TROPOSPHERIC WINDS OVER SUMATRA

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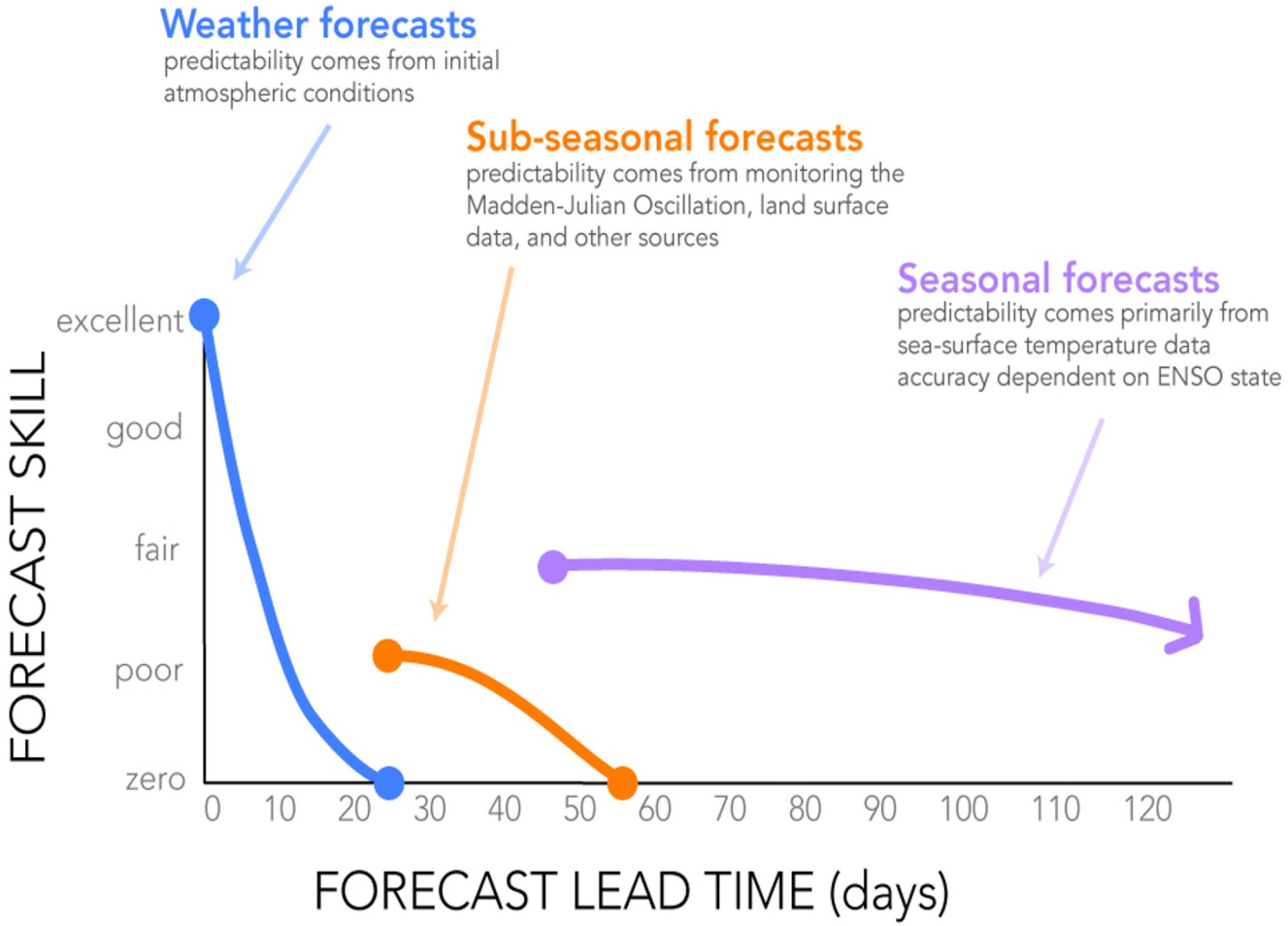
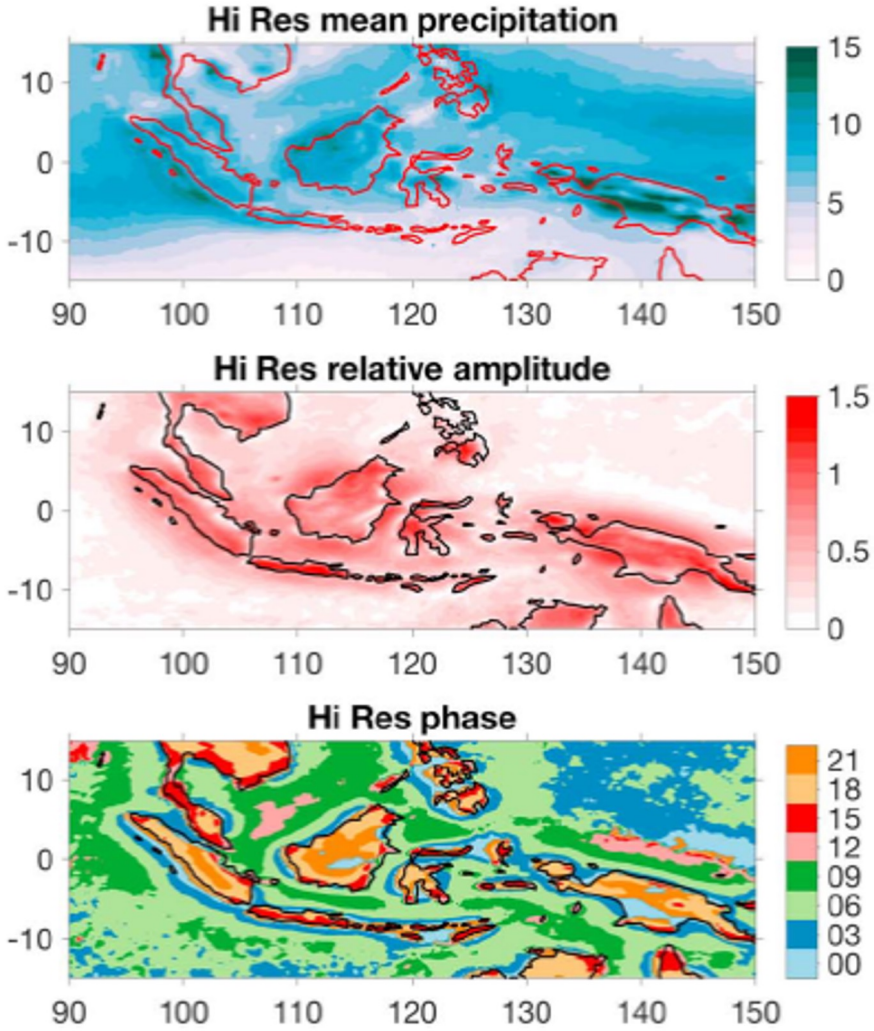
Motivation

Phenomena occuring in the tropical atmosphere have a proven impact on weather around the globe (El Nino oscillation, Pineapple Express, teleconnections, etc.).

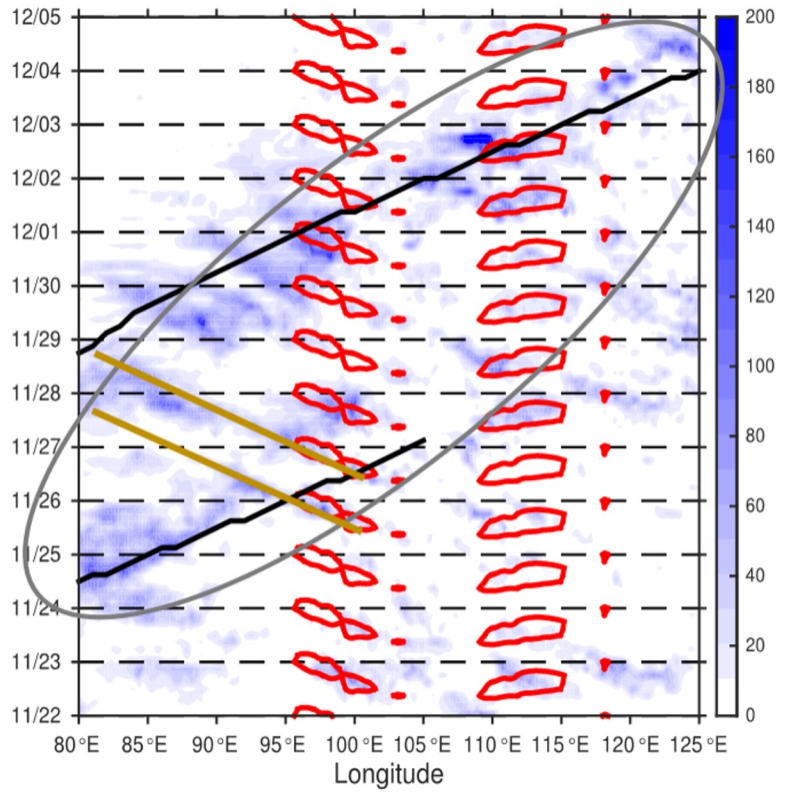
Better understanding of the tropical atmosphere behaviour leads to more accurate and faster prediction of the state of the atmosphere and extreme weather phenomena all over the Earth (also in Poland).



Motivation



TRMM precipitation



Baranowski et al (2016)

Madden-Julian Oscillation

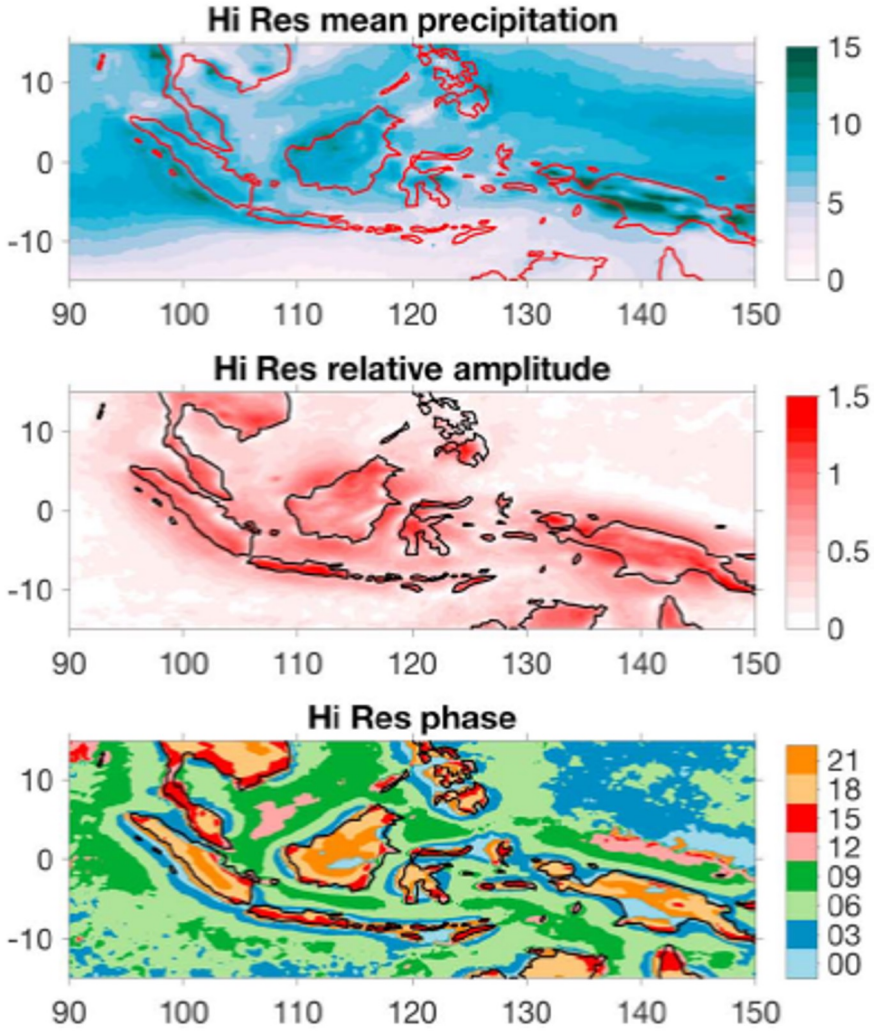
Convectively Coupled Kelvin waves

Mean Diurnal Cycle

Gravity waves

- weather over the Maritime Continent is dominated by the diurnal cycle
- large-scale phenomena like MJO and Kelvin waves are known to affect not only the amount of precipitation, but also modify the diurnal cycle

Motivation



Main goal:

- investigate the mean diurnal evolution of wind over Sumatra
- examine the impact of large-scale phenomena on mean flow and diurnal wind variability

- weather over the Maritime Continent is dominated by the diurnal cycle
- large-scale phenomena like MJO and Kelvin waves are known to affect not only the amount of precipitation, but also modify the diurnal cycle

Datasets and methodology

- Equatorial Atmospheric Radar (EAR), 2001-2019
- ERA-5 reanalysis, 2001-2019
- rain gauge in Kototabang, 2002-2016
- GPM (IMERG), 2001-2019

Methodology:

- Extended boreal winter, November-March
- Climatology and anomalies (seasonal cycle removed)
- Mean vertical profiles of wind components
- Mean diurnal evolution
- Mean values and diurnal variation for each day (standard deviation)
- Composites for El Nino Southern Oscillation (ENSO), Madden-Jullian Oscillation (MJO) and other phenomena

Equatorial Atmospheric Radar

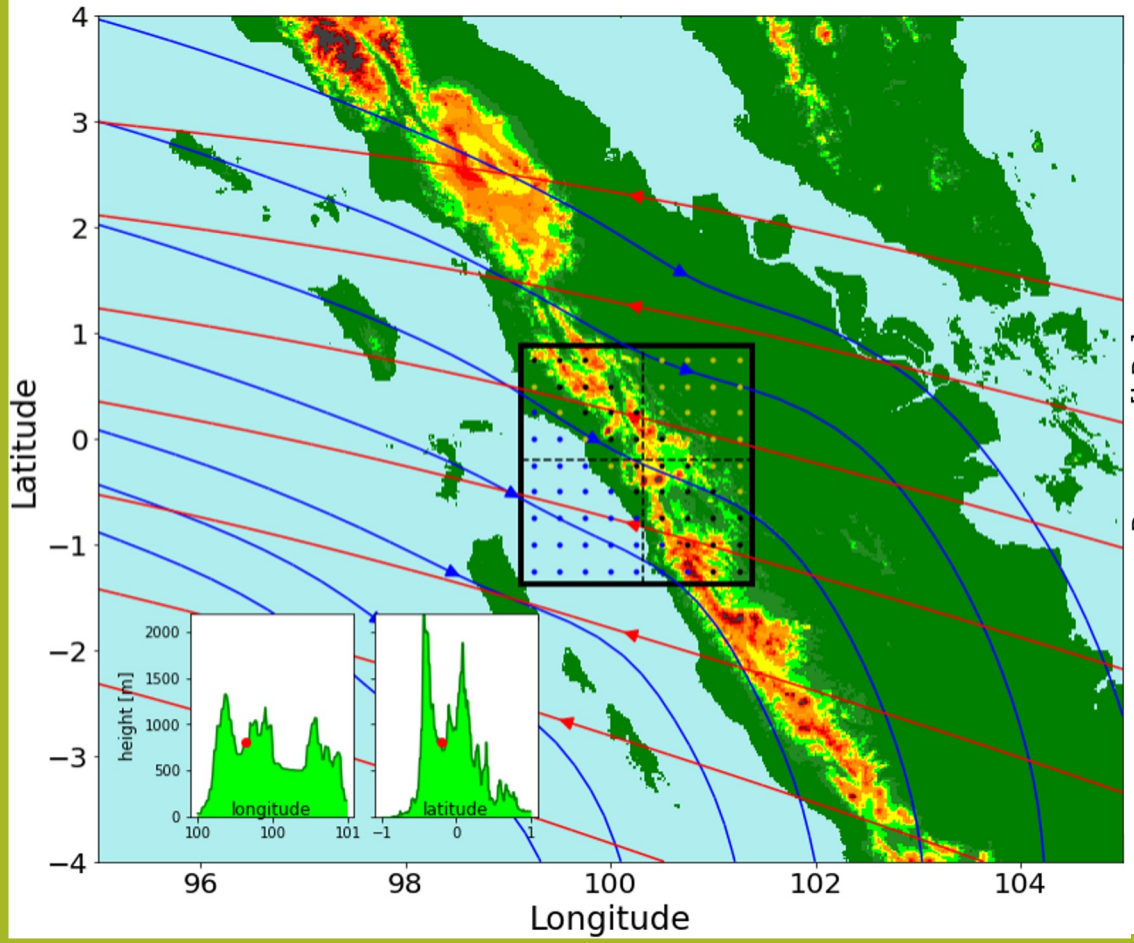
- Observation range: 1.5 km-20 km
- Time resolution: 10 minutes
- Vertical resolution: ~150m

