Variability of estimated dielectric constant obtained using theoretical models over Pacific Ocean in open sea for sea surface salinity varying from lower to higher values

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In this paper, the values of dielectric constant (ε) obtained by Blanch & Aguaca (B&A) as well as Klein & Swift (K&S) models using variable salinity in open seas in Pacific Ocean have been studied. The values of dielectric constant derived by B&A and K&S are compared with different salinities ranging 20-50 psu. The analysis has been done on eight days: three days in February and five days in March 2011. Each of these three days of February pair with the other three days of March before Tsunami and remaining two days of March taken after Tsunami pair with each other, in such a way that each pair have nearly same pass over Pacific Ocean and thus, in this way each of these four sets form the four different passes over Pacific Ocean near Japan. This analysis was initially done with Tsunami point of view over Japan which is under process but during this analysis, variability of ε has been seen using two models (B&A and K&S) for variable salinity and the analysis has been presented. This analysis shows that within certain acceptable limits both the models of K&S and B&A are useful for estimating dielectric constant of sea water and understanding the variability of estimated ε with sea surface salinities. The analysis also shows that the dielectric constant goes lower to higher value for B&A and higher to lower values for K&S with increase in the values of salinity.

Keywords: Sea surface salinity, Dielectric constant, Ocean salinity, Soil moisture

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1 Introduction
European Space Agency (ESA) launched Soil Moisture and Ocean Salinity (SMOS) satellite in November 2009. This is the first satellite having radiometer onboard operating at L-band (1.4 GHz frequency). The main objective of SMOS mission is to provide global observations of soil moisture and ocean salinity, which will enhance knowledge in realizing the importance of global hydrological cycle. The 2-D interferometric radiometer, Microwave Imaging Radiometer by Aperture Synthesis (MIRAS), onboard SMOS satellite provides the database of parameters like angle of observation, polarization, wind speed, sea surface temperature, sea surface brightness temperature, etc. Based on these parameters, a number of studies have been carried out by scientists for studying the electrical properties of sea water where they have estimated dielectric constant by different methods. Some of them include Klein & Swift (K&S), Ellison and Blanch & Aguaca (B&A).

This paper aims to study the variability of estimated dielectric constant using theoretical models in open sea for surface salinity varying from lower to higher values. For this analysis, three days have been taken from February and another five days from March that means total eight days. The three days from the months of February along with another three days of March before Tsunami and remaining two days after Tsunami combining with each other, in such a way that each pair shows the same pass in order to make four pairs with different passes of SMOS near Japan over Pacific Ocean and on each strip 45 points have been considered with salinities varying from 20 to 50 psu.

2 Methodology
In this paper, the dielectric constant has been estimated using B&A and K&S models for the sea surface salinity varying from lower to higher values. The variation of ε obtained from B&A and K&S models with sea surface salinity has been compared.
The dielectric constant is derived using the following equations.

The equation for the static dielectric constant in B&A model is given as:

$$\varepsilon_s(T, S) = \varepsilon_s(T, 0) \cdot \alpha(T, S) \quad \ldots (1)$$

where,

$$\varepsilon_s(T, 0) = 87.38 - 3.436 \times 10^{-1} T - 1.912 \times 10^{-3} T^2 + 3.812 \times 10^{-5} T^3 \quad \ldots (2)$$

$$\alpha(T, S) = 1 + 1.1552 \times 10^{-5} TS - 3.9073 \times 10^{-3} S + 3.0596 \times 10^{-5} S^2 \quad \ldots (3)$$

The equation for the static dielectric constant in K&S model is given as:

$$\varepsilon_s(T, S) = \varepsilon_s(T) \cdot \alpha(S, T) \quad \ldots (4)$$

where,

$$\varepsilon_s(T) = 87.134 - 1.949 \times 10^{-1} T - 1.276 \times 10^{-2} T^2 + 2.491 \times 10^{-4} T^3 \quad \ldots (5)$$

$$\alpha(S, T) = 1.000 + 1.613 \times 10^{-5} ST - 3.656 \times 10^{-3} S + 3.210 \times 10^{-5} S^2 - 4.232 \times 10^{-7} S^3 \quad \ldots (6)$$

where, for both the models, S is sea surface salinity and T is sea surface temperature.

