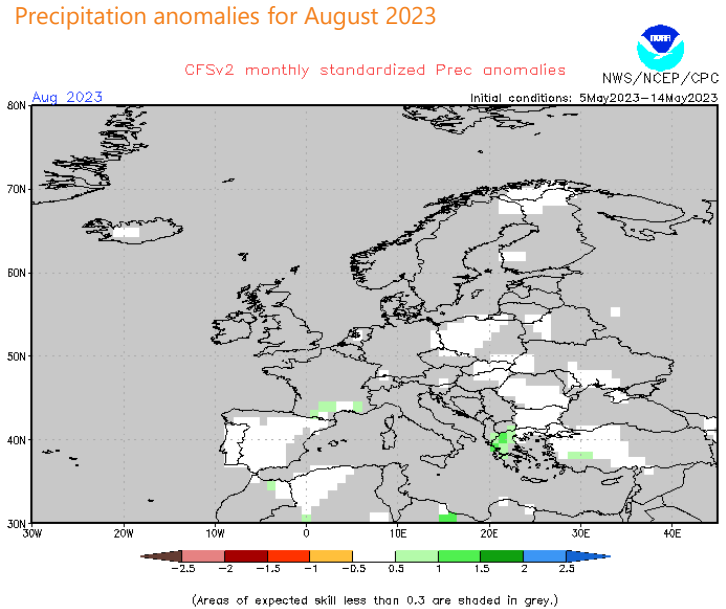


IEA PVPS

S2S in the Solar Community

Jan Remund, Task Manager, Meteotest AG

Seasonal Forecasting for the Weather Driven Energy System - 17.05.2023

Contents

- IEA PVPS Task 16
  - Team & Work
  - State of PV
- State of Seasonal Solar Forecasts
  - Work within Task 16
  - Review of publications

Current status of team

51 institutions

Science (labs and universities)

Met Services / utilities

Data providers

PVPS

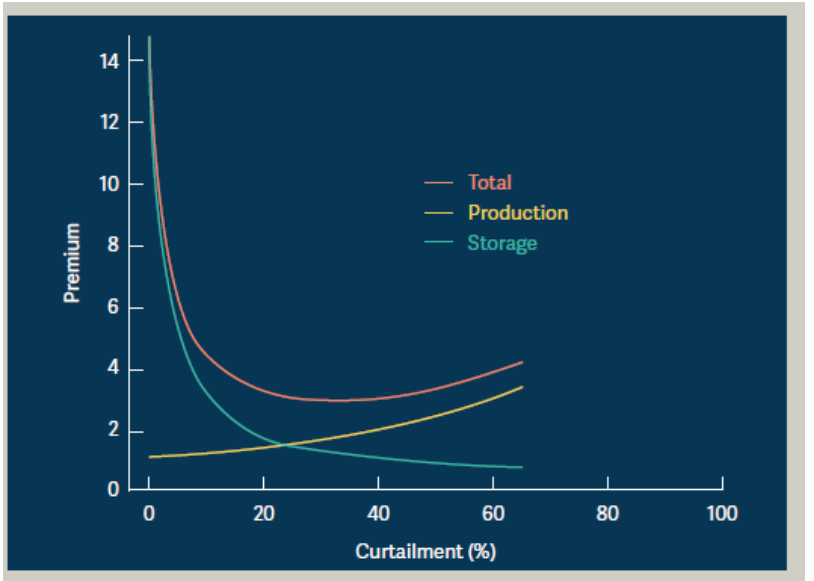
Subtask structure

- ST1: Current **methodologies** for solar data generation
- ST2: Enhancement of **data** and value-added products
- ST3: Solar **forecasting**
- ST4: Dissemination and Outreach

Hottest topic: Firm Power Generation: Europe

- Example of a pan-European study from Univ. Utrecht
- Input data for future cost levels are crucial (ATB NREL)
- 29% Europe wide curtailment optimal

	Solar PV	Onshore wind	Offshore wind	Li-on	Hydrogen
Economic life	30 years	30 years	30 years	15 years	18 years
WACC	4.4%	4.4%	4.4%	5.0%	5.0%
CAPEX	700 k€/MW	760 k€//MW	1945 k€//MW	243 k€//MW 81 k€/MWh	1300 k€//MW 1 k€//MWh
O&M	10 k€//MW/y	33 k€//MW/y	71 k€//MW/y	2.5% capex/y	2.5% capex/y
SoCmin				20%	0%
SoCmax				100%	100%
Efficiency				85%	40%



