Parametrizing microphysics in global models

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With help from

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Summary

- Future focus on
  - A consistent microphysical representation between the LEM, large-scale microphysics and convective parametrization microphysics
  - Improving warm-rain microphysics and its link to turbulence, aerosols and subgrid-scale structure
  - Model evaluation with new data sources
  - Including sufficiently accurate ice microphysics for high-resolution modelling and climate-change studies

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  - Why include microphysics in a large-scale model?
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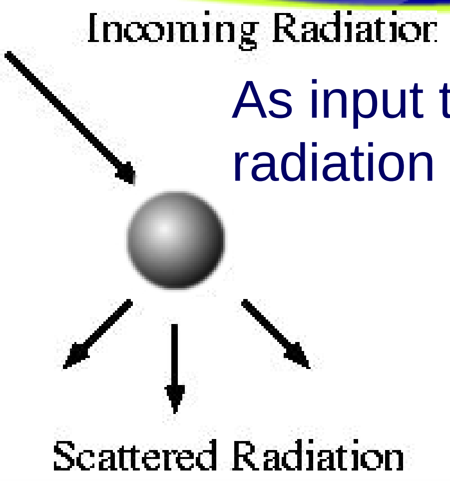
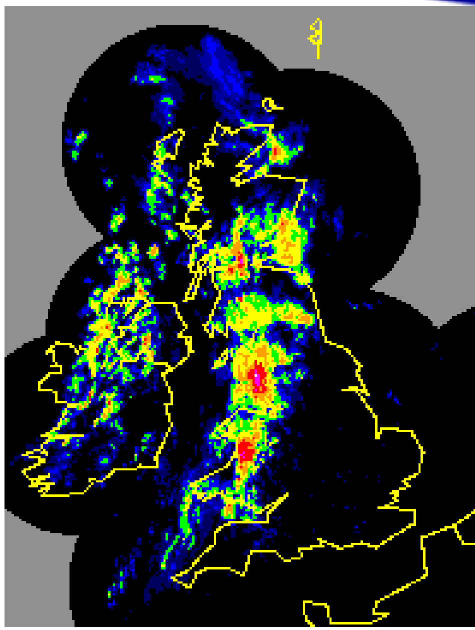
  - Turbulence
- Summary

Why do we need cloud microphysics in a large-scale model?

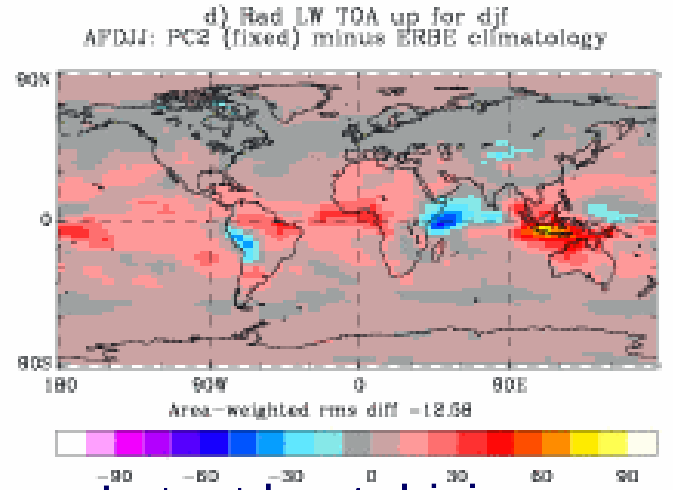


As input to the radiation scheme

To predict surface precipitation



Aircraft icing

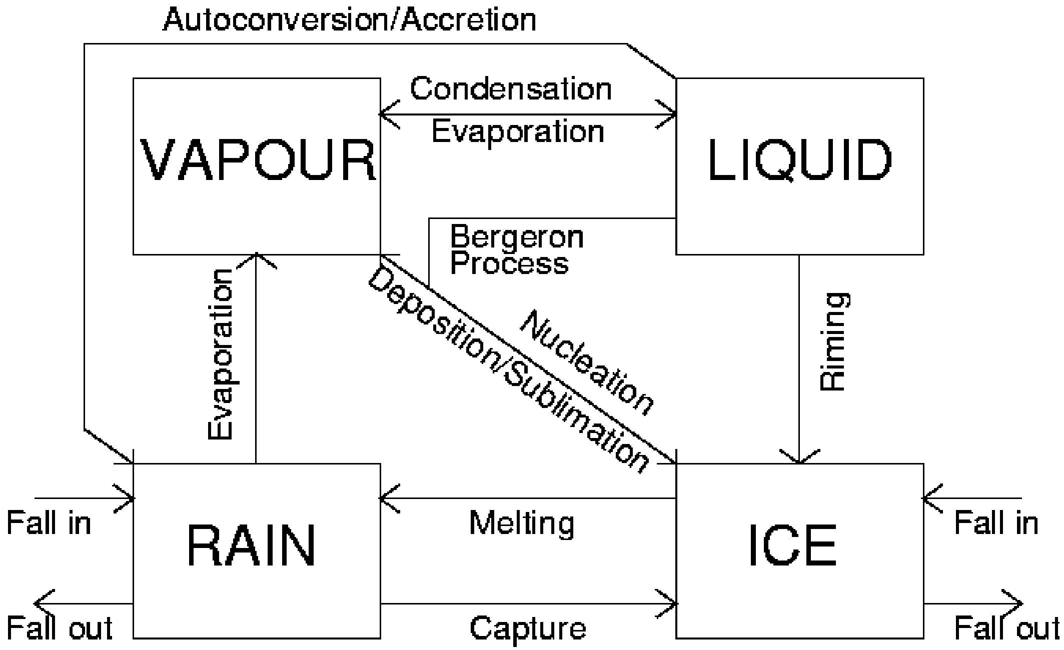


Latent heat driving general circulation

Surface visibility

Unified Model microphysics approach

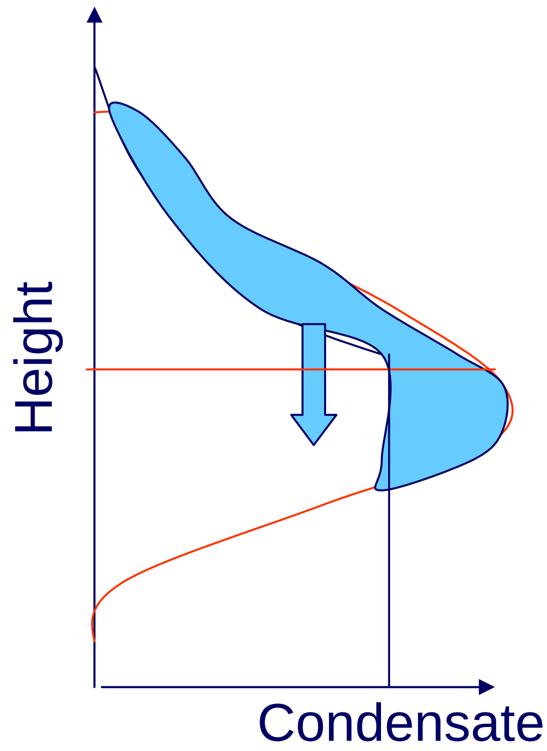
Large-scale scheme



For higher resolution can add other categories and transfers, especially to the ice phase – effectively an LEM

But missing crucial information about processes: aerosols, turbulence, vertical velocities, history etc.

