6. D3.1: Report of the injection heights of stratospheric smoke for selected events

6.1. Introduction

The largest known stratospheric smoke injection was associated with the fierce Australian wildfires in the New Year of 2019/2020 (ANY hereafter). Many pyroCbs injected over 1 million tons of smoke particles into the stratosphere, reaching altitudes up to 35 kilometers. The mass and reach of this aerosol injection exceeded all volcanic aerosol injections over the last 30 years. Satellite- and ground-based measurements subsequently detected self-lofting, significant stratospheric warming, and a considerable reduction in mid-latitude ozone that lasted several months. During November-December 2020, the Antarctic ozone hole reached a decadal high in magnitude and persistence, along with record-low polar temperatures and a strong polar vortex. The magnitude of the rec-ord-high ozone depletion event in 2020 corresponds to a ~10-year delay in ozone recovery.

6.2. Injection heights: model vs satellites

Wildfires need to be investigated with respect to their relation to weather, climate, and society. Here, we use the EMAC Earth System Model to simulate atmospheric and climatic responses to the ANY wildfires. The model is configured with a) aerosol microphysics, b) chemistry with heterogenous reactions, c) a scheme for PSCs, and d) comprehensive chemistry-radiation-dynamics interactions. EMAC links together all the key mechanisms between the stratosphere and surface, which makes it possible to quantify how strato-spheric smoke affects the global radiative balance, circulation, ozone concentrations, and surface UV levels and precipitation patterns.

As a first step, we carry out sensitivity simulations to examine the sensitivity of the stratospheric aerosol loading to injection height of the smoke (Table 2). The model is running with nudged meteorology from ERA5 till 28 December 2019 and freely thereafter till the end of 2020. We emit 0.9 Tg of smoke composed by 97.5% organic carbon and 25 % Black Carbon. The particles are emitted in the insoluble Aitken mode.

Simulation	Description
Free_13Km	Nudging ends 28 Dec 2019. Emission 11-13 Km
Free_14Km	As Free but emission between 11-14 Km
Free_15Km	As Free but emission between 11-15 Km
Free_16Km	As Free but emission between 11-16 Km

Table 4 List of the sensitivity simulations with the EMAC model.

Figure 13 shows aerosol extinction coefficients (1/Km) averaged from 20S to 60S at 14, 18 and 22 Km. Superimposed in dots are extinction coefficients from the monthly mean GLOSSAC merged aerosol dataset and SAGE-ISS observations. Our model generally shows a faster increase in the extinction coefficients in the fist months after the ANY pyroCBs whether observations indicate a more gradual buildup, peaking in March 2020. Similar behavior is simulated in 20 Km. At 24 Km the model underestimates considerably the magnitude of the aerosol extinction by the injected smoke in all sensitivity runs. Regarding the emission height, we find that a maximum injection of smoke at 16 Km gives the best similarity to the observed extinction.

