Evaluating clouds and radiation in the CCCma AGCM using CERES data

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Introduction

Evaluate clouds and radiation simulated by GCMs
Most AGCMs use TOA fluxes as part of model tuning
$\Rightarrow$ Makes evaluation of cloud radiative effects difficult
Are you getting the right answer for the right reasons?

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Cloud types (Webb, 2001; Chen, 2000)
Cloud objects (Xu, 2005)

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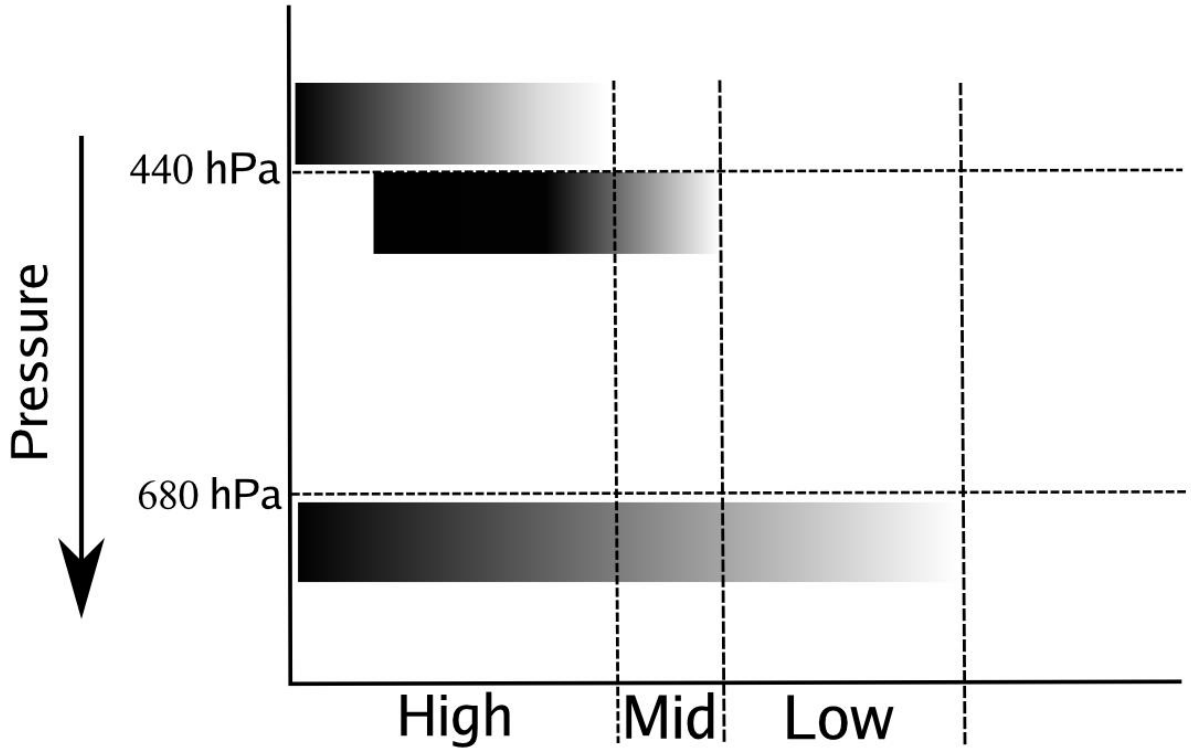
Evaluate properties as function of cloud top exposed to space

Cloud top exposed to space diagnostics

Computation of domain-mean flux using ICA

$$\langle F_{ICA} \rangle = (1 - A_c) F^{clr} + A_c \int p(\tau) F_{1D}(\tau) d\tau$$

$$\langle F_{ICA} \rangle = (1 - A_c) F^{clr} + \sum_{i=1}^{i=M} A_{c,i} p_i(\tau) F_{1D,i}(\tau) d\tau$$

