OMI, TROPOMI and Climate Studies: Solar Irradiances

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Sun and climate: TSI

"Climate change is governed by changes to the global energy balance."

G.Stephens et al., Nature Geoscience 5, 691-696 (2012)

"… most of the global warming in the first half of the 20th century was natural in origin, and much of this can be attributed to an increase in solar forcing... Results for the past 20 years continue to indicate that solar forcing is playing at most a weak role in current global temperature trends."

L.Gray et al., Rev. Geophys. 48, RG4001 (2010)

Total Solar Irradiance (TSI) measurements during the 'Space era' (1978 and on):

- accurate, robust, long-term TSIs
- reliable composite data records
- [mostly …] agreed upon $TSI_{min} = 1360.8 \pm 0.5\ W\ m^{-2}$ (2016)
- ~0.15% solar-cycle TSI variability

Sun and climate: Solar Spectral Irradiance (SSI) measurements

SSI variability affects:

UV range (mostly stratospheric; top-down):

atmospheric chemistry (photolysis + heating), O_3 in particular (1%-2% changes over Solar Cycle), with associated temperature changes;

VIS-NIR range (mostly trop. and surface; bottom-up): direct heating (tenths ^{o}C, altitude- / region- dependent) ⟶ global circulation/ temperature profiles (both strat. and trop.) / zonal winds (both strat. and trop.) / precipitation.

Coupled temperature/circulation/precipitation/cloud responses.

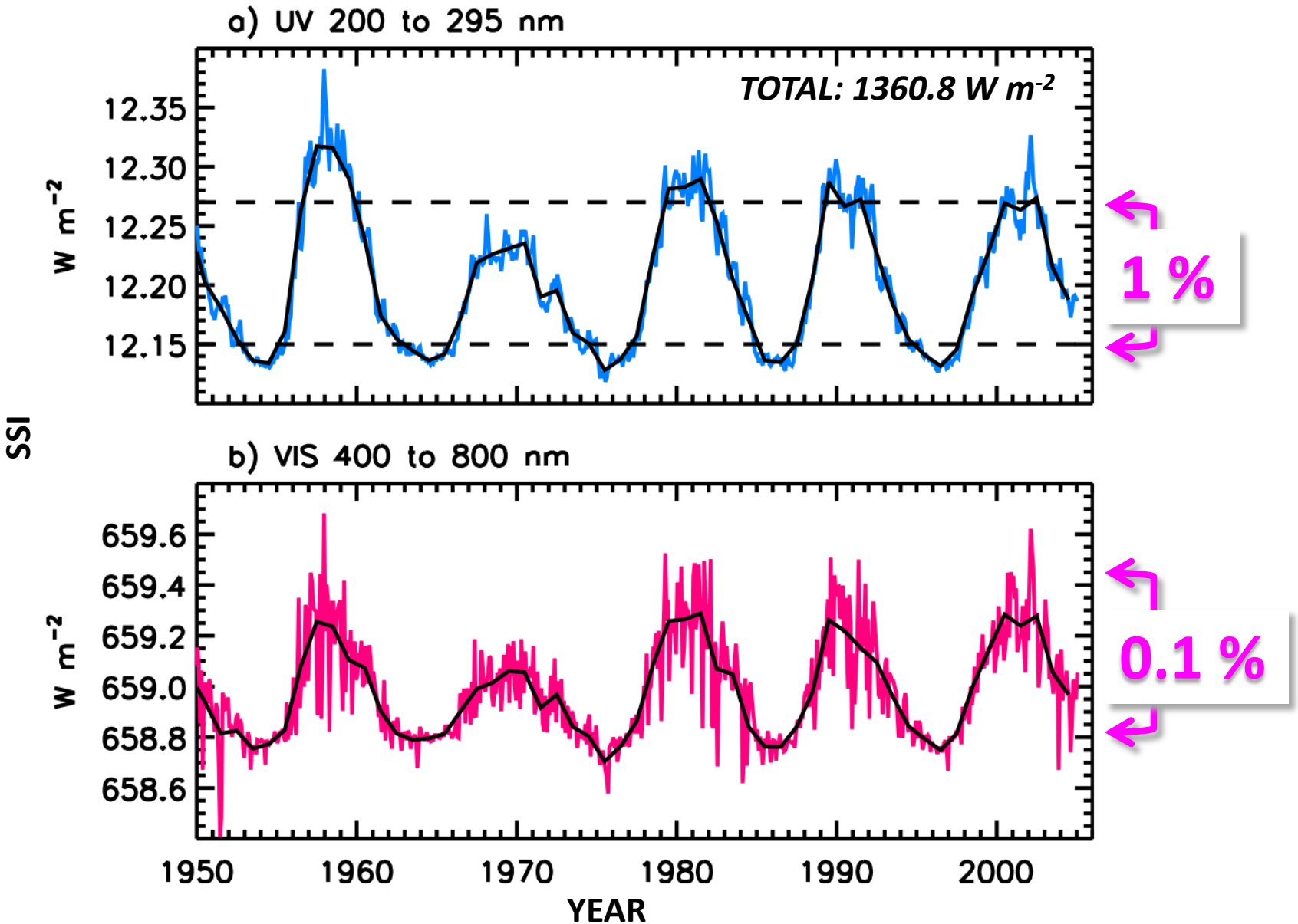
The tropospheric response to the solar forcing is rather 'modest' (high internal variability: seasonal, QBO, ENSO, …), while stratosphere reacts in a relatively strong, consistent manner.

Sun and climate: SSI measurements

"The majority of climate models employed to date … have a very poor, or no, representation of the top-down mechanism that requires spectral variations in solar radiative input and ozone feedback effects."

L.Gray et al., Rev. Geophys. 48, RG4001 (2010)

'Space era': limited progress with the 'climate-rated' SSI measurements due to outstanding instrument performance issues (mainly, long-term stability); ~**0.5%-2.0%** systematic errors ***prior to SORCE and OMI.***



Repr. from: D. Rind et al., JGRA 113, D24103 (2008)

SSI requirements for climate studies

Stability / year	**0.05% (λ < 400 nm), 0.01% (λ > 400 nm)**
Relative precision	**0.01%**

O. Coddington et al., 2016, BAMS, 97, 1265

- Long-term (decades), uninterrupted SSI records
- Preferably ~daily SSI observations

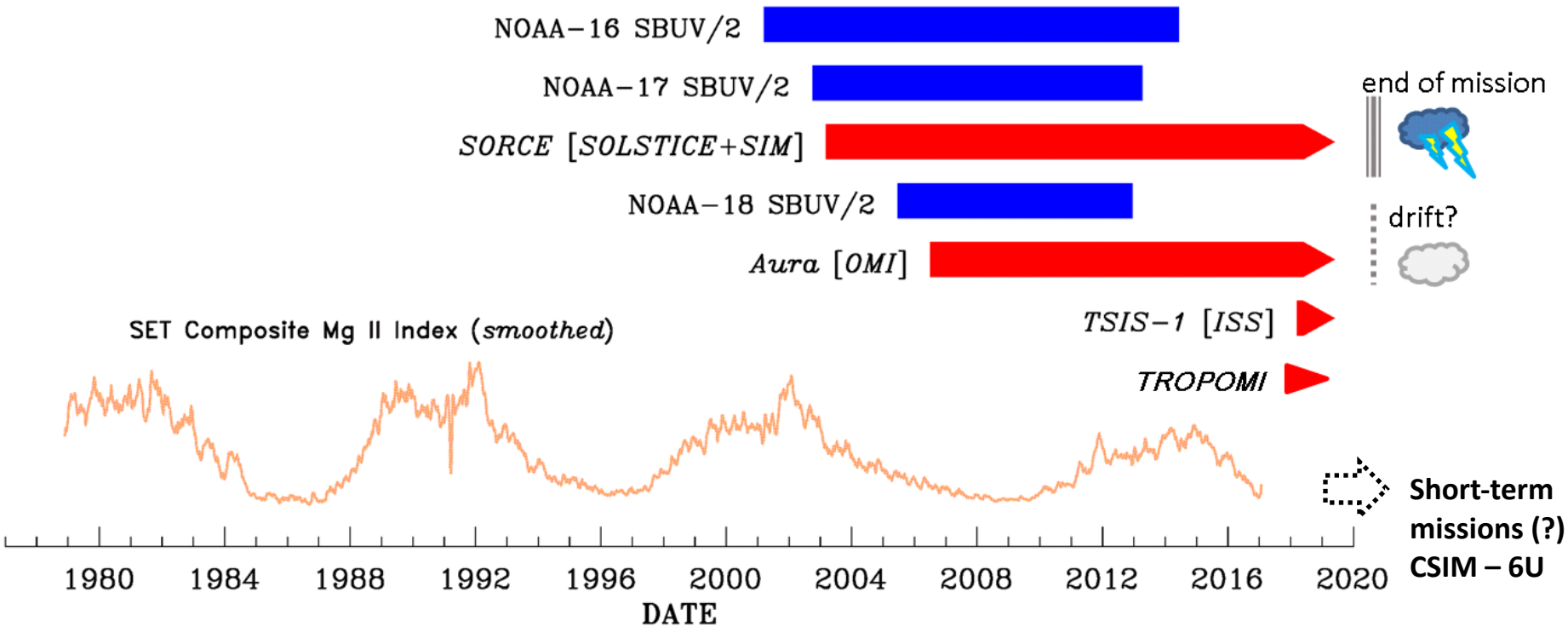
Daily OMI Solar Cycle 24 SSIs (2006-present, **V3**):

