Precipitation, Convection and Variability

Frightening yet fascinating

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CESM Tutorial 2018

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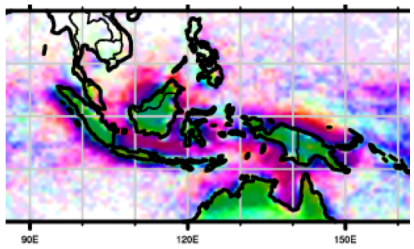
NCAR

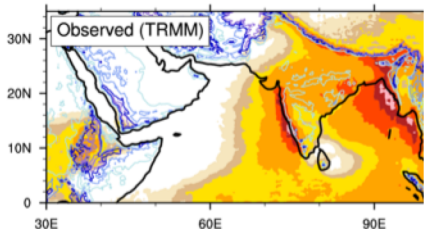
Community Earth System Model CESM

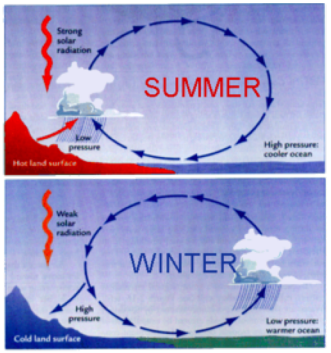
Tropical Atmospheric Variability Timescales

Diurnal Variability (days)
Forced

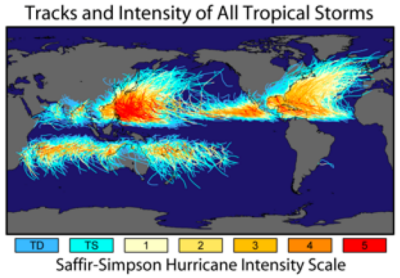


Monsoons (seasons)
Forced

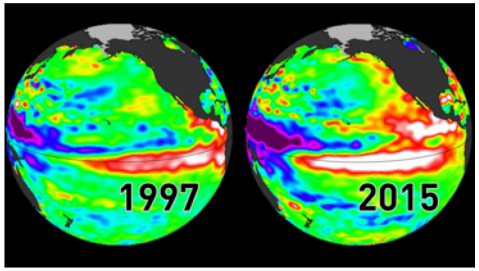


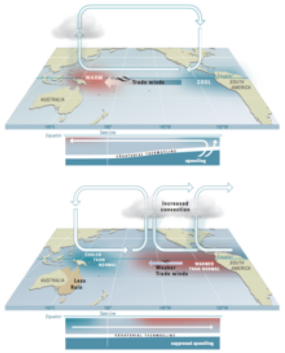


Tropical Cyclones (days->weeks)
Small/sub-tropical



ENSO (seasons->years)
Coupled

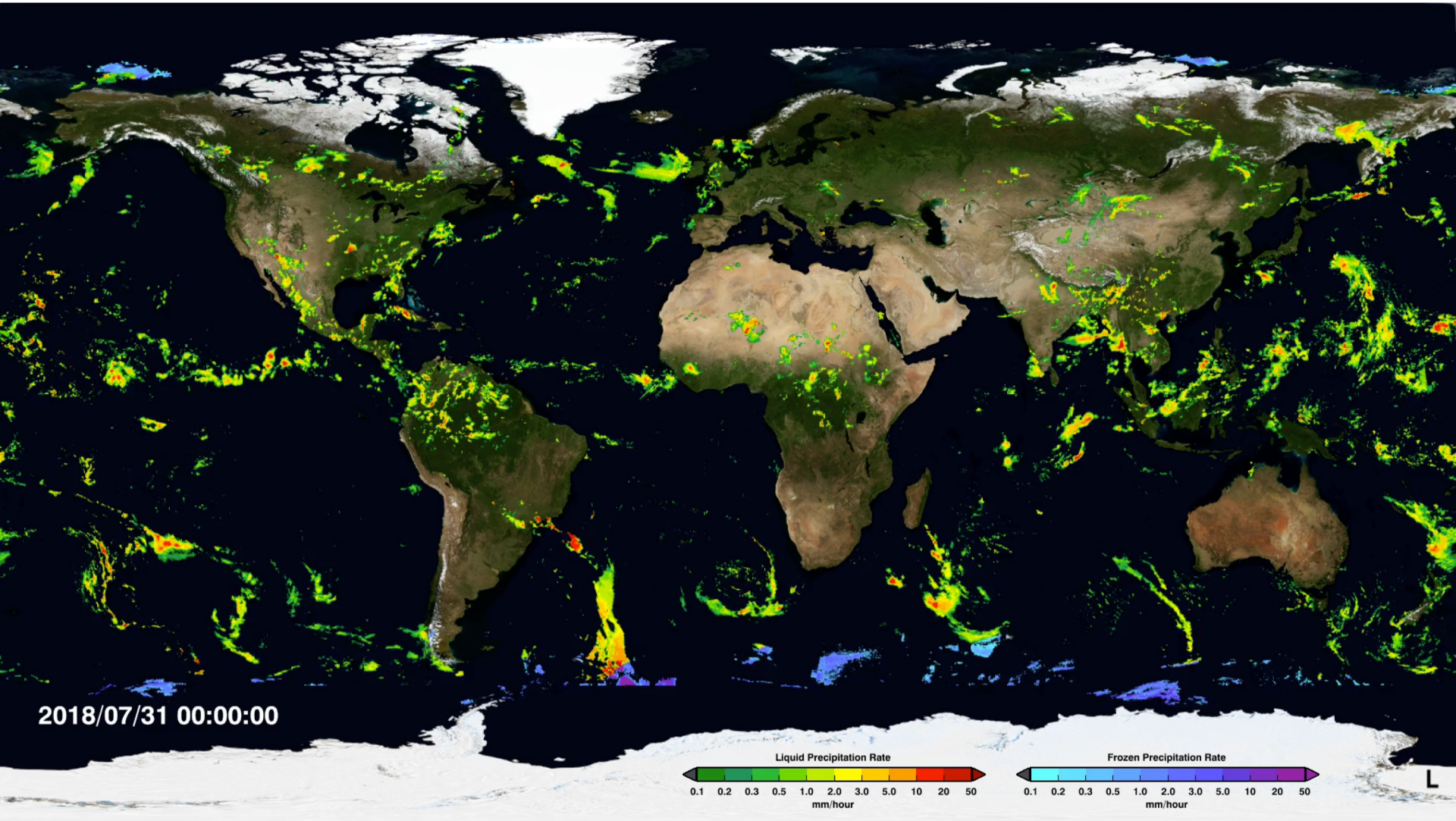




Intraseasonal Variability (days->months)
Sporadic, Propagating Wave Modes
e.g., MJO: Madden Julian Oscilliation, Kelvin waves
Convectively coupled (large-scale flow)
<u>Interactions with variability on other timescales</u>

Tropical Atmospheric Variability

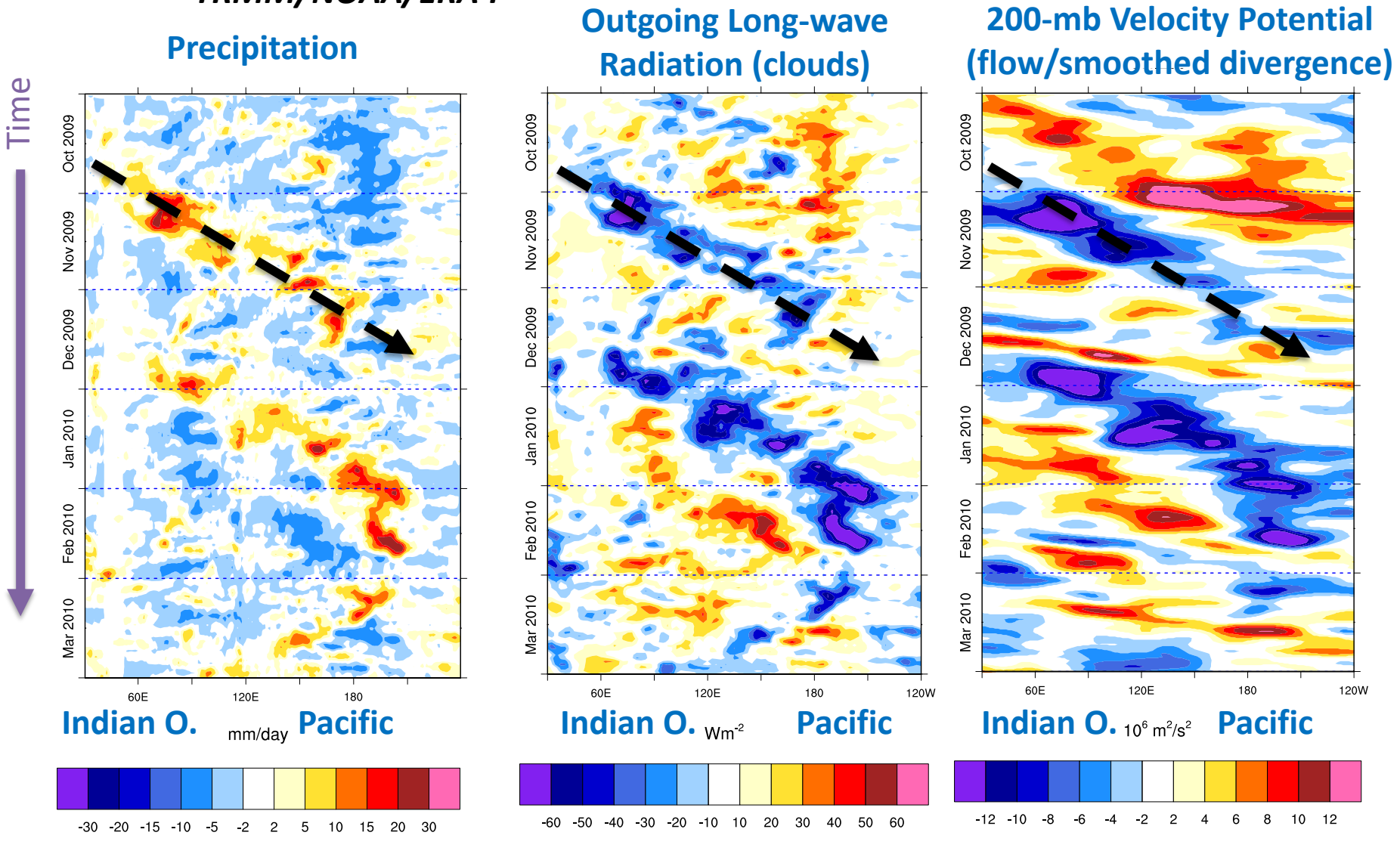
GPM Precipitation (every 30 mins for Last 7 days)



