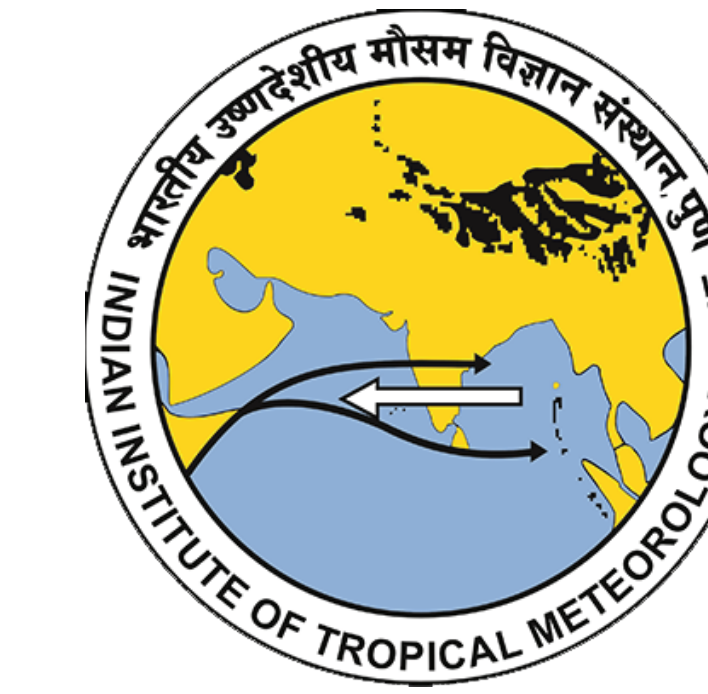


# Indo-Pacific warming warps the MJO and alters global rainfall pattern

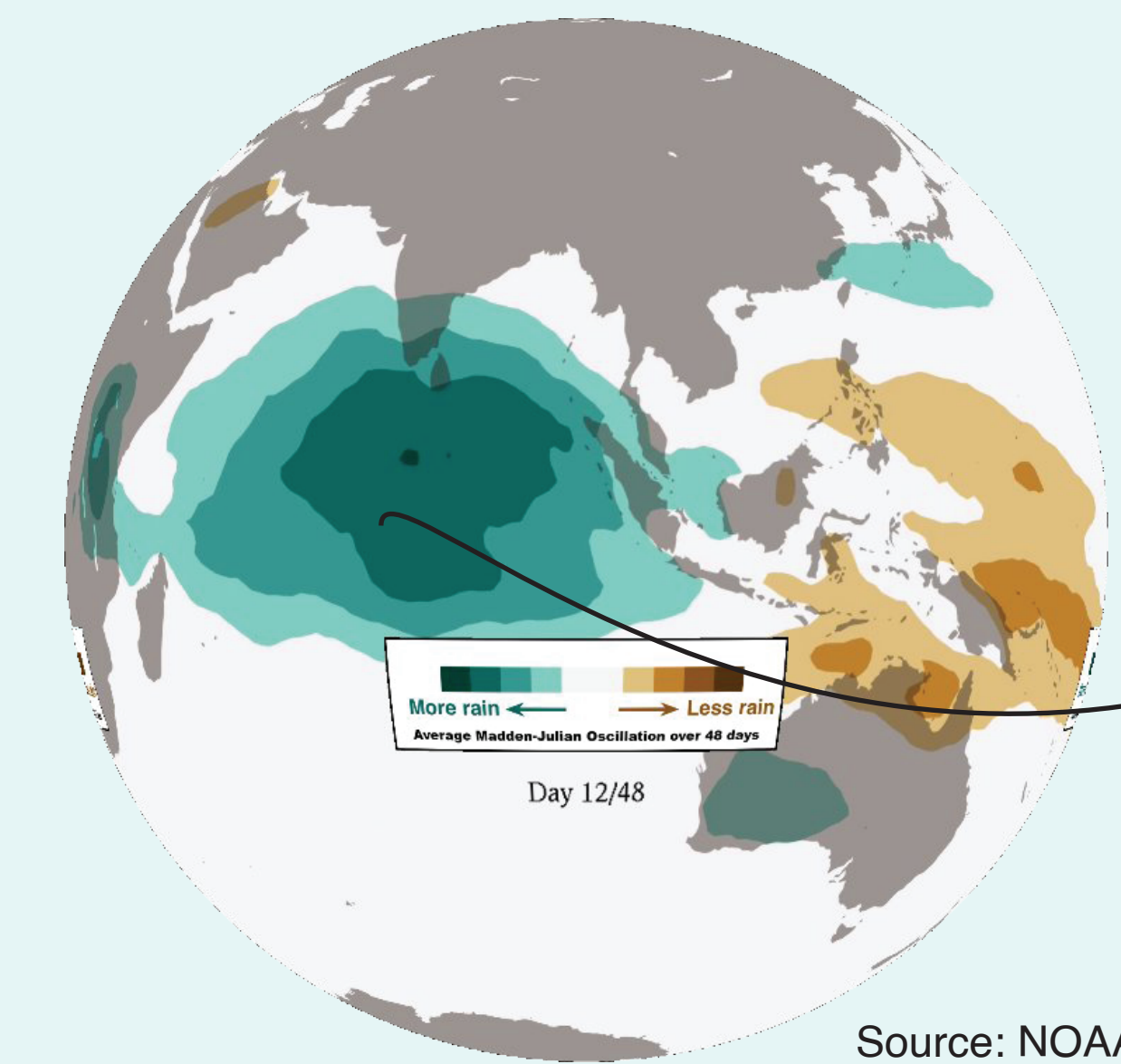


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## What is MJO?



Source: NOAA

Madden Julian Oscillation (MJO) is an eastward moving band of clouds, rains, winds and pressure that travels across the tropics, and is the dominant mode of intraseasonal variability in the tropics.

MJO modulates the Asian, Australian, African and American monsoons, tropical cyclones and El Nino Southern Oscillation. It contributes to extreme events in United States and Europe.

## Rise in extreme events—do they all have something in common?

Frequent California fires?



Source: USDA

African droughts?