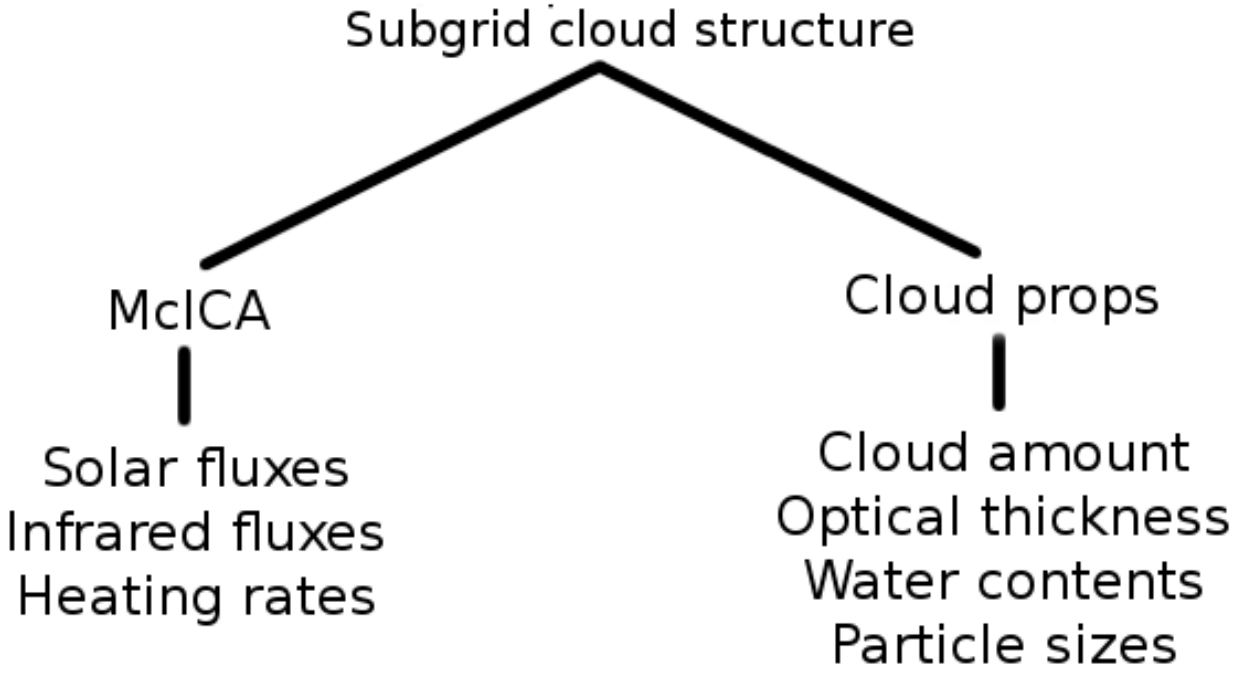


Cloud top exposed to space diagnostics

Observable from passive instruments

Can infer $F_{1D,i}$ from CERES and MODIS

Diagnose easily from GCM (esp. using McICA)



Daily data and GCM output

Observations

CERES July 2001-2005

Daily means computed from TERRA SSF data

Cloud props for low, middle and high clouds exposed to space

Radiative fluxes at TOA derived from MODIS and CERES data

24-hour solar fluxes computed assuming constant meteorology

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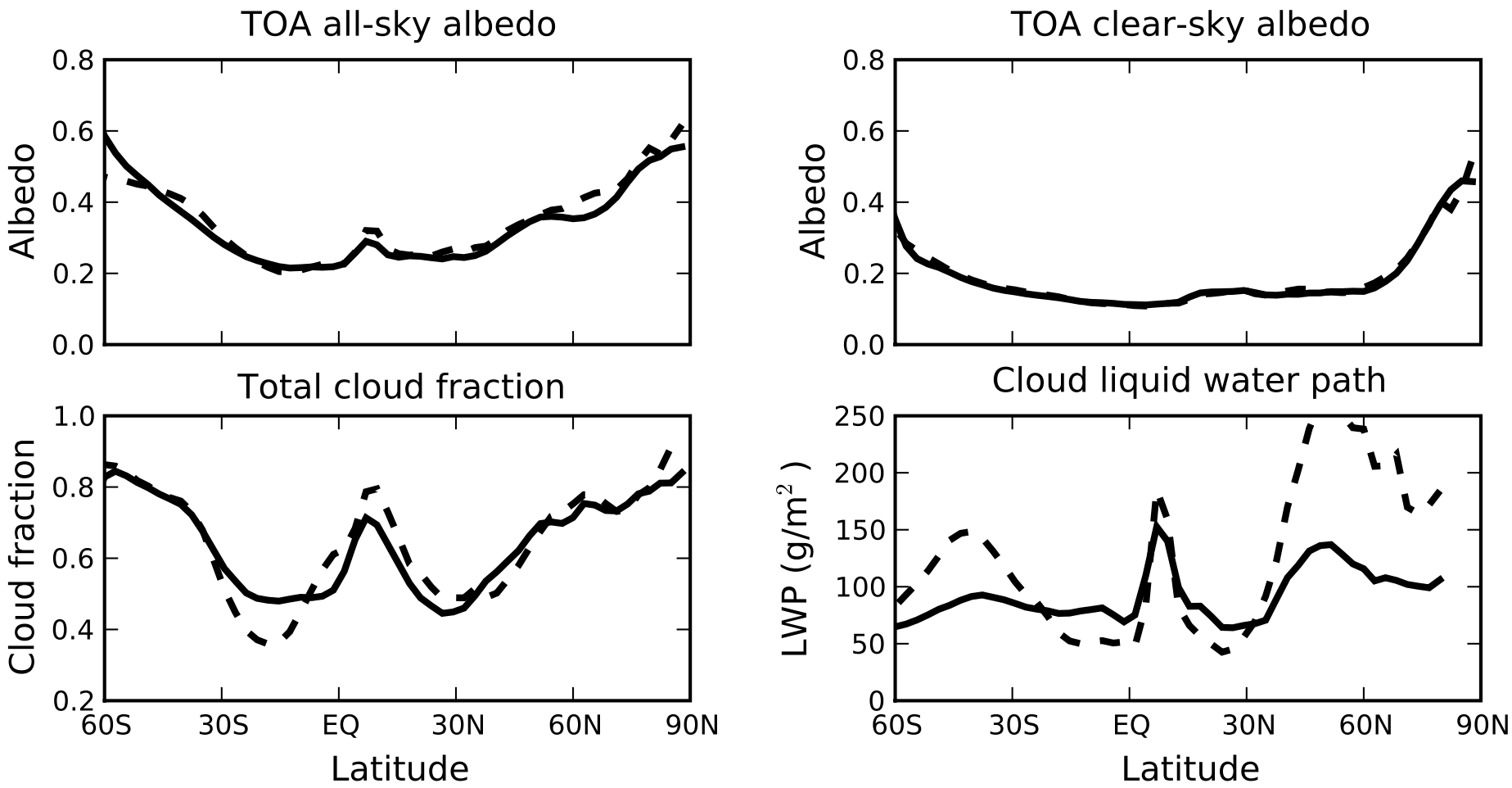
AGCM simulations
Two developmental, tuned, versions of CCCma AGCM
T63, 35 levels
GCM15G $\Longrightarrow$ January 2008 (McICA implemented)
GCM15H $\Longrightarrow$ January 2009
GCM15G $\Rightarrow$ GCM15H several changes to clouds and radiation
Sampled along TERRA orbit

