

Supporting information for:

In-plume and out-of-plume analysis of aerosol-cloud interactions derived from the 2014-15 Holuhraun volcanic eruption

5 Animation S1: Total column amount of SO₂ (DU) in the OMPS SO₂ plume mask for days retrieved in September 2014. The SO₂ plume mask is obtained using OMPS PCA L2 v2.0 product regridded to 1° x 1° resolution. A mask is created where the total amount of SO₂ is greater than 1 DU. The grey box shows the bounding box region surrounding the plume mask. Our in-plume vs out-of-plume analysis is conducted within this bounding box. The red star shows location of the eruption site.

10 Animation S2: Total column amount of SO₂ (DU) in the UKESM1-A Holuhraun simulation in September 2014. The plume mask is created from the when the OMPS data regridded to the simulation resolution is greater than 1 DU and shown in grey dots. The grey box shows the bounding box region surrounding the plume mask. Our in-plume vs out-of-plume analysis is conducted within this bounding box. The red star shows location of the eruption site.

15 Animation S3: Vertical mean of sulphate mass concentration ($\mu\text{g m}^{-3}$) in the UKESM1-A Holuhraun simulation in September 2014. The plume mask is created from the when the OMPS data regridded to the simulation resolution is greater than 1 DU and shown in grey dots. The grey box shows the bounding box region surrounding the plume mask. Our in-plume vs out-of-plume analysis is conducted within this bounding box. The red star shows location of the eruption site.

20 Animation S4: Plume analysis of the change in observed liquid cloud droplet number concentration (cm^{-3}) inside vs outside the Holuhraun SO₂ eruption plume. The top subfigure shows daily liquid N_d concentrations as observed from MODIS. The plume mask derived from OMPS SO₂ and bounding box is overlaid. The bottom figure shows a histogram of liquid N_d inside (blue) and outside (orange).

Animation S5: Plume analysis of the change in observed liquid cloud droplet effective radius (μm) inside vs outside the Holuhraun SO₂ eruption plume. The top subfigure shows daily liquid r_{eff} as observed from MODIS. The plume mask derived from OMPS SO₂ and bounding box is overlaid. The bottom figure shows a histogram of liquid r_{eff} inside (blue) and outside (orange).

25 Animation S6: Plume analysis of the change in observed liquid water path (g m^{-2}) inside vs outside the Holuhraun SO₂ eruption plume. The top subfigure shows daily LWP concentrations as observed from MODIS. The plume mask derived from OMPS SO₂ and bounding box is overlaid. The bottom figure shows a histogram of LWP inside (blue) and outside (orange).

