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The Continual Intercomparison of Radiation Codes (CIRC): A New Standard for Evaluating GCM Radiation Codes

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Abstract. The Continual Intercomparison of Radiation Codes (CIRC) is intended as an evolving and regularly updated permanent reference source for GCM-type radiative transfer (RT) code evaluation that will help in the improvement of radiation parameterizations. CIRC seeks to establish itself as the standard against which code performance is documented in scientific publications and coordinated joint modeling activities such as GCM intercomparisons. A feature that distinguishes CIRC from previous intercomparisons is that its pool of cases is largely based on observations. Atmospheric and surface input, as well as radiative fluxes used for consistency checks with the reference line-by-line calculations come primarily from the Atmospheric Radiation Measurement (ARM) Climate Research Facility measurements and satellite observations compiled in the Broadband Heating Rate Profile (BBHRP) product. Additional datasets beyond BBHRP such as measurements from ARM field campaigns and spectral radiances from the AERI instrument are also used to complete the set of desired cases and to ensure the quality of the input. For Phase I, launched in June, CIRC aims to assess the baseline errors of GCM RT codes and therefore provides test cases that evaluate performance under the least challenging conditions, i.e, well-understood clear-sky and homogeneous, single-layer overcast liquid cloud cases.

Keywords: radiative transfer, line-by-line, absorption, scattering, intercomparison, GCM.
PACS: 92.60.Vb

INTRODUCTION

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 differs 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 RT code evaluation, and similar to ICRCCM, its goal is to contribute to the improvement of solar and thermal radiation parameterizations. CIRC is supported by the Atmospheric Radiation Measurement (ARM) program and endorsed by the GEWEX Radiation Panel (GRP) and the International Radiation Commission (IRC). The first order objective of CIRC is to document the performance of the participating models relative to line-by-line (LBL) standards. Ultimately, however, model performance will be critically evaluated in terms of the accuracy needed to address operational GCM requirements for current and future climate simulations and comparisons with observations. CIRC is an open intercomparison that will be run in phases. All input and reference output (from state-of-the-art LBL RT codes by AER) is available at the CIRC website (http://circ.gsfc.nasa.gov). However, only registered participants will receive e-mail notifications about changes, updates, and corrections to the CIRC dataset and will be given priority to participate in workshops and publications. In return, they are expected to submit results from their RT code runs within predetermined deadlines. Currently, Phase I is underway and Phase II is at the planning stage. While it is understood that the CIRC reference calculations reflect current spectroscopic knowledge and may themselves be imperfect, our intent is to have them updated as algorithmic and database improvements become available, and expand them periodically with new cases as part of future phases of the effort.

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CIRC PHASE I DATASET AND RADIATIVE TRANSFER CALCULATIONS

The CIRC Phase I cases, with one exception, are based on cases from an extensive ARM radiative closure dataset, BBHRP, satisfying preset criteria that make them appropriate for the purposes of the intercomparison. The main criterion was good radiative closure at the surface and TOA (for both the solar and thermal part of the spectrum). For the cloudy cases additional criteria were: (a) overcast conditions; (b) the presence of only one water phase (liquid); and (c) cloud homogeneity (as indicated by small variability in the observed surface irradiances). For the clear sky cases additional criteria were: (a) a wide range of precipitable water loadings; (b) a significant range of aerosol loadings; and (c) a significant range of solar geometries. Based on these criteria we selected seven cases, five cloud-free, and two with overcast liquid clouds. The cloudless cases come from BBHRP Southern Great Plains (SGP) cases (three), and from one BBHRP Northern Slope of Alaska (NSA) case which spawns two experiments, one with nominal and one with doubled carbon dioxide. The cloudy cases come from a BBHRP SGP case and from a Pt. Reyes (California) ARM Mobile Facility (AMF) deployment case. A synopsis of the cases is provided in Table 1, while a detailed description and links to the respective input and output can be found at the CIRC website.

TABLE (1). Synopsis of Phase I cases. The four rightmost columns of the table shows observed and LBL-calculated (in bold) flux values (in Wm^{-2}) at the surface (SFC) and the top-of-the atmosphere (TOA) for both the longwave (LW) and shortwave (SW) part of the spectrum. Observed TOA fluxes are from GOES using narrowband to broadband conversion algorithms or from CERES (cases 4, 7), while observed SFC fluxes come from ARM instruments. PWV=Precipitable Water Vapor. The aerosol optical depth refers to 0.55 µm. Case 5 is as Case 4, but with doubled CO_2.

