Sonde observations from Boulder & Lauder

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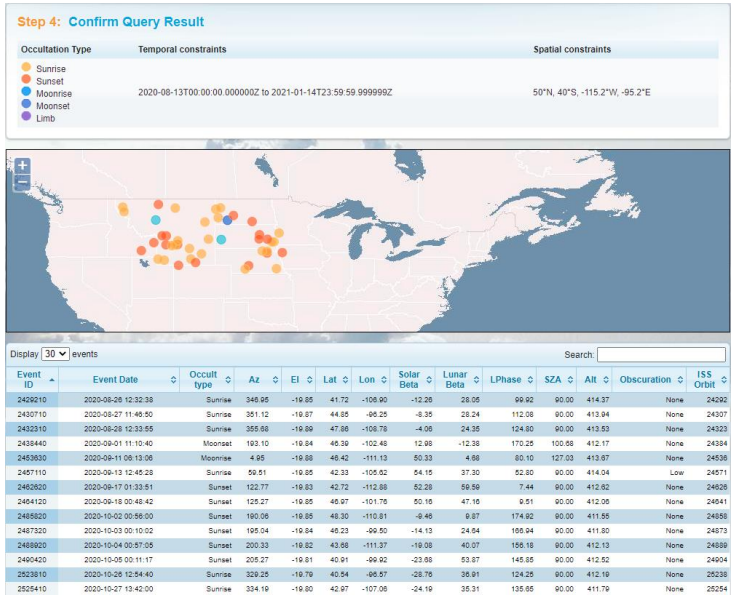
1: University of Colorado, CIRES
2: NOAA, Global Monitoring Laboratory
3: NOAA, Chemical Sciences Laboratory
4: NASA, Langley Research Center
5: Science Systems and Apllications, Inc
6: NIWA Lauder

SAGE III/ISS STM - October 19-20, 2020

Satellite / Balloon Coincident Overpasses

Boulder, Colorado



Step 4: Confirm Query Result

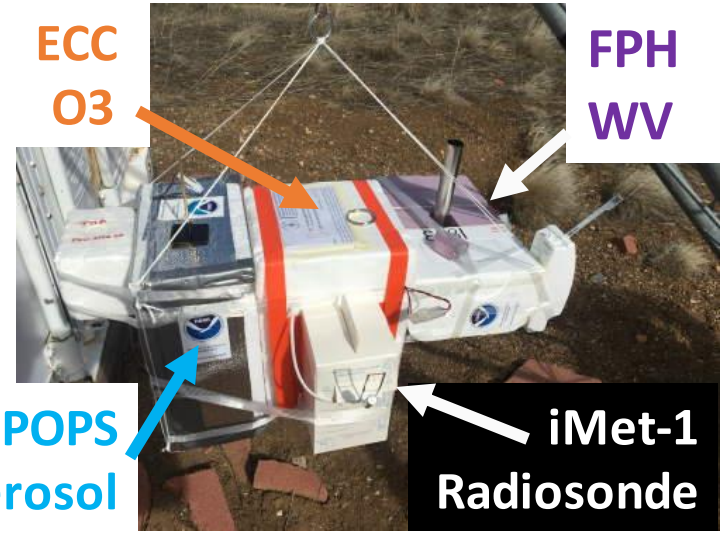
Occultation Type	Temporal constraints	Spatial constraints
Sunrise, Sunset, Moonrise, Moonset, Limb	2020-08-13T00:00:00.000000Z to 2021-01-14T23:59:59.999999Z	50°N, 40°S, -115.2°W, -95.2°E

Display 30 events Search:

Event ID	Event Date	Occult type	Az	El	Lat	Lon	Solar Beta	Lunar Beta	LPhase	SZA	Alt	Obscuration	ISS Orbit
2429210	2020-08-26 12:32:38	Sunrise	346.95	-19.85	41.72	-106.90	-12.26	28.05	99.92	90.00	414.37	None	24292
2430710	2020-08-27 11:46:50	Sunrise	351.12	-19.87	44.85	-96.25	-8.35	28.24	112.08	90.00	413.94	None	24307
2432310	2020-08-28 12:33:55	Sunrise	355.68	-19.89	47.86	-106.78	-4.06	24.35	124.80	90.00	413.53	None	24323
2438440	2020-09-01 11:10:40	Moonset	193.10	-19.84	46.39	-102.48	12.98	-12.38	170.25	100.68	412.17	None	24384
2453630	2020-09-11 06:13:06	Moonrise	4.95	-19.88	46.42	-111.13	50.33	4.68	80.10	127.03	413.67	None	24536
2457110	2020-09-13 12:45:28	Sunrise	59.51	-19.85	42.33	-105.62	54.15	37.30	52.80	90.00	414.04	Low	24571
2462620	2020-09-17 01:33:51	Sunset	122.77	-19.83	42.72	-112.86	52.28	59.59	7.44	90.00	412.62	None	24626
2464120	2020-09-18 00:48:42	Sunset	125.27	-19.85	46.97	-101.76	50.16	47.16	9.51	90.00	412.05	None	24641
2485820	2020-10-02 00:56:00	Sunset	190.06	-19.85	48.30	-110.81	-9.46	9.87	174.92	90.00	411.55	None	24858
2487320	2020-10-03 00:10:02	Sunset	195.04	-19.84	46.23	-99.50	-14.13	24.64	166.94	90.00	411.80	None	24873
2488920	2020-10-04 00:57:05	Sunset	200.33	-19.82	43.68	-111.37	-19.08	40.07	156.18	90.00	412.13	None	24889
2490420	2020-10-05 00:11:17	Sunset	205.27	-19.81	40.91	-99.92	-23.68	53.87	145.86	90.00	412.52	None	24904
2523810	2020-10-26 12:54:40	Sunrise	329.25	-19.79	40.54	-96.57	-28.76	36.91	124.25	90.00	412.19	None	25238
2525410	2020-10-27 13:42:00	Sunrise	334.19	-19.80	42.97	-107.06	-24.19	35.31	135.65	90.00	411.79	None	25254

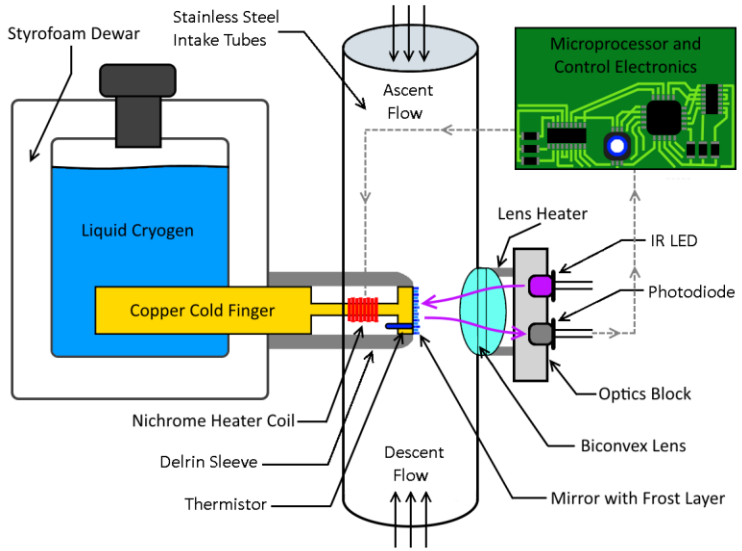
Lauder, New Zealand

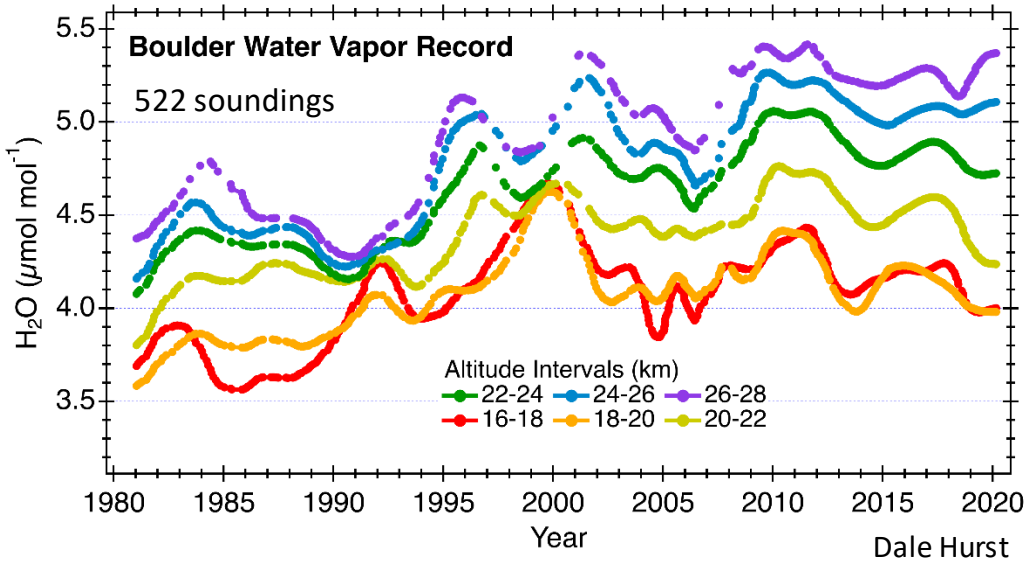
- 58 coordinated balloon flights
- 33 with a NOAA FPH water vapor sonde
- 57 with an En-Sci ECC ozonesonde
- 19 with a NOAA CSL POPS aerosol sonde
- Average difference in time, Lat, Long
  - 10.9 hours, 2.5° Lat, 5.0° Long



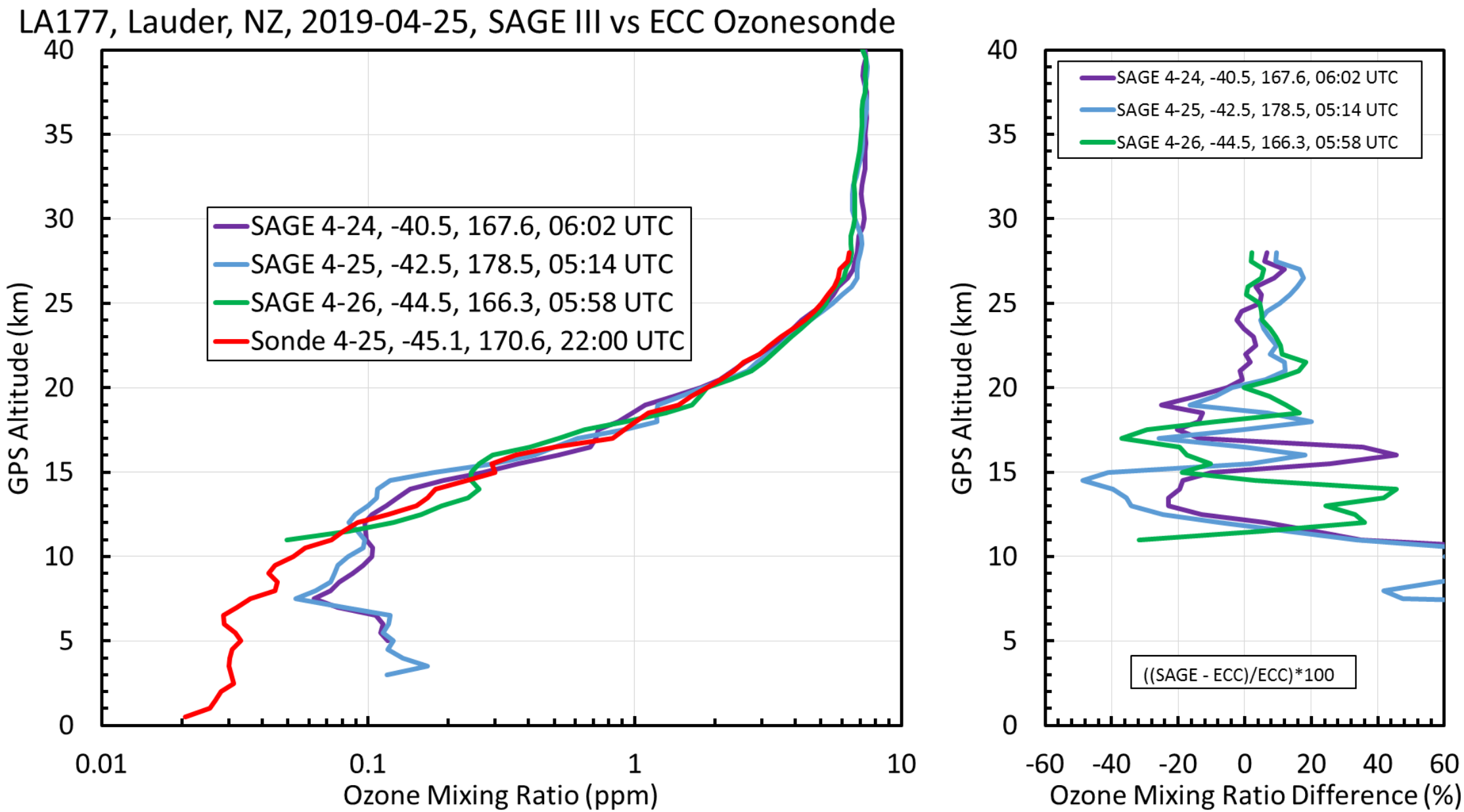
- 17 coordinated balloon flights
- 17 with a NOAA FPH water vapor sonde
- 17 with an En-Sci ECC ozonesonde
- 7 with a NOAA CSL POPS aerosol sonde
- Average difference in time, Lat, Long
  - 11.3 hours, 1.8° Lat, 5.6° Long

