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Evaluation of Predicted Shortwave Radiation

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Abstract

Forcing hydrological models with accurate radiation data can be crucial in the estimation of snow melt during spring. Radiation data covering Scandinavia is available from the operational forecasting system MetCoOp Ensemble Prediction System (MEPS).Predictions of downwelling shortwave radiation are compared with in situ observations and the MDSSF satellite product over Scandinavia during 2017. The predicted radiation has errors of same amplitude and similar spatial pattern as the satellite. Radiation from MEPS is found to be suitable as input to hydrological models as an alternative to the satellite product.

Keywords

shortwave radiation, AROME-MetCoOp, remote sensing

Abstract

Forcing hydrological models with accurate radiation data can be crucial in the estimation of snow melt during spring. Radiation data covering Scandinavia is available from the operational forecasting system MetCoOp Ensemble Prediction System (MEPS). Predictions of downwelling shortwave radiation are compared with in situ observations and the MDSSF satellite product over Scandinavia during 2017. The predicted radiation has errors of same amplitude and similar spatial pattern as the satellite. Radiation from MEPS is found to be suitable as input to hydrological models as an alternative to the satellite product.

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Contents

1 Introduction

This report describes the work done by the Norwegian Meteorological Institute on H4 in "Strålingsdata i tilsigsmodeller for kraftverksdrift". Downwelling shortwave radiation from the operational forecasting system MEPS are evaluated against in situ stations and the MDSSF satellite product. The evaluation covers the Norwegian mainland throughout year 2017.

2 Data

2.1 AROME-MetCoOp Model Data

Downwelling short wave radiation at the surface is obtained from the operational weather forecasting model AROME-MetCoOp (harmonie cy 40h1 (*Müller et al.*, 2017). The model has a horizontal grid spacing of 2.5 km and hourly outputs. Model data are interpolated to UTM-33 grid using nearest neighbor method to match MDSSF data. For comparison against in situ stations, the nearest neighbor from the original model grid is used. Data are read from forecast termine 00, 06, 12, and 18. 7th to 12th hours are used from each forecast, where each value represents the average over the last hour. Data is referred to as MEPS (MetCoOp Ensemble Prediction System). However only member 0 (control) is used in the evaluation. Model output files are available from `thredds.met.no`

2.2 MDSSF Satellite Product

Global shortwave radiation is derived from cloud cover observed by the SEVIRI sensor aboard the Meteosat Second Generation (MSG) satellite. Hourly data are based on snap shots every 30 minutes. The data have been processed by SINTEF/Enki Hydrologi AS, See report from H1 and H3 for more details.

2.3 In Situ Observations

Global incoming short wave radiation is measured from a number of stations in Norway. Observations from klimadatavarehuset (KDVH) are used in this report. This data is available from `eklima.no`. After flagging stations that have missing or poor measurements during the period, 56 stations are left and used in the evaluation. Flags are set based on visual inspection of time series, station by station.

3 Methods

3.1 Clearness Index

Since incoming short wave radiation has diurnal and annual periodicity, over optimistic values are obtained when calculating correlations. To avoid this, clearness index (CI) is calculated by dividing the modeled or observed radiation with the incoming radiation at top of atmosphere. In clear sky conditions, there is still a diurnal periodicity since the radiation has to travel a longer distance through the atmosphere when the sun angle is low. In this work this effect is not included in the CI calculations.

3.2 Metrics

Mean absolute error/difference (MAE/MAD), mean error (bias), and correlation coefficients averaged over stations and separately are calculated and presented in tables and on maps.

4 Results

4.1 Validation with In Situ Observations

Performance is summed up in Table 1. MDSSF scores slightly better than MEPS on all metrics, except for MEPS having higher correlation coefficient for daily averages. Increased correlation for daily averaged values indicates that variations from hour to hour is responsible for large part of the nois. A timeserie from a representative station is shown in Figure 1.

The quality of geostationary satellite observations are expected to decrease with higher latitude. Figure 2 and Figure 3 therefore show MAE and correlation coefficients, respectively, plotted against latitude of the station.

Figure 4, 5 and 6 show mean error, MAE and correlation coefficient for each station.

