Impact of wildfires and volcanic activity on the effective radius of stratospheric aerosol: insight from the B^2SAP network

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Introduction

The Balloon Based Stratospheric Aerosol Profiles (B2SAP) network launches high-altitude balloons (surface – 28 km altitude) from a range of latitudes to characterize the background stratospheric environment.

The payload measures water vapor, ozone and aerosol size distribution.

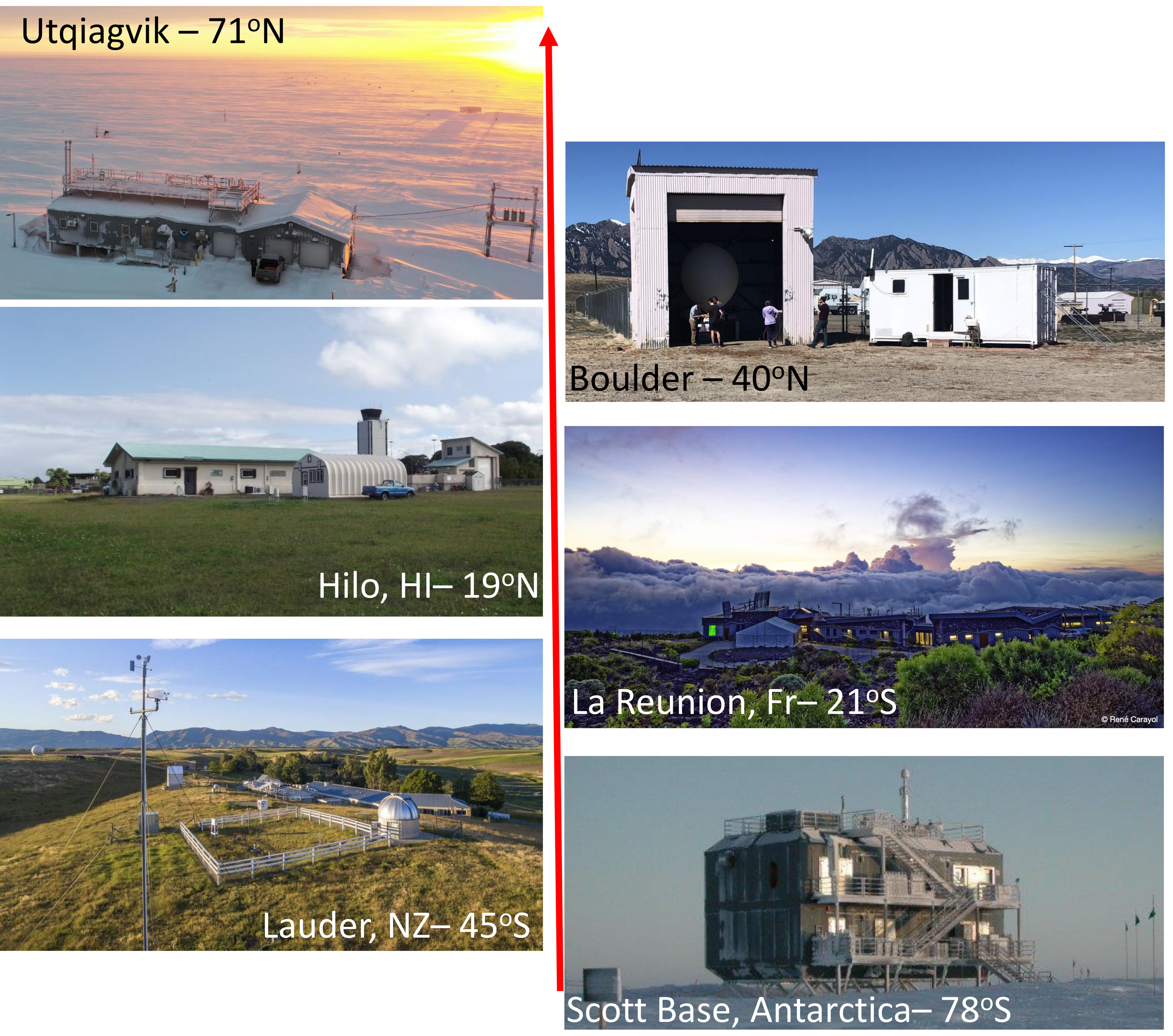
Water vapor – NOAA GML Frost Point Hygrometer

Ozone – NOAA GML ECC ozone sonde

Aerosol – Portable Optical Particle Spectrometer (**POPS**)

Balloon launch sites

Latitude



Why are stratospheric aerosol measurements important?

