The Impact of Major Equatorial Volcanic Eruptions on Extreme Extratropical Cyclone Characteristics in the Northern Hemisphere

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Objectives

Extreme extratropical cyclones (ETCs) and major volcanic eruptions are significant natural hazards. Still, understanding the impact of volcanic eruptions on extremes in ETCs is limited, leading to:

How strong are effects of strong tropical eruptions on extratropical cyclones of the Northern and Southern Hemisphere during the corresponding winter season?

Conclusions

- ✓ The first two years after an eruption are dominated by the direct thermal effect of volcanic eruption shifting ETC frequency away from the midlatitudes.
- ✓ The shifts go along with an increase of ETC-related precipitation and wind speed over areas of enhanced ETC frequency.
- ✓ A strong volcanic-induced La Nina response on ETC characteristics in the winters is evident in winter 4 and 5 after a strong tropical eruption.

Results

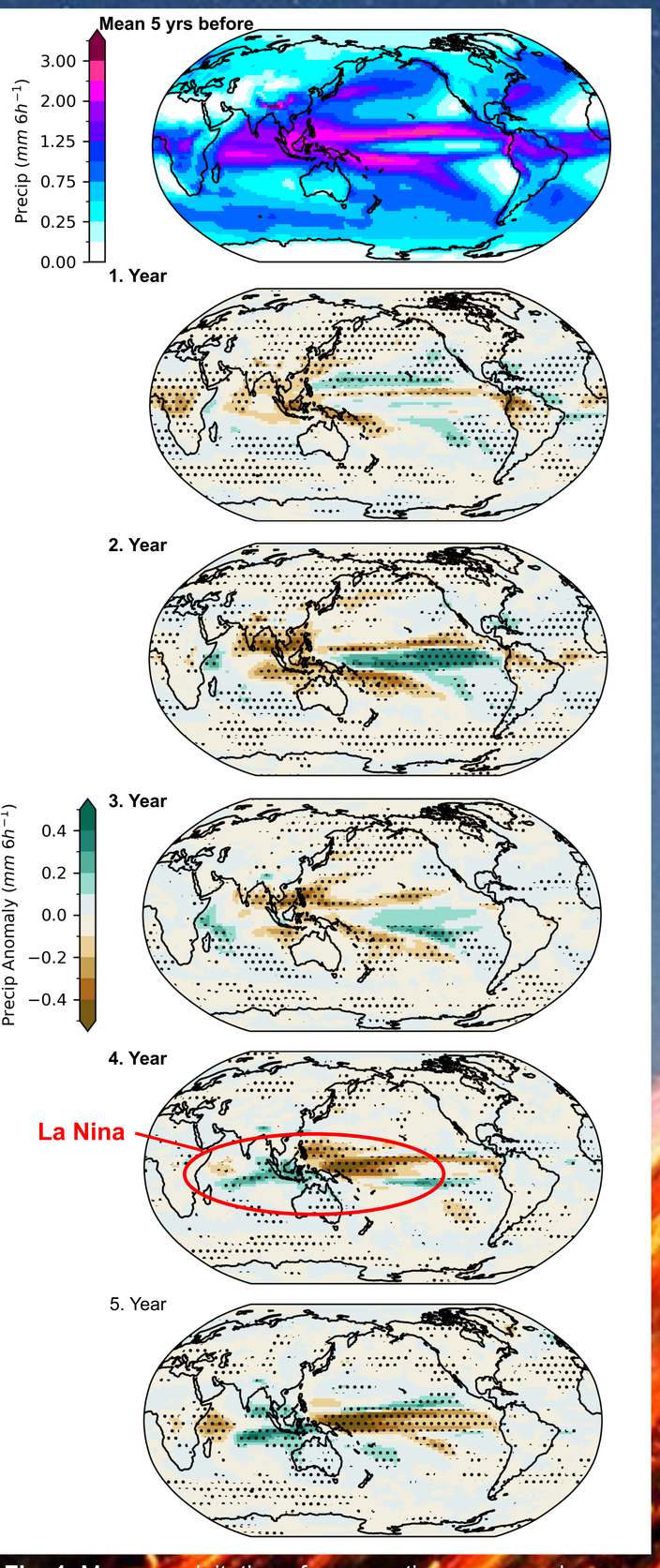

Fig. 1: Mean precipitation of pre-eruption years, and precipitation anomalies for 5 years after eruption. Stippling indicates where anomalies are statistically significant.

