



Libera and Continuity of the Earth Radiation Budget Climate Data Record

P. Pilewskie & Libera Team

Libera, Earth Venture Continuity-1 Mission

'Li-be-ra, named for the daughter of Ceres in ancient Roman mythology



Provides continuity of the Clouds and the Earth's Radiant Energy System (CERES) Earth radiation budget (ERB).

- ▣ Measures integrated shortwave (0.3–5 μm), longwave (5–50 μm), total (0.3–100+ μm) and **(new) split-shortwave (0.7–5 μm) radiance** over 24 km nadir footprint; **uncertainty ~ 0.3%**
- ▣ **Includes a wide FOV camera for scene ID and simple ADM generation to pave way for future free-flyer ERB observing system**

Innovative technology:

- ▣ **Electrical substitution radiometers (ESRs) using vertically-aligned carbon nanotube (VACNT) detectors**

Primary operational modes:

- ▣ Cross-track and azimuthal scanning; on-board calibrators; solar and lunar viewing.

Flight:

- ▣ **JPSS-3, 2028 launch; 5-year mission**

Partners:

- ▣ LASP, Ball Aerospace, NIST Boulder, Space Dynamics Lab; CU, JPL, CSU, UA, UM, LBL

JPSS-3 Instruments

Libera – Earth Radiation Budget

ATMS - Advanced Technology Microwave Sounder

CrIS - Cross-track Infrared Sounder

VIIRS – Visible Infrared Imaging Radiometer Suite

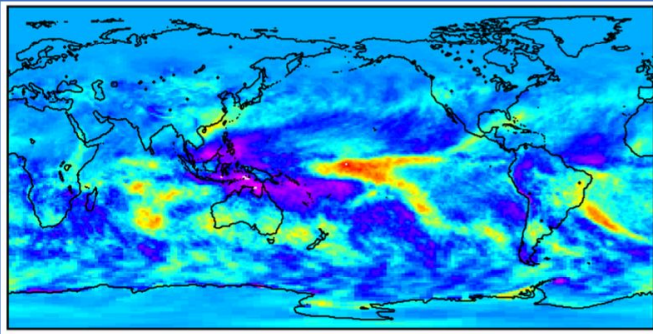
OMPS – Ozone Mapping and Profiler Suite

Libera completed Preliminary Design Review 8-10 Feb. 2022

Libera passed KDP-C 12 April 2022

Libera guided by the ERB Science Working Group Report

RECOMMENDED MEASUREMENT AND INSTRUMENT CHARACTERISTICS FOR AN EARTH VENTURE CONTINUITY EARTH RADIATION BUDGET INSTRUMENT



National Aeronautics and Space Administration

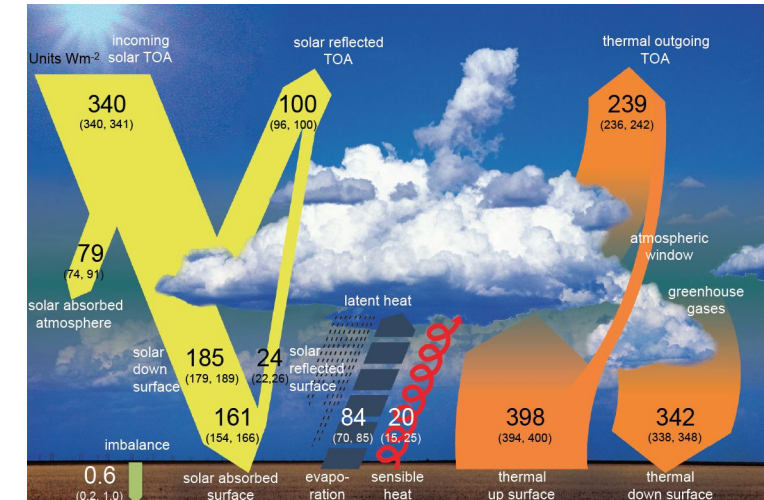
- Science Working Group formed February, 2018.
- Working Group consisted entirely of civil servants to avoid Federal Advisory Committee Act rules given time constraints.
 - 22 NASA and NOAA CS personnel.
- Goal of SWG to recommend instrument and measurement characteristics for a continuity-preserving instrument, within cost cap.
- Recommended solution was basically FM6, maybe with reduced scanning capability. (Cross track, with azimuthal rotation capability for lunar/solar calibration.)
- **Note: recommendations are not AO requirements!**
- SWG met periodically from February to August.
- First draft July 2018 published for public comment.
- Comments informed final draft.
- Final draft is complete.
- Final draft will be made available on NASA web site, and referenced in AO.

