Status of NOAA HD-SP2 Science Deliverables from SEAC4RS

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Introduction

In SEAC4RS we flew a Humidified Dual Single Particle Soot Photometer (HD-SP2) on the NASA DC-8 research aircraft. This unique instrument consists of two Single Particle Soot Photometers (SP2s) operating in parallel from the dry aerosol feed from the Univeristy of Hawaii aerosol inlet. One of the SP2s was operated dry while the other was humidified to constant RH typically near 90%.

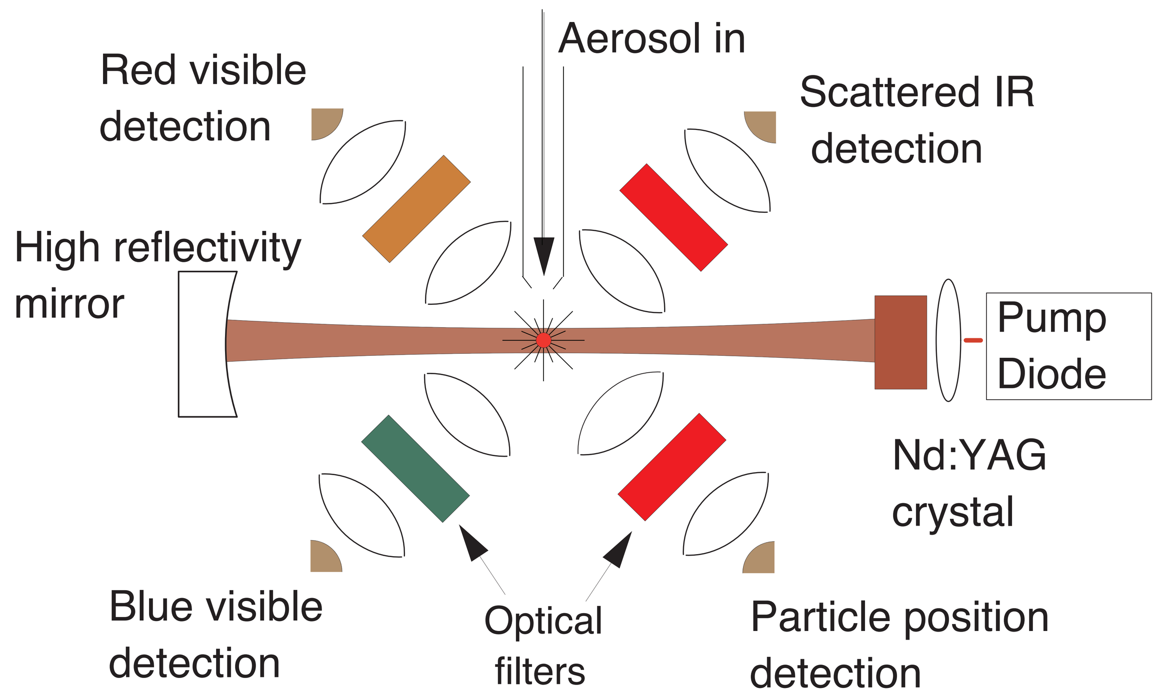
The dry SP2 provides, for individual particles in its detection range, the optical size, refractory black carbon (rBC) mass, and rBC mixing state of individual particles. These quantities are integrated in post-processing to provide rBC MMR and a Mie-theory based estimate of the amount of non-rBC material internally mixed with rBC. These outputs provide handles on many SEAC4RS science topics, some of which are presented here.