Stability / year *	**≤ 0.02% (λ < 400 nm), ≤ 0.01% (λ > 400 nm)**
Relative precision	**~ 0.1% (λ < 400 nm), ~0.02-0.1% (λ > 400 nm)**

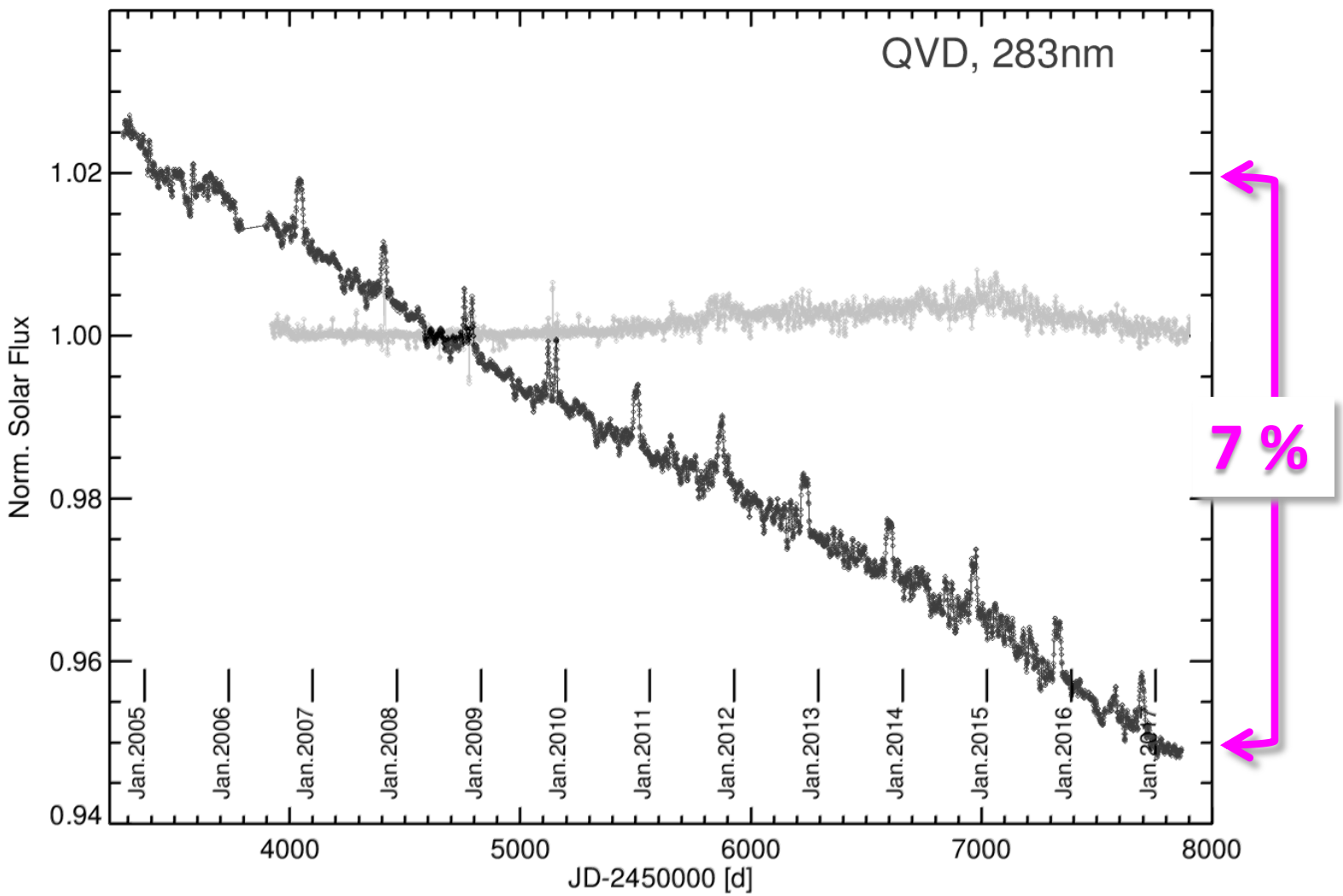
* linking the adjacent solar minima
i.e., talking in relative terms

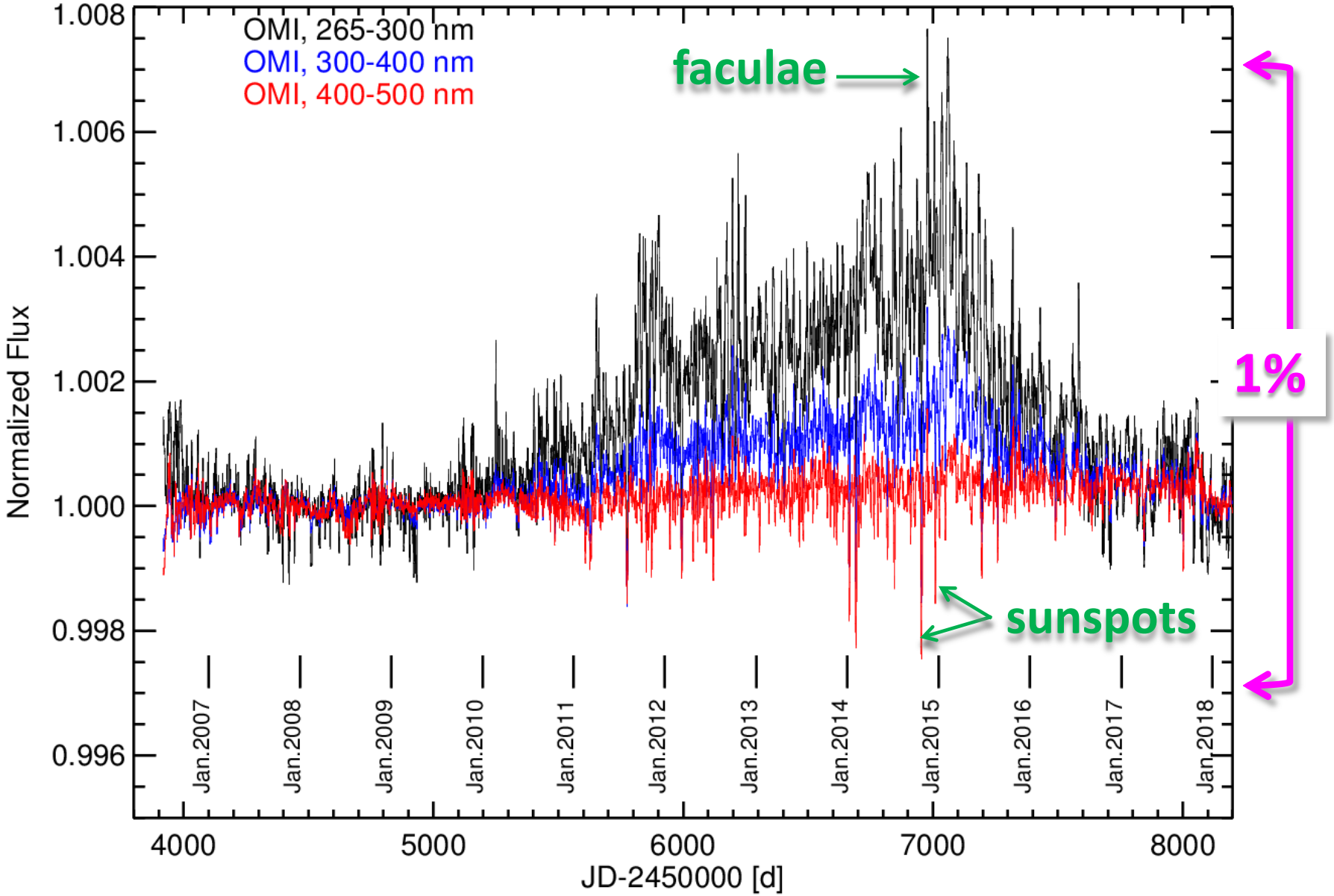
[Daily] SSI measurements in Solar cycle 24…