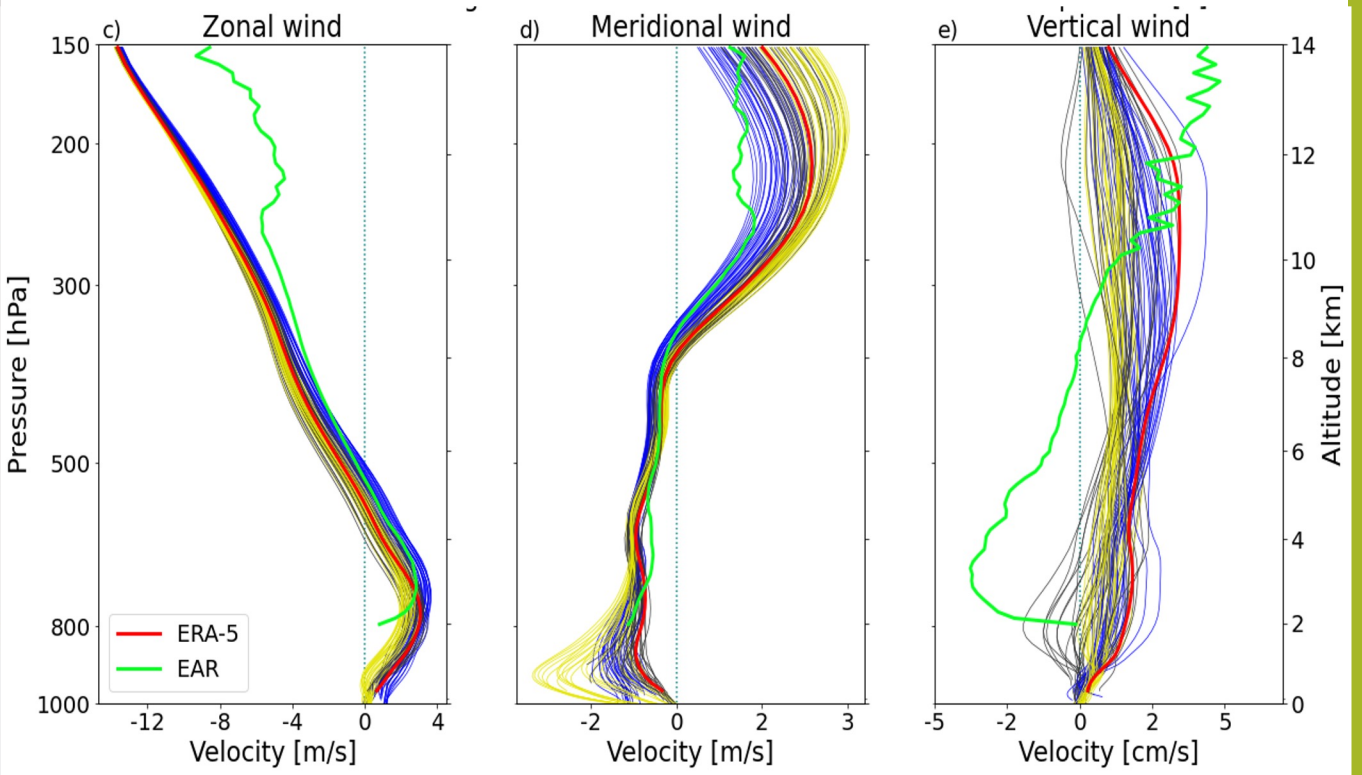
RISH

LAPAN

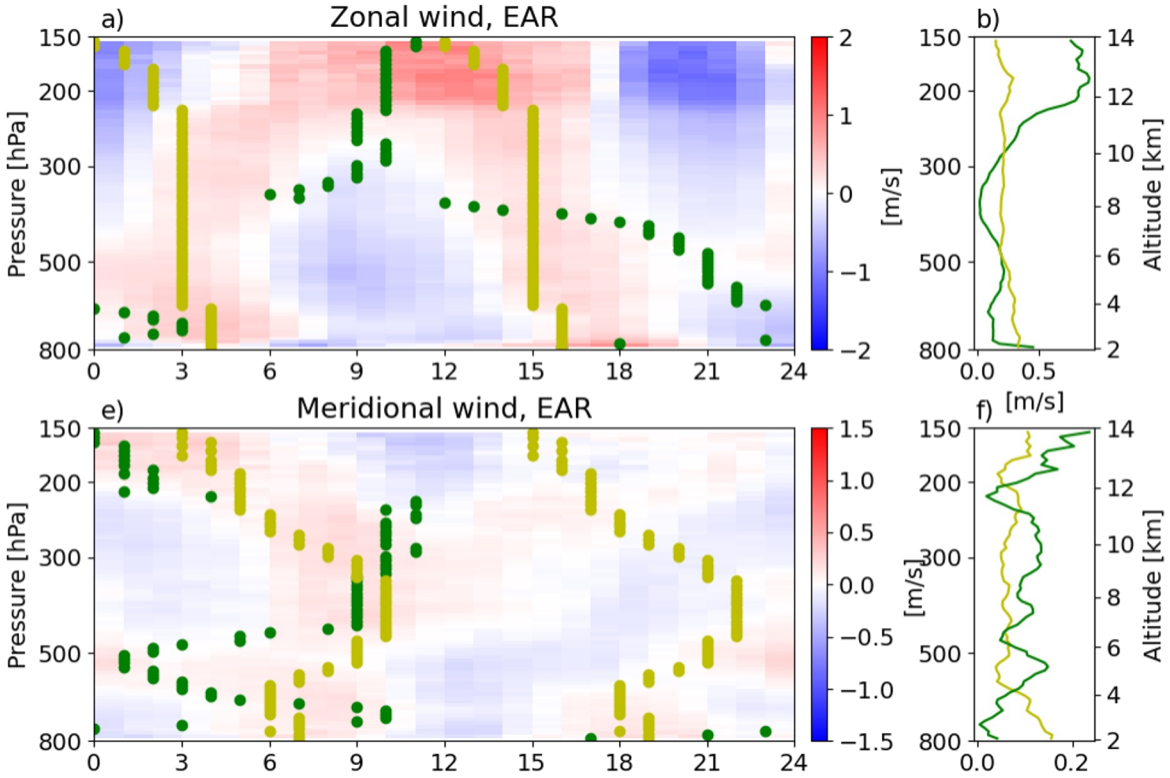
Mean conditions

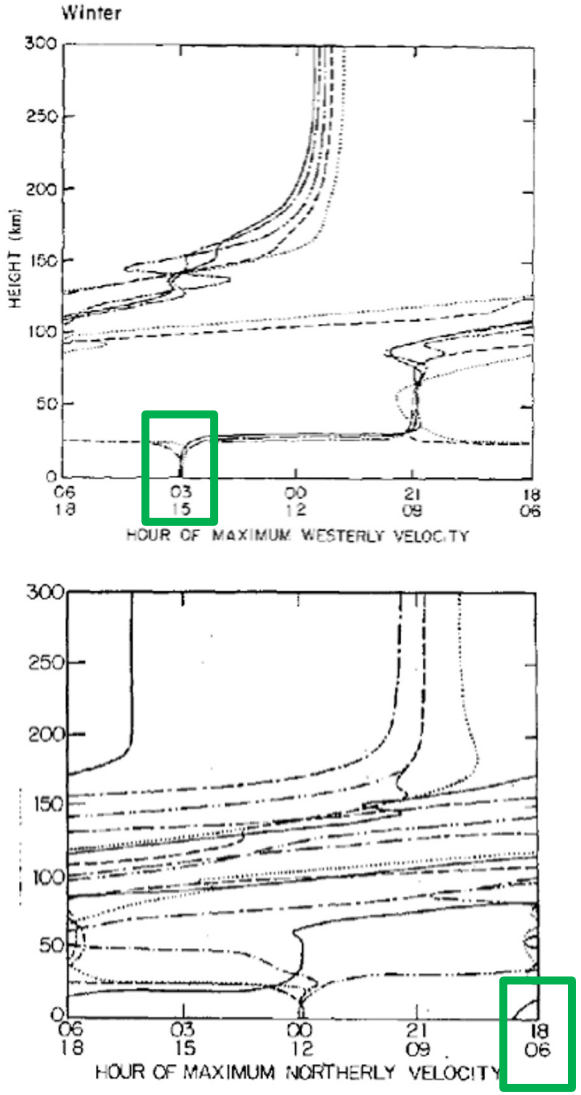
- Vertical shear of all wind components
- ERA-5 and EAR agree in horizontal wind data
- EAR observations of vertical wind differ with ERA-5 representation





Mean diurnal evolution

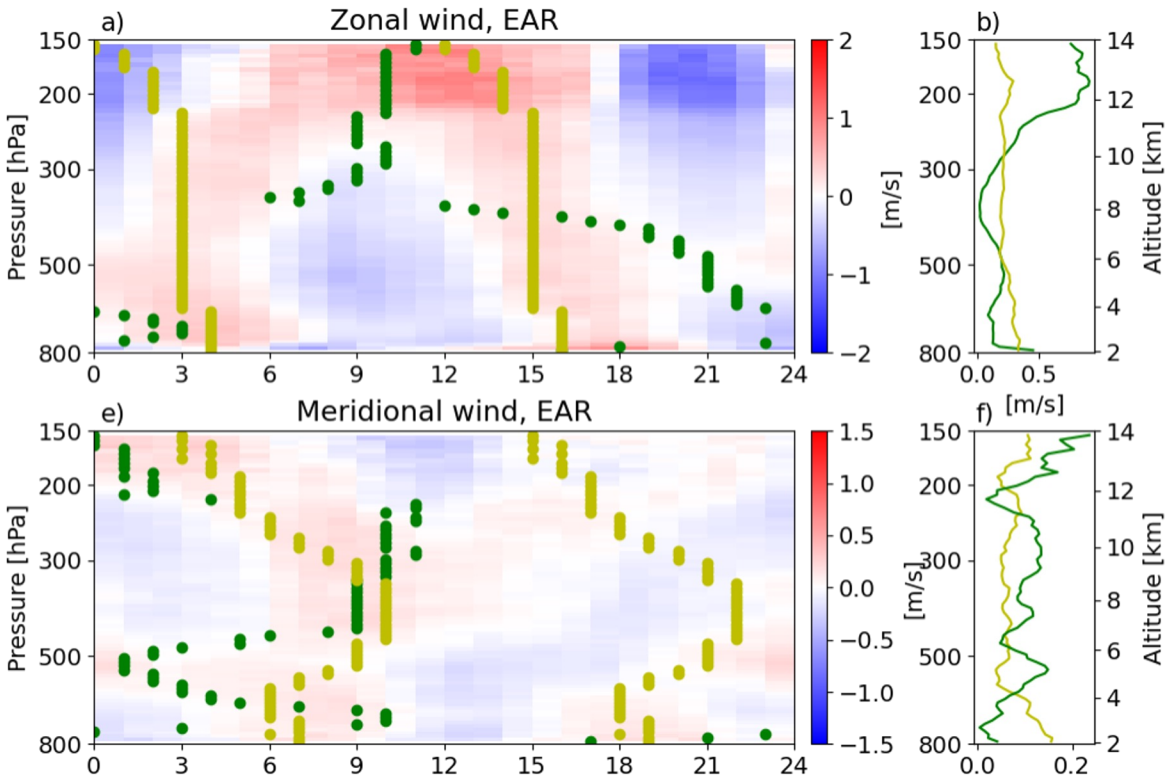


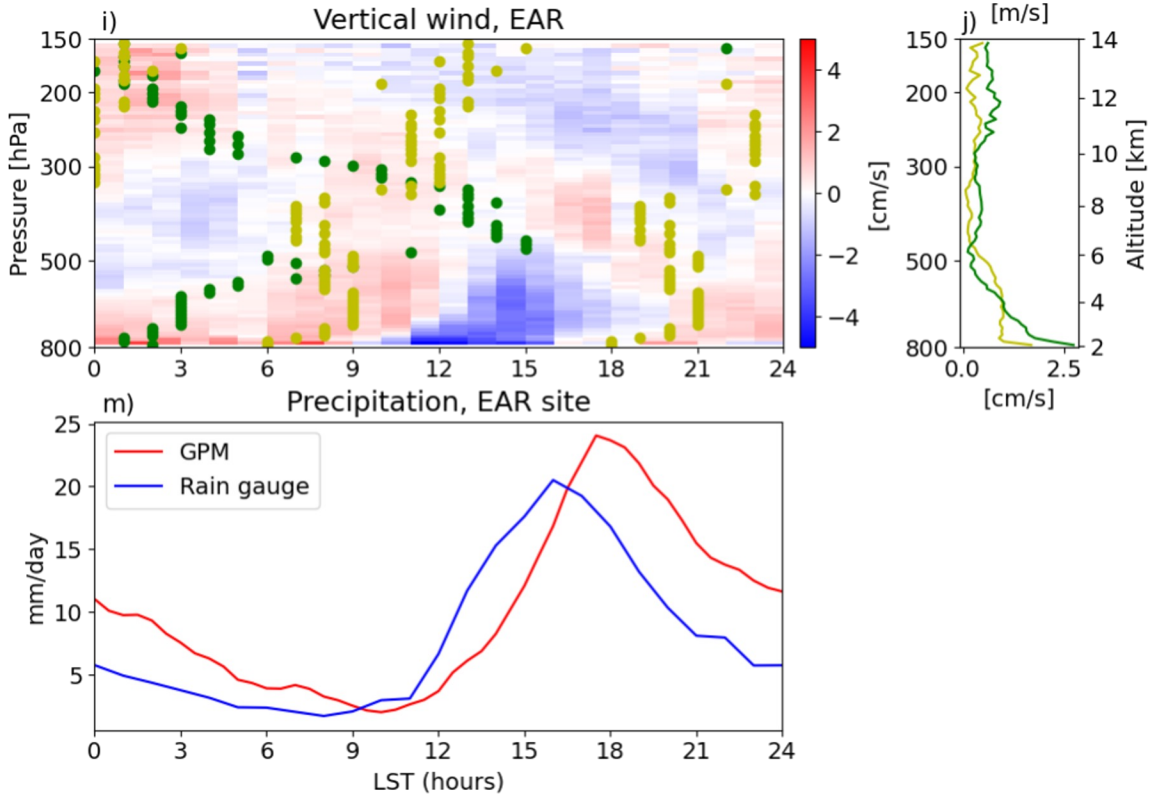


- Breeze circulation not visible (data above 2km, too high)
- Thermal tides visible in averaged horizontal wind diurnal variation

