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Correction of Daily Rain Gauge Measurements in the Baltic Sea Drainage Basin

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Within the framework of BALTEX regular measurements made at about 4,200 rain gauge sites have been collected by the BALTEX Meteorological Data Centre. This network of rain gauges is about 10 times denser than the synoptic network; here it is used for the objective analysis of daily precipitation fields on the grids of the mesoscale models developed in the research project NEWBALTIC during the pilot period PIDCAP (August to October 1995). The observations were corrected for systematic measuring errors with the *Dynamic Correction Model.* Its main purpose is to correct for the wind-induced losses which is the largest error. The correction formulae use the synoptic observations of wind speed, temperature and rain intensity at the rain gauge station considered. For non-synoptic stations the values of the closest synoptic station are used as estimates; the mean distance of the synoptic stations within the drainage basin is 30 km. For evaporation and wetting losses, which represent the second largest error of the precipitation measurements, climatological corrections are applied. The formulae in the *Dynamic Correction Model* take instrument-specific properties into account; these comprise HELLMANN UNSHIELDED, SMHI SHIELDED, H&H-90 SHIELDED and TRETJAKOV SHIELDED. The spatial distribution of corrected precipitation values were objectively analysed according to Rubel (1998). They yield daily gridded precipitation fields over the drainage basin which are systematically higher than the uncorrected fields. The corresponding increase of the freshwater input into the Baltic Sea drainage basin is 4.7% in August, 5.8% in September and 9.1% in October 1995. Finally, the perspective for further developments and the generation of a ten-year data base of the BALTEX main intensive observational and modelling period BRIDGE is introduced.

Introduction

A central goal of the Baltic Sea Experiment (BALTEX) is to yield an accurate estimate of the total input of water into the Baltic Sea drainage basin (Bengtsson 1998a). As part of the strategy for reaching this goal we have developed an objective analysis scheme for the spatial distribution of daily precipitation.

The purpose of the analysis scheme is twofold. First, the analyzed precipitation fields can be used in data assimilation procedures (Zupanski and Mesinger 1995); together with the objectively analyzed sub-gridscale fluxes in the free atmosphere (Haimberger *et al.* 1995) a complete diagnostic data set will become available. Second, these analyses may offer the possibility to verify the BALTEX and other precipitation forecasts gained by numerical weather prediction (NWP) models (Rubel 1998; Yang *et al.* 1998). In the long run, a comprehensive model verification of all 3D-atmospheric fluxes may become feasible, including the fluxes across the Earth's surface, both gridscale and sub-gridscale (Rubel *et al.* 1993; Hantel *et al.* 1995). Basis of the analysis will be an array of dense rain gauge networks. However, the gauge measurements include a series of errors which lead as a rule to an underestimation of the true precipitation. According to Sevruk (1986), the main components of this systematic error are losses due to wind field deformation above the gauge orifice (2-10% for liquid and 10-50% for solid precipitation), losses from wetting on internal walls of the collector and in the container (2-10%) and losses due to evaporation from the container (0-4%). Other sources of error are splash-out and splash-in as well as blowing and drifting snow.

The necessary corrections, depending on the type of the rain gauge, have been determined in various field intercomparison experiments and wind tunnel measurements, as well as in numerical simulations (Nespor and Sevruk 1999) and are well documented in various WMO reports (*e.g.* Sevruk 1992; Goodison *et al.* 1998). For example, the field experiment following the *WMO Solid Precipitation Measurement Intercomparison* standard in Jokioinen, Finland, indicated that the Nordic rain gauges caught about 70% (shielded gauges) to 50% (unshielded) of the true solid precipitation. In the case of liquid precipitation the underestimation is less severe, but still 5 to 8% (Førland *et al.* 1996).

Although several correction models for operational use have been proposed, only a few analyses based on corrected precipitation data have been published. These include precipitation climatologies in Sweden (Raab and Vedin 1995), in Switzerland (Kirchhofer and Sevruk 1992) and on the global scale (Legates and Willmott 1990; Reiss *et al.* 1992). Within the framework of BALTEX, investigations on the reliability of monthly and annual precipitation measurements have been done, *e.g.*, in the southern mountainous part of Poland (Woźniak 1997).

One reason for the scarcity of precipitation fields (areal estimates on the grids of NWP models) based on corrected gauge values is that the meteorological data needed for the correction models are usually not available at the location of the gauges.

Even if all meteorological parameters are measured at the gauge location, the wind is usually measured at 10 m and not at the height of the gauge orifice. This is also the case for most of the 4,200 rain gauges collected by the BMDC (*BALTEX Meteorological Data Centre*; Lehmann *et al.* 1997). In the BALTEX data base the additional information on wind speed, temperature and precipitation intensity, needed for corrections, is not available at all rain gauge locations but only at the synoptic stations. Taking this information, the so-called *Dynamic Correction Model*, proposed in the *Manual for Operational Correction of Nordic Precipitation Data* (Førland *et al.* 1996), was in the present study implemented and applied to PIDCAP (*Pilot Study for Intensive Data Collection and Analysis of Precipitation*, August to October 1995) data sets. The correction model is part of a comprehensive precipitation analysis tool, including collection, correction for systematic measurement errors, areal assessment using kriging, correction for orography and merging of rain gauge and radar data using co-kriging (see Bengtsson 1998a).

Precipitation estimates from satellite or radar have not been used in the present analysis since they are too inaccurate. Nevertheless, they may be quite useful as secondary input data sets for analysis schemes like co-kriging (statistical optimal field merging).

