# Remobilized volcanic ash may support autotrophic production in the oligotrophic subarctic Pacific Ocean

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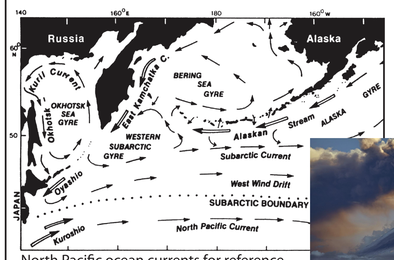
## Background

The subarctic Pacific Ocean is the second-largest HNLC regions on the planet, where terrigenous dust and volcanic ash can provide iron and other autotrophy-limiting nutrients (Martin et al. 1991, Boyd et al. 2007). Remobilized volcanic ash, or ash swept off the flanks of volcanoes after it has been deposited by an initial erruption, is a newly recognized potential source of such nutrients in the region. However, it is unknown whether this aged material can stimulate primary production the way newly errupted ash (Hamme et al. 2010), or wind-blown dust does (Bishop et al. 2002).

***We conducted a preliminary assessment of the impact that remobilized ash from the volcano Shiveluch has on primary production off the Kamchatka Peninsula.***

## Methods




North Pacific ocean currents for reference, from Harrison et al. 1999

The volcano Shiveluch, russia-ic.com

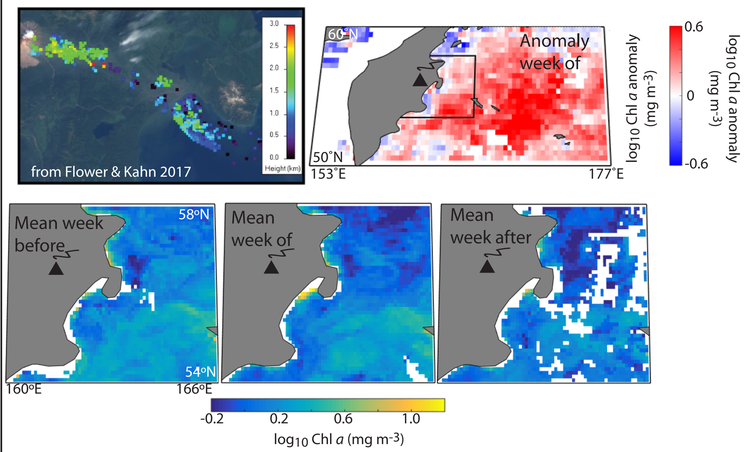
**Identifying remobilized ash plumes:** Flower & Kahn (2017) used NASA's Multi-angle Imaging Spectroradiometer (MISR) satellite to identify remobilized ash events from multiple volcanoes, including Shiveluch. Remobilized plumes were distinguished from emitted plumes by their lower height, topographic control of dispersion, and particle properties including consistent size throughout the plume, low light absorption, and high angularity.

**Estimating primary production:** Sea surface chlorophyll *a* concentration, from NASA's Moderate Resolution Imaging Spectroradiometer satellite (MODIS Aqua, daily Level 3 data, oceancolor.gsfc.nasa.gov), was used as a proxy for autotrophic phytoplankton biomass accumulation. We calculated daily, weekly and monthly mean chlorophyll *a* concentrations, as well as anomalies from the climatological mean. We used both 9 km and 36 km resolution data.

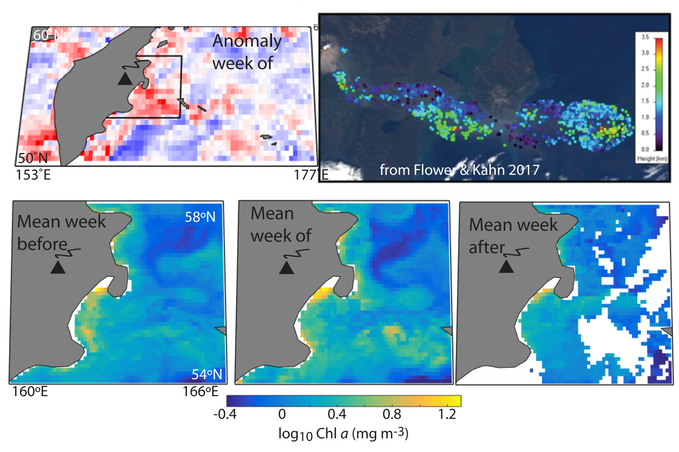
***We assessed sea surface chlorophyll a concentration and anomaly before, during and after five remobilized ash events, originating at Mt. Shiveluch, and deposited at the sea surface.***

