

Global daily precipitation estimates proved over the European Alps

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Abstract

This paper is a contribution to answer the question on how well do global precipitation fields, often used for climate model verifications, represent reality. Here we focus on the experimental version of the GPCP-1DD product, the daily precipitation estimates based on satellite measurements from the *Global Precipitation Climatology Projects* (GPCP) and t+6 to t+30 hours model predictions from the *European Centre for Medium Range Weather Forecast* (ECMWF). The spatial/temporal resolution of both data sets is 1 degree/daily. The ground truth is represented by 3100 daily rain gauge measurements operating during June/July 1997 in the region of *The Mesoscale Alpine Programme* (MAP). These observations have been analyzed within the MAP section of the global grid by statistical interpolation. Verification results are given in terms of difference fields (mean error GPCP = -0.59 mm/day; ECMWF = -1.13 mm/day), rank-order correlation coefficients (mean monthly value GPCP = 0.52; ECMWF = 0.67) as well as accuracy scores (probability of detection GPCP = 0.62; ECMWF = 0.80 and false alarm ratio GPCP = 0.21; ECMWF = 0.18) and skill scores (true skill statistics GPCP = 0.36; ECMWF = 0.54). These scores indicate that both global datasets have deficits in estimating realistically precipitation amounts. However, the ECMWF predictions have a high performance in forecasting the spatial distribution of the precipitating areas. A major result of this study is also that accuracy and skill of the GPCP-1DD estimates have been shown to be significantly lower than those of the ECMWF forecasts. Only the mean error of the GPCP-1DD products is low, due to the calibration with monthly synoptic data.

Zusammenfassung

Diese Arbeit ist ein Beitrag zur Beantwortung der Frage, wie gut globale Niederschlagsfelder, die oft zur Verifikation von Klimamodellen verwendet werden, die Realität abbilden. Untersucht wurden die experimentelle Version der GPCP-1DD Produkte, die täglichen Niederschlagsabschätzungen basierend auf Satellitenmessungen des *Global Precipitation Climatology Projects* (GPCP) und t+6 bis t+30 Stunden Modellvorhersagen des *Europäischen Zentrums für Mittelfristige Wettersvorhersage* (EZMW). Die räumliche/zeitliche Auflösung beider Datensätze ist 1 Grad/täglich. Zur Bestimmung der Bodenwahrheit stehen 3100 Ombrometermessungen der Monate Juni/Juli 1997 aus dem Gebiet des *Mesoscale Alpine Programme* (MAP) zu Verfügung. Diese Beobachtungen wurden mittels statistischer Interpolation auf dem MAP-Ausschnitt des globalen Gitters analysiert. Die Verifikationsergebnisse wurden in Form von Differenzfeldern (Mittlerer Fehler GPCP = $-0,59$ mm/day; EZMW = $-1,13$ mm/day), Rangkorrelationskoeffizienten (Mittlerer Monatswert GPCP = 0,52; EZMW = 0,67), sowie Genauigkeitsmasszahlen (Entdeckungswahrscheinlichkeit GPCP = 0,62; EZMW = 0,80 und Rate falschen Alarms GPCP = 0,21; EZMW = 0,18) und Skill Scores (True Skill Statistics GPCP = 0,36, EZMW = 0,54) angegeben. Diese Masszahlen belegen, dass beide globalen Datensätze hinsichtlich der mengenmässigen Erfassung der Niederschläge Defizite aufweisen. Hingegen zeigt die räumliche Erfassung der Niederschlagsgebiete vor allem der EZMW Prognosen eine gute Performance. Als wesentliches Ergebnis dieser Studie wurde gezeigt, dass Genauigkeit und Geschick der GPCP-1DD Abschätzungen deutlich geringer sind als jene der EZMW Prognosen. Einzig der mittlere Fehler der GPCP-1DD Produkte ist zufolge der Kalibrierung mit monatlichen Synopdaten klein.

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1 Introduction

The estimation of continuous global daily precipitation fields is a challenging task. It can be done either by numerical weather prediction (NWP) models or by the use of satellite observations. Both, precipitation estimates from NWP models and estimates based on satellite measurements contain uncertainties (RUDOLF, 1995; RUDOLF et al., 1996) which are in general larger than those of rain gauge analyses. Nevertheless, only NWP models and satellite observations provide the possibility to calculate global precipitation fields, because measurements of rain gauge or radar networks are not available over wide areas of the globe.

In this paper two global precipitation estimates, the experimental version of the 1-degree daily precipitation product from the Global Precipitation Climatology Project (GPCP-1DD)¹ and t+6 to t+30 hours operational forecasts from the European Centre for Medium Range Weather Forecast (ECMWF), have been examined. These products will be available in future for periods long enough to be used for climate studies or to verify climate models. It is therefore of essential importance to have some knowledge of the reliability of such global precipitation products. On the other hand there exist no global reference data sets of sufficient accuracy, not even for short time periods. For that reason a regional domain covered by high density rain gauge networks, the model domain of MAP, the *Mesoscale Alpine Programme* (BINDER and SCHÄR, 1995), was selected to verify the GPCP-1DD (Fig. 1) and the ECMWF (Fig. 2) precipitation fields.

Most rain gauge data from this region are stored in the MAP data archive. These data fulfil many requirements to be used as ground truth data for the verification of satellite estimates or model predictions. Further comprehensive information on the precipitation climatology of the Alps is available from FREI and SCHÄR (1998).

The GPCP-1DD fields (HUFFMAN et al., 2001) are based on a combination of different satellite estimates. In the 40°N–S belt IR estimates from geostationary satellites calibrated with SSM/I data have been used. Outside this region the rain estimates are based on TOVS data from the polar orbiting satellites NOAA-12 and NOAA-14. These two satellites, with 0130/1330 and 0730/1930 local time equator crossing times, are flying simultaneously and provide global precipitation estimates based on an empirical relationship between rain gauge observations and a function of the cloud-top pressure, fractional cloud cover and relative humidity profile (SUSSKIND et al., 1997). The GPCP-1DD precipitation estimates are calibrated with monthly precipitation data being near-realtime available based SYNOP and CLIMAT reports. These SYNOP and CLIMAT reports are

internationally disseminated via the Global Telecommunication System (GTS), processed by DWD and evaluated by GPCC (RUDOLF et al., 1992).

