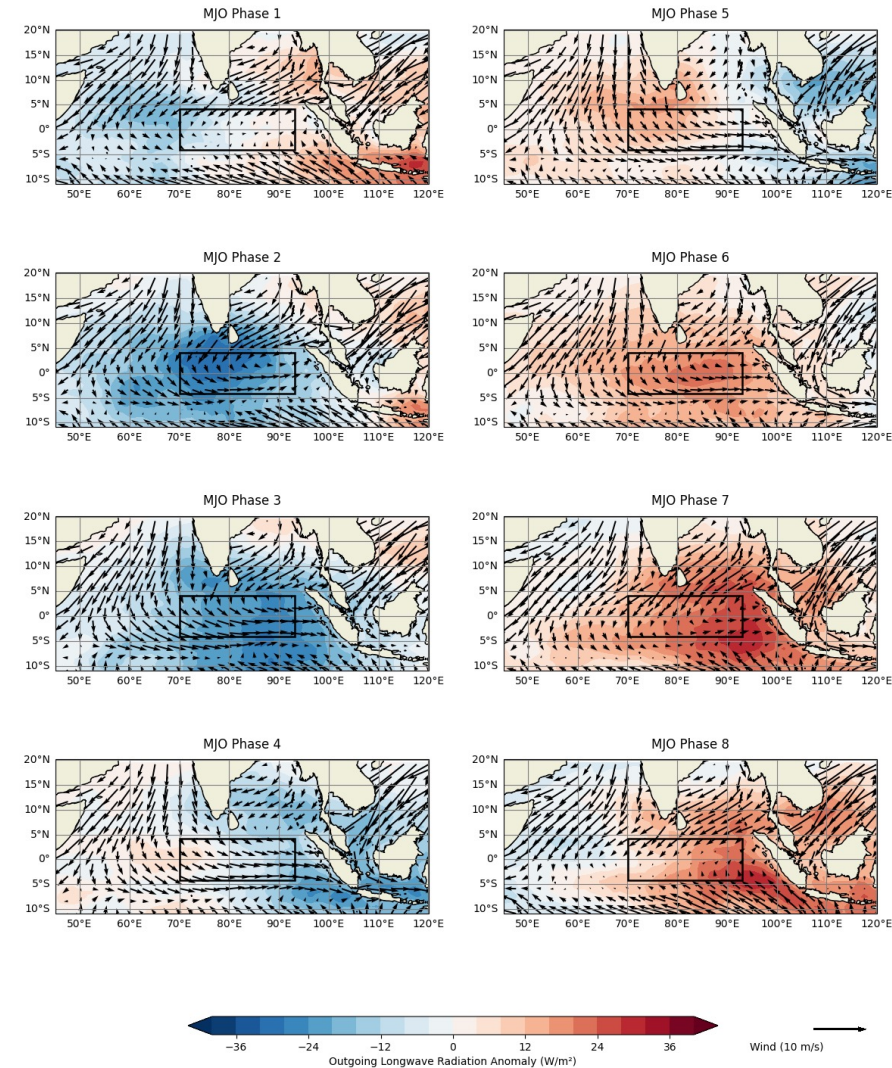
*Shinoda et al. (2013)*

# MJO Composite

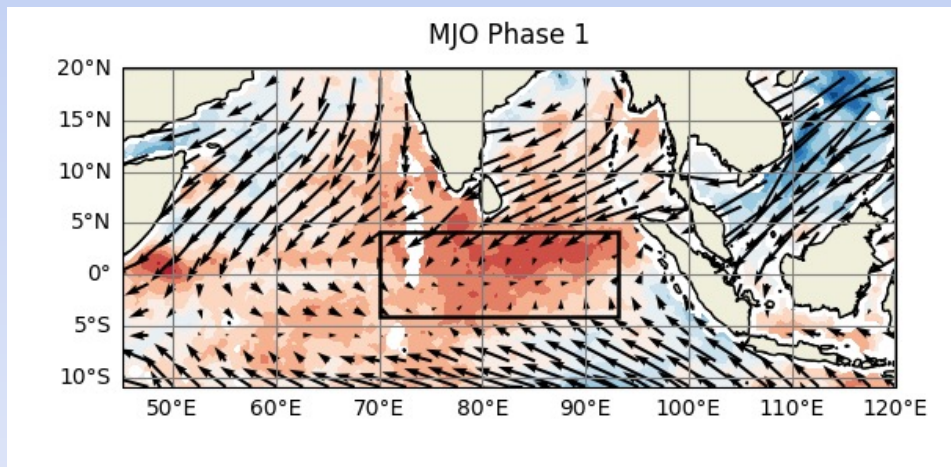
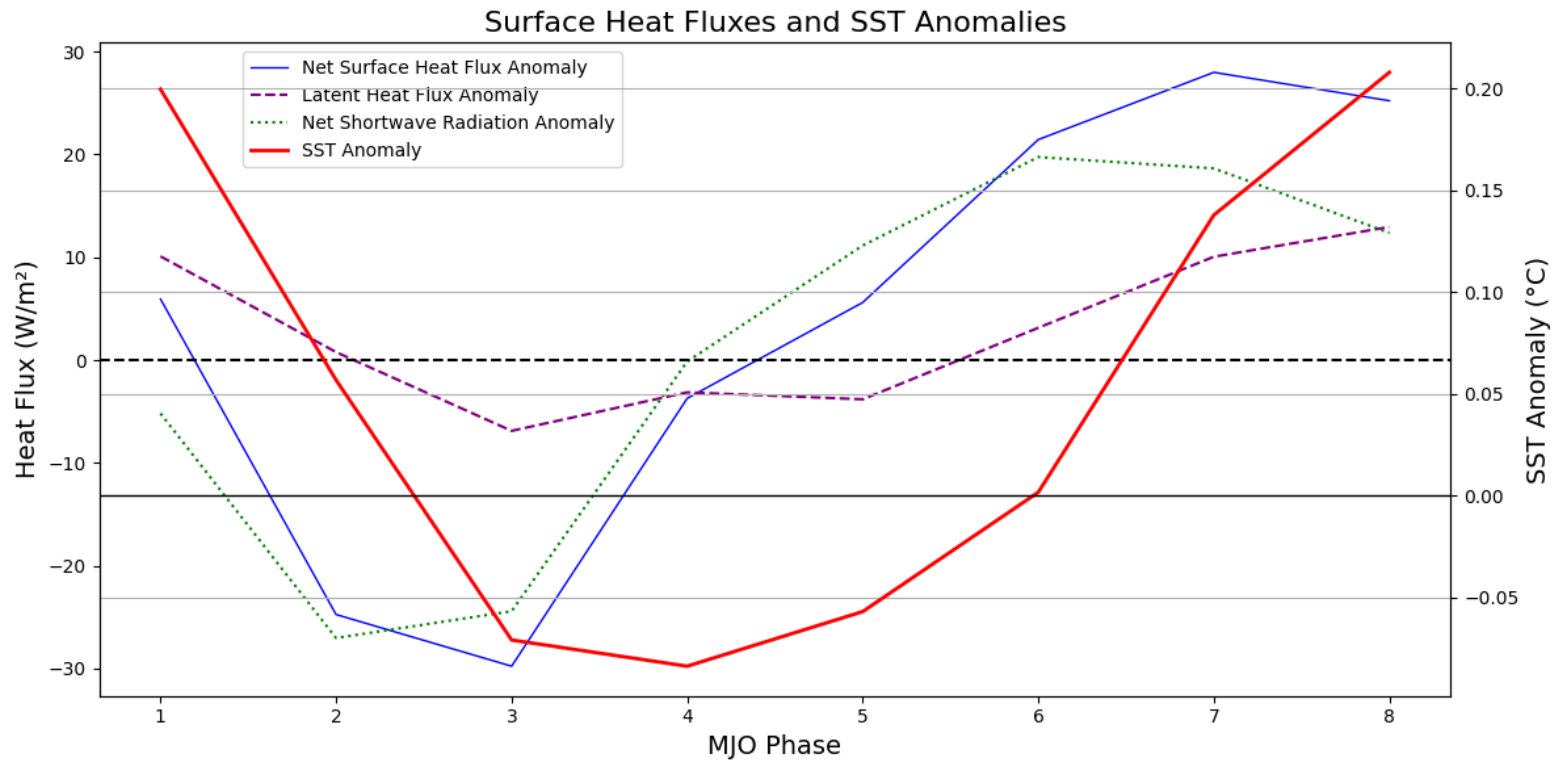
## OLR