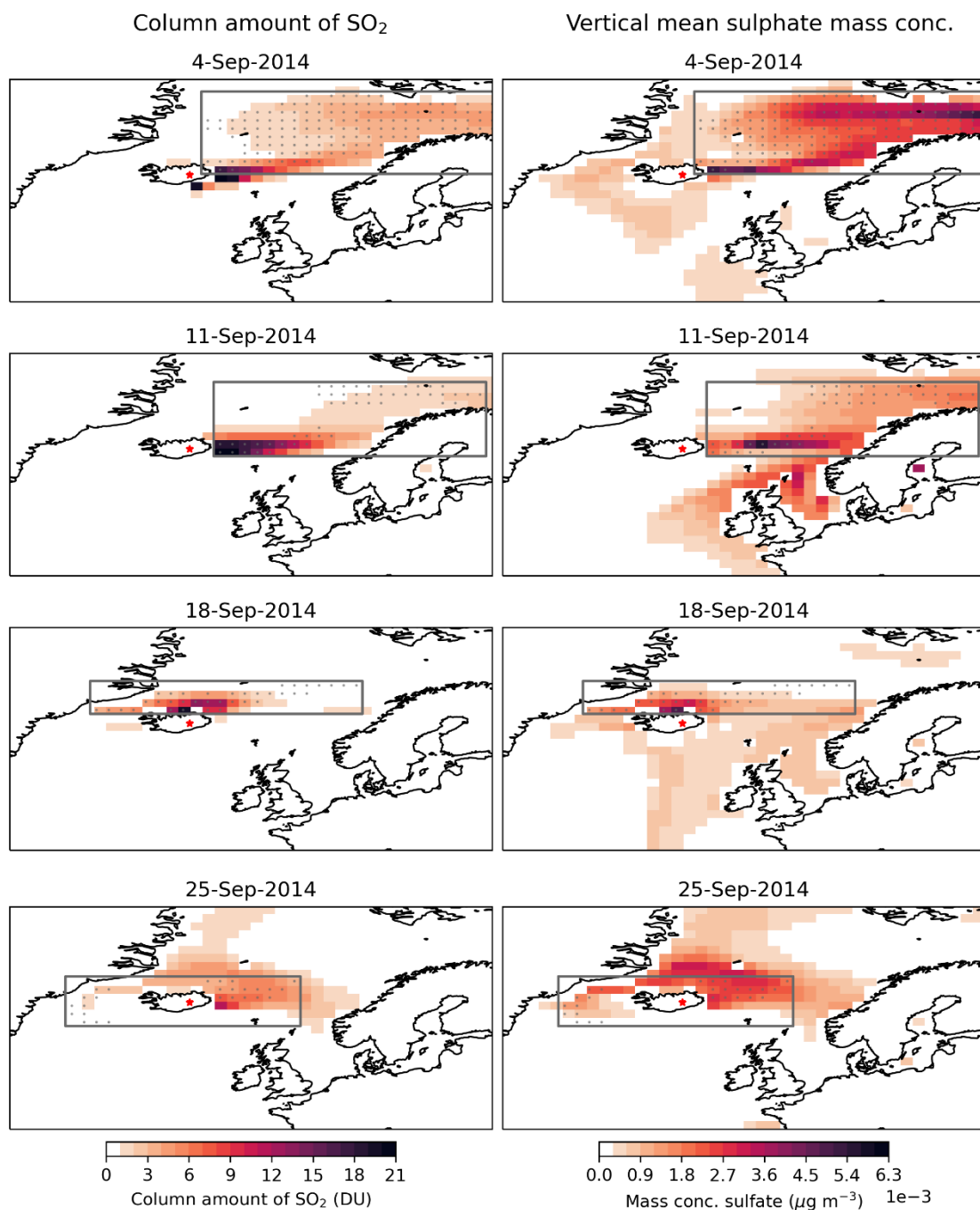
Animation S7: Plume analysis of the change in observed cloud fraction inside vs outside the Holuhraun SO₂ eruption plume. The top subfigure shows daily cloud fraction as observed from MODIS. The plume mask derived from OMPS SO₂ and bounding box is overlaid. The bottom figure shows a histogram of LWP inside (blue) and outside (orange).

30 Animation S8: Altitude of maximum SO₂ mole fraction in the Holuhraun simulation, IASI SO₂ plume height and MODIS liquid cloud top height where OMPS SO₂ > 1 DU. The bottom panel shows where the altitude of maximum SO₂ mole fraction in the Holuhraun simulation and IASI SO₂ plume are above/below the observed liquid cloud top height.

Animation S9: Vertical profile SO₂ mole fraction in the Holuhraun simulation, IASI SO₂ plume height and MODIS liquid cloud top height when averaged over latitude where OMPS SO₂ > 1 DU.

