Pergamon

Phys. Chem. Earth (B), Vol. 26, No. 5-6, pp. 397–401, 2001
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1464-1909/01/$ - see front matter

PII: S1464-1909(01)00025-9

BALTEX Precipitation Analysis: Results from the BRIDGE Preparation Phase

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Received 21 June 2000; accepted 9 October 2000

Abstract. The Baltic Sea Experiment (BALTEX) is the European contribution to the Global Energy and Water Cycle Experiment (GEWEX). During the preparation phase of the BALTEX main experiment BRIDGE a *Precipitation Correction and Analysis* (PCA) model has been designed and was tested using 3 years (August 1995 - December 1998) of about 4 000 rain gauge observations collected by the BALTEX Meteorological Data Centre (BMDC). The PCA model consists of two parts: (1) a bias correction and (2) a geostatistical module. The dynamic bias correction reduces the systematic underestimation of the rain gauges due to wind-induced, evaporation and wetting losses taking instrument-specific properties as well as additional information from synoptic observations into account. The mean correction factor has a maximum in February (1.25 - 1.50) and a minimum in August (1.02 - 1.05). The geostatistical module of the PCA model consists of an ordinary block kriging algorithm to estimate area averaged precipitation values on the grid of the meso-scale model REMO (spatial resolution: 1/6 degree or 18 km). Results, to be operationally produced during BRIDGE, will be daily, monthly and annual meso-scale precipitation fields based on quality checked, bias corrected rain gauge measurements. © 2001 Elsevier Science Ltd. All rights reserved

1 Introduction

The true precipitation input into the continental scale catchment of the Baltic Sea has not been estimated accurately until now (Kuusisto, 1995). Further there is a general need for high resolution precipitation analyses to validate precipitation fields predicted by numerical weather prediction (NWP) and climate models. For that reason an investigation has been started to provide the BALTEX community with high resolution precipitation fields based on bias corrected surface observations from dense climate rain gauge networks. The precipitation analysis has been started with the Pilot Study of Intensive Data Collection and Analysis of Precipitation (PIDCAP, Aug. to Oct. 1995) and will be continued during the main BALTEX Experiment BRIDGE (Oct. 1999 to Feb. 2002). The results for the BRIDGE preparation phase are available now and will be discussed in the following.

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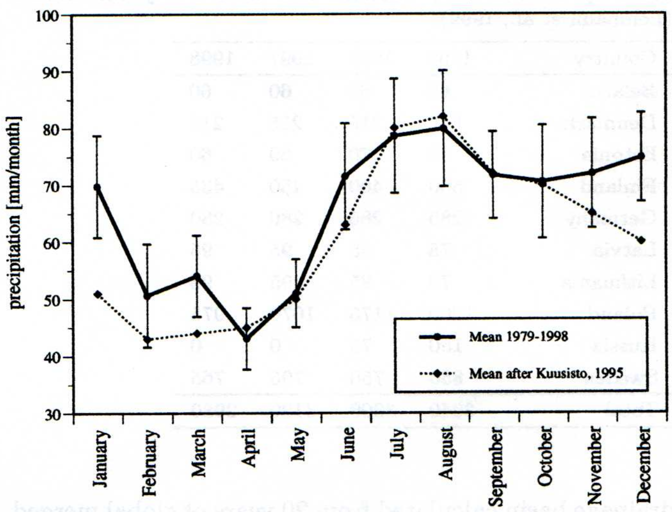

Fig. 1. Mean monthly precipitation averaged over the Baltic Sea drainage basin. The mean was calculated from 20 years of GPCP-V2X products of the period 1979-1998 (solid line with dots and 95 % confidence intervals). Earlier estimates (dashed line) from Kuusisto (1995) plotted for comparison.

