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Supplementary Material for

Probabilistic hazard analysis for a small island: quantifying tephra fall hazard and appraising the possible impact on Ascension Island

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Fig. S1 ERA5 reanalysis data 2010-2019: 3-monthly wind roses up to ~ 30 km above sea level

Model calibration and selection of eruption source parameters, including Table S1 Input parameters used to calibrate model

Table S2 Model vent locations for TephraProb simulations (UTM 28S)

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References for Supplementary material

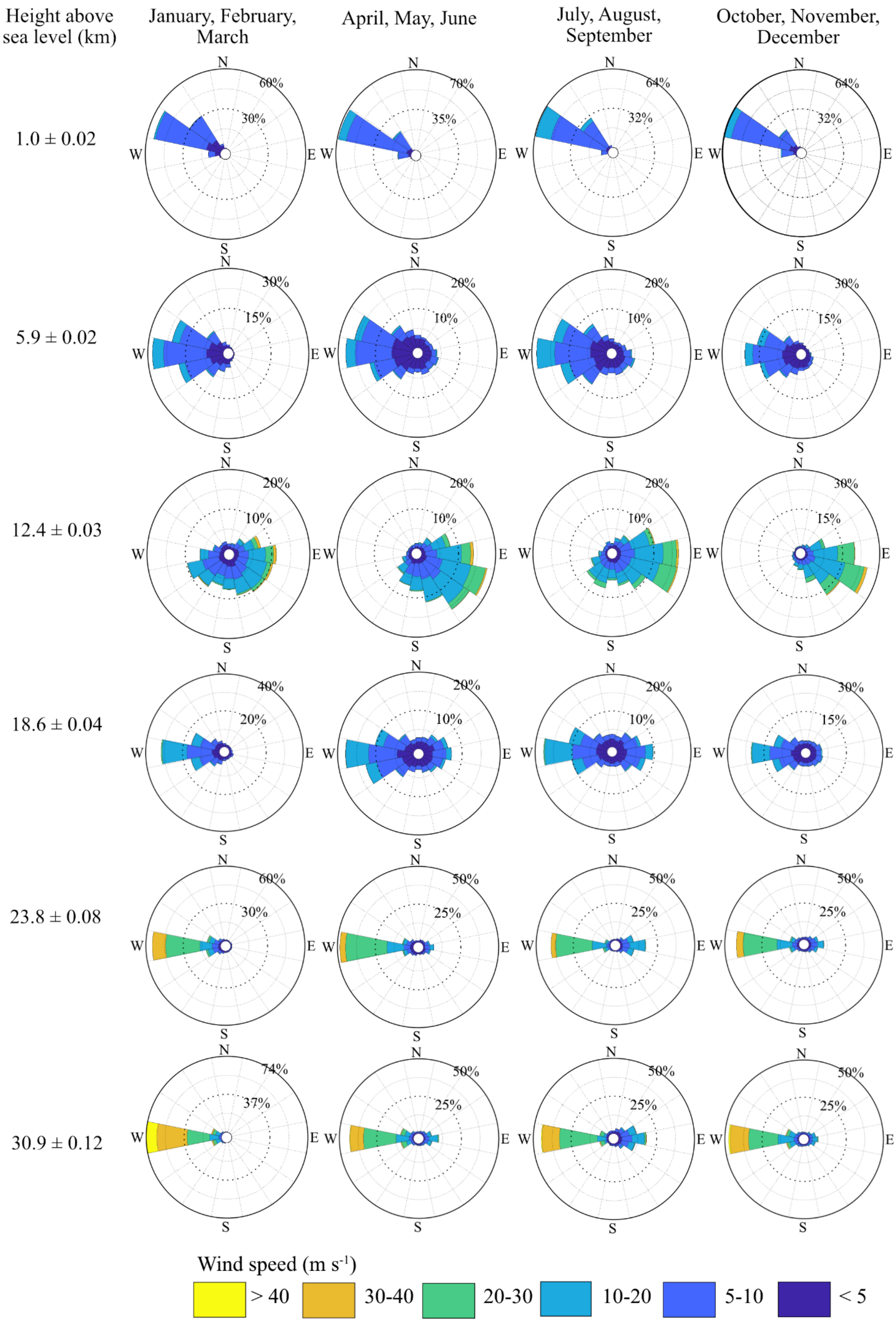

Fig. S1 ERA5 reanalysis data 2010-2019 for Ascension Island: 3-monthly wind roses up to ~ 30 km above sea level

