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Halogen chemistry in Mount Etna's volcanic plume in December 2018: Comparisons between 3D MOCAGE CTM simulations and TROPOMI satellite measurements

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Volcanoes are known to be important emitters of atmospheric gases and aerosols, both through explosive eruptions and persistent quiescent degassing (von Glasow et al., 2009). The most abundant gases in volcanic emissions are H_2O, CO_2, SO_2 and halogens (HCl, HBr, HF). In general, halogens play an important role in the atmosphere by modifying air composition and oxidizing capacity in the troposphere (von Glasow et al., 2004). The chemical processes occurring within the plume lead to the formation of BrO following the 'bromine explosion' mechanism as evidenced from both observations and modelling (e.g. Bobrowski et al., 2003; Roberts et al., 2009). Oxidized forms of bromine (BrO) are formed during daytime within the plume due to heterogeneous reactions of HBr on volcanic aerosols leading to ozone depletion. So far, modelling studies mainly focused on spatial scales ranging from 10m to ~1km and processes occurring within a few hours after eruption.

The objective of this study is to go a step further by analysing the impact at the regional scale namely over the whole Mediterranean basin of a single Mt Etna eruption event in December 2018. For this, we have further developed the MOCAGE model (Guth et al., 2016), a chemistry transport model run at a resolution of 0.2°× 0.2°, to quantify the impacts of the halogen species emitted by the volcano on air composition. We selected here the case of the eruption of Mt Etna around Christmas 2018 characterised by large amounts of emissions over several days.

The results show that MOCAGE represents the halogen chemistry in the volcanic plume quite well. The bromine-explosion cycle takes place during the day of the eruption, with a rapid increase in BrO concentration leading to a strong depletion in ozone and NO□ concentrations across the Mediterranean as well as to changes in the air composition in particular for bromine compounds such as Br, HOBr, BrONO□, Br_2 and BrCl. Adding to this, BrO is formed again on the following day (25/12/2018) during daytime from the bromine reservoir species from night time leading to

additional ozone depletion.

The comparison of the tropospheric columns of BrO and SO_2 retrievals from the TROPOMI spaceborne instrument with the MOCAGE simulations shows that the tropospheric BrO and SO_2 columns have the same order of magnitude and that the locations of the simulated and observed plumes are overall in good agreement during the main eruption period and the following six days. The comparison shows also the similarity of the order of magnitude of the BrO/SO_2 ratio between MOCAGE and TROPOMI, especially for the 25th of December 2018.