PRELIMINARY PERFORMANCE SIMULATION OF MICROWAVE IMAGER COMBINED ACTIVE PASSIVE -A NEW INSTRUMENT FOR CHINESE SALINITY MISSION Postprint

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Abstract

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Full Text

Preamble

Preliminary Performance Simulation of Microwave Imager Combined Active/Passive -A New Instrument for Chinese Salinity Mission

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Abstract

A 1-D interferometric system operating at 1.4 GHz, 6.9 GHz, 18.7 GHz, and 23.8 GHz combined with a scatterometer at 1.26 GHz, called the Microwave Imager Combined Active/Passive (MICAP), has been proposed to retrieve sea surface salinity (SSS) and reduce geophysical errors due to surface roughness and sea surface temperature (SST). The MICAP will serve as a candidate payload onboard China’ s Ocean Salinity Satellite. This paper analyzes the sensitivity of active/passive microwave observations to SSS, SST, and wind, and estimates the stability requirements of the instruments, with the objective of designing an optimized satellite instrument dedicated to an “all-weather” estimate of SSS with high accuracy from space.

Index Terms—combined instrument performance simulation, active/passive, SSS

1. Introduction

The development of sea surface salinity (SSS) observations using satellite L-band radiometers can improve temporal and spatial resolution and enable monitoring of large-scale salinity events. To satisfy the need for high-quality global SSS measurements from space, two L-band satellite missions were launched: SMOS (the European Soil Moisture and Ocean Salinity) in November 2009 and Aquarius (the NASA Aquarius/SAC-D) in June 2011. These missions provide new global SSS data complementary to in situ measurements [?, ?].

The L-band has been chosen for SSS remote sensing because it offers significantly greater sensitivity of sea surface radiometric measurements to salinity changes compared to higher frequencies, and it is protected against human-made emissions. However, even at this frequency, SSS remote sensing remains very challenging because the sensitivity of brightness temperature (TB) to SSS is low: in the range of $0.35\ \mathrm{K} \cdot \mathrm{psu}^{1}$ to $0.8\ \mathrm{K} \cdot \mathrm{psu}^{1}$ for vertical polarization and $0.2\ \mathrm{K} \cdot \mathrm{psu}^{1}$ to $0.6\ \mathrm{K} \cdot \mathrm{psu}^{1}$ for horizontal polarization. The main geophysical sources of error in SSS retrieval from L-band TB stem from uncertainties in ocean surface emissivity related to surface roughness and sea surface temperature (SST). However, the above salinity observation systems, like SMOS and Aquarius, require auxiliary information to retrieve SSS, such as sea surface wind field and SST predicted by the European Center for Medium-Range Weather Forecasts (ECMWF) operational system or the National Centers for Environmental Prediction (NCEP). The accuracy of this auxiliary information directly affects the quality of SSS retrievals.

A candidate payload called the Microwave Imager Combined Active/Passive (MICAP) has been proposed for the Sea Surface Salinity Remote Sensing Satellite mission of China’ s State Oceanic Administration to retrieve SSS simultaneously with SST and wind. The MICAP features L/C/K multi-band passive measurement capability and L-band active measurement. The new mission objective is to produce SSS with an accuracy of 1 psu at a single measurement and 0.1 psu for monthly averages, with a ground resolution of 50 km and global coverage in less than 3 days. Table 1 presents a comparison between China' s SSS satellite and other operational SSS satellites.

The configuration of the MICAP is briefly introduced in Section II, and the performance simulation method is presented in Section III. The results are presented in Section IV.

2. Microwave Imager Combined Active/Passive

The passive radiometer of MICAP employs an interferometric microwave imaging system to avoid problems associated with manufacturing and oscillation due to mechanical scanning of the large antenna required for traditional real-aperture radiometers. The combined active/passive multi-band microwave remote sensing system utilizes a common parabolic cylindrical-reflector antenna. Fig. 1 [FIGURE:1] shows the schematic diagram of the cylindrical-reflector antenna of MICAP. The L/C/K-band radiometer and L-band scatterometer share the same 3 m × 5.5 m cylindrical reflector, with multi-frequency array feeds arranged along the focal line of the cylindrical reflector. These components implement one-dimensional interferometric radiometry and digital beam-scanning scatterometry simultaneously. The perspective characteristics of MICAP are given in Table 2 .

