Overview of I3RC Phases I and II

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Accomplishments

- Bringing together cloudy 3D RT experts
- Reach out to other 3D communities
- I3RC results de-facto benchmark standard for newcomers in field
- Code improvement
- Wider exposure of 3D (BAMS paper, website, workshop proceedings)
- Community code

BAMS paper is out! (September 2005 issue)

THE I3RC

Bringing Together the Most Advanced Radiative Transfer Tools for Cloudy Atmospheres

BY ROBERT F. CAHALAN, LAZAROS OREOPOULOS, ALEXANDER MARSHAK, K. FRANKLIN EVANS, ANTHONY B. DAVIS, ROBERT PINCUS, KEN H. YETZER, BERNHARD MAYER, ROGER DAVIES, THOMAS P. ACKERMAN, HOWARD W. BARKER, EUGENE E. CLOTHIAUX, ROBERT G. ELLINGSON, MICHAEL J. GARAY, EVGUENI KASSIANOV, STEFAN KINNE, ANDREAS MACKE, WILLIAM O'HIROK, PHILIP T. PARTAIN, SERGEI M. PRIGARIN, ALEXEI N. RUBLEV, GRAEME L. STEPHENS, FREDERIC SZCZAP, EZRA E. TAKARA, TÁMAS VÁRNAI, GUOYONG WEN, AND TATIANA B. ZHURAVLEVA

An international Intercomparison of 3D Radiation Codes (I3RC) underscores the vast progress of recent years, but also highlights the challenges ahead for routine implementation in remote sensing and global climate modeling applications.

Community MC is available!

- Released July 20, 2005
- http://www.cdc.noaa.gov/people/robert.pincus/Software/I3RC/

Users' Guide to the

I3RC Community Radiative Transfer Mode

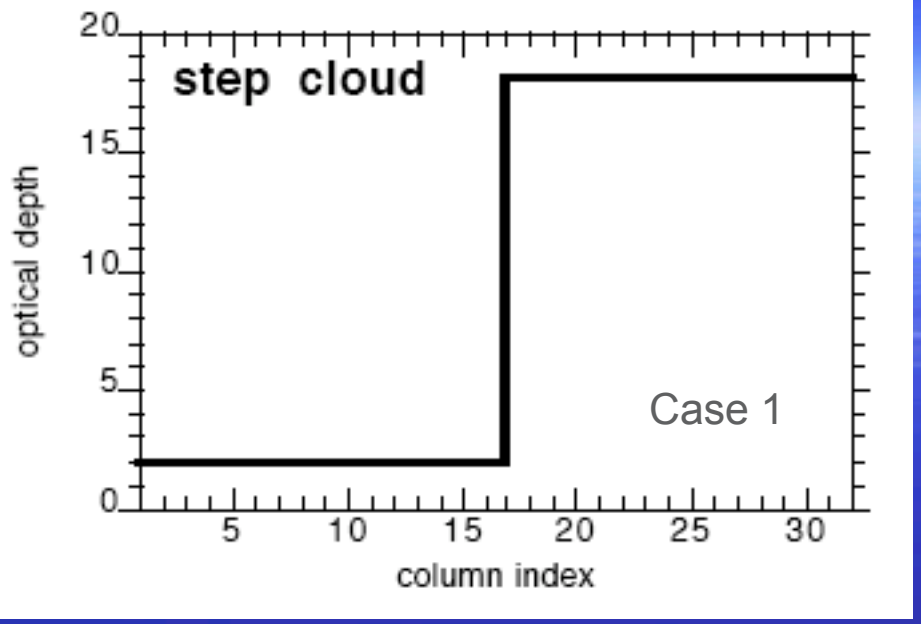
I3RC is the "Intercomparison of Three-Dimensional Radiation Code" project, funded by US National Aeronautics and Space Administration and the Atmospheric Radiation Measurement Program of the Department of Energy. See http://i3rc.gsfc.nasa.gov

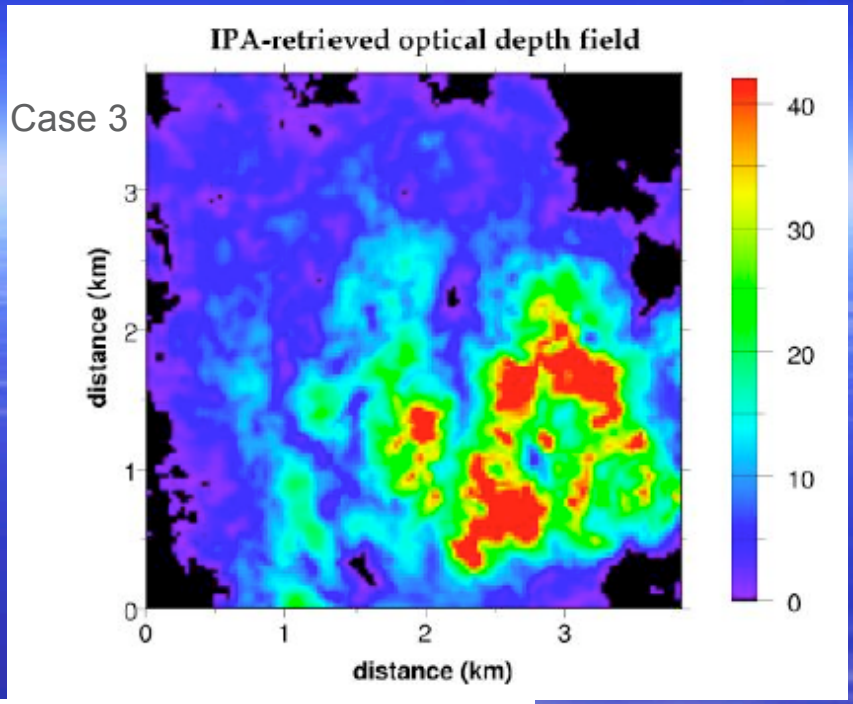
The community model and this documentation were written by Robert Pincus (Robert.Pincus@colorado.edu).

