The Continual Intercomparison of Radiation Codes (CIRC)

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CIRC motivation/history

- Issues with radiation codes found in Intercomparison of Radiation Codes used in Climate Models (ICRCCM) (~1990) led to DOE Atmospheric Radiation Measurement (ARM) program (early 1990s)
- ARM continuous measurements allowed in-depth comparisons of radiation measurements and models (i.e. radiative closure studies) ➔ improvements to RT models
- Maturity of ARM data streams led to overarching radiative closure study – Broadband Heating Rate Profile (BBHRP) project (~2002)
- Bill Rossow, then head of GEWEX Radiation Panel, proposed new RT code intercomparison effort based on BBHRP --- subsequently approved by GRP

From *Collins et al. (2006)* RT Code Intercomparison study*:*

- GCM RT codes exhibited “substantial discrepancies” relative to reference calculations from detailed “line-by-line” RT models

What CIRC is about

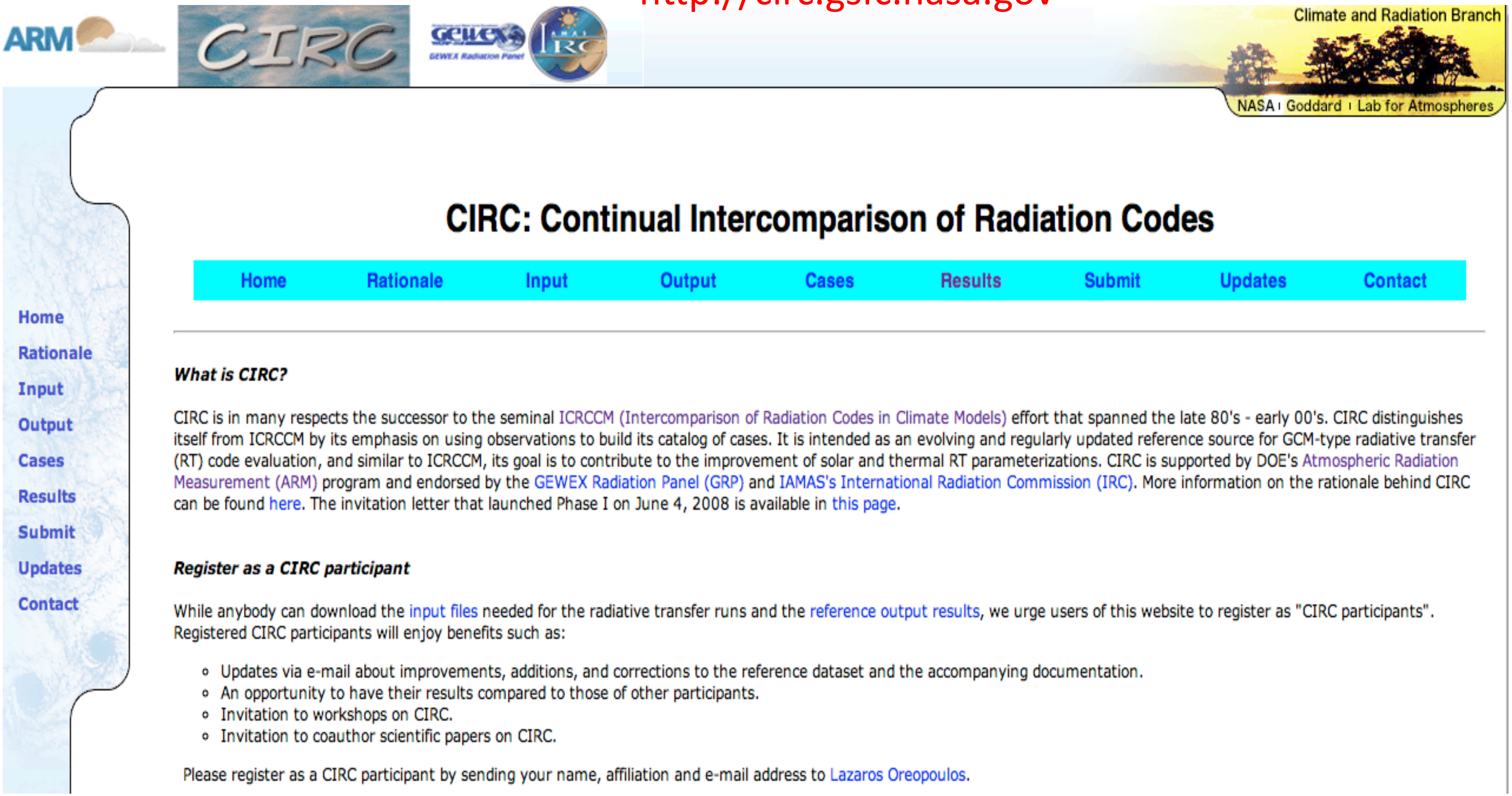
- RT model intercomparison intended to be the standard for documenting the performance of RT codes used in Large-Scale Models (LSMs)
- <u>Working group within International Radiation Commission (IRC) and GRP</u>
- Goal is to have RT codes of GCMs (incl. IPCC) report performance against CIRC
- Phase 1 was launched on June 4, 2008
- Phase "1a" was launched on January 19, 2010 (16 simpler variants of Phase I cases)
- Website: http://circ.gsfc.nasa.gov

How CIRC differs from previous intercomparisons:

- *<u>Observation-tested</u>* (LW) LBL calculations are used as radiative benchmarks
- Benchmark results are publicly available
- Observationally-based input (chiefly from ARM BBHRP product)
- Intended to have flexible structure and be continual (i.e. updated periodically)

CIRC website

http://circ.gsfc.nasa.gov



ARM
CIRC
GEWEX Radiation Panel
IRC
Climate and Radiation Branch
NASA | Goddard | Lab for Atmospheres

CIRC: Continual Intercomparison of Radiation Codes

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What is CIRC?

