



DEEP GENERATIVE REGRESSION MODELS FOR SOIL MOISTURE RETRIEVAL FROM GNSS-R OBSERVATIONS

G. Tsagkatakis* ^(1,2), A. Melebari⁽³⁾, R. Akbar⁽⁴⁾, J. D. Campbell⁽³⁾, E. Hodges⁽³⁾ and M. Moghaddam⁽³⁾

(1) Institute of Computer Science, FORTH, Greece e-mail: greg@ics.forth.gr

(2) Computer Science Department, University of Crete, 73100, Greece,

(3) Department of Electrical and Computer Engineering, University of Southern California, CA 90007 USA (e-mail: jamesc91@usc.edu, ehodges@usc.edu, amelebar@usc.edu, mahta@usc.edu).

(4) Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, Cambridge, MA 02139 USA (e-mail: rakbar@mit.edu).

Soil moisture content (SMC) is a crucial component in both the water and carbon cycles, significantly influencing weather and climate. Over recent years, numerous remote sensing platforms have been established to track soil moisture. Leading missions, such as NASA's SMAP and the ESA's SMOS, offer global-scale coarse-resolution soil moisture monitoring using active and passive microwave imaging at a moderate revisit frequency on the scale of days. Regrettably, current products' spatial and temporal resolution is often insufficient for many applications. Global navigation satellite system reflectometry (GNSS-R) is a prime example of a signal-of-opportunity (SoOP) which has been shown to be highly sensitive variations of SMC. An important source of such signals is the NASA Cyclone GNSS (CYGNSS) mission which consists of eight low-orbit observatories, each utilizing a zenith antenna to receive direct global positioning system (GPS) signals, as well as two nadir-looking antennas to receive reflected GPS signals, that are used to derive a delay-Doppler map (DDM). In order to extract SMC from DDM signals, the traditional approach involves inverting parameterized forward models which account for aspects like dielectric properties of the soil incidence angle among others. Despite their grounding in physical processes, these models typically involve simplified assumptions and demonstrate increased sensitivity to the values of different parameters. To address this challenge, a new line of research tries to address this challenge by utilizing machine learning models and treating the problem as that of supervised regression e.g.¹.

In this work, we propose a novel deep generative regression (DGR) model for instantaneous SMC retrieval from CYGNSS observations and ancillary data. The proposed model consists of two sub-networks that combine the characteristics of an autoencoder and a regression model. Specifically, the first sub-network is an autoencoder, a type of generative neural network used for learning efficient data encoding in an unsupervised manner. The purpose of the autoencoder is to learn a representation (encoding) for a set of data, by training to reconstruct the inputs, CYGNSS DDMs in this case. The second sub-network is a regression model, which is tasked to predict the SMC, using features extracted from the CYGNSS observations and ancillary data. A high-level block diagram of the proposed scheme is shown in Fig. 1. To train and validate the proposed framework, we consider observations from the SMAP Yanco site in Southeast Australia that houses 13 stations, each equipped to measure soil moisture, temperature, and precipitation every 20 minutes. To quantify performance, 70% of the observations were utilized for training the model, and the rest for validation. Fig 2 presents scatter plots from the training and validation cases. We observe that the performance is excellent for the training data (unbiased RMSE 0.015) while some overfitting effects are present in the validation dataset (unbiased RMSE 0.041)

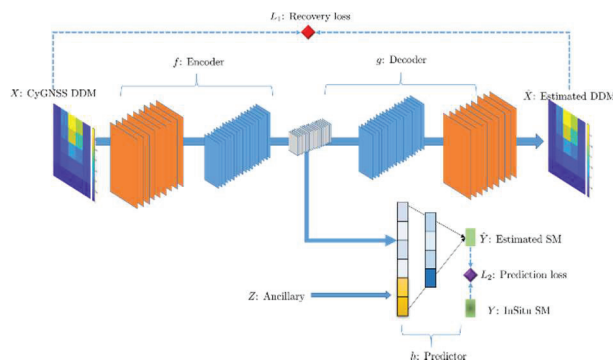


Figure 1: Block diagram of proposed deep generative regression model for SMC retrieval.

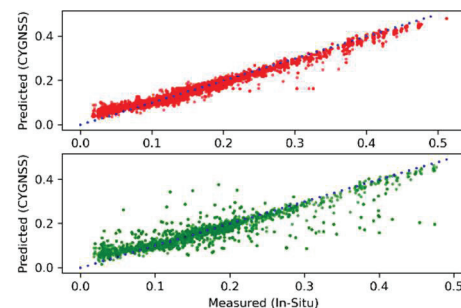


Figure 2: Scatter plots of in-situ and retrieved SMC for training (top) and validation (bottom) datasets.

¹ M.M., Nabi, et al. "Deep Learning-Based Soil Moisture Retrieval in CONUS Using CYGNSS Delay-Doppler Maps." IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing 15 (2022).