

# Air-sea interaction: Monsoon

---

ATM2106



Western Ghats in dry season (<https://en.wikipedia.org/wiki/Monsoon>)



Western Ghats in wet season (<https://en.wikipedia.org/wiki/Monsoon>)





“모내기하고 열흘. 6월 말. 장마가 시작되었고...”





Dry monsoon







Flooding during the summer monsoon, looks like in India  
(from <https://svs.gsfc.nasa.gov/12303>)



# Flooding in 2017 summer



Before the monsoon, May 2017





# Flooding in 2017 summer



After the monsoon, September 2017



More than 40 million people have been suffered!

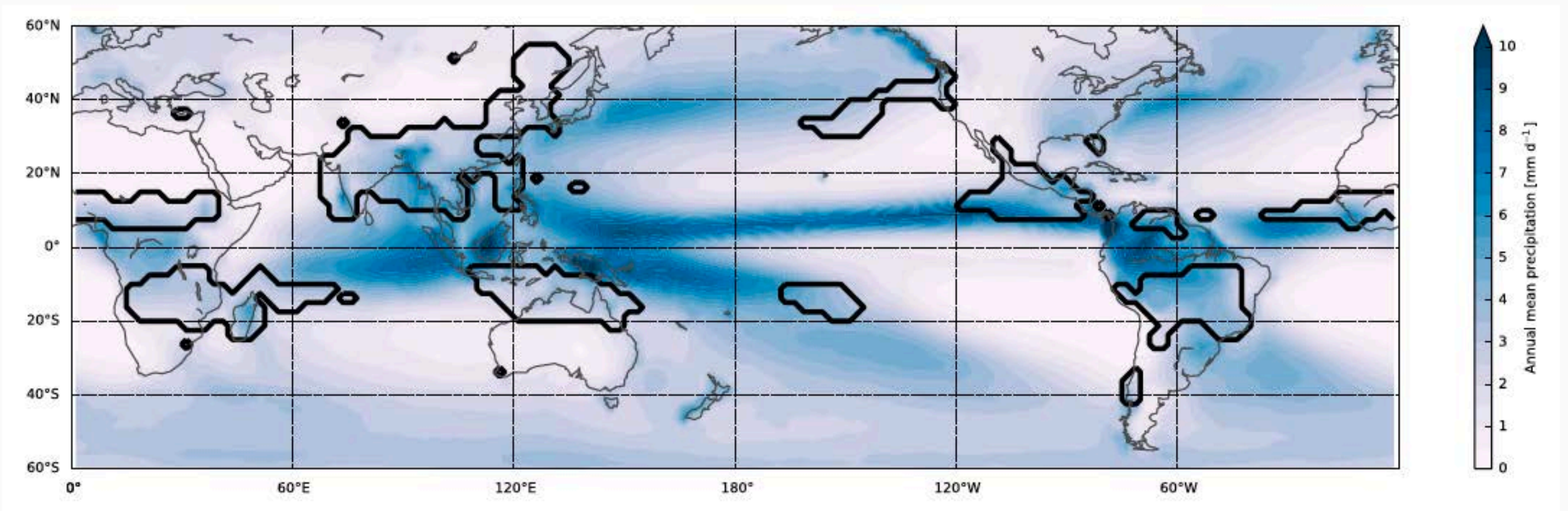








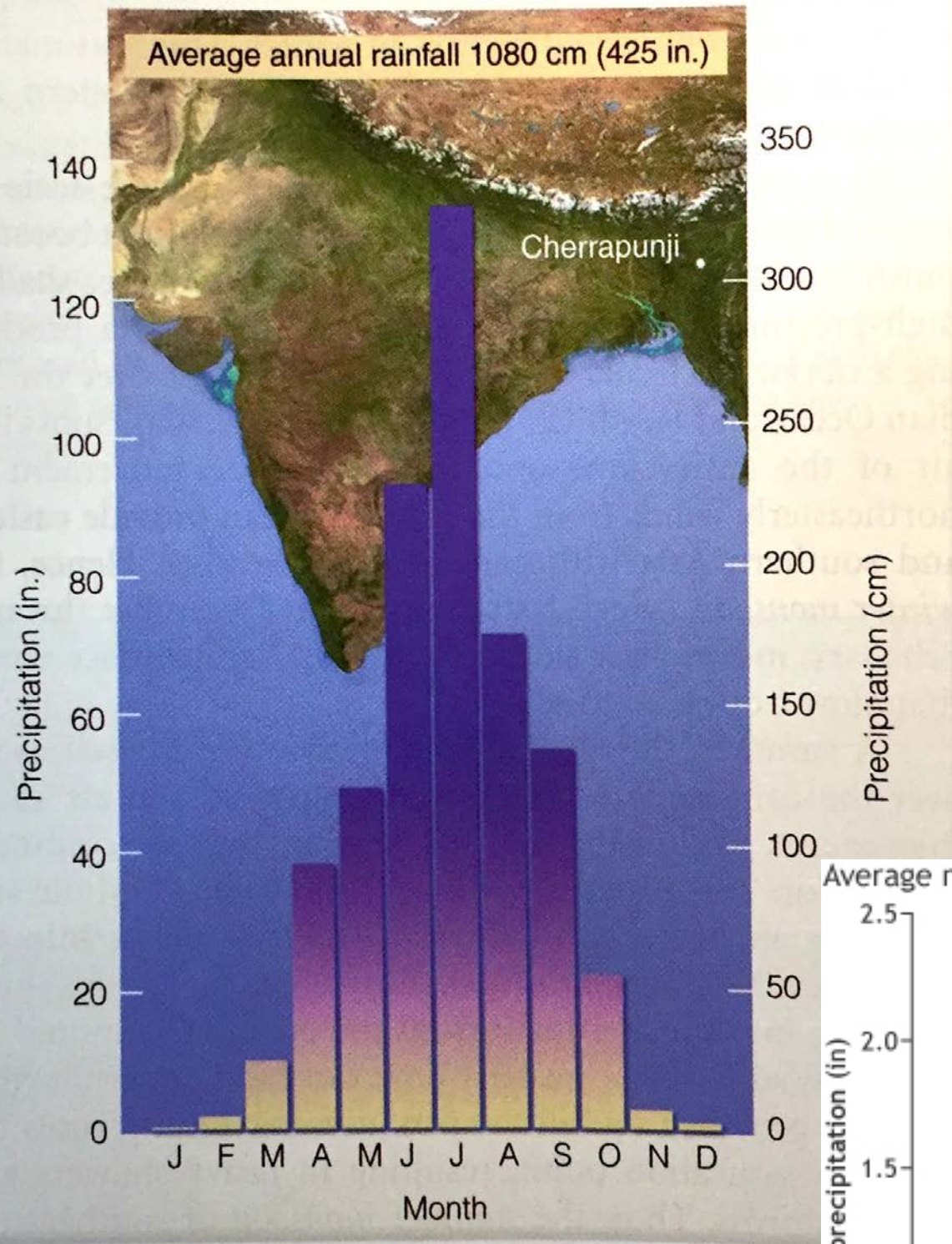
# One definition of the monsoon



At least 40% of precipitation during local summer  
AND  
Summer mean more than 2 mm/d above annual mean



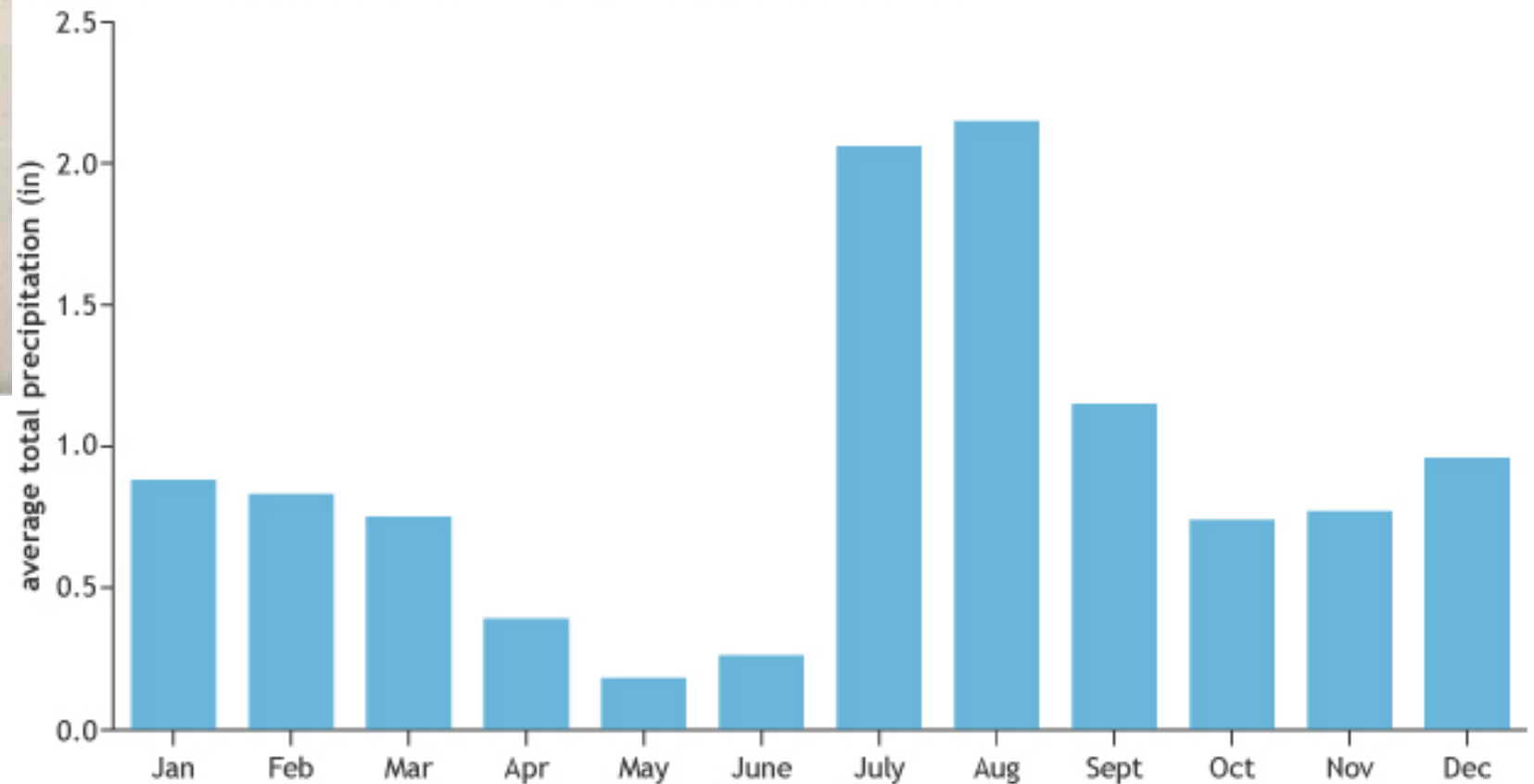
# Precipitation data



Cherrapunji, India

Tucson, Arizona

Average monthly precipitation in Tucson, Arizona (1981-2010)

