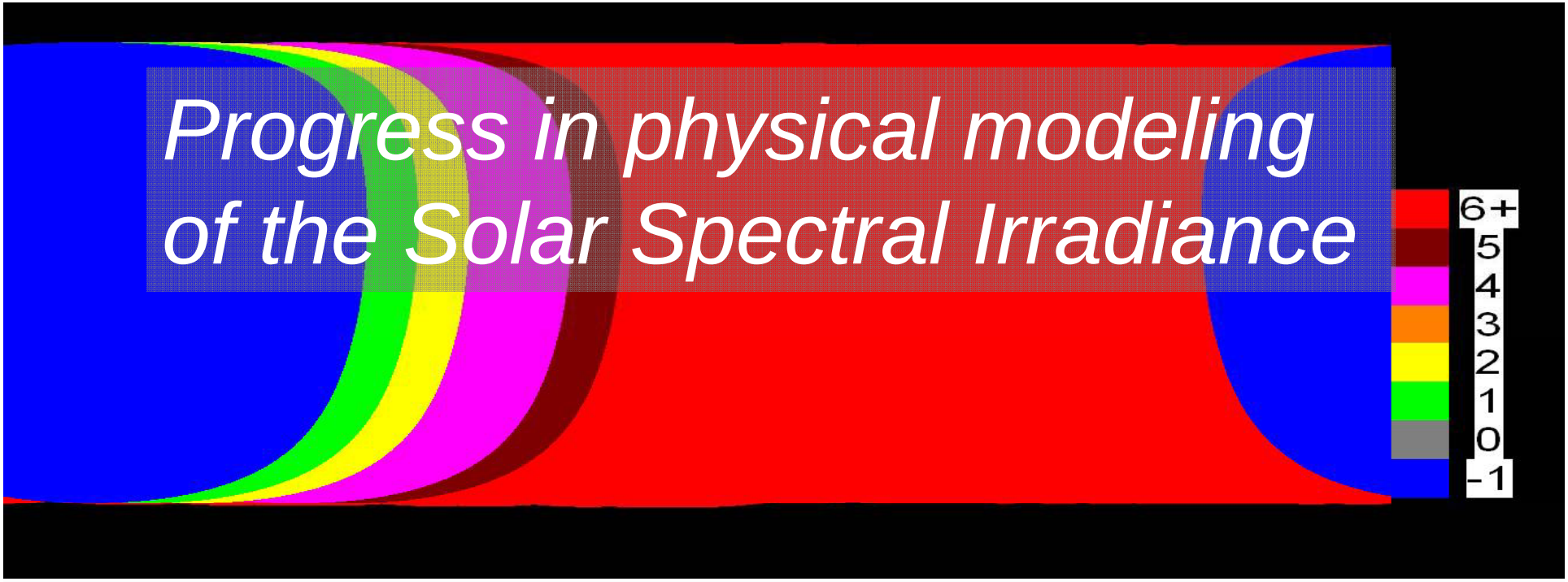
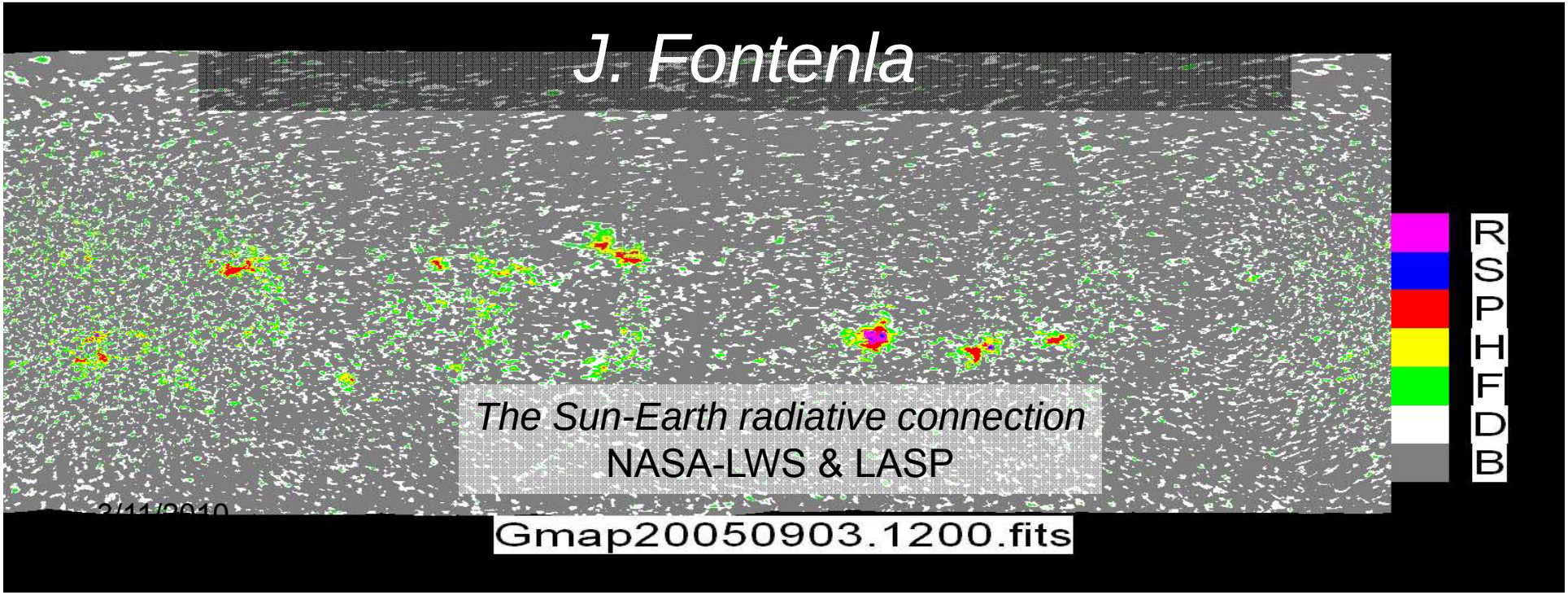
Progress in physical modeling of the Solar Spectral Irradiance



