

# Studying the Natural and Anthropogenic Factors of Climate Change

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**11th International Conference of the Balkan Physical Union  
28 August – 1 September 2022, Belgrade, Serbia**

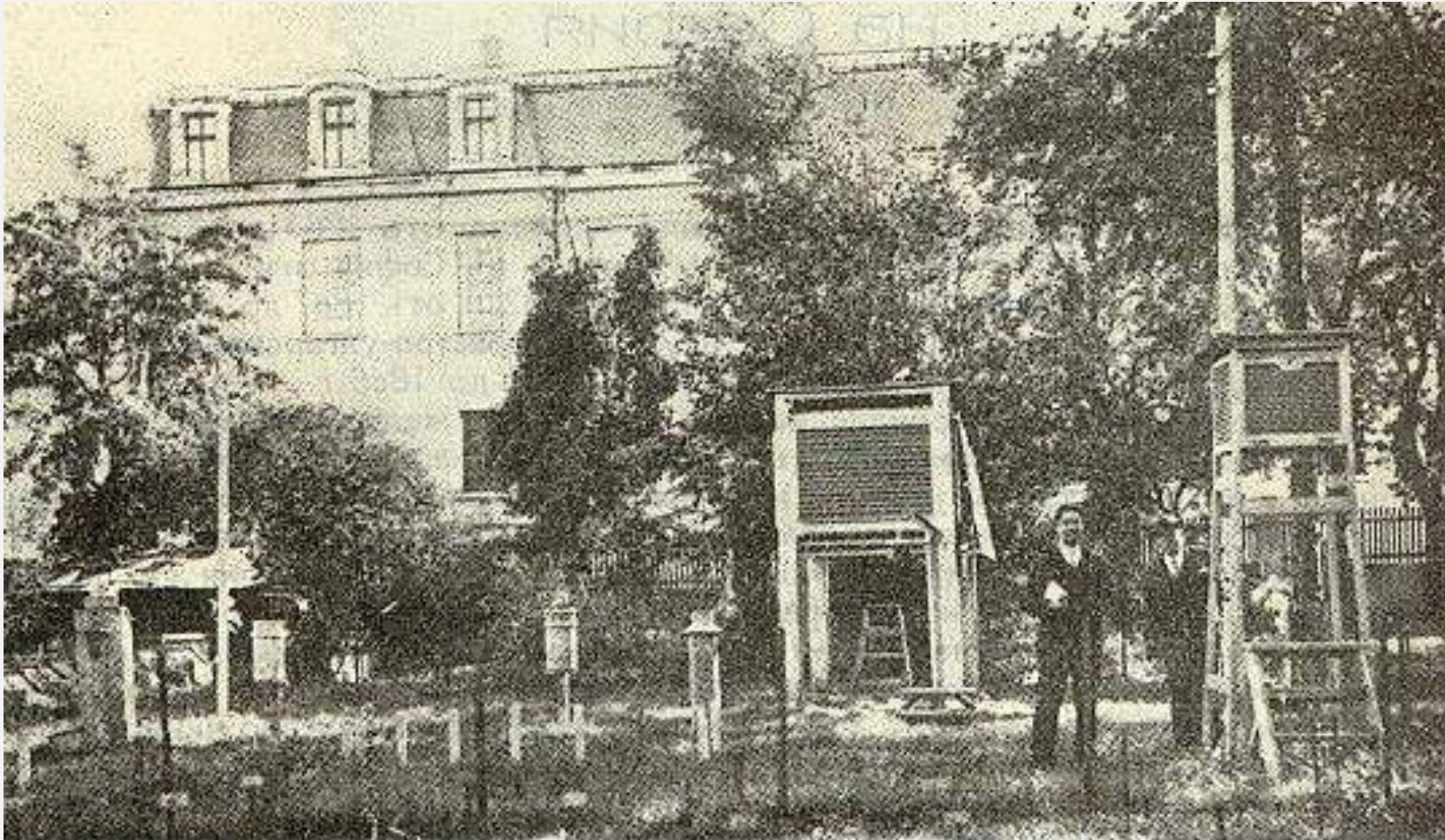


# Plan of the presentation and activities in the project

National Science Fund of Bulgaria, Contract KP-06-N34/1 /30-09-2020 "Natural and anthropogenic factors of climate change – analyzes of global and local periodical components and long-term forecasts"

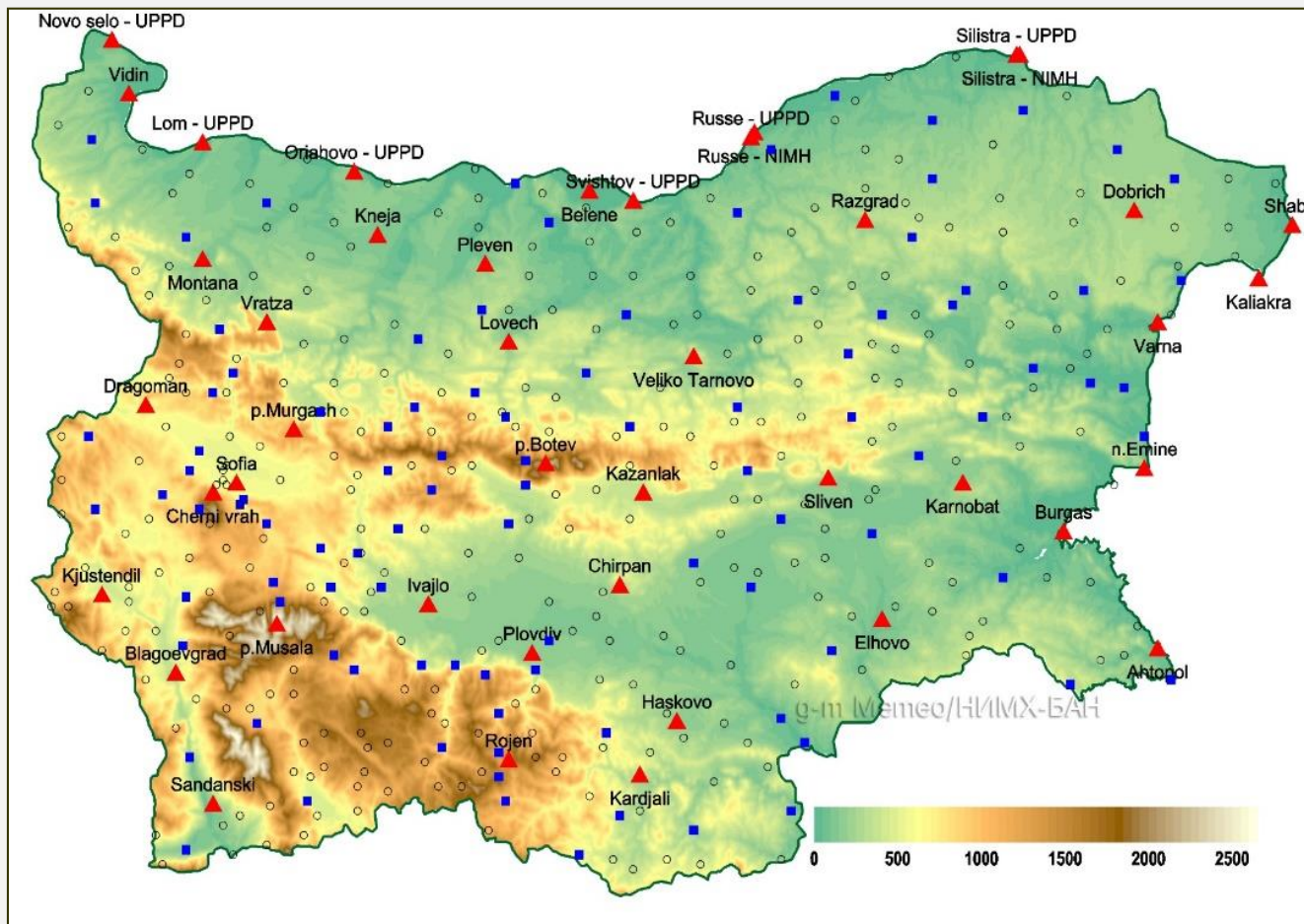
- Global and regional warmings are detected
- Anthropogenic vs solar factors with a known periodicity
- Studies on the periodicities of Solar Activity and different climate parameters and indexes
- Volcanic Activity
- Indirect influences of other cosmic factors
- Studies of regional and local climates

# One of the first weather stations in Sofia, beginning 20th century



**The World Meteorological Organization is created to set up regulations in order to get comparable information from stations across the world.**





