Reconstructing the History of Volcanic Forcing of Climate from Polar Ice Cores

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Background

Volcanic eruptions have caused the largest natural changes in climate over the last millennium. Released sulfate aerosols have a major cooling effect due to reflecting incoming sunlight. The eruption's climatic impact depends on when the eruption occurred during the year because of seasonal differences in the distribution of incoming solar radiation. During the last 2000 years, over 200 major volcanic eruptions have occurred, which are recorded as sulfate peaks in polar ice cores[1]. Over 90% of volcanic eruptions are unidentified and given an arbitrary January 1st or July 1st eruption date[2,3]. This information is used in state-of-the-art climate models, generating major uncertainty. In my project, I improved a computer model that systematically calculates the season of the unknown eruptions[4].

Method

Ice cores contain small air bubbles that capture a snapshot of past climates. The deeper the core the older the ice. Aerosol concentrations vary seasonally and their maximum concentration is recorded as an annual peak in ice cores. This method uses snow data sampled from 2003 to 2013 to determine the seasonality of aerosol concentrations . The seasonality is assumed to be constant over the past 2000 years[5] so this can be used to calculate the eruption season of the volcano by comparing aerosol and sulfur concentration peaks within the ice core.

My work focused on coding the aerosol seasonality of Calcium (Ca^{2+}), using MATLAB (a computer language) and time series analysis techniques such as fast Fourier Transforms (FFT).

Ice core example. Image credit: NASA

Summit Camp. Image credit: John Burkhart, GEOSummit

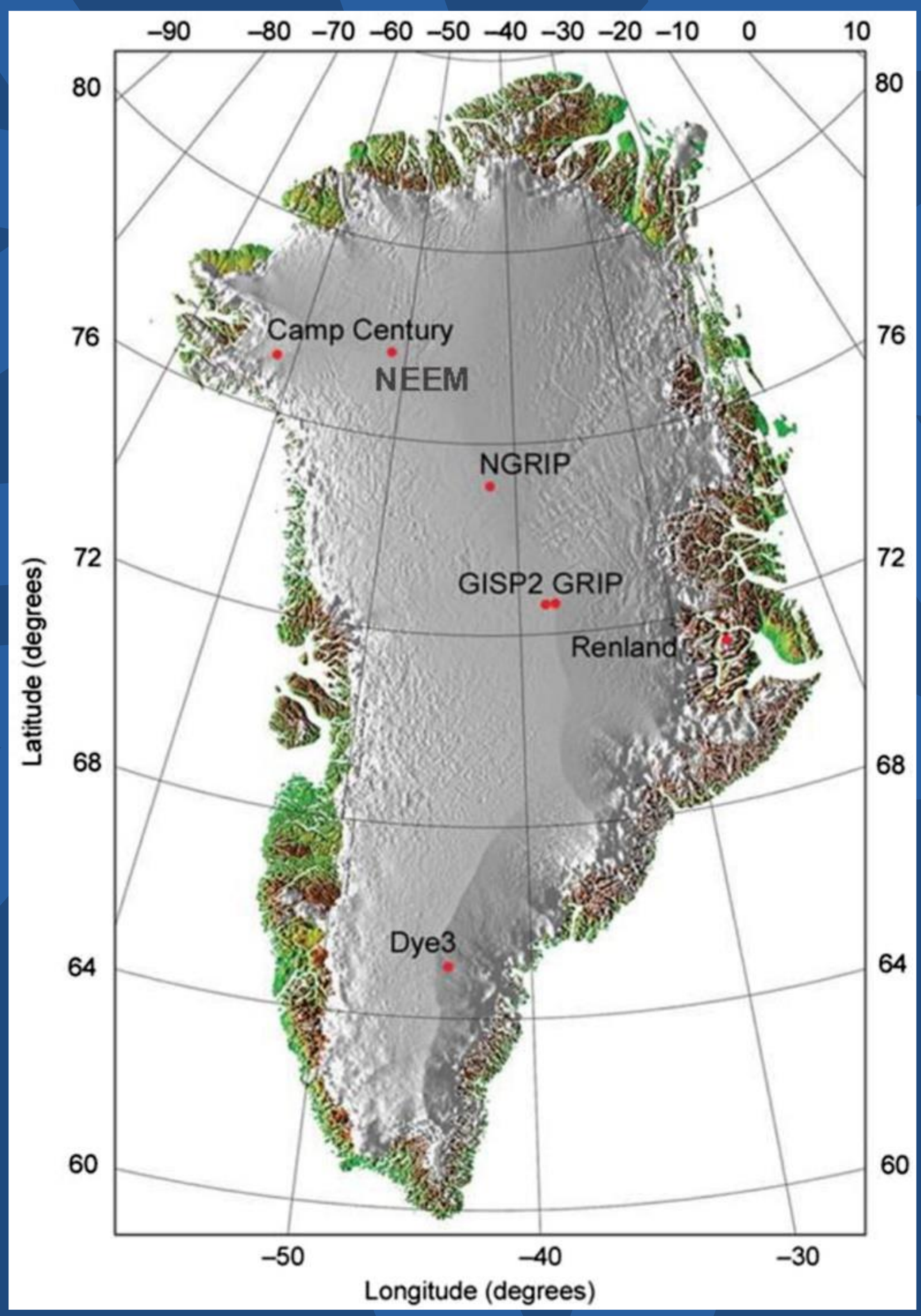


Figure 1. Sample areas in Greenland[8]

What drives aerosol seasonality?

