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Correction of Synoptic Precipitation Observations due to Systematic Measuring Errors with Special Regard to Precipitation Phases

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Abstract. A recently developed method for event-based daily bias-correction of synoptic precipitation observations regarding systematic measuring errors was transfered at the Global Precipitation Climatology Centre (GPCC) from regional to global applications. Using the reported present weather, an analysis based on more than 600 000 global synoptic data from 16 winter months was done, which made it possible to relate air temperature and dew point temperature to the probable distribution of liquid, solid and mixed precipitation phase. Based on this information, synoptic precipitation observations can be corrected regarding systematic measuring errors on a daily resolution, which makes the estimation of extreme precipitation events more reliable.

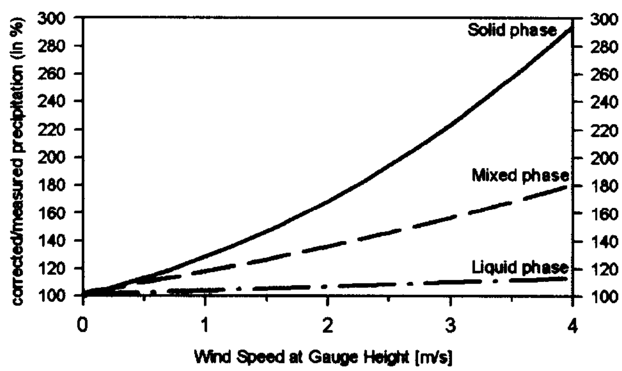

Fig. 1. Corrected precipitation totals in % of measured precipitation dependent on wind speed at gauge height and precipitation phase for Hellmann gauges without windshield (after Goodison et al., 1998).

1 Introduction

The Global Precipitation Climatology Centre (GPCC) is a component of the WCRP Global Precipitation Climatology Project (GPCP), which provides the climate research community gridded data sets of global precipitation based on observation data (Huffman et al., 1995). The GPCC (Rudolf et al., 1994) is specialized for terrestrial precipitation based on conventional observations from gauges.

Precipitation analyses based on conventional observations are erroneous due to systematic measuring errors of the gauges, mainly caused by wind influence and evaporation losses. Differences between the gauged precipitation and the true precipitation amount are largest for solid precipitation and heavy wind measured by unshielded gauges as illustrated in Fig. 1. The greatest biases are likely to occur at high altitude sites, the locations most critical for snowpack and water balance estimates.

Since national standard precipitation gauges vary in size, shape, and designs as well as in elevation of their orifice above ground level, the effect of the wind is gauge-dependent (Groisman and Legates, 1995).

Thus, gauge-dependent bias-correction of conventional observed precipitation is essential before using these analyses for calibration of remote-sensing data, for verification of model results, for water balance assessments (Rudolf et. al, 1999) as well as for climate change studies (Groisman and Legates, 1995, Forland and Hanssen-Bauer, 2000).

A crucial point is the determination of the phase of a precipitation event, because the correction factors for liquid and solid precipitation differ significantly (Fig. 1).

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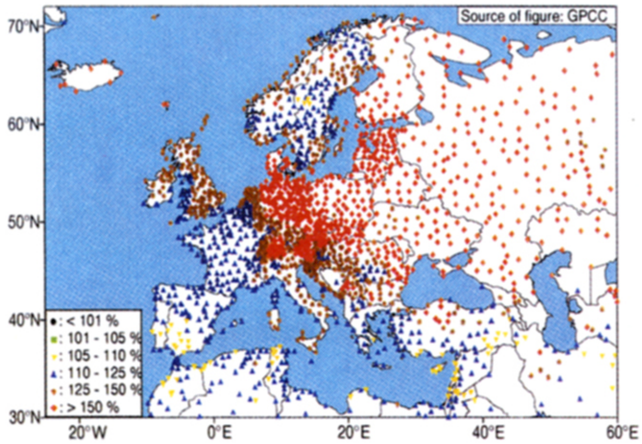

Fig. 2. Monthly mean of correction for systematic measuring errors in % of measured precipitation totals using Legates' (1989) monthly correction factors on a 0.5°-grid. Analysis month: January 1999.