the ones that can be used for climate studies, that is…

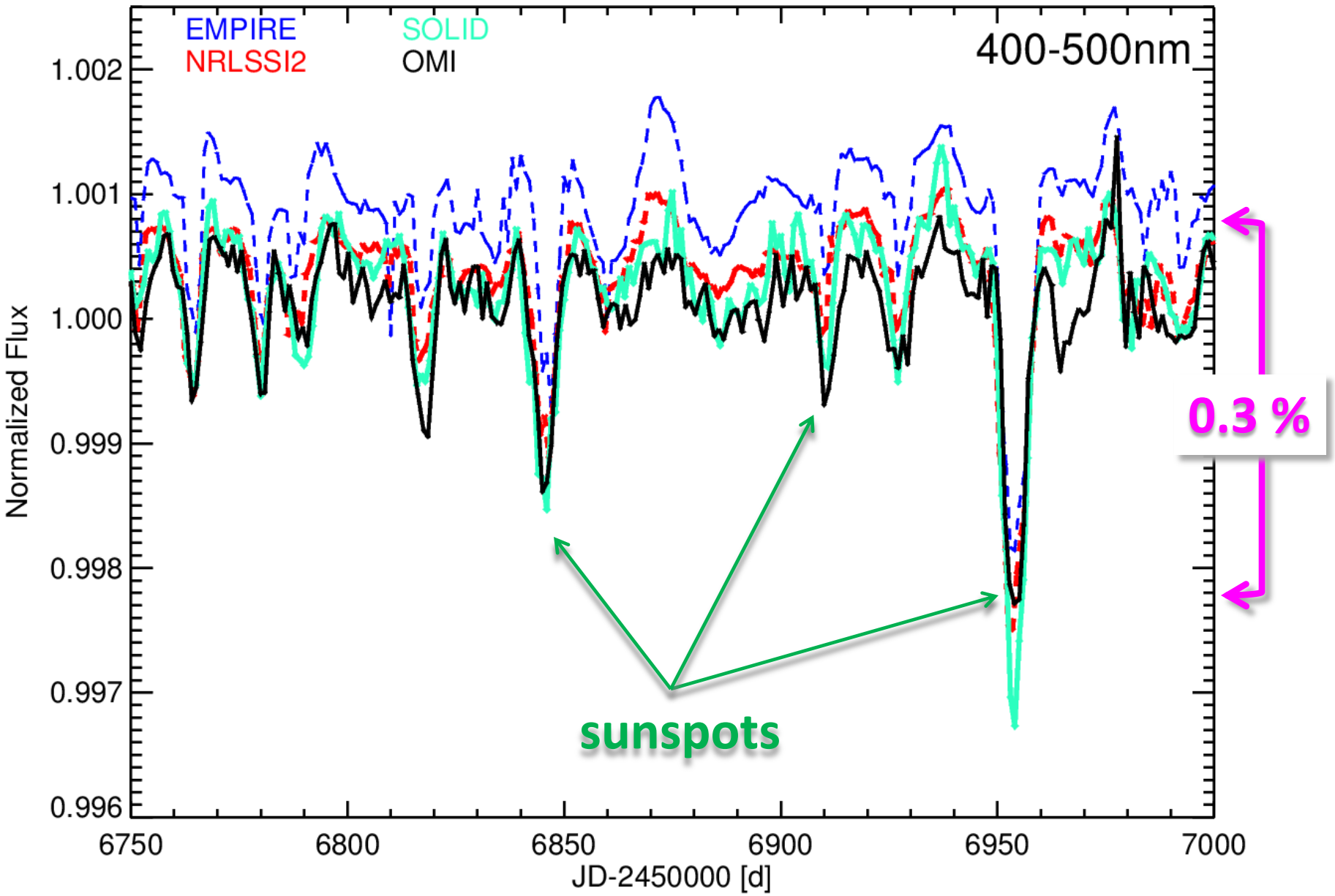


OMI SSI (V3): quest for « 0.1% long-term stability

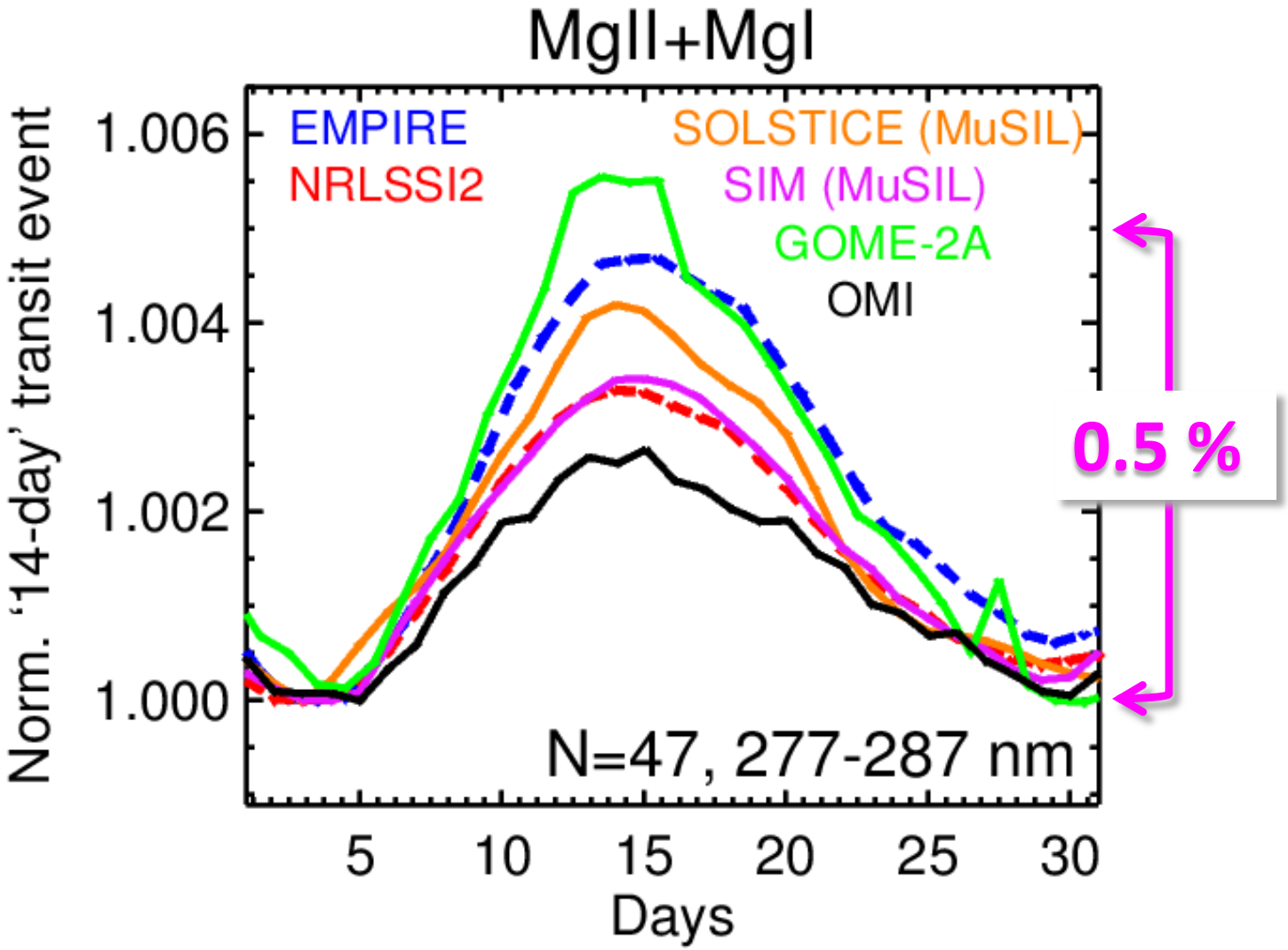



OMI, 265-300 nm
OMI, 300-400 nm
OMI, 400-500 nm
faculae
sunspots
1%
Normalized Flux
1.008
1.006
1.004
1.002
1.000
0.998
0.996
Jan.2007
Jan.2008
Jan.2009
Jan.2010
Jan.2011
Jan.2012
Jan.2013
Jan.2014
Jan.2015
Jan.2016
Jan.2017
Jan.2018
4000
5000
6000
7000
8000
JD-2450000 [d]

