Met Office GCM results

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- Boundary layer and convection scheme descriptions
- Results from GCM simulation:
  - shallow clouds
  - deep clouds

Met Office

Unstable boundary layer scheme Lock(2001)

- 1st order specified K-profile closure (HB 1993)
- Mix conserved variables θ_l and q_t
- Additional K profile for cloud-top driven turbulence
- Explicit diagnosis of cumulus based on comparison of q_t gradients in cloud and subcloud layer. If cumulus:
  - Cap K profile at LCL
  - Trigger massflux scheme from LCL

Boundary layer scheme (continued)

- Explicit entrainment parametrization (Lock, 1998)
- Diagnose vertical extent of K-profiles by imposing a limit on the buoyancy consumption of TKE, using a subgrid diagnosis of cloud-base height:

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

With D=0.1 taken from LES

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Convection scheme

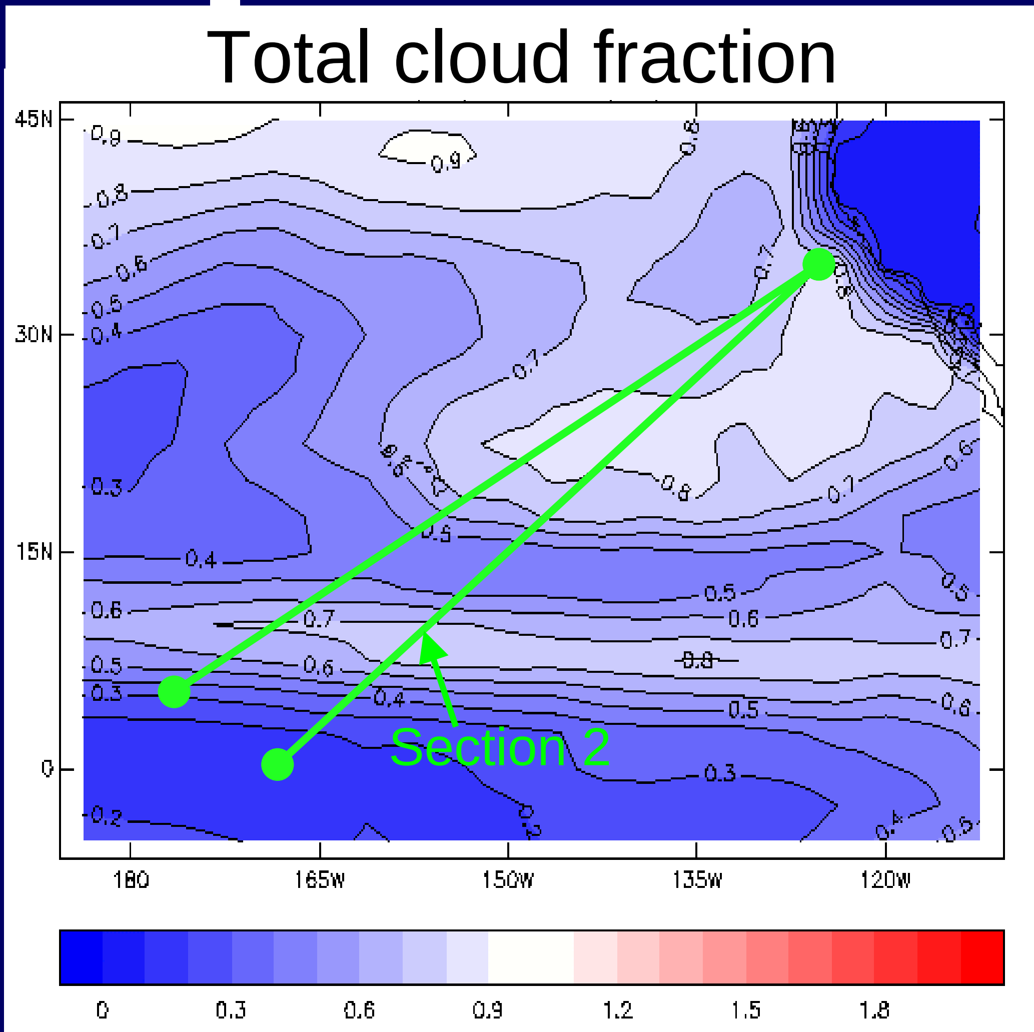
- Gregory and Rowntree (1990) mass-flux scheme (with RH-dependent CAPE closure for deep convection) plus:
  - Trigger at the LCL using cumulus diagnosis
  - Shallow convection parametrized with:
    - Grant and Brown (1999) entrainment/detrainment rates
    - $m_{LCL} = 0.03\ w_*$
    - parcel just saturated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

