PROJECT PROGRESS REPORT
For Period: 8/01/2013 - 01/31/2014
(First semiannual report for FY 3)

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 Year 3 in the proposal:

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

1. Creation of new production codes

(1) Status of RadE-1

The planned improvements for the project on the radiation code of NASA GISS ModelE, RadE, have been essentially completed while the release of the new ISCCP H-series product has been delayed again but it is expected to be available next month (February 2014) or so, when the code will be further revised for ingesting the ISCCP-H input datasets and the other ancillary datasets to build up the final production code, RadH, for the new ISCCP-FH production as the formal production for the project .

(2) Model improvements

As the planned LW improvements have already been completed and validated (see previous reports), the GISS radiation group's further improvements primarily for the Polar Regions, in addition to the planned for the project, on the current RadE are to be added to the new code for RadH.

The major work on improving SW flux calculation has been completed and added to the current developing radiation code. It involves reformulation of the line absorption for H2O, O2 and CO2 using most updated HITRAN2012 edition, which corrects some H2O deficiencies and is greatly extended in terms of accuracy, spectral coverage, additional absorption phenomena, and validity (Rothman et al., 2013). As an example, Fig. 1 shows that the new changes make SW absorption increase for clear sky for UTC 12, July 15, 2004, and Fig. 2 shows the same but for all sky. The

global mean absorbed SW amounts are increased by 3.076 and 2.653 W/m^2, respectively, for clear and all sky that is in the right direction in improving the radiation code.

We will also reformulate the SW absorption for CH4 and N2O using HITRAN2012 line absorption results as well as extend H2O continuum absorption also with HITRAN2012, which may be incorporated into the code any time later before formal ISCCP-FH production. However, the originally planned O2-O2 and N2 line absorption will be reassessed on if they need to be done as they have relatively very weak absorption effects.

In the meanwhile and after numerous tests, we have come up with a very first new vertical cloud layer configuration (VCLC) model for setting (1) Cloud Vertical Structure (CVS) that determines the number of overlapped cloud layers and how they are related (separated or connected) and (2) cloud layer thickness that determines physical positions of each of all the cloud layers of a CVS type. The new VCLC model is based on our old CVS model and new CloudSat and CALIPSO (C&C) cloud layer thickness climatology derived from observations of cloud layer profiles. Figures 3 and 4 illustrate the improvements from ISCCP-FD to the current on VCLC for ocean and land, respectively, for July, 2006. There appears substantial improvement in matching C&C vertical cloud amount profile in global mean.

The new ISCCP-H series on cloud parameter retrieval has some improvements. It exhibits a small shift of middle clouds to both high and low along with other improvements that may benefit the cloud vertical layer configuration. When ISCCP-H is ready, we will reassess our current VCLC model and possibly make some refinement on it.

2. New product processing

(1) Make all input datasets available

The H-series ISCCP product will become available within a month or two when we can start working on it, whose NetCDF data product will be used to extract the needed parameters in binary format for ISCCP-FH production.

(2) Create new ingestion codes

As the RadE-1's current version has essentially incorporated all the improvements we planned for the project, it is ready to be revised for ingesting H-series ISCCP in 1-2 months.