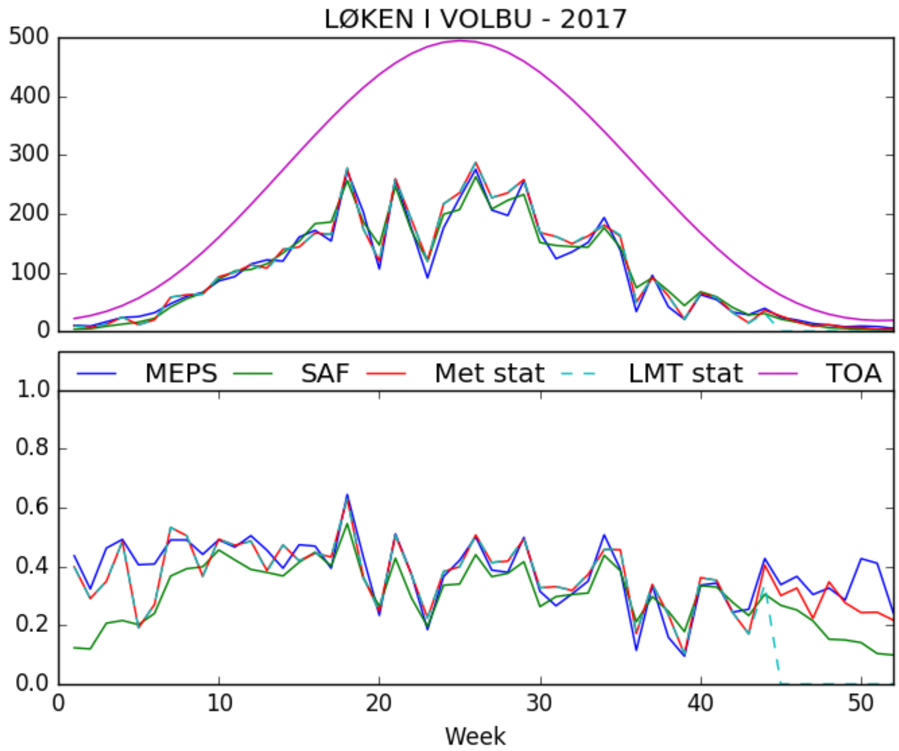

Figure 1: Weekly averages of downwelling shortwave radiation at a representative station (Løken i Volbu). Upper panel shows radiation in Watts per square meter, lower panel shows clearness index. purple line is model, green line is satellite product, red line is station observation, pink line is the radiation at the top of atmosphere. LMT-station and Met-station is the same station.

Metric	MEPS	MDSSF
Bias [W m-2]	5.46	1.37
MAE [W m-2]	34.85 (21.81)	28.89 (16.78)
CI correlation	0.66 (0.8)	0.67 (0.75)

Table 1: Station averaged metrics for hourly data. Values in parentheses are based on daily averages.

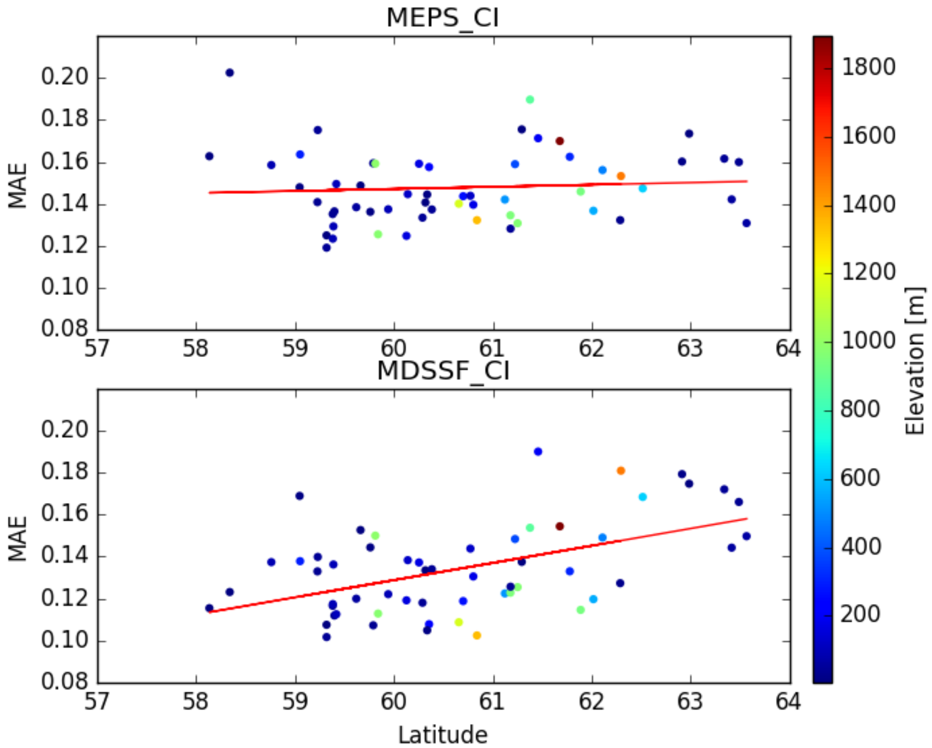

Figure 2: Dependency of mean absolute error of CI to latitude and elevation. Color of dots indicate the altitude of the station, line is the best fit using least squares method.