Source: Oxfam

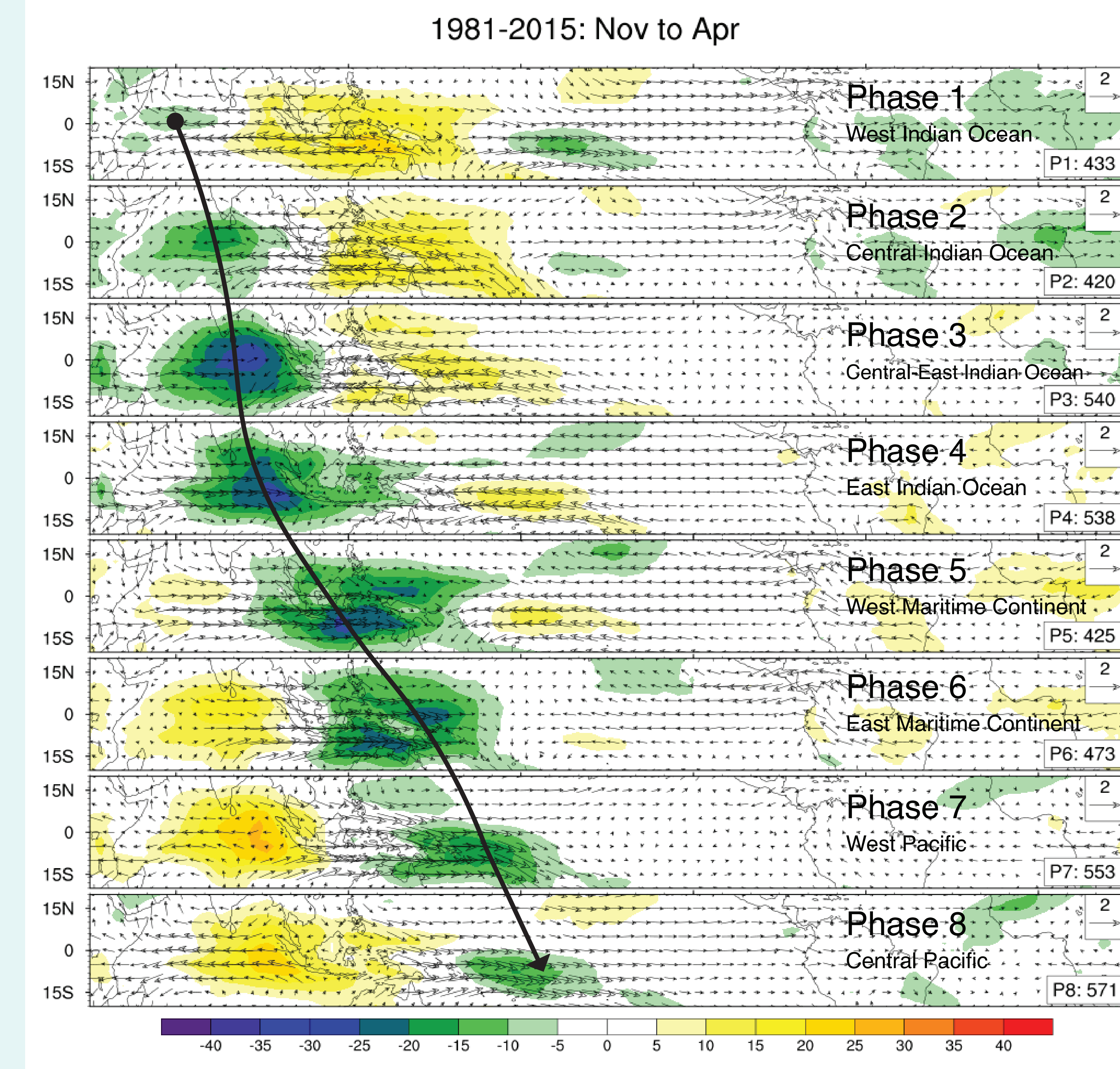
East Asian floods?



Source: VOA

## MJO lifecycle

From its usual initial starting point in the Indian Ocean (Phase 1), the MJO traverses until the Central Pacific (Phase 8) in about 30-60 days.

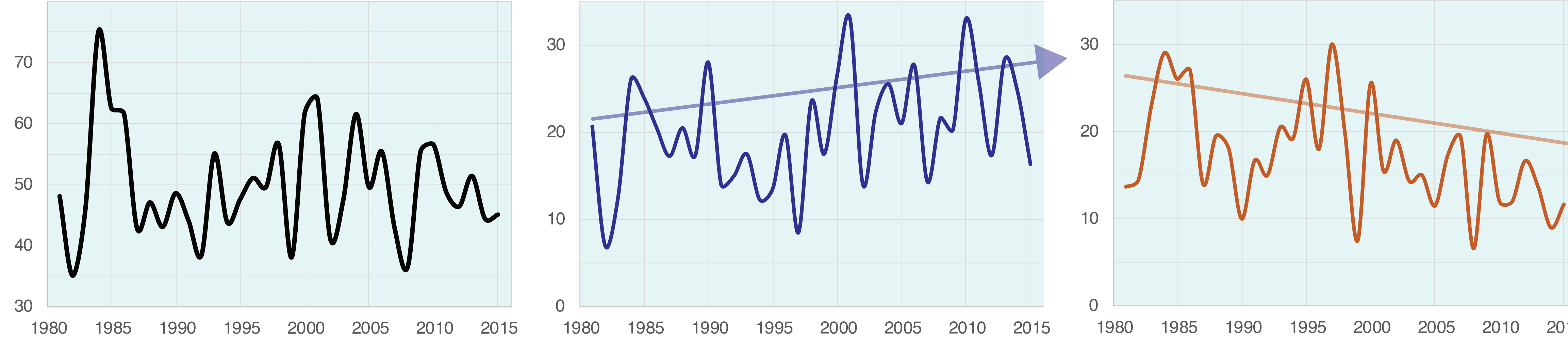


The phases of MJO regulate the global weather in a large way. For example, tropical cyclones are active over the Indian Ocean when MJO is in Phase 1,2 and the W.Pacific when it is in Phase 6,7. Phases 1,2,3 keeps the west and east coasts of US wet and cool while 5,6,7 makes it dry and warm.

