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Multiscale climate processes of ENSO Monsoon over the Maritime Continent of Southeast Asia

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Multi-Scale Climate Processes of ENSO, Monsoon and Diurnal Cycle in Rainfall variability over the Maritime Continent of Southeast Asia

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Outline

- **Maritime Continent climate: Why precipitation is concentrated over islands**

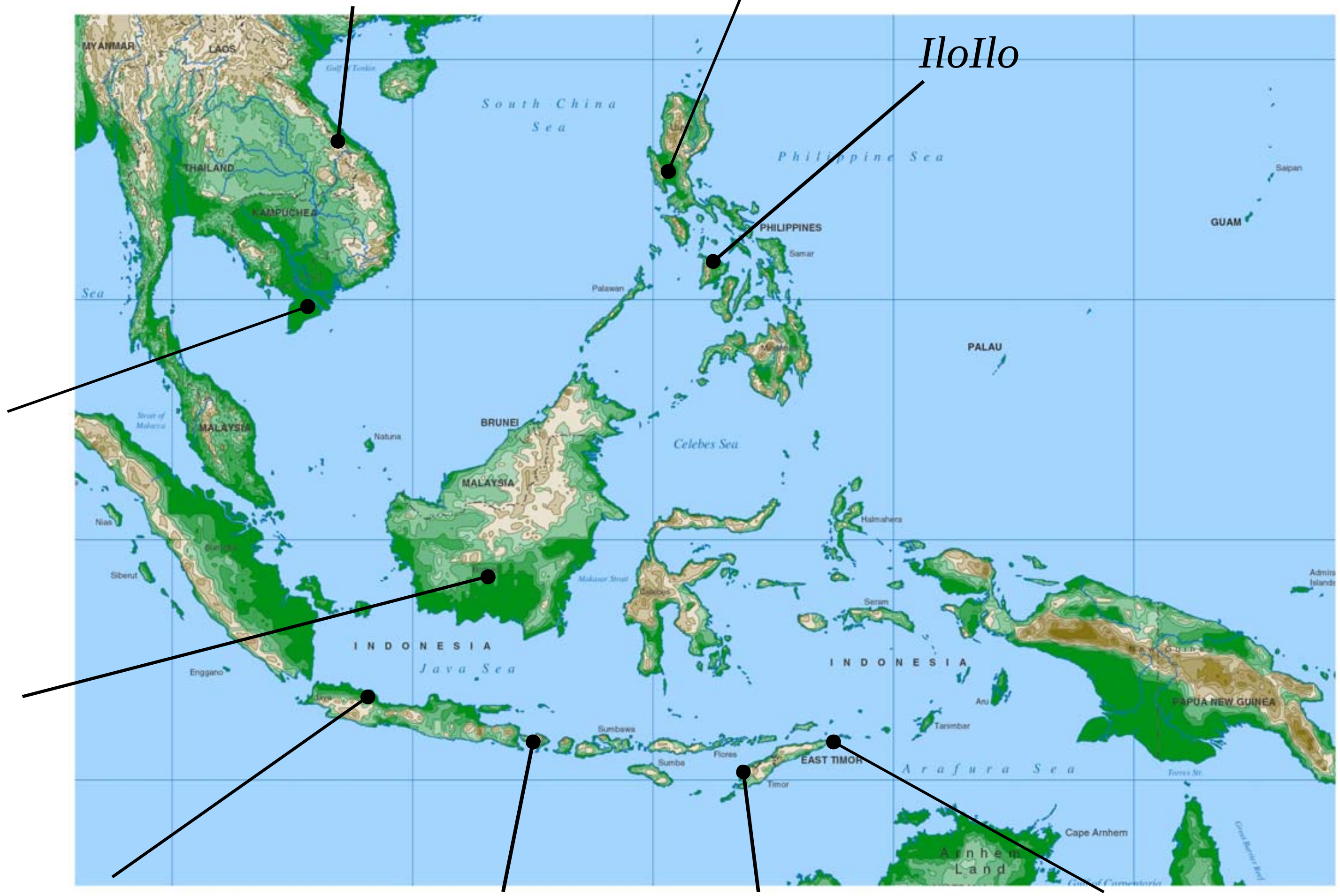
- **ENSO related dipolar patterns of precipitation anomalies over Java Island and Borneo Island – Multi-scale interactions between ENSO, monsoon and the diurnal cycle of land-sea breezes and mountain-valley winds.**

- **Implications for climate change at the regional scale.**

Climate risk management: Demonstration sites in SE Asia

Diversity of climate hazards + socio-economic systems

Multi-scale partnerships



ENSO Impacts

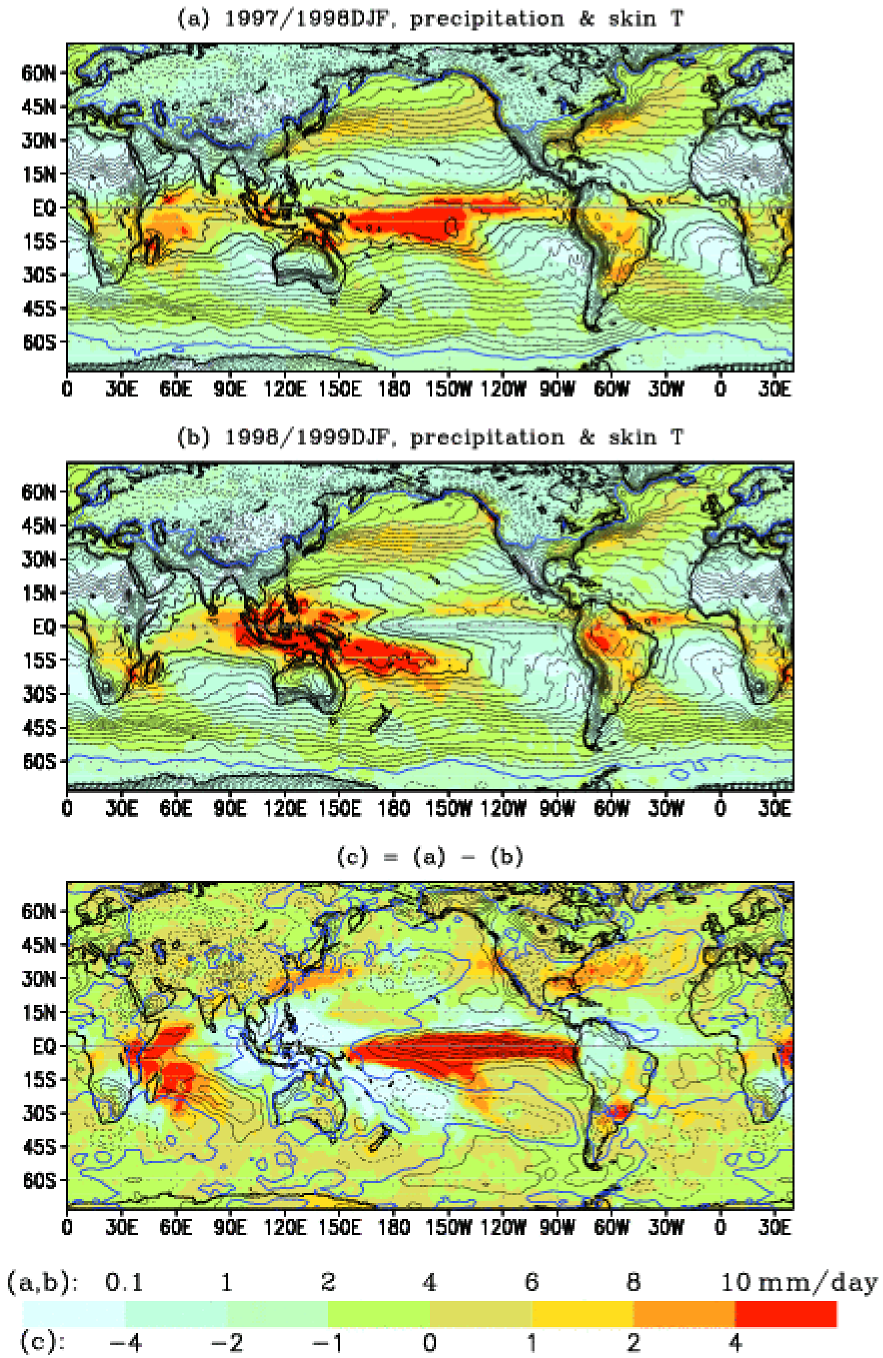
Observed global precipitation and surface temperature in boreal winter
(CMAP & NNRP)

(a) El Nino year, 97/98DJF

(b) La Nina year, 98/99DJF

© Inter-annual Variation

Map shows that precipitation (shading) is affected by SST (Sea Surface Temperature)



Multi-scale processes
(spatially and temporally)

ENSO

Monsoon

Diurnal Cycle

1. Why precipitation is concentrated over islands in the Maritime Continent?

CMORPH satellite observation (.25 x .25 degree): Rainfall is mostly concentrated over the islands in the Maritime Continent. Why?

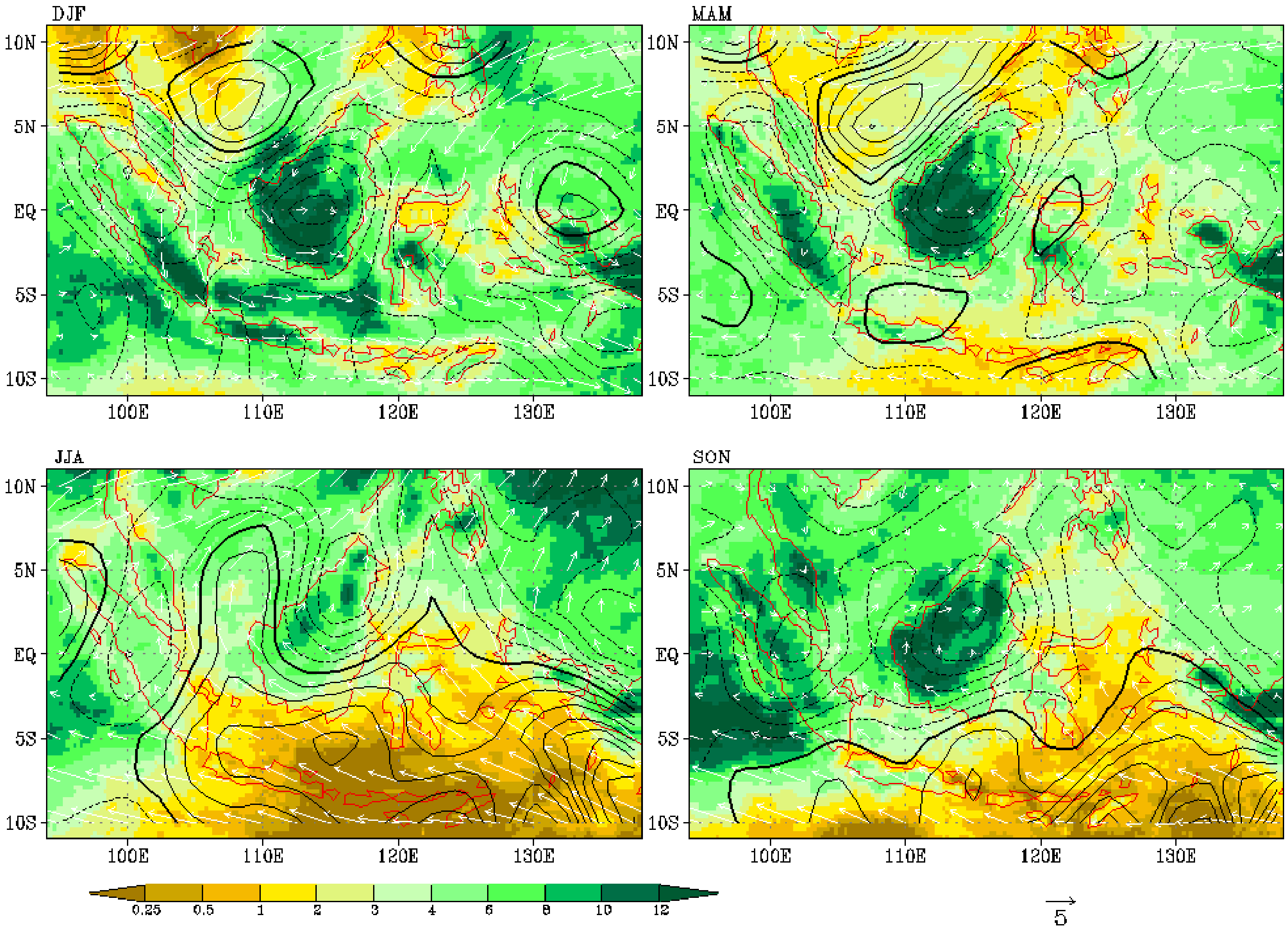


Fig.2 The averaged (2003–2005) CMORPH seasonal precipitation (mm/day, shaded), and the climatology (1971–2000) of the NNRP horizontal winds (vector) and divergence (contour) at 925 hPa in the Maritime Continent.