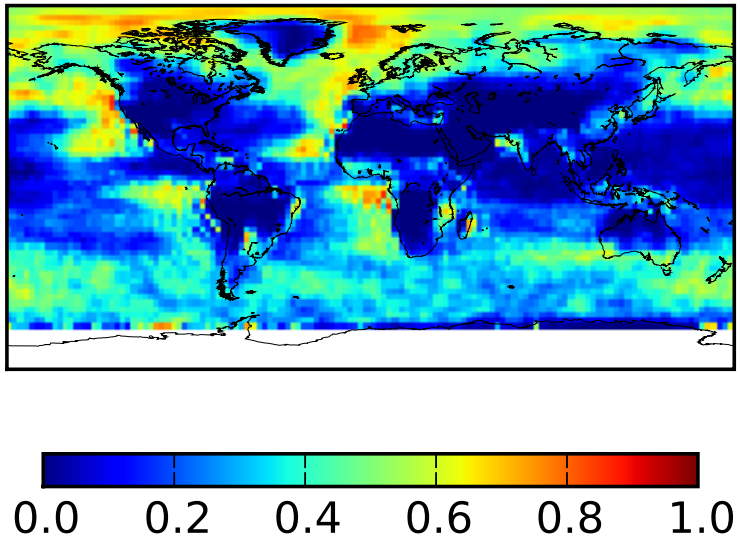
July climatology (GCM15H)



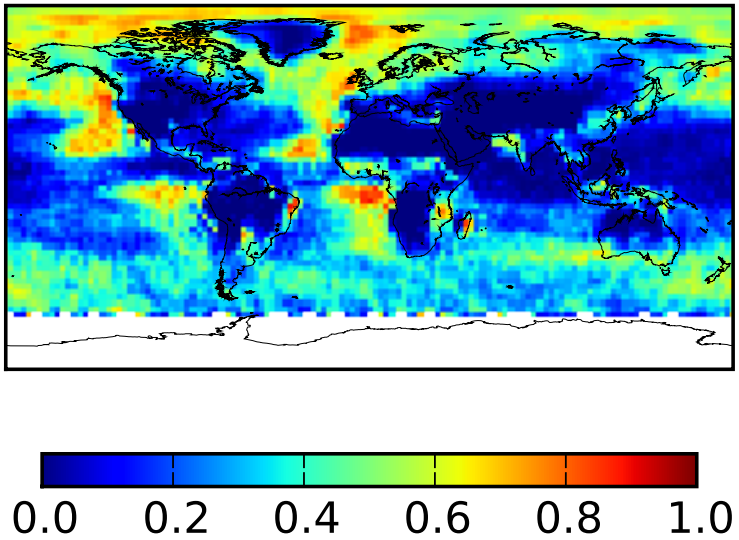
Solid line ⇒ obs, Dashed line ⇒ GCM15H

Sampling effects (Low cloud fraction July 2003)

