Monte Carlo Independent Column Approximation (McICA): Up and Running in North America and Europe

H. W. Barker (*MSC*) *J. N. S. Cole* (*UBC*) *J.-J. Morcrette* (*ECMWF*) *R. Pincus* (*NOAA-UC*) *P. Räisänen* (*FMI*)

Monte Carlo Independent Column Approximation (McICA): Up and Running in North America and Europe

H. W. Barker *MSC*
J. N. S. Cole *UBC*
J.-J. Morcrette *ECMWF*
R. Pincus *NOAA-UC*
P. Räisänen *FMI*

Funding Announcement (spring 2007):

"The goal of the ARM program is ... to improve the representation of clouds and radiation processes in GCMs."

Monte Carlo Independent Column Approximation (McICA): Up and Running in North America and Europe

H. W. Barker (*MSC*) *J. N. S. Cole* (*UBC*) *J.-J. Morcrette* (*ECMWF*) *R. Pincus* (*NOAA-UC*) *P. Räisänen* (*FMI*)

Funding Announcement (spring 2007):

"The goal of the ARM program is ... to improve the representation of clouds and radiation processes in GCMs."

in particular, the *radiative transfer algorithm:*

- RT solver
- handling of atmosphere-surface conditions

Radiative transfer for cloudy atmospheres in GCMs

Barker, H. W. + 31 others: 2003: Assessing 1D Atmospheric Solar Radiative Transfer Models: Interpretation and Handling of Unresolved Clouds

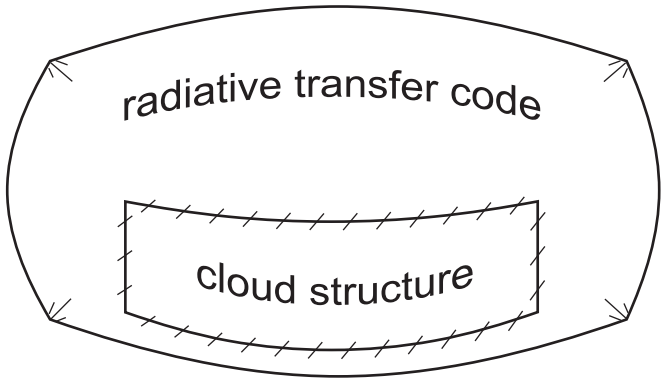
- "...*no single multi-layered, broadband, 1D solar code performs well for all conditions*."

  - inappropriate, and incorrect application of, cloud overlap assumptions
  - neglect of, and inappropriate, horizontal variability of cloud

- "...*the nature of subgrid-scale parametrization should be reconsidered and new methodologies invented for computing radiative heating in large-scale models*." (received April 8, 2002... St. Petersburg Apr. 8-12)

Why the complaint (challenge)?...

***Existing paradigm (1960s on up...)*:**

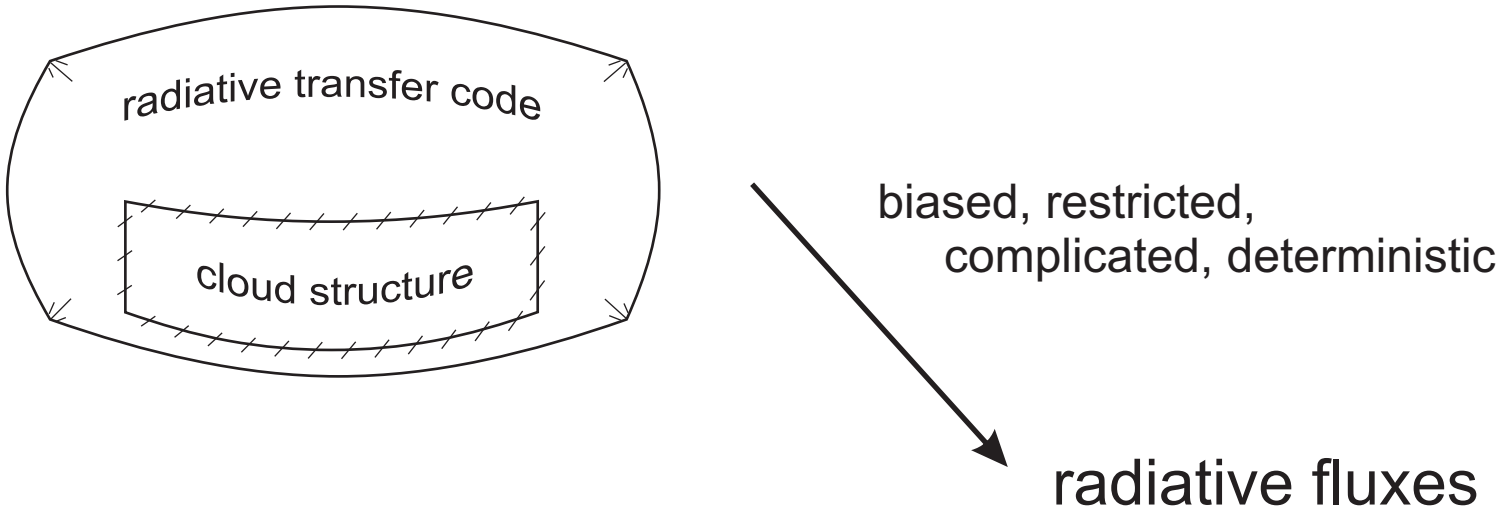


biased, restricted,
complicated, deterministic

radiative fluxes

Why the complaint (challenge)?...

***Existing paradigm (1960s on up...)*:**



April 10, 2002:

Robert intimates to me that stochastic sub-columns might be the way to go... but...

stochastic sub-columns in GCM radiation codes...

- Robert's stonewall:

$$\langle F \rangle = \frac{1}{\mathcal{N}} \sum_{n=1}^{\mathcal{N}} F_n \quad + \quad \mathcal{F}_n = \sum_{k=1}^{\mathcal{K}} F_{n,k}$$

ICA + CKD

$$\langle \mathcal{F} \rangle = \frac{1}{\mathcal{N}} \sum_{n=1}^{\mathcal{N}} \sum_{k=1}^{\mathcal{K}} F_{n,k}$$

BB - ICA

* * * intractable in a GCM * * *

stochastic sub-columns in GCM radiation codes...

