Impact of Tropical Convective Conditions on Solar Irradiance Forecasting based on Cloud Motion Vectors

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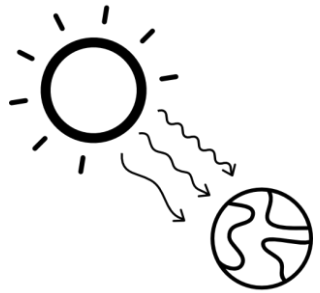
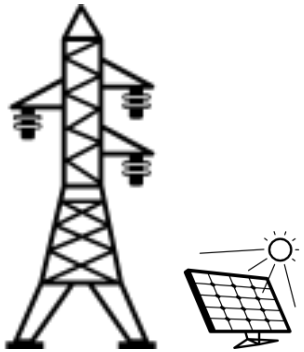
Introduction

- High solar irradiance received by tropical and sub-tropical regions



- Increasing grid connected solar PV capacity

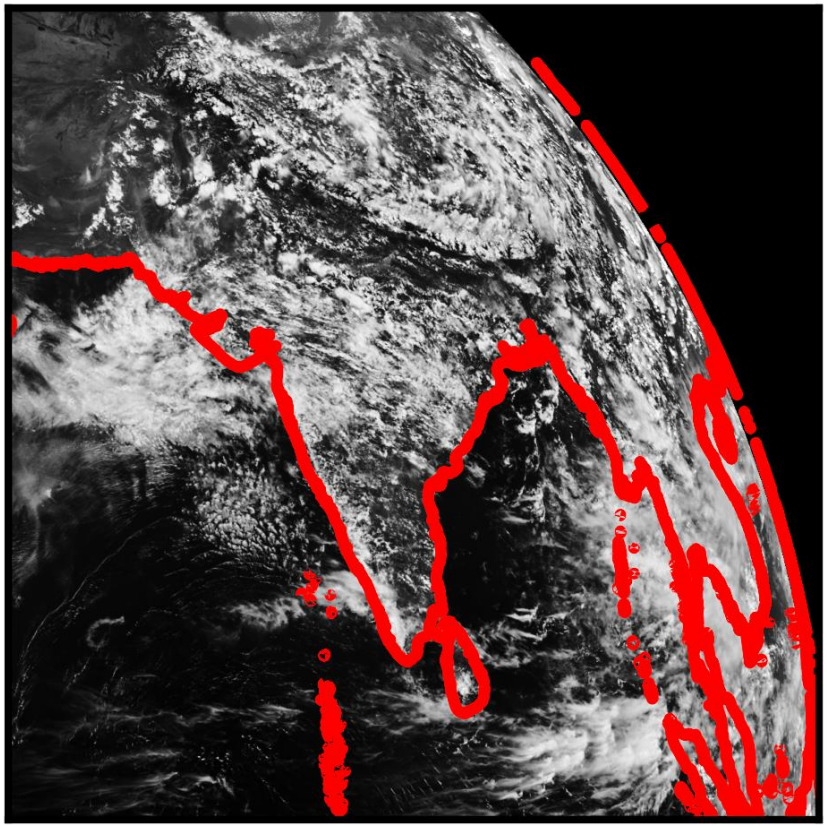
- Economic operation needs reliable forecasts



- Important regional meteorological conditions

Introduction

- Cloud motion vectors (CMV)
  - Techniques assume rigid cloud bodies
  - Purely advective motion
- South Asian Monsoon
  - Seasonal convection pattern
  - Formation and dissipation of clouds.



Meteosat-8 Image at 2018-08-09T09:00

Aim

- Investigation of seasonal variation of satellite-based forecast accuracy with three commonly used CMV methods
  - Block-match
  - Farnebäck (optical flow)
  - TV-L^1 (optical flow)

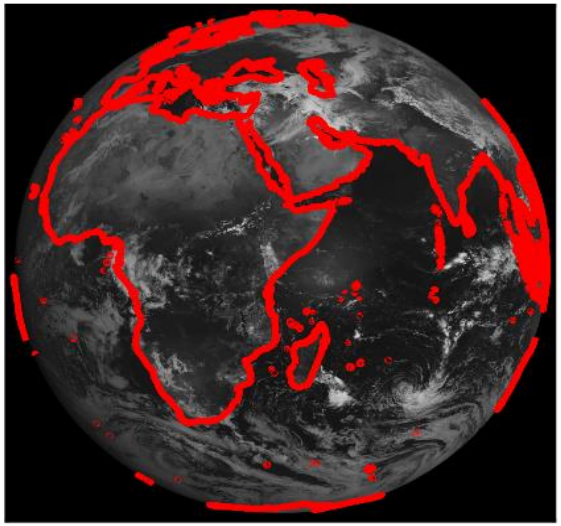
- Impact of monsoon convection on the forecast accuracy

- **Accuracy analysis**: Inter-method difference vs. inter-seasonal difference

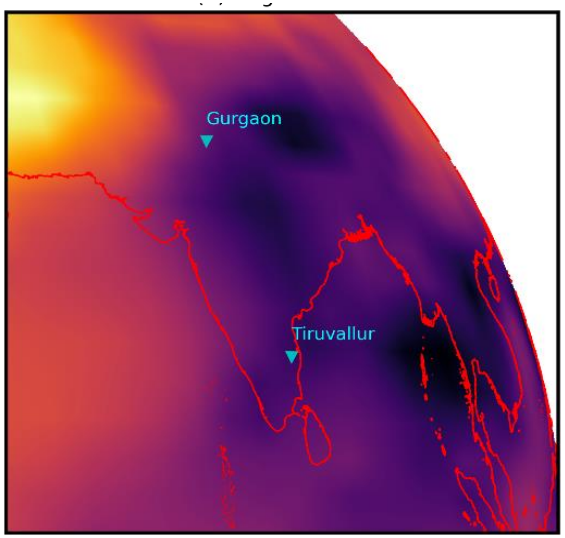
Data and Forecasting Methods

Dataset

- Satellite Data from MSG: Indian Ocean Data Coverage (low resolution)
  - For forecast generation
- Ground-measured data from BSRN* stations at Gurgaon (GUR) and Tiruvallur (TIR)
  - For forecast validation
- Outgoing longwave radiation (OLR) (NOAA* satellite product)
  - Used as metric for strength of convection



