Constraining the Timing of the 1257 Samalas Eruption: a Model and Multi-proxy Approach

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Objective: To place constraints on the timing of the 1257 Samalas Eruption using two modelled eruption dates (Jan/ July) and proxy records.

The Samalas 1257 eruption was one of the largest eruptions of the Holocene epoch, with a VEI = 7, it injected an estimated 120 Tg of SO_2 into the stratosphere. The eruption had significant but regionally heterogenous impacts on global climate.

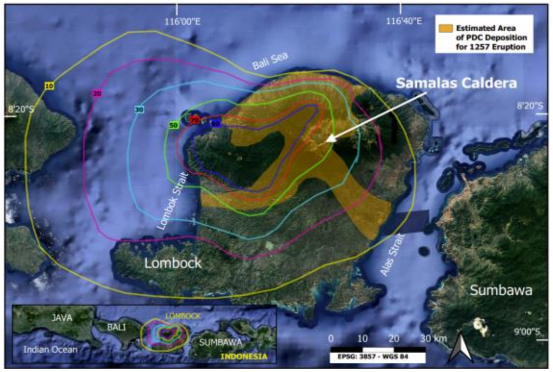


Figure 1: Map showing the Samalas Caldera on the Island of Lombok, Indonesia. Overlain are the mapped PDC flows and Ash Isopachs for the 1257 Eruption. From Lavigne et al., (2013)

Methodology

- 18 UK Earth System Model (UKESM) ensemble runs (column height = 18-20 km, stratospheric SO_2 load = 120Tg).
- 9 runs simulating a January 1257 eruption, 9 simulating a July 1257 eruption *(Fig 2).*
- Wide range of Quasi-Biennial Oscillation* (QBO) and El Niño Southern Oscillation (ENSO) initial starting conditions *(Fig 2).*

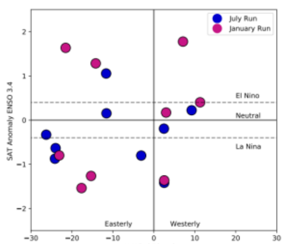


Figure 2: Plot showing ENSO and QBO initial conditions for each ensemble member.

- Constraints applied using a database of historical sources, tree ring chronologies, and stalagmite records.

* quasiperiodic oscillation of the equatorial zonal wind between easterlies and westerlies in the tropical stratosphere.

Tree Rings

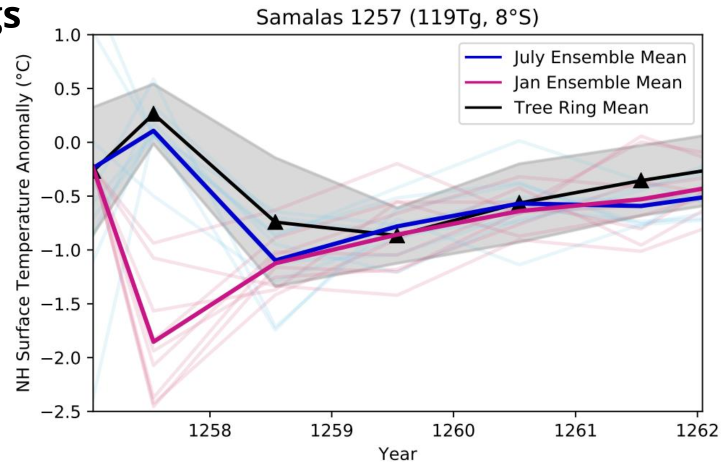
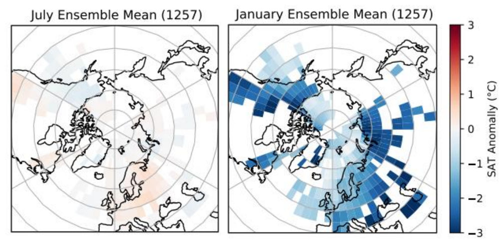


Figure 3: Plot showing Northern Hemisphere Land Surface Air Temperature Anomalies. Blue: July Ensemble Mean. Pink: January Ensemble Mean. Black line shows the mean of the SAT recorded in four tree ring chronologies. Grey band shows 2σ. Tree Ring data: Wilson et al., (2016), Schneider et al., (2015), Anchukaitis et al., (Personal Communication), Guillet et al., (2017)

Key Result: ***(Figure 3)*** Mean July (blue line) ensemble northern hemisphere land Surface Air Temperature (SAT) anomaly shown to lie within two standard deviations of the mean tree ring SAT anomaly (black line). Equivalent January (pink line) ensemble mean falls outside of two standard deviations, with peak cooling being both too large and too early relative to the mean tree ring SAT anomaly.

Spatially Resolved Anomalies *(Figure 4)*

- January ensemble SAT anomalies significantly overpredict cooling relative to spatially resolved tree ring data (on average by -2.3°C).
- July ensemble SAT anomalies do show observed warming in Europe for 1257, although this is still cooler than observations (by -0.5 °C).
- January and July ensembles both show significant cooling over Europe and Central Asia (1258-60). But fail to replicate the observed warming in Alaska recorded in the tree ring chronologies.



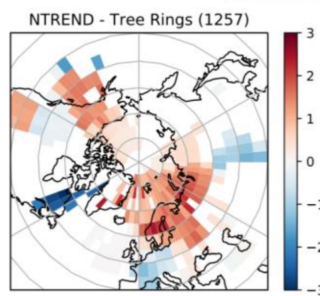


Figure 4: Top Left: July ensemble 1257 summer mean SAT anomaly. Top right: January ensemble 1257 summer mean SAT anomaly. Bottom Left: Spatially resolved NTREND SAT data. From Anchukaitis et al., (2017)

Historical Records

- Include medieval chronicles and economic records (see Guillet et al., 2017 and Stothers 2000).
- Distribution shows a significant bias towards NH records, predominantly in Europe.
- Enhanced precipitation and cooler temperatures in Europe + unusual snowfall in Mongolia summer 1258.
- July ensemble SAT anomalies agree with the onset of NH cooling in Summer 1258.
- January ensembles show cooling in summer 1257 which is not reported in records.

Stalagmites

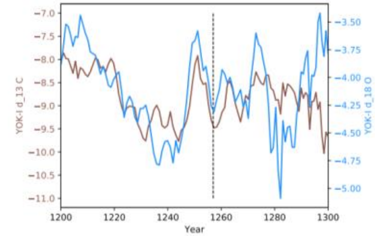


Figure 5: Plot showing δ13C and δ18O records for YOK-I Stalagmite from Yok Balum Cave, Belize. Data from Kenneth et al., (2017).

- Ongoing analysis in combination with modelled precipitation anomalies. Using a high-resolution Stalagmite record from Belize, Central America.
- Preliminary results suggest drying is observed following the eruption. Both January and July ensembles show potential ITCZ shifts which may explain this.

Conclusions

The UK Earth System Model was used to simulate the Samalas 1257 eruption under two different eruption timing scenarios. A January ensemble resulted in NH summer SAT cooling being too early and too extreme. Instead, proxy constraints favor the eruption having occurred in July/Summer 1257.