Global monitoring of Sea Surface Salinity with Aquarius

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ABSTRACT

Aquarius is an L-band microwave instrument to make precise sea surface salinity measurements from space. The objective is to study interactions between the ocean circulation, water cycle and climate by monitoring large scale seasonal and interannual salinity variations in the open ocean. Aquarius combines an ultra-stable radiometer as the primary instrument for measuring salinity with a scatterometer to provide a surface roughness correction. The instrument, which is being developed under NASA's Earth System Science Pathfinder program, is part of the Aquarius/SAC-D mission, a partnership between the USA (NASA) and Argentina (CONAE).

INTRODUCTION

Aquarius is a microwave remote sensing system designed to obtain global maps of the surface salinity field of the oceans from space. It will be flown on the Aquarius/SAC-D mission, a partnership between the USA (NASA) and Argentina (CONAE) with launch scheduled for late in 2008 or early 2009. The objective of Aquarius is to monitor the seasonal and interannual variation of the large scale features of the surface salinity field in the open ocean. This will provide data to address scientific questions associated with ocean circulation and its impact on climate. For example, salinity is needed to understand the large scale thermohaline circulation, driven by buoyancy, which moves large masses of water and heat around the globe. Of the two variables that determine buoyancy (salinity and temperature), temperature is already being monitored. Salinity is the missing variable needed to understand this circulation. Salinity also has an important role in energy exchange between the ocean and atmosphere, for example in the development of fresh water lenses (buoyant water that forms stable layers and insulates water below from the atmosphere) which alter the air-sea coupling.

Aquarius is a combination radiometer and scatterometer (radar) operating at L-band (1.413 GHz for the radiometer and 1.26 GHz for the scatterometer). The primary instrument for measuring salinity is the radiometer which responds to salinity because of the modulation salinity produces on thermal emission from sea water. This is illustrated in Figure 1 which shows brightness temperature at L-band (vertical axis) for an ideal (flat) surface as function of sea surface temperature (SST) for constant values of salinity. The response to salinity decreases rapidly with frequency and is quite small at C-band. The scatterometer will provide a correction for surface roughness (waves) which is one of the greatest unknowns in the retrieval.

PARTNERSHIP

This remote sensing mission is a partnership between the USA space agency, NASA, and the Argentine space agency, CONAE. The mission is called Aquarius/SAC-D. It consists of two parts: (a) Aquarius, the radiometer/scatterometer instrument for measuring salinity, which is being developed by NASA as part of the Earth System Science Pathfinder (ESSP) program; and (b) SAC-D, the forth spacecraft in the CONAE Satelite Aplicaciones Cientificas (SAC) program. NASA will provide the launch vehicle (Delta-II) and CONAE the data link. In addition to the SAC-D spacecraft, CONAE will be providing several additional remote sensing instruments including visible and infrared cameras and a microwave radiometer to monitor rain and wind velocity over the oceans, and sea ice. These are listed in Table I.

Table I: SAC-D Instruments

Instrument	Objective	Description	Resolution	Source
MWR: Microwave Radiometer	Precipitation, wind speed, sea ice concentration, water vapour	23.8 GHz and 37 GHz; Dual polarized; 390 km swath	40 km	CONAE
NIRST: New IR Sensor Technology	Hot spots (fires); Sea Surface Temperature	Bands: 3.8, 10.7 and 11.7 µm Swath: 180 km;	350 meters	CONAE
HSC: High Sensitivity Camera	Urban lights; Lightning Snow cover	Bands: 450-900 µm; Swath: 700 km;	200-300 m	CONAE
DCS: Data Collection System	Environmental data collection	Band: 401.55 MHz uplink	2 contacts/day w 200 platforms	CONAE
ROSA: Radio Occultation Sounder for Atmosphere	Properties of Atmospheric	GPS occultation	Hor: 300 km Vert: 300 km	ASI (Italy)
CARMEN 1: (ICARE and SODAD)	ICARE: Effect of cosmic radiation on electronics; SODAD: Distribution micro-particles and space debris	ICARE: Three depleted Si and Si/Li detectors SODAD: Four SMOS sensors	I: 256 channels S: 0.5 µ at 20 km/s sensitivity	CNES (France)
TDP: Technology Demonstration Pkg	Position, velocity and time; Inertial angular velocity	GPS receiver; Inertial reference unit	20 meters 1-2 m/sec	CONAE

