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. This poster presents a new methodology to compare satellite remote sensing observations and output of atmospheric models. Here observations of MODIS onboard TERRA and SEVIRI onboard MSG as well as of the Lokal Model (LM) are utilised. We discuss first applications of the method, namely to cloud cover[1], clear-sky integrated water vapour[2] (IWV), and tracking of convective systems. We separate between average cloud cover properties and single cloud features and use a tracking algorithm, 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. The methods are applied to data of five cases of various cloud situations. It is shown that the newly developed methodology is useful for long-term evaluation purposes.

Observations

We carry out a comparison between: LM from DWD: output every hour, spatial resolution Δx=2.8 km; MODIS: overpass over Europe 1-2 times a day, Δx=0.25-1 km; SEVIRI: full disk every 15 min., Δx=~5 km for Europe, since January 2004.

Approach

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

$$p1,2 = (N\_cld \pm N\_free) / n$$

with N_cld, N_free: number of cloud, cloud free areas, n: total pixel number; single cloud features: histograms of area, fractional degree (fragmentation) and brokenness of a cloud.[3]

In order to track convective clouds, a threshold has been applied to brightness temperatures, BT, or rain rate fields. Weigthed area differences and distances between two consecutive images define the assigment of clouds. Output is life time, growth rate, origin, and track and overall direction and speed. Merging and splitting will be identified with an overlap criterium.

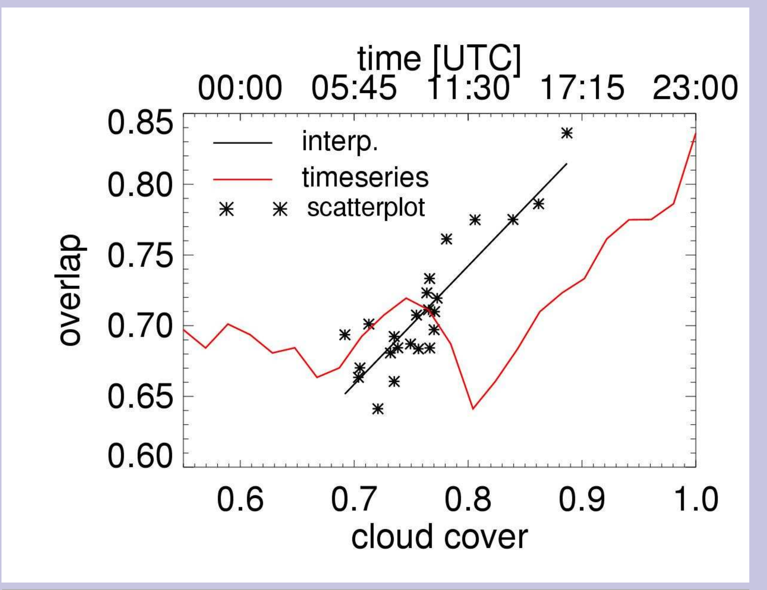
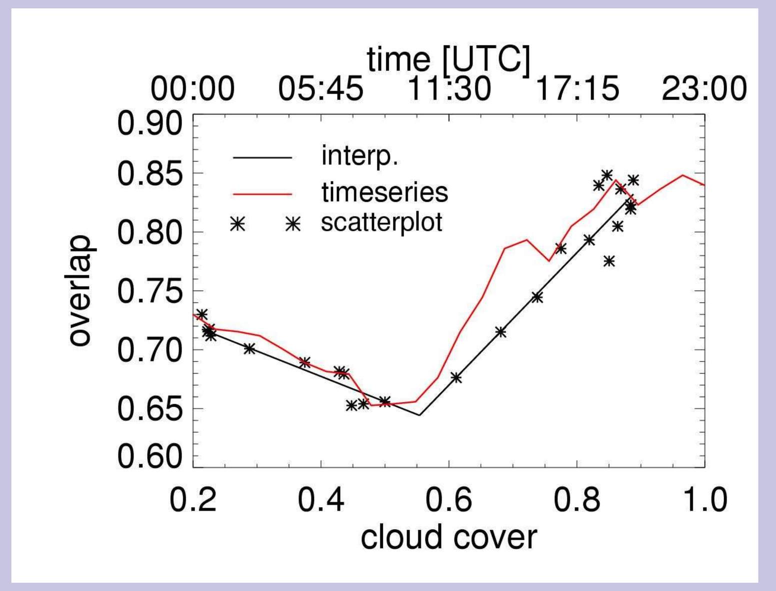