PVPS

Report: https://iea-pvps.org/key-topics/firm-power-generation/

Solar Resource Handbook

- Solar Resource Handbook
  - 3rd edition: Spring 2021
  - NREL and IEA PVPS versions
  - 4th version: End of 2023
- Additional: Online archives:
  - Data: www.solarstations.org
  - Code: www.assessingsolar.org

System Size

Phase

	Small	Medium	Large
1. Pre-feasibility & Planning	• Long-term averages • Monthly data • Solar cadastres / maps • Simple shading analysis	• TMY • Hourly data • Shading analysis	• Long-term satellite data • Hourly data
2. Feasibility			• Satellite data • Time series (>10 y) • Ground meas. (> 1 year) • Shading analysis • Further site and technology- specific meteo. parameters (e.g. albedo, soiling)
3. Due diligence & Finance		• Satellite data • Time series (>10 y) • Minute data • Shading • Further site and technology- specific meteo. parameters (e.g. albedo, soiling)	• Satellite data • Time series (>10 y) • Ground meas. (> 1 year) • Minute data • Shading analysis • Further site and technology- specific meteo. parameters (e.g. albedo, soiling)
4. Operation & Maintenance	• Simple monitoring	• Local measurements • Forecasts	• Local measurements • Forecasts

- https://iea-pvps.org/key-topics/best-practices-handbook-for-the-collection-and-use-of-solar-resource-data-for-solar-energy-applications-third-edition/
- https://www.nrel.gov/docs/fy21osti/77635.pdf

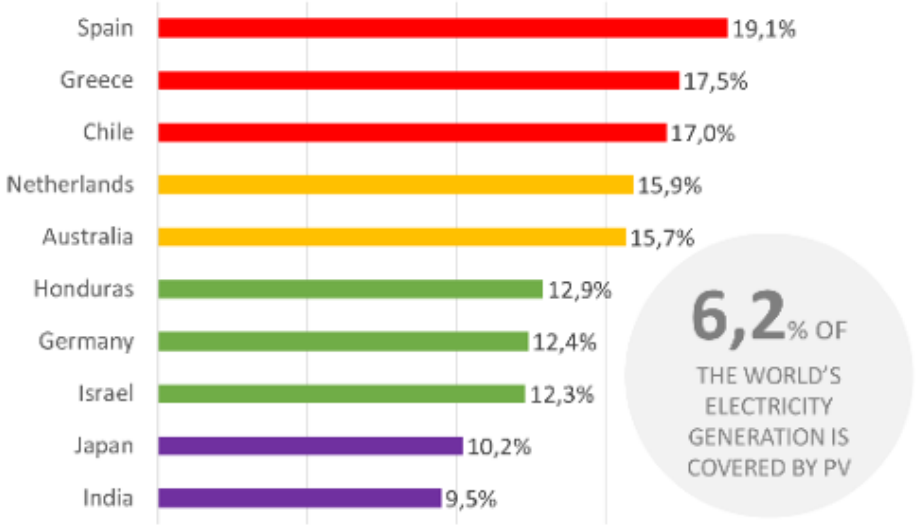
Seasonal Solar Forecasts at Task 16

- Not included in the work plans 2017 – 2020 / 2020 – 23
- Not included in the work plan 2023 – 2026
- Closest activities:
  - PV power forecasting at different spatio-temporal scales
  - Probabilistic solar forecasting
  - Climate change and long-term variability

