Attribution of the 11-year solar cycle in lower-stratospheric temperature

Ales Kuchar,[1,2] Eugene Rozanov,[2,3] Will Ball,[2,3] Andrea Stenke,[2] Laura Revell,[2,4] Petr Pisoft,[1] Thomas Peter[2]

[1]Department of Atmospheric Physics, Charles University in Prague, Czech Republic
[2]IAC ETH, Zurich, Switzerland
[3]PMOD, Davos, Switzerland
[4]Bodeker Scientific, New Zealand

SOLARIS-HEPPA, Boulder, November 10, 2015

Take aways

- solar signal in TLS over satellite era is reduced considering volcanoes (50%) and SST (+25%) correctly
- 1965–2009 sufficient to eliminate volcanic forcing aliasing in TLS
- significant methodology influence

Take aways

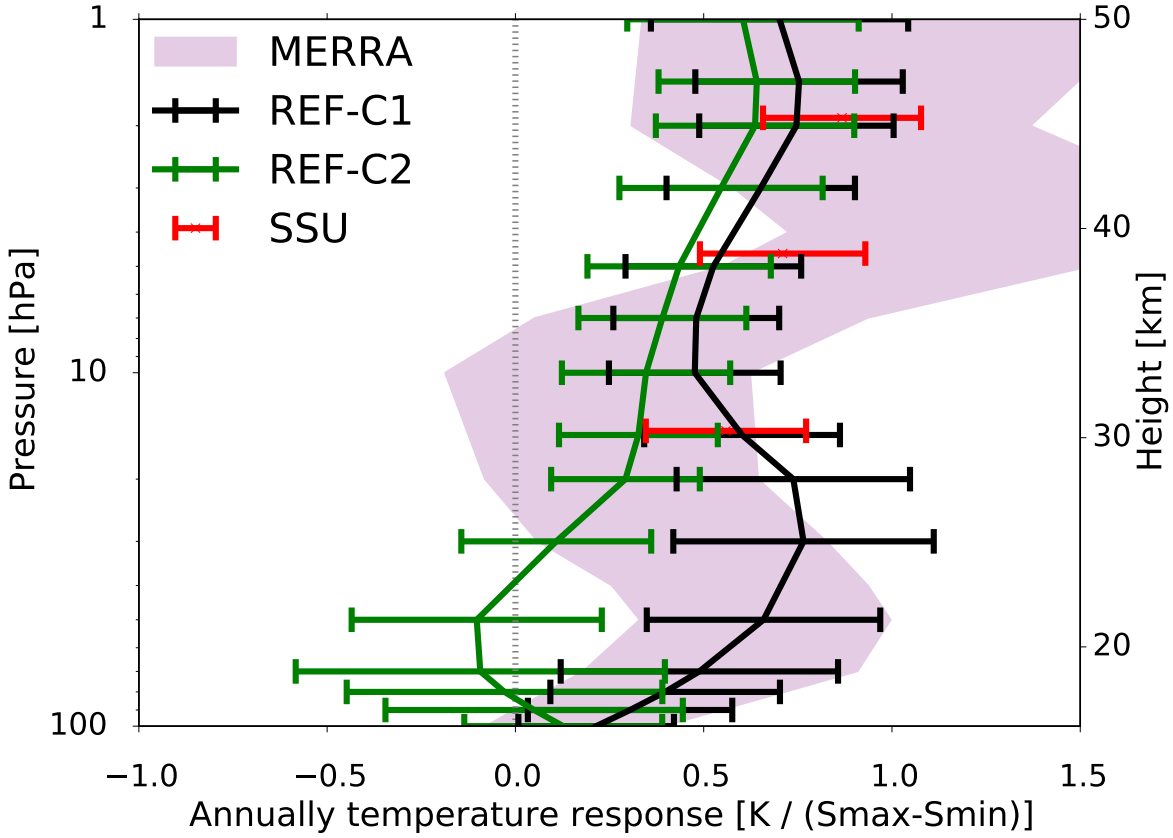
- solar signal in TLS over satellite era is reduced considering volcanoes (50%) and SST (+25%) correctly
- 1965–2009 sufficient to eliminate volcanic forcing aliasing in TLS
- significant methodology influence

Take aways

- solar signal in TLS over satellite era is reduced considering volcanoes (50%) and SST (+25%) correctly
- 1965–2009 sufficient to eliminate volcanic forcing aliasing in TLS
- significant methodology influence

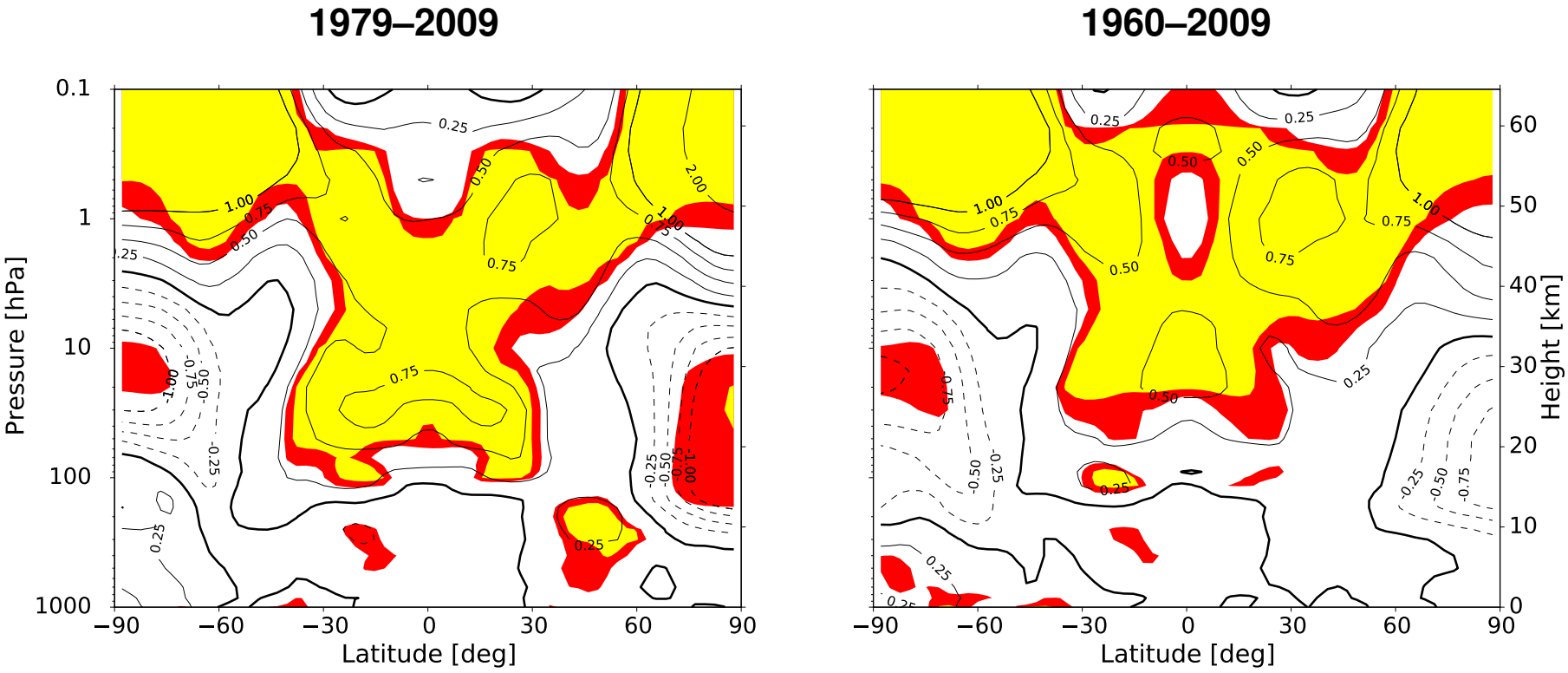
Motivation #1

- compare model results with observational and reanalysis data
- SC attribution in equatorial profile for the period 1979–2005



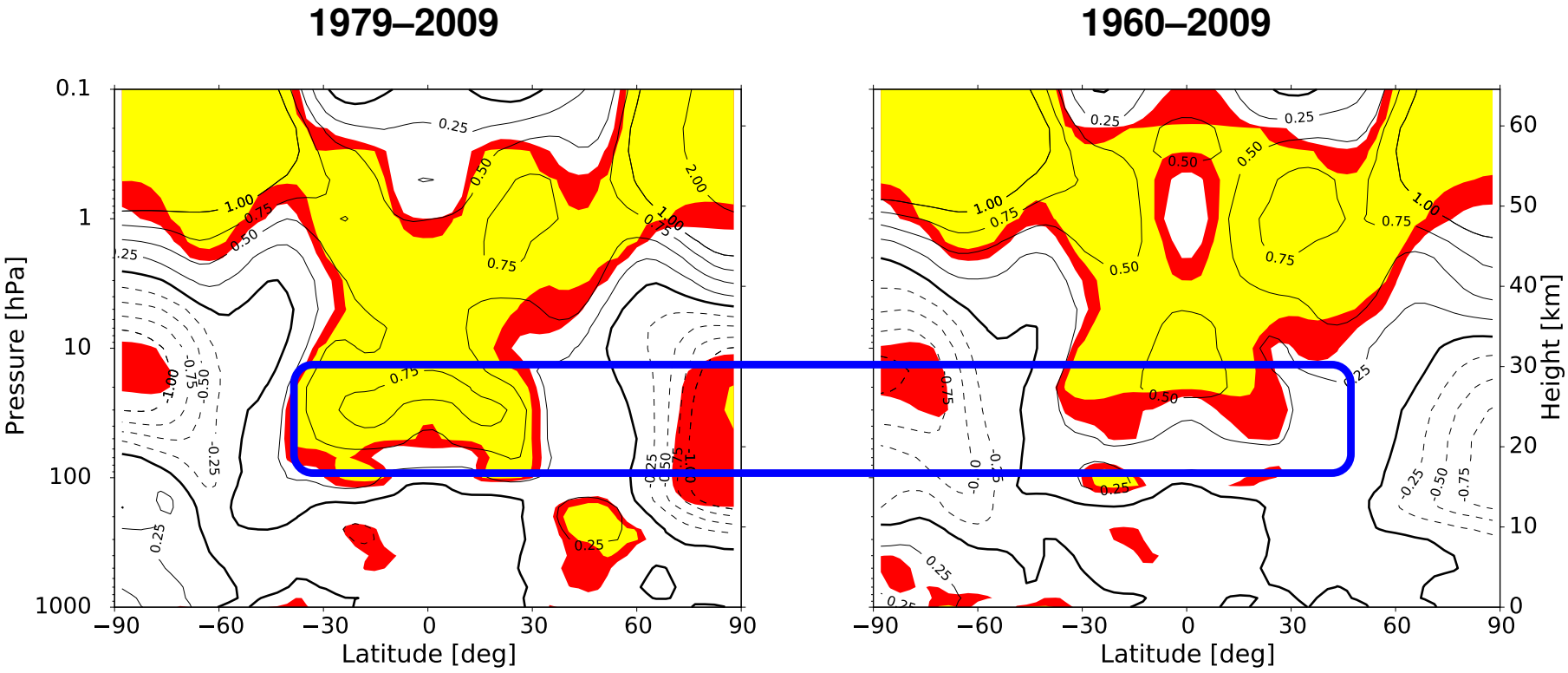
Motivation #2

- REF-C1 simulation
- SC attribution in zonal mean of temperature for 2 different periods



