Investigating the relationship between large-scale and convective states in the tropics

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October 2010

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Project aim

..the aim of this proposal to apply a combination of *long-term observations* taken by ARM (ASR) and BOM in the tropics and simulations using CRMs to comprehensively explore the *relationships between the large-scale and convective scales* and to use the findings to guide improvements of the representation of convection in NWP.

Project components

- Long term LARGE-scale data set
  - Define the observed large-scale the state of the atmosphere.
  - Use a combination of re-analysis, observations and constrained variational analysis.

- Long term SMALL-scale data set
  - Define the observed convective state.
  - Use radar data to derive properties of deep convection and convective cells
  - (and non-precipitating ice clouds)

- Cloud-resolving modelling (CRM)
  - Force a CRM with the large-scale state.
  - Derive an additional small-scale state from model data.
  - THEN, perform a 'limited' number of large domain radiative-convective equilibrium simulations.
  - Derive a new set of large-scale states and small-scale states from the model data.

Large-scale state

- Long term large-scale data set
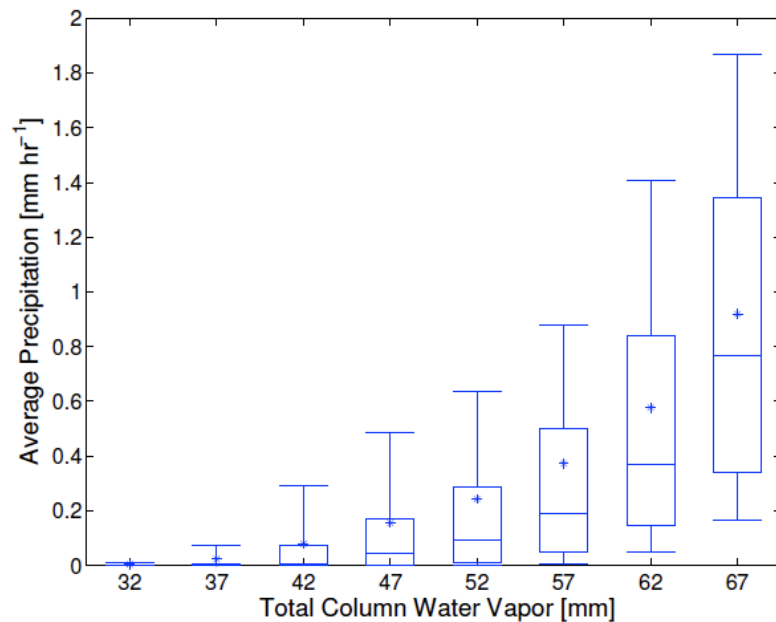 - Derived using ECMWF re-analysis in place of radiosonde data but constrained with observations.

Observed forcing

ECMWF analyses constrained by observations

Vertical velocity (hPa hour⁻¹)
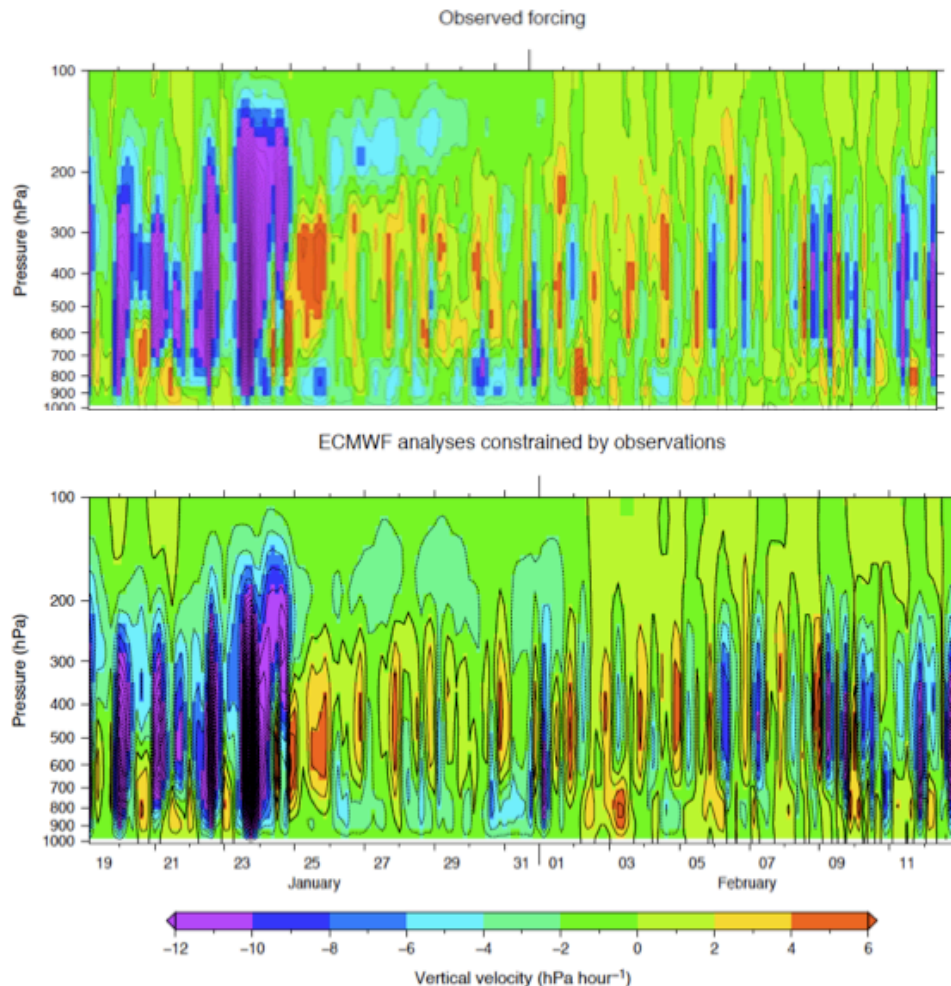
All observations

