DiSTAR Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse
UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II
SCUOLA POLITECNICA E DELLE SCIENZE DI BASE

Empirical assessment of the role of the sun in climate change using balanced multiproxy solar records

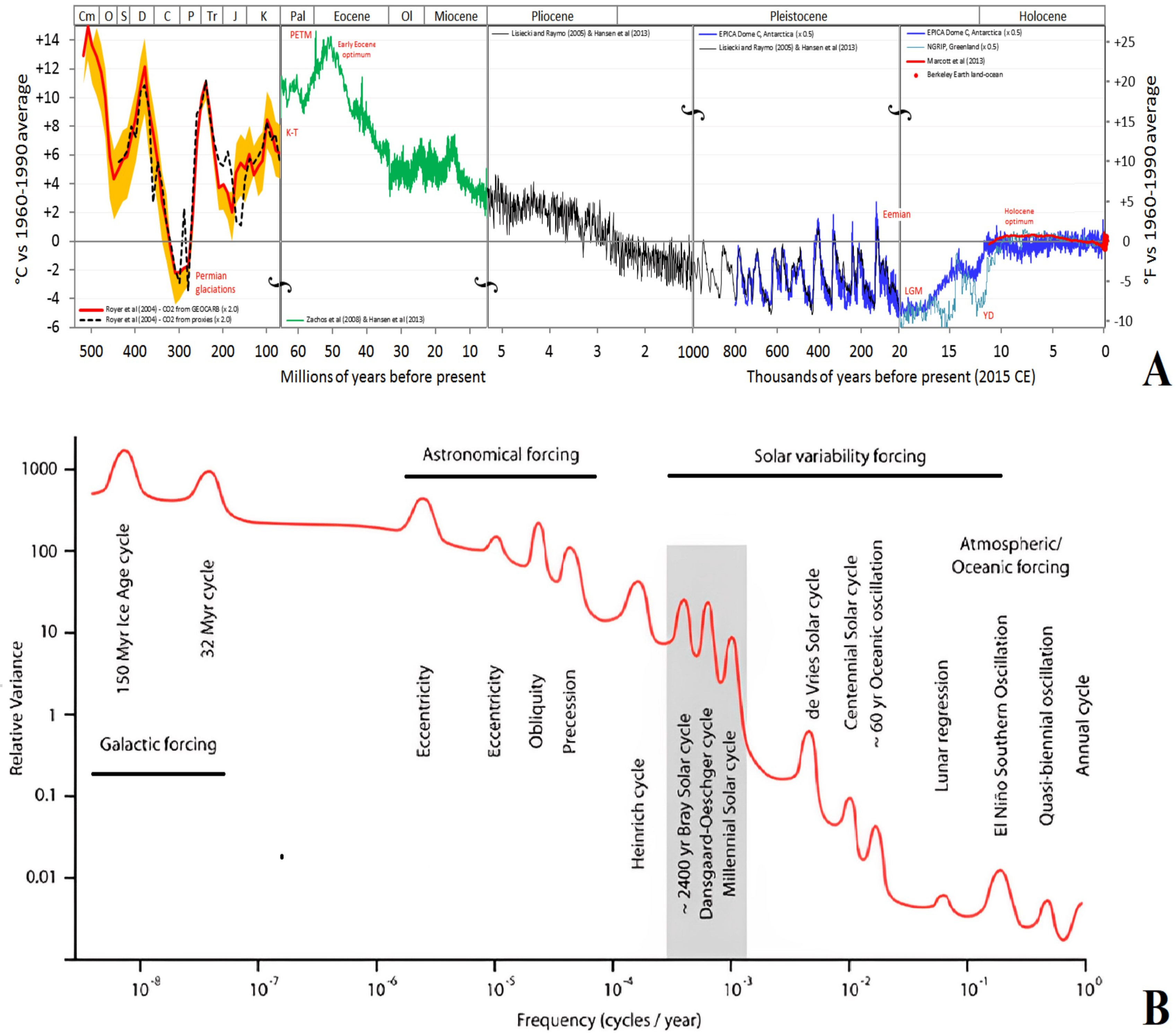
Nicola Scafetta
14 June 2024

How much will the Earth warm?

Nicola Scafetta. Empirical assessment of the role of the Sun in climate change using balanced multi-proxy solar records. Geoscience Frontiers, Volume 14, Issue 6, November 2023, 101650, 2023. https://doi.org/10.1016/j.gsf.2023.101650

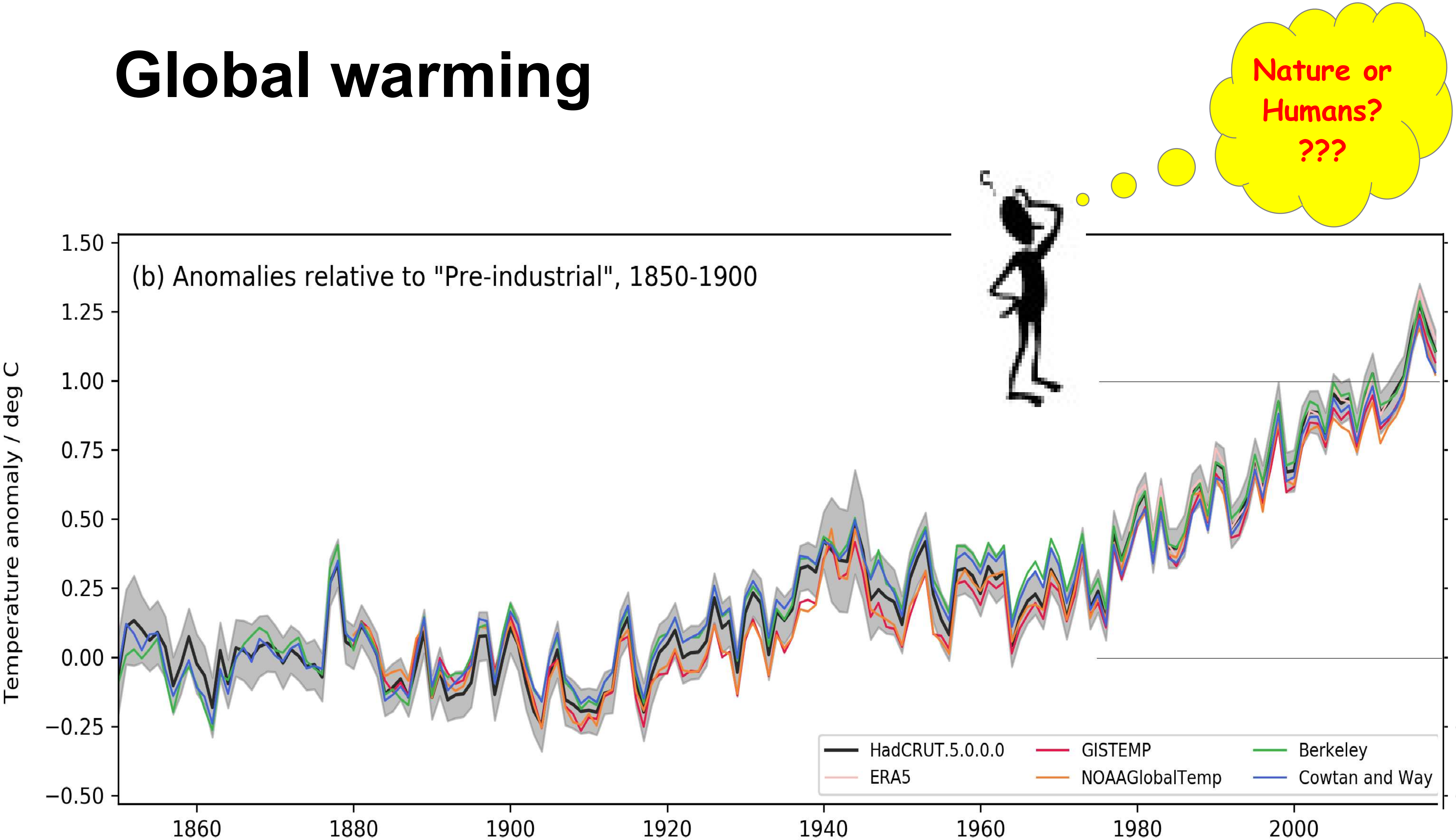
Nicola Scafetta. Impacts and risks of "realistic" global warming projections for the 21st century. Geoscience Frontiers 15(2), 101774, 2024. https://doi.org/10.1016/j.gsf.2023.101774

Climatic History of the Earth and its natural Oscillations

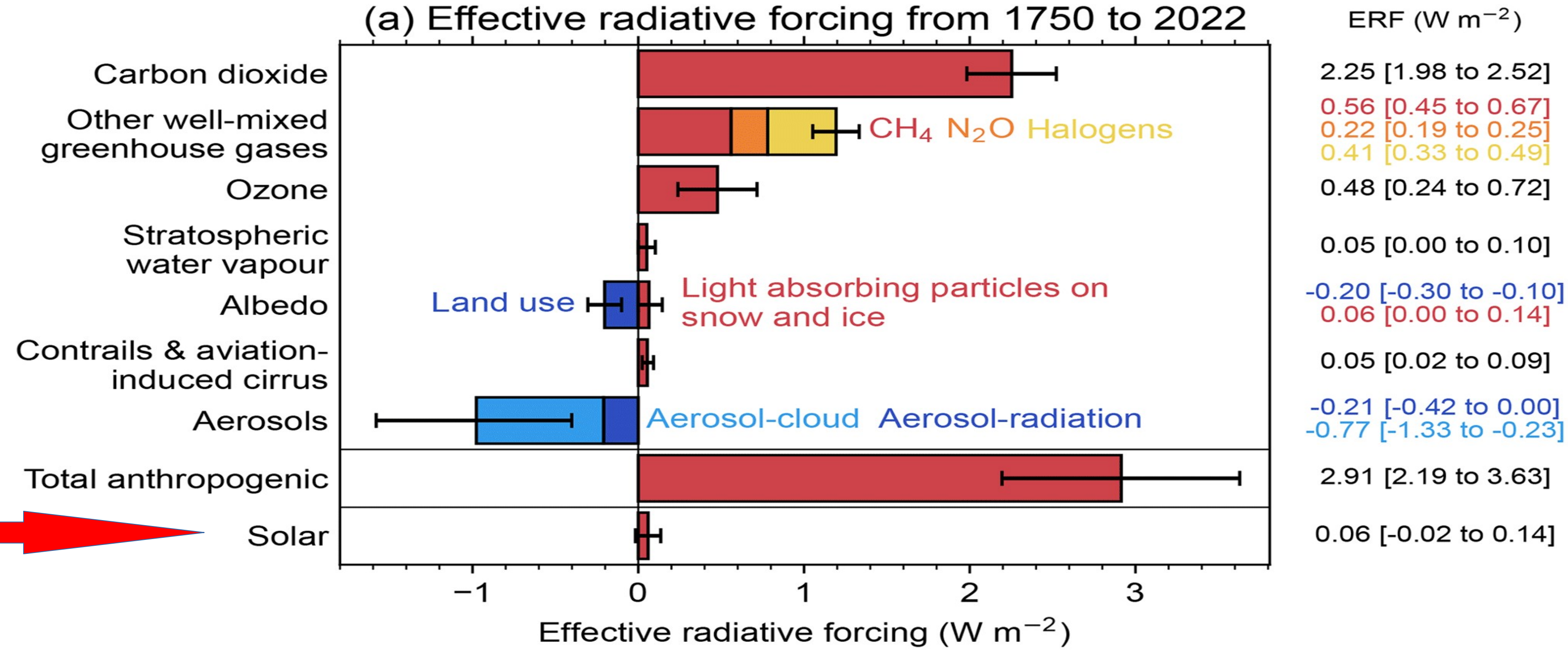


Scafetta, N.; Bianchini, A. Overview of the Spectral Coherence between Planetary Resonances and Solar and Climate Oscillations. Climate 2023, 11, 77.

Global warming

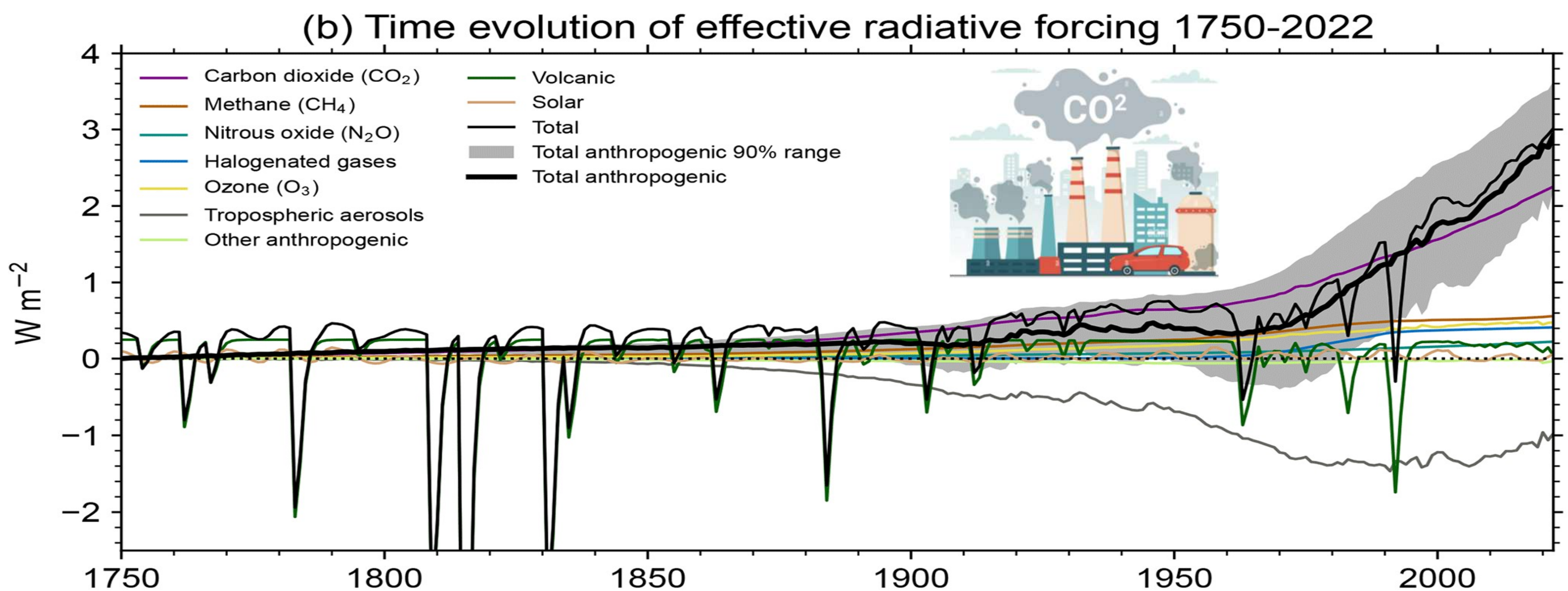


The solar contribution is negligible



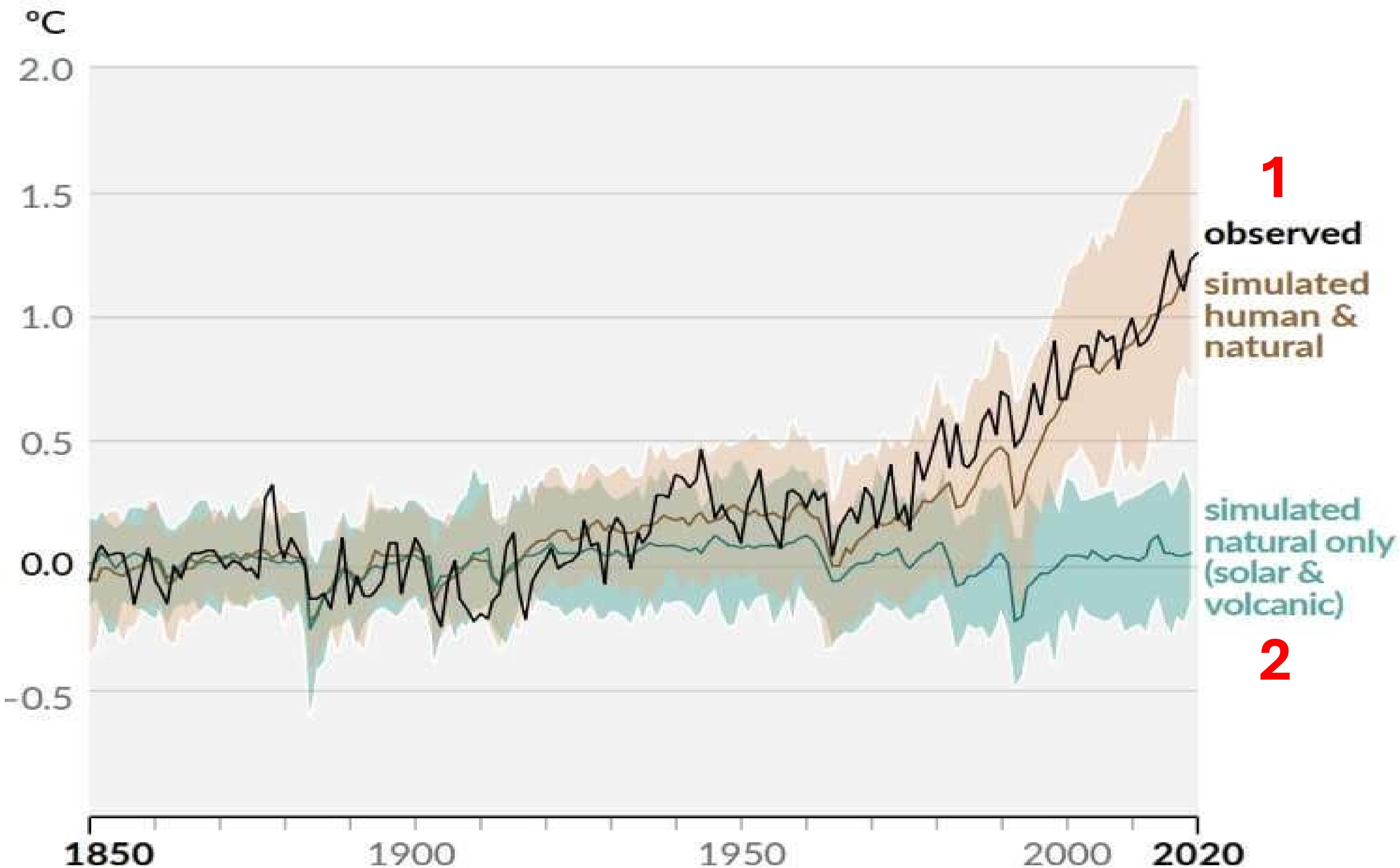
Nearly 100% of the forcing is man-made

(CO2 is pollution!)



The theory of anthropogenic global warming proposed by the IPCC

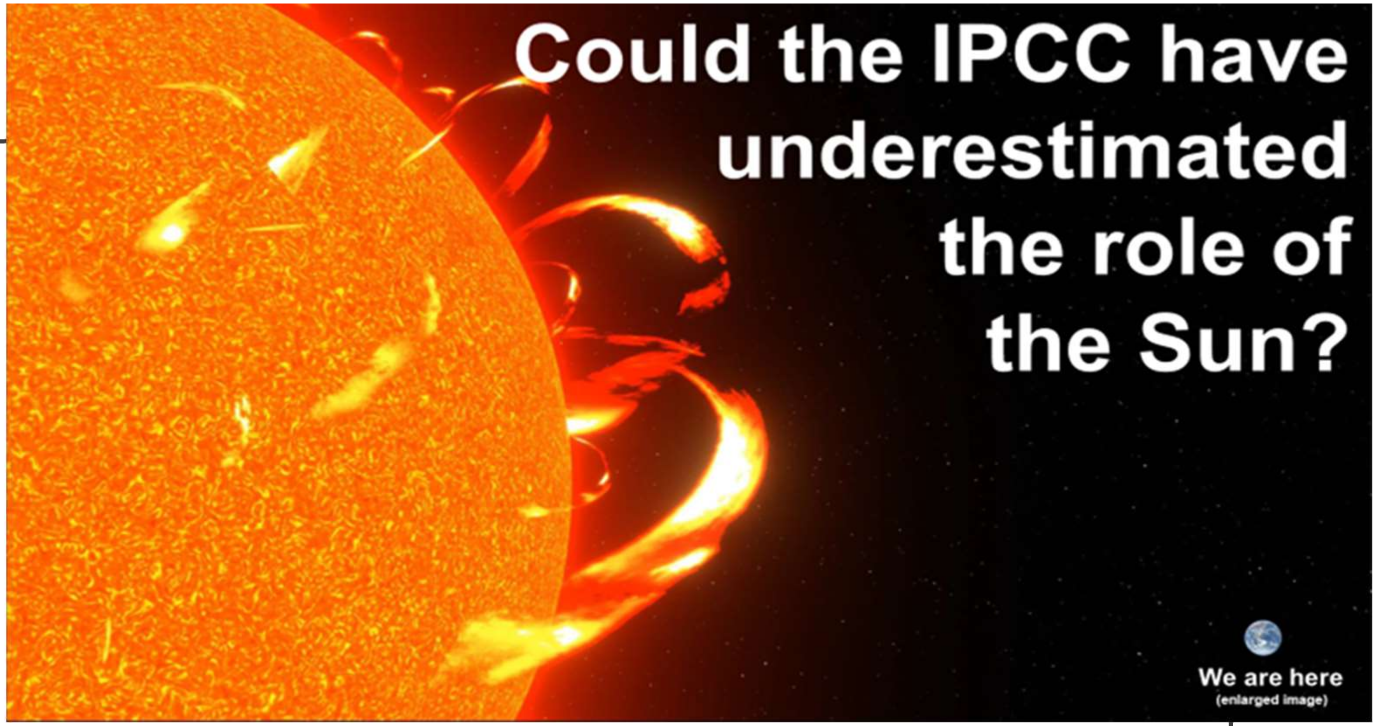
"Nearly 100% of the warming since 1850-1900 is caused by human emissions"



Without the anthropogenic contribution, climate models do not reproduce any warming from 1850-1900

With the anthropic contribution, climate models reproduce warming from 1850-1900

Point #2 does not satisfy the Scientific Method!!



