The Incorporation of Volcanic Ash into the CESM

2023 CESM Atmosphere Working Group

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Motivation

Volcanic emissions are recognized for their impact on the Earth system

Studies have focused primarily on the sulfuric emissions

Ash’s impact to the earth system has not been widely recognized, and it has not been incorporated into global earth system models such as the CESM

Eyjafjallajokull 2010 eruption
Source: Flickr Creative Commons

Ash Impacts

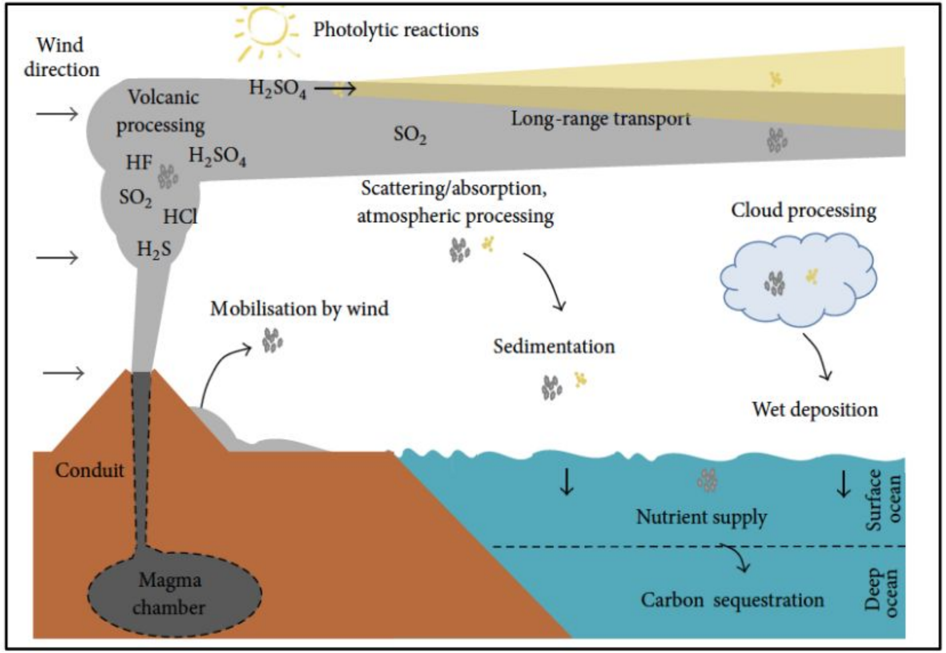
Want to quantify the impacts of ash to determine if it should be included in climate models

- Biogeochemistry
- Air quality (human health, transportation, economic impact)
- Weather and climate

Project Overview

This large scale interdisciplinary project focuses on volcanic ash, by combining remote sensing, in situ chemistry, and earth system models

My role: incorporate a volcanic ash tracer into the CESM



Project Steps

Incorporate volcanic ash tracer into CESM

Generate and run model with input files for the 2010 eruption of Eyjafjallajökull (Eyja) in Iceland

Compare model output with remote sensing data, in situ data, and previous model results

Tune model accordingly

Look at impact on radiative forcing, regional weather, and ocean biogeochemistry

Framework for modelling volcanic ash

Community Earth System Model (CESM2)

Community Atmosphere Model (CAM6) - speciated dust version (Li et al., 2020)

Modal Aerosol Model (MAM4)

Mechanism of Intermediate Complexity for Modelling Iron (MIMI) (Hamilton et al., 2018)

Biogeochemical Elemental Cycle (BEC)

NCAR

Modelling Steps

1. Begin by altering an existing version of the model that has 8 dust tracers (Longlei Li, Rachel Scanza) and 8 iron tracers (Douglas Hamilton) such that four types of ash with different optical properties exist in model
2. Using eruptive data, create input files for various sizes and compositions of ash
3. Upon successful incorporation into the model, optimize the input files to best match the observations by including sub-daily data and various vertical distributions