Meteosat-8 full disk image at 2019-03-31T08:00

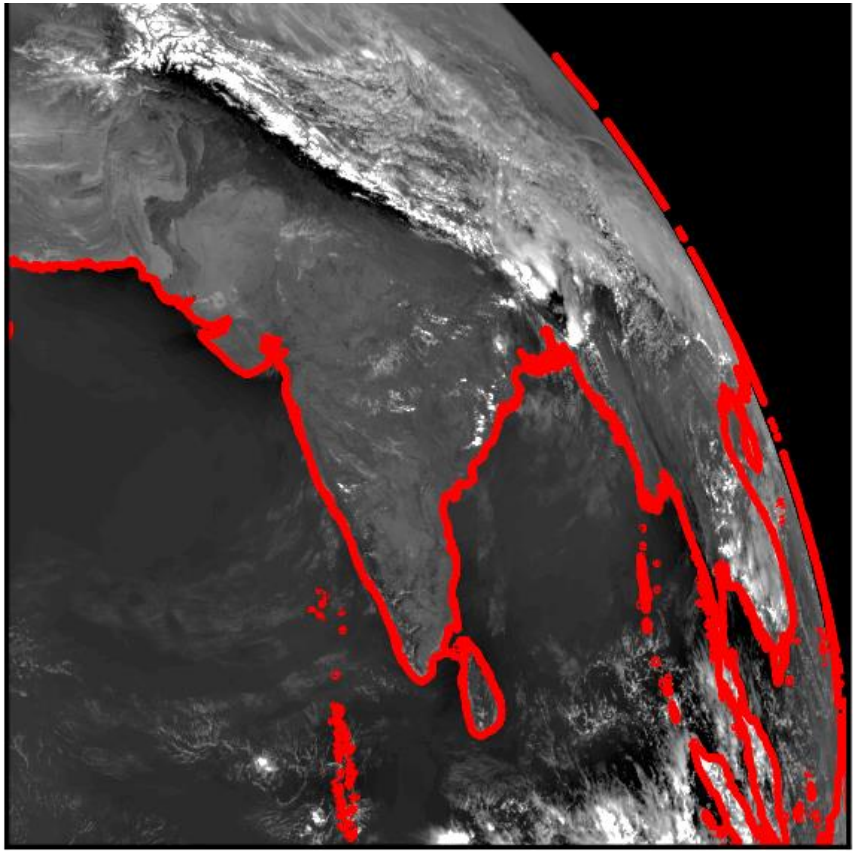


Monthly averaged OLR for August 2019 (NCEP)

*BSRN: Baseline Surface Radiation Network
*NOAA: National Oceanic and Atmospheric Administration

Satellite Image Preprocessing

South Asian section

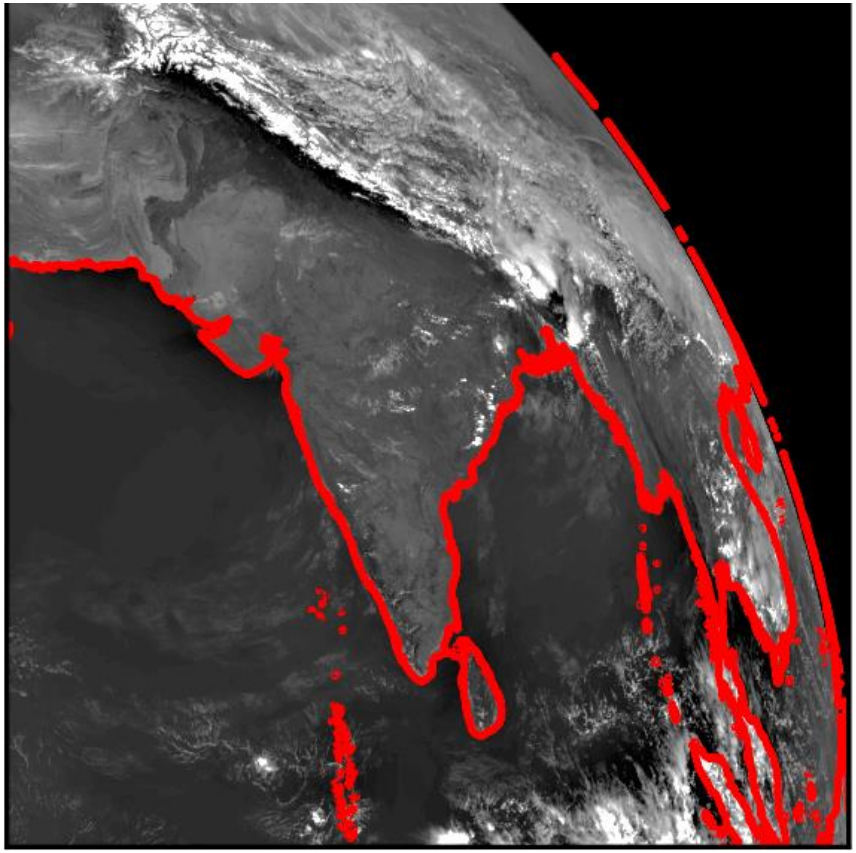


Cloud Index image n ∈ [0,1]

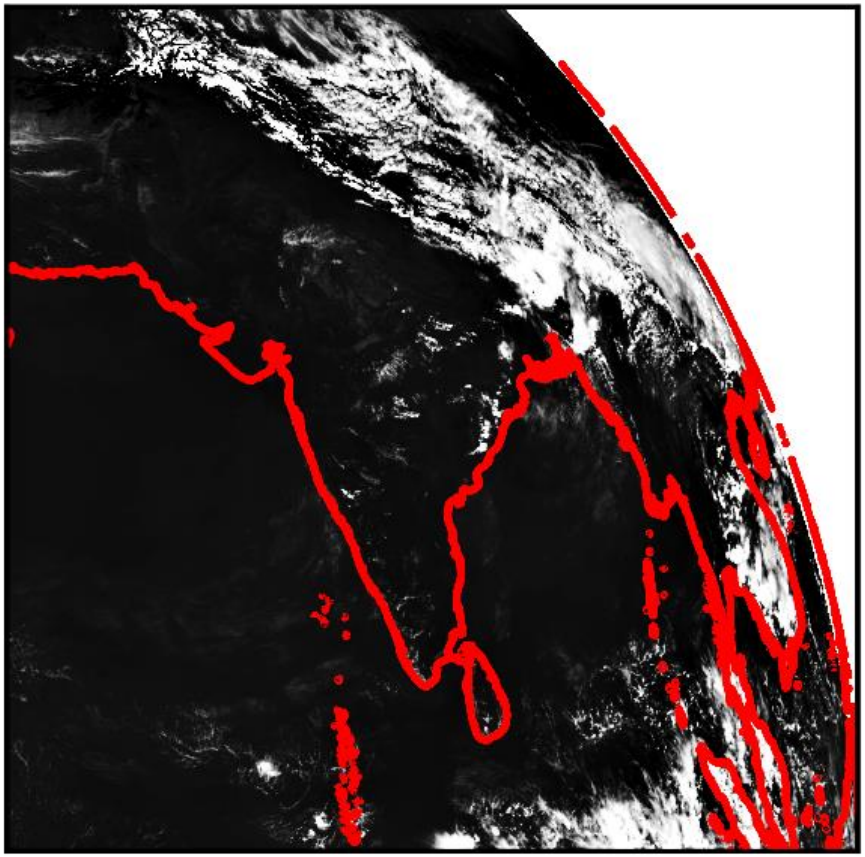
$$n = \frac{(\rho_{sat} - \rho_{clear})}{(\rho_{cloud} - \rho_{clear})}$$

