A New Solar Spectral Irradiance Reconstruction based on Mg II and Neutral Monitoring Indices for Use in Climate Modelling

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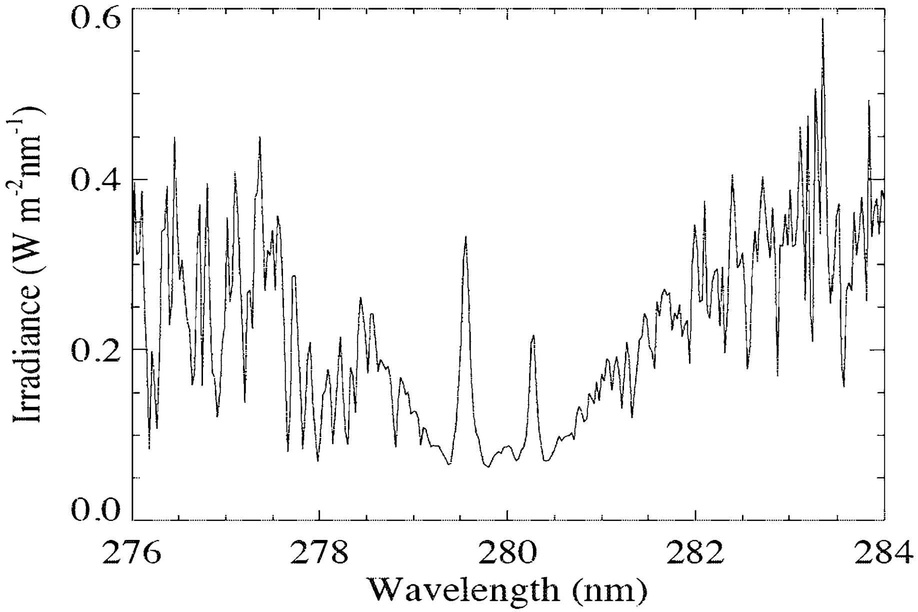
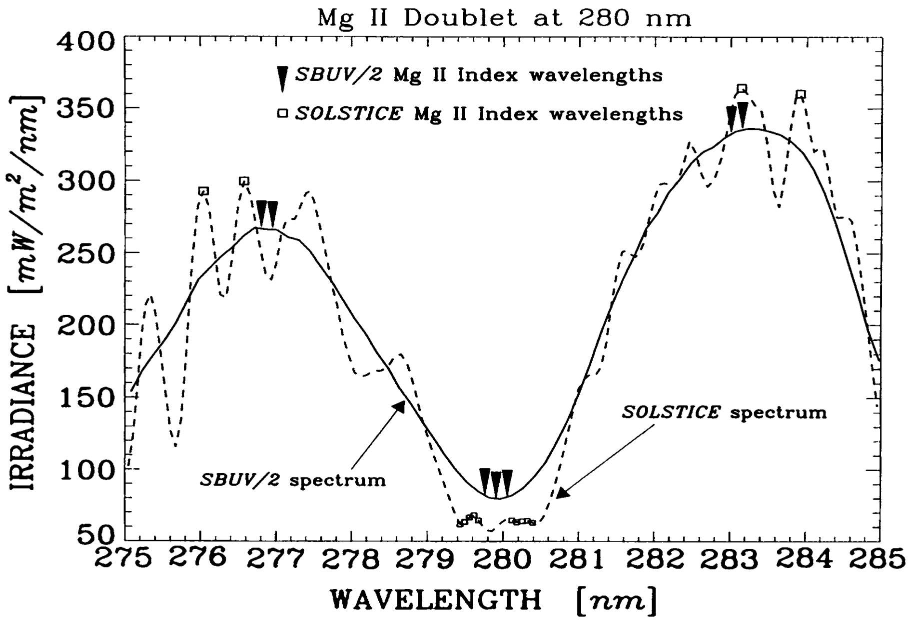
Abstract To carry out climate modeling, the Solar Spectral Irradiance (SSI) is necessary in terms of variability and absolute value. Furthermore, for studies of past periods, reconstruction based on proxies are necessary.

We present a new method to reconstruct the solar spectrum irradiance in the Ly α – 400 nm region, and its variability, based on the Mg II index and neutron-monitor measurements.

