Investigating the cloud scheme in the UM

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Charmaine Franklin

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PC2 - prognostic cloud, prognostic condensate

5 prognostic variables

- liquid water specific humidity
- ice specific humidity
- liquid cloud volume fraction
- ice cloud volume fraction
- bulk (liquid and/or ice) cloud fraction

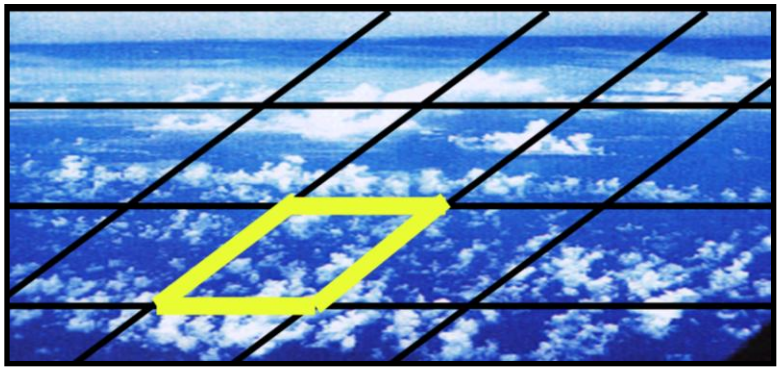
sources / sinks from physical processes

- advection
- convection
- radiation
- microphysics
- turbulence
- boundary layer
- pressure changes

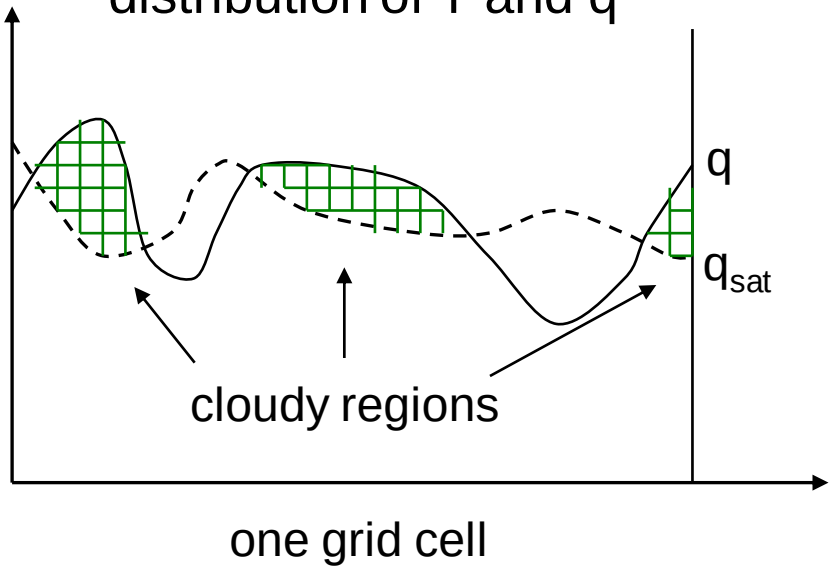
$$\frac{\partial \overline{q_{cl}}}{\partial t} = \frac{\partial \overline{q_{cl}}}{\partial t}\Big|_{advection} + \frac{\partial \overline{q_{cl}}}{\partial t}\Big|_{convection} + \frac{\partial \overline{q_{cl}}}{\partial t}\Big|_{radiation} + \frac{\partial \overline{q_{cl}}}{\partial t}\Big|_{microphysics} + \ldots$$