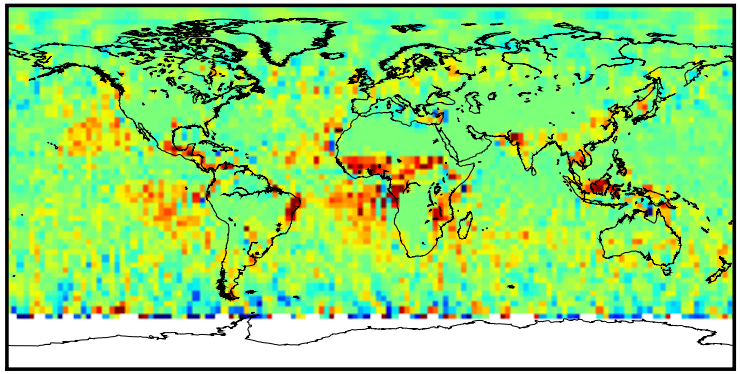
Low cld frac all data



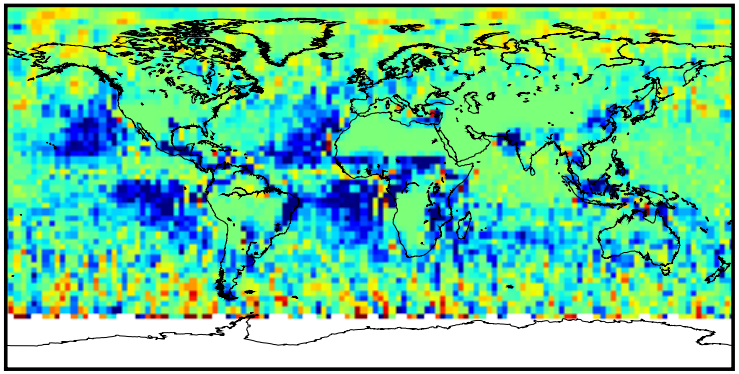
Low cld frac TERRA orbit



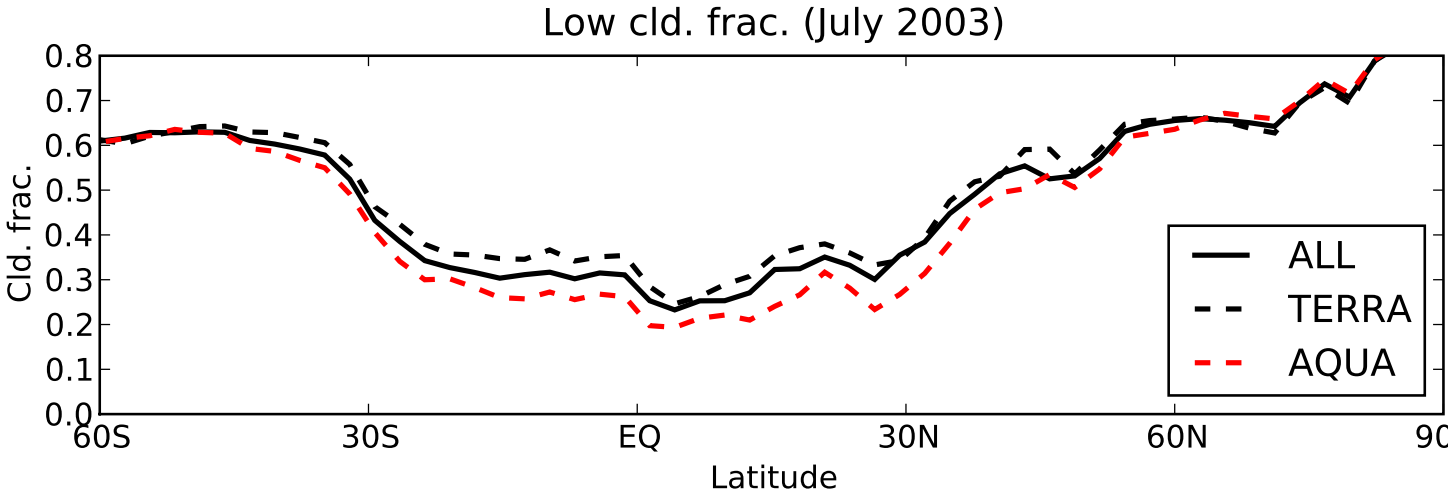
TERRA-ALL

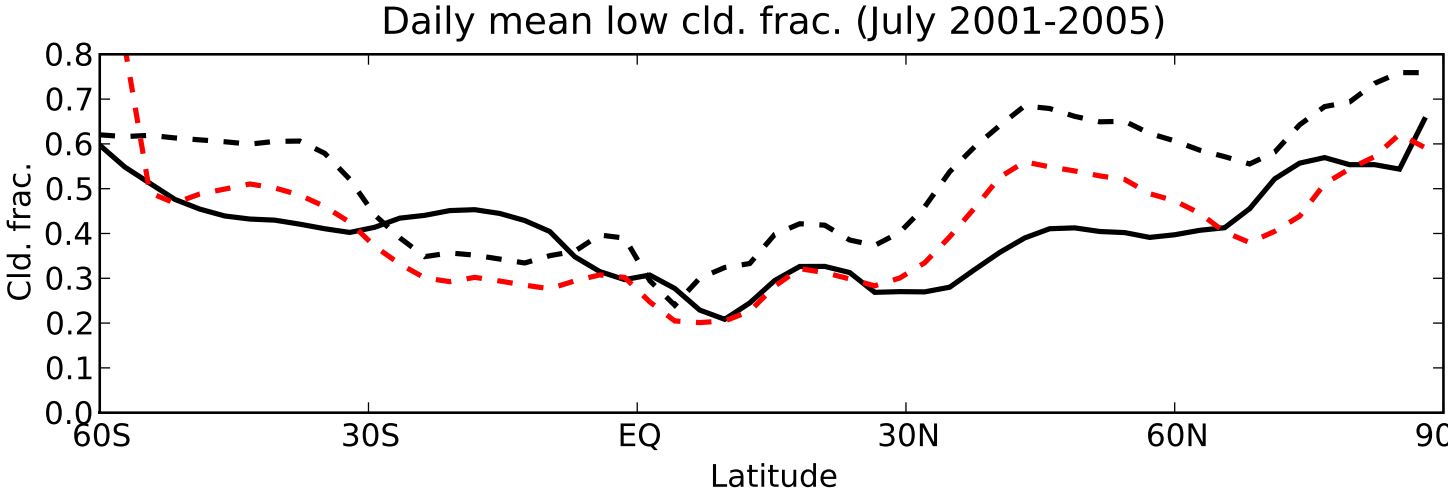


AQUA-TERRA



Sampling effects (Low cloud fraction when present)





