

The Solar spectral irradiance at solar activity minimum during the transition cycles 23 to 24*: A contribution to the PICARD-Climate program

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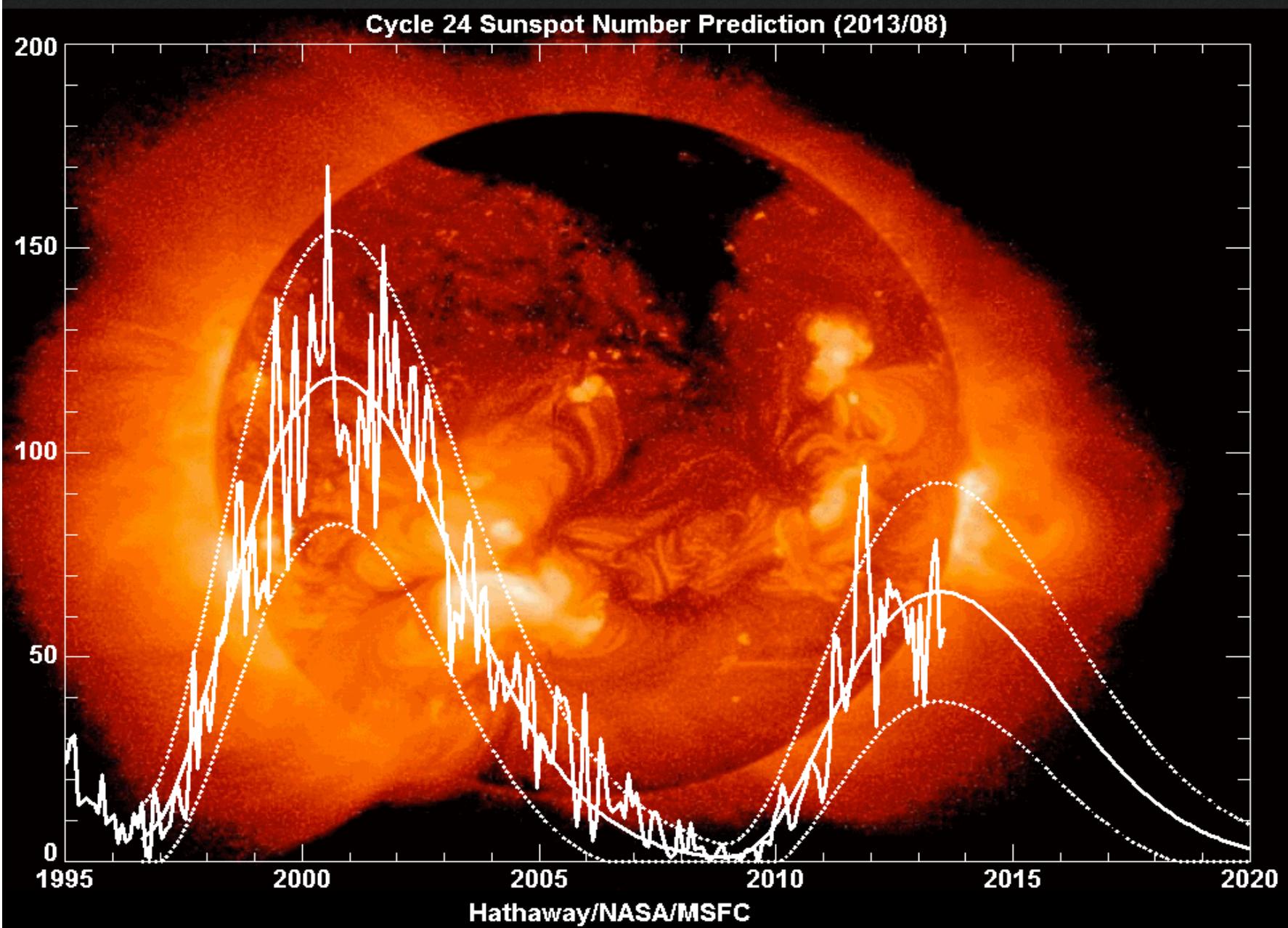
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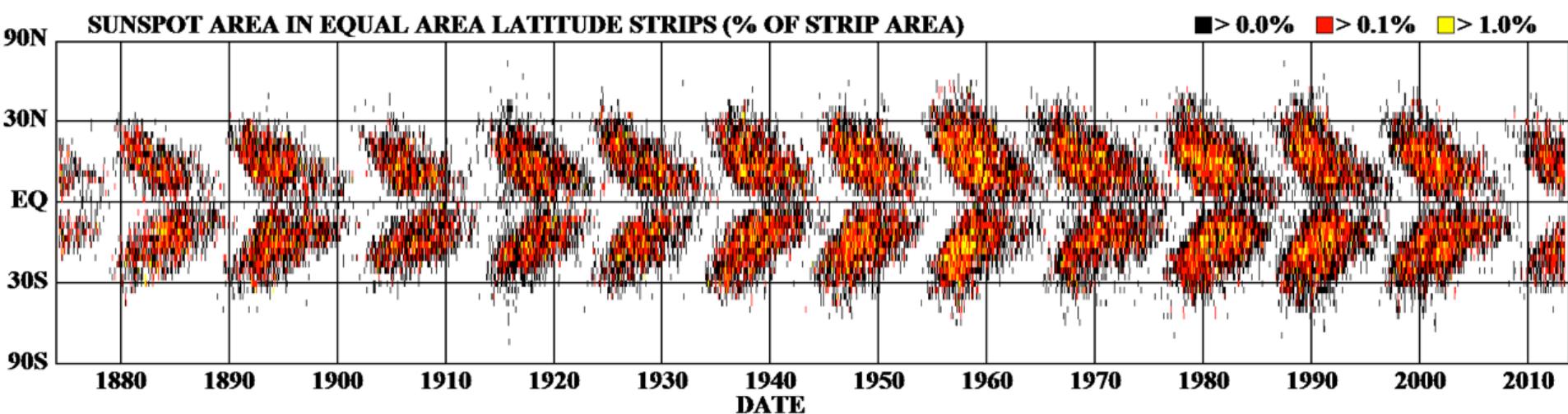
IMPORTANCE OF THE SOLAR MINIMUM OF 2008

