

A Machine Learning Demo

10-Day Solar Irradiation Prediction
based on weather forecast

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Solar Irradiation Forecasting

Data used for Demo:

Hourly weather data for selected sites (historical and forecasts)

Europe: Klagenfurt, Vienna, Frankfurt a.M., *training period: 2004-2005*

USA: Boston, MA (2004-2010); Elizabeth City, N.C. (2005-2007)

Historical solar irradiation data (hourly, for *same training periods*)

Data Sources:

weather data: www.wunderground.com

solar irradiation data:

Europe: SODA/Helioclim (satellite-derived data)

USA: NSRDB/METSTAT for Boston (satellite-derived data),
University of Elizabeth City (ground station measurements)

Solar Irradiation Forecasting

low complexity computer model with minimal data requirements

Input data (hourly):

Dry Bulb Temperature	[°C]
Dew Bulb Temperature	[°C]
Atmospheric Pressure	[hPa]
Air Humidity	[%]
Wind Speed	[km/h]
Wind Direction	[degrees]
Weather Condition	[verbal]

physical parameters:

Solar altitude angle,
Geolocation/Time Zone
location-specific turbidity parameter
sealevel altitude

Solar Irradiation Forecasting

computer model with minimal data requirements

Input data (hourly) - Preprocessing:

Verbal classifications of **Weather Conditions**

(e.g. Clear, Partly Cloudy, Overcast,
Rain, Thunderstorm,....)

are translated into a low-dimensional numerical space

Solar Irradiation Forecasting

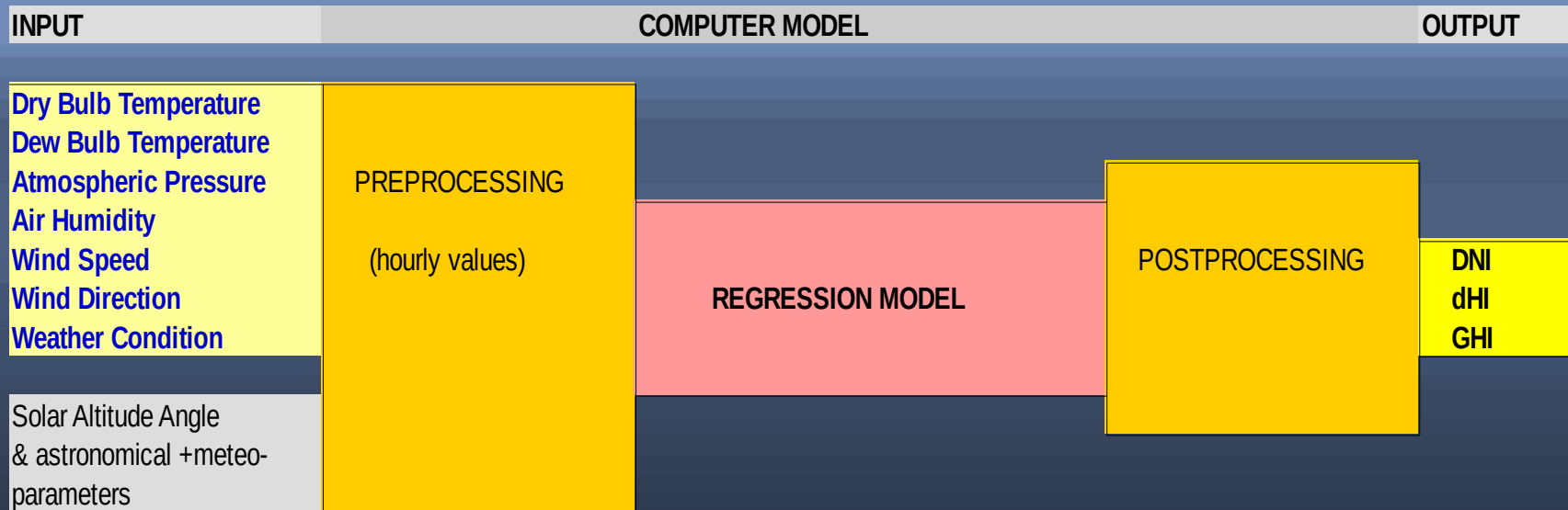
Output (hourly):

