

Ocean Surface Salinity Remote Sensing with the JPL Passive/Active L-/S-band (PALS) Microwave Instrument

William J. Wilson, Simon H. Yueh, Fuk K. Li, Steve Dinardo, Yi Chao
Jet Propulsion Laboratory, California Institute of Technology
4800 Oak Grove Drive, Bldg. 168-327, Pasadena, CA 91109
Tel: (818) 354-5699, FAX: (818) 393-4683, E-mail: william.j.wilson@jpl.nasa.gov

Chet Koblinsky¹, Gary Lagerloef², and Stephan Howden³

¹ NASA Goddard Space Flight Center, Greenbelt, Rd, Greenbelt, MD 20771

² Earth and Space Research, 1910 Fairview Ave E, Suite 102, Seattle WA 98102

³ University of Southern Mississippi, Stennis Space Center, MS 39529-6000

Abstract – This paper describes the measurements acquired by the aircraft Passive/Active L-/S-band (PALS) instrument from two field campaigns in 1999 and 2000. These measurements were in support of the development of ocean surface salinity remote sensing techniques for the future Aquarius space mission. The 2000 measurements demonstrated the aircraft radiometer stability of ± 0.3 K over time periods of 30 minutes with a salinity measurement accuracy of 0.2 PSS.

INTRODUCTION

The first space mission dedicated to globally measure ocean surface salinity, named Aquarius, will be proposed to the Earth System Science Pathfinder (ESSP) program in 2001. Global measurements of Sea Surface Salinity (SSS) will directly aid in characterizing and understanding the current variations in global ocean circulation. The goals of the Aquarius mission are to study the effect of the hydrologic cycle on the ocean circulation and dynamics and the ocean's feedback to climate variability.

In support of the Aquarius mission, the Passive/Active L-/S-band (PALS) microwave aircraft instrument has been used to make precision measurements of the ocean microwave emission to develop techniques for measuring SSS. The goal of the PALS measurements is to show that it will be possible to remotely measure SSS to an accuracy of 0.1 PSS (Practical Salinity Scale or parts per thousand). The microwave emission from the ocean is a function of the Sea Surface Temperature (SST), the surface roughness from wind and waves, the reflected sky emission and the SSS. Because the L-band brightness temperature variations associated with salinity changes are small, e.g. a salinity change of 0.2 PSS results in a brightness temperature change of 0.1 to 0.2 K, it was necessary to build a very accurate, sensitive and stable system, which include radiometers and scatterometers. The scatterometers are used to correct for the surface roughness. Corrections for the SST and the atmosphere are made using *in-situ* data. Details of the PALS instrument have been described in [1,2].

MEASUREMENTS

The first set of ocean measurements were made in July 1999, with the PALS instrument installed in the NCAR C-130 aircraft, flying south of Norfolk Virginia over the Gulf Stream. The advantage of flying across the Gulf Stream is the large change in SSS of ~ 5 PSS. These measurements shown in Fig. 1, indicated a clear and repeatable salinity signal across the Gulf Stream, which was in good agreement with the Cape Hatteras ship salinity data.

There were also observations from several areas with a strong wind gradient. It was estimated that the excess brightness temperature due to 1 m/s change of wind speed is about 0.2 K for Vertical polarization and 0.4 K for Horizontal polarization. It was also verified that the scatterometer measurements provide direct information on the surface roughness, which significantly improves the accuracy of the retrieved SSS.

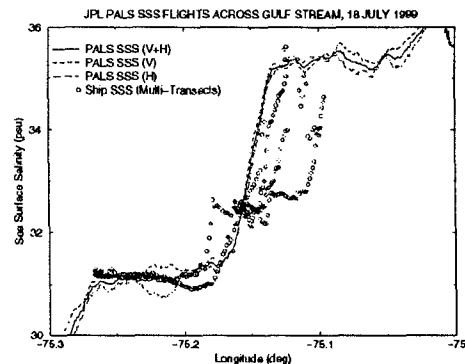


Fig. 1. PALS data across the Gulf Stream, south of Norfolk VA, on 18 July 1999. The SSS data (red dots) are data from a Thermo Salinograph on the Cape Hatteras ship, which made a number of transects across the Gulf Stream. The differences in the aircraft and ship data are due to small differences in location.

