Physikalisch-Meteorologisches Observatorium Davos
World Radiation Center

Assessment of the reliability of TSI-reconstructions by comparing PREMOS/PICARD TSI values to other TSI data

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Overview

- Motivation
- PREMOS in-flight calibration
- Towards a PREMOS calibration version 2

  Ball et al. (JSWSC 6, A32, 2016):

  Assessing the beginning to end-of-mission sensitivity change of the PREcision Monitor Sensor total solar irradiance radiometer (PREMOS/PICARD)

  Schmutz et el. 2017 (in preparation)

  PREMOS/PICARD TSI data version 2
- Comparing to TIM/SORCE and VIRGO/SOHO

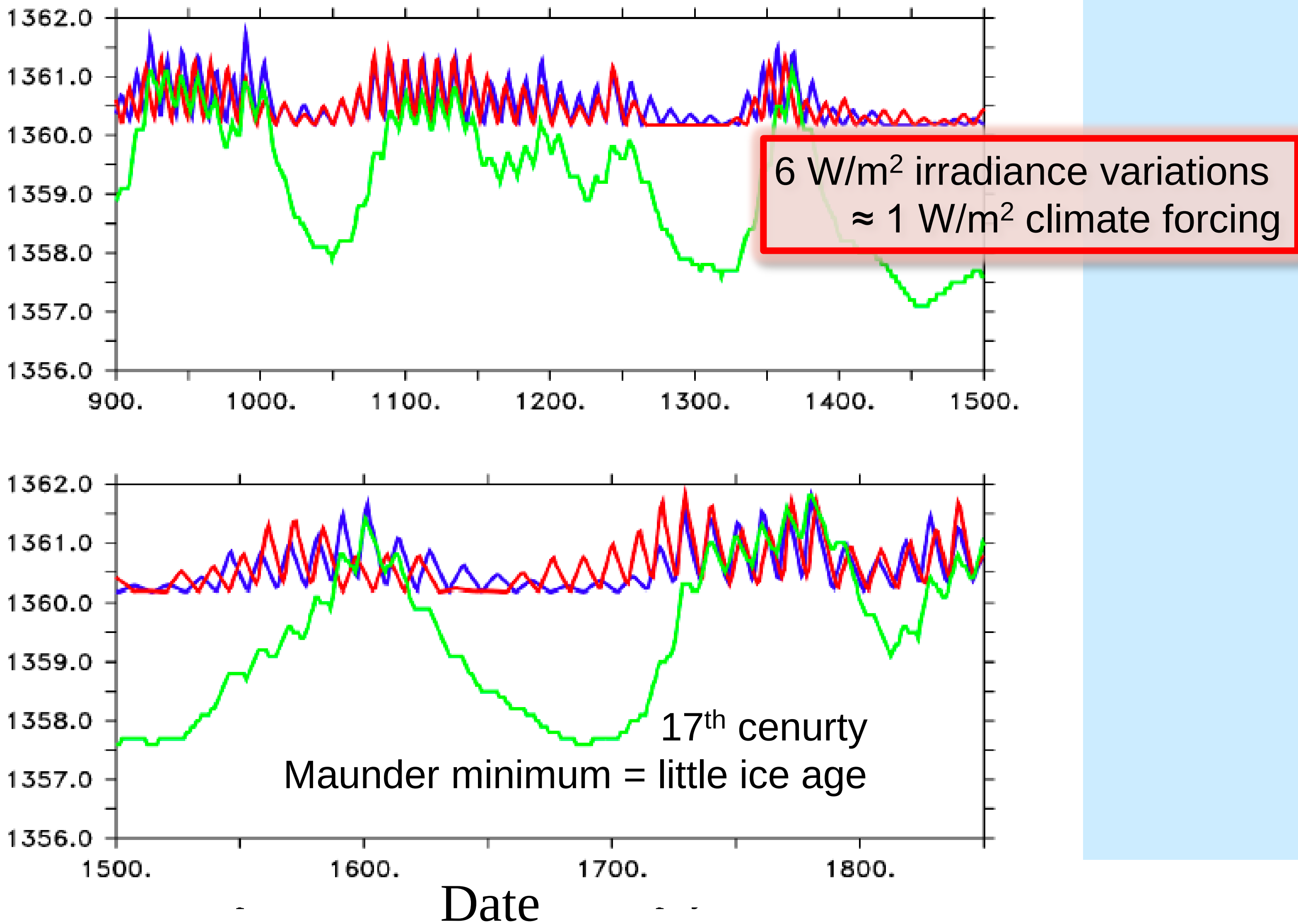
Sun – climate correlation

The Sunspot minimum 1600-1700, the Maunder minimum,

coincides with a climate minimum, the so called little ice age

In 1658 king Karl X Gustav of Sweden marched his army over the ice of the belts to defeat Denmark

Reconstructions of solar irradiance



From PMIP4 irradiance forcing data (Jungclaus et al. 2016, in preparation)

What do we know?

There are Total Solar Irradiance in space observation since 1979 ….

→ What are the amplitudes of TSI variations over centennial time scales?

Is there an observed TSI-trend?

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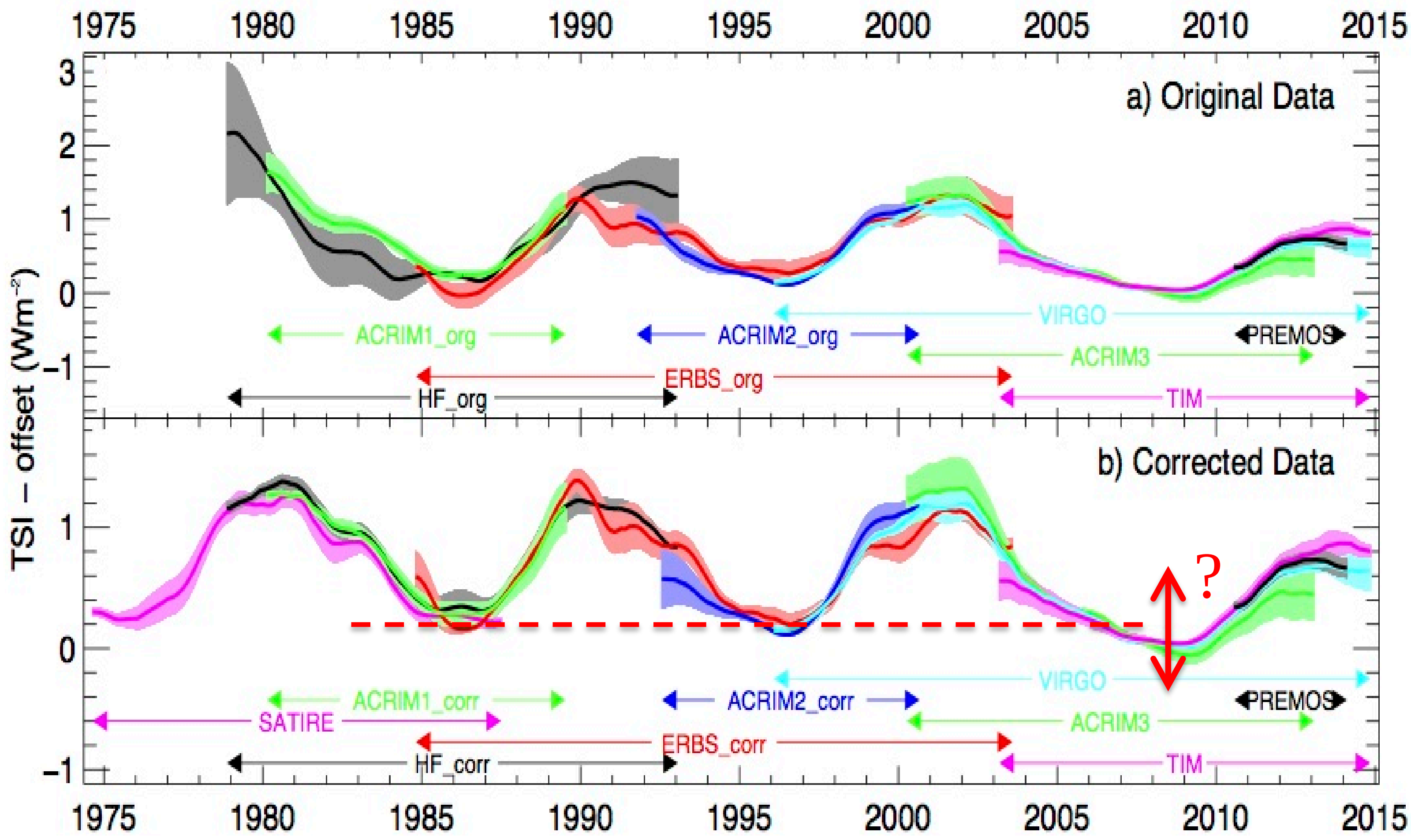

from Fröhlich (2016, PMOD/WRC website)

