The NOAA Baseline Balloon Stratospheric Aerosol Profiles (B^2SAP) Project

Description and Insights Using In Situ Observations Since 2019

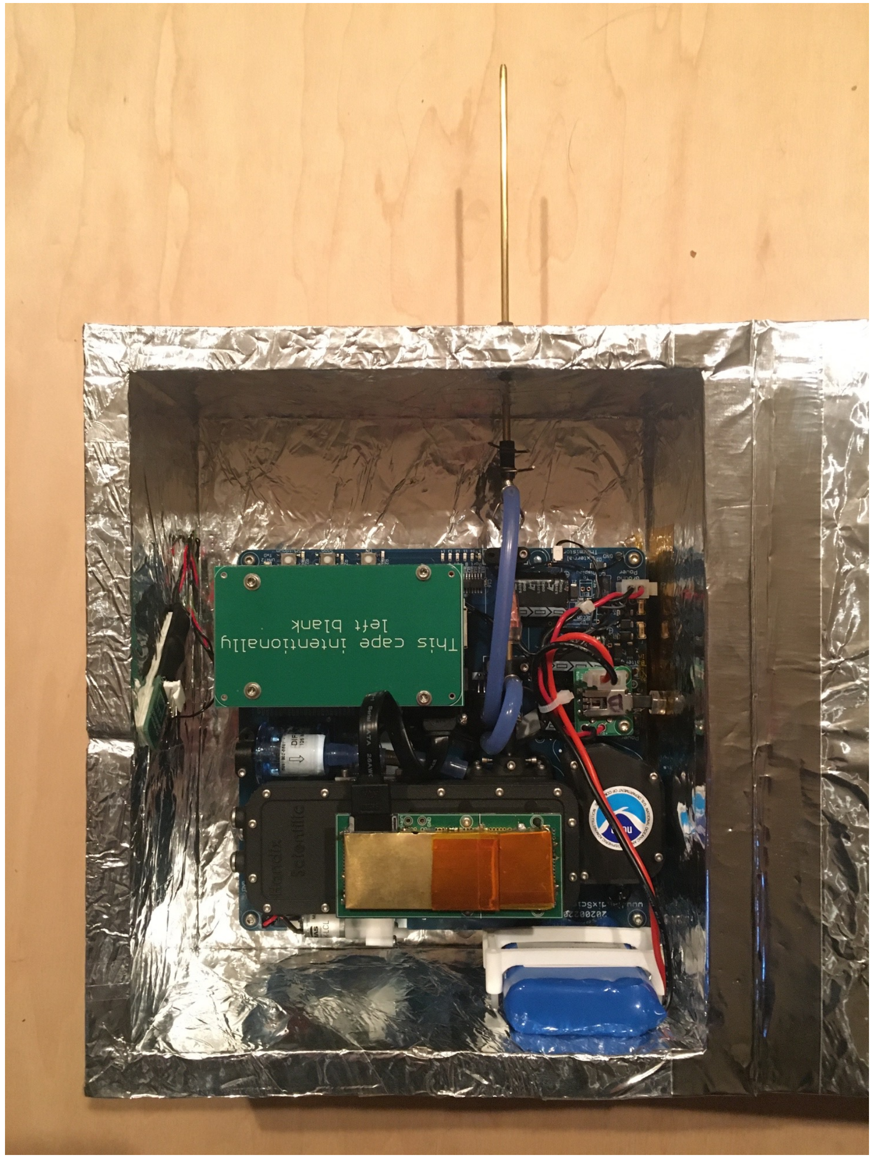
ICM-13 virtual Meeting
Session 2 – Ground-based and Emerging Technologies
Tuesday, November 16, 2021

Outline

- POPS instrument and measurement
- POPS sonde timeline
- NH & SH measurements since 2019
- Comparisons to CARMA model
- Status and plans

Photo credit:
Jim Elkins

The payload: Portable Optical Particle Spectrometer



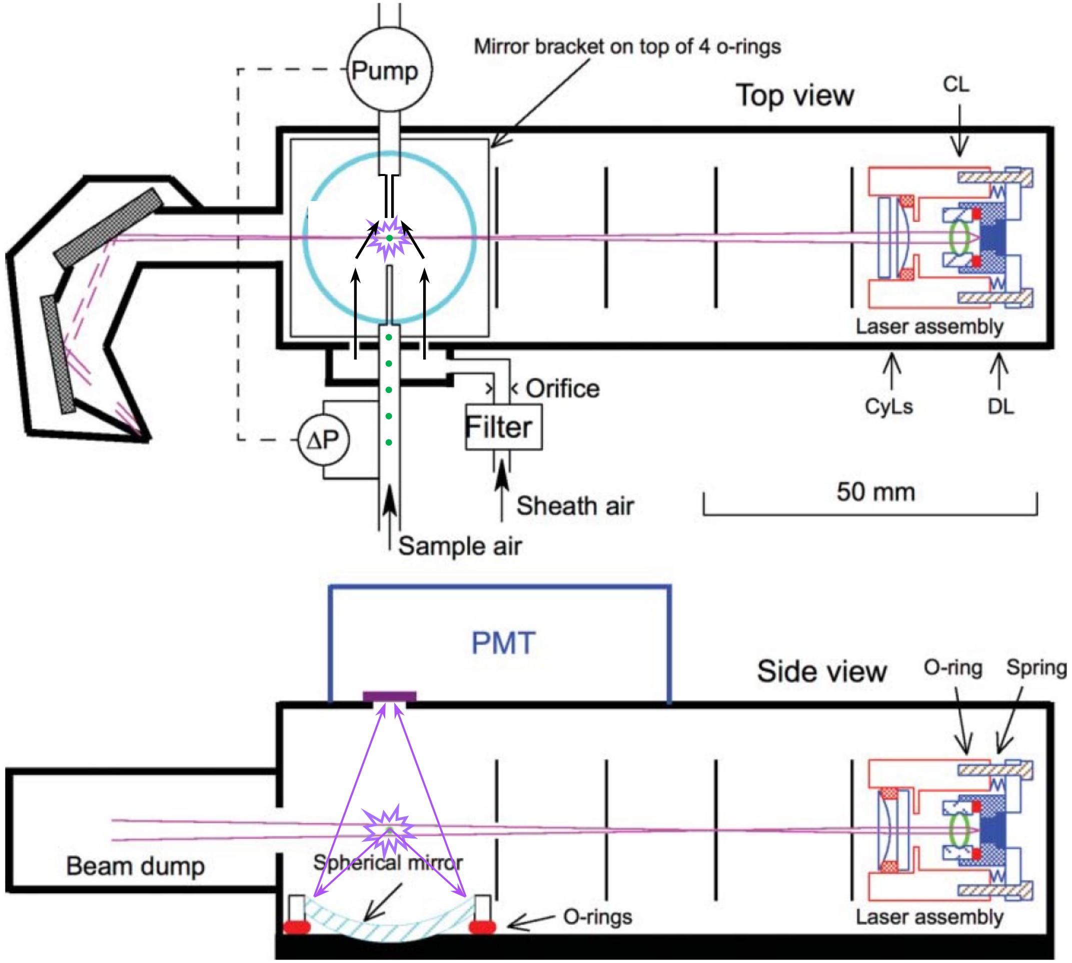
POPS specifications:

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

  Gao et al., AS&T 2016

- Flown with NOAA GML FPH, ECC Ozone sonde and iMET-1 on valved weather balloons

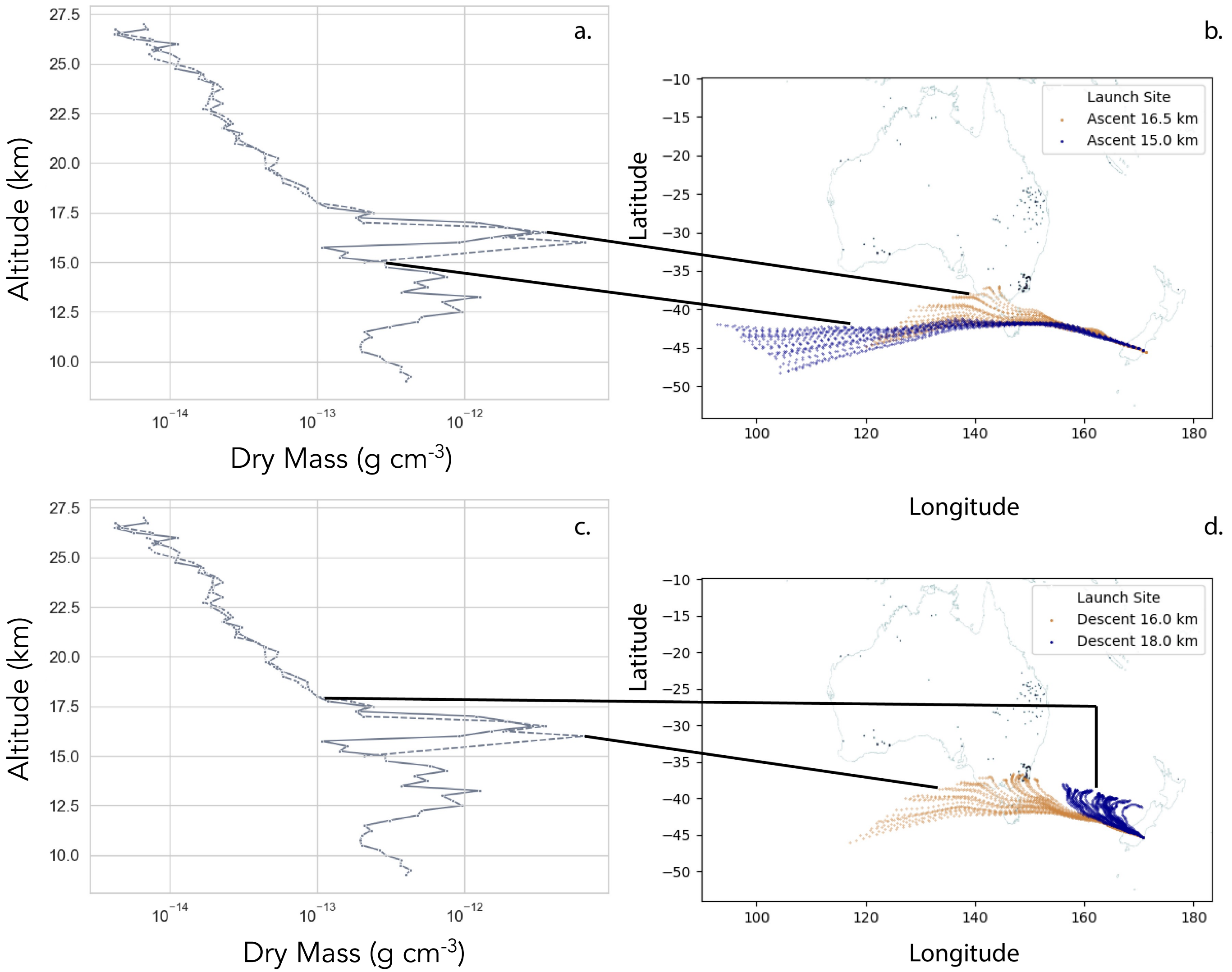
POPS Measurement is Simple and Robust



adapted from Gao et al., AS&T 2016

- Measures light scattered from a 405 nm laser (Blu-Ray)
- 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 predetermined size bins are reported each second
- Calibrated Mie theory to determine particle size from scattering signal peak height
  - Requires assuming an index of refraction and spherical shape (a requirement for all optical particle sizing instruments)

Ascent & descent in situ stratospheric measurements



- Ascending & descending vertical profile from 1/27/2020
- POPS sonde profiles provide snapshots in time and space
- Thanks to use of NOAA GML valved balloons, we acquire quality data during descent
- Consistency of stratospheric ascent and descent data (e.g. between 17.5 and 27 km) provides confidence in the measurement
- Here, distinct plumes on the ascent and descent can be traced back to the Southeastern continent of Australia during Australian New Years Event using NOAA HYSPLIT back trajectories

A brief timeline of POPS sondes in the stratosphere

POPS measurements of stratospheric aerosol size and abundance made increasingly since 2015

