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PIDCAP [1]
GROUND TRUTH PRECIPITATION ATLAS

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[1] Pilot Study for Intensive Data Collection and Analysis of Precipitation, August to November, 1995

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Preface

GEWEX, the *Global Energy and Water Cycle Experiment*, is an essential element of the *World Climate Research Programme* (WCRP). Five continental-scale experiments are being conducted within GEWEX; the *Baltic Sea Experiment* (BALTEX) is one of them. Its scientific objectives include comprehensive determination of the energy and water budgets of the BALTEX area. The components of the atmospheric branch of the hydrological cycle are the key elements to be investigated. Special observing campaigns for gaining basic data sets are being conducted within BALTEX. The first of these has been the *Pilot Study for Intensive Data Collection and Analysis of Precipitation* (PIDCAP) which covered the period from August through November 1995.

Immediately following the field phase of PIDCAP, Rubel (1996) published the *PIDCAP Quick Look Precipitation Atlas*, based upon the data of about 1 000 routine SYNOP stations available. This atlas gave an account of the spatial precipitation fields during each day of PIDCAP; together with the preliminary overview of the *Weather Patterns and Selected Precipitation Records in the PIDCAP Period, August to November 1995* (Isemer 1996) it served as a background for the detailed study of meteorological and hydrological processes.

The present atlas based upon an order of magnitude more surface data than the previous one, plus quality check and correction of measurements is the final evaluation of the daily precipitation during PIDCAP; it represents a key contribution of the convection group at the University of Vienna that has joined the BALTEX community within the research project *Numerical Studies of the Energy and Water Cycle of the Baltic Region* (NEWBALTIC). The present atlas is intended to become the observational reference for the BALTEX community as far as daily precipitation over the Baltic Sea catchment during summer/fall 1995 is concerned. The software used for producing the present atlas is now routinely running. Thus the upcoming field phase of BALTEX can benefit from applying the same high quality analysis as presented here with minimum time delay.

Michael Hantel
Principal Investigator IMG
NEWBALTIC
University of Vienna

Summary

PIDCAP is the BALTEX *Pilot Study for Intensive Data Collection and Analysis of Precipitation* in the Baltic Sea drainage basin. For the first time in 1996 a quick look atlas was compiled for the PIDCAP period of August to November 1995. Routinely GTS transmitted synoptic data only have been used (Rubel 1996). Now, the final version of the precipitation atlas, completed with data collected by the *BALTEX Meteorological Data Centre*, is presented. The used data base consists of more than 4 000 locations of daily precipitation observations within the catchment of the Baltic Sea. This is ten times more data than in the former data base. The raw data have been quality checked and corrected for systematic measurement errors before they are taken as input in a statistical analysis scheme calculating areally averaged precipitation. The analysis was done with *Ordinary Block Kriging*; the grid is identical with the one used by the mesoscale numerical weather prediction model REMO (resolution: 18 km).

The main part of the atlas shows 92 daily precipitation fields within the Baltic Sea drainage basin for the period 1 August to 31 October 1995. For each precipitation field an error field was calculated, but because of their similarity only presented for one date. The typical analysis error, given in relation of the variance of the observations, is lower than 10 % over wide land areas, but exceeds 40 % over some parts of the open sea. Further, both fields of monthly precipitation sums and time series of daily freshwater input into the entire Baltic Sea catchment are shown. The corresponding numbers, the basis of model verifications, are given for the whole catchment as well as for land/sea grid areas separately. Monthly areally averaged precipitation values are 59 (61/48) mm in August, 73 (74/69) mm in September and 51 (53/44) mm in October 1995. Further, this atlas contains a couple of comparisons with earlier analyses as well as with predictions from models (REMO, HIRLAM), demonstrating possibilities and limitations with using the precipitation analysis in model verifications.

Additionally to the printed fields, the gridded precipitation data as well as the corresponding error files are accessible for the BALTEX community (available from the BMDC).

Zusammenfassung

PIDCAP ist die Pilotstudie für intensive Datensammlung und Analyse von Niederschlag im Einzugsgebiet der Ostsee und Teil von BALTEX (*Baltic Sea Experiment*). Für die PIDCAP Periode August bis November 1995 wurde erstmals 1996 ein Übersichtsatlas erstellt, der ausschließlich auf routinemäßig via GTS übertragenen SYNOP Daten basierte (Rubel 1996). Nun liegt der endgültige Niederschlagsatlas, ergänzt mit den Daten des *BALTEX Meteorological Data Centres*, vor. Dieser Datensatz beinhaltet mehr als 4 000 Stationen mit täglichen Niederschlagsbeobachtungen im Einzugsgebiet der Ostsee. Gegenüber dem früher verwendeten Datensatz ist das eine 10 mal höhere Datendichte. Die Rohdaten wurden einer Qualitätskontrolle unterzogen sowie der systematische Meßfehler korrigiert. Aus den so aufbereiteten Beobachtungen wurden danach mit einem statistischen Analyseverfahren (Ordinary Block Kriging) Flächenniederschläge auf dem Gitter des mesoskaligen Numerischen Wettervorhersage Modells REMO (Auflösung: 18 km) erstellt.

Der Hauptteil des vorliegenden Atlas beinhaltet 92 Felder täglichen Niederschlags im Einzugsgebiet der Ostsee (1 August bis 31 Oktober 1995). Für jedes Niederschlagsfeld ist auch ein Fehlerfeld verfügbar. Der typische Analysefehler, angegeben als relative Varianz der Beobachtungen, ist über weiten Landteilen kleiner als 10 %, über der offenen Ostsee aber teilweise größer als 40 %. Weiters sind die Monatsfelder sowie Zeitreihen des mittleren täglichen Frischwassereintrages in das Einzugsgebiet dargestellt. Die entsprechenden Zahlenwerte sind für das gesamte Einzugsgebiet, sowie für Land/Wasserflächen getrennt angegeben und bilden die Basis für Modellverifikationen. Die Monatswerte des Flächenniederschlages betragen 59 (61/48) mm im August, 73 (74/69) mm im September und 51 (53/44) mm im Oktober 1995. Der Atlas gibt auch einen Vergleich mit früheren Analysen und zeigt anhand einzelner Prognosefelder (REMO, HIRLAM) die Möglichkeiten und Grenzen der Verwendung von Niederschlagsanalysen zur Modellverifikation auf.

Zusätzlich zu den gedruckten Feldern werden der BALTEX-Gemeinschaft auch die Gitterdaten, sowohl des Niederschlags als auch des zugehörigen Fehlers, zur Verfügung gestellt (erhältlich vom BMDC).

Acronyms

BALTEX	**BALT**ic Sea **EX**periment
BMDC	**B**ALTEX **M**eteorological **D**ata **C**entre
DIAMOD	**DIA**gnostic **MOD**el
DM	**D**eutschland **M**odell
DWD	**D**eutscher **W**etter**D**ienst
ECMWF	**E**uropean **C**entre for **M**edium Range **W**eather **F**orecasts
EM	**E**uropa **M**odell
GEWEX	**G**lobal **E**nergy and **W**ater Cycle **EX**periment
GTS	**G**obal **T**elecommunication **S**ystem
HIRLAM	**HI**gh **R**esolution **L**imited **A**rea **M**odel
IMG	**I**nstitute of **M**eteorology and **G**eophysics, University of Vienna
NEWBALTIC	**N**umerical Studies of the **E**nergy and **W**ater Cycle of the **BALTIC** Region
NWP	**N**umerical **W**eather **P**rediction
PIDCAP	**P**ilot Study for **I**ntensive **D**ata **C**ollection and **A**nalysis of **P**recipitation
REMO	**RE**gional **MO**del
SYNOP	**SYNOP**tic Observations
UTC	**U**niversal **T**ime **C**oordinated
WCRP	**W**orld **C**limate **R**esearch **P**rogramme
WMO	**W**orld **M**eteorological **O**rganisation

1 INTRODUCTION

BALTEX (Bengtsson 1995, Raschke et al. 1998), a continental-scale experiment covering the Baltic Sea and its drainage basin, is the European contribution to GEWEX. Within BALTEX, the project NEWBALTIC *(Numerical Studies of the Energy and Water Cycle of the Baltic Region)* focuses, among others, upon the water budget components of the region (extension: 1 721 200 km^2 or 17 % of Europe). The motivation to compile this precipitation atlas was the need for a high resolution ground truth for purpose of mesoscale NWP model verification. In addition the areally averaged precipitation is taken to define the freshwater input into the drainage basin of the Baltic Sea.

The precipitation fields presented here are valid for PIDCAP *(Pilot Study for Intensive Data Collection and Analysis of Precipitation)*, carried out from August to November 1995. PIDCAP was defined 1996 (Isemer 1996a) and only a few month later the first overview of precipitation events was presented in the *PIDCAP Quick Look Precipitation Atlas* (Rubel 1996a). For this atlas, measurements located at approximately 1 000 sites (400 within the catchment) of the synoptic network have been analyzed. These raw observations have not been quality checked nor corrected for measurement errors. Corresponding to the relatively low density of the synoptic rain gauges, the analysis grid from the German EM, having a horizontal resolution of 55 km, was taken. As the extended database collected by the BMDC *(BALTEX Meteorological Data Centre)* was available, these database (4 000 gauges, 10-times denser than the synoptic network) was used. The raw data have been analyzed in a preliminary form to provide the community with mesoscale precipitation fields for model verification (Rubel 1998b, Yang et al. 1998).

Now, the improved analysis based on quality checked, corrected rain gauges is completed and presented here. Because of the high data density available, it was possible to refine the analysis grid; the grid of REMO (18 km resolution) is used. A correction according to the *Manual for Operational Correction of Nordic Precipitation Data* (Førland et al. 1996) was implemented to eliminate the systematical underestimation of the gauge measurements. It considers wind-induced errors as well as wetting and evaporation losses, depending on the various types of rain gauges collected during PIDCAP (Rubel and Hantel 1998a). In opposite to changes in the data base and the resolution of the grid, the statistical analysis method has been adopted unchanged. As in former analysis, ordinary block kriging was used to estimate the areally averaged precipitation. The detailed description of the method, including numerical implementation, can therefore be taken from the *PIDCAP Quick Look Precipitation Atlas* (Rubel 1996). This linear statistical interpolation method has some advantages compared to other methods (e.g. Creutin and Obled 1982), is recommended by the WMO (Sevruk 1992) and is applied by many authors (e.g. Schönwiese and Rapp 1997). Nevertheless, it should be noted here that the linear technique does not take into account the principal non-Gaussian probability density function of precipitation; this property is particularly pronounced in precipitation records valid for short time intervals. And, it should not be forgotten that the best analysis method cannot replace real observations.

Additionally to the daily fields, the monthly precipitation distribution for the PIDCAP month August, September and October 1995 was estimated. Further, to demonstrate the reliability of the present analysis for the verification of NWP models, examples from forecasts from REMO (running at GKS Research Centre, Geesthacht and Max-Planck-Institut for Meteorology, Hamburg) and from HIRLAM (running at the Danish Meteorological Institute, Copenhagen) are plotted against the analysis. Although no statistical model verification has been made, a quick visual comparison shows good agreement.

2 MODEL DOMAIN AND DATA

Fig. 1, left shows the model domain with the grid of REMO (Regional Model) used in the project NEWBALTIC. The grid is a rotated latitude/longitude grid (DWD 1995) with the position of the north pole at 170° W and 32.5° N (−170°/32.5°). The lower left corner of the BALTEX grid has the rotated coordinate −5°/−14°; the upper right corner 15°/16°. The grid spacing in zonal and meridional direction is set to 1/6°, which corresponds to a grid distance of about 18 km. Therefore, the dimension of the whole grid is set to 121·181 grid points representing the surrounding grid area of 18 · 18 km for which the areally averaged precipitation is analyzed. The analysis was performed for only 91·127 grid points, starting at grid point 22/34, covering the region of the Baltic Sea drainage basin. This restriction was necessary, because the data density outside the drainage basin was much too low with respect to the resolution of the analysis grid.

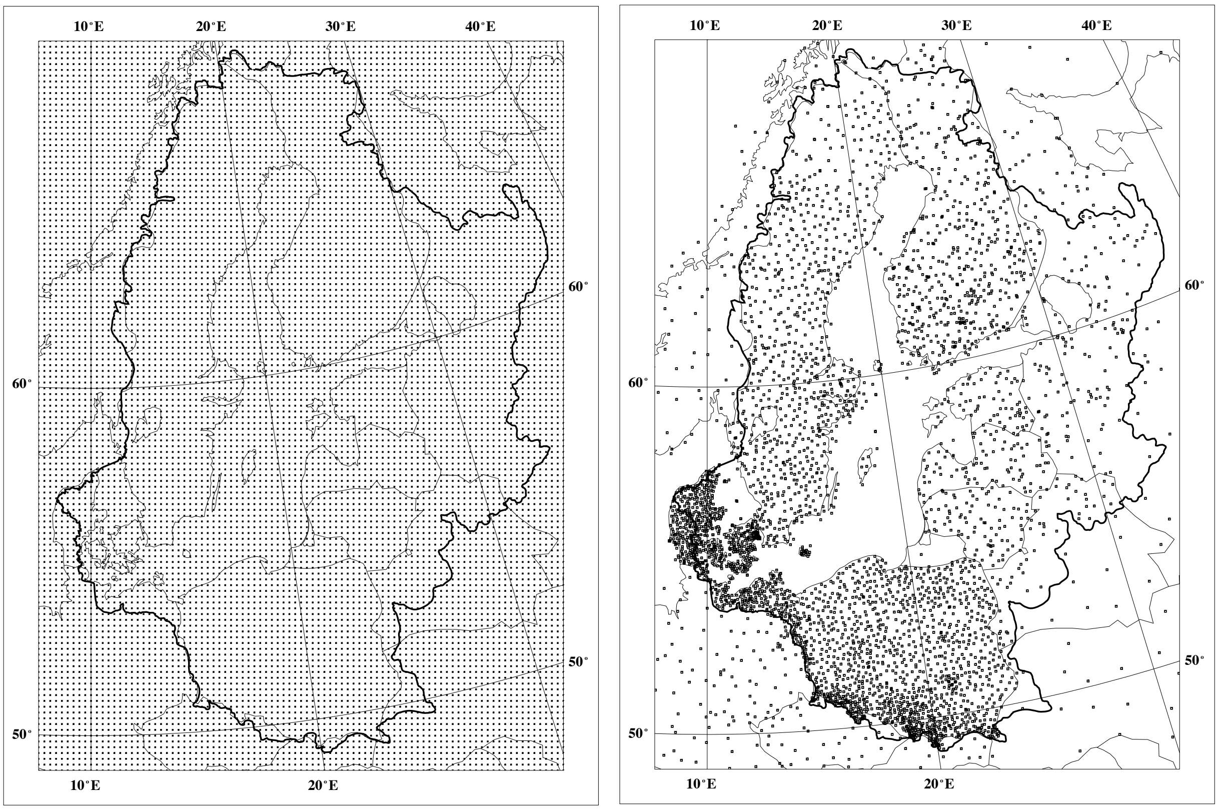


Figure 1 BALTEX model domain with the high resolution grid of the regional model REMO (left) and the locations of the available rain gauges (right). The boundary of the Baltic Sea drainage basin is marked by a solid line.