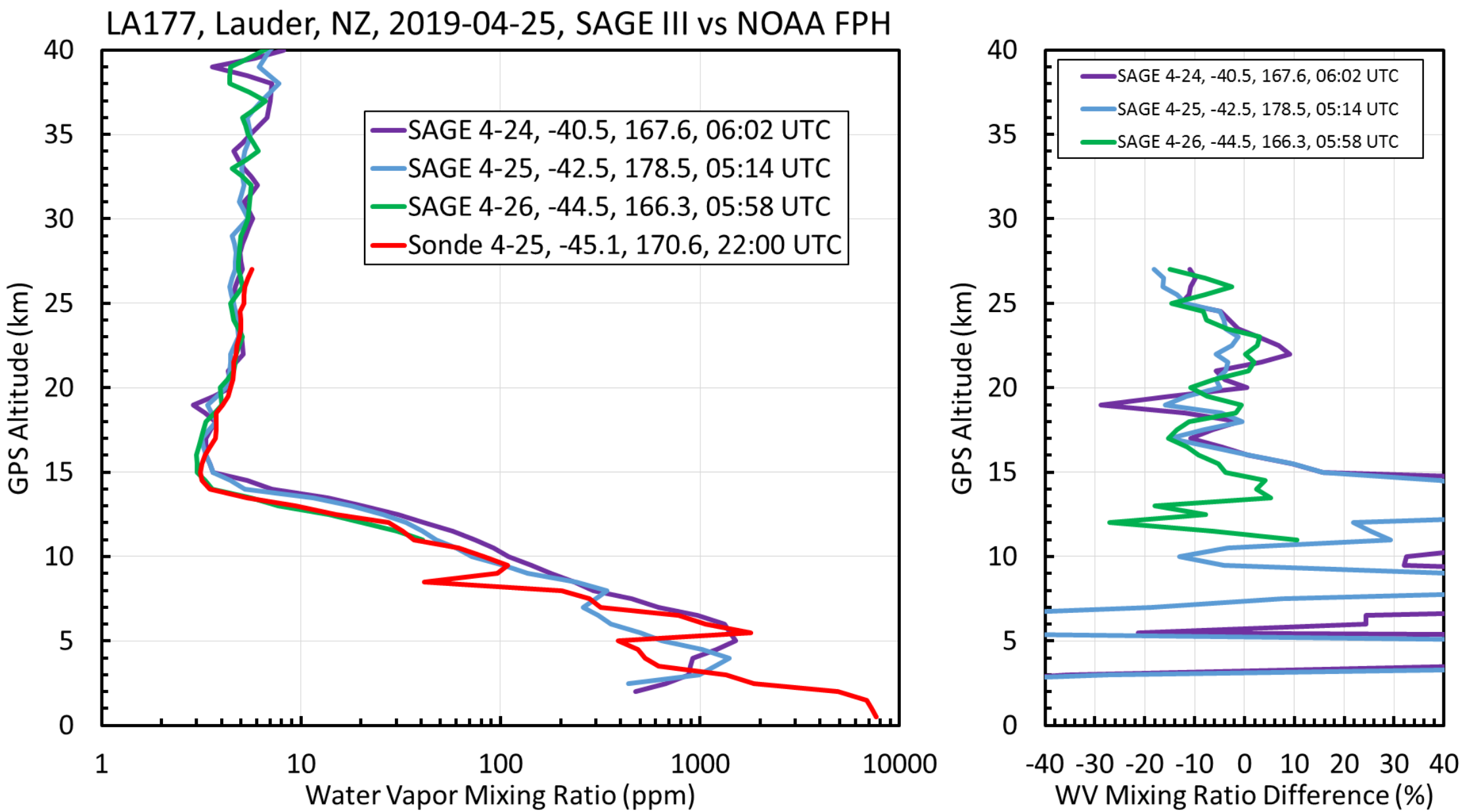
NOAA Frost Point Hygrometer (FPH)



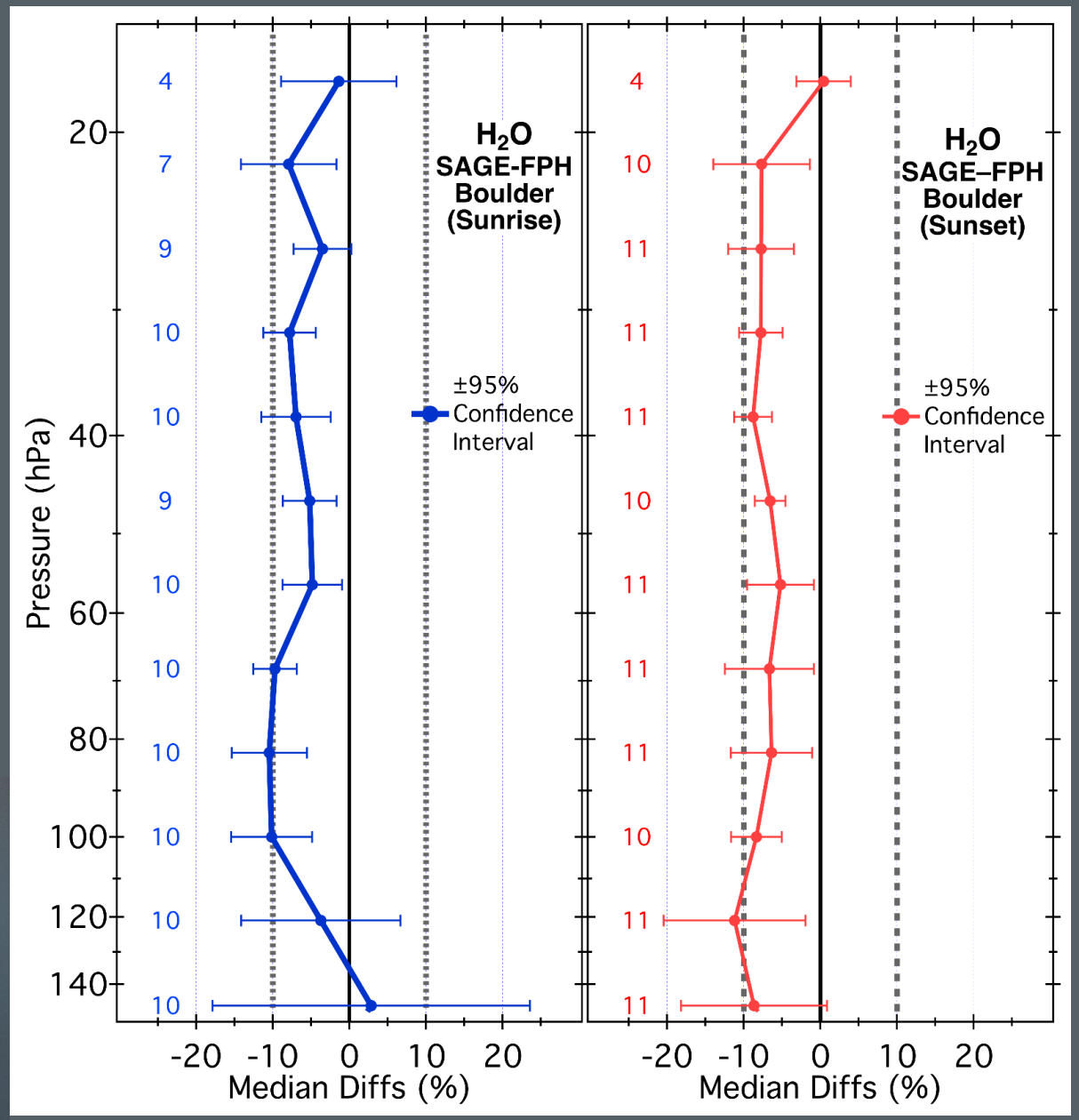


- Boulder has the longest continuous water vapor record
  - 1980 – present
- Lauder: 2004 – present
- Hilo: 2010 – present
- Weight = **850 g** (cryo + batts)
- Surface to ~ 28 km
- Vertical resolution ~ 10 m
- **< 6 % uncertainty** in stratosphere (2σ)


LA177, Lauder, NZ, 2019-04-25, SAGE III vs ECC Ozonesonde
SAGE 4-24, -40.5, 167.6, 06:02 UTC
SAGE 4-25, -42.5, 178.5, 05:14 UTC
SAGE 4-26, -44.5, 166.3, 05:58 UTC
Sonde 4-25, -45.1, 170.6, 22:00 UTC
GPS Altitude (km)
Ozone Mixing Ratio (ppm)
0.01
0.1
1
10
0
5
10
15
20
25
30
35
40
SAGE 4-24, -40.5, 167.6, 06:02 UTC
SAGE 4-25, -42.5, 178.5, 05:14 UTC
SAGE 4-26, -44.5, 166.3, 05:58 UTC
((SAGE - ECC)/ECC)*100
GPS Altitude (km)
Ozone Mixing Ratio Difference (%)
-60
-40
-20
0
20
40
60


LA177, Lauder, NZ, 2019-04-25, SAGE III vs NOAA FPH
SAGE 4-24, -40.5, 167.6, 06:02 UTC
SAGE 4-25, -42.5, 178.5, 05:14 UTC
SAGE 4-26, -44.5, 166.3, 05:58 UTC
Sonde 4-25, -45.1, 170.6, 22:00 UTC
GPS Altitude (km)
Water Vapor Mixing Ratio (ppm)
1
10
100
1000
10000
0
5
10
15
20
25
30
35
40
SAGE 4-24, -40.5, 167.6, 06:02 UTC
SAGE 4-25, -42.5, 178.5, 05:14 UTC
SAGE 4-26, -44.5, 166.3, 05:58 UTC
GPS Altitude (km)
WV Mixing Ratio Difference (%)
-40 -30 -20 -10 0 10 20 30 40