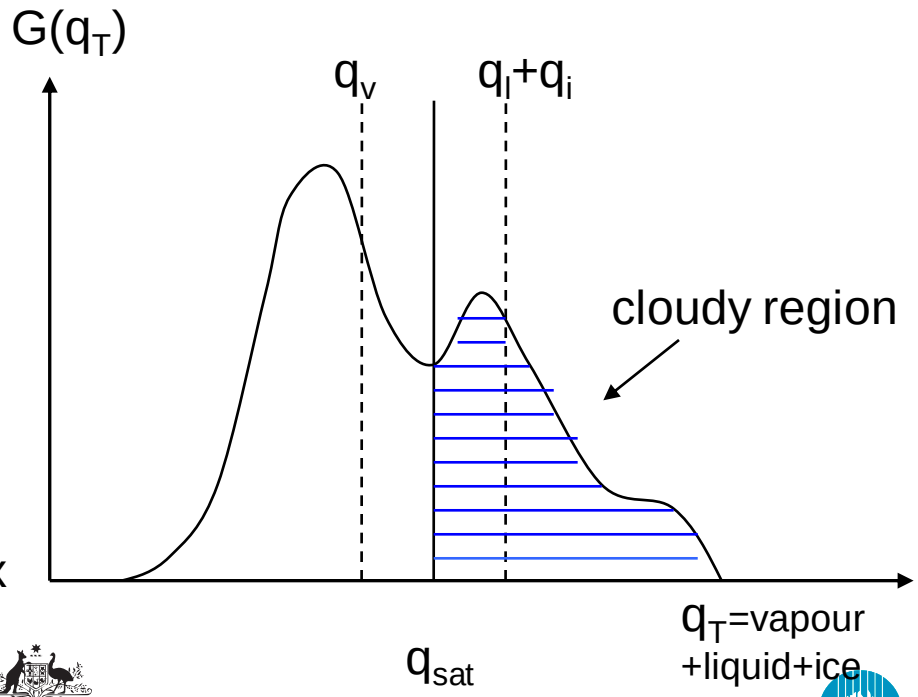
Each physical process in the model will update the cloud fractions and calculate a condensation term (transfer between liquid and vapour) associated with that process.

Cloud schemes in a statistical framework

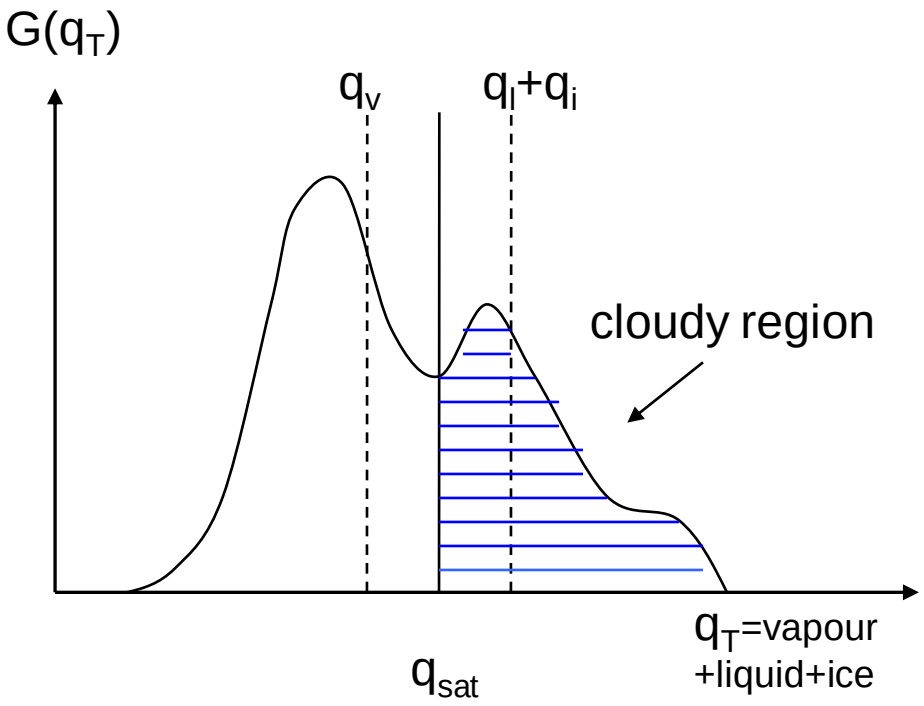


heterogeneous
distribution of T and q





Cloud schemes in a statistical framework



If we know PDF form & moments and mean q_{sat} we can derive cloud cover & mean condensate

$$C = \int_{q_{sat}}^{\infty} G(q_T)\, dq_T$$

$$\overline{q_{cl}} = \int_{q_{sat}}^{\infty} (q_T - q_{sat}) G(q_T)\, dq_T$$

PC2 calculates $\partial C/\partial t$ and $\partial \overline{q_{cl}}/\partial t$ for each process that alters T, p, q or qcl (and similarly for the ice terms). These calculations are all based on the underlying PDF.