- Robert's stonewall:

$$\langle F \rangle = \frac{1}{\mathcal{N}} \sum_{n=1}^{\mathcal{N}} F_n \quad + \quad \mathcal{F}_n = \sum_{k=1}^{\mathcal{K}} F_{n,k}$$

ICA CKD

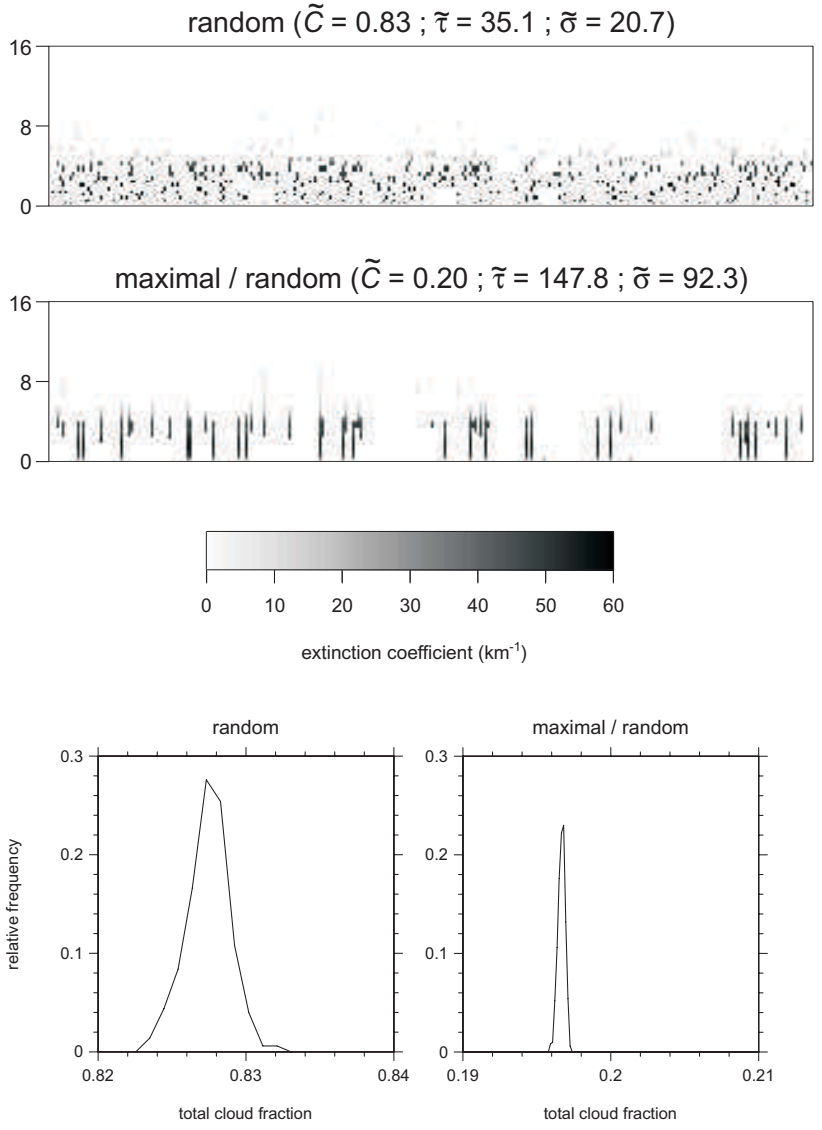
$$\langle \mathcal{F} \rangle = \frac{1}{\mathcal{N}} \sum_{n=1}^{\mathcal{N}} \sum_{k=1}^{\mathcal{K}} F_{n,k}$$

BB - ICA

* * * intractable in a GCM * * *

- but, I'm receptive having been there

same profiles... different overlap assumptions



from Barker, Stephens, Fu (1999)

stochastic sub-columns in GCM radiation codes...

- Robert's stonewall:

$$\langle F \rangle = \frac{1}{\mathcal{N}} \sum_{n=1}^{\mathcal{N}} F_n \quad + \quad \mathcal{F}_n = \sum_{k=1}^{\mathcal{K}} F_{n,k}$$

ICA CKD

$$\langle \mathcal{F} \rangle = \frac{1}{\mathcal{N}} \sum_{n=1}^{\mathcal{N}} \sum_{k=1}^{\mathcal{K}} F_{n,k}$$

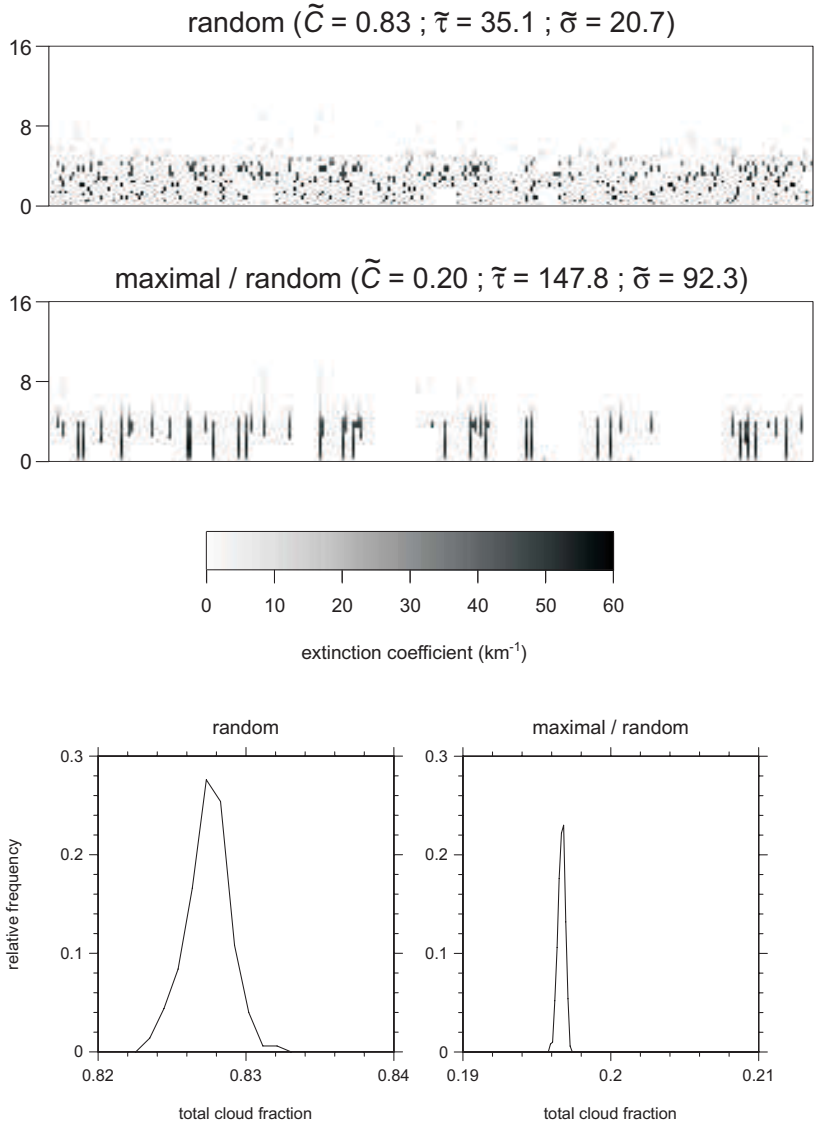
BB - ICA

* * * intractable in a GCM * * *

- but, I'm receptive having been there

- the next morning...

same profiles... different overlap assumptions



from Barker, Stephens, Fu (1999)

... a break in Robert's stonewall (and the GWTSA off my plate for ever... ☻)

... a break in Robert's stonewall (and the GWTSA off my plate for ever... ☻)

The Monte Carlo Independent Column Approximation

$$\langle \mathcal{F} \rangle = \frac{1}{\mathcal{N}} \sum_{n=1}^{\mathcal{N}} \sum_{k=1}^{\mathcal{K}} F_{n,k}$$

ICA

stochastic generation of unresolved cloud ***during spectral integration***

$$\langle \mathcal{F} \rangle' = \sum_{k=1}^{\mathcal{K}} F_{n_k,k}$$

McICA

... a break in Robert's stonewall (and the GWTSA off my plate for ever... ☻)

The Monte Carlo Independent Column Approximation

$$\langle \mathcal{F} \rangle = \frac{1}{\mathcal{N}} \sum_{n=1}^{\mathcal{N}} \sum_{k=1}^{\mathcal{K}} F_{n,k}$$

ICA

stochastic generation of unresolved cloud ***during spectral integration***

→

a ***complete*** separation of optical characteristics from the RT solver!

$$\langle \mathcal{F} \rangle' = \sum_{k=1}^{\mathcal{K}} F_{n_k,k}$$

McICA

... a break in Robert's stonewall (and the GWTSA off my plate for ever... ☻)

The Monte Carlo Independent Column Approximation

$$\langle \mathcal{F} \rangle = \frac{1}{\mathcal{N}} \sum_{n=1}^{\mathcal{N}} \sum_{k=1}^{\mathcal{K}} F_{n,k}$$

ICA

stochastic generation of unresolved cloud ***during spectral integration***

→

a ***complete*** separation of optical characteristics from the RT solver!

