

Portable Optical Particle Spectrometer measurements in support of SAGE III-ISS aerosol retrieval

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SAGE III-ISS Science Team Meeting 2020

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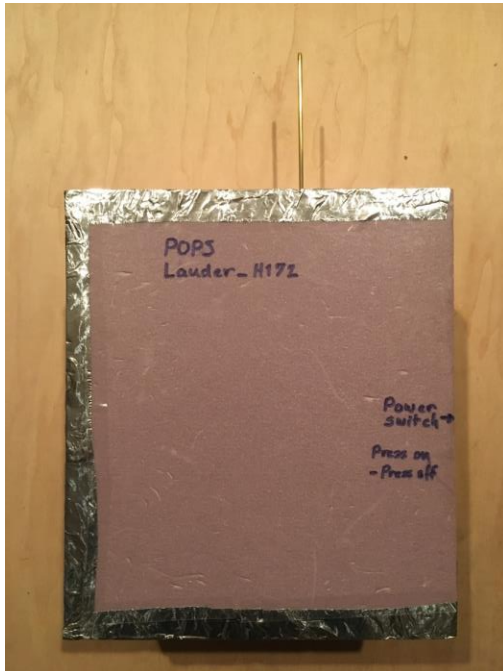
Outline

- POPS instrument and measurement
- Timeline of POPS stratospheric measurements
- SAGE III-ISS Boulder sondes
- SAGE III-ISS Lauder sondes
- Status and plans



Photo credit:
Jim Elkins

Portable Optical Particle Spectrometer

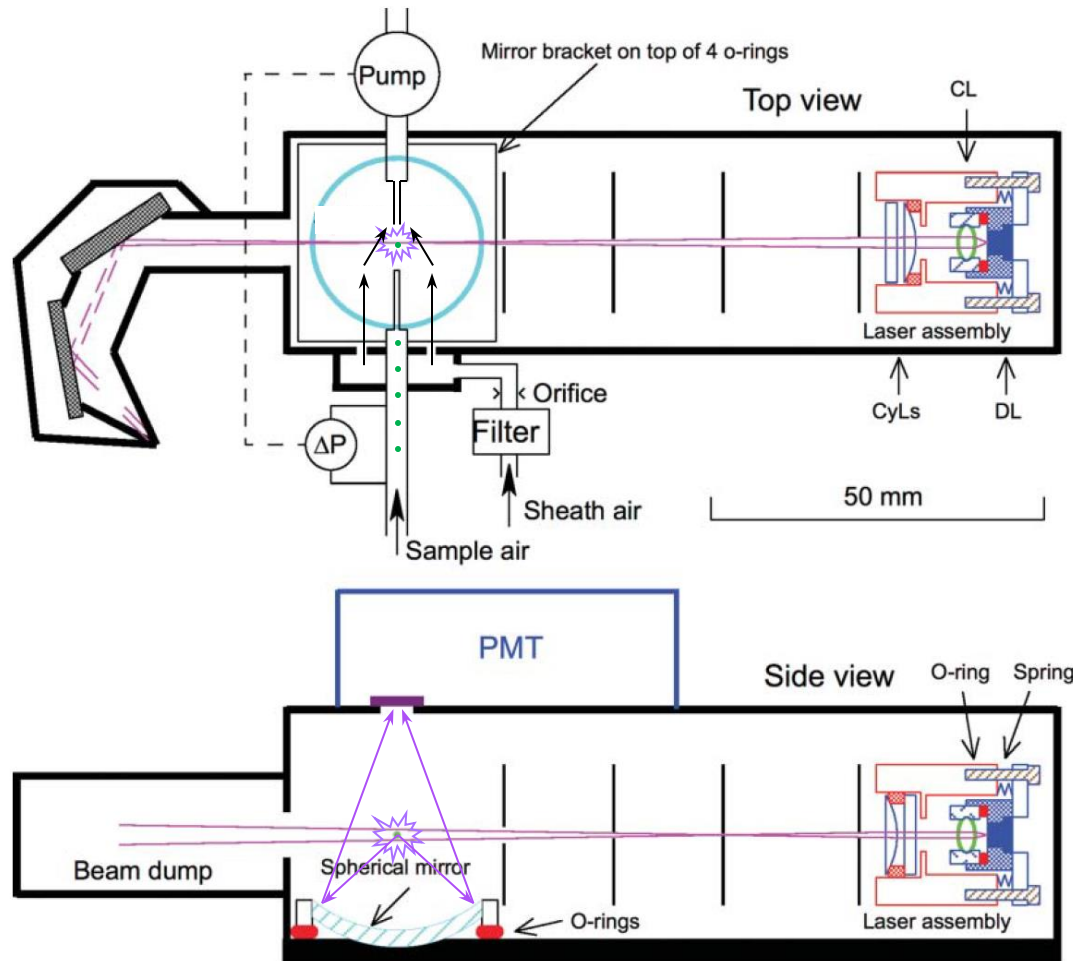


POPS specifications:

- 950 g
- 5 Watts
- Single-particle detection
- 140 – 2500 nm diameter range
- 3 - 5.5 cm³ s⁻¹ sample flow
- Measurements to > 28 km

Gao et al., AS&T 2016

POPS Measurement is Simple and Robust



- Measures light scattered from a 405 nm (Blu-Ray) laser when a particle passes through the beam
- The intensity of the scattered light is a function of the particle size
- Peak height and width are recorded for each individual particle
- Particle counts within preselected size bins are reported each second
- Calibrated Mie theory calculation used to determine particle geometric size from the measured signal
 - Requires assuming an index of refraction and spherical shape (a requirement for all optical particle sizing instruments)

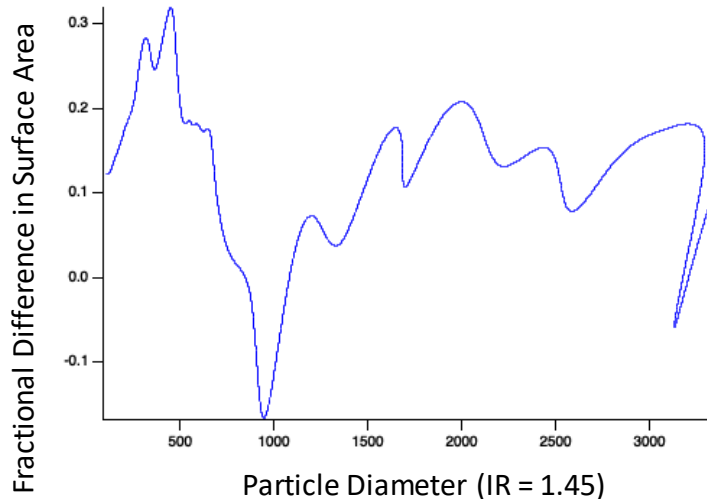
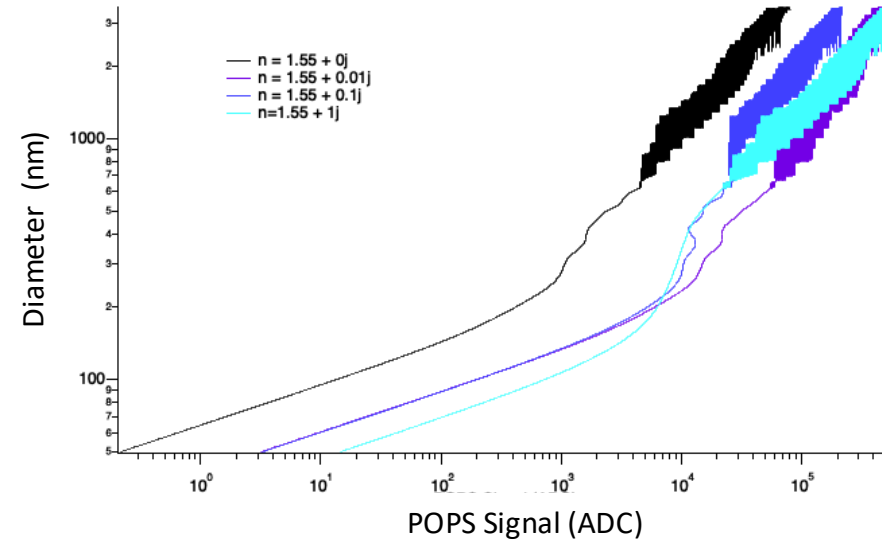
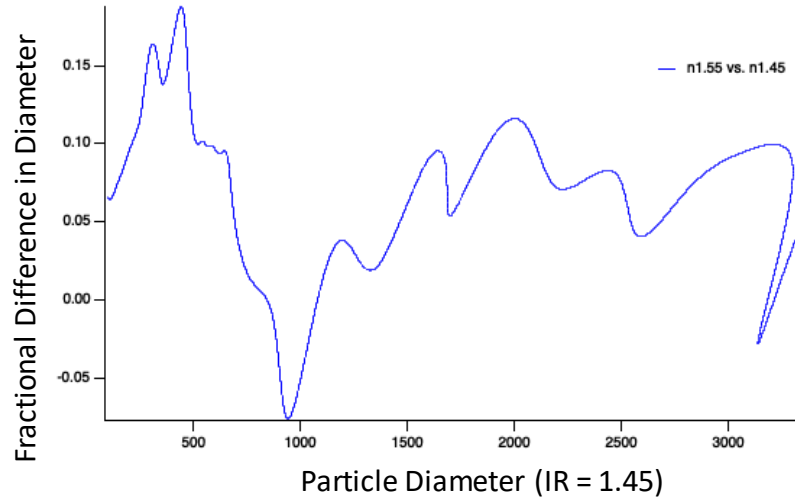
adapted from Gao et al., AS&T 2016

Sizing aerosol can be a bit like using a rear-view mirror-
objects may be larger (or smaller than they appear).