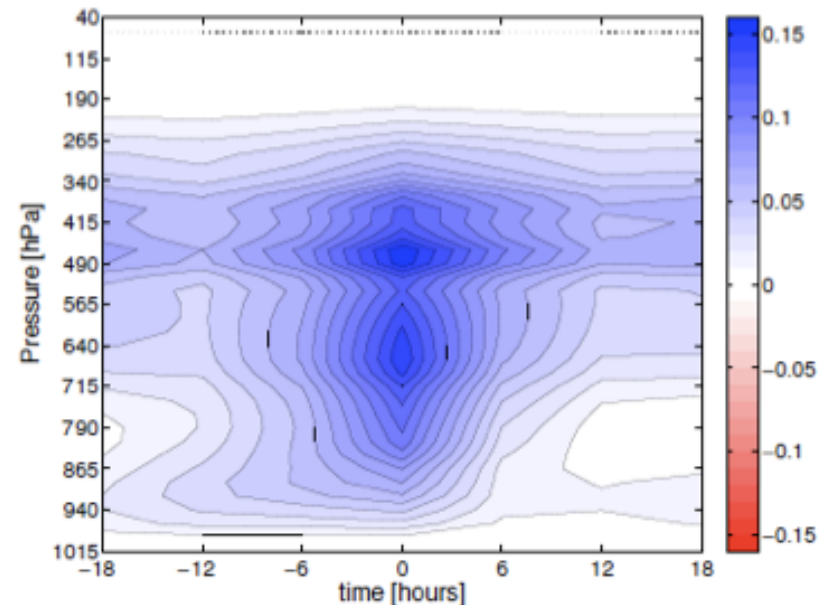ECMWF analysis constrained with variational analysis

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Using the large-scale state

- What can we do with the large-scale state alone?

Find behaviour at Darwin found in similar studies, e.g Holloway and Neelin JAS 2009

Attribute possible sources of moisture, e.g vertical advection?

Advertising the large-scale data set

- Long term large-scale data set now from ASR PI site
  - Best estimate and ensemble product.
  - One of the deliverable targets in year 1 of ASR project.

- 3 wet seasons: 2004-2005, 2005-2006 (which includes TWP-ICE) and 2006-2007

- Data only available when sufficient precipitation data, hence data available in sub-periods.

- Data in netcdf files of the exact same format of standard ARM best estimate forcing data products (except cloud data is missing).

