COMPARISON OF AN OPTICAL AND A PASSIVE MICROWAVE RAINFALL RETRIEVAL OVER NORTH-WESTERN AFRICA

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ABSTRACT

A comparison study between an optical and a passive MW rainfall retrieval over north-western Africa is presented. Therefore the Advective-Convective-Technique (Reudenbach et al. 2001, Reudenbach and Nauss 2004) has been applied to the WV and IR channel of Meteosat-7 for the detection of convective and advective/stratiform precipitation fields. Rainfall rates are assigned as a function of cloud-top temperature using 3-D cloud model calculations based on radiosonde datasets from Benin. The passive MW technique is from Bauer et al. (2002) and incorporates comparable channels of TRMM TMI, DMSP SSM/I, and Aqua AMSR-E. The resulting precipitation fields as well as the rainfall rates of the two retrieval techniques have been evaluated against each other. So far, probability matching and morphing techniques have precedently been used to interpolate microwave rain estimates, but the better detection and discrimination of the ACT-based precipitation fieldsmay lead to a better merging between geostationary IR and LEO data in the future. The results of this comparison study form a valuable base for an upcoming combined WV/IR and MW retrieval technique currently developed within the Advanced Multisensor Precipitation Estimate project (AMPE).

1. Description of the two retrieval techniques

1.1 Advective Convective Technique (ACT)

The ACT consists of two modules – one for the identification of rainfall connected with deep convection and one for the identification of mainly stratiform precipitating areas (see figure 1). The ACT convective module is based on the Enhanced Convective Stratiform Technique (ECST, Reudenbach et al. 2001, Reudenbach 2003) that uses positive TB_{WV}-TB_{IR} differences (DWI) in order to discriminate between deep convective, optically thick clouds (DWI>0) and non-raining cirrus (DWI<0, refer to Tjemkes et al. 1997). Pixels with positive DWI are subdivided by analysing the frequency distribution of brightness temperatures (TB_{IR}). Areas with TB_{IR}<1st quartile of the frequency distribution represent overshooting tops of convective cores, those who suit the 1st quartile reveal raining systems at tropopause level and pixels with TB_{IR}<3rd quartile identify potentially raining cloud systems of high vertical extension. As a result, isolated convective cores can be distinguished from directly adjacent stratiform raining areas.

The second module of the ACT detects rainfall areas in warmer frontal systems (e.g. warm frontal clouds). The method is based on an iterative k-means clustering algorithm (Bradley and Fayyad 1998) that is applied to TB_{IR}, TB_{WV} and 3x3 infrared standard deviations ($Stdv_{IR}$). It integrates the classified cloud process patterns from the convective module as core raining areas. The resulting clusters which represent potentially raining cloud types (advective-stratiform precipitation) are reallocated into single cloud entities and finally classified as raining/non-raining if their compactness index and centroid temperature fits predefined threshold values.

After the identification and classification of raining clouds, a specific rainrate is assigned to each pixel with respect to the identified cloud-type and the cloud-top temperature. The rainrates are derived from idealised 3D cloud model runs with the mesoscale Advanced Regional Prediction System (ARPS, Xue et al. 2003). For the current study a 2002 radiosonde dataset from a testsite in Benin kindly supplied by the GLOWA-Impetus project (see www.glowa.org) is used as initial input for the model