**3 types of  
NIMH  
weather  
stations:**

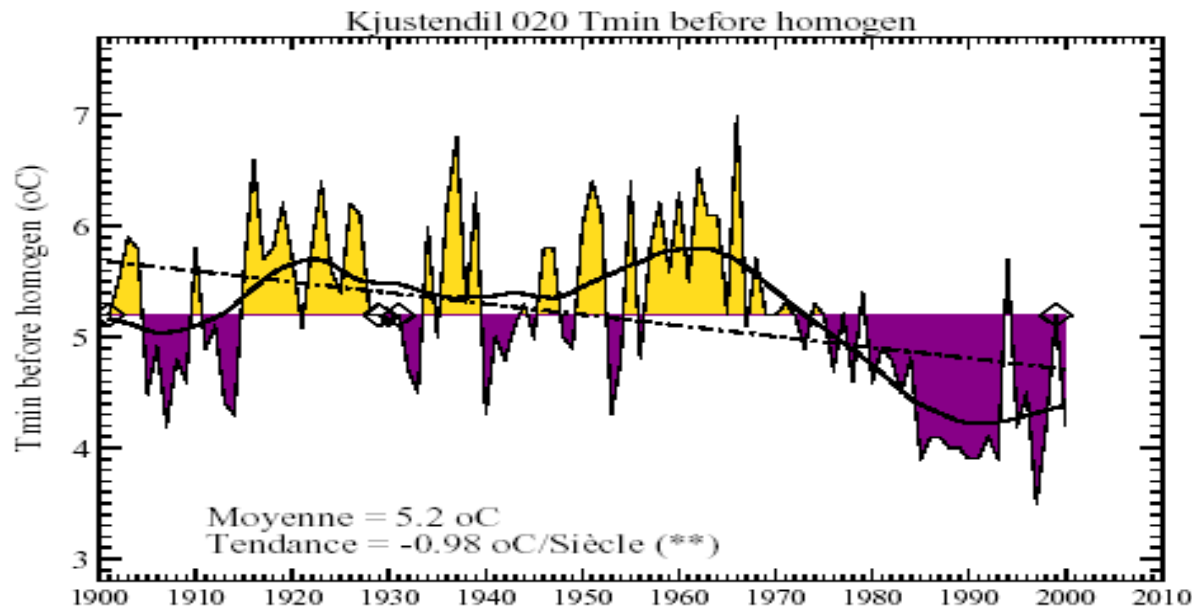
**synoptic  
(▲),**

**climatic  
(■)**

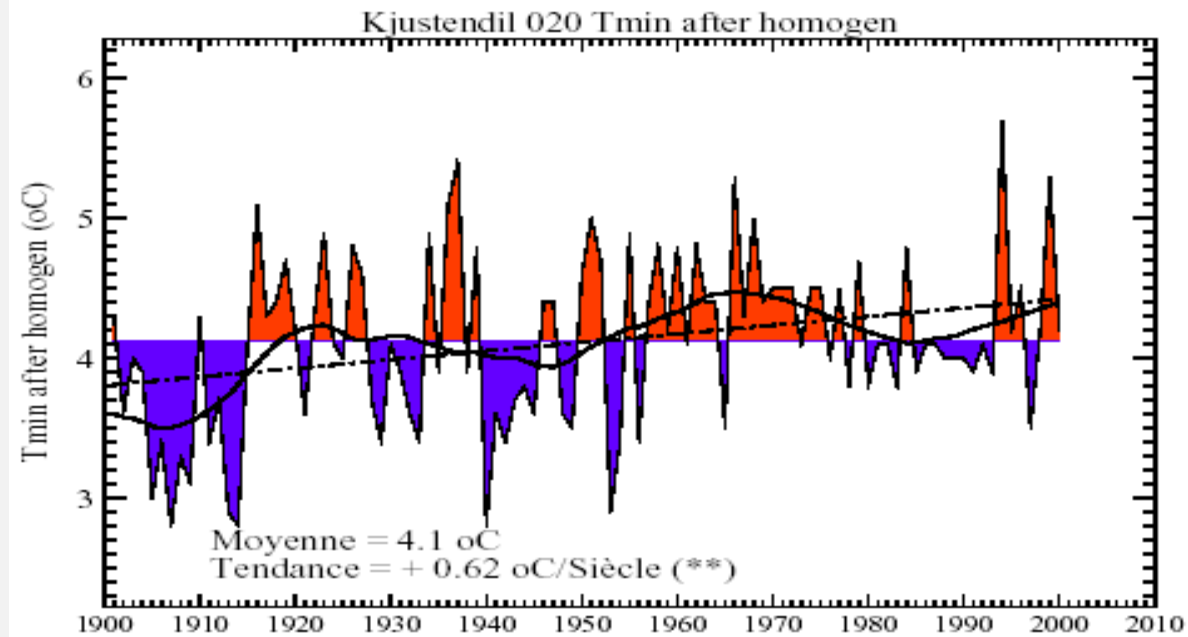
**rain-gauge  
(○)**

- **Automatic meteorological stations are not yet in operation, except for the wind.**
- **A growing number of stations between 1960 and 1980; shrinking after 1990.**
- **Data are delivered to international databases not from all 40, but from 12 synoptic stations.**
- **An open data policy is needed in order to involve the larger research capacity of the country in various climate studies.**

# Data CONTROL



## Homogeni- zation



**Anomalies of annual minimum air temperature  
Kjustendil: before and after homogenization**

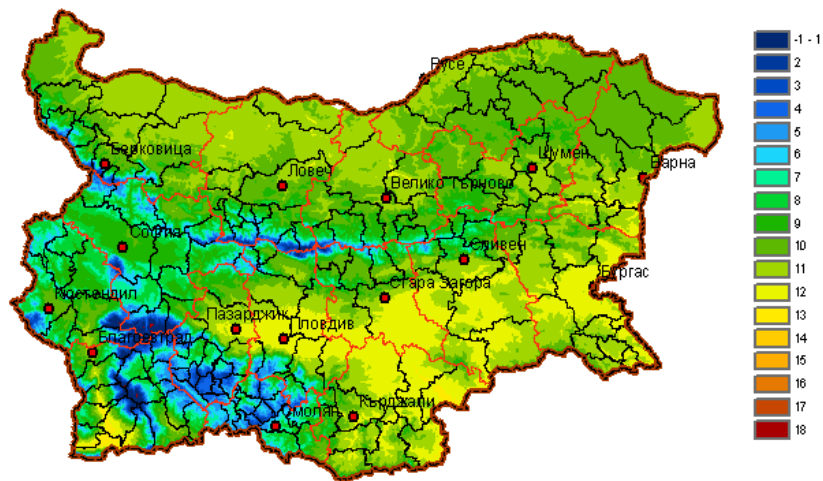


# Contemporary climate wake-up call: warming with increased extreme weather frequency

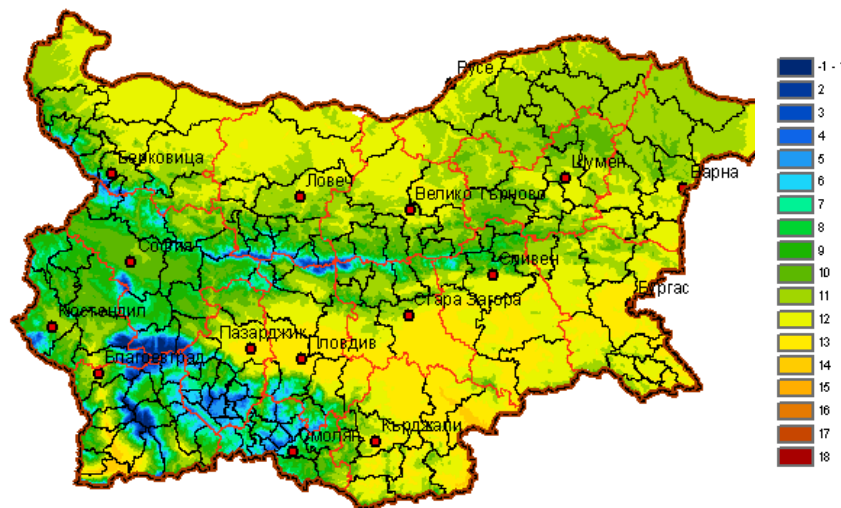




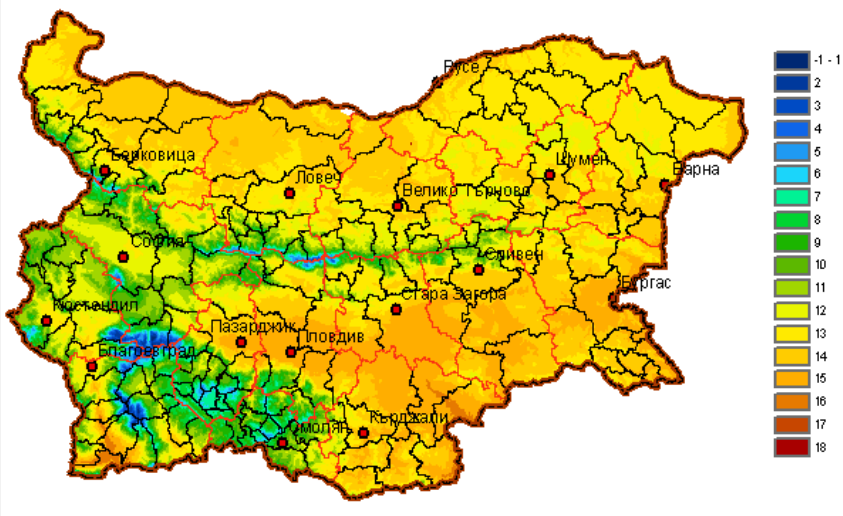
# Average annual air temperature



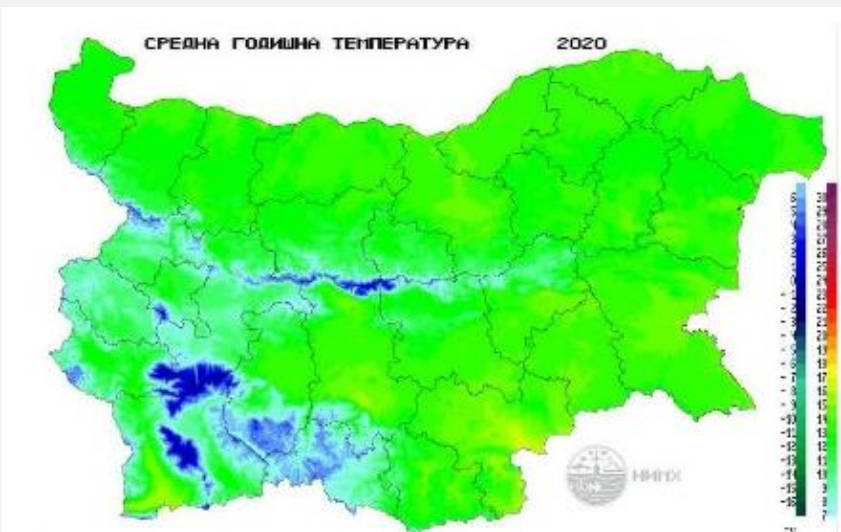
1961-1990



2020 - pessimistic



2050 - pessimistic

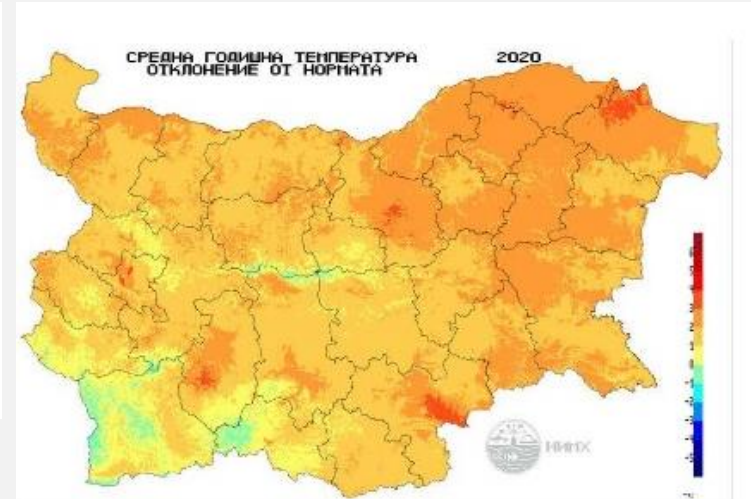


2020 – measured\*

Anomaly of the Mean annual temperature for years 1930 - 2020 compared to the average 1961-1990\*