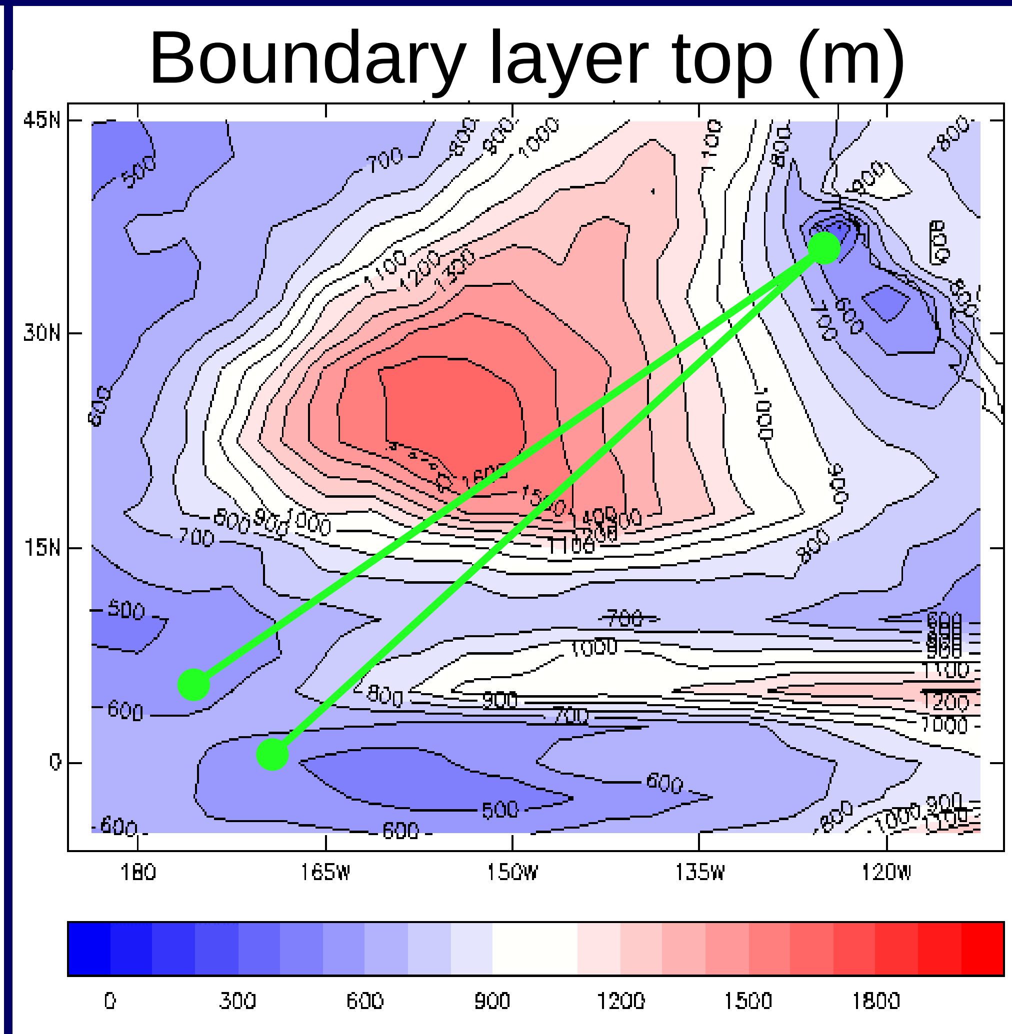
Met Office

Met Office GCM results

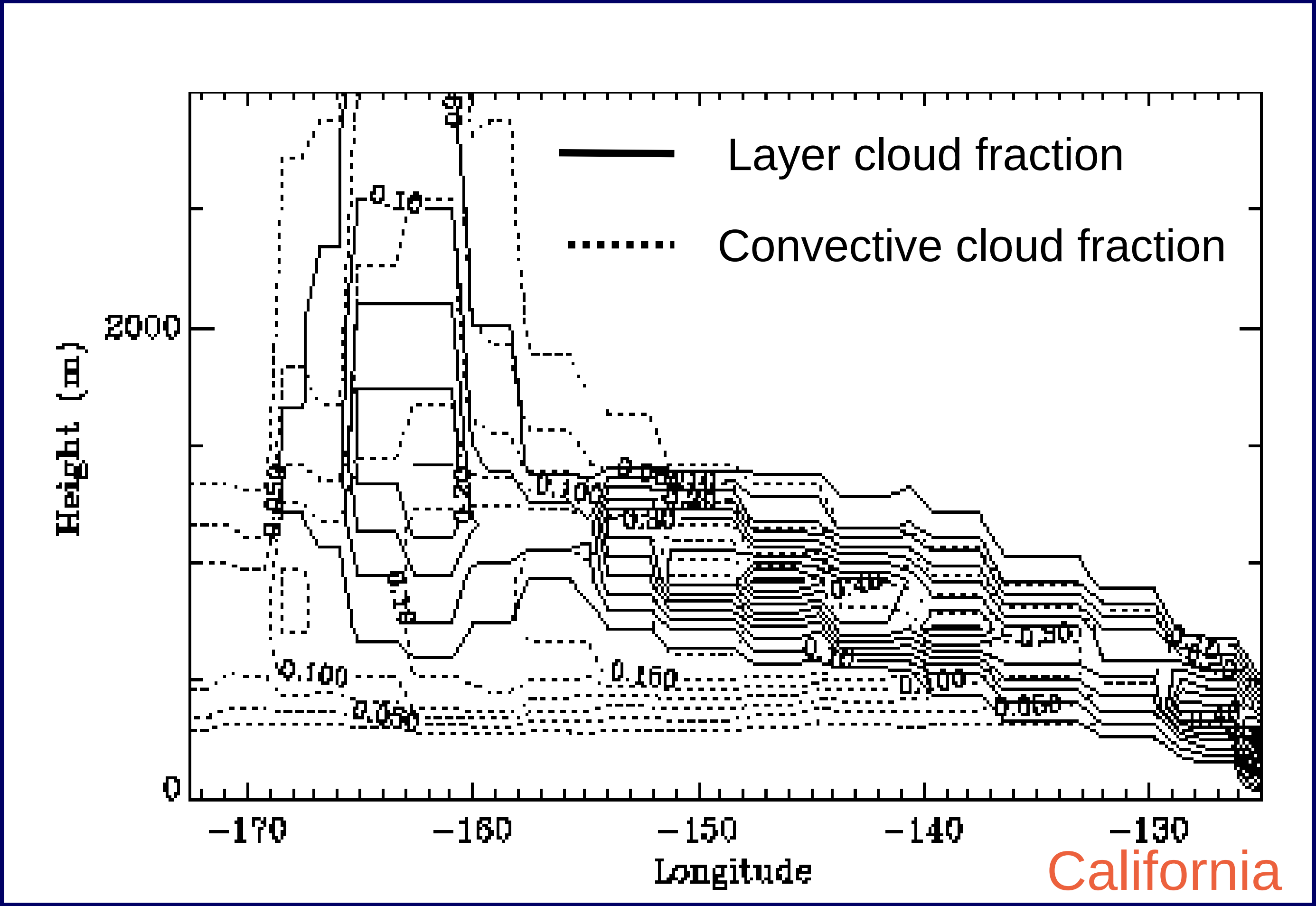
- ‘Climate’ model simulation
  - AMIP-style, prescribed SST
  - Resolution 2.5^0 latitude by 3.75^0 longitude (~300km in tropics)
  - 38 levels (~250m at 1km)