The data base used for the analysis is shown in Fig. 1, right. The rain gauge data of about 4 000 sites, mainly within the drainage basin, have been collected by the BMDC (Lehmann et al. 1997, Isemer 1998). This data set was completed by rain gauge, wind and temperature observations from the synoptic network, which are routinely available via GTS.

3 QUALITY CHECK OF RAIN GAUGE DATA

The task of an automatic quality check of rain gauge data has not been solved completely until now. Therefore the data used in this study have been checked for transmission errors and unrealistic high values have been fragged automatically. The final quality check was then done interactively by viewing analyzed fields. Beside the automatically cancelled observations, only two observations had to be corrected subjectively, because they are not representative for the scale of the analysis. These are the stations with number:

sn000017396 (date: 30 August 1995, $\varphi = 66°51'$, $\lambda = 23°04'$, Z=87.4 mm/day, Z_{cor}=8.7 mm/day)
26477 (date: 9 September 1995, $\varphi = 56°23'$, $\lambda = 30°36'$, Z=202.0 mm/day, Z_{cor}=101.0 mm/day)

The above precipitation values have been set to a lower value, even it might be that the observations are true. This guarantees undisturbed field structures.

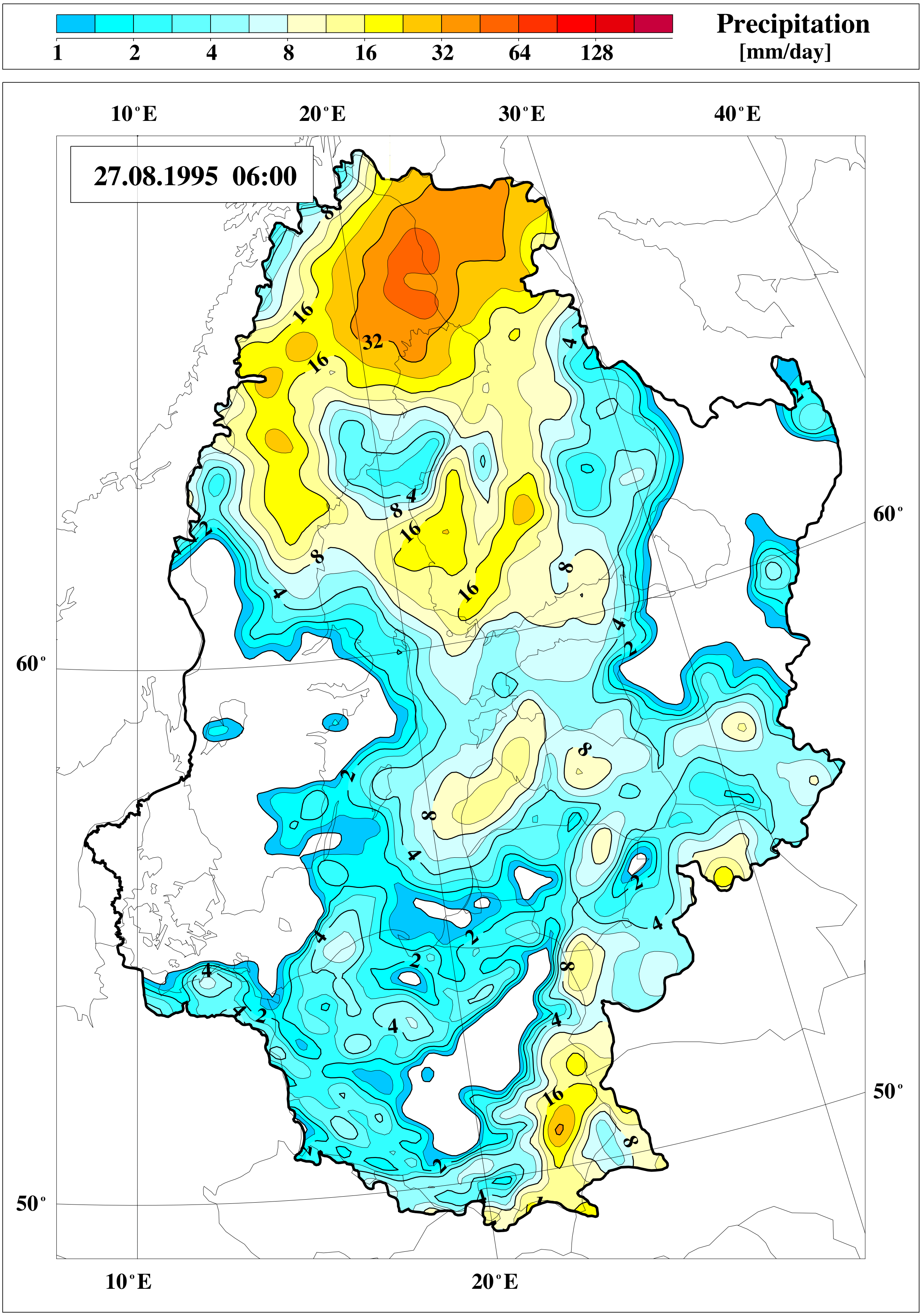
4 CORRECTION OF RAIN GAUGE DATA

There is a general agreement in the meteorological and the hydrological community that the systematic underrepresentation of the raw rain gauge measurements has to be corrected before they are taken to verify NWP models or to estimate the freshwater input into drainage basins. The underobservation is mainly caused by wind field deformation above the gauge orifice (2-10 % for liquid and 10-50 % for solid precipitation), losses from wetting on internal walls (2-10 %) and losses due to evaporation (0-4 %) and is well documented in various WMO reports (Sevruk 1982, Sevruk 1986, Goodison 1998).

To correct the rain gauges in the BALTEX model domain (Fig. 1) the *Dynamic Correction Model* proposed in the *Manual for Operational Correction of Nordic Precipitation Data* (Førland et al. 1996) was adopted. It takes instrument specific properties into account; these comprise the gauge types HELLMANN UNSHIELDED (used in Denmark, Germany and Poland), SMHI NIPHER SHIELDED (Sweden, Norway), TRETJAKOV SHIELDED (Belarus, Estonia, Latvia, Lithuania and Russia) and H&H-90 TRETJAKOV SHIELDED (Finland). The objectively analyzed precipitation fields, based on corrected measurements, are systematically higher than the uncorrected fields. The corresponding increase of the freshwater input into the catchment of the Baltic Sea is 7.7 % in August, 8.9 % in September and 7.4 % in October 1995 (Rubel and Hantel 1998).

Figure 2 Page 10: Objectively analyzed precipitation field for 27 August 1995, 06:00 UTC, accumulated from 26 August, 06:00 UTC to 27 August, 06:00 UTC. Units in mm/day.

Figure 3 Page 11: Interpolation error, normalized with respect to the kriging variance, of the objectively analyzed precipitation field for 27 August 1995, 06:00 UTC.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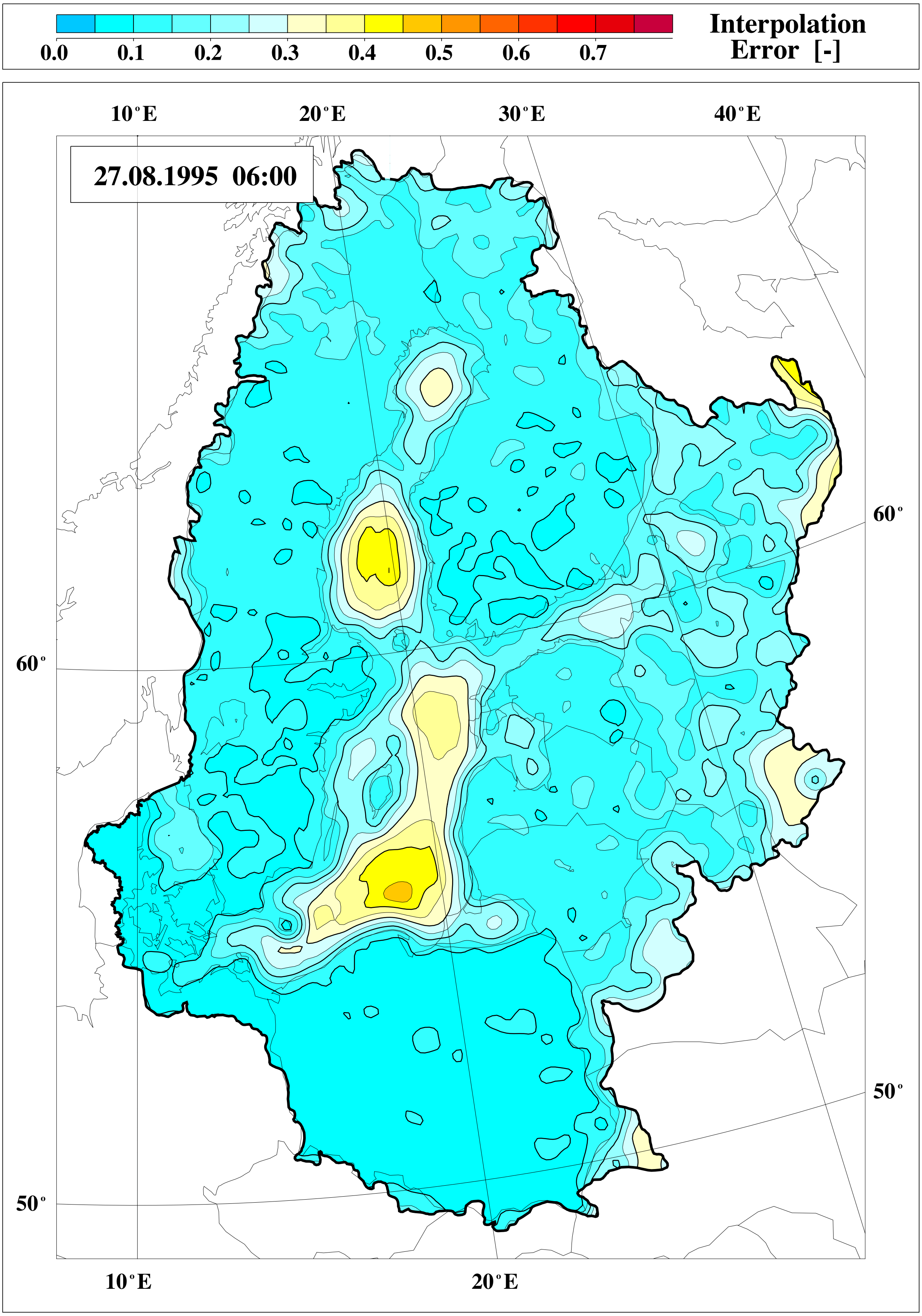
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5 DAILY PRECIPITATION FIELDS