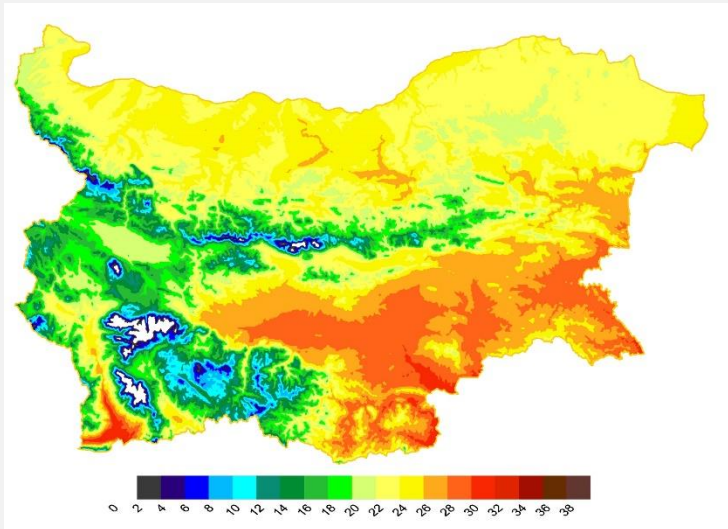


Anomaly of the Mean annual temperature in 2020 compared to the average 1961-1990\*

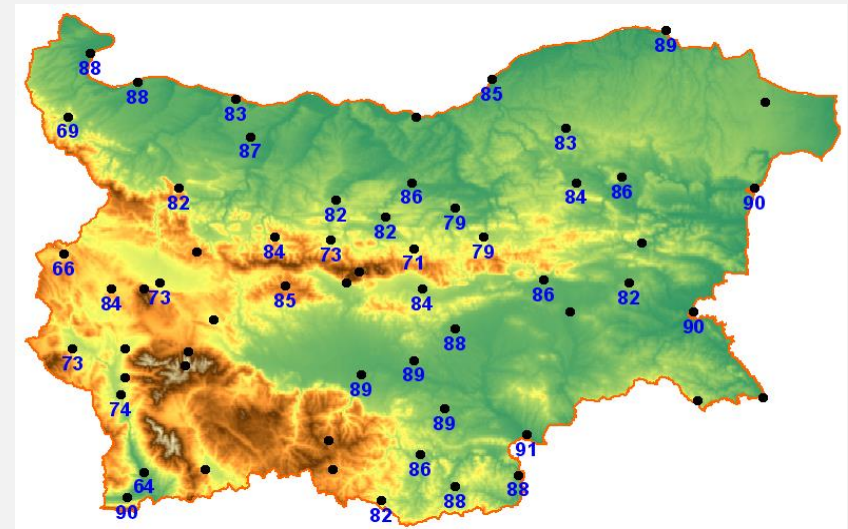


## OTHER PARAMETERS

Summer days with  $T_{max} > 25^{\circ}\text{C}$ , 1961-1990



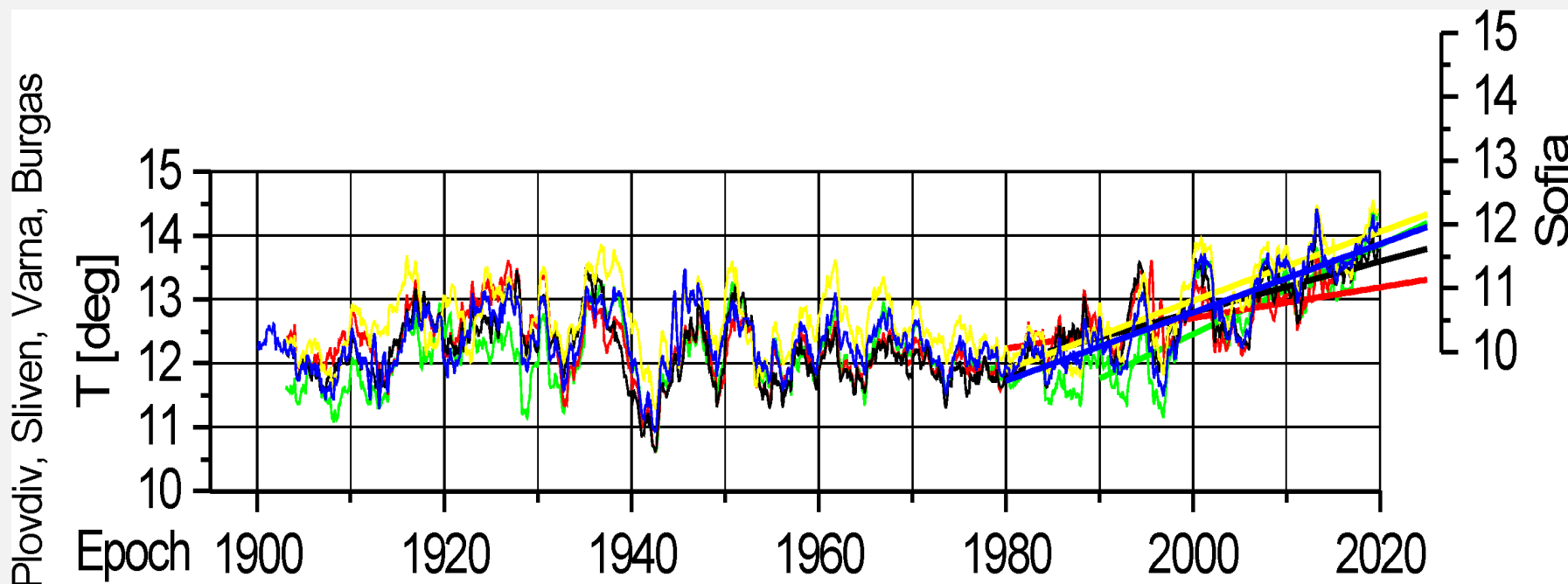
Summer days with  $T_{max} > 25^{\circ}\text{C}$ , 2021-2050, Regional climate model ALADINE





# Linear trends C/year for 5 NIMH stations provided to the international data exchange

| Station / Period | 1900-2020 | 1900-1980 | 1980-2020          |
|------------------|-----------|-----------|--------------------|
| Sofia            | 0.007     | -0.005    | 0.042              |
| Plovdiv          | 0.003     | -0.007    | 0.024; (1980-2015) |
| Sliven           | 0.007     | 0.0       | 0.053              |
| Burgas           | 0.006     | 0.0       | 0.054              |
| Varna            | 0.009     | 0.003     | 0.057              |

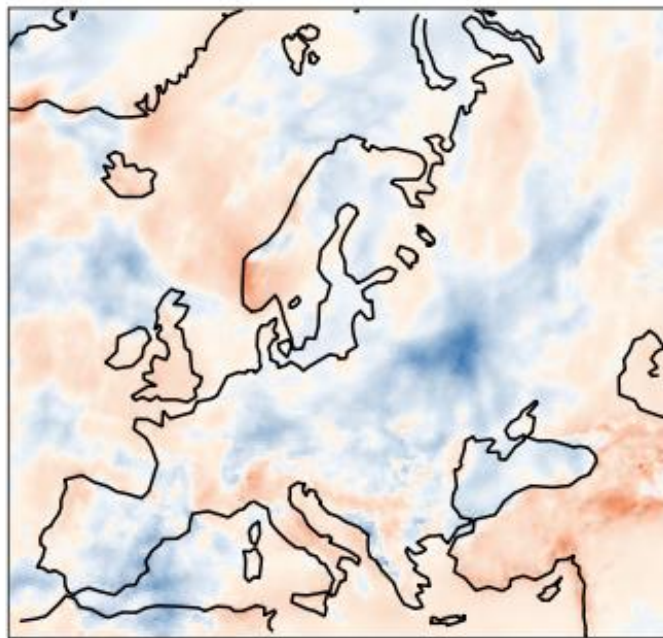


**NASA data**

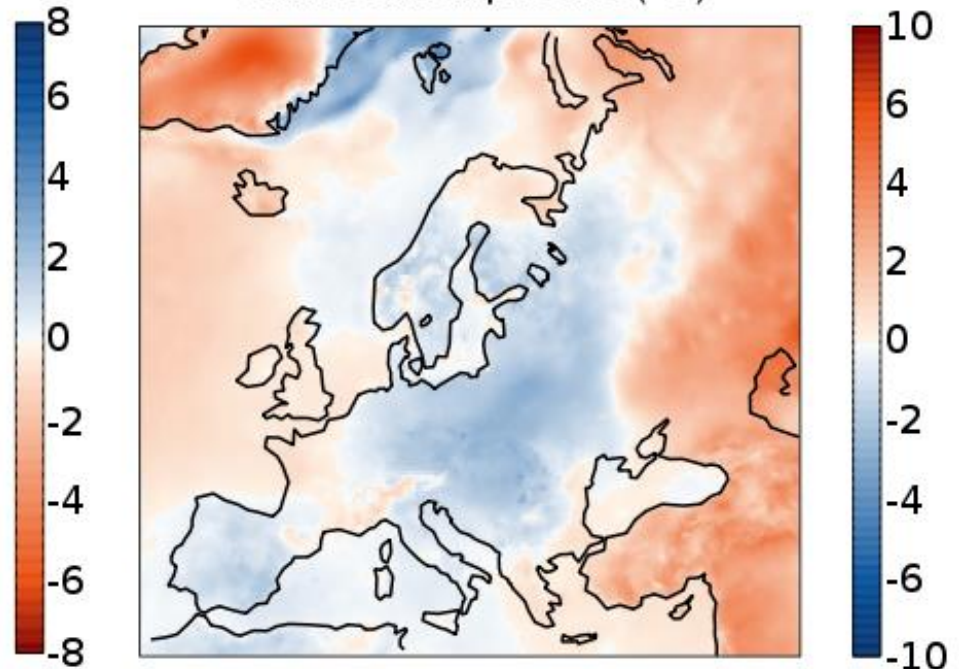
# Anomalies compared to 1991-2020 reference period

## Anomalies for April 2022

Precipitation (mm/day)