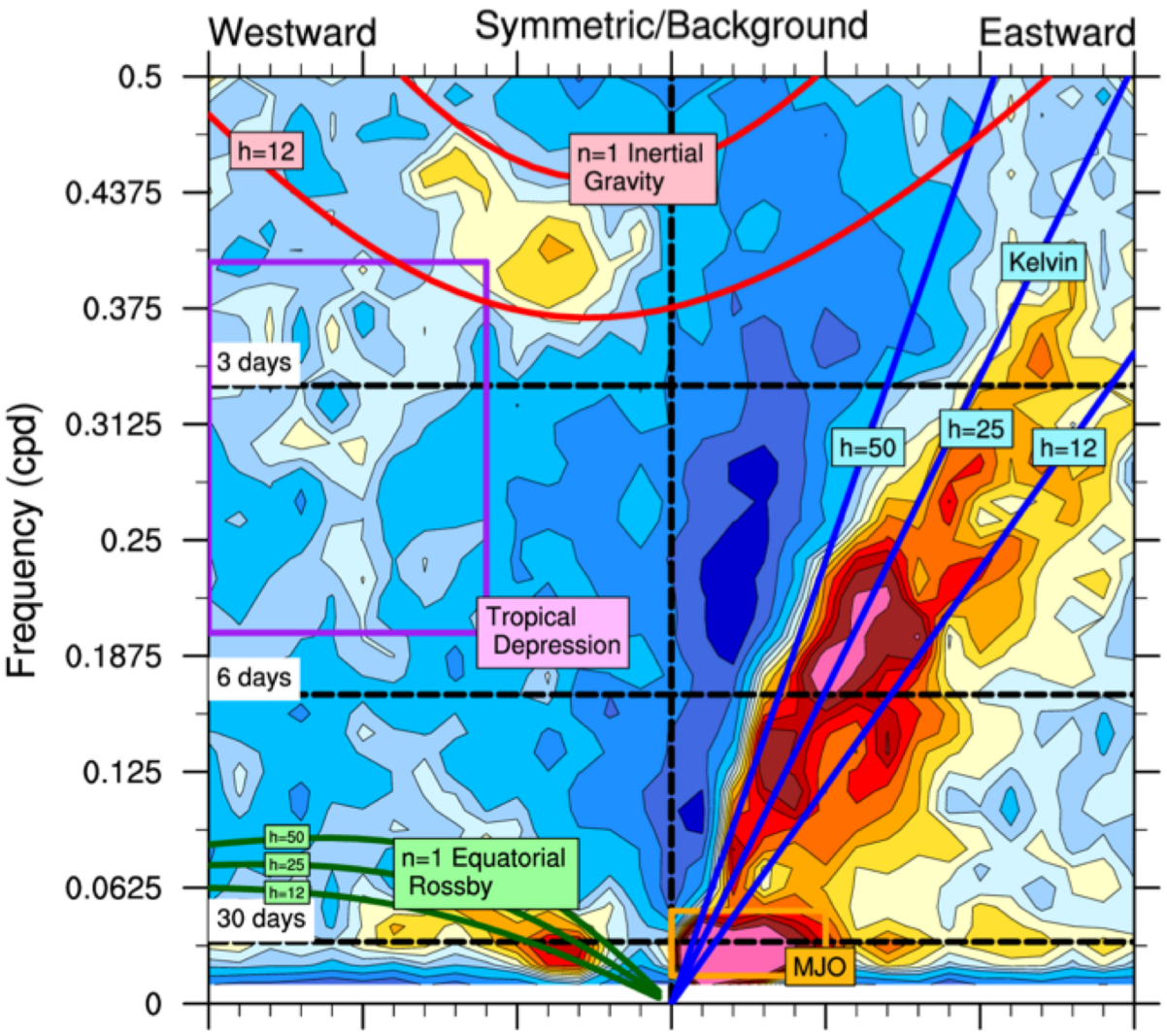
Observed Tropical Variability

Daily averages 10N-10S anomalies (2009/10)

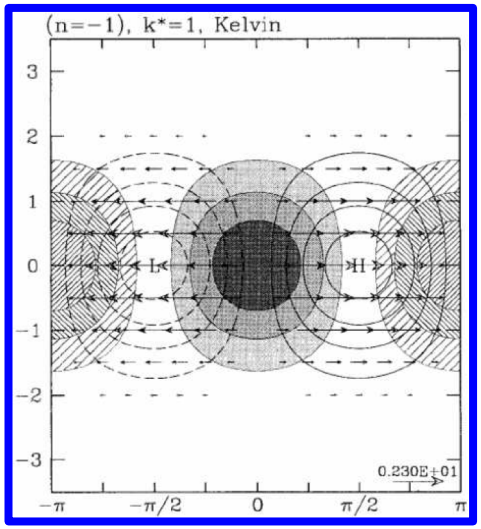
TRMM/NOAA/ERA-I



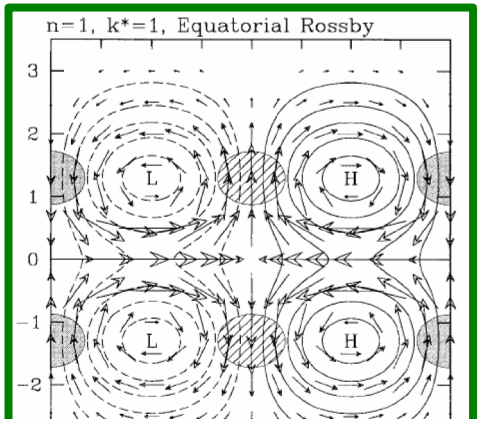
Filtered Equatorial Wave Modes



Kelvin



Rossby

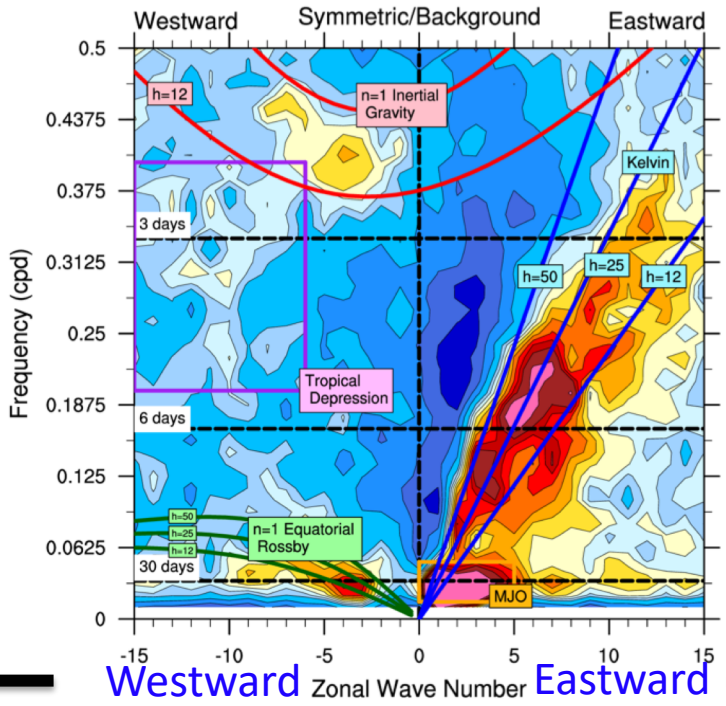


https://www.meteo.physik.uni-muenchen.de/~roger/Lectures/TropicalMetweb/TropicalMeteorology_Ch6.html

