New methods for the evaluation of atmospheric models with satellite remote sensing

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Introduction

A pressing task in numerical weather prediction and climate modelling is the evaluation of modelled cloud fields. Recent progress in spatial and temporal resolution of satellite remote sensing increases the potential for such evaluation efforts.

This poster presents a new methodology to compare satellite remote sensing observations of clouds and output of the Lokal Model (LM). We discuss first applications of this method, namely to cloud cover and integrated water vapour (IWV). The comparison is carried out for five cases which present various cloud situations. The cloud cover of LM as well as corresponding retrievals from remote sensing observations with MODIS onboard TERRA and SEVIRI onboard MSG form the basis of a statistical analysis to compare the data sets. While IWV is studied utilising standard statistical approaches, two different measures are defined for comparison of cloud cover: 1) average properties and 2) single cloud features, with the following objectives: A set of parameters which is suitable for an automated, unsupervised analysis and continuous and fast processing of data sets received during long-term studies is identified, and the applicability of these parameters is evaluated. It is shown that the newly developed methodology is useful for evaluation purposes and that the extension of average characteristics with single cloud features increases the reliability of the comparison.

The comparison shows that our method can clearly identify differences in cloud cover and IWV, and the algorithm is usefull for an automated and unsupervised evaluation of long-term data sets of model output.

Data pool

We carry out a comparison between:

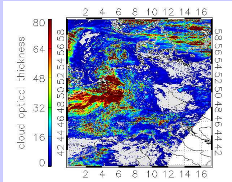
- LM from DWD: Initialised 12 UTC, integration 36 h, output every hour, horizontal resolution Δx=2.8 km, 328 x 378 spatial pixels.
- MODIS onboard the polar orbiting TERRA satellite: overpass over Europe 1-2 times a day at ~10:30 UTC, Δx=0.25 - 1 km, cloud mask after Ackerman et al. (1997), IWV after Albert et al. (2004), both with Δx=1 km.
- SEVIRI onboard the geostationary satellite MSG: full disk every 15 min., Δx= ~5 km for Europe.

Approach

Interpolate and determine average characteristics: total cloud cover (b), after application of a threshold: contingency tables, overlap plots and parameter based on the fraction of [1,1], [1,0], [0,1], and [0,0] pairs (e.g. [1,0]: satellite observes cloud but LM not), patchiness:

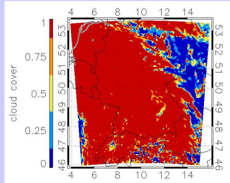
$$p1,2 = (N_{cld} \pm N_{free}) / n$$

with N_cld, N_free: number of cloud, cloudfree areas, n: total pixel number; single cloud features: histograms of area, fractional degree of a cloud border (fragmentation), brokenness within a cloud (Schröder et al., 2005); scatterplots.



MODIS cloud optical thickness
19.09.01, 11:10 UTC

SEVIRI true colour image
08.07.04, 10:30 UTC

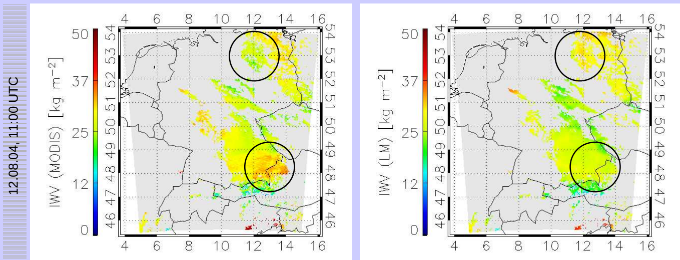


LM cloud cover
12.08.04, 15:00 UTC

Case studies

Comparison of average parameters (MODIS 1st and LM 2nd): MODIS has generally larger b and p1, dominated by cloudfree areas, see p2 (MODIS time in UTC).