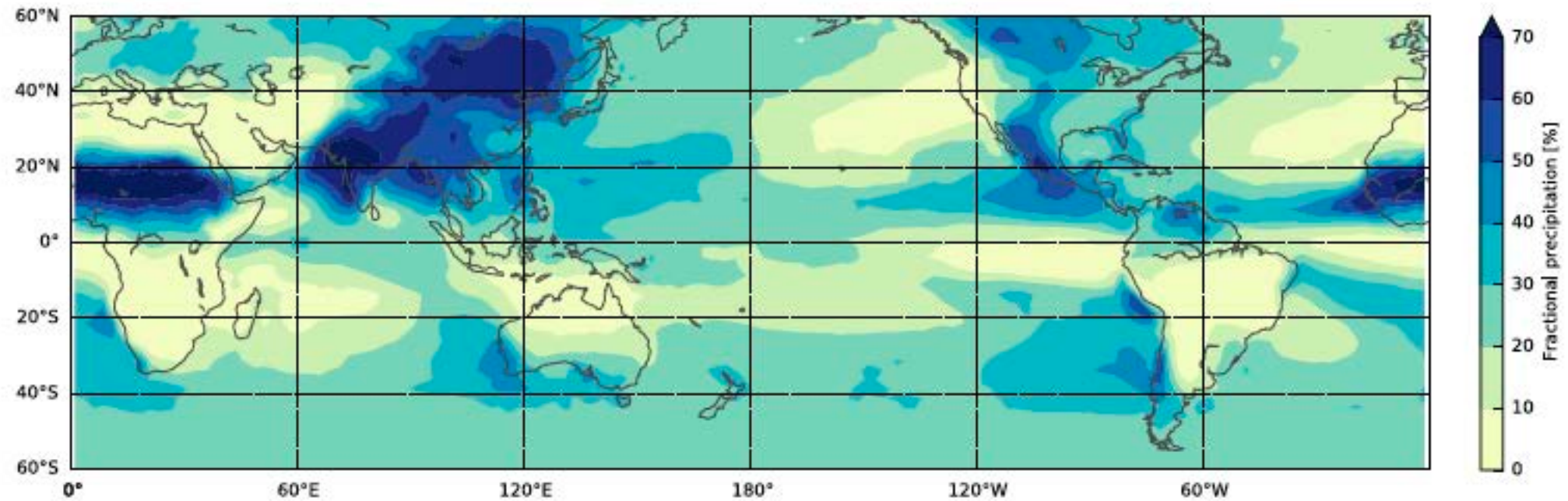




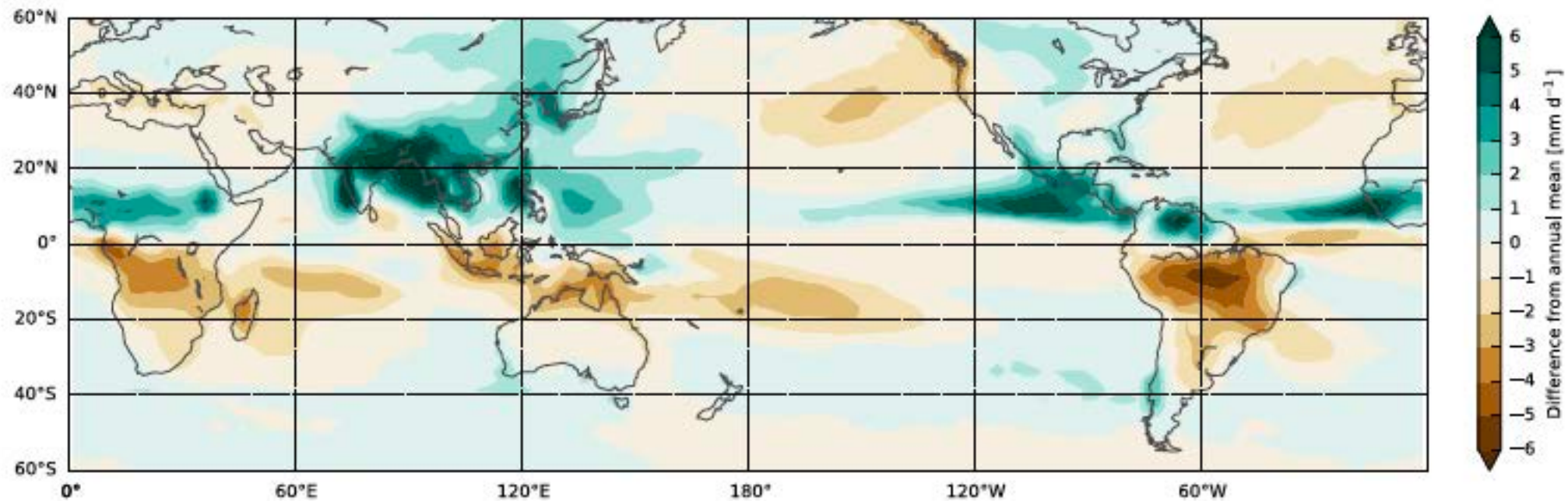
# Concentrated precipitation

Figure from the slide by Jonathan Wright

Precip. in JJA / Annual Precip.



Precip. rate in JJA - Annual mean Precip. rate

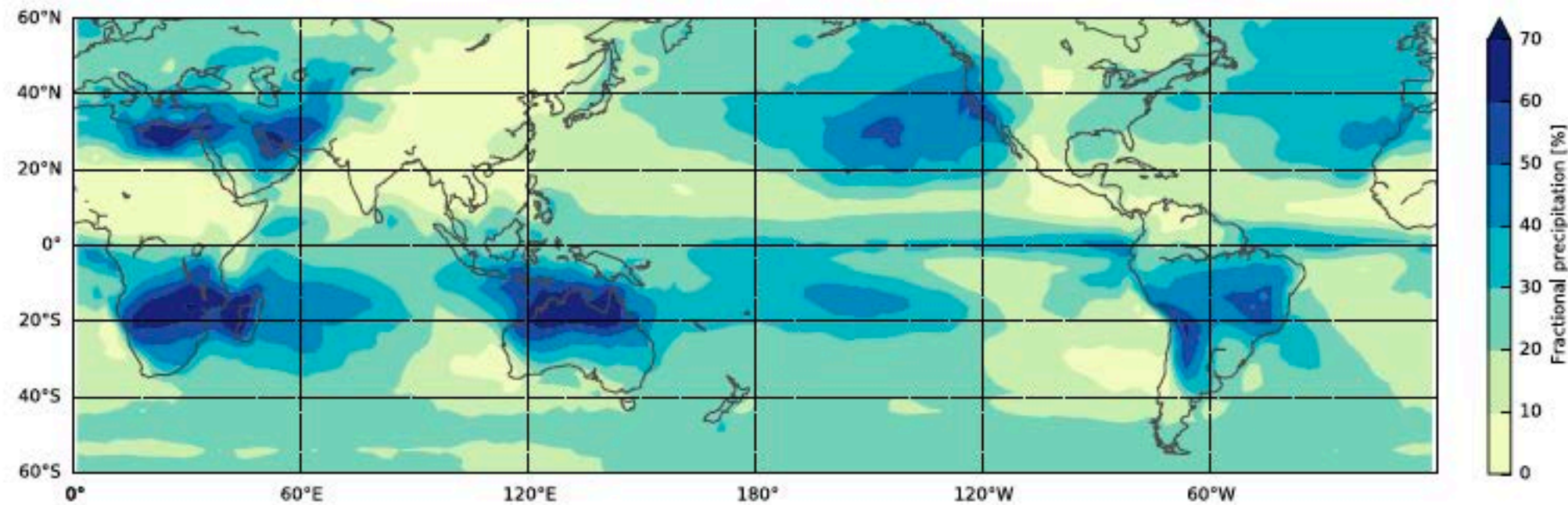




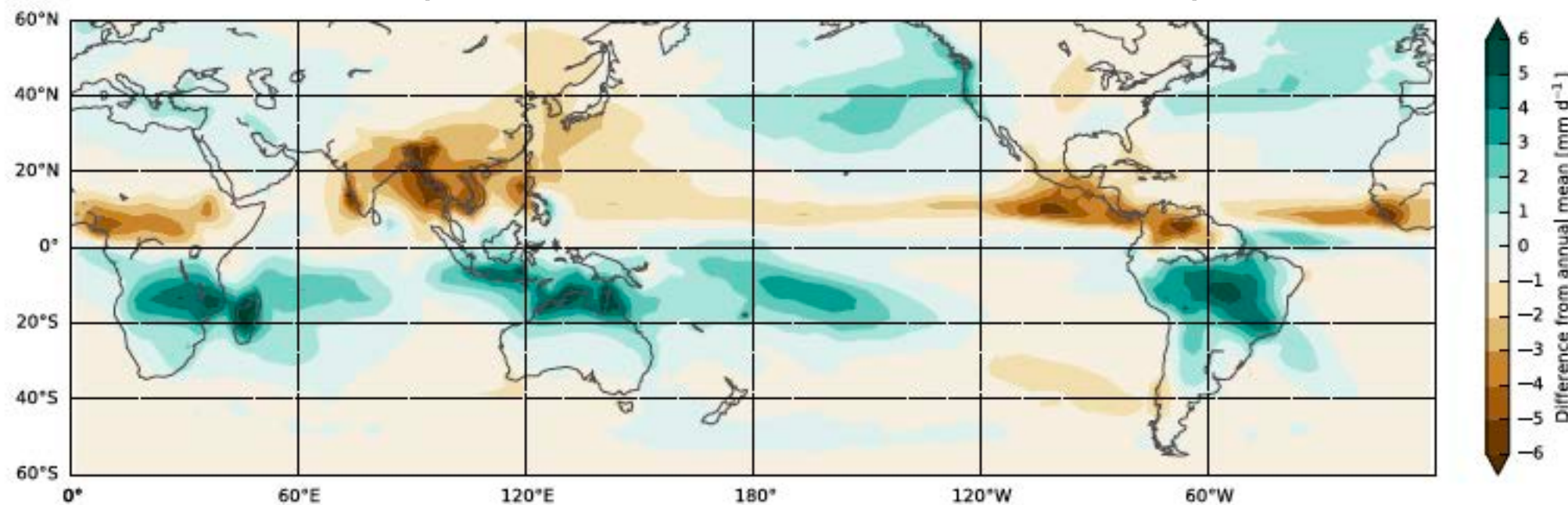
# Concentrated precipitation

Figure from the slide by Jonathan Wright

Precip. in DJF / Annual Precip.



