J1.7 EDUCATION & PUBLIC OUTREACH FOR THE NASA *AQUARIUS* MISSION

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Abstract -- *Aquarius* is a satellite mission being developed to measure global sea surface salinity (SSS). Scheduled to launch in 2008, it will provide the first global maps of SSS with unprecedented accuracy, resolution and coverage. Salinity measurements are key to understanding coastal ocean processes; because of its dynamic range in the coastal ocean, salinity is a critical factor in understanding and predicting biological and physical processes and their interactions with the food web, climate, and global water cycle. Salinity data acquired by coastal systems will complement *Aquarius's* open ocean measurements. Together, these pioneering efforts to deliver the "missing pieces of the climate puzzle" will undoubtedly intrigue broad audiences. Moreover, climate and its influence on humankind is an integral part of K-16 formal education and common to national learning standards.

INTRODUCTION

Seafarers through history have discovered that sea surface salinity (SSS) varies from place-to-place: SSS in the open ocean generally ranges between 32 and 37 (practical salinity units), but may be much lower near fresh water sources or as high as 42 in the Red Sea. Between 300 and 600 AD, awareness of changes in salinity, temperature, and smell helped Polynesians explore the southern Pacific Ocean. In the 1870s, scientists aboard H.M.S. Challenger systematically measured salinity, temperature, and water density in the world's oceans.

Understanding why the sea is salty begins with knowing how water cycles among its physical states: liquid, vapor, and ice. As a liquid, water dissolves rocks and sediments, and reacts with emissions from volcanoes and hydrothermal vents: this creates a complex solution of mineral salts in our ocean basins. In other parts of the cycle, however, water and salt are incompatible: water vapor and ice are essentially salt free. Through Earth's history, certain processes – including weathering of rocks, evaporation of ocean water, formation of sea ice – have served to make the ocean salty. These "salinity raising" factors are continually counterbalanced by processes that decrease salinity such as the continuous input of fresh water from rivers, precipitation of rain and snow, and melting of ice (Fig. 1).

Like on continents, some ocean regions are "rainy" whereas others are arid and "desert-like." In general, latitude zones dominated by precipitation have low SSS and those dominated by high evaporation have high SSS:

- Lowest SSS occurs in temperate latitudes (40 - 50° North and South), near coasts and in equatorial regions.
- Highest SSS occurs at about 25 - 30° North and South latitude, at ocean centers and in enclosed seas.

It is interesting to note, however, that SSS has been sparsely measured over the global oceans, limited mostly to summertime observations in shipping lanes. Based 1° latitude by 1° longitude squares, about 24% of Earth's ice-free oceans have never been sampled for SSS.

The cycling of water and energy through the atmosphere and oceans is crucial to life on Earth. Yet the ties among the water cycle, ocean circulation, and climate are poorly understood. Coupled with *in situ* coastal measurements (e.g., Integrated Ocean Observing System now under development), global measurement of sea SSS over time will provide a way to resolve key relationships. By tracking SSS we can directly monitor variations in the water cycle: land runoff, sea ice freezing and melting, evaporation and precipitation over the oceans. Global SSS data will allow us to create unprecedented computer models that bridge ocean-atmosphere-land-ice systems, with the goal of predicting future climate conditions.

AQUARIUS & ITS OBSERVATIONS

Aquarius is part of the Earth System Science Pathfinder Program of the National Aeronautics and Space Administration (NASA). The Project Team is institutionally comprised of the NASA Goddard Space Flight Center, NASA Jet Propulsion Laboratory, Argentina's Comisión Nacional de Actividades Espaciales (CONAE), and other co-investigator institutions including Bigelow Laboratory for Ocean Sciences, the education lead. The science instruments will include a set of three radiometers that are sensitive to salinity (1.413 GHz; L-band) and a scatterometer that corrects for the ocean's surface roughness. This configuration will achieve an accuracy of 0.2 (practical salinity units): this is about a "pinch" (i.e., 1/6 of a teaspoon) of salt per gallon of water.

Aquarius will provide the first global observations of SSS, covering Earth's surface once every eight days, delivering monthly 100-kilometer resolution SSS maps over the three-year mission lifetime. The research and education content goals are inextricably linked and include better understanding of:

- The water cycle 86% of global evaporation and 78% of global precipitation occur over the ocean; thus SSS is the key variable for understanding how fresh water input and output affects ocean dynamics.