Date(Site)	Case	SZA	PWV (cm)	τ_{aer}	LWP (gm^{-2})	LW_{SFC}	LW_{TOA}	SW_{SFC}	SW_{TOA}
9/25/00 (SGP)	1	47.9°	1.23	0.04		289.7	301.7	705.9	169.8
						288.5	**303.2**	**701.2**	**175.0**
7/19/00 (SGP)	2	64.6°	4.85	0.18		441.8	288.6	345.4	127.8
						439.3	**292.6**	**348.0**	**117.1**
5/4/00 (SGP)	3	40.6°	2.31	0.09		336.4	277.6	772.5	159.6
						333.0	**280.8**	**773.1**	**173.6**
5/3/04 (NSA)	4	55.1°	0.32	0.13		194.7	229.1	638.9	425.8
						192.4	**230.5**	**642.8**	**422.9**
5/3/04 (NSA, CO2)	5	55.1°	0.32	0.13					
						195.7	**229.2**	**641.3**	**422.7**
3/17/00 (SGP	6	45.5°	1.90	0.24	263.4	339.0	234.8	97.6	623.2
						335.2	**241.8**	**92.1**	**628.8**
7/6/05 (PYE)	7	41.2°	2.42		39.1	373.2	284.0	479.8	356.0
						372.6	**280.2**	**473.7**	**356.4**

We provide all the input typically needed by a GCM-type radiative transfer algorithm to calculate profiles of radiative fluxes and heating rates, namely profiles of atmospheric pressure, temperature, gas concentrations, aerosol single scattering properties, cloud fraction/water path/effective particle size, and spectral surface albedo both unweighted and weighted by the incident solar flux at the surface. A comprehensive list of these quantities and details about how they were specified or derived can be found in the CIRC website. The reference output consists of surface and TOA fluxes resolved at 1 cm^{-1} resolution and broadband LW flux and heating rate profiles. The LW reference results were obtained with the line-by-line radiation code LBLRTM [1], while the SW results were obtained with the adding-doubling code CHARTS (Code for High-Resolution Accelerated Radiative Transfer with Scattering; [2]) which uses LBLRTM gaseous absorption optical depths. CHARTS output is currently limited to radiative fluxes at the boundaries of the atmospheric column (TOA and surface), but fluxes at additional atmospheric levels may be provided in the future. The output requested from CIRC participants consists of broadband SW and LW flux and heating rate profiles. In order to run the CIRC cases we provide input formation that is typically not available in an operational GCM environment, for example, spectral surface albedo. On the other hand, we may not be providing input information that some models require, e.g., separate albedos for the ground and an overlying vegetation canopy. While we would like submissions that primarily come from runs where the model uses as much of the information provided as possible, even if it requires small modifications to the RT algorithms from operational settings, we would also like to receive submissions from runs where the algorithms operate with assumptions and input that closely resemble routine operational conditions.

INITIAL PHASE I RESULTS

Figure 1 shows percentage difference from LBL reference calculations (LBLRTM and CHARTS), of observations ("obs") and calculations with various radiative transfer codes: AER's Rapid Radiative Transfer Model (RRTM; [3]), GSFC (RT code of various NASA-Goddard Large Scale Models; [4]), CAM (RT code of the Community Atmospheric Model GCM, v. 3.1) were run for testing purposes by the authors and are not official CIRC submissions; FLCKKR (Fu, Liou, Charlock, Kato, Kratz, Rose; [5]) and COART (Coupled Ocean-Atmosphere Radiative Transfer by Jin and Charlock; [6]) are the first CIRC submissions. Both FLCKKR and COART have fixed CO_2 in the SW and therefore produce identical fluxes for Cases 4 and 5. Also note that the RRTM SW code uses the unweighted rather than the weighted surface albedos. Differences remain within 10% throughout, but certain models perform worse than their counterparts for specific cases, e.g., GSFC in SW TOA for the non-NSA cases and in the LW SFC for the (driest) NSA cases. The latter also causes problems for COART which uses somewhat outdated LOWTRAN-7 transmittances for its IR parameterization (Jin 2008, personal communication).

