UV SSI variability in proxy models

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MPS

UV SSI solar cycle variability in measurements & models

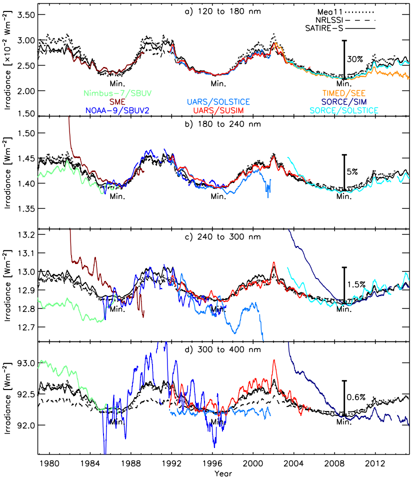


Figure 1 : Measured (colour) and reconstructed (black) UV SSI (Yeo et al. 2015).

Comparing...

- Measurements
- Morrill et al. 2011
  (fit Mg II index to SUSIM, Mea11)
- NRLSSI
- SATIRE-S

Agreement between the various records and reconstructions deteriorates with wavelength.

UV SSI solar cycle variability in measurements & models

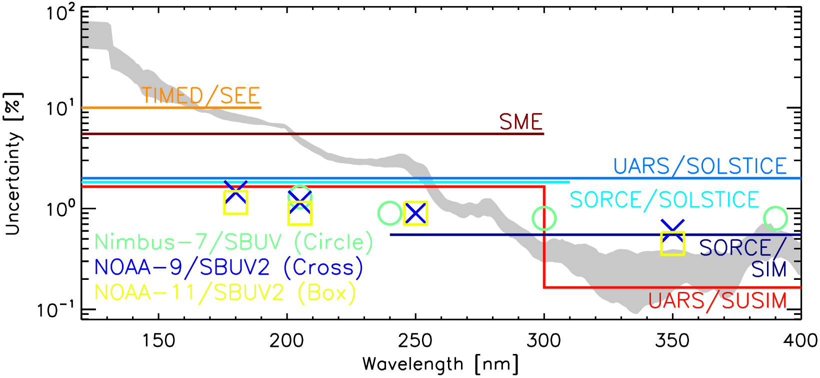


Figure 2 : Long-term uncertainty in measurements (colour) and solar cycle amplitude in models (grey) (Yeo et al. 2015).

Solar cycle variability weakens with wavelength. For certain instruments, solar cycle variability declines, towards longer wavelengths, below the limits of measurement stability.

UV SSI solar cycle variability in measurements & models

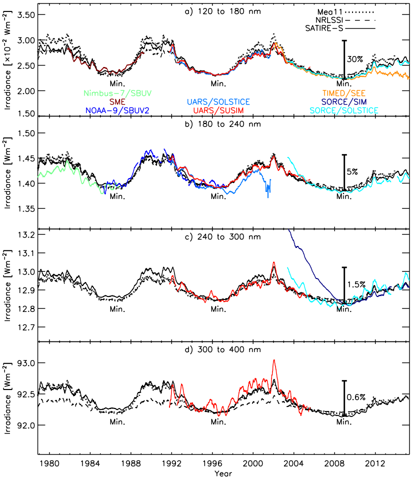


Figure 3 : Measured (colour) and reconstructed (black) UV SSI.

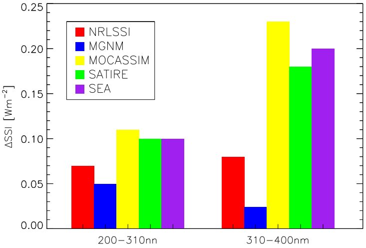
Excluding the measurements where solar cycle variability is obscured by the long-term uncertainty...

<300nm	Models fairly consistent with measurements and with one another.
>300nm	NRLSSI solar cycle amplitude weaker than Mea11, SATIRE-S & SUSIM.

UV SSI solar cycle variability in measurements & models

Data set	Spectral domains (nm)		
	200 – 310	310 – 400	400 – 650
MGNM	0.05	0.024	NA
MOCASSIM	0.11	0.23	NA
NRLSSI	0.07	0.08	0.20
SATIRE	0.10	0.18	0.22
SEA	0.10	0.20	0.14
SORCE	0.16	0.53	– 0.59

Figure 4 : ΔSSI between 04/2004 and 11/2007 in various models and SIM measurements (Thuillier et al. 2014).



Looking at models other than Mea11, NRLSSI & SATIRE-S...

- MOCASSIM (Bolduc et al. 2012) and SEA (Shapiro et al. 2011) reproduce similar UV SSI solar cycle variability as Mea11 & SATIRE-S.
- MGNM (Thuillier et al. 2012) takes the NRLSSI approach. Like NRLSSI, solar cycle variability is weaker than that from other models above 300 nm.
- The NRLSSI approach reproduces weaker UV SSI solar cycle variability than just about any other modelling approach.