CIRC is in many respects the successor to the seminal ICRCCM (Intercomparison of Radiation Codes in Climate Models) effort that spanned the late 80's - early 00's. CIRC distinguishes itself from ICRCCM by its emphasis on using observations to build its catalog of cases. It is intended as an evolving and regularly updated reference source for GCM-type radiative transfer (RT) code evaluation, and similar to ICRCCM, its goal is to contribute to the improvement of solar and thermal RT parameterizations. CIRC is supported by DOE's Atmospheric Radiation Measurement (ARM) program and endorsed by the GEWEX Radiation Panel (GRP) and IAMAS's International Radiation Commission (IRC). More information on the rationale behind CIRC can be found here. The invitation letter that launched Phase I on June 4, 2008 is available in this page.

Register as a CIRC participant

While anybody can download the input files needed for the radiative transfer runs and the reference output results, we urge users of this website to register as "CIRC participants". Registered CIRC participants will enjoy benefits such as:

- Updates via e-mail about improvements, additions, and corrections to the reference dataset and the accompanying documentation.
- An opportunity to have their results compared to those of other participants.
- Invitation to workshops on CIRC.
- Invitation to coauthor scientific papers on CIRC.

Please register as a CIRC participant by sending your name, affiliation and e-mail address to Lazaros Oreopoulos.

MENU

- RAMI-IV
- RAMI3
- RAMI2
- RAMI1
- DEFINITIONS
- FAQs
- FORMATS
- ORGANISATION

LINKS

PILPS

ROMC

RAMI, RAdiation transfer Model Intercomparison

This is the official site of the radiation transfer model intercomparison (RAMI) initiative. RAMI proposes a mechanism to benchmark models designed to simulate the transfer of radiation at or near the Earth's terrestrial surface, i.e., in plant canopies and over soil surfaces. As an open-access, on-going activity, RAMI operates in successive phases each one aiming at re-assessing the capability, performance and agreement of the latest generation of radiation transfer (RT) models. This in turn, will lead to model enhancements and further developments that benefit the RT modelling community as a whole. Currently the fourth phase of RAMI is open:

The fourth phase of RAMI aims at evaluating bi-directional canopy reflectance models, light transmission and absorption models, as well as models capable of simulating waveform Lidar signals and thresholded hemispherical photographs. RAMI-IV proposes two different types of test environments: 1) abstract canopies, that are generated only on the basis of disc-shaped scatterers, and 2) actual canopies,that are based on inventories of actual forest and plantation test sites. Submissions to RAMI-IV are welcome from both 1-D and 3-D models.

enter RAMI-IV

During the active submission period of a given phase of RAMI, participation is open to everyone willing to run a previously published model against an ensemble of prescribed test cases. Previous RAMI phases have not only led to improved computer codes and publications in the refereed scientific literature, but also to the development of the RAMI On-line Model Checker (ROMC). The ROMC is a web-based tool allowing users to compare their model simulations (in forward mode) against a reference solution derived from a series of 3D Monte Carlo models participating in the third phase of RAMI. For more information on RAMI, please consult the FAQs and our privacy and data-usage policy via this DISCLAIMER link.

Phase	Active Period	Participants	First Presentation of Results	Scientific Publication
RAMI-1	Mar - Aug 1999	1-D models: 3 3-D models: 5	Sep 1999: IWMMM-2, Ispra, Italy	JGR, Vol 106, D11, 11,937-11,956, 2001 Bibliography: LaTeX, Word, ASCII
RAMI-2	Feb - Jun 2002	1-D models: 3 3-D models: 10	Jun 2002: IWMMM-3, Steamboat Springs, USA	JGR, Vol 109, No. D6210, 2004 Bibliography: LaTeX, Word, ASCII
RAMI-3	Mar - Dec 2005	1-D models: 5 3-D models: 13	Oct 2005: ISPMSRS, Beijing, China (Homogeneous only) Mar 2006: IWMMM-4, Sydney, Australia (All results)	JGR, vol 112, 2007 doi 10.1029/2006JD007821, Bibliography: LaTeX, Word, ASCII