## Strong warming

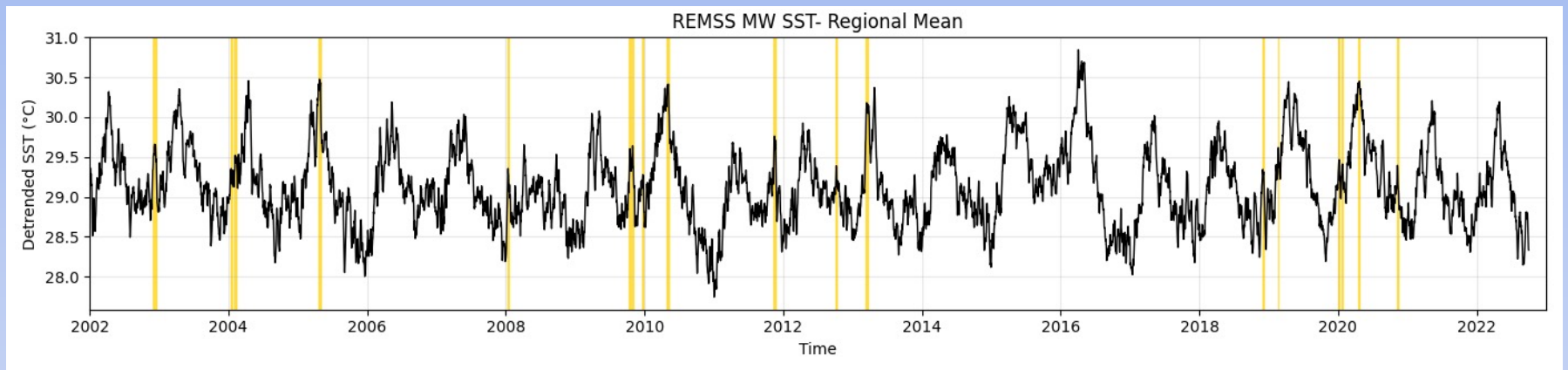
## SST



# Area average SST anomaly



# MHWs associated with the MJO detected from SST in the central tropical Indian Ocean

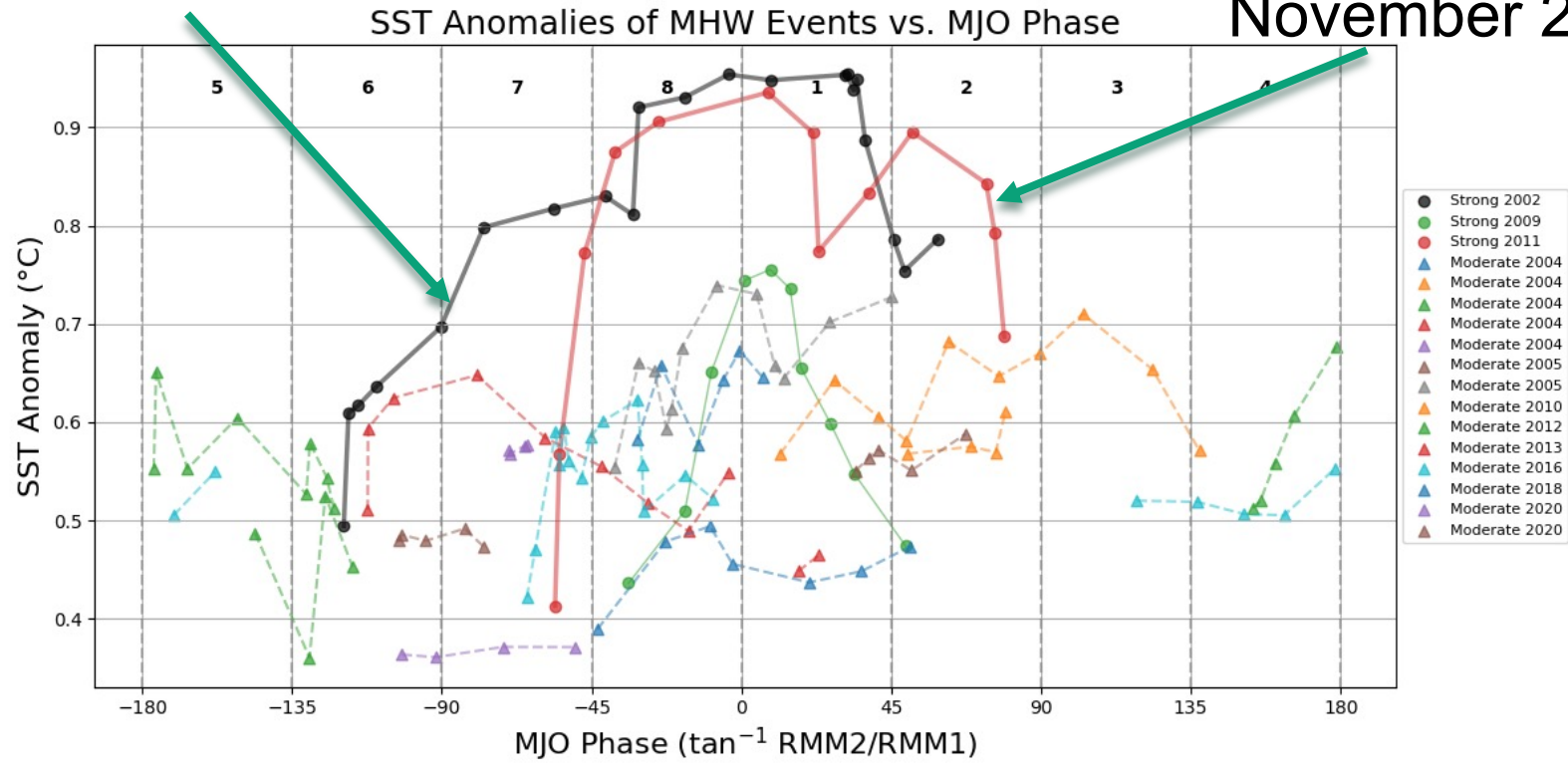


17 MHWs (out of 47 MHWs) associated with the MJO are identified based on the Hobday et al. (2016) criteria.

