Top-of-atmosphere radiation budget derived from ERBS wide field of view instrument

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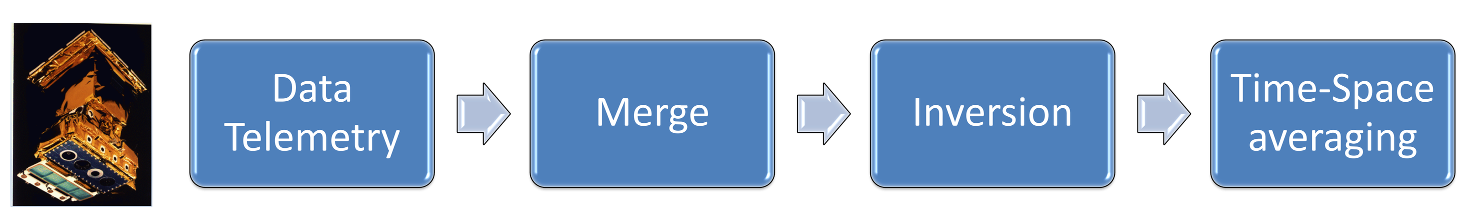
Introduction

- Earth Radiation Budget Satellite (ERBS) was a dedicated NASA science satellite, launched on October 5, 1984 into a precessing orbit with a 57º inclination and an altitude of 611 km. Its orbit precessed through the entire 24-hour local time every 72-day.
- ERBE Wide-field-of-view (WFOV) was a nonscanner instrument onboard ERBS which provided outgoing broadband irradiances at the top-of-atmosphere (TOA) from 1985 to 1999.
- The goal of this project was to better understand the Earth's climate by tracking the spatial patterns and temporal variability of the Earth's radiation fields.
- The ERBE nonscanner data processing system can be broken down into four major components.



- During its 15-year of nominal operations, the WFOV nonscanner instrument had experienced four anomalies:
  - Spacecraft battery power issue in the second half of 1993.
  - Spacecraft digital data recorder malfunction in March 1998.
  - Spacecraft battery power issue for one month in December 1998.
  - After the routine solar calibration operation on 10/6/1999, the instrument did not return to its nadir earth-view position.

Data and methodology

- *History of the ERBS WFOV NonScanner Data Product*
  - *Original*: Original data processed using ERBE nonscanner WFOV algorithm.
  - *Edition 2*: Use of time sampling algorithm to correct mean time sampling errors (High latitudes)
  - *Edition 3*: Corrections due to effect of satellite altitude changes (611 km to 585km) on TOA fluxes.
  - *Edition 3Rev1*: Correction on non-uniform degradation of the SW dome from direct sunlight.
  - *Edition 4*: Unfiltering of ERBS-WFOV nonscanner SW consistent to CERES, correcting spectral dependence of SW dome degradation, residual correction for day-night LW difference (Shrestha et. al. 2019), incorporating time varying TSI from SORCE project and tying ERBE data to absolute calibration of CERES EBAF data product.

Minor updates have been performed to produce a new ERBS WFOV data (Edition 4.1):

- Updated corrections to the absolute calibration of the CERES EBAF Ed4: SW (2.4 Wm^{-2} →2.63 Wm^{-2}) and LW (4.07 Wm^{-2} →4.75 Wm^{-2})
- TSI correction in the regional 72DayAnnual product: TSI was rescaled to CERES SYN Ed4 to account for 5/6 missing days at the end of calendar year. Then albedo, SW and NET fluxes were recalculated.
- Interpolation and filling of missing cycles in the production of 72DayAnnual Area Average Time Series data products.

Results

Spatial distribution of changes in reflected shortwave irradiances

- The ERBS nonscanner TOA fluxes have been validated and compared with other radiation budget datasets to ensure the quality of the entire dataset. The datasets used for this comparison have been the DEEP-C (Diagnosing Earth's Energy Pathways in the Climate system) (Allant et. al. 2014) and CERES (Clouds and Earth's Radiant Energy System).
- Figure 1 shows the time series of the annual global shortwave (top), longwave (middle) and net (bottom) fluxes from 1985 to 2015.
- Table 1 shows the mean and 1σ standard deviation for 3 different time periods where at least 2 dataset overlapped. For ERBS case (1985-1998) is divided in two in order to insolate the effect of the Mt. Pinatubo (1993).
- The average change in irradiances from 1985-1989 to 1994-1998 period for ERBS (DEEP-C) are:
  - SW: -2.3 (-0.4) Wm^{-2} LW: 1 (-0.2) Wm^{-2} Net: 1.3 (0.7) Wm^{-2}

	Shortwave			Longwave			Net		
	1985-1989	1994-1998	2001-2015	1985-1989	1994-1998	2001-2015	1985-1989	1994-1998	2001-2015
ERBS	102.1 ± 0.5	99.8 ± 0.1	n/a	238.4 ± 0.2	239.4 ± 0.5	n/a	-0.5 ± 0.5	0.8 ± 0.4	n/a
DEEP-C	100.2 ± 0.2	99.8 ± 0.3	99.8±0.2	239.6 ± 0.3	239.4 ± 0.3	239.6 ±0.3	0.2 ± 0.4	0.9 ± 0.5	0.64±0.3
CERES	n/a	n/a	99.2 ± 0.3	n/a	n/a	240.1 ± 0.3	n/a	n/a	0.7 ± 0.4

Table 1: Time series of annual global shortwave, longwave and net flux from 1985 to 2015.