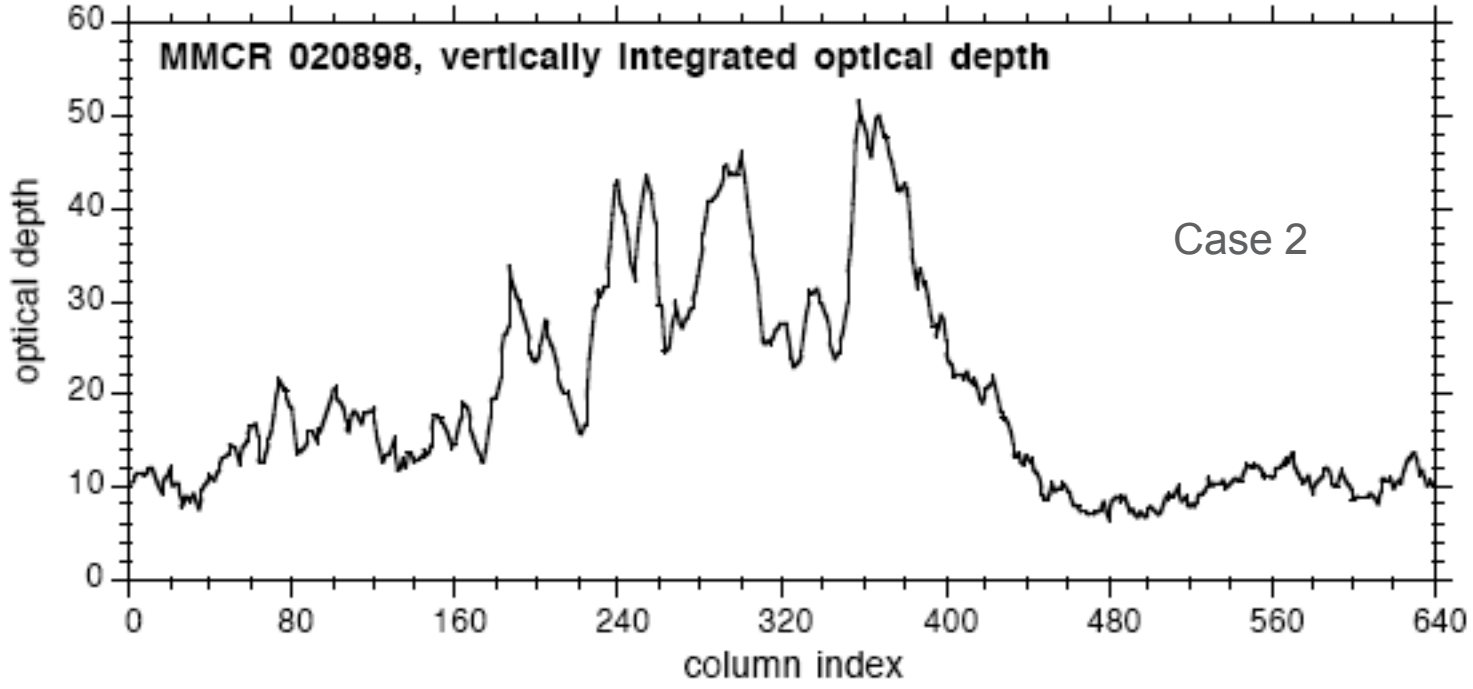
Table 1. List of participants in phase I of I3RC. See appendix for name expansion of methods and participating institutions. Italicized codes designate approximation methods that only participated in case 1 (step cloud) experiments. Documentation or application of these codes in scientific problems can be found in the papers entered in the reference column (see also reference list), whenever available, as well as in Cahalan and Davies (2000).

No.	Code	Institution	Contact person	Reference	Method description
1	ARIZ (United States)	Formerly University of Arizona, now at UCLA	M. Garay	Davies (1978)	Monte Carlo
2	COLS (United States)	Colorado State University	P. Partain	Partain et al. (2000)	Monte Carlo
3	IAOT (Russia)	Institute of Atmospheric Optics	T. Zhuravleva	N/A	Monte Carlo
4	KIAE1 (Russia)	Kurchatov Institute	A. Rublev	Geogdzhaev et al. (1997)	Monte Carlo
5	KIAE2 (Russia)	Kurchatov Institute	A. Rublev	Rublev et al. (2004)	Monte Carlo using adjoint RTE
6	*LANL1* (United States)	Los Alamos National Laboratory	A. Davis	Qu (1999)	3D delta-Eddington (ED3D) diffusion model
7	*LANL2* (United States)	Los Alamos National Laboratory	A. Davis	Davis et al. (1991)	DA (six-beam PDE model, using Monte Carlo)
8	*LANL3* (United States)	Los Alamos National Laboratory	A. Davis	Alcouffe et al. (1997)	TWODANT
9	MESC1 (Canada)	Meteorological Service of Canada	H. Barker	Barker et al. (2003a)	Monte Carlo
10	MESC2 (Canada)	Meteorological Service of Canada	H. Barker	Barker et al. (2003a)	Monte Carlo, delta-scaled optical properties
11	NCAR (Germany)	Formerly NCAR, now DLR	B. Mayer	Mayer and Kylling (2005)	Monte Carlo, libRadtran
12	PENN (United States)	The Pennsylvania State University	E. Clothiaux	Cole (2005)	Monte Carlo
13	PNNL (United States)	Pacific Northwest National Laboratory	E. Kassianov	Kassianov and Kogan (2002)	MC, max cross section, exact first-order scattering
14	UCOL1 (United States)	University of Colorado	K. F. Evans	Evans (1998)	SHDOM, low resolution
15	UCOL2 (United States)	University of Colorado	K. F. Evans	Evans (1998)	SHDOM, high resolution
16	UCSB (United States)	University of California, Santa Barbara	W. O'Hirok	O'Hirok and Gautier (1998)	Monte Carlo
17	UMBC1 (United States)	Formerly UMBC, now at GSFC	A. Marshak	Marshak et al. (1995)	Monte Carlo, local max cross section
18	UMBC2 (United States)	University of Maryland, Baltimore County	T. Várnai	Várnai and Marshak (2002)	Monte Carlo, max cross section
19	UMBC3 (United States)	Formerly UMBC, now at Max Planck Institute	S. Kinne	N/A	Monte Carlo
20	*UMBC4* (United States)	Formerly UMBC, now at Max Planck Institute	S. Kinne	N/A	DA (six-beam discrete-space model, using relaxation)
21	*UNBP1* (France)	Université Blaise Pascal	F. Szczap	Faure et al. (2001)	Neural networks
22	*UNBP2* (France)	Université Blaise Pascal	F. Szczap	Marshak et al. (1998)	NIPA
23	UNIK (Germany)	University of Kiel	A. Macke	Macke et al. (1999)	Monte Carlo

Phase I:
Submissions from 23 codes


step cloud
optical depth
column index
Case 1


IPA-retrieved optical depth field
Case 3
distance (km)
distance (km)


MMCR 020898, vertically integrated optical depth
optical depth
column index
Case 2

	Code	Exp1	Exp2	Exp3	Exp4
	Complete Set	F, r_u, r_o	F, r_u, r_o, t_d	F, r_u, r_o	F, r_u, r_o, t_d
1	ARIZ	F, r_u, r_o	F, r_u, r_o, t_d	F, r_u, r_o	F, r_u, r_o, t_d
2	COLS	F, r_u, r_o	F, r_u, r_o, t_d	F, r_u, r_o	F, r_u, r_o, t_d
3	IAOT	F, r_u, r_o	F, r_u, r_o, t_d	F, r_u, r_o	F, r_u, r_o, t_d
4	KIAE1	F, r_u, r_o	F, r_u, r_o, t_d	F, r_u, r_o	F, r_u, r_o, t_d
5	KIAE2	r_u, r_o	r_u, r_o, t_d	r_u, r_o	r_u, r_o, t_d
6	LANL1	F	F	F	F
7	LANL2	F		F	
8	LANL3	F	F	F	F
9	MESC1	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d
10	MESC2	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d
11	NCAR	F, r_u, r_o	F, r_u, r_o, t_d	F, r_u, r_o	F, r_u, r_o, t_d
12	PENN	F, r_u, r_o	F, r_u, r_o, t_d	F, r_u, r_o	F, r_u, r_o, t_d
13	PNNL	F, r_u, r_o	F, r_u, t_d	F, r_u, r_o	F, r_u, t_d
14	UCOL1	F, r_u, r_o	F, r_u, r_o, t_d	F, r_u, r_o	F, r_u, r_o, t_d
15	UCOL2	F, r_u, r_o	F, r_u, r_o, t_d	F, r_u, r_o	F, r_u, r_o, t_d
16	UCSB	F, r_u, r_o	F, r_u, r_o, t_d	F, r_u, r_o	F, r_u, r_o, t_d
17	UMBC1	F, r_u, r_o	F, r_u, r_o, t_d	F, r_u, r_o	F, r_u, r_o, t_d
18	UMBC2	F, r_u, r_o	F, r_u, r_o, t_d	F, r_u, r_o	F, r_u, r_o, t_d
19	UMBC3	F	F	F	F
20	UMBC4	F	F	F	F
21	UNBP1	F	F		
22	UNBP2	F	F		
23	UNIK	F, r_u, r_o	F, r_u, r_o, t_d	F, r_u, r_o	F, r_u, r_o, t_d