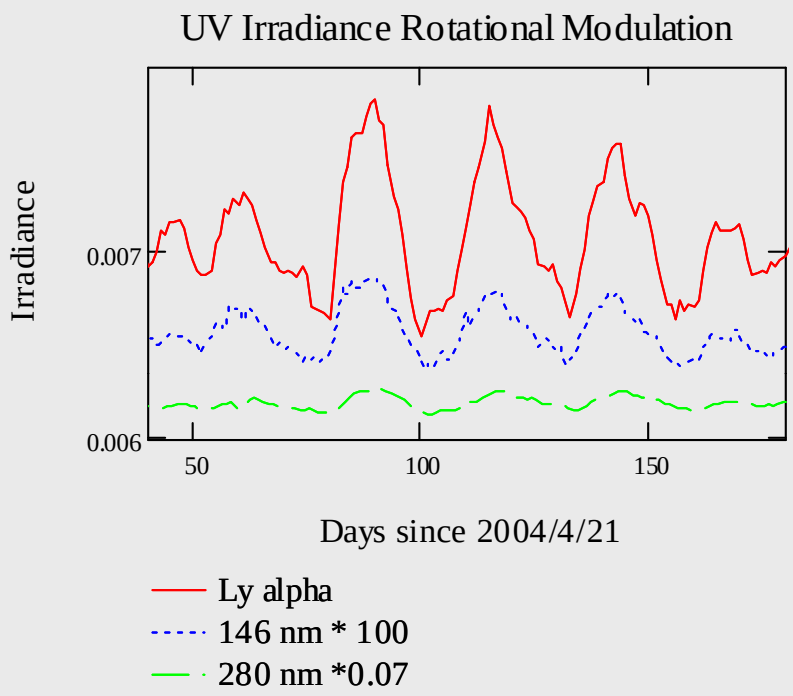
J. Fontenla

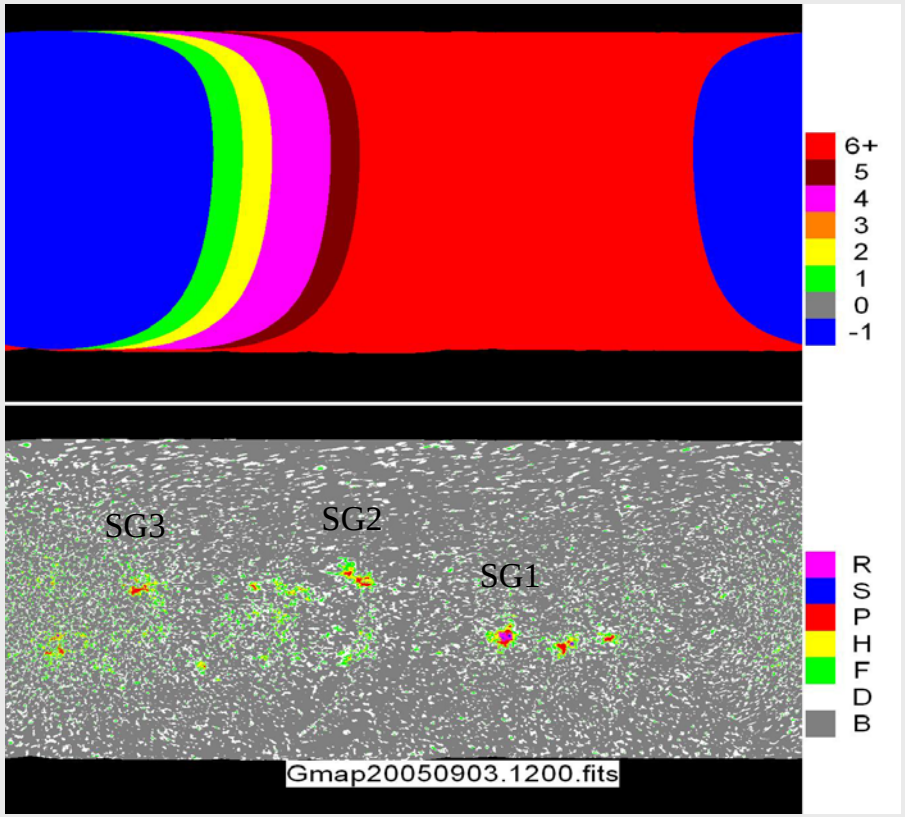


Physical Modeling of the Sun-Earth radiative connection

- Solar Radiation Physical Modeling (SRPM) is a physical modeling system for the solar spectrum radiance and irradiance.
- Medium resolution measured radiances and solar disk images at several wavelengths are currently used in concert with SRPM and with SSI measurements to understand Solar Spectral and Total Irradiance.

