PERFORMANCE EVALUATION OF THE SEMI-EMPIRICAL SOLAR ESTIMATION MODEL BASED ON SATELLITE DATA ENHANCED WITH GROUND MEASUREMENT

Onon Bayasgalan *[1], Atsushi Akisawa [1] Tokyo University of Agriculture and Technology (TUAT), Tokyo, Japan

Kenji Otani [2], Jun Hashimoto [2] Fukushima Renewable Energy Institute (FREA), National Institute of Advanced Industrial Science and Technology (AIST), Koriyama, Japan

Amarbayar Adiyabat [3] National University of Mongolia (NUM), Ulaanbaatar, Mongolia

INTRODUCTION

- Solar resource assessment is of great importance to the *efficient and economical use of solar devices*.
- Although the ground weather station provides the most accurate measurements of solar irradiance, its *accuracy degrades as the distance* from the ground monitoring site increases [1].
- Fortunately, remote sensing satellite data can be used for effectively monitoring *solar resources over a wide geographical area*.

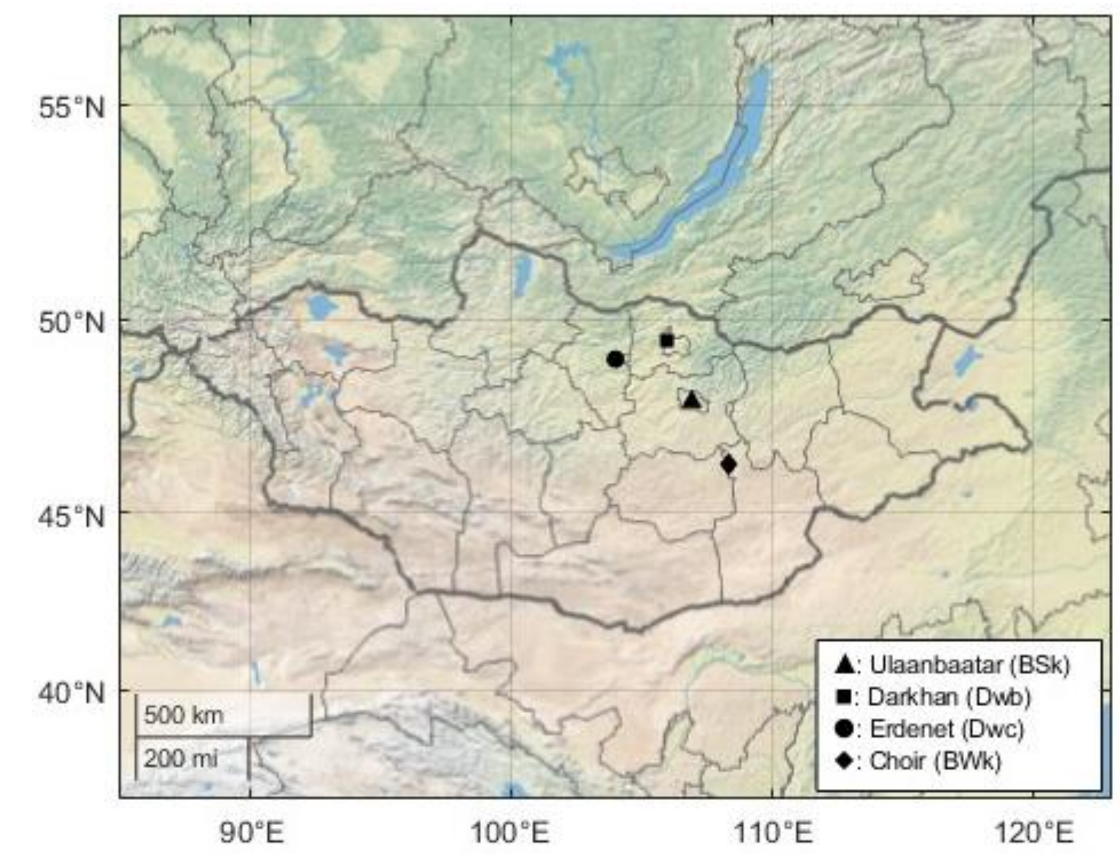
OBJECTIVE

The goal of the current study is to develop a semi-empirical solar estimation model by improving the previous study of Otani et al [2]:

- Considers the *high-resolution satellite data* retrieved from the *Himawari series*.
- Reduces uncertainty of *ground albedo* by using long-term measurement.
- Introduces correction to match the satellite observation to the corresponding *ground measurement*.

