

Seawater dielectric constant laboratory measurements at 1.4 GHz

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The dataset reports laboratory measurements of the dielectric constant of seawater at a frequency of 1.413 GHz (L-band), the center of the protected band (i.e. passive use only) used in the measurement of sea surface salinity from space. The objective of the measurements is to determine accurately the complex dielectric constant of seawater as a function of salinity and temperature. The measurements have been used to develop an analytical model for the dielectric constant of seawater at L-band which has been validated using space-borne radiometric data and in situ observation. The goal of the new model is the accurate retrieval of salinity at all temperatures and salinities in the open ocean. The data are from laboratory measurements funded by NASA grants NNX16AK40G and NNX17AK01G in support of NASA's satellite missions to measure sea surface salinity from space.

A cylindrical microwave cavity, resonant at 1.413 GHz, is used to measure the complex dielectric constant of seawater. Seawater, whose salinity is known to five places of accuracy, is inserted into a capillary tube which has been placed along the cavity's cylindrical axis. The brass cavity is put into a constant temperature fluid bath (± 0.01 °C) to stabilize its temperature. The cavity of the transmission type has small amounts of microwave energy coupled in and out by small coils placed in slots in its upper lid. The microwave frequency is generated by a Hewlett Packard (HP) network analyzer that is stable to 1Hz. The frequency is swept over a 500 kHz band to form a resonant response curve. The center frequency, f , and the quality factor, Q , are determined from this curve.

The real and imaginary dielectric constant are measured in a two-step procedure. First, the resonant frequency, f_0 , and the quality factor, Q_0 , are measured with no seawater in the cavity; second, seawater is inserted into the cavity and the resonant frequency, f , and the quality factor, Q are measured again. Using perturbation theory under the assumption that the amount of seawater added to the cavity is small (inner diameter of capillary tube is 0.1 mm) yields the following two equations:

$$\varepsilon' - 1 = 2C\Delta f / f, \quad \Delta f = f_0 - f \quad (1)$$

$$\varepsilon'' = C\Delta(1/Q), \quad \Delta(1/Q) = \frac{1}{Q} - \frac{1}{Q_0} \quad (2)$$

where ε' and ε'' are the real and imaginary parts of the dielectric constant (relative) respectively and C is a calibration constant that must be determined.

The measurements have been made at 12 temperatures (T °C) [-1.5,-1.0, 0, 1, 2, 3, 5, 10, 15, 20, 25, 30, 35] and 9 values of salinity (S psu) [0, 10, 20, 30, 33, 34, 35, 36, 38]. The measured quantities [f , f_0 , Q , Q_0] and four calculated quantities [Δf , $\Delta(1/Q)$, ε' and ε''] are given in [12×9×4] arrays. Here the rows are temperatures and the columns are salinities. These [12×9] arrays are repeated 4 times along the third dimension, one for each measurement at the same T and S . Because not all [T,S] combinations have 4 sample measurements, the fourth dimension can contain invalid fill value where valid values exist in the dimensions 1 - 3. In addition to the measured and calculated quantities, the average, standard deviation (std) and the $(\text{std}/\text{average}) \times 100$ (pc std) are given for each variable in [12×9] arrays. The averages of ε' and ε'' at the various combinations of T and S are the primary product of this data set.

The calibration constant, C , appearing in eqs. (1) and (2) is determined using a liquid (methanol at 20 °C) with a dielectric constant that has been measured to an accuracy of better than 0.5% by Gregory and Clark, 2012. The calibration measurements using methanol are similar to the seawater measurements. Equations (1) and (2) are employed again for methanol. Measurements are made with an empty cavity and with methanol that yield two frequencies and two values of quality factor, Q . Since ε' and ε'' are known, two values of C (called $C1$ and $C2$) are obtained, one for each equation. The calibration constant from the first equation is used as the calibration constant, i.e., $C=C1$ since the real part of methanol is measured more accurately and the standard deviation of the $C1$ values is generally smaller than the standard deviation of values for $C2$.

In the process of making the measurements, several different tubes were used. As a result, there is a calibration coefficient for each tube. In addition, if the cavity is opened for inspection, the system must be recalibrated even though the tube has not changed. There are 7 different calibrations and corresponding tube numbers [28, 30, 32, 35-1, 35-2, 35-3 and 37]. The cavity was opened three times for tube 35. Calibrations of individual tubes have a different number of methanol measurements which are placed in [32×1] array associated with each tube number. As in the case of the seawater measurements, there is a [32×1] array for f , f_0 , Q , Q_0 , and five calculated quantities: Δf , $\Delta(1/Q)$, $C1$, $C2$ and $\{(C1/C2)-1\} \times 100$. The latter quantity shows how close $C1$ is to $C2$ and is a measure of the consistency of our measurements. Finally, [7×1] arrays of the average, std and pc std are given for $C1$ and $C2$.

Each seawater measurement at [T,S] has to have a calibration constant. This correspondence is accomplished indirectly. Each element of a [12×9×4] data array is assigned a tube number from the [1×7] array of tube numbers. Each tube number corresponds to a unique calibration coefficient that is given in the calibration coefficient [1×7] data variable.