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Citation: AIP Conf. Proc. **1531**, 612 (2013); doi: 10.1063/1.4804844
View online: http://dx.doi.org/10.1063/1.4804844
View Table of Contents: http://proceedings.aip.org/dbt/dbt.jsp?KEY=APCPCS&Volume=1531&Issue=1
Published by the AIP Publishing LLC.

# Climate Monitoring with Earth Radiation Budget Measurements

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**Abstract.** The Earth Radiation Budget (ERB) and its geographical distribution is intimately linked with the earth's climate and with the general circulation. We analyze 10 years of global Clouds and the Earth's Radiant Energy System (CERES) measurements from 2000 to 2010 and 8 years of diurnally resolved Geostationary Earth Radiation Budget (GERB) from 2004 to 2011 to illustrate this link and to verify if we can detect climate variability or systematic change. In response to the diurnal wave of solar heating three tropical convection maxima exist over South America, Africa, and around Indonesia. The Indonesian convection maximum is unstable due to a lack of a stabilizing land mass; this is the root cause of the El Niňo/La Niňa inter-annual variation with a global pattern of teleconnected variations through the general Walker circulation. **Since 2000 a change in global dynamics seems to have occurred**. There was a general strengthening of La Niňa, coinciding with a '**break in global temperature rise**', and with an '**eastern dimming**', i.e. an increase of aerosols over Asia. There is a resemblance to the period of 'western dimming' from 1945 to 1980, and a contrast with the period of global temperature rise and El Niňo strengthening from 1980 to 2000. It is of paramount importance that the suspected link between the eastern dimming, the strengthening of La Niňa and the break in global temperature rise is thoroughly investigated. This can best be done by a **move of a satellite of the Meteosat Second Generation (MSG) series over the Indian Ocean**. MSG provides diurnally resolved measurements of the key variables of the ERB, clouds and aerosols, and of the auxiliary variables of Sea Surface Temperature (SST) and static stability.

**Keywords:** Earth Radiation Budget.
**PACS:** 96.60.Ub

## INTRODUCTION

The climate in a given region of the earth is determined by the earth's energy budget and its regional distribution [1-2]. At the top of the atmosphere the earth gains energy from the sun and looses energy to space by reflecting solar radiation and by emitting thermal radiation. As the incoming solar radiation is the highest around the equator, the earth has a net gain of radiative energy at the equator and a net loss of radiative energy at the poles. This radiative pole-equator imbalance drives a large scale meridional circulation both in the atmosphere and in the oceans which transports heat from the equator to the poles. In the atmosphere, due to the Coriolis force resulting from the earth's rotation, the meridional circulation breaks up in three separate cells: the directly thermally driven Hadley cell transporting heat from the Intertropical Convection Zone (ITCZ) to the subtropical high-pressure areas, the equally direct polar cell transporting heat from the midlatitudes to the poles, and the indirect Ferell cell in between where heat is transported polewards through transient eddies.

In time, the ERB has been monitored from space by various satellite instruments with increasing resolution and accuracy. In this paper, we analyse data from Clouds and the Earth's Radiant Energy System (CERES) [3], for which a ten year one degree global climatology has recently become available [4]. We also analyse 8 years of data from the Geostationary Earth Radiation Budget (GERB) instrument on the Meteosat Second Generation (MSG) series [5-6]. GERB is the only instrument to provide diurnally resolved measurements of the ERB, albeit for a limited part of the world.

## CERES CLIMATOLOGY

We use the so-called Energy Balance and Filled (EBAF) version of the CERES data, obtained following the methodology of [4]. In this dataset, monthly mean fluxes of incoming solar radiation $F_{IS}$, reflected solar radiation

*Radiation Processes in the Atmosphere and Ocean (IRS2012)*
AIP Conf. Proc. 1531, 612-615 (2013); doi: 10.1063/1.4804844

$F_{RS}$ and emitted thermal radiation $F_{ET}$ are available on a 1° latitude-longitude grid from February 2000 to March 2010. The global average of the net incoming flux $F_{net}$=$F_{IS}$-$F_{RS}$- $F_{ET}$ has been put equal to a prescribed value of 0.9 W/m² based on ocean heat storage measurements. In the following we discuss the climatological means over the available ten year time period from February 2000 to March 2010 of the components of the ERB.

