The National Climate Data Base (NCDB): A Bias-Corrected High-Resolution Climate Dataset

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1. INTRODUCTION

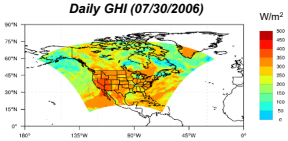
- Assessing solar energy resources under future climate scenarios has been highlighted to understand potential impacts of future climate change in solar generation on the power sector.
- Climate model projections have been recognized by the renewable energy community as a useful data set to analyze the impacts of future climate change on renewable resources.
- However, spatial and temporal resolutions of the GCMs (e.g., ~100 km and daily for spatiotemporal resolution) are too coarse for regional climate studies.
- Usually, regional solar resource assessments under future climate are performed using downscaled general circulation models (GCMs) using either-
  - regional climate models (RCMs) or
  - statistical/machine-learning based approaches.
- The main purpose of this study is to **develop statistical methods within an efficient framework** for downscaling future climate data sets tailored for solar energy applications.
- The **National Solar Radiation Database (NSRDB) (Sengupta et al. 2018)** is used to build and calibrate the statistical downscaling models with:

1) Bias-correction, 2) Temporal downscaling, and 3) Spatial downscaling

2. DATA

RCM Data

CanRCM4 forced by CanESM2 Daily GHI (07/30/2006)

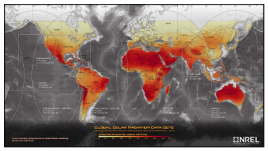


Feature	Specification
Forcing data (GCM)	CanESM2
Spatial resolution	0.22°
Temporal resolution	Daily
Variable	GHI
Data period	2006-2100
Scenarios	RCP4.5 and RCP8.5

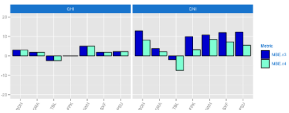
- RCM-based climate projections obtained from the North American Coordinated Regional Climate Downscaling Experiment (NA-CORDEX; https://na-cordex.org/) are used as inputs to the proposed statistical methods.
- We selected daily GHI simulated by the Canadian Regional Climate Model 4 (CanRCM4) forced by the second-generation Canadian Earth System Model (CanESM2).

Satellite-derived Observations

NSRDB



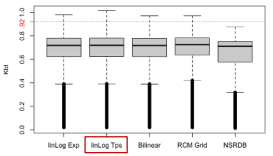
Mean Bias Error (MBE) for NSRDB compared to surface observations



- In order to be comparable with the RCM spatial resolution (0.22°), the 4-km NSRDB was averaged and aggregated to a 20-km grid.
- Jiménez et al. 2022 demonstrated that the accuracy of NSRDB is sufficient for regional model evaluation (e.g., WRF-Solar).

Regridding RCM Data to NSRDB Grid

Clear-sky index for different regridding methods

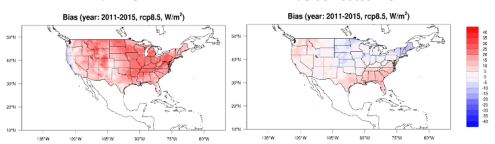


- Regridding RCM data (0.22° spatial resolution) to the 20-km NSRDB grid is the first step in downscaling the climate projections of solar irradiance.
- The uncertainty associated with this step was studied in Bailey et al. (2022) using a Bayesian hierarchical model.
- Bailey et al. (2022) showed that any uncertainty attributable to the regridding step in downstream modeling is negligible.
- We selected thin-plate splines (TPS) as a final spatial analysis method to regrid the RCM outputs to the 20-km grid.

3. BIAS CORRECTION

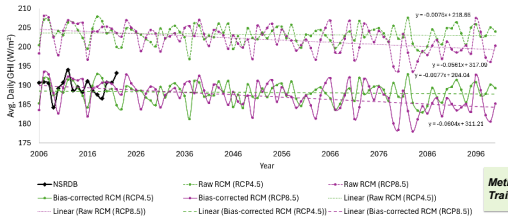
- We employed a bias correction technique based on quantile mapping (McGinnis et al. 2015) to reduce bias of RCM GHI.
- The quantile mapping method efficiently reduced the warm bias of RCM GHI for most regions across CONUS and produced a GHI bias within ± 20 W/m² in an out-of-sample application.

Raw RCM ***Bias corrected RCM***



95-years Bias-corrected GHI Projections

Daily GHI (2006-2100; RCP4.5 and RCP8.5)

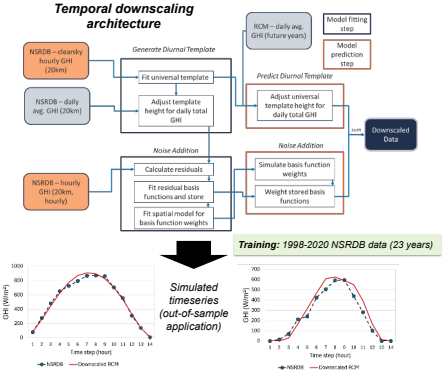


- The bias-correction method applied to the raw RCM conserves both the trend and pattern of the raw RCM GHI.
- This indicates that the quantile mapping reduces the bias of RCM GHI without adversely impacting the RCM's ability to represent future projections of solar irradiance trend and variability.

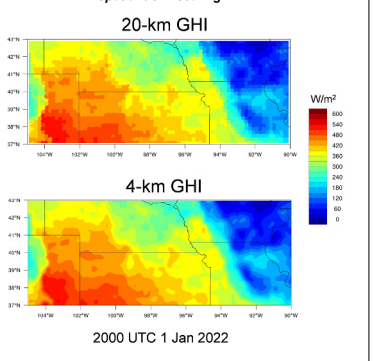
Method: *Quantile mapping*
Training period: *2006-2020 (15 years)*

4. TEMPOROAL AND SPATIAL DOWNSCALING

Temporal downscaling architecture



Spatial downscaling



- Bias-corrected daily GHI is used as input to the temporal downscaling model.
- Significant effort was made to produce hourly-scale clouds representative of NSRDB cloud distributions.
- We developed 1) the diurnal template model and 2) the residual basis functions and trained the models using the NSRDB data.
- Spatially correlated cloud patterns are also considered through spatial model simulating noise.
- MBE of downscaled GHI is less than 3% against the NSRDB (for CONUS).

- We developed a spatial model based on TPS to downscale the 20-km RCM data to 4-km resolution.
- The TPS smoothly downscales the RCM GHI data from the coarse resolution (20 km) to high-resolution (4 km) and conserves the spatial pattern of GHI.
- The empirical Direct Insolation Simulation Code (DISC) was used as a postprocessing tool for generating the 4-km DNI projections.
- For CONUS, the hourly-4-km climate projection showed a slight cold bias for GHI (-2.7%) and DNI (-9.7%), respectively.

5. SUMMARY

- A statistical method was developed to correct biases of future projections of GHI simulated using RCMs and to downscale daily–20-km RCM GHI to hourly–4-km resolution GHI.
- The NSRDB data sets were used to calibrate the RCM output (from CanRCM4) and validate the downscaled GHI projections for CONUS.
- MBE for the downscaled hourly GHI was calculated to be ~3% (DNI: ~10%) when compared to the NSRDB.
- The long-term solar radiation data set that covers entire CONUS will be publicly available.

REFERENCES

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