## Is the MJO lifecycle changing?

While the total lifespan remains same, it is increasing over Maritime Continent and decreasing over Indian Ocean

(a) MJO total (Phases 1-8) lifespan (number of days) (b) MJO Phases 5,6,7 (Maritime/W.Pacific) lifespan (c) MJO Phases 1,2,3 (Indian Ocean) lifespan

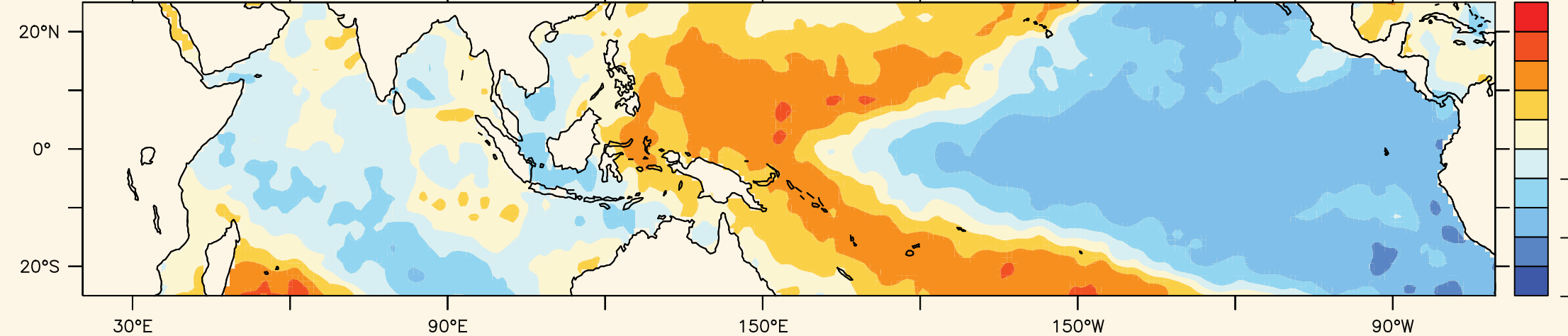


Here we first select the MJO events which show active eastward propagation and sufficient amplitude for Nov-Apr (1981-2015). We then count the number of days when MJO is active over each phase. MJO Phase 1,2,3 represents the Indian Ocean and Phase 5,6,7 represents the Maritime Continent/W.Pacific.

## Why is the MJO lifespan changing?

The changes in MJO lifespan appears to be related to rapid warming over West Pacific warm pool. Warm pool warming enhances the zonal gradient of moist static energy, between Indian Ocean and West Pacific. This accelerates MJO over the Indian Ocean and slows it down over the maritime region.

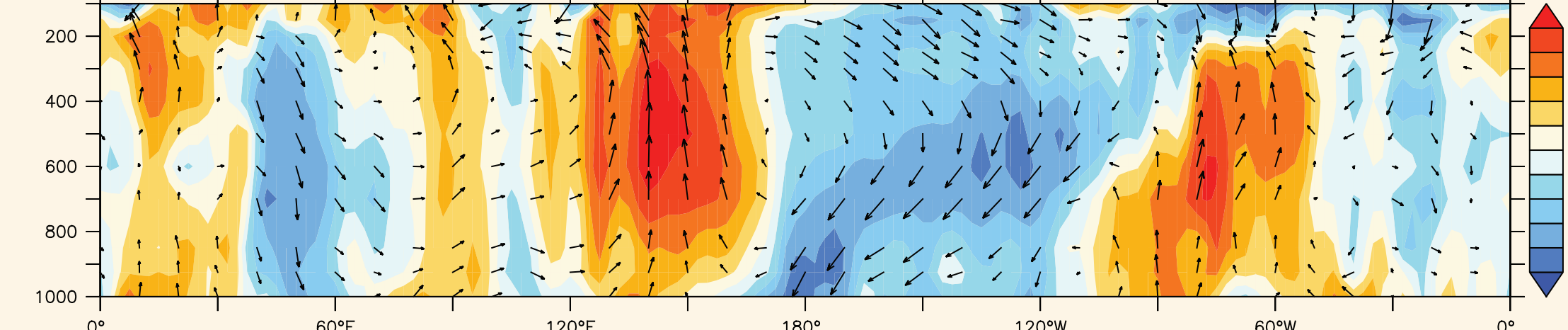
(a) Correlation: SST and MJO lifespan (5,6,7)



