Towards a Standard Procedure for Validation of Satellite Derived Cloud Properties with Ground-Based Observations

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Abstract: This paper presents a standard procedure for the validation of cloud properties retrievals from satellite measurements. We use cloud properties datasets from synthetic simulations and ground-based observations to disentangle validation uncertainties from retrieval errors, and suggest a procedure to optimize the validation of satellite retrievals.

1. Introduction

The validation of satellite retrieved cloud properties with ground-based observations is hampered by various sources of uncertainties, among which cloud inhomogeneities, differences in spatial resolution between the sensors and parallax shifts in Field Of View (FOV). Due to these uncertainties the precision of cloud properties retrievals are reduced. Most validation studies use simple sampling strategies to compare satellite retrieved and ground-based observed cloud properties. [1] showed for cloud liquid water path (LWP) retrievals from their cloud physical properties algorithm [2] that, even when using simple sampling strategies, high agreement was found between instantaneous LWP retrievals from the Spinning Enhanced Visible and InfraRed Imager (SEVIRI) onboard the Meteosat geostationary satellite and time-series of mean LWP retrievals from ground-based microwave radiometer (MWR) measurements. However, [3] showed that a substantial part of the differences between the two datasets are due to uncertainties in co-location, parallax, position of the ground station and differences due to sampling of different portions of the cloud. Part of these differences may be alleviated through improving the sampling strategy. The objective of this study is to disentangle validation uncertainties from retrieval errors, and to optimize the procedures to validate satellite retrieved cloud properties.

2. Methods

The validation uncertainties due to cloud inhomogeneities are investigated with a simulated dataset of satellite ($3x3km^2$) and ground-based ($0.1x0.1\ km^2$) observations for a set of realistic high-resolution Liquid Water Path (LWP) fields that have been generated from MODIS observations (see [3]). Moreover, real ground-based observations have been used to quantify the validation uncertainties, due to parallax shifts and due to comparing instantaneous satellite retrievals with time-series ground-based observations, for bi-directional reflectance observations (see [4]) and LWP retrievals (see [5]) from SEVIRI. The validation uncertainties were calculated for different interpolation methods (Gaussian weighting, spatial interpolation, and nearest neighbor interpolation) so as to find the most precise method for interpolating the satellite retrievals near the ground-based site, and the ground-based observations over time.

3. Results

The evaluation of simulated of LWP fields shows that the validation errors can be classified in two groups. The errors in the first group are related to the process of retrieving cloud properties from satellite observations, and include the plane parallel bias and the mismatch between different channels. The errors in the second group are related to differences in the scene that is observed by the satellite and ground-based sensor, which include parallax shifts as well as different field-of-views. Calibration errors are not considered in the present study. The LWP errors in the second group are significantly larger than those in the first group. The differences between simulated satellite and ground-based LWP values are found to be smallest for ground-based tracks with a length of about 7 km (corresponding to one SEVIRI pixel over Europe). Surprisingly, it was found that smaller satellite pixels do not alleviate the problem but rather aggravate it, unless the parallax error is corrected.

The comparison against real ground-based observations confirms that uncertainties due to the parallax shifts dominate the validation uncertainties of SEVIRI retrievals over Northern Europe (large viewing angles). These uncertainties can be reduced by using information on cloud top heights to correct for parallax shifts and by using Gaussian weighting to optimize spatial interpolation of SEVIRI retrievals and temporal interpolation of ground-based observations. Figure 1 shows, for the comparison between SEVIRI observed bidirectional reflectances and multifilter rotating shadowband radiometer (MFRSR) transmittances, that parallax corrections lead to an increase in explained variances from about 0.60 to 0.75. Similar results are found when these parallax corrections procedures are applied for the comparison of SEVIRI and MWR retrievals of LWP.