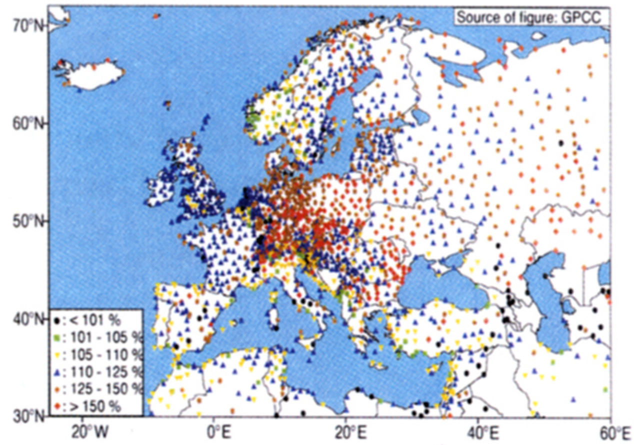

Fig. 3. Monthly mean of correction for systematic measuring errors in % of measured precipitation totals using Rubel's daily correction factors with GPCC's phase definition. Analysis month: January 1999.

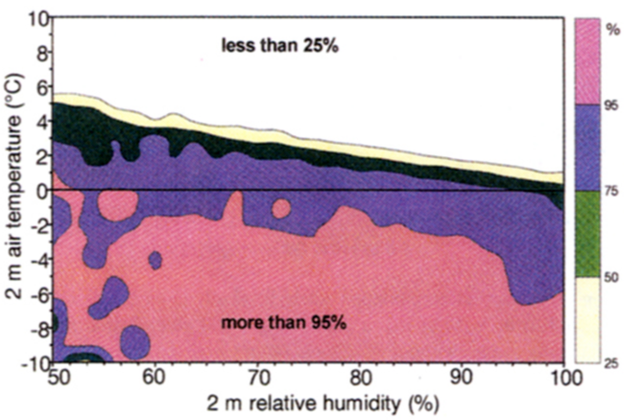

Fig. 4. Percentage of probable occurence of solid precipitation in daily precipitation totals dependent on 2 m air temperature and 2 m relative humidity. Derived by GPCC from more than 600 000 GTS-SYNOP reports of 16 winter months 1995-1999.

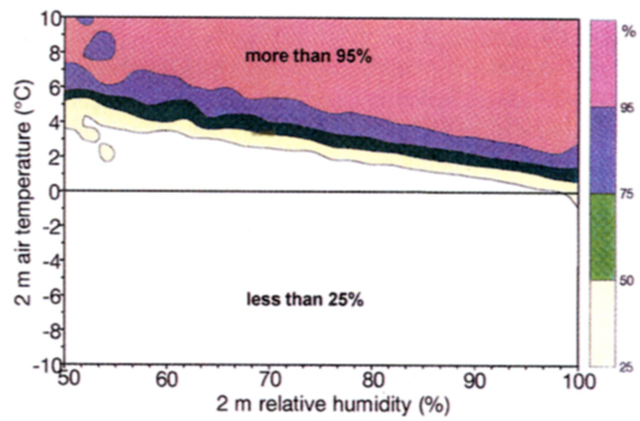

Fig. 5. Percentage of probable occurence of liquid precipitation in daily precipitation totals dependent on 2 m air temperature and 2 m relative humidity. Derived by GPCC from more than 600 000 GTS-SYNOP reports of 16 winter months 1995-1999.

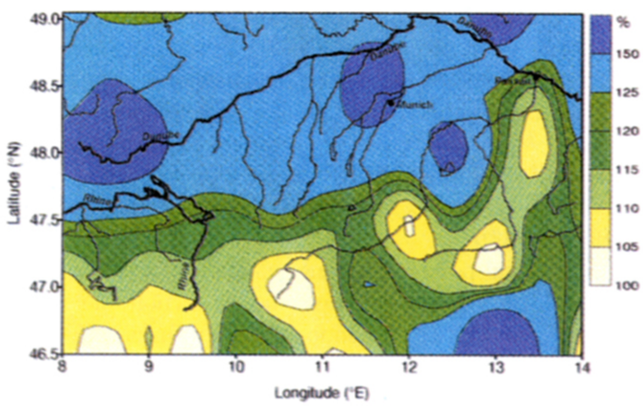

Fig. 6. Mean correction regarding systematic measuring errors in % of measured precipitation totals for the period Feb 17th - 23rd 1999 in Southern Germany and the Eastern Alps. Correction scheme after Rubel and Hantel (1999) using GPCC's phase definition.

