Impact of the mesoscale organization of deep convection on the tropospheric humidity and vapor isotopic composition: satellite observations, CRMs and GCMs

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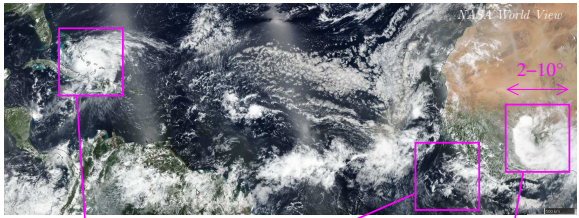
3rd Workshop on Cloud Organisation and Precipitation Extremes, September 2023

Mesocale organization of deep convection



tropical cyclone

isolated cumulonimbi

squall line

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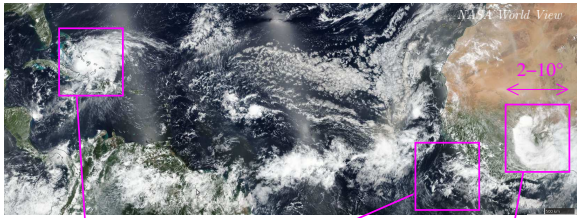

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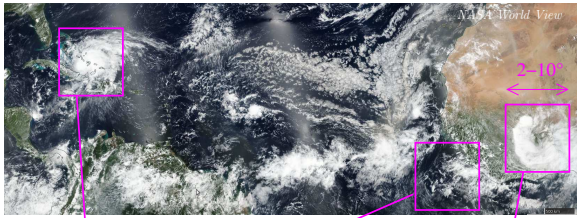
aggregation — aggregation

(Tobin et al 2012, Tomkins and Semie 2017...)

Spatial arrangement

Mesocale organization of deep convection



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Spatial arrangement → Tropospheric humidity ↘ *(Tobin et al 2012)*

Spatial arrangement → Upper-level cloudiness ↘ *(Stein et al 2017)*

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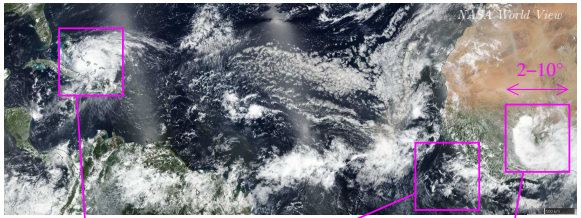

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Type

Temporal arrangement

(Tobin et al 2012, Tomkins and Semie 2017...)

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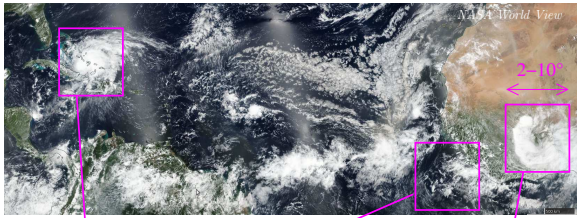

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Type
- Stratiform clouds ↗ *(Houze et al 2004)*

Temporal arrangement
- Water vapor isotopic composition $\delta D_v \propto HDO/H_2O$ ↘ *(Lawrence et al 2004, Risi et al 2008)*

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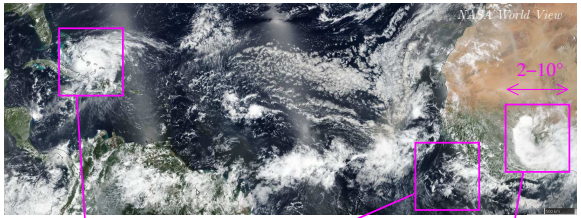
Mesocale organization of deep convection



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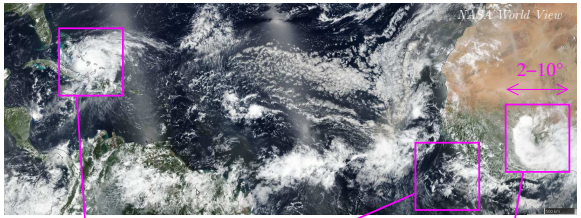

