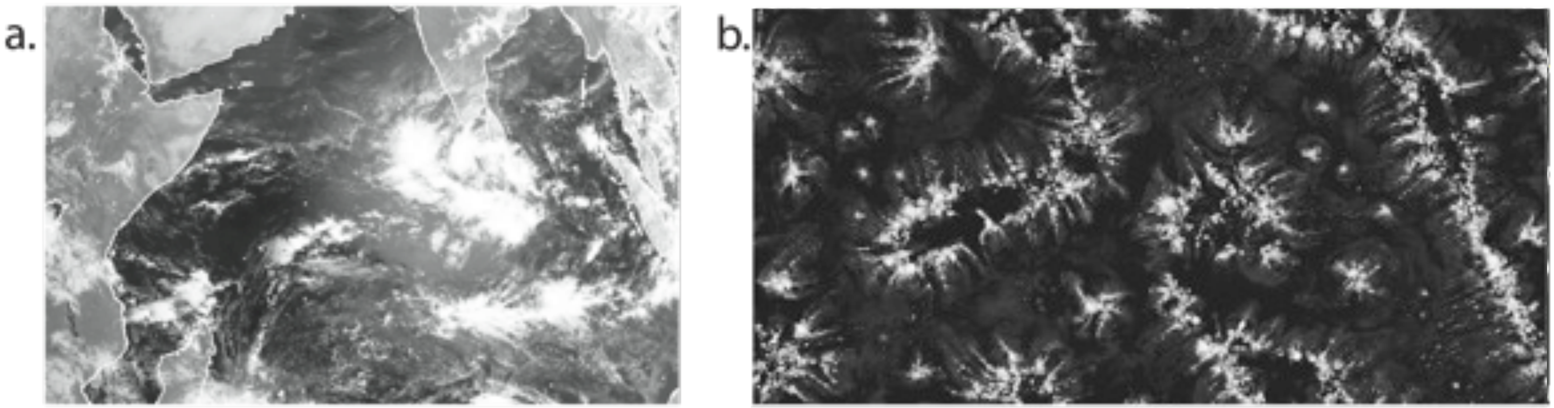
Wednesday 15 January, 2014, Tropical Dynamics Workshop, Honolulu

# The aggregation of tropical convection in observations, idealised models, and something in between.


Chris Holloway

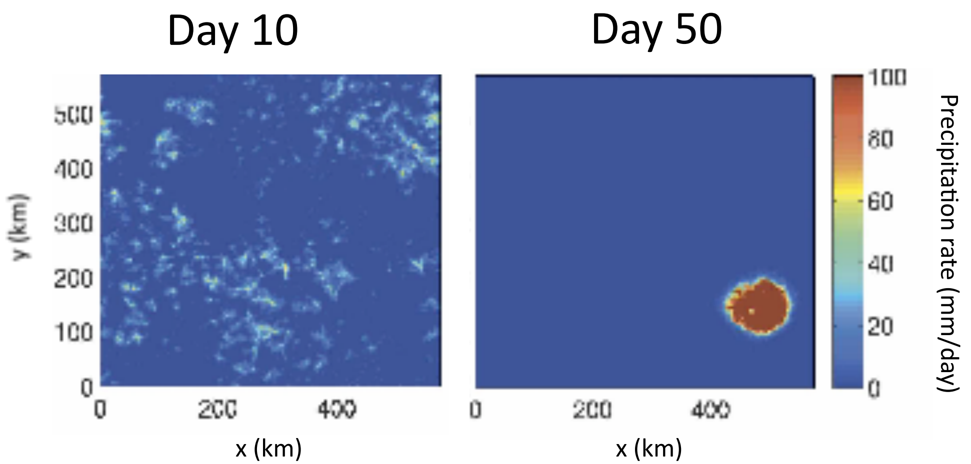
NCAS-Climate, Dept. of Meteorology, University of Reading

# Background: Organized tropical rainfall in idealized high-resolution models

- constant SST, no land, no Coriolis force (no rotation), periodic lateral boundaries
- initially scattered rainfall becomes aggregated into one region
- linked to feedbacks between convective rainfall, tropospheric water vapor, radiation, and surface fluxes

SAM model (CSU)




Bretherton et al. 2005

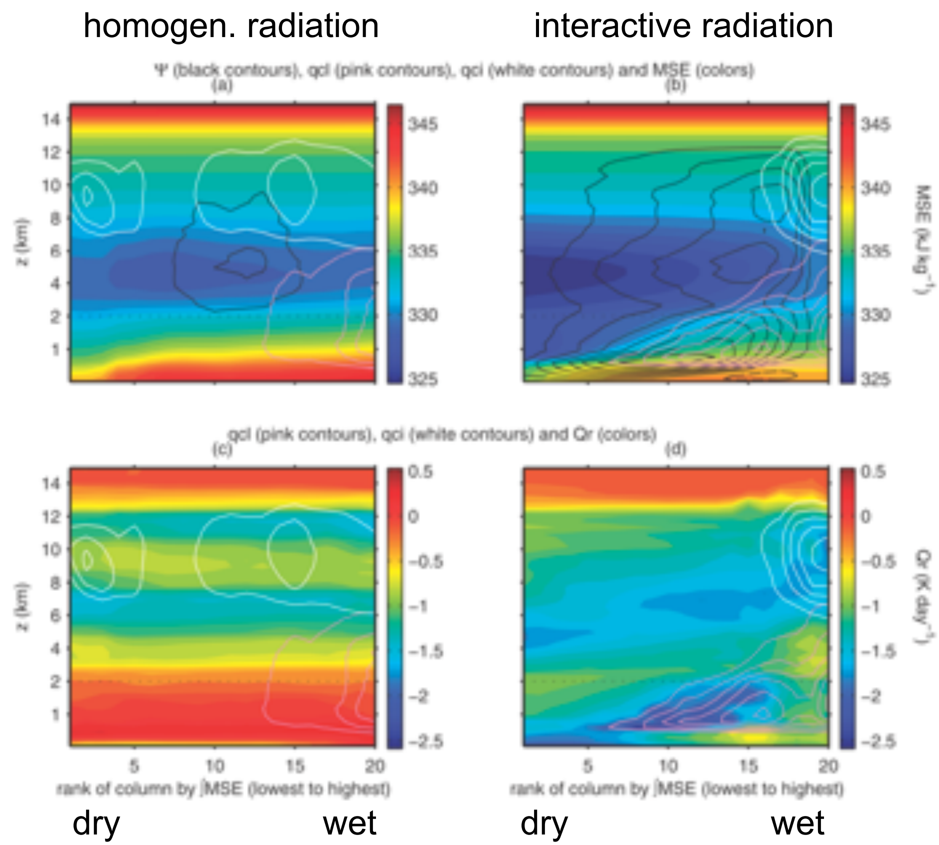
also previous work, e.g.:

Held et al. 1993 (2D Cloud-system resolving model [CRM] aggregation)

Tompkins 2001 (bands of convection in 3D CRM)

# hypothesised idealised self-aggregation mechanisms:

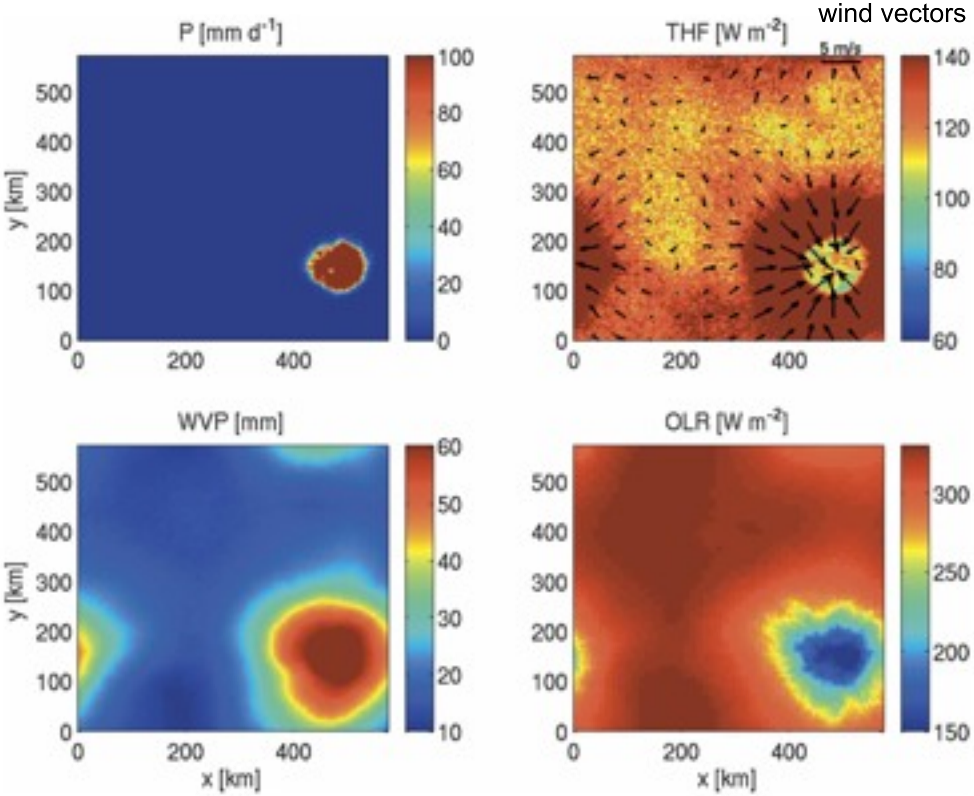
- low-level circulation forced by cooling at the top of the boundary layer in drier regions leads to moistening of moist, convective regions and drying of drier regions (vertical gradient of moisture/cloud at low levels is more negative in those regions)
- evaporation-wind interaction, stronger surface fluxes around moist, convective regions with strong low-level inflow leading to further moistening
- other moisture-convection feedbacks




