PREMOS/PICARD TSI Results and a revised TSI-composite

Werner Schmutz, PMOD/WRC, Switzerland
with contributions from the PREMOS team:
PMOD/WRC, LASP, NPL, LATMOS, CNES

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Overview

• The absolute value of TSI from first light of PREMOS/PICARD

• Sensitivity changes of the PREMOS radiometers

• Re-evaluation of 1996-1998 PMO6V sensitivity corrections → new cycle 23 composite

• Consequence for long term reconstructions
Space Measurements

4.5 W/m² difference in the absolute level of TIM/SORCE versus all other experiments
All TSI experiments are absolutely characterized, with uncertainties being much smaller than 4.5 W/m$^2$, typically 300 ppm (0.4 W/m$^2$) !

→ thus, the difference was unexplained !
New TSI measurements

A new absolute value of TSI from 1st light of PREMOS/PICARD

PICARD: A French micro satellite
PICARD was launched June 15, 2010

PICARD in DNEPR
PICARD satellite
PREMOS

PREMOS first light was July 27th, 2010
PREMOS/PICARD

Filter Radiometers

Total Solar Irradiance

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Traceability of PREMOS-TSI

PREMOS B

Comparison to cryogenic rad.
(power in vacuum)
NPL

Comparison to cryogenic rad.
(power and irradiance in vacuum)
TRF @ LASP

PREMOS A
PREMOS A is the *first and only* radiometer in space with a SI-traceable irradiance calibration in vacuum.

Traceable to the irradiance calibration facility at LASP in Boulder (TRF)
Uncertainty of calibration

= uncertainty of TRF comparison (220 ppm)

+ absolute uncertainty of TRF facility (70 ppm)
Traceable via TRF, LASP, Boulder → to NIST

• Irradiance in vacuum
  → PREMOS A uncertainty:  ± 280 ppm
  (± 0.4 W/m²)

• new: stray light estimate:
  PREMOS A 1800 ppm
  (previously thought to be 250 ppm;
  corresponding to 2 W/m² difference)
And the result is ....

<table>
<thead>
<tr>
<th>Date</th>
<th>PREMOS-A</th>
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<tbody>
<tr>
<td>27. July 2010</td>
<td>1360.9 W/m$^2$ $\pm$ 280 ppm (0.4 W/m$^2$)</td>
</tr>
<tr>
<td>VIRIGO/SOHO</td>
<td>1365.4 W/m$^2$</td>
</tr>
<tr>
<td>TIM/SORCE</td>
<td>1361.3 W/m$^2$</td>
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</tbody>
</table>
Conclusions on absolute TSI

- TSI-PREMOS-A is calibrated (fully SI-traceable!);
- Absolute uncertainty is 280 ppm or 0.4 W/m² (k=1);
- PICARD/PREMOS measures 0.4 W/m² lower than SORCE/TIM – thus, agrees with TIM within the uncertainty of the absolute calibration;
- PICARD/PREMOS is about 4.5 W/m² lower than SOHO/VIRGO – thus, the high value is outside the uncertainty limit (>11 sigma).
Comparison PREMOS to TIM

First light July 27, 2010

PREMOS A regular operation started in September 2010

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Ratio PREMOS to TIM

\[ \pm 100 \text{ ppm (0.1 W/m}^2) \]
Sensitivity changes

- The sensitivity of radiometers in space change with time.
- It is thought the sensitivity change is a function of exposure time, or more accurately, of a (UV-)radiation dose.
- The sensitivity changes are evaluated by comparing two radiometers which are as identical as possible; one observing the Sun operationally; the other only occasionally.
Ratio Level 1 A to Level 1 B

Increase
Plateau
Decrease
Change of slope

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Increase of A and B: Ratio to TIM

- **A real time**: 4 days
- **B real time**: 1 year
- **50 ppm**

Equations:
- \( \text{slope PREMOS L1A / TIM} = 95 \pm 8 \text{ ppm/day} \)
- \( \text{slope PREMOS L1B / TIM} = 65 \pm 10 \text{ ppm/day} \)
Discussion

• The ratio of PREMOS to TIM over the first year was constant → within ±100 ppm;

• Over one year PREMOS-B, corrected with the observed sensitivity change of A, drifted relative to TIM systematically by 50 ppm

• This can be interpreted as either:
  • TIM was drifting by 50 ppm
    or
  • The sensitivity changes of the two radiometers A and B are not identical as a function of exposure time!
The PREMOS radiometers are of the same type as the VIRGO PMO6V radiometers on SOHO:

What were the sensitivity changes applied to the PMO6-VIRGO radiometers?
Applied sensitivity changes to PMO6-V level 1 → composite
Applied sensitivity corrections