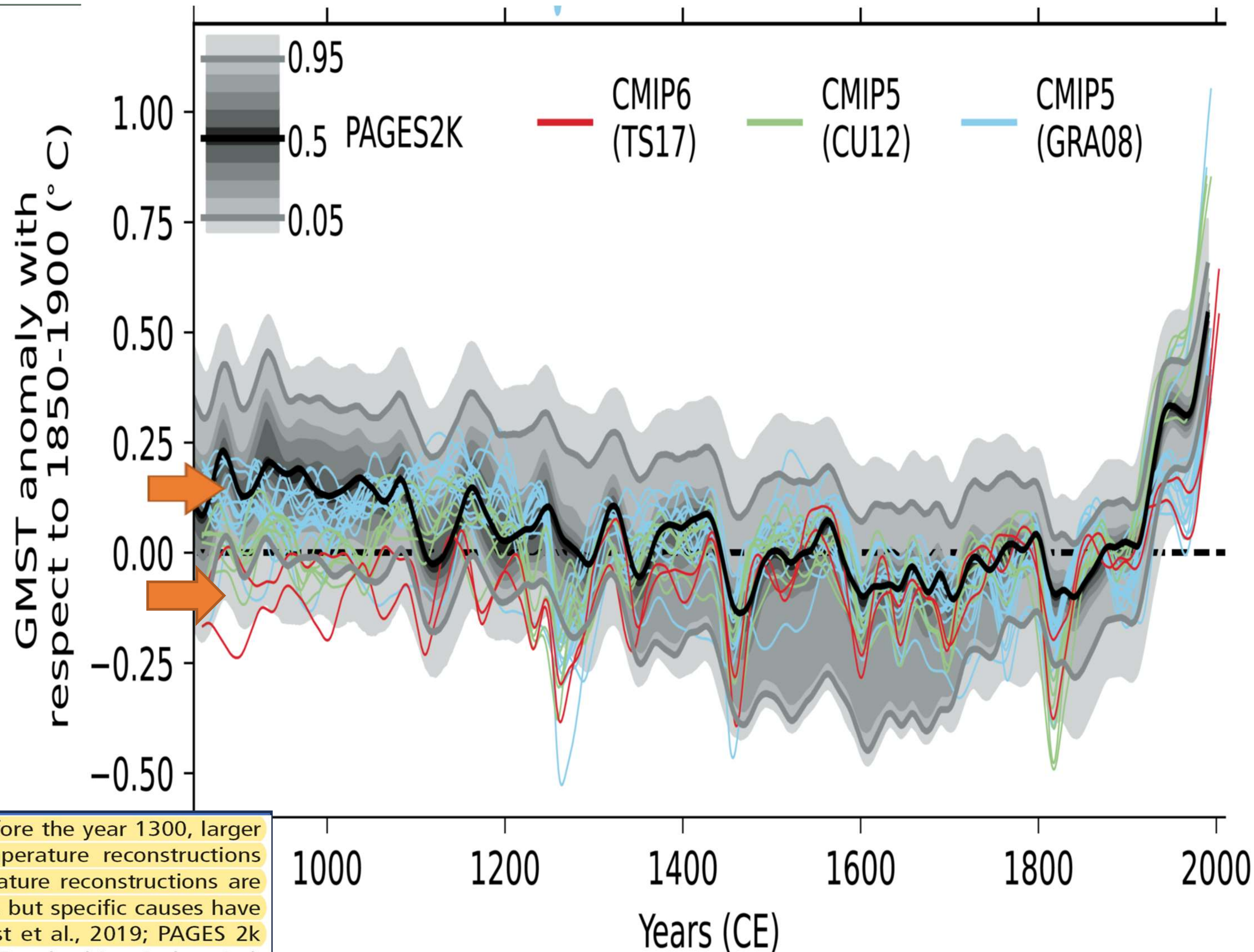
Critical Issue

Is there evidence that the models may be physically incorrect?

(Warm biases and natural variability)

IPCC AR6 Figure 3.2, p. 432

The Medieval Warm Period is NOT reproduced

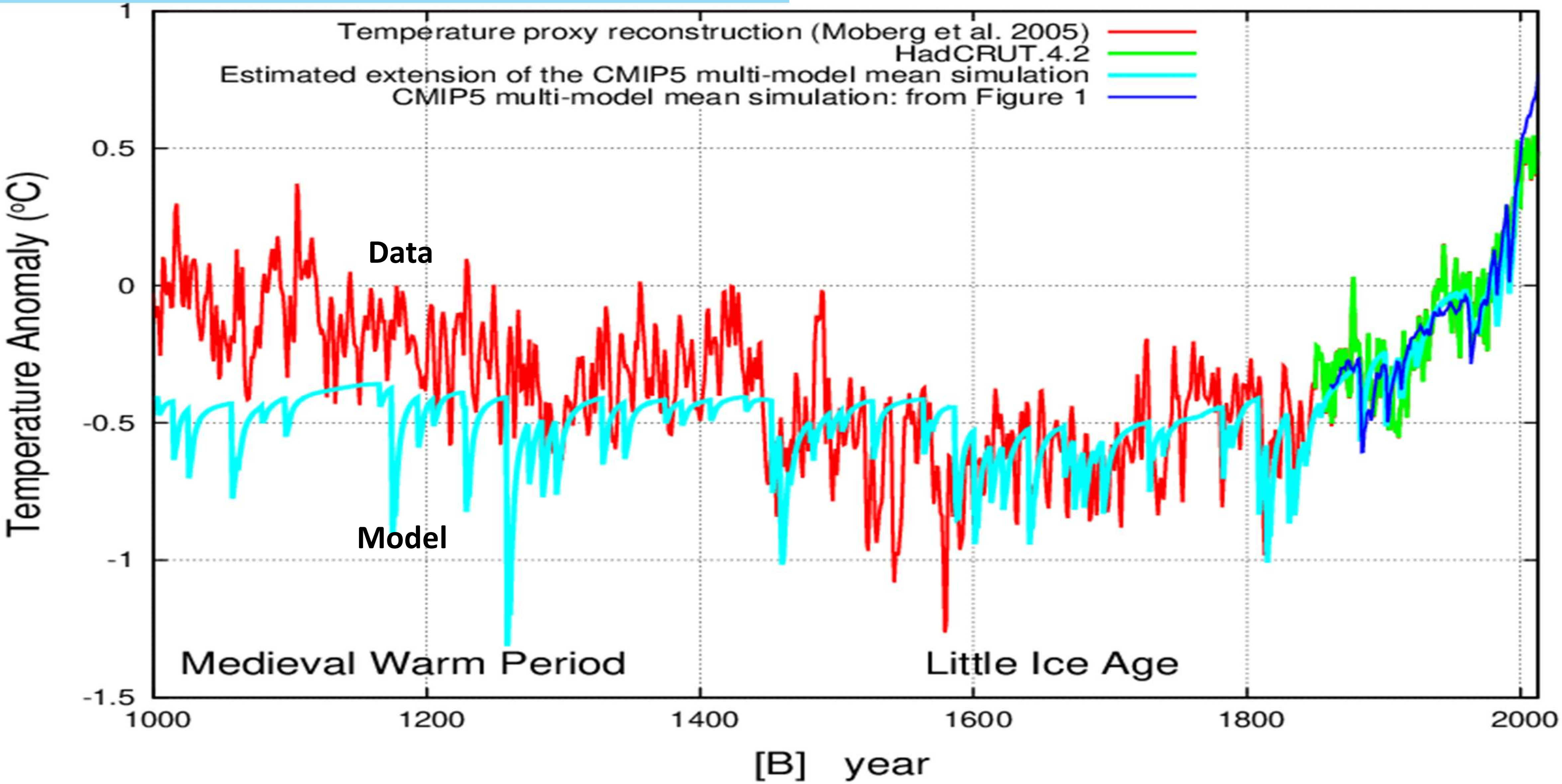


IPCC AR6, pp. 433

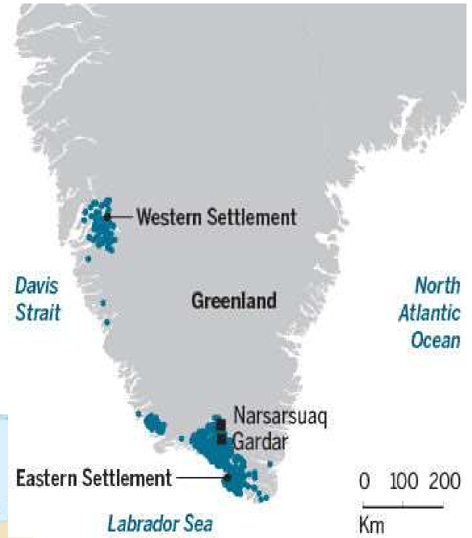
forcing datasets disagree (Figure 3.2c). Before the year 1300, larger disagreements between models and temperature reconstructions are expected because forcing and temperature reconstructions are increasingly uncertain further back in time, but specific causes have not been identified conclusively (Ljungqvist et al., 2019; PAGES 2k Consortium, 2019) (*medium confidence*). For the historical period,

The Medieval Warm Period is not reproduced by the models

Scafetta, N. Reconstruction of the Interannual to Millennial Scale Patterns of the Global Surface Temperature. Atmosphere 2021, 12, 147. https://doi.org/10.3390/atmos12020147



Vikings in Greenland



https://ancientfoods.wordpress.com/2012/02/17/viking-barley-in-greenland/

Each grain of barley is only a couple of millimetres long, and the grain weighs less than 0.01 mg – yet the find is now regarded as an archaeological sensation.
Photos: Peter Steen Henriksen

Evidence suggests Vikings grew barley in south Greenland

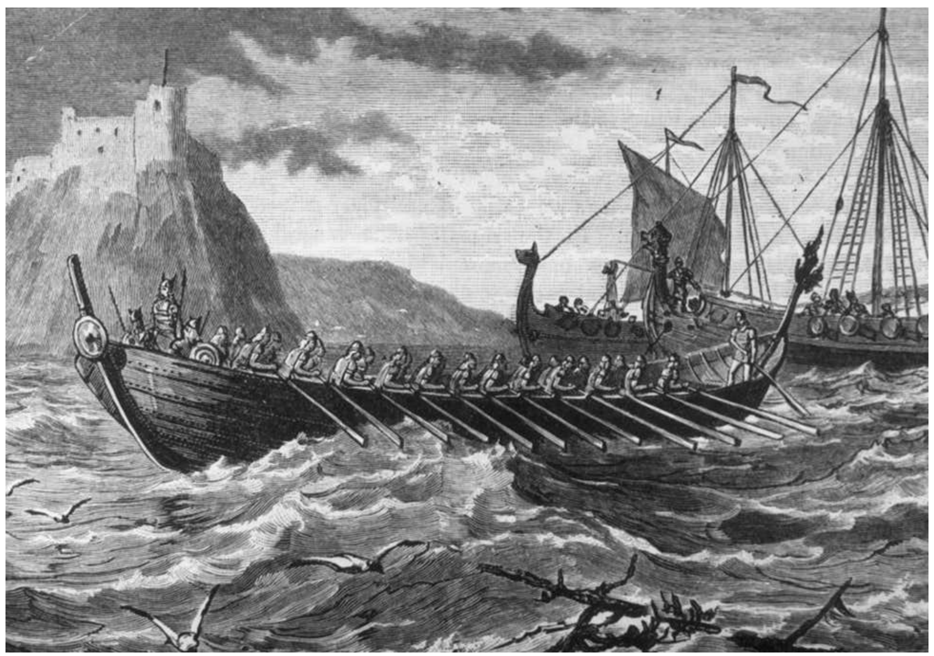
RESEARCH ARTICLE | FEBRUARY 06, 2019

Medieval warmth confirmed at the Norse Eastern Settlement in Greenland

G. Everett Lasher; Yarrow Axford

Geology (2019) 47 (3): 267-270.

https://doi.org/10.1130/G45833.1 **Article history**



The Qinngua valley

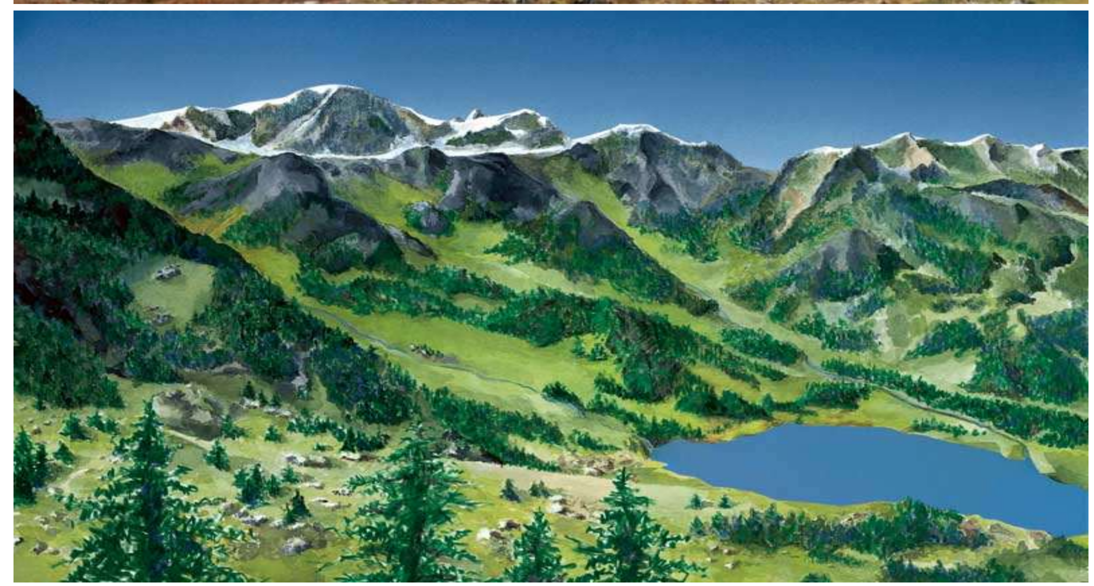
Trees under Glaciers

Melting glaciers in Western Canada are revealing tree stumps up to 7,000 years old where the region's rivers of ice have retreated to a historic minimum, a geologist said today.

Glacier-buried forests from ~1000 years ago uncover a warm Medieval period

Figure 2. Students learn how scientists combine living and dead trees to create millennial-length records of temperature, such as the buried forests emerging here from the wasting margin of Mendenhall Glacier (Credit: Jesse Wiles). Davi et al., 2019

Christian Schlüchter: "Alpen ohne Gletscher? Holz- und Torffunde als Klimaindikatoren“, Die Alpen, 6/2004; The Alps with little ice: evidence for eight Holocene phases of reduced glacier extent in the Central Alps, The Holocene, 2001, 11/3: 255-265



The Susten pass (Switzerland) as it is today (above) and as it probably was in Roman times, 2000 years ago green and with several trees (below). (Die Alpen / Atelier Thomas Richner based on a draft from Christoph Schlüchter).

- Only solar activity has a millennial cycle.

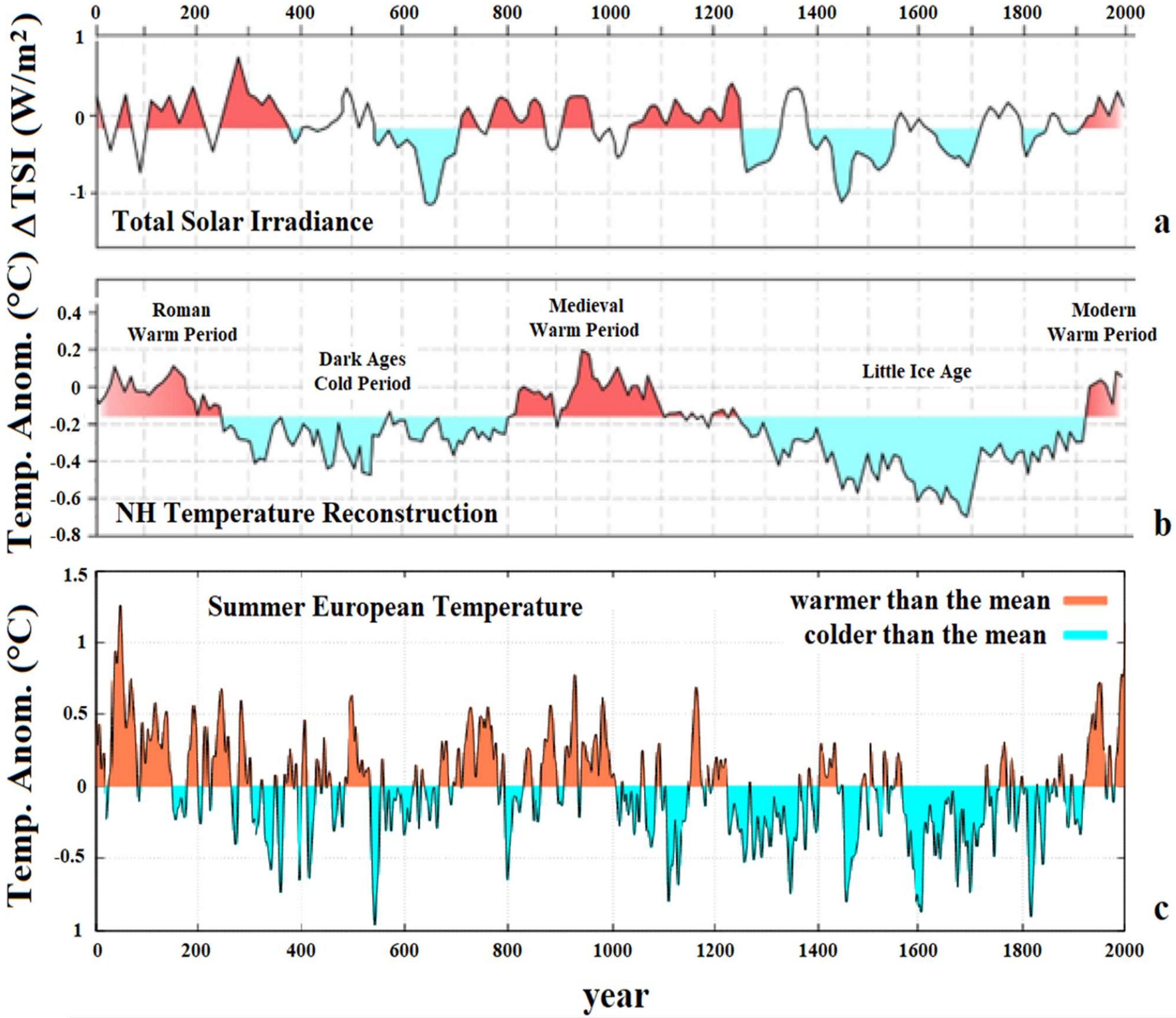
  (Steinhilber et al.,2012)

- Which correlates with the millennial cycle of temperatures

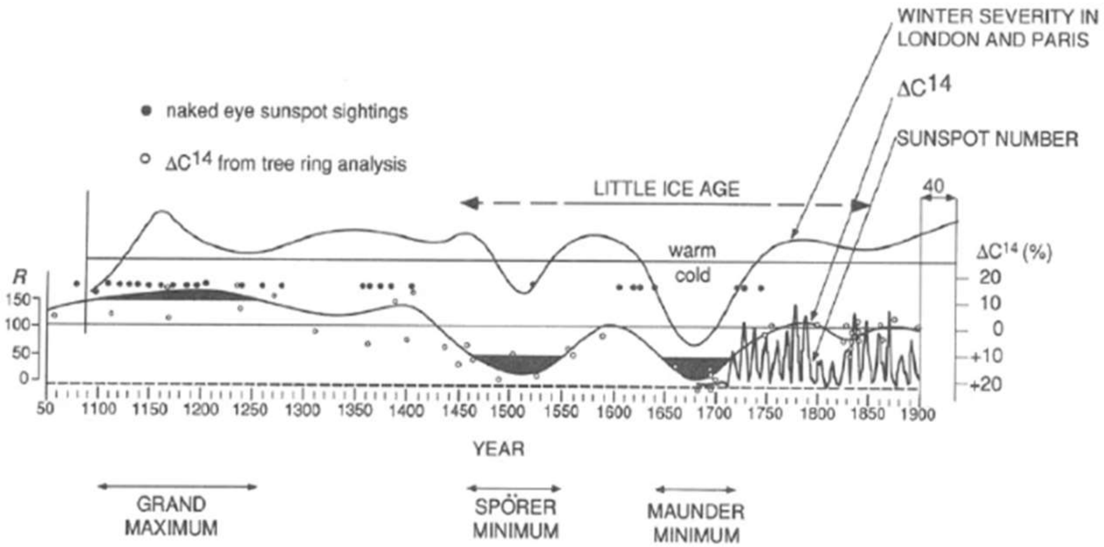
  (Ljungqvist, 2010)