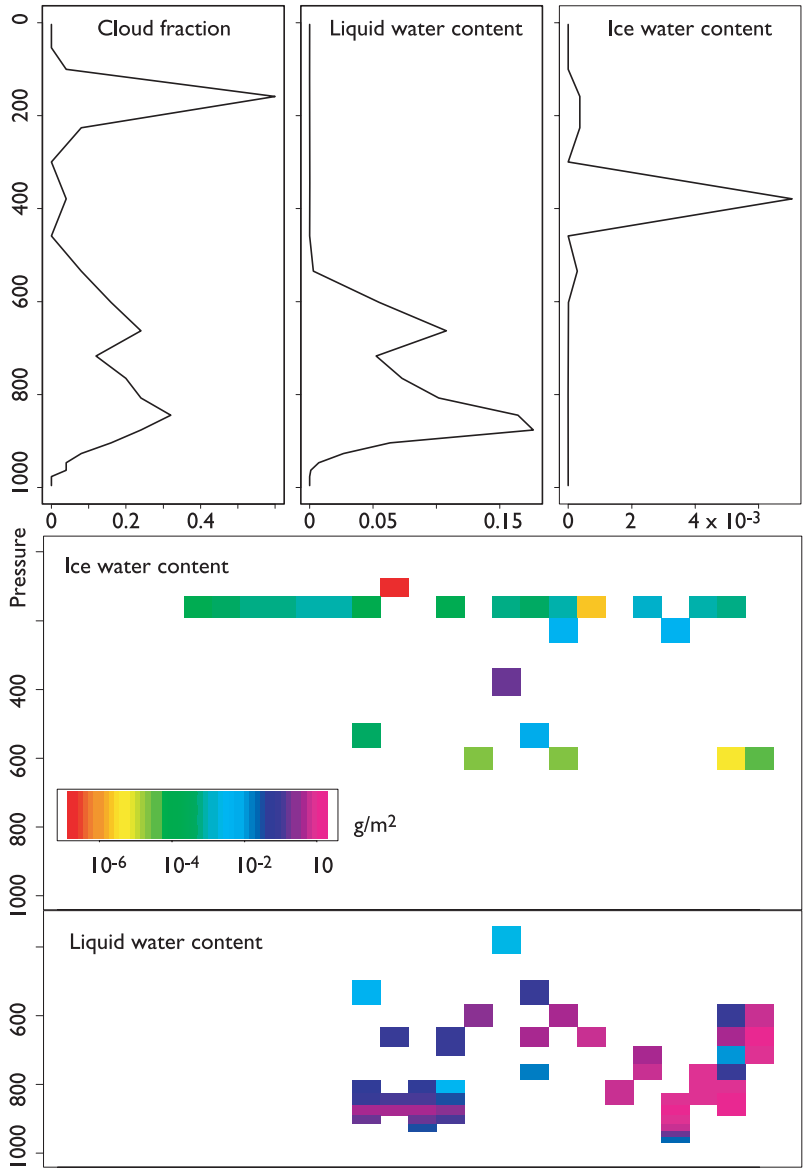
$$\langle \mathcal{F} \rangle' = \sum_{k=1}^{\mathcal{K}} F_{n_k,k}$$

McICA

- unbiased w.r.t the full ICA
- highly flexible relative to conventional 1D codes
- requires about the same (less) CPU time as conventional codes
- unlike conventional methods, it has sampling noise...

Stochastic subgrid-scale generators

- Räisänen et al. 2004 (QJRMS)
- Pincus et al. 2005 (JGR)

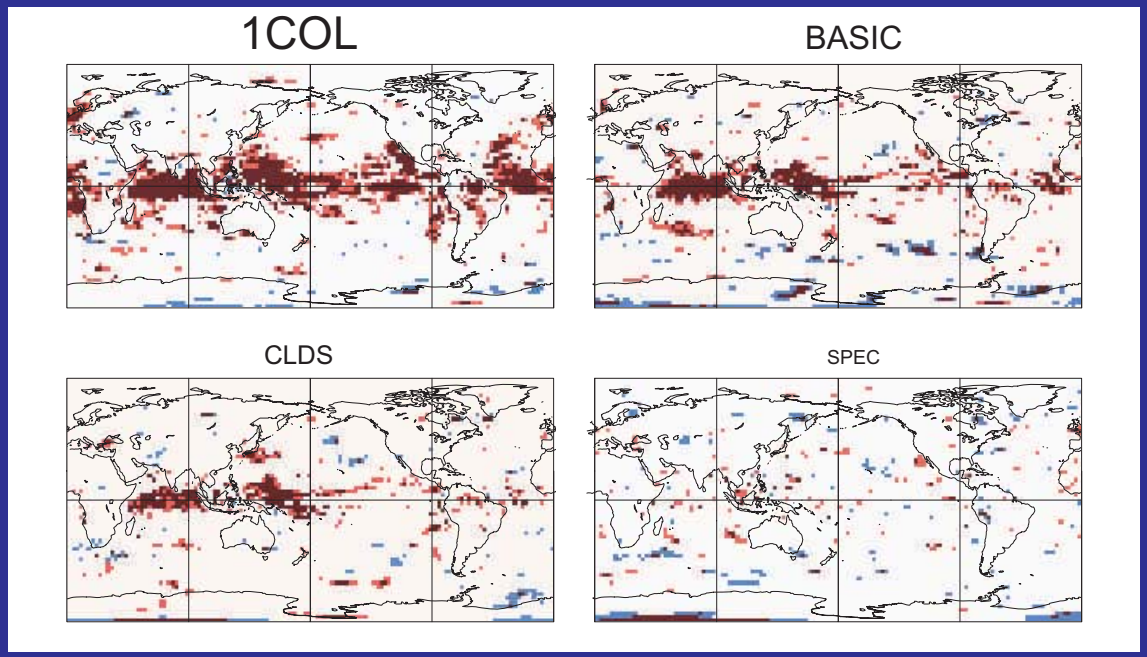


from a conventional GCM

from a generator
(+ variance & overlap)

