GCM Physics Developments at Met Office

Adrian Lock, Met Office, UK

- Boundary layer scheme development
  - arising from EUROCS stratocumulus simulation
- Convection scheme development
  - spawned by shallow cumulus simulation

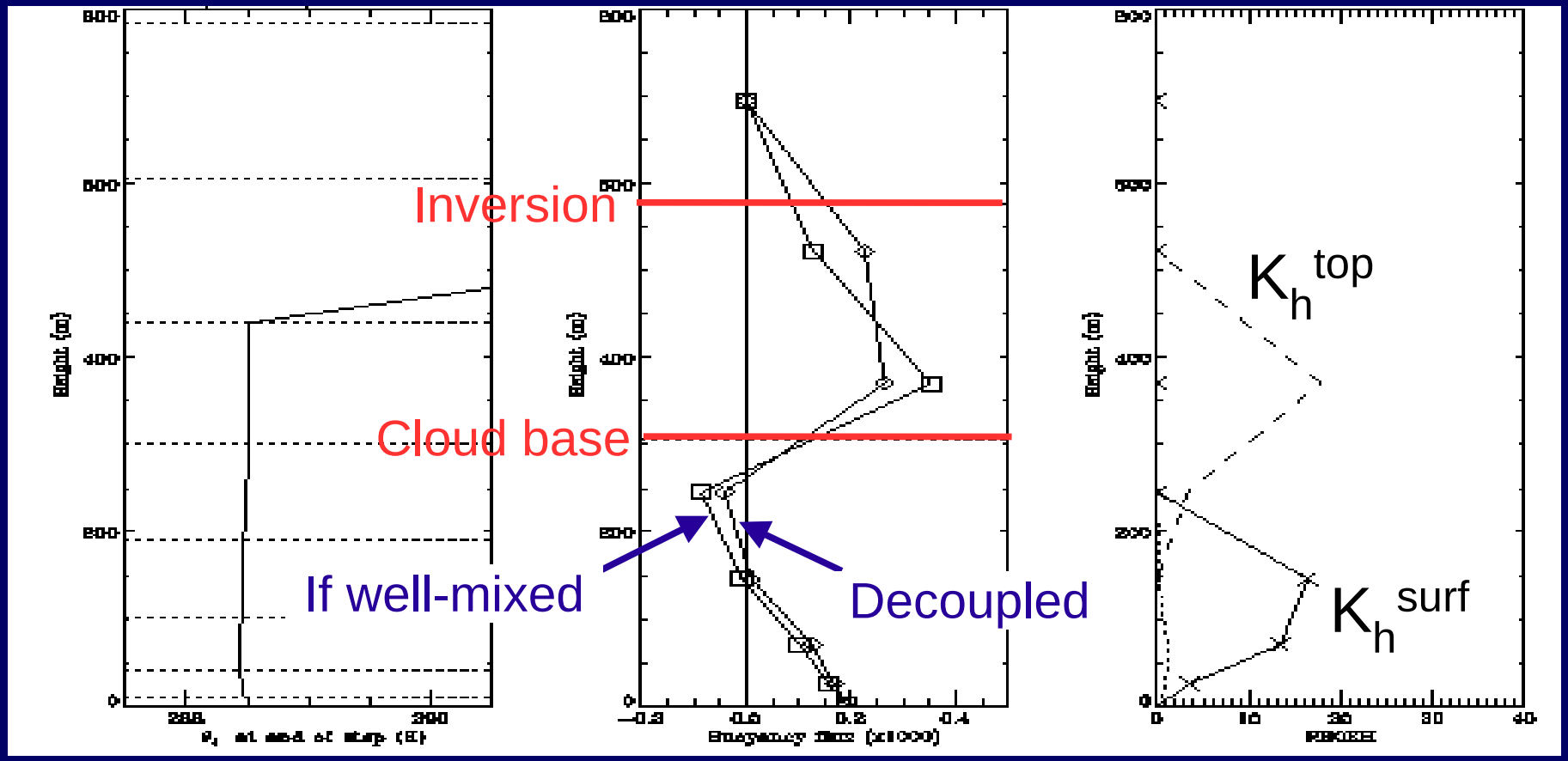
Boundary layer scheme plus development

- 1st order specified K-profile closure
- Diagnose vertical extent of K-profiles by imposing a limit on the buoyancy consumption of TKE, using subgrid cloud-base height diagnosis:

$$\int_0^{z_i} \left[\overline{w'b'} < 0 \right] dz < D \int_0^{z_i} \left[\overline{w'b'} > 0 \right] dz$$

With D=0.1 taken from the LES of the diurnal cycle of marine stratocumulus

SCM stratocumulus: decoupled phase (11Z local time)