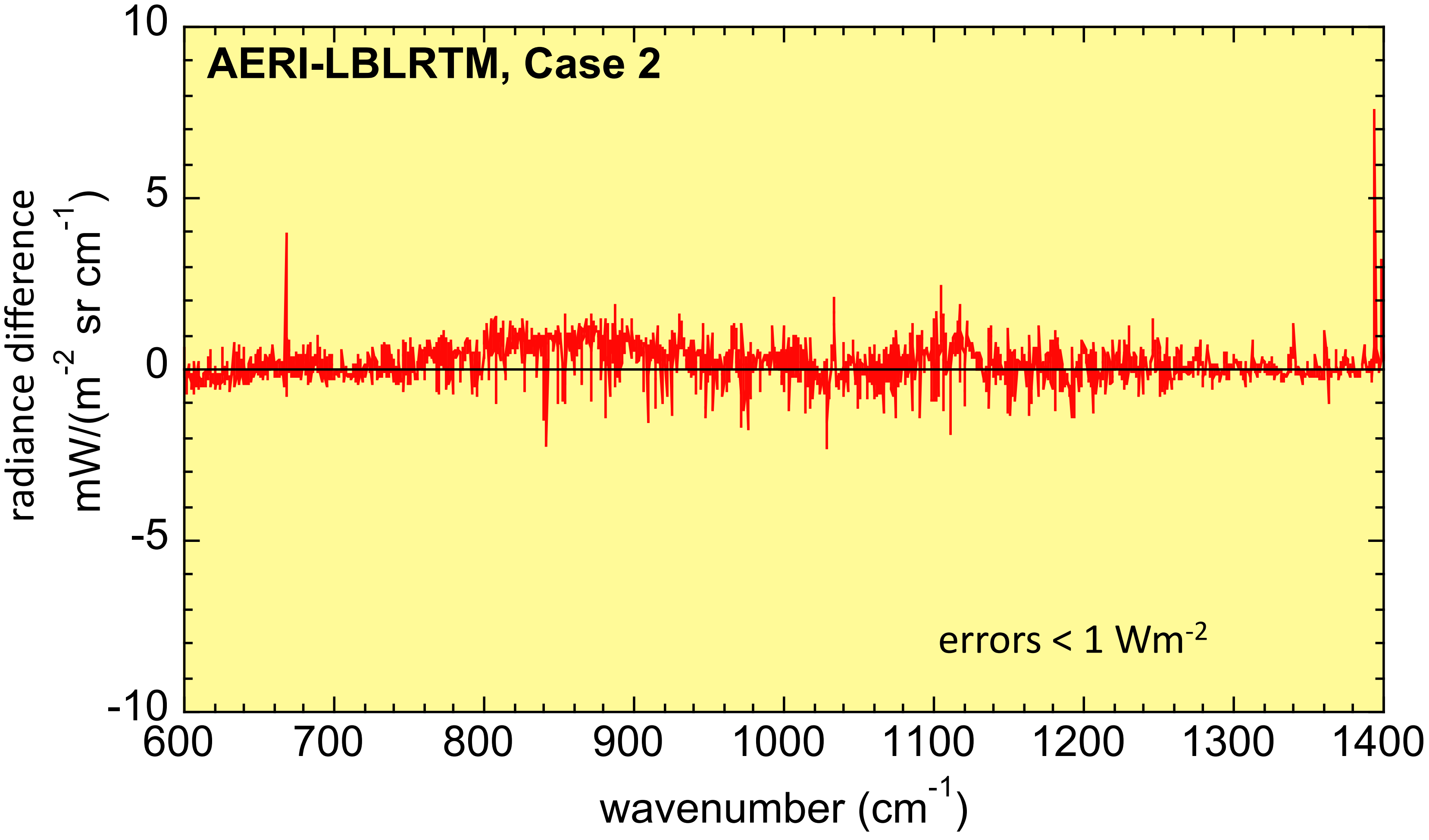
Related model intercomparison and quality assurance activities include:

I3RC	PILPS	QA4EO		CIRC
Intercomparison of 3-D Radiation Codes, I3RC	Project for Intercomparison of Land-surface Parameterization Schemes, PILPS	Quality Assurance for Earth Observation, QA4EO	Snow Model Intercomparison Project for forest snow processes, SNOWMIP2	Continual Intercomparison of Radiation Codes, CIRC

CIRC Phase I *baseline* cases

Case	SZA	PWV (cm)	τ_{aer}	LWP (gm^{-2})	LW_{SFC}	LW_{TOA}	obs - LBL (%) SW_{SFC}	SW_{TOA}
(1) SGP 9/25/00	47.9°	1.23	0.04		0.5	-0.9	0.5	-3.1
(2) SGP 7/19/00	64.6°	4.85	0.18		0.6	-1.4	-1.1	8.4
(3) SGP 5/4/00	40.6°	2.31	0.09		1.0	-1.2	-0.1	-8.7
(4, 5) NSA 5/3/04 2xCO_2)	55.1°	0.29	0.13		1.2	-0.6	-0.8	0.7
(6) SGP 3/17/00	45.5°	1.90	0.24	263.4	1.1	-3.0	4.9	-0.9
(7) PYE 7/6/05	41.2°	2.42		39.1	0.2	0.6	-0.4	-0.1

LW QC: LBLRTM spectral comparisons with AERI



Phase I subcases (“Phase 1a”)

- Launched January 2010
- Simplified versions of baseline cases
  - Spectrally flat surface albedo
  - No aerosol
  - No cloud
- 16 additional SW cases and 2 additional LW cases
- No radiative closure with observations (naturally)
- Expected better performance relative to LBL.

