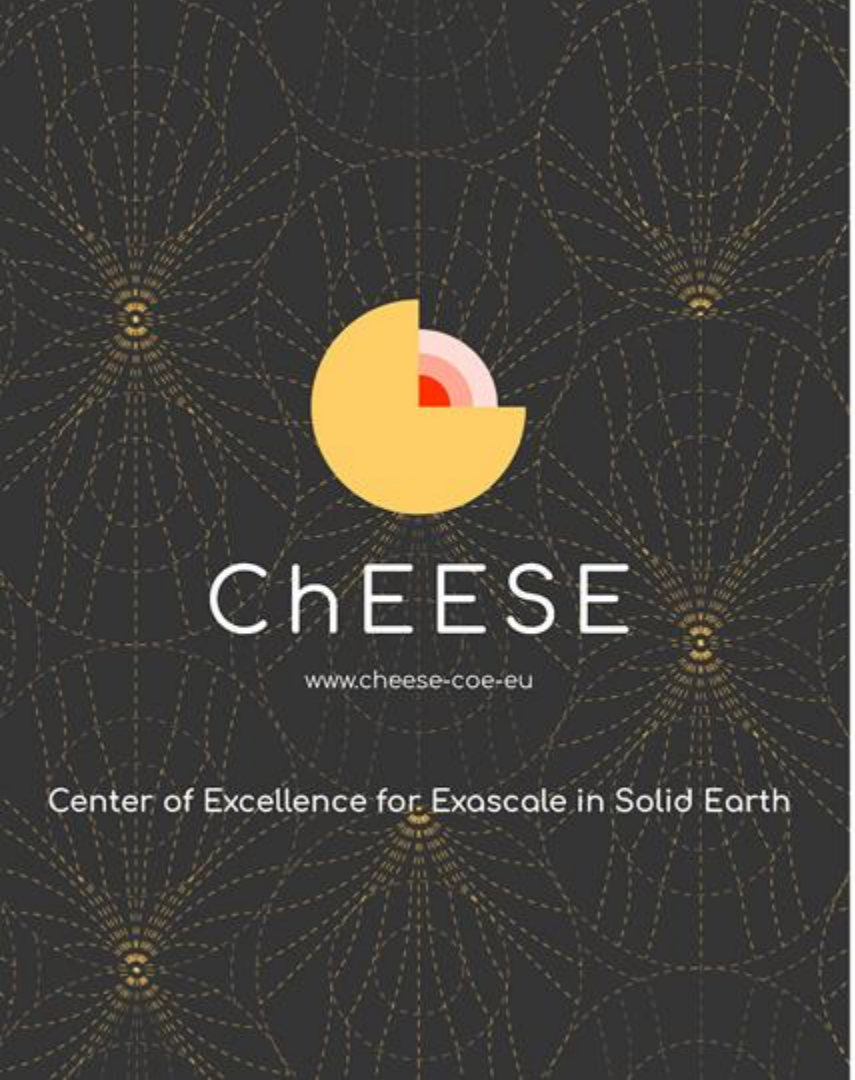

Assessing potential impacts on the air traffic routes due to an ash-producing eruption on Jan Mayen Island (Norway)

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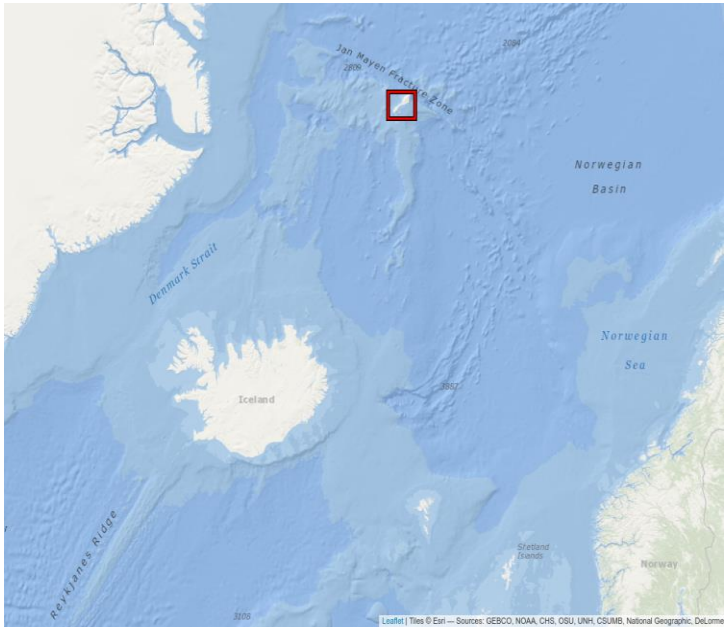
Outline

- Introduction
- Jan Mayen volcanism
- Probabilistic Volcanic Hazard Assessment (PVHA)
- Results: airborne tephra concentration on arctic and north-Atlantic air routes

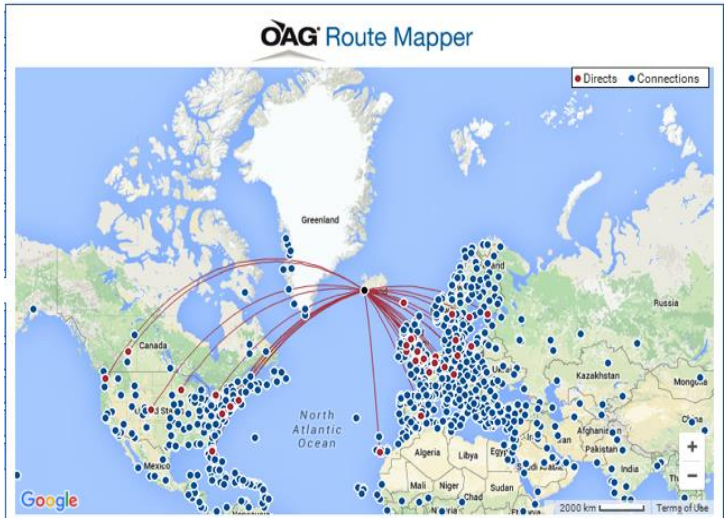
1. Introduction: Jan Mayen

- Norwegian volcanic island located in the North-Atlantic Ocean at 71° N, 8° W (around 600 km north of Iceland, in the Norwegian Greenland Sea).
- Considered as the world's northern most active subaerial volcano (Beerenberg)
- Potential impacts, especially those related to volcanic ash cloud dispersal, since it is located under air traffic routes in the Arctic Sea.



