PROJECT PROGRESS REPORT
For Period: 08/01/2011 - 01/31/2012

Award Number:	NA11NES4400002
Award Period:	08/01/2011 - 07/31/2014
Project Title:	Development of new 3-hourly, global, long-term, multisatellite-based TOA-to-surface radiative flux profile data product with high horizontal resolution and homogeneous quality
Recipient Name:	The Trustees of Columbia University in the City of New York
Project PI:	Yuanchong Zhang
Report Type:	Semiannual Project Progress Report
Reported by:	Yuanchong Zhang

Planned Tasks for the first half of Year 1 in the proposal:

- 1. Creation of new production codes
- 2. New product processing
- 3. Reengineering all the codes
- 4. Evaluation of new codes and products

1. Creation of new production codes

(1) Extracting radiation code from NASA GISS ModelE and making it runnable

With the help of the NASA GISS GCM group, the radiation code (RadE package) has been extracted from the original NASA GISS GCM ModelE of the current version, compliant with both the IPCC AR4 and AR5. We have made it runnable on both IBM RISC system/6000 work stations and Mac machines. After substantial, various tests, RadE and RadD (the previous radiation code for ISCCP-FD production since 2001) can be run in a closely intercomparable fashion. However, there are still a lot of sensitivity tests that are needed before we can freeze it to the RadE-0 version, the starting version that is somewhat 'standard' for further improvements, including reengineering.

(2) Working for RadE-0.

In the meanwhile, to work more efficiently, we have worked on those modules of the current (unfrozen) RadE-0 that are to be added to or replace RadE modules for improving RadE code to produce a first frozen version RadE-0. The progress to date on it has been focused on validating the GISS ModelE longwave (LW) radiation model results for radiative fluxes and

radiative cooling rates against HITRAN line by-line (LBL) benchmark calculations. The benchmark validation comparisons are being performed for representative Standard Atmosphere profiles exemplified by the Mid-Latitude Summer, Tropical, and Sub-Arctic Winter Standard Atmospheres depicted below. The project goal is to achieve radiative flux accuracies that are better than 1% compared to the LBL benchmarks, not only for LW fluxes at top of the atmosphere (TOA) and bottom of the atmosphere (BOA), but also for atmospheric fluxes as well as for atmospheric cooling rates.

As shown in the figures 1a to 1c for Mid_Latitude Summer, Tropical and Sub-Arctic Winter, respectively, both the upward and downward GCM fluxes (black lines) agree with LBL fluxes (red lines) to within about 1 W/m^2. This is significantly better than the design goal of 1% accuracy for the TOA and BOA LW upwelling and downwelling radiative fluxes.

The radiative cooling rates are of similar high accuracy throughout the troposphere. It is only high in the stratosphere (above 1hPa) that a small bias in the radiative cooling is still evident. Work is still ongoing to see if this remaining bias can be eliminated.

The standard atmosphere profile gases include H_2O, CO_2, CH_4, N_2O, O_3, and the CFCs, F11 and F12. The GISS ModelE radiation code uses the correlated *k*-distribution method (Lacis and Oinas, 1991) whereby 33 correlated *k*-intervals are used to represent the full LW spectrum, including the pressure-temperature dependence of the absorbing gases in an inhomogeneous atmosphere for a full range of absorber amounts encountered in the atmosphere. Work has started on the solar component of the radiation model.

