Title: Enhancing ocean monitoring and prediction with daily global altimetry and scatterometry

1. Abstract

Satellite altimetry has revolutionized physical oceanography by providing regular maps of sea surface height (SSH) on a quasi-global scale. These SSH maps have allowed the community to examine a wide variety of oceanic phenomena, including global and regional sea level change, barotropic (surface) tides, internal (baroclinic) tides, the large-scale oceanic circulation and its associated mesoscale eddy field, El Niño, and others. However, the current generation of altimeters have repeat times of order 10-30 days, limiting quasi-global ocean coverage to those time scales. We propose to deploy an array of unified Cubesat altimeter/scatterometers to provide high-resolution, high-precision global SSH coverage and other information daily. The Cubesats are based on the "COAST" (Cellular Ocean Altimetry/Scatterometry Technology) concept in development under the National Oceanographic Partnership Program (NOPP). The higher frequency of COAST SSH measurements, which will offer Jason-class precision, will yield substantial improvements in ocean estimation and prediction systems, which ingest SSH data and have a host of applications, including search-and-rescue, oil spill prediction, and coupled ocean/atmosphere effects in weather and climate prediction, among others. In addition, a COAST constellation will provide coincident high-resolution scatterometry measurements of ocean vector winds, sea state and other surface properties.

2. Addressing Challenges

COAST altimetry addresses Challenge 5, the improvement of predictions for the oceans, climate, and weather. Daily, global high-resolution SSH maps will enable far better tracking of oceanic mesoscale eddies, which, according to a growing body of literature, impact the atmosphere on "weather" time scales (of order 10 days), through their sea surface temperature signals. More frequent measurements of precise SSH and ocean surface winds addresses Challenge 7, to "Ensure a sustainable ocean observing system…that delivers accessible, timely, and actionable data and information to all users." Finally, COAST addresses Challenge 8, development of "…a dynamic ocean map…in a manner relevant to diverse stakeholders." The broad success of operational SSH products, such as AVISO, proves that global SSH maps are highly relevant to many stakeholders. A COAST array providing global daily SSH maps at high resolution will take this a major step forward.

3. Authors – alphabetically

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4. Challenges

Need to pick no more than 3 from the list below. I have written "Addressing challenges" with an eye towards Challenges 5, 7, and 8

- Challenge 1: Understand and map land and sea-based sources of pollutants and contaminants and their potential impacts on human health and ocean ecosystems, and develop solutions to remove or mitigate them.
- Challenge 2: Understand the effects of multiple stressors on ocean ecosystems, and develop solutions to monitor, protect, manage and restore ecosystems and their biodiversity under changing environmental, social and climate conditions.
- Challenge 3: Generate knowledge, support innovation, and develop solutions to optimize the role of the ocean in sustainably feeding the world's population under changing environmental, social and climate conditions.
- Challenge 4: Generate knowledge, support innovation, and develop solutions for equitable and sustainable development of the ocean economy under changing environmental, social and climate conditions.
- Challenge 5: Enhance understanding of the ocean-climate nexus and generate knowledge and solutions to mitigate, adapt and build resilience to the effects of climate change across all geographies and at all scales, and to improve services including predictions for the ocean, climate and weather.
- Challenge 6: Enhance multi-hazard early warning services for all geophysical, ecological, biological, weather, climate and anthropogenic related ocean and coastal hazards, and mainstream community preparedness and resilience.
- Challenge 7: Ensure a sustainable ocean observing system across all ocean basins that delivers accessible, timely, and actionable data and information to all users.
- Challenge 8: Through multi-stakeholder collaboration, develop a comprehensive digital representation of the ocean, including a dynamic ocean map, which provides free and open access for exploring, discovering, and visualizing past, current, and future ocean conditions in a manner relevant to diverse stakeholders.
- Challenge 9: Ensure comprehensive capacity development and equitable access to data, information, knowledge and technology across all aspects of ocean science and for all stakeholders.
- Challenge 10: Ensure that the multiple values and services of the ocean for human wellbeing, culture, and sustainable development are widely understood, and identify and overcome barriers to behavior change required for a step change in humanity's relationship with the ocean.

