A new way to Estimate the Earths Radiation Budget at the top-of-atmosphere

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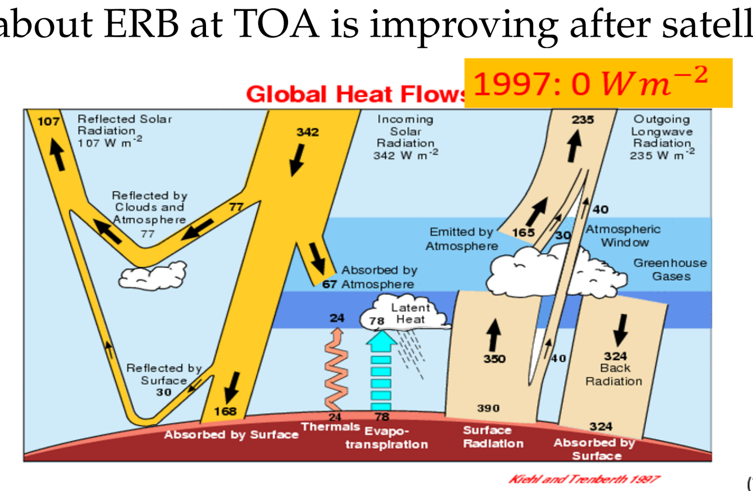
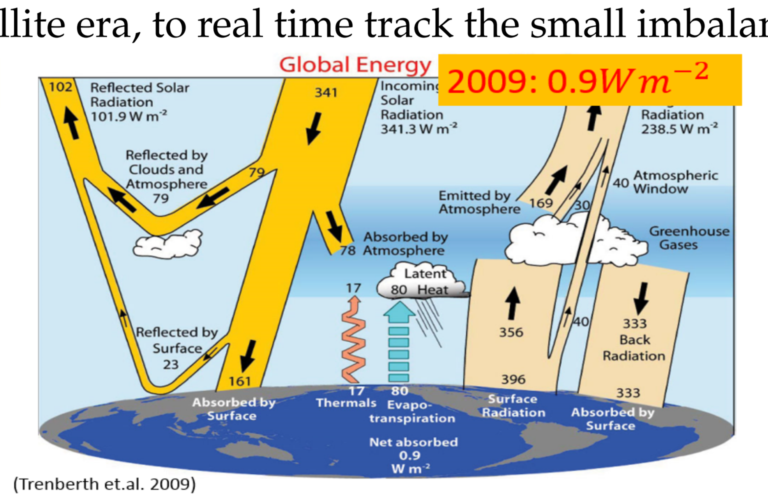
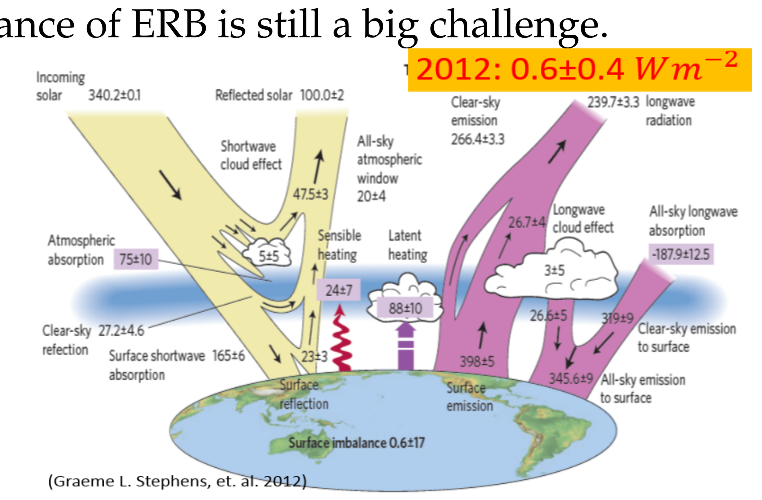
State-of-the-art

The Earth's Radiation Budget at the top-of-atmosphere (TOA) is investigated by combining remote sensing data from different Earth observing satellites and the solar radiation monitoring from dedicated missions. The ERB is the difference between incoming solar, reflected visible and remitted infrared thermal. When the incoming solar irradiance (F_{in}), reflected solar (F_{vis}) and remitted thermal infrared radiation (F_{ir}) is established, the net radiation is described as: $F_{net} = F_{in} - F_{vis} - F_{ir}$. Although the knowledge about ERB at TOA is improving after satellite era, to real time track the small imbalance of ERB is still a big challenge.