Presentation by David Considine, NASA HQ, at 2018 Earth Radiation Budget Workshop

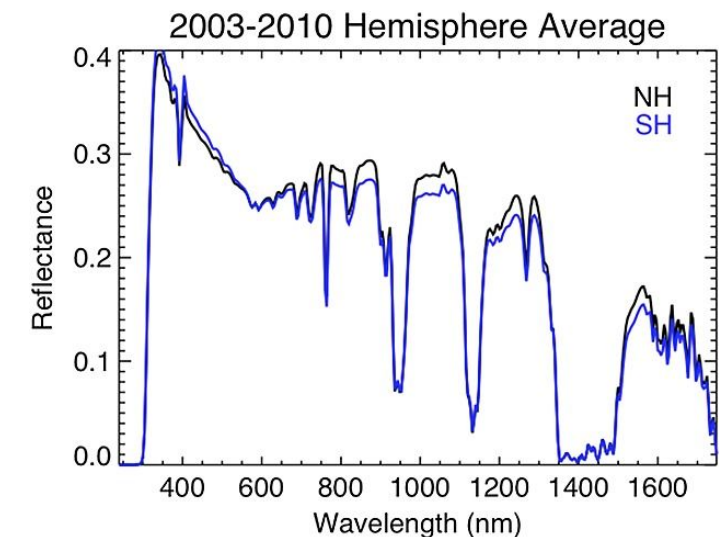
Libera Science Goals & Objectives

Overarching goals:

- 1) **Provide seamless continuity of the ERB measurement with characteristics identical to CERES**
 - Prevents gap in ERB data record critical for studies of global climate change
 - Tied to **Science objective 1**: Use extended record to identify and quantify processes responsible for the instantaneous to decadal variability of ERB
- 2) **Develop a self-contained, innovative, affordable observing system**
 - Novel, miniaturized detectors greatly improve accuracy & stability and pave way toward smaller & cost-effective follow-on projects.
 - **Science objective 2** *Libera* tests a miniature wide field-of-view camera to provide scene & angular context crucial for radiative flux retrieval
- 3) **Provide new and enhanced capabilities that support extending ERB science goals**
 - Employ Split-Shortwave channel to derive SW VIS and NIR fluxes and quantify SW energy disposition
 - Tied to **Science objective 3**: Revolutionize understanding of spatio-temporal variations in SW, VIS & NIR fluxes



Hemispheric Albedo Symmetry?

