Operational Generation of the HIRS Outgoing Longwave Radiation Climate Data Record

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Annual Report

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Summary

Most of the first year tasks are on track and in good progress, but some parts are delayed pending on recruit of research personnel. The first year (FY2007) project milestones and their status are summarized below with detailed information follows.

Year 1 Milestones (Sept 1 2007 – Aug 31 2008)

- Construct 0.5°x0.5° HIRS OLR diurnal model - diurnal model revision completed, investigation in HIRS OLR monthly mean fields continues
- Inter-comparison with CERES and GEWEX-RFA data sets – ongoing
- Validate/assess HIRS OLR diurnal model – investigation continues
- Initiate IASI OLR algorithm development – complete: radiation simulation software installed and tested; conceptual algorithms developed
- Evaluate HIRS radiance calibration methods – delayed
- Extend the ver.1 HIRS OLR CDR from 2003 to present – delayed
- Initiate real-time monitoring system design – pending

Publication

Lee, H.-T., A. Gruber, R. G. Ellingson and I. Laszlo, 2007: Development of the HIRS Outgoing Longwave Radiation climate data set. *J. Atmos. Ocean. Tech.*, **24**, 2029–2047.

Personnel Management

As we adjusted the personnel working in this project, the recruit of a research associate / post-doc is necessary. The person that we expected to come onboard in May (who has been offered the job since February) changed her mind at the last moment and took another job. This poses a personnel shortage and caused delays in some parts of the project, particularly in the system integration and data processing. We are still in the process of hiring hoping that a successful recruit will be completed in the September/October timeframe.

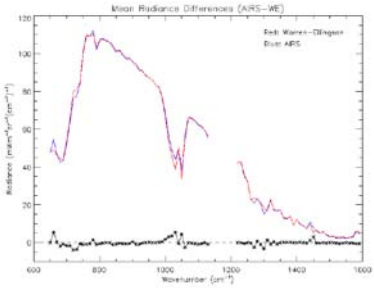
Computation and IT System

The IT infrastructure has been established with the requisition of a Darwin-based UNIX processing environment connected with dedicated working/storage space of total 1.5 terra-bytes mainly for the HIRS level1b data staging and processing purposes. One disc volume of 500 Gbytes with RAID-0 configuration guaranties data security and is mainly used for archival purpose. Intel FORTRAN and C++ pro suite compilers were purchased and installed to provide software development environment. The portability in computation codes and self-contained processing system are among the mandates for the deliverables. The real-time monitoring system design is pending since it would be part of the reprocessing system for generating OLR CDR. The integration in CDR production software is delayed.

IASI OLR algorithm development

The IASI OLR algorithm development follows the AIRS OLR algorithm development path. The assumptions and approaches of radiation simulations are kept consistent with the HIRS OLR development. We continue to use the 1600 Phillips sounding as the atmospheric profile samples and use the same cloud distribution to simulate OLR in overcast conditions. The total 3200 cases provide the regression database from which the OLR models were constructed.

Different from the HIRS, the AIRS and IASI radiance simulations were performed by the COMPRAD package (a re-package of UMBC fast transmittance algorithm by C. Barnet of NESDIS). Since the COMPRAD does not calculate broadband radiances and we do not have access to the original UMBC line-by-line codes, the irradiance and flux cannot be obtained from the same RTM the radiance was calculated. We took the OLR fluxes from Warner-Ellingson (2000) model. This creates an inconsistency between the radiance and flux simulations that later might show up as estimation biases. The mean clear sky spectral difference between the COMPRAD AIRS radiance simulation and the WE2000 spectrum simulation is shown on the right. The IASI simulation faces a similar situation.



We are also in collaboration with NESDIS/STAR in exploring the benefits of IASI's hyperspectral measurement. One approach is to estimate broadband radiance (e.g., the longwave radiance spectrum directly measured by CERES total channel during night) and convert to flux using certain angular dependence models (ADM). Huang et al. (2006) demonstrated this possibility with IRIS and a recent implementation on AIRS showed this approach very promising (Huang, 2008, at CERES-II 9th Science Team Meeting).

Diurnal Model Revision

We revised the gridding method and derived the corresponding diurnal models, hereafter referred to as Version 2 Diurnal Models. These models, if proven more accurate, will be used in deriving HIRS OLR CDR Ed. 3.

Problems in Ver.1 Diurnal Models

The initial generation of HIRS OLR time series was meant to only reprocess HIRS radiance data prior to the September 1998, after which the HIRS OLR were available operationally. The gridding approach and diurnal models at the time were designed to keep consistencies with NESDIS production system and NCDC archival practice. And one of the purposes is to provide users diurnal models that can be used to derive OLR monthly means using NCDC OLR orbital map archive. Since now that we are defining a standalone CDR production system, we will now produce gridded fields on an hourly-bin basis. The lat-lon equal-degree gridded fields include these three resolutions: 0.5°, 1° and 2.5°.