The Dynamic Correction Model

The correction of daily precipitation in PIDCAP was based on the *Dynamic Correction Model* presented by Førland *et al.* (1996). The meteorological information needed for correction of aerodynamic errors of rain gauges are wind speed at the rime of the gauge, size of rain drops and crystal structure of snow flakes. Size and structure of the hydrometeors are not measured routinely and, with the exception of some special observational studies, are not known. Therefore, rain intensity is used as a measure for estimating drop size and temperature is used to specifiy the crystal structure of solid precipitation. The corrected value of the precipitation amount Z is estimated in the present evaluations as

$$Z = k(Z_m + \Delta Z_w + \Delta Z_e) \tag{1}$$

where Z_m is the measured precipitation value, ΔZ_w the wetting loss, ΔZ_e the evaporation loss, and k the aerodynamic correction factor. The values of wetting loss and for mean daily evaporation loss are given in Tables 1 and 2.

The aerodynamic correction factor k depends on the type of precipitation. For liquid precipitation it is a function of wind speed v (m/s) and rain intensity Z_I (mm/h), calculated as follows [1]

$$k = \exp(-0.0010 \log(Z_I) - 0.0122\, v \log(Z_I) + 0.0343 v + 0.0077 + c) \tag{2}$$

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[1] log is the natural logarithm as used in mathematical parlance.

Table 1 – Recommended values for wetting loss ΔZ_w (mm/case) for Nordic manual gauges (after Førland *et al.* 1996). The mixed precipitation type value for HELLMANN unshielded is 0.18 in the original reference; since this is obviously a misprint we have subjectively switched to the tabulated value.

Precipitation type	HELLMANN unshielded	H&H-90 shielded	SMHI shielded	TRETJAKOV shielded
Liquid	0.14	0.13	0.07	0.14
Solid	0.10	0.05	0.02	0.09
Mixed	0.14	0.11	0.06	0.14

Table 2 – Recommended values for mean daily evaporation loss ΔZ_e (mm/day) for Nordic manual gauges (after Førland *et al.* 1996).

Month	HELLMANN unshielded	H&H-90 shielded	SMHI shielded	TRETJAKOV shielded
August	0.08	0.05	0.10	0.10
September	0.02	0.04	0.05	0.05
October	0.01	0.03	0.03	0.03

Table 3 – Recommended gauge coefficients c for Nordic precipitation gauges (after Førland *et al.* 1996).

Precipitation type		HELLMANN unshielded	H&H-90 shielded	SMHI shielded	TRETJAKOV shielded
Liquid	c	0.0000	-0.0500	-0.0500	-0.0500
	c_1	0.0459	-0.0756	-0.0887	-0.0482
Solid	c_2	0.2367	0.1100	0.1615	0.1338
	c_3	0.0180	0.0122	0.0113	0.0091
	c_4	-0.0154	-0.0070	-0.0088	-0.0051

c is the gauge coefficient given in Table 3. For solid precipitation the aerodynamic correction factor is a function of wind speed v (m/s) and temperature T (°C).

$$k = \exp(c_1 + c_2 v + c_3 T + c_4 v T) \tag{3}$$

The gauge coefficients c_1, c_2, c_3, and c_4 are given in Table 3. This regression model should only be applied for $1 < v \leq 7$ m/s and $T \geq -12$ °C. For wind speeds $v \leq 1$ m/s the aerodynamic correction factor for solid precipitation is set to $k = 1$. The aerodynamic correction factor for mixed precipitation could be calculated if the amount of liquid and solid precipitation is known by simply taking the weighted sum of the corresponding liquid and solid correction factors. Fig. 1 shows, for example, mean values of these correction factors for Jokioinen, Finland.

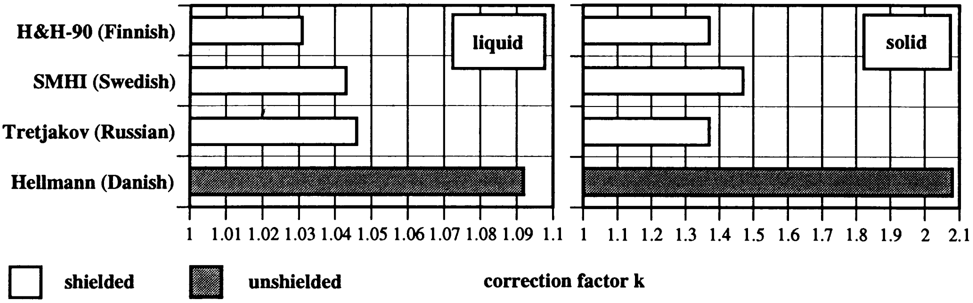

Fig. 1. Aerodynamic correction factors for the predominantly used gauge types in the Baltic Sea Drainage Basin. Mean values for Jokioinen, Finland, based on the field experiment 1987-1993 (after Førland *et al.* 1996).

Rain Gauges used in the Baltic Sea Drainage Basin

The Baltic Sea drainage basin covers 14 countries and therefore several different types of rain gauges are in use. The mainly used gauges are of type HELLMANN UNSHIELDED, SMHI SHIELDED, H&H-90 SHIELDED and TRETJAKOV SHIELDED. Additionally, RIMCO UNSHIELDED and GEONOR T200 SHIELDED are used in Denmark and METRA 886 UNSHIELDED are used in the Czech Republic and in Slovakia (Sevruk and Klemm 1989). The height of the gauge orifice varies between 1 and 2 m. Only in Estonia a correction is made for wetting and evaporation loss. The information on the rain gauge types is summarised as follows:

- **Belarus, Latvia, Lithuania, Russia, Ukraine**: The gauge type is TRETJAKOV SHIELDED with 2 m measuring height and 200 cm^2 orifice. The TRETJAKOV gauge is similar to the Finnish H&H-90 gauge and since 1952 the standard rain gauge of the former states of the Soviet Union.
- **Czech Republic, Slovakia**: The gauge type of the former CSSR is called METRA 886 UNSHIELDED, installed in a height of 1-1.5 m with an orifice of 500 cm^2.
- **Denmark**: Manual precipitation and climate stations: HELLMANN UNSHIELDED with 200 cm^2 orifice, synoptic stations: mainly HELLMANN UNSHIELDED, a few of them shielded, automatic precipitation stations: RIMCO UNSHIELDED with tipping buckets and 324 cm^2 orifice, automatic weather stations: GEONOR T200 SHIELDED, accumulating gauge with 200 cm^2 orifice. Measuring height is 1.5 m. A map of the locations of the different types of the Danish gauges is given by Goodison *et al.* (1998), page 66.
- **Estonia**: The gauge type is TRETJAKOV SHIELDED. The upper rim of the bucket is at the height of 2 m. The orifice is 200 cm^2. The wetting correction is 0.1 mm/day in case of liquid precipitation less than 0.1 mm/day or dry snow and 0.2 mm/day in case of liquid precipitation (rain, mixed rain and wet snow) or dew, fog, crystalline ice and freezing.
- **Finland**: The gauge type is Finnish H&H-90 TRETJAKOV SHIELDED with 200 cm^2 surface area. Measuring height is 1.5 m.
- **Germany**: The gauge type is HELLMANN UNSHIELDED with 1 m measuring height and 200 cm^2 orifice.

- **Poland**: The gauge type is HELLMANN UNSHIELDED with 1-1.5 m measuring height and 200 cm^2 orifice. It should be noted that the Polish HELLMANN gauge has a steeper outer angle of the bevelled rim (28° instead of 45° for the original HELLMANN gauge used in Germany and Denmark).
- **Sweden, Norway**: The gauge type is SMHI SHIELDED. It is made of aluminium and has an area of 200 cm^2 with a Nipher wind shield and a loose funnel to prevent evaporation losses during summer. Measuring height is 1.5 m. In Norway some stations are equipped with the Norwegian (DNMI) gauge.

Implementation of the Gauge Correction

The distribution of the routine synoptic rain gauges in the Baltic Sea drainage basin is shown in Fig. 2 left p. 198. Fig. 2 right shows the corresponding rain gauge distribution for the BMDC data set. The number of synoptic gauges is 400, the number of gauges in the BMDC data set is 4,200. In order to implement the rain gauge correction procedure discussed above information on the type of the rain gauge, the type of precipitation (liquid or solid), rain intensity, as well as air temperature and wind speed at the height of the gauge orifice is needed. The dynamic correction model was fitted to 4 types of gauges. These are the HELLMANN UNSHIELDED gauge, the FINNISH H&H-90 TRETJAKOV SHIELDED gauge, the SMHI SHIELDED gauge and the TRETJAKOV SHIELDED gauge. According to the gauge description given above, the Danish manual and synoptic gauges, the German gauges and the Polish gauges are of type HELLMANN UNSHIELDED. Finland and Sweden have their own gauge type and in Norway both the Norwegian DNMI gauge and the Swedish SMHI gauges are used. TRETJAKOV SHIELDED gauges are used in Estonia, Latvia, Lithuania, Belarus, Russia and Ukraine. The precipitation values from Estonia have been corrected for wetting and evaporation loss by the National Weather Service. Additionally, a low number of gauges (2% of all gauges in the catchment, mainly located in Denmark) now in use does not fall in one of the above described gauge categories. These are the gauges of type GEONOR T200 SHIELDED (14 gauges at automatic weather stations) which are handled like SMHI SHIELDED, RIMCO UNSHIELDED (72 tipping bucked gauges at automatic stations) and METRA 886 UNSHIELDED (9 gauges) which are handled like the HELLMANN UNSHIELDED gauges. These simplifications will be replaced in later versions of the correction model.

The next information required must be based on meteorological observations. Precipitation type and rain intensities are not available in the BMDC data base. Wind speed and air temperature are available at the synoptic stations. Thus it is possible to estimate all the parameters needed for the precipitation correction according to Eqs. (2) and (3) at the SYNOP stations. The wind speed, observed in 10 m height, is reduced to the wind speed v in m/s at the height of the gauge orifice using the standard logarithmic wind profile proposed by Sevruk and Zahlavova (1994)

$$v = \frac{\log(h/z_0)}{\log(H/z_0)}\,(1-0.024\alpha)\,v_H \tag{4}$$

with the height of the gauge orifice h in m and the wind speed v_H in m/s at measuring height H. At most synoptic stations $H = 10$ m. The parameters depending on the conditions at the gauge location, namely the roughness length $z_o = 0.02$ m and the angle $\alpha = 9°$ (average vertical angle to obstacles in the vicinity of the gauge) have been set constant. This is a necessary simplification, which could be replaced by more realistical parameters if information about the environment (vegetation, buildings, *etc.*) at the gauge site becomes available.

As precipitation type is not included in the BMDC data set, according to Førland *et al.* (1996) the temperature is taken to distinguish between liquid, mixed and solid precipitation as follows

$$\begin{array}{rl} 2^\circ\mathrm{C} < T & \text{liquid} \\ 0^\circ\mathrm{C} < T \leq 2^\circ\mathrm{C} & \text{mixed} \\ T \leq 0^\circ\mathrm{C} & \text{solid} \end{array} \tag{5}$$

The last unknown quantity is the mean daily rain intensity Z_I (mm/h), which is defined as the ratio of rain amount Z (mm) and duration D (h). However D is unknown and must be estimated. Instead of estimating D we estimate Z_I. For this purpose we have available four synoptic rain gauge observations per day. In order to illustrate the procedure we define the daily rain durations D^6 (in units h) based on these four 6-hourly precipitation observations Z_i^6 with duration D_i^6, $i = 1, \dots 4$

$$D^6 \equiv \sum_{i=1}^{4} D_{\underset{\sim}{i}}^6 \tag{6}$$

with

$$D_{\underset{\sim}{i}}^6 \equiv \begin{cases} 0\,\mathrm{h} & \text{for } Z_{\underset{\sim}{i}}^6 = 0 \\ 6\,\mathrm{h} & \text{for } Z_i^6 > 0 \end{cases} \tag{7}$$

and the rain intensity based on this duration

$$Z_I^6 \equiv \frac{Z}{D^6} \tag{8}$$

Defining equivalent durations based on 24-, 12- and 3-hourly observations lead to the following relation

$$D^{24} \geq D^{12} \geq D^6 \geq D^3 \geq D \tag{9}$$

Note, that in this notation $D^1 \equiv D$ and consequently,

$$Z_I^{24} \leq Z_I^{12} \leq Z_I^6 \leq Z_I^3 \leq Z_I \tag{10}$$

Here is $Z_I^1 \equiv Z_I$.