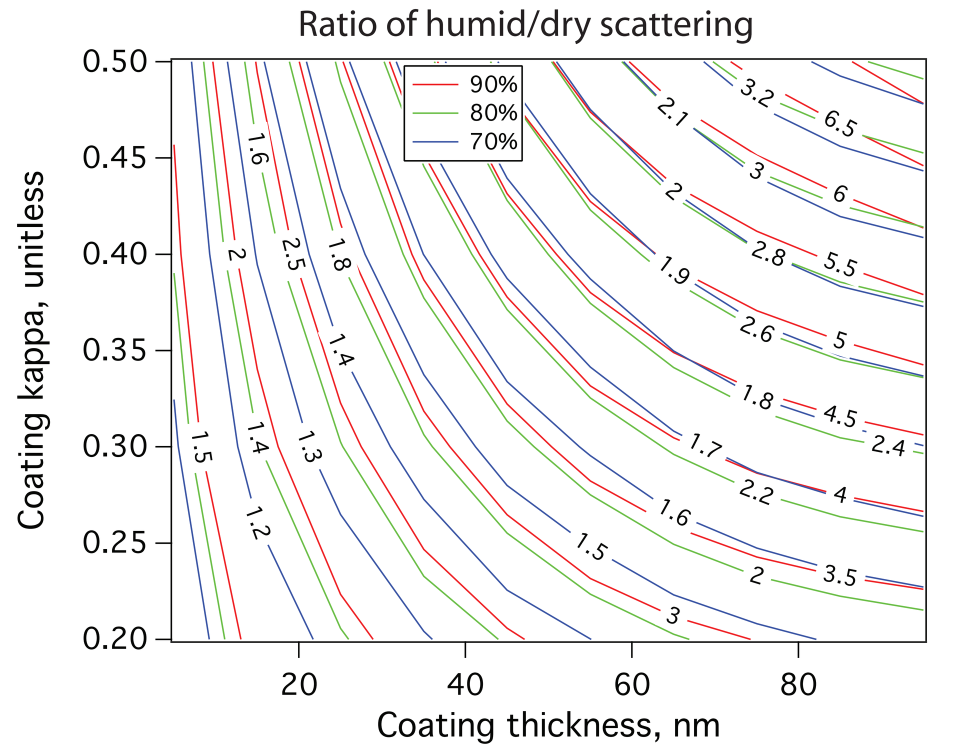
The wet instrument provides the same outputs for individual particles, but reflecting the uptake of water by the materials internally mixed with rBC. Hence, comparison of the optical size distributions associated with rBC between the wet and humidified samples constrains water uptake, with implications for BC aging, optical properties in the ambient, potential to act as CCN, lifetime, and thus radiative impact.

Overview of the science

We are focusing on BC vertical profiles to extend evaluation of AeroCom model performance to source regions. This analysis will include data from SEAC4RS, DC3 (from both the DC8 and DLR Falcon), and European missions including CONCERT (2011), ASCENT(2012), and SALTRACE (2013). Additionally, water uptake by BC-containing particles is explored for biomass burning emissions, with a focus on the Rim fire flights, as well as for more general airmasses sampled during the mission (e.g. marine boundary layer, continental background, urban airmasses...).

HD-SP2 rBC Measurement





Mie theory and kappa-Köhler theory provide an estimate of the ratio of scattering from BC-cores of a given mass with coatings of specified thickness and kappa (index of refraction of the coating is neglegible). The ratio is indicative of the relative impact of water uptake on BC scattering, and for more thickly coated BC, is strongly dependent on kappa.

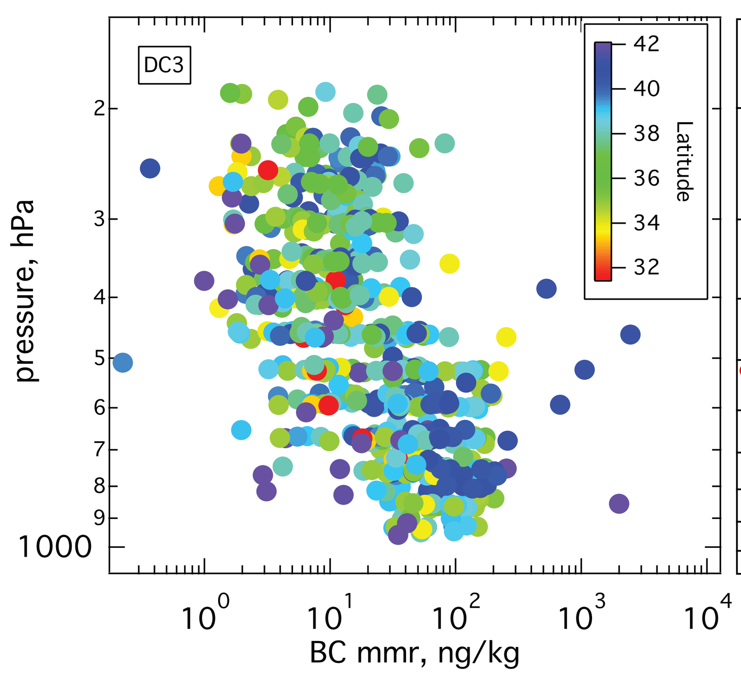
An gaussian intracavity laser (1 μm) heats rBC particles, first vaporizing internally mixed materials, and then heating rBC to its vaporization temperature. The visible light thermally emitted is proportional to its rBC mass. Light scattered from the laser can be analyzed for evidence of vaporization of internally mixed material and for the optical size of the whole, unperturbed particle.