- Ensemble product based on techniques and errors used in forcing data for ensemble TWP-ICE intercomparison.
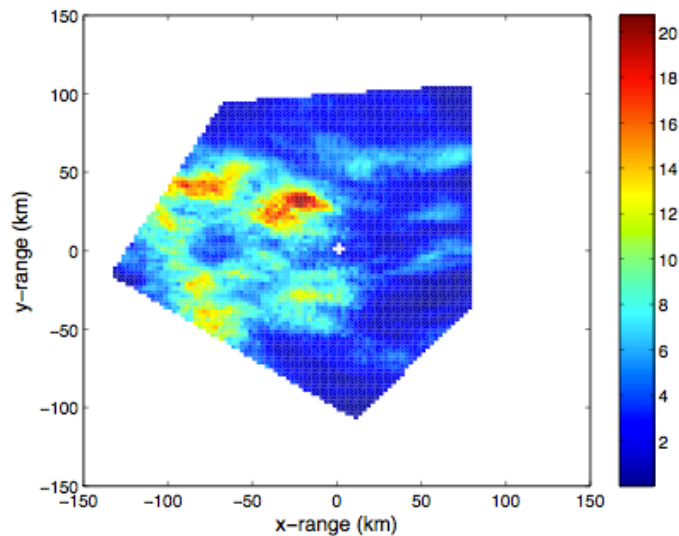
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Defining small-scale state
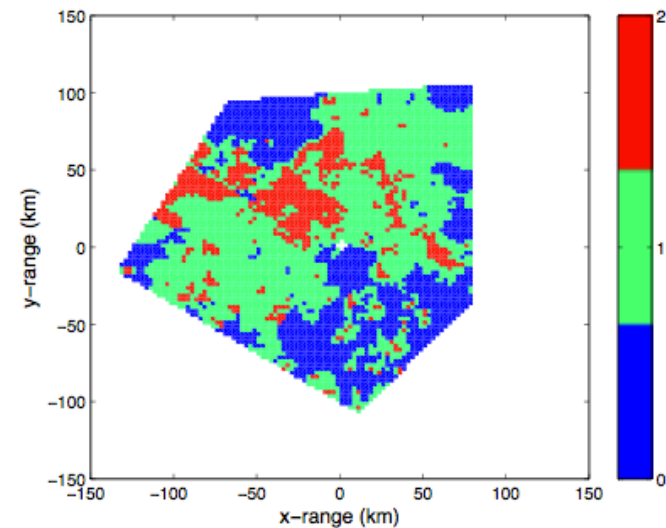
- **What we have...**
  Rain rate,
  Rain intensity,
  Area fraction,
  Classified rainfall data – convective/stratiform,
  Classified rain rate,
  Classified intensities,
  Classified area fractions,

- **Wish list...**
  Vertical velocities,
  Cell characteristics including
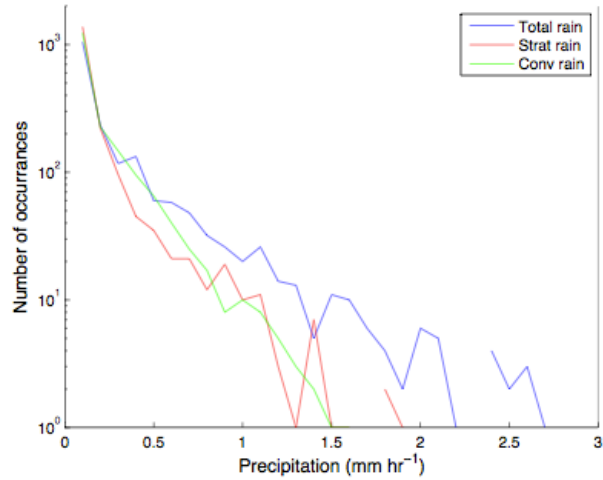 number, size and height.
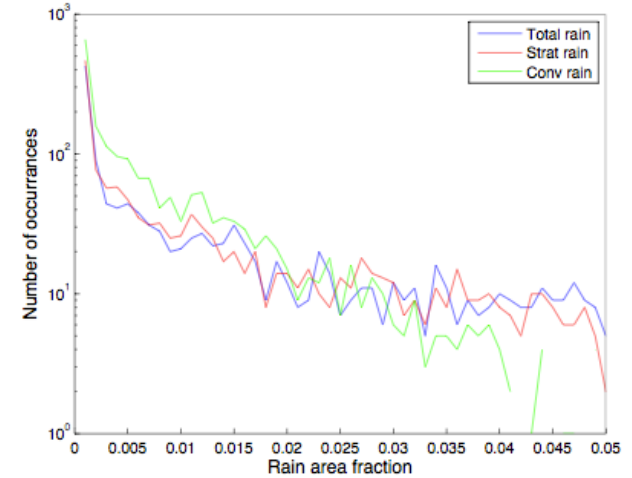 Anything else...?!

