The New Obervational SSI Composite and Related Activities

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Effects of Solar Radiation on the Earth‘s atmosphere

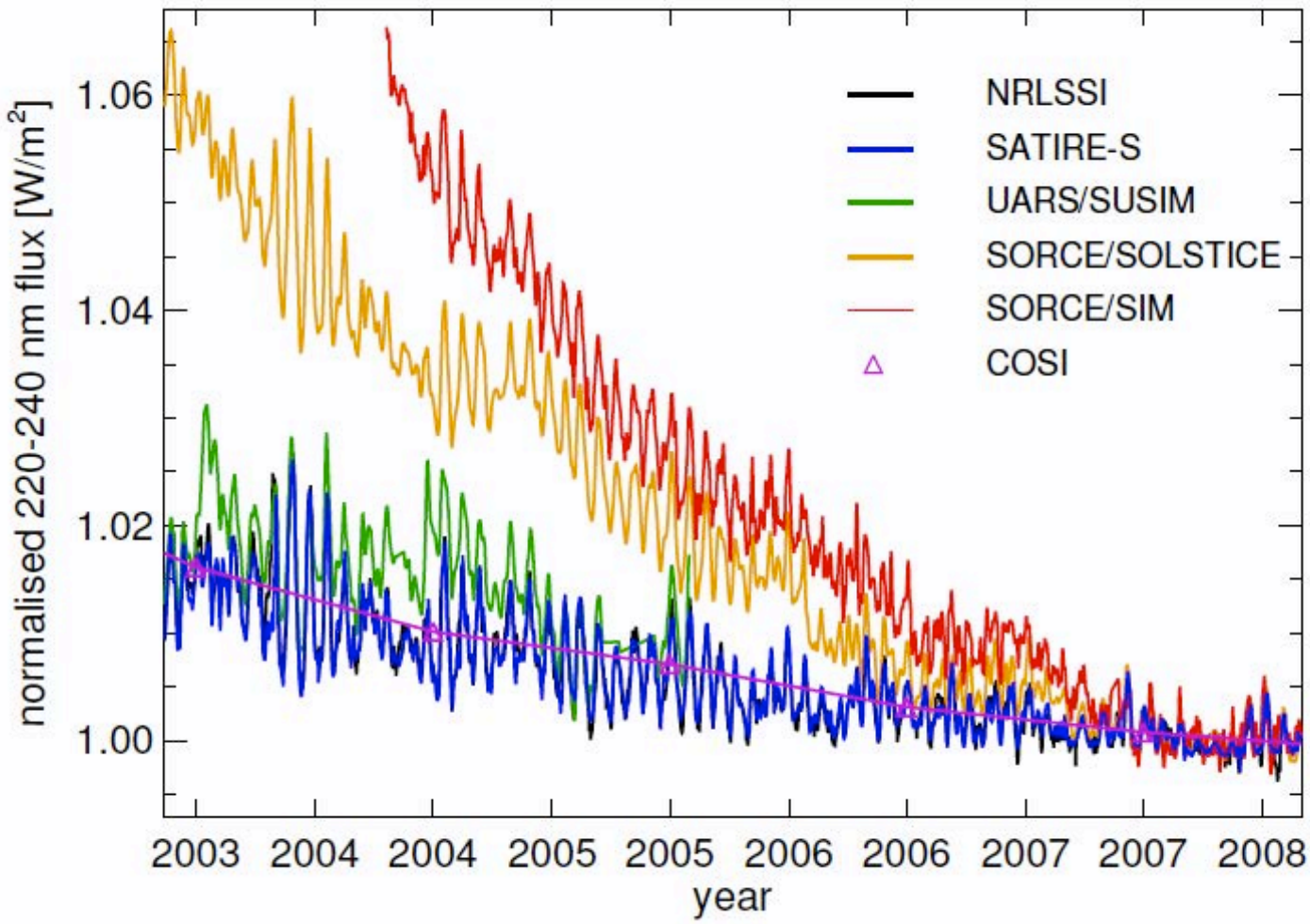
The absorption of solar radiation has an effect on the atmosphere due to:

- Radiative processes
- Chemical processes
- Dynamical processes

... and their interaction and coupling

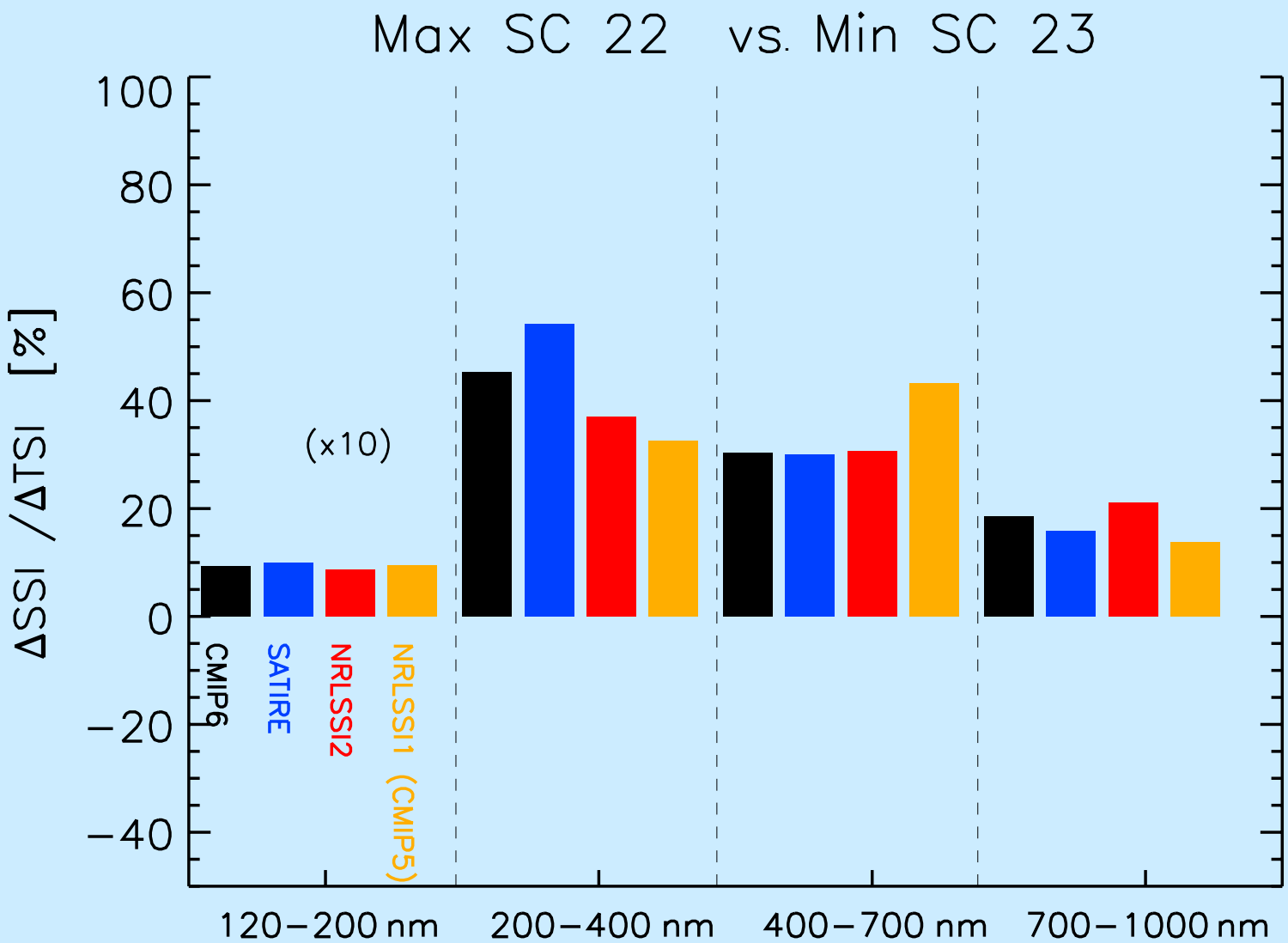
Solar signal is global, but shows a strong regional response