- It may depend on aerosol composition and the bulk index of refraction!

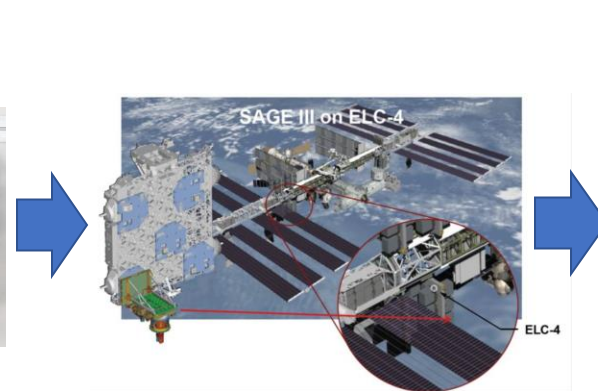
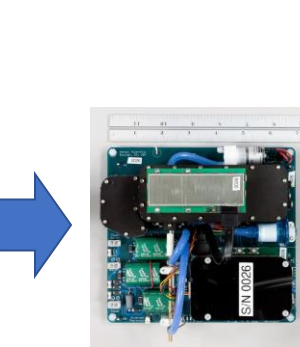
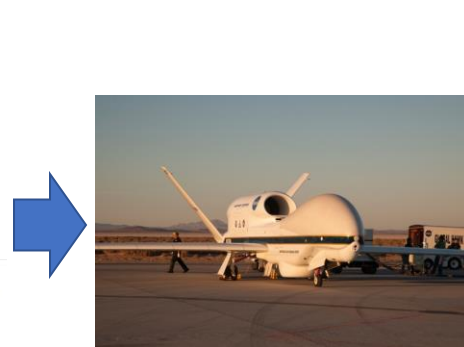
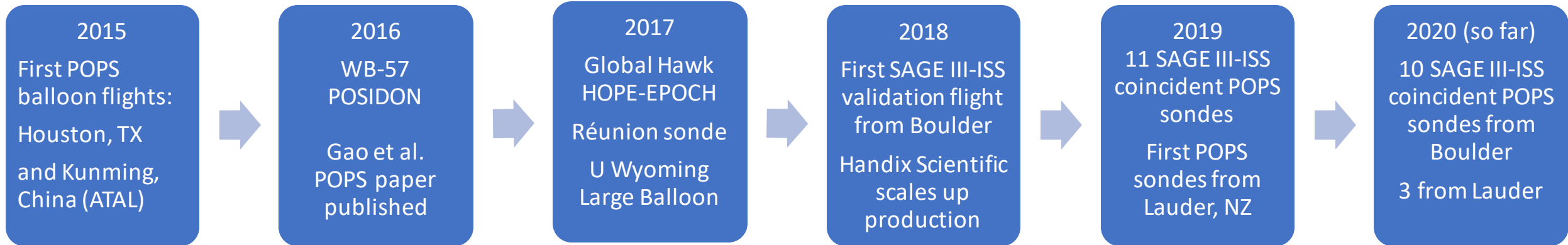
Refractive Index Effects on Aerosol Size Determination



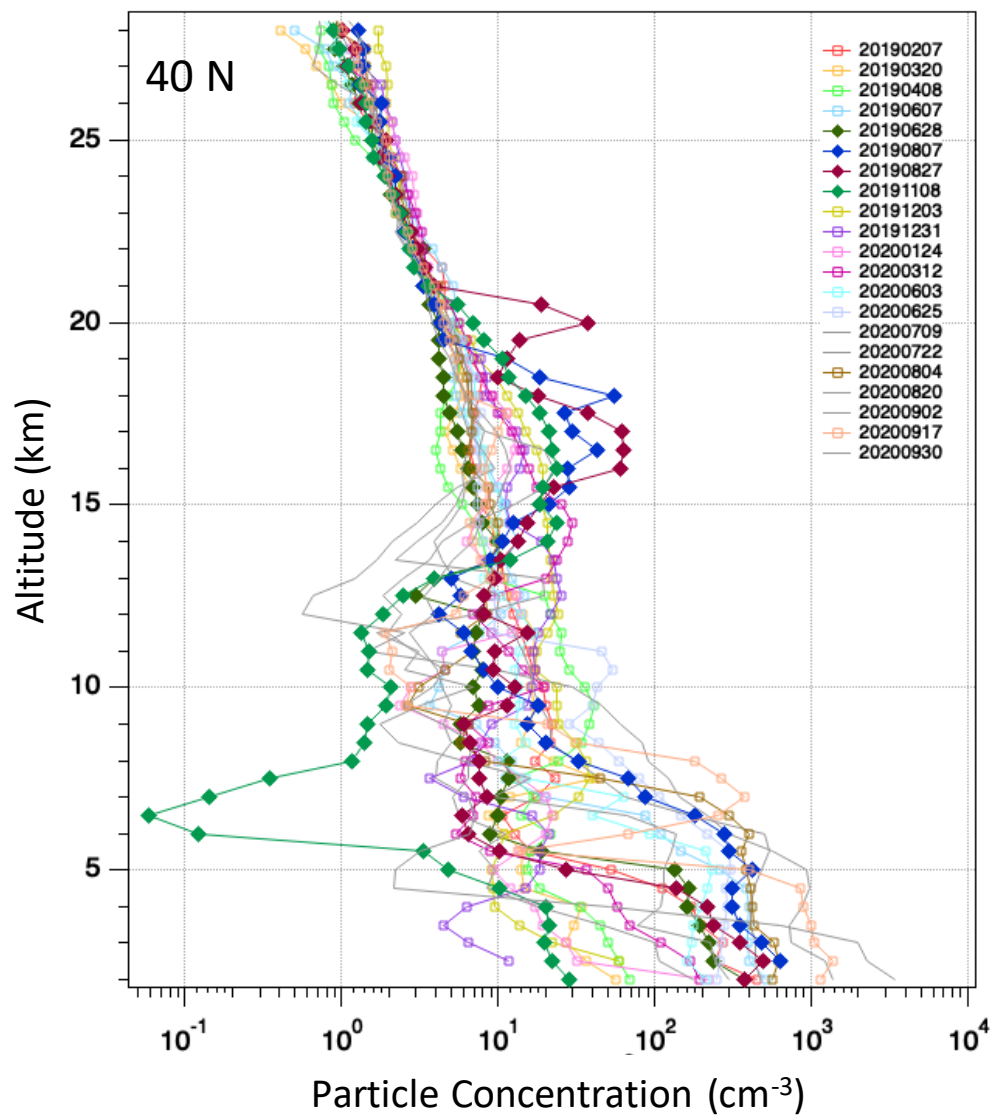
- Assuming the “wrong” bulk index of refraction, can lead to noticeable differences in aerosol sizing and large differences in aerosol surface area
- BB aerosols from very large fires, such as over Australia, may have a substantially higher uncertainty related to aerosol size distributions

A brief timeline of POPS in the stratosphere

POPS measurements of stratospheric aerosol size and abundance have been made from a number of different high altitude platforms since 2015