6-hr accumulated rainfall   Instantaneous classified rainfall
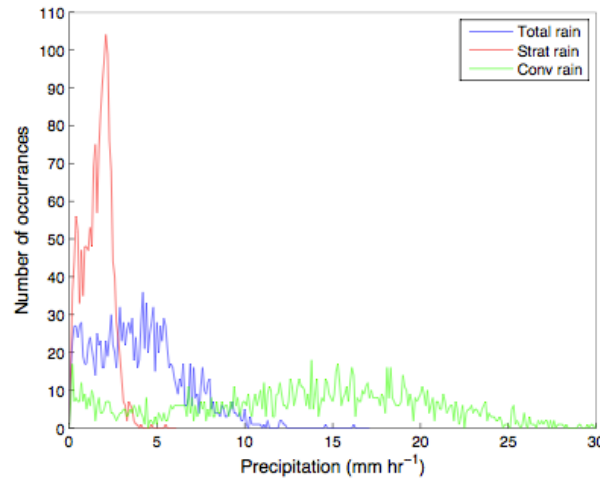
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Small-scale state

Rain rate
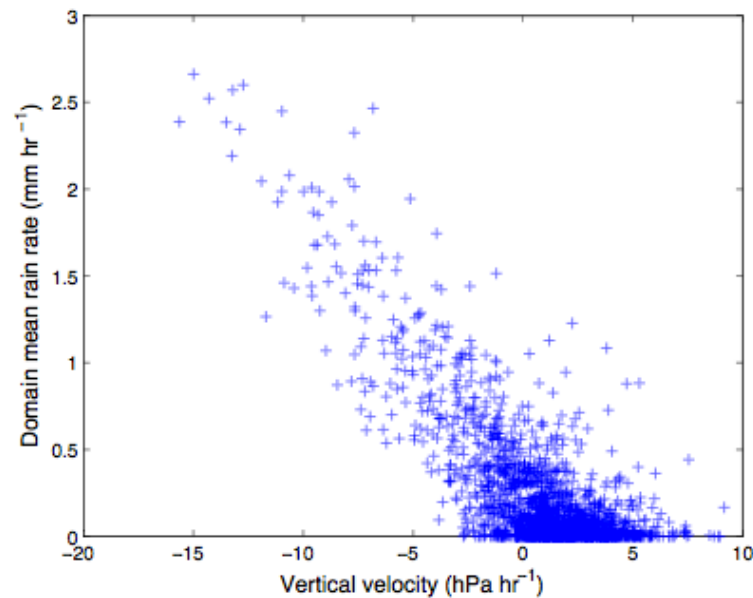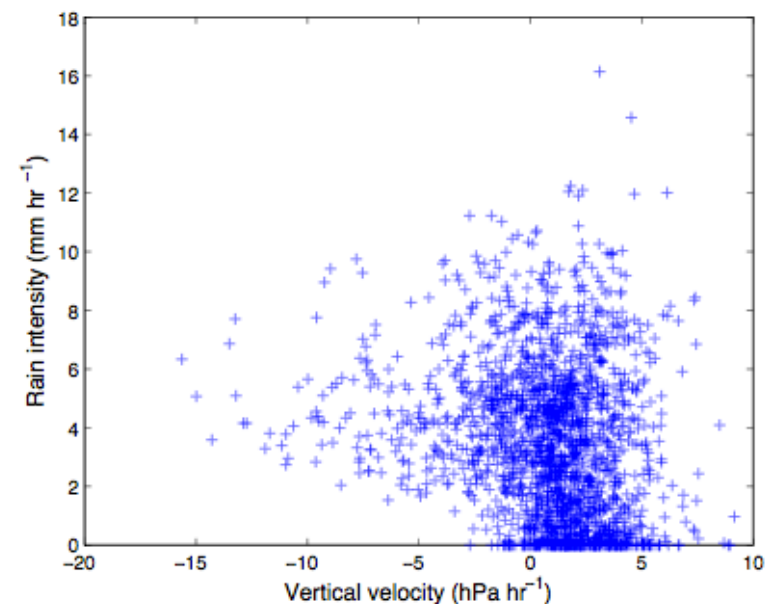
Rain intensity