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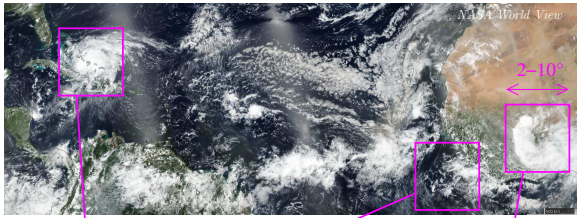

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2. How do different aspects of organization impact the large-scale (200-1000km) environment (humidity, δD_v)?
3. Mechanisms for this impact?
   Direct effect of mesoscale organization?
   Or mediated by large-scale circulation?

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Temporal arrangement

Spatial arrangement
- Tropospheric humidity ↘ *(Tobin et al 2012)*
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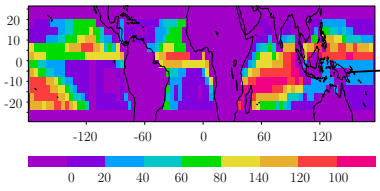
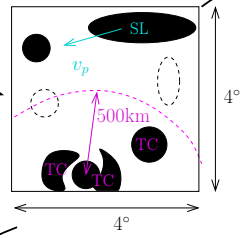
Composite method based on satellite observations

All 1-day 4x4° scenes
over tropical oceans over 2012-2016
(robust from 2° to 10°, 1 to 5 days)



For a given
rain rate
(Tobin et al 2012)
select scenes
with
$P_{TRMM} \simeq 5$ mm/d

TOOCAN tracking algorithm
of mesoscale convective system
(Fiolleau et Roca 2013)

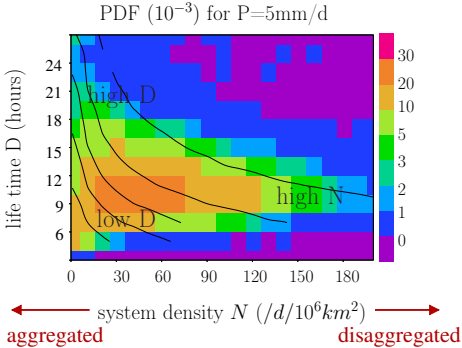


humidity and
δD_v (AIRS)
vertical velocity (ERA5)

compute composites

density of systems N
mean life time D
squall line ($N < 30/d/(1000km)^2$, $D > 15h$, v_p>10m/s)
cyclone ($N < 30/d/(1000km)^2$, $D > 15h$, <500km from named cyclone)

Is aggregation enough to document organization?



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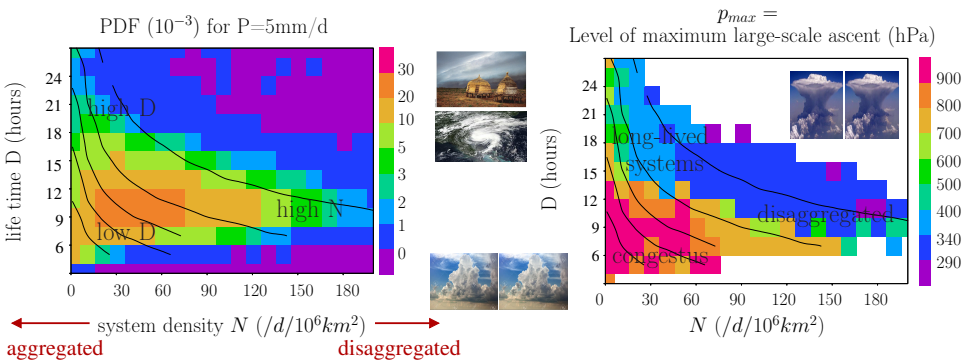

- More top-heavy ascent when disaggregated (Stein et al 2017) and long-lived systems (Houze et al 2004)
-