Satellite observation: diurnal cycle of 3-hourly rain rate

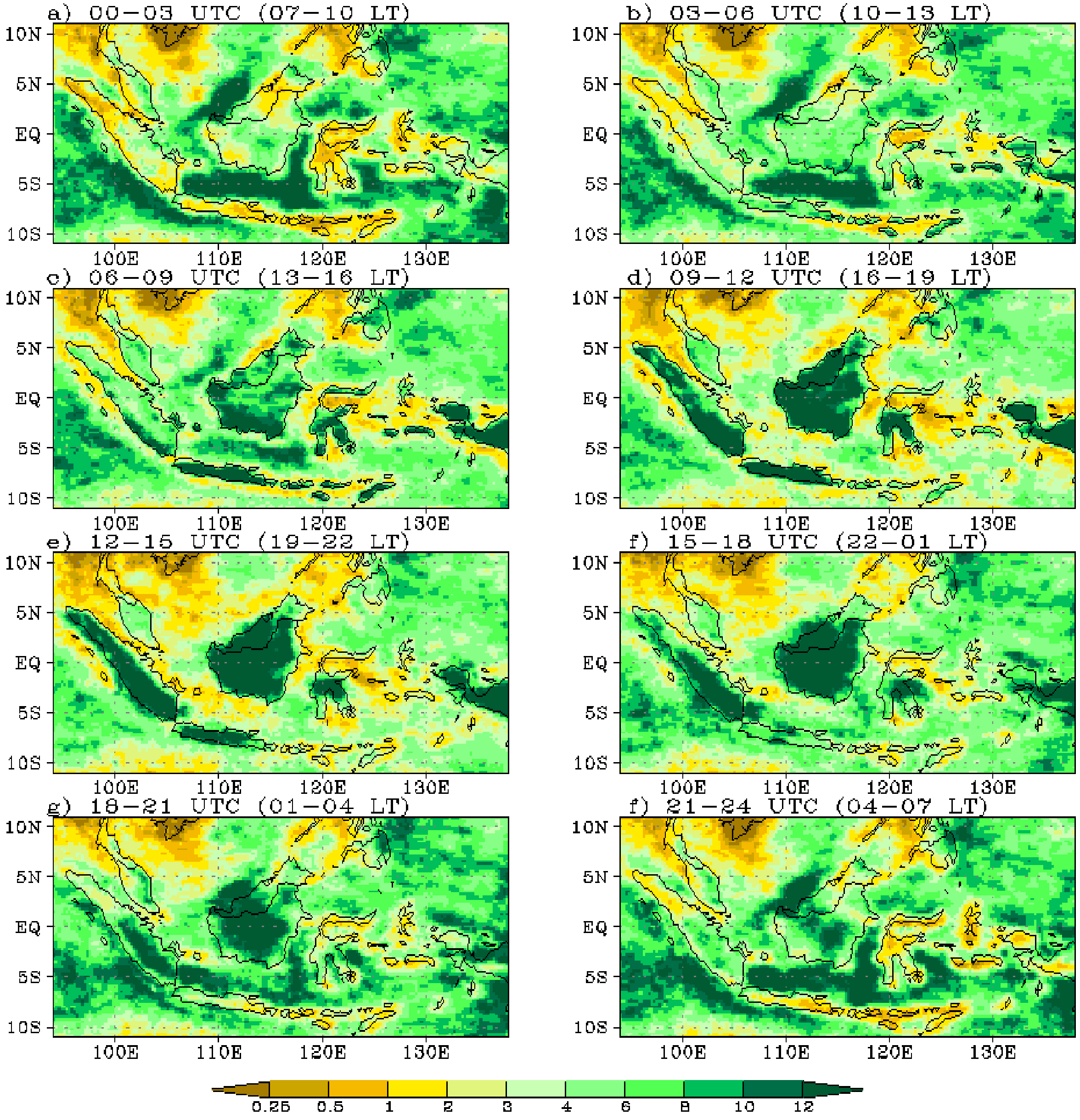
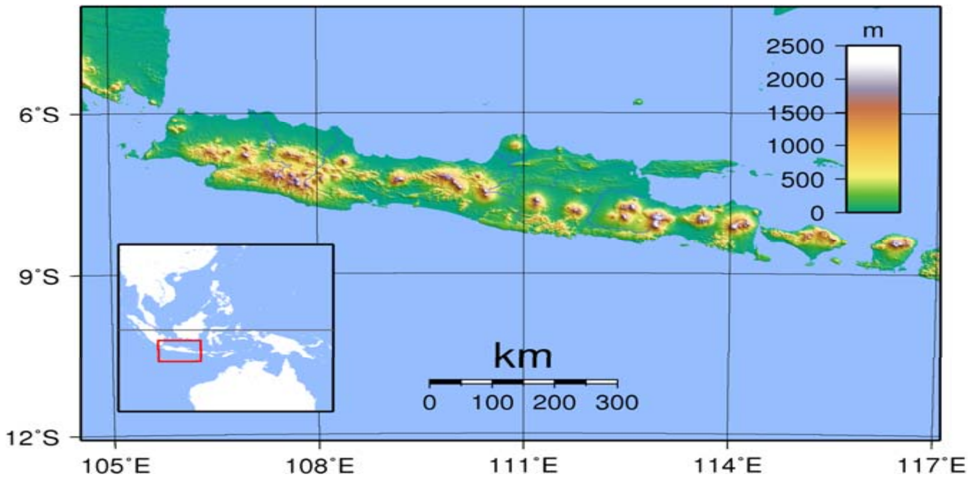


Fig.3 Diurnal cycle of CMORPH precipitation (mm/day) in DJF in the Maritime Continent.
The local standard time is denoted by LT, which is seven hours ahead of the UTC.

Java

Indonesia

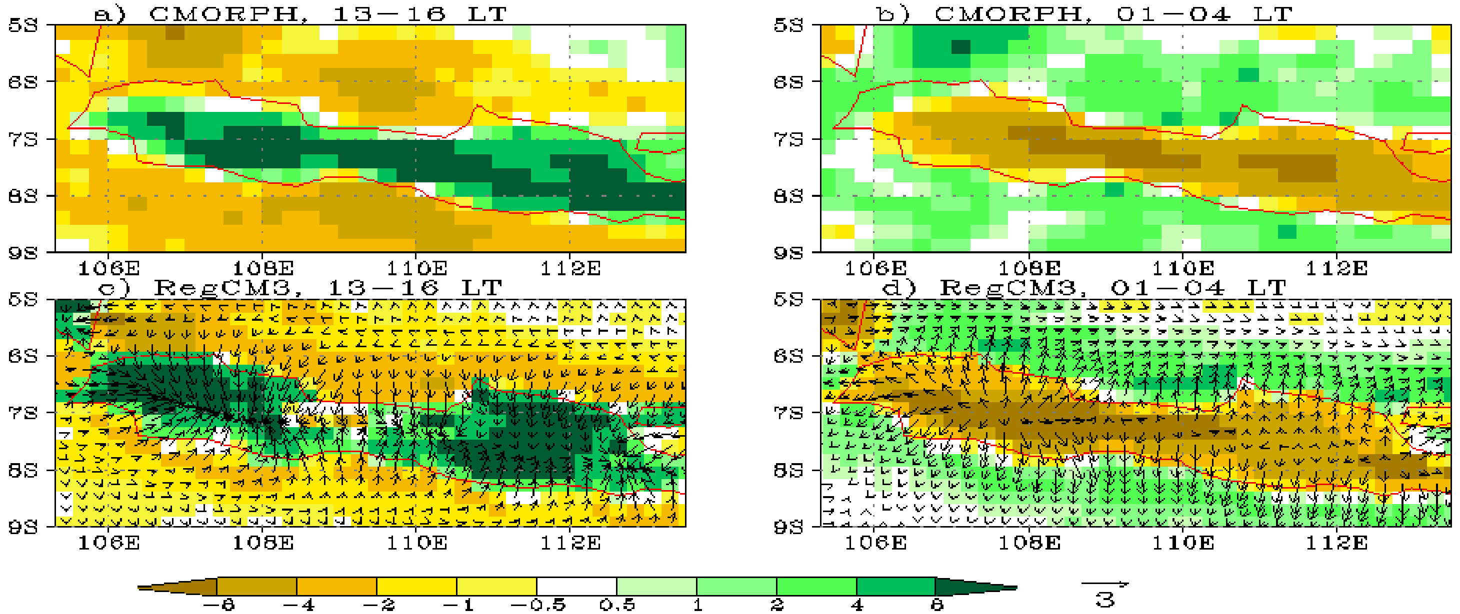


Sea breezes (pm)

Land breezes (am)

Observ.

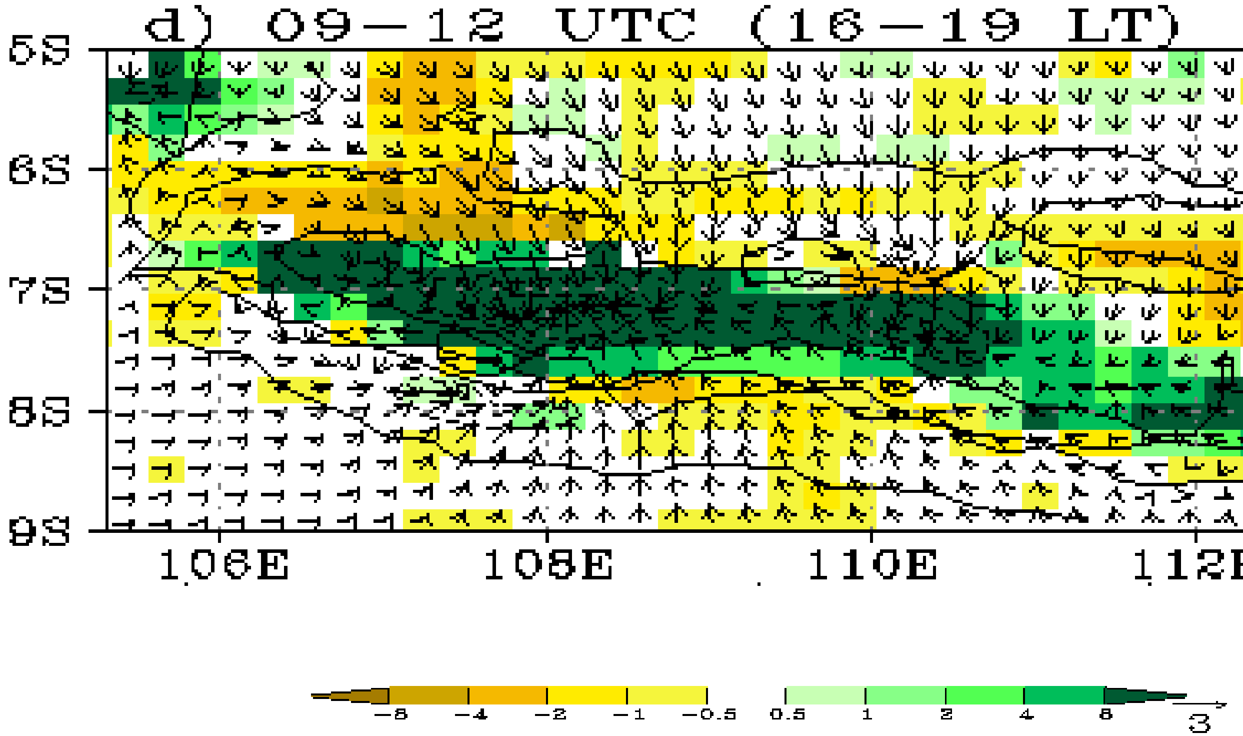
RegCM3



Diurnal cycle of rainfall over Java Indonesia associated with land−sea breezes, shown by the CMORPH satellite estimated rainfall in day (a) and night (b), and the RegCM3 regional climate model simulated rainfall (mm/day, shaded) and surface winds (m/s, vector) in day (c) and night (d), in the wet season of December to February. "LT" denotes local standard time in Jakarta, Indonesia. Daily means are substracted to highlight diurnal cycles. Coastlines are red.