Long term TSI trend

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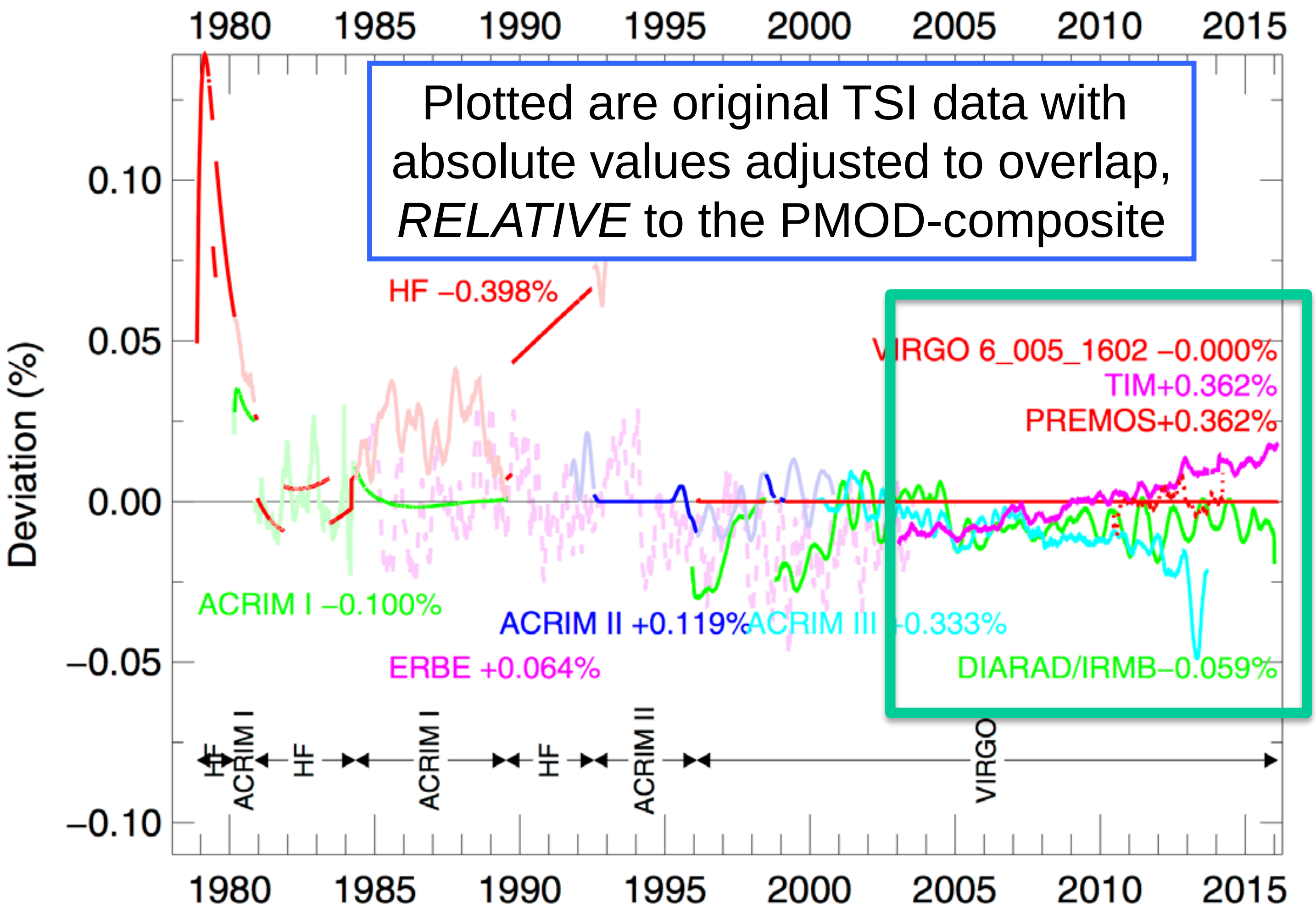
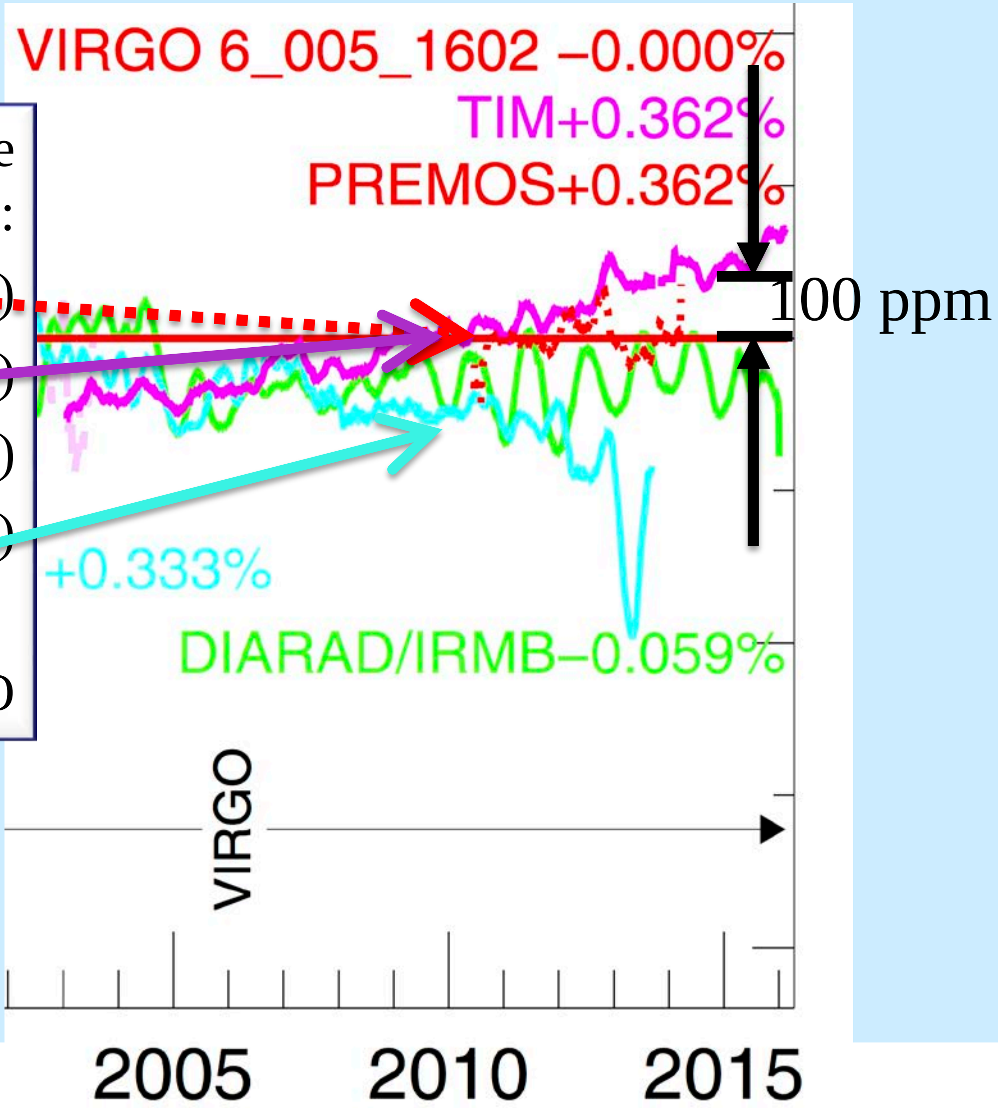


Diverging TSI trends

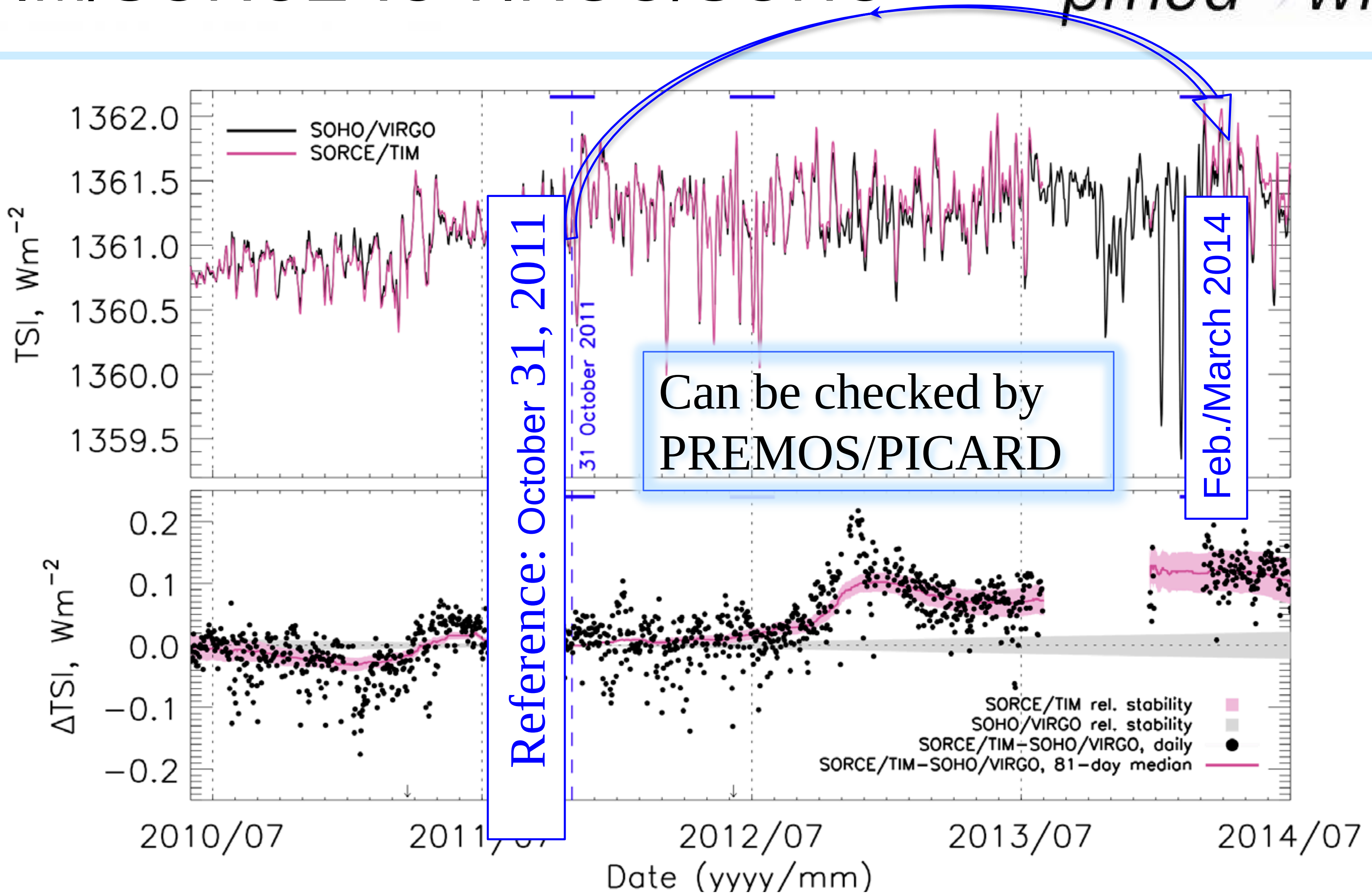
In 2010 there were
4 TSI space experiments:

- PREMOS (2010-2014)
- TIM (launched 2003)
- VIRGO (launched 1995)
- ACRIM III (2000-2013)

… relative to VIRGO/SOHO



TIM/SORCE vs VIRGO/SOHO



Relative head $\mathcal{B}$ correction

Standard tool to correct for inflight degradation:

→ two or more radiometers (PREMOS has 2):

$\mathcal{A}$ – exposed operationally

$\mathcal{B}$ – exposed rarely for calibration only

Hypothesis*: $\mathcal{B}$ has the *same* sensitivity change as $\mathcal{A}$ *as a function of the exposure time

Until 3. February 2014: $\mathcal{A}$ total exposure: 600 days

$\mathcal{B}$ total exposure: 3.75 days

→ Sensitivity change is evaluated from the measured $\mathcal{A}$ to $\mathcal{B}$ ratio

