The Variability of Tropical Rain and Cloud Heating
...and why it matters

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Intertropical convergence zone
The Maritime Continent is the rainiest place in the world

https://climatedataguide.ucar.edu/climate-data/gpcp-monthly-global-precipitation-climatology-project
To understand precipitation in the present and future world, we have to understand convection.
Mesoscale variability

Intraseasonal variability

Climate variability

Intraseasonal variability
Large MJO errors in GCMs

The NICAM GCM: Run for 12 hours at dx = 14km, 7km, 3.5km, 1.7km and 0.87km

Average global precipitation converged

Cloud area and cloud types did not

Less deep convective cores, with heavier rain-rates

More cirrus: better resolved anvils

Stratiform rain

Convective rain

http://www.atmos.washington.edu/Atlas/phot_ns01.html

http://www.clouds-online.com/cloud_atlas/nimbostratus/images/nimbostratus_praecipitatio_2.htm

Photo C Vincent
The type of rain affects latent heating
Precipitation propagates offshore during the afternoon and evening.
The observed diurnal cycle suggests a transition to stratiform rain.

The far offshore tropical seabreeze

Sea-land breezes southwest of Sumatra (Ewan Short)

Sea-land breezes North of Darwin (Andrew Brown)

The diurnal cycle is critical to Maritime Continent rainfall

Convective and stratiform rain in numerical models

Parameterised models: ‘parameterised’ and ‘resolved’ precipitation from cumulus and microphysics schemes

Convection permitting models: ‘Resolved’ precipitation from microphysics scheme
Classification of convective and stratiform rain

1. Is the rain-rate more than double the background value or more than 20 mm/hr?
   - no
   - yes
     - Deep convection

2. Is it raining?
   - yes
     - Is there cloud water mixing ratio > 0 between 500 and 2000 m?
       - no
         - no
           - Deep stratiform with surface rain
         - yes
           - Is the grid point isolated or adjacent to deep convection?
             - yes
               - Shallow stratiform
             - no
               - Elevated stratiform
     - no
     - Is there rain water mixing ratio > 0 anywhere in the column?
       - yes
         - Is there cloud water mixing ratio > 0 between 500 and 2000 m?
           - yes
             - Is there cloud water mixing ratio > 0.5 g/kg or updraft > 3 m/s below the freezing level?
               - yes
                 - Elevated convection
               - no
                 - Shallow convection
           - no
             - Elevated convection
       - no
         - no
           - Elevated convection
10 Austral summer seasons
All diabatic heating terms saved
WSM6 microphysics
MYJ PBL
ERA-I forcing
Simulated diurnal and intraseasonal variability
Average heating profiles from rain classes

Deep convection

Deep stratiform

Elevated stratiform

Shallow convection

Shallow stratiform

Legend:
- MJO 1
- MJO 2
- MJO 3
- MJO 4
- MJO 5
- MJO 6
- MJO 7
- MJO 8
WRF diabatic heating versus TRMM 3G25 latent heating

*relax MJO amplitude to 0.5

Peaks in phase 2 in WRF and TRMM

Peaks in phase 4 in WRF, phase 3 in TRMM

Stratiform

Convective
Rain-type classification

Deep convection

Shallow stratiform

Deep stratiform (no sfc rain)

Deep stratiform (sfc rain)

Shallow convection

[K day$^{-1}$]
Rain-type classification

- Deep convection
- Shallow stratiform
- Deep stratiform (no sfc rain)
- Deep stratiform (sfc rain)
- Shallow convection

x=0

1900 LST

[K day\(^{-1}\)]
Trade cumulus?


Cloud heating around Sumatra: MJO phase 2

Deep stratiform – no sfc rain

Deep stratiform – sfc rain

Deep convection

0100 LST

0700 LST

1300 LST

1900 LST
Cloud heating around Sumatra: MJO phase 4

Deep stratiform – no sfc rain    Deep stratiform – sfc rain                Deep convection

0100 LST

0700 LST

1300 LST

1900 LST
Cloud heating around Sumatra: MJO phase 7

Deep stratiform – no sfc rain

0100 LST

Deep stratiform – sfc rain

0700 LST

Deep convection

1300 LST

1900 LST
The simulated diabatic heating budget

\[ \frac{\partial \theta}{\partial t} = -u \frac{\partial \theta}{\partial x} - v \frac{\partial \theta}{\partial y} - w \frac{\partial \theta}{\partial z} + \text{MP} + \text{PBL} + \text{RA} \]

- 2-hour centred difference
- 5th order horizontal advection
- 3rd order vertical advection
- Microphysics tendency
- PBL scheme tendency
- Radiation schemes tendency
The diabatic heating budget over land and sea

1300 LST

MJO Active

Land

Sea

MJO Suppressed

Land

Sea

PBL scheme
Microphysics
Radiation
Horizontal adv.
Vertical adv.
RHS

\frac{\partial}{\partial t} \theta
The diabatic heating budget over land and sea

0100 LST

MJO Active

Land

Sea

MJO Suppressed

Land

Sea

Legend:
- PBL scheme
- Microphysics
- Radiation
- Horizontal adv.
- Vertical adv.
- RHS

$t$
Budget terms on Sumatra transect

\[ \frac{\partial \theta}{\partial t} \quad K \text{ day}^{-1} \quad \text{RHS} \quad K \text{ day}^{-1} \]

vertical advection

horizontal advection

microphysics

PBL

radiation

Phase 2
Budget terms on Sumatra transect

**Phase 2**
Budget terms on Sumatra transect

Phase 7
Budget terms on Sumatra transect

\(\frac{\partial \theta}{\partial t}\)

\(K \text{ day}^{-1}\)

RHS

\(K \text{ day}^{-1}\)

vertical advection

horizontal advection

microphysics

PBL

radiation

Phase 7
Getting the cloud heating right depends on the right convective / stratiform partitioning.

Surface rain-rate is only a proxy for cloud processes.

Proportions of convective and stratiform heating vary with intraseasonal variability.

Convective cloud heating peaks 1-2 MJO phases ahead of stratiform heating.
Summary and outlook

Ongoing questions:

*How does the partitioning of heating look in a parametrised model?*

*What are the model sensitivities to convective/stratiform rain in mesoscale and climate-scale models?*

*How can we better observe the partitioning?*

*What are the upscale implications of getting it wrong?*

*What are the hydrological implications of the partitioning?*

*What about the mid-latitudes?*
The peak diurnal cycle over the land precedes that over the sea.

Peak over the land at 6pm

Peak over the sea at 5am