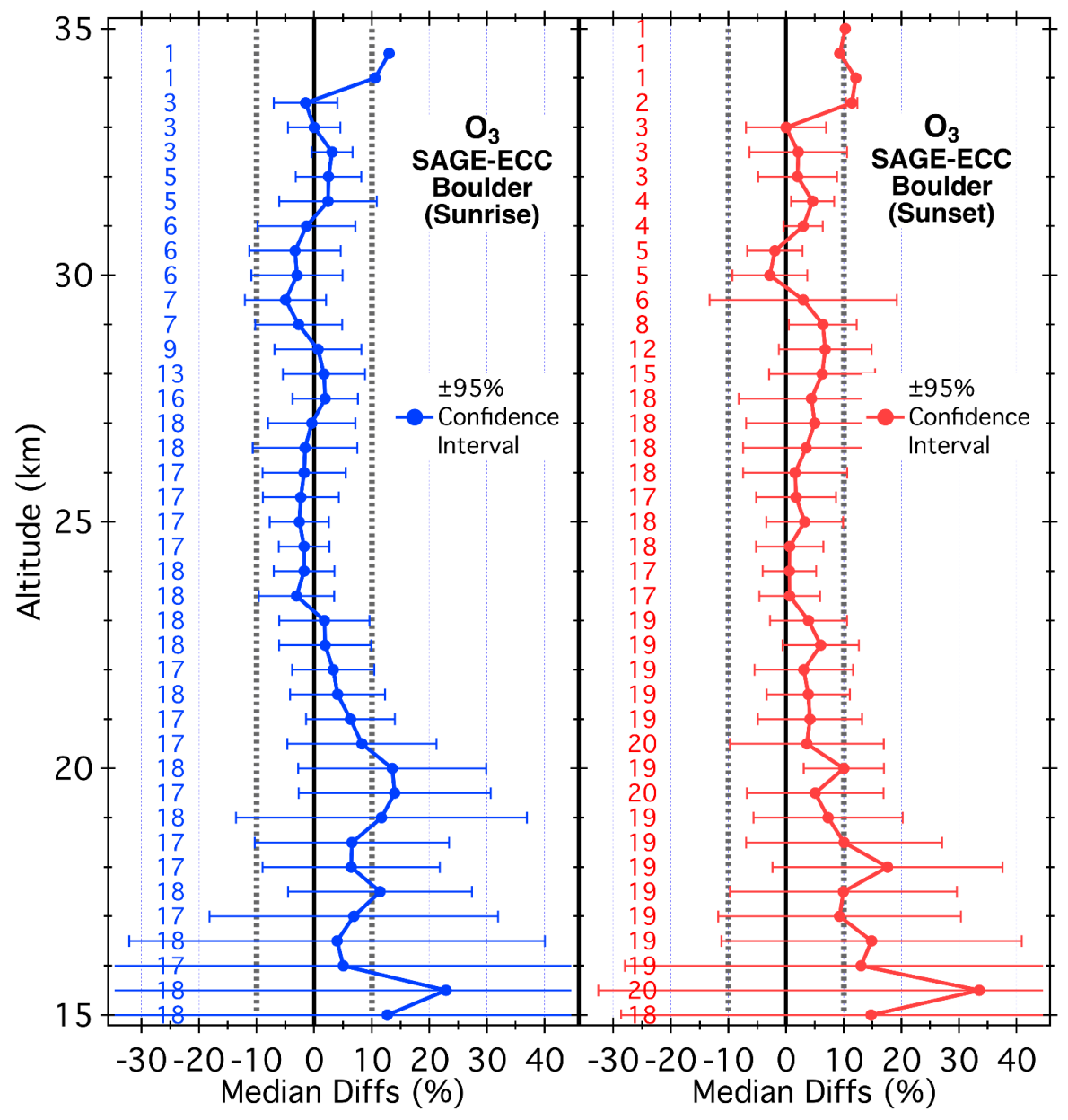
Water Vapor



- Statistically significant bias between SAGE III and NOAA FPH
- 5 – 10 % (0.2 – 0.5 ppm)
  - 100 – 20 hPa (sunrise)
  - 120 – 20 hPa (sunset)

Dale Hurst

Ozone

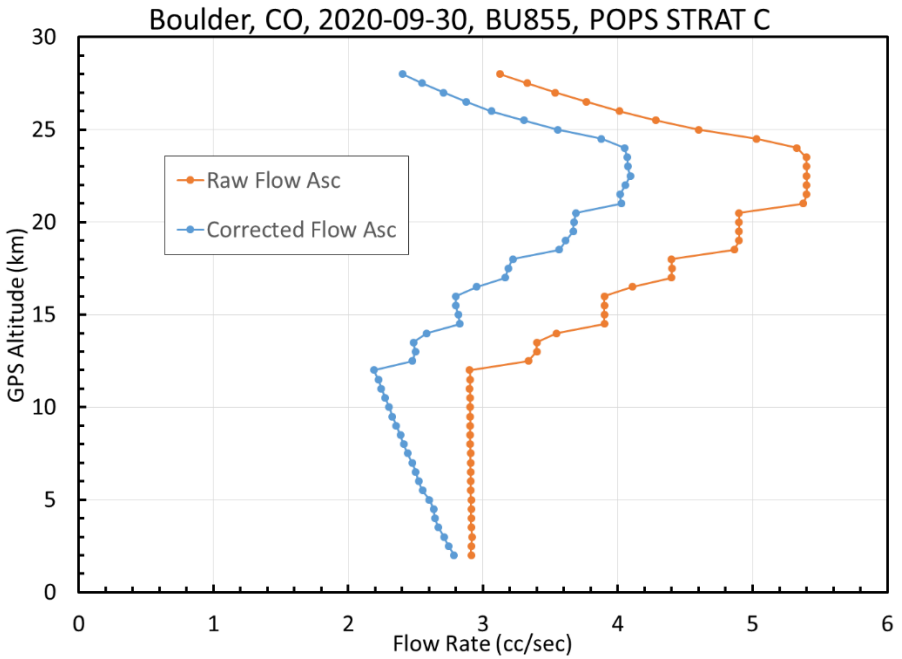


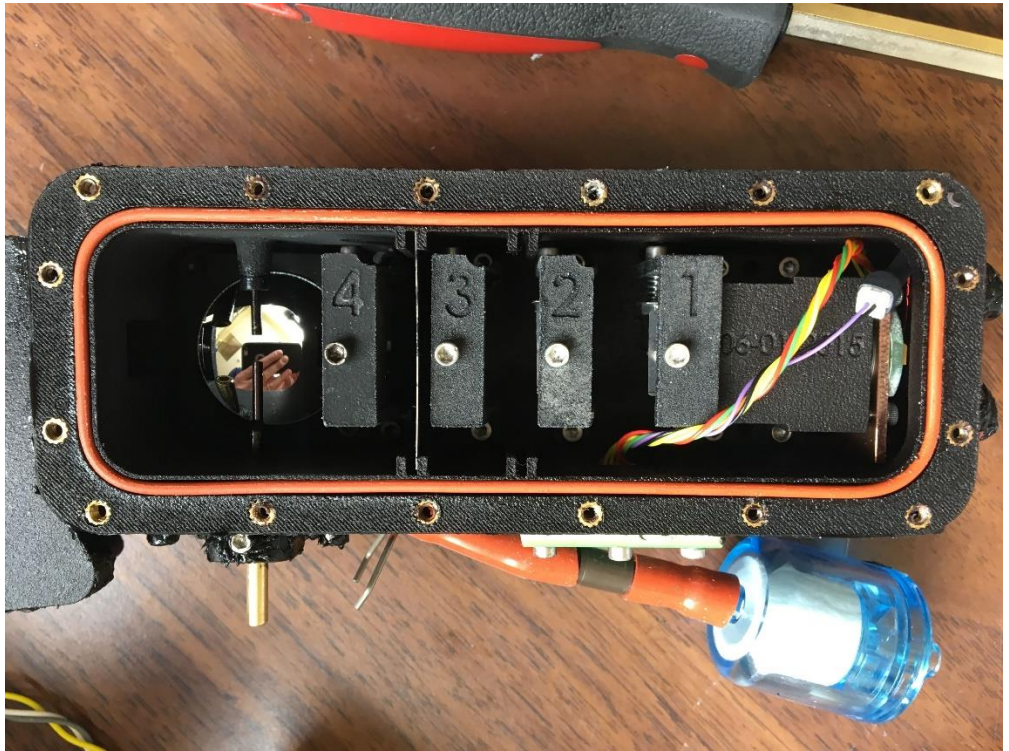
- No significant biases between SAGE III and ECC ozonesondes in the stratosphere
- Spatial and temporal variability of ozone increases in lowermost stratosphere