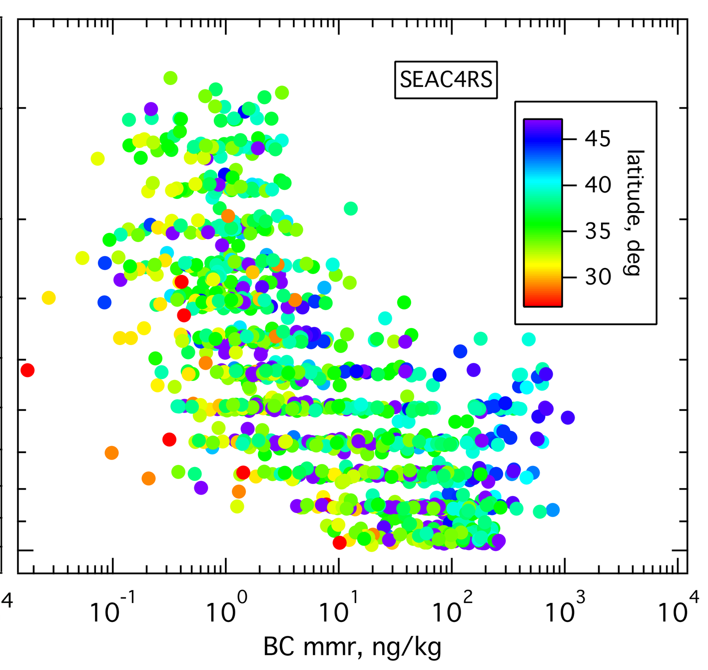
The two SP2s (humid and dry) were calibrated for laser intensity/scatter detector gain via independent calibrations, and via LARGE-group calibrations during flight. Additionally, we have explored the method using scattering off of bare rBC cores, just prior to incandescence, to cross-calibrate the two measurements of scattering.

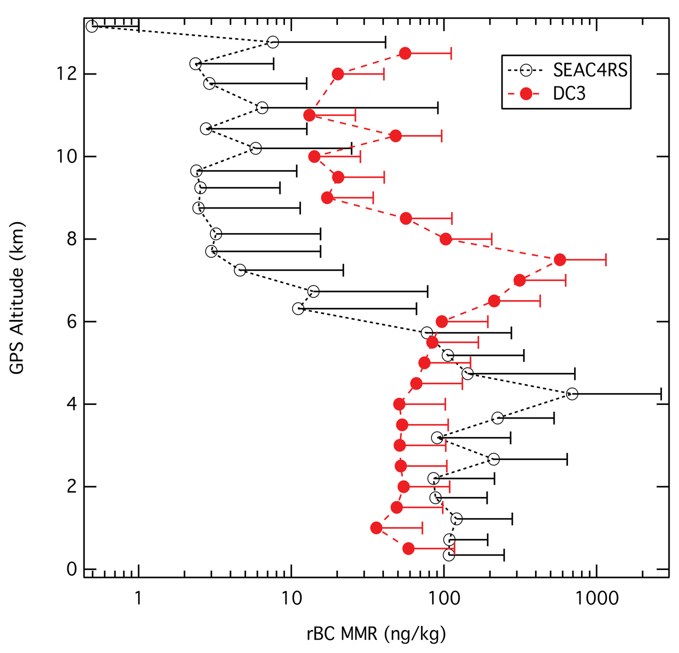
Bottom line

The HD-SP2 provides measures of light-scattering by dry and humidified aerosol. This basic quantification serves to constrain water uptake. For coatings thicker than ~40nm on a BC-core at the center of our detection range (of scattering) provide the hygroscopicity parameter of the non-BC material with an uncertainty on order 20%. These conclusions published in: Schwarz et al., J. Aerosol Science, 2015.

