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Satellite Mission Monitors Ocean Surface Salinity

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Understanding the links between ocean circulation, the global water cycle, and climate variations requires knowledge of ocean surface salinity. NASA's Aquarius satellite mission (http://aquarius.nasa.gov), which monitors the global open ocean surface salinity field, embarked on its science operations phase after completing the in-orbit performance assessment on 1 December 2011. The data (Figure 1) are already showing new and interesting information.

Aquarius is the prime sensor on the joint United States and Argentina Aquarius/Satélite de Aplicaciones Científicas (SAC-D) observatory, launched on 10 June 2011. The salinity measurements are obtained from the Aquarius microwave sensor developed by NASA. The Argentine space agency Comisión Nacional de Actividades Espaciales (CONAE; http://www.conae.gov.ar/eng/) developed the SAC-D spacecraft, which carries Aquarius and other scientific sensors developed by Argentina, Italy, France, and Canada. The Aquarius instrument has provided continuous data since becoming fully functional on 25 August 2011.

Within its first year of operations, Aquarius will yield a new mean global salinity map at higher spatial resolution than existing conventional data provide and will resolve a complete annual cycle and its connection to the annual cycle of rainfall and surface currents. Subsequent data will yield new information on El Niño and other interannual climate variations and improve scientists' knowledge of the marine freshwater budget. The ocean-atmosphere freshwater exchange, accounting for about 85% of global evaporation and 78% of global precipitation, dominates the global water cycle, governs the surface salinity distribution, and influences the density-driven ocean circulation. Aquarius salinity data will contribute to improved global coupled climate models and climate prediction.

In addition, Aquarius microwave data are gathered continuously around the globe, including land and ice-covered areas, and are also available to study soil moisture and changing cryosphere properties. Salinity data from Aquarius and the European Space Agency's previously launched Soil Moisture Ocean Salinity mission (http://www.esa.int/smos) represent a fundamentally new ocean remote sensing capability.

Salinity remote sensing is accomplished by measuring the ocean's surface microwave emission at 1.413 gigahertz (in the L band). This is modulated by the electrical conductivity of seawater, which in turn varies with salinity. The surface seawater optical depth is about 1 centimeter. Aquarius also measures radar backscatter at 1.26 gigahertz to mitigate the emissivity variations due to surface roughness. Aquarius has three separate sensors viewing at about 29, 38, and 46 degrees from nadir, with 90-, 130-, and 150-kilometer surface footprint sizes, respectively. Global coverage is obtained every 7 days. The mission's sampling resolution, expected accuracy, and other details are provided by *Lagerloef et al.* [2008].

Figure 1a shows mean composite global images of Aquarius salinity measurements averaged from the initial 4 months of data,