Direct Normal Irradiation (DNI)	[W/m ²]
Diffuse Horizontal Irr. (dHI)	[W/m ²]
Global Horizontal Irr. (GHI)	[W/m ²]

(W/m² as hourly averages)

corresponding to scope of
weather forecast data, e.g.
for next 10 days

Solar Irradiation Forecasting



The Regression Model is trained on historical data

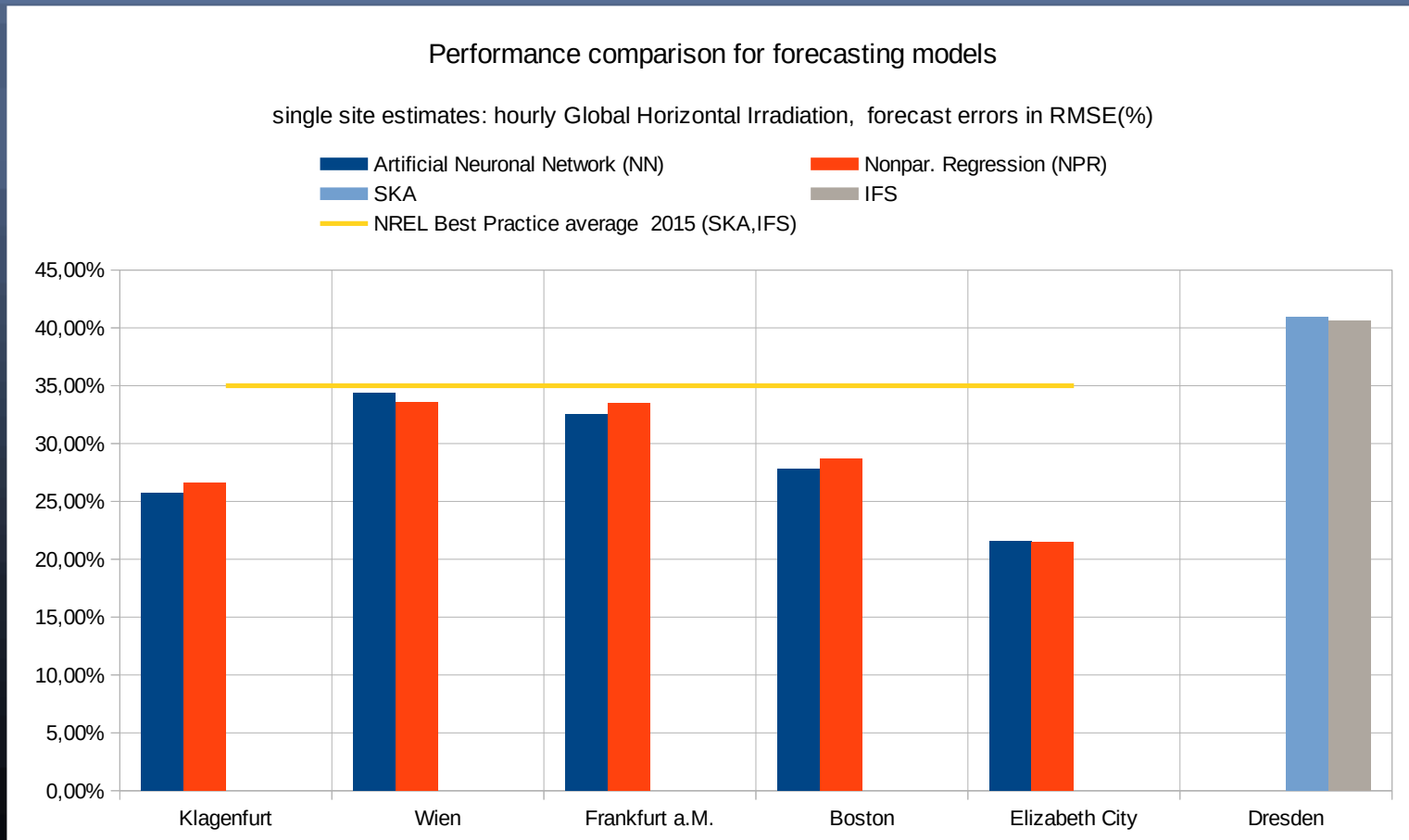
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Typical Alternatives for Regression modeling:

- * Artificial Neural Networks (NN)
- * Nonparametric Regression (NPR)
- * Random Forests (RF)
- * Support Vector Regression (SVR)

Solar Irradiation Forecasting

Single-site Forecasting Performance
apparently compares favorably with „best practice“



Solar Irradiation Forecasting

Single-site Forecasting Performance
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References for performance comparisons:

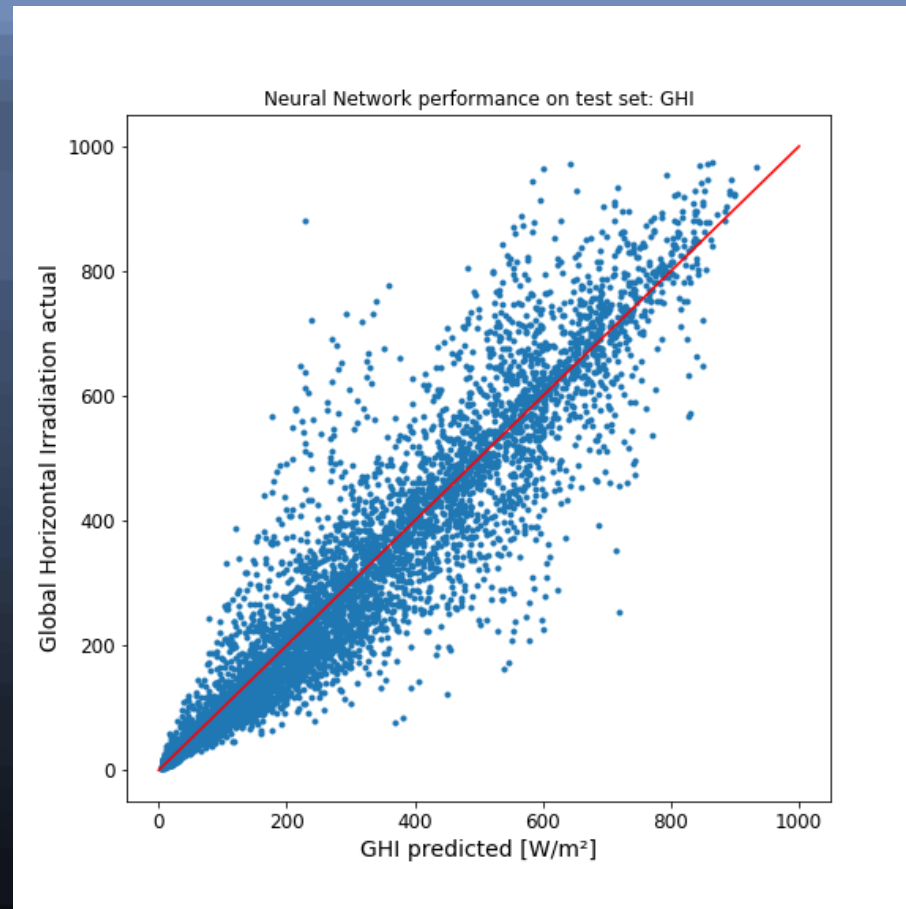
IFS computer model run by *European Center for Medium-Range Weather Forecasts*

SKA High Resolution limited area model by *Danish Meteorological Institute*

Manajit Sengupta, Aron Habte, Sarah Kurtz,
Aron Dobos, Stefan Wilbert, et al.:
Best Practices Handbook for the Collection and Use of Solar Resource Data for Solar Energy Applications. [Research Report]
Technical Report NREL/TP-5D00-63112,
National Renewable Energy Laboratory. 2015, 236 p.

