L/S-band Radiometer Measurements of a Saltwater Pond

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Abstract- L and S-band radiometer brightness temperature measurements from a salt-water pond were made of as a function of salinity and temperature. The L-band measurements are in excellent agreement with the Klein and Swift salinity model, and will provide accurate predictions for the L-band emission from the ocean for future ocean salinity satellite missions.

I. Introduction

In October and November 2001, L and S-band radiometer brightness temperature measurements from a salt-water pond were made of as a function of salinity and temperature. The purpose of these measurements was to verify the accuracy of current salt-water microwave emission models. Having accurate microwave emission models for the L-band emission from the ocean is necessary for future satellite missions to measure Sea Surface Salinity (SSS) as proposed in the GSFC/JPL Aquarius mission and the ESA Soil Moisture Ocean Salinity (SMOS) mission.

II. Experimental Setup

In October a 3.7 x 4.3 x 0.1 m (l x w x d) salt-water pond was built near the JPL antenna range on the hill above the laboratory. The Passive Active L/S-band (PALS) radiometric instrument [1] was mounted at a 45-degree incidence angle looking down on the pond in a north direction as shown in Fig. 1. The projected footprint of the L-band antenna beam was an ellipse with dimensions of 2.0 x 1.2 m. For salinities > 25 psu, the projected water depth of 14 cm was equivalent to > 9 skin depths. (The practical salinity unit (psu) corresponds to parts per thousand of salinity.) To eliminate any contribution from the ground or surrounding area, aluminum plates were placed beneath the vinyl pond, in front of the pond out to 3 m, and 1.5 m high aluminum side panels were placed along side the pond. The location, with a hill to the south towards Los Angeles, and the metal shielding, provided a relatively quiet Radio Frequency Interference (RFI) environment. During the three weeks of measurements made in the late afternoon and evening, there were no occurrences of L-band RFI. (The radiometer was tuned to 1405 to 1425 MHz. The protected radio astronomy band is from 1400 to 1427 MHz.)

The S-band antenna and radiometer were mounted above the L-band horn and were also used for measurements. RFI was apparent in the S-band radiometer on many nights – especially in the horizontal polarization. (The S-band radiometer was tuned to 2677 to 2683 MHz, which was selected for "minimum" RFI.)

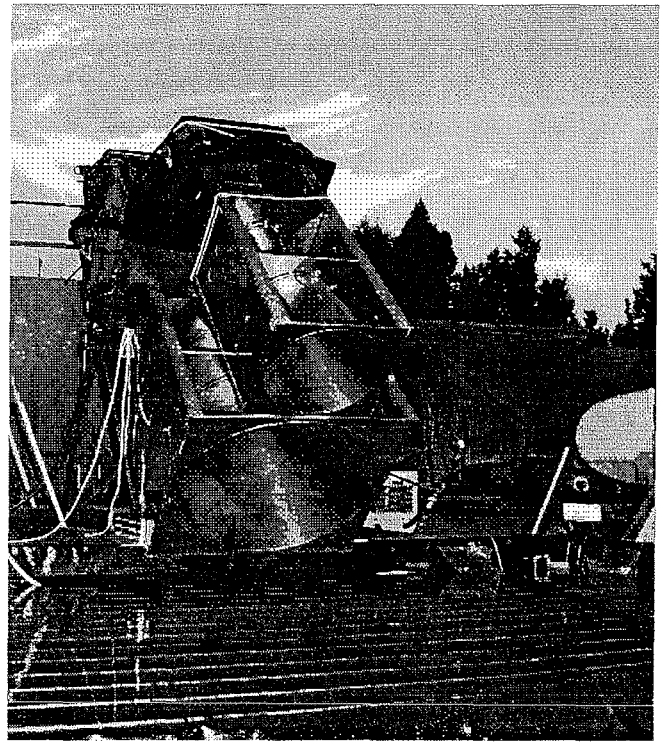

Fig. 1. Front view of the PALS instrument observing the salt-water pond. The water circulation system with the PVC pipes is shown under the water. L-band radiometric measurements were made over a salinity range between 25 and 40 psu and a temperature range of 9° C to 32° C.