Fig: Overlap versus time and b for 08.07.2004 (above) and 12.08.2004 (below)

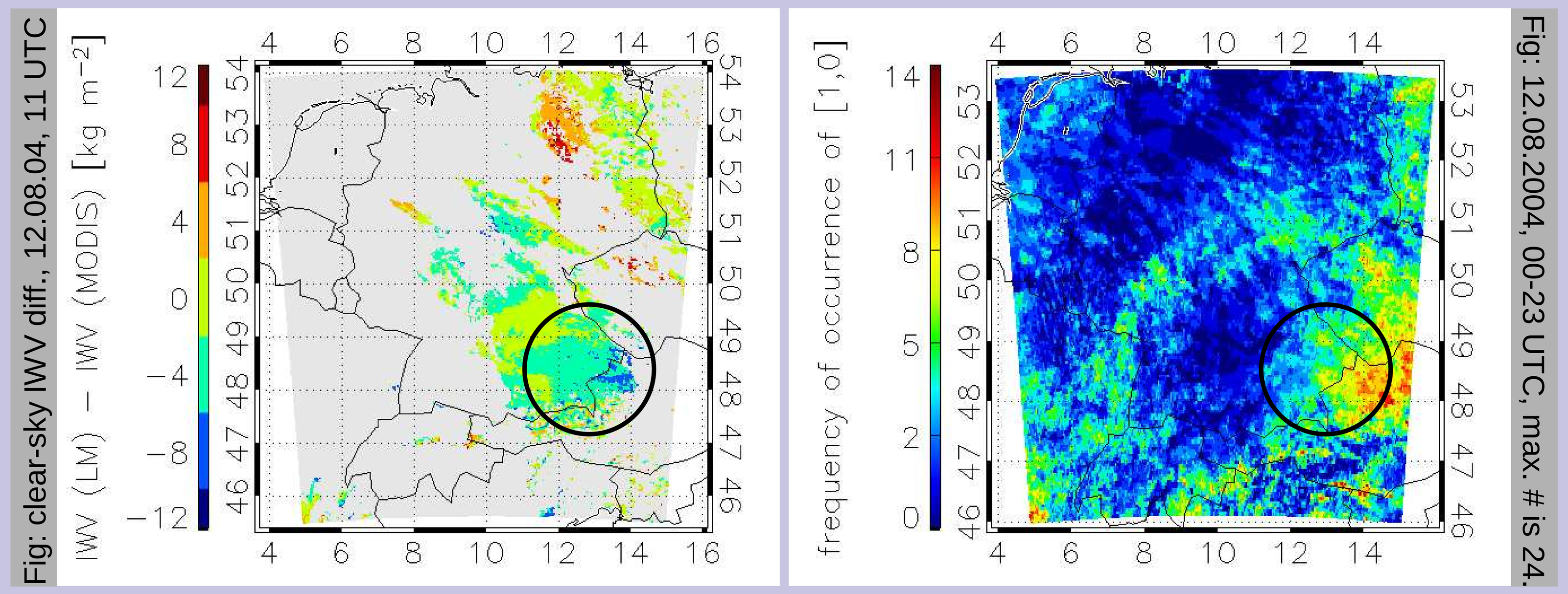


Overlap at minimum for b=0.5, linear in-/decrease with b. Use overlap together with b only.