Effect of **mountain-valley breezes** on the diurnal cycle of rainfall over Java

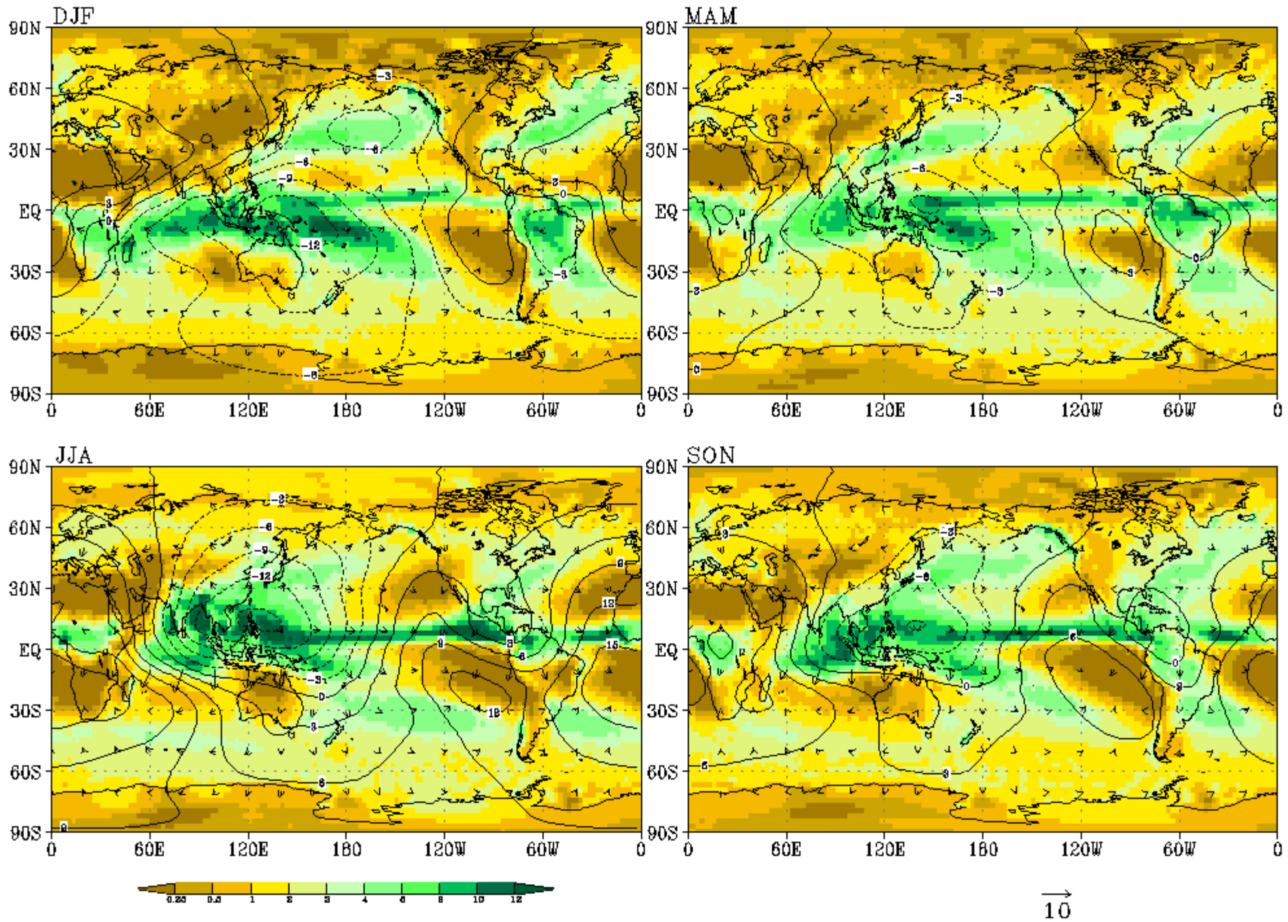
(RegCM3 control run – flat island run)



GCM Implication

Observed global precipitation & 200hPa velocity potential

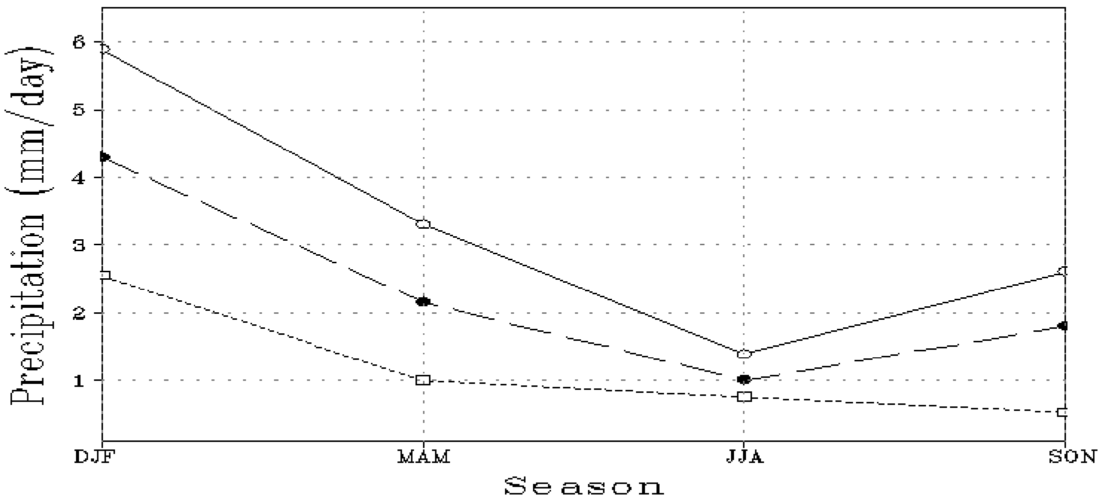
The eastern Indian/western Pacific warm pool and the Maritime Continent is the largest rainy region over the world – a "**boiler box**" for large-scale atmospheric circulation



Climatology (1982–2002) of CMAP Seasonal Precipitation (mm/day; shaded), and NNRP Velocity Potential (contour,1e6) and Divergent Wind (vector) at 200hPa

Global Implication

Regional model results: Underestimation of terrain and islands results in underestimation of precipitation



solid: island with mountain

long dash: flat island

Short dash: no island

Question: What if islands and terrain in SE Asia are under-represented in GCMs?

Systematic Errors: Under-representation of topography in coarse-grid global models systematically under-estimates rainfall in the Maritime Continent and then causes errors in the atmospheric general circulation

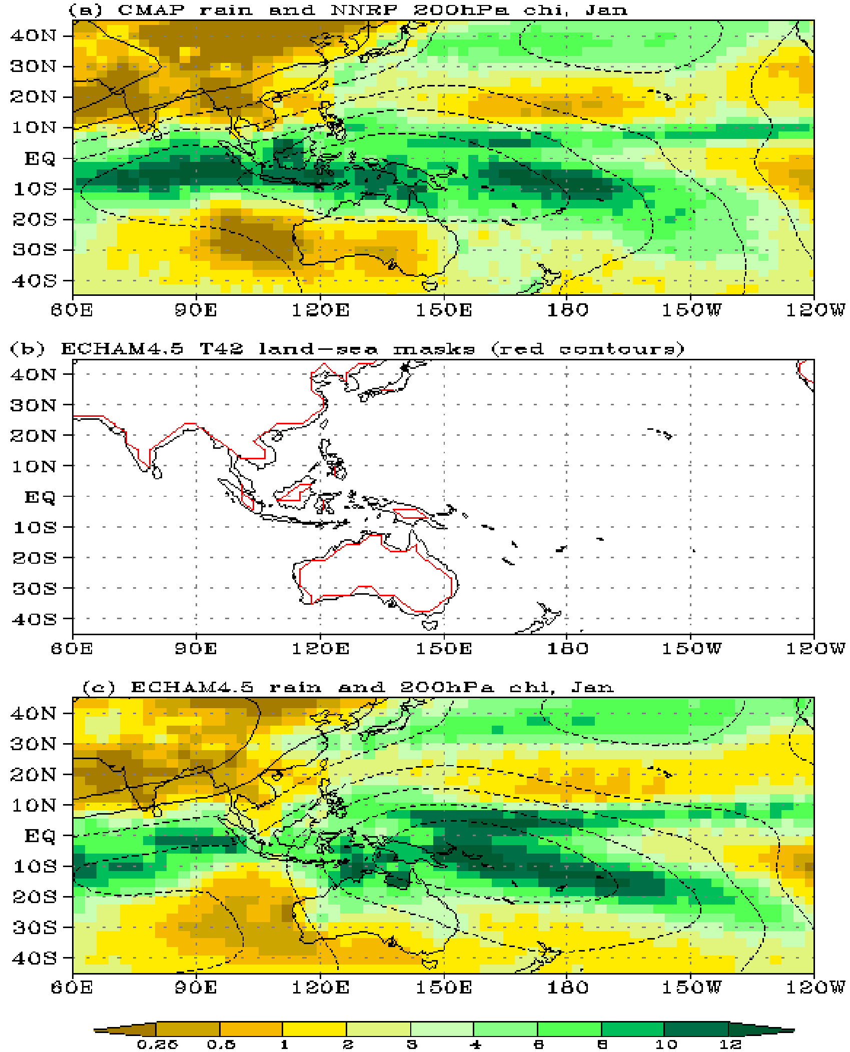


Fig.10 (a) Climatology (1982–2002) of the observed CMAP monthly precipitation (mm/day, shaded), and the NNRP 200hPa velocity potential (contour, interval 1e6) in January. (b) Land–sea masks in ECHAM4.5 T42 model (red contours). (c) Climatology (1982–2002) of the simulated ECHAM4.5 precipitation (mm/day, shaded), and the 200hPa velocity potential (contour).

Summary I

Rainfall is concentrated over islands

because of

(a) Sea breeze convergence

(b) Mountain-valley breeze, and

(c) cumulus merger in the sea breeze convergence zone

That also explains why more rainfall is over mountainous regions.

Implications

(Qian 2008, J. Atmos. Sci.)

2. Multi-scale Interaction

- A local dipolar structure of precipitation anomaly over Java associated with El Nino