Californian stratocumulus – 1998 JJA mean

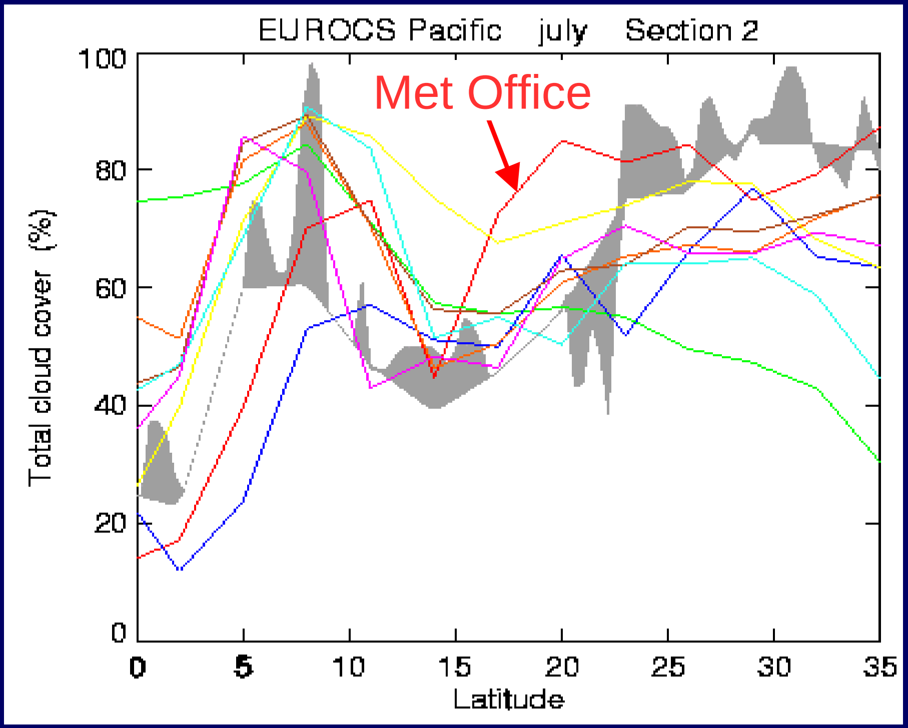


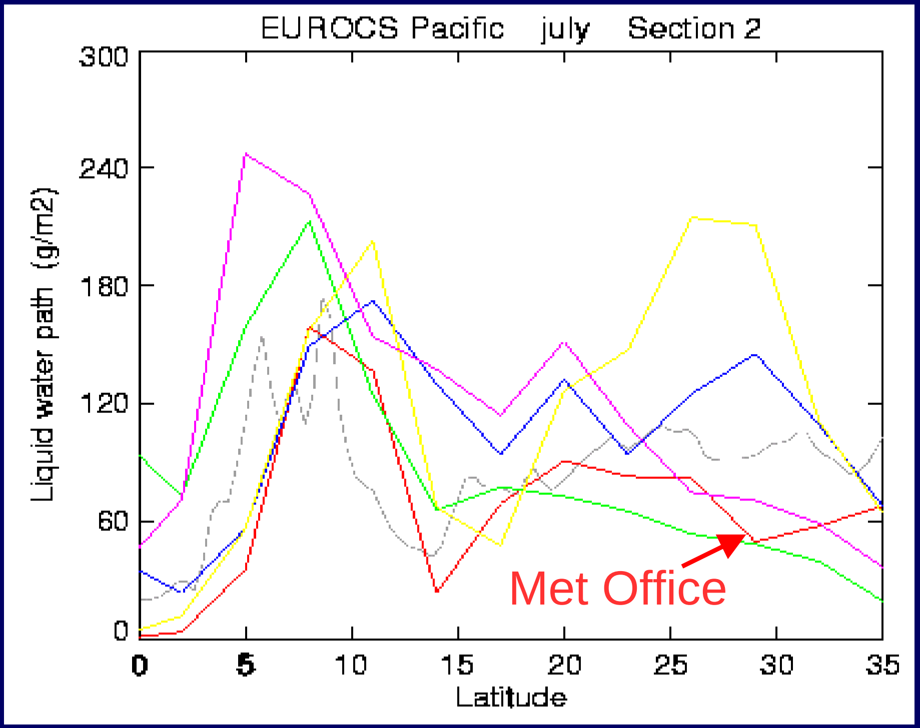


Cloud fractions, section 2 – 1998 JJA mean



