REGIONAL VALIDATION OF SATELLITE-BASED GLOBAL PRECIPITATION ESTIMATES

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ABSTRACT

The experimental version of the GPCP-1DD product provides the research community with 1 degree daily precipitation fields from satellite measurements. The GPCP-1DD rain rates over Europe are verified in the present study with surface precipitation measured in dense precipitation networks operated in countries of Baltic Sea Catchment Area and of the European alps. First results show differences between gauged data and satellite data, which are higher on a daily than on a monthly basis. Undercatchment of the satellite-based product prevails in most cases.

1. INTRODUCTION

The Global Precipitation Climatology Project (GPCP) provides the global climate research community with global gridded precipitation data sets using infrared (IR) and microwave satellite observations (SSM/I) as well as the raingauge-based analyses (Huffman, 1995). The current operational combined product (Version 1c) incorporates (1) geostationary and polar-orbiting satellite infrared temperature histograms for the estimation of convective-type precipitation in the 40°N to 40°S latitude belt, (2) polar-orbiting satellite 19GHz-microwave radiances for estimating frontal-type precipitation in oceanic regions, (3) polar-orbiting satellite 85GHz-microwave radiances for estimating frontal type precipitation in extra-tropical land and ocean regions and (4) for the land surface gridded analyses based raingauge measurements from about 7000 stations on earth's landsurface. The latter are processed by the Global Precipitation Climatology Centre (GPCC, see Rudolf et al., 1999) and used for bias reduction of the satellite-based estimates. The product series starts with July 1987 and is being updated on a near real-time basis. The spatial resolution is 2.5° by 2.5° latitude and longitude. Polar regions are not covered by data in this product.

A new experimental GPCP combined product (Version 2x) includes precipitation estimates from TOVS (Susskind et al., 1997) in addition to the Version 1c database filling data voids at high latitudes. It also retrospectively extends the combination to months January 1986 to June 1987 based on raingauge data, infrared temperatures and TOVS only, and further back to January 1979 using

raingauge observations and satellite outgoing longwave radiation data. This data set covers the entire globe and the period from 1979 to 1999 so far.

The GPCC is checking the performance of the monthly and daily GPCP products using additional in-situ data from dense raingauge networks out of selected regions. These data are carefully quality-controlled and corrected due systematic measuring errors caused by wind influences and evaporation losses. Under these conditions, raingauge-based precipitation analyses should be corrected with regard to systematic gauge measuring errors caused by wind influences and evaporation losses (Rudolf et al. 1997). A practicable on-event correction method based on synoptic data has been developed for the raingauge instrument types used in the countries located around the Baltic Sea within the BALTEX project (Rubel and Hantel, 1999, Rubel and Hantel, 2000) and transfered to global applications (Fuchs et al., 2000, Ungersböck et al., 2000).

The daily precipitation observations used for this verification study were corrected for systematic errors and transfered on a 1° by 1° grid using an ordinary Kriging technique (Rubel, 1998). To prove the reliability of the satellite-based products, the verification measures commonly used for model verification (according to Stanski et al. 1989) have been applied. Results in terms of scores are then directly comparable with corresponding scores from NWP or climate model verifications.

2. DATA AND METHOD

A new experimental GPCP combined product provides daily precipitation data on 1°x1° gridcells (Adler et al., 1999). Starting in October 1996 the GPCP began producing 3-hourly merged global infrared (IR) brightness temperature (Tb) histograms on a 1°x1° grid in the band 40°N- 40°S, and this collection has prompted this new global One-Degree Daily (1DD) product which has been computed for the period 1997-1998. In its first release, the 1DD uses the "best" quasi-global observational estimators of underlying statistics to adjust quasi-global observational datasets that have desirable time/space coverage: The Special Sensor/Microwave Imager (SSM/I; 0.5°x0.5° by orbit, GPROF algorithm) provides fractional occurrence. An example for the GPCC-1DD product is shown on Fig.1.

Daily raingauge data are not available on a global scale for a day by day adjustment of the daily satellite product. Thus the GPCP Satellite-Gauge Combination Version 2x (see above) provides only monthly accumulation for an overall adjustment of the 1DD. This dependence on scaled cloud information implies that users should expect large error bars on the individual daily values, while space and/or time averages should be more reliable.