2 Precipitation climatology of the Baltic Sea Drainage Basin

The total area of the Baltic Sea drainage basin is about 1 732 000 km^2, covering 14 countries. Fig. 1 shows the mean monthly values of the freshwater input into the

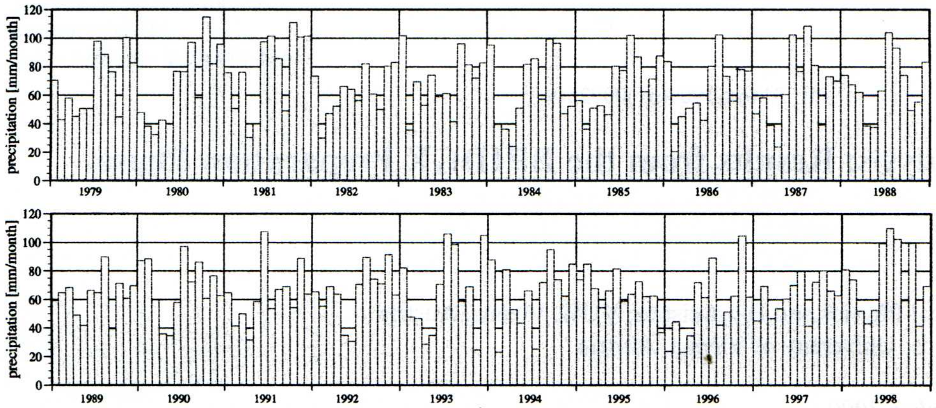

Fig. 2. Time series of monthly averaged precipitation within the Baltic Sea drainage basin calculated from GPCP-V2X products. A description of the GPCP data base is given by Huffman et al. (1997) and Rudolf et al. (2000). Period: 1979 to 1998, units mm/month.

Table 1. Average number of non-synoptic rain gauge data provided by 10 countries, collected and archived by the BMDC (Lehmann et al., 1999).

Country	1995	1996	1997	1998
Belarus	60	60	60	60
Denmark	610	215	215	215
Estonia	80	70	60	60
Finland	500	400	450	435
Germany	285	285	280	280
Latvia	75	85	95	95
Lithuania	70	85	95	95
Poland	1260	1175	1070	975
Russia	150	75	0	0
Sweden	850	750	795	765
Total	3940	3200	3120	2980

drainage basin calculated from 20 years of global merged satellite gauge analyses (GPCP-V2X products) as well as values given by Kuusisto (1995). Both estimates have been corrected for systematic measurement errors and agree well from April to October. During the winter months, however, the GPCP data are generally higher than the Kuusisto (1995) estimates; the major differences occur in January and December. For these months the estimates after Kuusisto (1995) are not within the 95 % confidence intervals of the precipitation calculated from GPCP data set. This may be due to different correction algorithms used for snow. The annual estimate of precipitation is about 700 mm/year with maximum in August (80 mm/month) and minimum in April (30 mm/month). A 20-year time series (1979 to 1998) of monthly precipitation within the Baltic Sea drainage basin is shown in Fig. 2.

3 Database

The major problem when analyzing meso-scale precipitation fields over Europe is the collection of the rain gauge data which are available only in data archives of