Annual mean cloud forcings (W m^{-2})

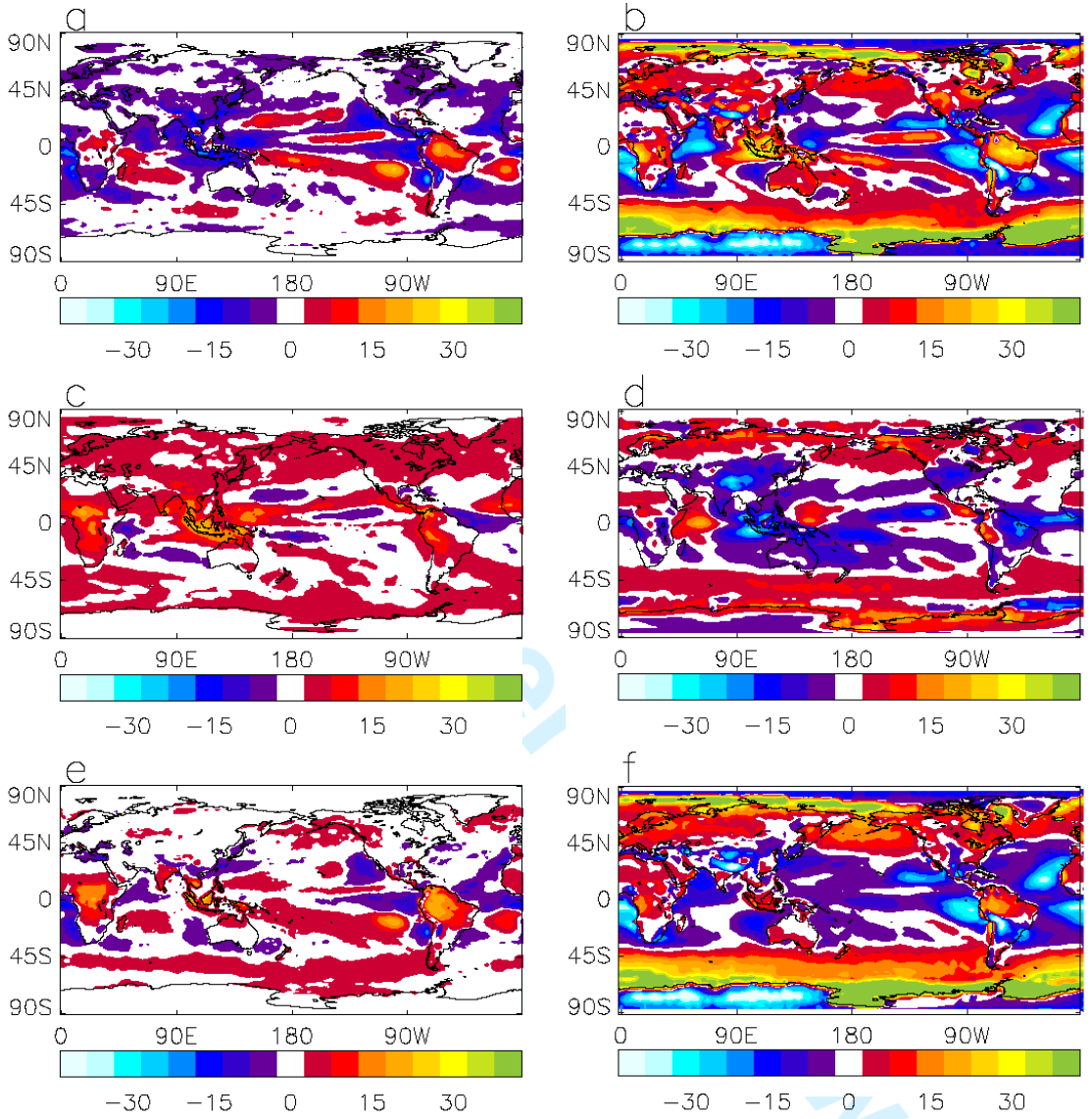
PC2 - HadGAM1a control

PC2 - ERBE

shortwave

longwave

net



From Wilson et al. (2008) QJ submitted

Surface radiation budget (W m^{-2})