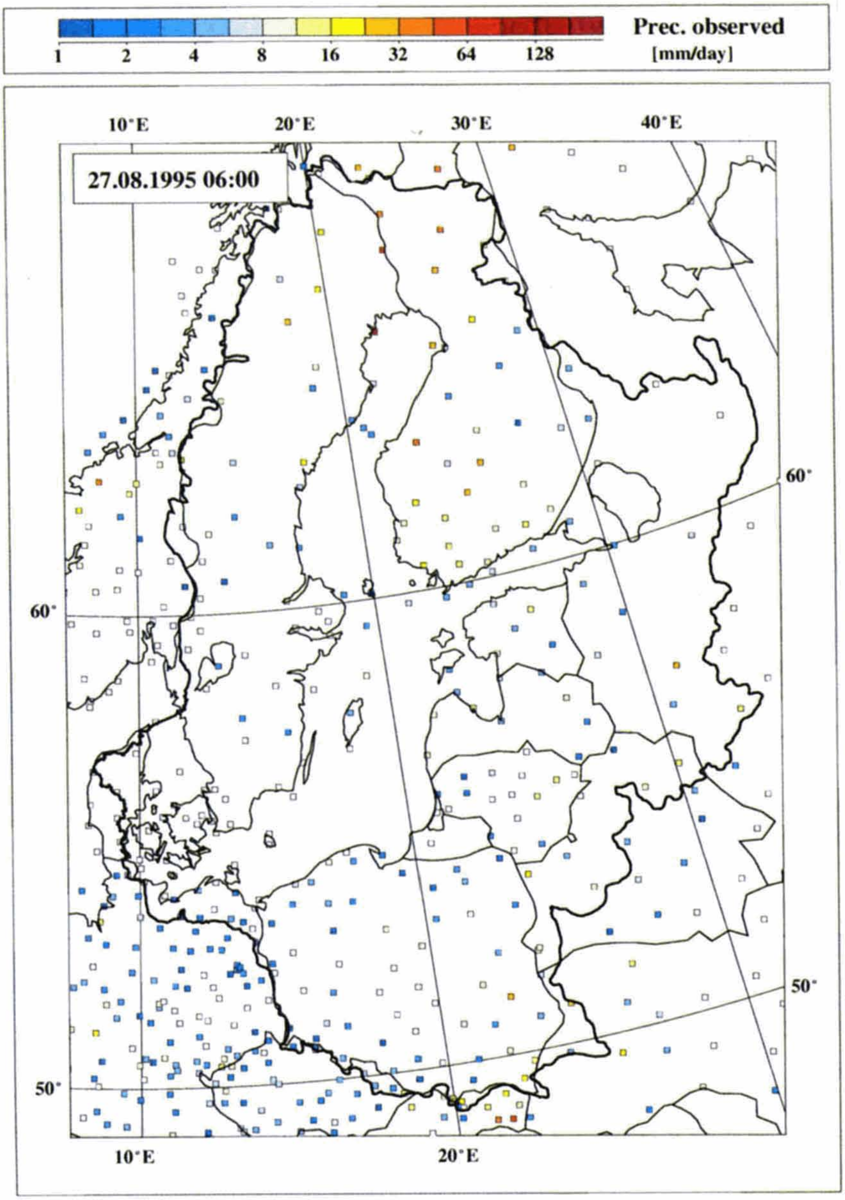

Fig. 2. Daily precipitation amount from the synoptic network (left) and from the extended database collected by the BMDC (right) within the Baltic Sea drainage basin for 27 August 1995. Units in mm. Stations observing values below 1 mm are marked by open squares.