1. Introduction: Jan Mayen

- More than 181300 flights and almost 10 millions of passengers passing through the Keflavik airport every year [ISAVIA].
- Air polar routes have shown a marked increase over the last years, increasing 15-fold between 2003 and 2015, and reaching more than 14000 flights per year since 2016 [NAV CANADA].

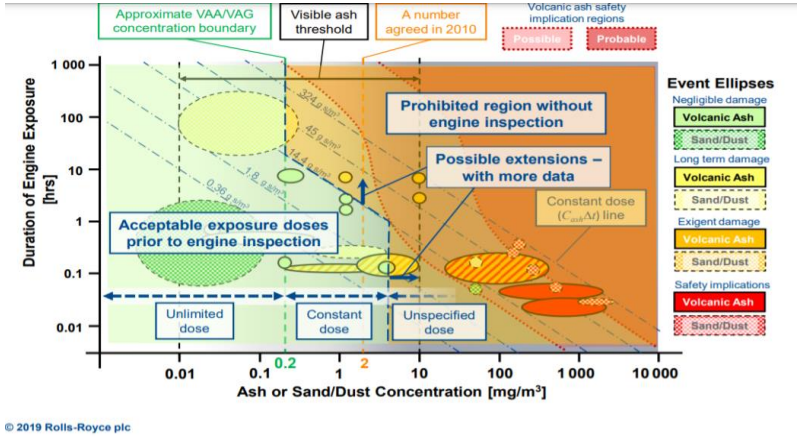


Direct and connecting flights from Keflavik Airport. Image obtained from CAPA - Centre for Aviation and OAG (Official Aviation Guide of the Airways). Direct flight cities are in red, connecting flights in blue.

ISAVIA (Iceland's civil air navigation services provider)
NAV CANADA (Canada's civil air navigation services provider)

1. Introduction: Purpose of the project

- To investigate and assess the **long-range** and **long-term** potential impact of an ash-rich eruption on the air traffic by using a numerical model (Fall3D) over a large domain with a very high spatial resolution



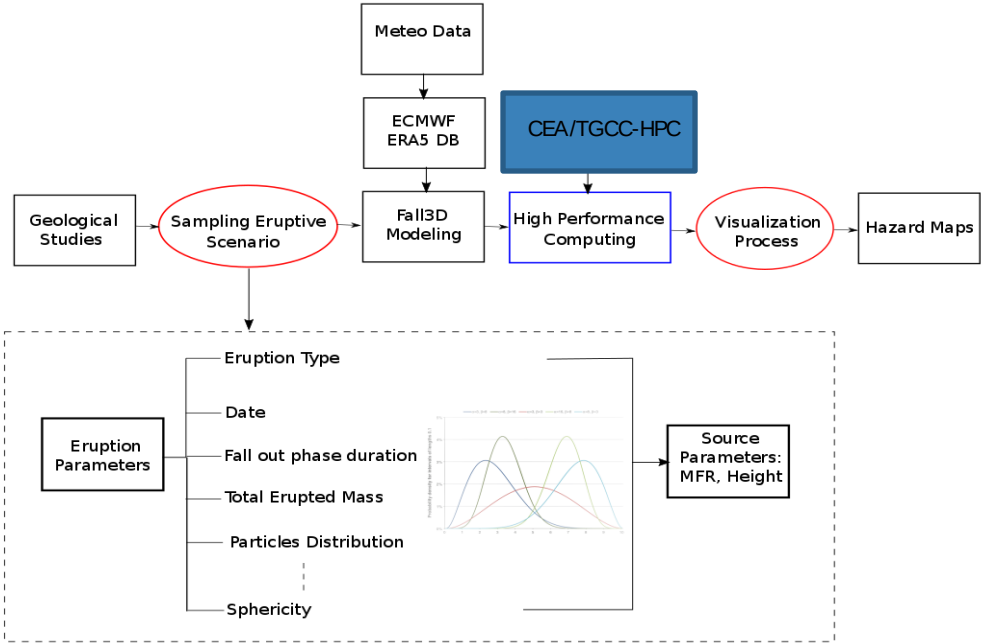
1. Introduction: Methods

- Probabilistic Volcanic Hazard Assessment to:
  - Account for the natural variability of volcanic processes and their intrinsic uncertainties
  - Evaluate the potential long-range and long-term impacts on air traffic

How ?

- **Averaging** thousand of numerical simulations (FALL3D model) in which eruption parameters are sampled within plausible ranges
- Delivering high resolution hazard **maps** over a 3D-grid covering a 2 Km-resolution 2000 km x 2000 km spatial domain
- Considering hourly estimation of a large number of atmospheric, land and oceanic climate variables (from the surface up to 45 km altitude)

1. Introduction: Methods



Workflow for Eruptive Source Parameter sampling

2. Jan Mayen volcanism

Possible Eruption	Total erupted Mass (km^3)	Eruption type	Duration of the eruption	Historical eruption
Small	Smaller than 0.1 **(10^7-10^8 kg)**	Small lava flows or small scoria cones	35 - 40 hours	1 out 5 (probability about 20%)
Moderate	0.1 - 0.5 **(10^8 –$10^{8.7}$ kg)**	Effusive and/or Volcanian to violent Strombolian. Surtseyan eruption	4 - 40 days	2-3 out of 5 (probability in the range 40-60%)
Large	Bigger than 0.5 **($10^{8.7}$–10^9 kg)**	Explosive and/or effusive activity	1 – 4 days	2-3 out of 5 (probability in the range 40-60%)

Summary of the possible eruption scenarios on Jan Mayen Island. The categorization is based on the volume of tephra emitted obtained from[1][2]

[1] Gjerløw, E., Haflidason, H., & Pedersen, R. B. (2016). Holocene explosive volcanism of the Jan Mayen (island) volcanic province, North-Atlantic. *Journal of Volcanology and Geothermal Research*, *321*, 31-43.
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2. Jan Mayen: fitting the PDF