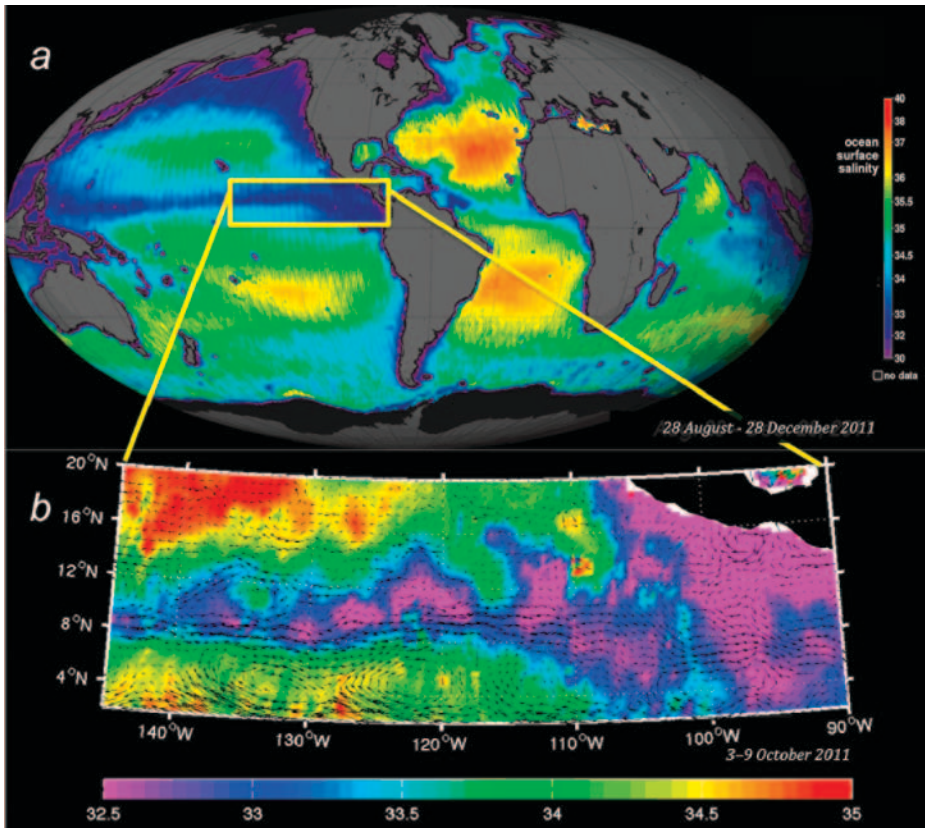

Fig. 1. (a) Mean global image for the first 4 months of Aquarius satellite sea surface salinity measurements. Measurements are on the Practical Salinity Scale-1978 (approximately parts per thousand by mass), where the open ocean range is about 32–37. The image is composited on a mean value for each point in a 2048-by-1024 lattice equal area Mollweide projection to improve the display quality. (Image by Norman Kuring, NASA Goddard Space Flight Center.) The north-south striped patterns are artifacts of small residual calibration errors. Values adjacent to coastlines, islands, and ice edges are biased low by the land-ice proximity. (b) A close-up 7-day snapshot of the eastern Pacific low-salinity zone showing small-scale salinity structure related to surface current meanders and eddies (satellite-derived surface currents from www.oscar.noaa.gov; image by H. Kao, Earth and Space Research).

28 August to 28 December 2011 [*Lagerloef et al.,* 2012]. Retrieving such good quality data this early in the mission is a notable achievement, given the many technical challenges. The global map clearly shows the predominant and well-known climatological ocean salinity features, such as higher salinity in the subtropics; higher average salinity in the Atlantic Ocean compared to the Pacific and Indian oceans; and lower salinity in rainy belts near the equator, in the northernmost Pacific Ocean, and elsewhere. These features are related to large-scale patterns of rainfall and evaporation over the ocean, river outflow, and ocean circulation. The values depicted in the Southern Ocean retain significant uncertainties associated with high winds and low surface temperatures that complicate the retrieval processing.

Other important regional features are clearly evident, including a contrast between the arid, high-salinity Arabian Sea west of the Indian subcontinent and the low-salinity Bay of Bengal to the east, which is dominated by the Ganges River and southern Asia monsoon rains. The data also reveal important smaller details, such as prominent low-salinity water associated with outflow from the Amazon and Orinoco rivers. Aquarius will monitor how these various larger- and smaller-scale features change over time and provide data to study their link to climate and weather variations.

Aquarius also reveals considerable surface salinity variation at much smaller scales than expected. Figure 1b provides an example close-up 7-day composite of a small region in the eastern subtropical North Pacific overlaid with surface current vectors [*Dohan and Maximenko,* 2010]. This lower salinity region coincides with the zonal heavy precipitation band in the Intertropical Convergence Zone. The current vectors reveal meandering and eddy features associated with the salinity patterns. Such detail of surface dynamical structure is not resolved with the conventional salinity observations, emphasizing the new capabilities now available for studying the ocean and new discoveries that are in store.

Algorithm updates and data reprocessing will be frequent and unscheduled during the first year. Evaluation data are publicly available at http://podaac.jpl.nasa.gov/SeaSurfaceSalinity/Aquarius. Registration is required, and users must recognize that the data are preliminary and are neither fully validated nor officially released for scientific purposes. Comments on problems and issues with the data are welcome. Validated data are to be released in late 2012, and new findings are expected in the months and years to come.

Acknowledgments

The Aquarius/SAC-D success is a tribute to the extraordinary talent, dedication, and hard work of the many scientists, managers, engineers, and technicians in the United States, Argentina, Brazil, Italy, France, and Canada whose individual contributions made this mission possible.

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