Motivation #2

- REF-C1 simulation
- SC attribution in zonal mean of temperature for 2 different periods



Model simulations

- CCMI hindcast simulation REF-C1 and REF-C2 (1960–2009)

Simulation title	SST/SIC bound. cond.	Volc. erupt.	# of ens. memb.
REF-C1	Hadley	✓	1
REF-C2	CESM1-CAM5	×	1

- in addition, sensitivity simulations testing boundary conditions on the solar signal

REF-C1-S	Hadley	×	3
REF-C1-S-clim	Hadley climatology	×	1
REF-C2-S	CESM1-CAM5	✓	1

Model simulations

- CCMI hindcast simulation REF-C1 and REF-C2 (1960–2009)

Simulation title	SST/SIC bound. cond.	Volc. erupt.	# of ens. memb.
REF-C1	Hadley	✓	1
REF-C2	CESM1-CAM5	×	1

- in addition, sensitivity simulations testing boundary conditions on the solar signal

REF-C1-S	Hadley	×	3
REF-C1-S-clim	Hadley climatology	×	1
REF-C2-S	CESM1-CAM5	✓	1

Model simulations

- CCMI hindcast simulation REF-C1 and REF-C2 (1960–2009)

Simulation title	SST/SIC bound. cond.	Volc. erupt.	# of ens. memb.
REF-C1	Hadley	✓	1
REF-C2	CESM1-CAM5	×	1

- in addition, sensitivity simulations testing boundary conditions on the solar signal

REF-C1-S	Hadley	×	3
REF-C1-S-clim	Hadley climatology	×	1
REF-C2-S	CESM1-CAM5	✓	1

Model simulations

- CCMI hindcast simulation REF-C1 and REF-C2 (1960–2009)

Simulation title	SST/SIC bound. cond.	Volc. erupt.	# of ens. memb.
REF-C1	Hadley	✓	1
REF-C2	CESM1-CAM5	×	1

- in addition, sensitivity simulations testing boundary conditions on the solar signal

REF-C1-S	Hadley	×	3
REF-C1-S-clim	Hadley climatology	×	1
REF-C2-S	CESM1-CAM5	✓	1

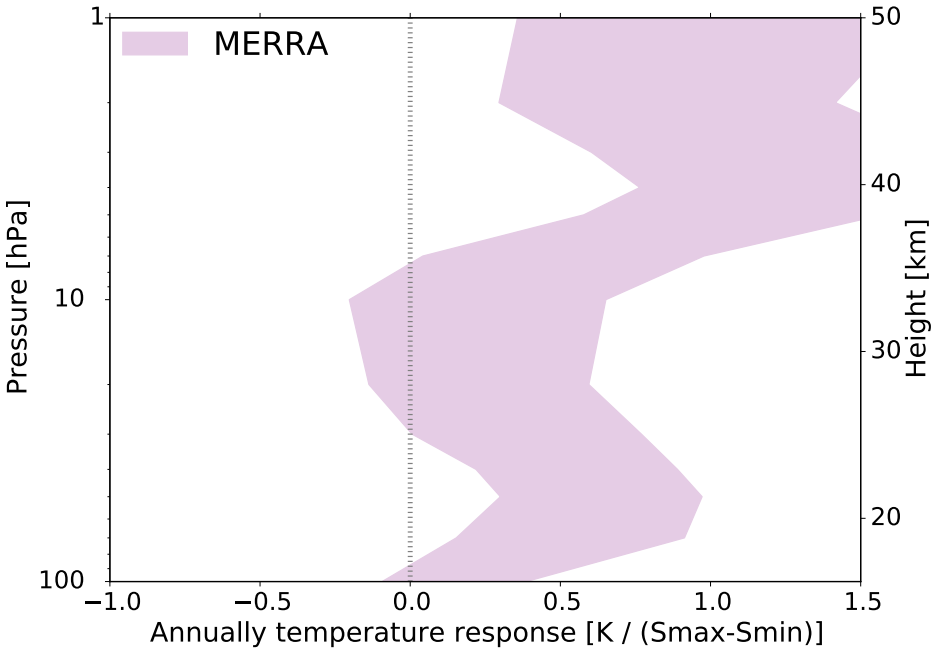
Multiple linear regression (MLR)

Regression model:

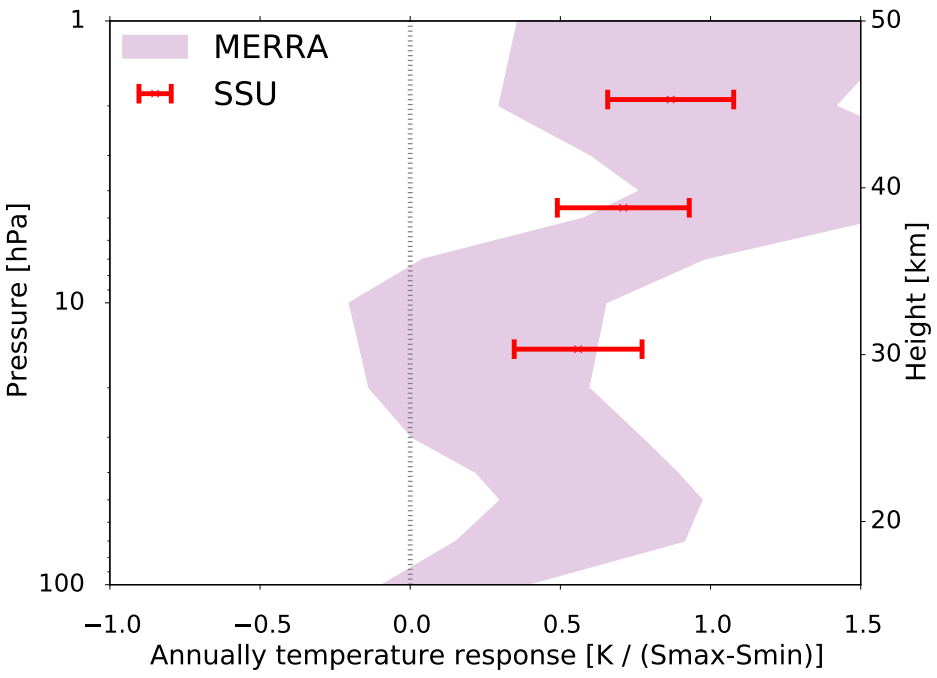
$$
\begin{aligned}
Y(t) \quad = \quad & \alpha + \beta\,\mathrm{SAD}(t) + \boxed{\gamma\,\mathrm{SOLAR}(t)} \\
& + \delta_1\,\mathrm{QBO}_1(t) + \delta_2\,\mathrm{QBO}_2(t) + \epsilon\,\mathrm{ENSO}(t) \\
& + \zeta\,\mathrm{TREND}(t) + \mathbf{e}(t).
\end{aligned} \tag{1}
$$

- using AR2 to remove residual autocorrelation **e** — Durbin-Watson test (DWT)
- $\mathrm{QBO}_{1,2}$ and ENSO3.4 index extracted by PCA
- t-test (95% confidence interval)

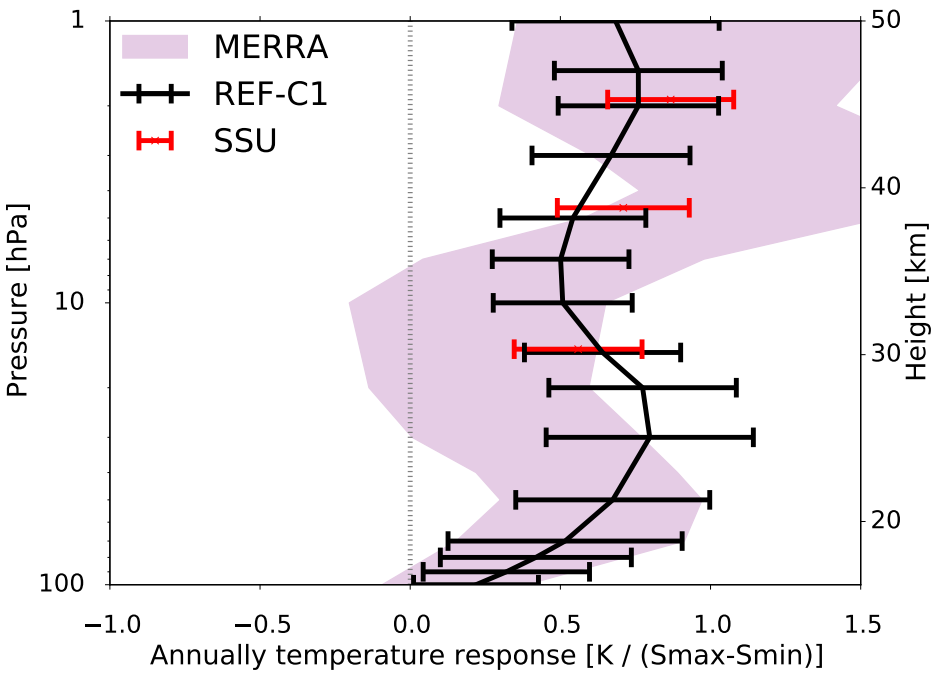
SC profile in tropical stratosphere (temperature)



SC profile in tropical stratosphere (temperature)