Solar Spectral Irradiance & Features



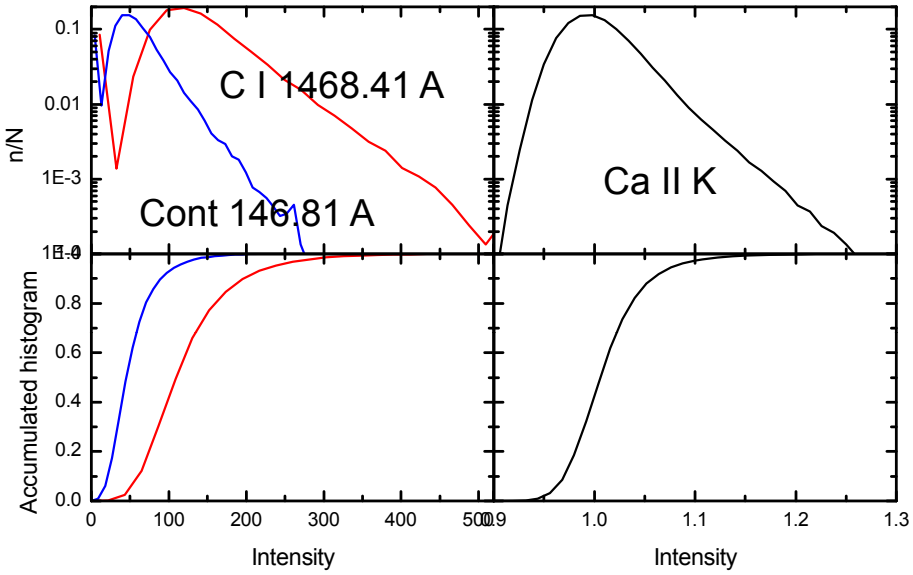


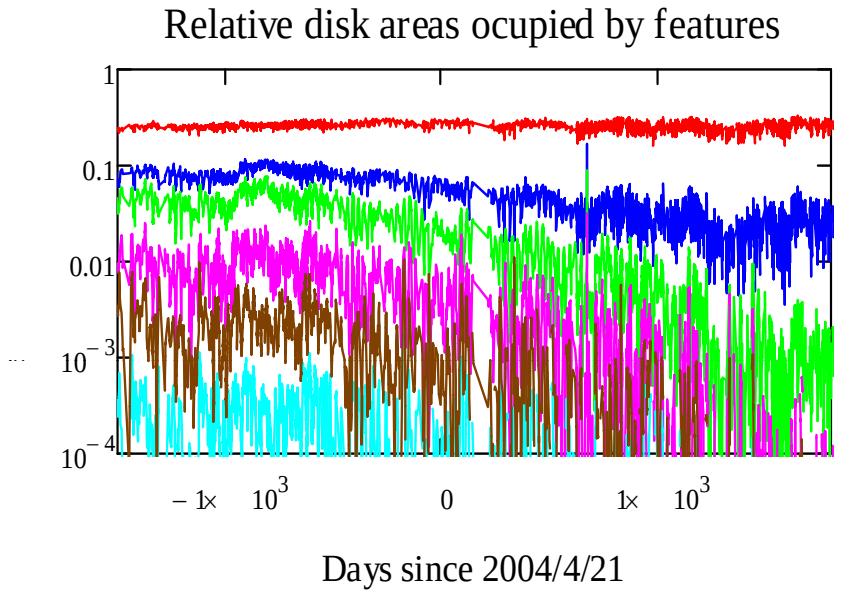
The passage of active regions (ARs) on the solar disk modulates the solar spectral irradiance (SSI).

SSI changes are also observed with the solar cycle time-scale.

All these changes affect the Earth radiative energy input.

Solar Activity Features Radiance





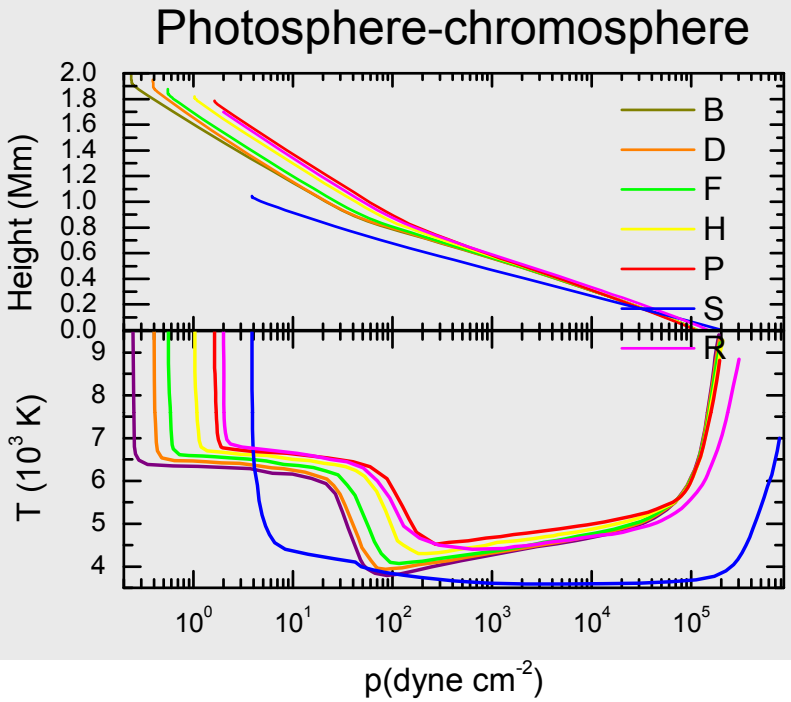
The surface features are related to magnetic fields but the magnetic effects and heating mechanism that are responsible for the observed radiances are not yet well understood.

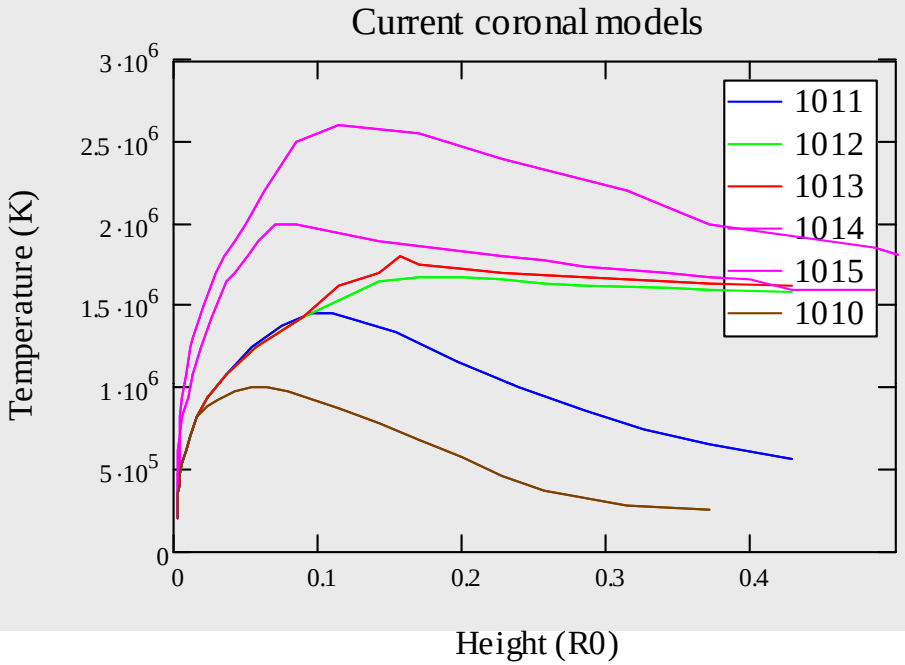
Features relative areas vary during the solar cycle. Not only of the active regions (AR) but also the pervasive “network”. Network varies through the cycle but less than ARs.