θ_l profile

Buoyancy flux

K profiles

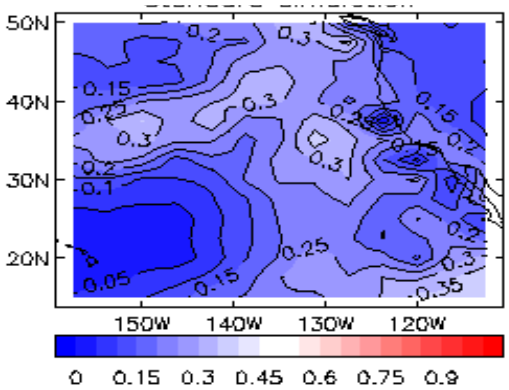
- Impact of the new subgrid cloud-base diagnosis

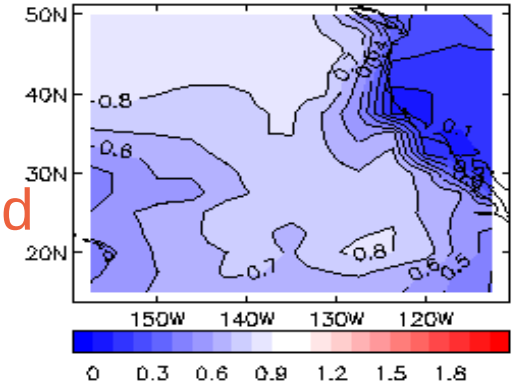
- JJA means

Occurrence of decoupling

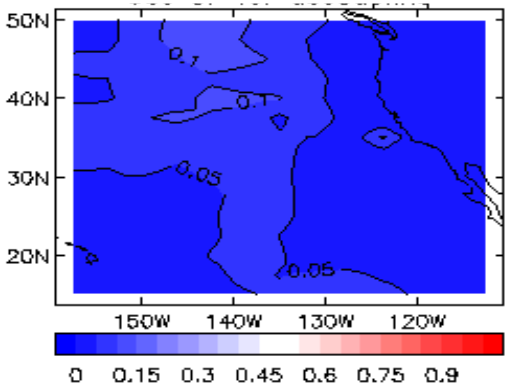
Total cloud fraction

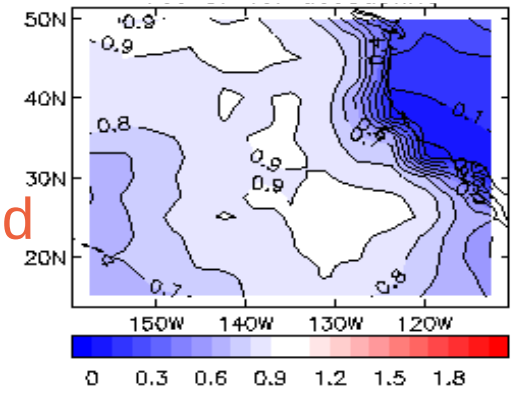
New method



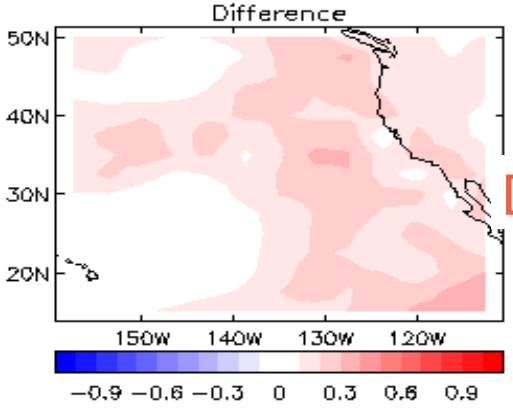


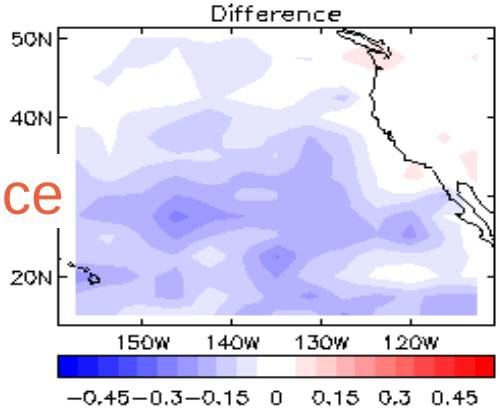
Old method