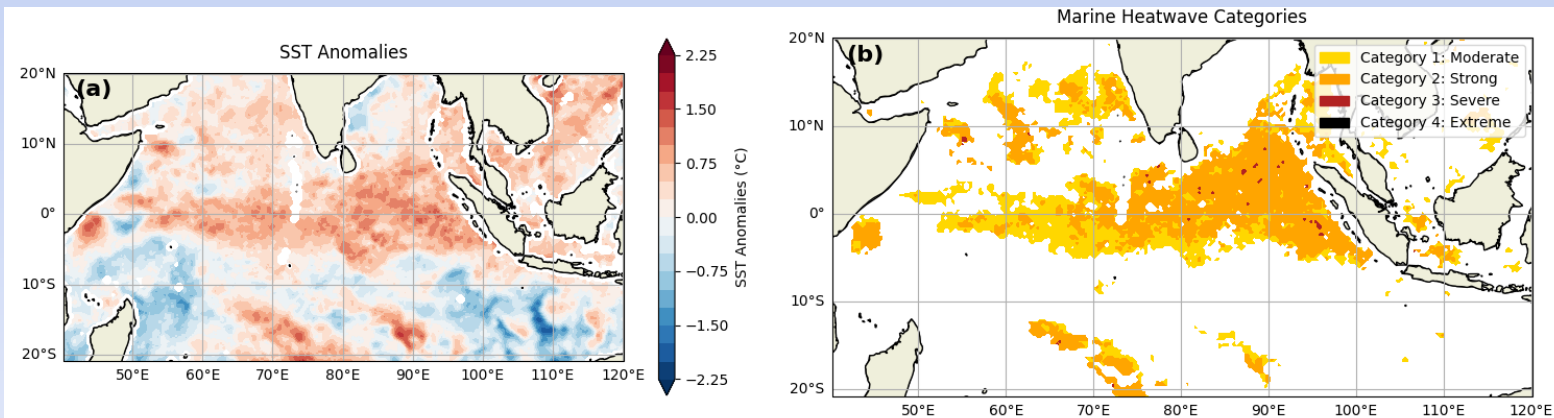
# SST vs. MJO phase

December 2002

November 2011

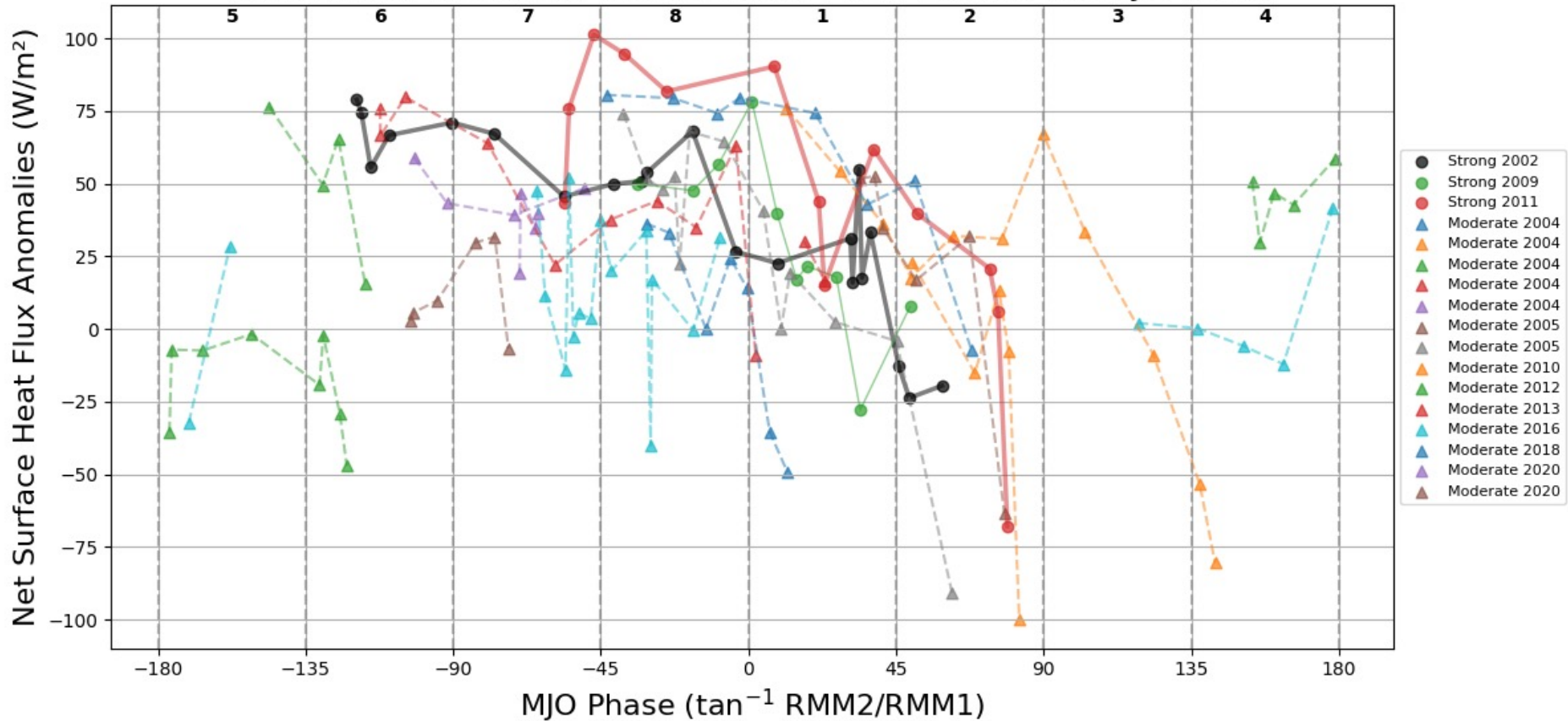


## 2002 MHW



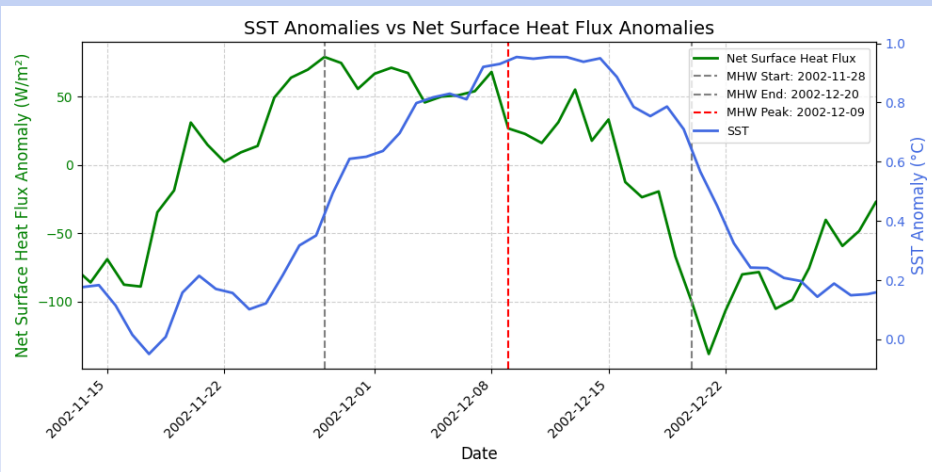
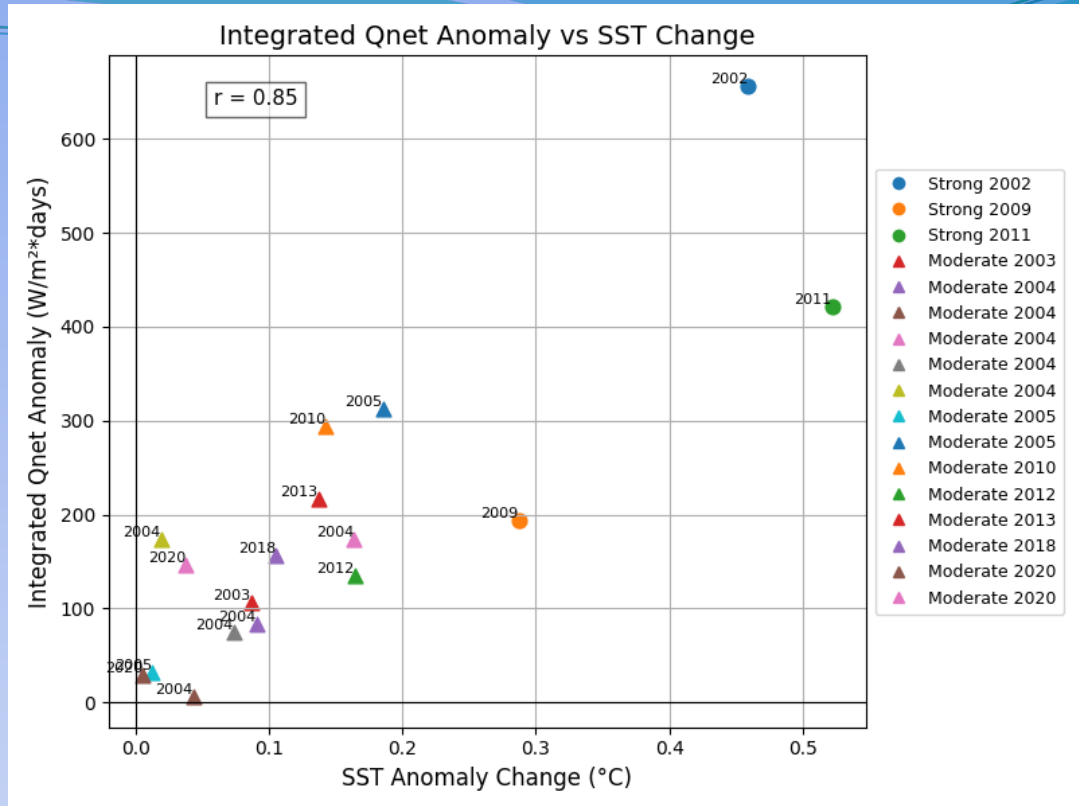
# Net surface heat flux vs. MJO phase