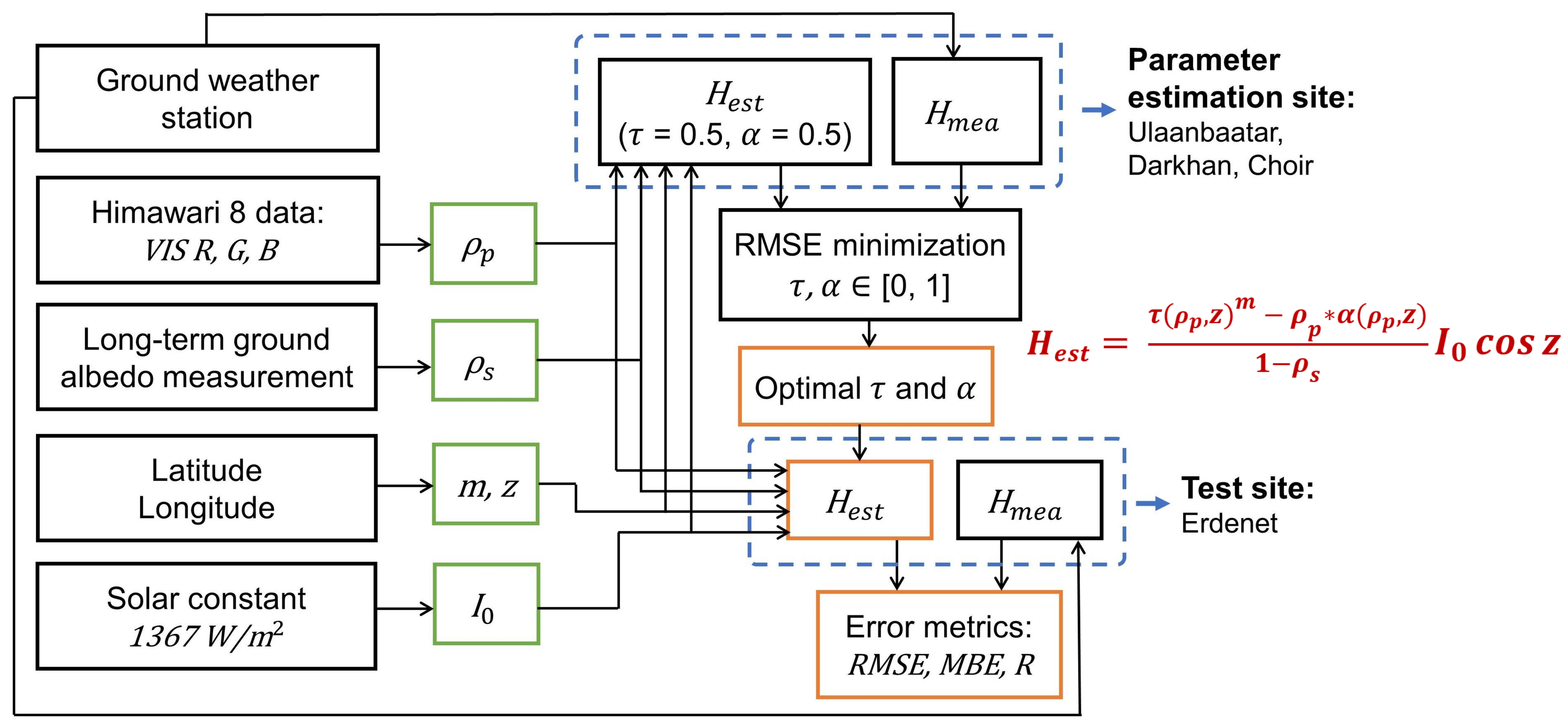
DATA AND METHOD

- **GHI measurements at different climates of Mongolia.**
  - Duration: 3 years from 2018/08 – 2021/07 with an interval of 10 minutes.



Climate classification of ground measurement sites is abbreviated as [3]: BSk - arid, steppe, cold; Dwb - cold, dry winter, warm summer; Dwc - cold, dry winter, cold summer; BWk - arid, desert, cold.

- **Satellite reflectance data from Himawari 8 [4].**
  - *Visible RGB channels*: centered at 0.47 µm, 0.51 µm, and 0.64 µm, respectively.
  - Spatial and temporal resolution: *2 km and 10 minutes*.

