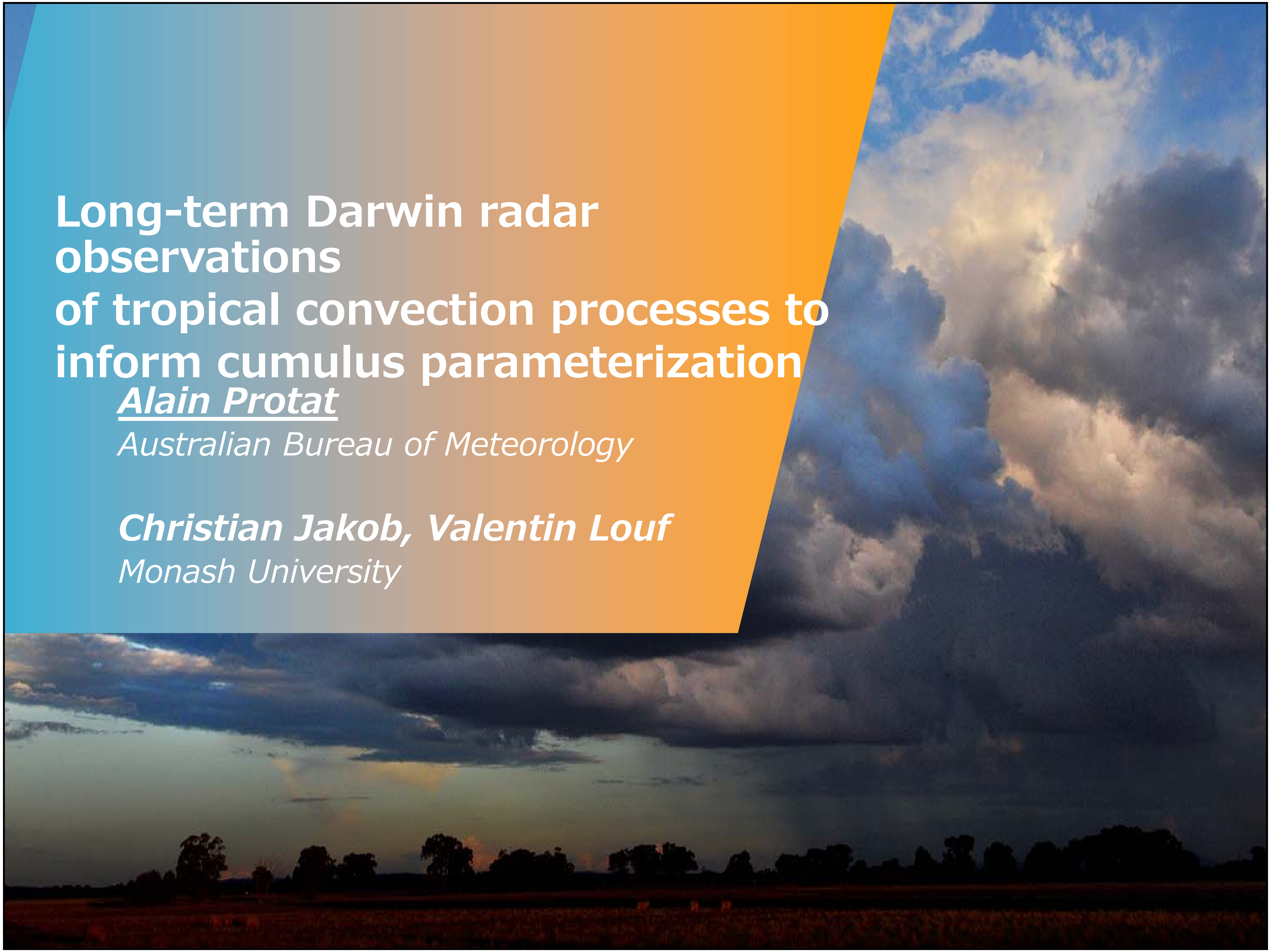

Long-term Darwin radar observations of tropical convection processes to inform cumulus parameterization

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Australian Bureau of Meteorology

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Motivation

- Tropical convection is still a major modelling challenge (at all scales)

- Although explicit convection at global scale will happen eventually, convective parameterizations will still be needed for a while (20 years ?)

- Major known deficiencies of most cumulus parametrizations are :

  - No co-existence of different types of convection
  - No convective organization
  - Relationship to large-scale assumed deterministic
  - No memory, no propagation (local in space and time)
  - Poor microphysics
  - No easy / physical way to deal with variable resolution of host model

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Radar to inform cumulus parameterization

- The best way to get quantitative information on statistical properties of convection at high resolution (1-2 km, 5-10 minutes) at the scale of a GCM grid box is a weather radar. Need lots of observations (many years) to build statistics and investigate processes and variability.

- Unravelling the relationship between sub-grid scale convective properties (as observed by radar) and the large-scale environment resolved by the model is the bread and butter of cumulus parameterization.

- Good estimates of large-scale parameters can be obtained from so-called "variational forcing analysis" using sounding arrays or model analysis + radar rainfall (e.g. Davies et al. 2013)

- Our approach : using 17 years of tropical radar data and associated large-scale forcing analysis to characterize tropical convection properties and their variability as a function of the

Darwin dataset: 1998 – 2017 (17 years)

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- **C-band dual-polarization (CPOL) Doppler radar**

  (+ Berrimah operational C-band Doppler radar for dual-Doppler retrievals)