Net Surface Heat Flux Anomalies of MHW Events vs. MJO Phase

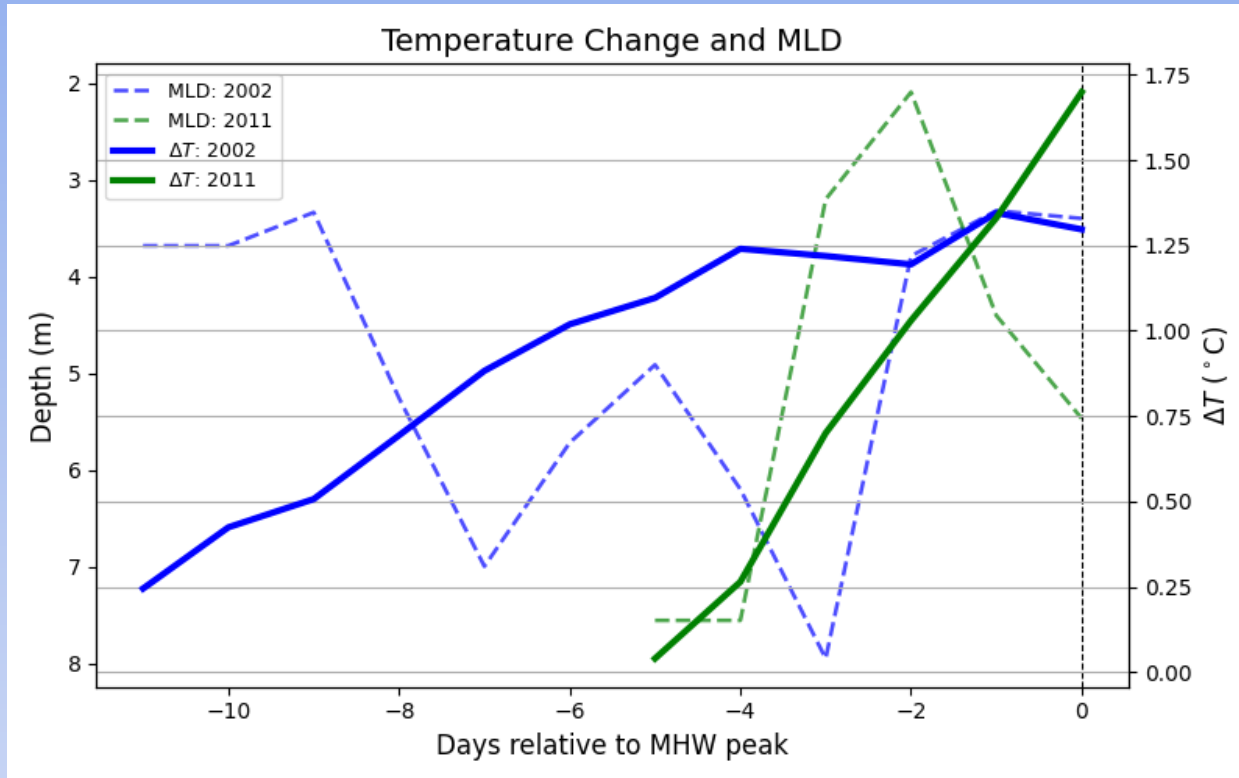


Net Surface heat flux ( $Q_{net}$ )  
integrated from start date  
( $t_0$ ) to peak date ( $t_{peak}$ ) of  
MHW

$$\int_{t_0}^{t_{peak}} Q_{net}(t) dt$$



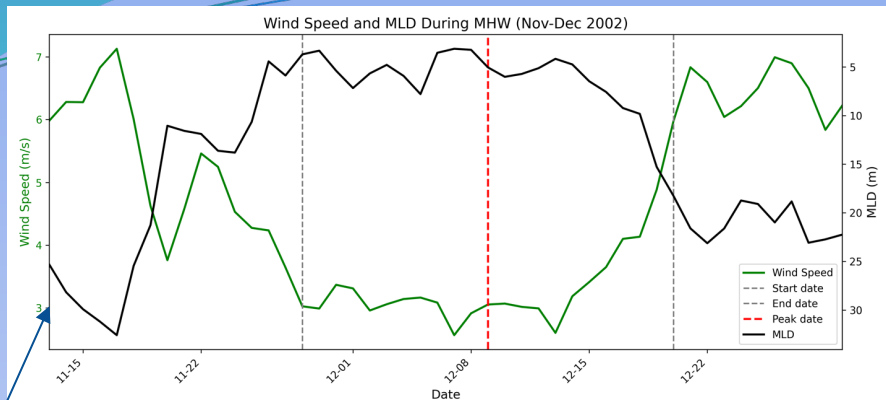
The difference between the peak  
and start date of MHW