Satellite Image Preprocessing

South Asian section



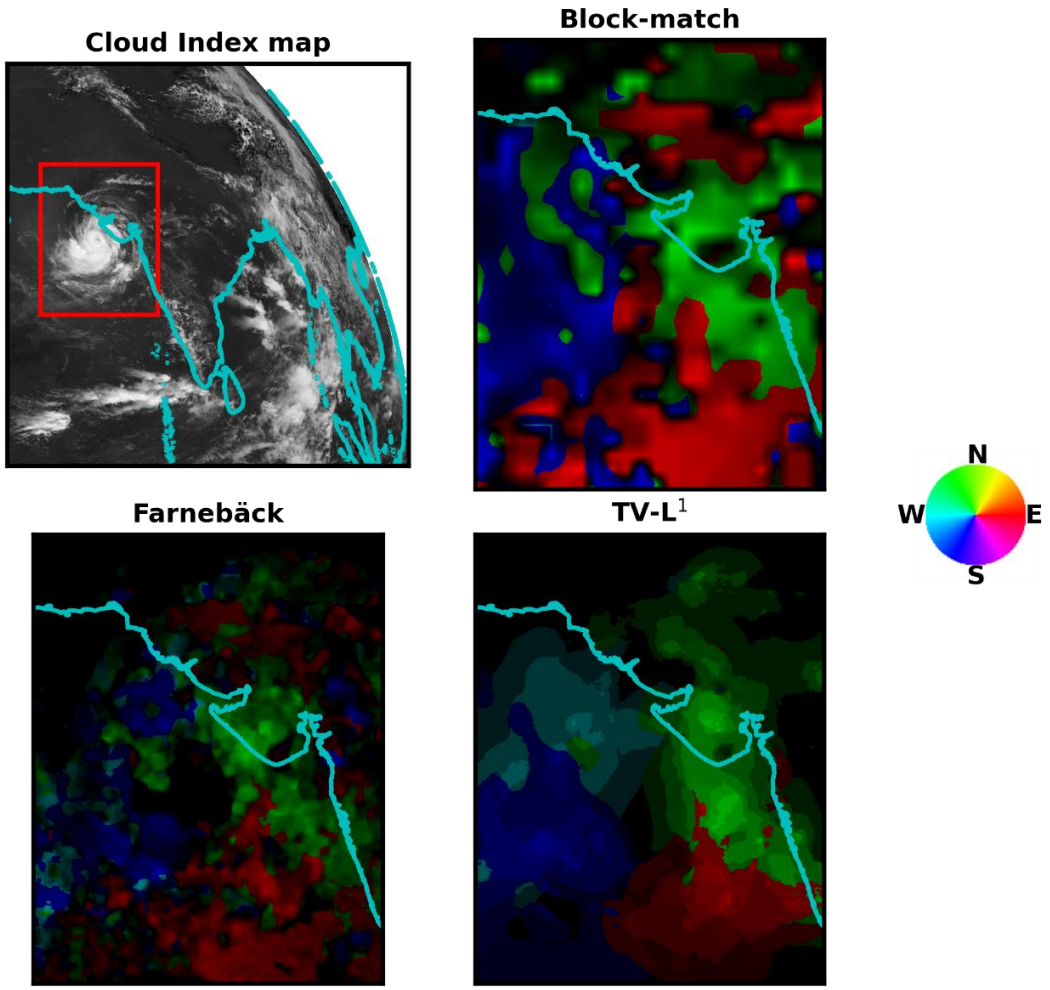
Cloud Index image n ∈ [0,1]



DLR

Cloud Motion Vector Techniques

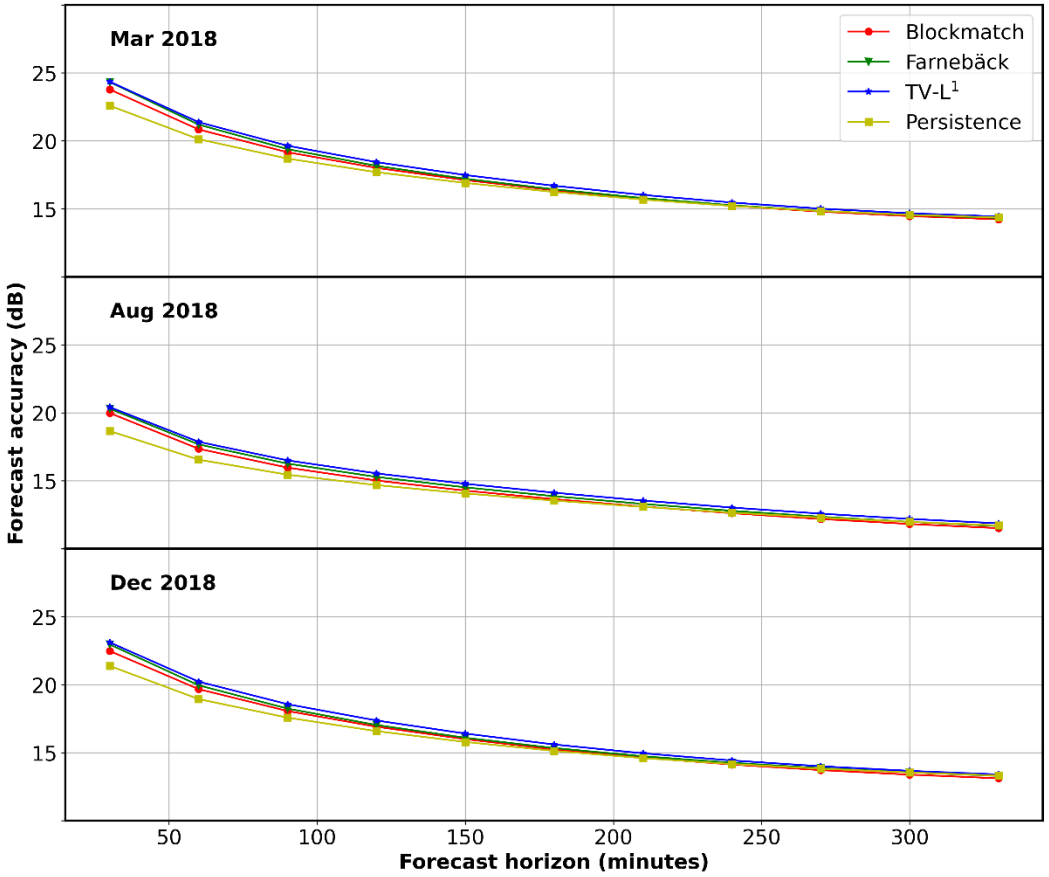
- Coarse resolution of block-match output; motion also assigned to cloudless pixels
- Finer resolution of Farnebäck output, with large gradients in motion
- Smooth output from TV-L^1 with a fine resolution



