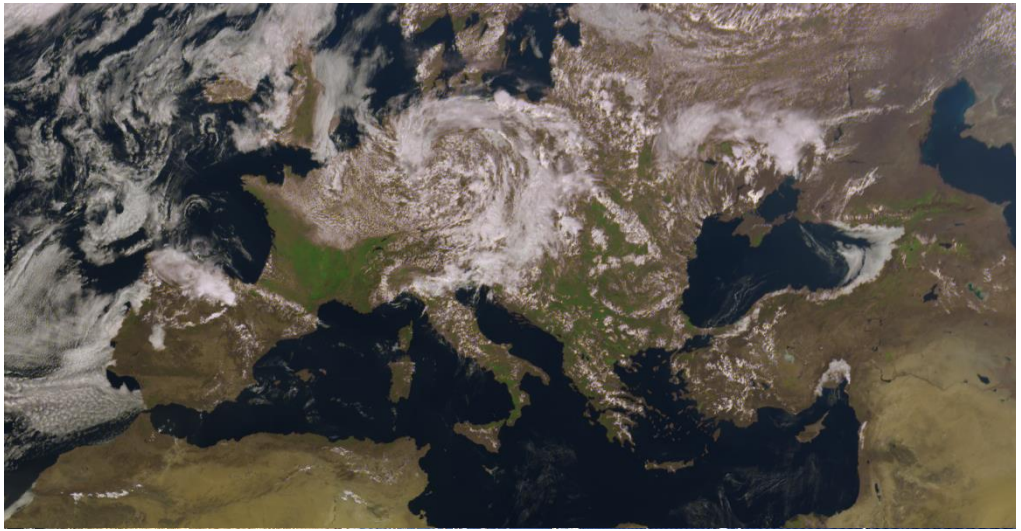


Chapter 8 Forecasting Solar Radiation and PV Power

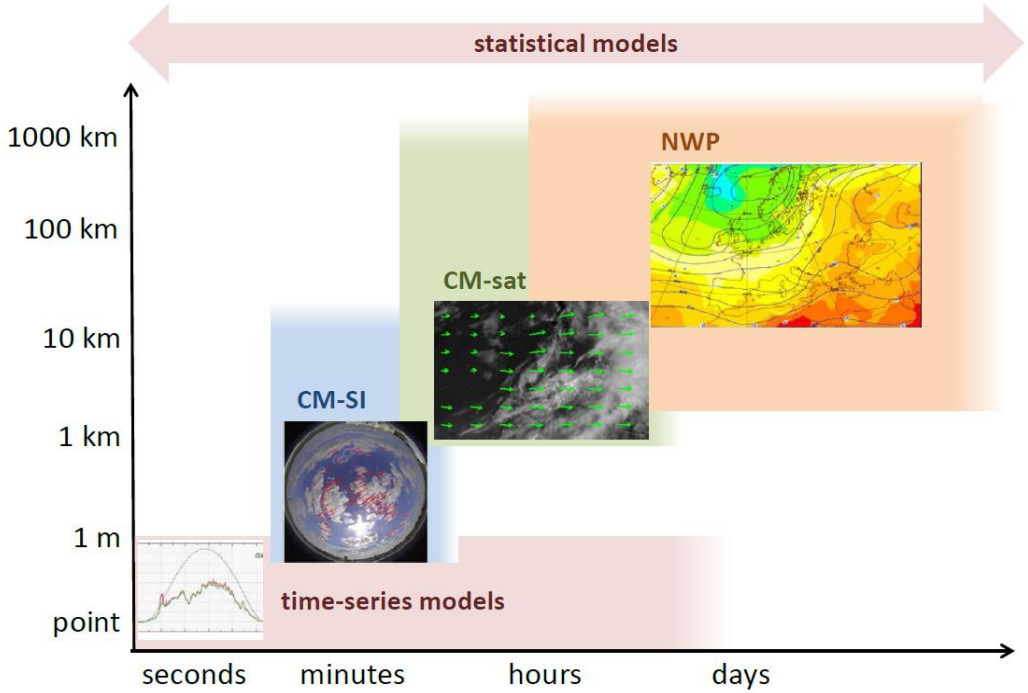
Elke Lorenz, Jose Antonio Ruiz-Arias, Luis Martin, Stefan Wilbert, Carmen Köhler, Rafael Fritz, Alessandro Betti, Philippe Lauret, Mathieu David, Jing Huang, Richard Perez, Andreas Kazantzidis, Ping Wang, and Yves-Marie Saint-Drenan