2015
First POPS sonde flights:
Houston, TX
and Kunming, China (ATAL)

2017
U Wyoming Large Balloon
Réunion Island sonde

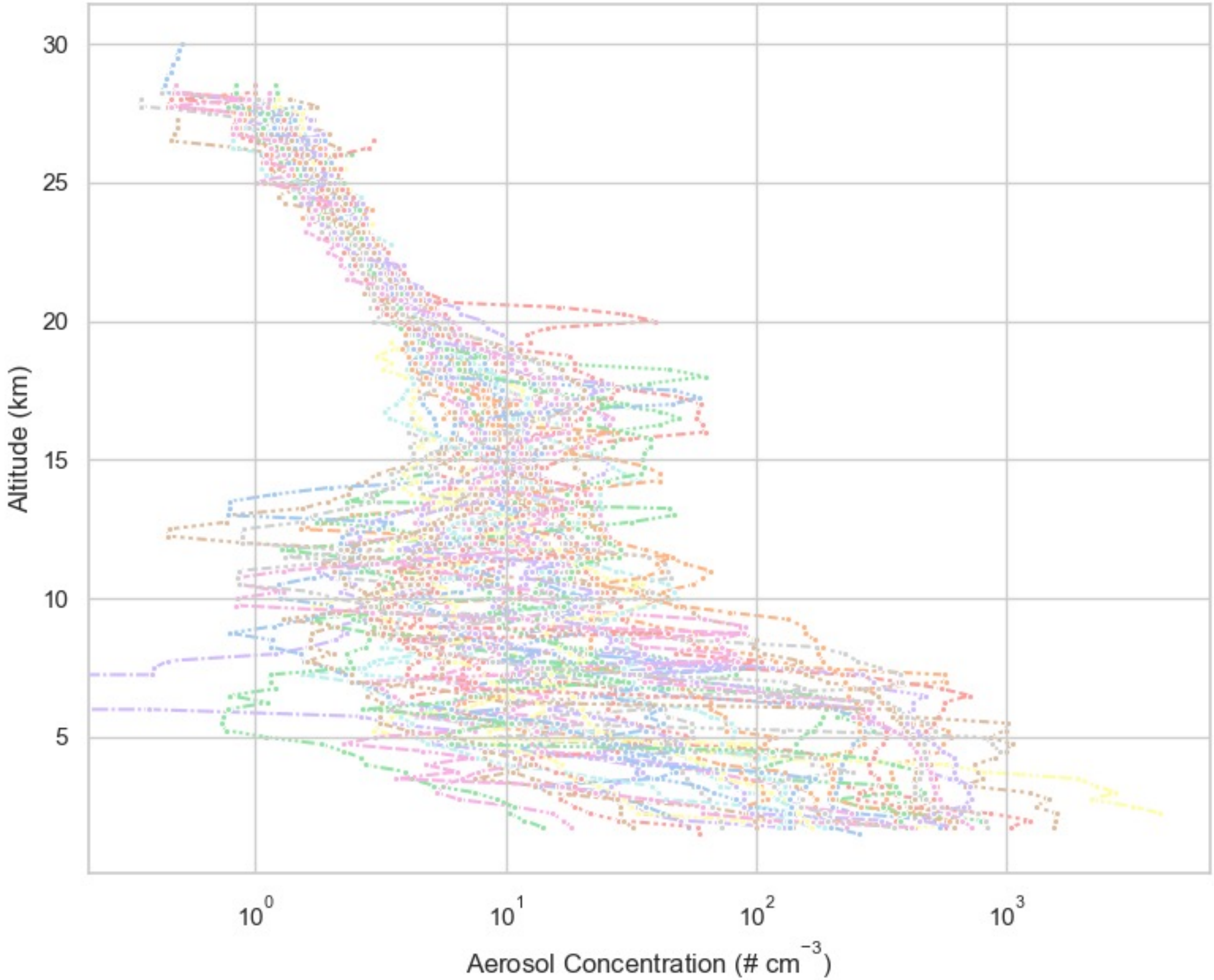
2019
11 SAGE III-ISS coincident POPS sondes:
Boulder, CO
Lauder, NZ

2020
SAGE III-ISS coincidences
Baseline Balloon Stratospheric Aerosol Profiles (B^2SAAP) Project

2021
B^2SAAP project (Boulder, CO)
SAGE III-ISS coincidences in Boulder & Lauder

Photos credits: RuShan Gao, Jim Elkins, and Emrys Hall

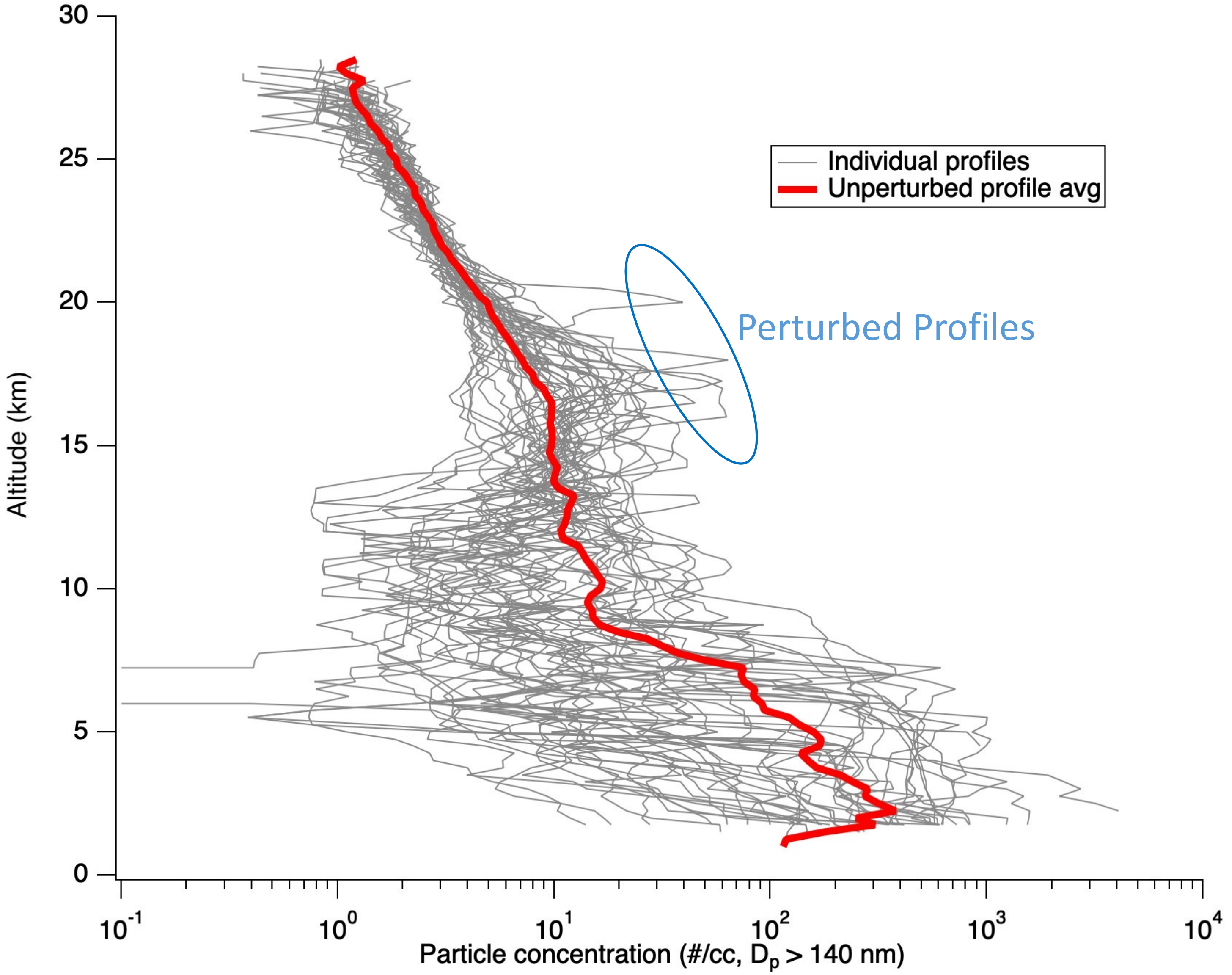
Approaching three years of POPS Sondes launched form mid latitudes in the NH and SH



- B^2SAP and SAGE III-ISS in NH and SH midlatitudes since 2019
- 46 launches from Boulder, CO; 8 launches from Lauder, NZ
- 0.25 km average particle concentration vs altitude
- Current iMet-1 telemetry allows 15 size bins log-spaced over D_p 140 nm to 2.5 µm when POPS is flown with both FPH and ECC;
- When sonde is retrieved, 36 size bins are typically calculated in raw data reprocessing (nearly all sondes launched from Boulder, CO are retrieved).