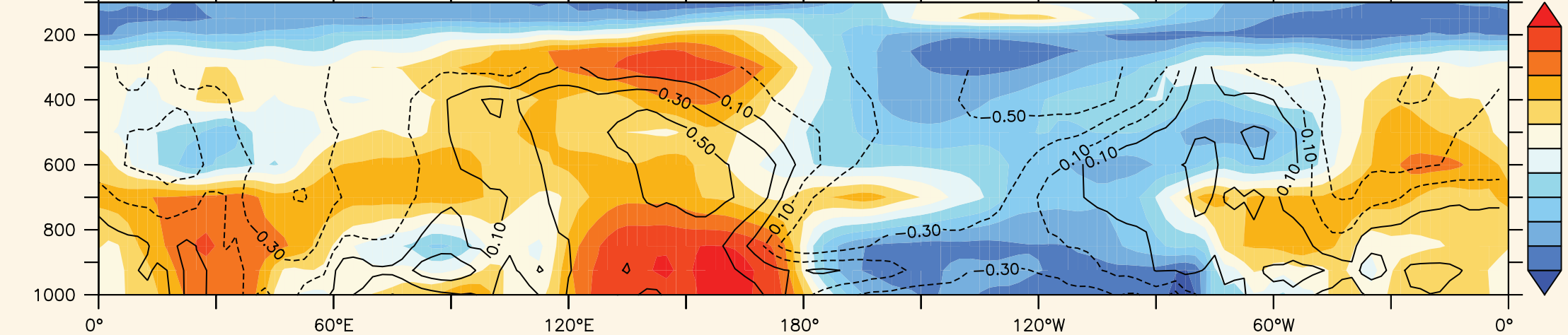
Correlation is maximum over the West Pacific, where the SST means and trends are the largest. It is interesting that the warming over the Indian Ocean does not play a major role compared to the West Pacific SSTs!

## Atmospheric circulation associated with MJO

(b) Correlation: atmospheric circulation and MJO lifespan (5,6,7)



(c) Correlation: temp. (colors) / humidity (contours) and MJO lifespan (5,6,7)

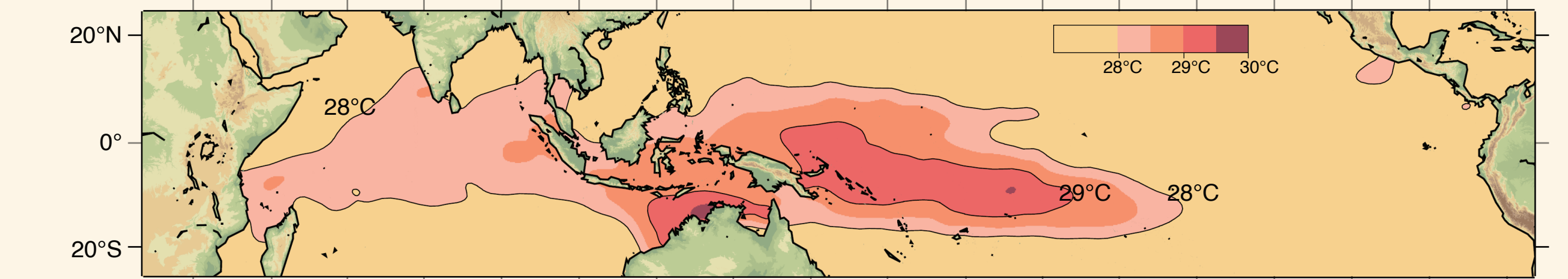


Observed changes in MJO is associated with enhanced convection over West Pacific and dry subsidence over Indian Ocean. Though the entire Indo-Pacific SSTs are warming, it appears that MJO response is more sensitive to the West Pacific SSTs.