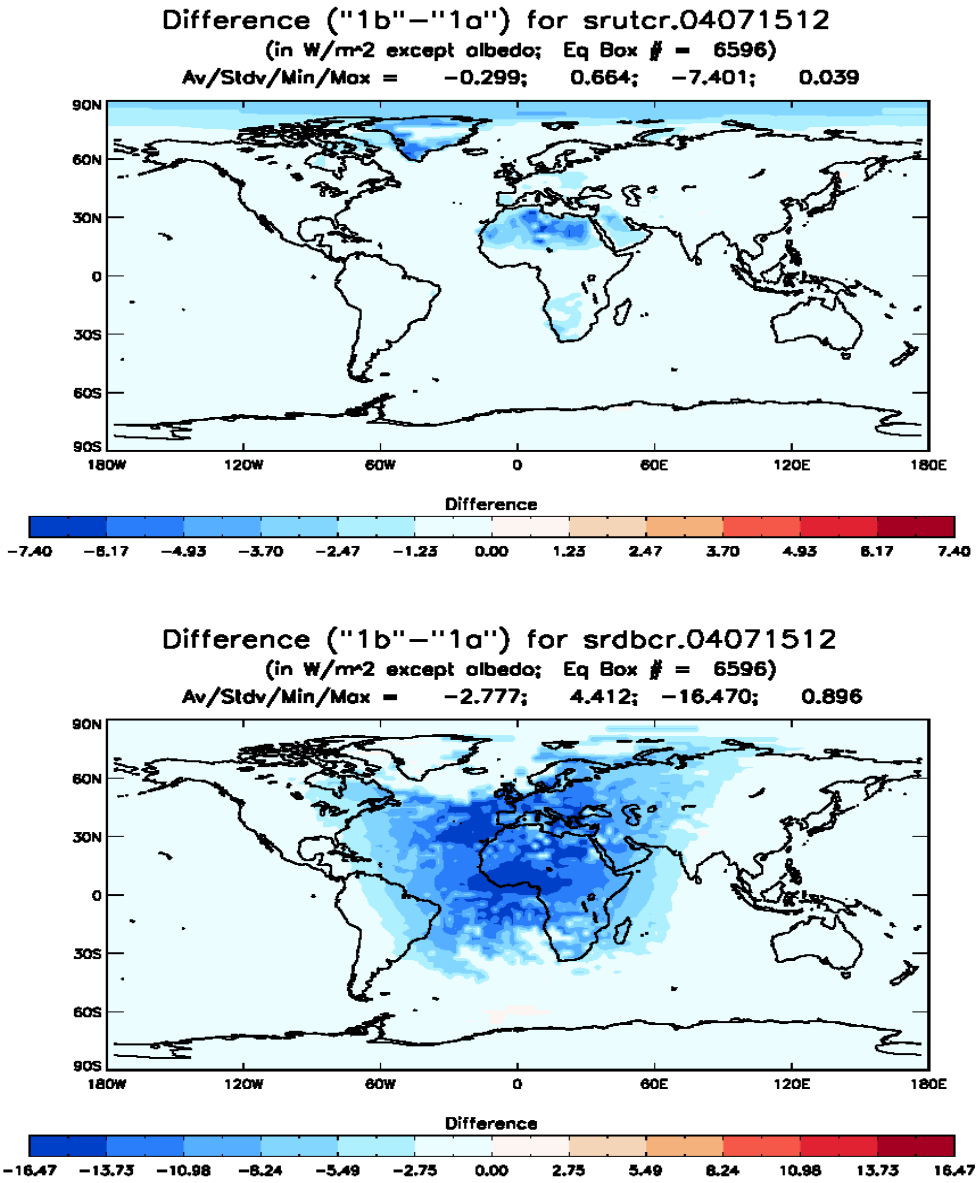

Fig. 1. Difference for changes from ISCCP-FD to the current code with newly formulated absorption for H2O, O2 and CO2 using HITRAN2012: The global average of the TOA upward SW for clear sky is reduced by 0.299 W/m^2 and the surface downward SW (lower panel) by 2.777 W/m2, which add to a total increase of 3.076 W/m2 of the atmospheric gas absorption for clear sky in global average for UTC=12, July 15 2004..