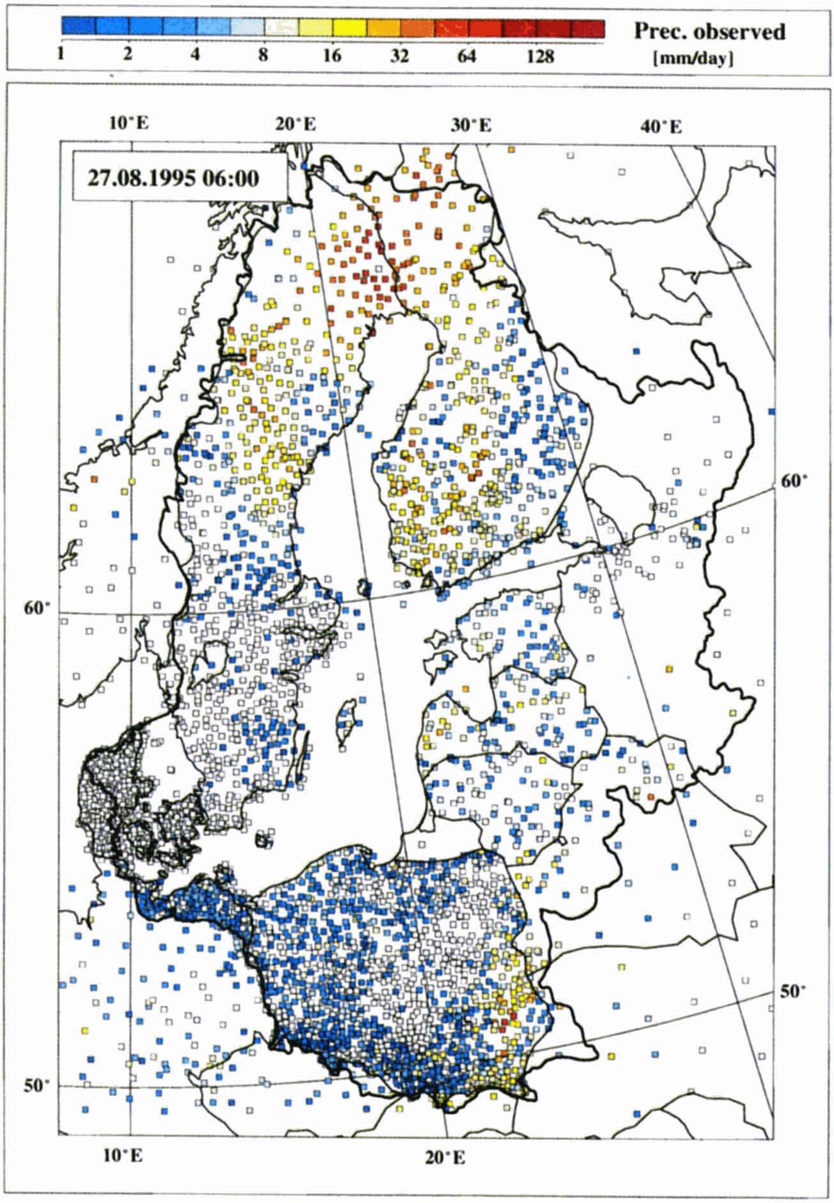

Fig. 2. Cont. (daily precipitation amount from the extended database collected by the BMDC).

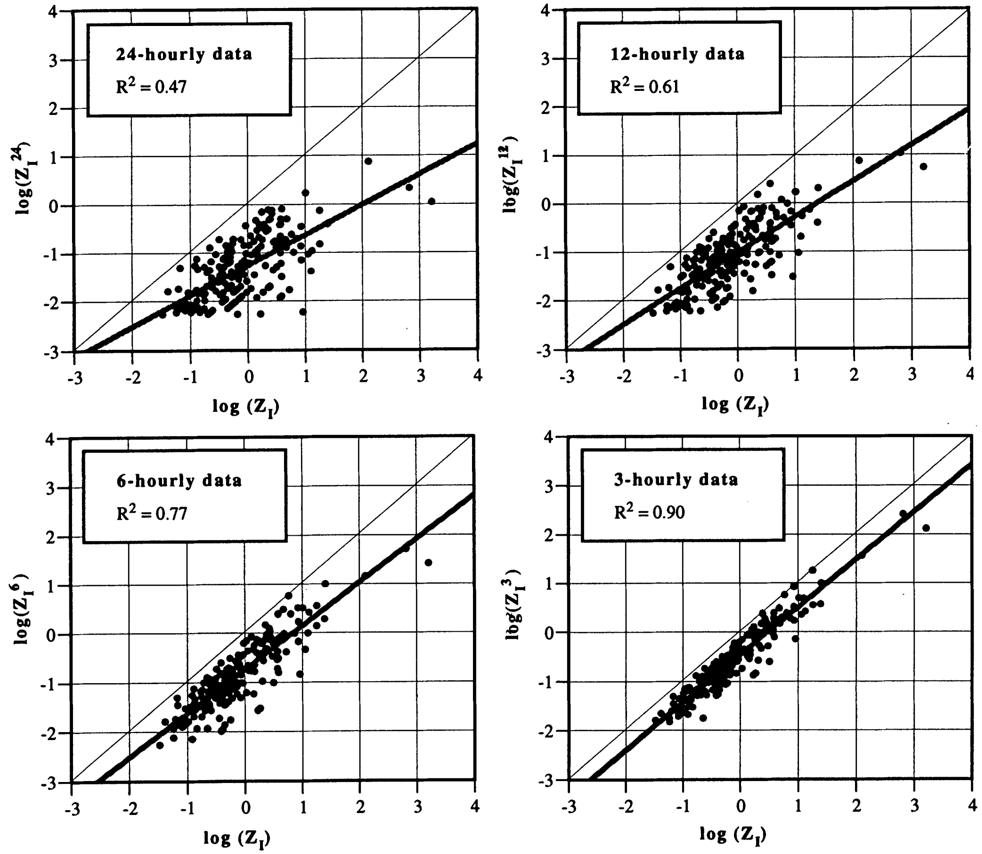

Fig. 3. Precipitation intensities log(Z_I^n) calculated from 24-, 12-, 6- and 3-hourly sums vs. precipitation intensity log(Z_I), based on hourly observations from 14 automatic weather stations GEONOR T200 during the 92 days of the PIDCAP period. Units in mm/h.

The relation between, for example, Z_I^6 and Z_I is illustrated in Fig. 3. We have used data from GEONOR T200 gauges, which are available at 14 Danish locations with a time resolution of 1 hour. From these observations the 24-, 12-, 6- and 3-hourly precipitation sums at the synoptic times have been calculated to get the intensities Z_I^{24}, Z_I^{12}, Z_I^6, Z_I^3 and Z_I. Fig. 3 shows that, for example, 77% of the variance of Z_I is explained by the 6-hourly observations. The corresponding percentages of the other classes are given in the figure. All correlations are significant at the 1% level.