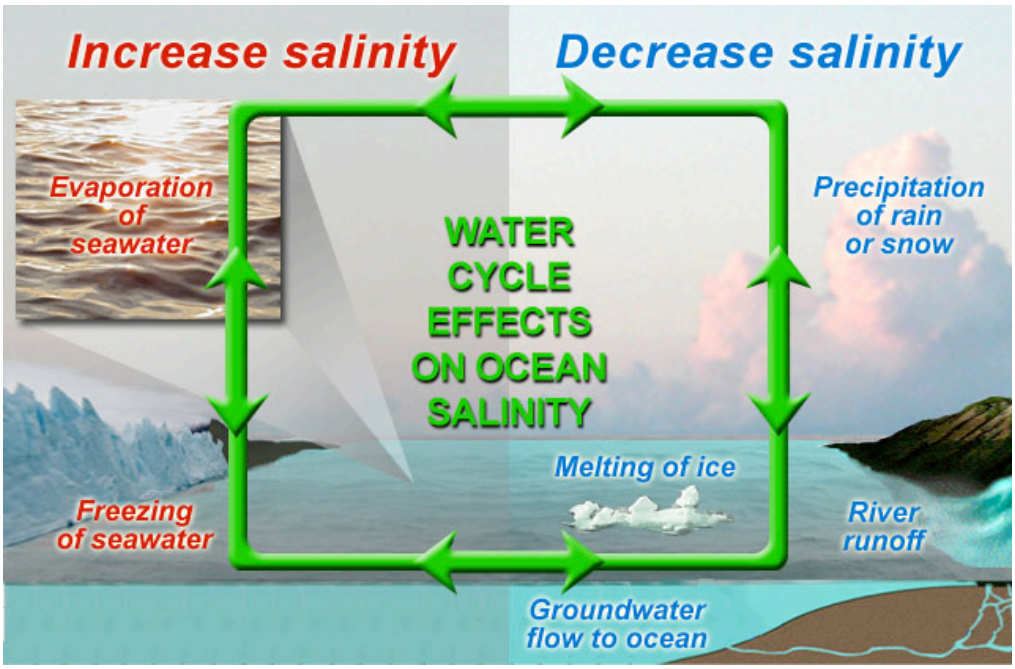

Figure 1: Diagrammatic representation of factors that increase and decrease salinity.

- Ocean circulation With temperature, salinity determines seawater density and buoyancy, driving the extent of ocean stratification, mixing, and water mass formation.
- Climate As computer models evolve, *Aquarius* will provide the essential SSS data needed to link the two major components of the climate system: the water cycle and ocean circulation.

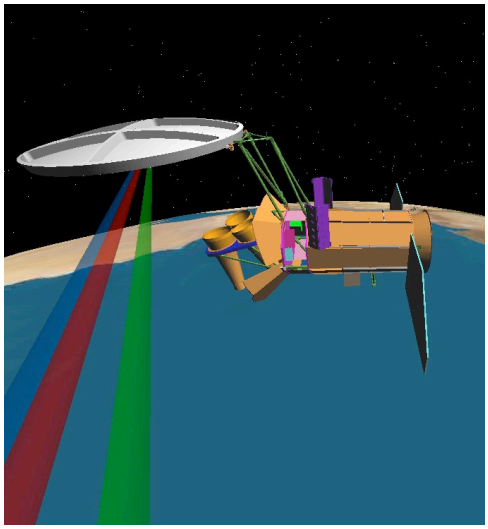

Figure 2: Depiction of the *Aquarius* instrument aboard the CONAE-provided spacecraft SAC-D.

EDUCATION & PUBLIC OUTREACH

While developing the Education & Public Outreach (EPO) plan, the team identified: 1) what is generally known or could be easily understood by most audiences; and 2) what the *Aquarius* mission can uniquely contribute to extended our audiences' knowledge base (Table 1). The approach is to bridge the gap between the "Known" and "Unknown" through a series of activities that highlight interesting and relevant issues for a wide variety of learners.

Aquarius EPO products will illustrate fundamental concepts about salinity variations and the role these changes play in controlling global ocean circulation and Earth's climate. Deliverables will appear as a series of modules that augment existing El Niño/La Niña materials with salinity based content, provide on-line interactive tools demonstrating environmental change through data sets and *in situ* time-series analysis, and engage students in activities designed to demonstrate salt-water interactions.