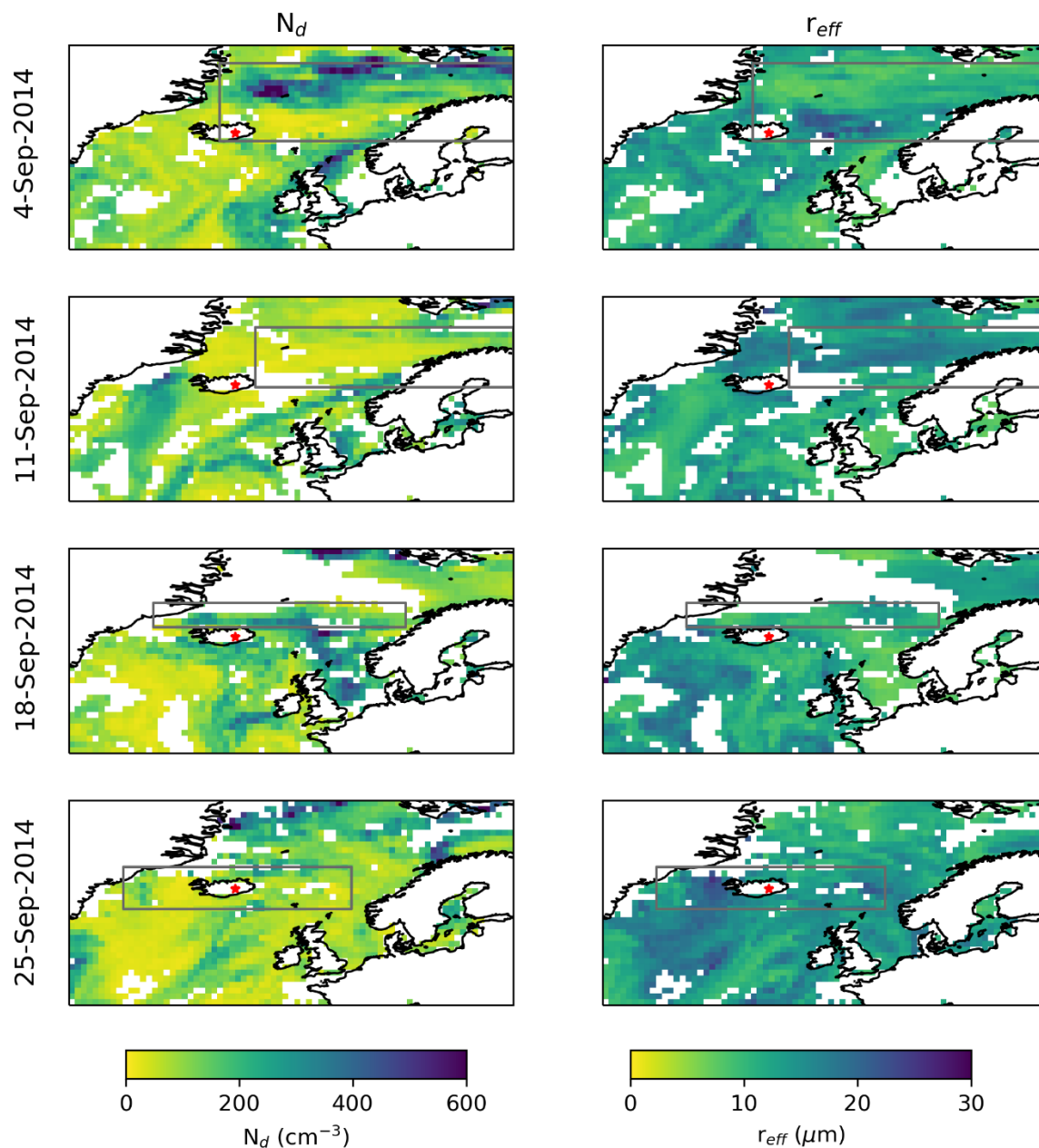
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Comparison of UKESM1-Hol daily mean SO_2 and SO_4^{2-}



40 **Figure S1:** Total column amount of SO_2 (DU) (left) and vertical mean of sulphate mass concentration ($\mu\text{g m}^{-3}$) as simulated in UKESM1-Hol for the midweek day of the four weeks in September 2014 being analysed. The OMPS-coarse plume mask and bounding box is overlaid in grey. The red star shows the location of the eruption site.

MODIS liquid cloud properties overlayed by plume mask bounding region



45 **Figure S2: Map of MODIS liquid cloud droplet number concentration (left column) and effective radius (right column) for the midweek days in September 2014. The plume mask bounding box derived from OMPS SO_2 is overlaid.**