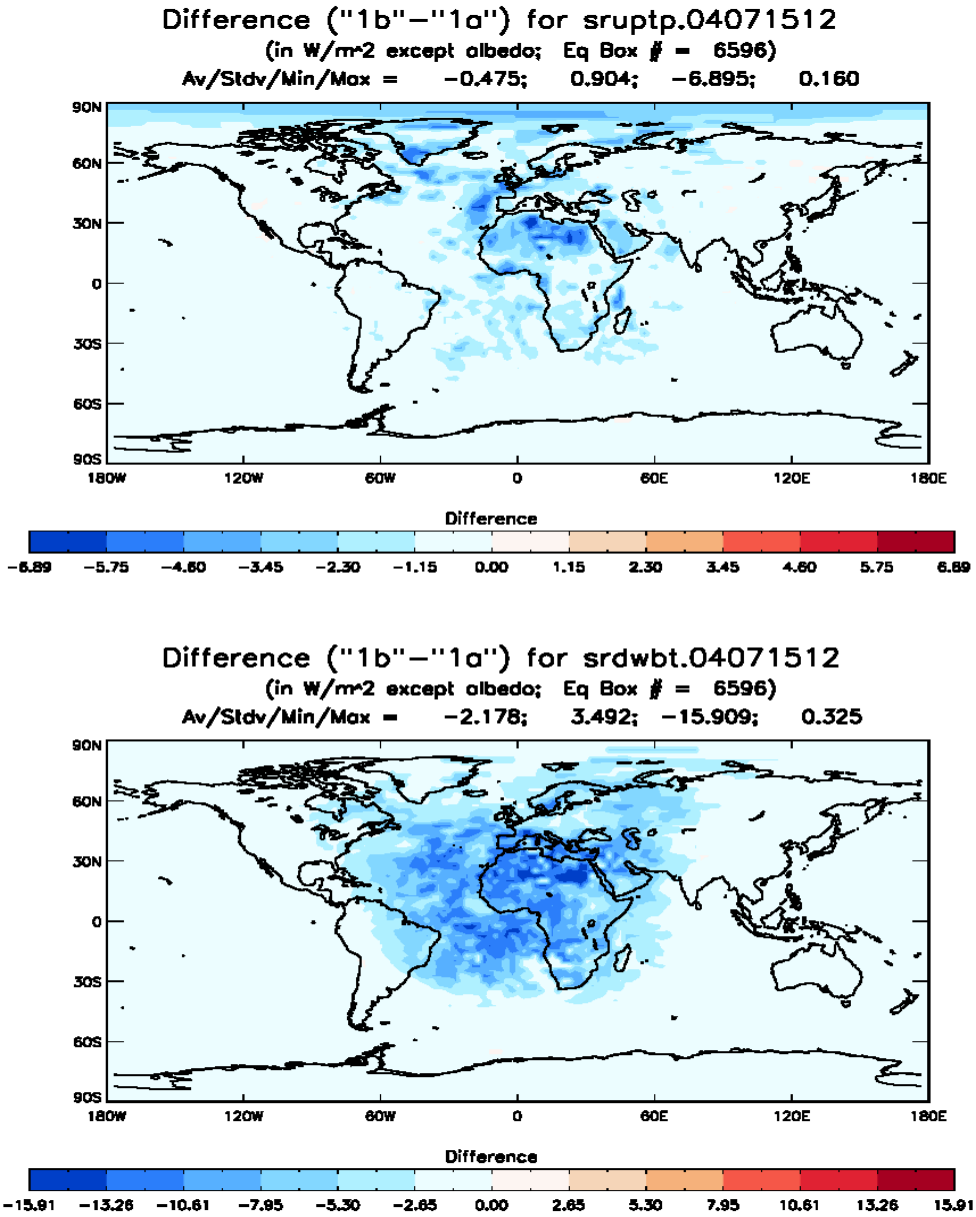

Fig. 2. Same as Fig. 1 but for all sky. The global mean TOA upward SW is reduced by 0.475 W/m^2 and the surface one (lower panel) by 2.178 W/m^2, which add to a total increase of 2.653 W/m^2 of the atmospheric gas absorption.

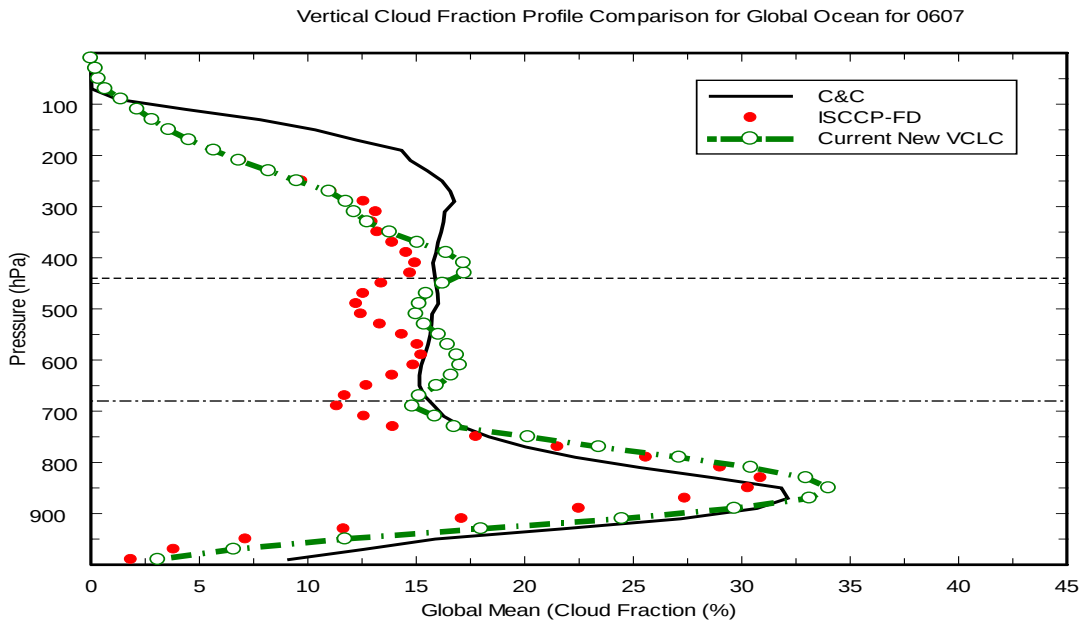

Fig. 3. Global mean cloud amount profile for global ocean for July, 2006, for old ISCCP-FD and the current working version of RadE-1, compared with the monthly cloud profile from C&C, illustrating the current cloud vertical layer configuration has a better match to the observed C&C.