Model calibration and selection of eruption source parameters

The model was calibrated with published data from field observations on São Miguel, Azores (Table S1): the trachytic Fogo A eruption for felsic simulations (Walker and Croasdale 1970; Carey and Sigurdsson 1989; Gaspar et al. 2015; Pensa et al. 2015) and the basaltic Serra Gorda eruption for mafic simulations (Booth et al. 1978). Tephra thicknesses were converted to loads using published deposit density of 500 kg m^{-3} for Fogo A (Walker and Croasdale 1970) and estimated deposit density of 1000 kg m^{-3} for Serra Gorda.

Table S1 Input parameters used to calibrate model

Parameter	Fogo A	Serra Gorda
Plume height (km asl)	21 – 30	12
Mass erupted (kg)	2 – 4 x 10^{12}	10^{10} – 10^{11}
Duration (h)	5 - 12	1 – 5
Φ range (Md Φ)	-5 – 6 (0.5)	-5 – 5 (-1)
σ Φ	2	2
ρ lithic (kg m^{-3})	2400	2900
ρ pumice (kg m^{-3})	800	1000
Aggregation	No	No
Model parameters tested		
Diffusion coefficient (m s^{-2})	1500 - 5000	3000 - 5000
Fall time threshold (s)	2000 - 10000	3000 - 7000
β distribution: α and β values	1, 1 2, 2 3, 2 2, 3	
Column integration steps	50-100	

Wind profiles were selected from a 10-year dataset of ERA5 6-hourly wind reanalysis (Hersbach et al. 2018). For Fogo A, only September profiles were used (1200 wind profiles in total), chosen as the month with light, south-westerly winds most likely to create deposits that matched observations. For Serra Gorda, south-easterly to south-westerly winds (provenance 110–260 °) were chosen as most likely to create deposits to match observations. However, it was difficult to match upwind deposition suggesting very light winds.

The diffusion coefficient (DC) and fall-time threshold (FTT) are empirical model parameters. DC accounts for atmospheric advection and diffusion and FTT represents the fall time at which diffusion changes from a linear function (for large particles) to power law (for small particles). Mass distribution in the modelled plume is controlled by a β distribution, with α and β values used to specify where most mass is released. The best fit values chosen for our Ascension Island simulations were:

- Felsic eruptions: DC 5000 m s-1, FTT 6000 s, α=1, β=1.
- Mafic eruptions: DC 4000 m s-1, FTT 5000 s, α=2, β=2.

When assessing the number of integration steps needed through the plume we found no difference between 50 and 100 steps for our model plume heights (mainly ≤ 15 km) and so chose 50 steps for all model runs.

Grid spacing of 1000 m produced angular contours, a 500 m grid produced smooth contours except very close to the vent and the only difference with a 250 m grid was smoother contours very close to the vent. We also found that 1000 runs were needed to produce stable load contours, with no change in contours between 1000 and 2000 runs. To optimise run time we therefore selected a 500 m grid and 1000 runs for individual scenarios and each element of the multiple vent scenario.

Table S2 Model vent locations for TephraProb simulations (UTM 28S)