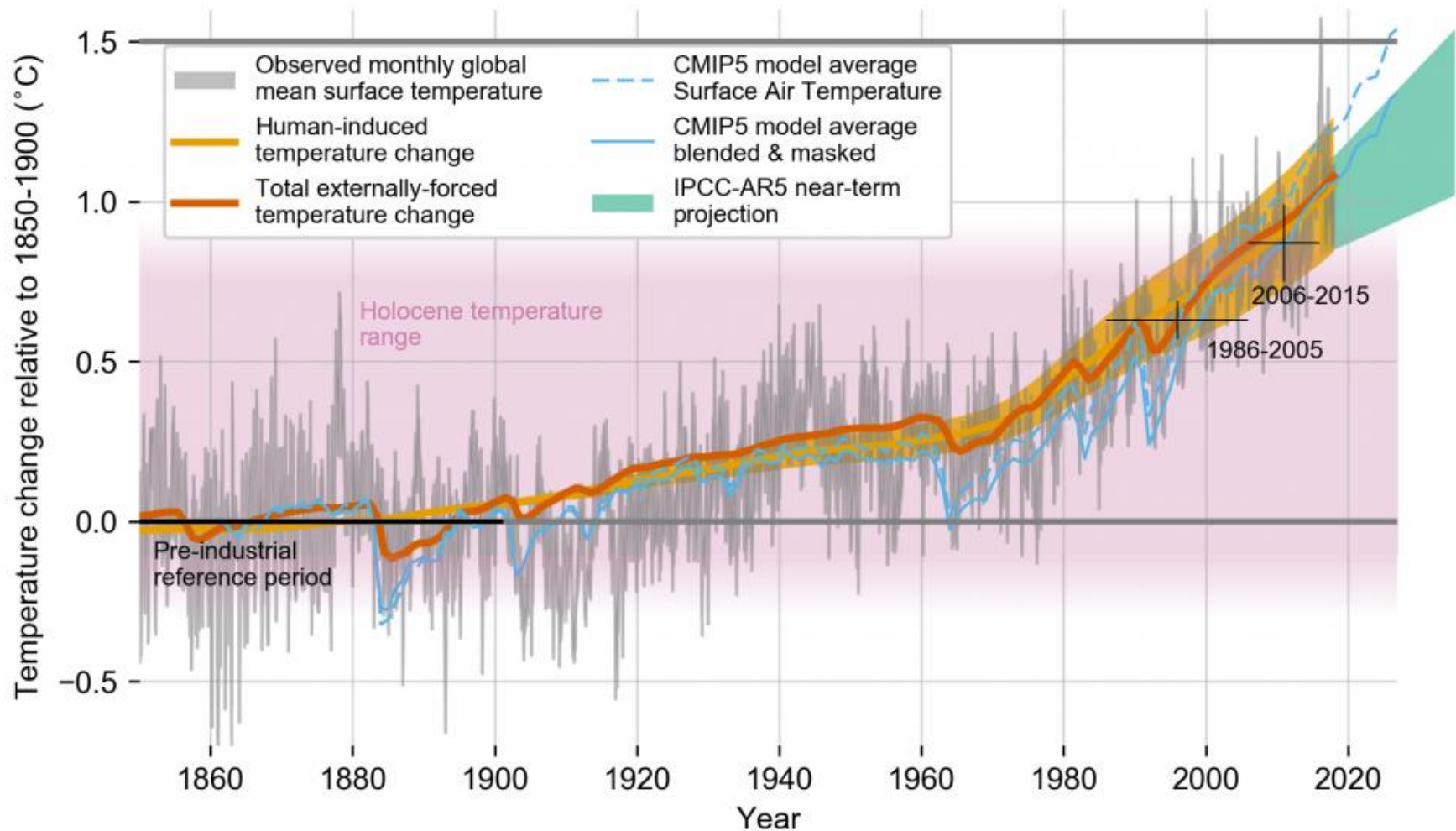


Surface air temperature (°C)



(Data: ERA5. Reference period: 1991-2020. Credit: C3S/ECMWF)

# Evolution of global mean surface temperature (GMST) over the period of instrumental observations





## Evolution of global mean surface temperature (GMST) over the period of instrumental observations

Grey shaded line shows monthly mean GMST in the HadCRUT4, NOAA GlobalTemp, GISTEMP and Cowtan-Way datasets, expressed as departures from 1850–1900, with varying grey line thickness indicating inter-dataset range. All observational datasets shown represent GMST as a weighted average of near surface air temperature over land and sea surface temperature over oceans. Human-induced (yellow) and total (human- and naturally-forced, orange) contributions to these GMST changes are shown calculated following Otto et al. (2015) and Haustein et al. (2017). Fractional uncertainty in the level of human-induced warming in 2017 is set equal to  $\pm 20\%$  based on multiple lines of evidence. Thin blue lines show the modelled global mean surface air temperature (dashed) and blended surface air and sea surface temperature accounting for observational coverage (solid) from the CMIP5 historical ensemble average extended with RCP8.5 forcing (Cowtan et al., 2015; Richardson et al., 2018). The pink shading indicates a range for temperature fluctuations over the Holocene (Marcott et al., 2013). Light green plume shows the AR5 prediction for average GMST over 2016–2035 (Kirtman et al., 2013). See Supplementary Material 1.SM for further details.

### Special Report

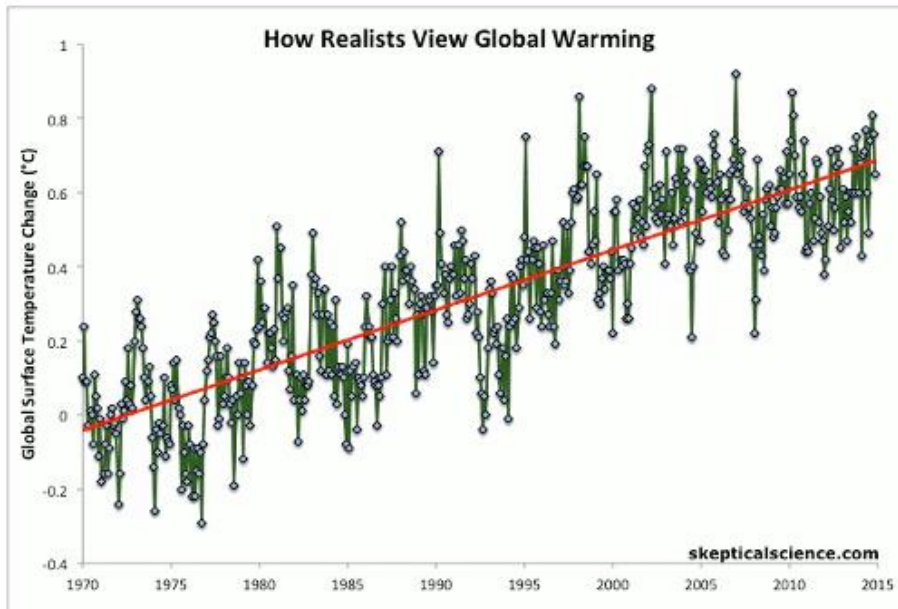
**Global Warming of 1.5 °C** An IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty

# Anthropogenic vs solar factors

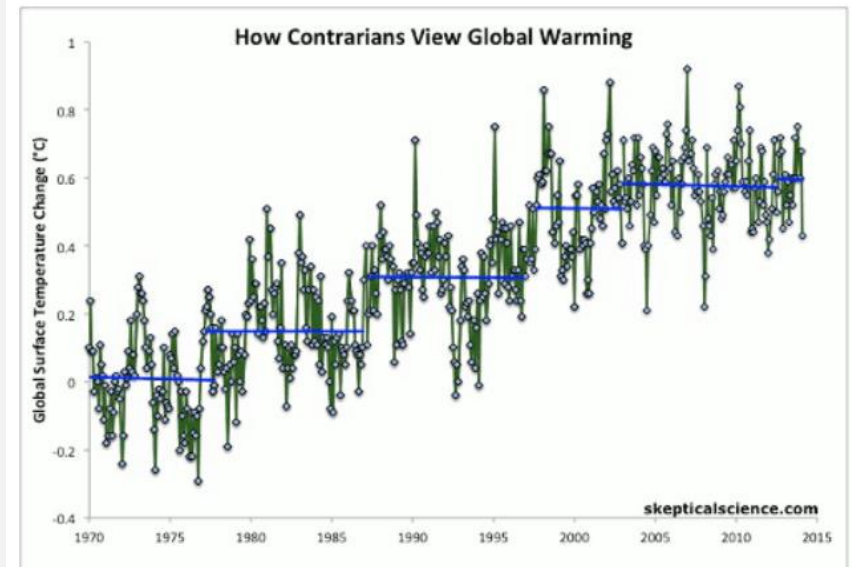
## NASA data on global surface air temperature

<https://www.youtube.com/watch?v=xWdJuNYLTLs>, <https://skepticalscience.com/escalator>

The Escalator



The Escalator



Six periods of cooling can add up to a clear warming trend over the last 40 years

Factors such as oceanic cycles like the El Niño Southern Oscillation (ENSO) or the 11-year solar cycle can have a large impact on short-term temperatures. These short-term cycles don't have long-term effects on the Earth's temperature, unlike the continuing upward trend caused by global warming from human greenhouse gas emissions.