Framework for ash tracers

Use existing framework of 8 dust tracers to incorporate several ash tracers

Separation of ash into several tracers will depend on the composition of the ash

Each tracer will require optics to be defined

```
/dust1_rrtmg_illite.nc:+',
/dust2_rrtmg_kaol.nc:+',
/dust3_rrtmg_mont.nc:+',
/dust4_rrtmg_hematite.nc:+',
/dust5_rrtmg_quartz.nc:+',
/dust6_rrtmg_calcite.nc:+',
/dust7_rrtmg_feldspar.nc:+',
/dust8_rrtmg_gypsum.nc:+',
```

Aerosol optics

Depending on optical properties of ash, net effect can be warming or cooling

8 initial optics for dust to choose from

Condense dust tracers to leave room for 4 optically or chemically distinct types of ash

- Calcite must be left separate for chemistry
- Feldspar must be kept separate for ice nucleation
- Iron bearing aerosols should be separated for biogeochemistry effects

Iron bearing/dark, bright, feldspar, and salts

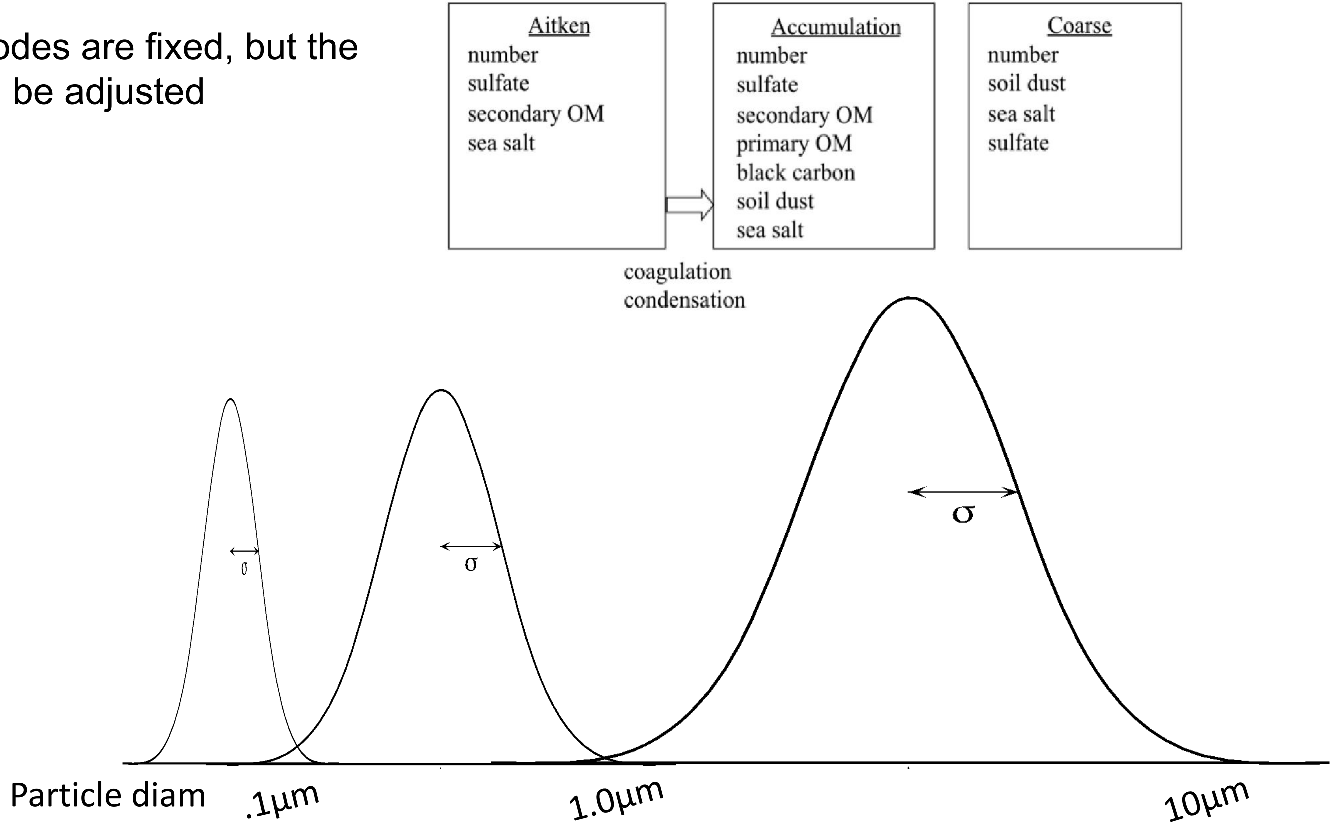
Original	New	Optics
Illite	Ash 1 : Iron bearing & dark glass	Hematite
Kaolinite	Ash 2 : Bright mineralogy	Quartz
Smectite (mont)	Ash 3 : Volcanic feldspar	Feldspar
Hematite	Ash 4 : Salts	Quartz
Quartz	Hematite	Hematite
Calcite	Calcite	Calcite
Feldspar	Feldspar	Feldspar
Gypsum	Other (Illite, Kaol, Mont, Quartz, Gypsum)	Quartz

