Responding to volcanic eruptions

Claire Witham

Met Office

ADMLC Seminar 2020

Met Office

Content

- Why is a modelling response needed?
- The response process
- Modelling requirements
- Key uncertainties in different components

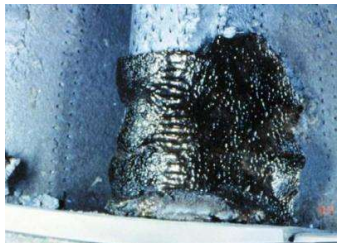
For the sake of time I will only focus on ash not gases

Met Office

Why is a response needed?

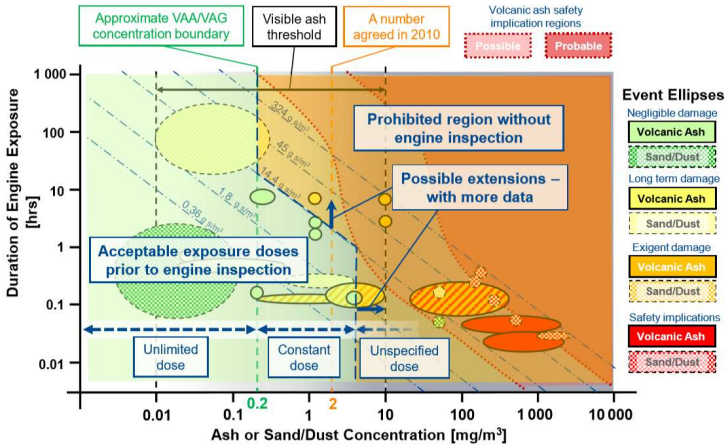
- Volcanic ash is damaging to aircraft engines, airframes etc
- Forecasts are needed out to 18+ hrs to allow flight planning by airlines to enable rerouting and/or flight changes
- Timeliness is essential

Melted volcanic glass on turbine blade



Abraded windscreen (Redoubt, 1989)

Image credits: USGS



R. Clarkson 2019

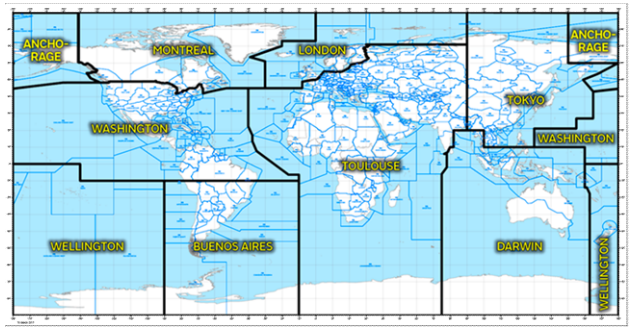
© 2019 Rolls-Royce plc

Met Office

Response Context

International

- Regulations, including products, stipulated by the International Civil Aviation Organization
- 9 designated Volcanic Ash Advisory Centres (VAACs) since mid 1990s
- Paid for by on-route charging of airlines
- VAACs provide **advice** to the wider aviation industry



Europe

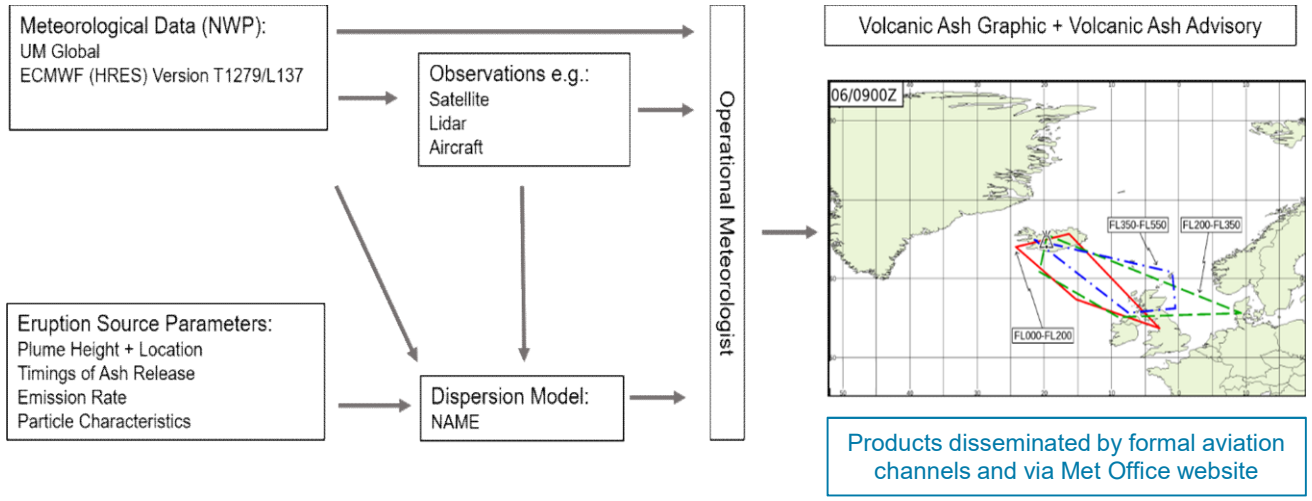
- Since 2010 ash concentration charts provided as supplementary material

