Multi-Modal Generative Video Prediction of All-Sky and MSG/MTG Satellite Imagery for Solar Irradiance Nowcasting

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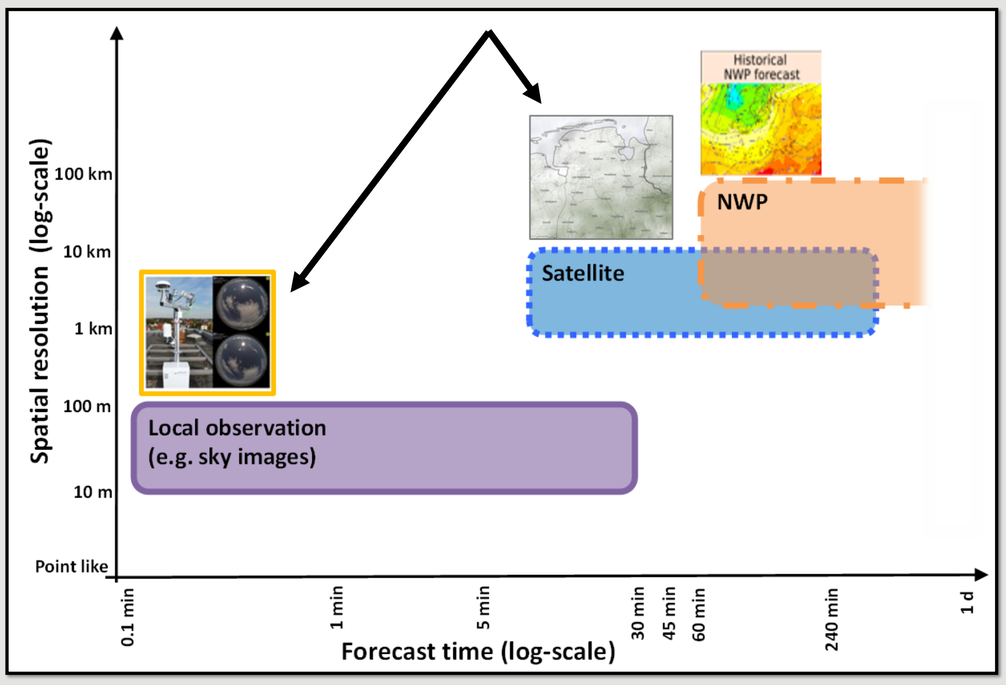
Abstract

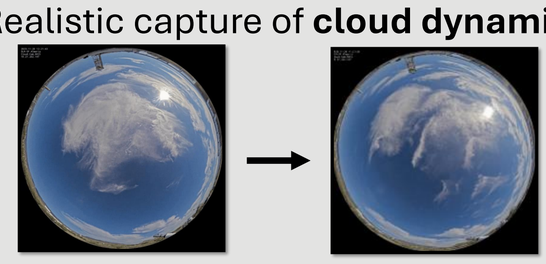
Reliable photovoltaic operation necessitates high-resolution solar irradiance forecasting to mitigate the challenges of solar power intermittency. State-of-the-art generative models have demonstrated exceptional performance in forecasting utilizing EUMETSAT's Meteosat Second Generation (MSG) satellite [1, 2] and All-Sky-Imager (ASI) data [3]. Since these data sources cover disparate scales in time and space, leveraging jointly their distinct advantages in forecasting models is subject of current research [4, 5, 6]. In this PhD project work, we propose a deep learning, diffusion-transformer-based generative video predicting architecture that processes ASI and satellite data, including MSG or in future next-generation MTG, to simultaneously generate future image frames and irradiance target quantities. Preliminary results are presented for a model variant utilizing MSG-only input data to perform both MSG video prediction and irradiance estimation.

Motivation & Background

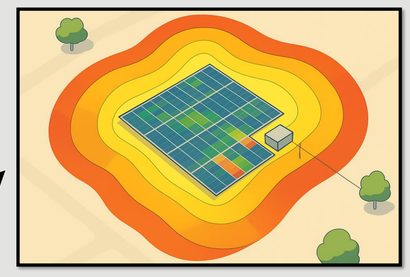
Multi-modal input (All-Sky-Imager and MSG/MTG) & **Joint forecasting** product with lead time ≥ 1h



