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Hybrid deterministic and machine learning approach for solar power forecasting with uncertainty estimation

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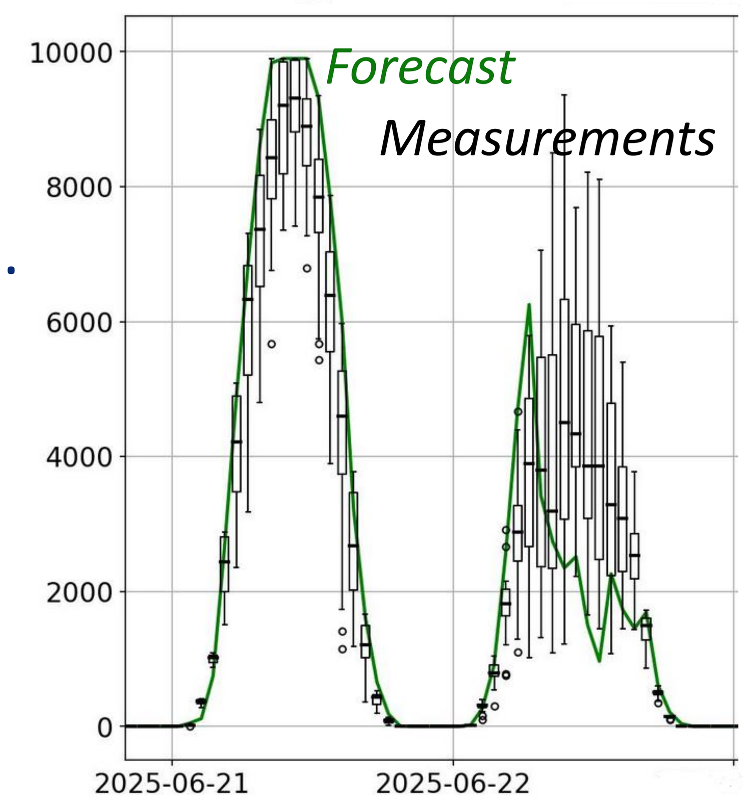
PROBLEM

Accurate solar power forecasting is essential for:
– Grid stability, balancing electricity supply/demand, preventing overloads.
– Optimizing bidding strategies and reducing penalties for imbalanced production.

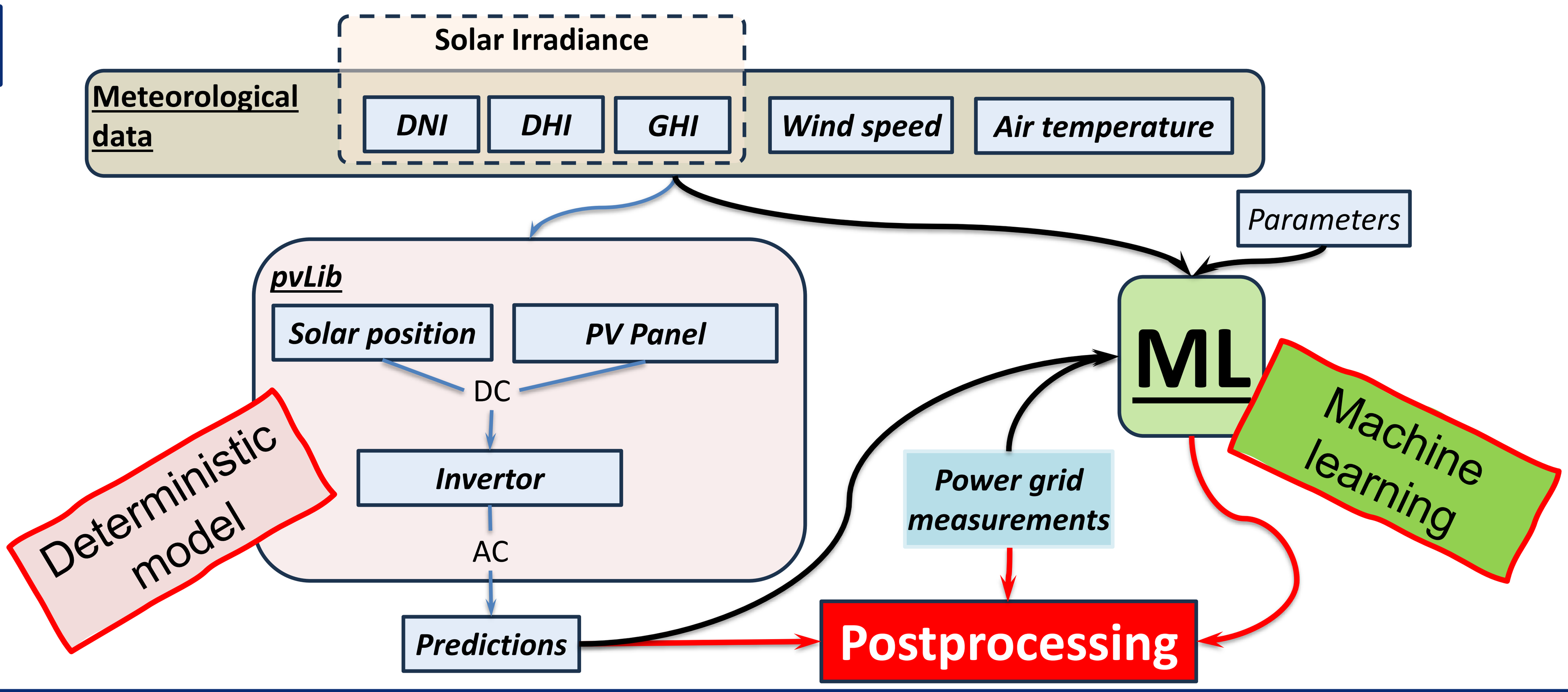
The used **2-day-ahead forecasting** systems (covering 44 power plants) **has limitations**:
– Significant discrepancies in peak values on sunny days
– Overestimation of production during winter