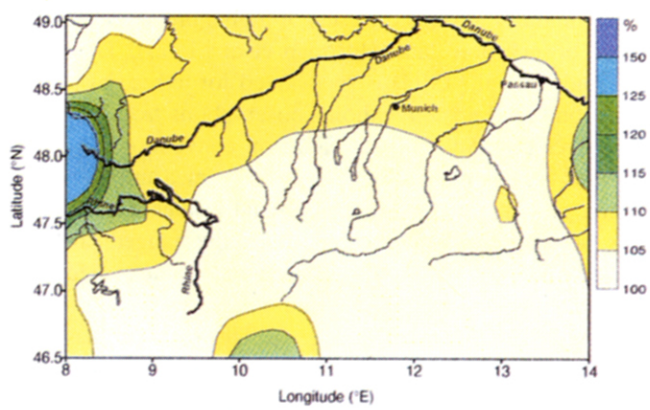

Fig. 7. Mean correction regarding systematic measuring errors in % of measured precipitation totals for the period May 20th - 22nd 1999 in Southern Germany and the Eastern Alps. Correction scheme after Rubel and Hantel (1999) using GPCC's phase definition.

2 Current climatological correction method at GPCC

The GPCC is currently using mean bulk correction factors on a 0.5°-grid for bias correction of monthly precipitation data (Reiss et al., 1992, Rudolf, 1995). These correction factors are based on the statistical assessment of correction factors from worldwide more than 25 000 gauges (Legates and Willmott, 1990). An example for the effect of Legates' correction factors is shown for the month of January in Europe on Fig. 2.

The quality of the gauge correction factors depends on information about the type of gauges used and their installation specifics. As the instrument parameters used in Legates' analysis (Legates and Willmott, 1990) are based on a World Meteorological Organisation (WMO) technical report (Sevruk and Klemm, 1989), whose information has been collected at the beginning of the 1980s, many of these instrument parameters may have become obsolete.

In addition to that, the used meteorological parameters (wind velocity, ratio of solid/liquid precipitation) have only roughly been estimated. Correction factors of more than 200 % (to be observed at unshielded gauges in case of snowfall and heavy wind, see Fig. 1) of the uncorrected value are a further problem, which sometimes leads to ‚over-correction' effects. Thus, it was very important to develop an improved correction method.

3 New daily bias correction method at GPCC

3.1 Data and Method

The precipitation correction method is based on the Dynamic Correction Model (Forland et al, 1996; Rubel and Hantel, 1999), which has originally been developed and implemented for precipitation gauges used in European countries participating in the Baltic Sea Experiment (BALTEX) of the Global Energy and Water Cycle Experiment (GEWEX). Based on synoptic observations, necessary parameters (wind speed at the rim of the gauge, air temperature, relative humidity and precipitation intensity) for station-related correction can be directly or indirectly derived on a daily timescale for individual precipitation events (Rubel and Hantel, 1999).

This method was enlarged in a GPCC-project to all worldwide used raingauge types. Literature-based information (Sevruk and Klemm, 1989) about the gauges (e.g. type of gauge, use of a windshield) and height of the rim of the gauge was collected for all countries of the world.

Based on this information, the bias correction for systematic measuring error of daily precipitation totals can be calculated, dependent on precipitation phase and intensity. Daily correction terms for wind-induced losses as well as climatological correction terms for evaporation and wetting losses can be added (Rubel and Hantel, 1999, Ungersböck et al., 2000).

3.2 Improved determination of the phase of precipitation events

The determination of the phase of a precipitation event is a very crucial point, because the correction factors for liquid and solid precipitation differ significantly. Suitable data for determination of the phase of precipitation events can be derived from synoptic reports, which are routinely exchanged via the Global Telecommunication System (GTS) of the WMO.

An often used parameter for diagnosis of the precipitation type is the air temperature, which was recently taken by Forland et al. (1996). They assume +2 °C as limit between liquid and mixed precipitation and 0 °C as limit between mixed and solid precipitation. But the combination of relative humidity and air temperature has a much closer relation to the precipitation phase than air temperature alone (Steinacker, 1983).

Good indicators for the phase of precipitation events are the reported present weather observations ww from synoptic data sets. The selection of a single unique code to represent observed weather conditions at a particular time and place is accomplanished via a well-defined set of criteria and priorities published by the WMO (WMO, 1974). This was used e.g. by Petty (1995) for an analysis of global oceanic precipitation based on shipboard present weather reports. Unfortunately for operational use ww is less often (e.g. in case of automatic stations) reported than air humidity and temperature.