Large scale climatology and ENSO impact on rainfall

ITCZ in the north in SON
ITCZ over Java in DJF

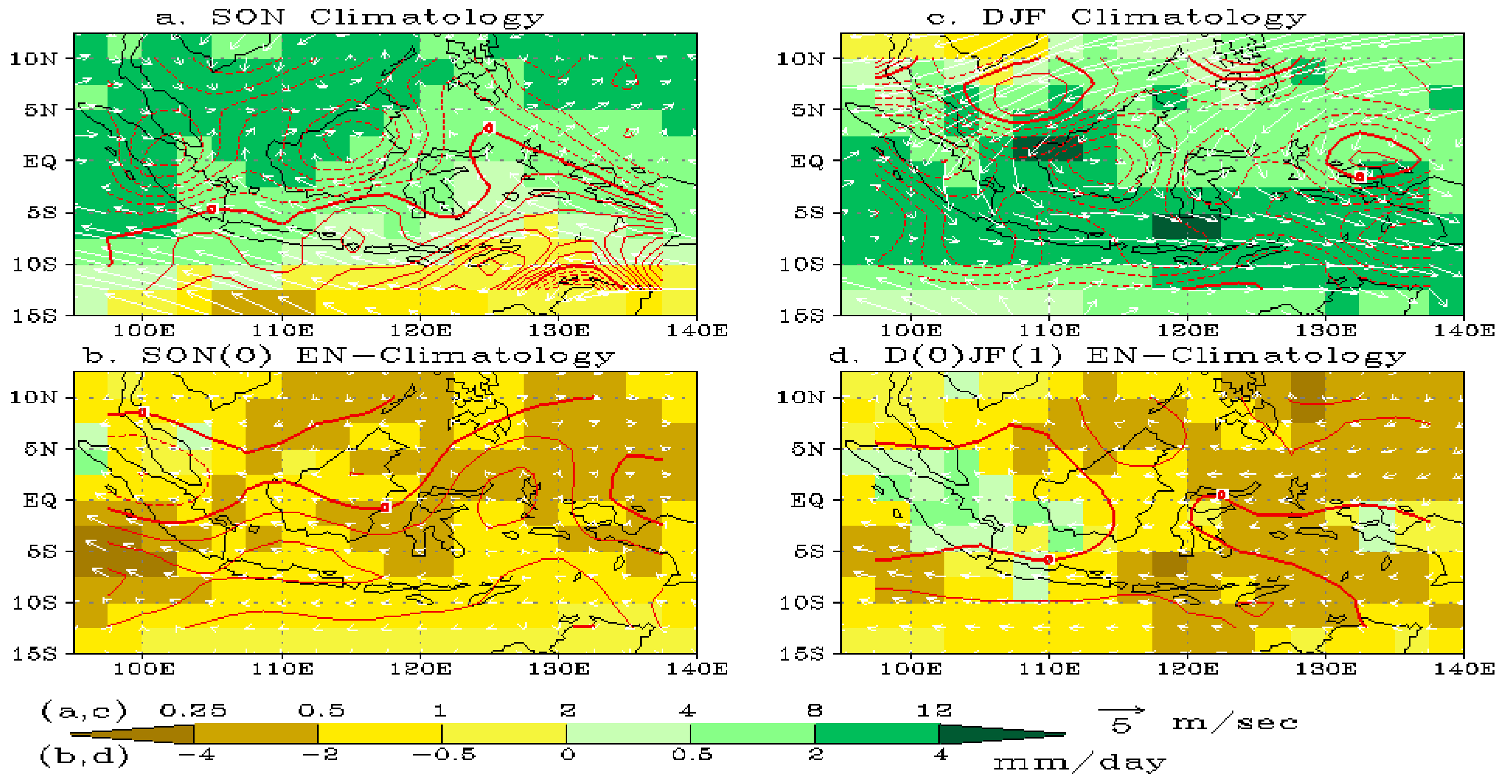


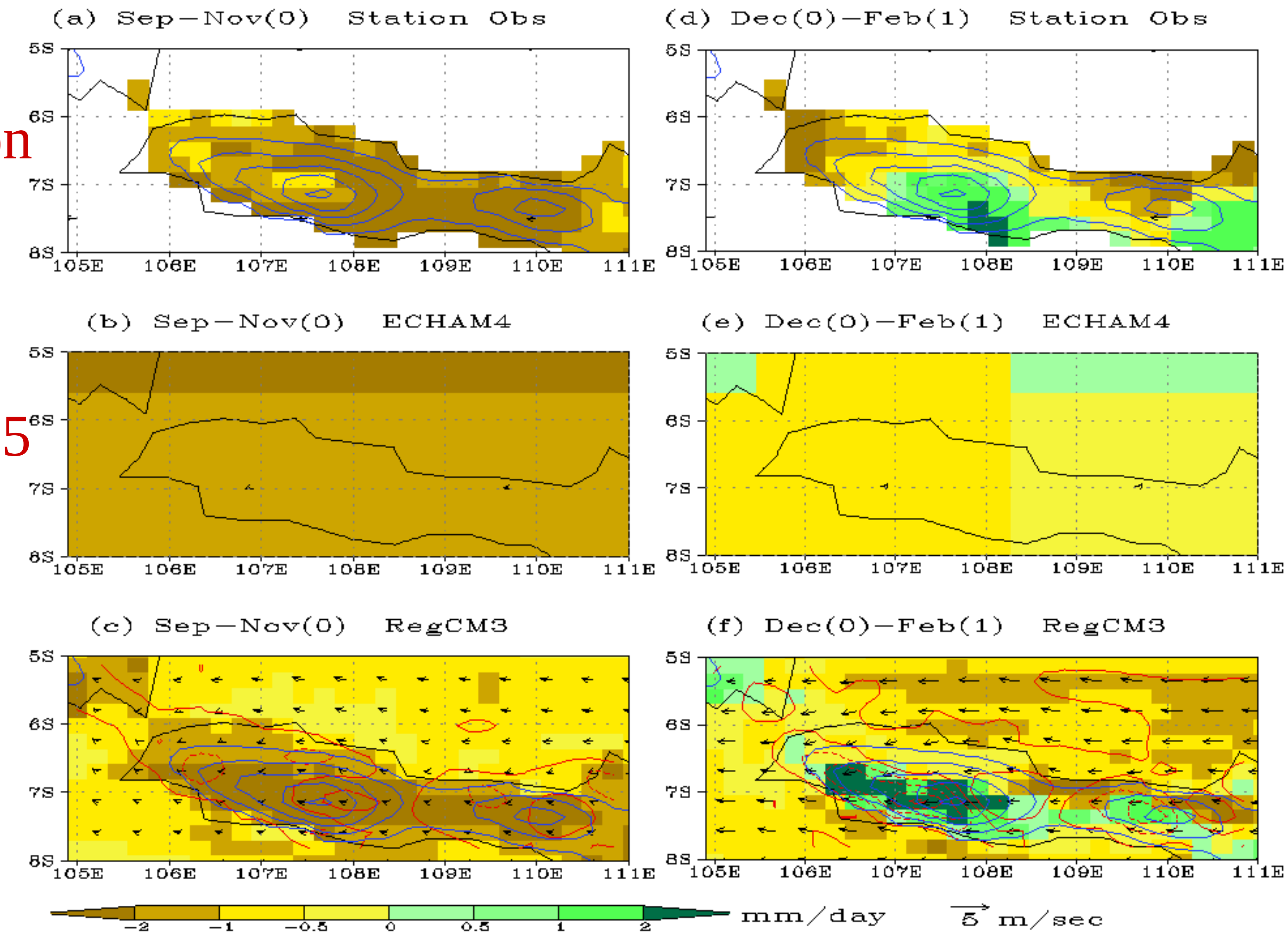
Fig.1 Climatology (1979–2000) and (El Nino – climatology) composite of CMAP precipitation (mm/day; shaded), and NNRP winds (vector) and divergence (red contours with interval of 0.5e–6/sec, divergence is thin solid, convergence thin dash, zero–curves thick solid) at 925hPa, for SON (a, b), and DJF (c, d). El Nino years used for the composite are: 82/83, 86/87, 87/88, 91/92, 94/95, 97/98. El Nino developing years are denoted by (0).

In SON (left), spatially coherent dry anomaly in El Nino years.
In DJF (right), dipolar pattern of El Nino impact: dry anomaly on north coast, but wet anomaly on south coast.

Observation

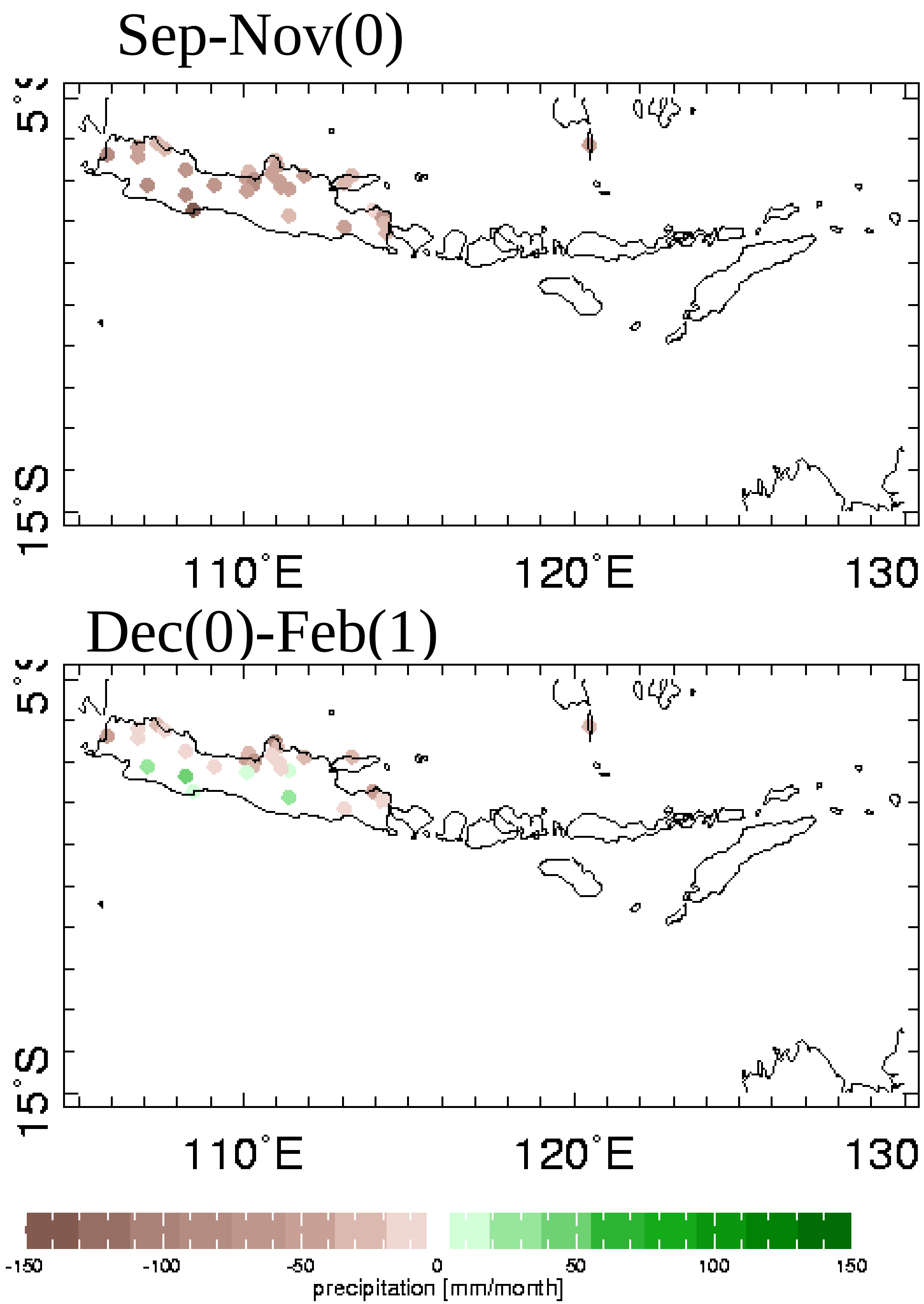
ECHAM4.5 GCM

RegCM3



(El Nino – Climatology) composite of seasonal precipitation (mm/day; shaded), low–level winds (m/s, vector) and divergence (red contour interval is 1e–5 in c&f). Top panels: observation, middle: ECHAM4, bottom: RegCM3. Terrain heights are shown by blue contours (interval 200 m) El Nino years: 72/73, 82/83, 86/87, 91/92, 94/95, 97/98; Java Indonesia

INTERNATIONAL RESEARCH INSTITUTE

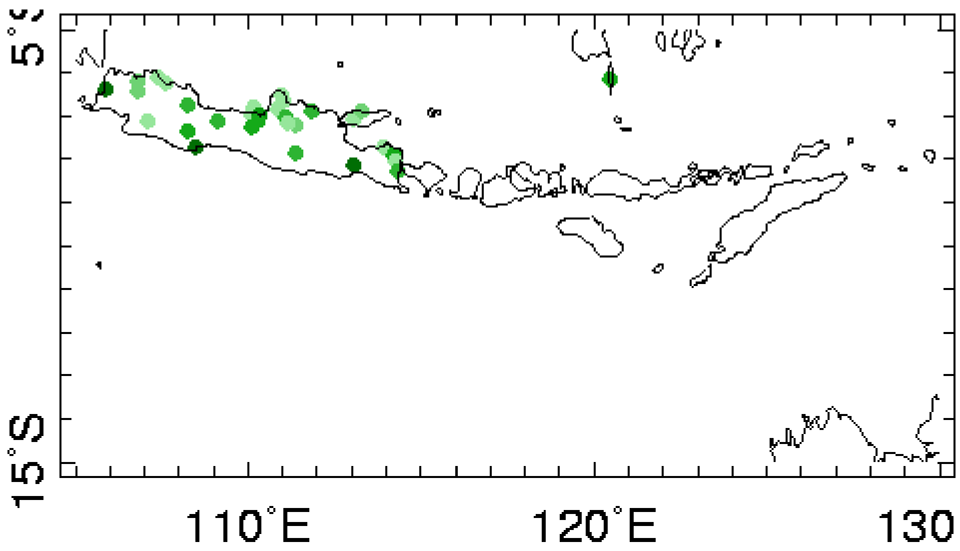


STATION OBSERVATION:

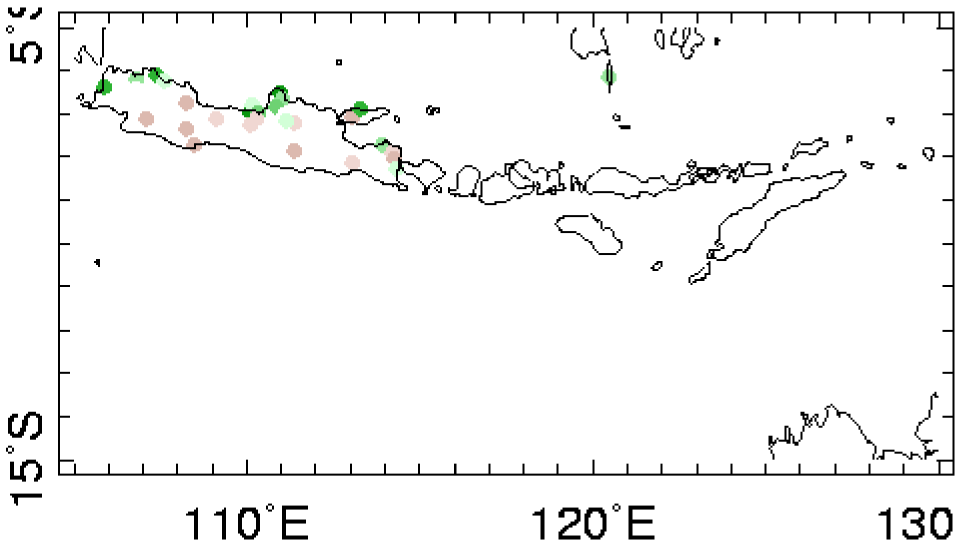
In SON, spatially coherent dry anomaly in El Nino years.

