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Authors

Clayson, Carol Anne
Centurioni, Luca
Cronin, Meghan F
et al.

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Super Sites for Advancing Understanding of the Oceanic and Atmospheric Boundary Layers

Carol Anne Clayson[1], Luca Centurioni[2], Meghan F. Cronin[3], James Edson[1], Sarah Gille[4], Frank Muller-Karger[5], Rhys Parfitt[6], Laura D. Riihimaki[7], Shawn R. Smith[8], Sebastiaan Swart[9], Douglas Vandemark[10], Ana Beatriz Villas Bôas[4], Christopher J. Zappa[11], Dongxiao Zhang[12]

Corresponding author email: cclayson@whoi.edu

[1]Woods Hole Oceanographic Institution; [2]Lagrangian Drifter Laboratory, Scripps Institution of Oceanography, University of California San Diego; [3]NOAA Pacific Marine Environmental Laboratory; [4]Scripps Institution of Oceanography, University of California San Diego; [5]University of South Florida; [6]Department of Earth, Ocean and Atmospheric Science, Florida State University; [7]CIRES: University of Colorado and NOAA GML; [8]Center for Ocean-Atmospheric Prediction Studies, Florida State University; [9]Department of Marine Sciences, University of Gothenburg; [10]University of New Hampshire; [11]Lamont-Doherty Earth Observatory of Columbia University, [12]CICOES/University of Washington and NOAA/Pacific Marine Environmental Laboratory

ABSTRACT

Air–sea interactions are critical to large-scale weather and climate predictions because of the ocean's ability to absorb excess atmospheric heat and carbon and regulate exchanges of momentum, water vapor, and other greenhouse gases. These exchanges are controlled by molecular, turbulent, and wave-driven processes in the atmospheric and oceanic boundary layers. Improved understanding and representation of these processes in models are key for increasing Earth system prediction skill, particularly for subseasonal to decadal time scales. Our understanding and ability to model these processes within this coupled system is presently inadequate due in large part to a lack of data: contemporaneous long-term observations from the top of the marine atmospheric boundary layer (MABL) to the base of the oceanic mixing layer.

We propose the concept of "Super Sites" to provide multi-year suites of measurements at specific locations to simultaneously characterize physical and biogeochemical processes within the coupled boundary layers at high spatial and temporal resolution. Measurements will be made from floating platforms, buoys, towers, and autonomous vehicles, utilizing both in-situ and remote sensors. The engineering challenges and level of coordination, integration, and interoperability required to develop these coupled ocean–atmosphere Super Sites place them in an "Ocean Shot" class.

Vision and Potential Transformative Impact

Super Sites will provide the long-term suites of state-of-the-art measurements that are critically needed to fully characterize coupled ocean–atmosphere boundary layer variability in different regimes of the climate system. This new measurement capability will provide the necessary data to allow us to improve and validate high-resolution atmosphere–ocean coupled models and satellite-based products; improve key process parameterizations for coarser-resolution models; and serve as a testbed for new and developing in-situ and remote sensors.

Testing and improving high-resolution models (which are essential for improving coarse-resolution climate simulations) requires statistically robust data samples over extended periods of time, which are not obtainable with typical short-term campaigns. Further, modeling needs require measurements that are often difficult to make due to specific platform, energy, and sensor needs. However, anchored and floating platforms are being developed that can support towers that span the boundary layers even over the open ocean. Moreover, these platforms will provide power to support newly-developed remote sensors and autonomous vehicles in the ocean and atmosphere to allow better 3D characterization of the coupled boundary layers.

Beyond sustained "core" observations, the Super Sites platforms will enable testing and validation of new technologies, serving as a catalyst for new scientific and engineering development.

Realizable, With Connections to Existing U.S. Scientific Infrastructure, Technology Development, and Public–Private Partnerships

The U.S. oceanographic community has experience with some aspects of this type of sustained observational capability. Particularly, the United States has important contributions through experiences including the NSF-funded Ocean Observatories Initiative (OOI), which has made strides towards a combined, sustained mooring/glider program that samples the ocean and air–sea fluxes. The ONR-funded CBLAST program built a long-term Air–Sea Interaction Tower (ASIT) that continues to provide key coupled boundary layer observations after more than a decade. U.S. research vessels have provided platforms for many of the usable remote sensors. NASA/NOAA satellites measure key components of the air–sea interface, and a satellite designed specifically for the ABL is in incubation phase. The DOE has deep investment in wind energy technology, with a developing focus on offshore installations. The offshore wind industry is a clear example of a possible public–private partnership, with expertise in developing large platforms and delivering energy, as well as a vested interest in marine conditions and forecasts.