Realistic capture of **cloud dynamics**

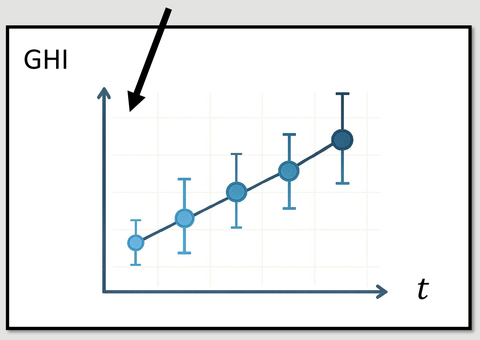


Prediction of PV plant scale **2D irradiance maps**



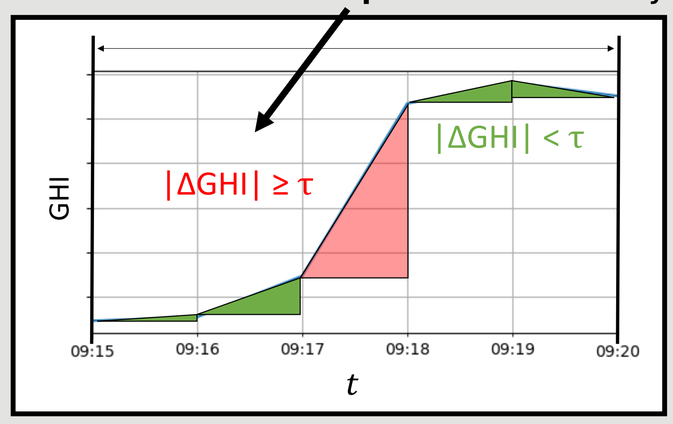
Cartoon generated by Open-AI DALL·E 3 Model

Feature **probabilistic** forecasts



Cartoon generated by Open-AI DALL·E 3 Model

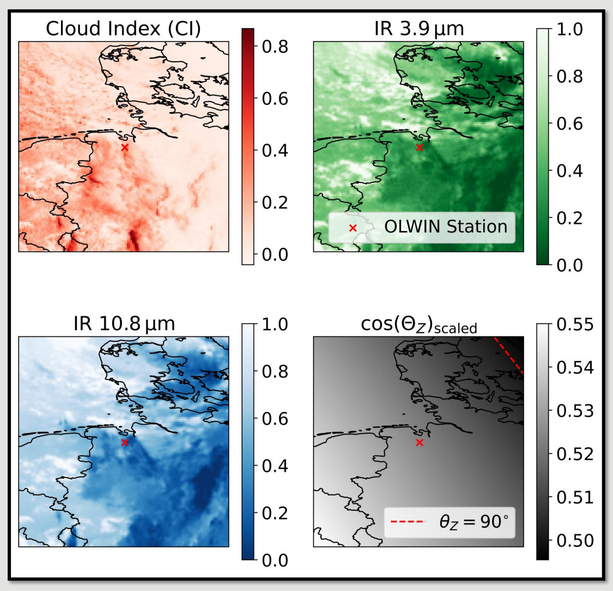
Ramp event sensitivity



Data Pipeline & Model Architecture

MSG & MTG ➡ 4-channel product

Adopted from [2]



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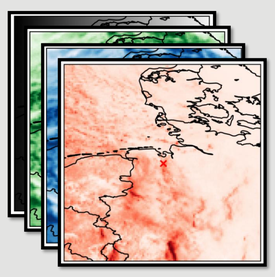
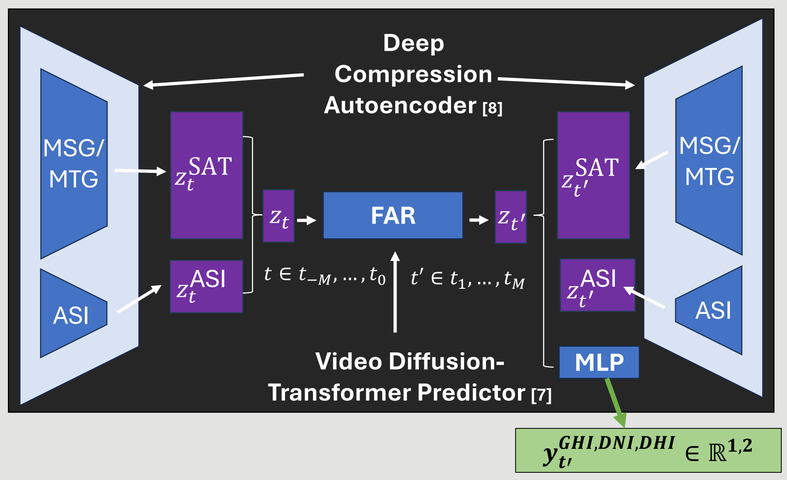
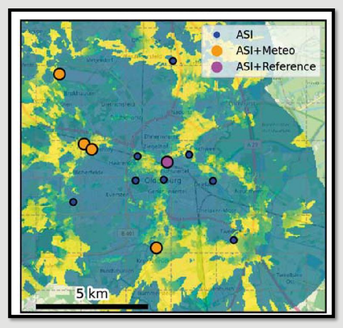


[9]



- Dimension reduction and data homogenization via **Deep Compression Autoencoder** into latent space
- Prediction of latents into the future via **Video Diffusion-Transformer Predictor**
- FAR model demonstrated **successful forecasting of ramp events** in ASI-only video + irradiance prediction via additional MLP head [8]