The following linear regression models fitted to the data in Fig. 3 could be used to estimate the rain intensity Z_I

$$Z_I = \exp\left(\frac{\log(Z_I^{24}) + 1.261}{0.626}\right) \qquad (11)$$

$$Z_I = \exp\left(\frac{\log(Z_I^{12})+1.017}{0.738}\right) \tag{12}$$

$$Z_I = \exp\left(\frac{\log(Z_I^{6})+0.740}{0.888}\right) \tag{13}$$

$$Z_I = \exp\left(\frac{\log(Z_I^{3})+0.456}{0.971}\right) \tag{14}$$

In this study 6- and 12-hourly synoptic observations were available and Eqs. (12) and (13) were applied to calculate an estimate of the unknown rain intensity Z_I.

The above formulae represent an estimate of all required input parameters of the *Dynamic Correction Model* at the locations of the synoptic stations. However, at the non-synoptic stations the parameters required, *i.e.* temperature, wind speed and rain duration, are not available. The simplest method, implemented presently, is to take them from the closest SYNOP station. Fig. 4 right shows the frequency distribution of the distances to the closest SYNOP station for one representative day during the PIDCAP period. Of the 4,200 stations more than 3,200 are in the local vicinity of a SYNOP station, not more than 45 km away; the mean distance to the closest SYNOP station is 30 km. We argue on basis of intuition that the interpolation error for wind speed and temperature may be small; at least it is not larger than in other routinely running meteorological applications.

We call the correction based on synoptic information *large scale correction* (Rubel *et al.* 1998), knowing that the local scale effects influencing the measurements could not be eliminated. However, the large scale correction does reduce the systematic underestimation of the rain gauge measurements.

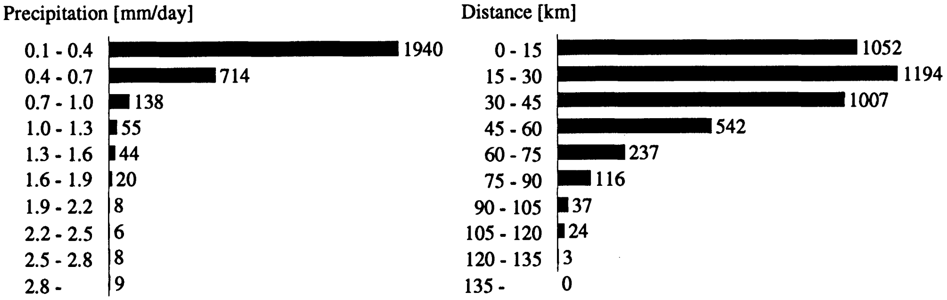

Fig. 4. Frequency distribution of corrected minus observed rain gauge values (left) for 27 August 1995, 06:00 UTC (units mm/day) and frequency distribution of distance to closest SYNOP station (right, units km). Statistics based on 4,212 rain gauges (see Fig. 2, right), of which 2,942 observe precipitation values greater than 0 mm/day. Mean correction 0.43 mm/day, mean distance to closest SYNOP station 30 km.

Next the rain intensity Z_I (mm/h) is calculated by dividing the observed 24-hourly accumulated precipitation value by the interpolated duration of the precipitation event. In convective situations single rain cells may not be resolvable by the synoptic network. For example, the rain duration, interpolated to a specific station, might be zero. At the same time, the observed precipitation at this station might be significantly above zero. Then it is assumed that the duration of precipitation is very short, 2 hours are taken for calculations. By this crude method we try to use the subsynoptic information contained in the data.

Another problem is the synoptic measurements in mountain areas. Since these measurements are often not representative for larger regions (Auer 1992) nor comparable with valley measurements, stations located above 1,500 m have not been used for interpolation to locations without meteorological observations. Precipitation measurements in high Alpine regions are in general difficult to correct even if additional measurements are available at the location of the gauge (Woźniak 1997). Within the framework of this paper this problem is not investigated in detail, because we are mainly interested in a correction method which could be applied routinely. Further, still higher errors in the estimation of the freshwater input into the Baltic Sea catchment are caused by the undersampling over the open sea.

After estimating all the needed meteorological quantities, the correction factor k could be calculated according to Eq. (2) for liquid and Eq. (3) for solid precipitation. In the case of mixed precipitation the simple arithmetic mean of the liquid and the solid correction coefficient is used. An example of corrections (corrected minus observed precipitation values) is shown in form of the frequency distribution for 27 August 1995 in Fig. 4, left. The distribution is highly skewed with most corrections lower than 0.7 mm/day and only a few higher corrections. This is due to the skewed (*i.e.* lognormal) probability density function of daily precipitation sums.

Results

The *Dynamic Correction Model* was applied to the whole PIDCAP data set which comprises 3 months of daily rain measurements from about 4,200 gauges. Fig. 5 shows the time series of the correction factor k for liquid precipitation. The PIDCAP time mean of the daily averaged correction factors for liquid precipitation is 1.044 (corresponding to 4.4% correction due to wind induced losses) for H&H-90, 1.066 for SMHI, 1.041 for TRETJAKOV and 1.091 for HELLMANN gauges. Comparison with the results from the WMO field experiment in Jokioinen, Finland (Fig. 1, liquid precipitation) supports the reliability of the calculated correction factors, having in mind, that a strict comparison is not possible. The mean correction factors for solid precipitation (not shown) are much less representative, because of the low number of days with snowfall. The corresponding correction factors are 1.196 for H&H-90, 1.120 for SMHI, 1.119 for TRETJAKOV and 1.956 for HELLMANN gauges.