## 2. Anthropogenic vs solar factors

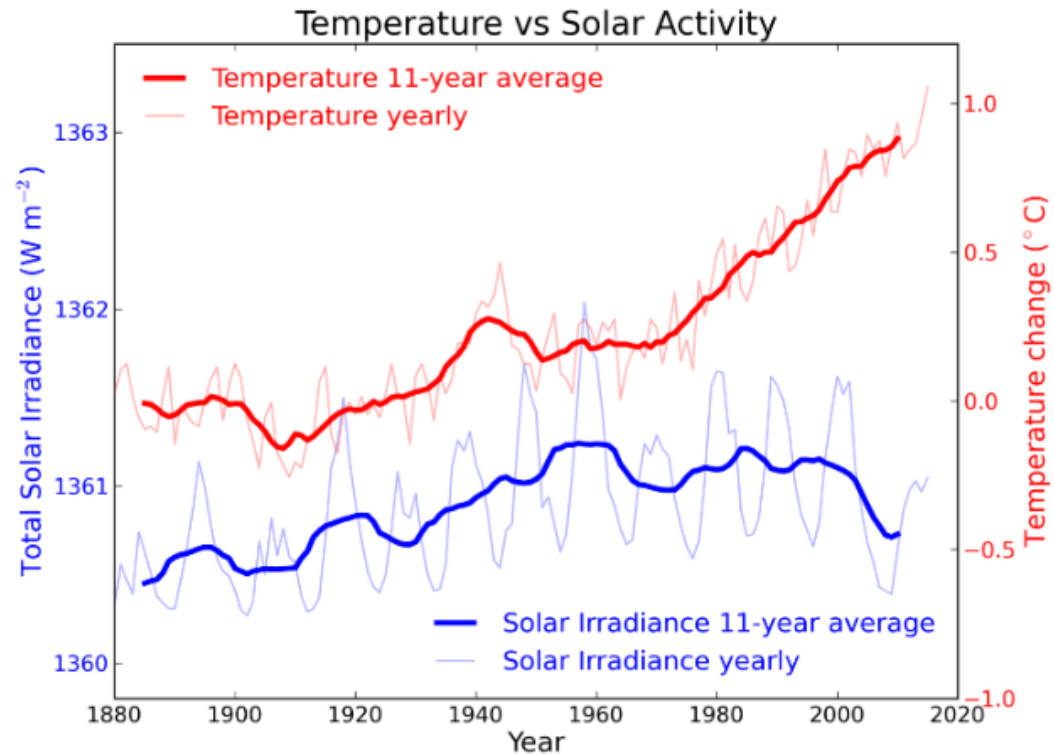
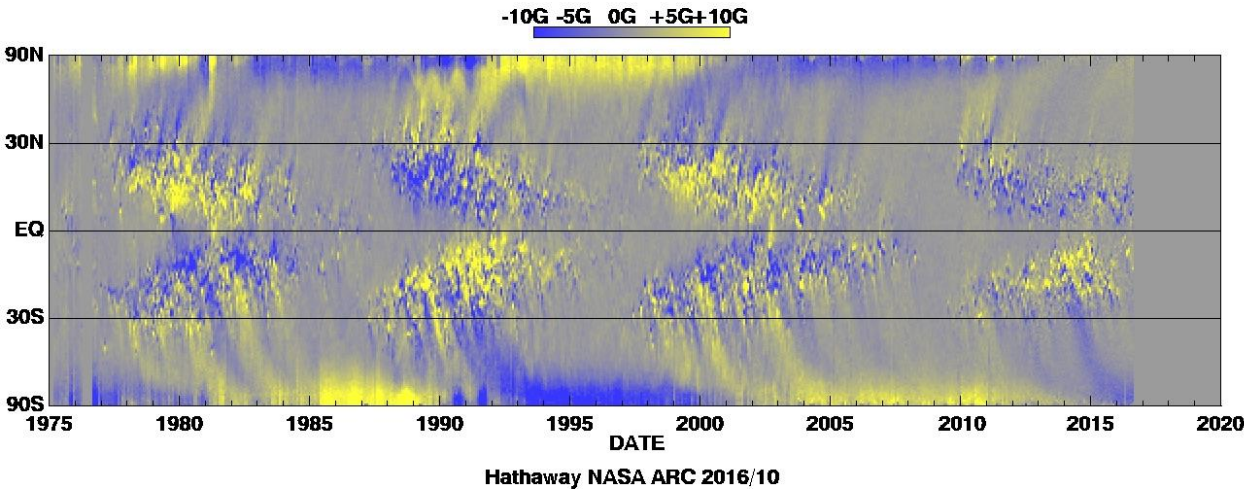
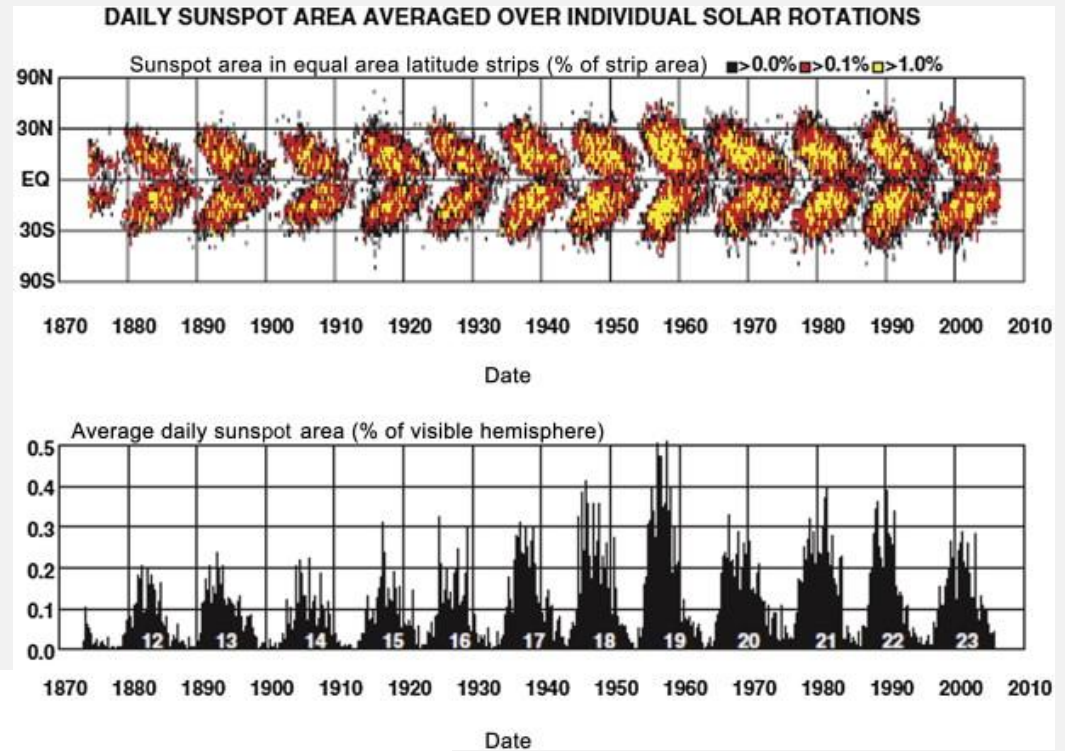
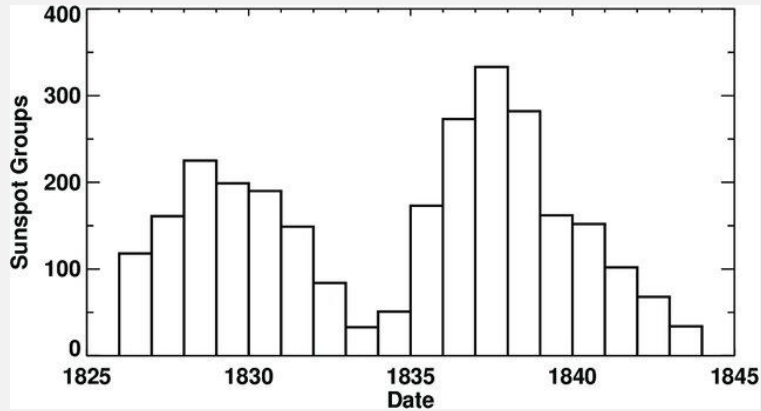


Figure 1: Annual global temperature change (thin light red) with 11 year moving average of temperature (thick dark red). Temperature from NASA GISS. Annual Total Solar Irradiance (thin light blue) with 11 year moving average of TSI (thick dark blue). TSI from 1880 to 1978 from Krivova et al 2007 (data). TSI from 1979 to 2015 from PMOD (see the PMOD index page for data updates).



# Suspot "butterfly" diagram

Heinrich Schwabe  
~11-year sunspot cycle



Magnetic  
"butterfly" diagram

# Sir William Herschel, 1801

Philosophical Transactions of the Royal Society of London

Vol. 91 pp. 265-318



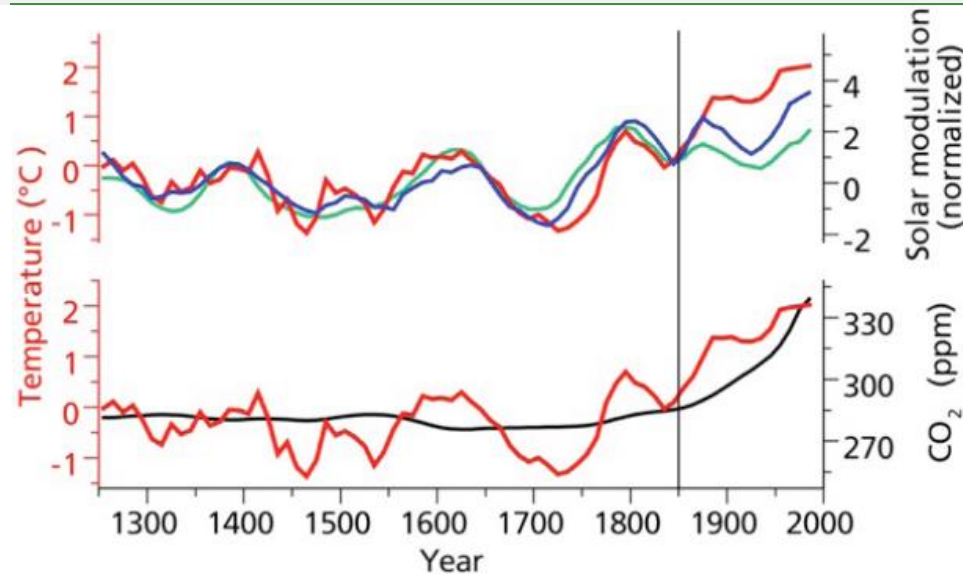
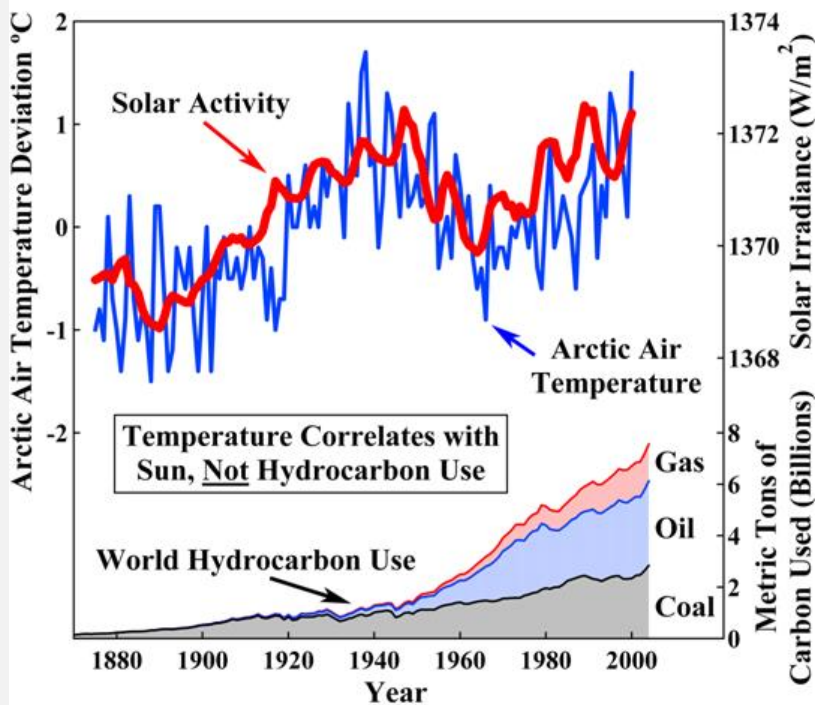
**Short-term solar climate connections: sunspots and the wheat price at the London stock market since 1650**

**(Fahrenheit's thermometer invented in 1714)**

Times of many sunspots "may lead us to expect a copious emission of heat and therefore mild seasons," and periods of few spots would signal "sparse emission of heat" and "severe seasons" which would raise the price of wheat.