Convection scheme

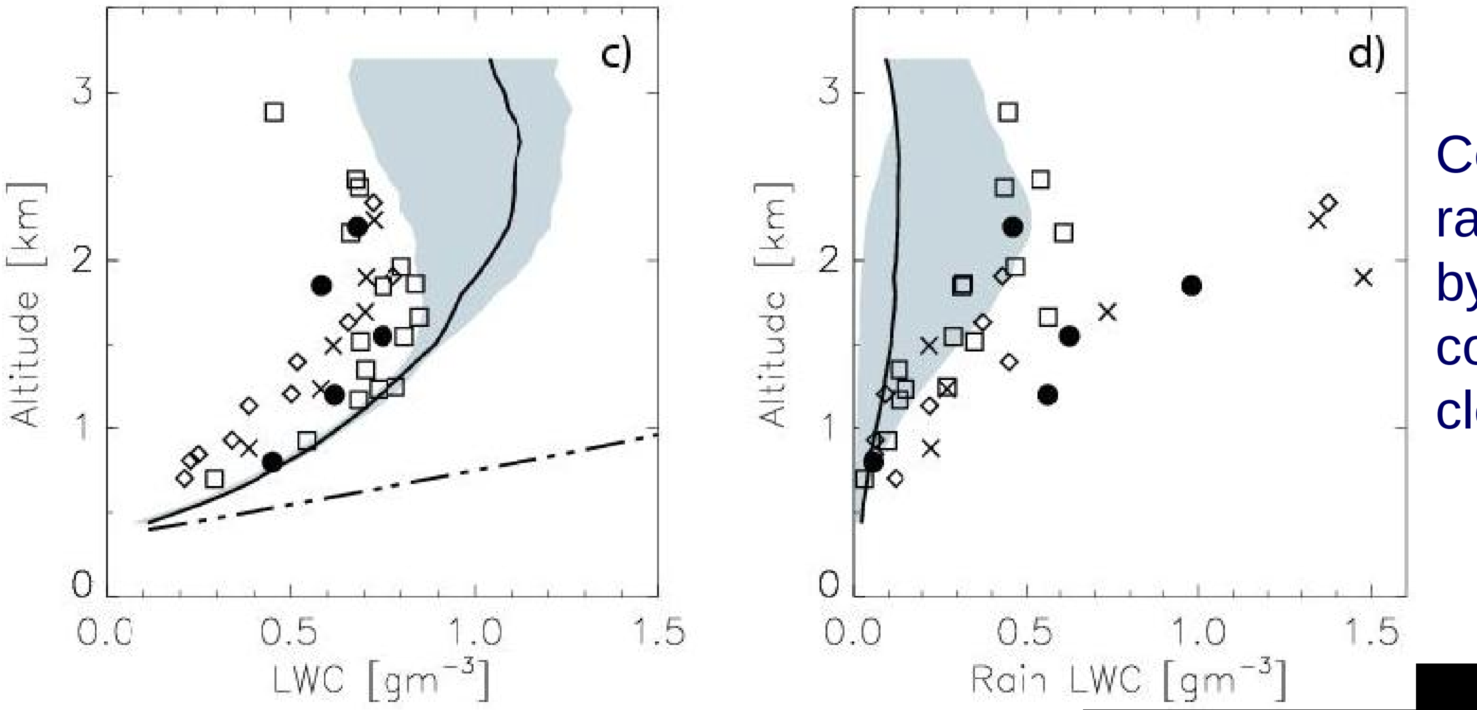


Very little microphysical information carried within the UM convection

Convective microphysics

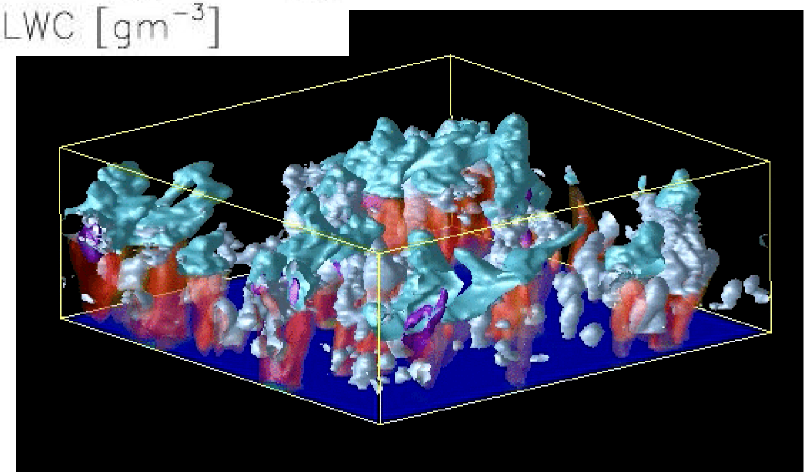
- Shallow convection
  - RICO observations and large-eddy modelling
- Deep convection
  - Condensate detrainment

Convective microphysics: RICO Shallow Cu

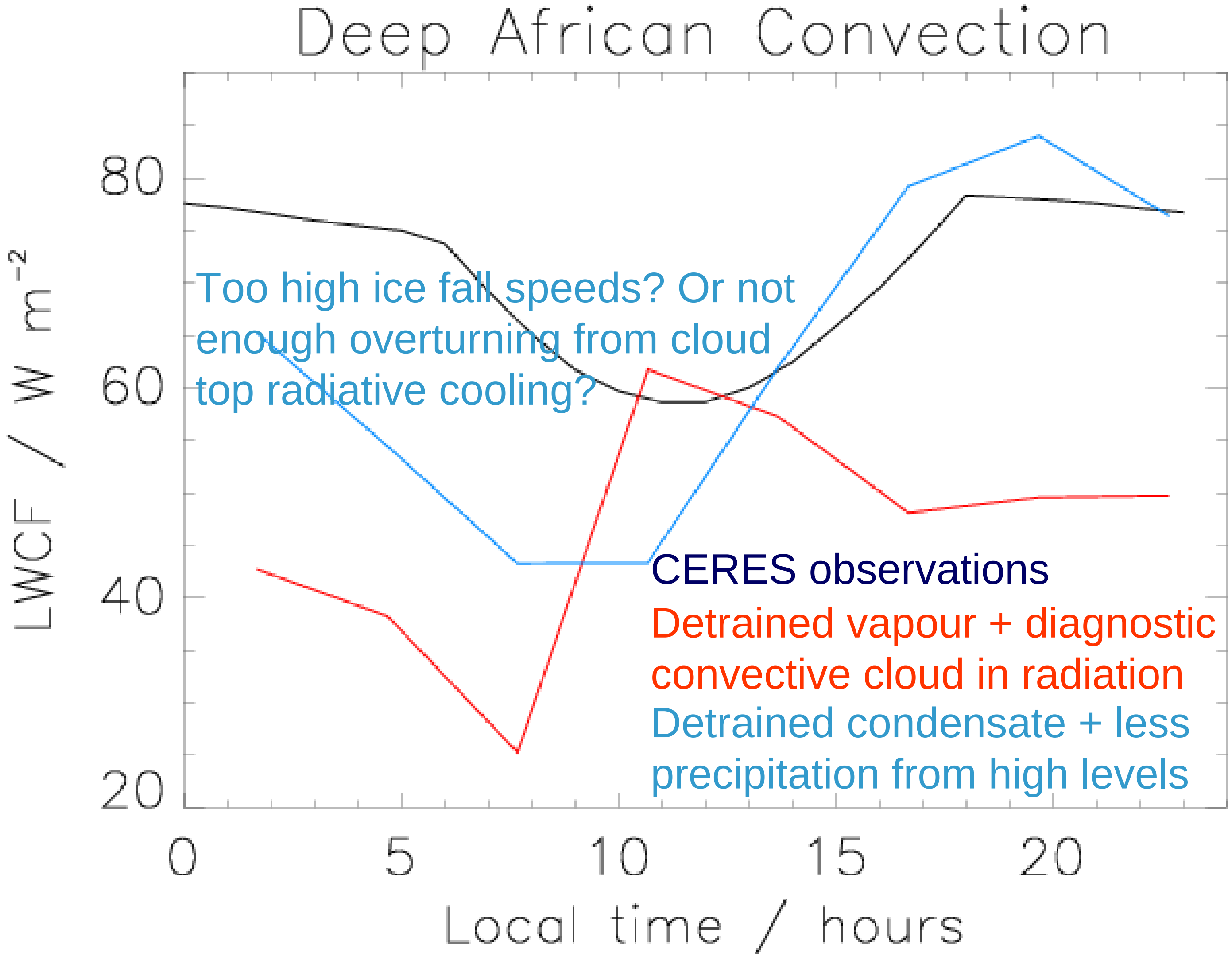


Considerable rain is produced by these shallow convective clouds

LEM data constrained by observations can start to be used to inform development of convective cloud microphysics representations. The challenge is to write a simple parametrization that does not lose sight of the small-scale microphysics.



