Risk assessment of the impact of future volcanic eruptions on direct normal irradiance

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Direct Normal Irradiance (DNI)

- **DNI is the direct solar irradiance received on a plane normal to the Sun direction [W/m^2] (Blanc et al. 2014)**
- **DNI is the primary fuel of Concentrated Solar Power (CSP) systems (Fig. 1)**
- **DNI transmittance T_{DNI} through the atmosphere depends on the optical depth τ, the solar zenith angle θ_0 and the scaling factor k.**

$$T_{DNI} = e^{\frac{-k\tau}{\cos\theta_0}}$$

BeyondTMY project 2015-2016

- **Investment of a CSP plant is of the order of 100 M€**
- **Solar resource assessment is essential to evaluate the economics of the project**
- Typical Meteorological Years and Reference Years are usually used for this TMY/RY have 12 typical months of solar and meteorological data
- **As part of the risk assessment**, It is essential to investigate the factors not represented in TMY/RY data sets
  - inter-annual variability
  - long terms trends and changes
  - extreme events having influence on CSP productions (e.g. DNI)
- **One of these is plinian and ultra-plinian volcanic eruptions**

Figure 1 SolarReserve's Redstone 100 MW tower CSP with 12 hours of storage in South Africa sited next to their three PV projects, Lesatsi, Lesedi and Jasper. Credit: SolarReserve & SolarPACES.

Volcanic eruptions

Sigl et al. (2015) studied 2 500 years of sulphate aerosol deposits in ice cores from Antarctica and Greenland. We use their data as they include 159 eruptions with Aerosol Optical Depth (AOD) > 0.1. This reduces the sampling uncertainty caused by using data only from the recent centuries (e.g. Sato el al. 1993) as done by (Jackson et al. 2015).

Sigl et al. studied historical ice core sulphate loads. Following their approach, we use a scaling factor of 0.011 AOD/(kg/km^2). The AOD is assumed to longitudinally representative at the time the sulphate is deposited on the ice sheets. Volcanic aerosols are not distributed equally across all latitudes. We therefore use the largest of the aerosol loads estimated from either the Greenland or Antarctic ice cores.

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Statistical assumptions

- **The Poisson distribution describes the number of events in the given time range.**
- **In Table 1 the estimated number of eruptions in a decade is shown for AODs larger than 0.1, 0.2, 0.5 and 1.0, respectively.**
- **It only depends on λ that is both the expected value and its variance.**

$$\lambda^n \frac{e^{-\lambda}}{n!}$$

- The e-folding time (decay time) is assumed to be 1 year (Crowley & Unterman 2013**).**
- The log-normal distribution is assumed for the amplitude of the eruptions
- A version that is truncated at an AOD of 0.1 is used in order to avoid double accounting of the smallest eruptions.

$$\frac{1}{x\sigma\sqrt{2\pi}} e^{-\frac{(\ln(x)-\mu)^2}{2\sigma}},$$
$$\sigma^2 = \ln\left(1 + \frac{Var(X)}{E[X]^2}\right)$$
$$\mu = \ln(E(X)) - \sigma^2/2$$

AOD bins	Number	Lambda	0	1	2	3	4
0.1-0.2	76	0.556	57.3%	31.9%	8.86%	1.64%	0.23%
0.2-0.5	46	0.252	77.7%	19.6%	2.47%	0.21%	0.01%
0.5-1.0	13	0.068	93.4%	6.35%	0.22%	0.00%	0.00%
>1.0	4	0.016	98.4%	1.57%	0.01%	0.00%	0.00%

Table 1: Estimated risks of given numbers of volcanic eruptions per decade causing larger AODs than the thresholds in the left column. The second column gives the number of eruptions during the full 2500 year past period.

Discussion

- **The 1982 El-Chichon eruption is missing in the Sigl et al. data from Greenland. This is surprising, as Sato et al. (1993) have this eruption to be affecting the northern hemisphere the most.**
- **The 1783 Laki eruption AOD and other Icelandic eruptions are likely to be overestimated due to their proximity to Greenland.**

References

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