Total cloud cover and LWP

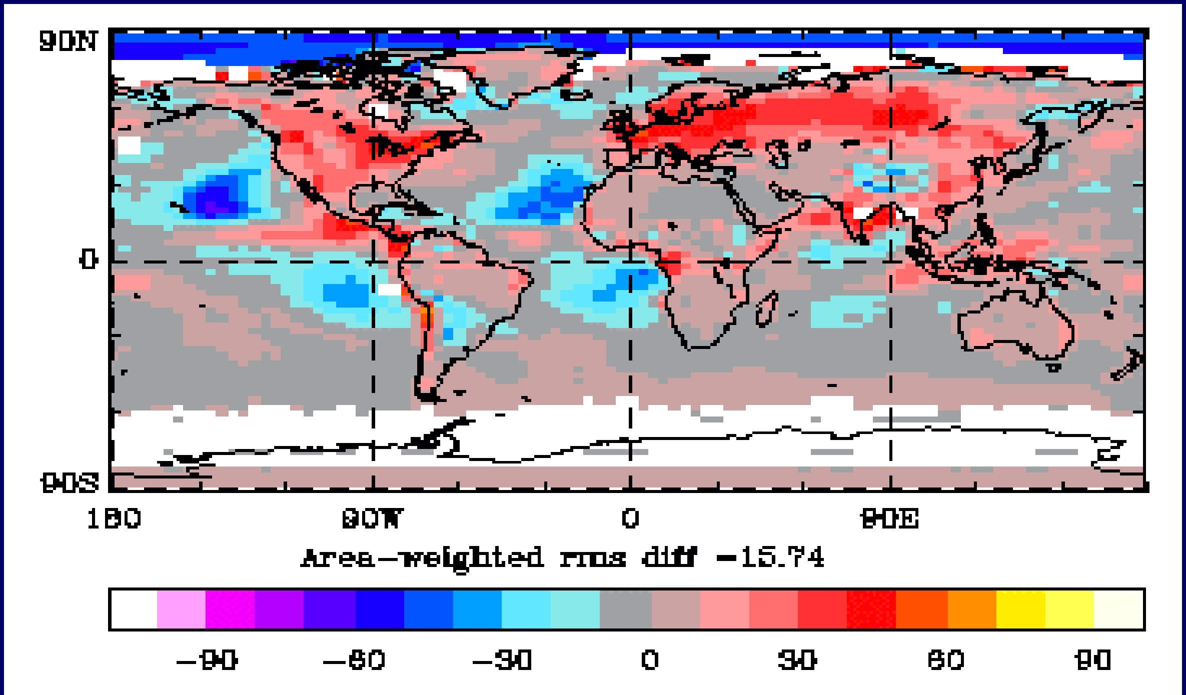




California

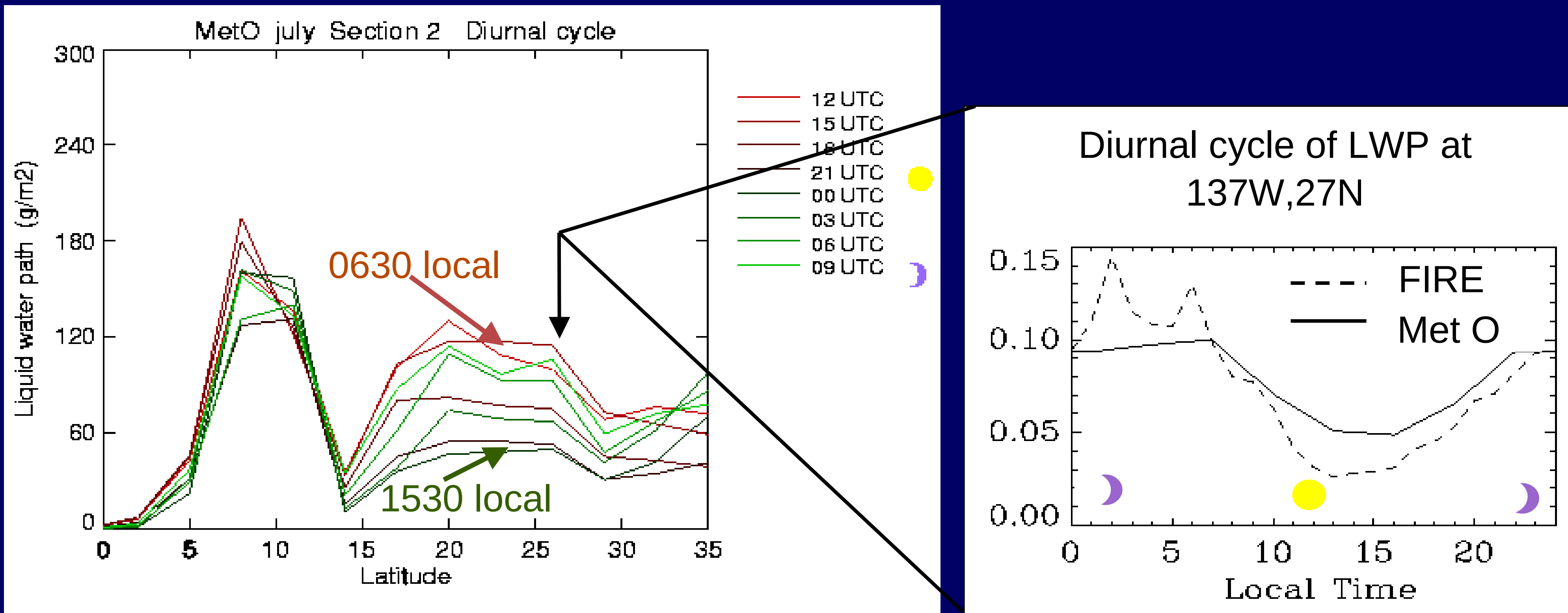
- Cloud cover too high where Sc overlies Cu
- LWP too low close to coast