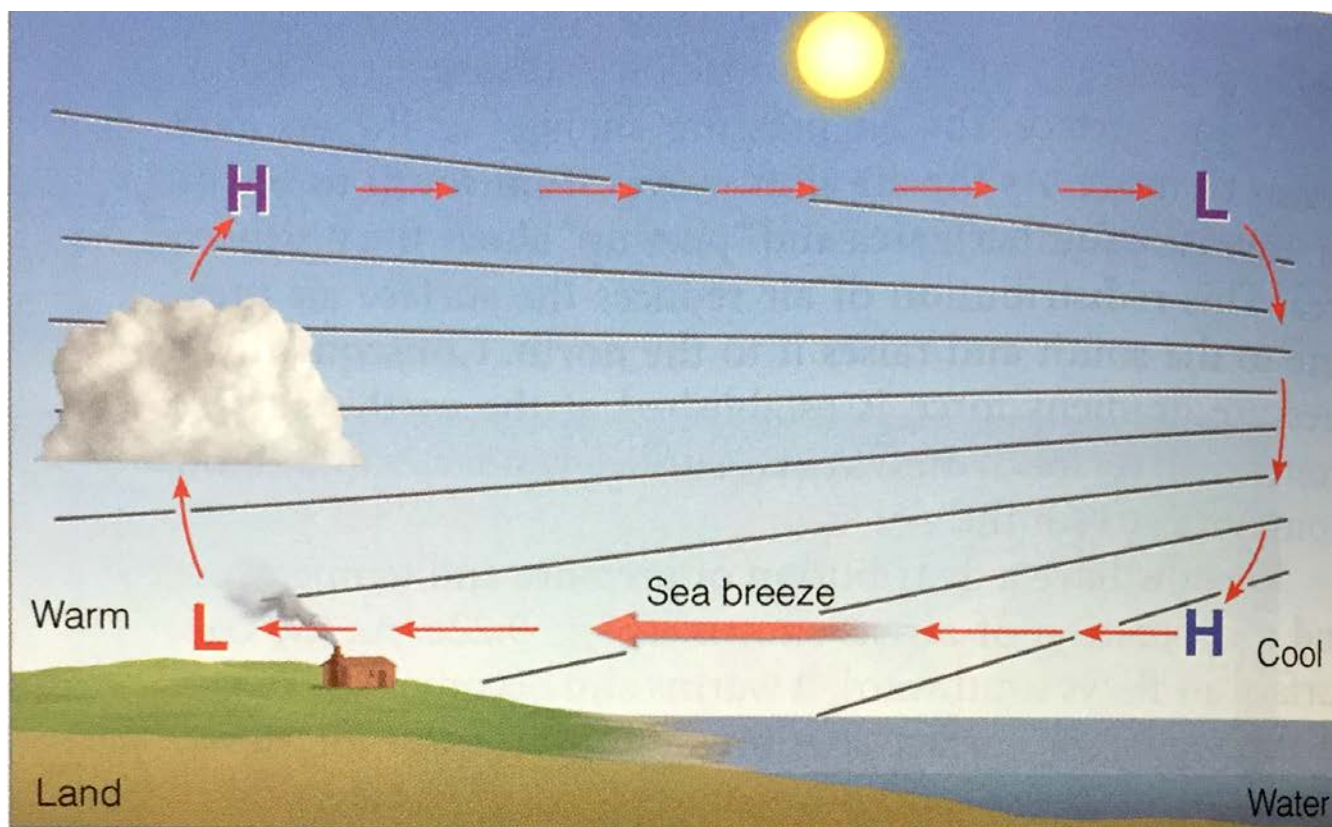
Precip. rate in DJF - Annual mean Precip. rate