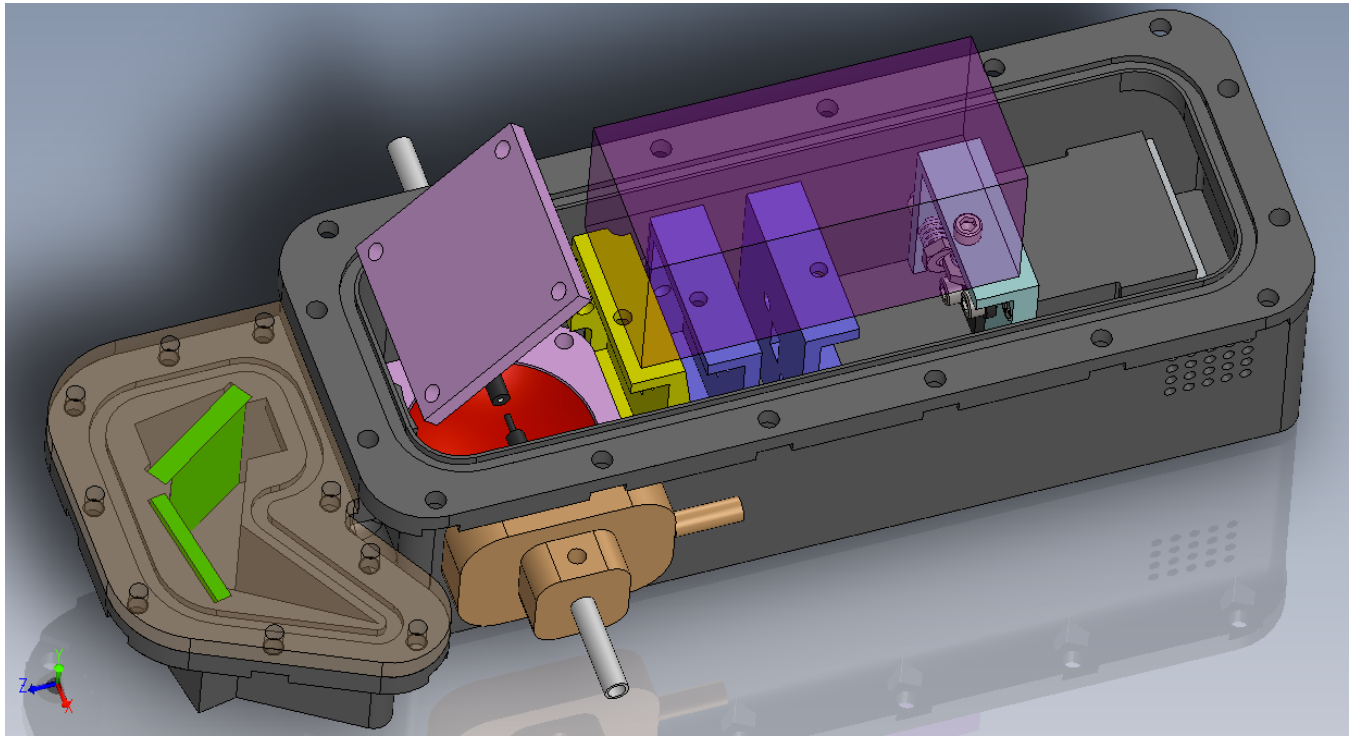
Dale Hurst

POPS Optical Particle Counter

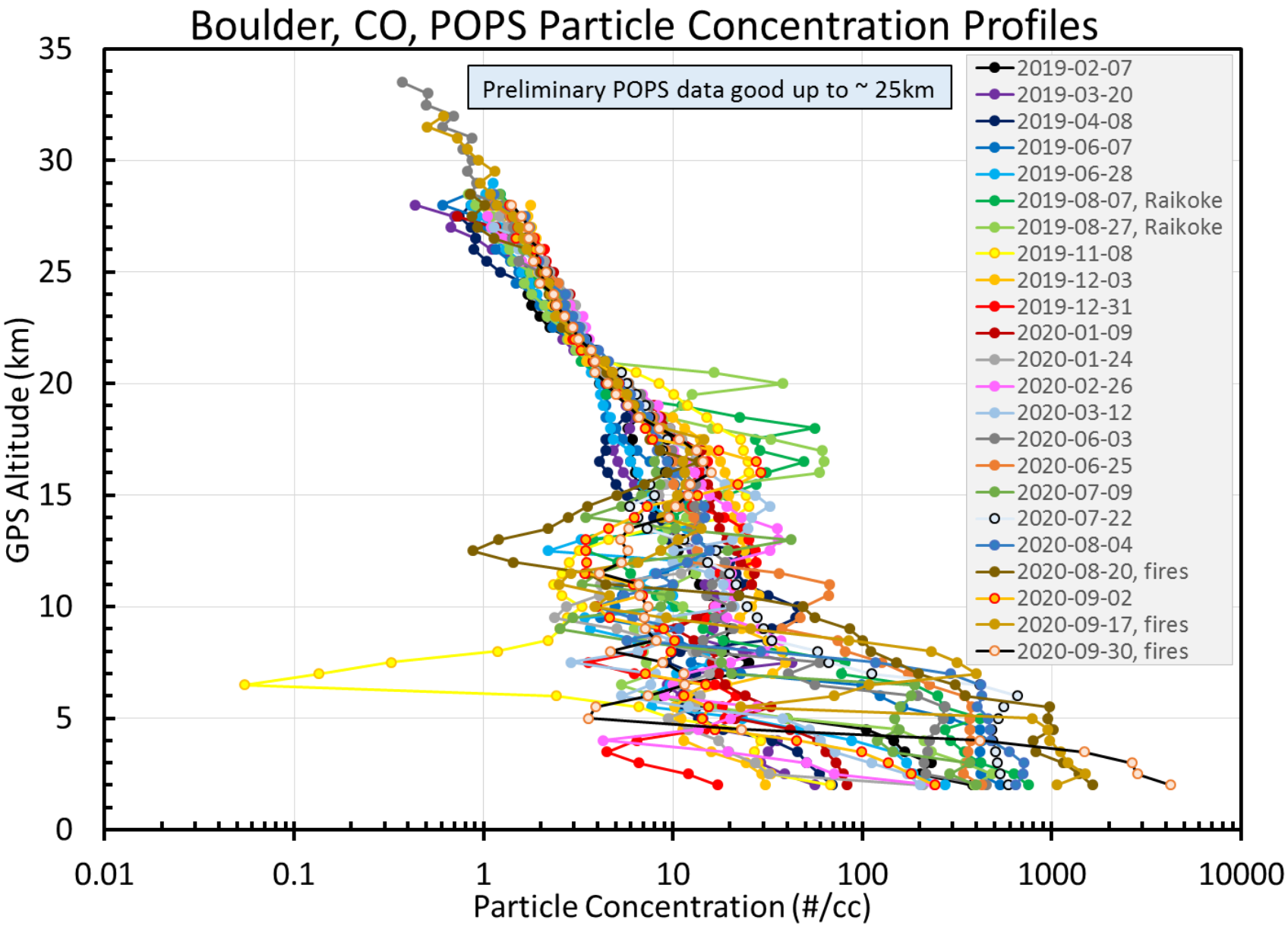
- Optical particle counter
  - Particle size distribution (140 – 2500 nm)
  - Bin sizes changed from being evenly spaced in log detector signal space to evenly spaced in log Dp (nm) Aug 15, 2019 (BLD) and Jan 1, 2020 (LDR)
- Weight ~ 1 kg (with foam and battery)
- Power < 5 W
- 15 size bins transmitted at 1 Hz with iMet radiosonde
- Flow rate ~ 2.0 – 4.5 cc/sec (altitude dependent)