UV SSI solar cycle variability in measurements & models

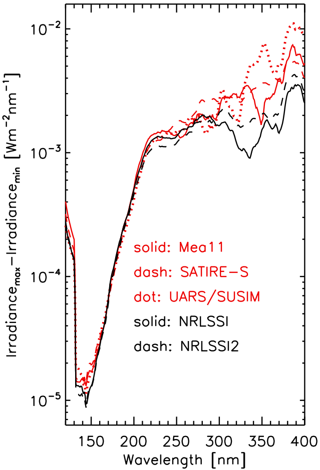


Figure 5 : Change in SSI between the 1996 minimum and 2000 maximum.

NRLSSI

Compare Mg II index & PSI to UARS/SOLSTICE SSI at rotational timescales.

NRLSSI2

Compare Mg II index & PSI to SORCE SSI at rotational timescales + corrections.

NRLSSI2 still weaker than Mea11, SATIRE-S and SUSIM above 300nm.

UV SSI solar cycle variability in measurements & models

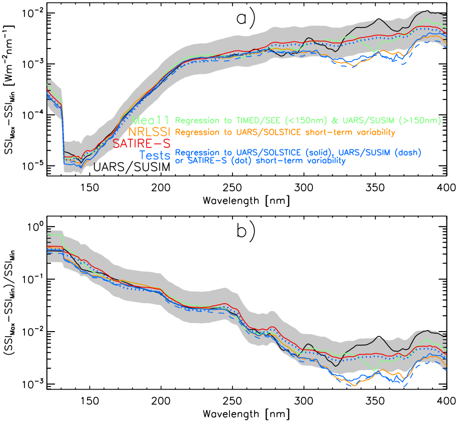


Figure 6 : a) Absolute and b) relative change in SSI between the 1996 minimum and 2000 maximum (Yeo et al. 2015).

Test reconstructions based on applying NRLSSI approach to UARS SSI (Yeo et al. 2015).

- Control: Test based on UARS/SOLSTICE (blue solid).
- Test based on SUSIM (blue dash), similar to NRLSSI, exhibit weaker solar cycle variability than SUSIM and other models above 300nm.
- SUSIM is stable enough to exhibit solar cycle variability above 300nm. Applying NRLSSI approach to SUSIM somehow does not reproduce the solar cycle variability indicated by this record here. Why?

Taking stock...

UV SSI solar cycle variability >300nm

- NRLSSI weaker than Mea11, SATIRE-S, MOCASSIM, SEA and SUSIM.
- MGNM, which applies the same approach, also weaker.
- NRLSSI2, which introduced certain corrections, still weaker.
- Applying NRLSSI approach to SUSIM cannot reproduce SUSIM variability.
- Weak UV SSI variability in NRLSSI. Is it real?

Weak UV SSI variability in NRLSSI - Could it be measurement error?

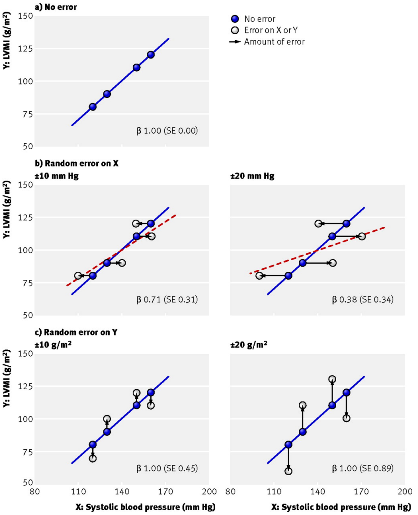


Figure 7 : Schematic of the effect of error on linear regression (Hutcheon 2010).

NRLSSI feature the ordinary least squares (OLS) fitting of the short-term variability in the Mg II index & PSI to the short-term variability in UV SSI records.

How does OLS respond to measurement error?

- Measurement error in the X variables (Mg II index & PSI) can bias the regression slope towards zero (systematic error).
- Measurement error in the Y variable (UV SSI) translate into statistical uncertainty in the regression slope.
- Measurement error can have an adverse effect on the result of OLS.

Weak UV SSI variability in NRLSSI - What if we take care of measurement error?

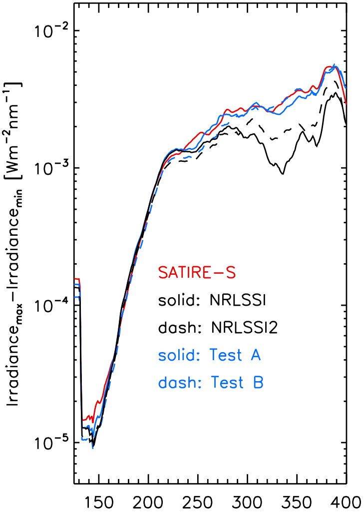


Figure 8 : Change in SSI between the 1996 minimum and 2000 maximum.

