Boundary layer Exploration of Aerosols and Clouds ON Ships (BEACONS) Pilot Study

R. Krishnamurthy, M. Christensen, C. Sivaraman, A. Ryan, G. Kulkarni, J. Muelmenstaedt, J. Fast, L. Berg; T. Bates; H. Fernando; L. Russell; A. Macdonald, R. Hudak, K. Strom; D. Coffman, P. Quinn. | Pacific Northwest National Laboratory; Cooperative Institute for Climate, Ocean, and Ecosystem Studies; University of Notre Dame; University of California San Diego; Woods Hole Oceanographic Institution; National Oceanographic Atmospheric Administration – Pacific Environmental Marine Laboratory

ASR Atmospheric System Research

Motivation

Addressing observational gaps over Ocean to reduce future weather uncertainty

To demonstrate autonomous and unattended deployment of a shipborne system for making routine observations of fundamental atmospheric, cloud, and aerosol properties that can be used by the scientific community to address key questions relevant to aerosol-cloud interactions of interest to DOE.

Cloud and aerosol observations can be leveraged to directly reduce process uncertainty in future weather projections. To advance the science, a comprehensive body of research is required, including:

- Long-term records: Commercial ships traverse diverse, repeated routes, providing broad geographic and temporal coverage across different regions and conditions
- Opportunistic experiments: Quantify the impact of reduced shipping emission aerosols on cloud radiative properties to pre-SECA policy changes using MAGIC data.
- Improved synergy with other observing platforms: Cloud lifecycle evolution using shipborne observations and recent generations of geostationary satellite products.

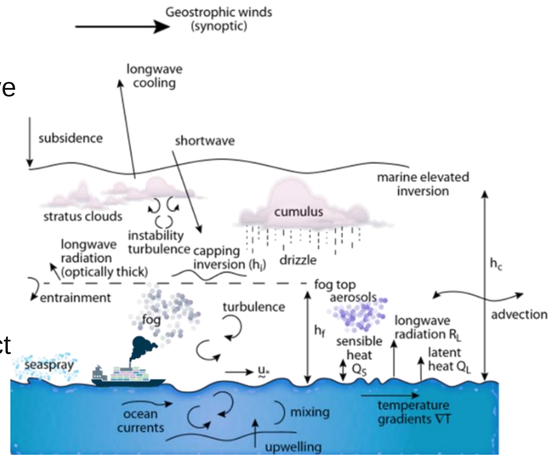


Fig 1: Physical processes of various clouds and aerosols identified using previous work (Koračin et al., 2014; Fernando et al., 2021).

Aerosol, Cloud, and Aerosol-Cloud Interaction Hypotheses

BEACONS plans to evaluate 5 testable hypotheses focusing on outstanding questions on:

- Marine aerosol sources, formation, and growth — Led by CICOES, with NOAA-PMEL
- Enhance understanding of cloud processes using Satellite and Ground based sensors — Led by PNNL, with NASA
- Marine aerosol size distribution — Led by UCSD
- The susceptibility of cloud brightness to aerosol properties — Led by UND
- Uncertainties in aerosol and cloud radiative effects — Led by PNNL, with NOAA

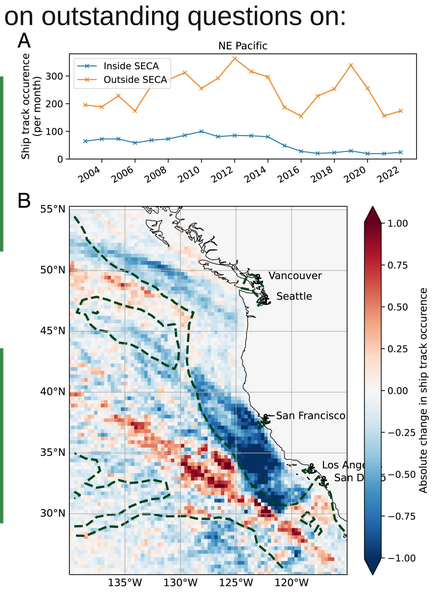


Fig 2: (A and B) Regional closeup of the difference due to Emission Control Area (ECA) regulations changes (2002 to 2014 minus 2015 to 2019) off the coast of California. A time series of the ship track frequency of occurrence inside and outside the ECA region is also shown (from Watson-Parris et al., 2022).

Autonomous and Modular Platform

Several unattended operation enhancements, including a) **automated sneeze system** for the Doppler lidar lenses, b) **weatherproof outer shells** for aerosol sampling platforms, c) remote power management, d) instrument collection alerts, e) **reduced/eliminated hazardous materials**, f) web data platform to provide **near-real time data** from all instruments to a public server, and more.