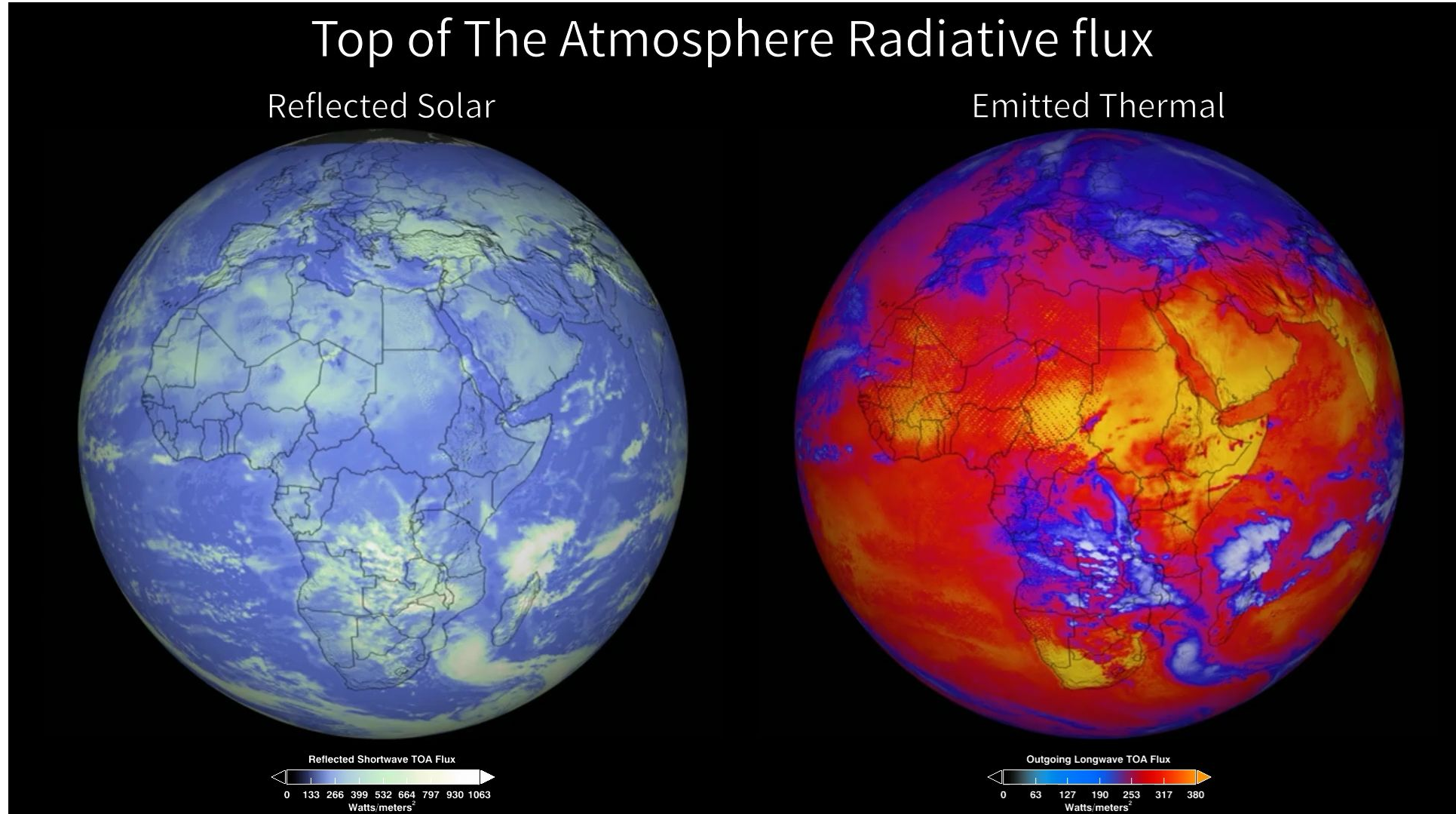


CERES Top of Atmosphere Irradiance

Top of The Atmosphere Radiative flux

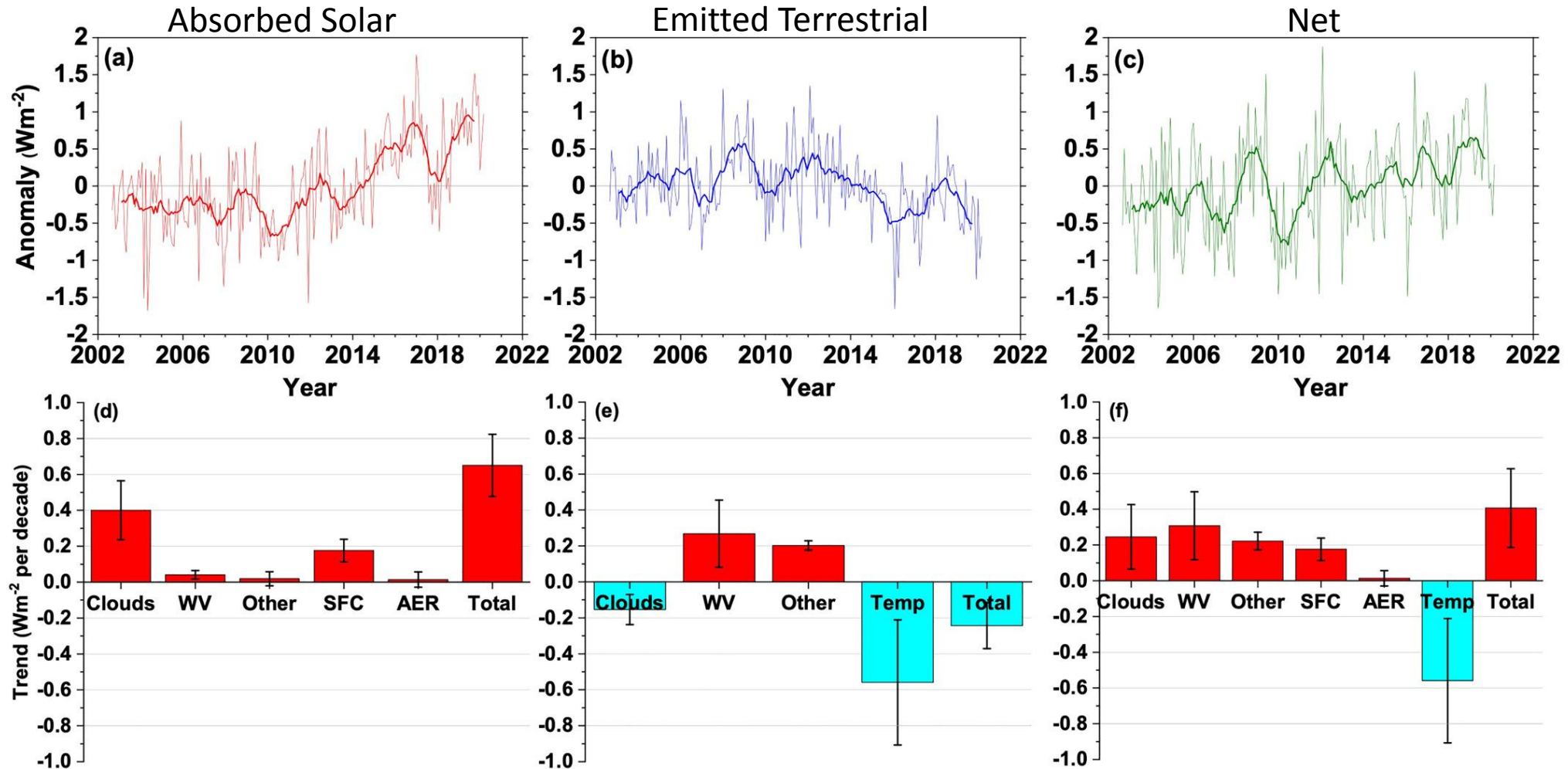
Reflected Solar

Emitted Thermal



CERES Short- and Long-wave Climate Data Records

Loeb et al., GRL, 2021, <https://doi.org/10.1029/2021GL093047>

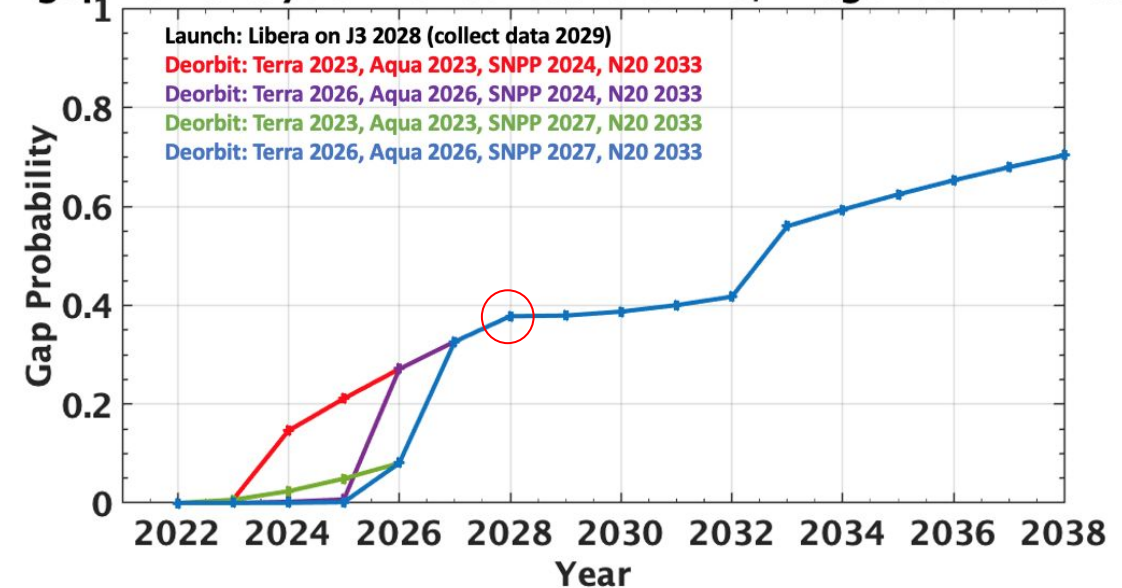


ERB Continuity

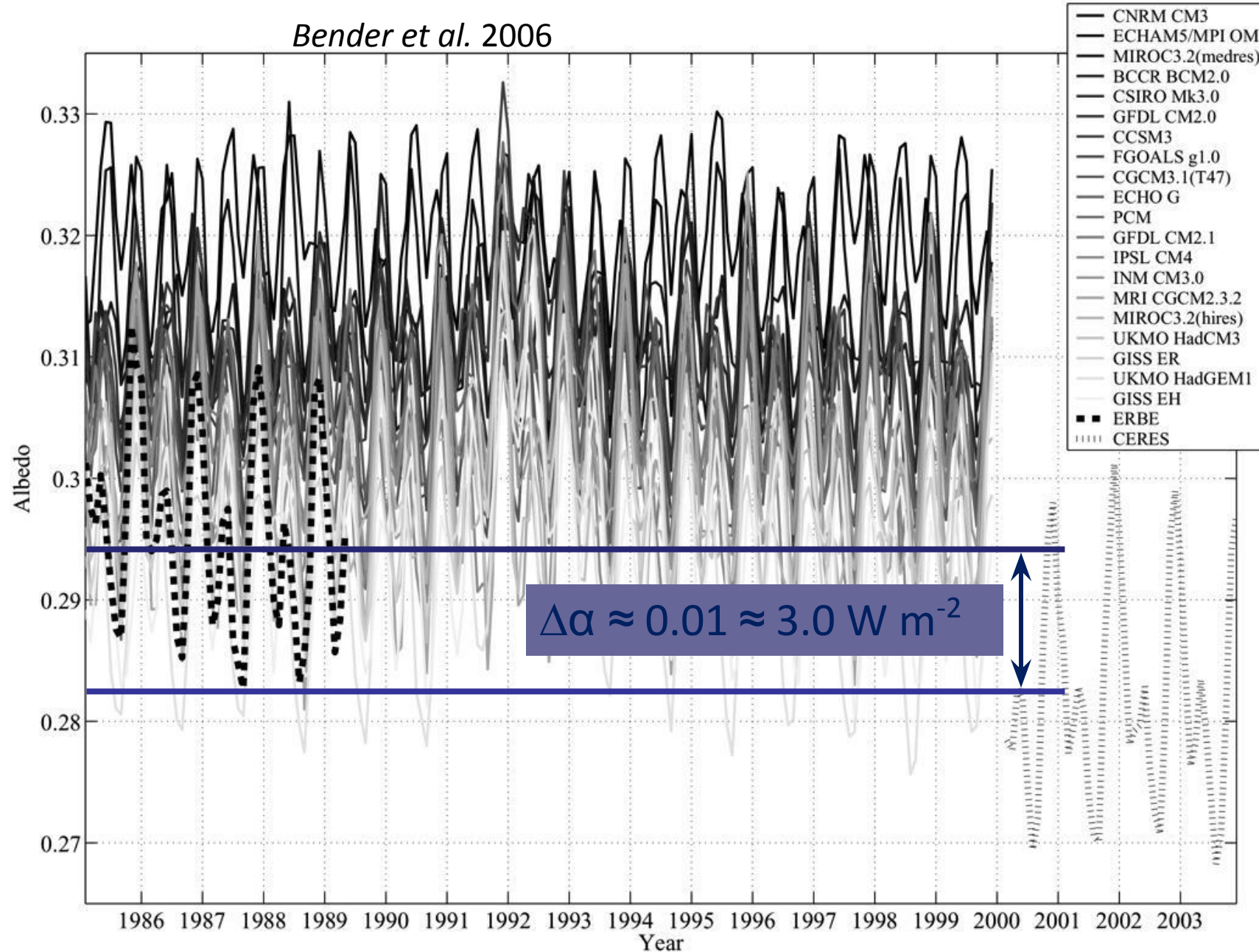
- CERES, the longest continuous global observational record of ERB, started in 2000.
- Six CERES instruments are in orbit flying aboard the Terra, Aqua, Suomi National Polar orbiting Partnership (SNPP) and NOAA-20 satellites.
- *Five of the six CERES instruments – that are well beyond their nominal five-year design lifetimes – are on satellites that are likely to be decommissioned before 2027*