Räisänen, Barker, & Cole, 2005... CAM3

significant changes in 2 m temp

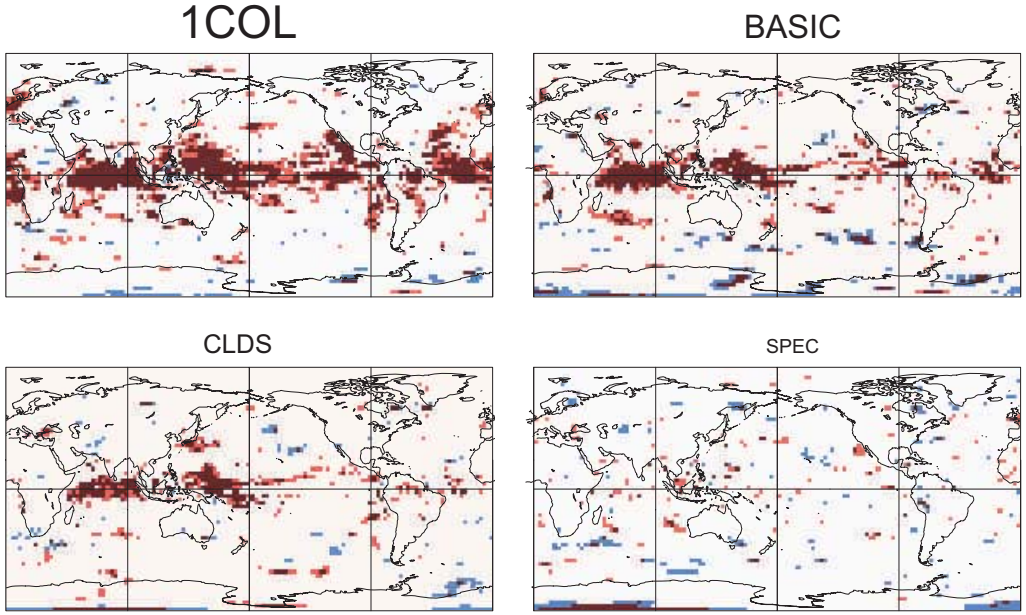


warmer tropical surface

increase noise

Räisänen, Barker, & Cole, 2005... CAM3

significant changes in 2 m temp

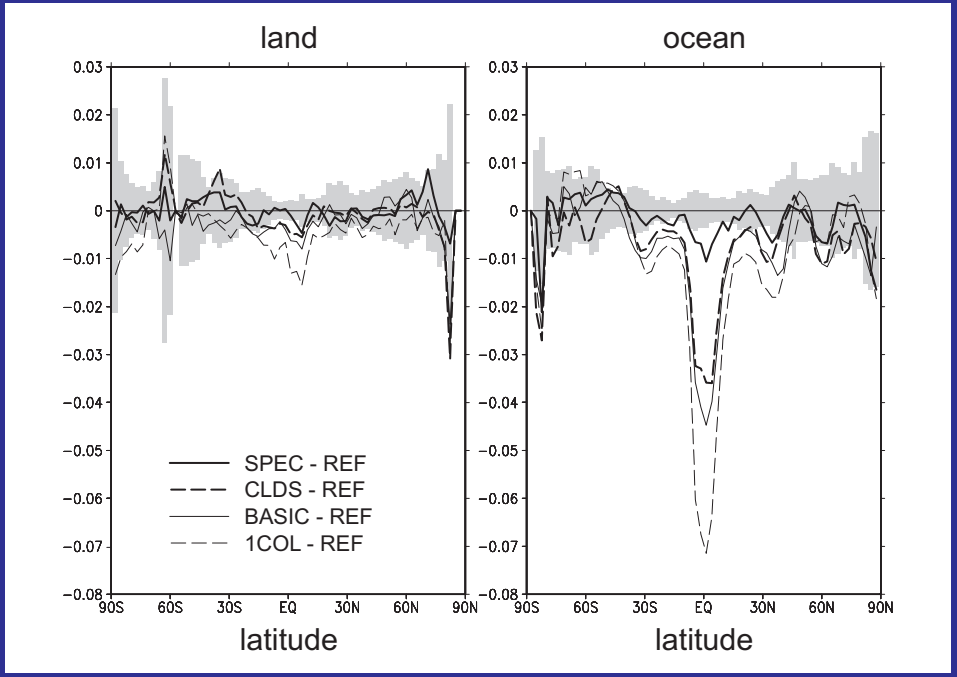


warmer tropical surface

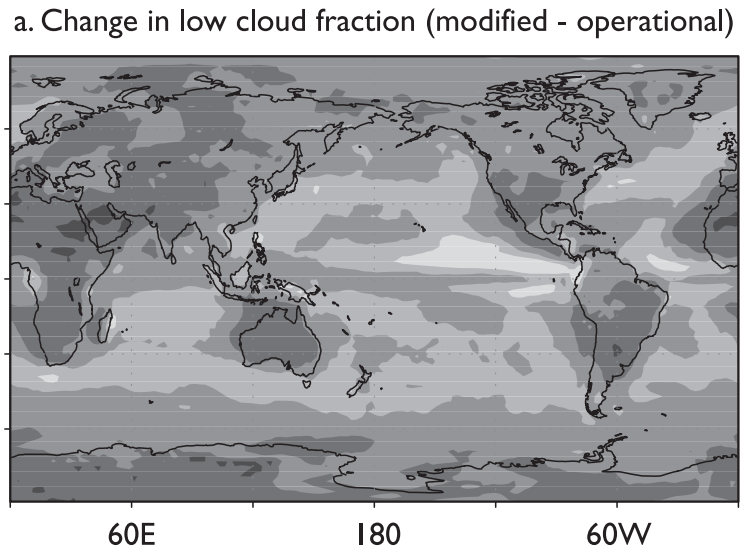
increase noise

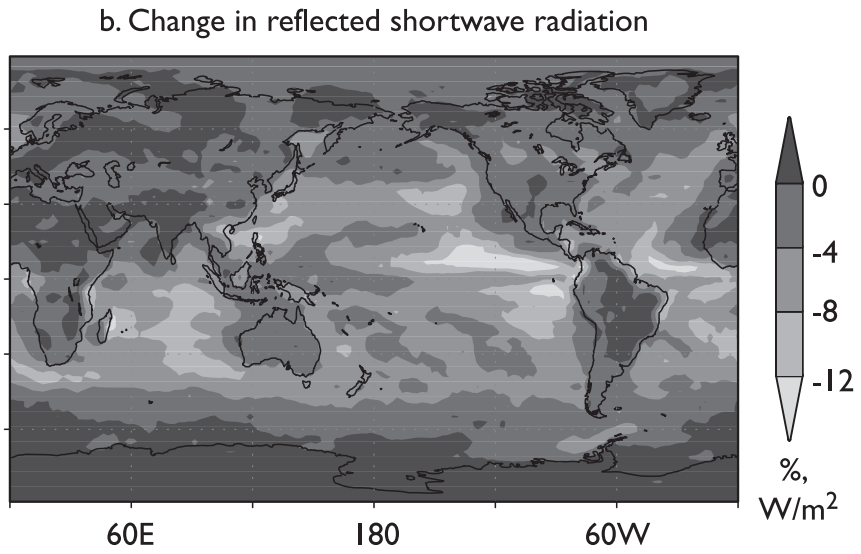
decrease low-level tropical ‘fog’

