New satellite results further confirming that Earth reflectivity changes are not driving Global Warming

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Abstract

Measurements of solar energy entering Earth are critical for comparison/validation of model simulated climate signals run in the present, for confidence in their predictions. Satellite systems detect the predicted climate trends being sought with decades of data, and so must minimize their on-orbit measurement calibration drifts, to prevent false conclusions. Reductions in Earths reflectivity would contribute to global warming by the more sunlight absorbed. New Earth reflectivity results are shown here from the Moon and Earth Radiation Budget Experiment (MERBE). As detailed in other works, this uses the constant lunar reflectivity, viewed monthly by NASA's CERES devices, allowing MERBE to track/compensate for otherwise undetectable telescope degradation. MERBE results find Earth mean reflectivity constant compared to that of the Moon, because Arctic warming is balanced by cooling elsewhere. This physical evidence confirms that the Sun does not contribute to recent global warming, confirming anthropogenic greenhouse gas increases as the likely cause.

Introduction

There is still much uncertainty surrounding how the Earth will respond to the rapid warming that has been observed since the last century. The resulting changes to clouds, often referred to as cloud radiative forcing/feedback or CRF (Bony et al., 2006), remains one of the largest unknowns. More specifically, it is unclear if the rapidly arriving warmer Earth shall result in more, less or simply different types of clouds, and whether changes to sunlight reflection will diminish or amplify warming (i.e. as a negative or positive feedback).

The time averaged solar flux of 1361 Wm^{-2} arriving at Earth is currently stable on decadal scales as in Fig. S1(a), so cannot by itself be responsible for current rapid surface temperature rises. However, changes to Earth solar reflectivity or albedo has the potential to be a primary driver of climate change, as it would alter the energy entering Earth from the currently stable Sun. For example, the rise in atmospheric reflectivity due to particulate aerosols emitted from the 1991 Pinatubo volcanic eruption, led to a temporary global cooling of around half a degree Celsius. Alternatively, a reduction in albedo due to less clouds or melting polar ice is expected to increase Earth temperatures even faster, by darkening the planet. Climate scientists and economists in (Wielicki et al., 2013; Cooke et al., 2013) estimated that the size of these CRF albedo climate signal trends being looked for are no larger than just over 0.8Wm^{-2}/decade, in terms of changes to fractional Earth reflectivity (multiplied with the 1361Wm^{-2} solar flux). The only way to globally measure Earth albedo is from satellites in orbit. Such a process utilizes space-based telescopes and detectors that measure the Earth Radiation Budget or ERB (Ramanathan et al., 1989), much of which is the broadband reflected solar flux leaving Earth. These scattered solar or Short Wave (SW) results between wavelengths 0.2 and 5μm, divided by measurements of incoming solar flux, allow calculation of Earth's fractional albedo (with a global mean around 0.29). Earlier analysis by (Wielicki et al., 2005), examined the first five years of the worldwide ERB reflected SW measurements made by a NASA satellite program called the Clouds and the Earth's Radiant Energy System or CERES (Wielicki et al., 1996). It was concluded there that due to natural climate variability or 'noise', more data over at least a decadal time scale would be required to draw conclusions on any statistically significant albedo changes. Additionally, it was later assessed by (Wielicki et al., 2013), that the calibration accuracy of CERES is not sufficient to detect the predicted $\approx 0.8\text{Wm}^{-2}$/decade or less CRF change trends, for decades to come. Requests were made in both the 2007 & 2017 National Academies decadal surveys on science that advise the US government (NA, 2020), to develop an observing system with better accuracy and stability. These surveys included comments such as, *"the single most critical issue for current climate change observations was their lack of accuracy and low confidence in observing the small climate change signals over long decade timescales".*

Today, years after (Wielicki et al., 2005), the now decadal length ERB device albedo measurements can and have been presented by (Dunn et al., 2020; N. G. Loeb et al., 2018; N. Loeb et al., 2020). It is done in this work however using an alternative approach to instrument calibration, initially for the CERES devices (European GERB data of (Harries et al., 2005) etc., will be done later). The new methodology achieves this by compensating for Ultra-Violet (UV) degradation to instrument optics, as discussed by (Wielicki et al., 2013). It is a project called the Moon and Earth Radiation Budget Experiment, or MERBE. Thousands of lunar scans by the instruments built for CERES are used by