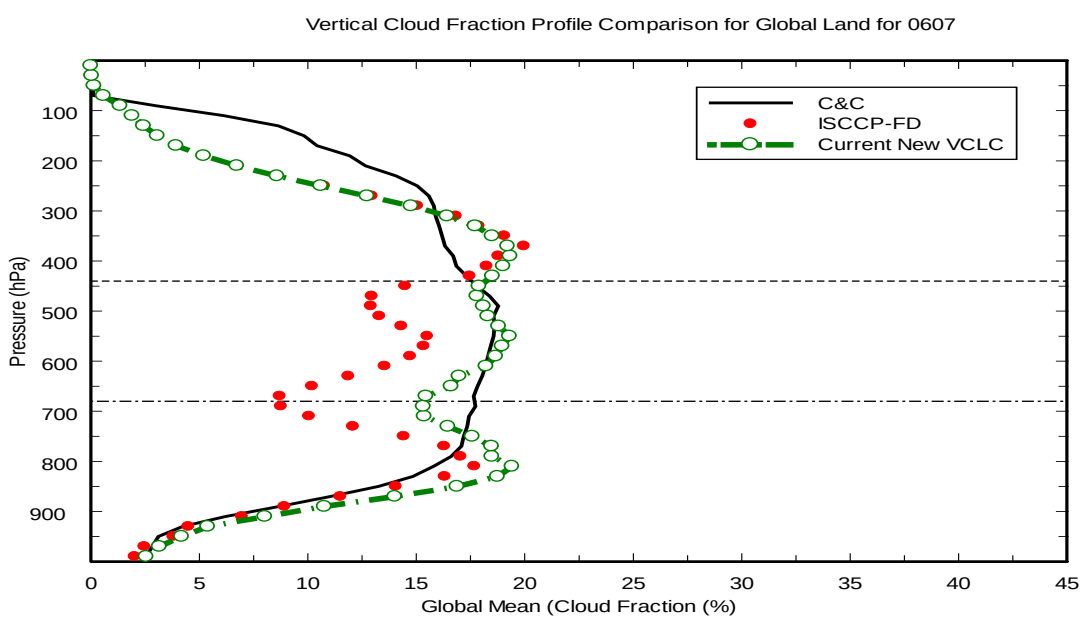

Fig. 4. Same as Fig. 3 but for global land areas.

3. Reengineering all the codes

Since the RadE-1(current new code) has been primarily reengineered, it is ready to take in new input datasets and new code changes with necessary further reenginnering.

4. Evaluating new codes and products

It is always true that we keep doing checking and validating work whenever the code is revised at every stage to make sure each revision is correct.

5. Short Summary

In short, over the first half year of the third fiscal year, we have accomplished essential code improvements and have had a first scheme of the vertical cloud layer configuration consisting of CVS model and layer thickness climatology for the new ISCCP-FH production. The project has generally been progressed as allowed by the reality that makes our work somewhat behind of the originally planned schedule but we still expect that all tasks be accomplished by the planned time period in the third year.

References

Rothman, L.S. and coauthors, 2013, The HITRAN2012 molecular spectroscopic database, *J. Quantitative Spectroscopy & Radiative Transfer, 130(2013), 4-50.*

PROJECT PROGRESS REPORT
For Period: 02/01/2014--7/31/2014
(Second semiannual report for FY 3)

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 Year 3 in the proposal:

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

1. Creation of new production codes

(1) Status of RadH

All the planned major, significant improvements of the radiation code from the NASA GISS ModelE, RadE, have been completed to produce the final radiation code, RadH. A few, originally planned improvements, remain but early testing has shown that they make only insignificant differences. However the new code, RadH, has some additional improvements that were not included in the original plan. RadH has now been successfully tested on two months of data from the beta-version of the new ISCCP H-series at 3-hourly, 110-km resolution. Some further revisions of the RadH code will be made to produce the final production code, called RadH-PRD, when the ISCCP-H series product is formally released.

(2) Model improvements

As mentioned in the last report, an unplanned improvement to the LW flux calculation was implemented and tested in the new RadH code. This improvement was motivated by the errors seen primarily in the polar regions, but it actually produces an overall improvement for the whole

globe. The differences between the old and new codes stem from differences in the way in which the so-called flux correction factors are determined. The old code used a 24-layer midlatitude summer atmosphere as the basis for calculating the correction factors, whereas the new version increases the vertical resolution by employing a 43-layer standard atmosphere. In addition, factors such as the amount of water vapor above and below a given layer as well as the water vapor gradient in the atmosphere are now taken into account. These improvements have been validated by NASA GISS GCM group but we will continue to evaluate them by comparison with surface flux measurements from BSRN.