For the verification of satellite-based global precipitation estimates, daily raingauge data are available from dense networks within international regional projects. Projects in Europe are e.g. the Baltic Sea Experiment (BALTEX) and the Mesoscale Alpine Programme (MAP). Gauge data from these 2 regions in Europe were selected for this verification study.

From these, the validation data base used in this verification study is:
- BALTEX (see Lehmann et al., 1998): ca. 4,200 raingauges (ca. 30 gauges per 1° gridbox)
- MAP (see Frei and Schär, 1998): ca. 3,100 raingauges (up to 50 per 1° gridbox).

First of all areal precipitation amounts using the grid of the GPCP-1DD products have been calculated. For that an optimum interpolation method has been applied. The daily station data have been transfered to 1° by 1° gridded data using the kriging method based on spatial correlations. The kriging variance is a measure of the reliability of the raingauge-based result for each individual gridbox and day. The verification of the GPCP-1DD products is then performed by using only grid boxes with low interpolation error (a kriging variance < 0.15).

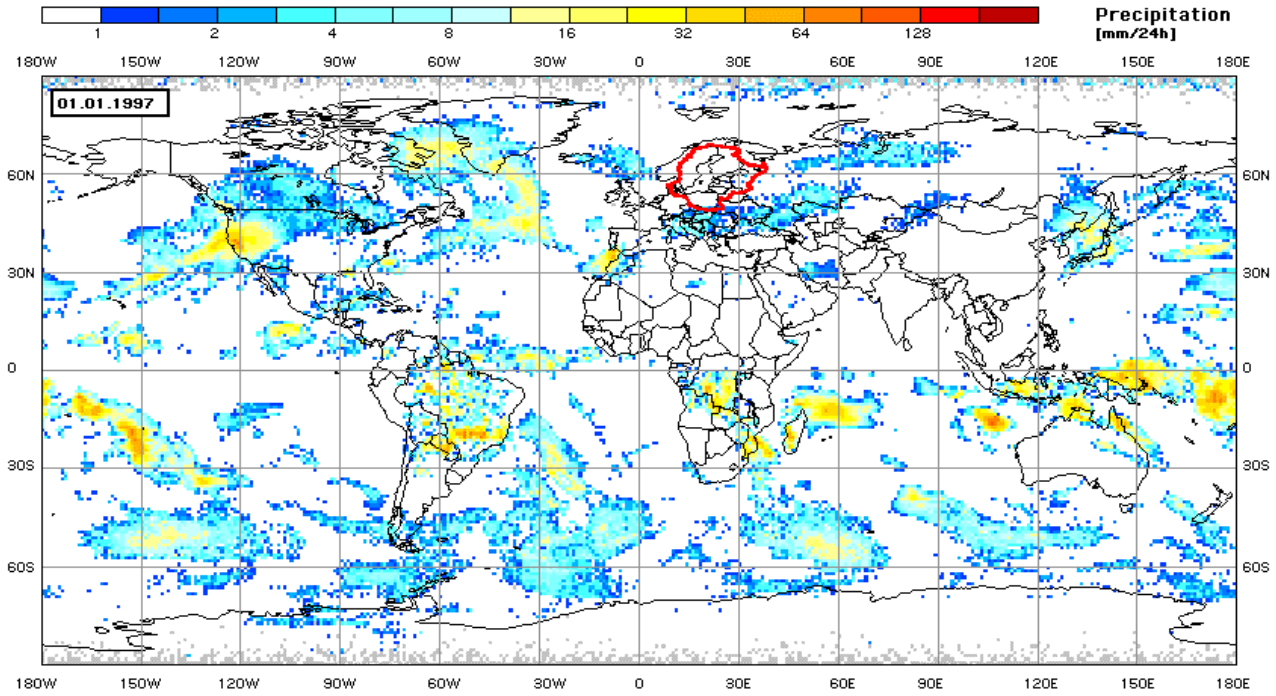


Fig. 1: GPCC-1DD product for January 1st 1997 with the BALTEX verification region (red polygon).