Plume analysis of MODIS liquid cloud properties

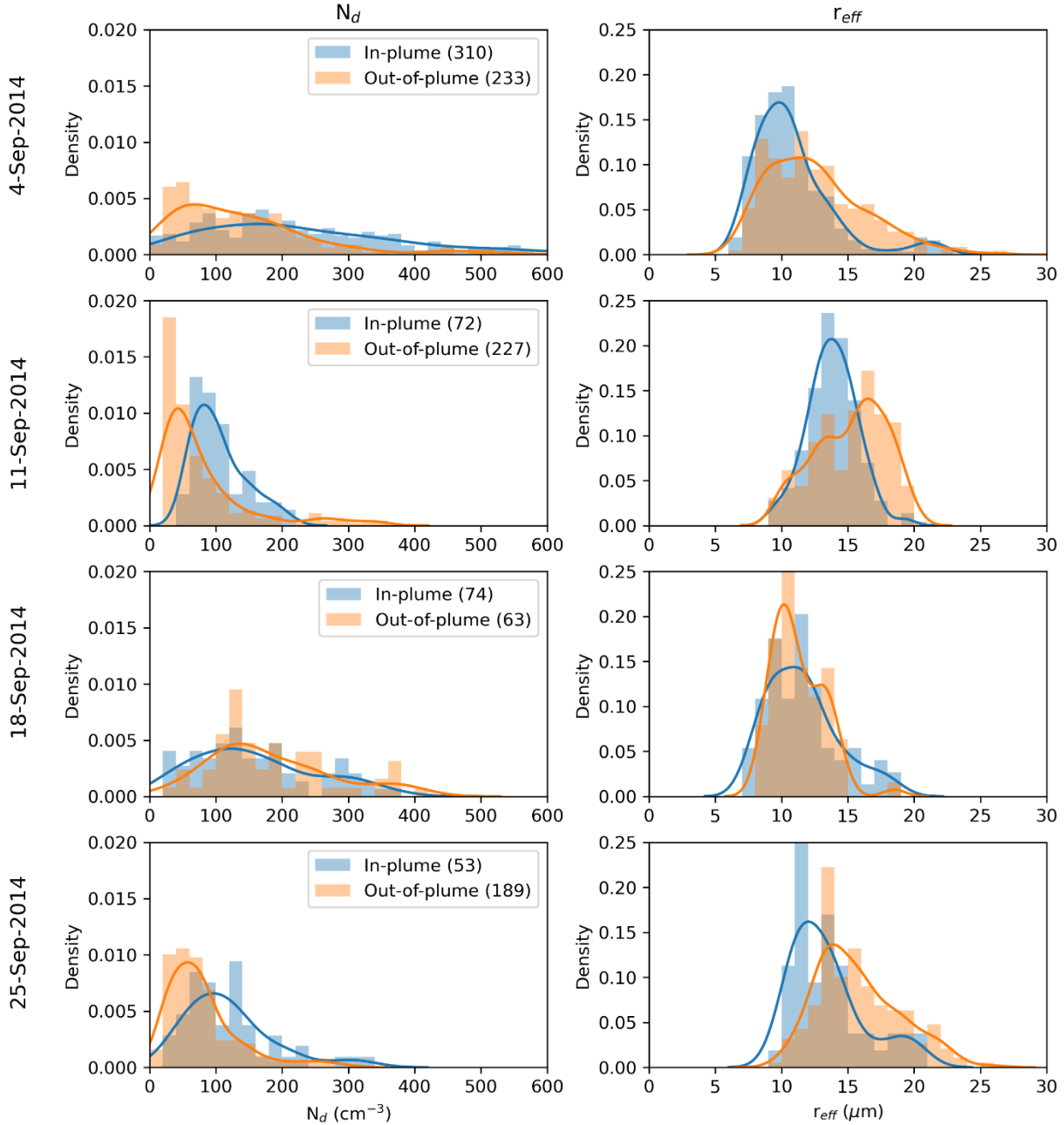


Figure S3: Histogram of MODIS liquid cloud droplet number concentration (left column) and effective radius (right column) in-plume (blue) and out-of-plume (orange) within the bounding box region for snapshot midweek days in September 2014. Only marine liquid cloud properties with are evaluated. The number of in-plume and out-of-plume data points are displayed.

	Week 1	Week 2	Week 3	Week 4
MODIS	989 (1785)	553 (1585)	309 (783)	270 (1308)
UKESM1-Hol	421 (601)	290 (337)	110 (197)	112 (224)
UKESM1-Ctrl	409 (591)	285 (331)	107 (196)	110 (224)

Table S1: Sample size weekly aggregated liquid cloud droplet number concertation for inside (outside) the plume across MODIS observation and UKESM1-A simulaitons.

