TSI and Earth OLW Measurements with CLARA onboard NorSat-1

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PMOD/WRC
Davos

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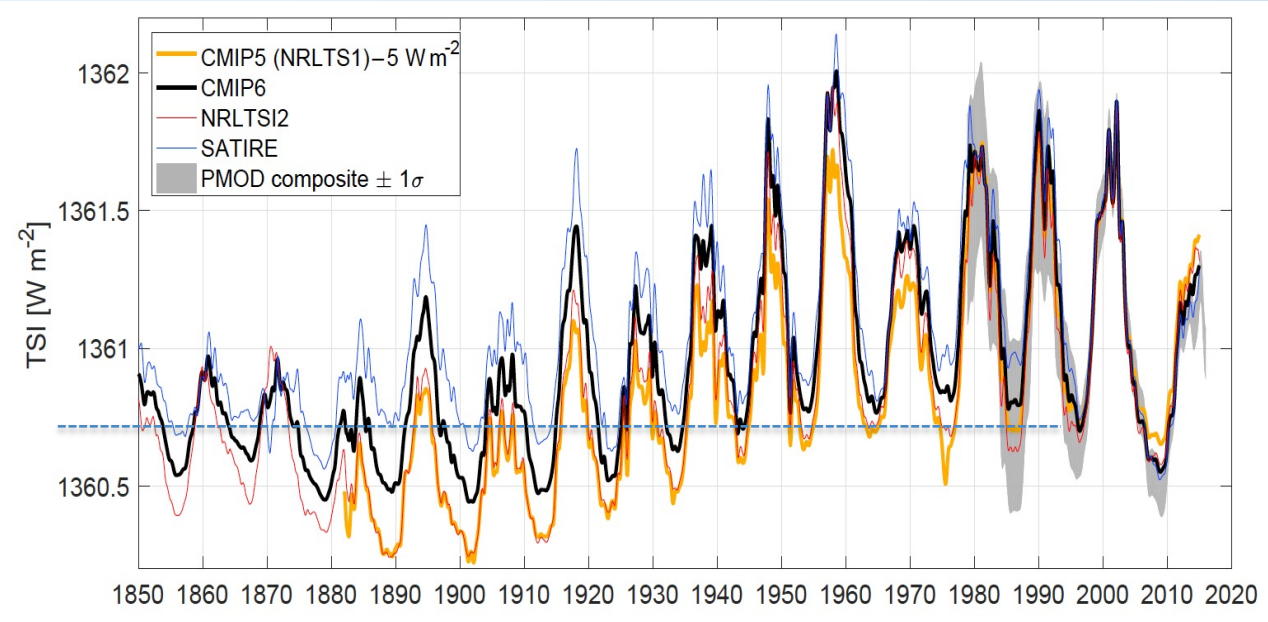
Overview

- Introduction
- Instrument operations
  - Flag poor solar pointing
  - Flag poor heater cycle performance
- TSI results
- Earth Observations
- Next steps

Motivation to measure TSI



- diverging reconstruction models
- continuous SI-traceable measurements from space are required
- improved TSI accuracy and stability is absolutely crucial

Matthes et al., 2017, *Solar Forcing for CMIP6*, Geoscientific Model Development, 6, 10

CMIP6: 6thCoupled Model Intercomparison Project; recommended dataset (TSI, SSI, particles)

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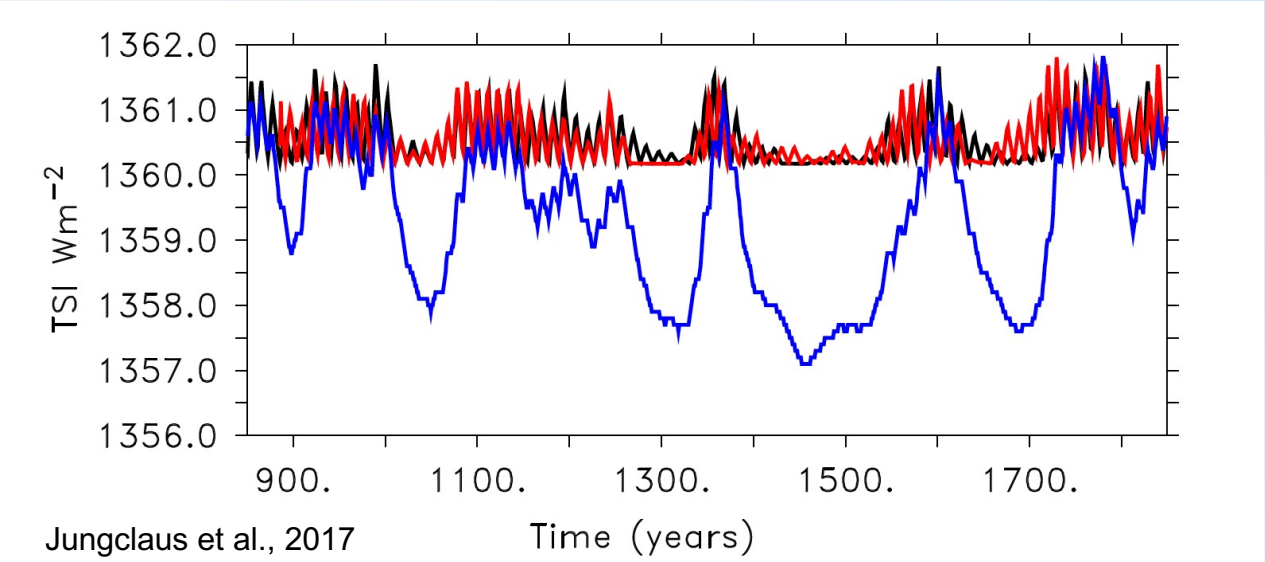
TSI reconstructions to the past



Jungclaus et al., 2017

Updated Shapiro et al., 2011 model

SATIRE-M model using ^{10}Be data

SATIRE-M model using ^{14}C data

Current Status TSI Observations (Ball et al.)

- TSI accuracy: 294 ppm
- TSI stability: 10-40 ppm/yr

Implications

- Strongly diverging long-term reconstruction models
- Impact on future projections
- improved TSI accuracy and stability absolutely crucial

-> Improved future projections will be possible

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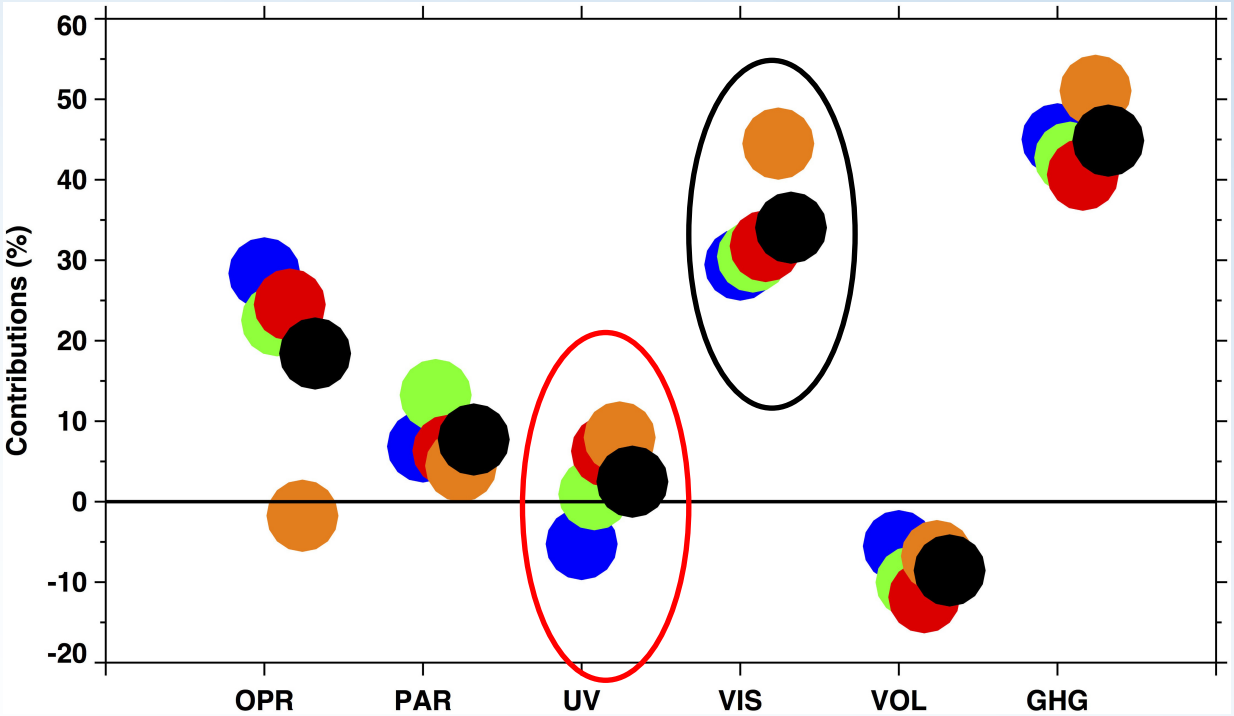
Forcing attribution to temperature trends