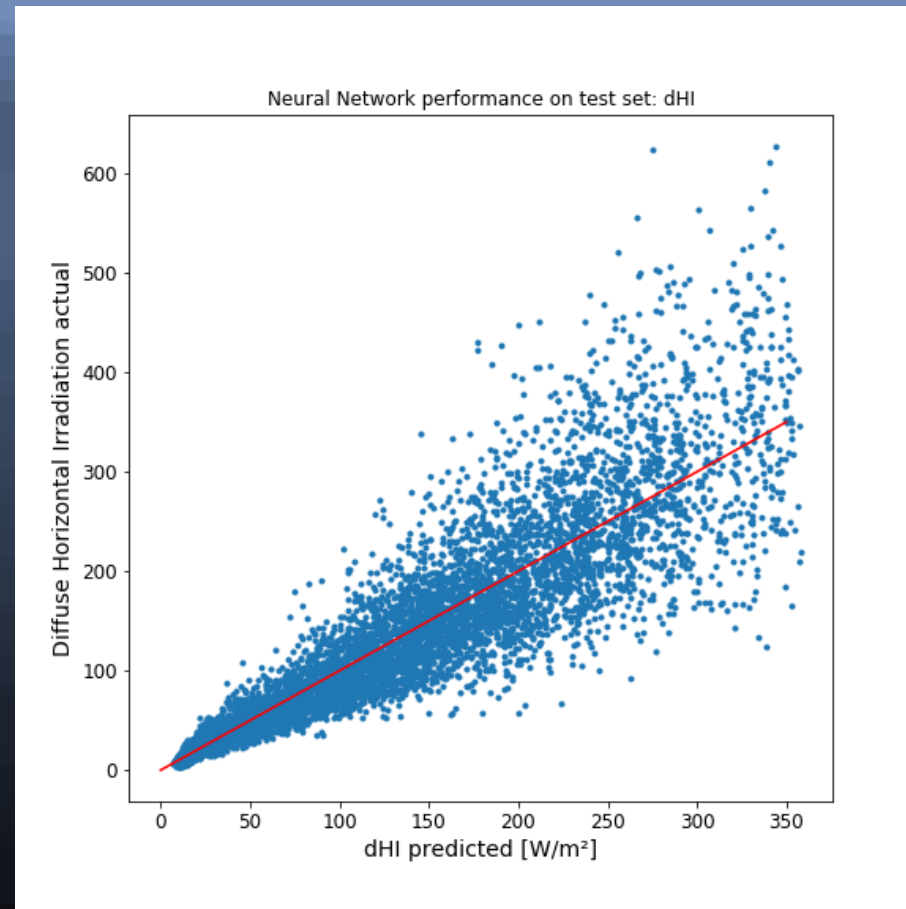
Solar Irradiation Forecasting

Estimation accuracy is evaluated on (random) test sets from historical data



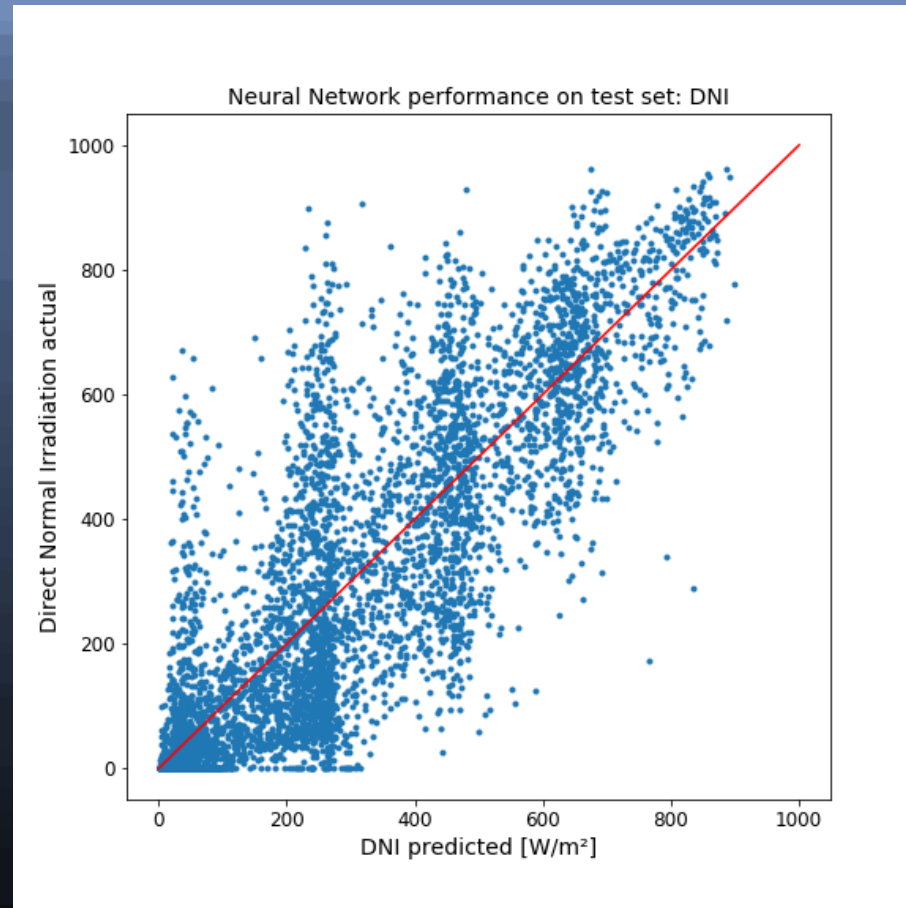