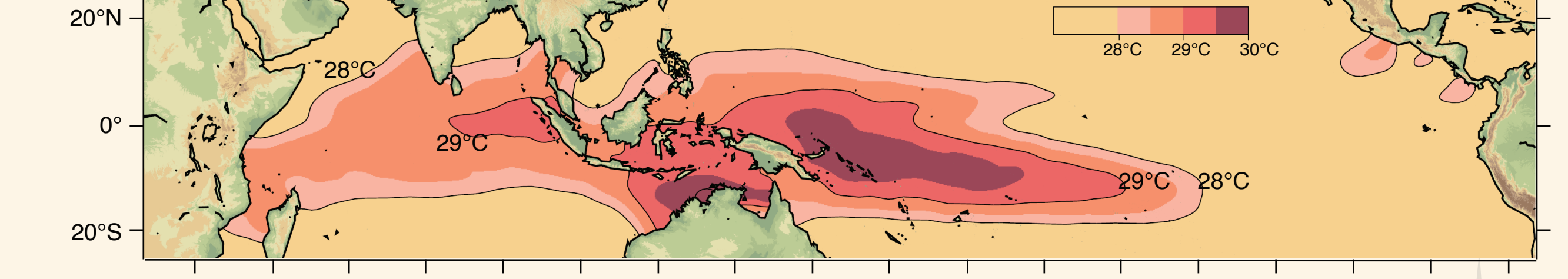
## Indo-Pacific warming

MJO initiates and evolves over the Indo-Pacific. This region is warming rapidly as a response to anthropogenic emissions—and may have an impact on the MJO characteristics.

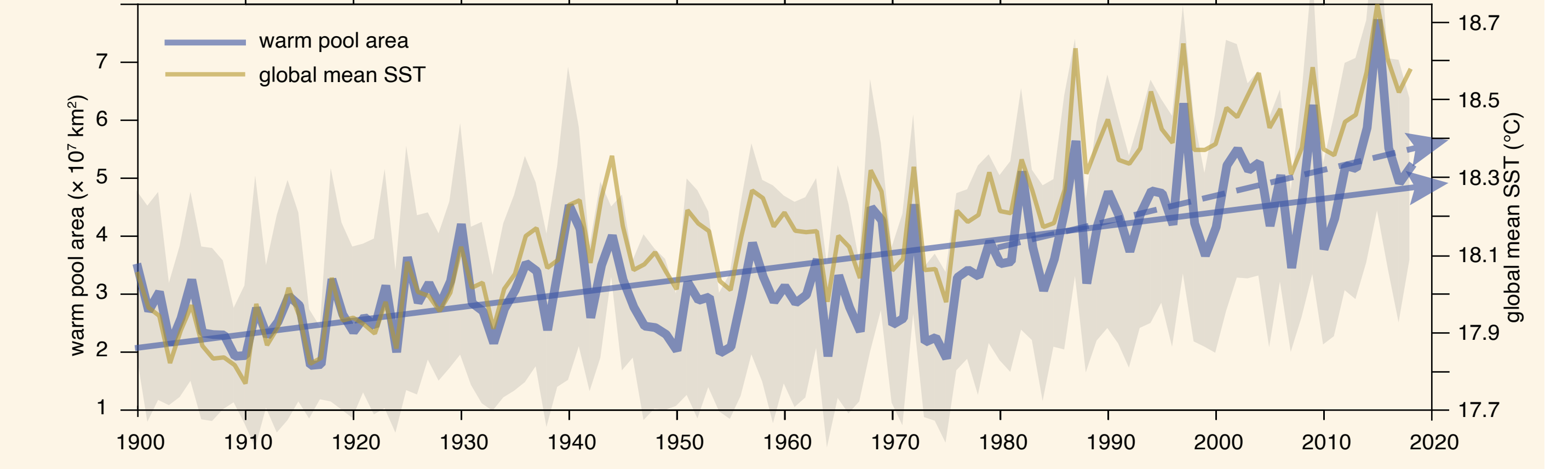
Indo-Pacific Warm Pool, Nov–Apr 1900–1980