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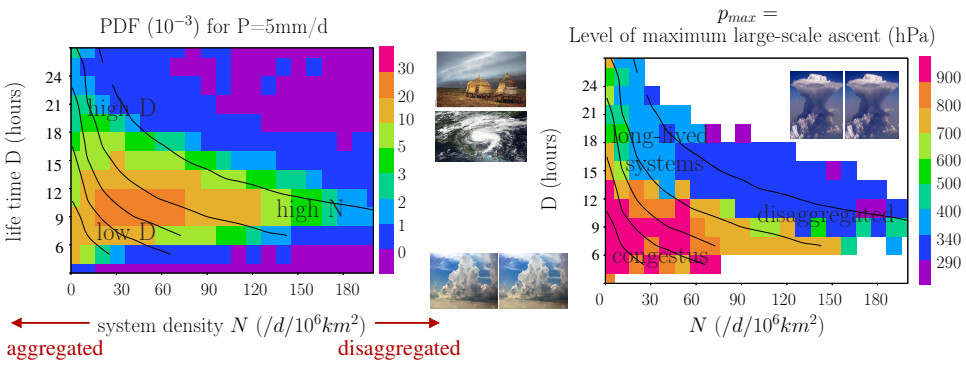
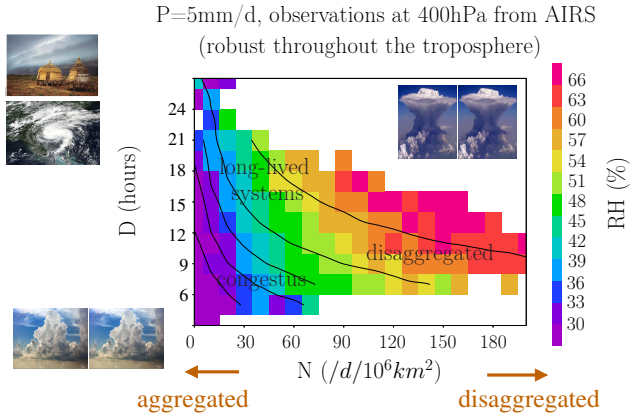


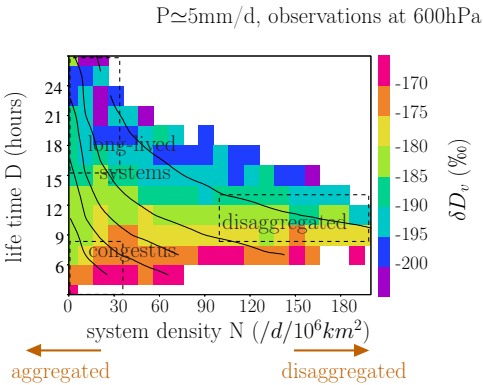
- More top-heavy ascent when disaggregated (Stein et al 2017) and long-lived systems (Houze et al 2004)
- For a given rain rate and aggregation, different large-scale circulation regimes are possible

Impact of convective organization sur humidity



- Humidity mainly controlled by N *(consistent with Tobin et al 2012)*,
- not strongly sensitive to life time D and system type

Impact of convective organization sur δD_v



- δD_v mainly controlled by life time D *(e.g. Lawrence et al 2004, Risi et al 2008)*
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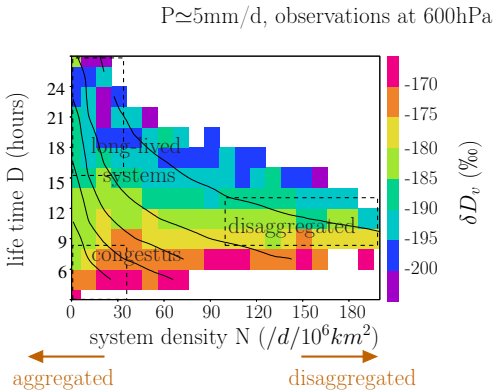
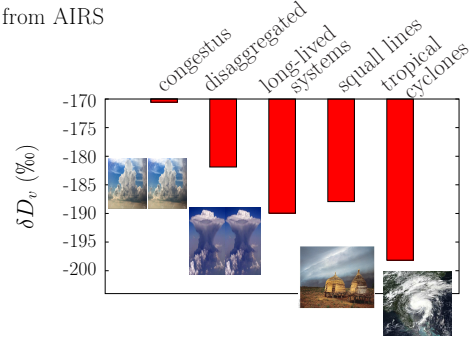
Impact of convective organization sur δD_v





