THE IMPORTANCE OF SOLAR IRRADIANCE

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TRUTHS for Climate Workshop
ECSAT, 27-28.06.2024

The Importance of Solar Irradiance

1. Solar Influence on Climate

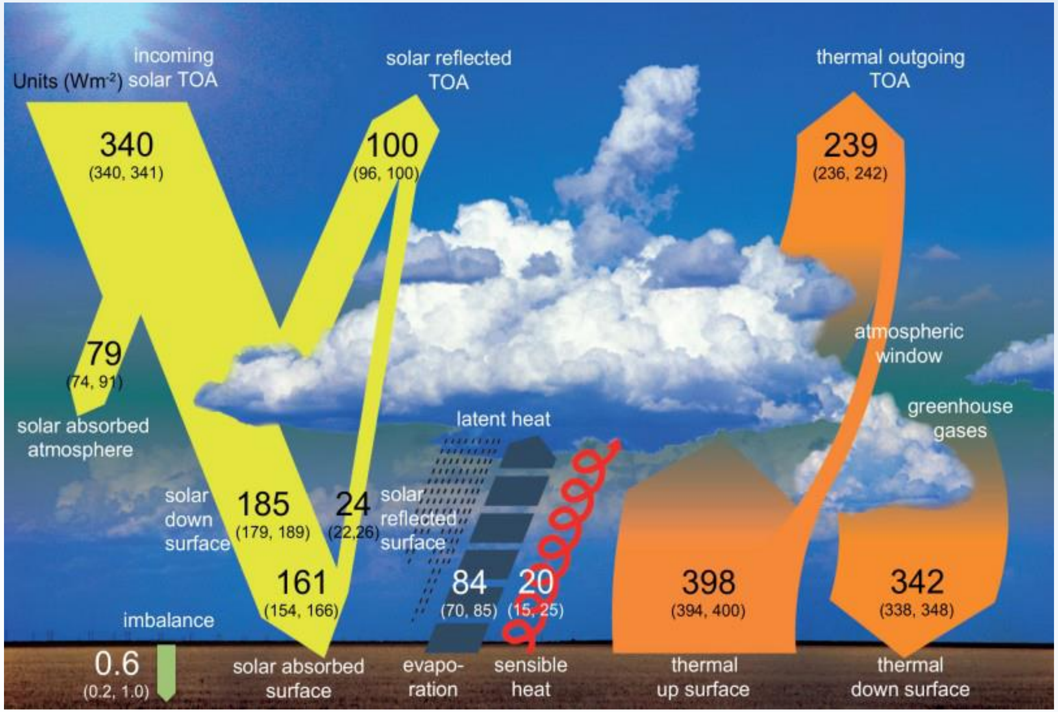
- TSI and SSI are **ECVs**
- Precise knowledge of TSI (and SSI) variability is key to our understanding of the role of the Sun for the Earth's climate
- Climate community depends on reconstruction models:
  - for the past when no observations are available
  - for future projections
  - Differences of the reconstruction models exist (but they get smaller)
- Models need to be constrained to the best possible observations

2. Earth Energy Imbalance

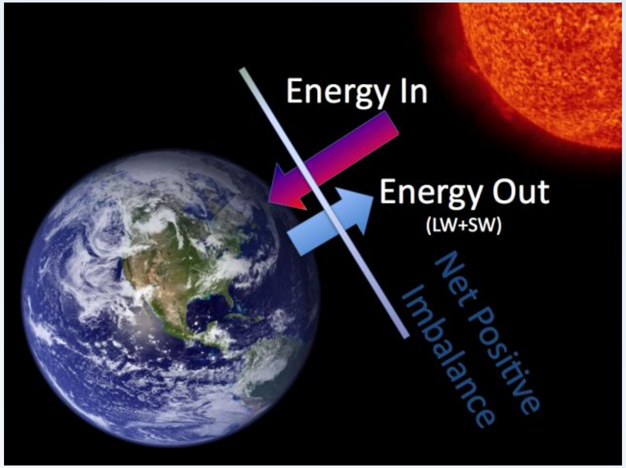
- the Earth Energy Imbalance (estimated to be up to 1.0 W/m^2)
- To determine EEI the incoming TSI needs to be known better than 0.1 W/m^2

or EEI is determined differentially as with ECO (EE12 Candidate Mission)

