NOAA Earth's Radiation Budget (ERB) Initiative
FY22 Directed Support - Project Proposal

Project Title: Balloon Baseline Stratospheric Aerosol Profiles (B^{2}SAP)

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Period of Performance: 1 June 2022 – 31 May 2023

Plain-language Project Summary: We will continue to launch instrumented balloons twice monthly at Boulder and quarterly at Lauder, New Zealand. The balloons carry compact, lightweight instruments that measure vertical profiles of water vapor, ozone, and aerosol number and size distribution from the surface to the middle stratosphere (~28 km). These measurements, made since June 2020, are being used to characterize the background state and variability of radiatively important aerosols in Earth's stratosphere. Measurements during the past two years have observed stratospheric air masses affected by strong volcanic eruptions and intense wildfires that injected material directly into the stratosphere. These measurements have helped us to better understand how these natural events alter stratospheric composition, especially the number and size distribution of aerosols, and how the aerosol perturbations evolve with time. During this period of performance, we also plan to investigate and likely initiate new ERB sounding programs at Hilo, Hawaii (20°N), Réunion Island (20°S) and Ross Island, Antarctica (78°S) to provide more comprehensive latitudinal coverage of stratospheric composition measurements.

Project Description: In this third year of the B^{2}SAP project, we will continue to launch instrumented balloons twice per month from Boulder and quarterly from Lauder, New Zealand, to measure the vertical profiles of water vapor, ozone, and aerosol number and size distribution (140 nm-2.5 µm) from the surface to the middle stratosphere (~28 km). We also intend to begin quarterly soundings at Hilo, Hawaii (20°N), but this has so far been impeded by COVID-19 and, more recently, by a shortage of dry ice in Hawaii. ERB soundings at these three sites will continue to enhance GML's longstanding program (Hurst et al., 2011) of routine balloon launches to monitor stratospheric ozone and water vapor (Fig 1), as well as the ongoing program of coordinated launches for SAGE III/ISS validation at Boulder (Fig 2) and Lauder by CSL, GML and NIWA personnel. We have plans to collaborate with scientists on Réunion Island (20°S) to launch several ERB payloads this (boreal) spring/summer and hopefully begin an ongoing program. We will also continue to work with our NIWA partners to evaluate the feasibility of conducting B^{2}SAP sonde launches at Ross Island, Antarctica (78°S). For these efforts, we will supply sondes and launch supplies to our partners that operate these sites, and train personnel to conduct the soundings in the same way we do in Boulder. When these initial soundings are proven successful, we can likely add these sites to the existing B^{2}SAP network to provide more comprehensive latitudinal coverage of stratospheric composition measurements.

The in situ measurements collectively provided by the ERB soundings at Boulder, Lauder, Hilo, Réunion Island and Ross Island will produce a unique dataset documenting the background state of Earth's stratosphere over a wide range of latitudes. The data will also provide insight into variability of the aerosol size distribution that is difficult to infer from satellite observations. In the event that even more perturbations to stratospheric aerosol loading due to a volcanic eruption or intense wildfire pyrogenic injection are sampled, the measurements will help us to better understand how these natural events alter stratospheric composition, especially the number and size distribution of aerosols, and how these perturbations evolve with time. Additional soundings will be performed as much as possible to sample such events.

Methods: The balloon payloads launched for this project include a NOAA Frost Point Hygrometer (FPH; Hall et al., 2016), an Electrochemical Concentration Cell (ECC) ozonesonde (Sterling et al., 2018), and a Portable Optical Particle Spectrometer (POPS; Gao et al., 2016) that measure water vapor, ozone, and aerosol number and size distribution, respectively. Also included is a radiosonde that measures temperature, pressure, and balloon location (GPS) while telemetering all data to a ground-based receiving system. Balloons carrying this large ERB payload are currently launched twice every month from Boulder, Colorado and once per quarter from Lauder, New Zealand, through collaborative efforts with colleagues at NIWA.

Staff of NOAA's Mauna Loa Observatory (MLO) on the island of Hawaii have been launching weekly ozonesondes and monthly FPHs at Hilo international airport for many years to support GML's ozone and water vapor monitoring programs. Pending approval from authorities at the airport launch site, MLO staff will be trained to also include a POPS as part of the balloon payload every three months.