Having the satellite-based and the gauge-based precipitation fields on the same grid, the following comparisons have been performed:

- Plots of time-series of full area-averaged daily precipitation.
- Scatter diagrams of the collectives of grid results.
- Regression analysis and correlation.
- Probability of detection (POD).
- False Alarm Ratio (FAR).
- True Skill Statistics (TSS).
- Discussion of exemplary cases (series of individual days).

3. RESULTS

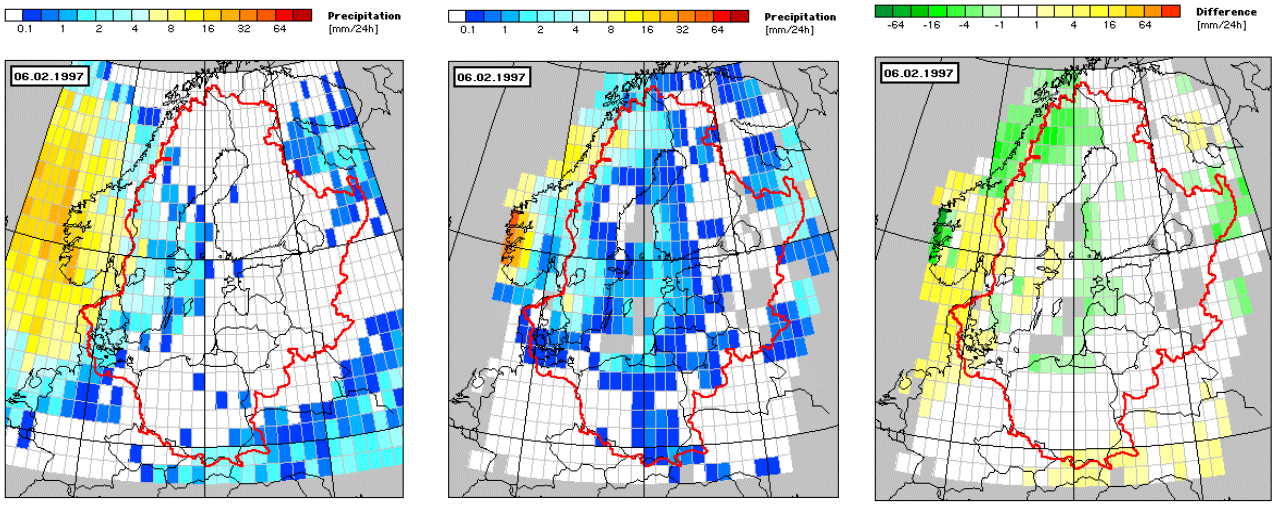


Fig. 2: GPCP-1DD product (left), GPCC verification analysis based on gauge data from BALTEX (middle) and difference field of GPCP-1DD gauge versus GPCC verfication analysis (right) for February 6th 1997

The spatial distribution of daily precipitation as derived from the different sources for the test area is exemplarily shown for the 6th of February 1997 in Figure 2. The GPCP-1DD result for the Feb 6th 1997 is shown on the left side of Fig. 2, the gridded precipitation on the middle side of Fig. 2. In order to eliminate gridcells with a high sampling error, such grids with a kriging variance above 0.15 are not displayed in the middle plot of Figure 2 and are not used for further statistical or visual comparisons. By this rule, the number of usable gridcells varies from day to day depending on the spatial variation in the precipitation field and is mostly smaller in summer than in winter. The difference field of the GPCP-1DD and the corresponding raingauge kriging analysis is given on the right plot of Fig. 2. It is important to know, that the raingauge observations are accumulated over a full day, observed at 7 am (Central European Time) while the GPCP-1DD is only based on two SSM/I images per day. The selected sample date does not represent a bad case of agreement of the two data sets. Readers should study the figures by themselves.

First impressions of the reliability of the GPCP-1DD products are given by scattergrams of daily GPCP versus gauge data from BALTEX and MAP. Fig. 3 shows large differences of correlation cofficientes for the BALTEX region on 2 successive days, June 1st and June 2nd 1997. While the agreement between satellite and gauge data is quite good on June 1st 1997 (correlation: 0.81), agreement is very low on the next day, June 2nd 1997 (correlation: 0.36).