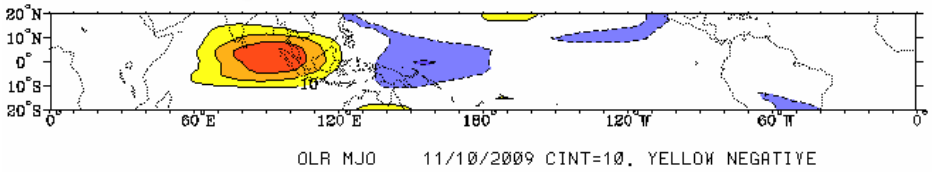
Filtered Equatorial Wave Modes

Propagating wave modes

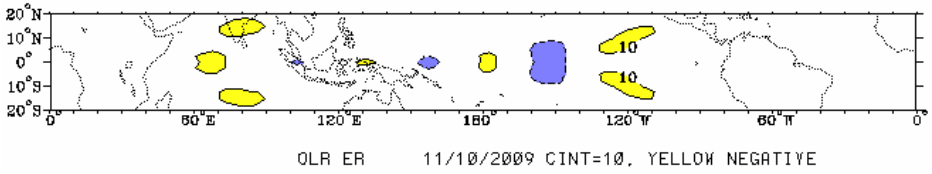
- Associated with most variability and extremes (monsoons, TCs, di-cycle)
- Falls on equivalent dispersion curves of shallow water modes
- Kelvin, Rossby, Inertio-gravity waves
- Madden Julian Oscillation (MJO) does not -- > Moisture mode



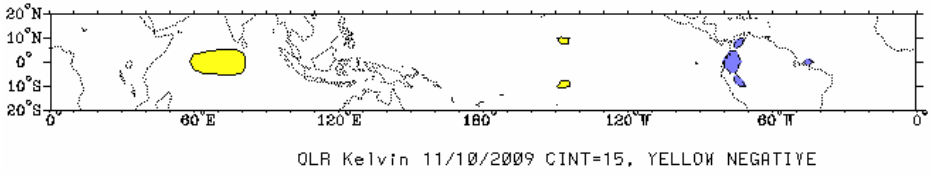
MJO



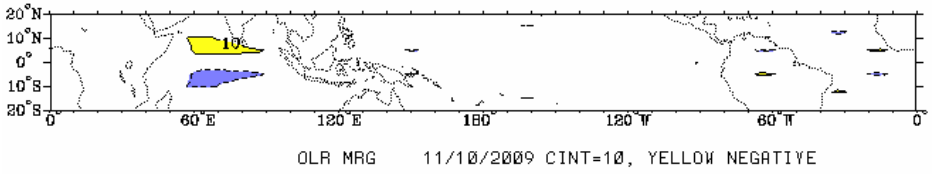
Rossby



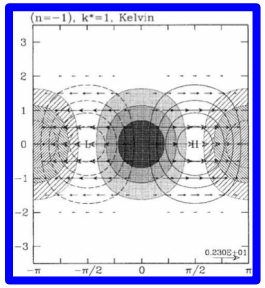
Kelvin



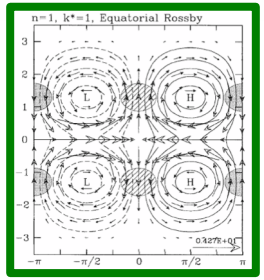
Inertio-gravity



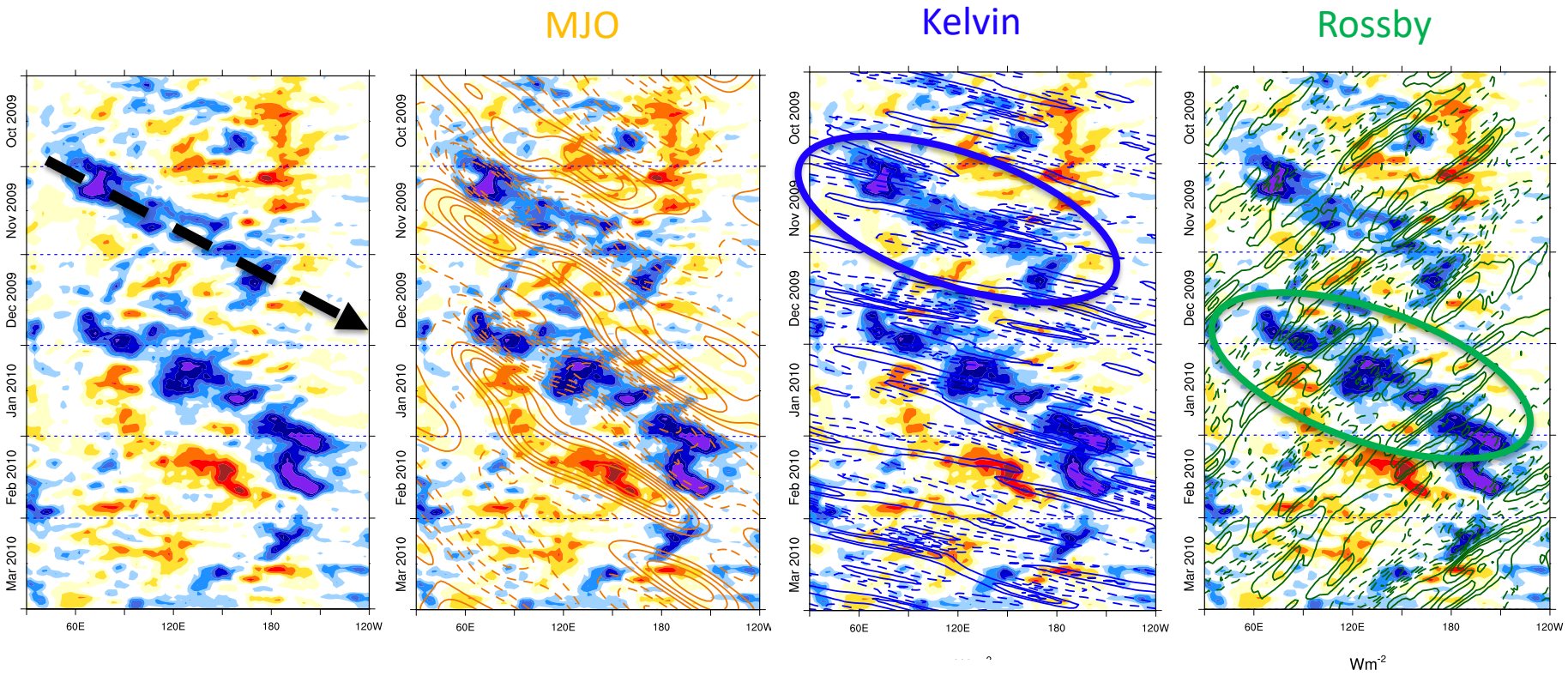
Kelvin

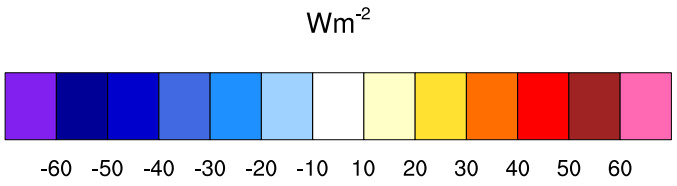


Rossby



Recompose Isolated Modes





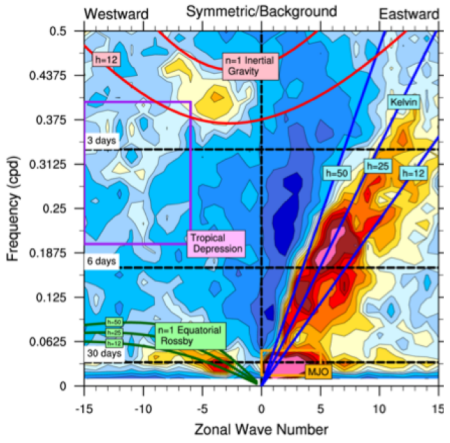
Outgoing Long-wave Radiation

- MJO dominant large-scale, long lasting
- Frequent wave-packets
- Multiple time and space scales