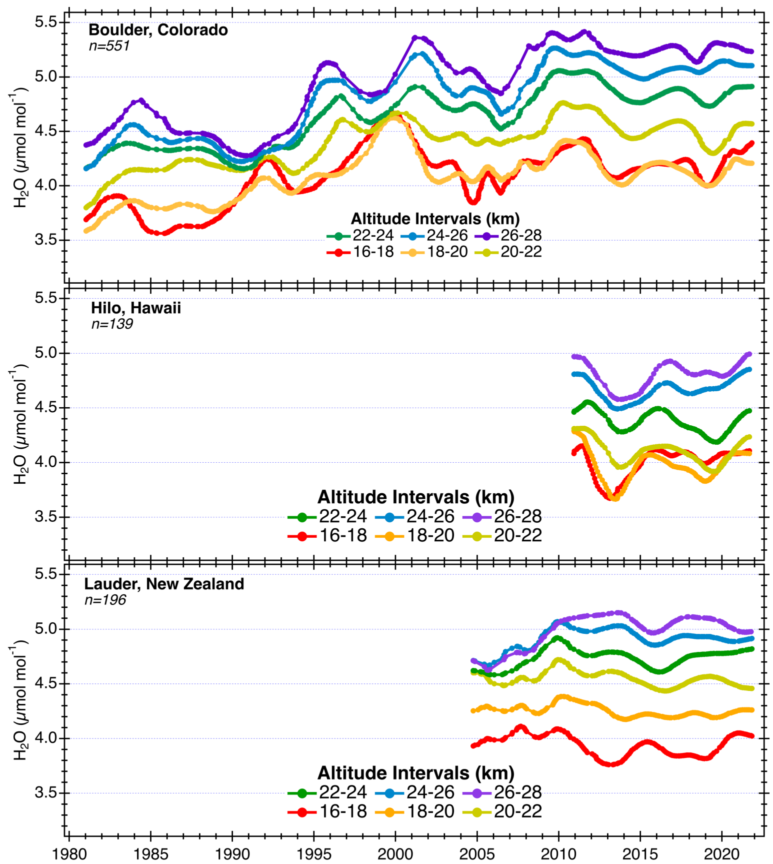

Figure 1. Stratospheric water vapor (SWV) records from NOAA FPH soundings at Boulder, Hilo and Lauder in six 2-km altitude layers. The 41-year FPH record at Boulder, now composed of 551 individual soundings, depicts a net increase in SWV since 1980. Inter-annual variability, largely driven by changes in dynamical phenomena like the QBO and ENSO, is evident at all three sites.

GML continues to make progress in the implementation of a new radiosonde, the iMet-54, that is capable of telemetering 300% more data to our receiving systems than the current radiosonde (iMet-1). COVID-19 has slowed progress on this activity that requires a deep collaboration with International Met Systems in South Africa. However, most of the iMet-54's data telemetry demodulation and signal decoding has already been incorporated into GML's flight reception and data processing software package "SkySonde". When completed, this upgrade will increase the telemetry bandwidth of POPS data and reduce the current requirement that every POPS data card be physical retrieved after each sounding to provide the desired aerosol size resolution and permit the requisite quality assurance procedures.

CSL personnel still plan to continue development of several additional instruments, such as a cirrus cloud measurement, a miniature ozone photometer, and balloon version of the Miniature Scanning Aerosol Sunphotometer (miniSASP).

Anticipated Outcomes: We will continue adding to the 19-month record of twice-monthly vertical profiles (to ~28 km) of stratospheric aerosol number and size distribution above Boulder that was begun in June 2020. Quarterly ERB soundings at Lauder will also continue, and it is anticipated that quarterly ERB soundings will begin at Hilo, Hawaii (20°N), during this proposal's period of performance. We also plan to supply two new sites, Réunion Island (20°S) and Ross Island (78°S), with all the requisite sondes, launch equipment and training to initiate trial programs of ERB balloon soundings.

Measurements of ozone and water vapor vertical profiles are important for interpreting the aerosol observations and serve to sustain and complement the existing long-term records of these measurements. Through this proposal we will be able to extend the climatological record of the "baseline" state of the stratosphere in the northern (Boulder) and southern (Lauder) mid-latitudes, and begin new records in the northern sub-tropics at Hilo (20°N), the southern sub-tropics at Réunion Island (20°S) and in the Antarctic at Ross Island (78°S). We will conduct analyses of the data to examine the variability of both the number and size distribution of "background" stratospheric aerosol over time and investigate perturbations to stratospheric aerosol loading from natural events like volcanic eruptions and wildfires.