For this reason GPCC analysed the correlation of air humidity and air temperature to the precipitation phase in more than 600 000 global synoptic data from 16 winter months. At first, all 99 present weather codes (WMO, 1974) were examined regarding information about the phase of current precipitation events. The classification of these present weather codes as belonging to solid, liquid and mixed phase was made from the viewpoint of similar systematic measuring errors due to wind influence (e.g. in accordance with this definition hail is treated as liquid precipitation phase).

As a result, 26 present weather codes (ww = 50-67, 79-82, 89-92) were assigned to ongoing liquid precipitation events, 13 present weather codes (ww = 70-78, 85, 86, 93, 94) to ongoing solid precipitation events and 6 codes (ww = 68, 69, 83, 84, 87, 88) to mixed precipitation events.

With GPCC's phase scheme, it is possible to estimate the phase of precipitation events at individual synoptic stations on a daily basis. Using this phase information, the distribution of solid (Fig. 4), liquid (Fig. 5) and mixed precipitation phase can be derived for every combination of air temperature and dew point temperature, which assists in applying more realistic correction factors to the measured precipitation amount.

The correction factors are weighted for a certain station and day according to the actual precipitation phase distribution derived from the actual air temperature and dew point temperature (Fig. 4 and 5), e.g. on a day with 70 % solid precipitation and 30 % liquid precipitation the applied correction factor is 0.7 times the one for solid precipitation and 0.3 times the one for liquid precipitation. Mixed precipitation is corrected according to 50 % solid and 50 % liquid precipitation.

4 Preliminary results

As the presented event-based correction method is very new, only preliminary results can be discussed in this paper. As an example for the correction regarding systematic measuring errors, mean correction values in % of uncorrected precipitation totals have been calculated for 2 episodes of heavy precipitation in Southern Germany and the Eastern Alps.

Heavy snowfall during the precipitation event of February 17th - 23rd 1999 caused severe avalanches. Due to the mostly solid precipitation phase, mean correction was quite high (Fig. 6). It is interesting, that there are lower corrections in the mountains than in lower altitudes. This may be caused by less intense snowfall in lower compared to higher altitudes. Precipitation intensity has an influence on the systematic measuring error: higher precipitation intensity leads to lower correction factors.

During May 20th - 22nd 1999 heavy rainfall triggered floods in the catchment area of Danube river. Because of mostly liquid precipitation and high rainfall intensity, correction in May 1999 (Fig. 7) was much lower (in most parts of the analysis region less than 110 % of the uncorrected data) than during the February event. It can be seen, that especially during snowfall events in winter months correction is very important and can increase the gauged value by more than 150 %.

A comparison of the climatological correction factors (Fig. 2) with the new event-based daily correction factors (Fig. 3) for a European winter month (January 1999) shows, that the on-event correction mostly reduces the magnitude of correction. But in few parts (e.g. along the north-west coast of the Baltic Sea) of the analysis region the new correction method leads to an increase in correction. Further studies for longer time periods are important to test the new correction method against climatological data and results from other authors and regional projects (e.g. from the GEWEX continental scale experiments). Especially water balance studies for hydrological catchment areas may help to find inconsistencies in analyses based on the new correction procedure.

5 Conclusions and Outlook

The presented method for event-based correction of precipitation measurements regarding systematic measuring errors is a very promising approach for practical use in operational precipitation analyses on a regional and global scale. Based on regularly exchanged and routinely available synoptic data, all necessary parameters for the correction procedure can be derived and applied to the gauged precipitation. This will lead to more realistic assessments of precipitation amounts on a daily timescale (e.g. Rubel and Hantel, 2000). Further on, a new monthly climatology of correction terms for gauges on earth's landsurface may be developed using this new method.

Improvements may be applied in future, because:

- the information about national standard precipitation gauges (e.g. type of gauge, use of windshield and height of the rim of the gauge) from Sevruk and Klemm (1989) will be updated. Recently WMO started an initiative regarding a new catalogue of national standard precipitation gauges. The application of these results will lead to an improvement in correction of gauged precipitation data;
- the correction terms for evaporation and wetting errors are only available for rain gauges in Northern and Central Europe. Evaporation and wetting losses for tropical regions are unknown. The currently used constant values should be replaced by more realistic values based on field experiments;
- the algorithm for deriving daily rain intensities out of synoptic reports (using the precipitation amount in relation to the duration of precipitation events) has been developed based on experimental results in Denmark (Rubel and Hantel, 1999). Especially in tropical regions the calculated precipitation intensities could be too low, which may lead to over-correction effects;
- for operational use in GPCCs analyses on a global scale there are some stations, of which no correction can be derived due to missing informations in the synoptic reports or no synoptic informations at all. Correction for these stations can only be applied using climatologies or interpolations from stations for which all necessary parameters for the correction procedure are available. A promising approach to be tested for correction on a monthly basis may be the use of Legates' climatology (Legates and Willmott, 1990) as base pattern, which can be adjusted for specific months using on-event correction factors derived at nearby synoptic stations.