Modal Aerosol Model (MAM4)

Standard deviation of the modes are fixed, but the center of the distribution can be adjusted

My current distribution :
98.9 % coarse
1 % accumulation
0.1% aitken

Future addition:
extra coarse mode
(Longei Li is incorporating
extra coarse mode from
Xiaohong Liu's group)



Figures courtesy of R. Scanza

Composition

Glass %	Feldspar %	CPx %	Opx %	Amph %	Oliv %	SiO2 %	FeOx %	Salts %	Phosphate	Other %	ID1	Other 2 '	ID2
35.6	24.0	21.0	0.0	0.0	0.0	3.0	4.4	0.0	2.6	9.3	Analcime	0.0	
40.0	37.6	12.8	5.3	0.0	1.3	0.0	3.0	0.0	0.0	0.0		0	

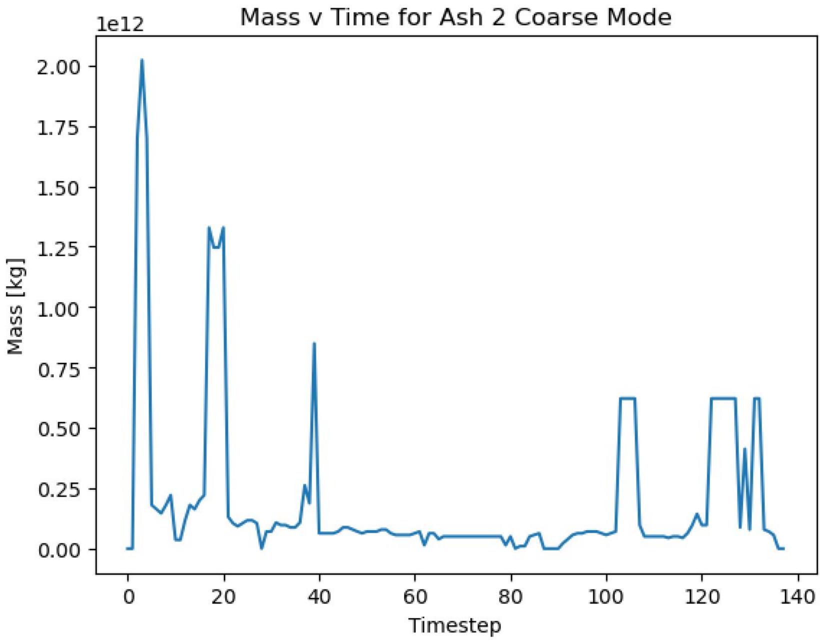
Tracers	Quantity	Optics
Ash 1 : Iron bearing & dark glass	CPx + FeOx = 25.4 %	Hematite
Ash 2 : Bright mineralogy	Glass + SiO2 + Other + Phos = 50.5 %	Quartz
Ash 3 : Volcanic feldspar	Feldspar = 24%	Feldspar
Ash 4 : Salts	Salts = 0%	Quartz