Cases

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

Date	Time	Case	b	p1	p2	overlap
19.09.01	11:10	frontal prec., 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

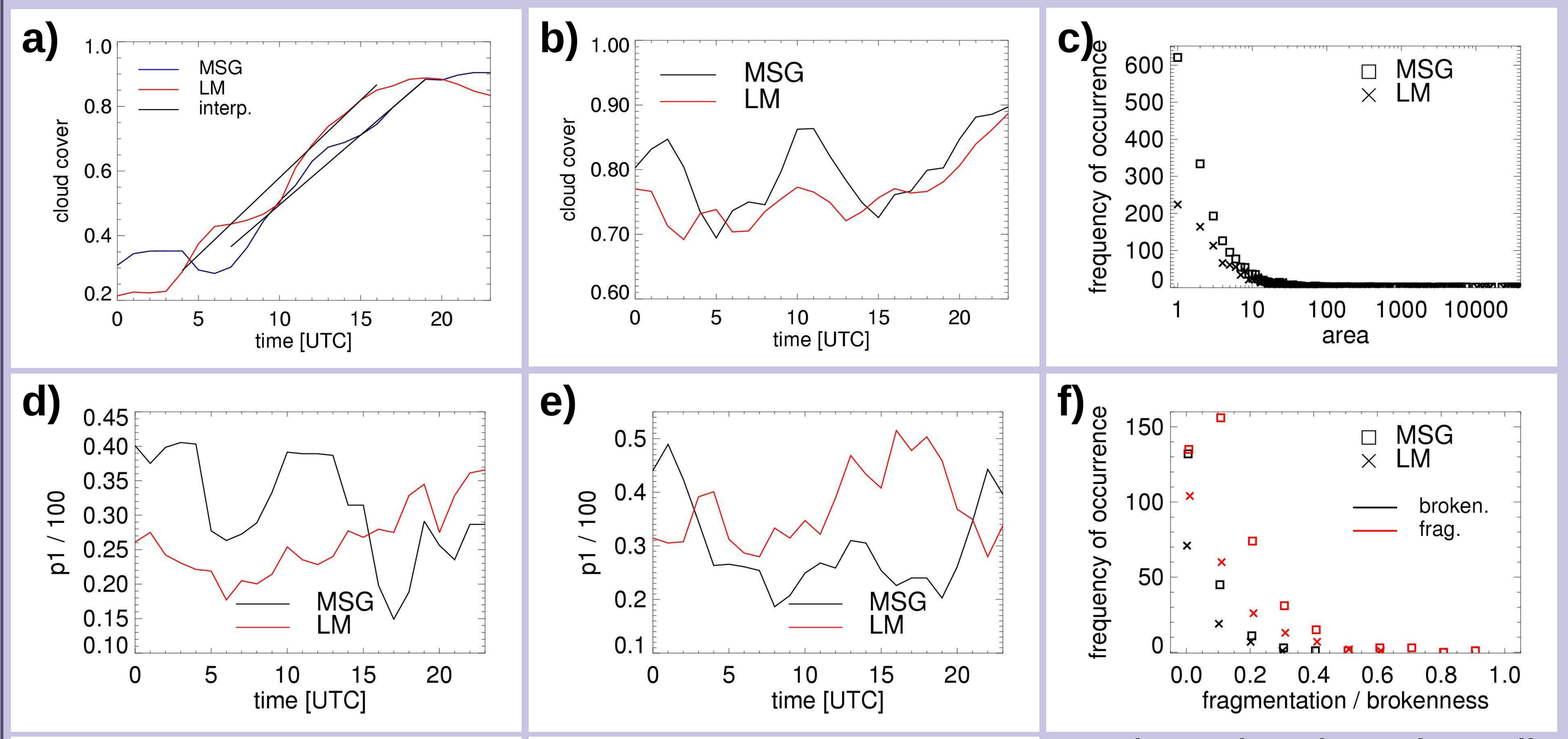


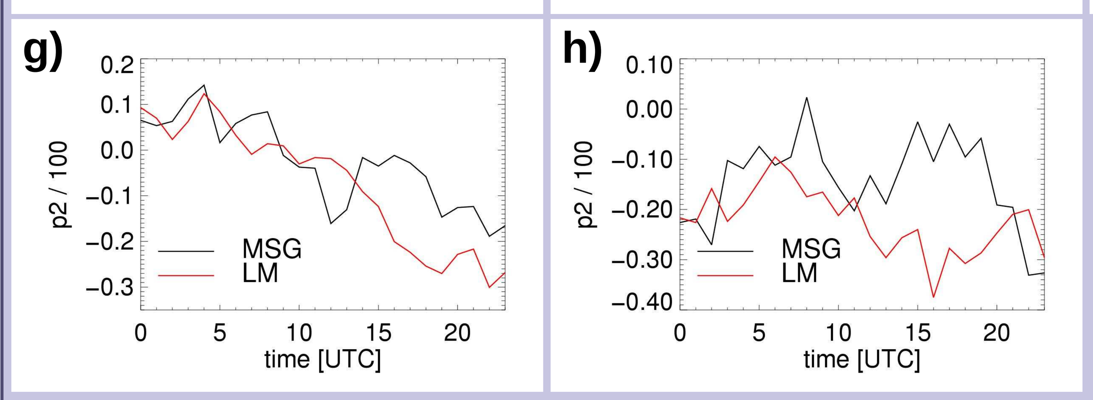
rmse = 3.16 kg m^{-2}, correlation = 0.64
bias = -1.34 kg m^{-2}

Differences due to cloud cover during the morning; [1,1] fraction is 71% and [0,0] fraction 57%.