Lindzen, Hong 1974

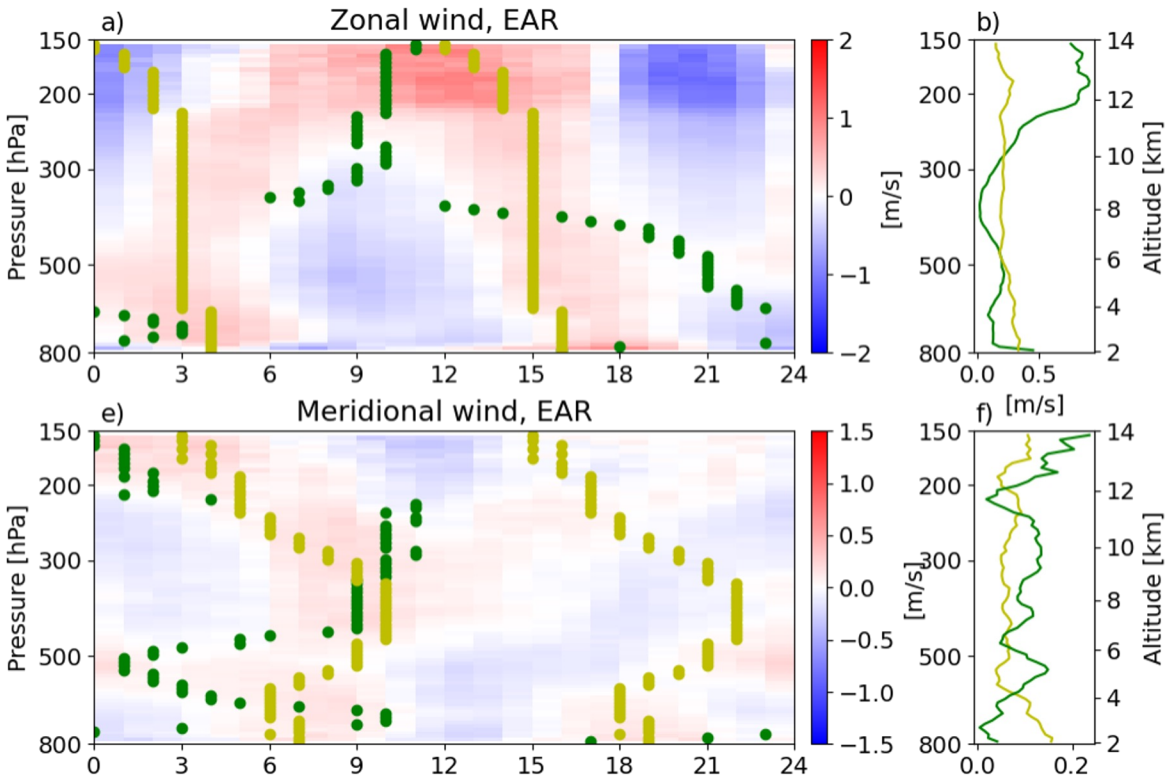
Mean diurnal evolution

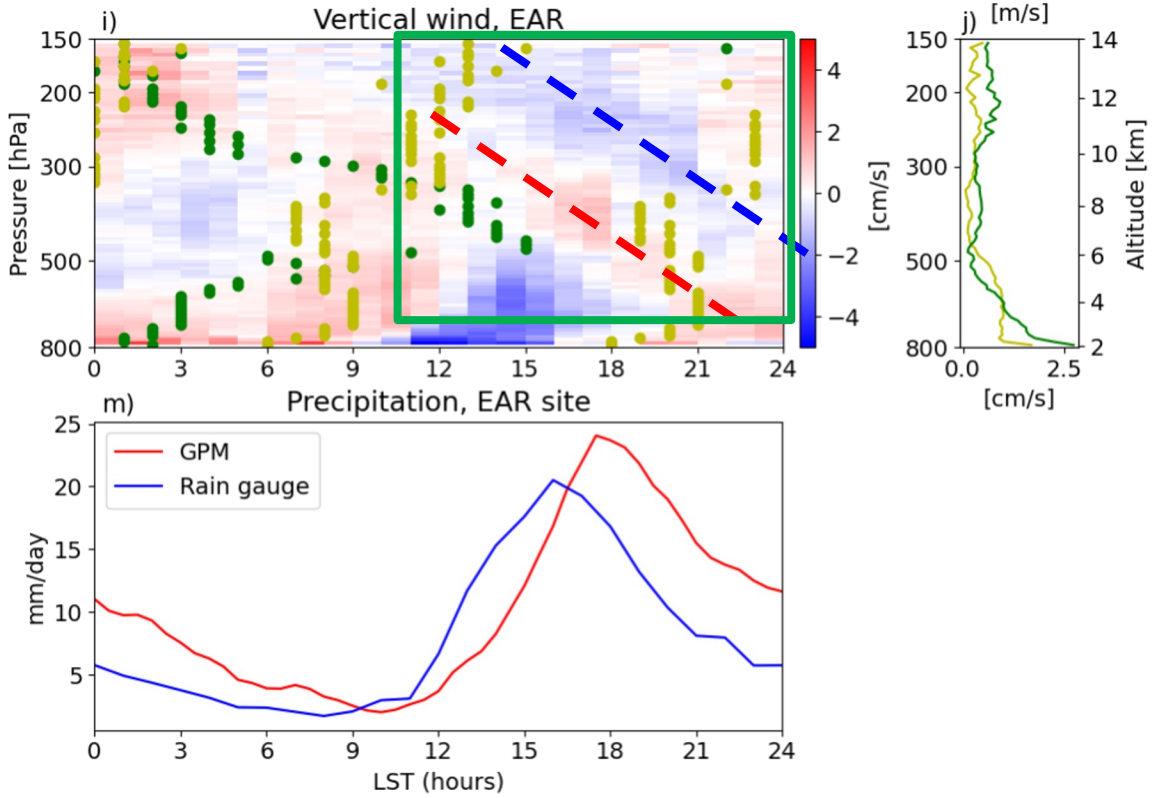




- Breeze circulation not visible (data above 2km, too high)
- Thermal tides visible in averaged horizontal wind diurnal variation
- Vertical wind evolution shows clear diurnal characteristic: most variability observed below 500mb;
  - positive anomalies (relative to the mean profile) before noon
  - negative anomalies between 12 and 18LST correlated with precipitation; both thicken over time

Mean diurnal evolution





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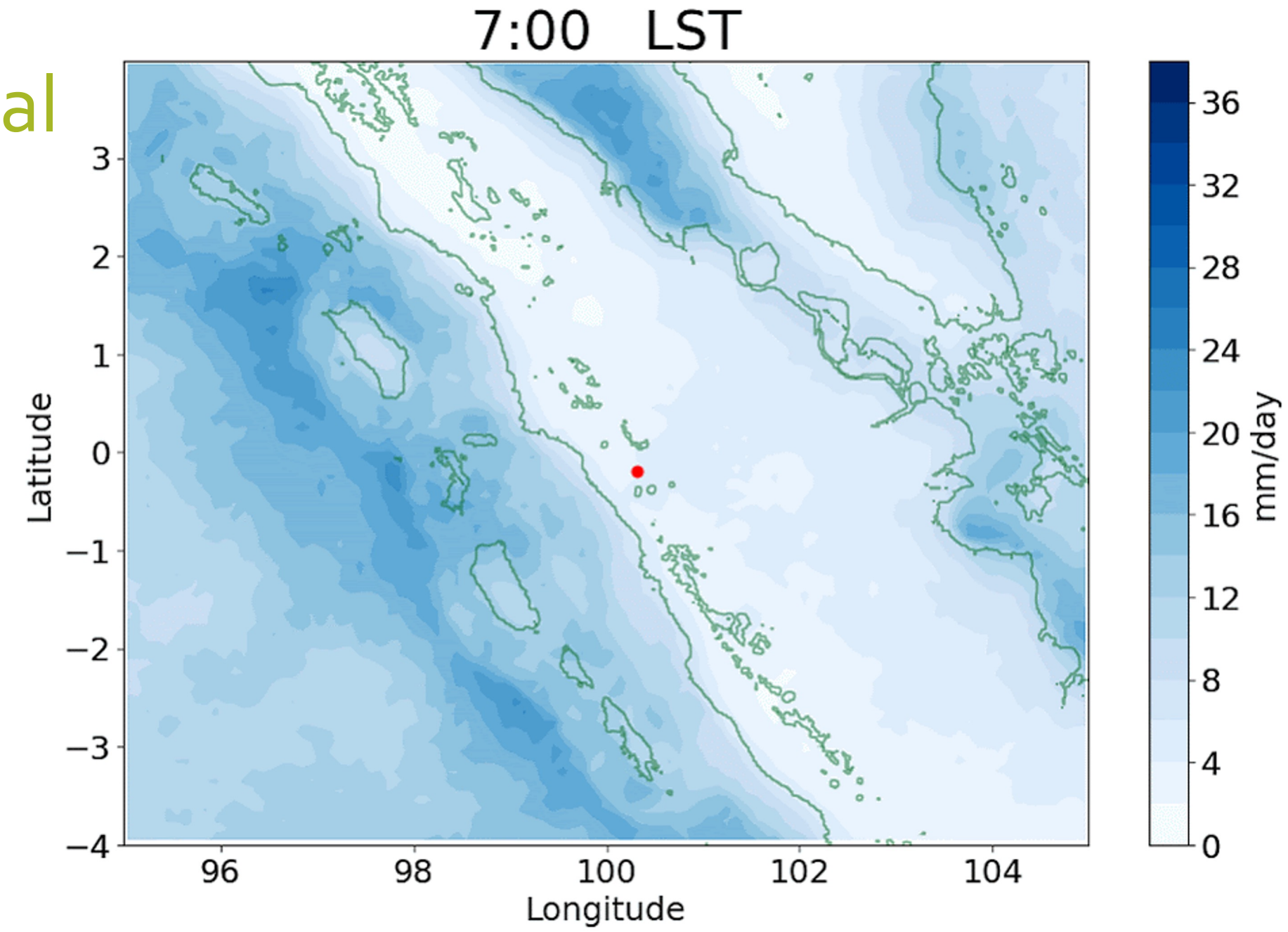
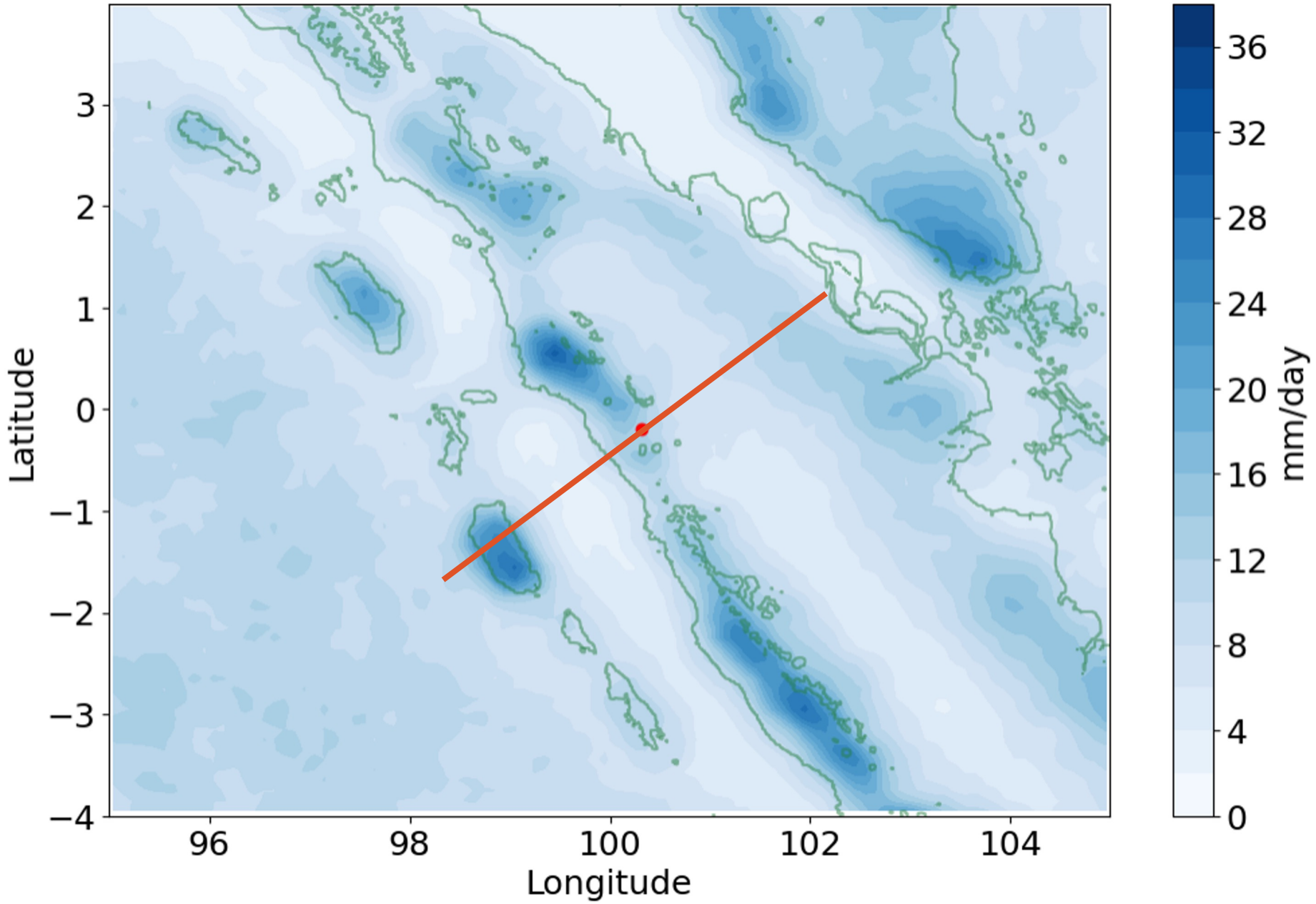
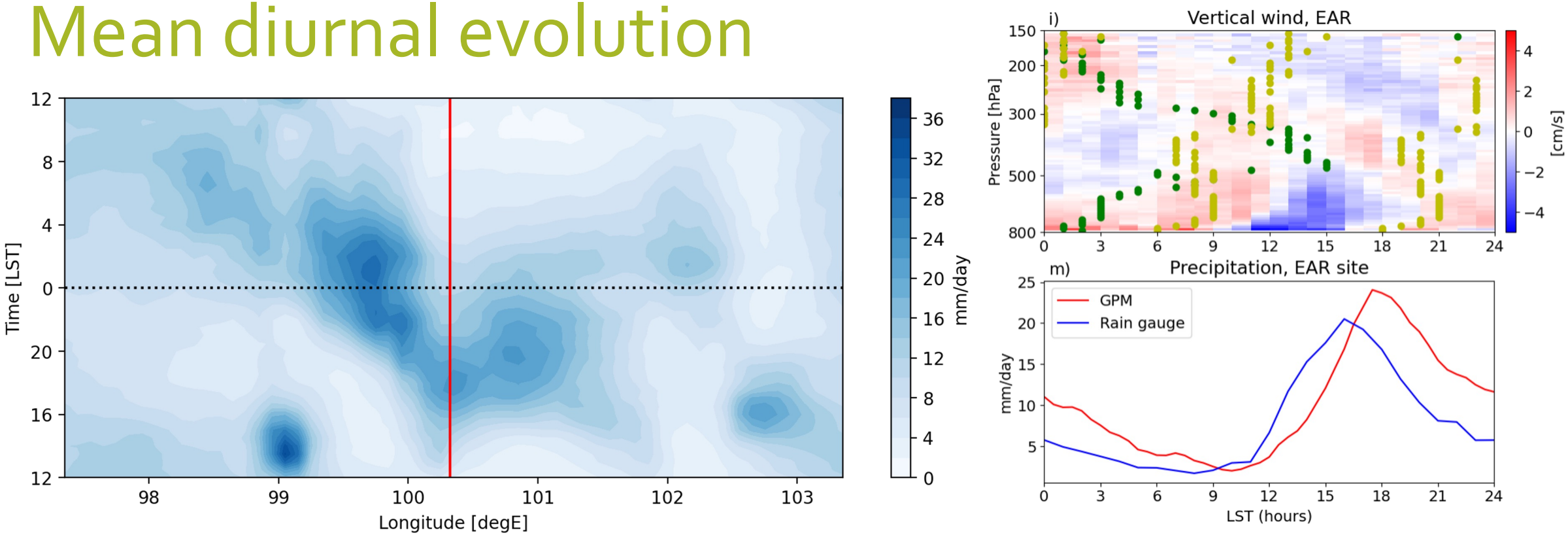
Mean diurnal evolution



