Total solar irradiance and terrestrial outgoing longwave measurements with CLARA onboard NorSat-1

Margit Haberreiter[1], Wolfgang Finsterle[1], Jean-Philippe Montillet[1], Manfred Gyo[1], Dany Pfiffner[1], Silvio Koller [1], Bo Andersen[2], and Werner Schmutz[1]

[1]PMOD/WRC, Davos, Switzerland, [2]University of Oslo, Norway

Abstract

Solar irradiance is the key energy input to Earth. In order to understand the Earth's climate system, it is of great importance to continuously monitor the Total Solar Irradiance (TSI) from space. The Compact Lightweight Absolute RAdiometer (CLARA) experiment onboard the Norwegian micro satellite NorSat-1 is a SI-traceable radiometer and as such contributes to the record of TSI measurements. Moreover, CLARA also measures the terrestrial outgoing longwave radiation (OLR) on the night-side of Earth. We present the latest status of the CLARA TSI and LOR datasets including the key data processing steps and compare the results with other available observations. Ultimately, we aim towards determining the Earth Energy Imbalance from space. We will discuss the achievements and limitations in direction of this goal.

The CLARA Instrument

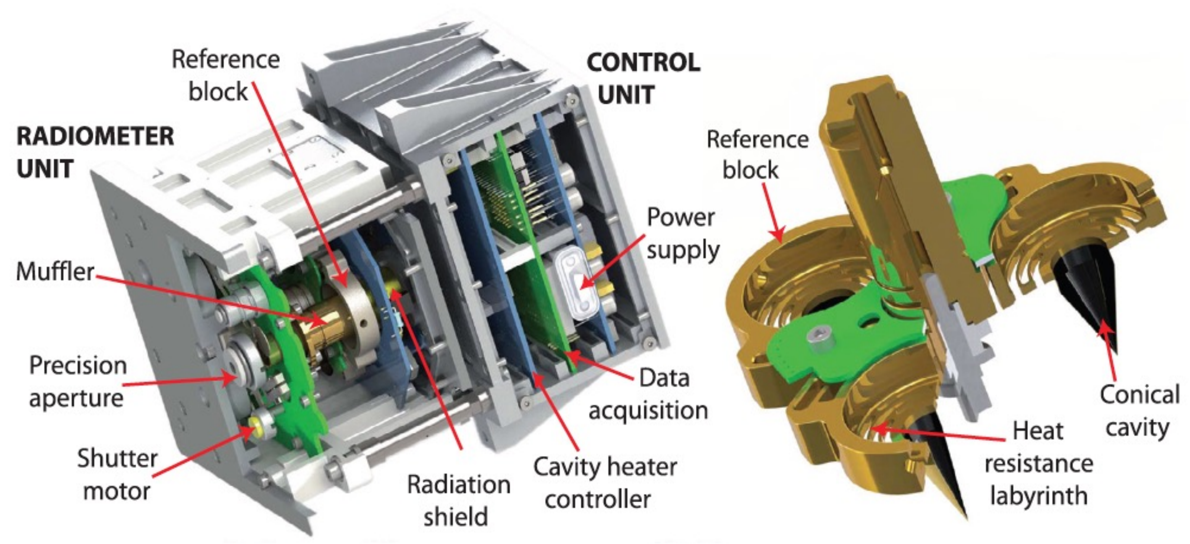

***Fig 1: Left Panel**: The radiometer unit and control unit of the CLARA instrument with the key components illustrated. **Right Panel:** Three cavity detectors (black inside, gold outside) of CLARA mounted to a common heatsink.*

The Compact Lightweight Absolute RAdiometer (CLARA) experiment (Finsterle et al. 2014; Walter et al. 2017) onboard the Norwegian micro-satellite NorSat-1 is one of the recent absolute radiometer built at PMOD/WRC and has been launched July 14, 2017. After SOHO/VIRGO (Fröhlich et al.,1995) and PREMOS (Schmutz et al. 2009; Schmutz et al. 2013), CLARA is the first of the "new generation" PMOD radiometers with a new cavity design and aperture setup along with a compact and light-weight design. CLARA, as PREMOS, is traceable to the National Institute of Standards and Technology (NIST) radiometric. From the pre-launch calibration Walter et al. (2017) determined the combined measurement uncertainty for the calibrated SI-traceable CLARA flight instrument to be 567–912 ppm (k = 1). After a reaction wheel failure in May 2018 measurements resumed Nov 2019. Here we focus on the CLARA data obtained during 2020 and 2021 when measurements were continuously taken. Due to a second reaction wheel issue no measurements can currently be obtained until the issue is solved.

