PARMIO: A reference quality model for ocean emissivity and backscatter from microwave to infrared wavelengths

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The lack of a reference-quality ocean emission and backscatter model has been recognised as a gap in the traceability of radiative transfer modelling for Earth observation. The International Space Science Institute (ISSI) sponsored a multinational team to develop new model capability. The resulting **Passive and Active Reference Microwave to Infrared Ocean (PARMIO)** model is a two-scale model which superimposes the effect of small-scale roughness (scattering) on top of the influence of large-scale waves (geometric optics). Recent advances in the contribution due to foam are included in the model. Optical properties of seawater combine a state-of-the-art dielectric constant in the microwave region with complex permittivity data extending up to 660 nm. PARMIO will be maintained in the long-term as a reference model, and is available in fast model form for the microwave region (SURFEM-Ocean) in the latest release of RTTOV.

ISSI science team

In late 2019 an international science team of the International Space Science Institute (ISSI) was formed.[1] Its goal was to develop a community reference-quality ocean emission and reflection model for use across a broad spectral range, supporting both passive and active remote sensing. The lack of a reference model was identified during the EU GAIA-CLIM project[2] as a key gap in the absolute calibration of Earth observations.

The team collaborated on updated code, based on existing[3,4] work: the Passive and Active Reference Microwave to Infrared Ocean (PARMIO) model.

Theoretical basis

The foam-free fraction of the ocean surface is represented using a two-scale model. Here (Fig. 1) roughness scales are treated according to size relative to the electromagnetic wavelength. The scattering effect of small-scale waves, modelled using the small perturbation method (SPM), is superimposed on the contribution due to large-scale slopes (geometric optics). The separation of the two scales is defined using an adjustable cutoff wavenumber.

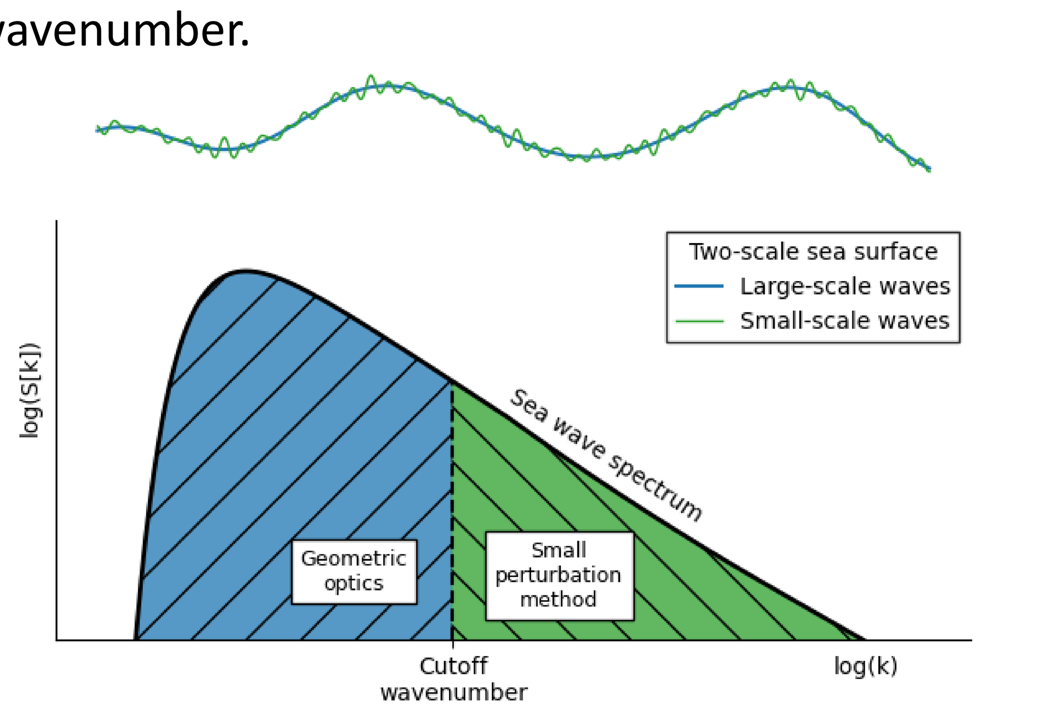

Fig. 1 Pictorial representation (top) of a two-scale sea surface. The graph, of sea wave spectrum S as a function of wavenumber k, illustrates the use of a cutoff wavenumber to separate the treatment of large-scale (blue) and small-scale (green) waves.