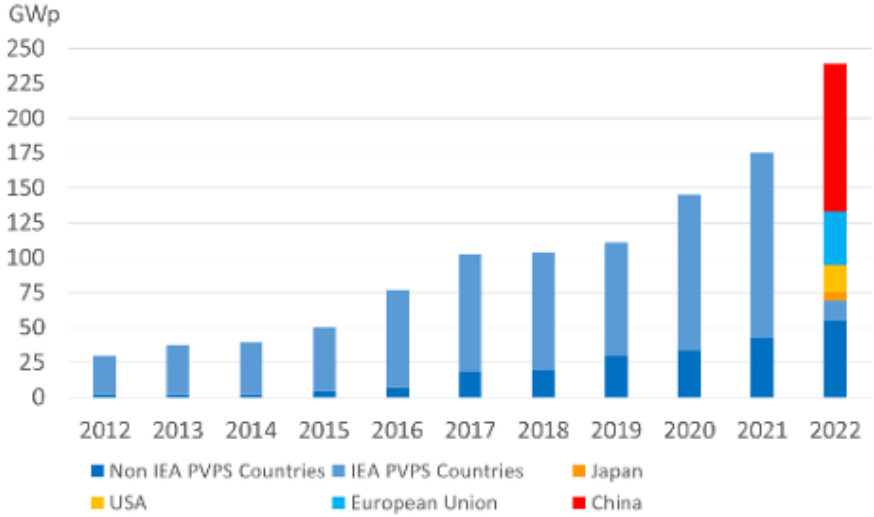
State of PV

- Market growth: 20-30% / year

COUNTRIES WITH HIGHEST PV PENETRATION



EVOLUTION OF ANNUAL PV INSTALLATIONS



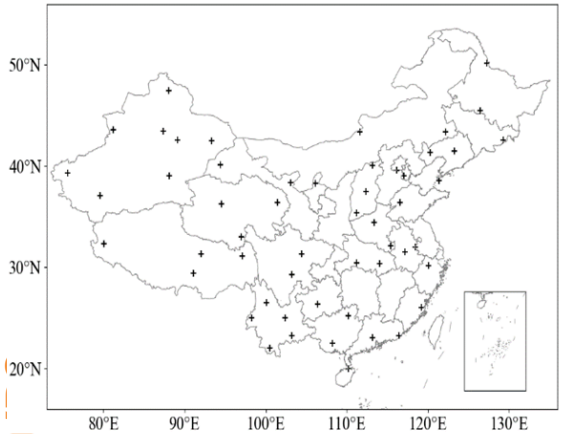
1185 GW installed

State of Seasonal Solar Forecasts

- Work of collaborating partners
  - CMA (own Seasonal Forecast project)
  - Univ. Tor Vergata (EU Project S2S4E – Climate Services for Clean Energy)
  - DWD (present in this workshop)

State of Seasonal Solar Forecasts

- CMA (own Seasonal Forecast project presented in Task Meeting Sept. 22):
  - Monthly mean total shortwave radiation at meteorological stations (1979-2020);
  - ECMWF ERA5 reanalysis dataset, including monthly geopotential heights, wind speed and 2 m air temperature (33 parameters) , 2.5×2.5° (1979-2020);
  - MRI-CGCM hindcast data（20 parameters ）, 2.5×2.5° (1979-2018).



2 m temperature	100 hPa geopotential height	200 hPa geopotential height	200 hPa temperature
200 hPa U wind	200 hPa V wind	300 hPa geopotential height	500 hPa geopotential height
500 hPa temperature	500 hPa U wind	500 hPa V wind	850 hPa geopotential height
850 hPa specific humidity	850 hPa relative humidity	850hPa temperature	850 hPa U wind
850 hPa V wind	Sea surface pressure	precipitation	Sea surface temperature
2 m temperature gradient	100 hPa geopotential height gradient	200 hPa geopotential height gradient	100 hPa temperature gradient
300 hPa geopotential height gradient	500 hPa geopotential height gradient	500 hPa temperature gradient	850 hPa geopotential height gradient
850 hPa temperature gradient	Sea surface pressure gradient	200 hPa wind speed	500hPa wind speed
850 hPa wind speed			

