Validation of NCEP Global Forecast Systems and Reanalyses with CERES/ERBE measurements

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Introduction

NCEP has been utilizing NASA/EOS/CERES (Cloud and Earth's Radiant Energy System) and its predecessor, ERBE (Earth Radiation Budget Experiment) for examining the GDAS (Global Data Assimilation System), Reanalysis and AMIP (Atmospheric Model Intercomparison Project). Radiation fluxes are modulated by cloud, temperature profile, and water vapor on the short time scale, and interact with dynamics in a longer time scale. Thus CERES/ERBE data are not only being used for evaluating the accuracy of radiative transfer parameterization, but also for detecting the errors of water vapor and surface temperature. Combined with associate data sets, such as ISCCP (International Satellite Cloud Climatology Project) and NVAP (NASA Water Vapor Project), the data set has proved to be valuable in detecting errors that are not easily identifiable by using mandatory meteorological data alone. CPC (Climate Prediction Center) is aiming to enhance seasonal prediction with Model-based dynamical forecasts, in conjunction with traditional statistical methods.

This study illustrates the ongoing effort in improving CPC's Climate Forecast model currently under development. The averaged radiation fluxes and water vapor fields from a 10 member ensemble runs are compared to the aforementioned data sets, as well as to NCEP/NCAR Reanalysis (R-1) and NCEP/DOE Reanalysis (R-2).

Data

During the past few months, we have established a unified satellite data set suitable for model validation. The data set are available at NCEP ftp site: ftp.ncep.noaa.gov. This simple dataset provides the monthly information about TOA and surface radiative fluxes, and the modulating clouds in between. All the files are in IEEE big ending binary format, and is described in 144 x 72 (ERBE type) grid. The control files for GrADS are included. Except NVAP starts on 1988, the rest of the data set all cover the period from 1985 through 1989.

In the directory /pub/cpc/wd53sy/ OBS_CLD_RAD, six subdirectories can be found: ERBE, ISCCP, LaRCsfc, CERES_TRMM, PATMOS and NVAP.

1. ERBE (Earth Radiation Budget Experiment) contains broadband TOA longwave (olr) and shortwave (sw) fluxes for both clear-sky (cs) and total-sky.
2. ISCCP (International Satellite Cloud Climatology Program) contains cloud amount (cld) for total, high(h), mid(m) and low(l) clouds. Also included are cloud top temperature (tc) and cloud top pressure (pc).
3. LaRCsfc (Langley Research Center Surface radiation fluxes) contains surface (sfc) longwave (lw) and shortwave (sw) fluxes for downward

(d) and net (n) components. Surface albedo and Clear sky (cs) components for downward shortwave is also included.

4 CERES_TRMM onboard TRMM satellite had its first phase from Jan. 1998 through Aug. 1998. Broadband TOA longwave (olr) and reflected shortwave (rsw) fluxes for both clear-sky (cs) and total-sky are included.