$$\Delta T = \int_{t_0}^{t_{peak}} \frac{Q}{\rho c_p h} dt$$

$h$ : mixed layer depth

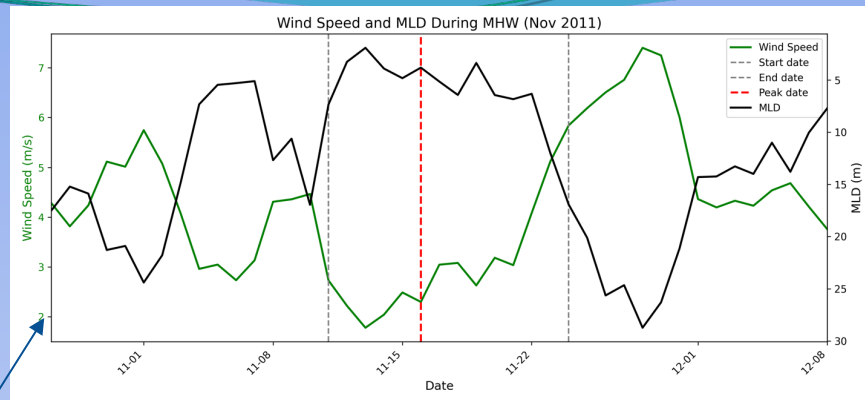
# 2002 MHW



3 m/s

$r = 0.96$

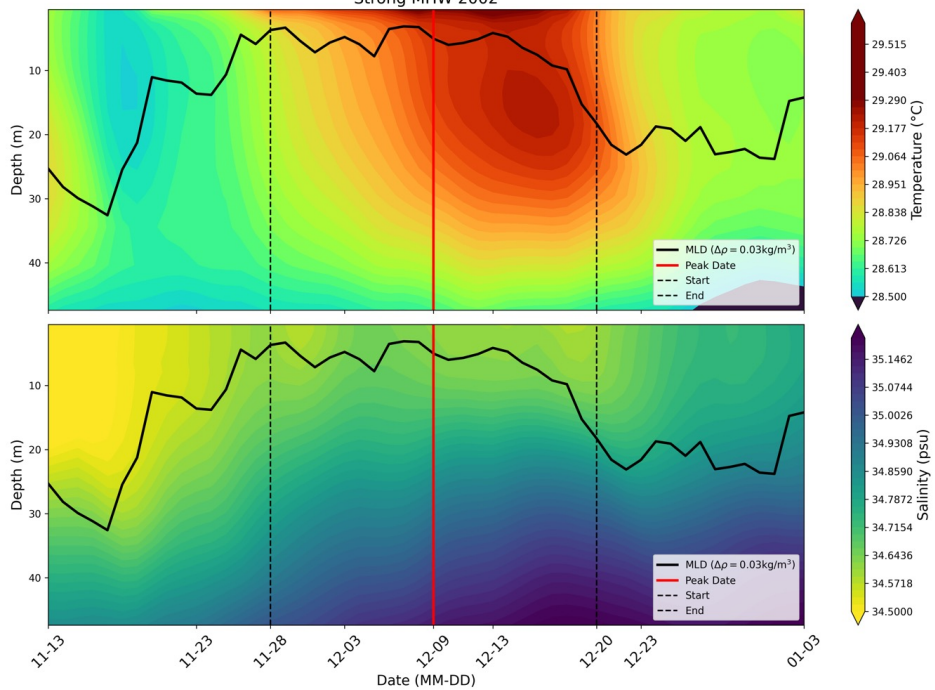