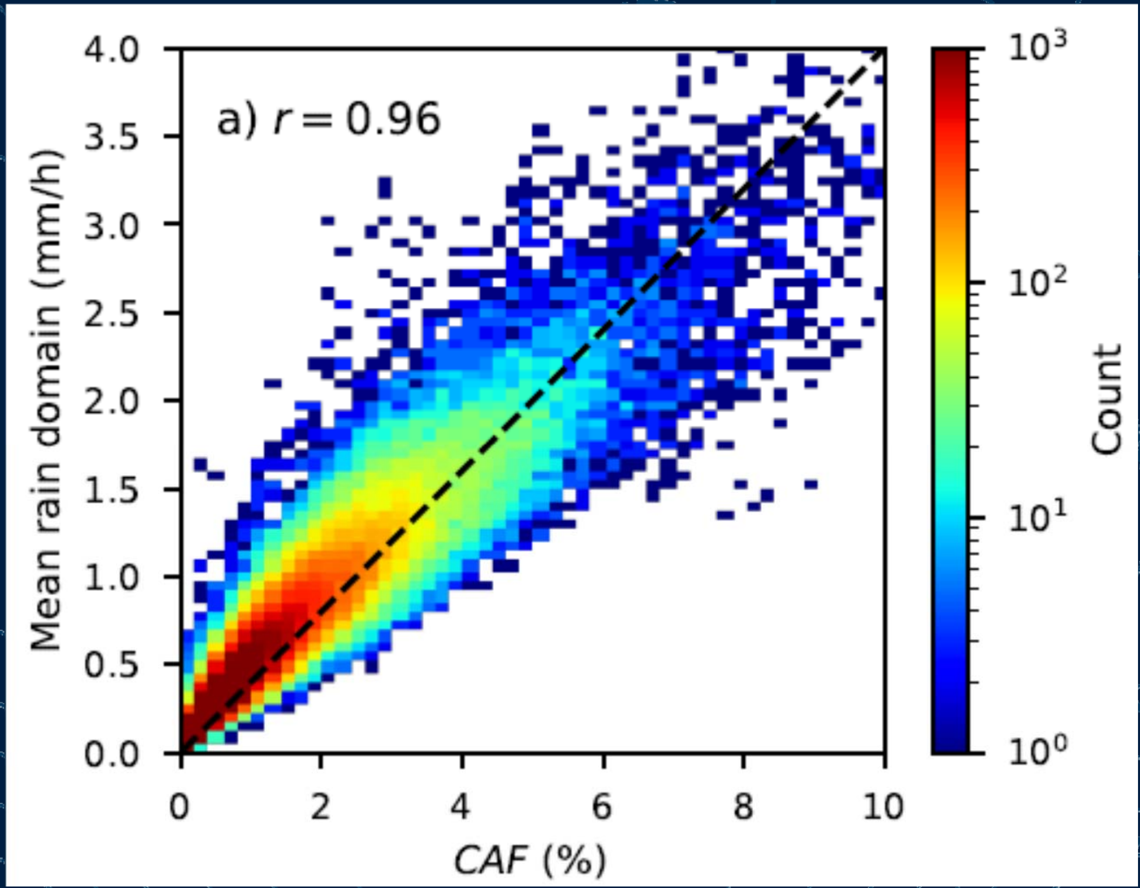
  - Range 150 km (so 300km domain) / 10-minutes 3D scan strategy
  - Constructed gridded data at :
    - 300 x 300 km domain, 2.5 km resolution
    - 150 x 150 km domain, 1.5 km resolution
  - *Existing products* : reflectivity, ETH, conv/strat classification, rainfall rate, hydrometeor classification, DSD parameters, convective and stratiform area fractions, parameterized convective vertical velocity (Kumar et al. 2016, JAMC)
  - *Products coming soon* : 3D winds (includes vertical velocity), pressure and temperature perturbations (cold pool detection), convective mass flux, TITAN convective cell tracking

- **Large-scale forcing variational analysis**

- **UHF + VHF Wind profiler dataset** :

Convective rain vs convective area fraction

(Re)-discovered strong relationship between rain rate and area fraction

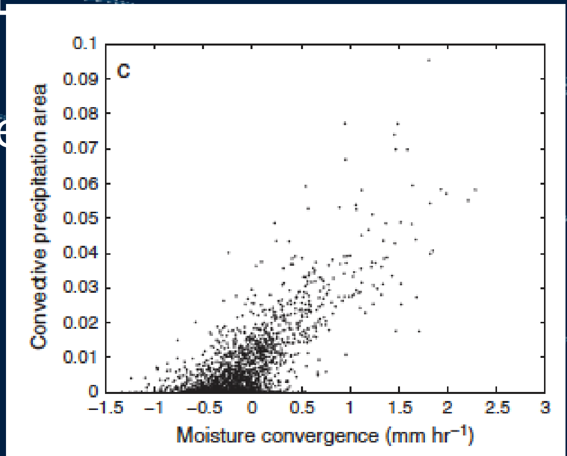


Increasing rain rate is achieved through increase of convecting area

What drives convective area fraction ?

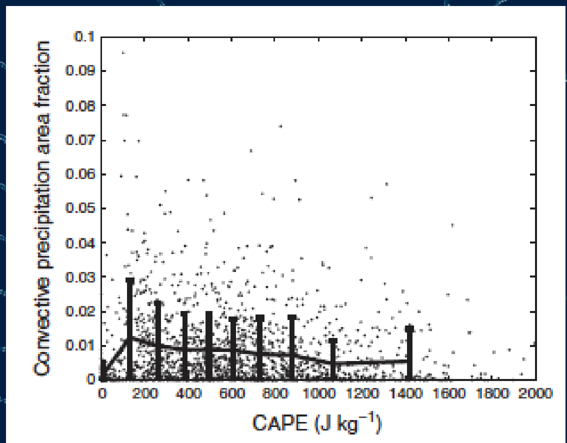
- Convective area fraction is strongly related to convergence (vertical motion, moisture), not to CAPE – most parameterizations use CAPE

