

# Variability of UV-vis-IR solar irradiance from GOME and SCIAMACHY for use in GCMs

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*background image from spacecenter.dk*



# Outline

(input)  
SSI  
11-yr cycle

Problem: No direct 11-year SSI measurements

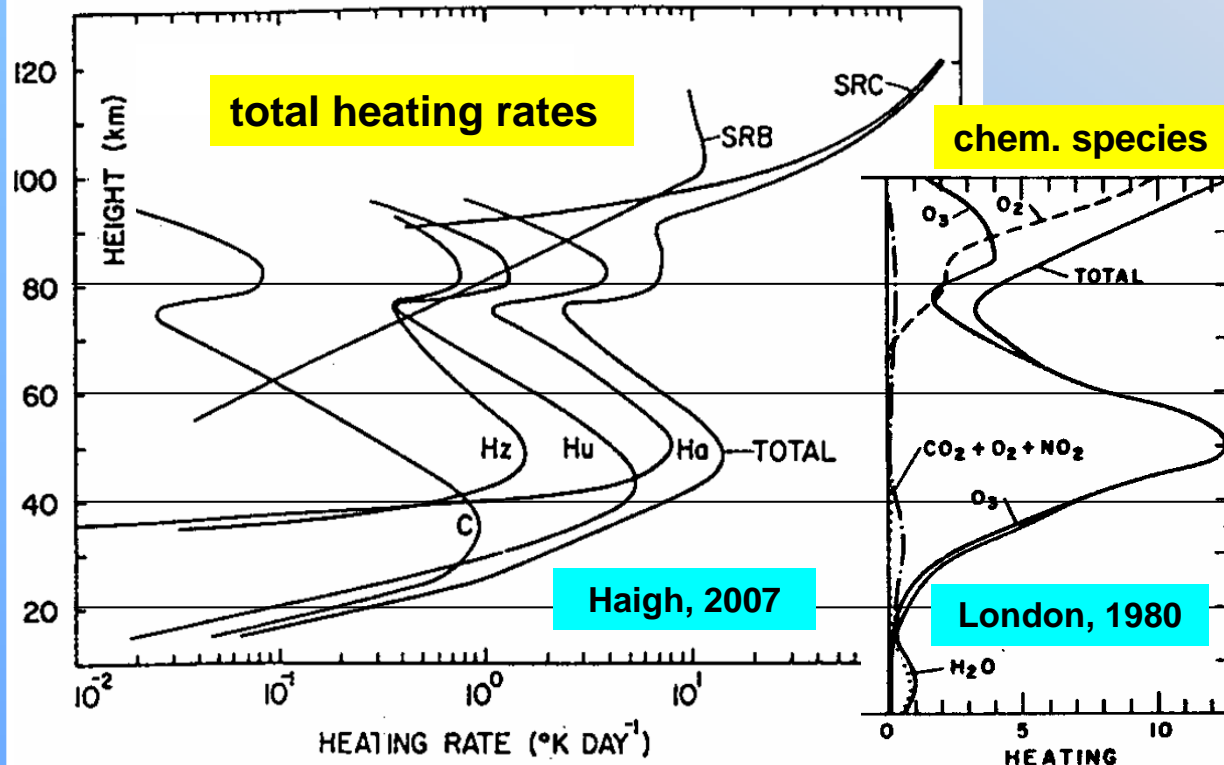
GCM  
(wavelength dependent)

How to increase sensitivity of climate  
to 11-yr solar cycle variability?

- Solar data from GOME and SCIAMACHY
- Modeling observed solar variability
- Validate model with other solar data
- Radiation intervals for GCMs
- Summary and Recommendation



# Radiative heating by O<sub>2</sub> and O<sub>3</sub> absorption



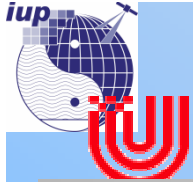
**O<sub>2</sub> absorption bands**  
 125 – 205 nm Schumann-Runge (SRB/SRC)  
 205 – 243 nm Herzberg contin (Hz)

**O<sub>3</sub> absorption bands**  
 243 – 278 nm Hartley band (Ha)  
 278 – 363 nm Huggins bands (H)  
 407 – 683 nm Chappuis band (C)

## Objective:

Estimate the best realistic TOA incoming radiation at

(1) solar min and (2) solar max conditions --- 11-year spectral dependence



# Simple irradiance model

SOLAR DYNAMO

SURFACE FIELD

SUNSPOTS

FACULAE

IRRADIANCE

TSI solar constant

SSI: UV-vis-IR

CLIMATE

SCIA solar data  
240-1700 nm  
2003-2004

choose best measurements

- \* when instrument is stable
- \* during least degradation
- \* during active sun periods
- \* of longer timeseries

$$I(\lambda, t)$$

$$= a(\lambda) \cdot P_{MgII}(t) + b(\lambda) \cdot P_{PSI}(t) + P_{ol}(t)$$

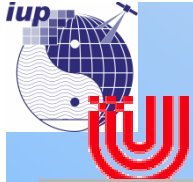
$\Delta I(\lambda, t)$

anomaly term

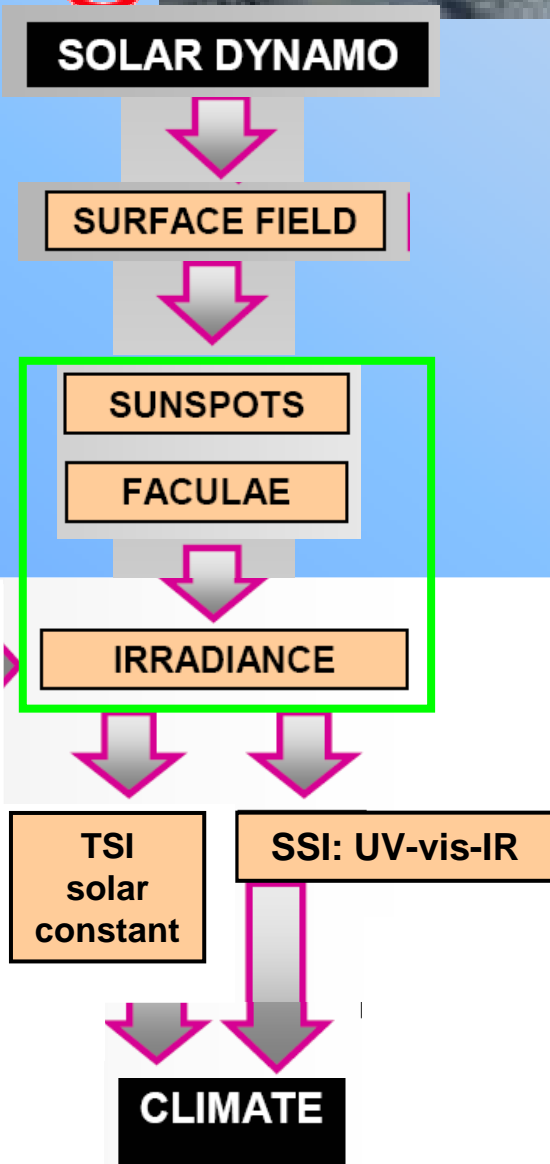
Mg II ctw from Viereck et al. (2004)

PSI from Balmaceda et al. (2007)





# Polynomial term

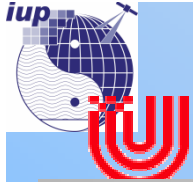


$$I(\lambda, t) = a(\lambda) \cdot P_{\text{MgII}}(t) + b(\lambda) \cdot P_{\text{PS}}(t) + \text{Pol}(t)$$