The second global precipitation product used in this study is the routine precipitation forecast provided by the *European Centre for Medium Range Weather Forecast* (ECMWF). To consider the model spin-off, forecasts for the range t+6 to t+30 hours have been used in this study. The forecasts from the 1997 model version have a horizontal resolution of T213 and 31 levels in the vertical. The parameterization (TIEDTKE, 1989) consists of a mass-flux convection scheme distinguishing between deep, shallow and mid-level convection and a moisture convergence as deep-convection closure.

In order to be compatible the ECMWF precipitation forecasts have been interpolated to the same 1 degree latitude/longitude grid as used by the GPCP-1DD data. Thus, the ECMWF T213 forecasts have been verified on a resolution that is coarser than the original fields. This should result in slightly better verification measures. On the other hand the interpolation procedure implies also some kind of interpolation error. Both, the coarser resolution as well as the introduced interpolation error must be accepted in order to compare MAP, GPCP and ECMWF precipitation fields at the same scale.

To objectively prove the performance of the two global precipitation products, the statistical measures commonly used for model verification (STANSKI et al., 1989) have been applied. Therefore verification results for the GPCP-1DD satellite estimates as well as for the ECMWF predictions are directly comparable. Moreover, results in terms of these scores are also comparable with scores given by other authors. For example, GHELLI and LALAURETTE (2000) investigated the performance of the ECMWF t+42 to t+66 forecasts during March to November 1997 by using the dense rain gauge networks from France. As in this study the authors used uncorrected rain gauges and renounced to verify winter conditions where the systematic measurement errors of the rain gauges could not be neglected.

Over the Alps currently no comprehensive model verifications have been done, but various case studies are documented in the literature. These comprise for example studies on the application of different parameterization schemes of the MM5 model (CHERUBINI et al., 1999) or on the accuracy of DM forecasts (KREIL and VOLKERT, 2000). Nevertheless, comprehensive results from model verifications are available from regions other than the Alps and give an idea of the accuracy and skill of modern NWP models. For example, the well documented verifications of the Australian LAPS model (EBERT and MCBRIDE, 1997) comprises scores from various climatic regions. As an example of a routine application MAHONEY et al. (2000) and LOUGHE et al. (2001) introduced an online verification systems for the verification of their Collaborative Convective Forecast Product (CCFP).

¹ The reader should note that the experimental version of GPCP-1DD discussed in this paper has completely been replaced by a new operational version in October 2000. This new version covers the period from January 1997 to near present.

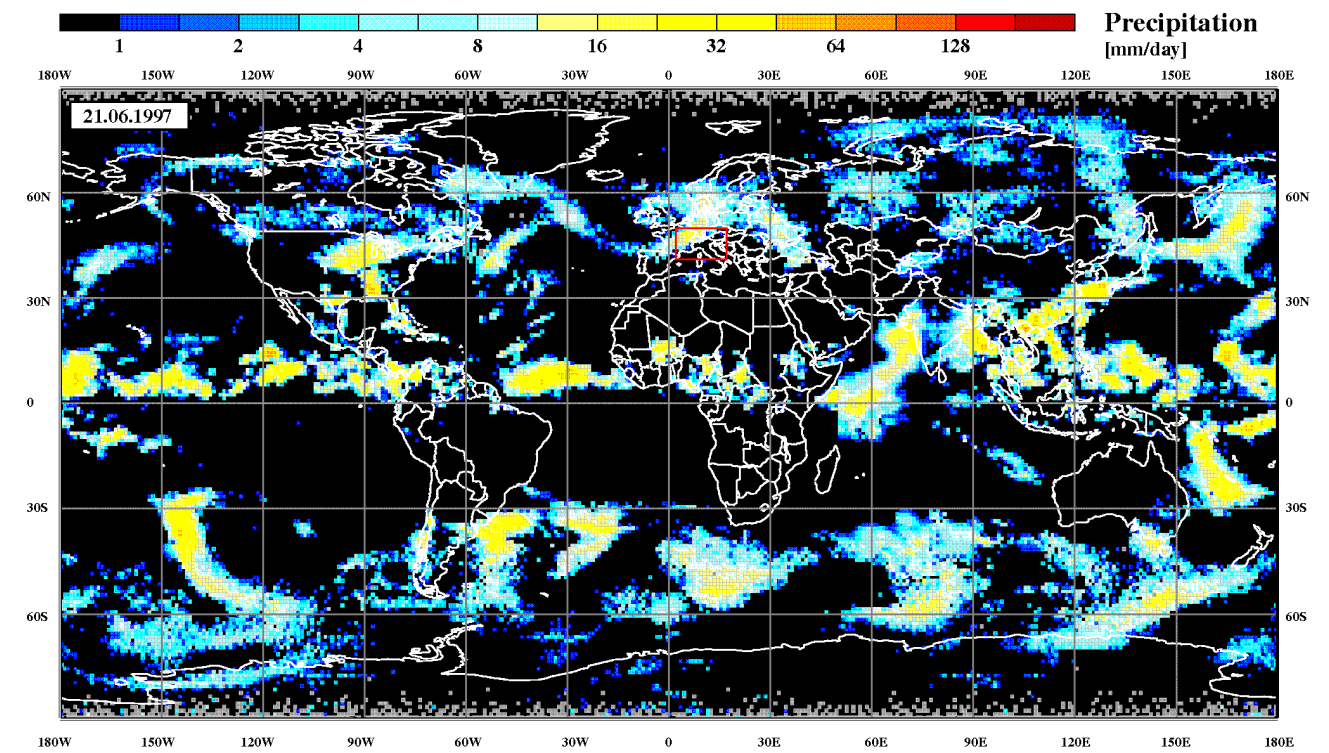


Figure 1: Global satellite precipitation estimates for 21 June 1997 with the MAP verification region of 15 x 9 grid boxes (longitude: 2°E to 17°E, latitude 41°N to 50°N) marked by a red rectangle. Units mm/day.

