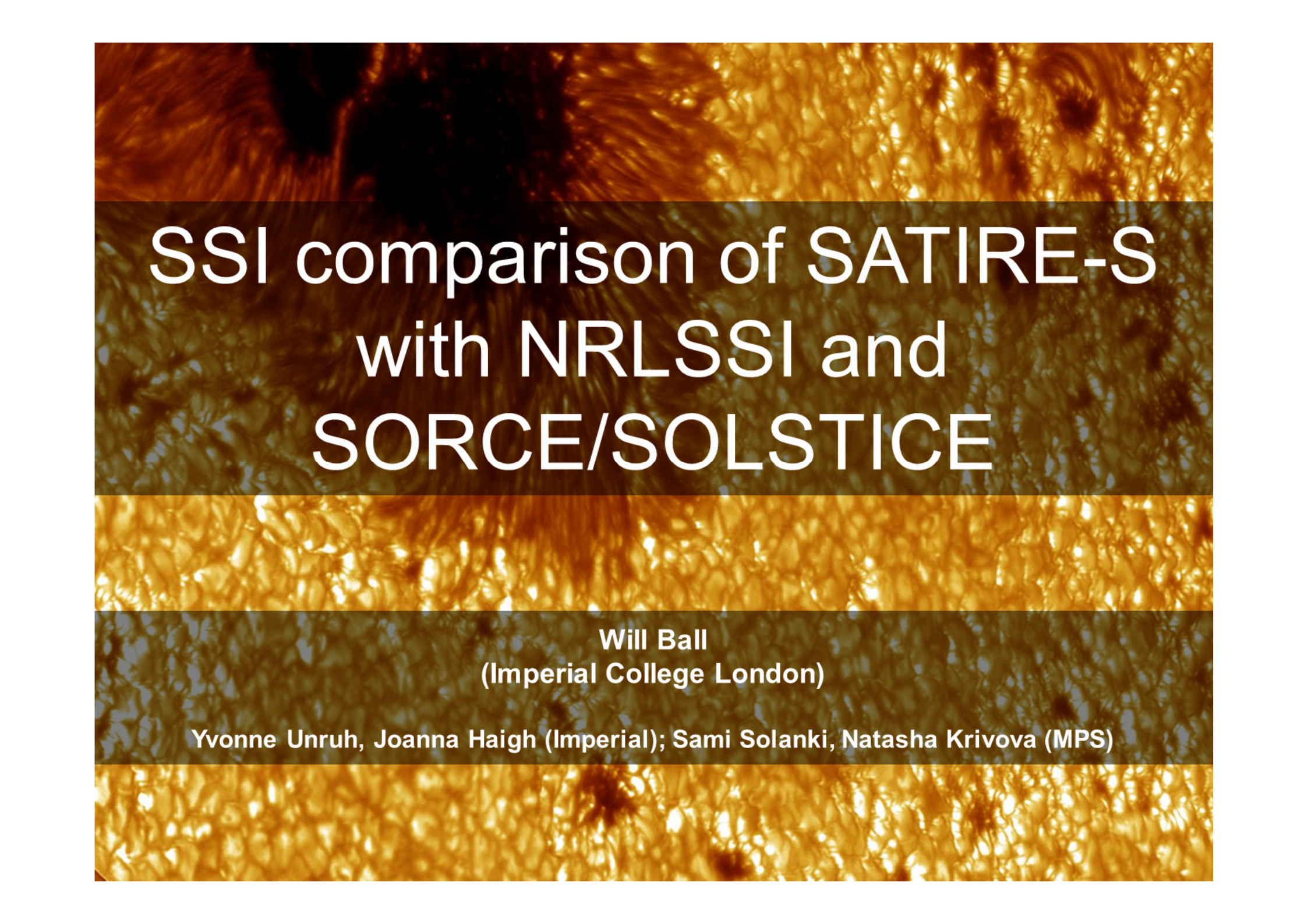




SSI comparison of SATIRE-S with NRLSSI and SORCE/SOLSTICE

Will Ball
(Imperial College London)

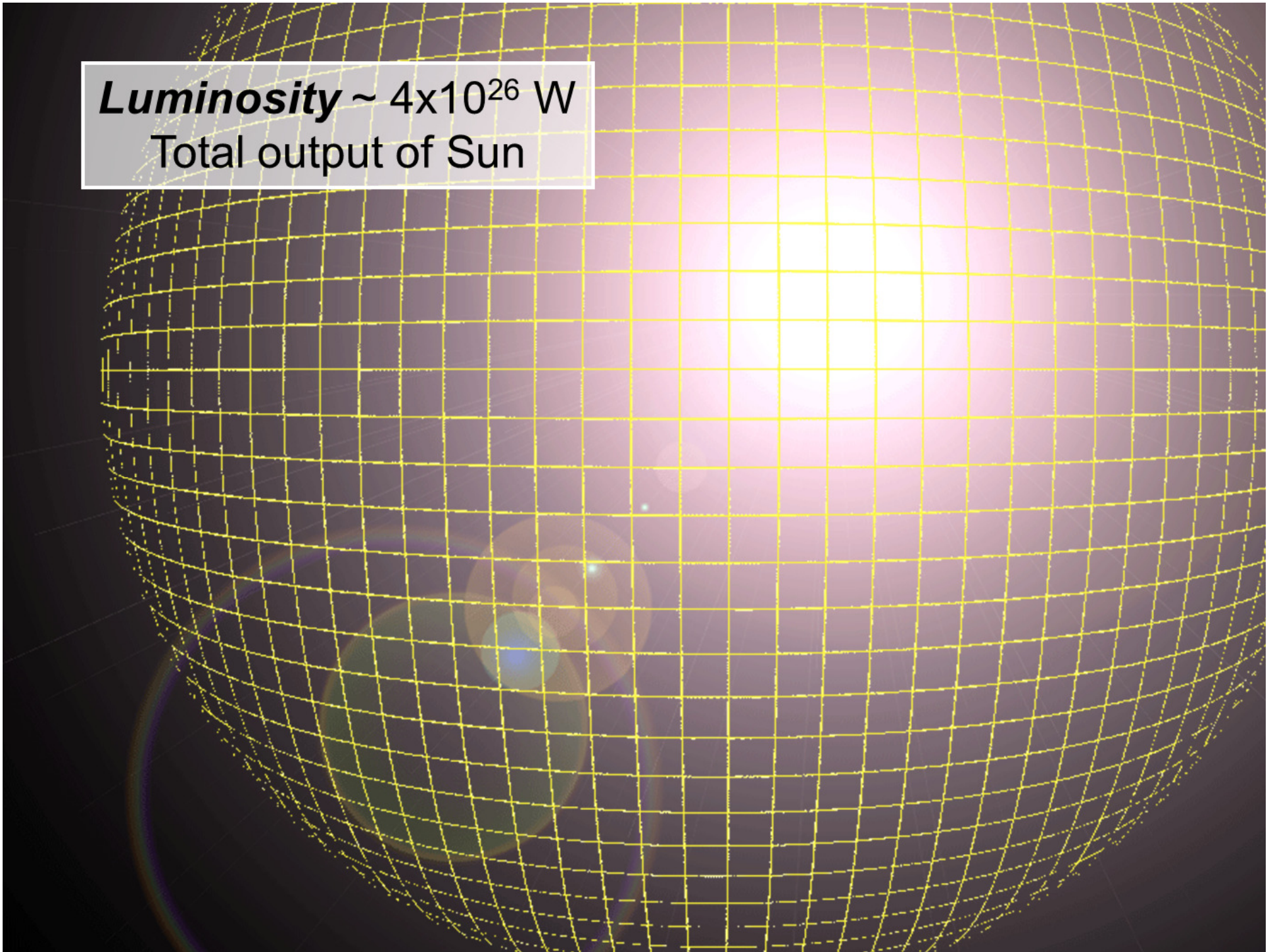
Yvonne Unruh, Joanna Haigh (Imperial); Sami Solanki, Natasha Krivova (MPS)

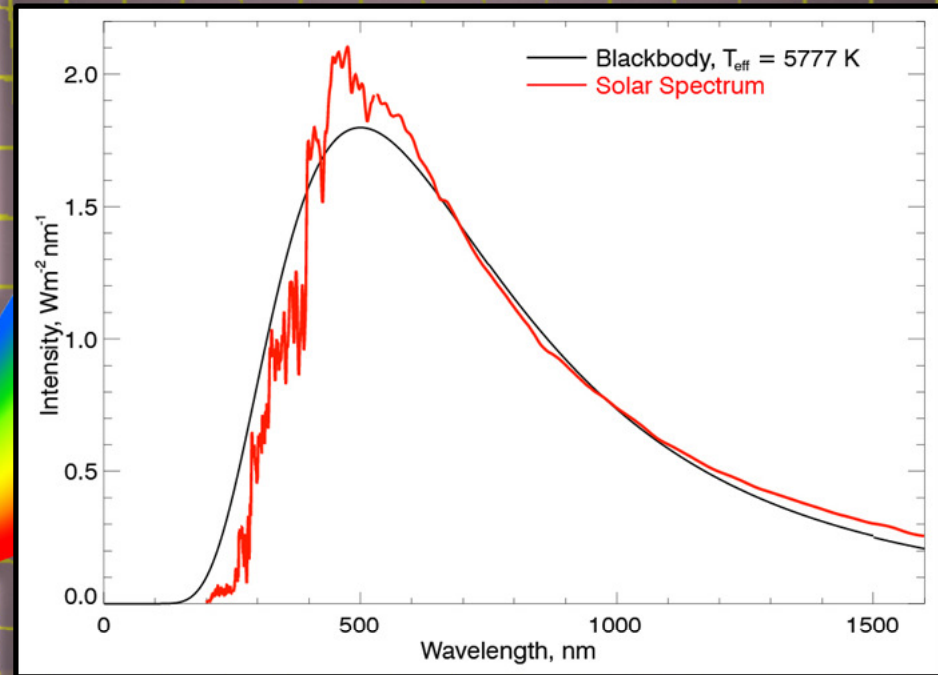


Outline

- **Motivation**
- **SATIRE-S Model**
- **NRLSSI and SORCE/SOLSTICE**
- **Spectral irradiance comparisons**
- **Impact on Stratospheric Ozone**
- **Summary**