### 3 Results and Discussion

Figure 1 illustrates the descending pass of 16 February 2011 over Pacific Ocean. The nearly same descending pass of SMOS satellite repeats on 03 March 2011 also, this figure gives the representation of descending pass on 16 February 2011 and 03 March 2011 over Pacific Ocean. Similarly, Fig. 2 illustrates the descending pass of 25 February 2011 and 07 March 2011 over Pacific Ocean and Fig. 3 illustrates the descending pass of 12 March 2011 and 25 March 2011 over Pacific Ocean. The SMOS ascending pass of 21 February 2011 and 01 March 2011 are shown in Fig. 4. The purple blocks shown in the snapshots depict the region on which 45 points have been considered for the analysis.
Here, the Figs [5(a-d), 6(a-b)] show the descending passes of SMOS over Pacific Ocean, which is the variation in the values of dielectric constant with respect to sea surface salinity for 16 February 2011, 03 March 2011, 25 February 2011, 07 March 2011, 12 March 2011 and 25 March 2011, respectively.

Fig. 5 — Estimated values of dielectric constant using B&A and K&S vs values of sea surface salinity (SSS1) on: (a) 16 February 2011; (b) 03 March 2011; (c) 25 February 2011; and (d) 07 March 2011
Similarly, the variation in the values of $\varepsilon$ with respect to sea surface salinity can also be studied from Figs 6(c and d) for 21 February 2011 and 01 March 2011 for the same ascending pass of SMOS.

It can be seen from the graphs that the dielectric constant estimated using B &A is less as compared to K&S when salinities vary from 20 to 30 psu, and in the range 30-34 psu. The estimated values of
dielectric constant remains same for both the models, but in the case of higher values of salinities starting from 34 to 50 psu, the dielectric constant of B&A is higher when it is compared with K&S. Here, for this paper only, the Sea Surface Salinity1 (SSS1) values of SMOS data have been considered.

4 Conclusions
From above graphs, it is clear that estimated dielectric constant ($\varepsilon$) using B&A is less as compared to K&S for salinity from 20 to 30 psu and for higher values of salinity starting from 34 to 50 psu, the $\varepsilon$ obtained from B&A model is greater as compared to K&S model and for salinities 30 to 34 psu, the $\varepsilon$ estimated by both B&A and K&S models is nearly equal. So, one can use any of models for salinity values from 30 to 34 psu but for lower salinity (20-30 psu) and for higher salinity (34-50 psu), both B&A as well as K&S models give opposite values of $\varepsilon$ that is the B&A model gives lower values of $\varepsilon$ for lower salinity, whereas K&S model gives higher value of $\varepsilon$ for lower salinity and the trend reverses for higher value of salinity. However, as it is known\(^5\)\(^6\) that the value of $\varepsilon$ is higher at lower salinity and lower at higher salinity which is due to the fact that the $\varepsilon$ of water\(^7\) is around 80 and the $\varepsilon$ of salt\(^7\) is between 3 to 15 and thus, when large quantity of salt is added to water, the $\varepsilon$ decreases and in case when quantity of salt is less as compared to water, then $\varepsilon$ of water becomes more prominent. This behaviour of $\varepsilon$ is validated in K&S model as at lower salinities, it gives higher $\varepsilon$ values and at higher salinities, it gives lower $\varepsilon$ values, whereas B&A model contradicts the behaviour of $\varepsilon$. Thus, one can say that K&S model is more suitable as compared to B&A.

The data used for analysis are of February and March. These data were taken to study effect of Tsunami on variability of salinity. But in this paper, only the behaviour of models is discussed. This effect of Tsunami will be discussed separately. This work provides a new insight to oceanographers.

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