## Results

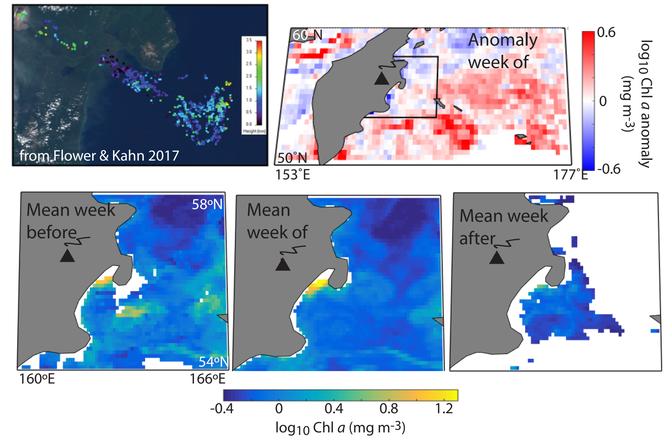
### 27 August 2008




### 16 September 2015

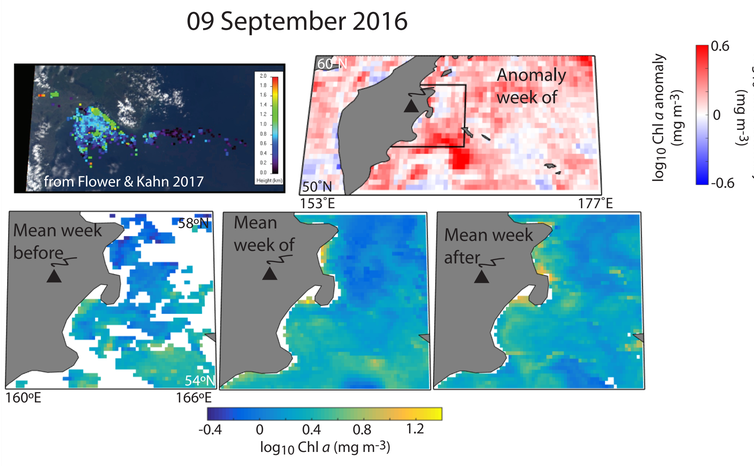



### 25 July 2016

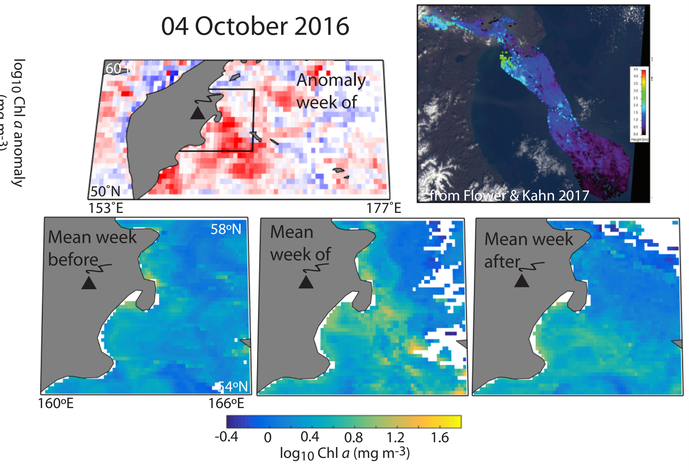



Four of the five remobilized ash events coincided with significant (more than one standard deviation above the 2003-2016 mean) positive chlorophyll *a* anomalies proximal to the ash deposition area (all but 25 July 2016). The positive anomaly during the week of the 27 August 2008 event was much more widespread than the area impacted by the plume, likely indicating another oceanographic driver at work. The event on 04 October 2016 had the largest ocean footprint, and was reflected clearly in the weekly mean chlorophyll *a* and anomaly plots .

### 09 September 2016




### 04 October 2016




## What next?

*These preliminary results provide the basis for a proposed project to investigate the composition of different terrigenous nutrient sources and their relative impact on cultured organisms, as well as to conduct a comprehensive survey of remobilized ash plumes and their impacts on primary production throughout the subarctic Pacific Ocean and Bering Sea.*

**Geochemical experiments:** Particle characterization and leaching experiments will be conducted to determine the amount, types and bioavailability of nutrients contained in dust from multiple geographic and geologic origins, as well as in volcanic ash at different stages of weathering.

**Microplankton culturing experiments:** Growth experiments will be conducted to learn about the impact of these nutrient sources on autotrophic and mixotrophic microplankton. We will measure cell health, growth and physiological response under different nutrient source treatments, including type and quantity.

**Scaling up:** We will scale the geochemical and culturing experiments up to test whether the estimated impact of deposition events detected in the MISR satellite record matches the apparent change in chlorophyll *a* concentrations from the SeaWiFS and MODIS satellite records.

***Schematic: scaling up***

Mass of available nutrients ($M_a$) per mass of parent material ($M_p$), $gM_a/gM_p$ *from leaching experiments*

Parent material ($M_p$) per event *from MISR satellite observations*

Phytoplankton biomass increase ($X$) per mass of available nutrients added ($M_a$), $X/gM_a$ *from culturing experiments*

$$gM_a/gM_p \times M_p \times X/gM_a = X_{predicted}$$

*compare*

$X_{observed}$ Observed increase in phytoplankton biomass, *from SeaWiFS & MODIS satellite observations*

**Alternative hypotheses:** For each deposition event considered, we will investigate other potential drivers of change in sea surface chlorophyll concentrations, including oceanographic features (e.g. fronts, upwelling regions), and changes in surface winds and temperature.

***This project will enable us to scale from laboratory experiments to the subarctic Pacific Ocean and Bering Sea, ultimately quantifying micronutrient deposition from different sources, and the coinciding ecological responses.***

Support for this proposed project is currently pending (B.G. Koffman & M.W. Lomas, NSF Arctic Natural Sciences)