Case 1 participation matrix
Approximate methods only provided fluxes

	Code	Exp1	Exp2	Exp3	Exp4	Exp5	Exp6	Exp7	Exp8
	Complete Set	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d
1	ARIZ	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d			
2	COLS	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d
3	IAOT	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d	F	F	F
4	KIAE1	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d
5	KIAE2	r_u	r_u	r_u	r_u	r_u			
6	LANL1								
7	LANL2								
8	LANL3								
9	MESC1	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d
10	MESC2	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d			
11	NCAR	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d
12	PENN	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d
13	PNNL	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d
14	UCOL1	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d
15	UCOL2	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d
16	UCSB	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d
17	UMBC1	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d
18	UMBC2	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d
19	UMBC3	F	F	F	F	F	F	F	F
20	UMBC4								
21	UNBP1								
22	UNBP2								
23	UNIK	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d	F, r_u	F, r_u, t_d	F, r_u, t_d

Case 2 participation matrix. No approximate methods

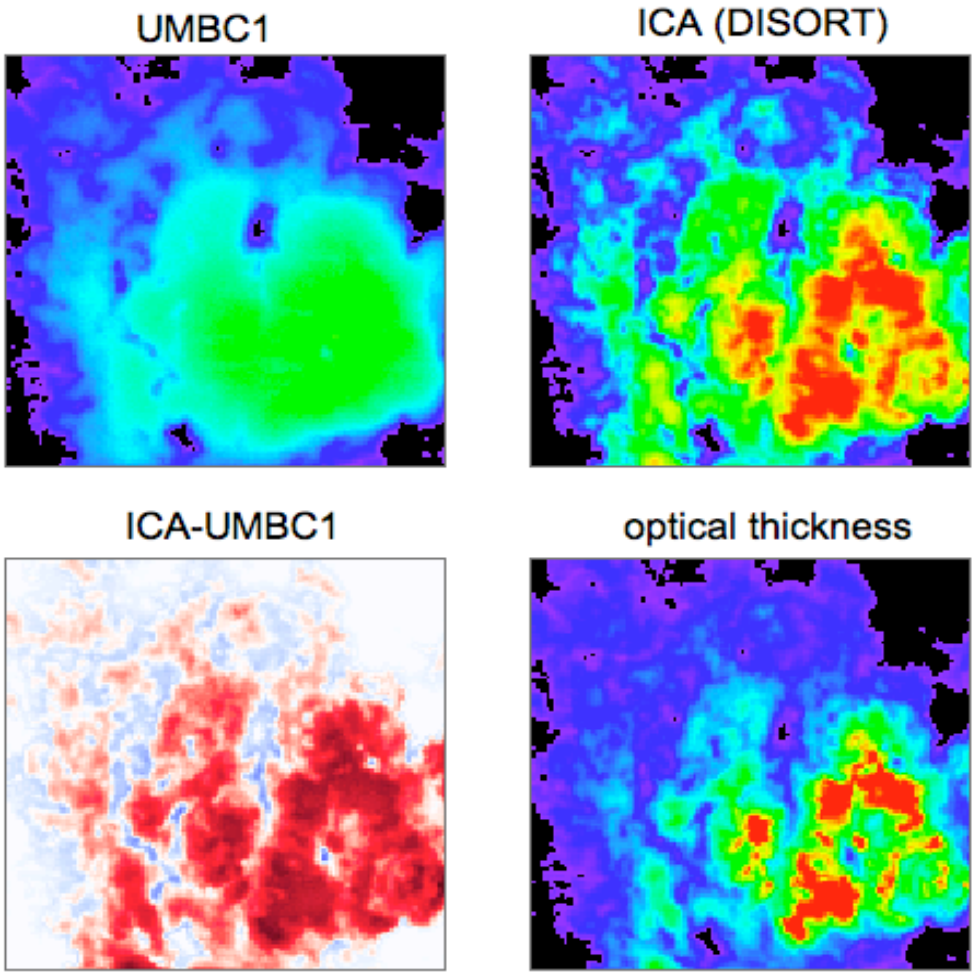
	Code	Exp1	Exp2	Exp3	Exp4
	Complete Set	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d
1	ARIZ				
2	COLS	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d
3	IAOT	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d
4	KIAE1	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d
5	KIAE2	r_u	r_u	r_u	r_u
6	LANL1				
7	LANL2				
8	LANL3				
9	MESC1	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d
10	MESC2	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d
11	NCAR	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d
12	PENN	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d
13	PNNL	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d
14	UCOL1	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d
15	UCOL2	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d
16	UCSB	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d
17	UMBC1	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d
18	UMBC2	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d
19	UMBC3	F	F	F	F
20	UMBC4				
21	UNBP1				
22	UNBP2				
23	UNIK	F, r_u	F, r_u, t_d	F, r_u	F, r_u, t_d

Case 3 participation matrix.
No approximate methods

Reflections on Phase I

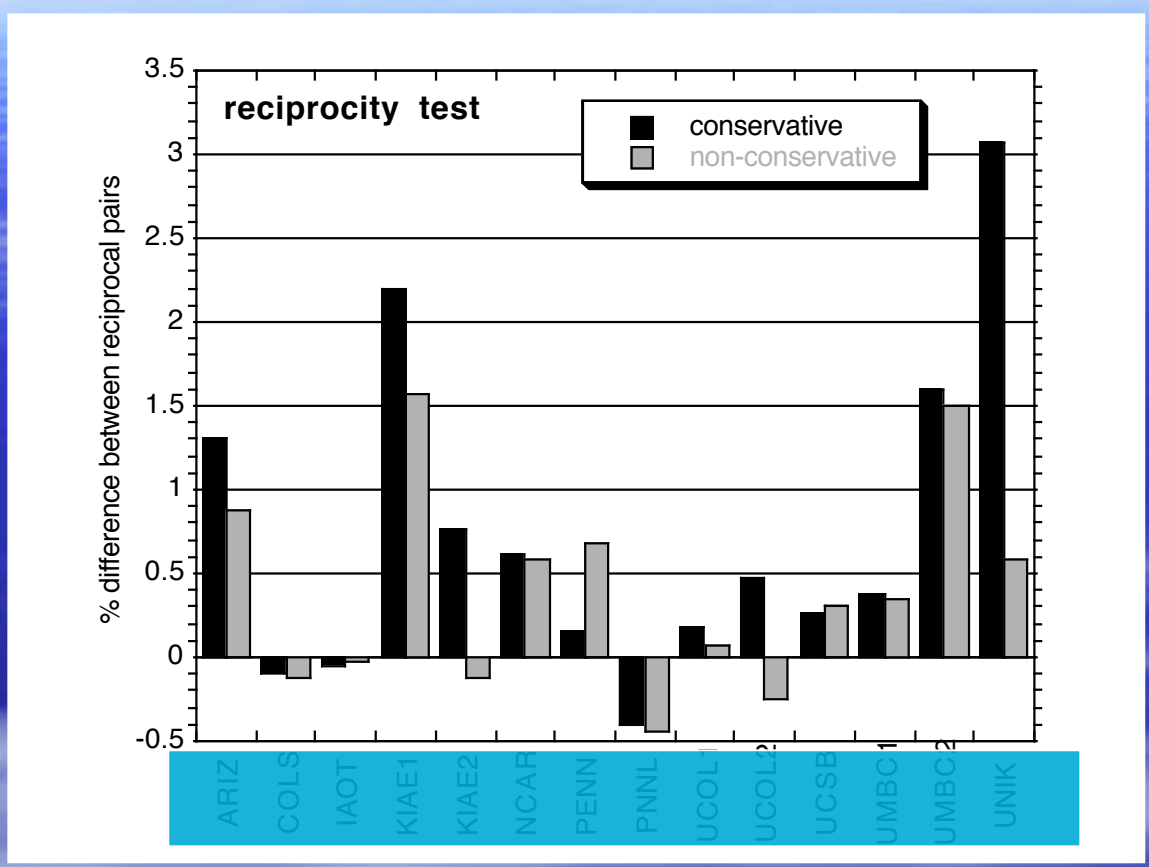
- Successful workshop
- Well balanced mix of cases and experiments
- Step cloud: Good entry-level case for approximate and/or modified codes
- Should have stressed more the importance of submitting error and CPU performance results
- Should have had formal documentation of results in form of paper (currently underway)