Sensitivity change of $\mathcal{A}$ relative to $\mathcal{B}$

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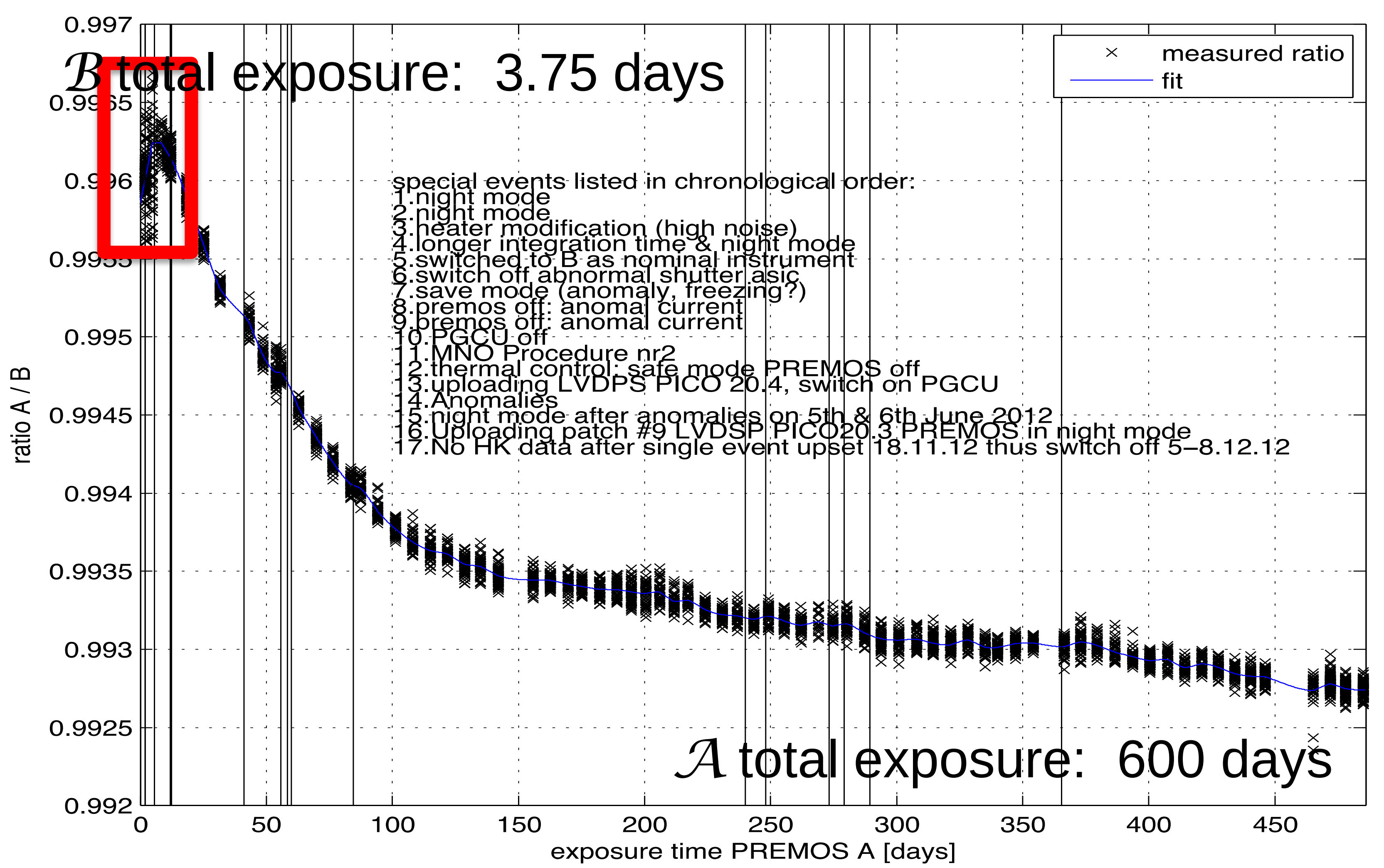

Ratios $\mathcal{A}$ to $\mathcal{B}$

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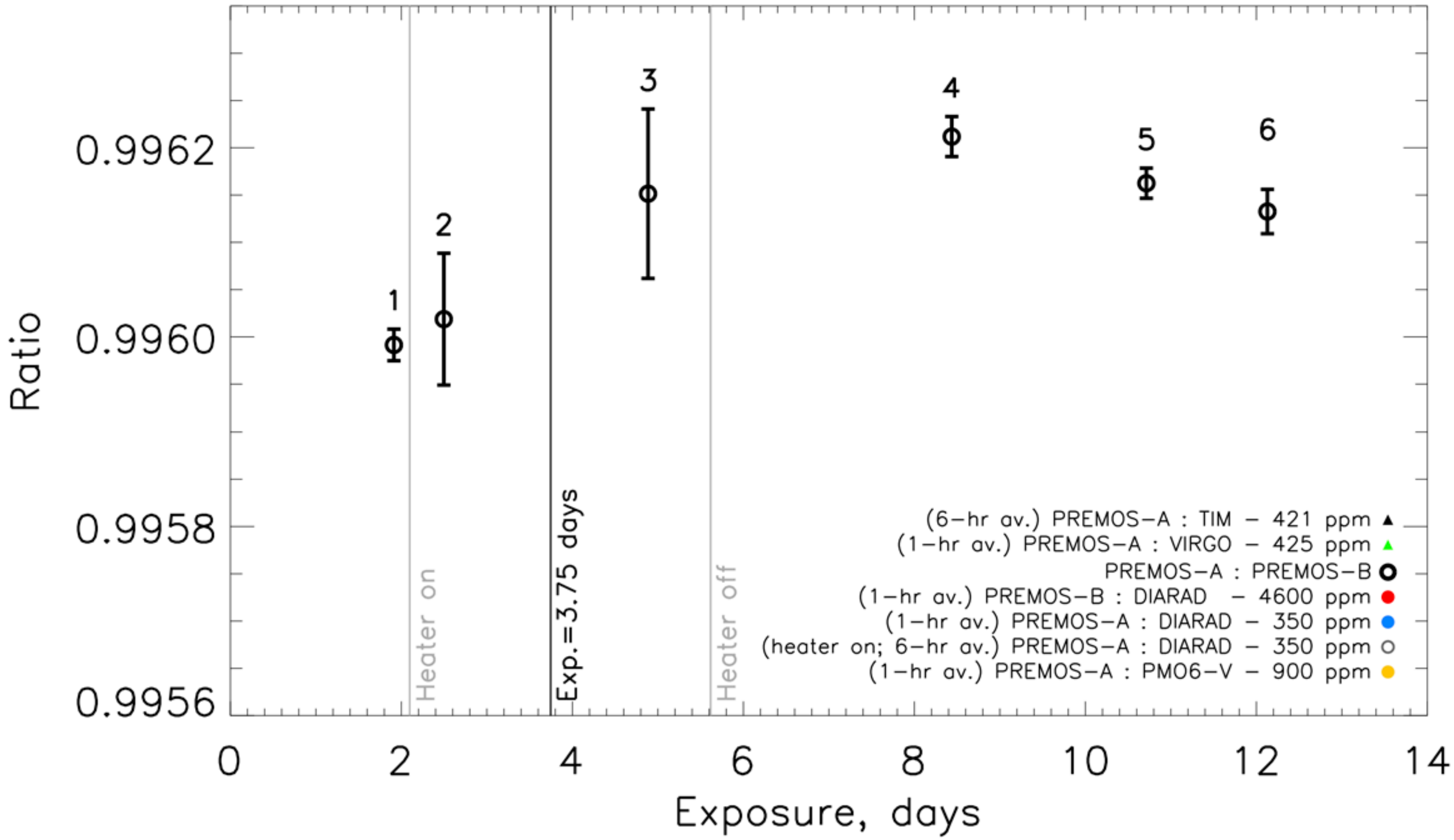
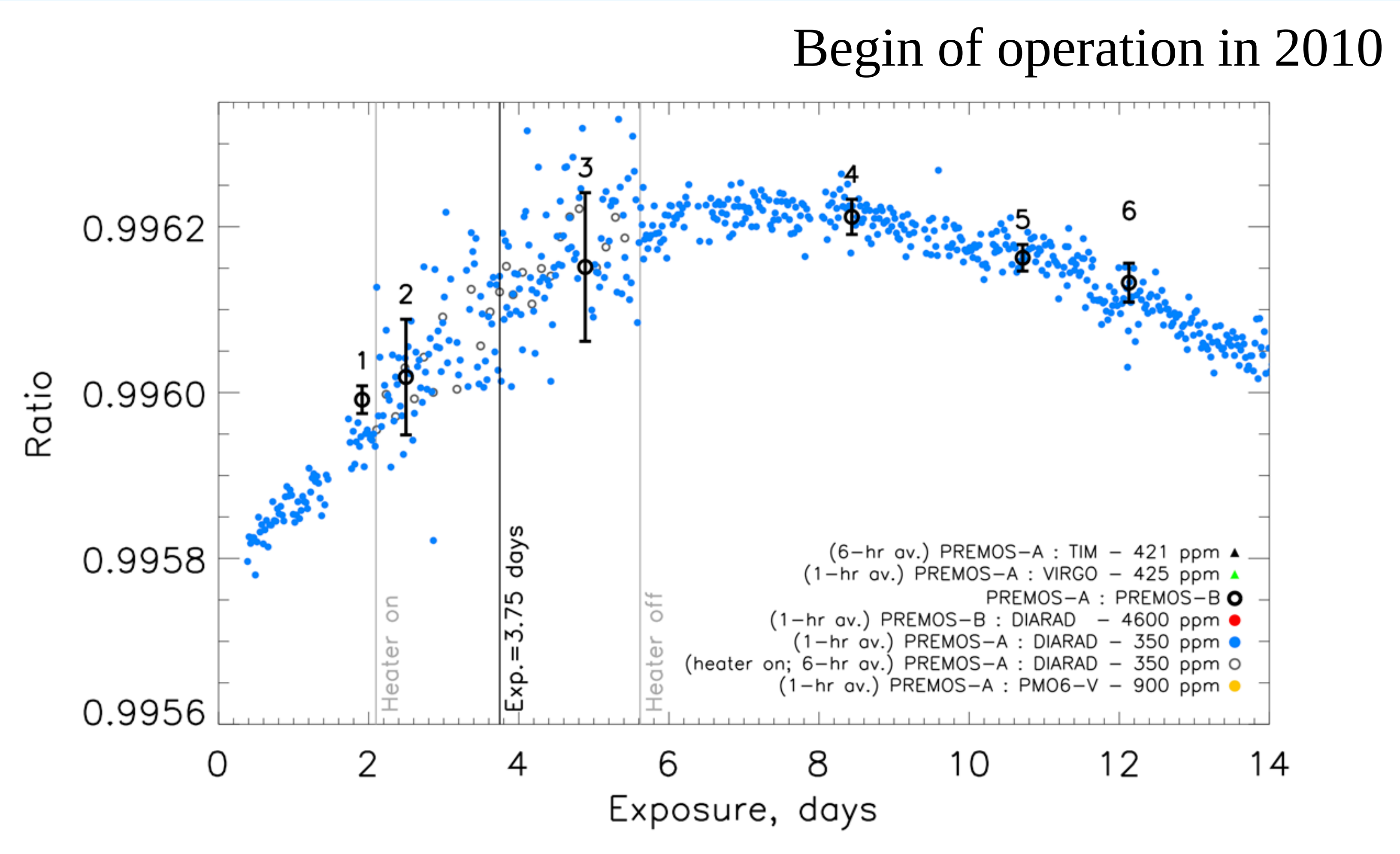
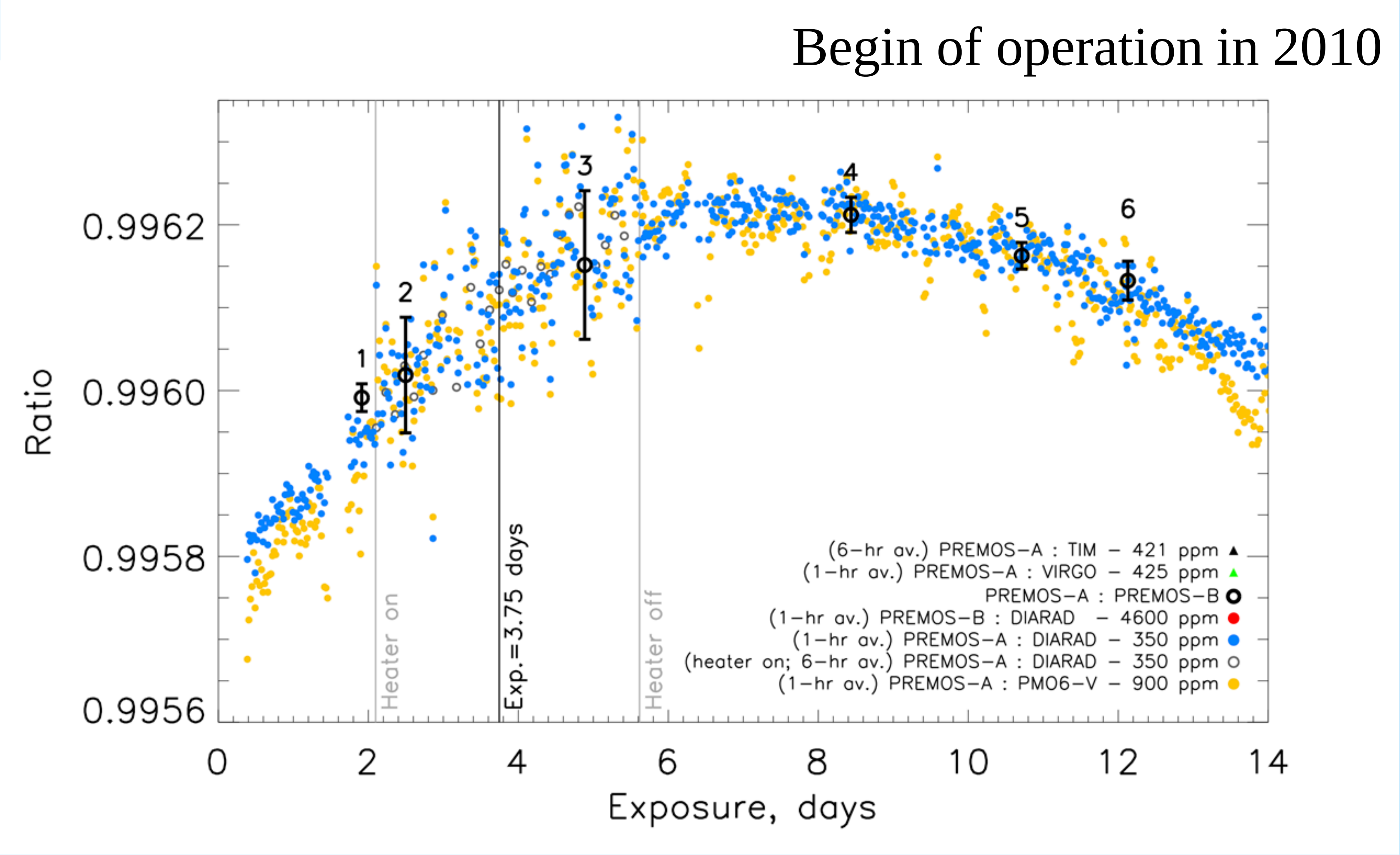
Begin of operation in 2010