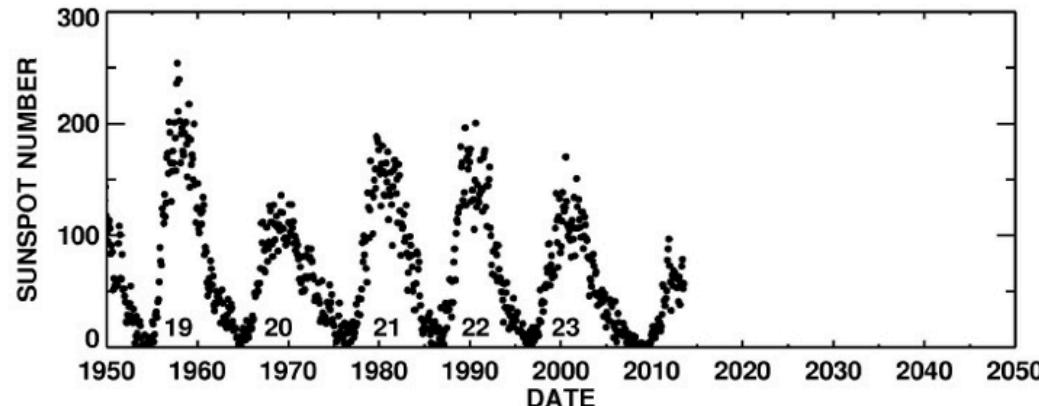
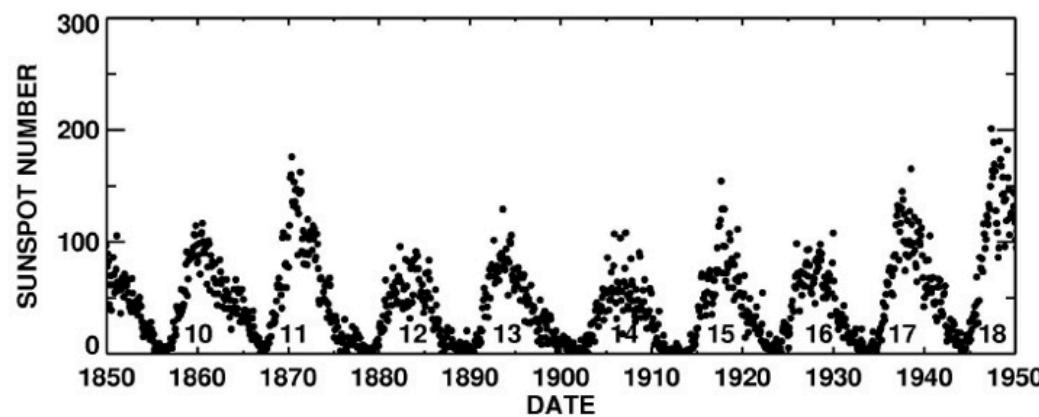
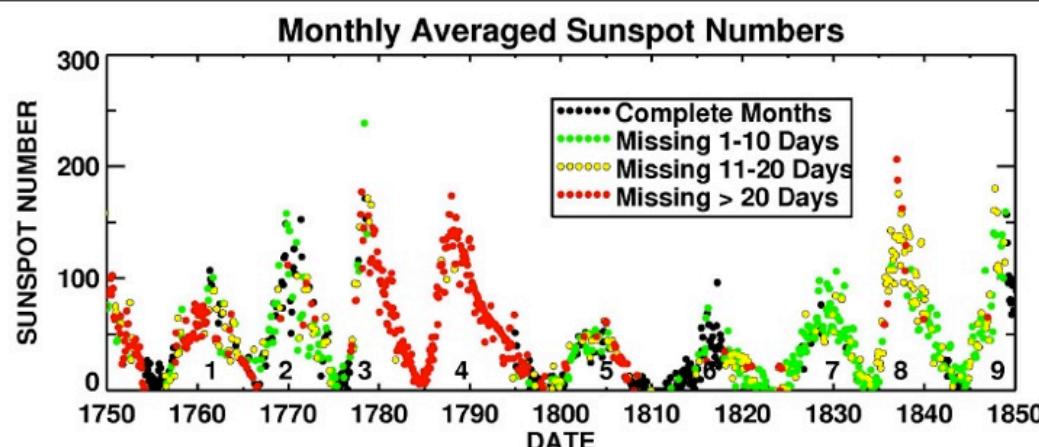
- Solar Spectral Irradiance (SSI) minimum is the base line of several reconstructions SSI models. Furthermore, it is used for checking the accuracy of the SSI reconstruction, before running climate models in low solar activity periods such as the Dalton minimum.
- By comparing several SSI minima, the long term trend of the solar activity can be studied.
- The values of the different solar parameters at solar minimum (SSI, TSI, proxies, ...) are essential to solar modelists to understand the cause of the minimum, in particular the recent 2008 minimum, lower than the others.

CYCLES 22 AND 23 MINIMA



DAILY SUNSPOT AREA AVERAGED OVER INDIVIDUAL SOLAR ROTATIONS





DATA USED IN THIS STUDY

SOLACES ON BOARD THE ISS. IT IS AN EUV SPECTROMETER SELF CALIBRATED USING GAS CELL.
SSI IS MEASURED FROM **17 TO 150 NM**.

SOLSPEC ON BOARD THE ISS. IT IS A SPECTROMETER MEASURING FROM **170 TO 2900 NM**, USING
ON BOARD LAMPS TO MAINTAIN THE STABILITY OF THE ABSOLUTE PHOTOMETRIC SCALE.

BOTH INSTRUMENTS WERE CALIBRATED AT PTB (G).

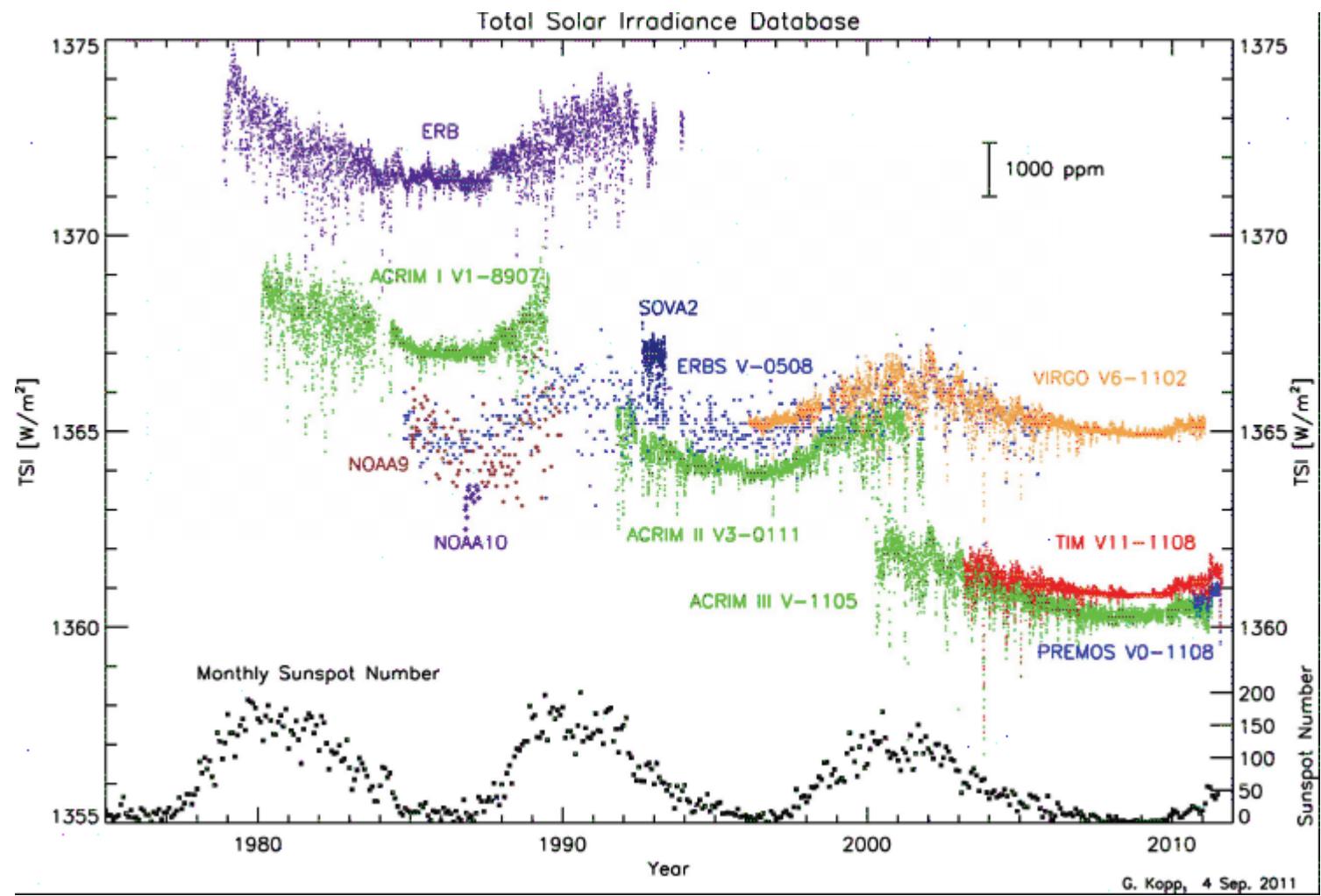
SOLSTICE ON BOARD SORCE.