Simulations	Easting	Northing	Elevation (m)	Simulations	Easting	Northing	Elevation (m)
Devil's Cauldron	574119	9122490	520	Sisters_grid	569086	9123019	197
Comfortless Cove	565917	9125544	30	Sisters_grid	569286	9123019	193
Airport_grid	567292	9118700	89	Sisters_grid	569686	9123019	226
Airport_grid	567492	9118700	79	Sisters_grid	569886	9123019	161
Airport_grid	567092	9118900	73	Sisters_grid	570086	9123019	161
Airport_grid	567292	9118900	72	Sisters_grid	568686	9123219	178
Airport_grid	567492	9118900	78	Sisters_grid	568886	9123219	206
Airport_grid	567692	9118900	71	Sisters_grid	569086	9123219	179
Airport_grid	567892	9118900	74	Sisters_grid	569286	9123219	187
Airport_grid	568092	9118900	88	Sisters_grid	569486	9123219	166
Airport_grid	568292	9118900	88	Sisters_grid	569686	9123219	198
Airport_grid	567092	9119100	80	Sisters_grid	569886	9123219	92
Airport_grid	567292	9119100	75	Sisters_grid	570086	9123219	145
Airport_grid	567492	9119100	83	Sisters_grid	568486	9123419	182
Airport_grid	567692	9119100	93	Sisters_grid	568686	9123419	171
Airport_grid	567892	9119100	84	Sisters_grid	568886	9123419	145
Airport_grid	568092	9119100	84	Sisters_grid	569086	9123419	157
Airport_grid	568292	9119100	93	Sisters_grid	569286	9123419	98
Airport_grid	567292	9119300	80	Sisters_grid	569486	9123419	164
Airport_grid	567492	9119300	84	Sisters_grid	569686	9123419	152
Airport_grid	567692	9119300	83	Sisters_grid	569886	9123419	156
Airport_grid	567892	9119300	87	Sisters_grid	570086	9123419	73
Airport_grid	568092	9119300	89	Sisters_grid	568486	9123619	197
Airport_grid	568292	9119300	107	Sisters_grid	568686	9123619	192
Airport_grid	568492	9119300	115	Sisters_grid	568886	9123619	220
Airport_grid	568692	9119300	135	Sisters_grid	569086	9123619	178
Airport_grid	567492	9119500	93	Sisters_grid	569286	9123619	119
Airport_grid	567692	9119500	91	Sisters_grid	569486	9123619	91
Airport_grid	567892	9119500	112	Sisters_grid	569686	9123619	150
Airport_grid	568092	9119500	101	Sisters_grid	569886	9123619	168
Airport_grid	568292	9119500	107	Sisters_grid	570086	9123619	156
Airport_grid	568492	9119500	133	Sisters_grid	568686	9123819	168
Airport_grid	568692	9119500	136	Sisters_grid	568886	9123819	141
Airport_grid	568892	9119500	146	Sisters_grid	569086	9123819	231
Airport_grid	567692	9119700	109	Sisters_grid	569286	9123819	145
Airport_grid	567892	9119700	101	Sisters_grid	569486	9123819	205
Airport_grid	568092	9119700	108	Sisters_grid	569686	9123819	92
Airport_grid	568292	9119700	129	Sisters_grid	569886	9123819	187
Airport_grid	568492	9119700	168	Sisters_grid	570086	9123819	125
Airport_grid	568692	9119700	143	Sisters_grid	568686	9124019	158
Airport_grid	568892	9119700	143	Sisters_grid	568886	9124019	176
Airport_grid	568292	9119900	198	Sisters_grid	569086	9124019	243
Airport_grid	568492	9119900	188	Sisters_grid	569286	9124019	217
Airport_grid	568692	9119900	162	Sisters_grid	569486	9124019	172
				Sisters_grid	569686	9124019	185
				Sisters_grid	569886	9124019	174
				Sisters_grid	570086	9124019	154
				Sisters_grid	568686	9124219	228
				Sisters_grid	568886	9124219	182
				Sisters_grid	569086	9124219	217
				Sisters_grid	569486	9124219	237
				Sisters_grid	569686	9124219	205
				Sisters_grid	569886	9124219	172