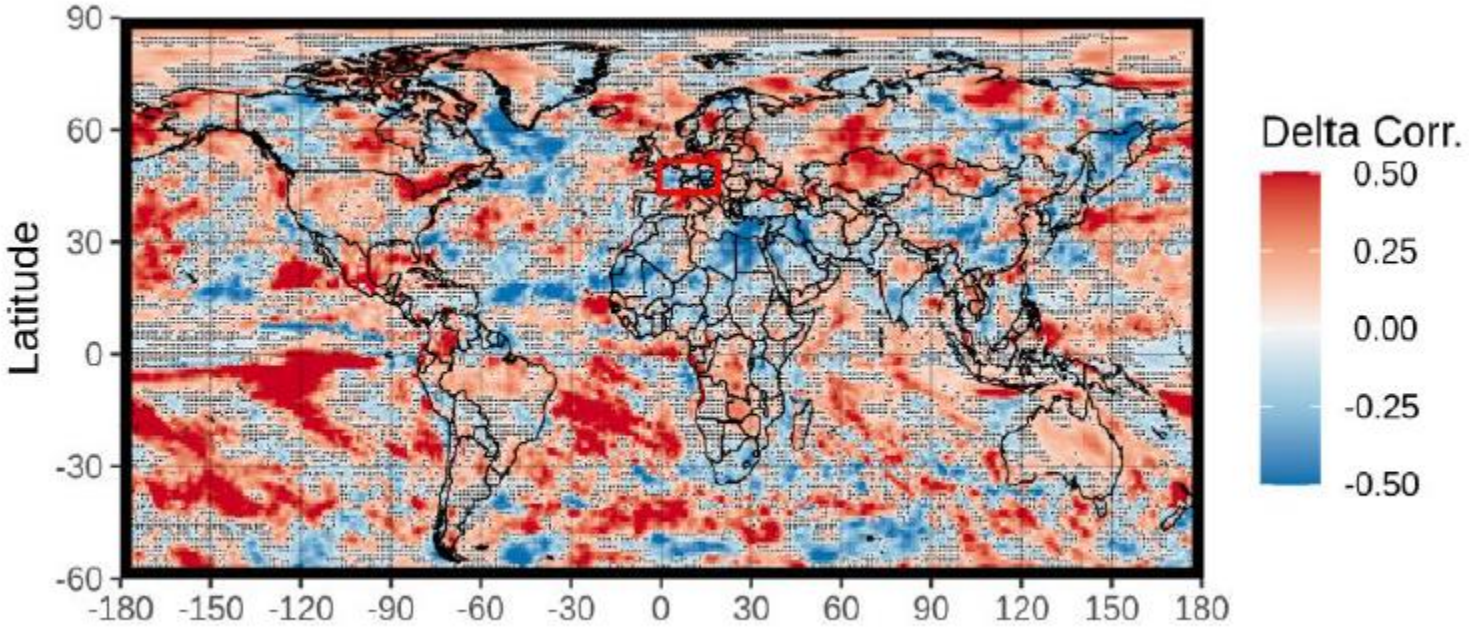
State of Seasonal Solar Forecasts

- Anomaly Correlation Coefficient (ACC): patchy: often < 0.4, depending on month and method; random forest regression is best

	2017						2018					
	Stepwise Regression	Random Forest	Gradient Boosting	Decision Tree	Bayesian Ridge	K-Neighbors	**Stepwise Regression**	Random Forest	Gradient Boosting	Decision Tree	Bayesian Ridge	K-Neighbors
Jan	0.48	0.64	0.66	0.57	0.71	0.39	0.01	0.38	0.12	-0.04	0.02	0.24
Feb	0.63	0.66	0.53	0.47	0.15	0.37	-0.22	0.00	-0.01	0.10	-0.52	0.08
Mar	-0.12	**-0.43**	-0.38	-0.17	-0.14	**-0.01**	0.55	0.44	0.33	0.40	0.63	0.40
Apr	0.46	0.45	0.15	0.14	0.60	0.59	-0.50	**-0.33**	-0.33	-0.41	-0.01	**-0.13**
May	-0.21	0.05	0.06	0.34	0.16	0.04	0.29	**-0.54**	-0.67	-0.50	-0.58	0.32
Jun	-0.02	0.12	0.09	0.02	0.25	**-0.04**	-0.08	**-0.14**	-0.10	0.15	-0.23	**-0.04**
Jul	0.48	0.41	0.32	0.21	0.47	0.44	0.24	0.15	-0.01	-0.03	0.05	0.25
Aug	0.04	0.24	0.19	-0.14	0.25	0.16	-0.02	0.53	0.47	0.36	0.35	0.55
Sep	0.33	0.08	-0.10	-0.12	0.07	0.24	-0.19	0.16	0.21	0.16	0.26	0.18
Oct	0.73	0.79	0.80	0.81	0.67	0.59	0.34	0.57	0.51	0.47	0.48	**-0.40**
Nov	0.25	0.40	0.43	0.44	0.27	0.15	0.33	0.39	0.40	0.50	0.30	0.20
Dec	0.56	0.56	0.54	0.53	0.02	0.55	0.33	0.32	0.38	0.22	0.49	0.56
Ave.	0.30	**0.33**	0.27	0.26	0.29	0.29	0.09	0.16	0.11	0.12	0.10	**0.18**