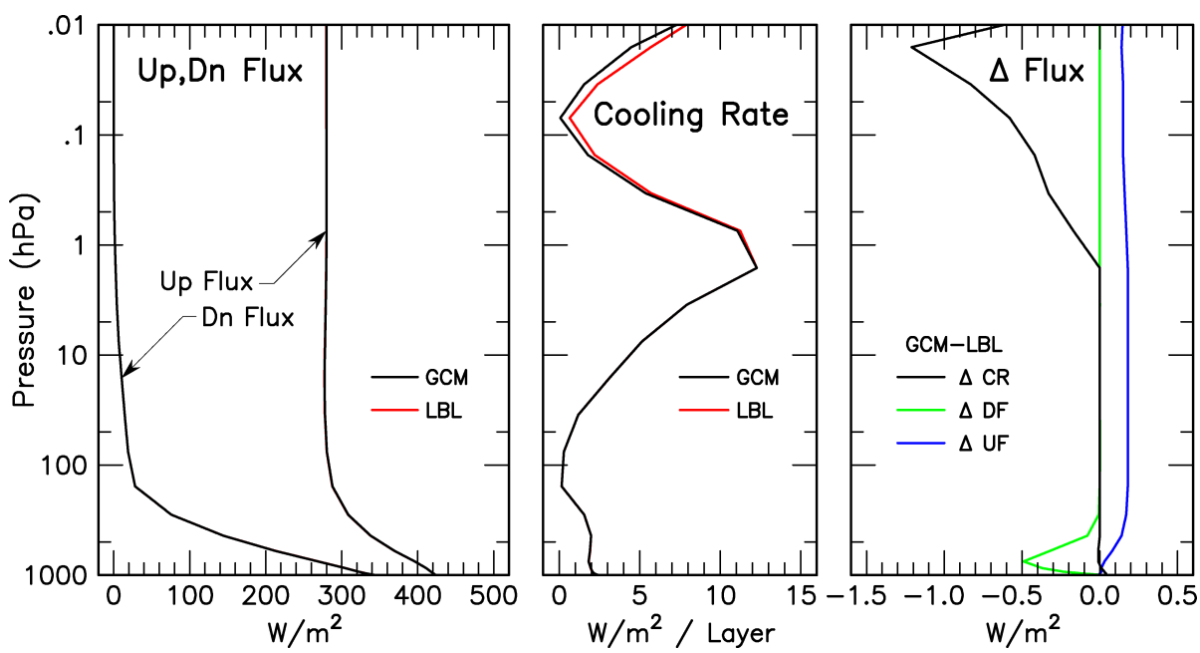

Fig. 1a. Comparison to HITRAN LBL values for the improved NASA GISS ModelE on LW fluxes and cooling rates over the whole atmospheric column for Mid-Latitude Summer.

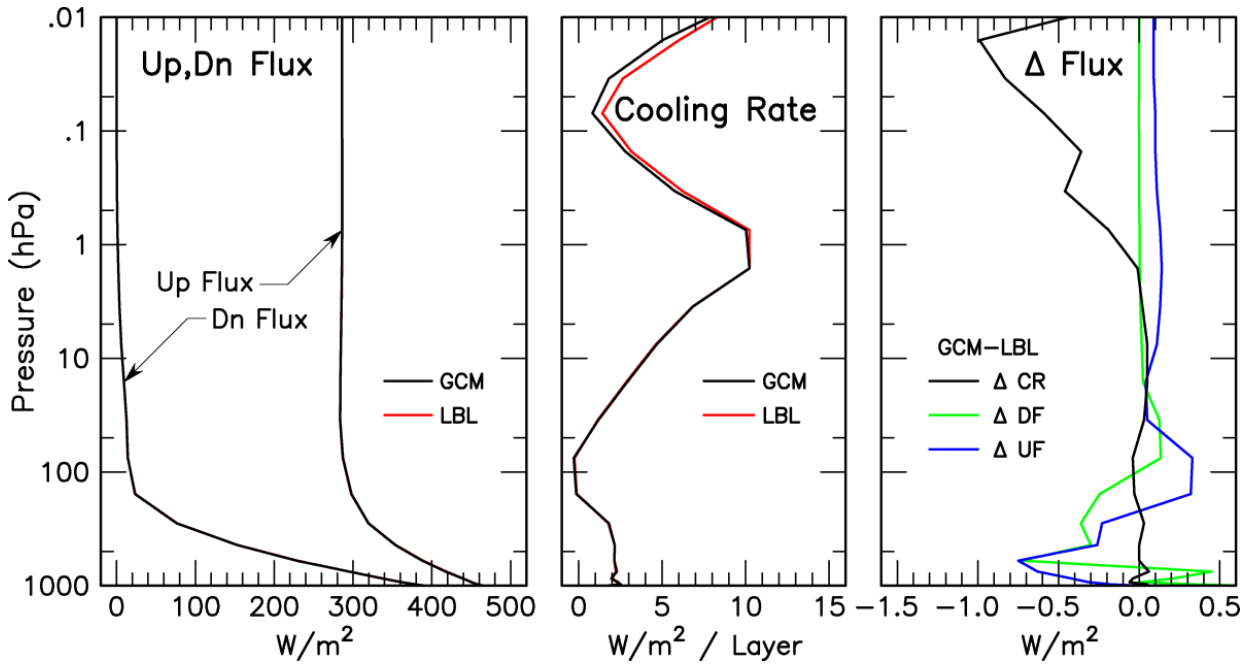

Fig. 1b. same as 1a but for Tropical (b).