Figure 2 shows the Aquarius/SAC-D observatory in its deployed configuration. The Aquarius instrument package consists of a 2.5 meter offset fed reflector with three beams. It is the large structure to the left in Figure 2. Aquarius is mounted at the end of the SAC-D opposite the solar panels. SAC-D and the several instruments in Table I are the cylindrical structure in Figure 2.

AQUARIUS

Aquarius is a combination radiometer and scatterometer (radar) operating at L-band (1.413 GHz for the radiometer and 1.26 GHz for the scatterometer). The antenna is an offset fed reflector with three feeds that are shared by the two instruments. The feeds produce three beams that image pushbroom-style. The beams look to the right across-track (i.e. 90 degrees with respect to the spacecraft heading) with look angles (direction measured at the spacecraft) of 25.8, 33.8 and 40.3 degrees. The sensor will be in a sun-synchronous orbit at an altitude of about 657 km with equatorial crossings of 6am/6pm (ascending at 6 pm). Thus, the spacecraft will fly near the day-night terminator and the three beams are positioned to look away from the sun toward the shadow side of the orbit to minimize sun glint.

The three beams are positioned to map a swath of approximately 390 km and the orbit will produce global coverage in a 7 day exact repeat cycle. To reduce measurement noise, the weekly maps will be averaged to produce maps of the salinity field globally once each month with an accuracy of 0.2 psu and a spatial resolution of 150 km. The spatial resolution will be adequate to address large scale features of the salinity field of the open ocean. The temporal resolution is sufficient to address seasonal changes. A three year mission is planned to collect sufficient data to look for interannual variations.

Details of the Aquarius mission and sensor system are listed in Table II and Figure 3 shows one of the antenna feed systems with the radiometer mounted around OMT. There are three radiometers, one for each of the beams (feeds). The radiometers are fully polarimetric. They make measurements at horizontal polarization, vertical polarization and at ± 45 degrees. The 3rd Stoke's parameter (obtained from the later measurement) will be used to derive a correction for Faraday rotation [2]. The internal radiometer sample interval is 10 ms and a pair of noise diodes are used for internal calibration. The design is quite demanding, calling for a ΔT = 0.06K and stability of better than 0.15K over 7 days [3]. There is one scatterometer which is dual polarized and samples sequentially among the three beams. The radar transmits between the radiometer samples (i.e. PRF = 100 Hz).

Table II: Parameters of the Aquarius Mission

Orbit		Antenna	
Altitude	657 km	Main Reflector	2.5 m offset fed
Sun-synch	6 pm ascending	Beams	25.8, 33.8, 40.3 degrees (at spacecraft)
Inclination	98 degrees	Resolution	42, 50, 61 km (equiv radius)
Coverage	7 days global	Swath	390 km

Radiometer		Scatterometer	
Frequency	1.413 GHz	Frequency	1.26 GHz
Polarization	Fully Polarimetric	Polarization	HH, VH, HV, VV
Sample time	20 ms	PRF	100 Hz
Integration	6 seconds	Pulse width	1 ms (BW = 4 MHz)

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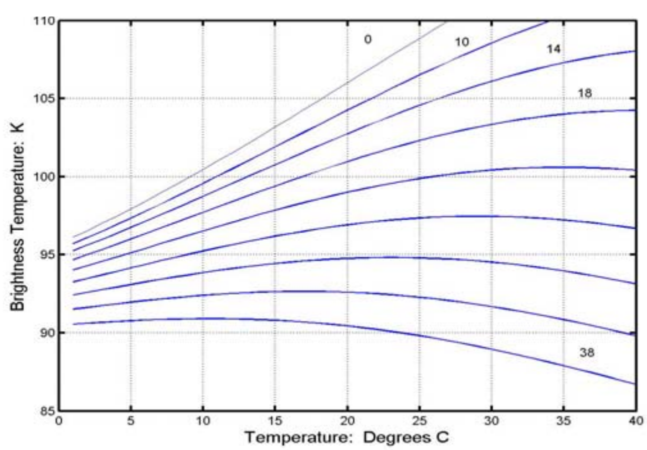

