**Volcanic-Climate Reading**

(Sigl et al., 2015)

* Resolve inconsistencies between the timing of aerosol loading in ice cores and subsequent cooling in tree rings. Based on new measurements from Antarctic and Greenland Ice cores.
* Show that large eruptions in the tropics and high latitudes were primary drivers of interannual-to-decadal temperature variability in the Northern Hemisphere during the past 2,500 years. Cooling was proportional to the magnitude of volcanic forcing.
* For Samalas 1257 estimate global volcanic aerosol forcing of ~ -30 Wm-2.

(Stoffel et al., 2015)

* volcanic surface cooling derived from climate model simulations is systematically much stronger than the cooling seen in tree-ring-based proxies – so either proxies underestimate or models overestimate cooling response.
* Simulate the climatic impact of the 1257 Samalas eruption using a climate model that accounts explicitly for self-limiting aerosol microphysical processes – reconciles tree ring and models.
* Use new annually resolved 1500-yr summer land temperature reconstructions from tree rings
* Predict a cooling of -0.8 to -1.3C during the first and second year after the Samalas eruption. Test two different plume heights and run the model for May/June and Jan – shows strong dependence on eruption height and timing.
* Higher plume height leads to more inter-hemispheric asymmetry in aerosol distribution – consistent with seasonal asymmetry of BDC (which transports more aerosol towards the winter hemisphere). So, predicts v strong NH cooling for a Jan eruption which is inconsistent which tree ring reconstructions.
* Must account for non-linear aerosol microphysics!

(Robock, 2000)

* Overview of volcanic forcing of climate
* Tropical eruptions produce an enhanced pole-to-equator temperature gradient, which produces a stronger polar vortex and stronger jet stream which alters tropospheric circulation and produces NH winter warming.
* SO2 and H2S react with OH and H2O to form H2SO4 aerosols.
* Solar radiation is backscattered at the surface by interaction with aerosols – net surface cooling (higher planetary albedo). Direct radiation decreases, whereas diffuse radiation increases.
* Whereas stratosphere is heated by absorption of upward longwave radiation from the surface
* Petrological method can only give minimum estimate of sulphur aerosol loading
* Highlights errors with VEI and IVI.
* Cooling due to eruption can be offset by El Nino warming events – climatic signals from both are of similar amplitude
* Land surfaces respond more quickly to radiative perturbations
* Reduced tropical precipitation (Robock and Liu, 1994)
* Discuss of Ozone

(Pinto, Turco and Toon, 1989)

* Using 1D aerosol-microphysical and photochemical model
* As SO2 injection rate is increased coagulation and condensation produce larger particles rather than a larger number of particles of the same size) – e.g 1982 el chichon found an increase in the size of large particles rather than in the number of particles.
* Larger particles have a smaller optical depth and also settle out faster – which moderates the impact on volcanic forcing (self-limiting)
* Covers SO2 chemistry

(Miller et al,. 2012)

* Intervals of sudden ice growth coincide with two of the most volcanically perturbed half centuries of the past millennium.
* Explosive volcanism produces abrupt summer cooling which is then maintained by sea-ice/ocean feedbacks/summer insolation minimum.
* Suggest Samalas was one of four eruptions which contributed to the onset of the LIA

(Liu et al., 2020)

* Using the community Earth System Model to suggest the NH experienced 2 decades of cooling following the Samalas eruption – but not sure if robust inclusion of aerosol microphysics?
* Also suggests asymmetrical response with much longer cooling in the Arctic

(Marshall et al., 2020)

* Simulated 82 explosive eruptions with different eruption source parameters (SO2 emissions, emission height, eruption latitude, eruption date) using aerosol-chemistry-climate model simulations.
* Difference between instantaneous and effective forcing due to positive effect of rapid adjustments to reduce overall forcing (due to SW cloud adjustment)
* Forcing per unit of SAOD is weaker in the first year following an eruption than in Years 2 and 3, is stronger for tropical eruptions than extratropical eruptions, and is stronger for winter eruptions than summer eruptions.

(Staunton-Sykes et al., 2021)

* Using an aerosol-climate-chemistry model to simulate stratospheric eruptions of two sizes with and without co-emitted halogens. To determine the influence of halogens on the life cycle of volcanic sulfur, stratospheric chemistry, and the resulting radiative forcing
* Find that the co-emission of volcanic halogens and sulfur into the stratosphere increases the volcanic effective radiative forcing – due to both aerosol interactions and changes to the composition of the stratosphere
* Volcanic halogens catalyse the destruction of stratospheric ozone – resulting in significant stratospheric cooling and therefore in reduced growth by condensation and coagulation meaning the peak radius is closer to the peak scattering efficiency radius of sulfate aerosol, and thus co-emission of halogens results in larger peak global-mean ERF
* Petrological analysis of the 1257 Mt Samalas eruption suggests as much as 227 Tg of hydrogen chloride (HCl) and 1.3 Tg of hydrogen bromide (HBr) could have been emitted
* The stratospheric injection of volcanic halogens depends on both the total mass of halogens released at the vent and the degree of scavenging, which is determined by the geochemistry of the volcano and the prevailing atmospheric conditions during the eruption, particularly the humidity.
* \*SAMALAS HALOGENS\* - see Wade and Vidal.

