Neural Network Model to Retrieve Solar Shortwave Irradiance from All-sky Camera Images

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Introduction

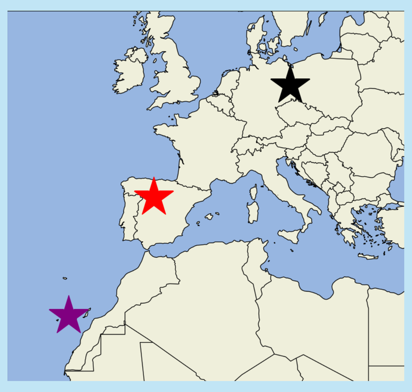
The present work proposes a new model, based on a convolutional neural network (CNN), to retrieve the solar global horizontal irradiance (GHI) through the cloud modification factor (CMF) estimation, from daytime sky images captured by all-sky cameras; this model is named as CNN-CMF.

Instrumentation and Sites

1) **Instruments:**
   a) **All-sky cameras:**
      - OMEA-3C (*Alcor System*) model.
      - Controlled by the *GOA-OMEA Capture* application.
      - Configured to take daytime images every 5 minutes.
      - 8-bits High Dynamic Range (HDR) 2000x2000-pixel pictures.

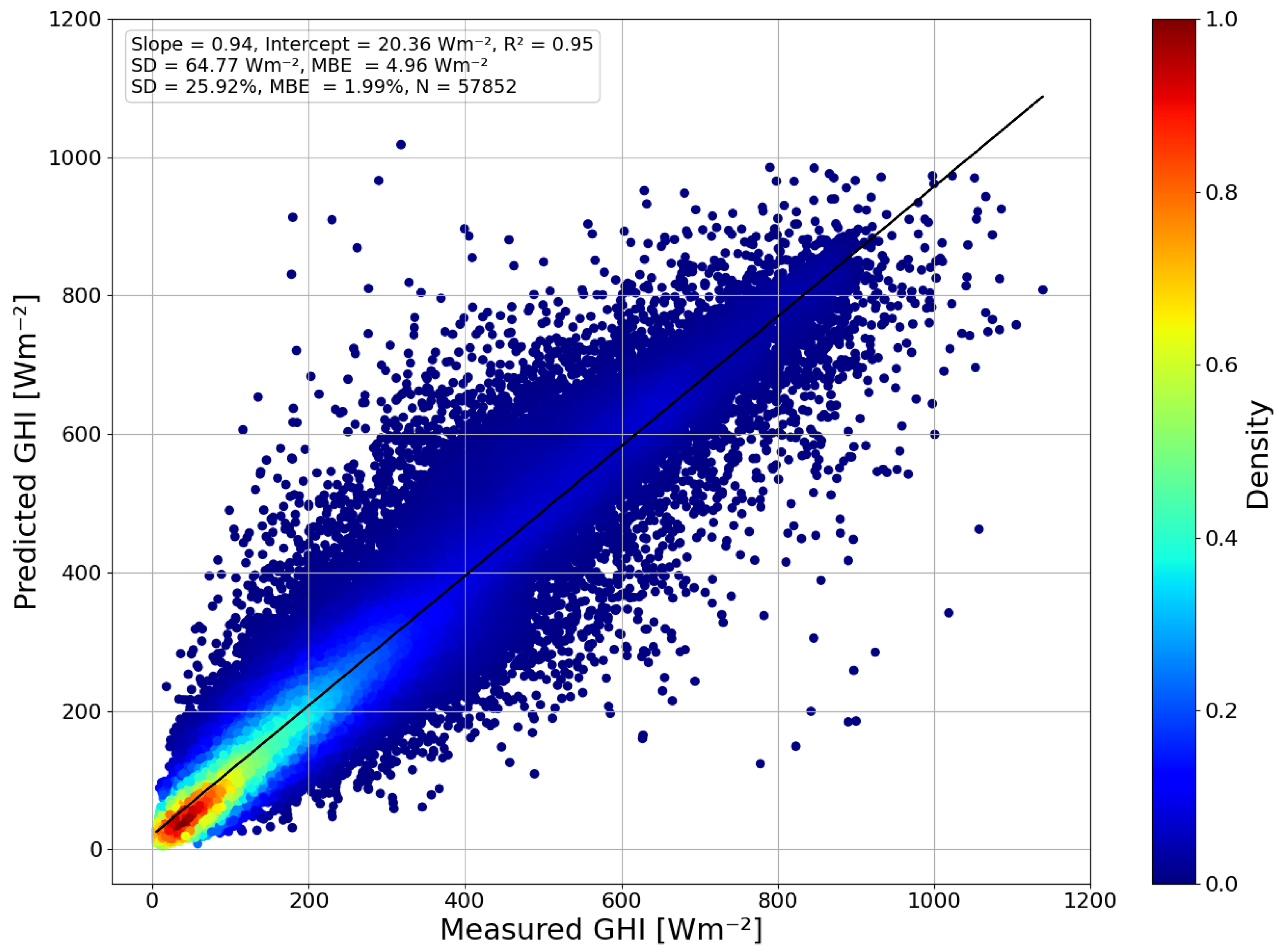
   b) **Pyranometers:**
      - *EKO Instruments:*
        - ★ MS-802F
      - *Kipp & Zonen*:
        - ★ CMP-11
        - ★ CM-21
        - ★ CM-22