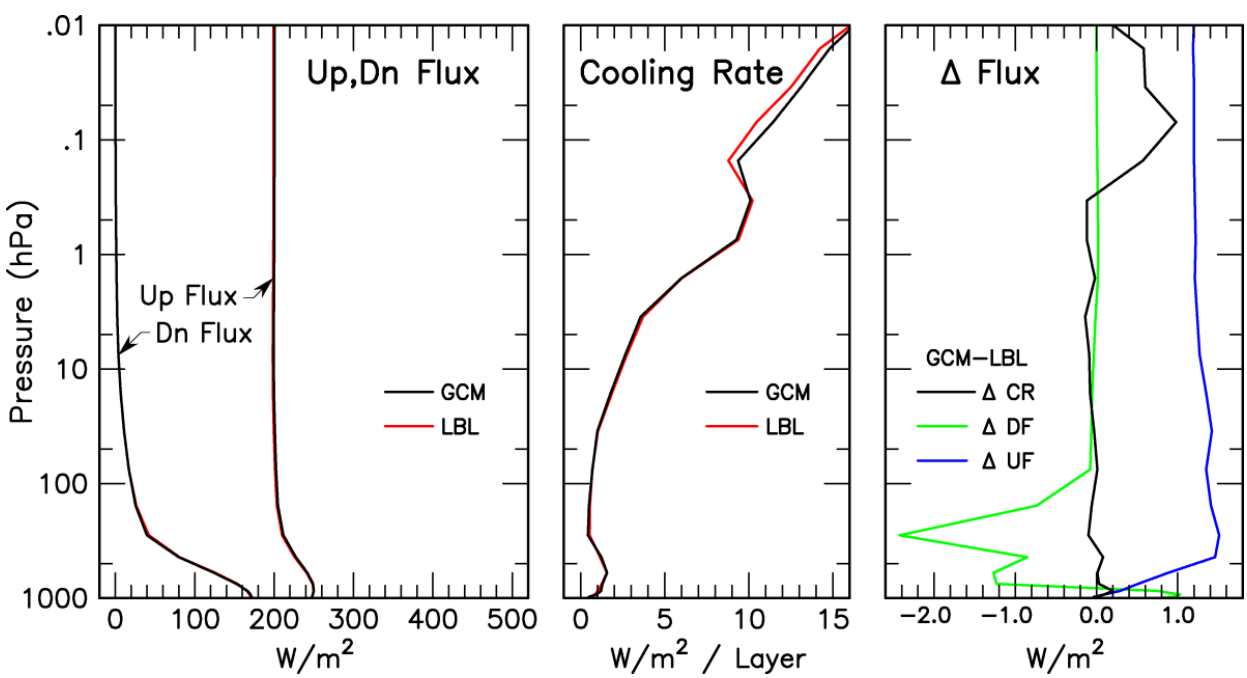

Fig. 1c. Same as 1b but for Sub-Arctic winter.

2. New product processing

(1) Make all input datasets available

Aerosol dataset is one of the major concerns for the new ISCCP-FD-like product and has large radiative effects in some regions, especially under clear-sky scene. After years of searching and tests for different datasets, it occurs to us that AeroCom (Kinne, 2008) seems the best aerosol dataset we can have at present though GISS is also working on new, improved dataset. Since the new RadE is now in test mode and being worked for various improvements, we still use old ISCCP-FD code (from RadD) to do tests. We have first tested column AOD (aerosol optical depth) only from AeroCom but there seem no substantial improvements; nevertheless, when we apply all the three column aerosol properties, namely, AOD, SSA (single scattering albedo) and ASY (asymmetric factor) from AeroCom, we have found that there are substantial improvements based on comparisons with surface observations while it maintains the similar uncertainties compared with CERES TOA fluxes. Table 1 shows the geographic and other basic information for 10 surface stations from BSRN, ARM and SURFRAD networks whose total column AOD at 0.55 micron is available.

Table 1. The Ten Stations with AOD available from BSRN, ARM and SURFRAD, in the order of latitude from north to south.

Station Acronym	Station Name [Owner]	Quality Rate-Network	Station Lat/Lon	FD Cell Lat/Lon	AOD
FPE	Fort Peck, MT [USA]	A-SURFRAD	48.5N/254.8E	48.8N/255.8E	AV
PSU	Rock Springs, PA [USA]	A-SURFRAD	40.7N/282.1E	41.2N/281.7E	AV
BOS	Boulder, CO [USA]	A-SURFRAD	40.2N/254.6E	41.2N/255.0E	AV
BON	Bondville, IL [USA]	A-SURFRAD	40.1N/271.4E	41.2N/271.7E	AV
DRA	Desert Rock, NV [USA]	A-SURFRAD	36.6N/243.9E	36.2N/243.6E	AV
GCR	Goodwin Creek, Mississippi [USA]	A-SURFRAD	34.2N/270.1E	33.8N/271.5E	AV
NAU	Nauru Island [USA]	B-ARM	0.5S/166.9E	1.2S/166.2E	AV
MAN	Momote, Manus Is., Papua New Guinea [USA]	B-ARM	2.1S/147.7E	1.2S/148.8E	AV
DAR	Darwin [Australia]	B-ARM	12.5S/130.9E	13.8S/129.9E	AV
SPO	South Pole, Antarctica [USA]	B-BSRN	89.8S/258.0E	88.8S/300.0E	AV

Fig. 2a shows monthly-mean column AOD comparison with surface observation-based values at 0.55 micron for FD and AeroCom, respectively, from all available 2004 3-hrly mean values. Overall FD's AOD is too large except tropic island (NAU and MAN) where FD is slightly too small and the South Polar Summer (winter for the Northern hemisphere) while Aerocom is overall better than FD (NASA GISS' aerosol climatology). Figures 2b and 2c show the corresponding clear-sky surface downwelling diffuse and direct SW flux comparisons for original FD and AeroCom-FD (with replacement of column AOD, SSA and ASY of FD by AeroCom). Evidently, AeroCom-based FD has substantial improvements over the original FD.