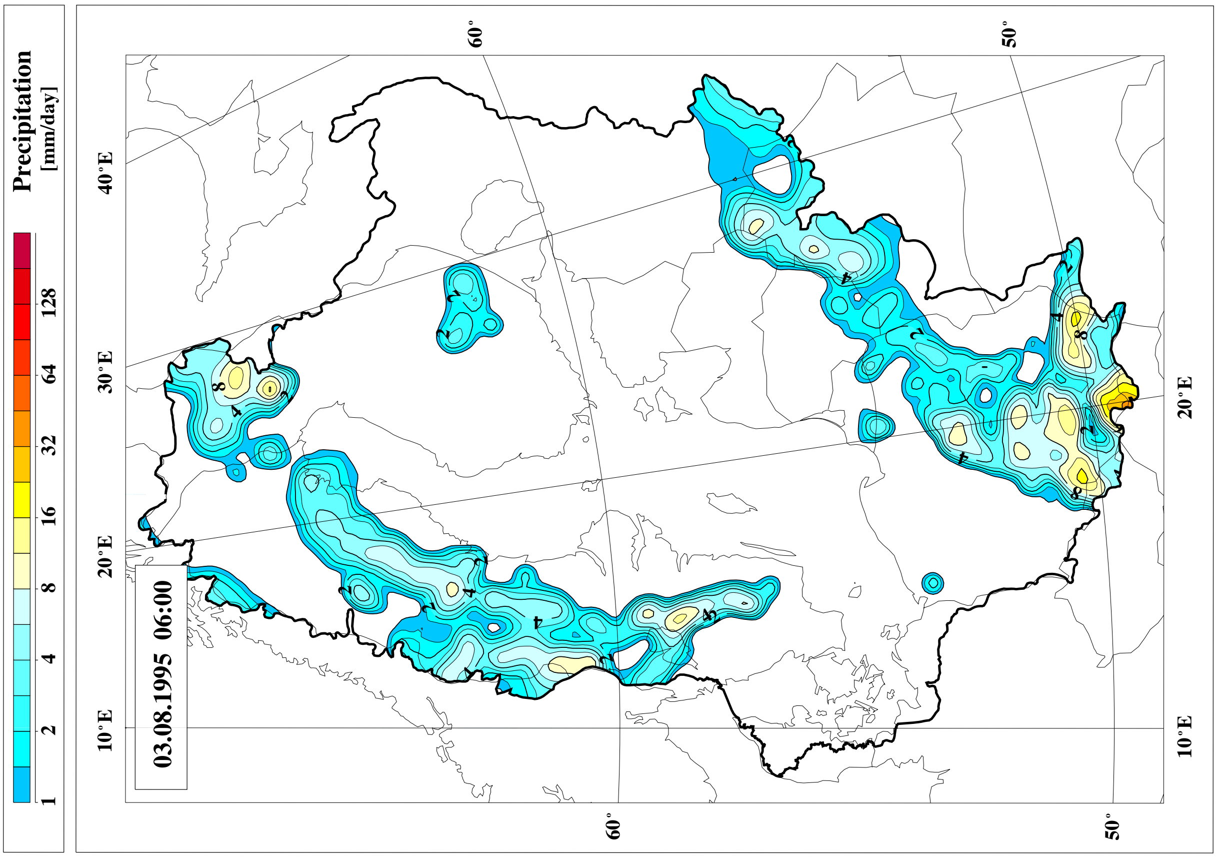
This is the main chapter of the *PIDCAP Ground Truth Precipitation Atlas*, containing three month of daily gridded precipitation fields. For the fourth month of PIDCAP, November 1995, no extended data base was available. In Fig. 2 an example of an objectively analyzed precipitation field is given. The field is dated with the end of the accumulation period. That means, the precipitation field labelde 27 August 1995, 06:00 UTC contains values accumulated from 26 August, 06:00 UTC to 27 August, 06:00 UTC. This differs from the labeling convention applied by some other working groups, but is in accord with the characterization of the SYNOP data. The data set used was merged from data collected by the BMDC and data transmitted routinely via GTS (see Fig. 1). According to the characteristics of rain events, the scaling of the contour lines in the precipitation plots are defined by powers of base 2, starting with 2^0 for values ≥ 1 mm/day, and ending with 2^7 for values ≥ 128 mm/day. Fig. 3 shows the corresponding kriging variance for the 27 August 1995, which can be interpreted as the normalized interpolation error. Note, that for each precipitation field an error field is available. This makes it possible, that e.g. for validation purposes, only grid areas with an analysis error above some specified threshold could be selected. This tool is recommended for model validation studies. Detailed descriptions of the analysis method (ordinary block kriging) can be found in the *PIDCAP Quick Look Precipitation Atlas* (Rubel 1996).

Fig. 4 shows the three months of daily precipitation fields analyzed from corrected rain gauges. Two periods with pronounced precipitation events within the Baltic Sea drainage basin are found (see also Fig.s 6, 7). These are:

- **23 August to 5 September, 1995:** Heavy precipitation over the whole Baltic region was caused by a cyclone moving from the North Sea over Sweden to the North Cap, followed from 3 cyclones moving northwards from their developing region near the Black Sea.
- **24 September to 2 October, 1995:** Two frontal systems moved across the BALTEX region from west to east. The structure of these systems was well represented by the corresponding precipitation field.

Beside these periods, several other periods are proposed in the *PIDCAP Quick Look Precipitation Atlas*, a descriptions of weather situations during PIDCAP is also available (Isemer 1996).

