Forecasting regional PV power in Great Britain with a multi-modal late fusion network

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Abstract

- Predicting solar power is important for grid balancing and reducing CO2 intensity of electricity
- Multi-modal data can be used to make more accurate predictions
- We propose a late-fusion model integrating two NWPs, and satellite imagery with realistic delays to create 0-8 hour forecasts for grid regions across Great Britain
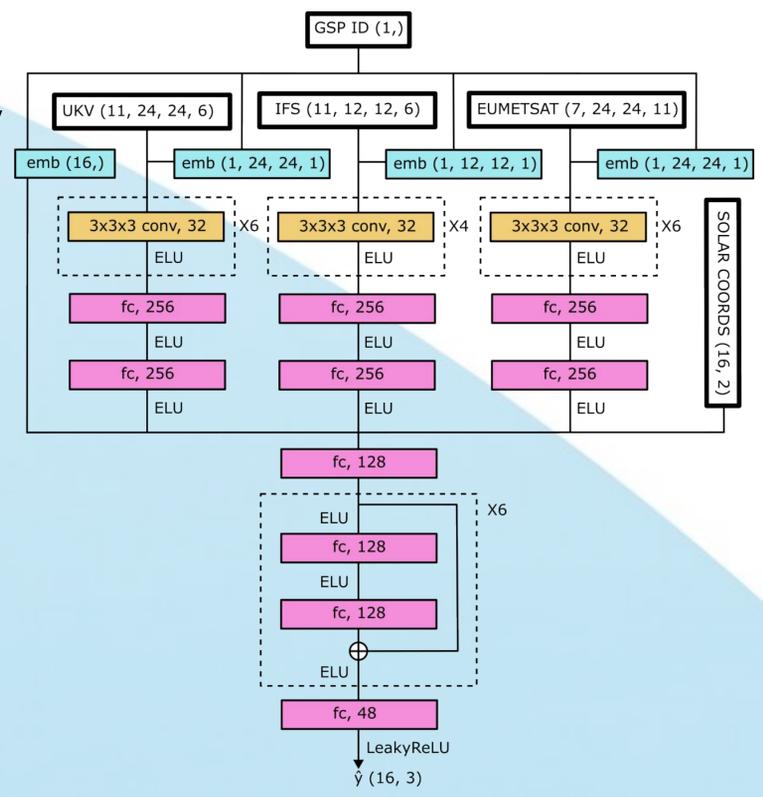
Data

Input sources:
- EUMETSAT SEVIRI Rapid Scanning Service Satellite Imagery
  - 11 Spectral Channels
  - 5 minutely temporal resolution
  - 4.6x7.1km resolution per pixel, and a 24x24 input size

- Numerical Weather Predictions
  - MetOffice UKV
    - Spatial resolution: 2x2km
    - 8 initialization times per day, with a 24x24 input size
  - ECMWF IFS
    - Spatial resolution: 0.05x0.05 degree (approximately 3.2x5.6km in GB)
    - 2 initialization times per day, with a 12x12 input size
  - 2-meter temperature, downwards short- and long-wave radiation flux, and high, medium, and low cloud cover
  - Hourly temporal resolution
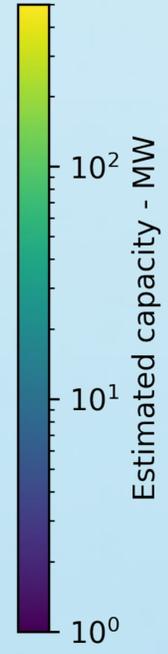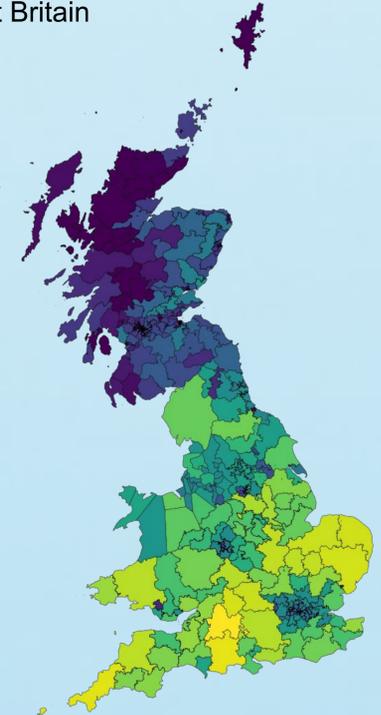
PV generation capacity for each Grid Supply Point (GSP) in Great Britain

- Solar coordinates (azimuth/elevation)

- All data has the same delays seen in production
  - NWP delayed 3 hours from initialization time
  - Satellite delayed 60 minutes

Target: PVLive estimate of generation for the given region (GSP), normalized by effective capacity between 0 and 1
- 1.6 million training examples between 2020-01-01 to 2022-05-07
- 32000 validation examples between 2022-05-08 to 2023-05-07