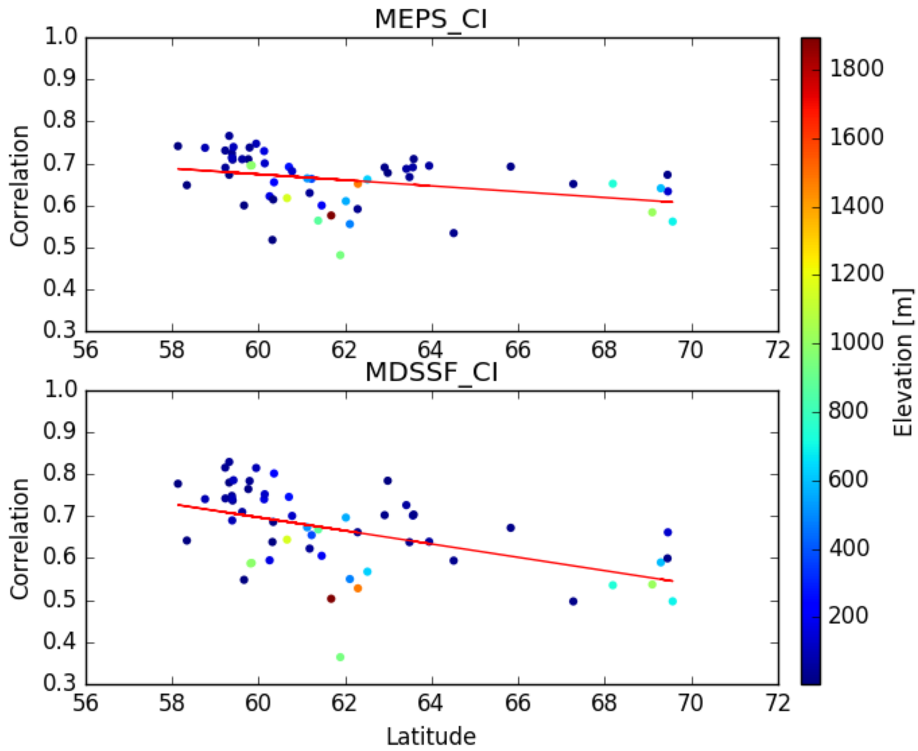

Figure 3: Dependency of correlation coefficient of CI to latitude and elevation. Color of dots indicate the altitude of the station.

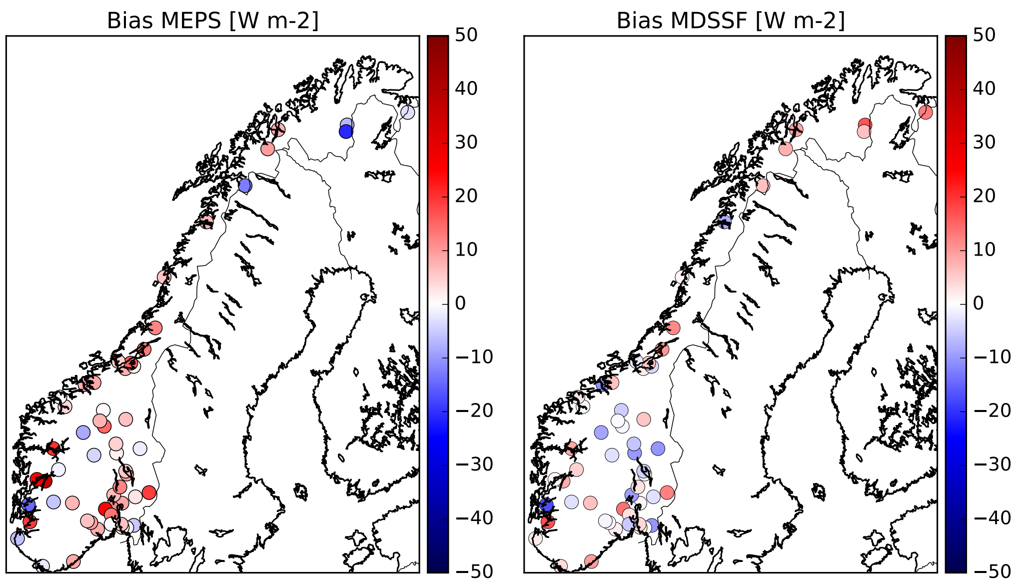

Figure 4: Mean error / Bias.