The challenge for the accurate determine the ERB value is due to the complicities of:

- Uncertainties of instrument calibration is one order of magnitude higher than ERB.
- Covering the diurnal cycle, it is achieved by interpolate polar orbit measurements to the geostationary orbit observations.
- The quantities of reflected solar and remitted infrared is influenced by the distribution and propensities of clouds, greenhouses gases and aerosol, which is also need to be precisely measured in space.

A new method

Theory

A new method is proposed here to provide a simplified solution to real time track Earth's Radiation Budget at TOA. The basic principle of the Earth's Radiation Budget measurement is illustrated at the sketch A. The incoming solar, reflected visible and remitted infrared is separately measured with dedicated mission or detector unit, which is represented by the green ellipsoid in Sketch A. Sketch B shows the concept of the new method. Instead of separately measuring solar and terrestrial radiation contributions, the detector unit is taking globally solar irradiance, the reflected visible and the remitted thermal infrared radiation.

Using the following equation(1), the F_{net} is accessible by the scenario A. However, if the F_{sum} could be measured directly from space, the F_{net} can be directly computed from equation(3).

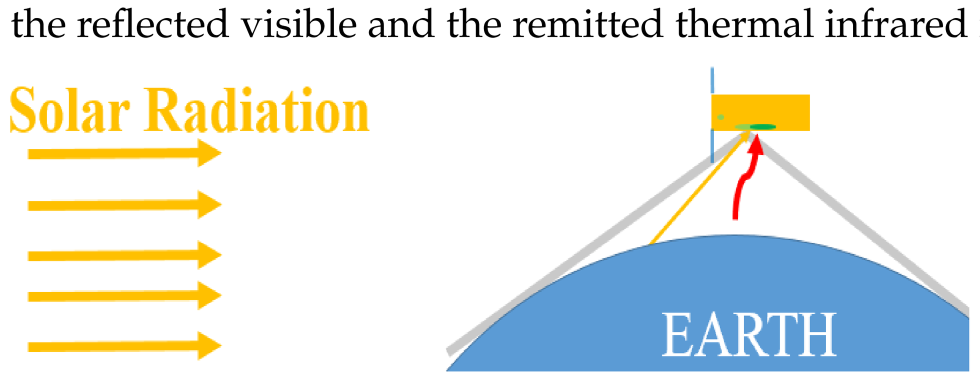
$$F_{net} = F_{in} - F_{vis} - F_{ir} \quad (1)$$

$$F_{sum} = F_{sun} + F_{vis} + F_{ir} \quad (2)$$

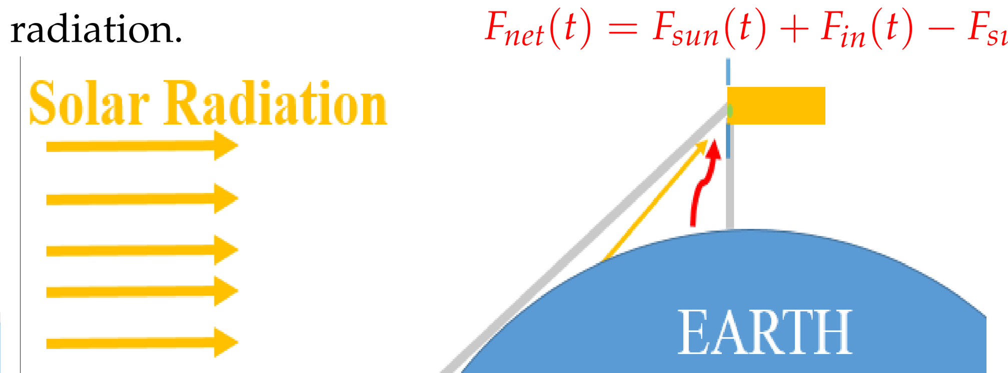
$$F_{net} = F_{sun} + F_{in} - F_{sum} \quad (3)$$