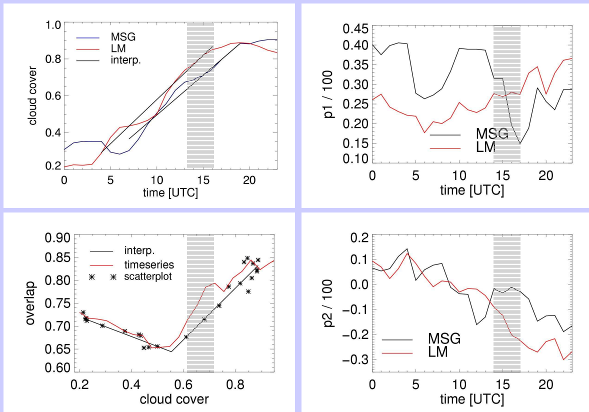
Date	Time	Case	b	p1	p2	overlap
19.09.01	11:10	frontal precip., NL	0.77 / 0.71	0.44 / 0.22	-0.16 / -0.06	0.72
23.09.01	10:45	Sc, later Cu, NL	0.74 / 0.83	0.66 / 0.28	-0.34 / -0.22	0.76
21.05.03	10:05	2 layers, Cu, NL	0.84 / 0.72	0.59 / 0.24	-0.55 / -0.21	0.74
08.07.04	10:25	strong precip., D	0.93 / 0.79	0.22 / 0.24	-0.18 / -0.14	0.77
12.08.04	10:55	strg. thunders., D	0.61 / 0.62	0.59 / 0.18	-0.13 / -0.03	0.65



rmse = 3.16 kg m^{-2}, bias = 1.34 kg m^{-2} (MODIS – LM), correlation = 0.64

Timeseries

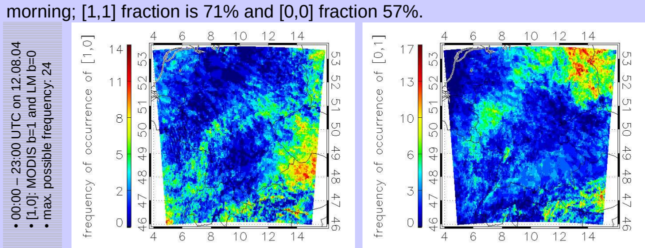
Comparison of timeseries of average parameters from SEVIRI and LM observations, taken between 00:00 and 23:00 UTC on 12 August 2004.

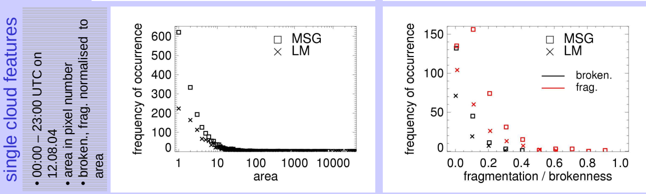


Time shift of 2 h in b. SEVIRI p1 smaller than LM p1 after 15 UTC. Dominance of cloud areas changes to dominance of cloudfree areas, if b exceeds 0.5 (9 UTC). Overlap at minimum for b=0.5, with linear increase for in-/decreasing b.

Histograms

Major under-/overestimations due to differences in cloud cover during the morning; [1,1] fraction is 71% and [0,0] fraction 57%.





Underestimation of small cloud areas and of fractional degree of clouds.

Conclusions and outlook

A new algorithm for the evaluation of atmospheric models is presented utilising LM, SEVIRI and MODIS observations. Average characteristics are complemented by single cloud features to provide a complete impression of differences and cloud structures. In particular, the patchiness parameters are able to identify differences between the LM and the satellites.

The remote sensing products of SEVIRI will be extended to allow a retrieval of IWV, cloud top pressure, and microphysical parameters. Furthermore, a precipitation index will be defined to assess the evaluation of precipitation. The presented evaluation approach needs to be adjusted to the new parameters, and a suitable subset of the parameters needs to be defined.

Special emphasis will be placed on the lifecycle of clouds, in particular their diurnal cycle, and the path of convective systems will be traced and compared.

References: Ackerman, S., and co-authors, 1997. Discriminating clear-sky from cloud with MODIS: Algorithm Theoretical Basis Document (MOD35). Algorithm Theoretical Basis Document ATBD-MOD-06, NASA Goddard Space Flight Center, 125 pp.

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