Convergence

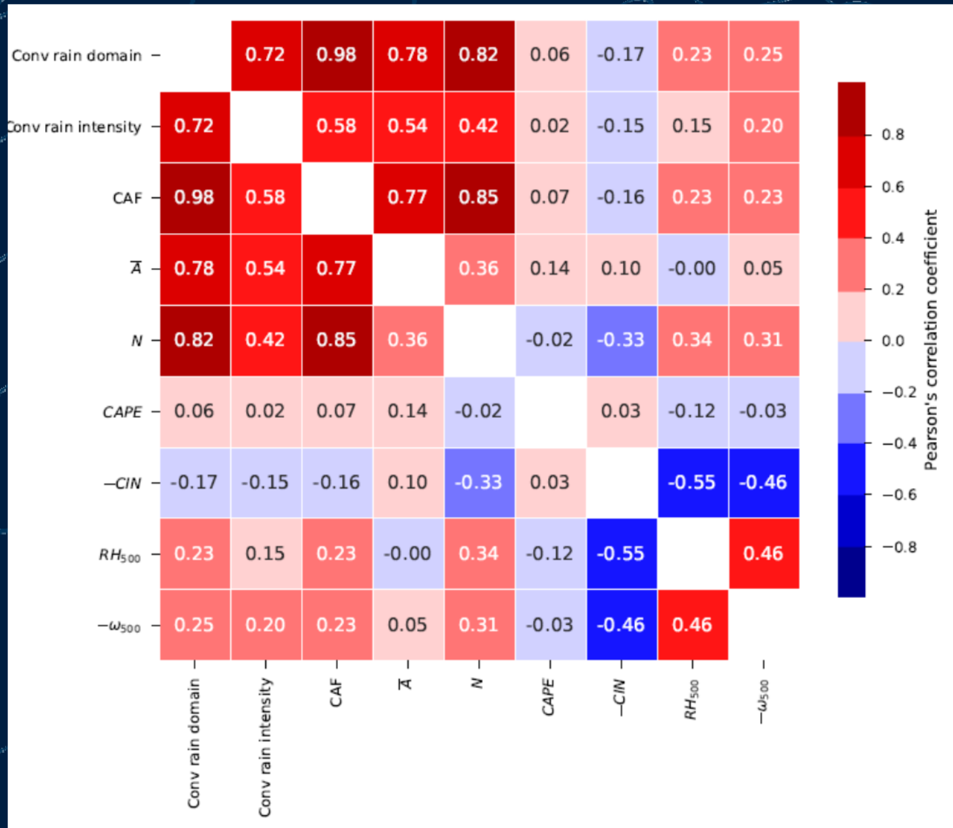


Davies et al., 2013, JGR

CAPE



Convective area fraction



	Conv rain domain	Conv rain intensity	CAF	$\overline{A}$	N	$CAPE$	$-CIN$	RH_{500}	$-\omega_{500}$
Conv rain domain		0.72	0.98	0.78	0.82	0.06	-0.17	0.23	0.25
Conv rain intensity	0.72		0.58	0.54	0.42	0.02	-0.15	0.15	0.20
CAF	0.98	0.58		0.77	0.85	0.07	-0.16	0.23	0.23
$\overline{A}$	0.78	0.54	0.77		0.36	0.14	0.10	-0.00	0.05
N	0.82	0.42	0.85	0.36		-0.02	-0.33	0.34	0.31
$CAPE$	0.06	0.02	0.07	0.14	-0.02		0.03	-0.12	-0.03
$-CIN$	-0.17	-0.15	-0.16	0.10	-0.33	0.03		-0.55	-0.46
RH_{500}	0.23	0.15	0.23	-0.00	0.34	-0.12	-0.55		0.46
$-\omega_{500}$	0.25	0.20	0.23	0.05	0.31	-0.03	-0.46	0.46	

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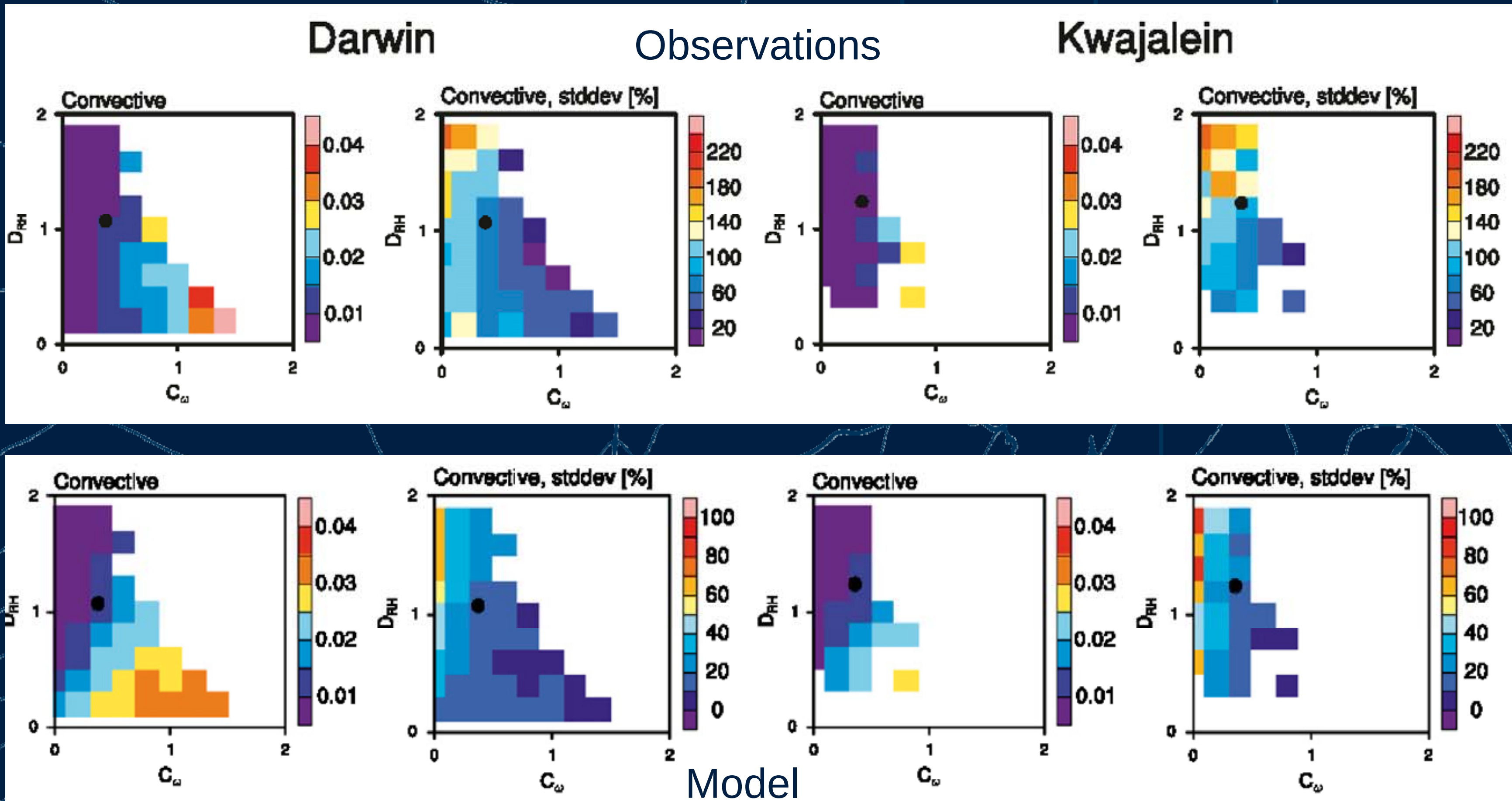
Using two predictors to constrain CAF

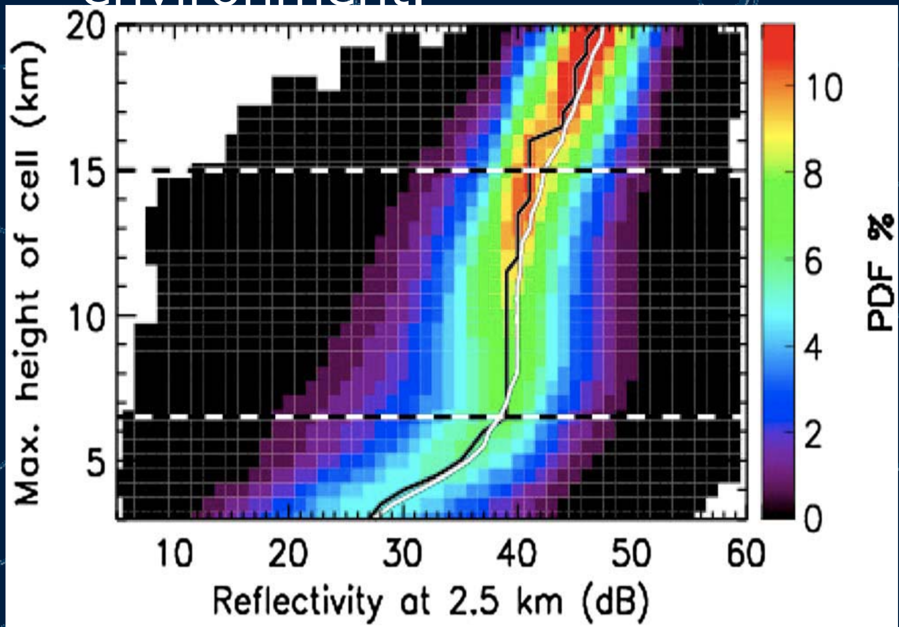
- GCM-resolved humidity and vertical velocity are great predictors to constrain convective area fraction. The degree of stochasticity of the relationship can also be constrained by these predictors.

