Projection of Photovoltaic Potential based on High-resolution SSP Scenarios over South Korea

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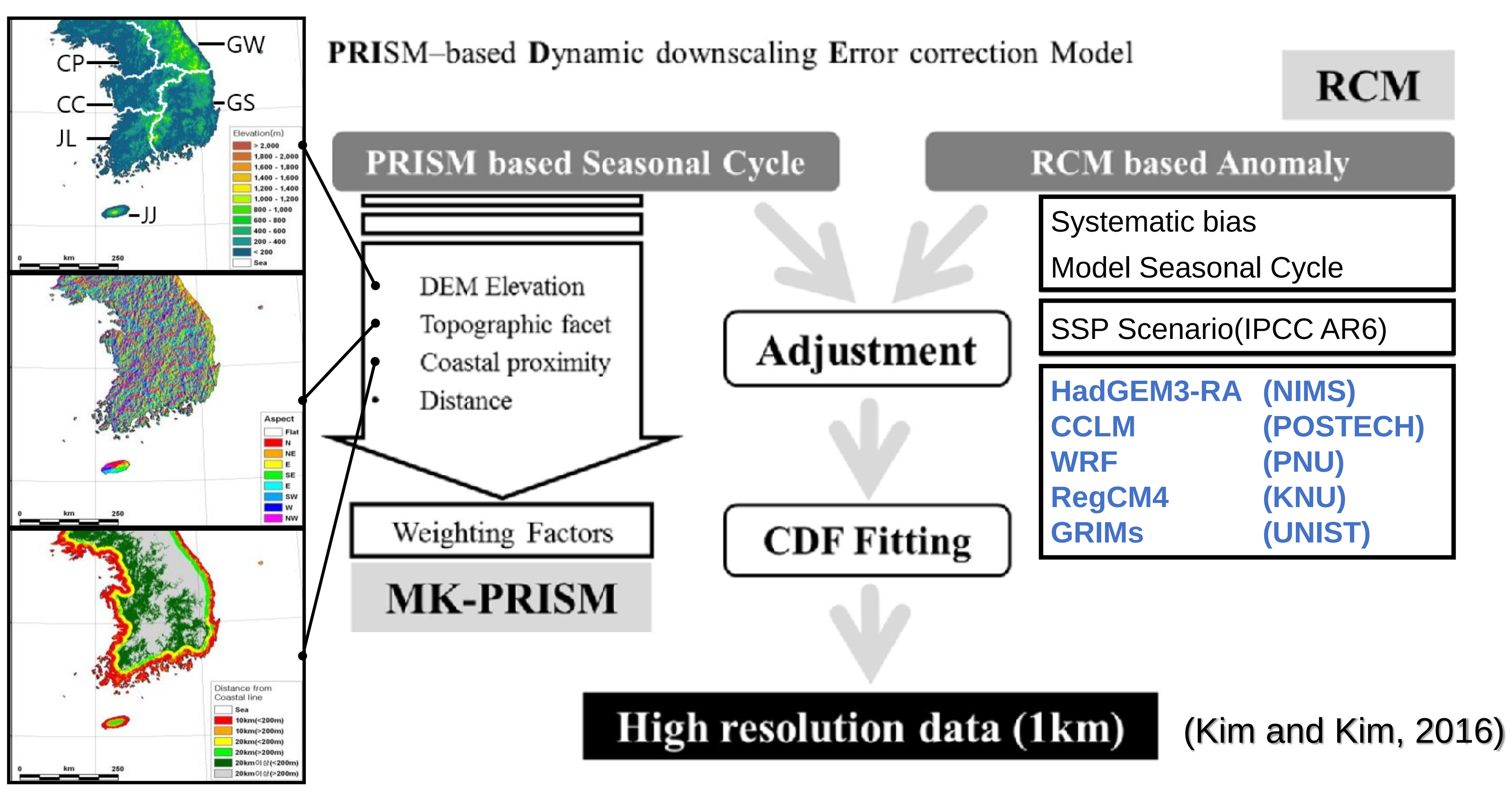
1. Introduction