5. Develops Global Capacity

The COAST Cubesat array will provide a daily quasi-global dataset of SSH and surface vector winds with unprecedented density and resolution, made available in near-real time to students, scientists, and decision makers worldwide. This will represent a dramatic leap forward in global ocean data capacity, enabling interested parties from citizen scientists and students to senior professionals and responsible government and commercial decision makers to address global environmental problems, advance their fields, and improve forecast skill. These rich, freely available new datasets will lower barriers to scientists in under-resourced countries and students and young ocean scientists beginning their careers.

6. International Participation

The proposal team works routinely with partners and collaborators in Europe, the Americas, and Asia/Oceania. The immediate instrument and Cubesat design and development work will involve students, suppliers, and technical professionals from all of these regions. Such collaborations are already in place. The resulting data will be available to users at all levels around the world and will be promoted at international scientific workshops and conferences. This will foster an enriching exchange of ideas and will spark international research collaborations that will accelerate advances in understanding, forecasting skill and ocean science generally.

7. Realizability

The COAST spacecraft and instrument have been in development under NOPP sponsorship for three years and are nearly ready to build. An instrument PDR and partial spacecraft PDR were held in 2021 and additional design details are now being completed. All required radar link analyses and related instrument performance studies are complete. Key antenna test hardware is now being built at the University of Colorado (CU). A functioning ALT/SCAT processor performing all proposed COAST radar functions and residing in a palm-size system-on-a-chip will be ready in Summer 2022, developed by JPL and GeoOptics initially for processing GPS ocean reflection (bistatic radar) data. The instrument and spacecraft designs draw on a rich technical heritage from GeoOptics, CU, and JPL and require no new technical advances. Most instrument and spacecraft components have already been selected. A full critical design review could be held 6-9 months after project start.

8. Scientific / Technological Sectors

A project of this kind is by nature multidisciplinary, involving a wide range of engineering and scientific skills. Requirements flow from scientists to a diverse instrument and spacecraft engineering team to deliver a novel product back to the science and applications communities. The COAST team brings together a major NASA research center, four universities, small and medium space technology companies (GeoOptics and partners BlueCubed, Stellar Exploration, Tyvak), and a diverse group of scientists, all partnering with multiple public agencies. It thus offers an assortment of “connections to existing U.S. scientific infrastructure, technology development, and public-private partnerships.”

9. Summary

We propose to place an array of Cubesat altimeter/scatterometers into low Earth orbit to provide daily high-precision, high-resolution maps of sea surface height (SSH) and ocean vector winds. Centimeter precision daily SSH data will dramatically improve global SSH maps, with far less interpolation in space and time. Precise daily SSH and ocean wind maps will greatly improve operational ocean models used in many critical applications, including oil spill prediction, search-and-rescue missions, and elucidating the effects of oceanic mesoscale eddies on the atmosphere over both short ("weather") and long ("climate") timescales.

10. Vision and Transformative Impact

The proposed COAST Ocean Shot will place an array of unified Cubesat altimeter/scatterometers into low Earth orbit, sufficient to provide daily global high-resolution maps of SSH and ocean vector winds. These daily SSH maps would represent a step change in the amount of information available for ingestion into advanced ocean models. Oceanic eddies have decorrelation times on the order of 30 days, meaning they change substantially over the ten-day repeat cycles typical of today's operational nadir altimeters. These maps will reveal the daily behavior of eddies in far greater detail than now possible. Higher-frequency internal tides and submesoscale processes and fronts would also be better mapped. While daily maps cannot fully capture such motions, their frequency and spatial coverage will yield far better information than the 10-day measurements we have today. Daily SSH maps would greatly reduce the analysis increments needed in operational ocean models, and therefore reduce the production of spurious internal waves generated by such increments. The combination of daily SSH and surface wind maps will greatly improve operational ocean models and thus enhance the utility of these models for oil spill predictions, search-and-rescue missions, weather forecasting, ocean state estimation, and many other applications.