National

- UK Government interested in impacts on UK
- Also on eruptions that affect UK nationals abroad, e.g. eruption of Mt Agung on Bali, and islands like the Falklands
- Possibility of SAGE being held

Met Office

Response Process



Met Office

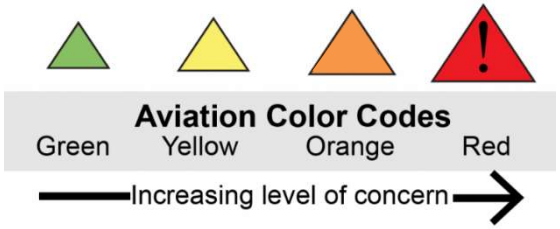
Modelling requirements

- Long-range:
  1000s km → hemisphere
  - Hence requires global meteorology
- Large altitude range:
  surface up to 30+ km
- Runs instantly on demand
- Relatively fast:
  18 hr forecast in ~5 mins
- Ability to represent particulate properties (e.g. size, density)

Eight of the VAACs use Langrangian models, one uses an Eulerian model

Simple schematic of a Lagrangian model simulation

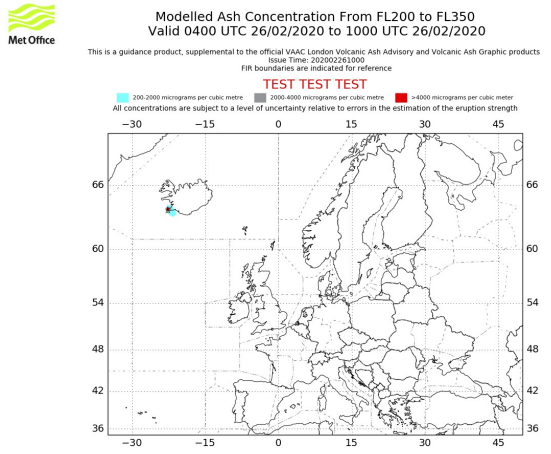
Uncertainties: unrest



- There may be warning...
- Similar approach to “planning phase”
- Using eruption scenarios to assess the hazard
  - Daily “what if”
  - Probabilistic
- Scenarios often determined based on previous eruptive history

Advisory measures: Avoid flying less than 4000 FT above vertical limits during eruption