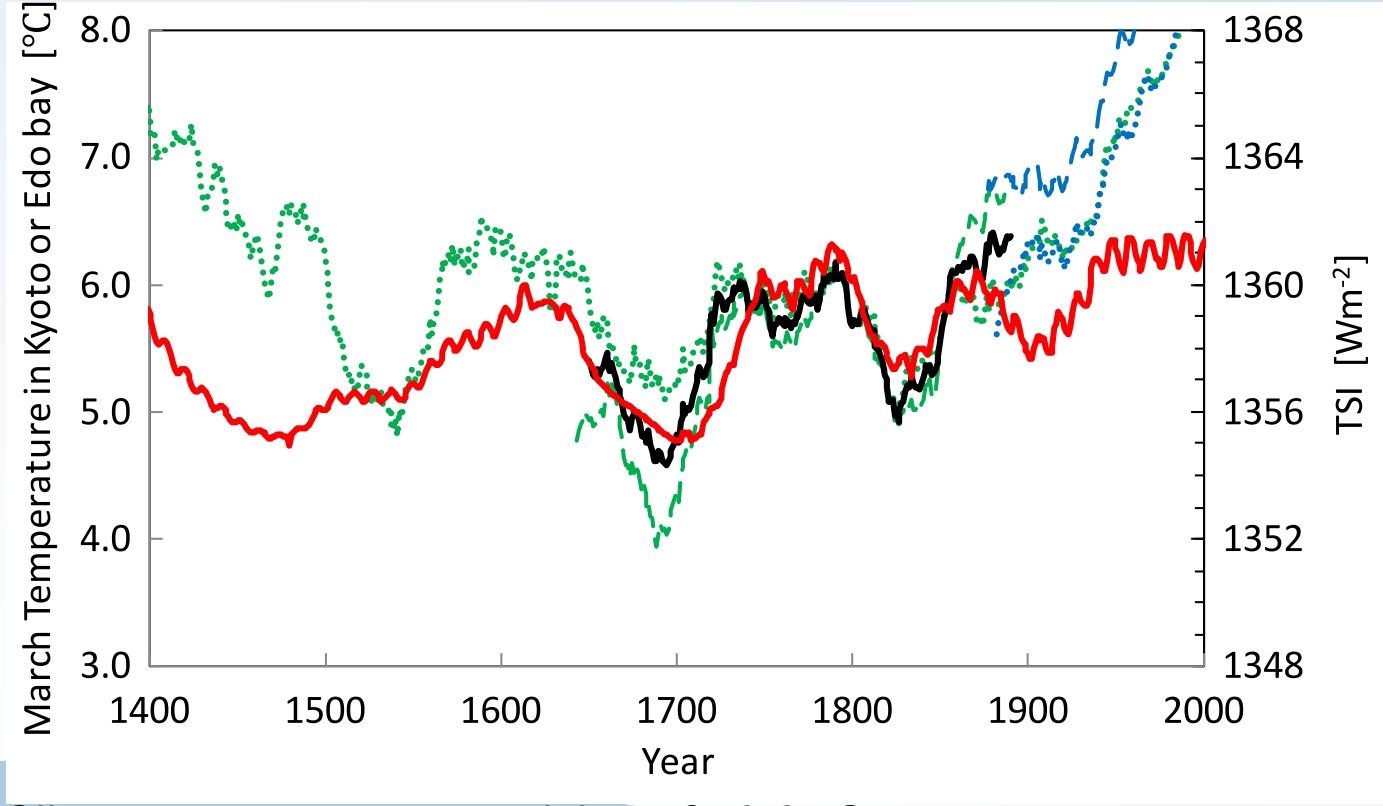
Contribution (%) of different forcing agents to global and seasonal mean temperature trends for the period 1910–1940 from the reference simulation.

Colors indicate different annual season means:
Annual
Dec/Jan/Feb,
Mar/Apr/May
Jun/Jul/Aug
Sept/Oct/Nov

OPR: ozone precursers fixed to pre-industrial
PAR: no energetic particle precibitation
UV: fixed solar UV
VIS: fixed solar VIS and IR
VOL: constant stratospheric aerosols
GHG: fixed WMGHG level

Egorova T, Rozanov E, Arsenovic P, Peter T and Schmutz W (2018) Contributions of Natural and Anthropogenic Forcing Agents to the Early 20th Century Warming. Front. Earth Sci. 6:206. doi: 10.3389/feart.2018.00206

TSI variation and March Temp in Kyoto / Edo bay



Reconstructed averaged March temperatures based on cherry blossom for Kyoto (dotted) and Edo bay (dashed), Aono & Kazui (2008), Aono & Saito (2010)
Thermometer measurements in Kyoto (dotted) and Edo bay (dashed)
Mean of reconstructed March temperatures based on cherry blossom
Reconstructed TSI (Egorova et al., 2018)

Probability of probability of solar forcing increases to 99.99%

Climate temperature precision of ±0.2 °C

Schmutz 2021, SWSC, J. Space Weather Space Clim. 2021, 11, 40, doi: 10.1051/swsc/2021016

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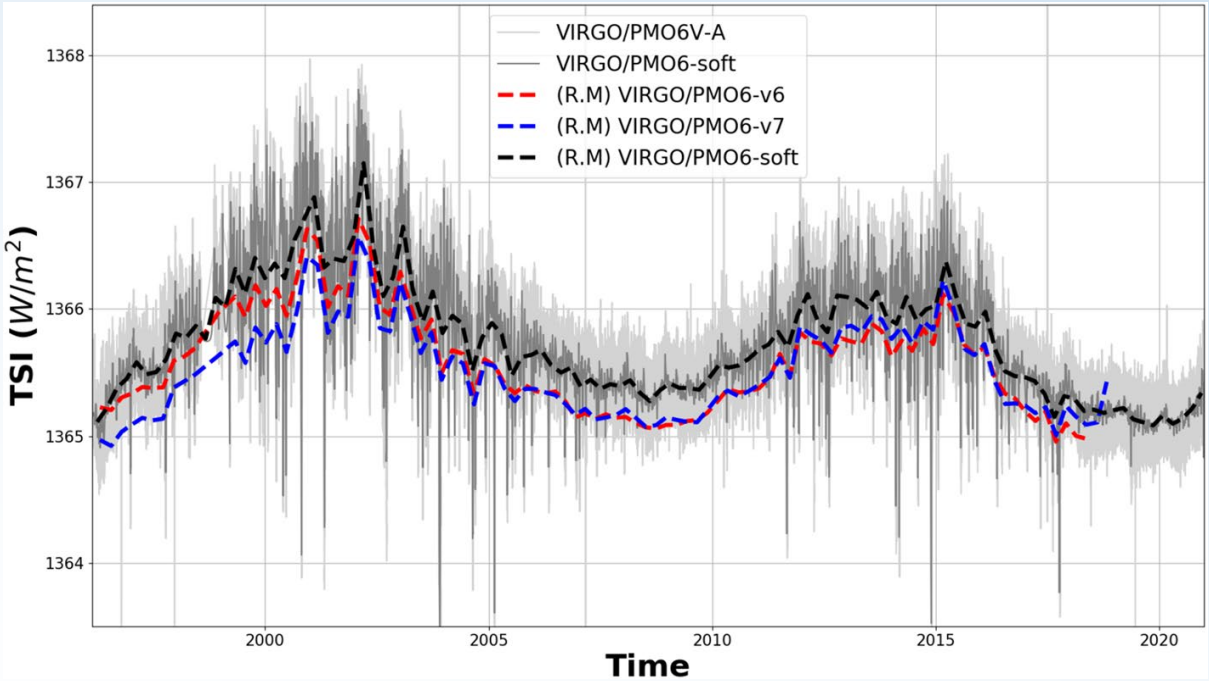
Total Solar Irradiance Variability



The degradation-corrected PMO6-VA time series (light grey)

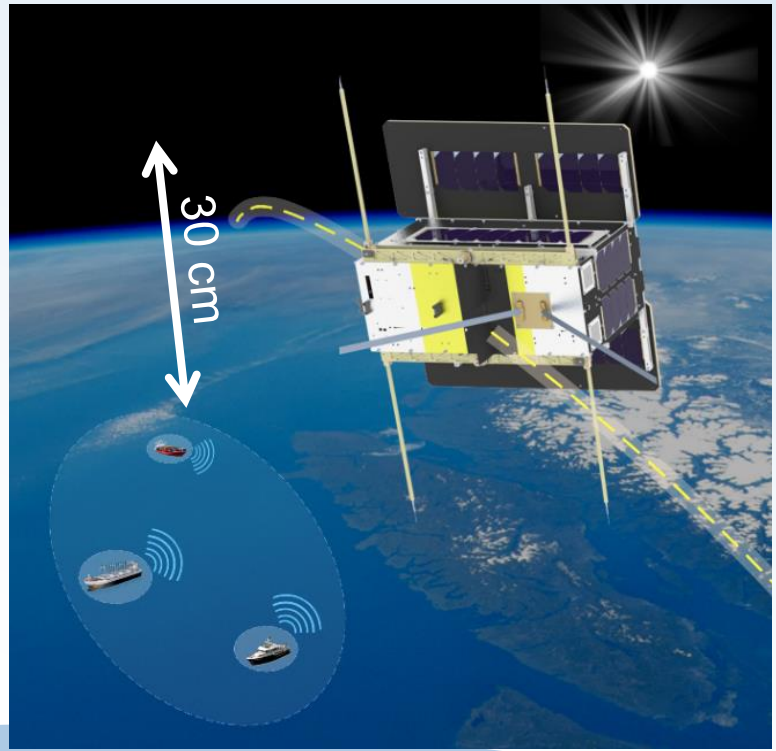
fused PMO6-V-A and -VB (PMO6-soft, dark grey)

and the previous versions of the VIRGO/PMO6 degradation corrected TSI time series (PMO6-v6 (red 2015), PMO6-v7 (blue, 2017)).

