The use of satellite data assimilation methods in regional NWP for solar irradiance forecasting
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The use of satellite data assimilation methods in regional NWP for solar irradiance forecasting

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1. Motivation

Photovoltaic energy offers an intermittent production. PV production forecasts are necessary to permit a safe integration into the electricity grids. The correct simulation of cloud evolution is essential to forecast accurately irradiance reaching the ground level. Besides solar power forecasting, accurate short-term forecasts of precipitating and non-precipitating clouds are important for various meteorological applications. Regional NWP is the state-of-the-art tool to provide highly resolved cloud forecasts for lead times beyond 6h. Clouds are currently rather poorly represented in NWP models. The precise simulation of cloud evolution requires accurate atmospheric analyses which are exploited through atmospheric observations using data assimilation methods. In this work we focus on the assimilation of geostationary satellite data into regional NWP models with the goal of improving short-term cloudiness forecasts at high spatial resolutions.

2. Advantages of satellite observations

Compared to other sources of observations, geostationary satellites provide many advantages regarding continuous solar irradiance forecasting:

- Large spatial coverage: high spatial and temporal resolution
- Lack of measured data around islands
- Satellite radiances are reliable radiometric signatures of cloud presence, properties and evolution
- Constant accuracy in space and time
- Comprehensive observations for large parts of the world
- Future-oriented

3. Indirectly influencing cloud evolution

In common state-of-the-art data assimilation procedures, primarily applied to global NWP models, all types of available observations are assimilated using the established methods (e.g. 3D-Var, 4D-Var, ENKF). The ultimate goal is to find the optimal initial conditions regarding the model’s state variables. The typically assimilated satellite observations are radiances and atmospheric motion vectors (AMVs). Assimilating such observations using variational data assimilation or ensemble Kalman Filter methods affects the model state variables in the first place and therefore influences the representation and evolution of clouds indirectly.

4. Recent developments and their shortcomings

In recent years, different approaches aimed at deriving atmospheric analyses for limited-area models with most realistic cloud features, using geostationary satellite observations. The focus is mostly set on the assimilation of cloud-top information (e.g. cloud top temperature), since optical and thermal sensors are not able to capture information inside clouds (Figure 2).

Table 1 sums up recent advances and their main limitations. Although the listed methods generally provide improved intraday (and even day-ahead) cloud cover forecasts in mid-latitudes, a major limitation for all methods is that only clear-sky or completely cloudy cases can be considered. This is because fractional clouds cause a measured signal mixing cold clouds and the warmer Earth surface.

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5. Outline

Progress being made regarding the assimilation of cloud-affected radiances into limited-area NWP models (Stengel et al., 2013). However, the indirect assimilation of quantities like radiances or AMVs has not been exploited so far in regional NWP regarding solar irradiance forecasting. The main reason for this is a number of problems that have to be overcome for each individual model domain: the choice of satellite channels, optimal thinning, bias correction, observation and background error estimation.

Future investigations address:

- the combination of both the classical ‘indirect’ assimilation methods with methods that explicitly assimilate cloud physical properties (e.g. cloud top height, cloud emissivity,...);
- the impact of such methods on different lead times, since the information from the driving global model is expected to dominate at a certain point;
- the influence of domain size and grid spacing in connection with satellite data assimilation in regional NWP;
- the use of different limited-area models and satellites, and respectively the applicability to different geographical regions (e.g. mid-latitudes and tropics).

The ultimate goal is an assimilation strategy that can be used independently of the model and satellite and which can