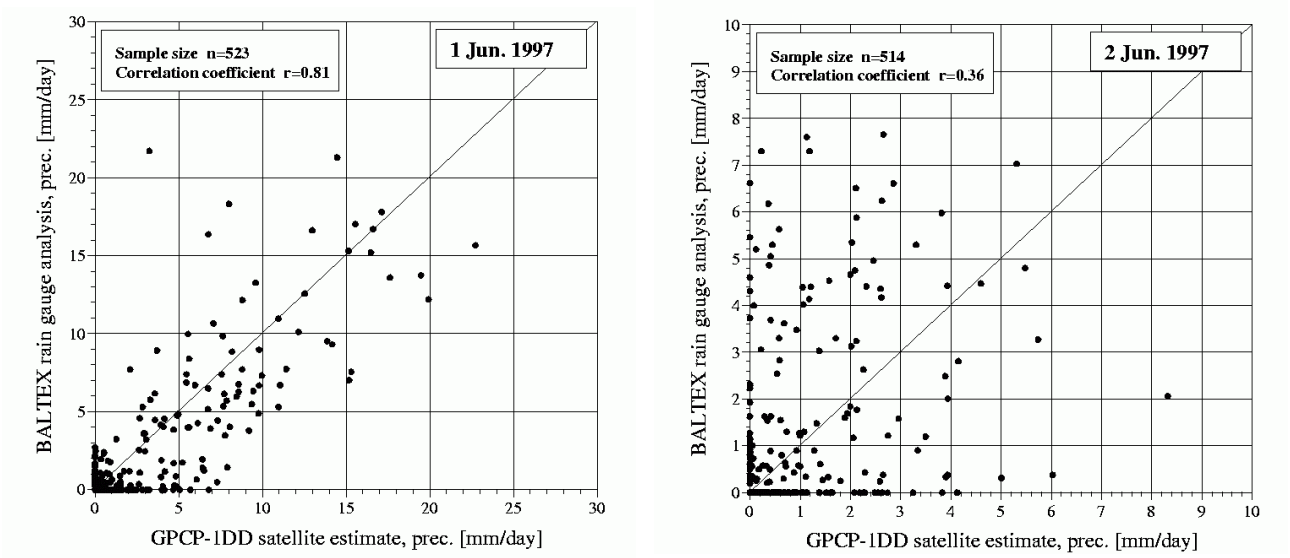


Fig. 3: Scattergrams of daily GPCP vs. BALTEX gauge analyses for June 1st (left) and June 2nd (right) 1997.