# 2011 MHW



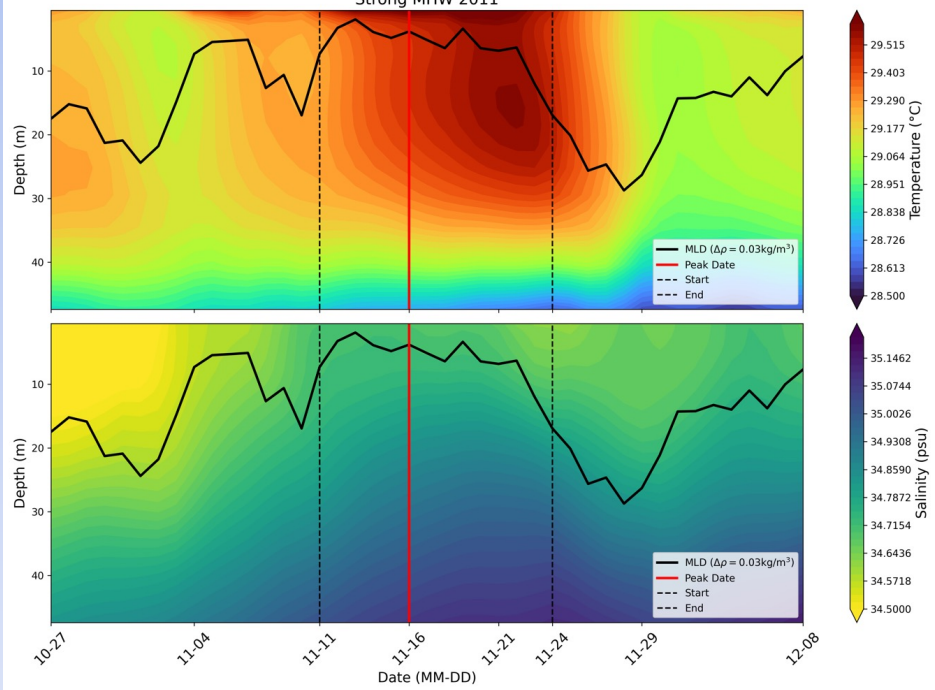
2 m/s

$r = 0.94$

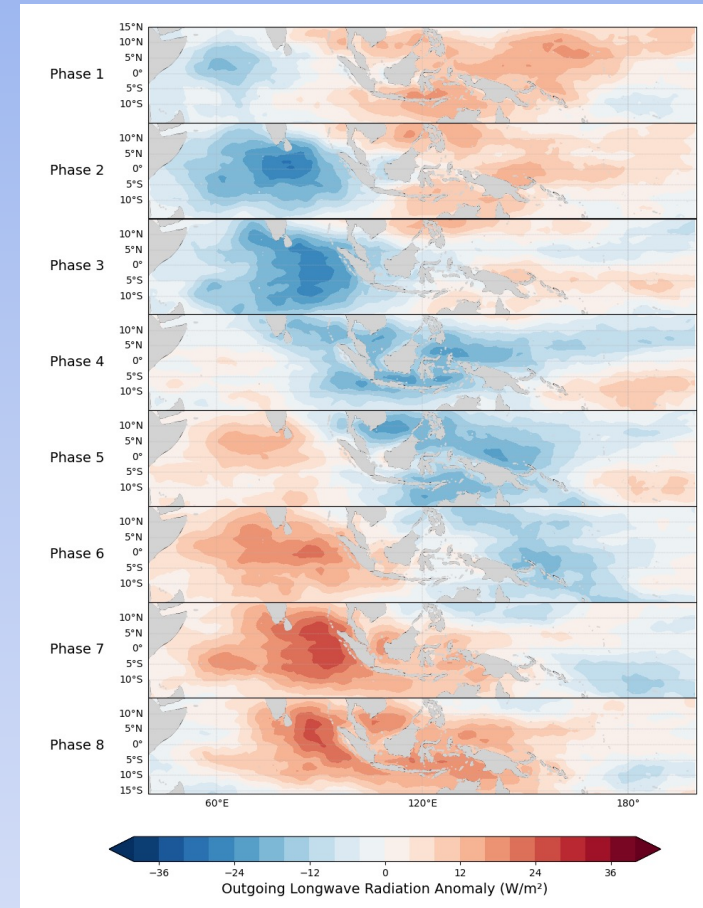
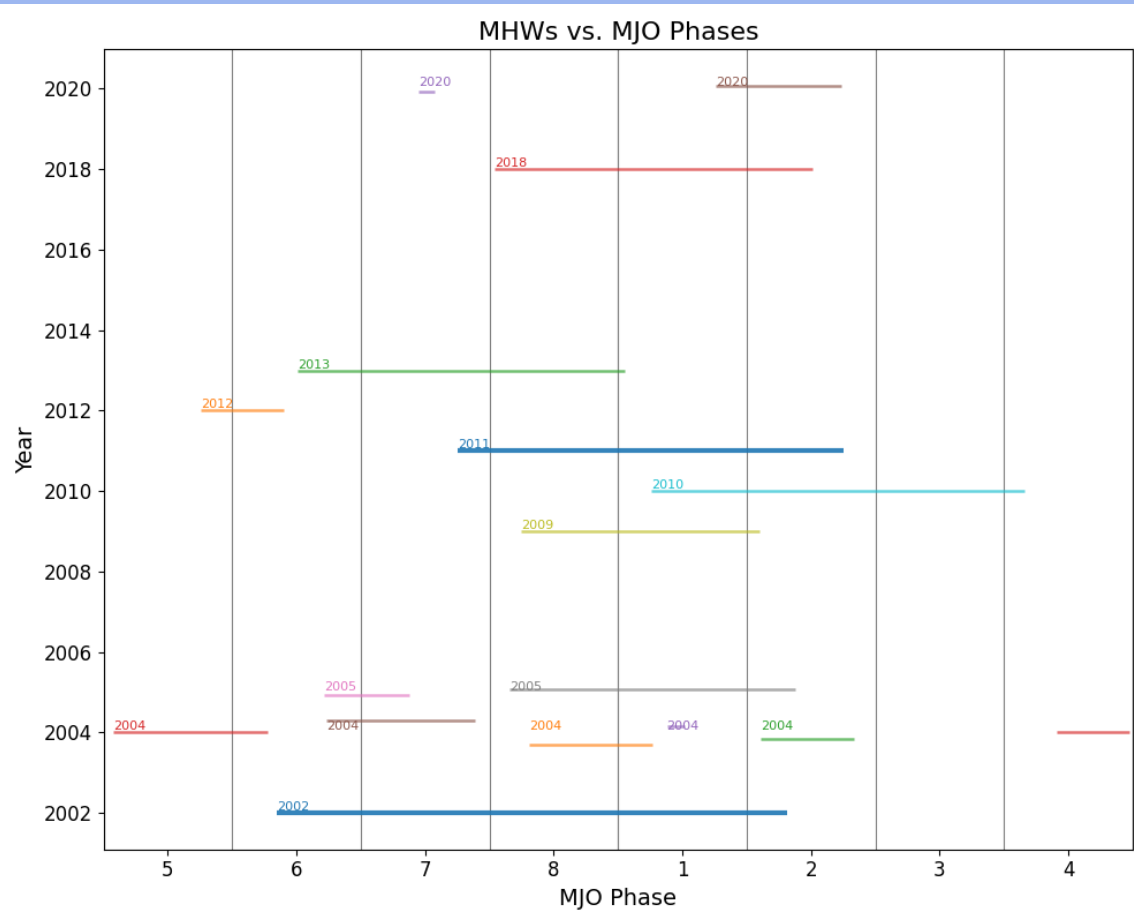
Strong MHW 2002