Compared to the two-dimensional interferometric radiometer onboard the SMOS satellite, the one-dimensional (1D) interferometric radiometer has lower complexity, enabling more accurate temperature control and thus achieving higher stability and calibration accuracy. Compared to the system onboard Aquarius/SAC-D, MICAP can achieve better spatial resolution and a wider swath.

The sensitivity of brightness temperature (TB) to SSS remains high only at low frequencies (~1 GHz, L-band) and decreases rapidly with increasing microwave frequency. The sensitivity of TB to SST remains high in C-band (peaking at 7 GHz), while sensitivity to wind speed is basically consistent at frequencies higher than 10 GHz. Atmospheric water vapor sensitivity is relatively high in K-band (peaking at 23.8 GHz). Therefore, the sensitivity of TB at different frequencies to various physical parameters differs, which forms the basic principle for simultaneous remote sensing of SSS, SST, wind speed, and other parameters with MICAP.

3. Forward Model and Simulation Method

A. Forward Model

The forward model used to compute TB at the top of the atmosphere, without considering Faraday rotation in the Earth reference frame, can be expressed as

$$T_B = \left[T_{b,\text{flat}} + T_{b,\text{wind}} + \Gamma T_{b,\text{DN}} + T_{b,\text{gal\_ref}}\right] e^{-\tau_{\text{atm}}} + T_{b,\text{UP}},$$

where $T_{b,\mathrm{flat}}$ is the brightness temperature for a flat sea, $T_{b,\mathrm{wind}}$ is the wind-induced contribution to sea surface TB, $T_{b,\mathrm{DN}}$ is the downward emitted atmospheric radiation, Γ is the sea surface reflection coefficient computed as $1-(T_{b,\mathrm{flat}}+T_{b,\mathrm{wind}})/\mathrm{SST}$ (which accounts for scattering by the ocean surface assuming $T_{b,\mathrm{DN}}$ is homogeneous in all directions), $T_{b,\mathrm{gal\_ref}}$ is the cosmic and galactic contribution already scattered by the sea surface taking into account directional inhomogeneities of the galactic signal, $T_{b,\mathrm{UP}}$ is the upwelling atmospheric emission to the antenna, and $e^{-\tau_{\mathrm{atm}}}$ is the atmospheric attenuation.

The L-band forward model implemented in the ESA L2OS processor is used. It simulates flat sea emission with the Klein and Swift (1977) model [?] and includes contributions from the rough sea surface, atmospheric emission and absorption [?], and scattering of galactic noise and atmospheric radiation by the ocean surface. The community radiative transfer code RTTOV [?] is used for the C-band and K-band forward model. An L-band ocean geophysical model function (GMF) derived from PALSAR [?] is used for the L-band scatterometer GMF.

B. Retrieval Method

The analysis of sensitivity and stability of MICAP observations is based on a simulated dataset. The retrieval method employs a nonlinear iterative convergence approach. The first-guess geophysical inputs—SSS, SST, wind speed (WS), vapor (V), and cloud liquid water (L)—are adjusted to minimize a cost function χ^2 expressed as

$$\chi^2=\sum_{p=V,H}\sum_{f=1.4,6.9,18.7,23.8}\left[\frac{T_{B,p,f}^{\mathrm{meas}}-T_{B,p,f}^{\mathrm{mod}}}{\Delta T_{B,p,f}}\right]^2+\sum_{p=V,H}\left[\frac{\sigma_{0,p}^{\mathrm{meas}}-\sigma_{0,p}^{\mathrm{mod}}}{\Delta\sigma_{0,p}}\right]^2+\left[\frac{\mathrm{SSS}^{\mathrm{guess}}-\mathrm{SSS}^{\mathrm{init}}}{\Delta\mathrm{SSS}}\right]^2+\Bigg[\frac{\mathrm{SST}^{\mathrm{guess}}-}{\Delta\mathrm{SS}}$$

where V and H denote vertical and horizontal polarization, $T_{B,p,f}^{\mathrm{meas}}$ and $T_{B,p,f}^{\mathrm{mod}}$ are the measured and simulated TB at multiple incidence angles for four frequencies f, $\sigma_{0,p}^{\mathrm{meas}}$ and $\sigma_{0,p}^{\mathrm{mod}}$ are the measured and simulated backscatter at 1.26 GHz, the superscript "init" denotes initial fields of variables, and Δ values represent expected errors for each term.