(Risi et al in prep)

- δD_v mainly controlled by life time D *(e.g. Lawrence et al 2004, Risi et al 2008)*
- Also controlled by system type
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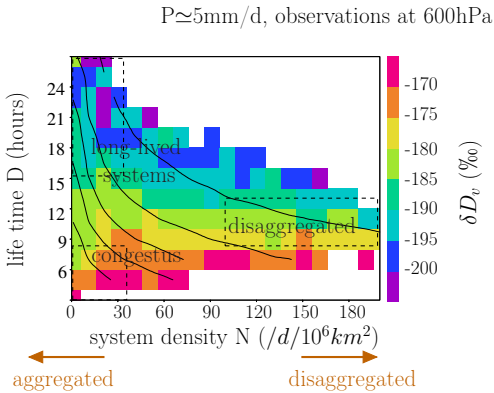
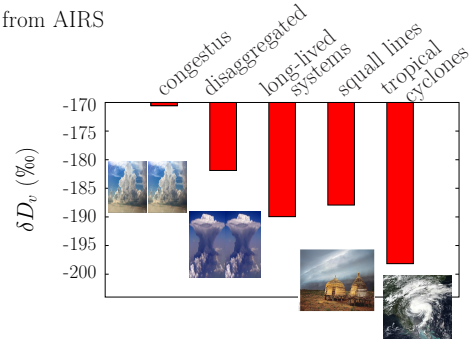
Impact of convective organization sur δD_v





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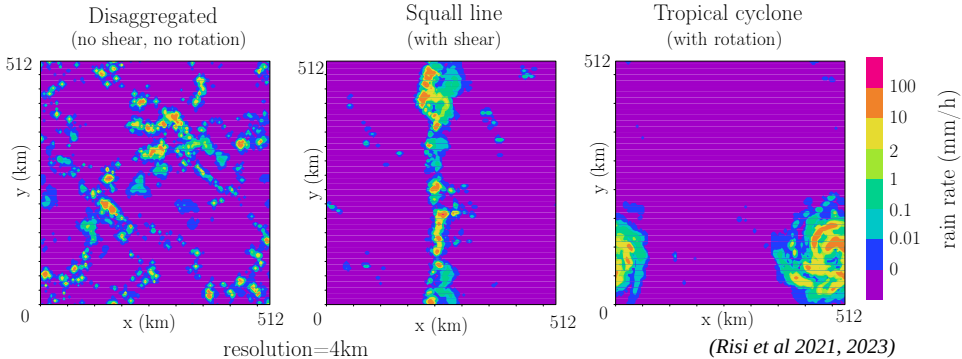
- δD_v mainly controlled by life time D *(e.g. Lawrence et al 2004, Risi et al 2008)*
- Also controlled by system type
- Same precipitation rate, aggregation and humidity, but $\neq \delta D_v$ -> $\neq$ processes

Mechanisms: Mesoscale organization or large-scale circulation?