State of Seasonal Solar Forecasts

- S2S4E: 1 month lead JJA: ECMWF minus Meteo France correlation diff. vs. ERA5
  - Dotted grip points did not pass significance test at 10% level

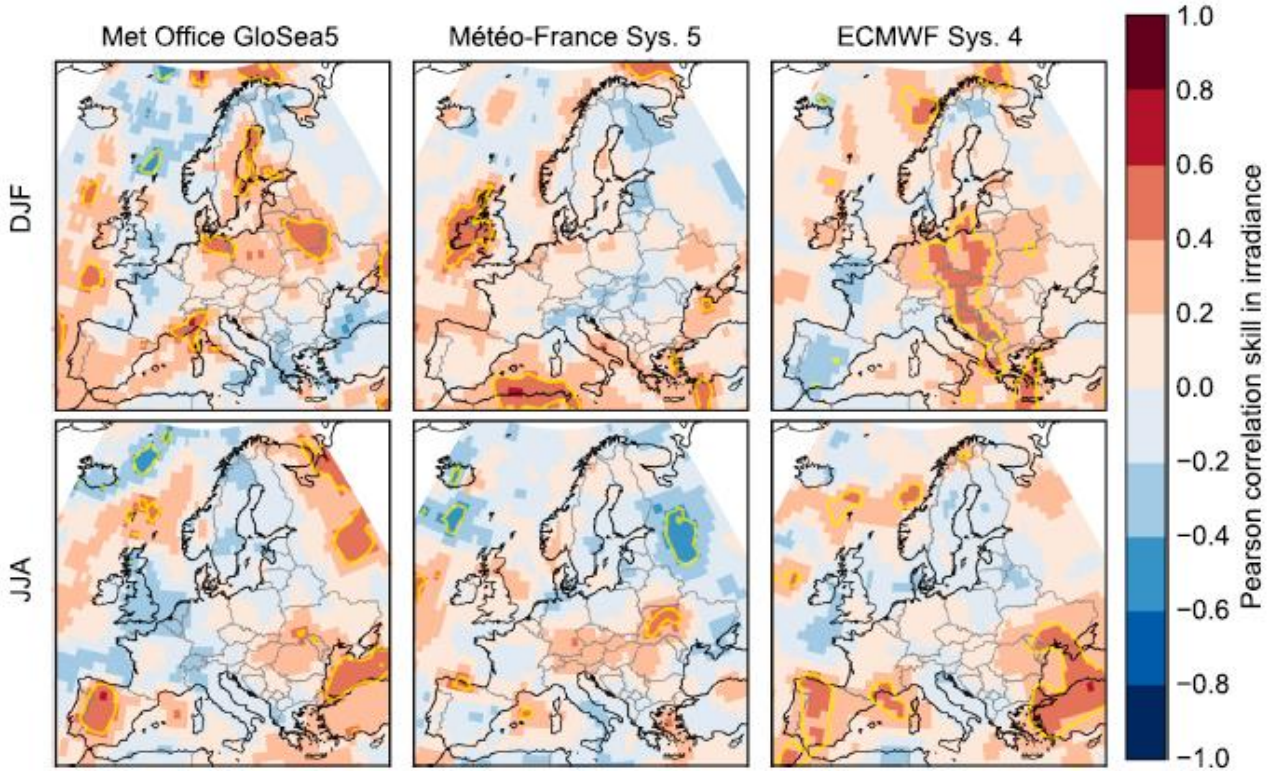


State of Solar Forecasts

- Referenced Papers:
  - Bett et al. 2022: A simplified seasonal forecasting strategy, applied to wind and solar power in Europe. https://doi.org/10.1016/j.cliser.2022.100318
  - Bloomfield et al. 2021: Sub-seasonal forecasts of demand and wind power and solar power generation for 28 European countries. https://doi.org/10.5194/essd-13-2259-2021
  - Aheli, Das and Somonath Baidya Roy, 2021: Evaluation of subseasonal to seasonal forecasts over India for renewable energy applications. https://doi.org/10.5194/adgeo-56-89-2021