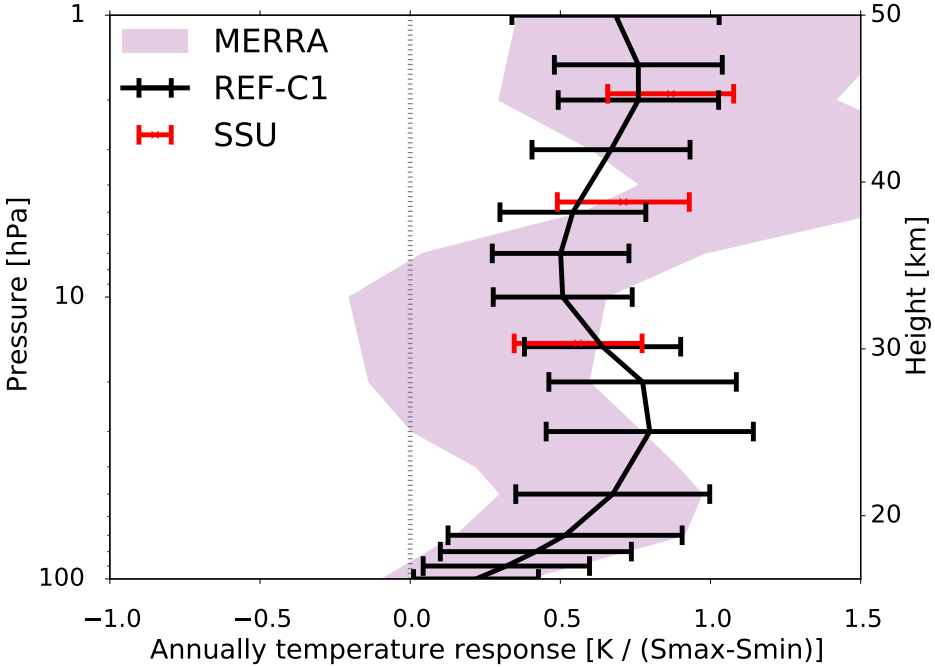


SC profile in tropical stratosphere (temperature)



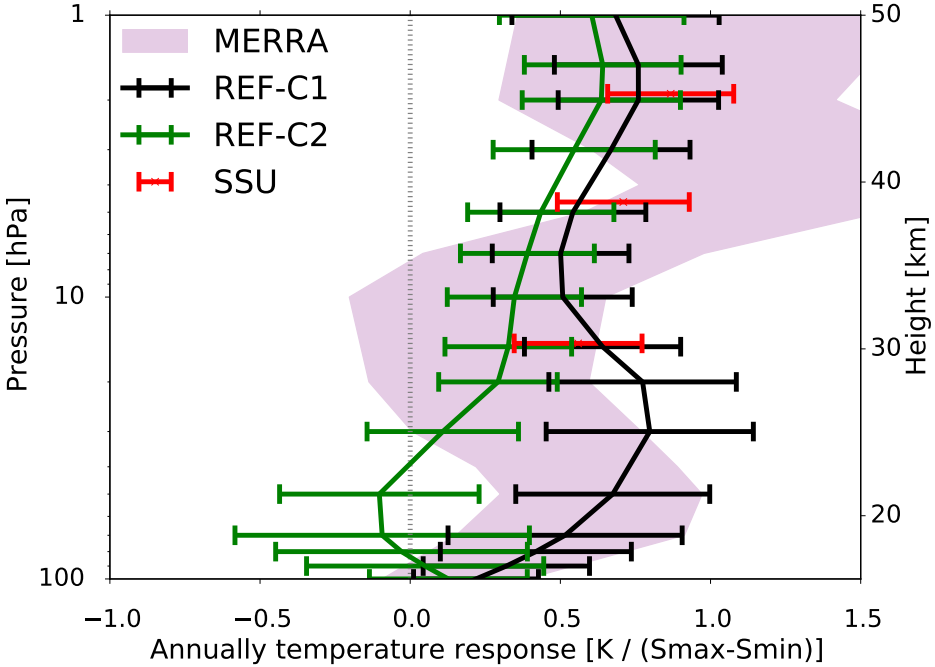
SC profile in tropical stratosphere (temperature)

- **REF-C1** is comparable with available data (MERRA, SSU)



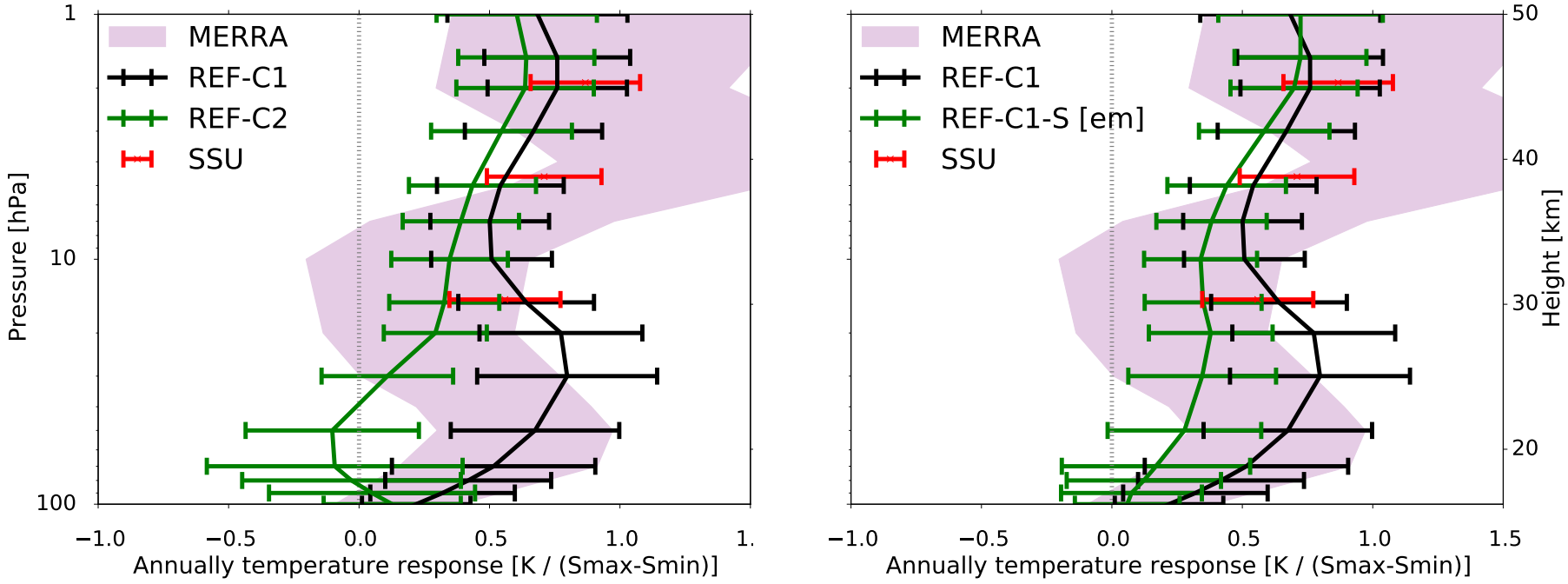
SC profile in tropical stratosphere (temperature)

- **REF-C1** is comparable with available data (MERRA, SSU)



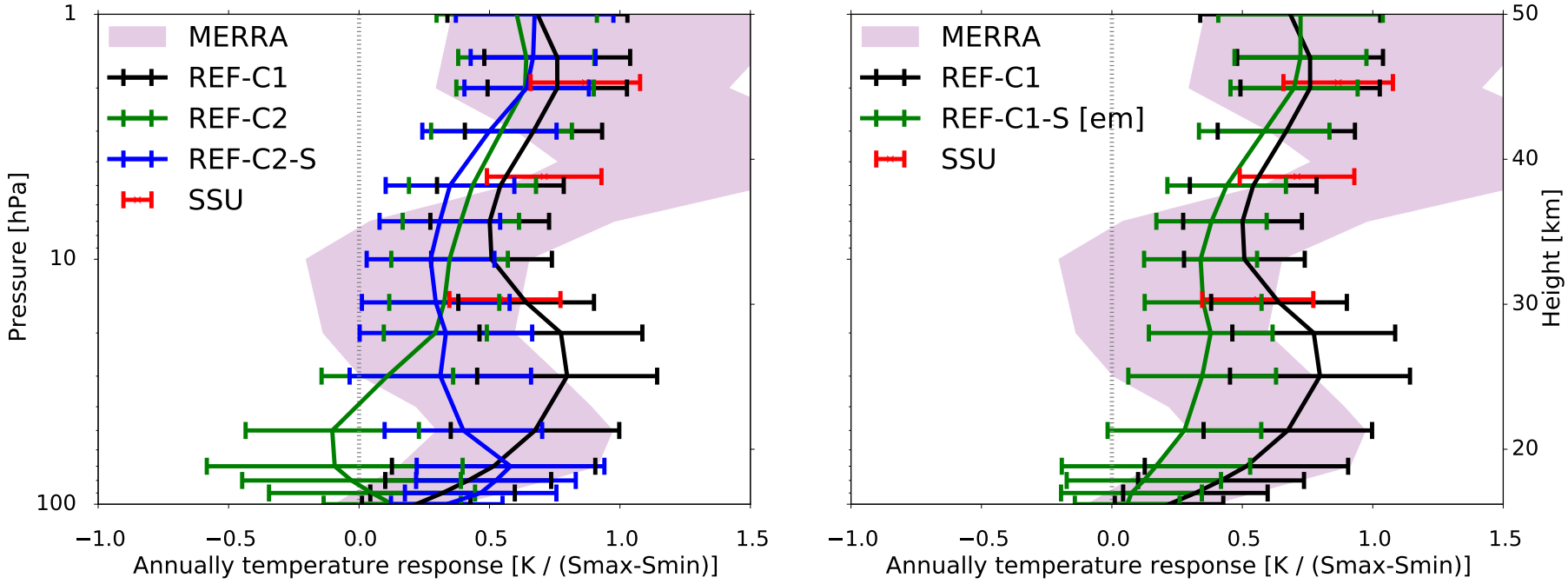
SC profile in tropical stratosphere (temperature)

- **REF-C1** is comparable with available data (MERRA, SSU)



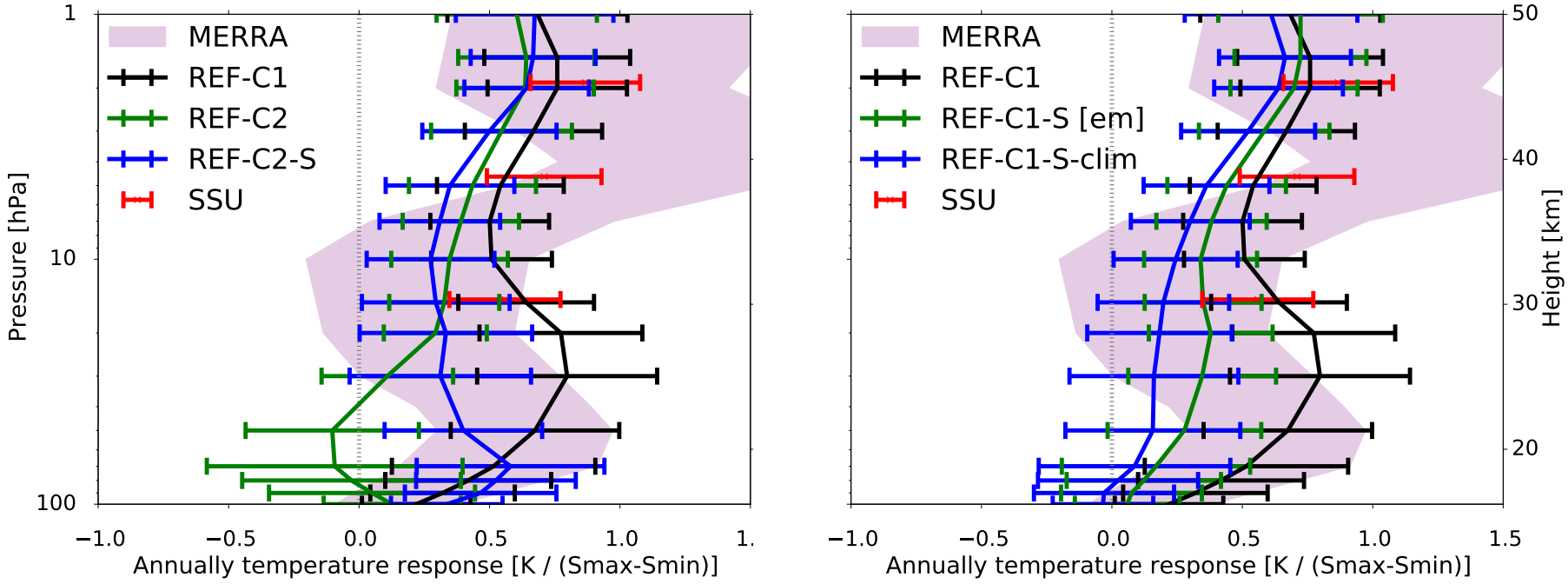
SC profile in tropical stratosphere (temperature)