Muller and Held 2012

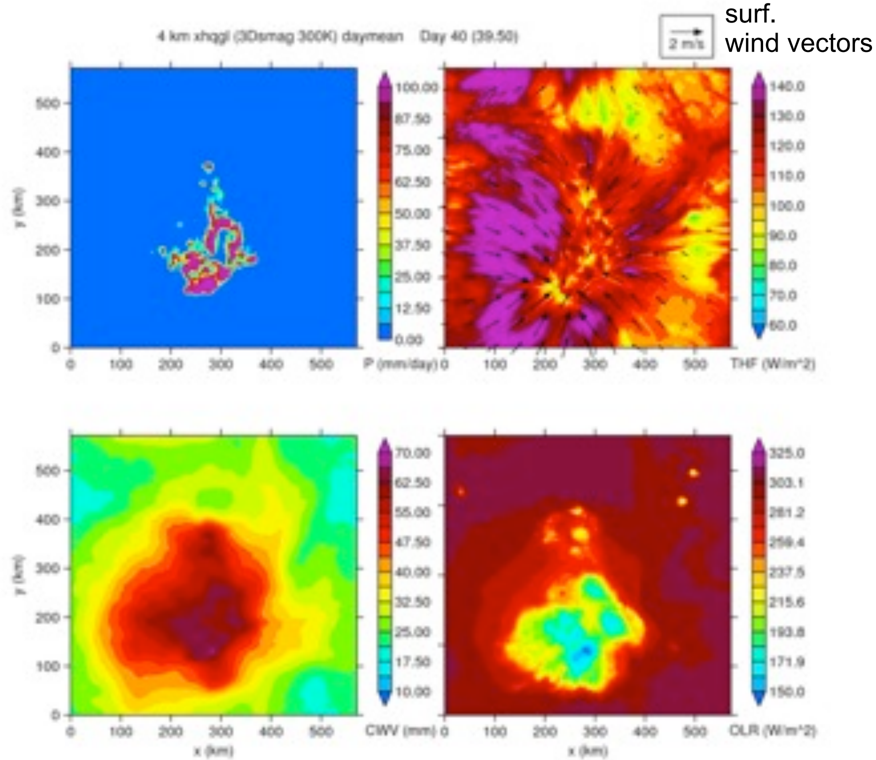
# Background: Organized tropical rainfall in idealised high-resolution models

SAM model (CSU)
3 km,   Day 50 mean



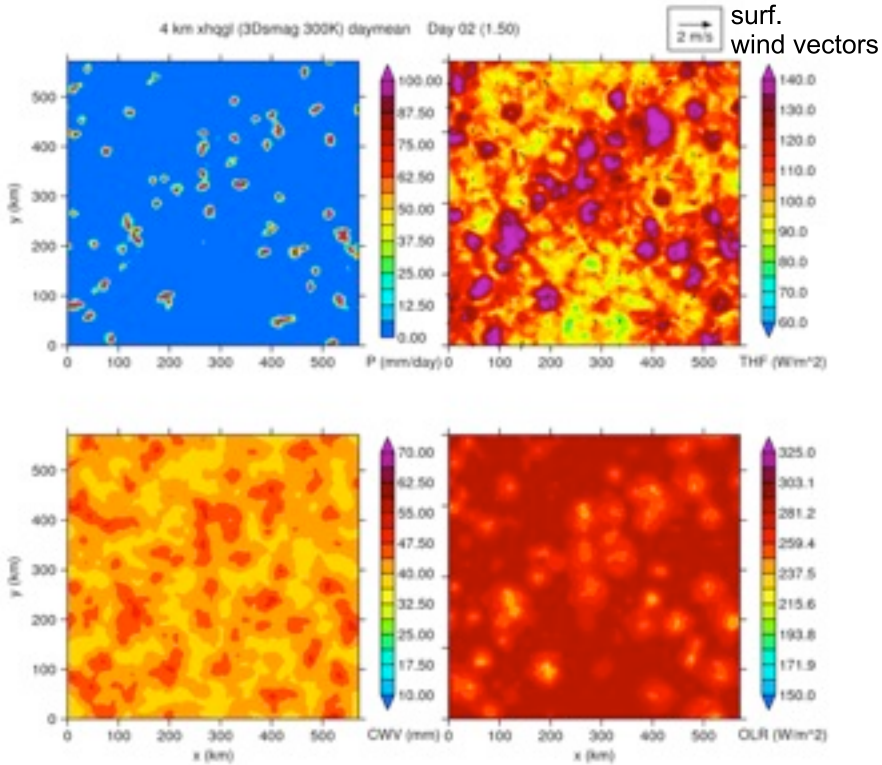

From Bretherton et al. 2005

UK Met Office Unified Model
4 km, Day 40 mean

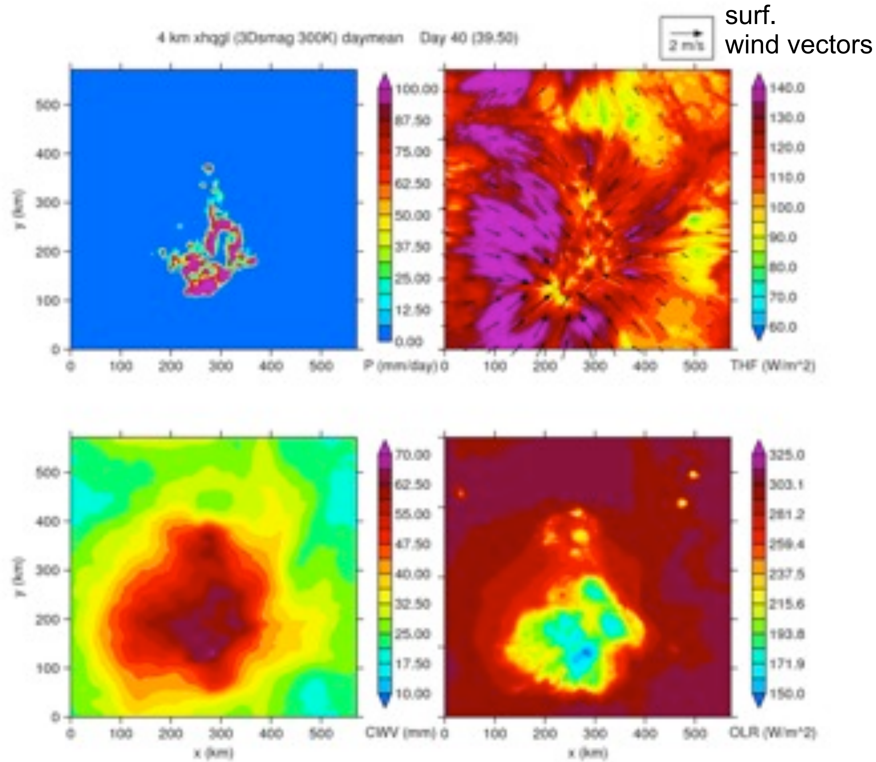


# Background: Organized tropical rainfall in idealised high-resolution models

UK Met Office Unified Model
Day 2 mean

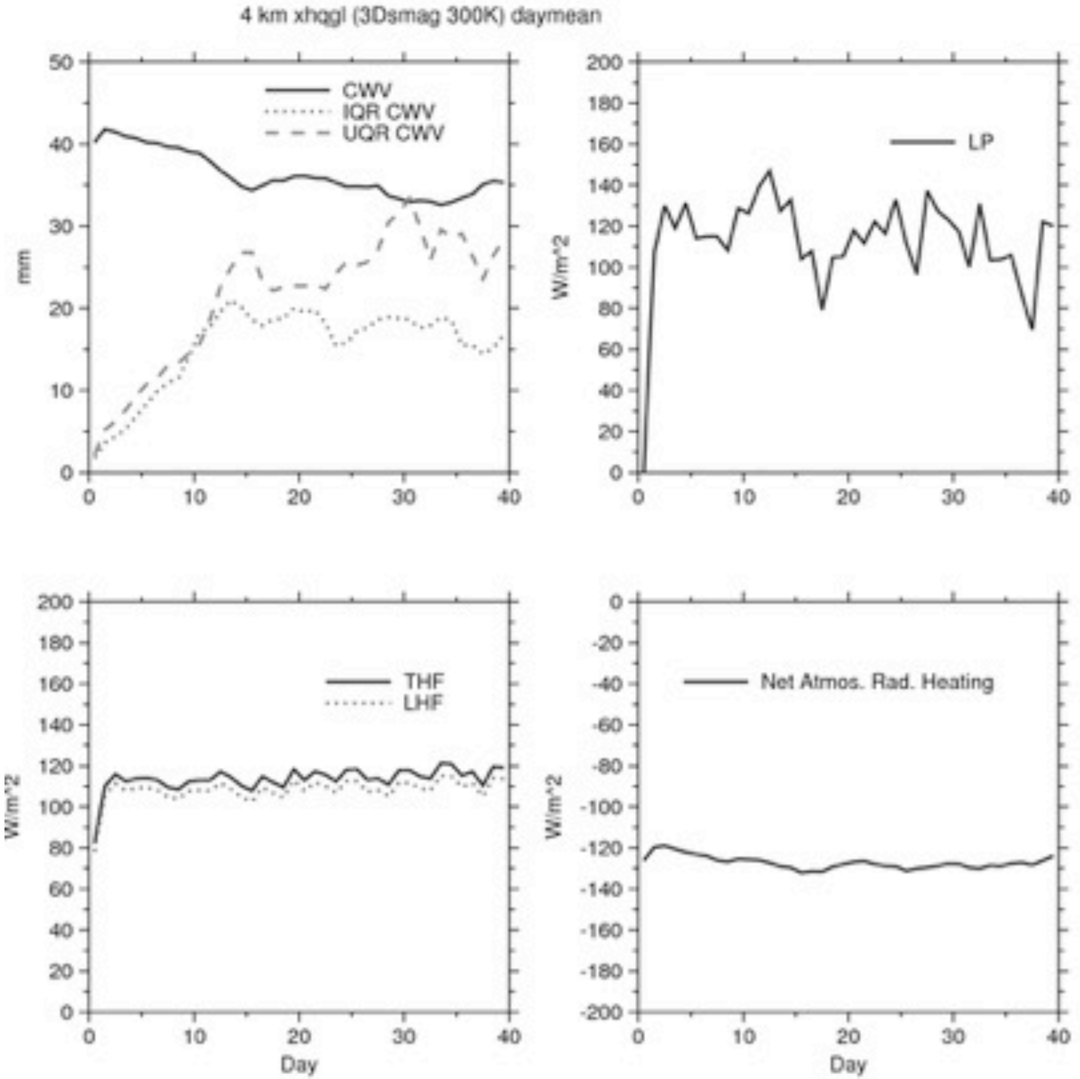



UK Met Office Unified Model
Day 40 mean




idealised model setup: 4 km, 3D-Smagorinsky mixing, explicit convection, Priestly moisture conservation, 3 prognostic microphysical fields