MERBE in Fig. S1(b) to track and compensate for in-flight telescope UV degradation, which cannot be detected using standard on-orbit calibration techniques. Such undetected instrument response reductions caused the false negative albedo trends already found in early CERES albedo data by (Wielicki et al., 2005). Lunar albedo is constant to better than 10^{-7}%/decade (Kiefer, 1997). The Moon therefore acts as a very low cost and useful calibration stability target for long term Earth observing orbital missions, including the highly stable SeaWIFS satellite (Hooker et al., 1992; Barnes et al., 2004). In addition, lunar albedo can be used to bridge time and space gaps between different satellites as a constant radiometric standard. Ultimately the Moon's reflectivity will also be fully SI traceable in the past, present and future, since eventually it shall be accurately measured using missions in development, such as (Stone et al., 2020). Importantly, lunar calibration and its coming full SI traceability can be applied to existing ERB data from 2002, when monthly CERES orbital device Moon scans began. The MERBE effort was therefore undertaken on already existing data, to not only meet the desire for an improved climate observing system, but also to more rapidly overcome the need to see through natural variability.

MERBE has completely recalibrated and regenerated all relevant instantaneous radiative flux data files from CERES devices. This was done using spectral characterization techniques of (Matthews, 2009), and the Moon as a primary radiometric standard as in (Matthews, 2008).

MERBE Edition 1.0 EBAF-like global albedo 2000-2015

Fig. S1(c) shows the mentioned albedo data from the Moon, rather than the Earth. It will be available to all via download and is normalized to a mean +7° lunar phase angle, before use as the primary MERBE SW calibration standard (Matthews, 2008, 2018a; Kieffer & Stone, 2005) (temporary note to reviewers, I include the data as and Excel file submitted with the manuscript). These two displayed separate results were taken by the most used CERES Flight Model instruments called CFM1 on the EOS Terra satellite, and CFM3 on Aqua (although Terra's CFM2 has been recalibrated by MERBE also). A fundamental MERBE principal is that instrument calibration parameters used have to meet established NASA criteria of (Priestley et al., 2011). At the same time though, they must additionally result in no statistically significant trends in final measured lunar albedo (Fig. S1(c)). As shown by (Matthews, 2018b), the first of these goals is achieved with significant improvements. The second goal is reached with $< \pm 0.104$ Wm^{-2}/decade two sigma stability error confidence for Terra, and ± 0.147 Wm^{-2}/decade for the newer Aqua satellite (Matthews, 2018a).

Fixed time day and night instantaneous Terra/Aqua ERB flux measurements are stored in hourly files known as 'Single Scanner Footprints' (SSF) by NASA, which have been recalibrated by MERBE. The monthly means of lunar calibrated SW SSF irradiances are also collected by MERBE in 1°x1° Lon/Lat bins. That creates a new version of NASA's Energy Balanced and Filled 'EBAF' product (N. G. Loeb et al., 2018), which is here called 'EBAF-like', and completed so far up to 2015. These data are all calibrated based on the same lunar reflectivity, making all used instruments on a common and constant radiometric standard.

MERBE EBAF-like global net average albedo change estimate results are displayed in Fig. S1(c) and show a slight Earth reflectivity drop, amounting to a $+0.054$ Wm^{-2}/decade solar forcing increase. At less than a third the trend's 95% confidence limit of ± 0.189

Wm^{-2}/decade, this is not statistically significant however. These monthly mean MERBE EBAF-like results can be downloaded on the EBAF 1°x1° Lon/Lat grid (temporary note to reviewers, I include the data as an IDL .sav file submitted with the manuscript). Spatial trend analysis can then also be performed on such results in as in Fig. S2(a), to determine two sigma statistically significant heating and cooling regions purely from changes to Earth reflectivity (i.e. under a constant Sun). These trends are shown projected on an Authagrath Earth map, to give equal visual area weighting for regions of solar warming and cooling in Wm^{-2}/decade. Comparison can also be made for reference, with continents, typical cloud distributions and lon/lat markings below in Fig. S2(b). This illustrates that the net rise in solar forcing at the warming Northern Arctic in red, is balanced by increases in reflectivity elsewhere in blue, to create no net albedo change in global MERBE results of Fig. S1(c).

Conclusions and Summary

Lunar calibrated MERBE results find no statistically significant change in Earth global mean reflectivity, relative to that of the Moon. The Moon's constant albedo reflects UV light from the Sun, making normally undetectable telescope on-orbit degradation trackable and correctable. MERBE therefore saw a drop in raw signal from the Moon, something which must become an unchanging lunar scattered solar measurement after calibration coefficients are applied. That allowed it to compensate also in Earth data for the CERES instrumental drifts, by changing the radiometric instrument gain numbers.