# Controversy about the relative impact of solar and human induced climate change



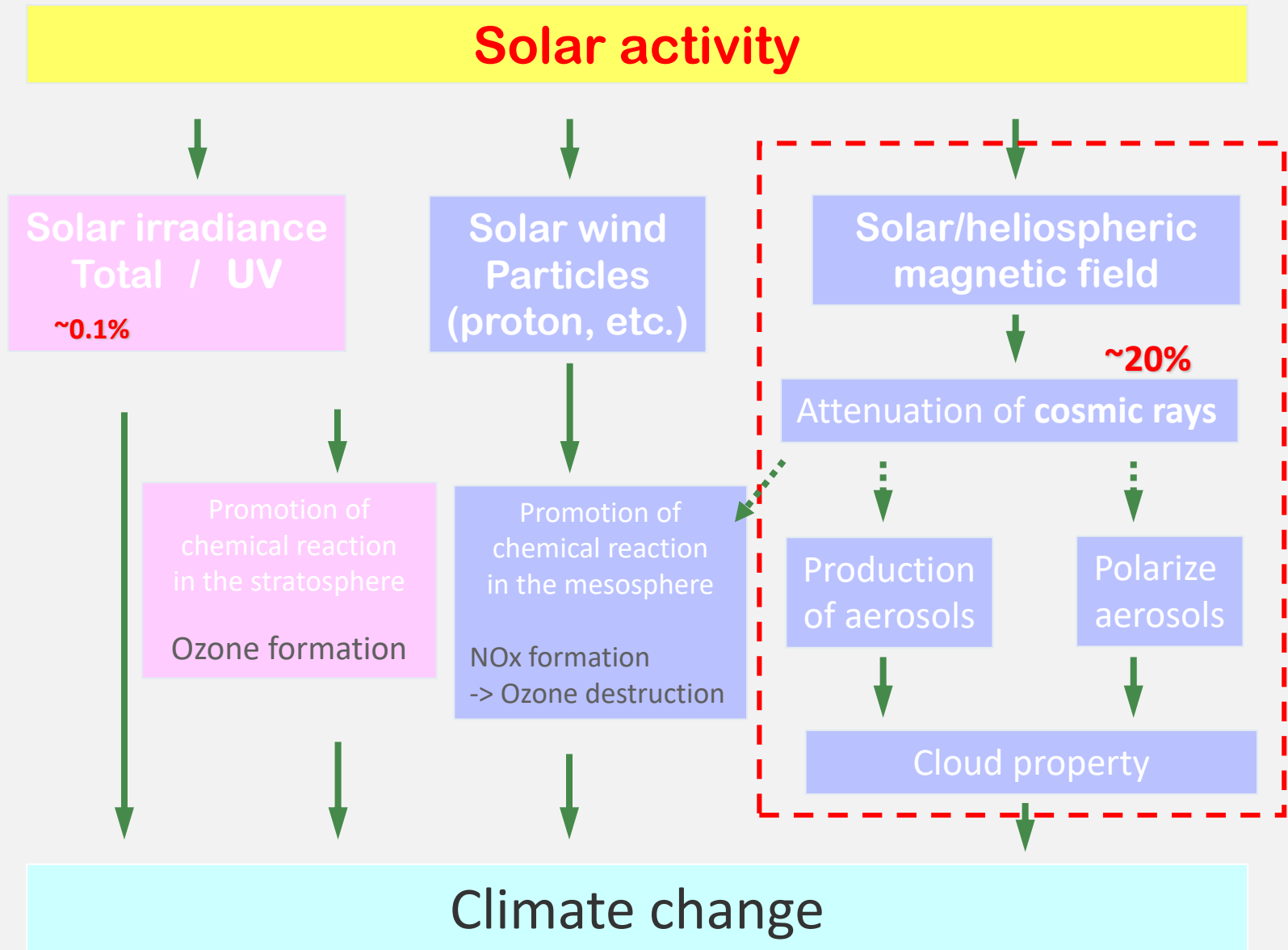
Eichler et al. GRL 36, 2009

Temperature correlates with solar activity, not with CO<sub>2</sub>

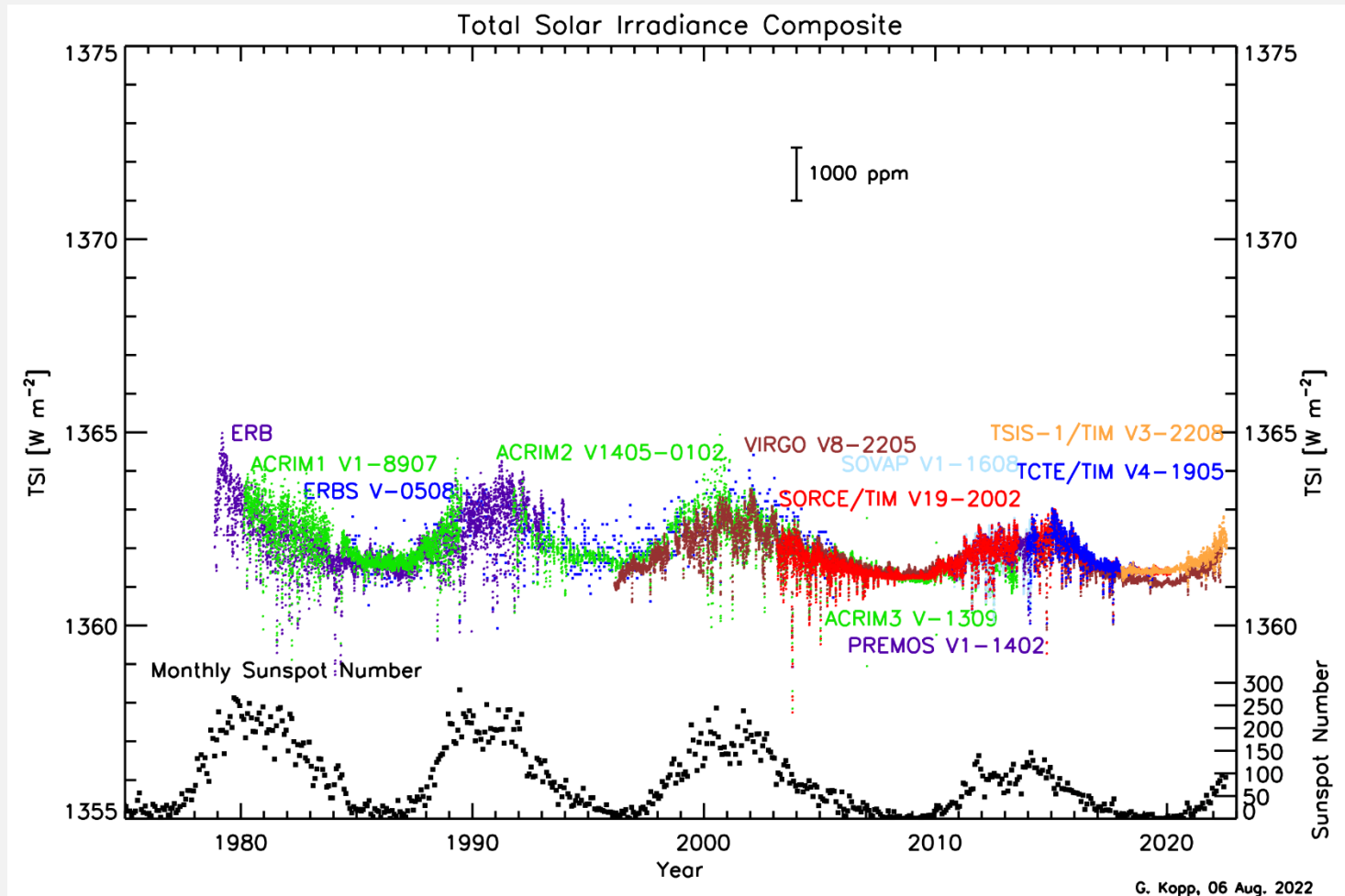
“Low level of scientific understanding of the solar influence” (IPCC, IV AR)