Case 3, strong 3D effects (overhead sun)



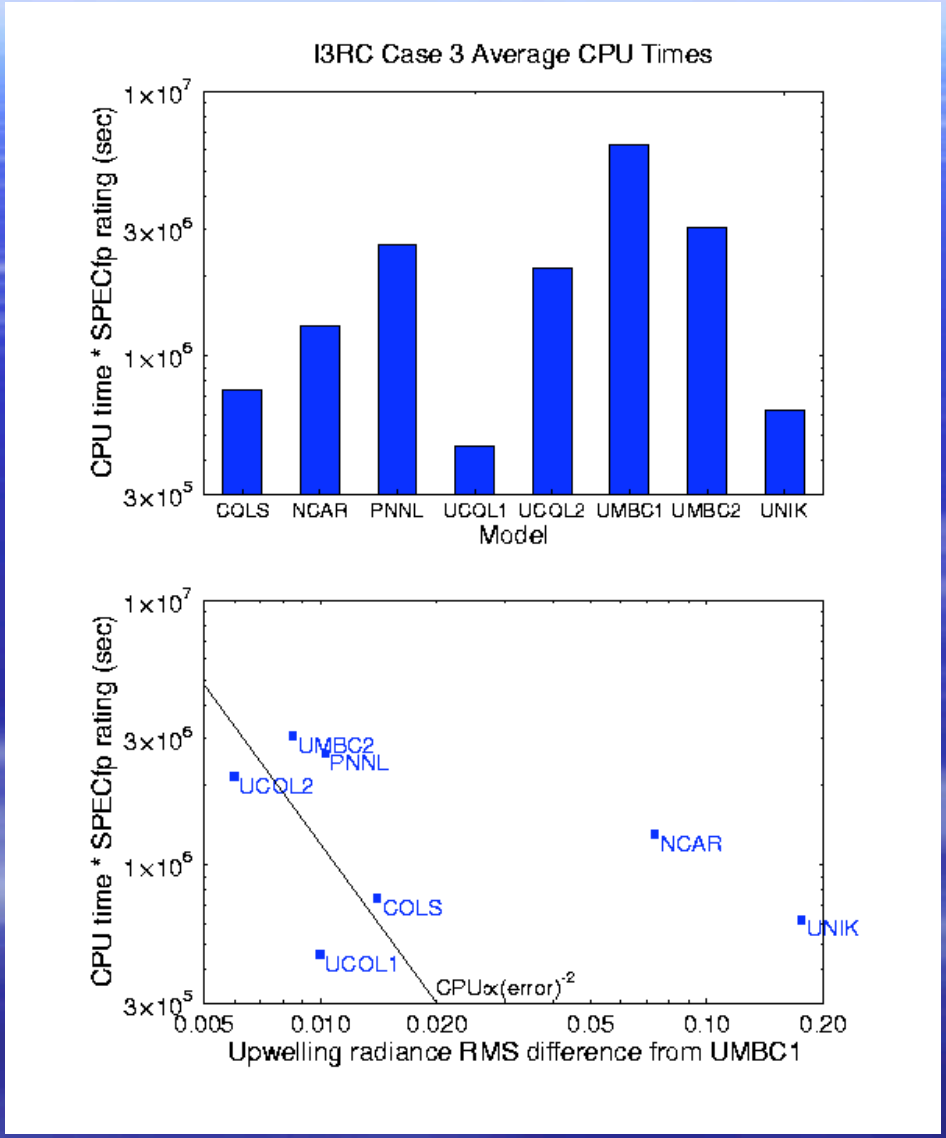
dispersion MC=0.69
dispersion ICA=0.86

Reciprocity test:
[overhead sun/oblique radiance]-[oblique incidence/nadir radiance]



14 submissions, only 6 provided errors for mean oblique radiance

Case 3 timing comparisons(by Frank Evans)



Local model deviation (see RAMI)

$$\delta_m(\psi) = \frac{200}{N_\psi N_{\exp} N_{\mathrm{mod}}} \sum_{l=1}^{N_\psi} \sum_{n=1}^{N_{\exp}} \sum_{k=1,k\neq m}^{N_{\mathrm{mod}}} \frac{\left| q_m(\psi) - q_k(\psi) \right|}{\left| q_m(\psi) + q_k(\psi) \right|}$$