Identifying a baseline in the NH midlatitudes

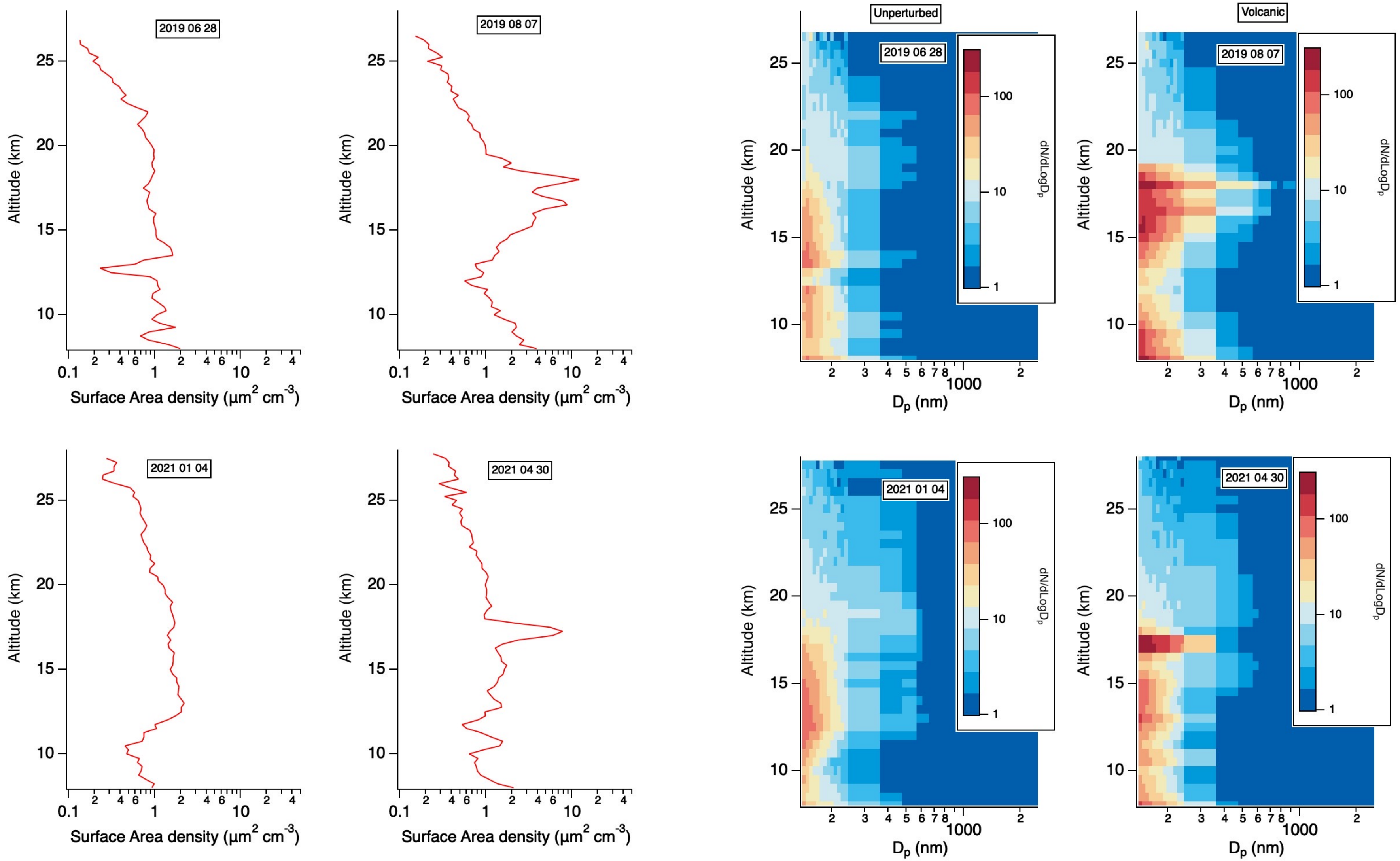
- Baseline compilation: SAGE III coincidence POPS sondes since 2019 & biweekly NH launches since July, 2020
- Average unperturbed vertical profiles represents those not influenced by volcanic eruptions
- Number concentration of unperturbed profile average (>140 nm) does not greatly exceed 10 cm^{-3} in the stratosphere
- Number concentration of unperturbed vertical profiles decreases consistently with altitude in the stratosphere



M. Todt, in preparation

A closer look at stratospheric aerosol structure – examples from the NH

- Size distributions provide information on the evolution of stratospheric aerosol
- Dry particle (0.14 = 2.5 μm) surface area and volume can be calculated using the mean bin diameter and assuming particles are spherical