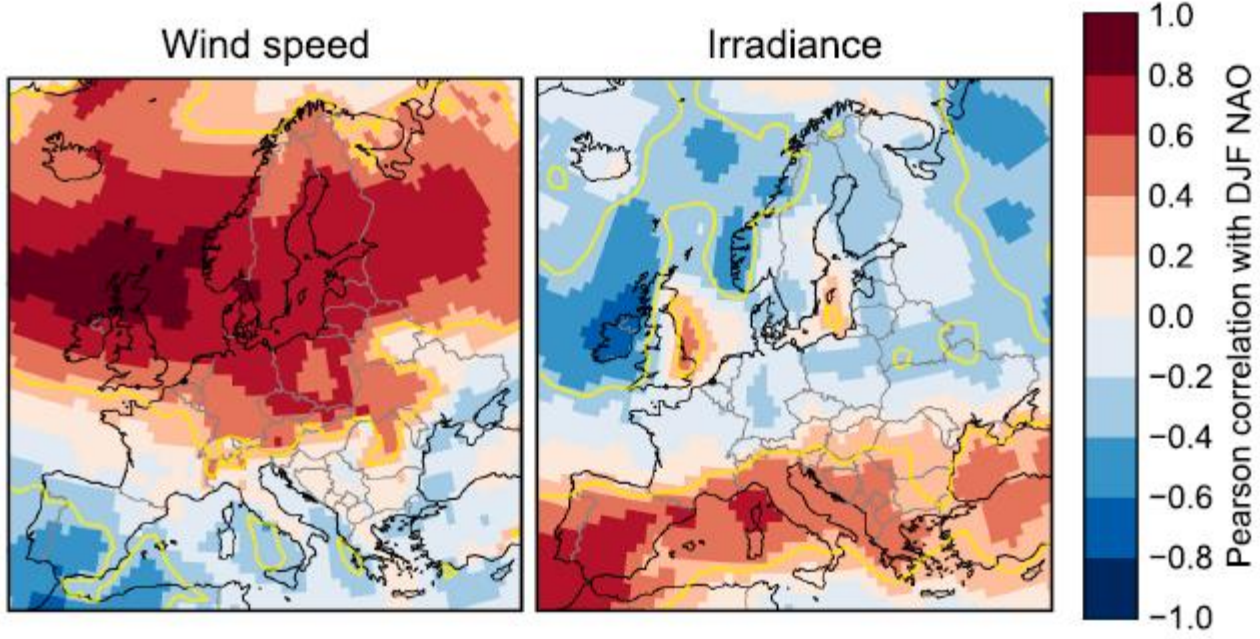
State of Solar Forecasts

Bett et al., 2022: “patchy skill”