  Summer European Temperature

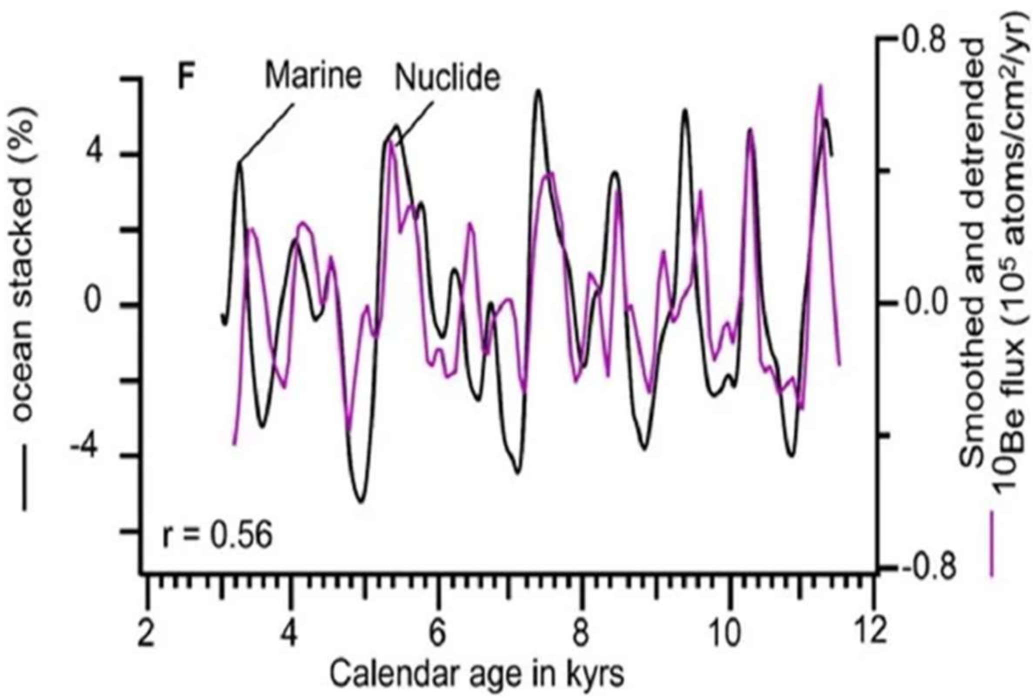
  (Luterbacher et al., 2016)



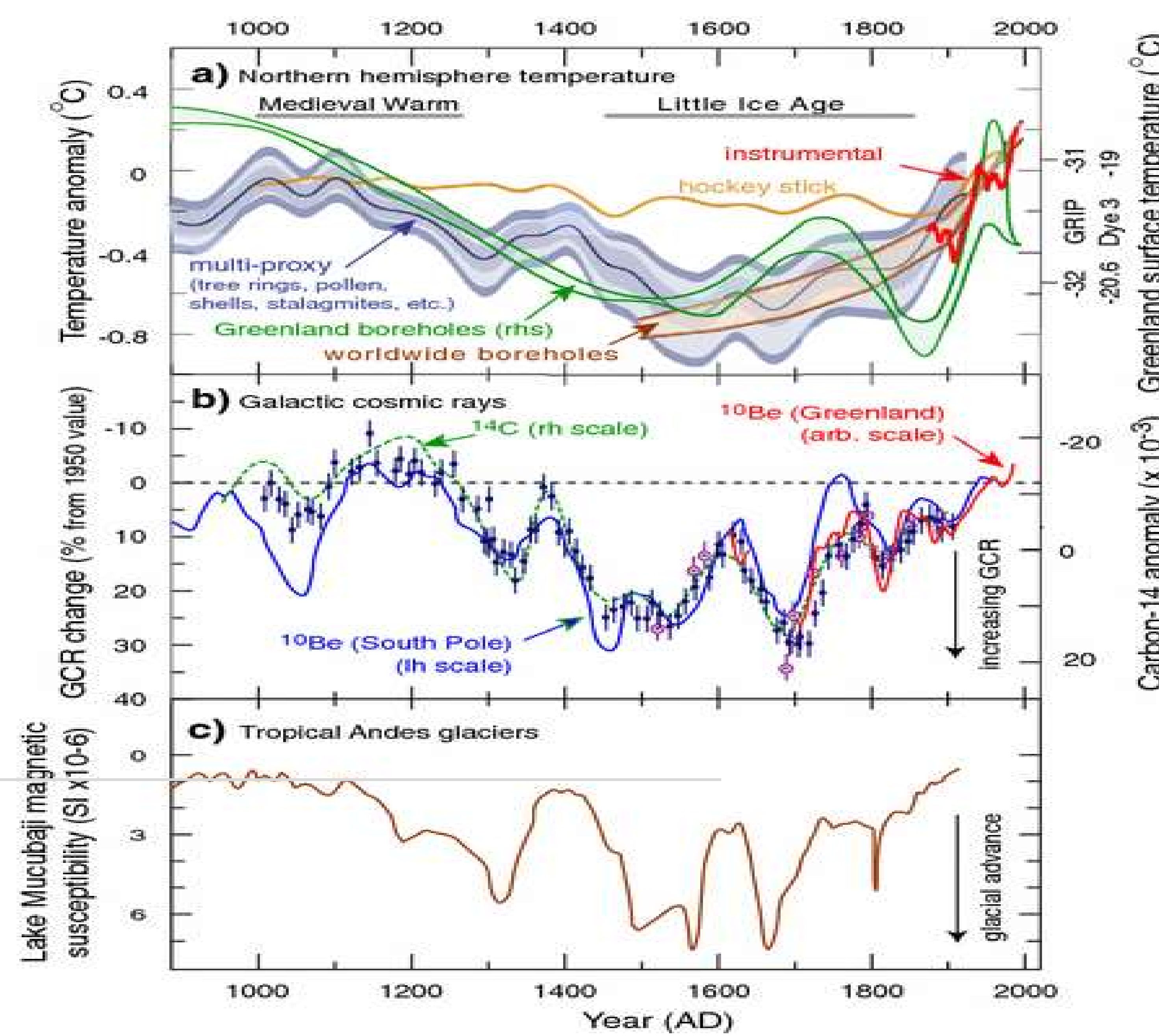
Numerous evidences of a solar induced Medieval Warm Period and of other Holocene warm periods



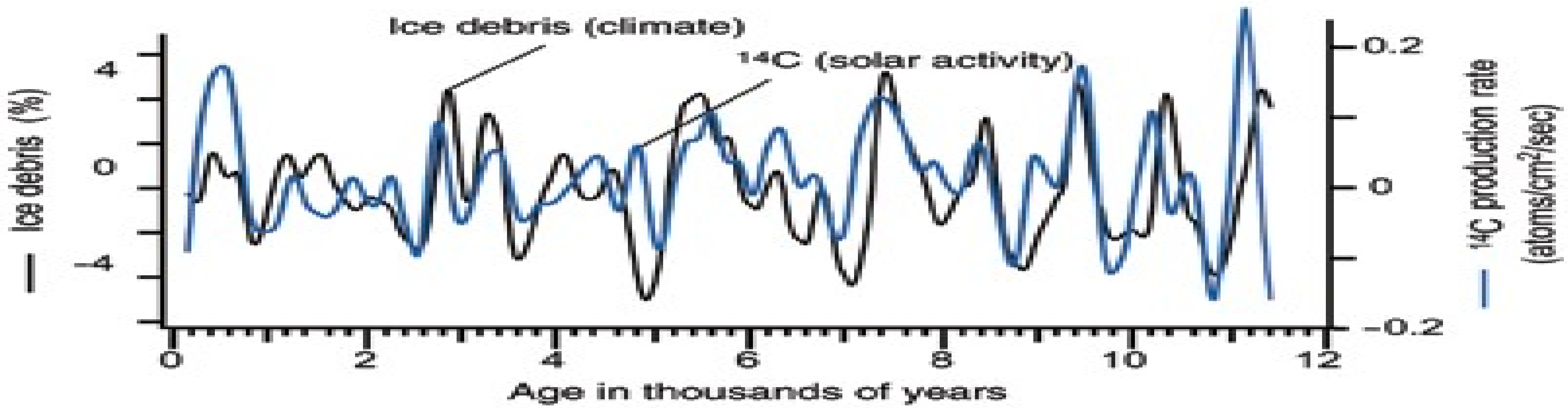
From a paper by Eddy (1976) suggesting that winter temperatures in NW Europe are correlated with solar activity. Note the coincidence of the "Little Ice Age" with the Maunder Minimum in sunspots.



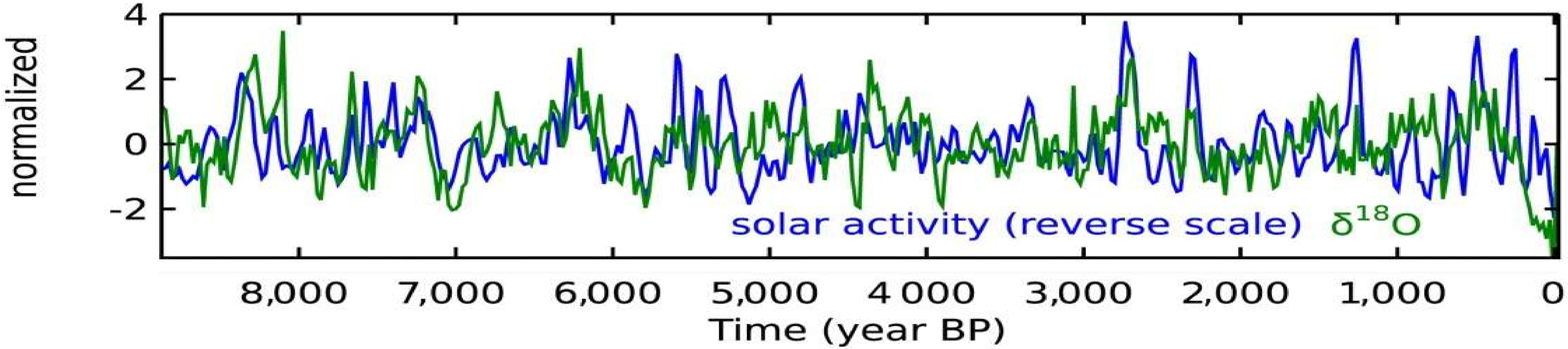
Records of ^{10}Be and ice-rafted minerals extracted from ocean sediments in the North Atlantic. From Bond et al. (2001).



Kerr, R. A., 2001. A variable sun paces millennial climate. Science, 294, 1431-1433.

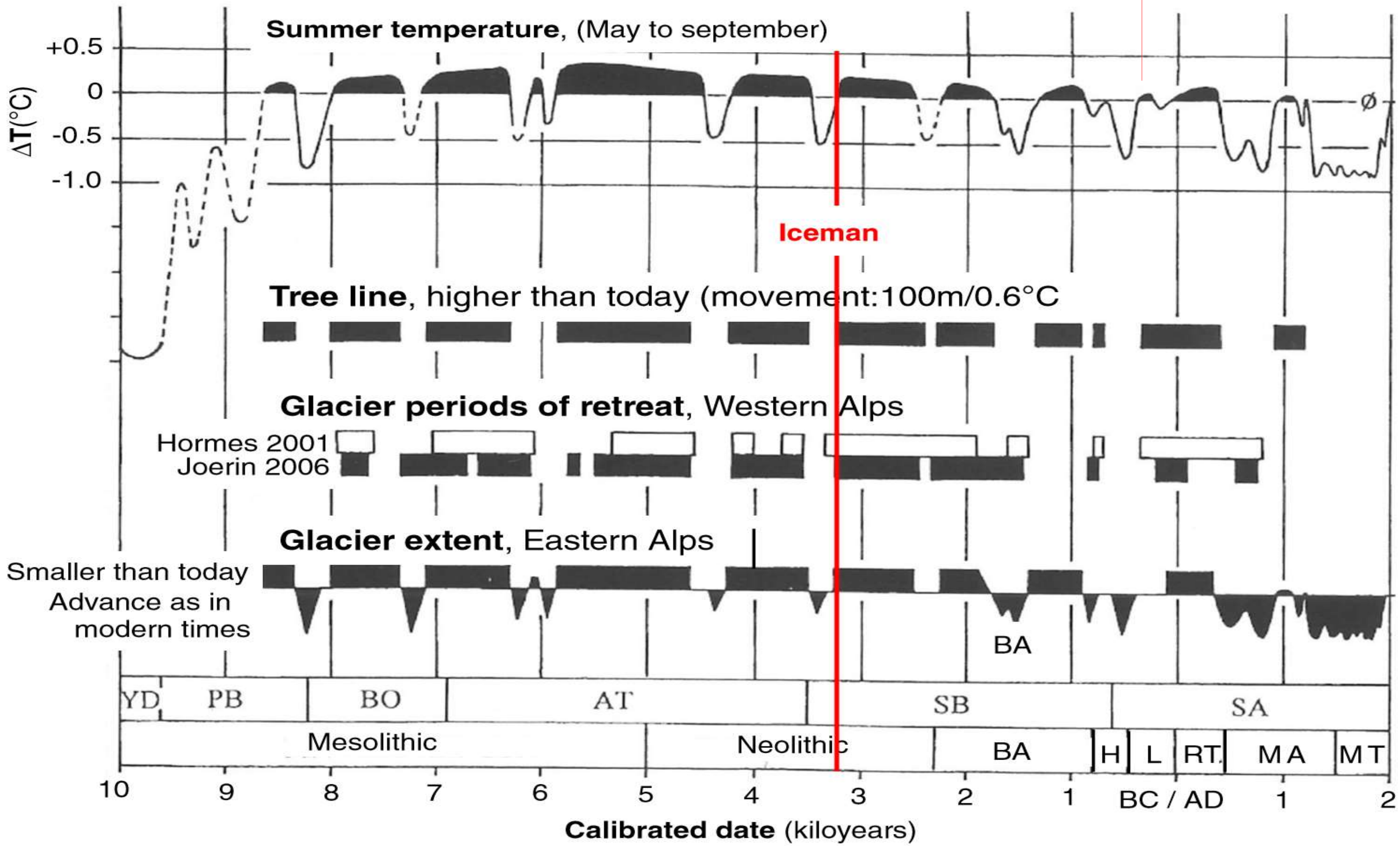


Steinhilber, F., Abreu, J. A., Beer, J., et al., 2012. 9,400 years of cosmic radiation and solar activity from ice cores and tree rings. PNAS, 109, 5967-5971, 2012.



A quasi-millennial oscillation in the Summer temperatures in the European Alps throughout the Holocene

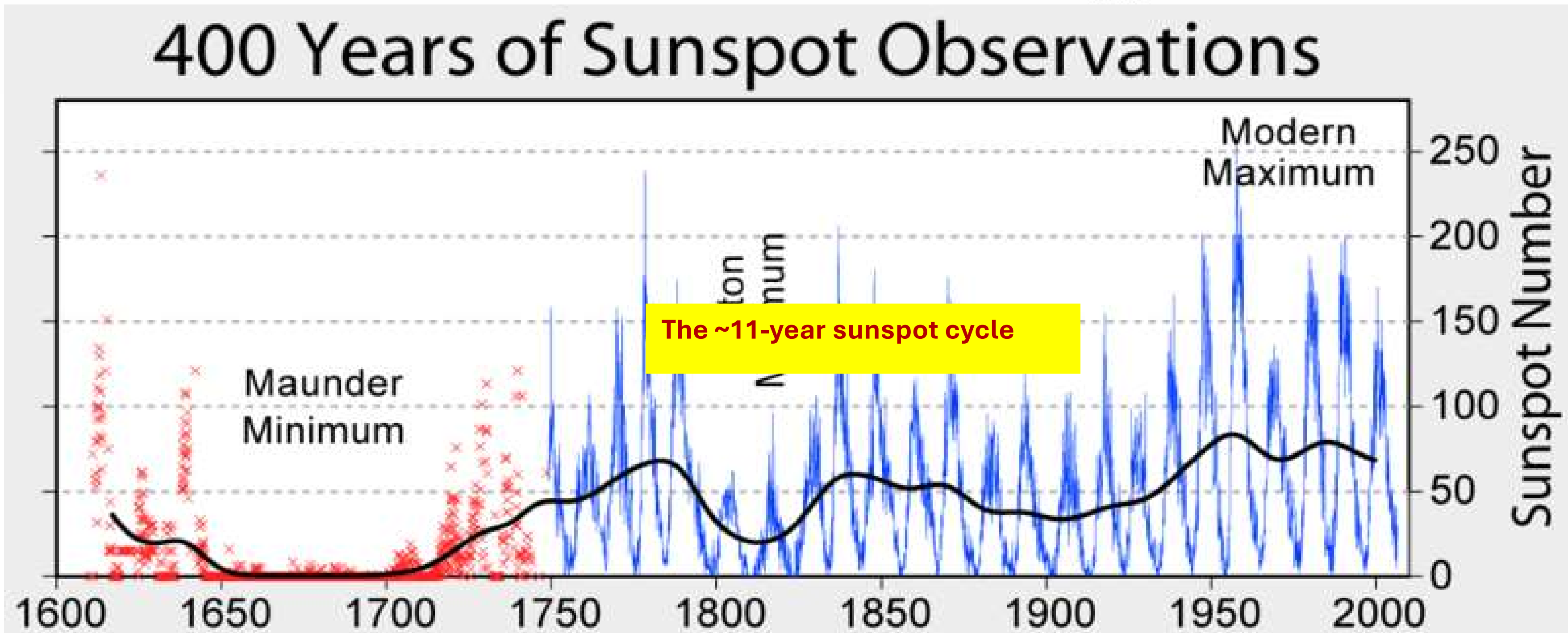
Hannibal



Kutschera, W., Patzelt, G., Steier, P., Wild, E.M.: 2017. The tyrolean iceman and his glacial environment during the holocene. Radiocarbon 59(2), pp. 395-405

A Planetary theory of solar variations

Extract of a Letter from Prof. R. Wolf, of Zurich, to Mr. Carrington, dated Jan. 12, 1859.



the same planets, the conclusion seems to be inevitable, that my conjecture that the variations of spot-frequency depend on the influences of *Venus, Earth, Jupiter, and Saturn*, will not prove to be wholly unfounded. The preponderating planet

The three main frequencies of the 11-year solar cycle

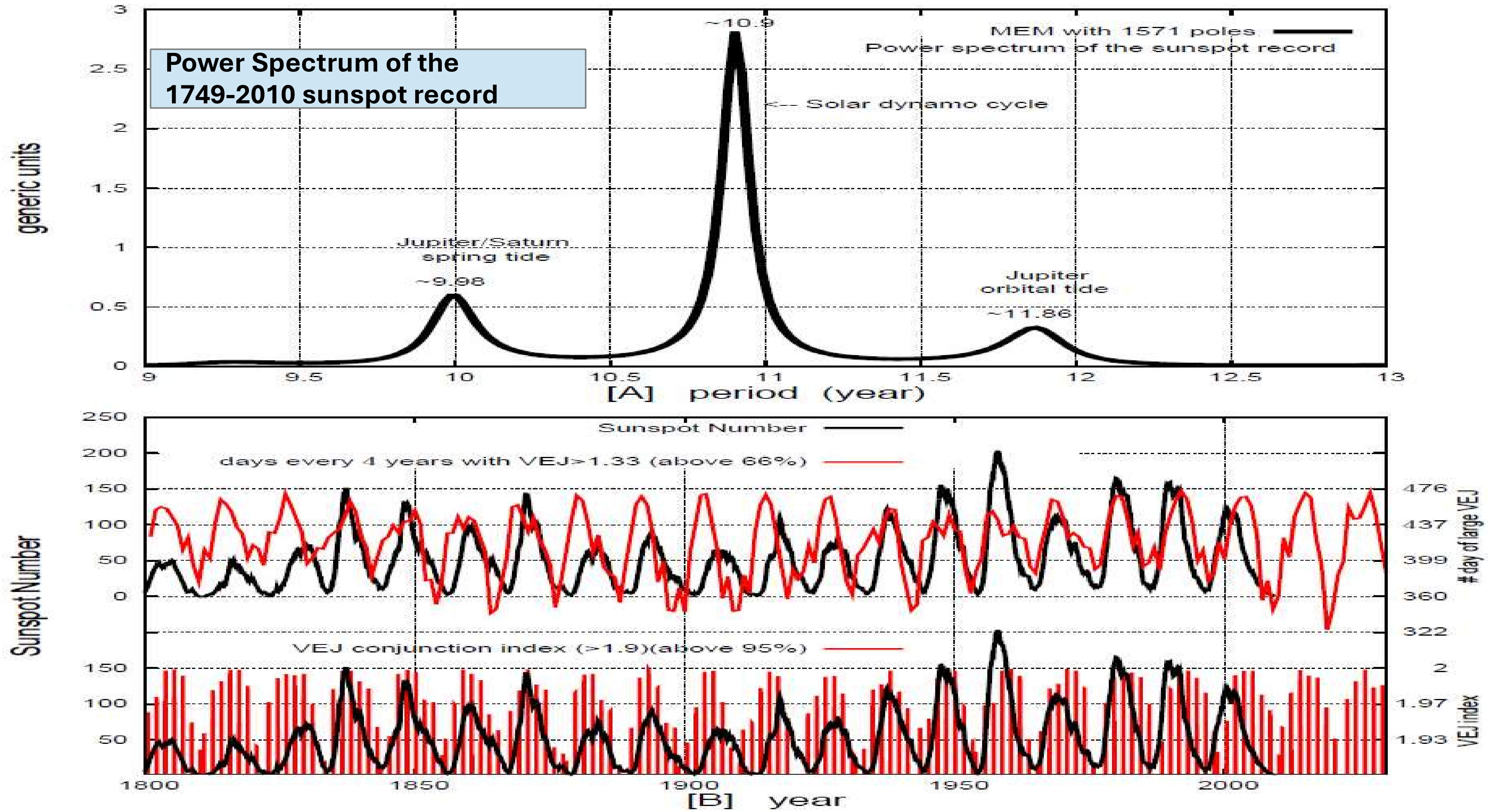
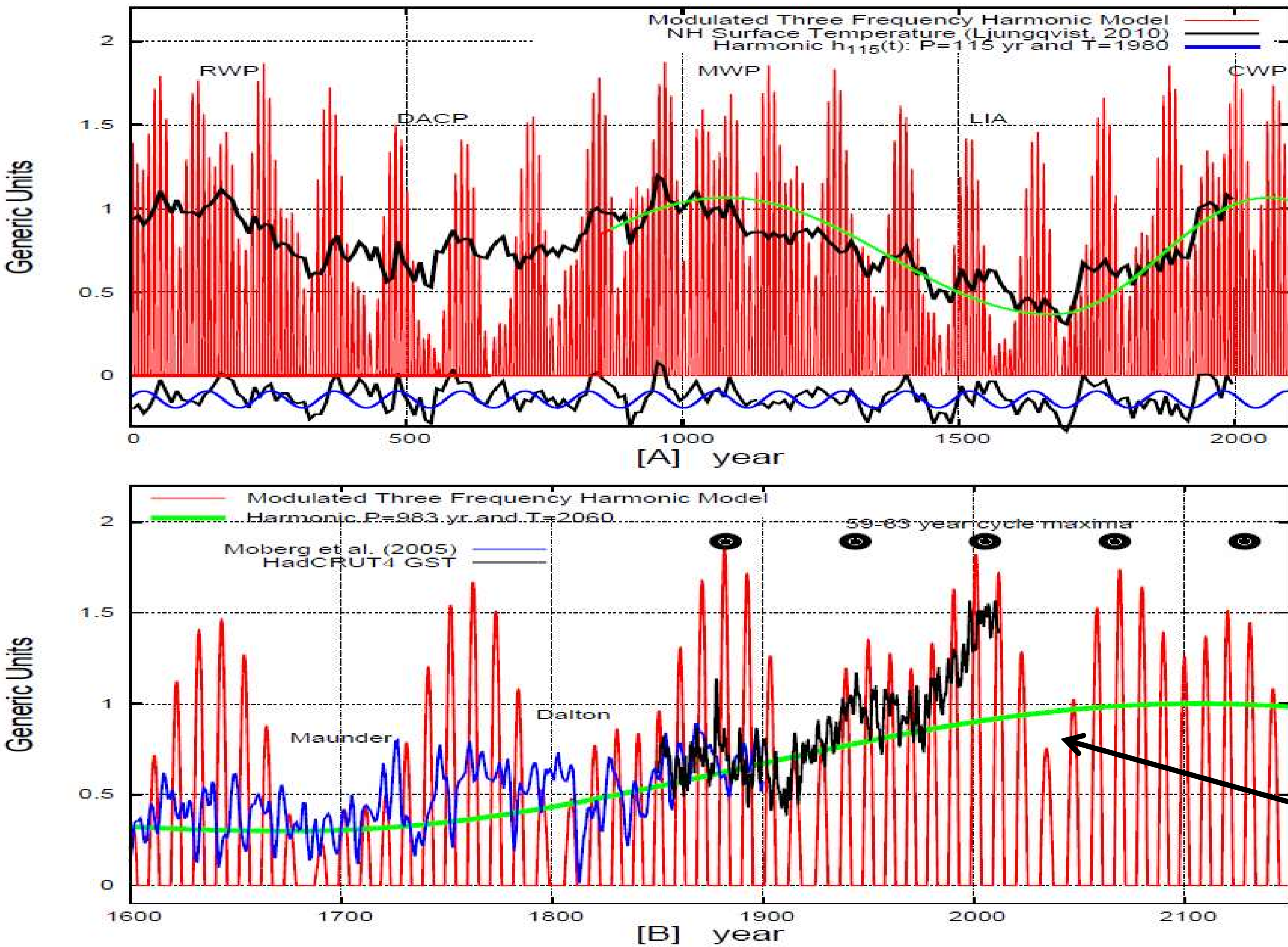