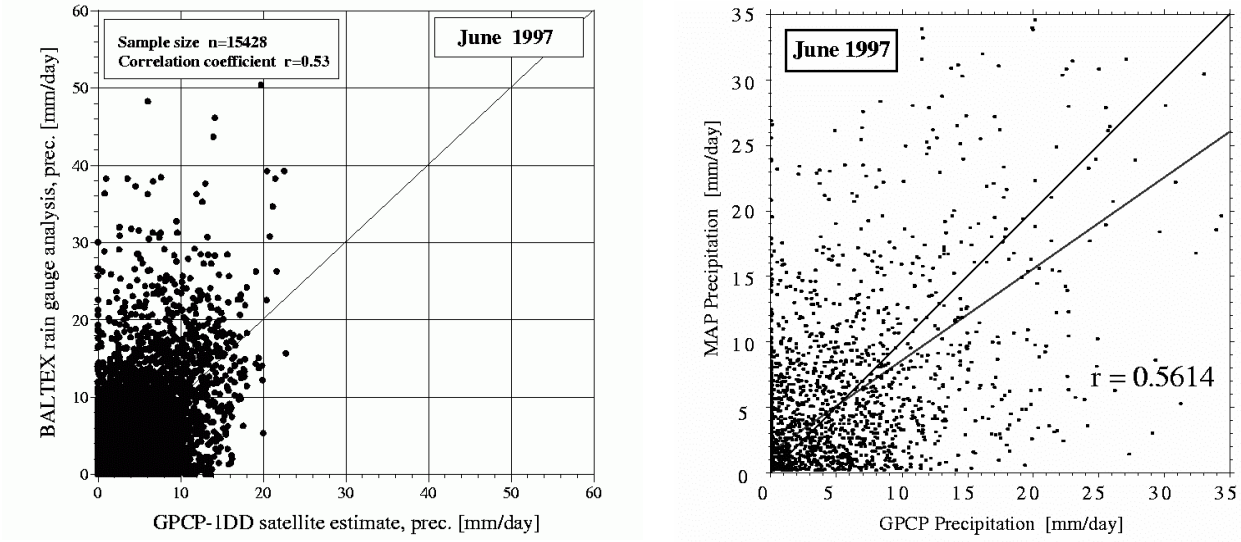


Fig. 4: Scattergrams of daily GPCP vs. gauge analyses for the BALTEX region (left) and the MAP region (right) in June 1997.

Scattergrams summarized for whole months have the advantage of larger sample sizes. Looking at examples on Fig. 4 for the BALTEX and the MAP (details in Skomorowski et al., 2000) region in June 1997 it can be seen, that correlation cofficients in both regions are quite similar, 0.53 and 0.56. This is in the range of what one could expect from correlations between satellite estimates and rain gauge measurements. Nevertheless, this correlation is very low, only 28 % resp. 31 % of the variations of the daily surface precipitation is explained by the satellite algorithms.

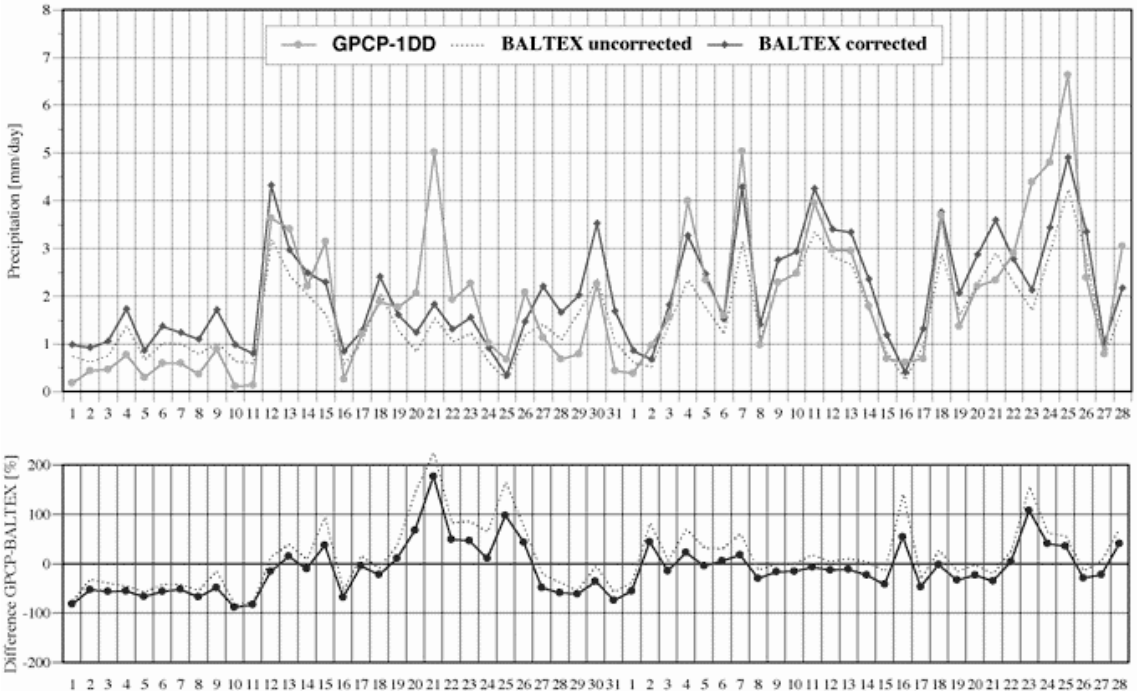


Fig. 5: Comparison of GPCP-1DD and BALTEX Raingauge Analysis (uncorrected and corrected for systematic measuring errors). Time-Series of GPCP-1DD and BALTEX-Area averaged daily precipitation (in mm, above) and differences (in %, below) for January and February 1997.