# Mean state dries (because of environment outside convection), mean OLR goes up with agg.

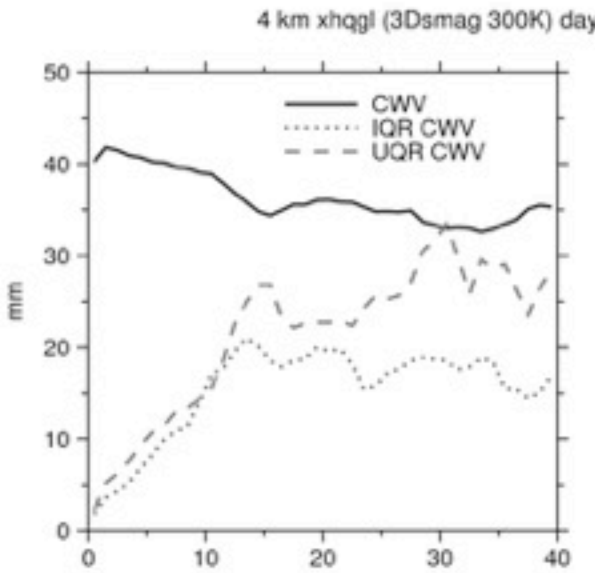



IQR = inter-quartile range of CWV
= 75$^{th}$ percentile – 25$^{th}$ percentile

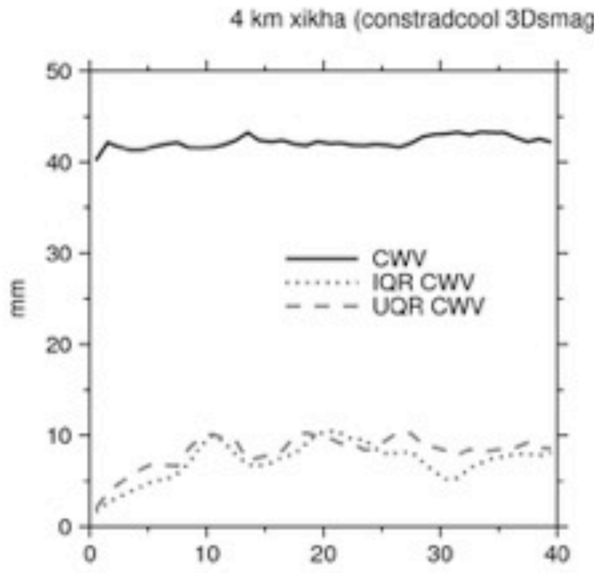
UQR = upper-quantile range of CWV
= 95$^{th}$ percentile – median