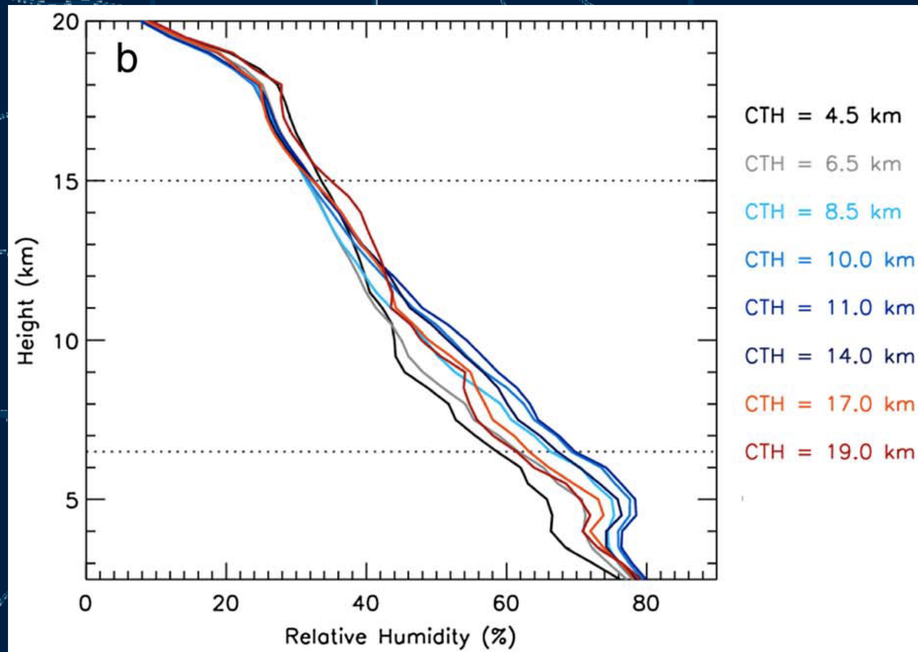


Peters et al., 2013, JAS

Convective types and associated rain

- Using CPOL radar echo top height, we identify 3 types of precipitating convection (not including shallow convection). The most extreme rainfall (at 10-mn timescale) originates in overshooting convection, which itself occurs in relatively dry environment.





CPOL 2.5 km Z as a function of ETH

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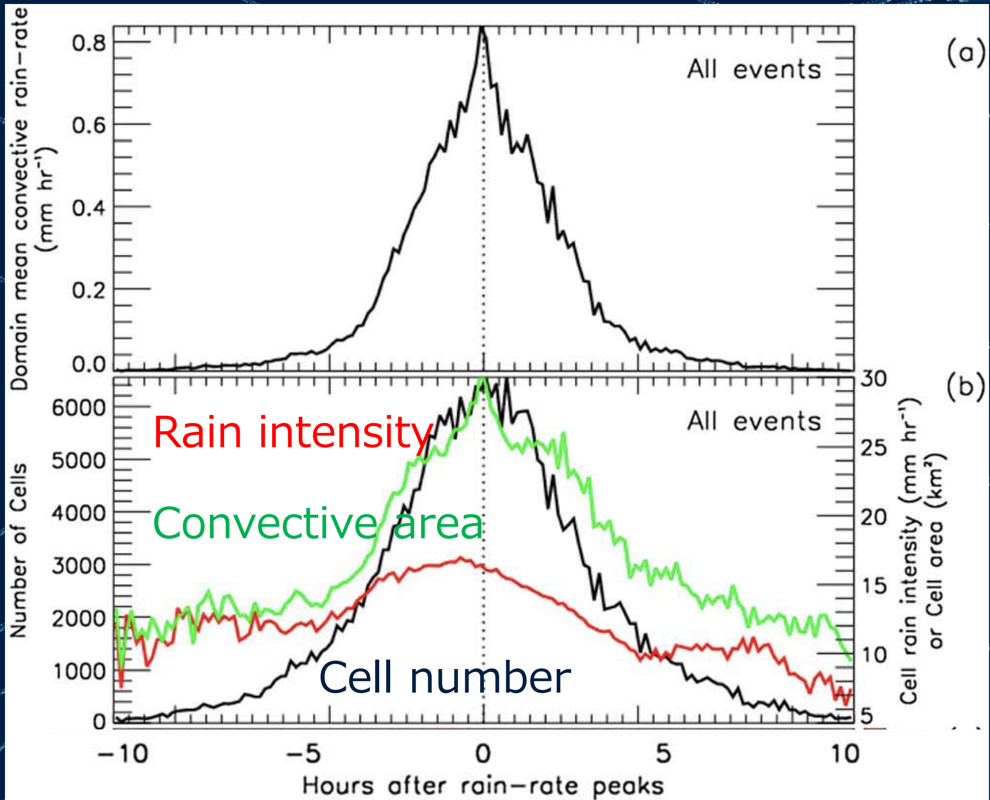
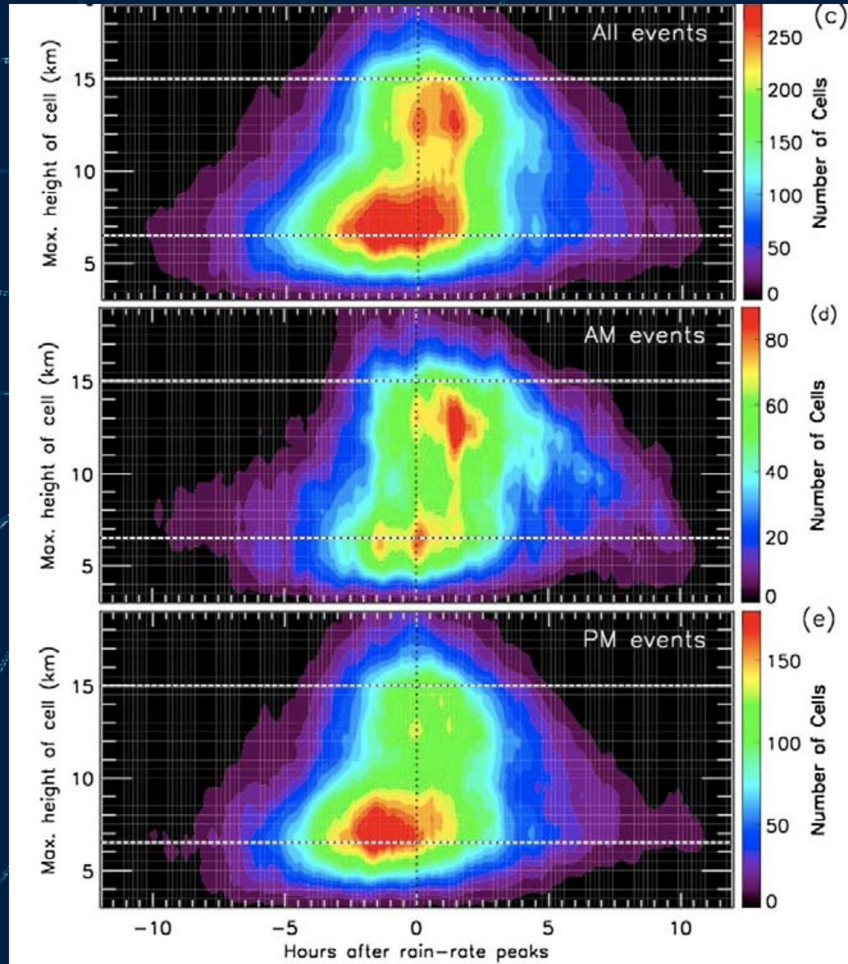
Convective Life Cycle: 144 heavy rain cases