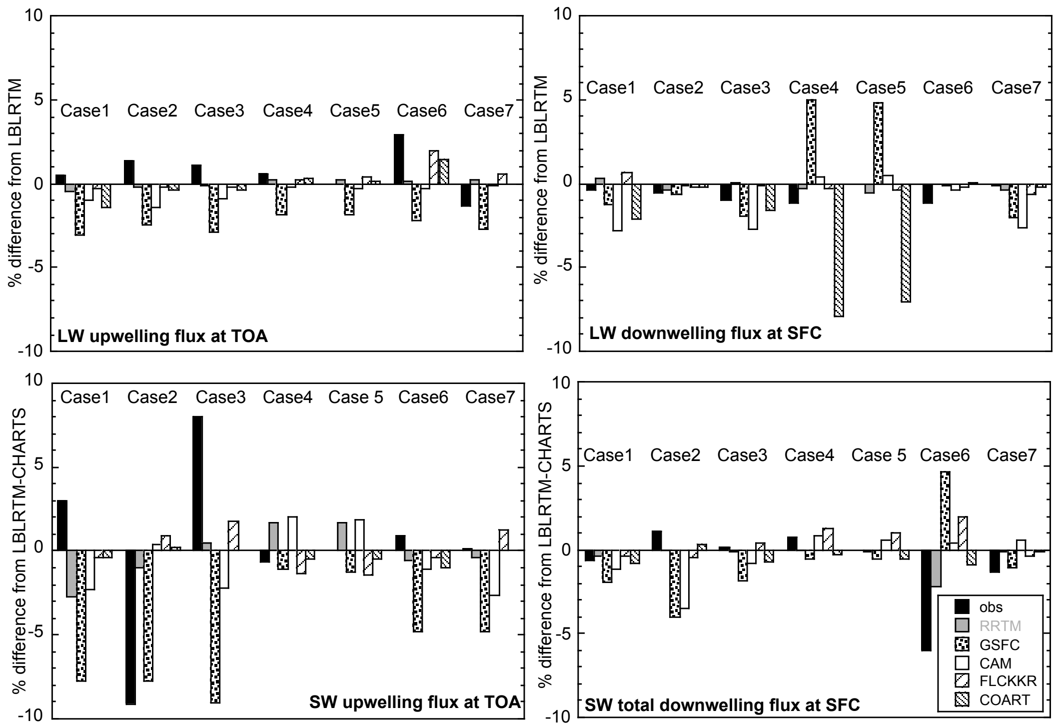

FIGURE 1. Comparison between reference LBL calculations, observations and output of various RT codes expressed as percentage difference from the reference results. Further details are provided in the text.

Figure 2 shows the TOA and SFC "forcing" produced by the different models when CO_2 is doubled for the driest of our cases (i.e., Case 4-Case 5 differences). As mentioned before, this experiment is ill-defined in the SW for the FLCKKR and COART models which have hard-wired CO_2 concentrations. Although the SFC SW forcing (reduction in downwelling flux upon doubling CO_2) produced by LBL calculations is significant (CAM fails to exhibit this), the TOA forcing is very small, a feature that is not be reproduced by the GSFC and CAM models which generate ~0.5 Wm^{-2} more upwelling SW flux for Case 5. Note, however, that the near-zero RRTM TOA SW forcing is replicated by GSFC and CAM when unweighted surface albedos are used. LW forcings have the expected signs, but there is significant spread in the magnitudes with COART and FLCKKR (only for TOA) being more at odds with LBL compared to the other models. Further analysis of these results will be performed in the near future.

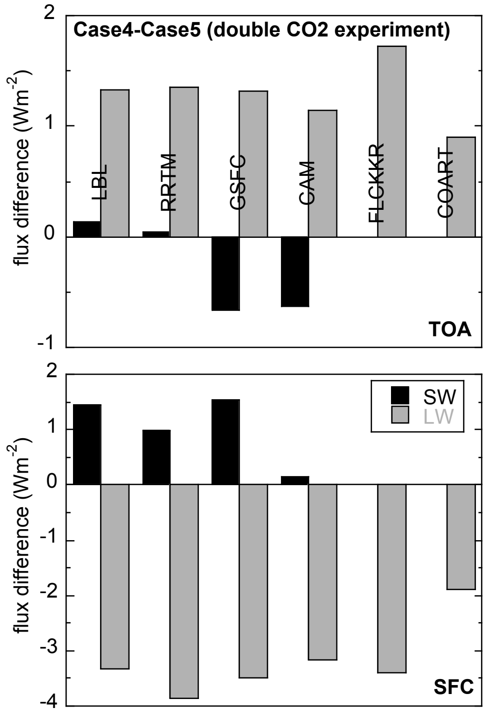

FIGURE 2. Comparison of flux differences between Cases 4 and 5 (which differ only in that the latter has double CO_2 of 750 ppmv) for the LBL reference calculations and the other RT codes discussed in the previous page. The flux is downwelling at the surface (total=diffuse+direct, in the case of SW) and upwelling at TOA.

FUTURE DIRECTIONS

As Phase I submissions come in and we start to better understand how the algorithms have processed the CIRC input to perform the requested runs, we plan to define performance targets for modelers to assess their model's performance. Since the participating algorithms may be adjusted to accomodate CIRC input and output requirements, performance evaluations may not reflect actual performance in a typical operational environment. It will therefore be valuable to receive multiple submissions where different interpretations or processing of the provided input are used. Future phases will add greater variety and complexity in the atmospheric description, or (depending on the lessons learned from Phase I and feedback from participants) may even include revisiting simpler, perhaps synthetic, idealized experiments. If you are interested in learning more or participate in CIRC please visit the CIRC website <http://circ.gsfc.nasa.gov> or contact Lazaros Oreopoulos <Lazaros.Oraiopoulos@nasa.gov>.

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