Longwave code participants

Model Index	Brief Model Description	In LSM?	Experiment variants	Submitted By	Reference(s)
0	LBLRTM v.11.1/HITRAN 2004, MT_CKD_2.0, AER_V_2.0	No	None	Delamere, Mlawer	Clough et al. (2005)
1	RRTM-LW, 10-3000 cm^{-1}, CKD, 16 bands, 256 g-points	No	None	Iacono, Mlawer	Mlawer et al. (1997); Clough et al. (2005);
2	RRTMG-LW, 10-3000 cm^{-1}, CKD, 16 bands, 140 g-points	Yes	None	Iacono	Mlawer et al. (1997); Iacono et al. (2008)
3	CLIRAD-LW, 0-3000 cm^{-1}, k-distribution and one-parameter scaling, 10 bands, 85/113 k-points	Yes	“High/Low” accuracy	Oreopoulos	Chou et al. (2003)
4	CCC 0-2500 cm^{-1}, CKD, 9 bands, 56 g-points	Yes	With/without scattering	Cole, Li	Li (2002); Li and Barker (2002); Li and Barker (2005);
5	FLBLM, 40-3000 cm^{-1}, line-by-line,	No	With/without scattering	Fomin	Fomin (2006)
6	FKDM, 40-3000 cm^{-1}, CKD, 23 g-points	No	None	Fomin	Fomin (2004)
7	CAM 3.1, 0-2000 cm^{-1}, absorptiviy-emissivity approach	Yes	None	Oreopoulos	Collins et al. (2004)
8	FLCKKR (LW), 0-2200 cm^{-1}, CKD, 12 bands, 67 g-points	No	None	Rose	Fu and Liou (1992); Fu et al. (1997)
9	RRTMG-LW (as implemented in FMI ECHAM5.4), 10-3000 cm^{-1}, 16 bands, 140 g-points	Yes	None	Räisänen	Mlawer et al. (1997); Iacono et al. (2008)
10	ES, 10-3000 cm^{-1}, 9 bands/33 g-points, ESF of band transmissions	Yes	With/without scattering	Manners	Edwards and Slingo (1996); Edwards (1996)
11	GISS, 50-2000 cm^{-1}, CKD, 33 g-points	Yes	With/without scattering	Zhang, Rossow	Zhang et al. (2004)

GCMs Using CIRC LW RT Codes

Model Index	Brief Model Description	In LSM?	Experiment variants Submitted By	Reference(s)
0	LBLRTM v.11.1/HITRAN 2004, MT_CKD_2.0, AER_V_2.0	No	-	Clough et al. (2005)
1	RRTM-LW, 10-3000 cm^{-1}, CKD, 16 bands, 256 g-points	No	-	Mlawer et al. (1997); Clough et al. (2005);
2	RRTMG-LW, 10-3000 cm^{-1}, CKD, 16 bands, 140 g-points	Yes	CAM5 (CESM), NCEP GFS/CFS, ECMWF IFS, LMDZ, CMA, GEOS-5 (dev.)	Mlawer et al. (1997); Iacono et al. (2008)
3	CLIRAD-LW, 0-3000 cm^{-1}, k-distribution and one-parameter scaling, 10 bands, 85/113 k-points	Yes	GEOS-4, GEOS-5	Chou et al. (2003)
4	CCC 0-2500 cm^{-1}, CKD, 9 bands, 56 g-points	Yes	CanAM4 (dev.)	Li (2002); Li and Barker (2002); Li and Barker (2005);
5	FLBLM, 40-3000 cm^{-1}, line-by-line,	No	-	Fomin (2006)
6	FKDM, 40-3000 cm^{-1}, CKD, 23 g-points	No	-	Fomin (2004)
7	CAM 3.1, 0-2000 cm^{-1}, absorptiviy-emissivity approach	Yes	CAM 3.1	Collins et al. (2004)
8	FLCKKR (LW), 0-2200 cm^{-1}, CKD, 12 bands, 67 g-points	No	- (production of CERES products)	Fu and Liou (1992); Fu et al. (1997)
9	RRTMG-LW (as implemented in FMI ECHAM5.4), 10-3000 cm^{-1}, 16 bands, 140 g-points	Yes	ECHAM 5.4	Mlawer et al. (1997); Iacono et al. (2008)
10	ES, 10-3000 cm^{-1}, 9 bands/33 g-points, ESF of band transmissions	Yes	HadGEM	Edwards and Slingo (1996); Edwards (1996)
11	GISS, 50-2000 cm^{-1}, CKD, 33 g-points	Yes	NASA GISS (also ISCCP flux products)	Zhang et al. (2004)

