**2.2 Configuration of Earth System Modelling**

The UK's Earth system model, UKESM1-0-LL, (referred to as UKESM1 here) has been developed based on the Global Coupled 3.1 (GC3.1) configuration of HadGEM3 (Williams et al., 2018) with the addition of various Earth system components such as ocean biogeochemistry, terrestrial carbon-nitrogen cycle, and atmospheric chemistry (Sellar et al., 2019). The atmospheric and land components of the model are described in Walters et al. (2019). The chemistry scheme used in UKESM1 is a combination of stratosphere-troposphere chemistry schemes (Archibald et al., 2020b) from the UK Chemistry and Aerosol (UKCA) model. The stratospheric chemistry scheme of Morgenstern et al. (2009) is combined with the tropospheric (TropIsop) chemistry scheme of O'Connor et al. (2014). Archibald et al. (2020b) is currently under discussion to describe and evaluate this stratosphere-troposphere scheme in UKESM1. The aerosol scheme used in the model is the two-moment scheme GLOMAP mode from UKCA, which models sulfate, sea salt, organic carbon, and black carbon. Dust is modelled separately in six size bins following a variant of the Woodward scheme. Improvements to the aerosol scheme were required for GA7.1 to address the strong negative aerosol forcing found with GA7.0, which are documented in Mulcahy et al. (2018). Mulcahy et al. (2020) provides a further discussion of the aerosol radiative forcing in UKESM1.

Anthropogenic and biomass burning emissions are prescribed using Hoesly et al. (2018) and van Marle et al. (2017a), while isoprene and monoterpenes emissions are interactive and based on the interactive biogenic VOC (iBVOC) emission model (Pacifico et al., 2011). Lightning emissions of NOx (LNOx) are also interactive, using the cloud top height parameterization of Price and Rind (Price and Rind, 1992, 1993). Other natural emissions are prescribed as climatology, and will be fully discussed in Archibald et al. (2020b). The model uses internally consistent stratospheric aerosol optical depth (AOD) and surface area density (SAD) for volcanic eruptions, both for the volcanic forcing and for the UKCA stratospheric heterogeneous chemistry.

UKESM1-0-LL considers 84 gas-phase species, 59 photolytic reactions, 224 kinetic reactions (199 bimolecular, 25 unimolecular and termolecular), and 5 heterogeneous reactions.

We use the fully coupled historical simulation endorsed into the DECK experiments to capture the realistic surface O3.

We developed the chemistry module of UKESM1-0-LL, the UKCA, and therefore we own the full knowledge of the chemistry kinetic rate coefficients applied in chemistry simulation. This is the reason for our choosing UKESM1-0-LL as base for analysis, rather than other CMIP6 models.