Analysis and Results

Forecast Evaluation – sectionwide

- Validation of forecasted CI map against analysis CI map
- Forecast horizon of 30 to 330 minutes ahead
- Forecast step of 30 minutes
- Period of validation: 2018-2019

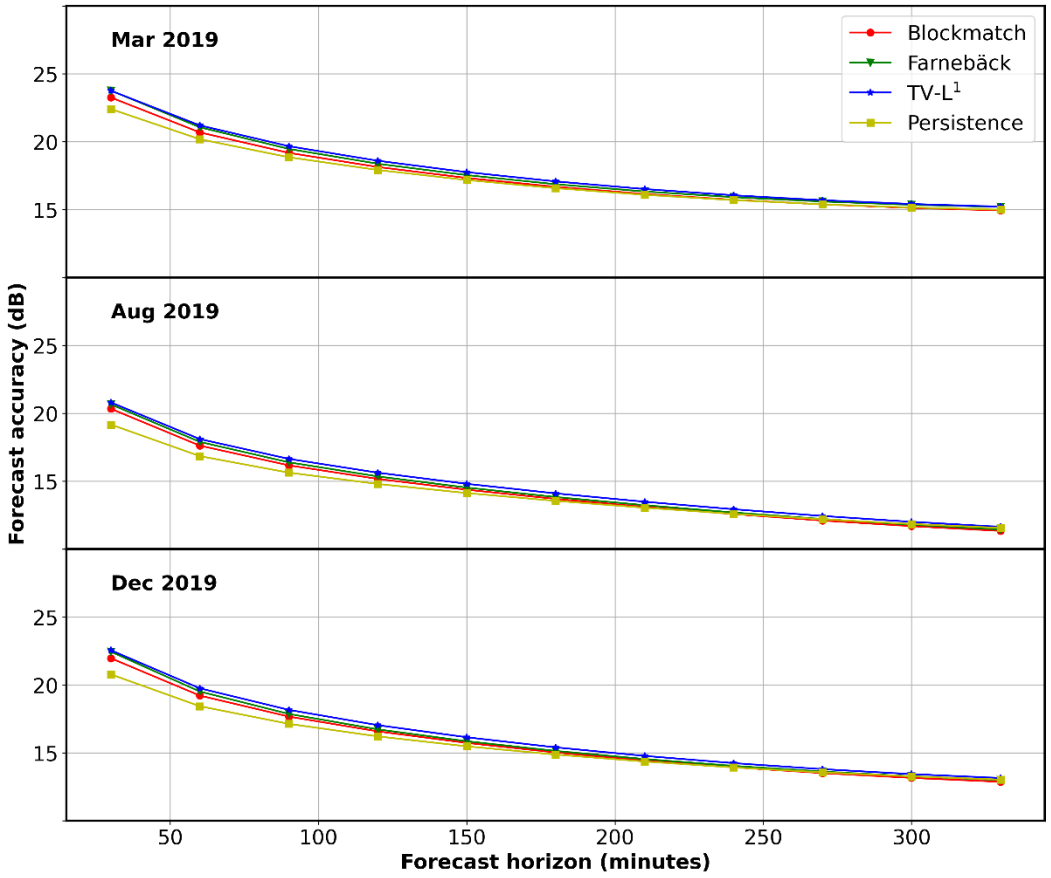


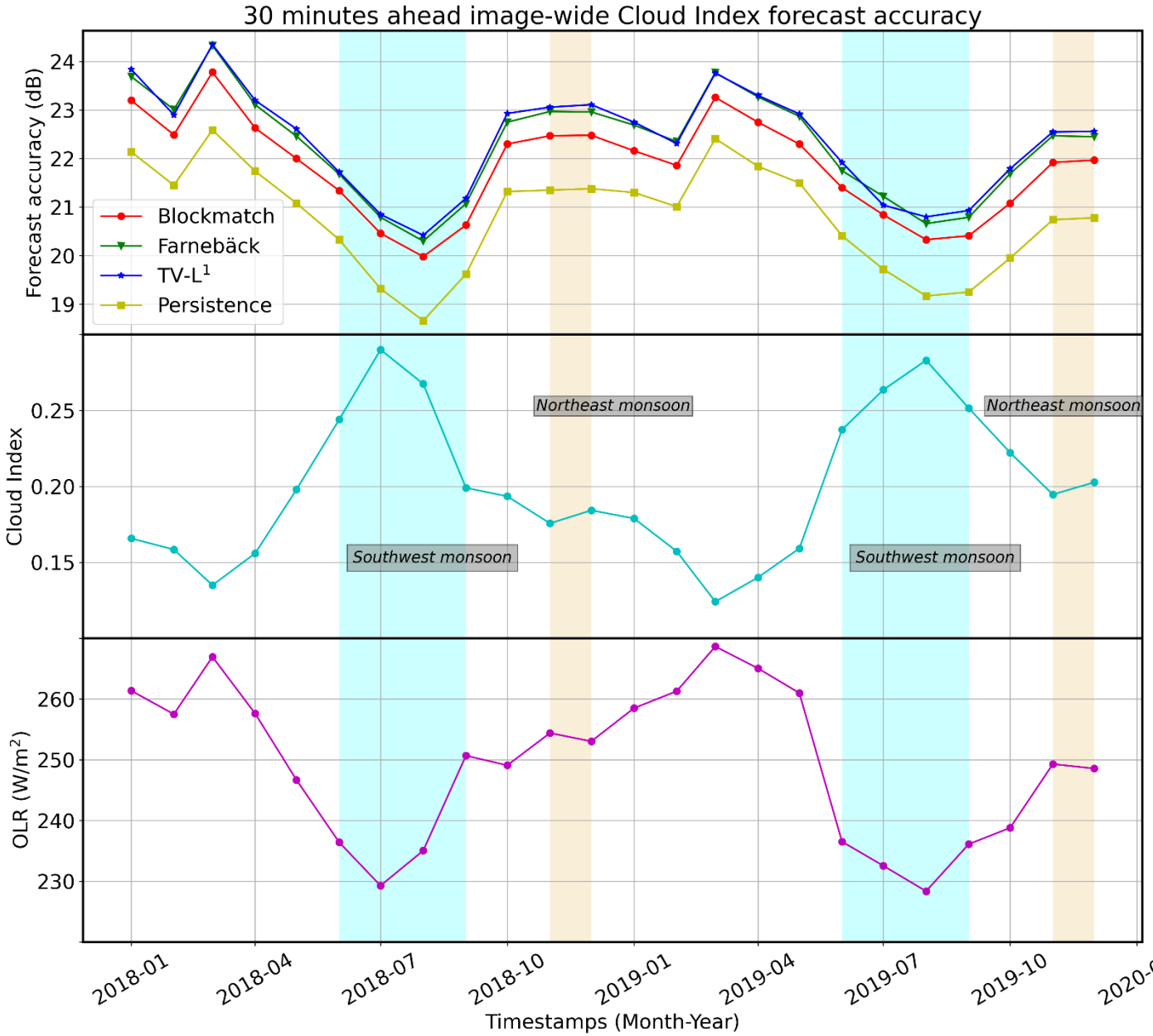
Forecast Evaluation – sectionwide

- Peak signal to noise ratio (PSNR)

$$PSNR_{section} = 20\log_{10}\left(\frac{MAX_f}{RMSE_{section}}\right)$$