The slope of the intensity distribution increases at solar min and decreases at max but the peak of the distribution probably changes too.

“Contrast” images can never tell if the whole intensity distribution shifts, only absolute radiances can answer this.

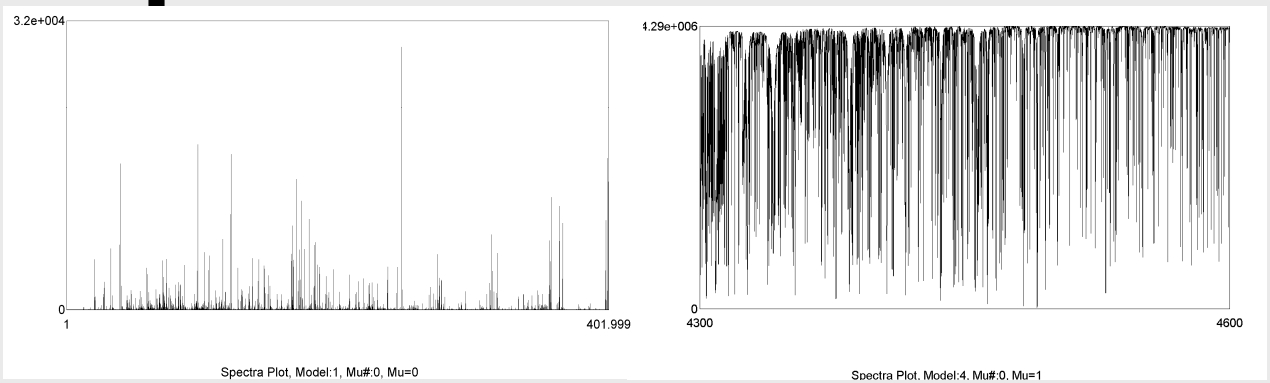
Solar Activity Features Models

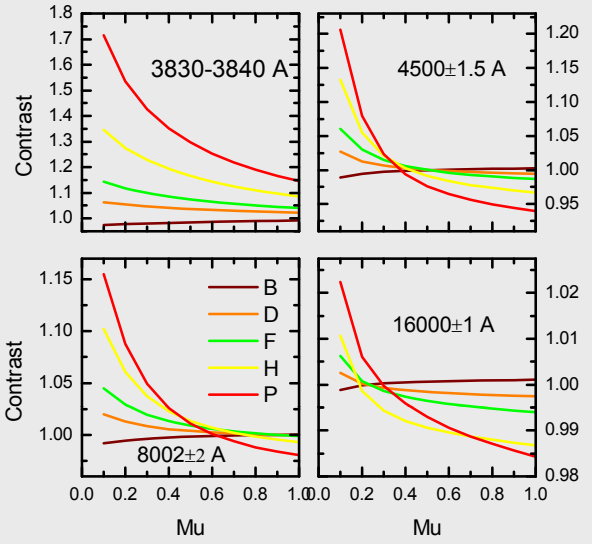


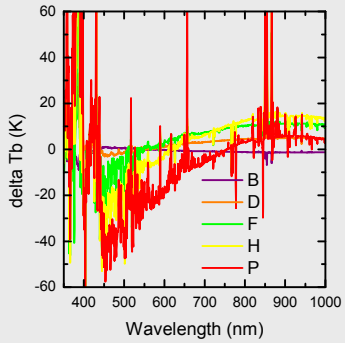


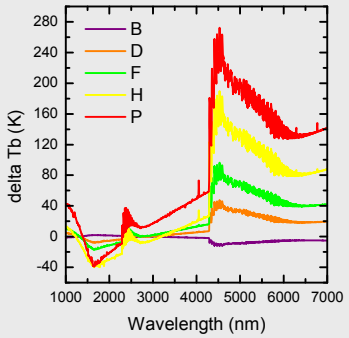
The current set of physical models are semi-empirical, 1D, steady, based on measured radiance and irradiance spectra.
The chromosphere-photosphere has been observed in great detail for a long time.
However, absolute observations of radiance are still lacking.
Coronal models are still in progress for active features data is spotty and incomplete.
SDO and EVE observations will help.