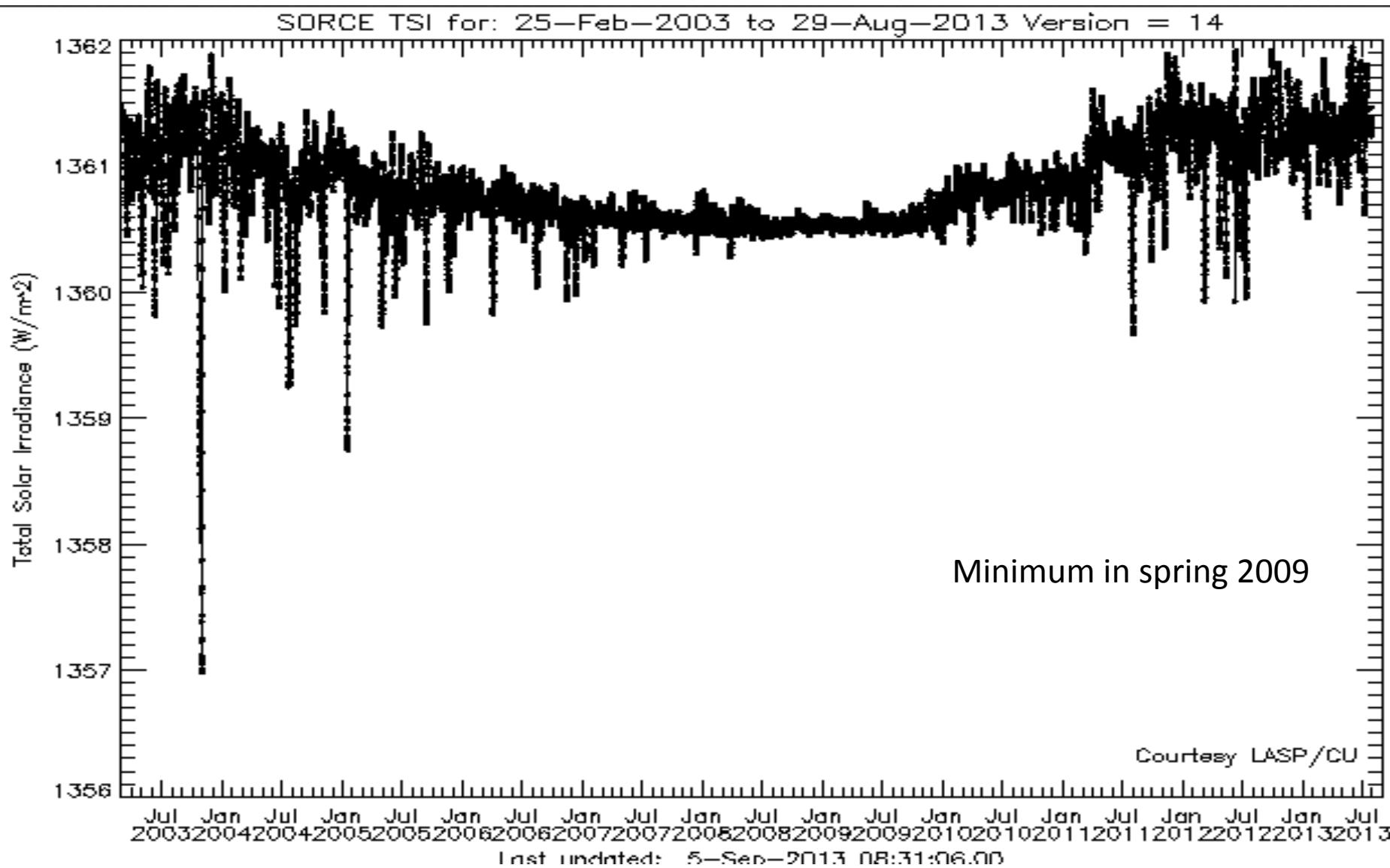
OTHER SPECTRA and MODEL SPECTRA USED IN THIS STUDY

SPECTRA: ATLAS 3 (Thuillier et al., 2004)
 Whole Heliospheric Interval (WHI, Woods et al., 2009) dated of 14 Feb. 2008
 EVE-SDO in preparation to SDO launch (14-4-2008)
 SCIAMACHY (Weber et al., 2010), (2002 in the IR part)
 SOLAR = SOLSPEC + SOLACES on board the ISS

TSI:

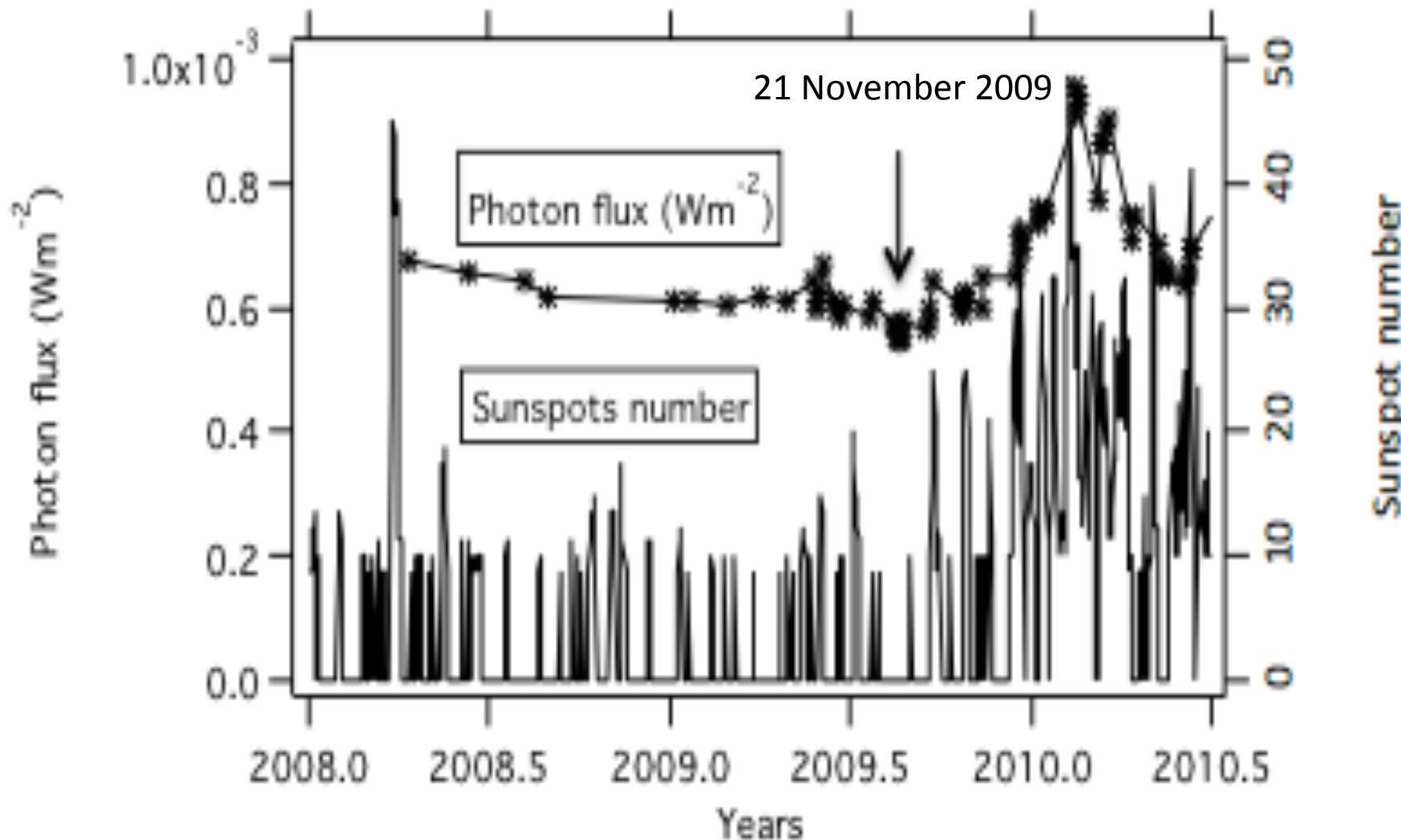
Theoretical models: COSI (Shapiro et al., 2011)
 SRPM (Fontenla et al., 2011)

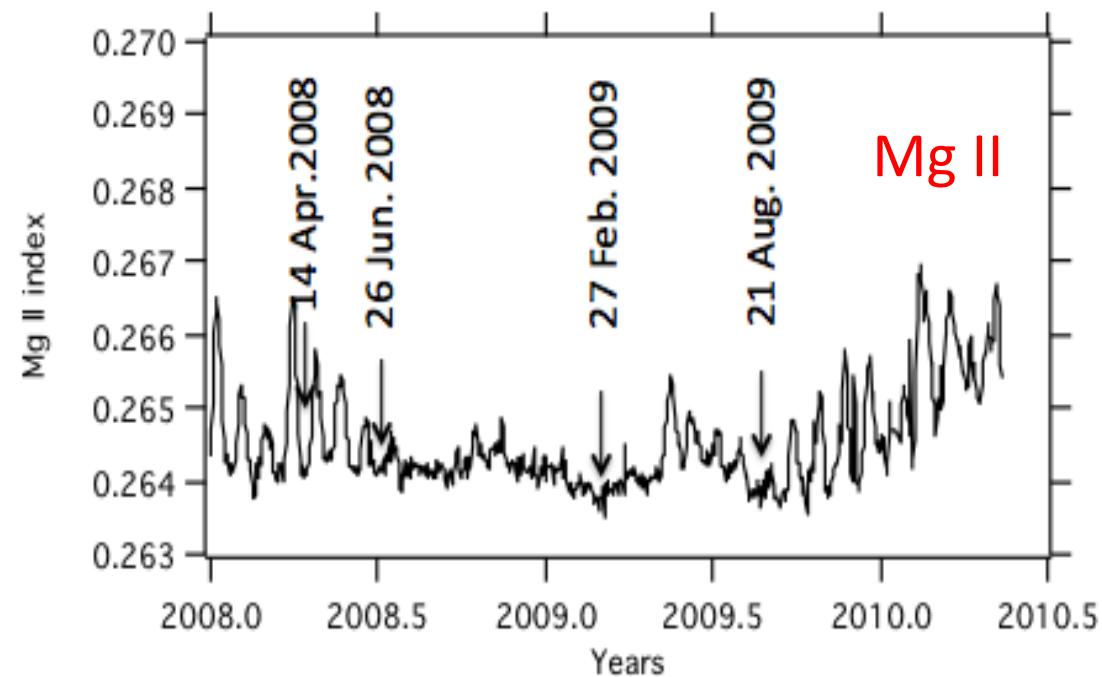
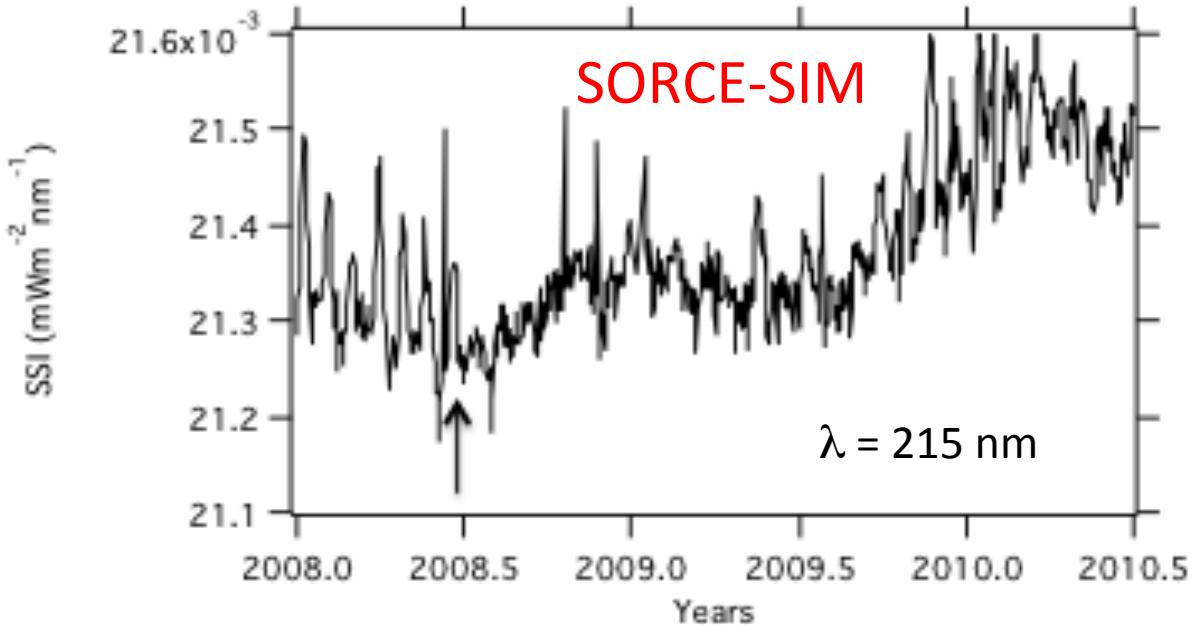




White et al., 2011 show that TSI, F10.7 and Mg II are not in phase.