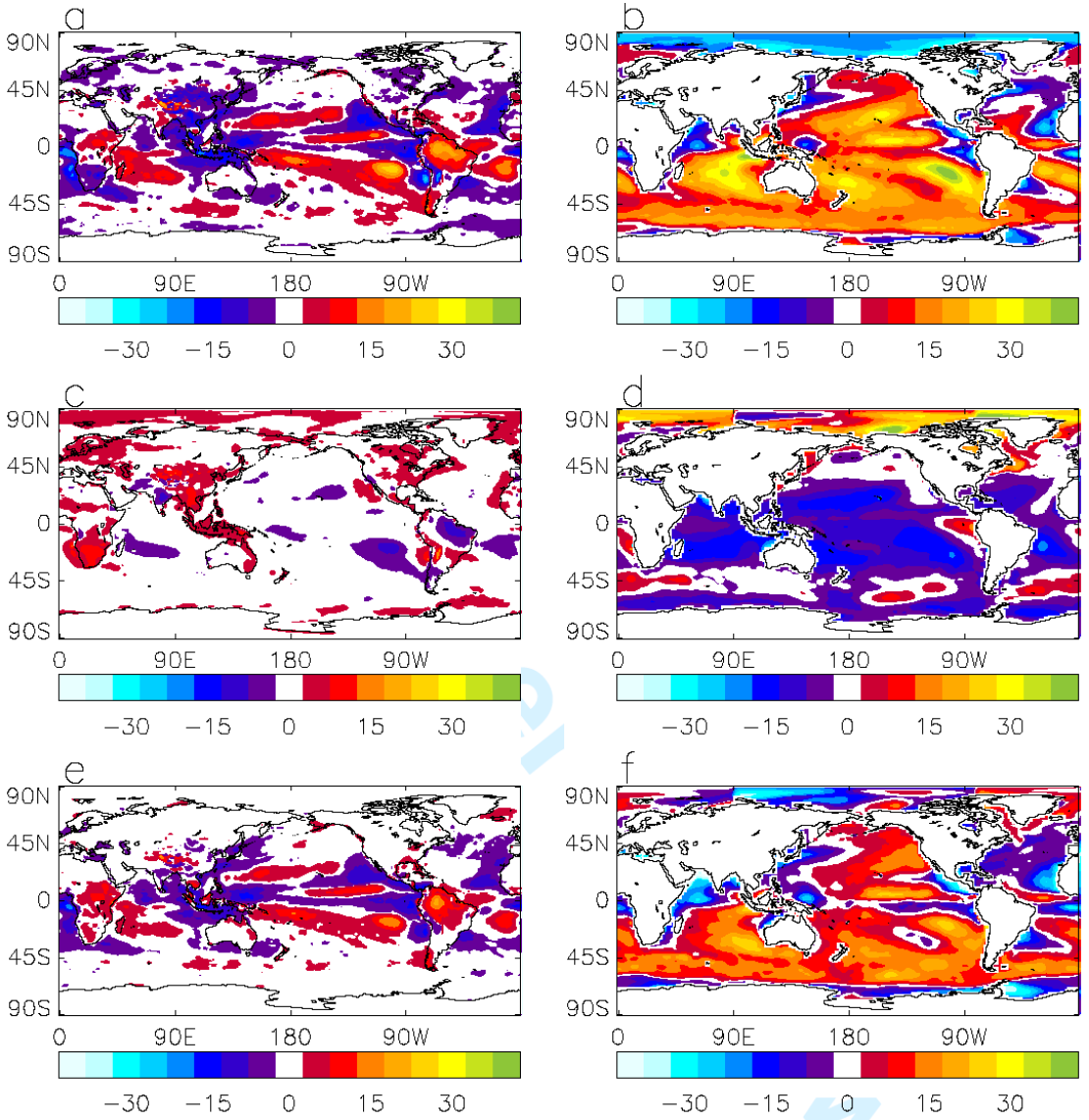
PC2 - HadGAM1a control

PC2 – Da Silva climatology

net downwards shortwave

net downwards longwave

net downwards shortwave + longwave



From Wilson et al. (2008) QJ submitted

Radiation budgets (W m^{-2})

