Using high resolution reanalysis to assess global radiation variability

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Motivation

The knowledge of where, when and to what extent renewable energy can be generated is crucial for planning the future energy system.

High resolution **reanalyses** can provide all necessary information on wind and solar energy in a consistent way.

Here we **assess the quality** of global radiation estimates over Europe provided by **COSMO-REA6**. Comparisons with reference observations from the Baseline Surface Radiation Network (BSRN) over two decades reveal systematic deficits under clear and cloudy sky cases. A **post-processing** is developed to ensure the correct statistical distribution.

Regional Reanalysis COSMO-REA6

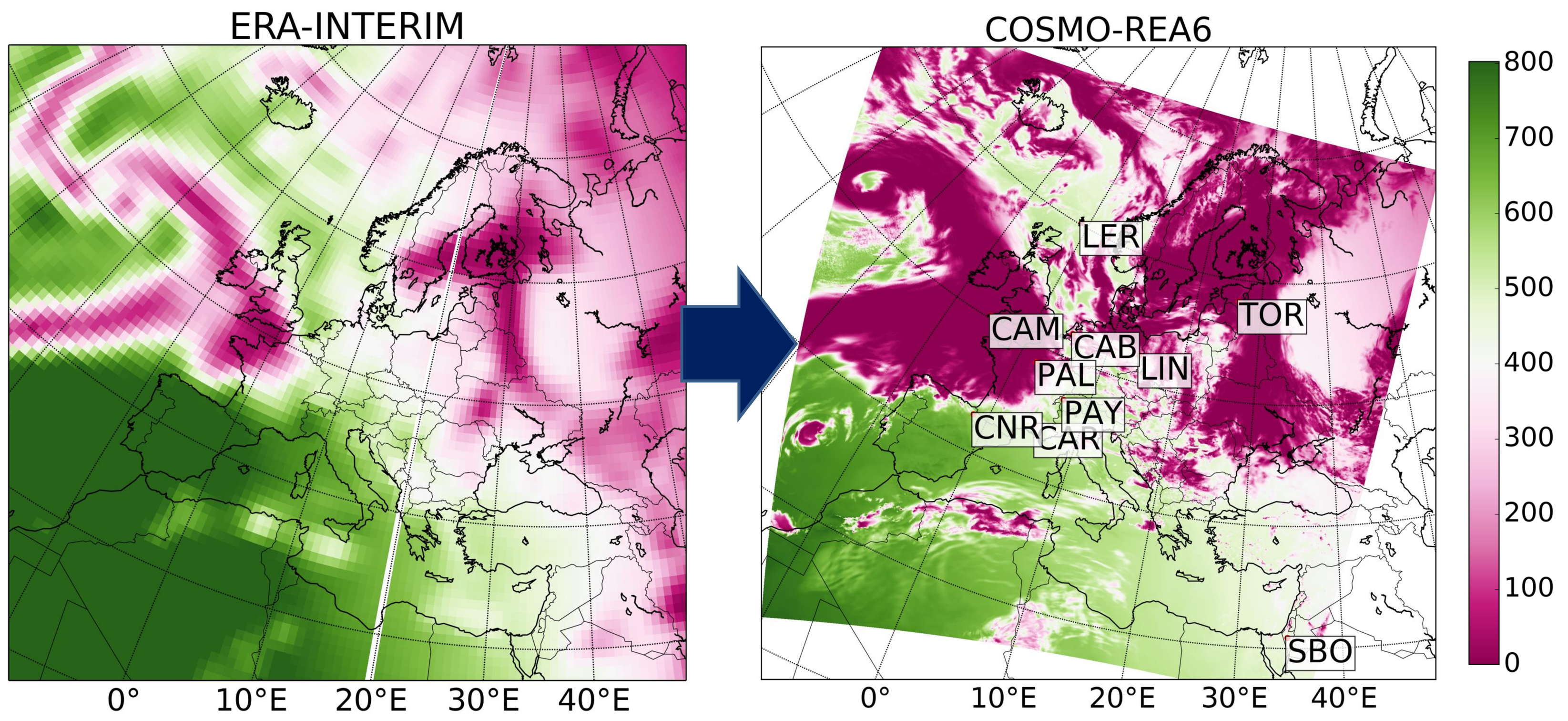