Solid line ⇒ obs

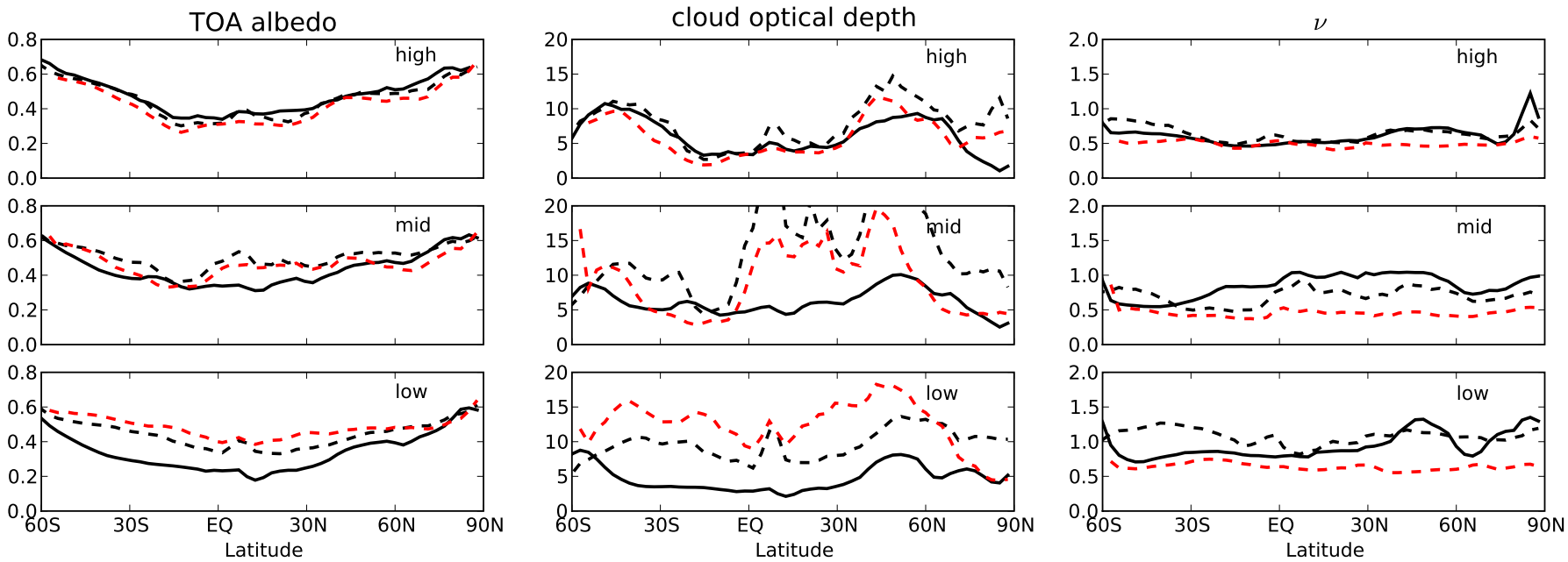
Dashed red line ⇒ GCM15G, Dashed black line ⇒ GCM15H

Zonal means (July 2001-2005)

Computed using gridboxes with cld. frac. > 5%

Cloud inhomogeneity decreases as ν increases

$p(\tau) = \frac{1}{\Gamma(\nu)}(\frac{\nu}{\overline{\tau}})^{\nu}\tau^{\nu-1}e^{-\nu\tau/\overline{\tau}}$, $\nu = (\frac{\overline{\tau}}{\sigma})^2$



Solid line $\Rightarrow$ obs

Dashed red line $\Rightarrow$ GCM15G, Dashed black line $\Rightarrow$ GCM15H

Need for consistency – ν parameter

GCM15G radiation code used minimum ν for "cloud blocks"
cloud blocks $\Rightarrow$ Adjacent cloudy layers
Necessary simplification for analytic solution