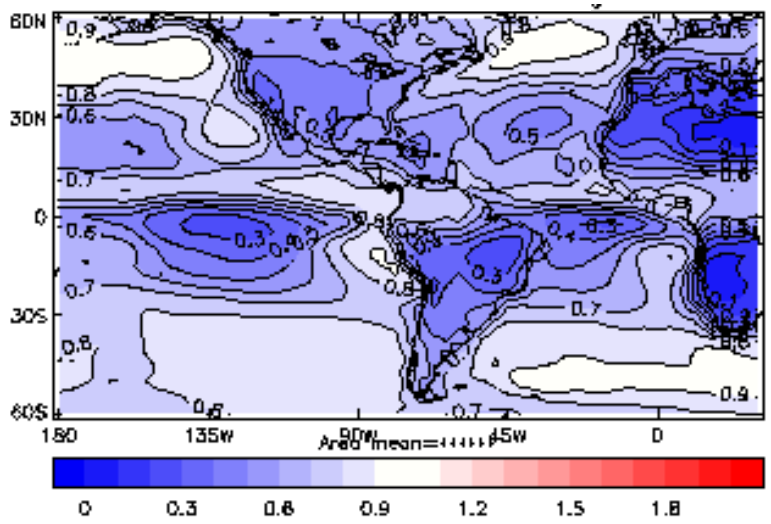
Difference



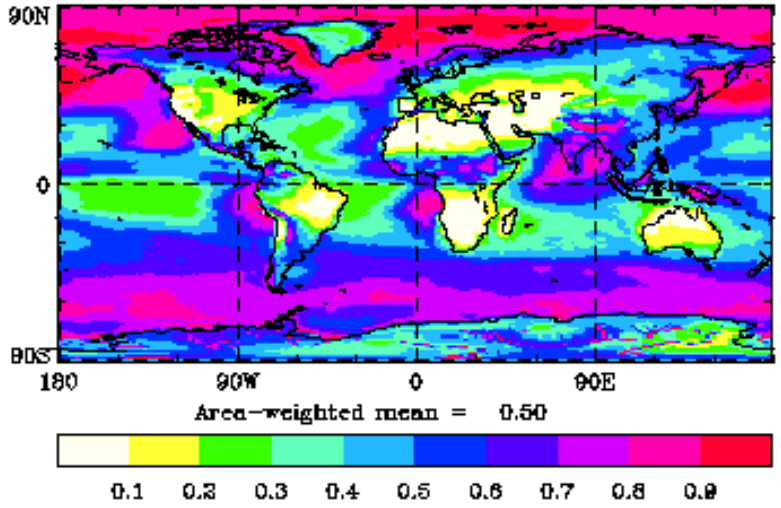


Climate model cloud fraction – 5 year JJA mean

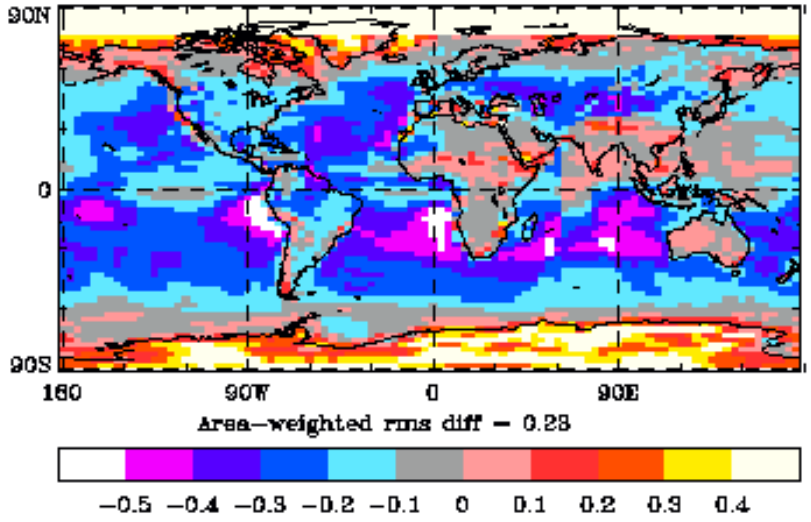
ISCCP



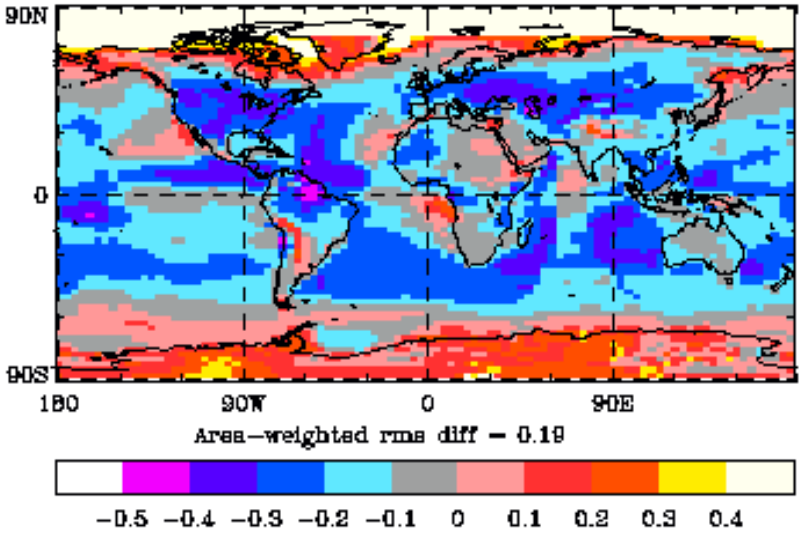
New model



Old model (HADAM3) – ISCCP



New model (HADGEM1) – ISCCP



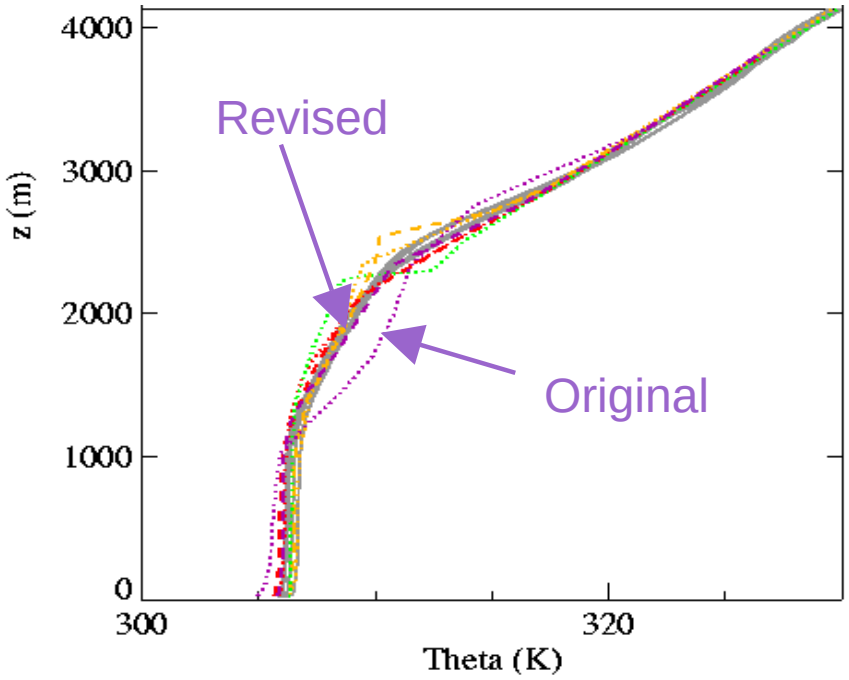
Convection scheme plus developments

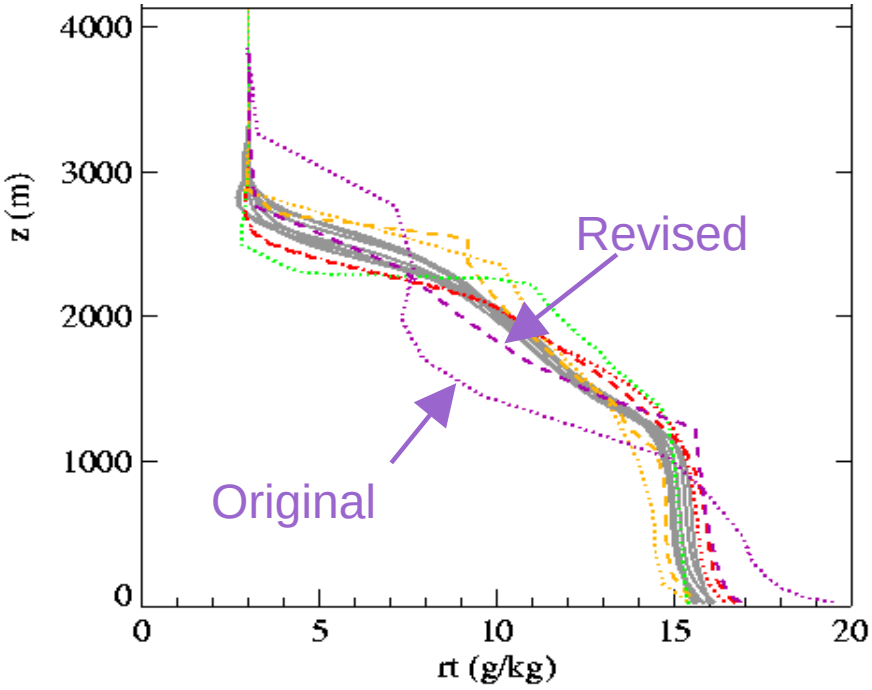
- Gregory and Rowntree (1990) mass-flux scheme (with RH-dependent CAPE closure for deep convection) plus:
  - Trigger at the LCL using explicit cumulus diagnosis
    - Cap K-profile at LCL
  - Shallow convection parametrized with:
    - Grant and Brown (1999) entrainment/detrainment rates
    - $m_{LCL} = 0.03\ w_*$
    - parcel just saturated with $\overline{w\theta_v}\big|_{LCL} = -0.2\ \overline{w\theta_v}\big|_{S}$