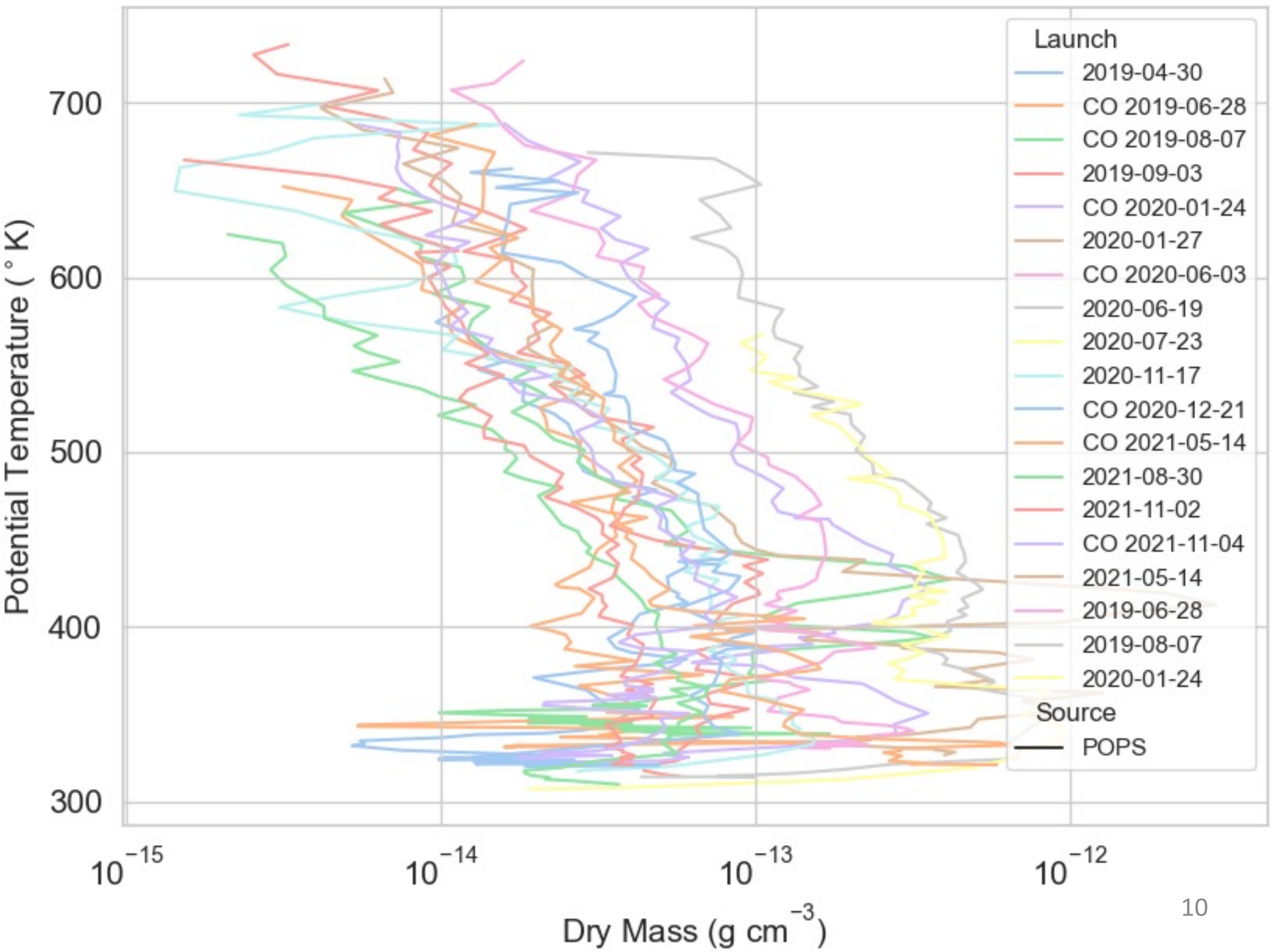


M. Todt, in preparation

Calculated dry mass from selected profiles in NH and SH midlatitudes between 2019 - 2021

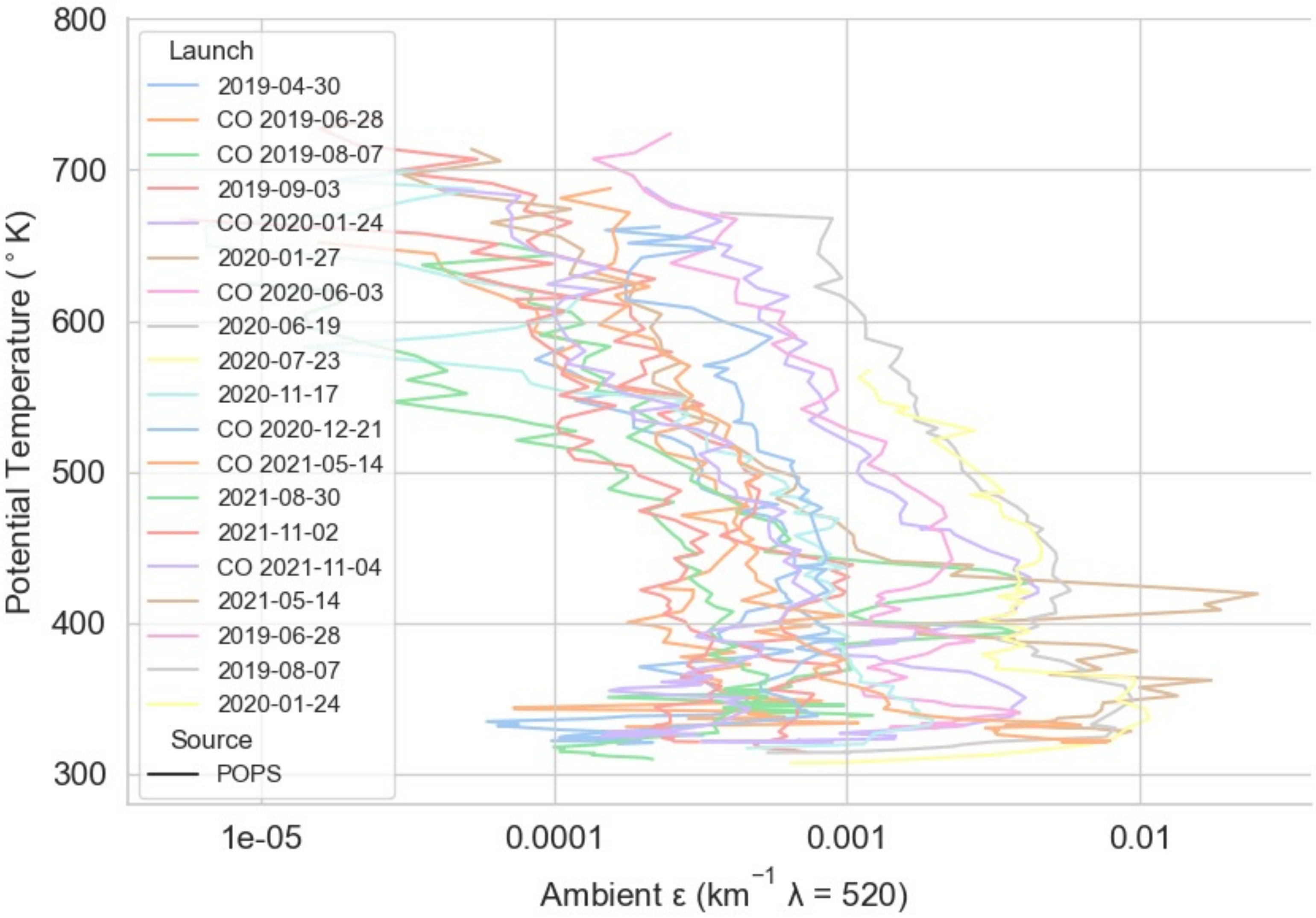
- Stratospheric profiles of aerosol mass density can be calculated using dry particle volume and density of sulfate aerosol (1.7 g cm^{-3}) or organic aerosol in plumes influenced by the Australian New Year (ANY) event (1.0 g cm^{-3})

- Plotted against potential temperature to facilitate comparisons between launches