Vertical Profiles comparison to AeroCom





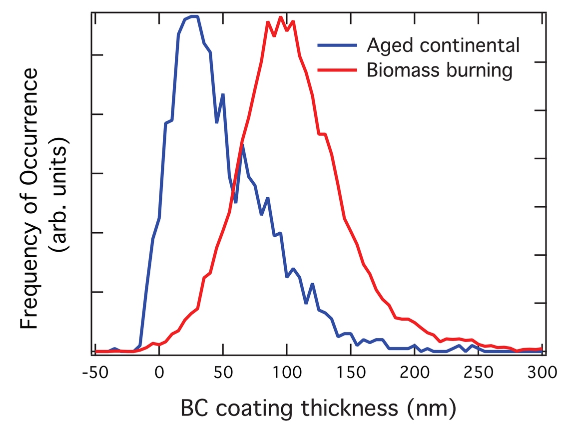


"Straight" averages of BC MMR from DC3 and SEAC4RS reveal overall trends in loadings

Here we show vertical profiles of BC MMR from SEAC4RS and DC3. Each data point represents the average BC MMR observed over 1 km in an individual ascent or descent of the DC8. Data from flat legs are not included in this analysis, which is aimed at using individual profiles as the basic unit of measurement. This approach allows us to easily generate estimates of variability in terms of vertical profiles and ultimately to fashion a strong comparision to models. There are substantial differences between the SEAC4RS and DC3 datasets, both in terms of BC MMRs (especially in the UT), and in terms of apparent latitudinal trends. Comparison to AeroCom should be completed in early Summer 2015.

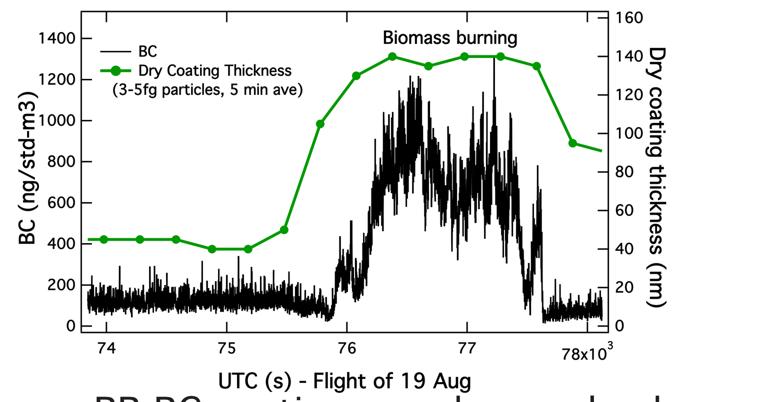
Water uptake by internally mixed material

Biomass Burning:

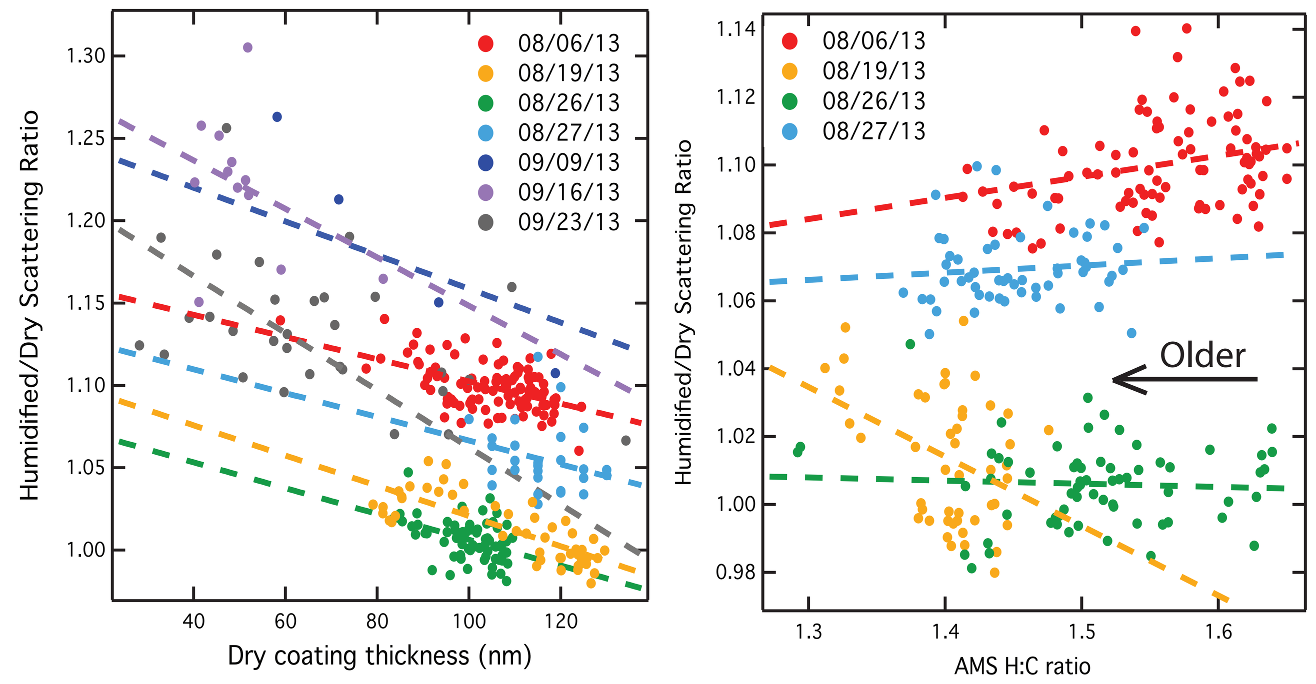


BB BC much more thickly coated than background BC

Coatings on BB BC observed in SEAC4RS are thick enough to dominate BC scattering properties: HD-SP2 can provide the hygroscopicity parameter to 20% (for high k).

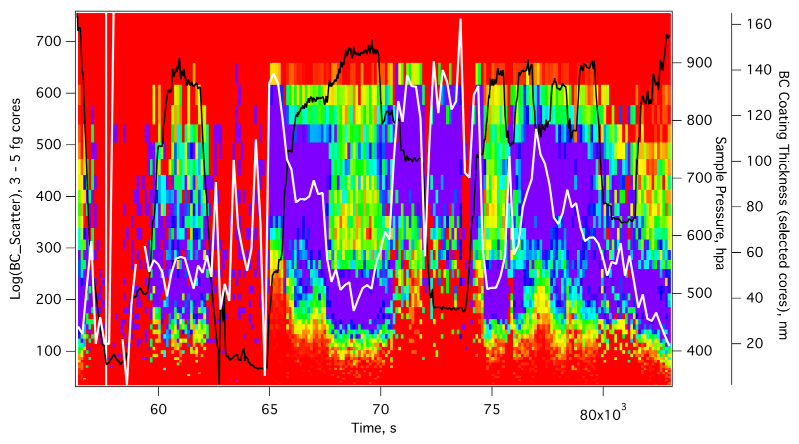


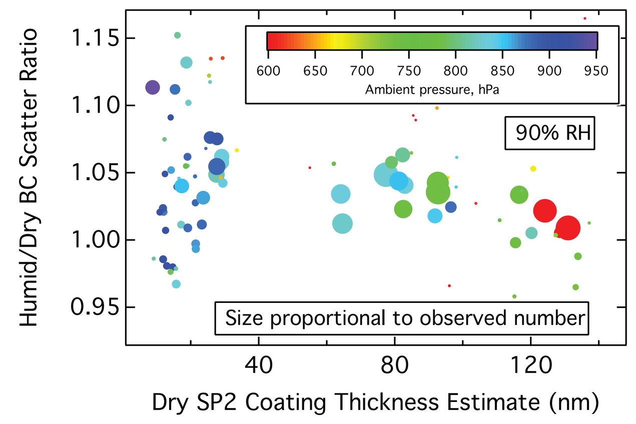
BB BC coatings can be resolved in time, and appear fairly consistent across a large BB plume



(Left) Correlations between wet/dry scattering ratio and coating thickness for biomass burning sampling during each flight and (right) correlations between wet/dry scattering ratio and the AMS H:C ratio indicate that the coatings do not take up substantial water, and aging does not strongly correlate to increasing affinity to water.