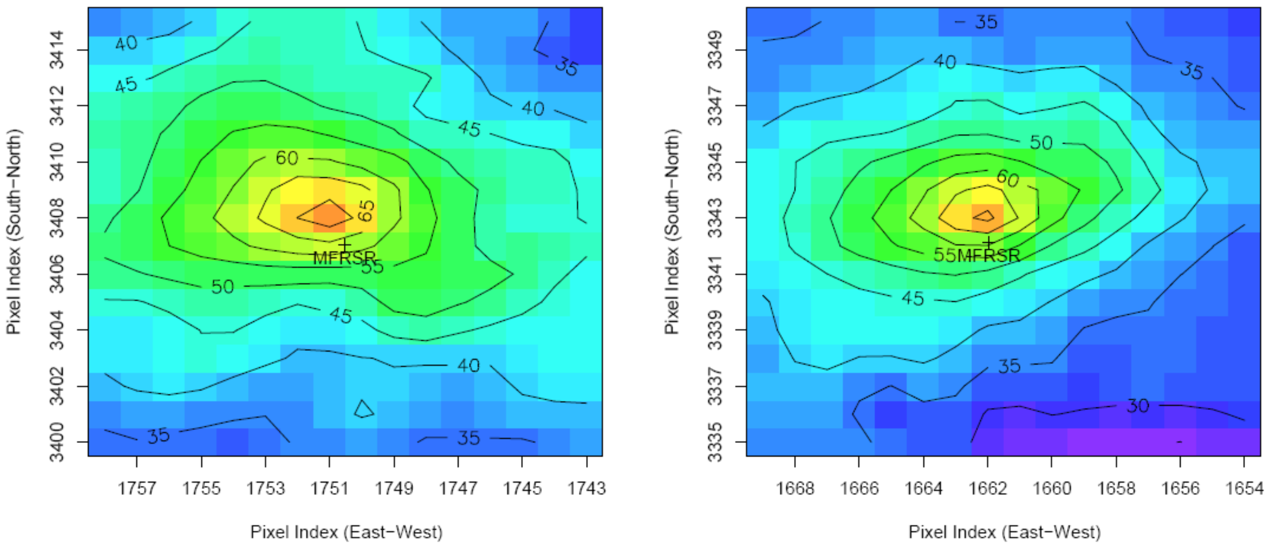

Figure 1 *Contour/intensity map of the explained variance [in %] between the 5 minute resolution time series of flux transmittance and SEVIRI bidirectional reflectance for a 16 × 16 pixel grid centred around the location of the MFRSRs at Cabauw, The Netherlands (left panel) and Heselbach, Germany (right panel).*

In contradiction with the study of simulated data, the optimum tracklength of real ground-based observations appears to be much longer, about 4 to 6 satellite pixels. Figure 2 shows that the explained variance and the retrieval precision (expressed by the 68th quantile of the difference between satellite and ground-based LWP values) reach their optimum at sample times *(f_t)* of about 10, which corresponds to a length of about five satellite pixels. Moreover, both explained variance and precision are highest when both the satellite and ground based LWP values are interpolated with a Gaussian weighing function. These validation results show that longer temporal averaging of the surface measurements is recommended to exclude frequencies with higher variance in ground-based observations. Temporal averaging of the surface measurements over a period of at least 40 minutes is recommended to exclude frequencies with higher variance in transmittance than in reflectance. The validation results may be further improved when the estimates from geostationary satellites are averaged over a period equal to that used for averaging the surface measurement to obtain an optimal agreement. In this respect the use of SEVIRI rapid-scan mode data, which are provided at a 5 minutes sampling frequency, turned out to be very useful.

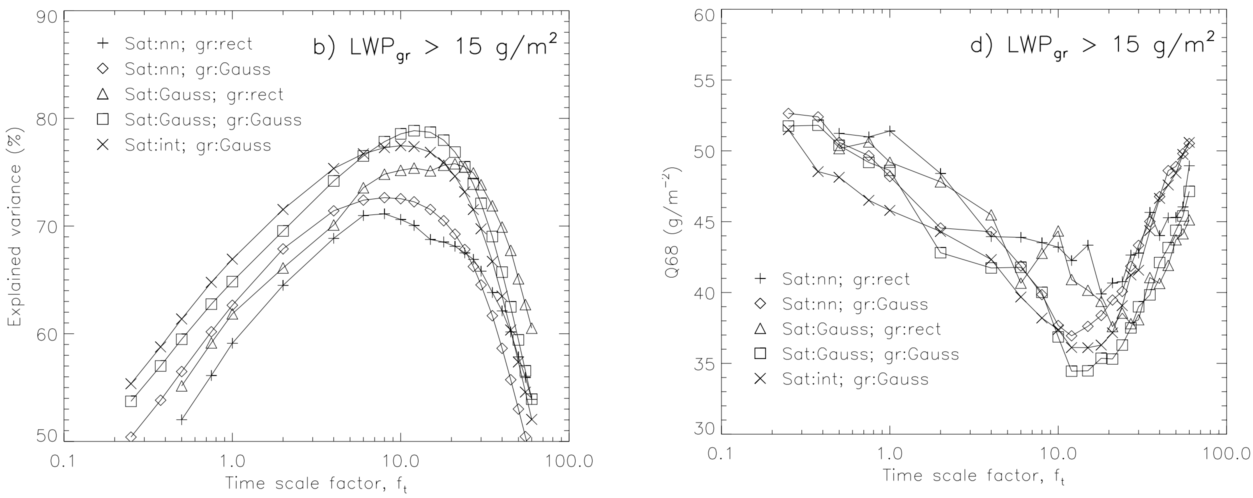

***Figure 2:** Explained variance (left panel) and precision (Q68) (right panel) as function of the sampling time (f_t) for different interpolation schemes. The SEVIRI retrievals were interpolated by nearest neighbor interpolation (nn) or by averaging with a Gaussian weight function (Gauss) or by spatial interpolation (int), while the ground-based observations were interpolated by rectangular (rect) or Gaussian (Gauss) weight functions (source Greuell and Roebeling, 2009).*

4. Conclusions

In conclusion, this study has shown that differences between satellite-derived and ground-based cloud properties in validation studies are partly caused by issues associated with the validation itself, in particular scale differences and the parallax. The analysis of a synthetic dataset of cloud properties reveals that significant reductions in validation uncertainties can be achieved by choosing the optimum sampling period for the ground-based observations and by correcting for parallax shifts. An optimum validation strategy is defined and tested for the validation of bi-directional reflectance observations and LWP retrievals from SEVIRI with real ground-based observations. The validation results confirm that the application of the optimum validation strategy leads to a significant decrease of the validation errors and increase of the explained variance. Finally, it was shown that the validation uncertainties can be further reduced when, instead of instantaneous observations, time-series of cloud properties retrievals from SEVIRI are compared against ground-based observations.

5. References

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