A grid of PVC pipes was used to circulate the salt water in the pond. The pipes were organized to have alternate pipes for inlet and outlet to achieve maximum mixing. A pump was used at low speed to constantly circulate the water, and no waves were present during measurements. There were four small pumps on the pond corners to circulate the water to the center to improve the mixing. A gas heater was in series with the pump to heat the water during the measurements. After a set of measurements, two water chillers with metal pipe radiators were placed into the pond to cool the water down for the next evening's measurements. This technique allowed us to make measurements over a temperature range from 9° C to 32° C.

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The salinity was varied over a range from 25 to 40 psu. To increase the salinity level, sea salt was mixed with filtered reverse osmosis water and fed into the pond through the pump line. To decrease the salinity, filtered reverse osmosis water was added to the pond. The level of the water was kept between 9.5 to 10.5 cm; however, it was noted that this level could change by 3 cm with no effect on the brightness temperature. Two new Thermosalinograph (TSG) instruments (Seabird Models SBE 45 MicroTSG) were used at opposite sides of the pond to measure the salinity and temperature of the water. There were also four temperature probes located near each corner. When the TSG's read within 0.1 psu, and all temperature sensors read within 0.2° C, the pond was considered mixed and measurements were taken to be valid.

All measurements were made after sunset to eliminate any solar interference. On October 26, November 3, and November 10, measurements were made with a constant salinity of 35 psu and a constant temperature to measure changes in the background radiation from 4 to 9 pm. Since the variations in the background would be mainly due to the reflected galactic background, all measurements were shifted in time to 10 November. These three days of data showed excellent agreement within 0.05 K. A constant bias term was added to each day's data to adjust the data close to the mean value. At L-band this constant bias varied over a 0.3 K range, during the 16 days of the measurements, and was probably due to small changes in the antenna sidelobe pickup or in the system calibration. Note that this constant bias term does not affect the shape of any of the curves and verified the excellent stability of the L-band PALS radiometer over the two-week period. (The S-band radiometer did not have the stability of the L-band radiometer, and the S-band bias term ranged over a 2 K range during the 16-day period.) These data show that the L-band galactic background decreased by ~0.2 K from 4 pm to 9 pm. The smoothed average data was subtracted from all the salinity measurements to correct for the small background changes.

III. Results

Most of the measurements were taken at fixed salinity levels of 25, 35 and 40 psu over a temperature range of 9° C to 32° C. These measurements cover most of the range expected in the oceans to be measured by the Aquarius instrument. All the averaged L-band measurements, at both Horizontal and Vertical polarization, are shown as the colored points in Fig. 2. The Klein and Swift (K&S) model data [2] are shown as the solid black curves.

The rms difference between the average curves and the K&S model is 0.1 K, which corresponds to a salinity error < 0.2 psu. This demonstrates the excellent stability of this measurement system. The most important result however, is that the measurements are in excellent agreement with the Klein and Swift SSS model.

The vertically polarized S-band data is shown in Fig. 3. These measurements were also in general agreement with the K&S model; however, there was a better fit with the Ellison et al. model [3} as shown in Fig. 3. The RMS difference between the vertically polarized data and the Ellison et al. model is 0.2 – 0.4 K. The stability of the S-band radiometer was not as good as the L-band radiometer, and with the RFI in the horizontal data, this data is considered to be less reliable for this comparison.

IV. Conclusion

The conclusion from this set of controlled measurements with a complete radiometer system, is that over most of the range of salinity and temperatures observed in the ocean, the K&S model, with minor corrections, will provide accurate predictions for the L-band emission from the ocean. This result then forms a sound basis for future spaceborne missions to accurately measure ocean salinity.