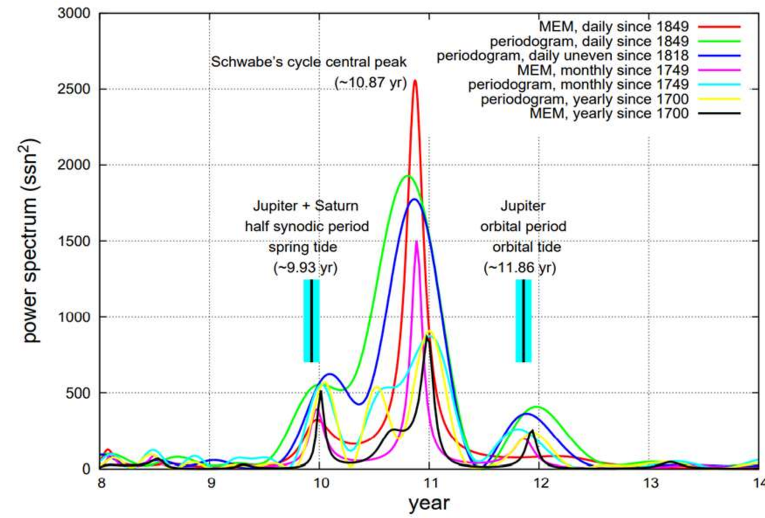
Figure 12: [A] Power spectrum of the sunspot record from 1749 to 2010 highlighting three peaks within the Schwabe frequency band (period 9-13 years) including the two major tides of Jupiter and Saturn. [B] Comparison between the sunspot record (black) and a particular tidal pattern configuration (red) made using Venus, Earth and Jupiter that reproduces on average the solar cycle length of 11.08 yr.

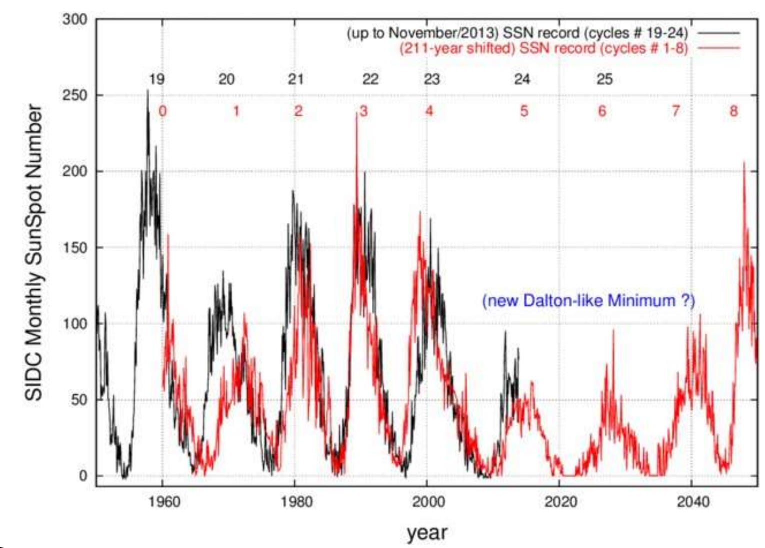
Scafetta N., 2012. Does the Sun work as a nuclear fusion amplifier of planetary tidal forcing? A proposal for a physical mechanism based on the mass-luminosity relation. Journal of Atmospheric and Solar-Terrestrial Physics 81-82, 27-40.

Three-frequency solar harmonic model based on Jupiter-Saturn tidal frequencies and sunspot cycle versus temperature reconstructions (~61-year, ~115-year, ~980-year cycles)

Scafetta N., 2012. Multi-scale harmonic model for solar and climate cyclical variation throughout the Holocene based on Jupiter-Saturn tidal frequencies plus the 11-year solar dynamo cycle. Journal of Atmospheric and Solar-Terrestrial Physics 80, 296-311.







Prediction Gran Solar Minimum 2020-2040

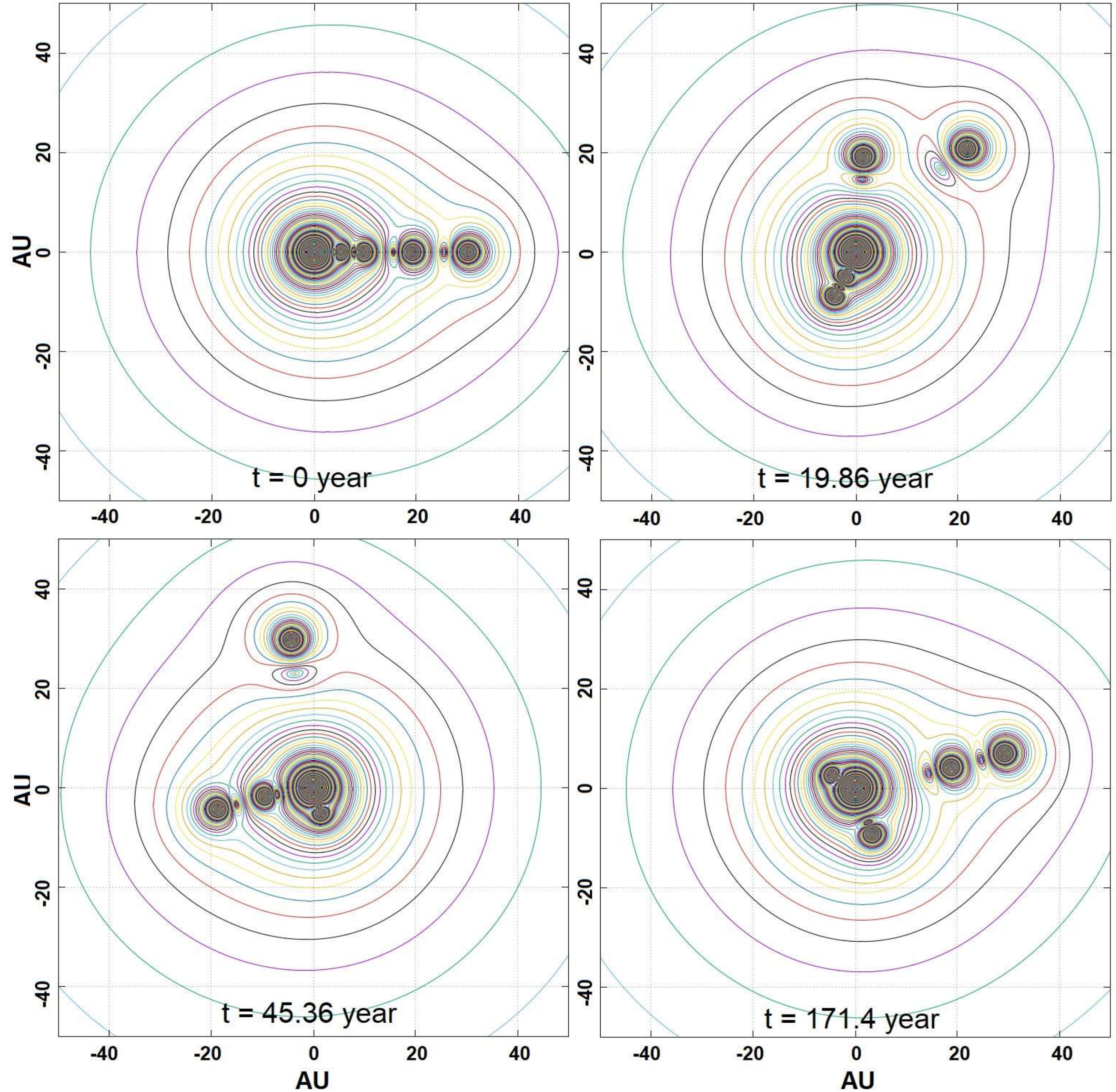
The Orbital Invariant Inequalities

$$f = \frac{1}{T} = \left| \sum_{i=1}^{n} \frac{a_i}{T_i} \right|,$$

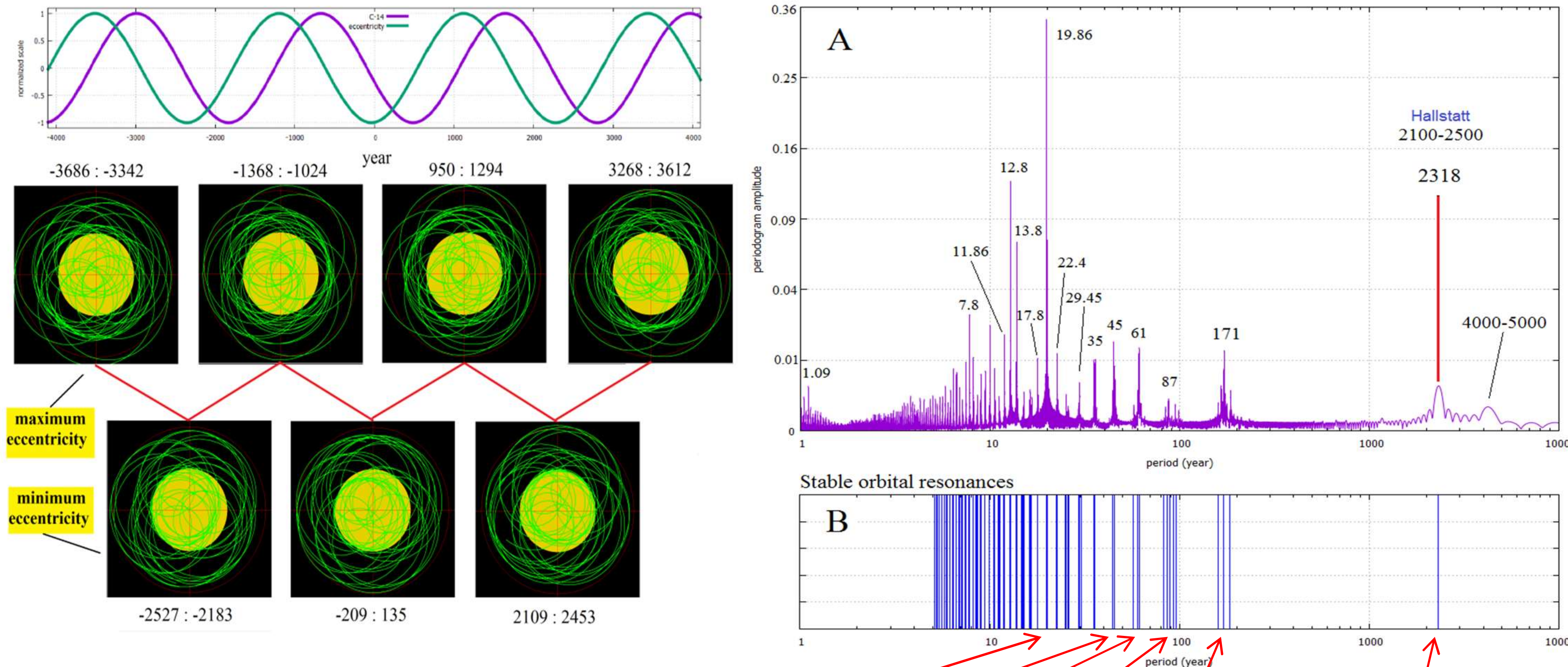
$$\sum_{i=1}^{n} a_i = 0.$$

$$f_i' = \frac{1}{T_i'} = \frac{1}{T_i} - \frac{1}{P}.$$

$$f' = \frac{1}{T'} = \left| \sum_{i=1}^{n} \frac{a_i}{T_i'} \right| = \left| \sum_{i=1}^{n} \frac{a_i}{T_i} - \frac{\sum_{i=1}^{n} a_i}{P} \right|.$$



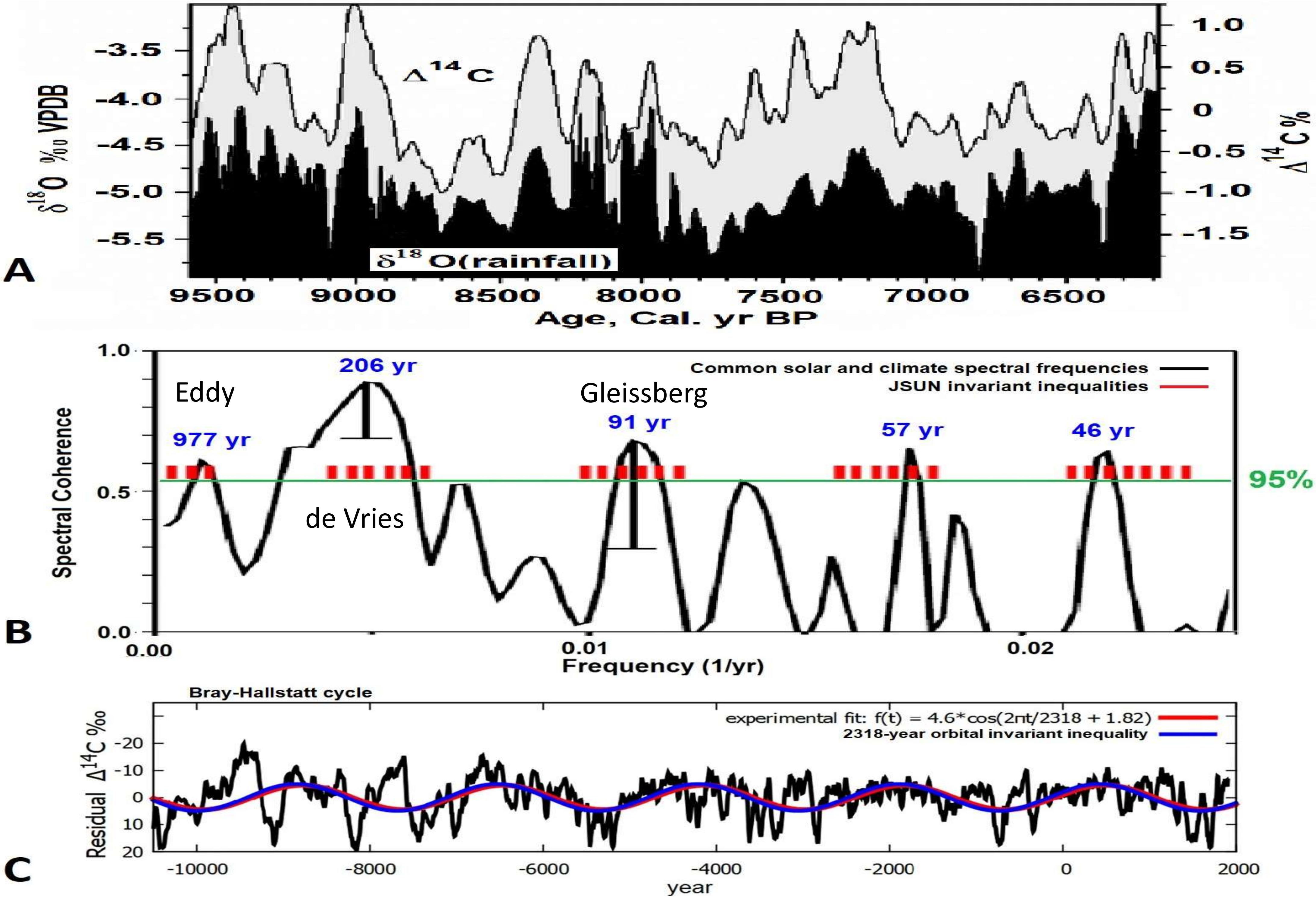
The Orbital Invariant Inequalities of the Jupiter-Saturn-Uranus-Neptune system



Stable resonances

20 yr 44-45 yr 57-61 yr 82-96 yr 159-171-185 yr 2318 yr

Gleissberg Jose HallStatt

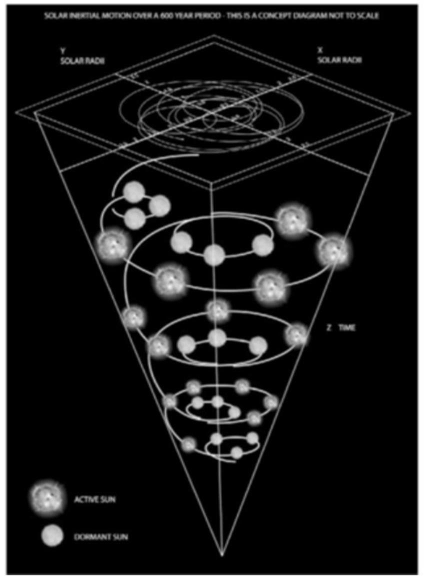


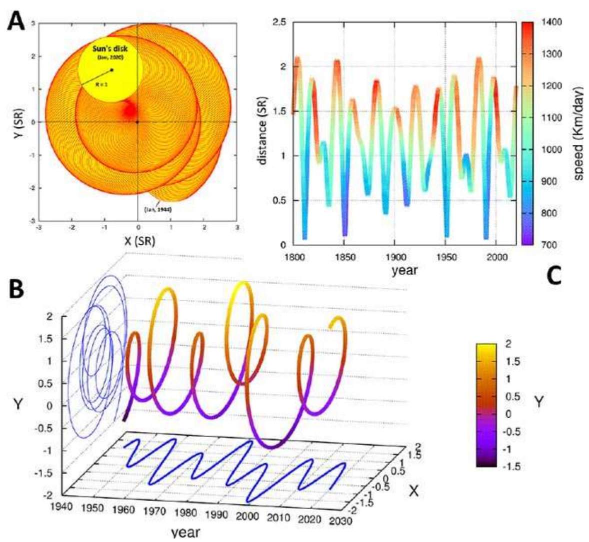
Scafetta, N.: 2020. Solar Oscillations and the Orbital Invariant Inequalities of the Solar System. Sol Phys 295, 33. https://doi.org/10.1007/s11207-020-01599-y