Figure 4 Page 13 - 58 Objectively analyzed precipitation fields for the period August to October 1995. Daily precipitation sums valid for the 24 hours preceeding the data given in the label of the figure. Units in mm/day.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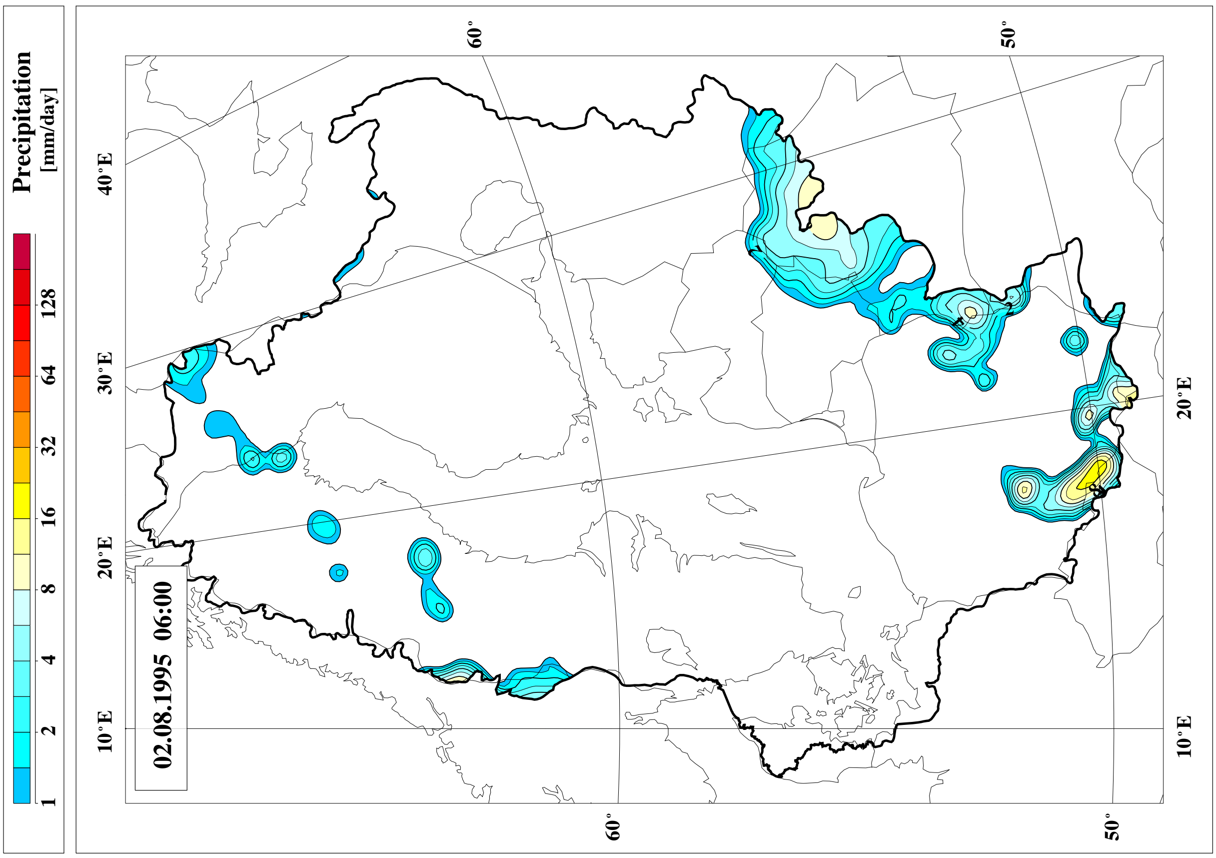
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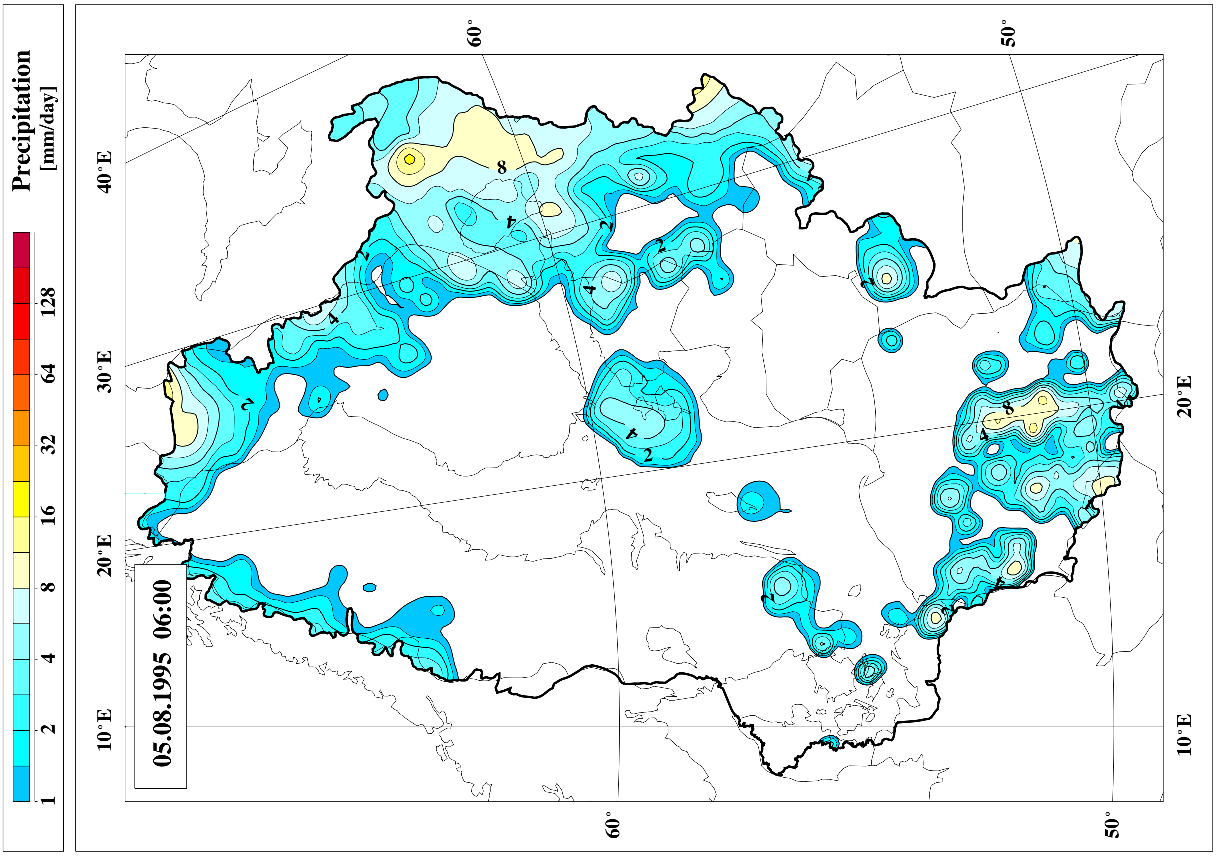
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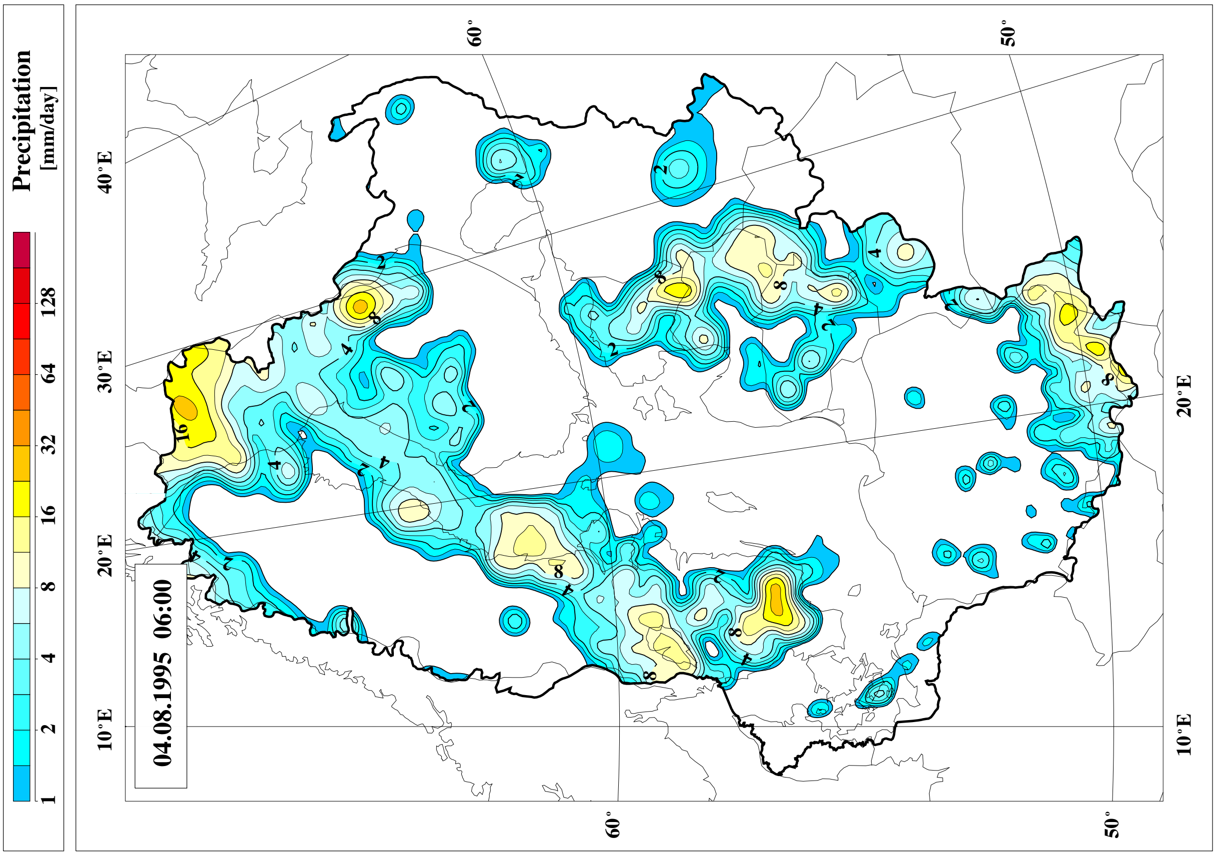