SW forcing climatology: 5 year JJA mean (Met O - ERBE)



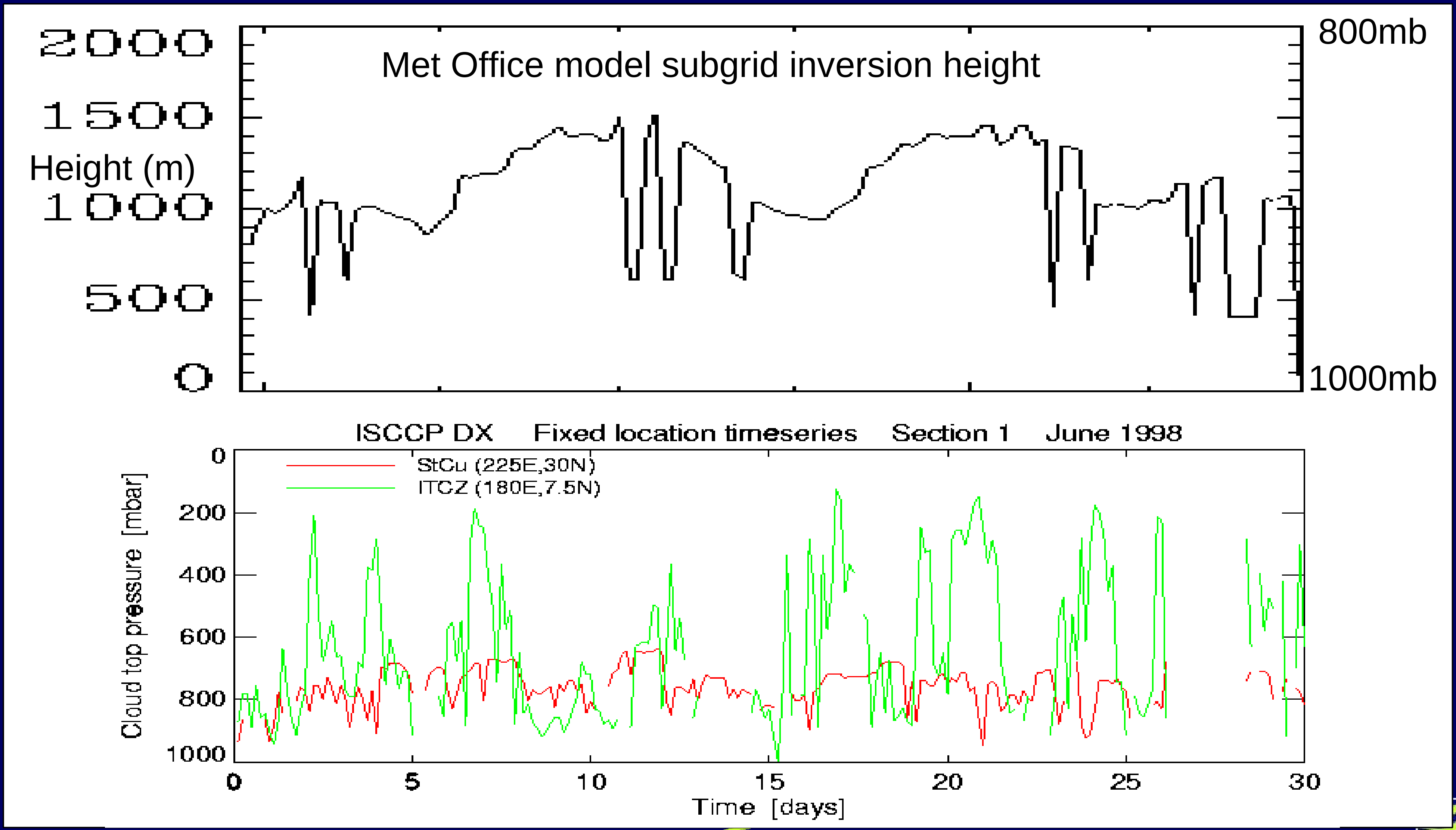
- Negative implies ‘too much’ cloud so:
  - Do need less cloud towards trade Cu regions
  - No more cloud ‘needed’ close to coast