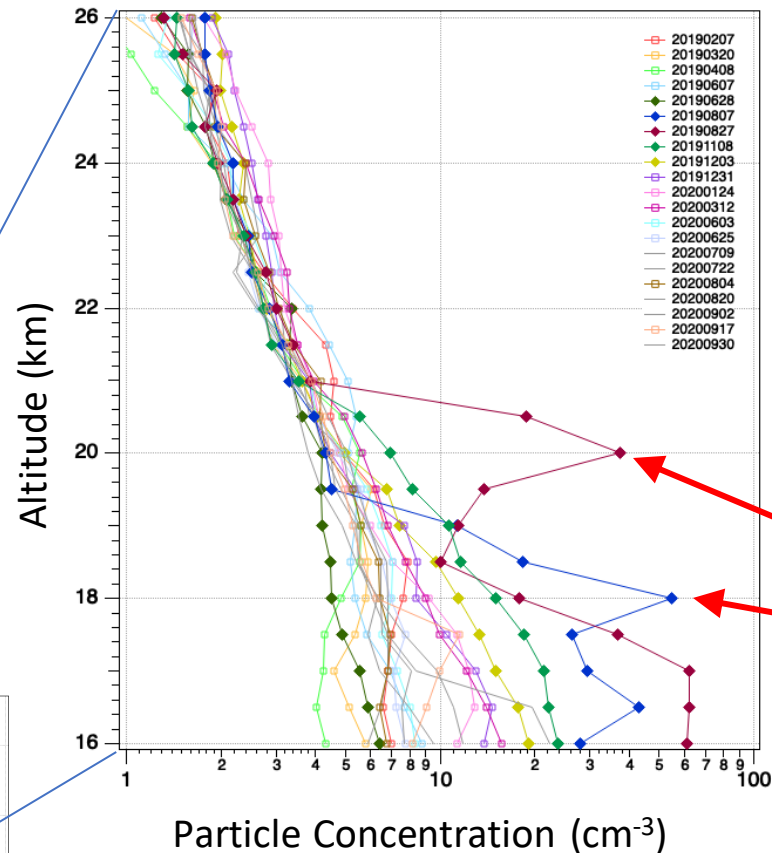


Approaching two years of POPS Sondes in Boulder, CO



- NASA supported POPS measurements of stratospheric aerosols for SAGE III-ISS aerosol retrieval validation began in December 2018
- POPS sonde launches from Boulder (12/year), timed to match SAGE III-ISS observations (21 shown here)
- 0.5 km average particle concentration vs altitude
- Current iMet telemetry provides 15 size bins log-spaced over D_p 140 nm to 2.5 μm

POPS observations in the NH stratosphere



SD between 21 – 25 km: $0.24 - 0.38 \text{ particles cm}^{-3}$

SD between 17 – 21 km: $0.76 - 9.9 \text{ particles cm}^{-3}$

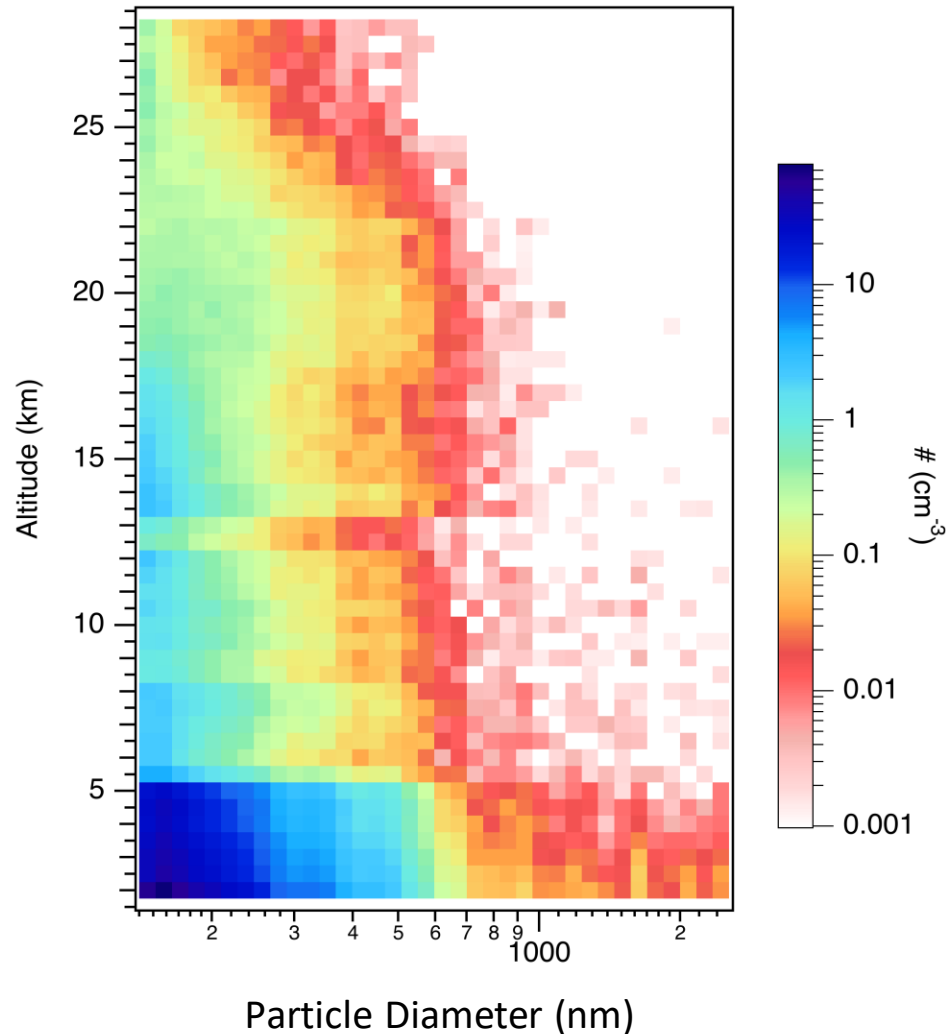
- June 22, 2019 Raikoke erupted
- 10x particle concentration increase observed in layers in August relative to June
- Return to $\sim$ baseline by Dec. 31