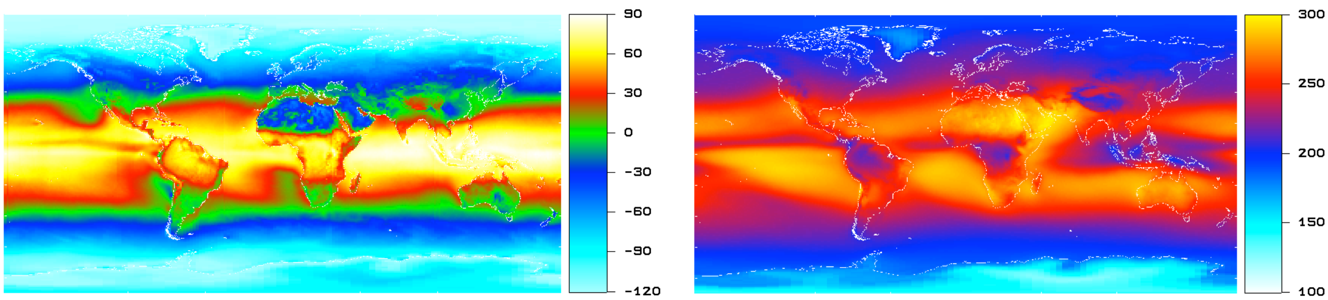


**FIGURE 1.** 10-year CERES climatology of net incoming radiation (left) and emitted thermal radiation (right). The color scales indicate fluxes in W/m².

Figure 1 – left shows the climatology of the net incoming radiation $F_{net}$=$F_{IS}$-$F_{RS}$- $F_{ET}$. The read and yellow colors near the equator indicate net cooling while the dark and light blue color near the poles indicate net cooling. Thus the geographical distribution of the ERB is the driver of the general circulation in the atmosphere and the oceans [7]. Most of the heat transport is done by the atmosphere, the oceanic heat transport is only important in the subtropics, and is dictated by the atmosphere.

Figure 1 – right shows the climatology of the emitted thermal radiation $F_{ET}$, also denoted as Outgoing Longwave Radiation (OLR). The blue colors around the equator indicate the low OLR values of the cold convective cloud tops corresponding to the ascending branches of the Hadley circulation, while the surrounding yellow colors indicate the high OLR values in the subtropical high pressure regions corresponding to the descending branches of the Hadley circulation.

The tropical convection is caused by the diurnal wave of solar heating that is travelling around the earth from east to west. Land masses heat up more quickly than oceans, therefore tropical convection occurs preferentially over land. Two stable convection maxima – visible as blue OLR minima in figure 1-right – exist over the land masses of South America and Central Africa. A third convection maximum exists around Indonesia, with a western branch towards the Indian Ocean, and an eastern branch towards the Pacific. Since not much land is present in this area, the 'Indonesian' convection maximum is unstable; this instability gives rise to the well known El Niňo/La Niňa variability [8], which is the main mode of inter-annual climate variability.

The ascending air in the tropical convection maxima is descending north and southward in the Hadley circulation but also east and westward in the general Walker circulation. The descending air in the high pressure areas over the oceans causes cold water upwelling, and the combination of low Sea Surface Temperature (SST) and the combination of descending air and low SST's favors the formation of marine stratus or stratocumulus. This marine stratocumulus has a strong shortwave cooling effect, resulting in the relative minima in the net radiation of Figure 1 -left visible by the green colors of the coasts of Namibia, Peru and California.

