SALINITY RETRIEVAL ALGORITHM FOR AQUARIUS

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1. INTRODUCTION

Aquarius is an L-band satellite radiometer designed to measure ocean salinity to an accuracy of 0.2 psu at monthly, 150-km scales. It is the primary instrument on the Aquarius/SAC-D mission, a partnership between NASA and the Argentine space agency, CONAE, scheduled to be launched in 2010 [1,2]. This talk is an overview of the salinity retrieval algorithm that will be used to estimate sea-surface salinity from the observed L-band antenna temperatures, T_A.

2. THE L-BAND BRIGHTNESS TEMPERATURE OVER THE OCEAN

The L-band T_B that will be observed by Aquarius over the ocean is a combination of many effects. The mainlobe of the antenna will see the following:

1. Emission from the sea-surface (the desired signal)
2. Emission from the atmosphere, both upwelling and reflected downwelling
3. Galactic and cosmic radiation reflected off the sea-surface
4. Solar radiation backscattered off the sea-surface (only at certain times of the year in the high latitudes)

In addition to these mainlobe signals, the antenna sidelobes and backlobes will see galactic and cosmic radiation as well as solar radiation, which is both directly received and reflected off the sea surface. Another complicating effect is that all signals coming from the Earth experience Faraday rotation as they pass through the ionosphere.

3. ESTIMATING SEA-SURFACE EMISSION

The major function of the salinity retrieval algorithm is to remove all the unwanted signals. The first step is to remove the solar, cosmic, and galactic radiation that is received by the sidelobes and backlobes. An on-orbit simulation is used to estimates these effects. The simulator employs a complete 4-stokes model of the antenna pattern and flies Aquarius in the expected orbit (sun synchronous with 6 pm local ascending time). The contribution $\Delta T_{A,space}$ of the solar/cosmic/galactic radiation to T_A is computed by doing the appropriate integration over the antenna pattern. The results are stored as finely incremented tables of $\Delta T_{A,space}$ versus intra-orbit position and time of year. In the first step of the algorithm, these values are subtracted from the T_A measurements.

The next step is to remove the galactic radiation that is reflected off the ocean surface into the mainlobe of the antenna. The on-orbit simulator is again used to estimate this effect in the same manner as described above. However, in this case one needs to consider the state of the sea surface. When the sea-surface is rough, the pattern of the reflected galactic radiation becomes more diffused. To account for the surface roughness effect, simulations are done for various roughness conditions using a geometric optics model to represent the scattering effects. The resulting tables then have the additional dimension of wind speed, which is used to characterize the roughness. In operation, the reflected galactic radiation is found from a table lookup based on the satellite position, time of year, and an ancillary wind speed value.

Once the solar and galactic effects are removed from the T_A measurement, the conversion to brightness temperature T_B is done according to:

$$\mathbf{T}_{\mathbf{B},toi} = \mathbf{A}\mathbf{T}_{\mathbf{A}} \tag{1}$$

where $\mathbf{T_A}$ and $\mathbf{T}_{\mathbf{B},\mathrm{toi}}$ are vectors having the first 3 Stokes values as components, and **A** is a 3 by 3 matrix. $\mathbf{T}_{\mathbf{B},\mathrm{toi}}$ is an estimate of the top-of-the-ionosphere (TOI) brightness temperature. The A-matrix is found from the on-orbit simulator so as to minimize in a least-squares sense the difference between the true $T_{B,toi}$ and the $T_{B,toi}$ estimate coming from (1). The main function of (1) is to remove the spillover and cross-polarization contamination in the antenna temperatures.

The TOI T_B is then converted to a top-of-the-atmosphere (TOA) T_B by removing Faraday rotation. The first Stokes is not affected by Faraday rotation, and the transformation of the 2nd and 3rd Stokes is as follows:

$$\begin{aligned} T_{B1,toa} &= T_{B1,toi} \\ T_{B2,toa} &= \sqrt{T_{B2,toi}^2 + T_{B3,toi}^2} \\ T_{B3,toa} &= 0 \end{aligned} \tag{2}$$

where the assumption is made that all of the 3rd Stokes in $T_{B,toi}$ is due to Faraday rotation. This is to say, we are assuming the natural 3rd Stokes from the Earth is negligibly small.

The final step in estimating the sea-surface emission is to remove the atmospheric contribution to $T_{B,toa}$. This is done by using atmospheric profiles of temperature, pressure, water vapor, and cloud liquid water that are routinely available from NCEP. These profiles are integrated vertically to obtain the upwelling and downwelling brightness temperatures, T_{Bup} and T_{Bdw}, and the total atmospheric transmittance τ. Given T_{Bup}, T_{Bdw}, and τ, $T_{B,toa}$ can be converted to surface emission, which is defined as emissivity E times surface temperature T_s.

4. ESTIMATING SALINITY FROM SEA-SURFACE EMISSION

The algorithm for estimating sea-surface salinity (*S*) takes the form

$$S = s_0\left(\theta_i, T_S\right) + s_1\left(\theta_i, T_S\right)T_{BV,sur} + s_2\left(\theta_i, T_S\right)T_{BH,sur} + s_3\left(\theta_i, T_S\right)W \tag{3}$$

where θ_i is the incidence angle, T_S is the sea-surface temperature, W is the sea-surface wind speed, and $T_{BV,sur}$ and $T_{BH,sur}$ are the v-pol and h-pol surface emissions ET_s. The *s* coefficients are functions of θ_i and T_S and are in tabular form. The algorithm is trained by deriving a set of *s* coefficients that minimize variance between the salinity *S* given by (3) and the true salinity. Separate sets of *s* coefficients are found for 251 incidence angles going from 25° to 50° in 0.1° steps and 451 T_S values going from –5°C to 40°C in 0.1°C steps. These 251×451 tables are interpolated to the specified value for θ_i and T_S. The best available SST database will be used to specify T_S and the Aquarius scatterometer is expected to provide the coincident wind speed *W*.

For a given θ_i and T_S, the relationship between surface brightness temperature and salinity is close to linear, but not quite. If necessary, we will supplement equation (3) by adding a second stage algorithm that will remove any error caused by the deviation from linearity. This type of two-stage algorithm has proven very effective in handling the non-linearity characteristic in the AMSR-E retrievals [3].

4. RESULTS AND CONCLUSION

We will present results of testing the above-described algorithm using the on-orbit simulator. These results show that the mission accuracy requirement of 0.2 psu at monthly, 150-km scales is generally being met, with some exceptions such as close (<400 km) to land and in cold water.

5. REFERENCES

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