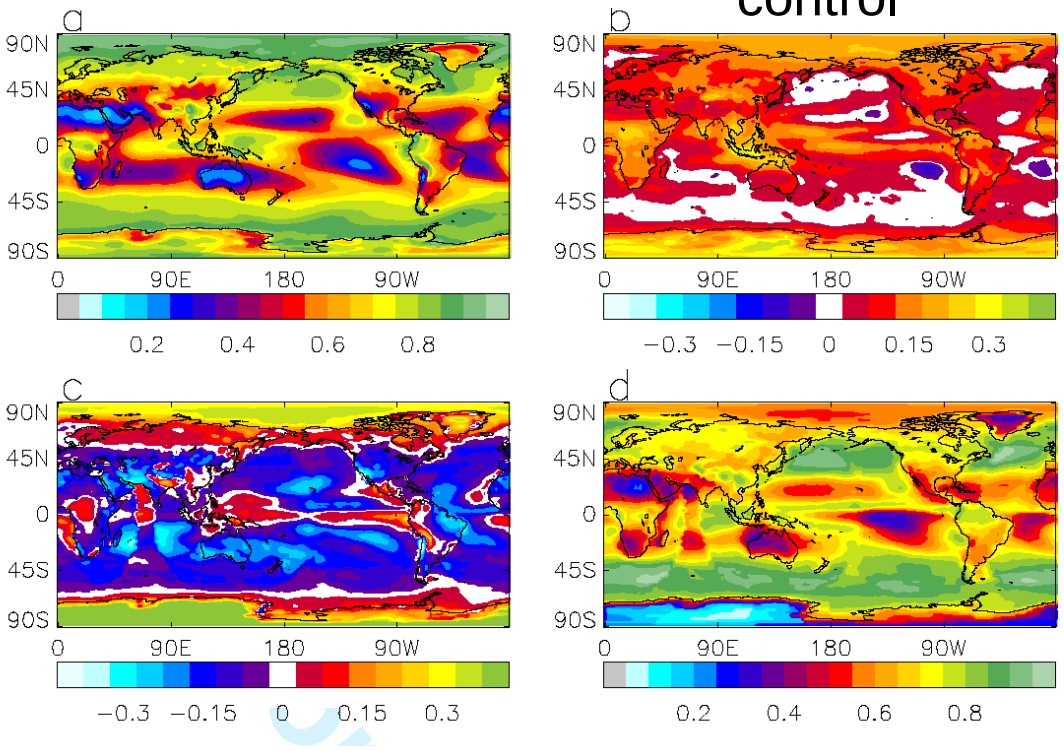
Cloud Forcing	RMS SWCF	RMS LWCF	RMS Net CF	Bias SWCF	Bias LWCF	Bias Net CF
HadGAM1a	14.2	8.2	13.7	3.8	-3.9	-0.1
PC2	14.3	6.6	14.6	2.0	-1.1	0.9
TOA	RMS OSW	RMS OLW		Bias OSW	Bias OLW	Net TOA
HadGAM1a	11.2	10.4		-3.7	6.4	1.6
PC2	11.4	8.3		-1.8	3.9	2.2
Surface	RMS SW	RMS LW	RMS Net	Bias SW	Bias LW	Bias Net
HadGAM1a	15.0	8.9	11.7	8.4	-5.4	2.9
PC2	15.8	9.4	12.4	7.6	-5.5	2.1