## LA NINA STRENGTHENING

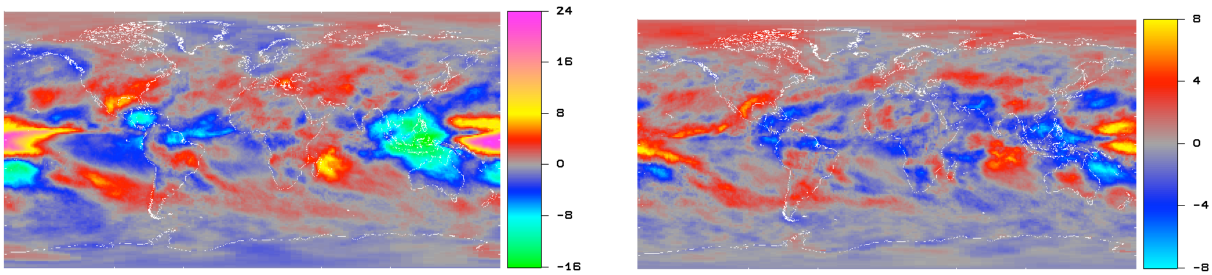


**FIGURE 2**. Left: changes in OLR in La Nina years compares to El Nino years.   Right: long term change of OLR from 2000 to 2010. The color scales indicate fluxes in W/m².

We use the Multivariate ENSO Index (MEI) from [9] to characterize the El Niño/La Niña inter-annual variation. With the MEI we composite the 10 CERES years in 5 La Niña years and 5 El Niño years.  Fig. 2 Left shows the mean variation of the OLR during the La Niña years compared to the El Niño years.  During La Niña the eastern and the western branch of the 'Indonesian' convection maximum move towards each other, as a result the OLR around Indonesia decreases (green color around  Indonesia in Fig. 2 Left).  The high precipitation corresponding to low OLR increases, causing floods in Indonesia, South-East Asia and Australia.  Through the general Walker circulation there is a 'communication' between the three convection maxima, resulting in a teleconnected pattern of variation over the entire tropics, visible in Fig. 2 Left, e.g. during  La Niña there is an increase in OLR – and corresponding drought – over the Southern US, visible in the red/yellow colors in Figure 2 Left.