2. Existing data and models do not agree



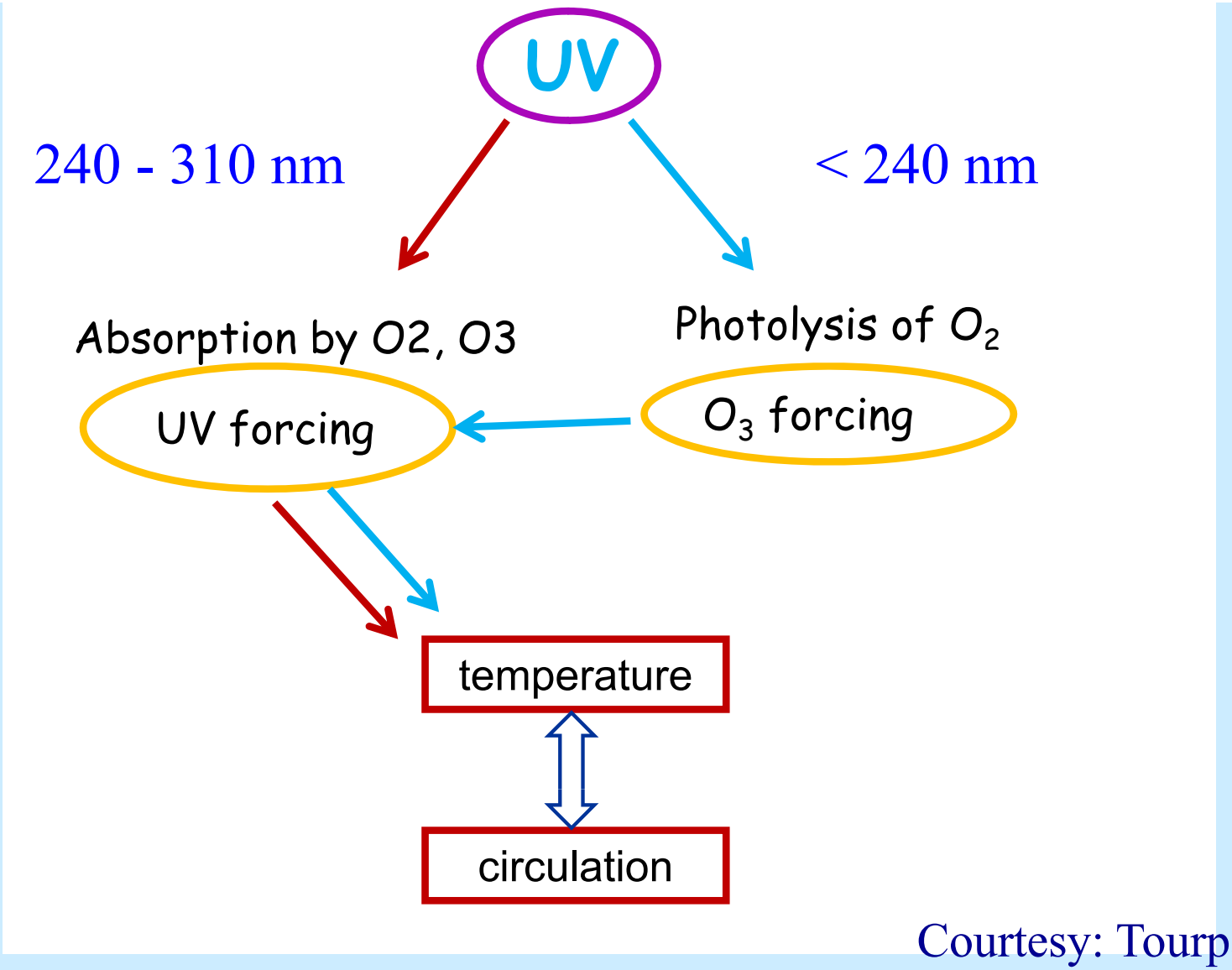
Ermolli et al., 2013, ACP

SSI Variability



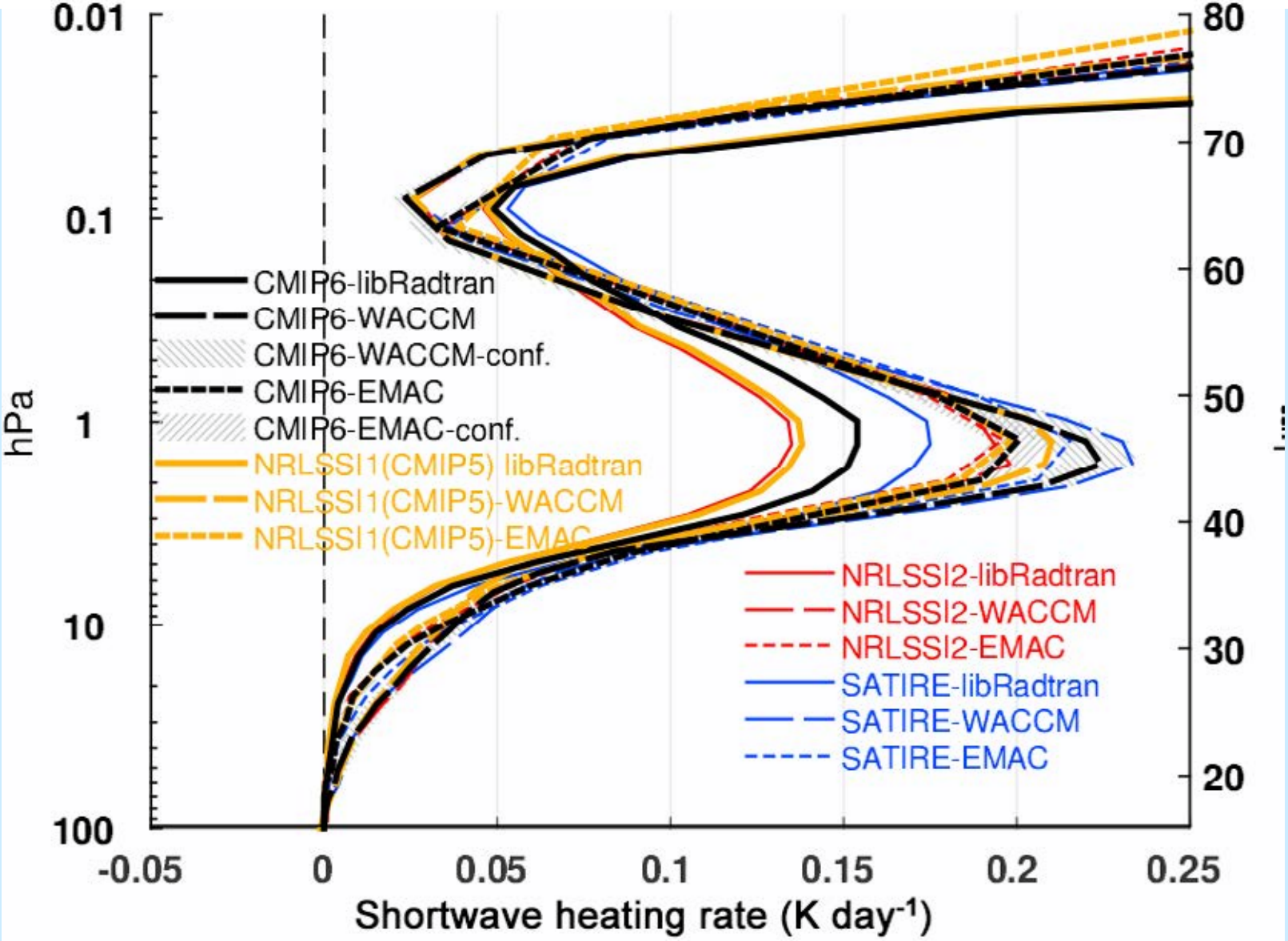
Matthes et al., 2017

Effects of Solar Variability on the atmosphere



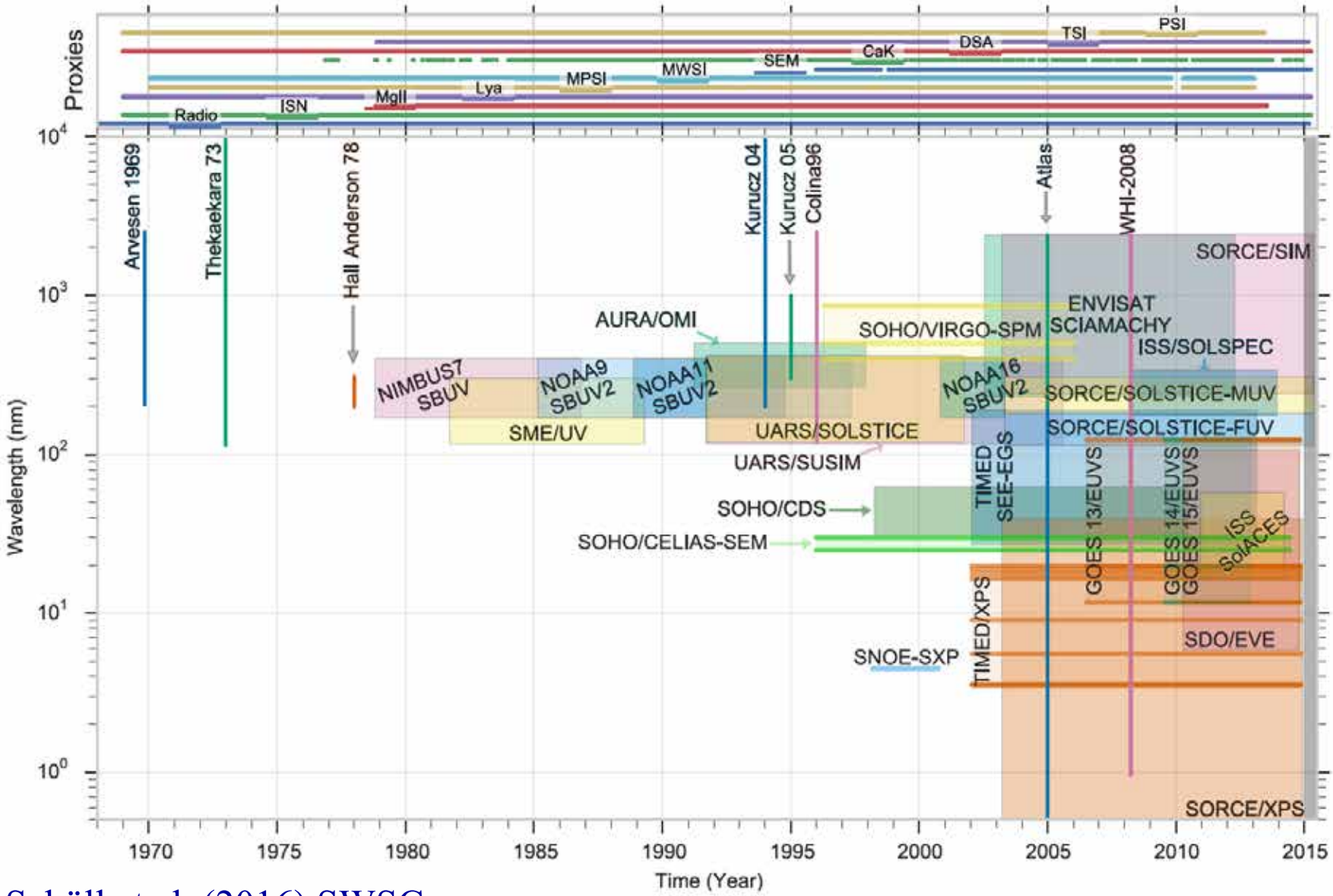
Courtesy: Tourpali

Differences in Shortwave heating rate (K day^{-1})



Matthes et al. (2017)