PARMIO may be configured with various statistical models of the surface roughness, such as the Durden and Vesecky sea spectrum.[5] The geometric optics calculation may optionally use a slope variance relationship e.g. Cox and Munk.[6] The latest version of PARMIO includes an improved treatment of multiple surface reflections.

Seawater optical properties

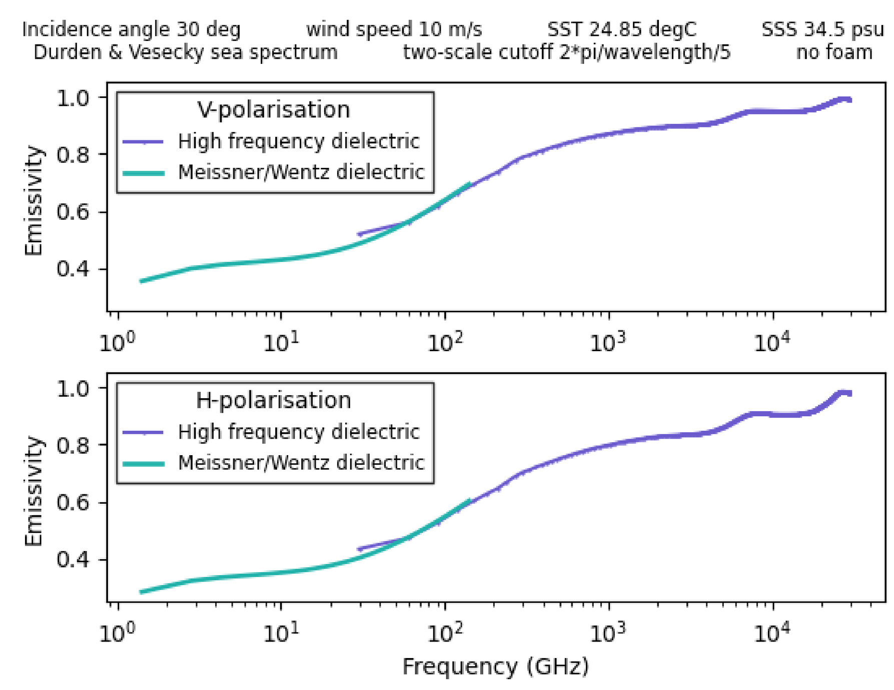

Fig. 2 Example PARMIO emissivity calculation for V- and H-polarisations using Meissner/Wentz seawater dielectric properties between 1.4-141 GHz and high frequency dielectric tabulation between 30-30,000 GHz (two-scale treatment at all frequencies).

PARMIO allows the user to select the formulation for seawater optical properties. Several dielectric models provide temperature and salinity dependent properties in the microwave region,[7] while a tabulated set of refractive indices extend up to 660 nm. Together, these data allow the calculation of sea surface emission/reflection spanning the microwave to infrared regions (Fig. 2).

Treatment of foam

A foam dielectric model and foam coverage model (both have options in PARMIO) are used to simulate the contribution due to sea foam. Treating foam as a multi-layered medium with varying vertical air fraction (see Fig. 3) leads to foam permittivity varying with depth. The foam coverage fraction is typically a power law function of the surface wind speed. The ISSI team developed tuned foam parameterizations to be used in PARMIO: (i) adjusting the foam thickness and vertical air fraction as a better fit to radiometric data between 1.4–89 GHz;[8] (ii) adjusting foam coverage and emissivity models for SURFEM-Ocean.[9]

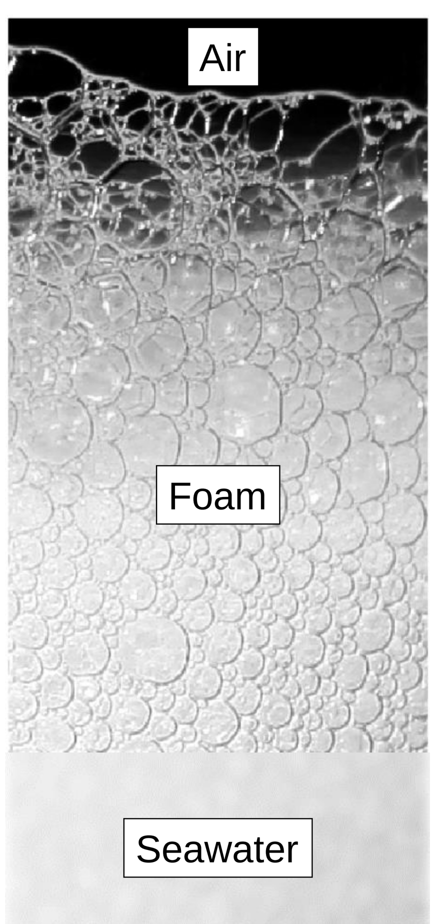

Fig. 3 Visualisation of stratified foam layer. Image: B. Somosvári PhD thesis.