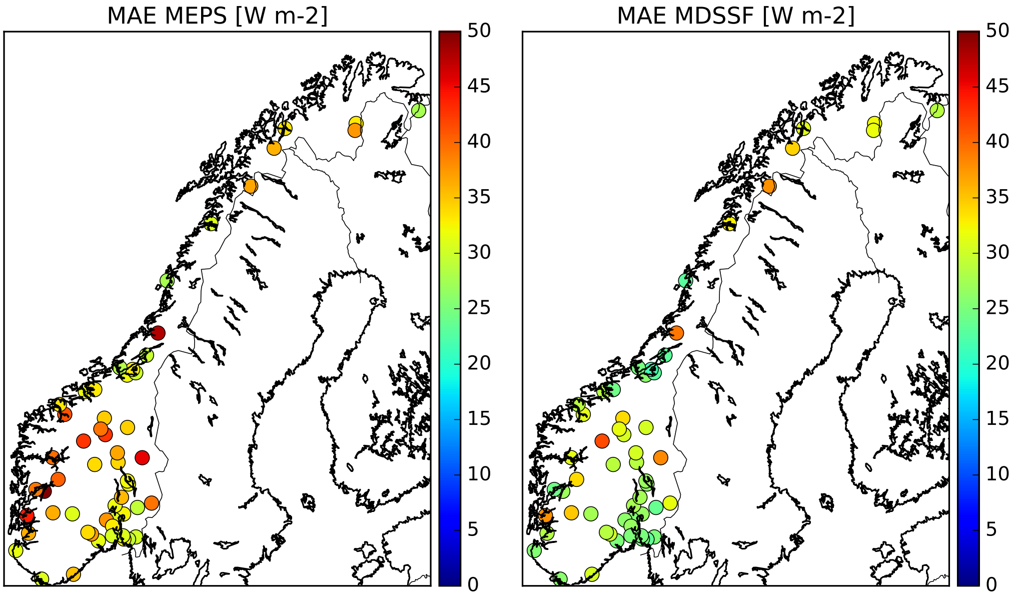

Figure 5: Mean absolute error.

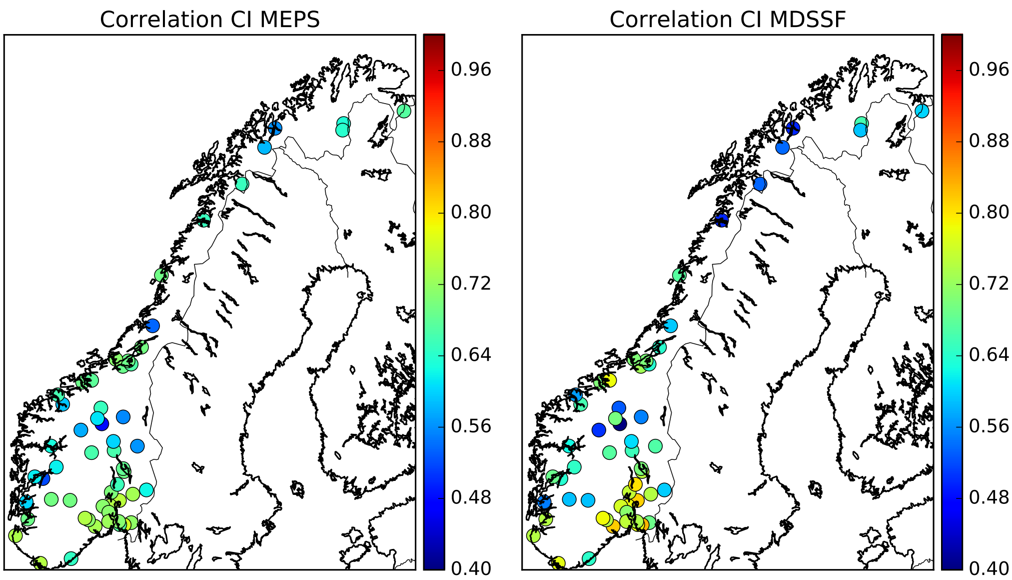

Figure 6: Correlation coefficient.