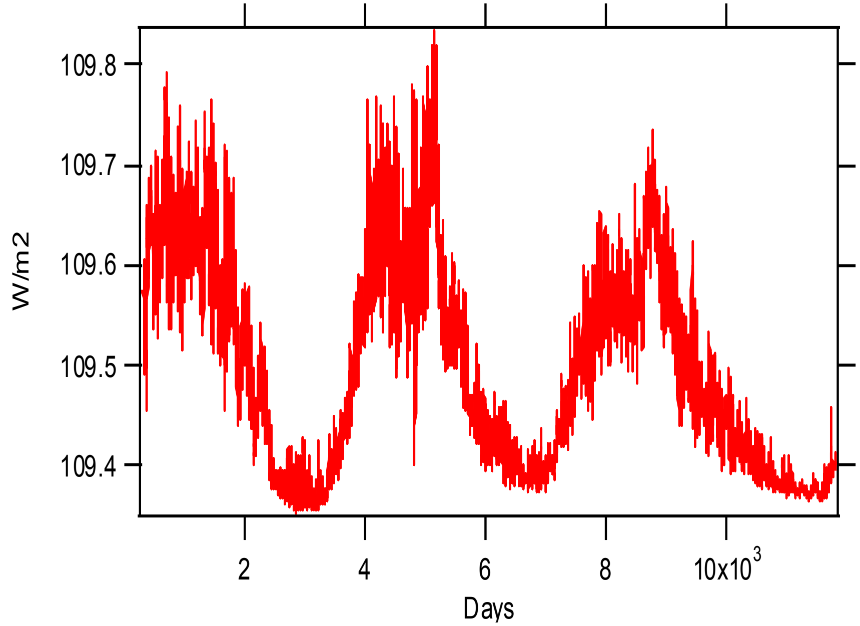
OUTLINE

- The Mg II index and its properties
- Principle of the Mg II index for reconstructing the solar spectrum at a given date
- Accuracy of the reconstruction
- Performance of the reconstruction
- Reconstruction of the past period

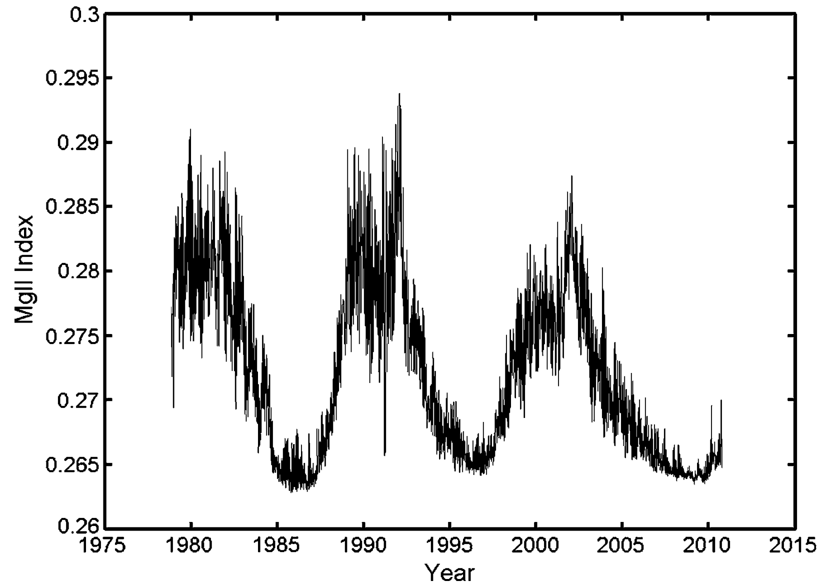




The Mg II line at high resolution (upper panel) and low resolution (lower panel)



Power variation in the Ly-α- 400 nm domain



The Mg II index as a function of time

PRINCIPLE OF THE RECONSTRUCTION USING THE Mg II INDEX and NEUTRON MONITOR DATA

First, the Mg II index is derived using solar spectra from Ly α (121 nm) to 410 nm measured from 1978 to 2010 by several space missions. The variability of the spectra with respect to a chosen reference spectrum is scaled to the Mg II index value as a function of time and wavelength.

Second, for a given date, the Mg II index is known as well as the percentage of variability for each wavelength. This percentage is then applied to a reference spectrum. Here, we have chosen the ATLAS 3 spectrum.

