# Bonanati et al.; Supplementary Text 1

This supplementary text provides a summary of the Eyjafjallajökull eruption and the Oceanographic setting of the study area which includes data that were used for the discussion in the manuscript.

The Eyjafiallajökull 2010 eruption and the preservation of medium-sized eruptions in marine surface sediment offshore southern Iceland

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# Eyjafjallajökull 2010

***Sequence of eruptive events and tephra dispersal***

The Eyjafjallajökull summit eruption lasted from April 14 until May 22, 2010. In total, 0.27±0.07 km³ of tephra were produced. In the following section, we give an overview on the eruption sequence and the distribution of the tephra plume.

On April 14 to 15, ice melting of glacier ice caused repeated Jökulhlaups, flowing down Eyjafjallajökull’s northern and southern slopes (Gislason et al., 2011; Gudmundsson et al., 2012b).

From April 14 to 18, during the initial explosive phase, evolved trachy-andesite and minor amounts of trachy-dacite and rhyolite were erupted from a water filled vent (Gudmundsson et al., 2012b), forming a water-vapor-rich plume. A series of discrete fragmentation events of small batches of magma, closely spaced in time, led to pulsating activity with varying mass eruption rates (Dellino et al., 2012). This semi-continuous re-feeding produced an unsteady eruption column that fluctuated in height between 5 and 10 km (Dellino et al., 2012; Gudmundsson et al., 2012b). The magma was discharged at a rate of 5-10\*105 kg s-1 (~0.2-0.4 km³s-1 DRE). The ash amount of 33±12 Tg was fragmented to grain sizes <28 µm (Gudmundsson et al., 2012b).

During the first two days of the eruption, strong westerly winds blew over Iceland. The wind speeds exceeded 50 m s-1 at 7-10 km altitude (Petersen et al., 2012a). During most of the explosive phase, the ash was advected to the southeast towards Europe. The ash cloud spread over an area of 1.5-2\*106 km2  (Gudmundsson et al., 2012b), reaching southern Norway on April 15 before traveling southwards over the Netherlands, Germany, the European Alps up to western Russia and Hungary (Gao et al., 2011; Schumann et al., 2011; Karlsdóttir et al., 2012).

In this initial pulse of the eruption from April 14-16, the total mass of ash which was transported beyond the Faroe Islands amounted to 2-6 \* 109 kg (Gudmundsson et al., 2012b). Out of the particles 94 % were <1 mm, while 8-50 % were <63 µm (Gudmundsson et al., 2012b). By April 15, the eruption cloud had spread out to a width of 80-100 km at 1 km vertical extension. Close to the eruptive vent, the plume density ranged at 10-35 mg m-3 (Gudmundsson et al., 2012b), decaying to 1 mg m-3 above Norway and to 0.025 mg m-3 above Leipzig, Germany, on April 19 (Schumann et al., 2011).

Between April 18 and May 4, a low-discharge effusive phase followed. Explosive activity sustained with 2-4 km high plumes and the tephra spread out over 0.1-0.2 \*106 km2 (Gudmundsson et al., 2012b).

During the second explosive phase from May 5-17, the plume was 5-6 km high (Langmann et al., 2012), being most powerful on May 6. Per second 0.3-9\*105 kg of mainly trachydacitic and minor trachyandesitic magma were discharged (~0.015-0.35 km3 s-1 DRE). Tephra was transported in a southerly direction (Petersen et al., 2012a), dispersing over an area of >5\*106 km2 (Gudmundsson et al., 2012b). After the final phase from May 18-22, the eruption declined.

***Total mass, grain-size and concentrations***

To obtain a figure on the amounts and sizes of particles that expectedly precipitated from the Eyjafjallajökull 2010 eruption plume in the study area, we here present results from remote sensing, in-situ measurements and isopach mapping about total mass, grain-size ranges and distributions, and particle concentrations.

From the first explosive phase 94% of tephra was finer than 1000 mm, and 48– 50% was ash finer than 63 mm (Gudmundsson et al., 2012b). In the proximity of the source, sedimentation of fine-grained material was enhanced by particle aggregation (Taddeucci et al., 2011). Tephra was dispersed 360° around the volcano forming a continuous blanket extending from 30 up to 80 km from the vent (Gudmundsson et al., 2012b). This distribution is also obvious from Meteosat images (EUMETSAT, NASA and e.g.Schumann et al., 2011; Stohl et al., 2011)

During stable anticyclonic conditions with little precipitation, the plume was carried by north-westerly winds at mean velocities of 12 m s-1 (Ansmann et al., 2010; Dellino et al., 2012; Petersen et al., 2012a; Pietruczuk et al., 2010; Schumann et al., 2011; Stohl et al., 2011). Within 1-2 days, the ash plume drifted over the North Atlantic towards central Europe, where it resided for several days, as observed, e.g., by ground based LIDAR (Flentje et al., 2010; Ansmann et al., 2010). In total, the cloud expanded to an area of 7 million km² (Gudmundsson et al., 2012b).