4.2 Comparison between MDSSF and MEPS

Figure 7 shows average radiation during March 2017. Amplitudes are similar, while MEPS has less scattered distribution of high and low values, notice western Norway.

In Figure 8 and Figure 9, MAD and correlation coefficient are presented respectively for three selected months.

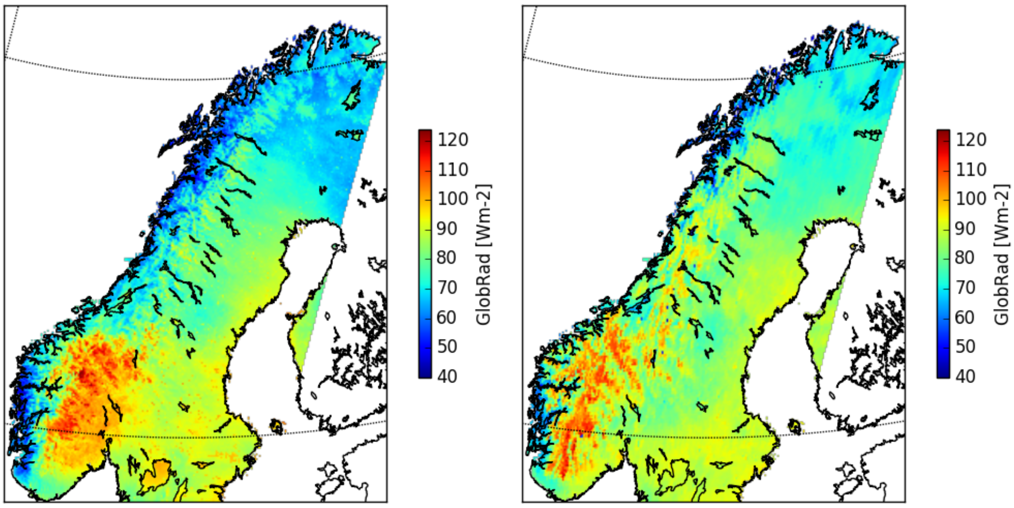

Figure 7: Mean downwelling short wave radiation March 2017. Left MEPS, right MDSSF.

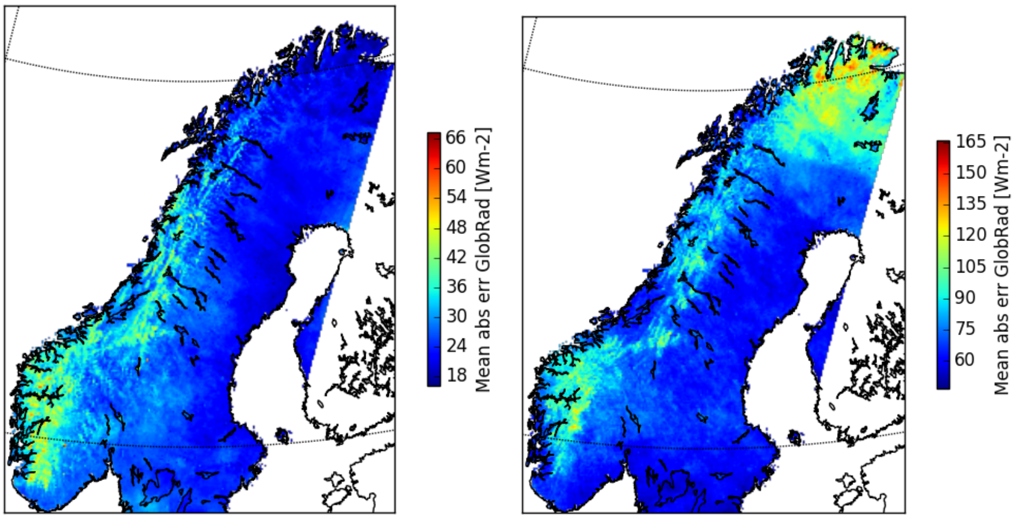

Figure 8: Mean absolute difference between MEPS and MDSSF [W m-2]. Left and right panel displays the month of March and June respectively. Note that each month has different color scale.