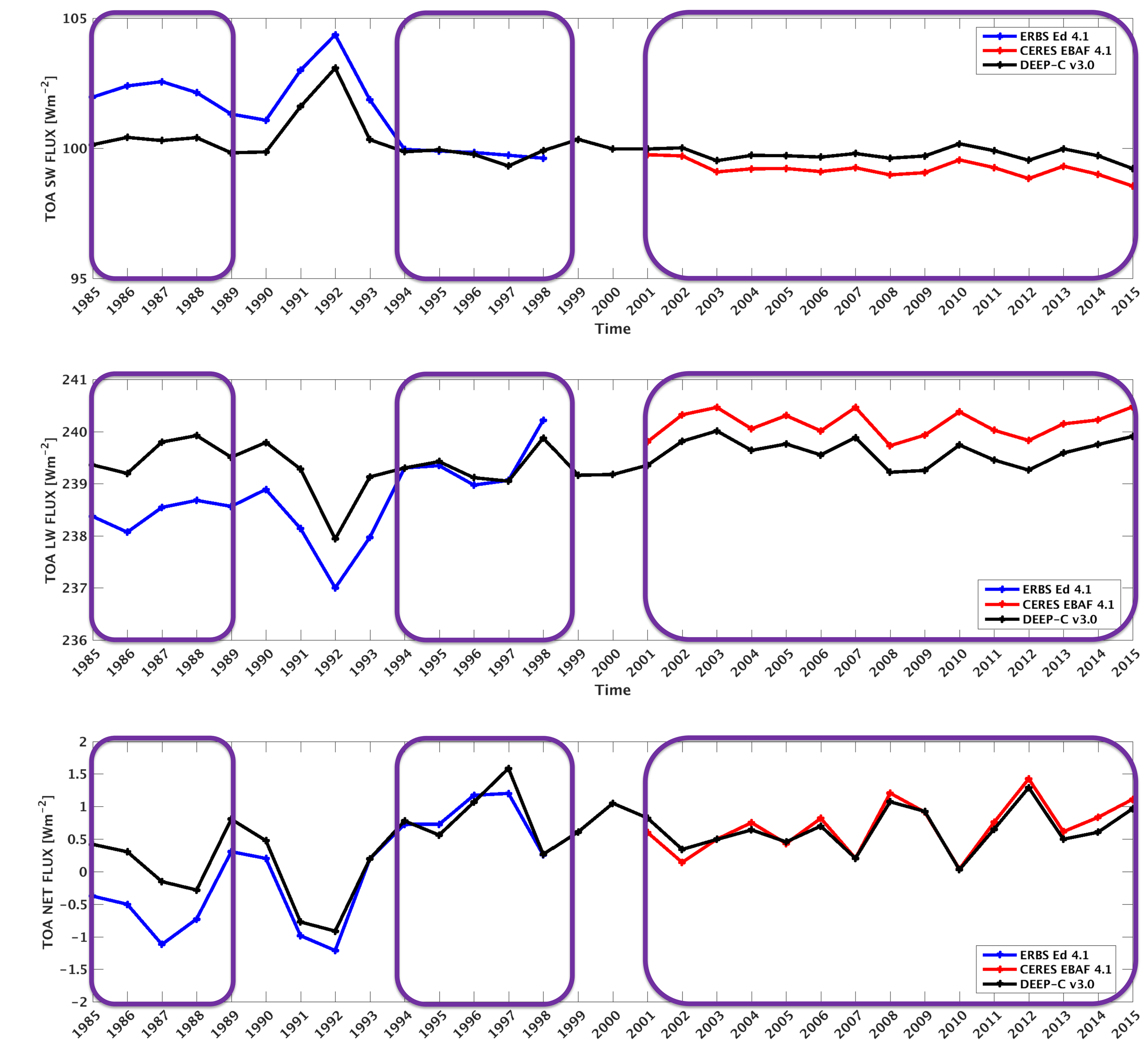


Figure 1: Time series of annual global (top) shortwave, (middle) longwave and (bottom) net flux from 1985 to 2015.

Changes of TOA albedo

- Besides ice covered regions, cloud variability is a dominant contributor in the regional albedo changes. Therefore, studying the albedo changes between two different periods of time, in our case between ERBS and CERES, can be very useful to understand the variability and trends in cloud amount.
- Figure 2 displays the spatial distribution of differences between the 2002-2014 CERES (CERES EBAF Ed4.1) albedo and the 1985-1989 ERBS albedo (ERBS WFOV Nonscanner Ed 4.1). Changes of albedo over the tropics and sub-tropical regions derived are related to the global cloud trend changes and consistent with previous studies (Norris et. Al. 2016).