- **REF-C1** is comparable with available data (MERRA, SSU)



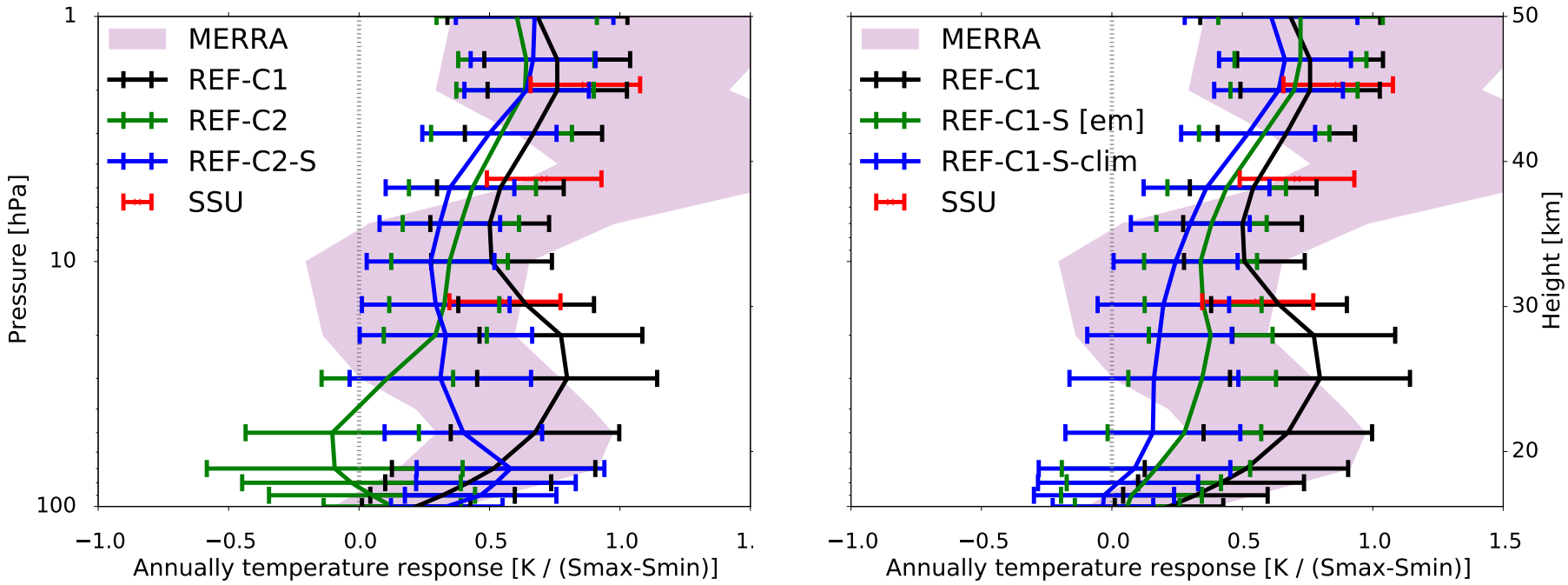
SC profile in tropical stratosphere (temperature)

- **REF-C1** is comparable with available data (MERRA, SSU)

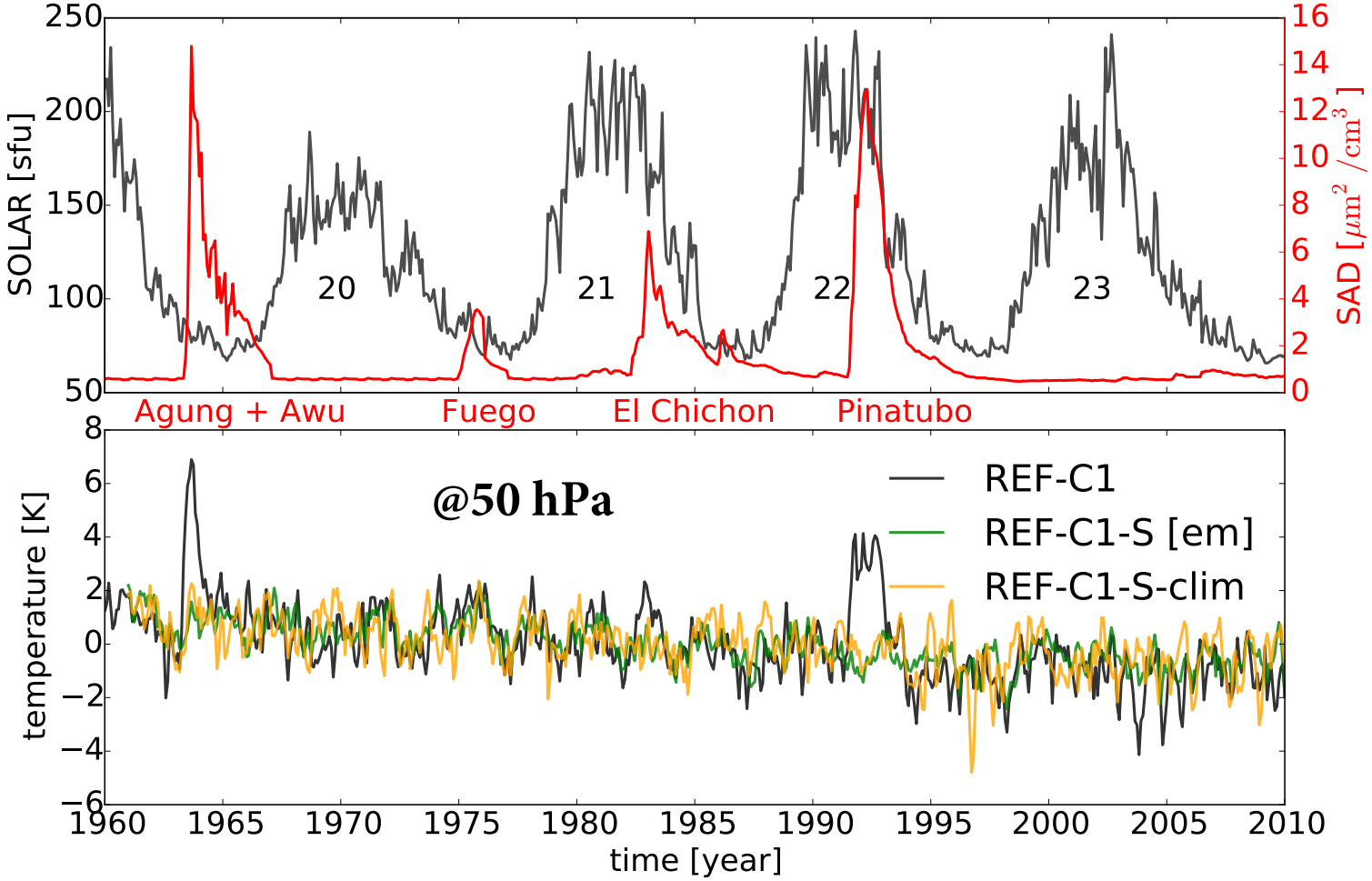


SC profile in tropical stratosphere (temperature)

- **REF-C1** is comparable with available data (MERRA, SSU)
- the solar signal is reduced in TLS (@50 hPa) to 50% in case of **REF-C1-S**, further 25% in case of **REF-C1-S-clim** for the period 1979–2005

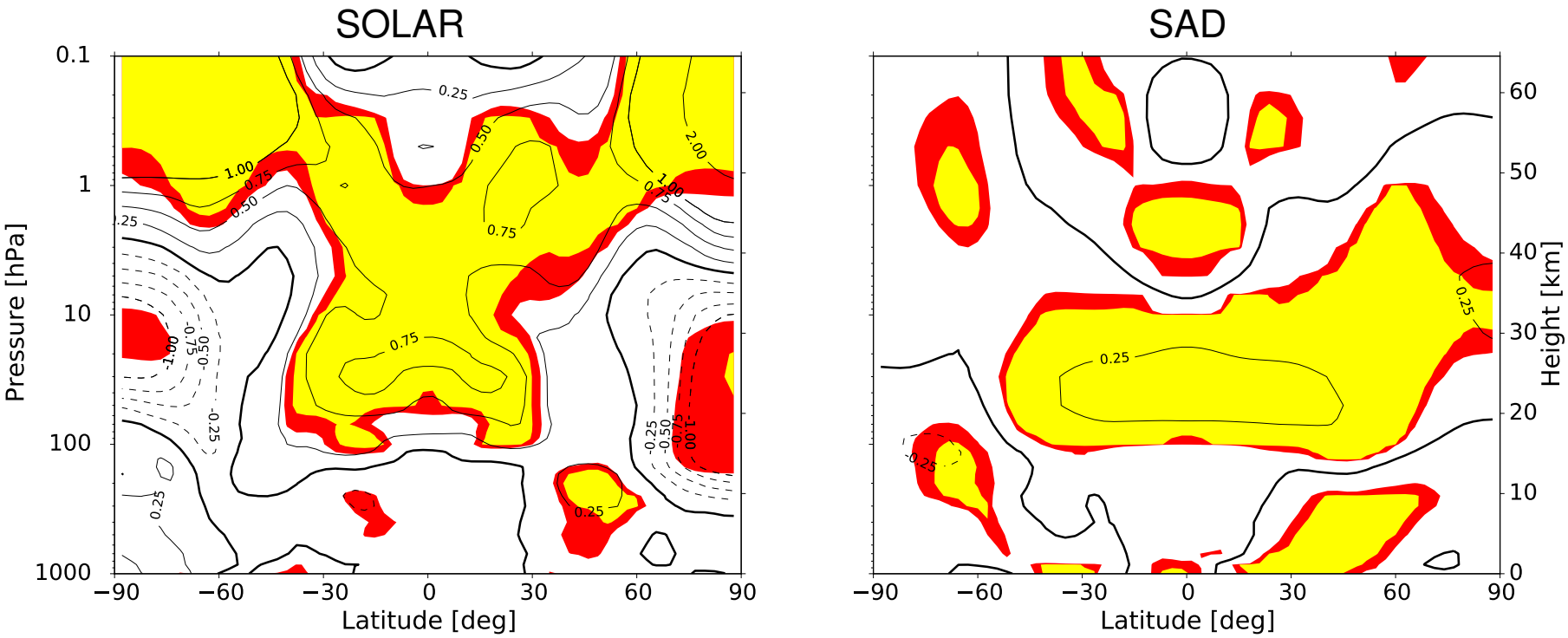


Why?