Ratios $\mathcal{A}$ to $\mathcal{B}$ compared to $\mathcal{A}$ *to* DIARAD

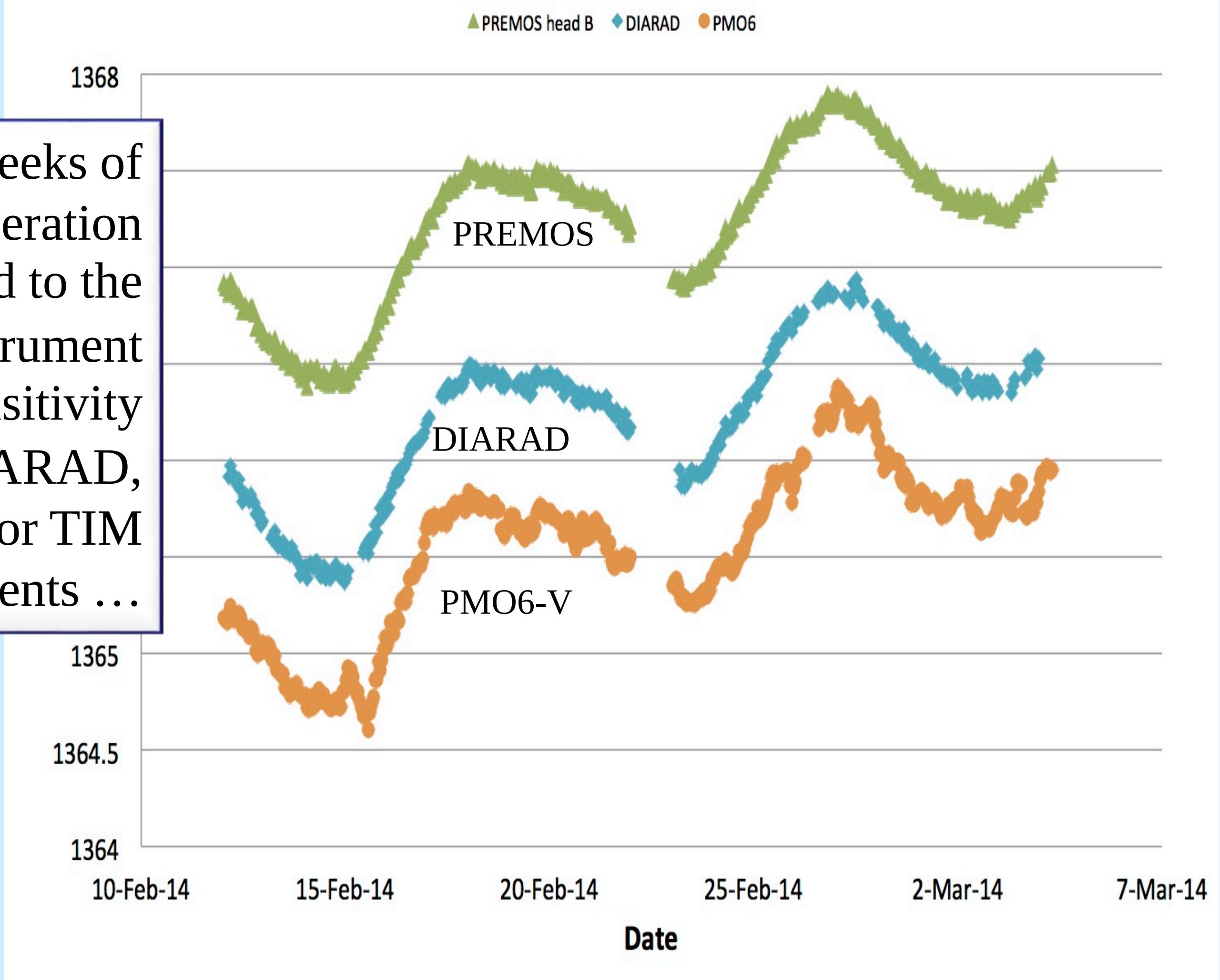


Ratios $\mathcal{A}$ to $\mathcal{B}$ compared to $\mathcal{A}$ to DIARAD and $\mathcal{A}$ to PMO6-V