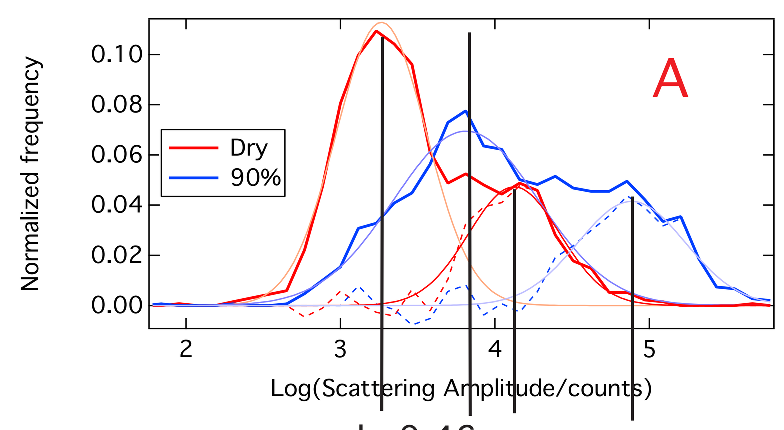
South-eastern airmasses

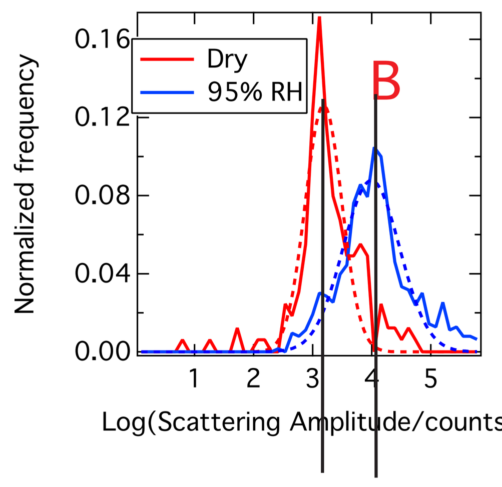




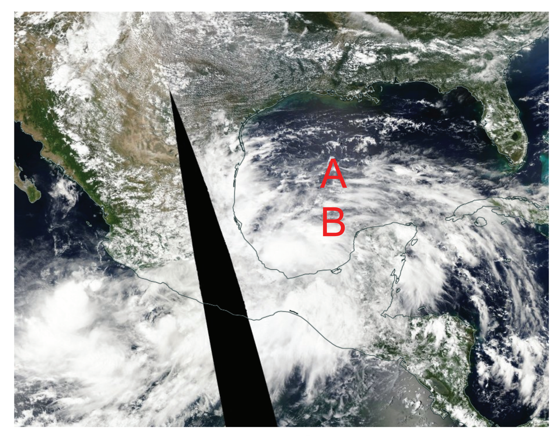
The result above is echoed at some level in the data taken in the South East during a chemistry/convection flight (RF04). Here, although wildly different airmasses were sampled, with very different coating thicknesses observed on BC, water uptake was minimal.

Marine Boundary Layer





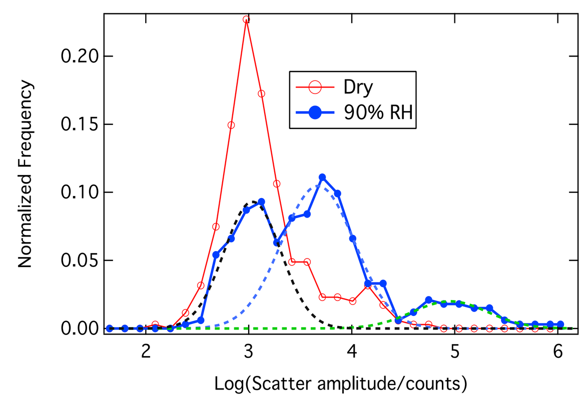
RF 17



Aqua Image

In RF 17 we sampled the Gulf boundary layer at points A and B in the Aqua image. The two airmasses sampled had different back-trajectory histories (B was influenced by the storm), but similar thin-coating water uptake. Could a more thickly coated marine BL mode been removed in the storm?

RF19:



In RF 19 we saw a 1wqathree-mode population of water uptake in the humid instrument. Are we resolving different coating materials or aging/coating accrecition times?

Acknowledgements

The HD-SP2 team thanks the pilots and crew of the DC8 for their support throughout the integration, mission, and disintegration phases of the experiment. Specific groups and individuals that played important roles in the successful deployment of the HD-SP2 (and eventual data analysis) include the DASH-SP team of Armin Sooroshian, Taylor Swift, and Ewan Crosbie; and the LARGE team including Bruce Anderson, Luke Ziemba, Andreas Beyersdorf, Lee Thornhill, and Rich Moore.