In the UK, aggregate particles with diameters up to 200 mm were detected (Stevenson et al., 2012). Most grains that were sampled in rain gauges were <45 µm, however, highly vesicular grains up to 100 µm also appeared. In Leicestershire, dusty coating on cars and other surfaces ranged in size from 60 to 200 µm, while aggregates comprised grains <5 µm. Particle loading in rain gauges was 218 grains m-2 in Benbecula, Scotland, and 9-179 grains m-2 in England (Stevenson et al., 2012). In the widespread dilute ash cloud above Europe, particle concentrations between 0.03-0.1 mg m-3 were determined from different simulations and sources (Webley et al., 2012). Tephra grains that were sampled in rainwater in Bergen, Norway on April 16-23 were 23-91 µm with a mean of 48 µm (Stevenson et al., 2012). In Budapest, Hungary, ~3000 km from the source, 2-4 µm-sized ash was collected on air filters on April 17, which coincides with the detection of ash over Hungary in Eumetsat data (Stevenson et al., 2012).

During later stages of the eruption, a falcon air craft was employed to determine concentrations of both non-volatile and gas particles, their grain sizes, and how they varied at the different altitudes, distances, and directions from source (Schumann et al., 2011). On May 2, the plume was entered 450 km southeast of the volcano about 200-400 m below plume top, detecting 3334 non-volatile particles >10 nm cm-3 (10 s mean), and mean and maximum ash mass concentrations were 219 and 600 µg m-3,respectively, during the 3 minute ash plume penetration (Schumann et al., 2011). At altitudes between ~2.7 and ~6.1 km, concentrations of total non-volatile particles >10 nm and maximum mass concentrations (for 10 s mean value) of 154 particles cm-3 and 21 µg m-3 were observed above NE England on May 16, 351 particles cm-3 and 19 µg m-3 above the Baltic Sea on April 23, and 677 particles cm-3 and 11 µg m-3 above Munich on May 5. The volcanic ash plume was observed with LIDAR from directly above the volcano and up to a distance of 2700 km downwind, giving a distal ash mass flux on the order of 500 (240–1600) kg s−1 on May 2 (Schumann et al., 2011). Estimates of mass eruption rates during the eruption period of may 8-10 2010 range from ~3 \* 104 kg s-1 (pulse-velocity-derived empirical models; Dürig et al., 2015) over ~30 104 kg s-1 (numerical wind-affected models; Devenish, 2016; Devenish et al., 2012; Woodhouse et al., 2013) up to ~110 104 kg s-1 (infrasound measurements; Ripepe et al., 2013).

# Oceanographic setting of the study area

Iceland splits the northwest-southeast trending Greenland-Iceland-Faroer Ridge (resp. Greenland-Scotland Ridge) into a western and an eastern region, the Denmark Strait and the Iceland-Faroe Ridge (IFR), respectively and separates the Nordic Seas (GIN: Greenland, Iceland and Norwegian Seas) from the southern North Atlantic. Part of the Mid-Atlantic Ridge, the Reykjanes Ridge to the southwest, and the IFR to the southeast, segment the Icelandic continental shelf into the Irminger Basin and the Iceland Basin.

The IFR consists of a shallow plateau with several intersecting trenches and sill depths between 300 and 480 m (Meißner et al., 2014). At the deep waters where the Iceland-Faroe Ridge (IFR) intersects the Icelandic shelf, the northwards flowing North Atlantic waters (South Icelandic Current) and the southwards flowing waters from the Nordic Seas (East Icelandic Current) converge and turn eastwards as the Iceland Faroe Current (IFC) (Beaird et al., 2013). On the Atlantic flank of the IFR (AIFR), a ~100-m thick overflow layer of dense Nordic Sea waters passes through the deeper channels as a 10–50-m-thick bottom-intensified current, the Iceland Scotland Overflow (ISOW) (Beaird et al., 2013) turning right on the Atlantic side of the IFR flowing along isobaths. Joined by overflow through the western valley, at the base of the rise southeast of Iceland, they reach mean velocities of up to 25 cm s-1 (Perkins et al., 1998). The IFC continues south-eastwards along the IFR, to north of the Faroe Islands (Hansen & Meincke, 1979). The root-mean-squared depths-averaged horizontal current over the entire IFR is 17.15 cm s-1, with higher values on the ridge shallower than 500-m isobaths and in the FBC outflow (Beaird et al., 2013). Near-bottom (75 m) geostrophic velocities of the ISO average 18-30 cm s-1 with maxima of 60-70 cm s-1 near the Faroe Bank Channel outflow (below 600 m isobaths, mean: 21.5 cm s-1, SD: 11 cm s-1) (Beaird et al., 2013). Across the ridge crest of the IFR the flow is rather diffuse at 15 cm s-1 (Meincke, 1983).