Volcano name	SI Volcano name	ICAO code	Lat (Nggmm)	Long (Wggmm)	Height (ASL) meters	Height (ASL) feet	Reasonable Worst Vertical Limits* km	Reasonable Worst Vertical Limits* thous. Feet	Most likely Vert. Limits km
Askja	Askja	373060	N6503	W01647	1516	4974	35	115	3-12
Bárðarbunga	Bardarbunga	373030	N6438	W01730	2000	6562	25	82	3-12
Brennisteinsfjöll	Brennisteinsfjoll	371040	N6357	W02145	610	2001	5	16	1-5
Eldey	Eldey	371022	N6344	W02300	70	230	15	49	3-10
Esjufjöll	Esjufjoll	374020	N6417	W01635	1745	5725	15	49	3-12
Eyjafjallajökull	Eyjafjallajokull	372020	N6338	W01938	1651	5417	25	82	3-12
Fremrinámar	Fremrinamar	373070	N6526	W01640	970	3182	5	16	1-5
Grímsnes	Grimsnes	371060	N6403	W02053	200	656	5	16	1-5
Grímsvötn	Grimsvotn	373010	N6425	W01720	1722	5650	25	82	3-12
Heidarspordar	Heidarspordar	373082	N6535	W01649	490	1608	5	16	1-5
Hekla	Hekla	372070	N6360	W01940	1490	4888	35	115	10-25
Helgrindur	Helgrindur	370020	N6452	W02315	986	3235	5	16	1-5
Hengill	Hengill	371050	N6405	W02118	803	2635	5	16	1-5
Hofsjökull	Hofsjokull	371090	N6448	W01854	1795	5889	Unknown	Unknown	unknow
Hrómundartindur	Hromundartindur	371051	N6404	W02112	550	1804	5	16	1-5
Katla	Katla	372030	N6338	W01907	1490	4888	35	115	10-25
Krafla	Krafla	373080	N6543	W01647	800	2625	15	49	1-5
Krýsuvík	Krisuvik	371030	N6355	W02204	360	1181	5	16	1-5
Kverkfjöll	Kverkfjoll	373050	N6439	W01640	1933	6342	25	82	3-12
Langjökull	Hveravellir	371080	N6451	W01947	1435	4708	Unknown	Unknown	unknow
Ljósufjöll	Ljosufjoll	370030	N6455	W02238	1083	3488	5	16	1-5
Prestahnúkur	Prestahnukur	371070	N6436	W02038	1385	4544	5	16	1-5
Reykjanes	Reykjanes	371020	N6349	W02243	140	459	15	49	3-10
Snæfell	Snaefell	374801	N6448	W01534	1833	6014	15	49	3-12
Snæfellsjökull	Snaefellsjokull	370010	N6448	W02347	1446	4744	25	82	3-12
Tindfjallajökull	Tindfjallajokull	372040	N6347	W01934	1464	4803	25	82	3-12
Torfajökull	Torfajokull	372050	N6356	W01908	1190	3904	25	82	3-12
Tungnafellsjökull	Tungnafellsjokull	373040	N6445	W01755	1523	4997	Unknown	Unknown	unknow
Vestmannaeyjar	Vestmannaeyjar	372010	N6325	W02021	283	928	15	49	3-10
Þeistareykir	Theistareykjr	373090	N6553	W01658	540	1772	5	16	1-5
Þórðarhyrna	Thordarhyrna	373012	N6416	W01737	1650	5413	25	82	3-12
Öræfajökull	Oraefajokull	374010	N6400	W01639	2110	6923	35	115	3-12
Beerenberg	*Beerenberg*	376010	N7105	W00808	2085	6841	25	82	3-15



Scenario simulation for recent unrest on Reykjanes peninsula

Met Office

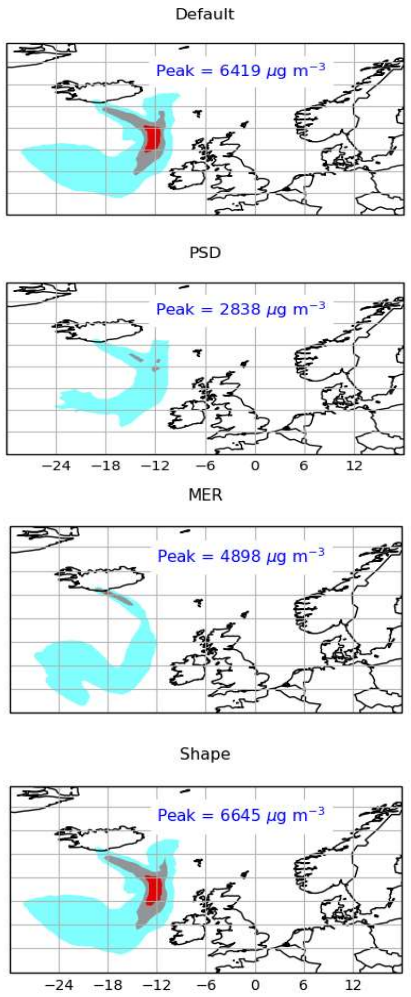
Uncertainties: source

Need to define the “Eruption Source Parameters (ESP)”

Uncertainties: source

Need to define the “Eruption Source Parameters (ESP)”

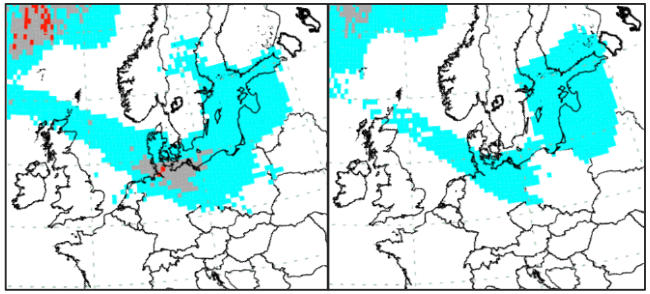
- +ve: the material is known
- -ve: unlikely to know how much or its properties (at least initially)
- Location, time and height are fundamental
- But for quantitative outputs, we need an estimate of the mass/flux
  - Cannot be directly measured
  - → Development of new plume modelling tools and observation techniques