Monte Carlo simulations are used to analyze the performance of MICAP (Fig. 3

). The simulated data are generated by adding a Gaussian random component to GMF predictions of TB and backscattering, repeated 2000 times. The passive GMFs benefit from SMOS L-band, AMSR-E C-band and K-band models, while the active GMF benefits from the PALSAR L-band model. Retrievals are based on the nonlinear iterative convergence method (Levenberg-Marquardt method).

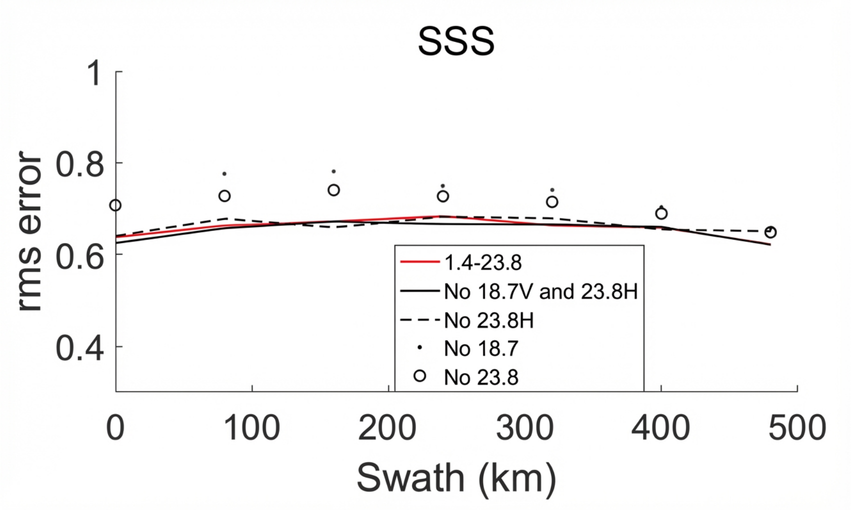

Figure 1: Figure 3

4. Results

In the case studied, root mean square (RMS) errors of SSS, SST, and WS are approximately 0.6 psu, 0.8°C, and 1.0 m/s, respectively, and vary with incidence angle since the radiometric resolution of MICAP changes across the swath (Fig. 4 [FIGURE:4]).

5. Summary

A 1-D interferometric system operating at 1.4, 6.9, 18.7, and 23.8 GHz combined with a scatterometer at 1.26 GHz, called the Microwave Imager Combined Active/Passive (MICAP), has been proposed as the candidate payload for the Ocean Salinity Satellite of China' s State Oceanic Administration. MICAP aims to retrieve SSS while reducing geophysical errors due to surface roughness and SST. The theoretical basis for synergetic retrieval of multi-parameters including SSS using MICAP is introduced, and the instrument' s performance is estimated based on Monte Carlo simulations and a combined active/passive SSS retrieval algorithm. The estimated RMS errors of SSS, SST, and WS are expected to meet the requirements of the Ocean Salinity Satellite of China' s State Oceanic Administration.

Fig. 4 [FIGURE:4] shows error estimates of SSS, SST, and wind speed from MICAP.

We have also tested MICAP performance with alternative configurations: without 23.8 GHz H-pol, without 18.7 GHz V-pol and 23.8 GHz H-pol, without 18.7 GHz H- and V-pol, and without 23.8 GHz H- and V-pol. The RMS error of

SSS without 23.8 GHz H-pol and without 18.7 GHz V-pol is close to that with the default configuration listed in Table 2 (Fig. 5 [FIGURE:5]). However, the RMS error of SSS degrades if either 18.7 GHz or 23.8 GHz is not used (Fig. 5 [FIGURE:5]).

6. References

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