Solar resource scenarios

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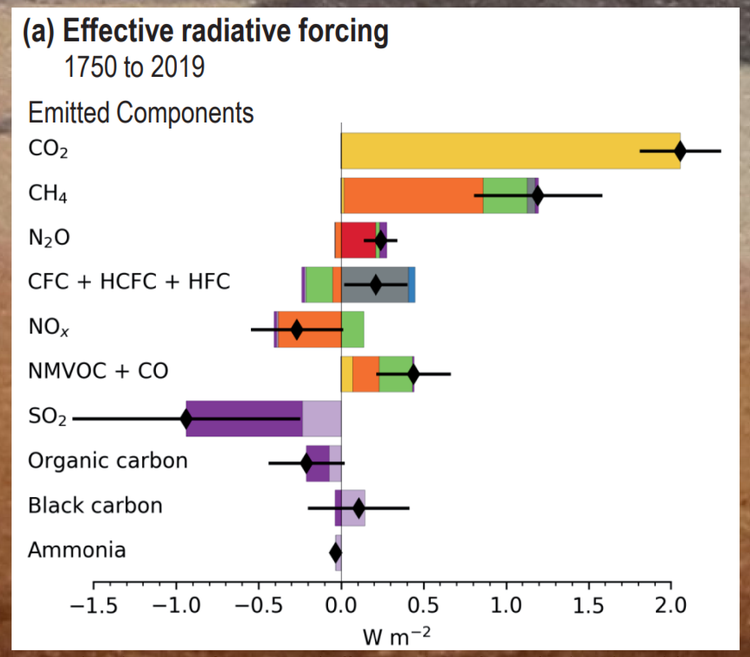
Long term and climate variability

Two types are considered:

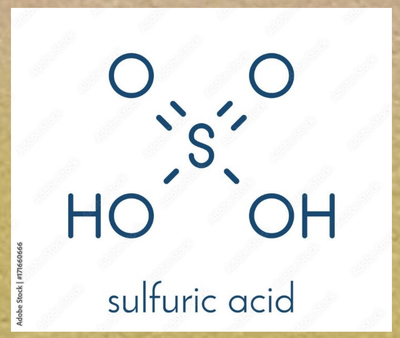
1. Physically forced
2. Chaotic oscillations

Physically forced climate variability

- Assumption: Chaotic oscillations in the climate system have little impact on the decadal scale
- "*Before the industrial period, explosive volcanic eruptions were the largest source of forced climate variability globally on interannual to centennial timescales*." Quote from the IPCC AR6 WG1 report
- Emitted greenhouses gas increases the temperature
- Human sulfate (SO_2) emissions are considered the biggest source of variability on the solar resource
- Aerosol-cloud effects (dark purple) have a larger effect than aerosol-radiation effects (light purple)



IPCC Technical Summary figure TS.15 a) Effective radiative forcing (ERF). Multi-model means based on analytic formulas and earth system model simulations that quantify the effect of individual components. Error bars are 5-95% and for the ERF account for uncertainty in radiative efficiencies and multi-model error in the means.



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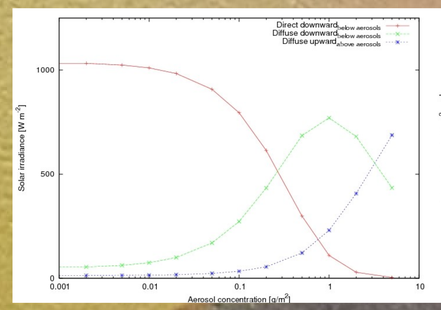
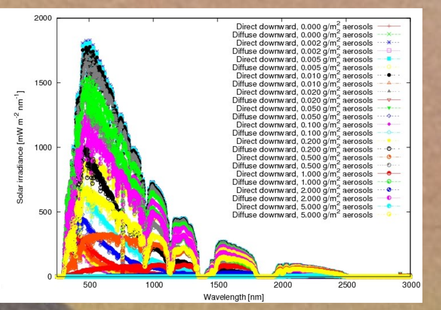
Sulfate aerosols

- **Sigl et al. (2015) studied historical ice core sulfate loads. Following their approach we use a scaling factor of 0.011 AOD/(kg/km2)**
- **They found 159 eruptions with AOD > 0.1 during 2 500 years**
- **The e-folding time (decay time) is assumed to be 1 year (Crowley & Unterman 2013).**





Left: Sulfate aerosols mainly scatter solar irradiance. Most is scattered in the forward direction. Thus, even for higher optical depths, much of the solar irradiance is still scattered toward the surface. Method: Gleeson et al.
Right: Spectral irradiance for both the direct and diffuse components. Here it can be seen that the loss is relatively less at the near infrared wavelengths utilized best by typical PV modules (700-1100 nm)

Discussion

- **Future volcanic eruptions are not included in the CMIP6 models**
- **The GCM's representations of aerosol and aerosol-cloud effects differ very much**
- **Sulfate emissions have been decoupled from greenhouse gas emissions to a large extent**
- **Future work: aerosol-cloud effect scenarios**

References

Crowley, T. J., M. B. Unterman, 2013. Technical details concerning development of a 1200 yr proxy index for global volcanism, Earth Syst. Sci. Data, 5, 187–197.

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Kkiessling, 1888. Dämmerungs-Untersuchungen. The background image of a sunrise on 4 September 1884. It shows the effect on sunlight following the Krakatau eruption.

Sigl, M, M.Winstrup, J. R. McConnell, *et al.*, 2015. Timing and climate forcing of volcanic eruptions for the past 2,500 years, Nature, 523, 543-549.