Machine Learning Applications in Community Surface Emissivity Modeling (CSEM) System
Ming Chen¹, Kevin Garrett²

1. CISESS-University of Maryland 2. NOAA/NESDIS/Center for Satellite Applications and Research

Introduction

The Community Surface Emissivity Modeling (CSEM) system developed at NOAA/NESDIS/STAR will be used in the next major release of the Community Radiative Transfer Model (CRTM) to support the direct radiance assimilation of satellite surface sensitive channels and to provide accurate surface emissivity condition in support of the quality-control processes of data assimilation. Both model accuracy and model computing efficiency are essential for data assimilation.

Machine learning techniques have been applied in developing the accurate and fast CSEM models from physically sound but computationally expensive physics models and from enormous observation data.

We present our latest work on utilizing the machine learning (ML) techniques to reconstruct fast microwave surface ocean emissivity from a computationally expensive two-scale physics model, and to develop prognostic land surface microwave emissivity model from the instantaneous satellite retrievals.

CRTM Ocean Surface Microwave Emissivity Model

The MW ocean surface emissivity model (FASTEM) in CRTM is a fast emulator of the two-scale physics model by Yool, 1997.

- Full Stokes Model (Yool, 1997):

\[ I = \frac{\sin(\theta)}{R^2} \sum_{i} A_i \left( \begin{array}{c} \sin(\theta) \\ \cos(\theta) \end{array} \right) \left( \begin{array}{c} e^{i k R} \\ e^{-i k R} \end{array} \right) \]

where \( I \) is Stokes vector for scattered waves, and \( A_i \) is phase model.

- Hybrid setting of the activation function types for different layers

\[ X_{k+1} = (X_k - J'(X_k)(X_k + \mu X_k))^{-1}J(X_k) \]

where \( J(x) \) is Jacobian Matrix

\[ J(X) = \begin{bmatrix} \frac{\partial v_1(X)}{\partial x_1} & \frac{\partial v_1(X)}{\partial x_2} & \cdots & \frac{\partial v_1(X)}{\partial x_n} \\ \frac{\partial v_2(X)}{\partial x_1} & \frac{\partial v_2(X)}{\partial x_2} & \cdots & \frac{\partial v_2(X)}{\partial x_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\partial v_n(X)}{\partial x_1} & \frac{\partial v_n(X)}{\partial x_2} & \cdots & \frac{\partial v_n(X)}{\partial x_n} \end{bmatrix} \]

- Steepest descent if \( \mu \) is very large, and Gauss-Newton if \( \mu \) is near zero, and otherwise Levenburg-Marquardt

CSEM Model Improvements & Functionality Expansion

- A new FASTEM version (NFASTEM) has been developed, which is based on physical two-scale ocean surface emissivity model and the latest machine learning technique. All the Stokes components of NFASTEM are in good agreement with the OBSERVATION in terms of both magnitude and phase.

- With adequate NN architecture (hidden layers, neurons of each layer, etc), multi-layer perceptron learning system is able to approximate complex physics models of high nonlinearity. It is found that NFASTEM may emulate the original two-scale ocean surface emissivity model at very high accuracy from 1GHz to 700GHz, and view angle from 0° to 85°.

- The tangent linear and adjoint modules of the ML-based MW land physical model were also implemented to support the radiance data assimilation of surface key variables.

References


Contact: ming.chen@noaa.gov