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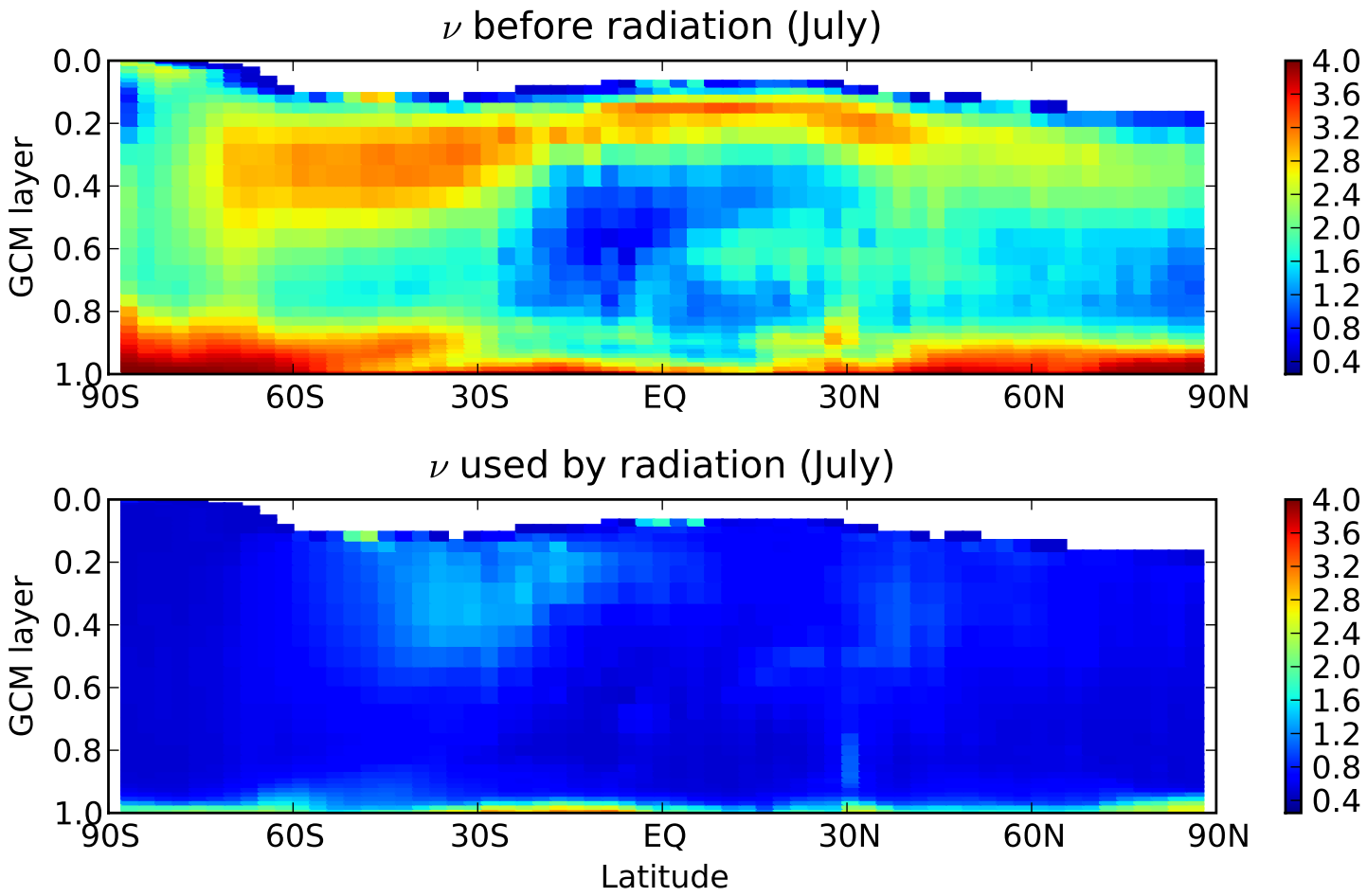