SOLAR [sfu]
SAD [$\mu m^2/cm^3$]
20
21
22
23
Agung + Awu
Fuego
El Chichon
Pinatubo
@50 hPa
REF-C1
REF-C1-S [em]
REF-C1-S-clim
temperature [K]
time [year]

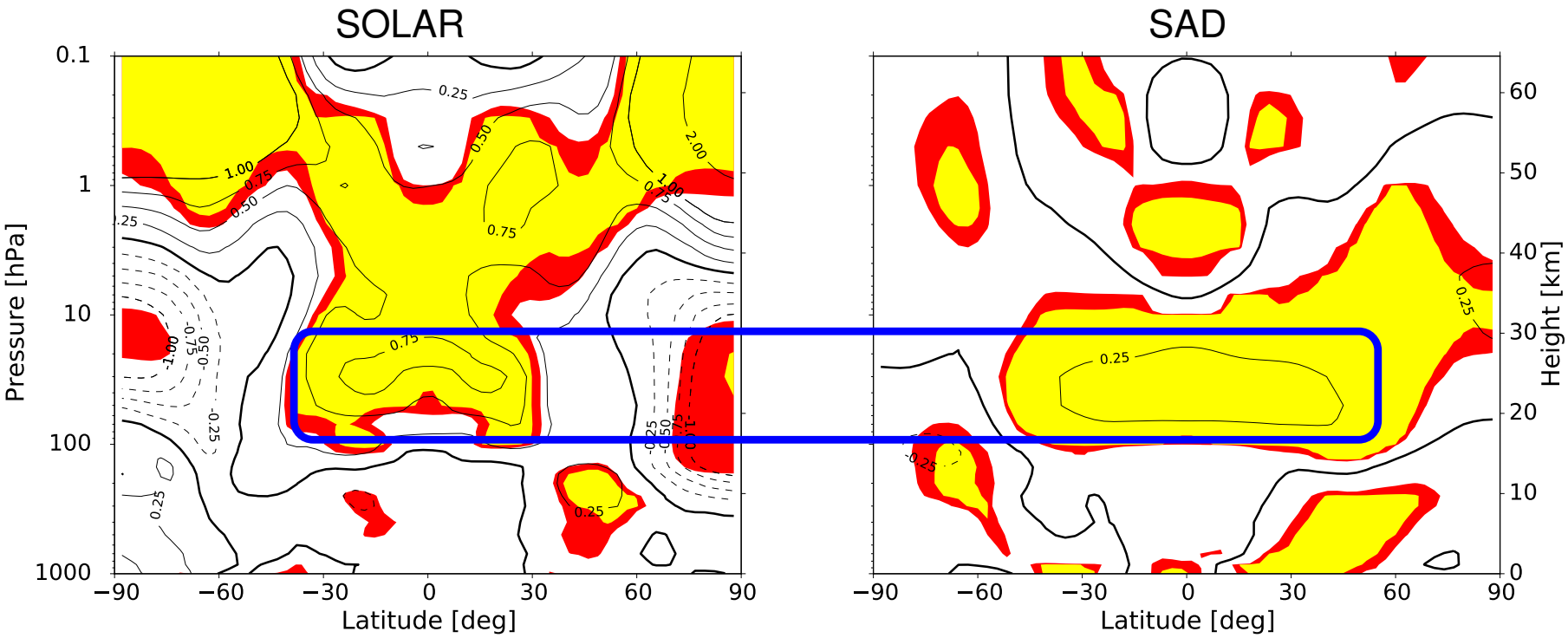
SOLAR and volcanic (SAD) aliasing

- SC and volcanoes attribution in zonal mean of temperature for the period 1979–2009

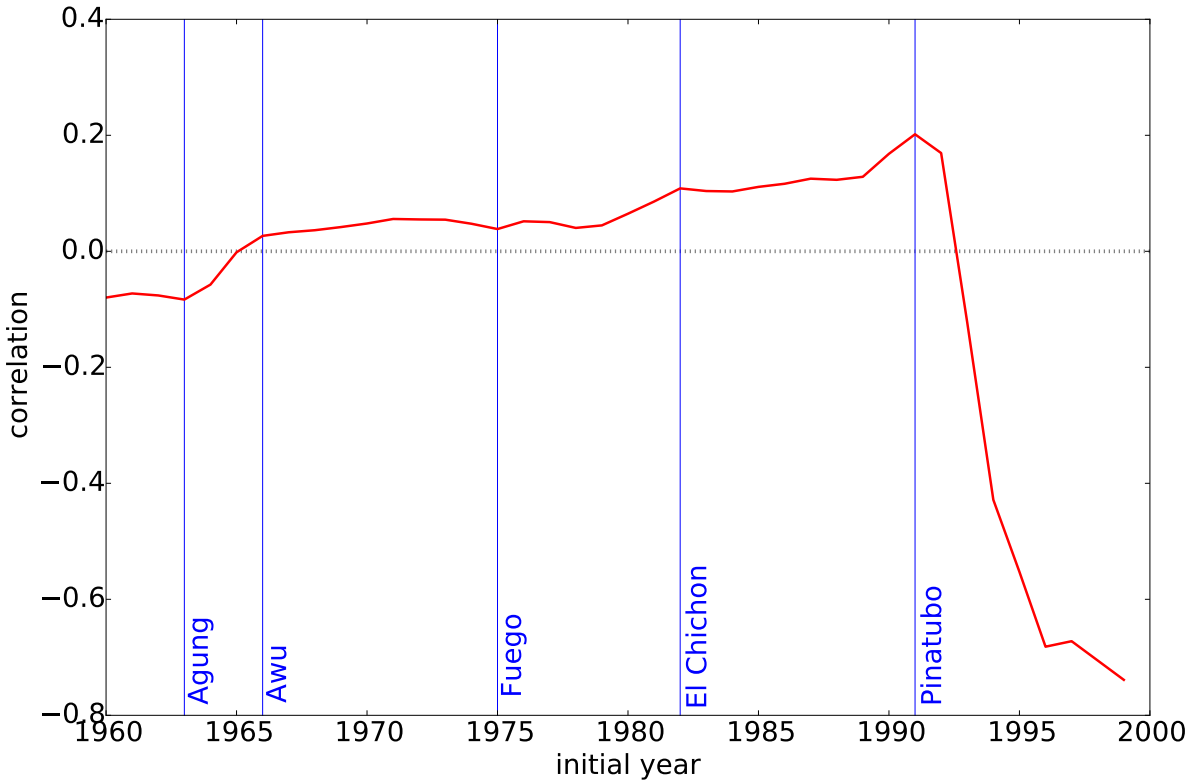


SOLAR and volcanic (SAD) aliasing

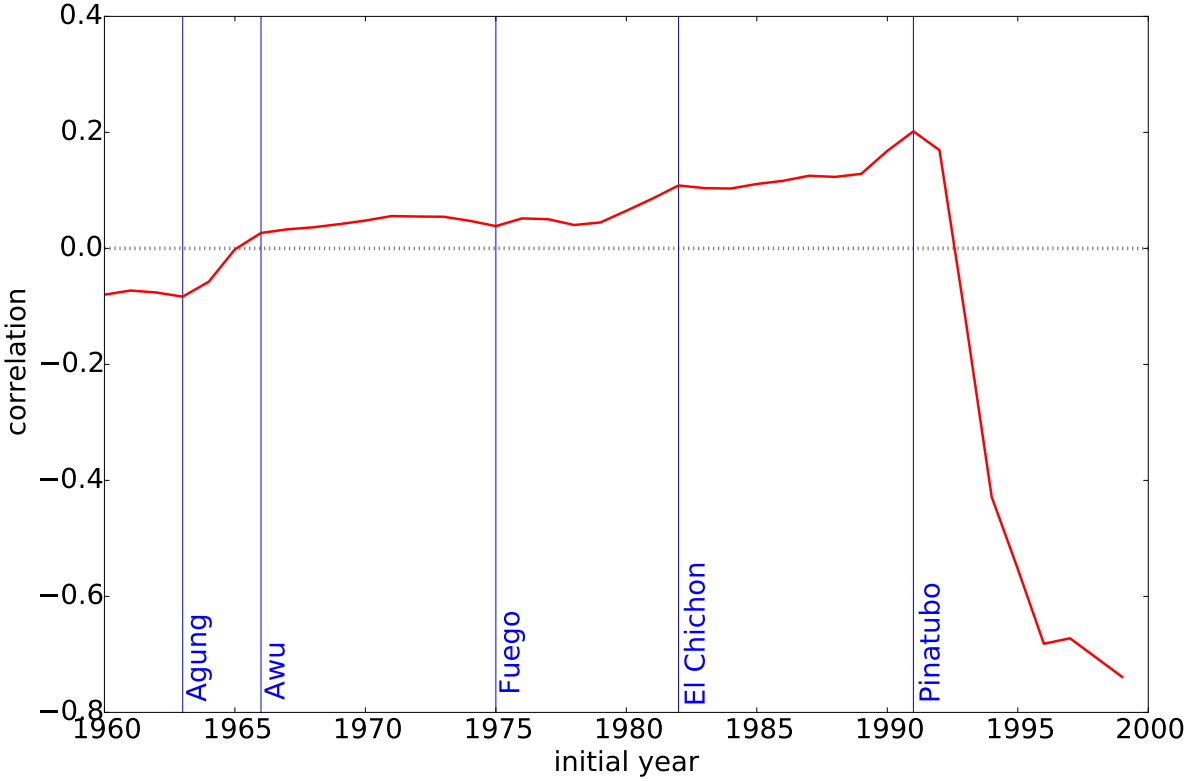
- SC and volcanoes attribution in zonal mean of temperature for the period 1979–2009