June 22, 2019
Source: NASA

Stratospheric Aerosol Structure in Summer 2019

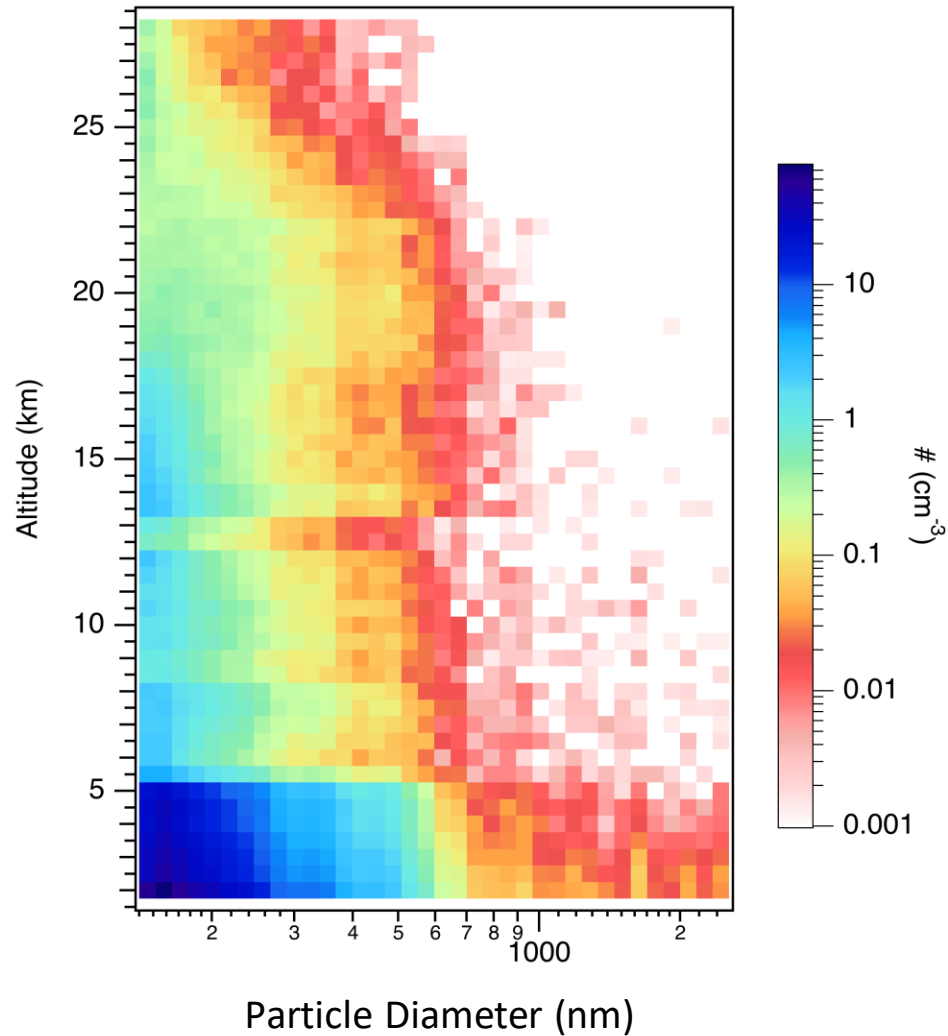
28 June 2019



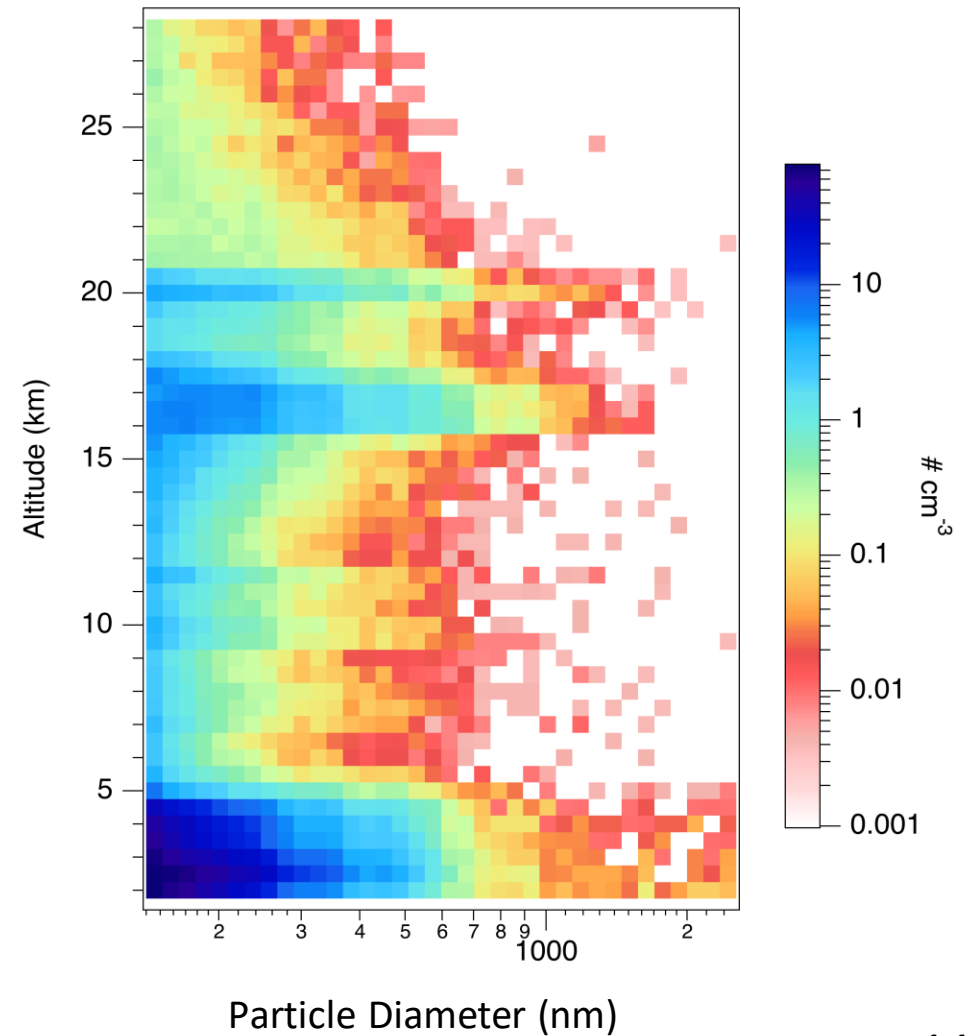
- Raikoke (48° N, 153° E) erupted on 21-22 June, sending a plume of ash and SO₂ into the stratosphere (to 13 km, local tropopause 11 km)
- The plume was transported around the northern hemisphere and rose through self-lofting due to heating by aerosol absorption
- In August, stratified layers of the plume at 16-17 km and 20 km are sampled by POPS in soundings from Boulder (40° N, 105° W)

Stratospheric Aerosol Structure in Summer 2019

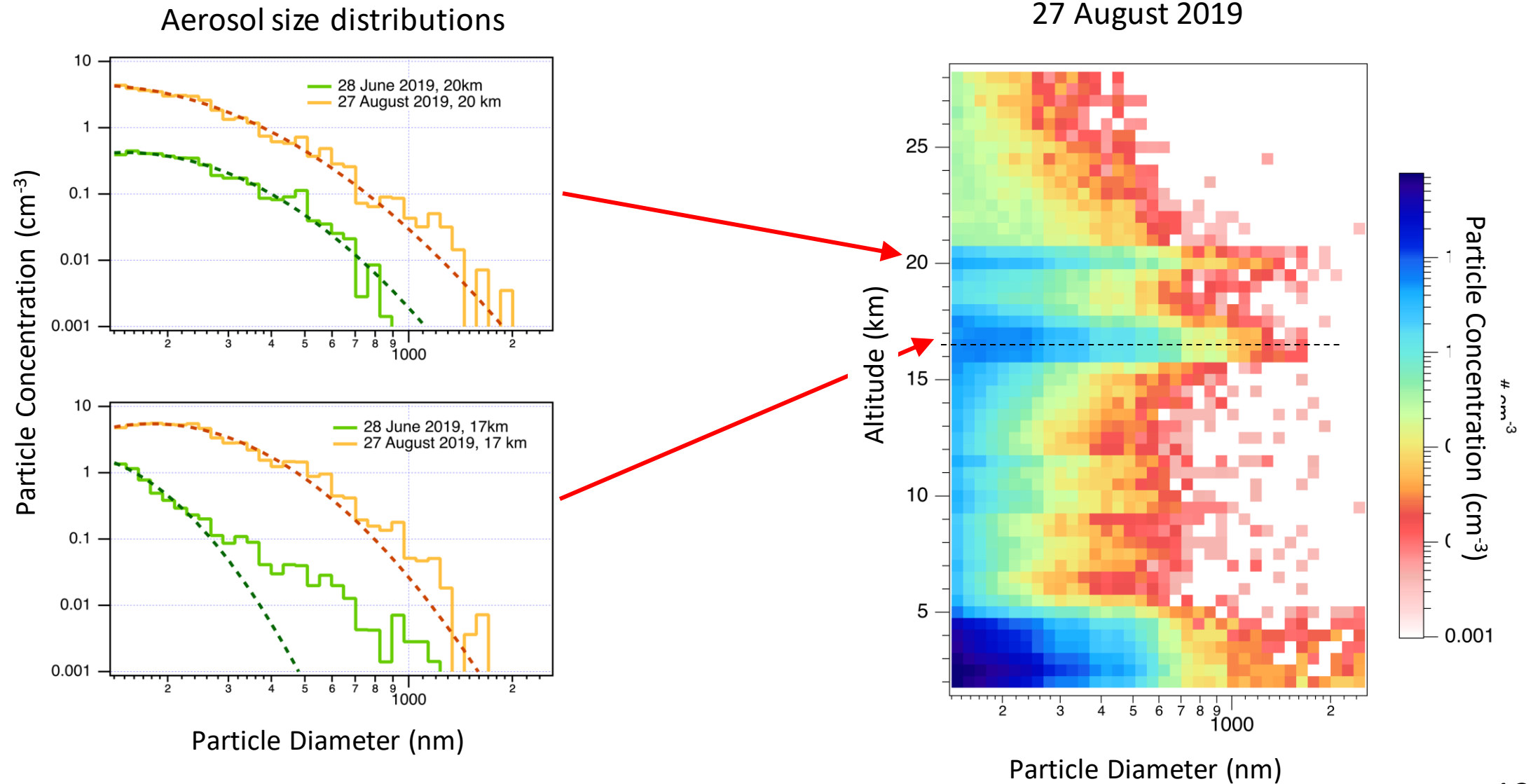
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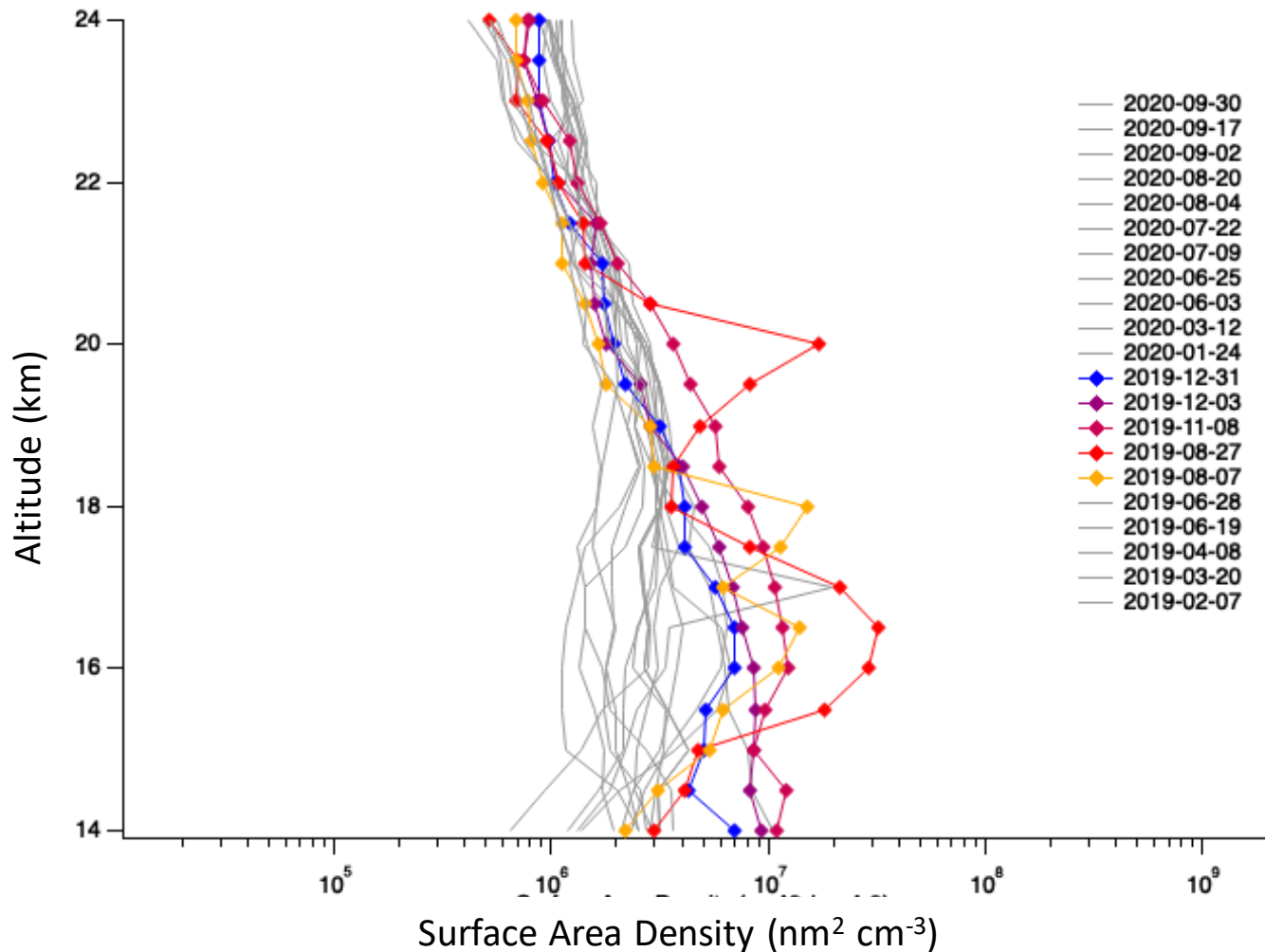
27 August 2019