SOLUTION

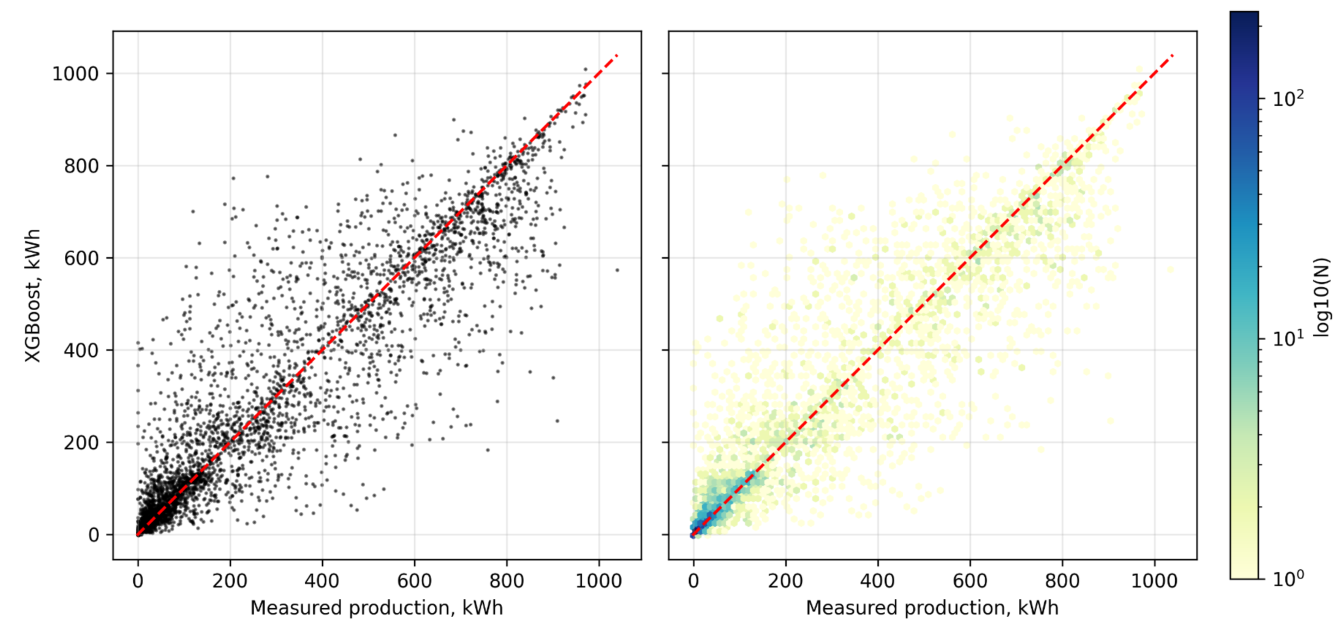
Hybrid Solar Power Forecasting:

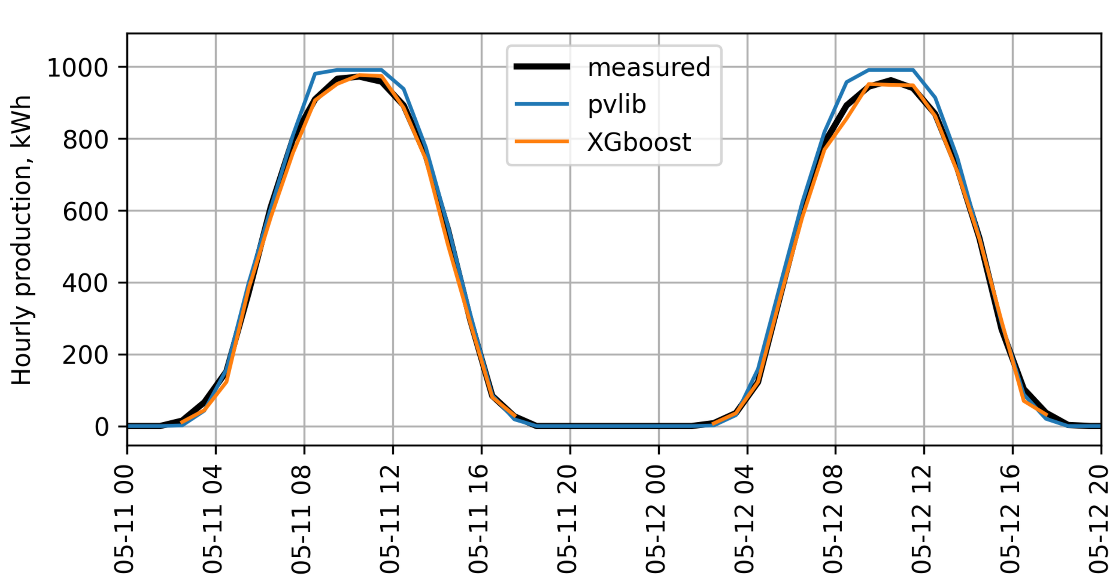
- Approach: Combines **deterministic** modeling (*pvLib*) with *XGBoost* **machine learning (ML)**.
- Goal: **Improve forecast** accuracy by correcting deterministic output.
- Solution: ML corrects systematic biases and improves uncertainty estimation.