From Wilson et al. (2008) QJ submitted

Mean annual cloud cover

PC2

PC2 – HadGAM1a control



PC2 – ISCCP-D2 data

ISCCP-D2 data

From Wilson et al. (2008) QJ submitted

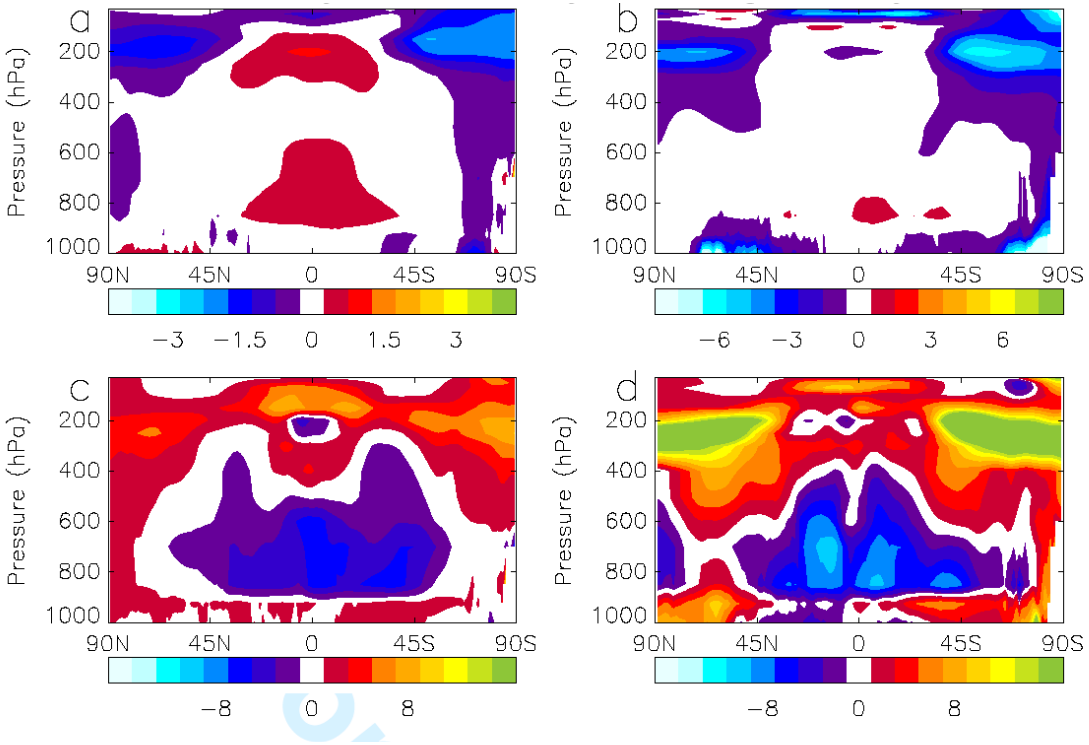
Zonal mean temperature and relative humidity