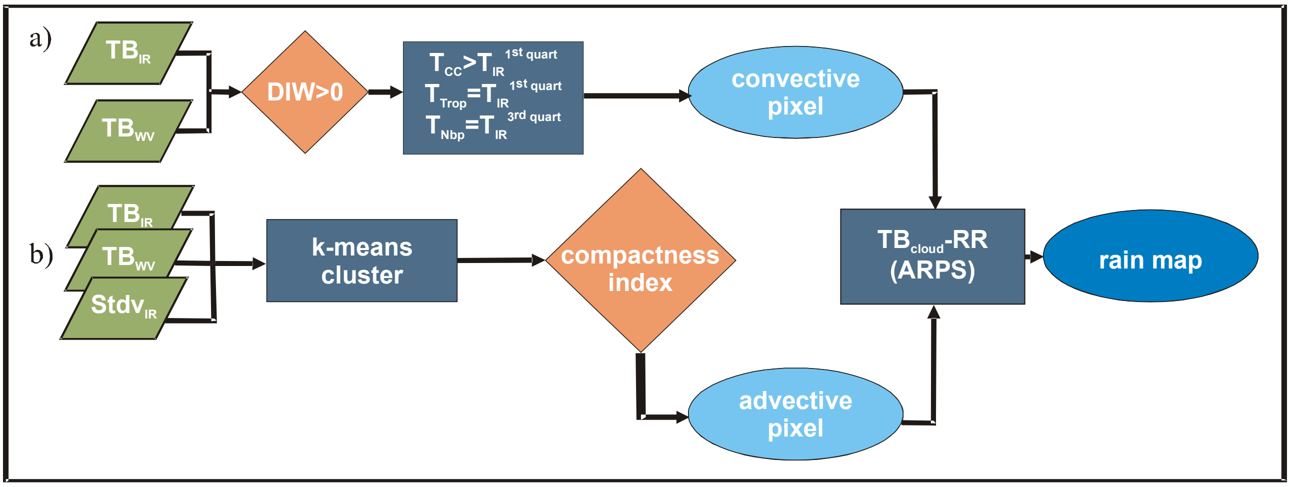

Figure 1: Overview of the ACT algorithm.

1.2 The passive Microwave Technique (PMWT)

The passive microwave technique consists of a two-stage approach to distinguish precipitation signatures from other effects (Bauer et al. 2002, see figure 2):

(1) Contributions from slowly varying parameters (surface type and state) are isolated by comparing observed brightness temperatures to those obtained from previous orbits only containing rain-free observations. This is achieved by generating maps of clear-sky temporal averages of brightness temperatures over land surfaces. Averaged TB distributions from cloud free observations are generated employing the globally applicable screening algorithm founded by Grody (1991) and refined by Ferraro and Marks (1995).

Based on this, all observations contaminated by wet land, precipitation, and snow cover were removed.
(2) Effects of more dynamic parameters, i.e., surface temperature and moisture, are reduced by successive subtraction from the observations by means of a principal component analysis. For this purpose, the general signatures of both temperature and moisture variations are deduced from radiative transfer simulations. The fundamentals of this approach are based on a methodology developed by Conner and Petty (1998). Their technique was modified by introducing radiative transfer calculations from cloud-free radiosonde profiles of temperature and moisture and a microwave surface emissivity model.
The final objective is the separation of the precipitation from the temperature and moisture signal content of the original TB. The resulting index (in units of K) is positively correlated to rainrate.
The technique incorporates comparable channels of TRMM TMI, DMSP SSM/I, and Aqua AMSR-E and the MW rain estimates are interpolated in time by means of a probability matching and a morphing technique using Meteosat IR images (see Bauer et al. 2002 for further details).

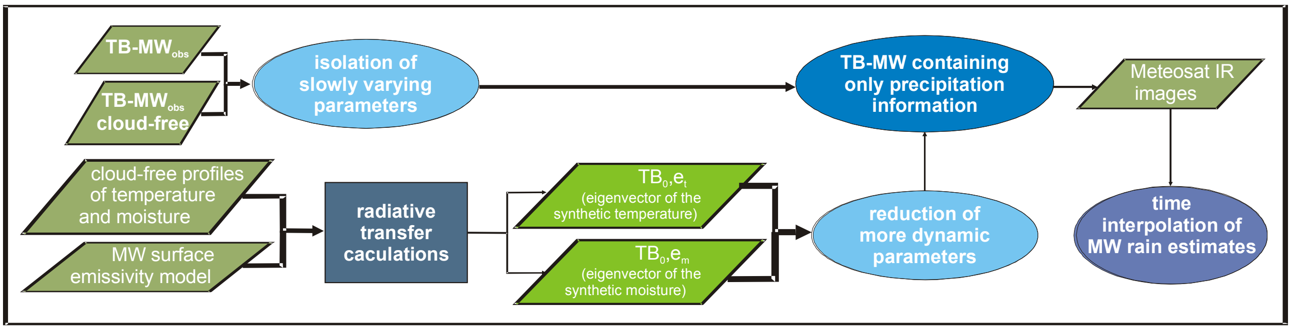

Figure 2: Overview of the passive microwave algorithm.