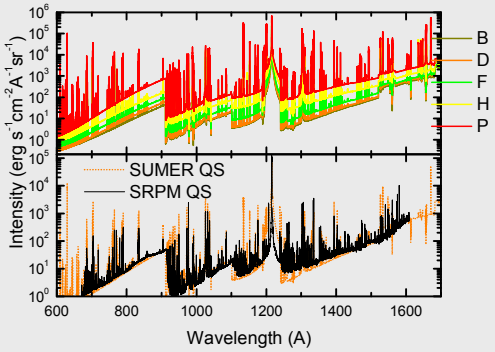
Spectral radiance calculations

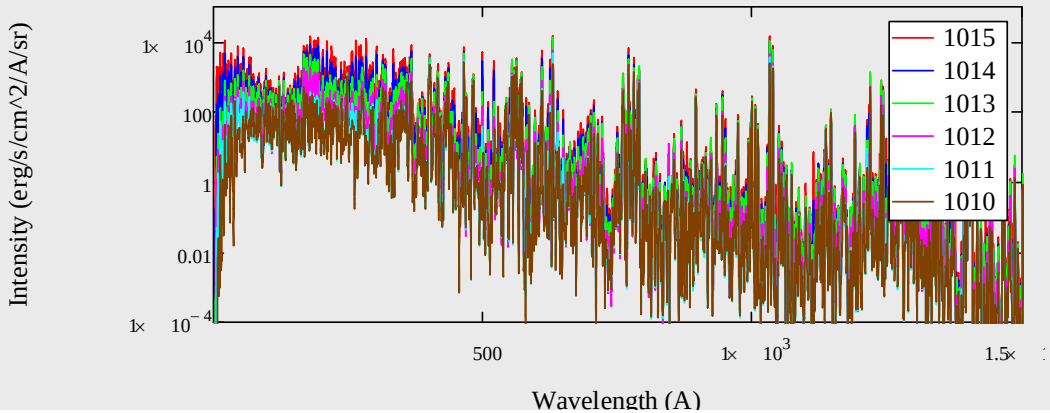






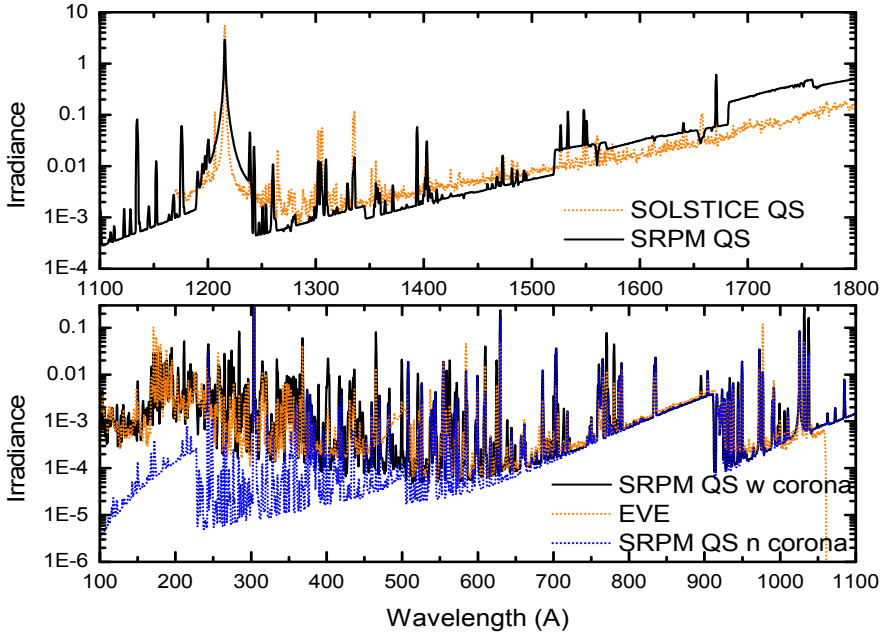


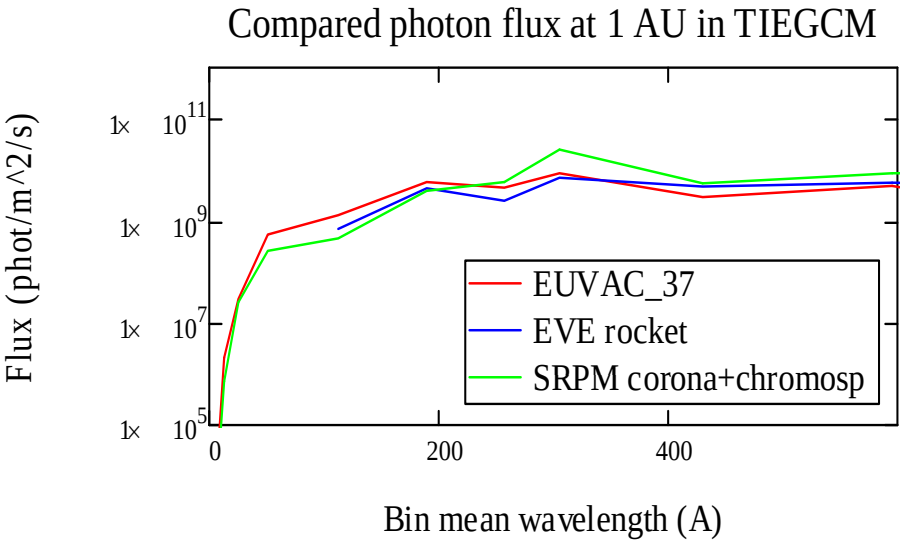


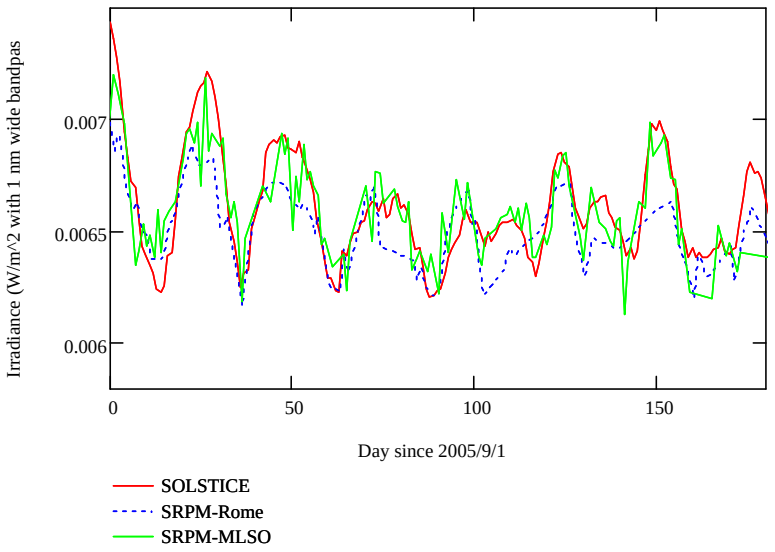


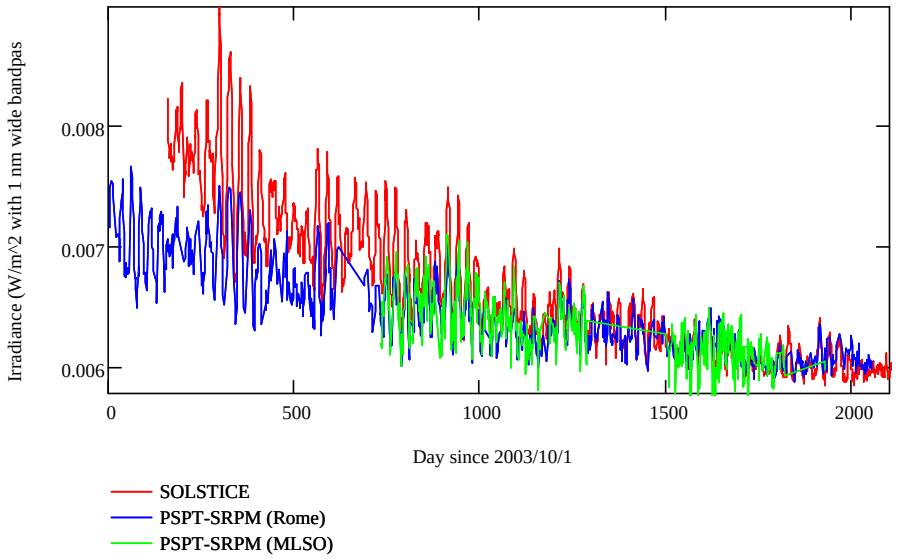
Throughout the entire spectrum (1 A to 100 μ), for each feature at 10 mu positions, all the atomic and molecular lines are resolved at 10^{-6}. Then smoothing at various instrument resolutions is done and binning for WACCAM.