In DJF, dipolar pattern of El Nino impact: with dry anomaly on north coast, but wet anomaly on south coast.

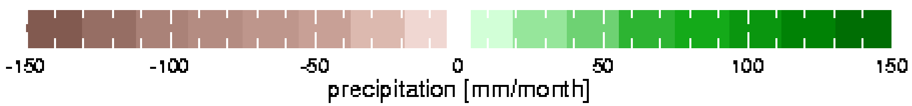
El Nino year
Station Precipitation Anomaly
(EN-Climatology Composite)



Sep-Nov(0)



Dec(0)-Feb(1)



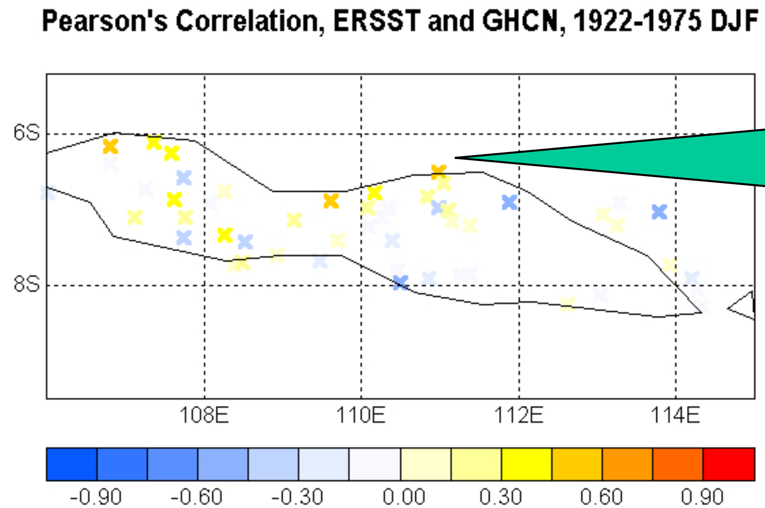
La Nina year

Station Precipitation Anomaly

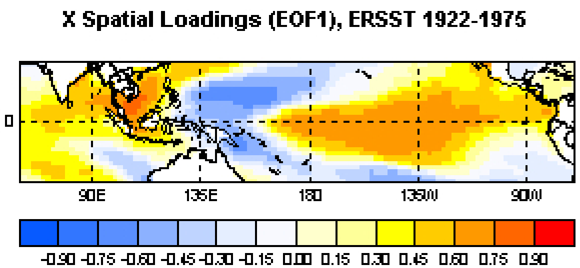
(LN-Climatology Composite)

Canonical Correlation Analysis, CCA (ERSST & GHCN rainfall)

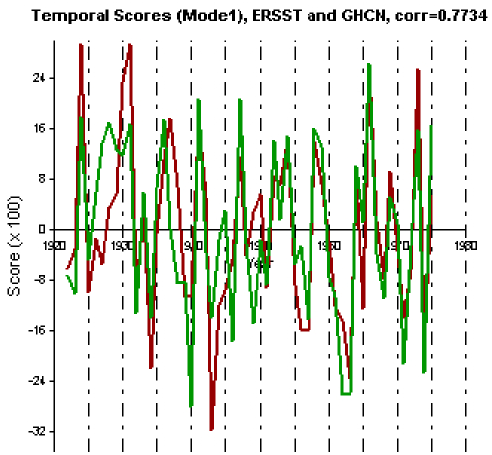
1922-1975 Dec-Feb (DJF)

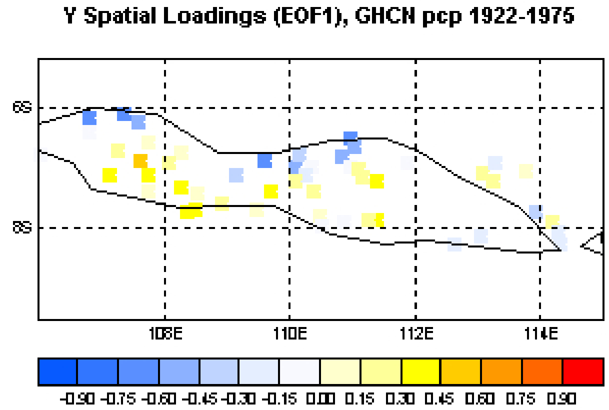


Low predictability in DJF, but slightly enhanced predictability at north coast



SST ENSO pattern





Java rainfall dipolar pattern

Inverse relationship *between monsoonal wind speed and diurnal cycle*

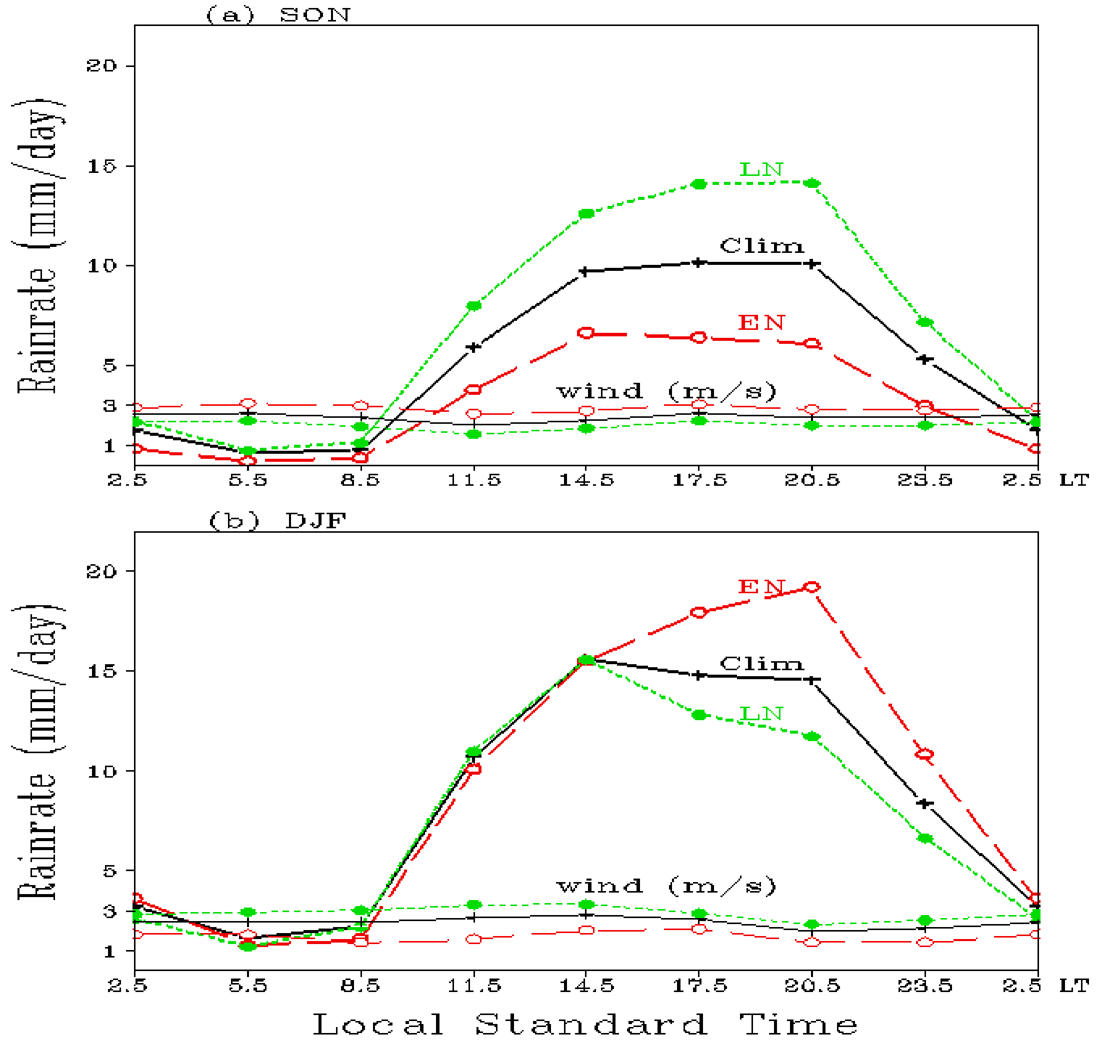


Fig.7 Diurnal cycles of RegCM3 rainfall (mm/day, thick) and wind speed (thin, m/s) over the whole area of Java Island in SON (a) and DJF (b) for climatology (black), El Nino year composite (red long dash), and La Nina year composite (green short dash). "LT" denotes the local standard time at Jakarta. Wind speeds at 10 m are plotted with the same scale, but with unit m/s.

EN wind anomalies & mean winds same direction

EN wind anomalies & mean winds opposite direction

Dry easterly monsoon WT1 & WT2

Strong westerly monsoon WT3

Quiescent monsoon WT4

Strong westerly monsoon WT5

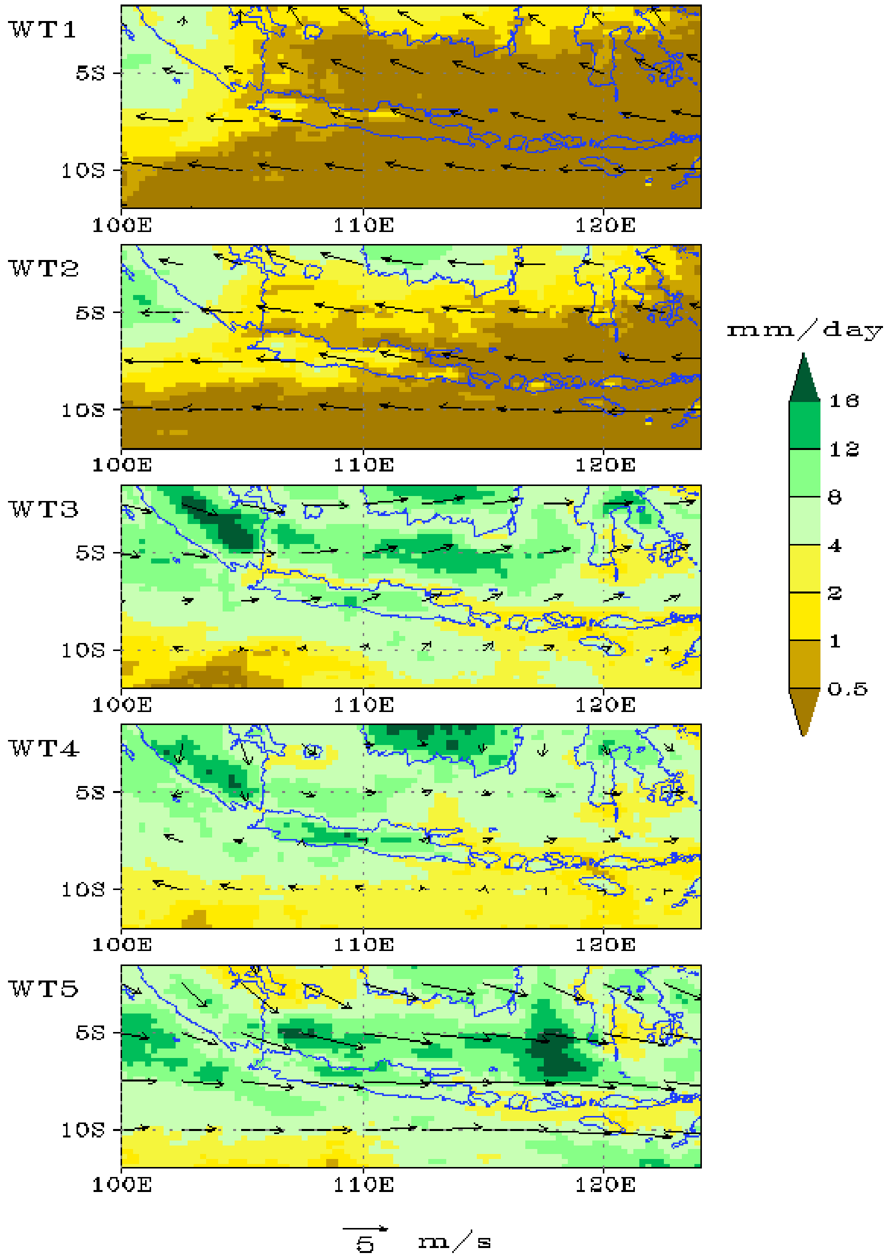


Fig.8 Climatology of CMORPH (2004–2007) precipitation WT1–5 (mm/day; shaded) and NNRP reanalysis winds at 850 hpa (m/s).