Fast model and validation

PARMIO has been used to train a fast passive microwave emissivity code (SURFEM-Ocean) which is available in RTTOV v13.2. A neural network was used to train the fast model.[9] Validation with GMI (Fig. 4) suggests SURFEM-Ocean is competitive with FASTEM-6 for NWP. Work remains to improve the performance of PARMIO for active sensors.

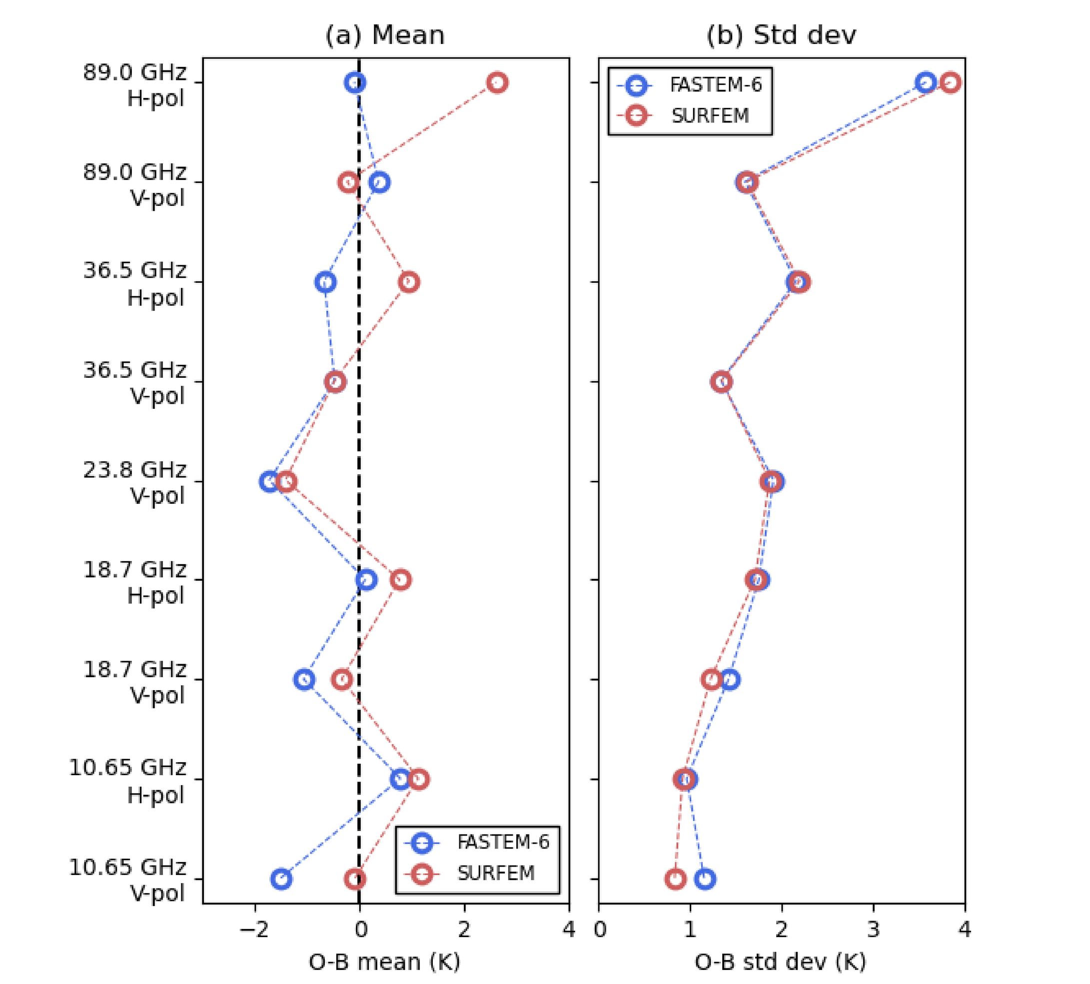

Fig. 4 Preliminary assessment of GMI observed-background (O-B) departures at the Met Office: (a) mean O-B, (b) std. dev. O-B comparing FASTEM-6 against SURFEM-Ocean. (NWP-SAF Radiance Simulator running RTTOV 13.2 with Met Office model fields for 48 hours of data from April 2018. GAIA-CLIM methodology was used.)

PARMIO will soon be released publicly. The reports and findings of the ISSI team are available at http://www.issibern.ch/teams/oceansurfemiss/.

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