CLOUDS AND THE EARTH'S RADIANT ENERGY SYSTEM (CERES)

VALIDATION PLAN

TIME INTERPOLATION AND SYNOPTIC FLUX COMPUTATION FOR SINGLE AND MULTIPLE SATELLITES (SUBSYSTEM 7.0)

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7.1 INTRODUCTION

7.1.1 Measurement and science objective

The satellites that carry the CERES (Wielicki et al., 1996, 1998) and Earth Observing System (EOS) instruments do not provide continuous spatial and temporal coverage of the Earth's entire surface. In order to obtain accurate monthly averages of the cloud and radiative parameters, accurate temporal modeling of their diurnal cycles is therefore essential. Using a state-of-the-art time and space averaging algorithm, CERES will calculate the monthly averages of the cloud and radiative parameters by producing accurate estimates of these quantities at the top of the atmosphere (TOA), within the atmosphere, and at the surface at 3-hourly GMT time intervals (Young et al., 1998). This synoptic information can be used to improve the overall quality of the global cloud and radiation database and to aid the validation and testing of global models.

7.1.2 Missions

The CERES instruments will be flown on multiple satellites, which include TRMM, Terra, and Aqua, to provide the diurnal sampling necessary to obtain accurate monthly averages of the TOA radiative parameters.

7.1.3 Science data products

The CERES Subsystem 7 data algorithm produces the synoptic flux and cloud data product (SYN). This data product contains regional longwave (LW) and shortwave (SW) radiative fluxes for the surface, within the atmosphere, and TOA and cloud properties within the atmosphere. The data are synoptically computed at 3-hourly GMT intervals on a CERES 1-degree equal-angle grid, and are based on measurements from multiple CERES instruments. This synoptic information will then be used in CERES Subsystem 8 to compute accurate monthly averages of the cloud and radiative parameters. There are 106 data parameters in the SYN data product. These include the synoptically averaged estimates of SW and LW flux at the TOA, within the atmosphere, and at the surface, the synoptically averaged estimates of cloud information within the atmosphere, the standard deviations of these estimates, their maximum and minimum value, and the scene type information. The complete list of data parameters is in the CERES Data Products Catalog (http://asd-www.larc.nasa.gov/DPC/DPC.html).

In the next section, we outline the method adopted by the CERES Time Interpolation and Spatial Averaging (TISA) working group for validating the SYN data product. Section 7.3 and 7.4 concentrate on pre-launch and post-launch validations. Section 7.5 discusses the implementation of the validation data set in data production. A summary is given in Section 7.6.

7.2 VALIDATION CRITERION

7.2.1 Overall approach

The cornerstone of the CERES SYN algorithm is the incorporation of the geostationary satellite data into the time and space averaging scheme to account for the diurnal cycles of cloud and radiation fields which are insufficiently sampled by the CERES and EOS instruments. Specifically, the algorithm uses the geostationary data to assist in determining the shape of the diurnal cycle while it uses the CERES observations as the absolute reference to anchor the more poorly calibrated geostationary data. The TOA LW flux is interpolated to the synoptic times in one of two ways. In method 1, the technique is identical to that used in ERBE-like processing (Subsystem 3.0). The second method is the geostationary-enhancement technique which uses narrowband geostationary information to provide a more accurate picture of the shape of the diurnal curve that is fit to the observation. The geostationary-enhancement technique is used whenever possible. Whenever narrowband data are not available or are inadequate, the TOA fluxes are derived using the ERBE-like technique. Time interpolation of the clear-sky TOA LW flux is performed in a manner identical to the total-sky product. The averaging of SW data is not as straightforward as LW data. Unlike the LW flux case, the SW flux interpolation process is heavily dependent upon angular dependence models. Time interpolation of cloud properties is performed using three main assumptions. First, the properties of the cloud pressure categories can be interpolated independently. Secondly, cloud properties for each region are interpolated independently from surrounding regions. Lastly, variations in cloud properties between CERES observation times can be modeled as linear. Atmospheric and surface fluxes at synoptic times are determined using radiative transfer models and synoptic input of cloud and atmospheric structure data within the atmosphere, and TOA fluxes. Additional information about this algorithm can be found in the CERES ATBD document (http://asd-www.larc.nasa.gov/ATBD/ATBD.html). The input to this subsystem includes (1) hourly gridded single satellite CERES fluxes and clouds data (FSW), (2) atmospheric structures data (ASTR), and (3) gridded geostationary narrowband radiances data (GGEO). The outputs are the synoptic flux and cloud data product (SYN).