In August 2000, an experiment was done to test the ability of the PALS instrument to measure very small changes in SSS. The PALS microwave instrument was flown again on the NCAR C-130, with seven flights over the buoys deployed by the Monterey Bay Aquarium Research Institute (MBARI) off the California coast near Monterey bay. Some of these flights were also over the research ship New Horizon and the vessel Vito-C with *in-situ* measurements of SSS and SST.

The data reconfirms the PALS flight observations in 1999 regarding the influence of surface roughness on the L-band microwave radar and radiometer signatures of ocean surfaces. Fig. 2 shows data taken on August 17, 2000 on a track flying south along the California coast from Monterey to San Francisco.

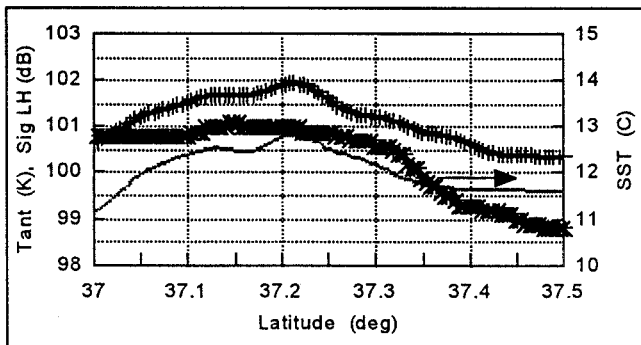


Fig. 2. PALS data over the New Horizon ship track on August 17, 2000. The black hatched curve is the uncorrected $\langle V+H \rangle$ radiometer data (K), the solid orange curve is the radar backscatter (dB), and the purple cross curve is the SST data ($^{\circ}\text{C}$). A bias of +120 dB has been added to the radar data to plot this data on the same plot.

This flight was over the path of the New Horizon ship, which followed 12 hours later. The black hatched curve shows the uncorrected radiometer data, which is the average of the Vertical and Horizontal signals. The scatterometer backscatter data is plotted in the solid orange curve. The scatterometer data shows how the surface roughness increased in the southern part of the track where the wind speed was 10-12 m/s. An empirical correction was used with the scatterometer data to correct the radiometer data for roughness. This radiometer data was also corrected for SST using a correction of 0.3 K per deg C and the corrected data is shown in Fig. 3 along with the SSS data from the New Horizon. Note that the corrected radiometer data is nearly constant, showing the importance of these corrections.

The corrected radiometer data show that the variations are consistent with the changes in the SSS. That is, the SSS decreased by ~ 0.3 PSS, and the radiometer brightness temperature increased by ~ 0.2 K. This data also shows the stability of the PALS L-band radiometer to be within ± 0.2 K over a 30-minute aircraft track.

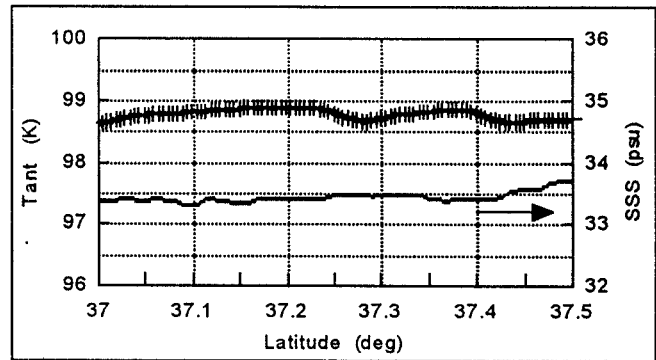


Fig. 3. The PALS radiometer data from Fig. 2, corrected for changes in SST and surface roughness, are shown in the red hatched curve. The SSS is shown in the solid blue curve (PSS).