SoIACES EUV MEASUREMENTS





14 Feb. : WHI

26 June = Minimum at 215 nm

27 Feb. = Minimum Mg II

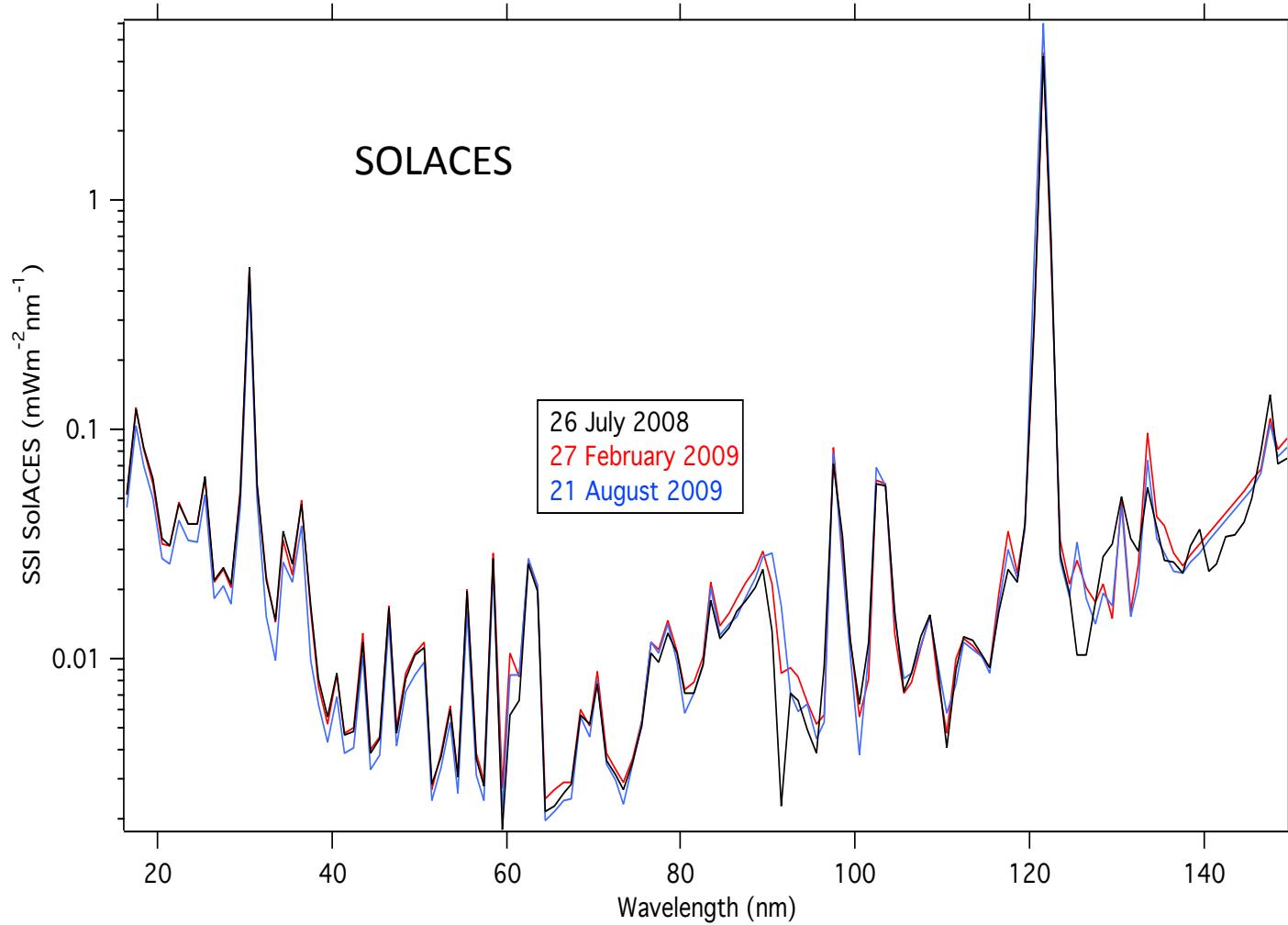
21 Aug. 2009 = Minimum EUV

Spring 2009 = Minimum TSI

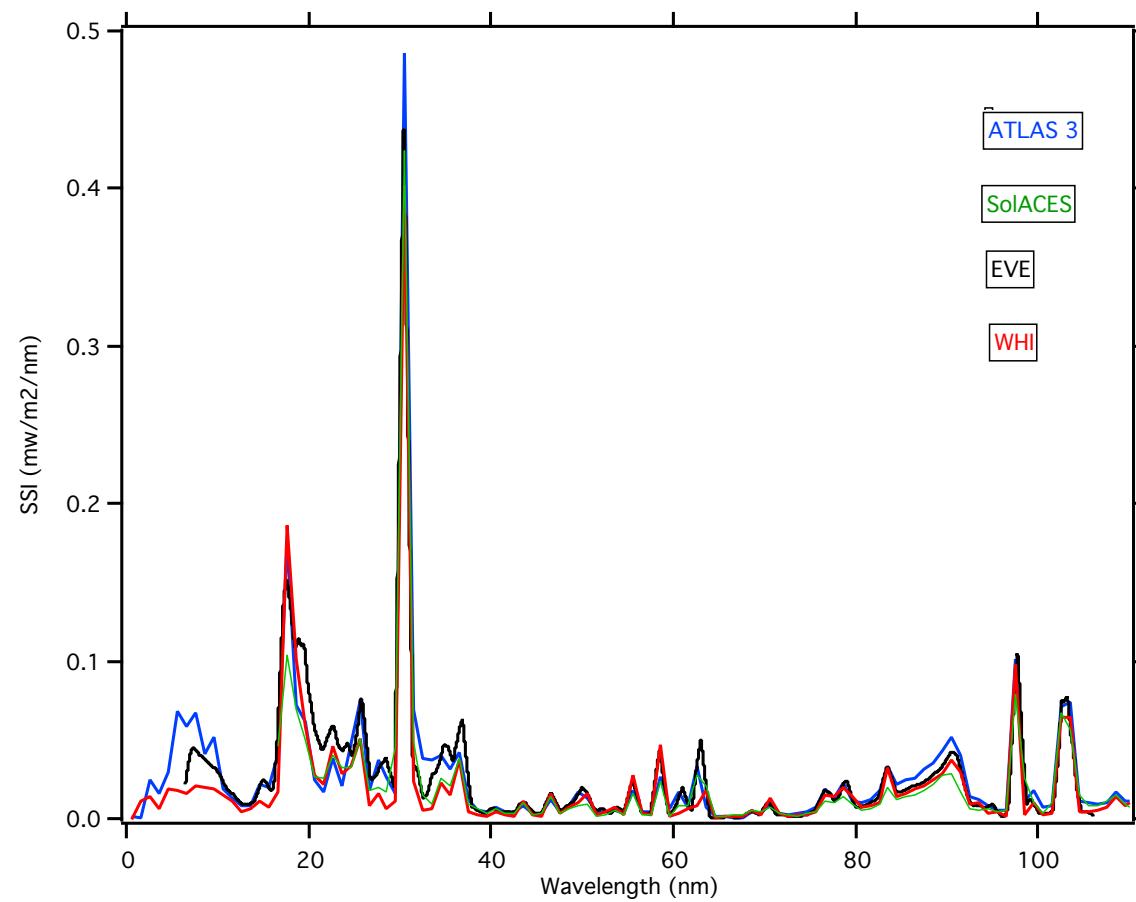
DATES and Mg II INDEX, F10.7 RADIO FLUX and SUNSPOTS NUMBER