Mean diurn evolution

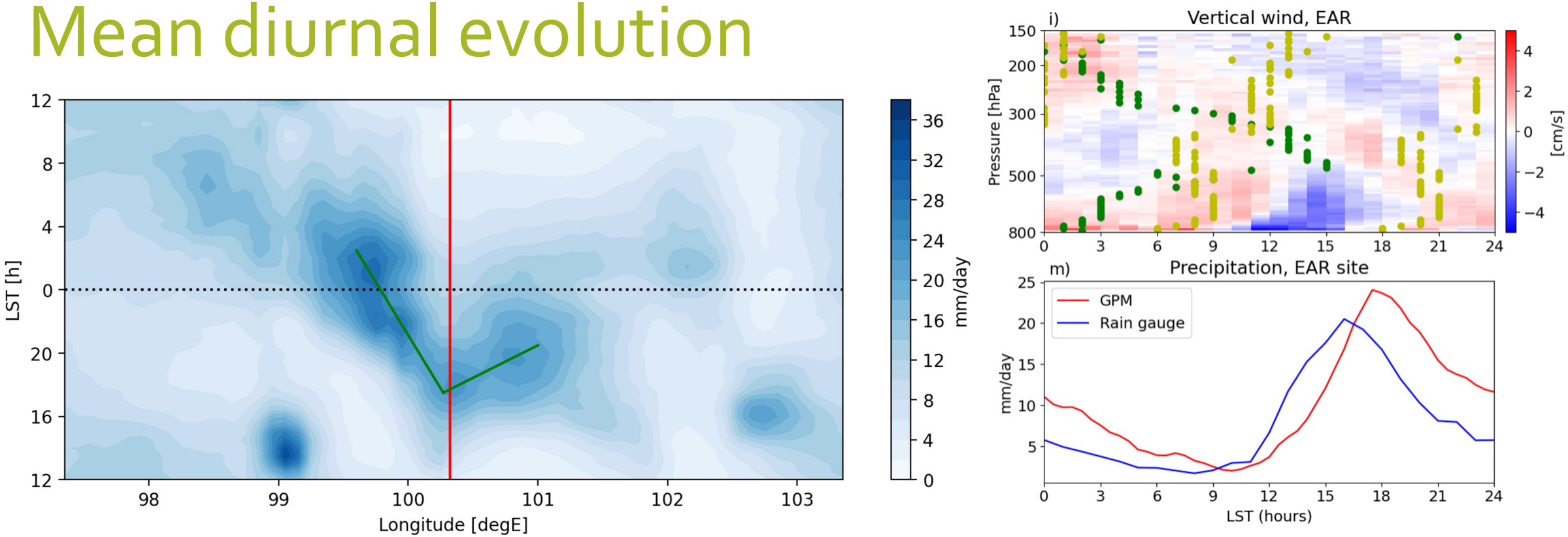


Mean diurnal evolution

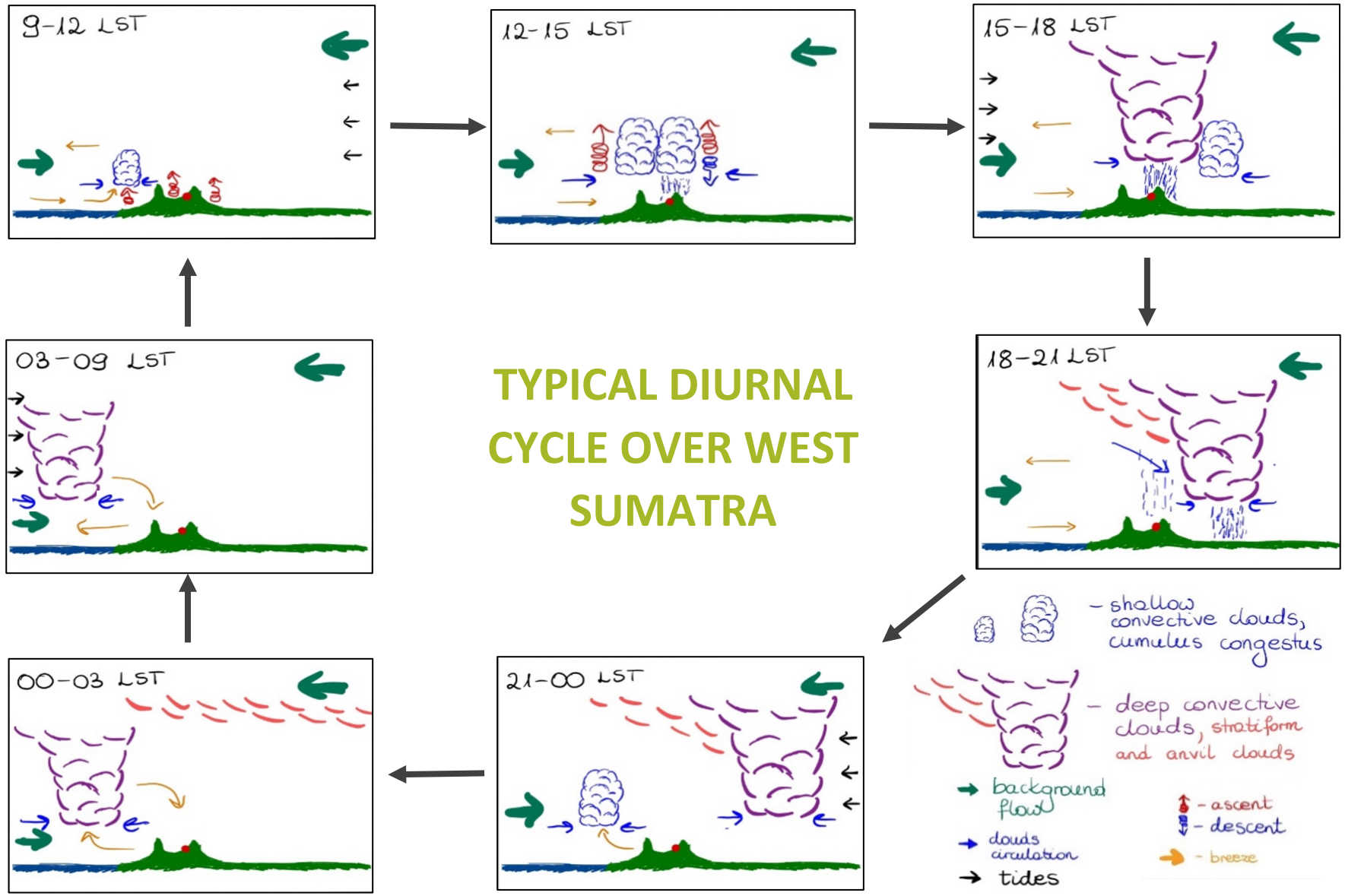


- Precipitation develops over west coast/mountain ranges and propagates inland and offshore; inland propagation is faster

Mean diurnal evolution



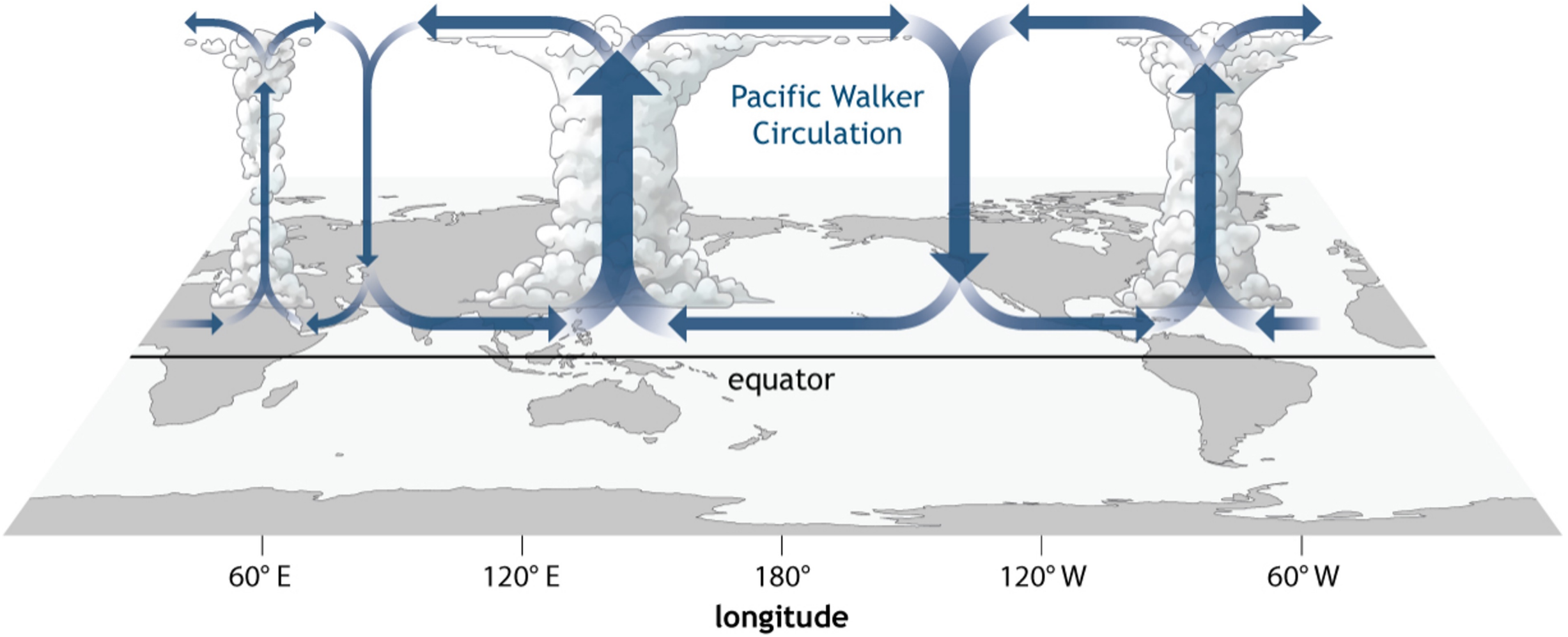
- Precipitation develops over west coast/mountain ranges and propagates inland and offshore; inland propagation is faster
- EAR location affected by in-land, eastward propagation of convective system and its typical structure:
  - convective rain between 12 and 16 LST and associated downward motions
  - then stratiform precipitation


9-12 LST
12-15 LST
15-18 LST
18-21 LST
21-00 LST
00-03 LST
03-09 LST
TYPICAL DIURNAL CYCLE OVER WEST SUMATRA
- shallow convective clouds, cumulus congestus
- deep convective clouds, stratiform and anvil clouds
background flow
clouds circulation
tides
- ascent
- descent
- breeze

Variations due to large-scale phenomena

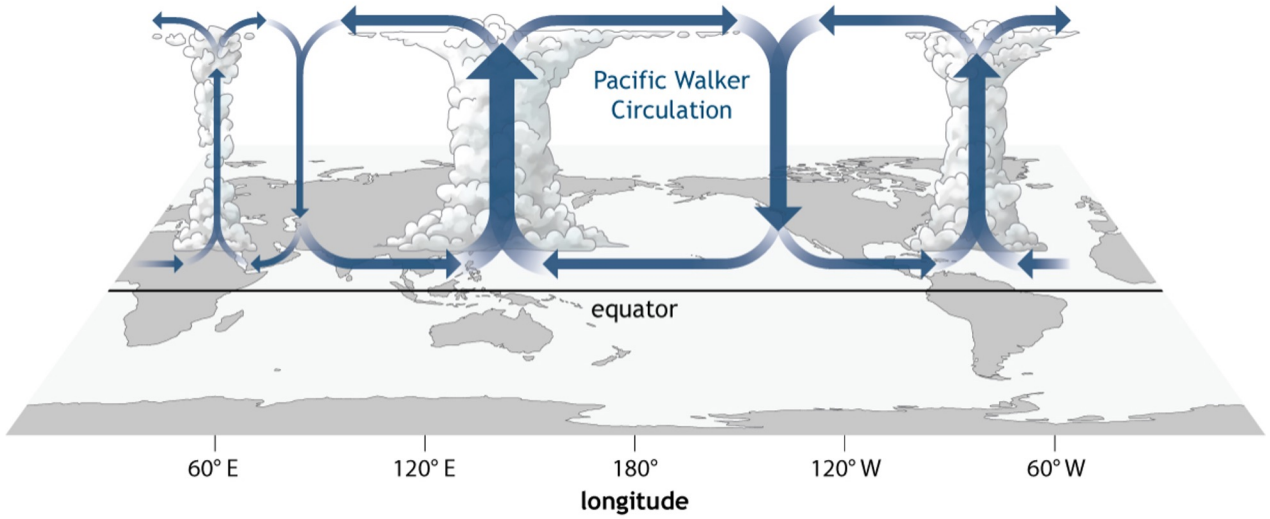
- Anomalies of all wind comopnents averaged over specific days (e.g. El Nino days, La Nina days)
- Comparison between mean standard deviation for those days
- Composites of diurnal evolution of precipitation data:
  - local at EAR site: rain gauge and GPM IMERG
  - regional along the line perpendicular to the mountains

El Nino Southern Oscillation (ENSO)