A Closer Look at Stratospheric Aerosol Structure

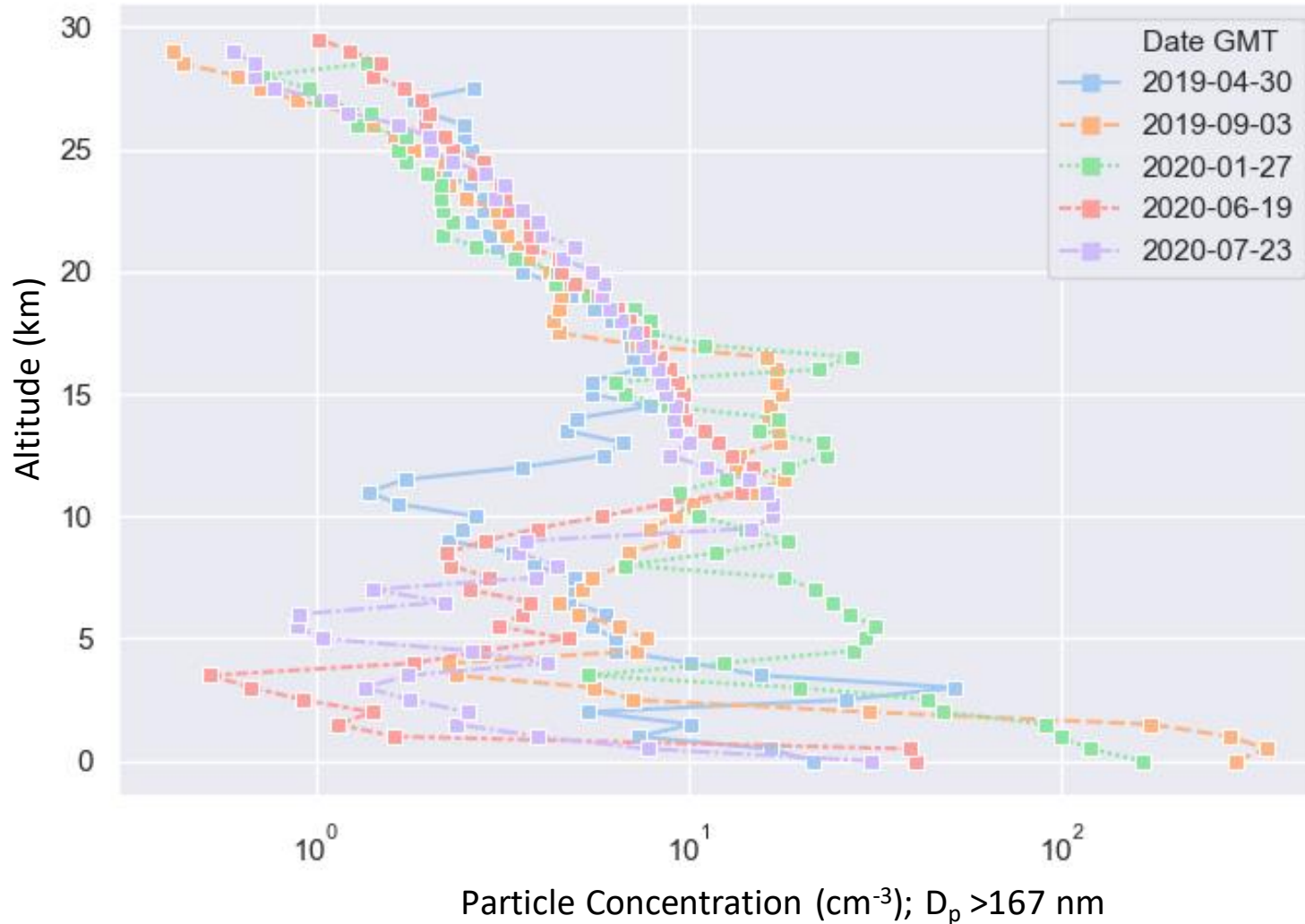


Vertical Distribution of Aerosol Surface Area Density



- Aerosol surface area density has a more direct relationship to aerosol radiative effects than aerosol number concentration
- Surface area is also the important aerosol parameter in heterogeneous chemistry (e.g. $\text{N}_2\text{O}_5 \rightarrow \text{HNO}_3$ on aerosol surfaces which has implications for O_3 chemistry)
- SAD in the lowermost stratosphere varied by more than an order of magnitude between profiles
- At higher altitudes (> 21 km), SAD was more consistent, though still varied by a factor of 3 between profiles

POPS sondes from Lauder, NZ (45° S)