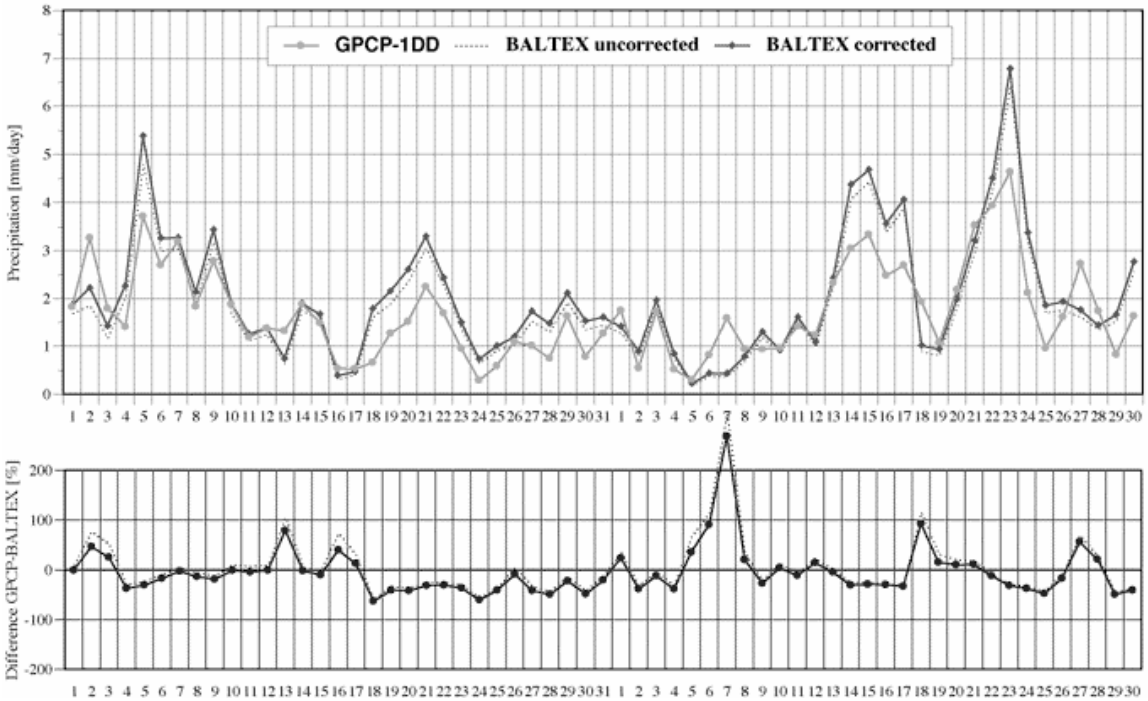


Fig. 6: Comparison of GPCP-1DD and BALTEX Raingauge Analysis (uncorrected and corrected for systematic measuring errors). Time-Series of GPCP-1DD and BALTEX-Area averaged daily precipitation (in mm, above) and differences (in %, below) for May and June 1997.