The dashed lines are 81-day running means (R.M.).
Here TSI is at the "VIRGO" absolute scale as it is based on raw VIRGO and DIARAD data

Finsterle, W., Montillet, J.-P., et al., Nature Scientific Reports, 2021

NorSat-1 key facts



Norwegian low-cost satellite

Payloads

- AIS ship tracker
- Langmuir probes
- CLARA TSI radiometer

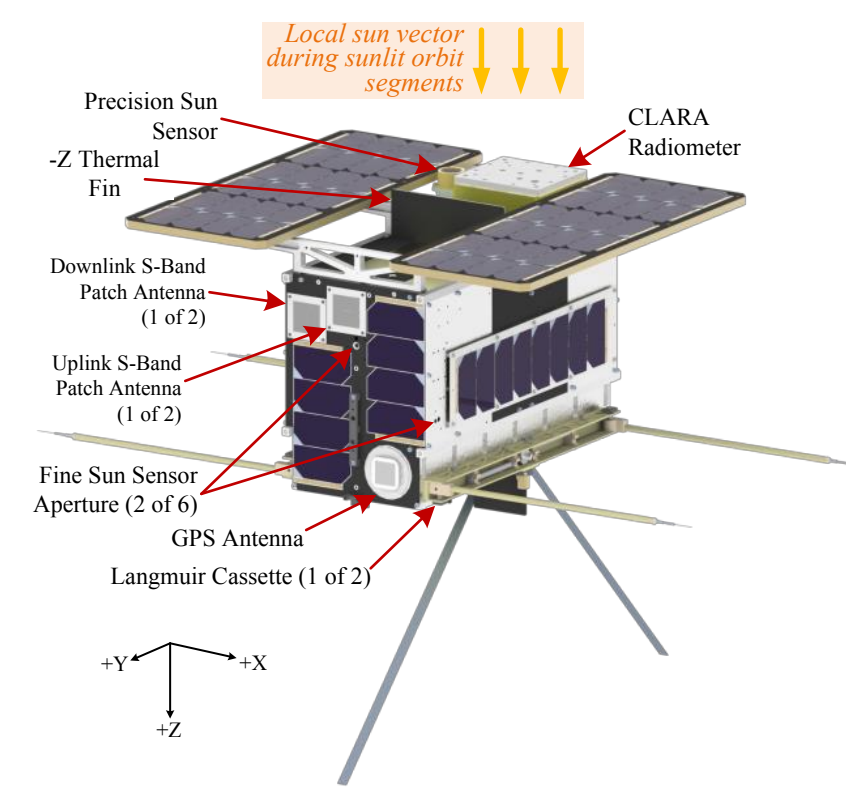
Launch

14 July, 2017

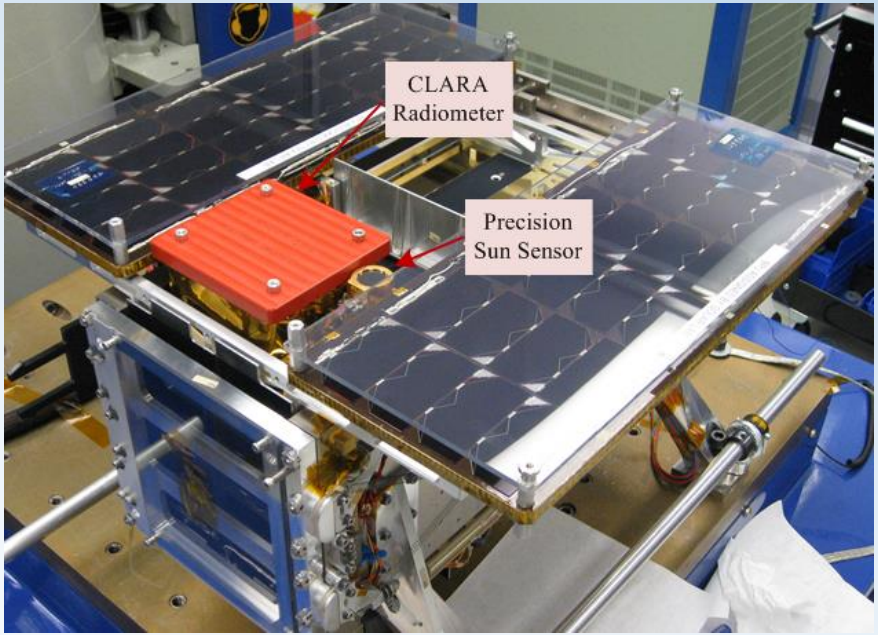
Orbit

Polar Low Earth Orbit
midnight-noon
at approx. 600 km

NorSat-1 Platform



Schematic view of the payload



NorSat-1 at SFL vibration test facility

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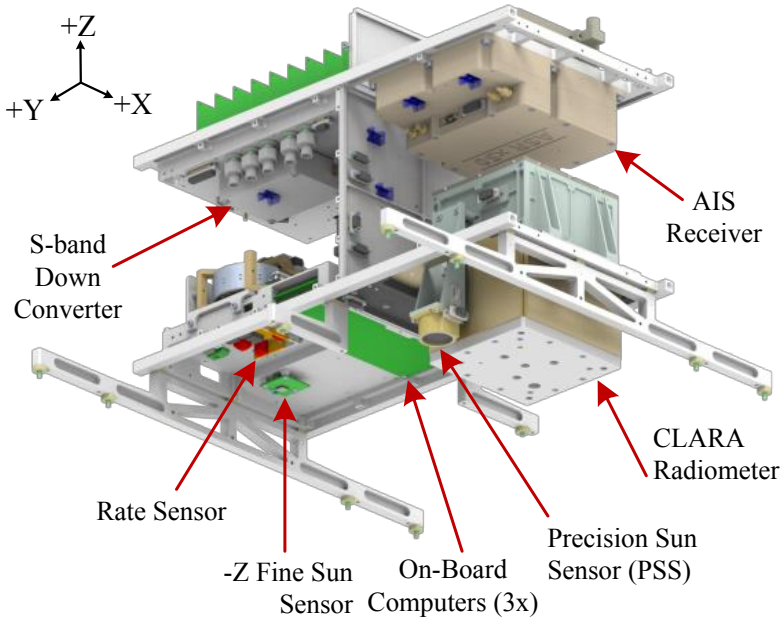
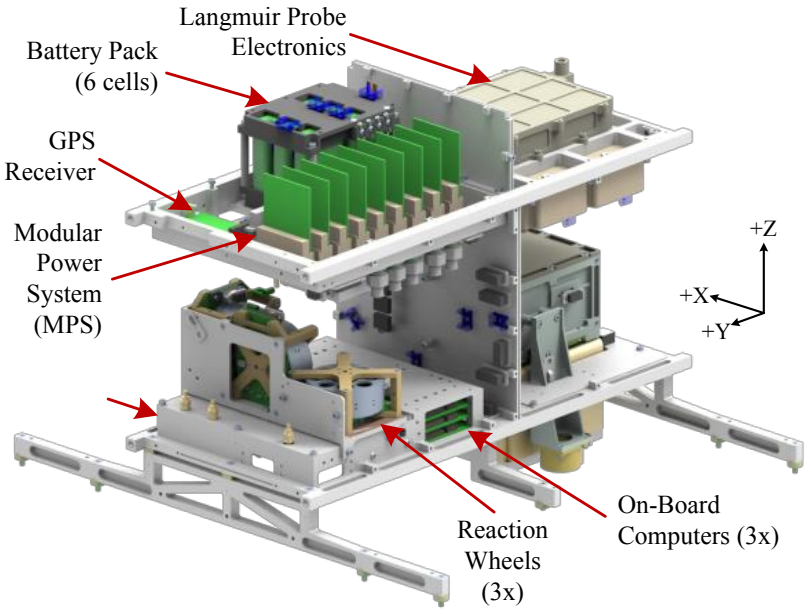
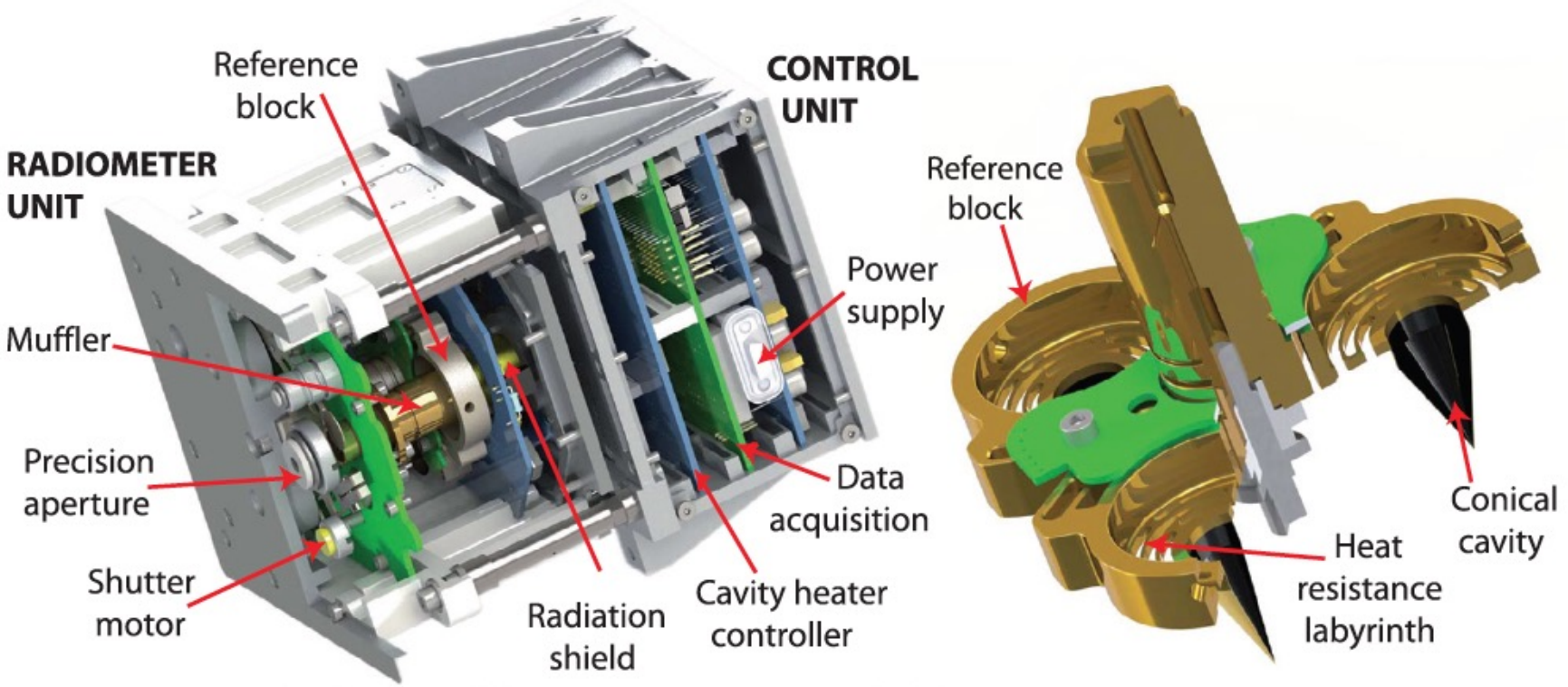
NorSat-1 internal layout