- Play a role in global radiation budget
- Impact climate change
- Chemistry on surfaces
- Important for ozone layer chemistry
- Stratospheric aerosol injection research

Knowing the aerosol size distribution is crucial for determining how changes to the characteristic background stratospheric aerosol will impact the Earths climate

Large scale events on the surface, such as volcanoes and wildfires can introduce aerosols to the stratosphere.

This perturbs the background stratospheric state and impacts the global radiative balance, chemistry and dynamics.

Hunga volano erupted in 2022 – Image from ABC News

California wildfire– Image from Business Insider

Background

There are aerosols at different levels of the atmosphere and the size of the particles determines the impact they have on their environment.

Aerosol size distribution describes the range of sizes of particles in the atmosphere. POPS measures between 140 nm – 2 µm sized particles.

Effective radius is a way to estimate the average size of these particles for any given aerosol size distribution.

Aerosol number concentration – a count of aerosols per cm^3 of air

Surface area concentration – the summed surface area of the particles in cm^3 of air

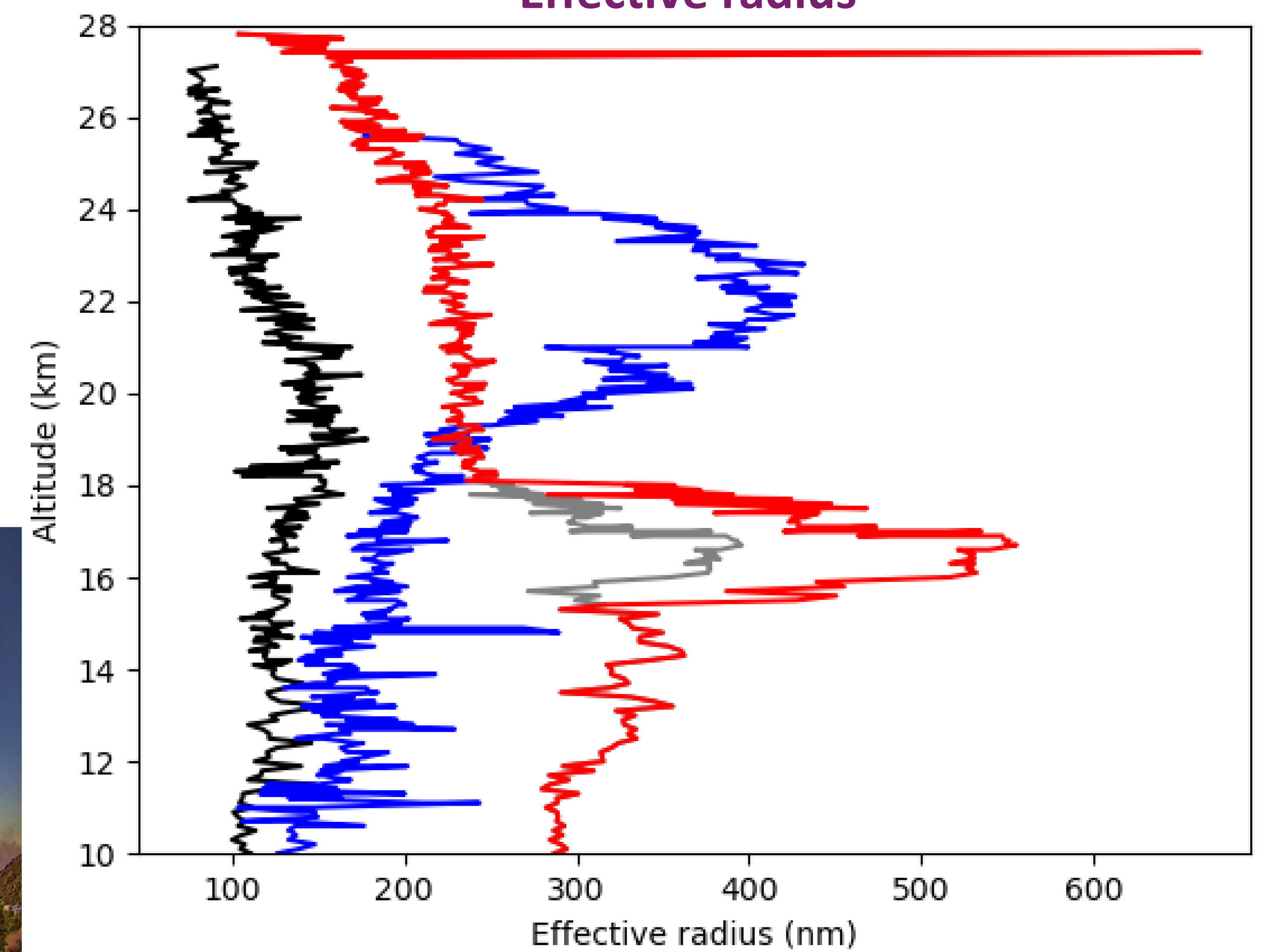
Volume concentration – the summed volume of the particles in cm^3 of air