Diurnal cycle of stratocumulus



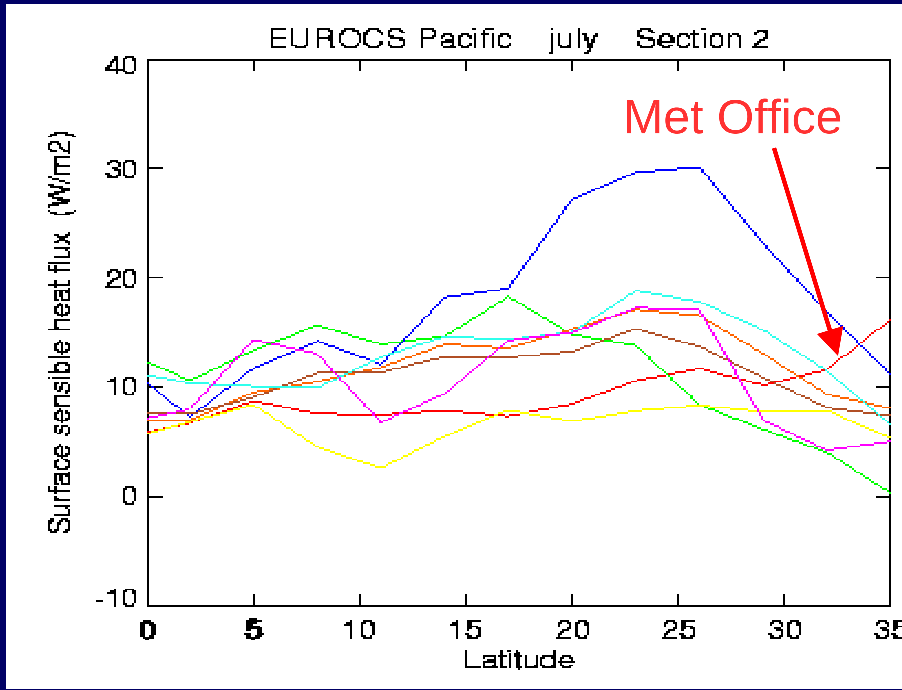
- Time lag in LWP relative to solar cycle well represented away from coast
- But FIRE observations were at San Nicolas Island!

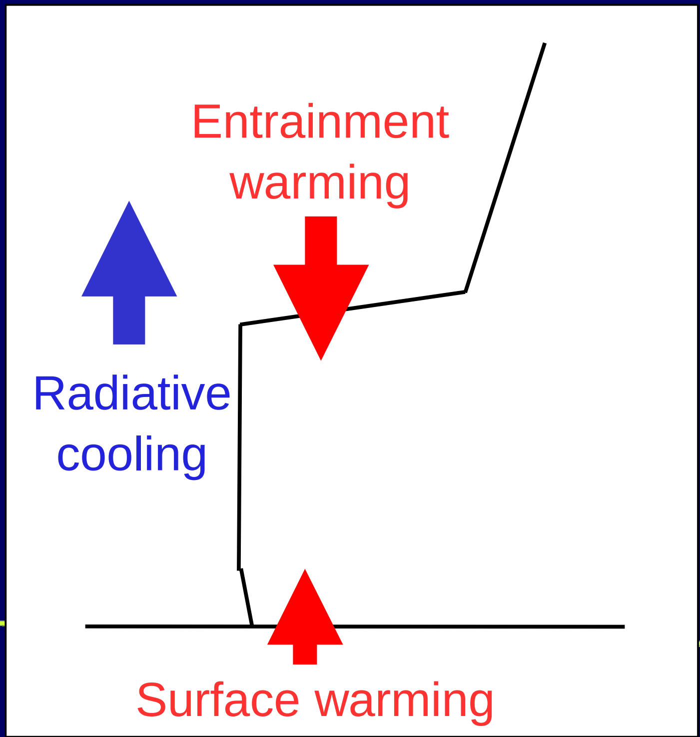
Stratocumulus cloud top height time series



Stratocumulus equilibrium

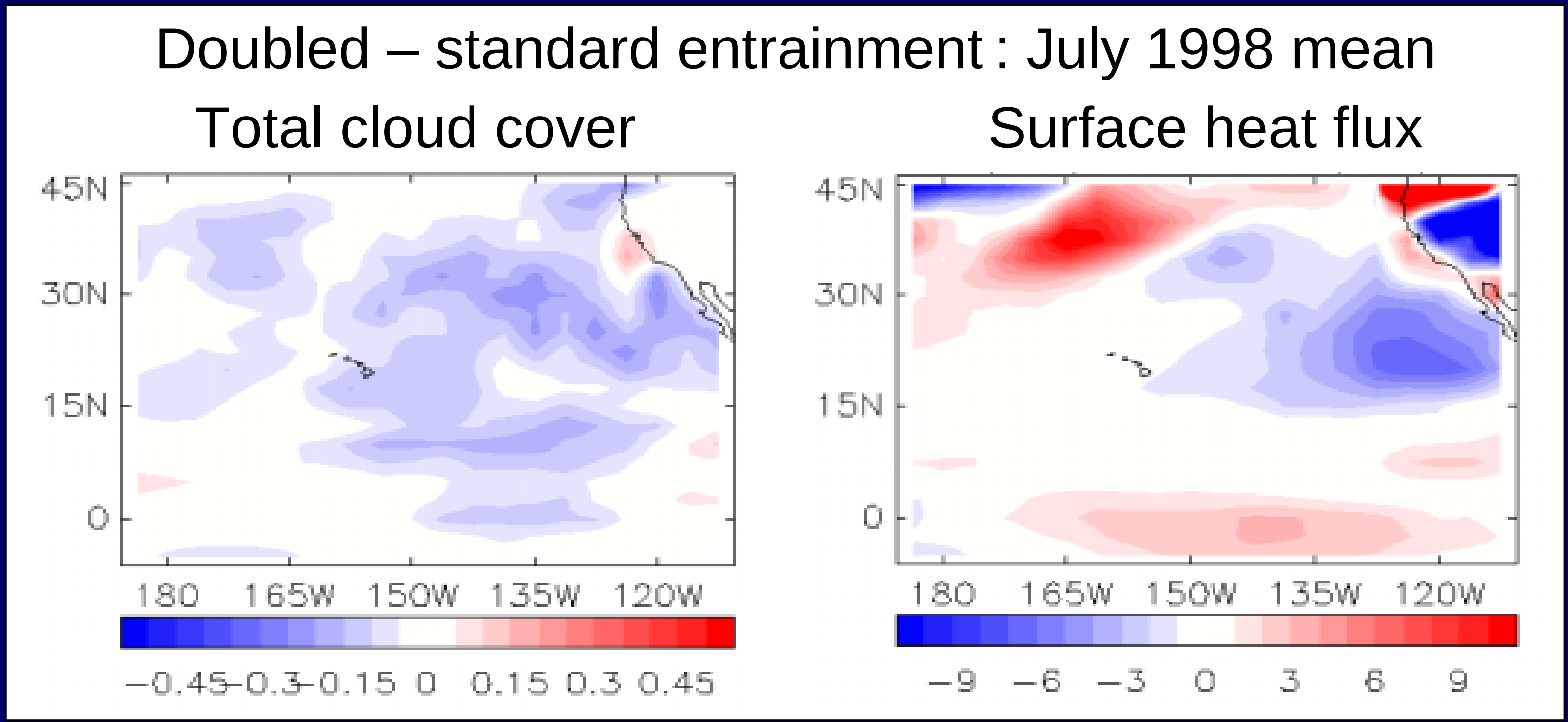
- The Met Office surface heat flux increases towards the coast, as the SST decreases. Is that because of its cloud-top entrainment rate?