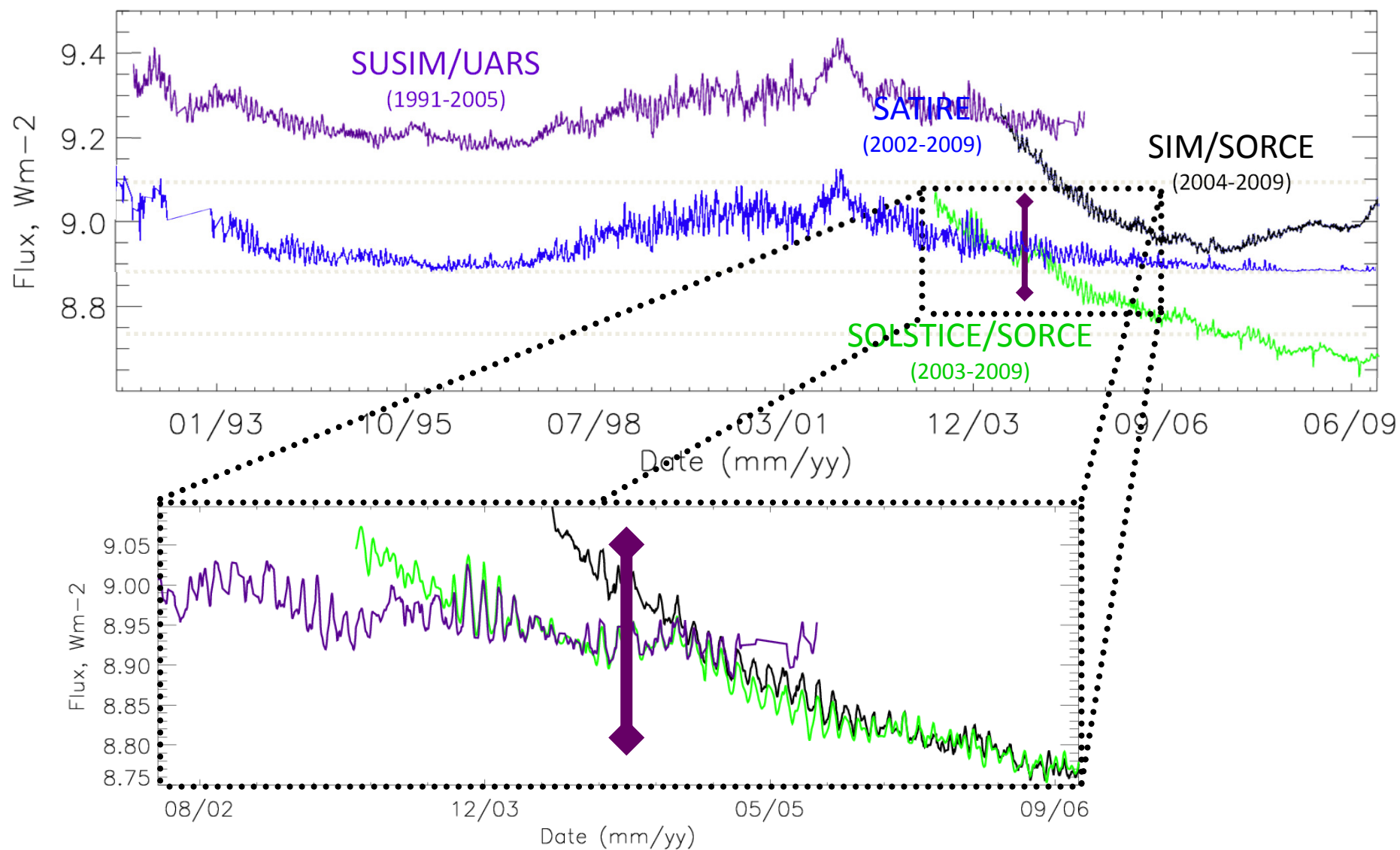
Luminosity $\sim 4 \times 10^{26}$ W
Total output of Sun





Solar Irradiance $\sim 1361 \text{ Wm}^{-2}$
Power passing 1m^2 at 1AU

Motivation



Motivation: SSI

SATIRE-S Model

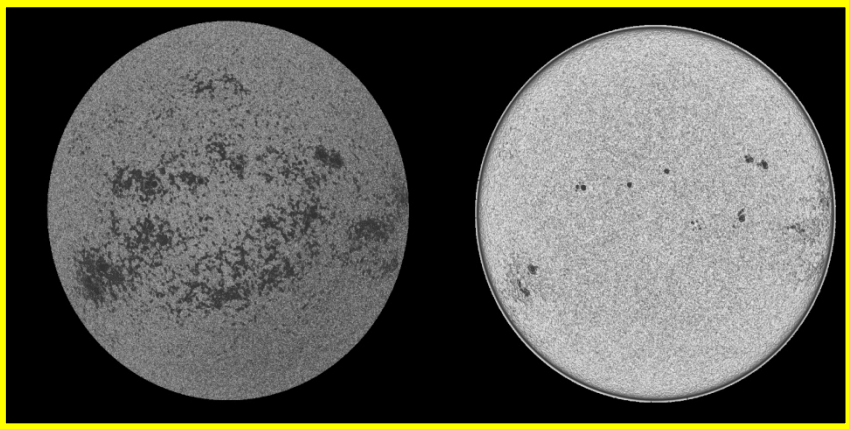
NSO / Kitt Peak
National Solar Observatory

Location: Kitt Peak, Arizona, USA
Active since: 1958
Instruments: Various; namely, SPM and '512' data

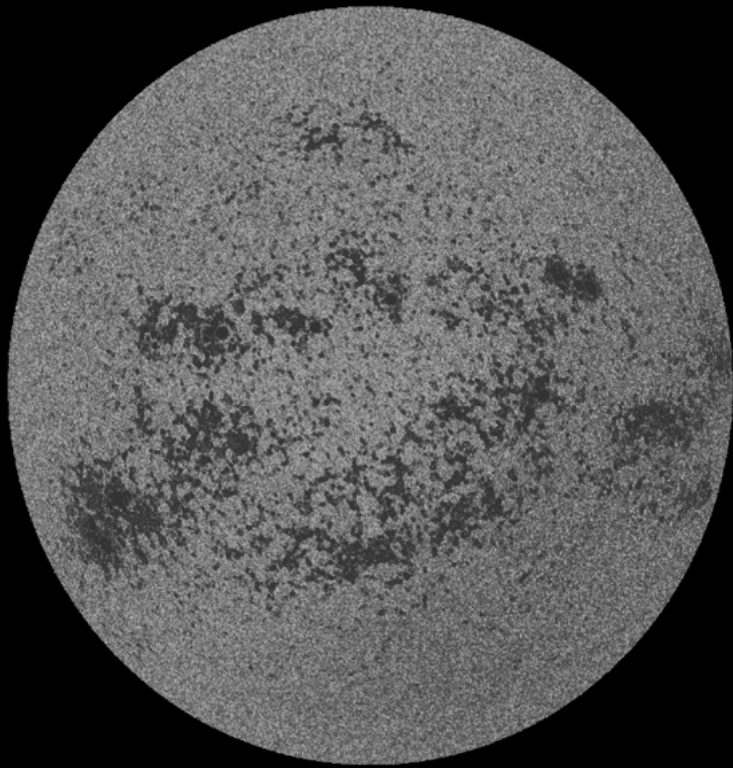
 **SoHO**
Solar and Heliospheric Observatory