Shortwave code participants

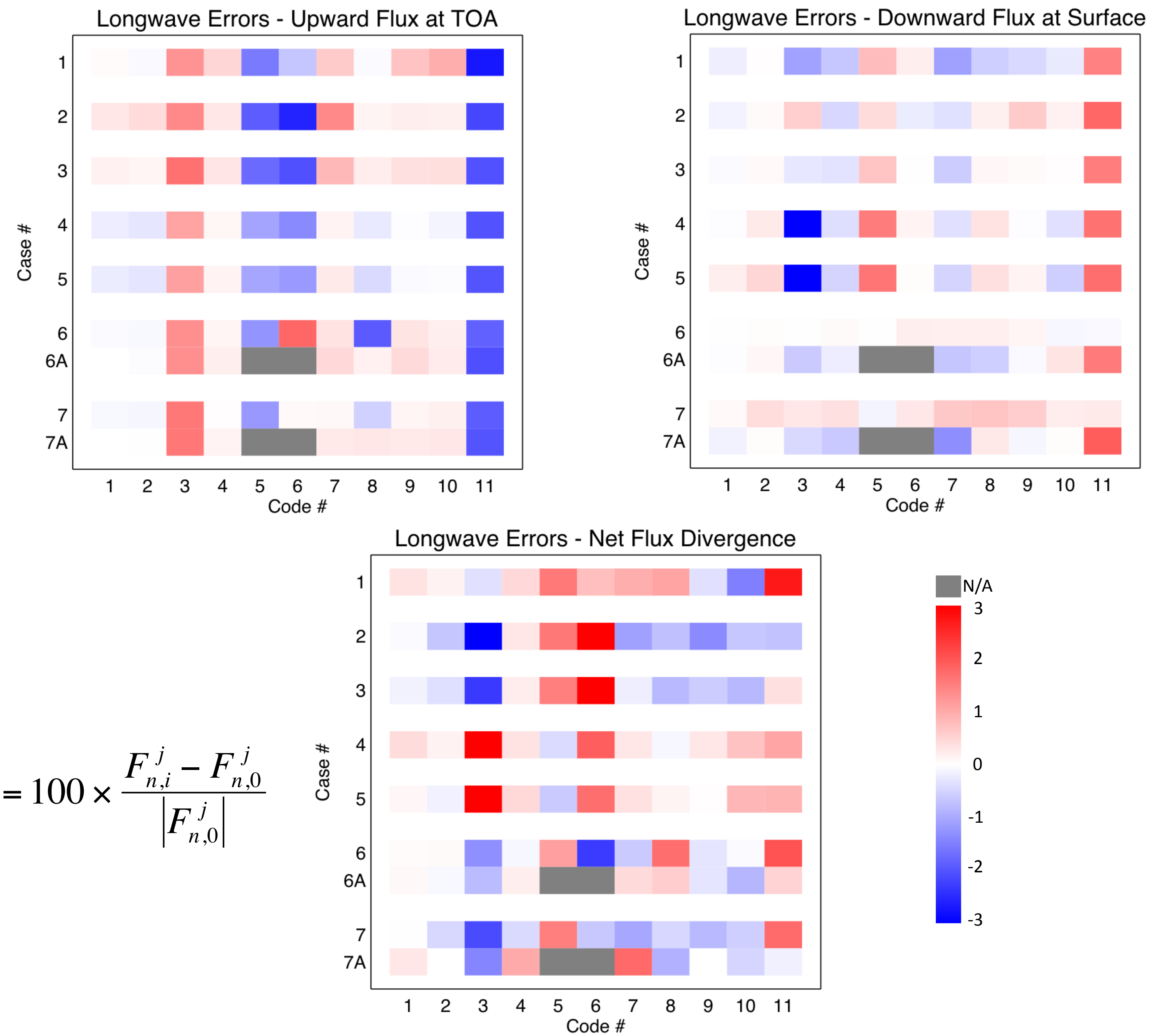
Model Index	Brief Model Description	In LSM?	Experiment variants	Submitted By	Reference(s)
0	CHARTS v.4.04/LBLRTM v.11.1/ HITRAN2004, line-by-line	No	None	Delamere, Mlawer	Moncet and Clough (1997); Clough et al. (2005)
1	RRTM-SW, 0.2-12.2 µm, CKD, 14 bands, 224 g-points	No	None	Iacono, Mlawer	Clough et al. (2005)
2	RRTMG-SW, 0.2-12.2 µm , CKD, 14 bands, 112 g-points	Yes	None	Iacono, Mlawer	Iacono et al. (2008)
3	CLIRAD-SW, 0.175-10 µm, 11 bands, pseudo-monochromatic/k-distribution hybrid, 38 k-points	Yes	Two R_{sfc} averaging methods	Oreopoulos	Chou et al. (1998); Chou and Suarez (2002)
4	CCC, 0.2-9.1 µm, CKD, 4 bands, 40 g-points	Yes	Three R_{sfc} averaging methods	Cole, Li	Li and Barker (2005); Li et al. (2005)
5	FLBLM/ HITRAN 11v, 0.2-10 µm, line-by-line	No	None	Fomin	Fomin and Mazin (1998)
6	FKDM, 0.2-10 µm, CKD, 15 g-points	No	Two treatments of cloud optical properties	Fomin	Fomin and Correa (2005)
7	CAM 3.1, 0.2-5.0 µm, 19 spectral and pseudo-spectral intervals,	Yes	Two R_{sfc} averaging methods	Oreopoulos	Briegleb (1992); Collins (2001); Collins et al. (2004)
8	FLCKKR (SW), 0.175-4.0 µm, CKD, 18 bands, 69 g-points	No	Two R_{sfc} averaging methods	Rose	Fu and Liou (1992)
9	FMI/ECHAM5.4, 0.185-4 µm, 6 bands, Padé approximants to fit transmission functions	Yes	Two R_{sfc} averaging methods	Räisänen	Fouquart and Bonnel (1980); Cagnazzo et al. (2007)
10	Edwards-Slingo 0.2-10 µm, 6 bands, ESF of band transmissions	Yes	Two R_{sfc} averaging methods	Manners	Edwards and Slingo (1996)
11	NASA-GISS v. D, 0.2-5.0 µm, CKD, 15 g-points	Yes	Three R_{sfc} averaging methods	Zhang, Rossow	Zhang et al. (2004)
12	COART, 0.25-4.0 µm, 26 bands, k-distribution	No	None	Jin	Jin et al. (2006)
13	CLIRAD-SW modified, 0.2 -10 µm, 8 bands, k-distribution 15 k-points	No	Two R_{sfc} averaging methods	Oreopoulos	Tarasova and Fomin (2007)