- The composite time evolution confirms dominant role of area fraction. Gradual growth of cloud depth from congestus to deep, but they also coexist.



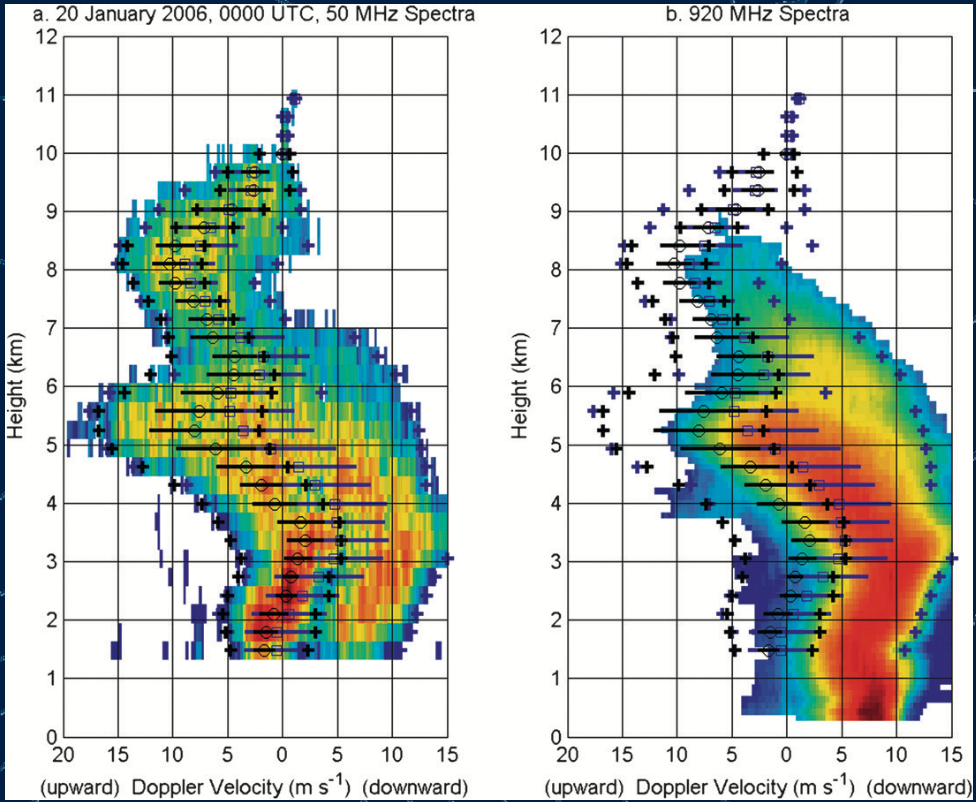


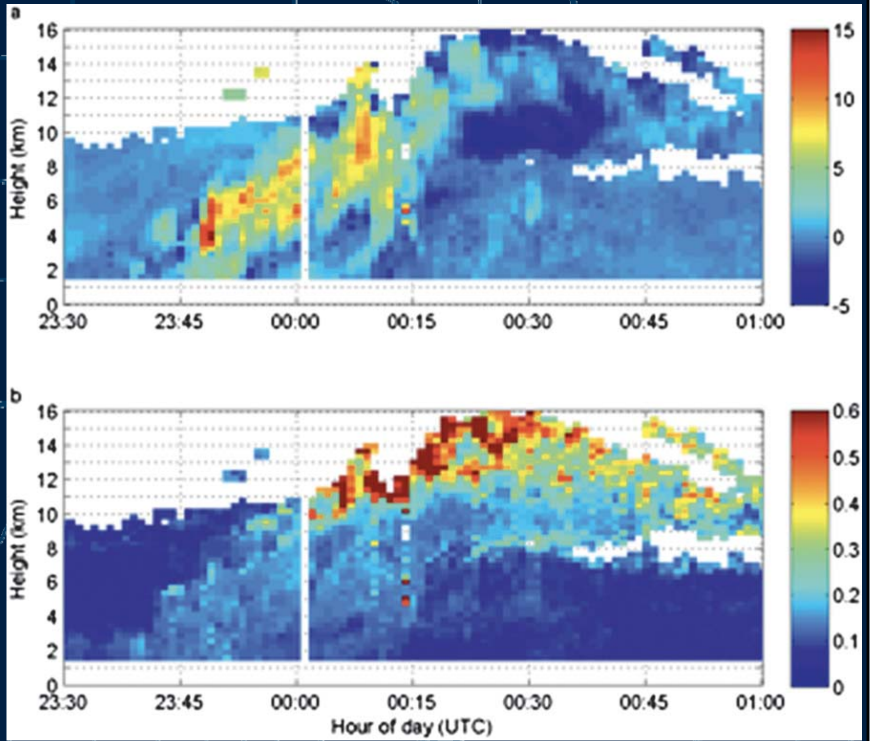
Kumar et al., 2013, JGR

Convective-scale dynamics

- A pair of wind profilers near CPOL radar allows us to retrieve convective vertical velocity