The HIRS OLR instantaneous retrievals are available in the NESDIS 'RBOBS' orbital data, which is not publicly available and were not archived. The HIRS OLR product released by NESDIS and archived by NCDC is in the form of 'orbital' maps. NESDIS produces the orbital maps (ascending and descending) a day per satellite in a certain size of grid, e.g., 1°x1°. The equator crossing time can be used to approximate the observation time for the OLR retrievals in low and mid latitudes. **Fig. 1** below shows the orbital time in local hour plotted as a function of latitude for NOAA10.

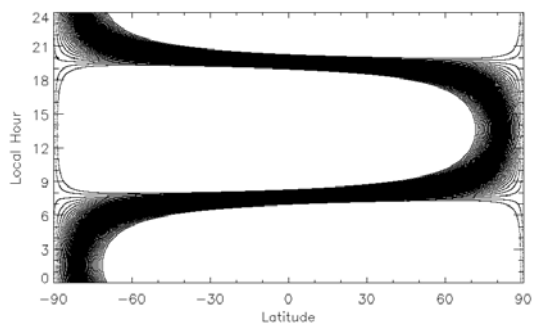


Fig. 1 Orbital time in local hour plotted as a function of latitude for NOAA10.

It can be seen that the observation time for latitudes higher than about 60° no longer can be properly represented by the equator crossing time. For lower latitudes, the orbital map contains OLR retrievals within a couple local hours, but for higher latitude (>60°) the orbital map would contain averaged values of OLR retrievals at different observation times — spanning about 6 hours (12 hours near the poles).

Fig. 2 show the January 1979 monthly mean HIRS OLR averaged for each local hour bins for 2.5° grid boxes at [10°E, 30°S/N] and [10°E, 80° S/N]. It can be seen that even at the lower latitude, the OLR were observed over 3 local-hourly bins due to the 2160 km of HIRS scan swath width. The data in higher latitudes are available in about 12 hourly bins. Relatively large variations in neighboring hours were seen at 30°N. The curve formed by the hourly bins at 80°S (Antarctica) seemed to suggest a diurnal cycle envelop with an amplitude of about 15 Wm^{-2}. In the NESDIS orbital map gridding practice, all these variations will be lost due to the averaging towards two

orbital nodal maps whose observing time (represented by equator crossing time) could have biases up to 6 hours for high latitudes. These will obscure the derivation of the diurnal models for high latitudes and possibly produced wrong phases. These problems will be eliminated in the Version 2 diurnal models.

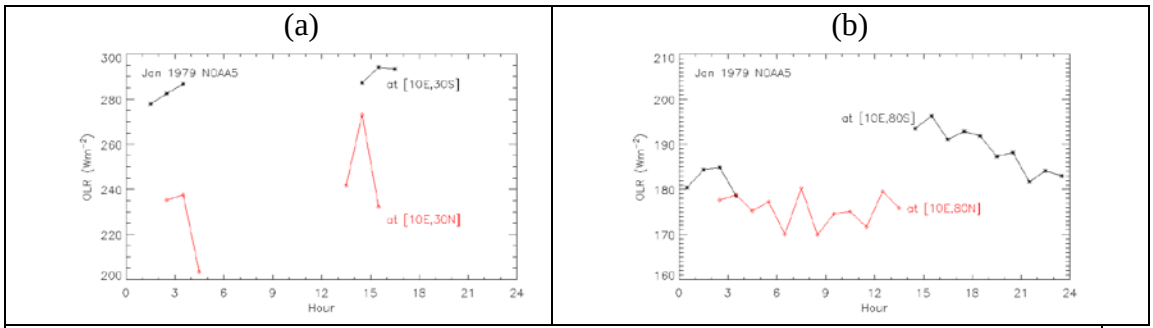


Fig. 2. Monthly mean HIRS OLR averaged for each local hour bins for 2.5° grid boxes at a) [10°E, 30°S/N] and b) [10°E, 80° S/N] for January 1979.

<u>Comparison of Ver.1 and Ver.2 Diurnal Models</u>

We use the same analytical expression to represent the OLR diurnal cycle. The fitting results were compared between ver.1 and ver.2 for Sahara (**Fig. 3**), Tsaidam Basin (**Fig. 4**) and Antarctica (**Fig. 5**). It can be seen that the hourly-bin data are 'noisier' than the orbital map data. This is due to the smoothing effects of inter-annual variations when the orbital map was used. The fitting regressions therefore explained less variance in ver.2 than the ver.1 (e.g., over the Sahara desert and Tsaidam basin where OLR diurnal variation is the most profound). However, it seems the diurnal models over the Antarctica are better defined when the observing times were kept separately.

