Facular brightening or sunspot darkening ? What the impulse response tells us

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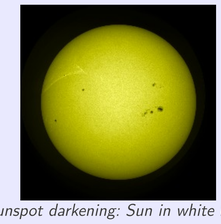
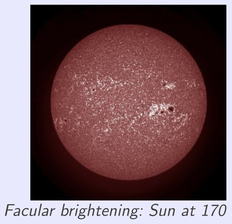
Facular brightening or sunspot darkening ?



Sunspot darkening: Sun in white light

or



Facular brightening: Sun at 170 nm

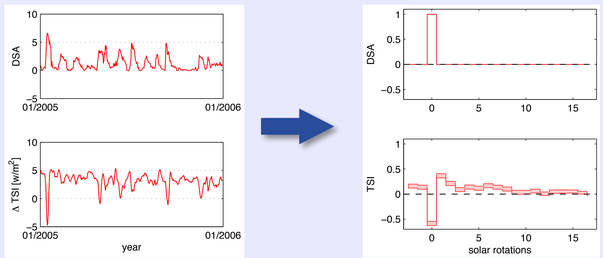
The response of the Solar Spectral Irradiance (SSI) to emerging sunspots is a mix of darkening by sunspots and brightening by faculae and network, both of which are time, and wavelength-dependent.

Which one prevails ? We answer this by estimating the impulse response of the SSI to emerging sunspots.

Impulse responses in a nutshell

The impulse response describes the reaction of the SSI to new sunspot that appears instantaneously and lasts for one solar rotation only = a condensed representation of the dynamical response of the SSI. We estimate the impulse response over several solar rotations by using a linear parametric model, with pre-whitening (better noise rejection than Fourier/ correlation methods).

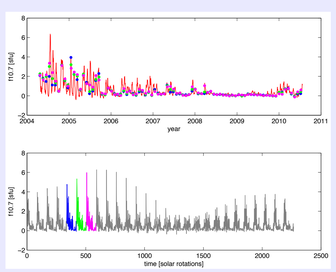
Example



Daily Sunspot Area (DSA) and concomitant response of the Total Solar Irradiance (TSI)

Estimated impulse response of the TSI to the DSA. Error bars represent ± 2 σ.

What is new ? Preminger and Walton [GRL 32 (2005)] were the first to estimate the impulse response of solar proxies but their results were convolved with projection effects. We use a more robust approach, and a 27-day cadence (stroboscopic view of the Sun) = **our results are not significantly affected by longitudinal projection effects**.



Snapshots are taken every 27 days (blue), thus giving a time series. This is appended by a second series of snapshots (green), taken one day later, etc. Finally we end up with as many observations as we had initially, but all with a 27-day cadence.

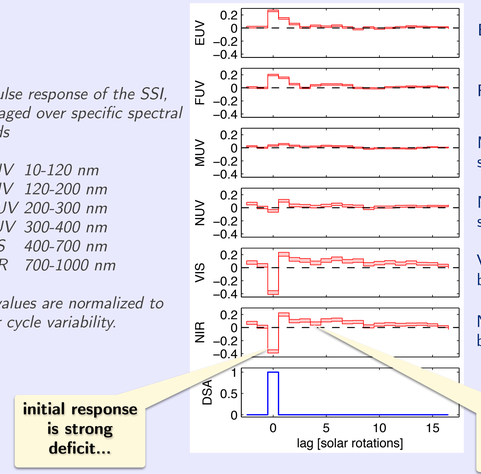
The impulse response of the spectral irradiance

We estimate the impulse response of the Solar Spectral Irradiance (SSI) using 6.5 years of observations from SORCE/SOLSTICE, SORCE/SIM and TIMED/SEE. The Daily Sunspot Area (DSA) is used as input, as in [Preminger and Walton, GRL, 2005].

Impulse response of the SSI, averaged over specific spectral bands

EUV 10-120 nm
FUV 120-200 nm
MUV 200-300 nm
NUV 300-400 nm
VIS 400-700 nm
NIR 700-1000 nm

All values are normalized to solar cycle variability.



EUV: sunspots lead to brightening

FUV: bright faculae prevail

MUV: competition between dark sunspots and bright faculae

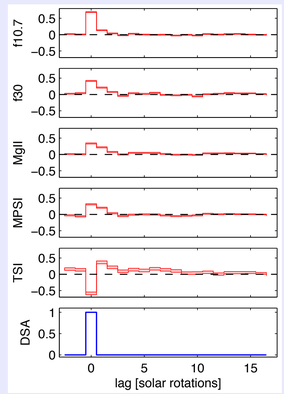
NUV: competition between dark sunspots and bright faculae

VIS: sunspot darkening followed by facular brightening

NIR: sunspot darkening followed by facular brightening

Impulse response of various solar proxies

f10.7 radio flux at 10.7 cm
f30 radio flux at 30 cm
MgII MgII index
MPSI Magnetic Plage Strength Index
TSI Total Solar Irradiance

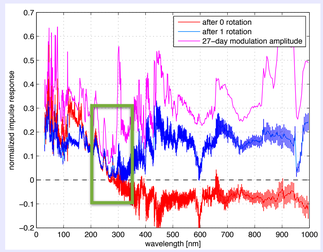


Conclusions

- New impulse response analysis of the SSI reveals the competition between brightness and darkening when a sunspot emerges, without longitudinal projection effects.
- Impulse response clearly reveals the inversion point (darkening = brightness). All wavelengths exhibit a nil to positive global irradiance budget.
- Work in progress: take into account solar cycle dependence (not so easy), correct for latitudinal projection effects, look for second inversion in the near-infrared range, and much more!

Brightening or darkening ?

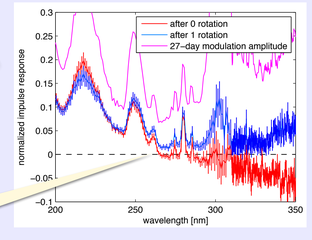
Now consider the instantaneous response versus wavelength, and the same response, one solar rotation later.



Instantaneous response reveals inversion point, where darkening starts prevailing over brightening (near 260 nm).

However, the picture is affected by instrumental artefacts: peaks at 220 and 250 nm, etc.

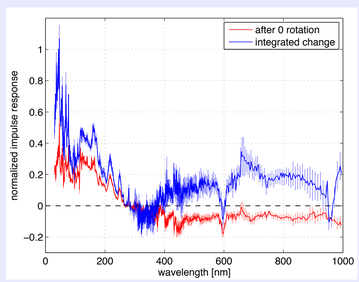
ZOOM



Impulse response: instantaneous (red) and one solar rotation later (blue). All values are normalized to the solar cycle amplitude.

Is there an excess or a deficit of irradiance ?

Key question: over time, does the brightening compensate for the initial darkening ? What is the global irradiance budget ? Our answer: integrate the impulse response over time, up to 8 solar rotations.



Integrated irradiance change (blue). If positive, there is a global excess of irradiance.

We find that

- **Almost all wavelengths now show an excess of irradiance**. Facular brightening thus exceeds the initial dip that is caused by sunspot darkening. Only the 300-400 nm range exhibits a nil / weakly negative irradiance budget.
- But... large error bars between 300 and 400 nm prevent us from investigating the fine structure of that range.

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