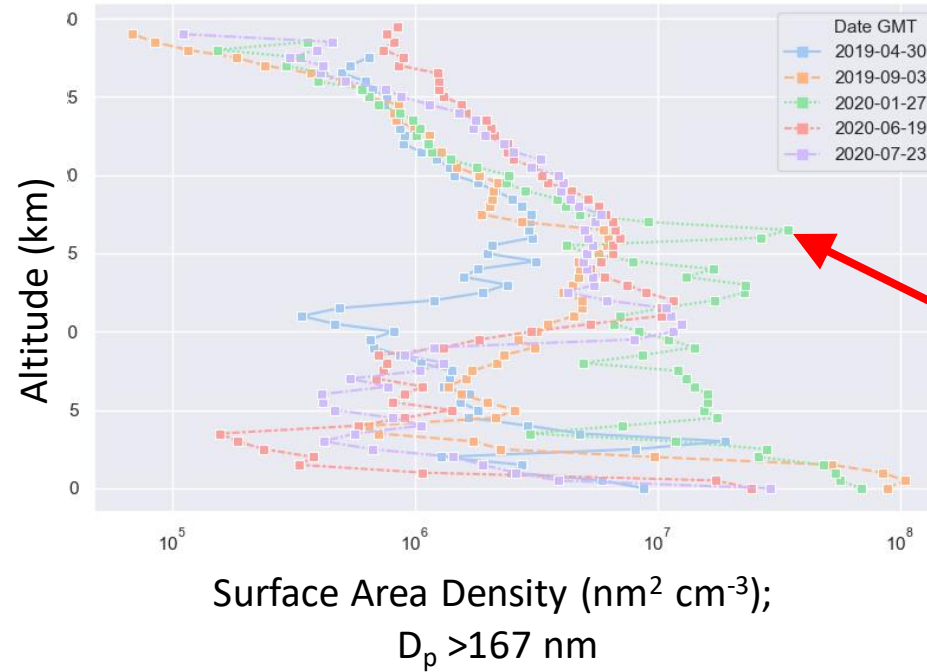
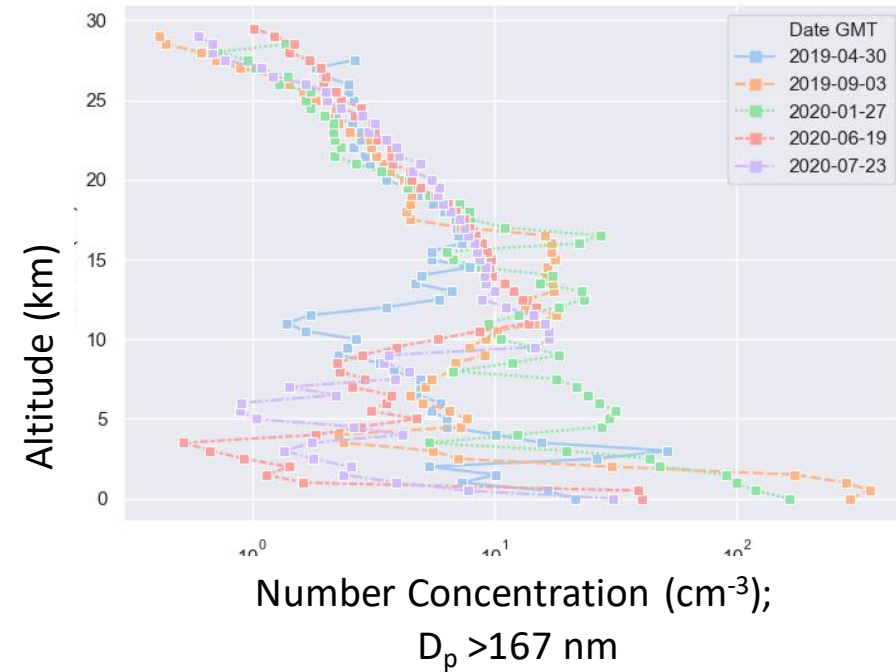


- POPS sonde launches from Lauder, NZ started in April 2019
- Good data from 5 out of 8 launches so far
- 0.5 km altitude bins
- Data currently limited to 15 size bins transmitted via iMET telemetry



Photo credit: Emrys Hall

Similar number concentration 2019-09-03 and 2020-01-27 but a large disparity in total surface area density



- 72,000 square miles burned
- 306 million tons CO_2 emitted
- Potential extinction of several endangered species

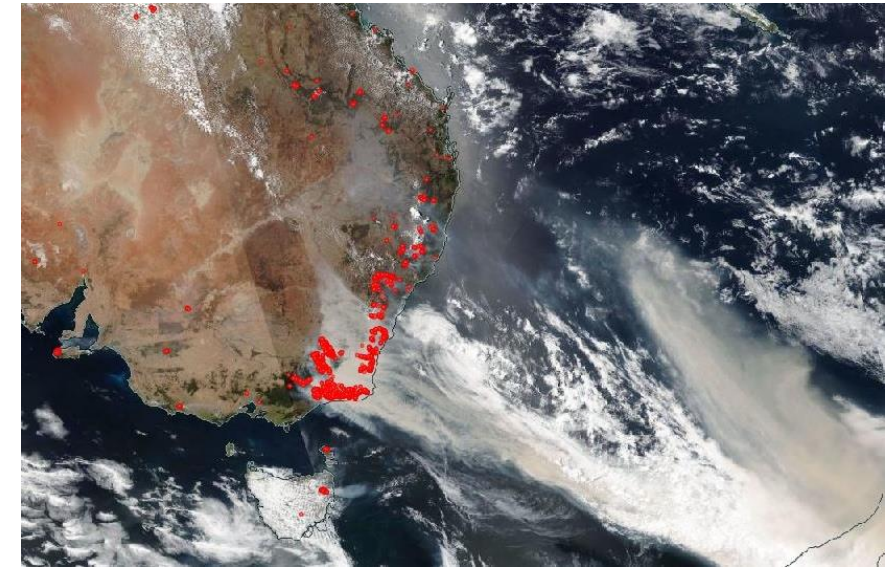
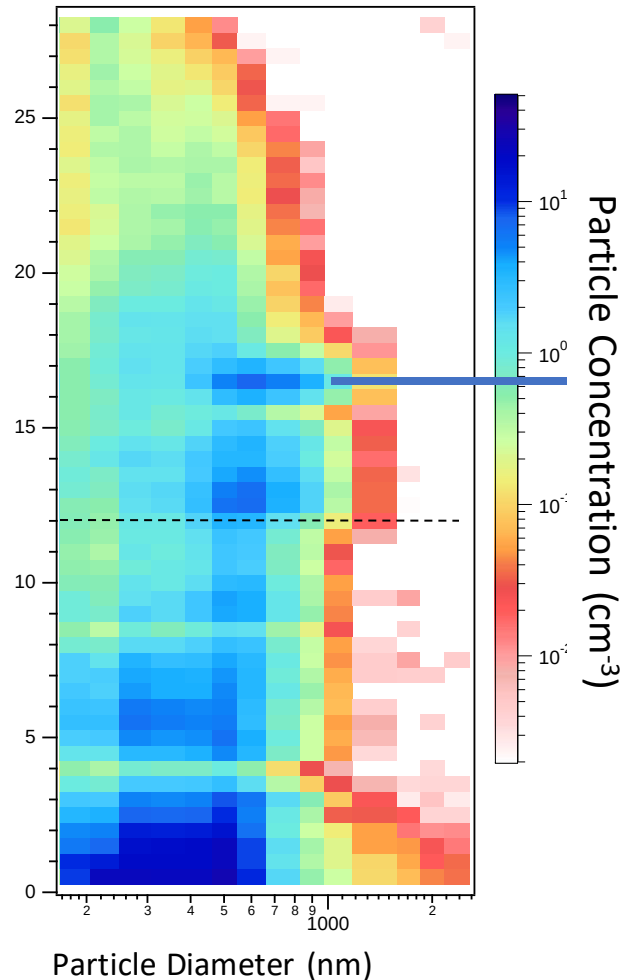
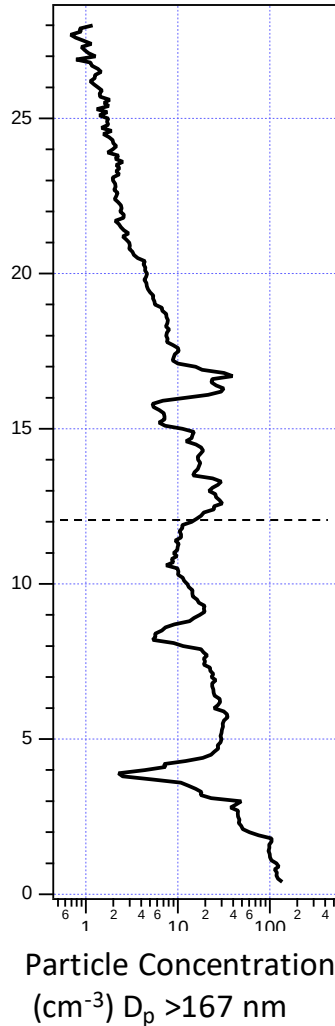
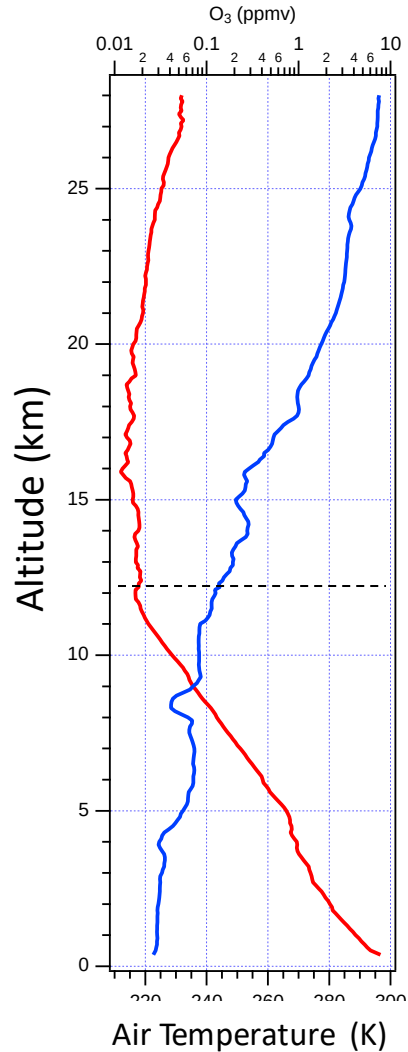