2) **Sites:**
   - ★ Valladolid (41.66ºN, 4.71ºW, 705m)
   - ★ Izaña (28.30ºN, 16.49ºW, 2400m)
   - ★ Lindenberg (52.21ºN, 14.12ºE, 122m)
   - ★ Marambio (64.24ºS, 56.52ºW, 200m)



GHI Results

Comparing the predicted GHI values against the pyranometer measurements at Marambio, the results show correlation with a R^2 value of 0.95. Some data pairs present high dispersion, which provides a higher value of SD about 26%, while the obtained MBE is about 2%.



Dataset Classification

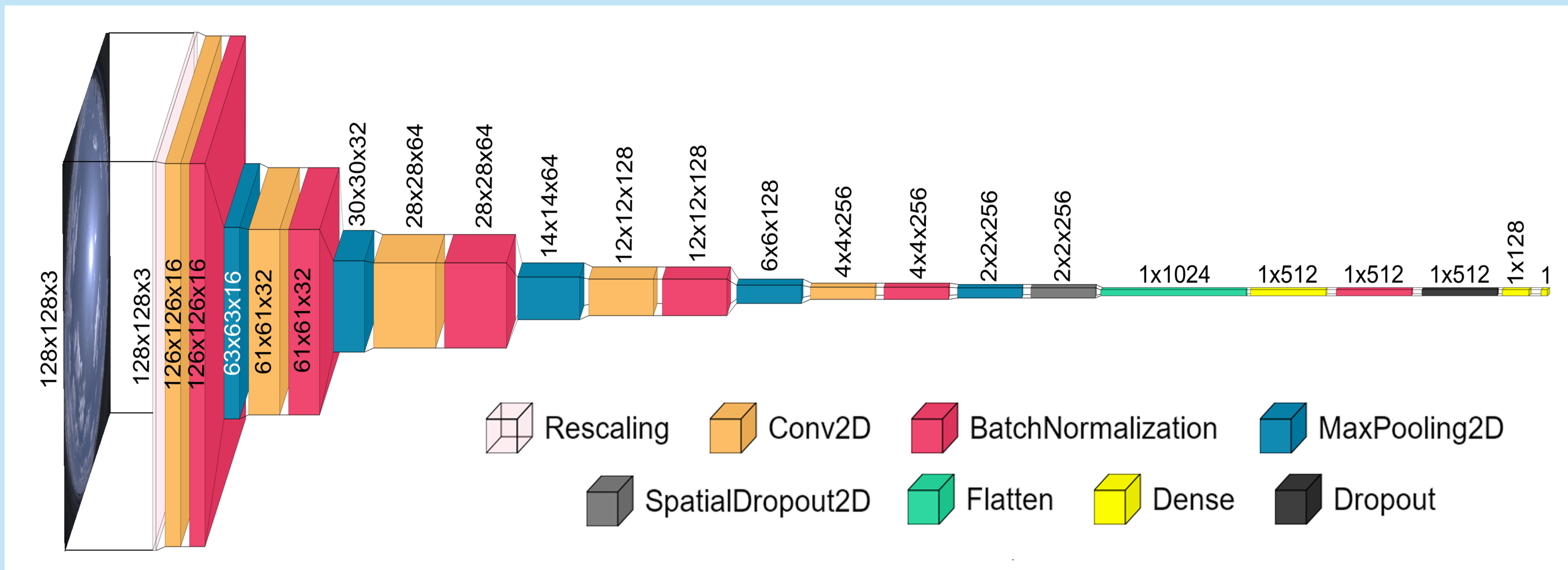
All the data have been filtered to avoid noisy results that introduce a high uncertainty in the CMF values:
- Solar zenith angle (SZA)>85º.
- GHI<5 Wm^{-2}.
- $|GHI\text{-}GHI{\pm}1_{min}|>30\%$.

The filtered datasets have been classified as follows:
1) 237669 sky images classified for training and test the model at Valladolid, Izaña and Lindenberg.
2) 57852 sky images classified at Marambio to evaluate the model.