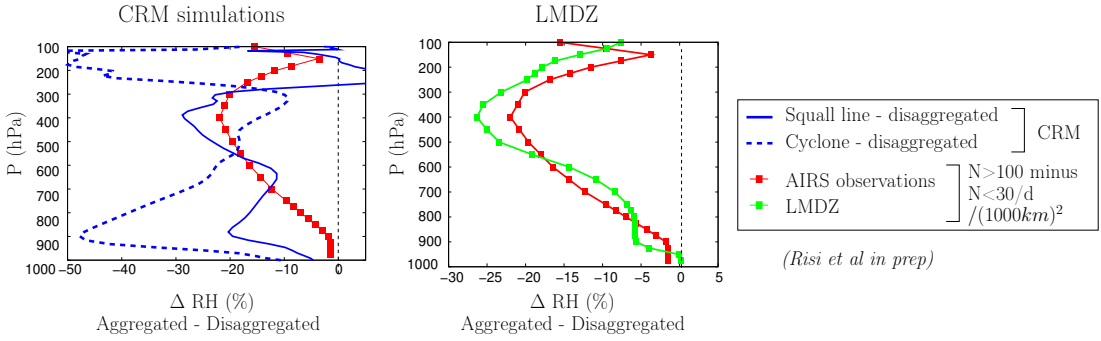
1. CRM (SAM) in radiative convective equilibrium + large-scale ascent (≃5mm/d)
   -> Impact of meso-scale organization only



(Risi et al 2021, 2023)

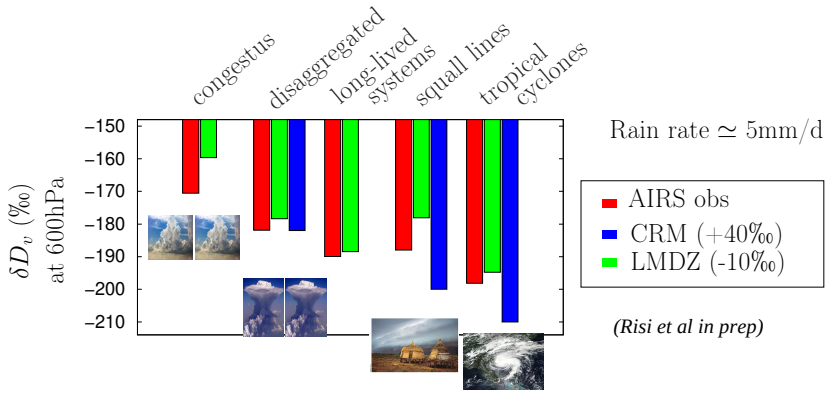
2. GCM (LMDZ) at very coarse resolution (2.5°x3.75°) -> blind to mesoscale organization.
   Nudged by ERA5 horizontal winds -> daily large-scale circulation realistic.
   -> Impact of large-scale circulation only

Humidity: Mesoscale organization or large scale circulation?



- CRM: Mesoscale organization only: qualitatively captures drier troposphere when aggregated *(e.g. Bretherton et al 2004)*
- GCM: Large-scale circulation only: captures drier troposphere as well! (*Sherwood 1996?*)
  - 50%: when disaggregated, more less rain during previous days and more top-heavy large-scale ascent
  - 50%: excessive rain when disaggregated

δD_v : Mesoscale organization or large-scale circulation?



- CRM: qualitatively captures depleted δD_v around squall lines and cyclones (rain evaporation in moister downdrafts, *Risi et al 2023*)
- GCM: captures δD_v as well! (rain during previous days, top-heaviness of large-scale ascent)

Summary

- Even for same precip rate, same spatial aggregation, different large-scale circulation regimes are possible. Same humidity but different δD_v
  -> **Different organization metrics needed depending on science application**
- Both mesoscale organization for same circulation regime, and large-scale circulation blind to mesoscale organization, can capture impact of different aspects of mesoscale organization on humidity and δD_v
  -> **At least partially mediated by the large-scale circulation**
  -> **What would need to be represented in GCMs**? e.g. for humidity, half is already represented through the large-scale circulation?
- In nudged GCMs, large-scale circulation is imposed. **Impact of mesoscale organization on the large-scale circulation?**
  e.g. longer-lived convective systems -> more top-heavy latent heating profile -> more top-heavy circulation *(Schumacher et al 2004)*?