Intraseasonal variability:

weather typing analysis

Frequency of Weather Types (%)

Blank bar: Climate, Red bar: El Nino, Green bar: La Nina

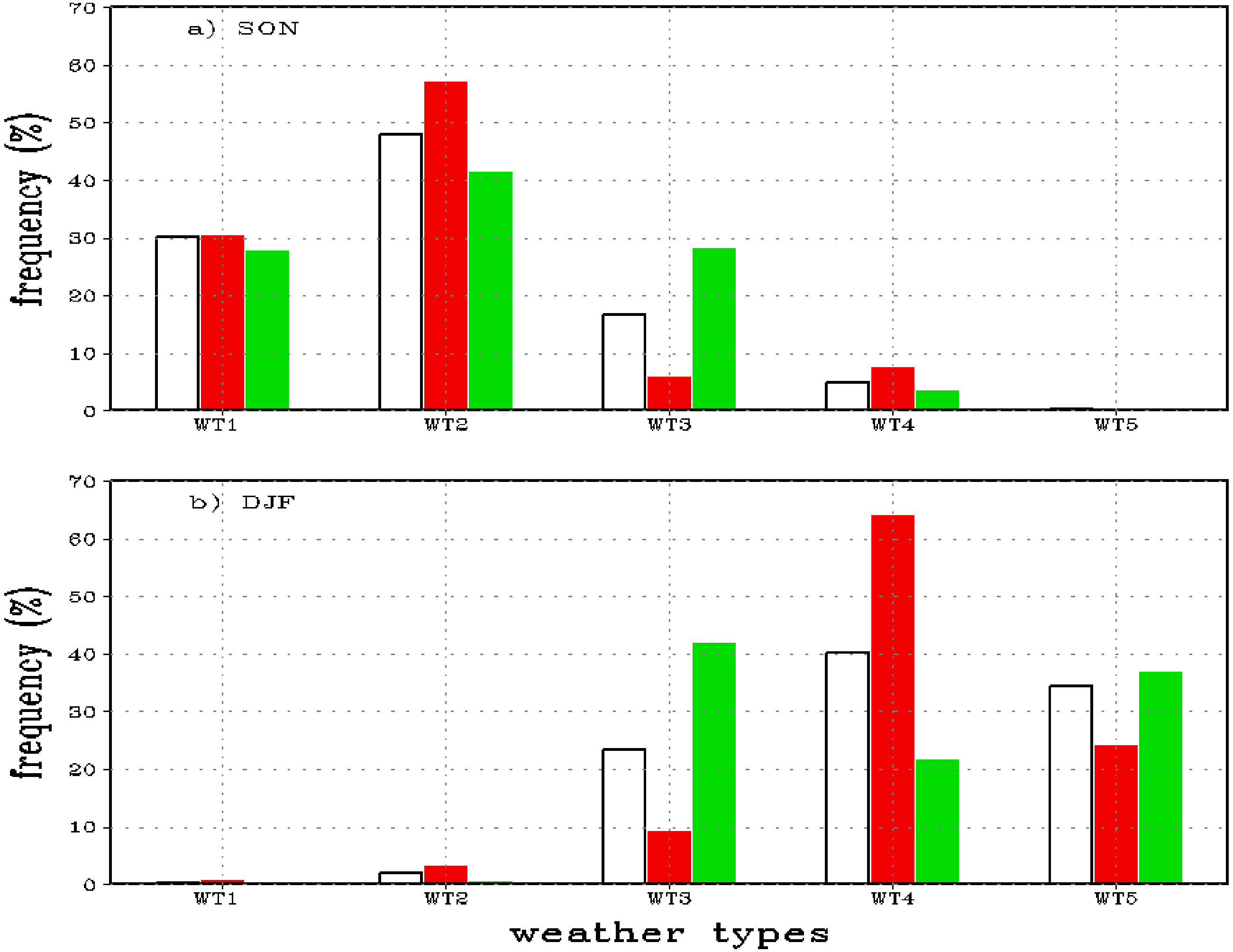


Fig.9 Frequencies of five weather types, WT1 to WT5, in all years (blank left bar), El Nino years (red middle bar), and La Nina years (green right bar) in the SON and DJF season, respectively.

Diurnal cycle of observed and simulated rainfall for the 5 WTs

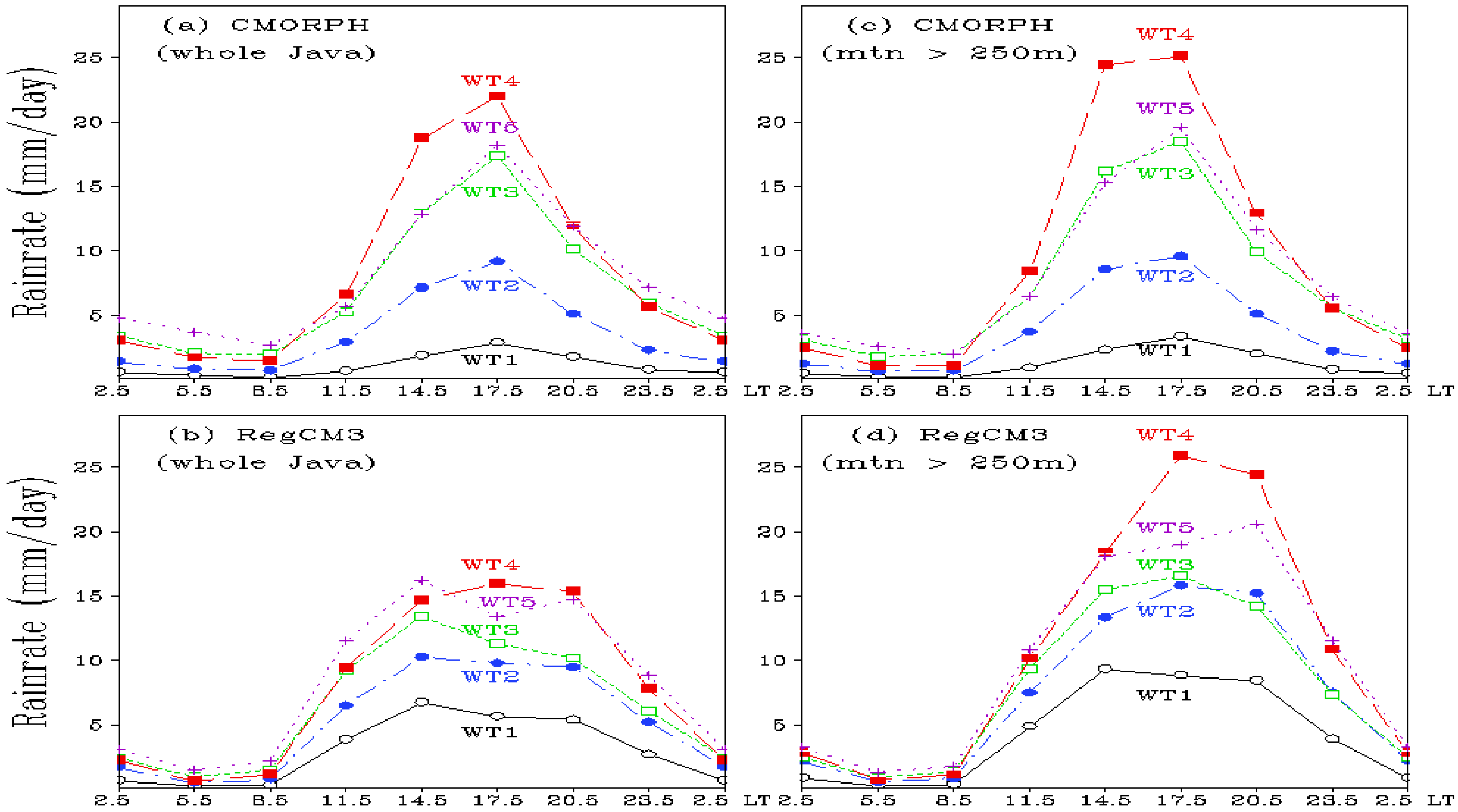


Fig.10 Diurnal cycles of CMORPH and RegCM3 rainfall (mm/day) over the whole area of Java Island (a, b) and over mountainous regions (terrain height > 250m) (c, d) for weather types: WT1 (black), WT2 (blue), WT3 (green), WT4 (red), WT5 (purple). "LT" denotes the local standard time at Jakarta Indonesia.

SUMMARY II

MULTI-SCALE PROCESSES (for Java Dipole):

**El Nino (with southeasterly wind anomalies)
Weaken northwesterly monsoon in DJF**

→ Strengthen diurnal cycle of winds

**→ Strengthen sea-valley-breeze convergence,
Produce more rainfall over mountains and less
rainfall over plains.**

**Key: Inverse relationship between monsoon
intensity and diurnal cycle !!!**

(Qian et al., 2010)