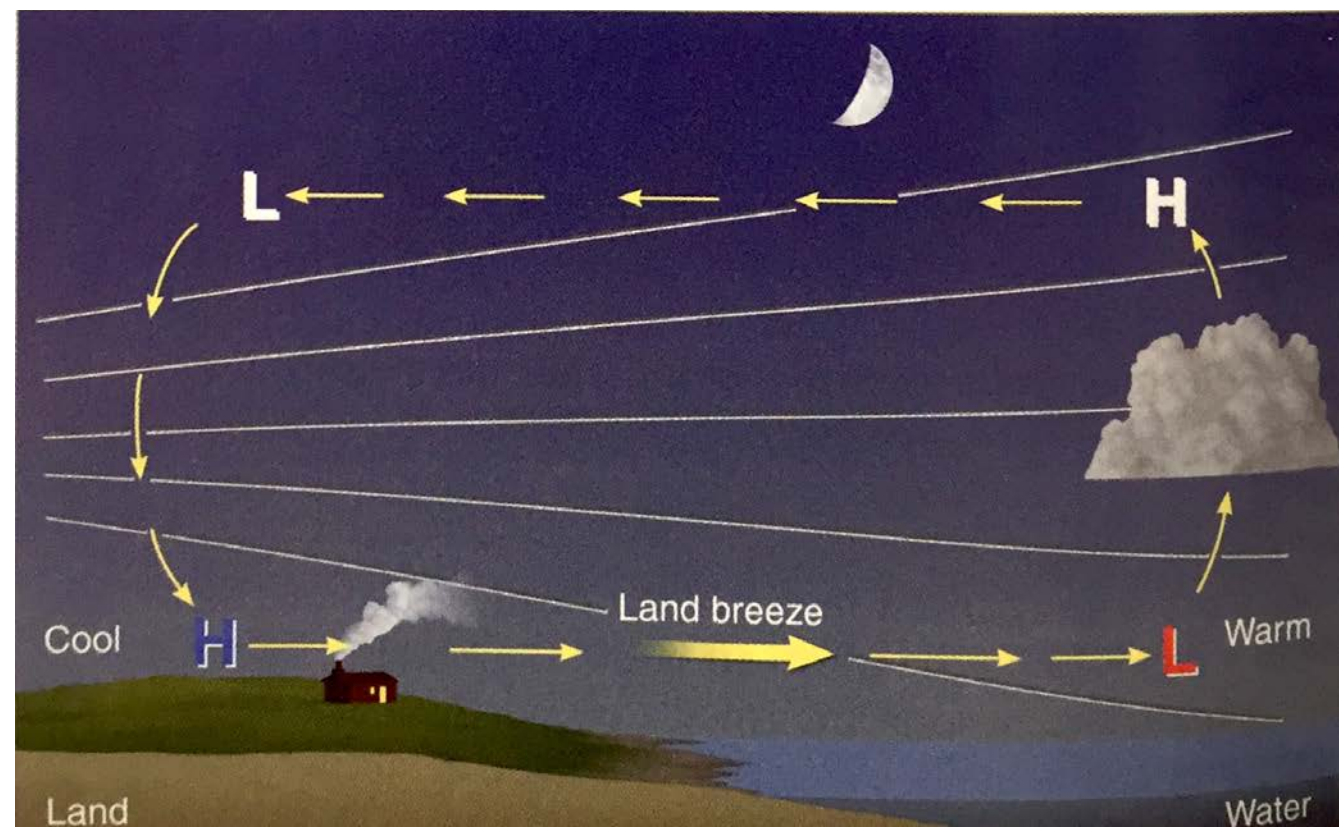


# How does the monsoon work?

- Strong land-sea contrasts in surface temperature like land-sea breeze



Sea breeze

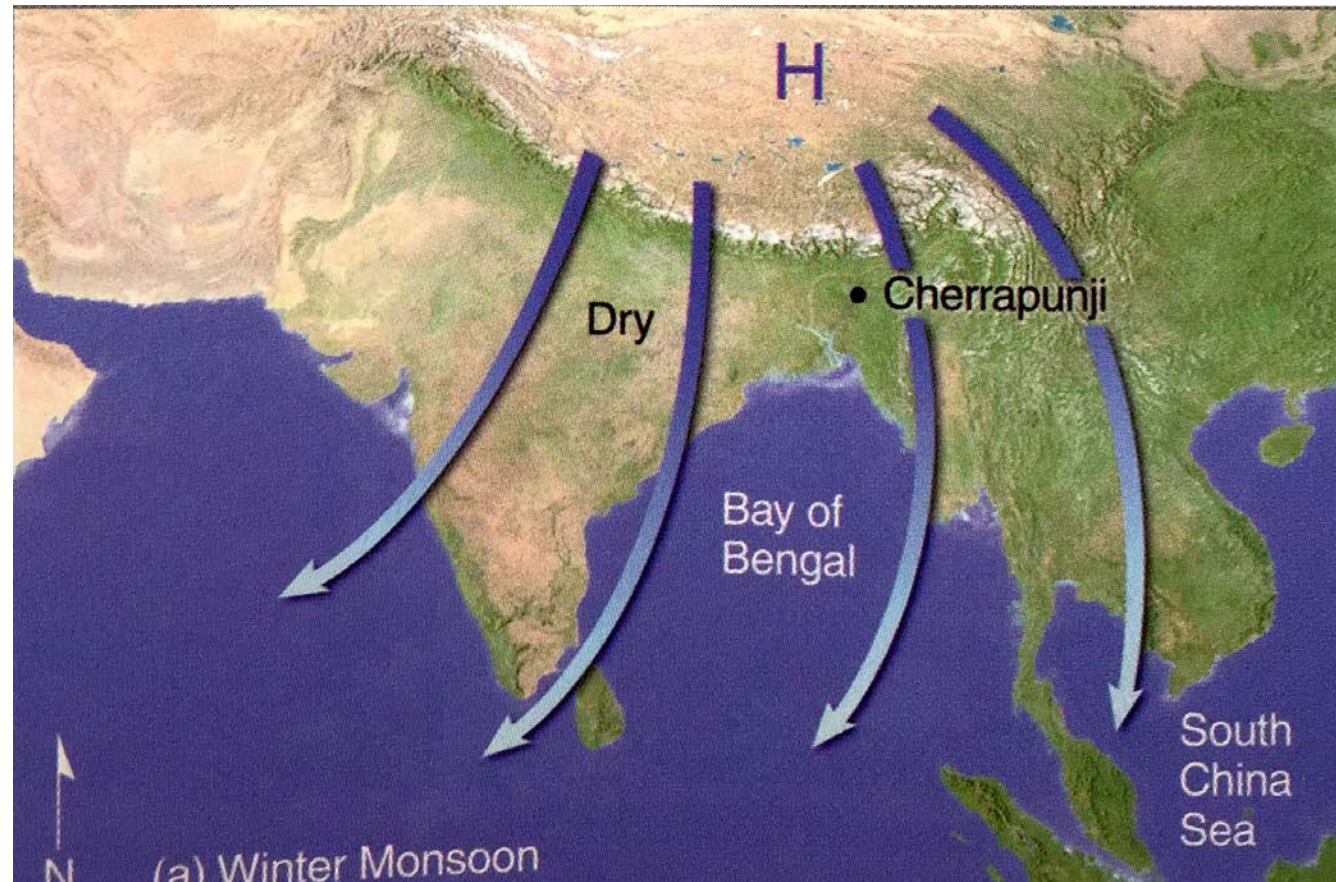
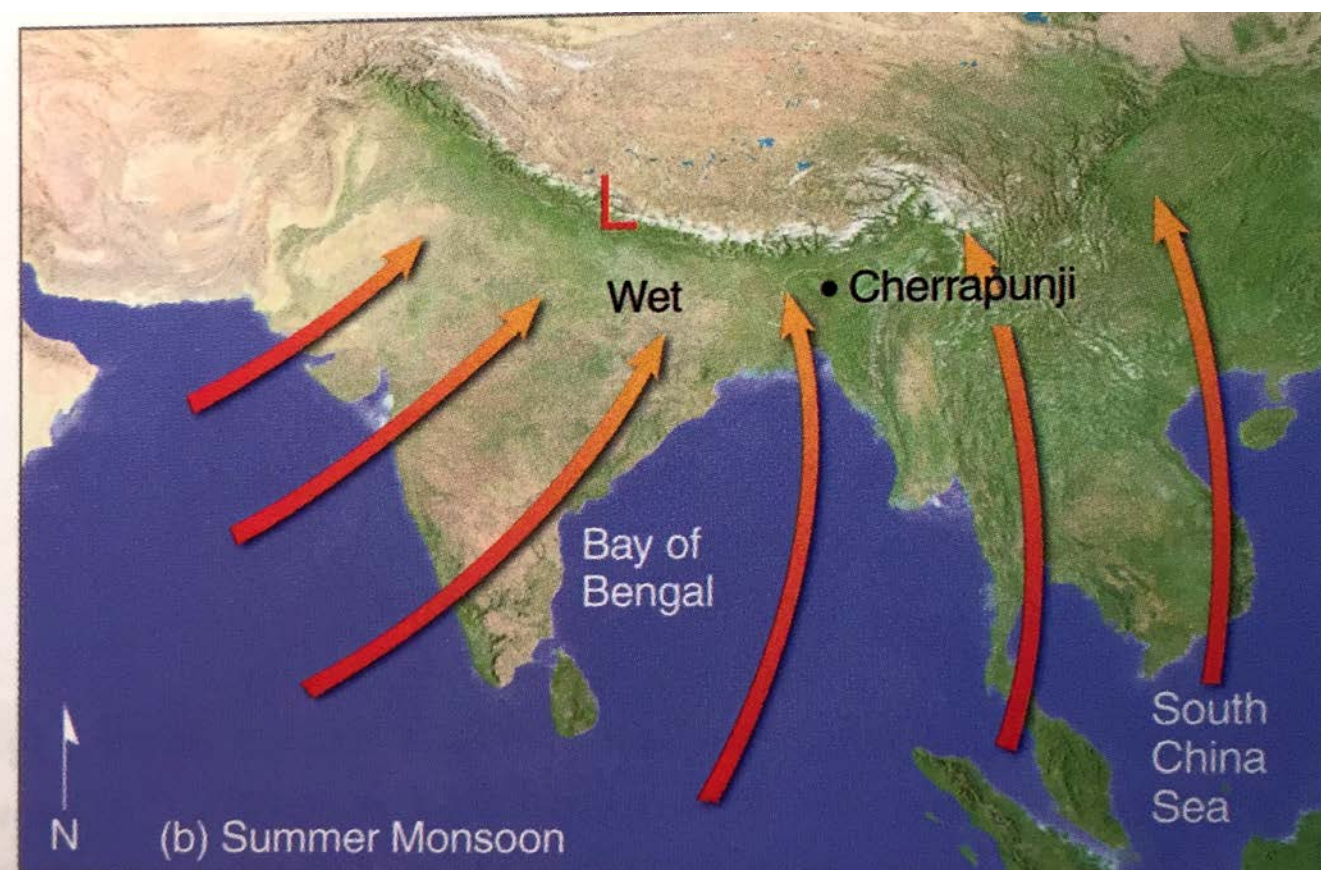


Land breeze



# How does the monsoon work?

- Strong land-sea contrasts in surface temperature like land-sea breeze
- Temperature difference affects the moist energy budget. (moisture transport)





# East Asia Monsoon

- Carries moist air from South Asia and the North Pacific to East Asia
- Driven by temperature differences between Asia and the Pacific Ocean

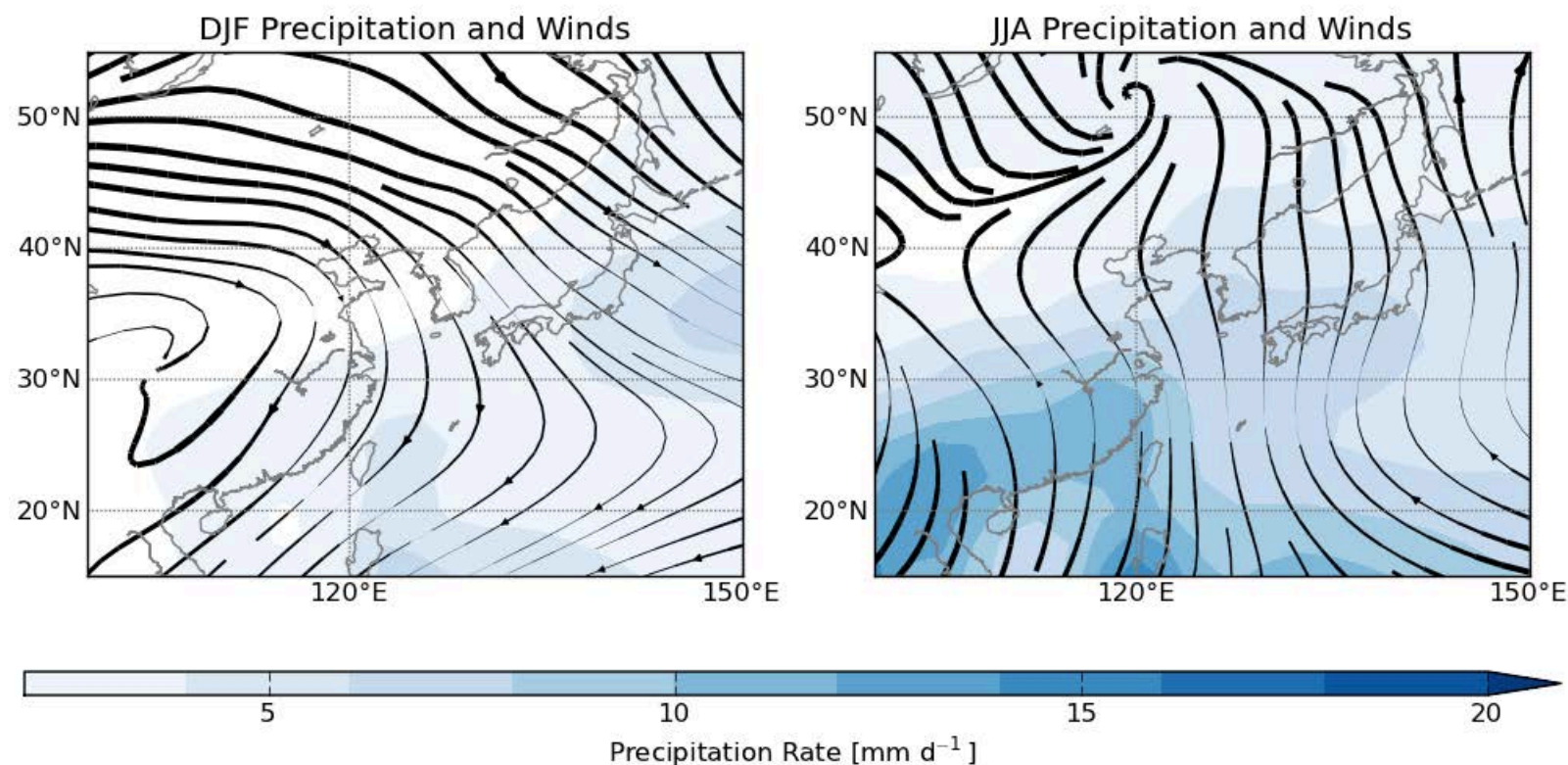


Figure from the slide by Jonathan Wright



# South Asian Monsoon

- The largest and most powerful of the regional monsoons
- Accounts about 80% of the rainfall in India
- Orographic effects are important.