Case 3

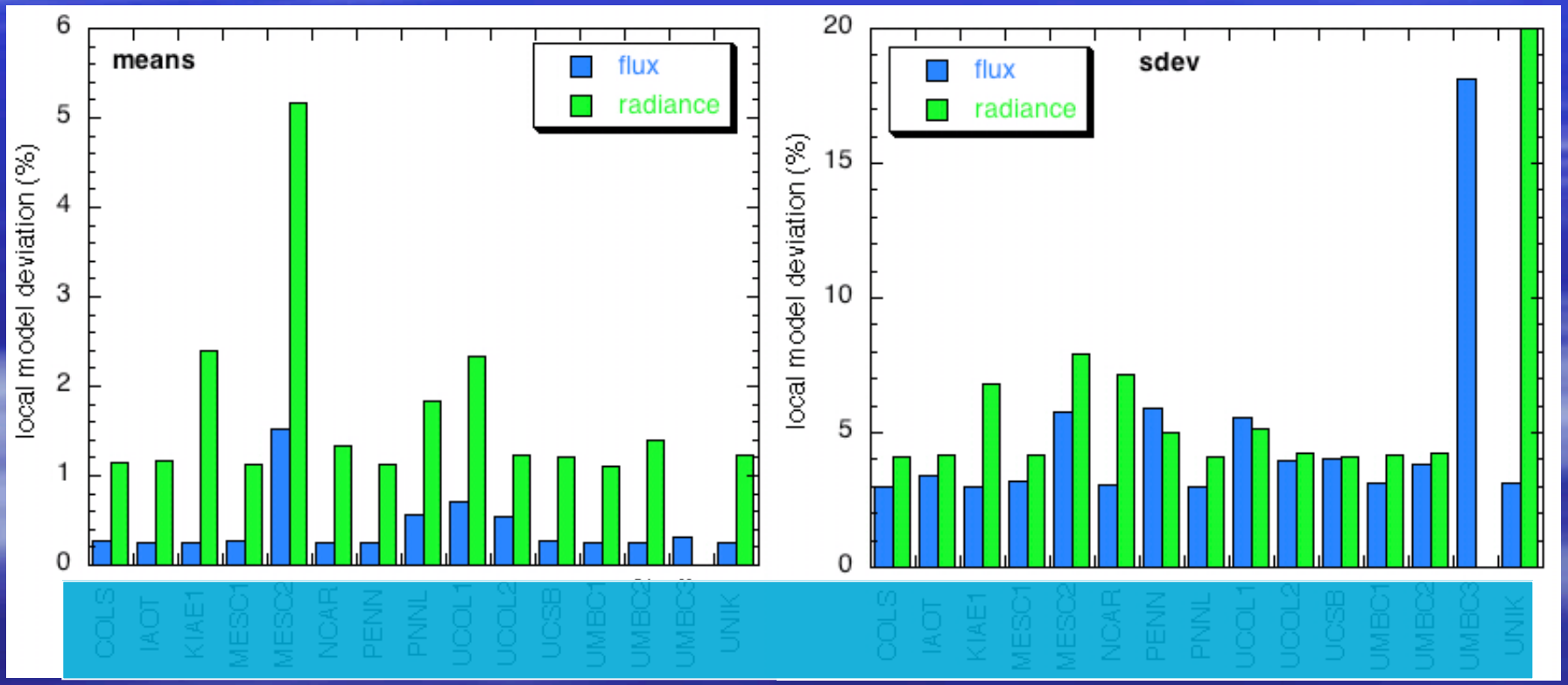
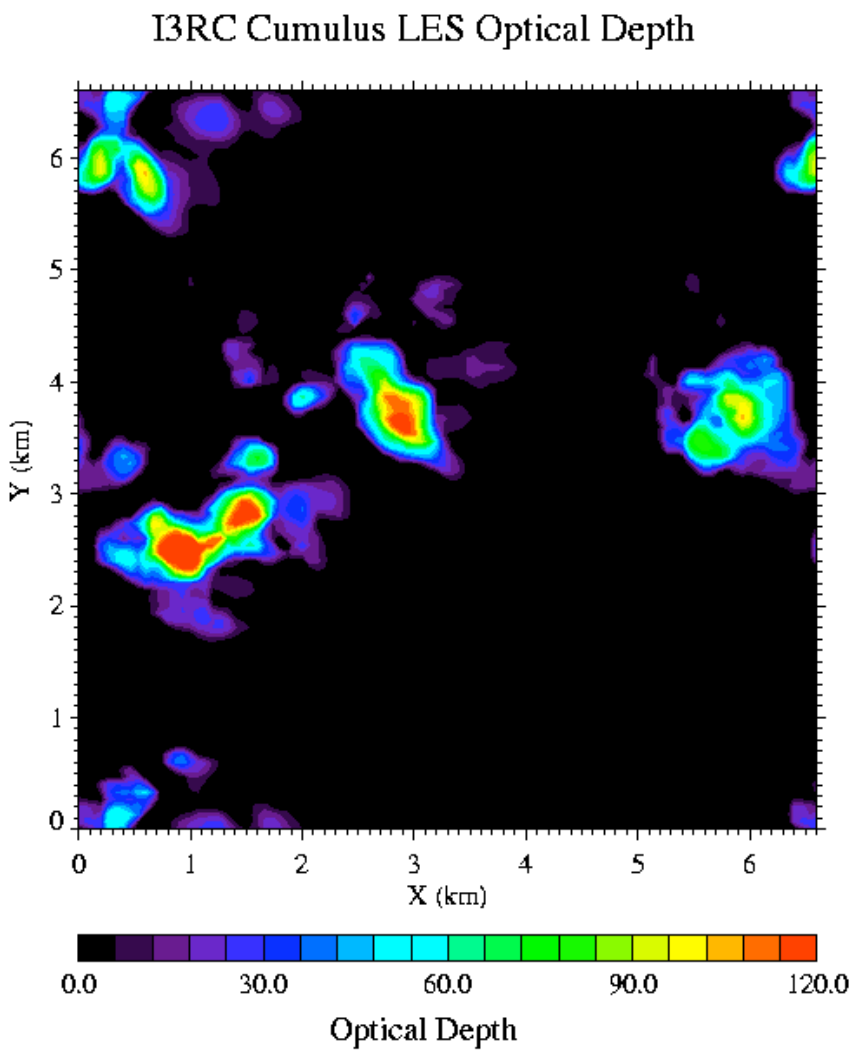


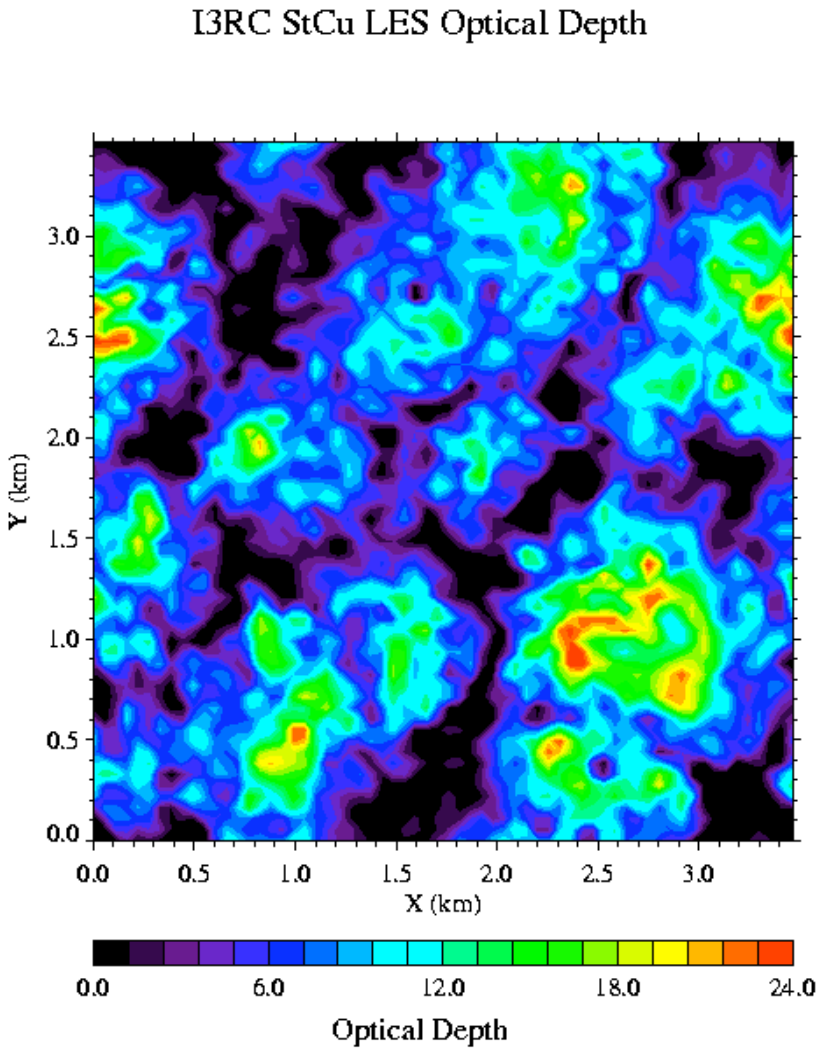
Table 2. List of participants of phase II of I3RC. See appendix for name expansion of methods and participating institutions. Documentation or application of these codes in scientific problems can be found in the papers entered in the reference column (see also reference list), whenever available, as well as in Cahalan and Davies (2000).