Solar Irradiation Forecasting

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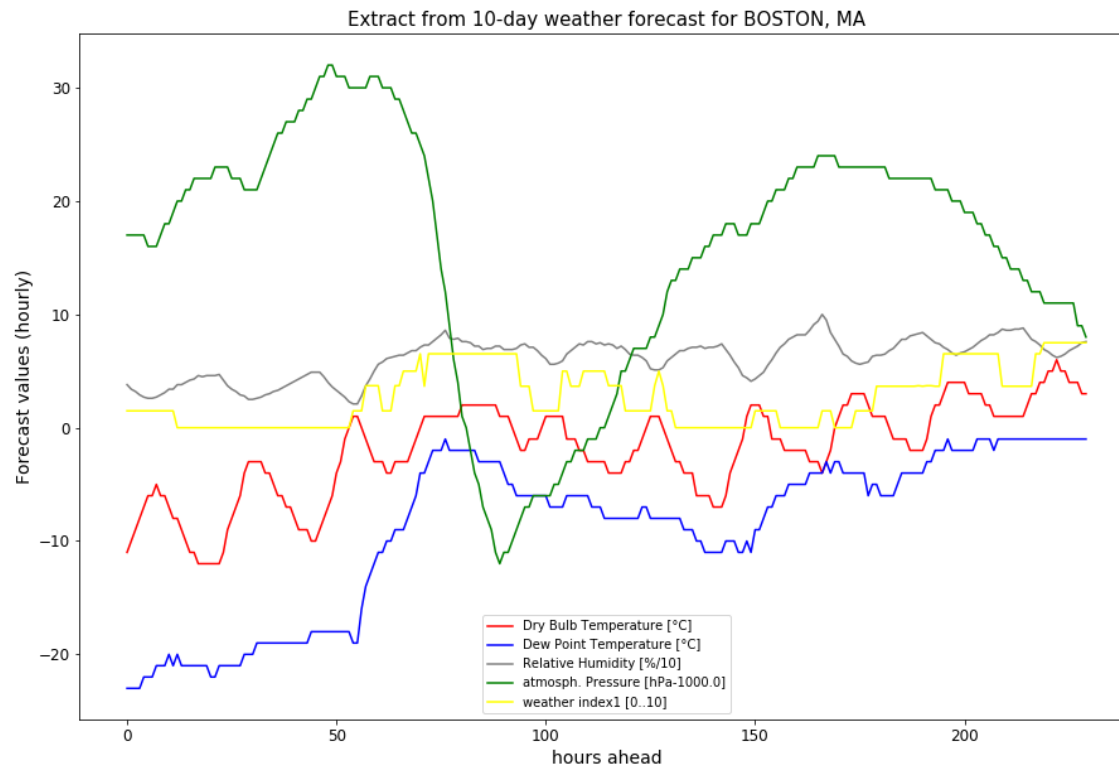
Solar Irradiation Forecasting