Indo-Pacific Warm Pool, Nov–Apr 1981–2018



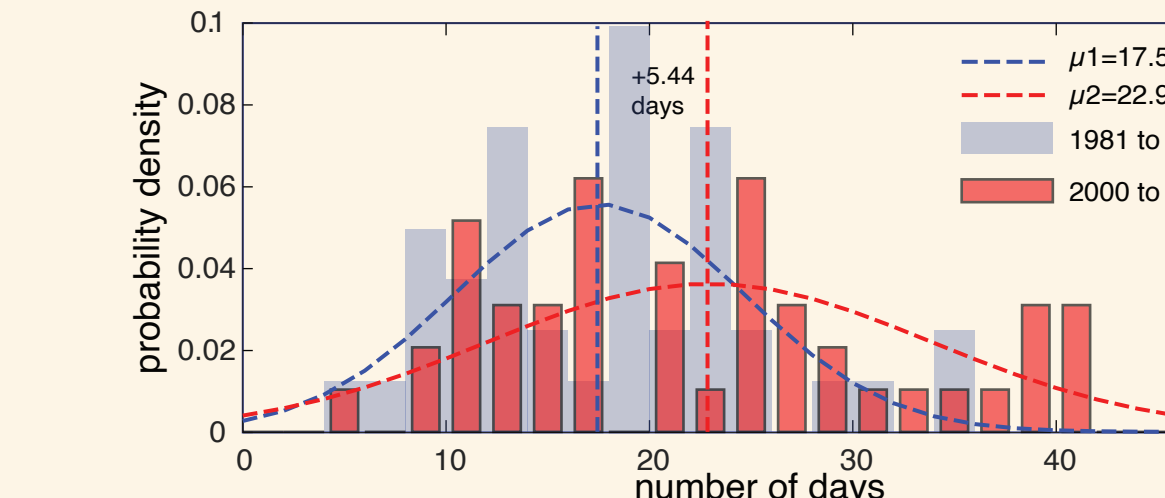
Indo-Pacific 28°C warm pool area, Nov–Apr 1900–2018



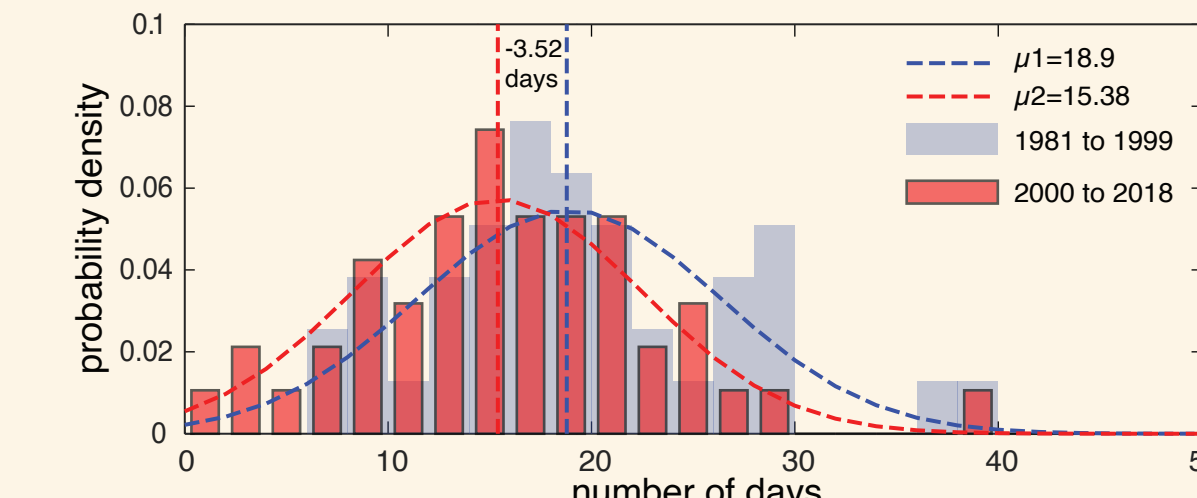
## What does the change in MJO mean?