Impact in SCM – shallow Cu diurnal cycle

- Parcel perturbation gives warmer/drier sub-cloud layer
- Larger entrainment/detrainment rates give
  - Colder and moister cloud layer
  - Lower cloud top

Profiles at end of simulation



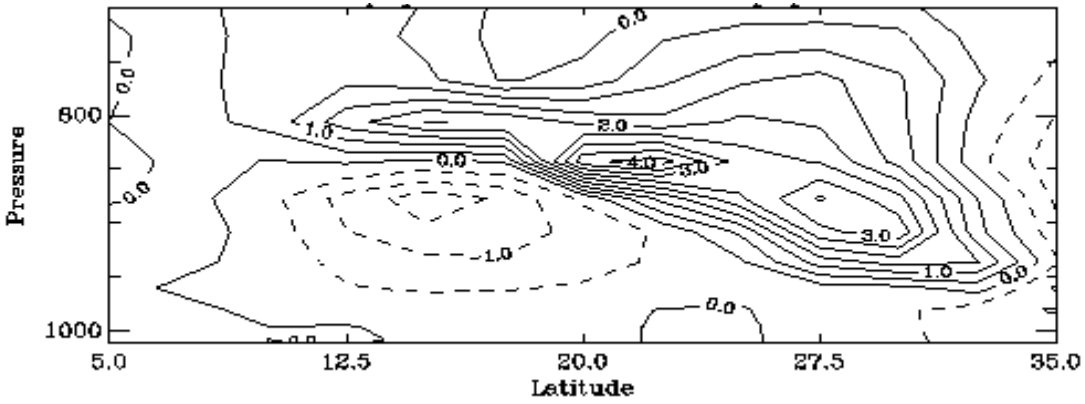


Impact in GCM on trade Cu

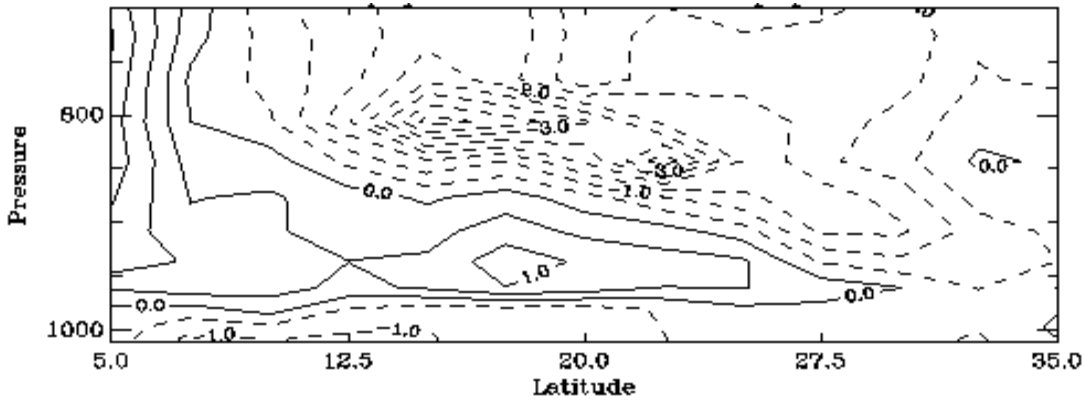
- Same warmer/drier sub-cloud layer
- Same colder and moister cloud layer
- Same lower cloud top