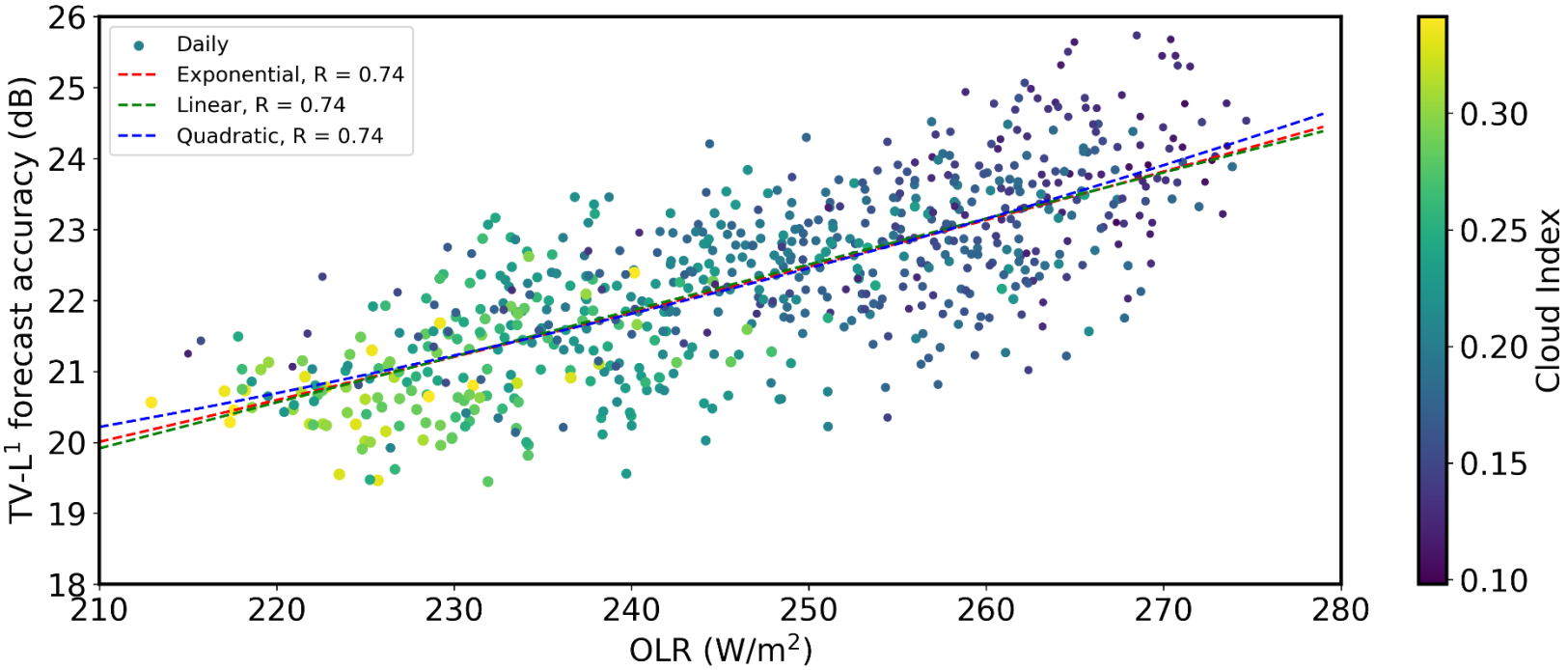
- MAX_f: Maximum possible pixel value (here 1)
- Expressed in decibels
- Higher PSNR implies better accuracy




30 minutes ahead image-wide Cloud Index forecast accuracy
Forecast accuracy (dB)
Blockmatch
Farnebäck
TV-L1
Persistence
Cloud Index
Northeast monsoon
Southwest monsoon
Northeast monsoon
Southwest monsoon
OLR (W/m2)
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04
2019-07
2019-10
2020-01
Timestamps (Month-Year)

