Progress report (Year 1)
Date: 02/16/2011
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Title: Development of a radiation climate data record combining ERBE and AVHRR
Award Period: 07/01/2010 – 06/30/2013.

Long-term research objective and objectives of this term
Reprocess NOAA-9 and NOAA-10 ERBE scanner data using CERES angular distribution models and cloud properties derived from AVHRR, and produce CERES standard products with NOAA-9 and NOAA-10 ERBE data. Objectives of this term were to generate Instrument Earth Scan (IES) product that contains, spacecraft position, viewing geometry, and ephemeris information and to prepare inputs to generate the level 1 Instrument Earth Scan (IES) product and SSF level 2 product from ERBE level 2 product S8. The IES and SSF products are base products of all other CERES products. Producing the IES and SSF products from the ERBE S8 product involved more than just a format conversion. It required the coordinate change by identifying satellite position, viewing angles, and scanning direction. To produce SSF and apply CERES angular distribution models, cloud properties derived from AVHRR need to be collocated with ERBE footprints.

Specific objectives of this term:
a) Change ERBE coordinate from geocentric to geodetic and reference all viewing geometry and solar zenith angle at the surface instead of at 30 km.

b) Work toward generating cloud properties from NOAA-9 AVHRR.

c) Generate common inputs to be used for various different processes in the project. The common inputs include temperature and humidity profiles, snow and sea ice maps.

Accomplishments/Highlights during Year 1 (this period)
1) **NOAA 9 and NOAA 10 ERBE scanners comparison**
We have established method to compare radiance measurements by two ERBE scanners. An example of the result of ERBS and NOAA-9 scanners comparison is shown below.

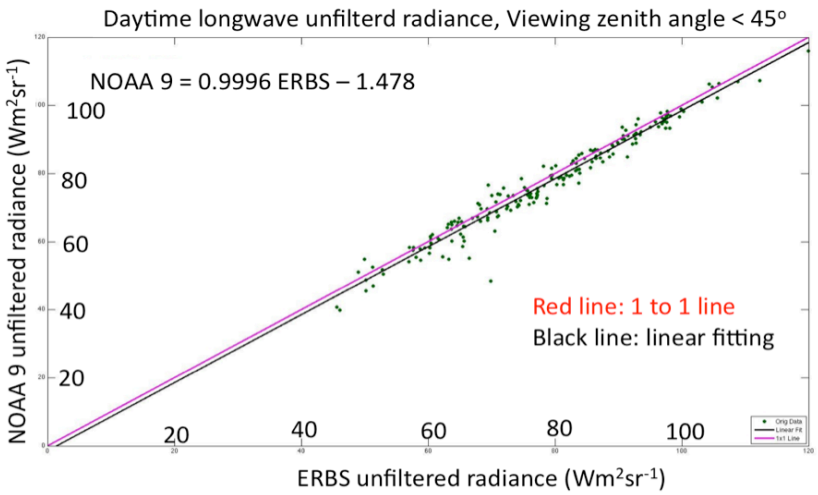

Figure1: Comparison of unfiltered radiances observed by ERBS and NOAA-9 ERBE scanners. Radiances are collocated and radiances from two scanners observed within 5 minutes and within 1° viewing zenith are used. Each dot represents a one degree by one degree grid average of collocated radiances.

2) **ERBE S8 data product to IES and SSF product conversion**

We have generated algorithms that take ERBE S8 data product and generate necessary inputs to produce IES and SSF products, which form foundations of all other CERES products.

In order to generate the CERES-like products from ERBE data taken from NOAA-9 and NOAA-10 satellites combined with AVHRR data, the first step is to produce ERBE Instrument Earth Scan (IES) data product that is similar to IES generated from CERES data. IES data product contains one hour of data from the scanner footprint and only records Earth-Viewing measurements. (For detail information on IES data product, see CERES Data Products Catalog R3V). The ERBE s8 Processed Archival Tape (PAT) files are readily available in the archive, and thus can be used to generate the IES data products for ERBE. Each s8 product contains ERBE data for a 24-hour period. All of the data in s8 products are ordered chronologically and are divided into 16-second records. More details on s8 data products can be obtained from "Earth Radiation Budget Experiment (ERBE) S-8 Processed Archival Tape (PAT) Data in Native (NAT) Format Langley ASDC Data Set Document".