MODIS liquid cloud fraction

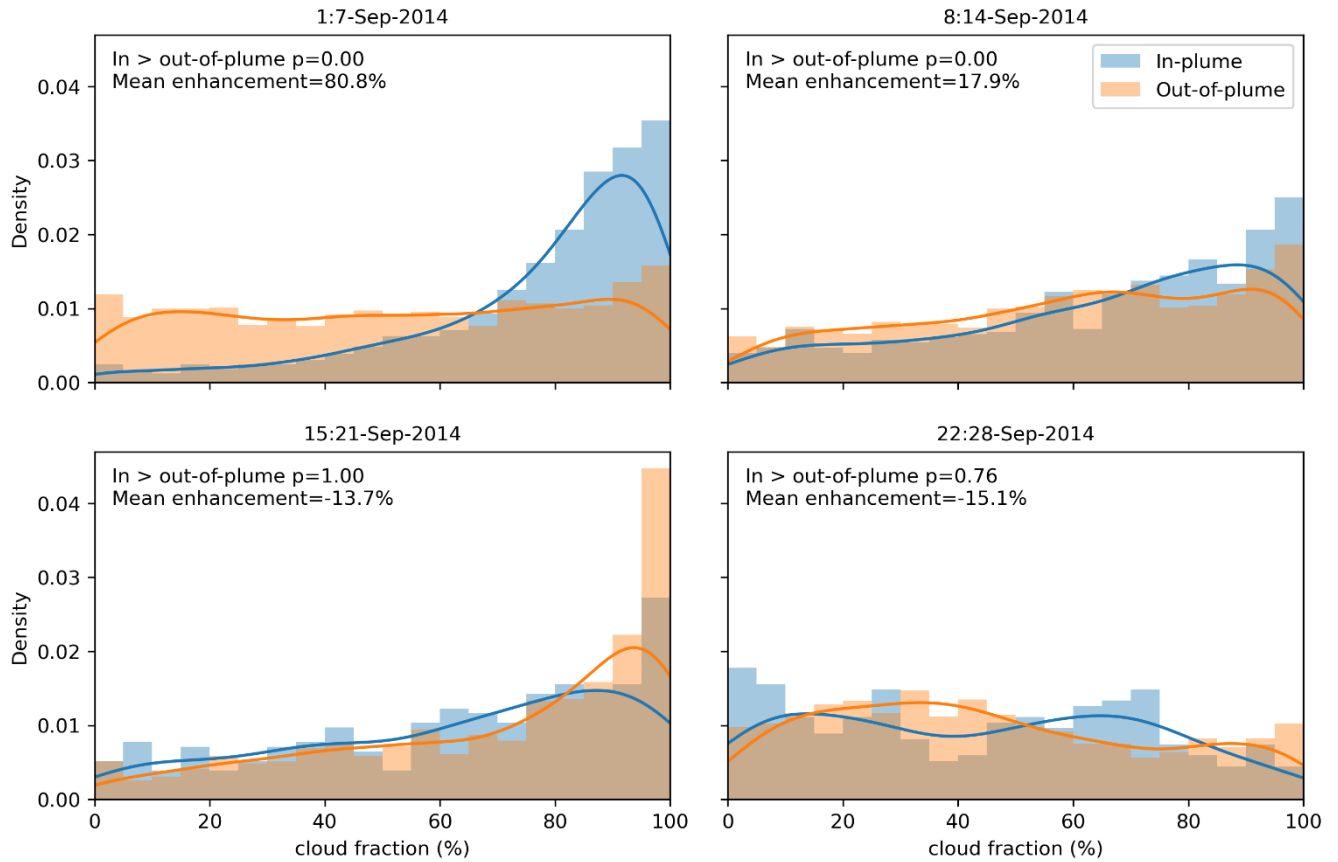
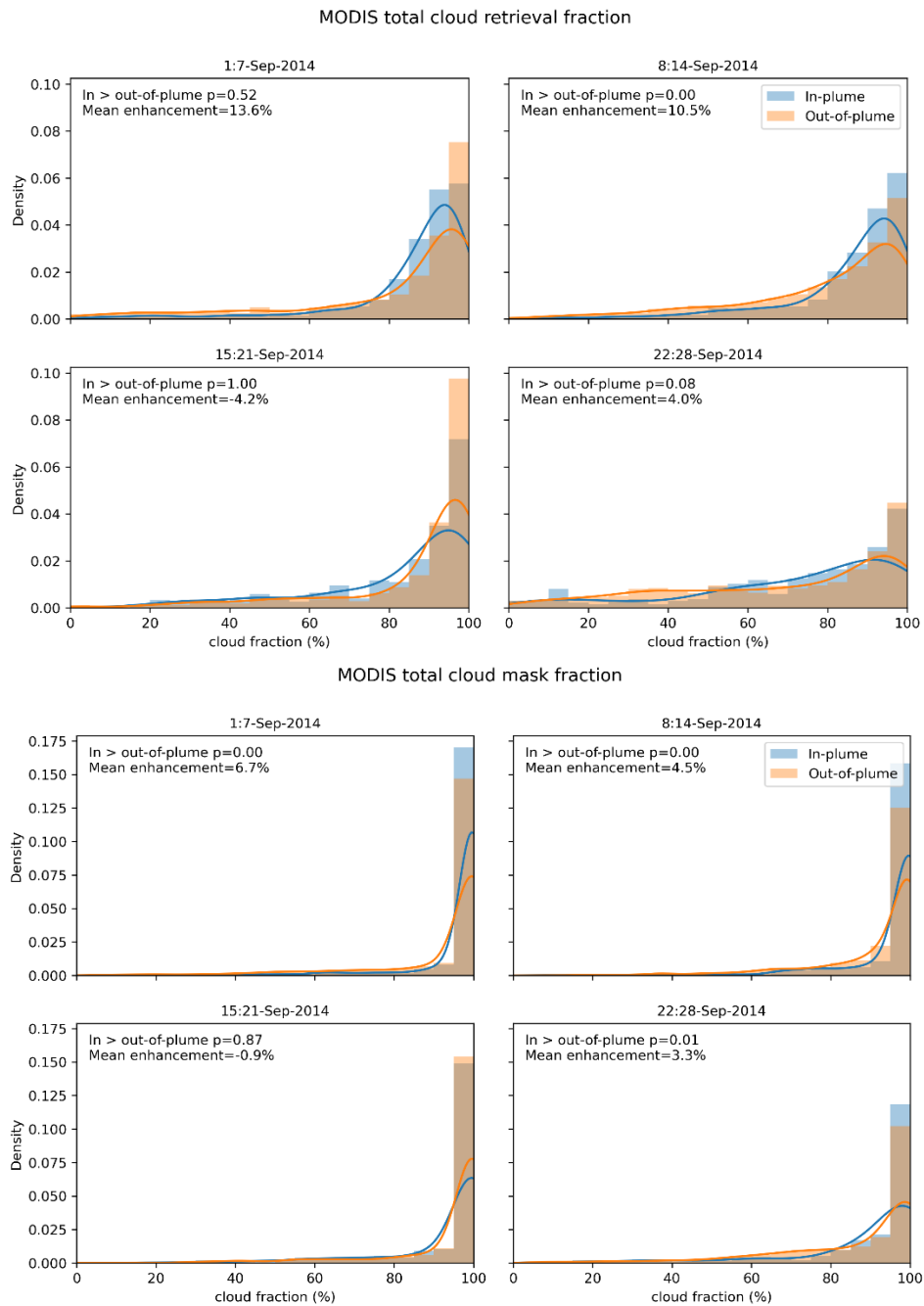