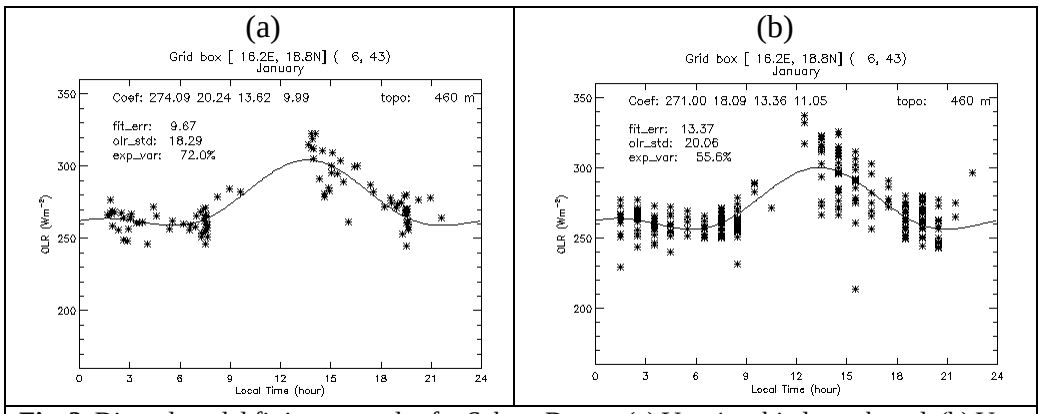


Fig. 3. Diurnal model fitting examples for Sahara Desert. (a) Ver. 1: orbital map based, (b) Ver. 2: hourly-bin based.

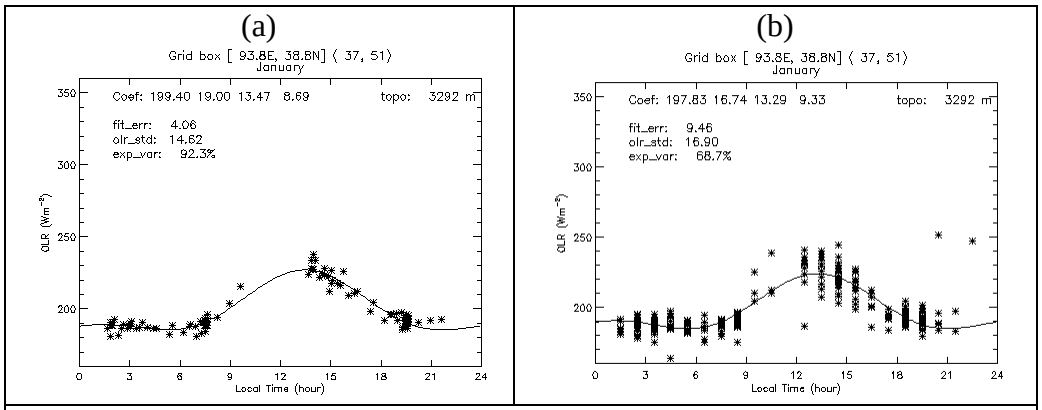


Fig. 4. Similar to Fig. 3 but are for Tsaidam Basin.

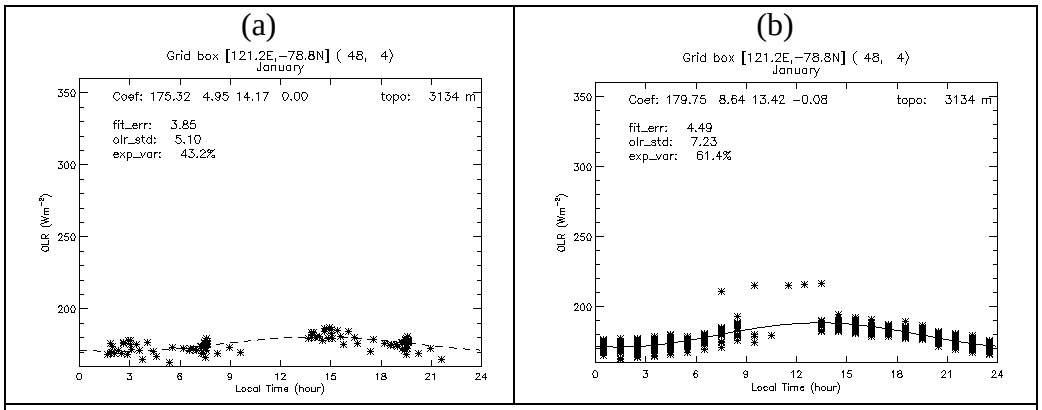


Fig. 5. Similar to Fig. 3 but are for Antarctica.