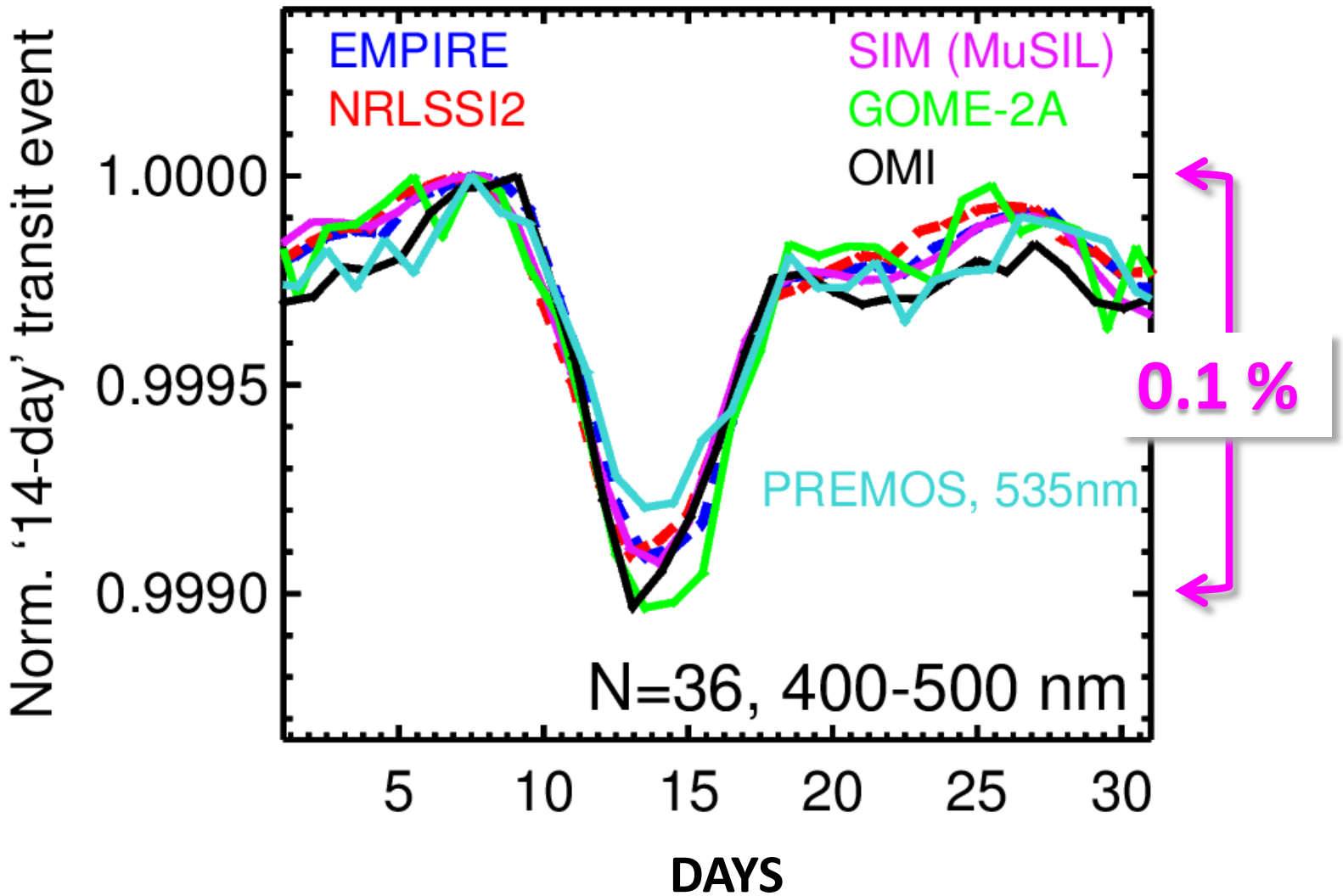
Sunspots: March-December 2014



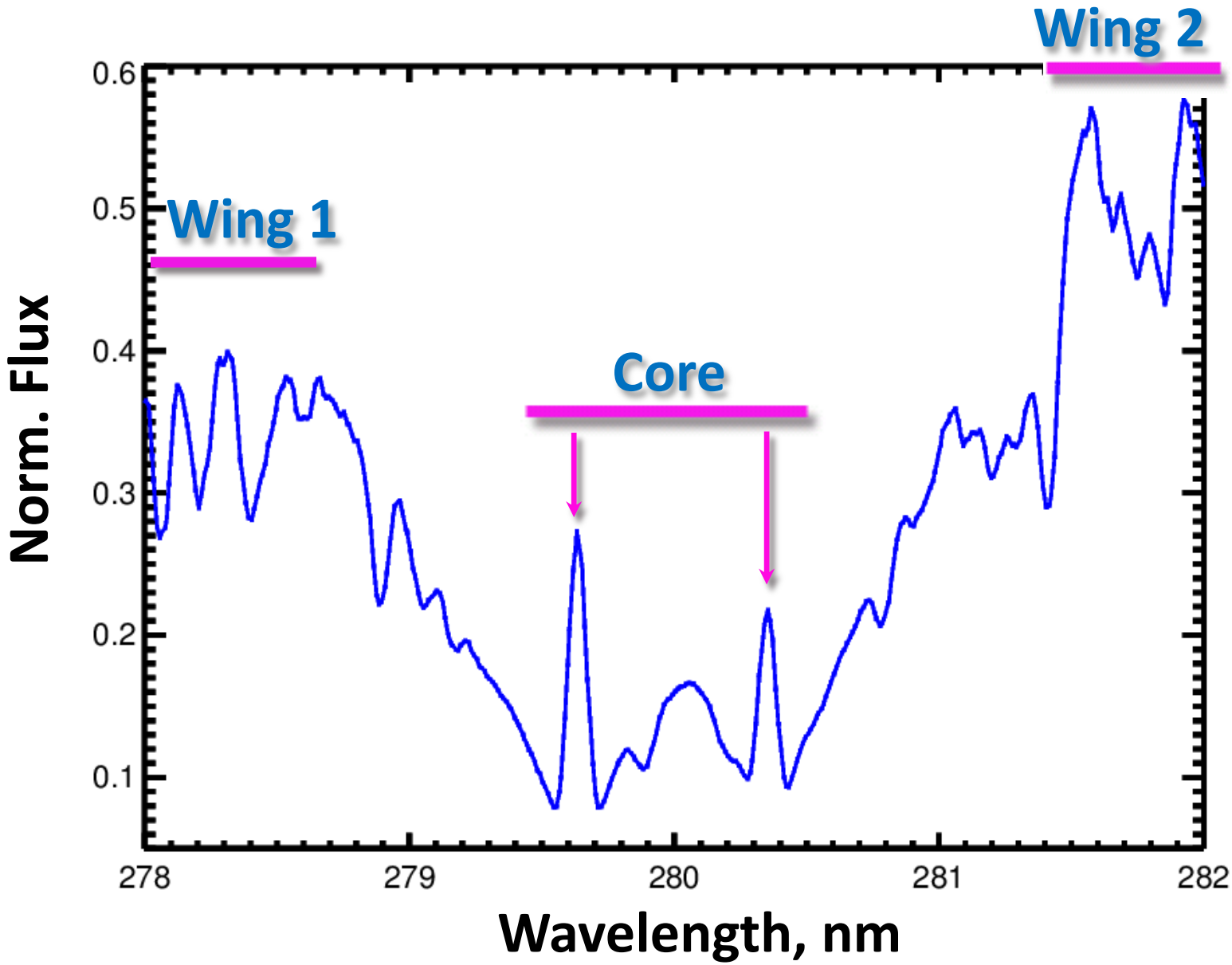
~27-day rotational cycle: faculae



~27-day rotational cycle: sunspots – W1 #1

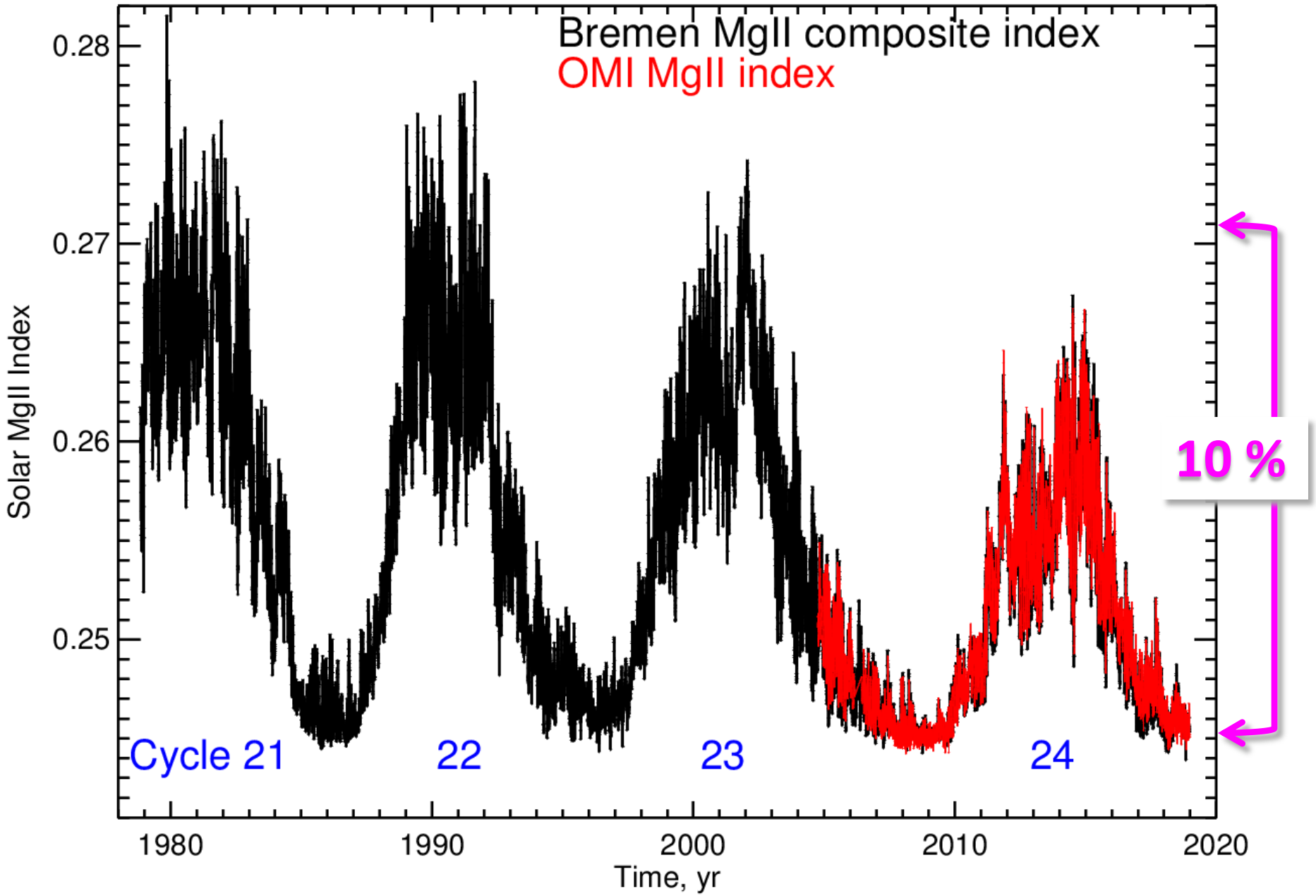


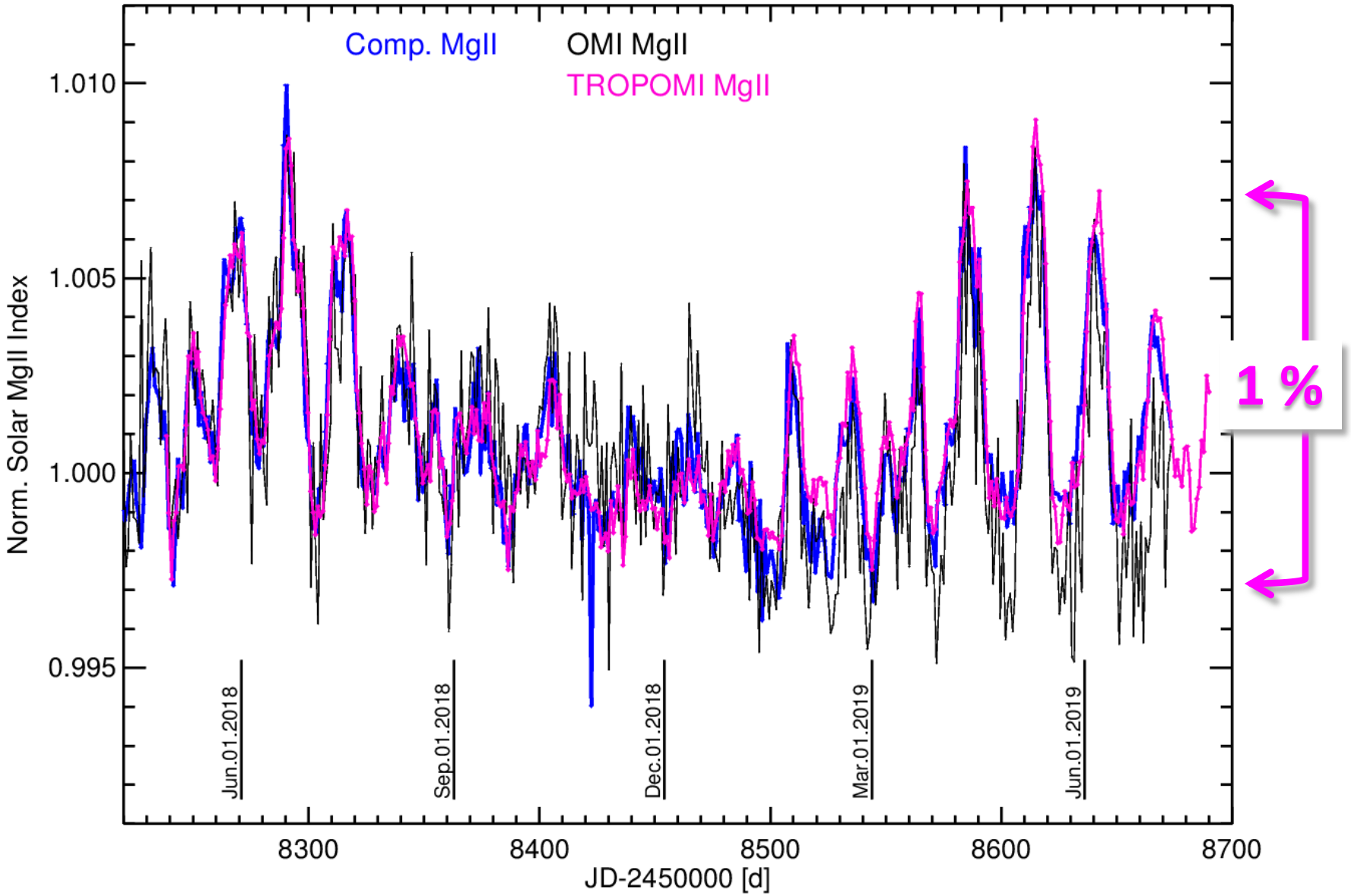
Solar activity: MgII index as a proxy