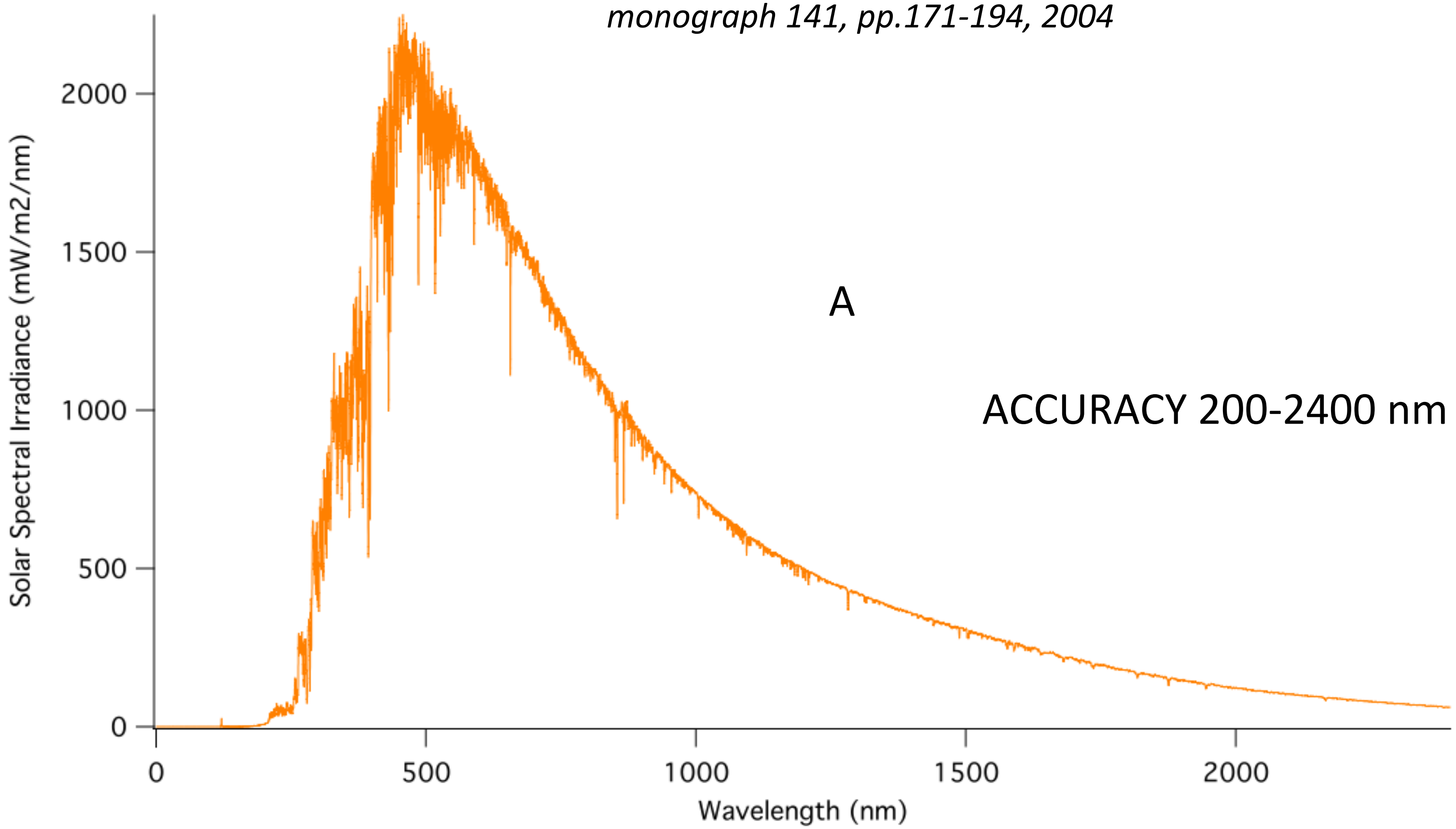
Third, the relationship between the Mg II index and neutron monitor data is established over the last 30 years (Neutron monitor data are measurements of the ^{10}Be concentration. ^{10}Be is generated by cosmic ray which is function of solar activity).
Given their common solar magnetic field variation origin, this relation is assumed to be valid in time.

Chosing a period (e.g. during the 18th century), the neutron monitor data are known allowing to derive the corresponding Mg II index. Then, step 2 is applied.

THE ATLAS COMPOSITE SPECTRA

Two composite spectra at two levels of solar activity as encountered during the ATLAS 1 and 3 missions covering the domain 0.5 nm to 2400 nm were built by using rocket data from 0.5 nm to Ly α from Woods et al. (1998), UARS (SUSIM and SOLSTICE), ATLAS 1-2-3 (SUSIM, SOLSTICE and SOLSPEC) data from Ly a to 400 nm, and SOLSPEC from 400 nm to 2400 nm from ATLAS and EURECA Missions.