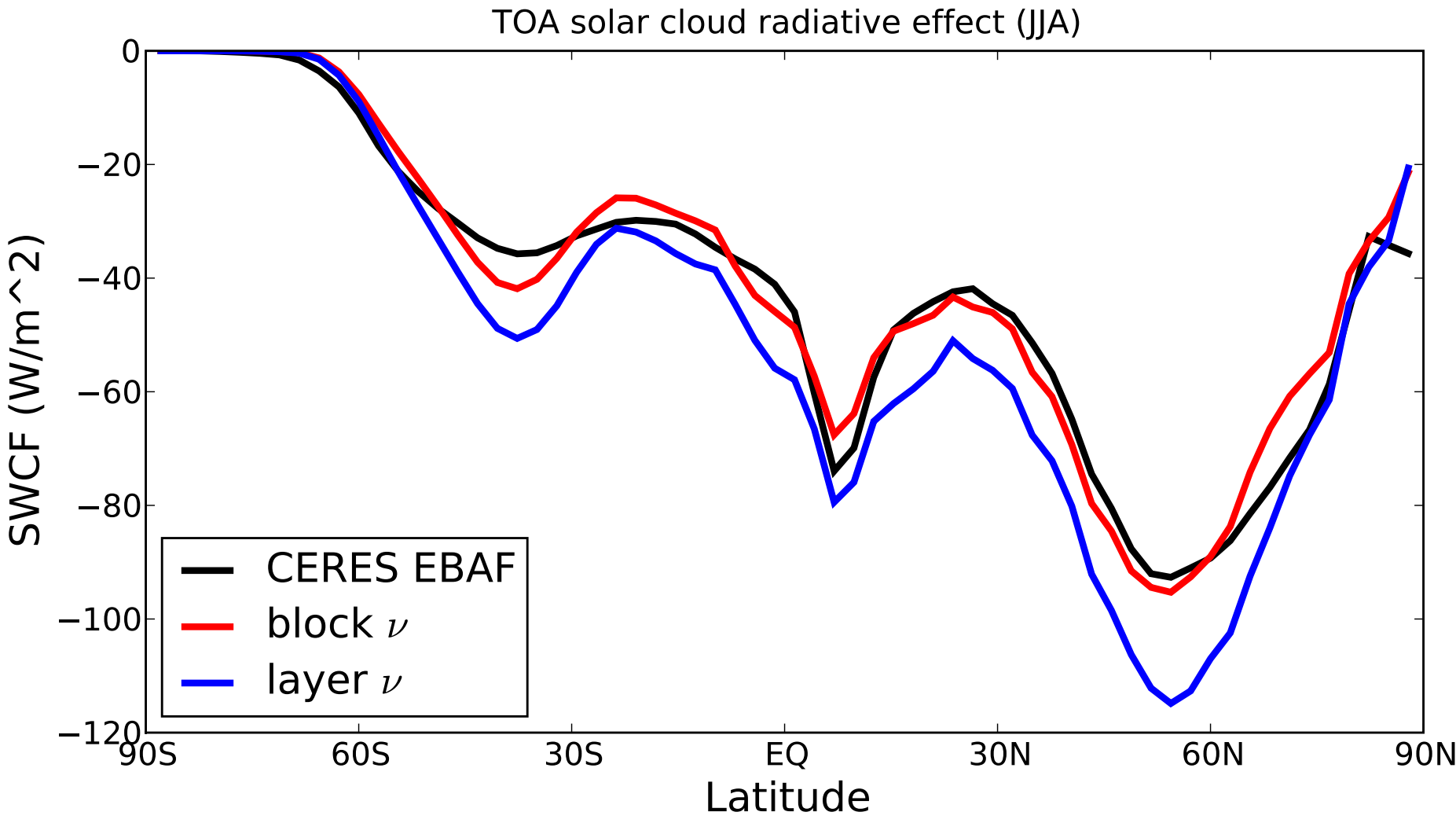
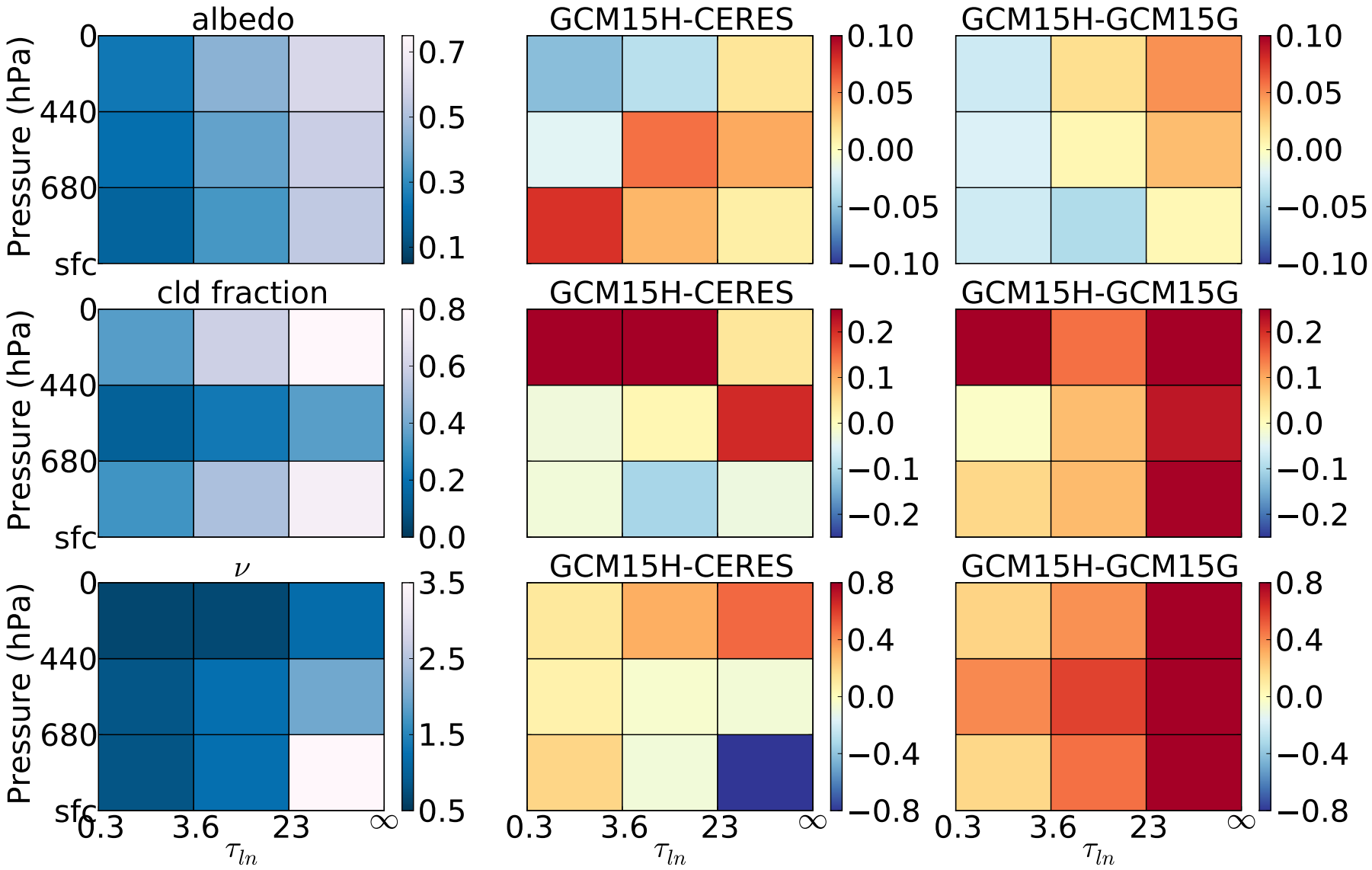