In addition to improving the atmospheric absorption of SW fluxes by adding more gas species, as mentioned in the last report, the solar code has also been improved to increase the accuracy of the treatment of water vapor absorption (also not included in the original proposal as well as in all the previous GISS radiation code). The combination of these two major improvements of the atmospheric SW absorption increases the atmospheric SW absorption by about 4 5 W/m^2 in the global average, which largely eliminates the bias of the GISS model as reported in the Continual Intercomparison of Radiation Codes experiment (CIRC, Oreopoulos, L., et al., 2012). All the new improvements have been compiled with the most up-to-date line-by-line results in the HITRAN2012 edition, which corrects some H2O deficiencies and is greatly extended in terms of accuracy, spectral coverage, additional absorption phenomena, and validity (Rothman et al., 2013).

We have worked out the final, new vertical cloud layer configuration (VCLC) model for setting (1) the Cloud Vertical Structure (CVS) that determines the number of overlapped cloud layers and how they are related (separated or connected) and (2) the cloud layer thicknesses that determine the physical positions and extent of all cloud layers for each CVS category. The new VCLC model is based on our old CVS model revised by a combination of the 20-year rawinsonde and the 5-year CloudSat and CALIPSO (C&C) cloud layer thicknesses. Figures 1 shows the improvements from ISCCP-FD to the current on VCLC for ocean and land, respectively, for the annual mean based on the 12-month test from July 2006 to June 2007. The overall mean bias is reduced by 2%. Note that the large high cloud layer bias can not be reduced much because the ISCCP cloud detection is unable to detect very thin, high clouds, which constitute about 10% of clouds (Stubenrauch *et al.* 2013); those thin, high clouds, however, only affect the LW fluxes by 1-2 W/m^2 (Chen *et al.* 2000).

The new ISCCP-H series cloud parameter retrieval has some improvements that will benefit the FH product. It exhibits a small shift of middle clouds to both high and low along with other improvements that may benefit the cloud vertical layer configuration, providing better agreement with Calipso and CloudSat results. When ISCCP-H series product is released in final form with a few years of coverage, we will reassess our current VCLC model and consider whether further refinements are needed.