Deep convection microphysics: diurnal cycle



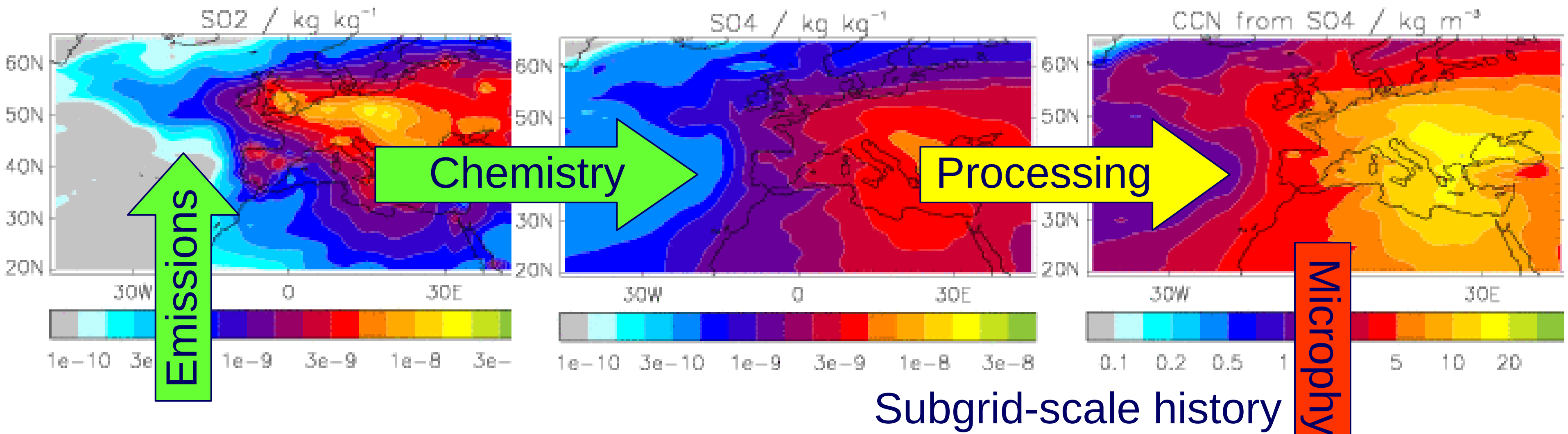
Mean diurnal cycle over *strongly convective points* in Africa

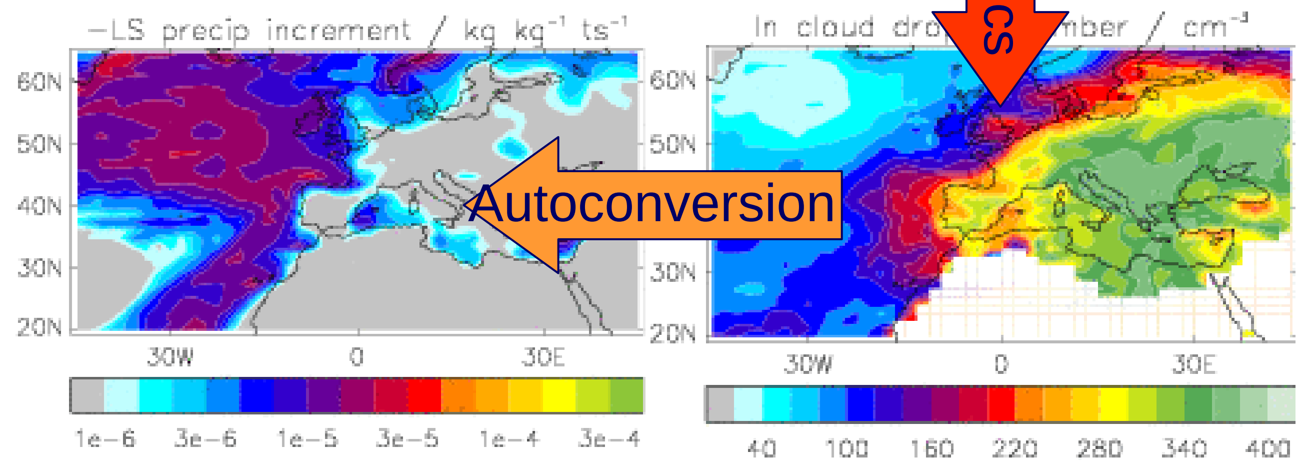
Diurnal cycle of the *convective activity* is unchanged – it is the *cloud* that changes

Aerosols

- Aerosol schemes are getting more complex
- Need to exploit this information as well as possible in linking to cloud properties:
  - Liquid cloud feedbacks: Effect on autoconversion ought to be understandable, but also dynamic impacts.
  - Ice cloud feedbacks – dust aerosol species could be used to guide ice nuclei parametrizations
- Crucial to development is the representation of *subgrid-scale* vertical velocities.

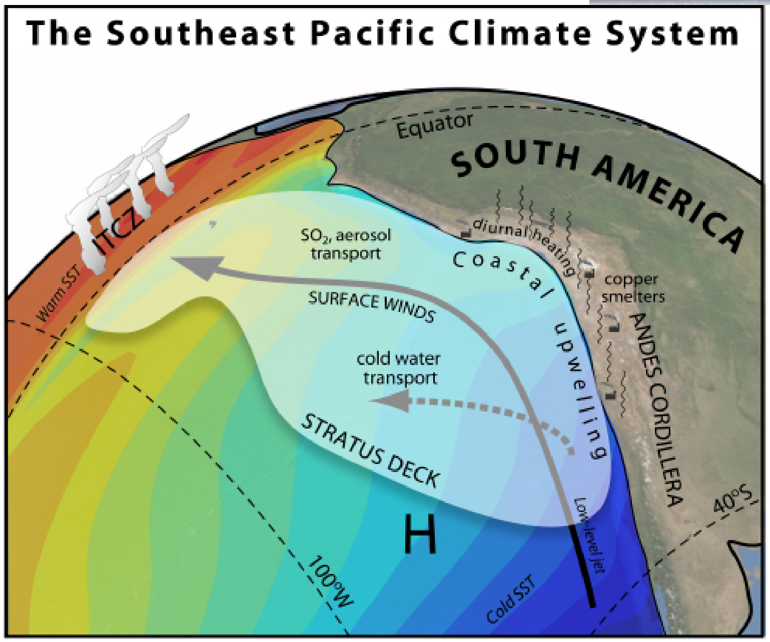
Aerosols to microphysics: 2nd indirect effect





The dry aerosol chemistry has had much recent work. Although Köhler theory is well know, how do we apply it to a large gridbox? How do we upscale collision-coalescence theory?

VOCALS

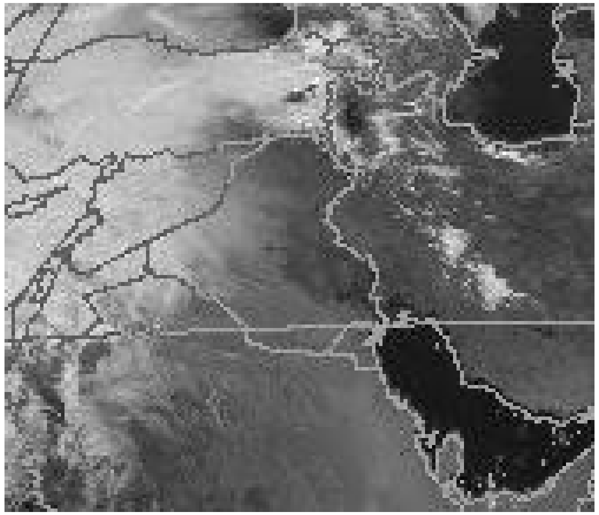


An opportunity to study a potentially complex cloud sheet strongly influenced by aerosols

Warm rain processes: Droplet settling

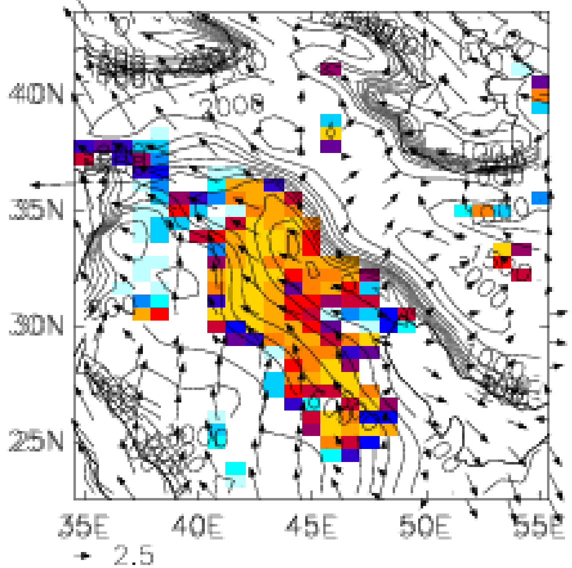
- Traditionally droplet settling is not a process that is included in large-scale microphysics schemes
  - Is its effect significant?
- How many processes should large-scale microphysics schemes include?