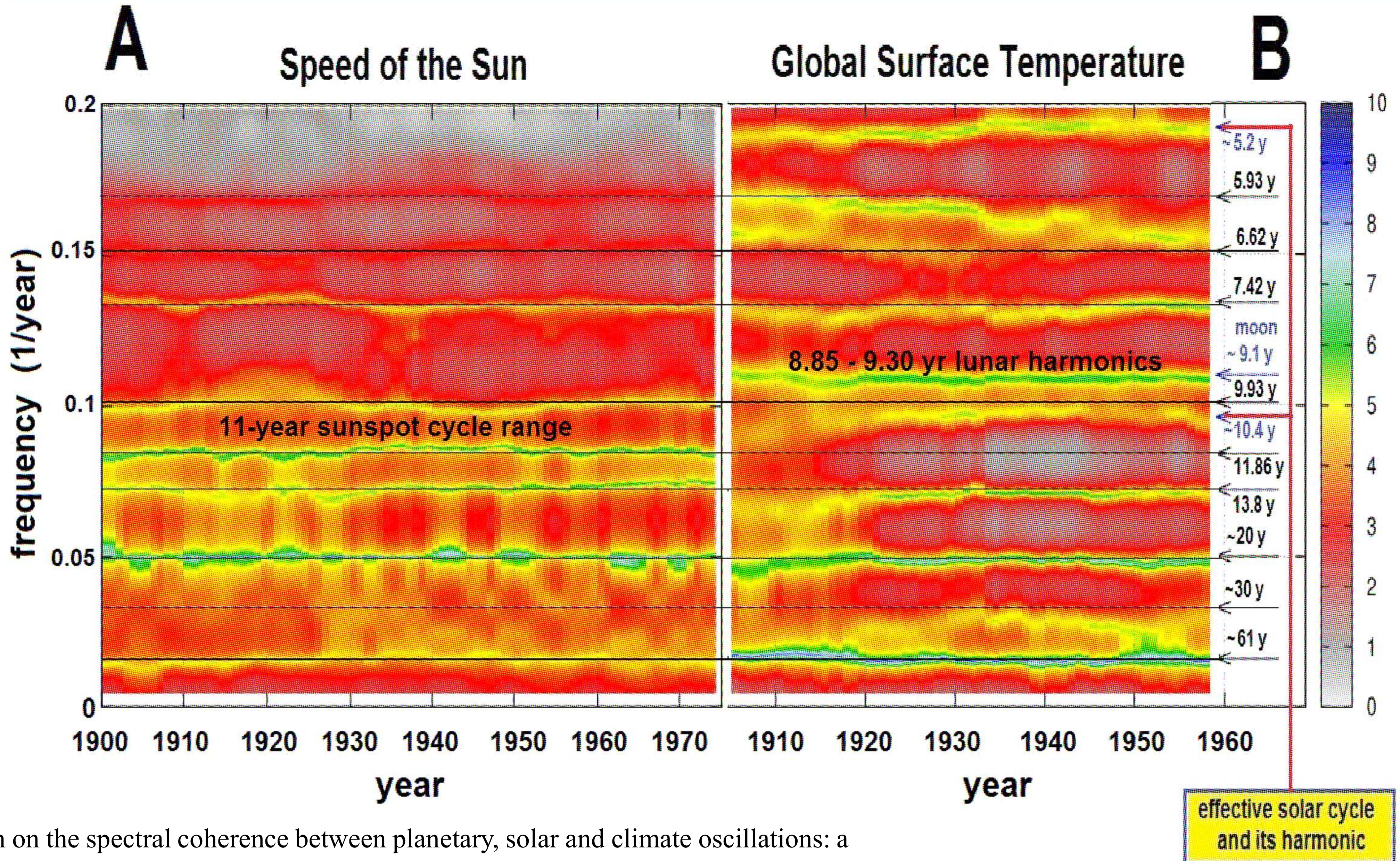
“Orbital Invariant Inequalities”

Beats among Jupiter, Saturn Uranus, Neptune

The Earth's climate has the same oscillations present in the solar system

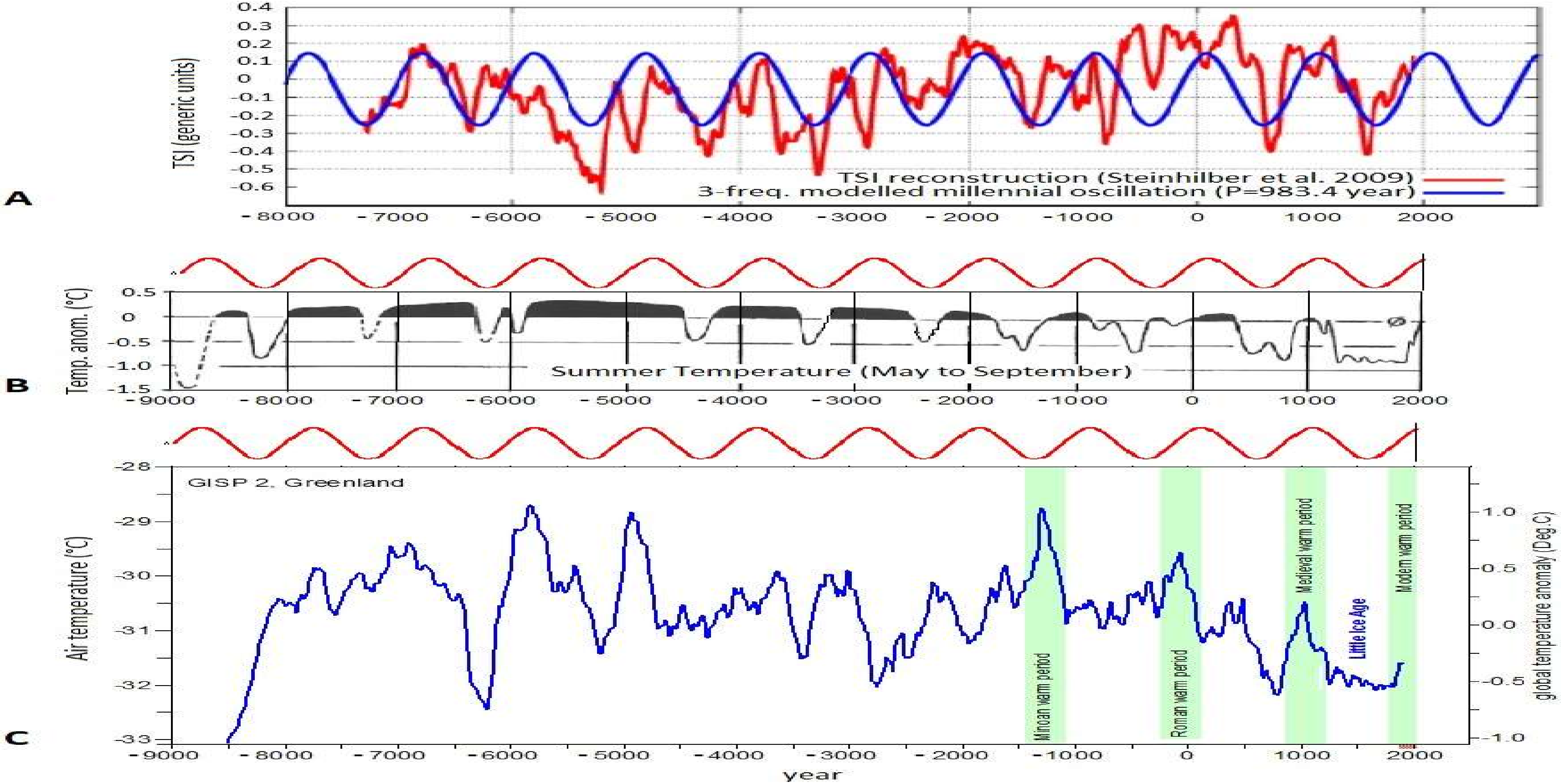






Scafetta, N., "Discussion on the spectral coherence between planetary, solar and climate oscillations: a reply to some critiques." *Astrophysics and Space Science*, vol. 354, pp. 275-299, 2014.

A quasi 1000-year cycle in both climate data reconstructed by the planetary model of solar variability



Luminosity production associated with tidal energy dissipated in the Sun

$$\frac{L}{L_S} \approx \left(\frac{M}{M_S}\right)^4 \approx 1 + \frac{4\Delta M}{M_S},$$

rewriting it

$$L(t) \approx L_S + 4L_S \frac{\dot{U}_{tidal}(t)}{\dot{U}_{Sun}} = L_S + A \cdot \dot{U}_{tidal}(t),$$

amplification factor used in $K(\chi)$

$$\dot{U}_{Sun} = -\dot{U}_{fusion} = \frac{1}{2} G \int_0^{R_S} m_S(r) \frac{d\dot{m}(r)}{dr} \frac{1}{r} dr = 3.6 \times 10^{20} W,$$

$$\frac{d\dot{m}(r)}{dr} = \frac{1}{c^2} \frac{dL(r)}{dr},$$

$$A = \frac{4L_S}{\dot{U}_{Sun}} \approx 4.25 \times 10^6.$$

Equation to convert gravitational energy released by the tides into luminosity anomaly

$$I_P(t) = \frac{3 G R_S^5}{2 Q \Delta t} \int_0^1 K(\chi)\, \chi^4 \rho(\chi)\, d\chi \cdot$$

$K(\chi)$ is the amplification function

$$\int_{\theta=0}^{\pi} \int_{\phi=0}^{2\pi} \left| \sum_{p=1}^{8} m_p \frac{\cos^2(\alpha_{p,t}) - \frac{1}{3}}{R_{SP}^3(t)} - m_p \frac{\cos^2(\alpha_{p,t-\Delta t}) - \frac{1}{3}}{R_{SP}^3(t-\Delta t)} \right| \sin(\theta)\, d\theta\, d\phi,$$

Solar luminosity L_S = 4x10^{26} W

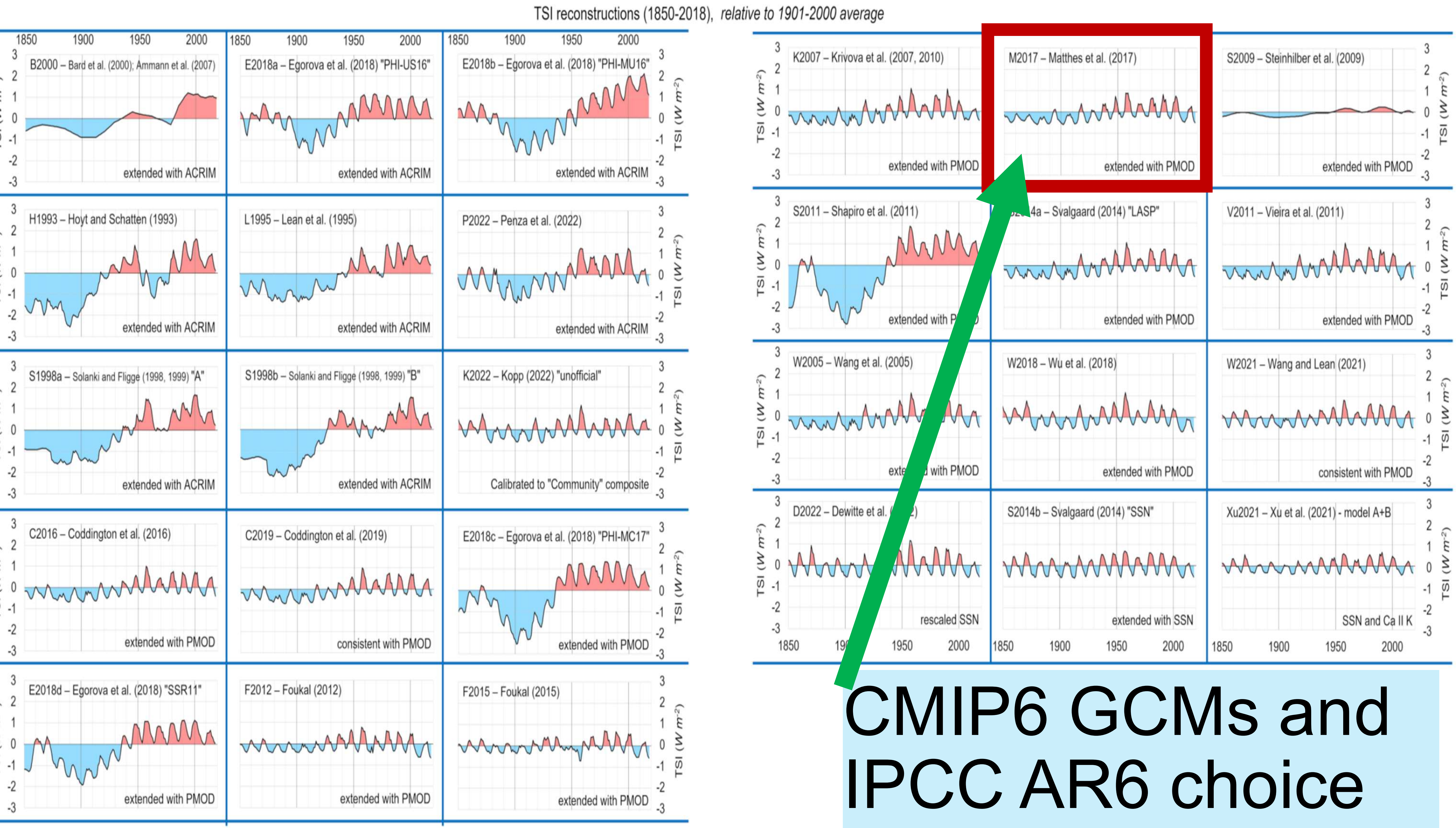
Scafetta N., 2012. Does the Sun work as a nuclear fusion amplifier of planetary tidal forcing? A proposal for a physical mechanism based on the mass-luminosity relation. Journal of Atmospheric and Solar-Terrestrial Physics 81-82, 27-40.

Why do the GCMs fail to reproduce the Medieval Warm Period?

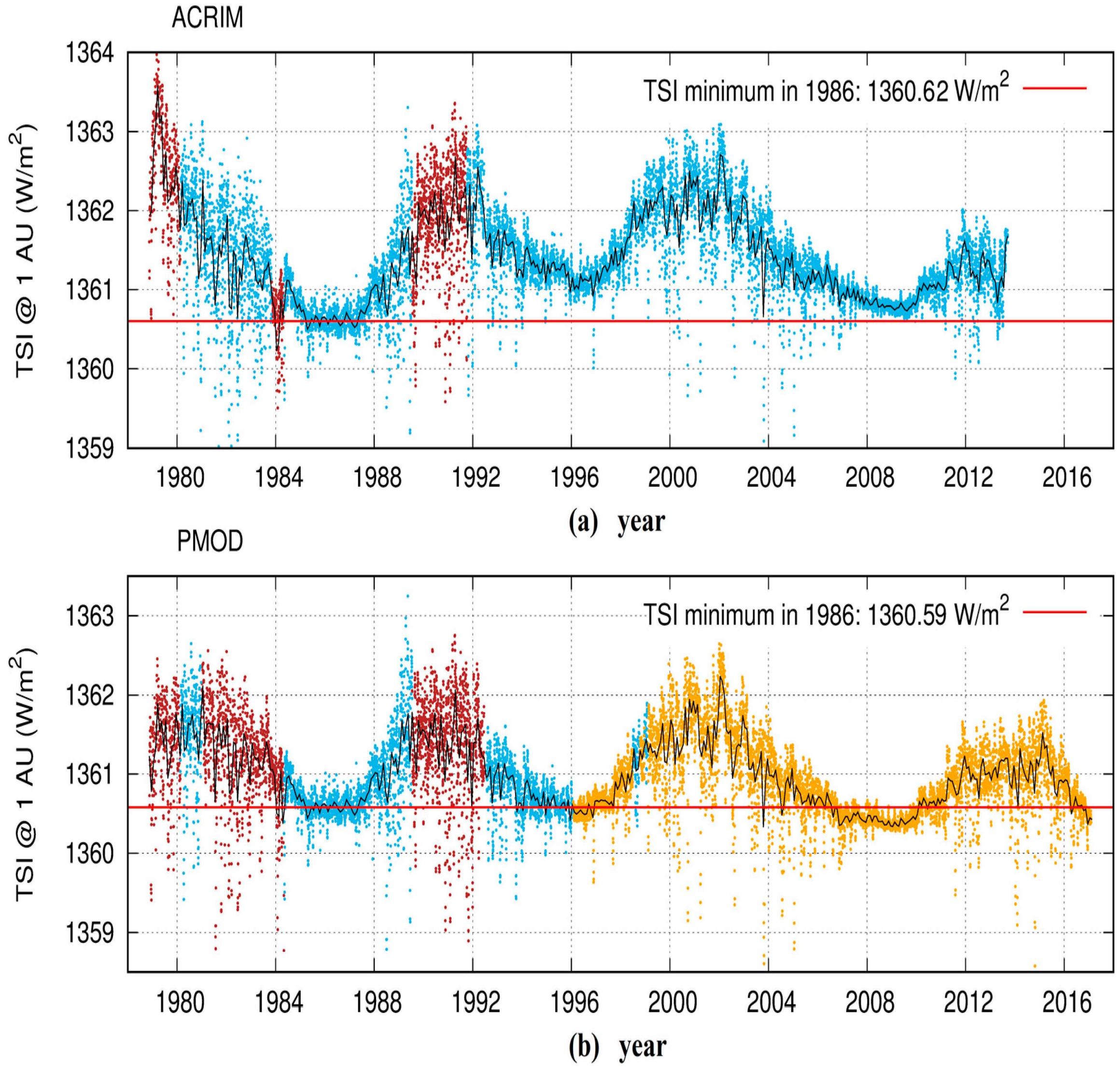
Scafetta, (2023). *Geoscience Frontiers* 14(6), 101650.
Connolly, …., Scafetta, et al. (2023). *Research in Astronomy and Astrophysics* 23, 105015.
Soon, …., Scafetta, et al. (2023). *Climate* 11, 179.
Scafetta, Bianchini, (2023). *Climate* 11(4), 77.
Scafetta, Bianchini, (2022). *Frontiers in Astronomy and Space Sciences*, 937930.
Connolly, …, Scafetta, et al. (2021). *Research in Astronomy and Astrophysics* 21, 131.
Scafetta, (2021). *Atmosphere*, 12, 147.
Scafetta, et al. (2019). *Remote Sensing*, 11(21), 2569.

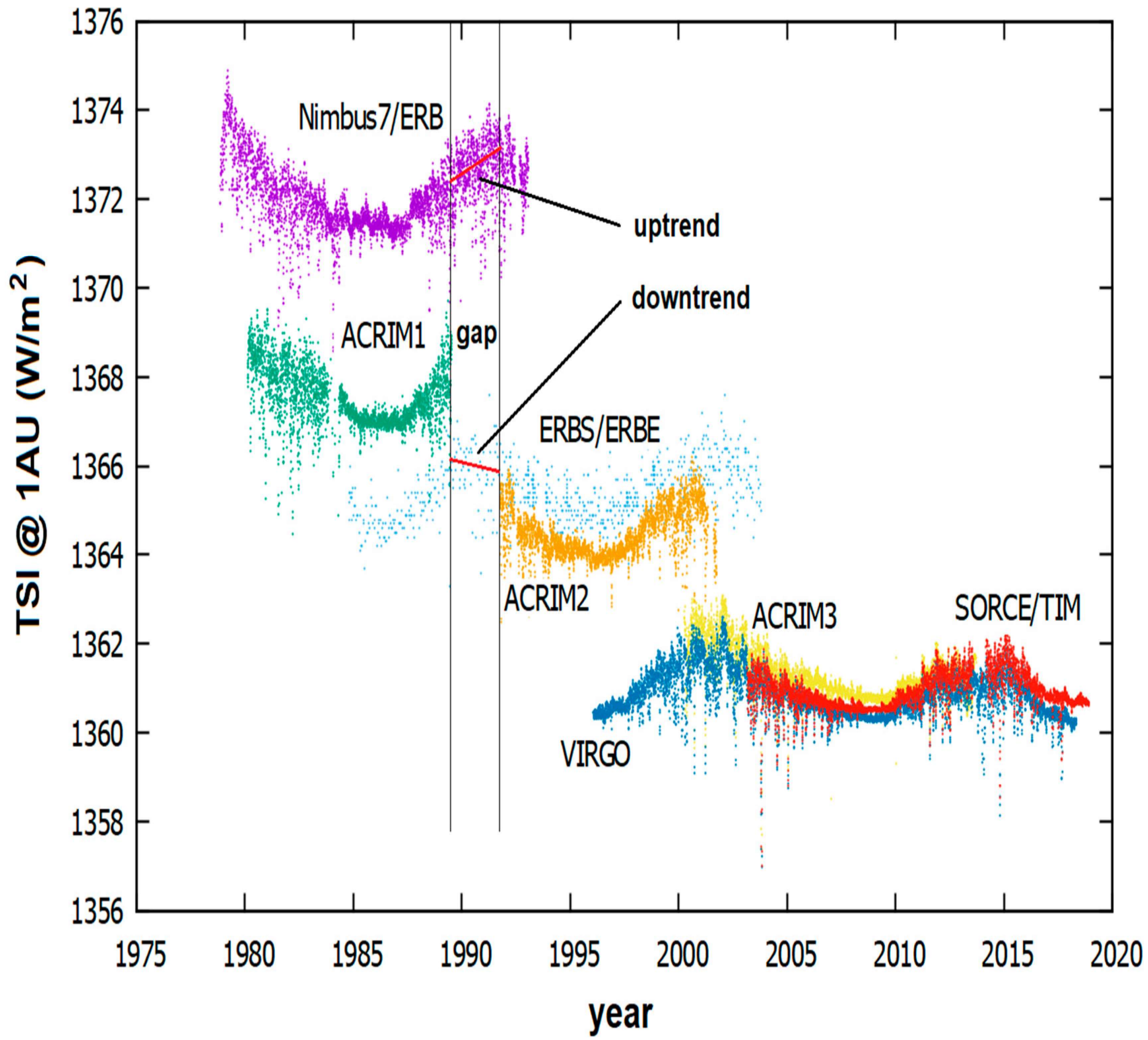
Wrong Total Solar Irradiance (TSI) forcing