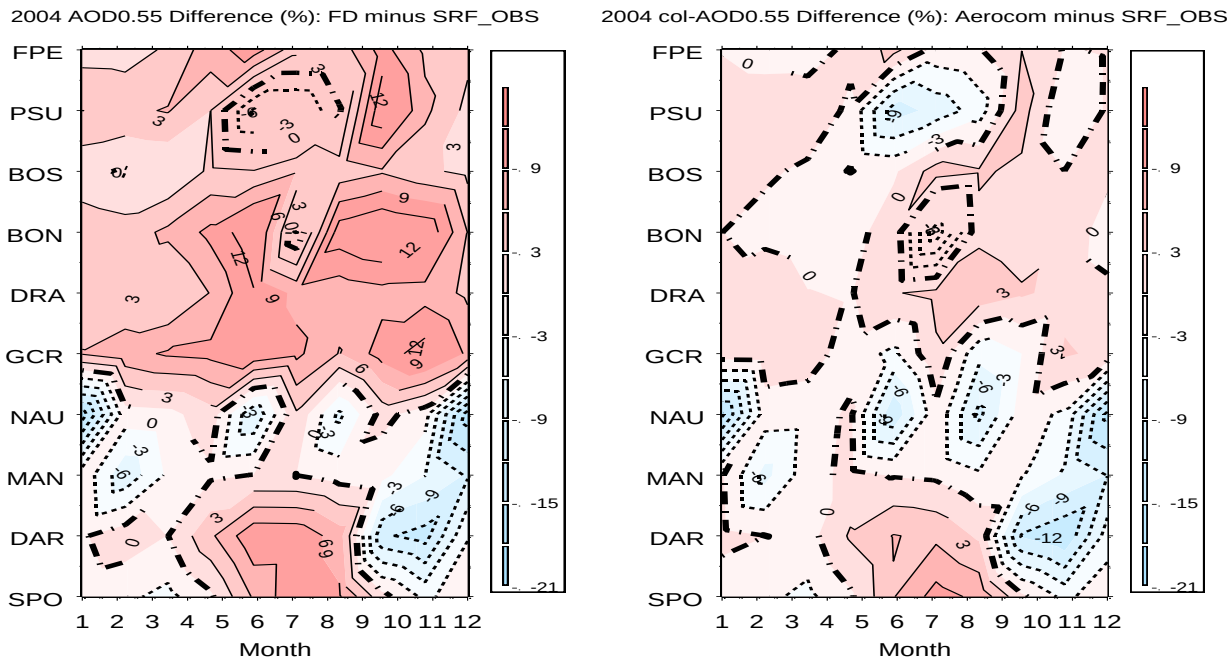

Fig. 2a. Monthly-mean column AOD comparison with surface observation-based values at 0.55 micron for GISS/FD (left) and AeroCom (right) in %, respectively, from all 2004 3-hrly values.

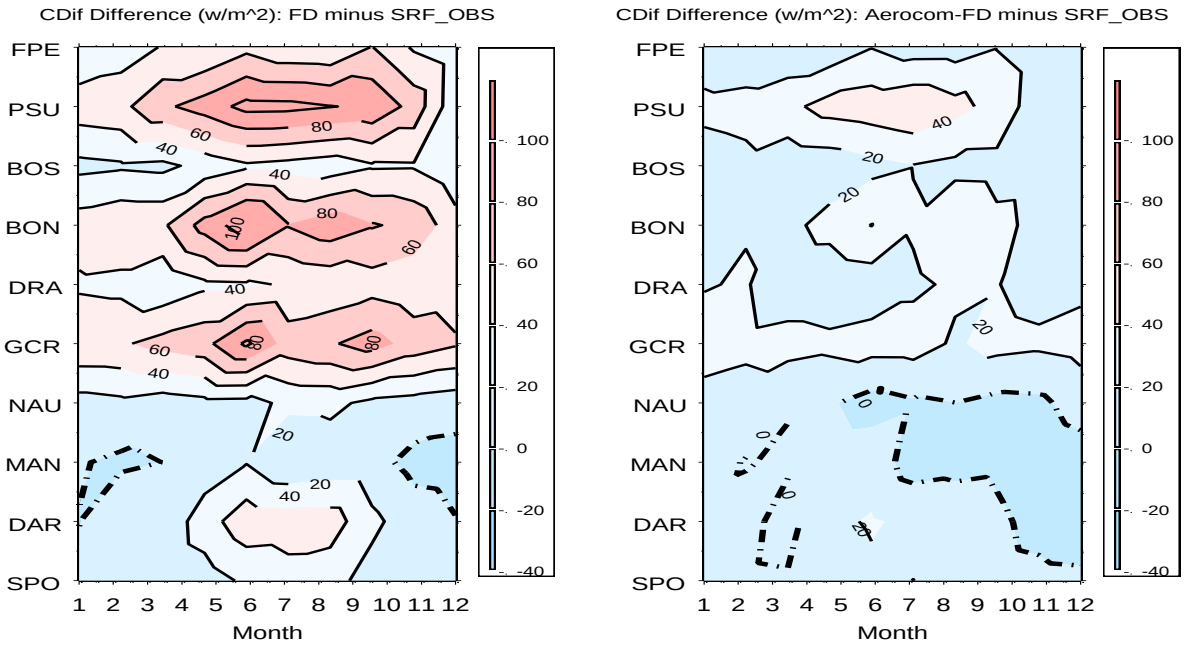

Fig. 2b. Monthly-mean surface downwelling diffuse flux comparison with surface observations (in Wm^{-2}), for FD (left) and AeroCom (right) respectively, based on all 3-hrly values of 2004.