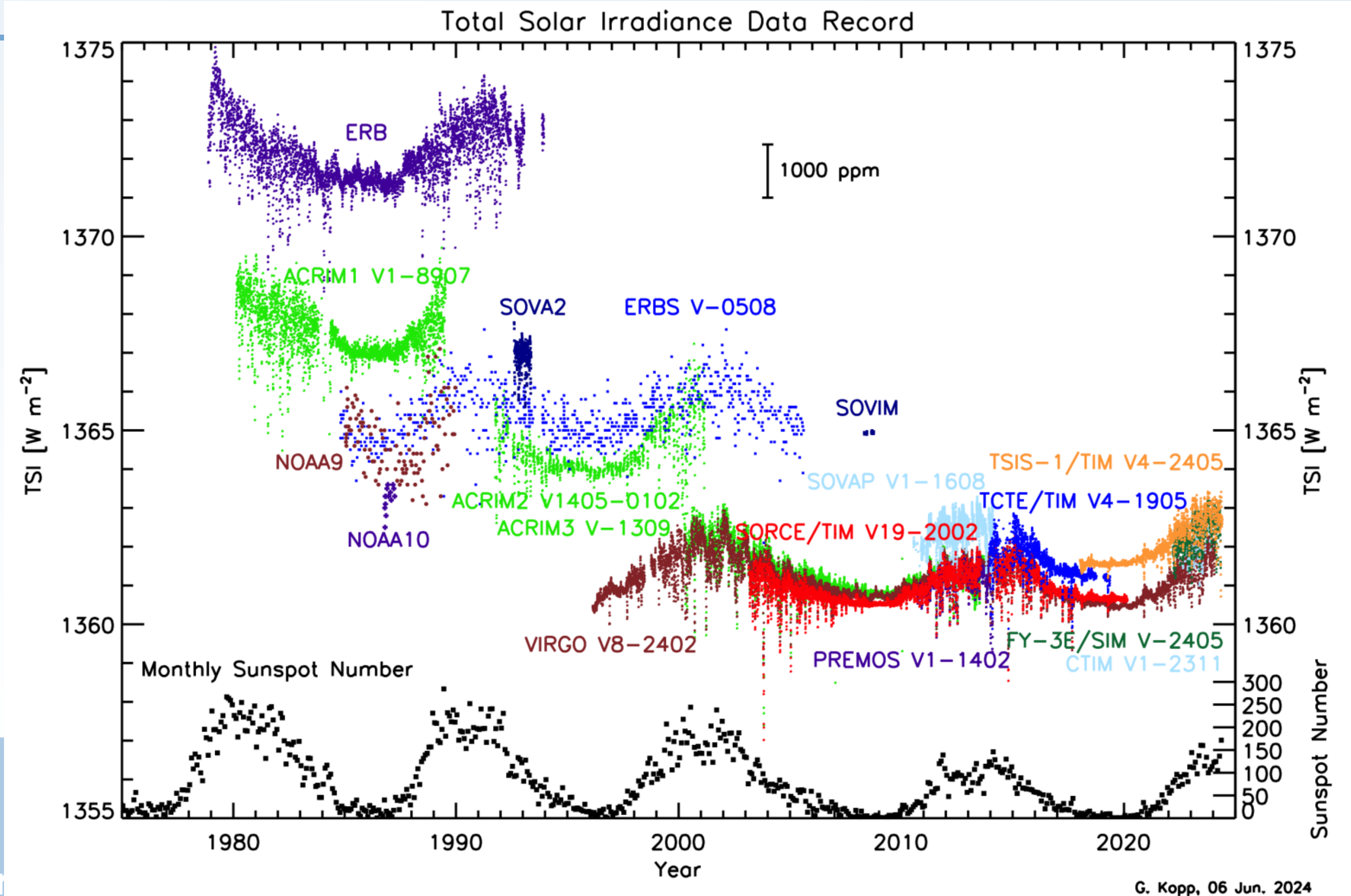
TSI is a key element of the Earth Radiation Budget



Wild et al. (2015)



TSI: We have come a long way…

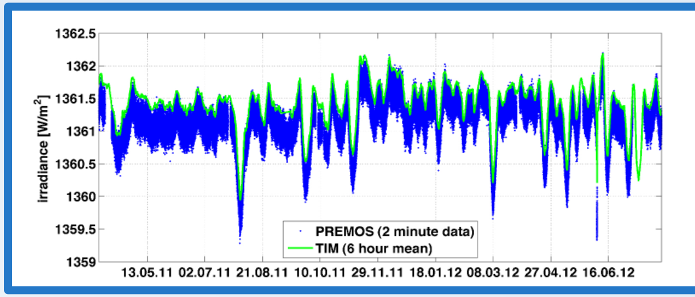


SI-traceable Total Solar Irradiance is key!

Total solar irradiance measurements with PREMOS/PICARD

Cite as: AIP Conference Proceedings 1531, 624 (2013); https://doi.org/10.1063/1.4804847
Published Online: 10 May 2013

Werner Schmutz, André Fehlmann, Wolfgang Finsterle, Greg Kopp, and Gerard Thuillier



IAU Resolution B2 2015

The Astronomical Journal, 152:41 (7pp), 2016 August doi:10.3847/0004-6256/152/2/41

NOMINAL VALUES FOR SELECTED SOLAR AND PLANETARY QUANTITIES: IAU 2015 RESOLUTION B3

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Solar Conversion Constants

$$1\mathcal{R}^{\mathrm{N}}_{\odot} = 6.957 \times 10^{8}\ \mathrm{m}$$
$$1\mathcal{S}^{\mathrm{N}}_{\odot} = 1361\ \mathrm{W\ m^{-2}}$$
$$1\mathcal{L}^{\mathrm{N}}_{\odot} = 3.828 \times 10^{26}\ \mathrm{W}$$
$$1\mathcal{T}^{\mathrm{N}}_{\odot} = 5772\ \mathrm{K}$$