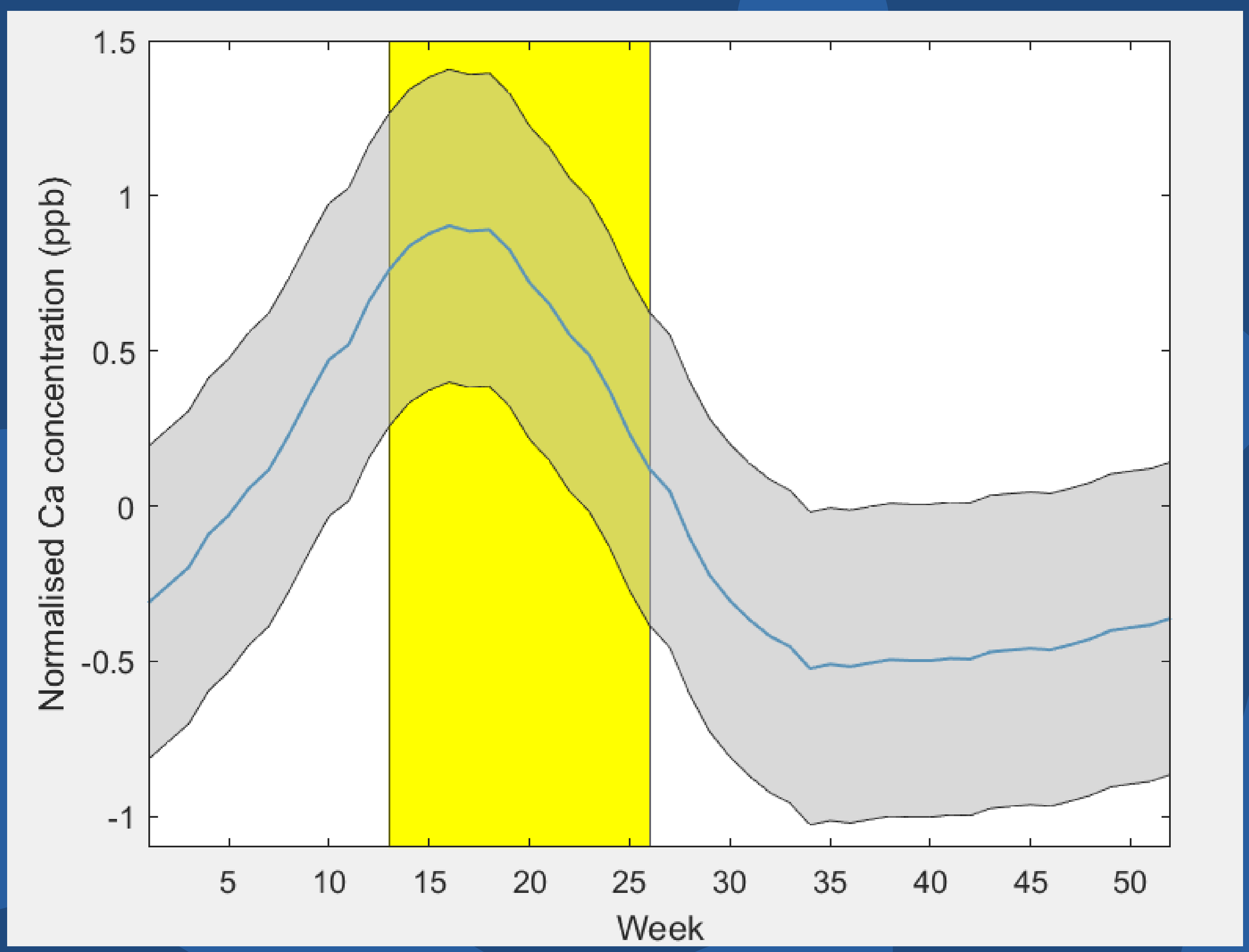
Aerosol seasonality is driven by the seasonal variability of air masses, dust sources, and atmospheric circulation patterns. The spring maximum in Ca^{2+} concentrations is primarily due to enhanced dust transport from Asian deserts - particularly the Takla Makan Desert – to the Greenland interior ice sheet by strong westerly winds[6].