The validation of this subsystem is an integral part of the CERES system. The purpose of this validation is to thoroughly test the subsystem and detect possible problems or errors. The overall approach to validating the SYN data product follows that outlined for the ERBE-like data product (Subsystem 3). This includes the validation of both the Subsystem 7 science algorithms and their associated science data product. Details of this approach can be found in the validation plan of Subsystem 3 and will not be repeated here. In order to conserve resources, the CERES TISA working group will not be validating every data parameter listed in the SYN science products. Instead, the validation is only performed for a set of emphasized parameters. These data parameters will include 1) LW and SW TOA all-sky flux, 2) LW and SW TOA clear-sky flux, 3) all-sky window radiance, 4) LW and SW surface flux, 5) all-sky atmospheric flux at tropopause and 500-

mb surface, 6) cloud amount, 7) cloud particle size, 8) cloud liquid and ice water path, 9) cloud emittance and optical depth, and 10) cloud height and thickness.

7.2.2 Sampling requirements

In order to validate SYN data product, the CERES TISA working group will require a minimum of six months of data from each of the CERES satellites. Validation priority will be for 1) the first month of data; 2) 4 seasonal months (January, April, July, October); 3) the first full year of data. Additional data months are also required to perform data consistency tests between different satellites (i.e., TRMM against Terra, TRMM against Aqua, and Terra against Aqua).

7.2.3 Measure of success

Some estimates of the uncertainties in the monthly mean data parameters due to time and space averaging processes can be obtained from limited case studies that are currently underway. These error estimates are given in Tables 1 and 2 below. Values for the cloud parameters and the atmospheric fluxes are based on first order assessment. When applicable, estimates are given for both clear-sky and all-sky conditions These tables show the best appraisals of the accuracy goal currently available for Subsystem 7. However, these values will be updated by the CERES TISA working group as more information becomes available.

In order to approach the validation activity in a systematic matter, the CERES Science Team has adopted a two-step process for validating this subsystem. This process can be broken down into the pre-launch and the post-launch validation. The details of these validations are outlined in the next two sections.

7.3 PRE-LAUNCH ALGORITHM TEST/DEVELOPEMENT ACTIVITIES

The pre-launch objective is to validate methods and algorithms. The procedures for the pre-launch validation activities are already given in Subsystem 3 and will not be repeated here. Instead, we concentrate on the description of the pre-launch validation activities and data set.

7.3.1 Field experiments and studies

The verification of the surface and atmospheric fluxes and the cloud product information can only be done using independent data obtained from intensive field experiments and/or special validation data sets. The CERES TISA working group is working very closely with CERES Clouds and SARB working groups during the pre-launch period to define suitable data sets for testing of these SYN algorithms. Examples of intensive field experiments that are currently being used to verify the quality of the pre-launch algorithm are the TOGA/COARE cloud and radiation data derived from GMS satellite, ARM cloud and radiation data derived from CAGEX (Charlock and Alberta, 1996) and GOES satellite, ASTEX cloud and radiation data derived from METEOSAT satellite, and cloud and radiation data derived during the ARESE experiment. Examples of special validation data include clouds and radiation data derived from the special Pathfinder data product

Table 1: TISA Error Estimates for Synoptic 3-hourly Radiative Parameters.

Parameter	Clear-sky Bias Error	Clear-sky RMS Error	All-sky Bias Error	All-sky RMS Error
TOA SW_{up} (Watts/m^2)	1	20	1	20
TOA LW_{up} (Watts/m^2)	0.3	6	0.3	6
Surface SW_{up} (Watts/m^2)	1	10	1	10
Surface SW_{down} (Watts/m^2)	10	30	10	30
Surface LW_{up} (Watts/m^2)	2	15	2	15
Surface LW_{down} (Watts/m^2)	8	15	8	20
Surface LW_{down} (Watts/m^2)	2	30	2	30
Surface LW_{down} (Watts/m^2)	4	10	4	10
Atmospheric LW_{up} (Watts/m^2)	5	15	5	15
Atmospheric LW_{down} (Watts/m^2)	2	5	2	5

Table 2: TISA Error Estimates for Synoptic 3-hourly Cloud Product.

Parameter	RMS Error
Cloud amount	20%
Cloud particle size	80%
Cloud liquid/ice water path	100%
Cloud emittance	30%
Cloud visible optical depth	80%
Cloud height	20%

and special high temporal resolution data derived from GOES satellite. A special validation output product from each of these data sources will be produced to aid this validation process. This product will contain the following items:

1. Time series plots of cloud and radiation parameters over a pre-selected set of validation regions, latitude zone, and the globe.
2. Zonal and global averaged monthly mean images of these parameters.
3. Two dimensional error analysis results of the data product (if available).