Aquarius EPO activities will build capacity for productive use of Earth science results, technology, and information in better understanding the earth system. This will be accomplished through the creation of engaging media rich, data-driven tools, models, and activities that allow non-scientists to see the implications of ocean change on the environment.

MOST AUDIENCES KNOW		MOST AUDIENCES DON'T KNOW
Oceans are salty	AQUARIUS EDUCATION	Salinity has NEVER been measured over 24% of the ocean
On land, the availability of salt varies (e.g., salt flats)		Ocean salinity patterns vary over time and space
Salt affects water's freezing point (e.g., salting roads)		Salinity is key to understanding interactions among the ocean, climate, and water cycle
Salinity affects water density (e.g., float easily in the Dead Sea)		
Icebergs from in polar regions & are made of fresh water		
Climate warming could cause polar ice to melt, sea level to rise, etc.		Tracking high latitude freshening will help to predict climate fluctuation
El Niño and La Niña influence weather patterns; both are related to ocean temperature		El Niño and La Niña are both influenced by ocean salinity

Table 1: *Aquarius* EPO activities will help bridge the knowledge gaps shown above

INFORMAL EDUCATION ACTIVITIES

The informal education activities will be designed to increase public awareness and understanding of how the earth functions as a system and technology's role in enabling development of that knowledge. Informal Education products will include:

- "Mission Overview" Module about the pioneering mission to map global salinity. Will focus on the following: 1) Salinity has never been measured over 24% of the ocean; and 2) Salinity can affect weather and climate over land areas.
- "Salinity & Climate" Module will augment existing El Niño / La Niña materials with salinity-based content. Will focus on how: 1) SSS data will improve climate forecasts; and 2) El Niño and La Niña are influenced by ocean salinity.
- "Modeling Simulation Tools" On-line interactive tools will show how environmental changes affect air-sea interchange and climate by allowing interactive exploration of data sets.
- "*Aquarius* / SAC-D 'Fact Sheet'" Easily duplicated documents will have basic information about the overall mission.
- "Launch Anniversary" Released each year on the anniversary of the *Aquarius* launch, updates will have synopses of the instrument performance, volume and status of data collected, science findings, and educational product releases.

FORMAL EDUCATION ACTIVITIES

Aquarius formal education activities will enable the use of Earth science information in the context of earth system science. In particular, *Aquarius*-related data and findings will be geared to age-appropriate student audiences. Formal Education products will include:

- "'Hands On' Salinity" Module will include activities to be conducted by students and / or educators to understand salt-water interactions. Will focus on the concept that salinity is vital to tracking interactions among the ocean, climate, and the hydrologic cycle.
- "Salinity Patterns & the Water Cycle" Module will illustrate the following concepts: 1) Ocean salinity patterns vary spatially and temporally; and 2) Changes in salinity patterns and the resulting effect on climate can have consequences for human civilization.
- "Time Series Analysis" Module will include *in situ* time-series salinity data for use in undergraduate and high school classrooms. Undergraduates at Duke University, under the guidance of Dr. Susan Lozier, will conduct much of the work.

EDUCATOR INTERACTION

Aquarius EPO will investigate, identify, and promote high standards of student academic achievement by increasing the capacity of educators, focusing on ocean-atmosphere and climate content. This activity will target in-service and pre-college educators, including the use and review of *Aquarius* materials, field-testing, and content development. Educator interaction activities will include:

- Investigating various scientific content delivery mechanisms to improve student learning.
- Researching written, instructional technology, and student learning value aspects of *Aquarius* education materials.
- Performing systematic evaluation of formal education products to assess their potential and sustained instructional value.
- Examining the outcomes of the overall *Aquarius* EPO program to determine its impact.

SUMMARY

Although everyone knows that seawater is salty, few know that even small variations in SSS can have dramatic effects on the water cycle and ocean circulation. This is why long-term, accurate, global maps of SSS are crucial to climate studies. Our highly integrated and complementary EPO goal is to

demonstrate how better understanding of salinity-driven circulation – and its affect on climate and the water cycle – can benefit student learning and society as whole. Learn more about *Aquarius* at http://aquarius.gsfc.nasa.gov

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