Possible Eruption	Total erupted Mass (**km³**)	Eruption type	Duration of the eruption	Historical eruption
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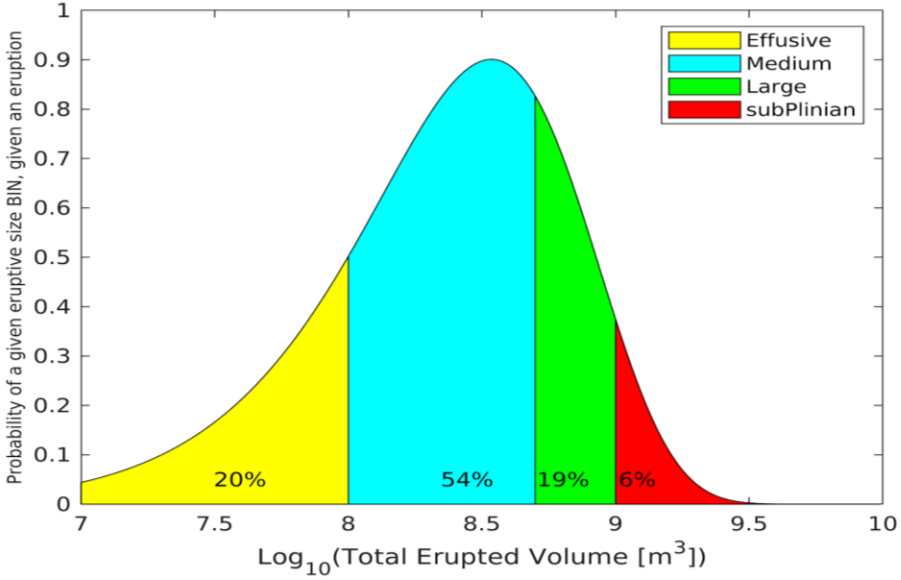
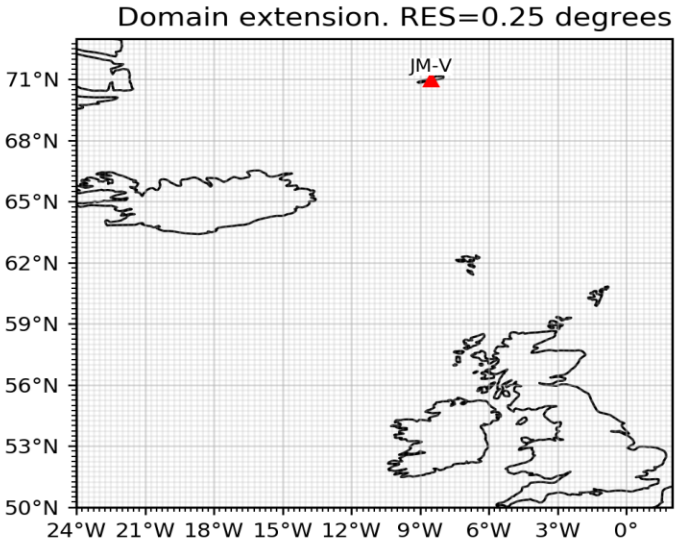


Weibull PDF (Probability Density Function) describing the conditional probability of different eruptive magnitudes in case of an eruption for Jan Mayen Island.

2. Jan Mayen: 3D computational domain



Selected domain for the Jan Mayen application. For visualization issues the grid was plotted with a resolution of 0.25 degrees (25 km). Red triangle indicates the location of Jan Mayen Island. Real resolution= 0.025 degrees

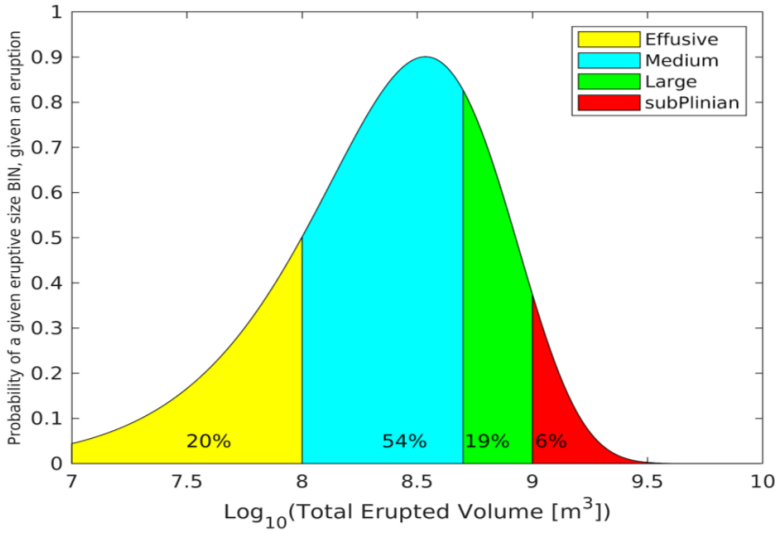
Computational domain:

	min	max	Res (resolution)
lat	50 N	73 N	0.025°(2.78 km)
lon	24 W	2 E	0.025°(0.81-1.79km)

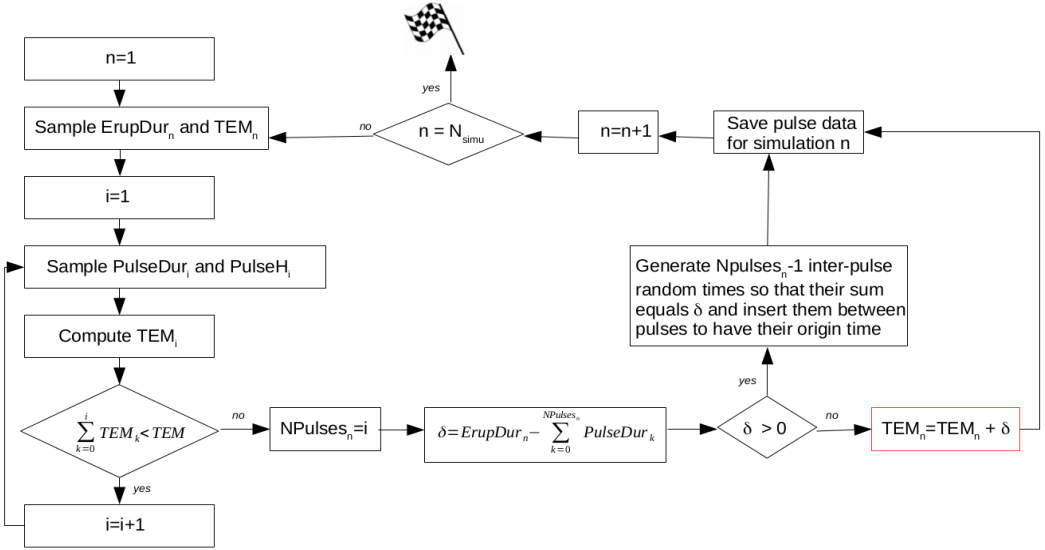
PVHA: Jan Mayen application

Size	Scenarios	Number of Fall3D Simulations
Medium	1500	3762 (375 continuous, 3387 pulses **)
Large	1500	1500

** According to [1], Medium eruptive size class is composed by phreatomagmatic pulses, w here in keeping w ith observations, each pulse could reach volcanic plumes betw een 3 and 11 km. Continuous means eruption w here there is no resting time betw een pulses.