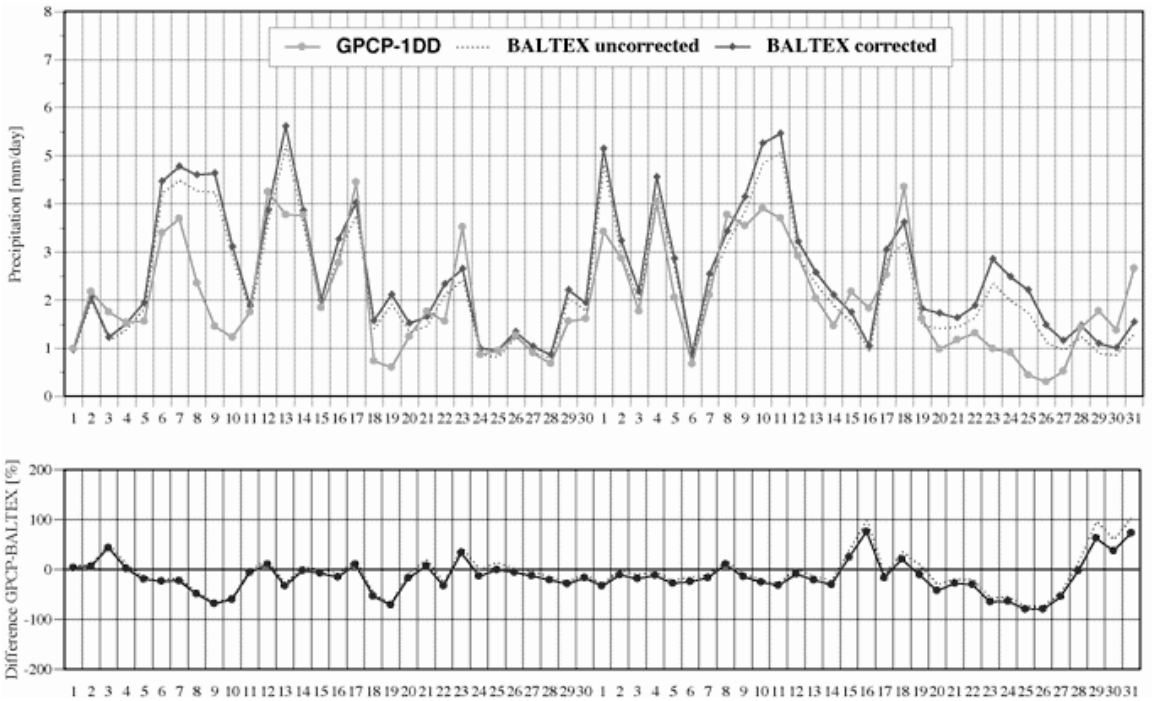


Fig. 7: Comparison of GPCP-1DD and BALTEX Raingauge Analysis (uncorrected and corrected for systematic measuring errors). Time-Series of GPCP-1DD and BALTEX-Area averaged daily precipitation (in mm, above) and differences (in %, below) for September and October 1997.