# Aggregation is slowed or reversed by non-interactive radiation

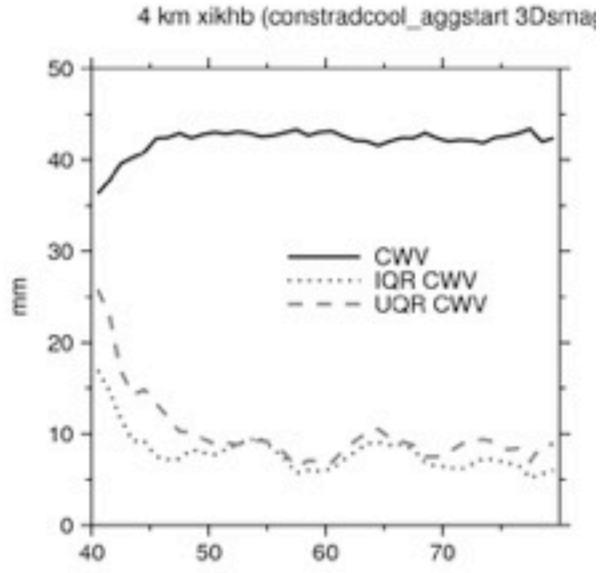
Control starting from homogeneous state



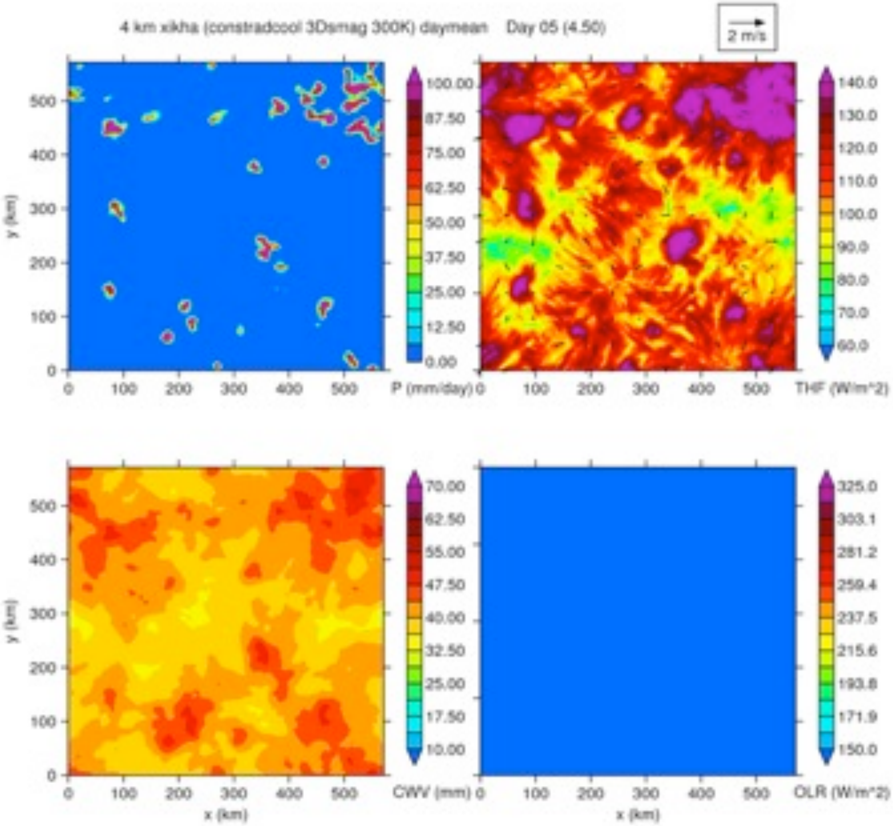

Const. radiation starting from homogeneous state

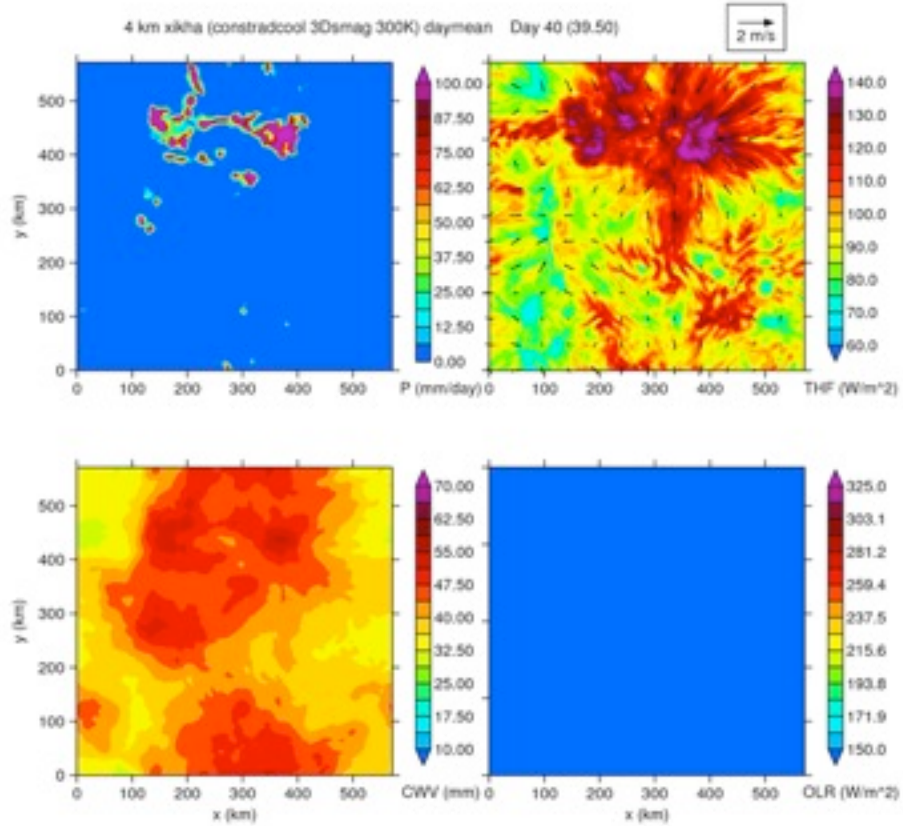



Const. radiation starting from aggregated state

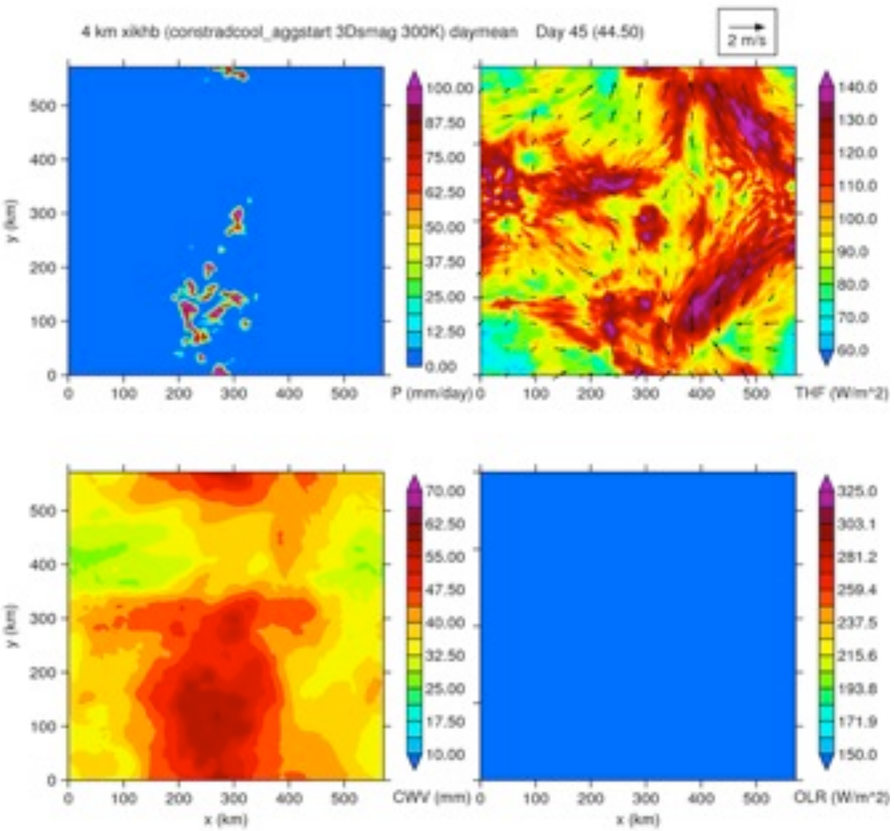


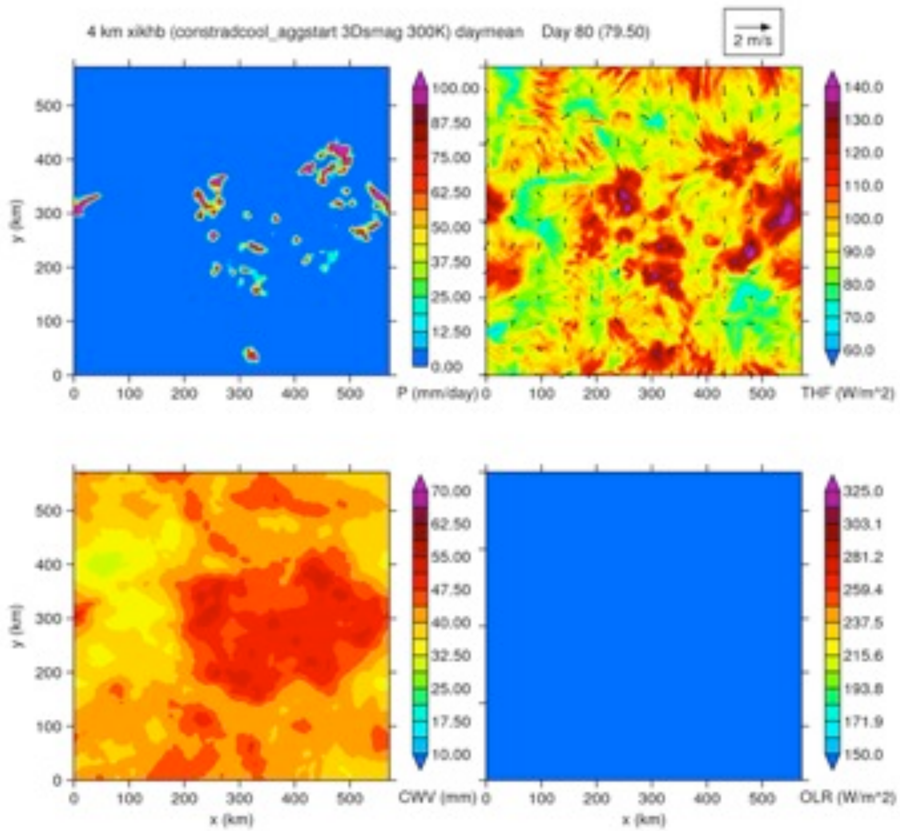
# idealised models 4km (starting with no radiation)



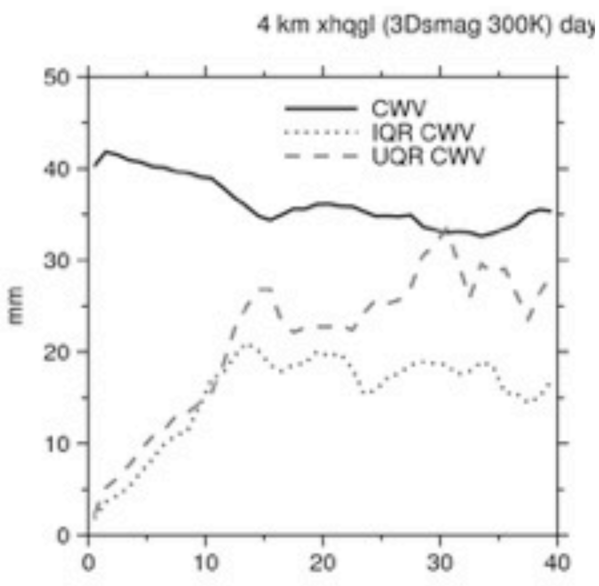
# idealised models 4km (no radiation after agg state)