increase noise



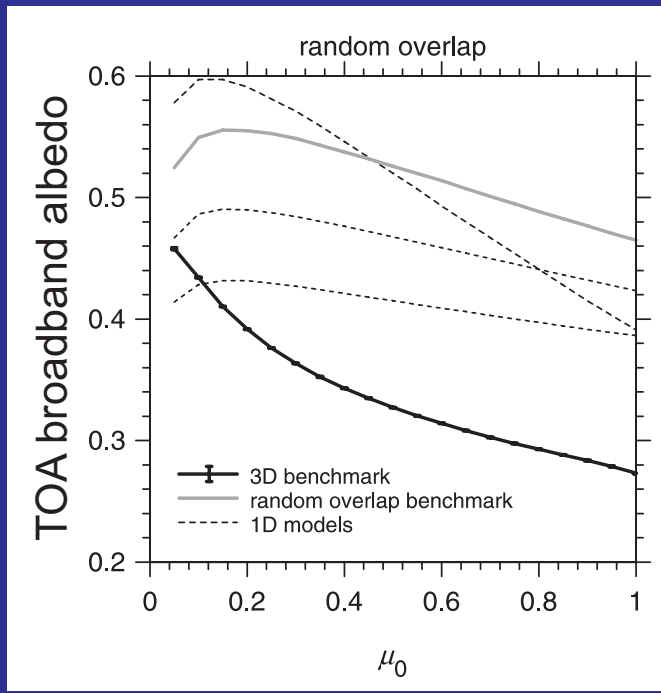
Pincus, Hemler, & Klein, 2006... no impact with GFDL-AM2



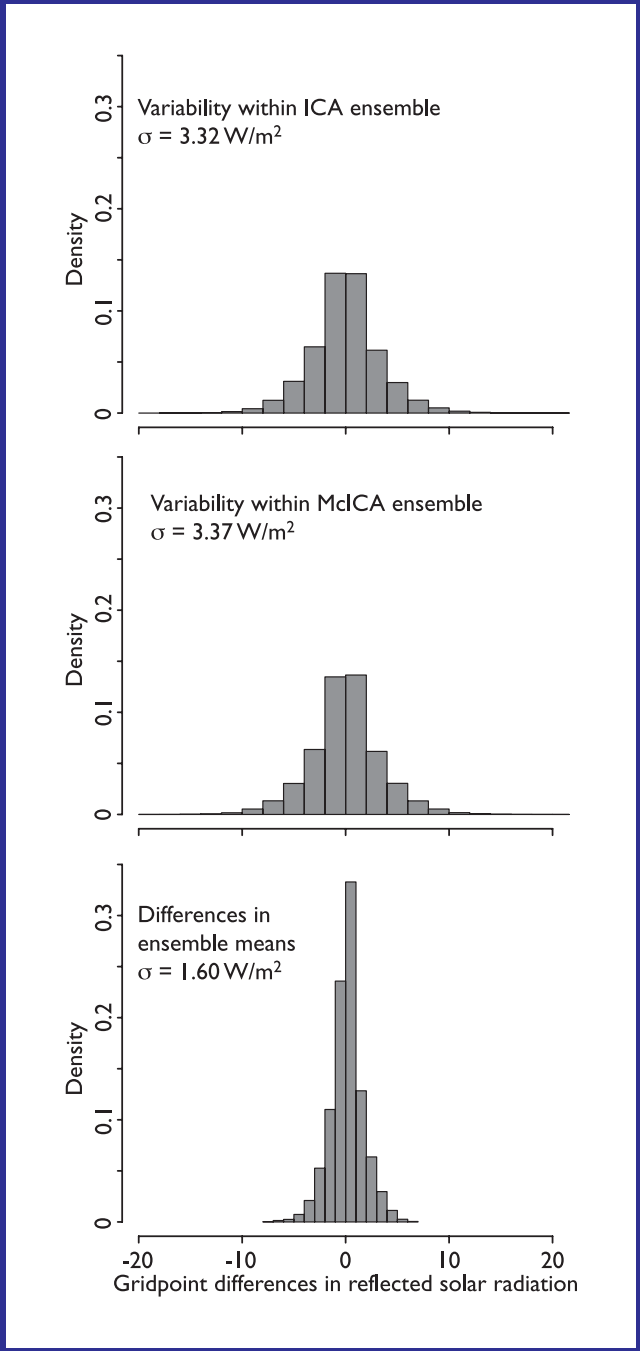


- demonstrable changes for the better relative to operational model

- exposes deficiencies in random overlap routine (cf. Barker et al. 2003)



Pincus, Hemler, & Klein, 2006... no impact with GFDL-AM2



- when superposed on cloud fluctuations, the diurnal cycle, and the annual cycle, McICA noise is minor

- variability *within* ensembles are substantially greater than *between* ensembles

McICA Model Intercomparison Project (McMIP)

- model dependence on noise?...
- ARM funded

- fixed SSTs and sea ice

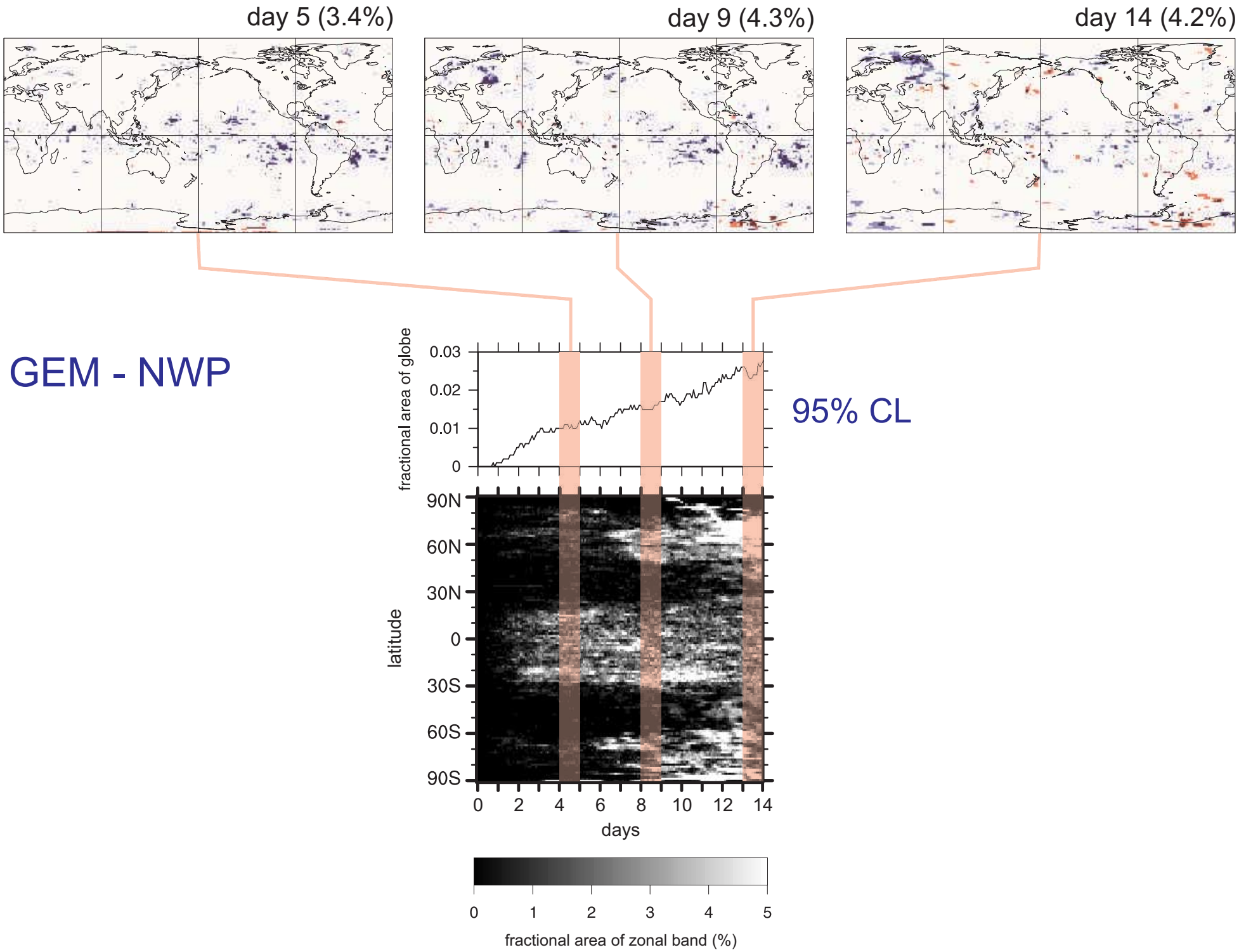
- 15 day simulations ; 10-member ensembles (cf. ARM's CAPT project)