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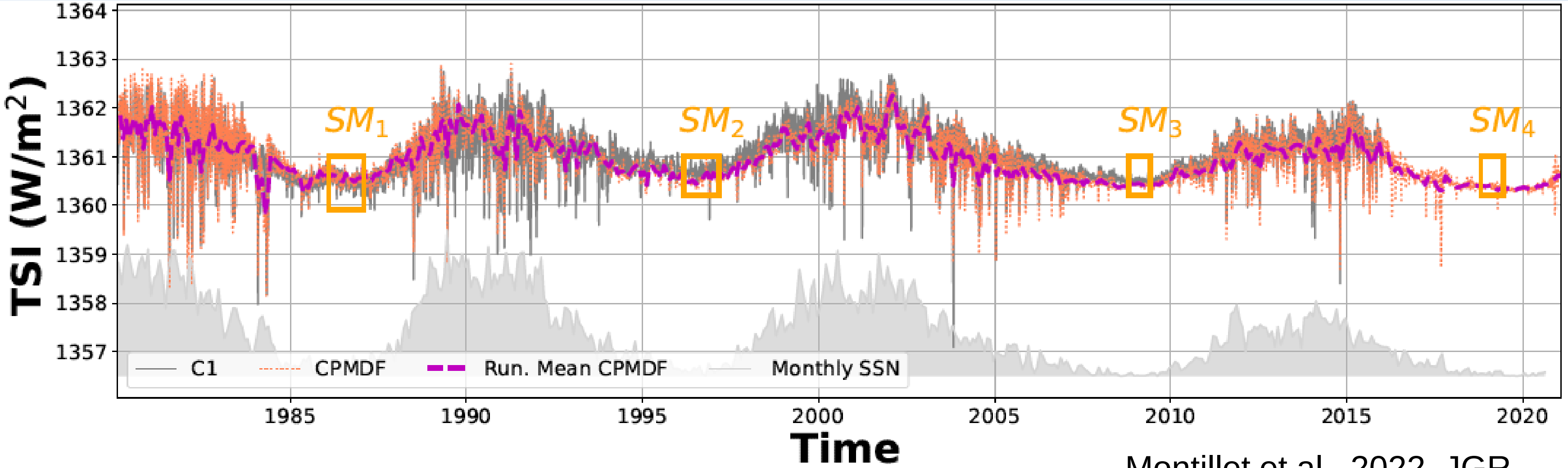
PMOD TSI Composite



Montillet et al., 2022, JGR

New PMOD composite based on merging 41 years of TSI measurements.

30-day running mean of Composite

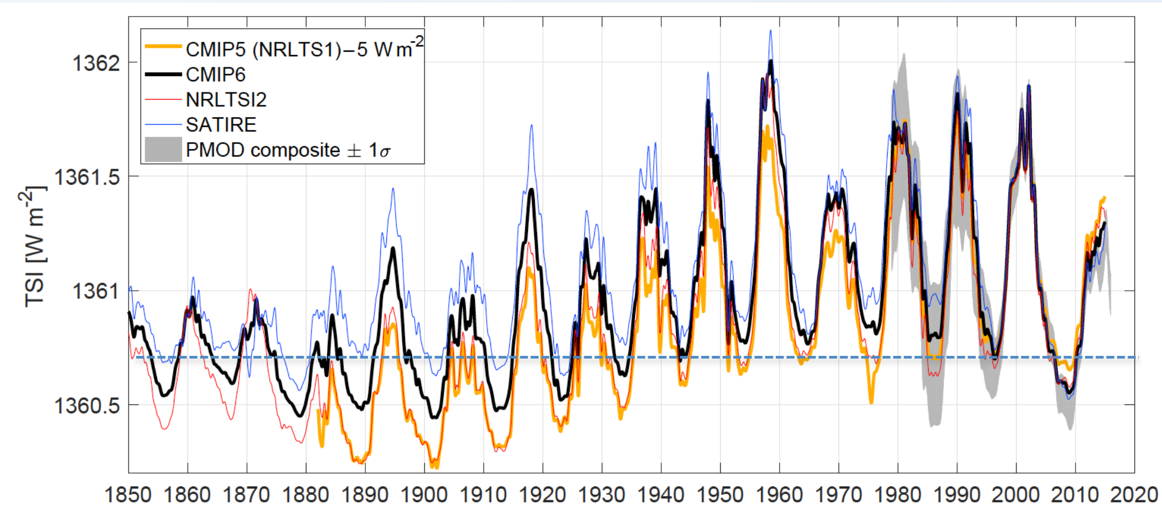
Community Composite C1 (Dudok de Wit et al., 2017)

Boxes: Solar minima (SM) for each solar cycle

Monthly sunspot number is also displayed.

Continuation of the PMOD-composite based on ML techniques

Total Solar Irradiance Variability



Matthes et al., 2017

Current Status TSI

- **TSI accuracy**: 294 ppm (k=1)
- **TSI stability:** 10-40 ppm/yr
- diverging reconstruction models
- overlapping measurements or SI-traceability in space are required
- improved TSI accuracy and stability absolutely crucial

New TSI User Requirements

- **TSI accuracy of TRUTHS**:

Threshold: 200 ppm or 0.27 W/m^2

Goal: 70 ppm or 0.1 W/m^2

- **TSI Stability:**

Threshold: 5 ppm/yr

(50 ppm or 0.07 W/m^2 in 10 years)

Goal: 1 ppm/yr

(10 ppm or 0.014 W/m^2 in 10 years)