- Balance between radiative cooling and entrainment warming leaves a 'residual' surface heating

Sensitivity to doubled entrainment rate



- So, a more active entrainment parametrization gives an equilibrium state with smaller surface heat fluxes and less cloud (Stevens 2002)

Summary - shallow clouds

- The Met Office GCM produces a reasonably realistic stratocumulus sheet over the NE Pacific:
  - Good cloud cover and LWP diurnal cycle

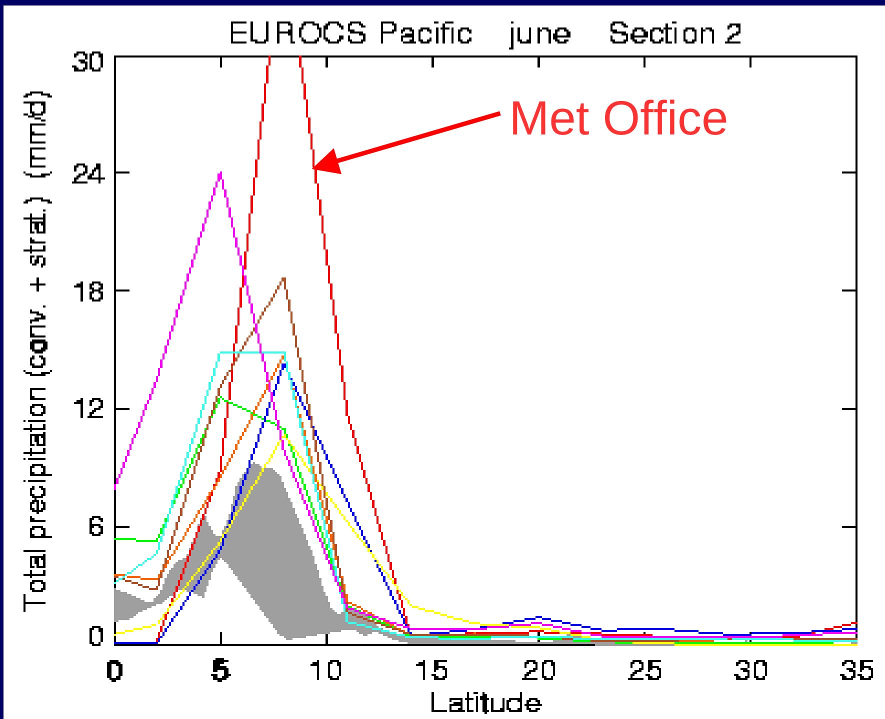
- Close to coast LWP is too small and diurnal cycle does not lag the solar cycle
  - Lack of resolution?
    - Horizontal: noise from the coastline
    - Vertical: cloud-top at 500m gives ~4 levels in the boundary layer so decoupling is hard