# Possible mechanisms of solar influence on climate change

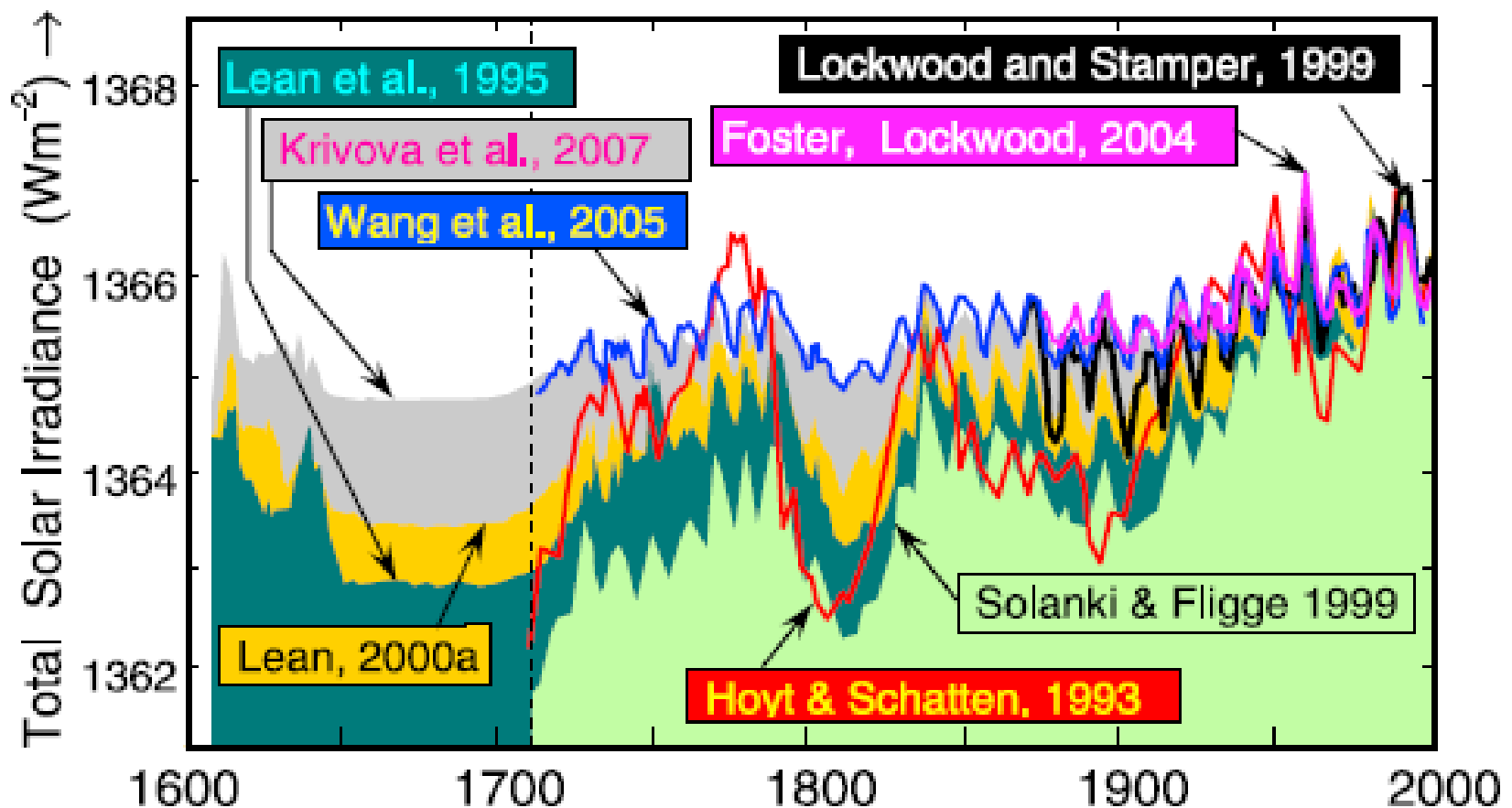


# Total solar irradiance (TSI) – decades ago known as the “solar constant”



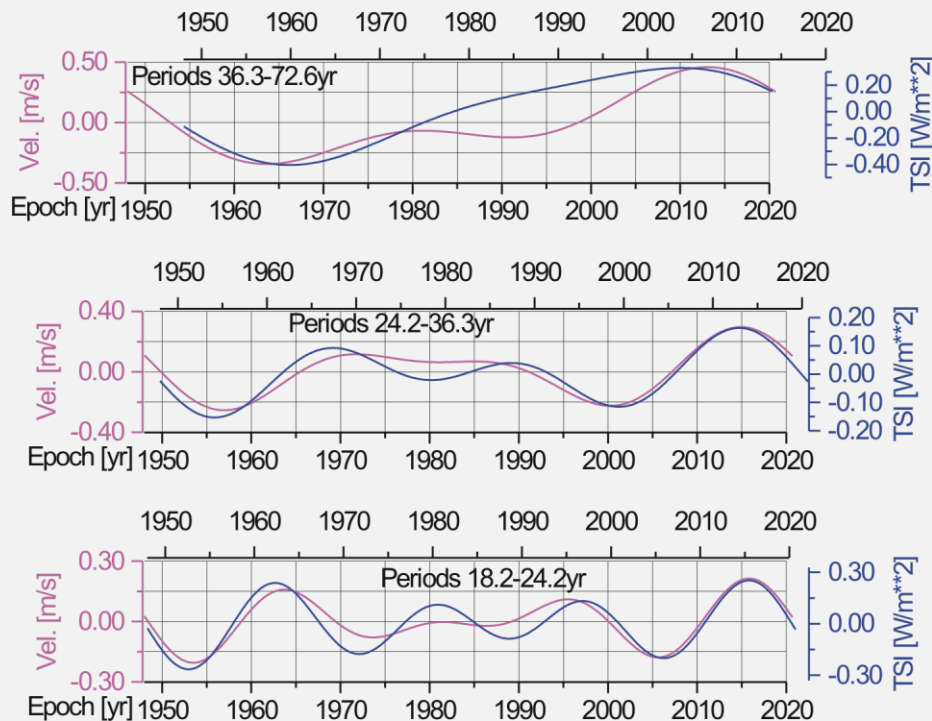
**The “solar constant” is not constant!**  
**TSI has solar cycle and cycle-to-cycle variations**

# Different reconstructions of century-scale variations of TSI





# Studies on the periodicities of Solar Activity and different climate parameters and indexes

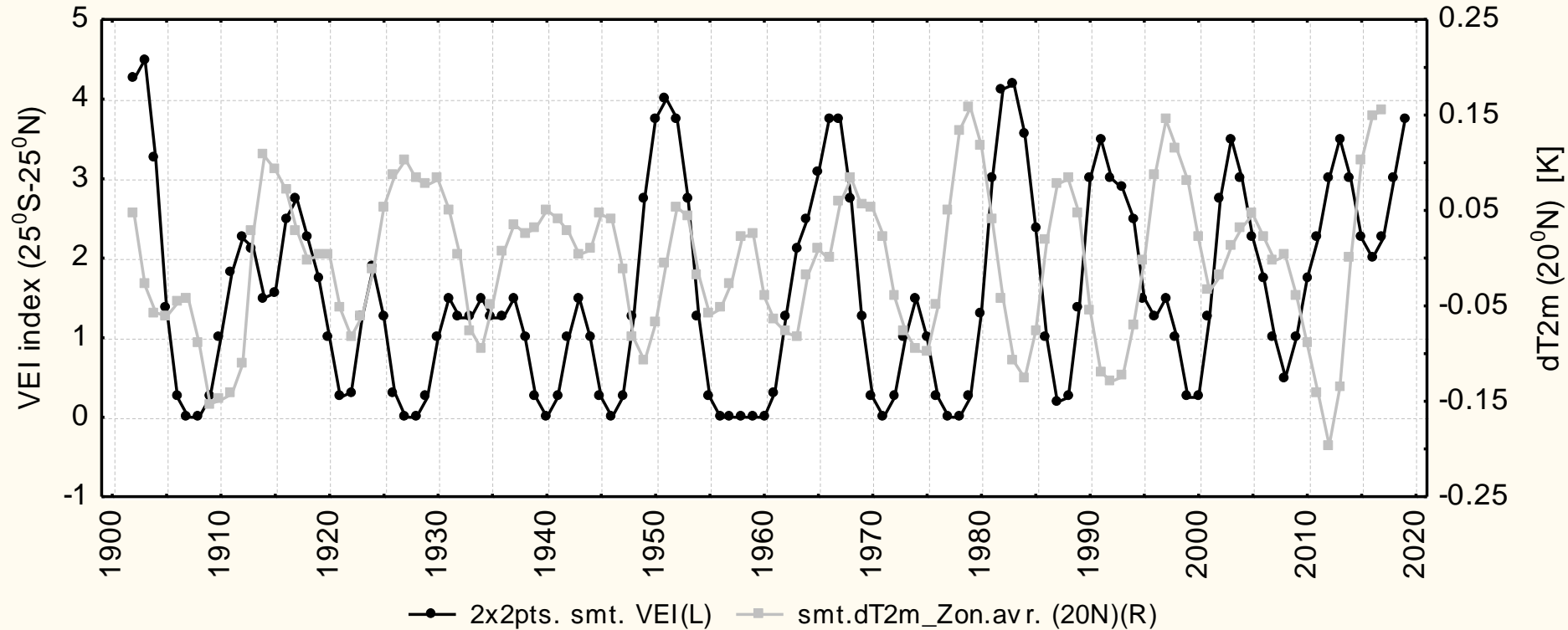


Similar studies are performed for temperature, rivers discharge, different climate indexes

Common cycles with periodicity 18.2-72.6 yr of wind speed over Sofia and TSI since 1948

# Volcanic Activity and its Imprint on Climate of 20th and 21st cent.

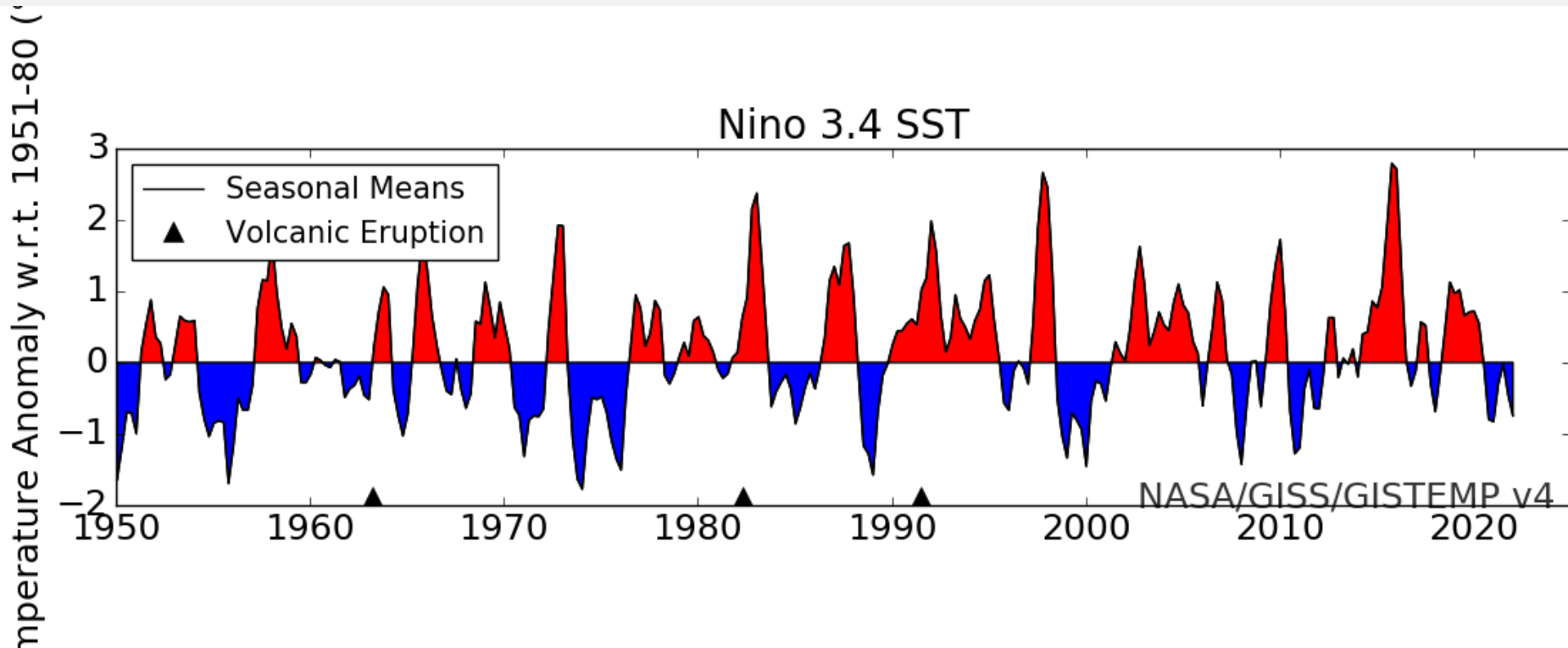
a.) Time sr. of VEI (25°N-25°S) & dT<sub>2m</sub> at 20°N; (1900-2019)