Fig. S2(a) spatially resolved MERBE results also show that large increases in solar heating at the melting Northern Arctic, are balanced globally by increases in reflectivity elsewhere at lower latitudes. MERBE SI traceable SW fluxes, therefore find no net global mean planetary albedo drop, providing further evidence that the current rapid global warming is not caused by changes in solar input to Earth, leaving anthropogenic greenhouse gas increases the most probable reason.

Acknowledgments

CERES instantaneous SSF and EBAF Edition 4.1 flux results were obtained from the NASA Langley Research Center Atmospheric Science Data Center. MERBE EBAF-like Edition 1.0 solar results will be down-loadable (temporary note to reviewers, I include the data as and an IDL .sav file submitted with the manuscript).

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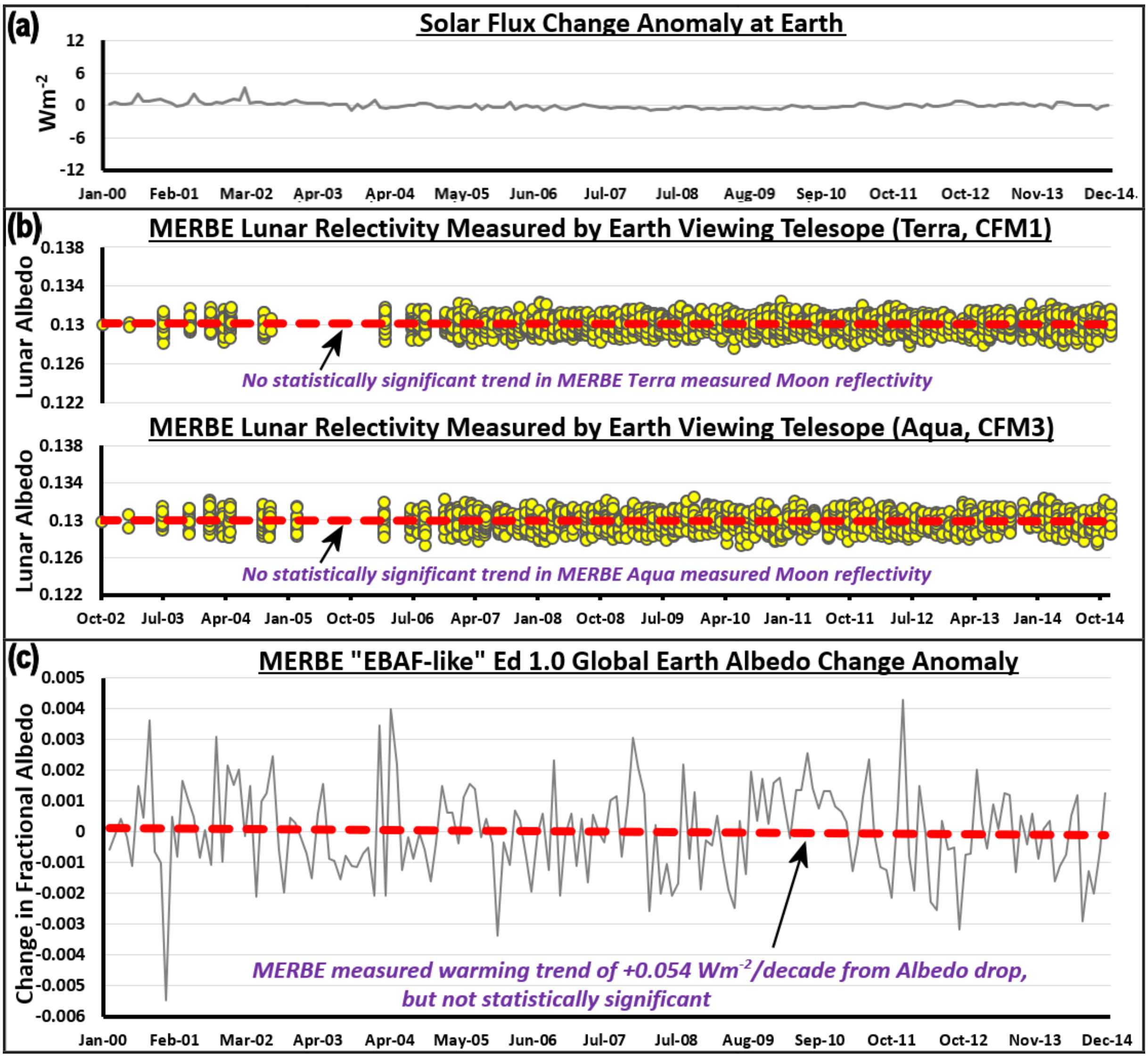

Figure S1. (a) 15-year anomalous change in solar flux arriving at Earth since 2000 from (LASP, 2020). (b) MERBE lunar albedo measurements. (c) 15-year anomalous MERBE Earth albedo change measurements, relative to that of the Moon.