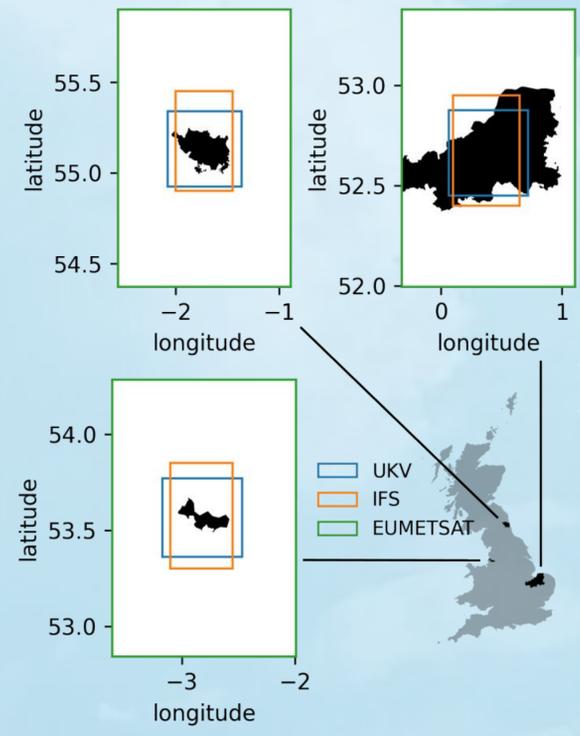*Examples of spatial coverage of the different inputs*

Architecture

- Late-fusion multi-modal network
- Separate 3D CNN encoders per input modality
- Learned embedding for GSP ID
- 1D encoding vectors concatenated with solar coordinates, GSP ID embedding
- Output fully-connected layers with skip connections
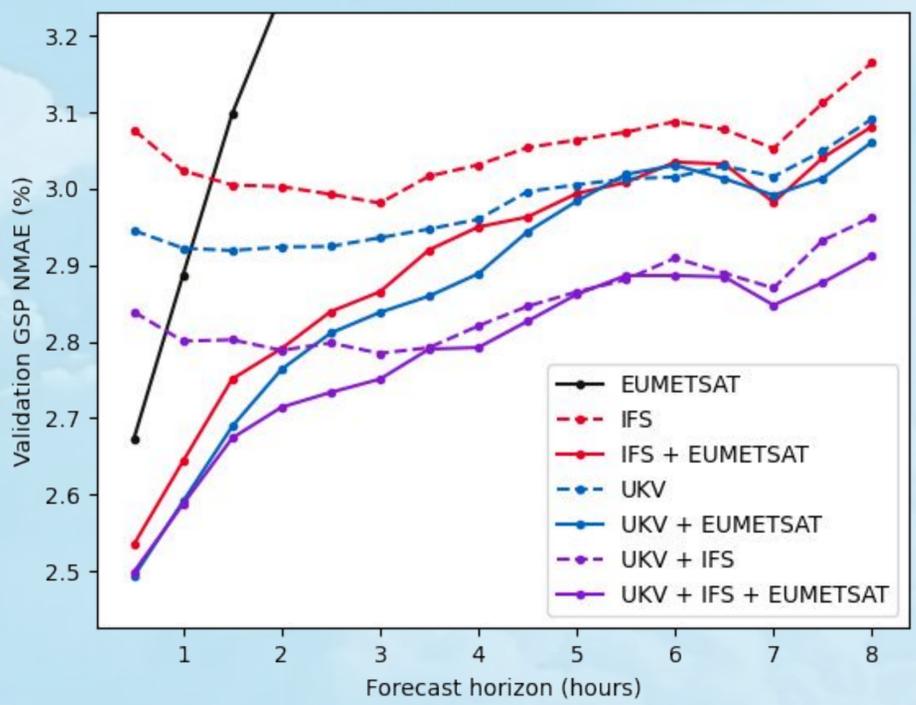- Probabilistic outputs
- Quantile regression loss

Architecture Diagram of the late-fusion model

Results

Normalized Mean Absolute Error (NMAE) for various combinations of input modalities

Data sources	Prediction percentile		
	10%	50%	90 %
UKV+IFS+EUMETSAT	0.0818	0.4462	0.8666
UKV+EUMETSAT	0.0904	0.4874	0.8919
IFS+EUMETSAT	0.1002	0.4870	0.8801
UKV+IFS	0.0879	0.4872	0.9060

Calibration of quantiles with various input modalities

- Pure satellite forecasting is more accurate than NWP-based forecasting for first 30 minutes
- Satellite + 1 NWP outperforms 2 NWPs out to 90 minute horizon
- Having satellite data as additional input results in decrease in NMAE out to 5 hour lead time
- Multiple NWPs outperform using a single NWP
- All quantiles in predictions are well-calibrated on the validation set
- Satellite imagery is helpful in short term forecasts, increasing skill out to lead time of 5 hours
- Simple late-fusion network with multi-modal inputs can accurately predict solar generation out to 8 hours