PC2 – HadGAM1a control

PC2 – ERA 40

Temperature

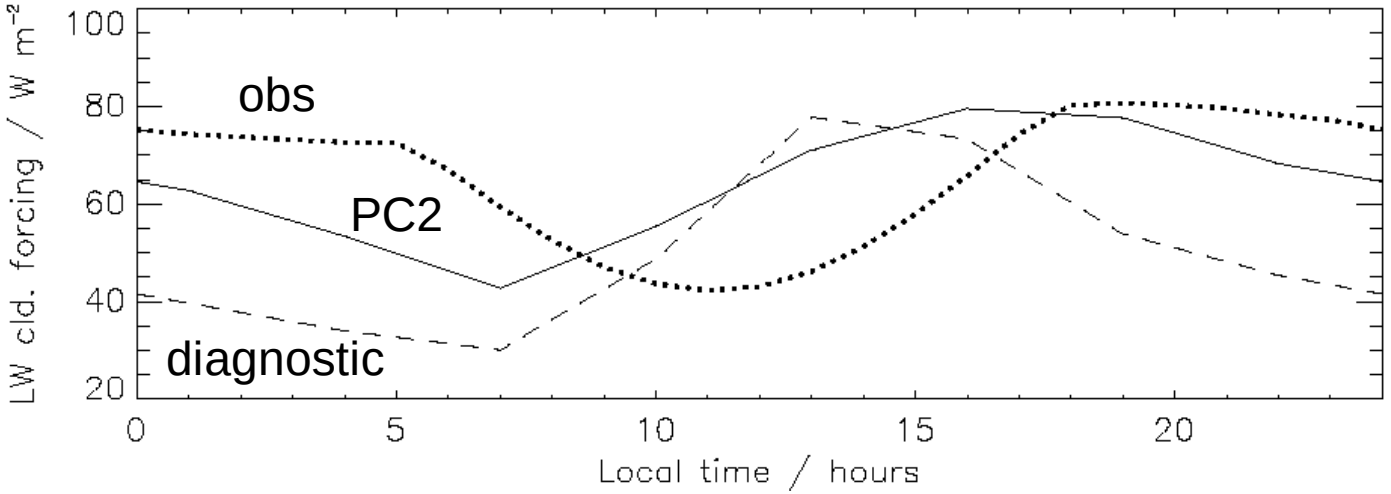
Relative humidity wrt ice



From Wilson et al. (2008) QJ submitted

Diurnal cycle of longwave cloud forcing

Averaged over deep convective points in Africa

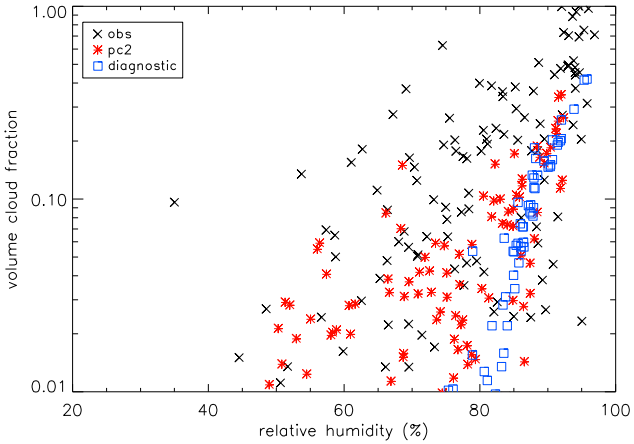


From Wilson et al. (2008) QJ submitted

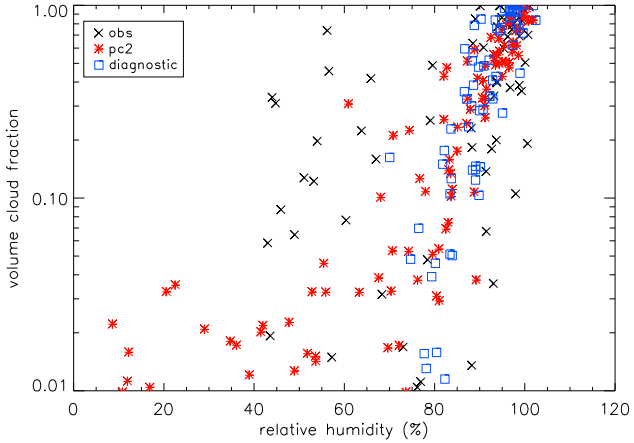
- CERES obs shows growth of high anvil cloud through afternoon due to detrainment of condensate from convective cores, evaporation from solar radiation reduces the forcing
- PC2 follows this pattern, however there is an early peak in longwave forcing due to the convection scheme triggering too early