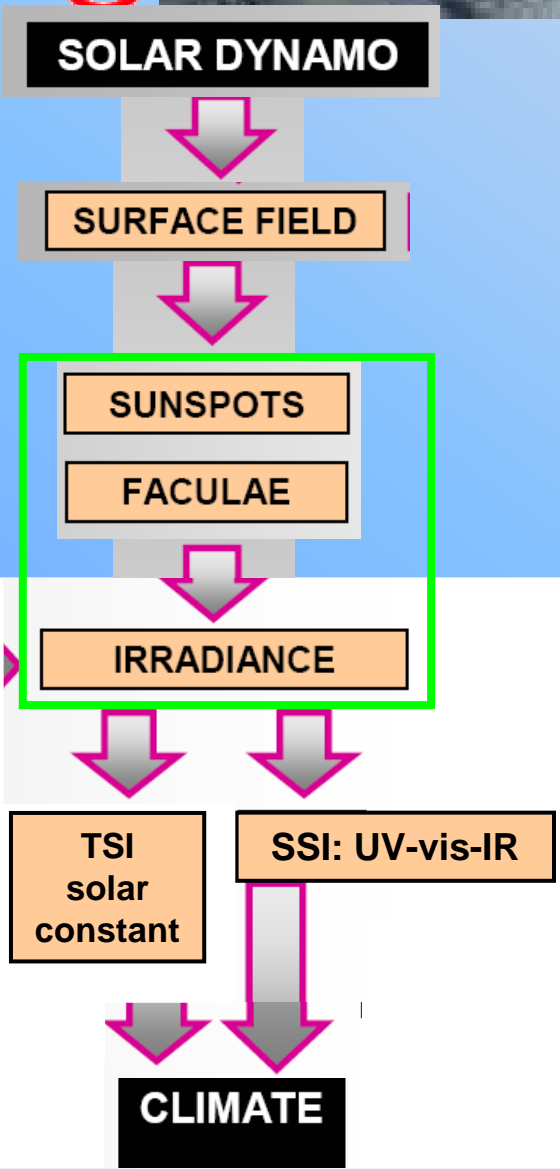
## Polynomial term

( polynomial degree kept minimum )

- \* slowly varying background
- \* instrument degradation



# Most desired objects: $a(\lambda)$ and $b(\lambda)$



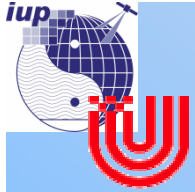
linear regression

$$I(\lambda, t) = a(\lambda) \cdot P_{\text{MgII}}(t) + b(\lambda) \cdot P_{\text{PSI}}(t) + \text{Pol}(t)$$

$a(\lambda)$

$b(\lambda)$

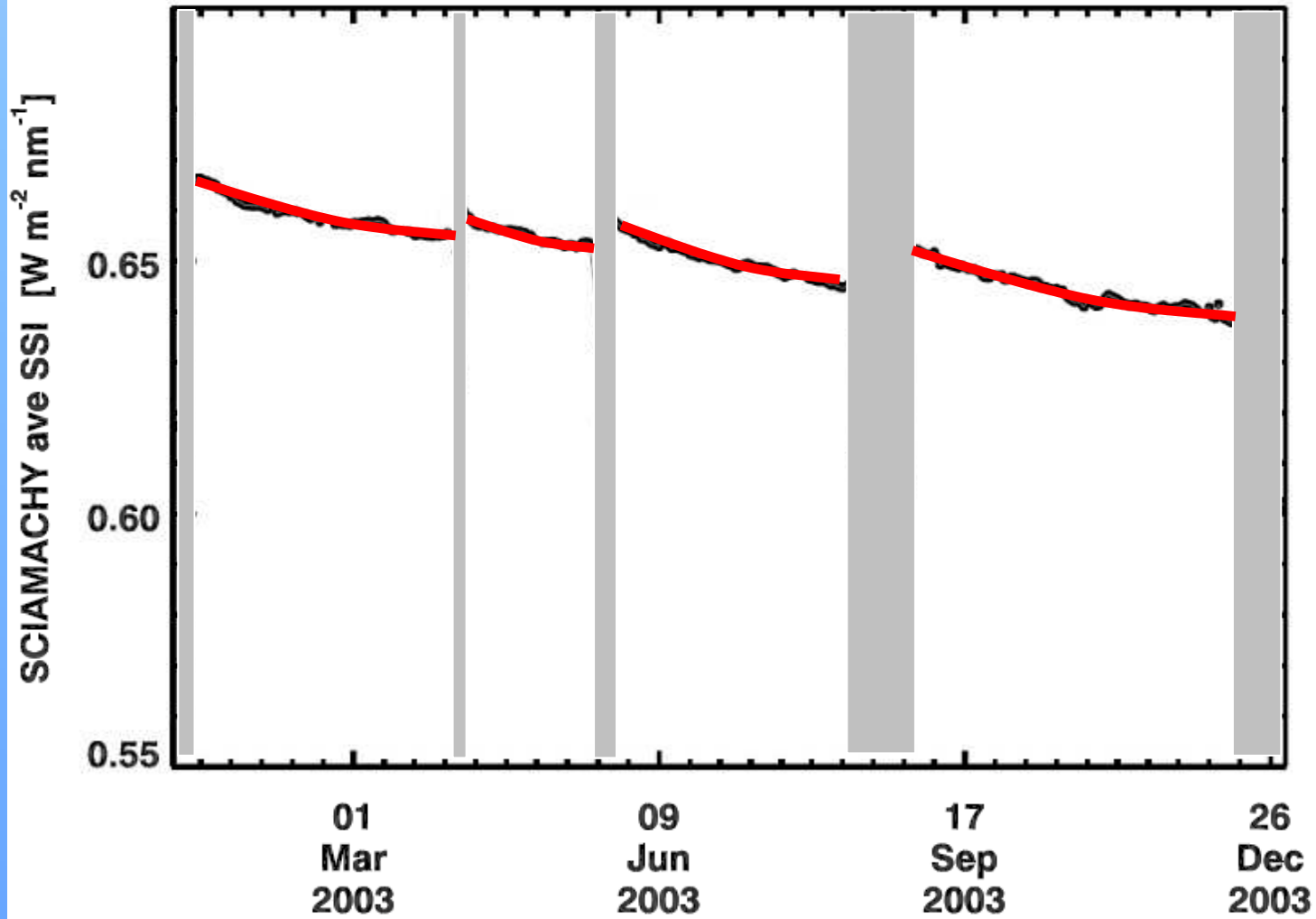
linearly scale 27-day SSI variability to 11-year decadal changes