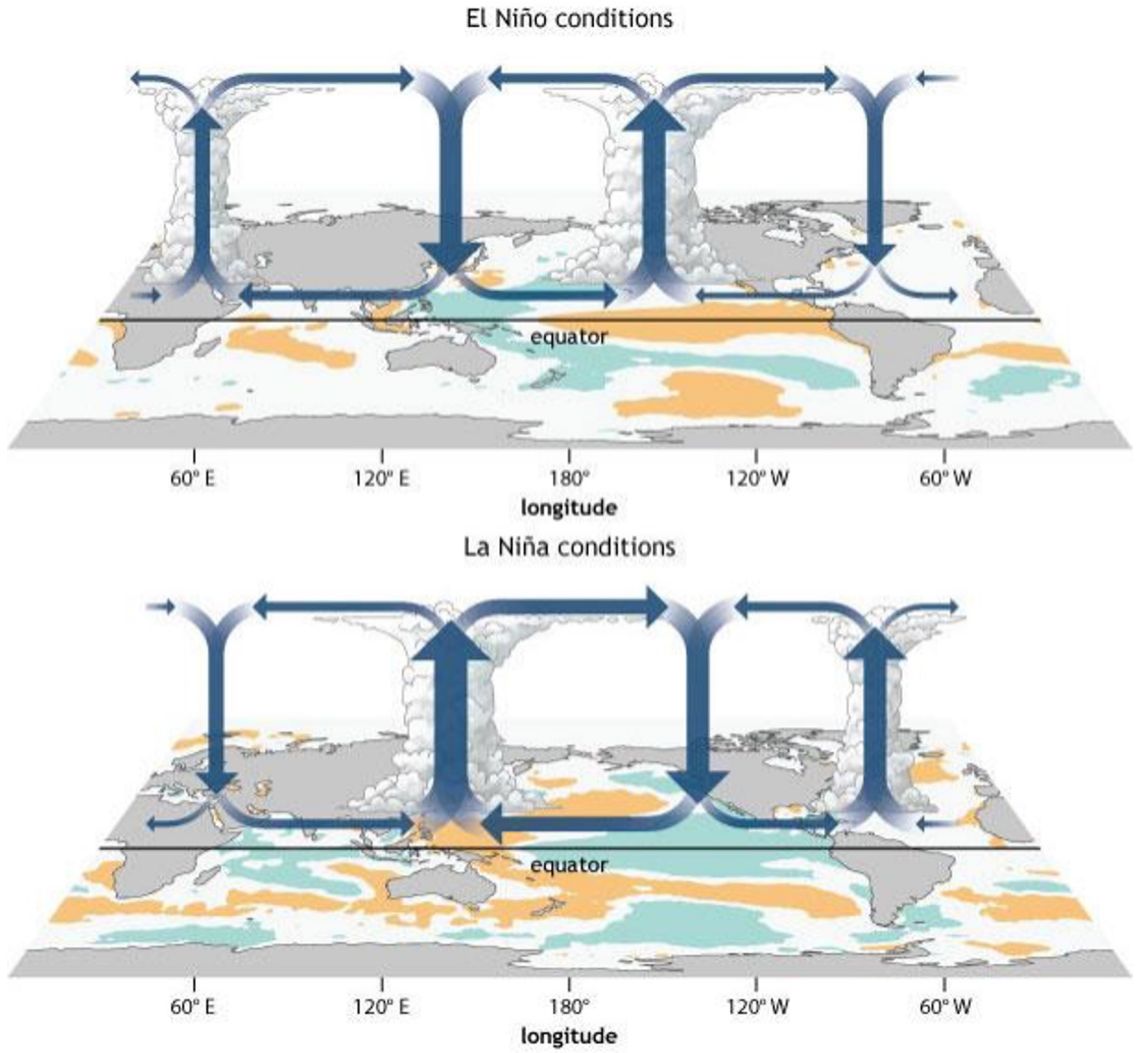


NOAA Climate.gov

El Nino Southern Oscillation

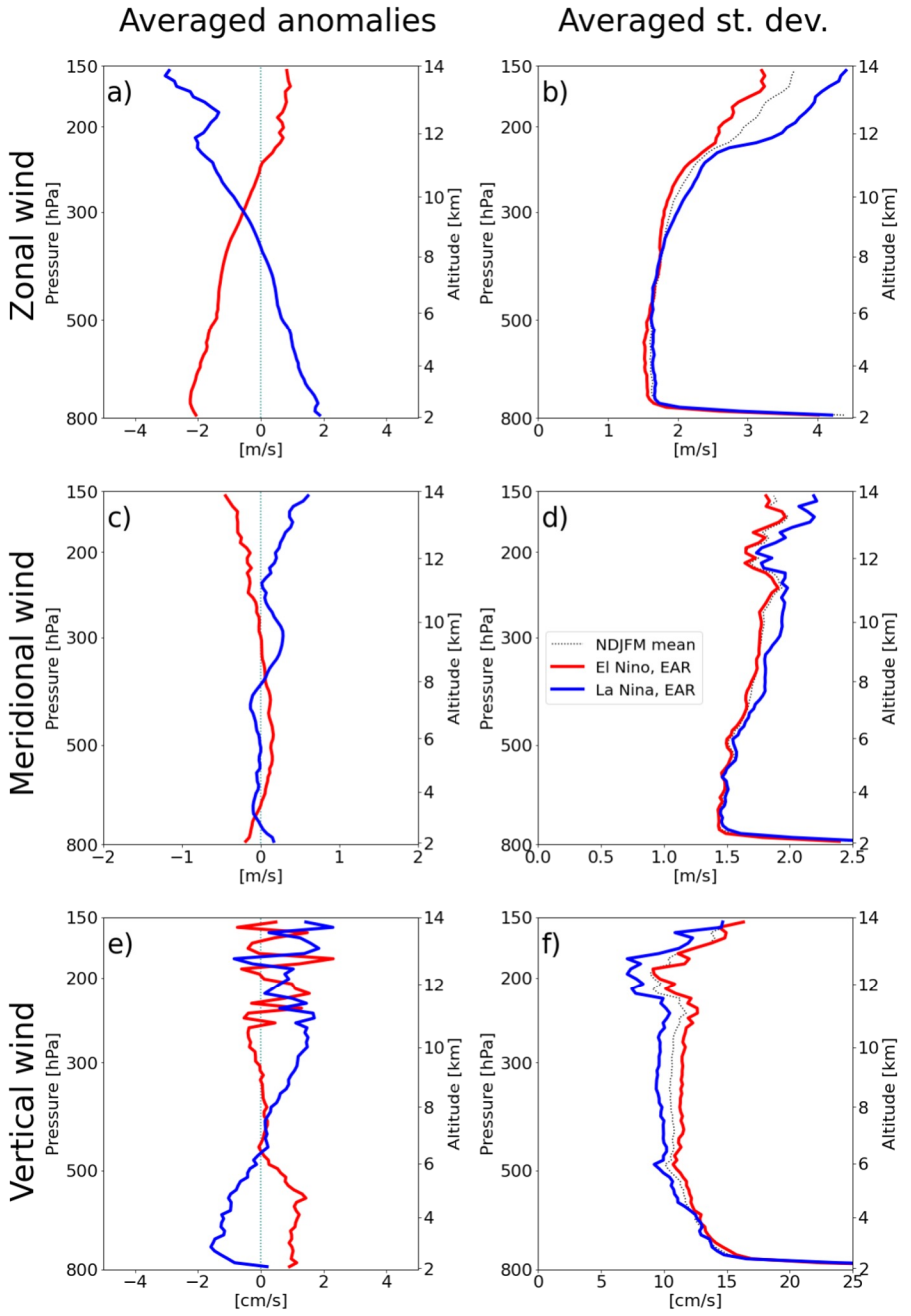


NOAA Climate.gov



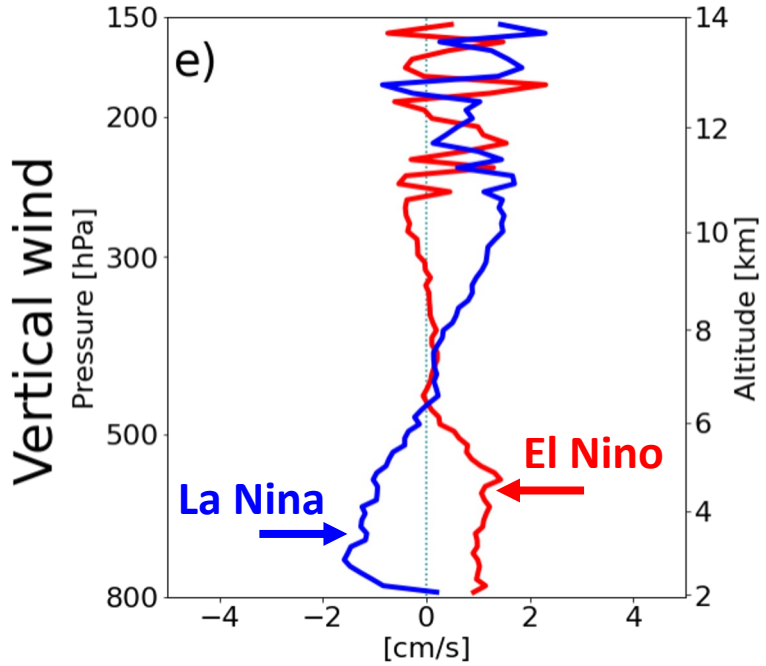
El Nino Southern Oscillation (ENSO)

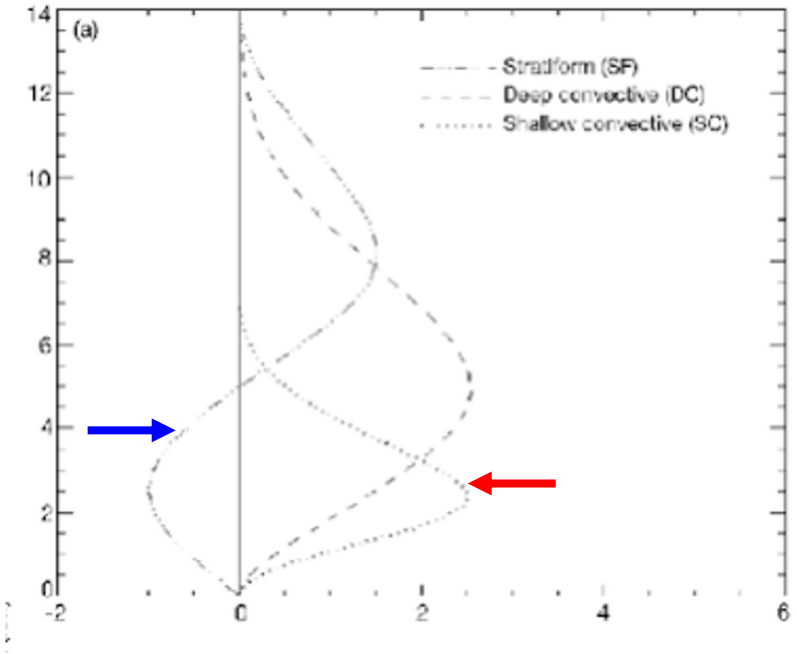
- Variations of zonal wind anomalies consistent with the large-scale circulation during El Nino/La Nina
- El Nino:
  - smaller than usual diurnal variations of zonal wind in the upper troposphere
  - positive anomalies of vertical wind in the lower troposphere
- La Nina:
  - larger than usual diurnal variations of zonal wind in the upper troposphere
  - negative anomalies of vertical wind in the lower troposphere and positive anomalies in the higher troposphere



El Nino Southern Oscillation (ENSO)

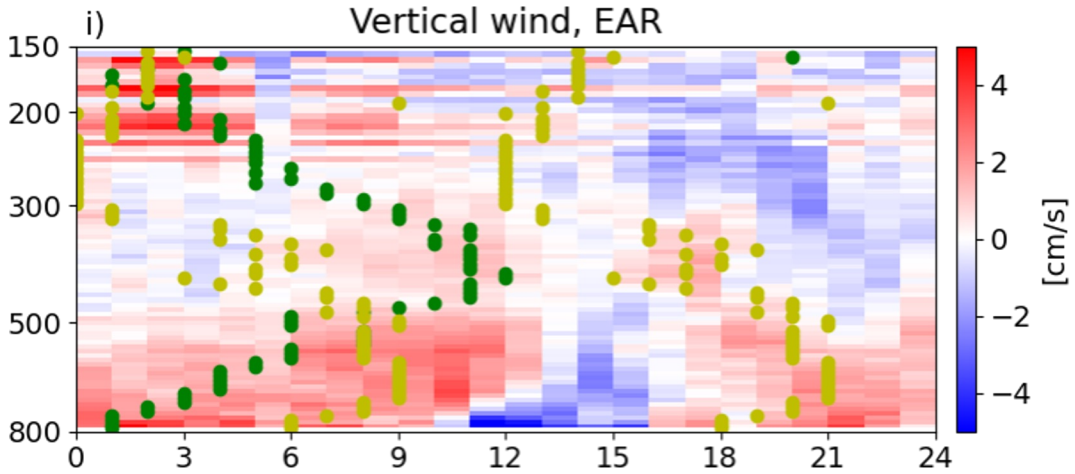
(Schumacher et al. 2003)

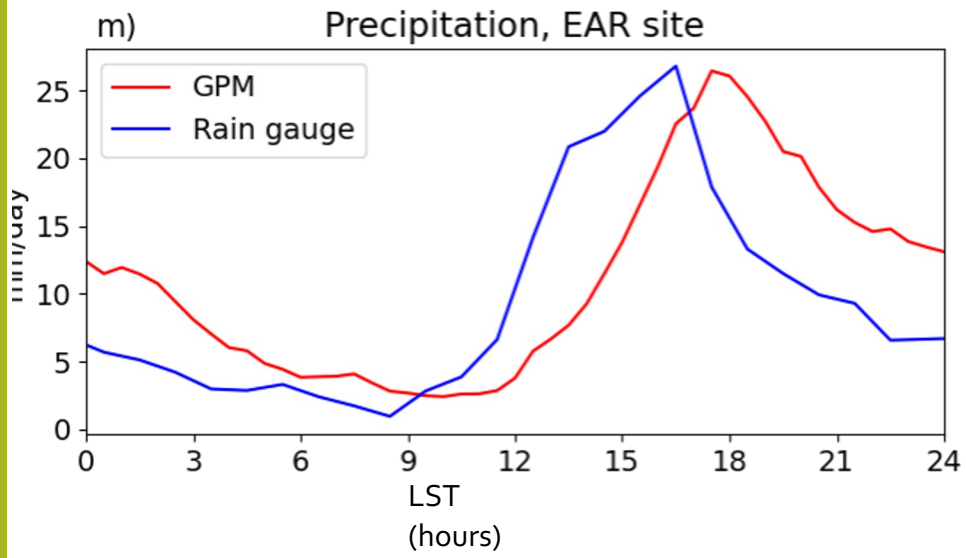




Hypothesis:

- **El Nino**: increased amount of shallow convective clouds
- **La Nina**: more stratiform clouds