Irradiance Predictions



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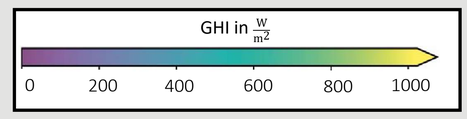
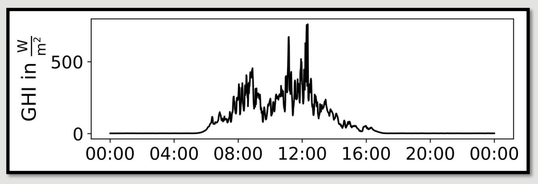
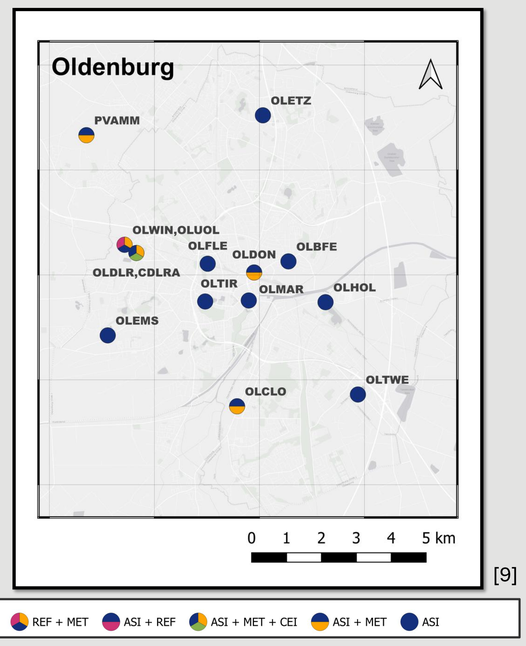




All-Sky-Imager ➡ Eye2Sky Network DLR Oldenburg [9]



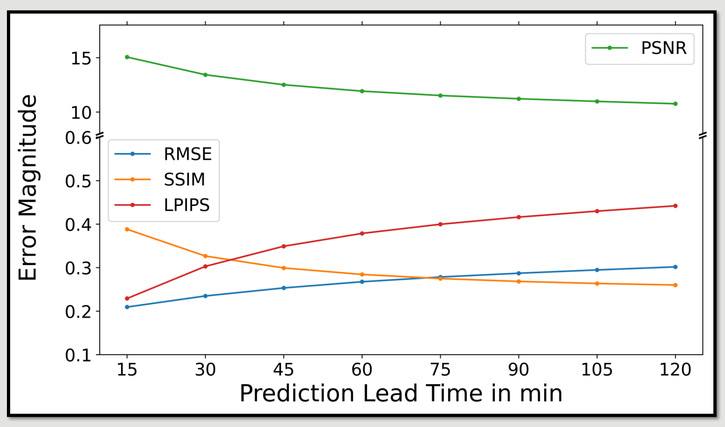
[9]

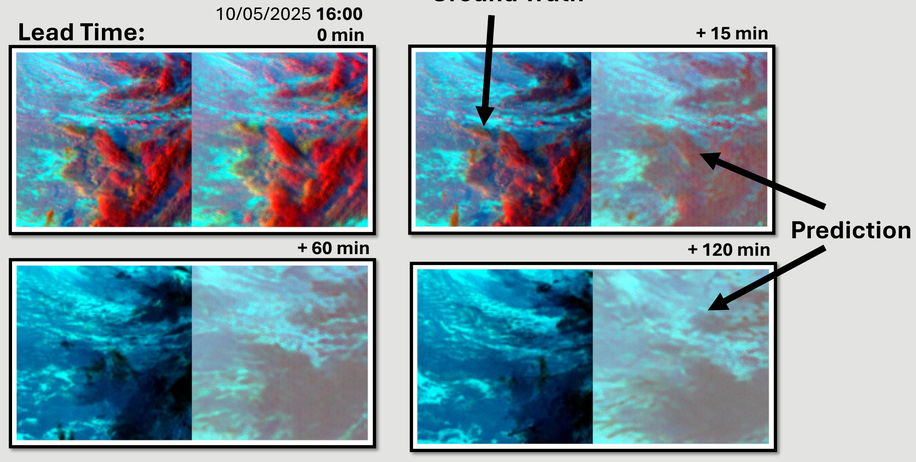
Preliminary Results

Current status of model: MSG 4-channel input & output (Lead Time 15-120 min)

- Training/Validation/Test data from 2020-2025
- 2(1) random day(s) per month for validation (testing)

Image Error Metrics (on entire test dataset, metrics definitions as in [7])





RGB (**R**ed: Cloud Index, **G**reen: IR 3.9 µm, **B**lue IR 10.8 µm)

Outlook

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- Data Pruning (day-time & early morning predictions)
- MTG Fine-Tuning/Full Training
- Multi-Modal Approach: Include ASI images
- Irradiance Target Prediction & Coincidence Tests

References

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