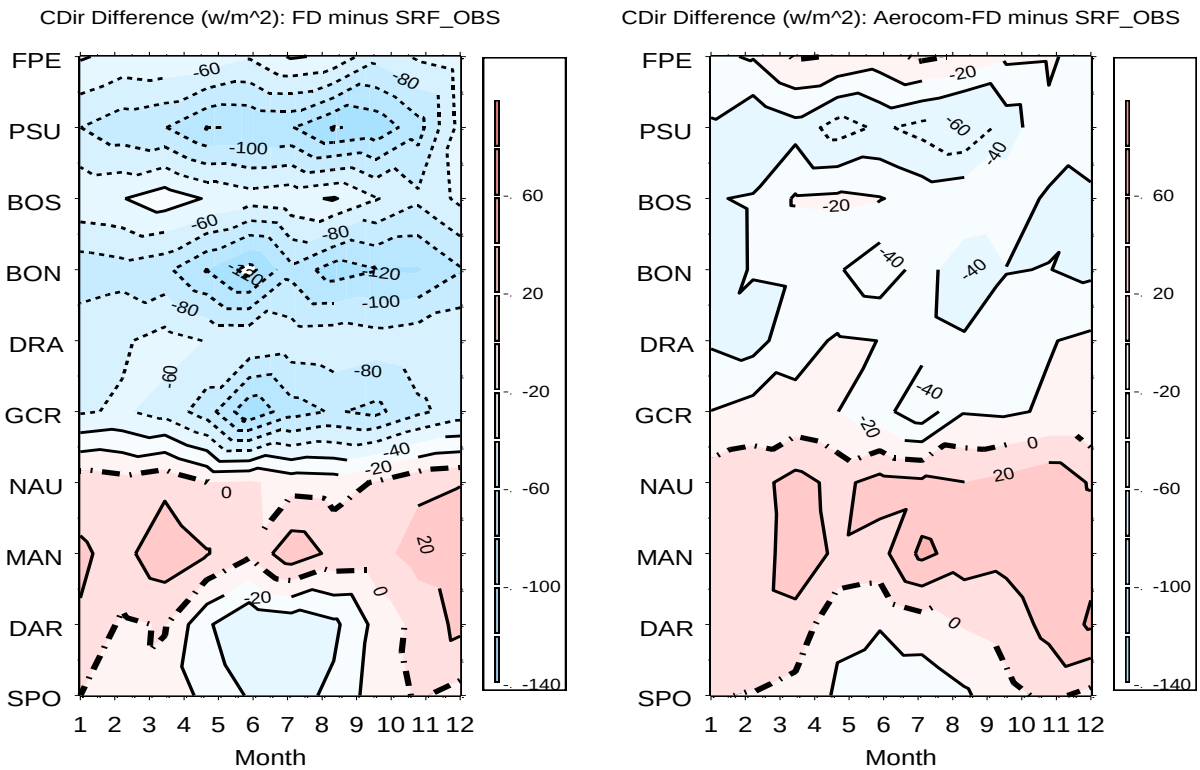

Fig. 2c. Same as Fig. 2b but for surface downwelling direct flux comparison with surface observation (in Wm^{-2}).

3. Reengineering all the codes

Because many tests are needed before reengineering, it has not been initialized yet.

4. Evaluating new codes and products

Generally speaking, RadE seems to reduce TOA upward SW flux slightly by a couple of Wm^{-2} and increase the atmospheric SW absorption amount by ~7 Wm^{-2} while not much is changed in LW with same input datasets as FD uses (the above new LW improvement is not incorporated in RadE). These changes are in the right direction. As RadE is under revision to have a beginning version RadE-0, we are closely looking at those improvements in the new ISCCP product that is crucial to new ISCCP-FD production.

5. Short Summary

In summary, the progress for this project has been going well over all the aspects and well within original expectations.

References:

Kinne, S (2008), Climatologies of cloud related aerosols- part 1 particle number and size, Clouds in the perturbed climate system, edited by J.Heintzenberg and J.Charlson, ISBN: 978-0-262-01287-4, 2008.

PROJECT PROGRESS REPORT
For Period: 02/01/2012 - 07/31/2012
(Second semiannual report for FY 1)

Award Number:	NA11NES4400002
Award Period:	08/01/2011 - 07/31/2014
Project Title:	Development of new 3-hourly, global, long-term, multisatellite-based TOA-to-surface radiative flux profile data product with high horizontal resolution and homogeneous quality
Recipient Name:	The Trustees of Columbia University in the City of New York
Project PI:	Yuanchong Zhang
Report Type:	Semiannual Project Progress Report
Reported by:	Yuanchong Zhang

Planned Tasks for the second half of Year 1 in the proposal:

- 1. Creation of new production codes
- 2. New product processing
- 3. Reengineering all the codes
- 4. Evaluation of new codes and products

1. Creation of new production codes

Following the successful extraction of the radiation code, RadE, from NASA GISS GCM ModelE, validation for its longwave (LW) radiation model results and other preliminary work (see last report), we have continued our work on the primary version RadE-0 of RadE in several aspects as described as follows.