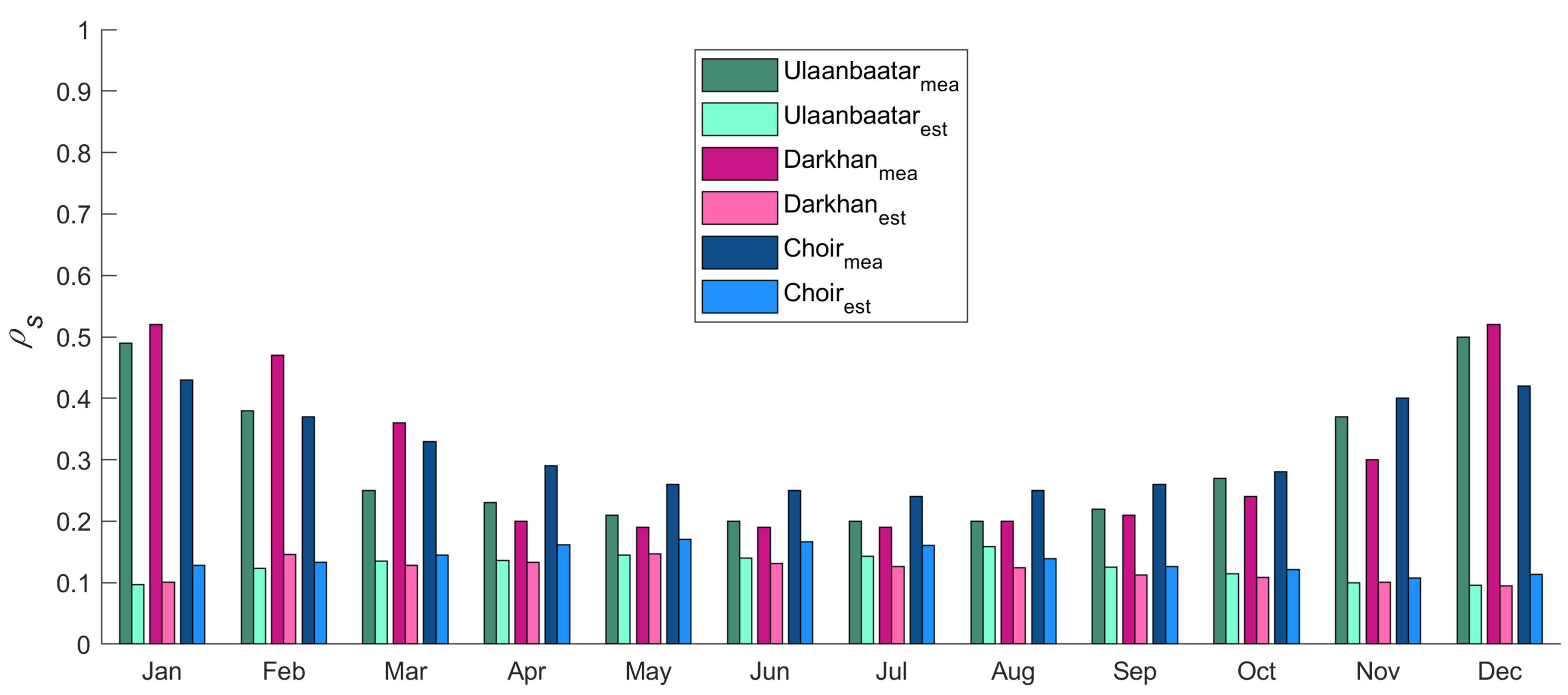


Schematics of the study design: inputs and outputs are shown in green and orange boxes, respectively. The equation to estimate the GHI is written in red.