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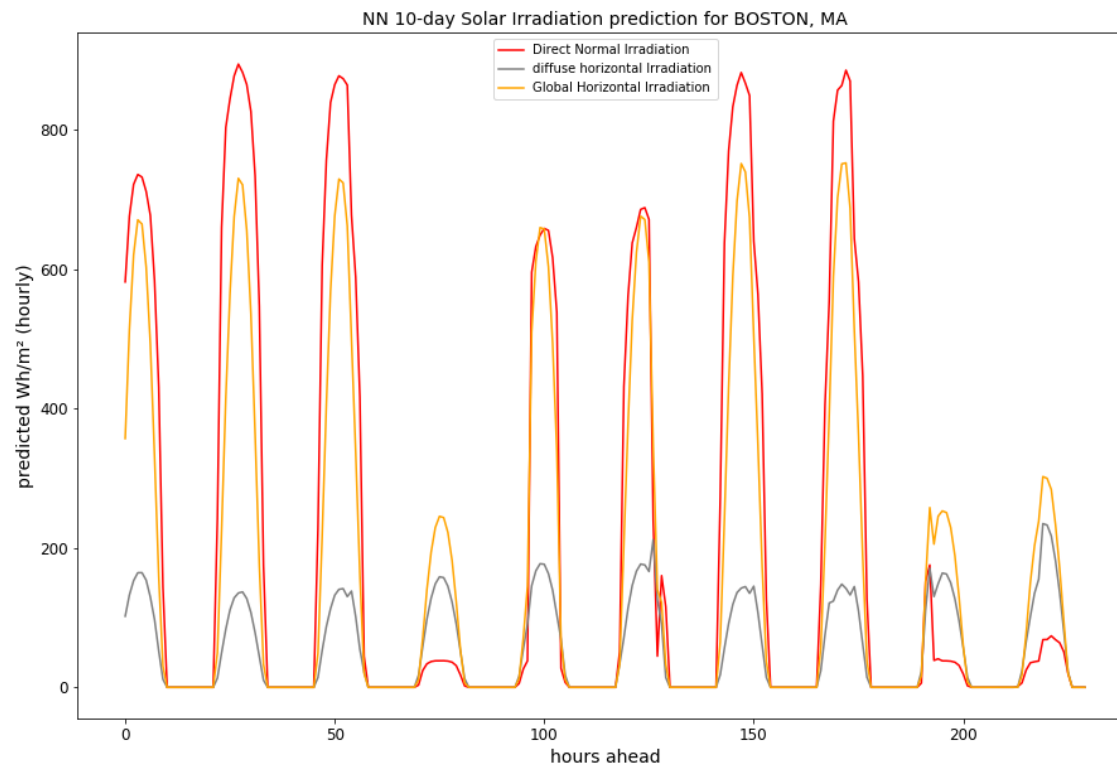
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A Forecast Example (10day-Demo for BOSTON, MA)