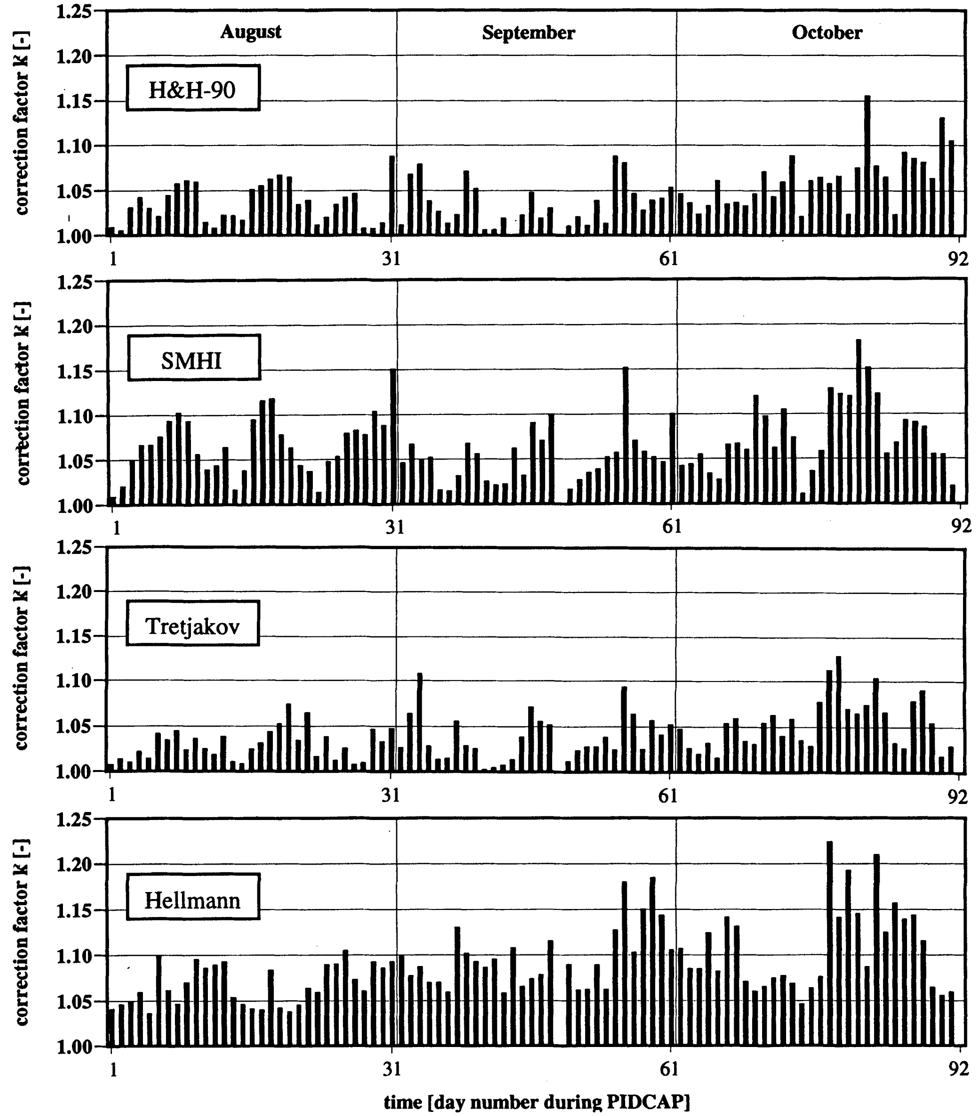

Fig. 5. Aerodynamic correction factor *k* for daily liquid precipitation values during the PIDCAP period August to October 1995, averaged over H&H-90, SMHI, TRETJAKOV and HELLMANN gauges respectively within the BALTEX model domain (see Fig. 2 right).

Our next step is to proceed from corrected point precipitation towards corrected areal precipitation; the influence of the correction procedure on the precipitation input into the Baltic Sea drainage basin is of special interest. In order to investigate the effect of the correction, both the uncorrected and the corrected rain gauge values have been objectively analyzed with a spatial resolution of 18 km. The technique used is a kriging algorithm, adopted for precipitation analysis and described by Rubel (1996). The time series in Fig. 6 has been calculated from these daily precipitation fields (Rubel 1998) and shows the comparison of the precipitation input into the Baltic Sea drainage basin based on uncorrected and corrected gauge values.

The application of the entire correction procedure (comprising not only k but also ΔZ_w and ΔZ_e, see Eq. (1)) to the original rain gauge observations lead to a higher areal precipitation input into the catchment of the Baltic Sea (4.7% in August, 5.8% in September and 9.1% in October 1995). The significantly higher values of the corrected areal precipitation in October are caused by some snowfall events in the second half of the month.

Conclusions and Outlook

A data set of corrected daily rain gauge measurements in the Baltic Sea drainage basin has been presented. Compared with uncorrected measurements the estimated freshwater input into the Baltic Sea catchment during the *Pilot Study for Intensive Data Collection and Analysis of Precipitation* PIDCAP (August to October 1995) was higher by about 5-9% which indicates the relevance of the correction. Although our correction procedure reduces the bias of the measurements, it has been impossible to eliminate the small scale noise of the observational sites. The presented results are thus preliminary, demonstrating only the usability as well as the limitations of the implemented version of the correction model applied to liquid precipitation.

The limitations are due to some uncertainties which have not yet been solved; for example, a more accurate information on the rain intensity and on the roughness length (*e.g.*, due to vegetation) at the gauge location is desired. Both the rain intensity and the information on the gauging conditions are difficult to obtain and up to now not included in the BMDC data base. Improved estimations of the rain intensity need additional information like the weather code (ww) or more automatic stations with higher time resolution. An approach considering the weather code is currently tested in co-operation with the *Global Precipitation Climatology Centre* and may improve further versions of the correction model. Further, the preliminary procedure discussed above (namely, taking the unknown parameters from the closest SYNOP station) should be improved at a later stage. An obvious technique would be to use optimum interpolation since it yields an objective estimate of the interpolation error. However, implementing this program would be beyond present computer capacity for running operationally.