- By late 2027, there is a 38% probability of a gap
- Gap-filling methods using imagery data have uncertainty on the order of current decadal trends $\sim 0.4 \text{ Wm}^{-2}$.
- The current ERB data record depends on continuity and overlap

gap risk analysis with constant CERES/imager survival rate

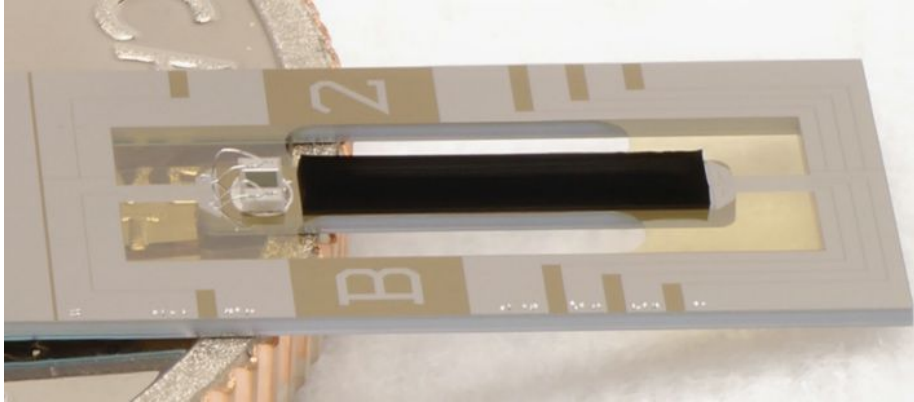


CERES vs. ERBE Albedo: Real Trend or Offset?

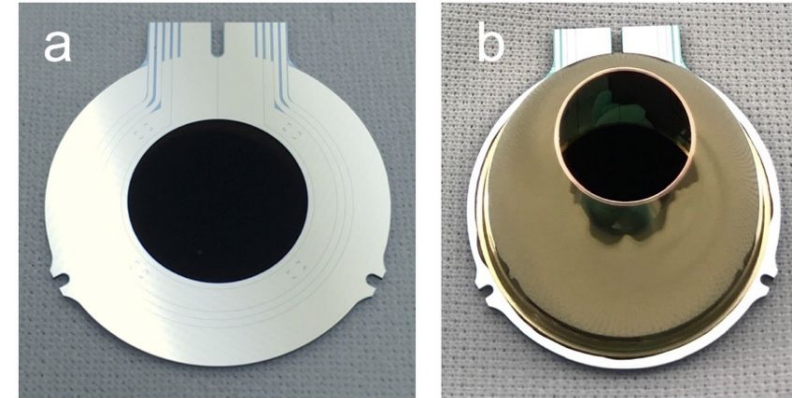


VACNT ESRs for Climate Studies

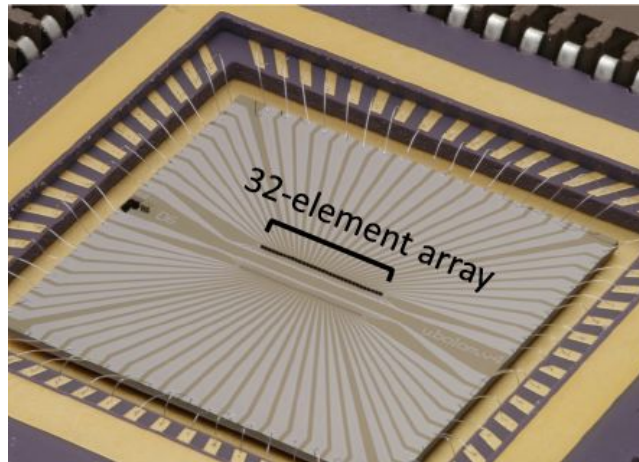
Compact Spectral Irradiance Monitor (CSIM)



Compact Total Irradiance Monitor (CTIM)



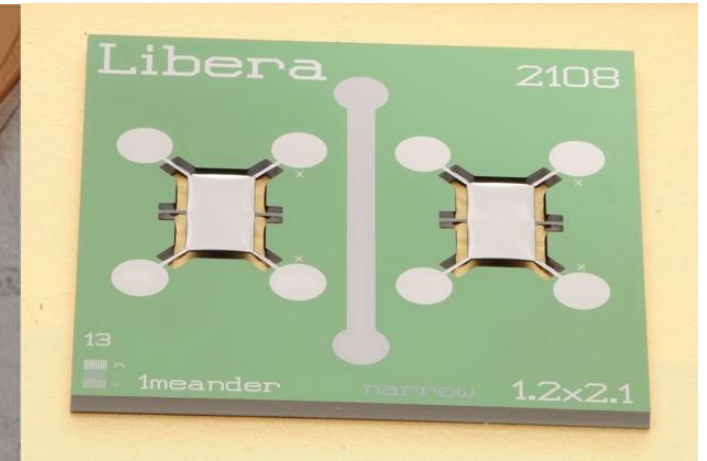
Black Array of Broadband Absolute Radiometers (BABAR)



