# The unidentified volcanic eruption of ~1809: why it remains a climatic cold case

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Max-Planck-Institut für Meteorologie

EGU pico presentation 27. 04. 2021

VOLIMPACT

**Pico talk**:
27 April 2021 11.12h - 11.14h EGU21-2314
**Session:**
Understanding volcano-climate impacts and the stratospheric aerosol layer
**Breakout text chat:**
11.38h to 12.30h 27 April 2021
**Corresponding paper:**
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# THE UNIDENTIFIED 1809 ERUPTION

The unidentified "1809 eruption" is one of the most recent unidentified volcanic eruptions with a global climate impact. Even though the eruption ranks as the 3rd largest since 1500 with an eruption magnitude estimated to be two times that of the 1991 Pinatubo eruption, not much is known of it from historic sources.

Based on a compilation of instrumental and reconstructed temperature time series, we show here that tropical temperatures show a significant drop in response to the ~1809 eruption, similar to that produced by the Mt. Tambora eruption in 1815, while the response of Northern Hemisphere (NH) boreal summer temperature is spatially heterogeneous (Fig. 1).

We test the sensitivity of the climate response simulated by the MPI Earth system model (MPI-ESM) to a range of volcanic forcing estimates constructed using estimated volcanic stratospheric sulfur injections (VSSI) and uncertainties from ice core records (Fig. 2).

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# Observed and reconstructed temperature anomalies