3. PVHA: pulse sampling



Being: ErupDur (eruption duration), TEM (total erupted mass), PulseDur (pulse duration), PulseH (pulse height)

3. PVHA: meteo data

- ECMWF ERA5 reanalysis
- 3-H temporal resolution
- 20 years (1999–2019)

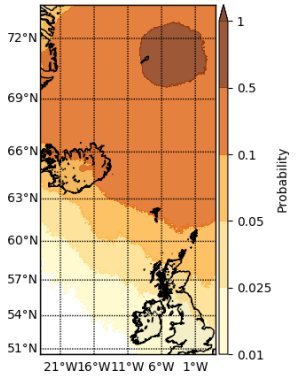
3. PVHA: eruptive parameters

Parameter	Eruption size	PDF type and parameters
Total erupted mass (Kg)[a]	Medium	Weibull on $[10^{8};10^{8.7}]$
	Large	Weibull on $[10^{8.7};10^{9}]$
Duration of fallout phase (hours)	Medium	Uniform on [96; 960] composed by pulses: Uniform on [12, 200]
	Large	Uniform on [24, 120]
Mass Eruption Rate (Kg/s)	Medium	$[3.009*10^{4};\ 1.5*10^{6}]$
	Large	$[6.94*10^{4};1.39*10^{6}]$
Total Grain Distribution modes (Φ − units)	Medium	Eggoya 1732 Surtseyan eruption reference
	Large	Grimsvötn 2004 eruption reference
Tephra Mass Fraction (%)	Medium	80
	Large	Uniform on [5; 10]

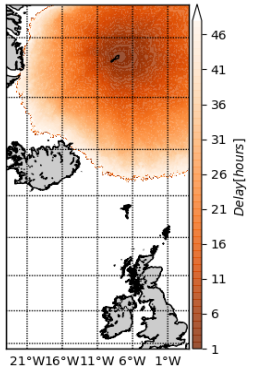
4. Results:

Results will be presented for both eruption sizes (Medium, Large) in two different probabilistic maps:

- Exceedance probability; i.e. the probability of reaching ash concentration above 2 mg/m3 or 4mg/m3 at different flight levels at some time during the eruption and 48 hours since its end

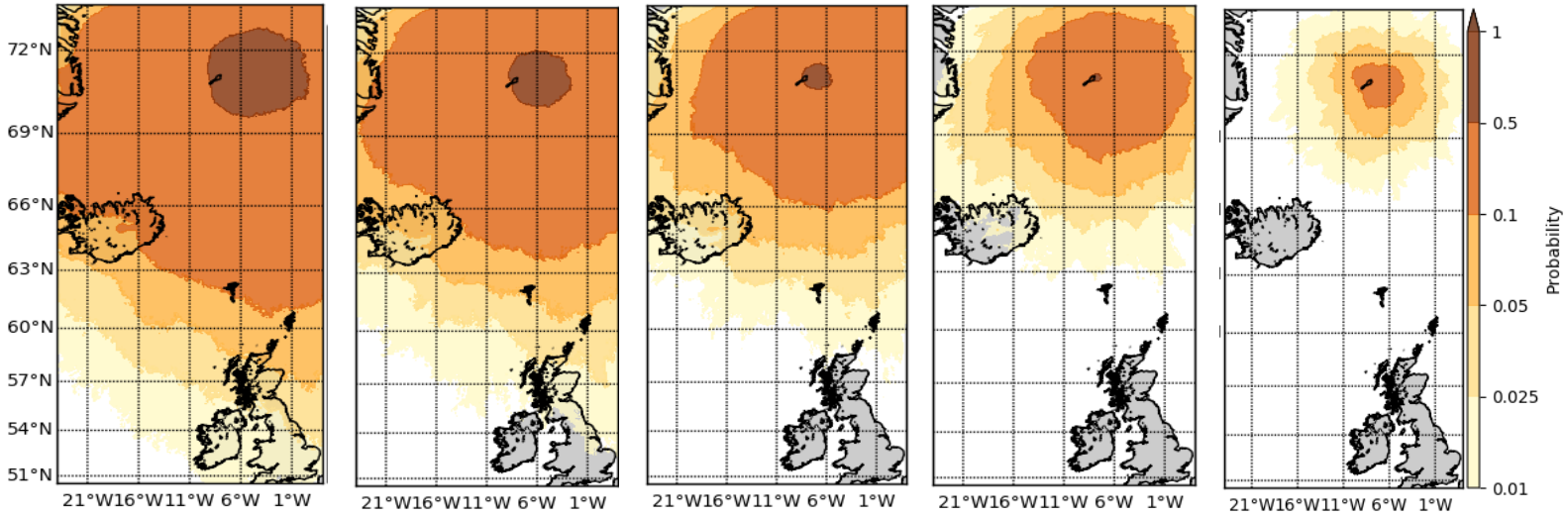


- Arrival time; i.e the expected time required for the ash concentration to exceed a threshold of 2 mg/m3 or 4mg/m3 with an exceedance probability of **5%** at different flight levels between 0 and 48 hours after eruption