(1) Substantial validating and sensitivity tests to make sure RadE-0 is correct and works well

More substantial validating and sensitivity tests have been completed and some shortcomings or bugs in RadE have been corrected or improved for this project's specific objectives. With the same input datasets used for ISCCP-FD production (using RadD, the previous GISS GCM ModelD's radiation code), we have produced a test flux product using RadE-0, thereafter ISCCP-FD_E0. Based on comparisons between FD_E0 and FD, RadE shows three major differences with RadD, namely LW fluxes, aerosols climatology and surface albedo specification in the radiation code. As validated in the previous report, the first one actually reflects the improvements on LW flux calculation of RadE over old code RadD. The improvements mainly include better water continuum parameterization based on new theoretical results, CFC cross sections from HITRAN dataset, inclusion of SO2 line absorption, better treatment of CH4 and

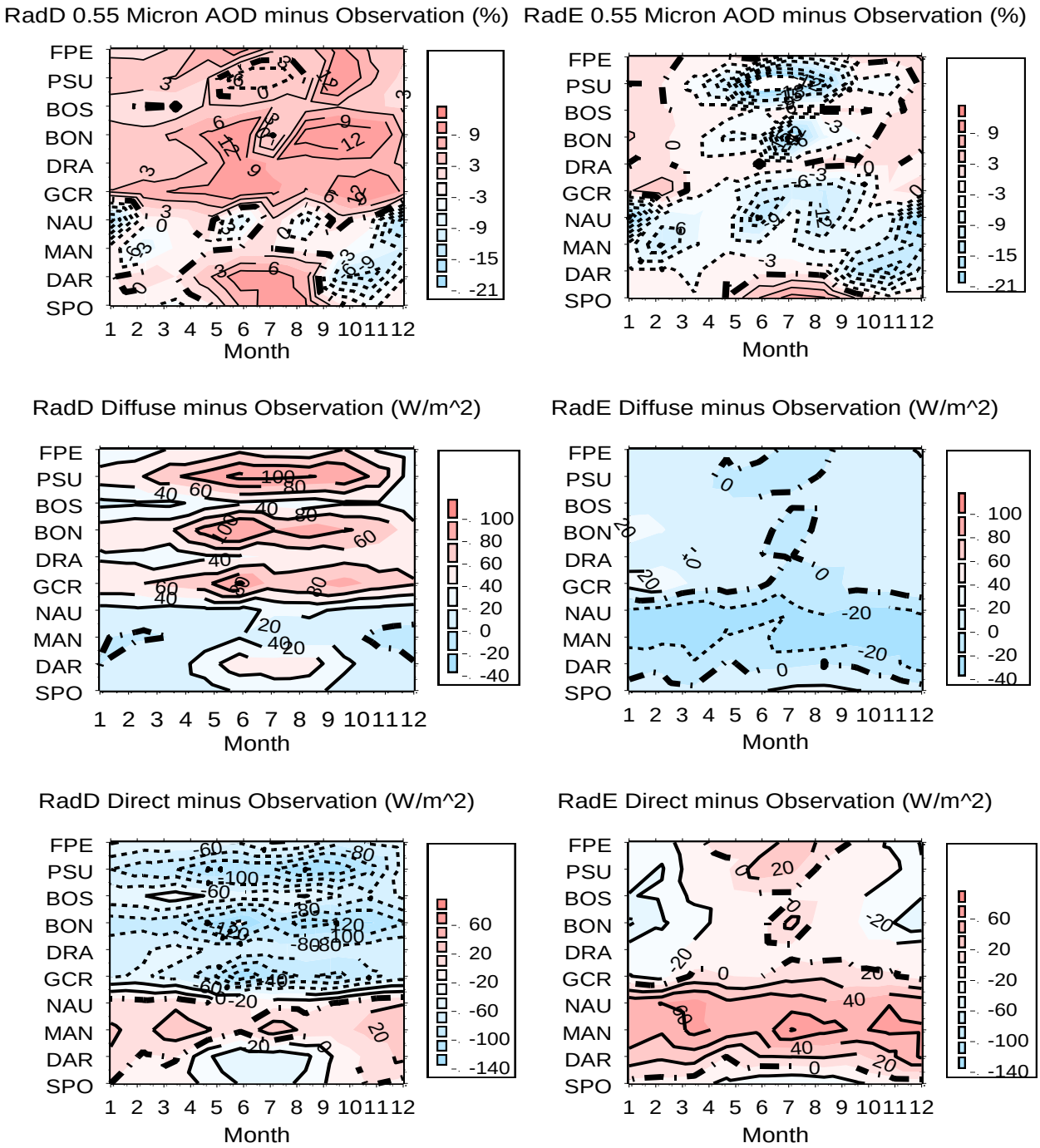

Fig. 1. Comparisons of (from top to down) AOD, diffuse and direct fluxes between model results (FD with RadD on left and FD_E0 with RadE-0 on right) and the best surface observations from ten high-quality stations as shown in Y-Axis labels (from the South Polar station, SPO, to FPE, in Fort Peck, MT.) for twelve monthly means of 2004. Shown are differences for model minus observed results.

N2O overlap with major absorbers. The second major one shows both the improvements and large uncertainties in constructing aerosol climatology as demonstrated in Fig. 1, which shows the comparisons of monthly-mean column AOD, surface downwelling diffuse and direct fluxes between model results from FD (left panels) and FD_E0 (right panels) and best surface observations for all the ten high-quality stations as shown in Y-Axis (see the last semiannual report for the detailed station information). From Fig. 1, we see RadE substantially improves diffuse and direct fluxes for the northern hemisphere (GCR to FPE stations) while not much change for the southern hemisphere, if not worse. Recalling the comparison with AeroCom-based aerosol climatology (also shown in the previous report), more studies are needed in order to have better aerosol climatology for the final radiation code, RadH (as we call it now) to adopt for its product ISCCP-FH.

