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 Applications, Inc
6: NIWA Lauder

SAGE III/ISS STM - October 19-20, 2020
Satellite / Balloon Coincident Overpasses

**Boulder, Colorado**
- 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

**Lauder, New Zealand**
- 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 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
Statistically significant bias between SAGE III and NOAA FPH
- 5 – 10 % (0.2 – 0.5 ppm)
- 100 – 20 hPa (sunrise)
- 120 – 20 hPa (sunset)
No significant biases between SAGE III and ECC ozonesondes in the stratosphere

Spatial and temporal variability of ozone increases in lowermost stratosphere
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 \(D_p\) (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 and Lauder Particle Concentrations

- 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

Boulder (40 N) and Lauder (45 S)
POPS Balloon Launches in Lauder, NZ

Lauder, NZ, POPS Particle Concentration Profiles

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

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Raikoke Eruption
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 ($Q_{scat}$)
- Calculated POPS scattering at each of the 9 different SAGE III wavelengths:
  - Scattering = ($\pi/4$) * $Q_{scat}$ * (particle size(nm)$^2$) * (particle concentration (#/cc))
Smoky Boulder POPS Flight

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

BU847, 2020-08-04, Boulder, CO

Preliminary POPS data

Figure: Lizzy Asher
Table Mountain 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
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