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

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Introduction

We present new methodologies for the comparison of satellite remote sensing observations and output of atmospheric models. We utilised observations of MODIS and SEVIRI to evaluate the LMK model. The comparison relies on observations and output from July and August 2004 and on two case studies: a stratiform cloud and a shallow convection case. We newly introduce the patchiness parameter and a novel and widely applicable method to spatially aggregate cloud optical thickness (τ). The comparison of τ revealed the inability of LMK to separate between the convective and stratiform cloud case. First results of the long-term evaluation show systematic overestimations of brightness temperature (BT) and underestimations of cloud top pressure. Further analysis relies on the diurnal cycle and regional dependencies of bias and RMSE. Finally, we apply a tracking algorithm to MSG and LMK data which allows the analysis of differences in life time, origin, and path of convective cells.

Observations

LMK from DWD: output every hour, Δx=2.8 km; MODIS: overpass Europe 1-2 times a day, Δx=0.25-5 km; SEVIRI: full disk every 15 min., Δx=~5 km for Europe.

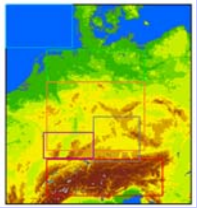
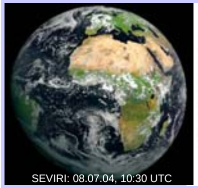


Fig: LMK domain and sub-domains.



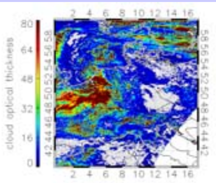


Fig: MODIS 19.09.01, 11 UTC

Approach

- Interpolate and determine total cloud cover (b), τ, BT and patchiness:

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

with N_cld, N_free: number of cloud, clear sky areas, n: amount of pixels.

- Aggregate cloud optical thickness:

Model:

$$\tau_{cloud} = -\mu \ln\left(\prod_j \left(1-b_j+b_j\exp(-\tau_j/\mu)\right)\right),$$

with j: cloud layer index, μ: cosine of sun zenith angle, b_j: layer cloud cover, normalised to columnar b

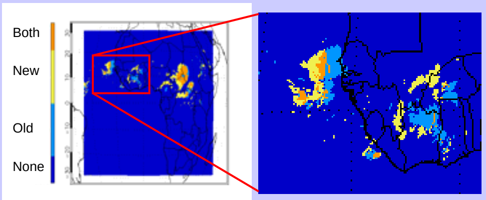
MODIS:

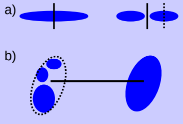
$$\tau = -\mu \ln\left(1/N \sum_i \exp(-\tau_i/\mu_i)\right).$$

with i: grid cell index, N: number of pixels.

For aggregation use τ=0 in clear sky cases and for domain averages use b_i>0.

- Tracking: 1) Use BT threshold to define convective cells, e.g.: BT < 220 K,
  2) Determine area A, distance r, overlap o in two successive images,
  3) Minimum in A / max(A) + r / max(r) + (1-o) defines pair of cells.

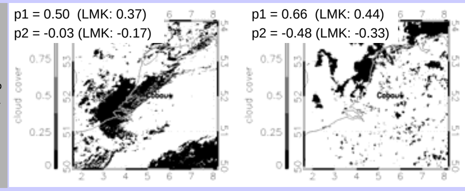




Counter for splitting a) and merging b).

Tracking stops if A<100 pixels and o=0.

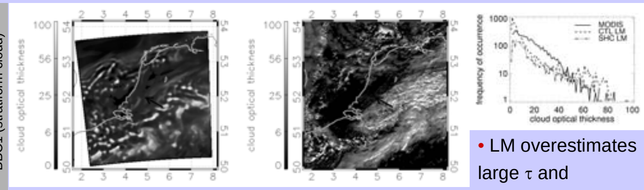
Patchiness, Cloud optical thickness

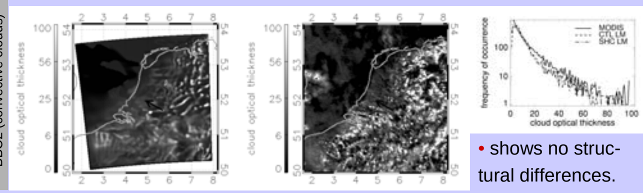


Figs: Cloud cover, MODIS, left: BBC1, right: BBC2.

The Netherlands
BBC1: 23 September 2001
BBC2: 21 May 2003

- Useful to test newly implemented turbulence schemes
- Model underestimates patchiness.