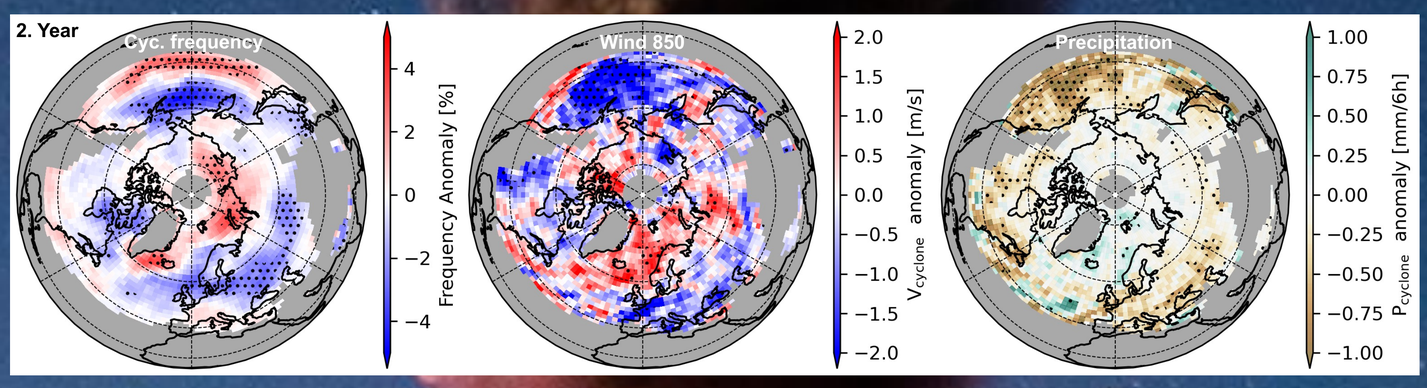

Fig. 2: Anomalies of cyclone frequency, extreme 850 hPa wind speed and extreme precipitation, related to cyclones in the 2. winter with respect to the 5-year mean before the eruption. Stippling indicates where anomalies are statistically significant.

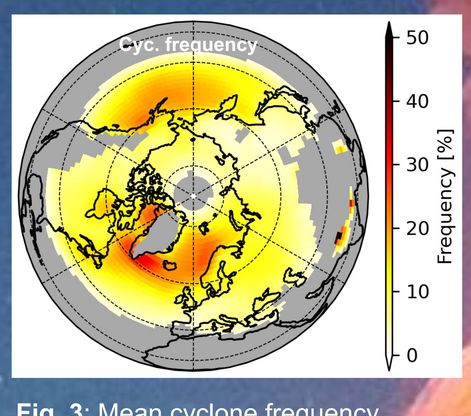

Fig. 3: Mean cyclone frequency averaged over 5 years before a tropical eruption.

- ➢ Fig. 1 shows a clear drying response in the extra tropics in year 2 and 3 after the eruption induced by the strong cooling, year 4 and 5 are dominated by a La Nina response in the tropics.
- ➢ In Fig. 2, the mean cyclone frequency (see Fig. 3) is shifted southward in the Pacific and northward in the Atlantic, the associated extremes in wind and precipitation follow the changes.
- ➢ Year 4 is dominated by a reduction of cyclones in the western Pacific and increase in the eastern well as a reduction over Southern and an increase over Northern Europe. This response resembles a La Nina-like response and shows that the ENSO response, which is induced by volcanic eruptions, dominates year 4.
- ➢ Wind extremes and partly precipitation extremes associated with cyclones are enhanced in northern Pacific and northern Atlantic in the 4. year.