Location: Earth-Sun L1
Active since: May 1996
Instruments: various, **MDI**

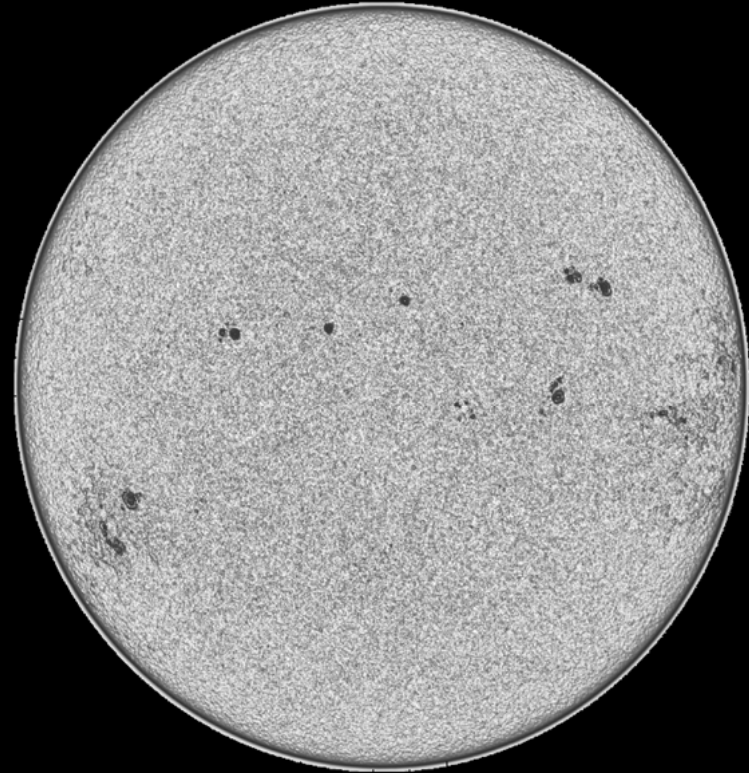
SATIRE-S Model



Magnetogram

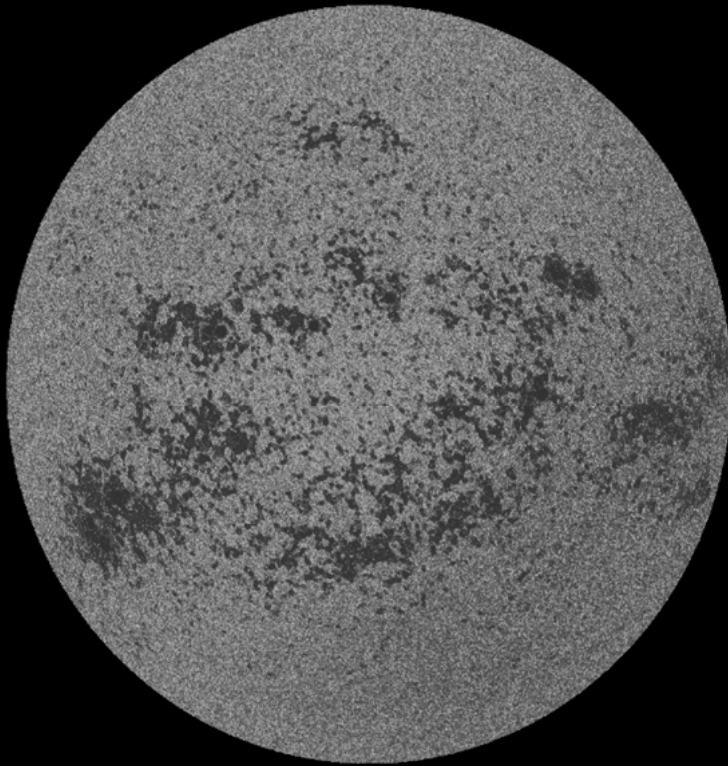


Continuum Image



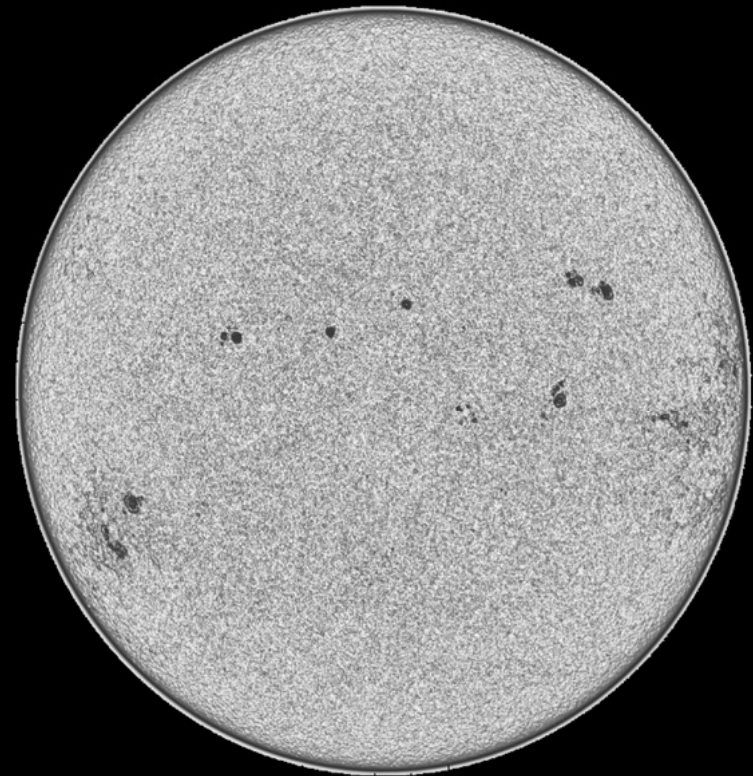
Magnetogram

Line-of-Sight Magnetic Field
Correction



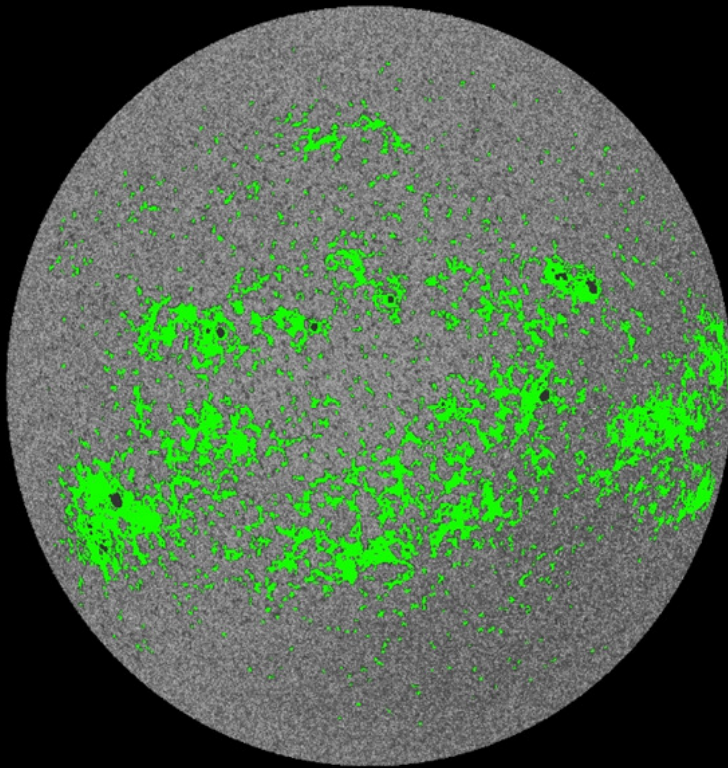
Continuum Image

Limb-darkening Correction



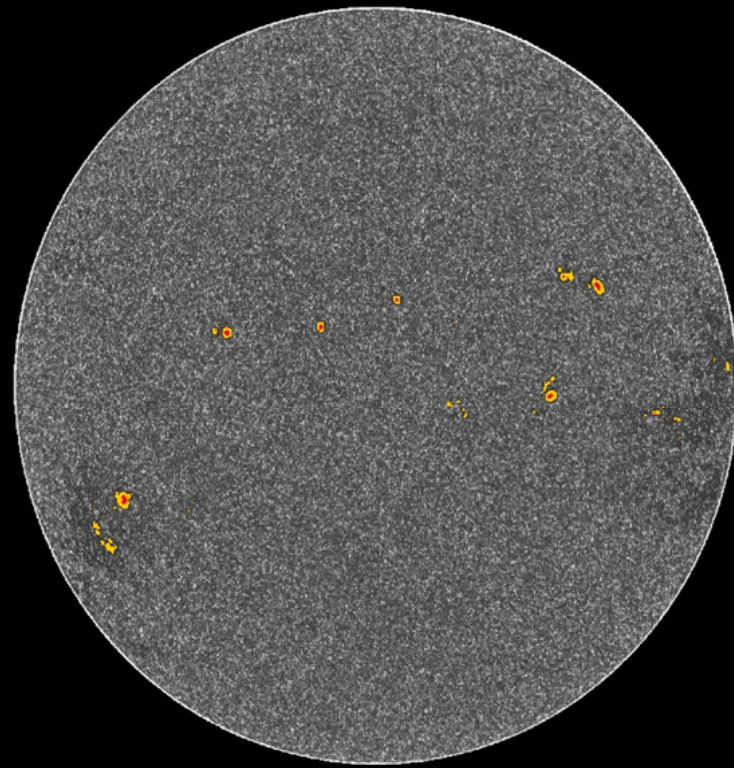
Magnetogram

Identify **Facular** Pixels



Continuum Image

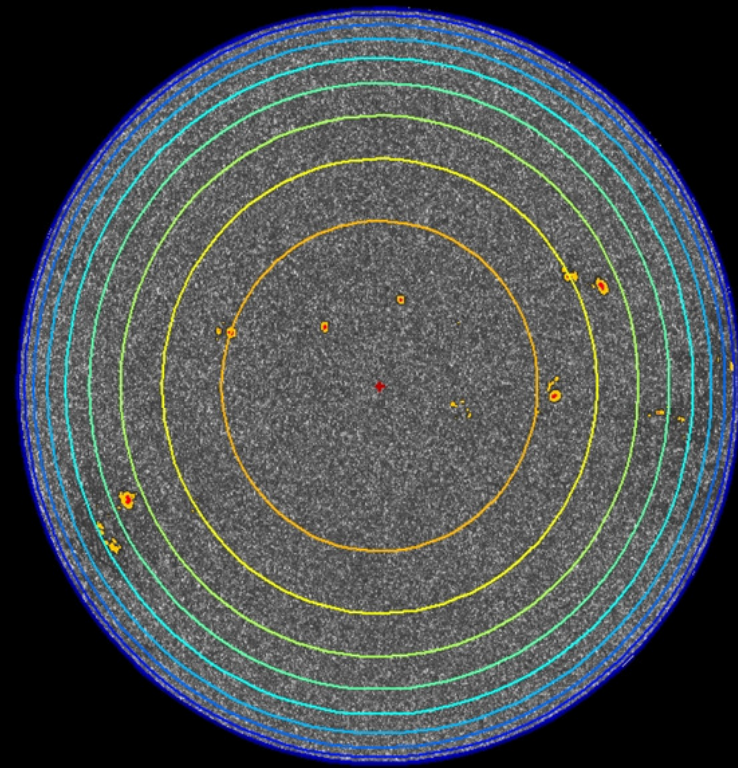
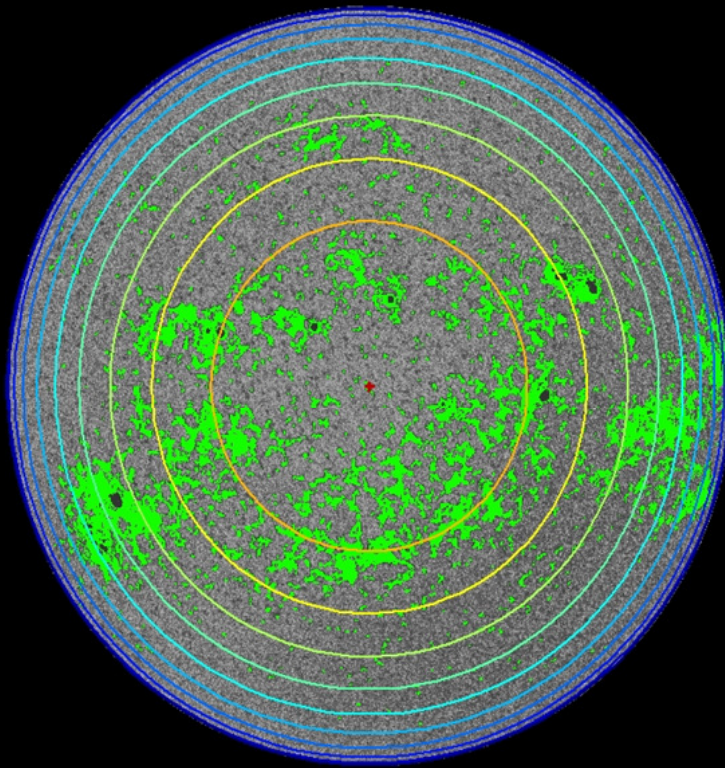
Identify **Umbral** and
Penumbral Pixels

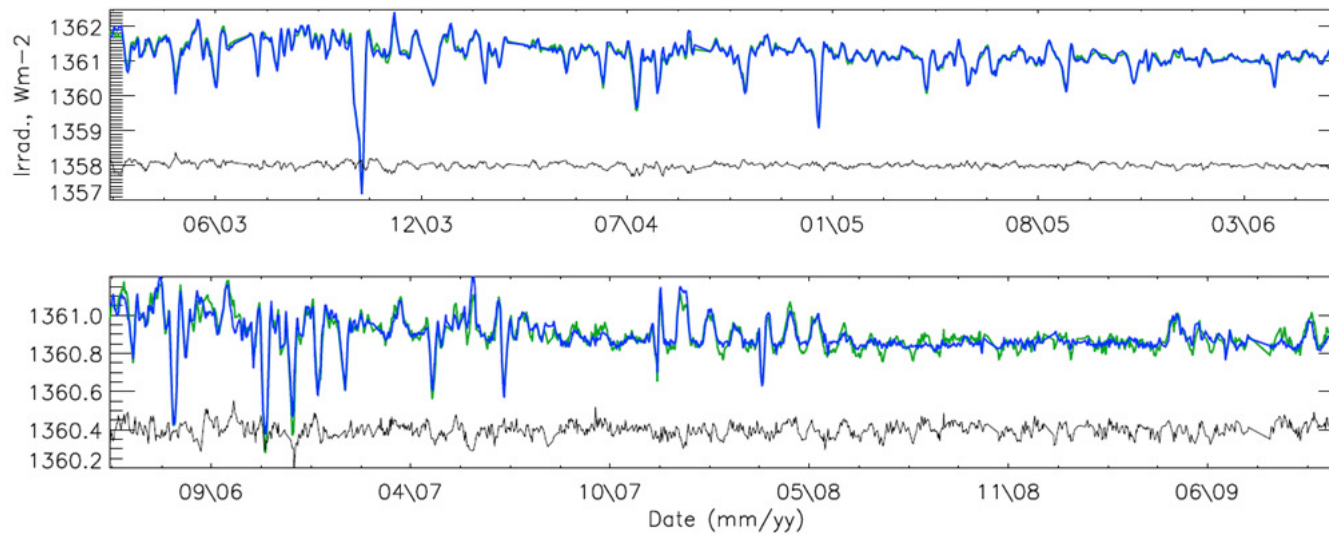
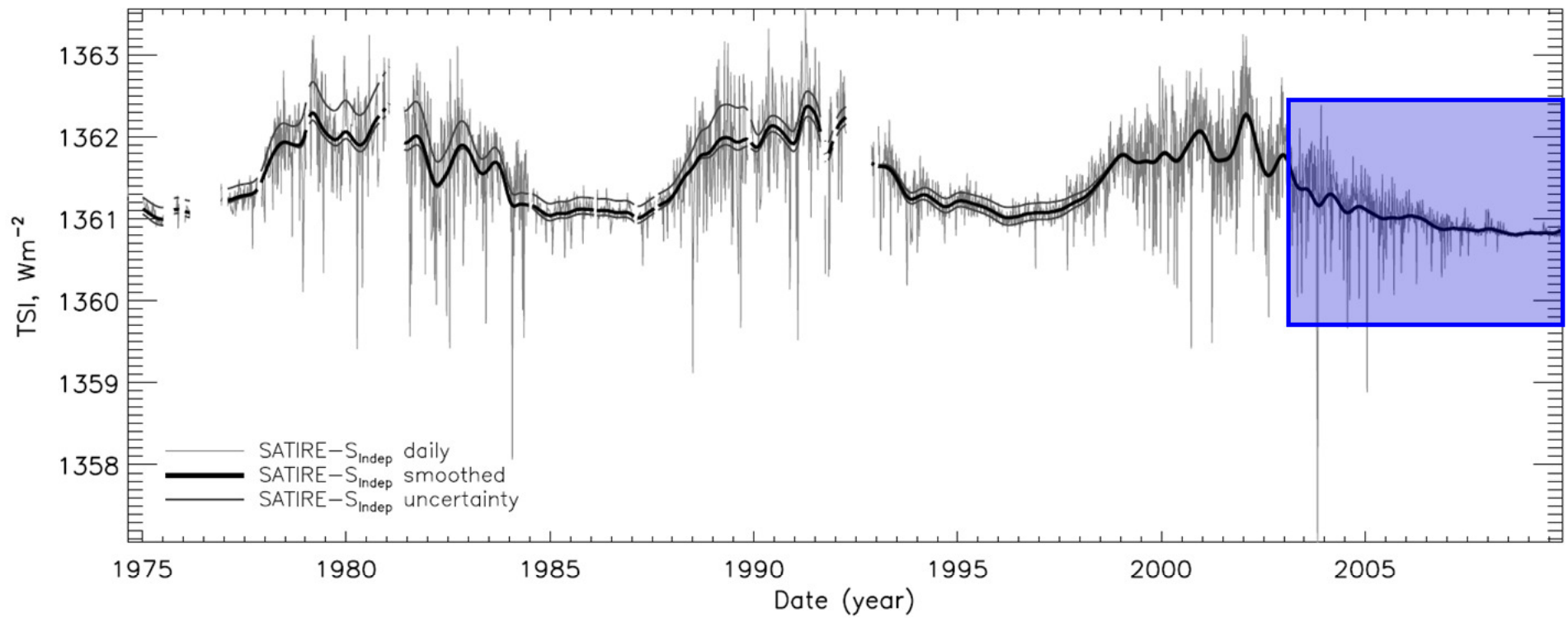