Additional solar forcings not related to TSI


TSI reconstructions (1850-2018), relative to 1901-2000 average
B2000 – Bard et al. (2000); Ammann et al. (2007)
extended with ACRIM
E2018a – Egorova et al. (2018) "PHI-US16"
extended with ACRIM
E2018b – Egorova et al. (2018) "PHI-MU16"
extended with ACRIM
H1993 – Hoyt and Schatten (1993)
extended with ACRIM
L1995 – Lean et al. (1995)
extended with ACRIM
P2022 – Penza et al. (2022)
extended with ACRIM
S1998a – Solanki and Fligge (1998, 1999) "A"
extended with ACRIM
S1998b – Solanki and Fligge (1998, 1999) "B"
extended with ACRIM
K2022 – Kopp (2022) "unofficial"
Calibrated to "Community" composite
C2016 – Coddington et al. (2016)
extended with PMOD
C2019 – Coddington et al. (2019)
consistent with PMOD
E2018c – Egorova et al. (2018) "PHI-MC17"
extended with PMOD
E2018d – Egorova et al. (2018) "SSR11"
extended with PMOD
F2012 – Foukal (2012)
extended with PMOD
F2015 – Foukal (2015)
extended with PMOD
K2007 – Krivova et al. (2007, 2010)
extended with PMOD
M2017 – Matthes et al. (2017)
extended with PMOD
S2009 – Steinhilber et al. (2009)
extended with PMOD
S2011 – Shapiro et al. (2011)
S2014a – Svalgaard (2014) "LASP"
extended with PMOD
V2011 – Vieira et al. (2011)
extended with PMOD
W2005 – Wang et al. (2005)
extended with PMOD
W2018 – Wu et al. (2018)
extended with PMOD
W2021 – Wang and Lean (2021)
consistent with PMOD
D2022 – Dewitte et al. (2022)
rescaled SSN
S2014b – Svalgaard (2014) "SSN"
extended with SSN
Xu2021 – Xu et al. (2021) - model A+B
SSN and Ca II K
TSI (W m⁻²)
1850
1900
1950
2000
CMIP6 GCMs and IPCC AR6 choice

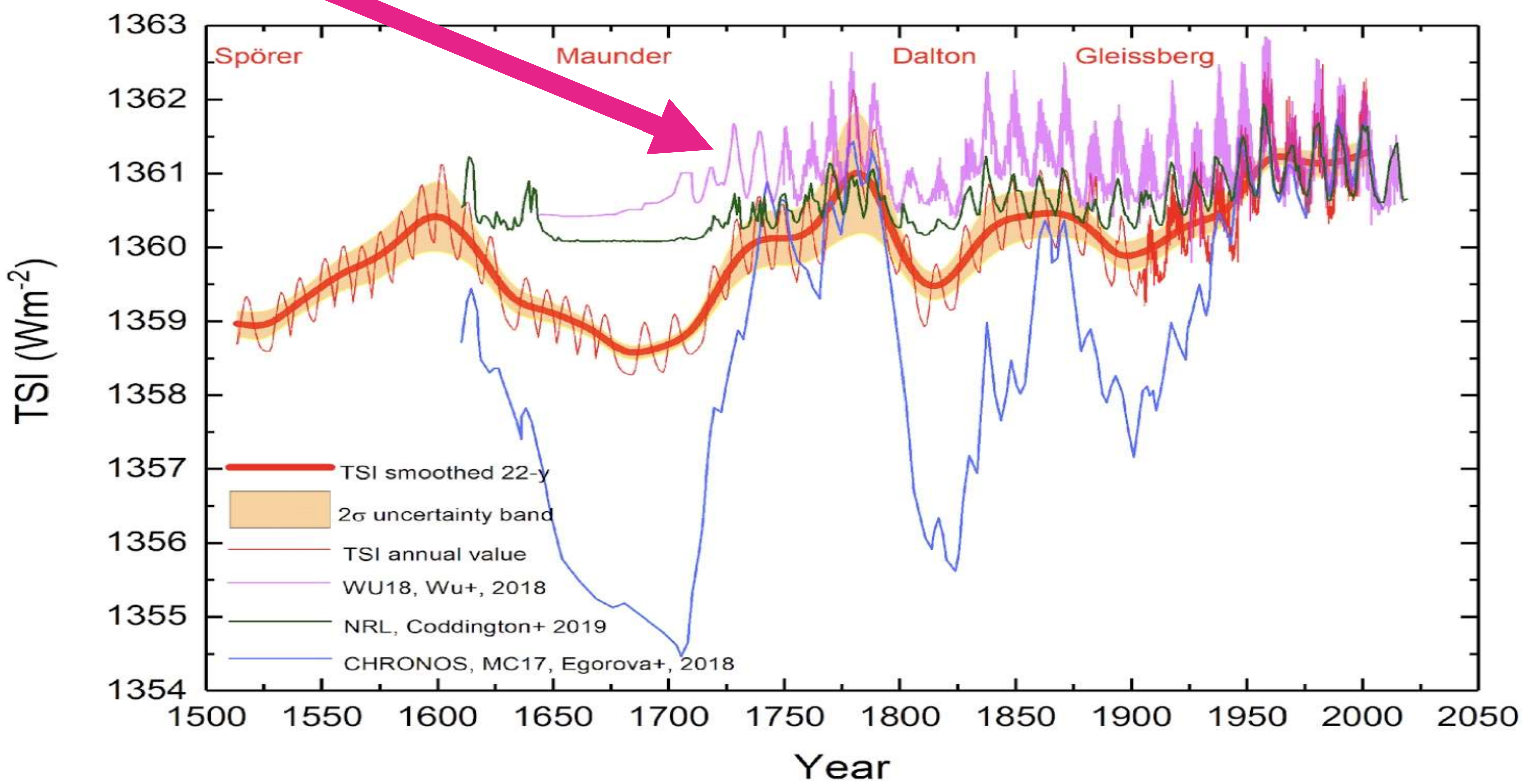
ACRIM vs PMOD TSI composites



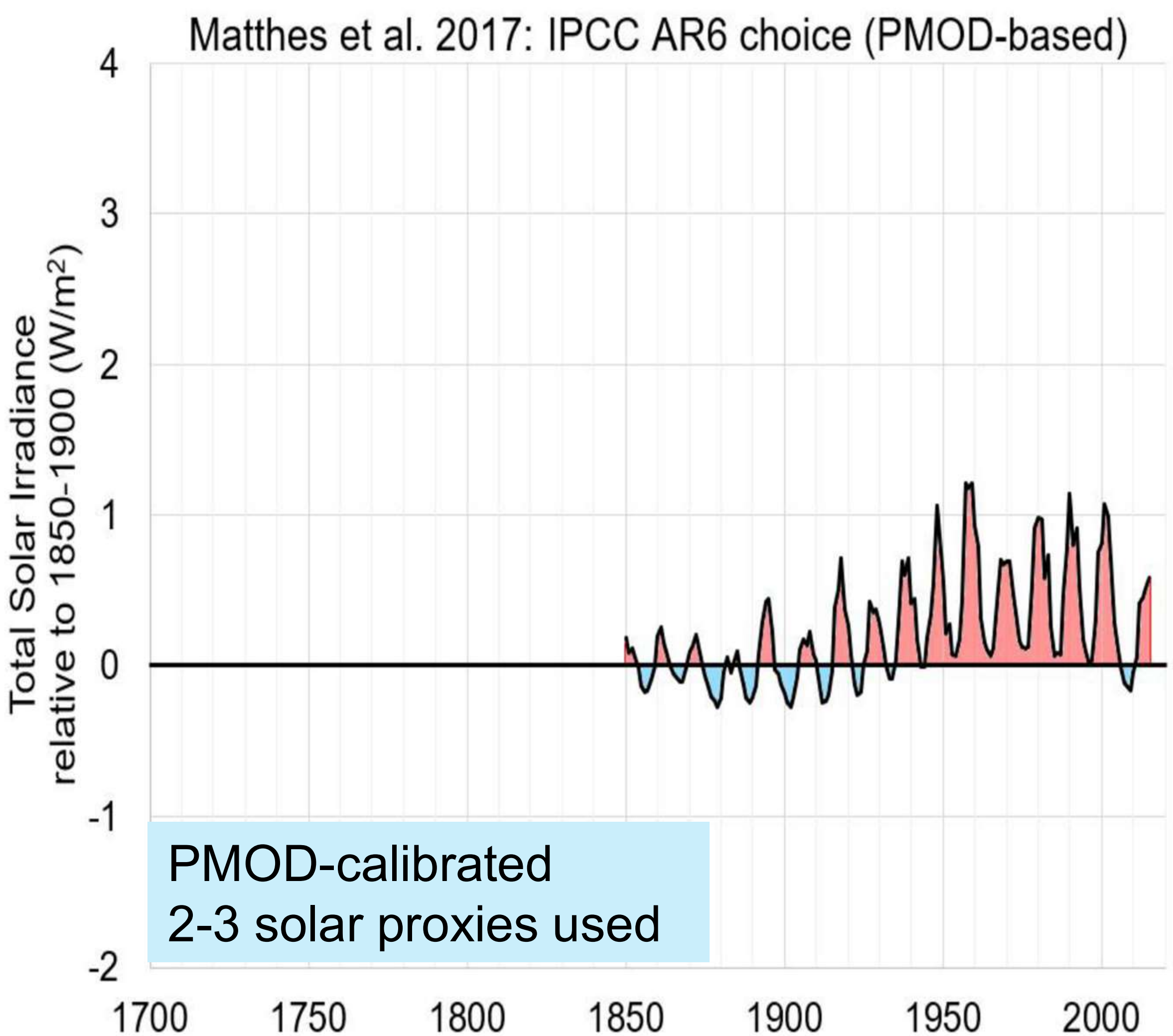


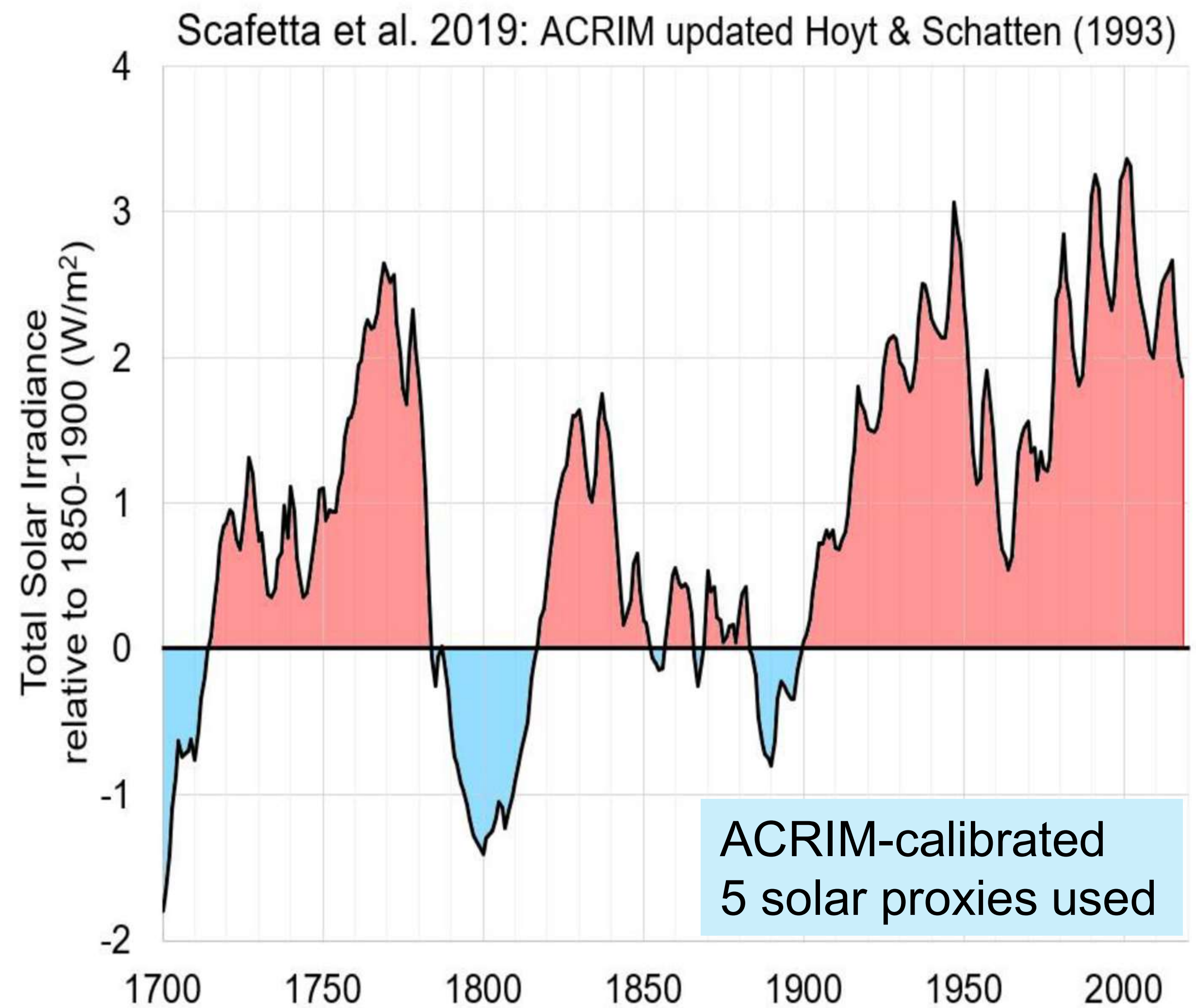
CMIP6 GCMs

- Penza, Berrilli, Bertello, Cantoresi, Criscuoli, Giobbi, Total Solar Irradiance during the Last Five Centuries, The Astrophysical Journal, 937:84, 2022



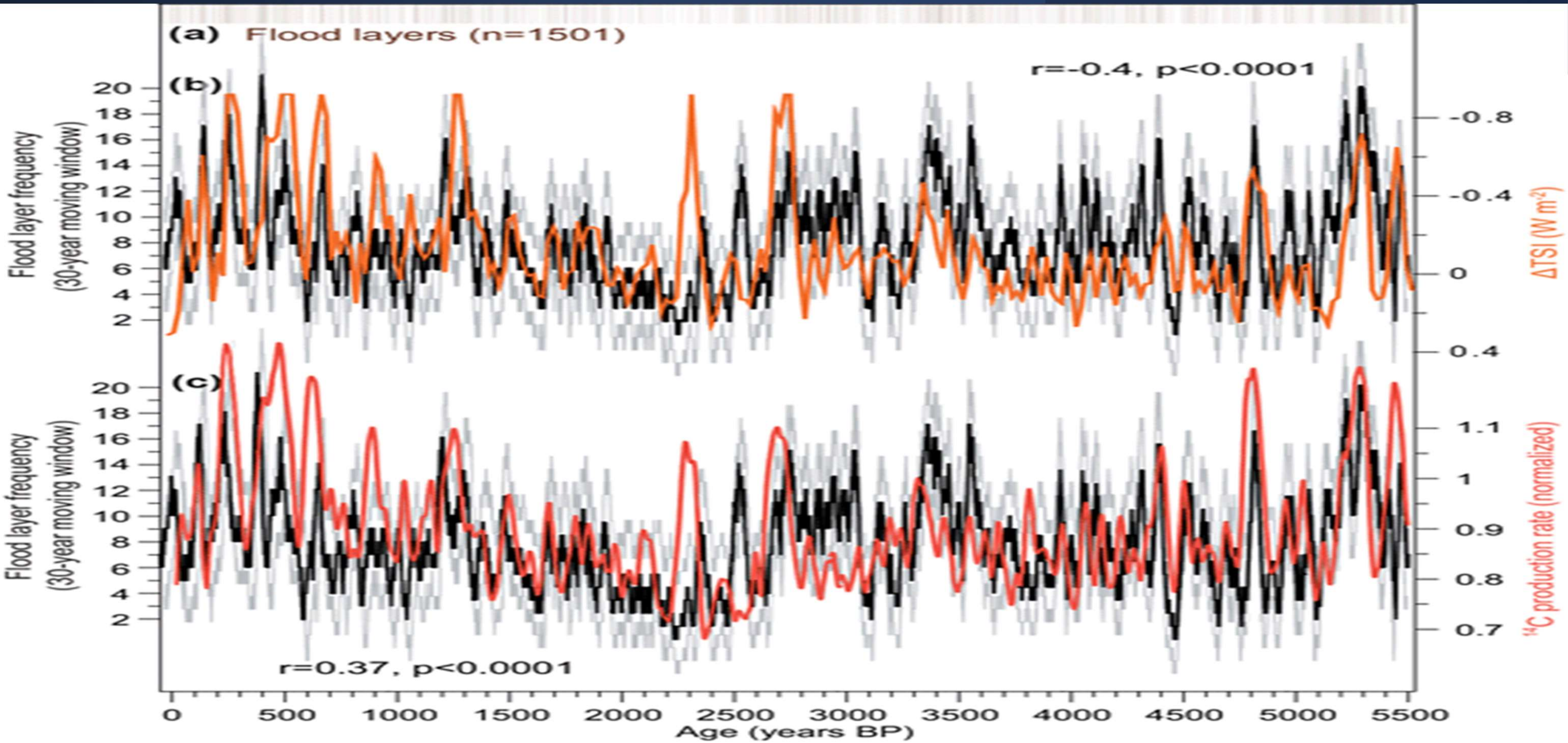
Using satellite TSI composites to calibrate solar proxies



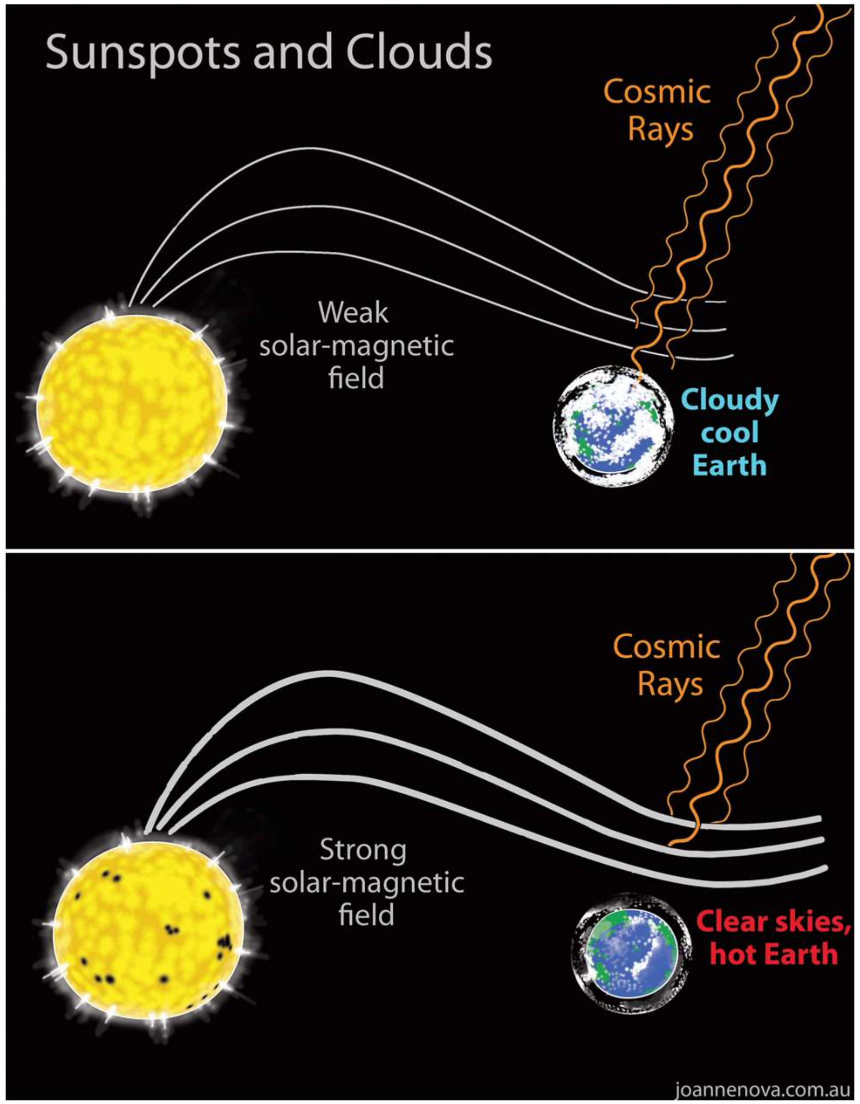


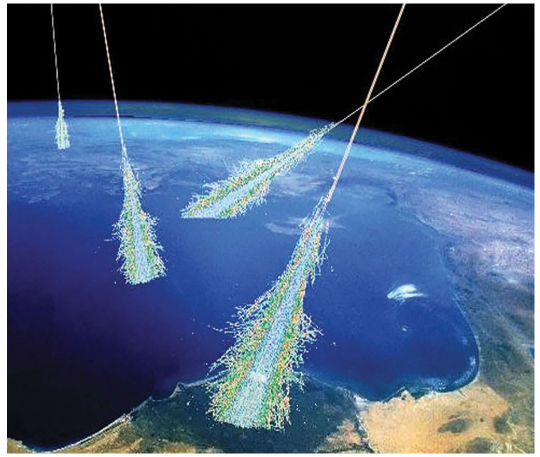
Czymzik, M., Muscheler, R., and Brauer, A.: Solar modulation of flood frequency in central Europe during spring and summer on interannual to multi-centennial timescales, Clim. Past, 12, 799–805, 2016.