CLARA optical geometry



CLARA: Compact Light-weight Absolute Radiometer
Walter et al. (2017)

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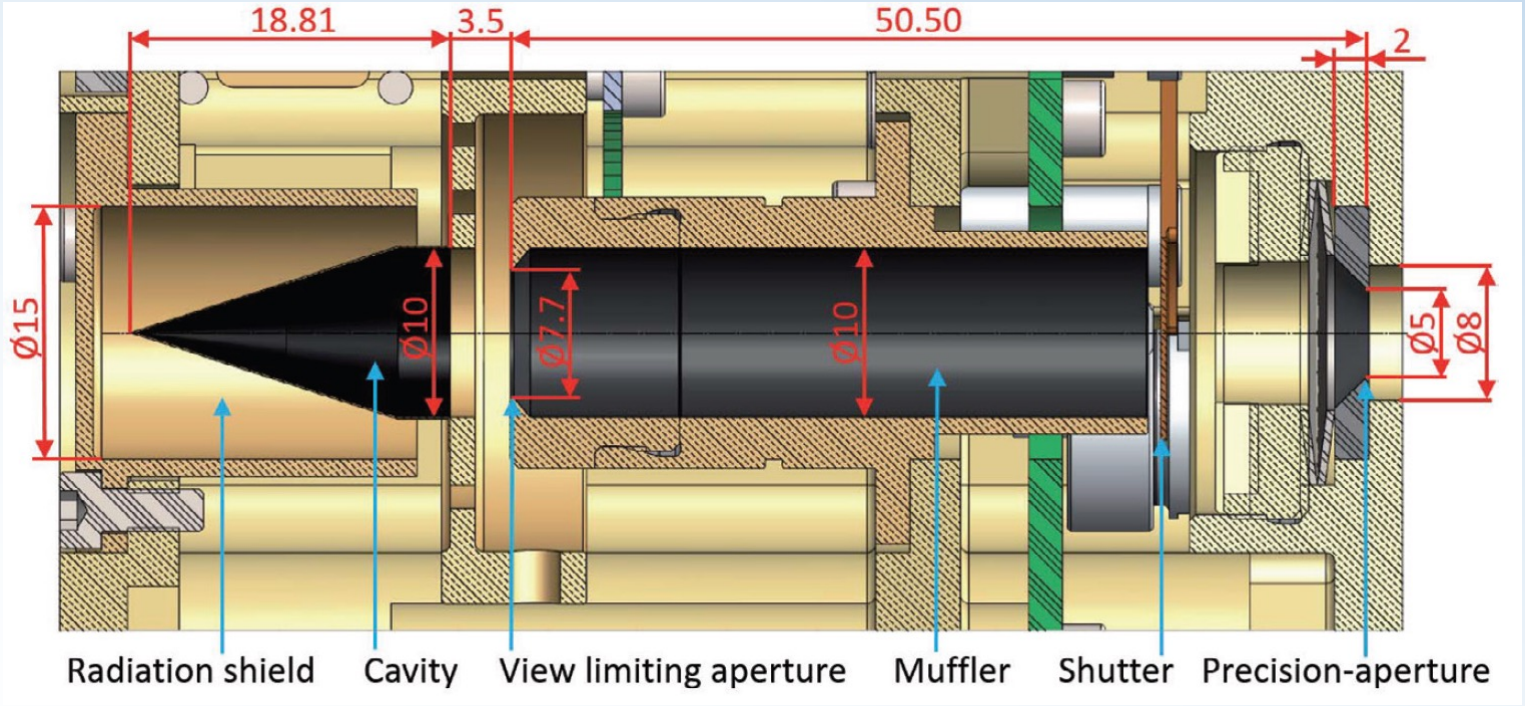
CLARA optical geometry



CLARA: Compact Light-weight Absolute Radiometer
Walter et al. (2017)

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CLARA Brief Operation History

July 14, 2017	NorSat-1 Launch
Aug 21, 2017	First Light
April 2018	Issues with reaction wheel started
May 13, 2018	CLARA was shutdown
Nov 8, 2019	"2nd First Light"

- NorSat-1 now operates only with two reaction wheels
- Limited fine pointing stability

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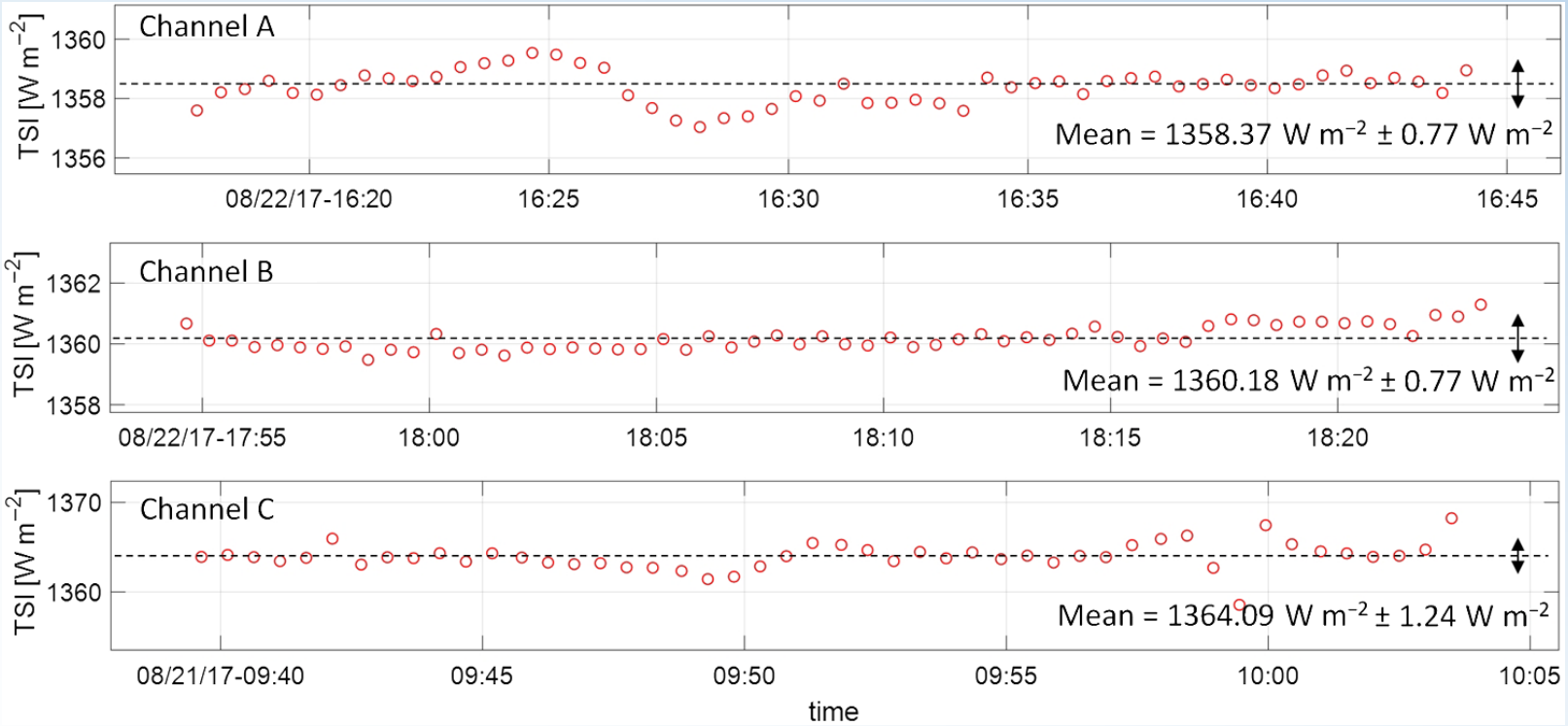
First Light Measurements



Walter, B., Andersen, B., Beattie, A., Finsterle, W., Kopp, G., Pfiffner, D., & Schmutz, W. (2018). First TSI results and status report of the CLARA/NorSat-1 solar absolute radiometer. *Proceedings of the International Astronomical Union, 14*(A30), 358-360. doi:10.1017/S1743921319004617