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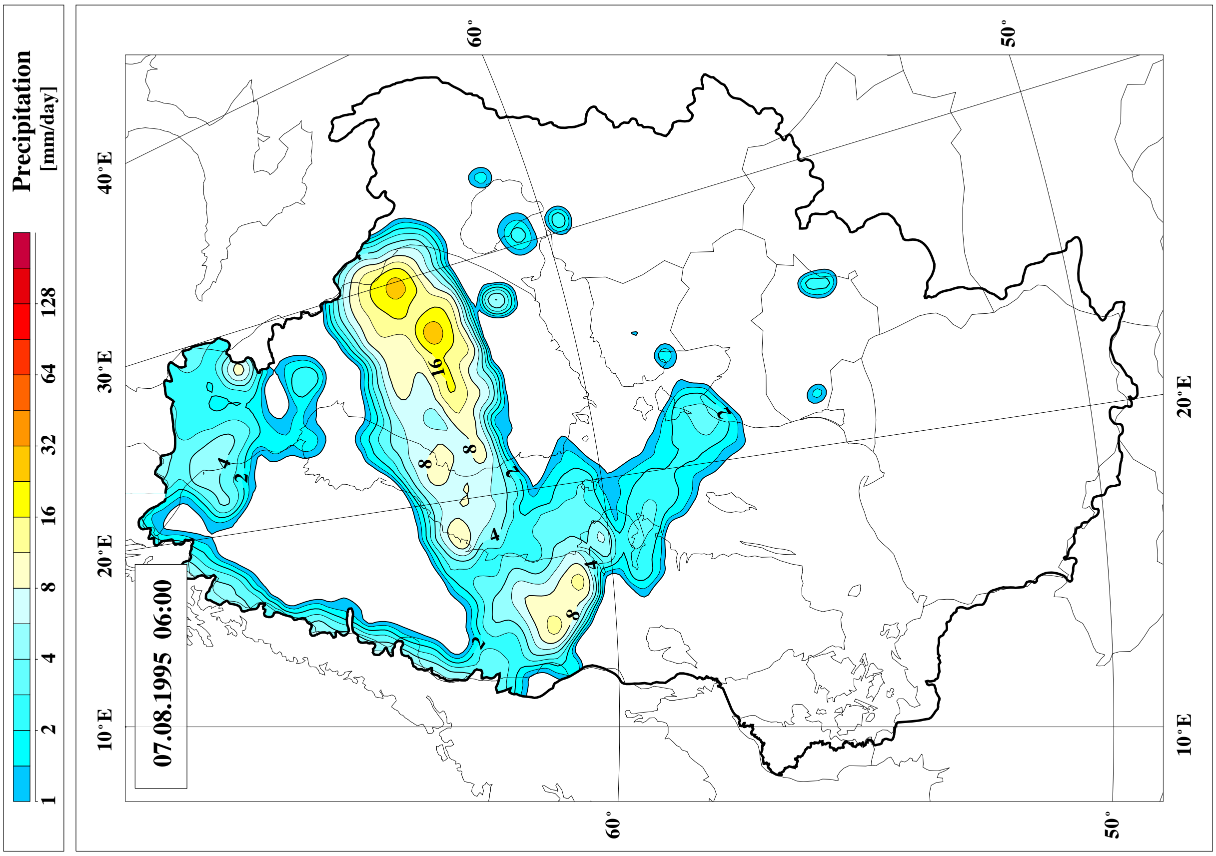
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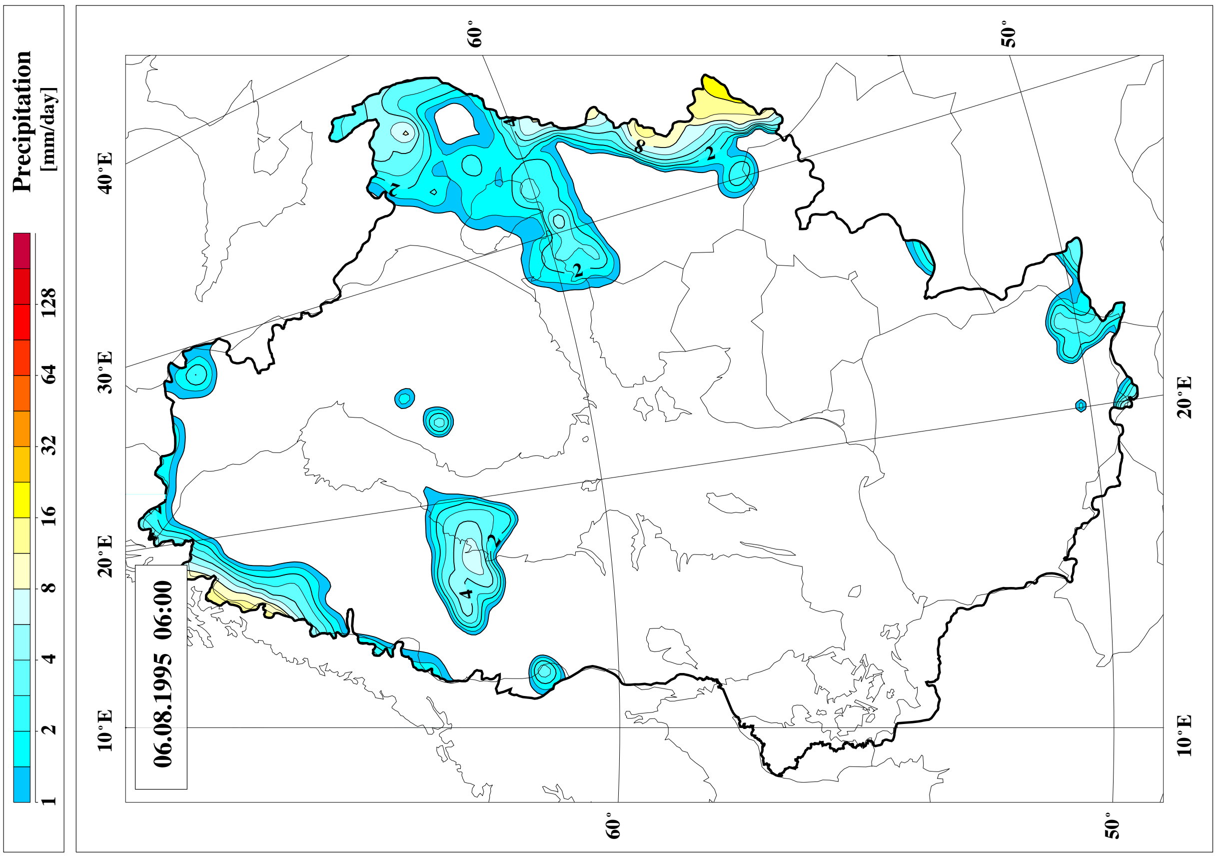
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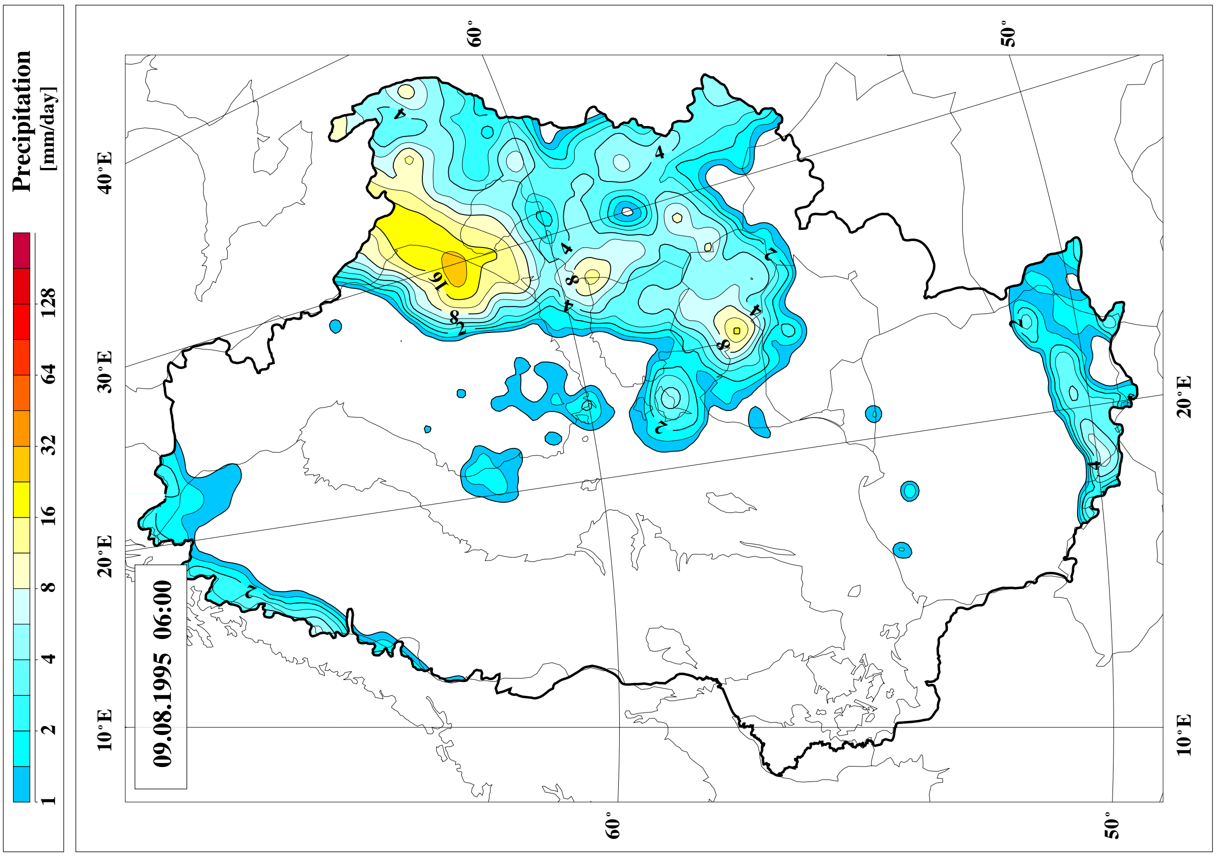
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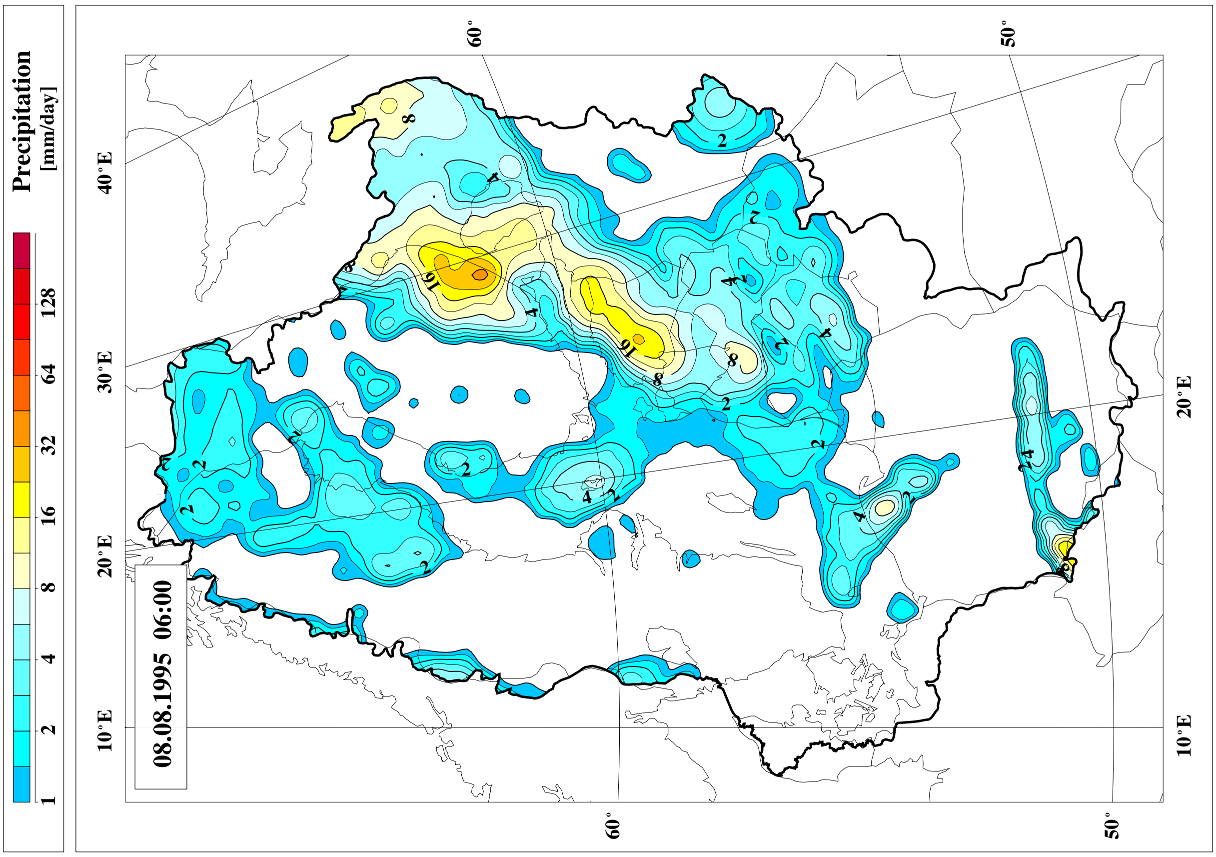
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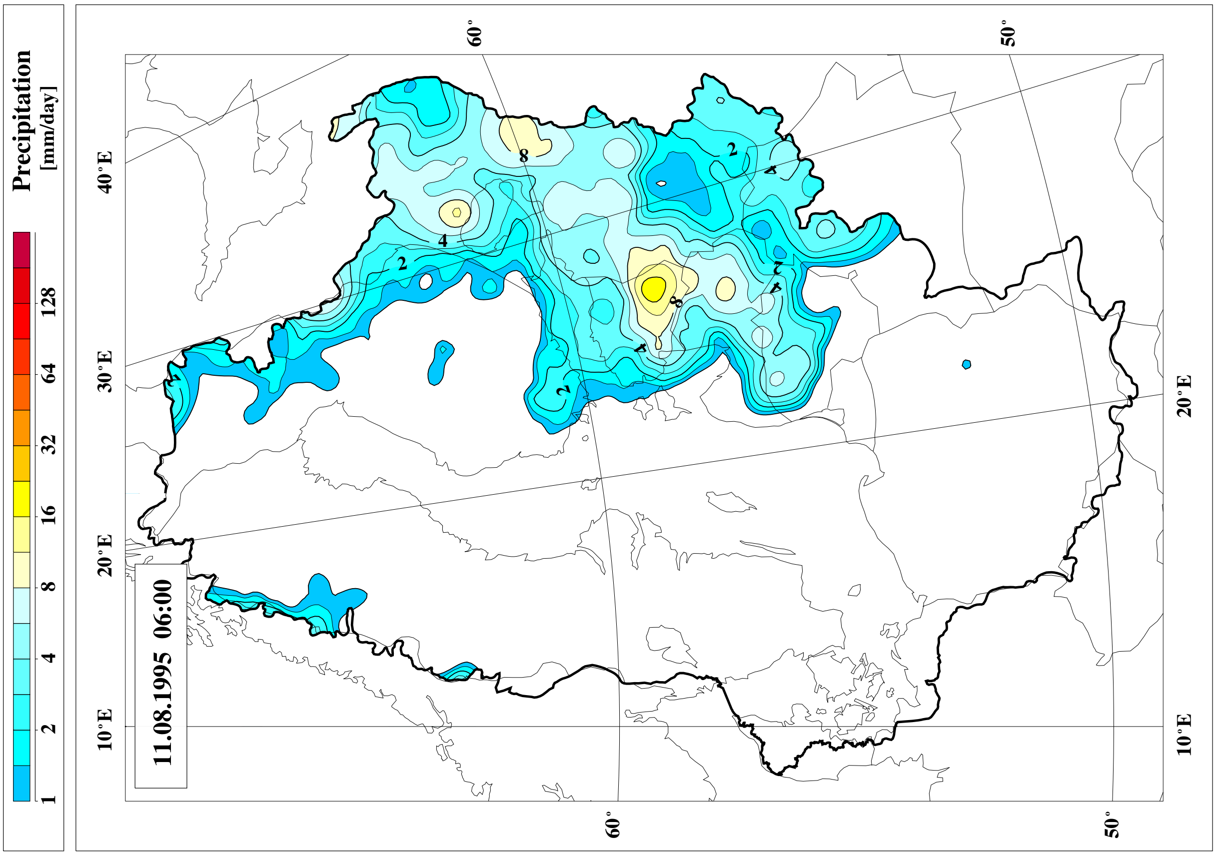