Coronal & Chromospheric Irradiance

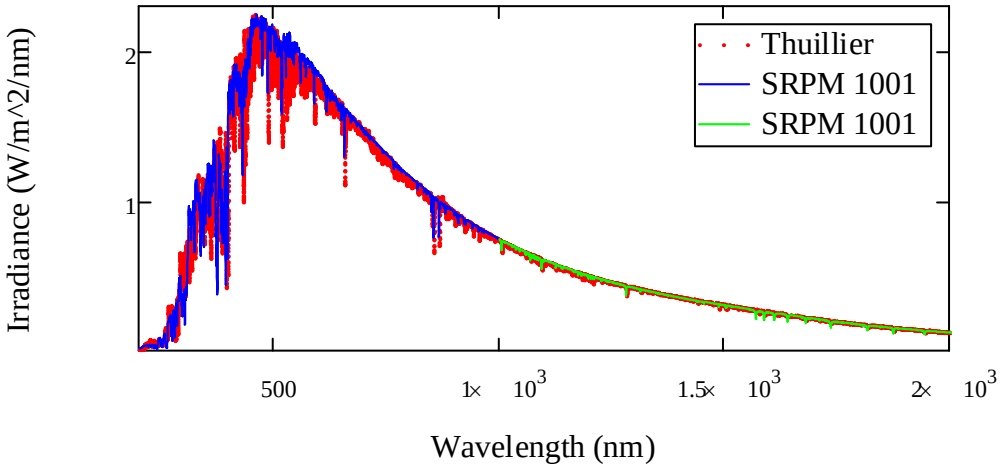


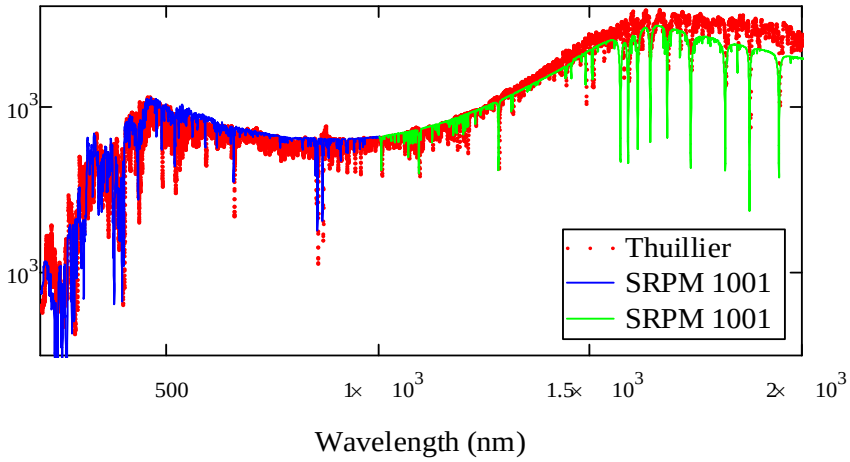






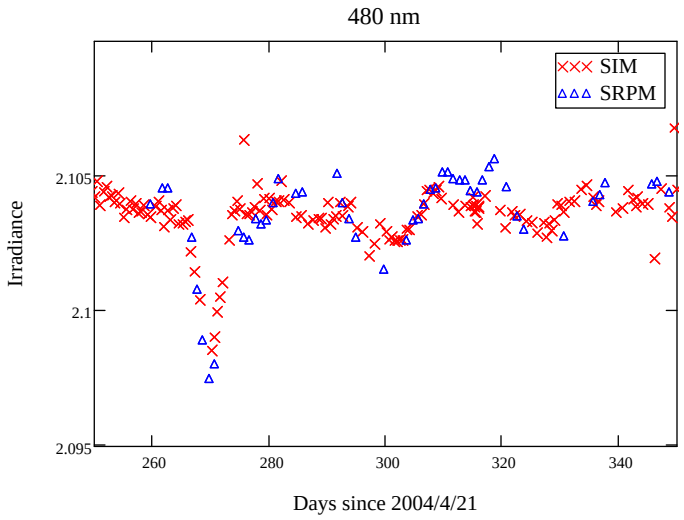
Photospheric & Chromospheric Irradiance

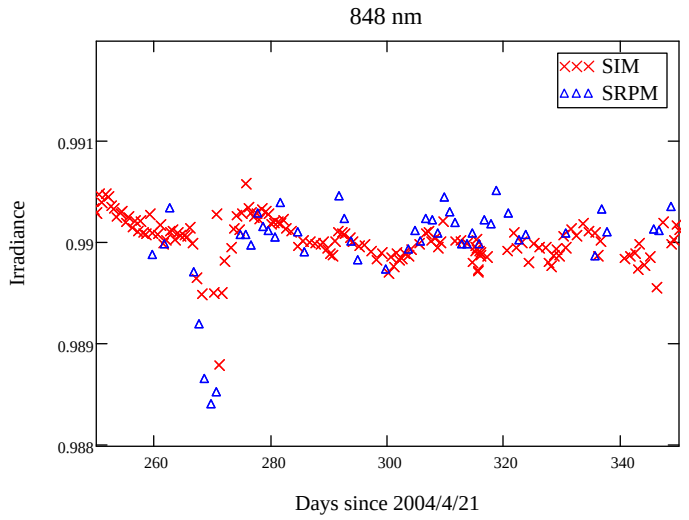




SRPM mostly matches the observed within ~2%, which is the observations accuracy. However, a less accurate match occurs in the near UV due to less certain atomic data