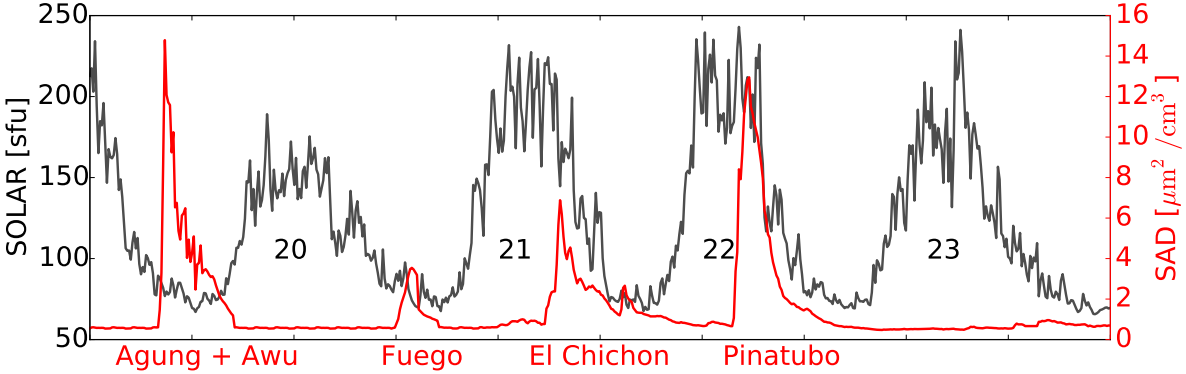


SOLAR and volcanic (SAD) aliasing

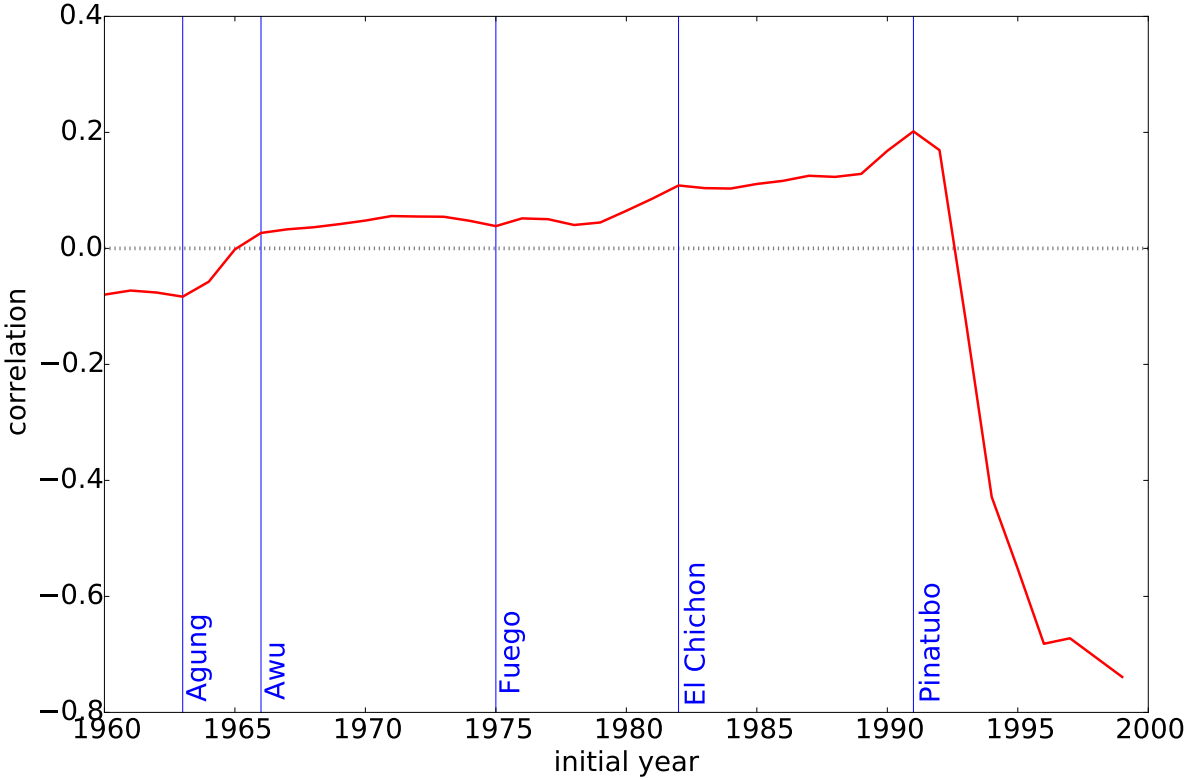


SOLAR and volcanic (SAD) aliasing

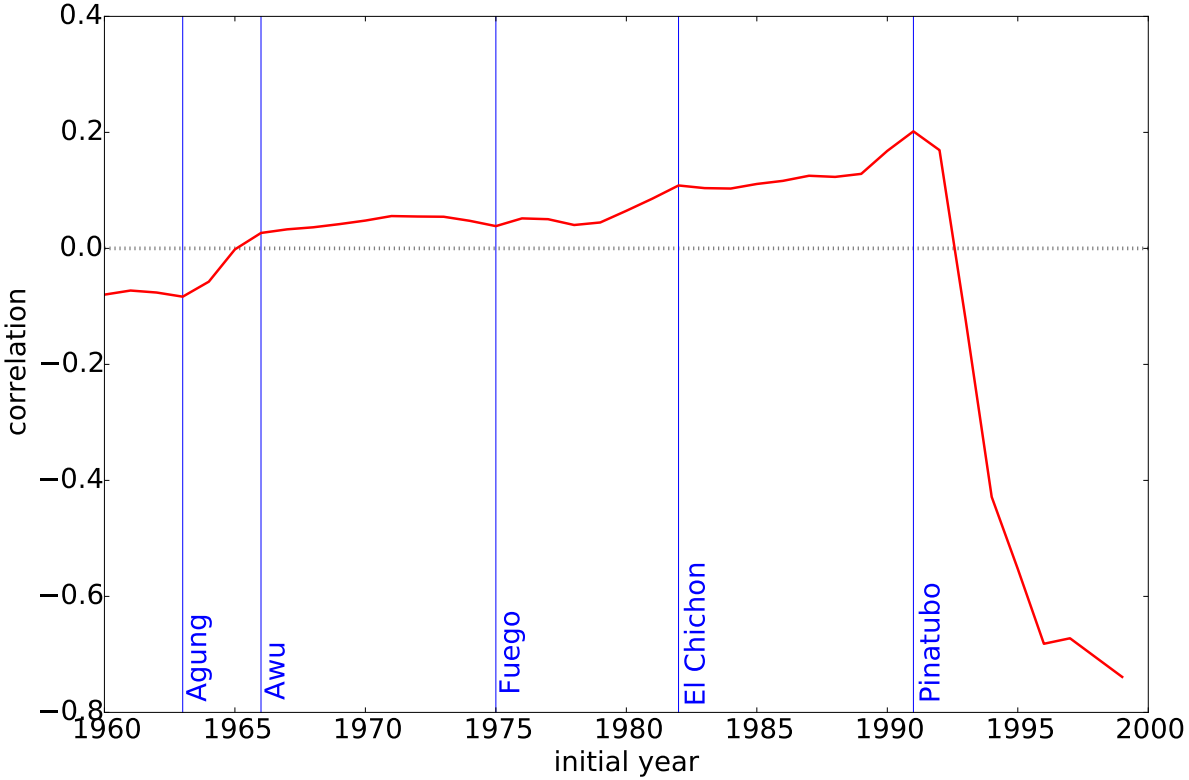


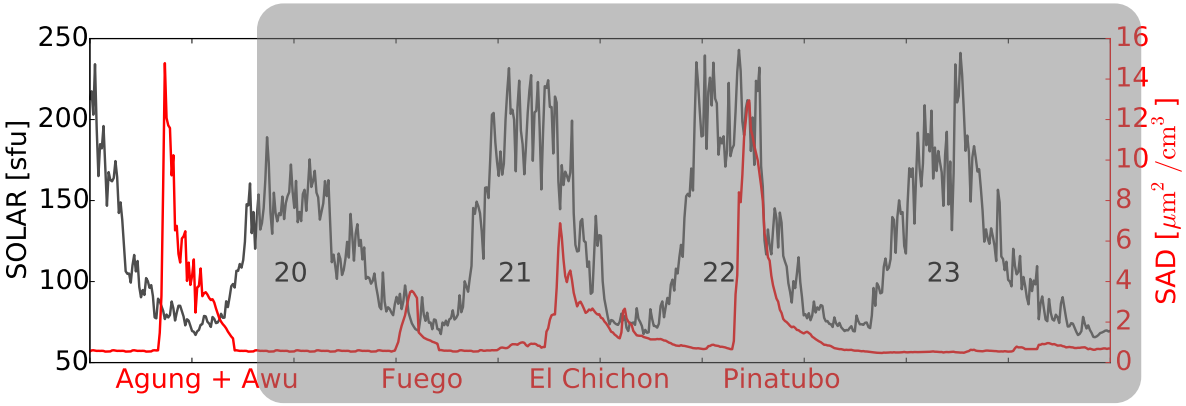


SOLAR and volcanic (SAD) aliasing