Fog: Droplet settling

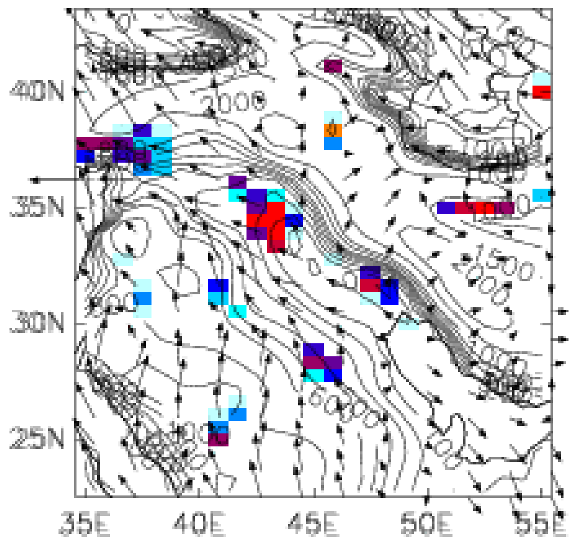


Iraq is not a foggy place except in the Met Office models… This can result in 10°C 1.5 m temperature errors

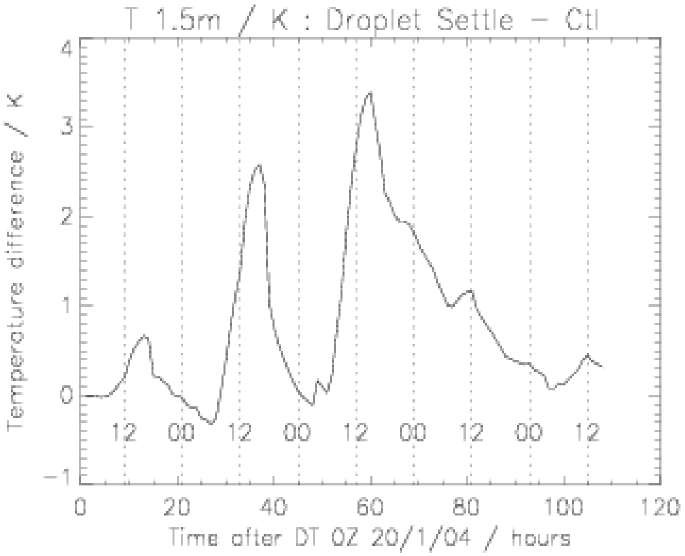
Control



+ Droplet settling



0 Fog fraction 1

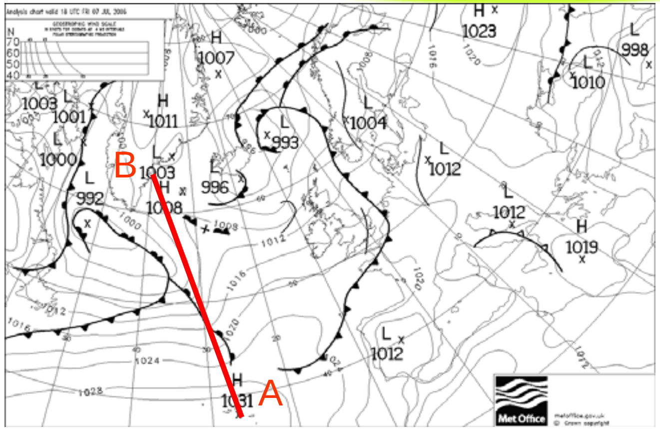


Significant improvements with the extra microphysics

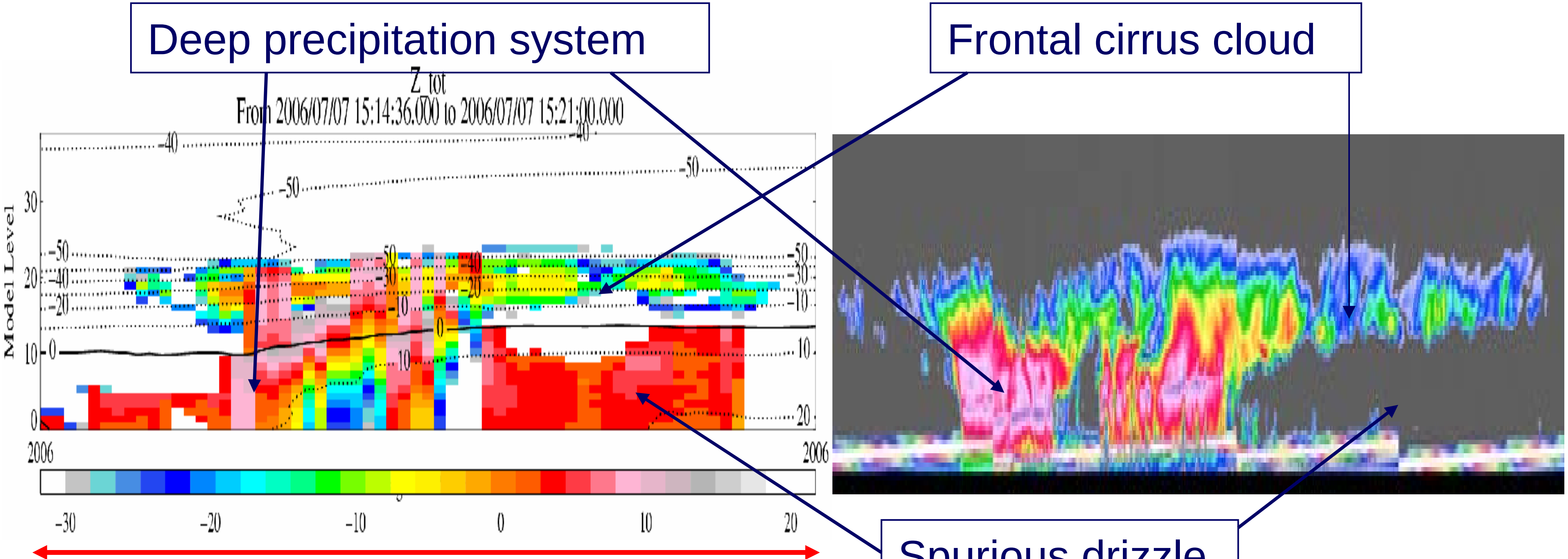
Warm rain processes: Drizzle

- Drizzle is a heavily parametrized process in models
  - Unified model overpredicts drizzle
- How do we best use observations to inform development of autoconversion schemes?
  - Collision / coalescence will vary considerably on the subgrid-scale

CloudSat Simulator: preliminary case study

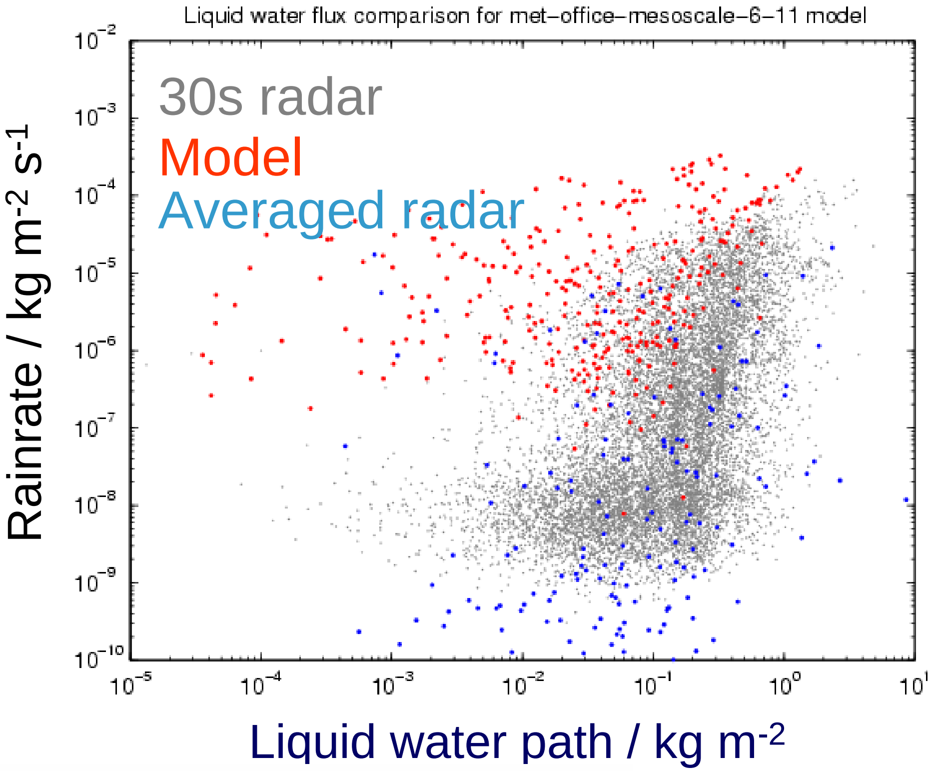


CloudSAT data has the potential to significantly help our understanding of the cloud processes we model well and poorly