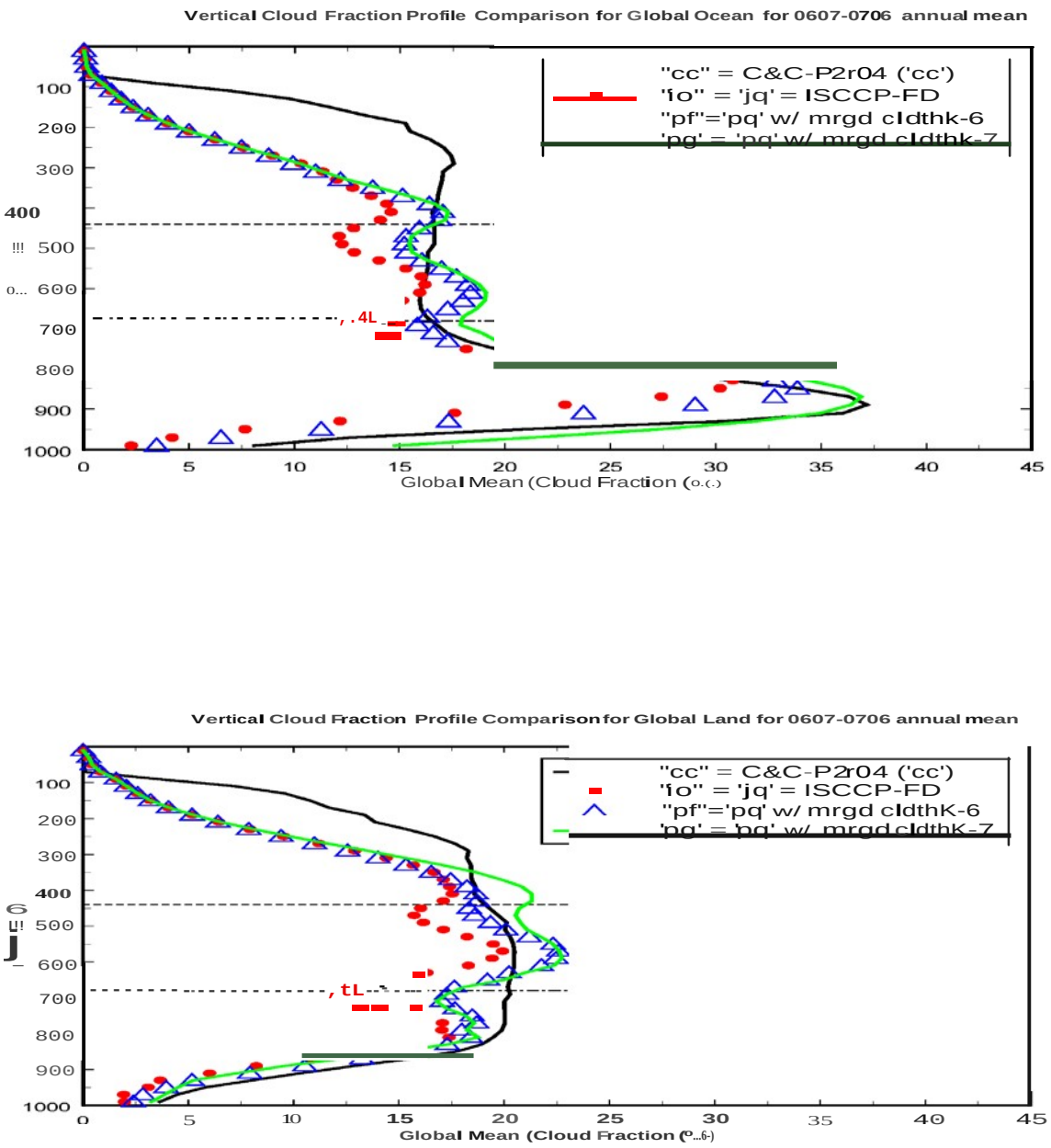

Fig. 1. Global, annual mean cloud amount profile for global ocean (upper panel) and land (lower panel) based on monthly results from July, 2006 to June 2007, for old ISCCP-FD ('io' = 'jq' in red solid dots), and the 'final' version ('pf' in blue triangle) ofRadH, compared with the counterparts ofC&C (black solid line), illustrating the current cloud vertical layer configuration has a better agreement with C&C. The green line is for another testing version.

A new aerosol climatology has been obtained from MACv1 (Kinne et al., 2013), which is an updated version in 1 X 1 resolution of the Aerocom data (in 2.5 X 2.5 resolution) that we have shown in the previous reports produces some improvement in the SW surface fluxes. The updated version is slightly improved over the previous version.

RadH has also implemented using a new dataset of the daily TOA Incoming Solar Irradiation at 1 AU (TSI), which is obtained from Shashi K. Gupta (Shashi.K.Gupta@nasa.gov, personal communication) who has produced a self-consistent TSI time series of 1983 to 2013 based on SORCE V-15, Davos composite for World Radiation and the Royal Meteorological Institute of Belgium (RMIB). The SORCE mission may be referred to http://lasp.colorado.edu/home/sorce/reference/. Overall, the new TSI gives day-to-day variations (very small), as well as variation over the solar sunspot cycle, and is more accurate; it reduces our TSI by a global average of about 2.5 W/m^2. In addition, the actual TSI at TOA, which depends on the changing Earth-Sun distance, is now based on actual Earth-Sun distance calculated from astronomical ephemeris to replace the 365-day constantly changing climatological daily variation that causes small deficiency, especially for a leap year.

2. New product processing

ISCCP has released the beta-version H-series product for 2007; we use two months (January and July of 2007) for testing. The 2-month, 3-hourly, 110-km-equal-area-gridded ISCCP-HGG product has been successfully tested using RadH. However, the production code, RadH-PRD, is not quite complete pending the release of more years of the final ISCCP H-series product. As in ISCCP-FD, we need at least 3-years of the ISCCP data to fill all the needed parameters for the flux calculations so that all quantities have full global coverage.

3. Reengineering all the codes

The RadH has been primarily reengineered and it will be further modified (if necessary) to comply with NOAA CDR Program requirements.

4. Evaluating new codes and products

In our evaluation of the gradually evolving ISCCP-FH results, every time we have added a new feature to our radiation code, all the results have been checked and rechecked by various comparisons with more direct flux measurements and other products as was done for the previous versions. As of today, the code successfully produces better results as expected, but we may not have a conclusive, final word on it until we fully implement using the final ISCCP product. One current issue concerns the remaining problems with the input atmospheric temperature and humidity data; the current version is known to underestimate near-surface temperatures and humidity which produce large changes in surface LW fluxes. The ISCCP project is working to resolve these problems but they would not really affect the FH radiation code.

5. Short Summary

In short, all the major tasks for the 3-year project have been satisfactorily completed leaving the final form of the production code (RadH-PRD) with filling procedures to be finished when 3-years of the final version of ISCCP H-series data product is released. The improvements of RadH over NASA GISS ModelE's RadE are significant, especially in the atmospheric absorption of SW, and in a smaller sense, in LW flux calculation improvement. The final quality of FH is still highly dependent on the input data sets, especially the new ISCCP H-series data product. Nevertheless, the RadH code and its product ISCCP-FH would both be valuable. Figures 2 and 3 show the examples for upwelling SW at TOA and downwelling SW at surface, and upwelling LW at TOA and downwelling LW at surface, respectively, for monthly-averaged hourly of UTC = 12 for July 2007.

References

Chen, T., Y-C. Zhang and W.B. Rossow, 2000: Sensitivity of atmospheric heating rate profiles to cloud layer overlap. *J. Climate*, **13**, 2941-2959.