Figure 1: Direct solar radiation (13.04.2013) at surface level for ERA-INTERIM (left, avg 12-15 UTC), and COSMO-REA6 (right, avg 12-13 UTC). The abbreviations show the locations of considered BSRN stations.

Reanalysis: Synthesis of heterogeneous observations with an atmospheric model

- Physically consistent variables in space and time

COSMO-REA6:

- Developed within the Hans-Ertel-Centre for Weather Research (HErZ)
- CORDEX EUR-11 domain
- 20 years (1995 – 2014)
- 6 km horizontal res., 40 vertical layers
- Assimilation scheme nudging: SYNOP, SHIP, PILOT, TEMP, AIREP, AMDAR, …
- Output: 150 atm. and surface variables:
- 15 min (2D), 60 min (3D)

Corresponding Publication: Bollmeyer et al.

Assessment of global radiation (Q)

Example time series at Lindenberg, Germany.

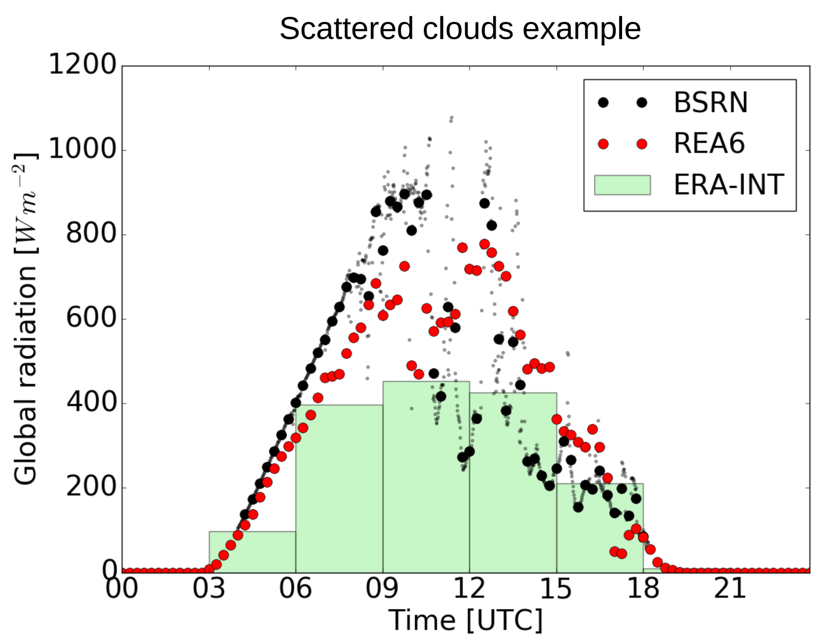
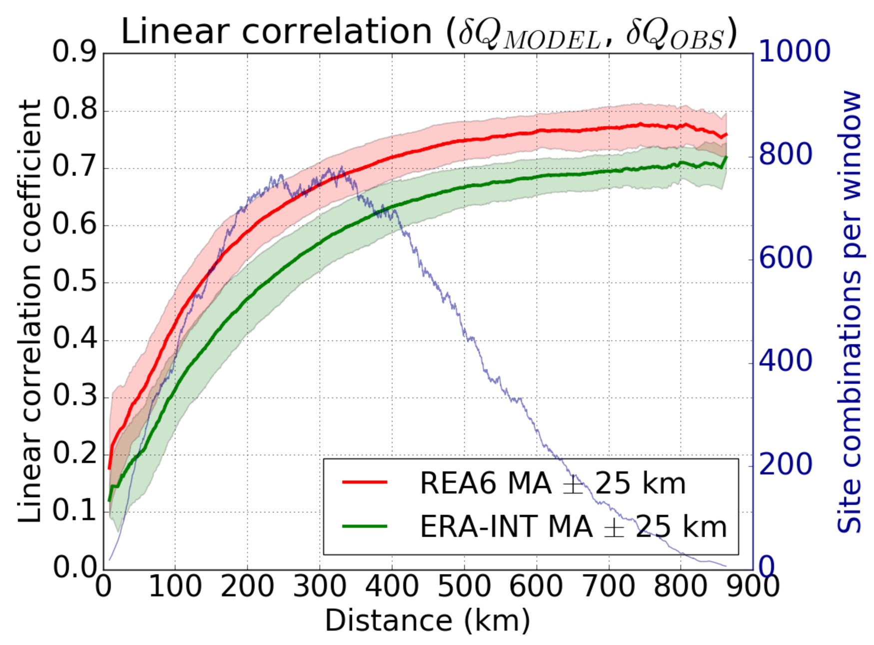
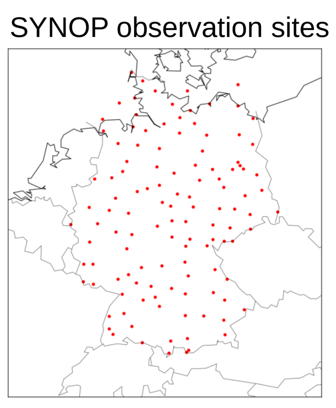