Accomplishments

- Published BAMS paper, March 2010 (intro to CIRC)
- Submitted JGR-Atmos paper, September 2011 (technical, analysis of Phase I results)
- Numerous presentations in meetings (ARM/ASR, AMS, GEWEX, etc) in addition to annual reports to IRC and GRP.
- Advocated for importance of RT evaluation within the community
- Was the impetus for the creation of a new ARM dataset (RIPBE)
- Has about a dozen “registered” members who did not formally submit in addition to participants

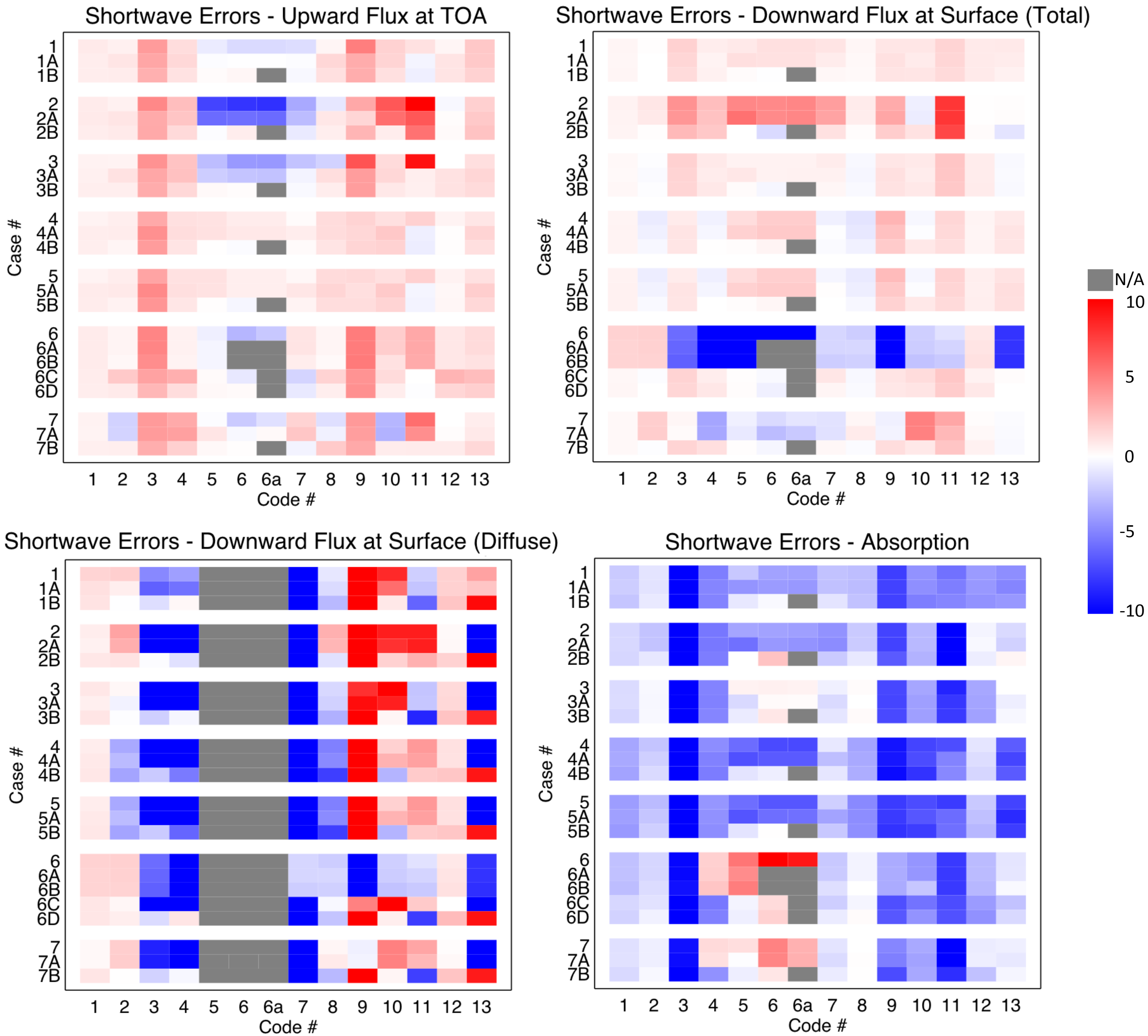
Some Phase I results

Longwave % errors (model-LBL)