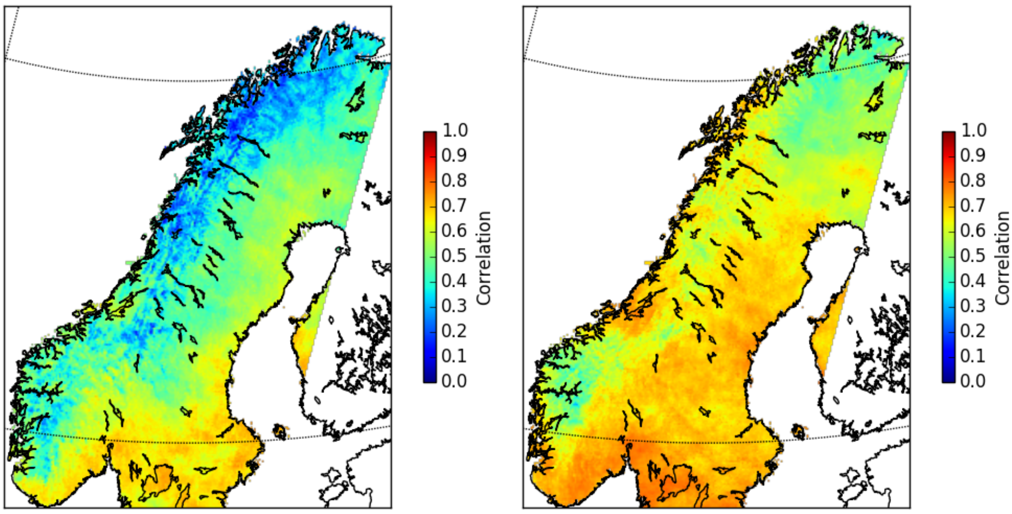

Figure 9: Temporal correlation coefficient between MEPS and MDSSF. Panels as in Figure 8.

5 Discussion & Conclusions

Key metrics presented in Table 1 show that on average, MEPS and MDSSF present downwelling shortwave radiation with similar accuracy. However, the satellite product scores slightly better than the model, when compared to 56 in situ stations.

The relation of errors to the latitude and elevation presented in Figure 2, show that the satellite is limited far north. This is expected due to the low angle of view from geostationary satellites. In Figure 8 right panel, large differences are seen in the northernmost part of the domain. This is caused by high values in the MDSSF data (not shown). During summer, the high latitudes are exposed to more solar radiation, and errors are thus expected to become larger. In southern regions the satellite performs better than MEPS with respect to MAE. For correlations presented in Figure 3, the same relation holds as above. However, with respect to correlation, altitude seems to play a bigger role. Stations above approximately 600 meters all have correlations below the best fit line. This is true for both data sets, which can indicate poor observation quality at elevated stations, or due to more complex terrain, lower clouds, and more rapid change in weather type.

Bias presented in Figure 4, MAE in Figure 5 and correlations in Figure 6 indicate that both products are similar in the amplitude of errors, variation of errors, and on spatial distribution. Stations around the Oslofjord have the best scores, while the mountain areas seems to be more problematic.

After comparing the data sets with in situ measurements, we see that both perform very similar with respect to the metrics used. The monthly average for March 2017 shown in Figure 7 reveals that MEPS has less incoming shortwave radiation than MDSSF along western Norway and in the northern coast and inland. A known issue with the current model setup, is a slight shift in the location of precipitation. During westerly winds, lifting along the coastal topography, cloud water are released too late and too far inland. This imply too much cloud water in a band along the coast, which will affect the incoming solar radiation. Otherwise, the patterns over mountain regions in south Norway are similar.

Mean absolute difference presented in Figure 8 indicates that the two data sets disagree most in areas with highest precipitation and cloud activity, that is mountain regions along the coast. More solar radiation during summer results in larger errors, the color scales are thus different for March and June. The correlation coefficients shown in Figure 9 share the same pattern as Figure 8, with better score in the south eastern part of the domain. Correlation coefficients are also larger during summer. this coinsides with the MAE score.

As the solar angle varies to a larger degree during summer the simplified CI calculations introduce a larger diurnal variability and thus better correlation.

Based on the above evaluation, the two sources of data succeed to provide radiation estimates in fairly good agreement with what is measured at in situ stations. The two products have errors of the same size and similar pattern. Daily averages provide more accurate estimates. A combination of the two data sets could provide a even more accurate estimate of the radiation. Note that the metrics are summarized over a year or a month. One product might thus be more suitable for special cases without showing up in this kind of comparison. Studies of special situations are thus required to identify these kinds of differences. The accuracy required for the application should also be taken into account.

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