Figure S4: Histogram of MODIS liquid cloud retrieval fraction (%) inside (blue) and outside (orange) the plume mask aggregated by week following the Holuhraun eruption. Only marine cloud properties are evaluated. The Mann-Whitney U test is used to calculate if the in-plume liquid cloud fraction is statistically greater than outside of the plume. The p value and mean in-plume enhancement is displayed for each week.



65 **Figure S5: Histogram of MODIS total cloud retrieval fraction (top) and total cloud mask fraction (bottom) (%) inside (blue) and outside (orange) the plume mask aggregated by week following the Holuhraun eruption. Only marine cloud properties are evaluated. The Mann-Whitney U test is used to calculate if the in-plume liquid cloud fraction is statistically greater than outside of the plume. The p value and mean in-plume enhancement is displayed for each week.**

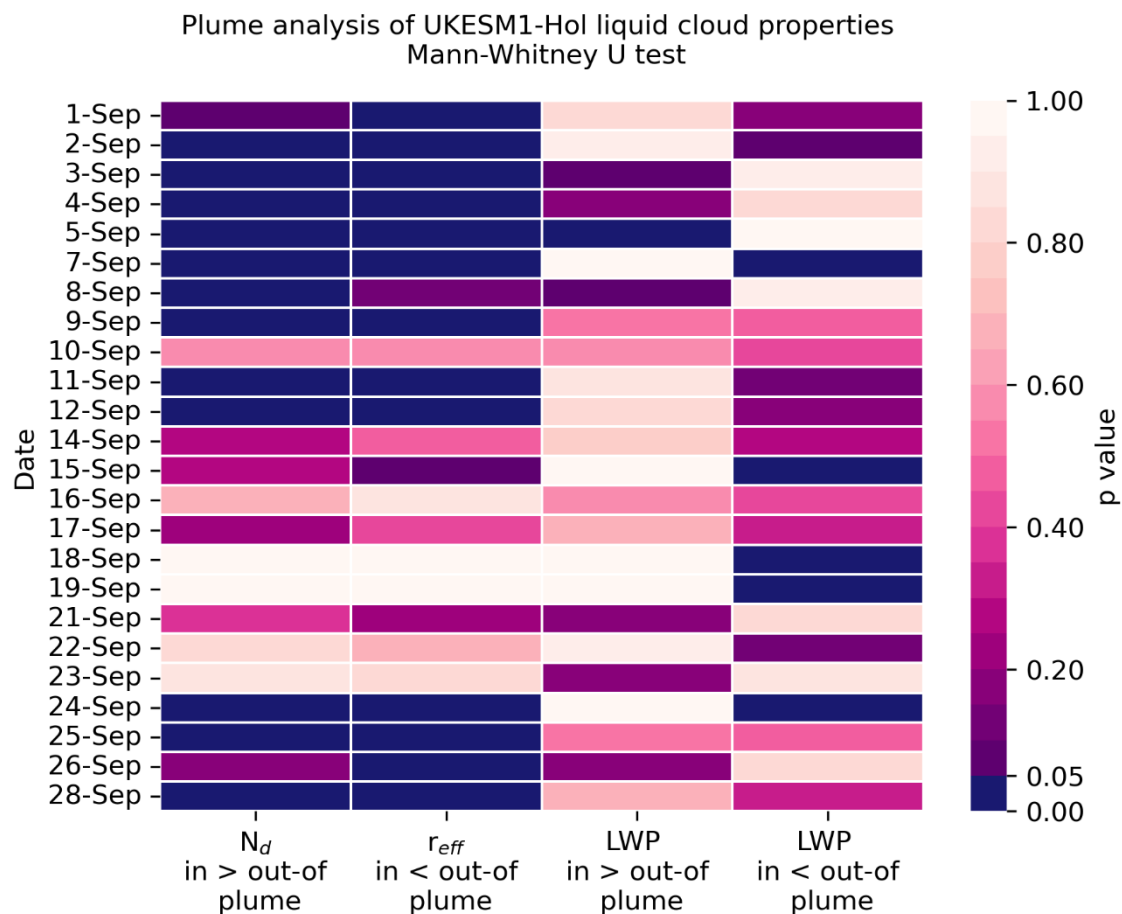


Figure S6: Statistical significance changes in cloud properties from the UKESM1-Hol simulations inside vs outside of the OMPS SO₂ plume mask regridded to UKESM1-A resolution. Significance is evaluated using the Mann-Whitney U test. For liquid cloud droplet number and effective radius, significance is evaluated for the direction of an expected increase in N_d and decrease in r_{eff} inside the plume. LWP is evaluated in both directions. The colour bar displays the p value, with dark blue indicating a statistically significant perturbation to cloud properties inside the plume for that day.