The pre-selected set of validation regions includes 1) the validation sites from Subsystem 3 (see Table 2 in Subsystem 3), 2) class 1 and 2 sites from Subsystem 5 (see Tables 1 and 2 from Subsystem 5), and 3) additional sites located at different universities (i.e., University of Utah, University of Miami, and Pennsylvania State University). These special validation regions cover a wide range of climatic locations and will be useful in testing the overall robustness of the SYN algorithm in handling data for various scene types and cloudiness conditions.

7.3.2 Operational surface networks

Operational surface networks are required for validation of the surface radiation fields. These networks are outlined in Subsystem 5 and will not be repeated here.

7.3.3 Existing satellite data

Many of pre-launch algorithm activities for testing the TOA fluxes and cloud information have already been performed using limited historical ERBE TOA scanner data and matching narrow-band geostationary information. Some of these results are given in the CERES ATBDs and in the proceedings of the CERES Science Team meetings. Additional tests based on CERES system-wide end-to-end pre-launch simulation of the Release 1 algorithm are currently being performed using inputs from archival October 1986 ERBE TOA scanner data and ISCCP B3 data set. These activities will be used to check the quality of the TOA TISA algorithms, verify improvements in sampling error, and validated algorithm I/O and operation. Questions concerning software and system-wide problems will also be addressed. In addition, the data processing system will be tested for interface compatibility with other CERES subsystems. Timing tests will also be performed to define future scheduling requirements.

7.4 POST-LAUNCH ACTIVITIES

Post-launch validation concentrates on examination and verification of the CERES results. Specifically, the main purpose is to determine whether the results are qualitatively acceptable and agree reasonably well with expected quantitative results derived from other independent data sources. The procedures for the post-launch validation activities were given in Subsystem 3 and will not be repeated here. Instead, we concentrate on the description of the post-launch validation data set.

7.4.1 Planned field activities and studies

Independent data sets from intensive field experiments are needed for post-launch validation of the SYN data product. Working in conjunction with CERES Clouds and SARB working group, the CERES TISA working group plans to acquire long-term records of cloud and radiation data from a number of intensive field experiments. This includes cloud and radiation data obtained from class 1 sites (i.e., ARM/Southern Great Plains (SGP), ARM/Tropical Western Pacific (TWP) and ARM/North Slope of Alaska (NSA)), future TOGA, FIRE, and UAV experiments. In addition, long term record of surface observations from class 2 sites, including NASA/LaRC Chesapeake Lighthouse, Boulder Tower, NOAA sites, and Baseline Surface Radiation Networks (BSRN) sites will also be used to validate surface radiation parameters. Additional information about these surface sites can be found in the CERES SARB validation plan (Subsystem 5).

Several EOS validation efforts will provide additional validation for CERES temporally interpolated and averaged products. These include “The Evaluation of Outgoing Longwave Radiation Budget Parameters using the GOES Sounders” with Robert Ellingson as PI; “Validation of the CERES Surface Radiation Budget Using Long-Term Observations from the Indian Ocean Experiment”, with William Collins as PI; and “Intercomparison of SCARAB, ERBE, and ISCCP Seasonal Flux Variability”, with Andrew Lacis as PI.

7.4.2 New EOS-target coordinated field campaigns

N/A

7.4.3 Needs for other satellite data

Independent data sets from special validation data sources are needed for post-launch validation of the SYN data product. Specifically, the CERES TISA working group plans to acquire 1-hourly (if available) geostationary data (i.e., GOES-8, GOES-9, METEOSAT, and GMS) as a source for validating CERES TISA TOA sampling errors. In order to facilitate intercomparison between the two data sets, the narrowband radiances from the geostationary satellites will be converted to broadband fluxes using narrowband-to-broadband conversion relationships and angular dependence models. In addition, the CERES TISA working group will also be acquiring data, if available, from the ERBE Nonscanner and the ScaRaB II scanner. An additional data set that would be extremely valuable for validating the temporal interpolation of clouds and radiative fluxes will be combination of the European Geostationary Earth Radiation Budget (GERB) and cloud properties derived from the SEVIRI instrument on the METEOSAT Second Generation Satellite. Cloud properties from SEVIRI would be of greatest value if derived with an algorithm that is consistent with CERES. The Triana hemispherical albedos and LW fluxes will also provide a measure of the globally integrated CERES fluxes.

A major component of the temporal interpolation process used in CERES is the addition of geostationary data. Crucial to the success of the algorithms using these data is the accurate calibration of these data. Extensive validation efforts to assure this calibration will include:

1. Calibration of geostationary visible radiances with angular-matched, coincident VIRS data.
2. Calibration of geostationary IR temperatures with coincident VIRS data.
3. Comparisons of geostationary-derived cloud properties with VIRS-derived cloud properties.
4. Derivation of monthly narrowband/broadband relations using coincident geostationary and CERES data.

