SERB, a nanosatellite to study the Sun and the Earth

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1 – Abstract

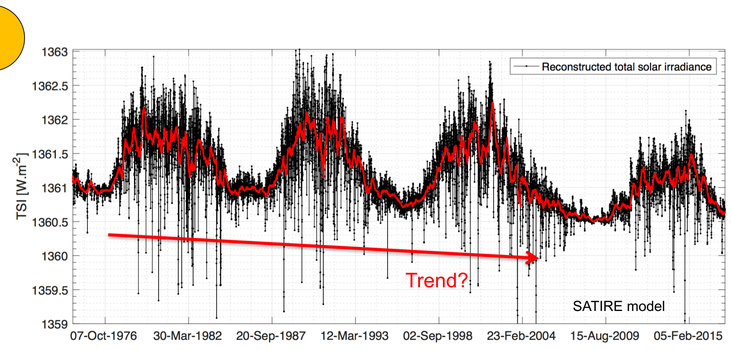
Within the past decade, satellites constellations have become possible and practical. One of the interest to use a satellites constellation is to measure the true Earth Radiation Imbalance, which is a crucial quantity for testing climate models and for predicting the future course of global warming. This measurement presents a high interest because the 2001–2010 decade has not shown the accelerating pace of global warming that most models predict, despite the fact that the greenhouse-gas radiative forcing continues to rise. All estimates (ocean heat content and top of atmosphere) show that over the past decade the Earth radiation imbalance ranges between 0.5 to 1 W.m^{-2}. Up to now, the Earth radiation imbalance has not been measured directly. The only way to measure the imbalance with sufficient accuracy is to measure both the incoming solar radiations (total solar irradiance) and the outgoing terrestrial radiations (top of atmosphere outgoing longwave radiations and shortwave radiations) onboard the same satellite, and ideally, with the same instrument. The incoming solar radiations and the outgoing terrestrial radiations are of nearly equal magnitude of the order of 340.5 W.m^{-2}. The objective is to measure these quantities over time by using differential Sun-Earth measurements (to counter calibration errors) with an accuracy better than 0.05 W.m^{-2}. It is also necessary to have redundant instruments to track aging in space in order to measure during a decade and to measure the global diurnal cycle with a dozen satellites. Solar irradiance and Earth Radiation Budget (SERB) is a potential first in orbit demonstration satellite. The SERB nano-satellite aims to measure on the same platform the different components of the Earth radiation budget and the total solar irradiance. Instrumental payloads (solar radiometer and Earth radiometers) can acquire the technical maturity for the future large missions (constellation that insure global measurement cover) by flying in a CubeSat. This paper is intended to demonstrate the ability to build a low-cost satellite with a high accuracy measurement in order to have constant flow of data from space.

2 – Scientific objectives

The « SERB nano-satellite » is a future innovative proof-of-concept, with three main science goals:

- *1st:* to **extend the Total Solar Irradiance (TSI) variability** measurement with a long-term stability (10 years) better than 0.05 W.m^{-2}
- *2nd:* to **monitor the Solar Spectral Irradiance (SSI) at 215 nm** (Herzberg solar continuum) with a long-term stability (10 years) better than 3.4x10^{-5} W.m^{-2}.nm^{-1}
- *3rd :* to **establish a radiation balance of the Earth** with an accuracy better than 1% and link with the imbalance (between 0.5 and 1 W.m^{-2})

1



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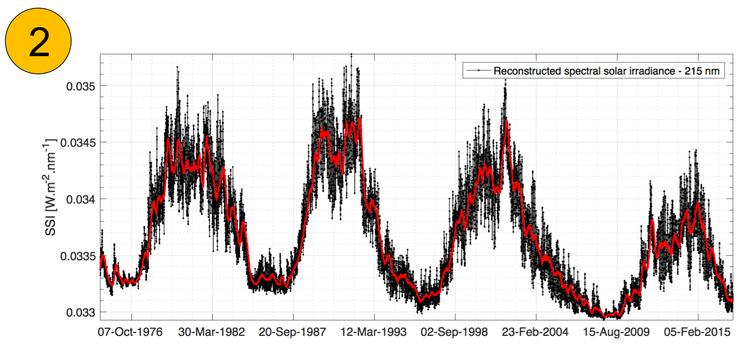