Rain area fraction

Small-scale vs large-scale

- Relationship between small-scale and large-scale 700 mb omega
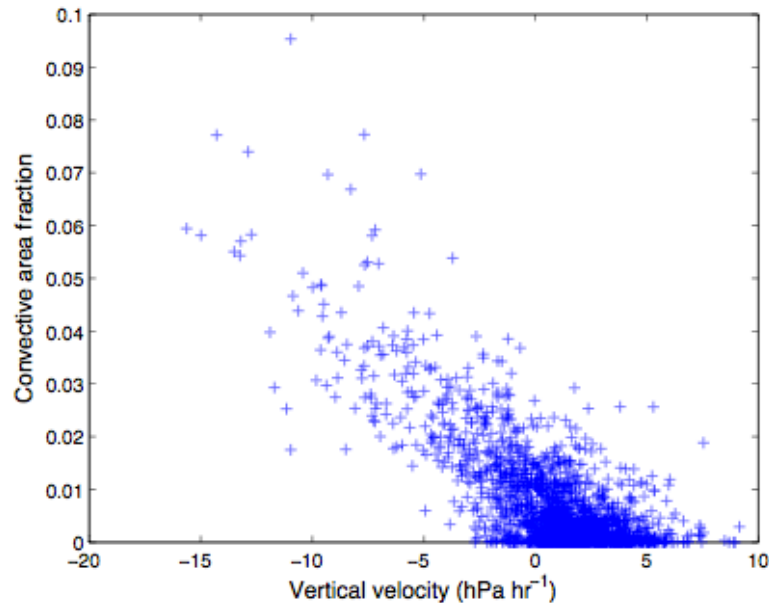
Rain rate

Rain intensity

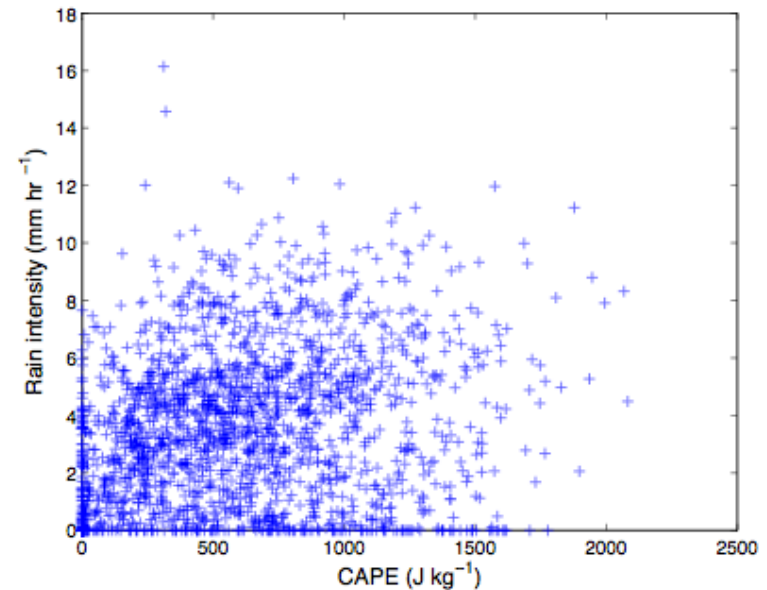Strong relationship with rain rate (expected) but not with rain intensity

Small-scale vs large-scale

- Why isn't there a relationship with intensity?

Convective area fraction

Rain intensity with CAPE

Strong relationship with convective fraction but rain intensity not related to CAPE.

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Summary

- We have created a long term large-scale data set for Darwin, Australia.
    - It's available to download on the ASR PI website.
    - It's as easy to use as the standard forcing data sets and comes with a 100 member ensemble.

- We are defining a long term small-scale data set.
    - At the moment we are using classified rainfall data but shortly we will have other radar derived characteristics of the convective state.
    - In time this too will be available as an ASR PI data product.

- We've started to investigate relationships between the large scale and the convective scale.
    - We've found relationships we were expecting like between rain rate and vertical velocity...
    - ... and new relationships like between convective area and vertical velocity.
    - We have not found strong relationships we might have expected, nothing so far is strongly related to CAPE.

Out standing questions
(some of them)

- What does control intensity?

- How indicative is this study of the tropics in general?

- What is the role of stratiform rain? How would a parameterisation relate convective rain to large-scale stratiform rain?

- Can we use better methods to find relationships? e.g. using multiple regression or clustering techniques.