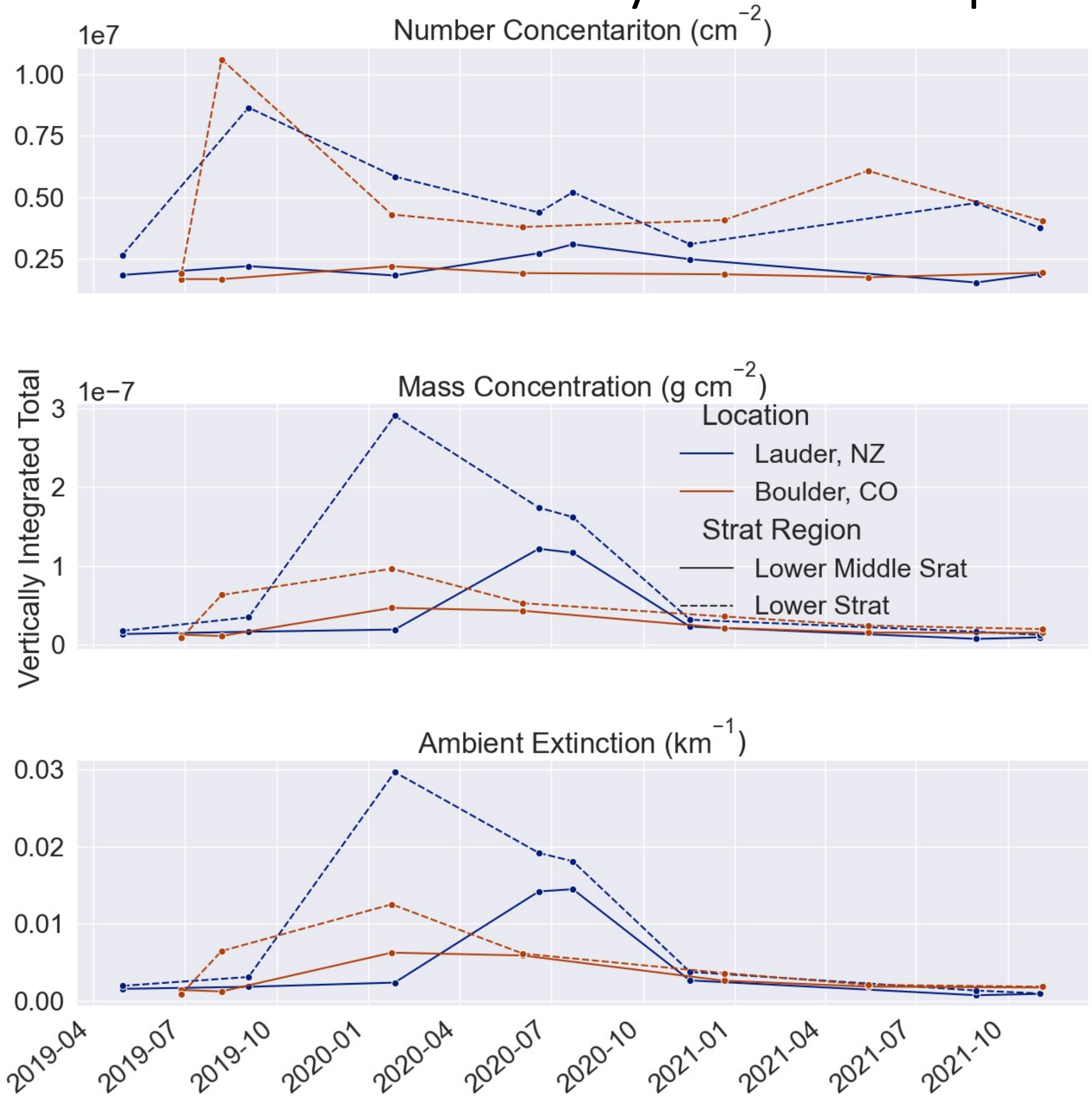


Calculated ambient extinction from POPS measurements in the NH and SH midlatitudes between 2019 - 2021

- Assumed bulk index of refraction m = 1.44 + 0j, similar to sulfate aerosol; *except for air masses influenced by ANYSO event*
- "Smokey" air masses air masses assigned a bulked index of refraction based on an internal mixture of 2.5% BC and 98% organic aerosol: 1.54 + 0.019j
- Ambient sizes of sulfate aerosol calculated based on NOAA FPH RH & kappa-Köhler theory
- Ambient extinction at λ = 520 nm) calculated using *PyMieScatt* python package



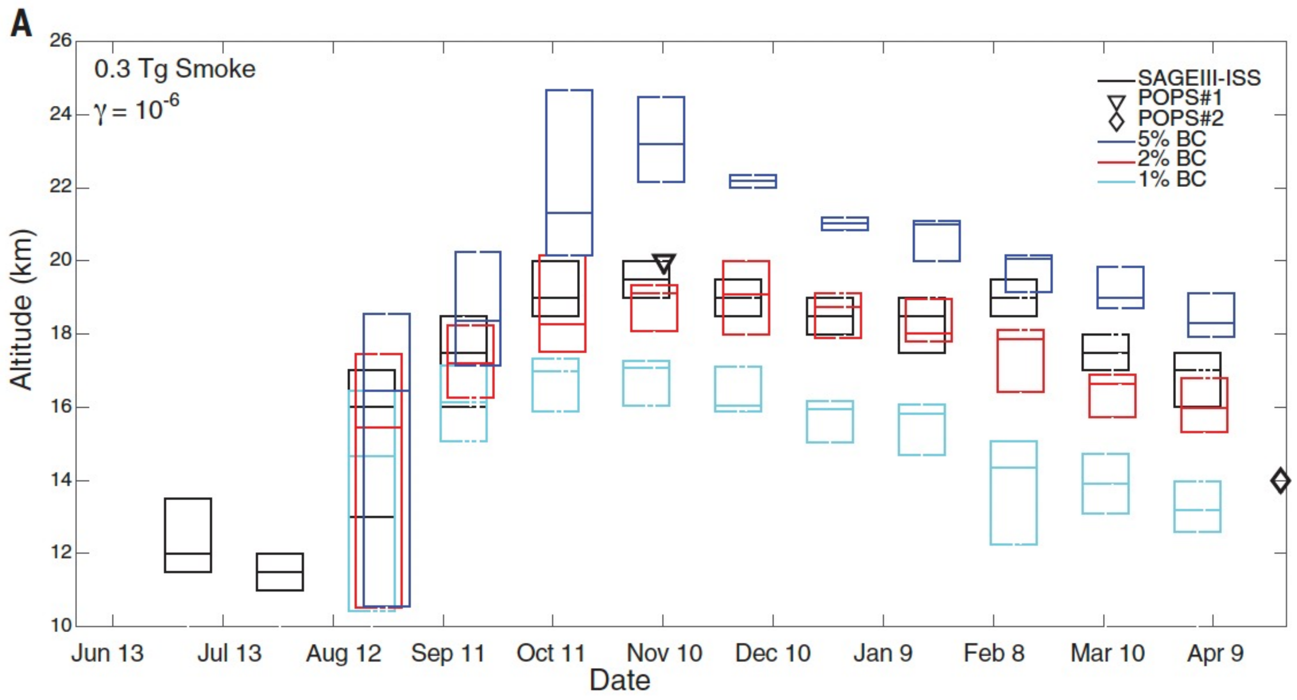
Variability in stratospheric aerosol since 2019



- Lower-middle stratosphere: 420 – 520 K
- Lower stratosphere: 380 – 420 K
- Lowermost stratosphere: tropopause – 380 K (not shown here)
- Higher variability of stratospheric aerosol at midlatitudes in the lower stratosphere than in the lower-middle stratosphere
- Higher variability in number concentration than in dry mass or ambient extinction.
- Ambient extinction and dry mass were heavily impacted by ANYSO event.