Fig. 2: Global radiation time series at Lindenberg, Germany (14.06.2008). BSRN observations are available every minute (shadowed), REA6 values every 15 minutes and ERA-INT provides 3 hour averages. Additionally shown are 10 minute averages of BSRN obs to match the spatial scale of COSMO-REA6.

- Clear sky situations are often slightly underestimated
- REA6 shows potential to represent short time cloud variability

Representation of atmospheric processes





Is there an added value by the use of regional reanalyses and which spatial scales are well represented in the reanalyses?

→ Look at differences in global radiation between stations i and j in observations and models.

$$\delta Q = Q_i - Q_j$$

Figure 3: Linear correlation of site to site global radiation differences in model and corresponding differences in observations as function of distance. Shadowed is the standard deviation of all correlations in the considered moving average (MA) window. The blue line shows the correlations per window. Compared are three hour averages from 2007 - 2013.

REA6 represents clouds significantly better than ERA-INTERIM

Representation of absolute values

- High standard quality controlled observations from 10 BSRN stations across Europe are used as baseline.
- Diurnal & seasonal cycle are eliminated by considering the hemispheric transmissivity (T). i.e. normalization with the maximum available radiation varying with the solar elevation angle.
- Good representation of yearly sums (-5%)
- REA6 shows distinct differences in the occurrence of low (<0.5) and high transmissivity (Fig. 4) compared with observations.

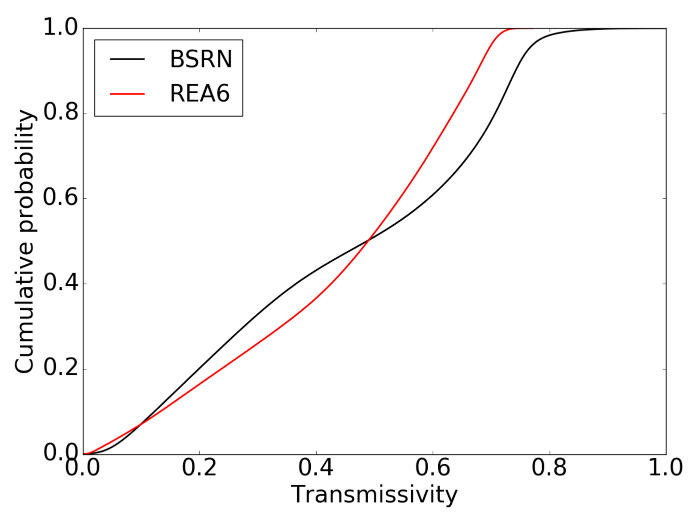


Fig. 4: Cumulative distribution function (CDF) for transmissivity for all BSRN observations and corresponding COSMO-REA6 estimates.