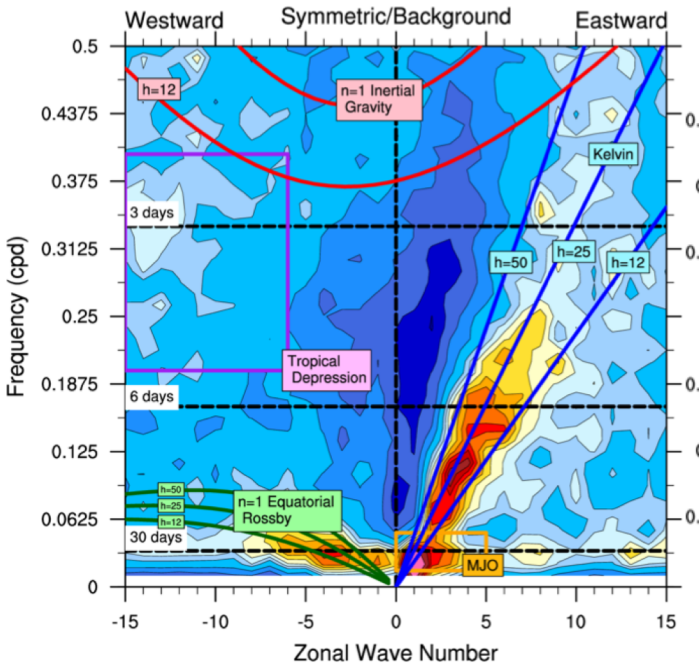
CAM Historical Tropical Variability

Coupled 1deg atmosphere/land (CAM,CLM) and ocean/ice (POP/CICE[CSIM])

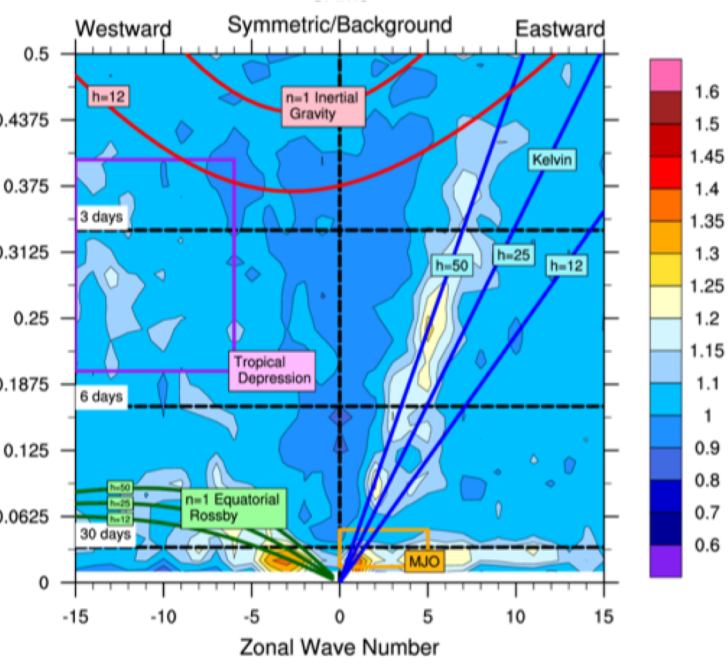
Obs./TRMM



CAM6/CESM2 (2018)

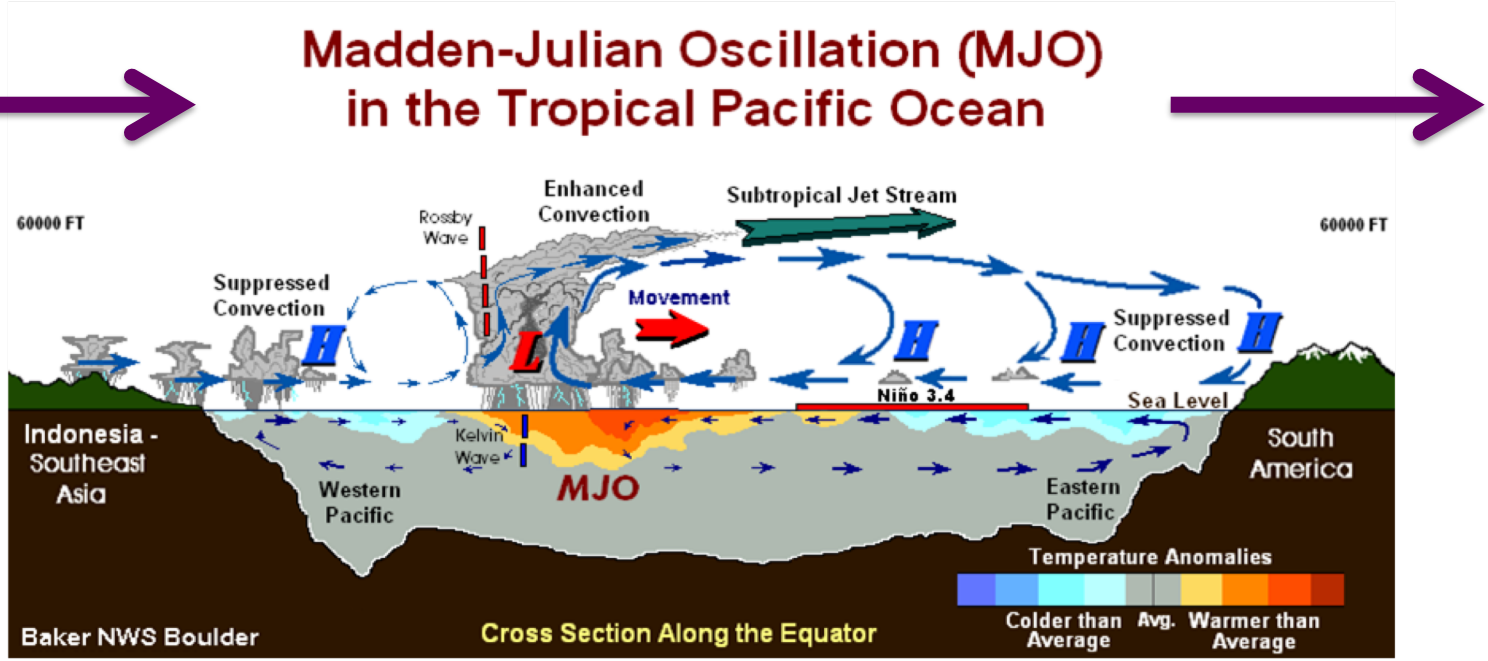


CAM3/CCSM3 (2004)



- Deep convection mostly responsible for improvements in wave-mode variability
- Improvements in Eastward propagating modes
- Poor Inertia-Gravity variability persists
- **MJO strongest and most important mode for weather and climate**

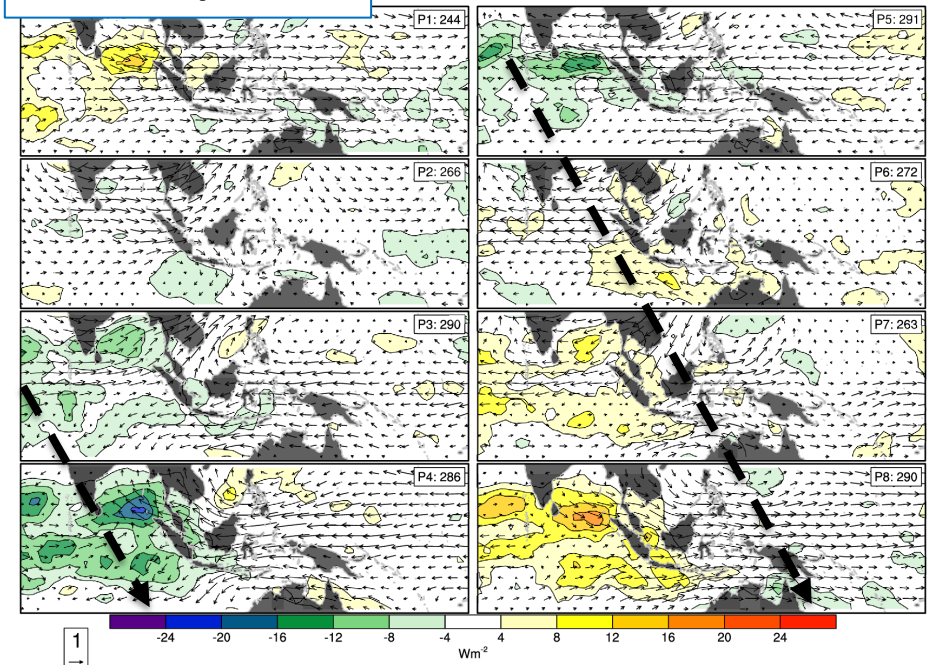
The Madden Julian Oscillation (MJO)



