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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

- Angat, Bulacan
- Quang Tri
- IloIlo
- Can Tho
- Kalimantan
- Indramayu
- Bali
- Nusa Tenggara Timur
- Timur
**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.
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 subtracted 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)
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.
Global Implication

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

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.
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 0.5–6/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, 85/87, 87/88, 91/93, 94/95, 97/98. El Nino developing years are denoted by (D).
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.
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.
La Nina year

Station Precipitation Anomaly

(LN-Climatology Composite)
Canonical Correlation Analysis, CCA (ERSST & GHCN rainfall)
1922-1975 Dec-Feb (DJF)

Pearson's Correlation, ERSST and GHCN, 1922-1975 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 MegCMS rainfall (mm/day, thick) and wind speed (m/s, m/e) over the whole area of Java Island in SON (a) and DJF (b) for climatology (black), El Niño year composite (red long dash), and La Niña 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.
Dry easterly monsoon WT1 & WT2

Strong westerly monsoon WT3

Quiescent monsoon WT4

Strong westerly monsoon WT5

Intraseasonal variability:
weather typing analysis

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

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

Fig. 2: Frequencies of five weather types, WT1 to WT6, 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 WT

![Diurnal cycle of observed and simulated rainfall for the 5 WT](image)

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) (a, d) for weather types: WT1 (black), WT3 (blue), WT5 (green), WT4 (red), WT8 (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)

**Figure 1**: Terrain heights (m) over Borneo island and surrounding areas based on the U90S observation.
Figure 3: Climatology and (ENSO - climatology) composite of GPCP (1981–2007) precipitation (mm/day; shaded) and NNRP (1970–2005) winds (vector) at 850mb, for SON (a,b,c) and DJF (d,e,f). ENSO developing years are denoted by (0). Composite of 23 El Niño years are in (b,c). Composite of 23 La Niña years are in (e,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 600hPa winds. QuickSCAT land–sea breezes are illustrated by the twice daily morning and evening passes in the 07–10LT and 19–22LT panels.
Anomalous rainfall and 850hPa winds for the five weather types (WT 1-5)

Fig. 5 Anomalous CMORPH precipitation (mm/day) and anomalous NNRP 850hPa winds (m/s) for the 5 weather types. WT-frequency-weighted averaged climatologies have been subtracted 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 ...*
Climate Change at the Regional Scale

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)?

Regional Climate Change Over Java Past & Future?

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

SST ENSO pattern
Thank you!
Timmerman et al. 1999: warming along the equator is more El Nino-like.
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 gauge rain (mm/day) in SON (e) and DJF (f).