SSI Observations



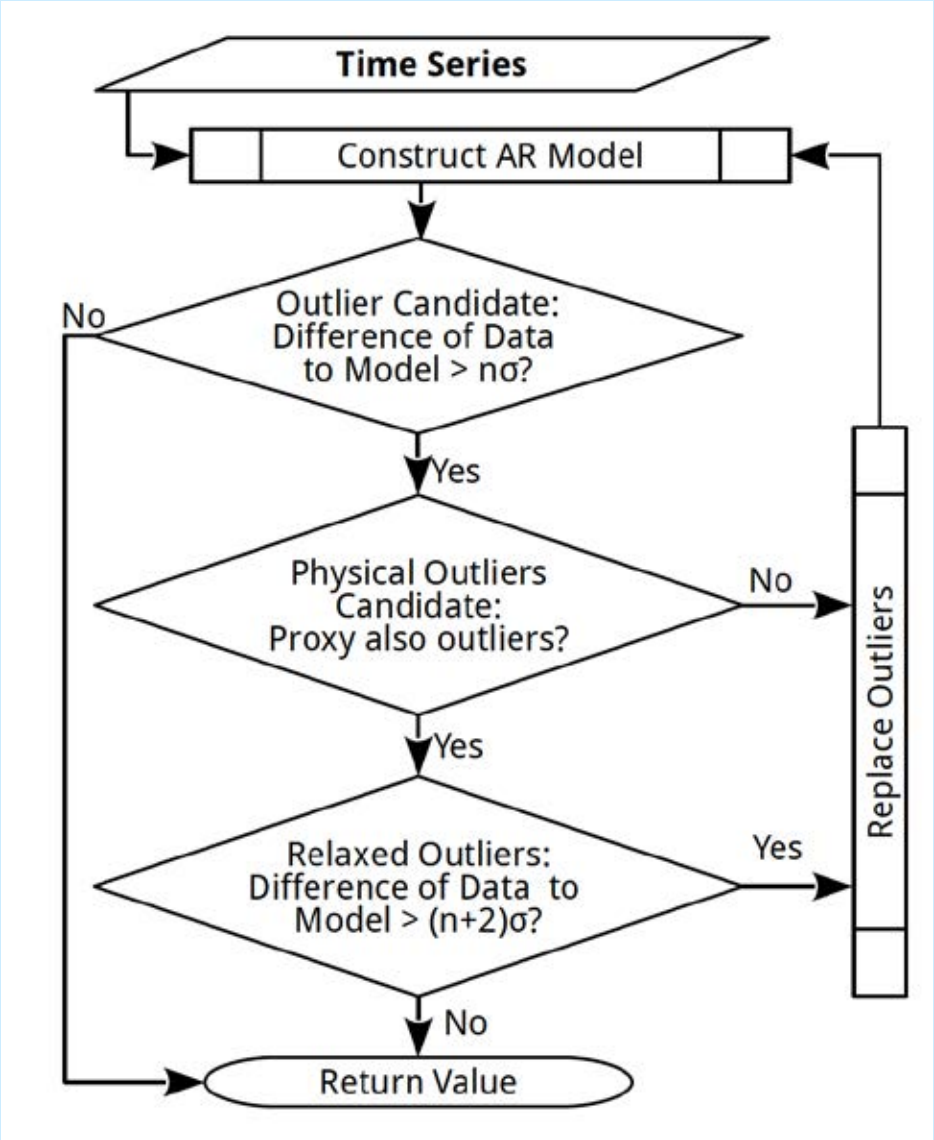
Schöll et al. (2016) SWSC

20 SSI datasets used in Composite

Name of the instrument	Wavelength range [nm]	Observation Period
GOES13/EUVS	11.7–123.2	07/2006–10/2014
GOES14/EUVS	11.7–123.2	07/2009–11/2012
GOES15/EUVS	11.7–123.2	04/2010–10/2014
ISS/SolACES	16.5–57.5	01/2011–03/2014
NIMBUS7/SBUV	170.0–399.0	11/1978–10/1986
NOAA9/SBUV2	170.0–399.0	03/1985–05/1997
NOAA11/SBUV2	170.0–399.0	12/1988–10/1994
NOAA16/SBUV2	170.0–406.2	10/2000–04/2003
SDO/EVE	5.8–106.2	04/2010–10/2014
SME/UV	115.5–302.5	10/1981–04/1989
SNOE/SXP	4.5	03/1998–09/2000
SOHO/CDS	31.4–62.0	04/1998–06/2010
SOHO/SEM	25.0–30.0	01/1996–06/2014
SORCE/SIM	240.0–2412.3	04/2003–05/2015
SORCE/SOLSTICE	115.0–309.0	04/2003–05/2015
SORCE/XPS	0.5–39.5	04/2003–05/2015
TIMED/SEE-EGS	27.1–189.8	02/2002–02/2013
TIMED/SEE-XPS	1.0–9.0	01/2002–11/2014
UARS/SOLSTICE	119.5–419.5	10/1991–09/2001
UARS/SUSIM	115.5–410.5	10/1991–08/2005

Haberreiter er al. (2017)

Quality check of SSI data



Schöll et al., 2016

Individual steps towards the SSI observational composite

1. Quality checked datasets
   - short-term uncertainty (noise) evaluation
   - long-term uncertainty (degradation) evaluation
2. Extension of datasets to first space observations (Nov 1978)
   - using expectation maximization (Dudok de Wit, 2011)
   - increased uncertainty for extrapolated values
3. Temporal decomposition of the datasets into 13 time scales (1 day to 22 years) for each wavelength;
4. Combined uncertainty at each wavelength and scale;
5. Weighted average of the SSI timeseries at all scales;
6. Absolute scaling of the SSI composite to ATLAS3 and TSI the date of ATLAS3

Extension of individual SSI datasets

- Multi-scale decomposition can only be performed on regularly sampled time series with no missing data
- Approach:
  - Maximum likelihood (Dudok de Wit, 2011)
  - Makes use of the correlation between specific SSI bands and a set of proxies to fill the gaps
  - Two temporal scales with a cut-off at 81 days
  - Extension of each dataset to Nov 1, 1978 (start of the space observations) and to “present”

Proxy datasets used for gap filling

Name of proxy	Origin (Observatory)	relevant for
30.0 cm radio flux	Nobeyama/Toyokawa	UV
15.0 cm radio flux	Nobeyama/Toyokawa	UV
10.7 cm radio flux	Penticton/Ottawa	EUV/UV
8.2 cm radio flux	Nobeyama/Toyokawa	EUV/UV
3.2 cm radio flux	Nobeyama/Toyokawa	EUV/UV
sunspot darkening	Greenwich/SOON netw.	VIS

Temporal Scale Decomposition

1. Decomposition of the original time series $d(t)$ into multiple orthogonal time series d^*: Convolution with Gaussian kernel $G(t)$ of width (scale) $a = 2^j$

$$d^*_{j,\lambda}(t) = d_\lambda(t) \star \mathcal{G}(t, 2^j)$$

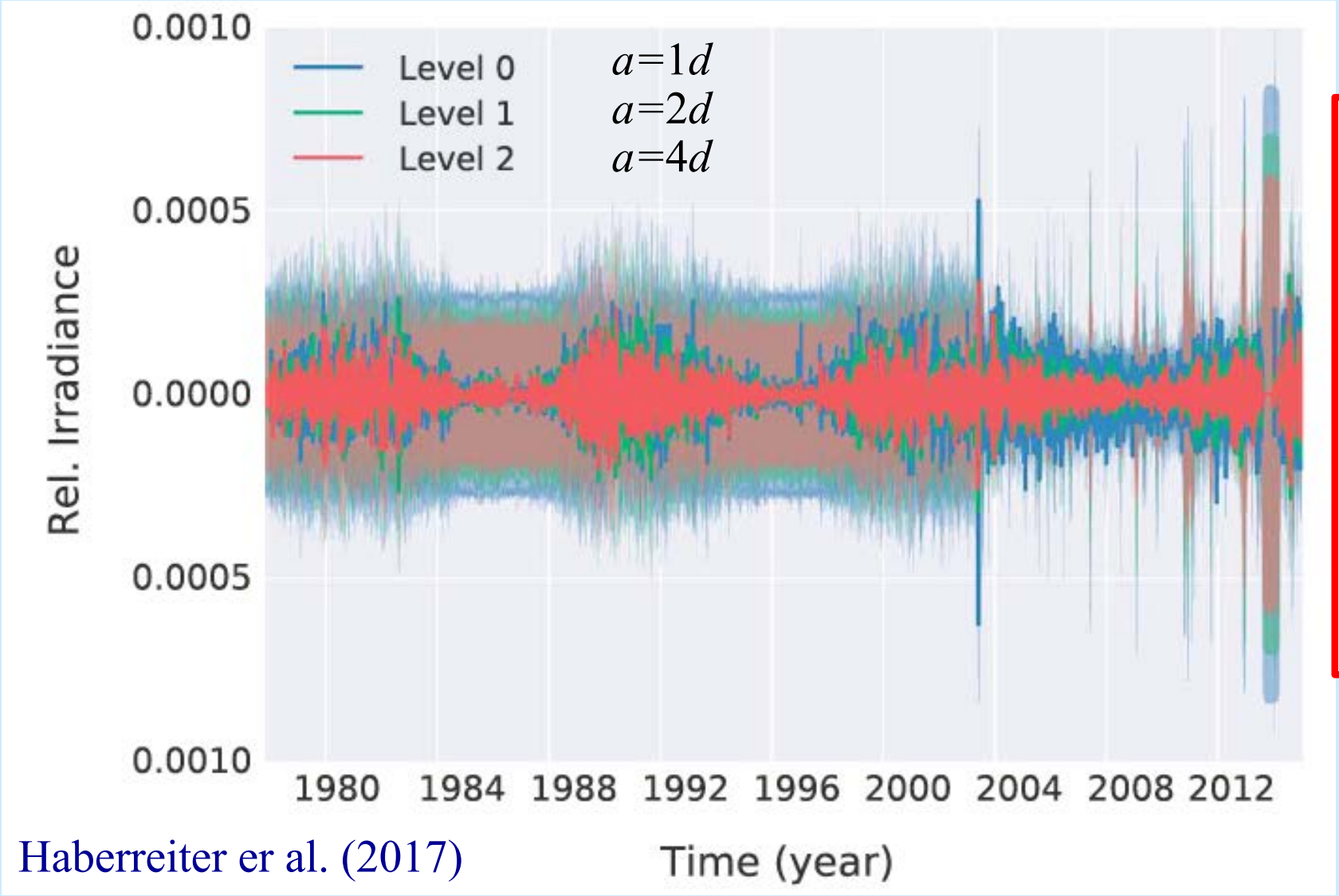
2. The wavelet transform at level j:

$$d_{j,\lambda} = \begin{cases} d^*_{j,\lambda} - d^*_{j+1,\lambda} & \text{if } j < J \\ d^*_{j,\lambda} & \text{if } j = J. \end{cases}$$

1. Summation of wavelet transforms yields original dataset:

$$d_\lambda = \sum_{j=0}^{J} d_{j,\lambda}$$

Temporal decomposition of the datasets
Example: SORCE/SOLSTICE at 220.5nm



Haberreiter er al. (2017)

$a = 2^j$

$a_J = 2^J \leq d$

Scale a

Level j

j=1 day, …., "22 yrs"

Temporal decomposition of the datasets
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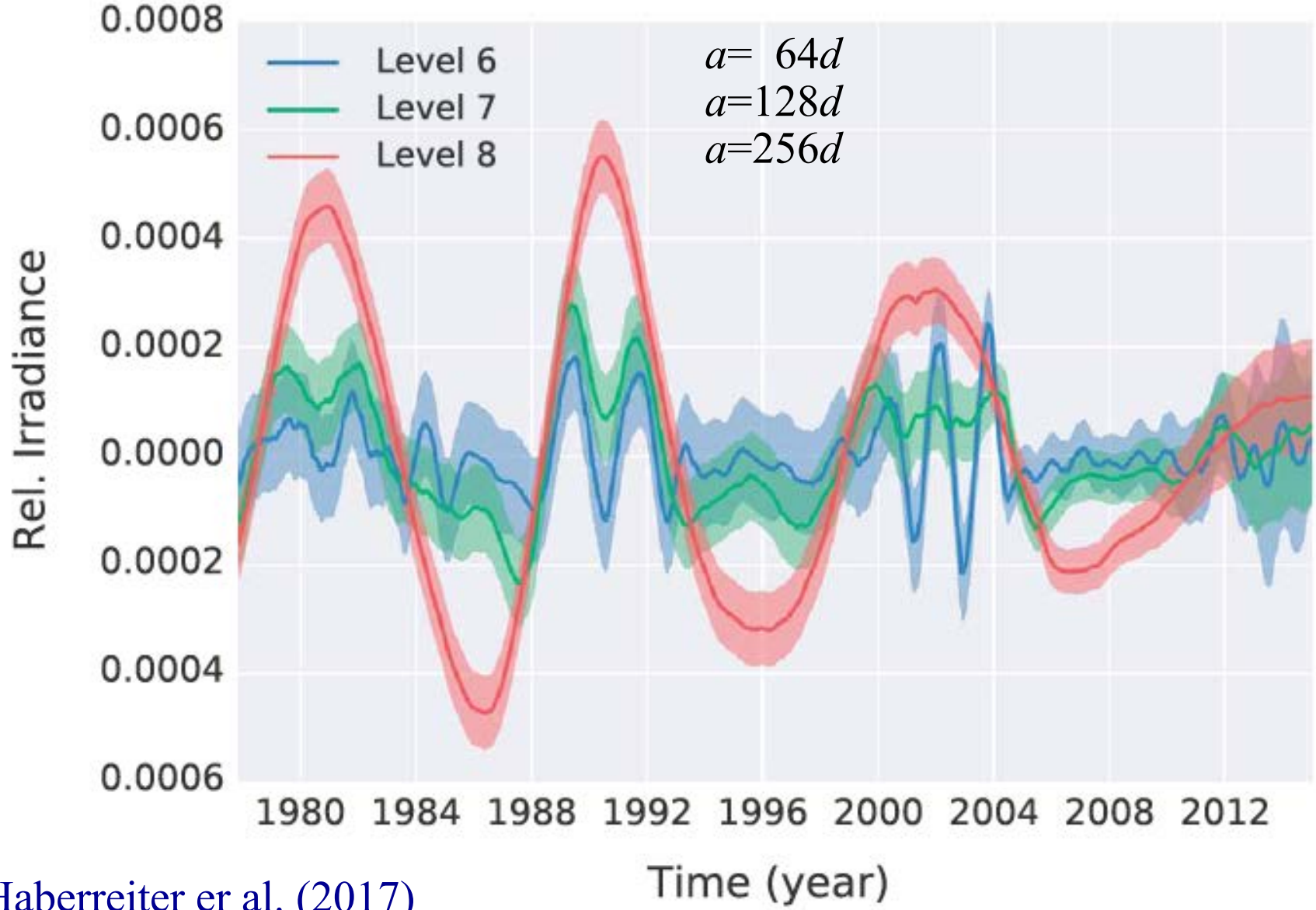