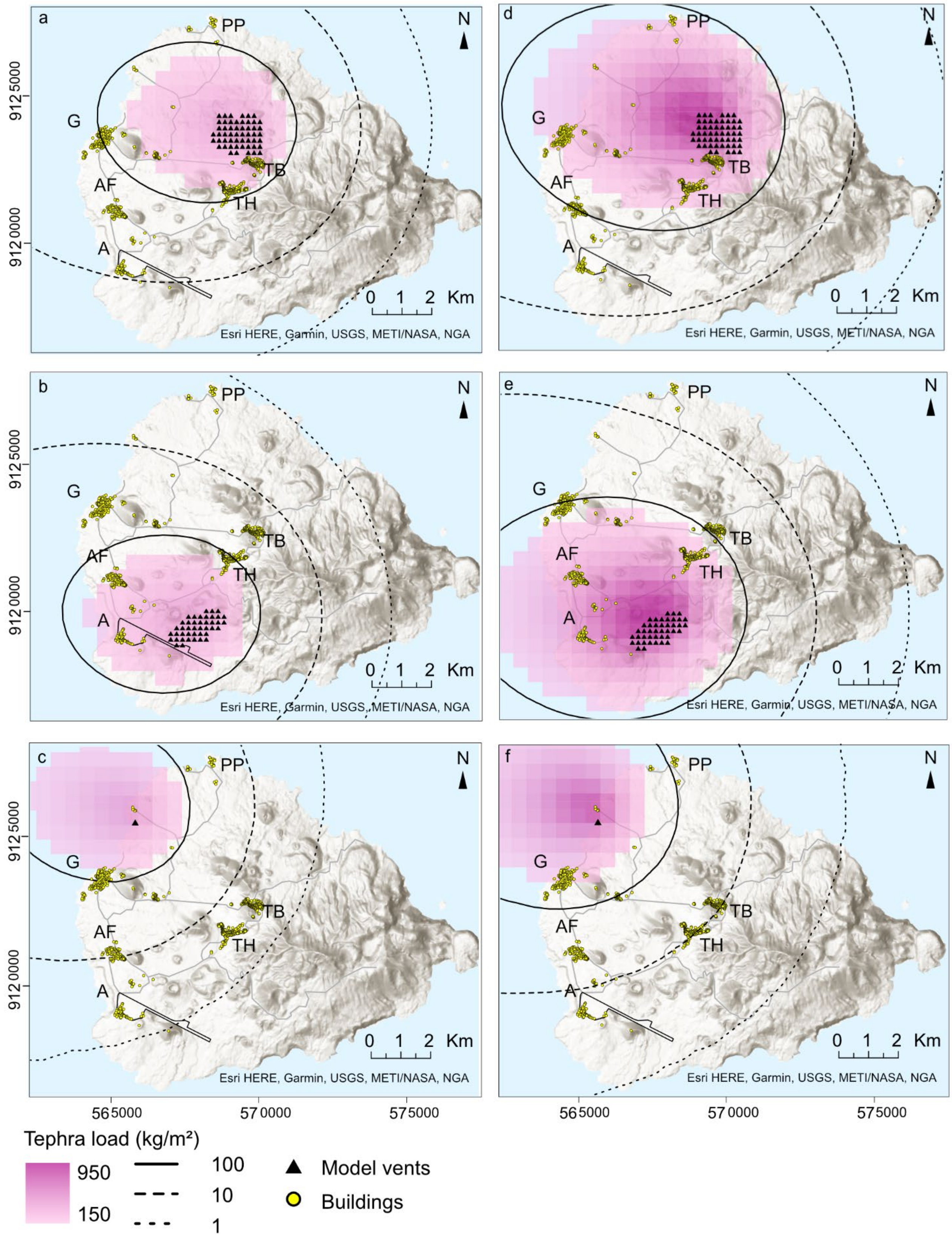

Fig. S2 Tephra ground loads with 10 % probability of exceedance for basaltic events. a), b) and c) show results for one event with 6–10 km plume height, d), e) and f) show results for three events, each with 6–10 km plume height from Sister's Peak, Airport East and Comfortless Cove respectively. For multiple events, we assume the tephra is not cleared or eroded between each pulse. Key locations: A: airport, G: Georgetown, PP: power plant and South Atlantic Relay station, TB: Two Boats, TH: Travellers Hill, AF: US Air Force Base. Coordinate reference system: WGS84 / UTM 28S