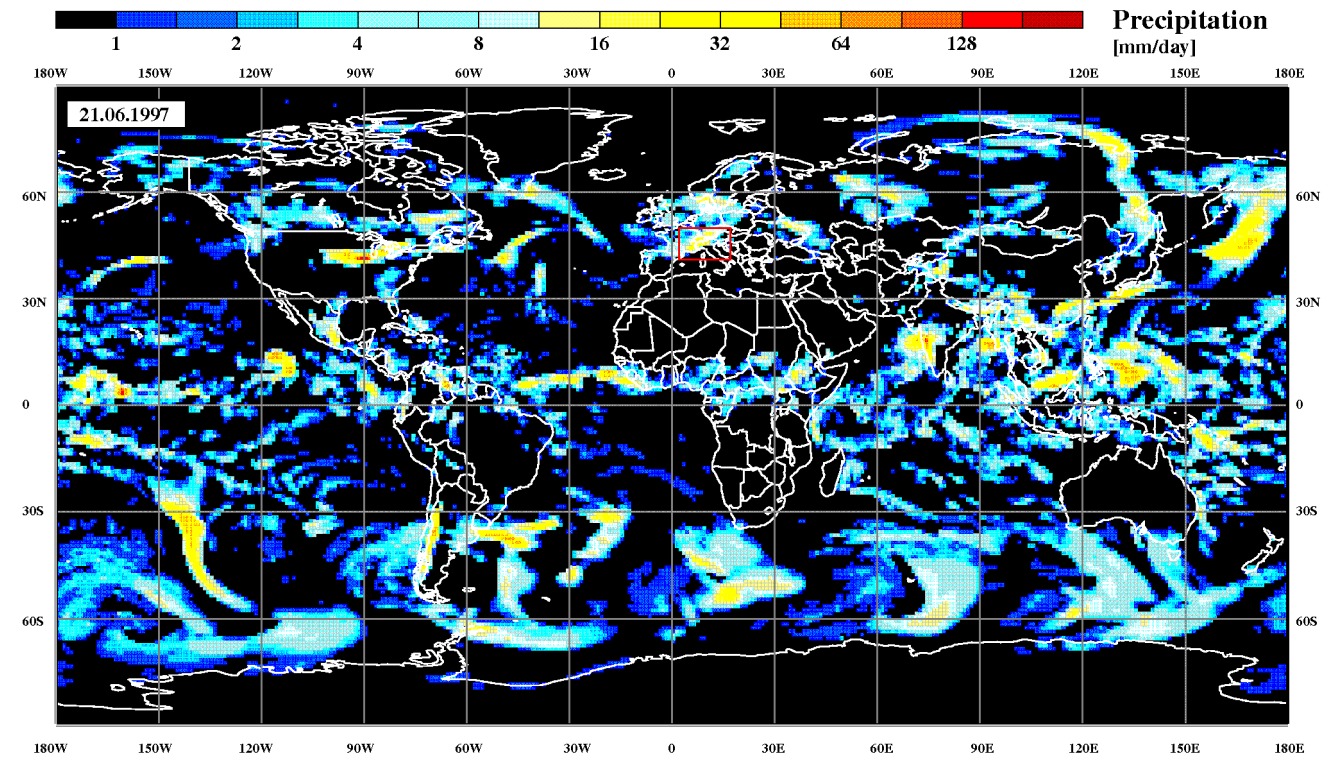


Figure 2: Global ECMWF precipitation forecasts for 21 June 1997 with the MAP verification region of 15 x 9 grid boxes (longitude: 2°E to 17°E, latitude 41°N to 50°N) marked by a red rectangle. Units mm/day.

		Observed MAP		
		yes	no	
Estimated GPCP, ECMWF	yes	h h...hits	f f...false	h+f
	no	m m ... misses	z z ... zero	m+z
		h+m	f+z	n=h+f+m+z

Figure 3: Contingency table for the calculation of accuracy and skill scores.

The purpose of this paper is to review the commonly used verification measures (Section 2), to demonstrate its application by a case study over the Alps (Section 3) and to present the results of a 2-month precipitation verification period of the GPCP-1DD satellite estimates and the ECMWF model predictions (Section 4). The conclusions are given in Section 5.

2 Data and method

About 3100 stations with rain gauge measurements, archived in the MAP data centre, have been used to verify the global precipitation fields. The distribution of the stations has been documented by FREI and SCHÄR (1998). However, during the verification period of June to July 1997, only for parts of the Alps the total number of rain gauges available has been collected. This is true for France, Switzerland and Slovenia, where the maximum coverage with stations is 10 times denser than the density of the synoptic network. For the other regions, comprising Austria and parts of Germany, Croatia and Italy only rain gauges from the synoptic network were available.

First of all areal precipitation amounts using the grid of the GPCP-1DD products have been calculated from the MAP rain gauge observations. For that an ordinary block-kriging method was applied. This method (see e.g. RUBEL and HANTEL, 2001) considers both the inhomogeneous distribution of the stations as well as the spatial structure of the precipitation process at the scale considered (RUBEL, 1996). Additionally to each areal precipitation estimate the normalized kriging variance is known. Note that this kind of interpolation error depends on the station density, the spatial auto-correlation function and the size of the grid boxes. The verification of the global precipitation products over the European Alps is then performed by using only grid boxes with normalized kriging variances below 0.15. Note further, that the

rain gauges have not been corrected for systematic measurement errors, because the correction model currently used (RUBEL et al., 2000) was adapted for gauges located at synoptic stations only. Thus, the analyzed precipitation amounts from the MAP fields are about 5% too low (SEVRUK, 1982).

Having MAP, GPCP and ECMWF precipitation fields comparable on the same grid, a first visual comparison has been done by viewing the fields (e.g. Fig. 2). To quantify the verification results continuous and categorical statistics have been used. An actual evaluation of continuous verification measures usually applied to hydrometeorological models is given by LEGATES and MCCABE (1999). These measures comprises mean error (ME), mean absolute error (MAE), root mean square error (RMSE) and correlation coefficient (R). Here, because of the non-Gaussian probability density function of daily precipitation values a nonparametric correlation coefficient, the Spearman rank-order correlation coefficient (R_s), has been applied. Additionally a t-statistic that tests the significance of a non-zero R_s was implemented using subroutines given by PRESS et al. (1994). Other measures, not used in this study, are the coefficient of efficiency and the index of agreement. LEGATES and MCCABE (1999) concluded, that correlation-based measures should not exclusively be used to assess model performance because they are oversensitive to extreme values and insensitive to proportional differences between predictions and observations. Therefore, in this study categorical scores will supplement the continuous measures.

The categorical statistics are based on two dimensional contingency tables (Fig. 1); one distinguishes between accuracy and skill scores (WILKS, 1995).