Cross-section 1, July mean, New – Old

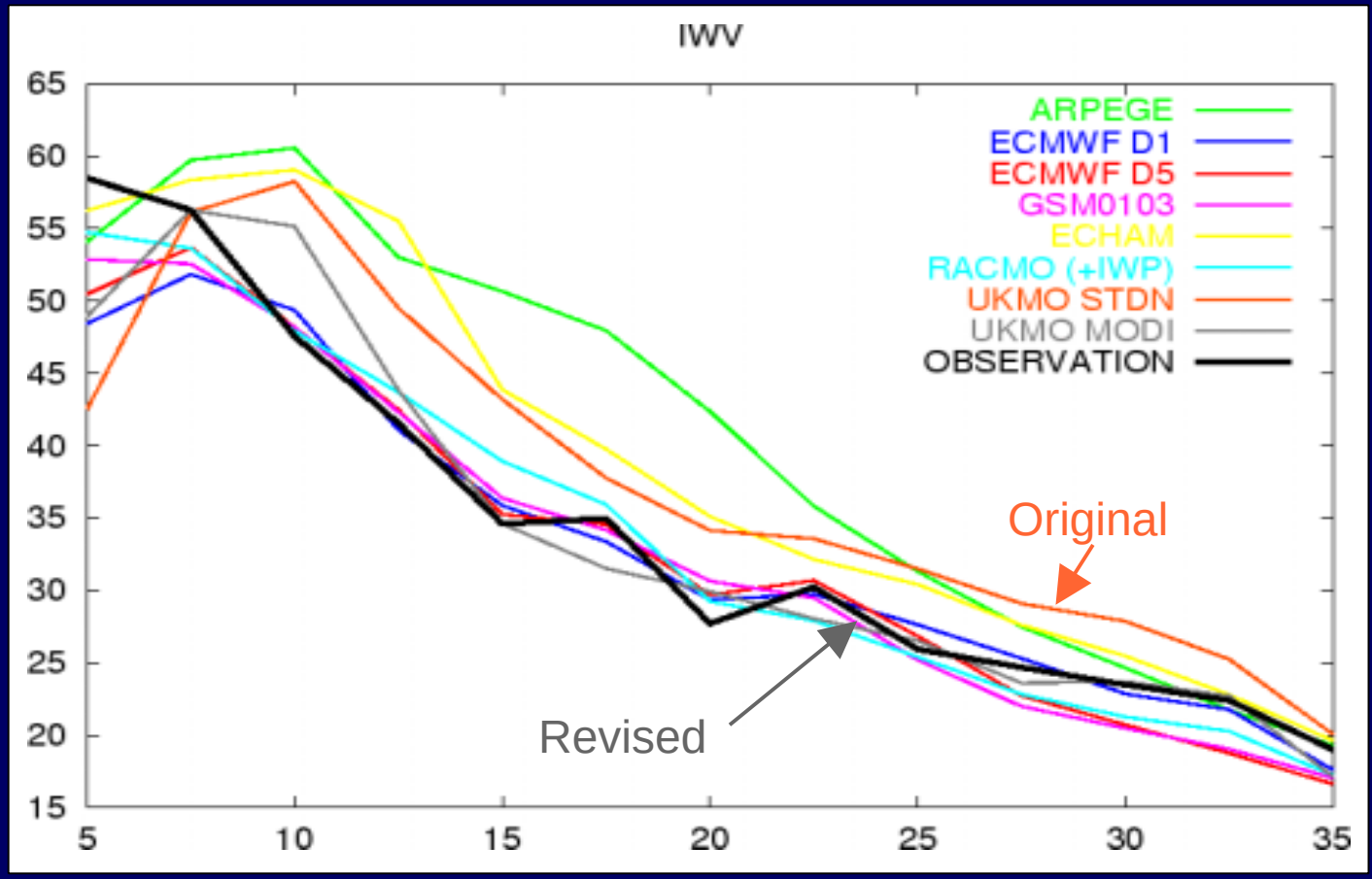
Theta



Humidity

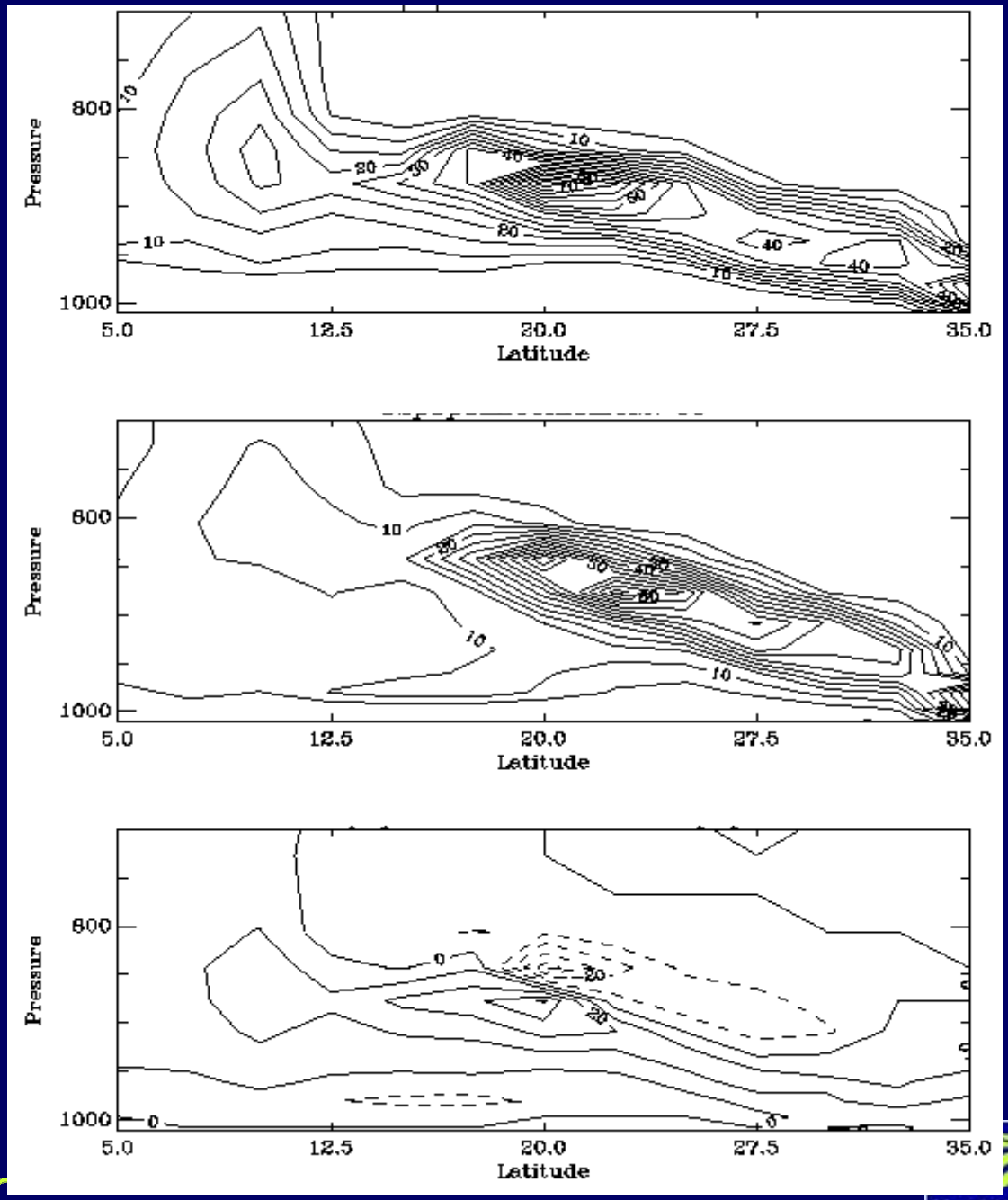


Impact in GCM on water vapour