Effect	Reason
Negative BIAS of Q for high transmissivity cases	Optically too thick aerosol climatology in COSMO-REA6
Positive BIAS of Q for low transmissivity cases	Optically too thin or too few clouds in COSMO-REA6

Compensation effects (Motivation for post-processing)

Post processing methodology

- Under- and overestimation motivates different scaling factors a for "clear" and "cloudy" conditions:

$$T_{post}(T) = \begin{cases} T\,a_{cloudy}\,, & T < T_{Th} \\ T\,a_{clear}\,, & T \geq T_{Th} \end{cases}$$

- A weight function guarantees a smooth transition from negative to positive adjustments.
- The scaling factors are the slope of the linear orthogonal distance regression (ODR) between observation and REA6.
- Relationship of transmissivity and cloud conditions motivates T_{Th} (Fig. 5)

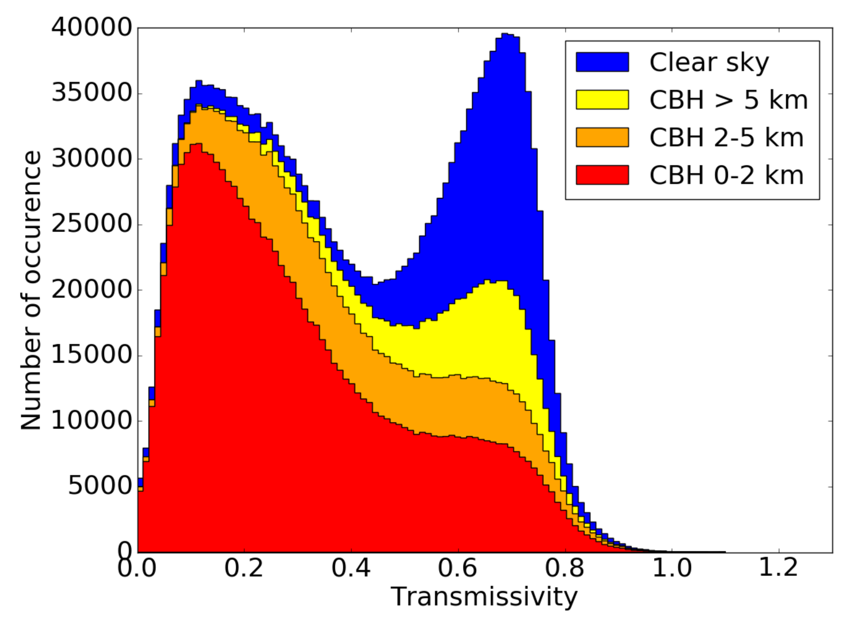


Fig. 5: Histogram of transmissivity fort three cloud base height (CBH) classes and for clear sky situations. Considered are only SYNOP observations with a corresponding Ceilometer obs of CBH

- Transmissivity distribution is bimodal
- Low transmissivity peak is mainly formed by liquid cloud conditions
- High transmissivity peak is mainly formed by clear sky and ice cloud conditions
- T_{Th} as transmissivity of the minimum

- Larger adjustments during winter and small solar elevation angles necessary
- Cross validation shows good spatial applicability