2. Results

In preparation for a future combination of infra-red and passive microwave rain retrieval techniques, a comparison of ACT and passive microwave rain rates was made in conjunction with the TRMM standard 2A12 microwave (Iguchi et al. 2000) and the TRMM precipitation radar (PR) (Kummerow et al. 2001) product, the last being the optimal validation source for instantaneous rain rate estimates. The studies were made for 10 scenes in July 2002 over West Africa, whereas the relatively low number of cases caused by the need for collocated rain estimates with sufficient non-zero values as well as limited data availability in the water vapor channel.
The example in figure 3 shows the co-located results of the ACT (figure 3a) and the PMWT (figure 3b) for a TRMM overpass on July 24th 2002. The areas detected by the ACT exhibit a more heterogeneous pattern than the rain fields detected by the PMWT because of the higher correlation between MW ice scattering and precipitation than precipitation and cloud top information. Comparison with the infrared image combined with the passive microwave and radar estimates in figure 4 shows the ACT's potential of identifying convective cores and discriminating high cirrus clouds: a high Cirrus arm in the

middle of the PR swath is correctly discriminated while a relatively low convective rain cell in Benin detected by the AMSU-B sensor is also classified as rain by the ACT algorithm.

Table 1

Skill against PR	TMI PMWT	TMI 2A12	ACT
Bias	-5.2%	+11.2%	-4.9%
False Alarm Ratio	0.205	0.238	0.609
Prob. Of Detection	0.602	0.584	0.574

In the considered scenes the ACT estimates produced a negative overall bias of 4.9% against the TRMM radar surface rain estimate (2A25), which is a good result considering that the algorithm had been calibrated neither with radar nor ground measurements. The PMWT algorithm had a negative bias of 5.2% against the PR, opposed to the 2A12 product which displayed a positive bias of 11.2% as already addressed by McCollum et al. (2000) and Furuzawa et al. (2005). The increased performance of the PMWT (see table 1) is not surprising since it was optimized with PR data over this region and over a long time period. The improvements were the most pronounced in the Sahel region. Figure 4b also shows rain detected by the TRMM PR (visible also in white in figure 4a) which remains hidden for the 2a12 product due to the problematic MW scattering signature of semi-arid soil (figure 4a), while the new PMWT remains more sensitive through the regional adaptation of the MW ground emmission maps (figure 3b).