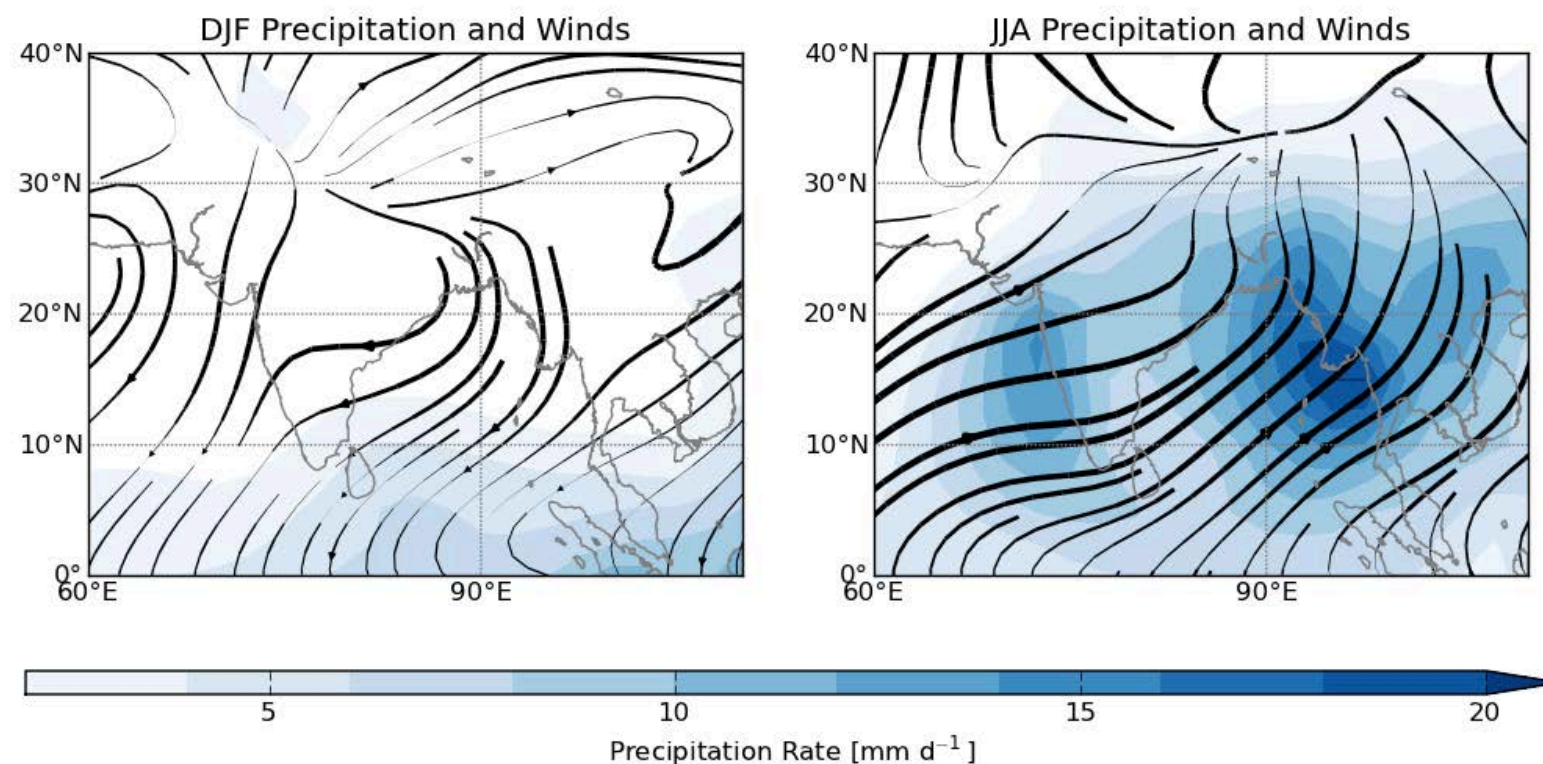


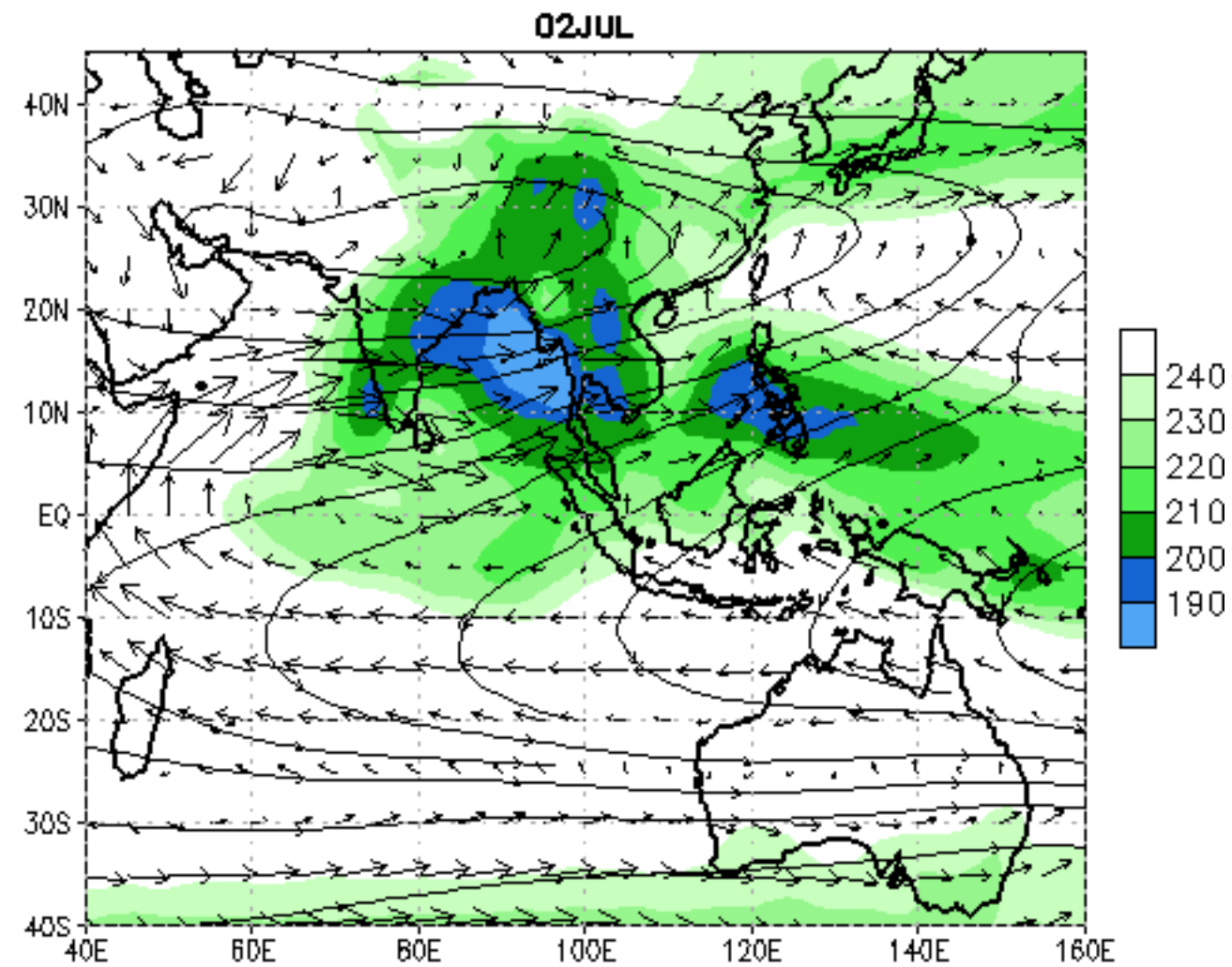
Figure from the slide by Jonathan Wright



# The development of the Indian monsoon

---

OLR, 200-hPa Streamlines and 850-hPa Wind Clim (1979–1995)