- During the recent decade (2011-2020), the global surface temperature has increase by about 1.09 C [0.95~1.20 C] compared to the reference period of 1850-1900, and this indicates the rapid progression of global warming (IPCC, 2021). The major driver of this temperature increase is the release of greenhouse gases, primarily from human activities.
- To combat the increase greenhouse gas emissions, the international community has been actively taking measures. The adoption of renewable energy sources, such as solar power generation, is one of the key measures to reduce greenhouse gas emissions.
- Considering the potential effects of climate change, the future prospects of solar power generation have become a subject of great concern. The recent **photovoltaic power generation potential (PVpot)** over East Asia did not exhibit any notable changes, but the future PVpot is expected to decrease by -4.3% in winter and by -1.5% in summer (Park et al., 2022). In this regard, more detailed analysis of solar power generation by region is needed.
- To this end, **a new high-resolution (1km) climate change scenario over South Korea based on four types of Shared Socioeconomic Pathways (SSP)** was used. This scenario was calculated through statistical downscaling based on five Regional Climate Models (RCMs) of the COordinated Regional climate Downscaling Experiment (CORDEX)-East Asia Phase 2 project (25km).

2. Data & Method

2-1. High-resolution climate change scenario over South Korea



- The high-resolution grid-type observation data (2000-2019) were calculated using the Modified Korean-Parameter elevation Regressions an Independent Slopes Model (MK-PRISM), a statistical downscaling method.
- This method takes into account various factors such as distance, altitude, topographic facet, and coastal proximity (Kim et al., 2012). Through, the daily temperature, precipitation, wind speed, and insolation data of the observation stations of KMA were detailed with a resolution of 1 km.
- The high-resolution (2021-2100) scenarios were developed using PRISM-based Dynamic downscaling Error correction (PRIDE), a statistical model.
- This method replaces the daily seasonal cycle of the climate model with the daily seasonal cycle of the observation data in order to correct systematic errors of the RCM. In this study, the ensemble average of five RCM based high-resolution scenarios were used.

2-2. Analysis methods

- calculated using **surface down-welling shortwave radiation (RSDS)**, **mean temperature (TA)** and **surface wind speed (WS)** following the method by Jerez et al. (2015).

$$PV_{pot}(t) = P_R(t) \times RSDS(t)/RSDS_{STC} \quad (1)$$

- $RSDS_{STC}$ = 1,000 Wm^{-2} : standard test conditions by the International Electrotechnical Commission,
- P_R : the performance ratio,

$$P_R(t) = 1 + \gamma[T_{cell}(t) - T_{STC}] \quad (2)$$

- T_{STC} = 25 ℃ : standard temperature of silicon solar cell panels,
- γ = -0.005 ℃$^{-1}$: temperature coefficient of cells (Tonui and Tripanagnostopoulos, 2008),

$$T_{cell}(t) = c_1 + c_2TA(t) + c_3RSDS(t) + c_4WS(t) \quad (3)$$

- c_1 = 4.3 ℃, c_2 = 0.943, c_3 = 0.028 ℃ m^2 W^{-1}, c_4 = -1.528 ℃ s m^{-1} (Tamizhmani et al. (2003)),

- RSDS-, TA- and WS-induced changes in PVpot.

by grouping equations (1)-(3), the expression of PVpot can be rewritten as:

$$PV_{pot}(t) = \alpha_1 RSDS + \alpha_2 RSDS^2 + \alpha_3 RSDS \cdot TA + \alpha_4 RSDS \cdot WS \quad (4)$$

- $\alpha_1 = 1.1035 \times 10^{-3}$, $\alpha_2 = -1.4 \times 10^{-7}$, $\alpha_3 = -4.715 \times 10^{-6}$, $\alpha_4 = 7.64 \times 10^{-6}$,