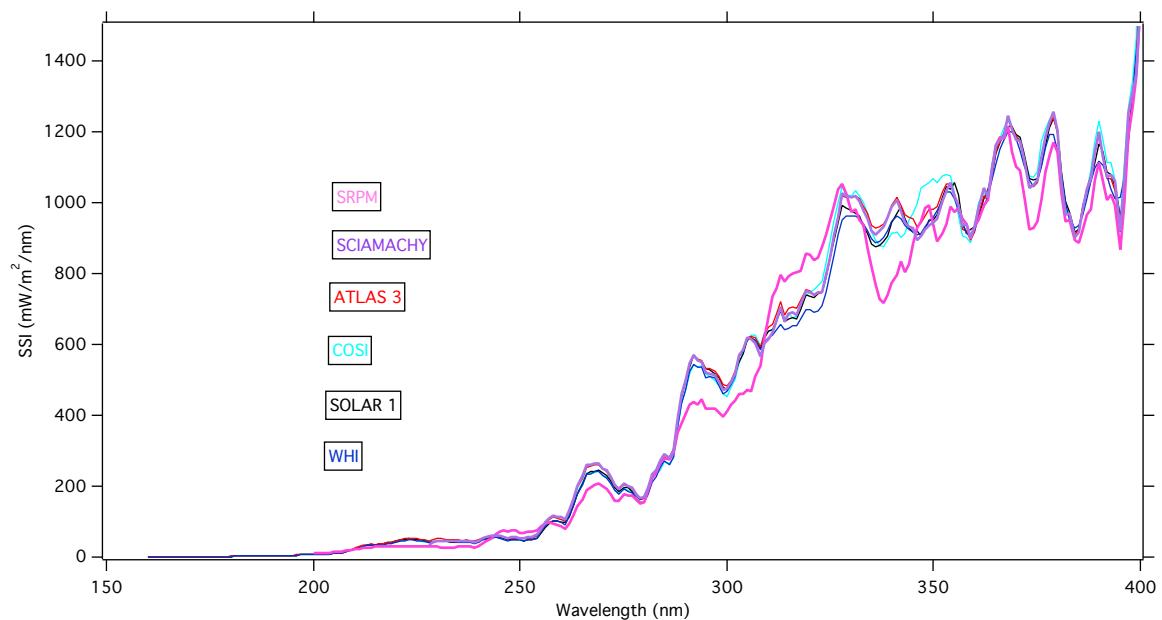
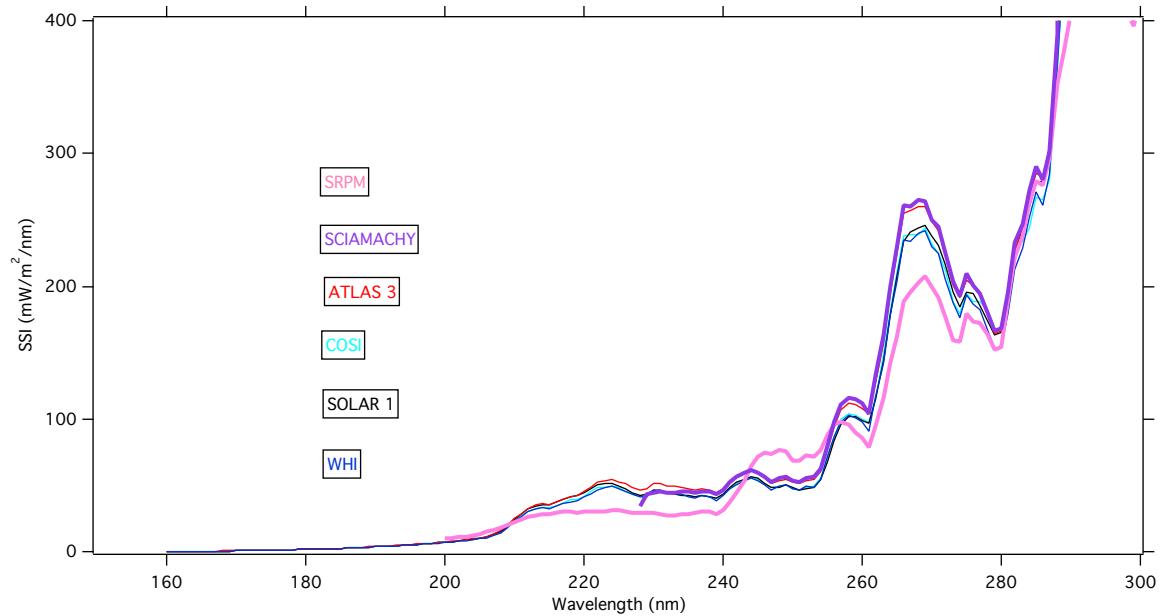
	ATLAS 3	WHI	SOLSPEC	SOLSTICE	SOLACES	EVE
Date	10/11/1994	10 to 16/4	5 and 8/4	5/4/2008	21/8/2009	14/4/2008
			2, 4, 5, 6/5			
SSN	18	<2>	<3>	0.	0.	7
F10.7	80.	<68.9>	<68>	71.3	67.	68.9
Mg II index	0.26747	<0.26416>	<0.26433>	0.26465	0.26375	0.26416