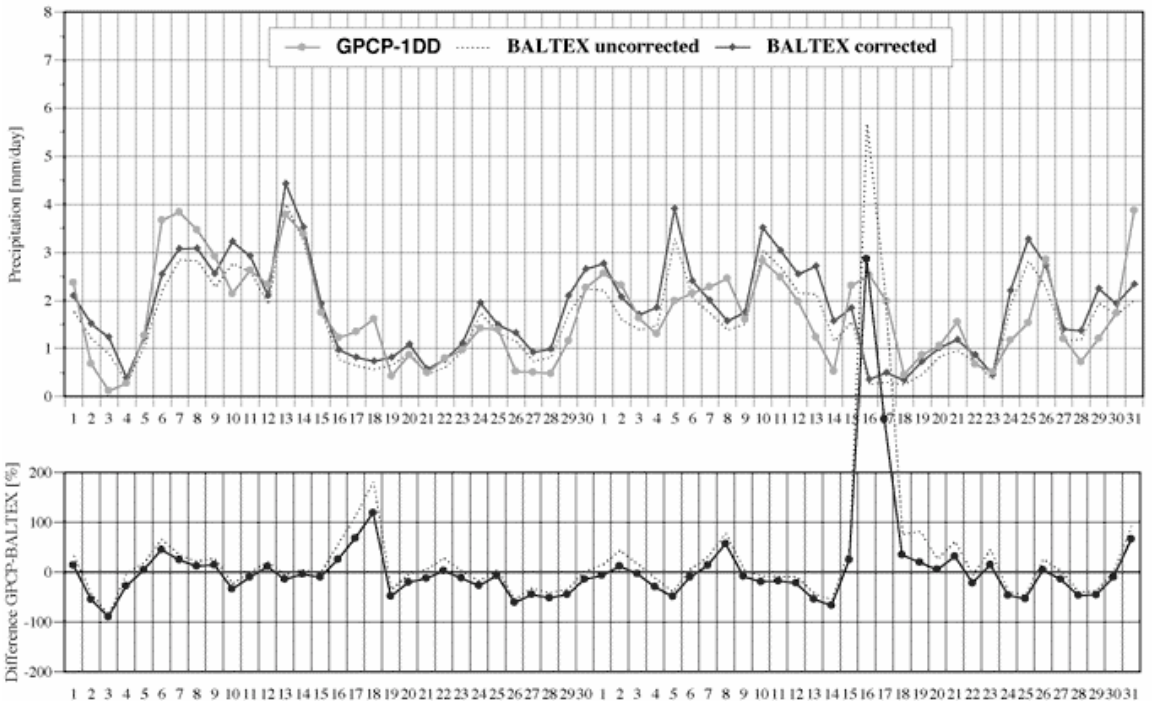


Fig. 8: Comparison of GPCP-1DD and BALTEX Raingauge Analysis (uncorrected and corrected for systematic measuring errors). Time-Series of GPCP-1DD and BALTEX-Area averaged daily precipitation (in mm, above) and differences (in %, below) for November and December 1997.

More details can be seen in the time-series of area averaged daily precipitation using all gridcells suffiently covered by raingauge data in the BALTEX region during the whole year of 1997. The results are averaged over the Baltic Sea Catchment Area separately for the GPCP-1DD product and the corrected and uncorrected kriging analyses of the gauge data. The results (examples are shown on Fig. 5 for the months of January and February 1997, on Fig. 6 for the months of May

and June 1997, on Fig. 7 for the months of September and October 1997 and on Fig. 8 for the months of November and December 1997) may be summarized to: Large overestimation of precipitation by GPCP-1DD is mostly limited for few days during episodes (maxima occured on Jan 21, Mar 26, June 7, Dec 16, 1997), while underestimation of precipitation is spread over longer periods (e.g. May 18-25, Sep 7-10, and Oct 20-26, 1997).

Continuous Statistics	
BALTEX mean (mm/day)	2.07
GPCP-1DD mean (mm/day)	1.77
Mean error (mm/day)	0.31
Mean absolute error (mm/day)	1.77
RMS error (mm/day)	3.56
Correlation coefficient	0.55
Categorical Statistics	
Probability of detection, POD	0.64
False alarm rate, FAR	0.33

Table 1: Summary statistics for 1997 based on 365 daily fields for the BALTEX-Area

A summary of verification statistics for the BALTEX-area in the whole year 1997 is shown in Table 1. It can be seen, that the GPCP-1DD product underestimates the gauged precipitation during the whole year 1997 by 0.31 mm/day. The RMS error of 3.56 mm/day indicates quite large day-to-day variations, the correlation coefficient of 0.55 shows, that only 30 % of the variations of the daily surface precipitation is explained by the GPCC-1DD product.

4. SUMMARY AND CONCLUSIONS

In this paper we presented first results of verifications of the experimental version of the new GPCP-1DD product based gauged data from the dense networks in the BALTEX and MAP region. Regarding the differences of the overall area-means, BALTEX gauge analyses versus GPCP-1DD, are mostly small (20%), but can be much larger during specific episodes. But the differences of individual daily gridbox results are partly very large and scatter widely. The correlation coefficient is low (between 0.3 and 0.6). Thus the GPCP-1DD product only explains less than 40 % of the variations of the daily gauged precipitation.

The location and size of individual precipitation areas does not exactly agree for many days. This partly results from a temporal shift between the satellite evaluation day (00-00 UTC) and the rain-gauge observation day (06-06 UTC). Also the satellite product is only based on 2 observations per day, whose information is extrapolated to a daily total value. Especially in case of quick moving precipitation areas location and magnitude can not be determined properly by the satellite. Regarding the gauged data, analysis problems may arise in regions with poor data density. Additional case studies on individual grids are necessary for further discussion and explanation.

The daily satellite-based precipitation estimates show well the temporal development of the large-scale spatial structure. A real-time product might be useful in monitoring large-scale precipitation regimes. But the results indicate, that the resolution of one degree and daily of the GPCP product might still be too high for its quantitative application in hydrological studies or for the verification of global NWP models or GCMs. Further development seems to be required.

For future verification studies, grid-related statistics, the evaluation of the differences for sub-regions, and the discussion of individual episodes are in preparation at GPCC. It is also planned to include the operational monthly GPCP products in further comparison studies based on dense

raingauge networks. An analysis using BALTEX data from the whole year 1998 has just started. A detailed verification analysis for the MAP region will follow soon.

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