Objectives

Characterize stratospheric background effective radius for 1 launch site. Assume stratospheric aerosol are mainly sulfuric acid and water, index of refraction (R_i) = 1.45 + 0j

Hunga eruption (**Hunga**) occurred in Dec 2021 and the aerosol plume traversed the globe. Image of Hunga aerosol plume (red c.a. 30 km altitude) taken at LaReunion. The aerosol vertical profile was recorded by balloon-borne POPS, launch from Lauder in May 2022 and the Hunga aerosol plume was observed as an enhancement in effective radius at 20 – 26 km altitude.

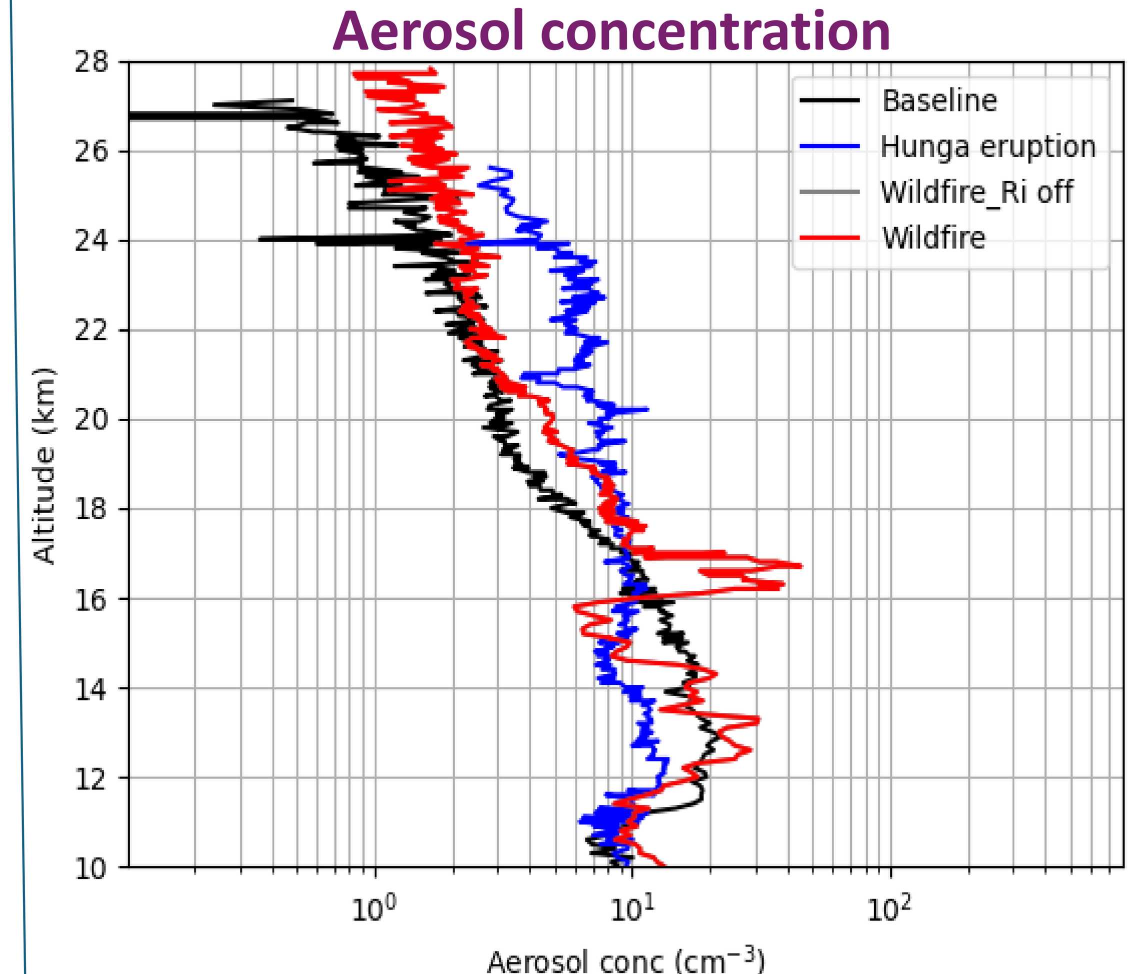
Effective radius



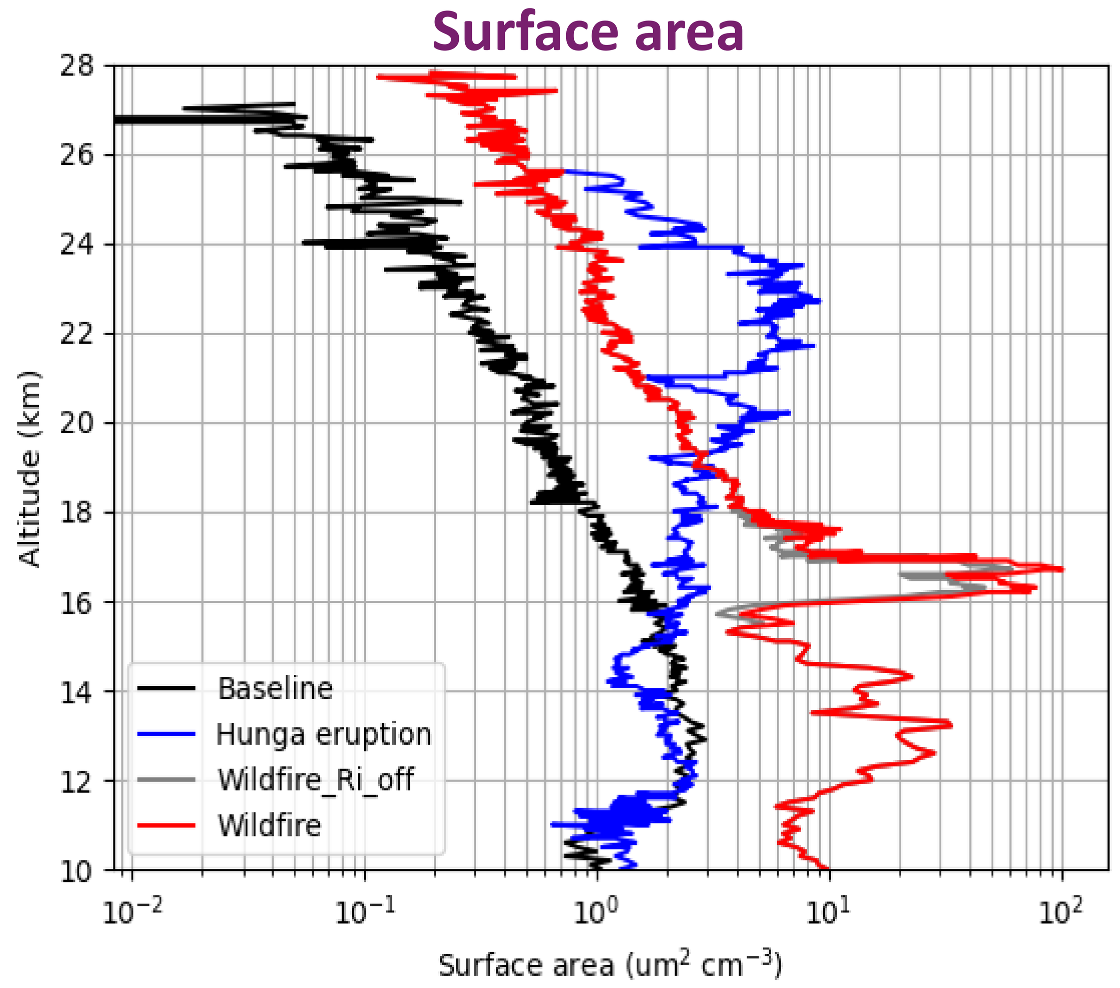
Australian wildfires (**ANYSO**) occurred in Jan 2020. Estimated 243,000 km^2 burnt. R_{eff} from POPS in smoke.

R_i = 1.54 + 0.018j used for the smoke particles between 15.5-18 km. The aerosol profile was recorded by balloon-borne POPS launch from Lauder in Jan 2020. The wildfire plume was a narrow band of enhanced effective radius at 16-18 km.