2.1 Accuracy measures

Accuracy measures sum up the quality of a set of forecasts by comparing individual pairs of forecasts and observations. Several scalar measures of the accuracy are known. The simplest measure is known as accuracy (ACC) or hit rate (HR) and is the ratio of correct estimates to the total number of estimates. It can be computed from the contingency table (Fig. 1) as

$$ACC = \frac{\text{correct estimates}}{\text{total estimates}} = \frac{z+h}{n} \quad (2.1)$$

Here we focus on probability of detection (POD) and false alarm ratio (FAR). POD is the fraction of those occasions where the estimation event occurred when it was also observed.

$$POD = \frac{\text{correct rain estimates}}{\text{rain observations}} = \frac{h}{h+m} \quad (2.2)$$

and ranges from one for perfect estimates to zero. FAR is the fractional number of times that the event was predicted to occur but it did not occur. FAR is computed as

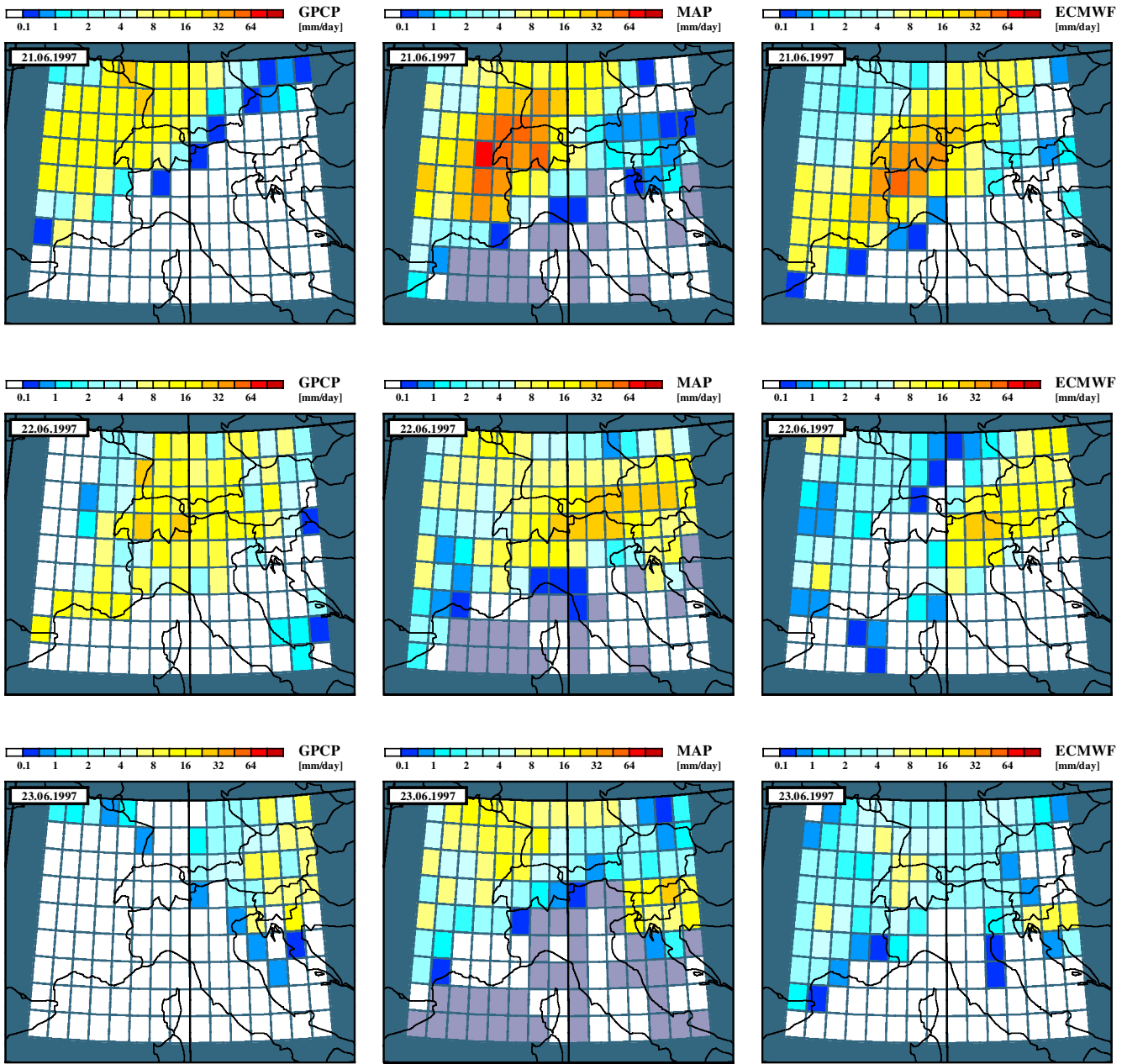


Figure 4: GPCP (left), MAP (middle) and ECMWF (right) precipitation maps for the MAP model domain. Dates: 21–23 June 1997. Units mm/day.

$$FAR = \frac{\text{false alarms}}{\text{rain estimates}} = \frac{f}{f+h} \quad (2.3)$$

The best FAR value is zero and the worst one.

2.2 Skill scores

With skill scores the improvement of the GPCP estimates over some reference estimates such as random chance, persistence or climatology can be measured. In general a skill score (SS) is defined as

$$SS = \frac{ACC_{estimate} - ACC_{reference}}{ACC_{perfect} - ACC_{reference}} \quad (2.4)$$

A perfect estimate always produces a skill of 1, while an estimate that is not better than the reference produces a skill of 0, and estimates that are worse than the reference have negative skills.

Here we used the true skill statistics (TSS) also known as HANSEN and KUIPERS score, which references for correct forecasts that would be made due to random chance. The TSS is computed as

$$TSS = \frac{hz - fm}{(h+m)(f+z)} \quad (2.5)$$

which could also be expressed as the probability of detection (POD) minus the probability of false detection (POFD).

$$TSS = \frac{h}{h+m} - \frac{f}{f+z} = POD - POFD \quad (2.6)$$

The TSS reaches from minus one to plus one and is the perfect verification measure because it does not depend on the fraction of rain/no rain events as other scores do. Some of these other frequently used skill scores are the critical success index (CSI), the equitable threat score (ETS) or the HEIDKE skill score (HSS).

3 Case study

In the following the term MAP denotes the fields analyzed from observations, the term GPCP denotes the experimental GPCP-1DD satellite estimates and ECMWF denotes the t+6 to t+30 hours operational model predictions.