Oreopoulos, L., et al. (2012), The Continual Intercomparison of Radiation Codes: Results from Phase I, J. Geophys. Res., 117, D06118, doi:10.1029/2011JD016821.

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Stubenrauch, C.J., W.B. Rossow, S. Kinne, S. Ackerman, G. Cesana, H. Chepfer, L. Di Girolamo, B. Getzewich, A. Guignard, A. Heidinger, B.C. Maddux, W.P. Menzel, P. Minnis, C. Pearl, S. Platnick, C. Poulsen, J. Reidi, S. Sun-Mack, A. Walther, D. Winker, S. Zeng and G. Zhao, 2013: Assessments of global cloud datasets from satellites: Project and database initiated by the GEWEX Radiation Panel. *Bull. Amer. Meteor. Soc.*, **94**, doi:10.1175/BAMS-D-12-00117.1, 1031-1049.

Stefan Kinne, Declan O'Donnel, Philip Stier, Silvia Kloster, Kai Zhang, Hauke Schmidt, Sebastian Rast, Marco Giorgetta, Tom F. Eck, and Bjorn Stevens (2013), MAC-v1: A new global aerosol climatology for climate studies, JOURNAL OF ADVANCES IN MODELING EARTH SYSTEMS, VOL. 5, 704–740, doi:10.1002/jame.20035, 2013.

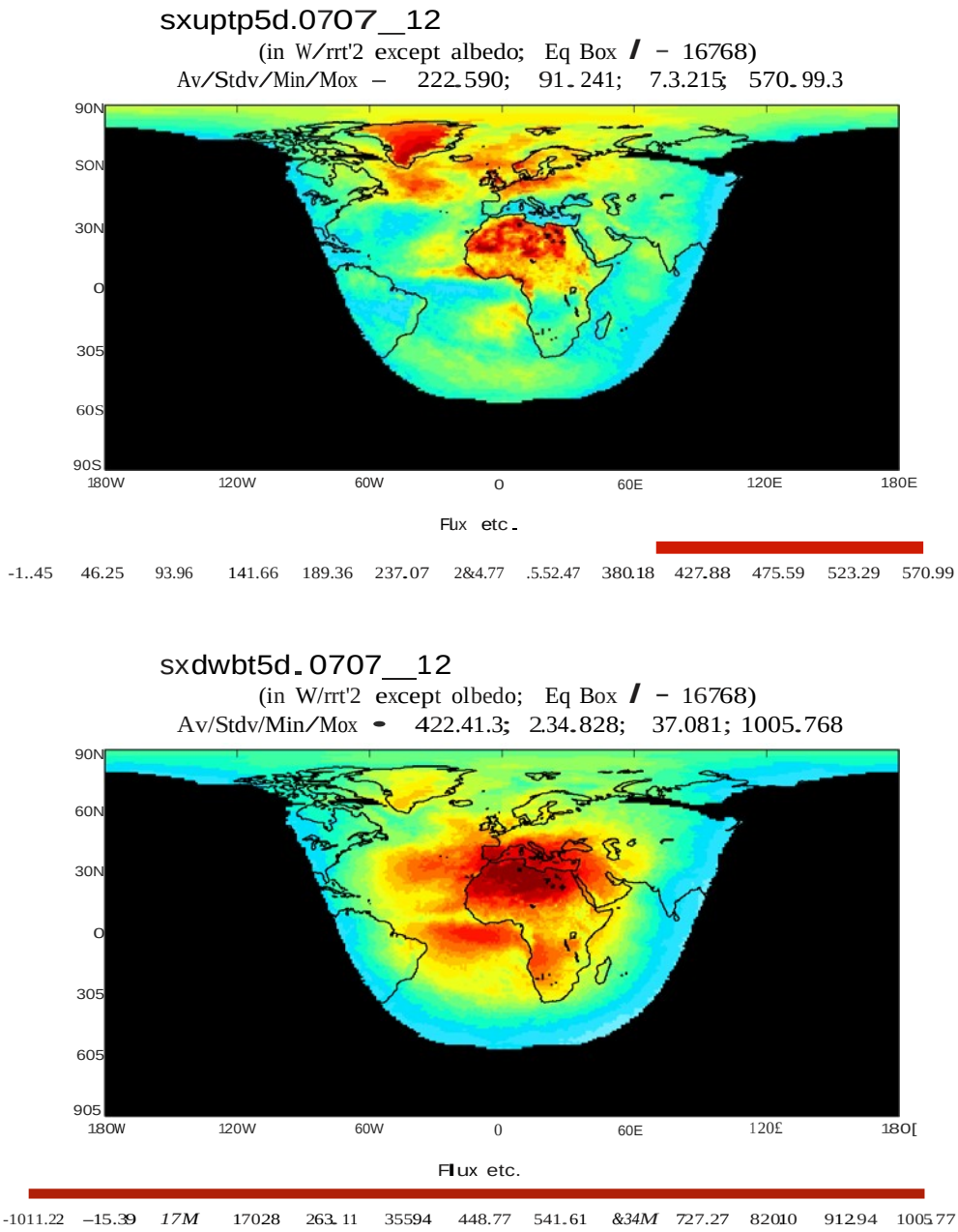
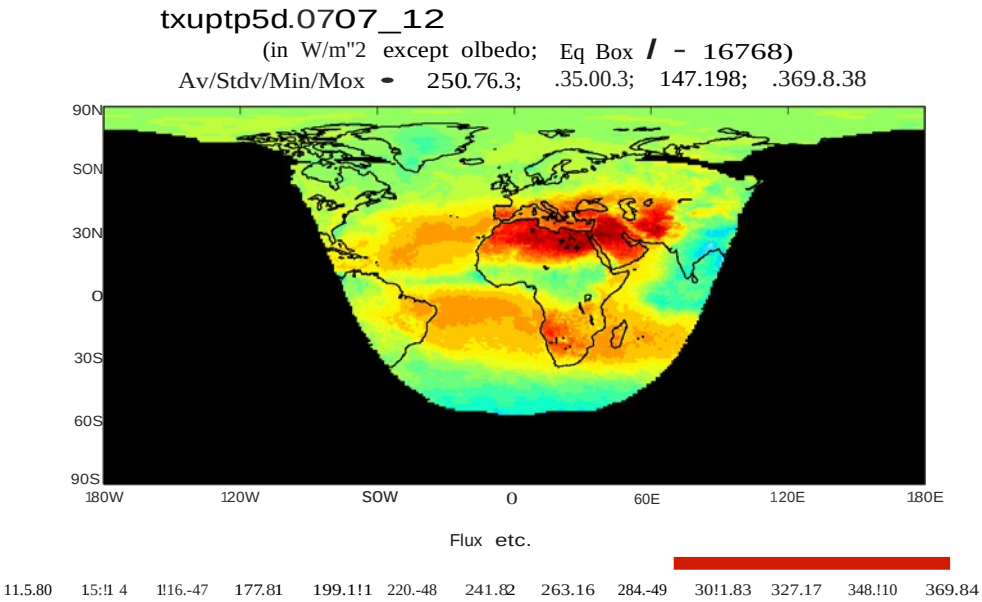