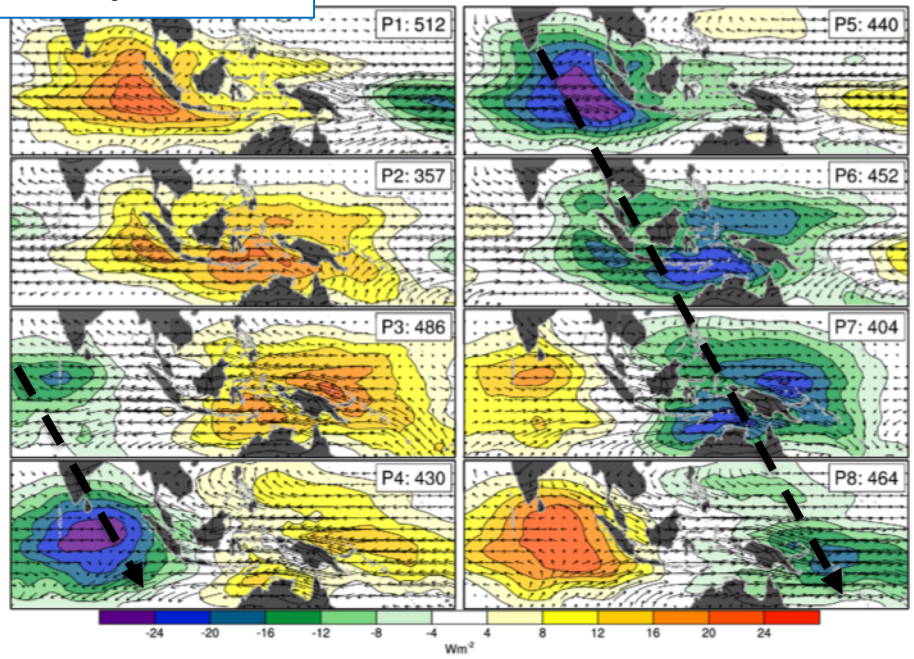
- Dominant large-scale east-ward mode of variability on intraseasonal (20-100 day) timescales in the tropics – strongest in winter-time
- Convection organizes in Indian Ocean propagates into the Pacific
- Multiple interactions: ENSO, Monsoons, North Pacific wave propagation, NAO
- Potential to extend predictability to multiple weeks
- **Emergent CONVECTIVELY COUPLED phenomenon**

Convectively Coupled Composite Event

CCCSM3/CAM3



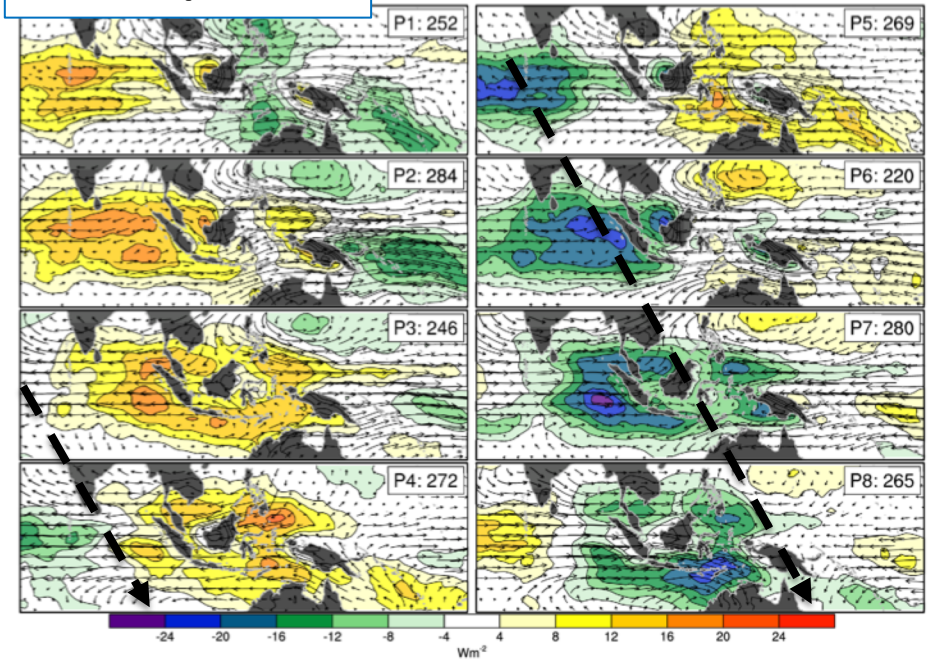
ERAI/TRMM



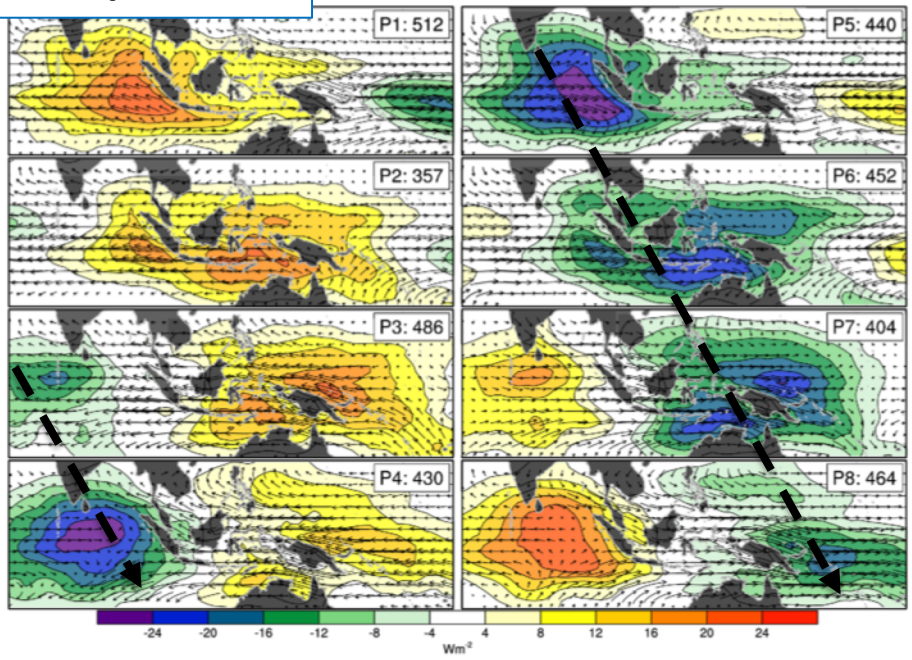
Outgoing Longwave Radiation (clouds - colors)
More cloud → Less cloud
850-mb winds (vectors)
1

Convectively Coupled Composite Event

CESM2/CAM6

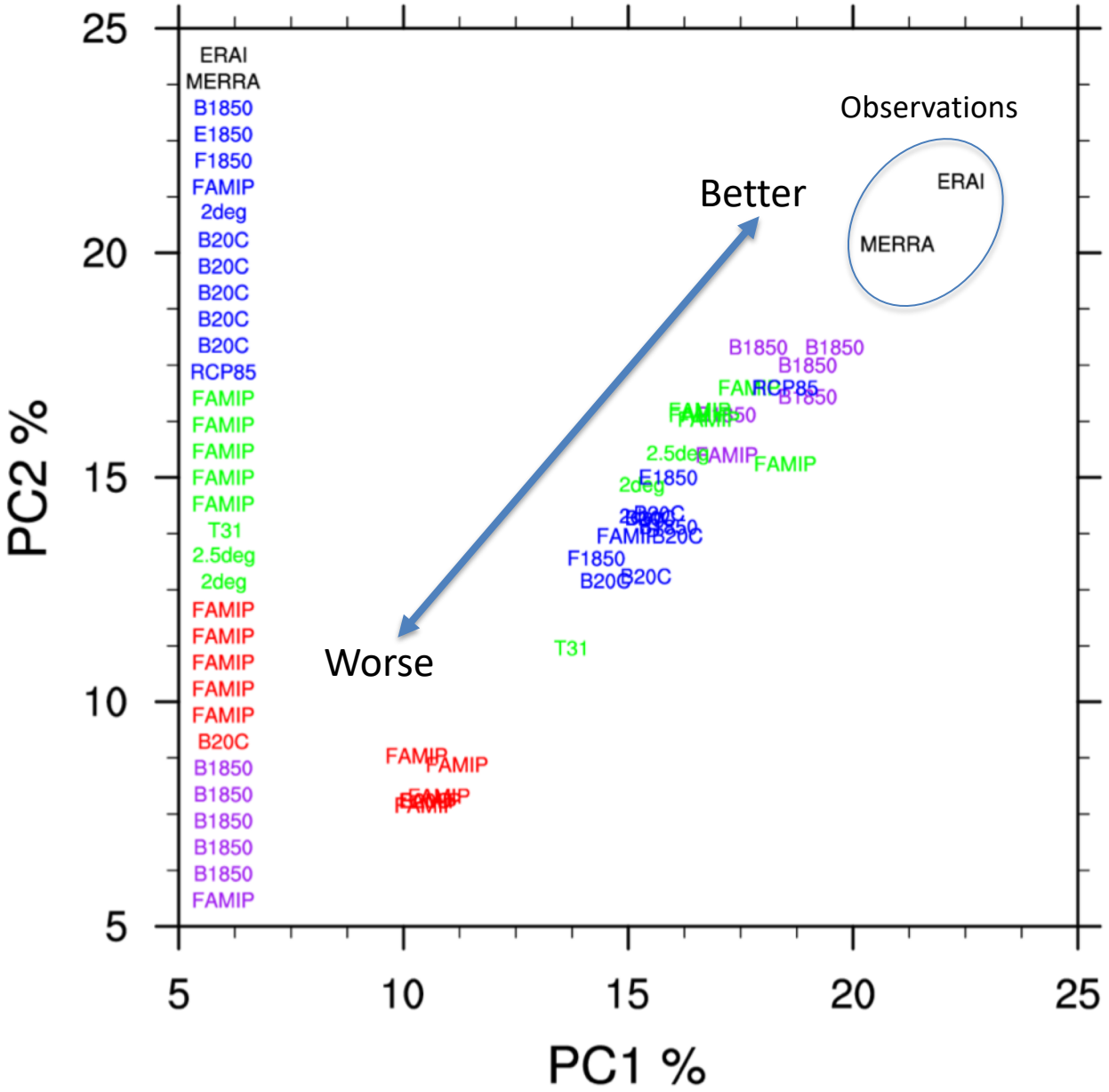


ERAI/TRMM



Outgoing Longwave Radiation (clouds - colors)
More cloud → Less cloud
850-mb winds (vectors)

CAM MJO performance: Convection



CAM3 (oldest)

Low convective entrainment

CAM4

High entrainment = moisture sensitivity

CAM5

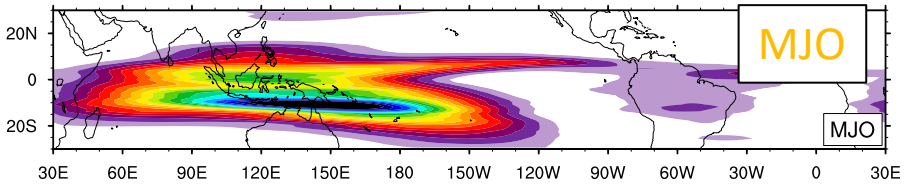
Convective retuning + changed params.