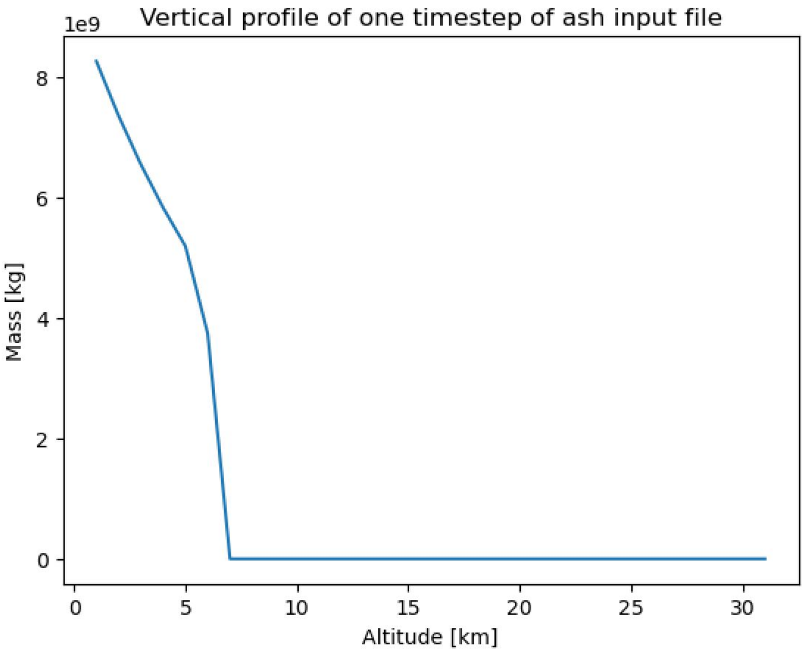
Composition provided by Adrian Hornby

Plot of input mass v time, plumeheight v time

Federico Galetto, Eruption at basaltic calderas forecast by magma flow rate
DOI:10.1038/s41561-022-00960-z