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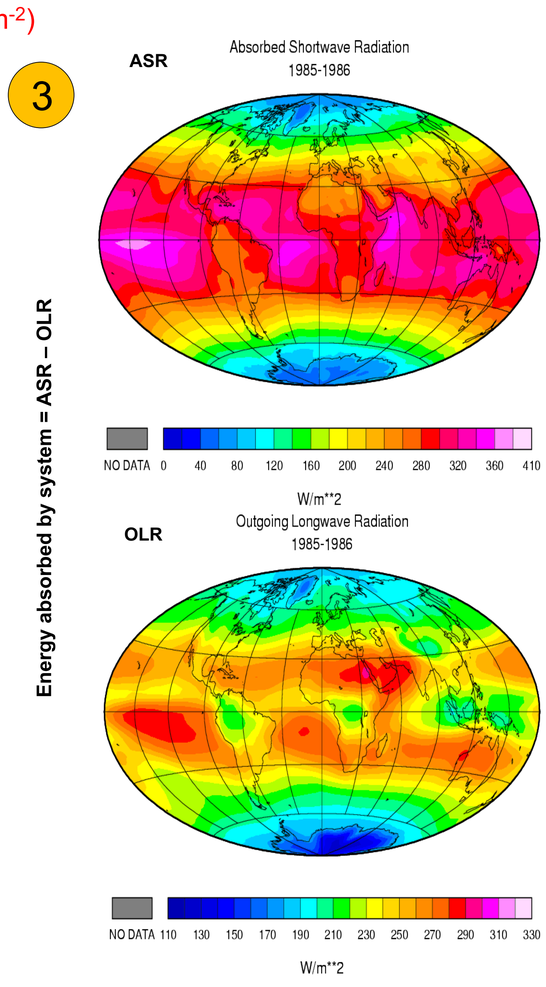
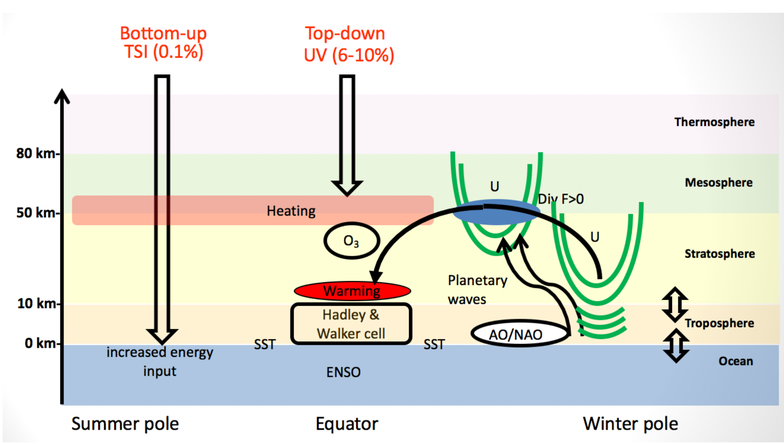




- ❑ Influence of solar variability on Earth climate and regional effects.
- ❑ Dynamical amplification of the stratospheric solar response.

Earth's Energy Imbalance characterizes how close the climate system to equilibrium.

Earth's Energy Imbalance reveals the future direction of the climate change and necessary measures to prevent excessive global warming.

Earth's Energy Imbalance helps to constrain poorly known forcing (e.g., aerosol, aerosol-cloud interactions or solar irradiance).

Directly measured three components of Earth's Energy Imbalance can help to improve climate models.

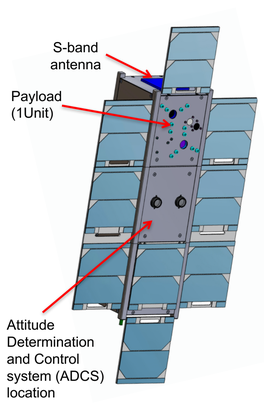
How to measure the Earth's energy imbalance:

- ❑ **Retrieval of ocean heat content (Ho) tendencies from the subsurface observations → Not accurate.**
- ❑ **Direct satellite measurements of shortwave and longwave radiation at the top of the atmosphere → Use of Satellites observations (constellation).**
- ❑ **Interest to develop a small satellites constellation to measure simultaneously all essential climate variables with revisit time and resolution. Moreover, we need pre-flight and flight calibrations.**