Data Sources: OLR – NESDIS/ORA, Winds – NCEP CDAS/ Reanalysis



# Wind and outgoing longwave radiation

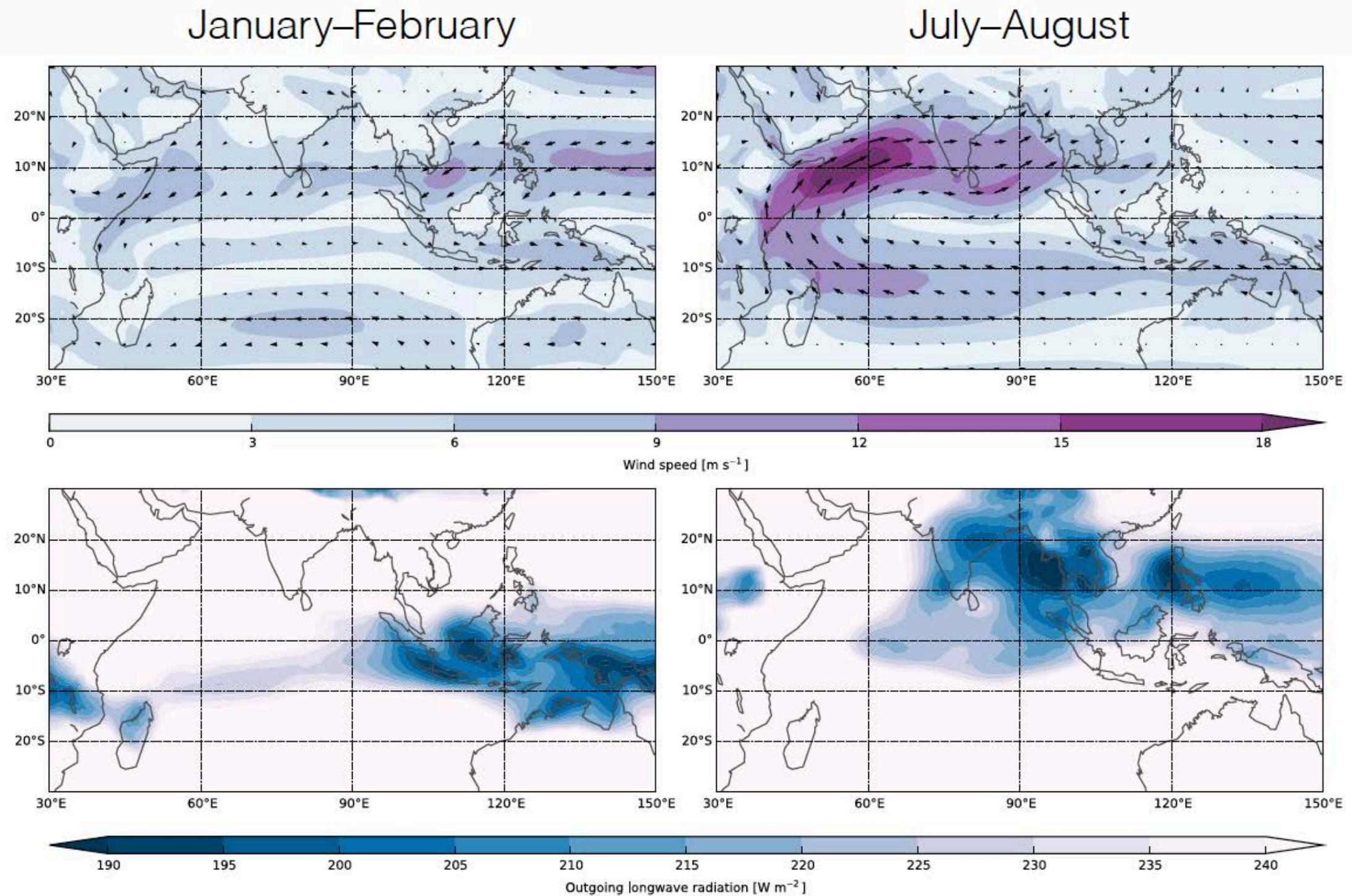


Figure from the slide by Jonathan Wright



# The coupled annual cycle

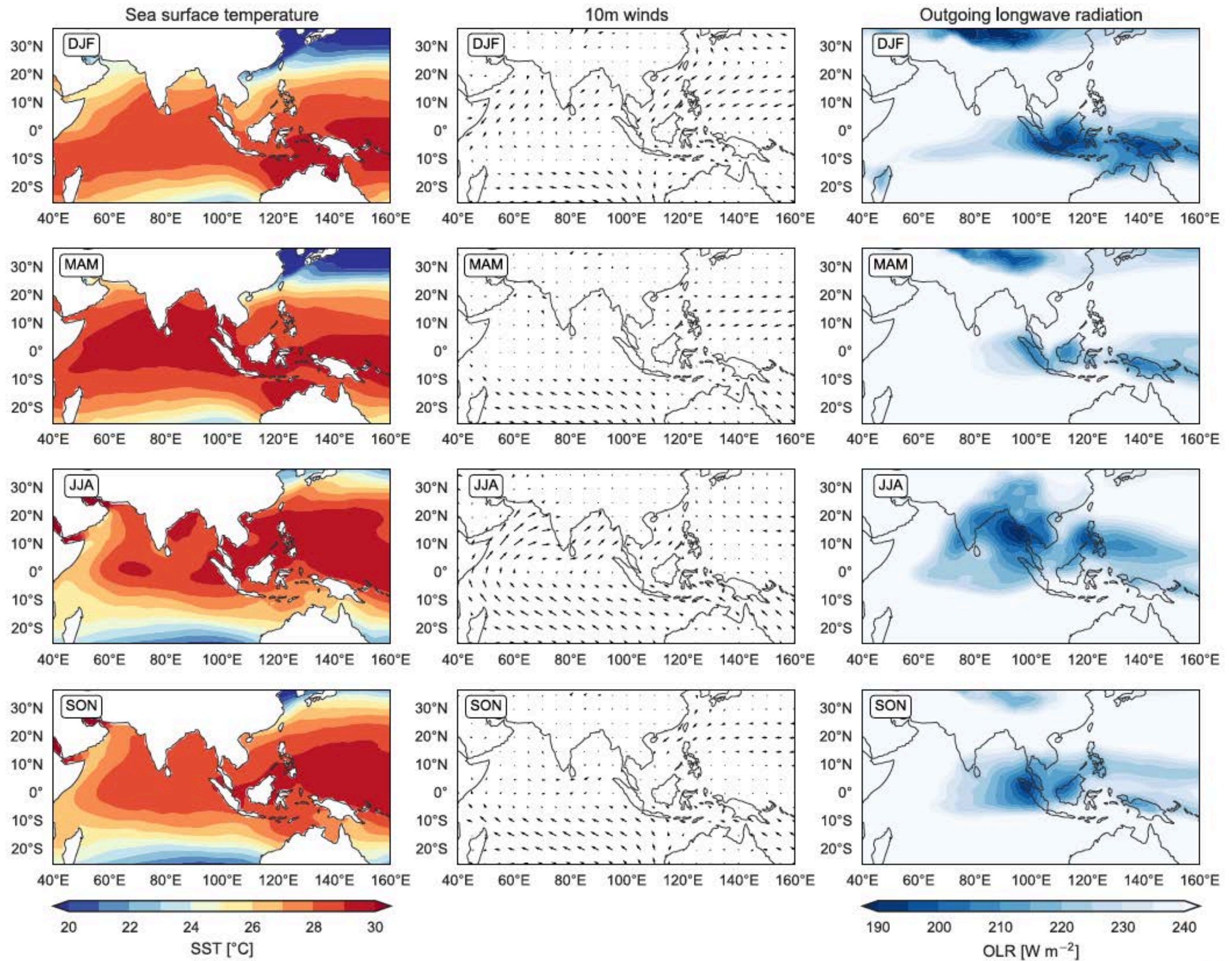
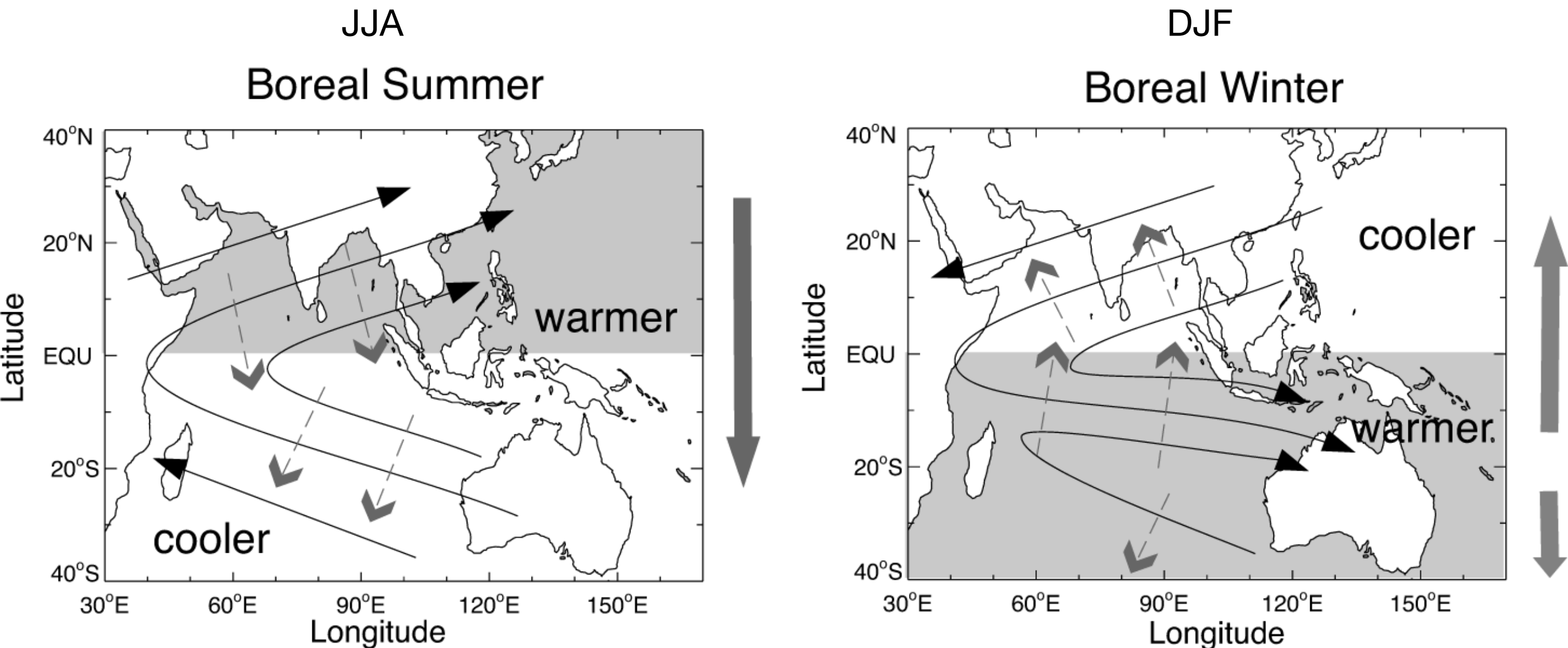