Magnetogram

Continuum Image

Bin pixel type with limb-angle

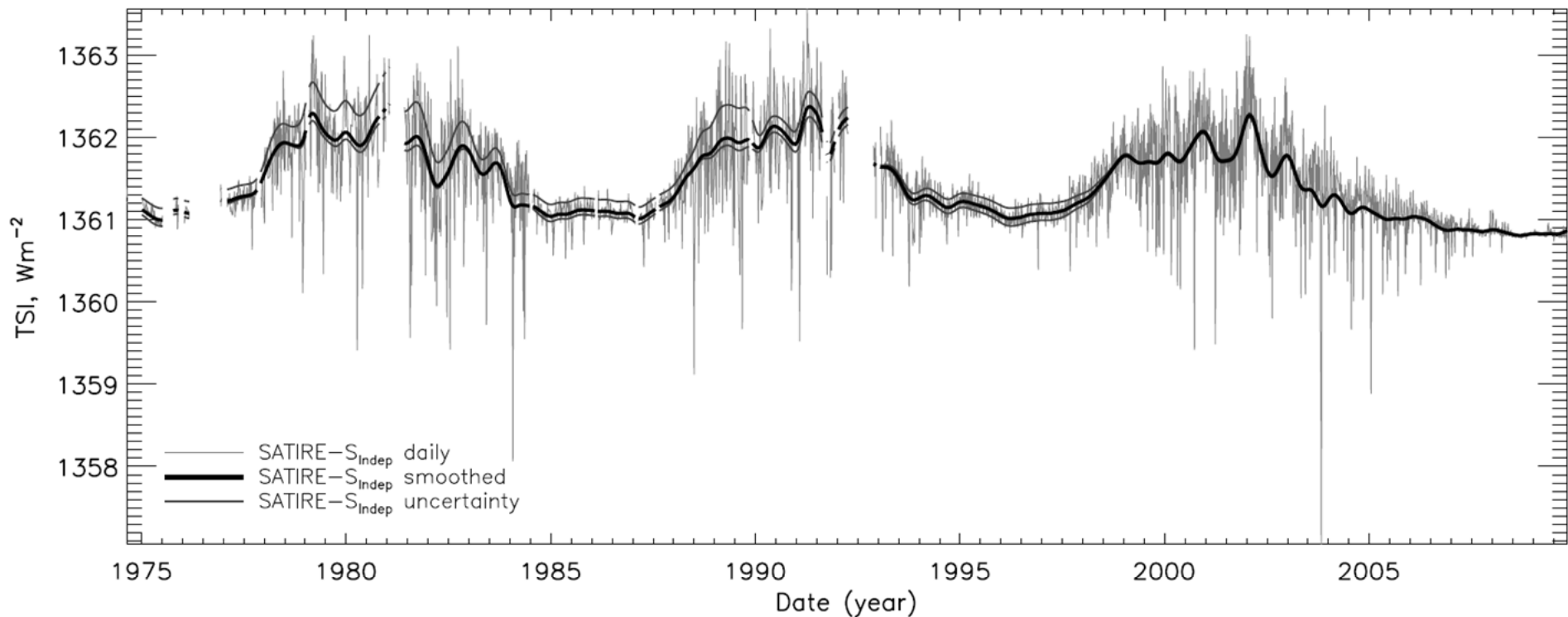




SATIRE
compared with
TIM/SORCE
Feb 2003 –
Oct 2009

New SATIRE-S Reconstruction of 1974-2009

Ball et. al., 2011, 2012



Old version (Ball et al. 2012)

TSI only; data gaps

New version (Ball et al., 2013, in prep.)

SSI + TSI

Fill all data gaps with MLR and proxies

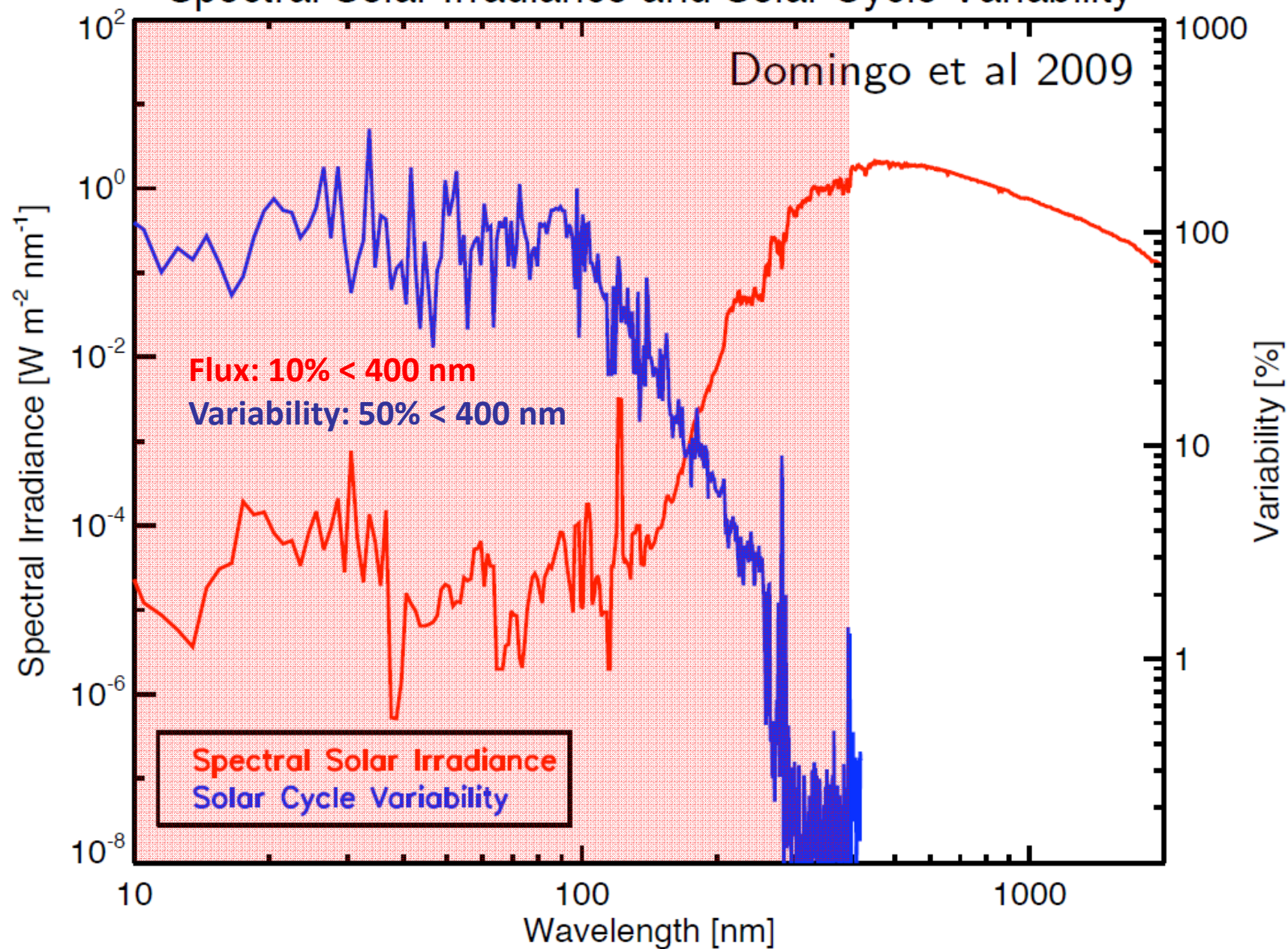
NLTE correction < 270 nm (Krivova et al., 2006)

Uncertainty range at all wavelengths

Ball et. al., 2011, 2012

New SATIRE-S Reconstruction of 1974-2009

Spectral Solar Irradiance and Solar Cycle Variability



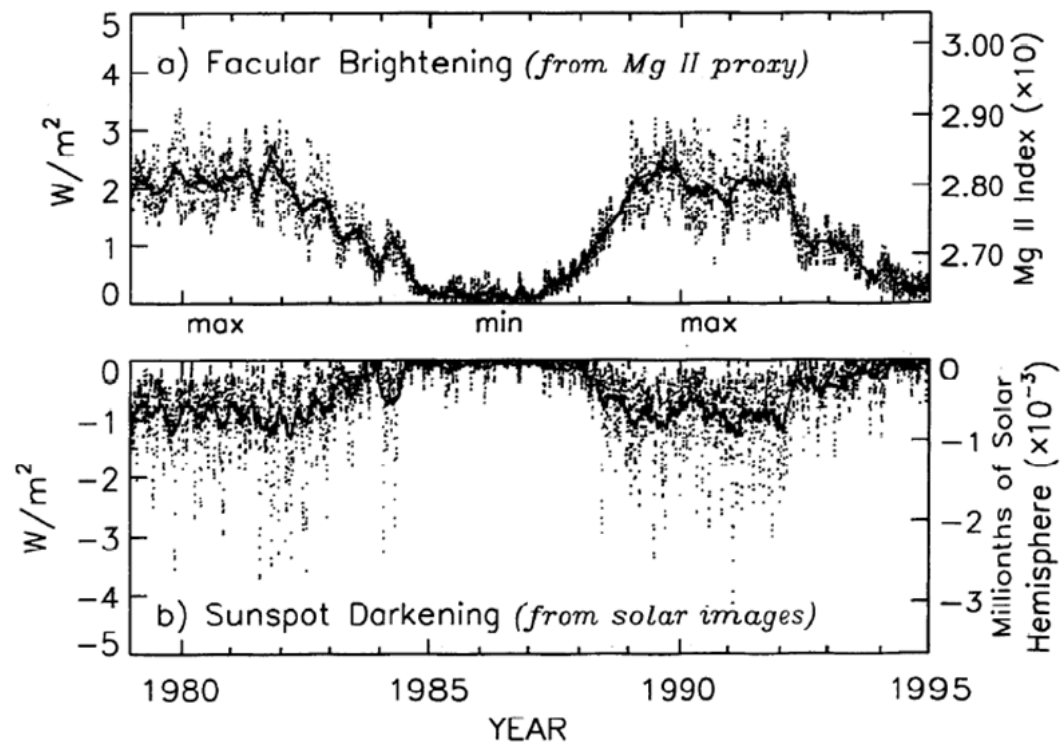
Spectral solar irradiance

NRLSSI Model & SORCE/SOLSTICE

Naval Research
Laboratory SSI Dataset
120 – 100,000 nm



Facular proxy: Mg II index
Sunspot proxy: Photometric Sunspot Index (PSI)



**Naval Research
Laboratory SSI Dataset**
120 – 100,000 nm

Facular proxy: Mg II index
Sunspot proxy: Photometric Sunspot Index (PSI)

120 – 400 nm

- i) Detrend
UARS/SOLSTICE,
PSI & Mg II
- ii) Multi-regress.
SOL., PSI & Mg II
- iii) Allow to scale with
PSI & Mg II cycle variation

TSI model

Direct from
PSI + Mg II

400 – 100,000 nm

Kurucz
fac & sunspot models
(Solanki & Unruh, 1998)

Scaled to agree with TSI

Combined 120 – 100,000 nm

Integrated flux constrained by direct
observations



NSO / Kitt Peak
National Solar Observatory

Location: Kitt Peak, Arizona, USA
Active since: 1958
Instruments: Various; namely, SPM and '512' data