UKESM1 liquid N_d

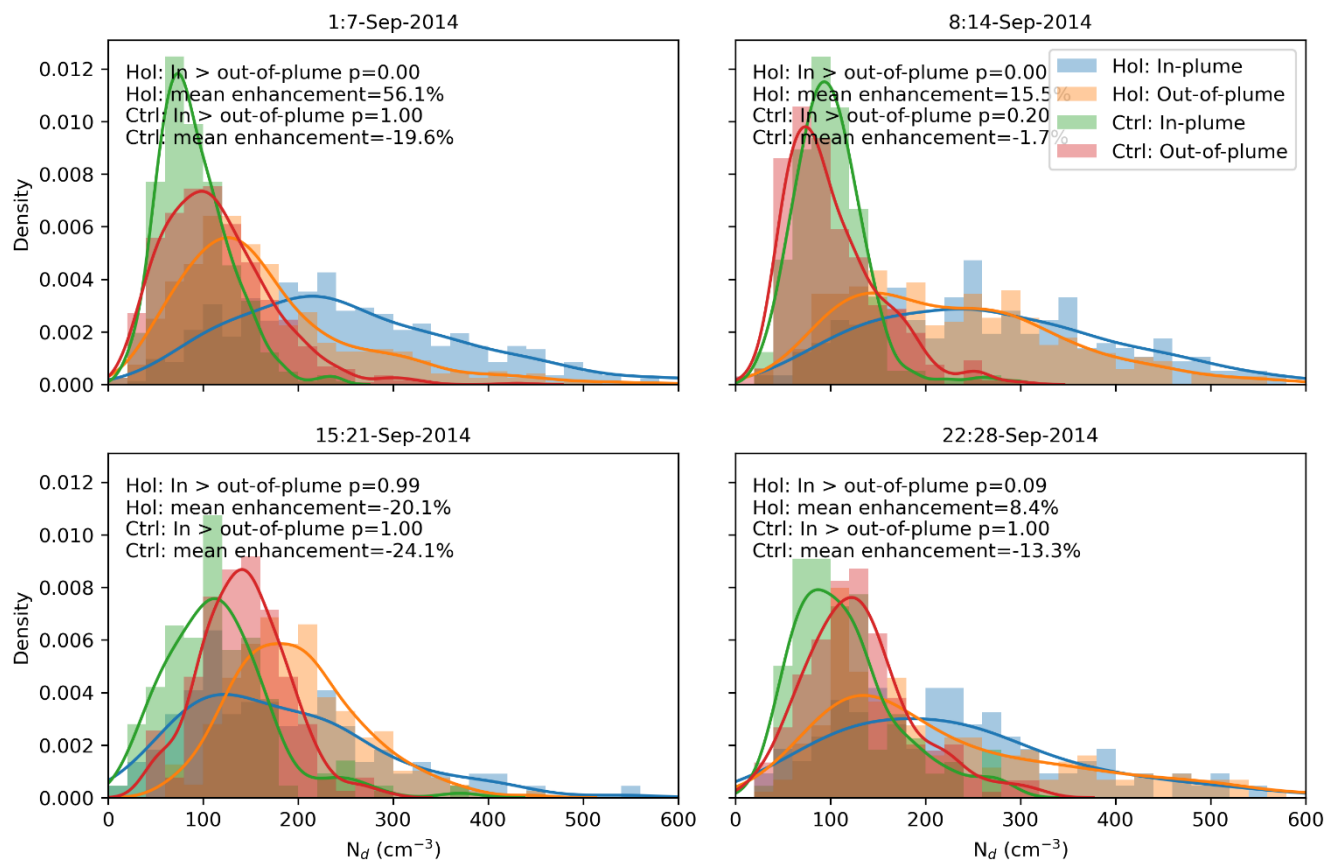


Figure S7: Histogram of liquid cloud droplet number concentration (cm^{-3}) inside and outside the plume mask aggregated by week following the Holuhraun eruption for UKESM1-A simulations daily average. The simulations with the volcanic eruption are shown in blue and orange, and the control simulations are shown in green and red. OMPS has been regridded to UKESM1 resolution prior to