SOLSTICE, Δλ ~ 0.1 nm

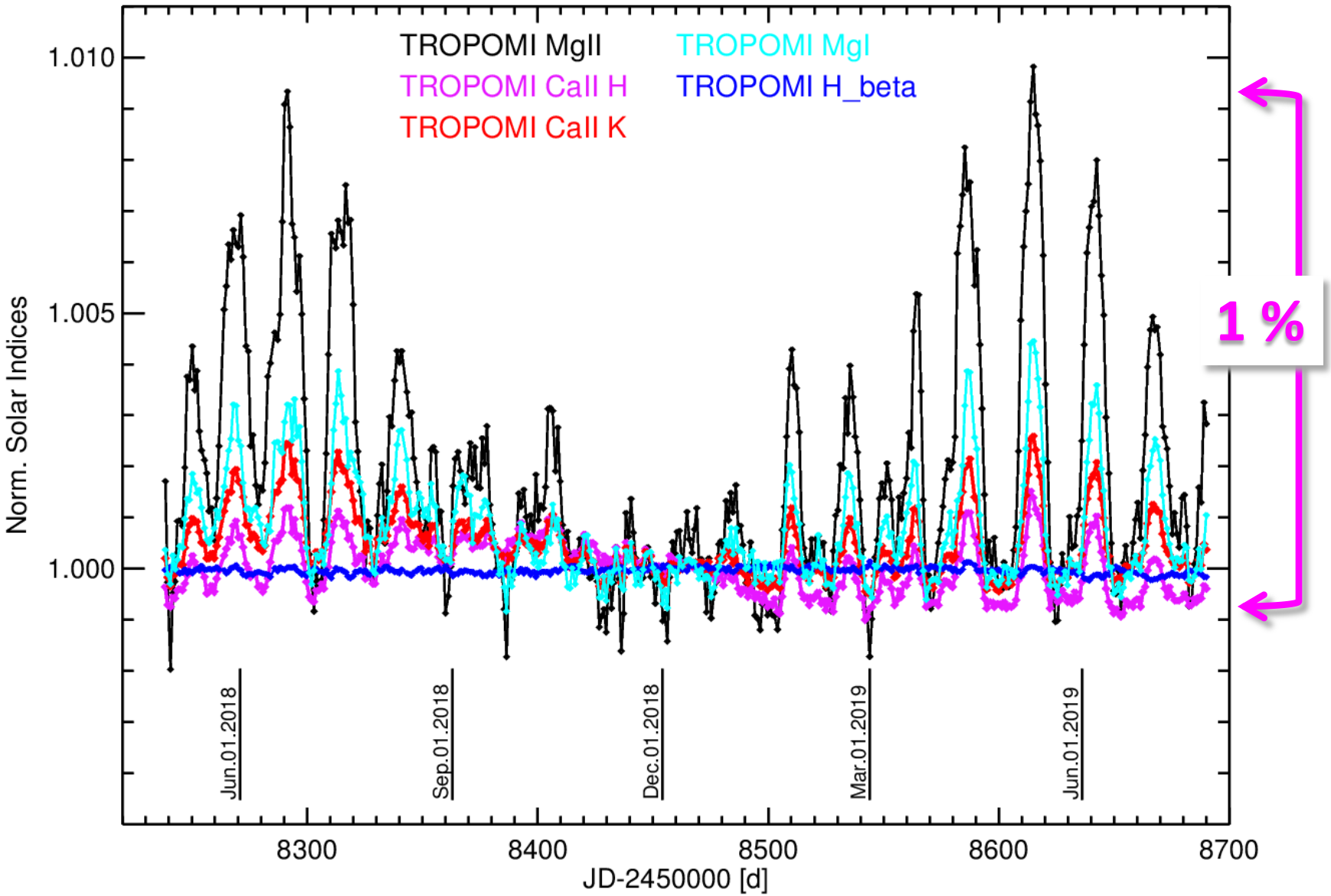
Solar activity: MgII index as a proxy



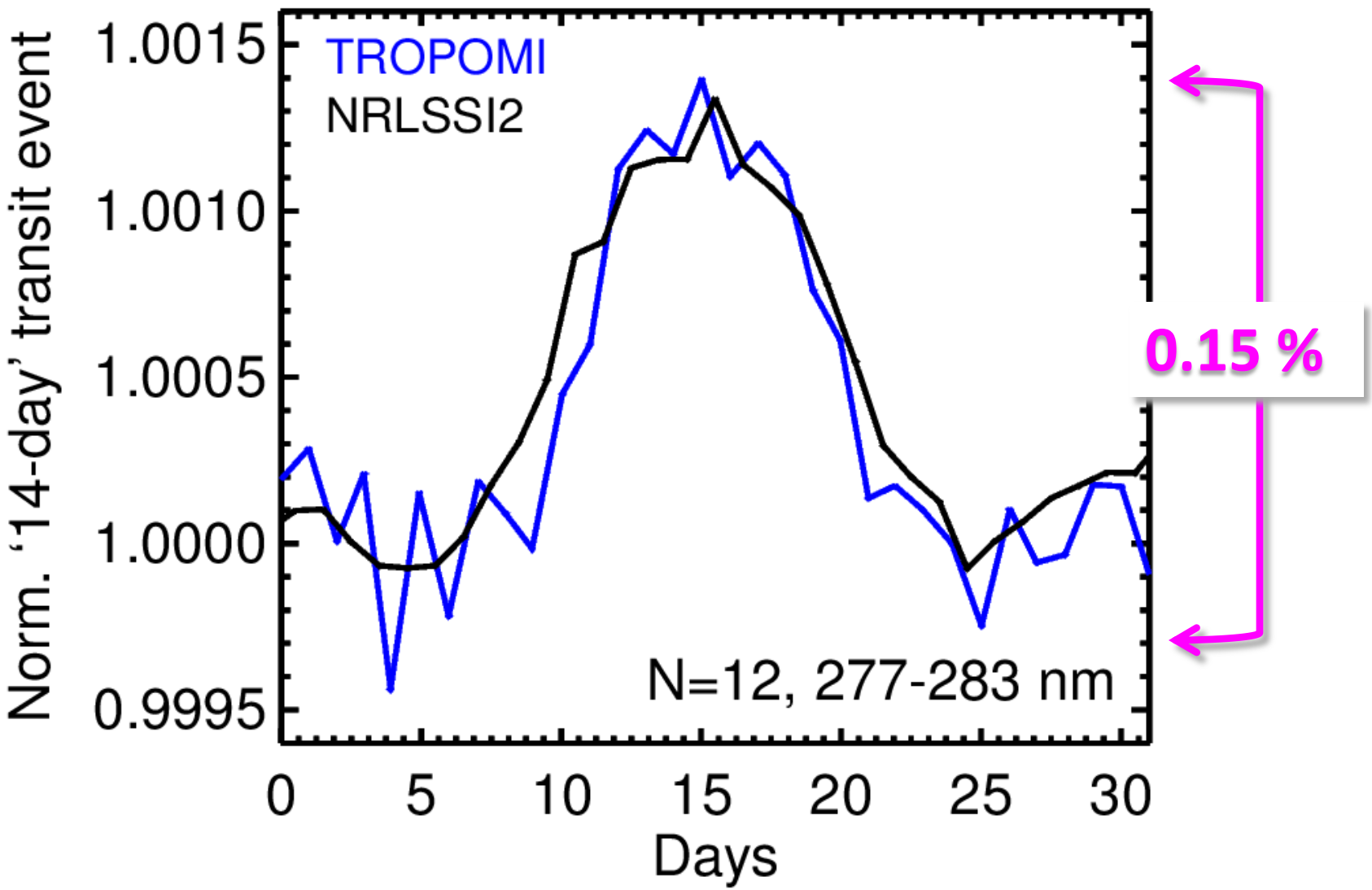


Solar MgII composite: M.Weber, *http://www.iup.uni-bremen.de/gome/gomemgii.html*

W2 # 2


TROPOMI MgII
TROPOMI MgI
TROPOMI CaII H
TROPOMI H_beta
TROPOMI CaII K
1.010
1.005
1.000
Norm. Solar Indices
Jun.01.2018
Sep.01.2018
Dec.01.2018
Mar.01.2019
Jun.01.2019
8300
8400
8500
8600
8700
JD-2450000 [d]
1 %

TROPOMI and NRLSSI2 model – W3 #3



Summary

- **OMI SSIs are firmly integrated into the climate-study data sets.**
  Lesson #1: instrument stability is crucial in climate studies