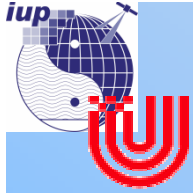


# Step-by-step illustration

## (4) Fit low deg polynomials

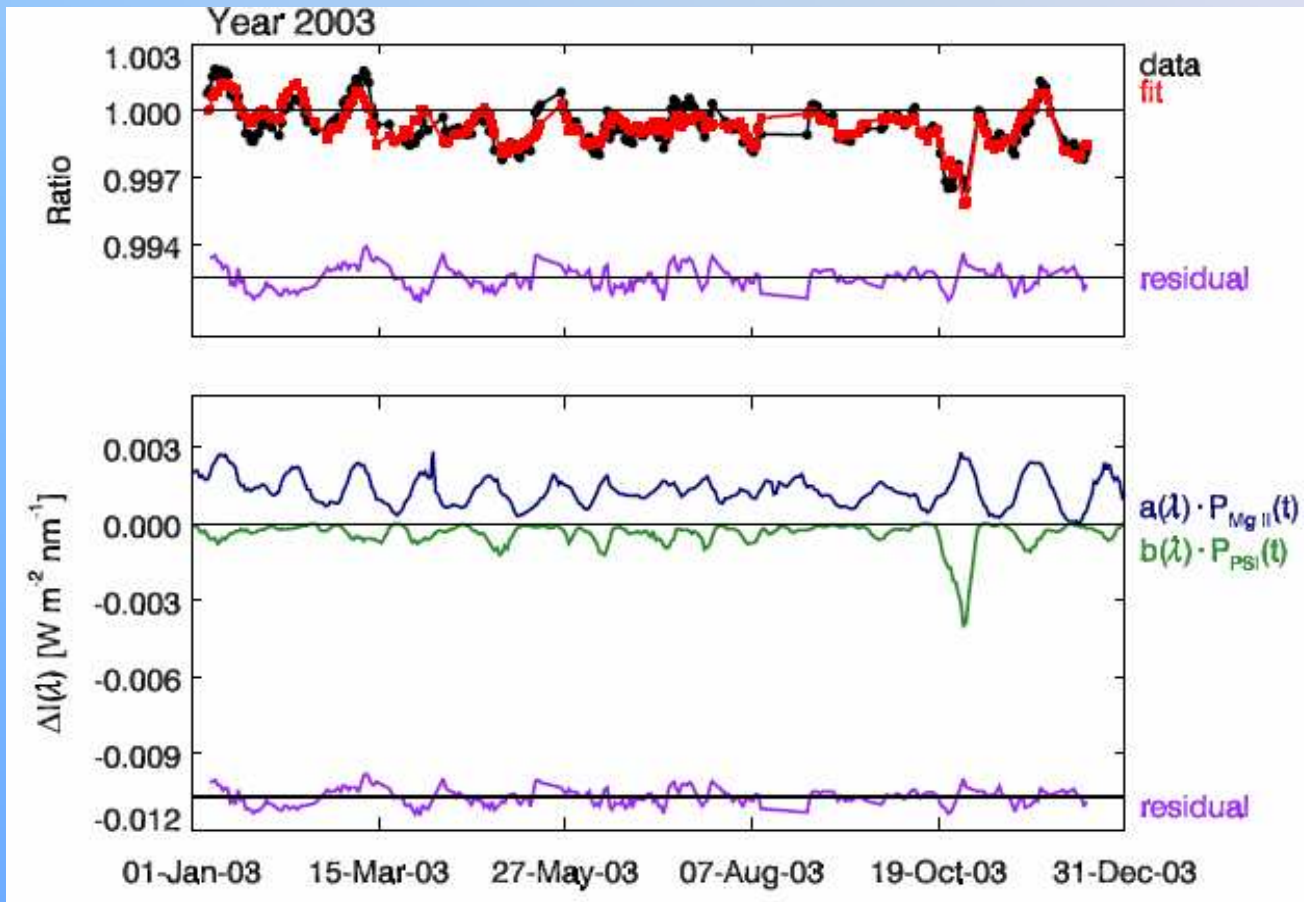
310 -- 320 nm





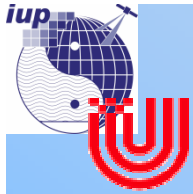
# Modeling: step-by-step illustration

## UV parametrization @ 310- 320 nm

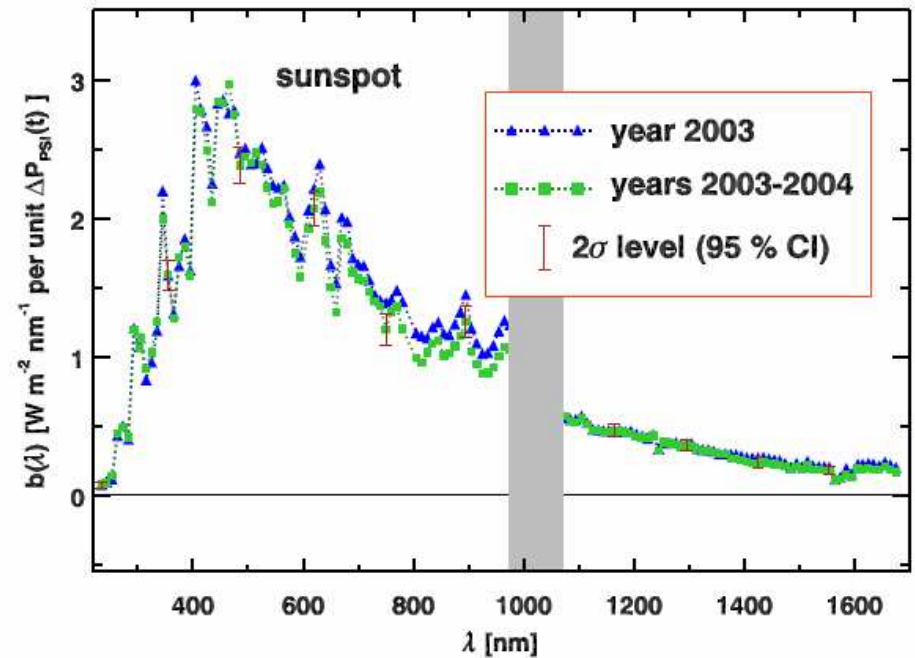
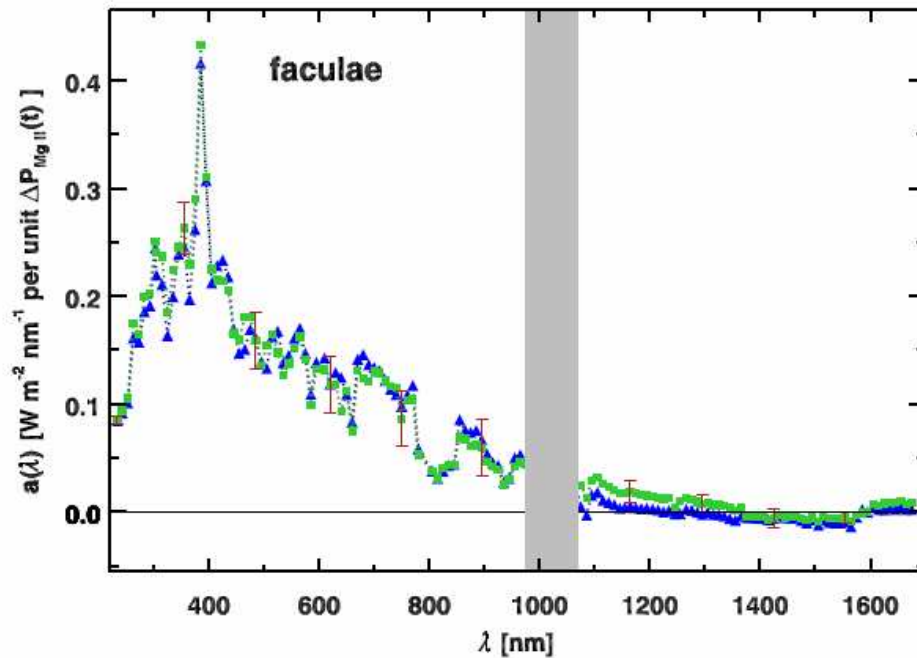


$$\text{Ratio} = \frac{I_{\text{data}}(\lambda, t)}{\text{Pol}(t)}, \frac{I_{\text{data}}(\lambda, t) - \text{Res}}{\text{Pol}(t)}$$





# Derived regression parameters



after parametrizing all 143 10-nm intervals



# Reconstruction of daily irradiances

SCIA ref spectrum

$a(\lambda)$

$b(\lambda)$

faculae + sunspot  
contribution

reconstruct  
daily variability

$$I(\lambda, t_j) = I(\lambda, t_{\text{ref}}) + \underline{\underline{\Delta I(\lambda, t_j)}}$$

where

$$\Delta I(\lambda, t_j) = a(\lambda) \cdot [P_{\text{MgII}}(t_{\text{ref}}) - P_{\text{MgII}}(t_j)] \\ + b(\lambda) \cdot [P_{\text{PSI}}(t_{\text{ref}}) - P_{\text{PSI}}(t_j)]$$