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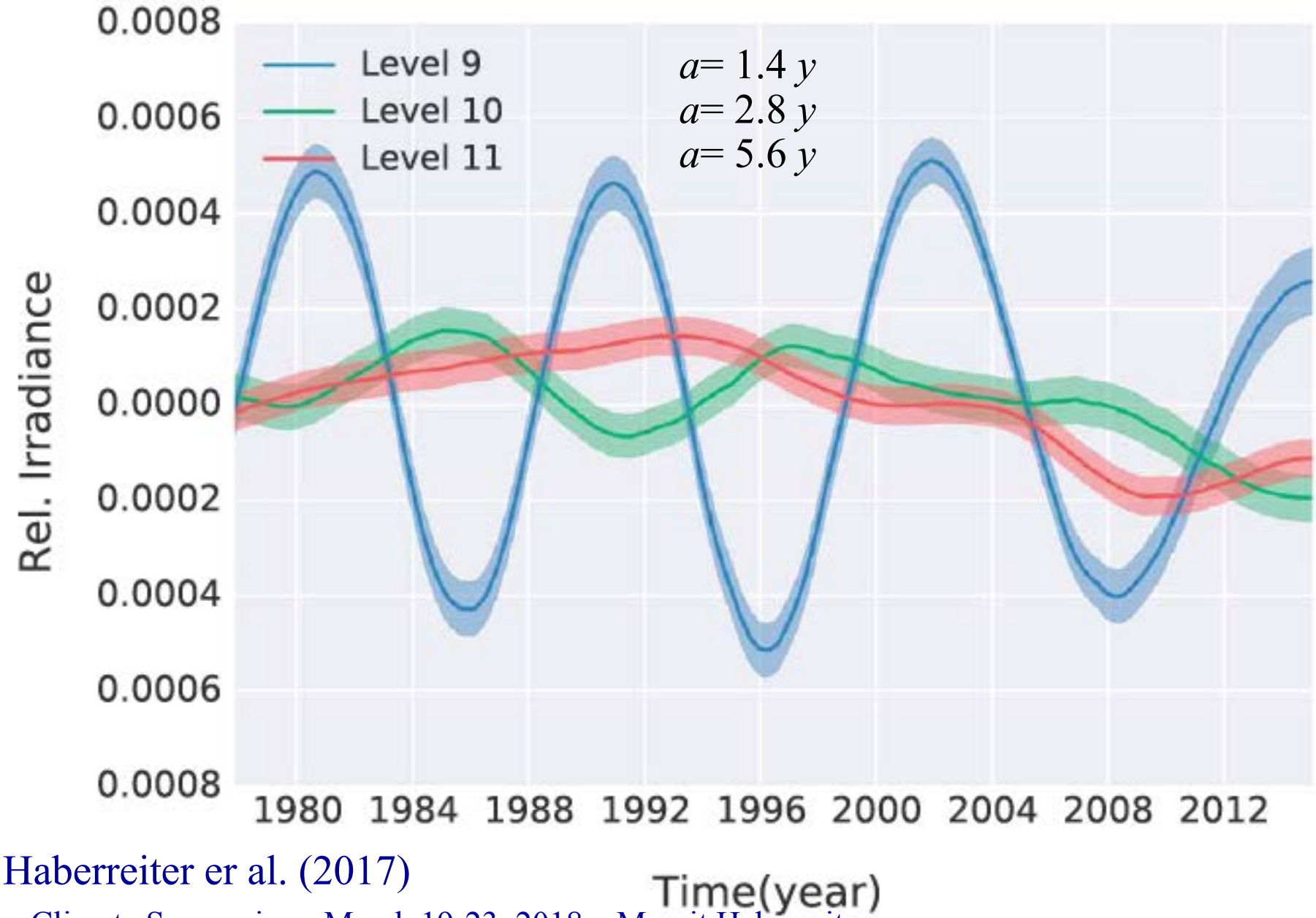


Haberreiter er al. (2017)

Uncertainty of the SOLID dataset

- At each level j both **stability** and **precision** contribute to the combined uncertainty
- The uncertainty $\epsilon_{\lambda,j}(t)$ at level j is the weighted spectrum of the squared **precision** $\boldsymbol{\epsilon_\lambda^2(t)}$, together with a weighted and scaled sum of the **stability** $\boldsymbol{s_\lambda(t)}$, where the weights are the Gaussian kernel for both precision and stability
- the stability is scaled proportional to the kernel width a.

$$\epsilon_{j,\lambda}(t) = \sqrt{\left(\epsilon_\lambda(t) \star \mathcal{G}(t, 2^j)\right)^2 + \left(a\, s_\lambda(t) \star \mathcal{G}\left(t, 2^j\right)\right)^2}$$

Uncertainty of SOLID dataset

Scale-wise components, $\bar{d}_j$, of the composite for each level j

$$\bar{d}_j = \sum_{i \in I} d_{i,j} w_{i,j}$$

Respective uncertainties, $\bar{\epsilon}_j$, again for each level j, instrument i

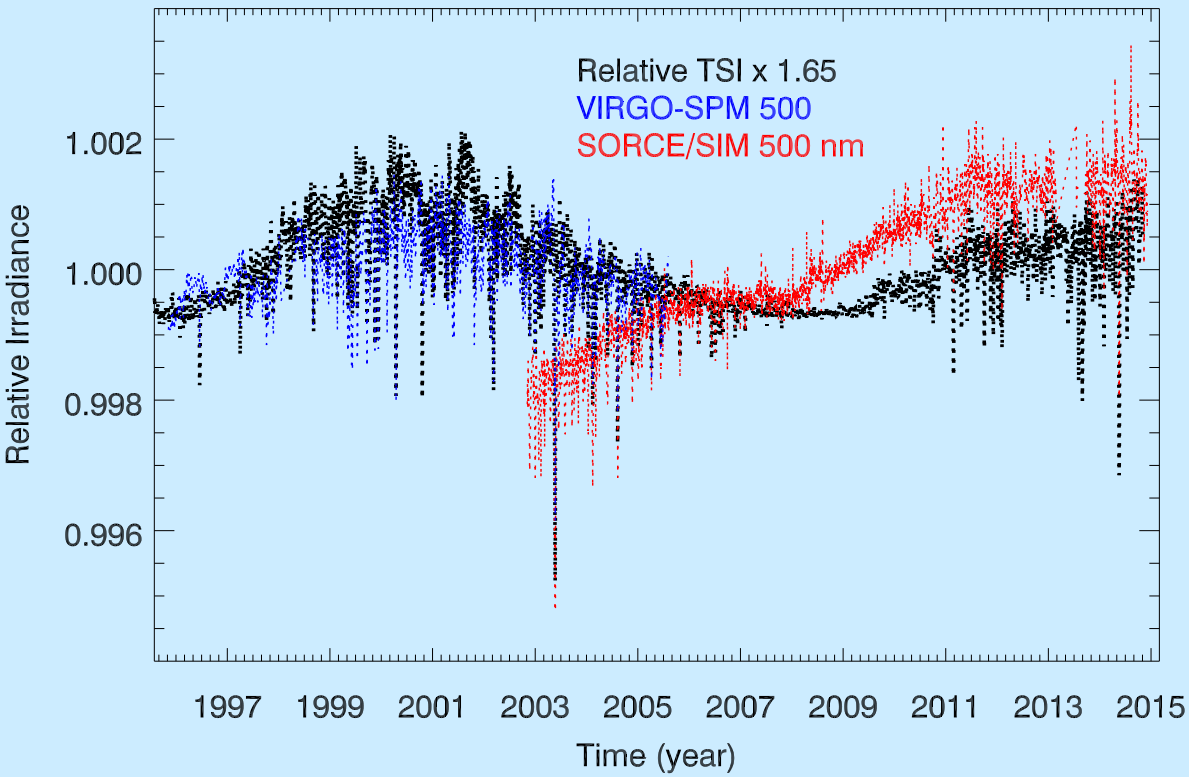
$$\bar{\epsilon}_j = \left(\sum_{i \in I} \epsilon_{i,j}^2 w_{i,j}^2 \right)^{1/2}$$

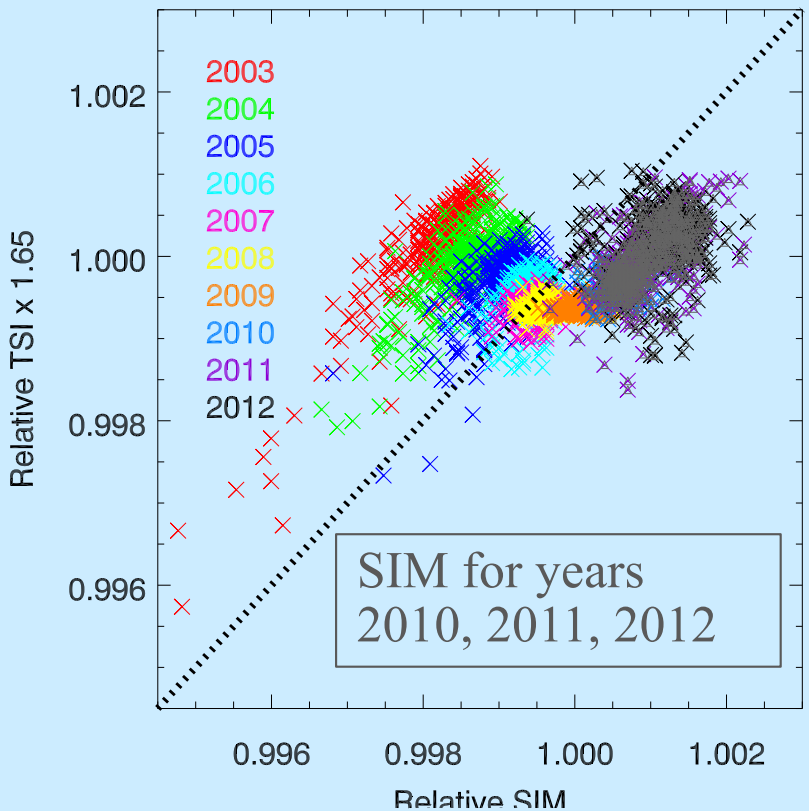
with weights $w_{i,j}$ for level (scale) j and instrument i for each wavelength