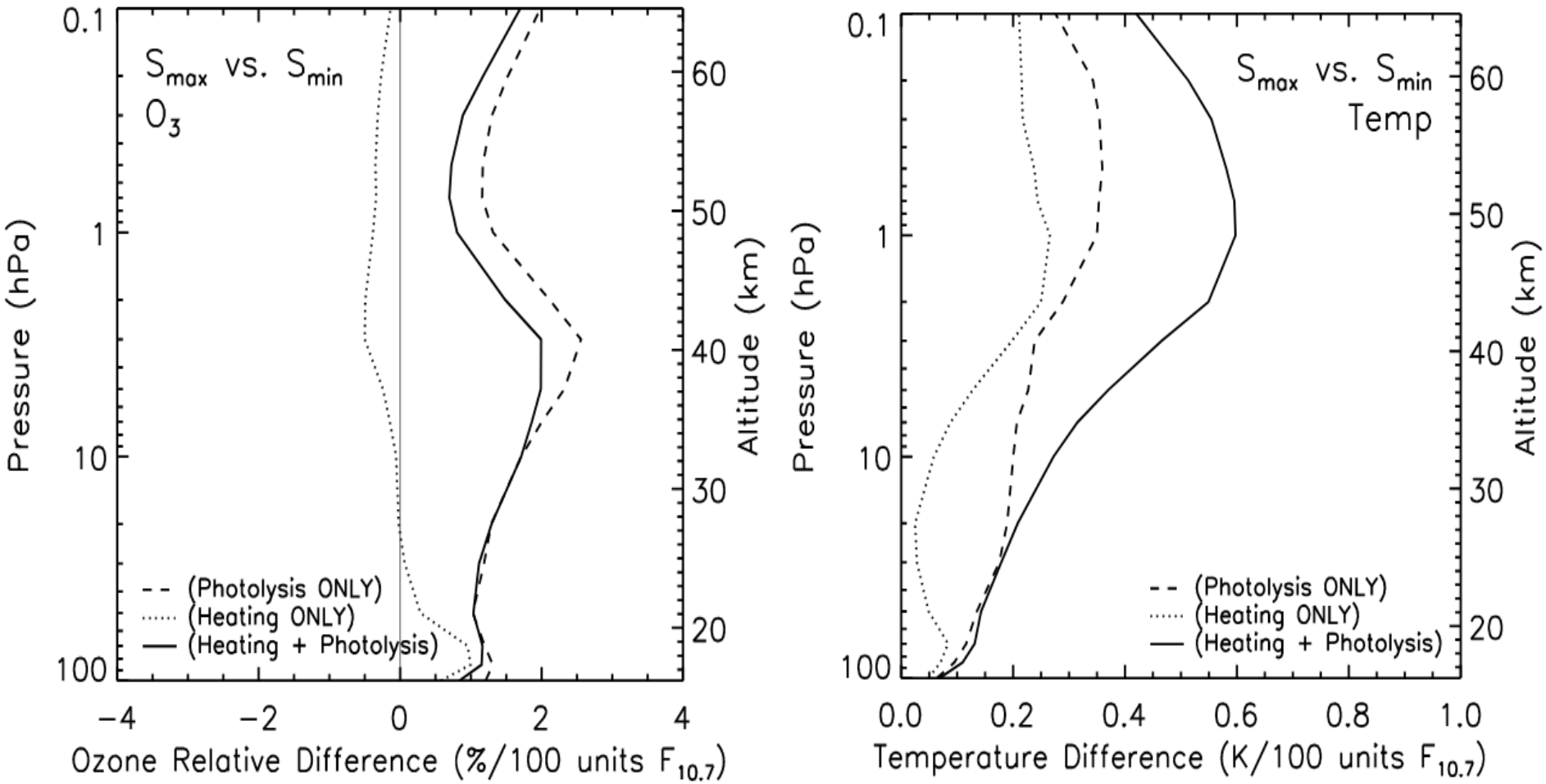
- **If (?) Aura starts drifting, there might be only TSIS-1 (ISS) left producing 'climate-study-graded' (long-term, stable, frequent and uninterrupted) SSIs.**

- **TROPOMI must pitch in!**

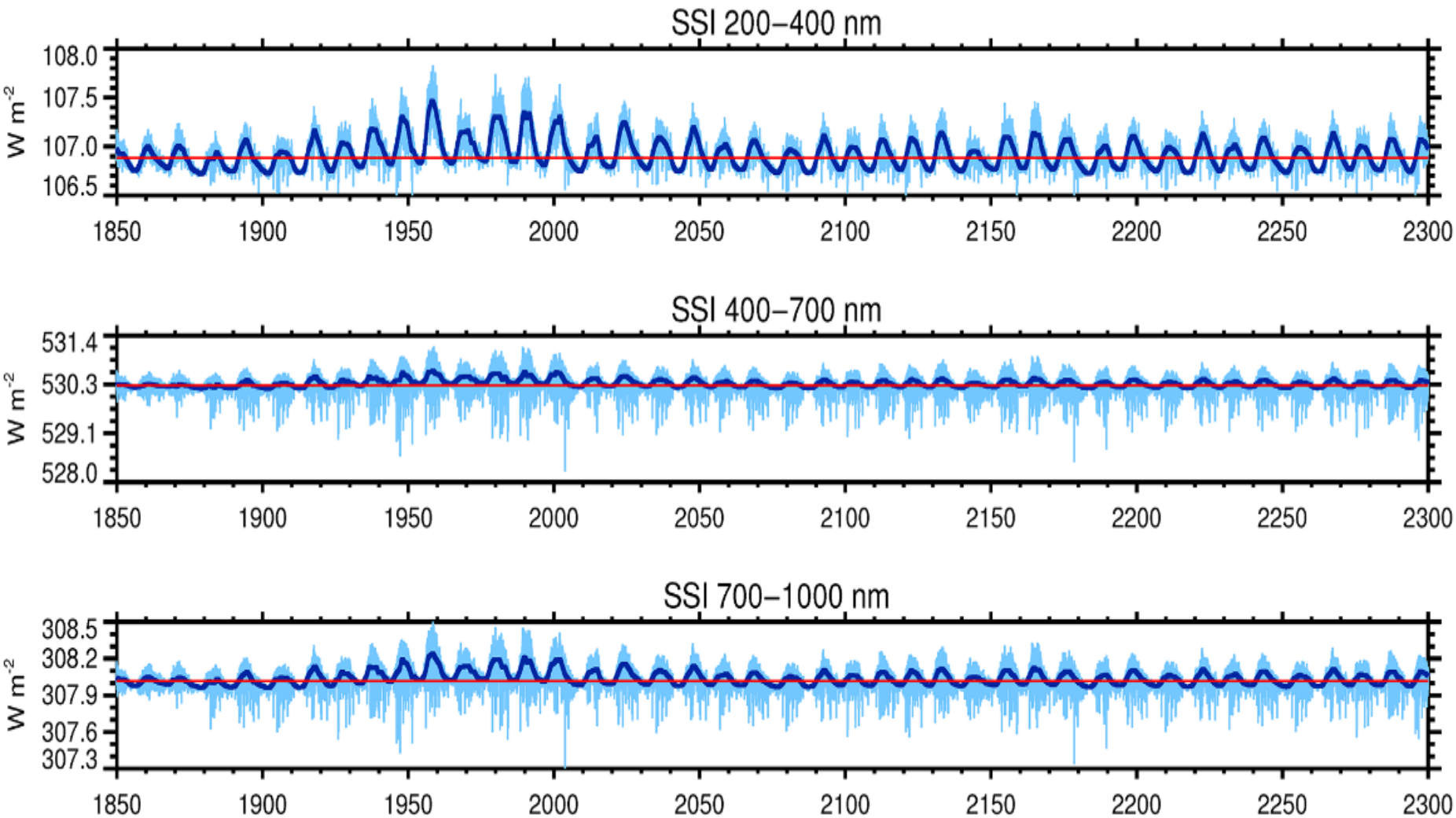
- **Solar data help to gauge short- and long-term instrument performance in unprecedented detail, down to ~0.05%-0.1% in OMI's case.**
  Lesson #2: the multiple benefits of DAILY solar data