For the demonstration of the verification scheme a period of high precipitation events, 21–23 June 1997, has been selected. Then, each of the proposed measures was calculated comparing daily grid values from observed (MAP) and estimated (GPCP, ECMWF) precipitation fields over the verification region. Fig. 4 shows the MAP, the GPCP and the ECMWF precipitation fields for these three days. The daily precipitation values analyzed from MAP observations and averaged over the model domain are 10.1, 6.7 and 4.3 mm/day. Compared to these values both the GPCP satellite estimates and the ECMWF predictions are significantly lower. The GPCP precipitation values for the 3 days considered are 5.0, 5.4 and 1.6 mm/day; the ECMWF values are 8.0, 3.7 and 2.3 mm/day. For the calculation of these values as well as for the scores described in the following, only grid cells which are covered by a sufficient number of observations have been used. The number of observations per grid cell varies from zero (Mediterranean Sea, Adriatic Sea) to more than 100 (France, Switzerland and Slovenia). In Fig. 4 grid cells which have not been used because of their low analysis accuracy are marked in grey colour. These grid cells are mainly located over the Mediterranean Sea but also over some land areas of Italy.

A first visual evaluation of the two global precipitation products was done with the help of the images shown in Fig. 2. Additionally, difference fields MAP minus GPCP and MAP minus ECMWF have been calculated and are useful to evaluate the spatial components of the mean error (not shown). Fig. 2 indicates that the GPCP and the ECMWF field are able to describe the large scale structure of the precipitation fields. But, going into detail, it becomes visible that especially the GPCP products may have problems to determine the exact position of moving precipitation systems. For example, the precipitation band shown in Fig. 2 with its extreme high rain amounts observed over the French and Swiss part of the Alps was caused by a cold front moving from west to east across the Alps. The GPCP satellite observations for 21 June 1997 estimate a precipitation field which is located too far west by about 1 degree (1 grid

box length). With the low temporal sampling rate of 4 satellite scans per day it is obvious that a more exact location of this rain band is hardly possible. Further, the extreme values have been underestimated by the GPCP product; maximal areal precipitation values of more than 60 mm/day analyzed from MAP observations are to be compared with 30 mm/day given by GPCP. At 22 June 1997 the situation continues, again the eastern part of the rain band has not been detected by the GPCP estimate. Moreover, the new precipitation event centred over Luxembourg has not been detected by the GPCP data, even not on the next day the 23 June. On the other hand the rain amounts at the French coast around Marseilles have been over-estimated by more than one order of magnitude and for no rain areas around Nice values above 10 mm/day have been estimated.

The forecast for 21 June 1997 given by the ECMWF represents the precipitating rain band caused by the cold front crossing the Alps obviously better than the GPCP estimates. This is true for both the spatial distribution as well as the rain amount of extreme values. But, the precipitation events in the southern regions of the Alps as have been observed on 22 June 1997 have not been forecasted by the ECMWF. However, on the last day of the case study period, the 23 June 1997, the ECMWF precipitation field is nearly perfect except the slightly too low maximum values.

These three days are typical for these two global precipitation products if one looks into detail. The deviations from analyzed MAP fields are significantly higher than the assumed errors estimated for the MAP data. These errors are composed of the various measurement errors of the rain gauges and the analysis error of the spatial interpolation method used. Both sources of errors are generally higher in mountainous regions than in flat lands. After SEVRUK (1982) the systematic measurement error (underestimation) of rain gauges is 2–10% for liquid precipitation. The analysis error is mainly caused by the spatial sampling, that is the density and distribution of the rain gauges available for the study. Because of the high density of the stations, see e.g. FREI and SCHÄR (1998), this error is assumed to be below 5%. Thus, the maximum error of the MAP precipitation fields is estimated to be about 15%; the error for the great majority of well gauged grid areas to be below 5%.

For the quantitative evaluation of the GPCP and ECMWF precipitation fields daily calculations of continuous and categorical verification scores have been used. Only the combination of both types of scores gives a consistent picture on the ability of the global precipitation products (EBERT and MCBRIDE, 1997; LEGATES and MCCABE, 1999). The mean error (bias) of the three days was calculated as –5.1, –1.3 and –2.7 mm/day for GPCP and –2.1, –2.9 and –1.9 mm/day for ECMWF predictions. The mean errors are therefore 20–60% of MAP and both GPCP and ECMWF gives too low mean values. Note that the MAP fields are based on uncorrected rain gauge measurements. As mentioned above, the systema-