Webinar 18.2.2021

Chapter 8

- Introduction
- Empirical and Physical Solar Irradiance Forecasting Methods
- Irradiance forecasting with statistical and machine learning methods
- PV power forecasting and Regional Upscaling
- Evaluation of Irradiance and PV Power Forecasts
- Probabilistic Solar forecasts
- Recommendations for Solar Irradiance Forecasting

Overview of Solar Irradiance Forecasting Methods



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Empirical and Physical Solar Irradiance Forecasting Methods

- **Irradiance Forecasting with Cloud Motion Vectors**
  - Forecasting Using Ground-Based All Sky Imagers
  - Satellite-Based Forecasts
- **Irradiance Forecasting with Numerical Weather Prediction**

Introduction of basic principles of the different methods

Discussion of advantages and limitations of the different models

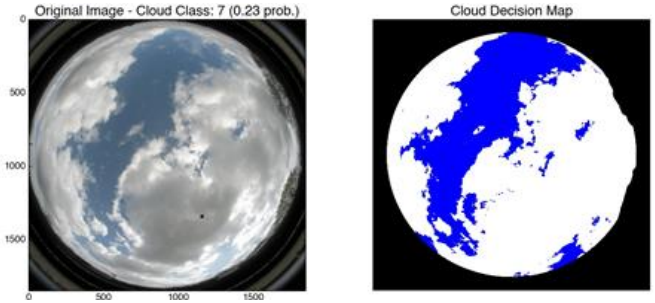
Many References for further explanation

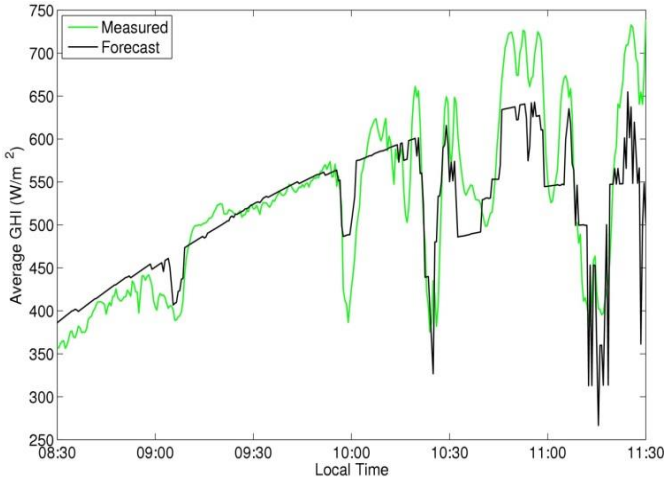
Forecasting Using Ground-Based All Sky Imagers

- Prediction of irradiance ramps with high temporal resolution
- High spatial resolution
- Typical forecast horizon 10-20 min
- Forecast for small areas