Acknowledgment

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References

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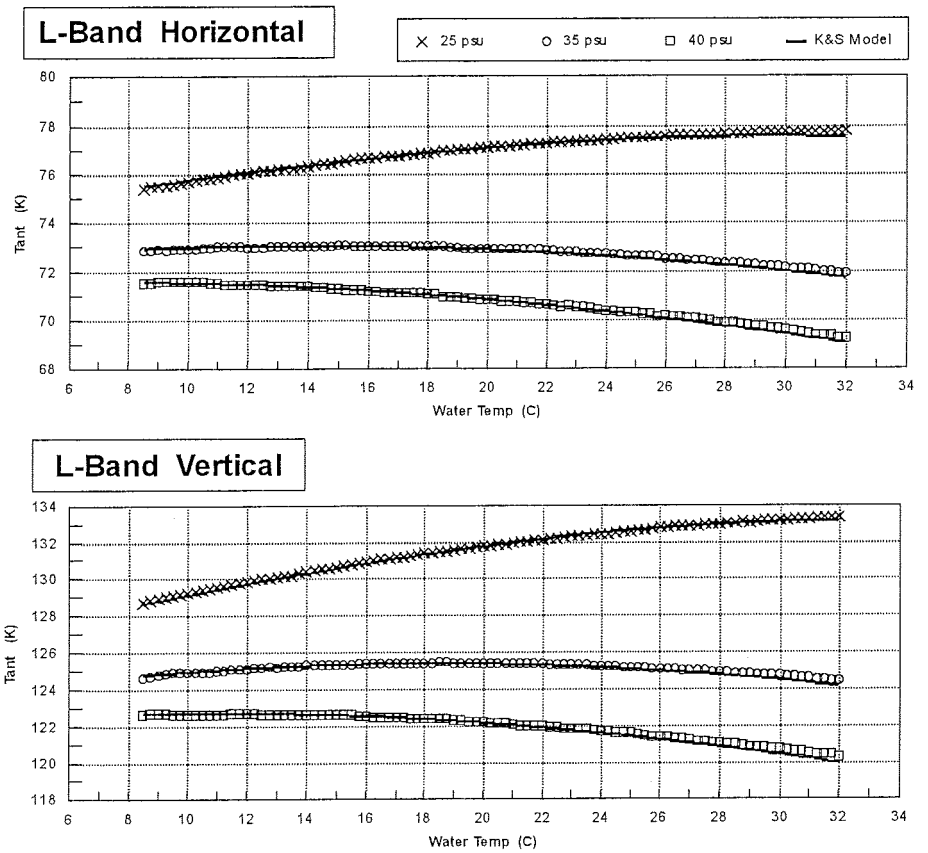

Fig. 2. L-band saltwater pond brightness temperature measurements at 25, 35 and 40 psu over a temperature range of 9° C to 32° C. The colored curves represent average data from 5 different days. The width of the data curves represents the peak-to-peak variation (0.25 K) of the different days of the data. The solid black curves are from the Klein and Swift model, showing excellent agreement between the L-band PALS's data and the model. The RMS difference between the measured data and the Klein and Swift model is ~0.1 K.

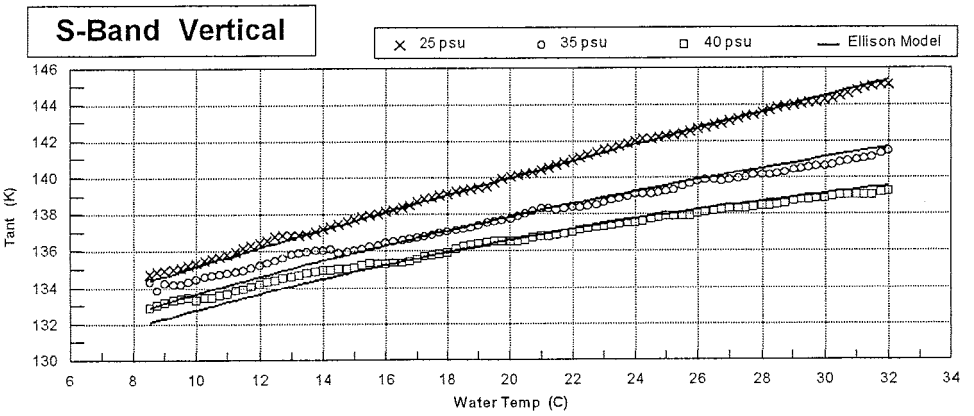

Fig. 3. S-band saltwater pond brightness temperature measurements at 25, 35 and 40 psu over a temperature range of 9° C to 32° C. The colored curves represent average data from 5 different days. The solid black curves are from the Ellison et al. model, showing reasonable agreement with the PALS's data. The RMS difference between the measured data and the Ellison model is 0.2 – 0.4 K.