Met Office

Uncertainties: meteorology

- Errors in positioning and timing of fronts and pressure systems can lead to ash being forecast in the wrong location



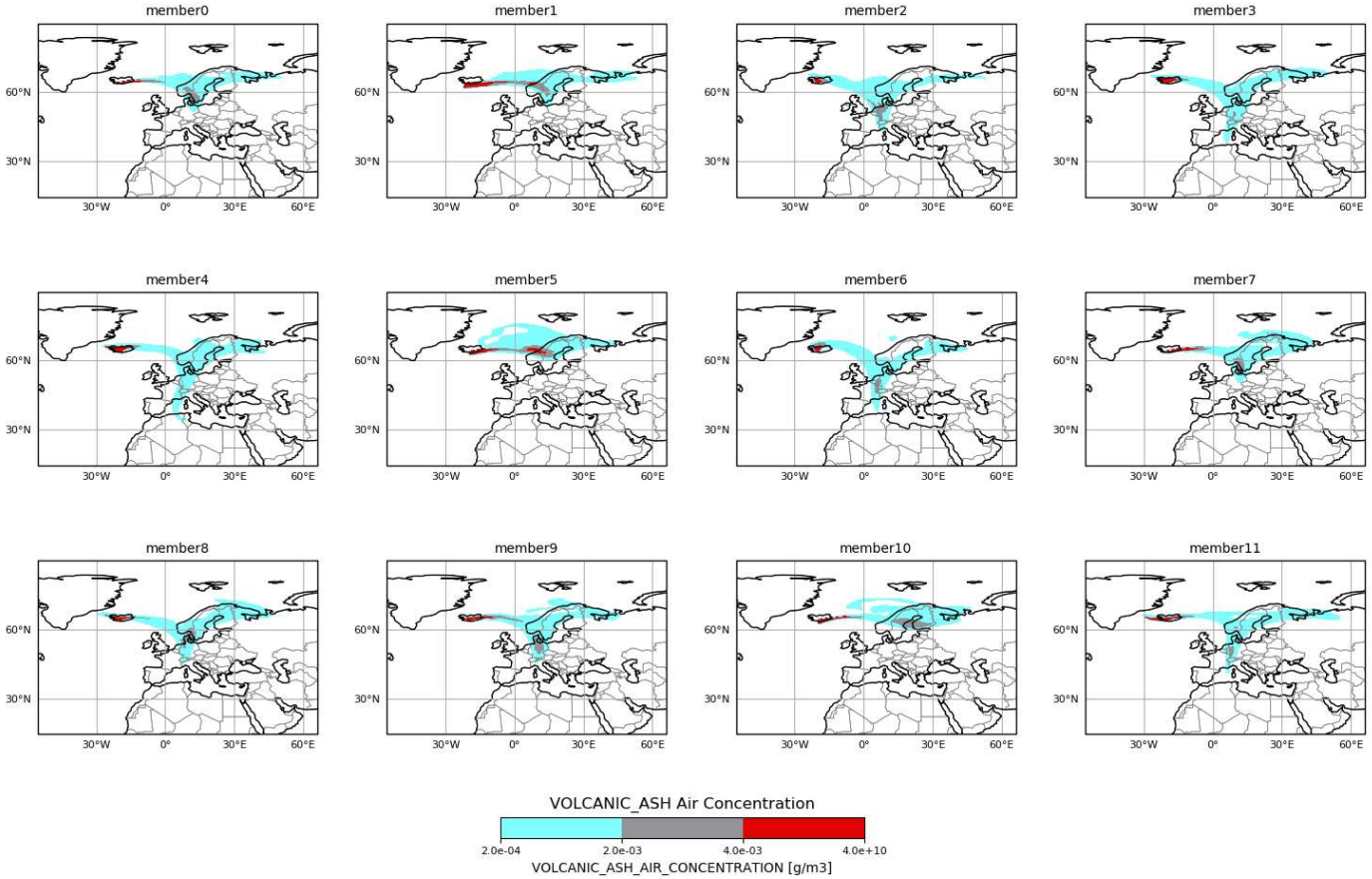
Met data 1 Met data 2

Real example from Grimsvotn 2011

- Such meteorological uncertainty can be represented by an ensemble of NWP forecasts