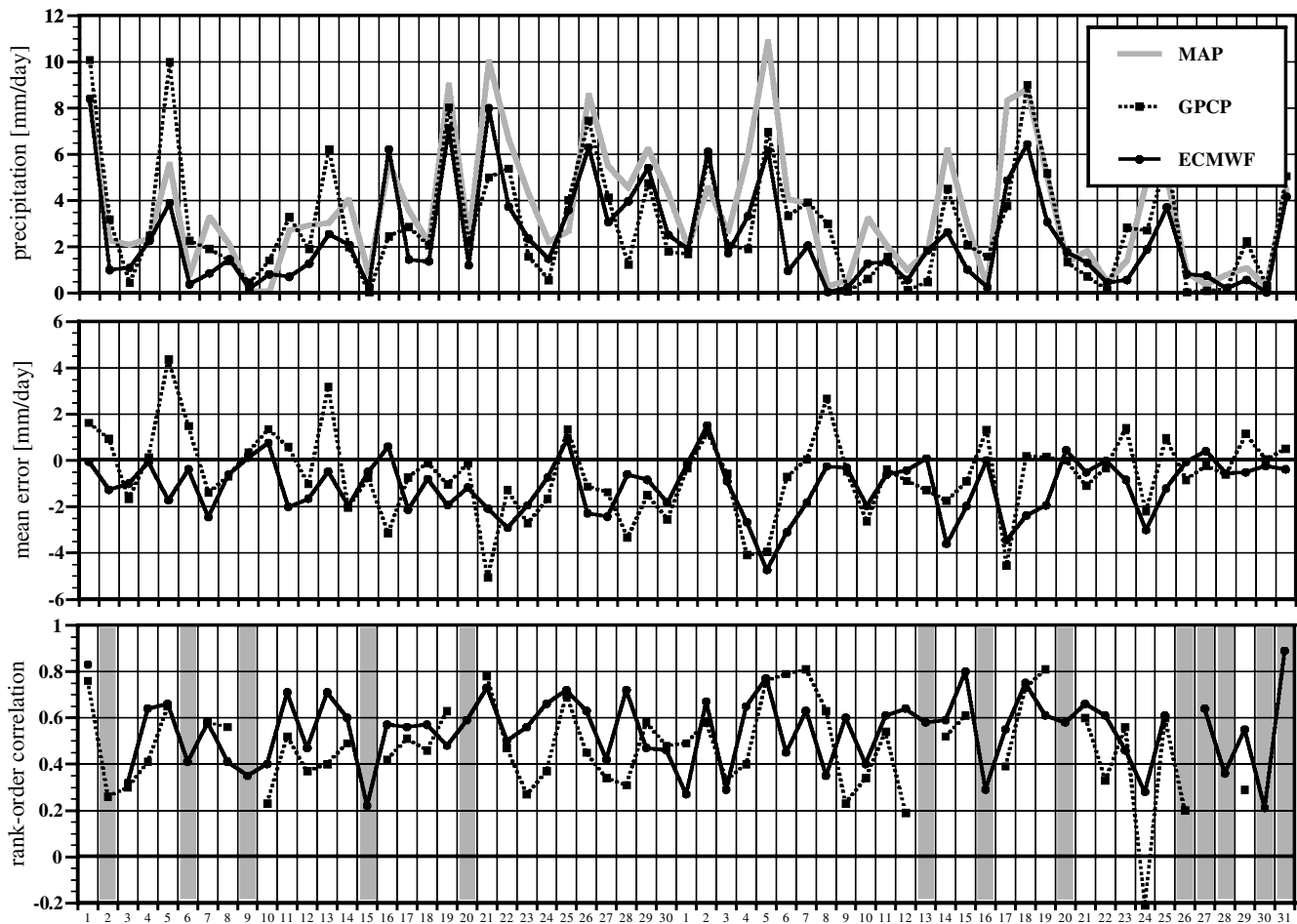


Figure 5: Time series of continuous statistics for the verification region (Fig. 4): mean daily precipitation amounts analyzed from rain gauges measurements (MAP), estimated from satellite (GPCP), forecasted from NWP model (ECMWF), mean errors of GPCP and ECMWF estimates (difference GPCP minus MAP; ECMWF minus MAP) as well as Spearman rank-order correlation coefficients for June to July 1997. Grey bars indicate days with one or both correlation coefficients not significant at a level of $\alpha = 0.05$.

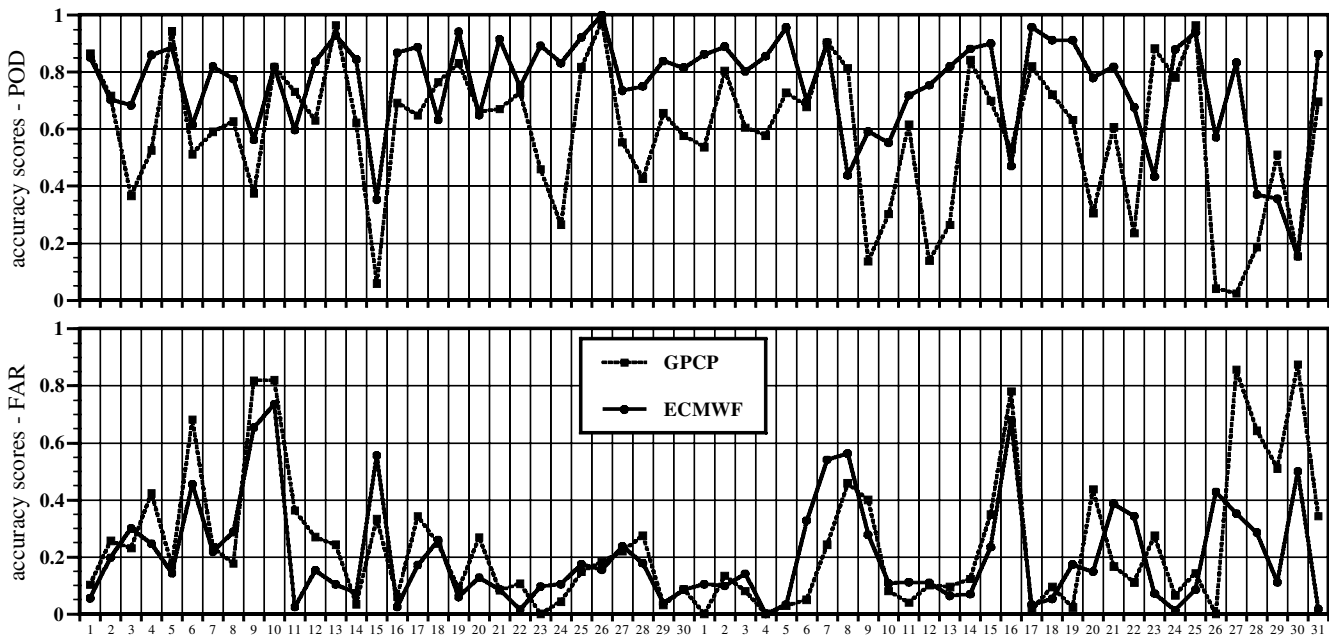


Figure 6: Time series of categorical statistics for the verification region (Fig. 4): Accuracy measures probability of detection (POD) and false alarm ratio (FAR) for June to July 1997.

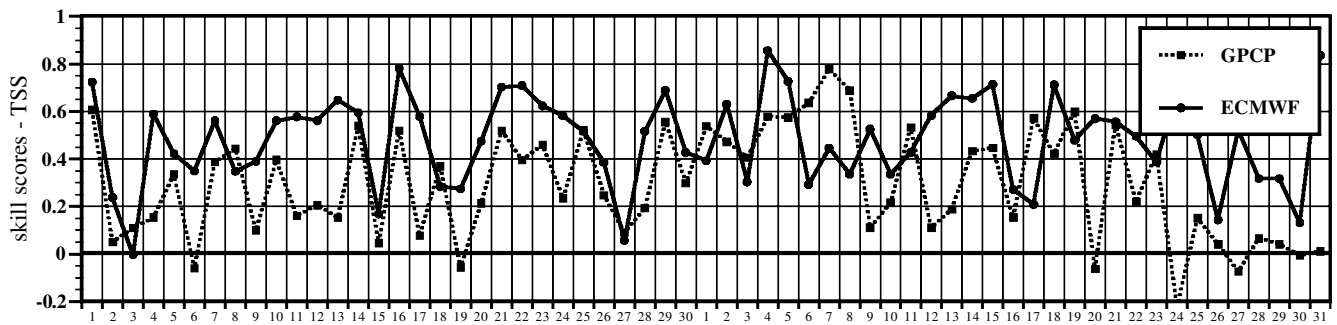


Figure 7: Time series of categorical statistics for the verification region (Fig. 4): True skill statistics (TSS) for June to July 1997.

tic underestimation of the rain gauge measurements is about 2–10% and therefore the mean errors of GPCP and ECMWF would be slightly higher if compared with MAP analysis based on bias-corrected rain gauge observations. The next continuous measure of interest is the SPEARMAN rank-order correlation coefficient. It has been calculated as 0.78, 0.47 and 0.27 for GPCP vs. MAP as well as 0.73, 0.50 and 0.56 for ECMWF vs. MAP. Both, GPCP and ECMWF precipitation fields are generally higher correlated to the observed fields at days with higher total rain amounts.