Figure from the slide by Jonathan Wright



# Ocean heat transport

Figure from the slide by Jonathan Wright

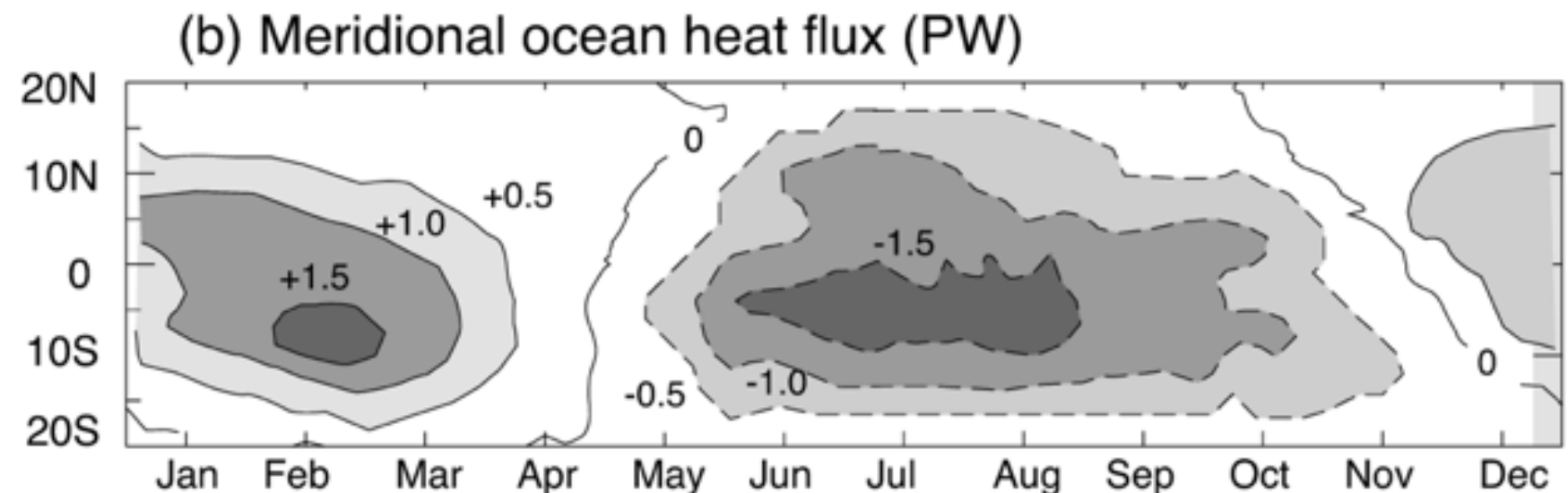


- Ocean heat transport by atmospheric circulation
- Atmospheric circulation is driven by surface heat flux
- **A negative atmosphere-ocean feedback**

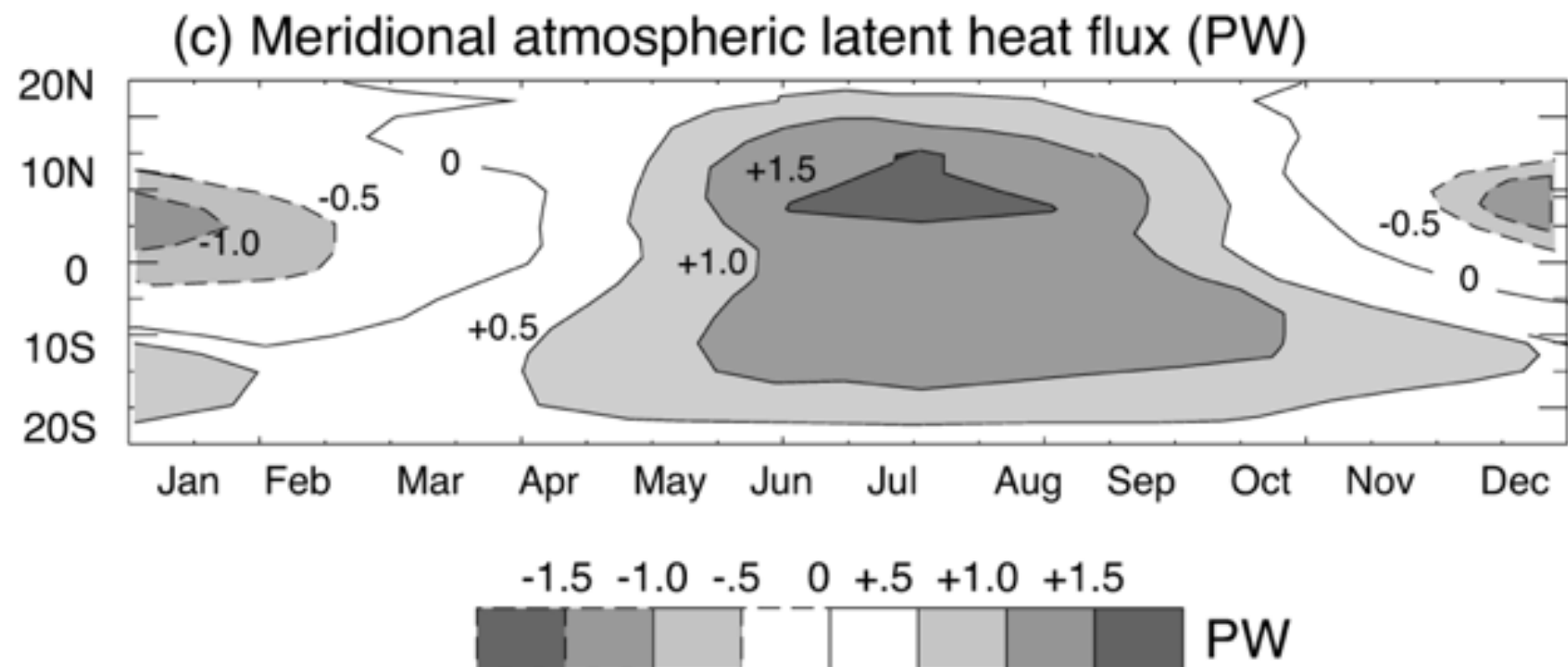


# Atmospheric latent heat flux

The ocean moves energy from the summer hemisphere to the winter hemisphere

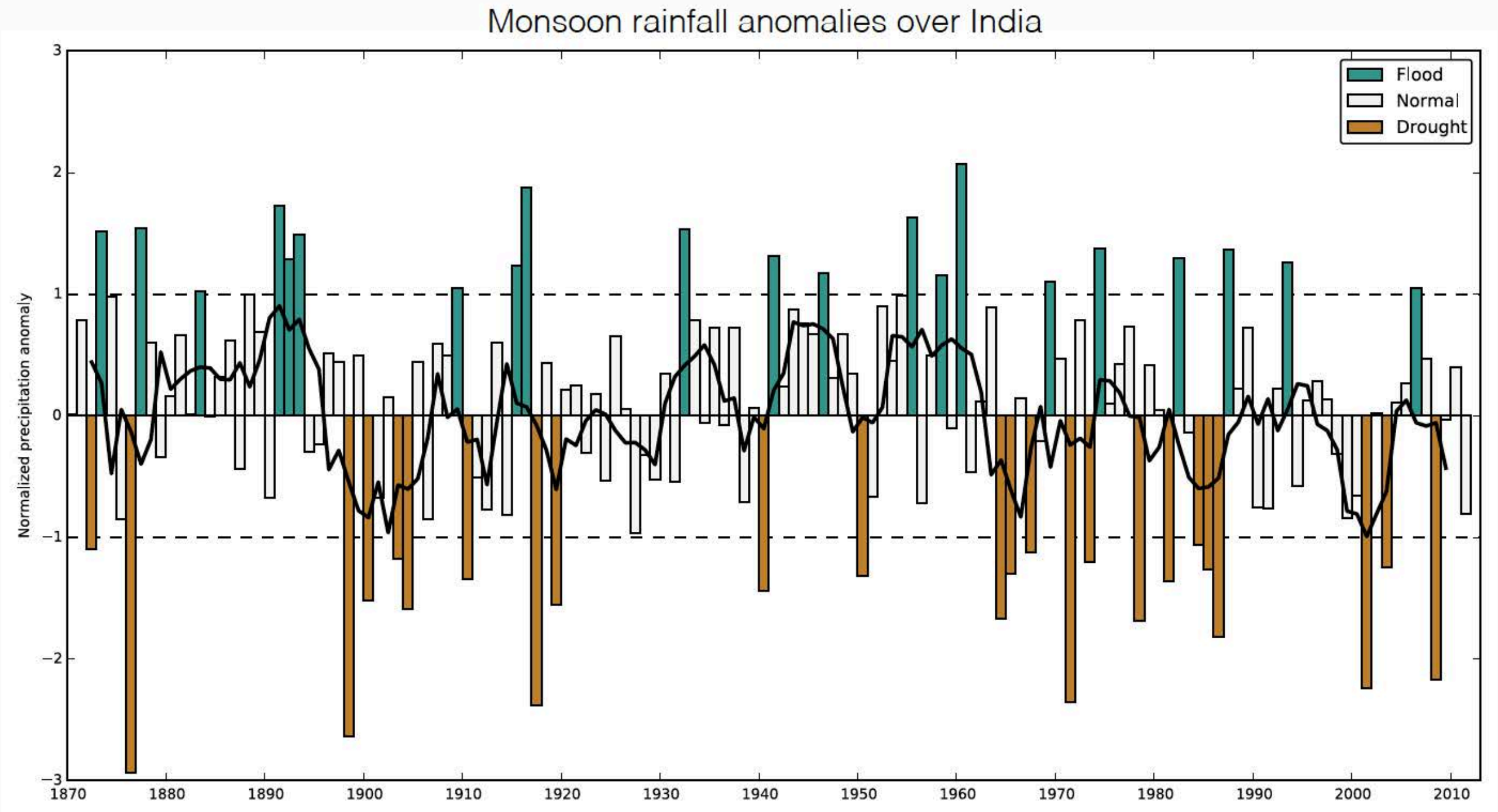


The atmosphere moves energy from the summer hemisphere to the winter hemisphere





# Variability of the monsoon in India



# Variability of the monsoon in India

---

“In India, where more than 60% of agricultural land is rainfed and the average farm size is only 3.5 acres, a failed monsoon often means complete loss of a crop. Recent increases in suicides among heavily indebted farmers have highlighted the extreme desperation in some areas.”