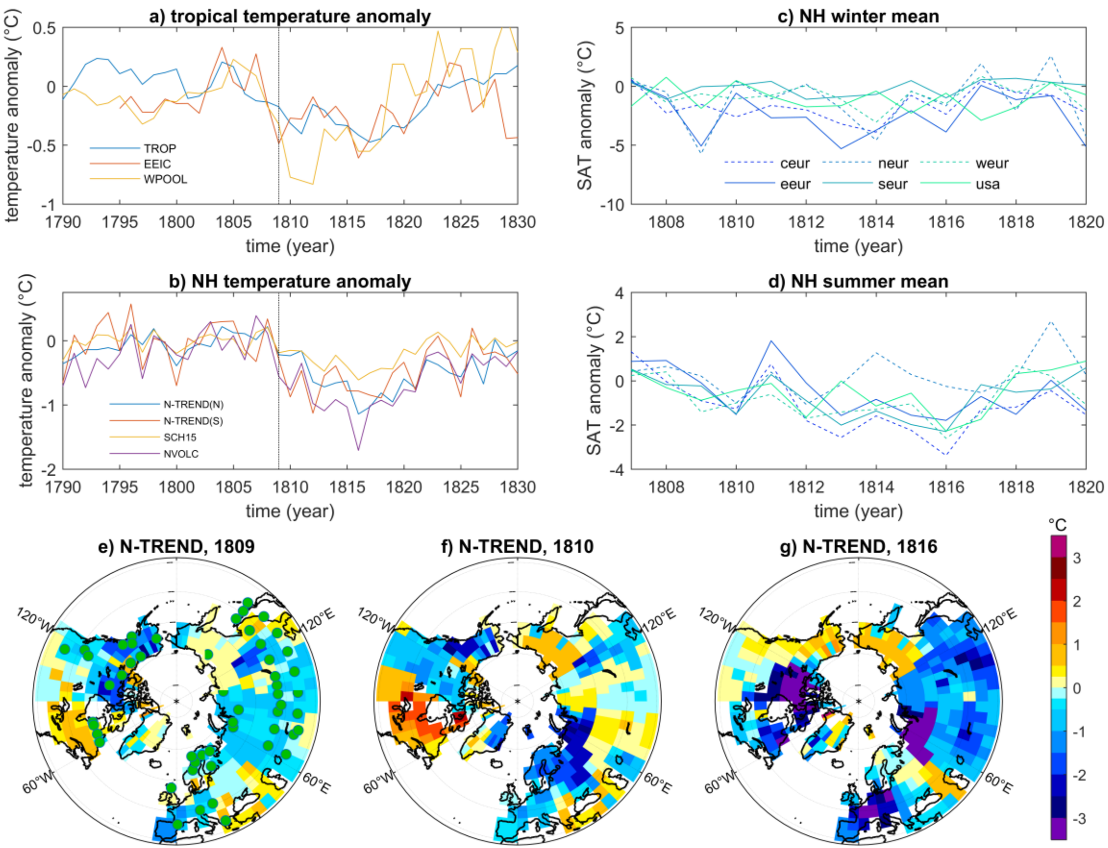


**Figure 1:**

**a)** Reconstructed tropical SST (TROP, D'Arrigo et al., 2009), tropical marine surface air temperatures from ship logs (EEIC, Brohan et al., 2012) and Indo-Pacific warm pool data (D'Arrigo et al., 2006).

**b)** NH summer land temperatures from four tree-ring based reconstructions (Wilson et al. 2016 (N-TREND(N)), Anchukaitis et al., 2017 (N-TREND (S)), Guillet et al., 2017 (NVOLC), Schneider et al., 2015 (SCH15)).

**c-d)** Monthly mean NH winter (c) and summer (d) temperature anomalies (◦C) from 53 station data averaged over different regions: Central Europe (CEUR), Eastern Europe (EEUR), Northern Europe(NEUR), Southern Europe (SEUR), Western Europe (WEUR) and New England (NENG).

**e-g)** Mean surface temperature anomalies (◦C) for boreal summers of 1809 (e), 1810 (f) and 1816 (g) in N-TREND (S) (Anchukaitis et al., 2017). Green dots illustrate the location of the tree-ring proxies in N-TREND.

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# MPI-ESM ENSEMBLE SIMULATIONS

10 member ensemble simulations with the MPI-ESM1.2 –LR for four different volcanic forcing scenarios.

MPI-ESM1.2-LR (Mauritsen et al., 2019)

- Atmosphere: ECHAM6.3, T63 (~200km,) 47 levels
- Ocean: GR15 (256x220 bipolar grid, 12 to 180km), 64 levels

Volcanic forcing:

eVolv2k provides estimates of the uncertainty in volcanic stratospheric S injection derived from ice cores:

Two additional forcing data sets (High,Low) are constructed for the 1809 ± 2σ from the central VSSI estimate (Best) and an additional sensitivity run based on Best but without NH extratropical volcanic forcing (nNHP).