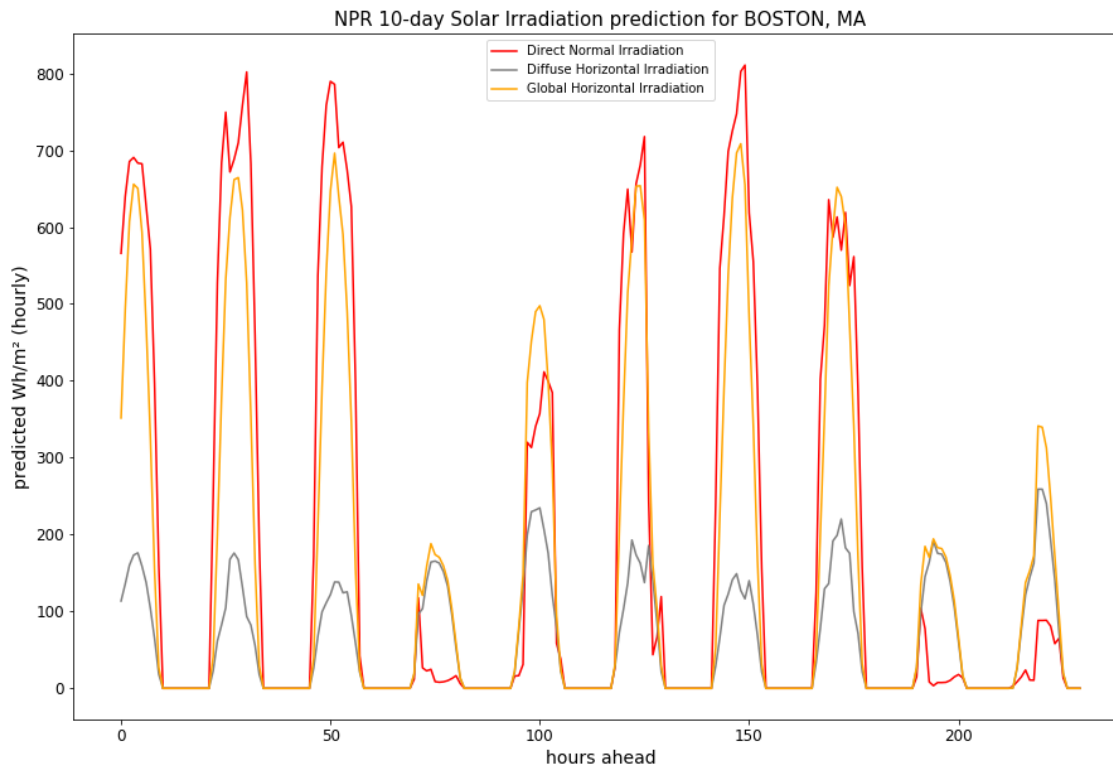
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A Forecast Example (10day-Demo for BOSTON, MA)



Solar Irradiation Forecasting

A Forecast Example (10day-Demo for BOSTON, MA)



Solar Irradiation Forecasting

Assessing Prediction Errors:

the accuracy of the solar prediction depends on the accuracy of the *weather forecast*: the RMSE estimates for **single-site hourly predictions** given for the demo NN and NPR models apply only, if the weather forecast is *accurate*.

improvement potentials such as corrections based on model output statistics (MOS) have not been used.

Even greater improvement could be achieved by **regional combined multi-site forecasts**, which allow „averageing out“ statistical errors, and by **higher quality data**, e.g. on cloud formation and movement, higher temporal and spatial resolution, ground-based measurements etc.

Solar Irradiation Forecasting

Assessing Prediction Errors:

there is room for substantial improvements

- * also with **mathematical models of higher complexity**, c.f. e.g. Mohana Alanazi, Mohsen Mahoor, Amin Khodaei: *Two-Stage Hybrid Day-Ahead Solar Forecasting (2017)*, University of Denver, USA
with reported RMSE for GHI at 10% and lower for location Denver, (but with different assumptions from models considered here on availability of solar radiation data for forecasting)
- * with **short-term forecasts** (5min -30min ahead) by *sky imaging* (Univ. of California San Diego, Center for Energy Research, vgl. NREL Best Practices Handbook, p.173)

A Machine Learning Demo: Solar Irradiation Forecasting

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