#	Code	Institution	Contact person	Reference	Method description
1	ARIZ (United States)	Formerly University of Arizona, now at UCLA	M. Garay	Davies (1978)	Monte Carlo
2	DZLR1 (Germany)	Deutsches Zentrum für Luft und Raumfahrt	B. Mayer	Mayer and Kylling (2005)	Monte Carlo, libRadtran
3	DZLR2 (Germany)	Deutsches Zentrum für Luft und Raumfahrt	B. Mayer	Mayer and Kylling (2005)	Monte Carlo, libRadtran truncated forward peak
4	IAOT (Russia)	Institute of Atmospheric Optics	T. Zhuravleva	N/A	Monte Carlo, max cross section
5	ICOM (Russia)	Institute of Computational Mathematics	S. Prigarin	N/A	Monte Carlo, max cross section
6	PENN (United States)	The Pennsylvania State University	E. Clothiaux	Cole (2005)	Monte Carlo
7	PNNL (United States)	Pacific Northwest National Laboratory	E. Kassianov	Kassianov and Kogan (2002)	MC, max cross section exact first-order scattering
8	UCOL (United States)	University of Colorado	F. Evans	Evans (1998)	SHDOM
9	UCSB (United States)	University of California, Santa Barbara	W. O'Hirok	O'Hirok and Gautier (1998)	Monte Carlo
10	UMBC1 (United States)	Formerly UMBC, now at GSFC	A. Marshak	Marshak et al. (1995)	Monte Carlo, local max cross section
11	UMBC5 (United States)	University of Maryland, Baltimore County	T. Varnai	Várnai and Marshak (2003)	Monte Carlo, max cross section
12	UMCP (United States)	Formerly University of Maryland, College Park, now at FSU	E. Takara	Takara and Ellingson (1996)	Monte Carlo, LW, backward
13	UNIK (Germany)	University of Kiel	A. Macke	Macke et al. (1999)	Monte Carlo, local estimation for radiances

Phase II:
Submissions from 13 codes

Remote sensing and heating rate application areas





	Code	Exp1	Exp2	Exp3	Exp4	Exp5	Exp6	Exp7	Exp8	Exp9	Exp10	Exp11	Exp12	Exp13	Exp14	Exp15	No.
	Requested	r_u	r_u	r_u	r_u	ε_u	r_u, r_o	r_u, r_o	r_u, r_o	r_u, r_o	$\varepsilon_u, \varepsilon_o$	r_u, r_o	r_u, r_o	r_u, r_o	r_u, r_o	$\varepsilon_u, \varepsilon_o$	360
1	ARIZ	r_u	r_u	r_u	r_u												16
2	DZLR1	r_u	r_u	r_u	r_u	ε_u	r_u, r_o	r_u, r_o	r_u, r_o	r_u, r_o	$\varepsilon_u, \varepsilon_o$	r_u, r_o	r_u, r_o	r_u, r_o	r_u, r_o	$\varepsilon_u, \varepsilon_o$	180
3	DZLR2	r_u	r_u	r_u	r_u		r_u, r_o	r_u, r_o	r_u, r_o	r_u, r_o		r_u, r_o	r_u, r_o	r_u, r_o	r_u, r_o		108
4	IAOT	r_u	r_u	r_u	r_u					r_u							20
5	ICOM	r_u	r_u	r_u	r_u												16
6	PENN	r_u	r_u	r_u	r_u		r_u, r_o	r_u, r_o	r_u, r_o	r_u, r_o							48
7	PNNL	r_u	r_u	r_u	r_u		r_u, r_o	r_u, r_o	r_u, r_o								20
8	UCOL	r_u	r_u	r_u	r_u	ε_u	r_u, r_o	r_u, r_o	r_u, r_o	r_u, r_o	$\varepsilon_u, \varepsilon_o$	r_u, r_o	r_u, r_o	r_u, r_o	r_u, r_o	$\varepsilon_u, \varepsilon_o$	360
9	UCSB	r_u	r_u	r_u	r_u		r_u, r_o	r_u, r_o	r_u, r_o	r_u, r_o							96
10	UMBC1	r_u	r_u	r_u	r_u		r_u, r_o	r_u, r_o	r_u, r_o	r_u, r_o							48
11	UMBC5	r_u	r_u	r_u	r_u	ε_u	r_u, r_o	r_u, r_o	r_u, r_o	r_u, r_o	$\varepsilon_u, \varepsilon_o$	r_u, r_o	r_u, r_o	r_u, r_o	r_u, r_o	$\varepsilon_u, \varepsilon_o$	16
12	UMCP					ε_u											2
13	UNIK	r_u	r_u	r_u	r_u		r_u, r_o	r_u, r_o	r_u, r_o	r_u, r_o		r_u, r_o	r_u, r_o	r_u, r_o	r_u, r_o		182

Remote sensing application area participation matrix
Note limited participation for thermal experiments (5,10,15)