3. Results

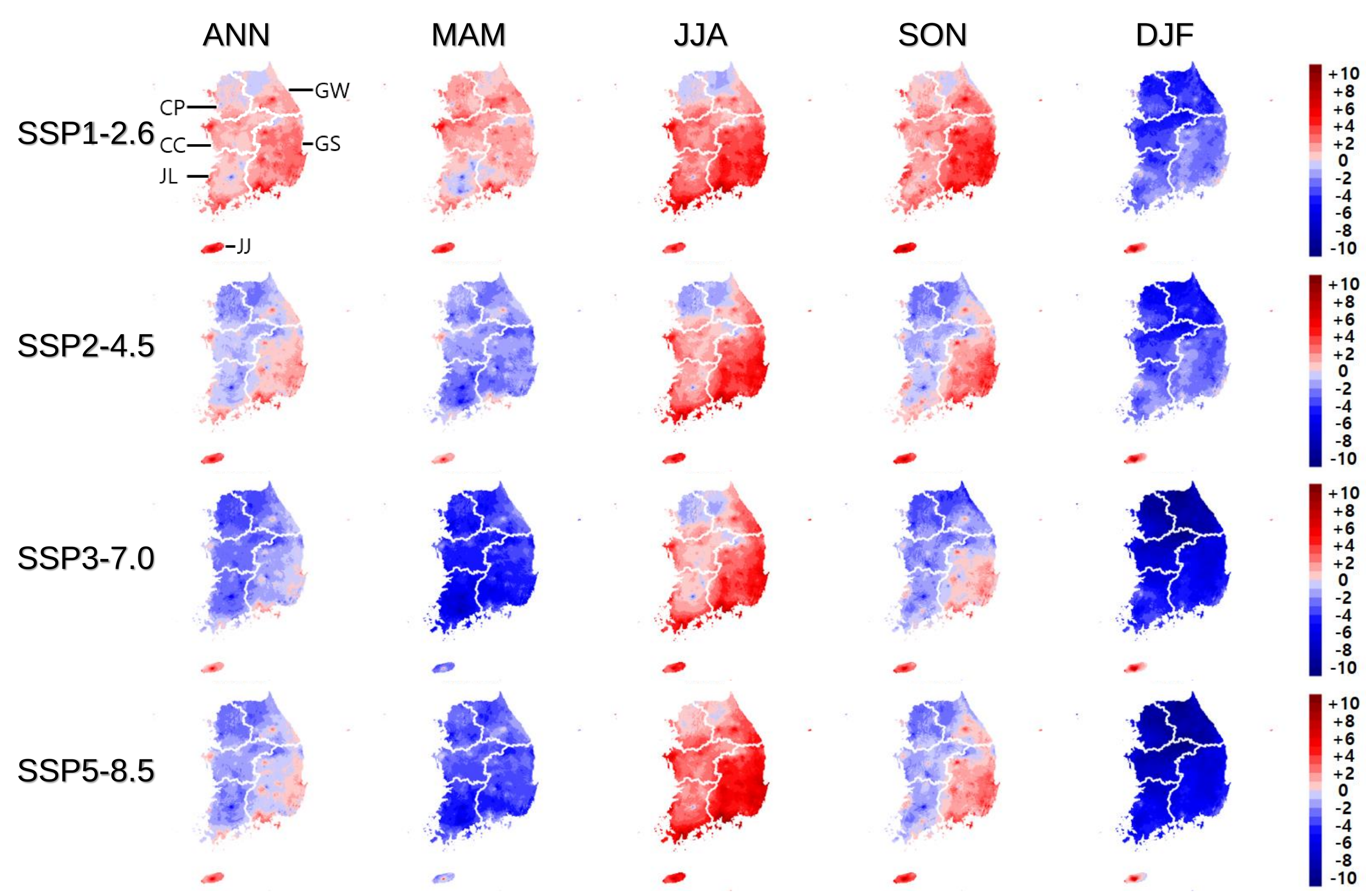
3-1. PV_{pot} projections for South Korea

(Changes in PV_{pot}, RSDS, TA and WS from 2014-2018 to 2070~2099)

	SSP1-2.6	SSP2-4.5	SSP3-7.0	SSP5-8.5
PV_{pot} (%)	+1.3	-	-2.0	-0.7
RSDS (Wm^{-2})	+3.6	+2.0	+0.7	+2.8
TA (℃)	+2.0	+3.1	+4.7	+5.6
WS (ms^{-1})	+0.03	-0.02	-0.06	-0.06

- PVpot : to increase in low-emission scenario and decrease in high-emission scenarios
  - In the case of high-emission scenarios : despite the increase in RSDS, significantly TA increase ⇨ reduced panel efficiency ⇨ decrease in PVpot