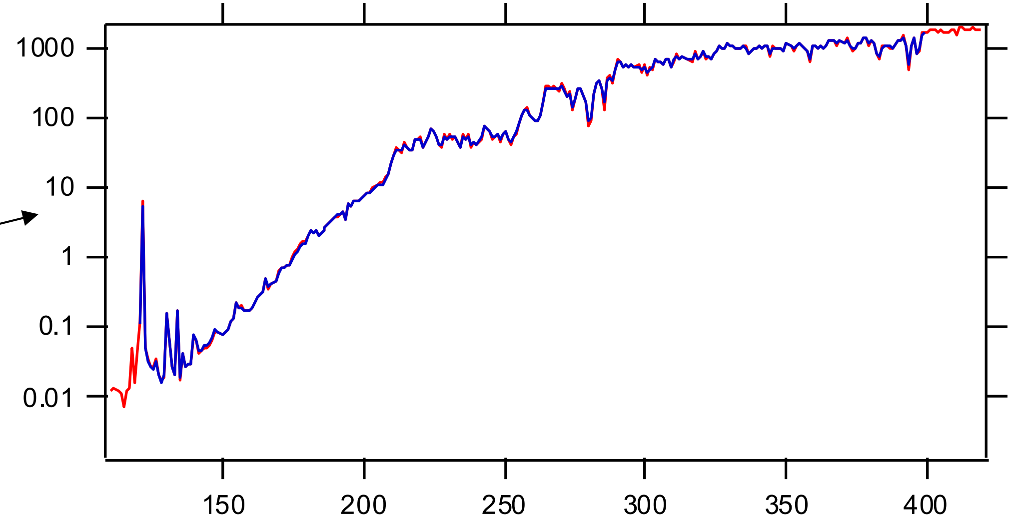
Thuillier et al., Solar irradiance spectra, in Solar variability, AGU monograph 141, pp.171-194, 2004



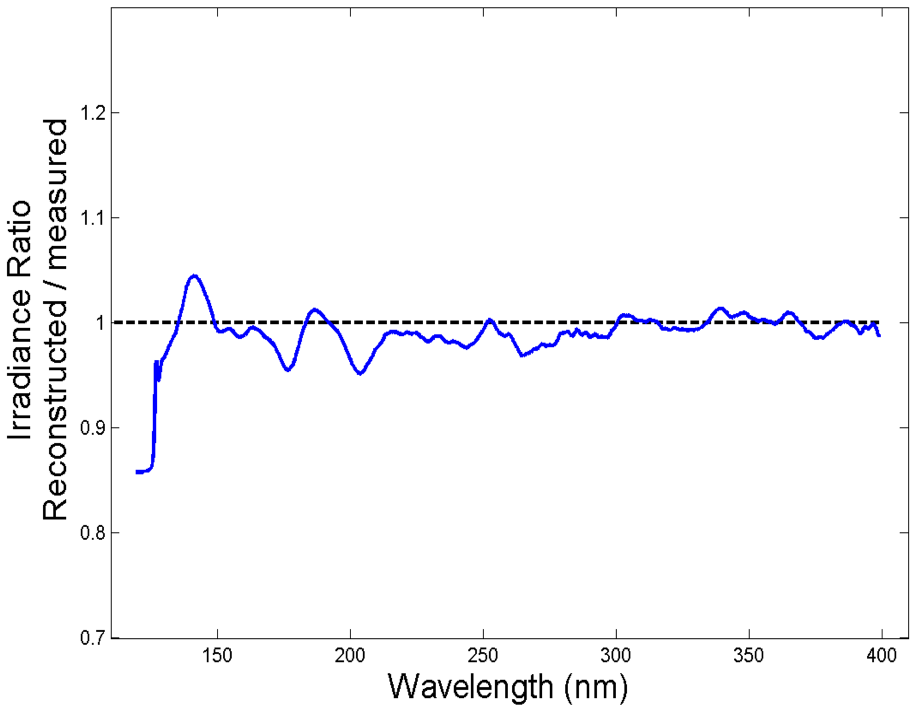
ACCURACY 200-2400 nm : 3%

RECONSTRUCTION OF THE WHI SPECTRUM USING THE Mg II MODELING AND ATLAS 3 AS REFERENCE SPECTRUM

WHI (red) is a composite spectrum using SORCE and SEE data. Its reconstruction is shown in blue. Their ratio is displayed below.