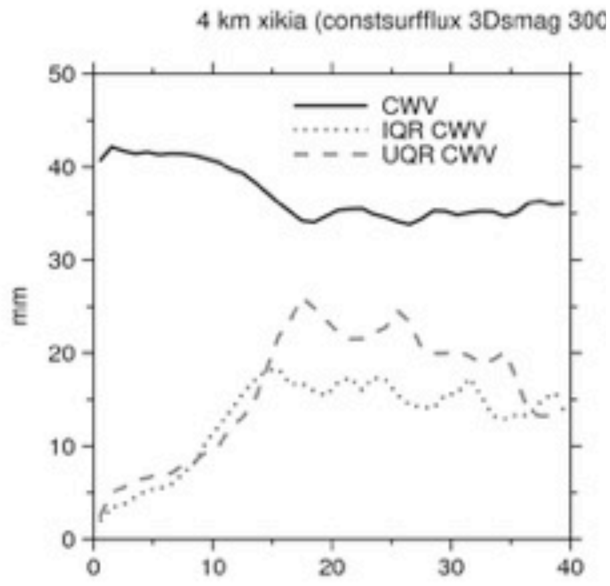



# Aggregation is slowed a bit by non-interactive surface fluxes

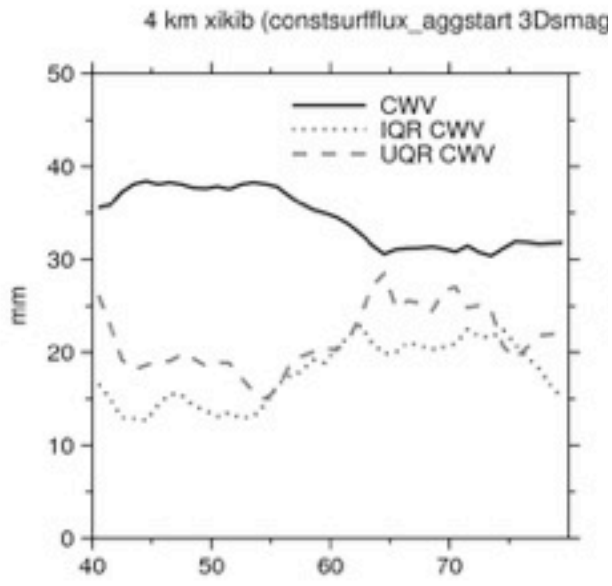
Control starting from homogeneous state




Const. surf. fluxes starting from homogeneous state




Const. surf. fluxes starting from aggregated state

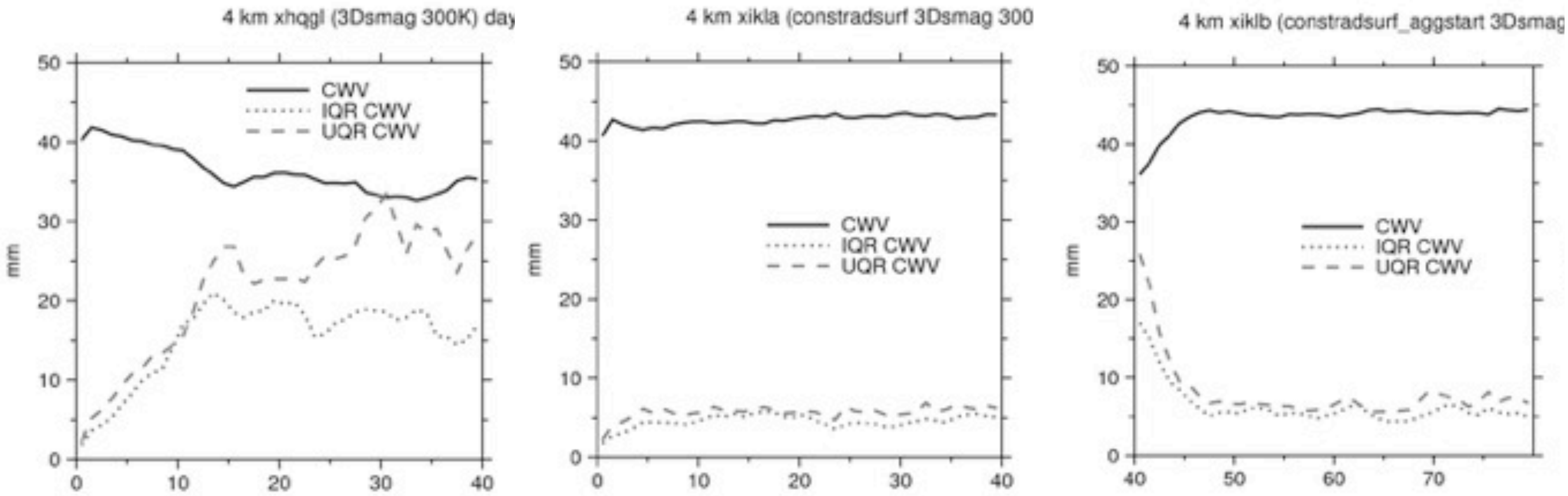


# Aggregation is slowed or reversed by combined non-interactive radiation and surface fluxes

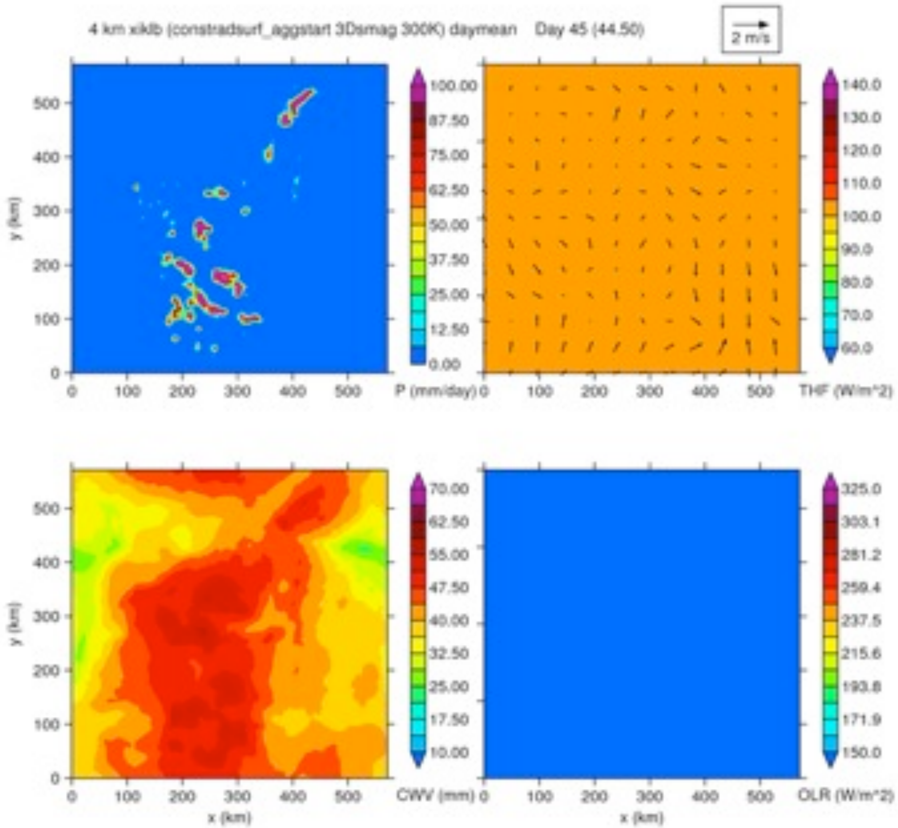
Control starting from homogeneous state

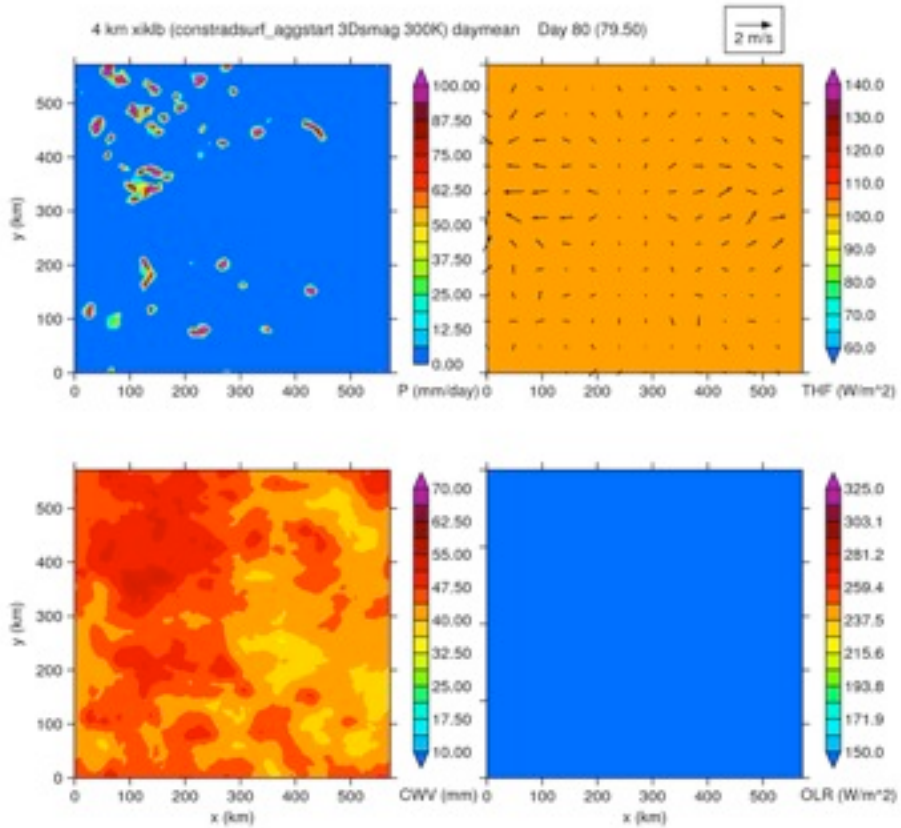
Const. radiation and surf. flux. starting from homogeneous state

Const. radiation and surf. flux. starting from aggregated state



# idealised models 4km (no rad and c. S.F. after agg. state)

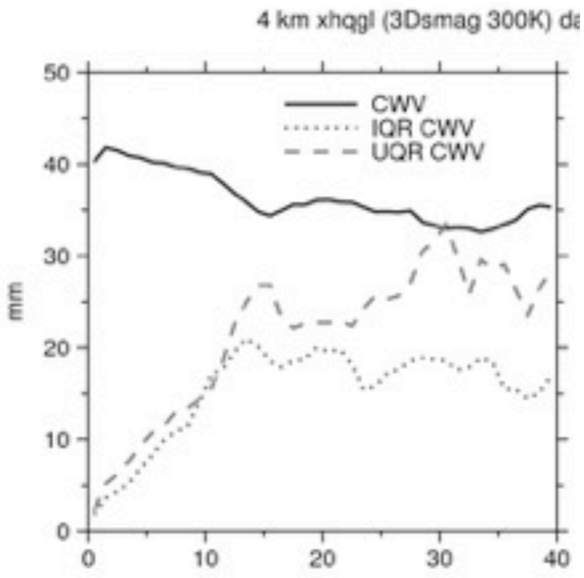


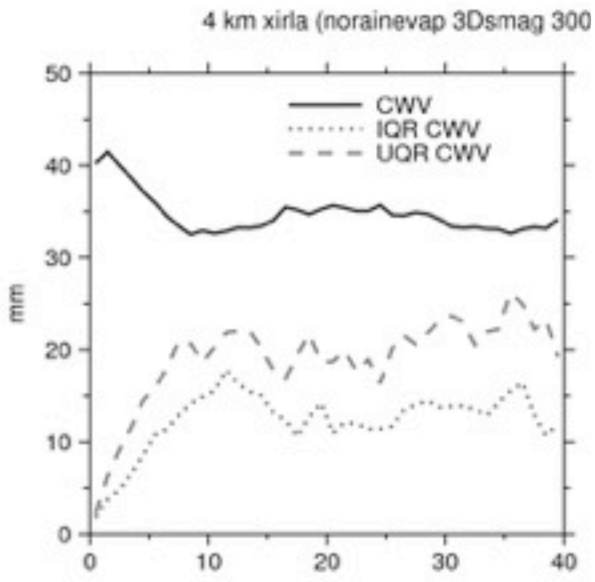
# cold pools slow aggregation

Jeevanjee and Romps 2013 argue that cold pools slow down aggregation by spreading low-level moisture from convective areas to the drier environment. We also see slower aggregation when we prevent cold pools by turning off the evaporation of rain in the UM.

Control starting from homogeneous state

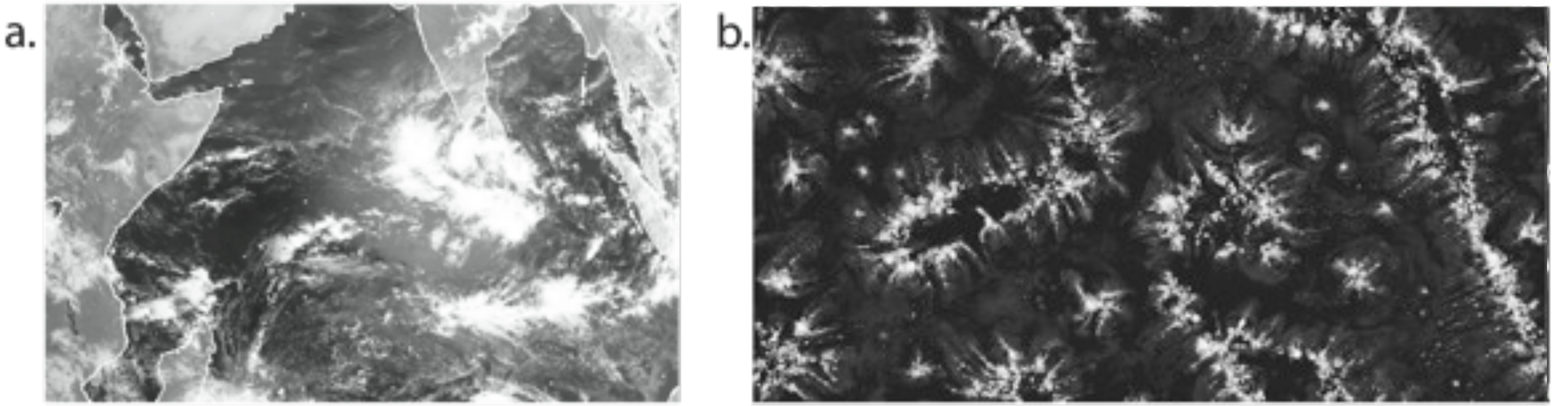



No evap. of rain starting from homogeneous state



## Current and Future Work

Can we find links between convective self-aggregation in idealized models and organized tropical convection in observations or more realistic simulations?