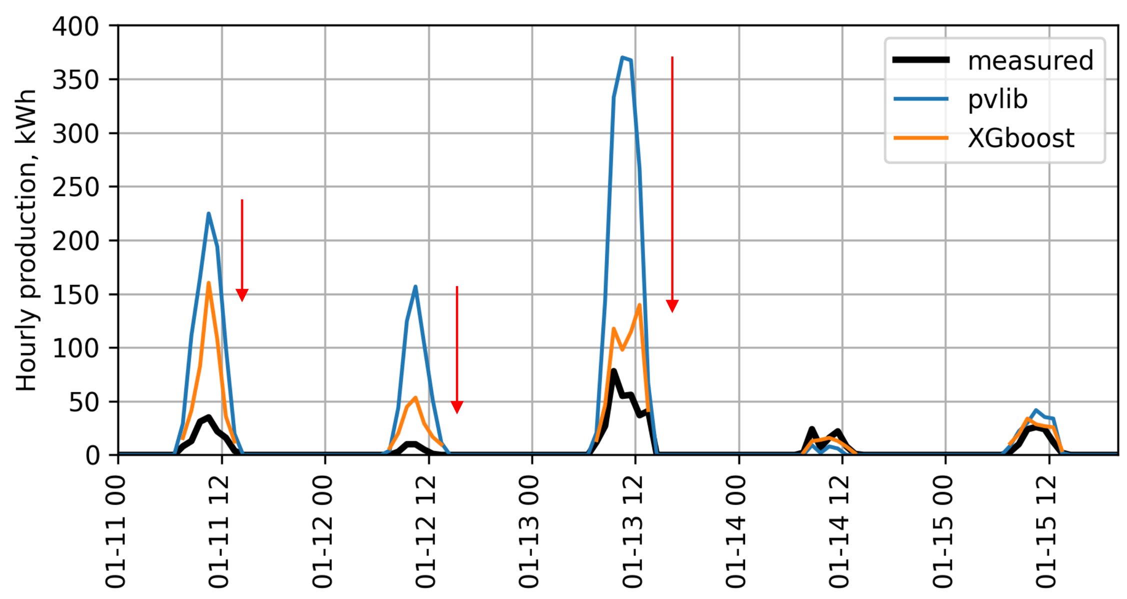
RESULTS: forecasts

	pvlib			XGBoost		
	DWD-e	DWD-ICON	MEPS	DWD-e	DWD-ICON	MEPS
sum of absolute errors, kWh	855	942	1092	712	778	817
sum of errors, kWh	292	325	26	15	-13	4
mean daily accuracy index, -	0.32	0.28	0.28	0.57	0.53	0.53
integrated accuracy index, -	0.73	0.71	0.66	0.78	0.76	0.75

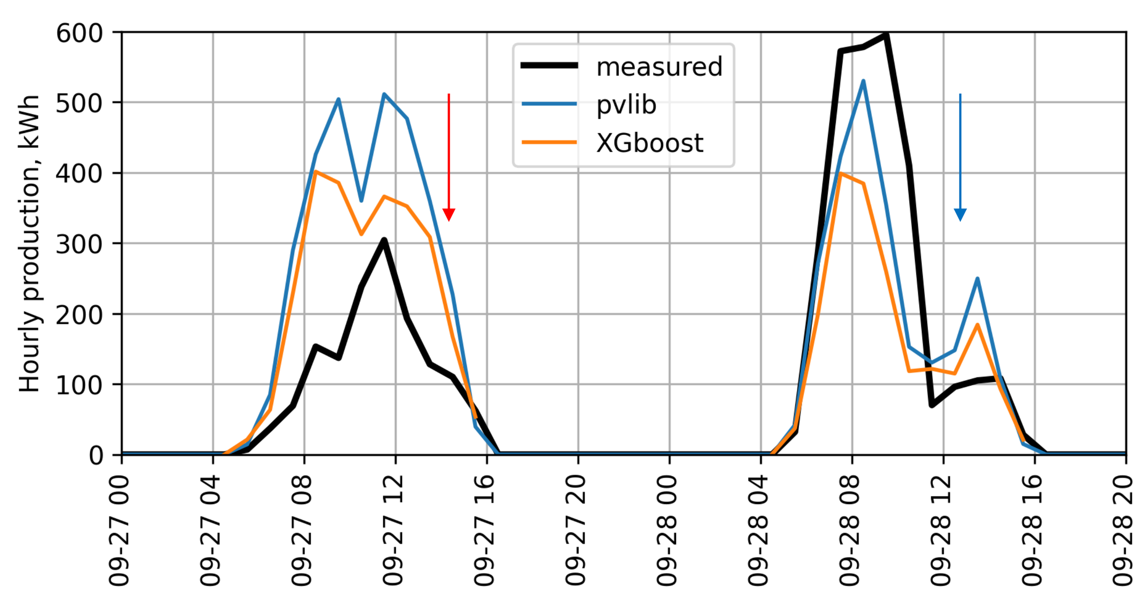




clear-sky day



winter day / low energy



day with variable cloudiness

CONCLUSION: performance

Clear-Sky: Deterministic model captures the shape but overestimates peaks; **ML** correction improves peak accuracy.
Winter Days: Forecasts often overestimate due to DNI errors and unmodeled snow losses; **ML** offers slight improvement.
Variable Clouds: Both models struggle; **ML** reduces bias but fails to track rapid irradiance fluctuations fully.

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