The basic idea



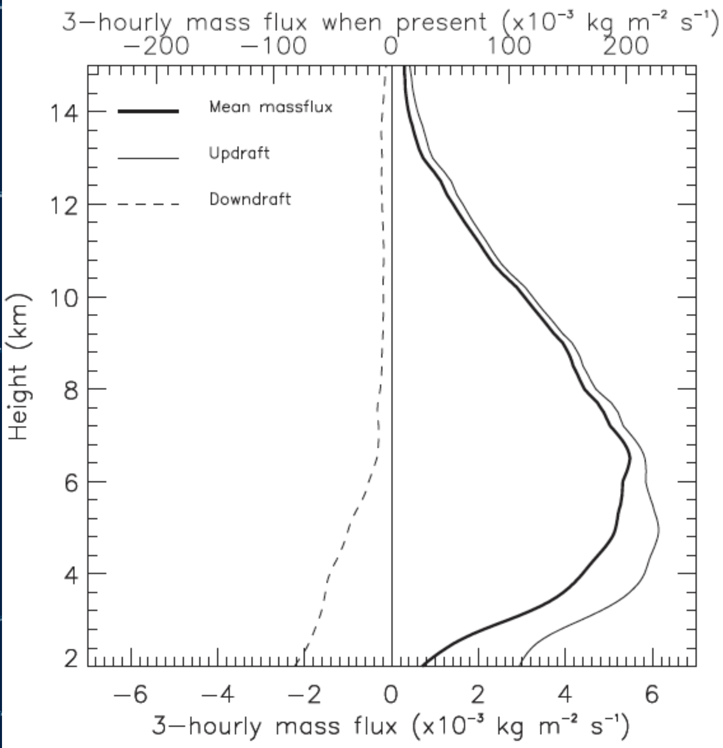


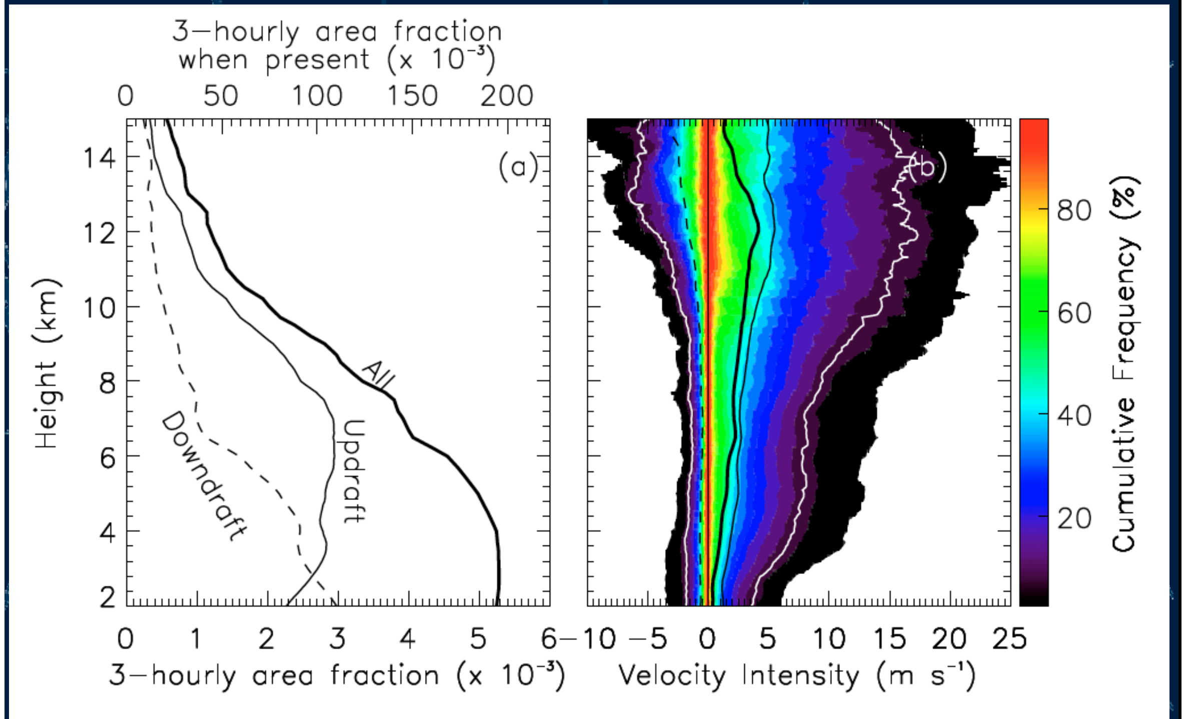
Protat and Williams, 2011, JAMC

Williams, 2012, JAOT

Convective mass flux estimates

- Vertical velocity + convective area fraction = convective mass flux and its components