# Aggregation in Observations

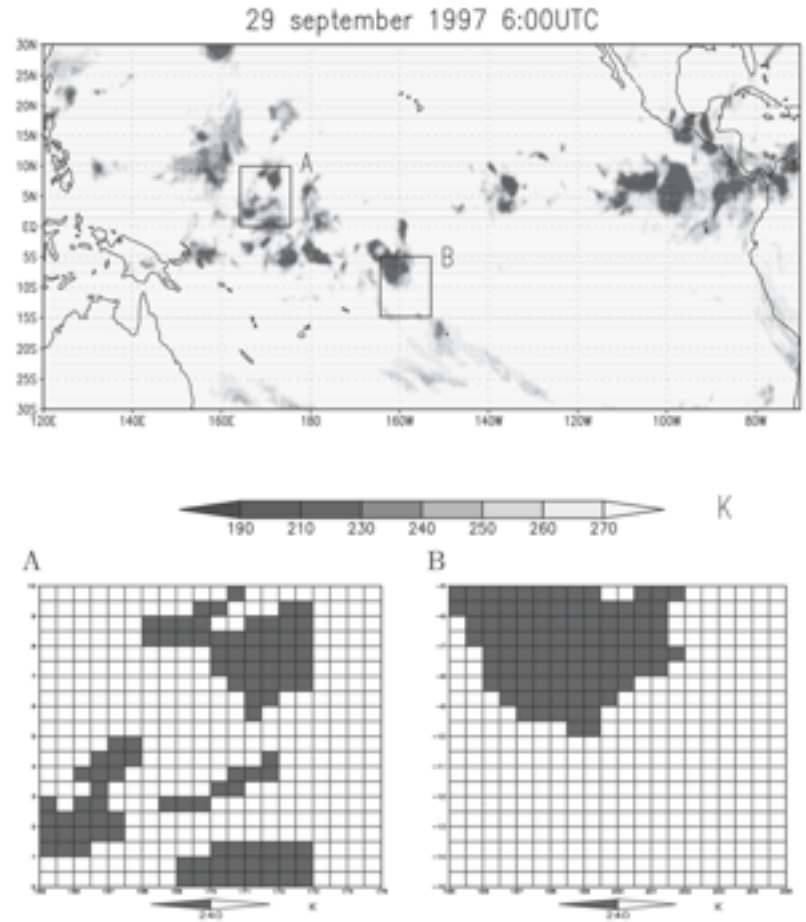
Tobin et al. 2012, Tobin et al. 2013 look at aggregation state in snapshots of tropical observations.

they define a "Simple Convective Aggregation Index" (SCAI) based on clusters with IR brightness temperature below 240 K :

$$\mathrm{SCAI} = \frac{N}{\mathrm{Nmax}} \frac{D_0}{L} \times 1000 = \tilde{N}\tilde{D}_0 \times 1000.$$

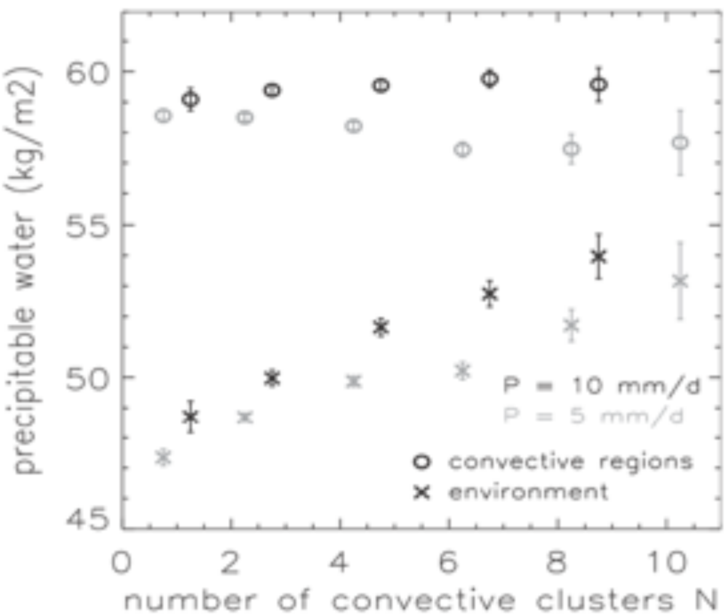
where N is the number of clusters and $D_0$ is the average geometric distance between clusters (with some constants used for normalisation). They found that N itself correlates extremely well with SCAI, and so they mostly use the smallness of N as a proxy for aggregation.

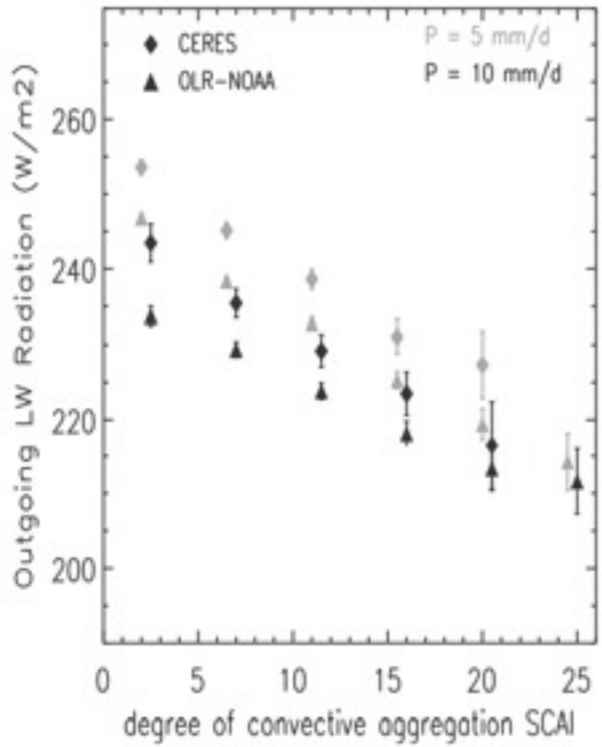
**Low SCAI** (or **N**) means **more aggregated**.



# Aggregation in Observations

Tobin et al. 2012 show that aggregation of convection in observations over 10°×10° boxes leads to some of the same things as in idealised models (when holding large-scale forcing roughly constant).



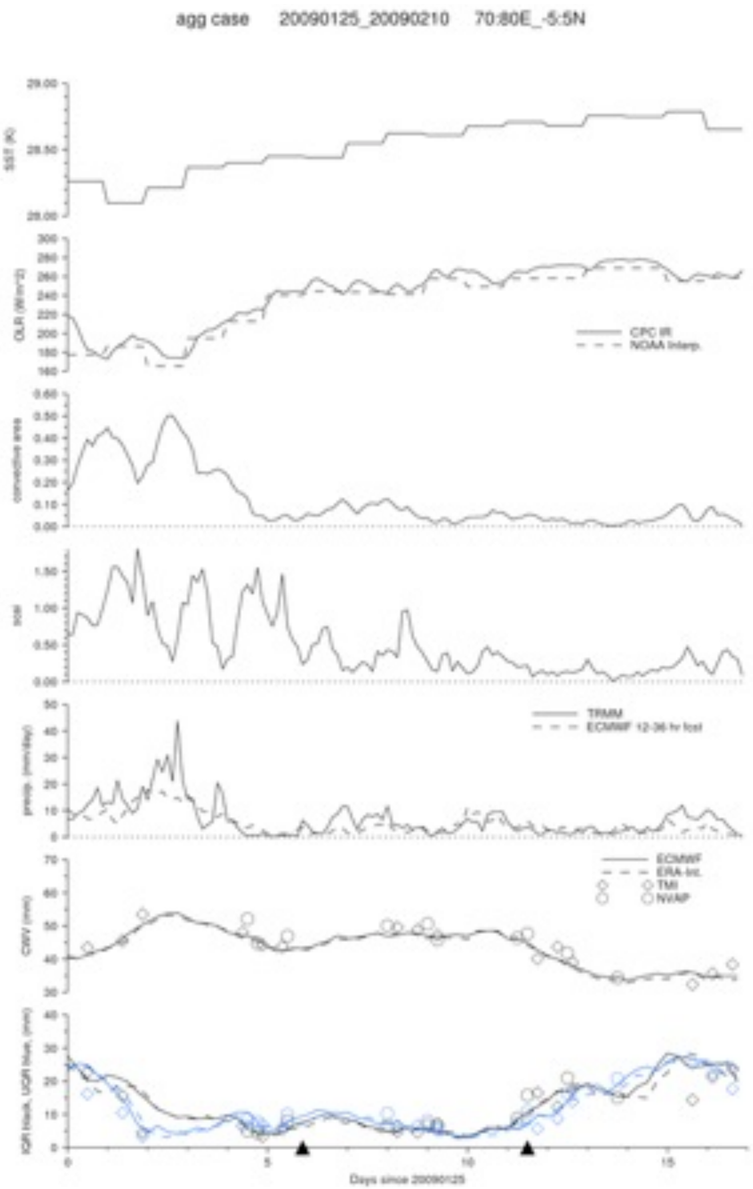
# observed "aggregation" cases during YOTC (May 2008- April 2010)

- 10°×10° box centered on equator, Indian or W. Pac.
- SST ≥ 26°C (299 K)
- convec. area ≥ 0.01
- precip. ≥ 3 mm/day
- SCAI < 0.5

minimum length for above criteria true = 5 days (but gaps of up to 12 hours are permitted)

in these 2 years, 166 cases (10°N – 10°S), 16 cases on equator, 5 in central/eastern Indian or W. Pacific (I will investigate these 5).