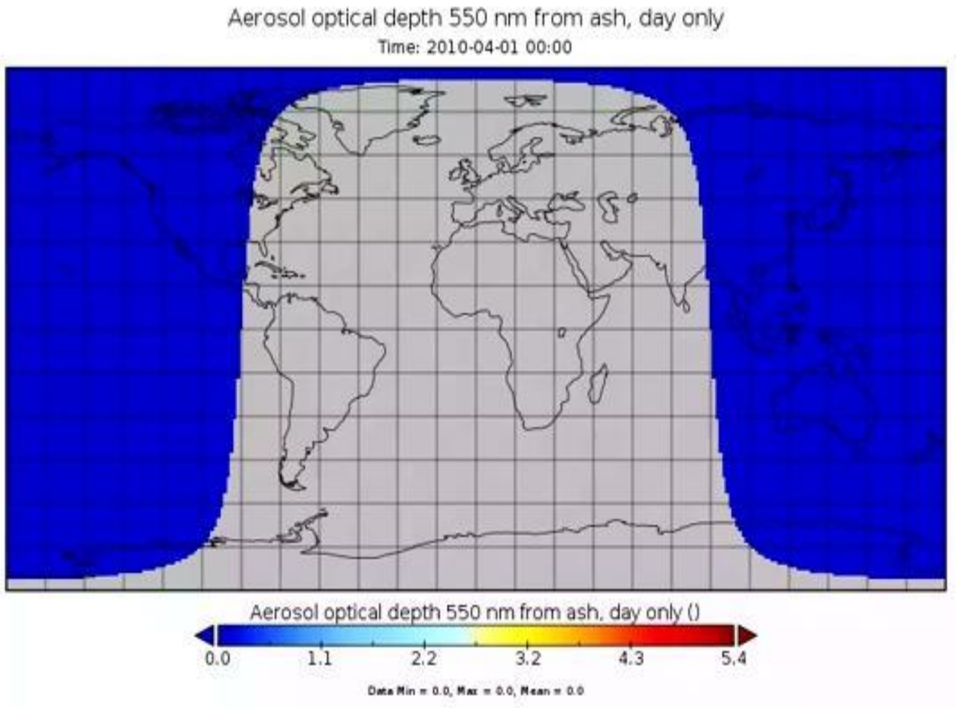
Input file for ash2 coarse mode



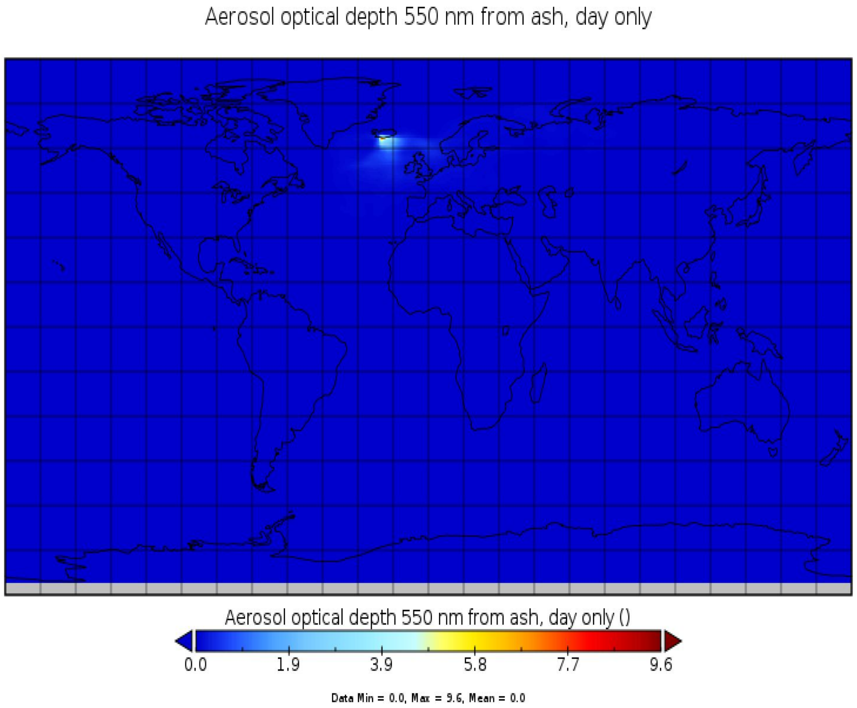


Current model simulation

Video of ash transport

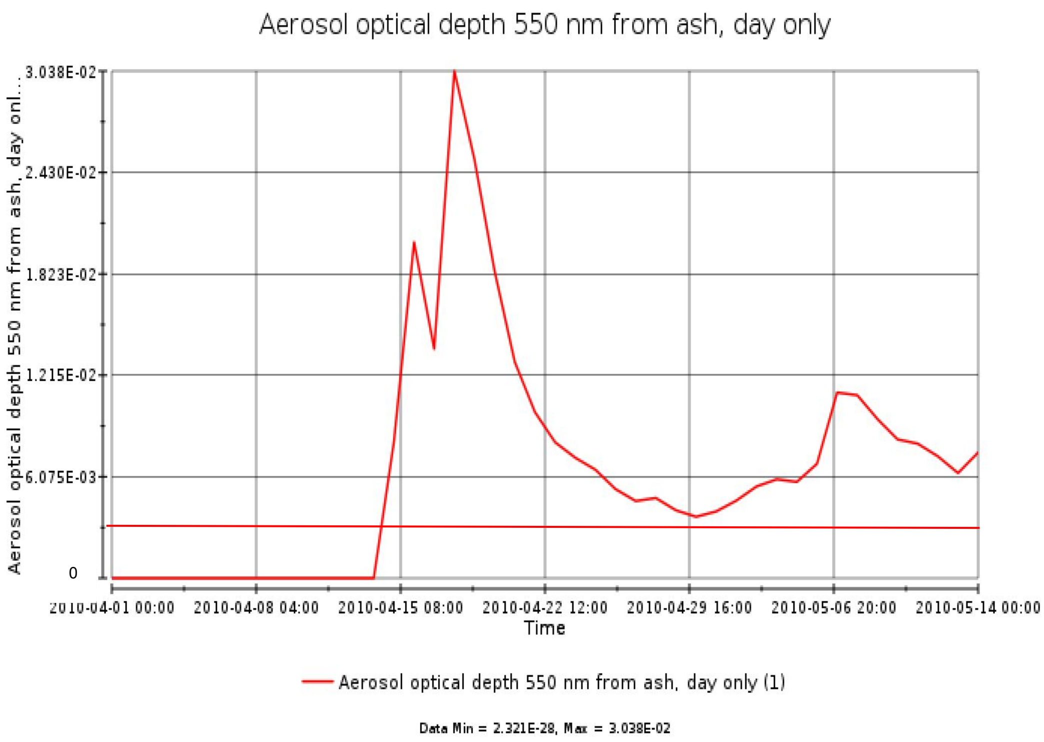


Average AOD spatial distribution



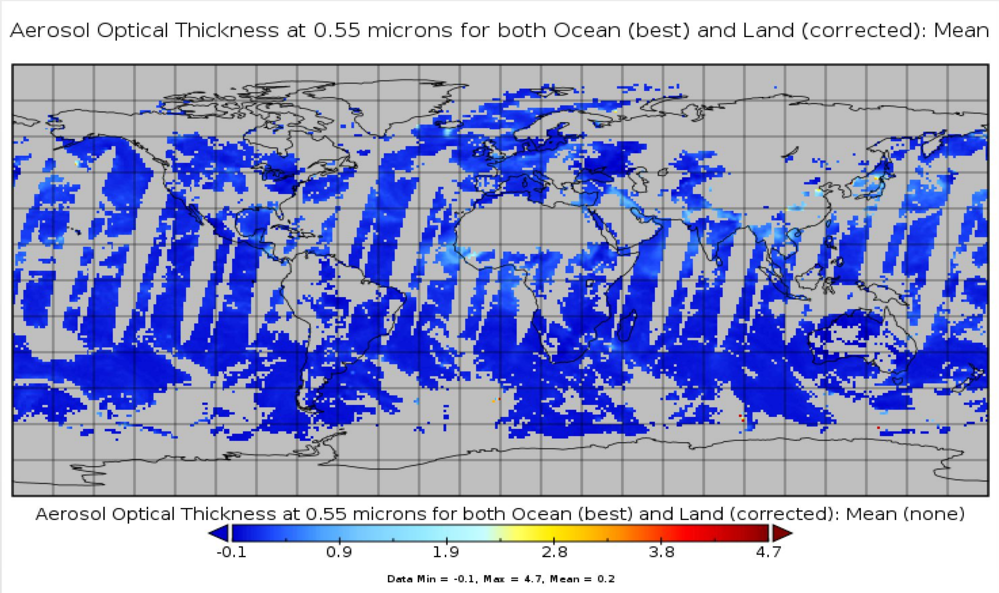
Globally averaged AOD for ash for all dates of model run: AODASH = 0.006475105