Model-Measurement comparisons: Background on the CESM2-CARMA aerosol model

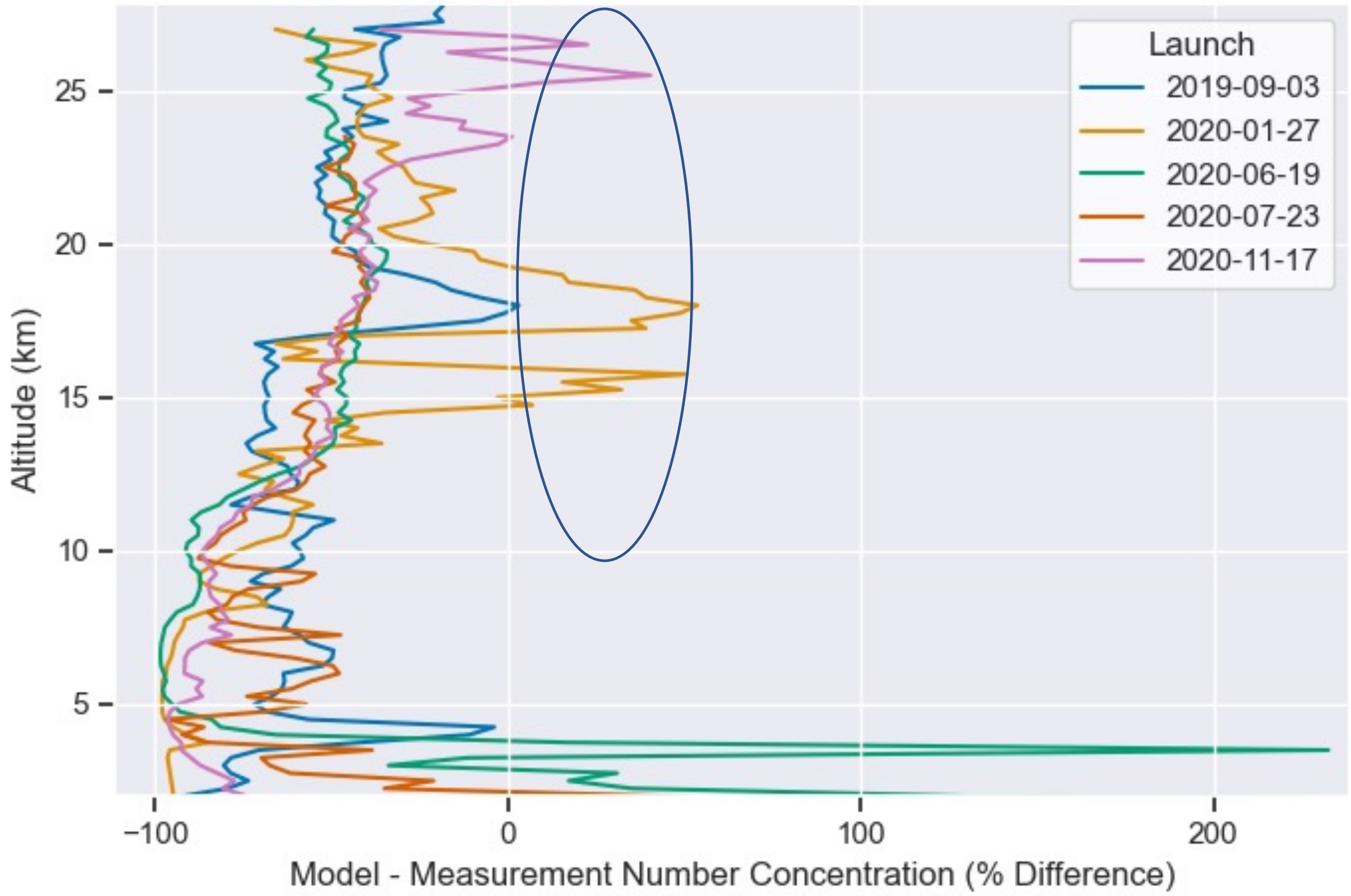
- Sectional (size-resolving) aerosol model coupled with NCAR's Community Earth System Model (CESM2)
- Simulating aerosol microphysics, radiative properties and cloud interactions
- 20 particle size bins; 56 vertical pressure/ altitude levels
- Routinely compared with satellite, ground-based, airborne measurements; occasionally compared with balloon-borne measurements



Adapted from Yu et al. 2019

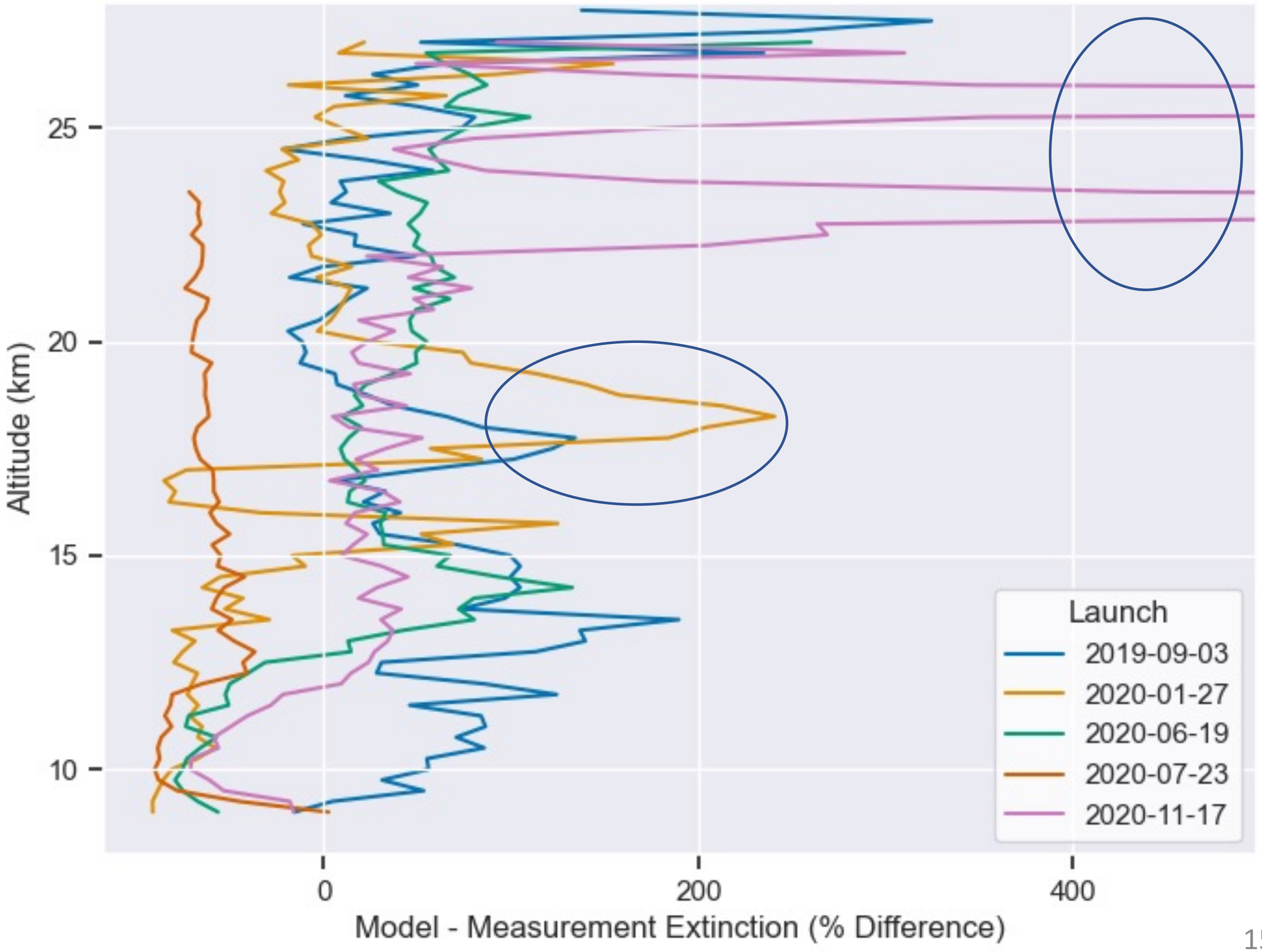
POPS size distribution measurements can be used to assess skill of aerosol processes in models (e.g. CARMA)