The phases of the versions 1 and 2 diurnal models are shown in **Figs. 6 and 7** for January and July, respectively. The most notable changes occurred in the high latitudes. In January, the version 2 has more uniform phases around 23 to 01 hour local time for north polar cap while the Antarctica has a near noon phases. The phases over north polar cap and Antarctica have large changes in July between version 1 and 2 that the version 2 now indicates a late morning to noon phases for the Antarctica while the north polar cap has relatively uniform phases around local noon. Although we think the version 2 would have more realistic diurnal variations, these diurnal models are yet to be verified objectively.

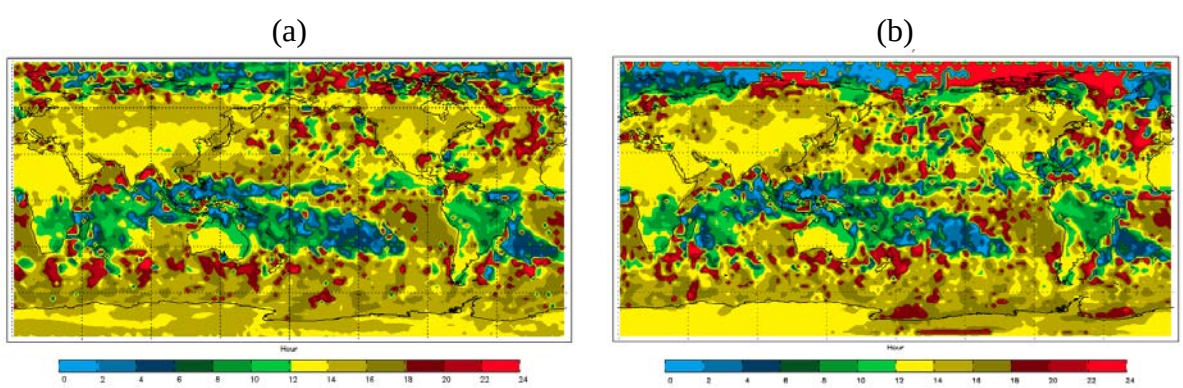


Fig. 6. Phase of the diurnal models for January. (a) Version 1. (b) Version 2.

(a) (b)

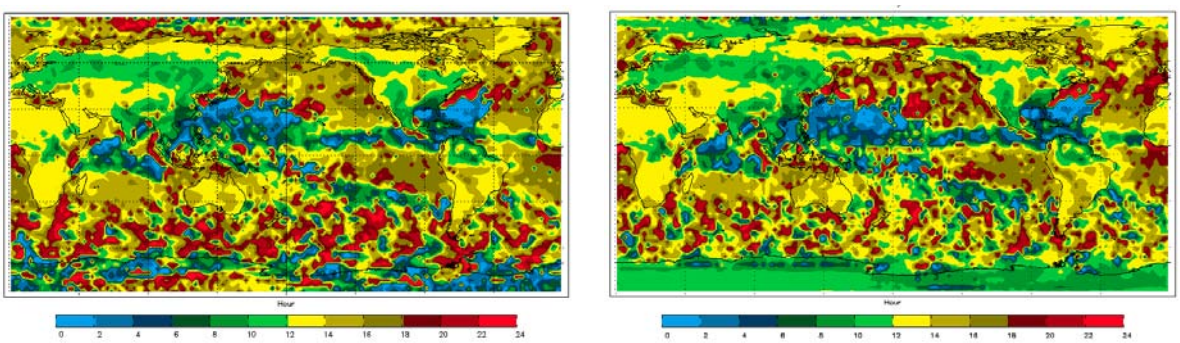


Fig. 7. Phase of the diurnal models for July. (a) Version 1. (b) Version 2.

We expect the OLR monthly mean derived with version 2 diurnal models and hourly-bin gridded time series will be slightly different from the Ed.2 HIRS OLR CDR, particularly in the tropics. The impact from diurnal modeling change is yet to be assessed.