New research topic

Currently a benchmark of all sky imager forecasting methods is performed





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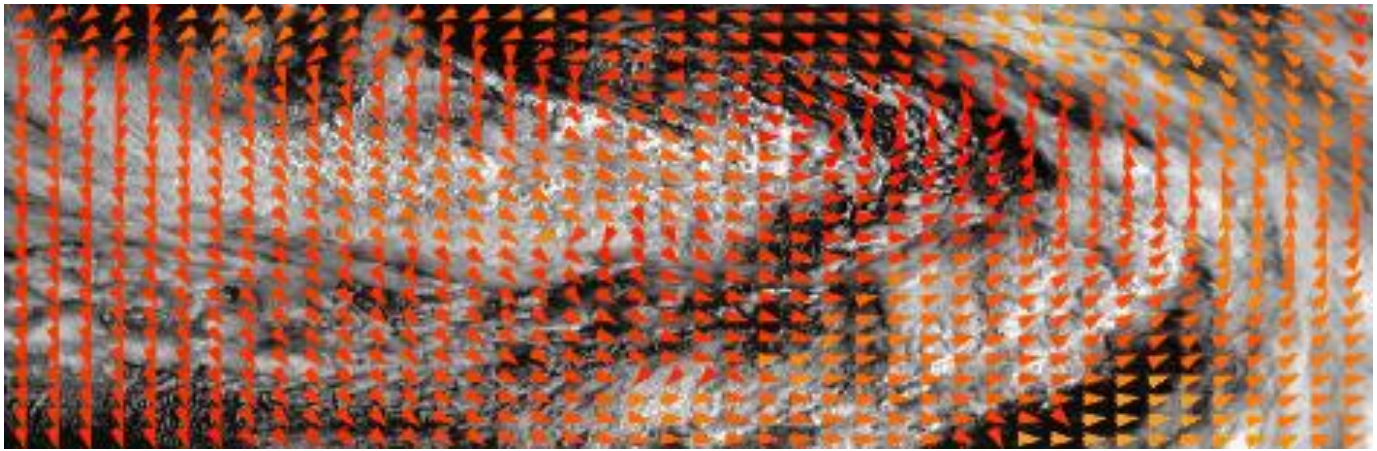
Satellite-Based Forecasts

- Prediction for large areas
- Forecast horizon:
  several hours ahead



Irradiance Forecasting with Numerical Weather Prediction

- Worldwide
- Forecast horizon: up to many days ahead

Examples of operational models and weather services operating these models

Irradiance Forecasting with Machine Learning Methods

- **Examples of Machine Learning Models**
- **Time-Series Models Based on Measurements**
- **Statistical Post-Processing Methods/Hybrid models**
  - Model Output Statistics to Reduce Forecast Errors
  - Combination of Forecast Model Outputs

Increasing importance in solar irradiance forecasting

Short general introduction to machine learning

Examples for machine learning in solar forecasting with references

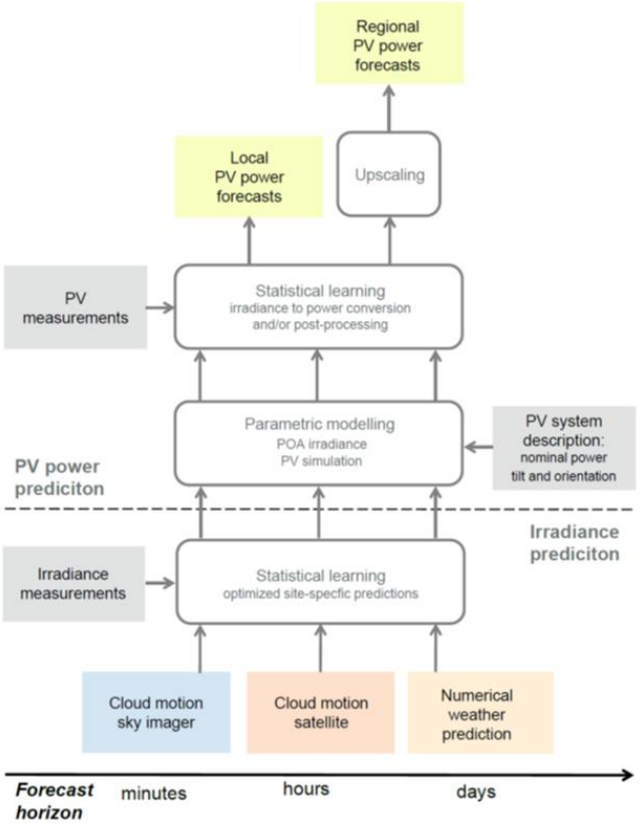
Discussion of advantages and limitations of different methods