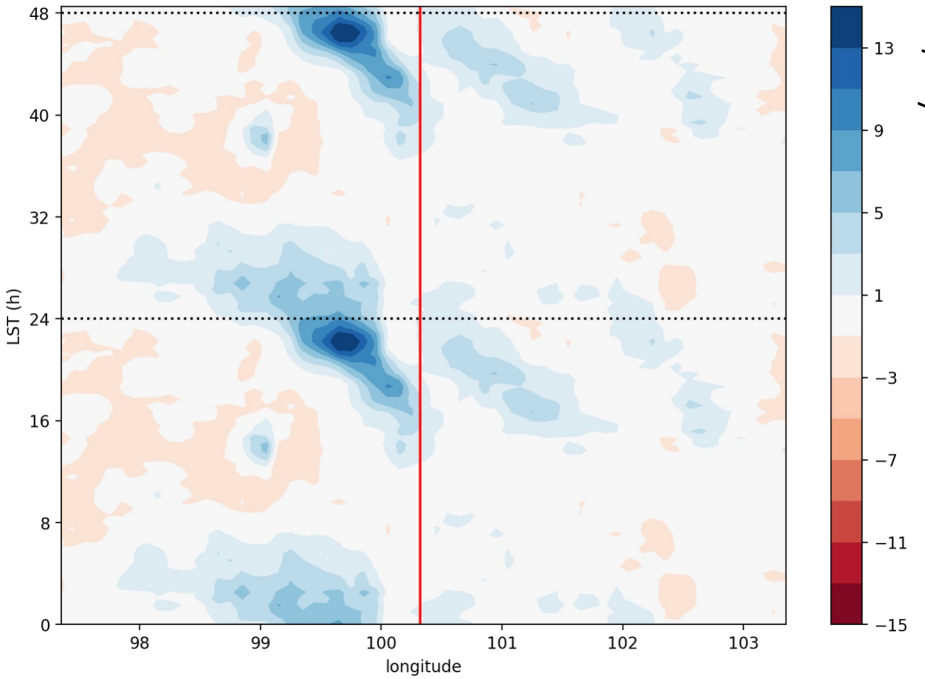


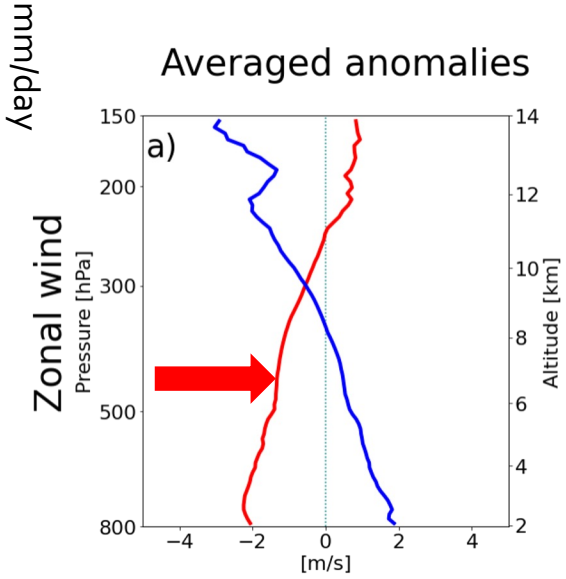


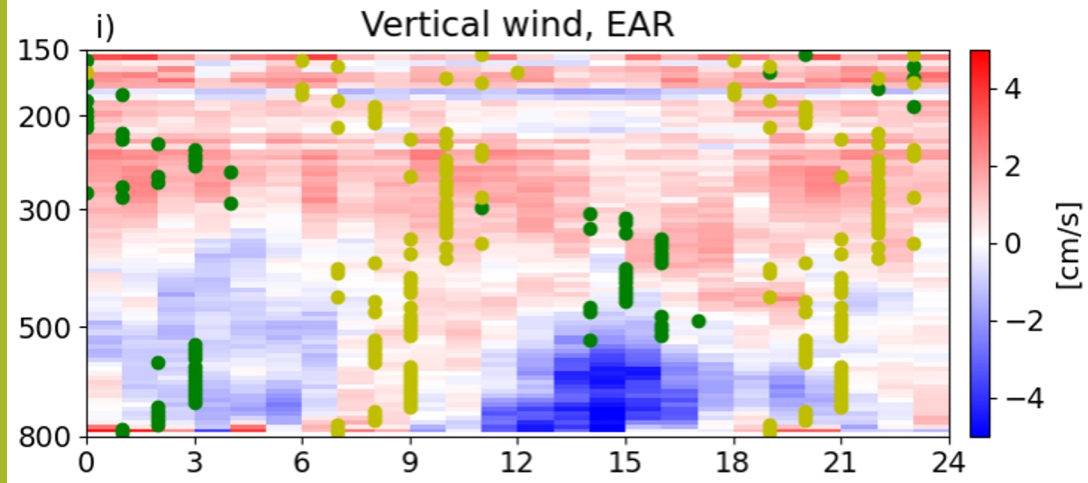
El Nino

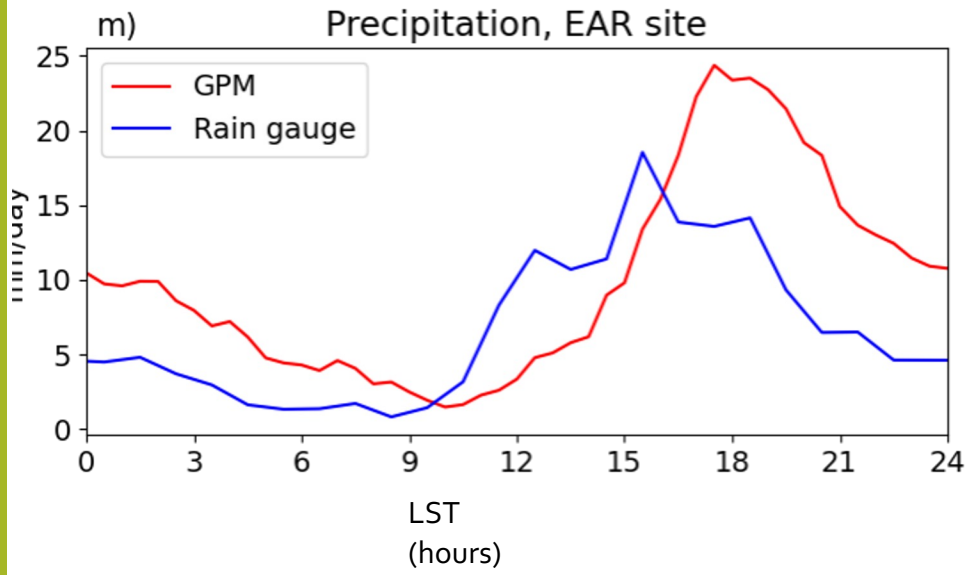
- less downdrafts
- weaker easterlies in the lower troposphere
- suppressed eastward and enhanced westward propagation of precipitation
- positive anomalies of vertical wind in the lower troposphere – shallow convective clouds

- higher precipitation rates; no change of phase





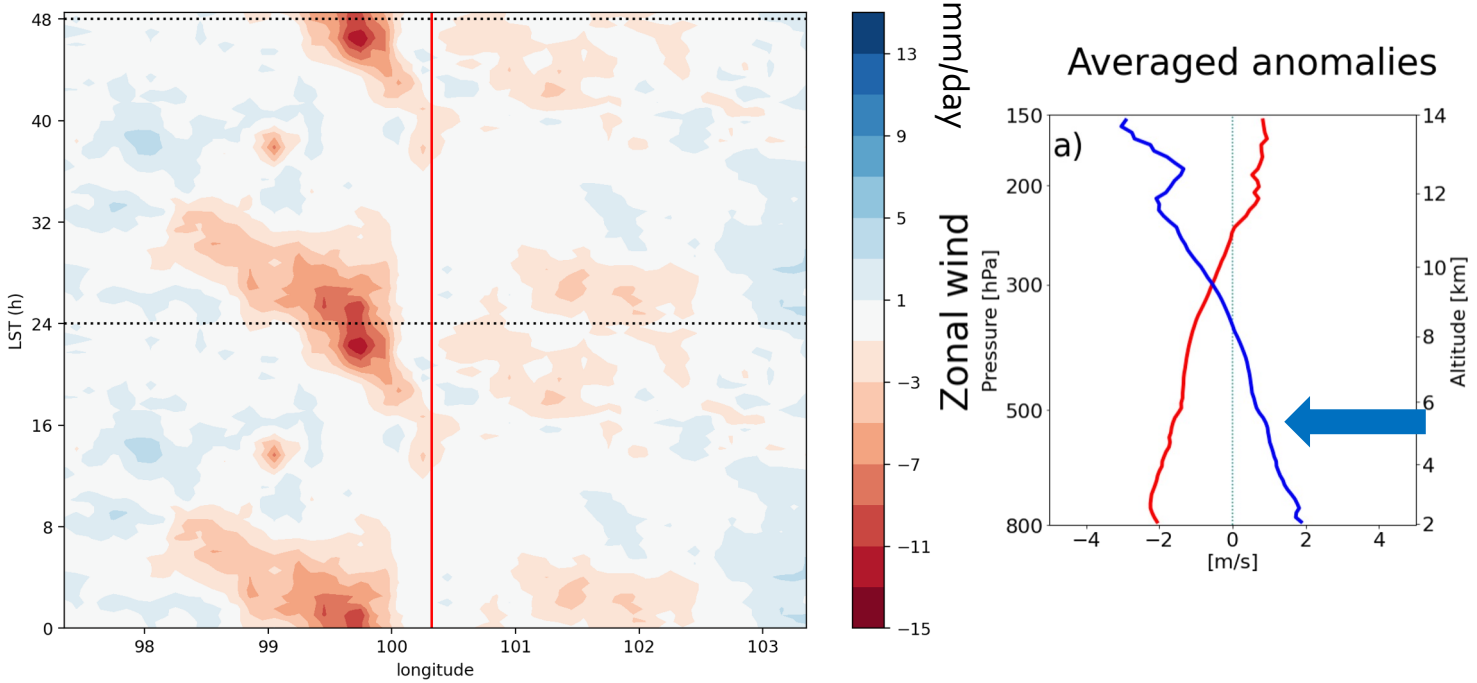




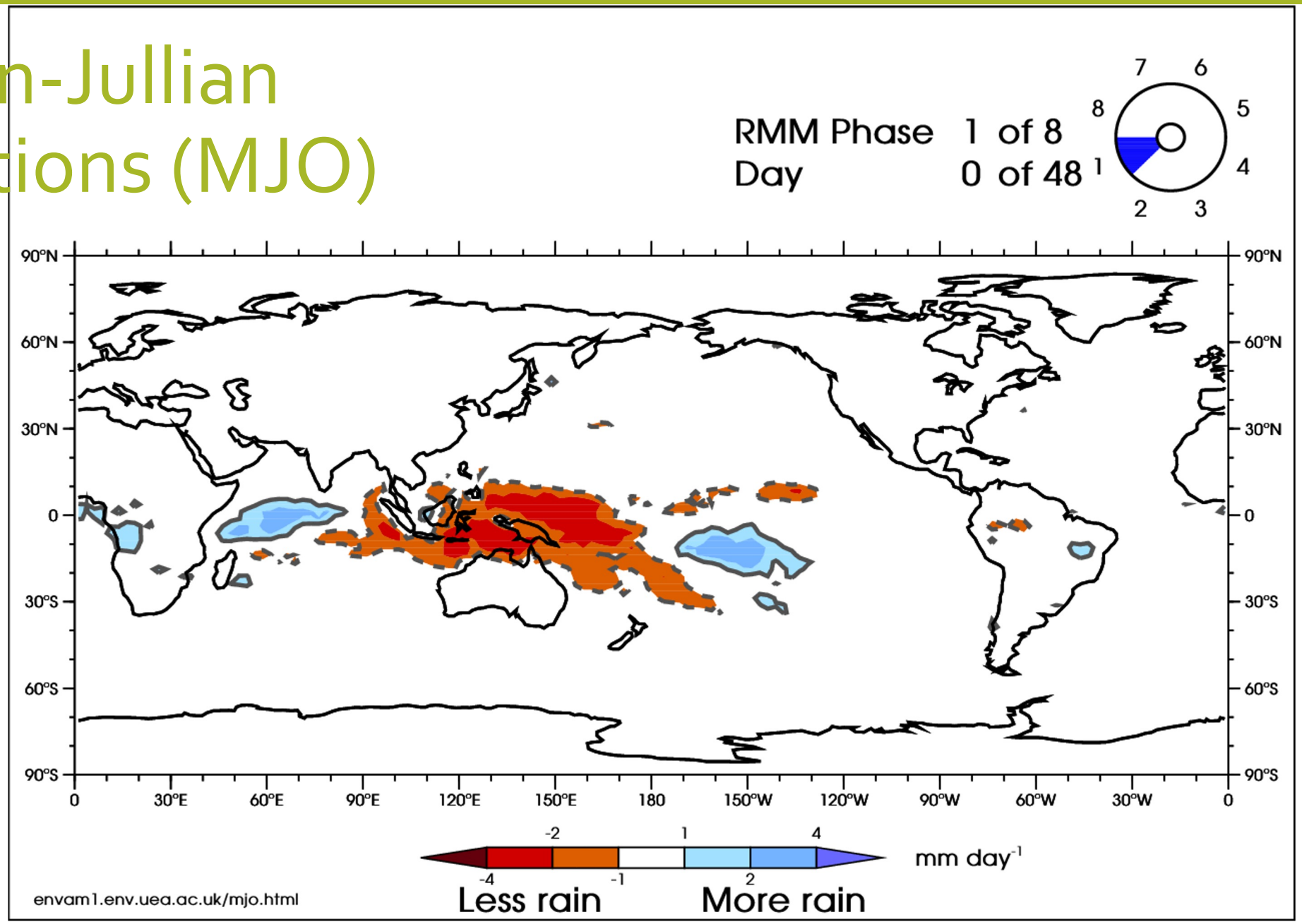
La Nina

- more downdrafts
- stronger easterlies in the lower troposphere
- enhanced eastward and suppressed westward propagation of precipitation
- positive anomalies of vertical wind in the upper troposphere – stratiform clouds

- lower precipitation rates; no change of phase



Madden-Jullian Oscillations (MJO)



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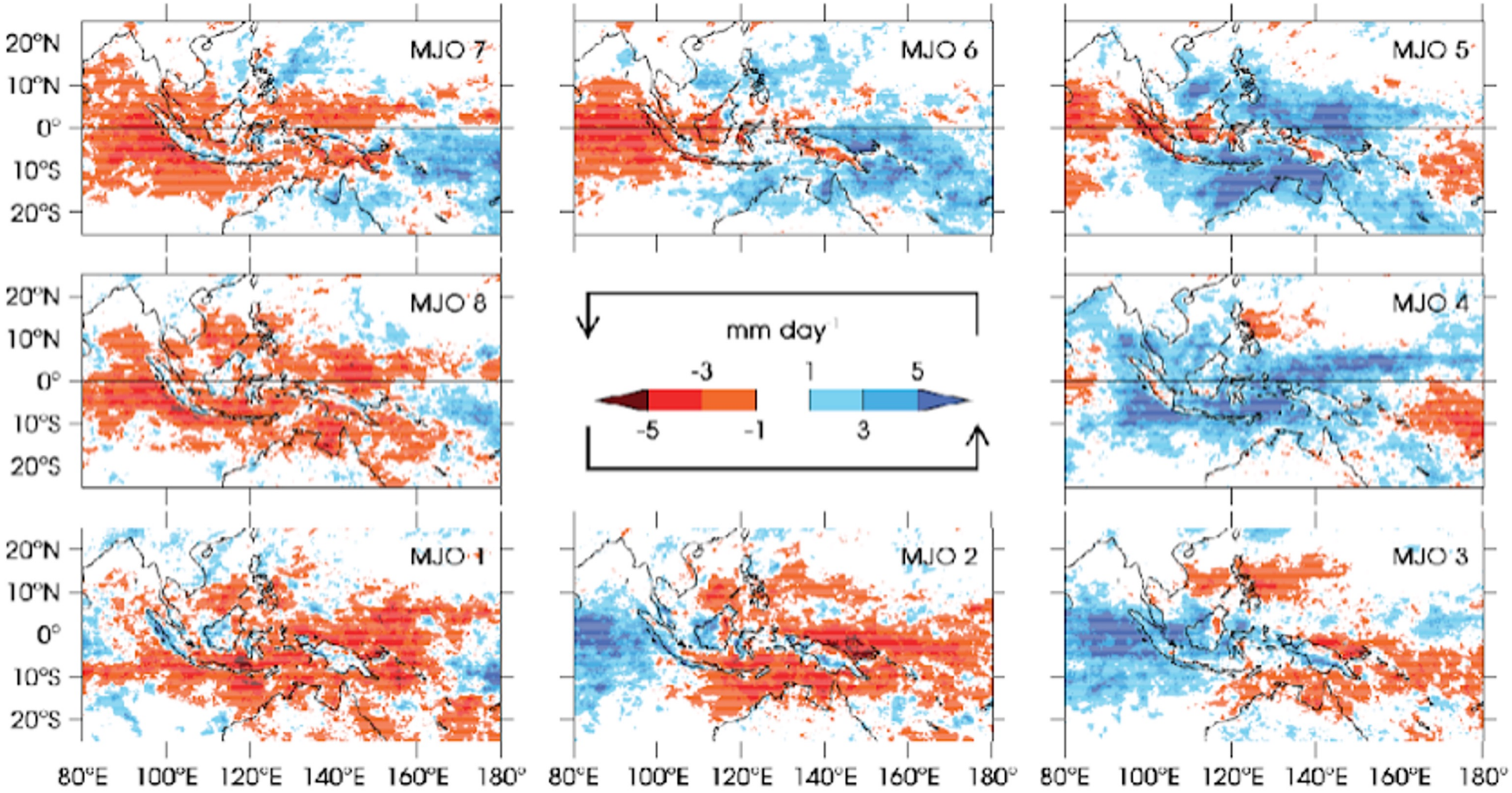
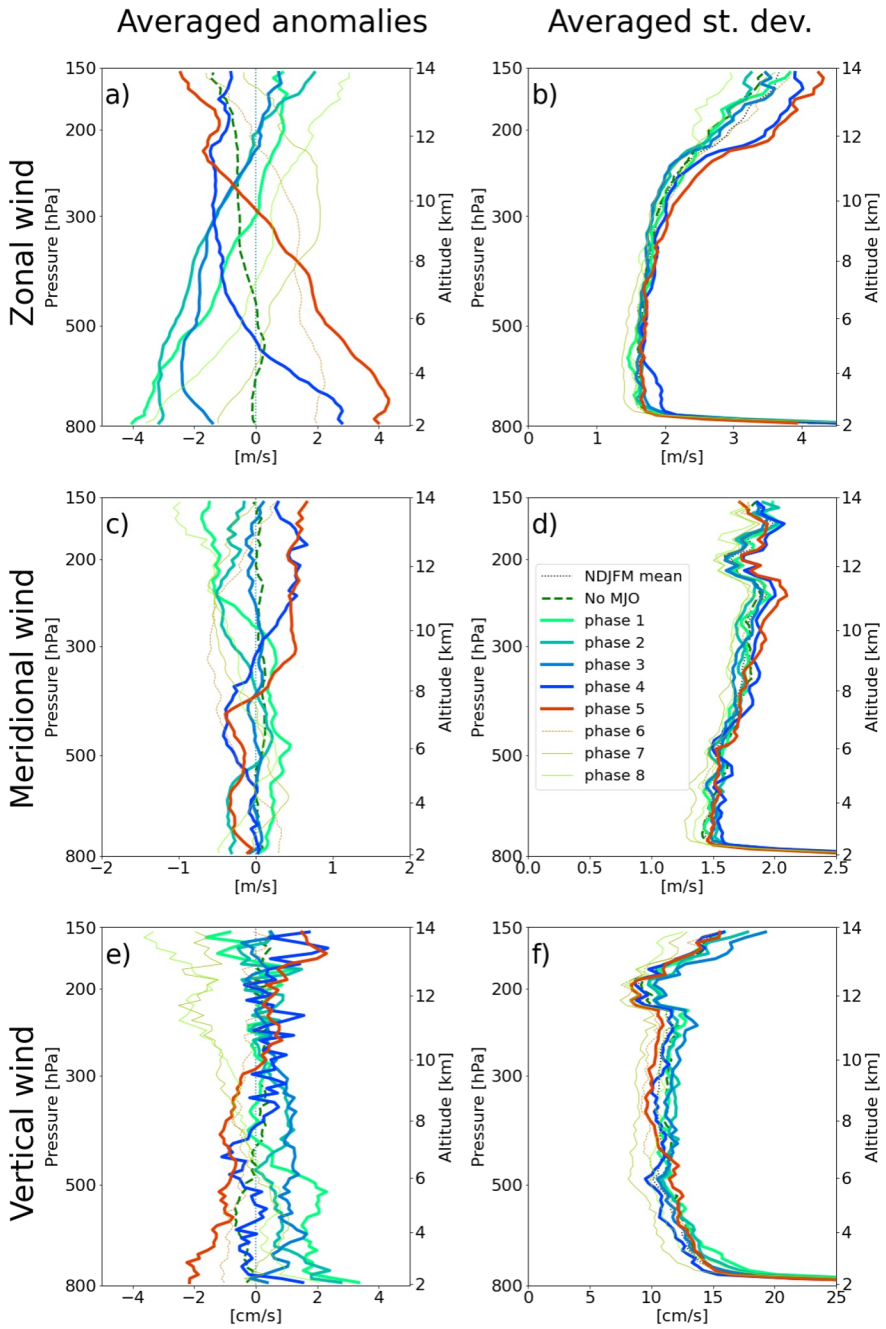