Diurnal Model Validation

We use two approaches to validate the OLR diurnal models. First is a direct comparison of the climatological OLR diurnal model with those observed by the geostationary satellites. OLR products from geostationary satellites were derived routinely or experimentally from GOES sounder/imager, GERB, and SEVIRI. Those are sources of references. However, it is difficult to gauge this comparison. Besides that we will be comparing instantaneous observations (even from a monthly mean) to climatology, there is not a good measure for describing the realism of diurnal models. The second method is to assess its effect on the OLR temporal integration. Again, this method does not exactly produce a measure on the diurnal models as other factors are involved in such comparisons. Nevertheless, the second method (assessing on the OLR itself) is more or less the objective for using realistic and robust diurnal models. Before the geostationary observations can be integrated into daily/monthly mean OLR production, the diurnal model is an invaluable tool to handle the observation time changes in the polar observing system.

The following assessments were in part performed under the GOES-R risk reduction project that the GOES imager OLR data were compared to the HIRS diurnal models. The example shown in **Fig. 8 and 9** compares the phase of the climatological August OLR diurnal models (derived from HIRS OLR data) to that of the GOES Imager observed in August 2002. The two fields agreed in a great extent including most of the land, over the Atlantic, and over the south Pacific.

Fig. 10 shows several typical OLR diurnal cycles over Andes, Sierra Madre Occidental, Amazon, Subtropical Pacific Ocean and Gulf of Mexico. The curves are the fitting results of the GOES imager 3-hourly OLR estimates fitted to the analytical form of the HIRS OLR diurnal models. The goodness of the fit in the various patterns of diurnal variations indicates the robustness of the analytical expression as well the fitting procedures. The large variety of OLR diurnal variation also supports the need for regional-based modeling.

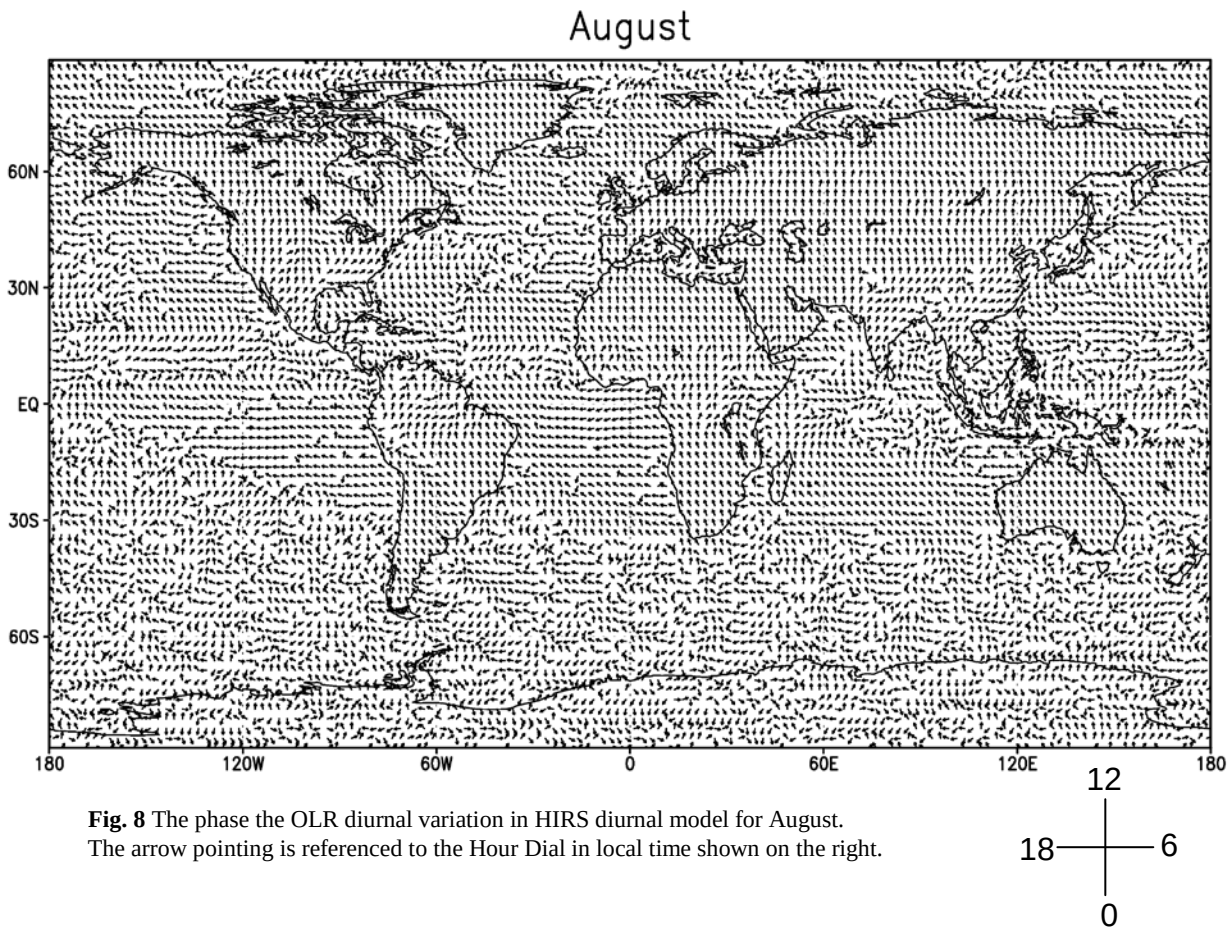


Fig. 8 The phase the OLR diurnal variation in HIRS diurnal model for August. The arrow pointing is referenced to the Hour Dial in local time shown on the right.