From sill depths of 500-800 m the overflow water eventually descends to 200-2500 m as it circulates cyclonically in the Iceland Basin (Beaird et al., 2013, and references therein). Then it crosses the Reykjanes Ridge and joins the Denmark Strait overflow in the Irminger Basin.

South of Iceland, the topography of the shelf and the steep continental slopes with deep canyons drives a complex system of interacting currents (Logemann et al., 2013; Meißner et al., 2014). Over the narrow southern and south-eastern Icelandic shelf, the South Icelandic Current flows intensely towards the east and north-east with highest current velocity of >20 cm s-1 (Logemann et al., 2013). Further downstream the current flows further offshore and broadens as the shelf broadens, joining with North Atlantic Waters flowing as surface current parallel to the shelf break northeastwards at 10-20 cm s-1, before leaving the shelf at 65°N to join the IFF (Meincke, 1983). Near the shoreline, the narrow (~10 km) Icelandic Coastal Current flows clockwise around Iceland (Logemann et al., 2013). Further offshore flows the Icelandic Coastal Undercurrent, mixing with the South Icelandic Current, flowing on the shelf in easterly direction and subsequently becoming the Faroe Current. Further off, the Icelandic Slope Current flows along the South Icelandic slope in westerly direction. Northwards along the western flank of the Reykjanes Ridge, flows the Irminger Current (IC), the strongest current in Icelandic waters. Parallel, between the continental slope and the Icelandic coast, streams the West Icelandic Irminger Current (WIIC) over the West Icelandic Shelf.

Northeast of Iceland three weak currents fork off the North Icelandic Irminger Current (NIIC). Arctic waters flow southeastwards along the eastern flank of the Kolbensey Ridge, where they join the East Icelandic Current (EIC). The EIC follows the continental slope until it turns eastwards continuing along the northern flank of the IFR, finally joining the Iceland Faroe Front (IFF). Another branch leaves the shelf to form the shallow, southeastward flowing Iceland Current (IC). The third branch follows deeper contours of the continental slope into the northern flank of the IFR. Below the EIC, at depths between 200 and 1000 m, an undercurrent, the North Icelandic Jet (NIJ), flows in counter-direction (Logemann et al., 2013).

Inter-annual variabilities (Pollard, 1992) and locally strong tidal currents occur particularly in the shelf regions (Perkins et al., 1994). The flow velocities can strongly vary locally in response to bathymetry, e.g., geostrophic currents which are driven by temperature and salinity gradients and are enhanced by steeper slopes, which locally support steeper isopycnal gradients and faster currents (Bowden 1960; McCave 1982; McCave et al. 1995b). Higher sedimentation rates occur as a result of the deposition of terrigeneous material from both turbidity and bottom currents.

Long-term current meters situated ~100 km upstream east of the Katla Ridges record near-bottom flow speeds of 15-20 cm/s between 1600 and 2000 m (Saunders, 1996 in Thornalley et al., 2010), sufficient to resuspend lithic grains and move foraminifera in excess of 125 µm diameter.

Using Stoke’s law to determine the settling velocity, and taking into account sampling depths of 1,600 m, particles in the water column could have residence times of more than one month (>32 µm) up to one year (10 µm; detection limit in this study). This time can be shorter due to aggregation of particles and downward fluxing in gravity currents (Carey, 1997). Tephra sampled out of the Eyjafjallajökull 2010 ash fall on board of RRV Discovery best represent the particle sizes of tephra that reached the sampling locations. For particle sizes of 4-420 µm (median: 187 µm) (Cassidy, unpubl. data), the settling velocity is 2 cm s-1, resulting in residence times in the water column of only a couple of days. However, Stoke’s law does not take into consideration the particle shape (Komar and Reimers, 1978; Oehmig and Wallrabe-Adams, 1993). Especially flat, slightly arched walls of large bubbles sink slower than the law predicts (Fisher, 1965). Under laboratory conditions, the settling velocity for thin platy glass shards in water were estimated to be 3 cm s-1 (Oehmig and Wallrabe-Adams, 1993). Current velocities in the study area range between 15 and 100 cm s-1 (Meincke, 1983; Perkins et al., 1998; Beaird et al., 2013; Logemann et al., 2013;Blockley et al., 2014).

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