For ERBE, the scanner cycle is 4 seconds so that 4-cycles are recorded on each 16-second record of s8 product. Each 4-second cycle is divided into 120 time increments or 30 increments per second. The scanner views the earth during increments 9 to 70. Thus, there are 248 Earth-viewing footprints stored in each 16-second record. IES being the hourly data product, the ERBE-IES will contain approximately 55800 (248 × 225) measurements. Though s8 can be used to generate ERBE-IES, not all of the measurements present in IES are readily available in s8. In addition, measurements such as location and viewing angles in ERBE s8 are at the top of the atmosphere (TOA) and

geocentric while it is at the surface and geodetic in CERES-IES. Thus, missing data needs to be either calculated using available data in s8 products or converted from one unit to another.

As explained earlier, the CERES-IES data products contains one hour of data records where each record contains following information:

a) Time of Observation
b) Geolocation Data (at both the TOA and the Earth's surface)
c) Filtered Radiance (at Satellite Altitude), with associated quality measures
d) Spacecraft Orbital data
e) Footprint viewing geometric data

For ERBE s8 product, the Julian date and time at the beginning of each 16-second record is present. As discussed previously, 16-second record consists of 4-cycles with total of 480 (120 × 4) measurements. Using this information, the time of observation for each footprint measurement can easily be calculated.

In addition to the Julian date and time, s8 product also contains the position and velocity of the spacecraft at the beginning and end of every 16-second records. Using these start and end spacecraft positions and velocities, the spacecraft position and velocity during observation can be computed by interpolation. (For interpolation the CERES toolkit (scf_toolkit5.2.16v1-gcc-xlf) function *PGS_EPH_interpolatePosVel* is used.). By using these satellite positions, the subsatellite point at the Earth's surface during observation can easily be computed. (To calculate the subsatellite point at surface using satellite position, the CERES toolkit (scf_toolkit5.2.16v1-gcc-xlf) function *PGS_CSC_ECRtoGEO* is used.).

ERBE data set coordinates alignment with CERES data set. Those include

- 30 km to the surface level to compute viewing geometry of instruments
- Geocentric to geodetic coordinate

Above changes of ERBE data were necessary to reduce the difference between ERBE and CERES data so that any coordinates, reference level differences do not alias into climate analyses. For the conversion, we express the spacecraft position in Cartesian coordinates of which the origin of axes is at the center of the Earth. Two vectors, one is the position vector of the spacecraft and the other is the vector of the line of the sight of the instrument (FOV vector), are computed based on the information provided in S8. The intercept of the FOV vector with Earth's surface is the center of the field of view (FOV) of the ERBE scanner on the surface of the Earth (target point). The solar zenith angle at the target point for the time of the observation is computed in a similar way. The process of computing viewing geometry and the solar zenith angle at the target point is explained below.

Surface reference

Viewing zenith angle at the target point

The viewing zenith angle at the surface is the angle between the FOV vector and the vector perpendicular to the Earth's surface at the target point. The process to compute the viewing zenith angle is:

(i) Compute the Satellite Position vector.
(ii) Compute the FOV vector based on viewing geometry at the instrument.
(iii) Compute the target point, which is the intercept of the FOV vector and the Earth's surface. From available geodetic coordinate of the target at surface, convert to the rectangular coordinates.
(iv) Compute the angle between the FOV vector and the vector perpendicular to the Earth's surface at the target point.

Solar zenith angle

The solar zenith angle at the target point is the angle between the vector perpendicular to the Earth's surface at the target point and the vector from the target point to the sun.

(i) Obtain the Sun position vector.
(ii) Compute the target position. From available geodetic coordinate of the target at surface, convert to the rectangular coordinates.
(iii) Compute the angle between the vector from the target point to the sun (the sun position vector minus the target point position vector) and the vector perpendicular to the Earth's surface at the target point.

Geocentric to geodetic coordinates

The latitude and longitude of each FOV records in S8 are geocentric and defined at 30 km, while the CERES Instrument Earth Scan (IES) product, which is necessary to produce the SSF product, requires the geodetic latitude and longitude both at the Earth's surface and TOA. Thus, proper algorithm is required to convert the coordinates from geocentric to geodetic and from TOA to Earth's surface.

To use geodetic coordinate, the Earth's surface used to compute the target pint is an oblate spheroid instead of a sphere.