Essential Climate Variable	Required measurement uncertainty at 1σ	Stability (per decade) at 1σ
TSI	+/-0.04% (+/-0.5 W.m^{-2})	+/-0.004% per decade (+/-0.05 W.m^{-2})
SSI (215 nm)	+/-0.5% (+/-1.7 10^{-4} W.m^{-2}.nm^{-1})	+/-0.1% per decade (+/-3.40 10^{-5} W.m^{-2}.nm^{-1})
Top of atmosphere Outgoing longwave radiations (infrared)	+/-0.4% (+/-1 W.m^{-2})	+/-0.04% per decade (+/-0.1 W.m^{-2})
Top of atmosphere Shortwave radiations (reflected)	+/-0.9% (+/-1 W.m^{-2})	+/-0.09% per decade (+/-0.1 W.m^{-2})

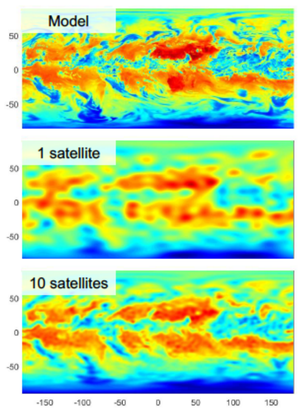
- ➢ **Top of the atmosphere (TOA) measurements of radiation from space** can track changes over time but **lack absolute accuracy**.
- ➢ **All estimates (ocean heat content and TOA) show that over the past decade the energy imbalance ranges between 0.5 and 1.0 W.m^{-2}.**
- ➢ **The imbalance at TOA is too small to measure directly from spacecraft?**

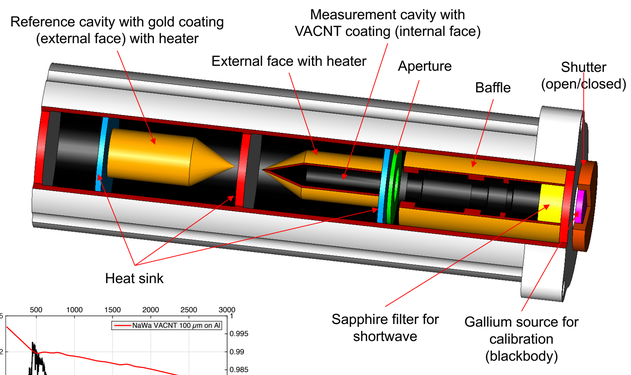
3 – The SERB nano-satellite prototype

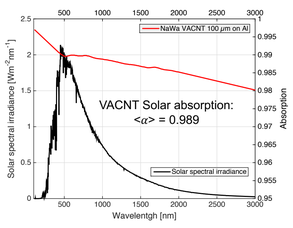


- Launch schedule: 2022?
- Launch Vehicle: with PSLV, Vega, DNEPR, SOYUZ …
- Target Orbit: Helio-synchronous Orbit
  - Altitude: 680 +/-30 km
  - Local time at ascending node: 06H00 +/-00H30
  - Orbital inclination: 98.21 +/-0.2°
- Life time: ~ 12 months
- ADCS
  - Sun pointing: 0.2°
  - Nadir pointing: 1°

➢ **Final Objectives: constellation with 10 nanosatellites.**







Radiometer technology with nanotube of carbon

4 - Conclusions

The SERB nano-satellite aims three main scientific objectives in connection with the observations of the Earth and the Sun. Scientific requirements are established.

The first step of our program is to develop an innovative proof-of-concept nano-satellite.

At the end of life, the nano-satellite will become a debris. At an altitude of 680 km, the orbit would naturally decay within the allotted 25 years. Thus, the rule of the 25 years to avoid space debris is respected.

The second step is to launch a minimum of 10 nano-satellites to obtain a global distribution of Earth fluxes.

- ✓ Use of nano-satellite is an interesting tool for quickly addressing key scientific problems.
- ✓ A cost-effective means for the flight demonstration of new spacecraft and instrument design concepts and hardware.
- ✓ An opportunity to develop scientific research, engineering, and project management capabilities.
- ✓ The capability for a timely response to targets of opportunity.
- ✓ An opportunity for international cooperative missions.
- ✓ **Small satellites constellation (cost optimization) for resolution and revisit time → a mean to solve problems of the 21 century climate change.**

Acknowledgments

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