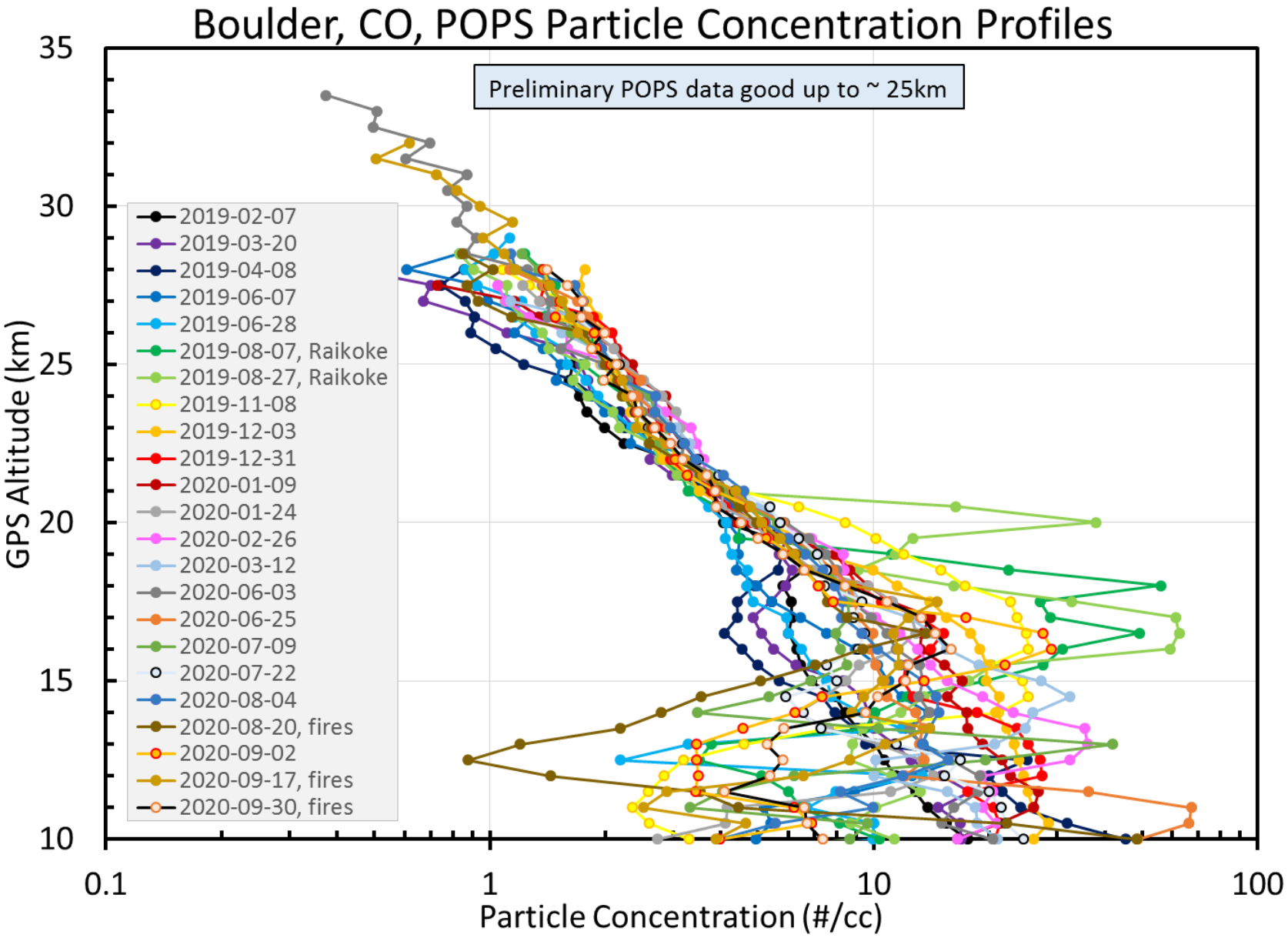
POPS Balloon Launches in Boulder, CO



- 23 balloon launches with POPS in Boulder

Photo credit: Jim Elkins

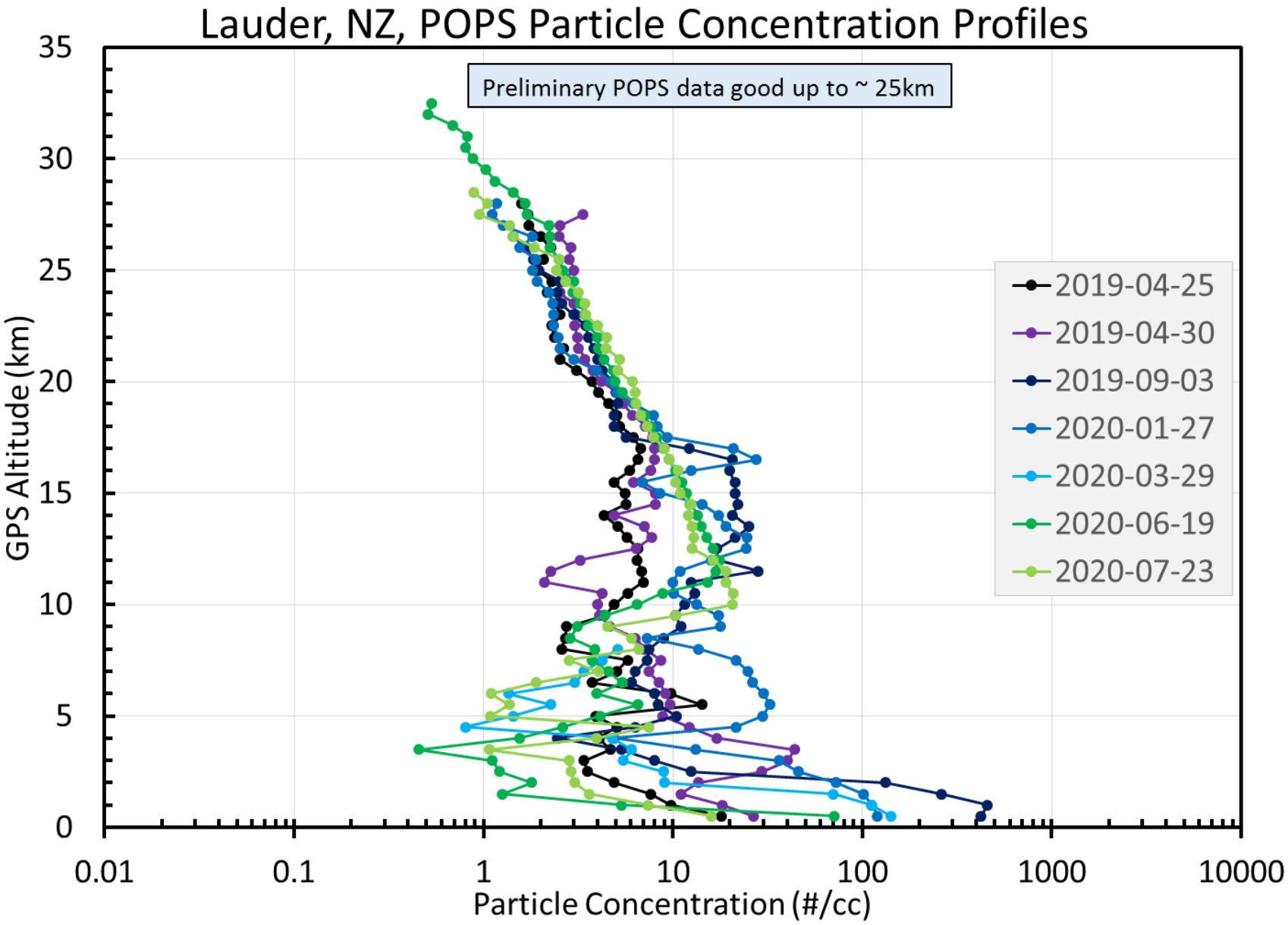
POPS Balloon Launches in Boulder, CO



- Less variability above 20 km
  - Starting to see the stratospheric baseline

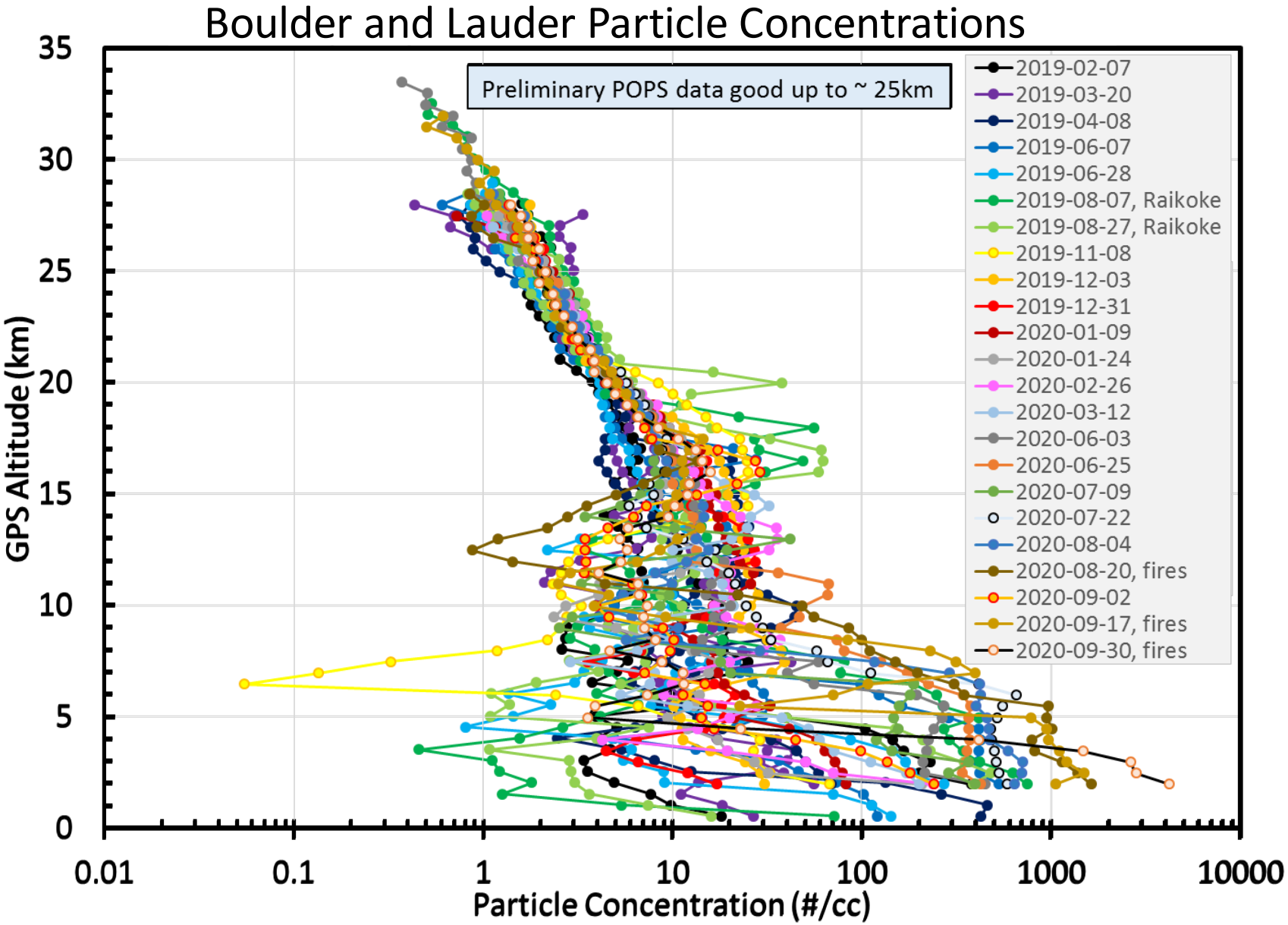
Photo credit: Jim Elkins

POPS Balloon Launches in Lauder, NZ



- 7 balloon launches with POPS in Lauder
- Particle concentrations > 40 #/cc were rarely observed, even in the lower troposphere

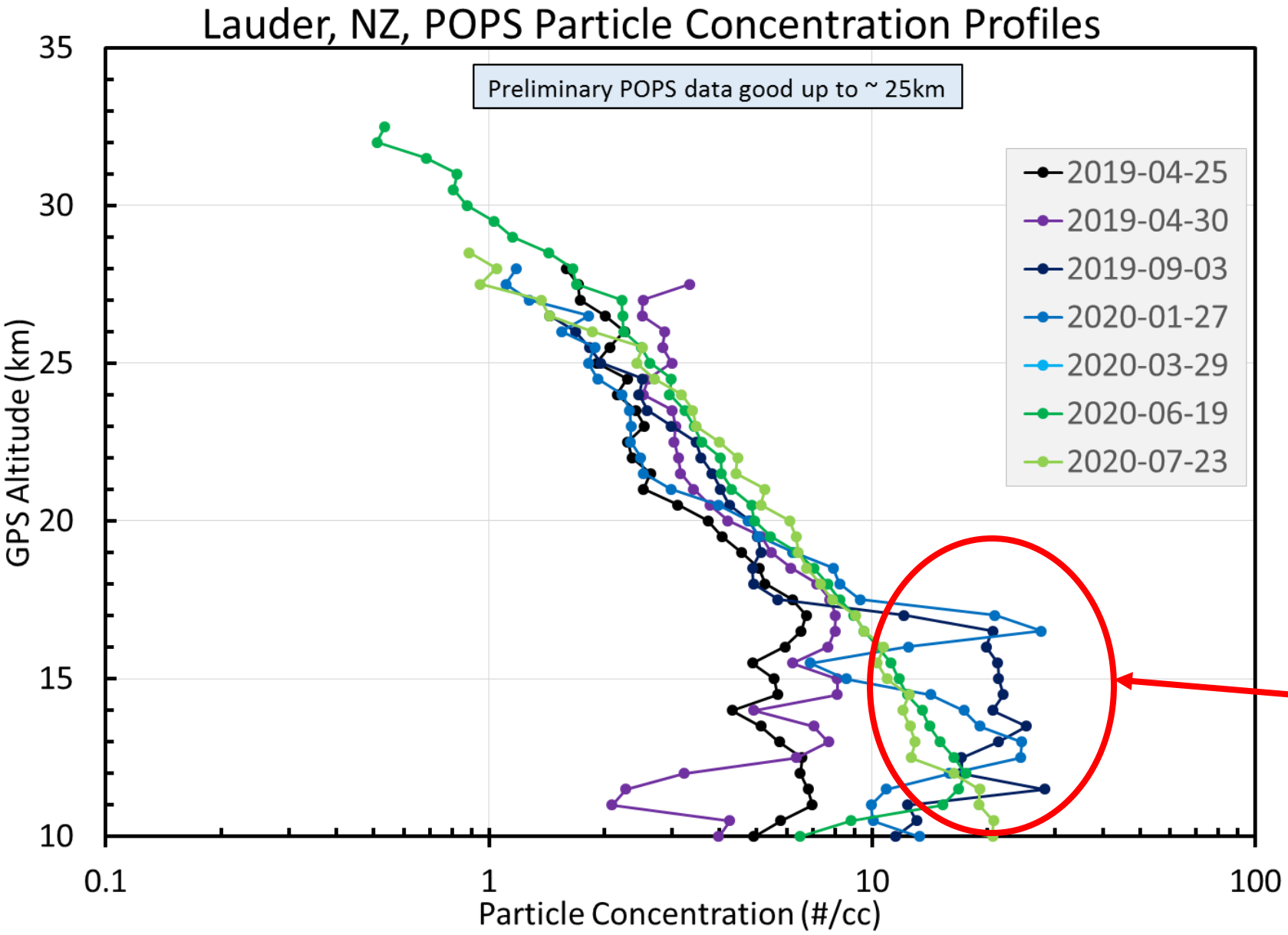
Boulder and Lauder POPS Comparison



Boulder (40 N) and Lauder (45 S)

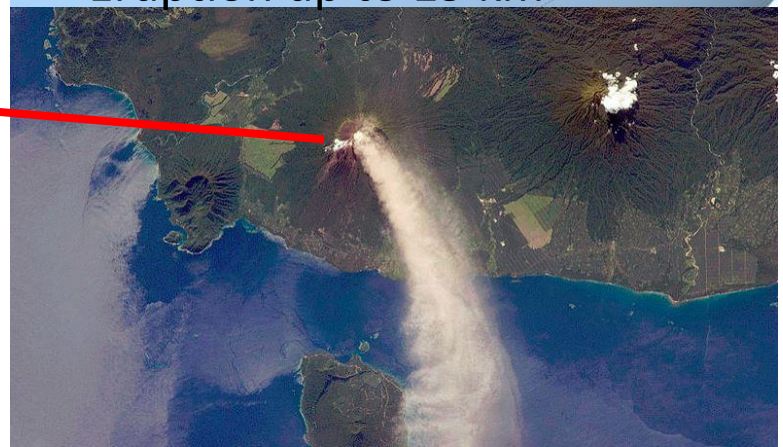
- Similar stratospheric aerosol profiles > 20 km
- Lauder shows lower aerosol particle concentrations < 10 km
- Boulder has much higher tropospheric concentrations
  - Concentrations > 100 #/cc were frequently measured up to 9 km in Boulder
  - Partially due to ongoing wildfires in the western US

POPS Balloon Launches in Lauder, NZ



Ulawun Eruption June 26, 2019

- Papua New Guinea
- Elevation = 2334 m
- 5° S, 151° E
- Eruption up to 19 km



Raikoke Eruption

- 22 June 2019
- Kuril Islands
- Latitude 48.3° N
- Tropopause height ~ 11 km
- Ash plume ejected up to ~ **13-17** km