Timeseries and single cloud features

Figs: Timeseries of b, a)+b), and patchiness, p1 in d)+e), p2 in g)+h), 00-23 UTC on 12 August (left) and 08 July (middle) 2004; (right) area in # of pixels, c), frag./broken. normalised to area, f), 12 August 2004, 00:23 UTC.



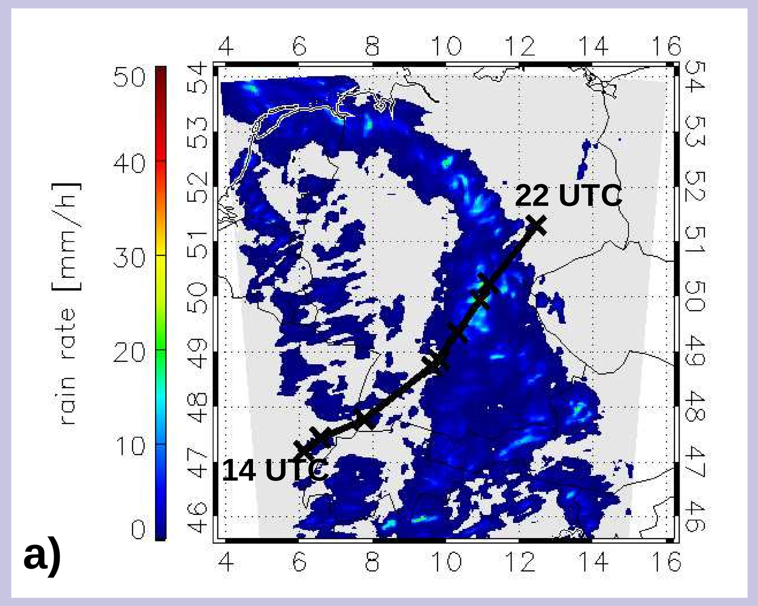


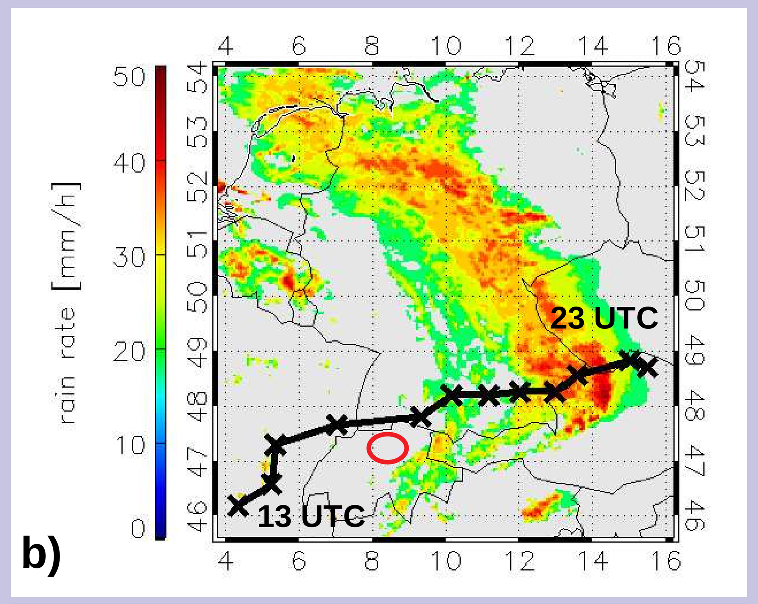
Underestimation of small cloud areas and fract. degree of clouds, c)+f).