Site	Initial dataset	Filtered dataset	Train dataset	Validation dataset	Test dataset
Valladolid	82865	70962	25654	7096	38212
Izaña	46509	41327	6104	4133	31090
Lindenberg	146575	125380	54679	12539	58072
Total	275949	237669	86527	23768	127374

Model

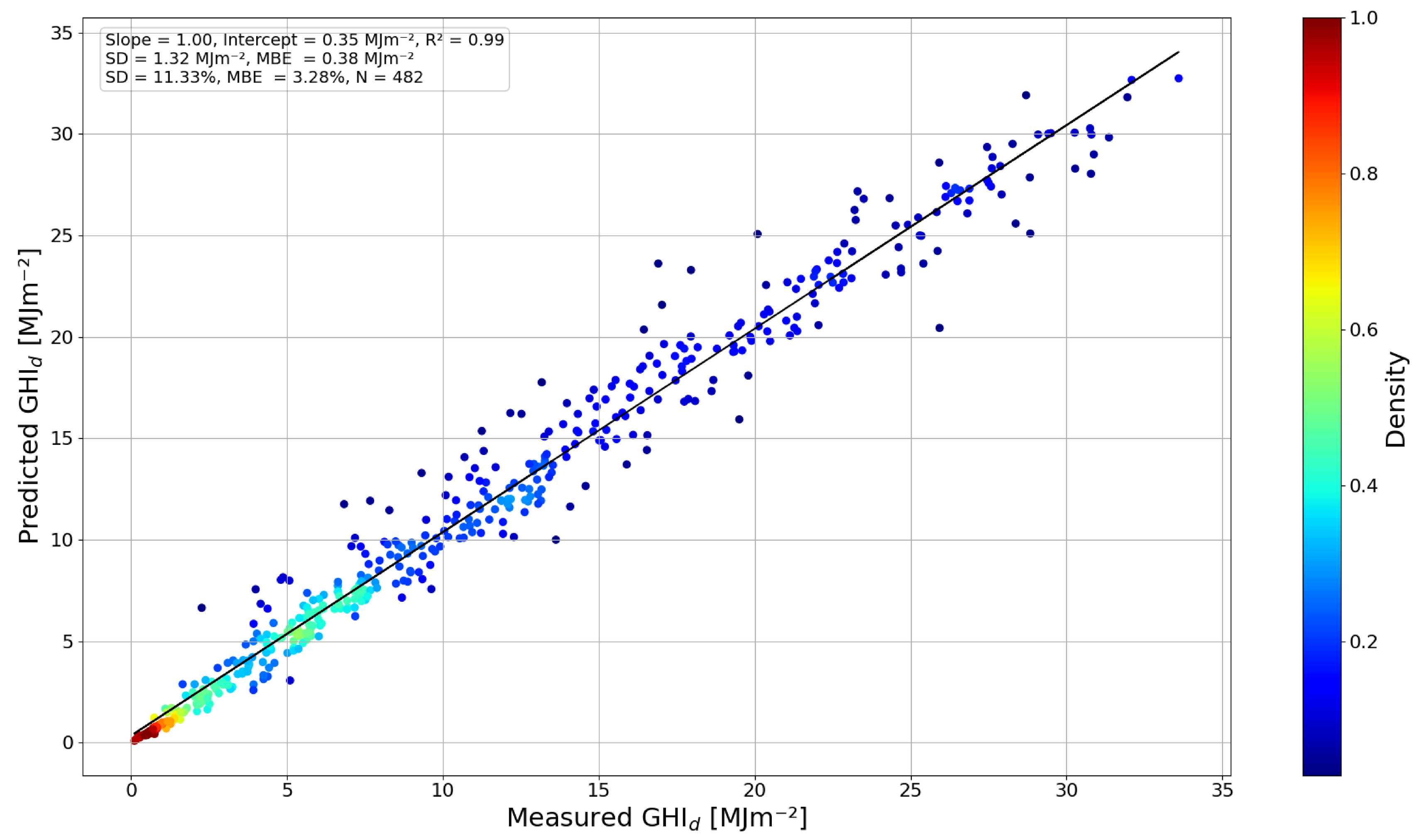
CNN-CMF model:
- Designed with Keras.
- Processes 128x128x3 pixel HDR sky images.
- Uses data augmentation to increase variety and reduce correlation.
- Training uses mean squared error (MSE) loss with the Adam optimizer and dynamic learning rates.
- Preventing overfitting stops training if validation set loss is not improved for 10 consecutive epochs.



- $CMF = \frac{GHI_{meas}}{GHI_{cf}}$ ⟶ 'meas': measurements and 'cf': cloud-free. GHI_{cf} are simulated with the *libRadtran-2.0.5* package.
- All-sky images ⟶ classified in [0.01, 1.30] every 0.01 CMF value.
- Model's test gives high correlation between the measurements and the predicted values with a R^2 of 0.97.
- The standard deviation (SD) is around 9% and the mean bias error (MBE) is near -2%.

GHI Daily Results

In this case, the comparison between the model and the measured values show higher correlation with a R^2 of 1.00. The SD presents better precision with a value near 11%, while the MBE is now around 3%.



Conclusions

- We recommend using the model for GHI time series reconstruction and comparing the model with other measurements to enhance uncertainty quantification.
- While pyranometers remain the gold standard for monitoring solar irradiance, this model offers a viable alternative proving to be a good proxy for estimating GHI.
- Future work will involve using long-term series to reconstruct shortwave radiation values and assess the model's ability to predict trends observed in periods like global brightening or dimming.

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