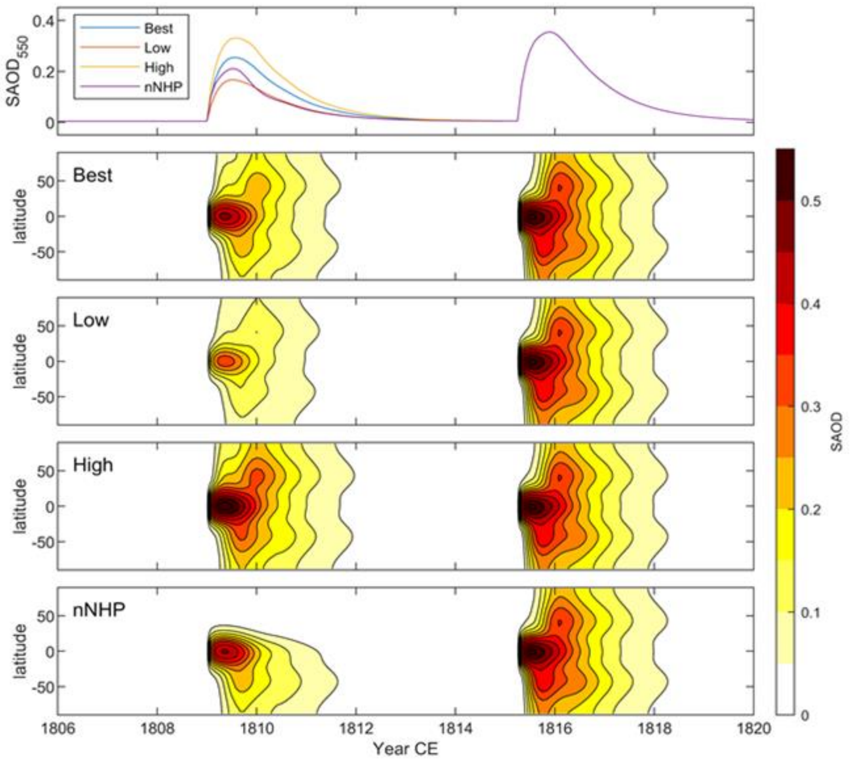


**Figure 2. Top**: Global stratospheric aerosol optical depth (SAOD) at 0.55 µm based on eVolv2k VSSI estimates (Toohey and Sigl, 2017) and calculation with the EVA forcing module (Toohey et al., 2016) for four different forcing scenarios: "Best", "Low", "High" and "nNHP" for the 1809 eruption and the "Best" scenario for the Mt. Tambora eruption. **Bottom:** Spatial and temporal distribution of a zonal mean stratospheric SAOD for the four experiments.

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# TROPICAL TEMPERATURES

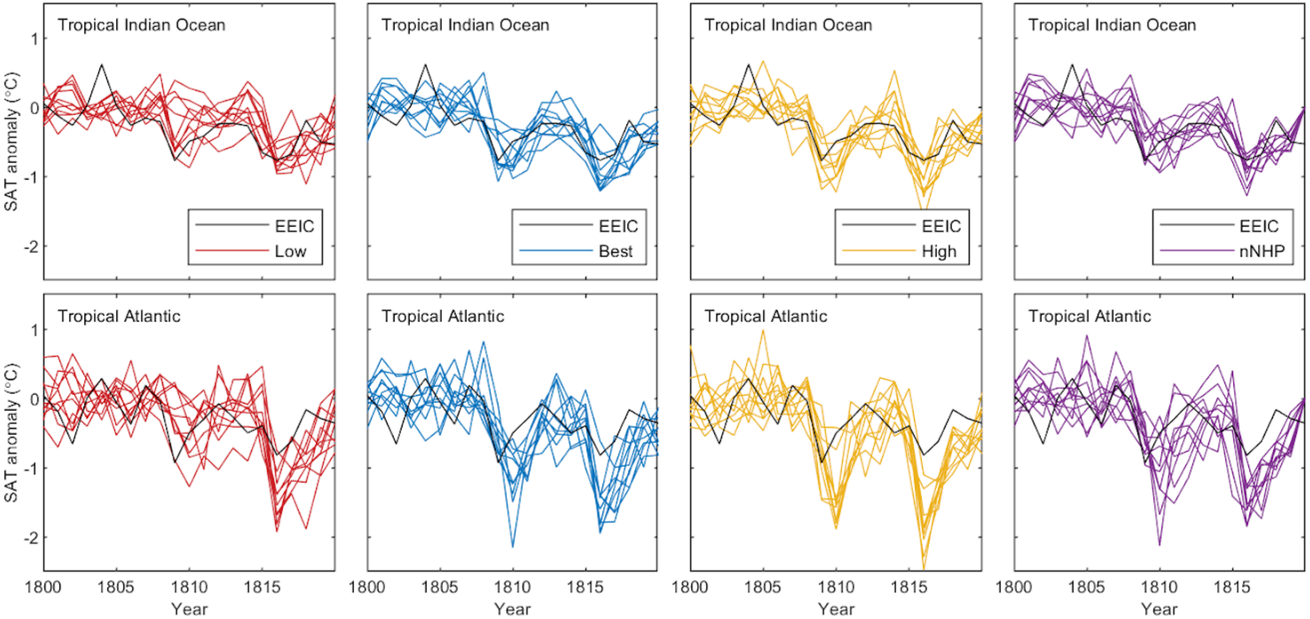


**Figure 3:**
Annual mean surface-air temperature anomalies from shipbourne measurements of the English East India Company (EEIC) (Brohan et al., 2012) over the tropical Indian and Atlantic oceans (black line) compared to similarly sampled model simulations from the Low, Best, High and nNHP forcing ensembles as labeled. Anomalies are taken with respect to the years 1800 to 1808.