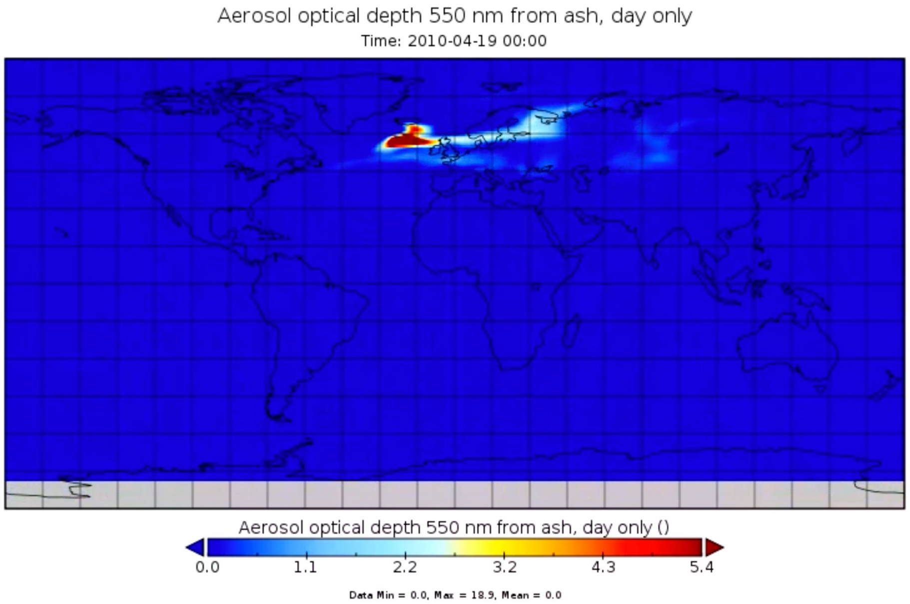
AOD over time



Globally averaged AOD for ash for all dates of model run: AODASH = 0.006475105

Plumes April 19 2010





Next Steps

Conducting a literature review to gather observational and model data for comparisons

Tune the model according to observations

Quantify impacts

Thank You