$\epsilon_{i,j}$ is the corresponding uncertainty at level (scale) j.

$$w_{i,j} = \frac{\epsilon_{i,j}^{-2}}{\sum_{k \in I} \epsilon_{k,j}^{-2}}$$

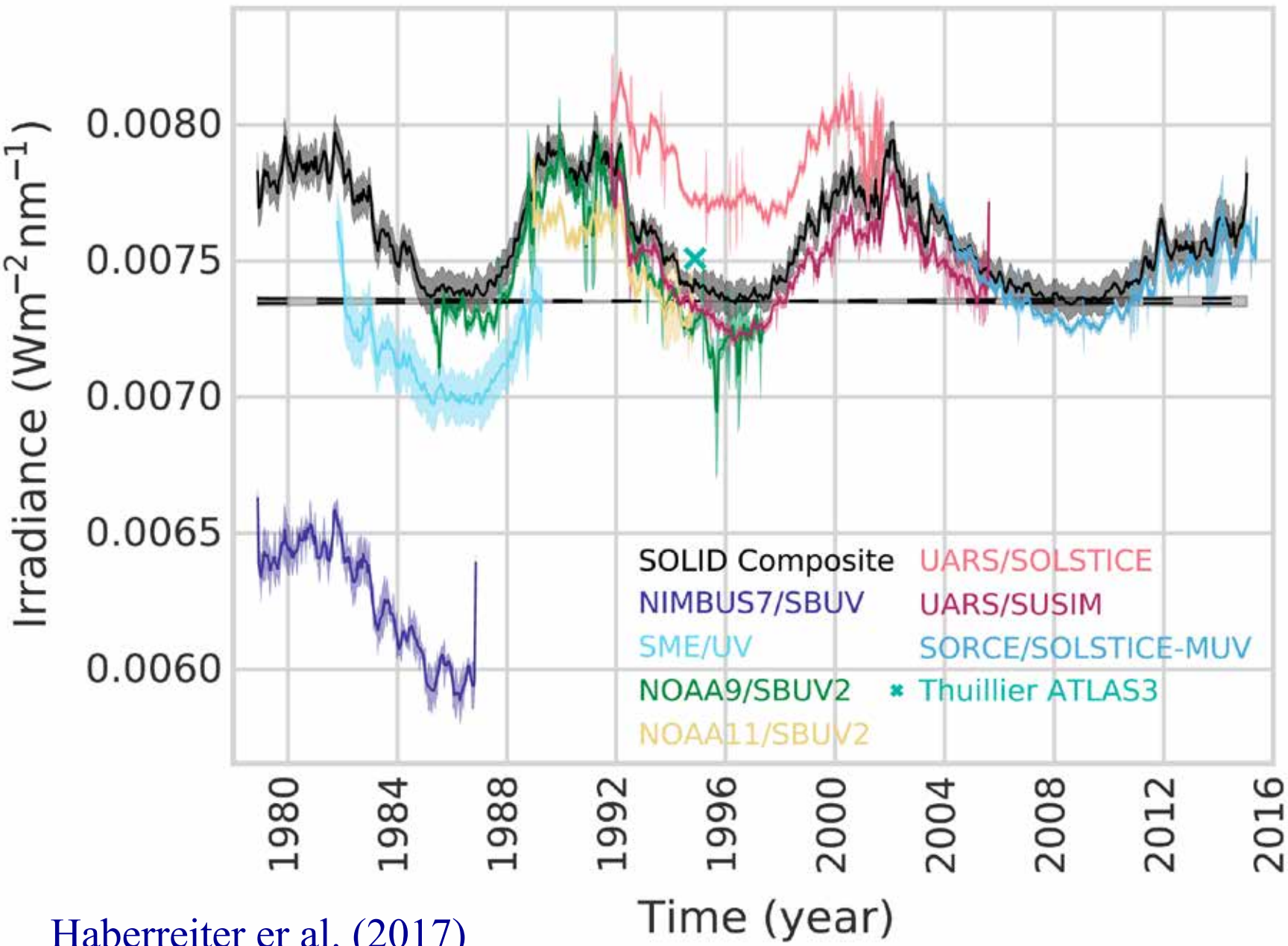
Evaluation of SORCE/SIM @500nm vs TSI





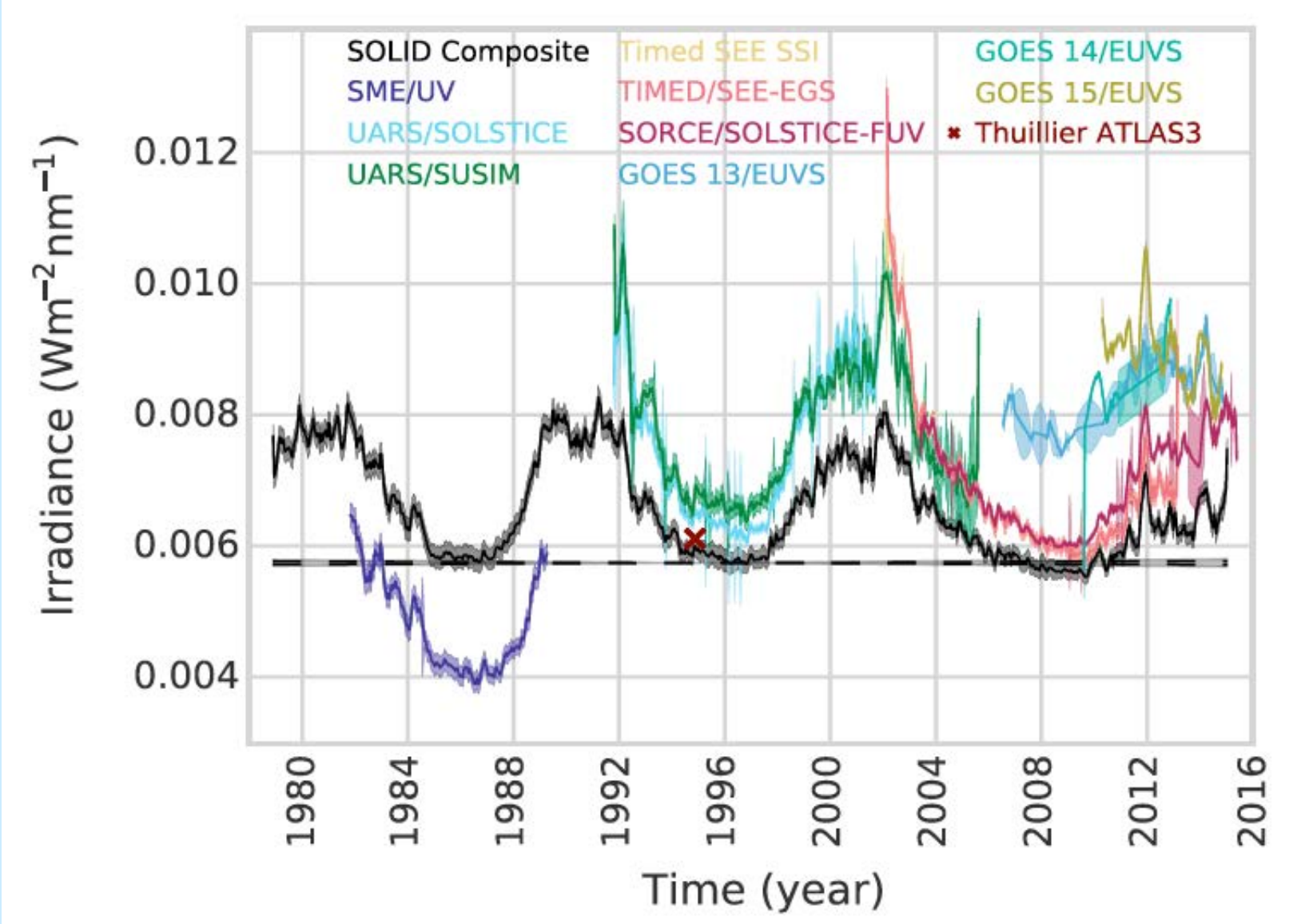
Wehrli et al. (2013):
Statistically significant scaling law between TSI and SPM@500nm
With slope 1.65 between TSI and SPM@500nm