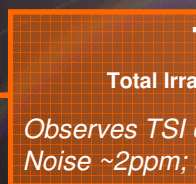
SoHO
Solar and Heliospheric Observatory

Location: Earth-Sun L1
Active since: May 1996
Instruments: GOLF, VIRGO, **MDI**, SUMER, CDS, EIT, LASCO, SWAN, CELIAS, COSTEP, ERNE



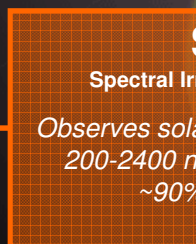
SORCE
Solar Radiation and Climate Experiment

Location: 600 km Earth-orbit
Active since: February 2003
Instruments: **TIM**, XPS, SOLSTICE, **SIM**



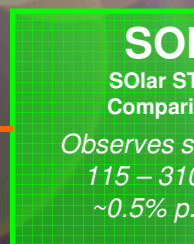
TIM
Total Irradiance Monitor

*Observes TSI on four-times daily;
Noise ~2ppm; stability <10ppm/yr.*



SIM
Spectral Irradiance Monitor

*Observes solar spectrum from 200-2400 nm, twice daily;
~90% of TSI.*

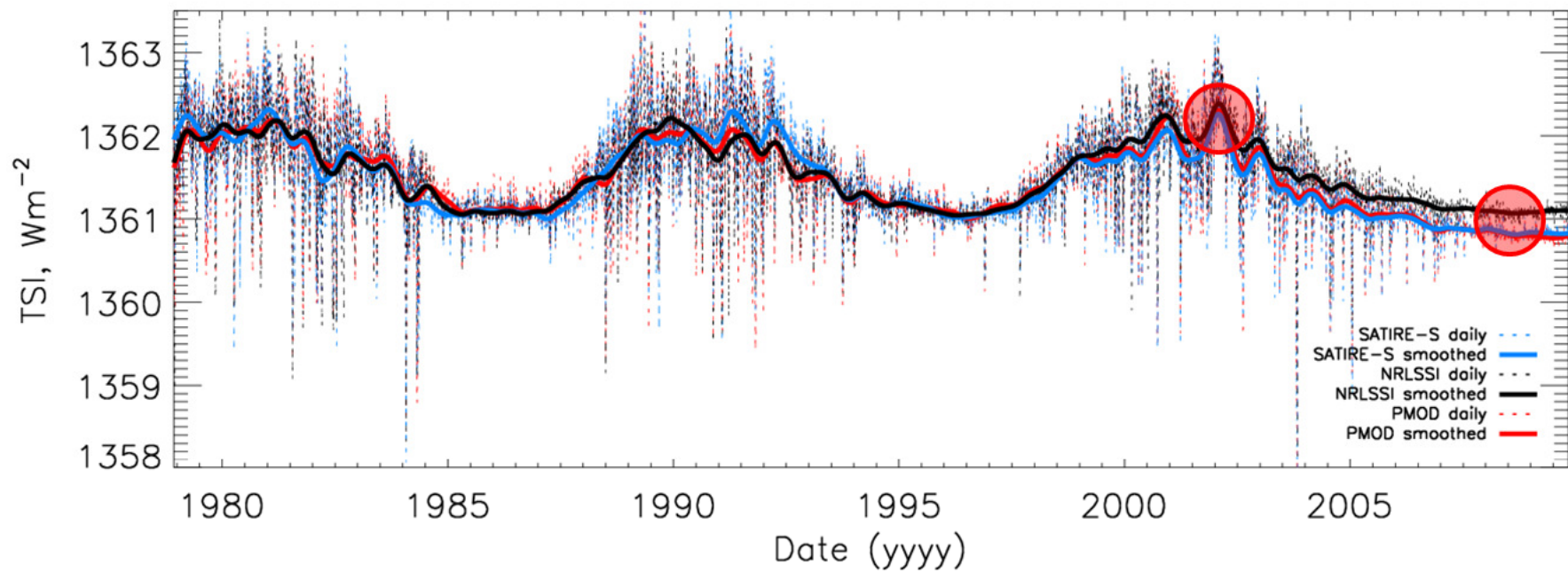


SOLSTICE
Solar STellar Irradiance Comparison Experiment

*Observes solar spectrum from 115 – 310 nm, twice daily;
~0.5% p.a. rel. accuracy.*

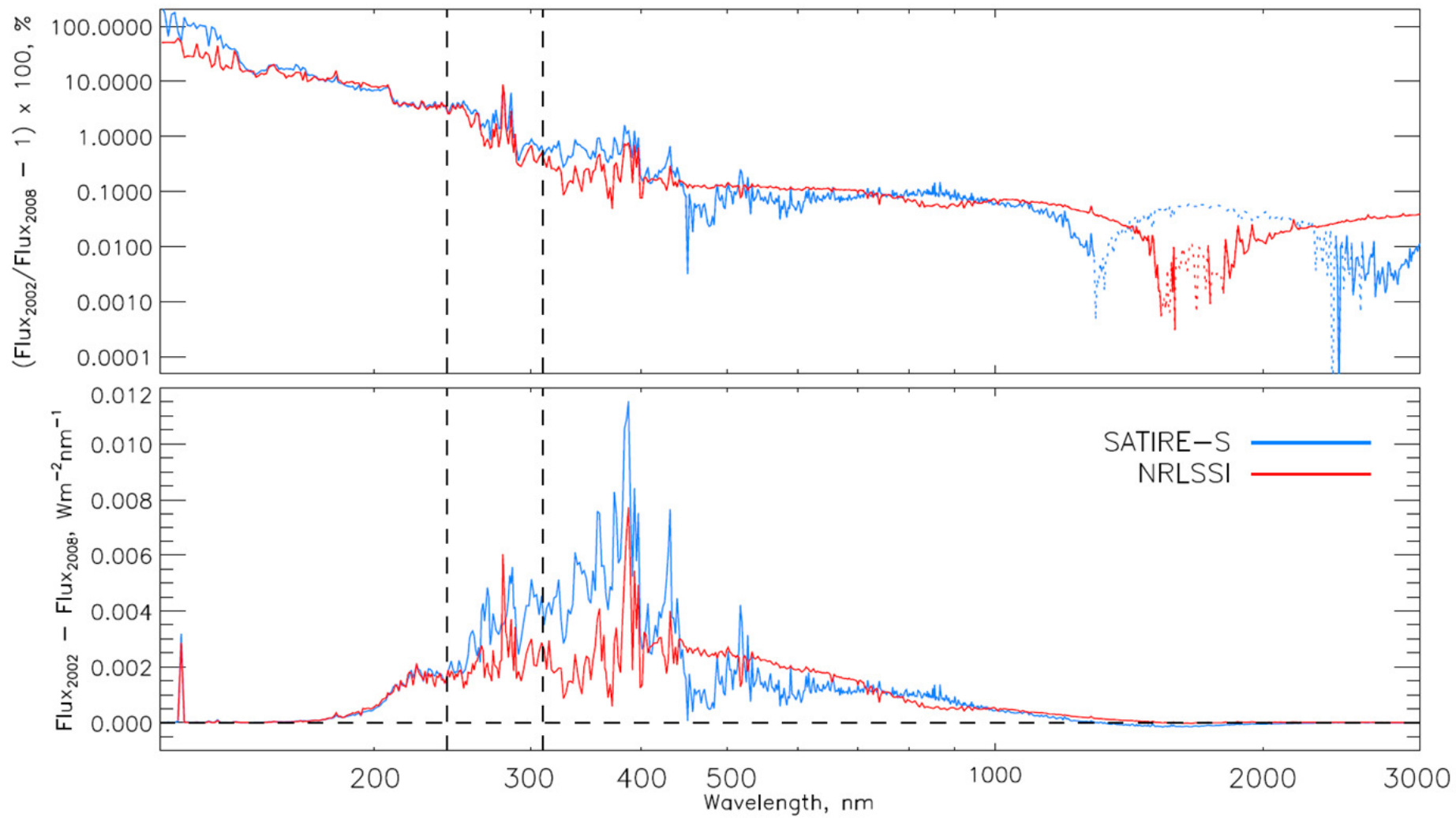
SORCE/SOLSTICE

Rottman et al., 2005; McClintock et al., 2005

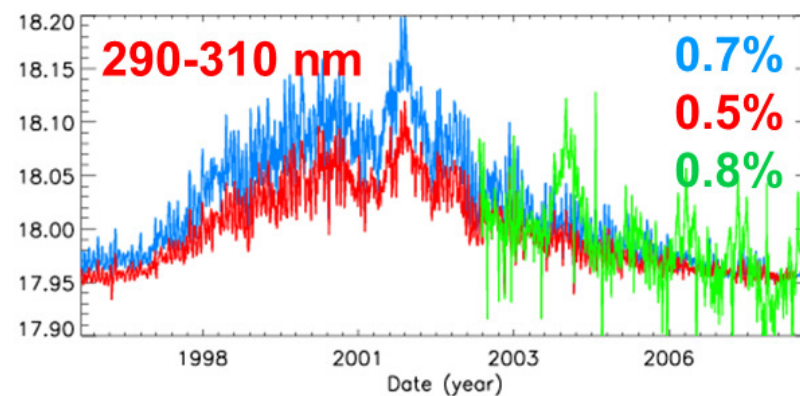
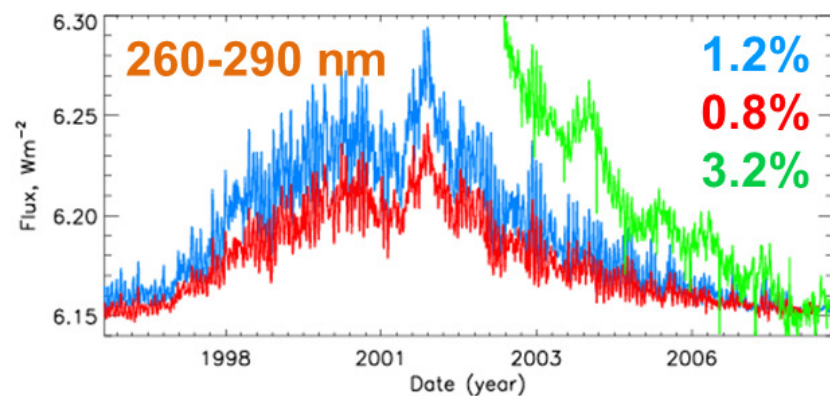
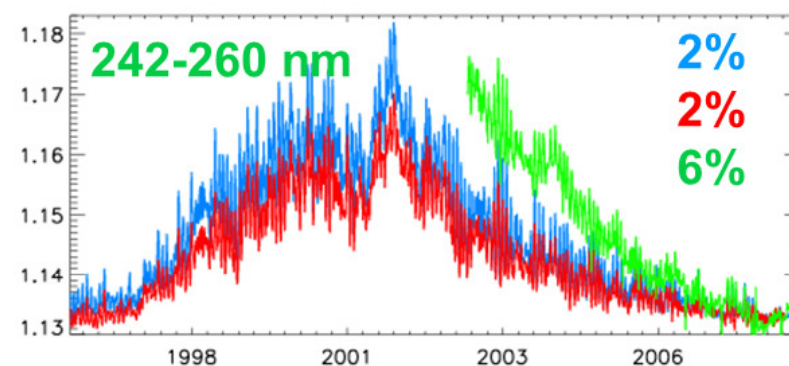
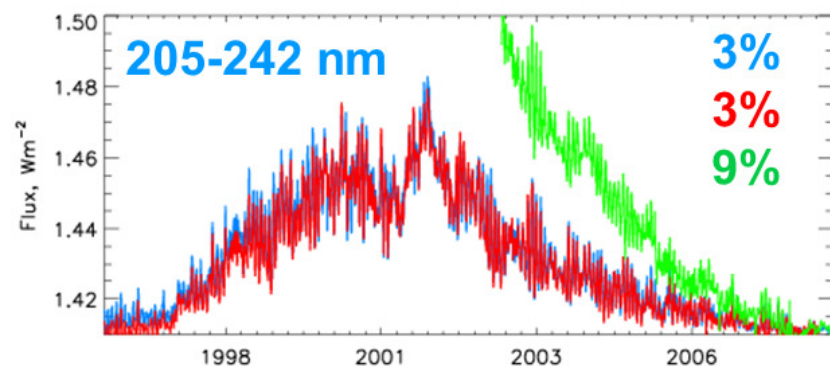
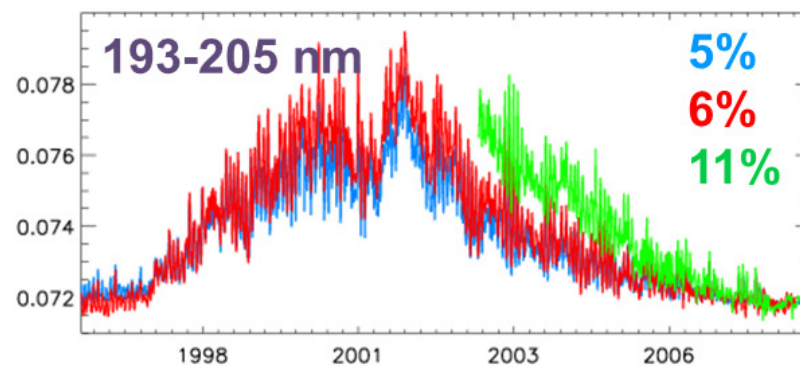
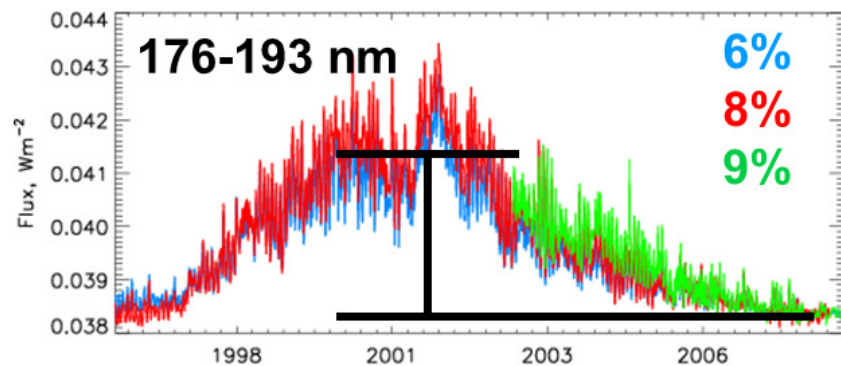