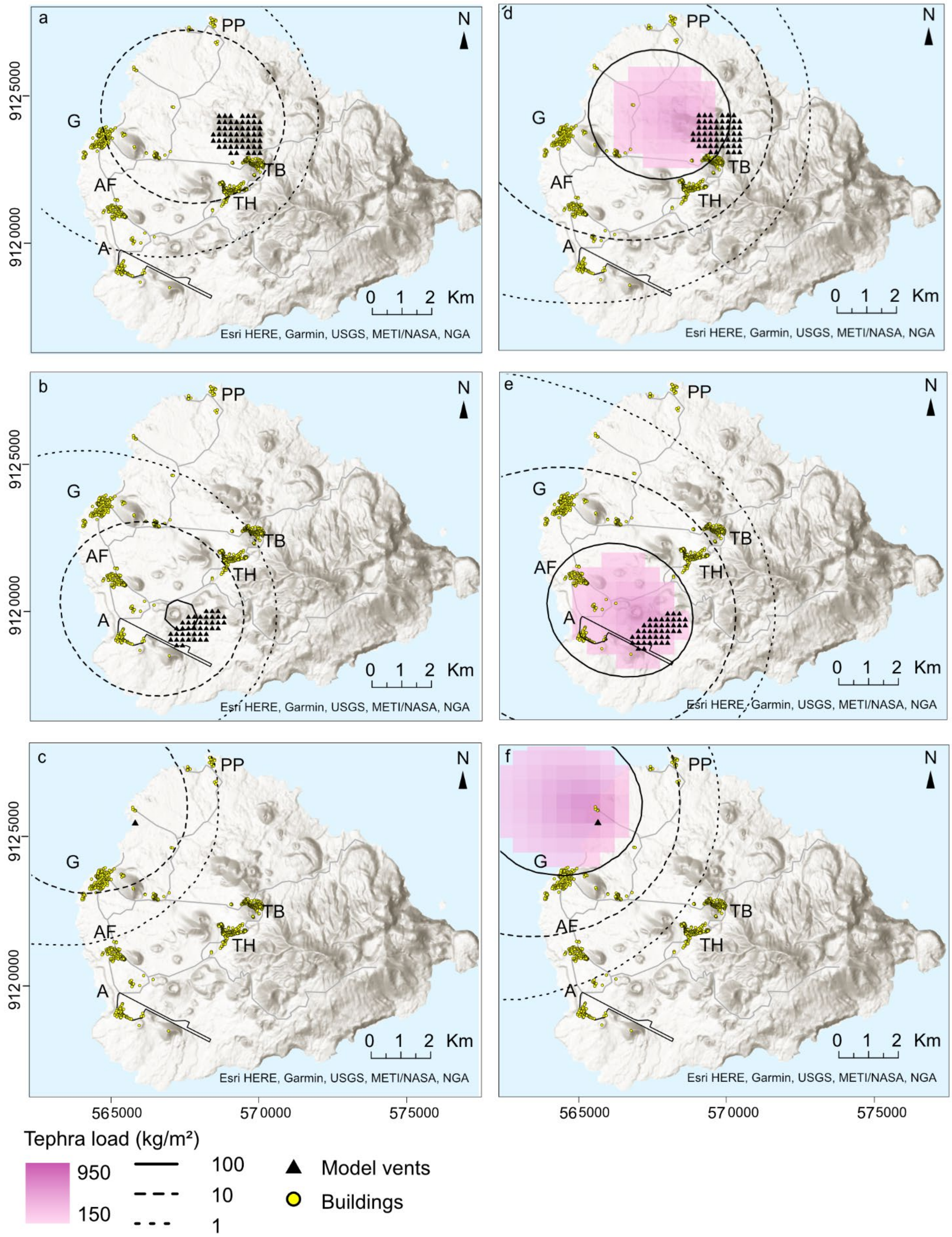

Fig. S3 Tephra ground loads with 90 % probability of exceedance for basaltic events. a), b) and c) show results for one event with 6–10 km plume height, d), e) and f) show results for three events, each with 6–10 km plume height from Sister's Peak, Airport East and Comfortless Cove respectively. For multiple events, we assume the tephra is not cleared or eroded between each pulse. Key locations: A: airport, G: Georgetown, PP: power plant and South Atlantic Relay station, TB: Two Boats, TH: Travellers Hill, AF: US Air Force Base. Coordinate reference system: WGS84 / UTM 28S