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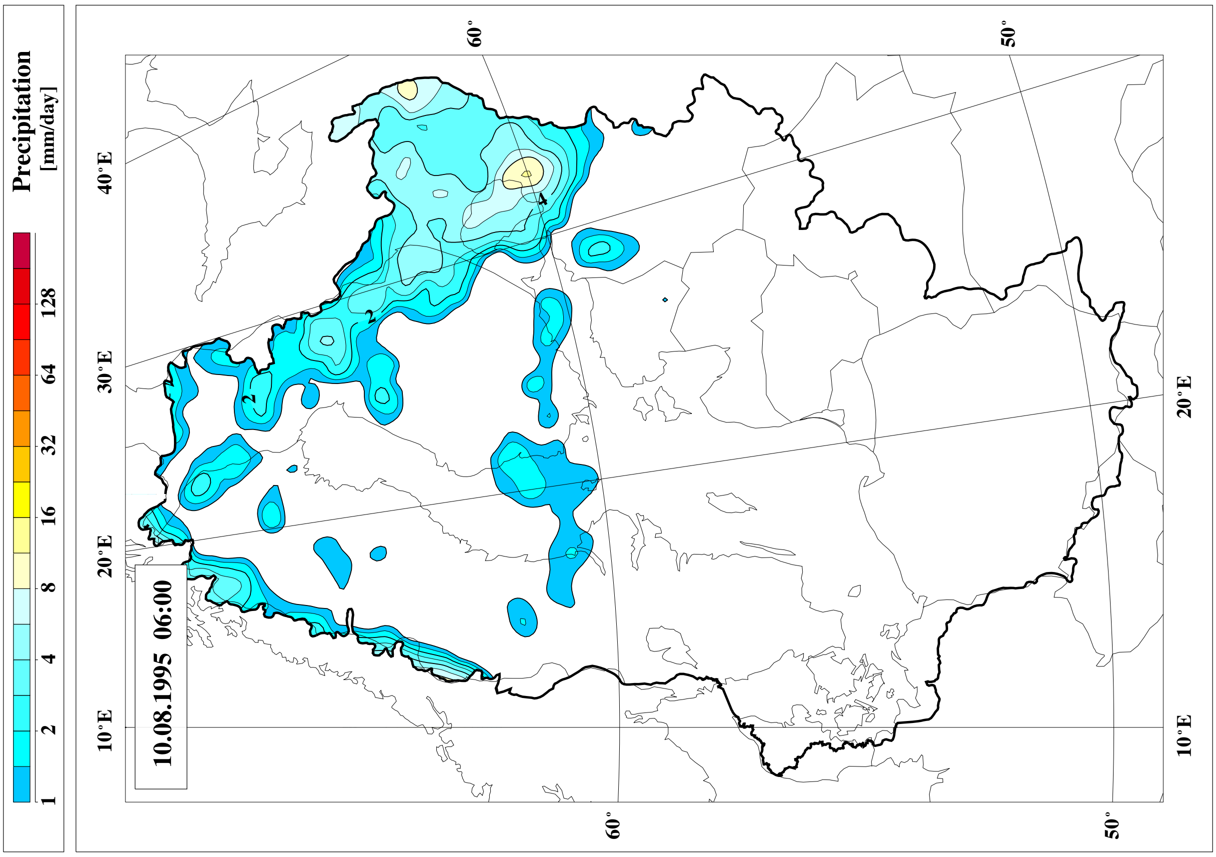
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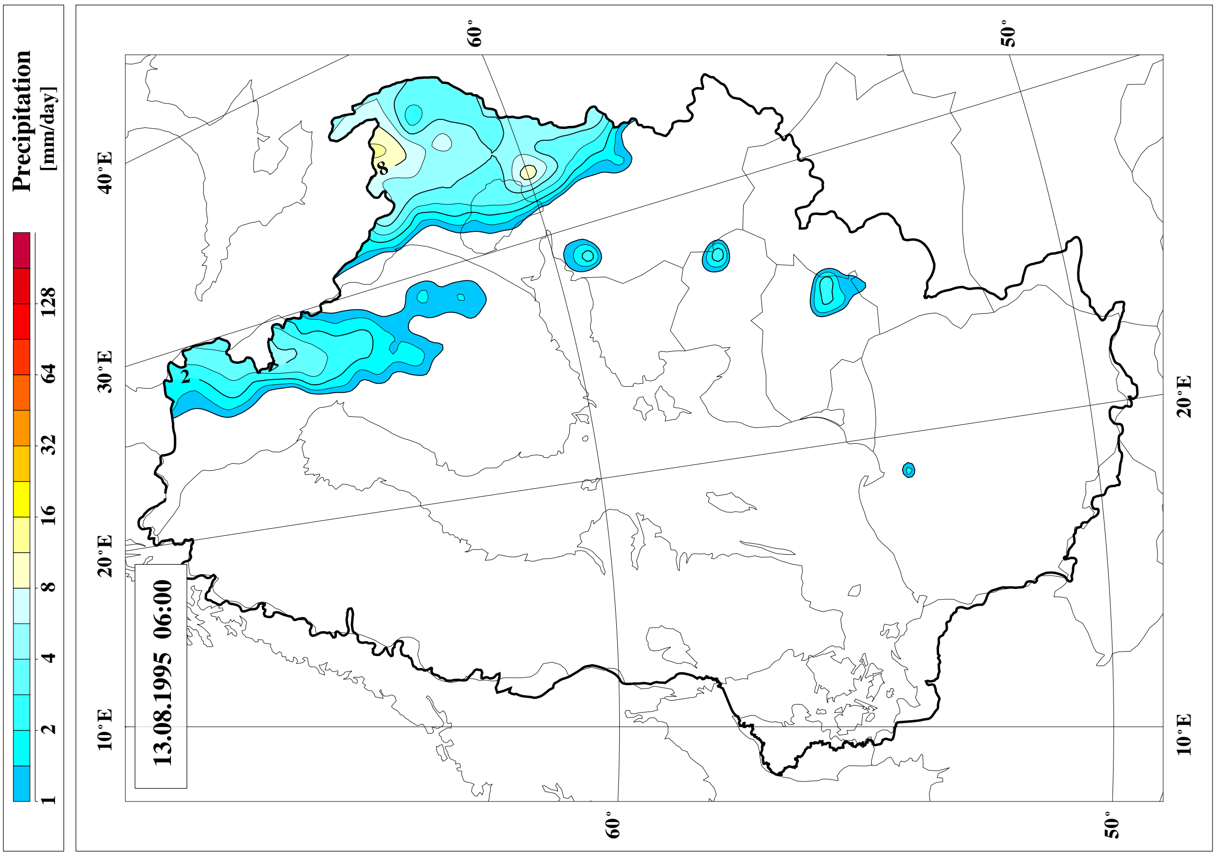
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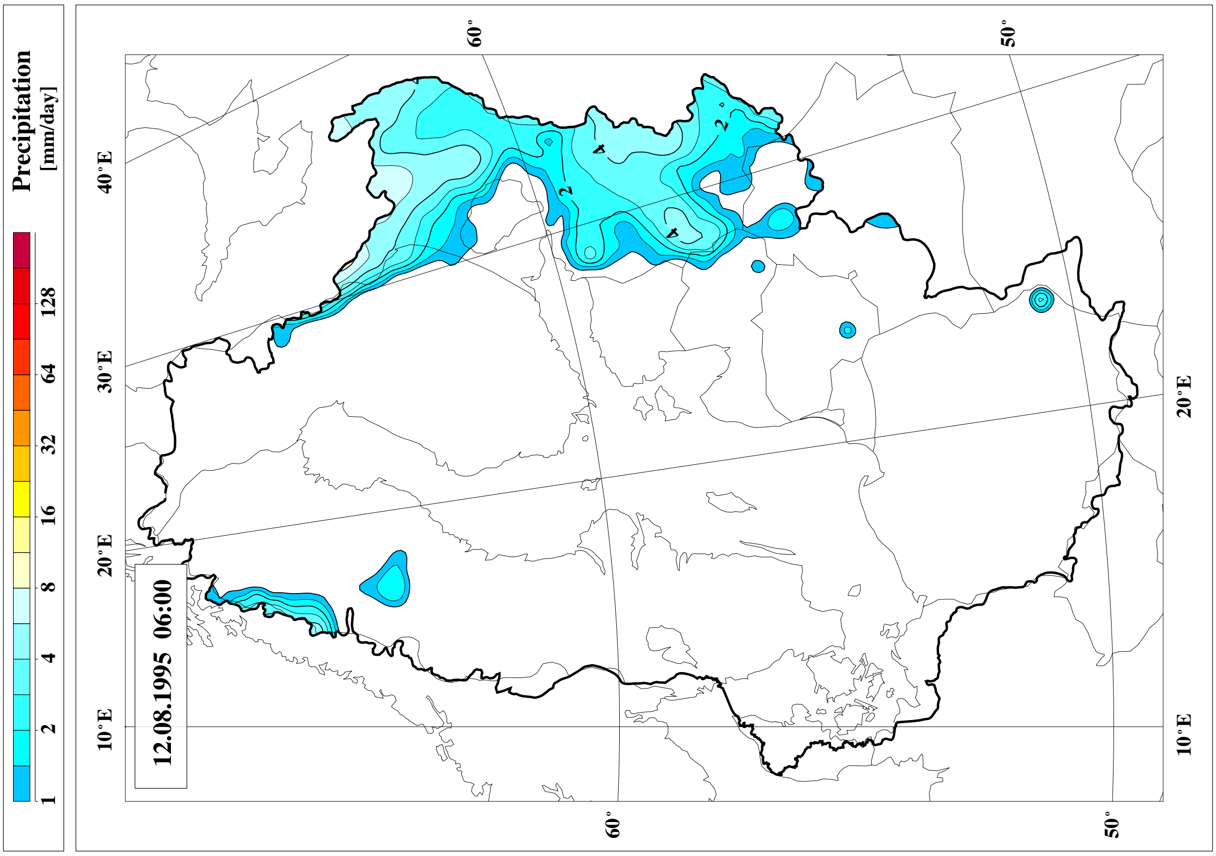
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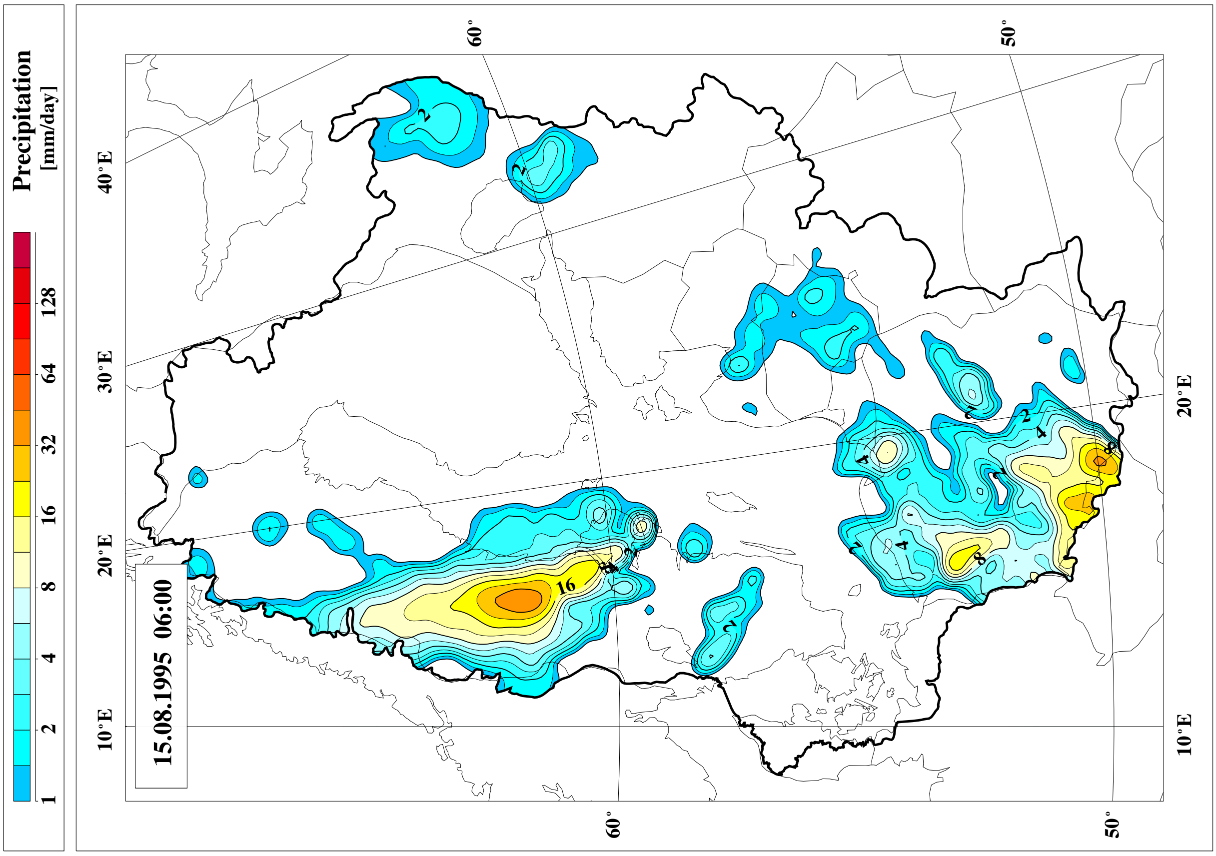
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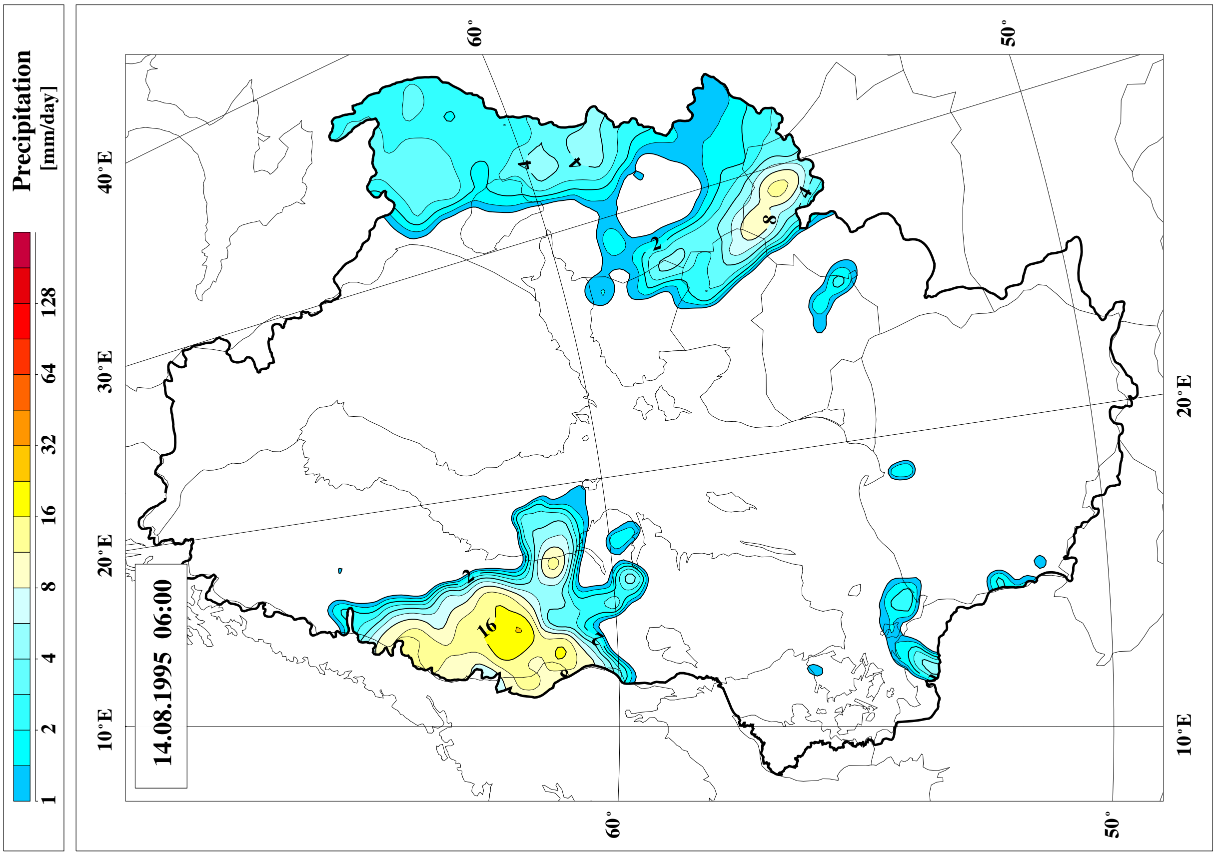
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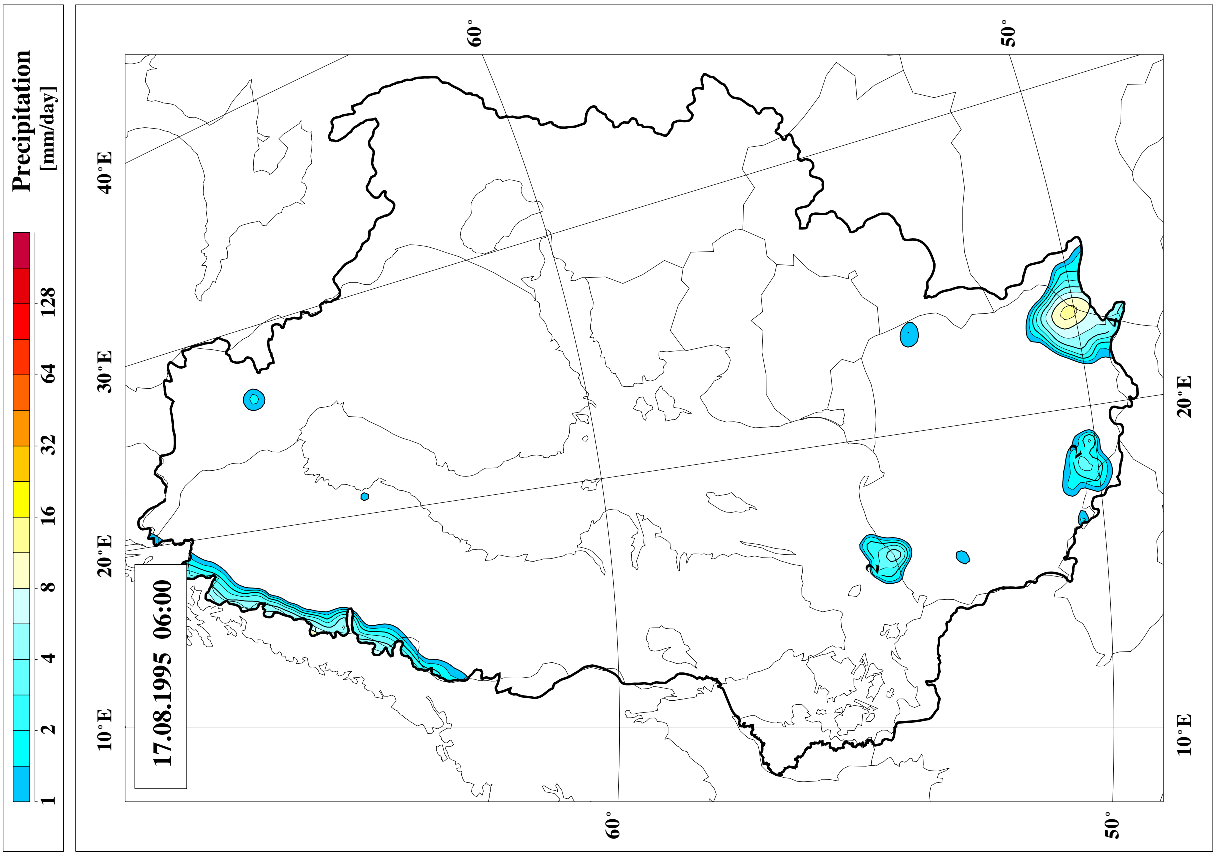