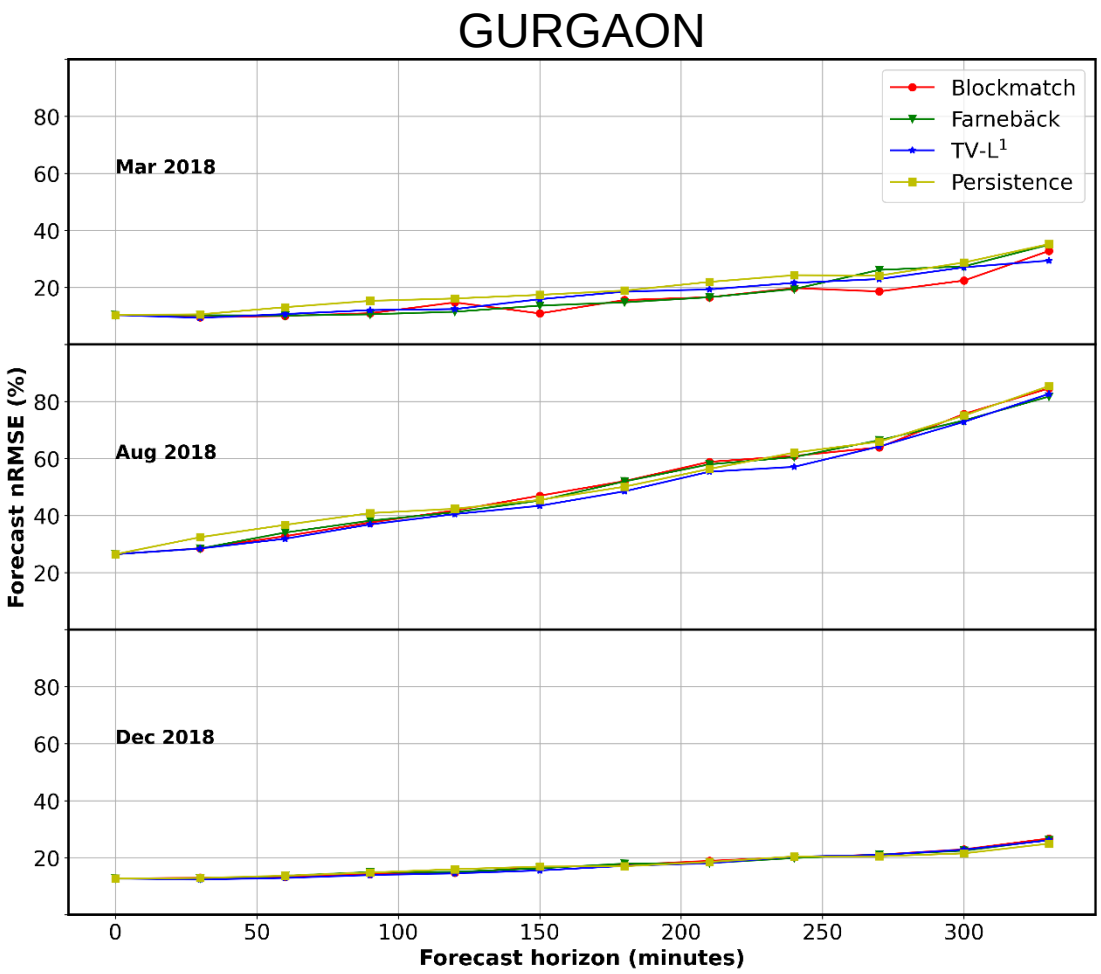
Forecast Evaluation – sectionwide

Method	PSNR (dB)
Persistence	20.75
Blockmatch	21.80
Farnebäck	22.26
TV-L[1]	22.33



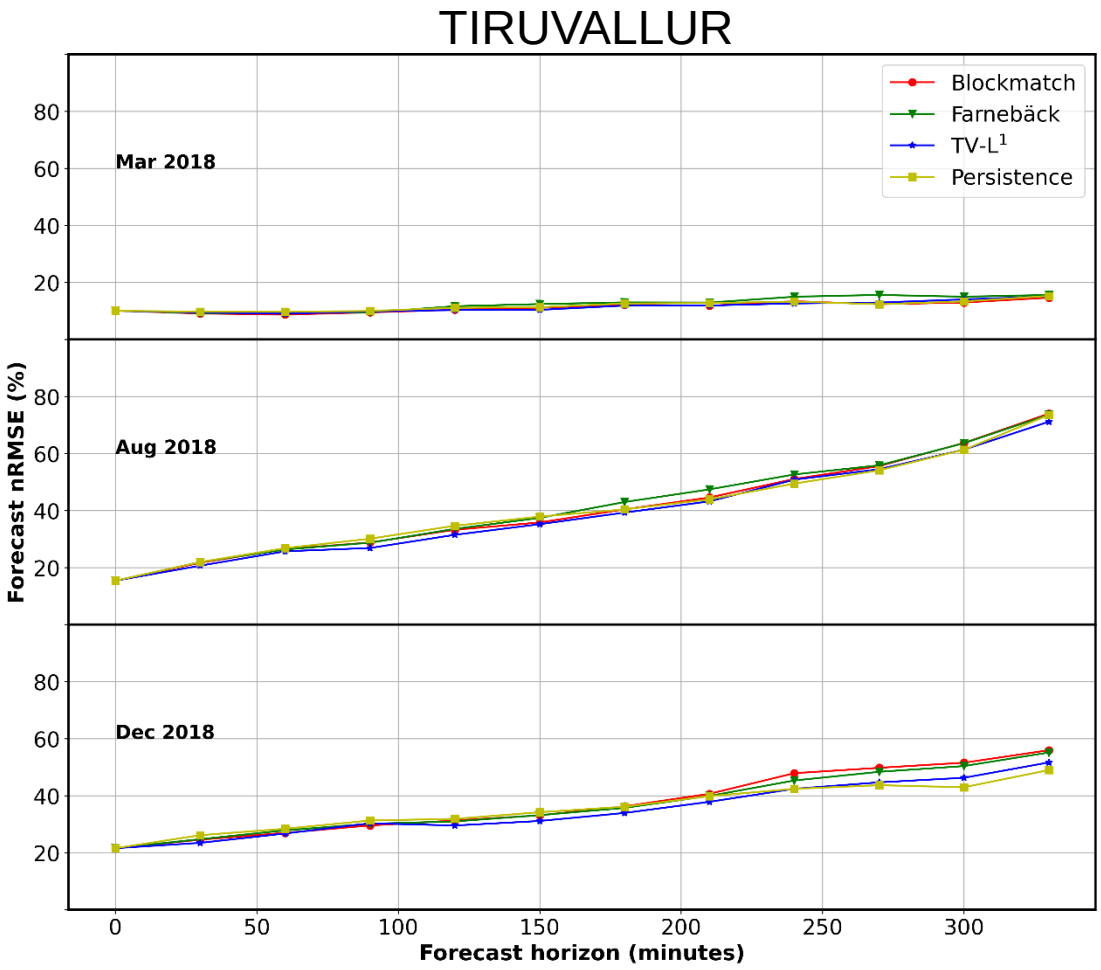
Forecast Evaluation – individual site

- Validation of forecasted GHI against ground measurements
- Forecast horizon of 0 to 330 minutes ahead
- Forecast step of 30 minutes
- Period of validation: 2018