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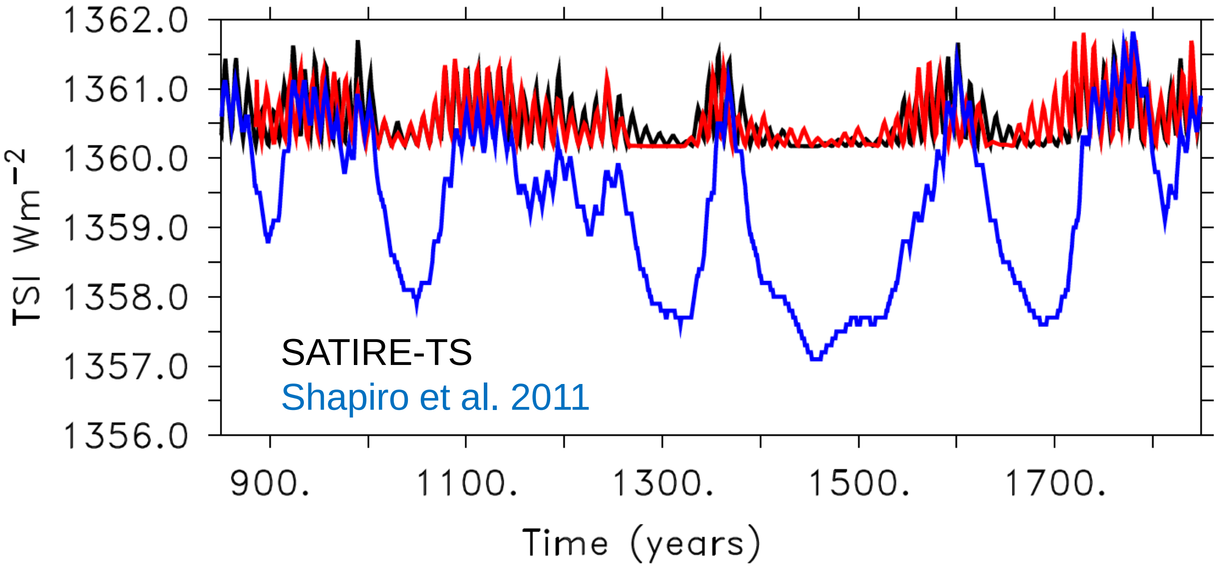
Irradiance reconstructions to the past



Jungclaus et al., 2017

Current Status TSI

- TSI accuracy: 294 ppm
- TSI stability: 10-40 ppm/yr

Implications

- Strongly diverging long-term reconstruction models
- Impact on future projections
- improved TSI accuracy and stability absolutely crucial

-> Improved future projections will be possible

Spectral Solar Irradiance (SSI)

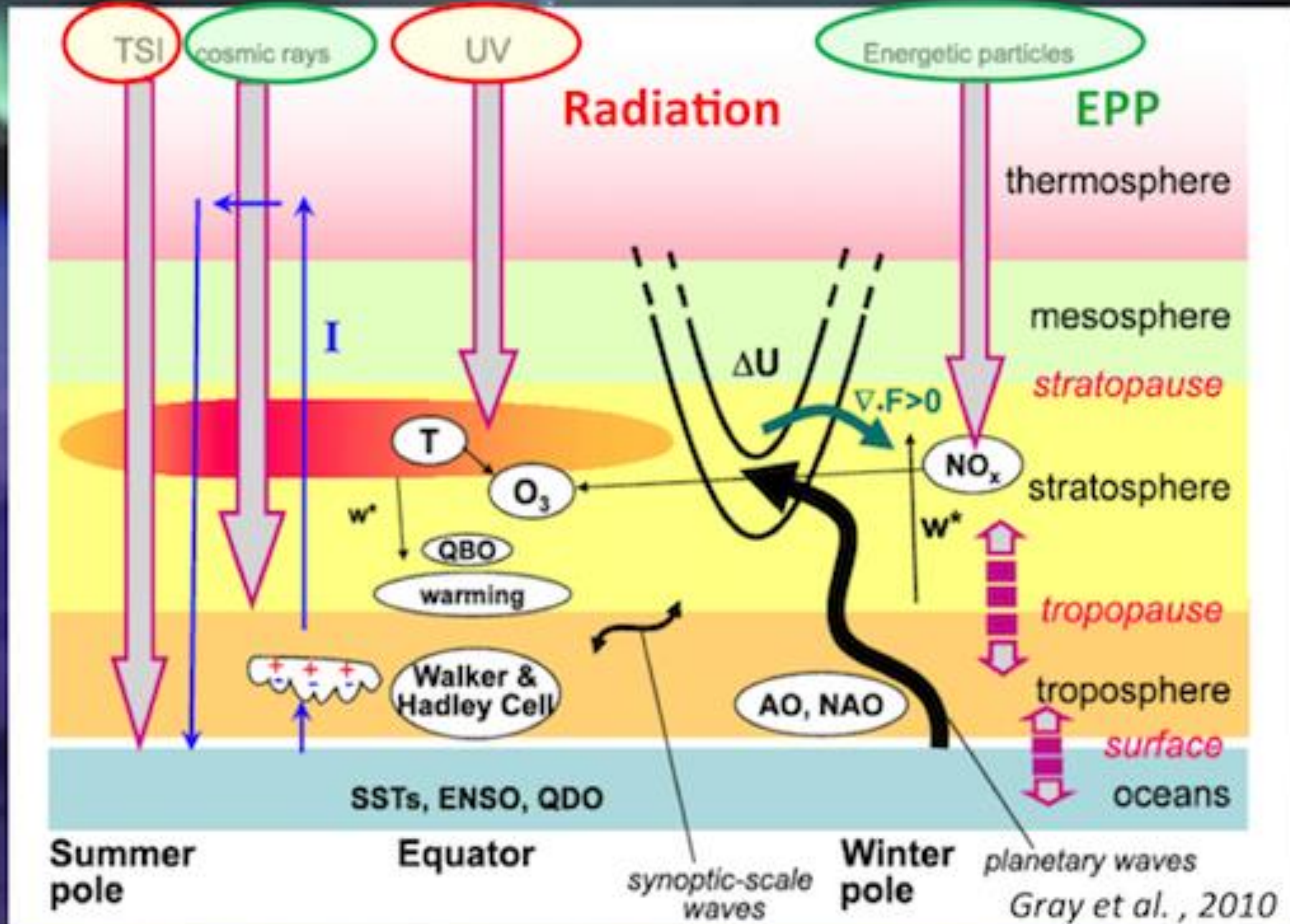
Solar Influence on atmospheric chemistry and climate