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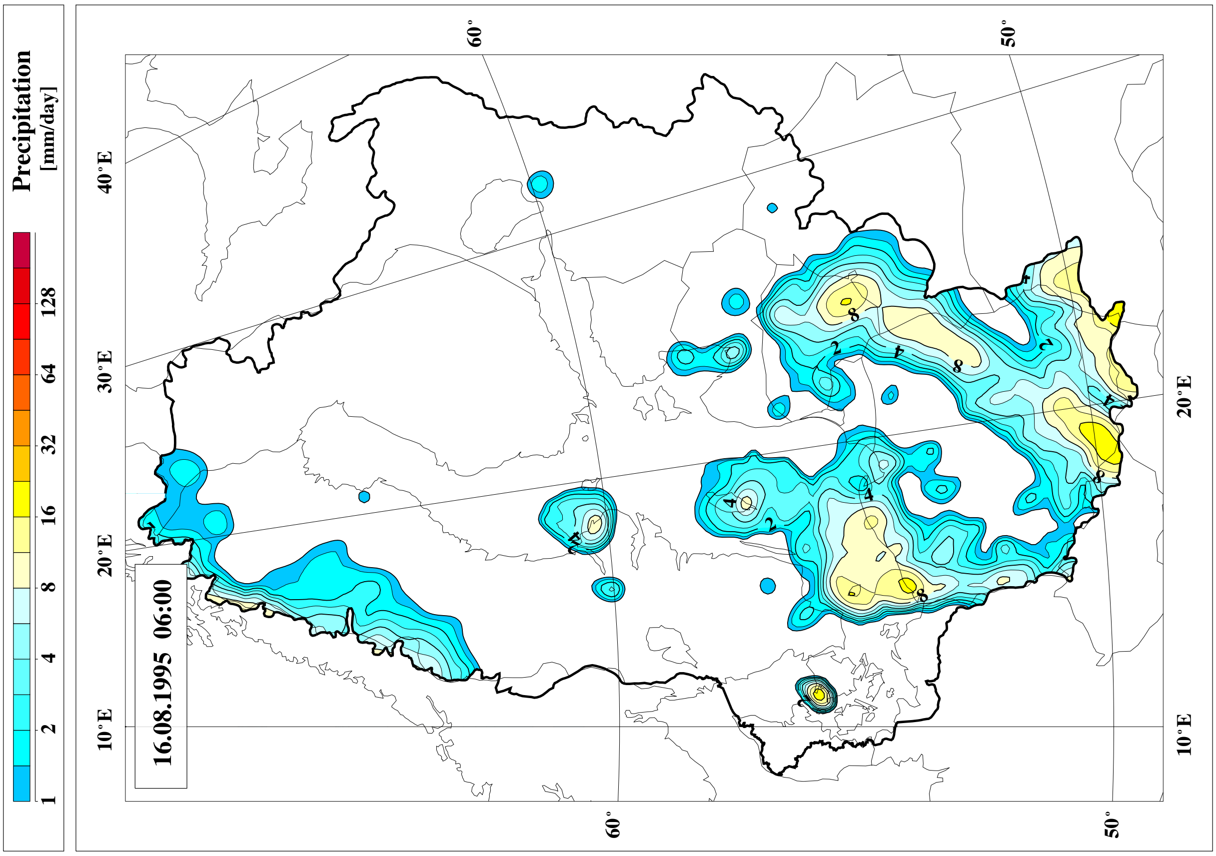
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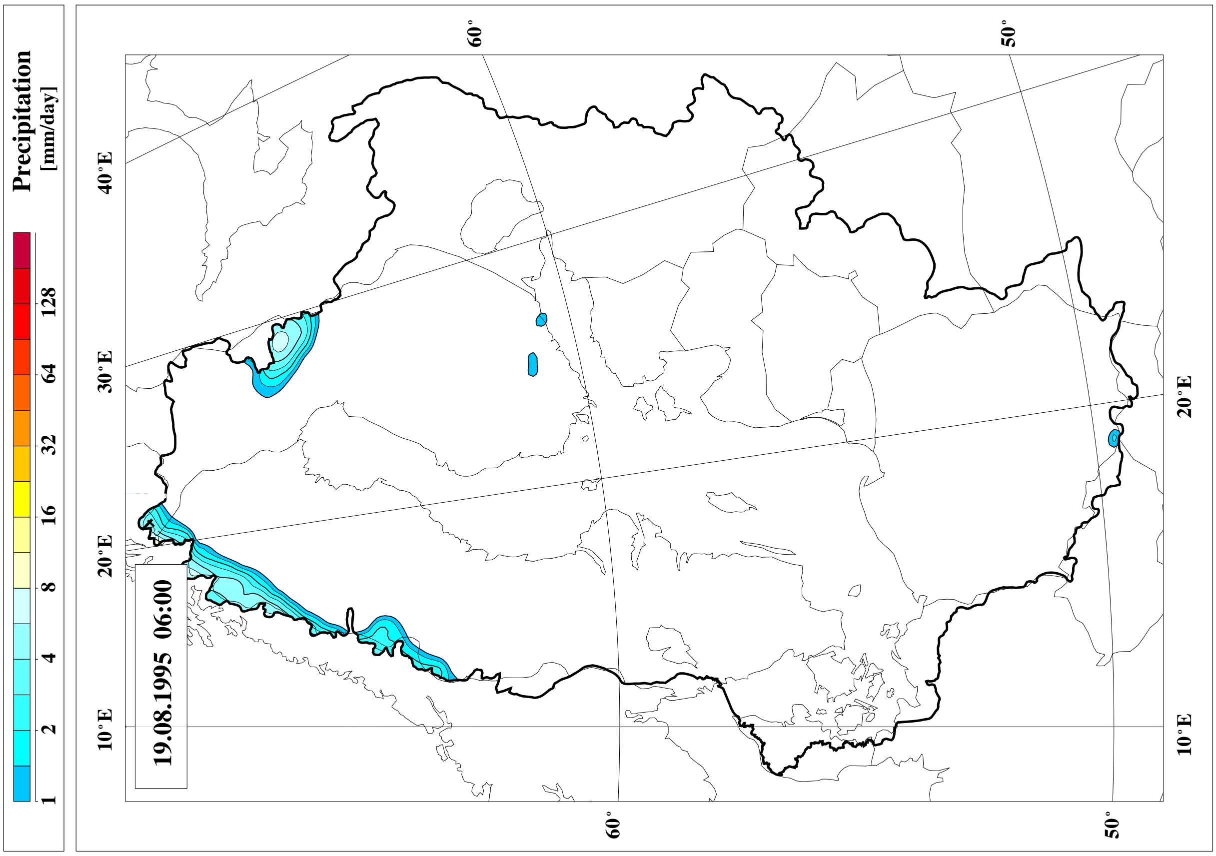
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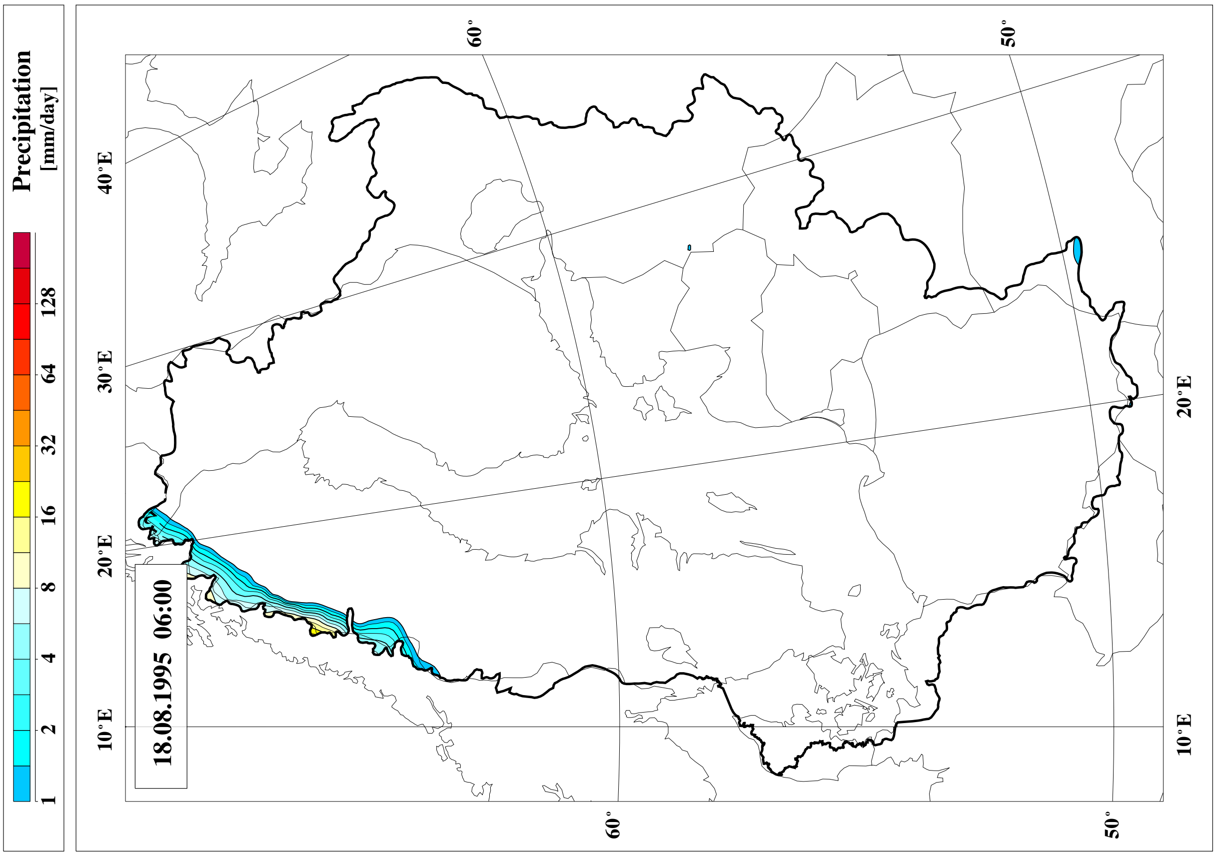
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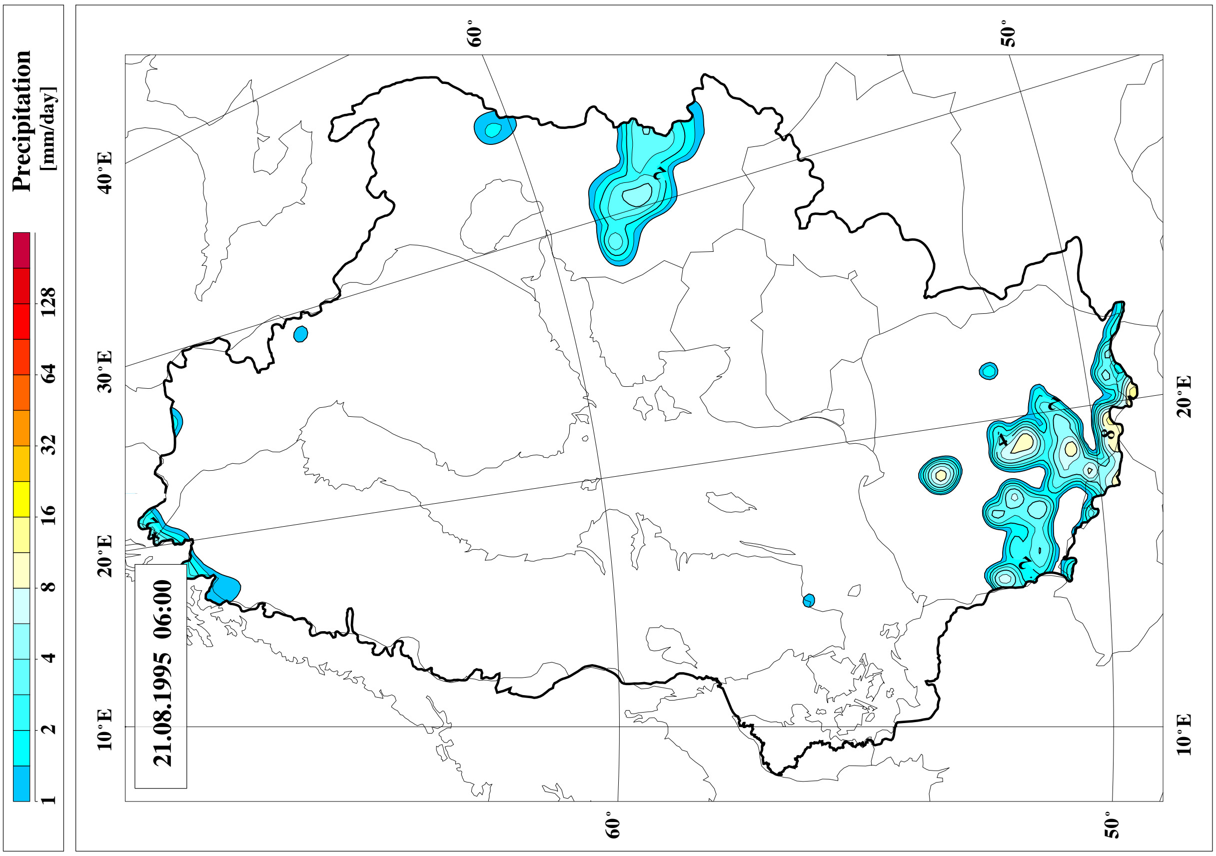
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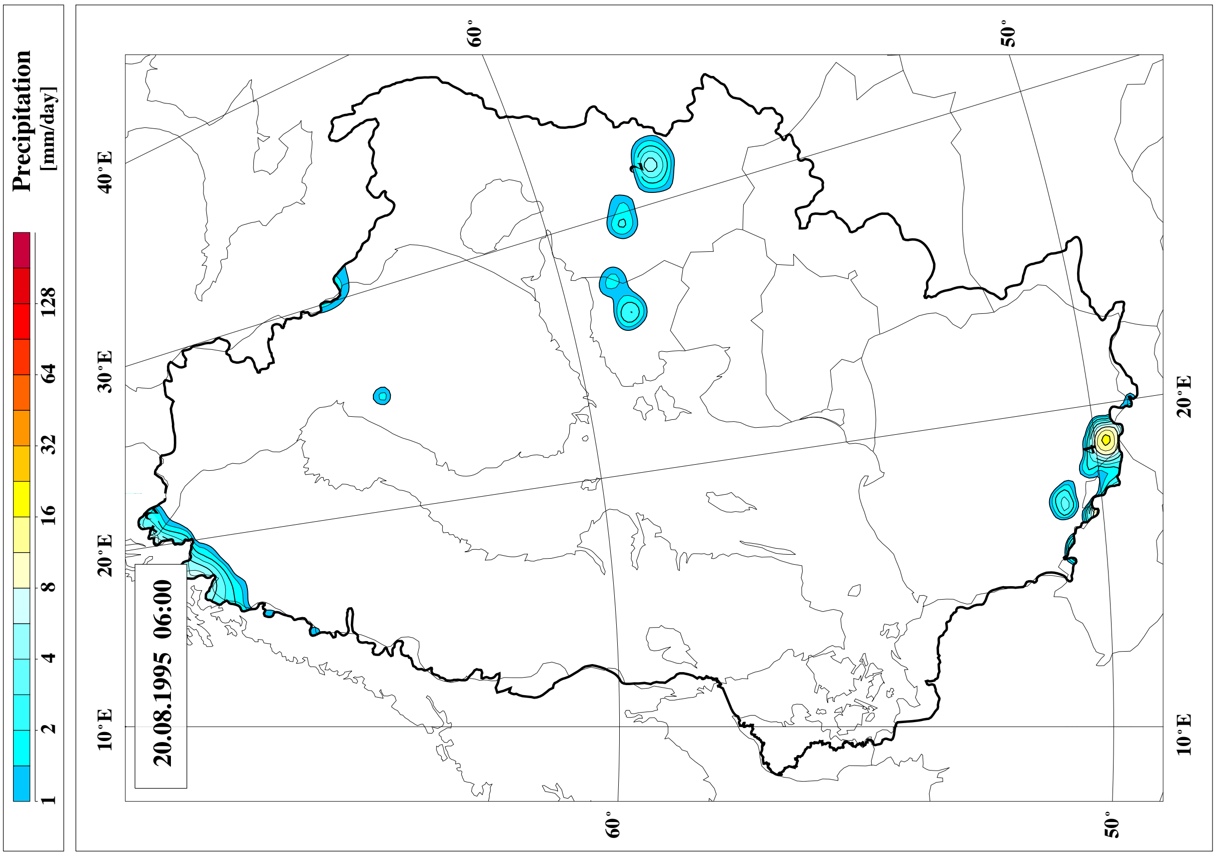