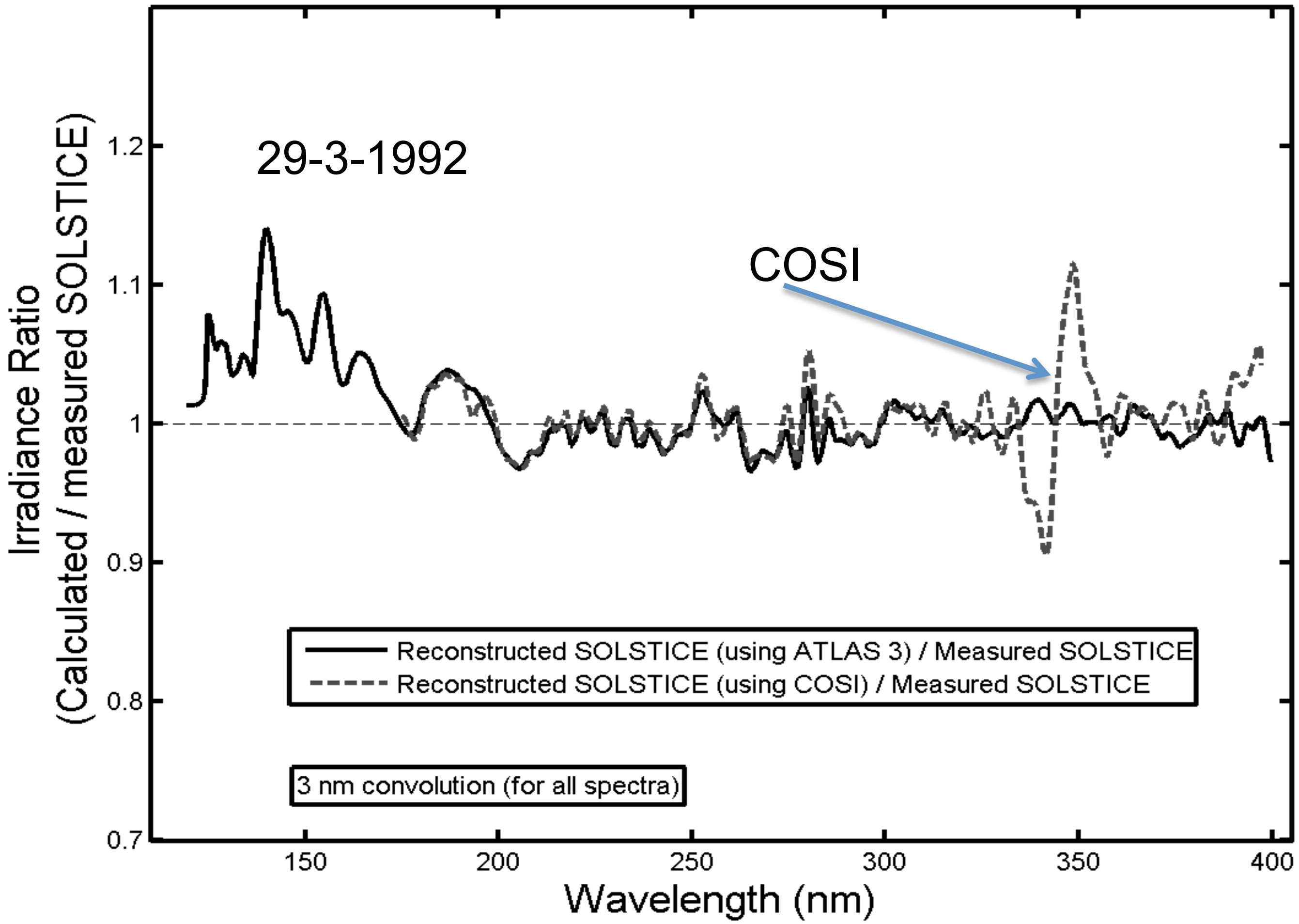


Comparison between the 'WHI' spectrum
and the spectrum retrieved for 1st June 2008 from ATLAS 3
MgII Index: 0.26419 - 5 nm convolution



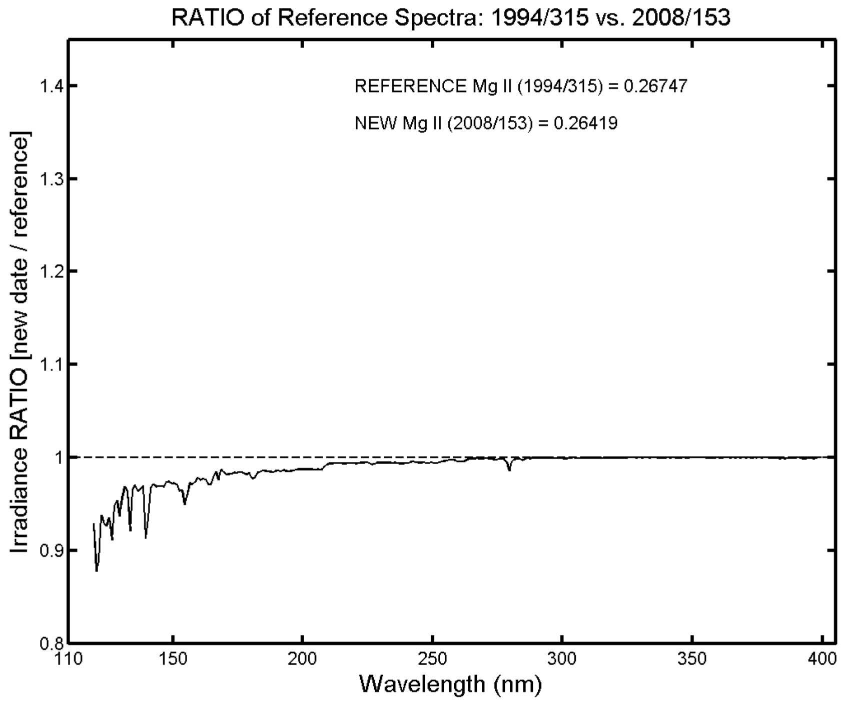
Ratio WHI/reconstruction. RMS above 150 nm is about 1%.