3) **Production of common inputs such as temperature and humidity profiles**

Temperature and humidity profiles are shared among cloud retrieval, surface flux computations, and time and spatial sampling processes. We have used MERRS and generated common temperature and humidity profile data sets that will be shared within our project. Use of MERRA was determined by comparing GEOS-4 and MERRA. An example of GEOS-4 and MERRA comparison is shown in Figure 2.

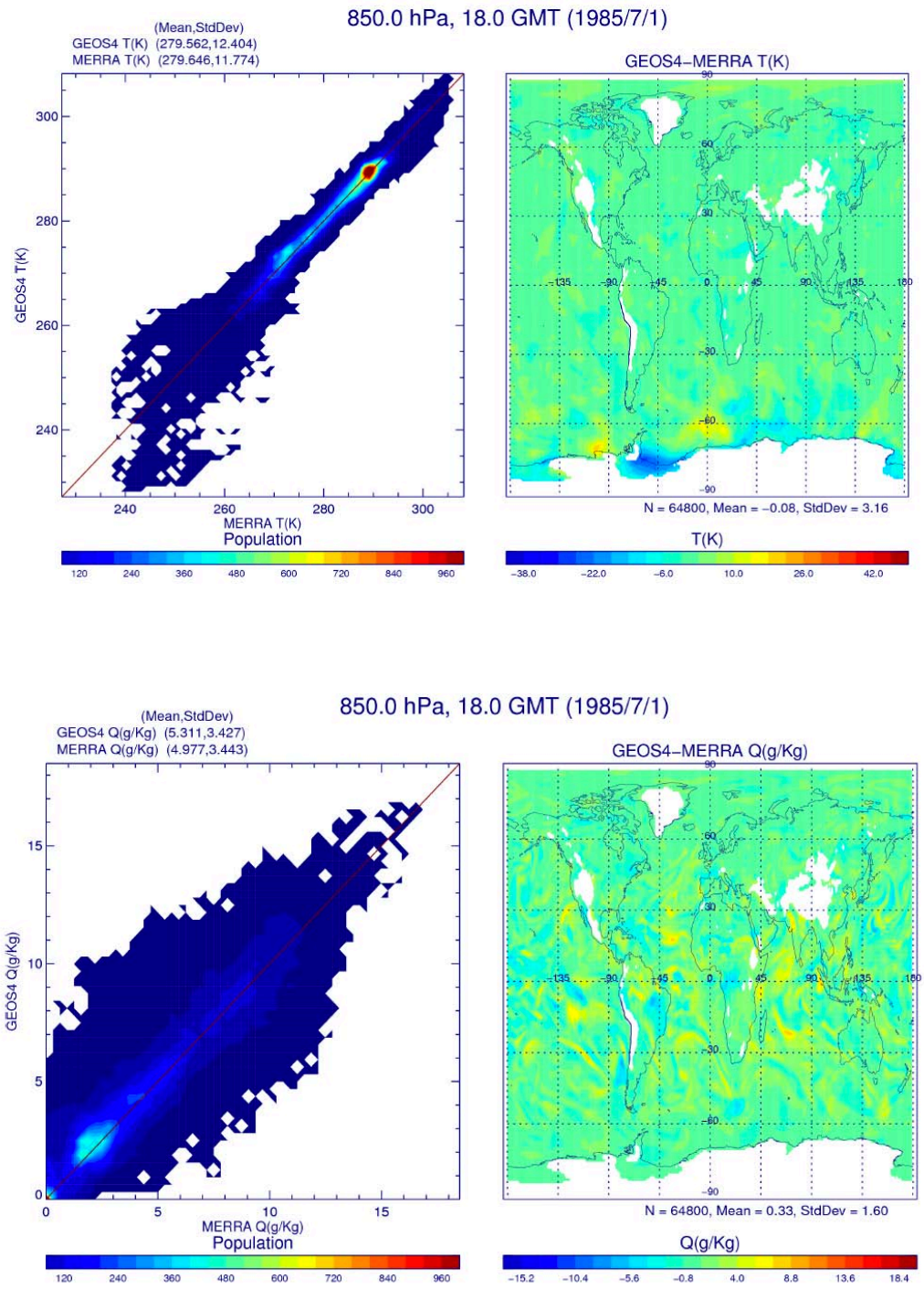

Figure2: Comparison of MERRA and GEOS-4 derived 850 hPa temperature (top) and humidity (bottom) from July 1, 1985

Goals for next reporting period

- Generate SSF file
- Conduct NOAA-9 ERBS non-scanners comparison
- Generate aerosol input files