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# NH EXTRATROPICAL SUMMER LAND TEMPERATURES

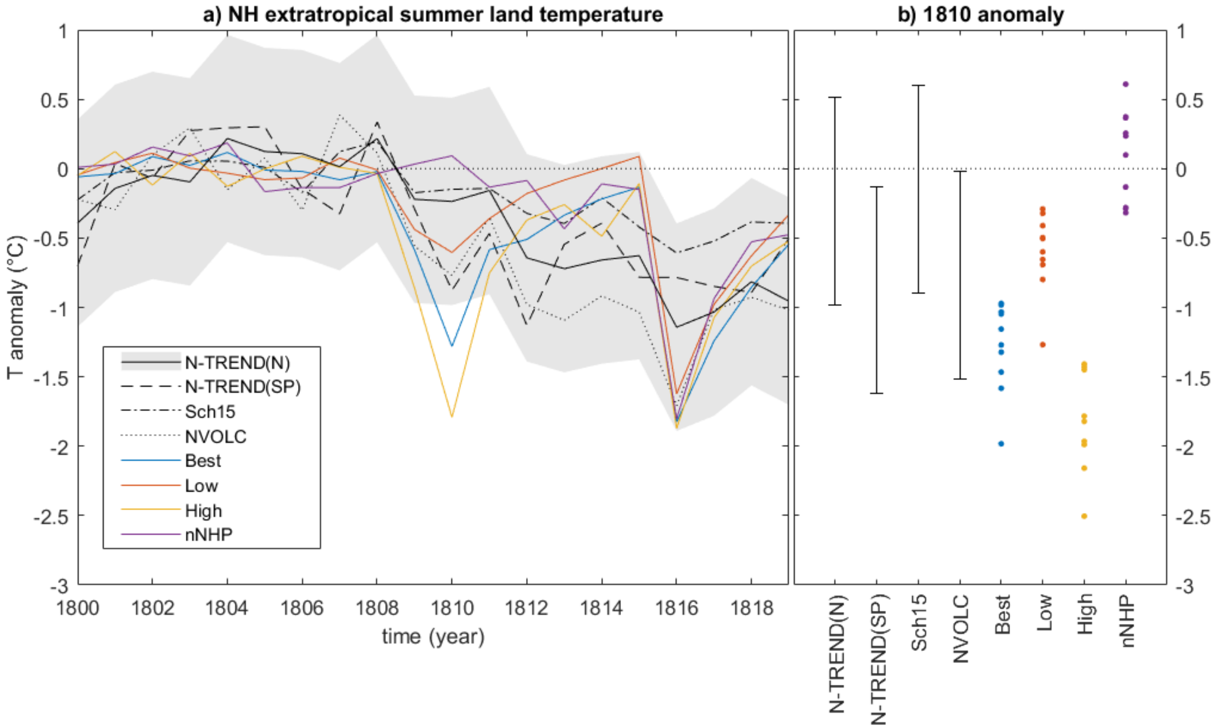


**Figure 4:**

**a)** Comparison of simulated NH extratropical (40-75◦N) summe land temperature anomalies (seasonal and spatial averaged) with four different NH TR-based temperature reconstructions (Wilson et al., 2016 (N-TREND (N)), Anchukaitis et al., 2017 ((N-TREND (S)), Guillet et al., 2017 (NVOLC), Schneider et al., 2015 (SCH15)). Anomalies are taken with respect to the years 1800-1808. Black lines: tree-ring records, colored lines: ensemble mean of the four model experiments. The shaded grey area indicates the 2 sigma uncertainty range for N-TREND (N).

**b)** Comparison for the reconstructed and simulated anomalies for the year 1810. Uncertainty ranges for all reconstructions are based on the 2-sigma of the N-TREND (N) reconstruction. Simulated anomalies are shown as individual realizations.