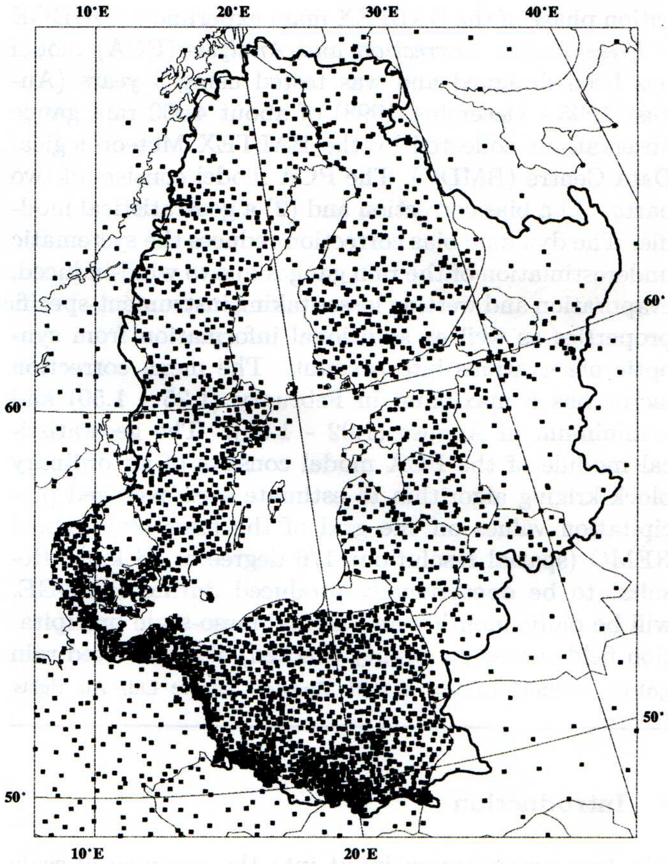

Fig. 3. Typical density of rain gauges collected by the BMDC and completed with synoptic rain gauges provided by the GPCC for 1996.

national services. In the case of the Baltic Sea drainage basin data from 10 countries have been collected by the BALTEX Meteorological Data Centre (BMDC). Additional meteorological data have been provided by the Global Precipitation Climatology Centre (GPCC). Fig. 3 shows the station density used in this study. The density of the rain gauges is about 10 times denser within the catchment than outside, where only data from the synoptic network (transmitted via GTS) are available. The number of rain gauges provided by 10 countries contributing to BALTEX are summarized in Tab. 1. Together with about 500 gauges from the synoptic network the total number of gauges is 4400 in 1995 and decreases to about 3500 in 1998.

4 Precipitation correction and analysis (PCA) model

The PCA model was developed in order to calculate high resolution precipitation fields based on dense networks of rain gauges within the Baltic Sea drainage basin. It consists of 2 parts: a dynamic correction model for the reduction of systematic measurement errors and a geostatistical model to estimate spatial averaged precipitation values representative for the grid areas.

4.1 Bias correction of measurements

To reduce the systematic measurement errors a statistical correction model based on the methods proposed in the *Manual for Operational Correction of Nordic Precipitation Data* (Førland et al., 1996) was developed and applied to daily precipitation data in the BALTEX model domain (Rubel and Hantel, 1999). Its main purpose is to correct for the wind-induced losses which is the largest error.

The corrected precipitation value Z is estimated as

$$Z = k\,(Z_m + \Delta Z_w + \Delta Z_e) \qquad (1)$$

where Z_m is the measured precipitation value, ΔZ_w the wetting loss, ΔZ_e the evaporation loss, and k the aerodynamic correction factor. While the values of the wetting and evaporation losses are taken from climatology, the aerodynamic correction factor contains actual information on the weather event (wind speed, temperature, rain intensity) as well as specific information on the rain gauge (gauge type, height of the orifice, shielded or unshielded). As an example, Fig. 4 shows the monthly mean of the daily correction factors k for 1996. The total average aerodynamic correction factor k is about 1.25 during the winter months and 1.05 during the summer months. The correction factors calculated for unshielded gauges (e.g. HELLMANN) are 30 - 50 % higher than those used for shielded gauges (e.g. TRETJAKOV, SMHI, H&H-90).

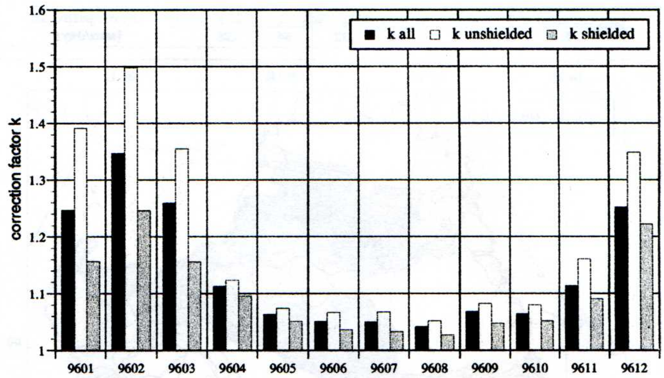

Fig. 4. Monthly mean of the daily correction factors k averaged over the BALTEX model domain for 1996.