$t_{\text{ref}} = 4\text{th Mar } 2004, \quad t_j \in \text{satellite era}$

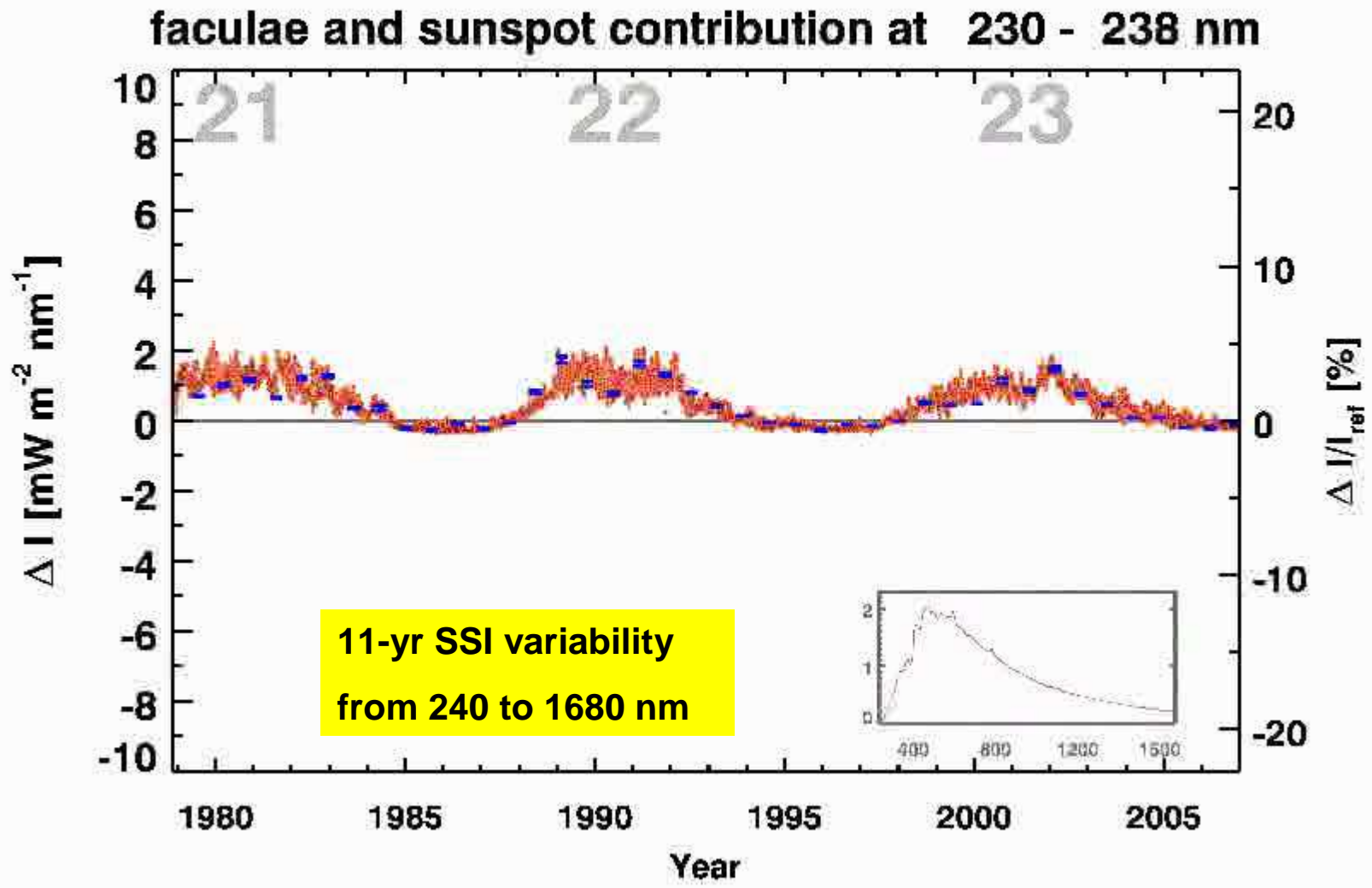
extrapolate 11-year  
variability

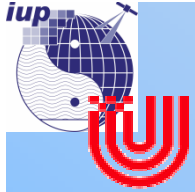
If  $t_j = \text{solar min (3yrs ave)}$ , then  $I(\lambda, t_{\text{sol min}}) = I_{\text{min}}(\lambda)$

If  $t_j = \text{solar max (3yrs ave)}$ , then  $I(\lambda, t_{\text{sol max}}) = I_{\text{max}}(\lambda)$