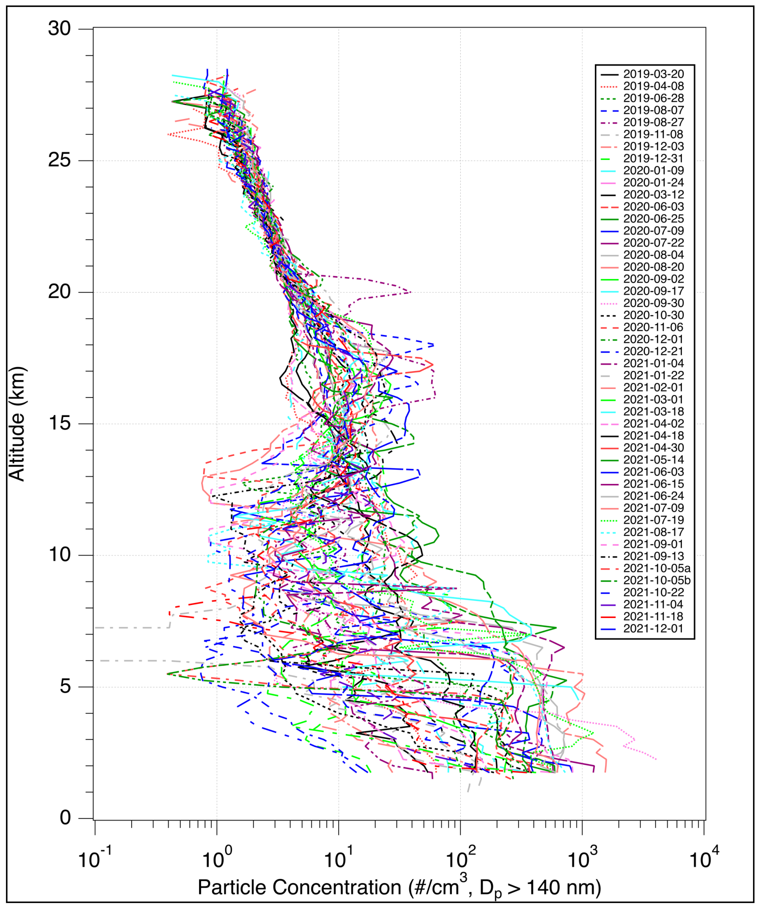

Figure 2. POPS aerosol concentration profiles over Boulder, CO (40°N) from March 2019 to December 2021.

Publications

Asher, E., et al. (*in prep*), Insights into the variability in stratospheric aerosol in SH midlatitudes using in situ observations (2019-2021).

Todt, M., et al (*in prep*), Baseline Balloon Stratospheric Aerosol Profiles (B^2SAP): Systematic stratospheric aerosol measurements working towards long-term datasets.

References

Gao, R.S., H. Telg, R.J. McLaughlin, S.J. Ciciora, L.A. Watts, M.S. Richardson, J.P. Schwarz, A.E. Perring, T.D. Thornberry, A.W. Rollins, M.Z. Markovic, T.S. Bates, J.E. Johnson, and D.W. Fahey (2016), A light-weight, high-sensitivity particle spectrometer for PM2.5 aerosol measurements, *Aerosol Sci. Tech*., *50*(1), 88-99, doi:10.1080/02786826.2015.1131809.

Hall, Emrys G., Allen F. Jordan, Dale F. Hurst, Samuel J. Oltmans, Holger Vömel, Benjamin Kühnreich and Volker Ebert, (2016), Advancements, measurement uncertainties, and recent comparisons of the NOAA frost point hygrometer, *Atmos. Meas. Tech.*, *9*, 9, 4295-4310, 10.5194/amt-9-4295-2016.

Hurst, D.F., S.J. Oltmans, H. Vömel, K.H. Rosenlof, S.M. Davis, E.A. Ray, E.G. Hall and A.F. Jordan, (2011), Stratospheric water vapor trends over Boulder, Colorado: Analysis of the 30 year Boulder record, *J. Geophys. Res.-Atmos.*, *116*, D02306, 1-12, doi:10.1029/2010JD015065.

Sterling, C.W., B.J. Johnson, S.J. Oltmans, H.G.J. Smit, A.F. Jordan, P.D. Cullis, E.G. Hall, A.M. Thompson, and J.C. Witte (2018), Homogenizing and estimating the uncertainty in NOAA's long-term vertical ozone profile records measured with the electrochemical concentration cell ozonesonde, *Atmos. Meas. Tech.*, *11*, 3661–3687, doi:10.5194/amt-11-3661-2018.