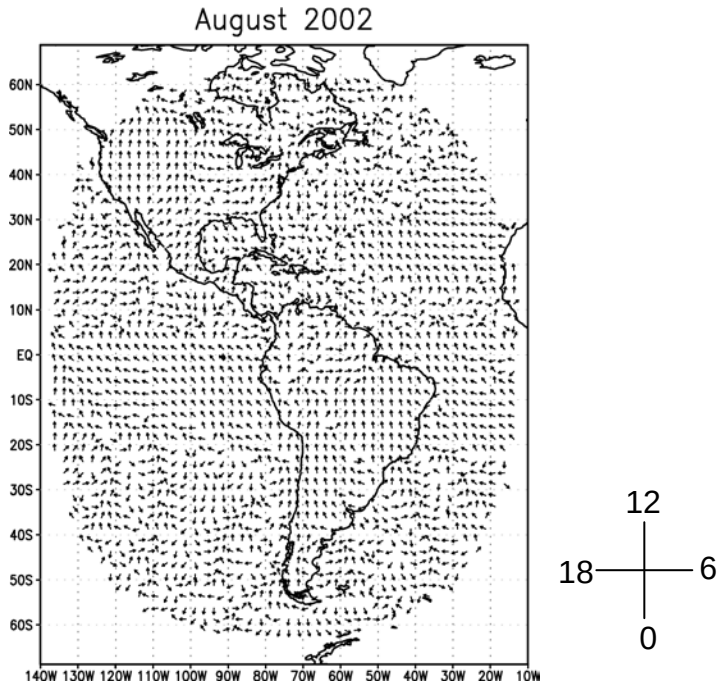


Fig. 9 Similar to Fig. 8 but is with GOES Imager OLR averaged for August 2002.

