Impact of convective organization on tropospheric humidity and isotopic composition

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1. Introduction

Deep convection in the tropics can take the form of small isolated cumulonimbus (fig 1a), or organize into bigger and longer-lived convective systems, e.g. squall lines or tropical cyclones (fig 1b-c). Convective aggregation measures the degree to which convection is clustered into a small number of systems. Over the oceans, for a given rain rate in average over some large-scale domain (a few degrees), the tropospheric relative humidity (RH) is drier when convection is more aggregated [8]. If convective aggregation is effectively responsible for the drying and if it depends on sea surface temperature, it could be involved in a climate feedback that is not accounted for in global climate models.

In this study, we set 2 questions:

1. Do aspects of convective organization other than aggregation, such as life duration of convective systems or their propagation speed, covary with tropospheric humidity?
2. What are the mechanisms (convective or large-scale) underlying the organization-humidity relationships? What is the role of microphysical processes?
   Can water isotopic measurements help address this question?
   ⇒ Look at δD_v in addition to RH.

This work has also paleoclimate implications. More depleted water vapor and precipitation is observed in/near squall lines [9] or tropical cyclones [3]. Isotopic paleo-records have thus been used to reconstruct past cyclonic activity [1] or large continental organized convective systems [4].

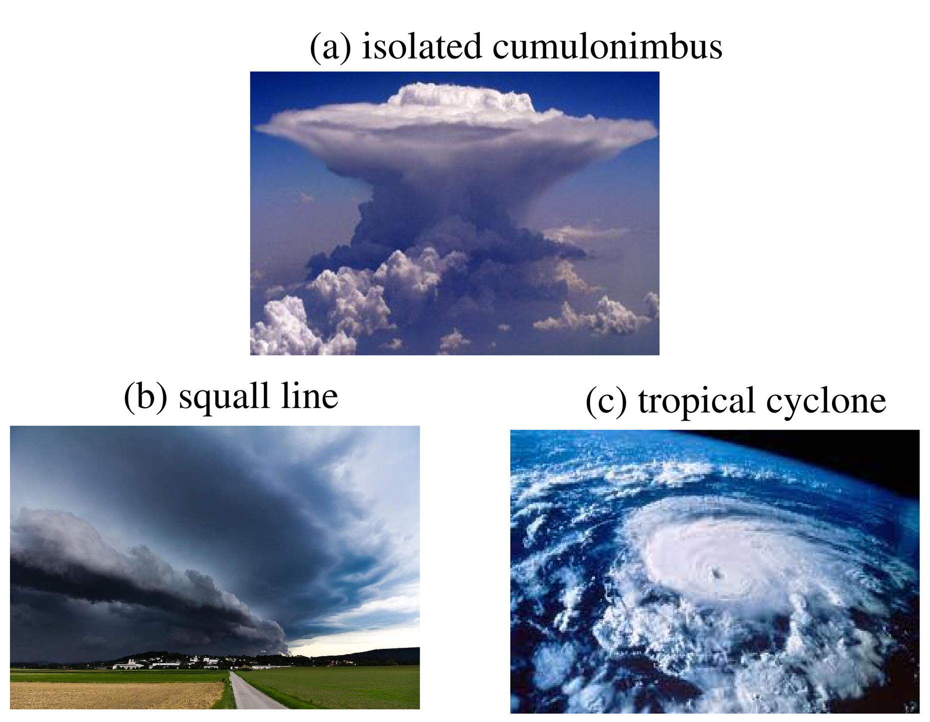
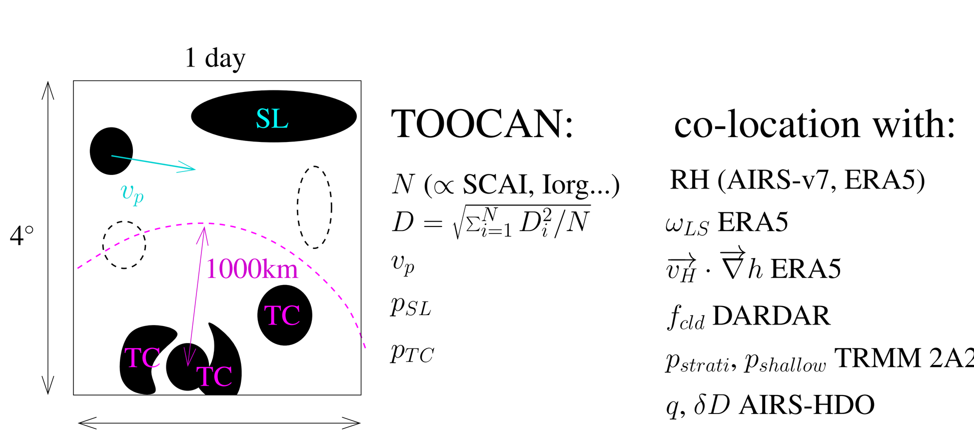