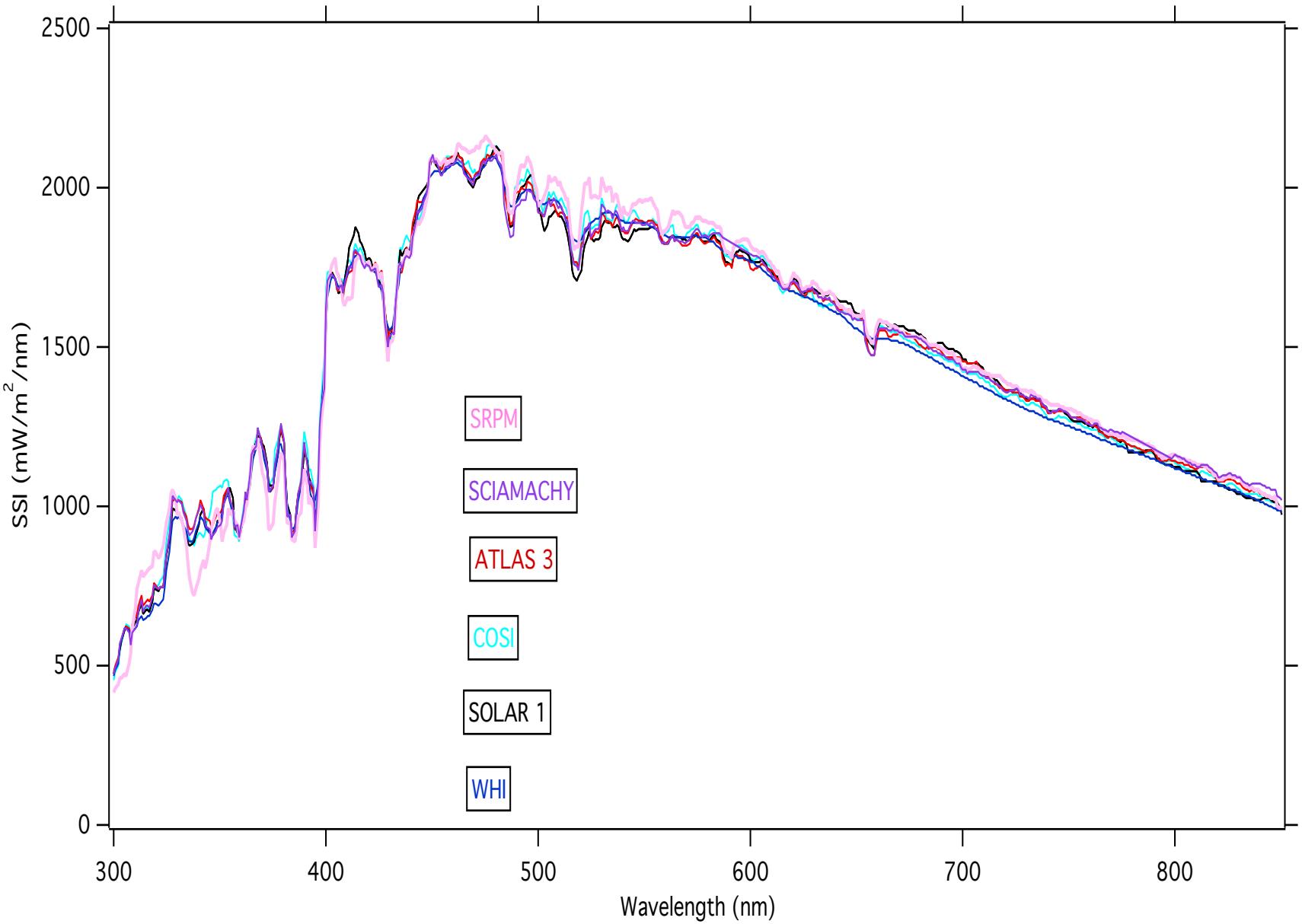
Dates, sunspots number (SSN), F10.7 cm radio flux and Mg II index used in this article. For data covering several days, the mean values of the SSN, Mg II index and F10.7 solar radio flux is shown by <>.



SolACES SSI on 21 August is the lowest among these three dates. This is obtained by calculating the SSI ratio of 26/7/08 and 27/2/09 to 21/8/09 and comparing to the combined uncertainty of each spectrum.