# Reconstruction of daily spectra (1978-2007)



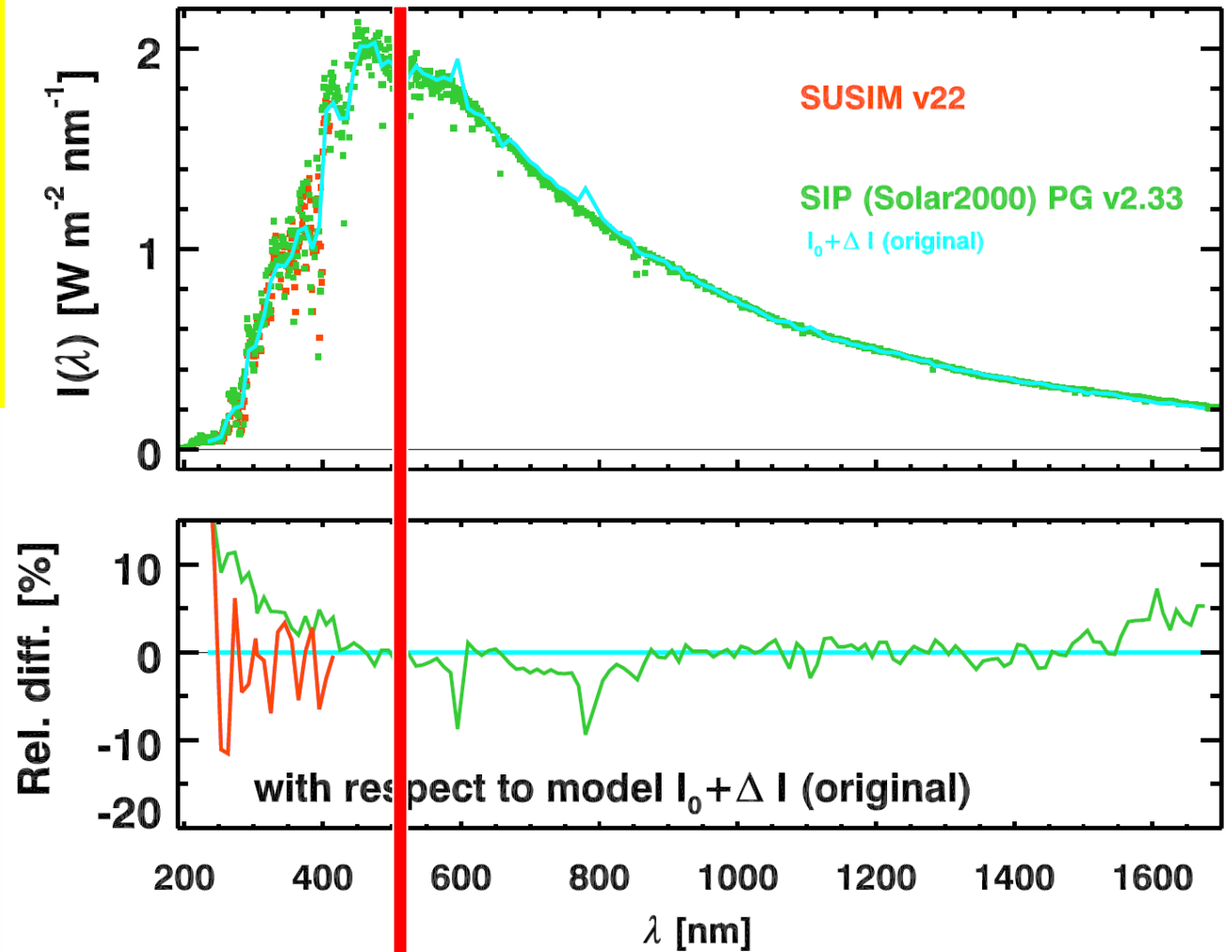


# Validation: spectral aspect

4th March 1994

distant past:  
outside time domain  
where parameters  
are derived

Reconstructed  $I(\lambda, t)$  on 1994-Mar-04



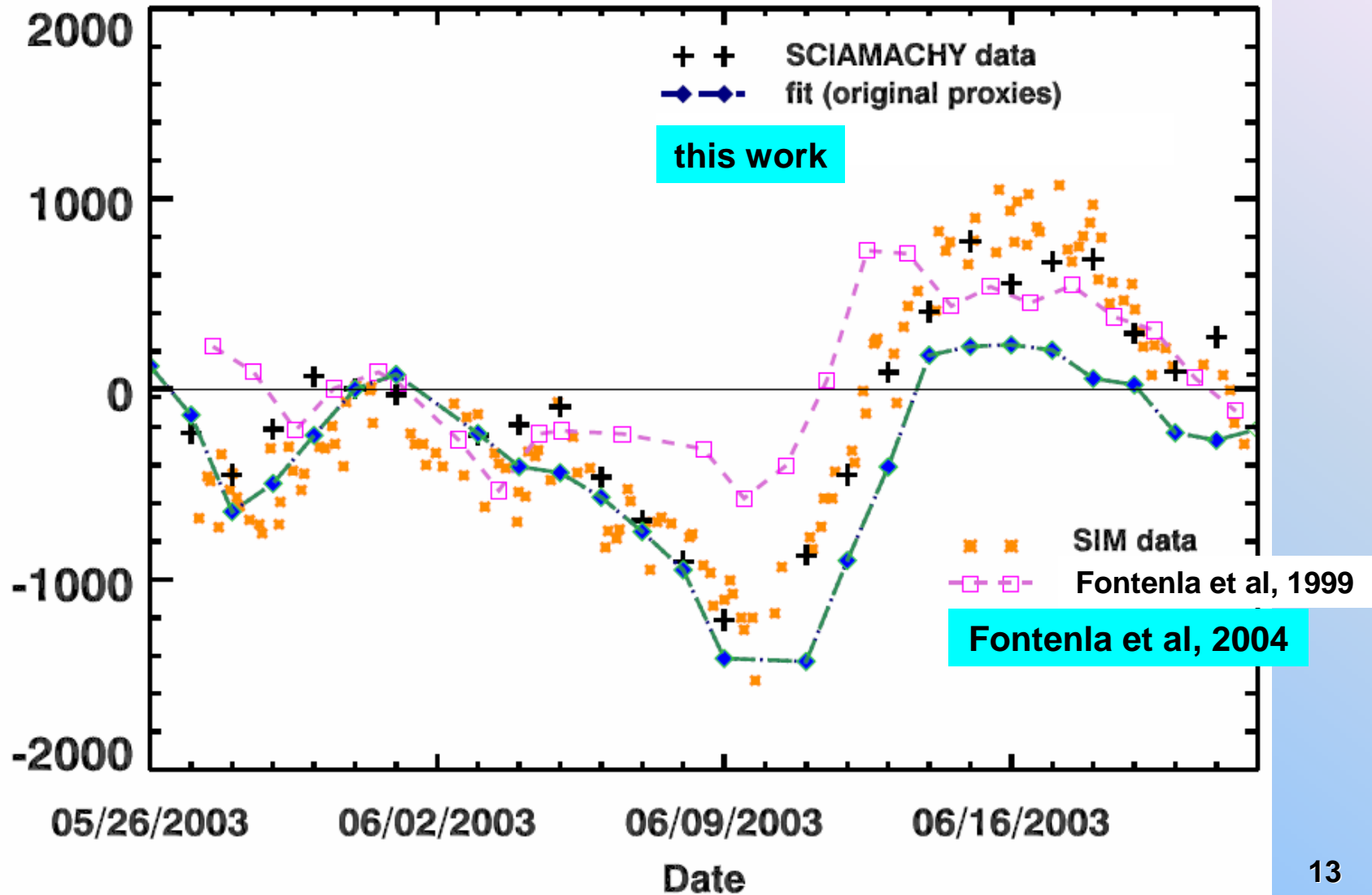
time slice: from 26 May 2003 to 22 Jun 2003



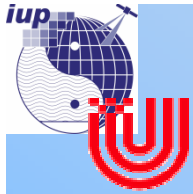
# Validation: temporal aspect

at visible: 515 nm

Irradiance relative to 05/31/2003 (ppm)