Fig 1

2. Methods

- TOOCAN [2]: algorithm tracking mesoscale convective systems (MCS)
- For a given domain and period, number of convective systems (N), mean life duration (D), mean propagation speed (v_p), proportion of MCS area belonging to cyclones and squall lines (p_{TC} and p_{SL}) from TOOCAN (fig 2).
- N describes spatial aggregation: highly correlated with Iorg or SCAI
- Composites as a function of TRMM precipitation rate (P), N, D, v_p, p_{TC} and p_{SL}.



$$P = K \cdot N \cdot D^2$$

Fig 2

3. Aggregation, meso-scale properties and large-scale conditions

- For a given P and N, a wide range of D is possible (fig 3).
- All variables listed in Methods are composited in the $D - N$ diagram (not shown) ⇒3 poles are identified (fig 3).
  1. red: long, large MCS, strongly "organized" at the meso-scale, frequent cyclones and squall lines, high v_p, often at the edges of the ITCZ
  2. blue: disaggreated convection, typical of deep ITCZ (e.g. Western Pacific)
  3. green: small and/or shallow MCS, typical of shallow ITCZ (e.g. Eastern Pacific)
- When P increases, about 50% is due to increase in N and 10% to increase in D (not shown).

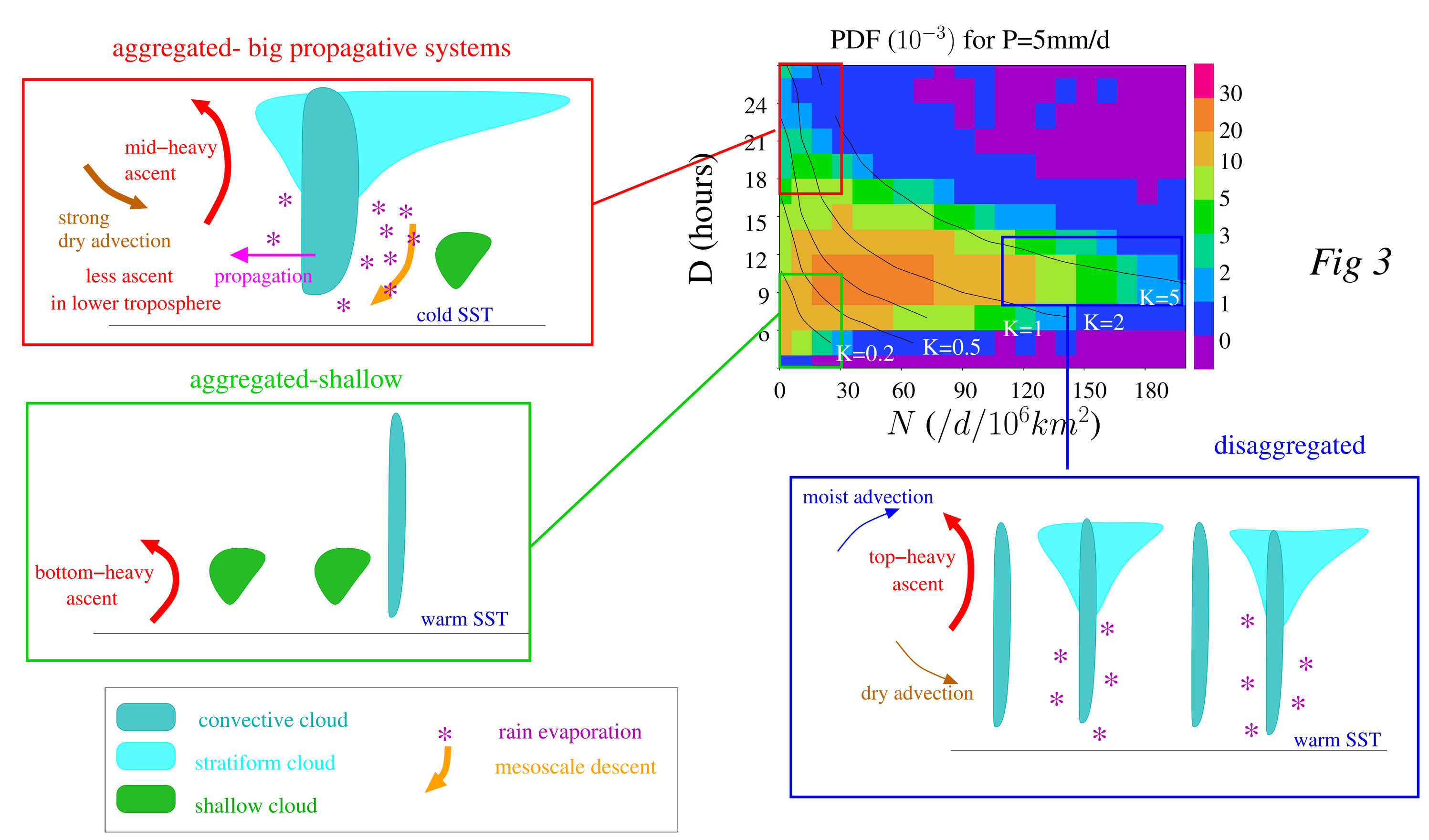


Fig 3

4. Impact on RH and δD_v

- RH:
  - increases with N [8] (fig 4a-b blue)
  - RH also increases slightly with D and, in the upper-troposphere, with v_p (fig 4a-b red, pink).
- δD_v:
  - decreases with D and v_p (fig 4c-d red, pink)
  - the decrease with D explains about 50% of the amount effect (decrease of δD_v with P) (not shown)
  - environment around tropical cyclones stand out as very depleted (fig 4d purple).