SSI datasets – 200.5

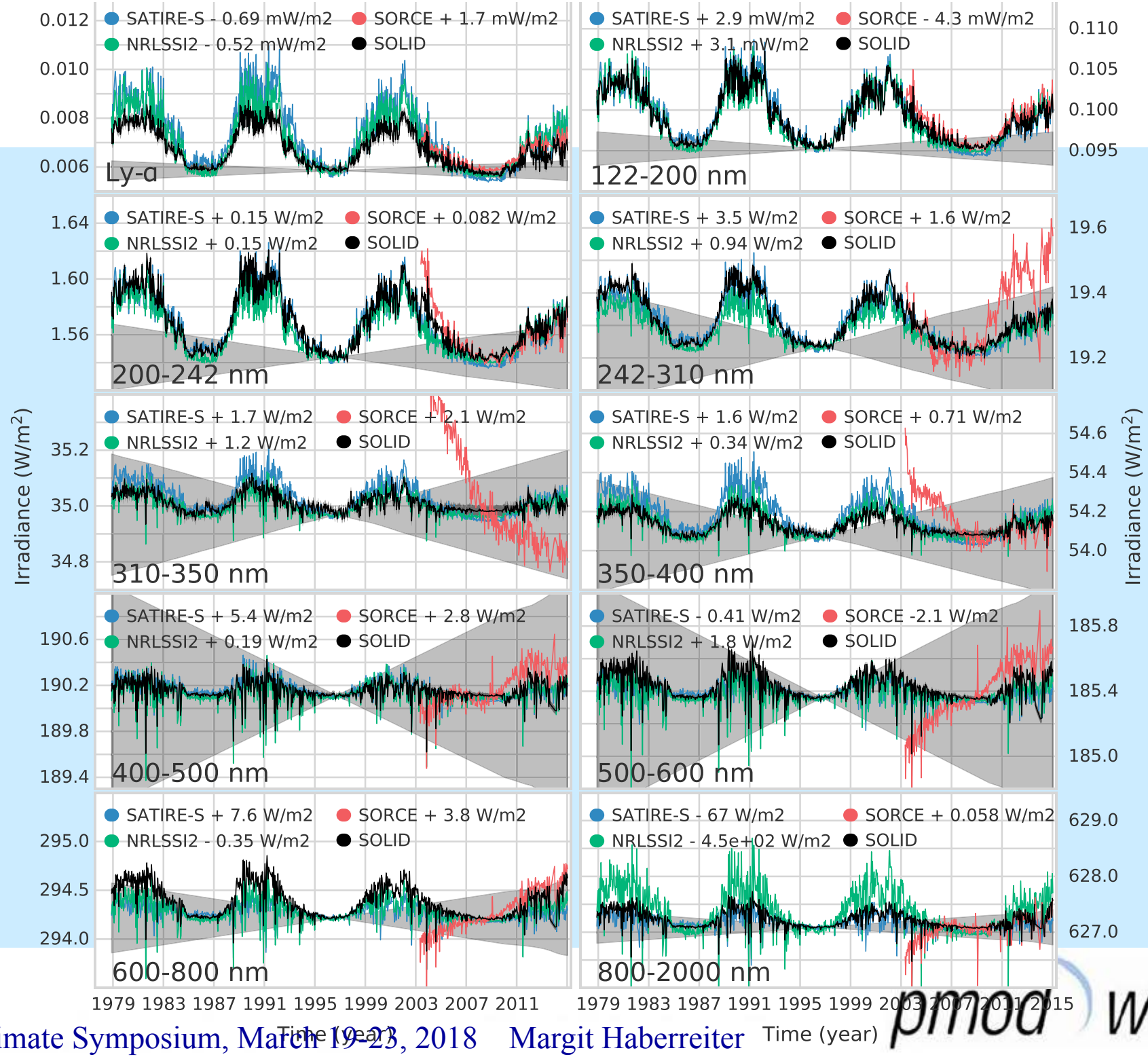


Haberreiter er al. (2017)

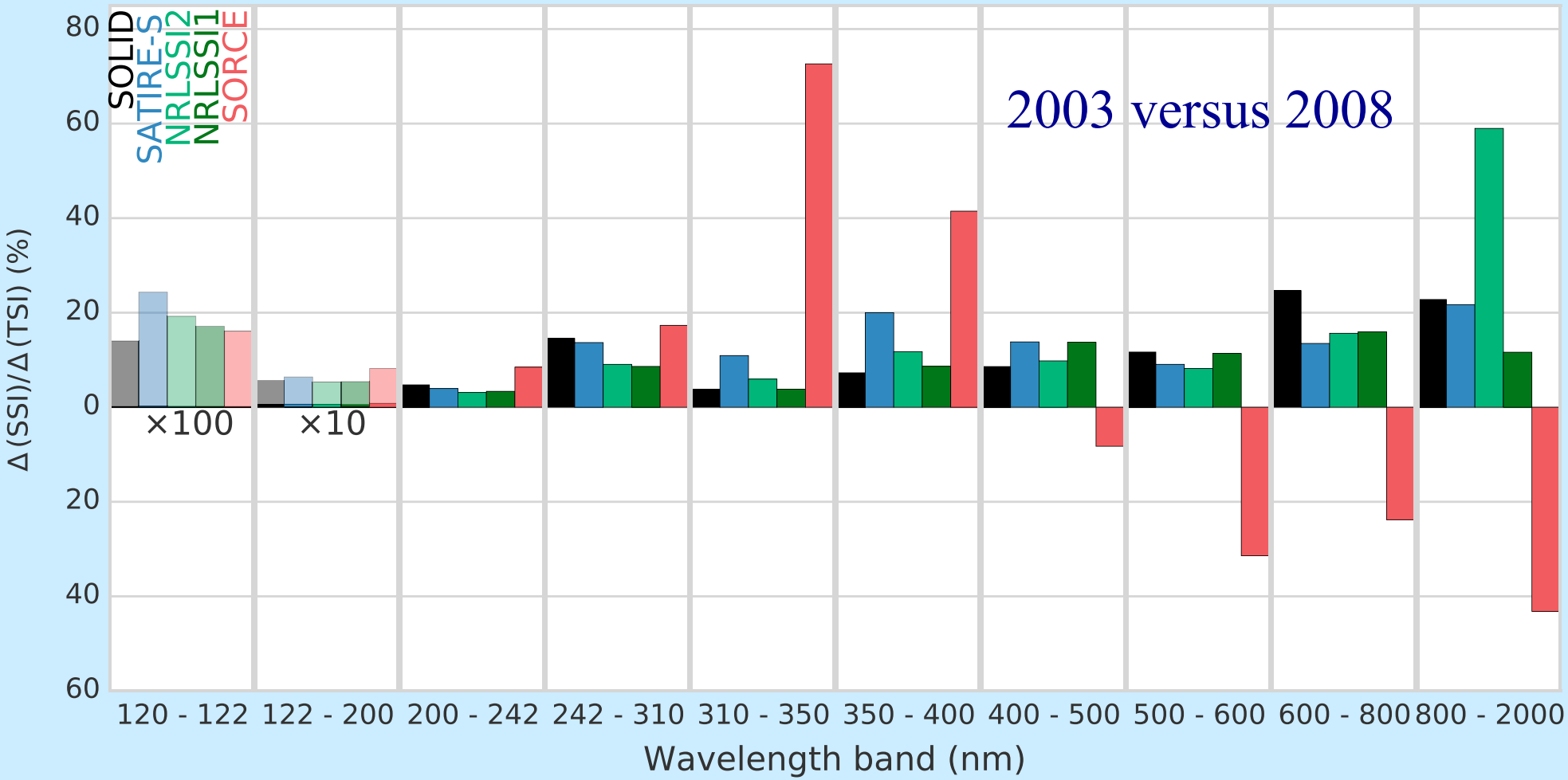
SSI datasets – 121.5



Haberreiter er al. (2017)


SATIRE-S - 0.69 mW/m2
SORCE + 1.7 mW/m2
NRLSSI2 - 0.52 mW/m2
SOLID
Ly-α
SATIRE-S + 2.9 mW/m2
SORCE - 4.3 mW/m2
NRLSSI2 + 3.1 mW/m2
SOLID
122-200 nm
SATIRE-S + 0.15 W/m2
SORCE + 0.082 W/m2
NRLSSI2 + 0.15 W/m2
SOLID
200-242 nm
SATIRE-S + 3.5 W/m2
SORCE + 1.6 W/m2
NRLSSI2 + 0.94 W/m2
SOLID
242-310 nm
SATIRE-S + 1.7 W/m2
SORCE + 2.1 W/m2
NRLSSI2 + 1.2 W/m2
SOLID
310-350 nm
SATIRE-S + 1.6 W/m2
SORCE + 0.71 W/m2
NRLSSI2 + 0.34 W/m2
SOLID
350-400 nm
SATIRE-S + 5.4 W/m2
SORCE + 2.8 W/m2
NRLSSI2 + 0.19 W/m2
SOLID
400-500 nm
SATIRE-S - 0.41 W/m2
SORCE -2.1 W/m2
NRLSSI2 + 1.8 W/m2
SOLID
500-600 nm
SATIRE-S + 7.6 W/m2
SORCE + 3.8 W/m2
NRLSSI2 - 0.35 W/m2
SOLID
600-800 nm
SATIRE-S - 67 W/m2
SORCE + 0.058 W/m2
NRLSSI2 - 4.5e+02 W/m2
SOLID
800-2000 nm
Irradiance (W/m²)
Time (year)