Source: The New York Times

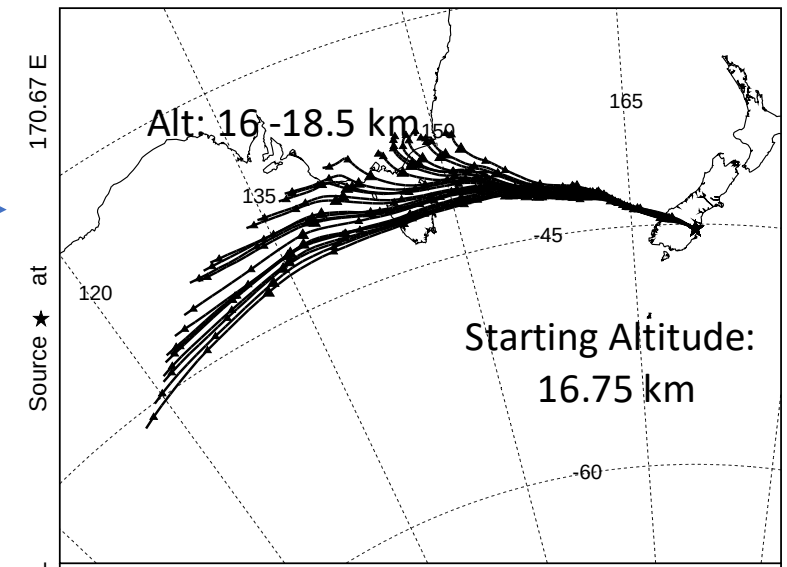
Stratospheric aerosol from Australian bushfires

January 27, 2020

POPS + FPH + ECC sonde, Lauder, NZ, 20200127



NOAA HYSPLIT MODEL
Backward trajectories ending at 2300 UTC 27 Jan 20
GFSQ Meteorological Data

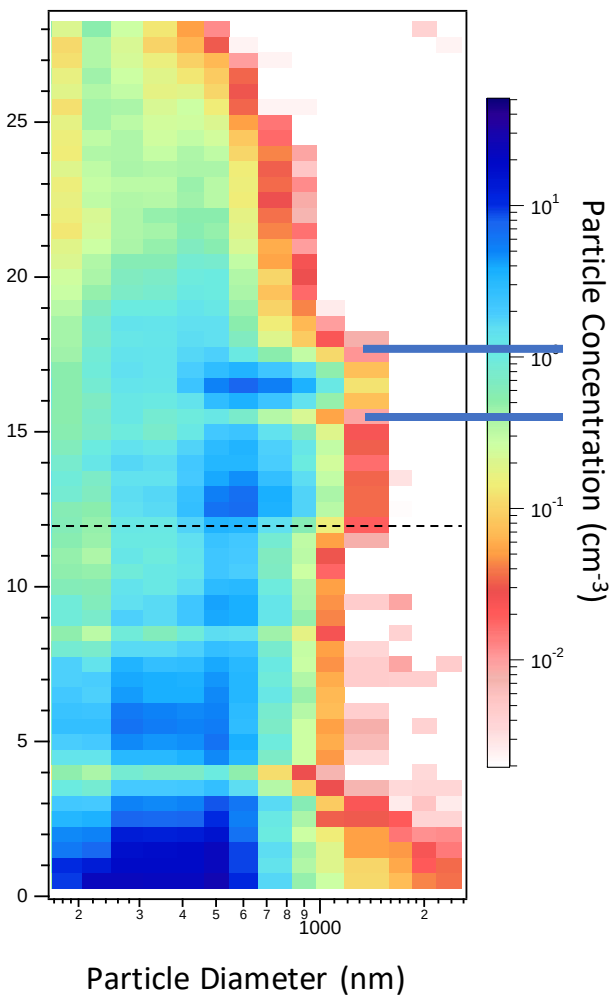
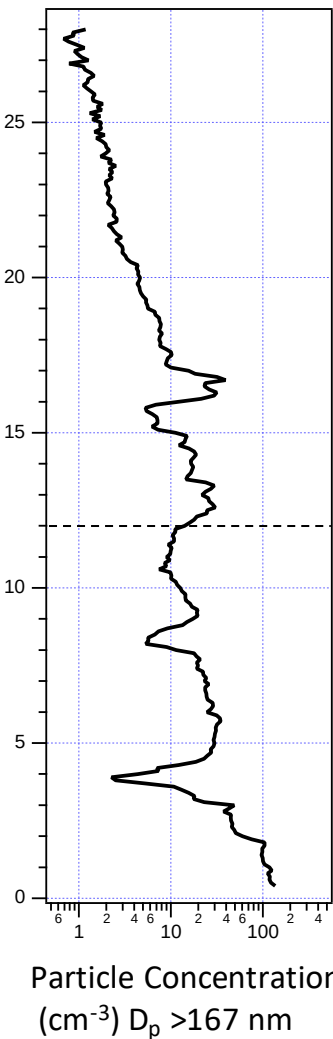
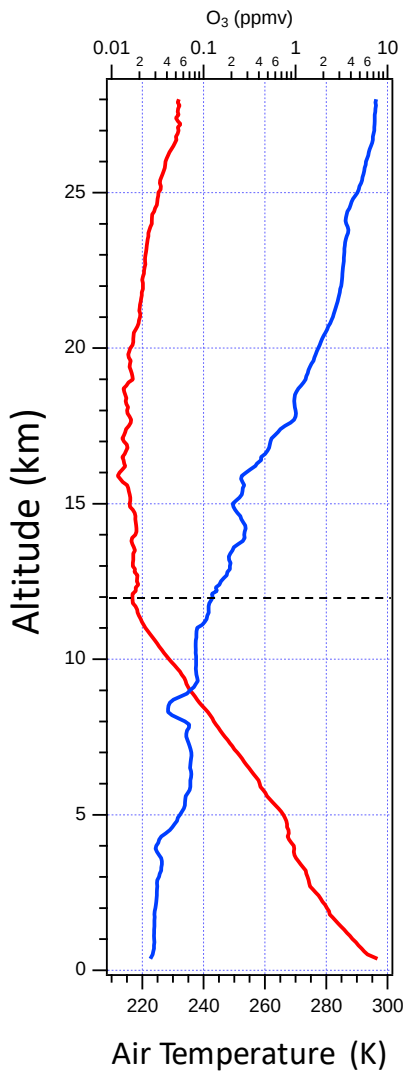