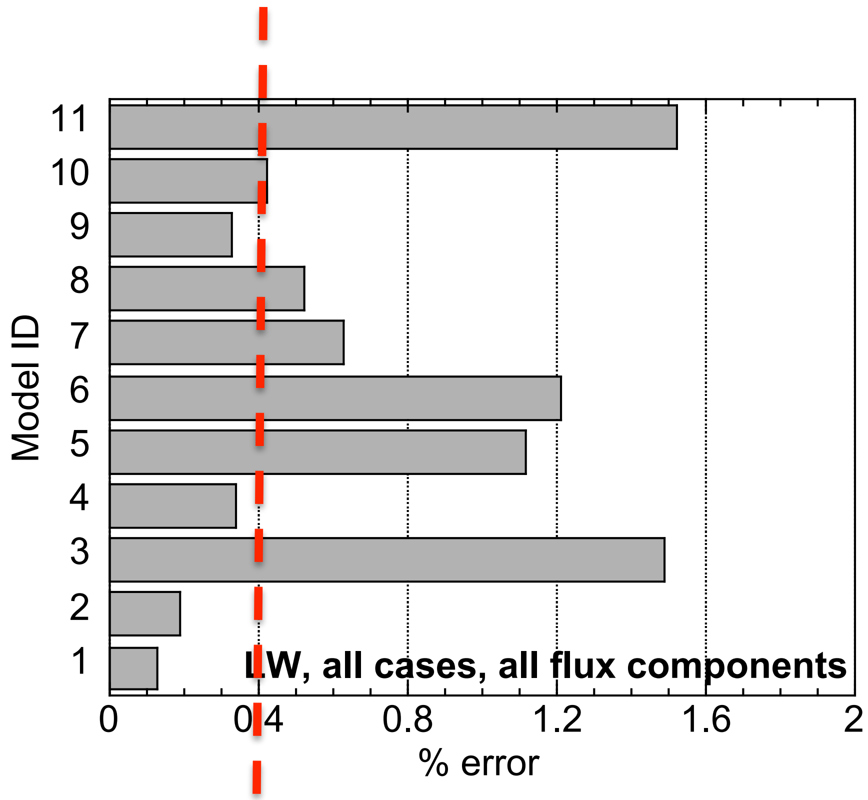
$$e_{n,i,j}(\%) = 100 \times \frac{F_{n,i}^{j} - F_{n,0}^{j}}{\left|F_{n,0}^{j}\right|}$$

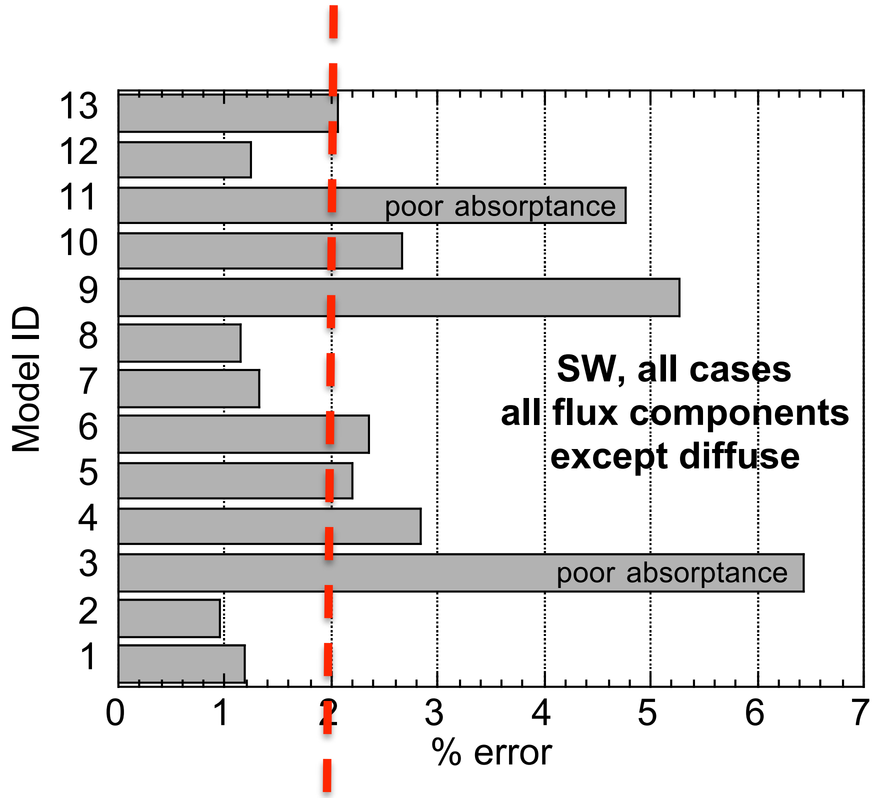
Shortwave % errors (model-LBL)