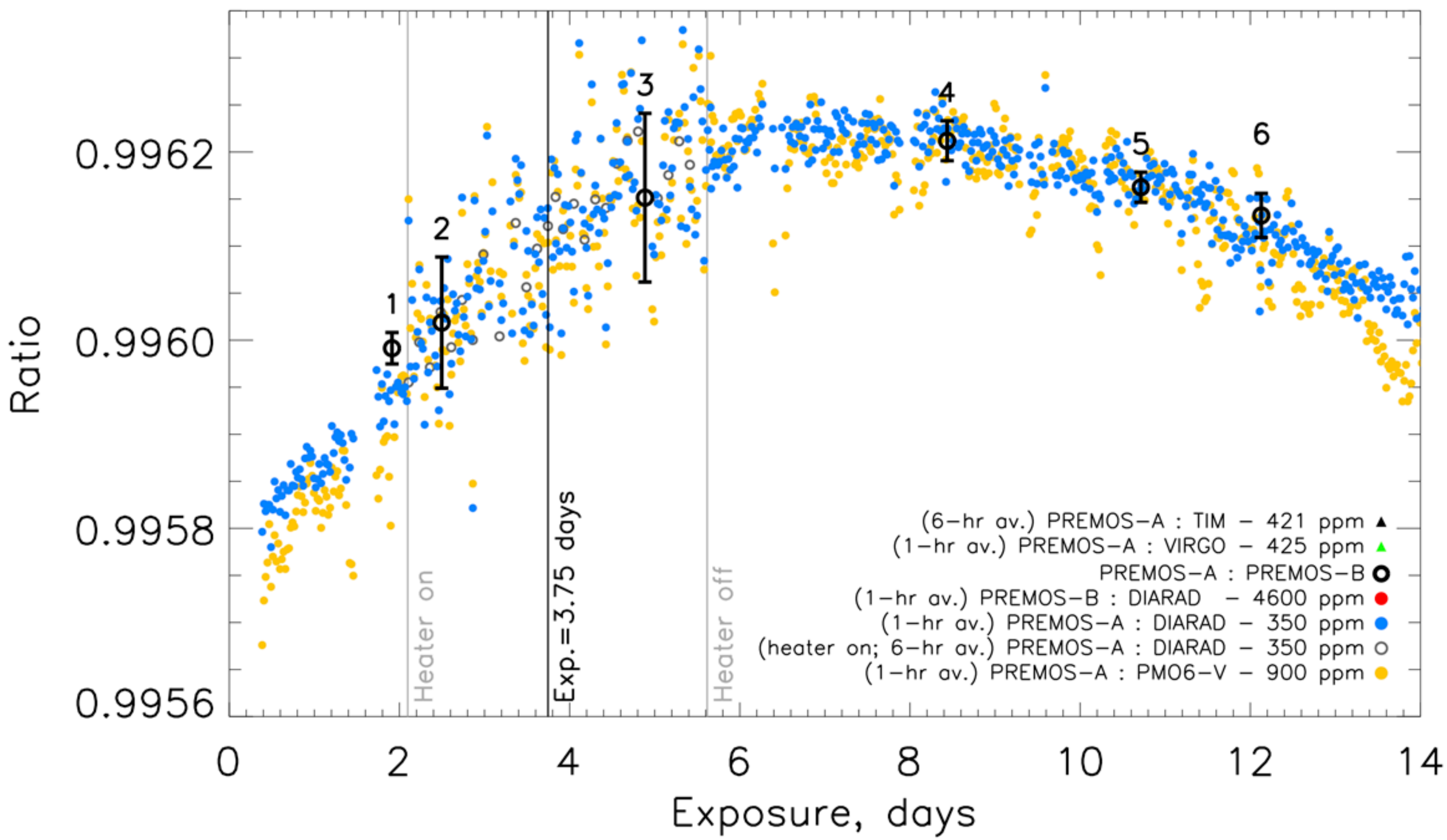


PREMOS head $\mathcal{B}$ Feb-March 2014

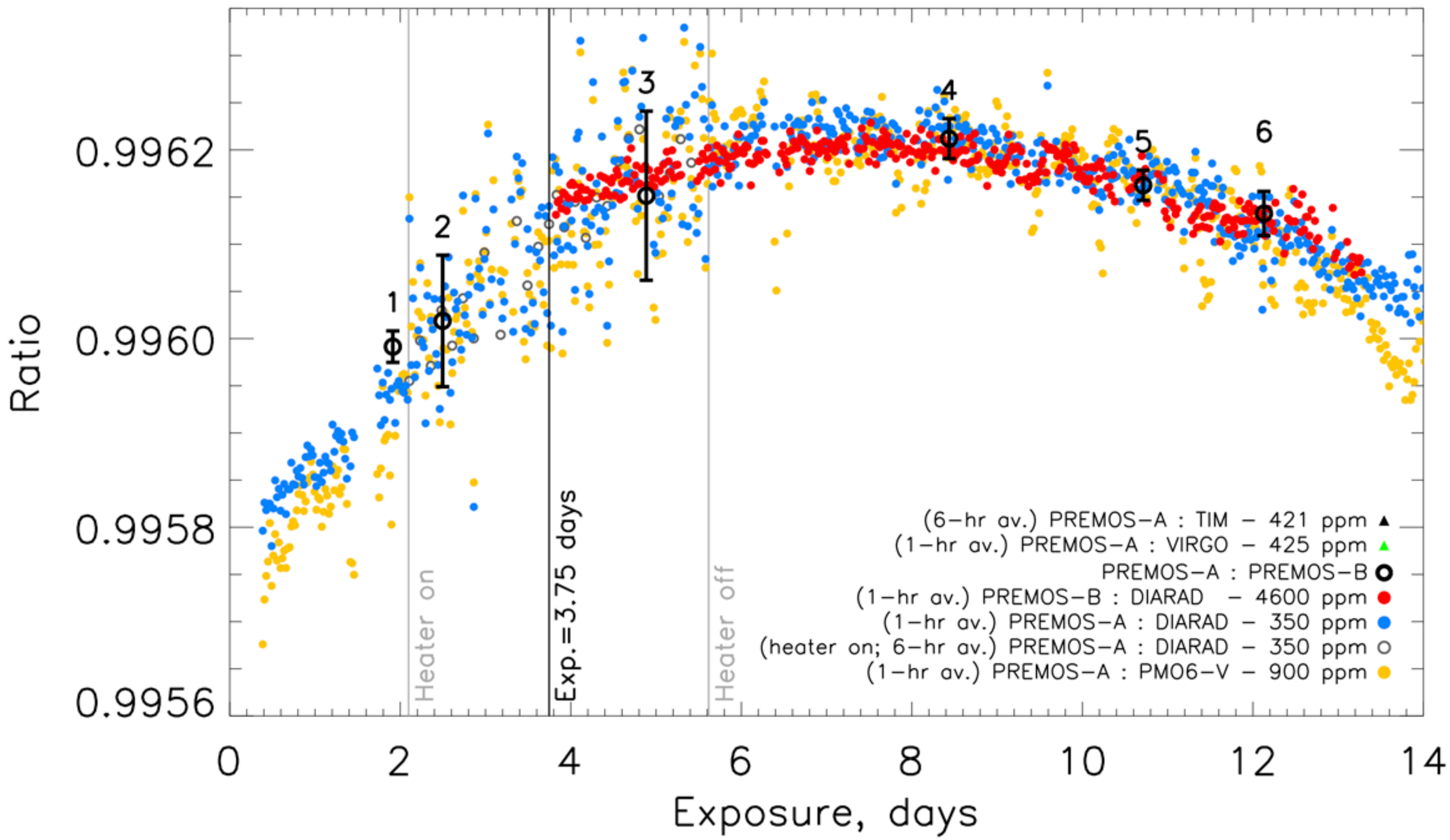
During the last two weeks of PREMOS operation head $\mathcal{B}$ was switched to the operational instrument
→ evaluate $\mathcal{B}$ sensitivity change relative to DIARAD, PMO6-V, or TIM instruments …



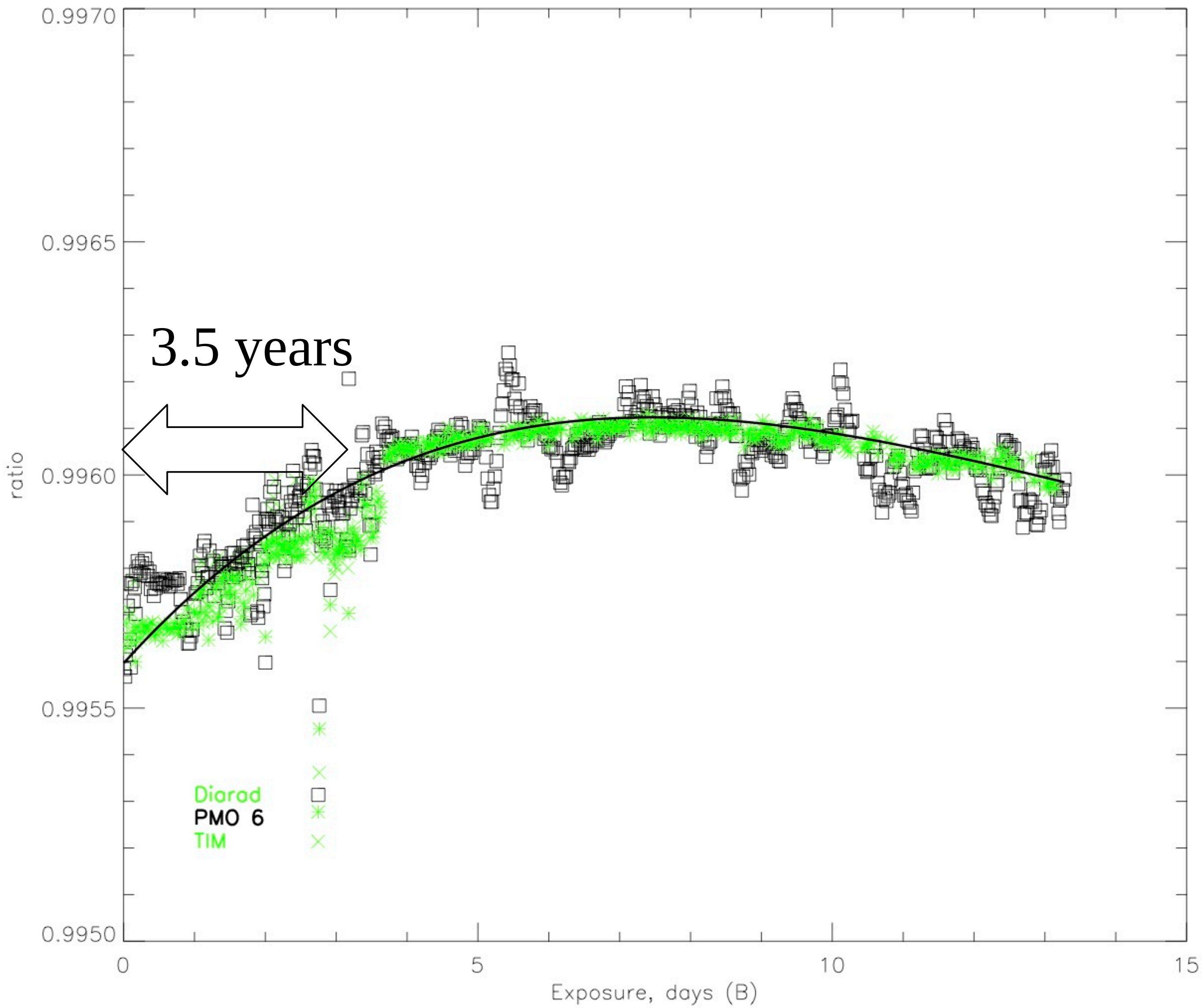
Ratios $\mathcal{A}$ to $\mathcal{B}$ compared to $\mathcal{A}$ to DIARAD and $\mathcal{A}$ to PMO6-V



+ ratio PREMOS-$\mathcal{B}$ to DIARAD
2014 Feb12 - March 4



PREMOS-$\mathcal{B}$ to DIARAD
July 2010 to March 2014



Using $\mathcal{A}$ to $\mathcal{B}$ ratios

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Hypothesis is verified:

$\mathcal{B}$ (in 2014 starting at t_E=3.75 days) had the *same* sensitivity change as