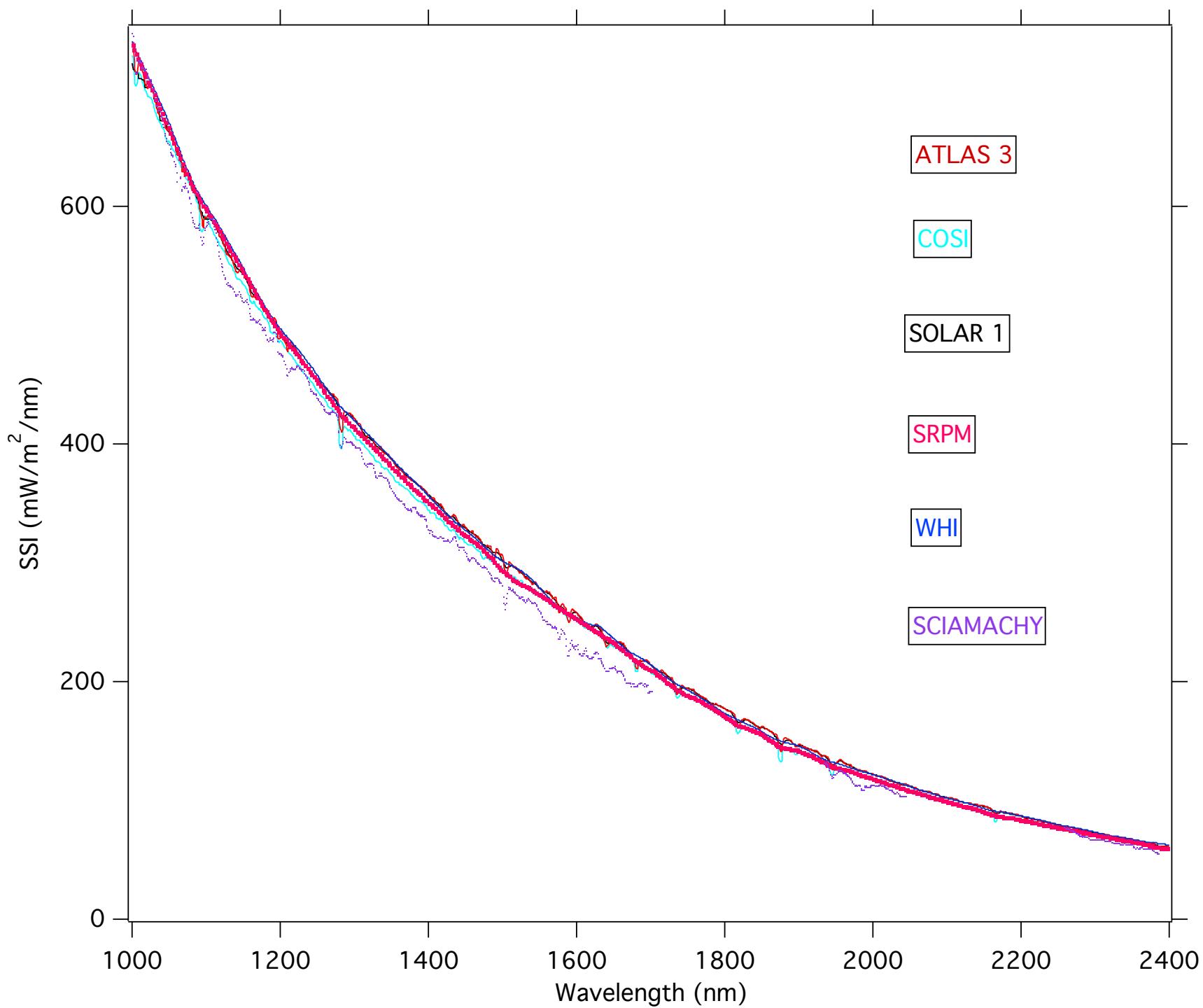




DATA SETS ACCURACY

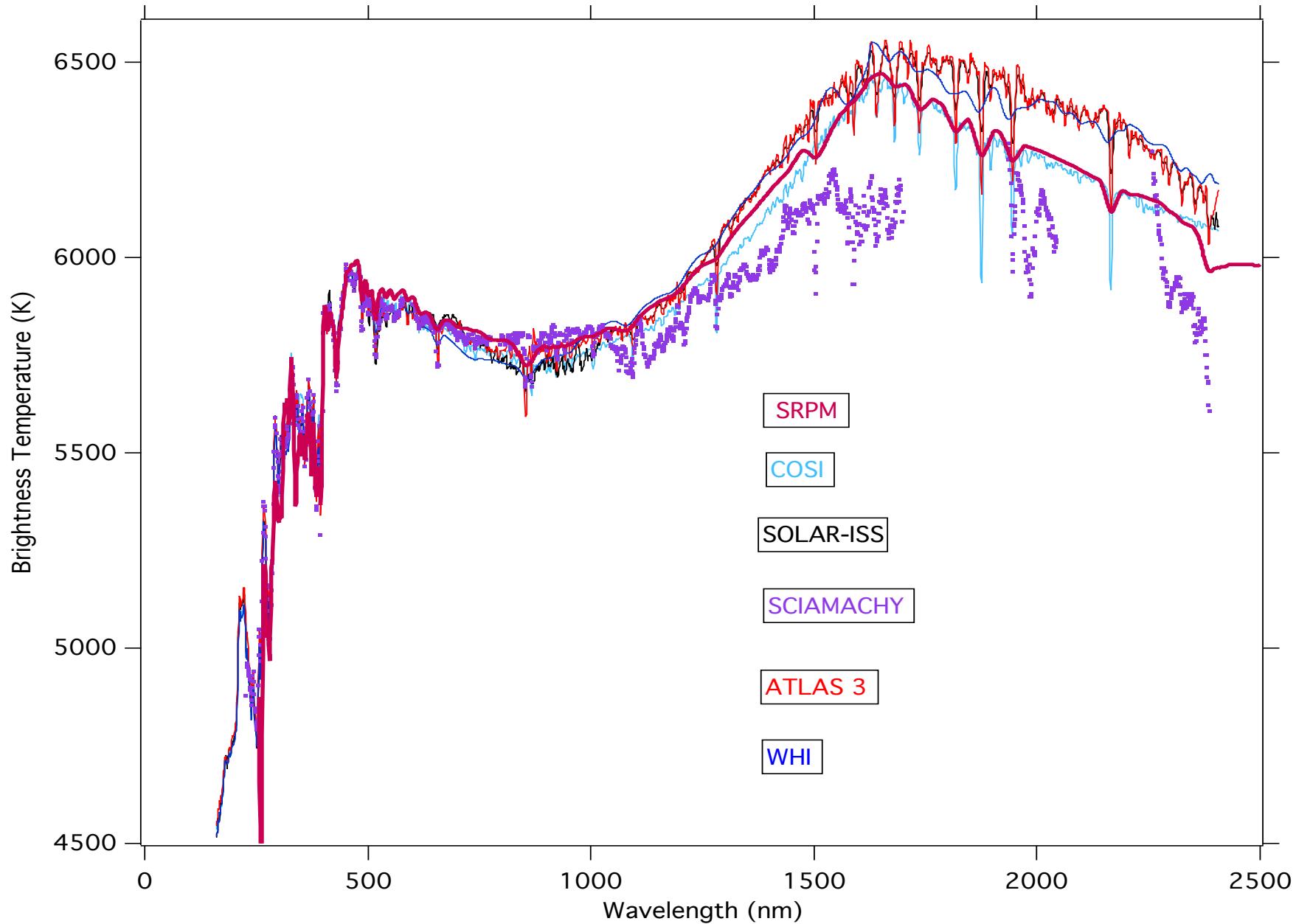
$\Delta\lambda$ (nm)	SRPM/SOL	COSI/SOL	A3/SOL	WHI/SOL	WHI/A3	WHI/COSI	SRPM/COSI
210-350	0.96	1.01	1.03	0.98	0.95	0.96	0.95
350-500	0.99	1.00	1.00	0.99	0.99	0.98	0.98
350-850	1.01	1.00	1.00	0.99	0.99	0.99	1.01
220-260	0.95	1.00	1.09	0.98	0.90	0.99	0.95
260-300	0.85	0.97	1.02	0.97	0.94	0.99	0.87
300-340	1.01	1.02	1.03	0.98	0.95	0.96	0.99
340-370	0.96	1.02	1.00	0.99	0.98	0.97	0.95
350-425	0.97	1.00	0.99	0.99	0.99	0.98	0.96
425-500	1.00	1.00	1.00	0.99	0.99	0.99	1.00
500-575	1.05	1.02	1.01	1.02	1.01	1.00	1.02
575-650	1.01	0.99	0.99	0.99	0.99	0.99	1.01
650-725	1.00	0.98	0.99	0.97	0.98	0.99	1.02
725-800	1.02	0.99	1.00	0.98	0.98	0.99	1.02

SOL = SOLAR-ISS; A3 = ATLAS 3



DATA SETS ACCURACY

$\Delta(\lambda)$	SRPM/A3	COSI/A3	WHI/A3	SOL/A3	COSI/SOL	SRPM/SOL
210-2400	1.00	0.99	0.99	0.99	1.01	1.02
1000-2000	0.99	0.98	1.00	1.00	1.03	1.04
1000-1761	0.99	0.98	1.00	1.00	1.02	1.03
1000-2400	0.99	0.98	1.00	1.00	1.03	1.04
2100-2200	0.96	0.95	1.00	1.00	1.06	1.06
2400-2900					1.05	1.04



CONCLUSION

We dispose of a spectrum at the lowest activity observed during the transition between cycle 23 and cycle 24.

WHI, SOLAR are in agreement taking into account their respective accuracy.

The smallest differences between the measurements and the theoretical models are obtained with COSI. The missing opacities are likely the source of the differences.

For past solar activity studies, SSI at solar minimum is important to check the accuracy of the SSI reconstructions, which usually are working less precisely at low than at high activity.

Climate studies are part of PICARD program using climate model and SSI reconstructions of the past periods. These reconstructions are necessary to run the climate model.

The 2008 minimum will be useful to study the Dalton minimum period (in preparation).

A reconstruction using the Mg II index and the ^{10}Be cosmogenic isotope concentration variation has been published (Thuillier et al, 2012, Solar Physics). The existing reconstructions have been compared (variability, absolute values) at different epochs to assess their agreement/disagreement. It appears that by running the CMAN, the variability of the atmosphere heating using these models is greater than the variability induced by the solar activity effects predicted by each models (Thuillier et al., 2013, Solar Physics). Inferred solar variability by modeling is in preparation.