MJO residence time is now 3–4 days over the Indian Ocean and 5–6 days longer over the Maritime Continent.

(a) distribution of MJO Phases 5,6,7



(b) distribution of MJO Phases 1,2,3



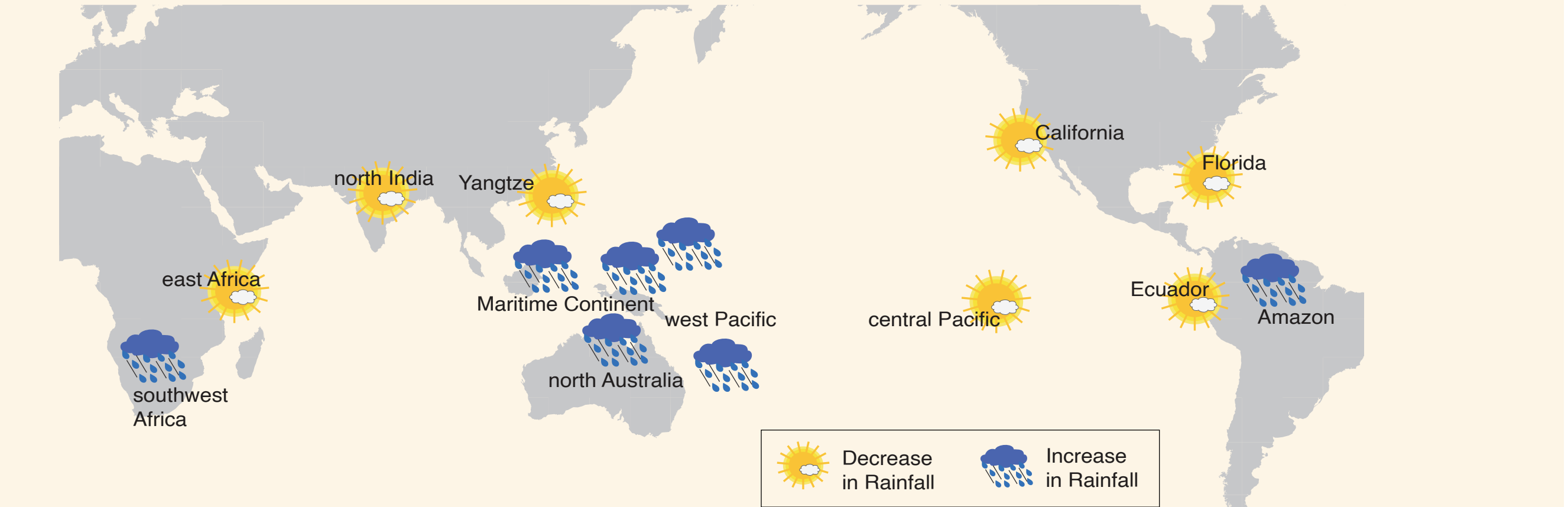
This means that in the recent decades, during northern winter/spring (Nov–Apr), convection is more active over the Maritime Continent and the West Pacific (Phases 5,6,7) while it is less active over the Indian Ocean (Phases 1,2,3). Such a large change in MJO can have direct implications on the global climate which is tightly linked to the MJO phases.

## What are the impacts on global climate?

The observed change in MJO lifespan is associated with: Increased rainfall over Maritime Content, West Pacific, Amazon and SW Africa and decreased rainfall over CE Pacific, E Africa, Ecuador, east/west coasts of USA and South Asia.

Global impacts due to the changes in MJO

Figure shows regions where MJO (p5/6/7)-rainfall correlation and rainfall trends match



The changes in MJO is consistent with the trends in rainfall, implying that the frequent California fires, East Asia floods and Africa droughts may be related to MJO changes.