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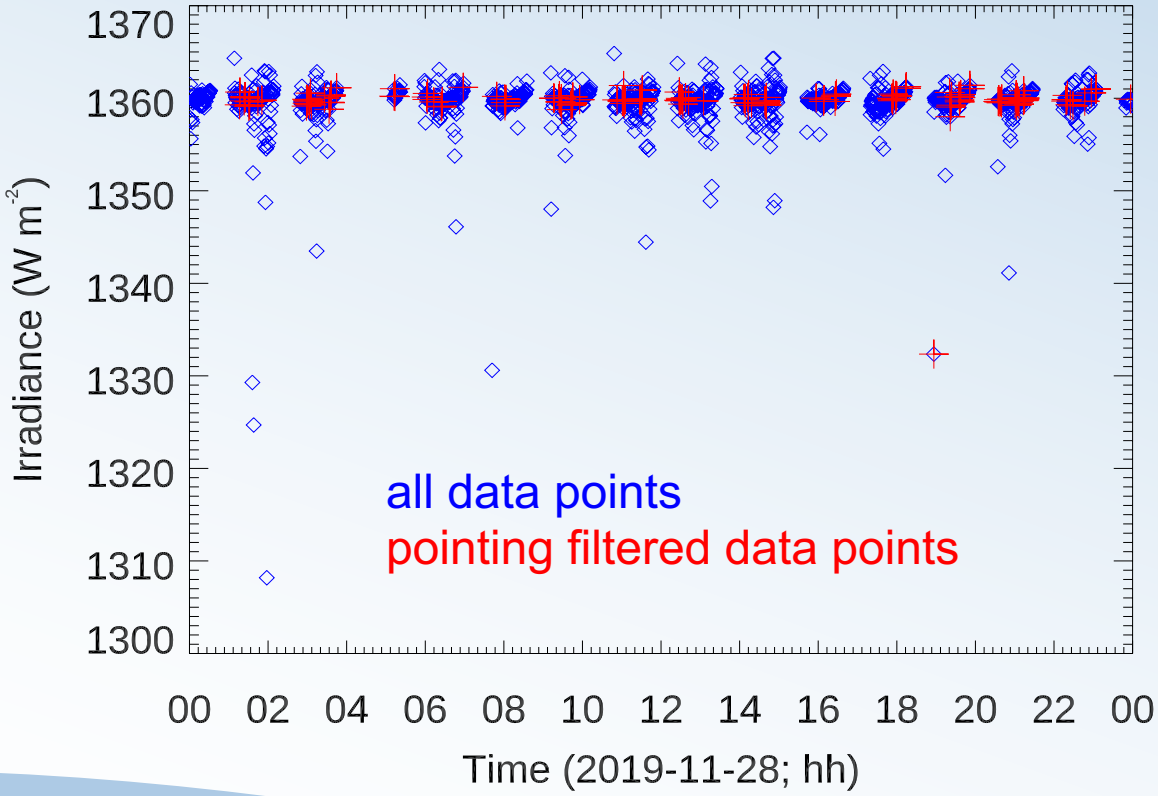
CLARA TSI pointing filter



Solar Pointing +/- 0.2º

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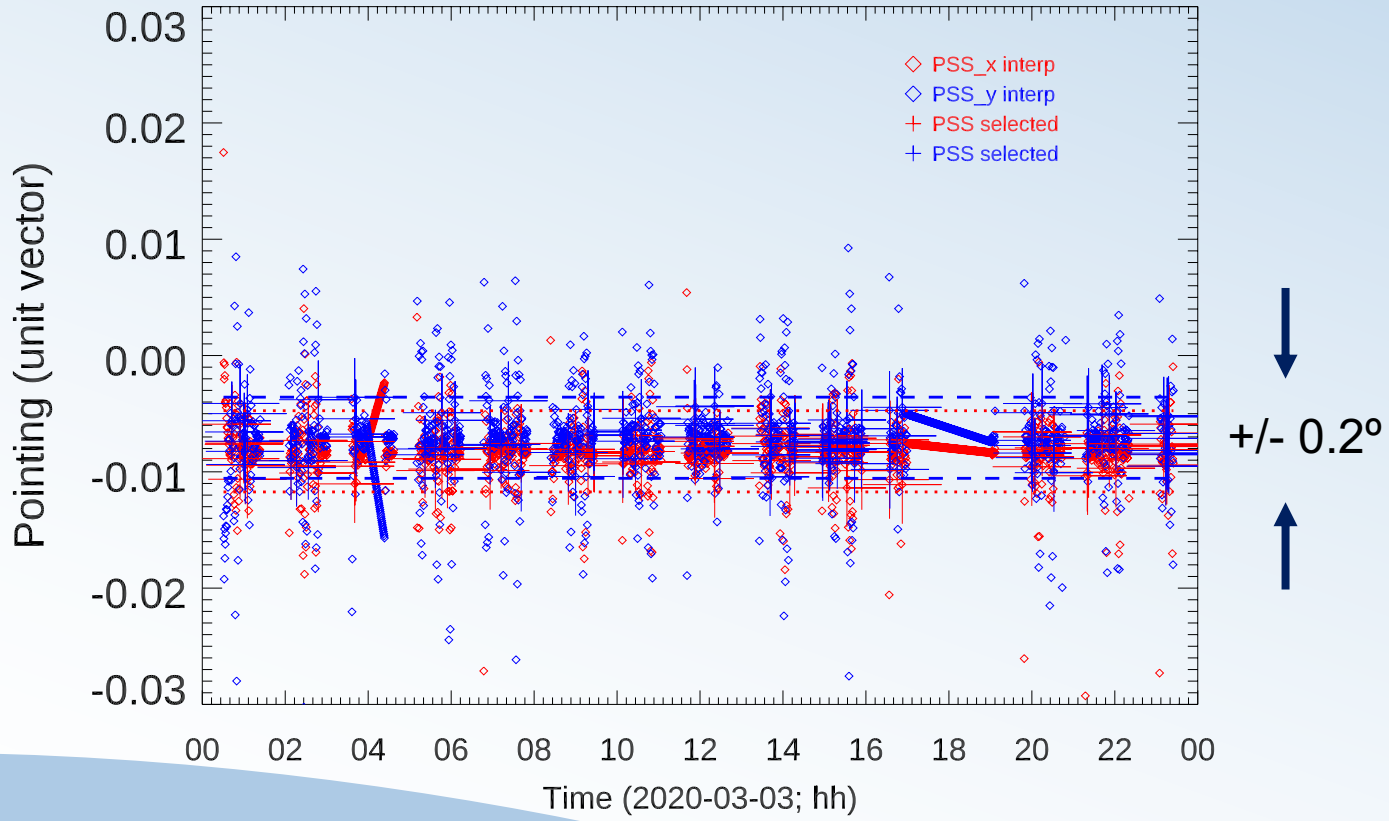
CLARA Fine pointing



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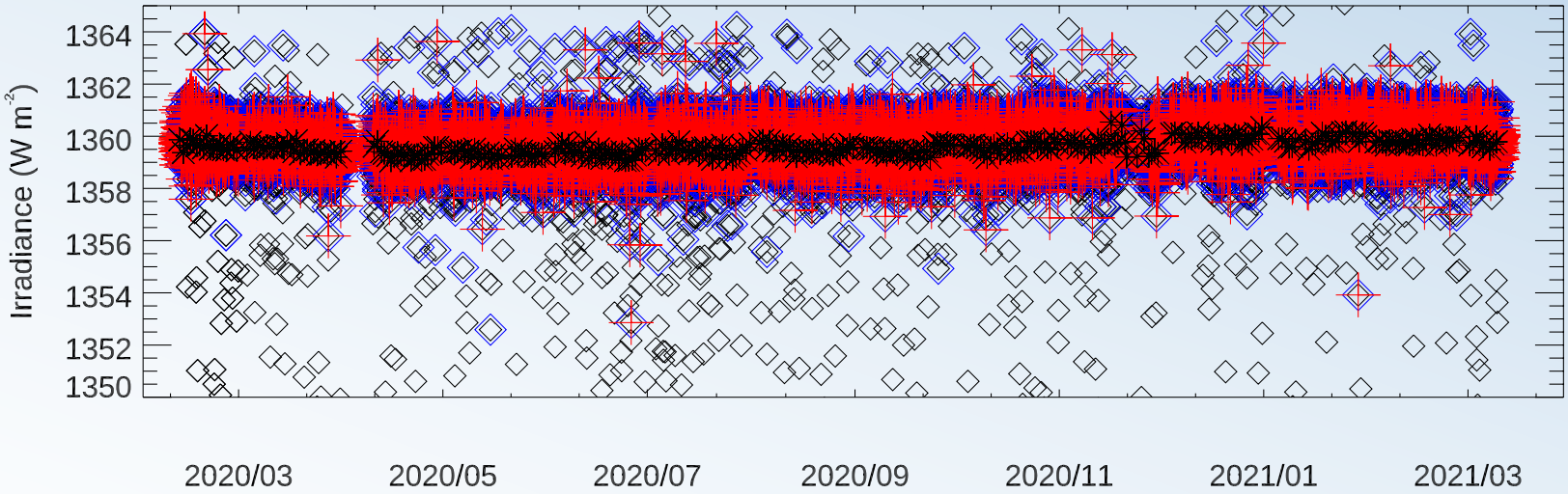
Effect of filtering steps



- ◆ Unfiltered CLARA data
- ◆ Pointing filter
- \+ Pointing and error filter
- ★ Filtered daily CLARA data

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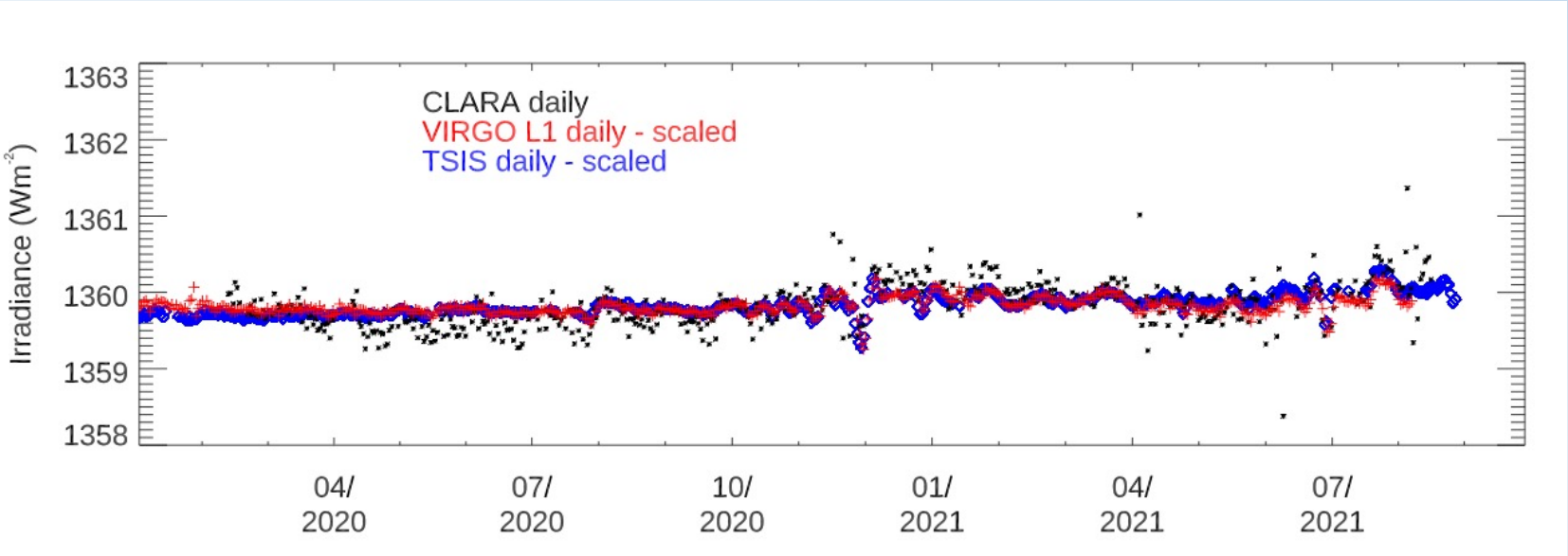
TSI measurements with CLARA