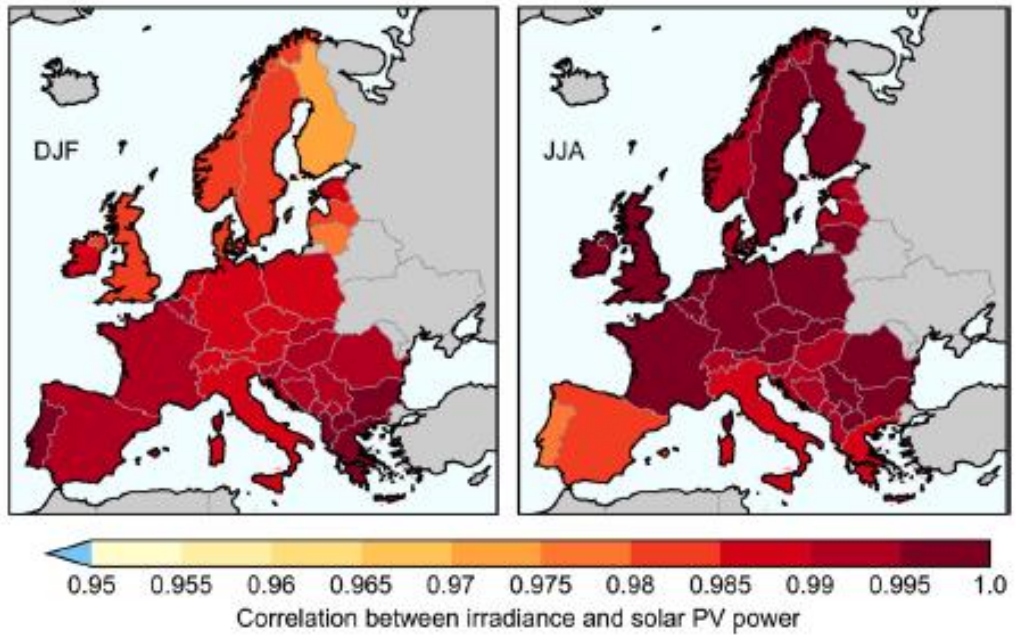
State of Solar Forecasts

- Correlation with DJF NAO Index
  - Less for solar than for wind, but existing in Mediterranean region



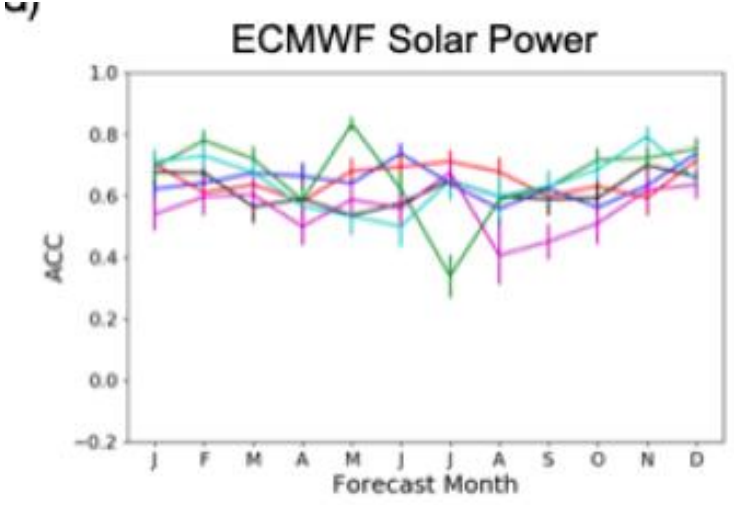
State of Solar Forecasts

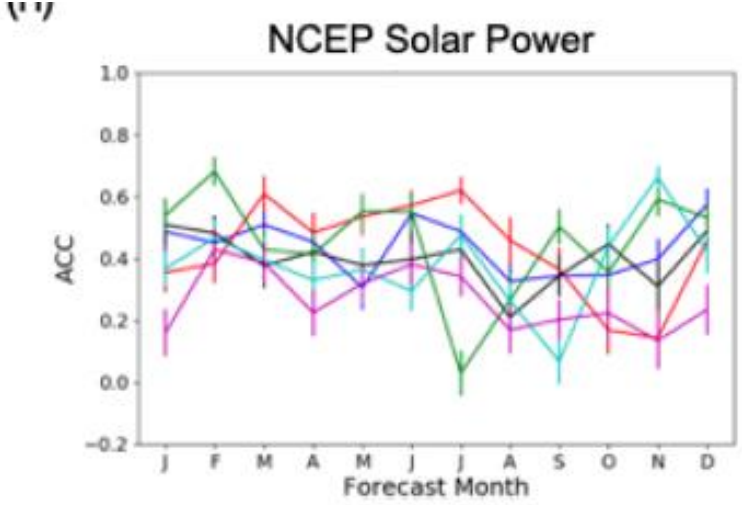
- GHI and PV highly correlated
- “If skill is in the underlying climate variable, simple linear regression to make a probabilistic forecast of the energy variable can be used” (slightly abbreviated)