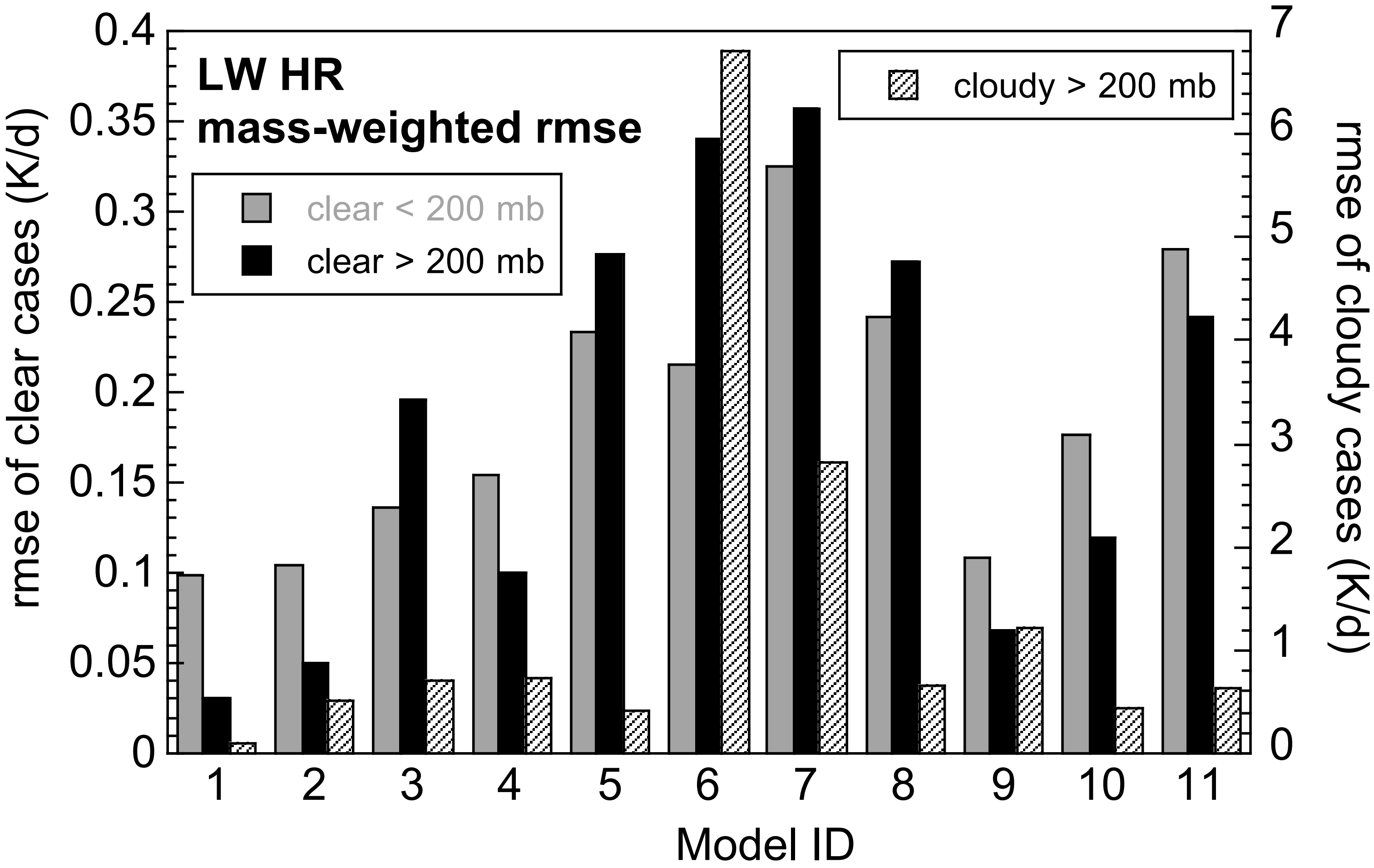
Overall performance

$$e_{tot,i}(\%) = \frac{100}{N_c N_f} \sum_{n=1}^{N_c} \sum_{j=1}^{N_f} \frac{\left| F_{n,i}^{j} - F_{n,0}^{j} \right|}{F_{n,0}^{j}}$$





Heating rate performance



Main Findings from Phase I

- LW is in OK shape, SW not so good
- SW performance is particularly poor wrt to absorbed and diffuse flux
- Band-averaging SFC albedo in the SW also creates discrepancies
- SW CO2 forcing is problematic (confirming *Collins et al. (2006)* results)
- The are discrepancies about the magnitude of LW scattering among the models that have such capability (not shown in this presentation)
- Mass-weighted rmse LW heating (cooling errors) for clear skies exceed 0.25 K/day for some models
- Accuracy vs. computational speed has not been evaluated

Potential cases for Phase II

- Also selected based on radiative closure with observations
- Can be drawn from ARM/BBHRP and/or other similar data sets
- Single-layer ice clouds
- Single layer liquid cloud (OD between Phase I Cases 6 and 7)
- Extreme dry and humid conditions
- Forcing calculations (like Phase I, Case 5)
- Spectral variations of aerosol properties
- Synthetic, but <u>not</u> pure single-gas, atmospheres

Challenges/Funding status

- CIRC has received support from DOE-BER (ARM) through PI funding to the two co-chairs
- This funding has now expired
- Future funding by DOE-BER is unlikely
- The aspects of the CIRC project requiring the most manpower:
  - choosing cases that have radiative closure at all boundaries wrt LBL calcs
  - running and validating the LBL calculations (expertise at AER)
- Co-chairs currently volunteer time
- IRC and GRP are aware of this and try to advocate for funding
  - WGCM ideas?

Recommendations to GCM community

- From IRC letter to WGCM "IRC Request for CMIP5 GCM modeling groups"

  IRC's long-standing position is that accurate radiative forcing estimates due to various atmospheric constituents are an essential aspect of realistic present and future climate simulations and should be one of the main criteria for evaluating a GCM's standing among its peers … We therefore strongly recommend that an assessment and documentation of the performance of the RT codes within CMIP5-participating GCMs against standard reference calculations and metrics are similarly undertaken.

  WGCM should support and urge their membership to participate in CIRC.

- GCM groups should maintain off-line column versions of their radiation codes that are in sync with in-line version(s)
- Maintain column versions with more flexibility in receiving arbitrary atmospheric/surface input
- Create and maintain archive of diagnostic flux calculations (i.e., without feedback) for various forcing scenarios
- Assess impact of common approximations (e.g., neglect of scattering in thermal IR, neglect of radiation interactions with precipitating particles)
- Carefully assess the trade-offs between speed and loss of accuracy (CIRC can help)