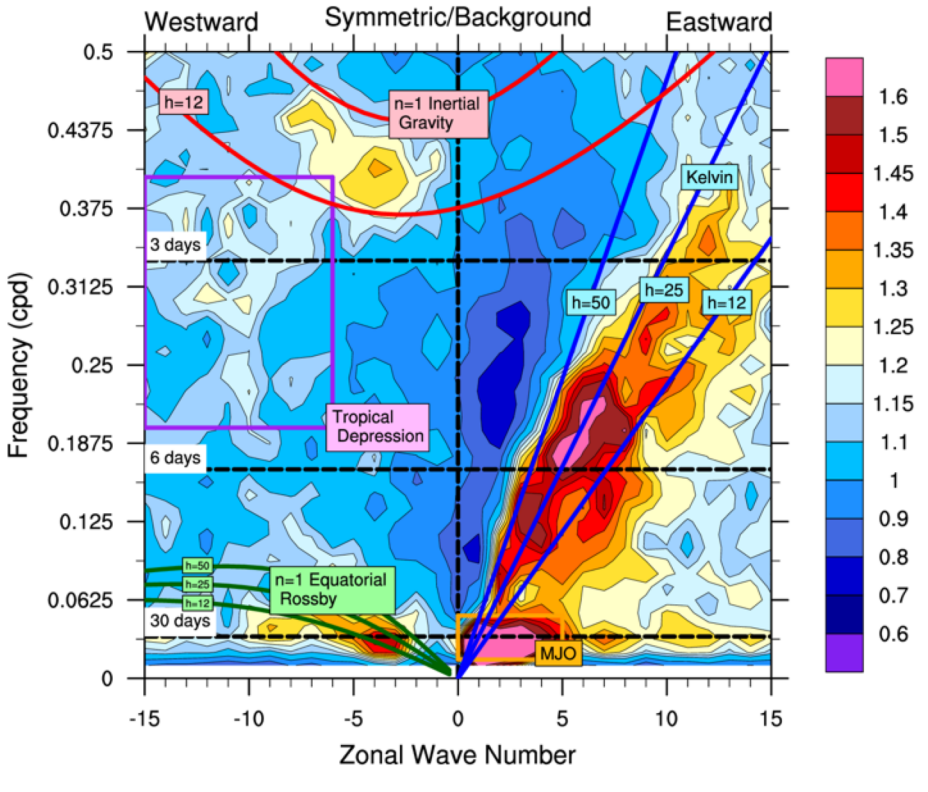
CAM6 (newest)

Increased stability sens. + coupling + new params

Tropical Wave Mode Variance (DJF)

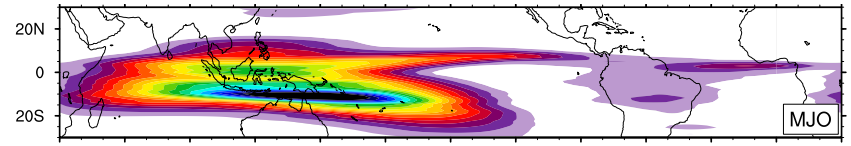
Observations (Precipitation, TRMM)



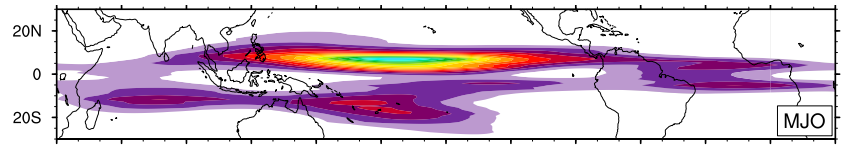


Which Convection Parameters Affect Variability? - MJO

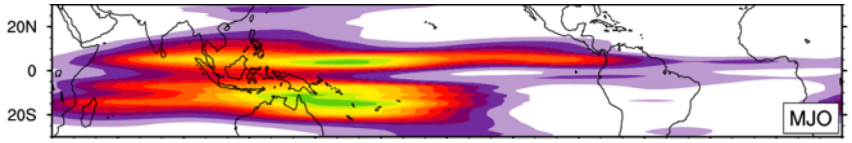
Observations (TRMM)



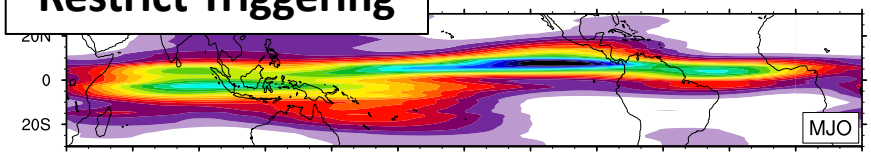
Reduced Conv. Entrainment (1e-5/m)



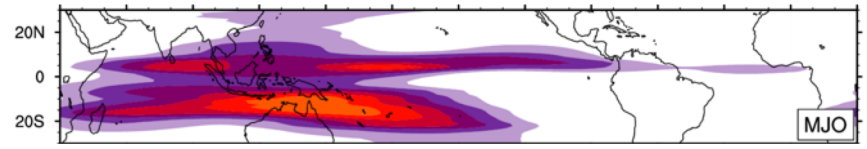
Enhanced Conv. Entrainment (2e-3/m)