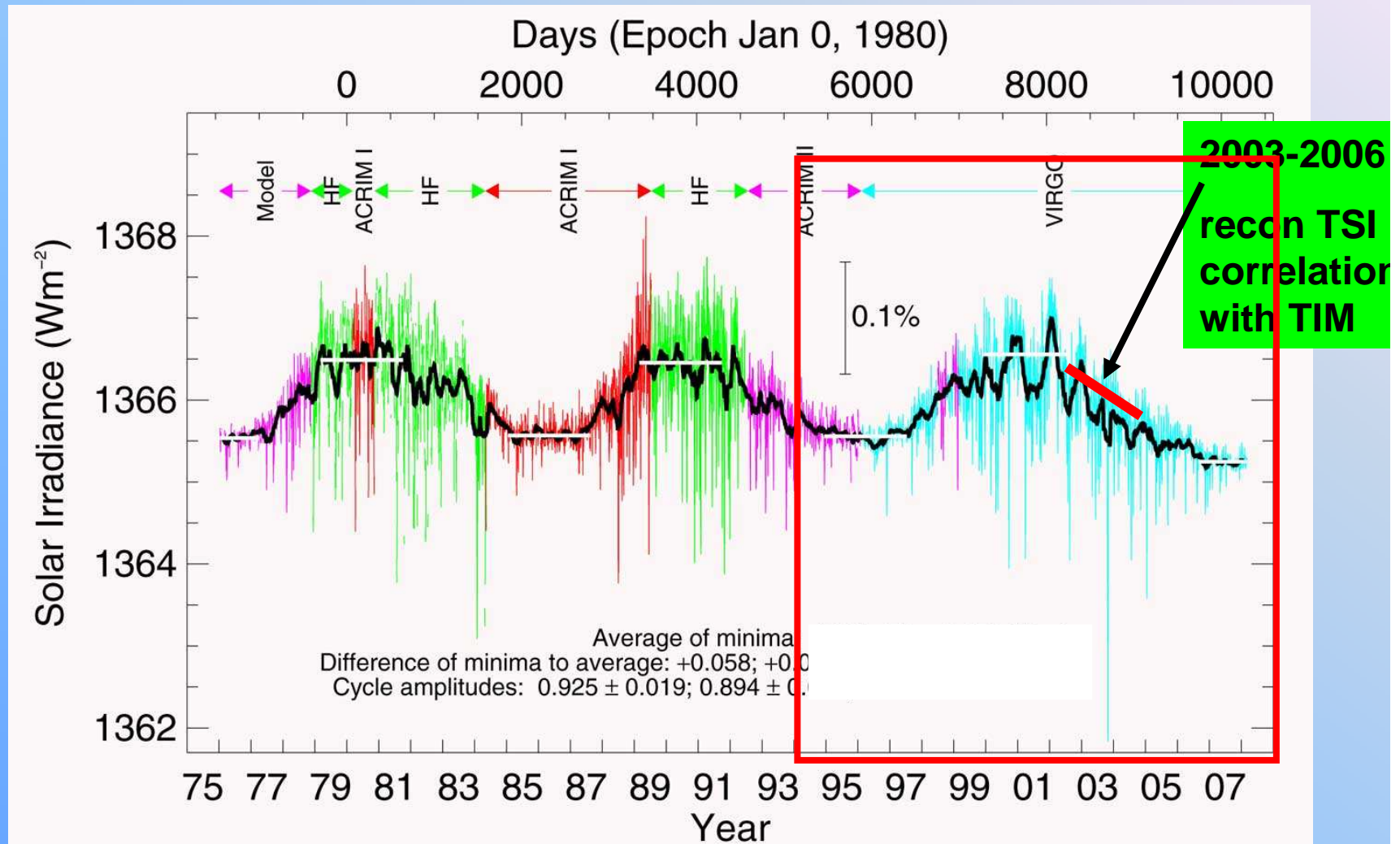


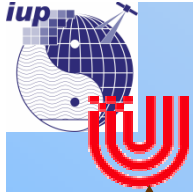




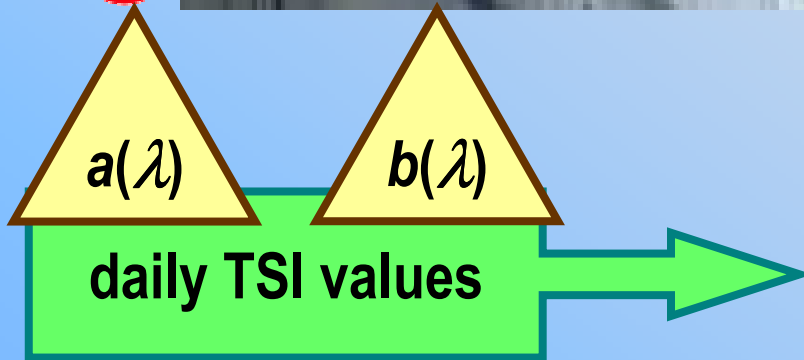
# Validation: temporal aspect

fig from Fröhlich





## Validation: temporal aspect



$$TSI_j = \int_{240 \text{ nm}}^{1670 \text{ nm}} I(\lambda, t_j) d\lambda$$

$t_j \in \text{satellite era}$

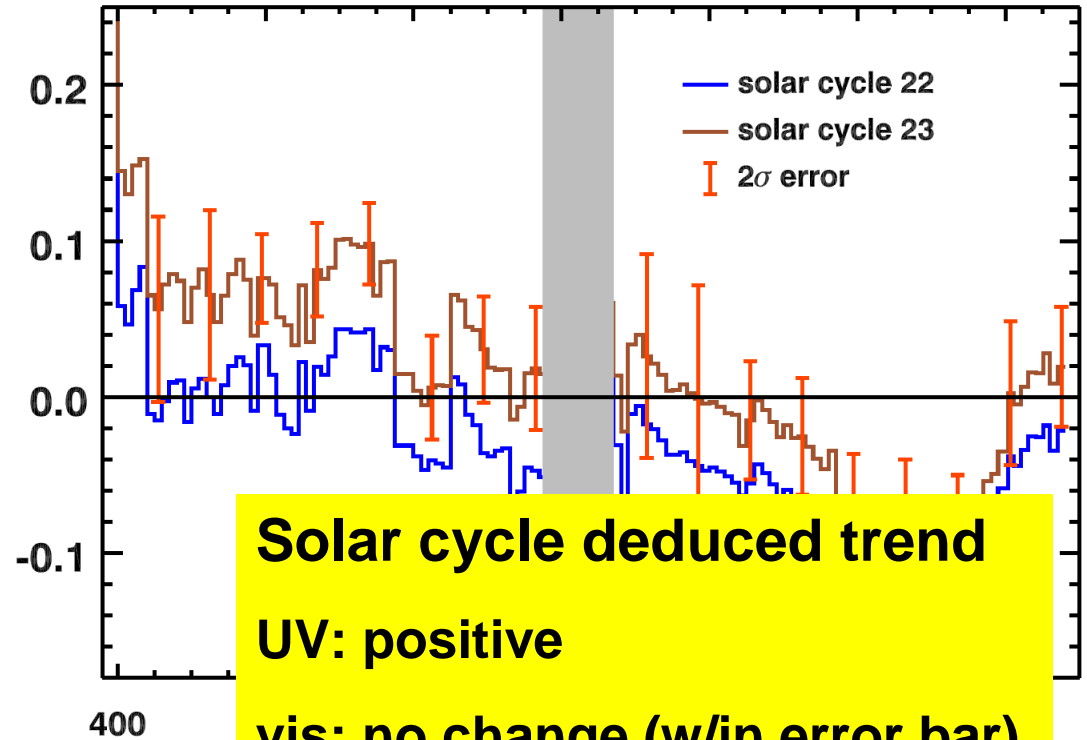
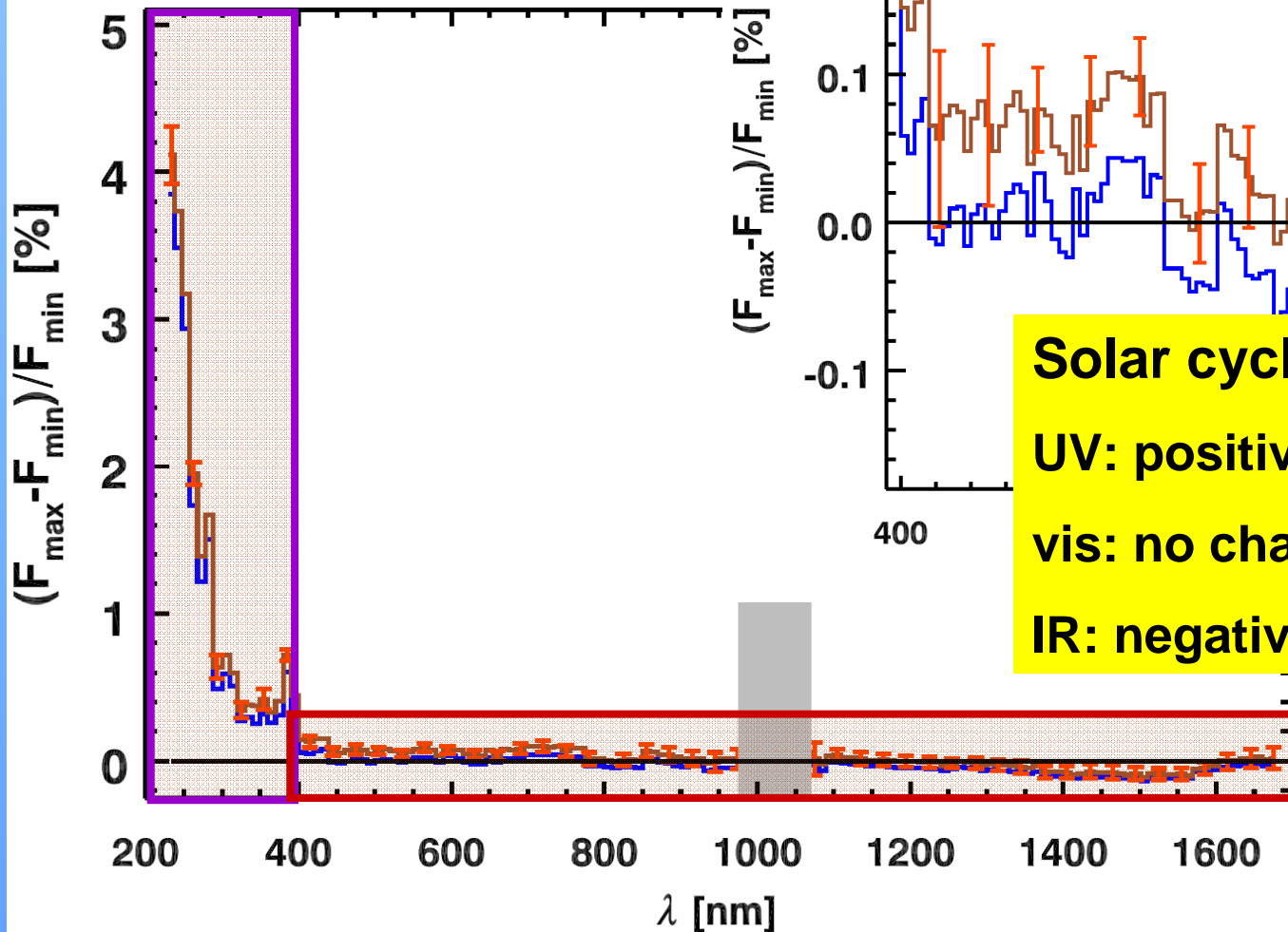
TSI record	Mean value (W m <sup>-2</sup> )	Standard deviation (W m <sup>-2</sup> )	Correlation with TIM (2003-2006)	Slope per year (W m <sup>-2</sup> )
TIM	1360.98	0.579	1.	- 0.182
PMOD	1365.76	0.573	0.9964	- 0.134
ACRIM	1366.09	0.582	0.9829	- 0.261
Lean (model)	1365.95	0.479	0.9634	- 0.069
<b>this work</b>	<b>1232.62</b>	<b>0.523</b>	<b>0.9186</b>	<b>- 0.038</b>