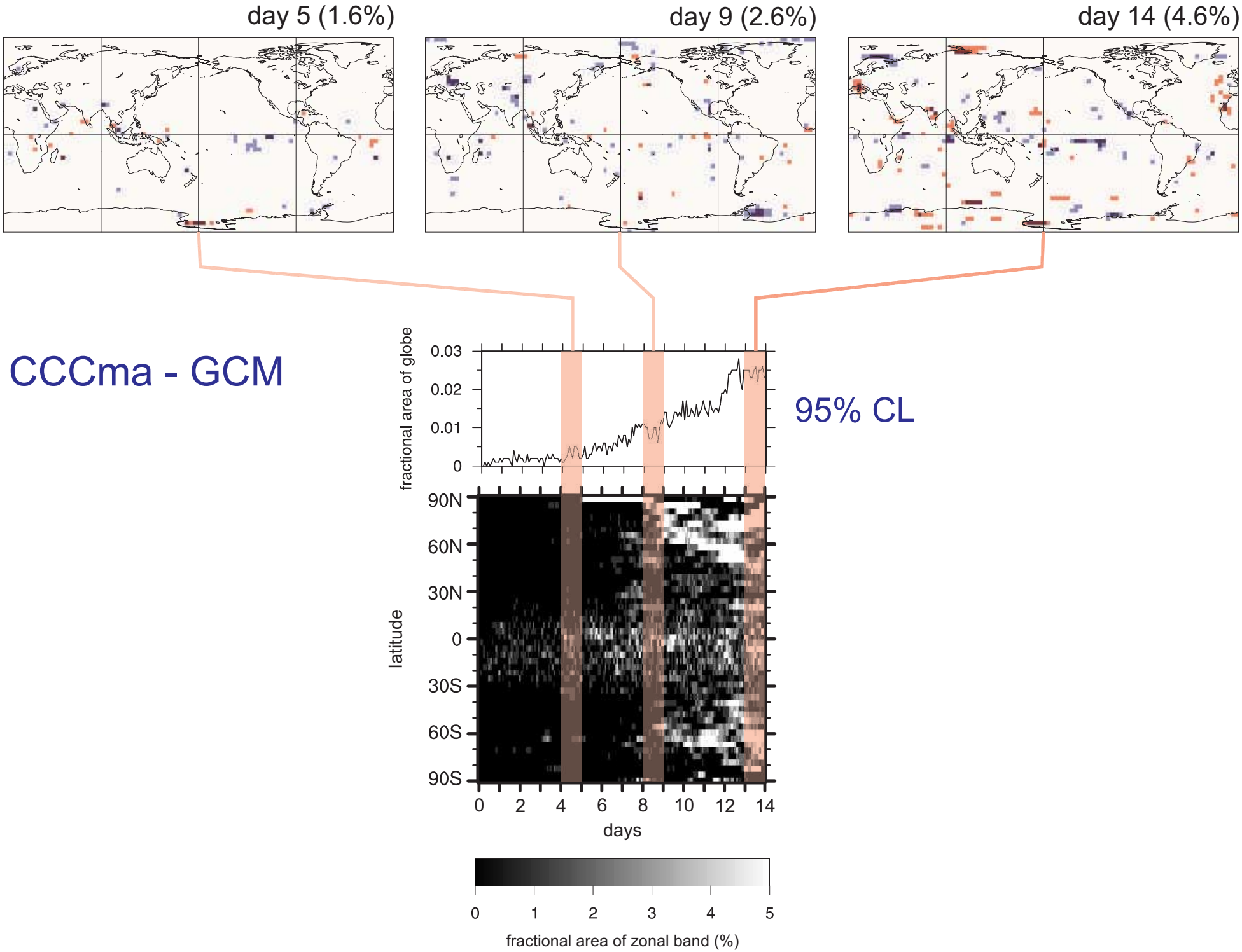
- response of *fast* components of climate system (primarily clouds)