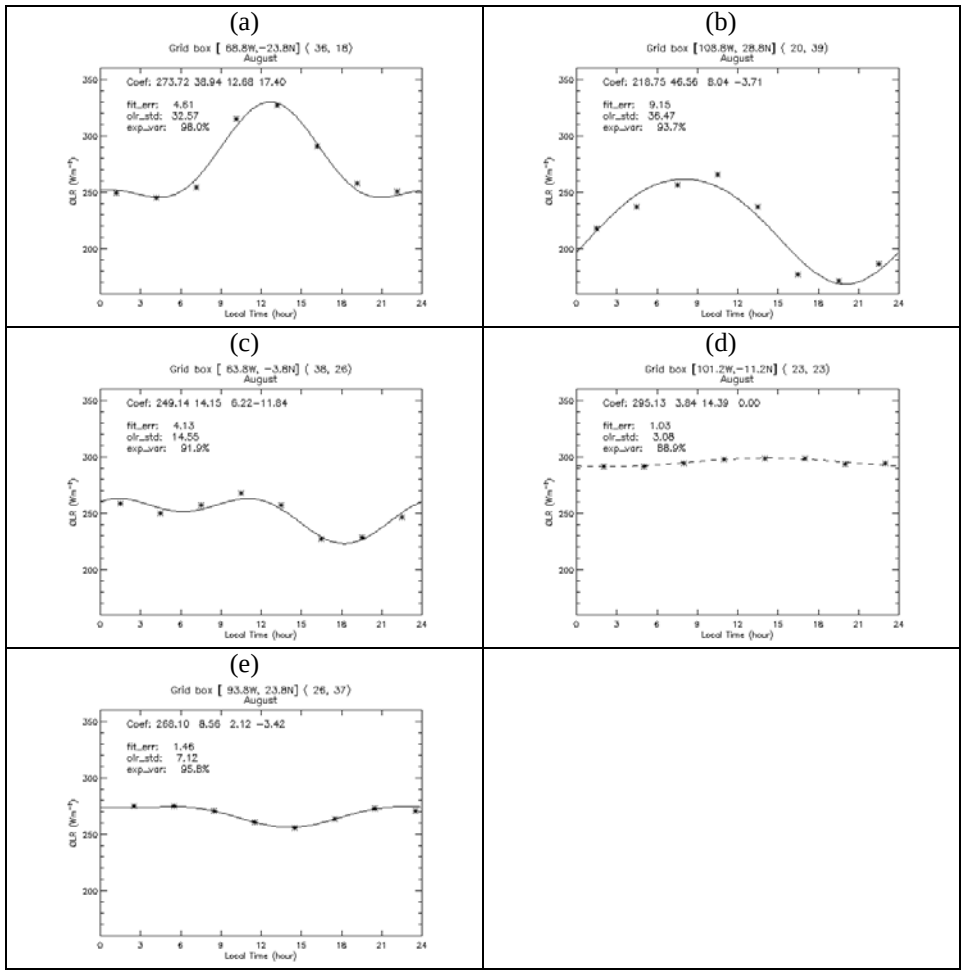


Fig. 10 Examples of OLR diurnal variation. a) Andes, b) Sierra Madre Occidental, c) Amazon, d) Subtropical Pacific Ocean, e) Gulf of Mexico

Inter-comparison with CERES and GEWEX-RFA data sets

We continue to actively participate in the GEWEX radiative flux assessment (RFA) activity. The first GEWEX RFA meeting in June 2007 in GISS New York brought the survey and status of radiative data set up to date. A RFA draft report is under preparation by the group.

Recently Takmeng Wong (NASA/Langley) derived the OLR relative biases over the tropics for all broadband data sets from NIMBUS-7 to Aqua. This extended the time period range that the HIRS OLR time series can be compared with broadband products. **Fig. 11** shows the tropical mean (20S-20N) OLR from broadband measurements before and after the relative biases removed. Three other OLR data sets were overlaid for comparison purposes, including the HIRS OLR (labeled as NOAA OLR), and the two GEWEX OLR products – ISCCP-FD and GEWEX SRB. These relative biases agree closely with our earlier assessment comparing HIRS OLR CDR to ERBE non-scanner/scanner and CERES scanners (Lee *et al*, 2007). With the biases removed, the agreement between the broadband OLR time series and that of the HIRS OLR is superior. The HIRS OLR shows very good quality in absolute radiometry, variability, and stability. All of these attribute to the success of being a climate data record.