Passing on to categorical scores, the picture one gets on the ability of the global precipitation products changes. The GPCP estimates have POD values of 0.67, 0.72 and 0.46; the corresponding values for the ECMWF predictions are 0.92, 0.75 and 0.89. Therefore, the probability of detecting grid cells with rain (a threshold of 0.1 mm/day was used to distinguish between rain/no rain values) is in the range of 46–92%. Particularly the ECMWF product shows a high performance in detecting precipitating areas. On the other hand the ratio of false alarm, that is giving rain estimates where it does not rain, is very low. The FAR values are 0.08, 0.11 and 0.00 for GPCP and 0.09, 0.01 and 0.10 for ECMWF. Thus, FAR is in the range of 0–11%. Further the superiority of the ECMWF over the GPCP product becomes more visible if one looks at the TSS scores, a measure of the improvement over chance. The TSS values for GPCP are 0.52, 0.40 and 0.46, while the corresponding values for the ECMWF predictions are 0.70, 0.71 and 0.62.

4 Results

The representativity of the case study results discussed in the previous section is now investigated by discussing the complete 2-month period of daily verification scores. Fig. 5 shows the time series of MAP, GPCP and ECMWF precipitation values averaged over the model domain as well as the daily continuous verification scores mean error (ME) and rank-order correlation coefficient (R_s). During June to July 1997 the mean daily rain amount averaged over the MAP region is about 3.5 mm. At single days more than 10 mm have been observed. Both GPCP and ECMWF precipitation time series are in good correspondence with the MAP time series and

no time-lag could be detected. As has been shown for the case study, also the time series of the ME shows that the GPCP products give estimates closer to the observed rain amounts. The GPCP products underestimate the MAP precipitations much less than the ECMWF predictions, which was expected because of the calibration of the daily GPCP satellite products with monthly synoptic rain gauge data. On the other hand the time series of the R_s values indicate a better representation of the spatial structure of the observed rain fields by the ECMWF products. Also the number of days where the rank-correlation coefficients are not significant at level of $\alpha = 0.05$ (grey bars in Fig. 5) is lower for ECMWF than for GPCP. Only at two days the ECMWF predictions are not correlated with the MAP observations, while the GPCP estimates are uncorrelated with MAP at 11 days. This indicates, that the reliability of the GPCP products depends much more on specific weather situations or rain events than those of ECMWF.

The time series of the used categorical accuracy measures POD and FAR are shown in Fig. 6; those of the skill measure TSS in Fig. 7. Again, a default threshold value of 0.1 mm/day was defined to distinguish between rain yes/no events. Thus precipitation values below 0.1 mm/day are treated as zero values, assuming that such low values are questionable in both analyses and predictions. Note that the values of the categorical scores generally increase (with the expectation of FAR which decreases) with increasing threshold. Note further that different threshold values have been proposed in the literature; EBERT and MCBRIDE (1997) for example used 1.0 mm/day. This should be considered if one compares scores from different studies. How POD, FAR and TSS calculated for the GPCP verification investigated here depends on the threshold is documented in SKOMOROWSKI et al. (2001).

Coming back to the accuracy scores POD and FAR in Fig. 6, one can see that the probability of detection of the ECMWF products is of general high level, at most days 60–100% of the grid cells with rain have been forecasted. At only 1 day the ECMWF predictions detected less than 20% of the grid cells with rain. In contrast to this the POD scores calculated for the GPCP product are generally lower; 7 days with POD scores below 20% have been recognised. Also, it is generally noticed that

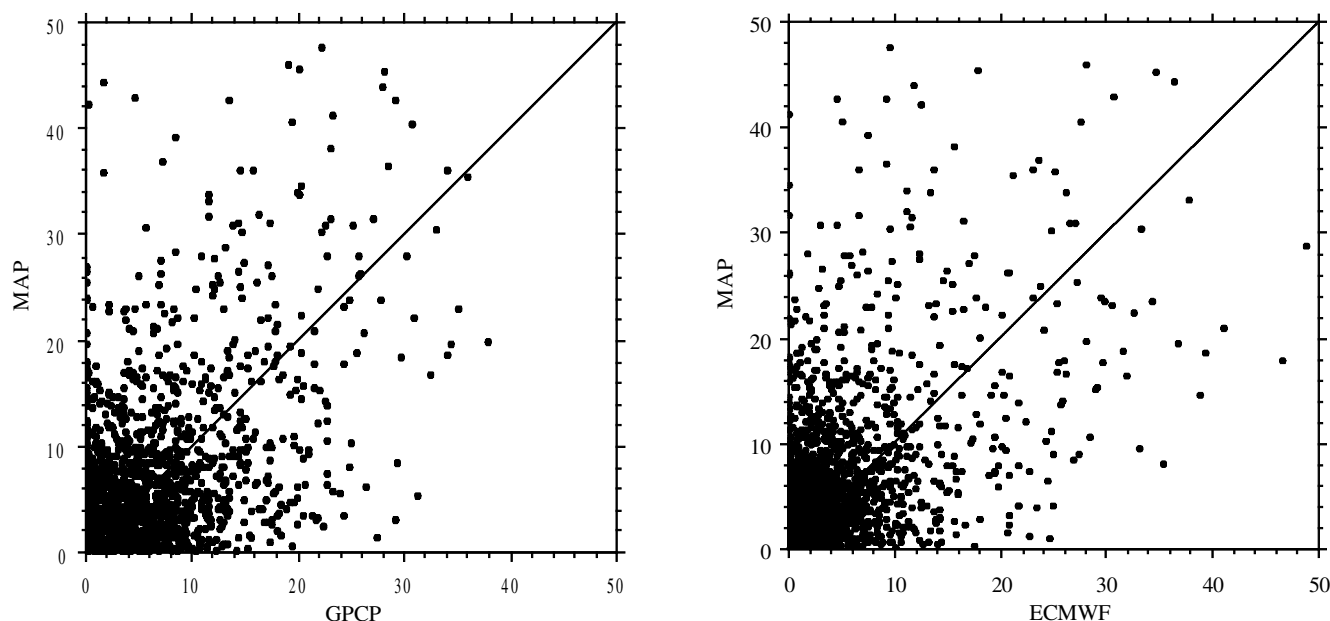


Figure 8: Monthly scattergram of daily values, GPCP vs. MAP (left) and ECMWF vs. MAP (right) for June 1997. Similar results have been calculated for July 1997 (not shown).

specifically at days with low values of mean precipitation within the model domain the performance of GPCP and ECMWF products measured by POD and FAR scores is poor (e.g. 15 June or 9 July).