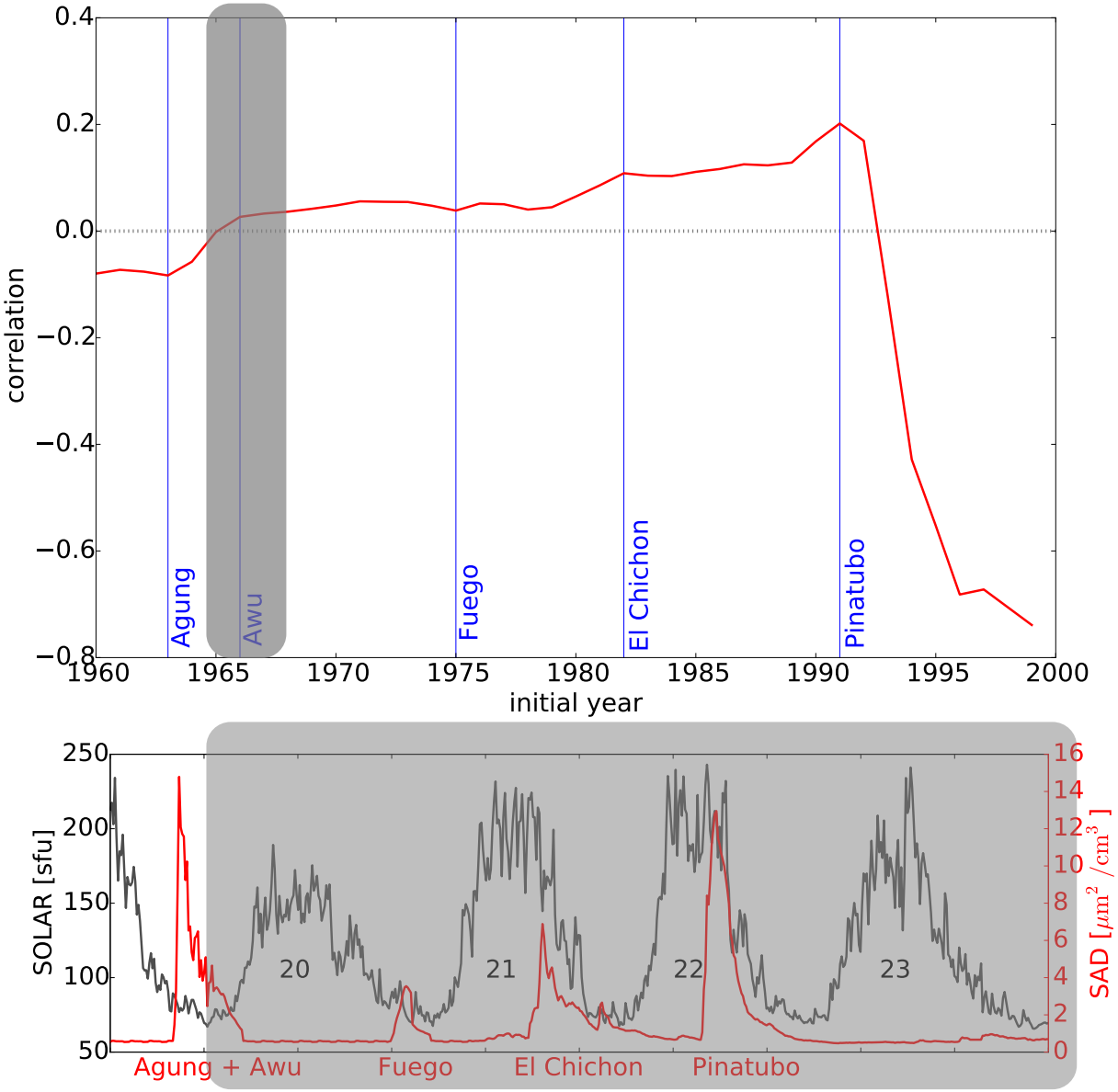


SOLAR and volcanic (SAD) aliasing

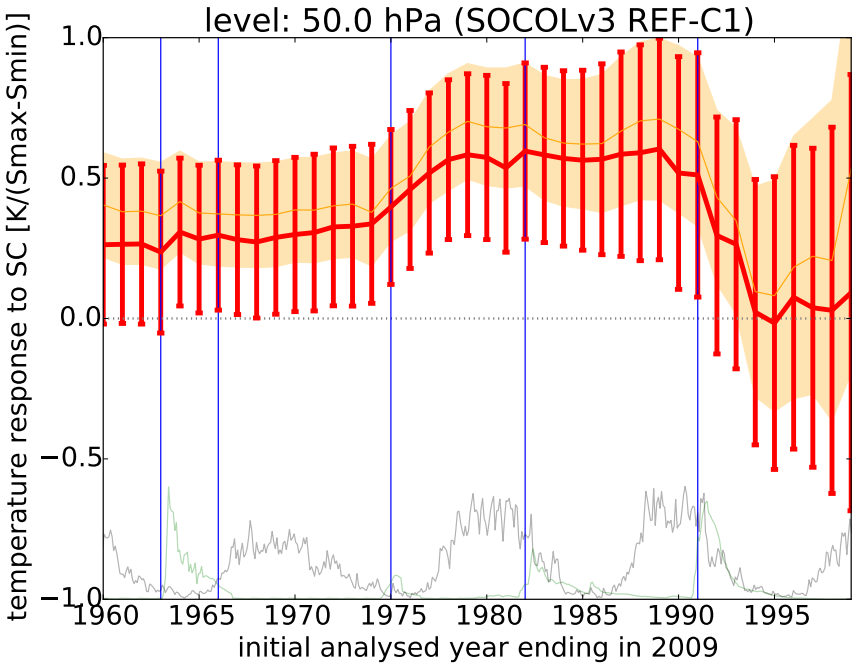




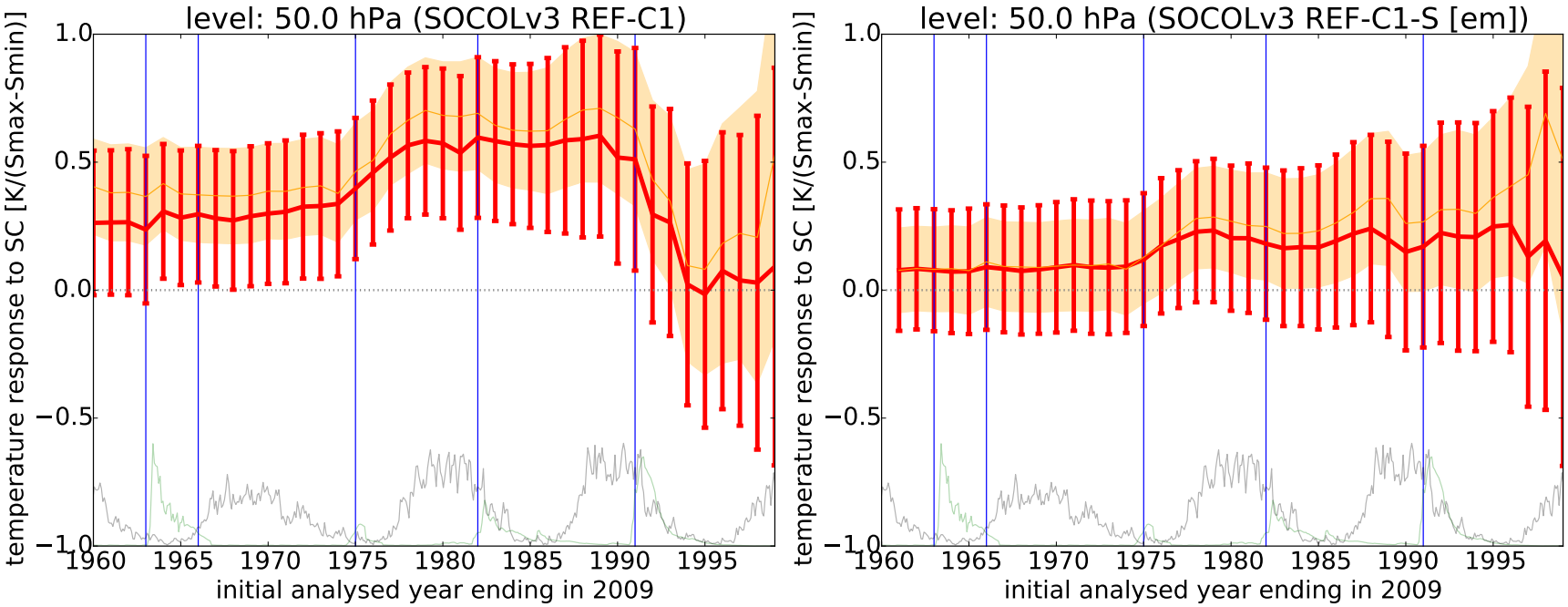
SOLAR and volcanic (SAD) aliasing



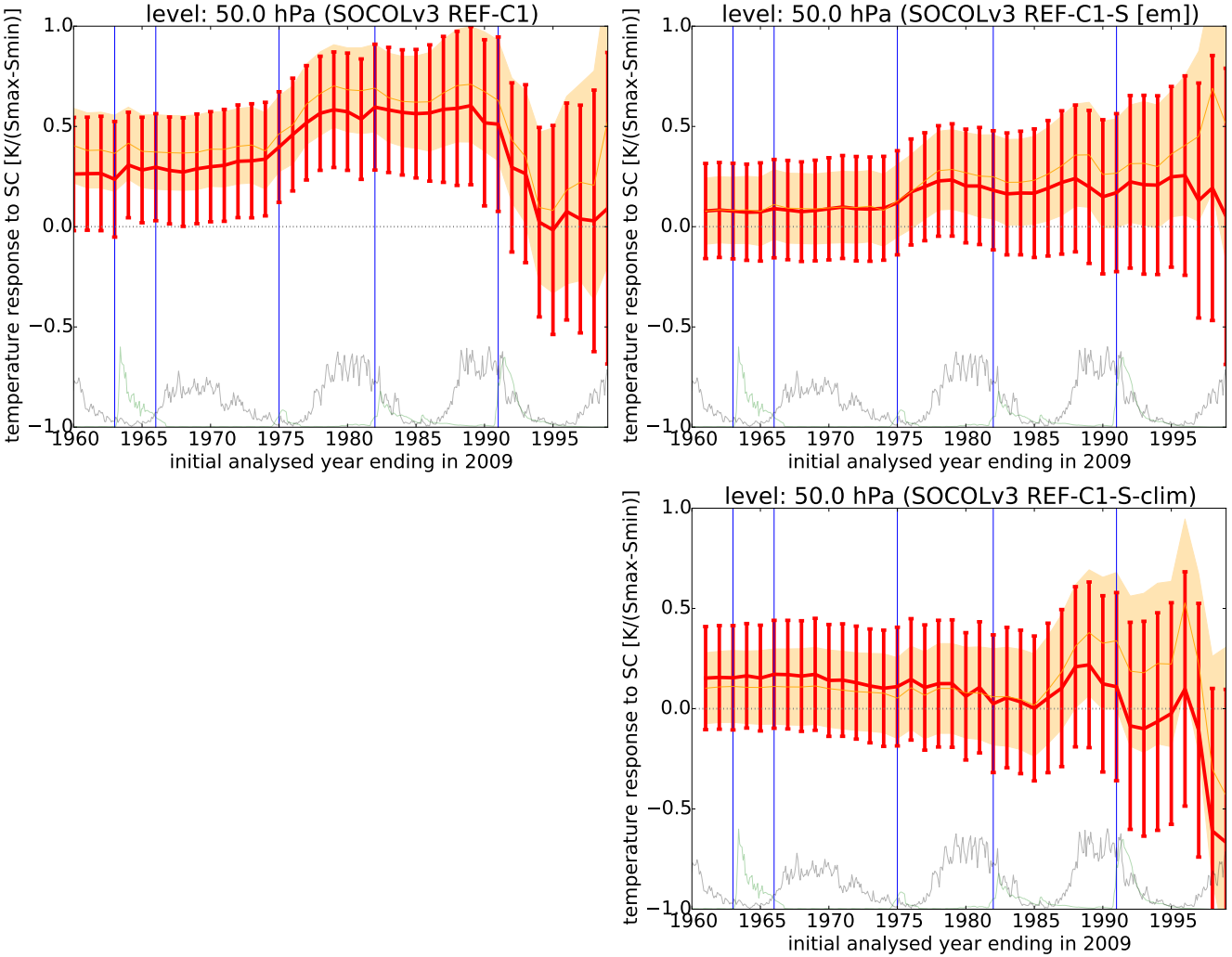
Sensitivity to the length of regression window — model simulations