State of Solar Forecasts

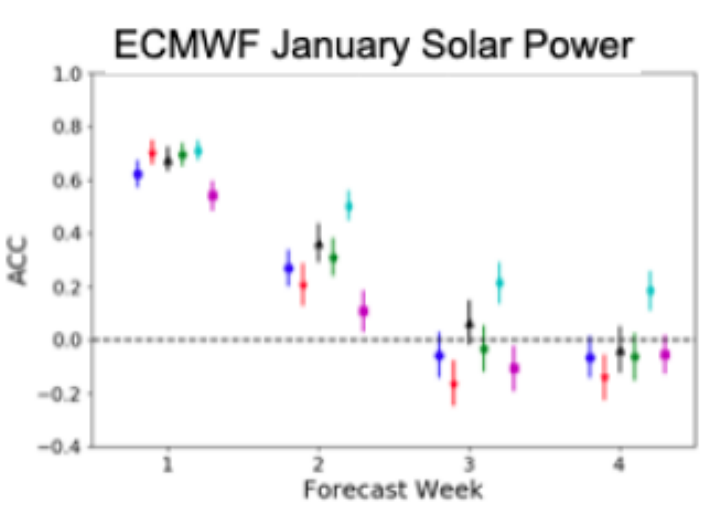
- Bloomfield et al., 2021
- Monthly anomaly correlation coefficient for Solar Power
  - ECMWF: 0.6 (demand: 0.8)
  - NCEP: 0.4 (demand: 0.4-0.8)

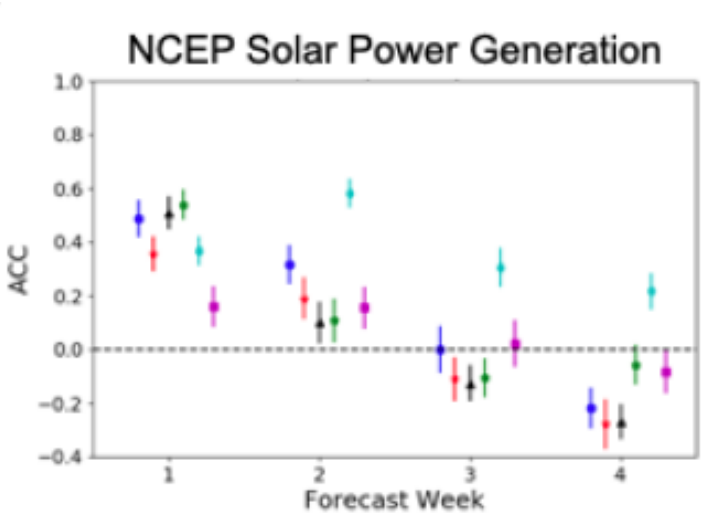




State of Solar Forecasts

- Monthly anomaly correlation coefficient for Solar Power
  - ACC is zero after 2-3 weeks





Conclusions

- Knowledge of solar production 0.5 – 3 months ahead is important
- Seasonal Forecasts exist operationally
- Skills are patchy
- PV production linear to GHI / Downward SSW
- Simple methods to calculate ensemble exist
- Still a lot of work to do

https://iea-pvps.org/research-tasks/solar-resource-for-high-penetration-and-large-scale-applications/

Thank you

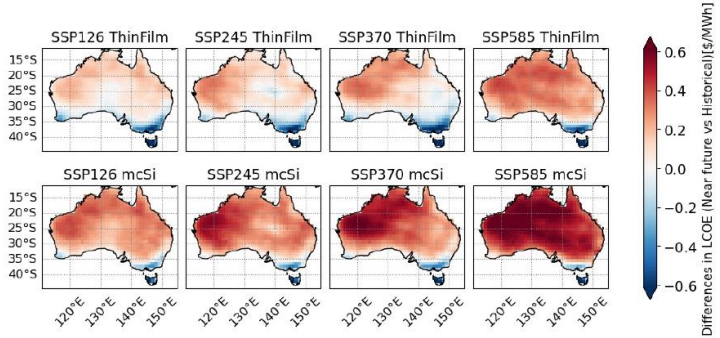
Jan Remund, Task Manager

Technology Collaboration Programme
by iea

Jan.remund@meteotest.ch

Climate change

- Activity 2.4: **New focus on climate change**
  - Climate change is visible and will have effect on PV-Production (with life times of 30 y)
  - What's the accuracy of the climate models (hypothesis: not that high)?
  - Are there visible trends – where and when? (taking into account the uncertainty)
  - How to use climate model forecasts for resource assessments
  - **Similar issue to seasonal forecasts: noise to signal ratio**
  - Lead: Kristian Nielsen, DMI



A. Isaza et al., UNSW (WCPEC-8, 2022)

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