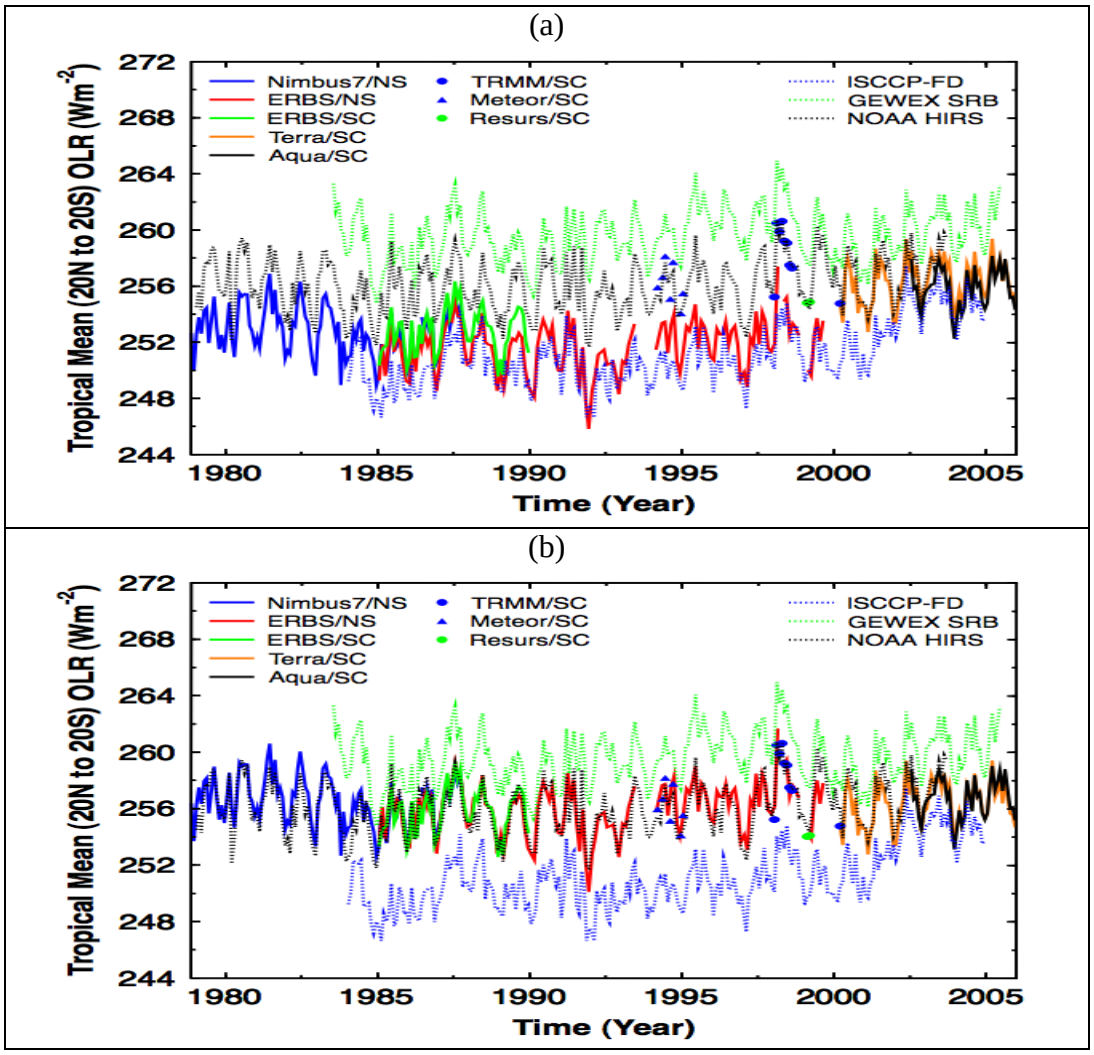


Fig. 11. Tropical mean OLR time series derived from broadband measurements from NIMBUS7 to Aqua (a) before and (b) after bias adjustment. (Plots courtesy T. Wong). HIRS OLR (black dots) and the two GEWEX products (ISCCP-FD (blue dots) and GEWEX SRB (green dots)) were shown in both plots. The agreement between the adjusted broadband OLR time series and the HIRS OLR is superior.

Extension of the ver.1 HIRS OLR CDR (delayed)

We obtained the updated HIRS level1b data from NCDC. We want acknowledge the help provided by Axel Graumann of NCDC on this laborious and lengthy process. While the level1b data is stored locally ready for processing, the processing system is yet to be streamlined. Our design is to create a reprocessing and production system that integrate all the components, modularize the various aspects that would ease the upgrade of techniques or absorption of new science input. This implementation and software engineering task is partially delayed.

Evaluate HIRS radiance calibration methods (delayed)

There are several candidate HIRS radiance calibration methodologies that we'd like to evaluate. The McMillin (POES Users Guide, 1998) algorithm that we currently are using secures the scans with calibrations at both ends (the beginning and ending of 40 scan lines), while empirically

adjusting gain factor as a function of the ambient temperature. The current NESDIS operational calibration method, named as Version 4, was developed by C. Cao to address specifically the temperature fluctuation issues (started in NOAA15). Whether the latest calibration method can improve radiance quality (and reduce OLR uncertainty) is yet to be examined.

Publication

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Milestones for Second Year (FY2008)

2007 Extend the ver.1 HIRS OLR CDR from 2003 to present
Inter-comparison with CERES and GEWEX-RFA data sets
Construct 0.5°x0.5° HIRS OLR diurnal model
Validate/assess HIRS OLR diurnal model
Evaluate HIRS radiance calibration methods
Initiate IASI OLR algorithm development
Initiate real-time monitoring system design

2008 Establish near real time HIRS OLR CDR production system
Inter-comparison and quality assessment (continue)
Complete IASI OLR algorithm development
Initiate design of version 2 HIRS OLR CDR
Initiate CrIS OLR algorithm development
Initiate implementation for operational production
Initiate operational real-time monitoring system

2009 ATBD for Version 1 HIRS OLR CDR
Inter-comparison and quality assessment (continue)
Complete CrIS OLR algorithm development
Operational production of HIRS OLR CDR
Opertaional real-time monitoring
Reprocessing for version 2 HIRS OLR CDR

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Budget (thousands of Dollars) Year 2 update

	FY07 Year 1	**FY08** **Year 2**	FY09 Year 3
Salary			
Dr. Hai-Tien Lee, Co-PI (YR2: 3 MOs)	3.4	17.8	37.7
Dr. Arnold Gruber, Co-PI (YR2: 3 MOs)	20.0	10.0	22.1
Res Associate (YR2: 4.5 MOs)	28.5	28.2	0
Fringe Benefits	13.8	15.7	15.3
Equipments			
PC	2.5	0	0
Other Direct Costs			
Research Materials	0.3	0.3	0.3
Publications			
Page charges	3.0	1.9	2.2
Direct Cost	71.5	74.1	77.6
Indirect Cost	33.5	35.9	37.6
Total Request (K)	105.0	110.1	115.2