Table of values from Lean, NRL

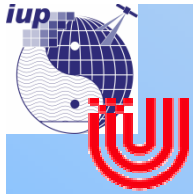


# 11-yr solar cycle UV-vis-IR variability

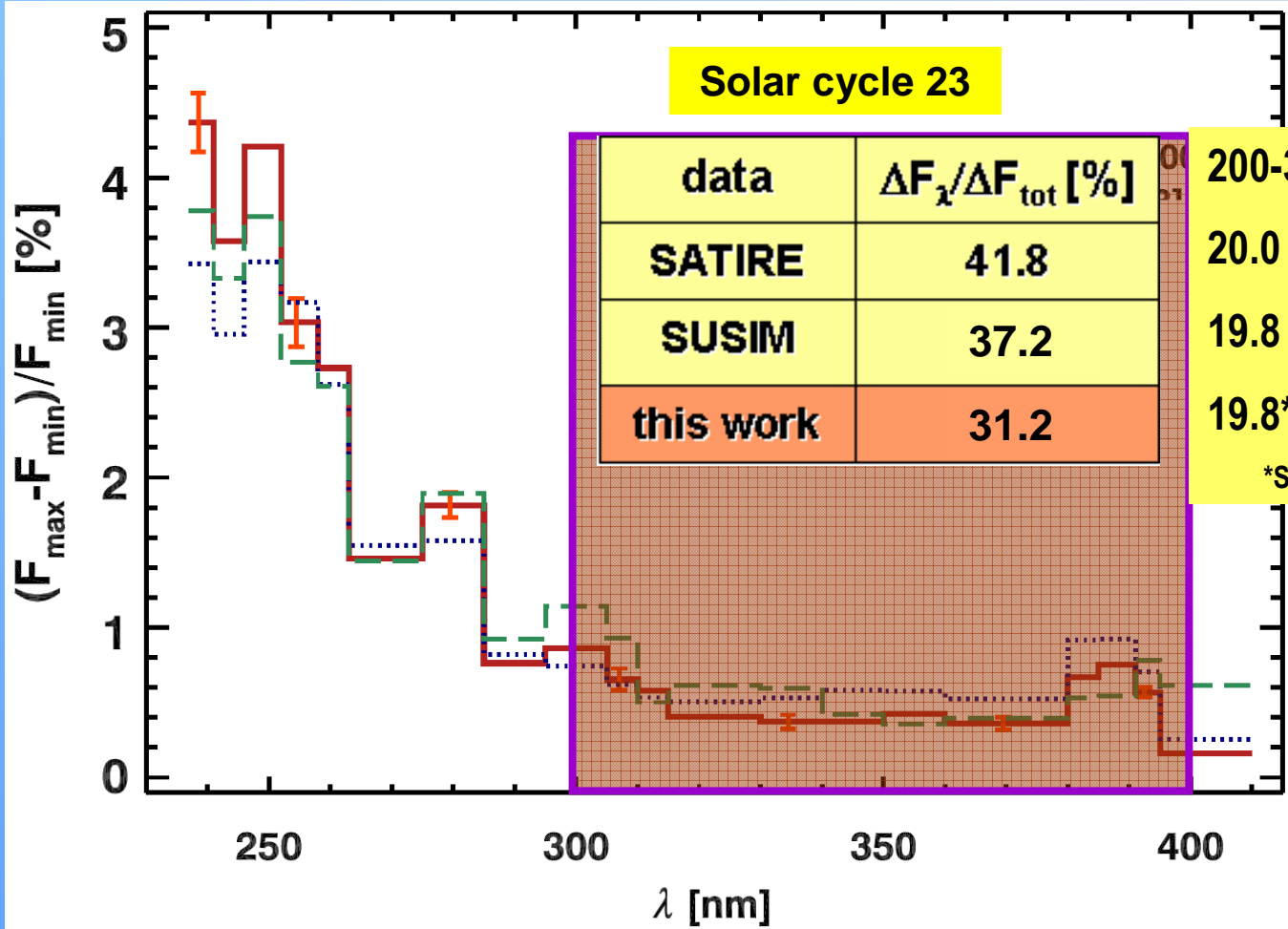
Vis-IR: 400-1700 nm



**Solar cycle deduced trend**  
**UV: positive**  
**vis: no change (w/in error bar)**  
**IR: negative at opacity min**



# UV contribution to 11-year $\Delta TSI$

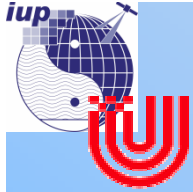


data	$\Delta F_{\lambda} / \Delta F_{tot}$ [%]
<b>SATIRE</b>	41.8
<b>SUSIM</b>	37.2
<b>this work</b>	31.2

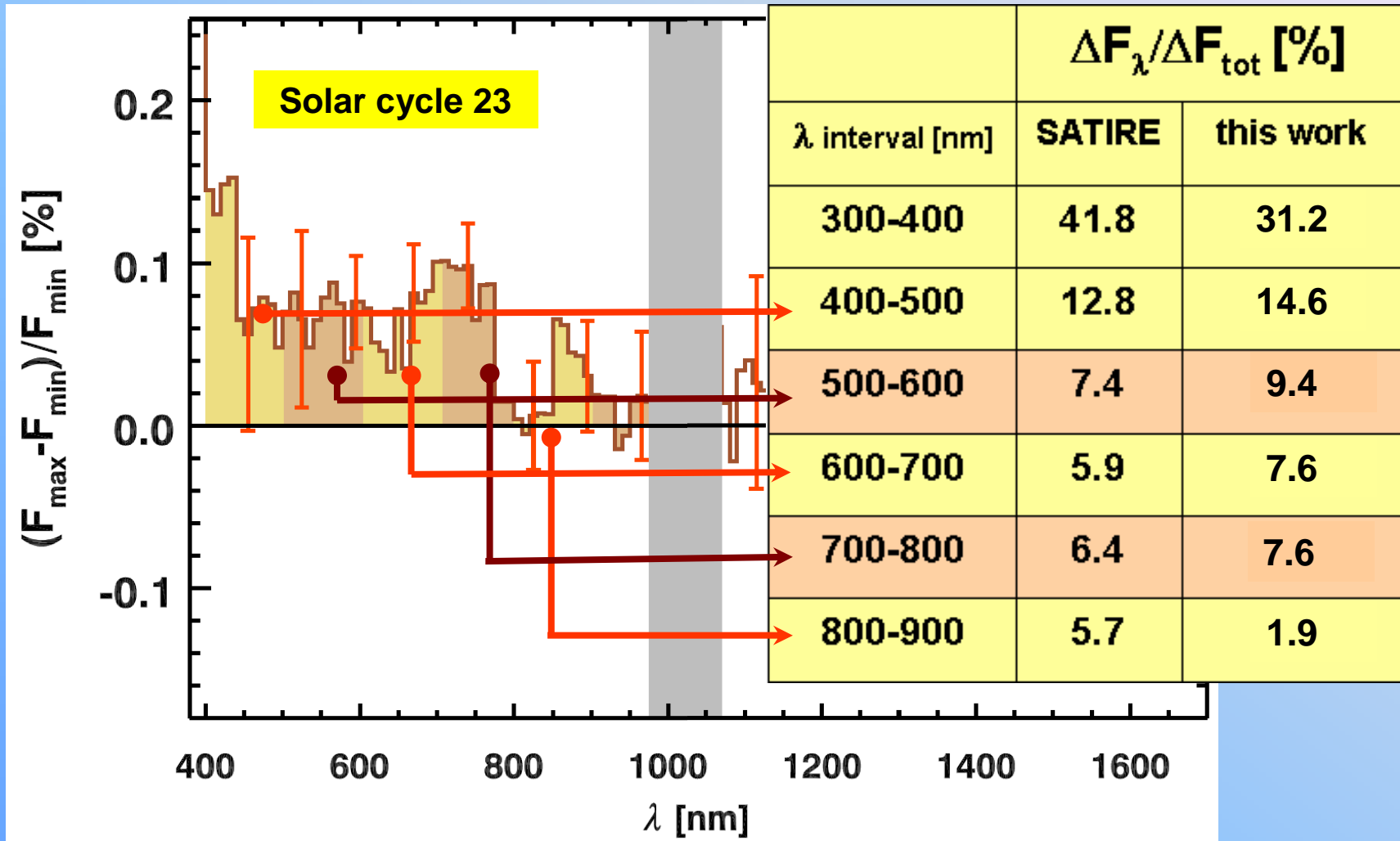
200-300 total UV	
20.0	/ 62
19.8	/ 57
19.8*	/ 51