Impact in GCM on low cloud

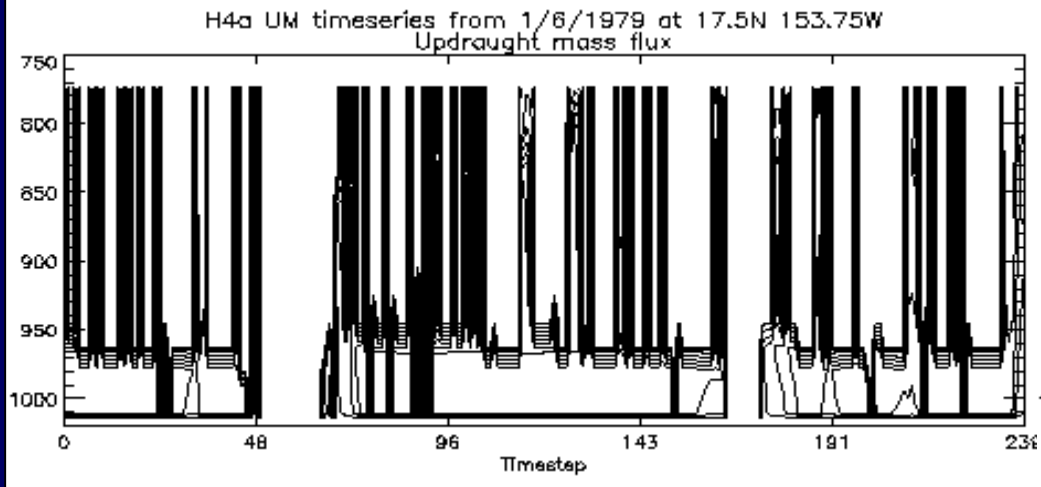
- Cloud-top lower but little impact on cloud cover except towards the ITCZ