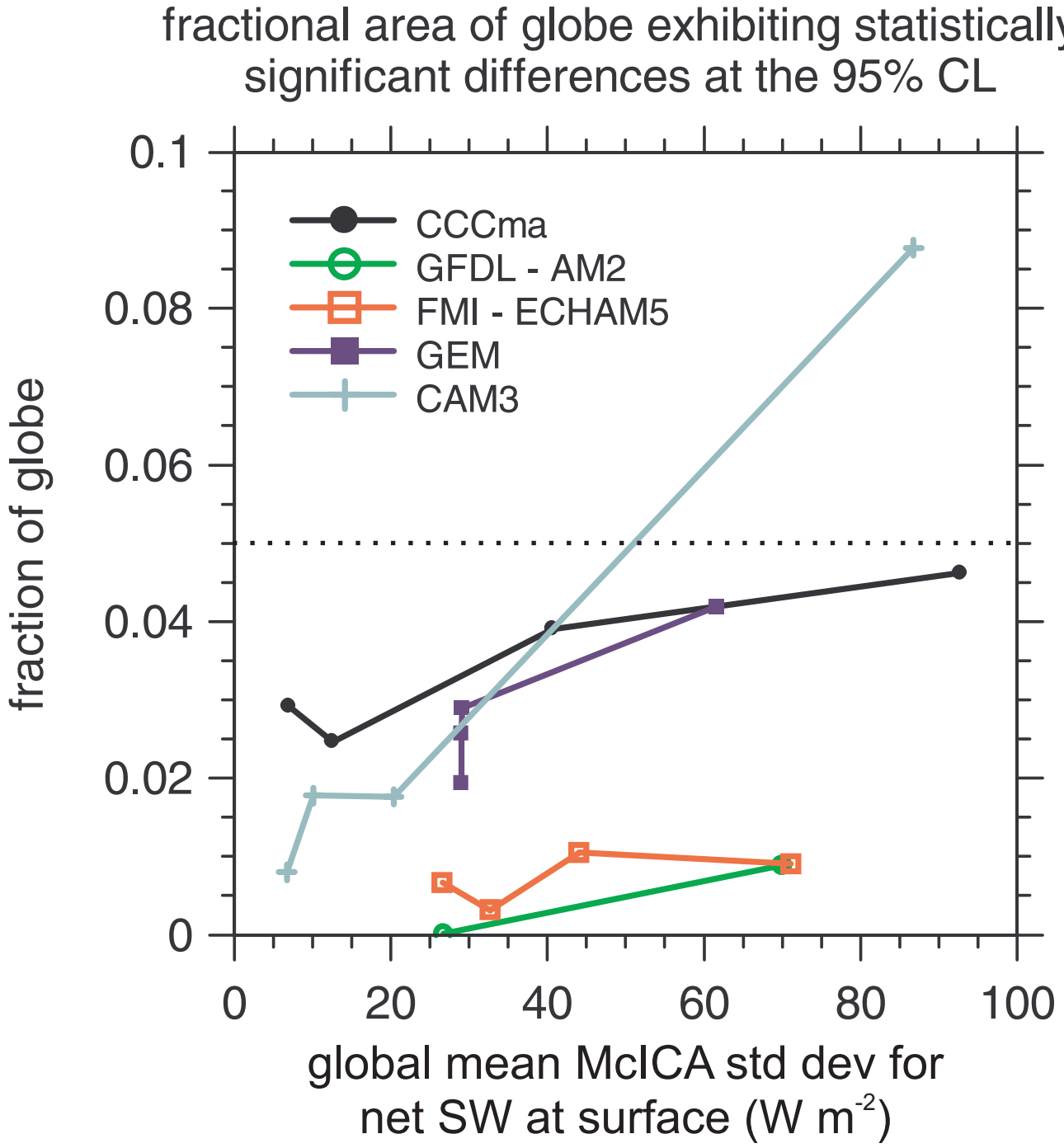
- divergence(noise)

- GCMs: CCC, GFDL, NCAR, ECMWF, ECHAM, GEM (KNMI, CSU, GSFC)

e.g., impact on 2 m air temperature


day 5 (3.4%)
day 9 (4.3%)
day 14 (4.2%)
GEM - NWP
95% CL
fractional area of globe
0.03
0.02
0.01
0
90N
60N
30N
0
30S
60S
90S
latitude
0
2
4
6
8
10
12
14
days
0
1
2
3
4
5
fractional area of zonal band (%)

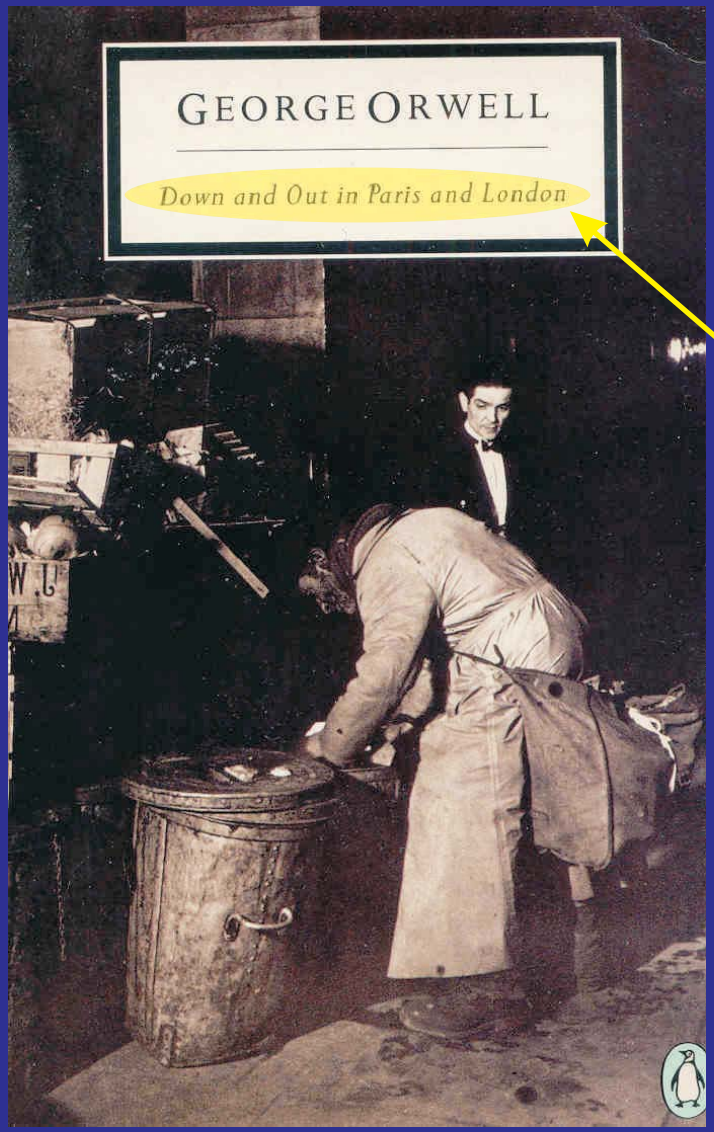

day 5 (1.6%)
day 9 (2.6%)
day 14 (4.6%)
CCCma - GCM
95% CL
fractional area of globe
0.03
0.02
0.01
0
latitude
90N
60N
30N
0
30S
60S
90S
0
2
4
6
8
10
12
14
days
0
1
2
3
4
5
fractional area of zonal band (%)


fractional area of globe exhibiting statistically significant differences at the 95% CL
fraction of globe
0.1
0.08
0.06
0.04
0.02
0
CCCma
GFDL - AM2
FMI - ECHAM5
GEM
CAM3
0
20
40
60
80
100
global mean McICA std dev for net SW at surface (W m-2)