\*SUSIM

cyc  $d\lambda$   
 $W m^{-2} nm^{-1}$



# vis-IR contribution to 11-year $\Delta TSI$







# Radiation intervals for GCMs

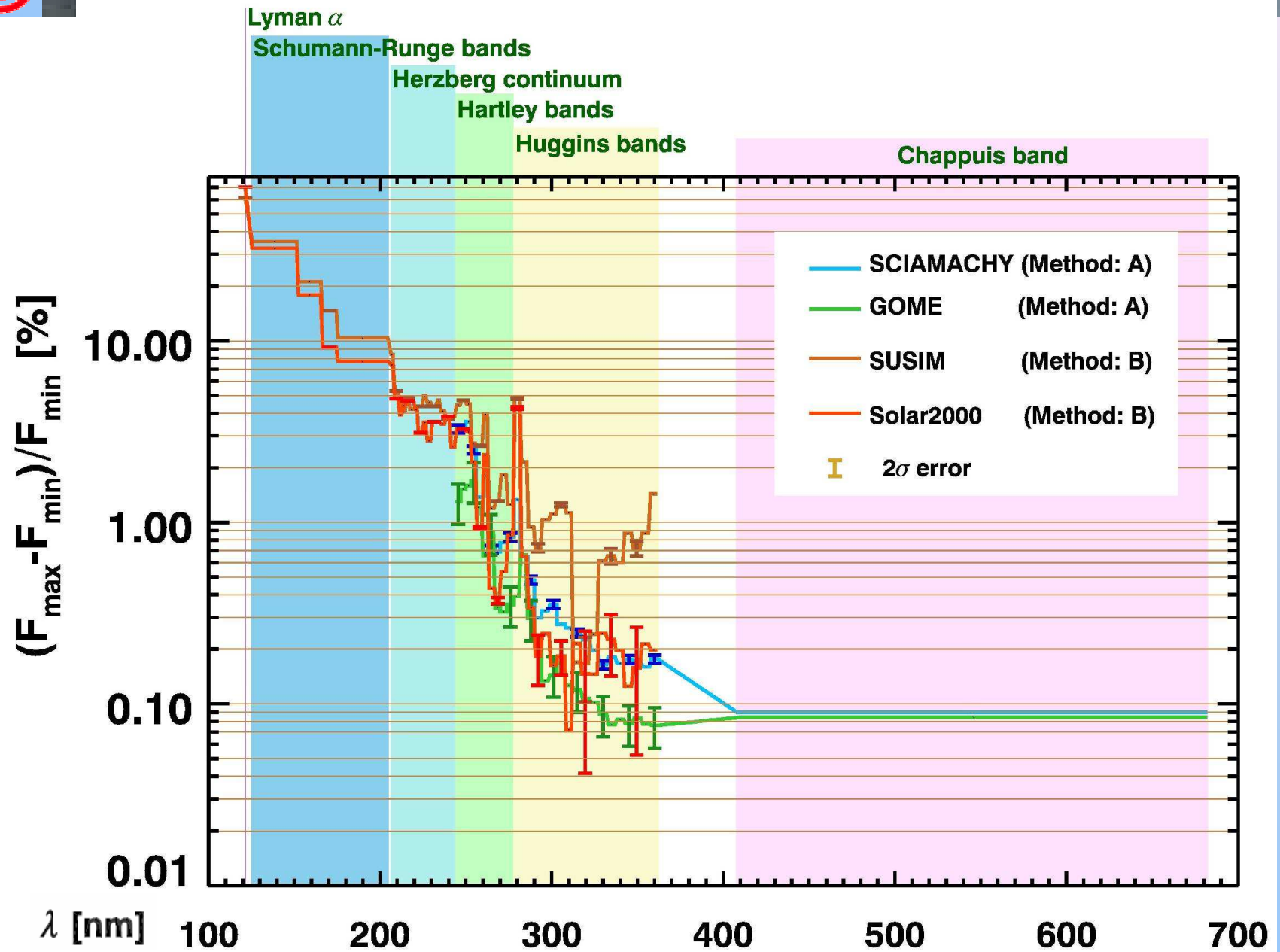
Band name Wavelength interval	No. of intervals	No. of modeled or calculated intervals			
		SCIA	GOME	SUSIM	SIP
Lyman $\alpha$ 121.5 nm	1 point	0	0	1	1
Schumann-Runge 125 – 205 nm	4 bands	0	0	4	4
Herzberg continuum 206 – 243 nm	15	0	0	15	15
Hartley bands 243 – 278 nm	10	10	10	10	10
Huggins bands 278 – 363 nm	18	18	18	18	18
Chappuis band 407 – 683 nm	1	1	1	0	0
<b>Total</b>	<b>49</b>	<b>29</b>	<b>29</b>	<b>48</b>	<b>48</b>
<b>Method</b>		<b>A</b>	<b>A</b>	<b>B</b>	<b>B</b>

**SIP (Solar2000)**  
from Tobiska, SpaceWx

**Method**  
A 11-yr extrapolation  
B direct ratio



# Radiation intervals for GCMs





## Summary and Recommendation

- \* A simple irradiance model parametrizes GOME and SCIAMACHY observed solar variations
    - using Mg II (faculae brightening) and PSI (sunspot darkening)
  - \* Using the simple model,
    - we estimate the 11-yr solar cycle variability radiation intervals that are relevant for GCMs
- after doing model validations:
- \* reconstructed daily spectra with SUSIM, SIM & SIP (**within 5%**)
  - \* reconstructed TSI and correlate with TIM  
(**slope comparable with Lean's model**)
  - \* 11-year contribution to  $\Delta$ TSI with SUSIM & SATIRE  
(**large difference at 300-400 nm**)

**We recommend that GCMs use our estimates of 11-year variability to improve sensitivity of solar cycle influence on climate.**



## Acknowledgements



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„Solar variability and ozone interaction“

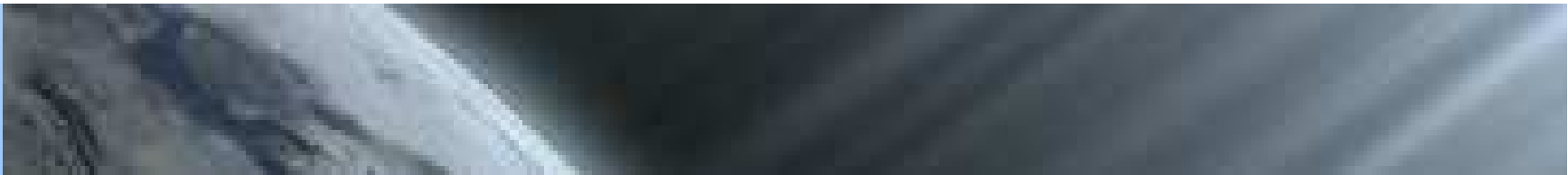
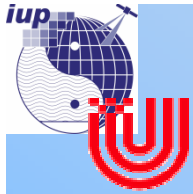
Deutsche  
Forschungsgemeinschaft

(2) **ISSI, Bern, Switzerland**

„Solar data, interpretation, and modeling“







Institut für Umweltphysik



Universität Bremen



# Bremen

## COSPAR

18-25 July 2010

Bremen, Germany