Results

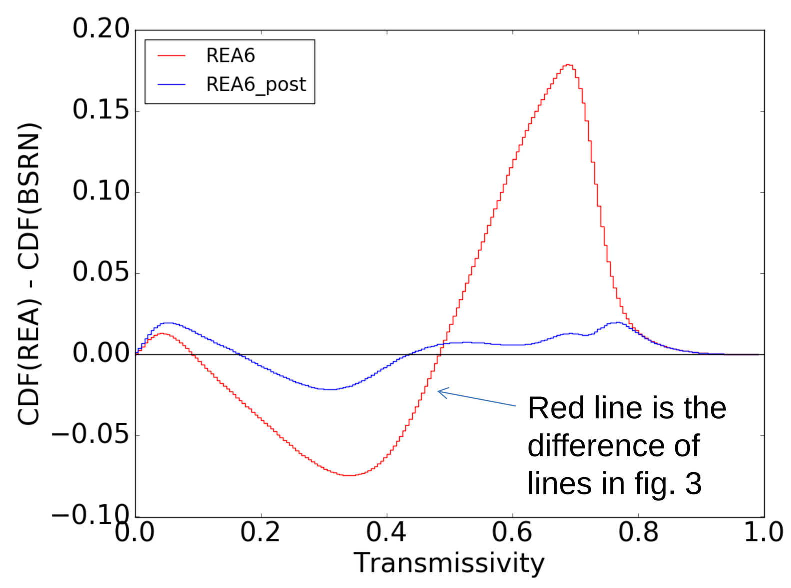


Fig. 6: Difference of cumulative distribution functions before and after the post-processing. The reference distribution is the observed one.

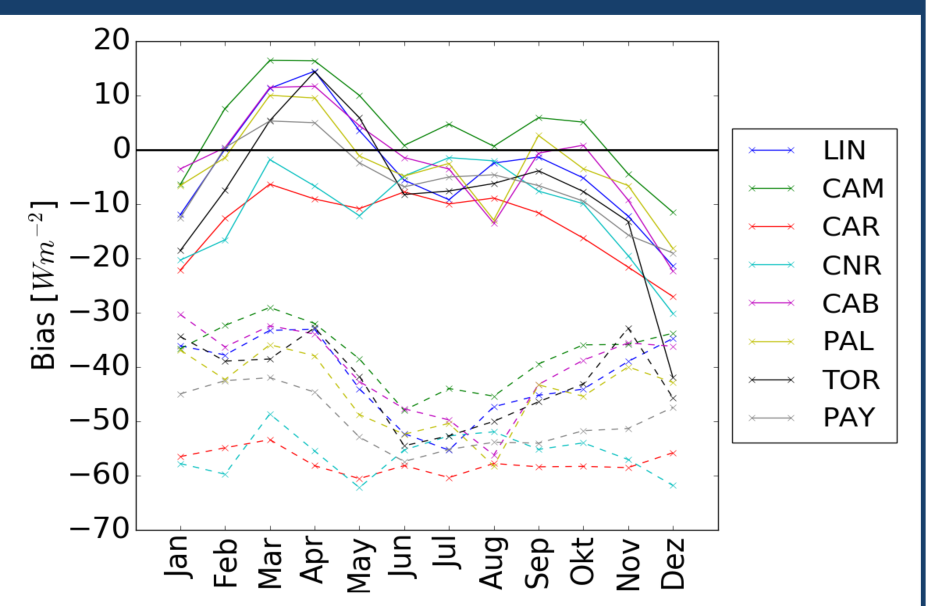


Fig. 7: Monthly mean BIAS between REA6 and observations in cases with $T > 0.5$ only. Dashed lines show the mean bias before the post-processing and solid lines the mean bias after the post processing.

Post-processing reduces over and underestimation effects in transmissivity to less than 2 % in CDF.

Underestimation in clear sky global radiation of 30 to 80 Wm-2 depending on station and month is strongly reduced.

Outlook

- Investigate contribution of Q adjustments from direct and diffuse components
- Generate a data set of theoretically available photovoltaic power (REA6)
- Study extreme events of power generation and study spatial compensation effects
- Add wind power → extremes and spatial compensation effects

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