CLARA performance

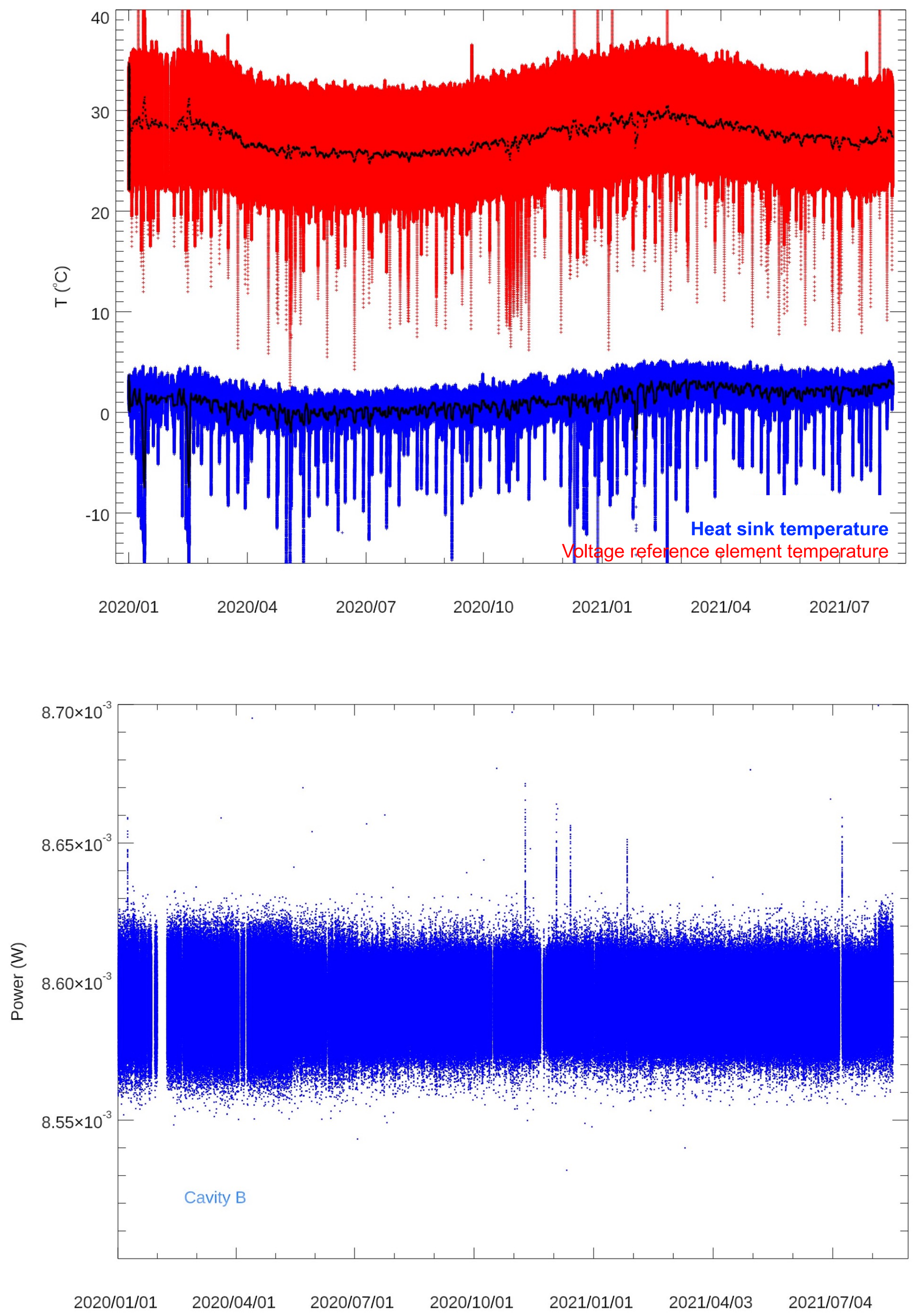

***Fig 2: Top Panel:** Voltage reference element temperature in the Ebox (red line) and heat sink temperature on the sensor head (blue line) from Jan 2020 to Aug 2021. **Bottom Panel:** Power of the closed shutter cycles of the nominal cavity.*

The reference and heat sink temperatures (Fig. 2, top panel) show an expected annual modulation. The power during closed shutter cycles (Fig. 2, bottom panel) is flat, which shows that all temperature dependencies has been correctly considered. It further indicates that some other than a temperature effect might be the cause for the low TSI reading during 2020 (Figure 3).

The following instrumental and operational points have been carefully considered:

- Alignment-offset determined before launch and during commissioning phase
- good quality solar pointing
- T-dependent radiative loss to deep space
- upper limit for the heat sink T-gradient (1 K/h)