# first observed “aggregation” case: 25 (30) Jan to 10 (5) Feb 2009

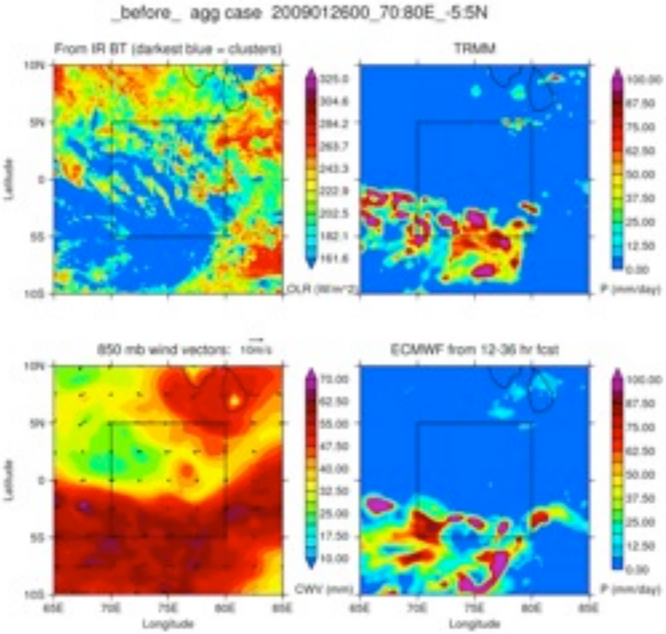


# first observed “aggregation” case: 25 (30) Jan to 10 (5) Feb 2009

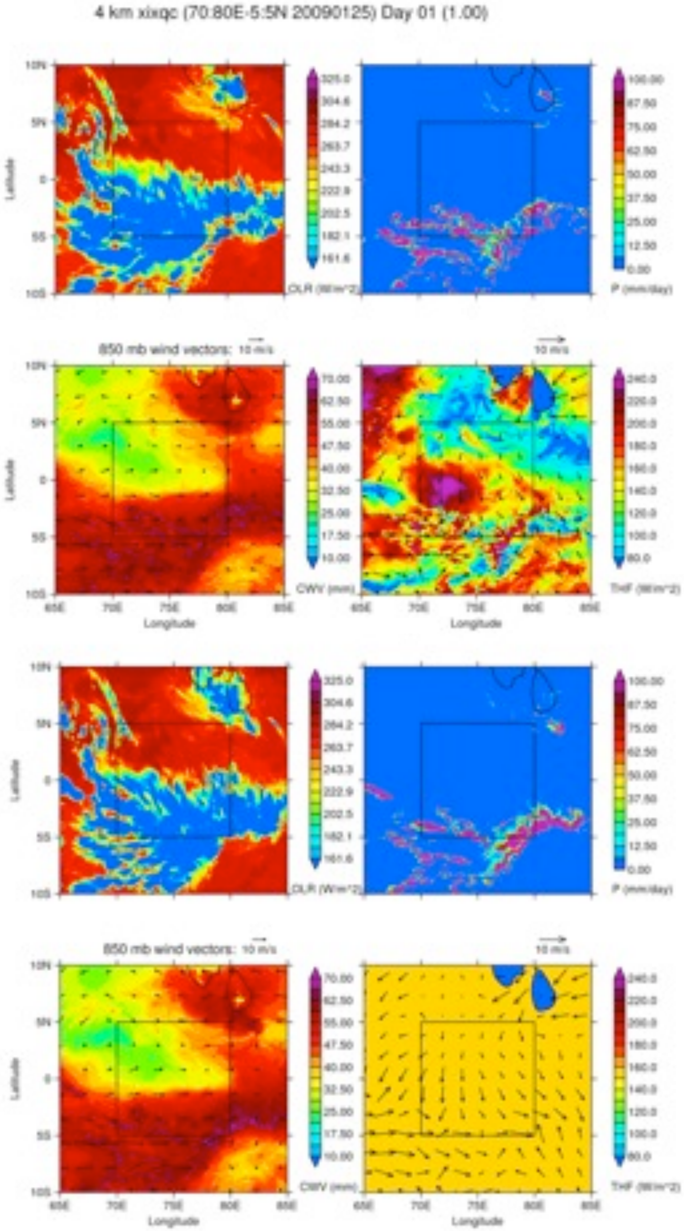
limited-area model setup for observed case studies:

- 4 km grid spacing
- 3D-Smagorinsky mixing
- explicit convection
- “qtidy” moisture conservation
- 3 prognostic microphysical fields
- constant SST from initial analysis
- lateral boundaries taken from 12 km LAM just outside 4 km model, which is in turn forced from ECMWF YOTC analyses

# first observed "aggregation" case: after 1 day



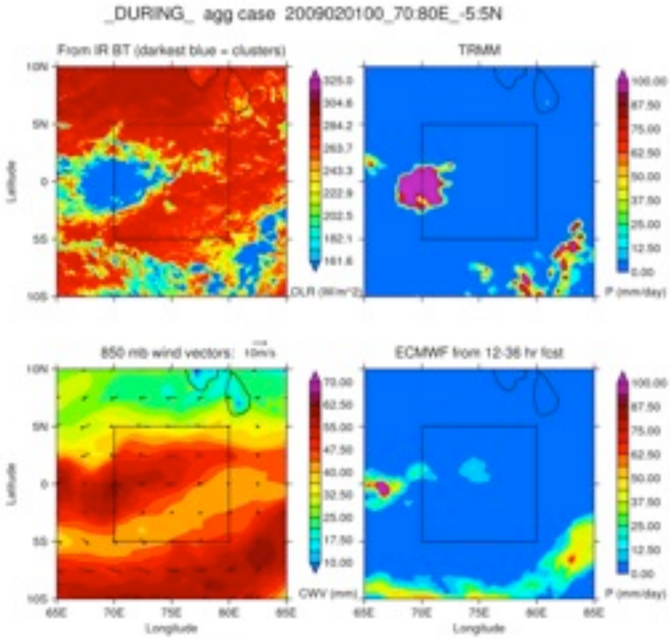

**obs.**



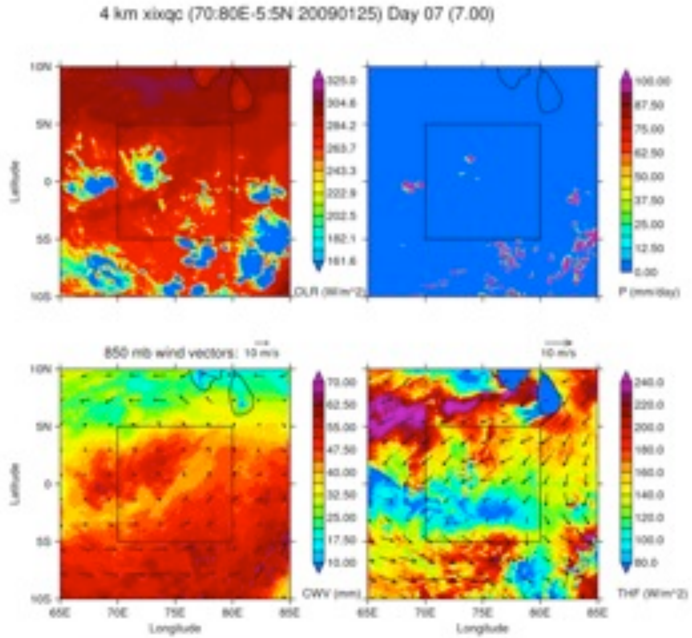

**control run**

**const. surf. flux.**

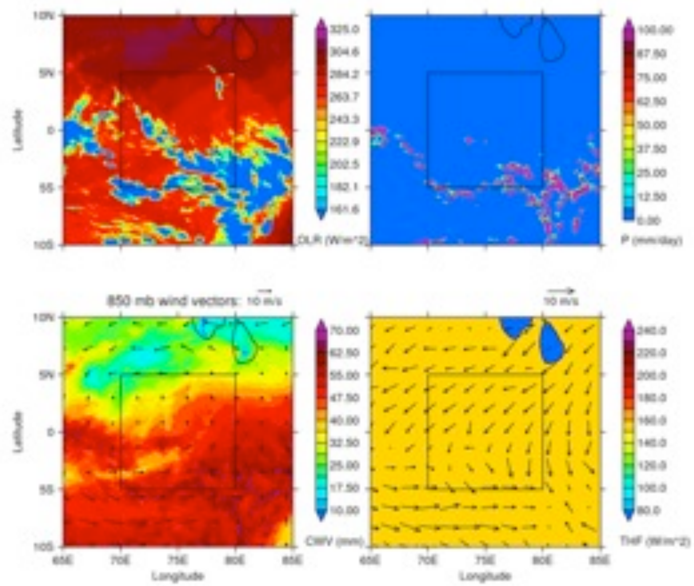
# first observed “aggregation” case: after 7 days