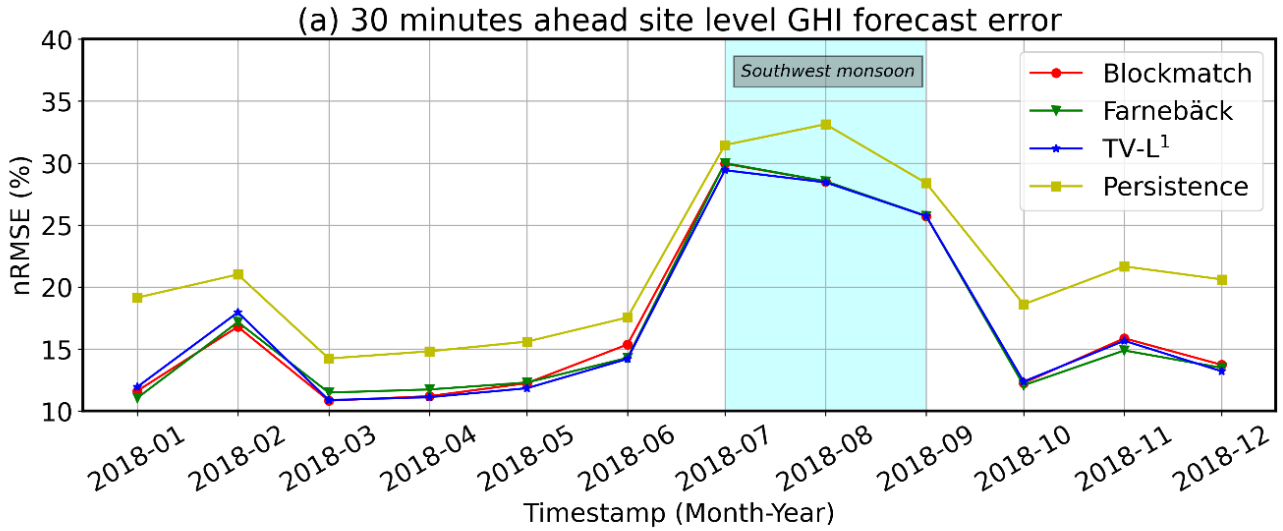


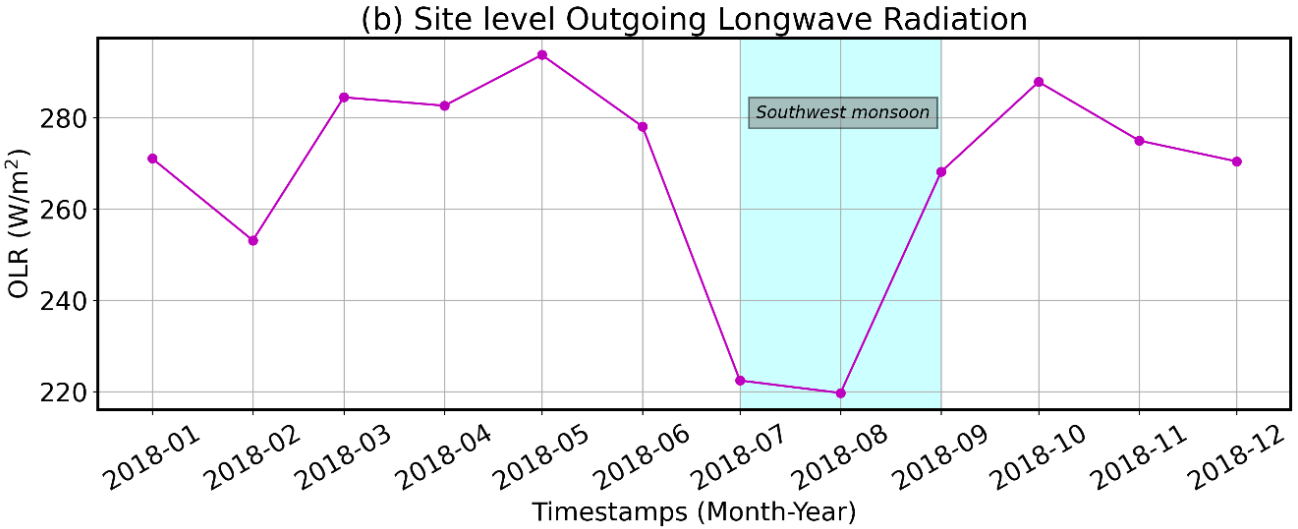
Forecast Evaluation – individual site

- Normalized root mean squared error
- Normalized by averaged GHI for each forecast step