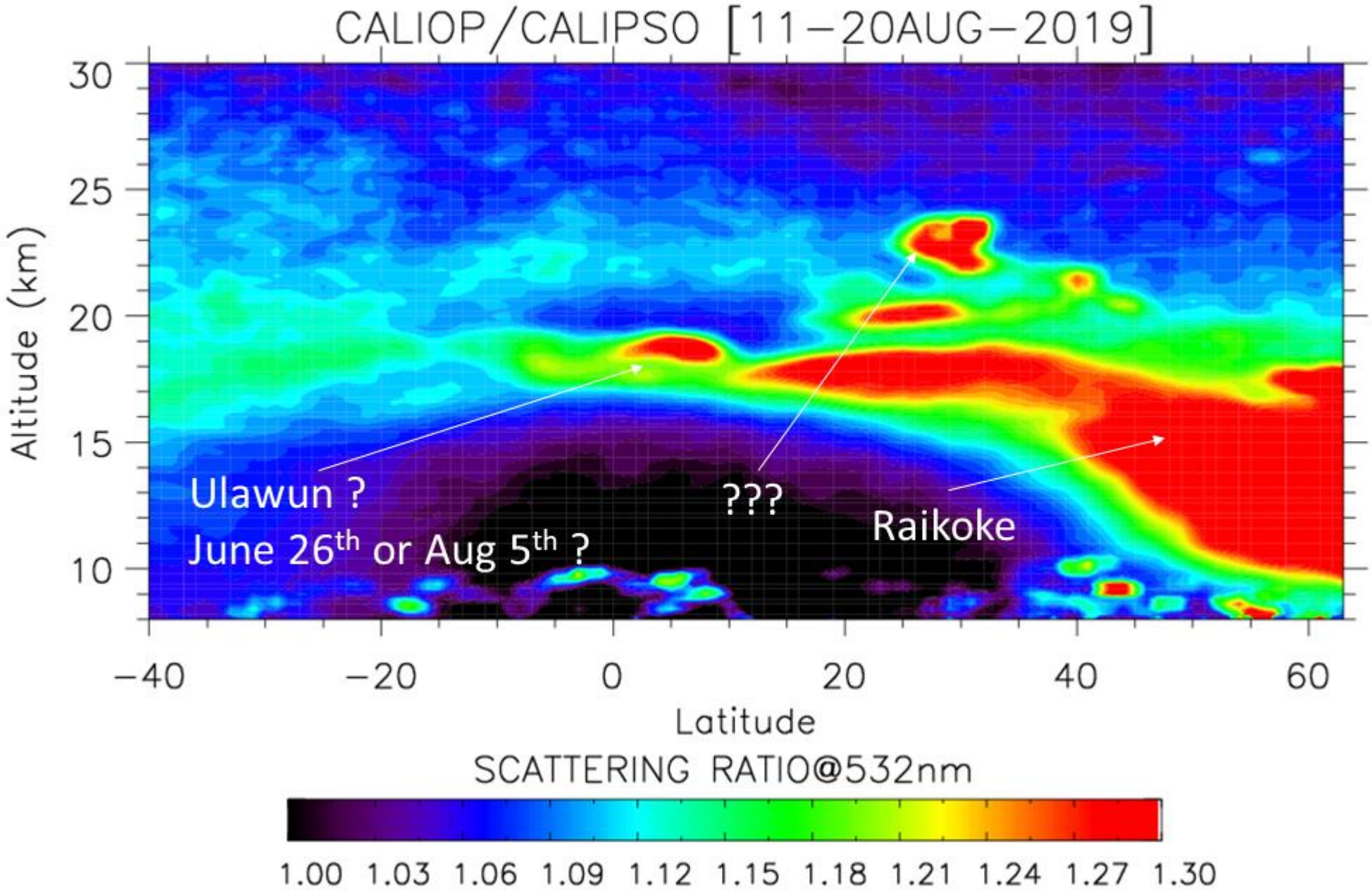
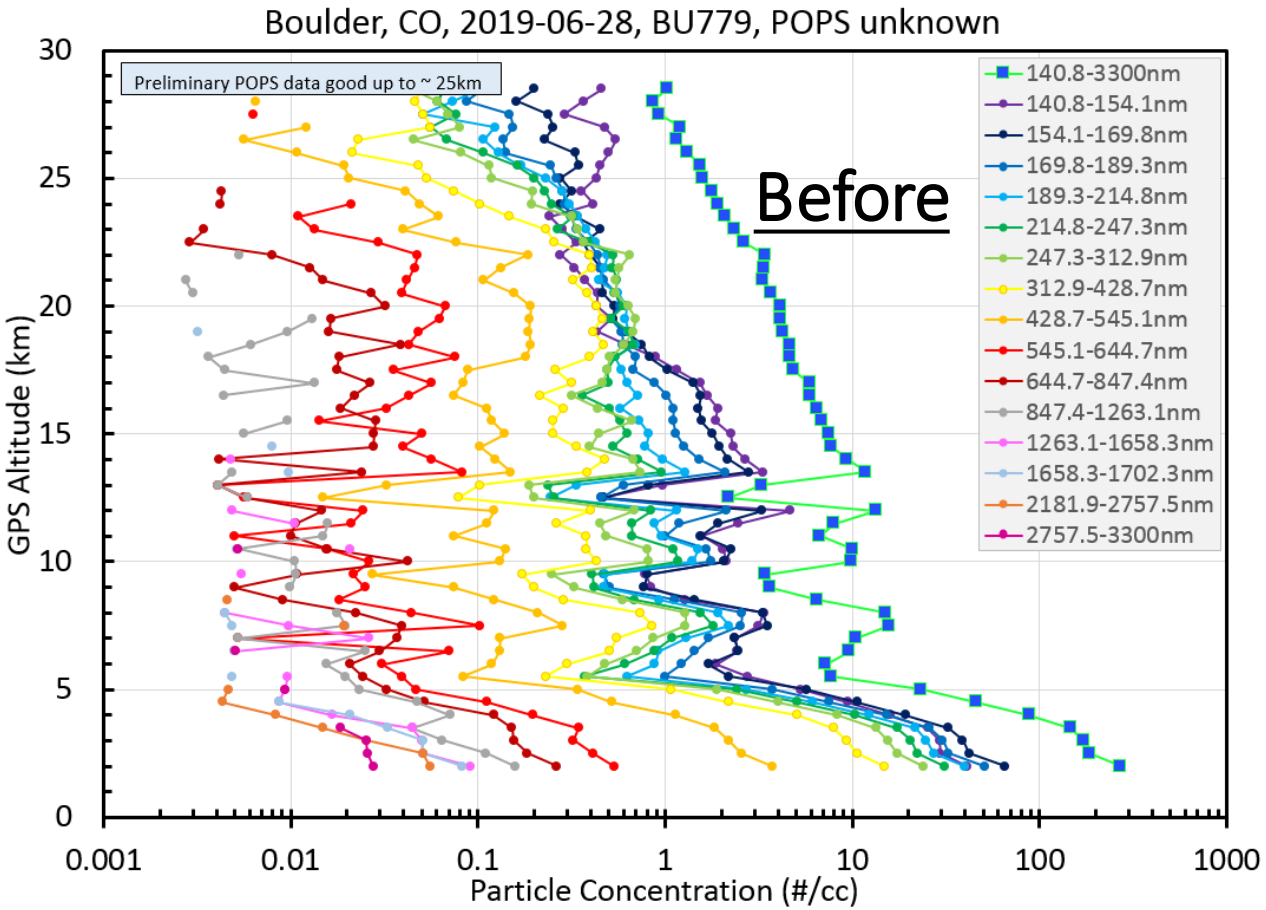
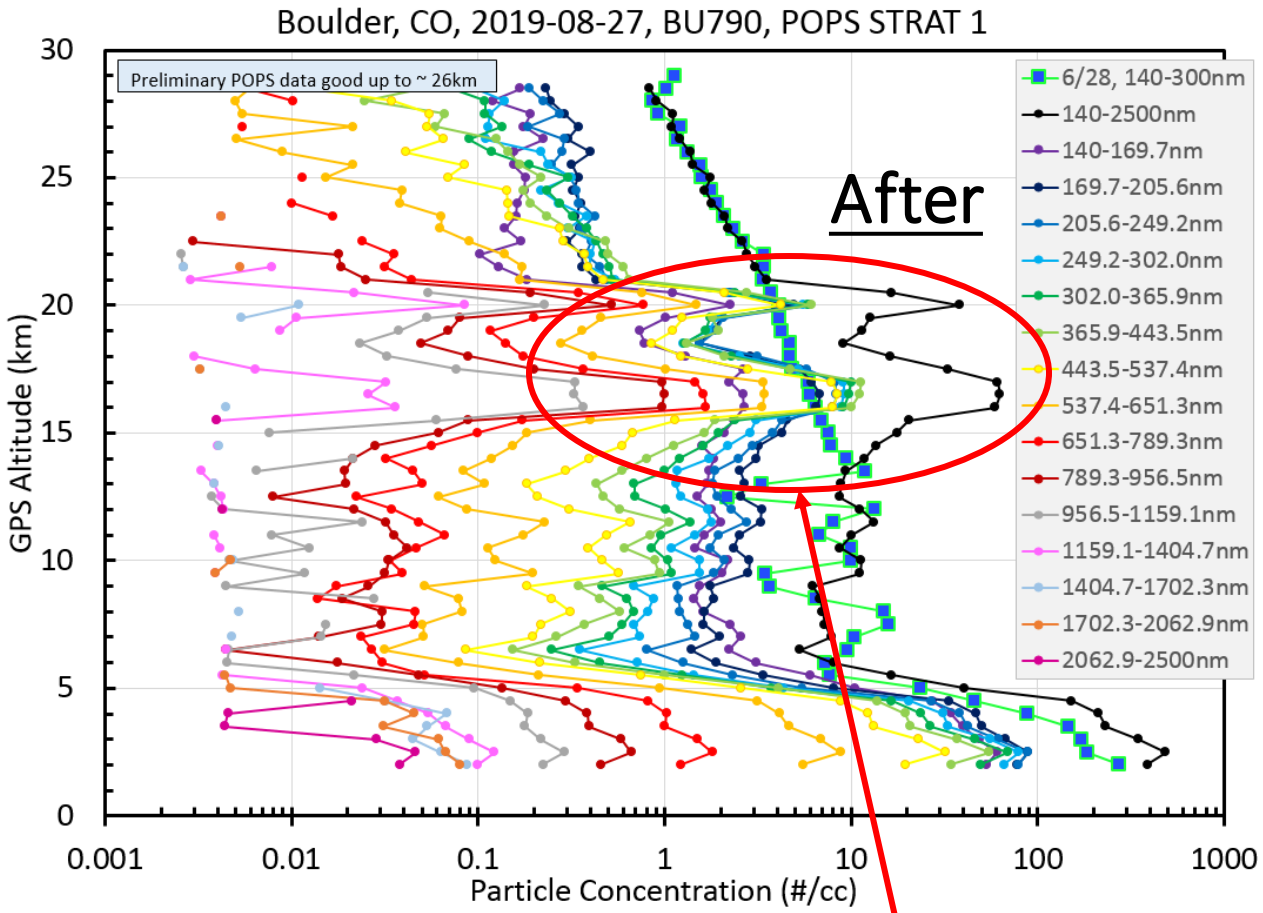


