Impact of climate change on photovoltaic energy production in Italy using convection permitting models

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PhD SDC SUSTAINABLE DEVELOPMENT AND CLIMATE CHANGE

1 Introduction

Renewable energy sources, like solar, wind and hydro, are crucial for mitigating climate change, but are susceptible to climate variability and climate change.

Research Questions:

- Can km-scale climate models, called convection permitting (CPMs), be used to represent photovoltaic (PV) energy production in Italy?
- How is PV production potential in Italy projected to evolve in a warming future?

2 Methods and data

Calculation of PV production:

$$PVpotential = P_R(t)\frac{RSDS(t)}{RSDS_{STC}}$$

(Adapted from Jerez et al., 2015)

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

$$T_{cell}(t) = c_1 + c_2 TAS(t) + c_3 RSDS(t) + c_4 VWS(t)$$

- PV production = PV potential x Installed Capacity

Observation data:

- PV plant production data: Hourly energy production in 4 PV plants (2 fixed and 2 axial tracking), 2019-2023
- ENTSOE hourly energy production at bidding zone level form 2021-2023
- GSE installed capacity at province level and auto-consumption data at region level, 2021-2023

Shortwave radiation data:

- GEBA: station data (monthly resolution)
- SARAH-3: satellite derived radiation dataset (~5km, daily resolution)

Model data:

- ERA5-land reanalysis (~9km, hourly resolution), remapped on 3km grid, 2000-2023
- 9 CPMs from CORDEX-FPSconv (2-3km hourly resolution)
  - ERA-Interim driven simulation: 2000-2009
  - Historical simulation: 1996-2005
  - Future simulation: 2041-2050, 2090-2099

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3 Validation

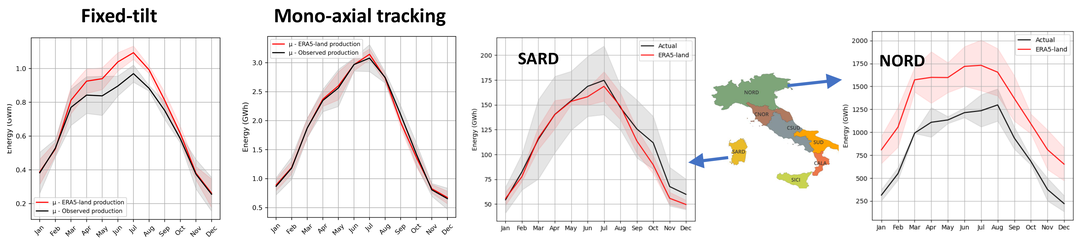

Figure 1. Monthly mean total energy production recorded at PV plants (black lines) and calculated using ERA5-land (red lines) over 2018-2023

Figure 2. Monthly mean total energy production in bidding zones from ENTSOE (black lines) and calculated using ERA5-land (red lines) over 2021-2023

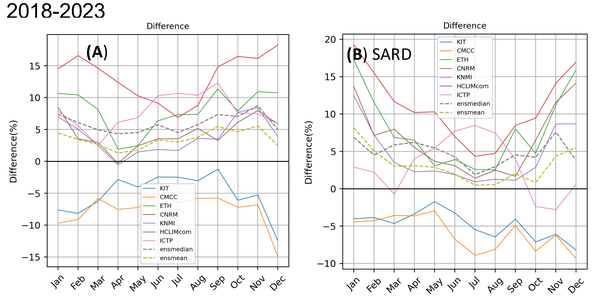

Figure 3. % Difference in monthly total energy production between CPMs and ERA5-land for a PV station (A) and in SARD (Sardinia) bidding zone (B)

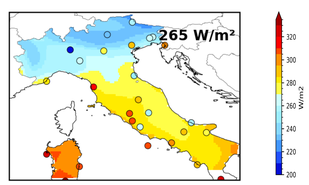

Figure 4. Summer mean surface shortwave radiation in ERA5-land and GEBA (dots) during 2000-2009