Libera Prototype 0



Libera Prototype 4



Pre-launch Calibration and Characterization

- Component-Level Characterizations

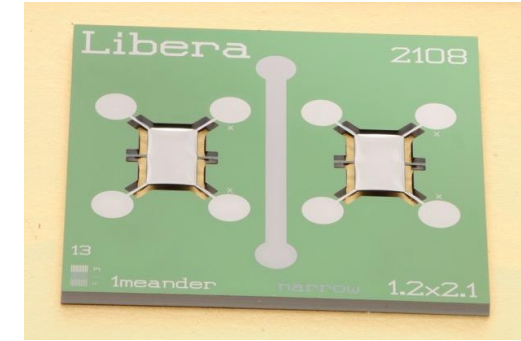
- Properties of all optical surfaces (mirrors, filters, detectors) measured at NIST and PTB, Germany
- Used in instrument model to generate expected spectral response functions

- Radiometer Calibrations

- End-to-end channel calibration at LASP against NIST-traceable absolute irradiance standard detector
- Uses laser tie-points from 300 nm to 16 μm and broadband blackbody sources.

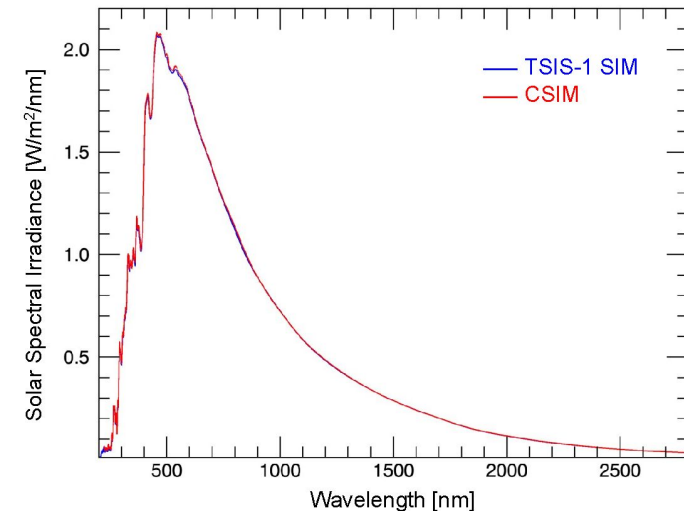
- System Level Validation

- Integrated system transported to SDL for independent validation using SW & LW targets at a facility developed for RBI



Libera utilizes advanced carbon nanotube detector technology developed by LASP and NIST over a number of ESTO projects: BABAR ACT, CTIM-FD, CAESR, and CSIM-FD.

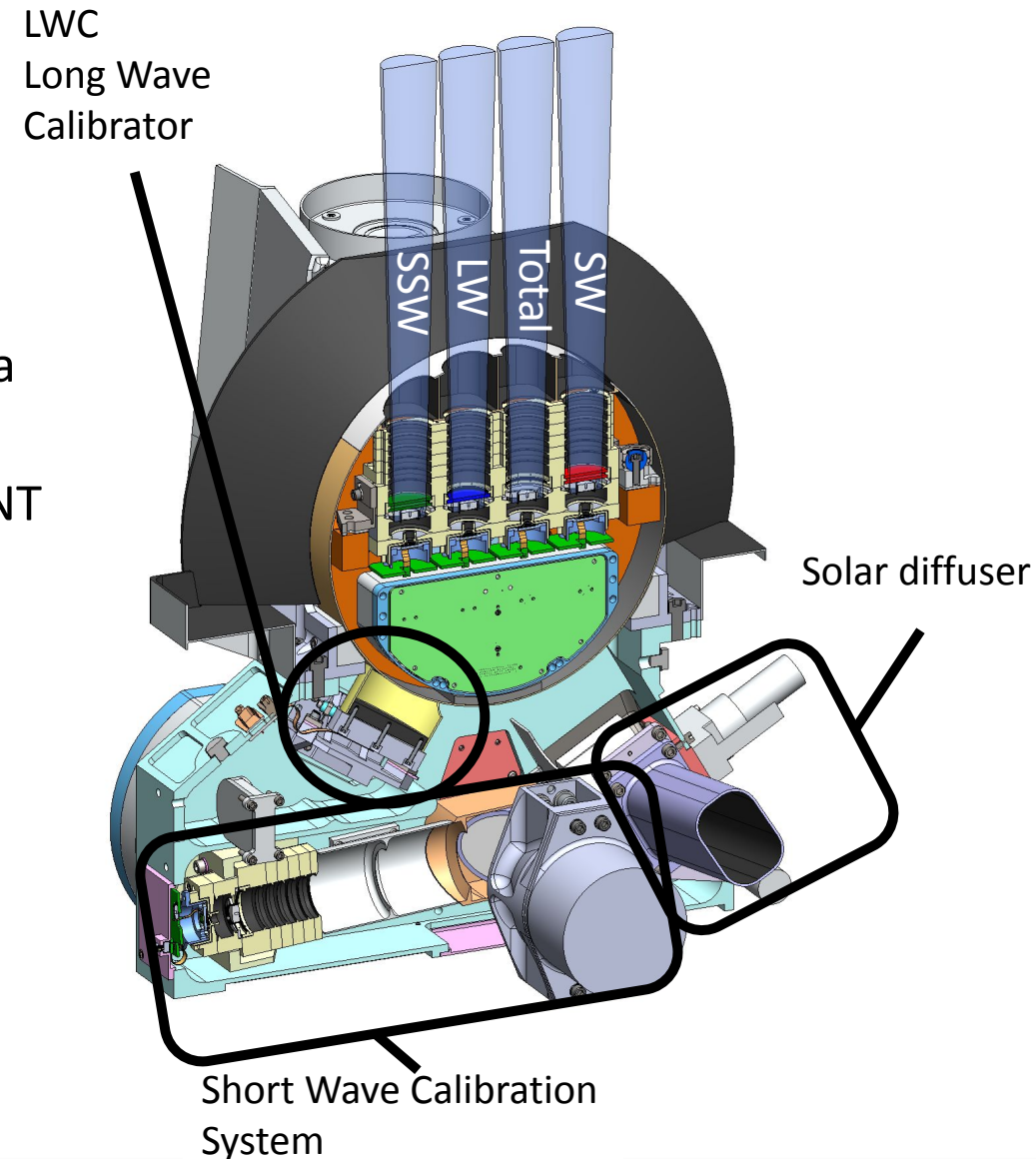
On-Orbit Demonstration of ESRs Using VACNTs