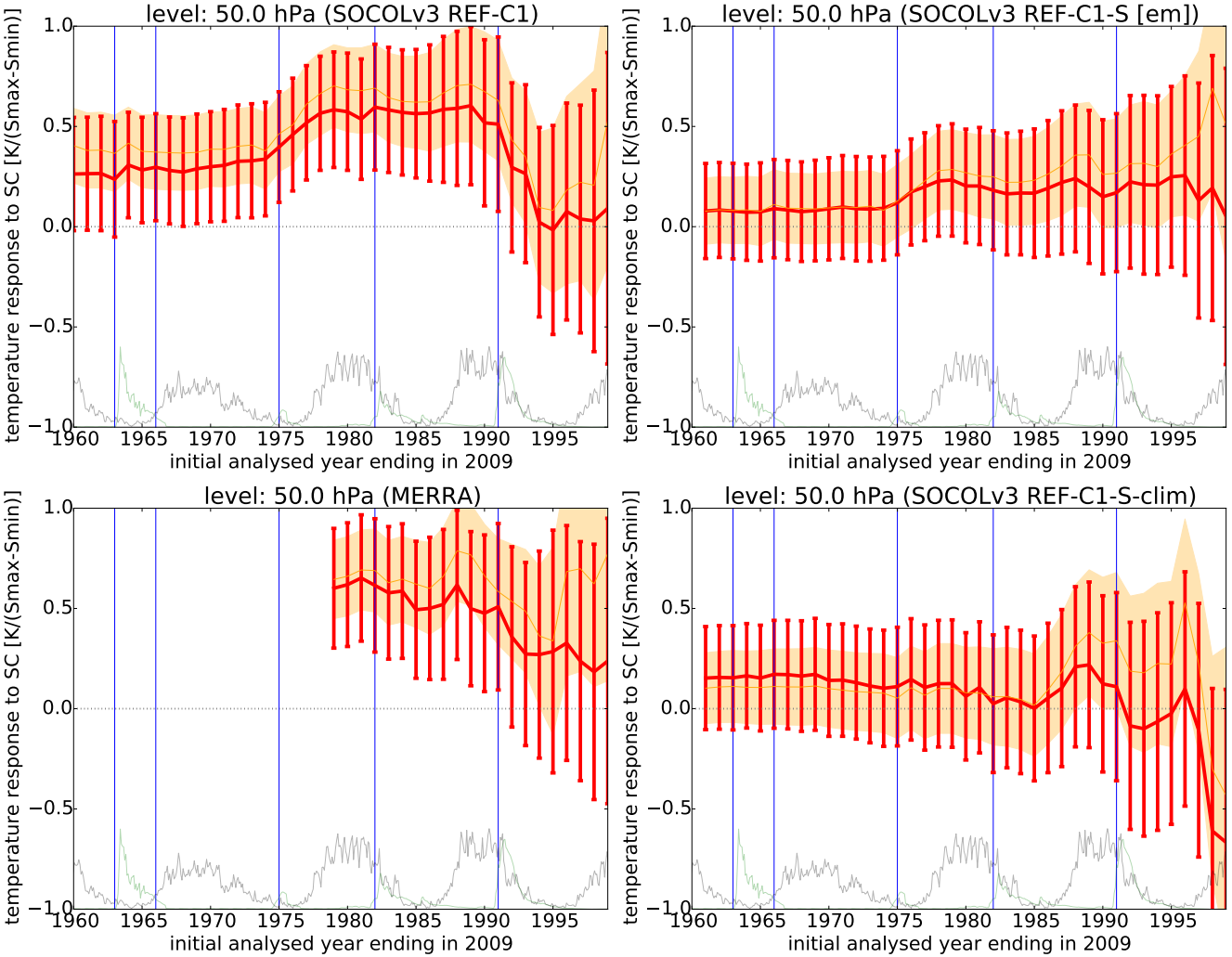
Sensitivity to the length of regression window — model simulations



Sensitivity to the length of regression window — model simulations



Sensitivity to the length of regression window — model simulations



Sensitivity to the length of regression window — DWT

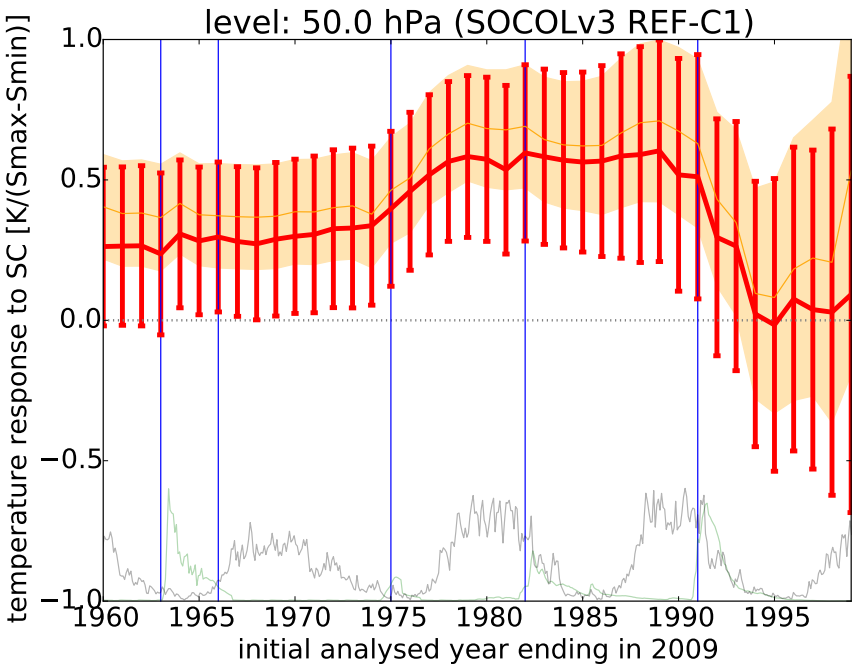
$$\mathrm{DWT} = \frac{\sum_{t=2}^{n}(e_t - e_{t-1})^2}{\sum_{t=1}^{n} e_t^2} \approx 2(1 - r);$$

where r is residual autocorrelation.

Sensitivity to the length of regression window — DWT

$$\mathrm{DWT} = \frac{\sum_{t=2}^{n}(e_t - e_{t-1})^2}{\sum_{t=1}^{n} e_t^2} \approx 2(1-r);$$

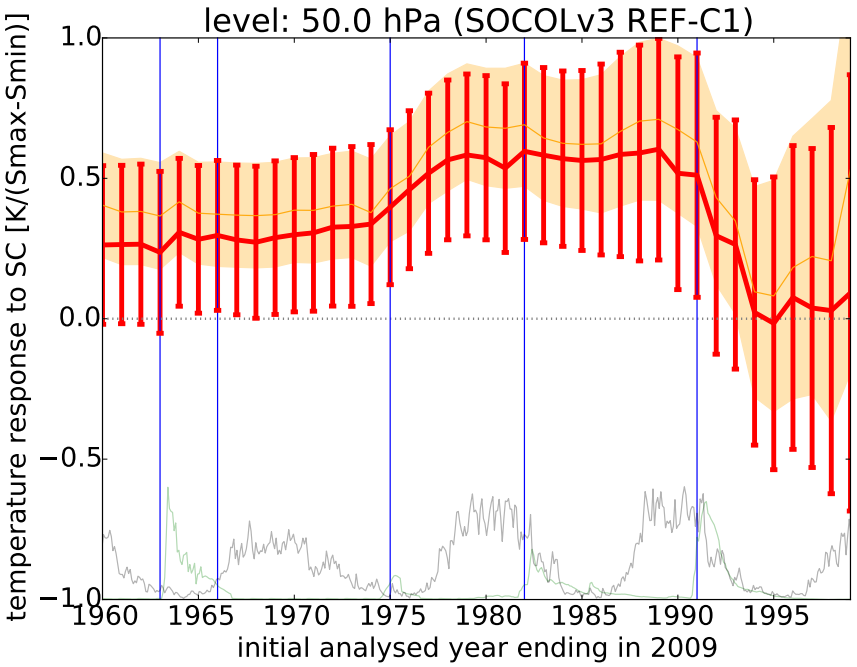
where r is residual autocorrelation.

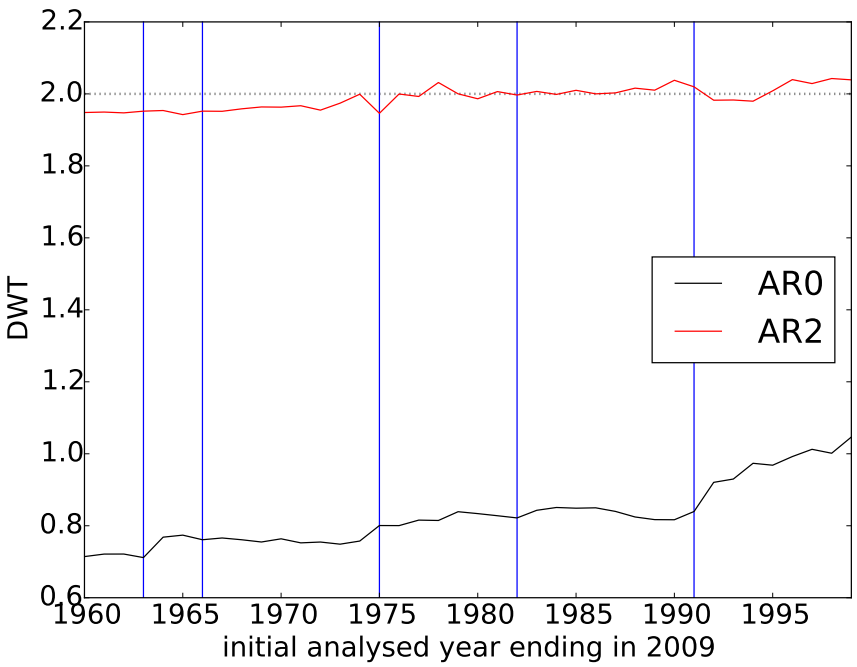


Sensitivity to the length of regression window — DWT

$$\mathrm{DWT} = \frac{\sum_{t=2}^{n}(e_t - e_{t-1})^2}{\sum_{t=1}^{n} e_t^2} \approx 2(1-r);$$

where r is residual autocorrelation.





Conclusions

- solar signal in TLS over satellite era is reduced considering volcanoes (50%) and SST (+25%) correctly
- 1965–2009 sufficient to eliminate volcanic forcing aliasing in TLS
- significant methodology influence

Conclusions

- solar signal in TLS over satellite era is reduced considering volcanoes (50%) and SST (+25%) correctly
- 1965–2009 sufficient to eliminate volcanic forcing aliasing in TLS
- significant methodology influence

Conclusions

- solar signal in TLS over satellite era is reduced considering volcanoes (50%) and SST (+25%) correctly
- 1965–2009 sufficient to eliminate volcanic forcing aliasing in TLS
- significant methodology influence