Strong MHW 2011

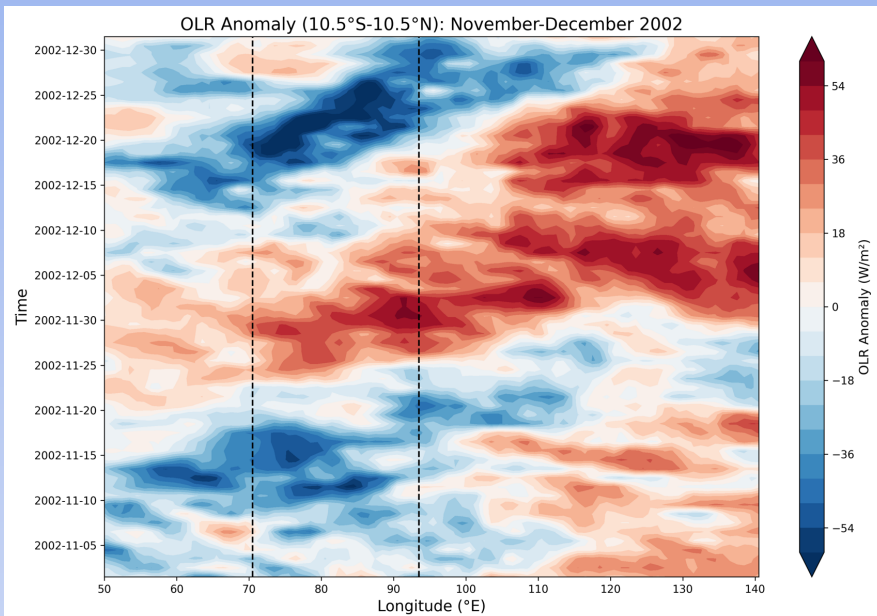


# What drove the persistence of the 2002 and 2011 MHW events?

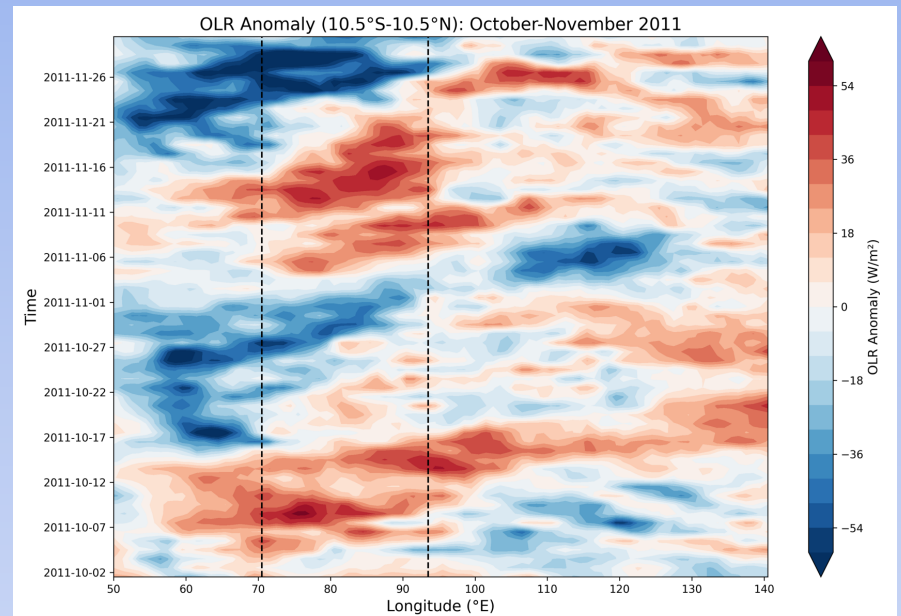


# Two successive MJO convective envelopes during the 2002 and 2011 MHWs

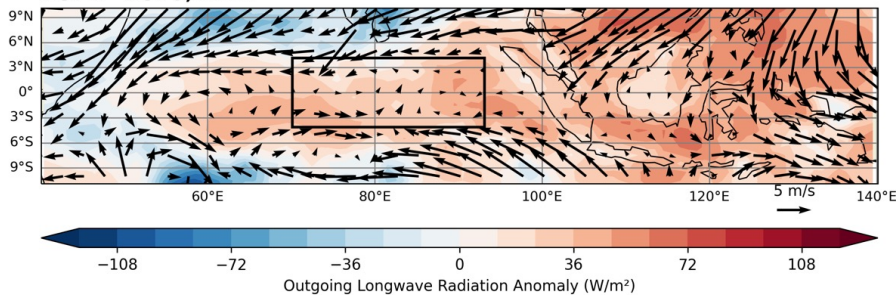
## December 2002



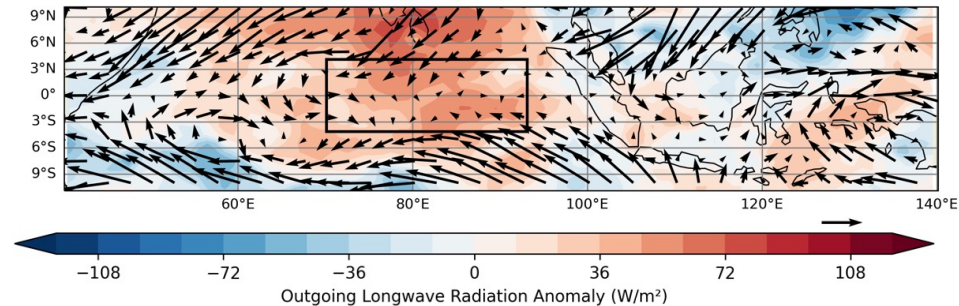
## November 2011



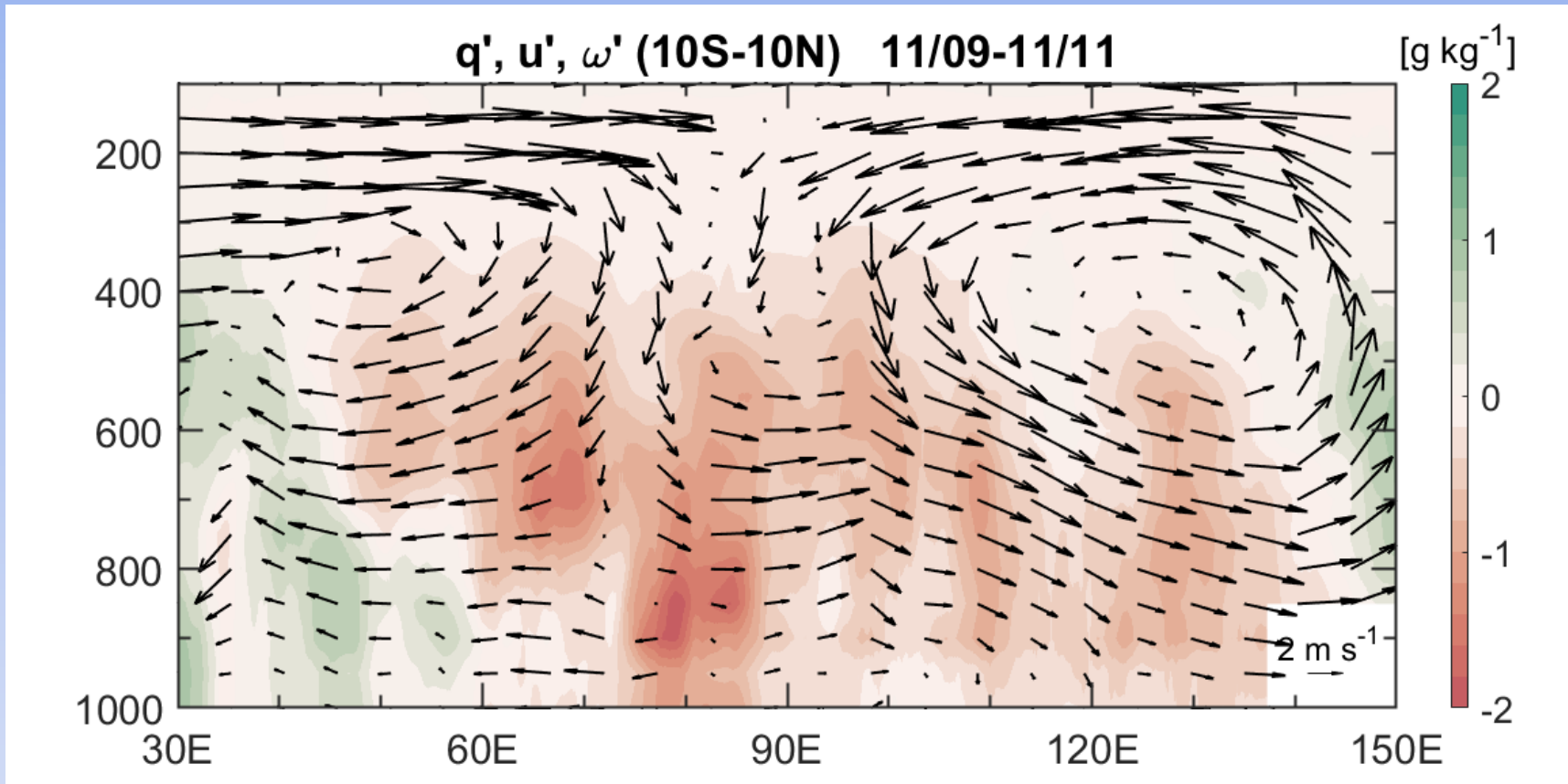
Dec 6 - Dec 9, 2002



Nov 13-14 2011



# November 2011



# Summary

- The MJO exerts a clear and consistent influence on MHW development; events occur primarily during and after the suppressed phase, when clear skies and weak surface winds enhance shortwave radiation and reduce latent heat flux.
- The 2002 and 2011 MHWs were substantially more intense than other events, even though the net surface heat flux during these periods was comparable to that of more moderate events.
- These two intense events persisted through four consecutive MJO phases (phases 7–8–1–2). This resulted from two successive convective envelopes propagating across the Indian Ocean, which led to prolonged surface heat flux anomalies and sustained upper-ocean warming.
- Mixed-layer shoaling, triggered by weak winds during the MJO's suppressed phase, is critical for sustaining this extreme warming.

## Discussion

- Accurate wind and surface flux estimates during calm conditions are critical for MHW research.
- The penetrative component of shortwave radiation (influenced by ocean turbidity) must be accurately estimated to determine MHW intensity and duration.