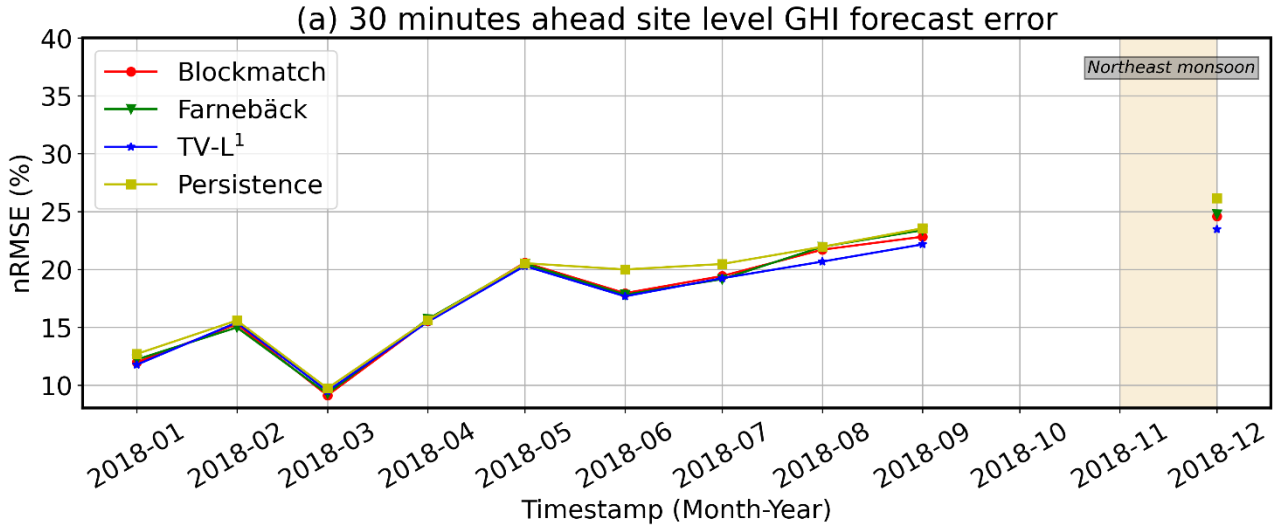


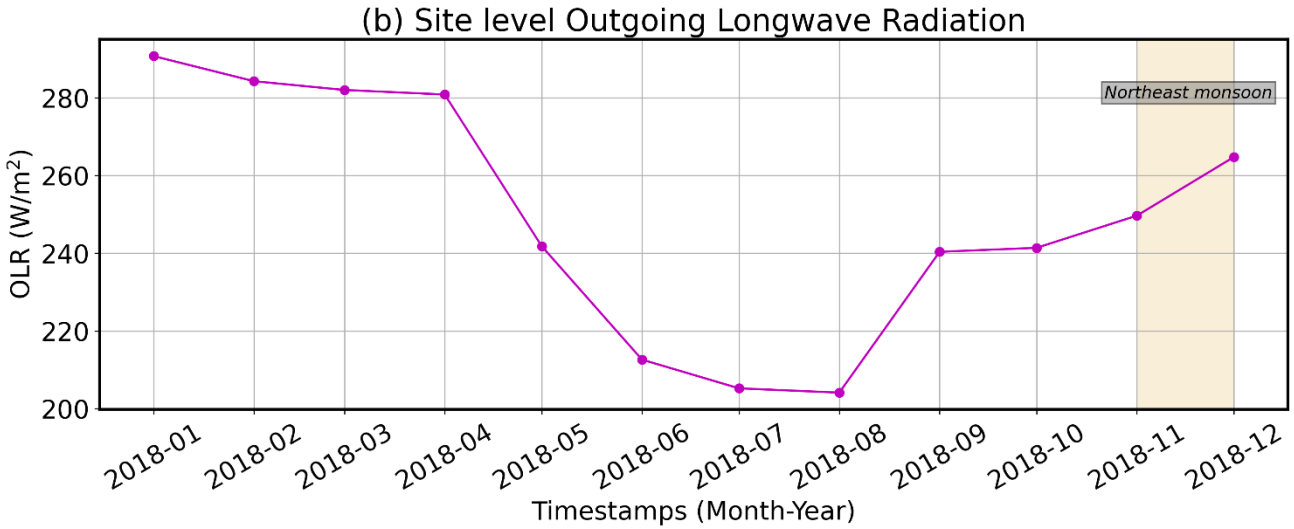
Forecast Evaluation – individual site: Gurgaon





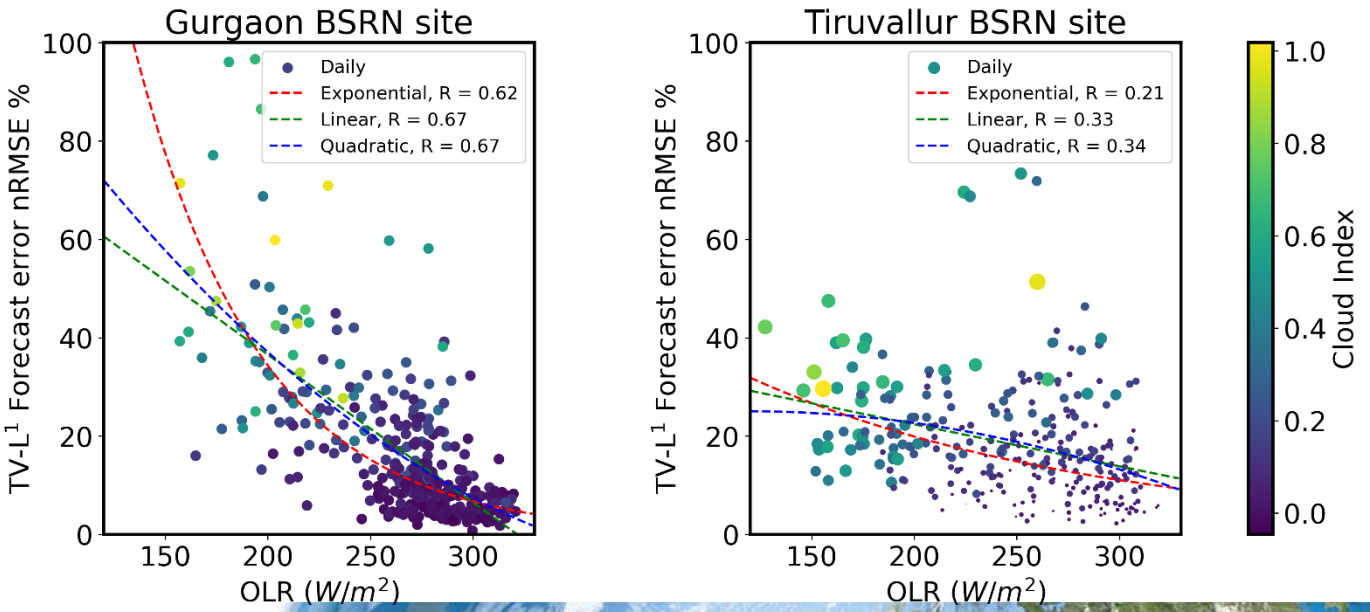
Forecast Evaluation – individual site: Tiruvallur





Forecast Evaluation – individual site

Method		
	Gurgaon	Tiruvallur
Persistence	19.00 %	19.10 %
Blockmatch	18.12 %	18.39 %
Farnebäck	17.93 %	18.47 %
TV-L[1]	17.91 %	18.07 %



Summary

- Inter-seasonal difference in accuracy more significant than inter-method
- Low forecast accuracy is expected for periods with heavy convection and high cloudiness
- Tropical savanna (Aw):
  - higher cloudiness throughout the year
    → larger forecast errors at the Tiruvallur site
- Hot semi-arid (BSh):
  - cloudiness primarily associated with monsoon
    → steep rise in forecast error with decrease in OLR
- Seasonal pattern of forecast error is location-dependent