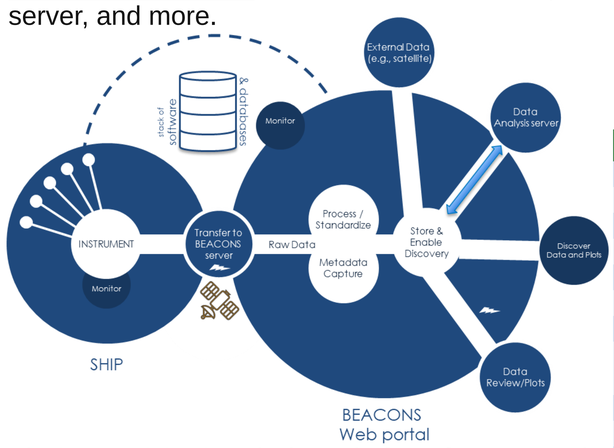


Fig 3: BEACONS web data platform for near real-time data transfer.

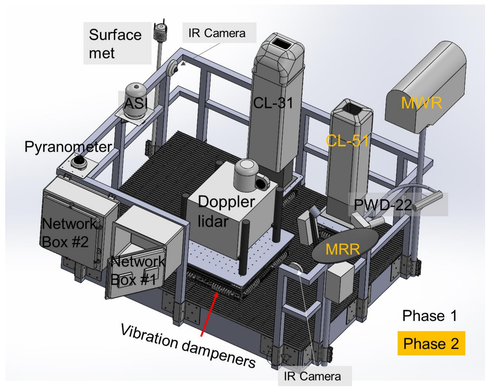


Fig 4: BEACONS marine cloud platform

Aerosol Instrumentation
1. Water-based CN Particle Counter (MAGIC250)
2. DMA using water-based CPC
3. Portable Optical Particle Spectrometer (Handix)
4. Aerodynamic Particle Sizer (TSI APS)
5. Nephelometer (Acoem Aurora 3000)
6. Absorption Photometer (Brechtel TAP)
7. CO monitor (Vaisala AQT560)
8. Thermodenuder (Brechtel Thermodenuder) and mobility size spectrometer using water-based CPC
9. AlphaSense OPC-N_3
10. Gondola Platform (Fog monitor)
11.Cloud Condensation Nuclei Counter (DMT CCN)
12.Mini Scanning Electrical Mobility Sizer (Brechtel)

Pilot Study – Commercial Ship (PASHA)

Deployment Phase 1 (FY26 Q2) – deploy key aerosol and cloud measurements

Deployment Phase 2 (FY26 Q4) – expand the deployment by integrating more complex instruments that require significant modifications for operation in marine conditions and increased automation to minimize crew intervention.

Instrument platforms will be located approximately **30.4 m** above sea level.

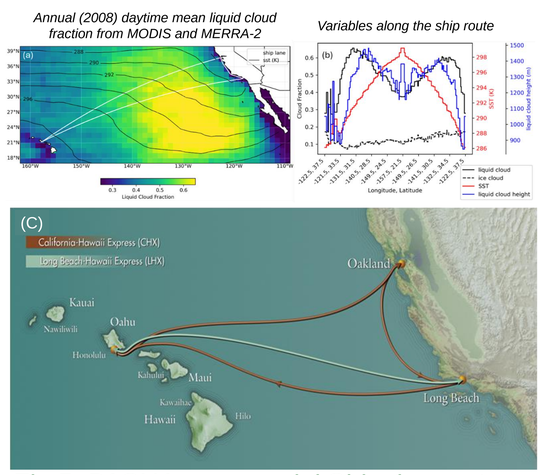


Fig 5: PASHA commercial Shipping route

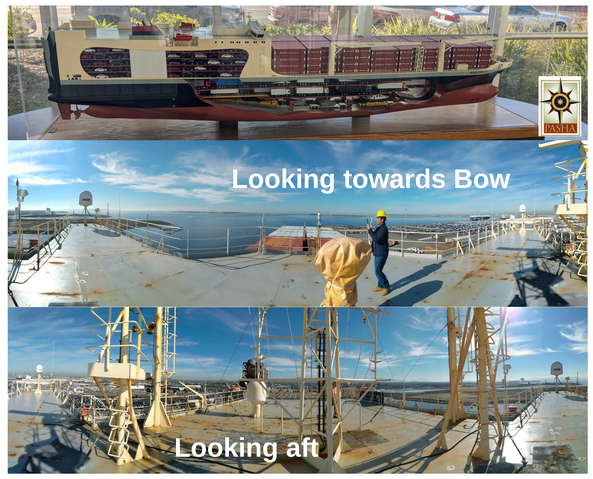


Fig 6: PASHA commercial Ship

Acknowledgments: *PNNL is operated for DOE by the Battelle Memorial Institute under Contract DE-AC05-76RLO1830.*

Contact Information: Raghu Krishnamurthy, raghu@pnnl.gov

Send all inquiries to beacons@pnnl.gov

Pacific Northwest National Laboratory · University of Notre Dame · UC San Diego · CICOES · Woods Hole Oceanographic Institution · Science RoCS Research on Commercial Ships · U.S. Department of Energy