You are welcome to peruse the corrected OMI SSIs (**V3**):
https://sbuv2.gsfc.nasa.gov/solar/omi/

http://lasp.colorado.edu/lisird/data/omi_ssi/

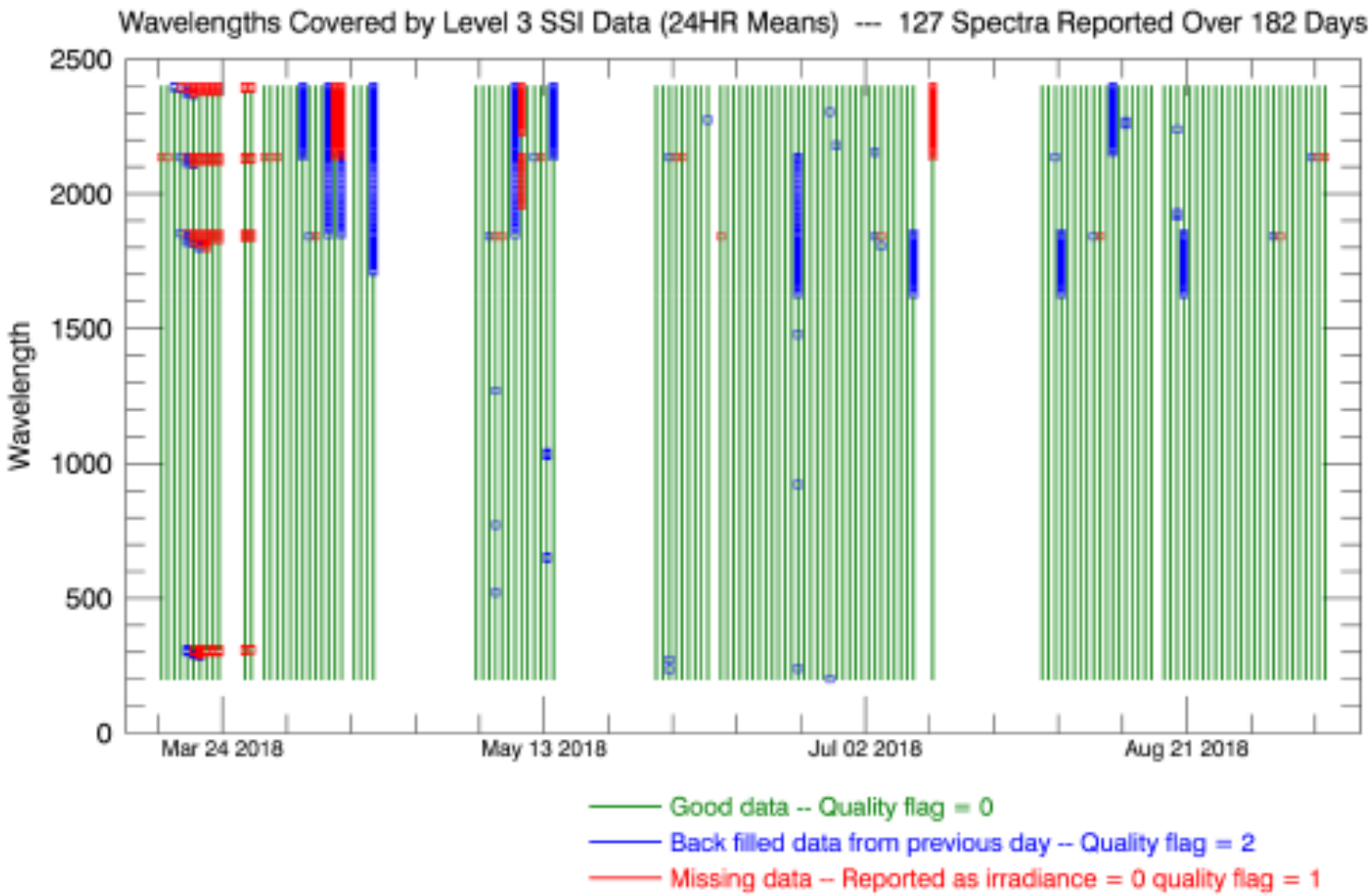


Repr. from: W. Swartz et al., ACP, 12, 5937 (2012)

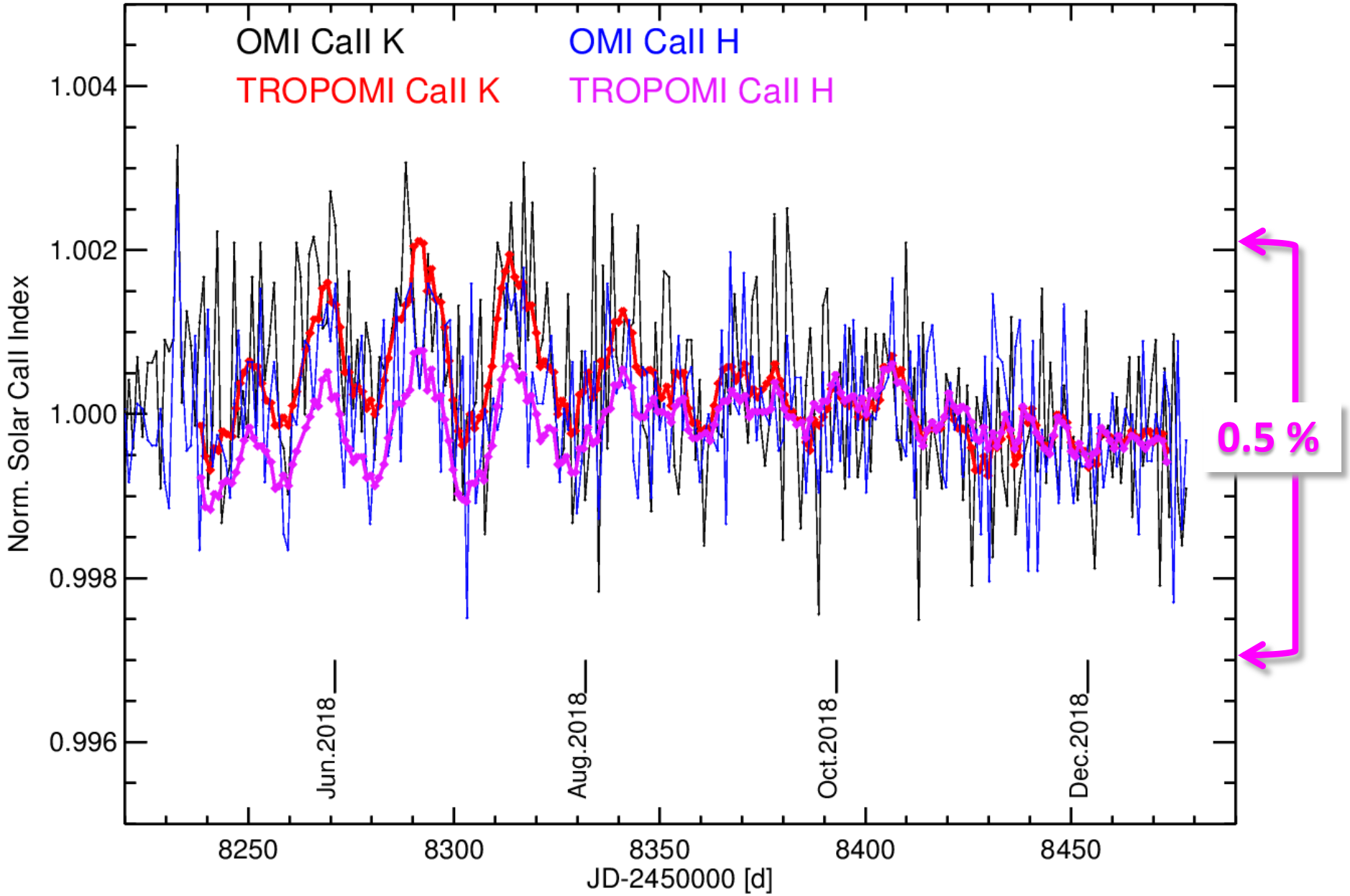


Repr. from: K. Matthes et al., Geosci. Model Dev., 10, 2247 (2017) - 'Reference scenario'

SSIs from TSIS-1 (ISS)



Repr. from: TSIS SIM V01 Release Notes


OMI CaII K
OMI CaII H
TROPOMI CaII K
TROPOMI CaII H
1.004
1.002
1.000
0.998
0.996
Norm. Solar CaII Index
Jun.2018
Aug.2018
Oct.2018
Dec.2018
8250
8300
8350
8400
8450
JD-2450000 [d]
0.5 %