ICRCCM - Phase 3

Longwave Radiation Model Intercomparisons

and

Comparisons of Model Calculations With Observations

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Introduction

The first phase of the Intercomparison of Radiation Codes used in Climate Models (ICRCCM 1) was completed in 1991 following the publication of several papers summarizing the results of calculations from many GCM radiation codes in a special issue of the Journal of Geophysical Research. That study found that for clear-sky conditions, there was a clustering of many models in the ±2% range relative to line-by-line models. This was in the marginal range to meet the relative accuracy requirements of many major climate programs ongoing at that time. However, not all of the models were within that range. For overcast conditions, the longwave (LW) calculations agreed closely with each other near cloud boundaries, but at distances away from the boundaries, the differences resembled those for clear-skies. For optically thin clouds, there was a flux spread of 35 to 80 W m$^{-2}$ at the atmospheric boundaries that appeared to be attributable to the manner by which clouds were treated in the models. For the shortwave (SW), large flux differences occurred for the various cloud calculations, and these were attributed to the manner by which multiple scattering was taken into account in the low-resolution models.

In the years since the completion of ICRCCM 1 there have been significant advances in detailed methods for calculating radiative transfer under realistic cloud conditions for both long- and shortwave radiation. However, climate model codes have not, in general, undergone scrutiny as regards calculations under realistic cloudiness conditions. Moreover, there have been few checks to determine whether or not the new clear-and-cloudy advances have actually found their way into climate model calculations. Furthermore, observations with higher accuracy (both spectral and broadband) are now available with which to test radiation codes. Such observations were not possible under ICRCCM 1 or used extensively in the ICRCCM 2.

Motivation and Objectives

With this background in mind, in 1997 the co-chairs of ICRCCM – Howard Barker and Robert Ellingson – proposed a third phase of ICRCCM (ICRCCM 3) that was directed at testing radiation models for realistic cloudiness conditions. Initially, ICRCCM 3 was directed at shortwave radiation models, although it was understood that a longwave study would follow using the same general format as the shortwave.

The study is motivated by the fact that GCMs and NWP models have almost no choice but to use 1D short- and long- wave codes that assume that clouds are plane parallel horizontal (PPH) and follow simple, fixed overlap rules at unresolved scales. This can lead to systematic
errors for domain averaged fluxes. Major questions concerning GCM cloud-radiative feedback are, how much is clouds, and how much is radiative transfer?

The major objectives of LW ICRCCM 3 follow those of the SDW study, namely:

- Assess 1D and 3D longwave flux estimates for clear- sky and PPH overcast clouds (10+ years after ICRCCM 1)
- Assess how well 1D longwave codes interpret and handle unresolved clouds:
  - operate on identical columns:
  - variance among themselves
  - deviations from 3D benchmarks
  - strengths and weaknesses of assumptions about unresolved clouds
- Establish an evolving public website with input data, benchmark results and validation data.

**Procedural Information**

The overall purpose of the short- and long-wave components of ICRCCM is to assess how well 1D-radiation codes used in NWP models and GCMs interpret and handle unresolved clouds. This will be achieved by first doing Monte Carlo simulations on 3-D atmospheres simulated by cloud-resolving models (CRMs) and then passing corresponding profiles of cloud properties to 1D radiative transfer codes. Detailed information on how this was done for SW is available at [http://reef.atmos.colostate.edu/icrccm/](http://reef.atmos.colostate.edu/icrccm/)

Briefly, the project will proceed as follows. First, profiles of cloud and atmospheric properties will be supplied to the participants. The participants will return Up- and down-welling fluxes at all levels and heating rate profiles. The model atmospheres will include clear-sky references, homogeneous overcast clouds, and CRM fields. The comparisons will be made with each other and with Monte Carlo benchmark calculations.

It is important to establish benchmark fluxes for the calculations. The LW activity will follow the SW approach of using the line-by-line model LBLRTM code for the 1-D clear and overcast cases since it is known to compare well with observations. The 3-D Monte Carlo models will be compared with LBLRTM to be satisfied that they are reliable for the simplest cases, although we are quite confident they perform the scattering and absorption numerics appropriately. However, we are still exploring whether or not these models can perform the full set of 3D longwave benchmarks for all of the CRM fields. Once established, the 3D Monte Carlo codes will be used set conditional benchmarks to assess 1D codes that assume horizontal variable clouds, detailed overlap patterns, maximum/random overlap and random overlap.

Three separate model comparisons are proposed. Part A, the clear-sky cases will be similar to ICRCCM 1, but fewer in number. Calculations will be performed for but three AFGL atmospheres, Sub-arctic winter, Mid-latitude winter and Tropical. The idea is to document the range of agreement found for a wide range of temperature and moisture profiles.

Part B, the plane parallel overcast cases, will assume identical inputs as for the shortwave, namely liquid water clouds, the Tropical sounding, \( r_c = 10 \, \mu m \), a low cloud layer (location - 3.5 - 4 km; 0.159 g/ kg liquid water ->visible optical depth ~10) and a high cloud layer (location - 10.5 - 11 km; 0.034 g/ kg liquid water ->visible optical depth ~1).
Part C will extend the study beyond ICRCCM to study 3-D cloud fields. Following the SW study, the study tests how 1D codes interpret and handle unresolved cloud. The 3D fields from CRMs used in shortwave study included one from ATEX \((6.8 \, \text{km})^2\) with \(\mathcal{D}x = 0.1 \, \text{km}\), one with OPEN CELLS \((50 \, \text{km})^2\) with \(\mathcal{D}x = 0.4 \, \text{km}\), and one from GATE \((400 \, \text{km})^2\) with \(\mathcal{D}x = 2.0 \, \text{km}\). The 1D codes were provided with domain-averaged profiles of pressure and temperature, mean water vapor inside and outside clouds, cloud fraction; upward and downward accumulated cloud fractions, and mean, standard deviations, and mean log of cloud water mixing ratio. The 3-D codes were provided with entire domain of cloud mixing ratio, and the entire domain of water vapor or mean inside and outside of clouds.

The benchmark calculations that were performed for the shortwave study included:

1. Full 3D (set by four MCs)
2. ICA (Independent column approximation)
3. Perfectly overlapping PPH clouds
4. Maximum - random overlapping PPH clouds
5. Maximum overlapping PPH clouds
6. Random overlapping PPH clouds

We plan similar benchmarks for the longwave. The calculations from the various climate model codes will be studied to determine the differences between the 1-D and full 3-D codes. If a 1-D code aims at a particular approximation (e.g., maximum overlap of PPH clouds), it will be compared to appropriate benchmark.

LW ICRCCM will have a component - Part D - directed at comparing model calculations with ARM observations. ARM is establishing a database of clear, overcast and all-sky radiation observations, atmospheric column radiation properties and model calculations under the banner of BroadBand Heating Rate Profiles (BBHRP). The database is currently being prepared for intensive observation periods dating to 1997, but it will eventually be done for all operational soundings at the southern Great Plains site. In this part of ICRCCM, we will extend the BBHRP to the ICRCCM community with the goal of demonstrating the accuracy of radiation codes - detailed and GCM - relative to flux observations in an operational setting. This, along with the other parts noted above will be carried out through a Web interface to be developed by Ellingson during 2002/3.