TSI r_c	All data	Detrended
PMOD: NRLSSI	0.92	0.87
PMOD: SATIRE	0.96	0.95

Spectral solar irradiance: SATIRE, NRLSSI



Spectral solar irradiance: SATIRE, NRLSSI



SATIRE-S Model

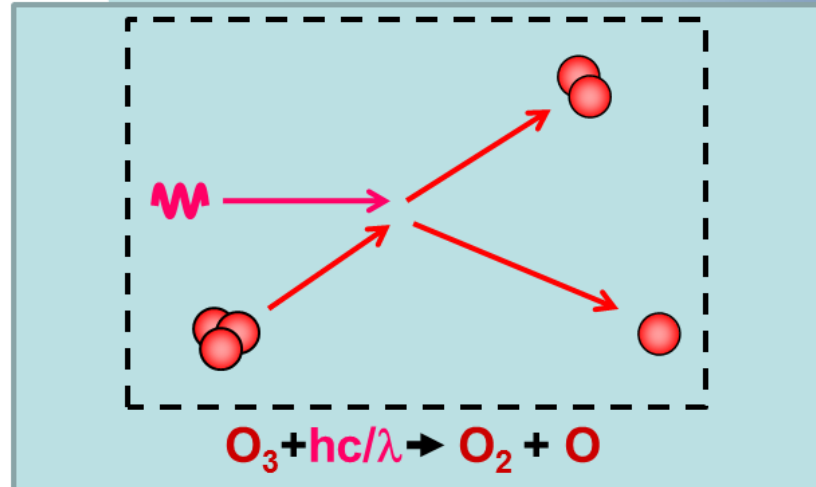
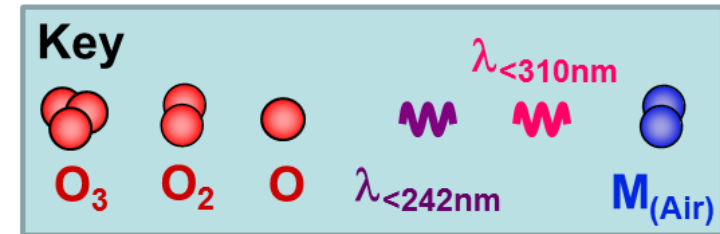
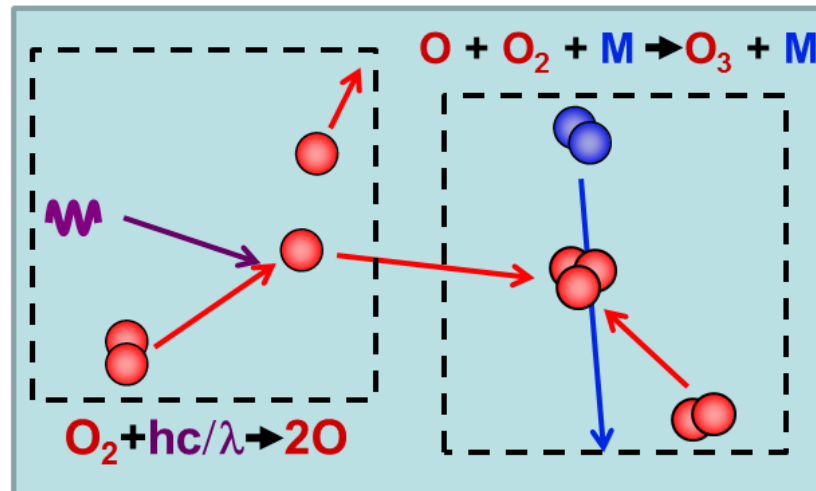
NRLSSI Model

SORCE/SOLSTICE Obs.

Spectral solar irradiance: SATIRE, NRLSSI, SORCE/SOL.

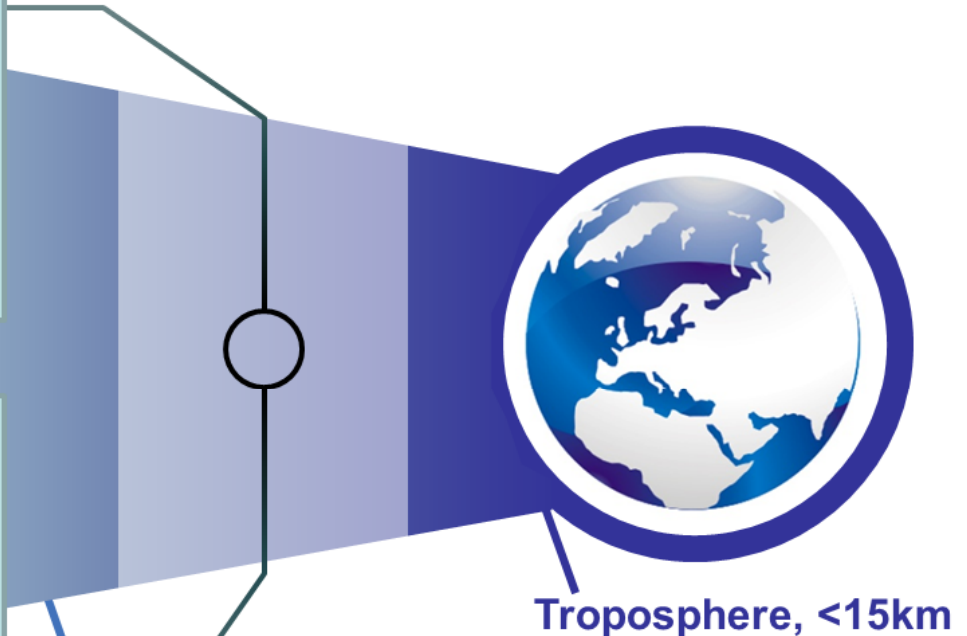
An example:
**SSI Impact on
Stratospheric Ozone**