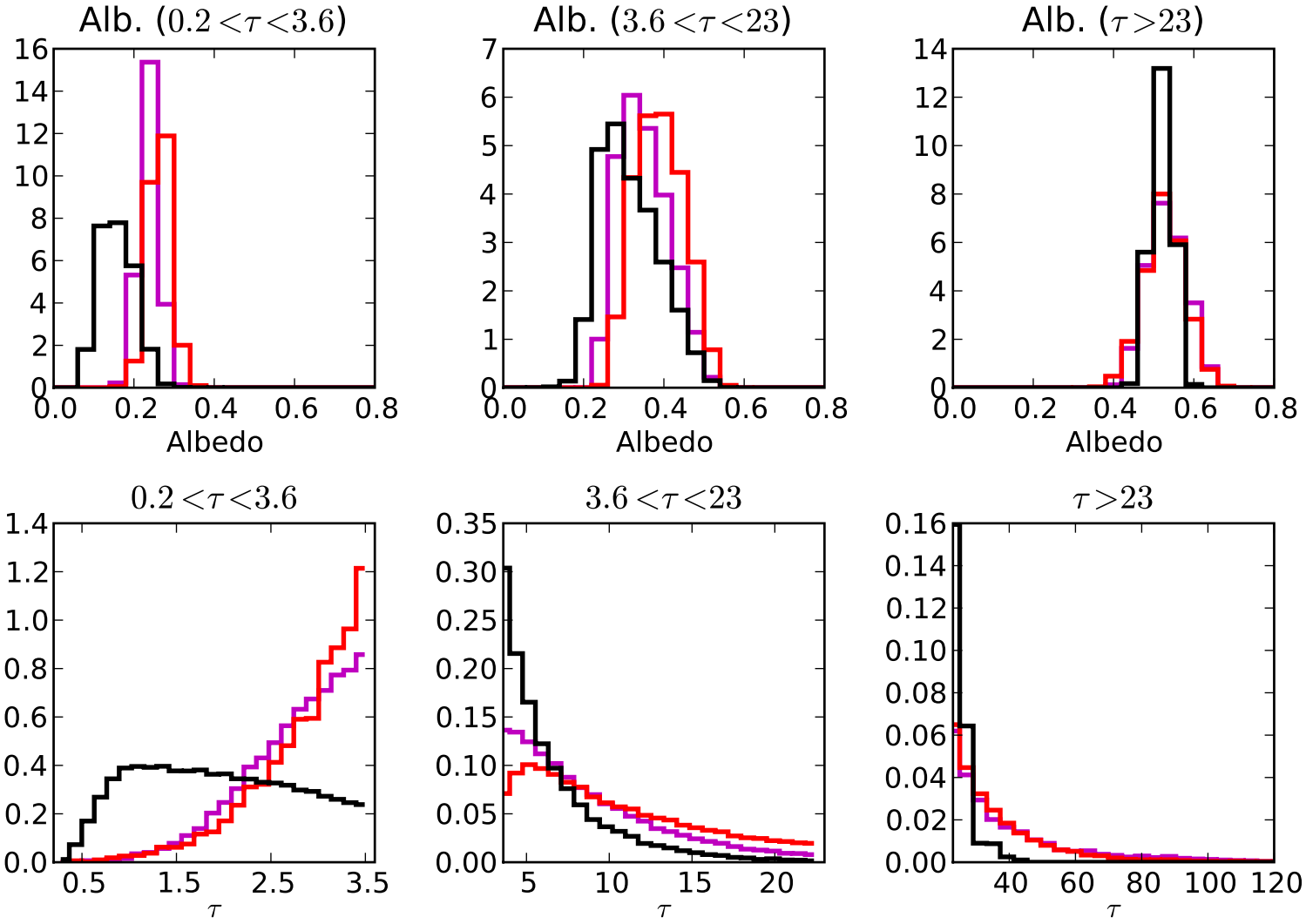
Solar cloud radiative effect



Binning by pressure and cloud τ (20°S – 20°N)



Histograms of daily-means low clds (20°S – 20°N)



Black line ⇒ obs

Red line ⇒ GCM15G, Purple line ⇒ GCM15H

Summary

Diagnostic can highlight biases in GCM clouds and radiation

Direct link between cloud properties and radiation
$\Rightarrow$ Not inferred radiative effects

Straightforward to implement in GCMs with McICA

Couple with information from CloudSat/CALIPSO and COSP
$\Rightarrow$ Further analyse cloud vertical structure