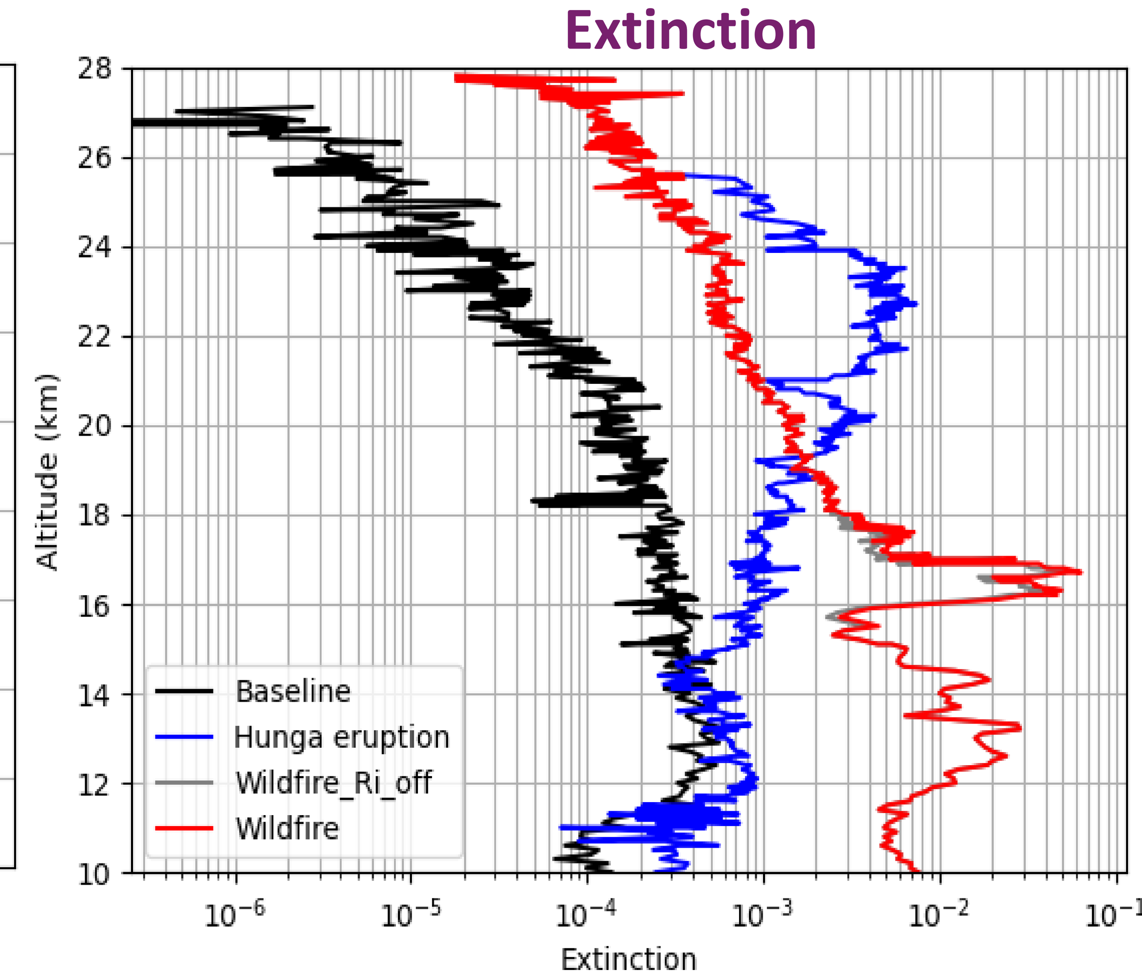
Aerosol concentration



Surface area



Extinction



A plume from the Hunga eruption was observed by POPS as:

- Enhancement in effective radius between 20 – 26 km altitude.
- Slight increase in aerosol concentration > 18 km altitude.
- Larger increase in surface area > 18 km.
- Increase in effective area is therefore caused by larger particles but the amount of particles per cm^3 wasn't enhanced much above background.

The Wildfire plume was measured by POPS as:

- A narrow enhancement in effective radius
- A sharp enhancement in aerosol concentration and surface area
- Therefore, the increase in effective radius is likely due to an increase in aerosols per cm^3, rather than particles increasing in size.

Importance of enhancement in effective radius in the lower stratosphere:

Increased surface area – more surfaces for chemical reactions to occur, altering stratospheric chemical reactions > 20 km. The ozone layer is situated 20-24 km altitude, thus vulnerable to changing ozone chemistry.

Increased particle size and aerosol : alters dynamics and scattering of light, potential to impact climate and radiation budget.

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