Data from another flight on August 24, 2000, over the ship Vito-C just south of Monterey bay, is shown in Fig. 4. This track was across a small SST and SSS front at -122.4° longitude. At this location, the wind speed was ~ 8 m/s, the scatterometer backscatter had a small increase and the SST increased by ~ 4 C.

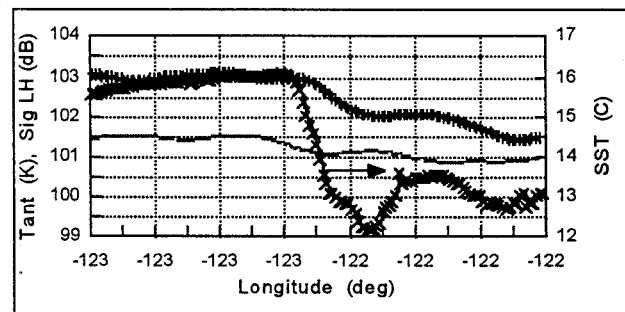


Fig. 4. PALS data over the Vito-C ship track in Monterey Bay on August 24, 2000. The black hatched curve is the uncorrected $\langle V+H \rangle$ radiometer data (K), the solid orange curve is the radar backscatter (dB), and the purple cross curve is the SST data ($^{\circ}\text{C}$). A bias of +125 dB has been added to the radar data to plot this data on the same plot.

The corrected radiometer data and the SSS data are shown in Fig. 5. Across the front, the SSS decreased by ~ 0.4

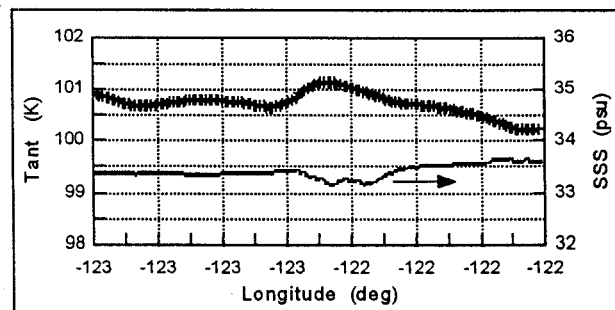


Fig. 5. The PALS radiometer data from Fig. 4, corrected for changes in SST and surface roughness, are shown in the red hatched curve. The SSS from the VITO-C ship is shown in the blue curve (PSS).

PSS and the radiometer brightness temperature increased by ~ 0.4 K. Over the length of the track, the SSS decreased by ~ 0.3 PSS, and the radiometer brightness temperature increased by ~ 0.3 K.

After correcting the data for the roughness, it was necessary to use a temperature correction of 0.3 K per deg C, to get the radiometer data to be consistent with the change in salinity as predicted by the Klein and Swift salinity model [3]. It must be noted that this temperature dependence factor is much larger than predicted by the Klein and Swift model. This is one of the biggest uncertainties in analyzing this SSS data. To reduce this error, it is planned to make a controlled "pond" experiment where measurements will be made with the PALS radiometer under a variety of temperature and salinity values.

ACKNOWLEDGMENT

This work represents one phase of research carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the NASA. The NASA Code Y Earth Science Enterprise Office, Ocean Science Program supported this work.

REFERENCES

- [1] W. J. Wilson, S. H. Yueh, S. J. Dinardo, S. Chazanoff, A. Kitiyakara and F. Li, "Passive Active L- and S-band (PALS) Microwave Sensor for Ocean Salinity and Soil Moisture Measurements," Accepted by IEEE Trans. Geosci. Remote Sensing, in press 2001.
- [2] F. K. Li, W. J. Wilson, S. H. Yueh, S. J. Dinardo and S. Howden, "Passive Active L/S-band Microwave Aircraft Sensor for Ocean Salinity Measurements", Proc. International Geoscience and Remote Sensing Symposium, Honolulu, HI, July 2000.
- [3] L. A. Klein and C. T. Swift, "An improved model for the dielectric constant of sea water at microwave frequencies," IEEE Trans. Antennas and Propagation, Vol. AP-25, no. 1, pp. 104-111, January 1977.