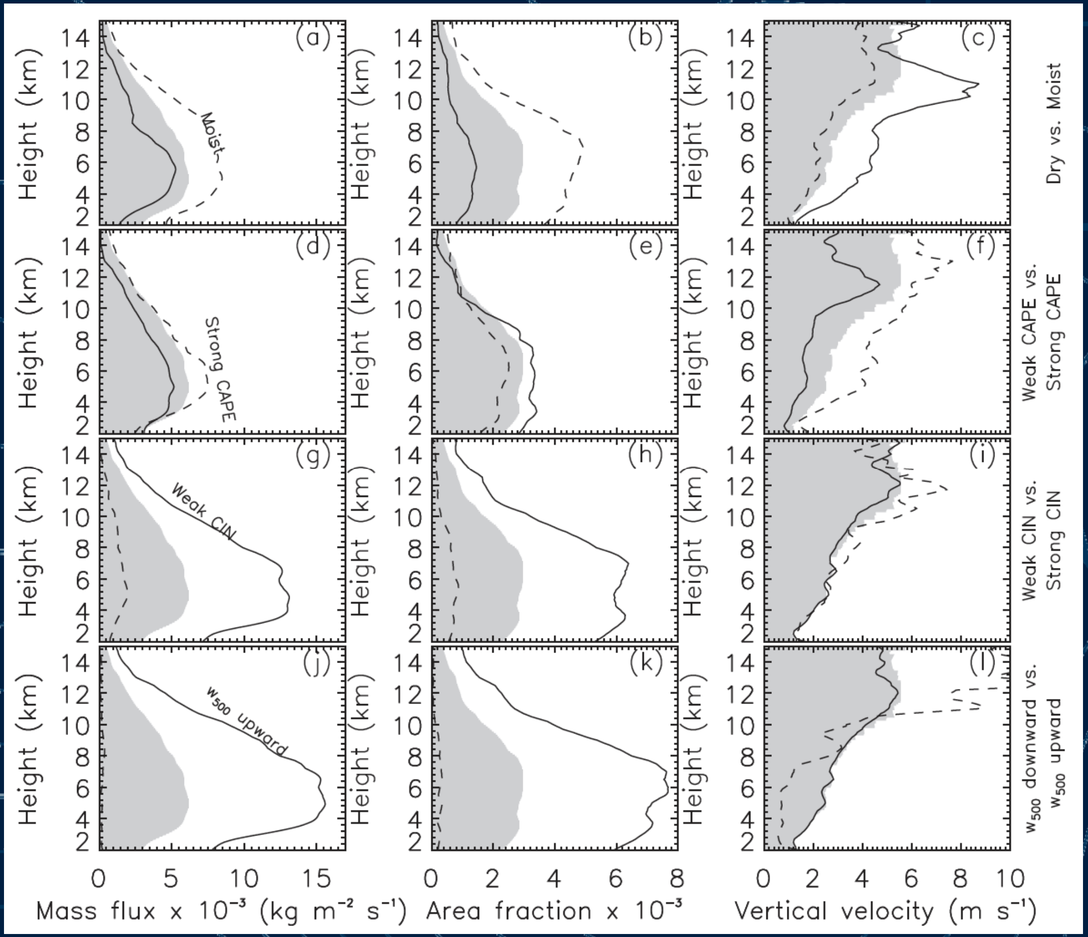


White line = 90th percentile

Kumar et al., 2015, JAS

Large-scale controls of convection

- Moisture strongly affects area fraction and velocity in opposing ways, CAPE mostly affects velocity and CIN and w_{500} control the existence of convection.



Moisture

CAPE

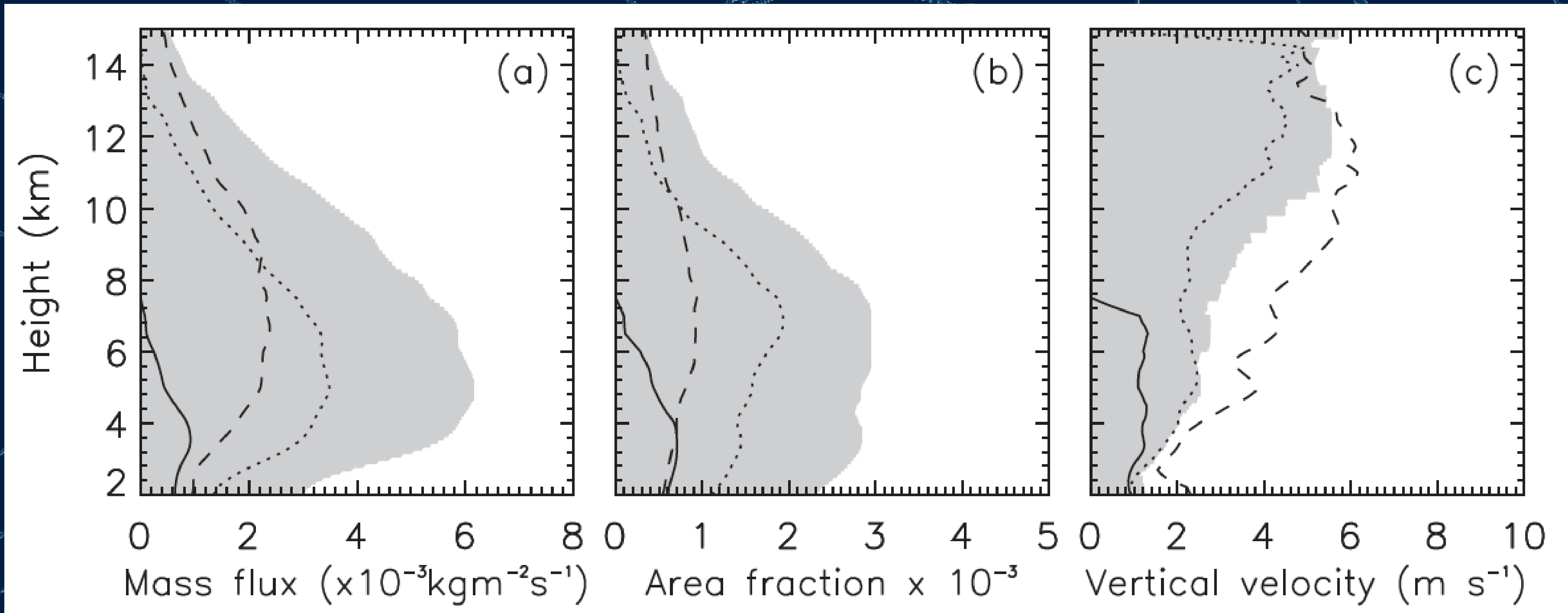
CIN

w_{500}

Kumar et al., 2015, JAS

Contribution of convection types to total convective mass flux

- The three convection types contribute to total mass flux in unique ways, with different vertical distribution.



Limitations of profiler :

Land – only

CAF not directly measured (time/space conversion)