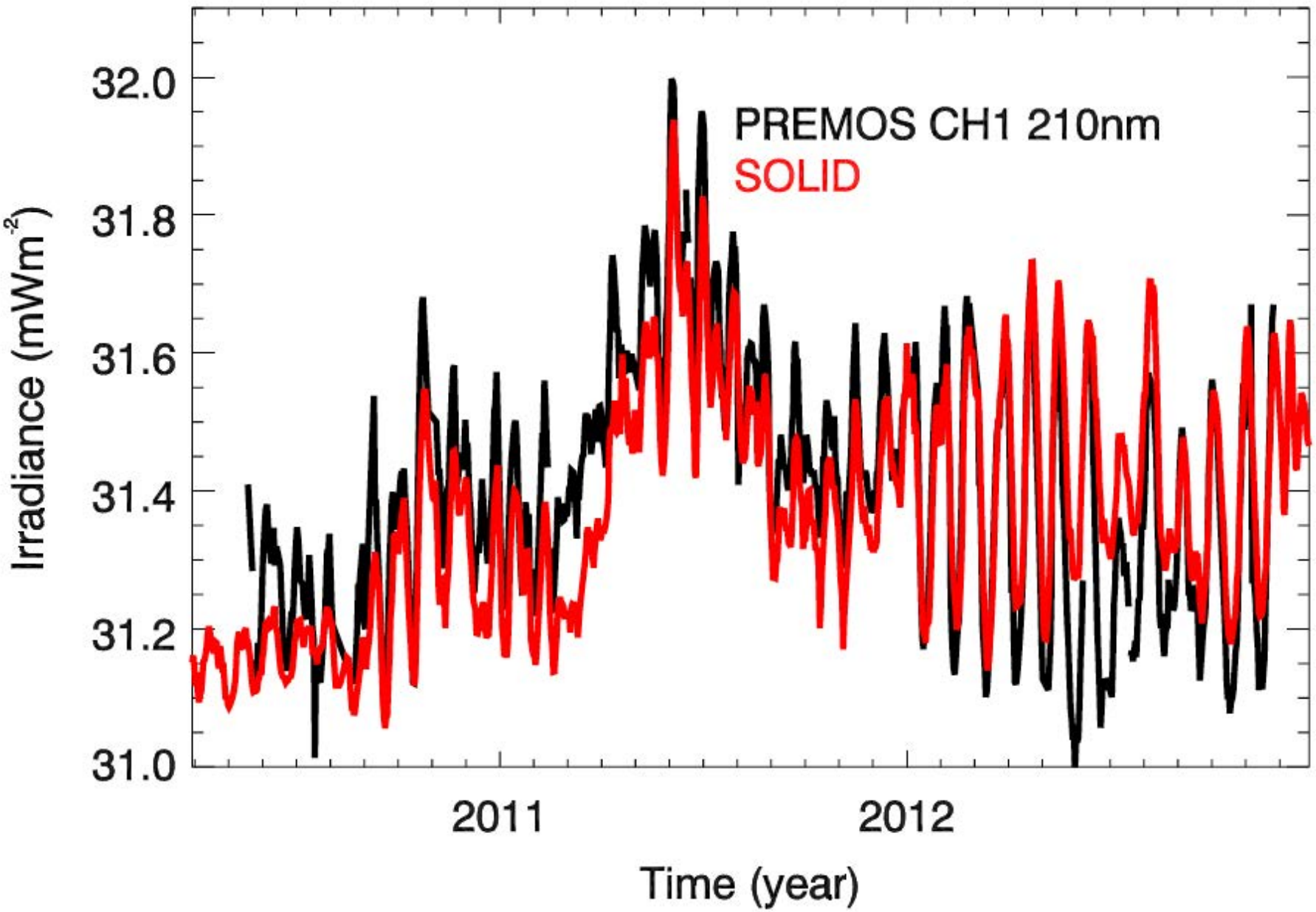
SOLID dataset



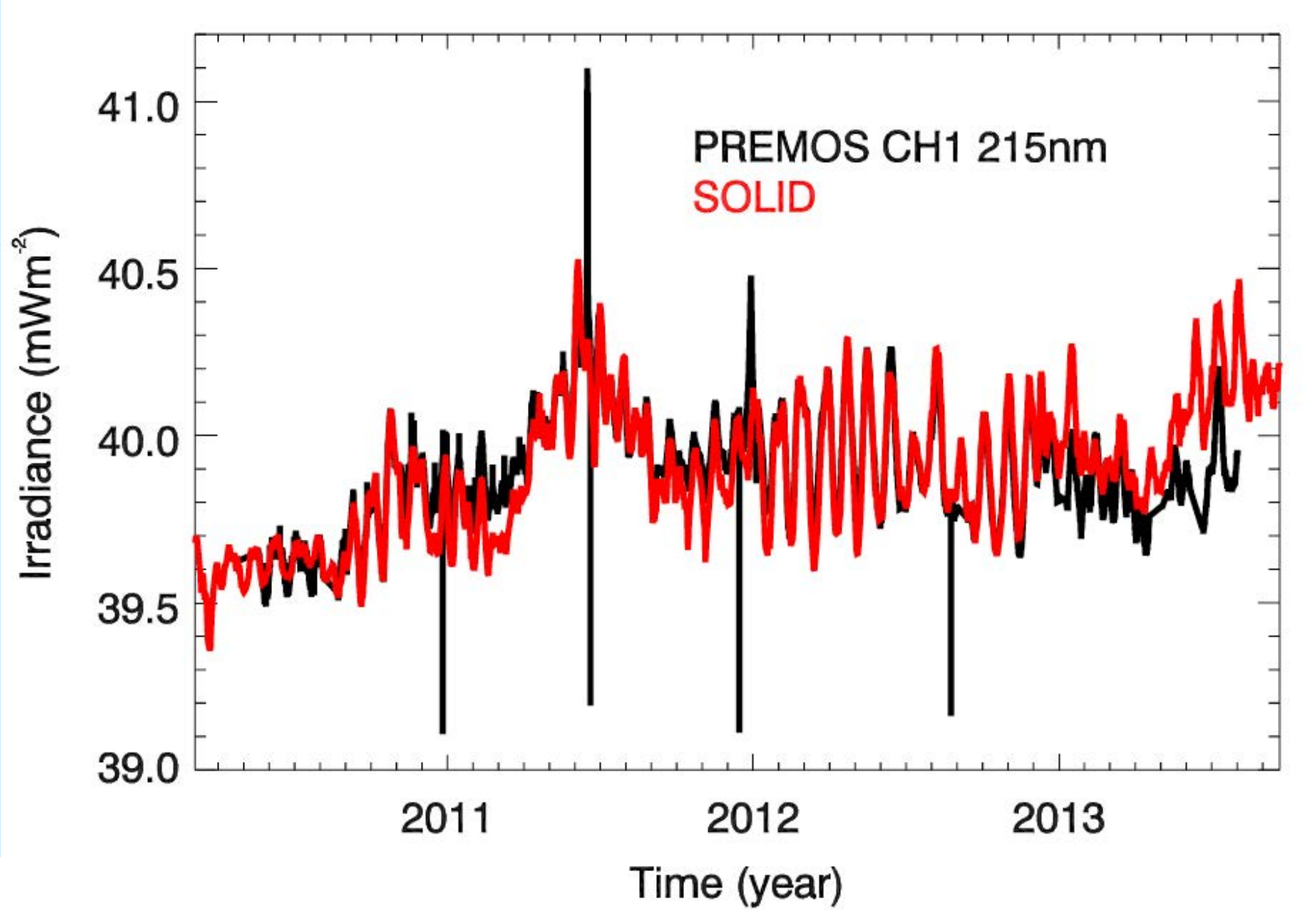
Explains 98.5 % of TSI solar cycle change without applying additional constraints