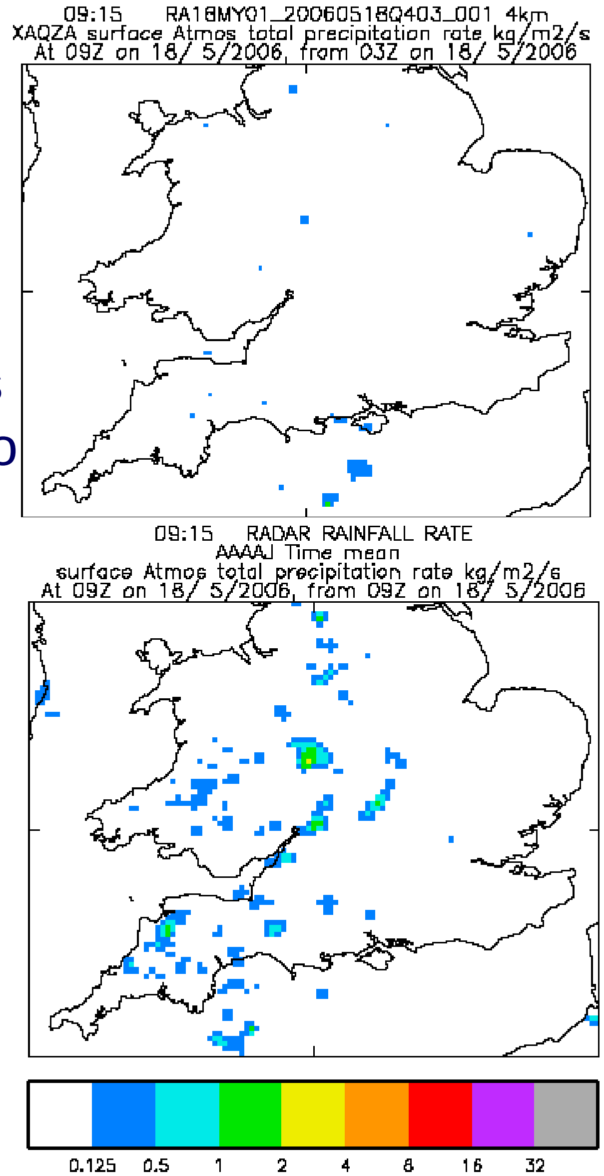


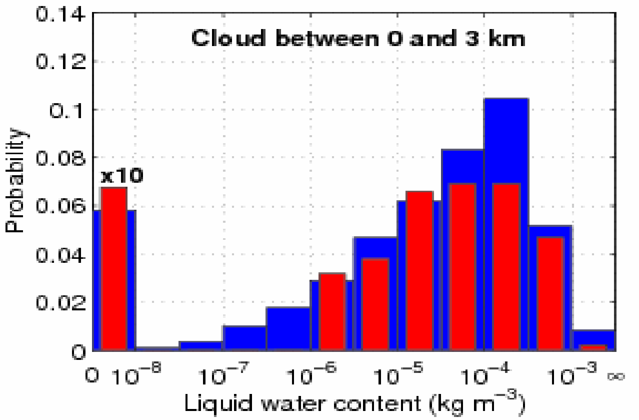
B A

Drizzle in the model



Shallow convection is producing too little precipitation



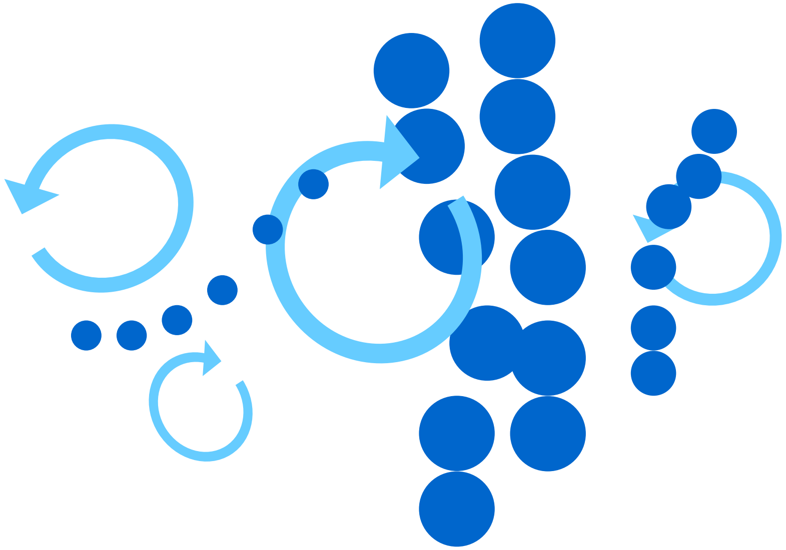


Stratocumulus cloud is producing too much drizzle. Yet the liquid water contents look reasonable

Turbulence

- Turbulence is becoming recognized as an important factor influencing cloud properties
  - Recent theoretical work on how this can influence the collision / coalescence mechanism
  - Observational evidence not clear cut
  - Should this be introduced to large-scale parametrizations? How?

- Increasing understanding of the link between turbulence and autoconversion



1. Increase in fall speed – more sweepout of smaller particles

2. Same size particles can collide

3. Clustering of particles away from the turbulent cores

4. A Maxwellian like distribution of particle velocities in high turbulence

Summary

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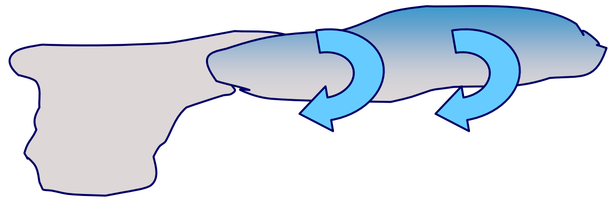
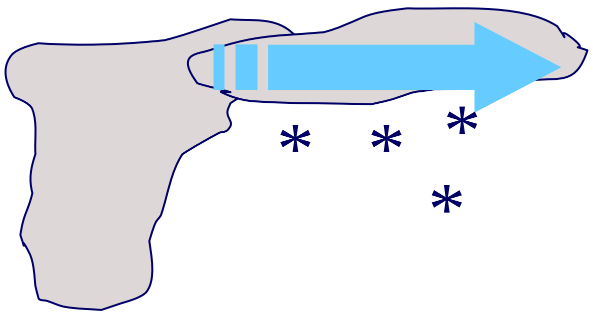
Questions

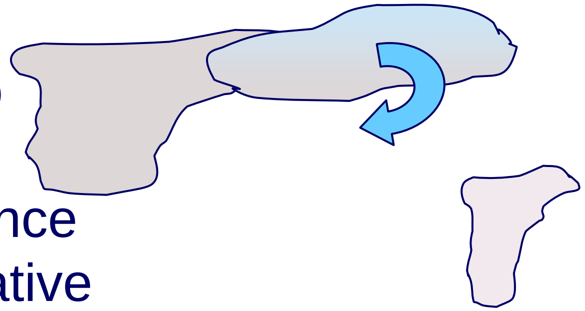
Key impacts of convective cloud parametrization

More detrainment of vapour leads to more cloud

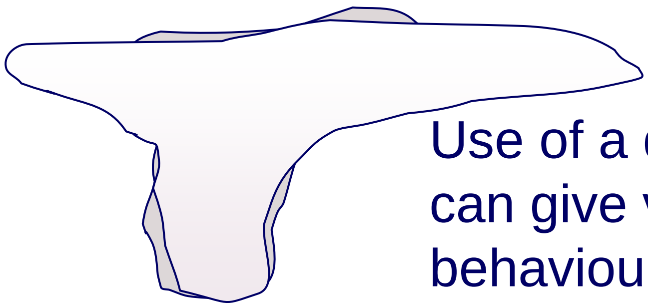




Detrainment of condensate leads to more rapid anvil precipitation and hence reduced cloud, radiative cooling and convective activity



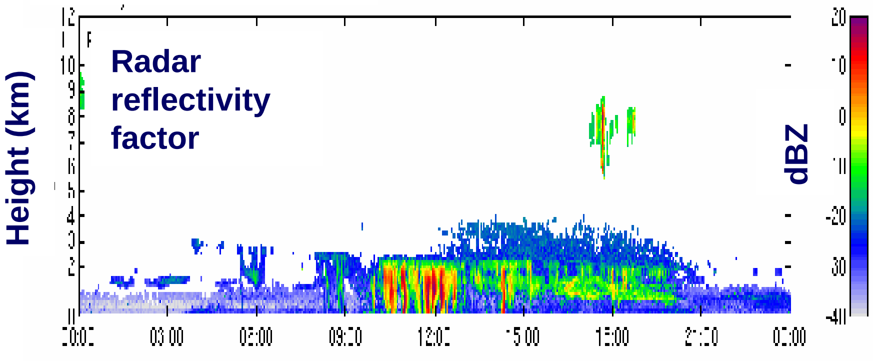
New convection can trigger in hotter spots