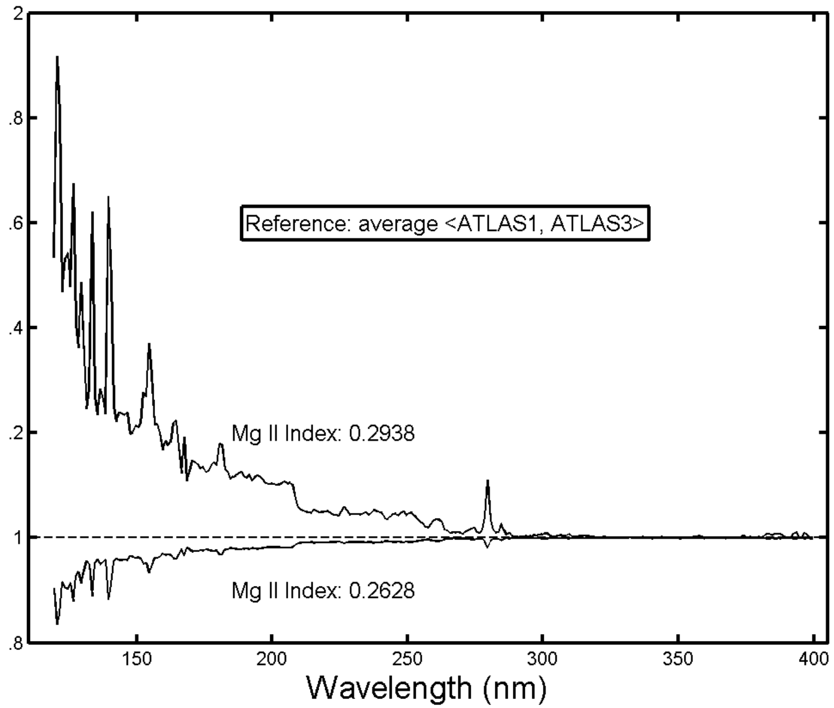
RECONSTRUCTION OF THE SOLSTICE-UARS SPECTRUM USING THE Mg II MODELING AND TWO DIFFERENT REFERENCE SPECTRA



The reference spectra are ATLAS 3 (Thuillier et al. 2004) and COSI (Shapiro et al., 2010). Except at 340 nm, the results are very close.

SOLAR VARIABILITY INFERED FROM Mg II MODELING





Ratio of the calculated spectrum at the minimum of solar activity between cycle 23 and 24 to ATLAS 3 using the Mg II modeling

Ratio between the calculated spectra for the minimum and maximum Mg II index with respect to the mean ATLAS 1 and 3 spectra used as reference.

RECONSTRUCTION PRECISION

	120-150	150-200	200-250	250-300	300-350	350-400
Δ1 (ISS)	11.3	5.3	4.1	4.0	3.3	2.9
Δ2(SORCE)	3.7	5.7	8.0	7.9	4.9	0.9

Table 2: Mean difference [%] with respect to unity of the ratio between the reconstructed ISS and SIM and SOLSTICE onboard SORCE spectra from ATLAS 3 and the corresponding measurements.