PMO6V-B:
- exposure days 0-6: Increase
- exposure days 7 to 10: “flat”
- exposure days 10 to 12: increase …

… in contrast to PMO6V-A that decreased after exposure days 10

→ compare to ACRIM II
PMO6V-B level 1 compared to ACRIM

fit PMO6VB / Acrim

exposure time B [d]
Real time

fit PMO6VB / Acrim

date
Comparison to ACRIM II

PMO6V-B:
- exposure days 0-6: Increase confirmed
- exposure days 7 to 10: “flat” (confirmed)
- exposure days 10 to 12: increase no (but noisy)

→ compare PMO6V-A to ACRIM II
Comparison of the sensitivity changes of PMO6V-A

![Graph showing sensitivity changes over time for different PMO6V-A models.](image_url)
Re-evaluation of 1996-1998 PMO6V sensitivity corrections

use ACRIM trend
New composite 1996-2010

Monthly mean: ACRIM, DIARAD, PMOD, PREMOS composites
PREMOS composite 1996-2010

Irradiance [W/m²]

- New PMO6V L2 (f2)
- PMOD Composite

0.2 W/m²
• Absolute level of TSI is 1360 W/m²
• Sensitivity changes are rather complex: increase – plateau – decrease – change of slope
• Sensitivity increase of PREMOS A and B are not identical (relative to TIM)

→ this questions the usual assumption that two cavities are sufficient to correct for in flight sensitivity changes!
• The early (1996-1998) sensitivity changes of PMO6V A and B radiometers on SOHO are different (as applied for the PMOD composite)
• We suggest to adapt the ACRIM trend to assess the early PMO6V sensitivity changes
• Observational 1996-1998 TSI data are uncertain
• Observed data do not support a measureable TSI trend between the minima in 1996 and 2008!

When assessing long term trends, allow for an uncertainty of at least 0.2 W/m² for the 1996 solar minimum!
Consequences for long term reconstructions?

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For stars with log $R'_{\text{HK}}$ there is a relatively well-defined increase in the amount of photometric variability relative to the chromospheric variability. Six outliers lie well below the rest, including the unusually active star HD 129333. As before, the nine stars with only one usable comparison star are plotted using inverted triangles.

Left of the Sun's location on this diagram there is considerable scatter, which we attribute mainly to the poorly known level of photometric activity of these stars rather than to an astrophysically meaningful effect.

This figure, which we consider a key exhibit in the morphology of stellar variability for the Sun and its analogs, raises an interesting question. Is the Sun's location, just slightly above the dividing line, fixed for historical time or could it shift around a bit? Certainly, during the three solar cycles of modern observation, there is nothing to suggest that spot activity could overtake facular activity as the principal component of solar variability. The answer, apart from whatever theoretical ruminations might arise, lies in expanding the sample of stars and pushing down the limits of estimated photometric variability as far as possible. The answer, therefore, lies in the indefinite future.

In this section we discuss how our results might have been improved had we known in 1984 what we know today. We began our survey of Sun-like field stars in 1984 with the new knowledge that young F7–Y2 stars in the Hyades vary at the easily detected level of a few percent (Radick et al. 1983; Lockwood et al. 1984). This was a revelation, since Jerzykiewicz & Serkowski (1966) had shown that stars in this spectral range, if they vary at all, do so at levels below 0.5% on a decadal timescale. The Sun itself, shown from spacecraft observations in 1980 to be a variable star on a timescale of days (Willson et al. 1981), had yet to reveal its minuscule cycle timescale 0.1% variation (Frohlich 2003a, 2003b).

The challenge, as we perceived it in 1984, was therefore to map out variability downward from the easily detected several-percent range of Hyades dwarfs to whatever level our instrumentation would allow. To be reasonably certain of not coming up empty handed, we included a number of young, presumably active stars (based on their log $R'_{\text{HK}}$ values) in our sample. These rewarded us almost immediately by showing variability.

Fig. 7.—Long-term (cycle timescale) photometric variation vs. average chromospheric activity level.

Fig. 8.—Correlation between photometric brightness and HK emission variations for long timescales based on 13 Y20 yr of observation. (top) and 7 Y12 yr of observation from Paper II. (bottom). Many correlations are strengthened and none of the 32 surviving stars in the longer sample show reversal in the sense of the correlation.

Fig. 9.—Slope of the regression of photometric brightness variation on HK emission variation, plotted as a function of average chromospheric level.
rms(b+y), %

Year

long-term trend

min - 0.04%
max - 0.1%
mean - 0.05%

present Sun
Factor 1.3 “inclination effect”

(Factor 1.3 from Knaack et al. 2001)
Thank you for your attention

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