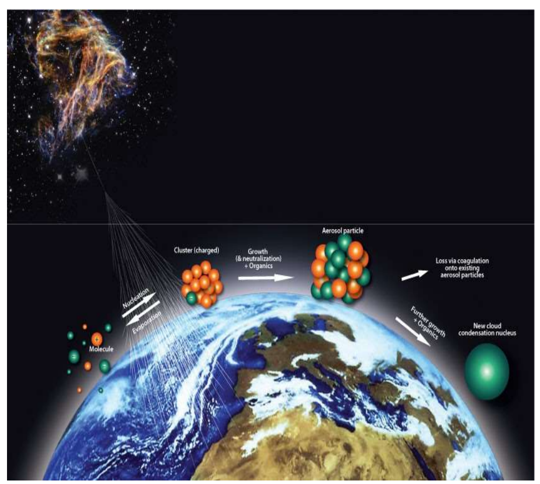
Strong Correlation

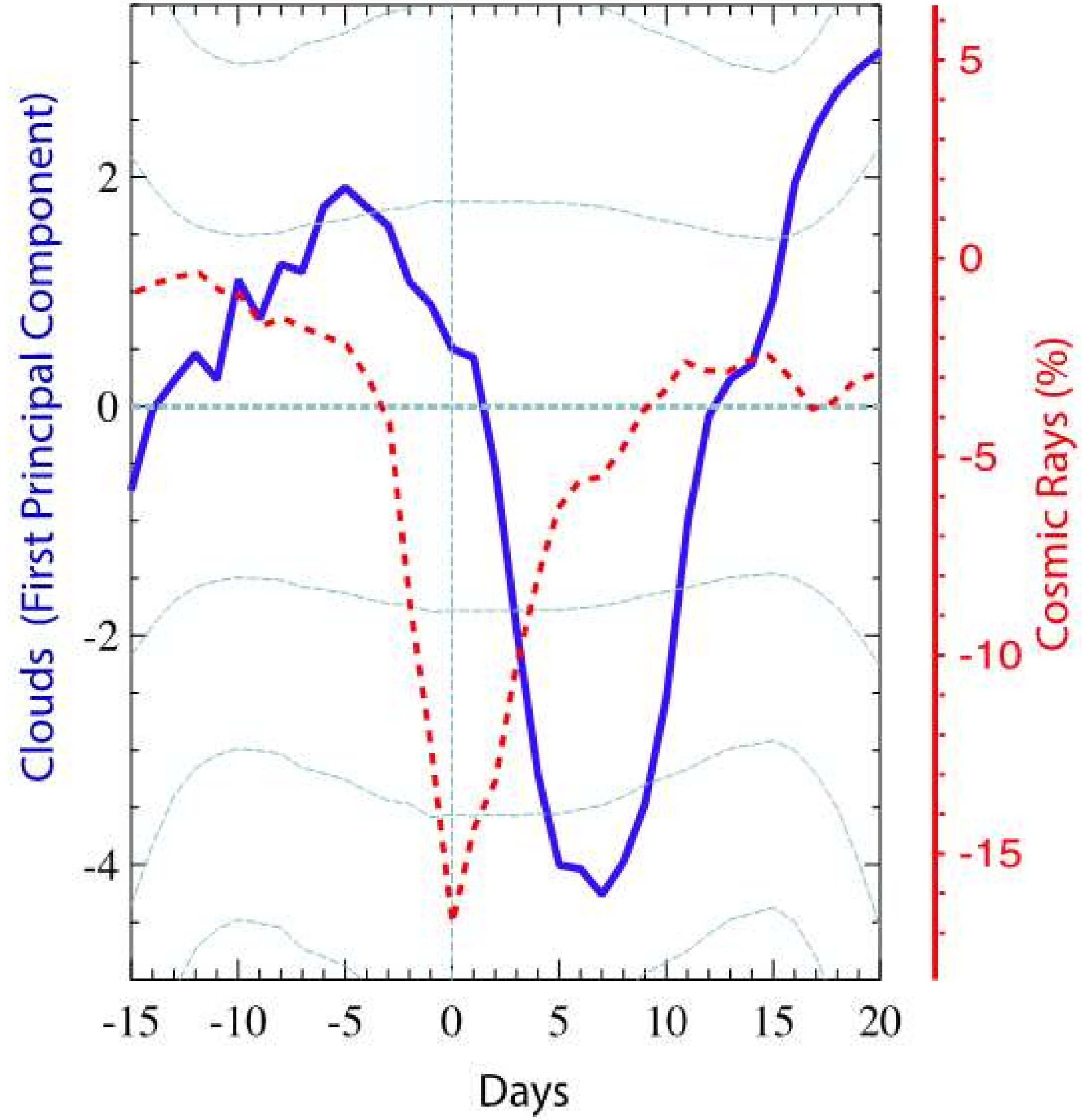


Forbush decreases: significant response is found in all studied aerosol and cloud data suggesting that cosmic ray ionization is important for cloud physics.

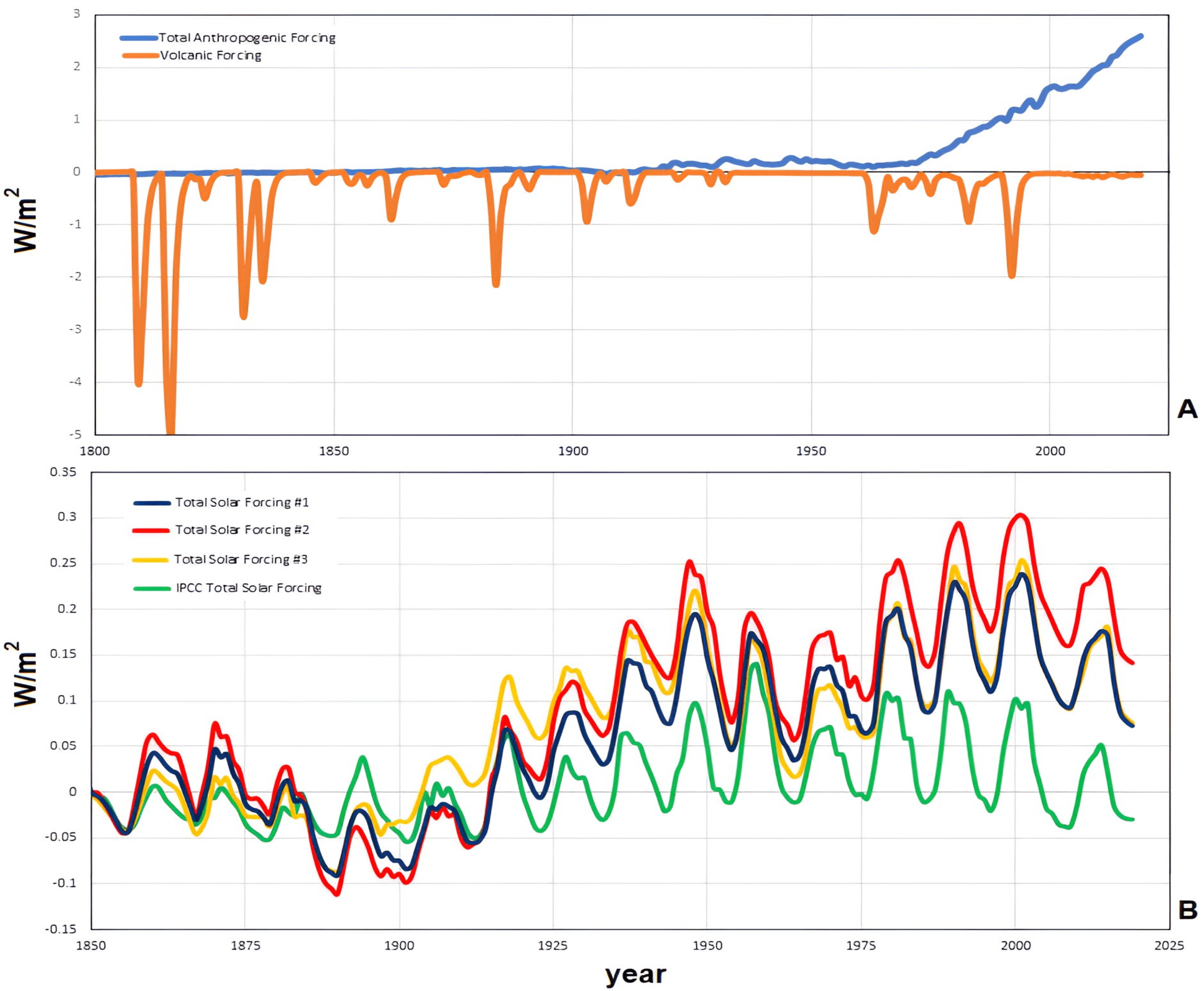






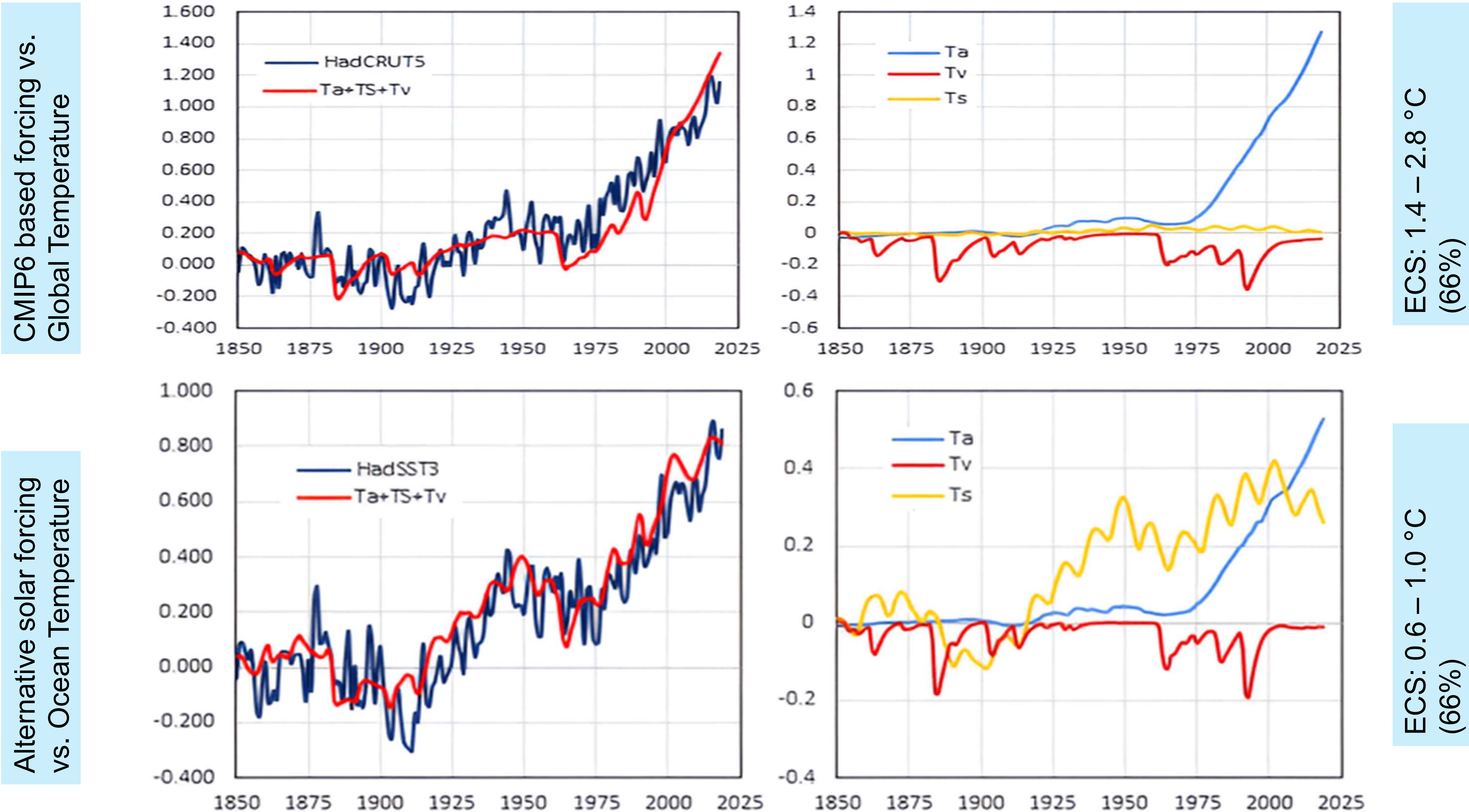


Svensmark, Enghoff, Shaviv, Svensmark, (2016). The response of clouds and aerosols to cosmic ray decreases. Journal of Geophysical Research: Space Physics 121 (9), 8152–8181.



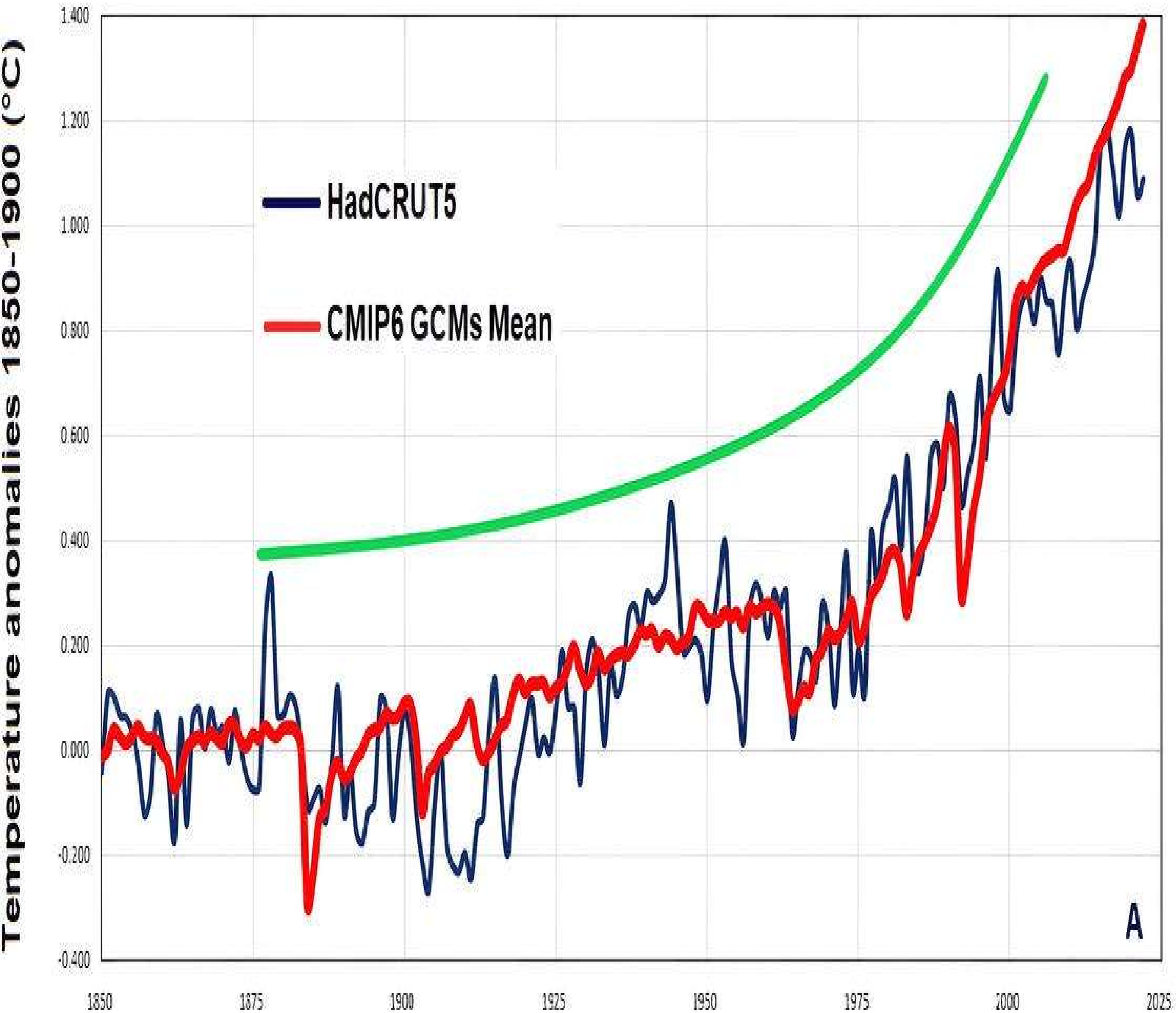
The CMIP6 GCMs accepted by the IPCC imply that the Sun can only influence climate through its secular brightness variation, which is likewise assumed to be very small.

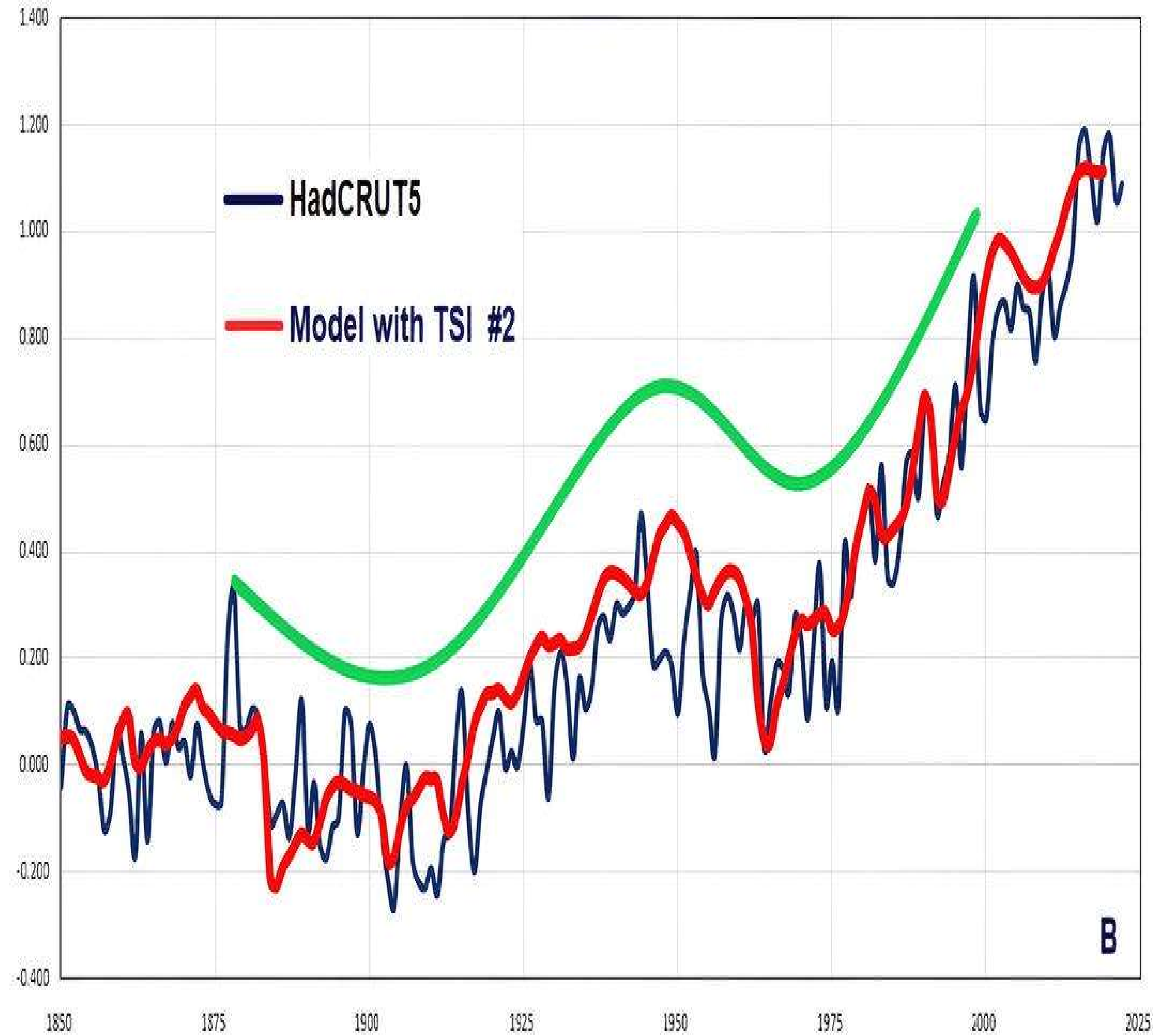
However, there are TSI reconstructions with higher secular variability, and the Sun likely influences climate mostly through mechanisms connected to variations in its magnetic activity (e.g. cosmic rays, solar wind, interplanetary dust fluxes, etc.).


CMIP6 based forcing vs. Global Temperature
HadCRUT5
Ta+TS+Tv
Ta
Tv
Ts
ECS: 1.4 – 2.8 °C (66%)
Alternative solar forcing vs. Ocean Temperature
HadSST3
Ta+TS+Tv
Ta
Tv
Ts
ECS: 0.6 – 1.0 °C (66%)
1850
1875
1900
1925
1950
1975
2000
2025

The 80% of solar influence on climate may not be caused solely by total solar irradiation forcing, but rather by other solar climate processes (e.g. cosmic rays).