where, F_{sun} the solar irradiance normalized to 1 AU. For a real-time tracking, F_{net} is function of time

$$F_{net}(t) = F_{sun}(t) + F_{in}(t) - F_{sum}(t) \quad (4)$$



A



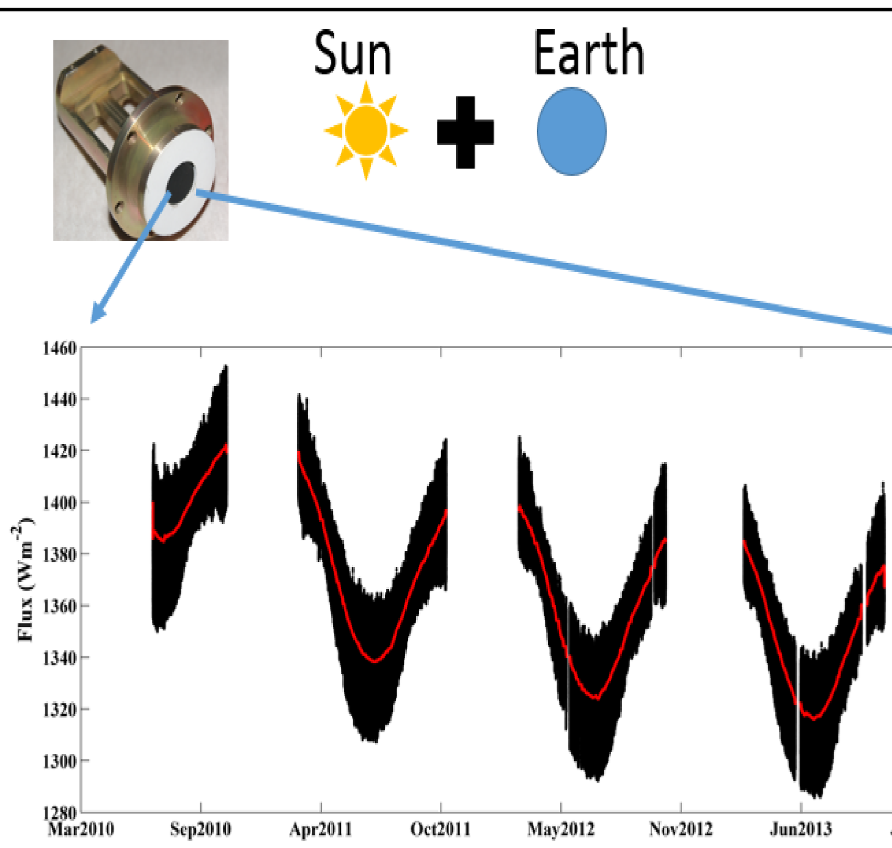
B

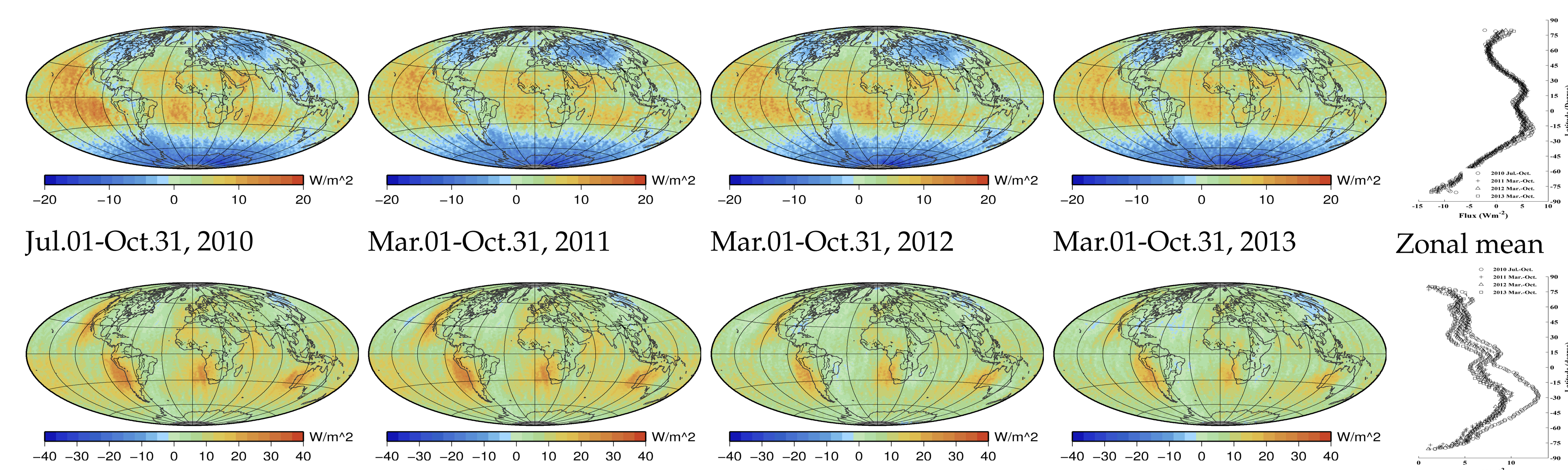
Feasibility

We firstly need a broadband detector to measure the F_{sum} with a sub Wm^{-2} accuracy, once it is identified. Then it becomes the selection of orbit to satisfy the measurement requirement of F_{sum}. The preferred satellite orbit is a sun synchronous orbit (SSO). The advantage of SSO is that it keeps the Sun always in the field of view of the instrument. In addition, the satellite is scanning over same amount area above the Earth around same local time. It is another interesting feature to cover the diurnal cycle of the reflected visible and outgoing infrared radiation by multiple SSO satellite observations.

Towards ERB estimation with the new algorithm

There is a Bolometric Oscillation Sensor(BOS) payloads on past PICARD microsatellite mission is fulfill the aforementioned condition. The PICARD was orbiting the Earth with a heliocentric orbit, the ascending and descending node time is 6 a.m. and 6 p.m.. The schema on the right shows the BOS instrument and its records during entire PICARD missionary duty cycle. The main detector of BOS instrument is black coated, by principle, it gets all electromagnetic radiation in space. The sensor was installed in the front face of PICARD, where it is always pointing to the Sun for solar observation purpose. Since there is not any cavity or optical lens attached to the main detector, it basically has a hemispherical field of view. Then the instrument is continuously receiving the solar as well as the terrestrial radiation at the same time, which is the part of F_{sum}.