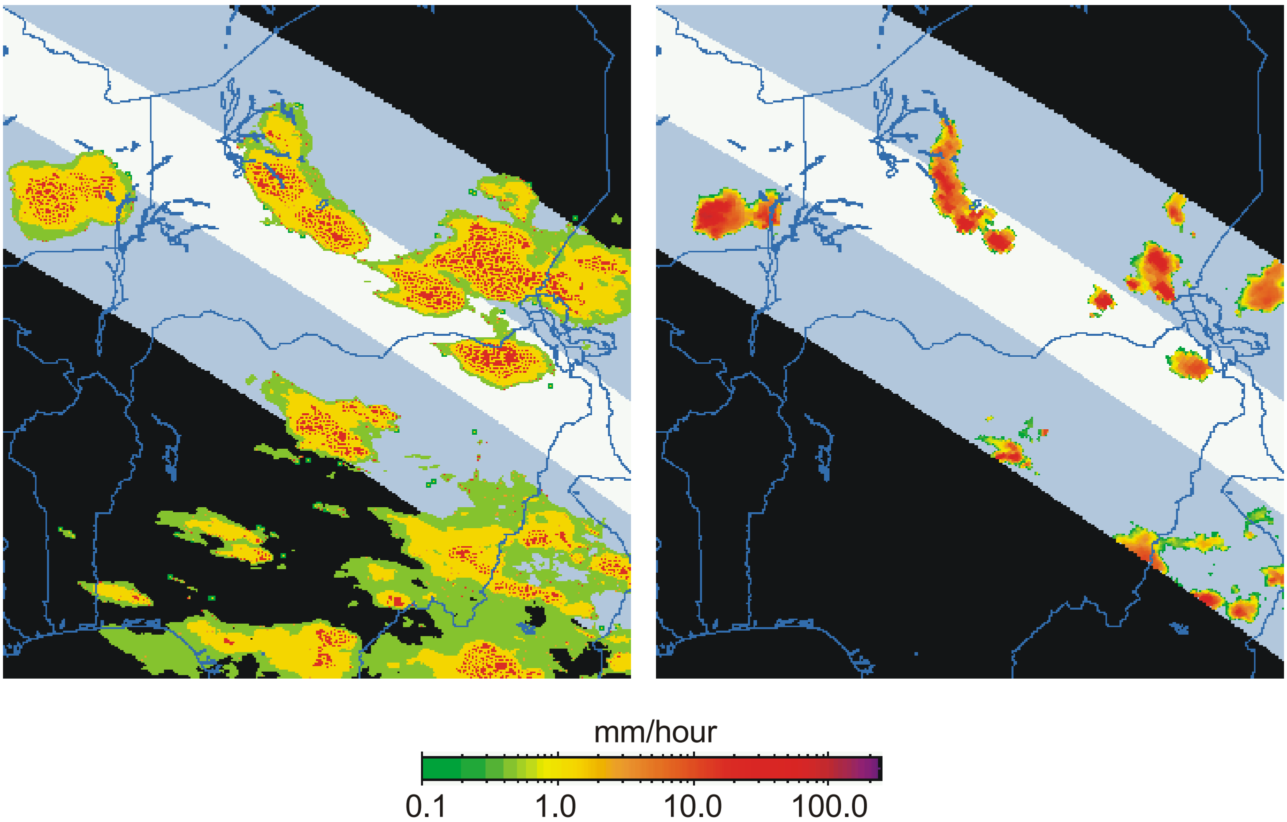

Figure 3: co-located measurements of the ACT (a) and the PMWT (TRMM TMI) (b) for the 24th July 2002 at 19:10 UTC.