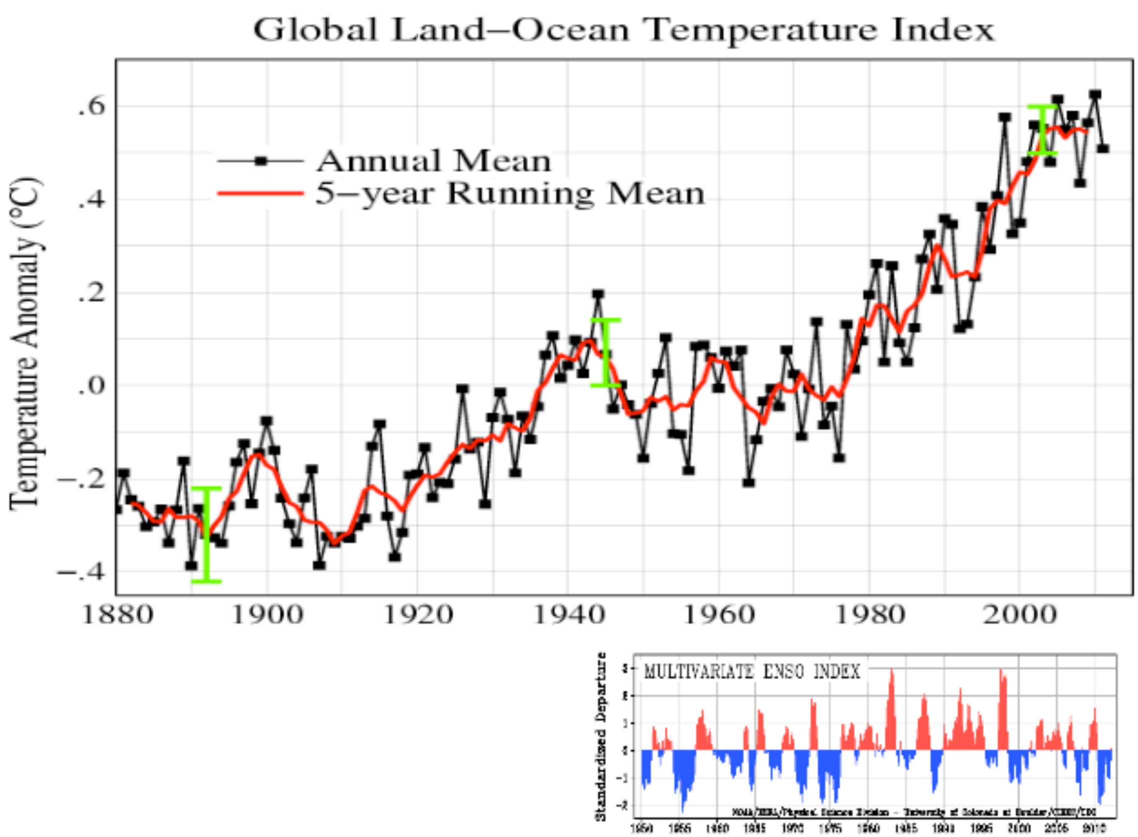


**FIGURE 3** : Global temperature change fr. [10] (top) compared to change in Multivariate ENSO Index fr. [9] (bottom-right).

Figure 2 Right shows the long term change of the OLR over the 10 year CERES period from 2000 to 2010, obtained as the mean OLR over the last 5 years minus the mean OLR over the first 5 years. The pattern of Figure 2 Right looks quite similar to the pattern of Figure 2 Left, so that we can conclude that over the 2000-2010 period a general strengthening of La Niňa has occurred.

Figure 3 shows the global temperature rise from [10] compared to the variation of the MEI from [9]. The g**eneral La Niňa strengthening after 2000 corresponds to an apparent 'break in global warming'** where the global temperature seems to be stagnating instead of rising.

Before 2000, from 1980 onwards there was a contrasting time period with a clear general temperature rise and with in general strong El Niňo's, which can be recognized from the dominating red colors in the MEI curve at the bottom-right of figure 3.

Interestingly, **before 1980, there was a period similar to the one after 2000**, with a lack of global temperature rise and in general strong La Niňa's which can be recognized from the dominating red colors in the MEI curve at the bottom-right of figure 3. We now know with increasing confidence [11] that the lack of temperature increase before 1980 was likely due to the so-called 'global dimming' which was actually a '**western dimming**' since it was mainly due to air pollution in the US and Europe.

We also know that recently the air pollution over South-east Asia has strongly increased [12]. It becomes than a distinct possibility that the recent '**eastern dimming**' due to the increase of pollution over South-East Asia, would be causing the lack of temperature increase and the La Niňa strengthening after 2000, in a similar way as the lack of temperature increase and the strong La Niňa's before 1980 would have been caused by the past 'western dimming'.

**It is of paramount importance that the apparent change in climate change after 2000**, and its underlying mechanisms, **is investigated with our best possible satellite tools**. In the section hereafter we will summarize the benefits from Meteosat Second Generation for this purpose.

## BENEFITS OF METEOSAT SECOND GENERATION

Meteosat Second Generation carries on board the Geostationary Earth Radiation Budget instrument, which is the only one which measures the diurnal cycle of the ERB. The diurnal cycle of the ERB, and particularly of the tropical convection over land is of prime importance for the basic structure of our climate system. Moving a GERB over the Indian Ocean would allow to investigate the inter-annual variability and the long term La Niňa change in its source region of the 'Indonesian' convection maximum.

MSG also carries the advance SEVIRI imager which has excellent aerosol detection capabilities. With an MSG over the Indian Ocean, SEVIRI would observe all the major aerosol sources over land, in particular the Asian ones. SEVIRI would also provide additional information such as cloudiness, SST and atmospheric stability which are all key elements of the tropical climate machine.

Thus we **strongly advocate the move of one of the MSG satellites over the Indian Ocean**, in order to study the basic mechanisms of the apparent change in climate change after 2000. In our opinion it is **difficult to overestimate the importance of this endeavor in the global climate change debate**.

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