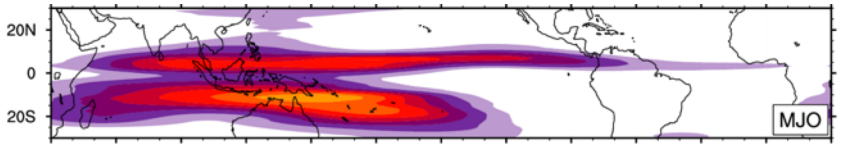
Restrict Triggering



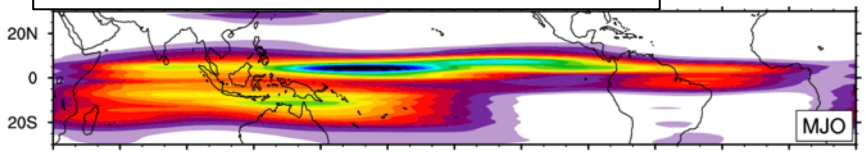
Enhance Triggering



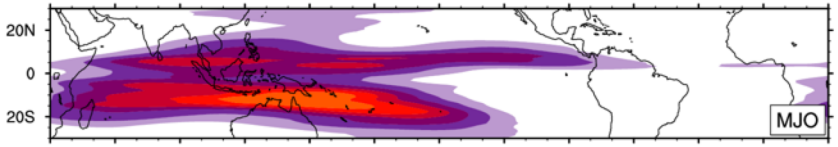
CAM5



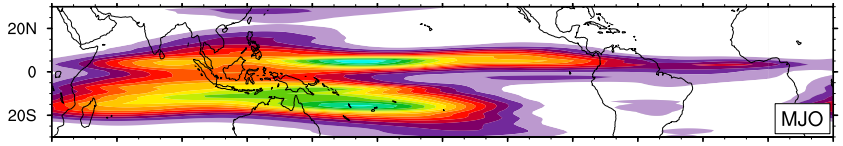
Increased Timescale = 7200s



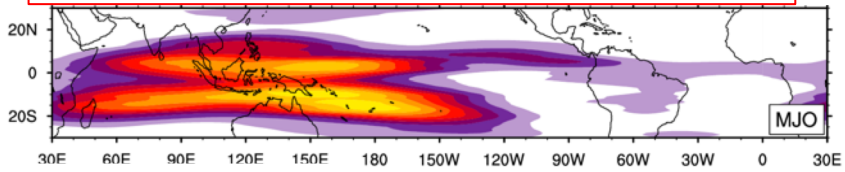
Decreased Timescale = 1800s



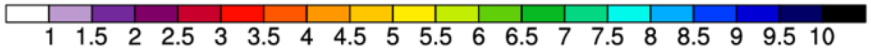
Convective Gustiness Feedbacks



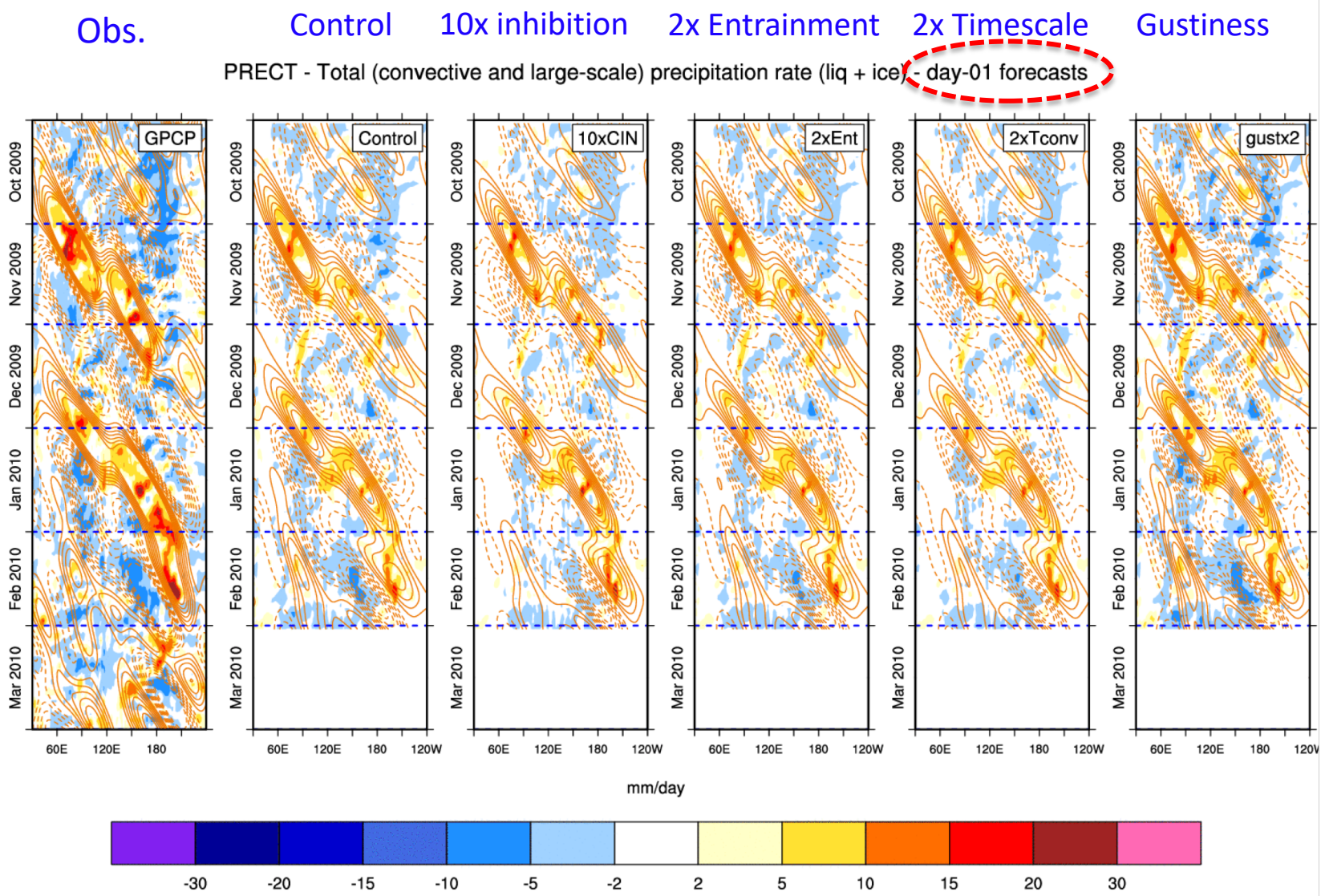
Enhanced Stability factor (capeten)