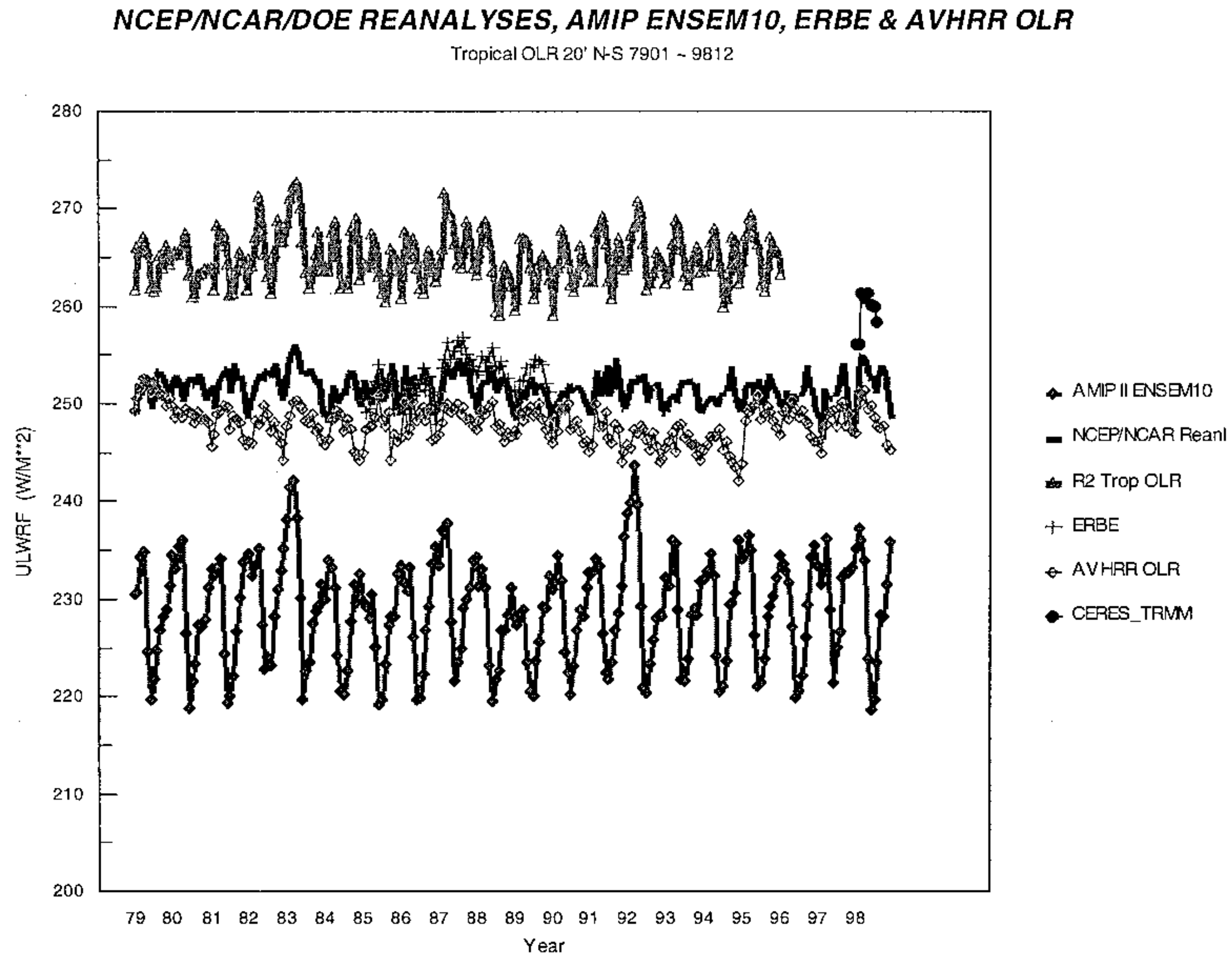

Fig.1: Intercomparison of tropical OLR from satellite, reanalyses and AMIP ensemble runs.

5. NOAA/NESDIS/PATMOS/CLAVR total cloud is in the directory /pub/cpc/wd53sy/OBS_CLD_RAD/PATMOS. It covers the period from Jan 1985 through Dec 1990. The monthly average is the mean of the ascending node and the descending node from NOAA polar satellites. As such, the data field is smoother than ISCCP, which suffers "rims" along the edges of GOES FOV. Also the global mean is ~ 59.5%. ISCCP is ~ 68%. Also, CLAVR has larger seasonal variations.

6. NVAP is in the directory /pub/cpc/wd53sy/OBS_CLD_RAD/NVAP. NVAP is a merged water vapor analysis using TOVS HIRS water vapor channel, SSM/I and rawinsonde. Since SSM/I was not available until July 1987, this data set starts at Jan 1988, and ends at Dec. 1995. Four parameters of precipitable water are included: total column, 1000-700 hPa, 700-500hPa and 500-300 hPa.

We anticipate to add a number of parameters in the near feature.
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The 10 member ensemble runs were conducted on CPC Climate Model similar to the operational Medium Range Forecast model, but with a reduced resolution of T40, and the convection scheme is slight different. The model run for 40 years starting on 1949. Here we focus on period after 1979, the year that satellite measured data became available.