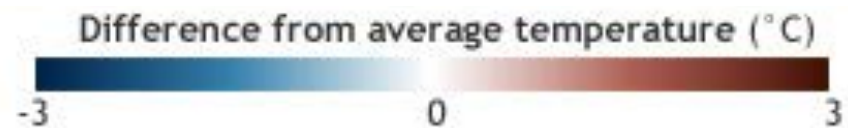
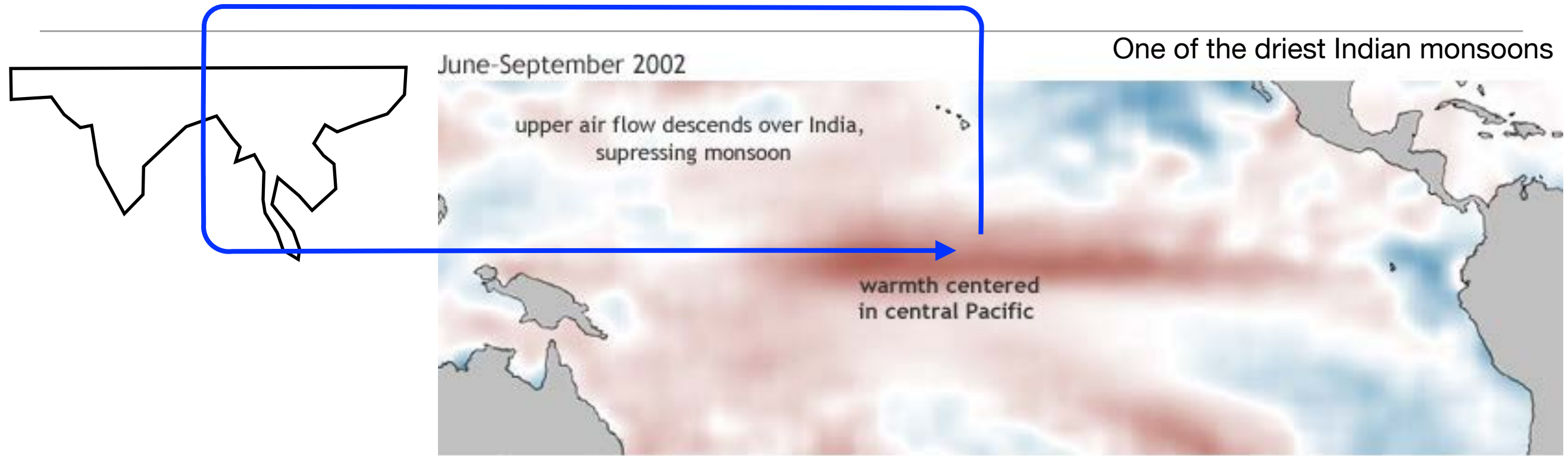
“According to the agriculture ministry, relief expenses totaled about \$5 billion during the last major drought in 2002.”



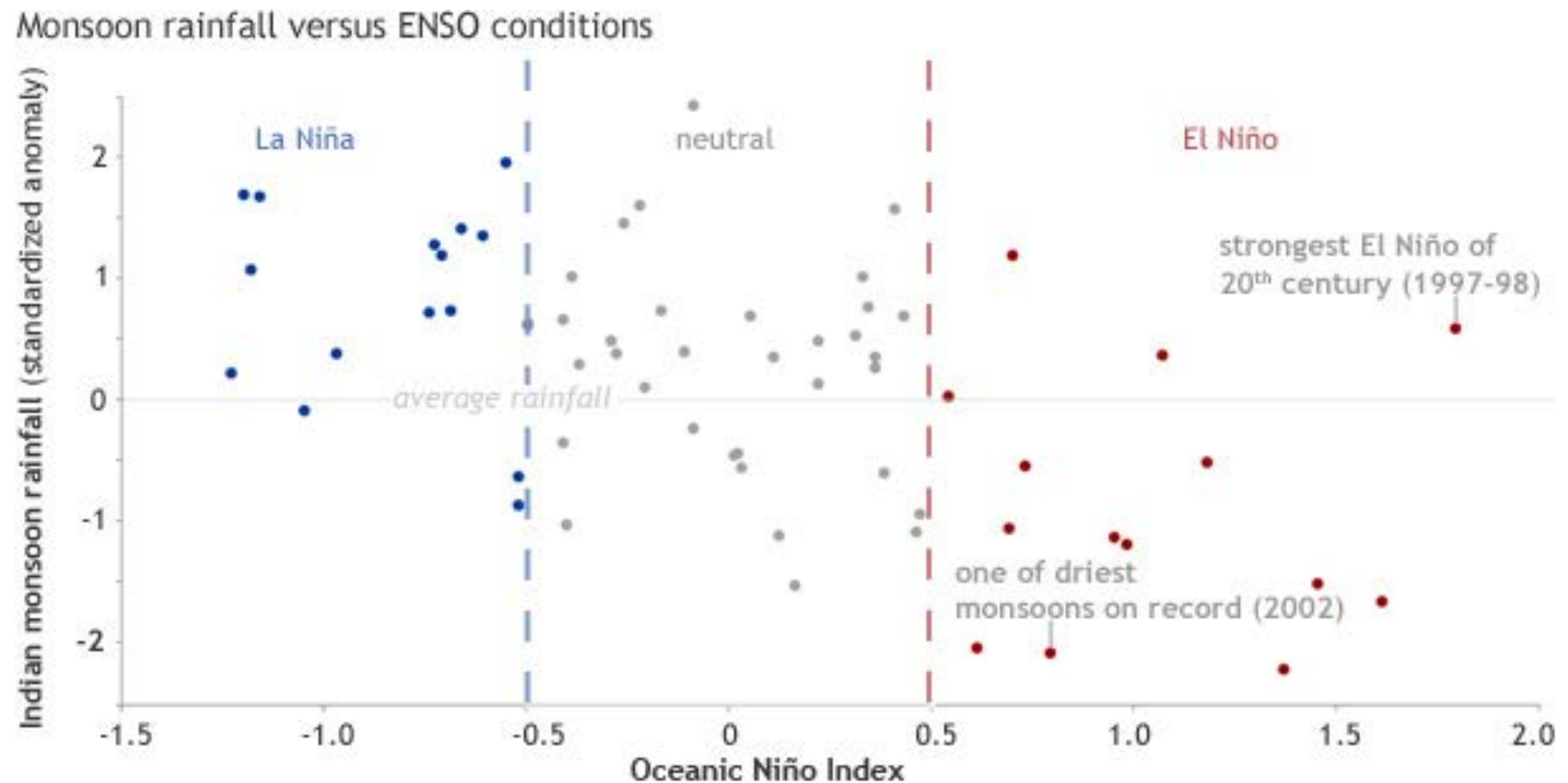
**\$5 billion = 5,408,700,000,000.00 South Korean Won**



# ENSO and Monsoon



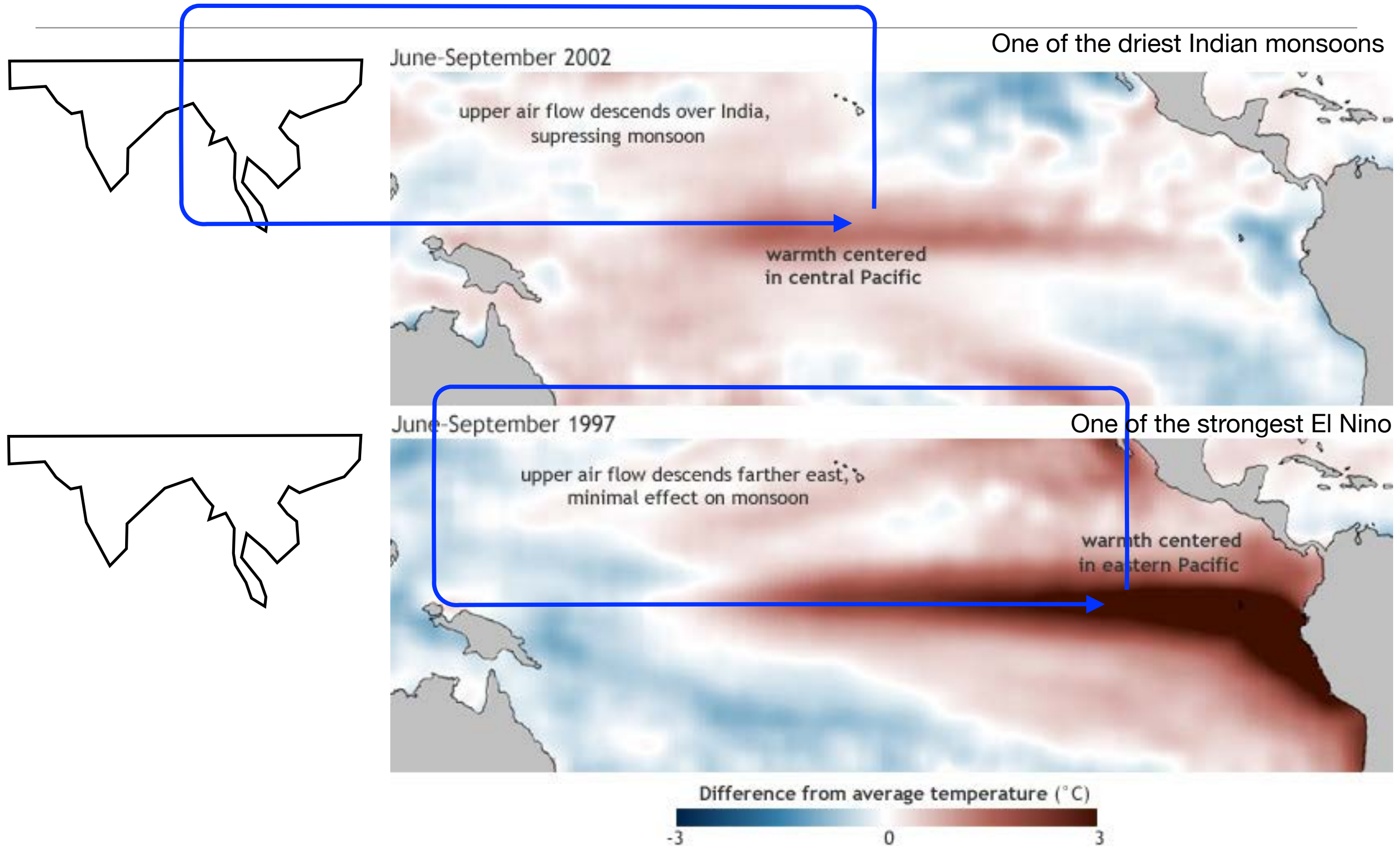
# ENSO and Monsoon



Comparison of the [Oceanic Niño Index](#) to [Indian monsoon rainfall](#) from 1950-2012. La Niña years are blue, neutral years are gray, and El Niño years are red. El Niño years *tend* to be drier than average, but the strongest El Niño of the century (1997-98) produced a monsoon season with above-average rainfall. Graph adapted from Kumar et al. 2006.



# ENSO and Monsoon



# Summary

---

- Monsoons are seasonal variations in precipitation and winds, showing concentrated precipitation in summer.
- Different heating and temperature gradient can drive the monsoon.
- The interplays between the atmosphere and ocean are important to understand the monsoons.
- Interannual variability associated with large scale climate events (e.g. El Nino) makes it difficult to predict the monsoons.