$\mathcal{A}$ (in 2010) as a function of the *exposure time*

→ We can use the measured $\mathcal{A}$:$\mathcal{B}$ ratios in 2010 to correct for the sensitivity change of head $\mathcal{B}$ in 2014:

1) Determine the accumulated exposure time t_E of head $\mathcal{A}$ for the measured $\mathcal{A}$:$\mathcal{B}$ ratios 1, 2, .., 6, …
2) Determine the dates of head $\mathcal{B}$ when it has accumulated the corresponding dose
3) Use “ratios of ratios”, e.g. ratio-4/ratio-1, to correct for the sensitivity change of head $\mathcal{B}$ in 2014 *relative* to the date when B had accumulated the same exposure time as A in 2010 for ratio-1

PREMOS/PICARD vs TIM and VIRGO

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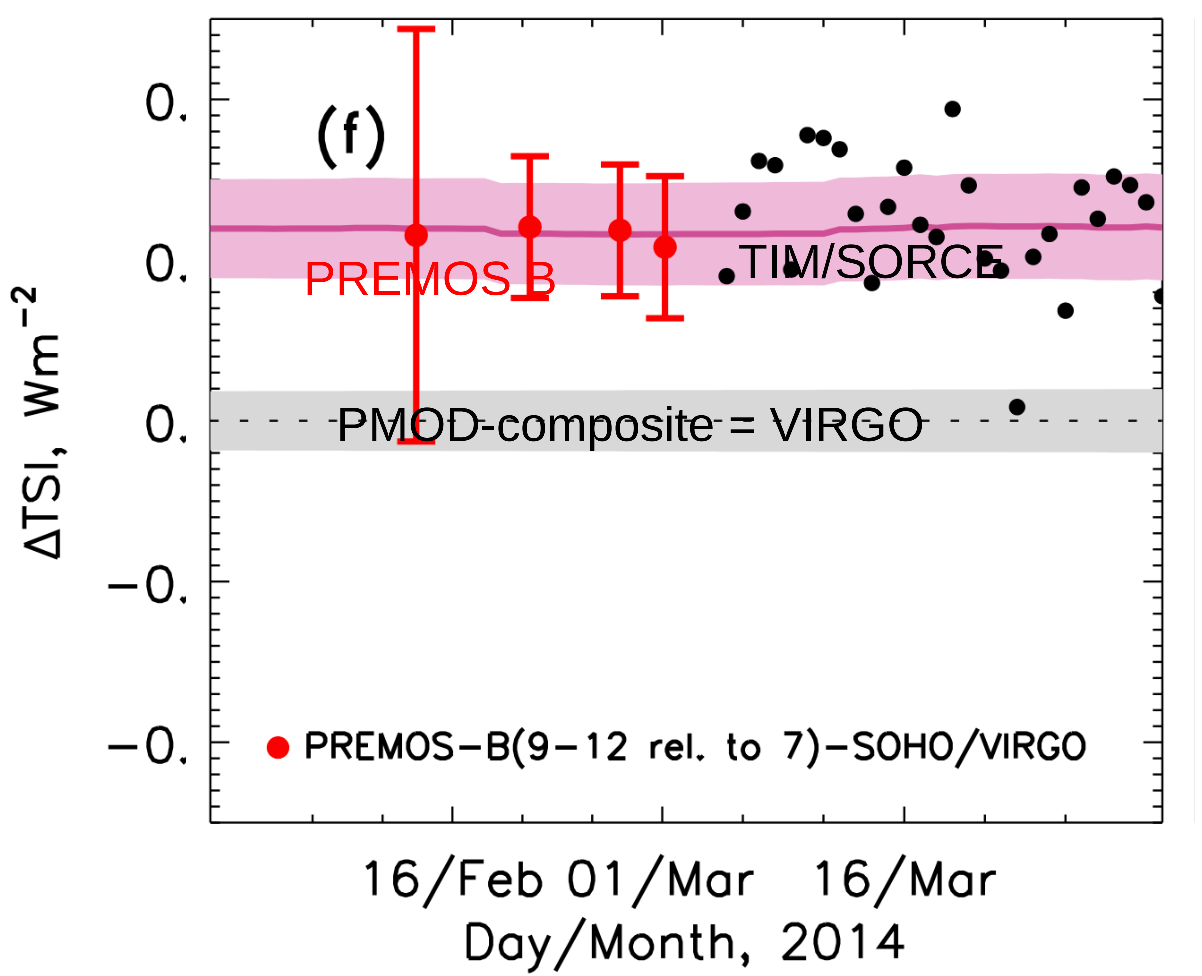

Ball et al. (JSWSC 6, A32, 2016)

Ball et al. 2016 conclude

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PREMOS $\mathcal{B}$ sensitivity correction has an uncertainty
October 2011 to February 2014 ratio: +-0.02 Wm^{-2} (over 2.3 yr)
→ 6 ppm per year

PREMOS $\mathcal{B}$ agrees with TIM
(October 2011 to March 2014)
→ TIM stability confirmed to ≤ 6 ppm/yr

PREMOS $\mathcal{B}$ disagrees with PMOD composite
Difference: 0.12 Wm^{-2} or 90 ppm after 2.3 years
→ PMOD-composite stability not better than ≥ 38 ppm/yr
(not known: systematic or random ?)

Extrapolate → TSI-composite
cycle-cycle minima uncertainty:
11 x 38 ppm = 418 ppm → 0.6 Wm^{-2} *!*

Extrapolating the disagreement

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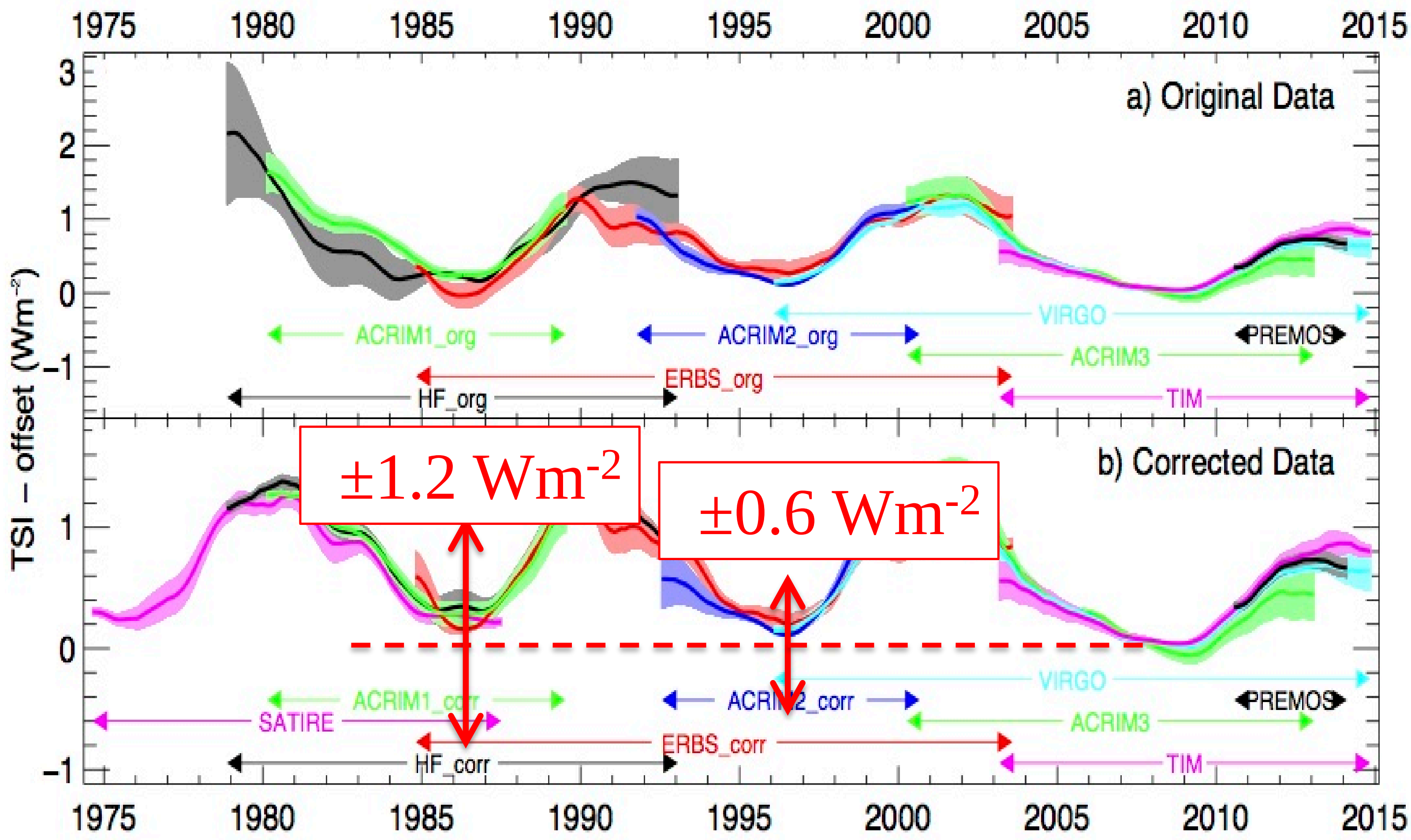

Kopp (2016)