TSI and OLR as observed with CLARA

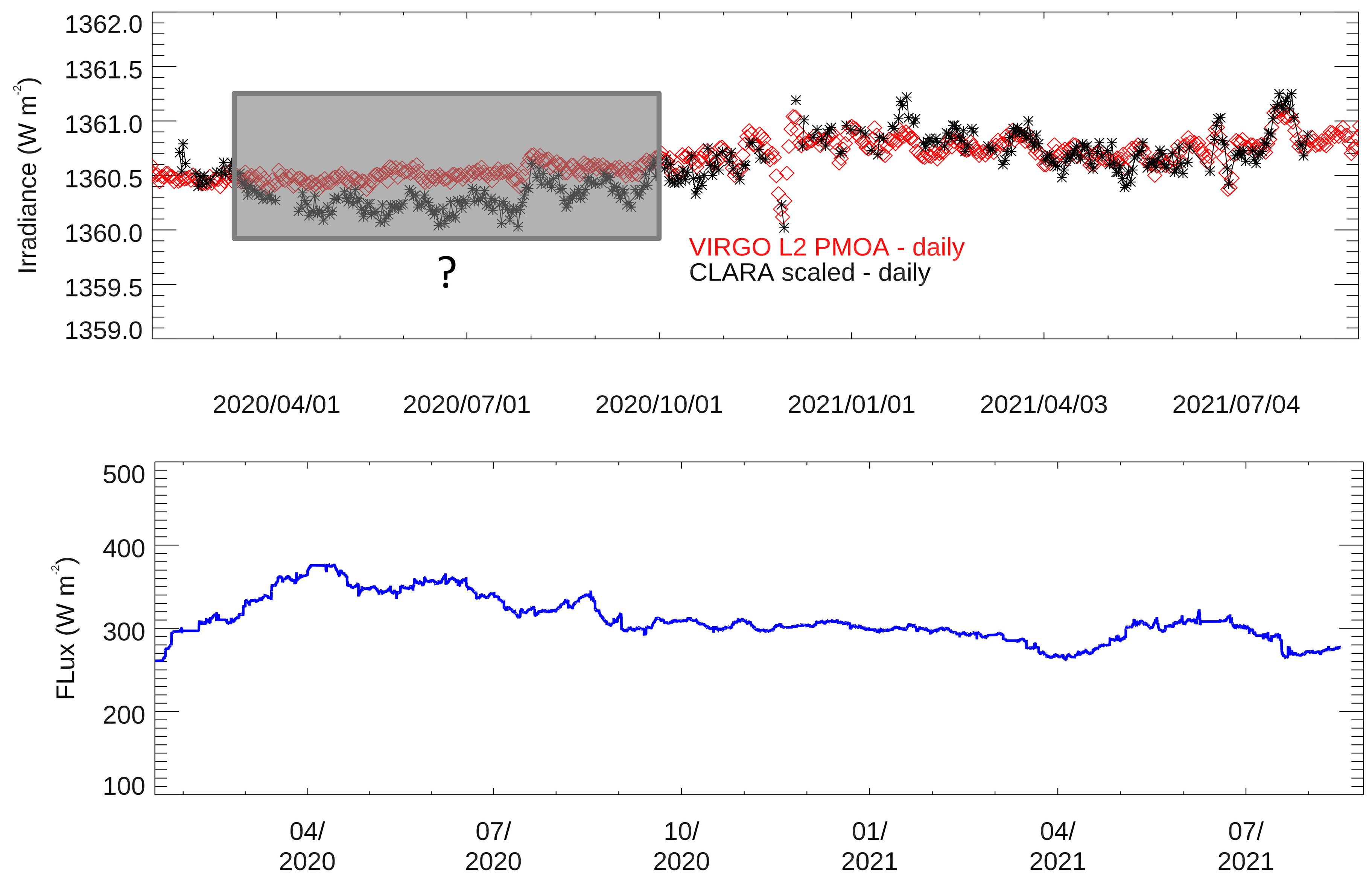

***Fig 3: Top Panel:** Daily TSI values as measured with CLARA from Nov 2020 to Aug 2021 compared with latest VIRGO dataset by Finsterle et al. (2021). The lower reading of CLARA before Nov 2020 still needs further investigation. **Bottom Panel:** Preliminary dataset of the monthly mean of the terrestrial OLR at the top of the atmosphere. After a careful nadir pointing filtering, we expect the variation to reduce.*

Summary

The midnight-noon orbit of NorSat-1 allows simultaneous measurements of TSI and OLR with CLARA. **TSI measurements:** From Nov 2020 onward CLARA detected solar variability in line with VIRGO L2 measurements. Before that the CLARA TSI measurements give a significantly lower values. The reason for this and the degradation correction is currently being worked on. **OLR measurements:** Continuous OLR measurements could be taken since Jan 2020. Additional Earth pointing filtering is currently being implemented. The goal is to determine the global and latitudinally dependent SI-traceable OLR. These measurements will serve as important step towards determining the radiation budget of Earth with SI-traceable absolute radiometers.

References

Finsterle, W., et al., Proc. SPIE, 9264, Earth Observing Missions and Sensors: Development, Implementation, and Characterization III, 92641S, doi:10.1117/12.2069614, 2014.
Finsterle, W., Koller, S., Beck, I., et al. 2014, in Society of Photo-Optical Instru- mentation Engineers (SPIE) Conference Series, Vol. 9264, Earth Observing Missions and Sensors: Development, Implementation, and Characterization III, ed. X. Xiong & H. Shimoda, 92641S
Finsterle, W., Montillet, J. P., Schmutz, W., et al. 2021, Scientific Reports, 11, 7835
Haberreiter, M. et al., in preparation
Fröhlich, C., Romero, J., Roth, H., et al. 1995, Sol. Phys., 162, 101
Schmutz, W., Fehlmann, A., Finsterle, W., Kopp, G., & Thuillier, G. 2013, AIP Conference Proceedings, 1531, 624
Schmutz, W., Fehlmann, A., Hülsen, G., et al. 2009, Metrologia, 46, 202