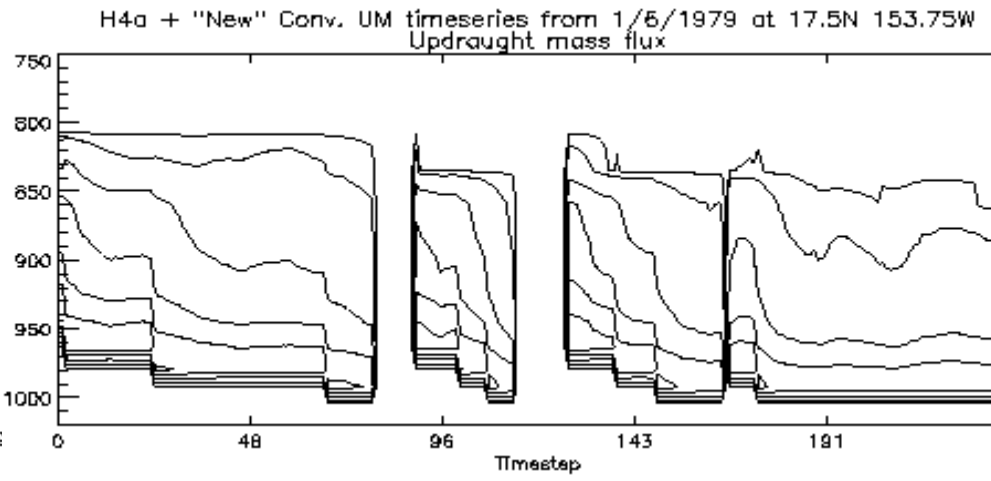
Reduced intermittency of convection

Massflux time-height sections from a point near Hawaii

Original

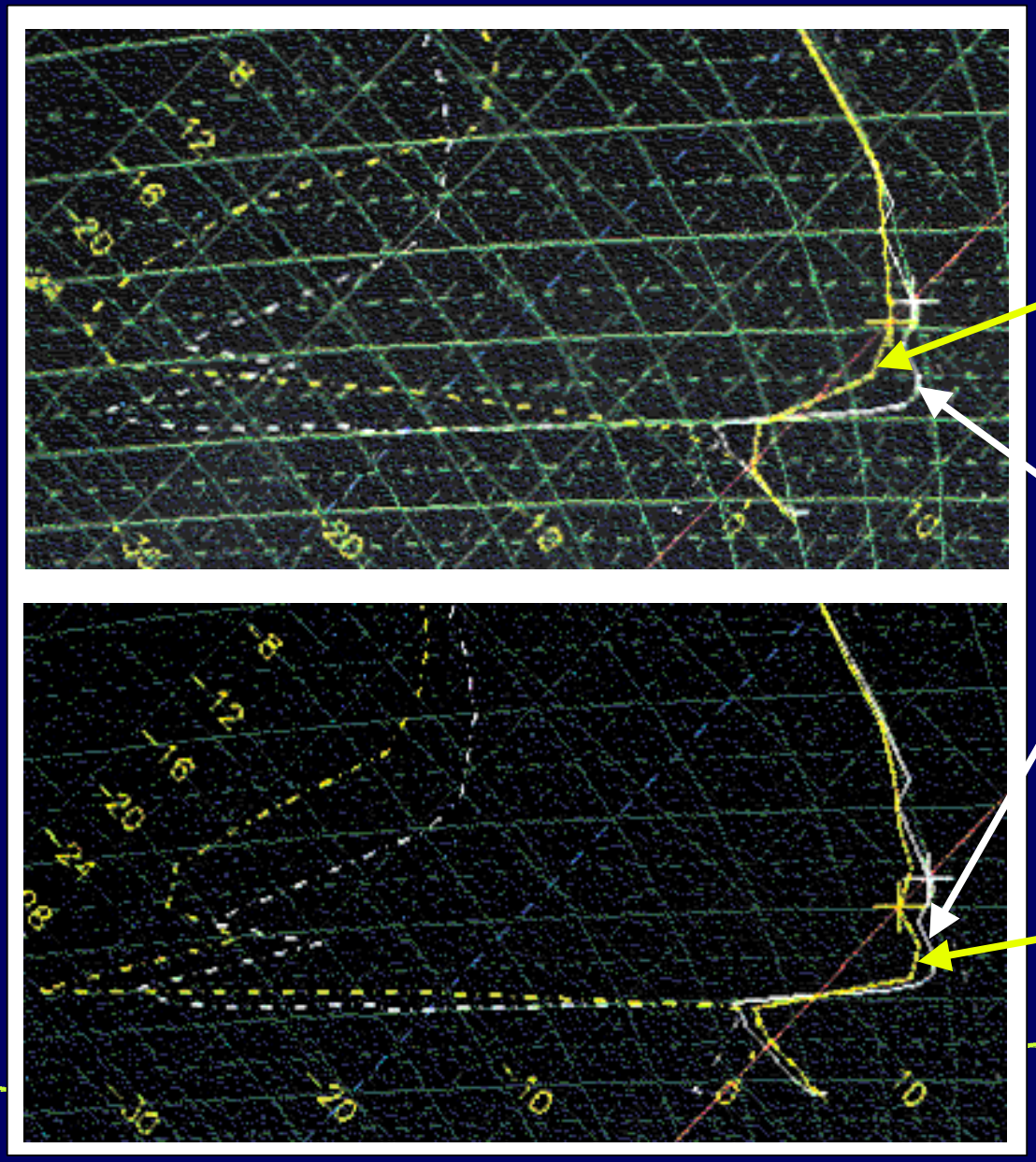


Revised



- Partly a more robust trigger, partly more balanced increments...

NWP representation of stratocumulus (T+12)



Old NWP model
(Ri bl scheme)

Radiosonde ascent

New NWP model
(non-local bl scheme)

Summary and future work (low cloud)

- Both K-profile boundary layer and revised convection schemes are now operational for NWP
- Further work required on the interaction between cumulus and stratocumulus
- Extend the principle of K-profile mixing between layer interfaces to:
  - cumulus convection (both shallow and deep)
  - stable boundary layers