4.2 Geostatistical analysis

The irregularly distributed, bias corrected, daily rain gauge data have been analyzed on a meso-scale grid with a spatial resolution of 18 km. An optimum interpolation scheme, the ordinary block-kriging method was used. This method estimates the areal precipitation Z_A:

$$Z_A(\mathbf{u}_o) = \frac{1}{A}\int\limits_A Z(\mathbf{u})\,dA \qquad (2)$$

from the following linear combination:

$$\hat{Z}(\mathbf{u}_o) = \sum_{i=1}^{n} \lambda_i\, Z(\mathbf{u}_i) \qquad (3)$$

where $\hat{Z}(\mathbf{u}_o)$ is the estimate of the areal precipitation, the values $Z(\mathbf{u}_i)$ are the corrected point precipitation measurements at locations $\mathbf{u}_i \equiv (x_i, y_i), i = 1, 2, \ldots n$ and λ_i are the weighting factors which have to be estimated. The vector $\mathbf{u}_o \equiv (x_o, y_o)$ represents the central point of the grid box considered.

The statistically optimal determination of these weighting factors follows from a linear system of $n+1$ equations written here in terms of the spatial auto-correlation function $\hat{R}$:

$$\begin{aligned} \sum_{j=1}^{n} \lambda_j \quad \hat{R}(\mathbf{u}_i, \mathbf{u}_j) + \mu &= \frac{1}{A}\int\limits_A \hat{R}(\mathbf{u}, \mathbf{u}_i)\; dA \\ \sum_{i=1}^{n} \lambda_i \quad &= 1 \end{aligned} \qquad (4)$$

Additionally, for each precipitation field the error variance

$$\begin{aligned} \sigma_\epsilon^2(\mathbf{u}_o) \quad &= \quad \frac{1}{A^2}\int\limits_A \int\limits_{A'} \hat{R}(\mathbf{u}, \mathbf{u}')\; dA dA' - \\ &- \quad \sum_{i=1}^{n} \lambda_i \frac{1}{A} \int\limits_A \hat{R}(\mathbf{u}, \mathbf{u}_i)\; dA - \mu \end{aligned} \qquad (5)$$