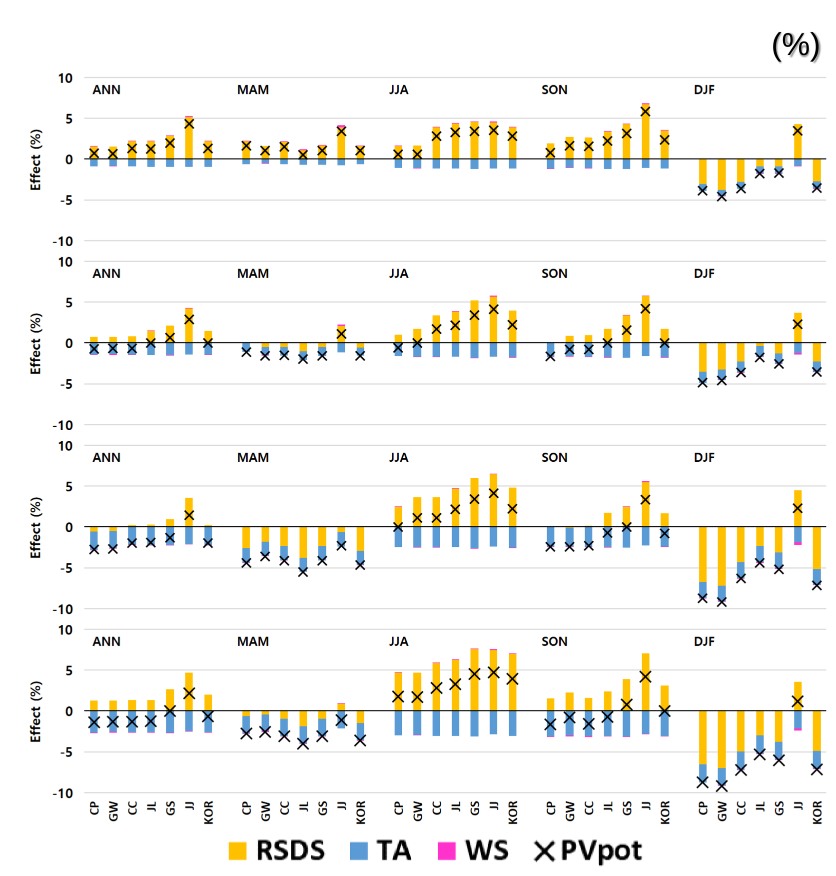
3-2. PV_{pot} projections by region



- In Jeju-island (JJ), PV_{pot} is expected to increase under all scenarios
- Inland regions, PV_{pot} is expected to decrease under high-emission scenarios

⇨ Changes in PV_{pot} by region are related to changes in the number of rainy days

3-3. Influence of RSDS, TA and WS on changes in PV_{pot}



	PVpot	RSDS	TA
SSP1-2.6	+1.3	+2.2	-0.9
SSP2-4.5	-	+1.5	-1.5
SSP3-7.0	-2.0	+0.2	-2.2
SSP5-8.5	-0.7	+2.0	-2.7

*WS has no significant influence on changes in PV_{pot}

4. Summary

- **The study predicts the future photovoltaic power generation potential (PV_{pot}) changes over South Korea based on high-resolution climate change scenarios.** According to the four Shared Socioeconomic Pathways (SSP) scenarios (SSP1-2.6, SSP2-4.5, SSP3-7.0, SSP5-8.5), at the late 21st century, surface down-welling shortwave radiation, which has a major impact on PV_{pot}, is expected to increase (by about +0.7~+3.5Wm^{-2}) compared to the present-day.
- However, the increase or decrease of PV_{pot} depends on the level of emissions in the future. **In the low-emissions scenario, PV_{pot} is expected to increase (by about +1.3%), while that in the high-emissions scenarios are expected to decrease (by about -0.7~-2.0%).** As the temperature increases significantly, the temperature of the solar cell panels increase, and the performance ratio of PV_{pot} decreases. This means that, even though the surface down-welling shortwave radiation increases, the increase in temperature may offset the positive impact on PV_{pot}.
- Overall, this study highlights the importance of considering the impact of climate change on solar energy. It also emphasizes the need to adopt low-emissions policies to mitigate the negative effects of climate change on renewable energy generation potential.

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