Determining the Earth Radiation Budget

Climate change is a major and growing threat to natural, managed and human systems. There is already increasing evidence of its adverse impacts on the natural and human environment (e.g. ecosystems, biological diversity, water resources and economy). Global climate is largely determined by the radiation budget at the top of the atmosphere which regulates the overall energy content of the Earth system, i.e. atmosphere and ocean. The system is heated up by the absorption of incoming solar (short-wave) radiation and is cooled down by radiating to space terrestrial (long-wave) infrared radiation. Human activities have led to rising levels of heat-trapping greenhouse gases in the atmosphere with less terrestrial radiation being able to escape, creating the so-called positive Earth energy imbalance (EEI). As a result, the Earth system is warming up. The most obvious sign of it is the long-term increase in global surface temperatures which enhances the flux of outgoing energy and thus tends to restore the Earth energy balance.

Since the EEI is driving climate change, its continual monitoring has been identified early on as a fundamental diagnostic for analyzing climate variability and anticipating future changes. The imperative to monitor EEI and its variations is constantly reported because the closure of the Earth energy budget is seen by the climate science community as a key step in improving further our understanding of global climate change. Ideally, EEI should be measured continuously from space. So far, existing satellite instruments have not been able to measure the solar and terrestrial radiative fluxes accurately enough to determine directly the absolute value of EEI, though there is much more confidence in the measurements of EEI relative changes. This lack of accurate satellite measurements of EEI is a major issue because climate change is first of all a perturbation of the Earth energy balance. Furthermore, accurate satellite measurements of solar and terrestrial energy fluxes also represent essential constraints and benchmarks in the evaluation and improvement of climate models, for example their representations of clouds and aerosols radiative effects. Finally, the risk of gaps in the multi-decadal record of Earth Radiation Budget (ERB) data will be extremely high by about 2025, when all the current satellite ERB sensors will be close to the end of their lifetimes. Ensuring continuity of the existing ERB data time series is an absolute priority. The ERB record is a critical source of information in disentangling the externally forced climate variability from the internal variability and in assessing climate sensitivity to various forcings (including also volcanic eruptions, solar variability, and anthropogenic aerosols).

This scientific and instrumental context calls for new instrument technologies and observing methods that allow to measure and continuously monitor the energy imbalance and its different components with high accuracy and in a traceable manner such that they can ultimately be concatenated across subsequent missions. The lunar surface provides a unique vantage point to measure terrestrial outgoing radiation integrated over a very large area of the Earth’s surface. From the Moon scanning of the full Earth takes only 24 hours with a single instrument, whereas dozens of satellites in low-earth orbit would be required to achieve the same. In the course of a month full-earth scans of the outgoing radiation will be measured for all local times, to form a comprehensive data set of the Total Outgoing Radiation (TOR). Measurements from low-earth orbiting (polar) satellites could complement the data set by providing TOR at higher spatial resolution and individual scene-specific measurements.

The technical challenges obviously include the low signal level at the distance of the Moon. At the top of the atmosphere the TOR is on average ~340 Wm^{-2}. At the distance of the Moon it is less than 0.1 Wm^{-2} , which is roughly equal to the resolution (precision) of today’s state of the art absolute (solar) radiometers. A ~100-fold improvement of the radiometric precision compared to current absolute solar radiometers is required in order to measure the TOR from the lunar surface. We believe that this is achievable with a combination of new high-sensitivity sensors with specifically optimized measurement procedures and operating concepts. These concepts might include spectrally selective measurements, which allow the use of the highly sensitive semiconductor-based sensors as well as providing additional information on the spectral composition of the TOR and to distinguish between reflected (short-wave) and emitted (thermal) radiation.