- The spectral distribution of the energy is the key input to climate models
- SSI models need to be constrained to the best possible observations
- Spectral variability crucially depends on the used model or data composite

Solar forcing

Impact on dynamics & chemistry

Impact on climate



SSI – Important spectral bands

Spectral region	Gases	CESM1(WACCM)	EMAC
SW radiation[a,b]			
Lyman-α	O_2		[121–122]
Schumann–Runge continuum	O_2		[125–175] (3)
Schumann–Runge bands	O_2		[175–205]
Herzberg cont./Hartley bands	O_2, O_3	[200–245]	[206.5–243.5] (15)
Hartley bands	O_3	[245–275] (2)	[243.5–277.5] (10)
Huggins bands	O_3	[275–350] (4)	[277.5–362.5] (18)
UV-A/Chappuis bands	O_3	[350–700] (2)	[362.5–690] (58)
Near Infrared/Infrared	O_2, O_3, CO_2, H_2O	[700–5000] (10)	[690–4000] (3)
Photolysis			
Lyman-α		[121–122]	[121–122]
Schumann–Runge continuum		[122–178.6] (20)	
Schumann–Runge bands		[178.6–200] (12)	[178.6–202]
Herzberg cont./Hartley bands		[200–241] (15)	[202–241]
Hartley bands		[241–291] (14)	[241–289.9]
Huggins bands		[291–305.5] (4)	[289.9–305.5]
UV-B		[305.5–314.5] (3)	[305.5–313.5]
UV-B/UV-A		[314.5–337.5] (5)	[313.5–337.5]
UV-A/Chappuis bands		[337.5–420] (17)	[337.5–422.5]
Chappuis bands		[420–700] (9)	[422.5–682.5]

