Cloud feedbacks relevant to the tropospheric energy budget

Hugo Lambert¹ and Mark Webb²

<u>1</u> College of Engineering, Mathematics and Physical Sciences University of Exeter, UK

<u>2</u> UK Met Office Hadley Centre, Exeter, UK



Thanks to James Manners²



From Lambert and Webb (2008)

Outline

- Longwave cloud feedbacks at the TOA and surface.

Using data from the QUMP $2xCO_2$ slab ensemble:

- Changes associated with the cloud masking effect and cloud changes. (These early results using radiation code are rather approximate.)

Brief preliminary analysis of tropical cloud changes

Overall changes in atmospheric longwave radiative cooling associated with clouds.





- Clear-sky flux increases by \boldsymbol{x}
- Cloud C does not change.
- Cloud radiative forcing (CRF) = -x

 $CRF = \Delta all-sky flux - \Delta clear-sky flux$ (Cess et al., (1990))



TOA radiative cooling

CRF

Cloud Masking

Cloud PRP



Surface radiative cooling

CRF

Cloud Masking

Cloud PRP



<u>Anomalies in Clear-sky</u> <u>radiation</u>

Double CO2 and let the model warm.

(Approximate changes with radiation code.)

(see also Previdi, 2010)



Cloud masking effect

Double CO2 and let the model warm.

(Approximate changes with radiation code.)



Net atmospheric radiative cooling

CRF

Cloud Masking

Cloud PRP



(b) Total longwave radiative cooling cloud masking



(c) Total longwave radiative cooling PRP



TOA radiative cooling

CRF

Cloud Masking

Cloud PRP

(Approx. with radiation code)





(b) TOA cloud masking



(c) TOA PRP





Surface radiative cooling

CRF

Cloud Masking

Cloud PRP

(Approx. with radiation code)



(b) Surface cloud masking



(c) Surface PRP







Changes in tropical cloud fraction as a function of **temperature**

Cloud top looks like Hartmann and Larson (2002), Zelinka and Hartmann (2009)





in summary...







Surface clear-sky cooling dominated by water-vapour change

TOA + surface \neq 0



Surface clouds mostly mask water-vapour change

TOA + surface ≈ 0

Add changes due to changes in cloud... (PRP)



Less change in radiation at the surface in the tropics, as **cloud base stays at the same pressure**.

Some effects over land apparently related to cloud coverage.

Conclusions

- Cloud effects produce ~25% reduction in longwave radiative cooling under simulated global warming.

Our early approximate study suggests that:

- Substantial TOA and surface cloud masking effects cancel.
- Changes in clouds dominate.

Future work:

- Hope to do calculations properly using MIROC PRP.
- Try to understand robustness of cloud changes.

<u>Net atmospheric radiative</u> <u>cooling, 2σ</u>

CRF

Cloud Masking

Cloud PRP

(Approx. with radiation code)



(b) Total longwave radiative cloud masking, 2σ



(c) Total longwave radiative cooling PRP, 2σ





TOA radiative cooling, 2σ

CRF

Cloud Masking

Cloud PRP



Surface radiative cooling, 2σ

(a) Surface CRF, 2σ



Cloud Masking

CRF

Cloud PRP