Different approach – same conclusion

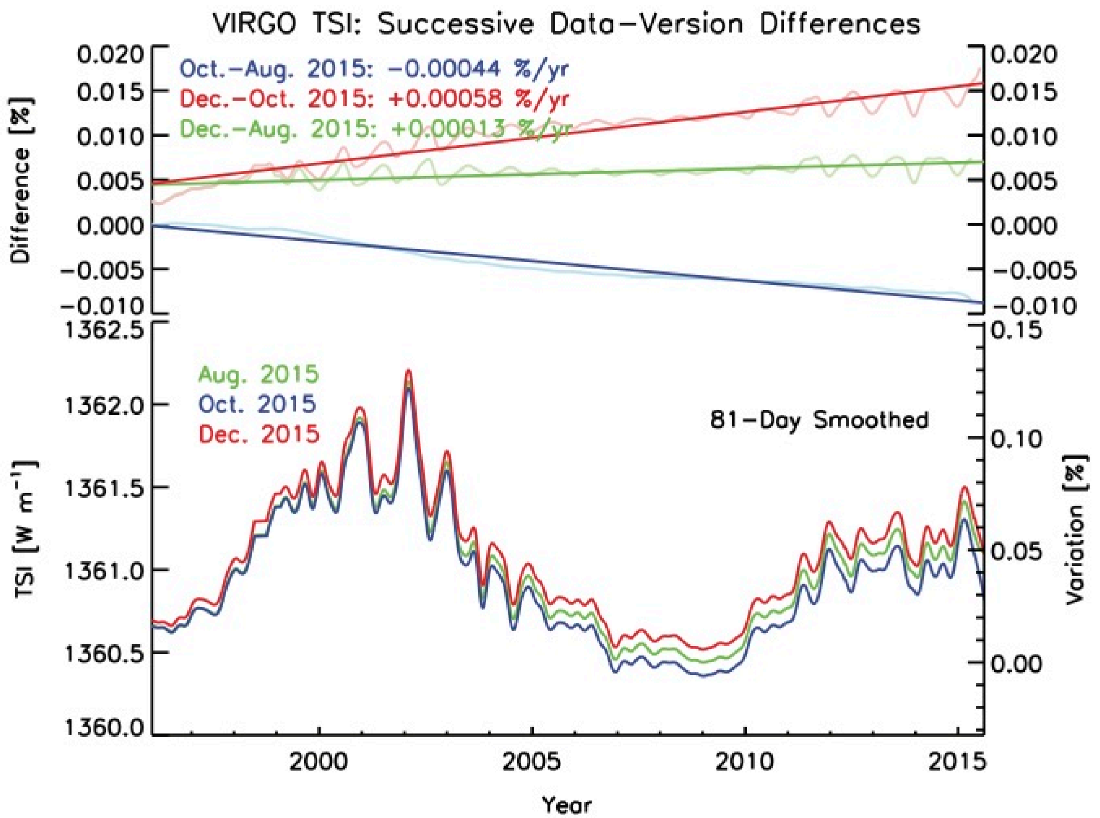

Fig. 7. Successive releases of VIRGO TSI data separated by 2 months each (lower plot) show significant trend differences (upper plot) due to variations in data-processing and estimates of instrument degradation with time.

Ongoing data evaluation …

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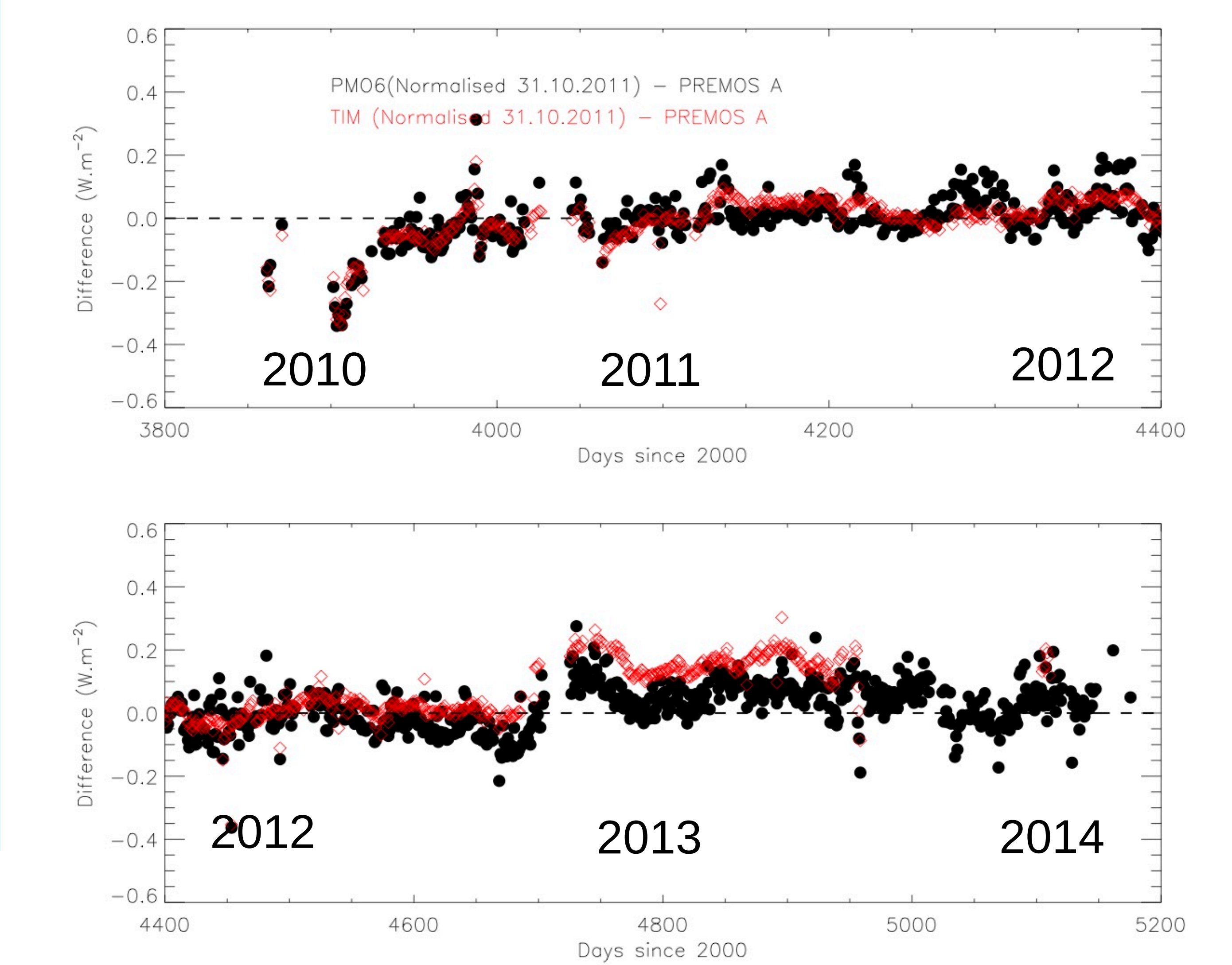
TIM and PMO6V minus PREMOS



Conclusions

- ➔ TSI-composite has a problem 2013/2014 at the transition from the *VIRGO-ACRIM-III-TIM-PREMOS* to the *VIRGO-TIM-TCTE* period
- ➔ New assessment of the relative calibration of PREMOS/PICARD supports the TSI record of TIM and disagrees with VIRGO
- ➔ Ongoing data evaluation disagrees with TIM and agrees better with PMO6V and DIARAD
- ➔ In any case: TSI trends <40ppm/yr cannot be reliably assessed with present-day instruments !
- ➔ *The next TSI experiment will be CLARA/NORSAT-1*
  TRF end-to-end calibrated!
  launch end 2016/beginning 2017

Community support for TSI (and SSI) monitoring is still needed:
It is important to get multiple and overlapping irradiance data !

What TSI variations are important?

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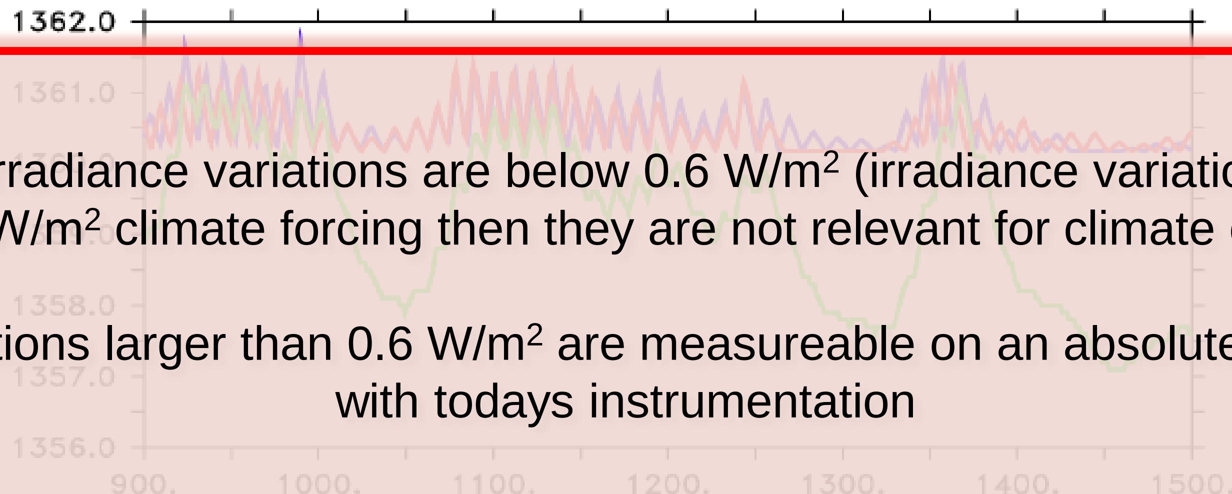
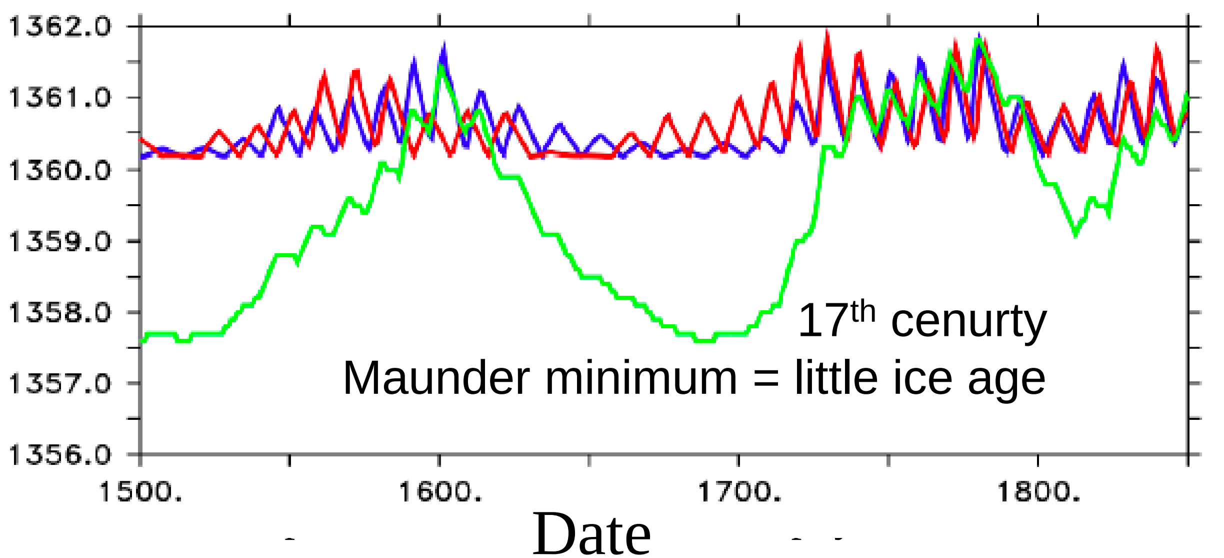