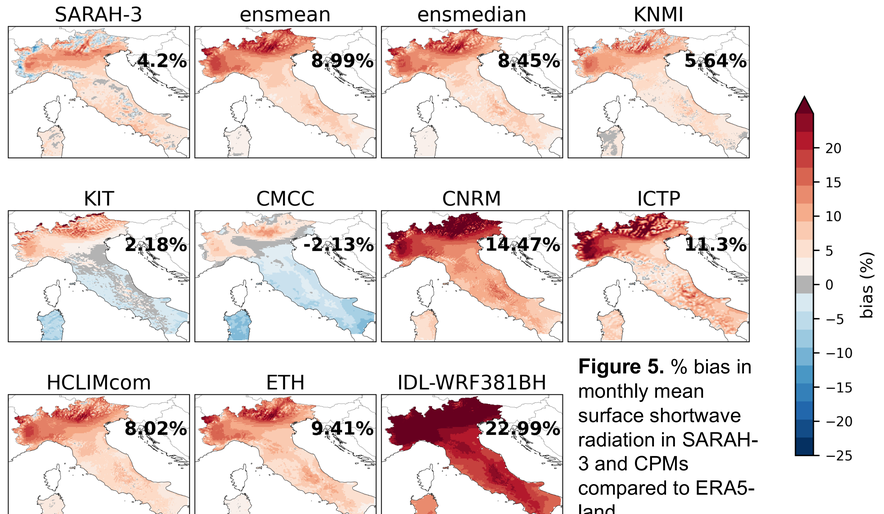

Figure 5. % bias in monthly mean surface shortwave radiation in SARAH-3 and CPMs compared to ERA5-land

4 Future Change

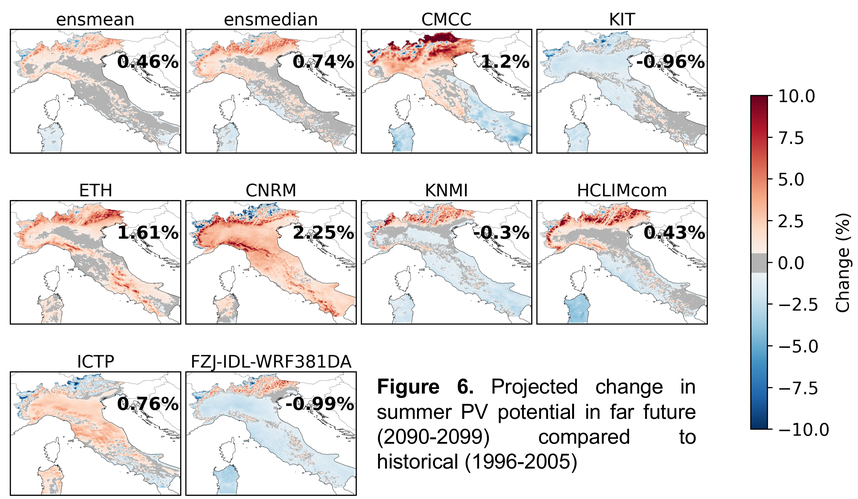

Figure 6. Projected change in summer PV potential in far future (2090-2099) compared to historical (1996-2005)

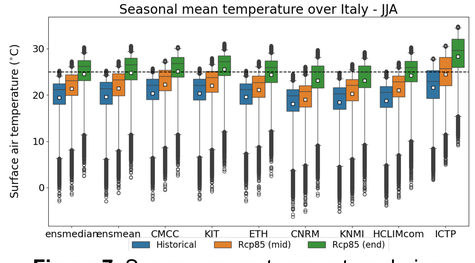

Figure 7. Summer mean temperature during historical and future periods

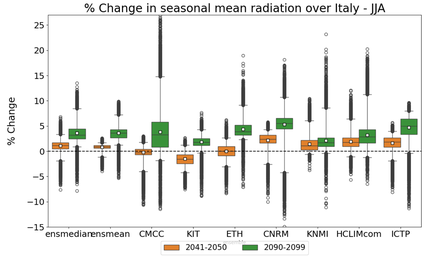

Figure 8. Future change in radiation

5 Conclusions and perspectives

- The energy model forced with ERA5-land well represent PV production at station level, but shows large variability among the bidding zones.
- While ERA5-land underestimates shortwave radiation, most CPMs tend to be closer to observations
- CPMs can represent PV potential at stations and bidding zones with monthly mean bias within 15% compared to ERA5-land.
- PV potential is projected to slightly decline (~2%) over most of Italy by mid-century, but rise by 2-5% towards end of the century especially in the North.
- Radiation is projected to increase towards mid and end centuries by ~2% and ~4% respectively over most parts of Italy. However, rapid rise in temperature by ~2^0 and ~5^0 offsets the effect of increased radiation leading to a net decrease in energy potential.
- Technological advancement in reducing the effect of temperature on cell efficiency can leverage the projected increase in surface solar radiation.