Fig. 2. The outgoing SW flux at TOA (upper panel) and downwelling SW flux at surface (lower panel) from testing /SCCP-FH flux product for monthly-averaged UTC = 12. Black color is for undefined areas.Thefluxes are calculated based on 18-type clouds from /SCCP HGG product.



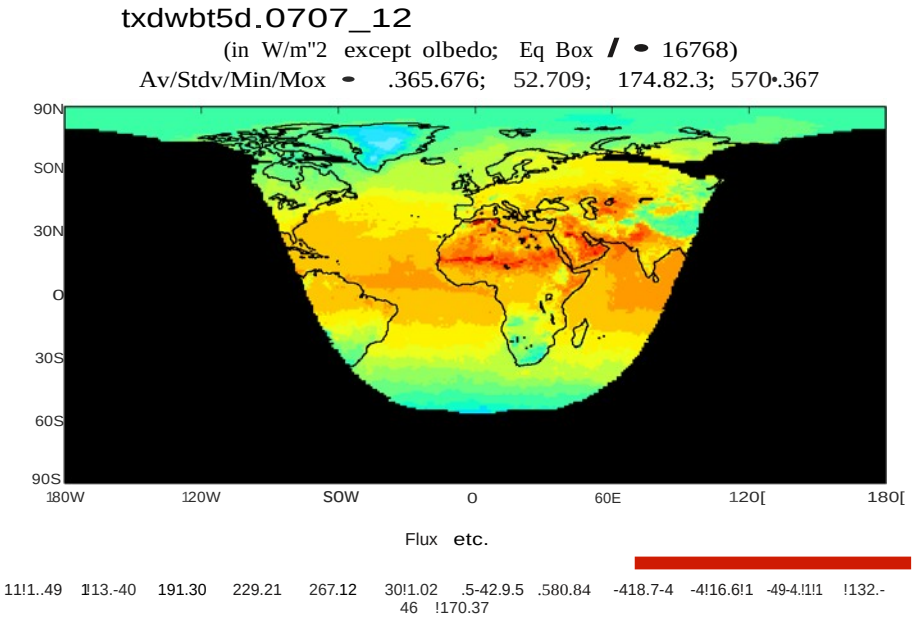


Fig. 3. Same as Fig. 2 but for LW fluxes now.