(Marshall et al., 2018)

* Volcanic radiative forcing often estimated from sulphate ice core deposition – but this is parameterized for Mt Pinatubo – therefore unlikely to be directly applicable to other large eruptions.
* Polar sulphate deposition is modulated by season, atmospheric variability, and magnitude of SO2 injection
* magnitude of the forcing depends on the global spread of the volcanic aerosol in the stratosphere, its lifetime, and the microphysical properties of the aerosol (size, mass, and number of the aerosol particles – all of which depend on eruption source parameters + means potentially ‘non-unique solutions’
* Use aerosol-climate model to simulate a wide range of large-magnitude eruptions – to build a description of how sulfate deposition and radiative forcing vary with eruption source parameters.
* Could not constrain plausible eruption parameter combinations for Samalas – likely as SO2 emission > 100Tg

(Aubry et al., 2020)

* New EVA\_H model – come back to this if relevant.

**ENSO**

(Dee et al., n.d.)

* Models suggest volcanism can induce an El Nino like response in the tropical Pacific up to 2 years after eruption.
* Linked to o basin-scale cooling patterns that drive an equatorward shift of the Intertropical Convergence Zone, which favors weaker trade winds in the western and central tropical Pacific changes in the zonal sea surface temperature (SST) gradients with cooling in the west and a reduction in mean upwelling typically associated with an El Niño event.
* Additionally depends on the background ENSO state during the time of the eruption and the eruption size, with a potential influence from the season in which the eruption occurs.
* Use absolutely dated fossil coral records to assess ENSO response to volcanic forcing – suggest tendency for El Nino-like response is not statistically significant/ doesn’t appear after Samalas.

BUT Reply from (Robock, 2020)

* Suggest Dee interpretations wrong as haven’t accounted for volcanic cooling of the surface (which masks El-Nino warming) – need to account for relative SST rather than absolute SST.
* Highlights Samalas does not show large cooling one year after the eruption in the coral record – likely volcanic cooling is offset by El Nino warming.

(Zhu et al., 2021)

* Overview of current state of Volcano-ENSO forcing
* Tree ring observations (experience ENSO via teleconnections) have been used to support the relationship, and 5 mechanisms proposed to account for it (see paper)
* Models suggest ENSO only sensitive to the very largest eruptions.
* But coral record (though maybe biased from Dee) suggests no statistically significant relationship
* ENSO sensitive to the phase of the quasi-biennial oscillation (QBO), the forcing magnitude, location, and season of the eruption, as well as pre-conditioning of the ENSO state.
* Observational studies limited by lack of large well documented eruption events and temporal resolution of proxy recprds.

(Brad Adams, Mann and Ammann, 2003)

* Use two paleoclimate reconstructions/proxy chronologies to support an ENSO response to explosive volcanism.
* Results imply a doubling of the probability of an el Nino event occurring in the winter following a volcanic eruption. Also suggest a subsequent La Nina rebound in years 4-6.
* Statistical analysis limited by only having a small number of events
* Suggest explosive volcanic eruptions drive ocean-atmosphere system to favouring el Nino events (not a causal relationship)

(McGregor et al., 2020)

* Most up-to-date review of ENSO response to volcanic eruptions
* 70% of (tropical) eruptions in the last 550 years display a significant El Nino-like response. Extra tropical NH vs SH display opposite responses (Nino Vs Nina).
* Large volcanic eruptions can also reduce ocean heat content and sea level during cool period
* Difficult to disentangle ENSO response from other climate phenomena (E.g Asian Monsoon has much larger amplitude)
* Winter tropical eruptions produced larger aerosol optical depth (AOD) due to stronger Brewer-Dobson circulation leading to higher SO2 entrainment + smaller radius and longer aerosol lifetime in winter (although this effect is reduced for very large tropical eruptions)
* Initial state of the pacific is also important (significant el nino response not likely in a pre-existing la nina state)
* El nino response also stronger for boreal summer eruptions
* Outlines various proposed mechanisms

(Emile-Geay et al., 2008)

* Look at ENSO in the context of the 1257 eruption
* But date eruption to 1258/1259
* Show using models that the majority of models produced a moderate-to-strong El Nino response to the 1258 eruption during prevailing La nina-like conditions – the medieval climate anomaly (although this conflicts with McGregor?)
* From proxy records: Tree rings in North Western America indicate strong el nino, Tree rings in Chile is also consistent with this. South American Ti sediment contents also suggests an el nino event

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