3. Borneo Island Terrain Height (meter)

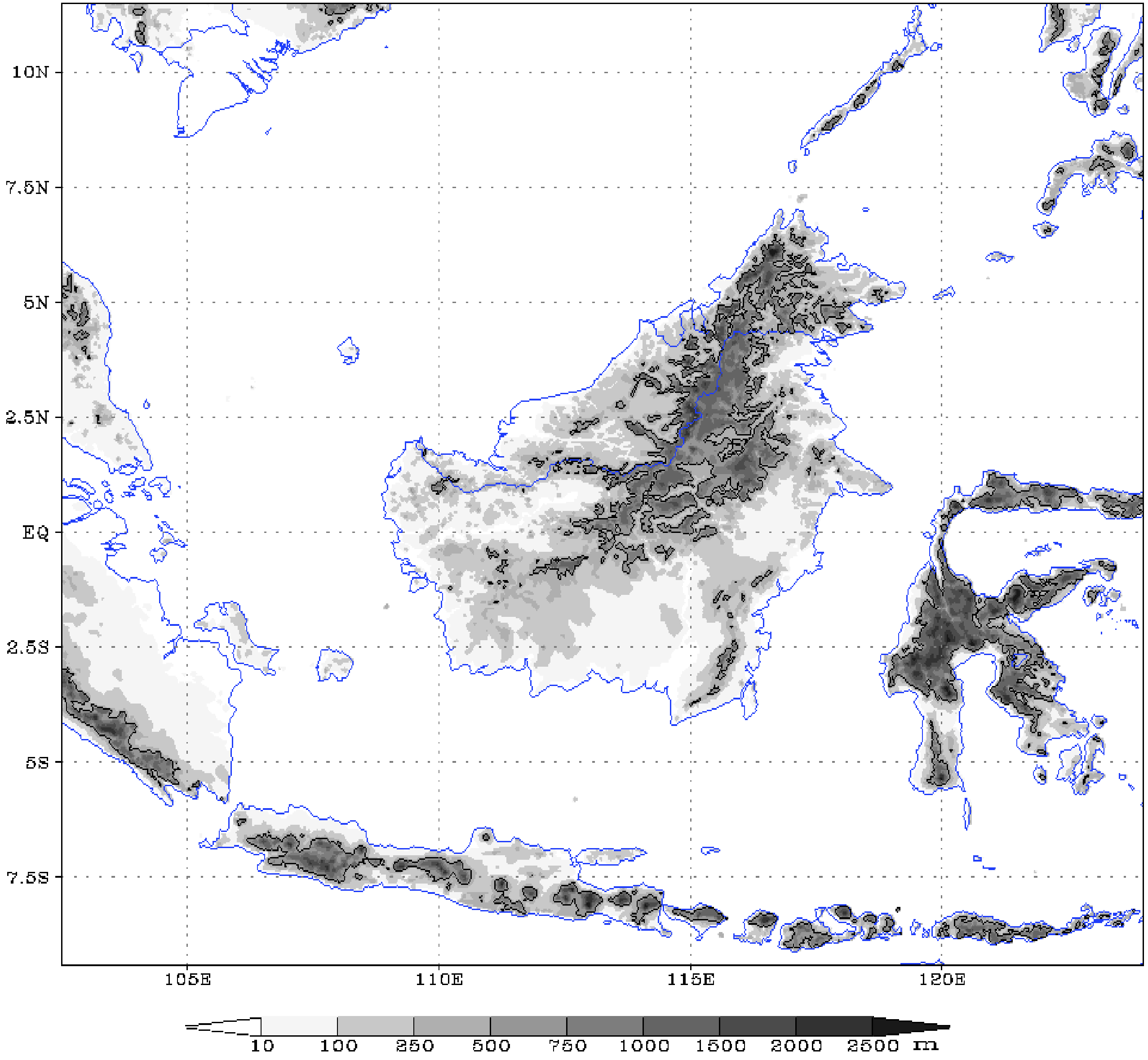


Fig.1 Terrain heights (m) over Borneo Island and surrounding areas based on the USGS observation.

Borneo Dipole

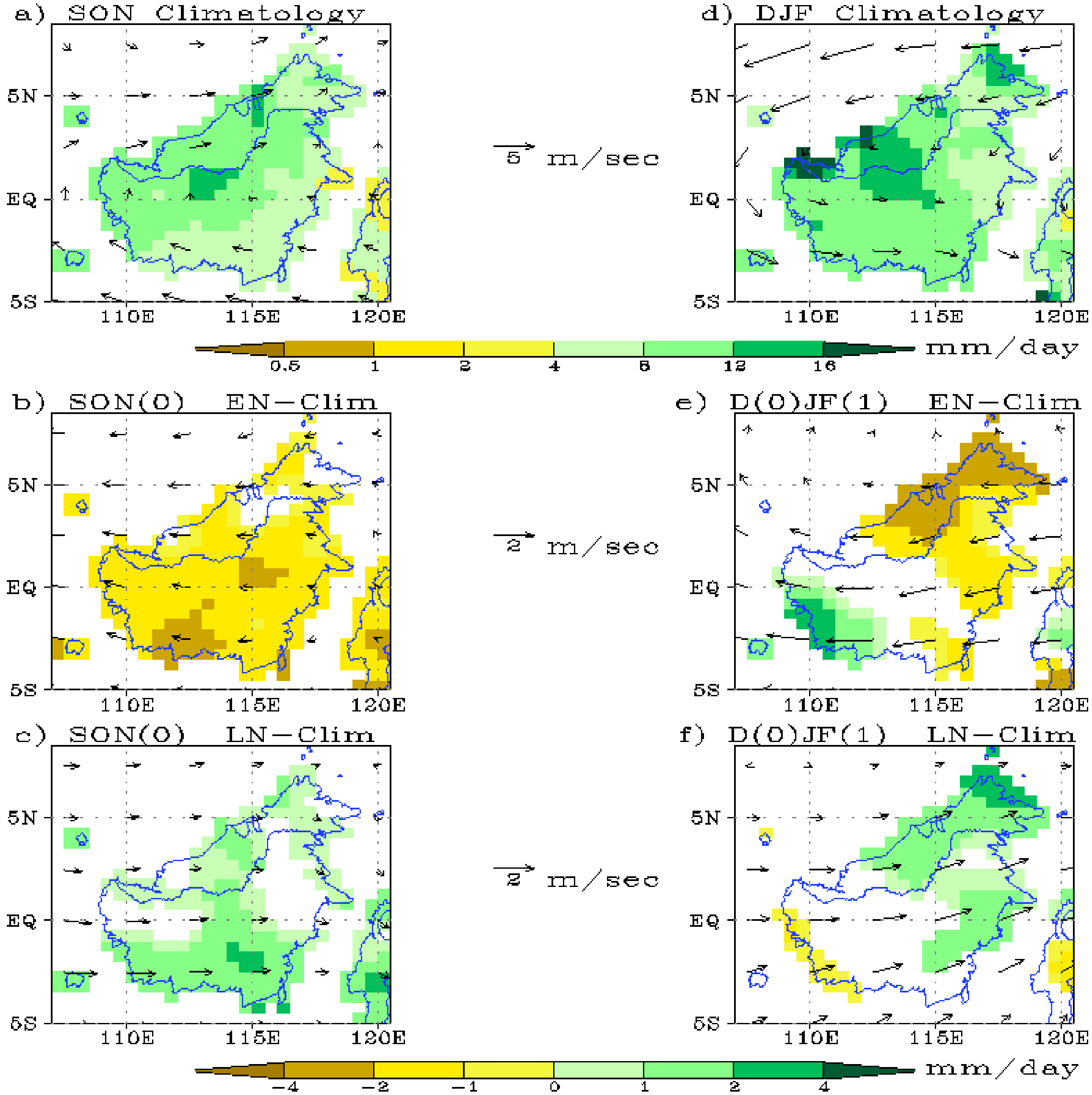


Fig.2 Climatology and (ENSO − climatology) composite of GPCC (1901−2007) precipitation (mm/day; shaded) and NNRP (1979−2005) winds (vector) at 850hPa, for SON (a,b,c), and DJF (d,e,f). ENSO developing years are denoted by (0). Composite of 22 El Nino years are in (b,e). Composite of 25 La Nina years are in (c,f). Differences significant above 90% level of t−test are shown.

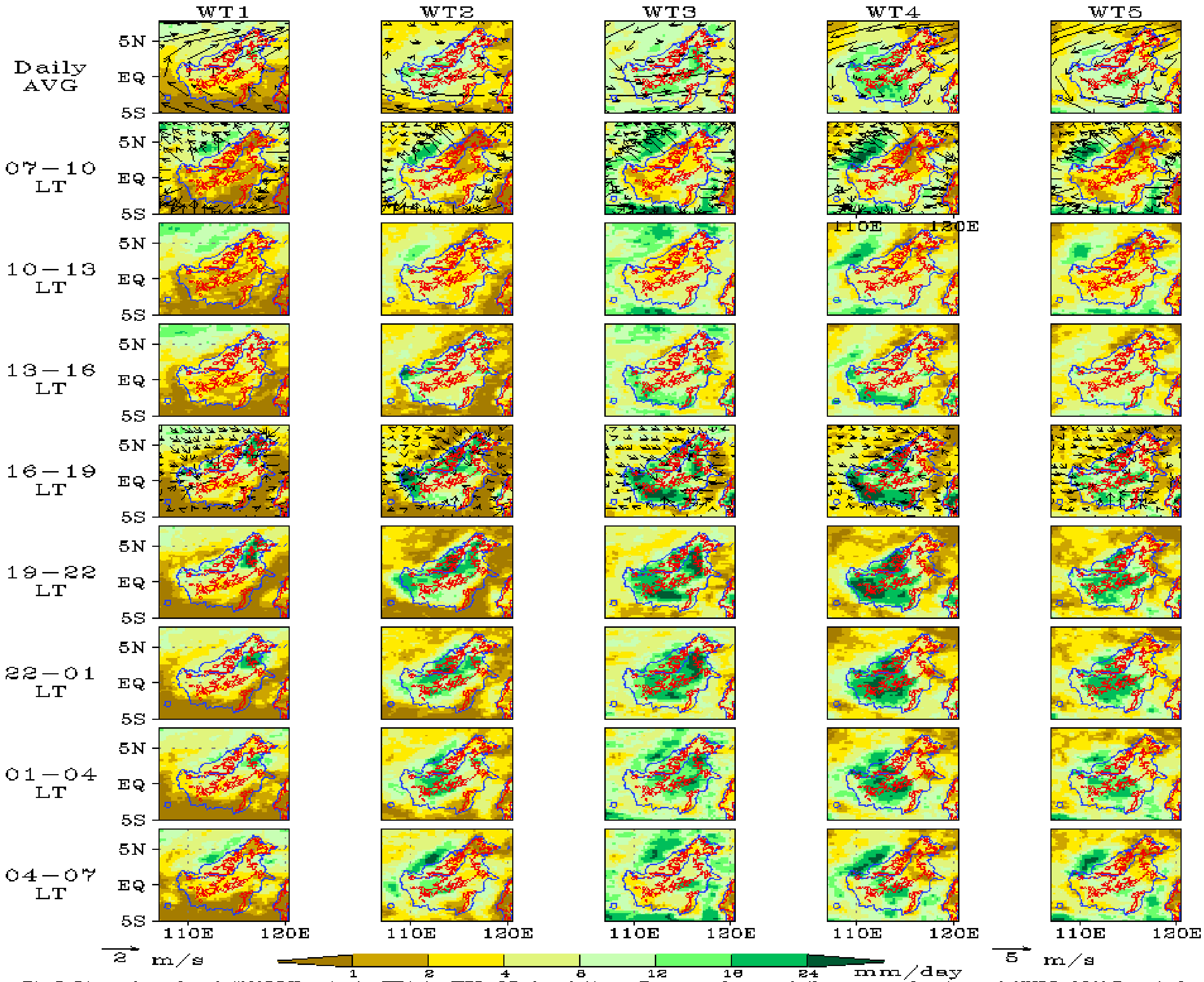


Fig.5 Diurnal cycle of CMORPH rain in WT1 to WT5. LT: local time. Top panels are daily averaged rain and NNRP 850hPa winds. QuickSCAT land–sea breezes are illustrated by the twice daily morning and evening passes in the 07–10LT and 16–19LT panels.

Anomalous rainfall and 850hPa winds for the five weather types (WT 1-5)

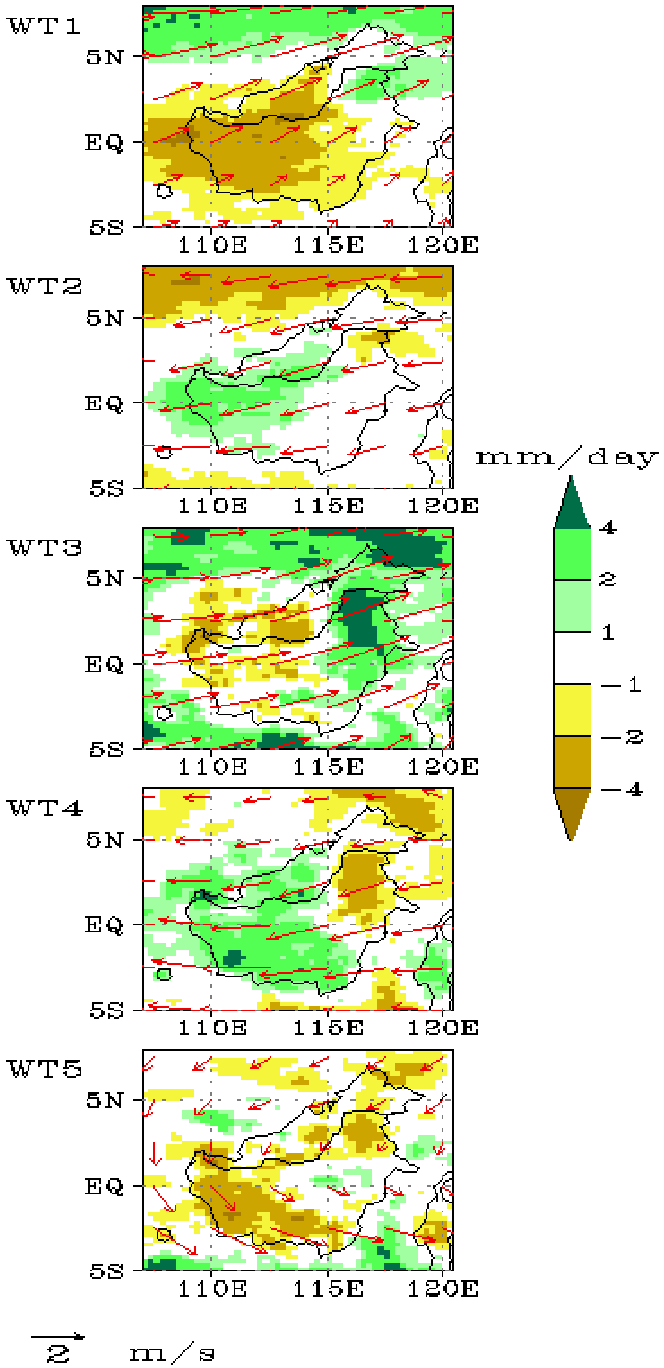


Fig.6 Anomalous CMORPH precipitation (mm/day) and anomalous NNRP 850hPa winds (m/s) for the 5 weather types. WT-frequecy-weighted averaged climatologies have been substracted to show the anomalies for the WTs.