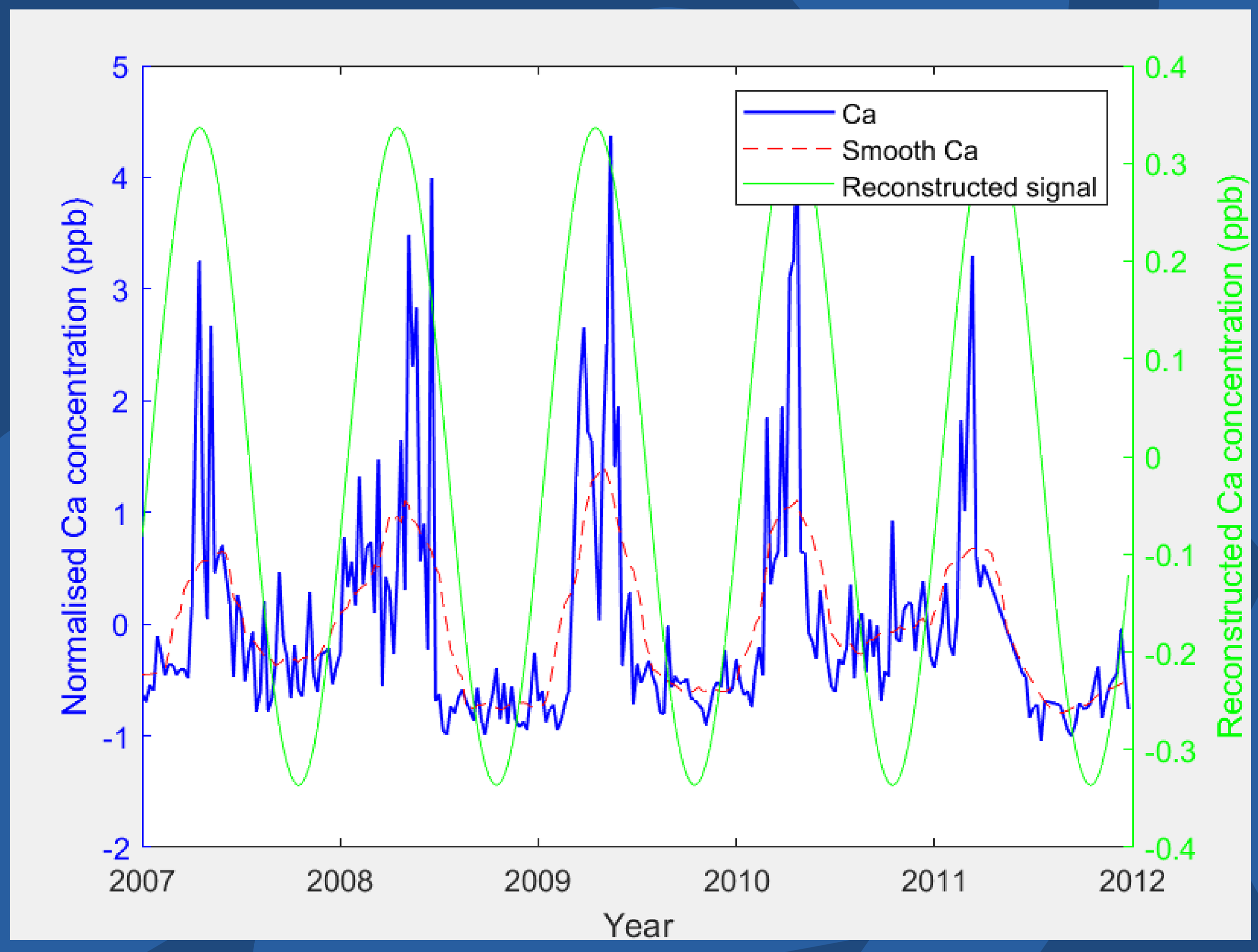
Data collection

Surface snow measurements were taken at the Summit Greenland Environmental Observatory 72° N, 38° W., 3250m above sea level, below 0 degrees all year.

Ice core data was collected from the North Eemian Ice Drilling (NEEM) camp, at 77˚N, 51 ˚W 650km from Summit[7]. See figure 1.

Both remote locations have low snow accumulation rates which experience little post depositional changes. This accurately represents the global seasonality of the aerosols.





Results

Code Improvement:

Rewrote unclear and error-prone code, enhancing legibility through commenting (adding descriptions), version control (process of tracking and managing changes to code), and useful variable names.

These improvements laid the groundwork for easier future research.

Noise Reduction:

Previous analysis generated noisy outputs, obscuring true trends in the data.

Applied smoothing techniques that reduced noise while maintaining the data's periodicity and trends (as shown in both graphs).

Graphical Analysis:

Left: Displays the annual cycle of Ca^{2+} concentration, with a spring peak consistent with outside literature (highlighted in the yellow box)[9,10].

Right: Time series of Ca^{2+} in surface snow, clearly showing annual seasonality. Green line (FFT product) provides further evidence of this annual pattern.

References

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