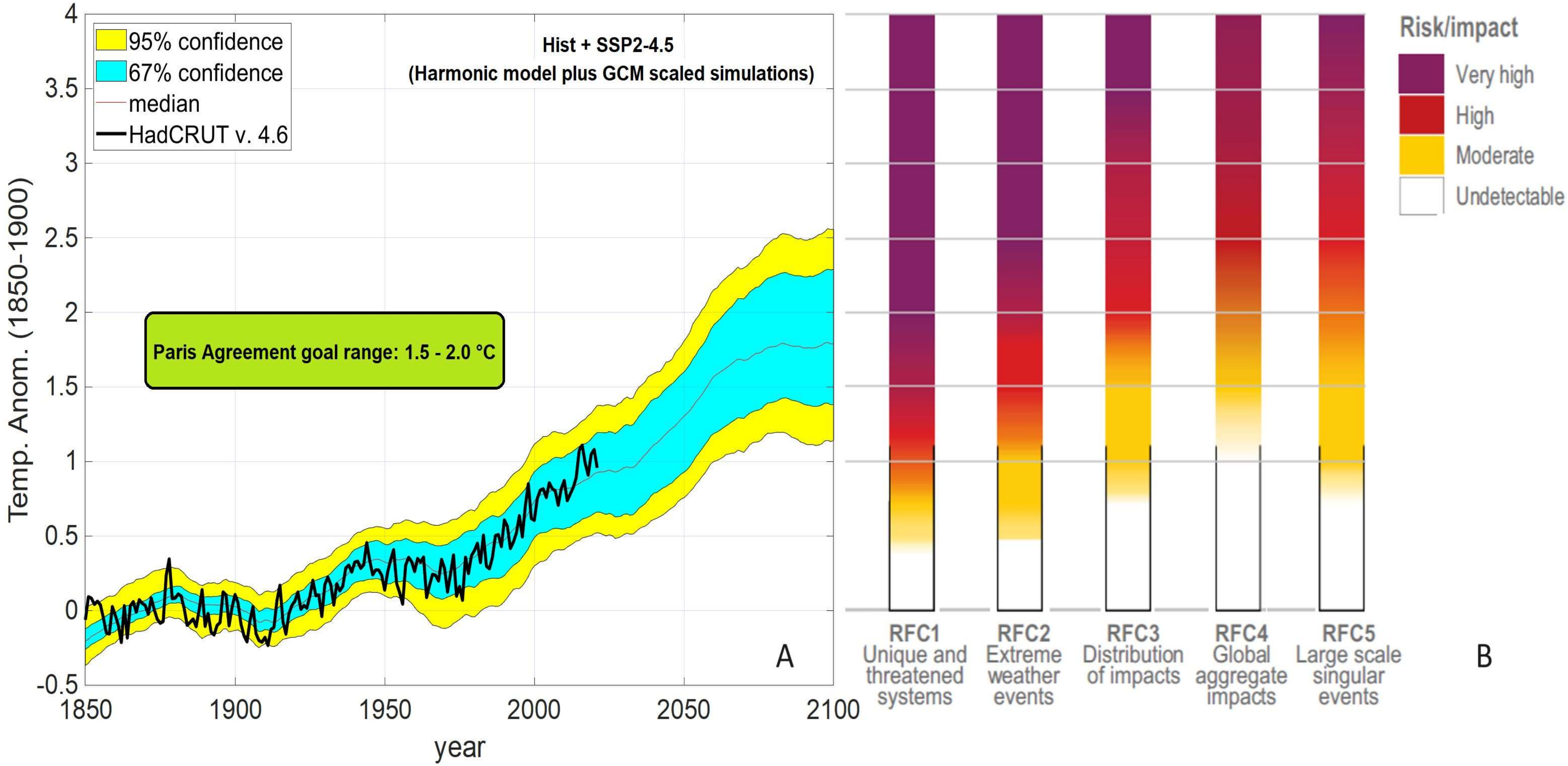
Scafetta, N.: Empirical assessment of the role of the Sun in climate change using balanced multi-proxy solar records. Geoscience Frontiers 14(6), 101650, 2023.
Pagina Web: https://doi.org/10.1016/j.gsf.2023.101650



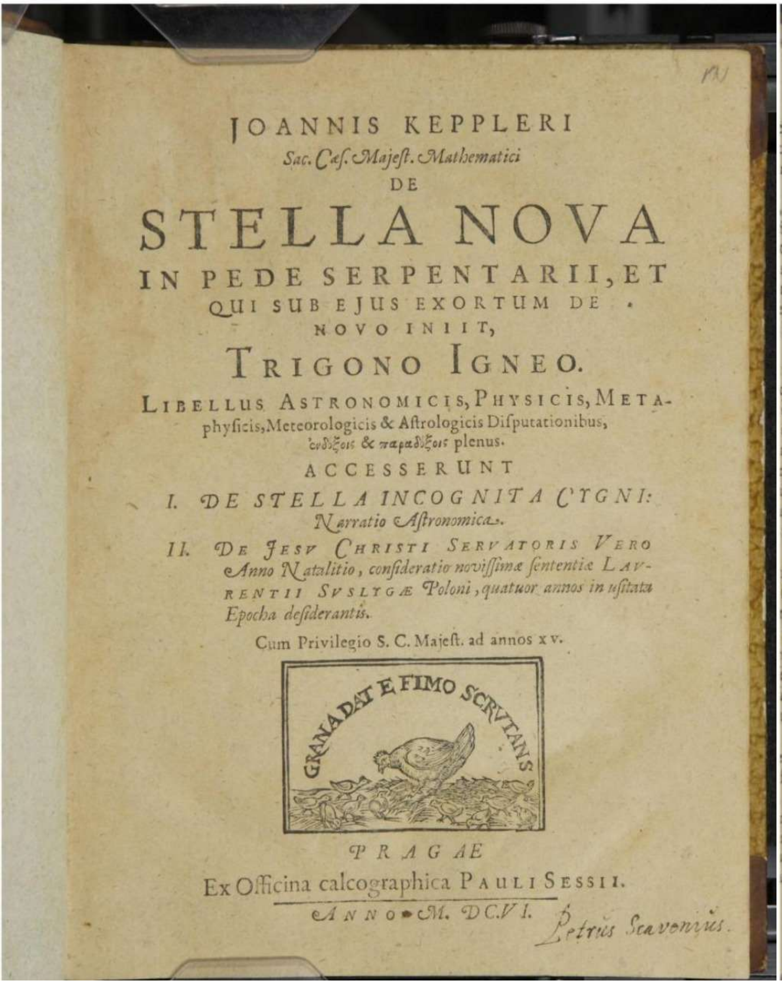


GCM optimization assuming natural variability non reproduced by the models

Scafetta, N., 2013. Discussion on climate oscillations: CMIP5 general circulation models versus a semi-empirical harmonic model based on astronomical cycles. Earth-Science Reviews 126, 321–357.

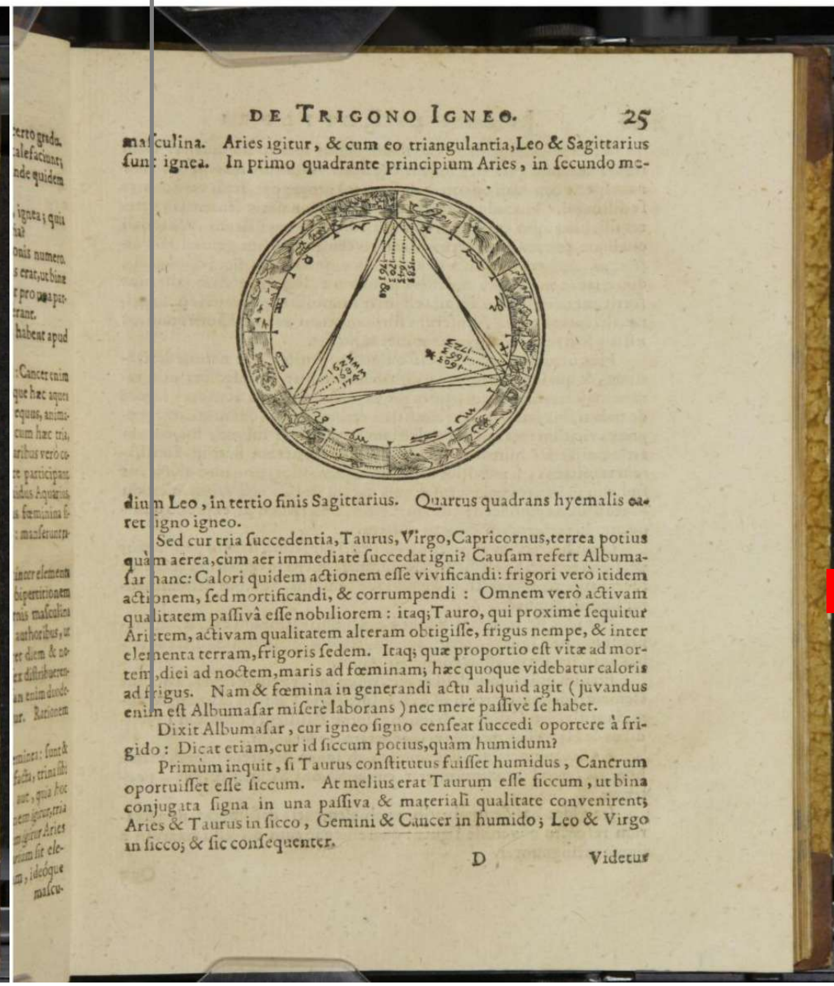


Did Kepler predict the warming from 1600 to 2000 using the great inequality of Jupiter and Saturn? (quasi millennial cycle)



JOANNIS KEPPLERI
Sac. Cæſ. Majeſt. Mathematici
DE
STELLA NOVA
IN PEDE SERPENTARII, ET
QUI SUB EJUS EXORTUM DE
NOVO INIIT,
TRIGONO IGNEO.
LIBELLUS ASTRONOMICIS, PHYSICIS, METAphyſicis, Meteorologicis & Aſtrologicis Diſputationibus, ἐνδόξοις & παραδόξοις plenus.
ACCESSERUNT
I. *DE STELLA INCOGNITA CYGNI: Narratio Aſtronomica.*
II. *DE JESU CHRISTI SERVATORIS VERO Anno Natalitio, conſideratio noviſſimæ ſententiæ LAURENTII SUSLYGÆ Poloni, quatuor annos in uſitata Epocha deſiderantis.*
Cum Privilegio S. C. Majeſt. ad annos XV.

PRAGAE
Ex Officina calcographica PAULI SESSII.
ANNO M. DCVI.
Petrus Scavenius.



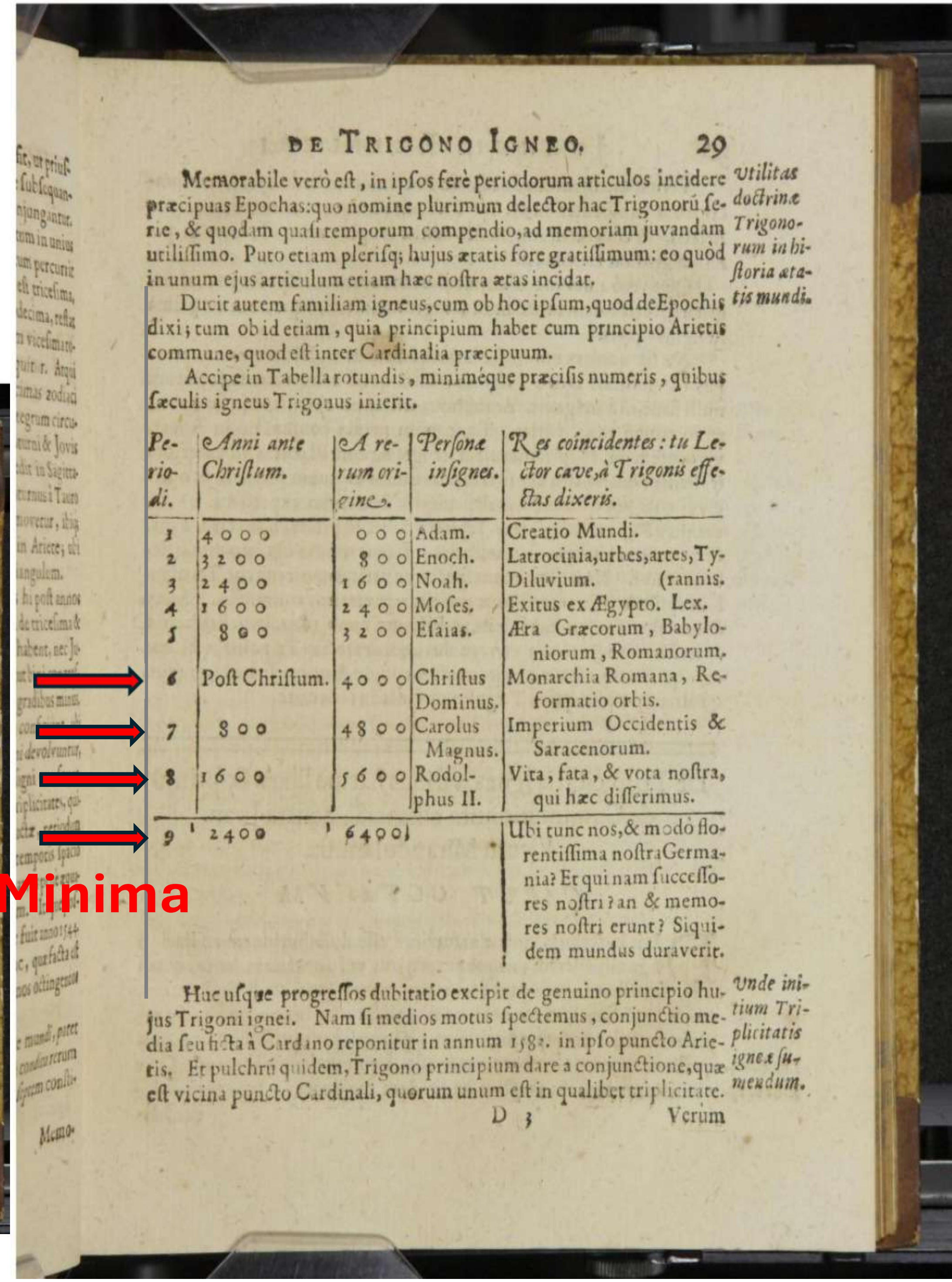
maſculina. Aries igitur, & cum eo triangulantia, Leo & Sagittarius ſunt ignea. In primo quadrante principium Aries, in ſecundo medium Leo, in tertio finis Sagittarius. Quartus quadrans hyemalis caret ſigno igneo.

Sed cur tria ſuccedentia, Taurus, Virgo, Capricornus, terrea potius quàm aerea, cùm aer immediatè ſuccedat igni? Cauſam refert Albumaſar hanc: Calori quidem actionem eſſe vivificandi: frigori verò itidem actionem, ſed mortificandi, & corrumpendi: Omnem verò activam qualitatem paſſivâ eſſe nobiliorem: itaq; Tauro, qui proximè ſequitur Arietem, activam qualitatem alteram obtigiſſe, frigus nempe, & inter elementa terram, frigoris ſedem. Itaq; quæ proportio eſt vitæ ad mortem, diei ad noctem, maris ad fœminam; hæc quoque videbatur caloris ad frigus. Nam & fœmina in generandi actu aliquid agit (juvandus enim eſt Albumaſar miſerè laborans) nec merè paſſivè ſe habet.

Dixit Albumaſar, cur igneo ſigno cenſeat ſuccedi oportere à frigido: Dicat etiam, cur id ſiccum potius, quàm humidum?

Primùm inquit, ſi Taurus conſtitutus fuiſſet humidus, Cancrum oportuiſſet eſſe ſiccum. At melius erat Taurum eſſe ſiccum, ut bina conjugata ſigna in una paſſiva & materiali qualitate convenirent; Aries & Taurus in ſicco, Gemini & Cancer in humido; Leo & Virgo in ſicco; & ſic conſequenter.

 Videtur



Memorabile verò eſt, in ipſos ferè periodorum articulos incidere præcipuas Epochas: quo nomine plurimùm delector hac Trigonorũ ſerie, & quodam quaſi temporum compendio, ad memoriam juvandam utiliſſimo. Puto etiam plerisq; hujus ætatis fore gratiſſimum: eo quòd in unum ejus articulum etiam hæc noſtra ætas incidat. *Utilitas doctrinæ Trigonorum in hiſtoria ætatis mundi.*

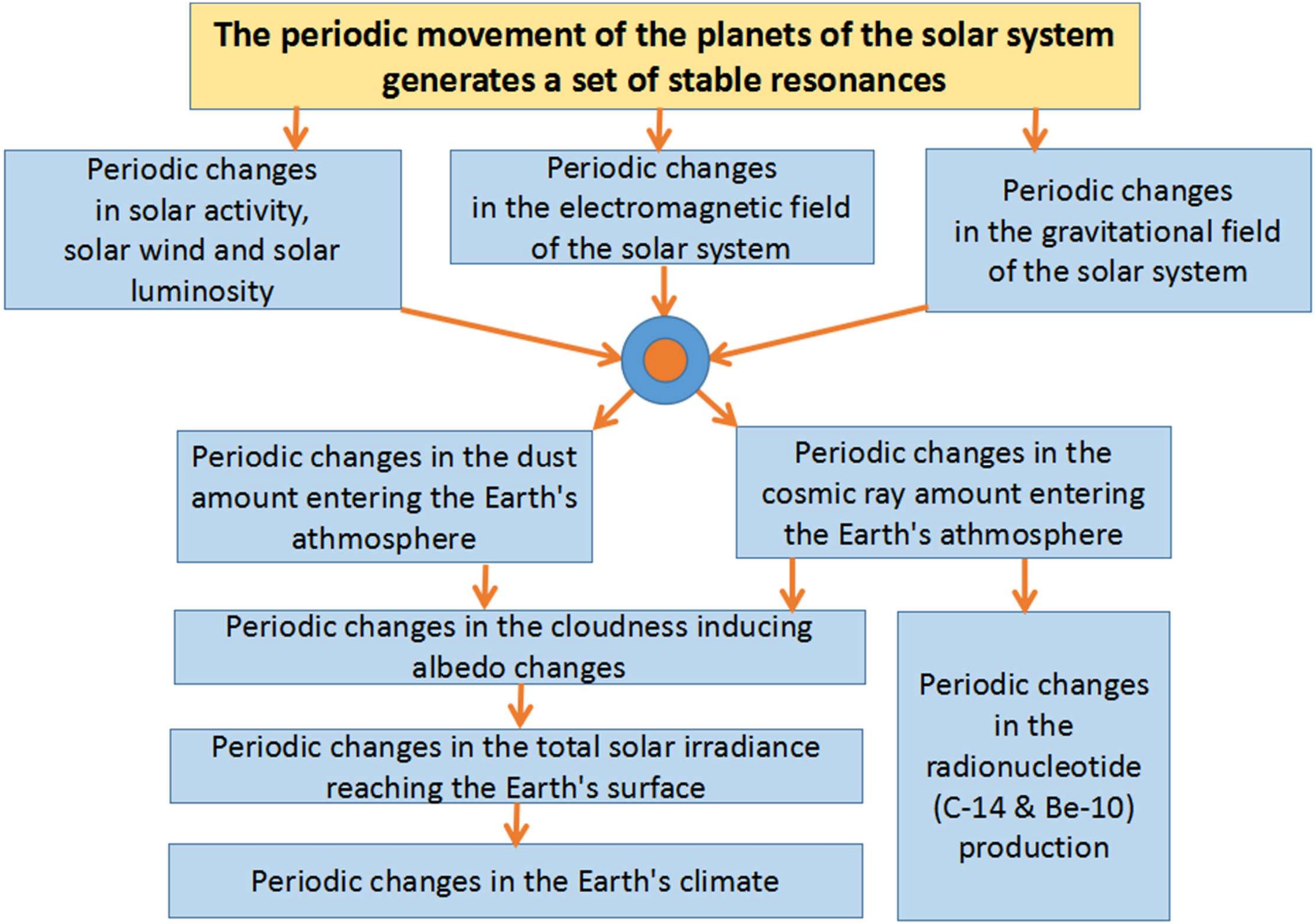
Ducit autem familiam igneus, cum ob hoc ipſum, quod de Epochis dixi; tum ob id etiam, quia principium habet cum principio Arietis commune, quod eſt inter Cardinalia præcipuum.

Accipe in Tabella rotundis, miniméque præciſis numeris, quibus ſæculis igneus Trigonus inierit.

Periodi.	*Anni ante Chriſtum.*	*A rerum origine.*	*Perſonæ inſignes.*	*Res coincidentes: tu Lector cave, à Trigonis effectas dixeris.*
1	4000	000	Adam.	Creatio Mundi.
2	3200	800	Enoch.	Latrocinia, urbes, artes, Tyrannis.
3	2400	1600	Noah.	Diluvium.
4	1600	2400	Moſes.	Exitus ex Ægypto. Lex.
5	800	3200	Eſaias.	Æra Græcorum, Babyloniorum, Romanorum.
6	Poſt Chriſtum.	4000	Chriſtus Dominus.	Monarchia Romana, Reformatio orbis.
7	800	4800	Carolus Magnus.	Imperium Occidentis & Saracenorum.
8	1600	5600	Rodolphus II.	Vita, fata, & vota noſtra, qui hæc diſſerimus.
9	2400	6400		Ubi tunc nos, & modò florentiſſima noſtra Germania? Et qui nam ſucceſſores noſtri? an & memores noſtri erunt? Siquidem mundus duraverit.

Huc uſque progreſſos dubitatio excipit de genuino principio hujus Trigoni ignei. Nam ſi medios motus ſpectemus, conjunctio media ſeu ficta à Cardano reponitur in annum 1583. in ipſo puncto Arietis. Et pulchrũ quidem, Trigono principium dare a conjunctione, quæ eſt vicina puncto Cardinali, quorum unum eſt in qualibet triplicitate. *Unde initium Triplicitatis igneæ ſumendum.*

 Verùm


The periodic movement of the planets of the solar system generates a set of stable resonances
Periodic changes in solar activity, solar wind and solar luminosity
Periodic changes in the electromagnetic field of the solar system
Periodic changes in the gravitational field of the solar system
Periodic changes in the dust amount entering the Earth's athmosphere
Periodic changes in the cosmic ray amount entering the Earth's athmosphere
Periodic changes in the cloudness inducing albedo changes
Periodic changes in the radionucleotide (C-14 & Be-10) production
Periodic changes in the total solar irradiance reaching the Earth's surface
Periodic changes in the Earth's climate