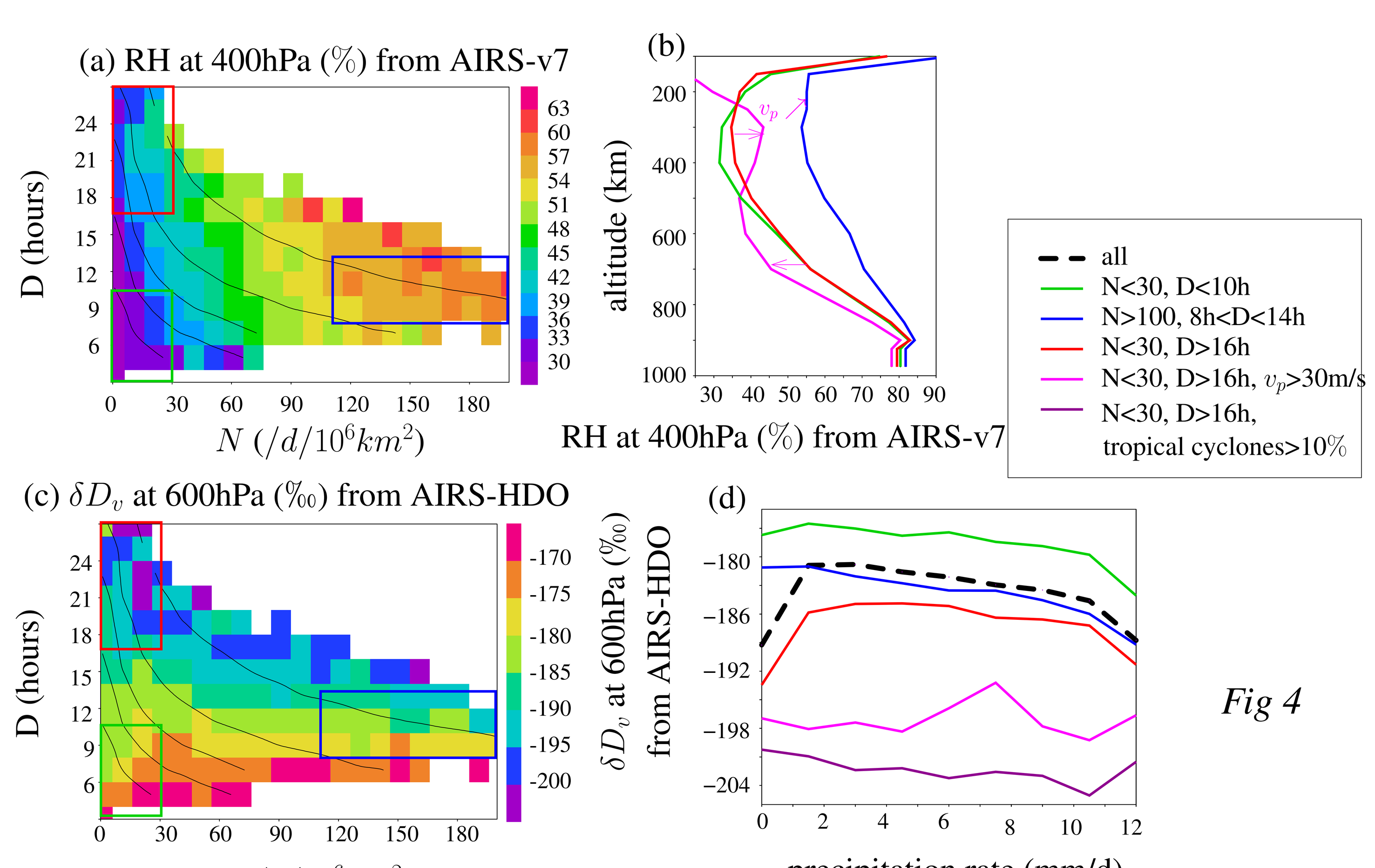


Fig 4

5. Added value of δD_v to understand mechanisms?

One hypothesis to explain larger RH for larger N is the larger surface of exchange between clouds and their environment, leading to more moistening by rain evaporation or cloud detrainment [8].
⇒Use $q - \delta D_v$ relationships to test this hypothesis (fig 5a-b):

- Indicates more rain evaporation when N increases (fig 5c red) and D increases (fig 5c green) and for tropical cyclones (fig 5d blue)
- Limitation due to the high vertical coherence of δD_v: e.g. larger rain evaporation in the lower tropospere impacts δD_v at all altitudes, but does not contribute to the moister upper-troposphere...