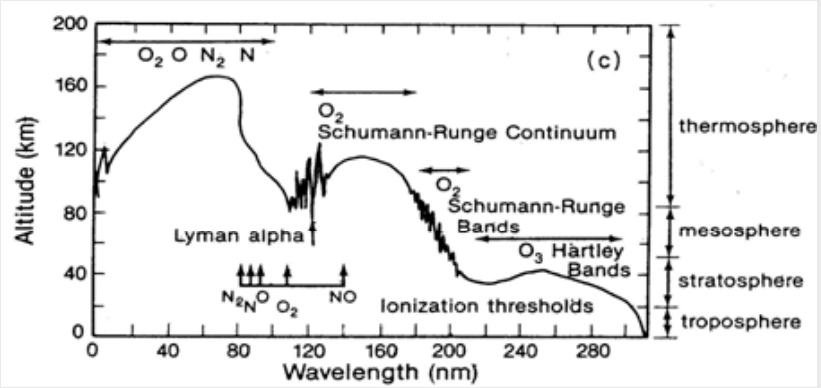
Computed short-term (rotational modulation) SSI variations also match the SORCE/SIM observations.





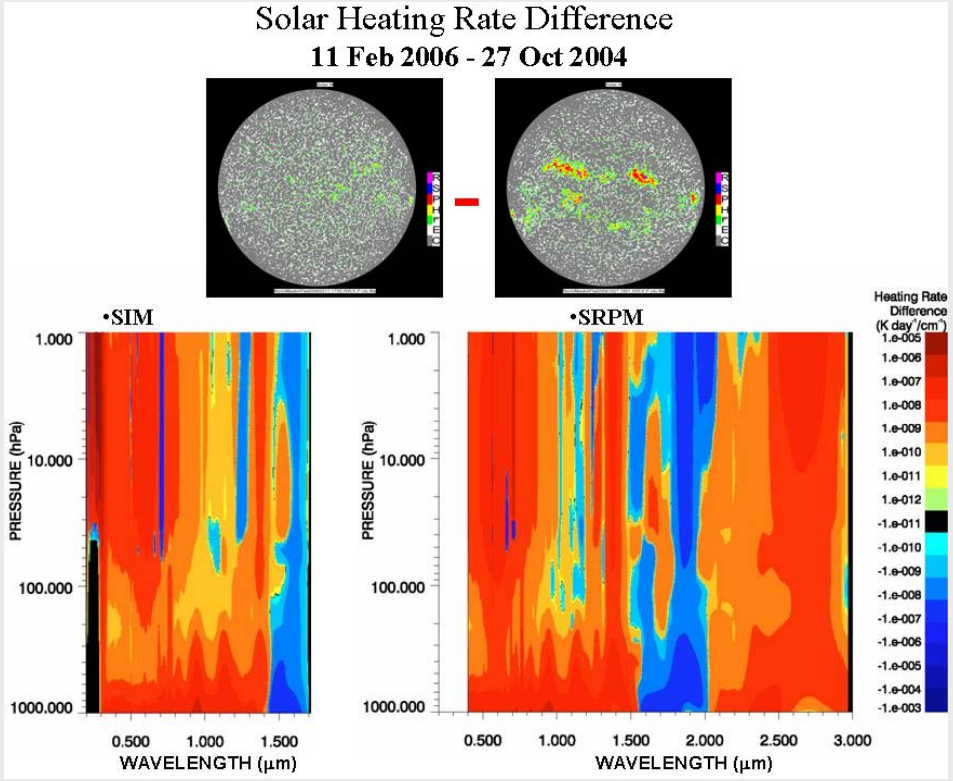
Effects on the Earth atmosphere (so far never well modeled)

Photo-ionization & photo-dissociation determine the upper-atmosphere temperature, chemical equilibrium, & ionization



Near-UV (200-300 nm) is very influential in Ozone heating, but also visible Chappuis bands are important. Ozone heating affects stratospheric temperature and maybe its dynamics.

Heating of the lower-atmosphere



Heating changes of atmosphere, land & ocean by visible & IR have small effects. But how important are these?