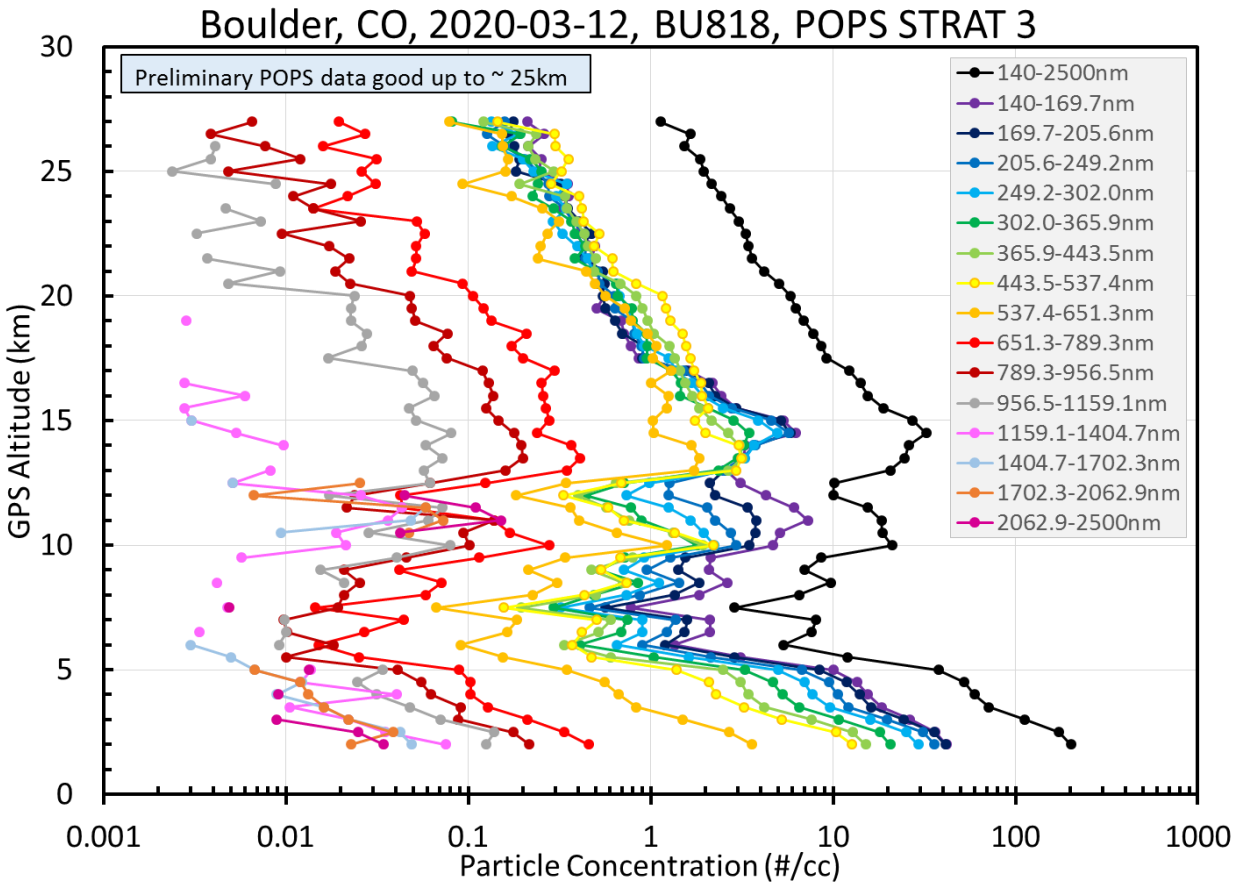
Figure: Jean-Paul Vernier

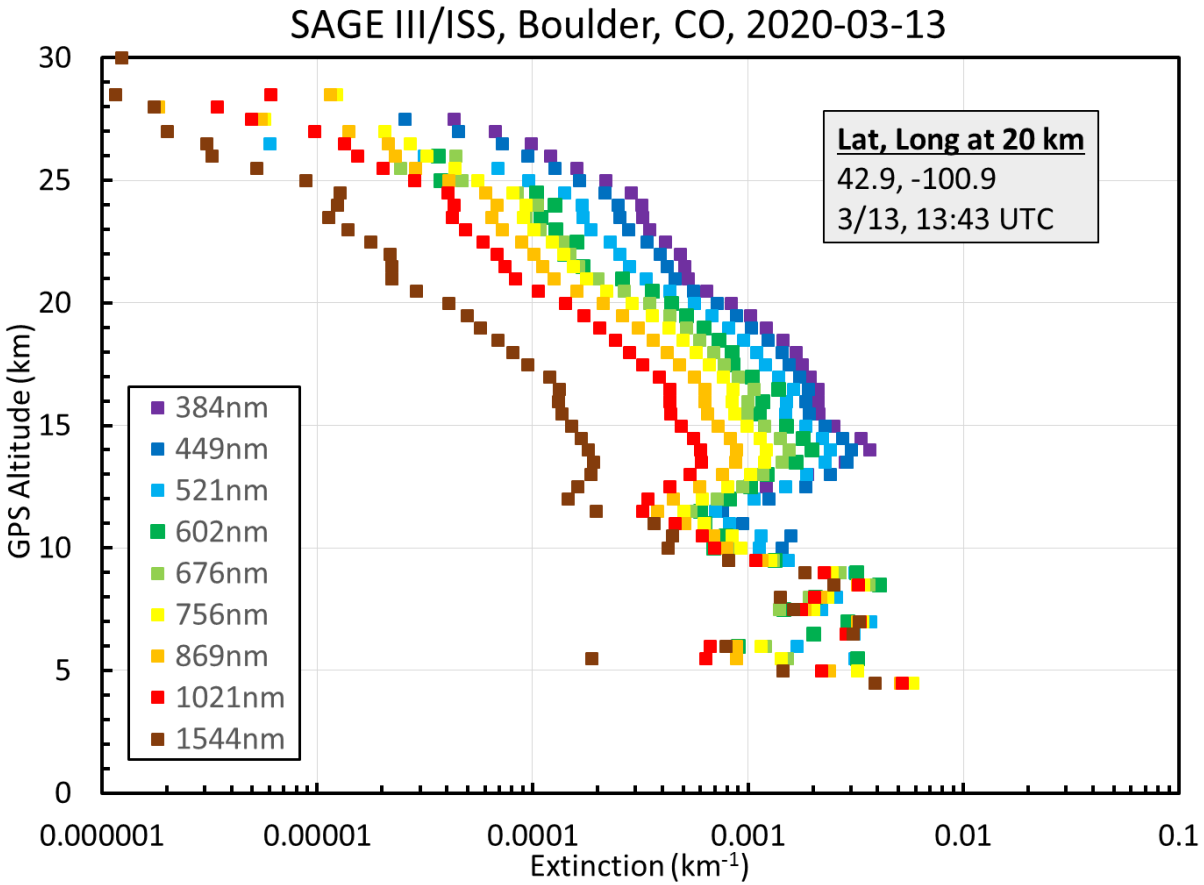




- Distinct plumes observed at 16-18 and ~20 km above Boulder on 27 Aug 2019
- x10 increase in concentration at 17 km in August (61 cm^{-3}) compared to June (6 cm^{-3})
- Size distribution peak near 300 nm

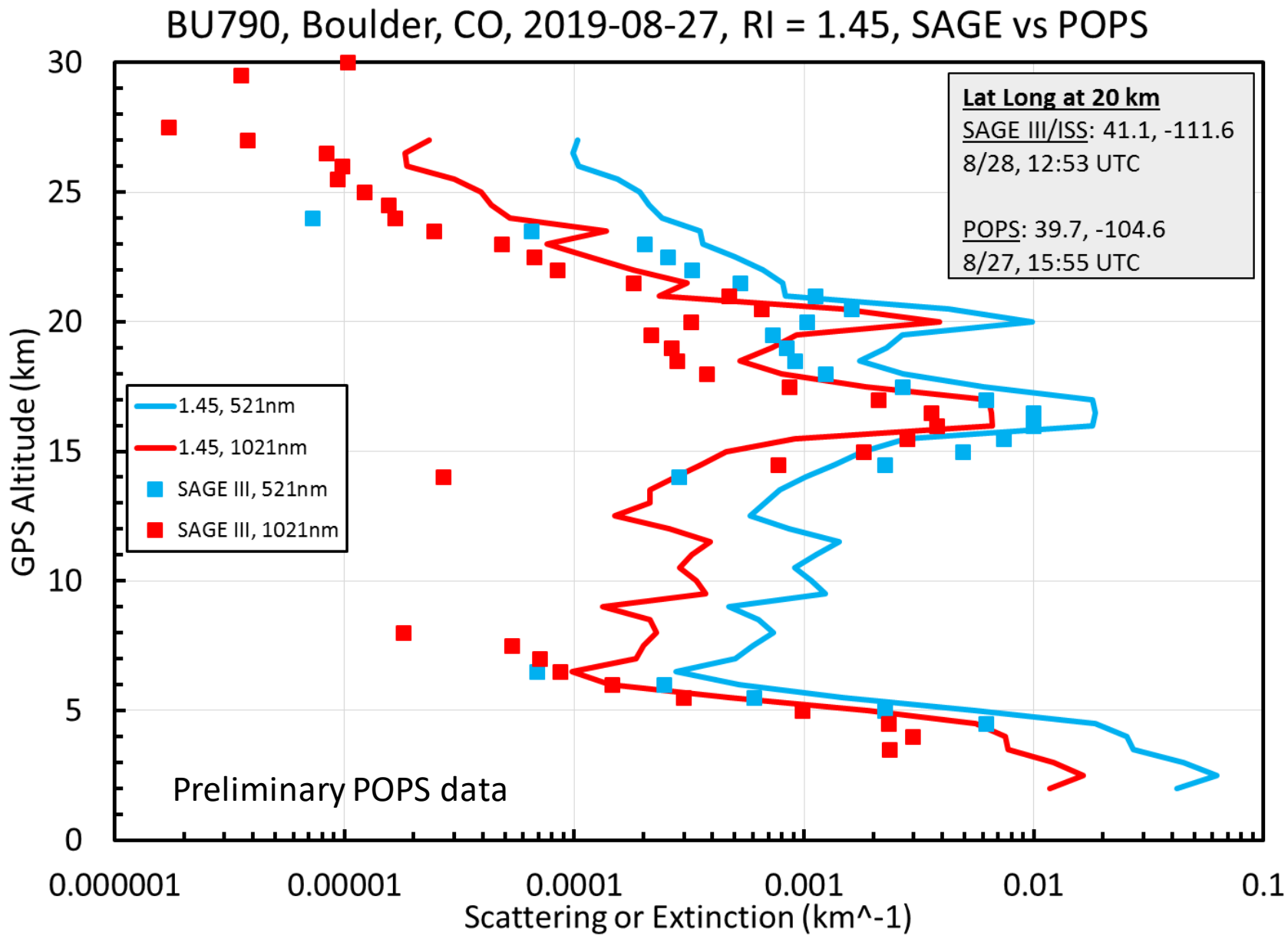
Comparing Particle Concentration to Extinction





Calculating POPS Scattering

- Ran Mie scattering code for the 9 different SAGE III wavelengths between 384 – 1544 nm
  - Used 3 different refractive indices = **1.33, 1.45, and 1.55 (pure water, sulfate, dust/sea salt)**
  - Calculated scattering coefficient (Qscat)
- Calculated POPS scattering at each of the 9 different SAGE III wavelengths:
  - Scattering = (π/4) * Qscat * (particle size(nm)^2) * (particle concencentration (#/cc))


BU790, Boulder, CO, 2019-08-27, RI = 1.45, SAGE vs POPS
Lat Long at 20 km
SAGE III/ISS: 41.1, -111.6
8/28, 12:53 UTC
POPS: 39.7, -104.6
8/27, 15:55 UTC
1.45, 521nm
1.45, 1021nm
SAGE III, 521nm
SAGE III, 1021nm
Preliminary POPS data
GPS Altitude (km)
30
25
20
15
10
5
0
0.000001
0.00001
0.0001
0.001
0.01
0.1
Scattering or Extinction (km^-1)

Smoky Boulder POPS Flight

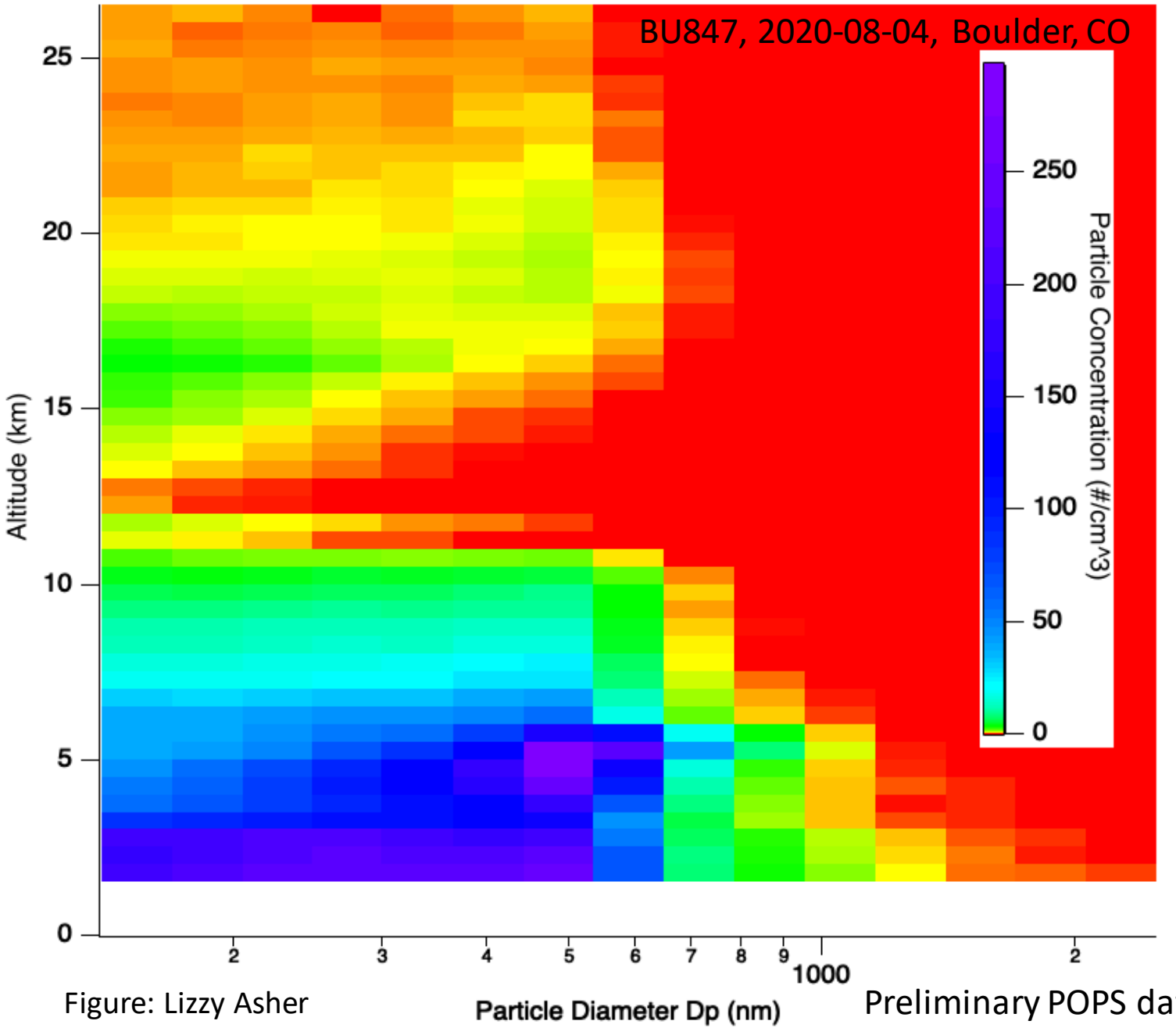
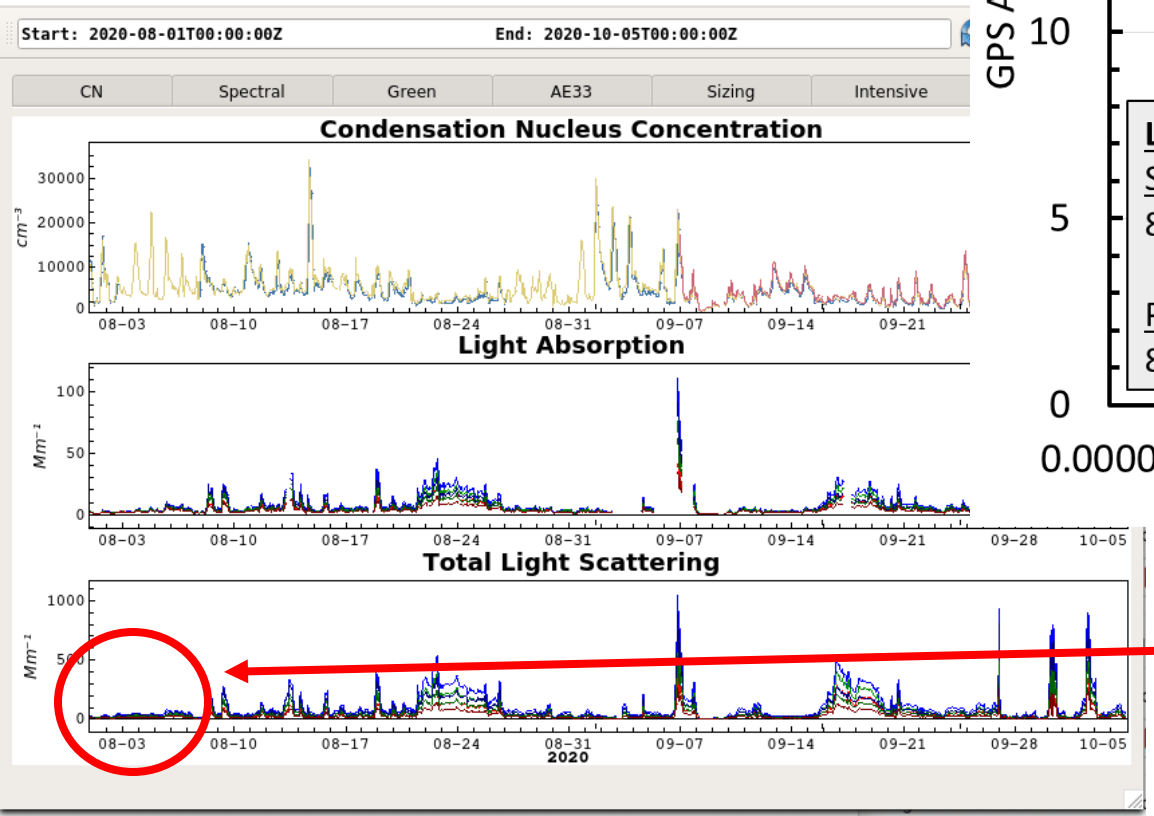