NRLSSI(2)

Fit Mg II index & PSI to UARS/SOLSTICE & SORCE SSI rotational variability.

Test A

Fit Mg II index & PSI to UARS & SORCE SSI rotational variability taking measurement noise into account (Orthogonal Distance Regression, ODR).

Test B

Fit Mg II index & PSI to UARS & SORCE SSI rotational variability denoised by averaging the data from multiple solar rotation periods.

If we take care of measurement error, solar cycle variability from the NRLSSI approach becomes closely similar to that in SATIRE-S.

Test A

Fit Mg II index & PSI to UARS & SORCE SSI rotational variability taking measurement noise into account by apply ODR instead of OLS regression.

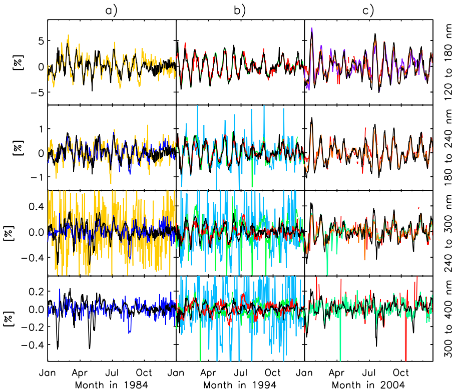


Figure 9 : Test A (black) & measured (coloured) UV SSI rotational variability.

Acid Test

Proxy modelled (i.e., Test A & NRLSSI) & measured rotational variability must match.

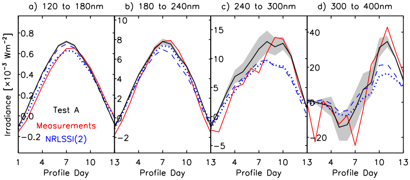


Figure 10 : Test A (black), NRLSSI(2) (blue dotted/dashed) and measured (red) UV SSI rotational variability (average of periods corresponding to active region transits).

EMPIRE

We asked...

NRLSSI approach - Is the weaker UV SSI variability real?

We showed...

If we take care of measurement error, either via ODR or denoising, solar cycle variability from the NRLSSI approach becomes closely similar to that in SATIRE-S.

EMPIRE (EMPirical Irradiance REconstruction, Yeo et al. submitted)

Proxy model of TSI & SSI based on NRLSSI approach, except measurement error is accounted for by applying ODR instead of OLS regression in the derivation of UV SSI variability.

	EMPIRE	NRLTSI/NRLSSI
TSI	Fit Mg II & PSI to TIM.	Fit Mg II & PSI to PMOD.
UV	Fit Mg II & PSI to UARS & SORCE rotational variability via ODR.	Fit Mg II & PSI to UARS/SOLSTICE rotational variability via OLS.
Visble & IR	Unruh et al. 1999 facular & sunspot intensity spectra (solution to radiative transfer equation).	Solanki & Unruh 1998 facular & sunspot intensity contrast (empirical model).

EMPIRE

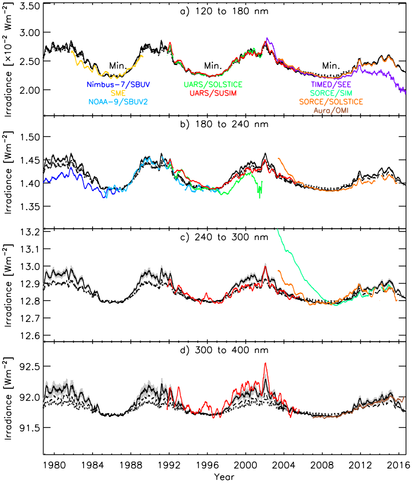


Figure 11 : EMPIRE (black solid), NRLSSI(2) (black dotted/dashed) and measured (coloured) UV SSI. SSI records where solar cycle variability is obscured by long-term uncertainty excluded (c.f. Yeo et al. 2015).

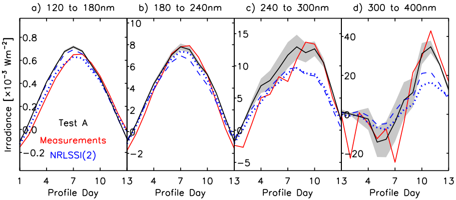


Figure 10 : EMPIRE (black solid), NRLSSI(2) (blue dotted/dashed) and measured (coloured) UV SSI rotational variability.

EMPIRE reproduces measured rotational & solar cycle variability. NRLSSI(2) rotational & solar cycle variability weaker >300nm. Weak variability in NRLSSI(2) is from the limitations of OLS regression, not because the Mg II index and PSI scale differently with solar irradiance at rotational and solar cycle timescales.