**obs.**

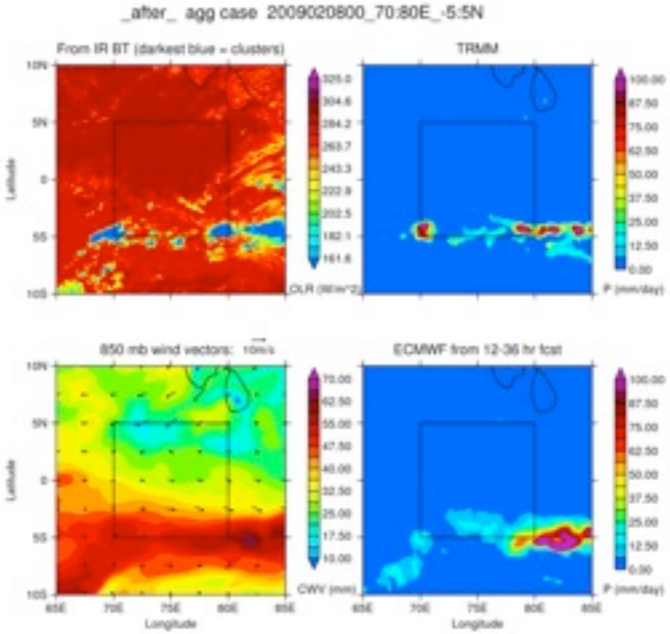



**control run**

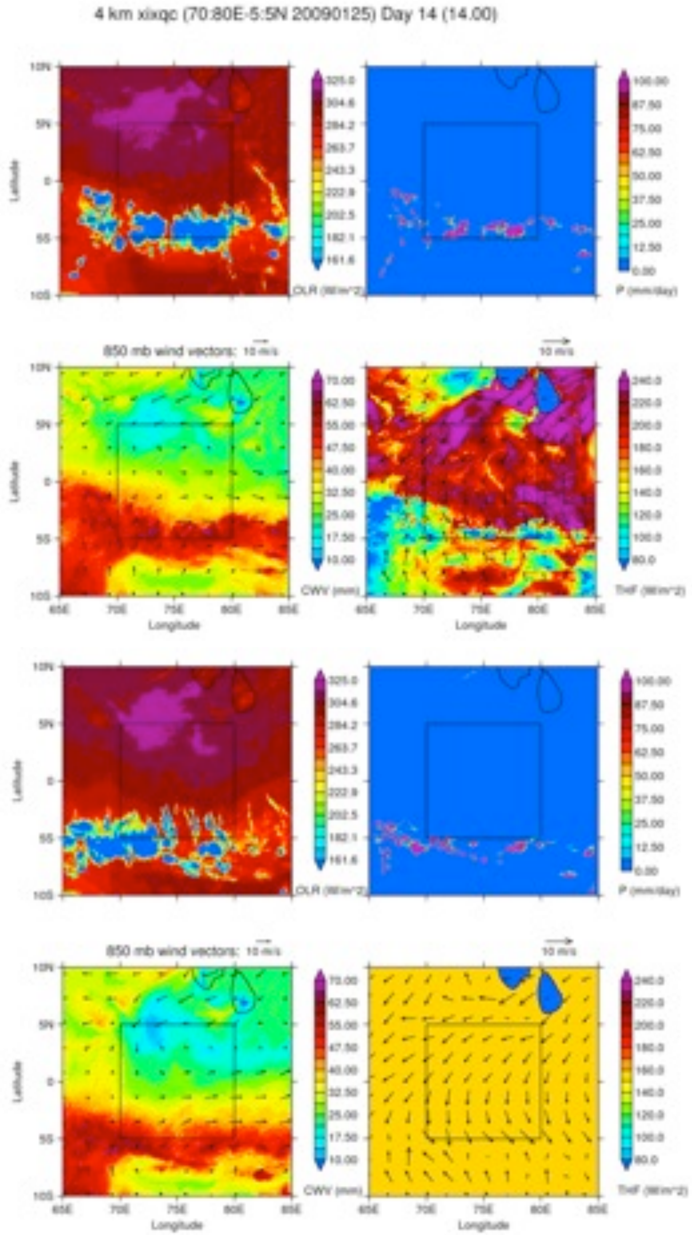



**const. surf. flux.**

# first observed “aggregation” case: after 14 days

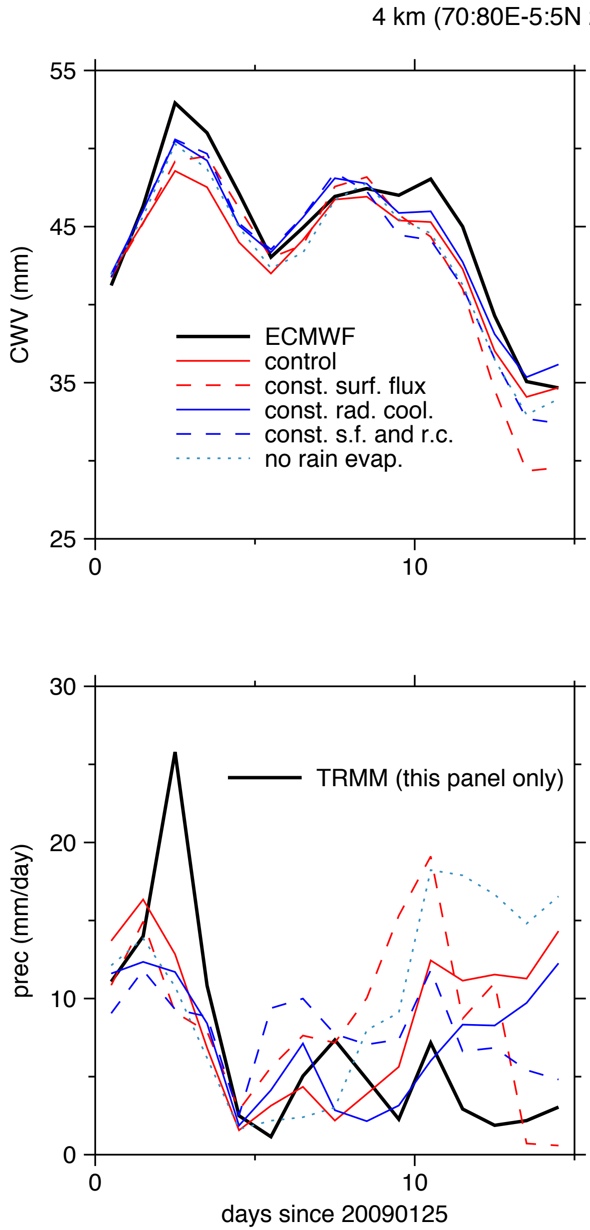



**obs.**

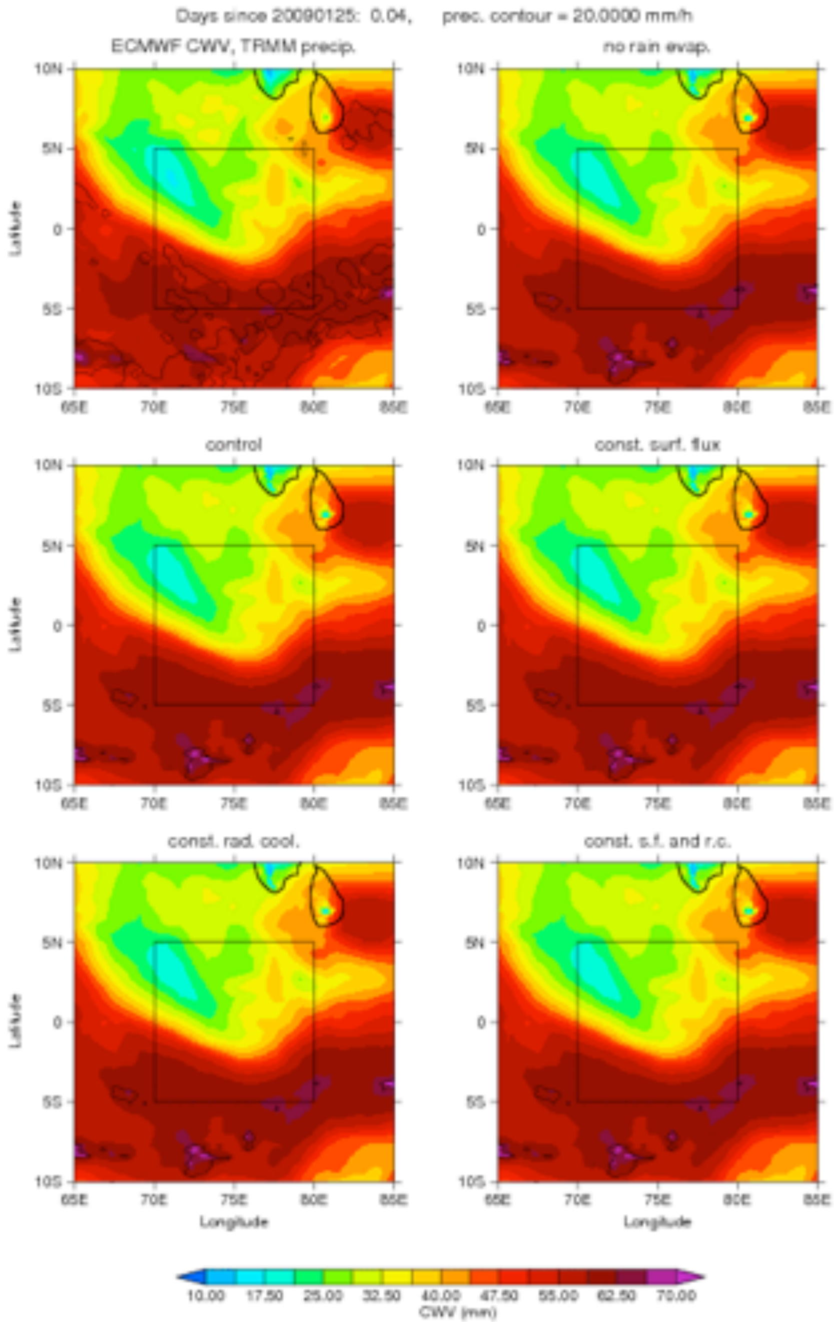



**control run**

**const. surf. flux.**


4 km (70:80E-5:5N 20090125 ) daymean
CWV (mm)
IQR (mm)
prec (mm/day)
UQR (mm)
ECMWF
control
const. surf. flux
const. rad. cool.
const. s.f. and r.c.
no rain evap.
TRMM (this panel only)
days since 20090125
days since 20090125

first observed "aggregation" case: hourly CWV and precip contour (20 mm/day)



# Conclusions

- The idealised UM in radiative-convective equilibrium reproduces many of the findings of previous work: interactive radiation is crucial for idealised self-aggregation of convection, and interactive surface fluxes also play a role.
- Observations show that, after controlling for large-scale conditions, a more aggregated state has a less humid, less cloudy environment and mean state, similar to idealised models.
- The UM allows the exploration of both idealised and realistic cases of organised convection using the same model. Preliminary results show some possible connections between the organization of convection and the CWV field and interactive radiation in the realistic cases.