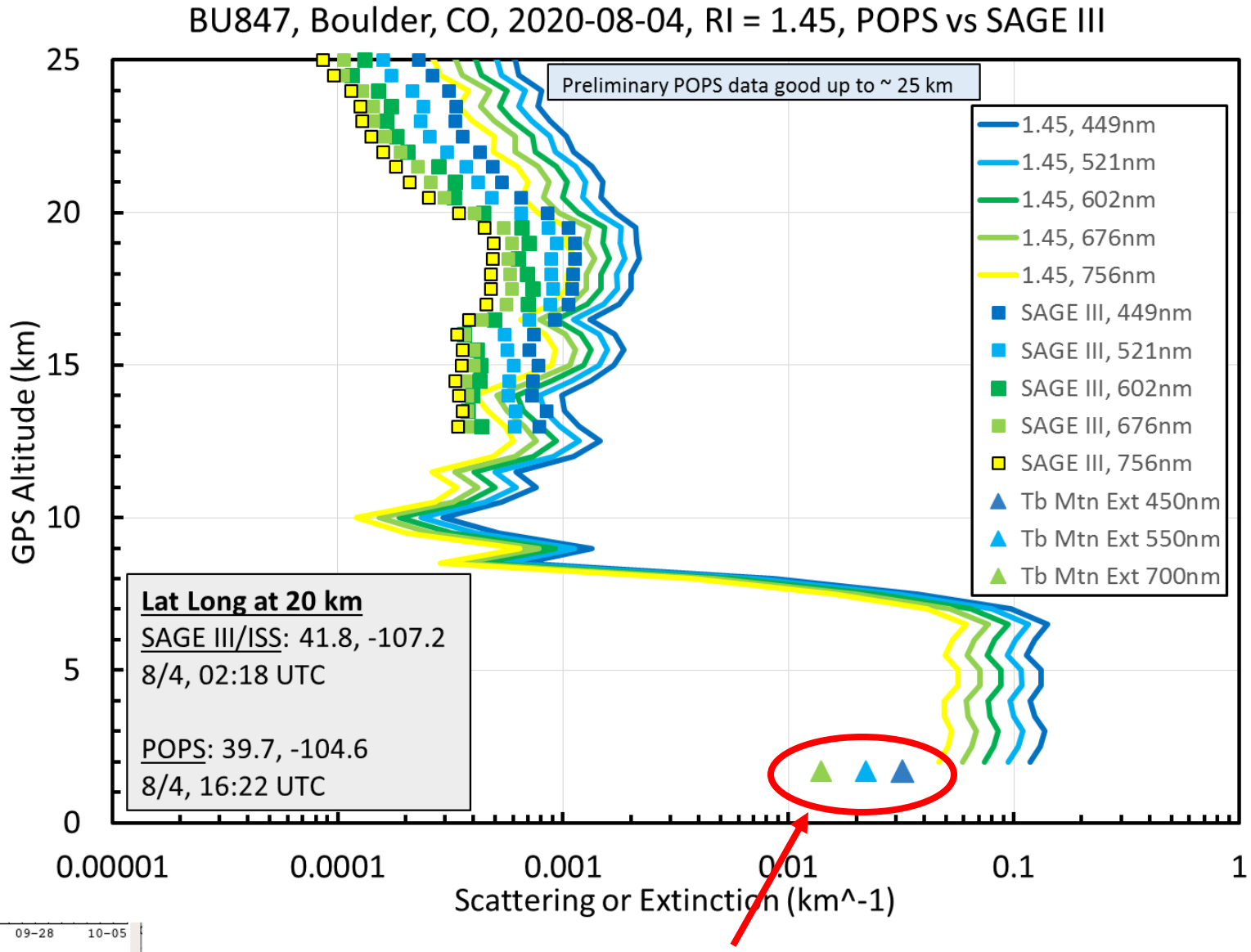
Figure: Lizzy Asher

Preliminary POPS data

Aug 4th, 2020

- West coast fires + local Colorado fires
- **200 – 550 nm** peak particle diameter near the surface
- Maximum particle concentration
  - between **4 - 5.5 km**
  - Particle diameter near **440 – 540 nm**
- Clean air layer at 11 km





- Table Mountain Surface Aerosol site shows much lower scattering values just 12 miles north of balloon launch facility

What a balloon launch looks like in Boulder, CO

https://www.youtube.com/watch?v=_fdE0dexw2A&feature=youtu.be

A one minute video showing what a balloon launch looks like in Boulder

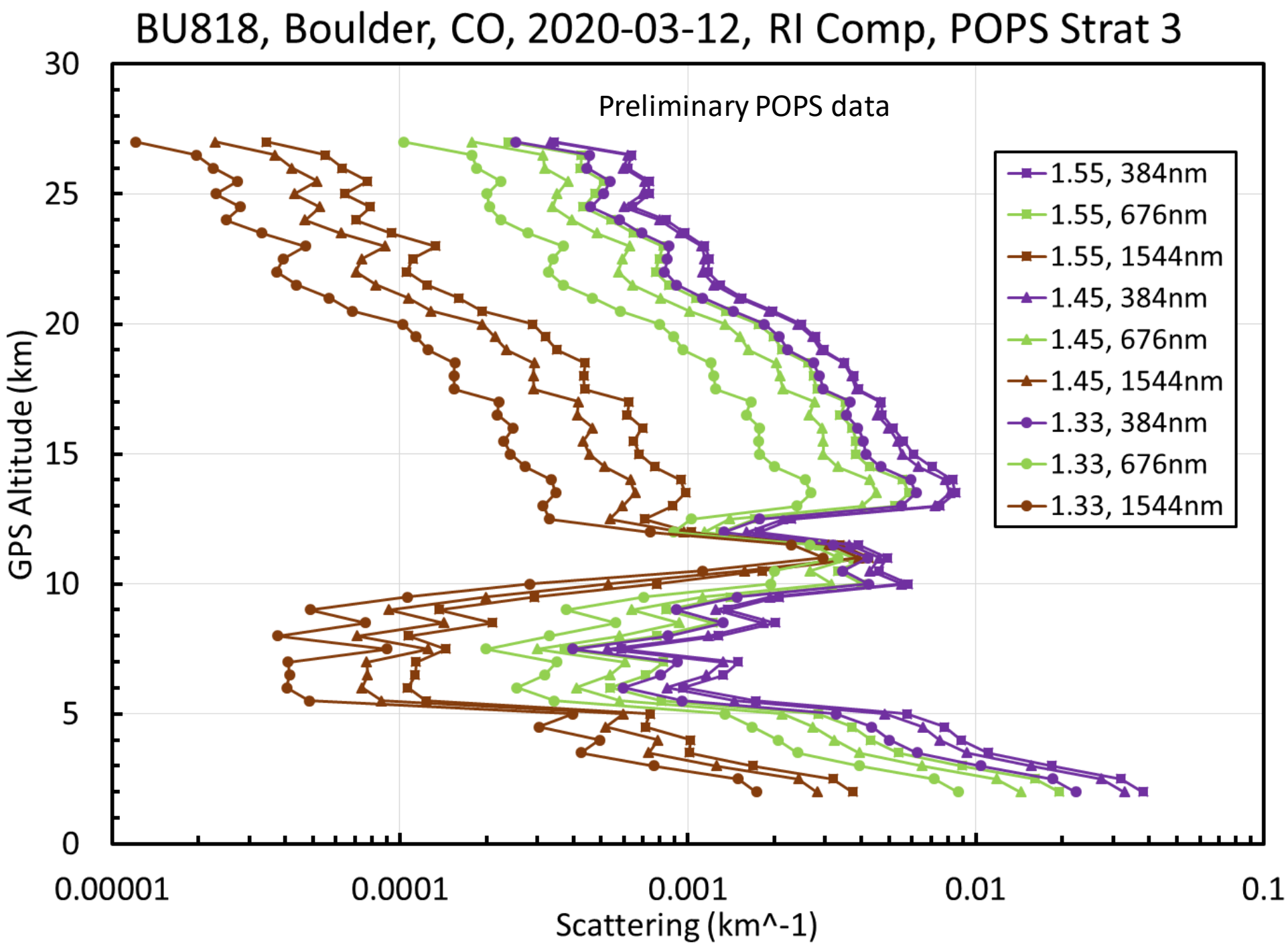
Video: Patrick Cullis

Summary

- We have many successful coincident balloon flights since 2017
  - 58 flights from Boulder
  - 17 flights from Lauder
- Significant stratospheric water vapor biases between SAGE III vs NOAA FPH
  - 0.2 – 0.5 ppm (5-10%)
- No significant biases in SAGE III stratospheric ozone vs balloon
- POPS aerosol instruments attached to the water vapor and ozonesonde package provides a nice set of data on each validation overpass flight
  - Feb 2019 – Boulder
  - April 2019 – Lauder

Thank you for your attention
Any questions?

Extra


BU818, Boulder, CO, 2020-03-12, RI Comp, POPS Strat 3
Preliminary POPS data
1.55, 384nm
1.55, 676nm
1.55, 1544nm
1.45, 384nm
1.45, 676nm
1.45, 1544nm
1.33, 384nm
1.33, 676nm
1.33, 1544nm
GPS Altitude (km)
30
25
20
15
10
5
0
0.00001
0.0001
0.001
0.01
0.1
Scattering (km^-1)