ftp://ftp.pmodwrc.ch/pub/projects/SOLID/database/composite_published

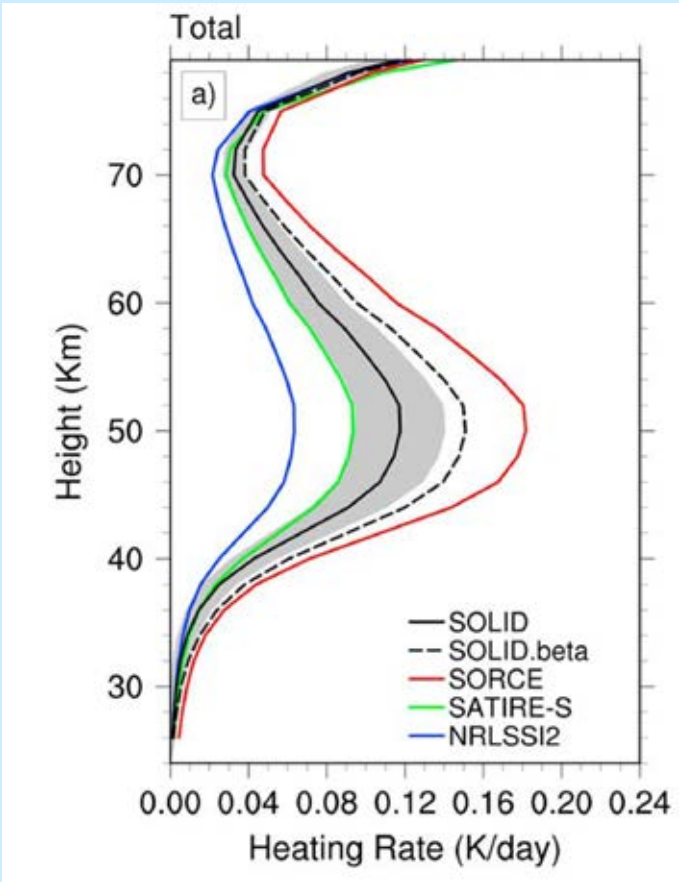
SOLID versus PREMOS 210 nm

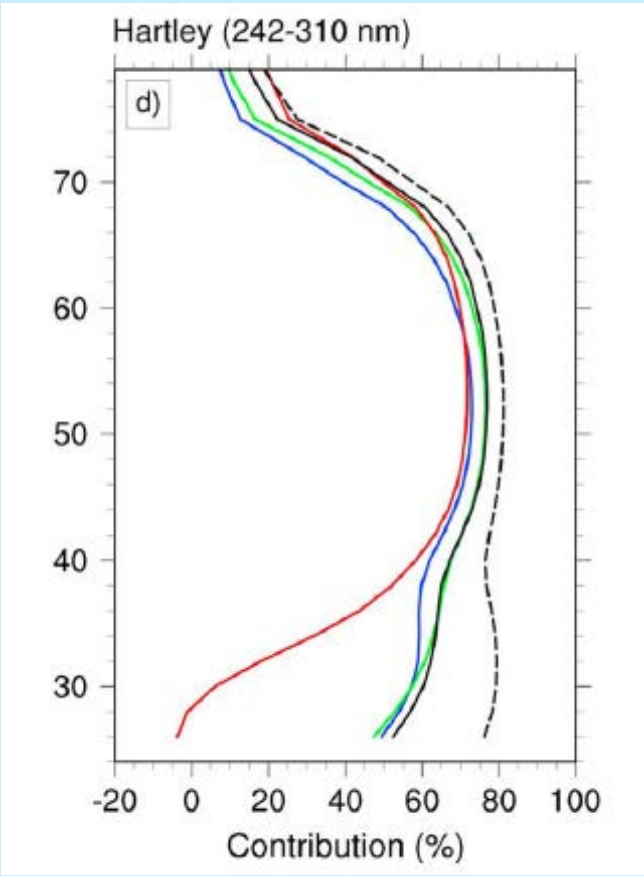


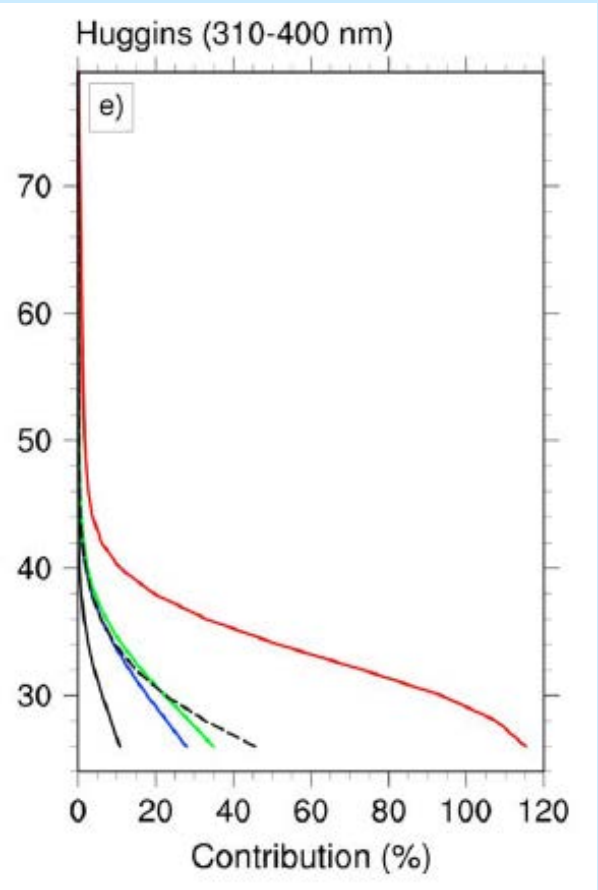
SOLID versus PREMOS 215 nm



Heating Rates





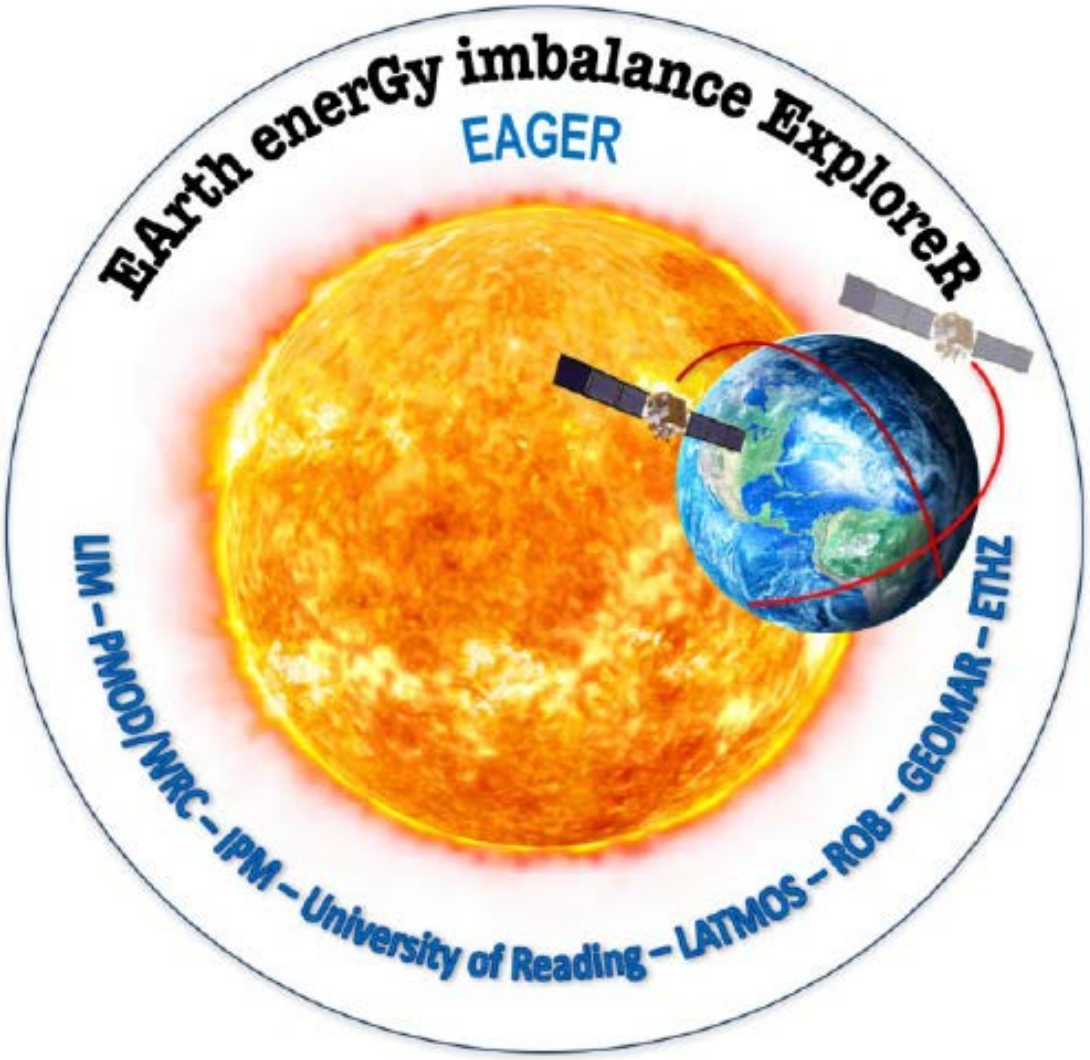


Haberreiter er al. (2017)

What's next?

- Update the SOLID composite on a routine basis
- E.g. use newly available data, in particular TSIS SSI

EAGER – ESA Earth Explorer "Idea"



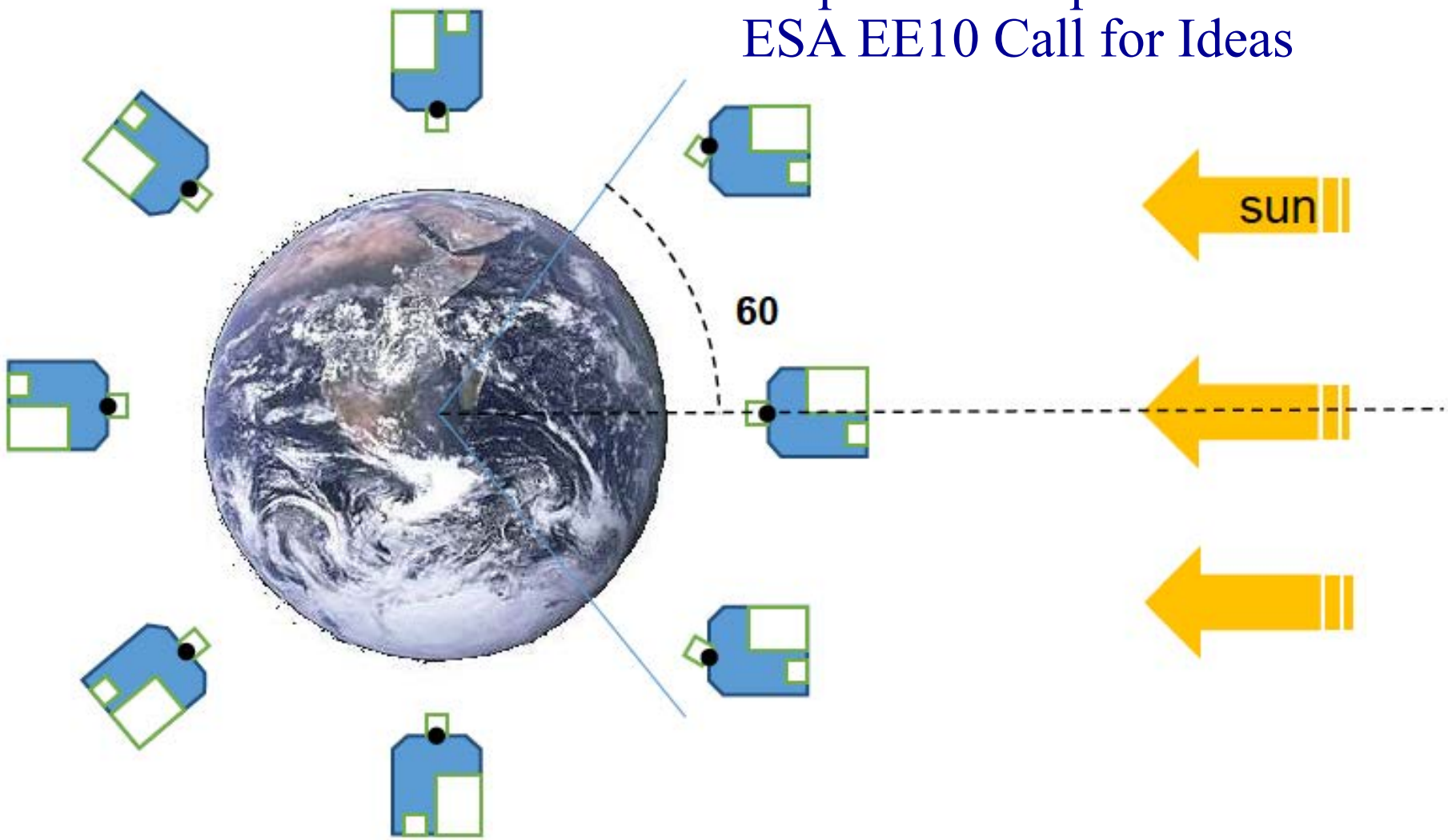
See Poster by Jacobi C., Haberreiter M. et al.,

and

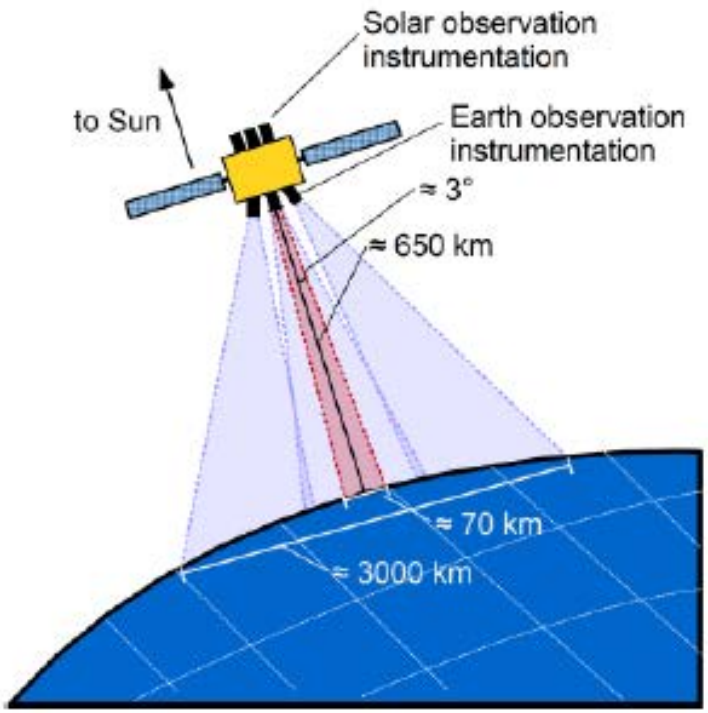
talk by Wolfgang Finsterle, Wednesday

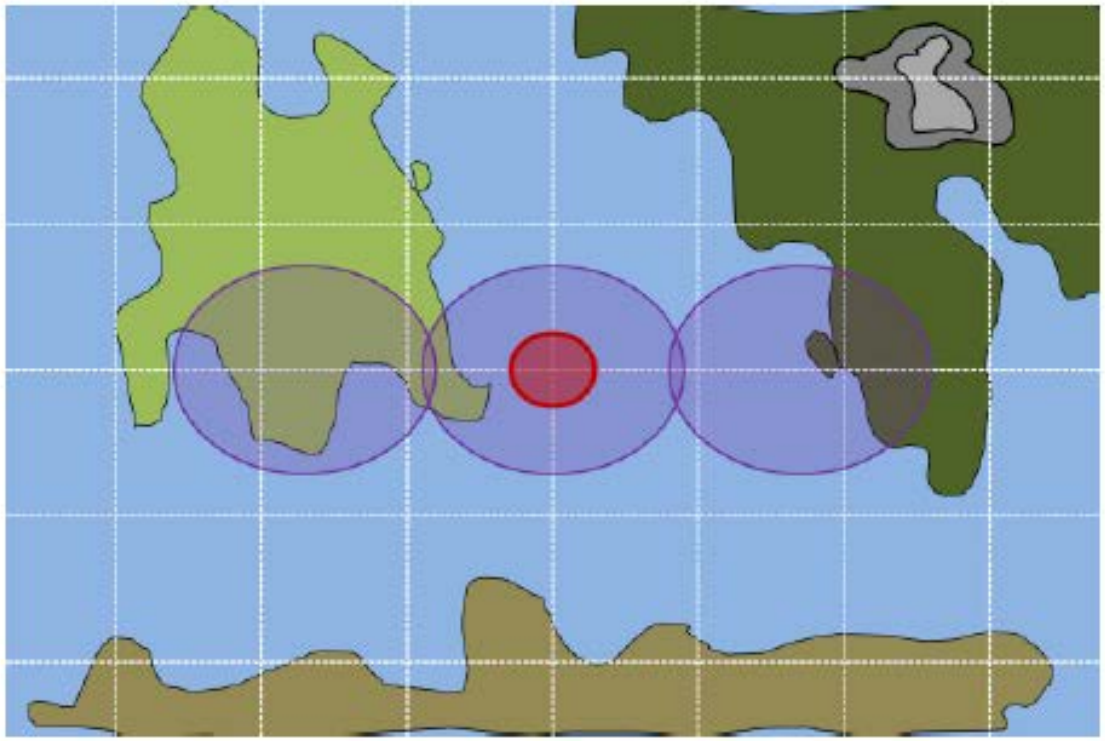
EArth Energy imbalance ExploreR: EAGER

Proposal in response to the ESA EE10 Call for Ideas



EAGER Observations





Simultaneous observation of

- SI-Traceable TSI, SSI, ToA Outgoing Radiation, OLR

Objective: Determine absolute Earth Energy Imbalance

Come to see the poster!

Thank you!

In Memory of Juan Fontenla