Kumar et al., 2015, JAS

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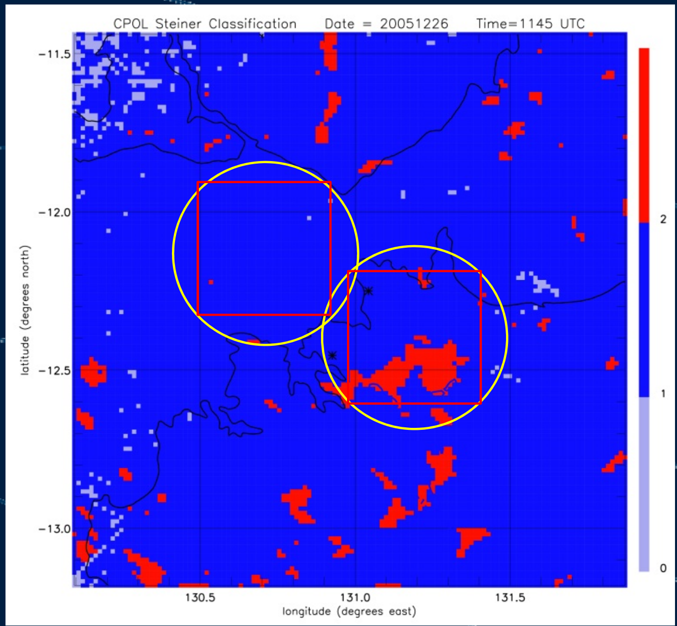
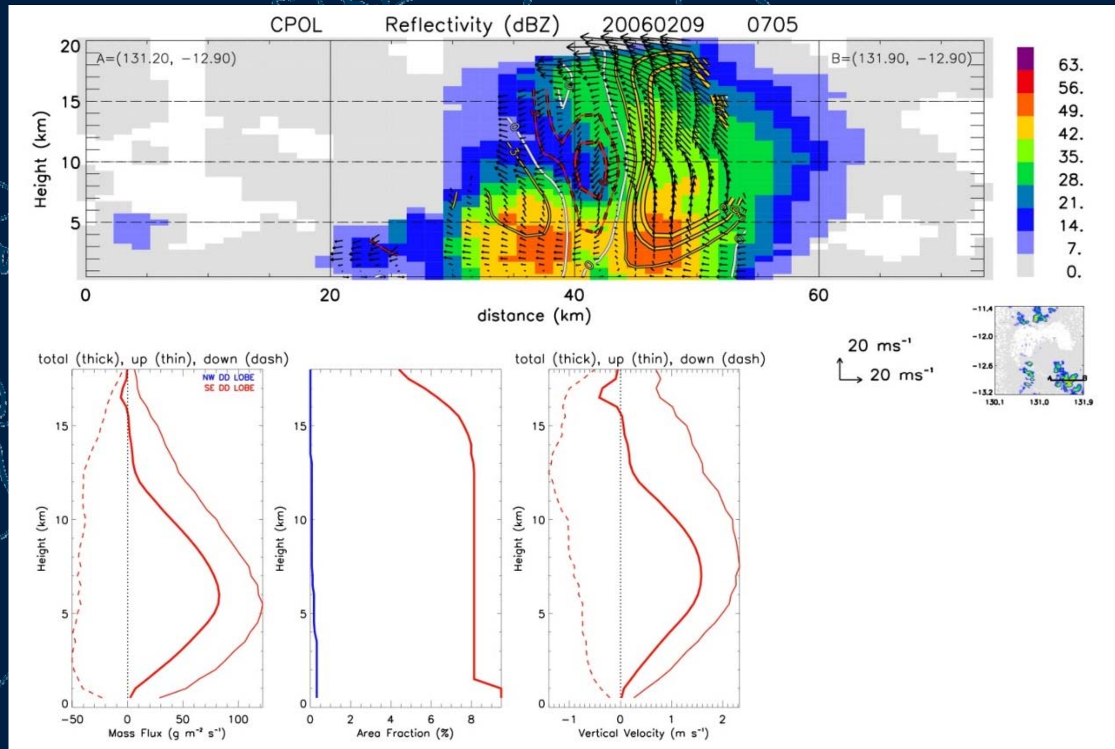
Next step : 3D wind retrieval + convective area fraction from CPOL radar





Red boxes are the two 80-km GCM grids for mass flux. One oceanic, one continental

New UNRAVEL Doppler dealiasing technique (Louf et al. 2019).
Next we will produce 17 years of dual-Doppler 3D winds and convective mass flux

Thermodynamic perturbations will also be retrieved (cold pool detection …)

Feeding this into the SMCM concept …

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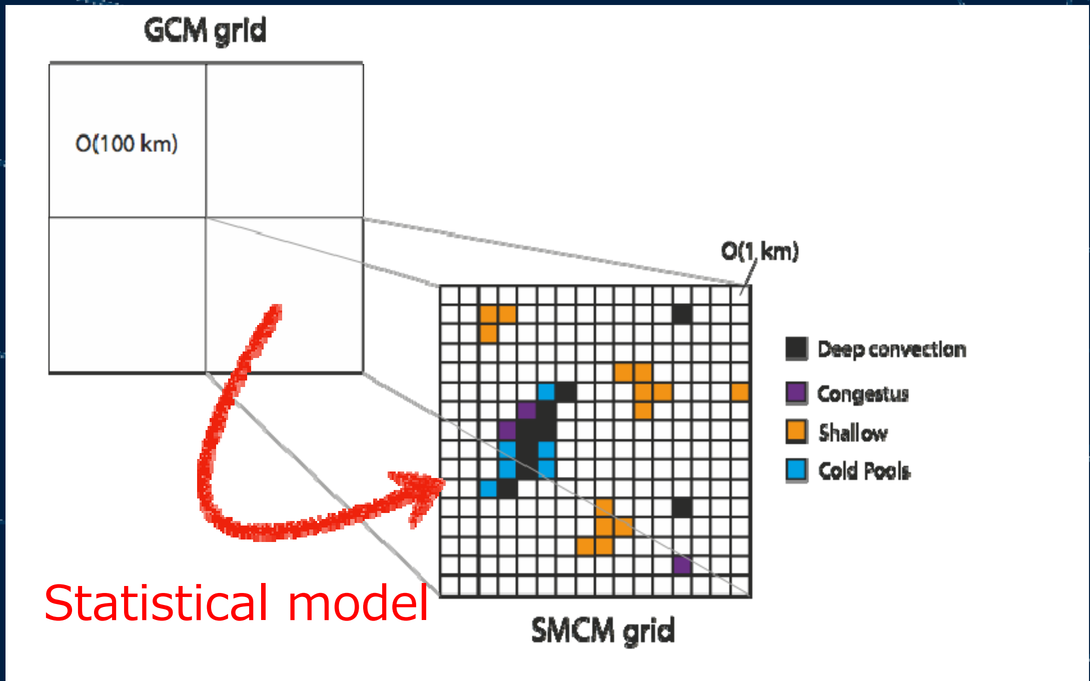
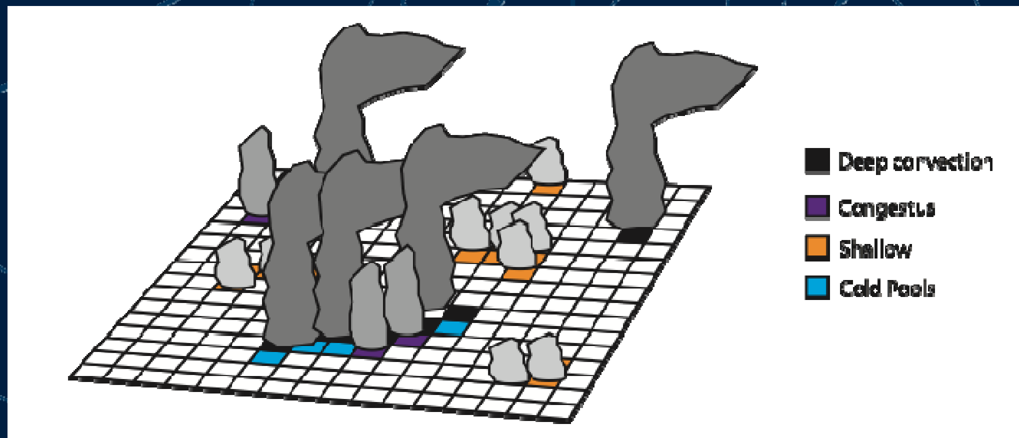


Physical model



Great, not my job …