- CARMA data 10-day temporal averages
- Corresponding latitude and longitude of Lauder NZ.
- Model-Measurement % difference = (Model – POPS meas.)/ POPS meas.
- The CARMA model number concentration (0.14 – 2.5 μm) *is biased low* in SH midlatitudes between 2019-2021
- Perturbed plumes or very clean air masses may be biased high

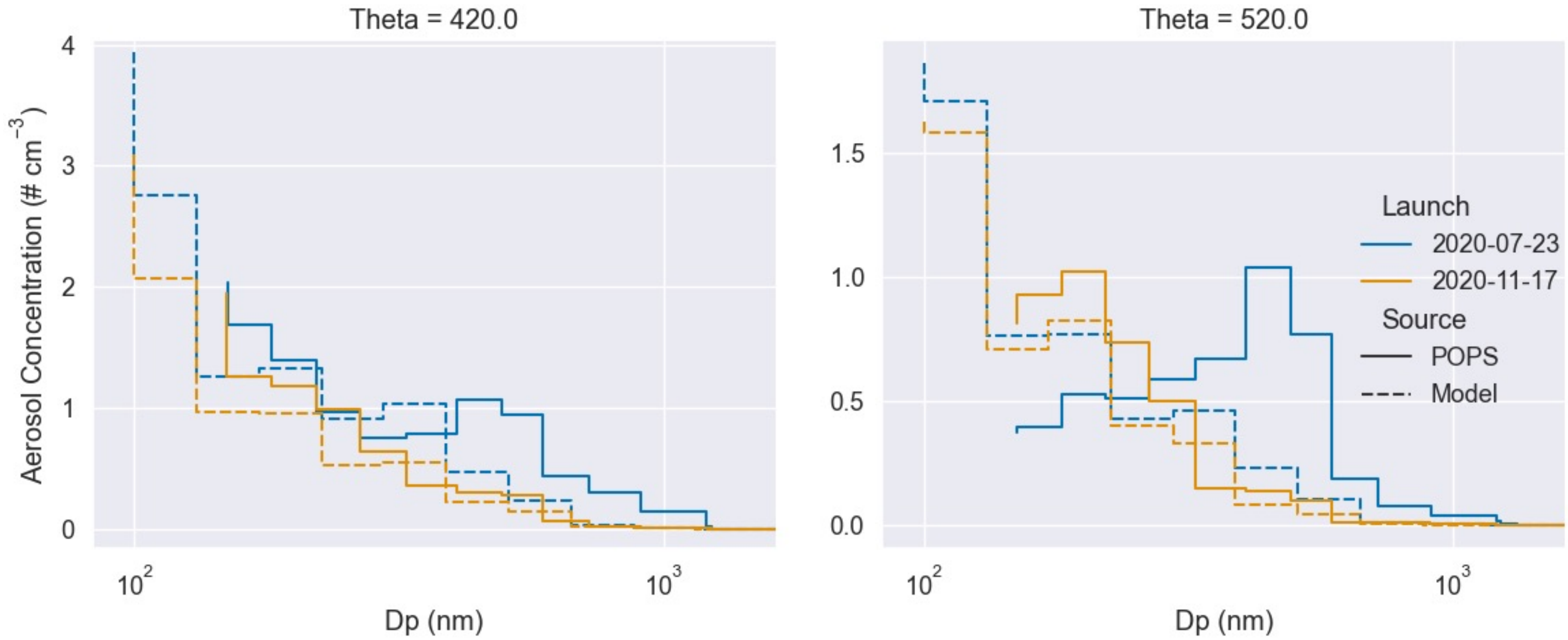


POPS size distribution measurements can be used to assess skill of aerosol processes in models (e.g. CARMA)

- Model-Meas. % difference = (Model – POPS meas.)/ POPS meas.
- Ambient extinction is generally biased high
- Notable exception – CARMA model *underestimates* ambient extinction in July, 2020
- CARMA does best simulating extinction in unperturbed stratospheric air masses



Model-measurement size distributions are biased low in perturbed air masses



B^{2}SAP Project Status and Plans

- Continue bi-weekly launches from Boulder, CO
- Continue launches from Lauder, NZ and target 4-6 profiles per year
- Planning launches from Hilo, Hawaii; Réunion Island in the boreal spring of 2022
- Looking to expand B^{2}SAP program to include regular launches from a range of latitudes
- 2019 – 2021 data will be archived and publicly available by early spring 2022

The Team

Michael Todt[1,2], Troy Thornberry[2], Pengfei Yu[3],
Emrys Hall[1,4], Patrick Cullis[1,4], Allen Jordan[1,4], Kensy Xiong[1,4], Dale Hurst[1,4], Penny Smale[5], Richard Querel[5]

[1] Cooperative Institute for Research in Environmental Sciences, Chemical Sciences Laboratory, Boulder, CO, United States
[2] NOAA Chemical Sciences Laboratory, Boulder, CO, United States
[3]Institute for Environmental and Climate Research, Jinan University, Guangzhou, China
[4] NOAA Global Monitoring Laboratory, Boulder, CO, United States
[5] *National Institute of Water and Atmospheric Research, Lauder, New Zealand*

Contact: elizabeth.asher@noaa.gov