Ozone production

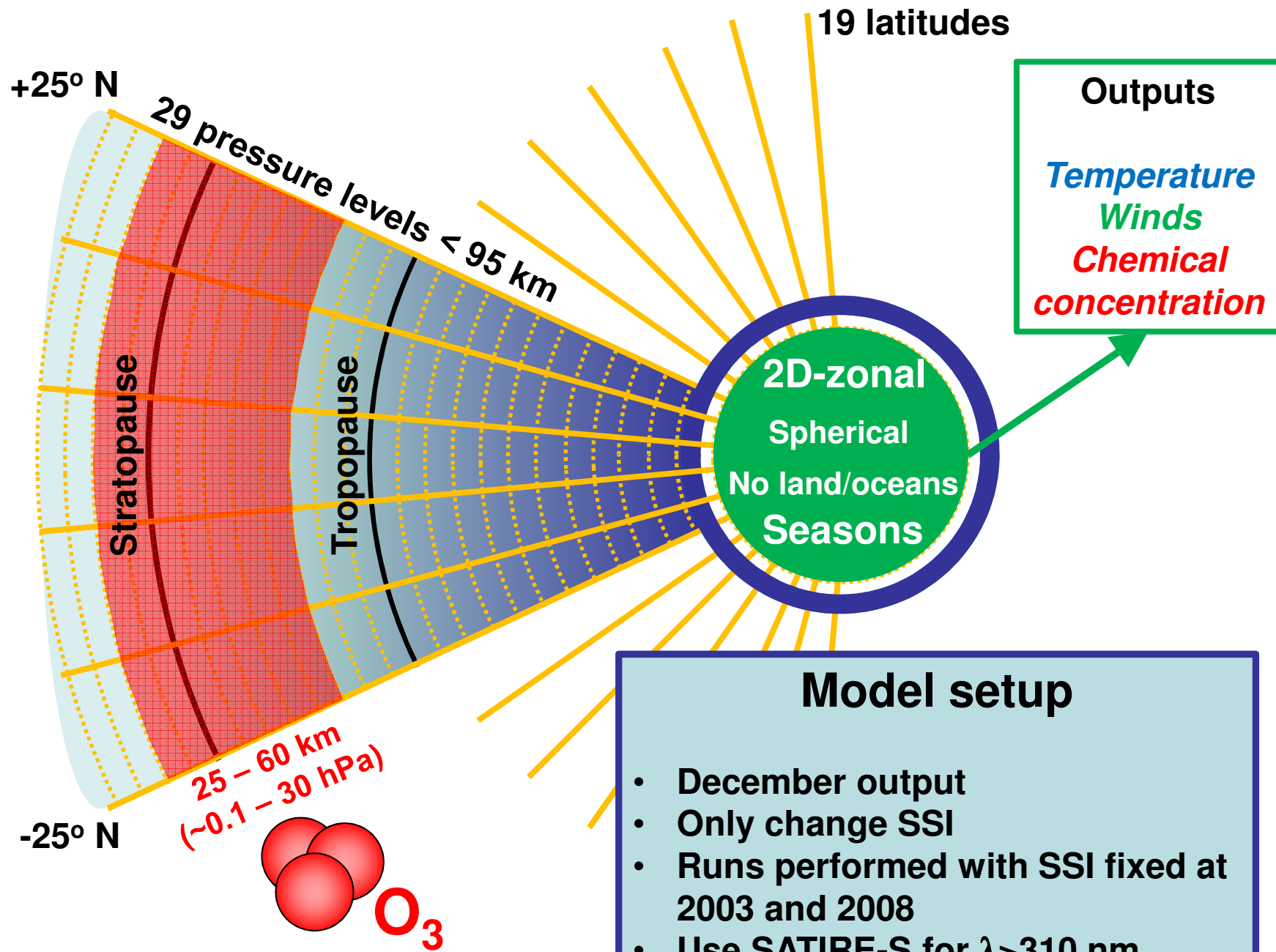


Ozone destruction

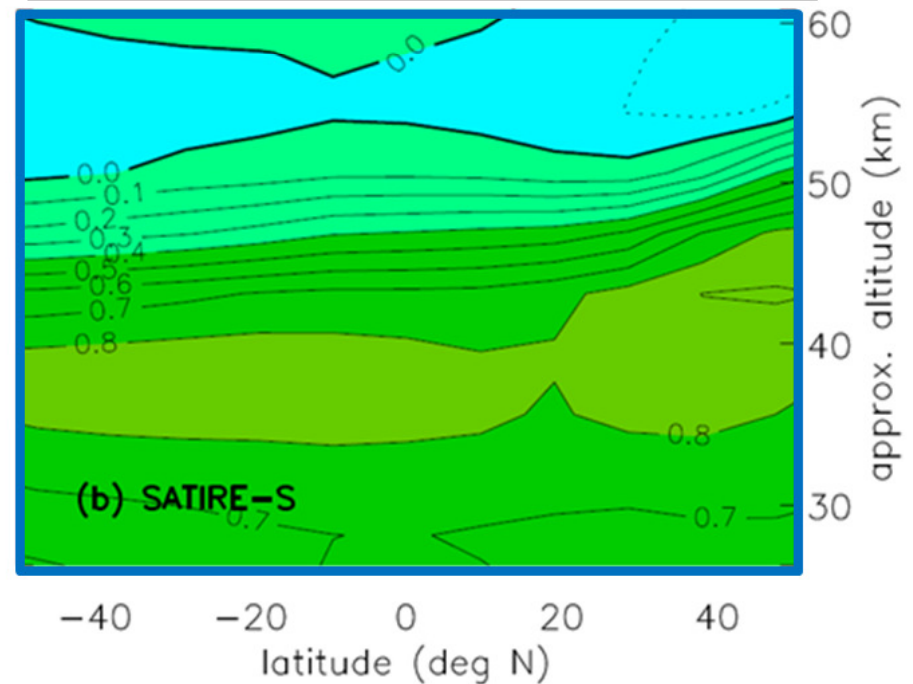
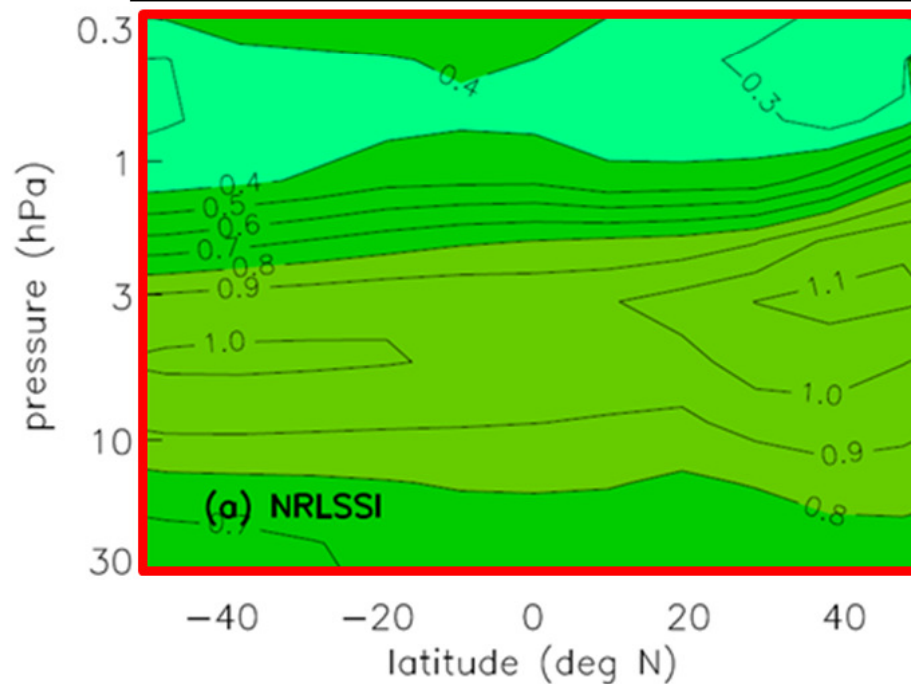
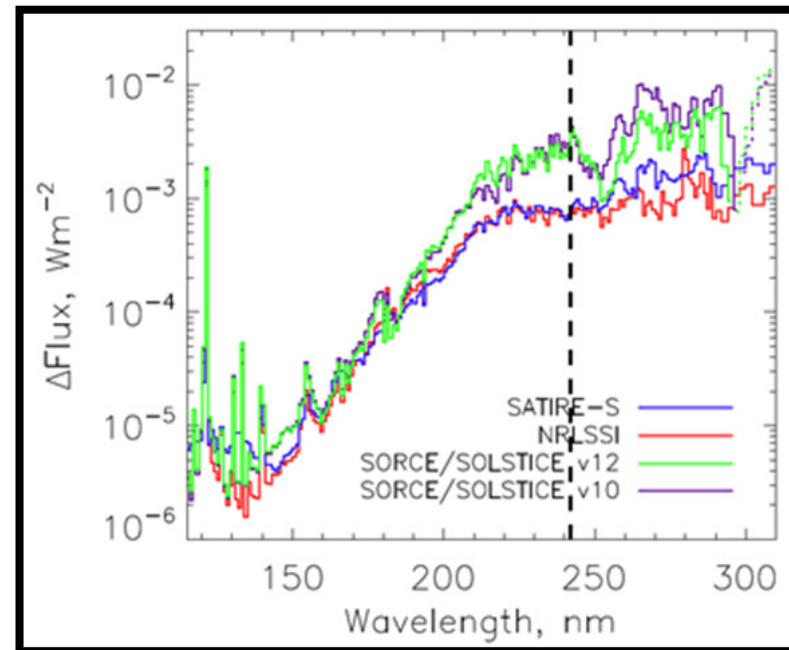
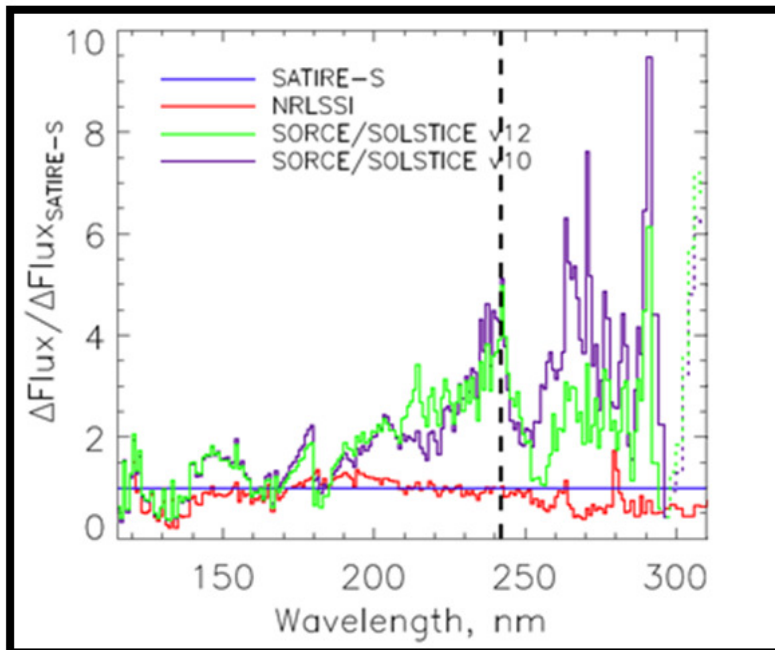
How does *SSI* affect stratospheric ozone?



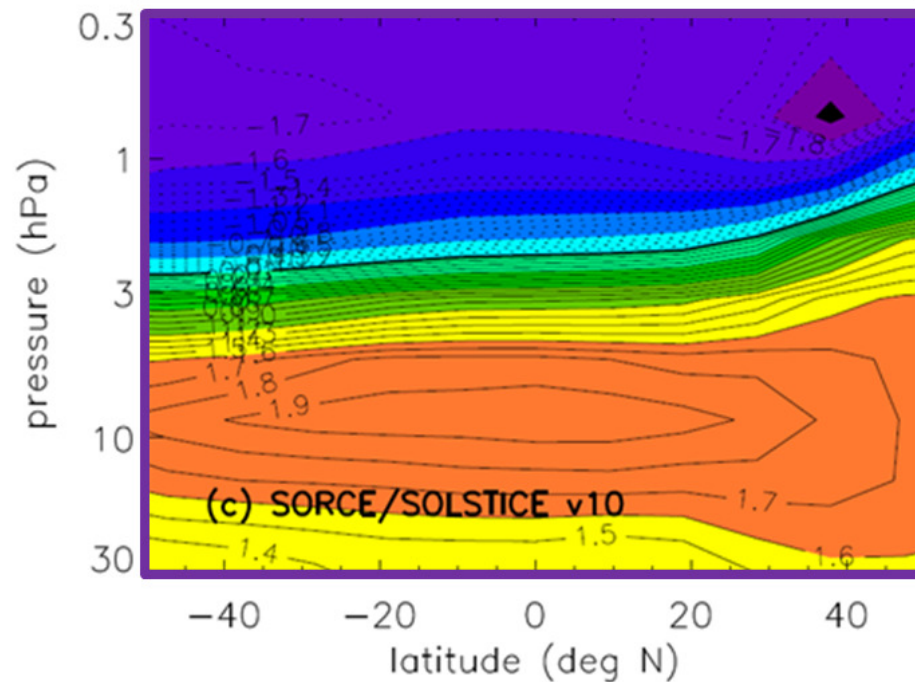
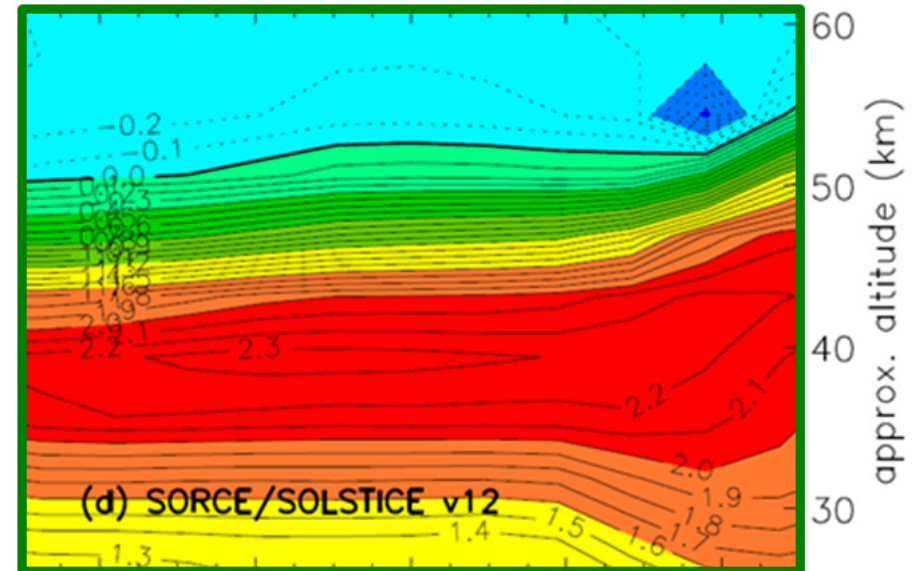
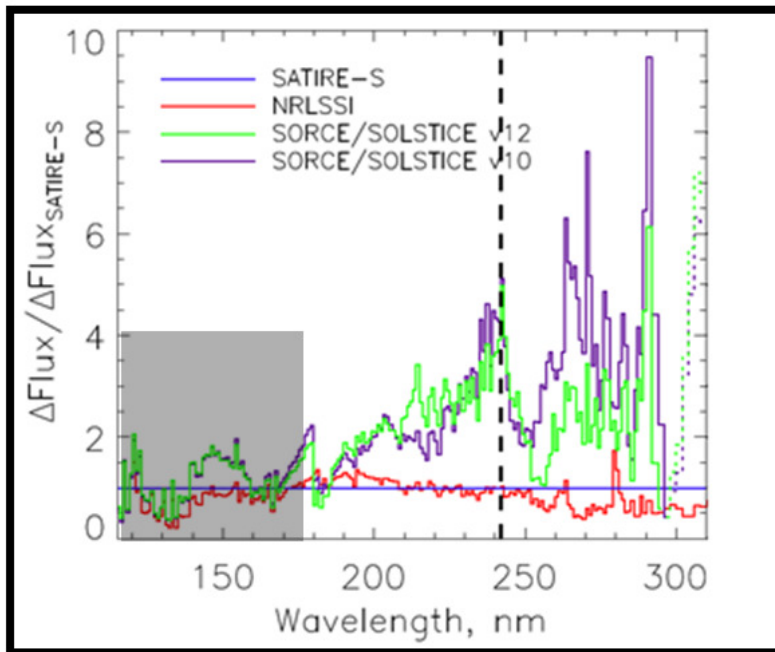
- Solar Maximum rel. to Solar min:**
- % change $\lambda < 242\text{nm}$ $\gg$ $\lambda < 310\text{nm}$
 - 2% increase in O_3
 - Reduction in $\lambda < 330\text{nm}$ and $\lambda > 500\text{nm}$ at surface/ocean
 - Non-linear; latitude/season dep.