- Continuous TSI measurement for more that 1.5 years since the restart of CLARA
- Solar activity (in particular around 12/2020) is detected with CLARA
- CLARA data show a large scatter compared to VIRGO or TSIS
- Indication of a spurious annual modulation in the CLARA data

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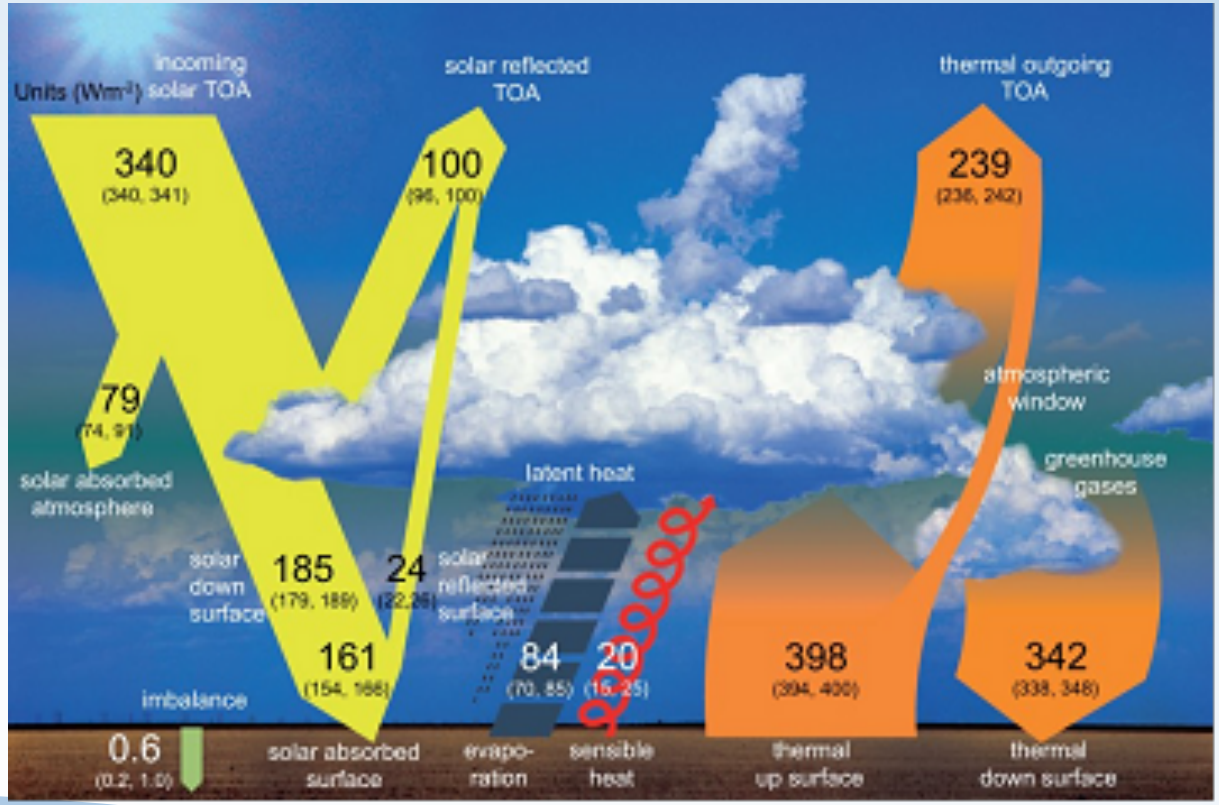
Earth Radiation Budget



(from IPCC 2013; adapted from Wild et al., 2013).

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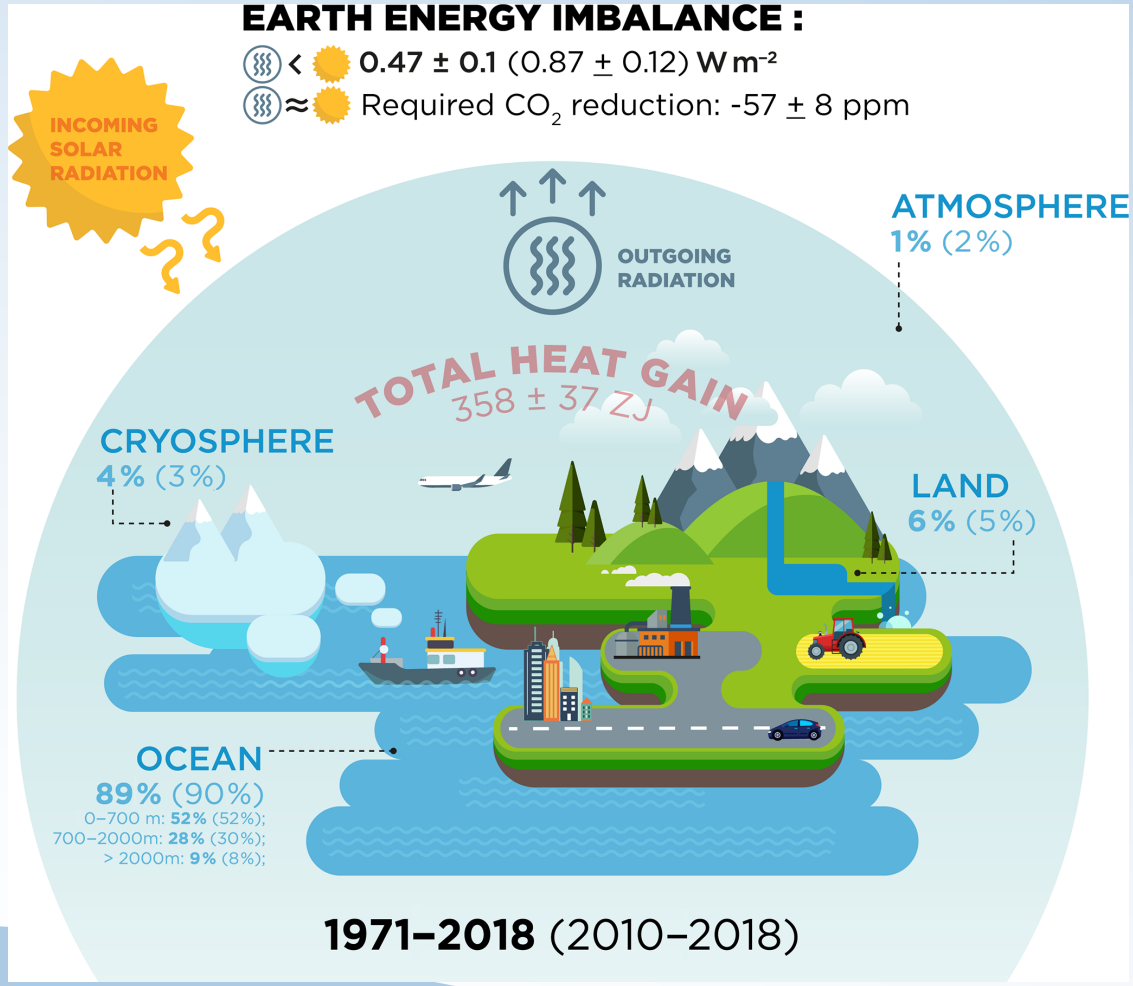

Von Schuckmann et al., 2020, Earth Syst. Sci. Data

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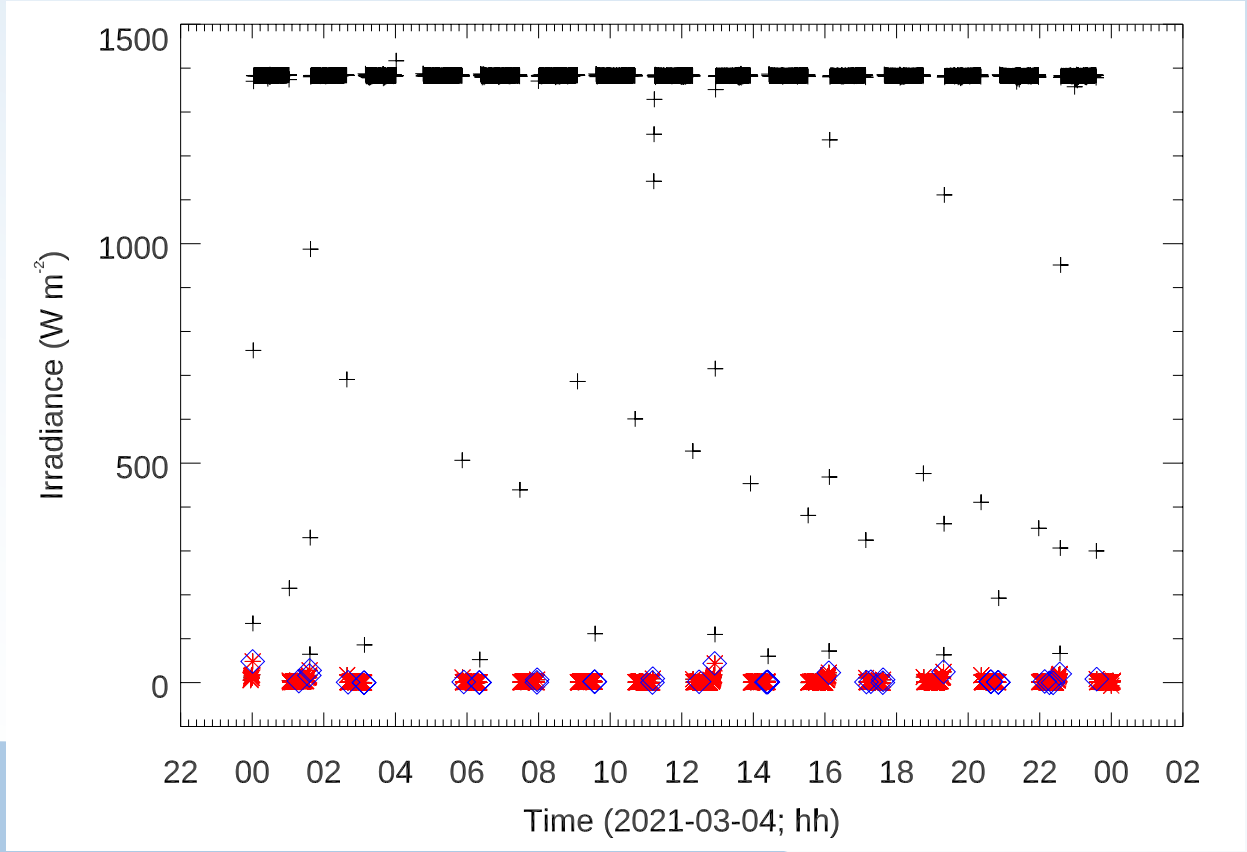
Raw CLARA TSI and OLR data