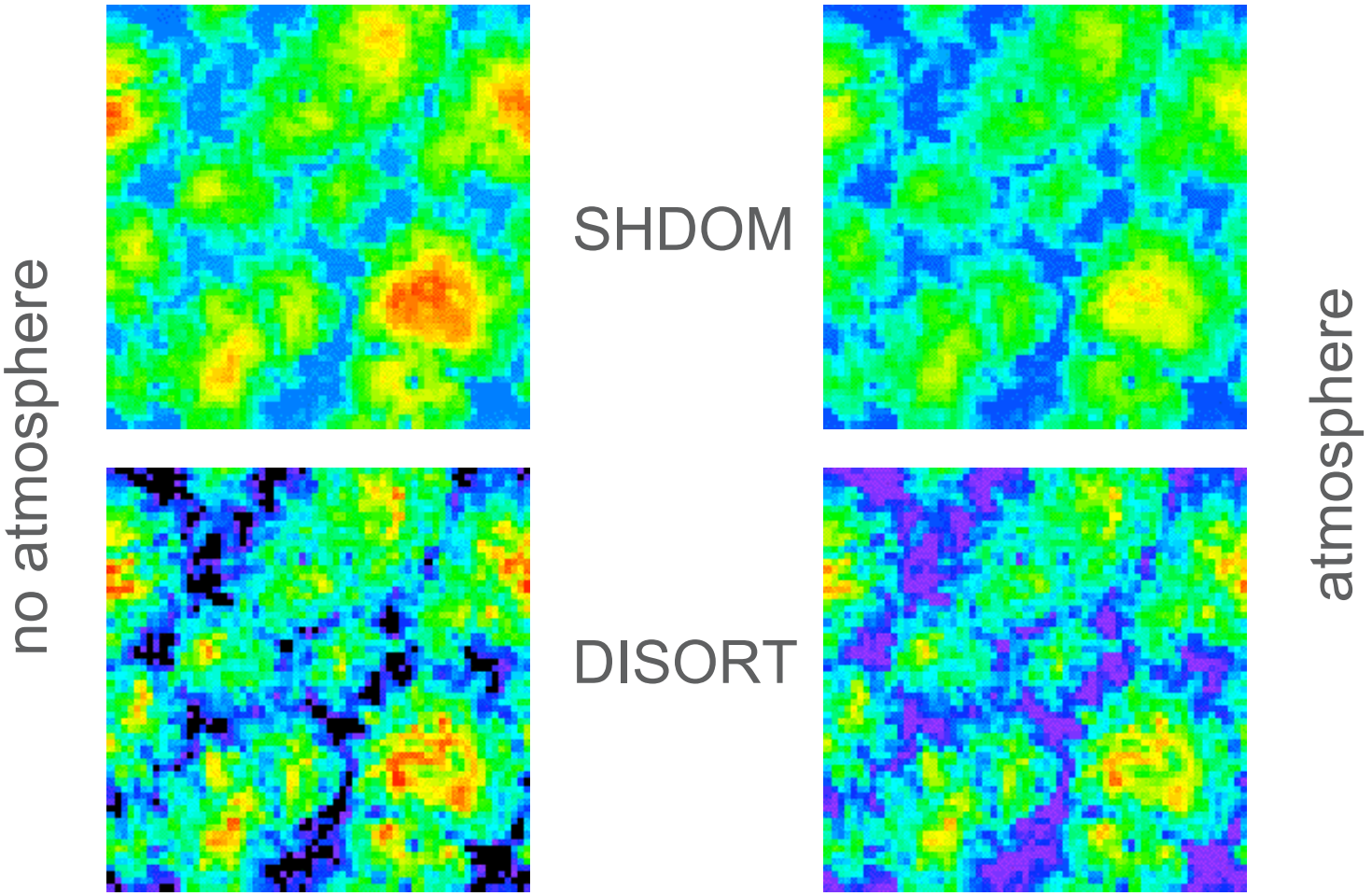
	Code	Exp1	Exp2	Exp3	Exp4	Exp5	Exp6	Exp7	Exp8	No.
	Requested	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c	96
1	ARIZ									0
2	DZLR1	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c		42
3	DZLR2									0
4	IAOT									0
5	ICOM									0
6	PENN	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c		48
7	PNNL									0
8	UCOL	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c		73
9	UCSB									0
10	UMBC1	F_u, F_d, F_c	F_u, F_d, F_c	F_u, F_d, F_c						18
11	UMBC5									0
12	UMCP				F_u, F_d					4
13	UNIK									0

Heating rate application area participation matrix
Nobody attempted optional experiment 8!

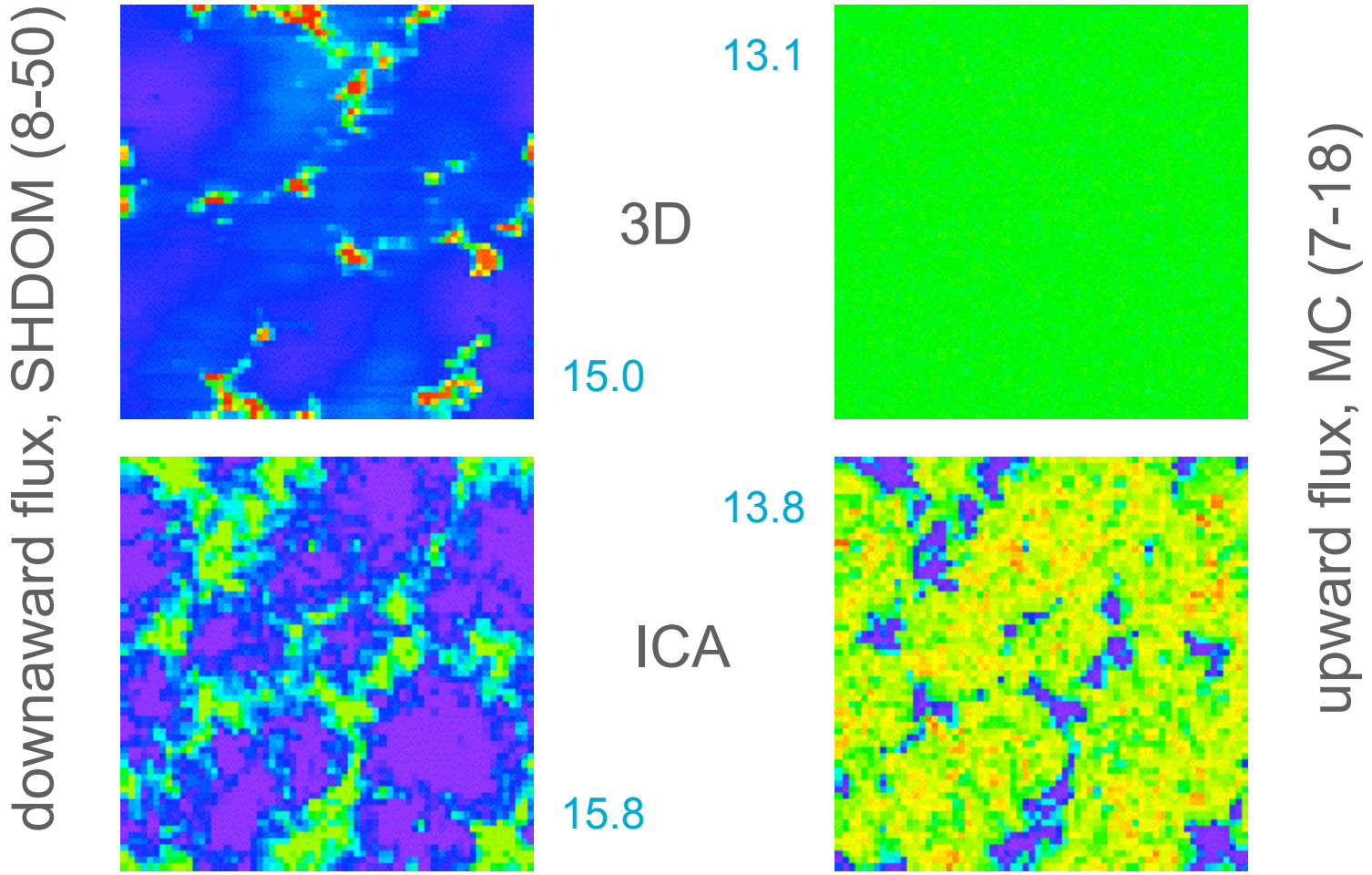
Reflections on Phase II

- Productive 2nd workshop
- Good strategy to separate into HR and RS application areas
- Good to add atmosphere
- One cloud field (Cu) a bit more interesting than the other; strong 3D effects
- Fluxes at 30 km not very interesting
- Not too many people (at the time) ready for BB/LW
- We had too many experiments and asked way too much output
- Again, should have published results when fresh