	120-150	150-200	200-250	250-300	300)350	350-400
Δ(ATLAS 3)	3.7	3.6	1.3	1.0	0.5	0.7

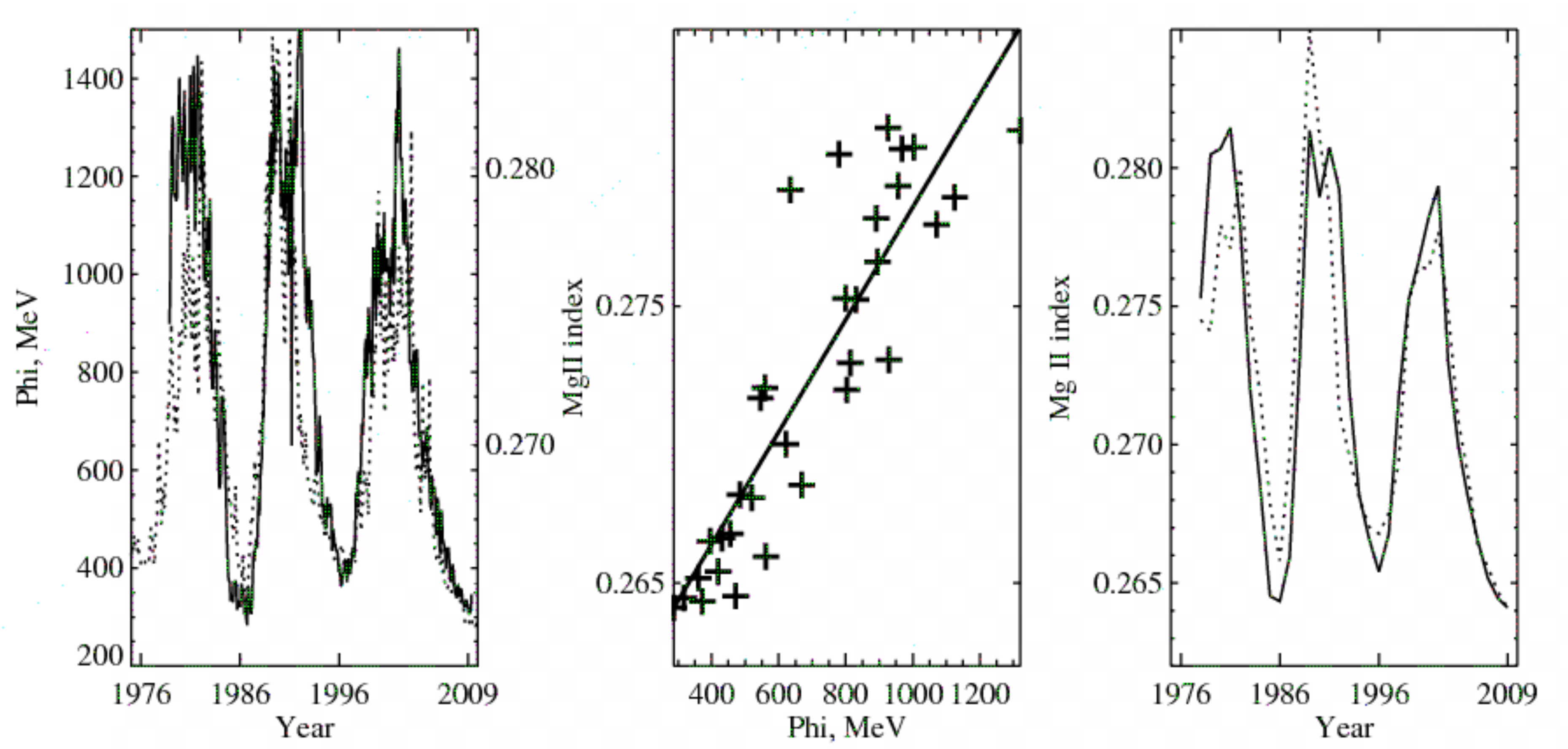
Table 3: Mean difference [Δ1] in %, with respect to unity, of the ratio between the reconstructed ATLAS 1 from ATLAS 3 using the Mg II index and the measured ATLAS 1

UV SOLAR VARIABILITY BETWEEN 2004 AND 2007

Authors	200-310 nm	310-500 nm
Lean (2000)	0.02	0.04
This work	0.05	0.024*
SORCE	0.16	0.11