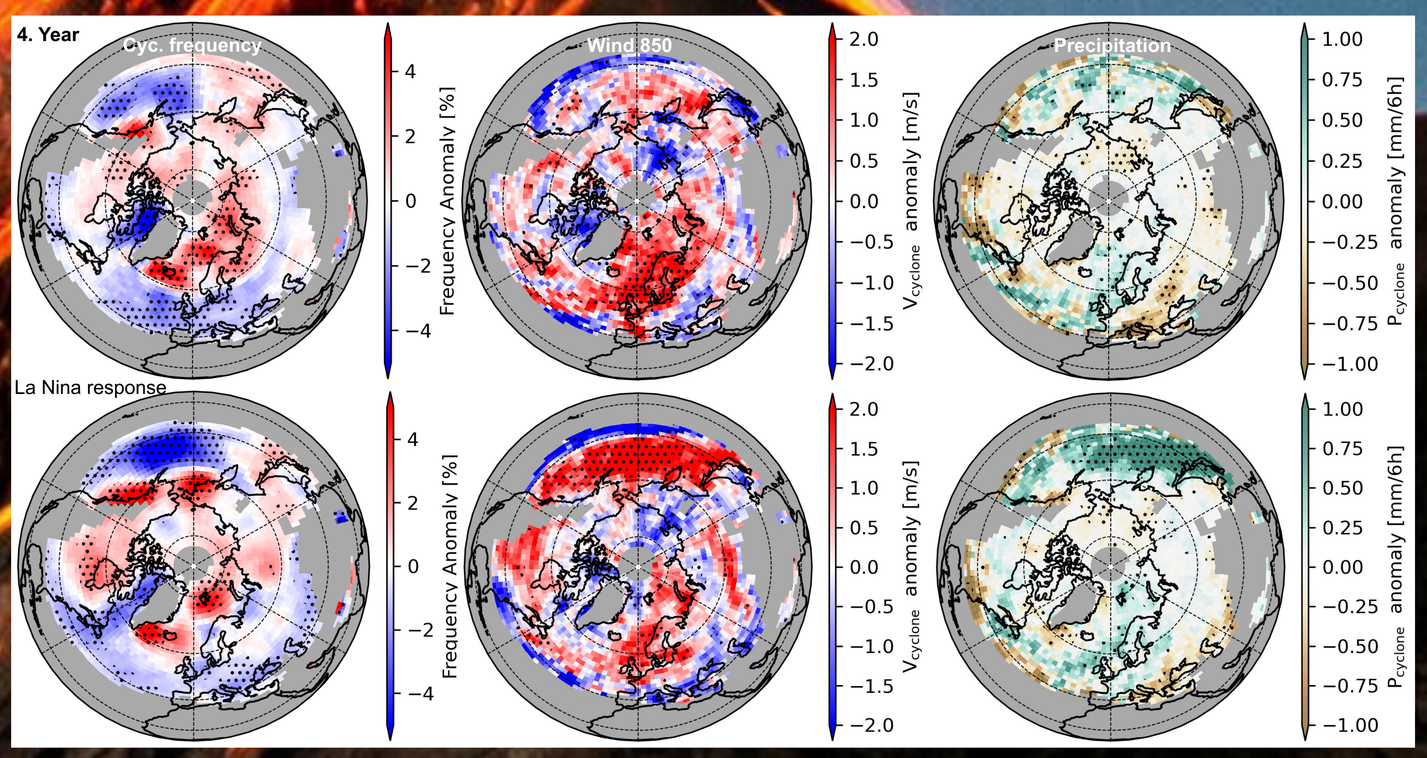

Fig. 4: First row: Anomalies of cyclone frequency, extreme wind speed at 850 hPa and extreme precipitation, related to cyclones in the 2. winter with respect to the 5-year mean before the eruption. Second row: as the first row but showing the anomalies between La Nina years and normal years excluding volcanic eruption years. Stippling indicates where anomalies are statistically significant.

Model & Simulations

- ➢ CESM (version 1.2):
  - ➢ 2º × 2º resolution in land/atmosphere
  - ➢ 1º × 1º resolution in sea ice /ocean
- ➢ External forcing
  - ➢ Solar irradiance
  - ➢ Greenhouse gases
  - ➢ Land use change
  - ➢ Volcanic eruptions
- ➢ Initial condition ensemble
  - ➢ 1500 BCE - 2100 CE
  - ➢ 1500 BCE - 638 CE
  - ➢ 1500 BCE - 608 CE

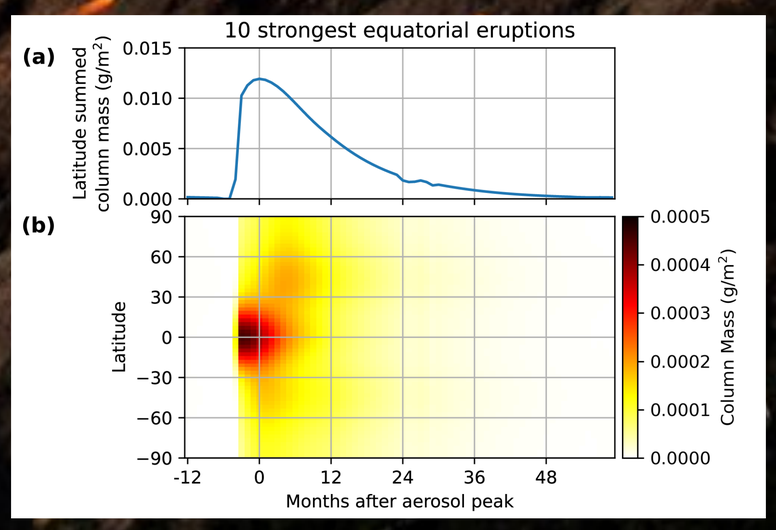

Figure: Stratospheric aerosol column mass for the 10 strongest equatorial volcanic eruptions: (a) Latitude-integrated column mass and (b) latitude-time distribution of column mass [gcm^{-2}].

Methods

- ➢ Selection of the 10 strongest eruption
- ➢ Composite analysis
- ➢ Superposed epoch analysis

References:
Doensen O. and C. C. Raible, 2026: The Impact of Major Equatorial Volcanic Eruptions on Extreme Extratropical Cyclone Characteristics in the Northern and Southern Hemisphere to be submitted to Clim Past.

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