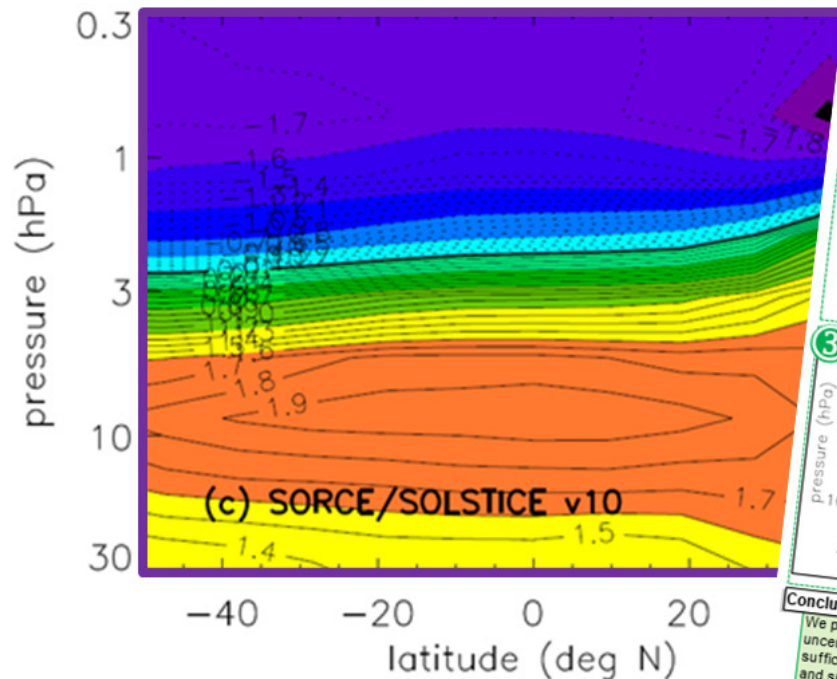
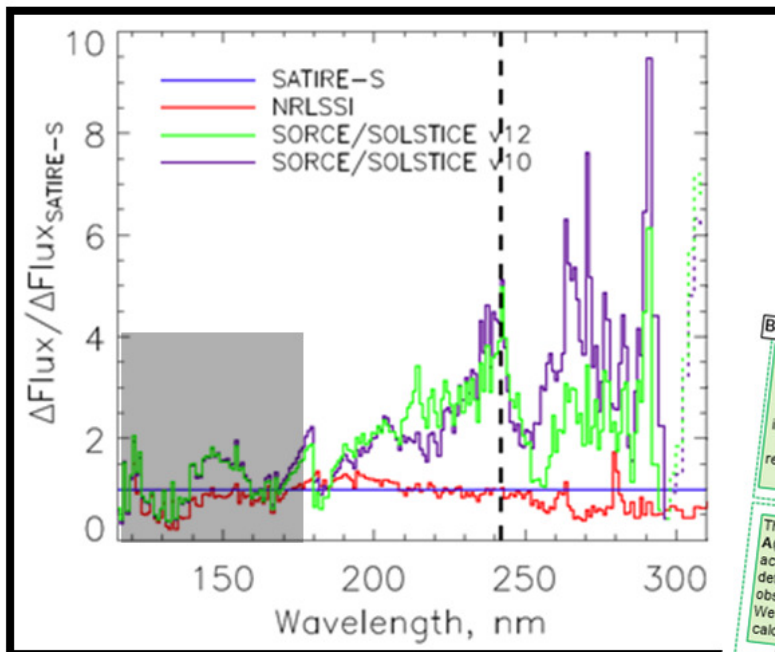


2D atmospheric model (Harwood & Pyle 1975)



2D atmospheric model (Harwood & Pyle 1975)





2D atmospheric model (Harwood & Pyle 1975)

Can stratospheric ozone observations tell us anything about solar spectral irradiance?

W.T. Ball, D.J. Mortlock, J. Egerton, J.D. Haigh
Department of Physics, Imperial College London

Abstract

Heating within the stratosphere mainly results from the absorption of solar ultraviolet (UV) radiation by ozone. Variations of incoming solar UV modulate stratospheric ozone concentration and heating rates and can lead to a dynamical response throughout the middle and lower atmosphere. Despite three decades of ozone and spectral solar irradiance (SSI) observations, the magnitude of SSI cycle variations is still to be accurately determined and, therefore, so is the Sun's effect on ozone. Observations from the SORCE¹ satellite suggest much larger solar cycle UV variations compared to SSI models based on previous data. The solar signal in ozone derived from observational data shows some similarity with that found in atmospheric models in response to SSI from SORCE and solar models, but the uncertainty in both SSI and ozone observations makes comparisons difficult. We show that the response in the tropical ozone profile to variations in the solar spectrum can be reconstructed from a linear combination of individual responses to separate spectral bands. Based on this, we use a Bayesian statistical approach to show that it is possible, in principle, to combine SSI and ozone observations to better determine variations in both, but that the large observational uncertainties in both make it difficult to make any claims about solar variability from current ozone data.

Background

Ozone concentration is largely determined by the ratio of solar irradiance from wavelengths below 242 and 310 nm, respectively initiating production and destruction processes (Fig. 1). Thus, the response of ozone to solar variability is sensitive to changes in SSI.

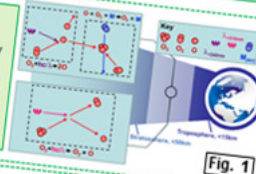


Fig. 1

The linear model ozone profile, $\Delta O_3(h)$ profile is encoded in the matrix, $A(h, \lambda)$, giving the weightings of each spectral band, $f(\lambda)$, while taking account of the noise, $n(h)$. By inverting the equation in Fig. 3, $f(\lambda)$ can be determined for any $\Delta O_3(h)$ profile. However, the large error bars on the observations allow many combinations of $f(\lambda)$ that produce similar $\Delta O_3(h)$. We therefore apply priors (see below right) and use Bayesian inference to calculate the most likely $f(\lambda)$.

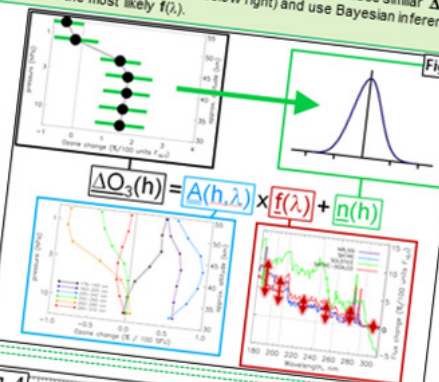


Fig. 3

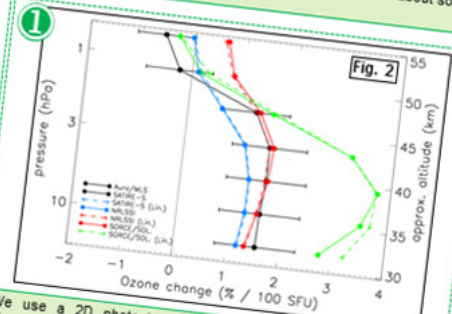


Fig. 2

We use a 2D photochemical dynamical model of the middle atmosphere to deduce the response in tropical ozone, ΔO_3 , to the changes in UV suggested by the SATIRE-S^{1,2} solar model in six spectral bands between 176 and 310 nm (Fig. 3, lower left). We find that the full response (as determined by the 2D model) to any prescribed change in SSI can be accurately represented by a linear combination of the six profiles. An example for three different SSI linear model in dashed lines) The profile in black is derived from Aura/MLS observations between 2004 and 2012.

- 1) maximum SC change in each $f(\lambda)$ is limited to 5x SATIRE-S, ~50% larger than any observations
- 2) minimum changes below 242 nm must not be less than zero
- 3) minimum changes over 242-310 nm must not be less than -1 x SATIRE-S
- 4) SC changes below 242 nm must be larger than the largest change above 242 nm

Priors

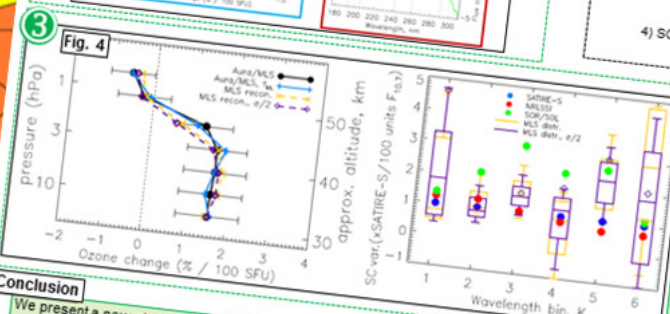


Fig. 4

We make one million random samples within the priors to produce a distribution of the most likely SSI SC changes $f(\lambda)$, relative to SATIRE-S (blue dots), that can produce the observed ozone profile. Fig. 4, right: the box and whisker plots give the mode, 68% and 95% ranges for standard (yellow) and halved (purple) errors in the Aura/MLS ΔO_3 profile in each spectral band. The diamonds indicate the best fit values. SC and green dots in the right plot. Fig. 4, right: best profile fits (from the priors, yellow/purple from diamonds in right plot).

Conclusion

We present a new statistical approach to investigate the relationship between SC SSI changes and ozone using Bayesian inference to incorporate uncertainty in ozone and prior knowledge in SSI. Similar ΔO_3 SC changes can be produced with different SC SSI changes. The current data are not sufficient to distinguish between competing SSI datasets. We do, however, consider this approach to be more robust than single profile comparisons and suggest that it may provide significant advances in analysis of longer datasets.

Imperial College London

Science & Technology Facilities Council

¹Ball, W. T., & Pyle, J. R. (2005). Solar Physics, 221, 1-20. ²Ball, W. T., & Pyle, J. R. (2005). Solar Physics, 221, 1-20. ³Ball, W. T., & Pyle, J. R. (2005). Solar Physics, 221, 1-20.

Summary

- New SSI dataset (SATIRE-S)
 - last three cycles (extension underway)
 - different SSI variability w.r.t. NRLSSI
- SSI models and recent observations disagree
 - differences up to 4x cycle variability
 - models more similar than SORCE observations
- SSI is important for studies of the atmosphere, e.g. stratospheric ozone
 - model and SOLSTICE O3 response very different
 - large difference in O3 between SOLSTICE versions
- Errors on SSI observations are large
 - cycle SSI variability is still uncertain

Data available very soon on **LASP LISIRD** & www.mps.mpg.de/projects/sun-climate