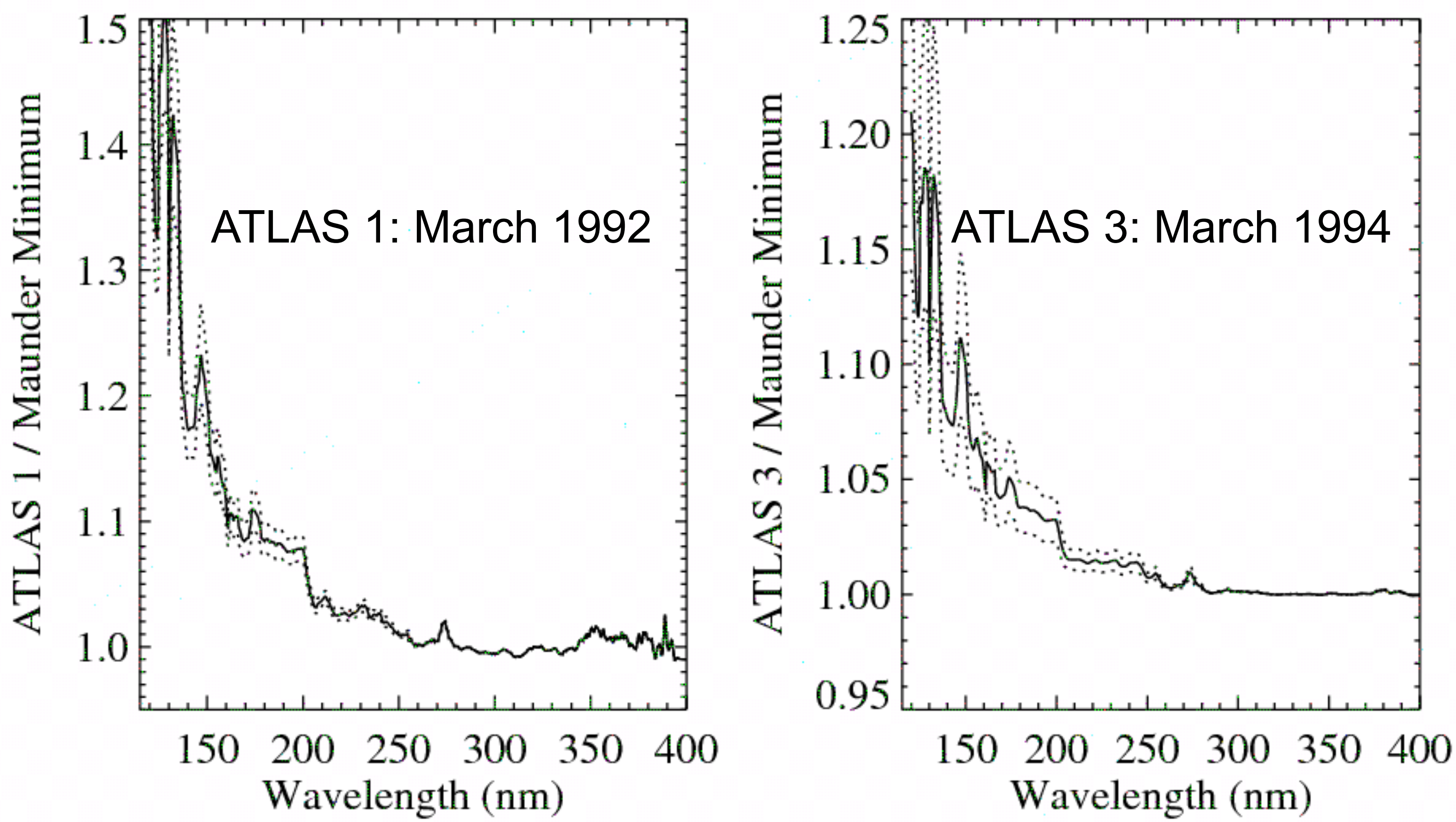
Table 1 For the time range April 2004 –November 2007, the irradiance [Wm−2] changes predicted by Lean's model, the present model using Mg II, and the solar spectral irradiance measured by SIM and SOLSTICE (Harder et al. 2009, 2010) onboard SORCE are shown. The data from line 2 are extracted from Table 1 of Haigh et al. (2010). The asterisk indicates that the calculation has been carried out only up to 410 nm.

Mg II INDEX AND NEUTRON MONITOR DATA OVER THE 1978-2010 TIME FRAME



a, (left panel) shows the variation with time of the Mg II index (solid line) and the modulation potential (dotted line) data between 1978 and 2010. b, (central panel) shows the relationship between the yearly mean of the Mg II indices and neutron monitor data sets. The heavy straight line results from a linear fit between these two datasets. c, (right panel) shows the variations of the yearly mean values of the measured (solid line) and reconstructed from modulation potential (dotted line) Mg II index.

SPECTAL VARIATION BETWEEN THE MAUNDER MINIMUM AND THE ATLAS 1 AND 3 SPECTRA



The Maunder minimum is defined by the maximum of the ^{10}Be concentration. It occurs in 1706 and is different from the minimum of the sunspot number.

Ratios of the ATLAS 1 and 3 spectra to the Maunder minimum spectrum. The dotted lines indicate the uncertainty of our approach. For that period, the Ly a line intensity has decreased of 20% with respect to its value in March 1994 (close to minimum of cycle 22-23 transition).

Mg II AND NEUTRON MONITOR DATA FOR PAST PERIODS MODELING

Authors	ΔSSI (Ly a-400 nm) (W/m2)
Lean(2000)	0.8
Krivova et al., 2010	0.5
Shapiro et al., 2010	4.1
This modeling	0.2

Comparison of different estimates of the SSI variation in the interval Ly α – 400 nm between the mean irradiance during Cycle 22 and the irradiance during the Maunder Minimum.

CONCLUSIONS

The reconstruction has an accuracy which depends on

- the chosen reference spectrum
- the accuracy of the Mg II data
- The accuracy of the scaling factors.

Above 150 nm, the mean RMS is about 4%. Precision degrades below 150 nm as likely due to the Mg II index not performing with effciency at short wavelength.

Variability inferred from Mg II index is closer to the one provided by the Lean (2000) model than by the SORCE-SIM measurements, which show larger variability.

The Mg II modeling associated to Neutron Monitor data has allowed to reconstruct the solar spectrum during the Maunder Minimum. As an example the Ly-α emission is 20 % lower than for ATLAS 3 period (close to minimum of cycle 22-23 transition).

The Mg II modeling has also been applied to minor constituents variability estimate. It is consistent with ozone measurements.

The SSI reconstruction will be use in the LMDz and CMAN models to estimate the variability of the minor constituents and compare with observations.

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