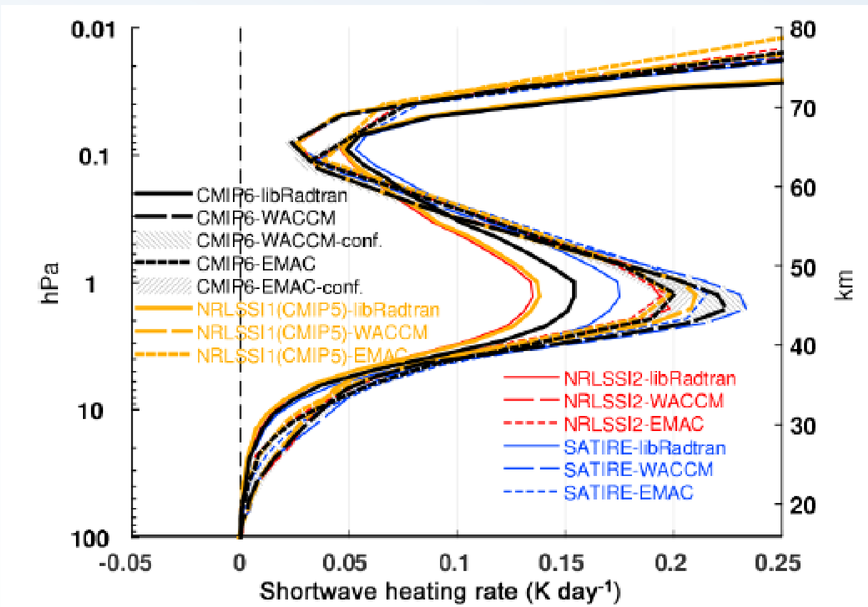
Not observed by TRUTHS

Observed by TRUTHS

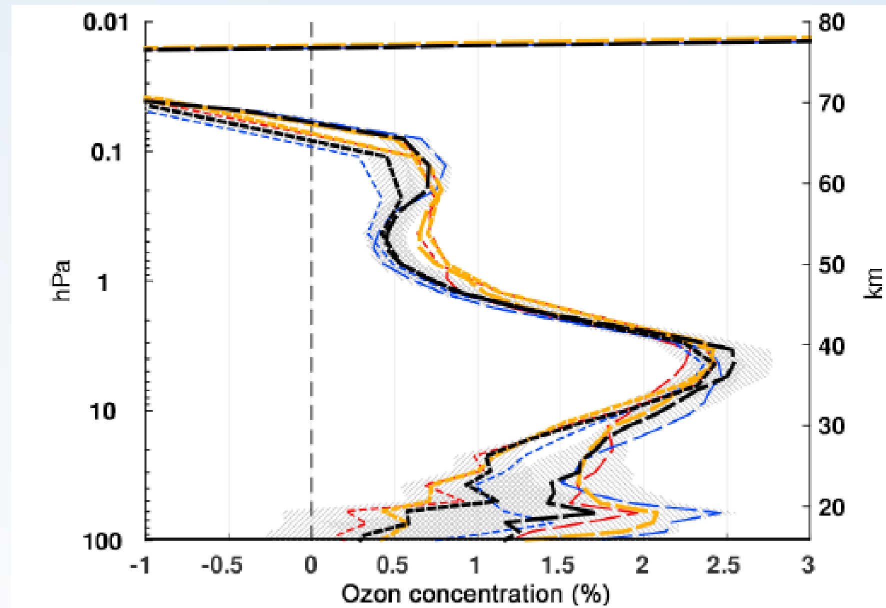
Matthes et al., 2017

Detailed Effects of SSI on Earth's atmosphere

Shortwave Heating Rate

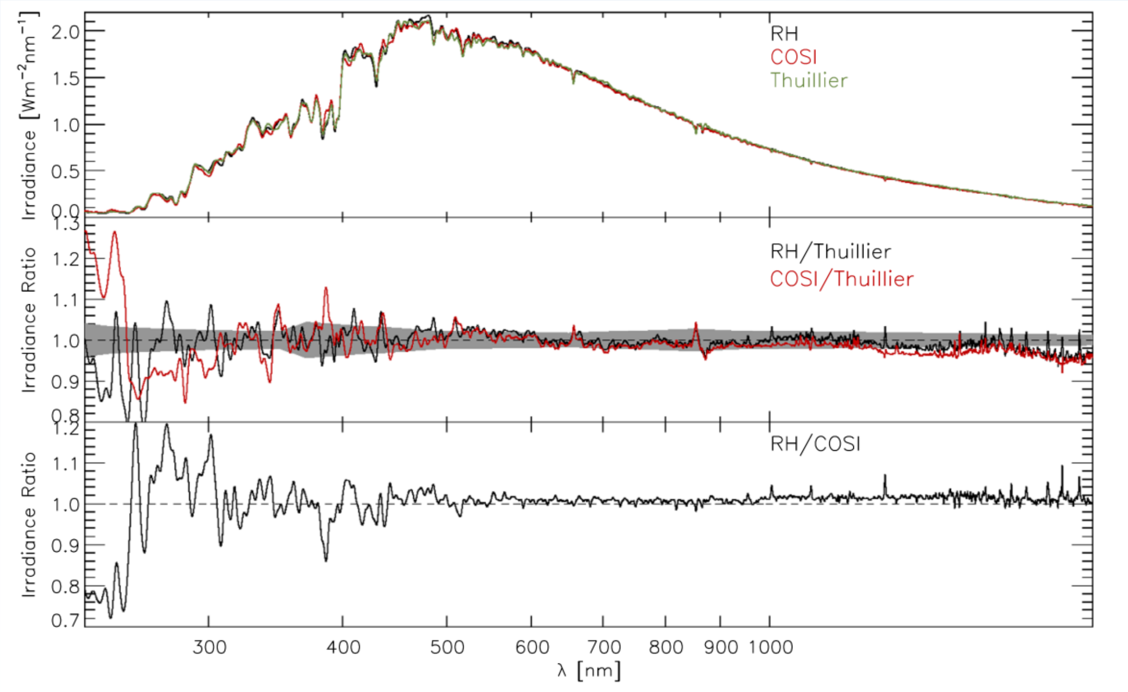


Ozone concentration



Matthes et al., 2017, GMD, Solar Forcing for CMIP6

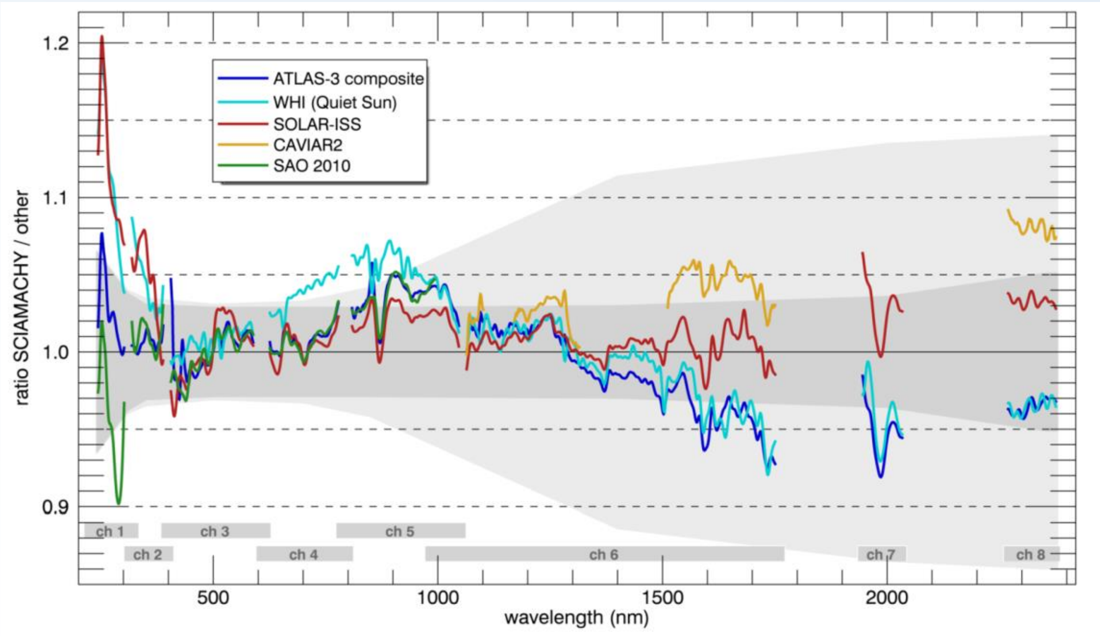
Solar Reference spectrum



Criscuoli, Rempel, Haberreiter et al. (2020)

- ATLAS3 (Thuillier et al. (2004) up to now standard observational reference
- Radiative transfer codes (COSI, RH) agree well with the ATLAS3 Thuillier spectrum
- If IR part of the spectrum needs to be revised: challenge for solar irradiance modelling community

SSI – Infrared spectral range



Current Status SSI

- ATLAS3 (Thuillier et al., 2004) up to recently standard observational reference; see also high-resolution standard spectrum: ftp://ftp.pmodwrc.ch/pub/data/SolarReferenceSpectrum/
- SORCE/SIM (part of WHI) also linked to ATLAS3 spectrum
- Recent measurements lead to a significantly lower IR level (i.e ratio > 1)
- Large uncertainty in the IR part of the spectrum
- Conservative uncertainty of SSI instrument: e.g. SCIAMACHY: ~ 5-13 %

Ratio of SCIAMACHY dataset to the ATLAS3, WHI, SOLAR-ISS, CAVIAr2 and SAO 2010 datasets. The lower limit of the SCIAMACHY uncertainty (2σ) is indicated in dark grey while the light grey area indicates an additional estimated uncertainty in the NIR because of the ad hoc stray-light correction. (Hilbig et al. , 2018)