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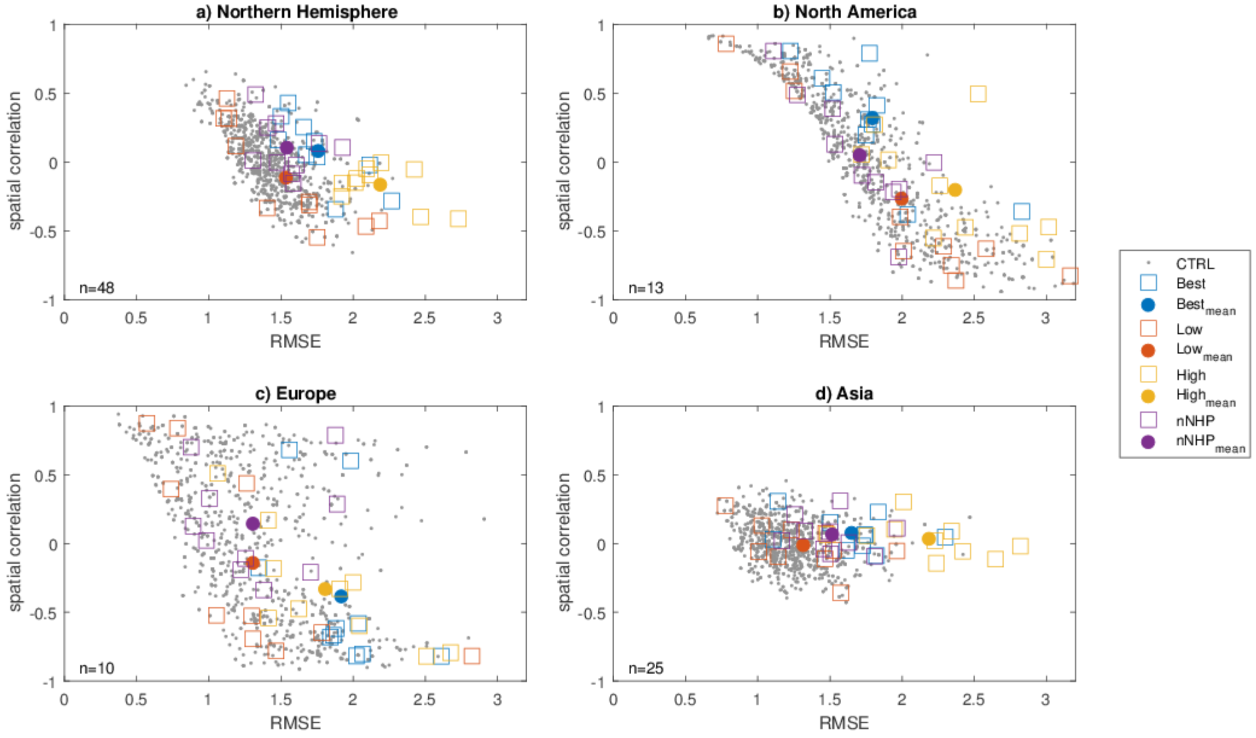
# SPATIAL CORRELATION OF NH SUMMER LAND TEMPERATURES




## Figure 5

Scatterplots of Root Mean Square Error (RMSE) versus spatial correlation between simulated NH summer temperature and the N-TREND (S) reconstruction (Anchukaitis et al., 2017) for summer 1810 and different regions: a) whole Northern Hemisphere, b) North America (180-60◦W), c) Europe (60◦W-60◦E), d) Asia (60-180◦E).

Individual model realizations are indicated by squares, the ensemble mean with a full dot; small grey dots are for 1000 random samples from the control period (1800 to 1808). Analysis is restricted to grid-points where proxy data are available (number of data used for each region reported in the respective panel).

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# SUMMARY

Assuming the model climate sensitivity is correct, the VSSI estimate is accurate within the uncertainty bounds.

Comparison of observed and simulated tropical temperature anomalies suggests that the most likely VSSI for the 1809 eruption would be somewhere between 12 -19 Tg of sulfur (Fig 3.).

Observed and reconstructed post-volcanic surface NH summer land temperature anomalies lie within the range of all our scenarios but the reconstructed cooling trend between 1810 and 1815 is not reproduced by the simulations (Fig. 4).

Spatial correlations are similarly weak for the volcanic forcing scenarios and the control run, suggesting that the mismatch is not attributable to the volcanic forcing only (Fig 5) -> More information in particular spatial reconstruction needed.

The forcing estimate of 1809, which is currently based on ice core data, can only be improved by modelling experiments to narrow down the uncertainty range. This will be facilitated if further information on location and eruption season is identified.

An increase in reconstruction accuracy by improving spatial coverage, including also the southern hemisphere, is needed.

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