Figs: Cloud optical thickness, first LM, second MODIS, third PDF. BBC1 (stratiform cloud) BBC2 (convective clouds)

- LM overestimates large τ and
- shows no structural differences.

Long-term analysis

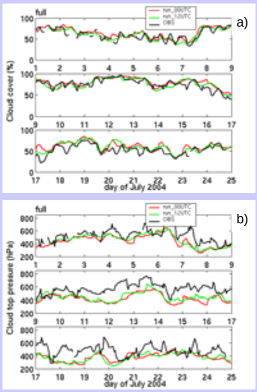
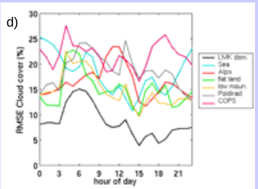


Fig: Time series of cloud cover a), cloud top pressure b), July 2004 (OBS=SEVIRI).



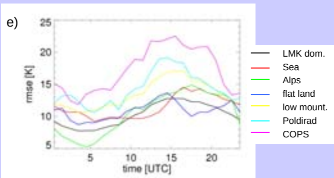


Fig: Diurnal cycle of RMSE of cloud cover d), BT 10.8 µm e)

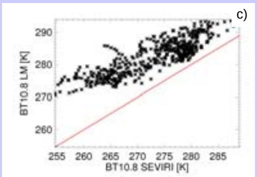
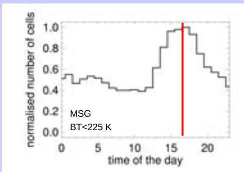


Fig: Scatter plot of BT, August 2004.

- Agreement in b, diurnal cycle in RMSE.
- Underestimation of cloud top pressure.
- Overestimation of BT (large bias, high correlation (0.86)), diurnal cycle in RMSE.
- Latter possibly due to erroneous implementation of viewing geometry. This would also explain the increasing bias with decreasing BT and cloud top pressure.

Tracking



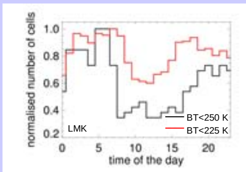
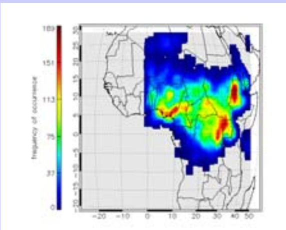
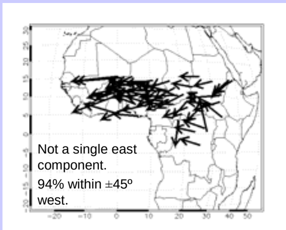


Fig: Diurnal cycle of convective activity, expressed in number of low temperature cells, August 2004, LMK (GOP) domain.





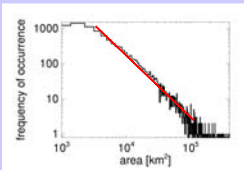


Fig: Origin, path and PDF of area, June, July, August 2005. Paths plotted only if length > 700 km (central Africa).

Tracking of convective cells and comparison of origin, path, diurnal cycle, and PDFs of area, path length and life time as well as merging and splitting of cells (not shown) contains large potential for evaluation purposes.

Conclusions and outlook

New algorithms for the evaluation of atmospheric models have been presented utilising LMK, SEVIRI and MODIS observations. The patchiness parameters are able to identify differences between LMK and satellites. The aggregation of cloud optical thickness is widely applicable, and cloud optical thickness turned out to be a valuable parameter for evaluation purposes. LMK tends to overestimate the frequency of large cloud optical thicknesses and shows no significant structural differences in cloud optical thickness fields, probably due to an overestimation of updrafts (see also Van Lipzig et al. 2006 and Schröder et al. 2006).

For July 2004 we found reasonable agreement in cloud cover and underestimations in cloud top pressure. RMSE of cloud cover has a distinct diurnal cycle. For August 2004 BT 10.8 µm shows a large RMSE with diurnal cycle. Future work will concentrate on possible uncertainties in the implementation of viewing geometry in the radiation module of LMK.

Due to the large RMSE the application of the tracking algorithm should be seen as a preliminary study. In the near future the tracking algorithm will be used for evaluation purposes.

References:

Van Lipzig, N.P.M., and co-authors, 2006. Model predicted low-level cloud parameters. Part I: Comparison with observations from the BALTEX Bridge Campaigns. Atm. Res. (in press).

Schröder, M., and co-authors, 2006. Model predicted low-level cloud parameters. Part II: Comparison with satellite remote sensing observations during the BALTEX Bridge Campaigns. Atm. Res. (in press).

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