Time series of volcanic eruption index (VEI) – black curve, and surface air temperature ( $T_{2m}$ ) at 20°N latitude – grey curve, for the period 1900-2019

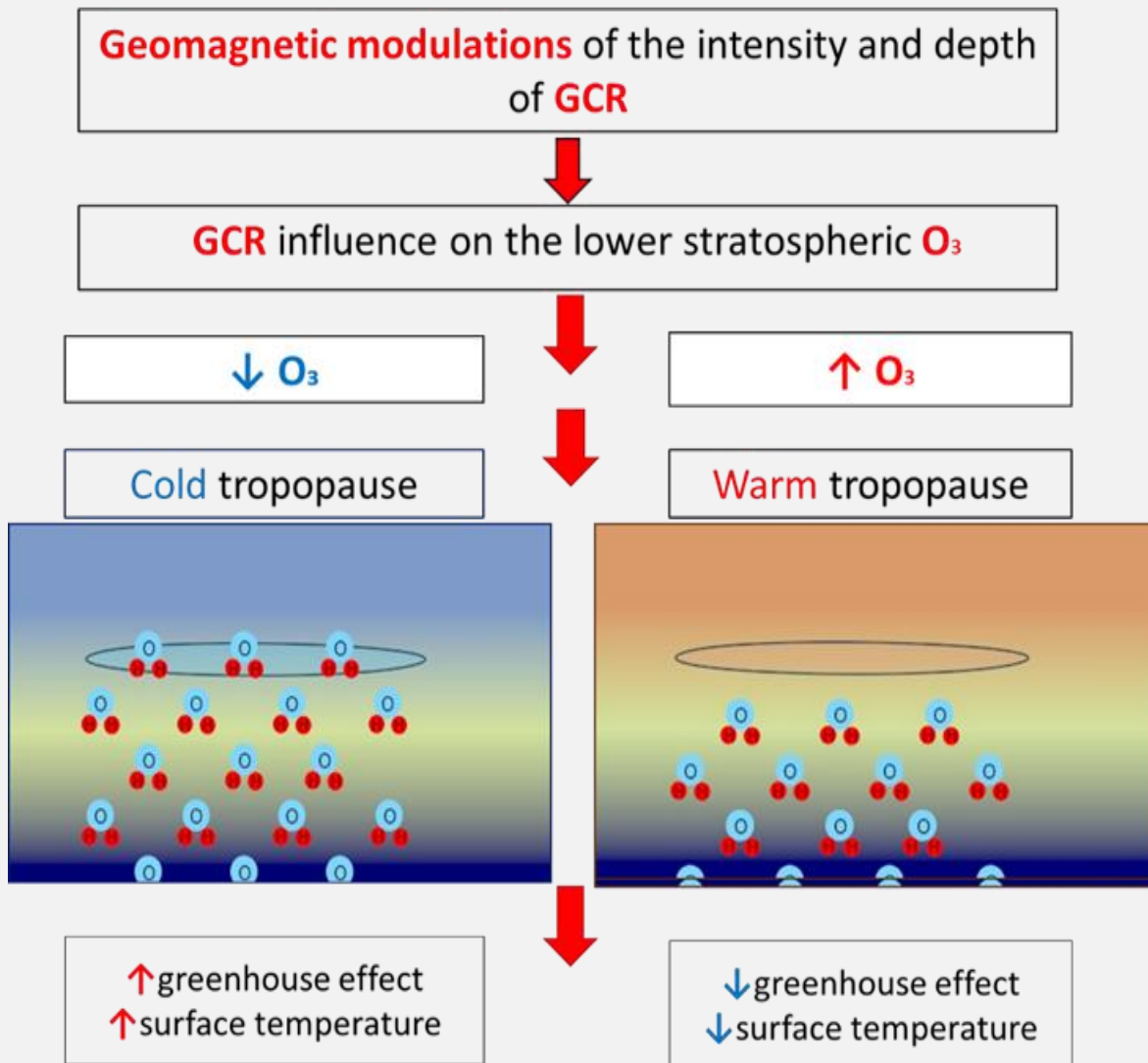
At certain latitudes the temperature responds *positively* to the enhanced VEI index. Such a response contradicts to the well-known cooling effect of volcanic aerosols. One explanation of temperature raise could be the recently suggested warming effect of SO<sub>2</sub> on the planetary surface – when the atmospheric oxidising capacity is overwhelmed (Ward, 2009)

# There is link between volcanic activity and ocean temperature – NASA data





# Indirect influences



Galactic cosmic rays (GCR) ionize the upper atmosphere.

GCR contribute to Ozone content at 15-20 km height – the lower stratosphere.

This modifies the troposphere and near-surface air temperature.

Then ocean temperature is modified and this is related to El Nigno/La Nigna Oscilations, as well as climatic modes like NAO.

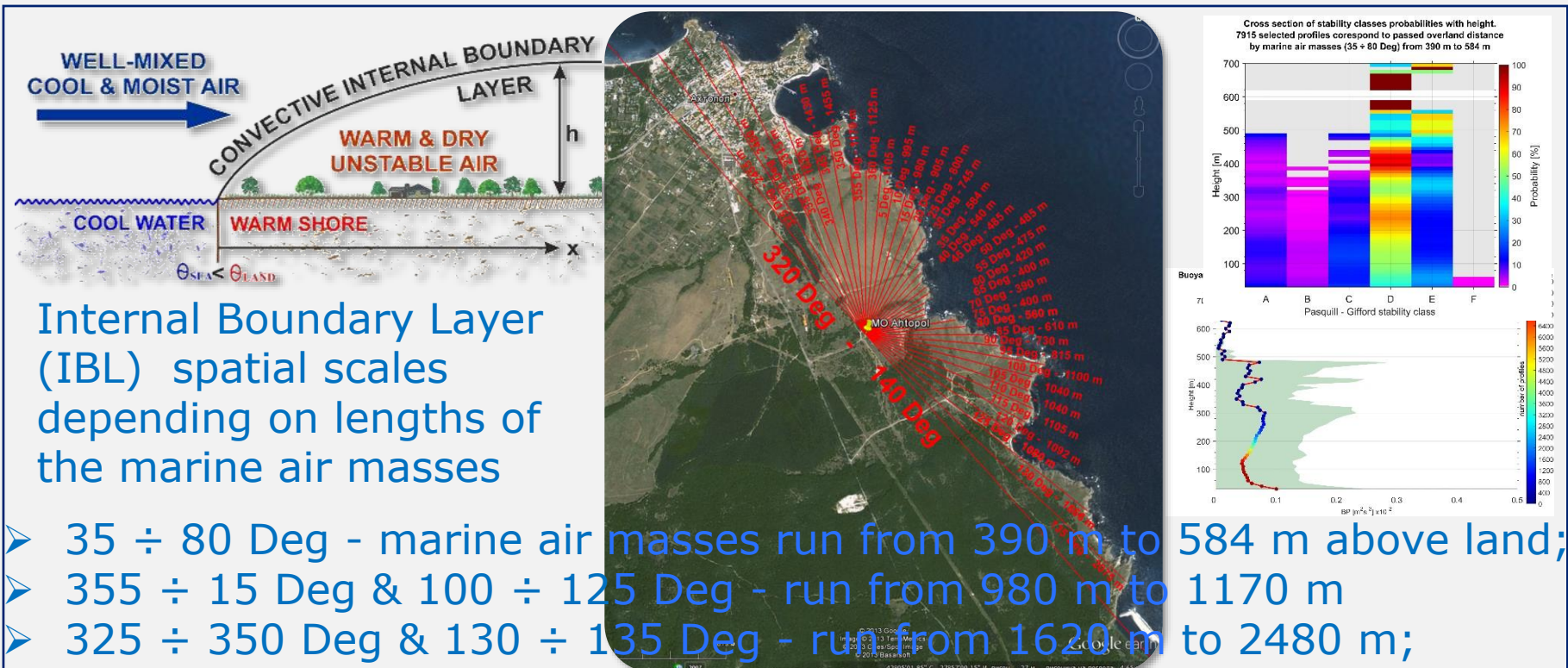
# Studies of regional and local climates – coastal boundary layer meteorology

P.39

EMS European Meteorological Society

## Internal boundary layer characteristics at the southern Bulgarian Black Sea coast

Barantiev, D. and Bachvarova, E.



# Studies of regional and local climates - Cloud cover and boundary-layer studies of Arctic climate based on long-term ceilometer data at Station Nord in Greenland (81° 36' N 16° 40' W)



The height of the aerosol layer is found to be about 250 m with no significant season variability, based on ceilometer data CL51 for the period 12 May 2011 - 12 April 2019.

The aerosol layer in the Arctic is strongly influenced by the transport of air masses and the physics used for boundary-layer height detection is different from the one at mid and low latitudes.

The aerosol and meteorological studies in the Arctic are of increasing importance because of the extraordinary rate of warming named the Arctic amplification.

# Acknowledgements

The project of CAWRI-BAS with the National Science Fund of Bulgaria, Contract KP-06-N34/1 /30-09-2020 "Natural and anthropogenic factors of climate change – analyzes of global and local periodical components and long-term forecasts“

One of the aims of the project is to harmonize results of climate change studies performed in the scope of different disciplines.

Thank you for your attention!