Madden-Jullian Oscillations (MJO)

- Zonal wind variations agree with the structure of propagating convection
- Significant variations in the mean profiles of vertical wind:
  - upward anomalies in the lower and middle troposphere during wet phases of MJO
  - downward anomalies during dry phases of MJO



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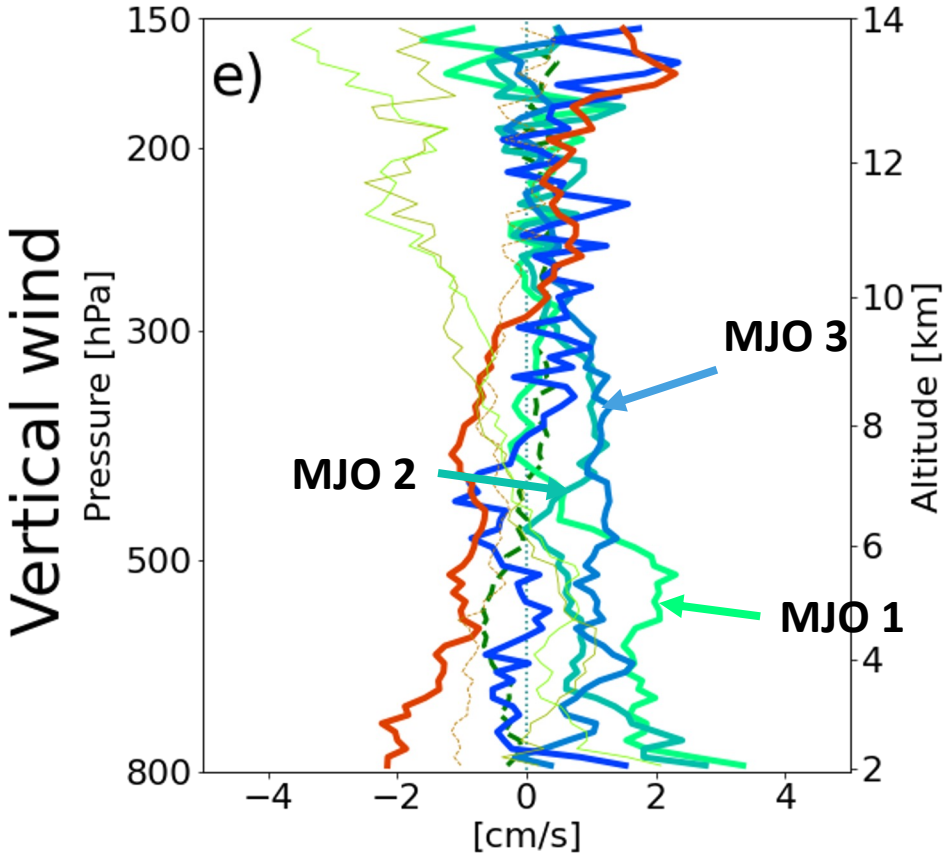
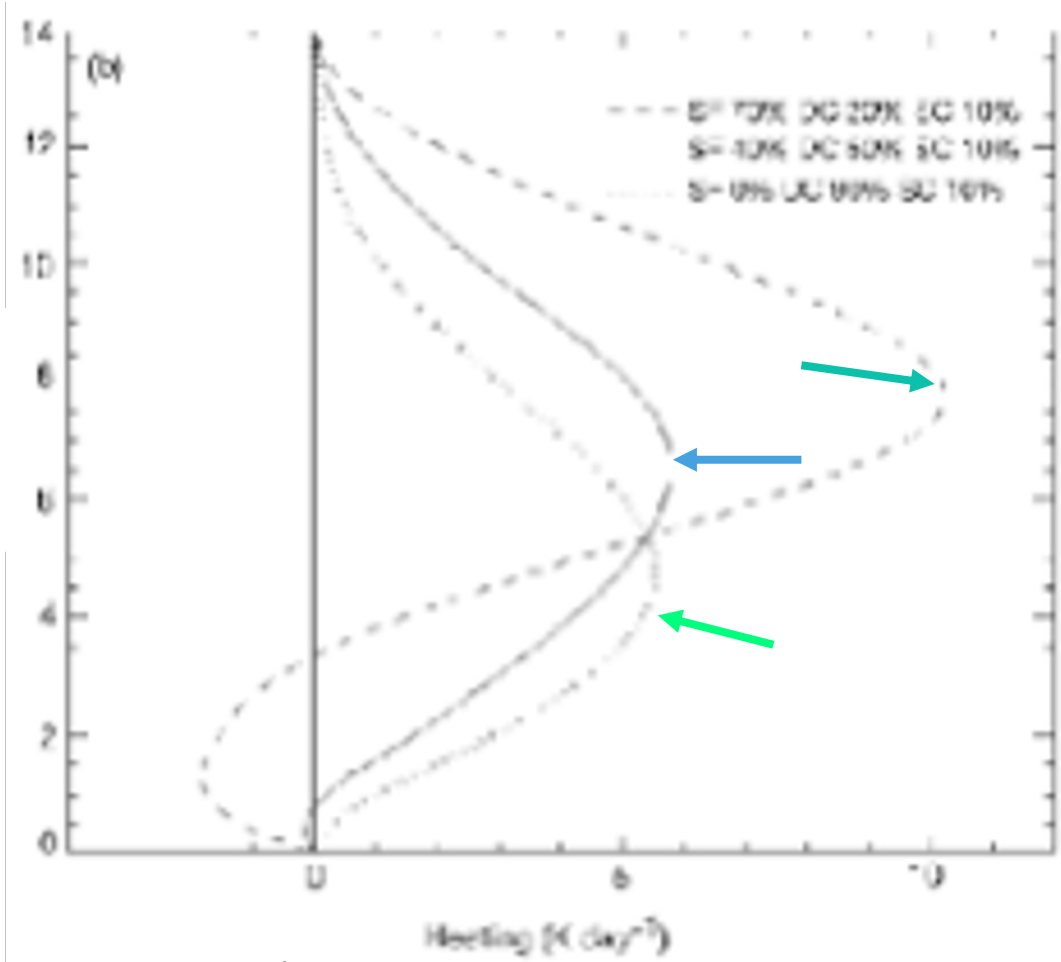




Hypothesis:

- **MJO 1**: increased amount of convective clouds (shallow and deep)
- **MJO 2**: more stratiform and shallow convective clouds
- **MJO 3**: increased amount of startiform and deep convective clouds

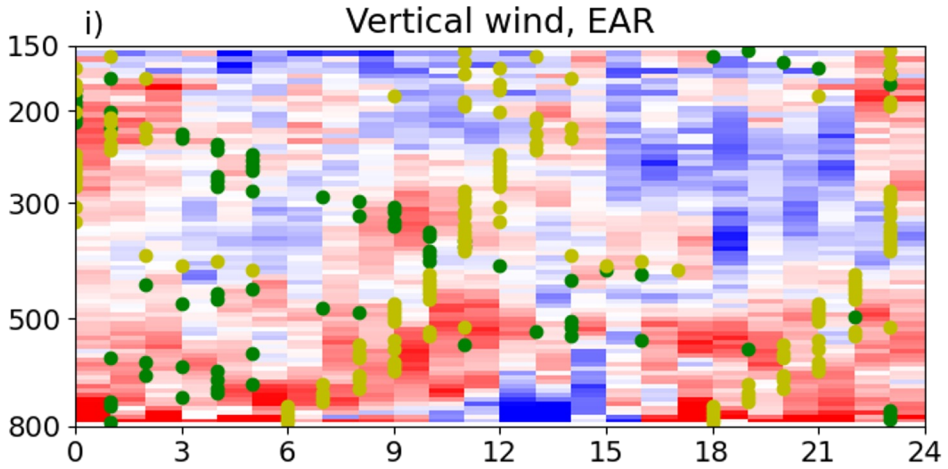
(Schumacher et al. 2003)

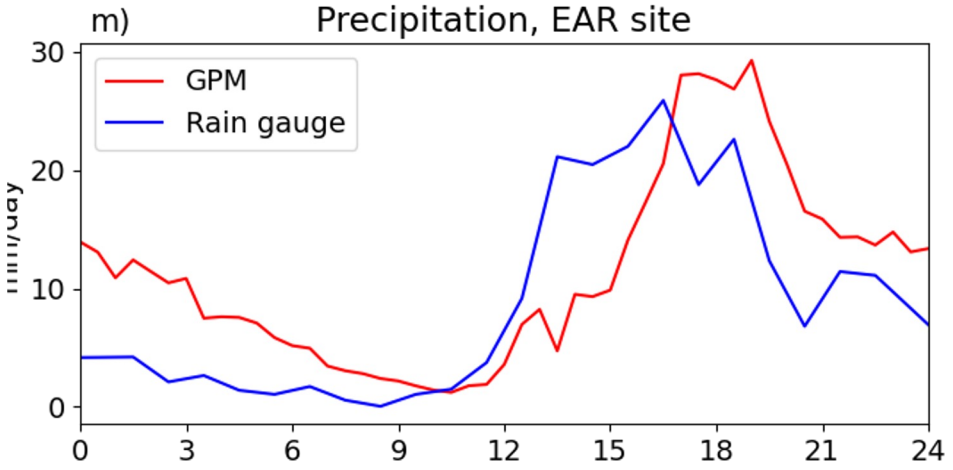
MJO phase 1

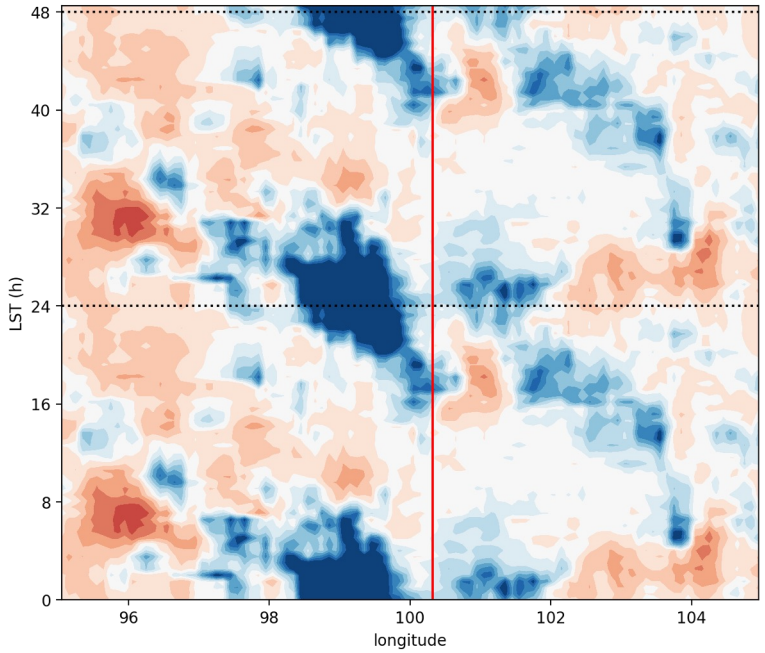
Hypothesis:

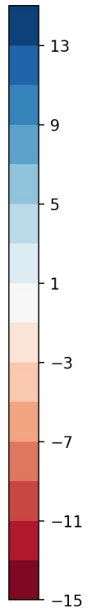
- **MJO 1**: increased amount of <u>convective clouds (shallow and deep)</u>

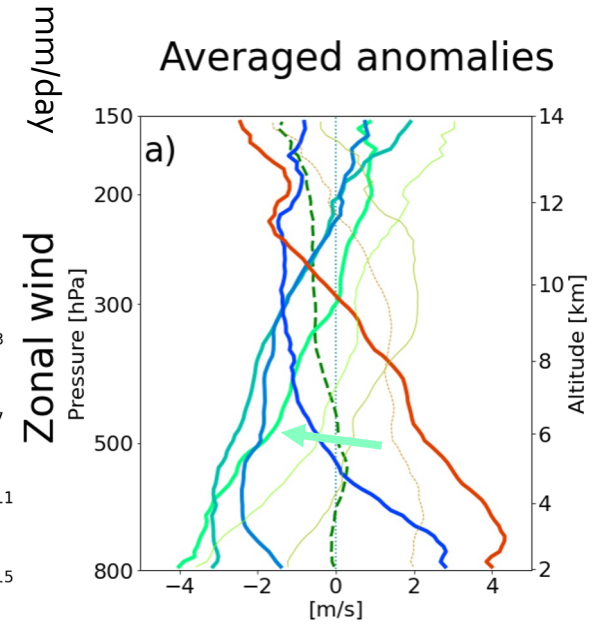
- less downdrafts
- weaker easterlies in the lower troposphere
- suppressed eastward and enhanced westward propagation of precipitation
- positive anomalies of vertical wind in the lower troposphere – shallow convective clouds