On-Orbit Calibration and Validation

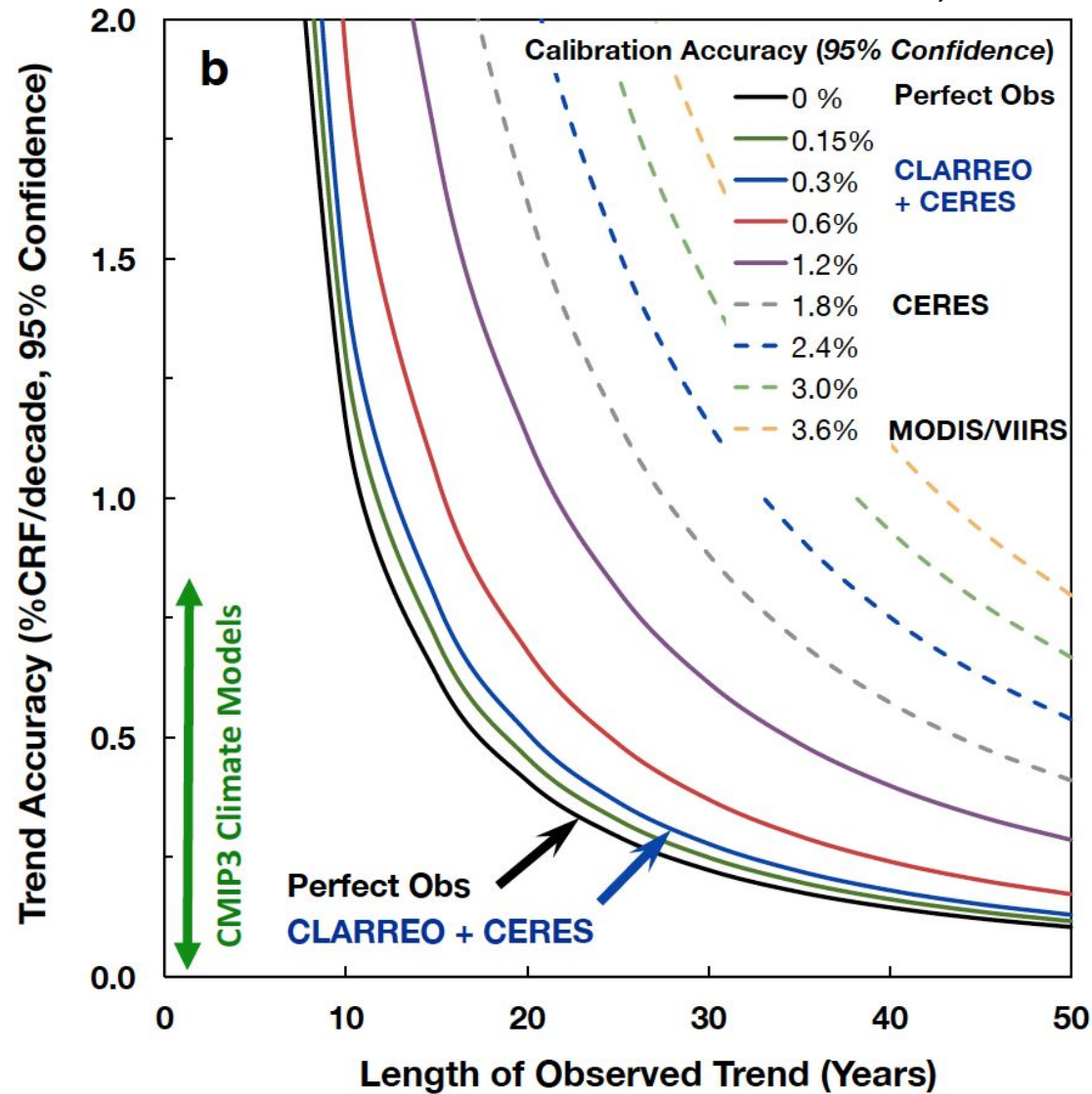
A belt-and-suspenders approach:

- Onboard calibration targets (daily)
 - Shortwave calibrator using LED sources (365, 410, 520, 625, 810, 1550 nm) and engineered diffuser; stability tracked via a SW calibration radiometer
 - Longwave calibrator: flat-plate blackbody (310-330K) with CNT coating, Si-traceable PRTs to NIST standards.
- Solar calibrations (bi-monthly)
 - Three Spectralon diffusive panels viewed bi-monthly/monthly/semi-annually for degradation tracking
- Lunar calibrations (~ 8-12 per year)



Trend Detection and Measurement Accuracy

Wielicki et al. *Bull. Amer. Meteorol. Soc.*, 2013.



L0, L1b



L3

L3

L3b

Libera Science Team

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Libera, Earth Venture Continuity-1 Mission

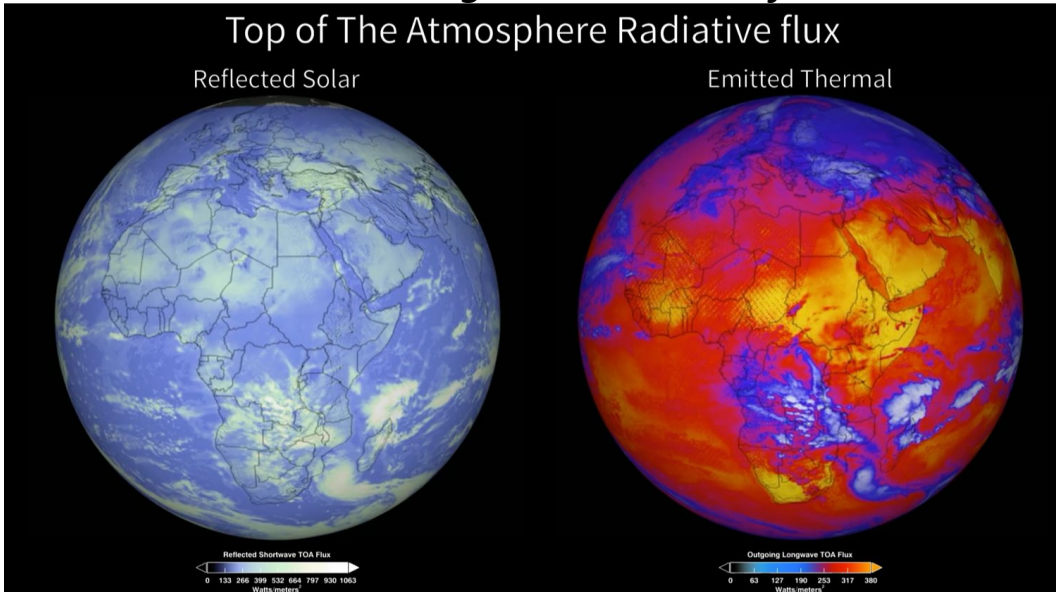
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Earth Radiation Budget Observations from CERES

Top of The Atmosphere Radiative flux

Reflected Solar

Emitted Thermal



Joint Polar Satellite System-3



Libera continues the 22-year CERES Climate Data Record for the Earth Radiation Budget (ERB).

- *Measures reflected solar and emitted infrared radiation from Earth*
- *Provides fundamental climate information about the balance between incoming and outgoing energy from Earth*
- *Continuity of this climate record over time reveals the signals of climate change – connects temperature trends to energy flow*

Libera is Innovative:

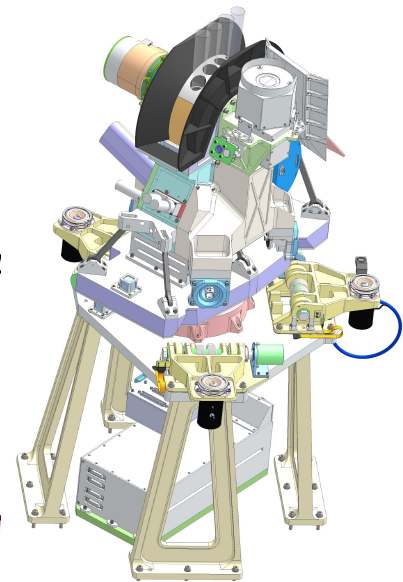
- *Uses state of the art detectors with carbon nanotube technology, the blackest substance on Earth*
- *Adds a split-shortwave measurement to isolate where energy from the Sun is deposited in the Earth system.*
- *Adds a wide-field-of-view camera to support split shortwave science*

Partners:

- *LASP, Ball Aerospace, NIST Boulder, Space Dynamics Lab*
- *Science Team: CU, JPL, CSU, UA, UM, LBL*

Flight:

- *JPSS-3, 2027 launch; 5-year mission*



Thanks!