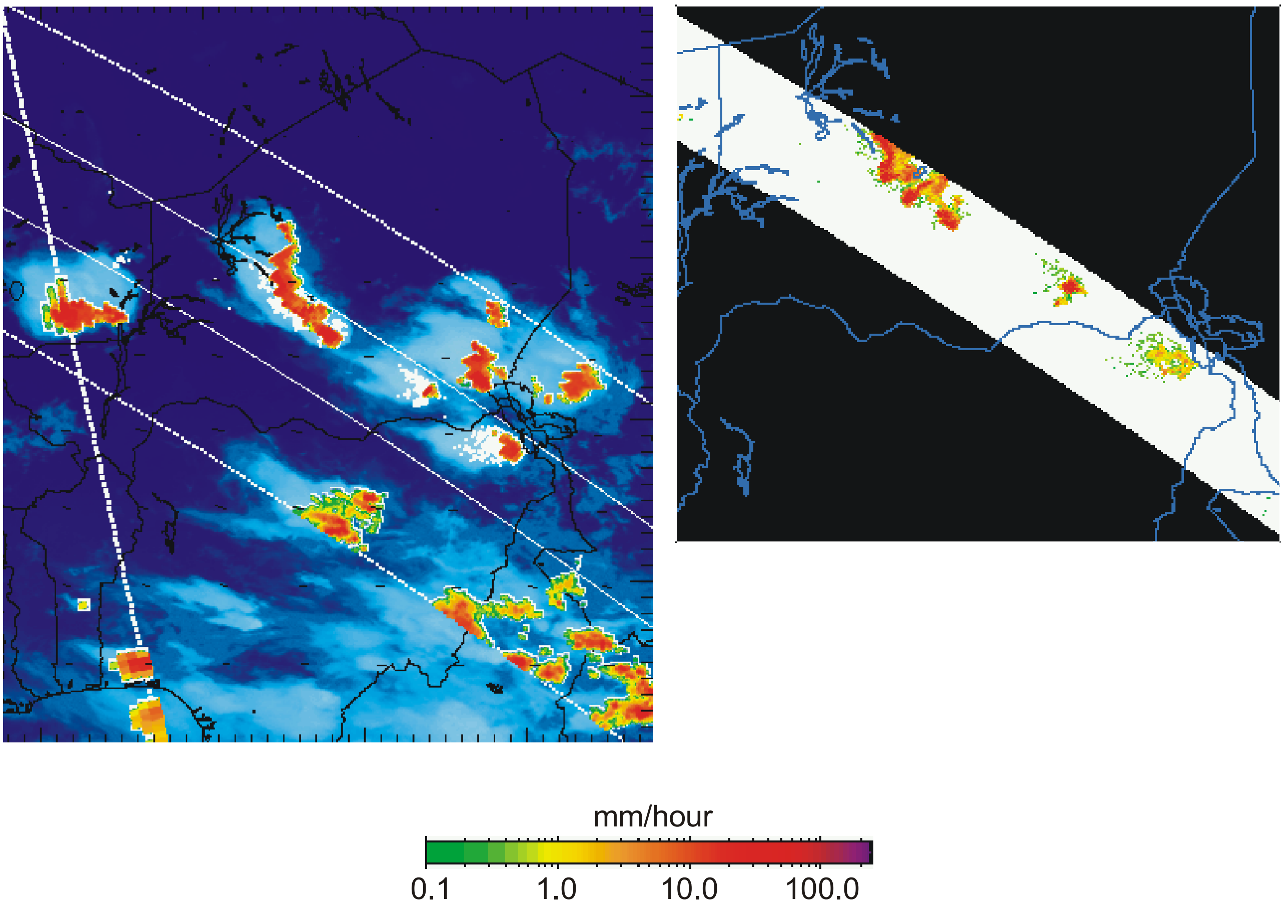

Figure 4: Meteosat IR with collocated TMI 2A12 product, TRMM PR in white (under 2a12), and AMSU-B measurement (a) and TRMM PR product alone (b) for the 24th July 2002 at 19:10 UTC

The next step of our work will be towards a combined passive microwave/IR product, so the relation of PMWT and ACT is of special interest. Figure 5 shows skill parameters between the ACT and the PMWT for 10 co-located scenes representing different weather situations. A mean CSI of 0.32 together with a high mean POD of 0.85 indicates a relatively good consistency between the PMWT and the ACT regarding the precipitation areas. The high mean FAR of 0.65 is due to the overestimation of the rain areas by the ACT as compared to TMI (figure 1 and 2), which may be addressed either by further adapting the ACT to the region or through existing probability matching techniques in a combined PMW/IR product. The temporal evolution of the skill parameters in different weather situations from one scene to the next suggests the necessity of an adaptive ACT/PMW algorithm, which will combine the strengths of the ACT cloud classifications in the continuous infrared data and the high correlation of PMW ice scattering with rain. Note, that the ACT algorithm has been originally developed for mid- to high-latitudes and has never been applied to the tropics before. Therefore, further adaptations especially with respect to the assigned rainfall rates are necessary.

The PMW retrieval scheme will furthermore be enhanced to adapt to regionally and temporally dependent biases found in passive microwave products (McCollum et al. 2000 and Furuzawa et al. 2004), caused not only by ground emmission but also by changes in premature evaporation of rain and cloud characteristics. These will be investigated over a period of several West African rainy seasons. This first comparison study shows a good performance of both algorithms and the upcoming integration of the ACT and the PMWT within the framework of the Advanced Multisensor Precipitation Estimate project bears a great potential for further improvements.

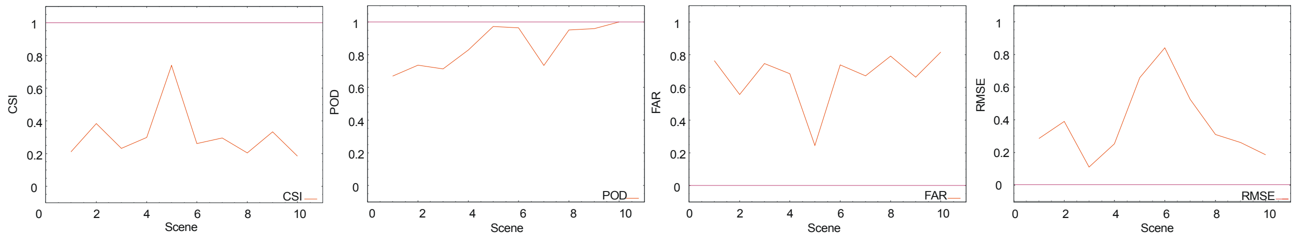

Figure 5: Critical Success Index, Probability of Detection, False Alarm Ratio and Root Mean Square Error for a comparison of 10 co-located measurements of TMI and the ACT in July 2002

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