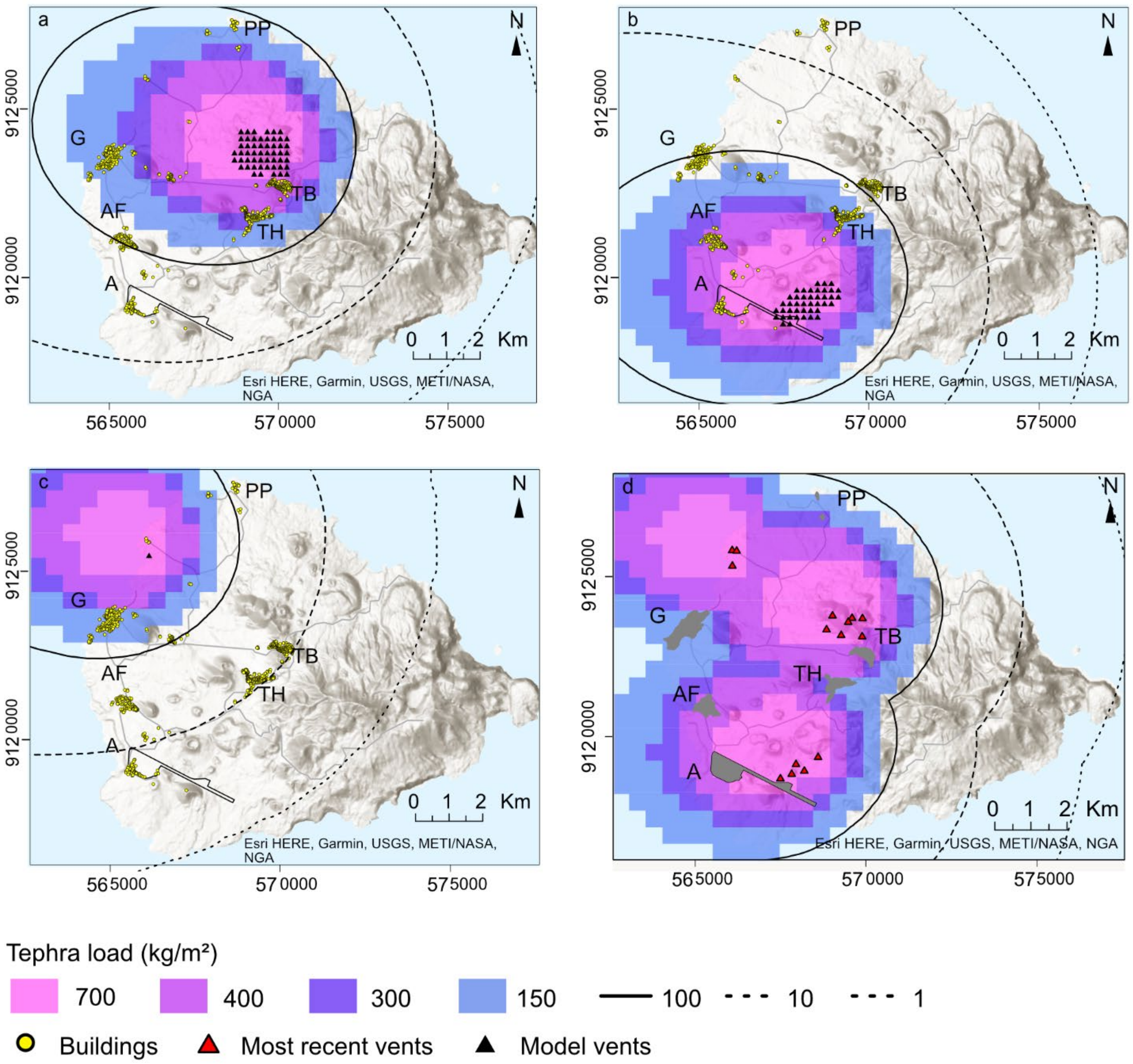

Fig. S4 Tephra ground loads likely to cause roof collapse (≥ 150 kg m^{-2}) with 10 % probability of exceedance for three basaltic eruptions, each with 6–10 km plume from a) Sister's Peak, b) Airport East and c) Comfortless Cove, d) one of Sister's Peak, Airport East and Comfortless Cove. Contours show likely collapse loads for different roof types (Table 1). We assume the tephra is not cleared or eroded between each pulse. Key locations: A: airport, G: Georgetown, PP: power plant and South Atlantic Relay station, TB: Two Boats, TH: Travellers Hill, AF: US Air Force Base. Coordinate reference system: WGS84 / UTM 28S