Cloud fraction as function of relative humidity

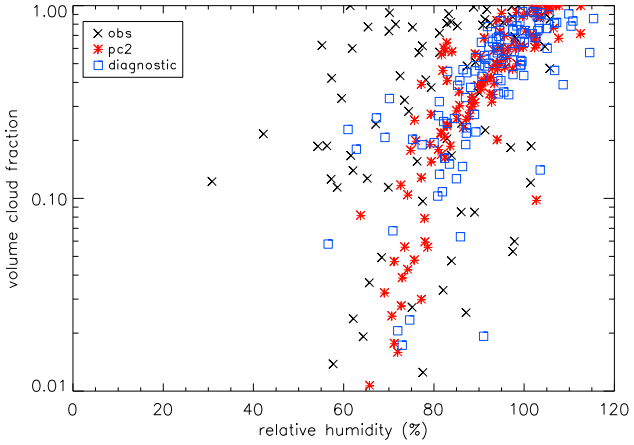
2 km



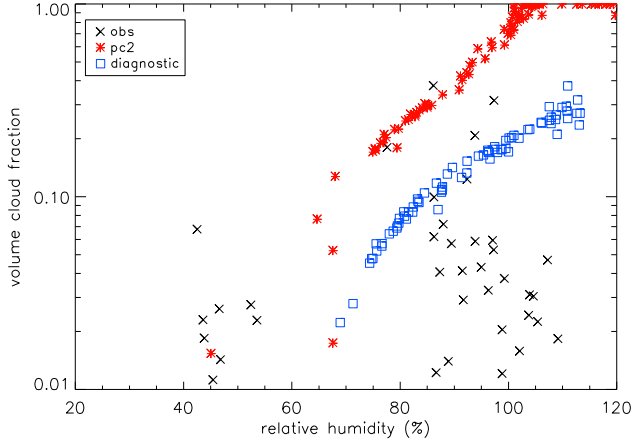
5 km



10 km



15 km



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Summary

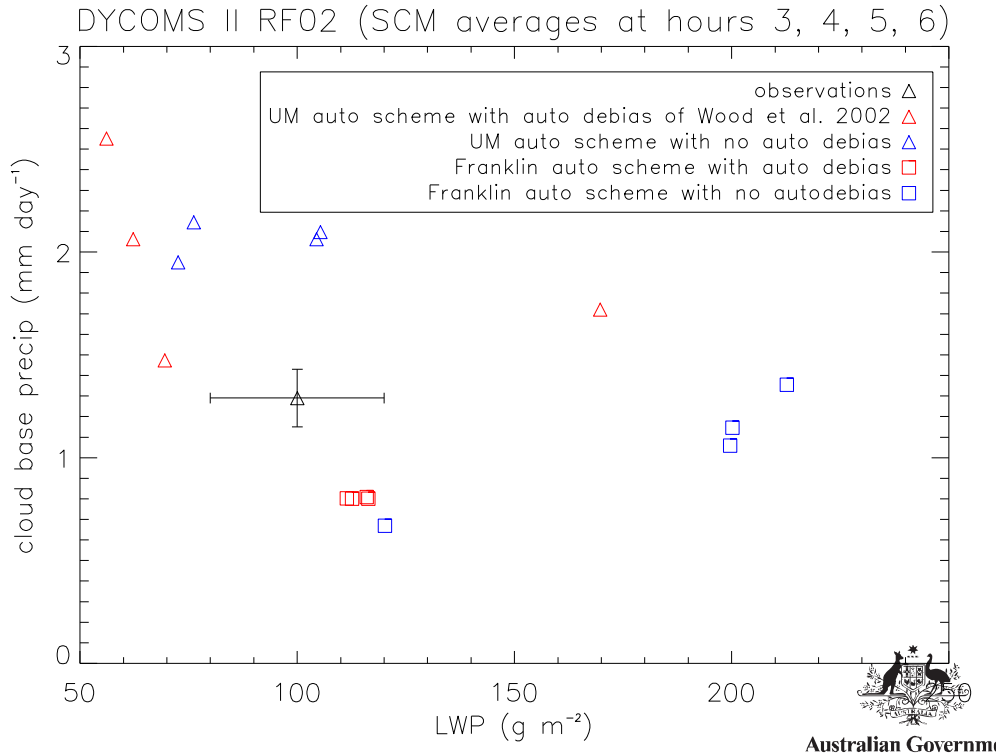
- PC2 prognostic cloud scheme has a more direct link to physical processes
- Longwave cloud forcing is improved with PC2 and the underestimate in HadGAM1a is largely removed
  - this is mostly due to better simulation of deep convective clouds and the increase in ice that is detrained rather than precipitated
- No change in zonal mean temperature between the cloud schemes
  - increase in tropical high cloud in PC2 and associated radiative warming is offset by decrease in the intensity of convection
- PC2 improves the upper troposphere dry bias due to increased detrainment, consequently though introduces a dry bias below
- Increased cloud cover from PC2 is in better agreement with obs
- PC2 produces more variable cloud properties in line with observations
  - strong link between relative humidity and cloud fraction present in diagnostic scheme is broken with the prognostic formulation of PC2

Future work

- Autoconversion rate bias in stratiform boundary layer clouds

- Using gridbox mean quantities to predict autoconversion rates results in biased mean rates since cloud water distribution is spatially nonuniform

-LES (UCLA) to provide subgrid scale information to evaluate existing autoconversion debiasing parameterisations and potentially develop a better parameterisation



-LES to aid validation and development of existing subgrid scale information in PC2 that can then feed into the microphysics

-Plan to test different autoconversion formulations and thresholds

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Charmaine Franklin

Email:charmaine.franklin@csiro.au
Web: www.cawcr.gov.au

Thank you

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