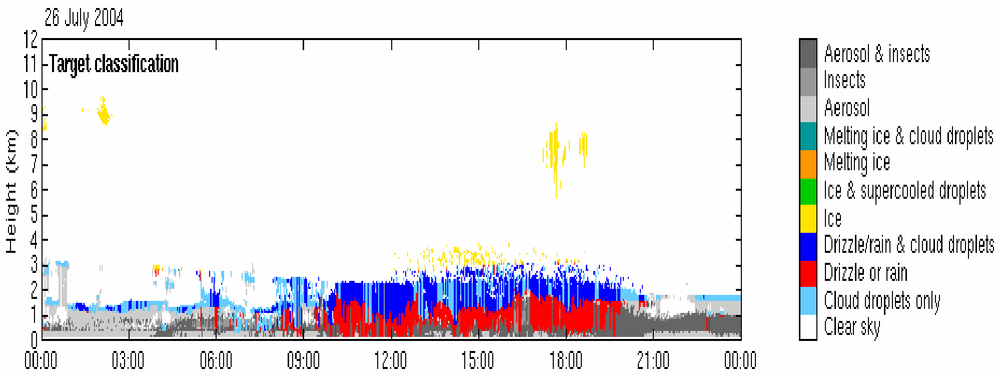


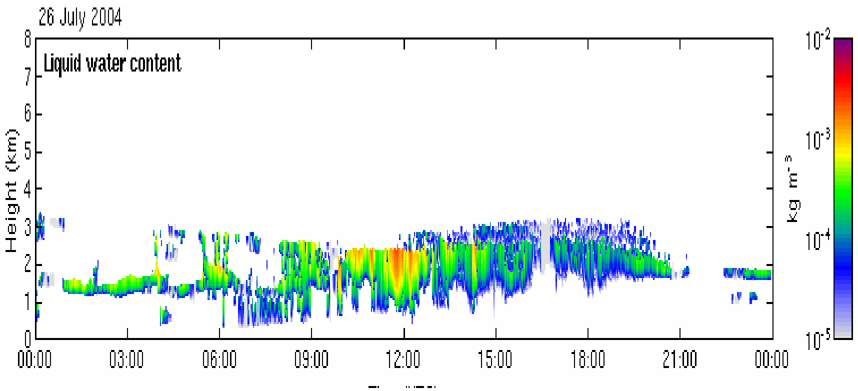
Use of a diagnostic convective cloud can give very bright on-off cloud behaviour

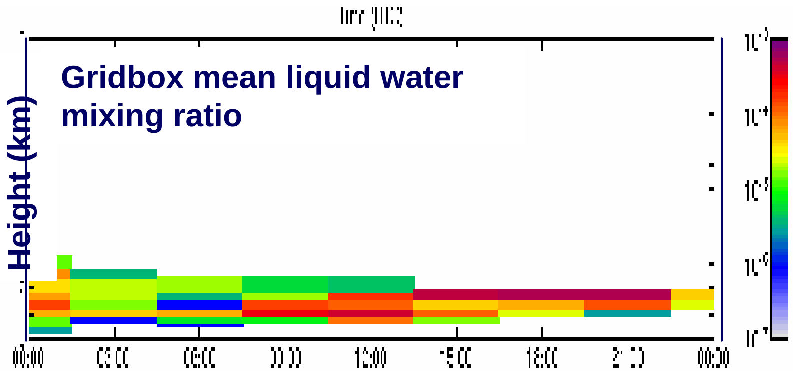
CloudNet: Radar/lidar/radiometer retrievals