Summary

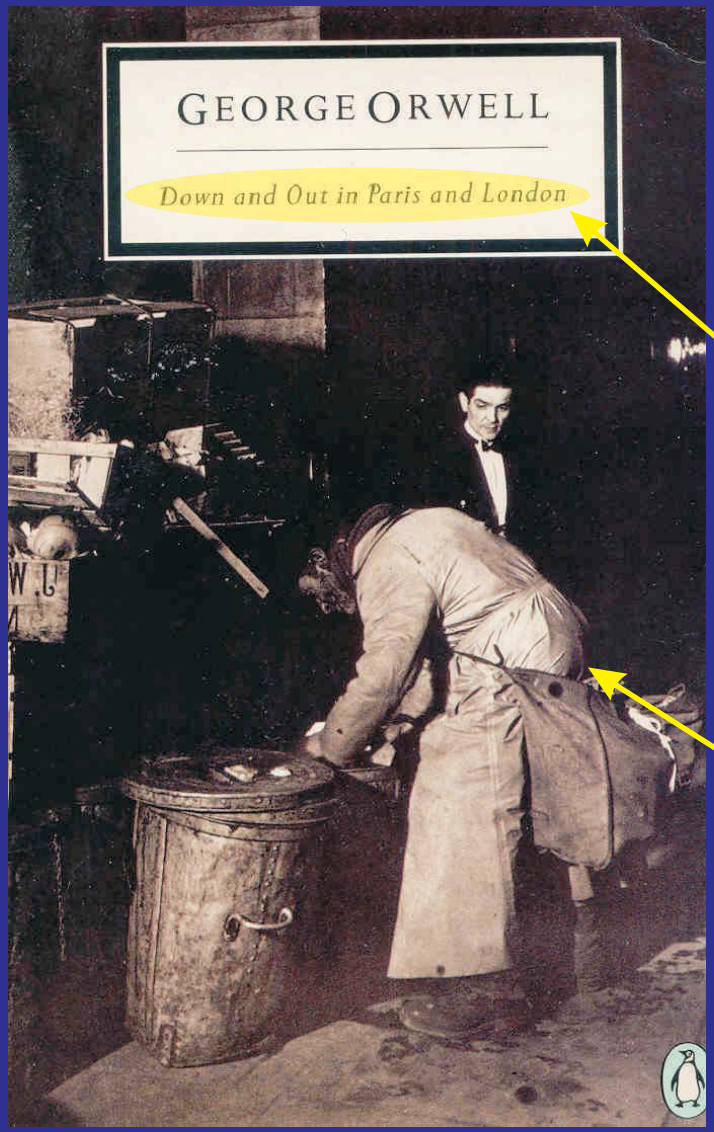
- McICA
  - unbiased estimator (wrt full ICA)
  - flexible
  - CPU-friendly
  - paradigm shift?... solves problems, broadens scope
- McMIP
  - noise turning out to be a *very minor* issue (squelchable anyway...)
    - NWP (*JJM's talk*) & climate (*PR's poster*...)
  - implemented in 6+ GCMs:
    - operational in at least 2
    - ARM-funded and -tested RRTMG (AER)...

Monte Carlo Independent Column Approximation (McICA): Up and Running in North America and Europe



McICA is now up and running in at least 6 GCMs in the USA, Canada, UK, and Finland

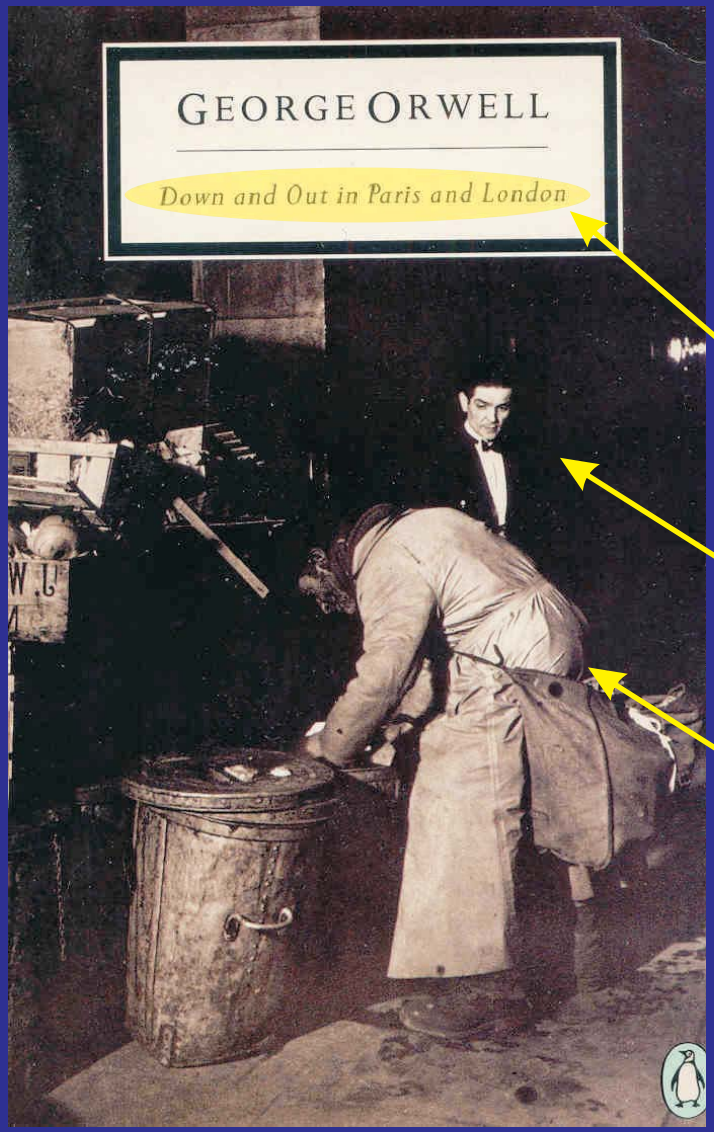
Monte Carlo Independent Column Approximation (McICA): Up and Running in North America and Europe



McICA is now up and running in at least 6 GCMs in the USA, Canada, UK, and Finland

Me, looking for a *fix* for the GWTSA and the like...

Monte Carlo Independent Column Approximation (McICA): Up and Running in North America and Europe



McICA is now up and running in at least 6 GCMs in the USA, Canada, UK, and Finland

Robert, wondering what on Earth I'm doing...

Me, looking for a *fix* for the GWTSA and the like...

Barker, H. W., R. Pincus, and J.-J Morcrette, 2002: The Monte Carlo Independent Column Approximation: Application within Large-Scale Models. In proceedings of the *GCSS-ARM Workshop on the Representation of Cloud Systems in Large-Scale Models*, May 2002, Kananaskis, AB, Canada. Available at: http://www.met.utah.edu/skrueger/gcss-2002/Extended-Abstracts.pdf.

Pincus, R., H. W. Barker, and J.-J. Morcrette, 2003: A fast, flexible, approximate technique for computing radiative transfer in inhomogeneous cloud fields. *J. Geophys. Res.*, **108(D13),** 4376, doi:10.1029/2002JD003322.

Raisanen, P., H. W. Barker, M. Khairoutdinov, and D. A. Randall, 2004: Stochastic generation of subgrid-scale cloudy columns for large-scale models. *Q. J. R. Meteorol. Soc.*, **130,** 2047-2068.

Raisanen, P. and H. W. Barker, 2004: Evaluation and optimization of sampling errors for the Monte Carlo independent column approximation. *Q. J. R. Meteorol. Soc.*, **130,** 2069-2086.

Barker, H. W. and P. Raisanen, 2005: Radiative sensitivities for cloud structural properties that are unresolved by conventional GCMs. *Q. J. R. Meteorol. Soc.*, **131,** 3103-3122.

Raisanen, P., H. W. Barker, and J. Cole, 2005: The Monte Carlo Independent Column Approximation's Conditional Random Noise: Impact on Simulated Climate. *J. Climate*, **17,** 4715-4730.

Pincus, R., R. Hemler, and S. A. Klein, 2006: Using Stochastically Generated Subcolumns to Represent Cloud Structure in a Large-Scale Model. *Mon. Wea. Rev.*, **134,** 3644–3656.

papers in the works:

- McMIP
- 2 by Petri (mixed ocean + ECHAM5)
- 1 by Jason (ISCCP simulator + CCCma)
- 1 by Jean-Jacques (NWP + ECMWF)