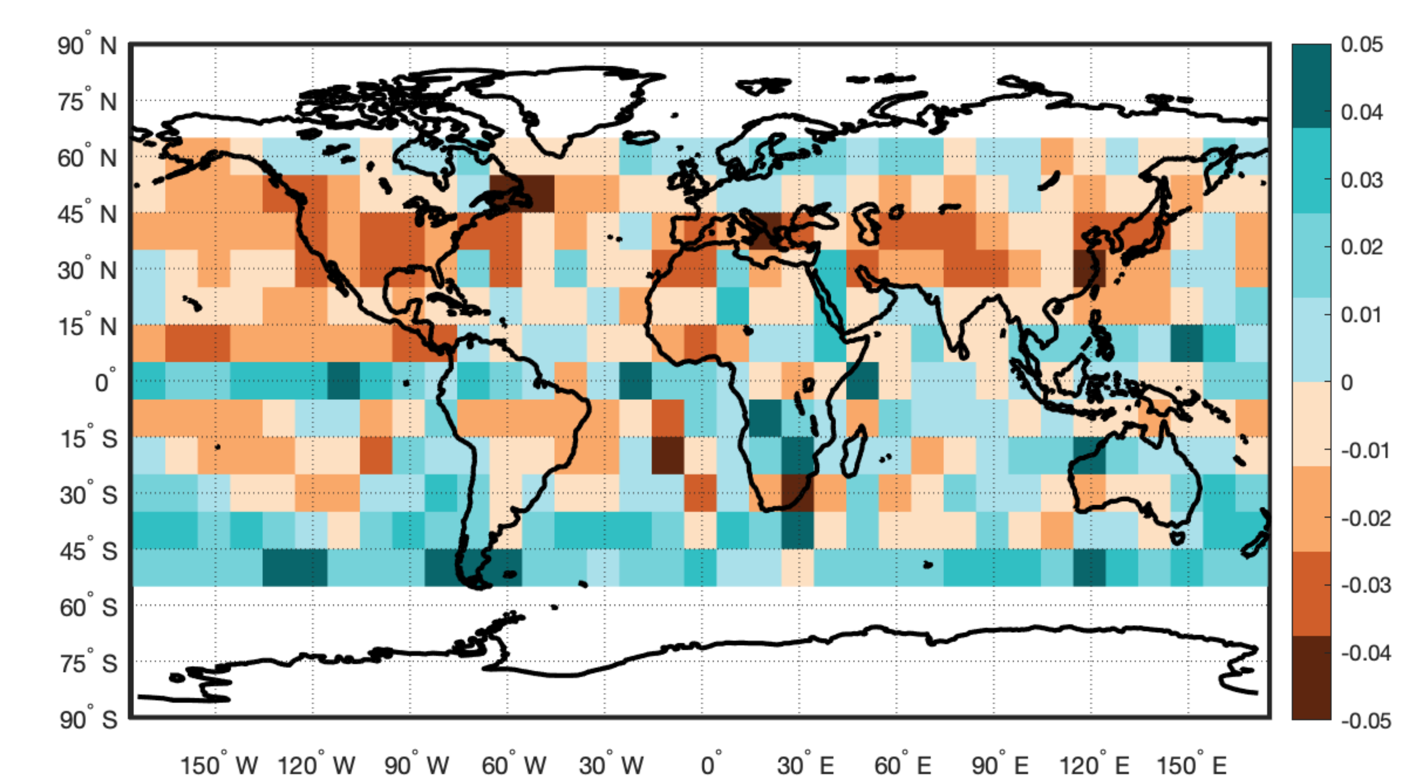


Figure 2 Change in albedo from January 1985-December1989 (ERBS Ed 4.1) to July 2002-June 2014 (CERES EBAF Ed 4.1). 10º x10º spatial resolution from 60ºN to 60ºS.

Conclusions:

- A new Edition 4.1 data for the ERBS WFOV Nonscanner instrument can help to understand quantitively changes in the Top-of-Atmosphere radiation budget.
- Tying ERBE data to the absolute calibration of CERES EBAF data allowed to use it for long term climate studies and observe changes in the TOA albedo related to regional changes in the cloud amount.

References:

- Allan, R. P., C. Liu, N. G. Loeb, M. D. Palmer, M. Roberts, D. Smith, and P.-L. Vidale. Changes in global net radiative imbalance 1985-2012. Geophysical Research Letters, 41 (15):5588{5597, 2014. ISSN 1944-8007. doi: 10.1002/2014GL060962. URL http://dx.doi. org/10.1002/2014GL060962.
- Norris, J. R., R. J. Allen, A. T. Evan, M. D. Zelinka, C. W. O'Dell, and A. A. Klein: Evidence for climate change in the satellite cloud record, Nature, DOI:10.1038/nature18273.
- Shrestha, A. K., S. Kato, T. Wong, P. Stackhouse, R. P. Loughman, 2019: New temporal and spectral unfiltering technique for ERBE.ERBS WFOV nonscanner instrument observations, IEEE Trans. Geo. Remote Sens., DOI:10.1109/TGRS.2019.2891748.