26 July 2004

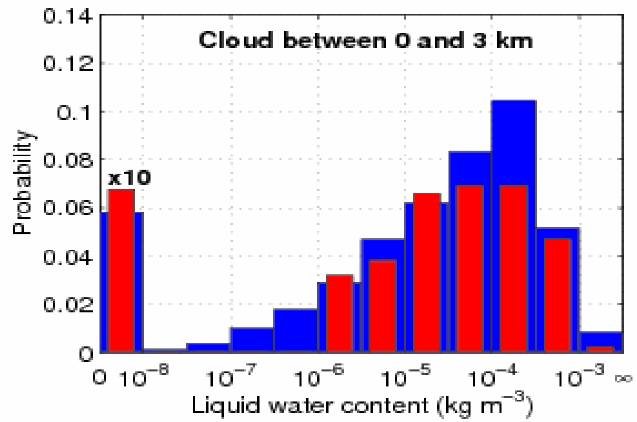






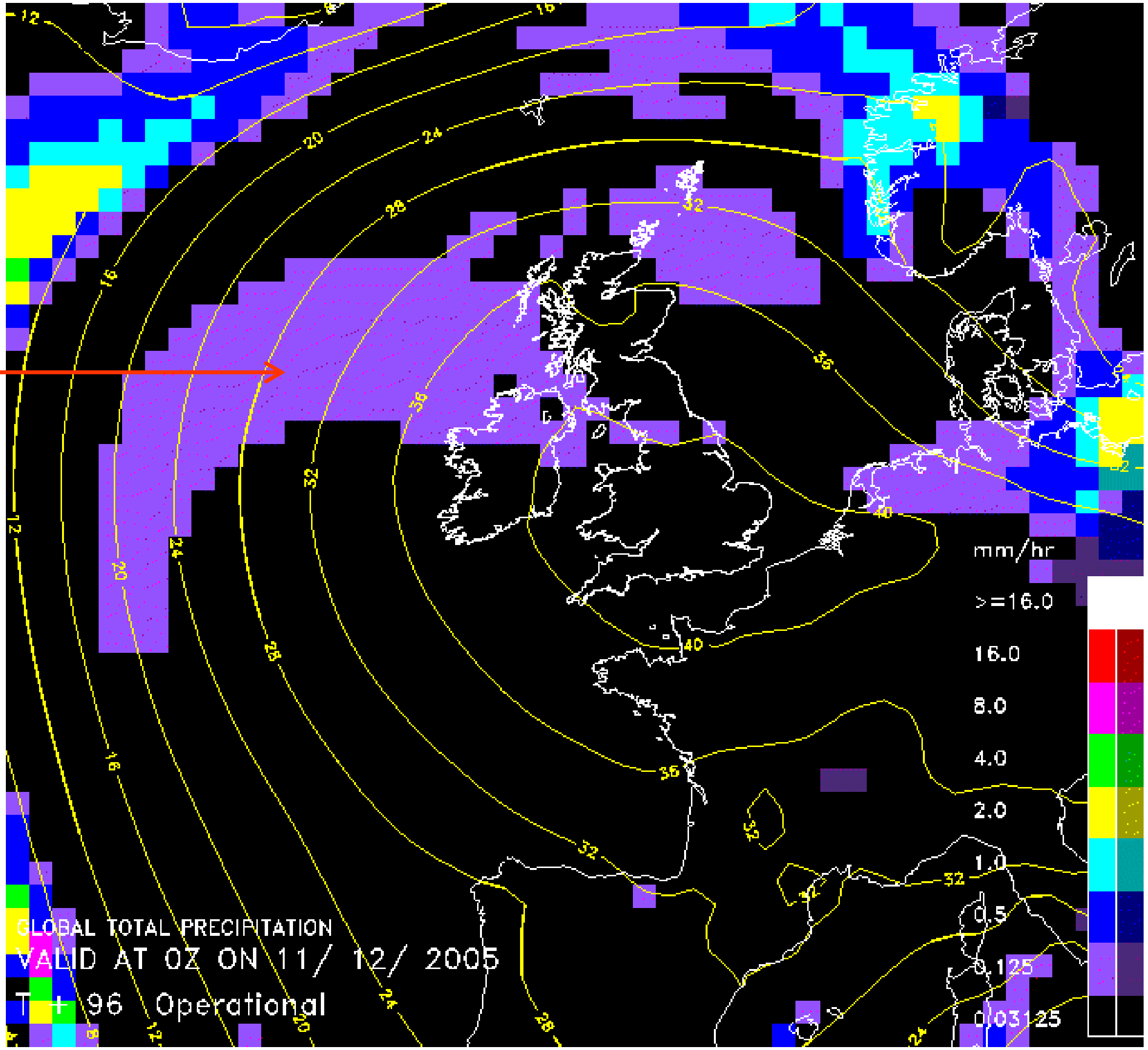


The forecast model predicts reasonable liquid water contents

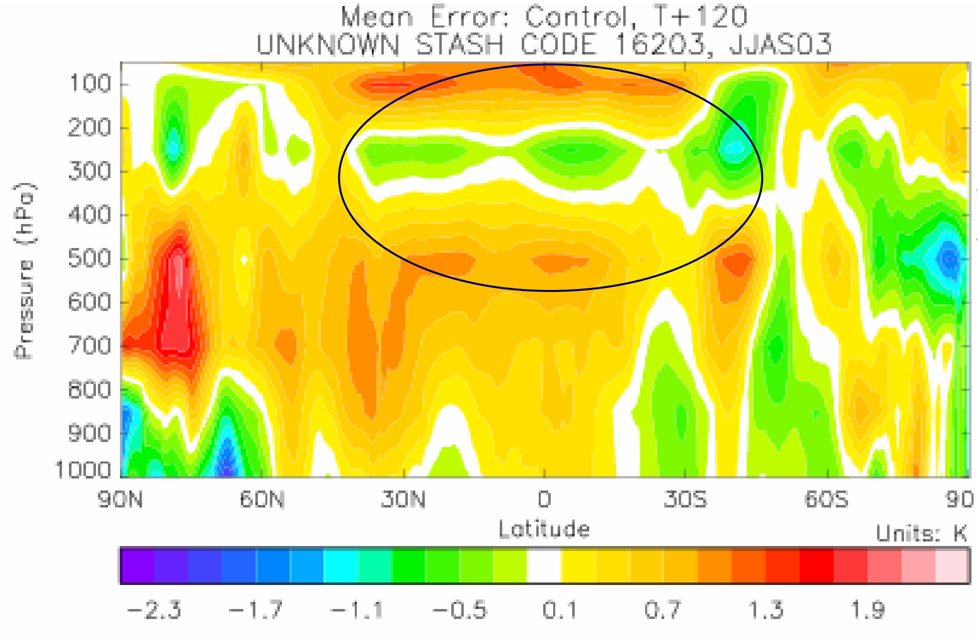


Excessive prediction of drizzle?

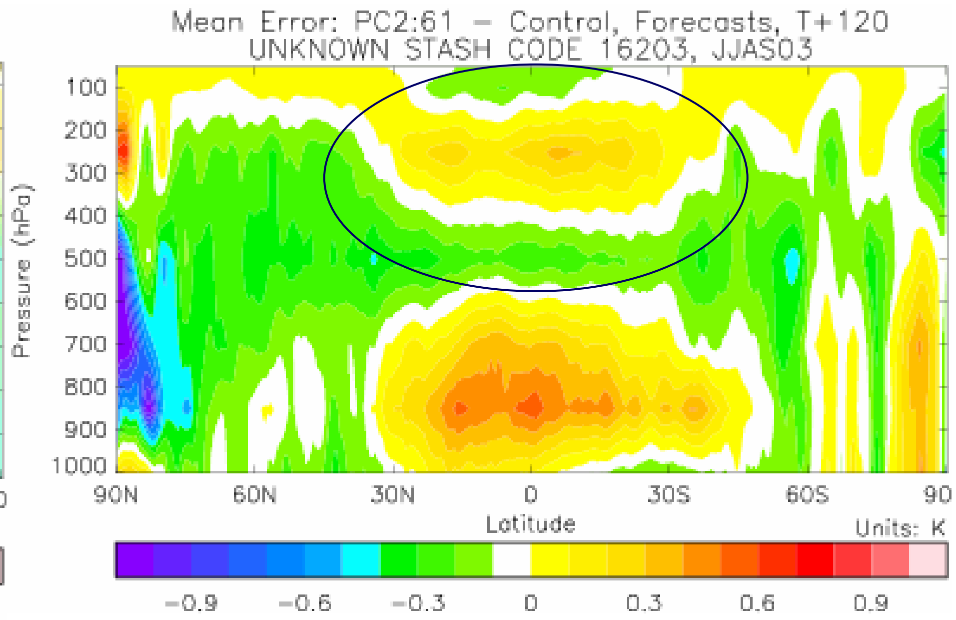
Large regions of very light rain in high pressure regions represent drizzling stratocumulus cloud. But is this really excessive?



PC2 tropical performance: temperatures



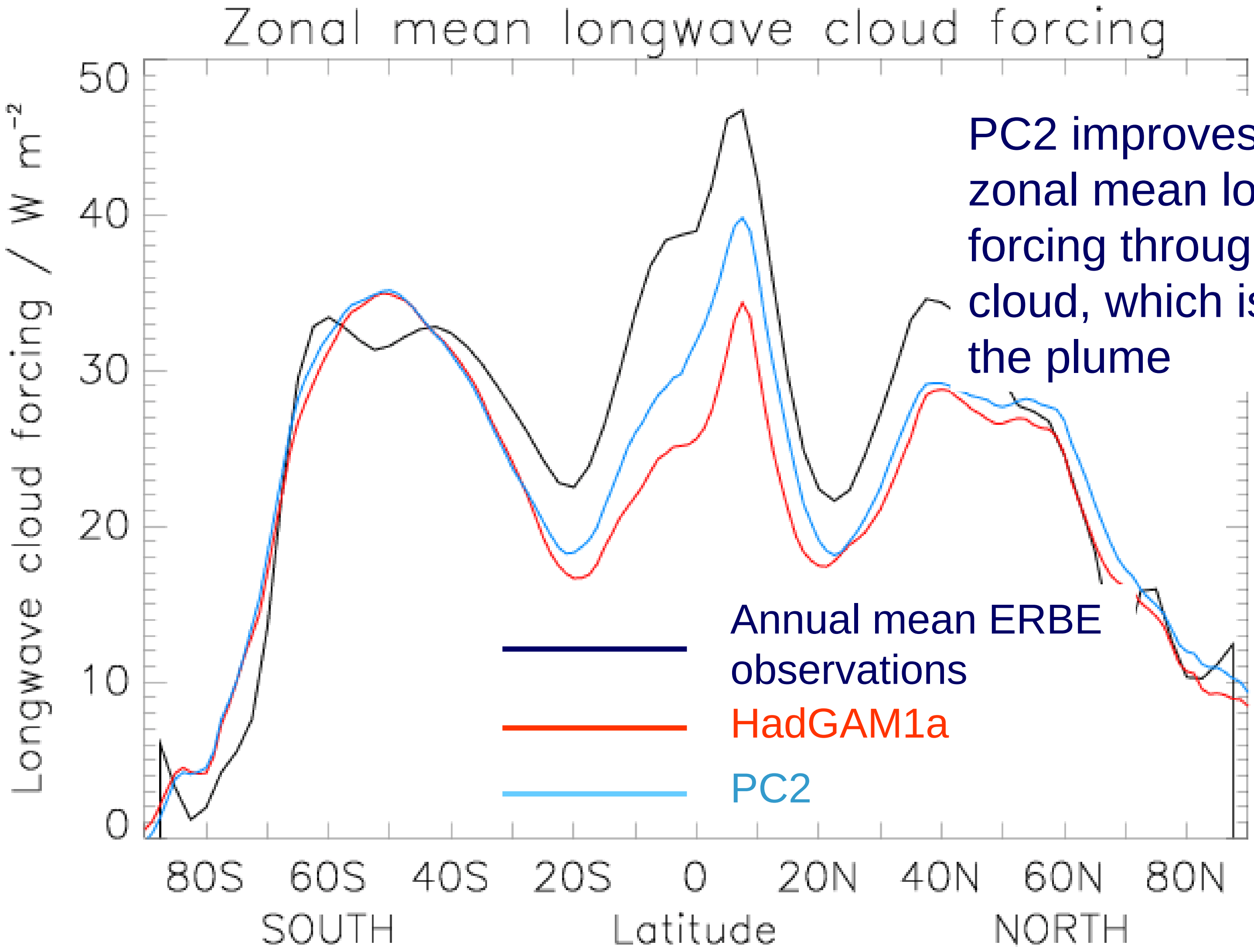
Temperature bias in T+120 control forecasts