Fig. 7 shows the time series of TSS, indicating the improvement over change. Because the TSS score is independent from the fraction of rain/no rain cells within the model domain, it will be used to investigate the dependence of the global precipitation product performance on precipitation events. Tab. 1 gives a definite answer to this question concerning the dependence on rain events. The ability of GPCP as well as ECMWF precipitation fields increases with increasing precipitation values averaged over the model domain. Thus both precipitation products are more useful for practical applications focusing on high or extreme precipitation events. Again, Tab. 1 shows the higher skill of the ECMWF product. The skill of GPCP comes up with scores comparable to those of ECMWF for 1 mm/day not before the mean precipitation values within the MAP region exceed 5 mm/day.

Finally, the scatterplots GPCP vs. MAP and ECMWF vs. MAP (Fig. 8) and the most important verification scores (Fig. 9) are summarized for June/July 1997. As shown for individual days the scores for the entire period confirm the significantly higher scores for the ECMWF predictions. For example the values of the rank-correlation are 0.52 for GPCP and 0.67 for ECMWF and the TSS values are 0.36 for GPCP and 0.54 for ECMWF. In addition to the above described scores, the commonly used verification measures hit rate (HR), critical success index (CSI) also known as threat score (TS) and bias score (BS) have been calculated. It opens the possibility to compare the verification results with those of other authors.

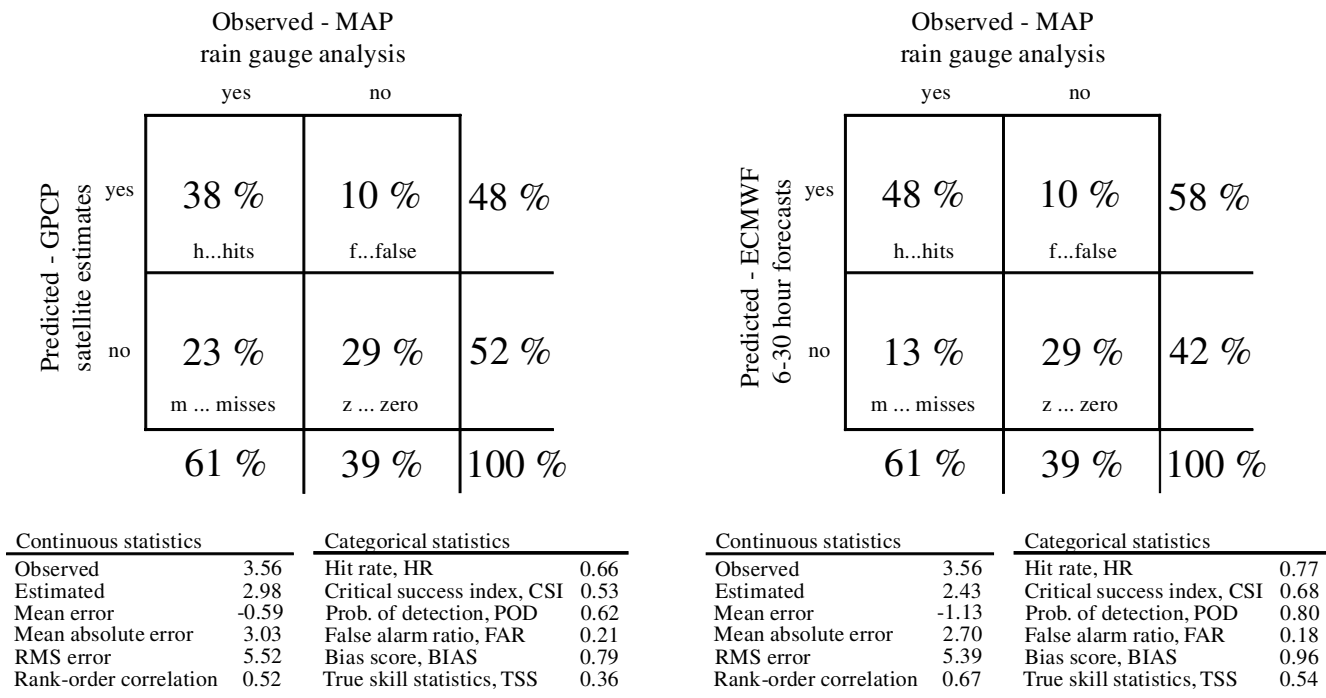
Table 1: True skill statistics (TSS) for GPCP and ECMWF precipitation products as function of analyzed mean precipitation in the model domain.

MAP (mm/day)	GPCP	ECMWF
≤ 1	0.04	0.40
1–2	0.25	0.42
2–3	0.27	0.44
3–4	0.34	0.48
4–5	0.38	0.56
5–6	0.40	0.53
6	0.45	0.59

5 Conclusions

Global precipitation products are valuable datasets for improving our understanding of the global water balance and for verifying climate model predictions (RUDOLF et al., 2000). Up to now such global precipitation products have been calculated on monthly basis; recently, efforts have been undertaken to compile global daily precipitation products (HUFFMAN et al., 2001). It is important to know the performance of such datasets, preferably for different climatic regions. In this study we have investigated the t+6 to t+30 hours accumulated precipitation forecast provided by the European Centre for Medium Range Weather Forecast and the GPCP-1DD product, the new experimental 1-degree daily satellite estimate provided by the Global Precipitation Climatology Project.

The verification region selected was the model domain of the Mesoscale Alpine Programme. It is well



will be used to validate the improved, new operational version of the GPCP-1DD product in more detail. The NASA/GSFC provides this final version of the GPCP-1DD data since Oct. 2000 covering 4 years (Jan. 1997 to Dec. 2000) of daily precipitation fields².

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³ Online available at

<http://www-med-physik.vu-wien.ac.at/staff/rub/pub.htm>

⁴ Online available at

<http://www-med-physik.vu-wien.ac.at/staff/rub/abs.htm>

² Available at <http://www.ncdc.noaa.gov/wdcamet-ncdc.html>

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