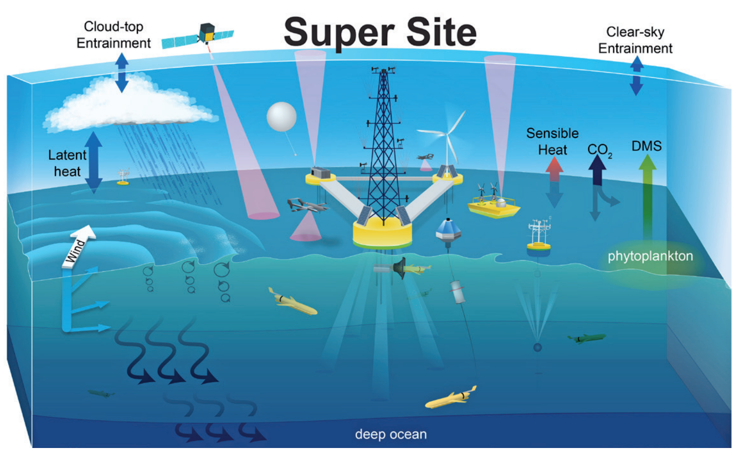

FIGURE 1. A schematic of possible types of deployments and instruments for a Super Site, including both passive and active atmospheric sensors, ocean gliders, atmospheric UAVs, multiple buoys, a central tower, wind- and solar-energy generating capabilities, and self-docking and charging AUV stations for multiple gliders.

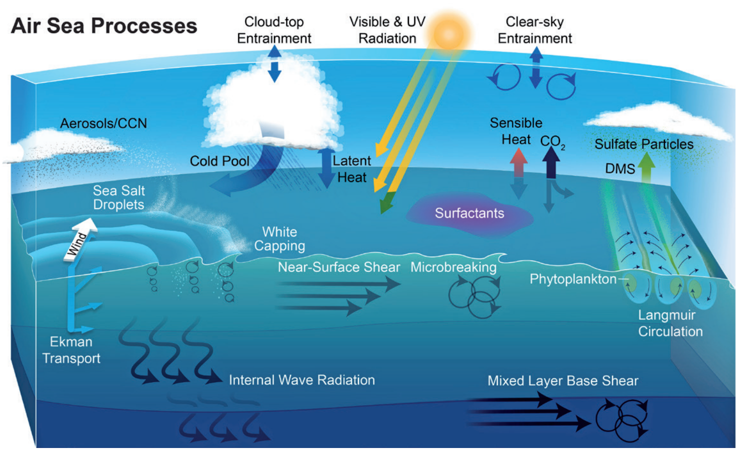

FIGURE 2. Schematic of key processes in the coupled ocean–atmosphere boundary layer system.

Scientific/Technological Sectors Engaged Outside of Traditional Ocean Sciences

The atmosphere–ocean coupled modeling community will be a key partner in the development and design of these Super Sites. In addition, atmospheric chemists, boundary layer meteorologists, cloud and radiation physicists, and remote sensing experts will be involved in their design and use. Creative engineering will be needed to envision and build all-new types of observing platforms with expanded power generation, data communications, and asset deployment capabilities. The telecommunications and informatics industries will be needed for expertise with the resulting big data. Industries associated with the development of autonomous platforms, drones, and sensors will also be key to Super Site success.

Opportunities for International Participation and Collaboration

Super Sites have been recommended by national and international groups, including the World Climate Research Program-Data Advisory Panel (WCRP-WDAC) surface flux team, OceanObs19 Community Strategy Papers, the Tropical Pacific Observing System (TPOS) Second Report, and the Observing Air–Sea Interactions Strategy (OASIS) SCOR Working Group. Super Site installations will be placed in carefully selected locations throughout the global oceans for several years and then relocated. Such a significant undertaking will require the expertise of the international community, working in partnership with local scientists, particularly for development and maintenance of the Super Sites, as well as any legacy observations.

Develops Global Capacity and Encourages the Development of the Next Generation of Ocean Scientists, Engineers and Technologists

A key program aspect will be to engage and enhance the scientific and technical expertise of the scientific communities in the relevant local country(ies), as well as provide more general public educational opportunities. As a testbed for new platforms and sensors, some capacity will be reserved for both early career scientists and local scientists to propose and develop novel capabilities. The science defining exchanges between the upper ocean and the atmospheric boundary layer is a leading-order challenge. Super Sites will provide the scientific opportunities needed to train the next generation of ocean and atmospheric scientists to tackle these problems.

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