T+120 Temperature: PC2-control

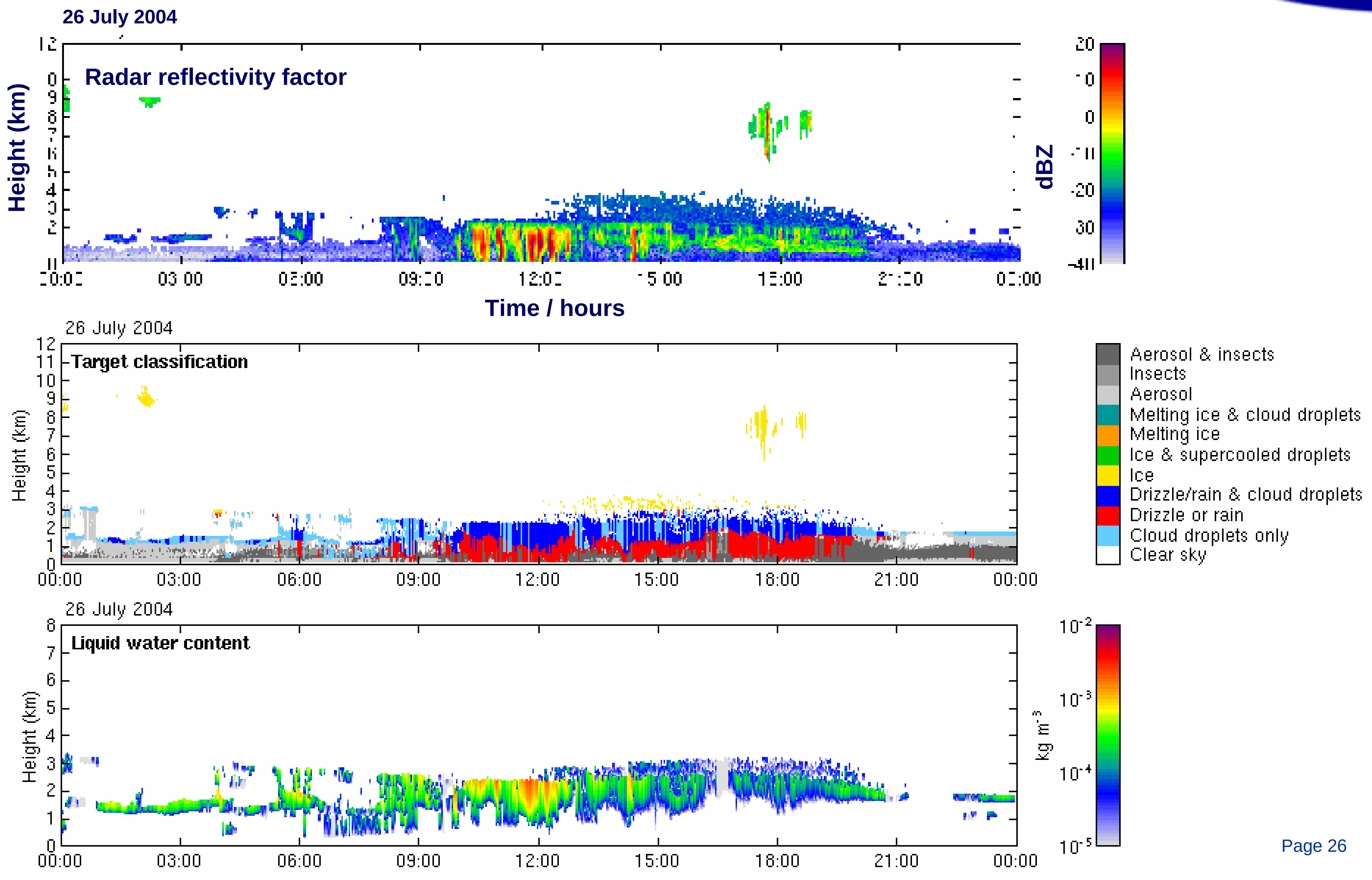
PC2 improves the upper tropical tropospheric temperatures through the radiative interaction of cloud changes

PC2 tropical performance: LW cloud forcing

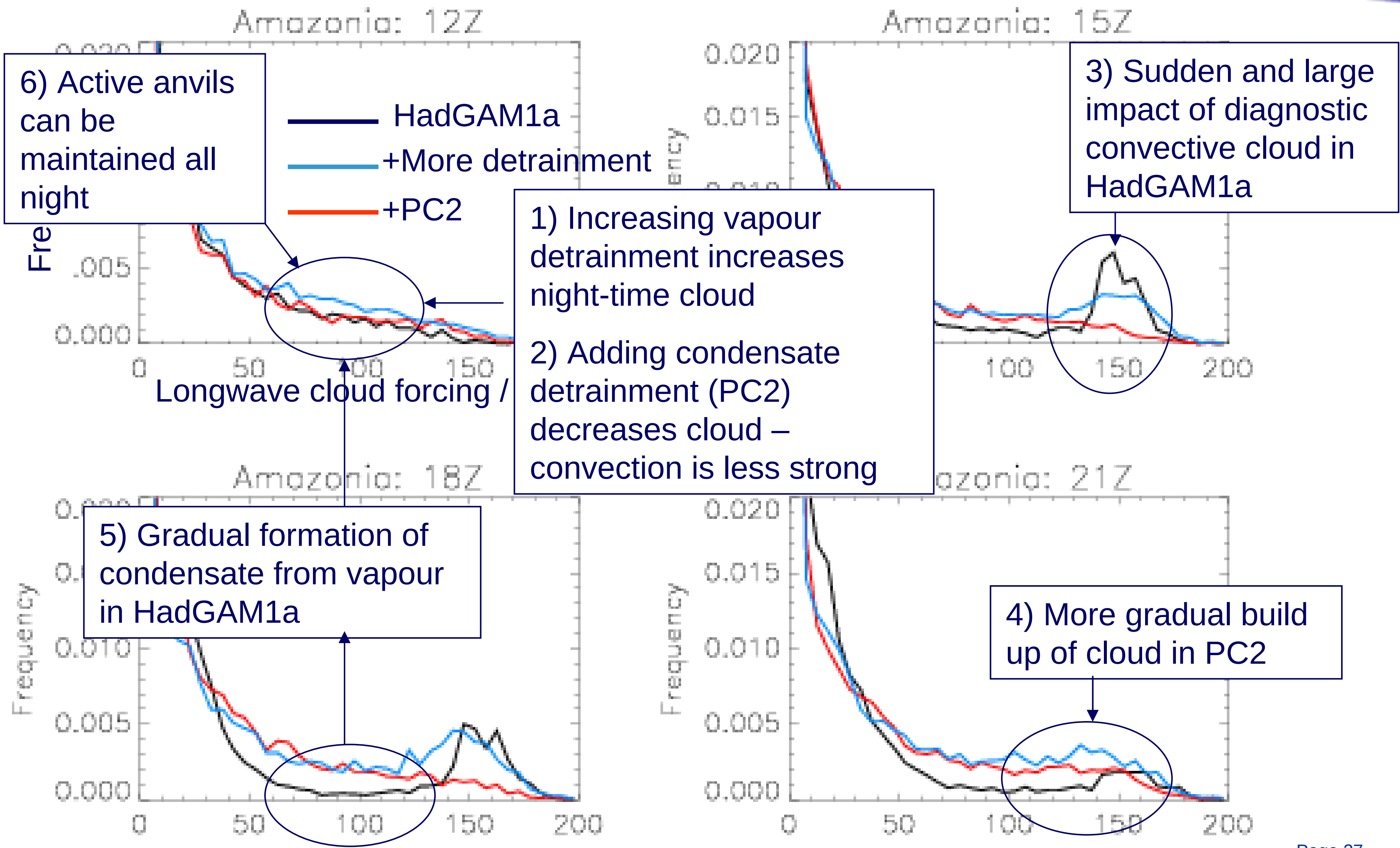


PC2 improves the tropical zonal mean longwave cloud forcing through the increased cloud, which is detrained from the plume

CloudNet radar/lidar/radiometer retrievals

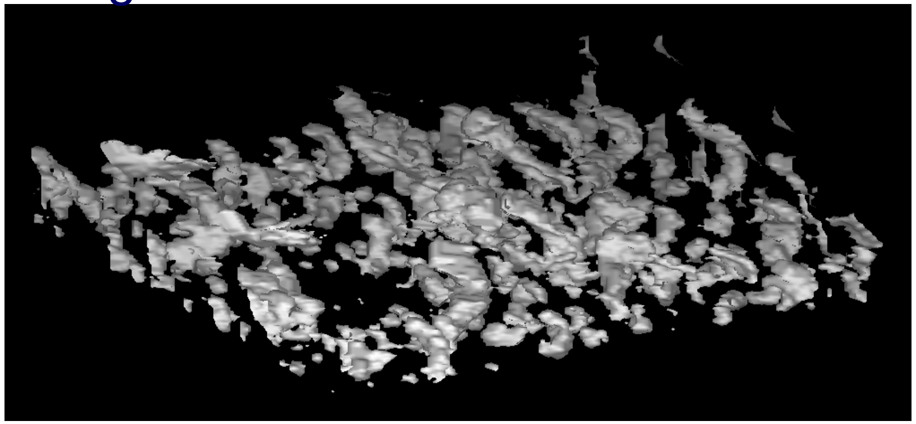


Analysis of longwave cloud forcing



A Cloud Inhomogeneity & Overlap Parametrisation for Radiation

The radiative effect of unresolved cloud within a model grid box can be studied using CRM data



- Increased condensate variance gives reduced albedo
- Can parametrize by scaling the mean water content
- A better method is to parametrise the variability by sampling a generated cloud field.

- How do we define the variance?