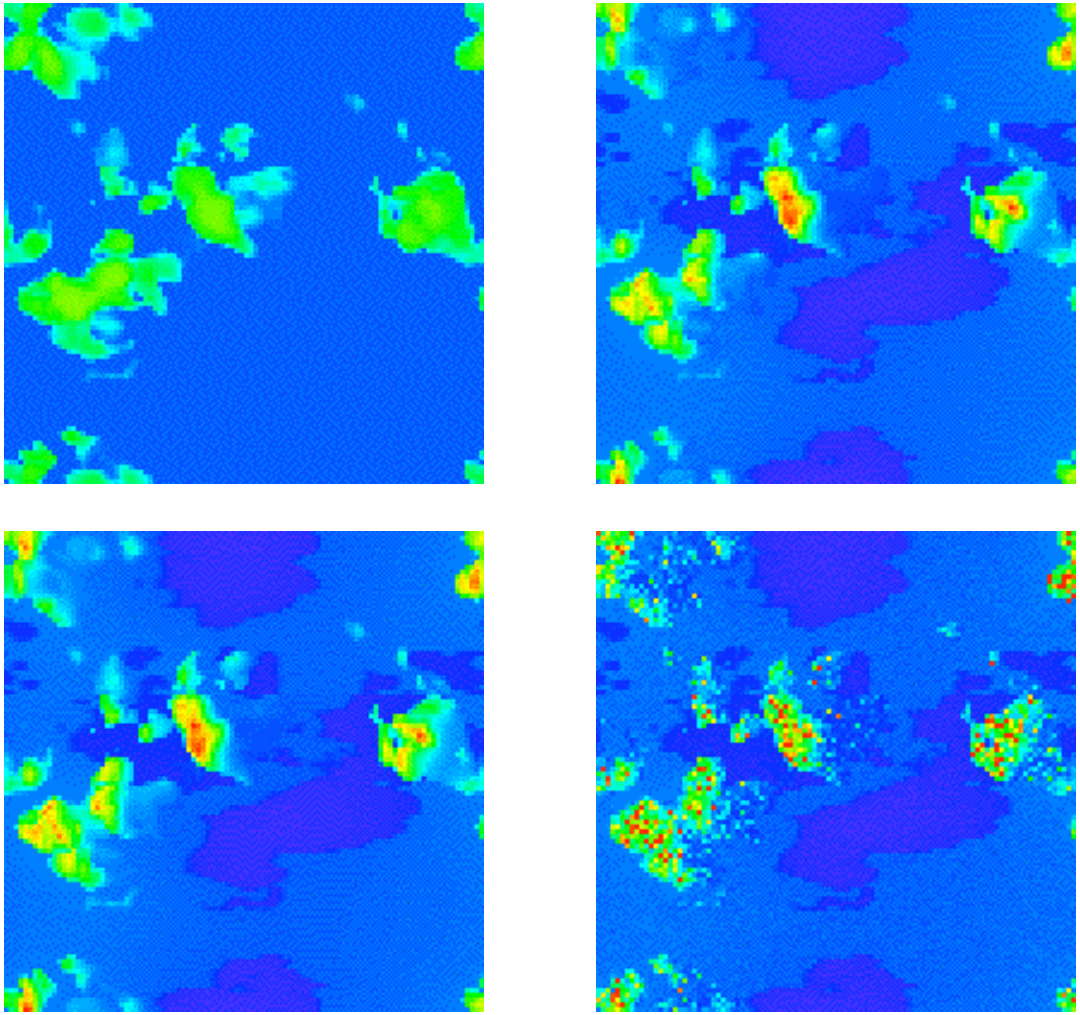
3D vs. ICA, Case 5 (SZA=0°, SSA=1.0)



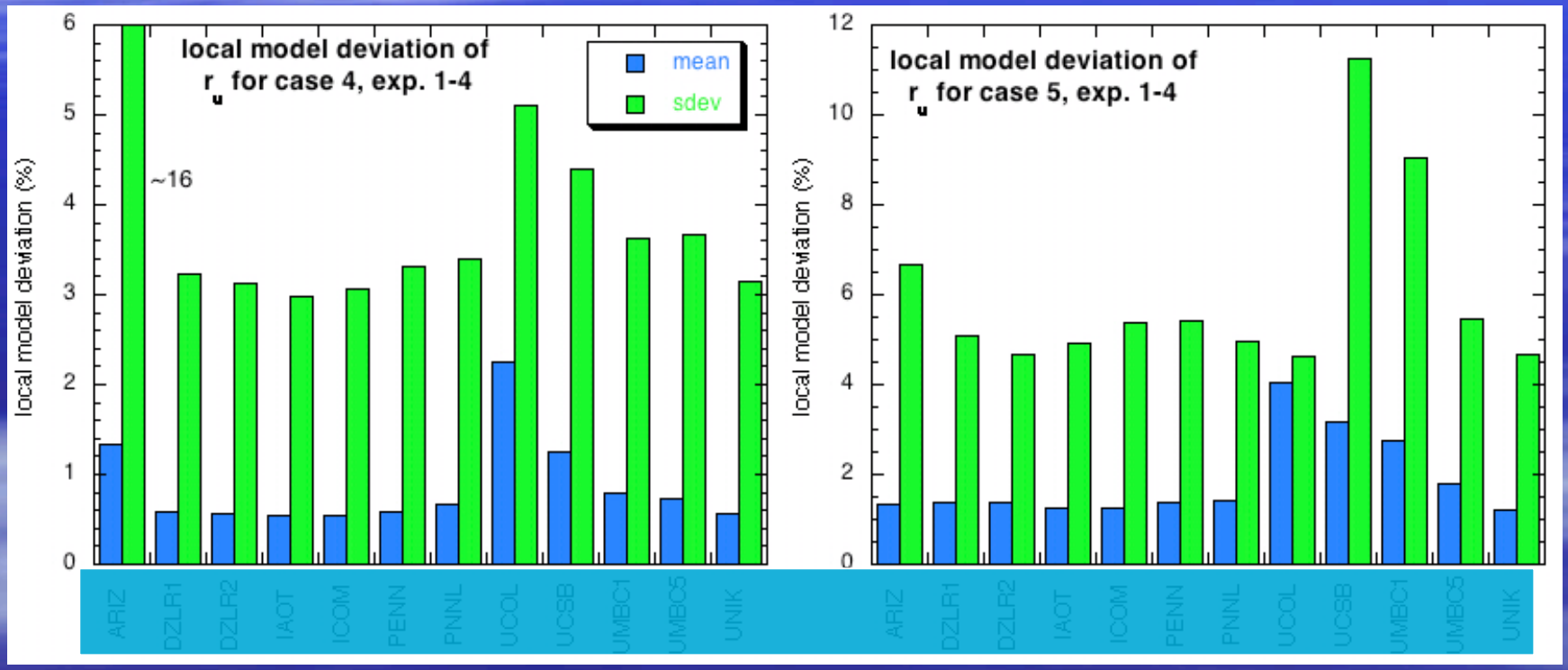
3D vs. ICA, Case 5 (SZA=60°, SSA=1.0)



ICA vs. 3D, Cu case of Phase II (reflectance, oblique illumination)



Phase II, but Phase I-like experiments (Mie instead of HG)



Some closing thoughts

- We did well, can always do better
- I3RC is pretty well-known/referenced and many people still look/ask our data; three of our cases appear in the new 3D book
- We lost a bit of momentum after completion of Phase II, now we're back strong with Phase III, BAMS paper, MC code
- Phases I and II were relatively well-funded, but now funding environment is tougher
- Publishing the Phase I-III results will further help our image and morale
- Meeting Summary in BAMS or EOS?