References

Forland, E.J. (Ed.), Allerup, P., Dahlström, B., Elomaa, E., Jonsson, T., Madsen, H., Perälä, J., Rissanen, P., Vedin, H., and Vejen, F., Manual for Operational Correction of Nordic Precipitation Data, *Norwegian Meteorological Institute*, Oslo, 66 pp, 1996.

Forland, E.J., and Hanssen-Bauer, I., Increased Precipitation in the Norwegian Arctic: True or False?, *Climatic Change, 46(4)*, 485-509, 2000.

Goodison, B., Louie, P., and Yang, D., WMO Solid Precipitation Measurement Intercomparison, Final Report, *WMO/TD-No. 872, Instruments and Observing Methods No. 67*, Geneva, 88pp, 1998.

Groisman, P.Y., and Legates, D., Documenting and detecting long-term precipitation trends: where are we and what should be done, Climatic Change, 31, 471-492, 1995.

Huffman, G., Adler, R., Rudolf, B., Schneider, U., and Keehn, P., Global Precipitation Estimates based on a technique for combining Satellite-based estimates, Raingauge analyses and NWP model information, *Journal of Climate, 8(5)*, 1294-1295, 1995.

Legates, D.R., and Willmott, C.J., Mean seasonal and spatial variability in gauge-corrected, global precipitation, *Internat J. Climatol., 10*, 111-127, 1990.

Petty, G., Frequencies and characteristics of global oceanic precipitation from shipboard present-weather reports, *Bull. Amer. Met. Soc, 76. No.9, September 1995*, 1593-1616, 1995

Reiss, M., Hauschild, H., Rudolf, B., and Schneider, U., Compensation for the systematic measuring error in precipitation measurement, *Meteorol. Zeitschrift N.F, 1*, 51-58, 1992 (in German).

Rubel, F., and Hantel, M., Correction of daily rain gauge measurements in the Baltic Sea drainage basin, *Nordic Hydrology, 30*, 191-208, 1999.

Rubel, F., and Hantel, M., BALTEX 1/6 -Degree Daily Precipitation Climatology 1996-1998, Submitted to *Meteorology and Atmospheric Physics*, 2000.

Rudolf, B., Hauschild, H., Rueth, W., and Schneider, U., Terrestrial Precipitation Analysis: Operational method and required density of point measurements. In: Desbois, M., and Desalmond, F. (Ed.): *Global precipitation and climate change, NATO ASI Series I, Vol. 26*, Springer-Verlag, 173-186, 1994.

Rudolf, B., Die Bestimmung der zeitlich-räumlichen Struktur des globalen Niederschlags, *Berichte des Deutschen Wetterdienstes Nr. 196*, Offenbach am Main, 153 pages (in German), 1995.

Rudolf, B., Gruber, A., Adler, R., Huffman, G., Janowiak, J., and Xie, P., GPCP Precipitation Analyses Based on Observations as a Basis of NWP and Climate Model Verification, *Proceedings of the 2nd WCRP International Conference on Reanalyses*, Reading UK, 23.-27.08.1999, WCRP-109, WMO/TD-No. 985, 197-200, 1999.

Sevruk, B., and Klemm, S., Catalogue of national standard precipitation gauges, *Instruments and Observing methods No. 39, WMO/TD-No 313*, Geneva, Switzerland, 50pp, 1989.

Steinacker, R., Diagnose und Prognose der Schneefallgrenze, *Wetter und Leben, 35*, 81-90, 1983 (in German).

Ungersböck, M., Rubel, F., Fuchs, T., and Rudolf, B., Bias correction of global daily rain gauge measurements. *Phys. Chem. Earth*, This issue, 2000.

World Meteorological Organisation, Manual on Codes, *Vol. 1, WMO Publ 306*, WMO, Geneva, Switzerland, 1974.