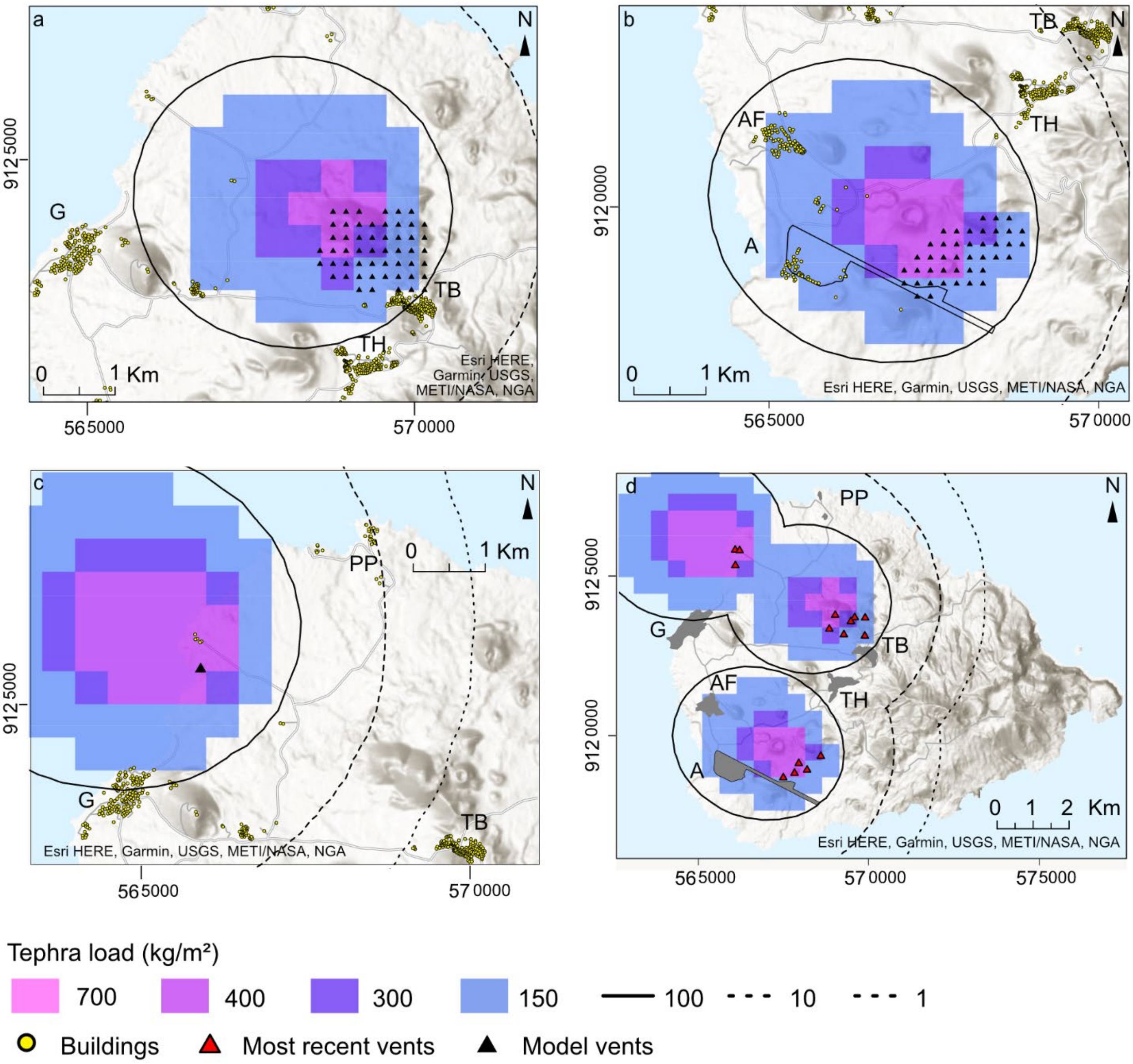

Fig. S5 Tephra ground loads likely to cause roof collapse (≥ 150 kg m^{-2}) with 90 % probability of exceedance for three basaltic eruptions, each with 6–10 km plume from a) Sister's Peak, b) Airport East and c) Comfortless Cove, d) one of Sister's Peak, Airport East and Comfortless Cove. Contours show likely collapse loads for different roof types (Table 1). We assume the tephra is not cleared or eroded between each pulse. Key locations: A: airport, G: Georgetown, PP: power plant and South Atlantic Relay station, TB: Two Boats, TH: Travellers Hill, AF: US Air Force Base. Coordinate reference system: WGS84 / UTM 28S

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