PV Power Forecasting and Regional Upscaling

Simulation of PV Power Plant Production

- irradiance on plane of array
- PV simulation

Overview of basic steps and short introduction to methods



PV Power Forecasting and Regional Upscaling

Estimation and Forecasting of Regional PV Power Feed-In

Challenges

- PV power feed-in by many small systems is not measured
- PV system details not known for many small systems

Overview of different upscaling methods

Evaluation of Irradiance and PV Power Forecasts

Questions:

- How to quantify the overall uncertainty of irradiance forecasts?
- What has to be considered specifically for irradiance and PV power forecast evaluation?

Evaluation of Irradiance and PV Power Forecasts

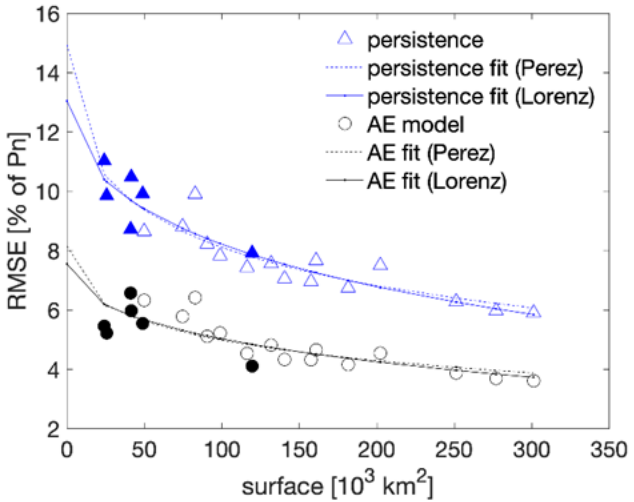
Questions:

- How to quantify the overall uncertainty of irradiance forecasts?
- What has to be considered specifically for irradiance and PV power forecast evaluation?

- **Error Measures**
  - Statistical error measures: RMSE, MAE and more
  - Skill scores and persistence: Is a forecast better than a trivial reference model?
    - Introduction of “smart persistence”
- **Analysis of Forecast Error with Respect to Solar Elevation and Cloud conditions**

Analysis of Regional Forecasts

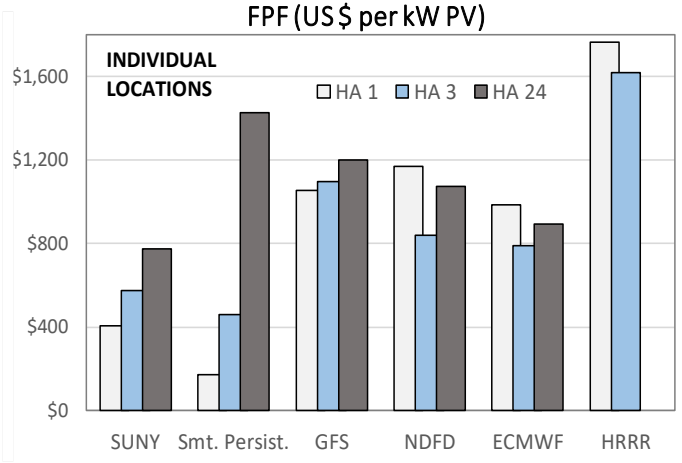
- Averaging effects reduce forecast errors for regional forecasts
- Quantification of forecast accuracy for regional averages for regions of different size



Effective Model Benchmark: Firm Solar Forecasts

Aim:
Evaluating the benefit of forecasts in terms of costs rather than using statistical error measures

Concept of firm power forecasts:
Cost to covert a given forecast to a „firm solar forecast“, e.g. using batteries, oversizing of plants



Probabilistic Solar Forecasts

Why probabilistic forecasts?