Results and Discussion

Fig 1 shows a comparison of the area averaged time series of OLR over the tropics, from 20° N to 20 ° S. It reveals that OLR from NCEP/NCAR Reanalysis (R-1) agrees best with satellite observations, either ERBE or NOAA/NESDIS OLR, which is estimated from the window channel of AVHRR. At the first glance, the 8 months observation of CERES on TRMM in 1998 appears to be overestimated by 5 W/m^2. However, not shown here is an independent measurement from ERBE non-scanner instrument, which has excellent agreement with not only ERBE scanner and CERES, but also with French-Russian ScaRAB measurement performed during 1995. (The analysis was provided by T Wong and B. Wielicki of LaRC) This result indicates that there is a decadal trend of tropical OLR from late '80s to '90s. This result suggests that although R-1 has less bias with respect to satellite measurements, it does not subscribe to the observed trend. Also noted is the slight drift of NESDIS AVHRR OLR in the late '80s and early '90s and a significant jump in 1995. The drift is caused by the fact that the equator crossing time of NOAA polar-orbiting satellites drift. The jump in '95 is caused by the new launch of NOAA-15 satellite. The intercomparison among satellite data provide a bound of accuracy for validating model performance.

Comparing the OLR from ensemble run to satellite measurements shows that ensemble runs poses much stronger seasonal cycles with low bias of more than 20 W/m^2. On the other hand, the NCEP/DOE Reanalysis (R-2), which uses a similar global model for data assimilation, shows a positive bias with much reasonable seasonal cycles. Neither R-2 nor the ensemble run exhibit the tropical OLR trend of ~4 W/M**2 from late '80s to '90s. In our previous study of R-2, it was found that the tropical OLR is much more sensitive to upper tropospheric humidity than the surface temperature. Using MacClatchey tropical profile for radiative transfer calculation, it was found that OLR has 2 W/m^2 sensitivity per 10% change of 300 mb relative humidity. Relative humidity in the upper troposphere exhibits very high variability with no concrete confidence of accuracy, while the accuracy of the surface temperature is better understood and only pose 1 W/m^2 /^{o}K sensitivity for the clear sky case.

An independent verification of water vapor from ensemble run is provided by using a 5 year averaged NVAP data, 1988~1992. Shown in Fig 2 is the seasonal variations of total column and layered integrated water vapor. The difference between NVAP and the ensemble run on Fig. 2c clearly shows that ensemble overestimates the water vapor for the total column and all the individual layers. The top layer, the UTH, also shows the largest bias. This result reconfirms that the underestimation of OLR of ensemble run shown in Fig. 1 can be attributed to water vapor biases and the related physical parameterization within the model.

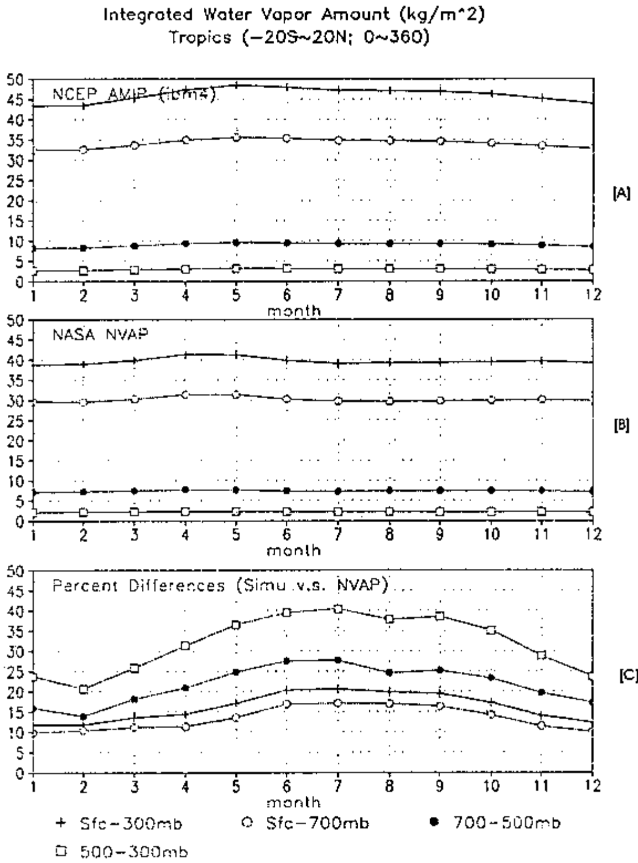

Fig 2: Comparison of R-2 and NVAP integrated water vapor amount