Fig 1: Level curves of constant salinity as function of sea surface temperature (abscissa) and microwave brightness temperature (ordinate) for L-band (1.4 GHz) and normal incidence. The model for dielectric constant in [1] was used to obtain these curves.

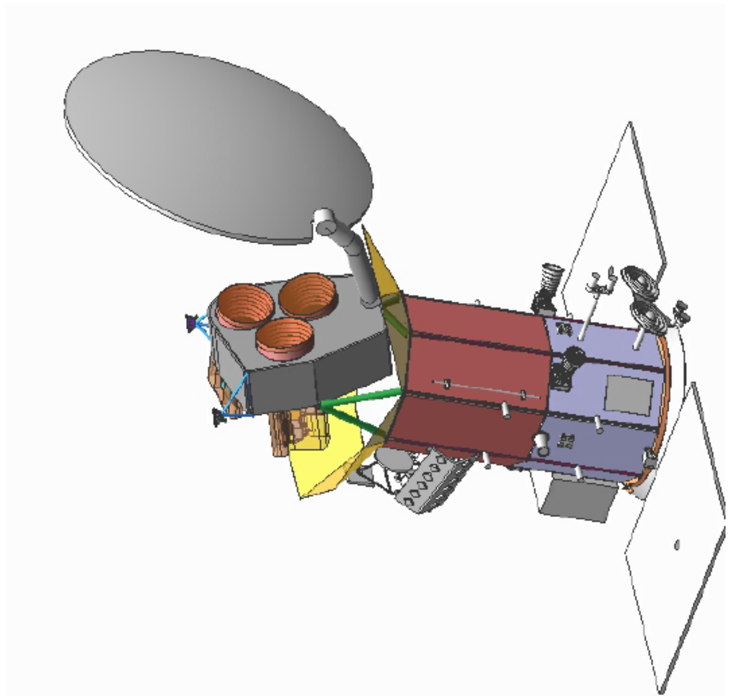

Fig 2: The Aquarius/SAC-D hardware in the deployed configuration. SAC-D is the spacecraft (cylindrical structure plus solar panels) and also includes the several instruments listed in Table I. Aquarius consists of the large offset-fed reflector and feed system mounted to the left at the end of the spacecraft.

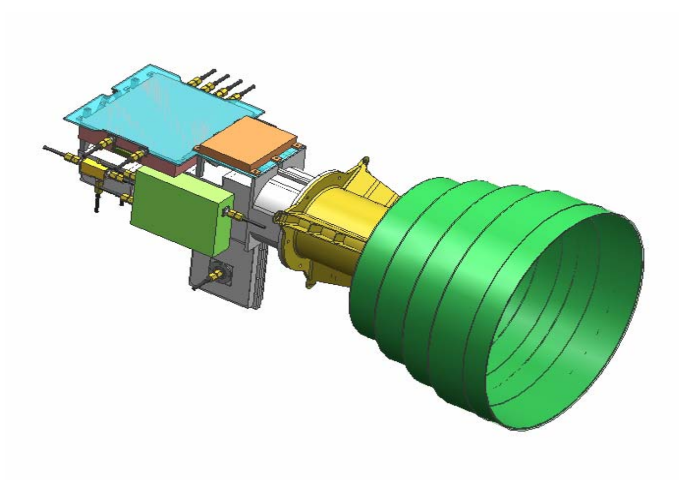

Fig 3: Drawing showing the Aquarius antenna feed system with the radiometer hardware mounted around the orthomode transducer (OMT).