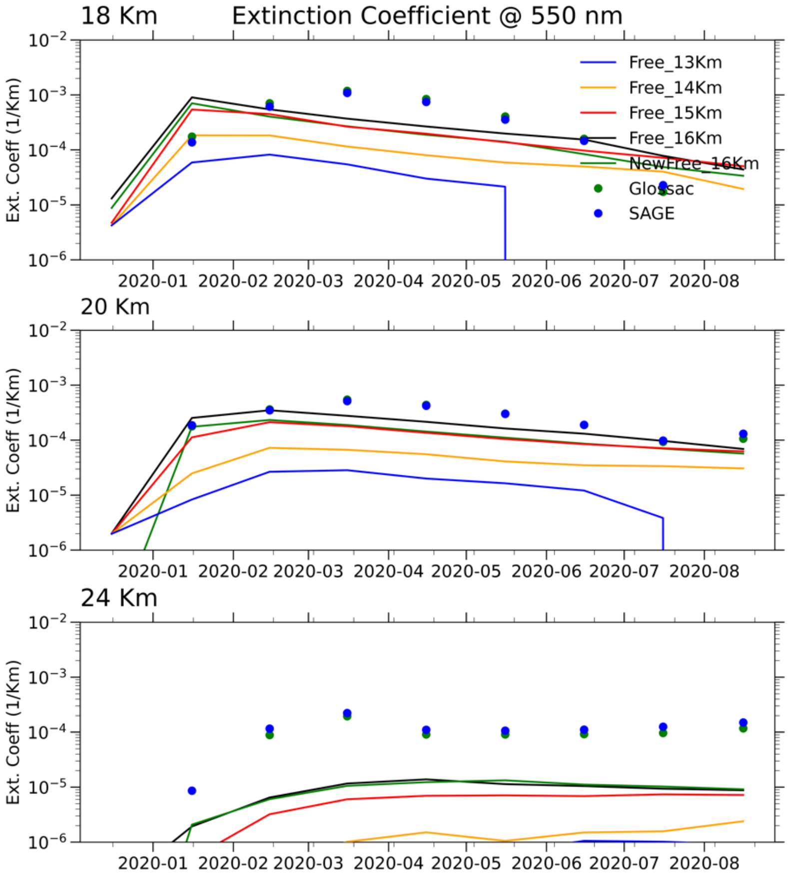

Figure 13 Extinction coefficients (lines) averaged between 20S-60S in the simulations with EMAC. Dots indicate extinction coefficients from SAGE (blue) and Glossac (green) datasets. Units in 1/Km.

Figure 14 compares the time evolution of the stratospheric aerosol optical depth (SAOD) from the ANY wildfires assuming different emission heights. We find that an injection height at 13 Km perturbs aerosols in the stratosphere for 5 months only. In contrast, an injection at 16 Km height causes an aerosol perturbation in both hemispheres. In the Southern Hemisphere, SAOD is perturbed even in the following year with values above 0.001. Interestingly, smoke penetrates in the Northern Hemisphere and reaches the Arctic in June-July 2020.

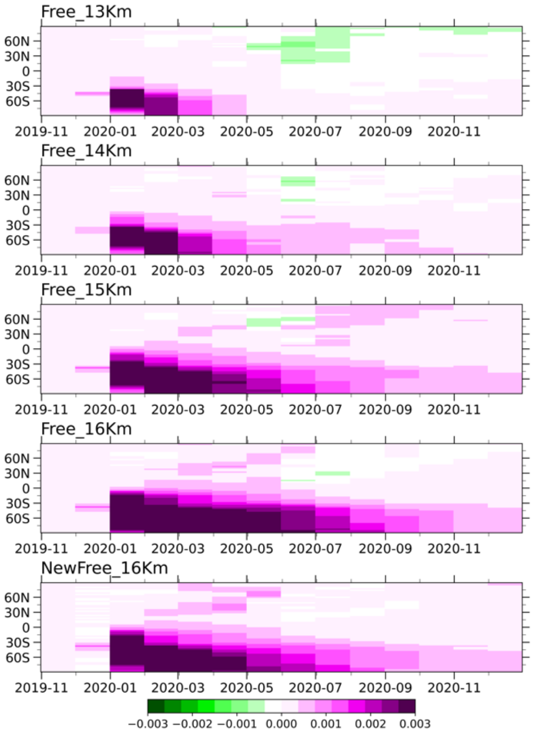

Figure 14 Latitude-time cross sections of stratospheric aerosol optical depth in the EMAC sensitivity simulations.

In the first set of simulations presented here, we examined the sensitivity of the SAOD to the injection height of the smoke plume. The best agreement with observations is found by assuming a maximum injection height at 16 Km. The next step will be to quantify the radiative perturbations in the stratosphere and the global radiative forcing after ANY. Smoke, however, presents rather different properties from the liquid, spherical, less light-absorbing sulfuric acid droplets of volcanic origin that are usually found at strato-spheric altitudes. StratoFIRE will explore a detailed characterization of the optical and microphysical properties of stratospheric smoke, which at present remain poorly understood mainly due to the sparsity of the remote sensing /in-situ observations in the LS. This uncertainty complicates considerably any assessment about the radiative impacts of stratospheric smoke.