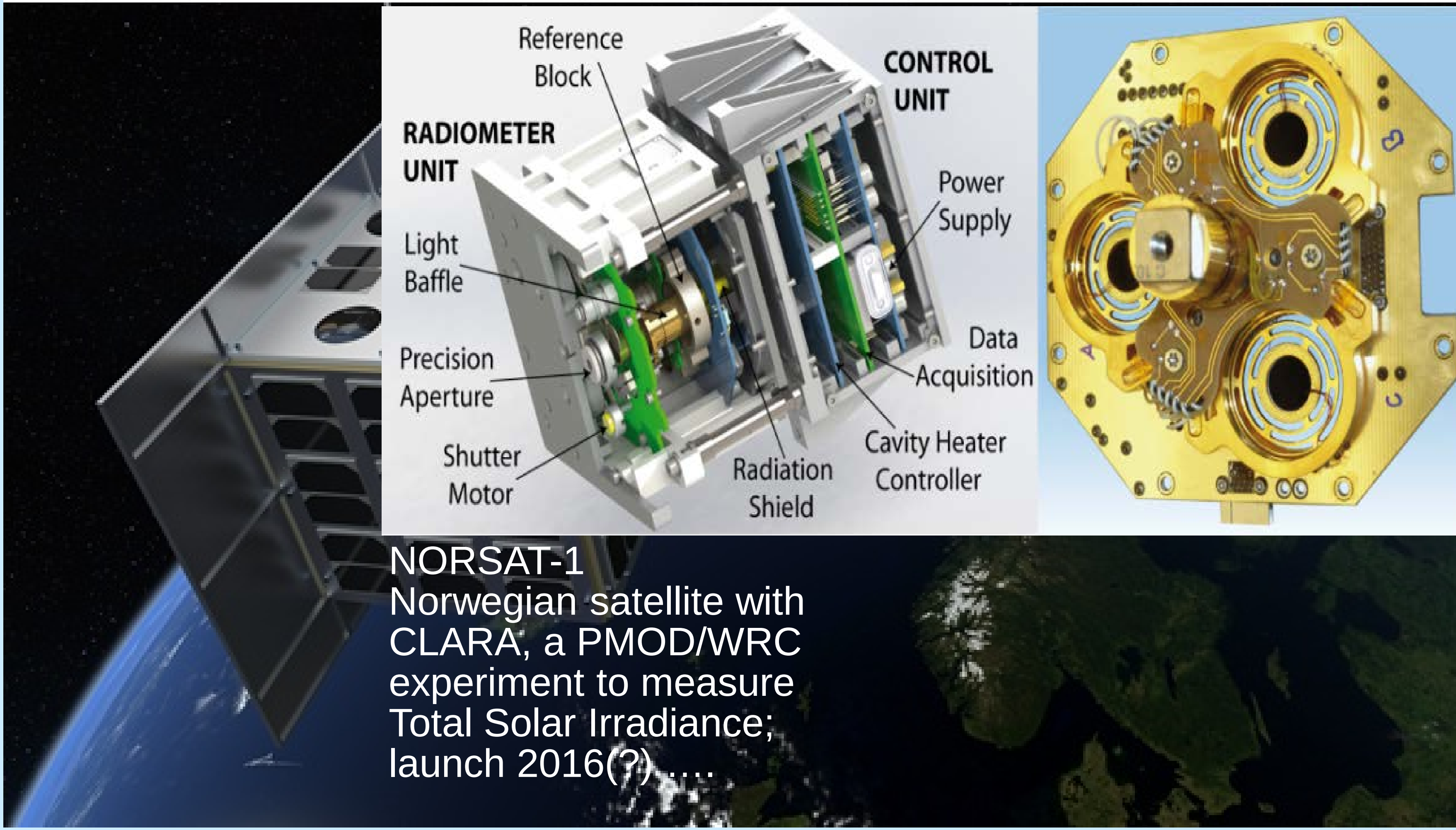
If irradiance variations are below 0.6 W/m^2 (irradiance variations ≈ 0.1 W/m^2 climate forcing then they are not relevant for climate change

Variations larger than 0.6 W/m^2 are measureable on an absolute level with todays instrumentation



From PMIP4 irradiance forcing data (Jungclaus et al. 2016, in preparation)

Our next TSI experiment: CLARA/NORSAT-1



NORSAT-1
Norwegian satellite with CLARA, a PMOD/WRC experiment to measure Total Solar Irradiance; launch 2016(?) ….

CLARA calibration at TRF

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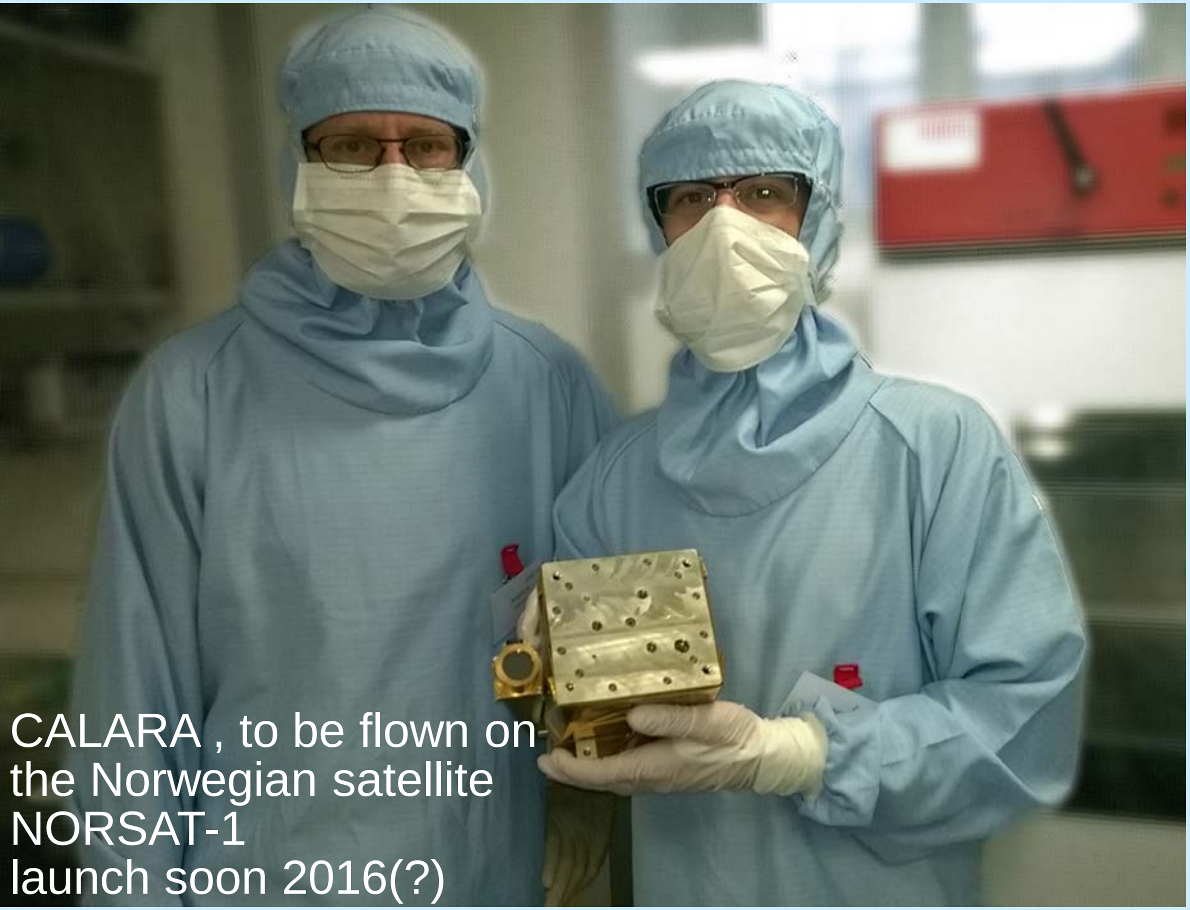
05

Scale	Characterization Item	TRF Ground (532 nm laser, vacuum) Channel A Value	σ [ppm]	Channel B Value	σ [ppm]	Channel C Value	σ [ppm]	Space (solar spectrum, vacuum) Channel A Value	σ [ppm]	σ [ppm]²	Channel B Value	σ [ppm]	σ [ppm]²	Channel C Value	σ [ppm]	σ [ppm]²
	Aperture area (1/ C_{aper}) [mm²]	19.6299	28	19.6242	28	19.6235	28	19.6299	28	-	19.6242	28	-	19.6235	28	-
Native Scale	Aperture Temperature	-	31	-	31	-	31	-	31	31	-	31	31	-	31	31
Native Scale	Absorptivity (C_{abs})	1.002060	354	1.002202	378	1.002051	352	1.002192	375	21	1.002343	400	22	1.002183	372	20
Native Scale	Pointing	-	-	-	-	-	-	-	30	30	-	30	30	-	30	30
Native Scale	Diffraction (C_{dif})	1.000491	18	1.000491	18	1.000491	18	1.000867	31	13	1.000867	31	13	1.000867	31	13
Native Scale	Non-Equivalence (C_{ne})	1.000007	4	1.000007	4	1.000007	4	1.000830	65	65	1.000830	65	65	1.000830	65	65
Native Scale	Heater Voltage Measurement	-	3180	-	3180	-	3180	-	3180	258	-	3180	258	-	3180	258
Native Scale	Shunt Voltage Measurement	-	3180	-	3180	-	3180	-	3180	258	-	3180	258	-	3180	258
Native Scale	Shunt Resistance Measurement	-	80	-	80	-	80	-	80	80	-	80	80	-	80	80
Native Scale	Lead heating (C_{lh})	1.000950	50	1.001084	50	1.001009	50	1.000950	50	-	1.001084	50	-	1.001009	50	-
Native Scale	Scattered Light (C_{scl})	0.999690	150	0.999690	150	0.999690	150	0.999690	150	-	0.999690	150	-	0.999690	150	-
Native Scale	**Calibration Factor**	**1.003200**	**4515**	**1.003477**	**4517**	**1.003251**	**4515**	**1.004536**	**4517**	-	**1.004822**	**4519**	-	**1.004586**	**4517**	-
Cryogenic Lab Scale	Repeatability	-	145	-	109	-	179	-	-	145	-	-	109	-	-	179
Cryogenic Lab Scale	TRF Comparison Factor	1.000650	285	1.000650	285	1.000650	285	1.003261	-	285	1.002595	-	285	1.004269	-	285
Cryogenic Lab Scale	**Calibration Factor**	**1.003261**	**4526**	**1.002595**	**4527**	**1.004269**	**4527**	**1.001271**	-	**498**	**1.002221**	-	**489**	**1.000316**	-	**509**



Thank you for your attention !