Thornberry and Asher unpublished data

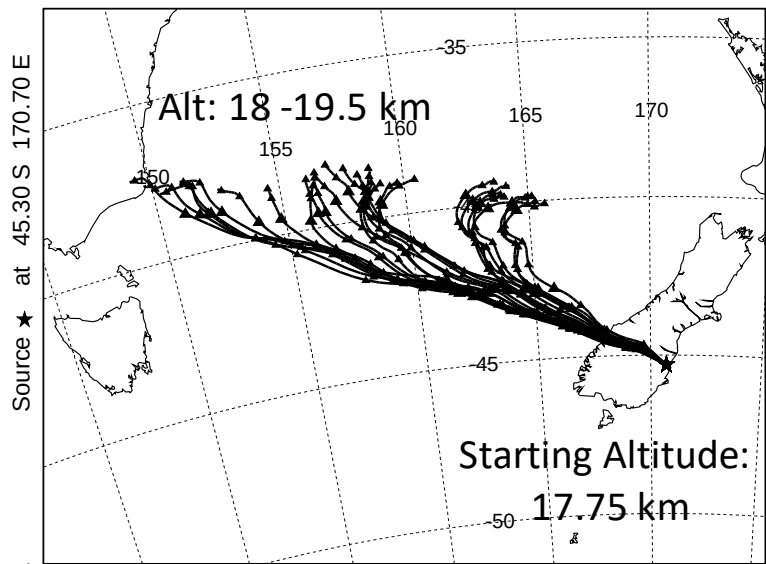
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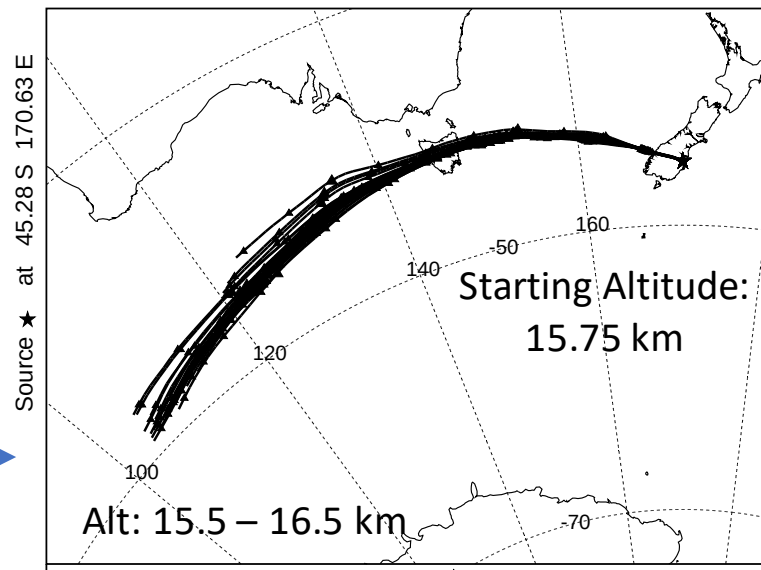
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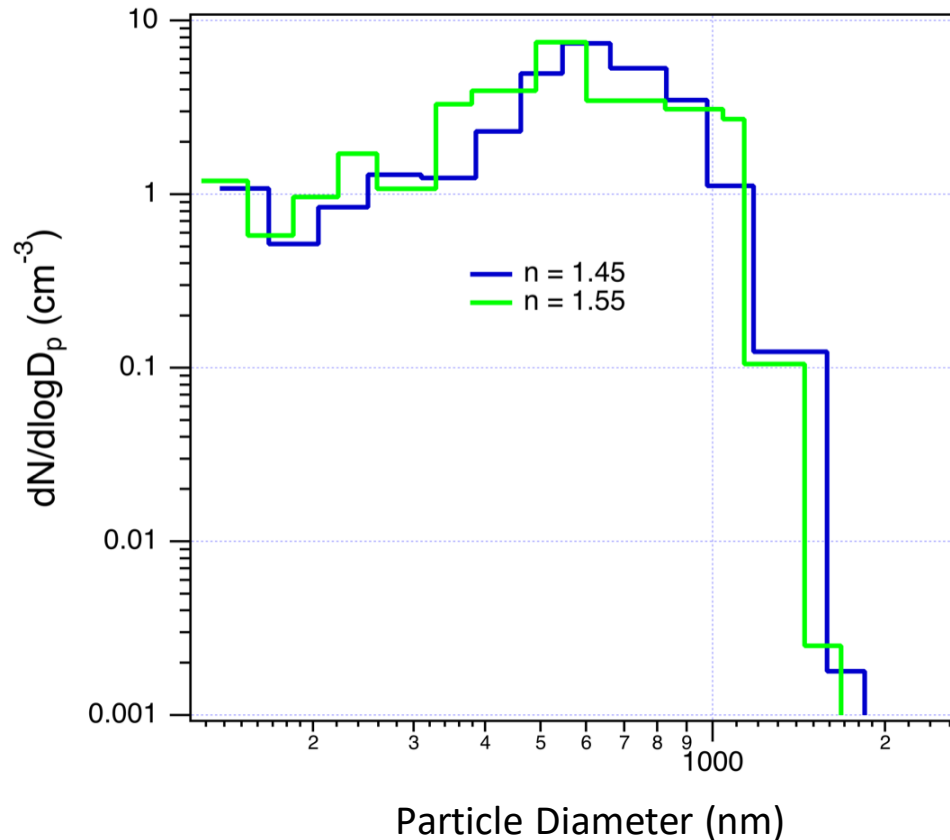
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Impact of Refractive Index Uncertainty on Derived Surface Area Density

Particle Size Distribution for different assumed indices of refraction



- SAD calculated for BB plume sampled at 16.5 km on Jan. 27, 2020 from Lauder, NZ
- Total SAD for $n = 1.45$ is $35.7 \mu\text{m}^2/\text{cm}^3$
- Total SAD for $n = 1.55$ is $36.2 \mu\text{m}^2/\text{cm}^3$
- This difference is well within the overall uncertainty of the POPS measurement
- The values in the pyrogenic plume fall at the upper end of SAGE II 1984 – 1994 climatology (Thomason et al. 1997)

Status and Plans

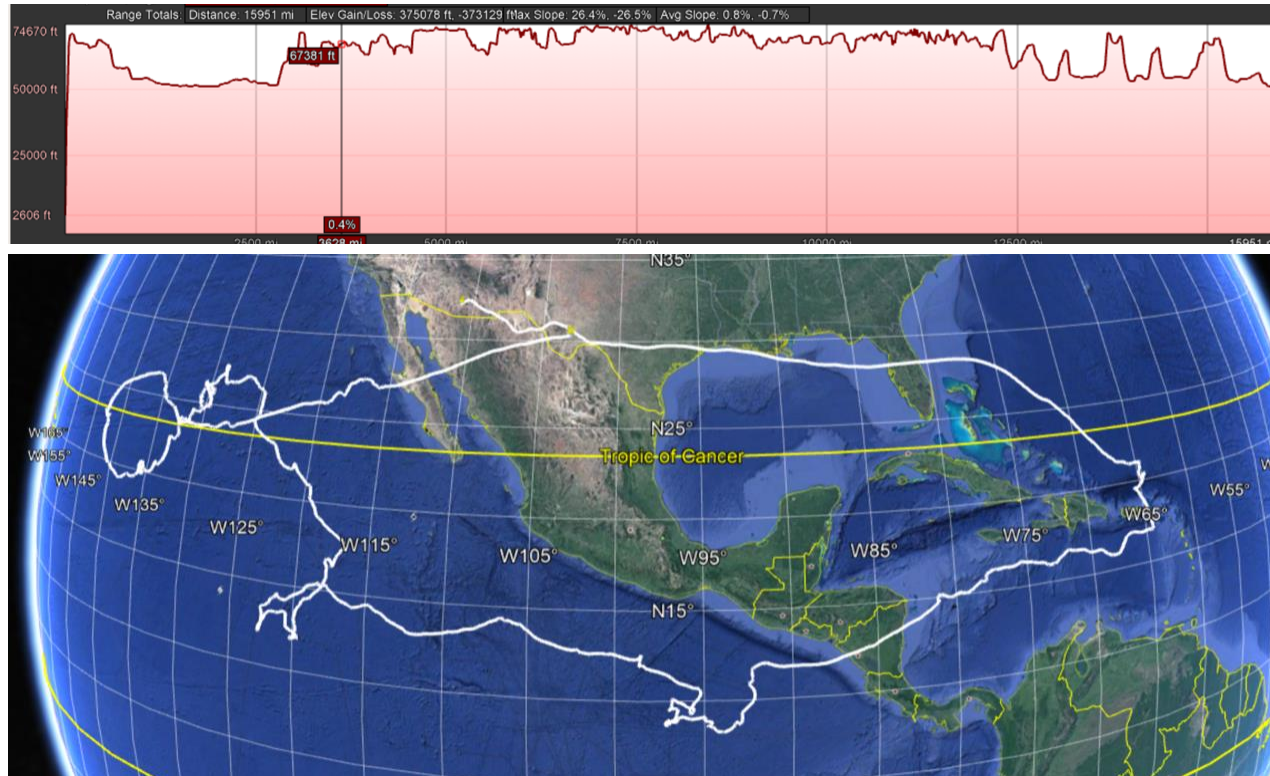
- Since early 2019, 21 SAGE III-ISS coincidence POPS sondes from Boulder and 5 from Lauder (and continuing)
- Within this period, these launches have captured episodes of altered stratospheric aerosol loading and size distribution from both volcanic eruption (Raikoke) and pyrogenic injection (Australian bush fires)
- Currently finalizing data reprocessing with higher resolution from recovered POPS and formatting (ICARTT) for public archiving. Code and protocols will be applied immediately for processing after future launches.
- Anticipating a potential change in iMet to allow higher resolution size data to be telemetered along with additional engineering data to improve data QA/QC from non-recovered sondes
- Additional POPS sondes with the NOAA B²SAP project and multiple flights in 2021 with the WorldView Stratollite will enhance our understanding of stratospheric aerosol seasonal variability and the influence of volcanic and pyroCb events

NOAA CSL working with Worldview to fly POPS on the Stratollite in 2021

Profiling capability : 15 km (50,000 feet) - 23 km (75,000 feet)

Large geographic extent in both hemispheres

Potential for multiple flights in 2021



Thank You

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