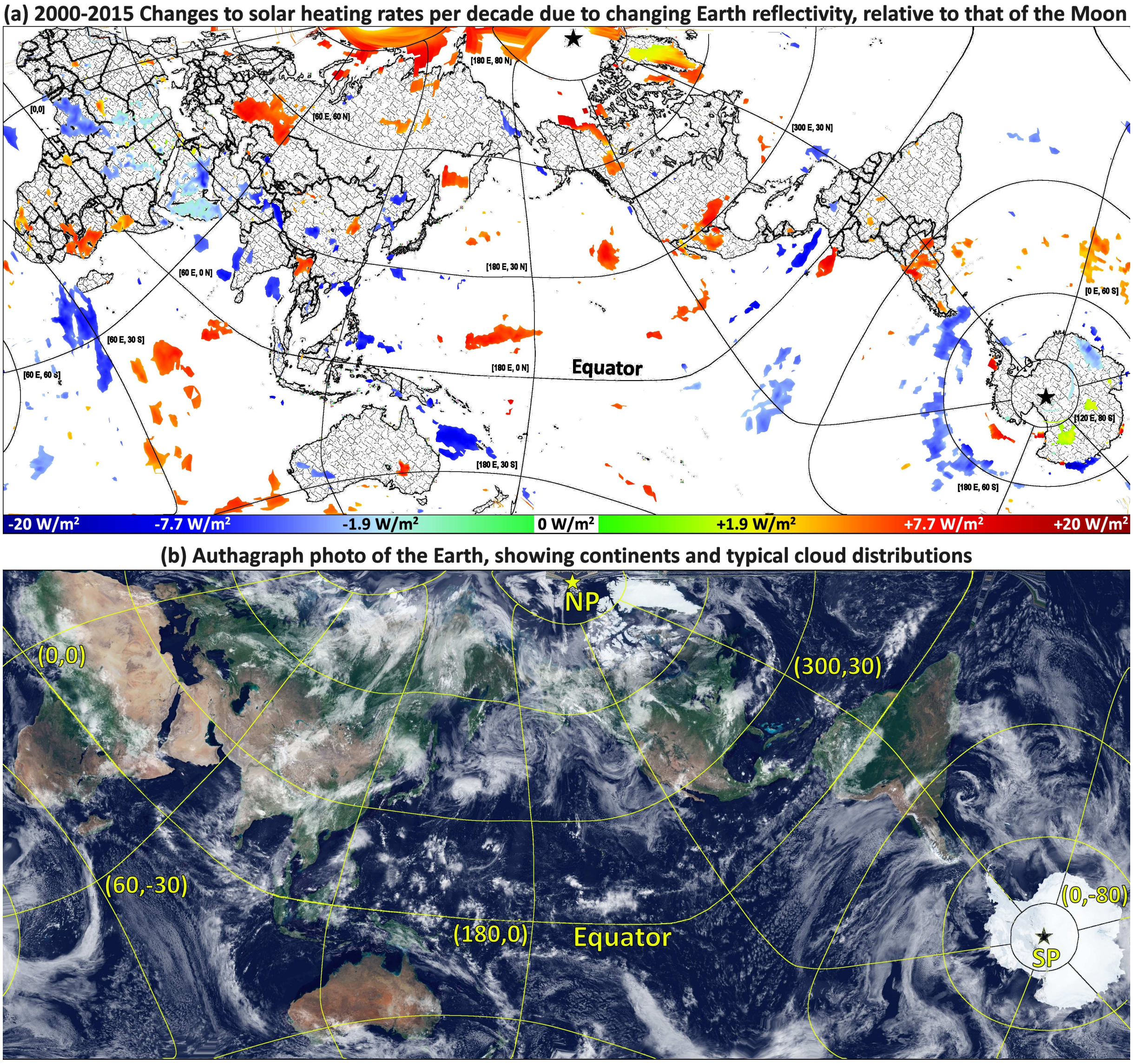

Figure S2. (a) 2000 to 2015 spatially resolved MERBE two sigma statistically significant changes to solar heating of Earth purely due to albedo changes, relative to that of the Moon and under a constant Sun. (b) Example orbital worldwide Earth photograph projected on same grid as Fig.(a) above.