calculating the plume mask. Only marine clouds are retained. The Mann-Whitney U test is used to calculate if the in-plume N_d is statistically greater inside the plume than outside of the plume. The p value and mean in-plume enhancement is displayed for each week for the eruption and control simulations.

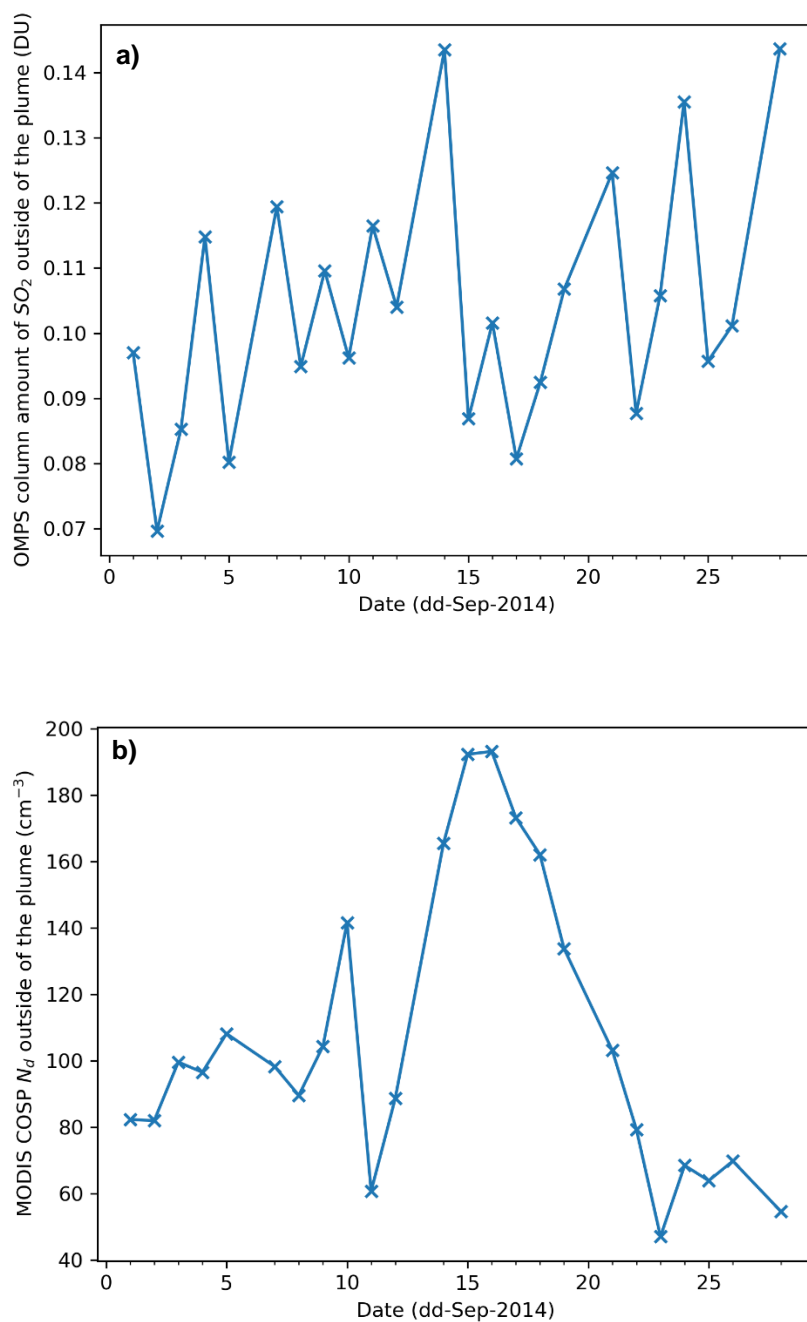


Figure S8: Area-weighted geometric mean of out-of-plume (a) OMPS SO_2 and (b) MODIS liquid N_d .