A schedule of post-launch validation studies that will be performed for the SYN products is given in Table 3 below.

Table 3: CERES Monthly Mean SFC/TOA/Atmosphere Validation Schedule

Year	**1998**				**1999**				**2000**				**2001**				**2002**			
Quarter	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Instantaneous vs. Integrated										x										
Validate Monthly Averaging Code											x									
Synoptic vs. GCMs											x									
TRMM SS8 vs. SS10													x							
TRMM instantaneous vs. surface data														x						
TRMM instantaneous vs. COVE & CAGEX														x						
Terra SS8 vs. SS10																x				
Terra instantaneous vs. surface data																	x			
Terra instantaneous vs. COVE & CAGEX																	x			
Aqua SS8 vs. SS10																			x	
Aqua instantaneous vs. surface data																				x

Table 3: CERES Monthly Mean SFC/TOA/Atmosphere Validation Schedule

Year	**1998**				**1999**				**2000**				**2001**				**2002**			
Quarter	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Aqua instantaneous vs. COVE & CAGEX																				x

7.4.4 Measurement needs (in situ) at calibration/validation sites

Special in situ measurement of cloud and radiation parameters are needed at validation sites to verify the SYN products. Details of these measurements can be found in the validation plan for Subsystem 4 (clouds product) and 5 (surface and atmospheric radiation product) and will not be repeated here.

7.4.5 Needs for instrument development

N/A

7.4.6 Geometric registration site

N/A

7.4.7 Intercomparision

After the launch of the Terra and the Aqua satellite, the new CERES radiation data set can be validated by comparison with special validation data products from TRMM satellite. Furthermore, Terra can be used to validate Aqua data.

7.5 IMPLEMENTATION OF VALIDATION RESULTS IN DATA PRODUCTION

7.5.1 Approach

The procedures for pre-launch and post-launch validation of this subsystem were outlined in the previous section. The results of these validations should, in general, lead to further improvement in the quality of the CERES data set. Major problems discovered after data production will be recorded and techniques for resolving problems will be developed. Correction of these problems will be implemented during the CERES data reprocessing period.

7.5.2 Role of EODSIS

EOSDIS will provide special processing of SYN data products for regions containing validation sites.

7.5.3 Plans for archival of validation data

The results of the validation and their associated problems will be stored at the NASA Langley Research Center. The user community can access these information either through an anonymous FTP account or through the use of World Wide Web browser technology.

7.6 SUMMARY

This document describes a plan for validating the CERES SYN data product. The validation plan is broken up into two stages; the pre-launch and the post-launch stage. A minimum of one year of data from each of the CERES satellites will be required to validate the data products. The validation efforts will be concentrated on a set of emphasized parameters. A set of special validation regions will be used to identify and to record problematic areas associated with the SYN data product. EOSDIS will provide special processing of CERES SYN data product for regions containing these validation sites.

Working very closely with the CERES clouds and SARB working group, the CERES TISA working group has completed some of the pre-launch testing of the SYN algorithm. The results of these activities are reported in the CERES ATBDs and in the proceedings CERES Science Team meetings. Additional pre-launch tests based on CERES system-wide end-to-end simulation using archival October 1986 ERBE TOA scanner data set are currently underway. The post-launch validation will employ geostationary narrowband data to verify the CERES TISA TOA sampling errors. Additional data sets, if available, will be obtained from ERBE nonscanner, ScaRaB II scanner, and GERB for direct TOA comparison. Validation of cloud and surface and atmospheric fluxes will require independent data sets from intensive field experiments. Working in conjunction with the CERES Clouds and SARB working groups, the CERES TISA working group plans to acquire long-term records of cloud and radiation data from a number of intensive field experiments. This includes cloud and radiation data obtained from class 1 sites (i.e., ARM/Southern Great Plains (SGP), ARM/Tropical Western Pacific (TWP) and ARM/North Slope of Alaska (NSA)), future TOGA, FIRE, and UAV experiments. In addition, long-term records of surface observations from class 2 sites, including the CERES CAVE network, NASA/LaRC Chesapeake Lighthouse, Boulder Tower, NOAA sites, and Baseline Surface Radiation Networks (BSRN) sites will also be used to validate surface radiation parameters (see Subsystem 5 for additional information). The results of the validation and their associated problems will be stored at the NASA Langley Research Center. The user community can access these information either through an anonymous FTP account or through the use of World Wide Web browser technology.

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