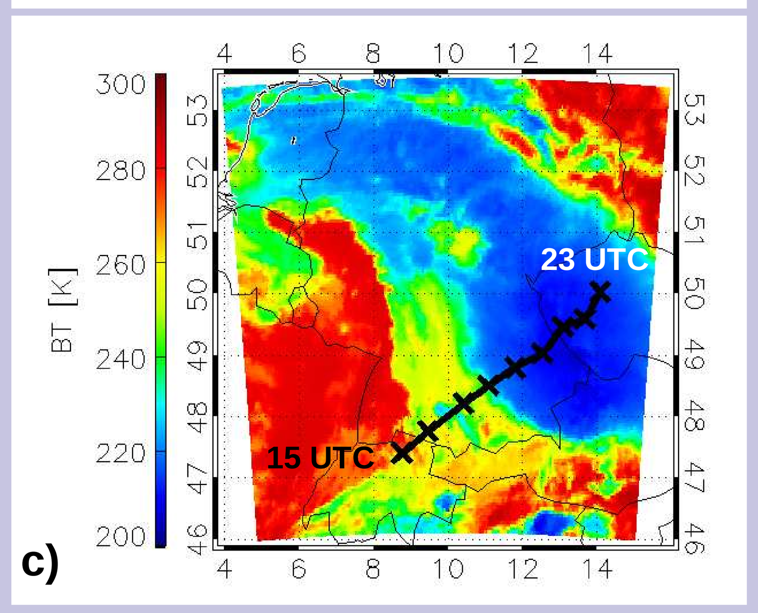
Time shift of 2 h in a). Besides peak values in b good agreement in b). At 15 UTC change in cloud distribution between SEVIRI and LM, d)+g); dominance of clouds changes to dominance of cloud free areas, g). In e)+h): Larger patchiness in LM due to larger amount of cloud free areas.

Tracking

Figs: Tracking of largest area after application of threshold to rain rate, a): LM and b): radar, and BT, c): SEVIRI, each for 12 August 2004; images taken at 20 UTC (time of max. area in c)); start and stop times are also provided.







Similarities between LM and radar rain rate (LM: rain shifted to NE). Visual inspection of radar rain rate reveals origin of thunderstorm in Switzerland (red circle). Presented path due to merging and splitting.

Correlation between BT from SEVIRI and rain rate, with a shift of cloud tops to NW and larger coverage.

Next: Compare BT from LM and SEVIRI.

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. First applications of a tracking algorithm are presented.

The evaluation will be extended to cloud top pressure, optical thickness, and phase. Furthermore, a precipitation index will be defined to assess the evaluation of precipitation, and its outcome is compared to a tracking of BT fields from LM and SEVIRI, after introducing a flag for merging and splitting.

A long-term evaluation will be carried out to identify systematic differences. Special emphasis will be on the life cycle of clouds.

References: [1] 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.
[2] Albert, P., and co-authors, 2005. Remote sensing of atmospheric water vapor using the Moderate Resolution Imaging Spectrometer (MODIS). J. Atm. Ocean. Tech., 22, 309-314.
[3] Schröder, M., and co-authors, 2005. The representation of low-level clouds in atmospheric models. Part II: Spatial distributions from satellite remote sensing during the BALTEX Bridge Campaigns. Submitted to Atm. Res.

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