We have also compared all 3-hourly surface fluxes and other input parameters between the two models' products (FD and FD_E0) and surface observations for the best fifteen climate-representative stations for the whole 2004 (for the information of the surface observations and the fifteen stations, see Zhang et al., 2010). For all 2004 3-hourly mean surface downward shortwave (SW) flux, FD_E0 has near-zero mean bias for clear-sky but 4.3 W/m^2 mean bias for all sky while the corresponding FD has -7.65 and -0.58 W/m^2 bias, respectively. Their standard deviation (stdv) are comparable for all sky but 2 W/m^2 better for clear sky in FD_E0. For the separated diffuse and direct downwelling fluxes, FD_E0 has near-zero bias for clear sky and smaller bias for all sky: 21.99 and -18.05 W/m^2 versus FD's 29.05 and -29.97 W/m^2, respectively, with comparable stdv. These results are consistent with Fig. 1 and indicate that RadE does improve aerosols substantially but not perfectly as it actually increases all-sky bias; possibly RadE over-reduces aerosols in an overall sense. For LW, FD_E0 has higher bias than FD by about 2 W/m^2, which does not necessarily mean RadE is worse than RadD and it is likely that there are some input data problems in TOVS from ISCCP D-series product.

With ISCCP-FD_E0, we have also validated RadE at TOA by comparing with CERES for the whole 2004. As examples, Fig. 2a and 2b show how FD_E0 is improved over FD in agreement with CERES TOA measurements for July 2004. For TOA upwelling SW, the global mean bias is improved from 3.5 and 6.8 to -0.2 and 5.2 W/m^2 for clear and all sky, respectively, while the stdv are comparable (~7 – 9 W/m^2), indicating RadE has a right direction in aerosol climatology improvements in terms of TOA flux values.

Besides the mentioned validation studies on RadE, we have performed substantial sensitivity tests. These tests have led to a number of corrections or adjustments on RadE-0. We now have a good understanding on the behaviors of the both the previous (RadD) and the current radiation models (RadE), based on which, the final RadH will be built with the new ISCCP H-series data products as the major input datasets.

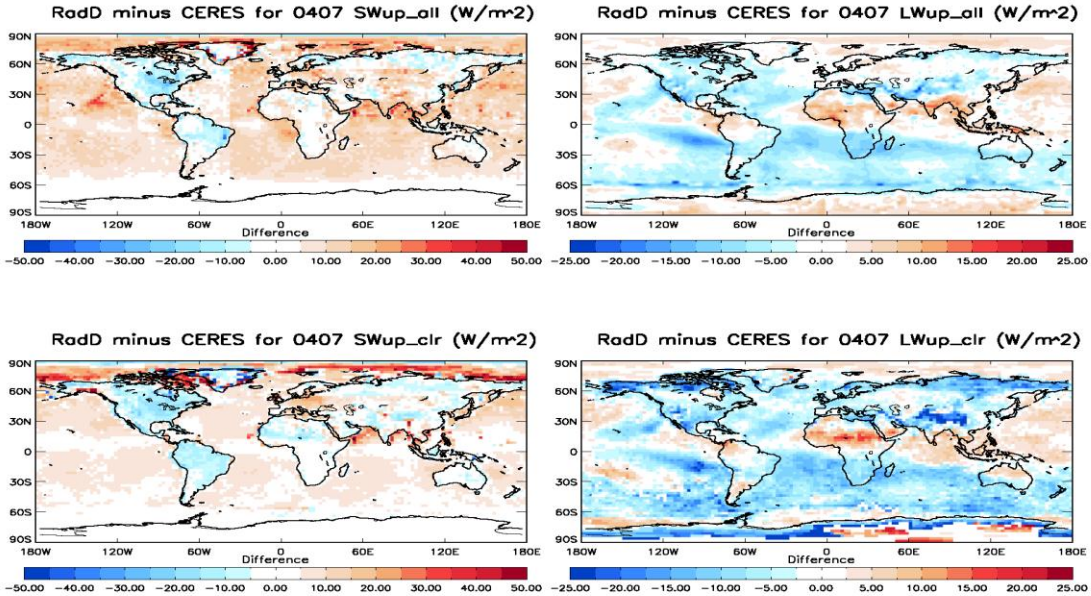

Fig. 2a. TOA comparison for FD (using RadD) minus CERES for July 2004 monthly mean: all-sky (upper panels) and clear-sky (lower panels) SW upward (left) and LW upward (OLR, right) in W/m^2.

