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Topic: Critical drivers for ocean salinity science and applications and the future need for high-resolution technologies

Title: A Promising Avenue for High-Resolution Remote Sensing of SSS From Space

Abstract: SMOS and SMAP continue to provide excellent SSS observation products at a 50-100 km resolution with weekly revisit. The continuity of SSS measurements is planned through the ESA Copernicus CIMR mission. CryoRad (a candidate for ESA Earth Explorer 12) is currently competing to pilot sensitive SSS measurements with wide bandwidth receivers over a narrow swath which could contribute measurements in the polar regions. However, there is no agency-backed, explicit path forward for significantly improved products in either revisit or spatial resolution. Observations at higher spatial resolution would be of particular interest for coastal applications (e.g. ocean-land hydrologic exchanges, aquaculture) and to study sub-mesoscale ocean energetics (Vinogradova et al. 2019).

L-band microwave radiometry is the preferred tool for SSS sensing; radar observations (even at P band) have surprisingly poor sensitivity to SSS variability, and SSS inference from ocean color observations require strong assumptions and achieve limited accuracy. Since radiometers are diffraction-limited, achieving mesoscale spatial resolution requires extremely large apertures (~20m or more. This is a significant increase over the large apertures flying today (6 m for SMAP, 8 m for SMOS). Furthermore, the increase in spatial resolution must be paired with an increase in sensor sensitivity since many ocean processes follow an inverse power law spectral dependence (e.g. signals decrease at smaller scales). And, because sub-mesoscale and coastal ocean processes evolve fast (~1 day), this sensitivity must be achieved in a single pass. Averaging of high-resolution observations over a week (as is currently done) would also average over rapidly variable small-scale dynamics; we would achieve higher spatial resolution, but we would not significantly advance our understanding of ocean processes. A 10 kilometer spatial resolution SSS target serves as a reasonable trade between science/operational desires and the challenges of maturing the associated technologies. In pursuing simultaneous high sensitivity and high resolution, uncertainty in ocean roughness and temperature becomes as significant as instrumentation uncertainties in the achievable SSS precision; ocean wind speed and temperature must be measured contemporaneously. An ideal observing system would simultaneously observe SSS, SST, and vector winds.

Synthetic aperture radiometry (like SMOS) is currently favored for observing at 10 km resolution; swath formation with a real aperture system would require a large antenna to be spun at high speeds. Synthetic aperture systems can be deployed cost-effectively in space, similar to large solar arrays, to dimensions of > 20m. Single pass dwell-averaged 0.2 psu sensitivity at 10 km resolution requires an array of order 20 m diameter. However, the same array design used in SMOS will not achieve an integrated 0.1 K brightness temperature sensitivity. We will discuss a path forward for accomplishing this measurement using a hybrid beamforming/interferometry approach. This technique has the benefit of both focusing the receiving area within the target swath while simultaneously reducing system power consumption compared to either beamforming or interferometry on their own. We will present progress on instrument design trades, technology development, observing simulations, and discuss their implications for a future high-resolution, high-sensitivity SSS observing system. We will discuss the pathways to a future mission and potential partnerships.

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