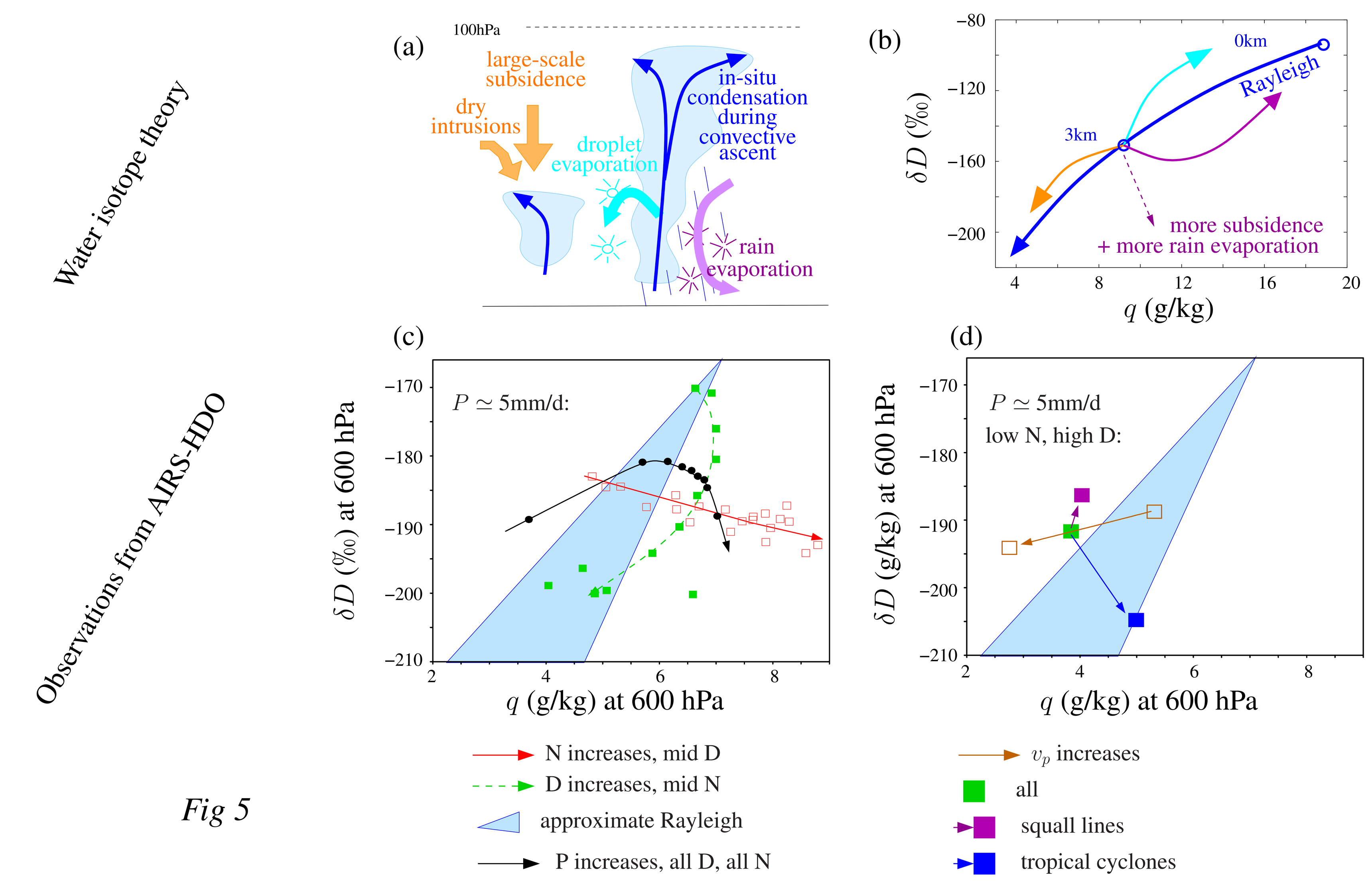


Fig 5

6. Conclusions

- Convective aggregation (N) not sufficient to describe convective organization.
- RH sensitive to N, but also to meso-scale properties of convective systems (D, v_p).
- δD_v observations to understand the mechanisms? Indicate effect of N on rain evaporation, but limitation due to the high vertical coherence of δD_v...
- **Paleoclimate implications**: in tropical regions, D is the main factor affecting δD_v.
  ⇒confirms isotope-based paleo-tempestology studies.

7. Perspectives

- Mechanisms for impact of D and v_p on RH and δD_v? Can we use CRM simulations?
  - RH: idealized (RCE) CRM simulations capture higher RH when N increases, but simulates smaller RH when D increases [5]... Why?
    ⇒Use global CRMs (DYAMOND, [7])? Capture higher RH when N and D increases (paper in prep).
  - δD_v: idealized CRM simulations show δD_v lower inside cyclones and squall lines due to rain evaporation [6]. But domain-mean δD_v more enriched for cyclones than for isolated convection... Why? Global CRMs have no isotopes yet...
- Is the impact of D and v_p on RH associated with climate feedbacks? ⇒ sensitivity to SST in idealized CRM simulations [10].

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