"uncalibrated TSI"

Raw "OLR"

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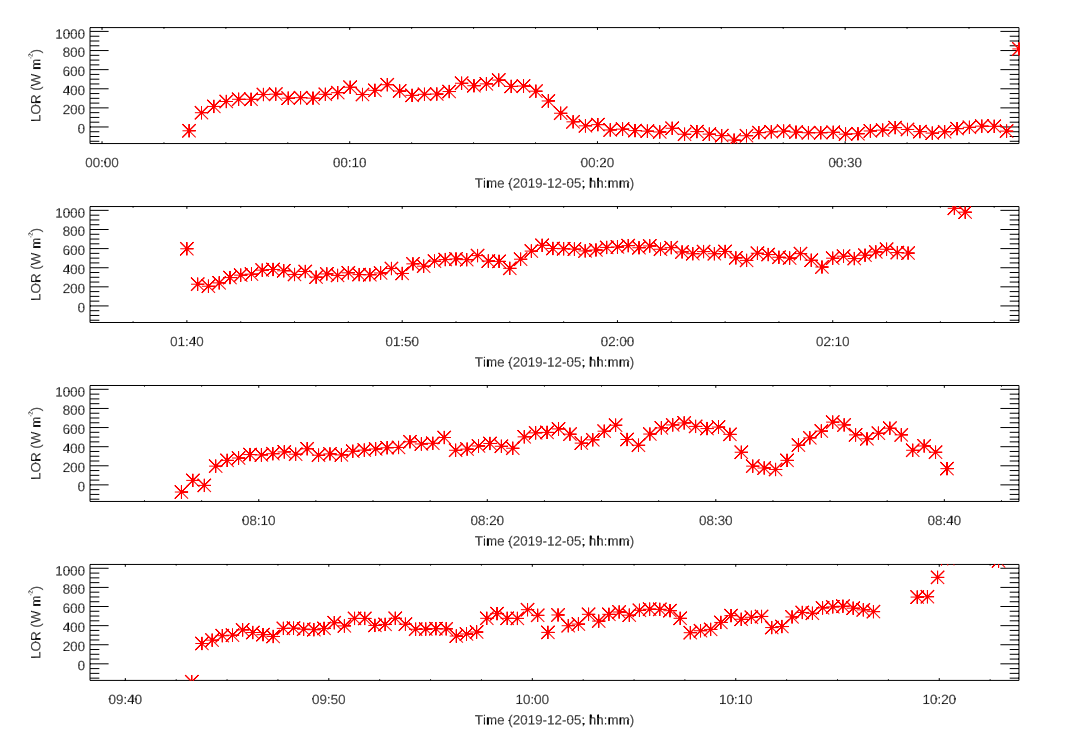
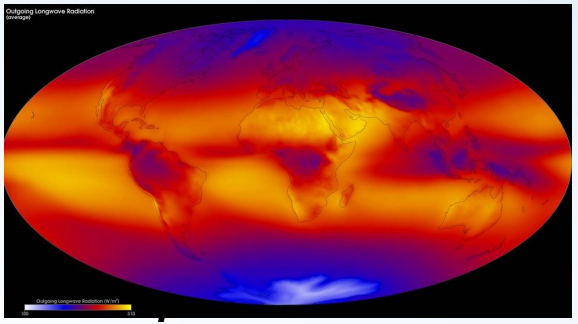
Earth Observation with CLARA

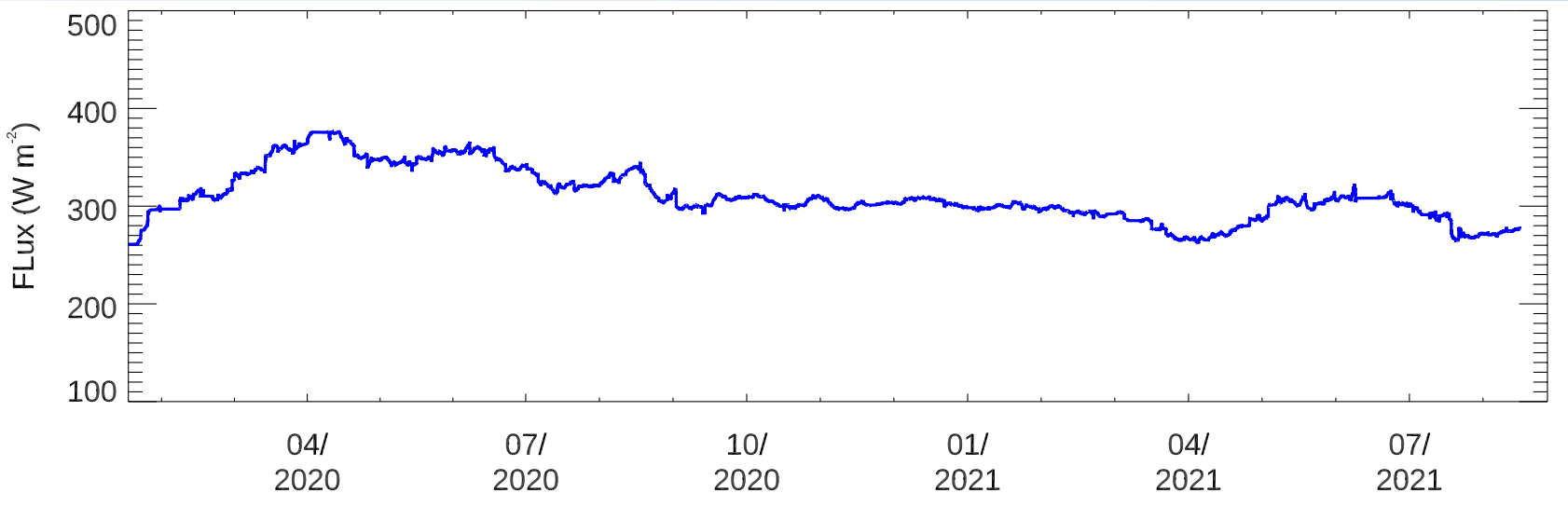


- Longwave Outgoing Radiation (LOR)
- when NorSat-1 is in eclipse
- new application for PMOD's absolute radiometers
- Partial coverage of NASA CERES observation as SI-traceable measurements

NASA CERES



Earth OLR measurement with CLARA



- CLARA Earth outgoing radiation (OLR) measurements, smoothed with a monthly running mean.
- Preliminary data!!!!
- Needs to be further filtered for nadir-pointing measurements only