RESULTS

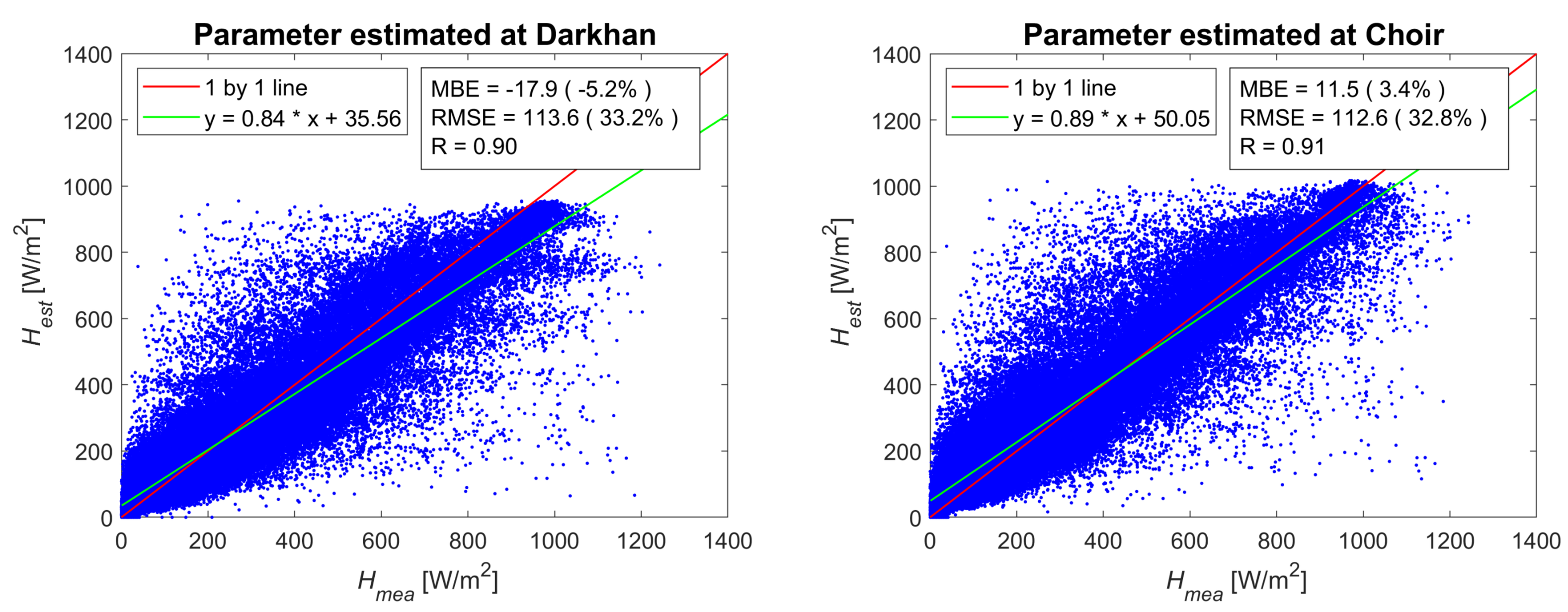
**It should be noted that only selected sites are illustrated here because similar results were obtained between ground measurement sites.*

- The monthly surface albedo is *systematically underestimated* when compared to long-term measurement, especially for winter months.
- The *seasonal trend* of the estimated ground albedo was the opposite of the long-term measurement, where ground albedo is slightly higher in summer than in winter despite the ground being no longer covered by *highly reflective snow*.



Estimated vs measured monthly ground albedo at selected ground measurement sites

- There was not a significant difference between results using different parameter estimation sites/climates in terms of RMSE and correlation coefficient.
- While the negative biases were present for Ulaanbaatar and Darkhan sites in the central and northern parts, the Choir site resulted in positive bias. This may be related to its lower albedo during the winter months caused by the desert climate. Because lower brightness data in the visible spectrum can be *misinterpreted as a clearer atmosphere*, it is highly probable to *overestimate the surface radiation*.



Model performance evaluation at the test site: Erdenet

CONCLUSION

- The *remote sensing data allows us to monitor solar resources* with known uncertainty on a large scale.
- Because *ground albedo plays an important role* in separating surface information from the visible channel satellite data, it should be neatly optimized.
- As opposed to the initial assumption that error metrics would be lower when similar climates are used for parameter estimation and model evaluation, *the weight of the climatic differences is small*.

FUTURE WORK

- Since capturing *cloud info* from the visible channel satellite data is hard, additional data sources regarding cloud fraction, optical depth, and structure should be included in the modeling, such as utilizing an *all-sky imager*.
- Considering the continuously increasing installation of PV and the intermittent nature of solar energy, highly accurate *solar forecasting* methods should be developed as a countermeasure to the ramp events. Because *deep learning models* are showing promising results in various prediction tasks, they should be explored further.

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CONTACT

bayasgalanonon@gmail.com

s227389t@st.go.tuat.ac.jp