SUMMARY III

MULTI-SCALE PROCESSES (for Borneo Dipole):

El Nino (with southeasterly 850hPa wind anomalies)
Weaker northwesterly monsoon in DJF

→ More frequent quiescent monsoon weather type (WT4) with easterly low-level winds over Borneo

→More days with westward propagation of daily maximum rainfall

→More (less) rainfall over West (East) Borneo in El Nino years

Key: Propagation of daily maximum rainfall down wind !

Conclusion

•Rainfall in the Maritime Continent is found mostly concentrated over islands. This is caused by the diurnal cycle of sea-breeze convergence, reinforced by mountain-valley breezes and cumulus-merger processes.

•Mechanisms for the north-south **Java Dipole** of rainfall variability: ENSO → Monsoon wind speed → Diurnal cycle of winds → Rainfall over mountains versus plains.
Key: Inverse relationship between the monsoonal wind speed and the diurnal cycle of land-sea & mountain-valley breezes.

•Mechanisms for the east-west **Borneo Dipole** of rainfall variability: ENSO → Monsoon wind regime → Diurnal cycle → Propagation of daily maximum rainfall down stream of monsoonal winds.

•*What is next? Climate Change at the regional scale …*

IRI

Climate Change at the Regional Scale

Regional
Climate Change
Over Java
Past & Future?

HYPOTHESIS:

Climate change (more warming over the poles)

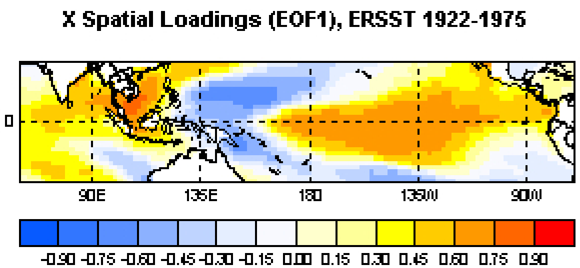
→ Smaller Equator-Pole temperature difference

→Weaker monsoonal wind speed

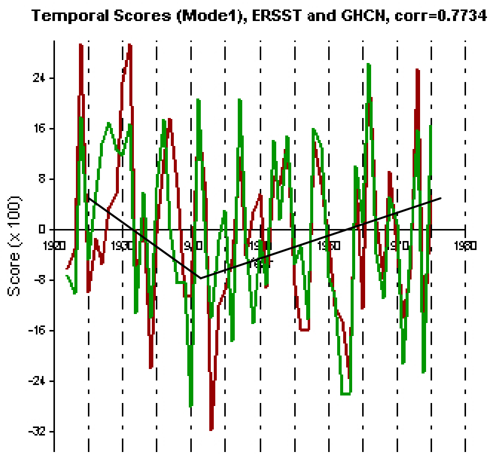
→Stronger diurnal cycles of land-sea and mountain-valley breezes and rainfall

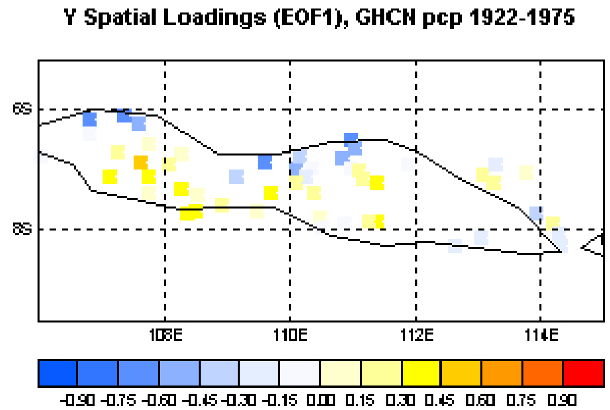
→More (less) rainfall over mountains (plains)?

CPT, CCA (SST & rainfall)
1922-1975 DJF



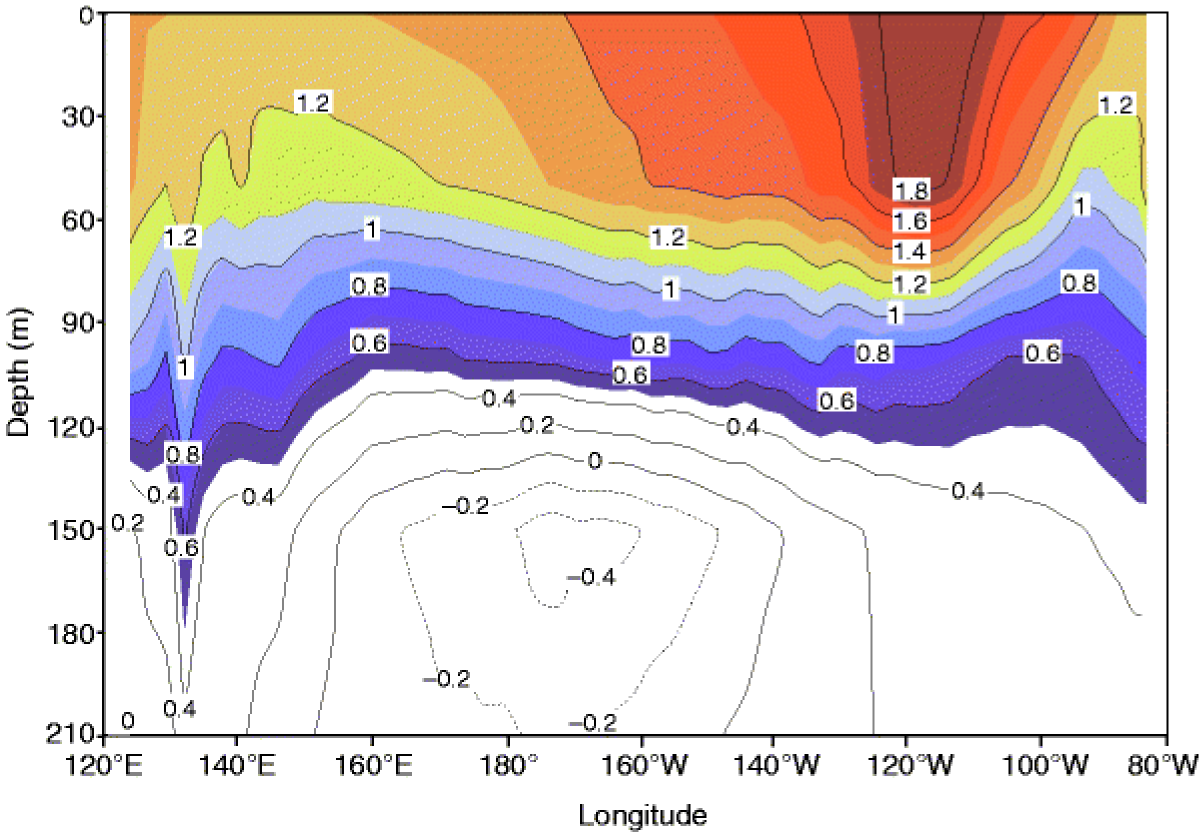
SST ENSO pattern





Java rainfall dipolar pattern

Thank you!



Timmerman et al. 1999: warming along the equator is more El Nino-like.

Java Dipole

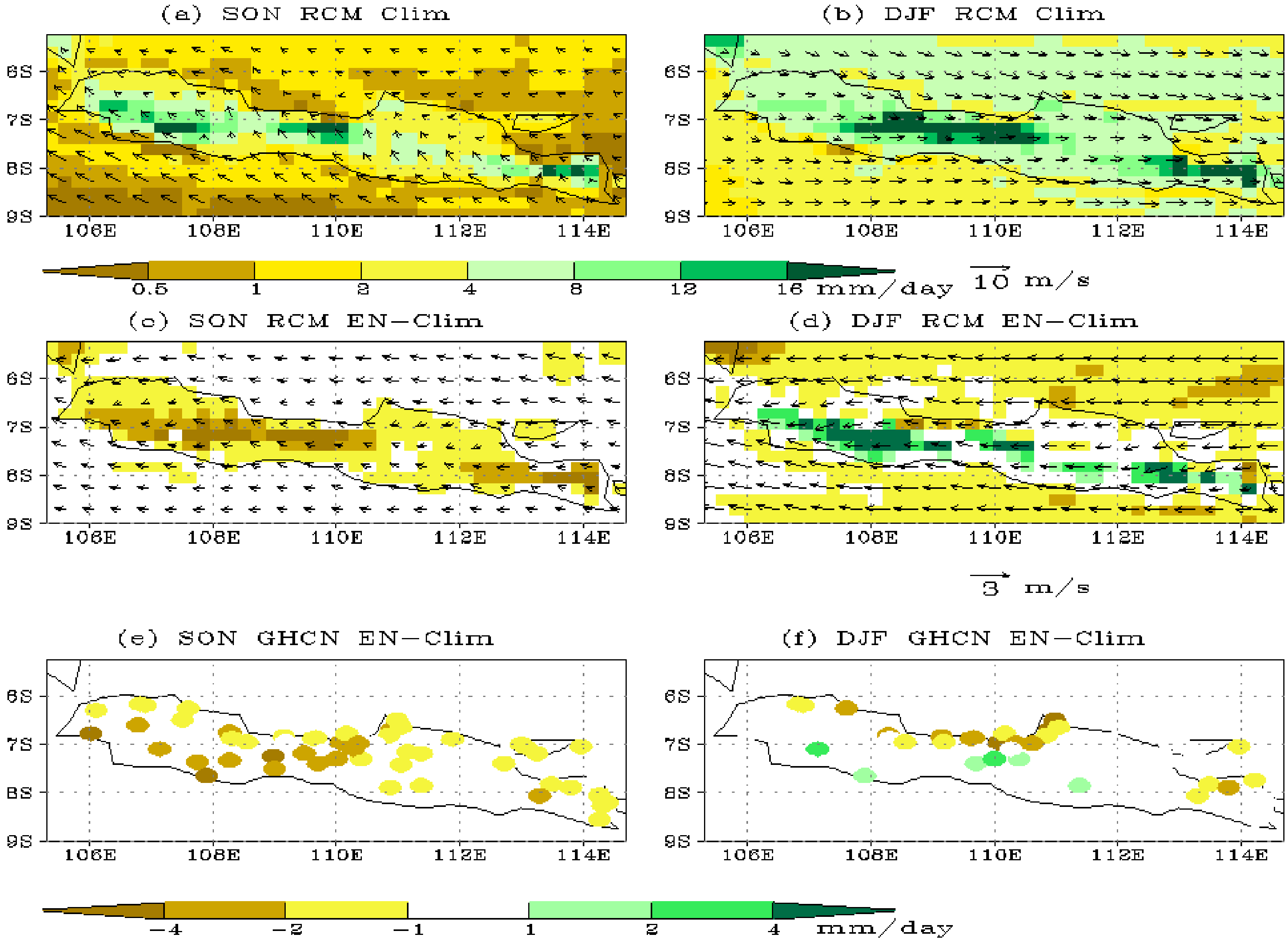


Fig.3 Climatology of NCEP-reanalysis-driving RegCM3 simulated rain (mm/day) and low level winds (m/s) (at sigma=0.995) in SON (a) and DJF (b); (El Nino – climatology) composite of RegCM3 simulated rain (mm/day) and winds (m/s) in SON (c) and DJF (d); and (El Nino – climatology) composite of GHCN guage rain (mm/day) in SON (e) and DJF (f).