Met Office

12 ensemble members using the same source term but different NWP



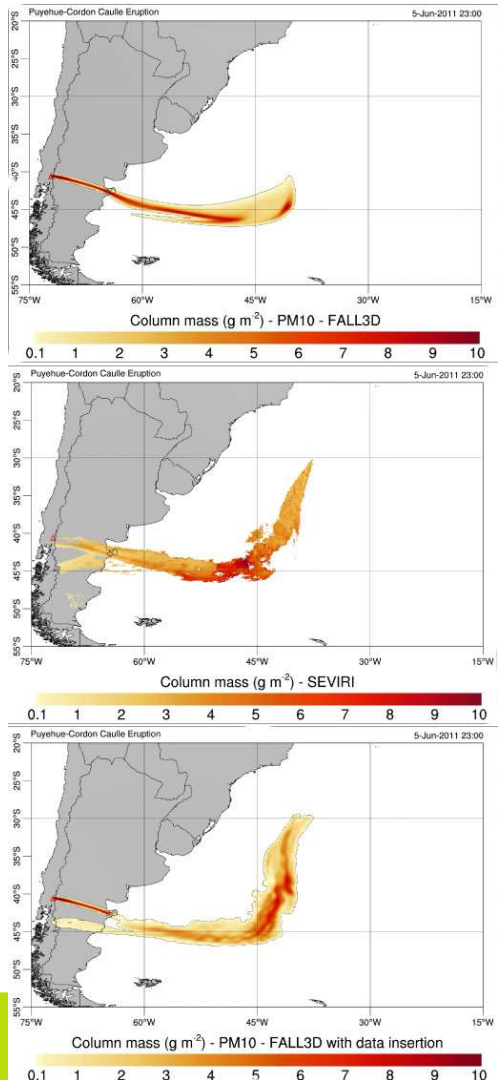
Use of measurements

Key tools:

- Satellite | Radar | Lidar

Uses:

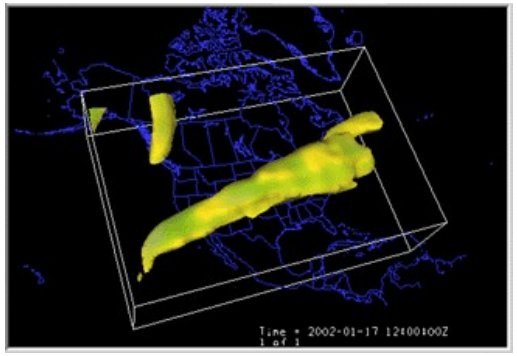
- Detection of erupted material
- Verification of model forecasts
- Modifying model results (e.g. data assimilation)
- Informing model sources (e.g. inversion)



Example data for Puyehue-Cordon Caulle 2011 courtesy of Arnau Folch and Solidad Osores

The future

- Aviation requirements demand the production of quantitative ash concentration products globally by the mid 2020s
- This is a 4-dimensional issue



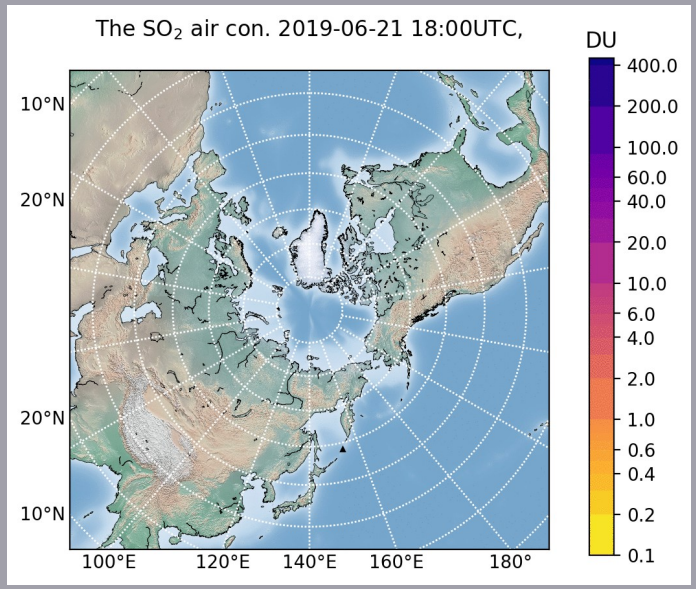
Illustrative example from unidata IDV

Challenges and cross-cutting topics:

- Quantitative source information
- How to capture uncertainty
- How to present and communicate this uncertainty (both in data and map form)
- Ensuring consistency between different centres
- Introducing more complexity to models
- Combining models, including for inputs and impacts

Met Office

Questions?



The plume from the June 2019 eruption of Raikoke volcano modelled using the Met Office's NAME dispersion model. Credit: Hans de Leeuw, VPLUS project