Forecasts are inherently uncertain

-> Uncertainty information allows more informed decision-making

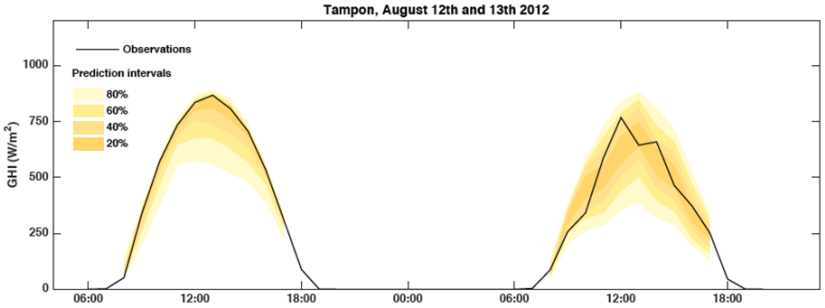
-> Probabilistic forecasts give uncertainty information for each forecast value

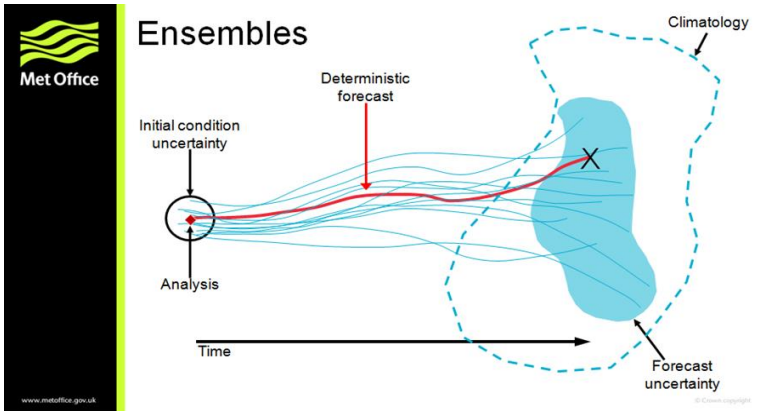
Types of probabilistic forecasts

- Quantile Forecasts
- Ensemble Prediction Systems

New topic in irradiance and PV Power forecasting

Overview basic principles and methods





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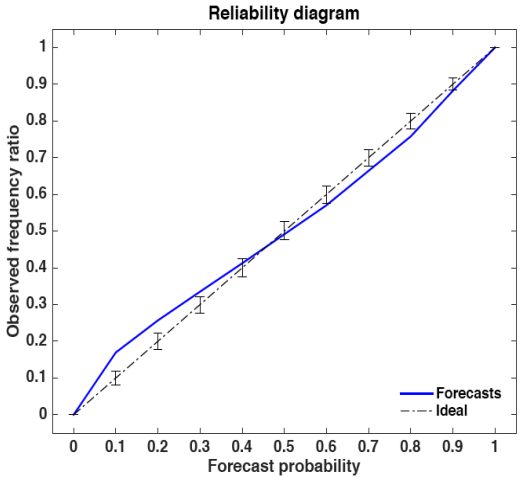
Verfication of probabilistic forecasts

Question:
How to assess the quality of probabilistic forecasts?

-> “Reliability” is one important additional criterium

Introduction to probabilistic forecast verification

- *Basic concepts*
- *Frequently used scores and diagrams*



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Summary for irradiance forecasting

- Overview of different forecasting methods
  - Introduction to basic principles of different methods
  - Many references for more detailed information
  - New sections: forecasting with machine learning and regional PV power forecasting
- Discussion of advantages and limitations of the different methods for different requirements
- Recommendations on irradiance forecast evaluation
- Introduction to probabilistic solar forecasting
- Focus on models and uncertainty assessment rather than on products:
  No list of forecasting products (yet)

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