With the orbit property of PICARD, two points (around 6.a.m. and 6 p.m.) of a diurnal cycle was covered by the records of BOS. The 'net' flux is obtained with equation 4. Then it is interpolated to a 1 degree by 1 degree map with the coordinate of the satellite's footprint. The first line of the upper map is the mean radiation between 6 a.m and 6 p.m. and the second line is difference radiation between 6.p.m and 6 a.m.

Summary

- The 'net' of Earth's Radiation Budget is derived with the Equation(4). The mean value of global radiation (reflected solar + remitted thermal) around local time 6 a.m. and 6 p.m., for year of 2010 between 1 Jul. and 31 Oct., is 0.56Wm^{-2}, year of 2011 between 1 Mar. and 31 Oct. 0.44Wm^{-2}, year of 2012 between 1 Mar. and 31 Oct. 0.40Wm^{-2}, year of 2013 between 1 Mar. and 31 Oct. 0.40Wm^{-2}. It hints a positive feedback of the Earth's Climate to space.
- Comparing to the classical method, the new method shed a light on: real time tracking ERB with one instrument; covering the diurnal cycle with the same instrument aboard several satellites orbiting the Earth with different ascending and descending nodes. The new approach will essentially reduce the system errors than by comparing the measurements of multiple sensors of several missions.
- It is possible to design a detector payload on a nanosatellite mission based on proposed new algorithm. It will provide a flexible and economy solution to study the net of ERB with a nanosatellite consultation network. In turn, it will add valuable information for the global climate change from the energy budget point of view.
- The method is also applicable for other planetary missions, to study their climates even the inner activities.

Conference: EGU2014, 27 April-02 May,2014, Vienna-Austria

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