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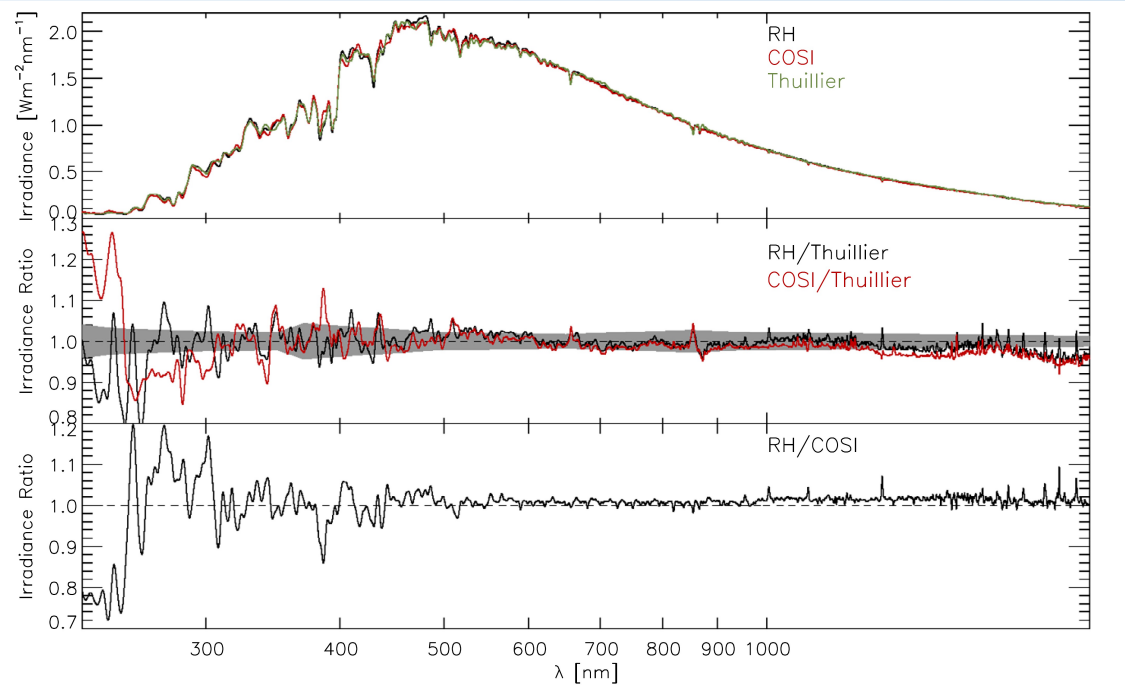
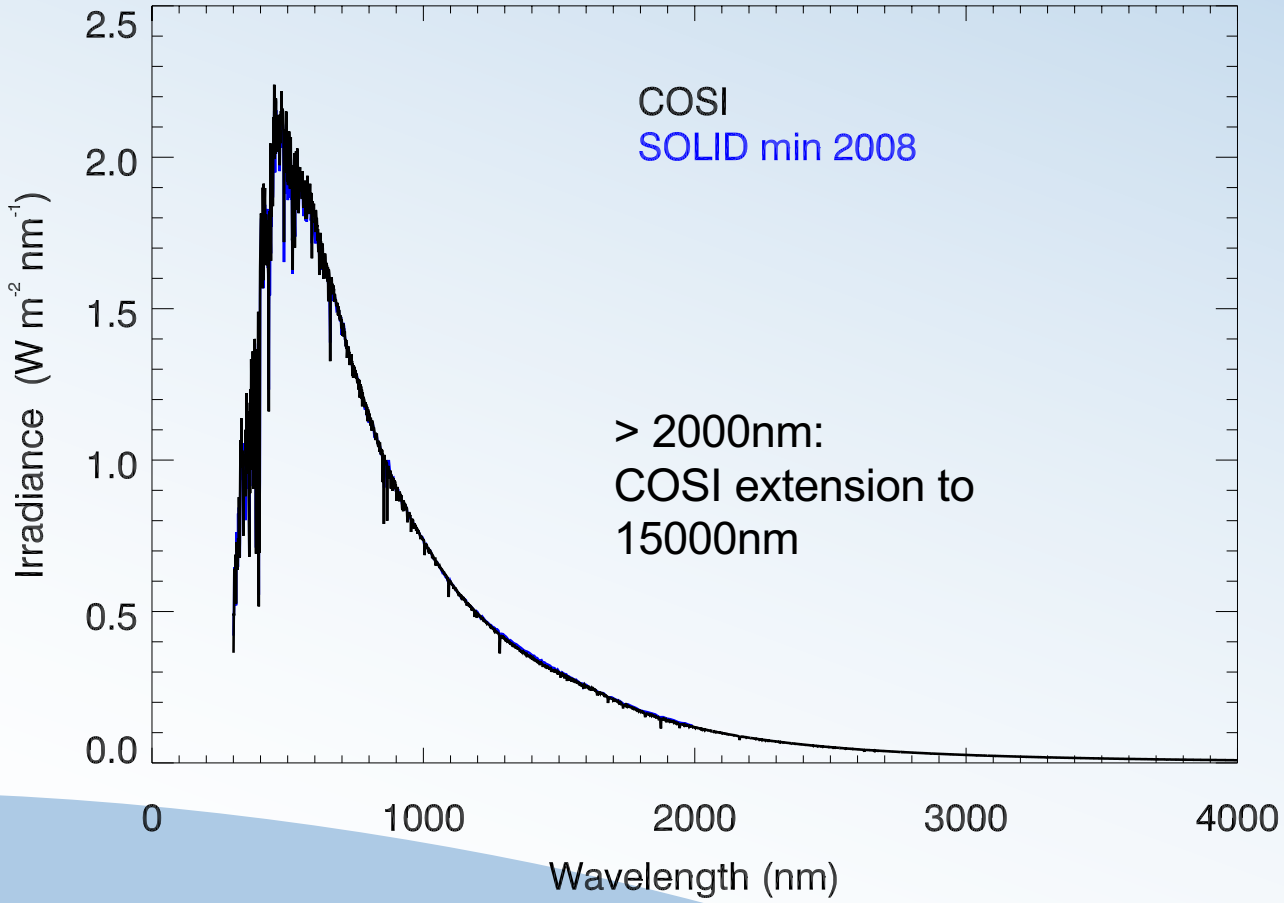
SSI Top of Atmospphere Spectrum



Criscuoli, Rempel, Haberreiter et al. (2020)

- COSI synthetic spectrum (red) agrees well with the ATLAS3 spectrum by Thuillier et al. (2003)
- Available for all spectral ranges
- New Reference spectrum:
  - Normalized to SSI observational dataset (Haberreiter et al., 2016)
  - Consistent with nominal TSI value by Prsa et al. (2016)

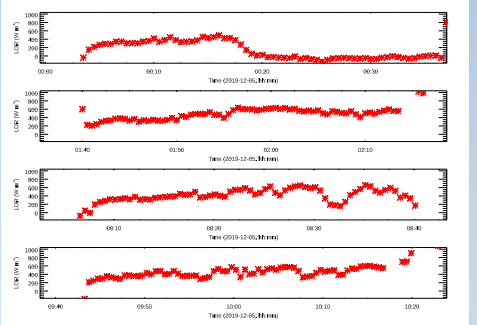
SSI ToA Spectrum



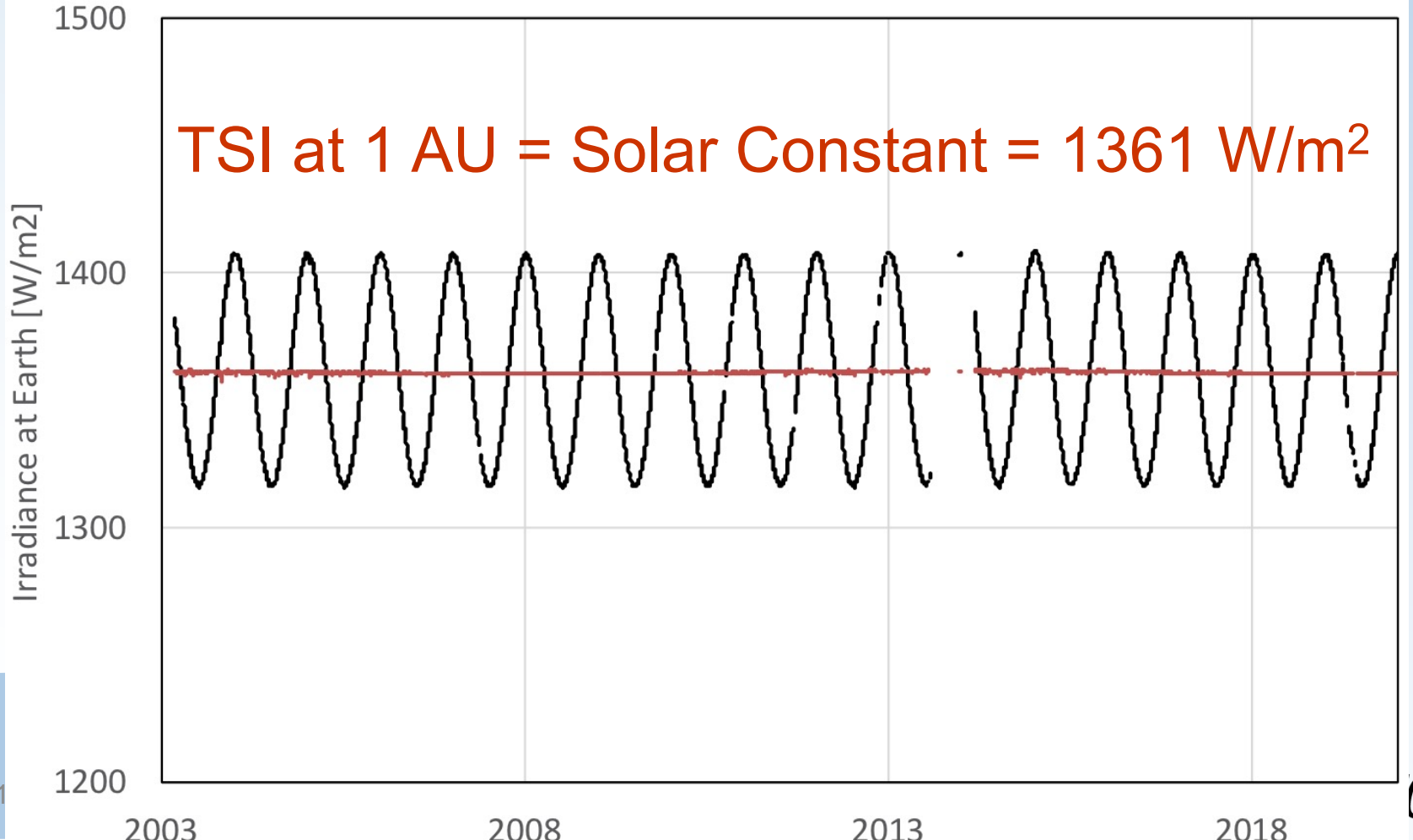
Summary

- CLARA TSI
  - scatter could already be reduced
  - However more analysis is required
  - indication that CLARA detects solar irradiance variability
- CLARA TOR
  - 1.5-year long time series available
  - Filter for nadir pointing needs to be applied
- ToA SSI spectrum available for comparison

Next steps



- ISSI International Team lead by Margit Haberreiter
  - *Towards determining the Earth Energy Imbalance from Space*
  - Dedicated to compare CLARA TOR data with CERES, PICARD/BOS, RAVAN and SIMBA
  - Review paper on capabilities and challenges expected outcome


TSI at 1 AU = Solar Constant = 1361 W/m2
Irradiance at Earth [W/m2]
1500
1400
1300
1200
2003
2008
2013
2018