In summary, in applying the *Dynamic Correction Model* to Nordic precipitation data we had to make various simplifications. These have particular impact for continental scale catchments like the one described here; the impact is less severe in regions of the catchment which are well equipped with meteorological measurements,

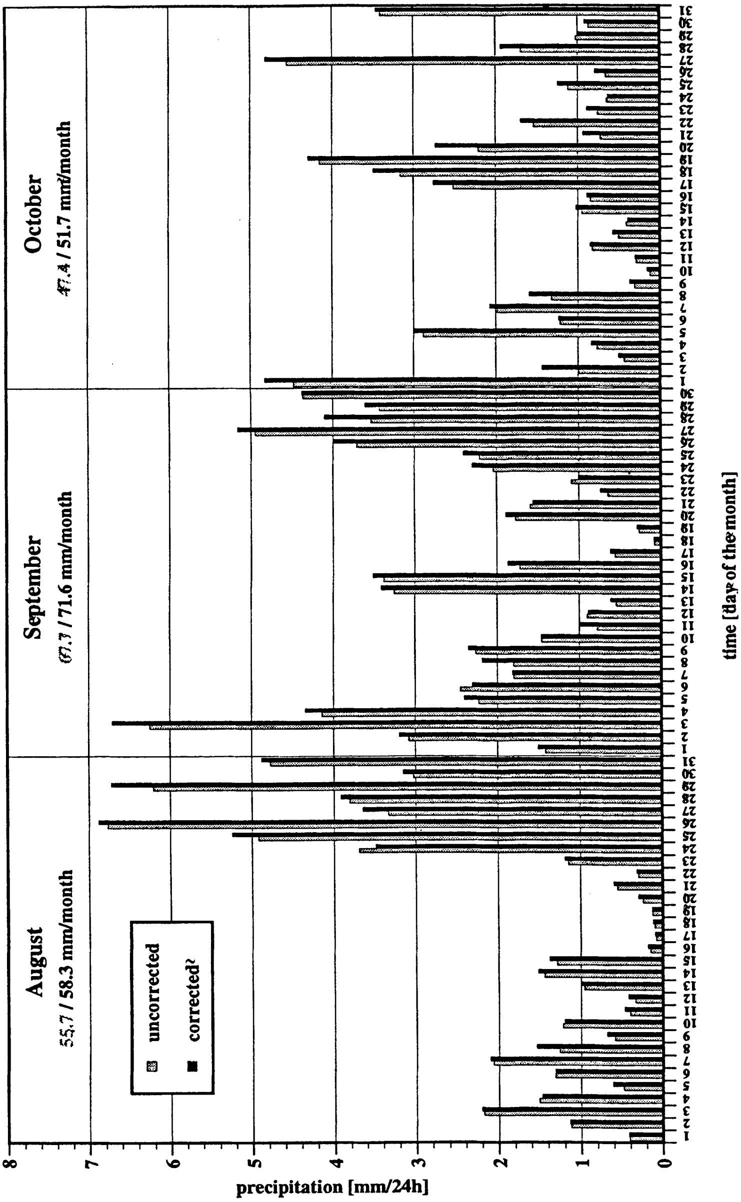

Fig. 6. Daily precipitation sums averaged over the Baltic Sea drainage basin, calculated from objectively analyzed precipitation fields (see Rubel 1998), for the PIDCAP period of 1 August to 31 October 1995. Units in mm/day. Monthly area precipitation for the drainage basin, calculated from gauge corrected analysis, is 58.3 mm (August), 71.6 mm (September) and 51.7 mm (October). Note that different values given in Rubel (1998) have been calculated with an earlier version of the correction model.

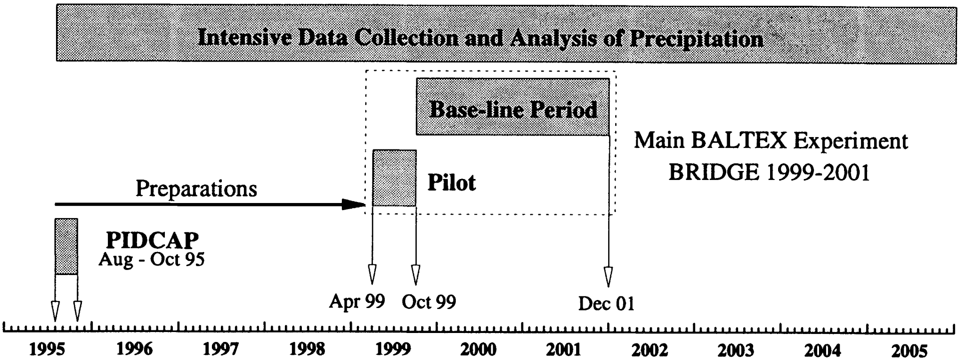

Fig. 7. Time-line for BRIDGE related precipitation analysis. The period of intensive data collection and analysis of precipitation beginning with PIDCAP is at present foreseen to be executed during October 1999 to December 2001 and to extend to at least 2005. At the end of 2005 more than 10 years of daily precipitation fields based on more than 4,200 corrected rain gauge observations within the Baltic Sea drainage basin will be archived in the data base of the BMDC.

e.g. in Denmark and Sweden, where national meteorological and hydrological services could apply more sophisticated methods (*e.g.* Allerup *et al.* 1997).

It is planned to use this correction procedure routinely to improve the reliability of the precipitation analysis during the *Main BALTEX Experiment BRIDGE* to be performed 1999-2001. Fig. 7 shows the time-line for BRIDGE (Bengtsson 1998b), adapted for intensive data collection and analysis of precipitation only. In the framework of PIDCAP an analysis model for routine use was set up of which the presented correction procedure is a part. Results from PIDCAP have been mainly used to validate NWP models (Yang *et al.* 1998). In the BRIDGE preparation phase (Fig. 7) more than 3 years of daily rain gauge observations collected by the BMDC will be analyzed. This extended data base will then be used in the Pilot Period of BRIDGE to finally adjust and calibrate the presented correction model by comparing it with the well documented results from field experiments (Goodison *et al.* 1998). This considerably extended data set, covering three complete annual cycles, should serve then also for hydrological and climatological purposes.

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