Sources of Tropical Mid-tropospheric Water Vapour

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1. Motivation: Vertically integrated water vapour vs. rainfall

Several recent studies have reported an exponential relationship between tropical column water vapour and rainfall. Those studies also showed that this relationship is largely one between rainfall and free tropospheric water vapour. We are able to reproduce these results using three years of radar-derived rainfall and objectively analyzed large-scale states at the Darwin ARM site. **Our goal is to extend previous work by elucidating the sources of mid-tropospheric water vapour associated with rainfall.**

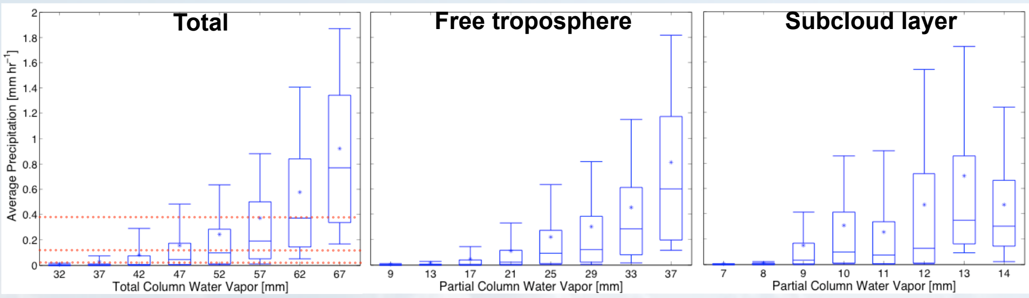

Figure 1: Precipitation as a function of column water vapour integrated from the surface to 200 hPa (left), 850 hPa to 200 hPa (middle), surface to 950 hPa (right) for three wet seasons at Darwin.

It is evident that rainfall increases exponentially with column water vapour with a pickup at around 50 mm. It is evident that this relationship is strong with the free troposphere (middle), but not the sub-cloud layer (right).

2. Water vapour tendency as a function of rainfall intensity

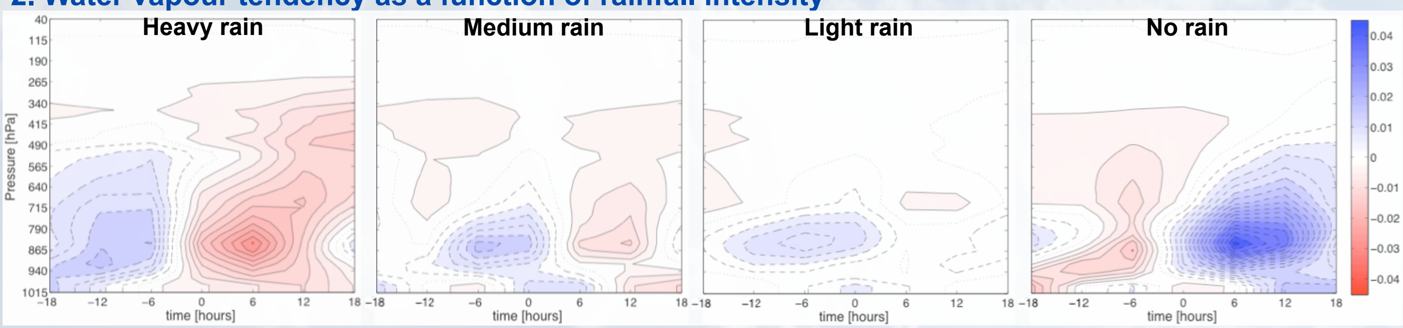

Figure 2: Specific humidity tendency (g/(kg*hour)) before and after rainfall by rainfall tercile (as indicated by red lines in left panel of Fig. 1) as well as for no-rain events.

There is strong lower to mid-troposphere moistening before rainfall events. The magnitude of the moistening increases with rainfall intensity. **What is the source of moisture - vertical advection, horizontal advection or small-scale processes?**

3. The source of mid-tropospheric moisture

The low to mid-level moistening in advance of **heavy rainfall** is caused by two processes. 12-18 hours before the event sub-domain scale processes (i.e. convection) weakly moisten the lower mid-troposphere. However, **by far the strongest pre-rainfall moistening is due to large-scale vertical advection, and hence dynamical processes**. Horizontal advection weakly dries the atmosphere pre- and post-rainfall.

In contrast **during the no-rain events large-scale processes lead to drying of the mid and lower troposphere, with a strong moistening from sub-domain scale processes**, as expected in a shallow cumulus-dominated situation.

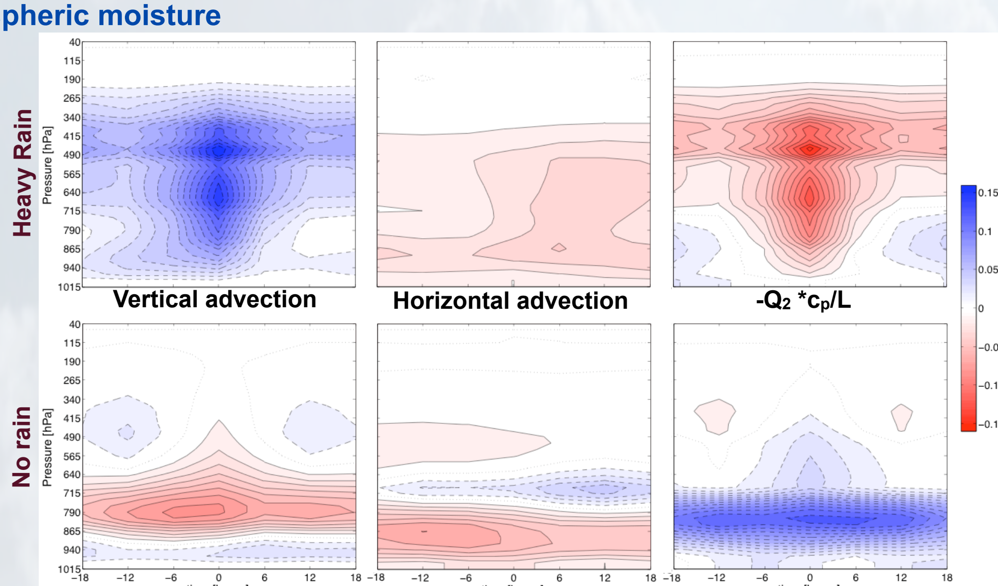

Figure 3: Moisture sources (in (g/(kg*hour)) as a function of height and time around rainfall events. Left: Vertical advection; Middle: Horizontal advection; Right: Sub-domain scale processes (as represented by Q2). Top: Heavy rain. Bottom: No rain.

4. Conclusions

Tropical rainfall and mid-tropospheric humidity show a strong relationship whereby higher mid-tropospheric humidity is associated with stronger rainfall events. Using ARM data at the TWP Darwin site and the objective variational analysis we show conclusively that **the strong pre-rainfall moistening of the lower mid-troposphere is a result of large-scale vertical advection**. This is in contrast to the often hypothesized pre-conditioning of the atmosphere by shallow and congestus-type convection and **highlights the importance of large-scale dynamical processes in shaping the occurrence and strength of tropical convection**.