Visible, near-UV & IR long-term

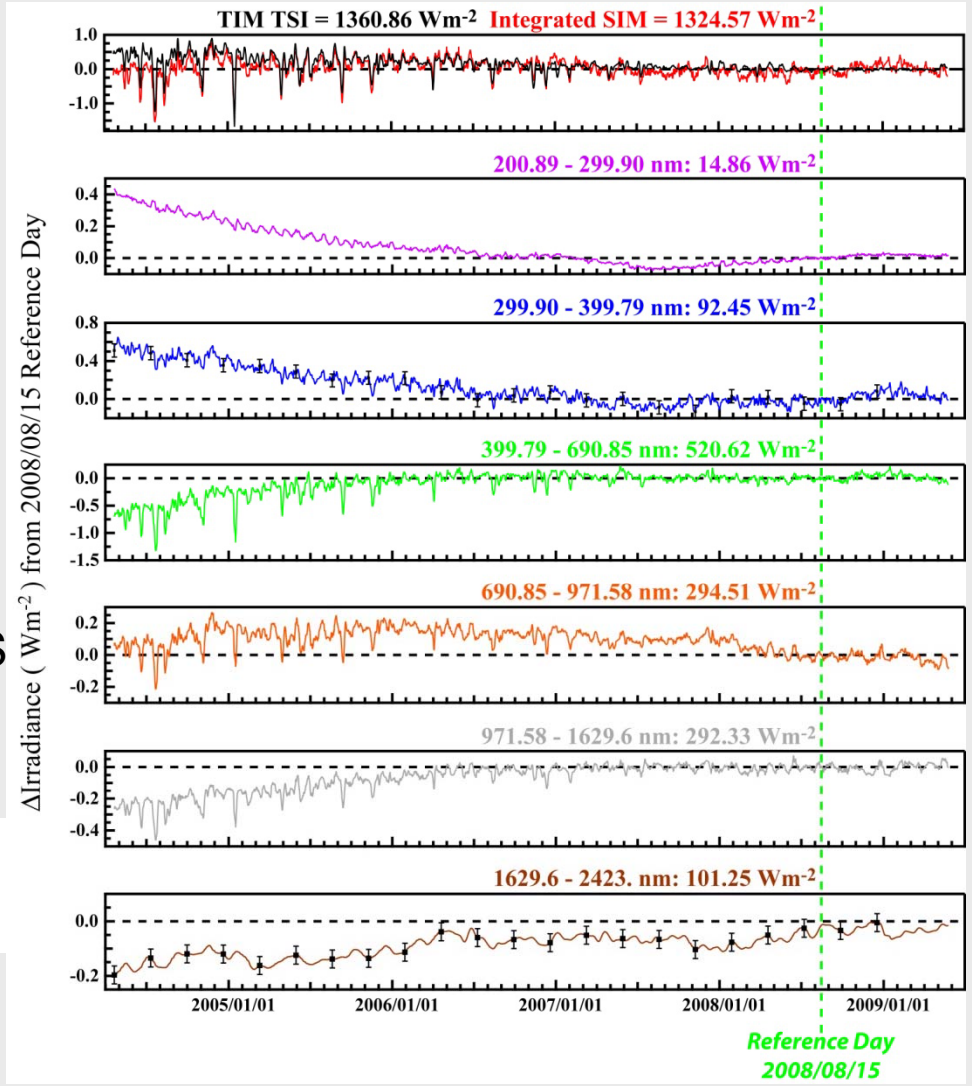
SIM integral matches TSI (but a small correction was applied to SIM at the early times for this integral to match better than a tenth of a percent).

Shown here are broad integrals over the regions of same sign variations.

The near UV shorter and λ<400 nm varies much more than the TSI.

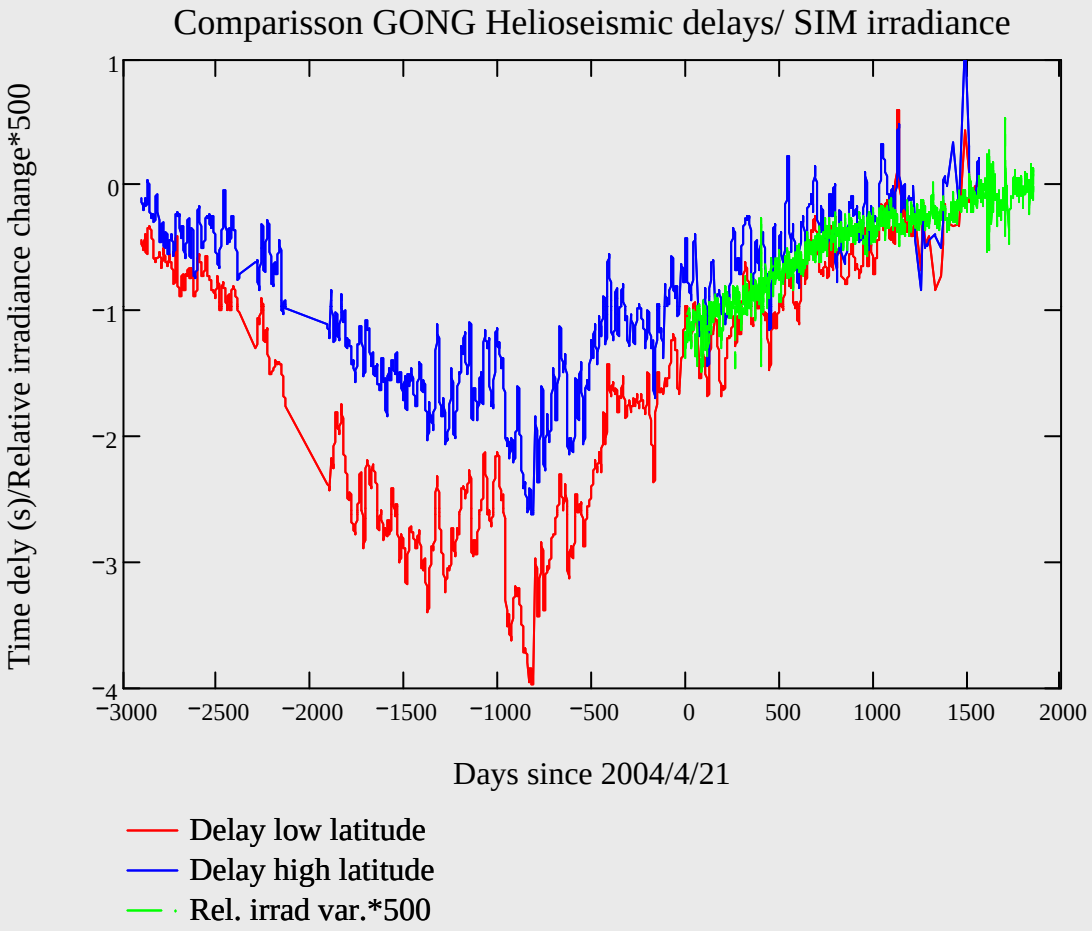
Most of the visible varies opposite to TS and UV. The same is true for the IR at λ>~1μm.

A small portion of the visible, 700<λ< 1μm varies much like the TSI.



Other indicators of global changes

Work By Gonzalez-Hernandez et al. (2009) shows that helioseismic signals travel slower or over less distance during high-activity periods. Here is shown that the behavior of the solar irradiance at 1.6 μm is very similar to that of these signals propagation. These irradiance variations correspond to a decrease in the brightness temperature of the deep photosphere of ~8 K. While the helioseismic waves propagation can be affected directly by magnetic fields, the irradiance signal is primarily affected by thermal effects and only indirectly by B effects.



NUV, VIS, IR long-term