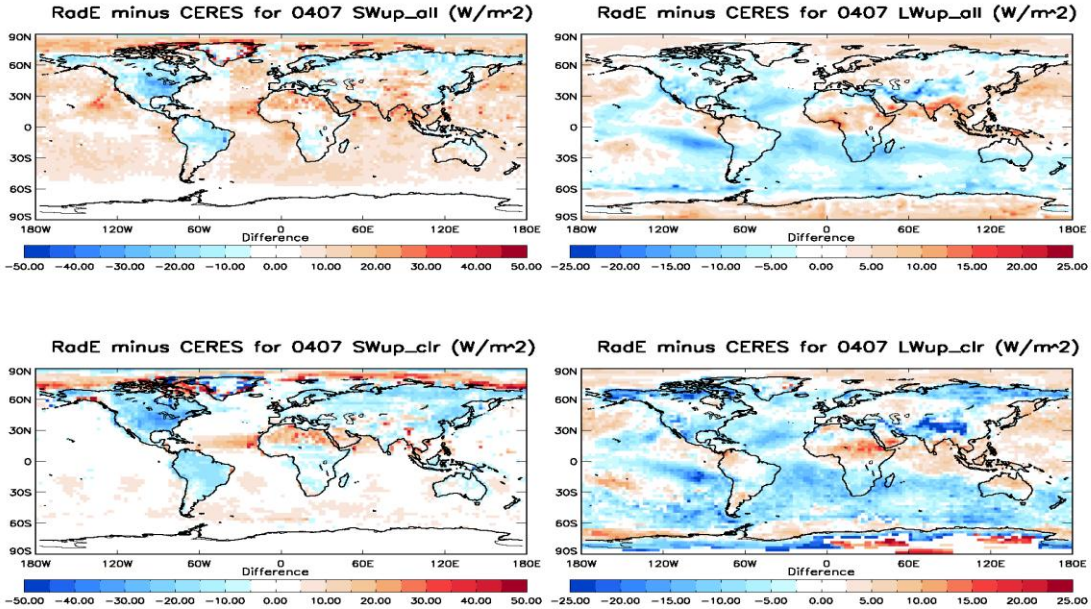

Fig. 2b. TOA comparison for FD_E0 (using RadE-0) minus CERES for July 2004 monthly mean: all-sky (upper panels) and clear-sky (lower panels) SW upward (left) and LW upward (OLR, right) in W/m^2.

(2) Model improvements

As we have validated RadE's LW performance, we now focus on the improvements for solar flux calculation. The line absorption in the current GISS model (RadE) is calculated by formulas that have been fit to optical depths as functions of temperature, pressure and absorber amount. For standard absorber amounts the resulting solar flux throughout the atmosphere is in reasonably good agreement with line-by-line calculations. However, for larger amounts the formulas and thus the solar fluxes become increasingly inaccurate. The line absorption for the final target radiation code, RadH, will be from the new HITRAN2008 data compilation for all molecules. The approach in improving RadE involves calculating Malkmus B and S coefficients for absorption due to lines of H2O, CO2, O2, CH4 and N2O in 38 bands into which the solar spectrum has been subdivided (RadE does not include CH4 and N2O lines). The coefficients have been calculated by fitting to line-by-line transmittance values for a wide range of temperatures, pressures and absorber amounts, and have been used to set up a look-up table for each band. In the solar subroutine of RadE, the B and S coefficients are found for each atmospheric layer by interpolation in temperature, pressure and absorber amount in the look-up table, followed by application of the Malkmus formula to give the optical depths. The resulting transmittances are mean values for each layer, and as such, their multiplication to yield a net transmittance will introduce errors. The expected errors have been minimized to a certain extent by choosing bands that contain lines of similar strength. In order to further decrease the errors, correction factors multiplying the optical depths have been calculated by forcing agreement between solar fluxes calculated line-by-line and by the 38-band method for various standard atmospheres. For a given atmosphere, the required correction factors are obtained by interpolating between the values from the standard atmospheres. This last step is still in development. In addition, efforts are underway to streamline the entire procedure in order to decrease the run time.

2. New product processing

(1) Make all input datasets available and (2) Create new ingestion codes

In the above various validation and sensitivity tests, we have built up the capabilities of RadE (RadE-0 version now) for ingesting different input datasets and possible further improvements. We should have a beta version of the new ISCCP H-series product within next couple of months and final versions before the end of this calendar year; once they become available, we will begin the coding for ingestion after some primary tests.

3. Reengineering all the codes

All the above work has laid a foundation for actual reengineering, which will be conducted for the frozen version RadE-X, which is still under development based on RadE-0. Pre-reengineering examination is under way and the reengineering should start within the next couple of months.

4. Evaluating new codes and products

During the validation and sensitivity tests, we have located some problems in applying RadE to our radiative transfer flux calculation as well as some bugs and made all necessary corrections and revisions. Based on the various tests for different parameters, we now have a good understanding in RadE. Generally speaking, RadE does have some improvements over the previous RadD, especially in LW flux calculation and aerosol climatology, as shown above but there are some issues (whether listed above or not) remaining resolved. We now have a good plan to work on the primary version, RadE-0, toward the final, even more improved RadH for final product of this project, ISCCP-FH.

5. Short Summary

In short, the first year for the project has been successful and all the developments have been going well with some slightly left behind schedule. We expect that all tasks be accomplished by the planned time schedule.

References

Zhang, Y., C. N. Long, W. B. Rossow, and E. G. Dutton (2010), Exploiting diurnal variations to evaluate the ISCCP-FD flux calculations and radiative-flux-analysis-processed surface observations from BSRN, ARM, and SURFRAD, J. Geophys. Res., 115, D15105, doi:10.1029/2009JD012743.