Summary - shallow clouds

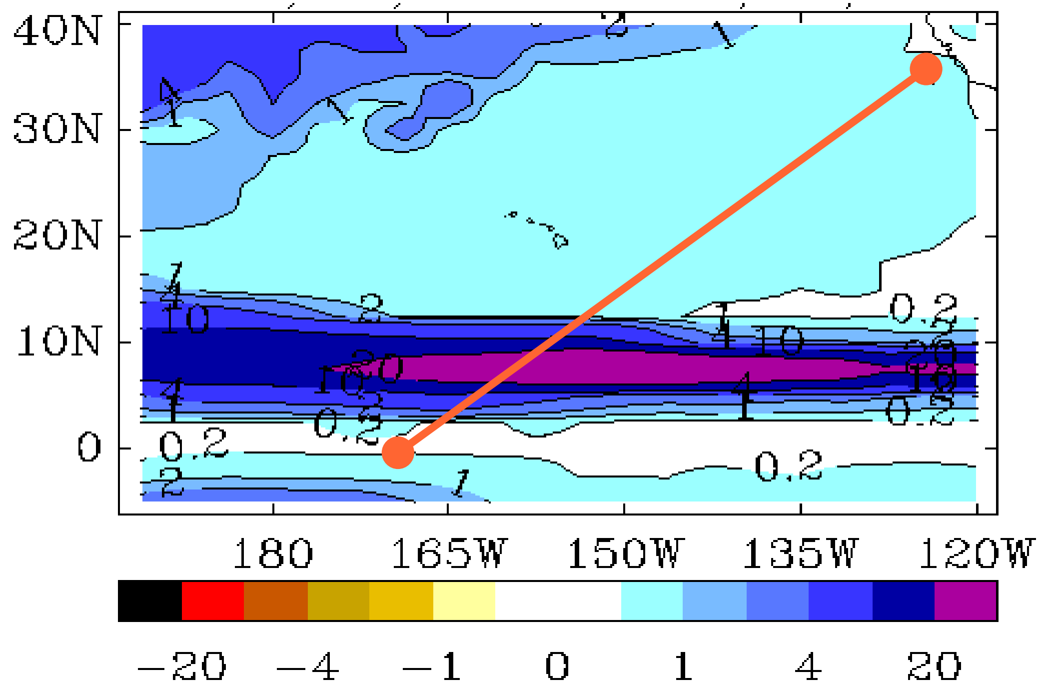
- Stratocumulus is too reflective, particularly when over shallow cumulus
  - Possible problem with Sc/Cu interaction (also with Cu/inversion interaction in general)
  - Radiative impact of cloud inhomogeneity?
- The entrainment parametrization is behaving as predicted by Stevens (2002) – good or bad?

Deep convection

- It rains in the ITCZ - sometimes too much:



Precipitation rate (mm/day) – June mean submitted results



Deep convection

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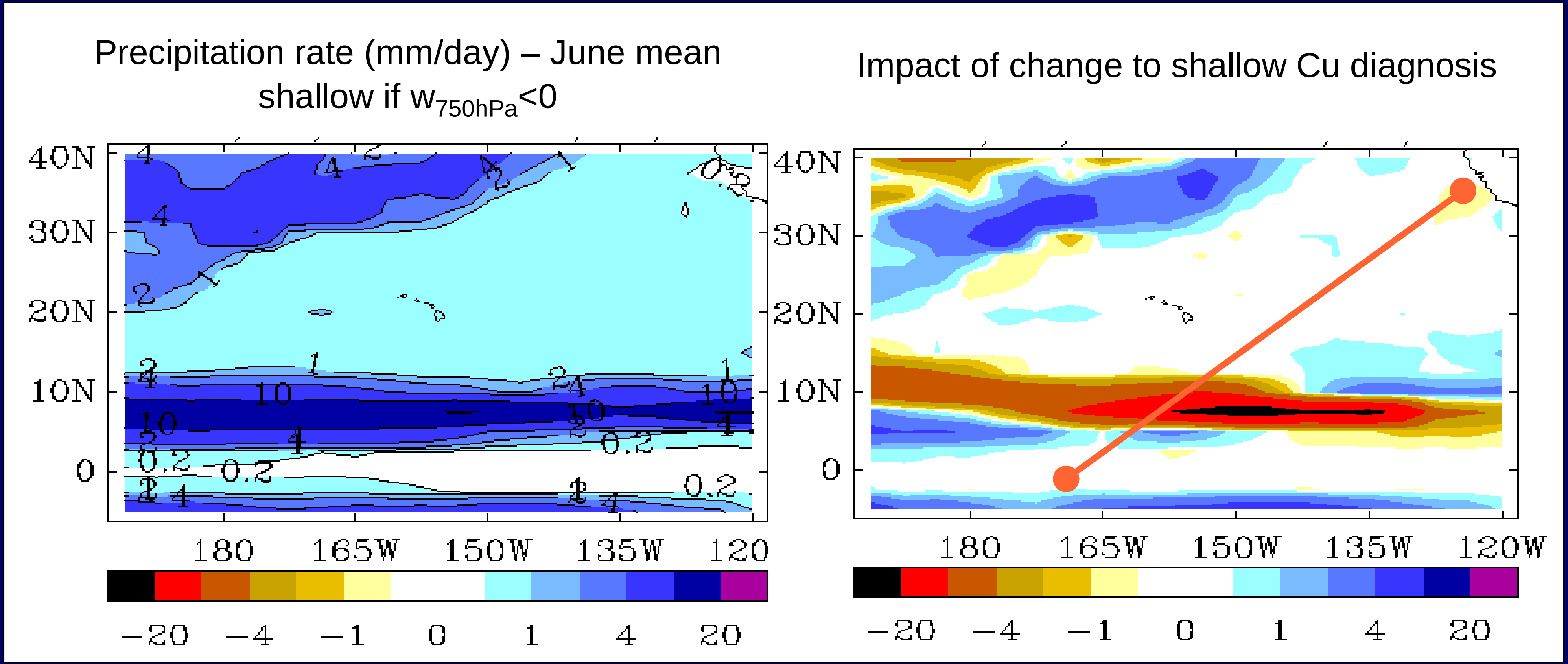
- Much improved by recent change to diagnosis of when convection is shallow (require $w_{750hPa} < 0$)



Future work

- Extend the K-profile scheme, now operational for convective momentum transport, to the thermodynamic variables (shallow and deep)
- Explore the interaction between cumulus, inversions and stratocumulus in LES (and thence improve its parametrization!)