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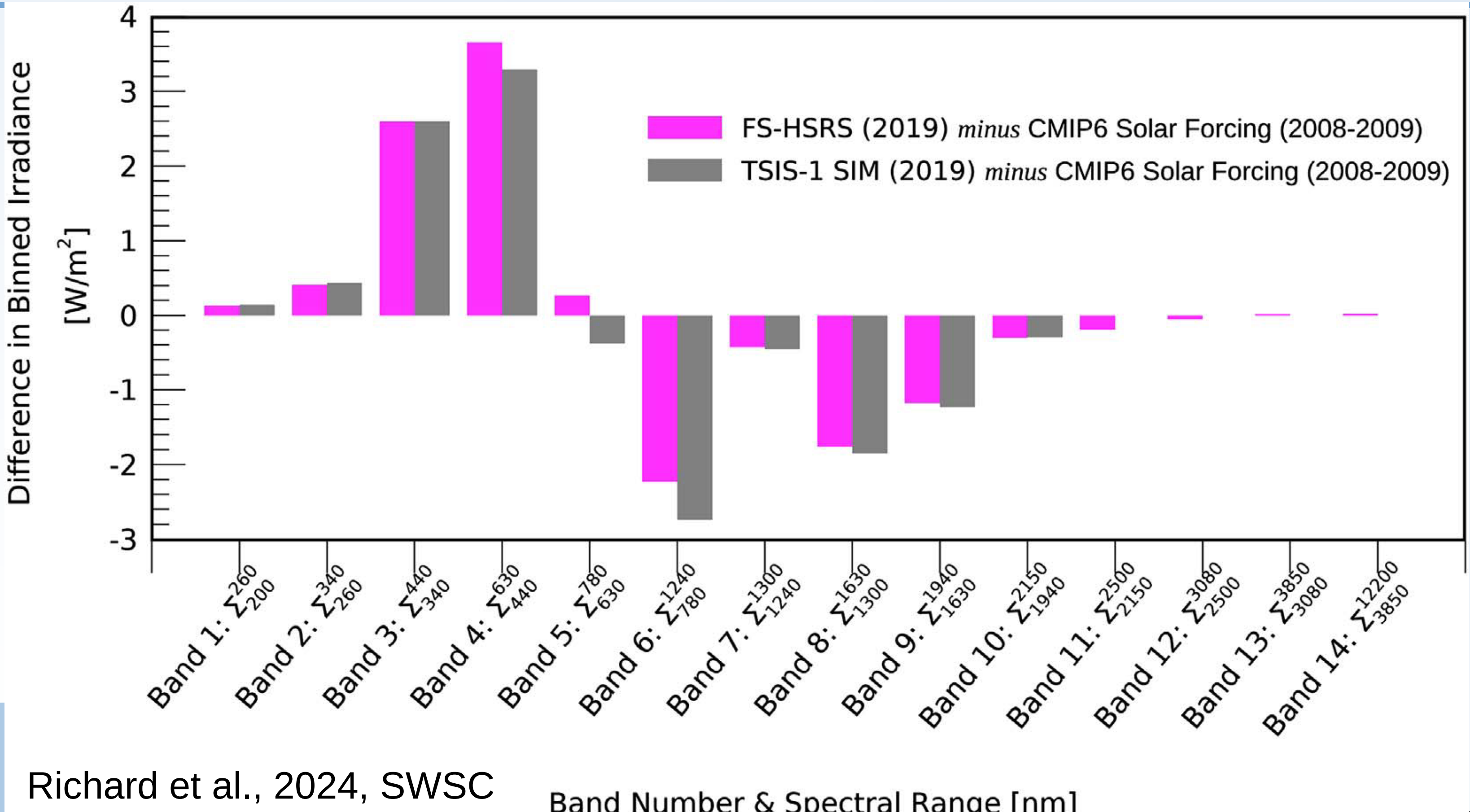
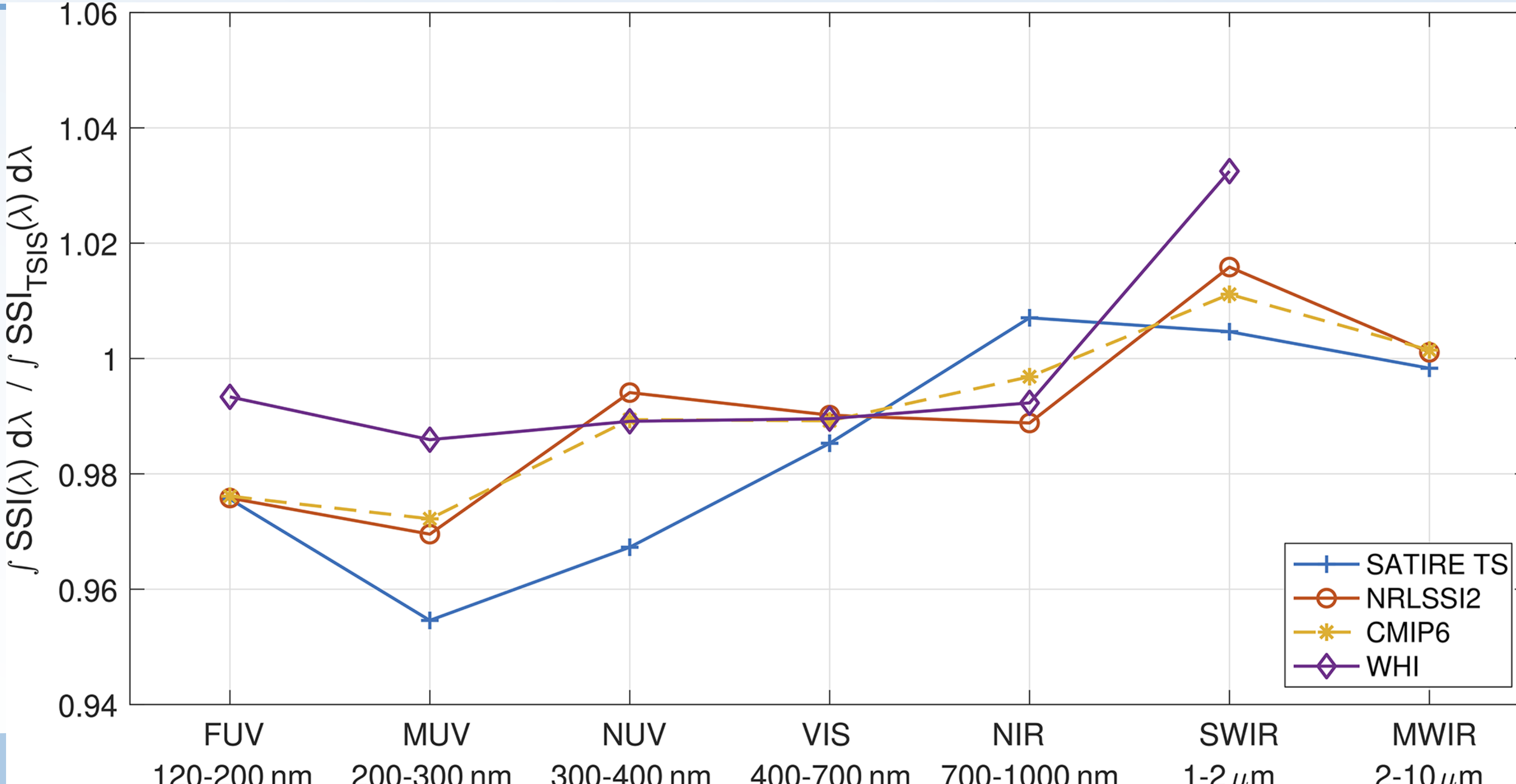
Difference TSIS-SIM to CMIP6



Richard et al., 2024, SWSC

New Solar Reference Spectrum



Funke et al., 2024, GMD

Summary

- Total Solar Irradiance is important for the Earth Radiation Budget (and its imbalance)
  - TRUTHS TSI will be incorporated in the PMOD TSI composite
- Solar Spectral Irradiance variability is key for the understanding of the atmospheric chemistry and climate
  - TRUTHS SSI data product will improve our capabilities to constrain SSI reconstruction models
- New solar reference spectrum - will TRUTHS confirm it?
  - TRUTHS can give insight to the spectral shape of the quiet Sun spectrum