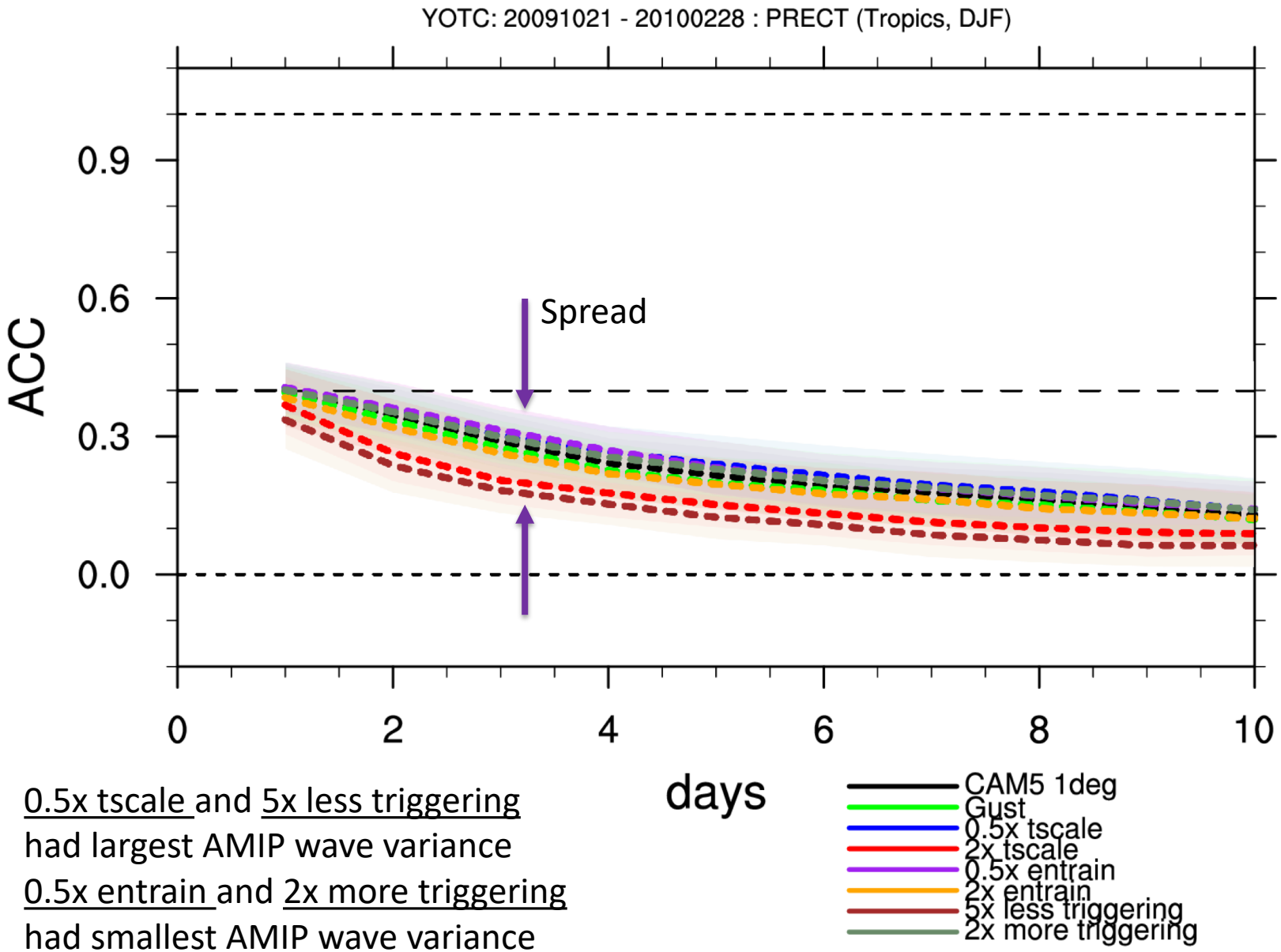
$(mm/day)^{-1}$



Hindcasts: Convection changes

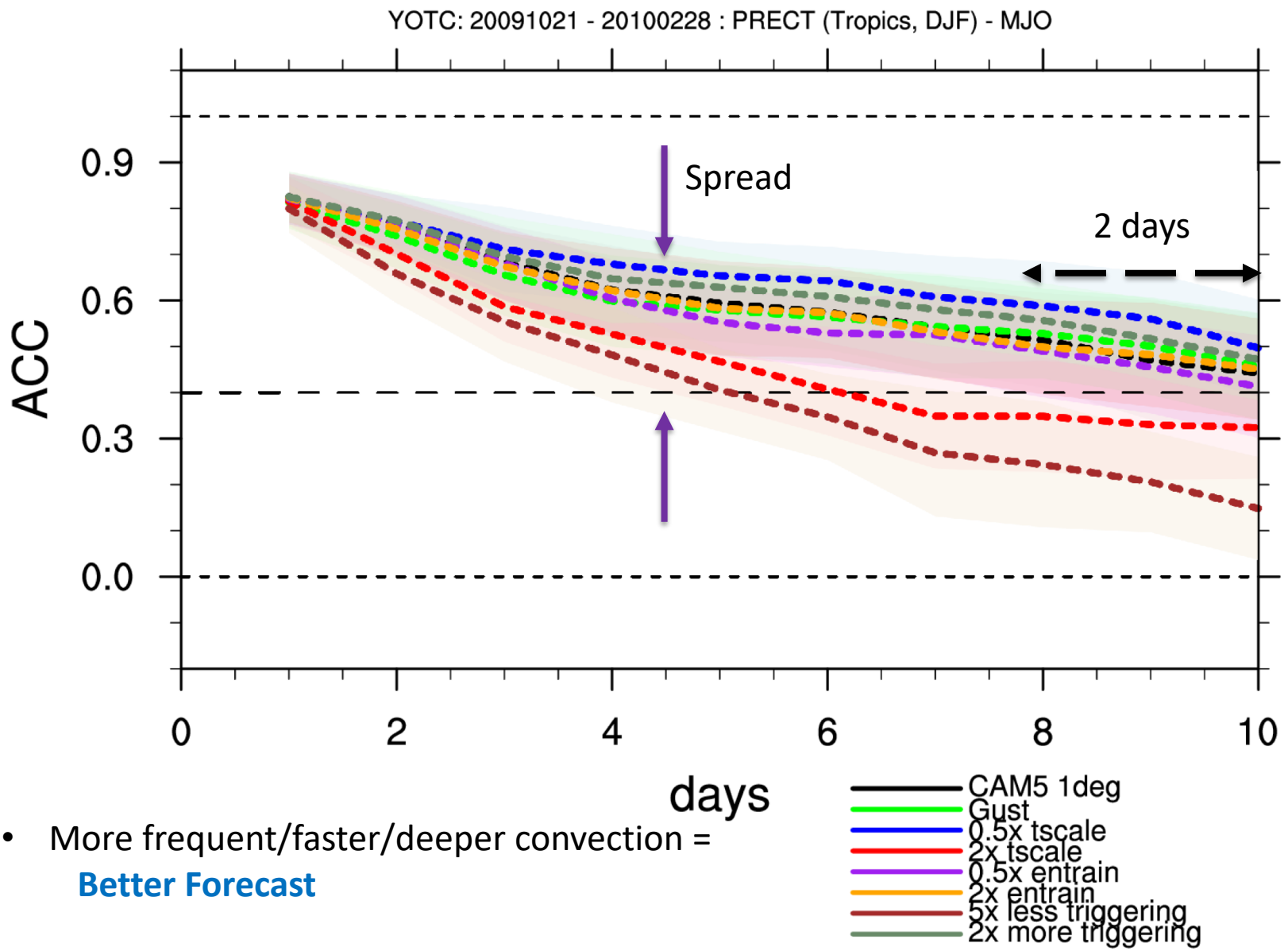


Hindcasts: Wave mode skill (unfiltered)



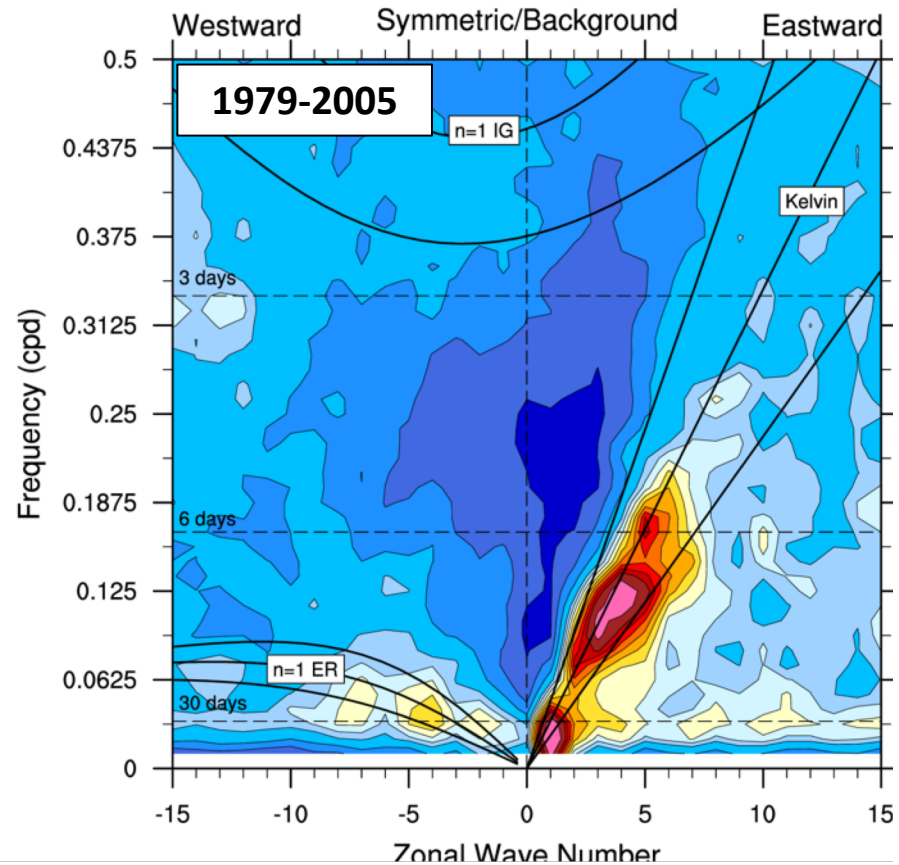
- 0.5x tscale and 5x less triggering had largest AMIP wave variance
- 0.5x entrain and 2x more triggering had smallest AMIP wave variance

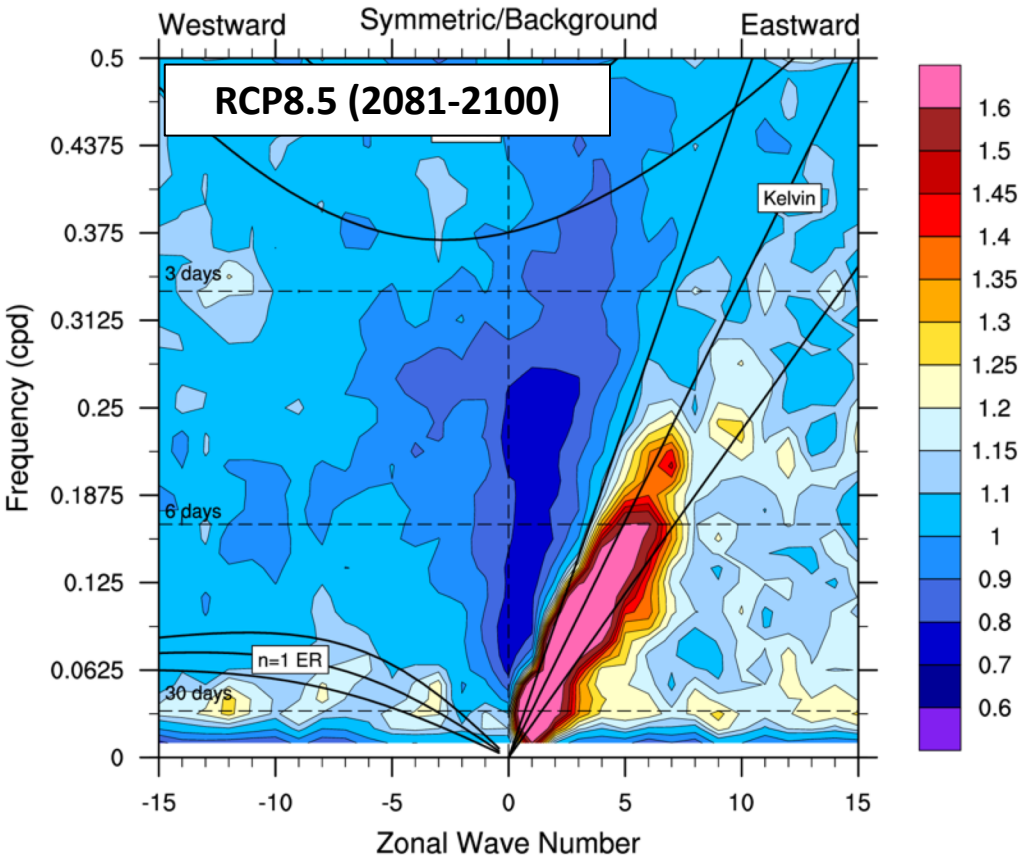
Hindcasts: Wave mode skill (MJO)



- More frequent/faster/deeper convection = **Better Forecast**

Filtered Equatorial Wave Modes - Future





- Improved predictability?
- Associated extreme events?
- Different remote effects?

Summary Thoughts

- Vast array of tropical variability interacting on intra-seasonal timescales
- Convectively coupled wave modes explain much of the variance
- Interaction with multiple phenomena (climate/forecast)

- Improving CESM performance has been a huge challenge
- Intimately related to deep convection processes
- Utility of different CESM configurations key to further improvements
  - *Coupled, prescribed SSTs, forecast mode, (single column)*

Questions?