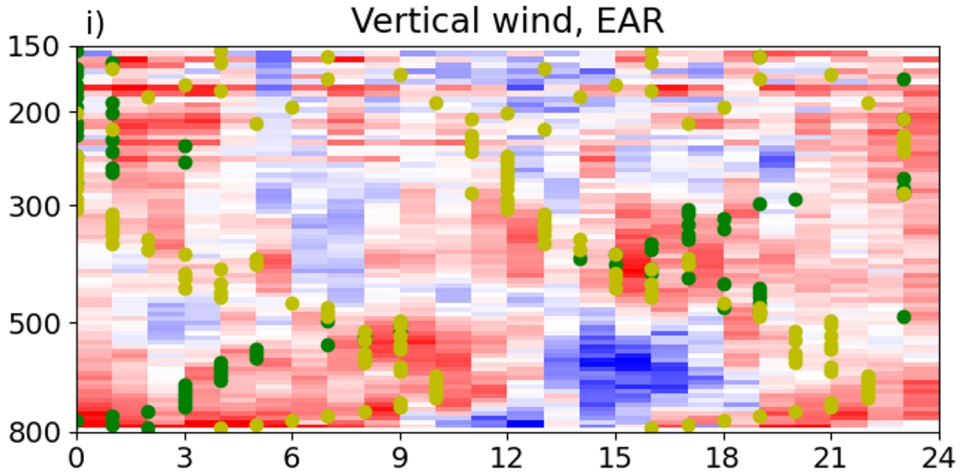


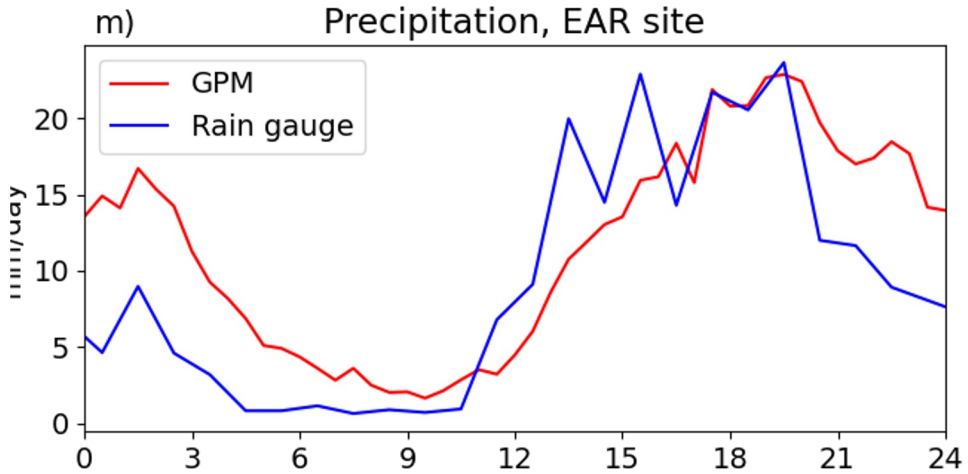


MJO phase 2

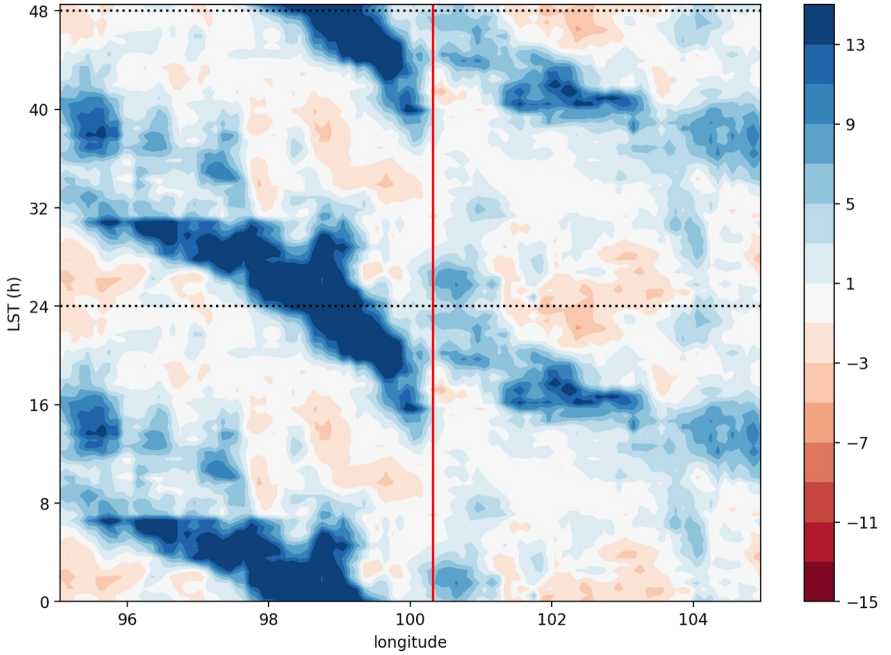
Hypothesis:

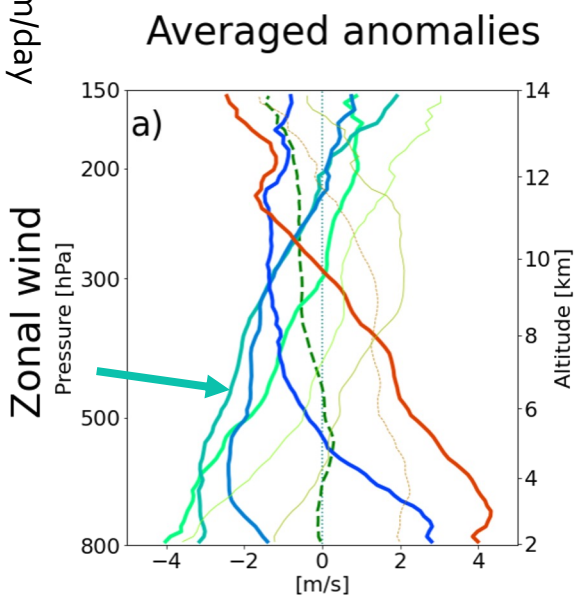
- **MJO 2**: more <u>stratiform and shallow</u> convective clouds





- weaker easterlies in the lower troposphere
- suppressed eastward and enhanced westward propagation of precipitation
- positive anomalies of vertical wind in the lower troposphere – shallow convective clouds;
  positive anomalies in the middle troposphere during afternoon and evening – stratiform clouds



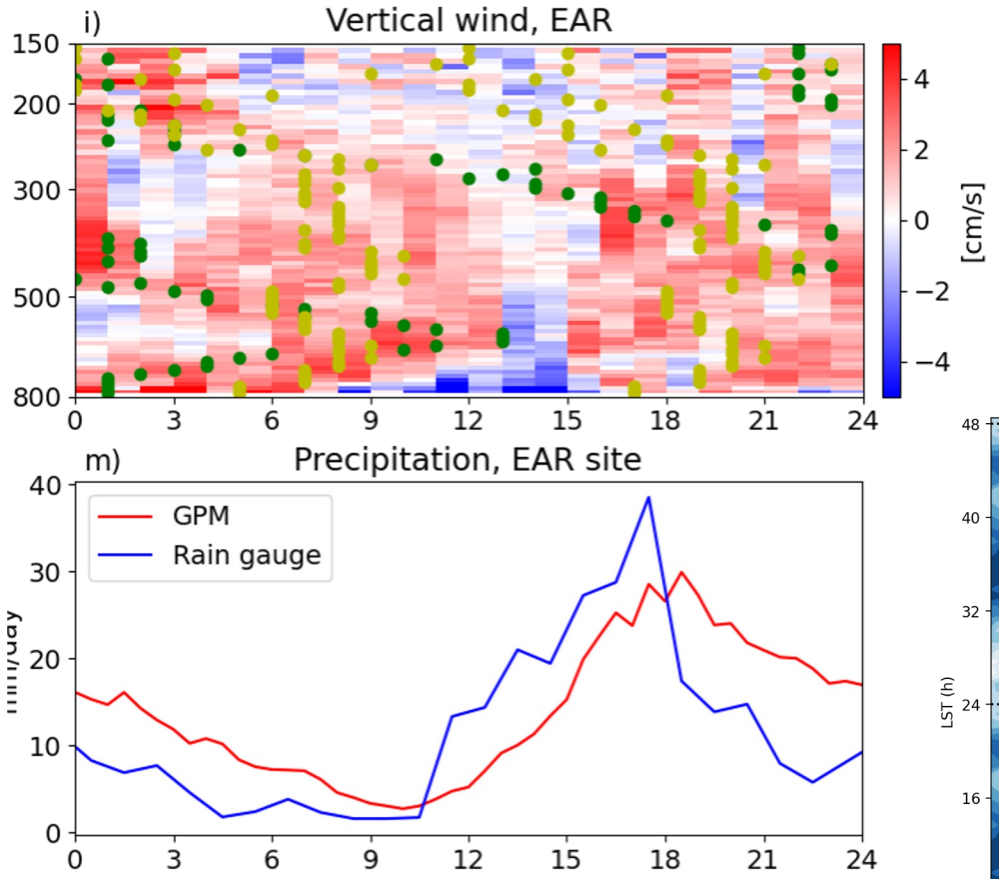


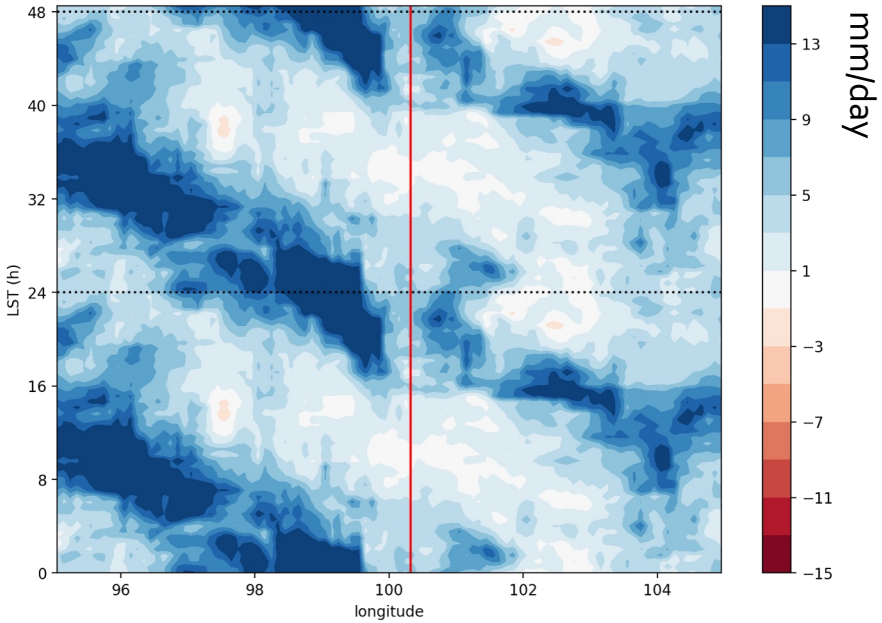
MJO phase 3

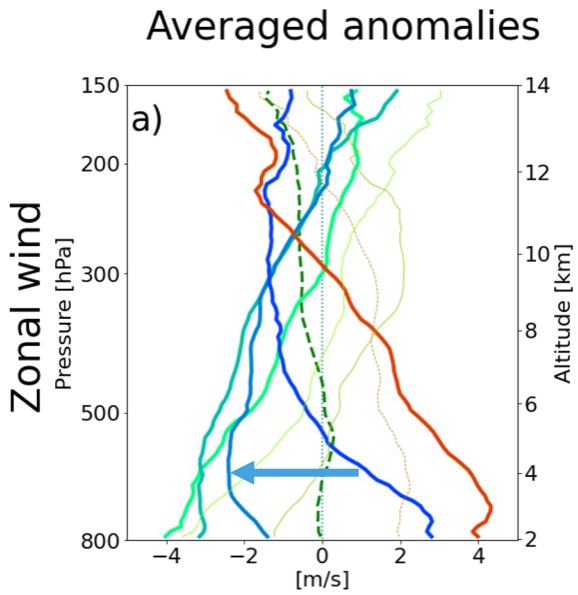
Hypothesis:

- **MJO 3**: increased amount of <u>startiform and deep convective clouds</u>

- weaker easterlies in the lower troposphere
- suppressed eastward and enhanced westward propagation of precipitation
- significant positive anomalies of vertical wind in the middle troposphere throuought the day – deep convective and stratifom clouds







Summary

EAR observations of horizontal winds agree with ERA-5 reanalysis, but vertical wind observation differ with ERA-5 representation

Mean diurnal evolution of horizontal winds has characteristics of thermal tides

Diurnal variability of vertical wind is accociated with evolution of clouds and precipitation

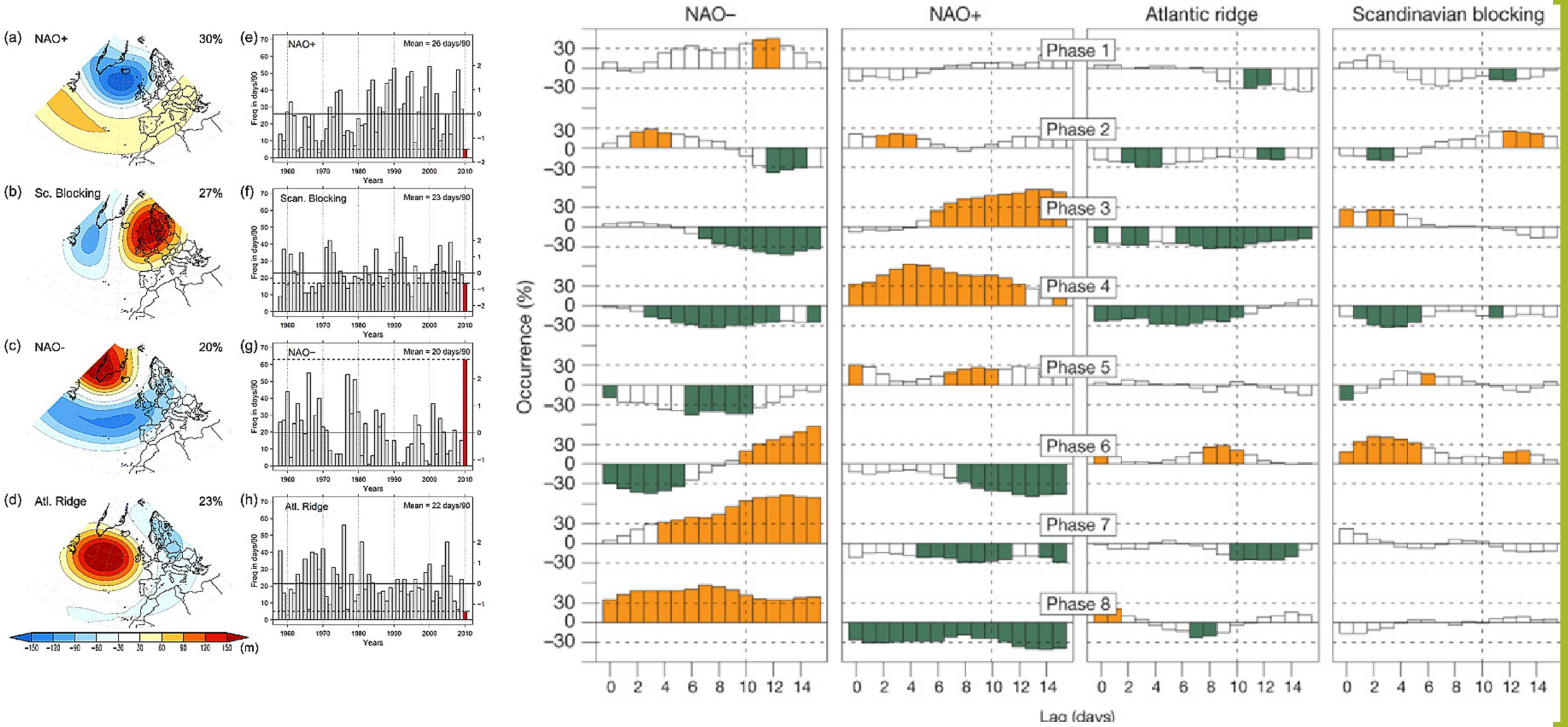
Variations of zonal wind in the lower troposphere correlate with the propagation of precipitation around Sumatra mountains

stronger westerlies – enhanced inland and suppresed offshore propagation

weaker westerlies – suppressed inland and enhanced offshore propagation

THANK YOU

Don’t hesitate to ask questions


(a) NAO+ 30%
(b) Sc. Blocking 27%
(c) NAO- 20%
(d) Atl. Ridge 23%
−150 −120 −90 −60 −30 30 60 90 120 150 (m)
(e) NAO+ Mean = 26 days/90
(f) Scan. Blocking Mean = 23 days/90
(g) NAO− Mean = 20 days/90
(h) Atl. Ridge Mean = 22 days/90
Freq in days/90
Years
NAO−
NAO+
Atlantic ridge
Scandinavian blocking
Phase 1
Phase 2
Phase 3
Phase 4
Phase 5
Phase 6
Phase 7
Phase 8
Occurrence (%)
Lag (days)