The relationship of large and small scales in a convecting atmosphere

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Motivation

- Task of any parametrization is to relate large and small scales to each other
- When early convection parametrizations were built, data on both scales was sparse
- Yet, almost all existing convection parametrizations are still based on ideas formulated then
- It is timely to revisit convection parametrizations with 21st century data
Starting point

- Need many samples of concurrent large and small scale observations
- ASR/ARM data provides a perfect background to do this
- Use three years of Darwin data 6-hourly to
  - build a large-scale data set using the variational analysis
  - build a small-scale data set using C-band radar data
Some questions

- Which variables show the strongest large to small scale relationships?
  - Is mass-flux a good variable for convection schemes?
- How stochastic is the problem?
  - Do we need fully stochastic convection schemes?
- How much memory is in the large-scale alone?
  - Do we need fully prognostic convection schemes?
Some basic relationships

- Total rainfall
- Convective rainfall

Factors:
- Large-scale $q$ convergence
- CAPE

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Some basic relationships

Relationship to large-scale q convergence

Domain-mean convective rainfall     Convective area fraction     Number of convective cells
Learning more about intensity

\[ I_c = \frac{\bar{R}_c}{f_c} = \frac{\bar{R}_c}{NA_i} \times A_0 \]

- **\( R_c \) - domain mean convective rainfall
- **\( f_c \) - convective area fraction
- **\( A_i \) - mean convective cell size
- **\( N \) - Number of convective cells

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How stochastic is convection?

- Both mean and standard deviation increase with large-scale “forcing”.
- However, the signal to noise ratio decreases.
- Hence, overall convective behaviour becomes more “predictable” as the “forcing” increases.
- This is contrary to some implementations of “stochastic” convection.
Back to 1974 - The convective moisture budget

How is moisture supply distributed among rainfall and moistening of the grid-box?

Column Moistening ($\Delta q$) vs Moisture input ($M_t$)

Prec/$\Delta q$ vs $M_t$

Colours indicate mean rainfall (grey=0; red=large)

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Back to 1974 - The convective moisture budget

How is moisture supply distributed among rainfall and moistening of the grid-box?

\[ P = (1 - b)M_t \]

\[
\frac{1}{g} \int_0^{p_0} \frac{\partial q}{\partial t} dp = \Delta_i q = bM_t
\]

\[
M_t = -\frac{1}{g} \int_0^{p_0} \nabla \cdot \bar{v} q \cdot dp + E_s
\]

\[ b = \frac{\Delta_i q}{\Delta_i q + P} \]

Kuo parameter \( b \) vs \( M_t \)

Colours indicate mean rainfall (grey=0; red=large)

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Conclusions and next steps

* ASR/ARM data provides a great opportunity to revisit key ideas in convection parametrization

* More observational analysis is required - add another location

* Run “forced” CRM for three years and compare the results with the observations

* Run large-domain “free” CRM and compare results with the observations

* Define key variables and relationships as design specs for a new parametrization
Thank you!