was calculated. The error variance is a function of the

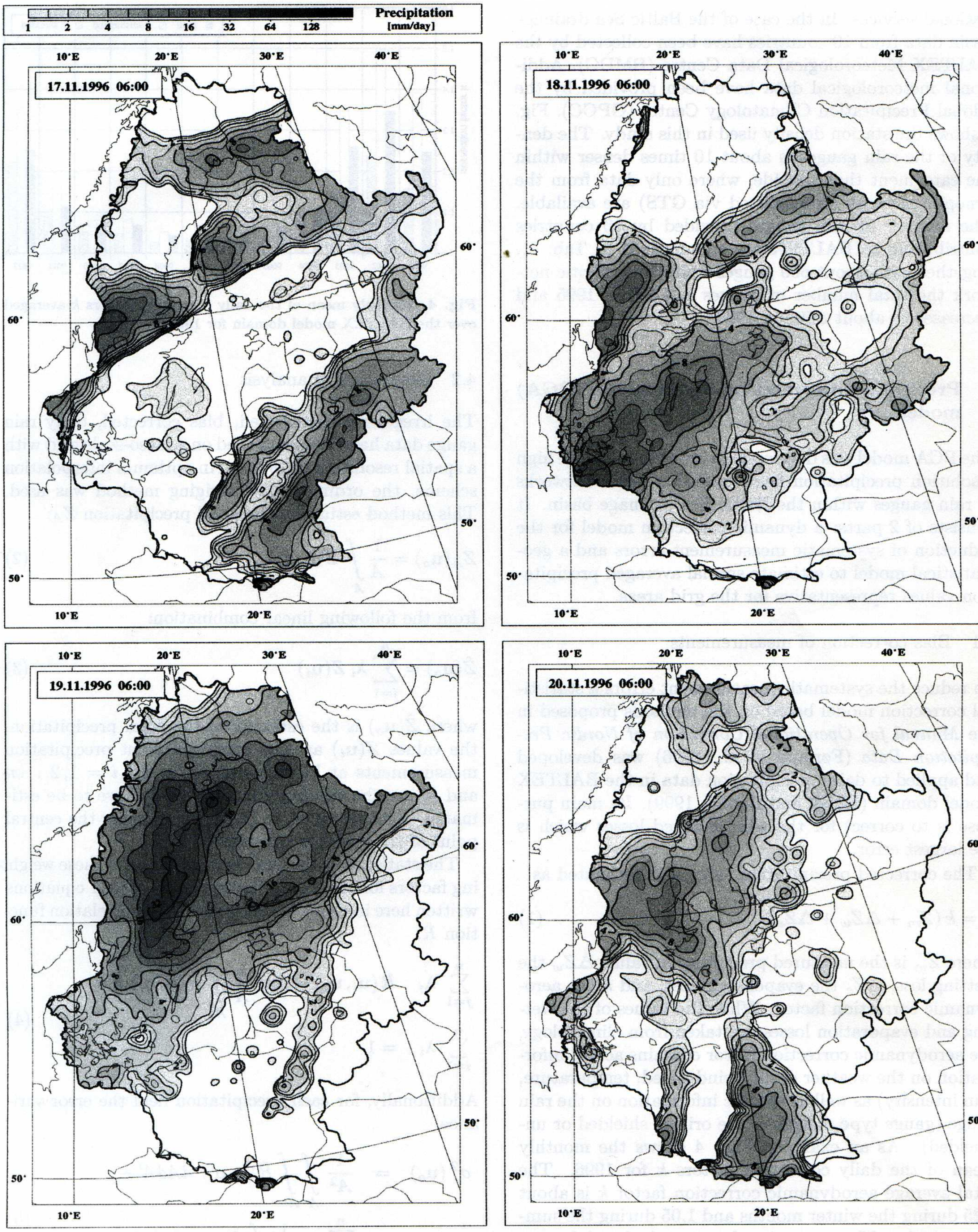

Fig. 5. Analyzed daily precipitation fields of the period 17 to 20 November 1996. Units mm/day.

size of the grid area, the station density and the statistical structure of the precipitation field, which depends on the scale to be resolved (Rubel, 1996b).

5 Results

Within the framework of BALTEX a PCA model was developed and applied to the precipitation data base of the BRIDGE preparation phase. The set of analyzed precipitation data contains daily precipitation fields from 1 August 1995 to 31 December 1998. Fig. 5 shows the sequence of daily rain gauge fields of the period 17 to 20 November 1996, demonstrating the high resolution of the observed precipitation pattern as compared to meso-scale NWP models. For each of the observed fields the corresponding spatial distribution of the error variance (not shown here) is available (Rubel, 1998). This allows potential users to select precipitation grid area estimates above a pre-defined threshold of theoretical error, depending on the accuracy needed for further applications.

Additional to the daily fields, monthly and annual fields have been calculated and will be used for climatological studies, while for hydrological applications time series of the freshwater input into the drainage basin have been calculated.

One goal of GEWEX is to transfer developed methodologies to other regions of the globe. Following this concept, the correction model developed within the framework of BALTEX was applied to the global synoptic database with special emphasis to the other continental-scale experiments of GEWEX (Ungersböck et al., 2000).

6 Conclusions

During the Pilot Study of Intensive Collection and Analysis of Precipitation (PIDCAP; see Isemer, 1996) the statistical precipitation analysis model PCA was developed (Hantel et al., 1997). Purpose of the present study has been to implement the most recent version of PCA for application in the upcoming BALTEX main experiment BRIDGE. First results for PIDCAP have been published by Rubel (1996a) and Rubel (1998). The results presented in this paper are the first of a series of precipitation fields based on several years of quality checked, bias corrected rain gauge data from the very dense climatological networks of the 14 countries within the catchment of the Baltic Sea. These data, comprising daily, monthly, annual fields as well as time series of the freshwater input into the Baltic Sea drainage basin, will be archived by the BMDC and provided to the BALTEX community.

Acknowledgements. This research was supported by the EC Environment and Climate Research Programme (NEWBALTIC II, No. ENV4-CT97-0626, Climatology and Natural Hazards) and by the Jubiläumsfonds der Österreichischen Nationalbank (Project No. 7875). The Global Precipitation Climatology Centre (GPCC) provided the synoptic data and the BALTEX Meteorological Data Centre (BMDC) the extended rain gauge data base.

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