4. Ash concentration (2mg/m3). 5000 feet. Large eruption

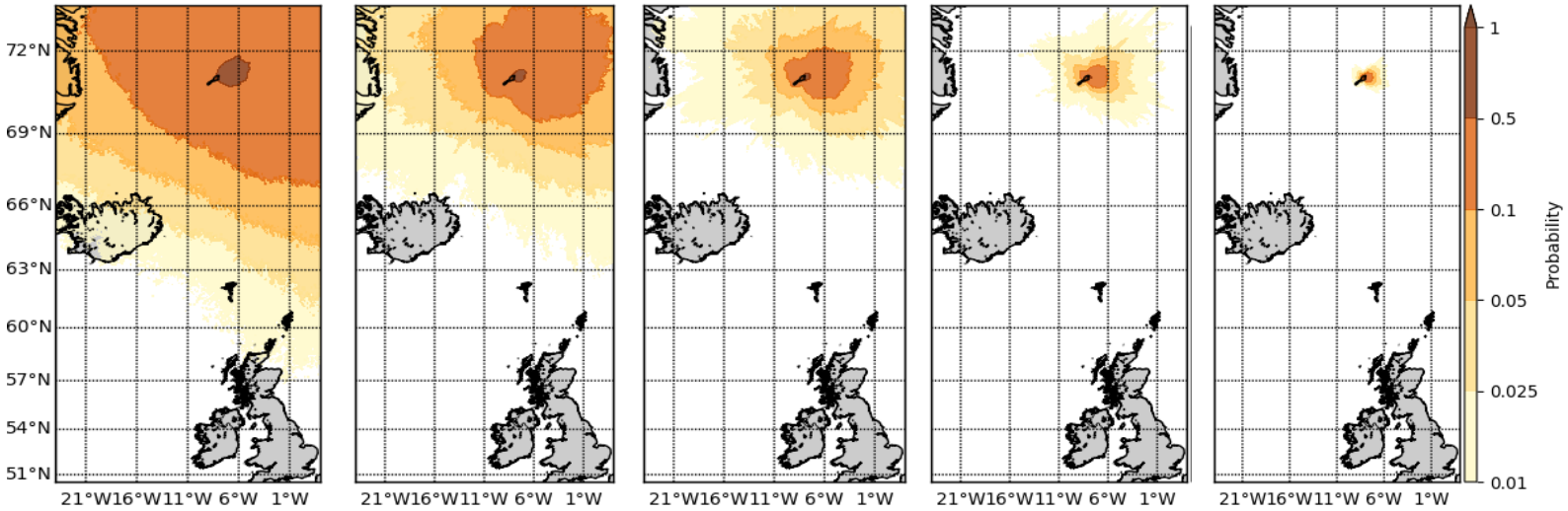
Exceedance probability maps:



Persistence 1 **3** **6** **12** **24** (hours)

4. Ash concentration (2mg/m3). 25000 feet. Large eruption

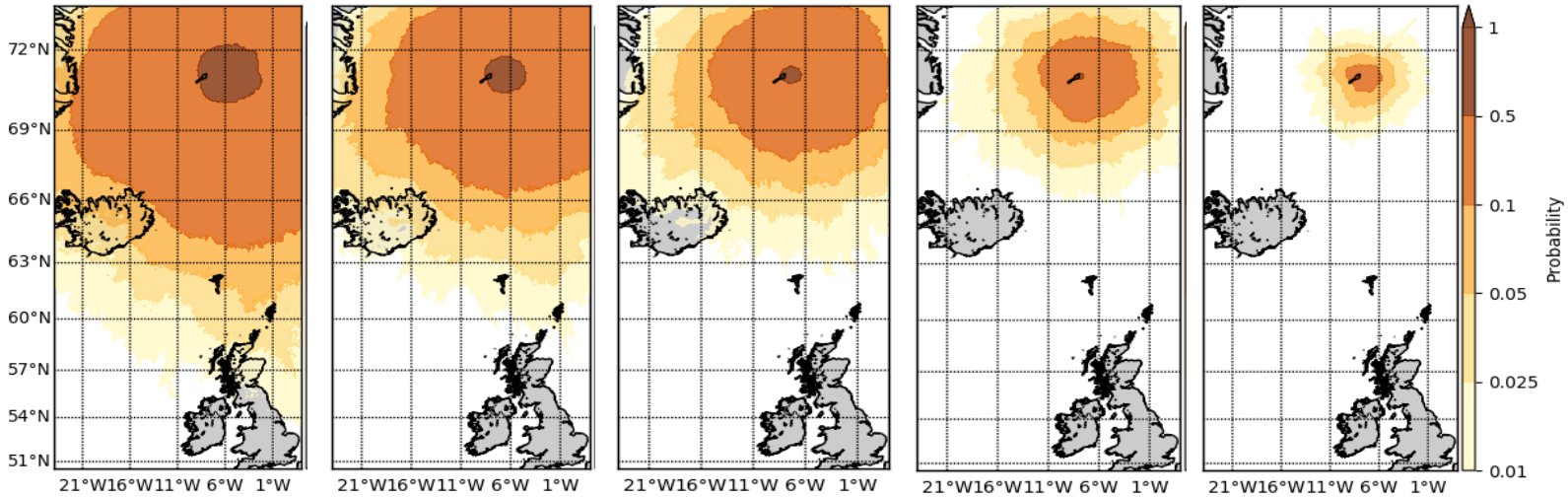
Exceedance probability maps:



Persistence 1 **3** **6** **12** **24** (hours)

4. Ash concentration (4mg/m3). 5000 feet. Large eruption

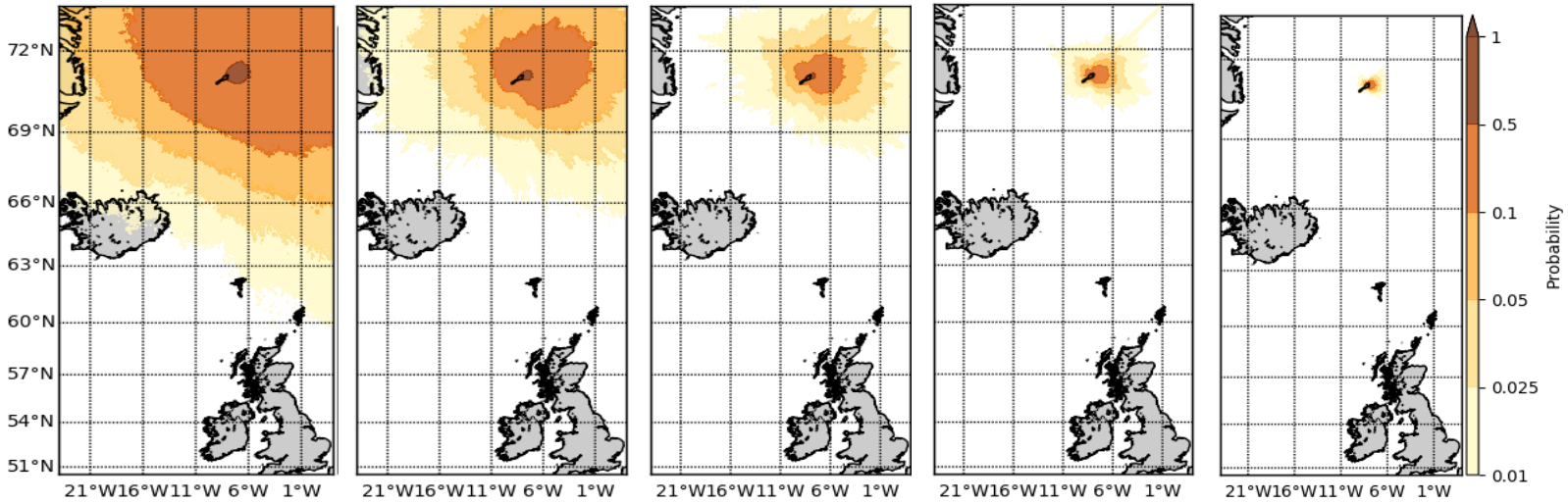
Exceedance probability maps:



Persistence 1 3 6 12 24 (hours)

4. Ash concentration (4mg/m3). 25000 feet. Large eruption

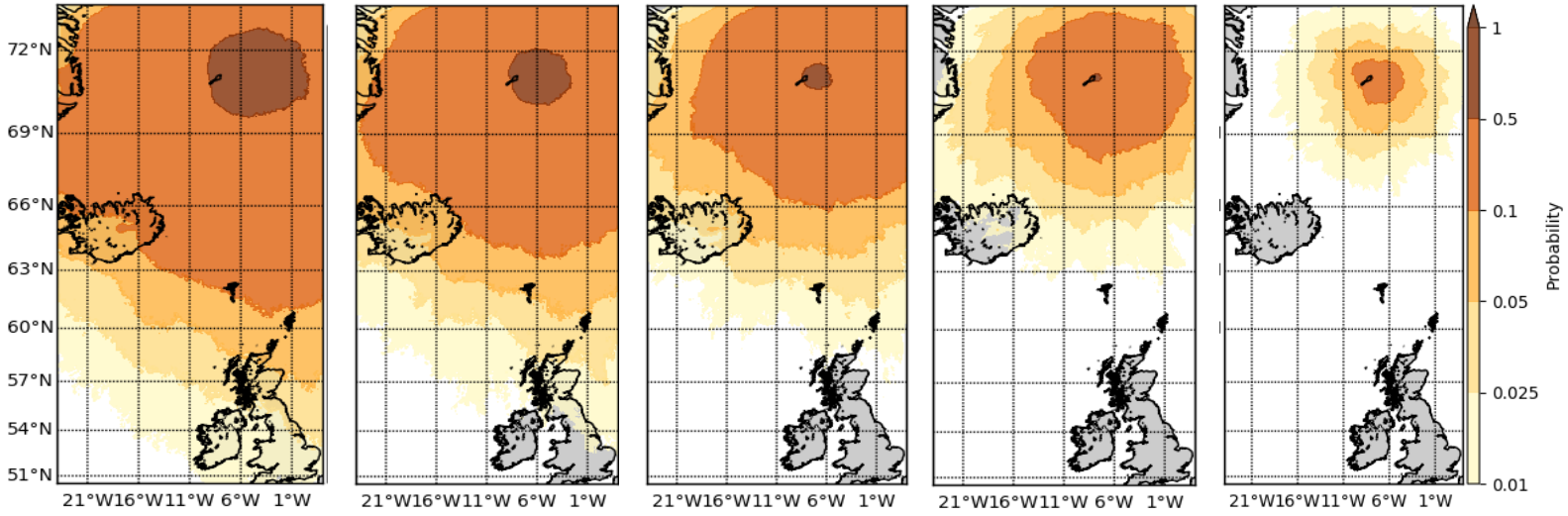
Exceedance probability maps:



Persistence 1 **3** **6** **12** **24** (hours)

4. Ash concentration (2mg/m3). 5000 feet Medium eruption

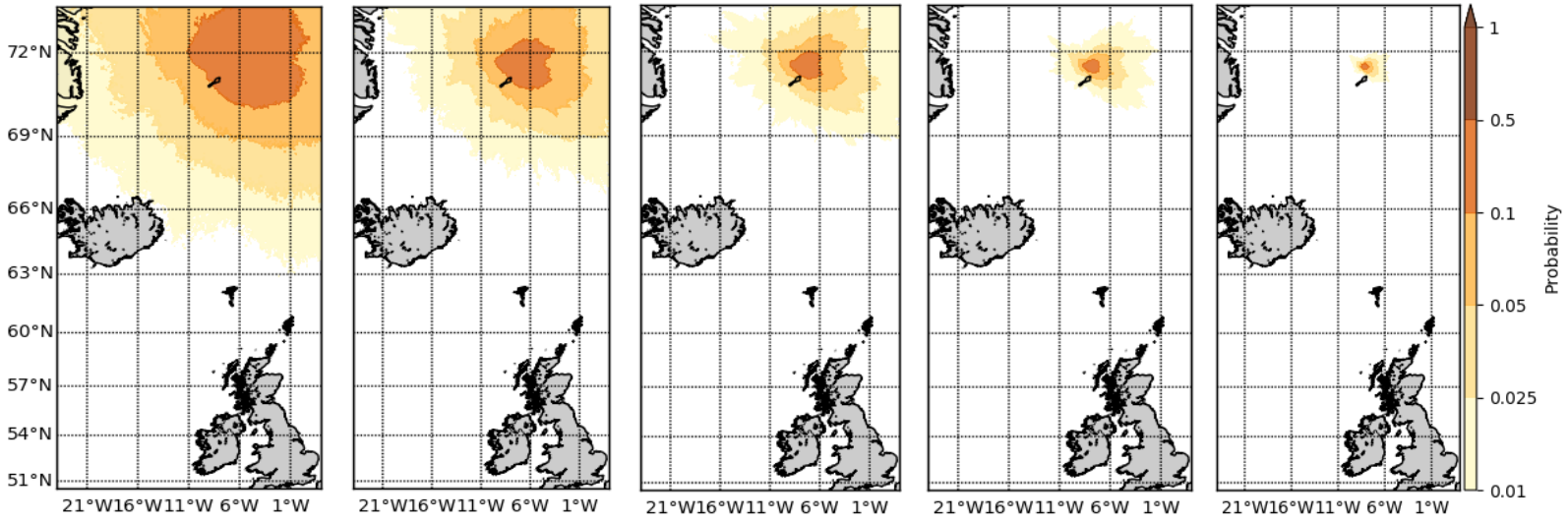
Exceedance probability maps:



Persistence 1 3 6 12 24 (hours)

4. Ash concentration (2mg/m3). 25000 feet. Medium eruption

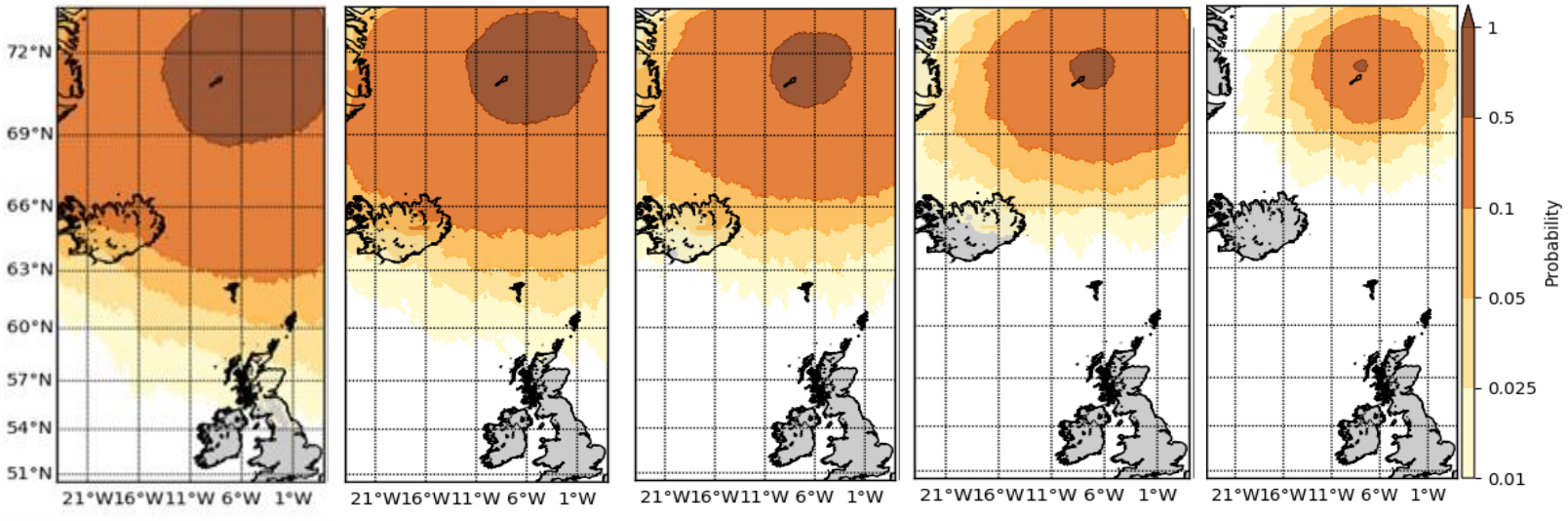
Exceedance probability maps:



Persistence 1 **3** **6** **12** **24** (hours)

4. Ash concentration (4mg/m3).5000 feet

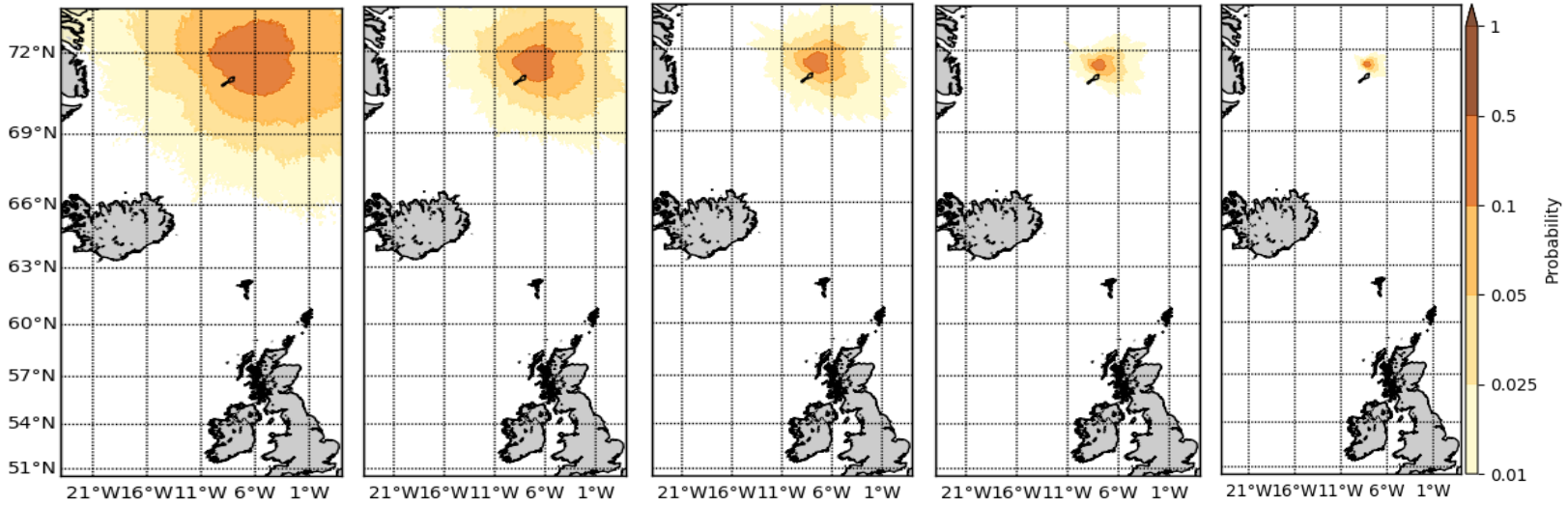
Exceedance probability maps:



Persistence 1 3 6 12 24 (hours)

4. Ash concentration (4mg/m3). 25000 feet. Medium eruption

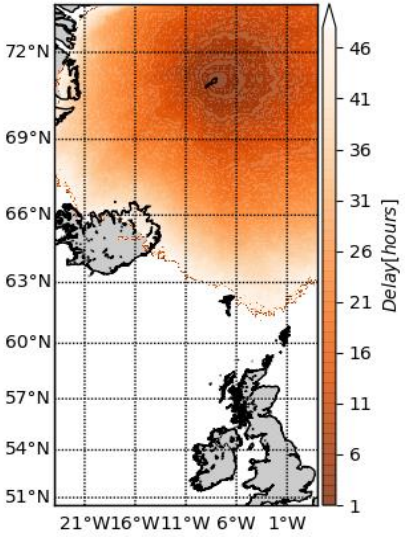
Exceedance probability maps:



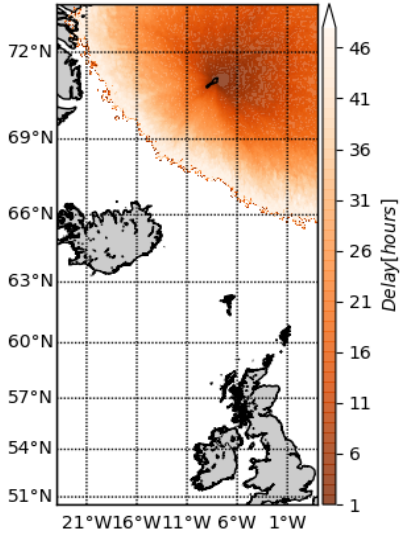
Persistence 1 **3** **6** **12** **24** (hours)

4. Arrival time maps. Large Eruption

Exceedance probability of 5% to find 2mg/m3 ash concentration after 48 hours



5000 feet



25000 feet

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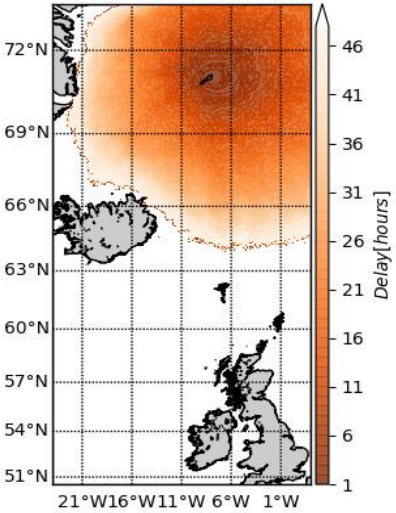
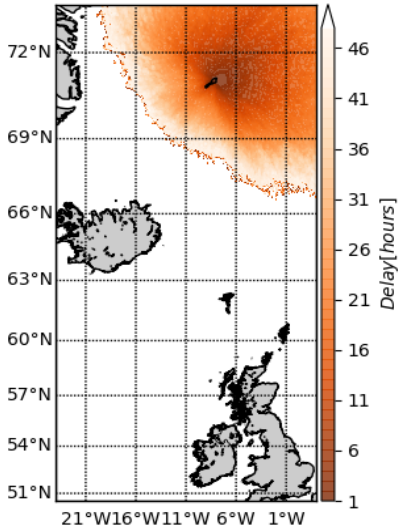


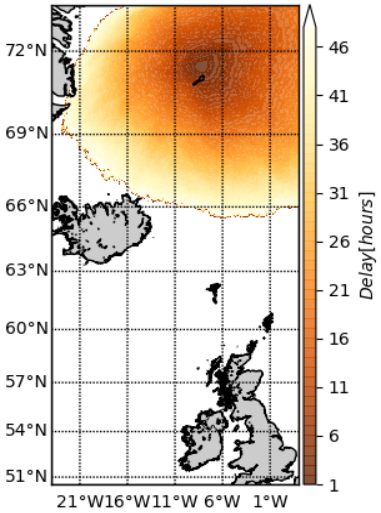
5000 feet



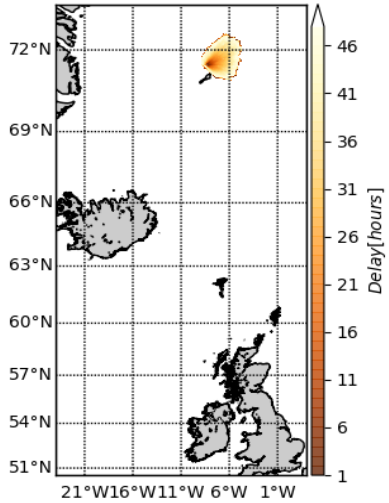
25000 feet

4. Arrival time maps. Medium Eruption

Exceedance probability of 5% to find 2mg/m3 ash concentration after 48 hours



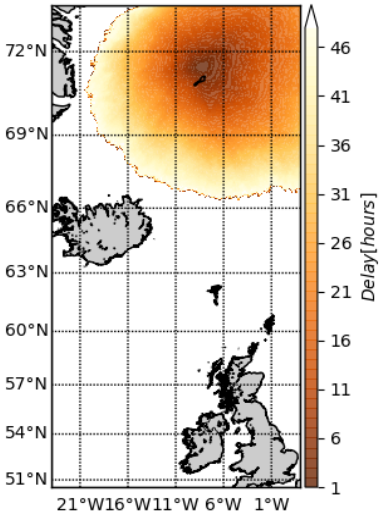
5000 feet



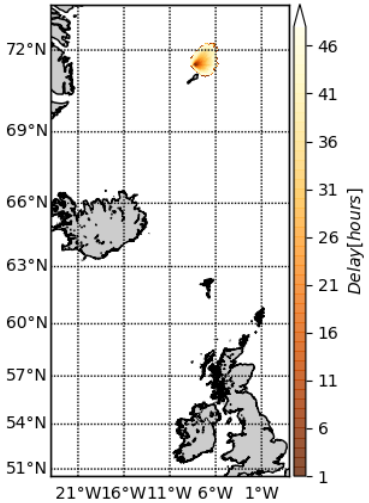
25000 feet

4. Arrival time maps. Medium Eruption

Exceedance probability of 5% to find 4mg/m3 ash concentration after 48 hours



5000 feet



25000 feet

5. Conclusions

- An ash-rich eruption originating from Jan Mayen volcano has potential to affect the air traffic over Iceland and, to some extent, the UK.
- A concentration above 4 mg/m3 (originally considered no fly zone) might reach a distance of 500 km (approx) after 24 hours.
- In case of a **Large** eruption scenario the volcanic ash cloud might reach the NE part of Iceland with concentrations that will require aircraft engine check with a probability higher than 5% - exposing several of the incoming flights and those flying the north pole routes.
- In case of a **Medium** eruption scenario the volcanic ash cloud will have minor impact on the north-atlantic flight routes and a very local impact on high-altitude aircrafts.

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