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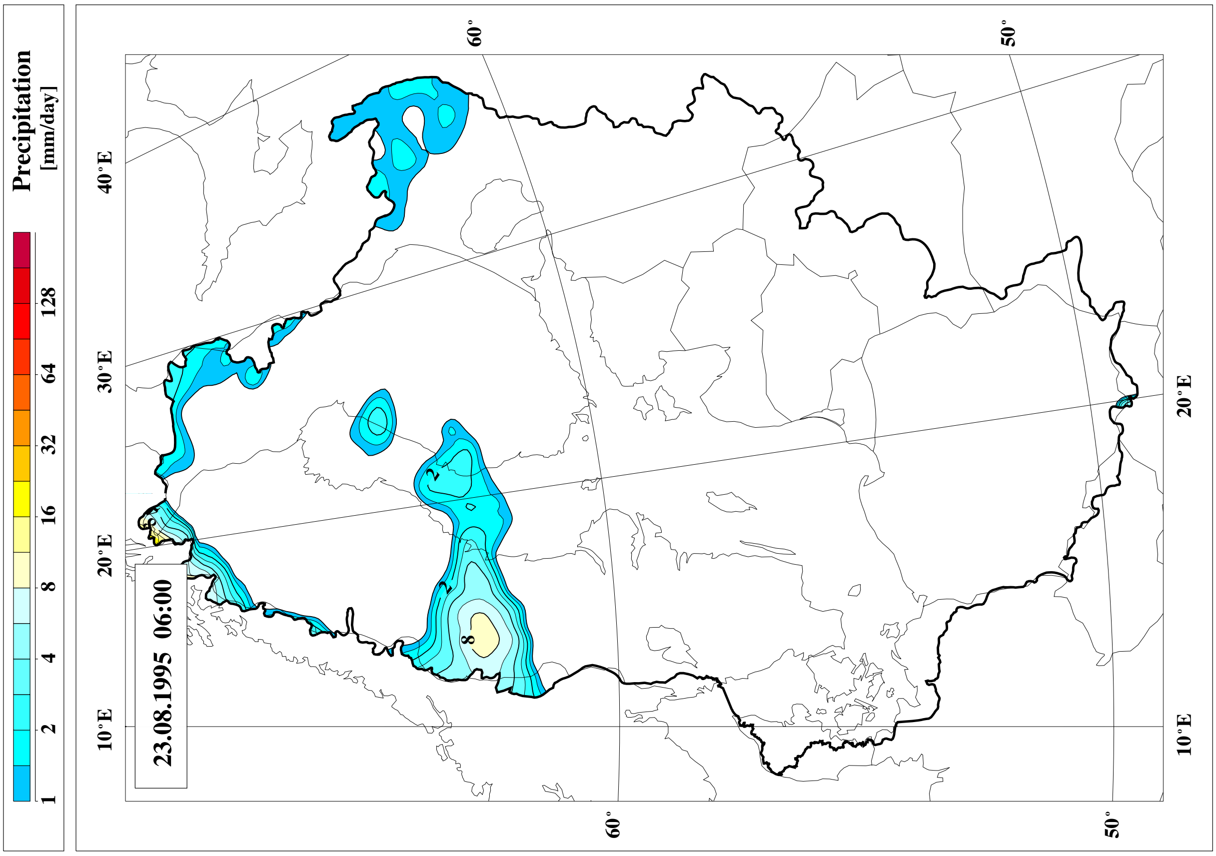
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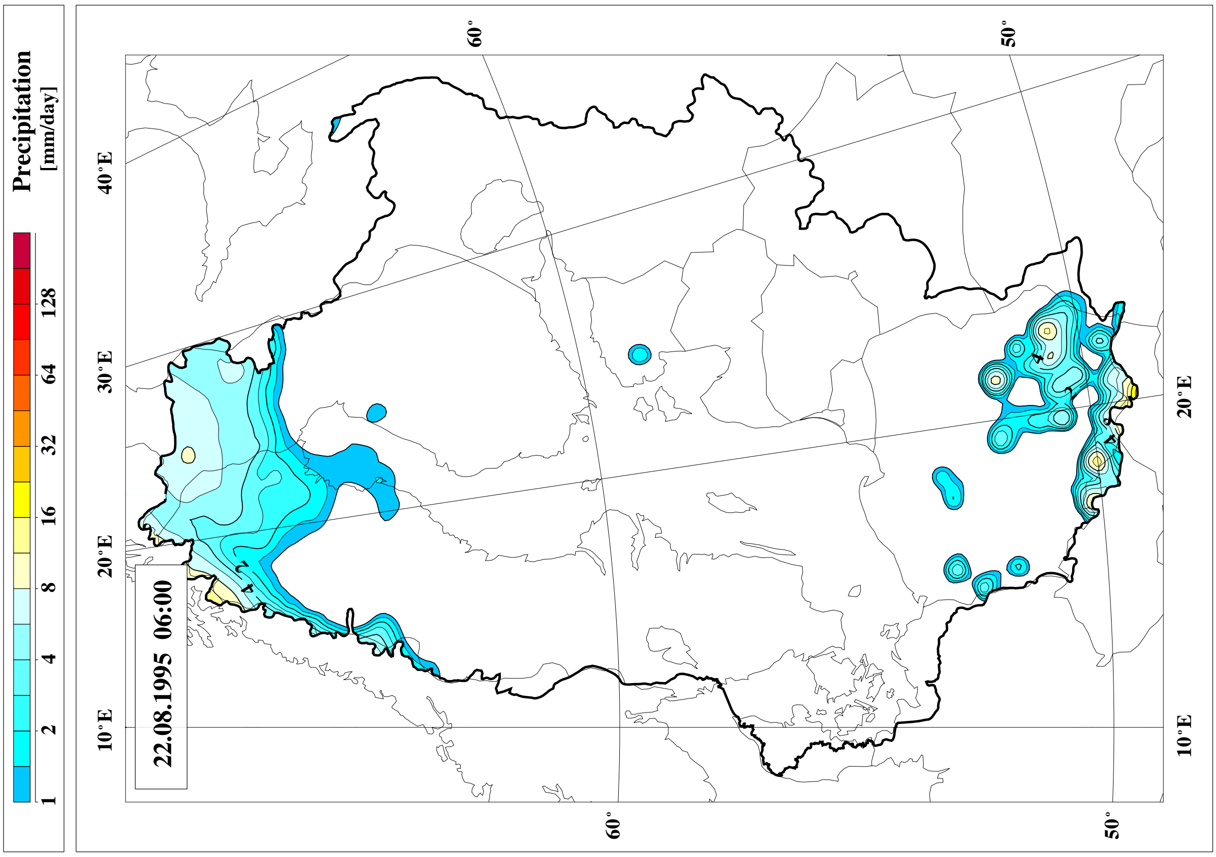
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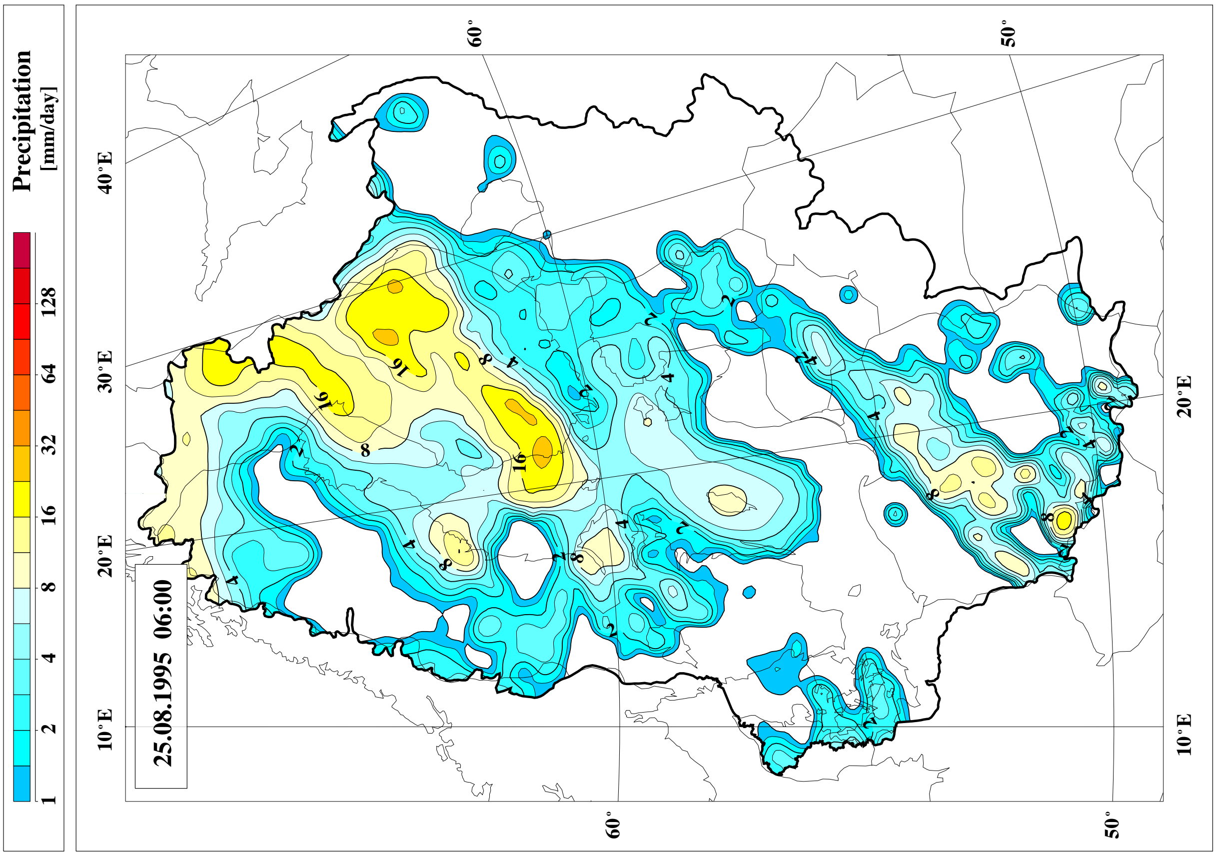
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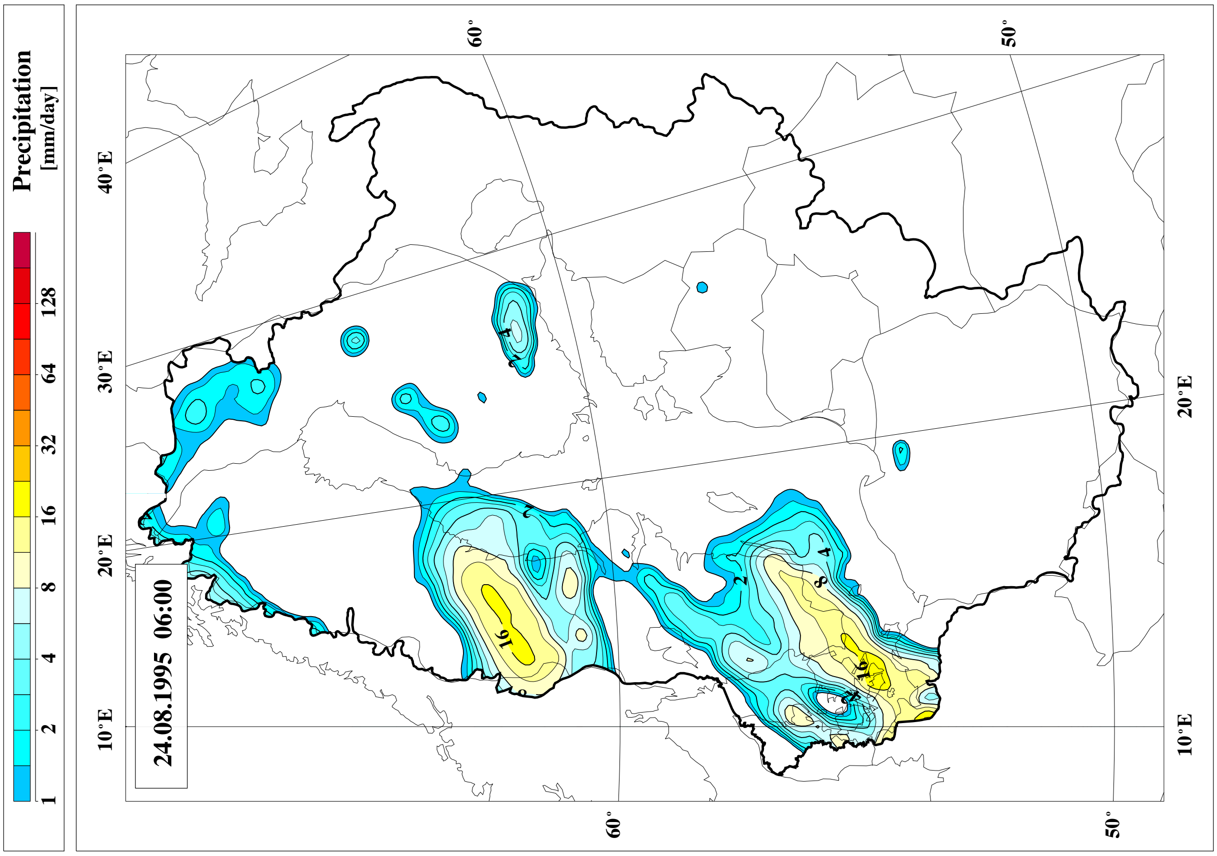
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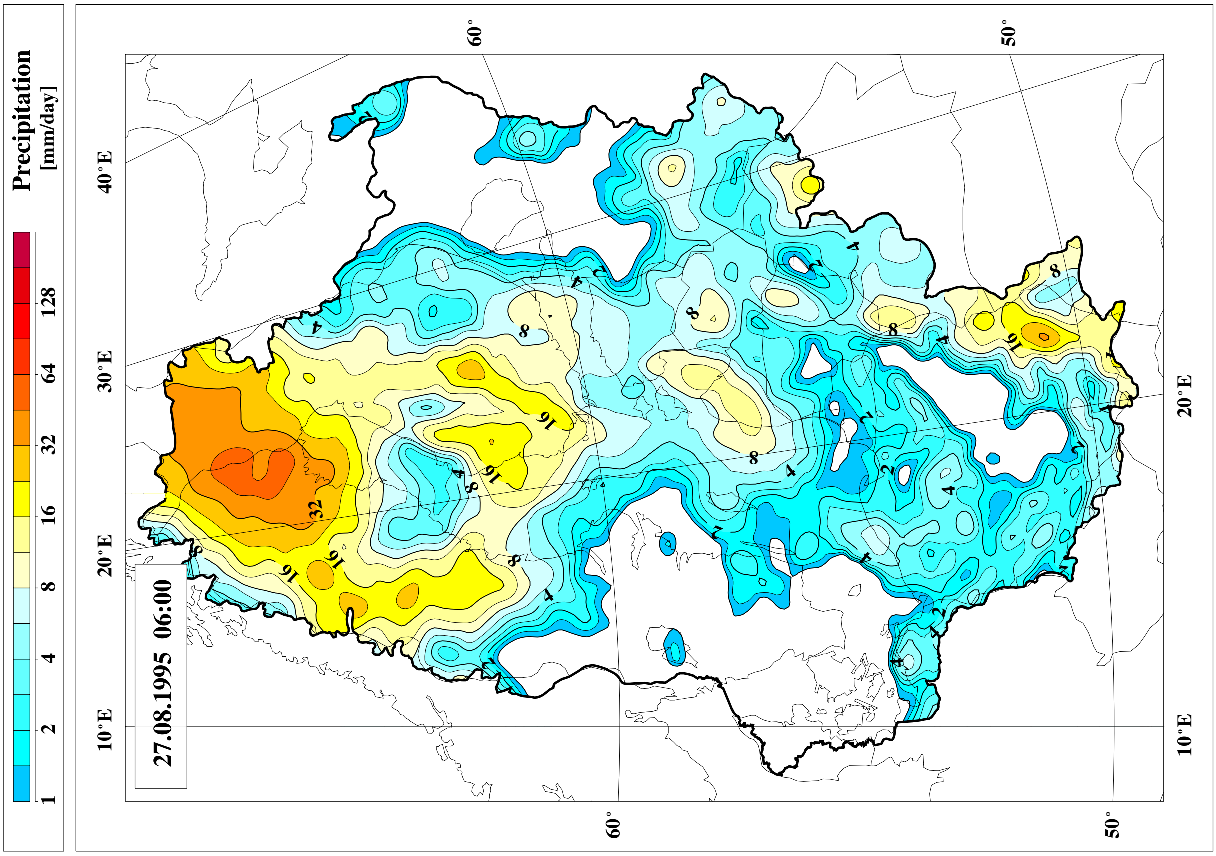
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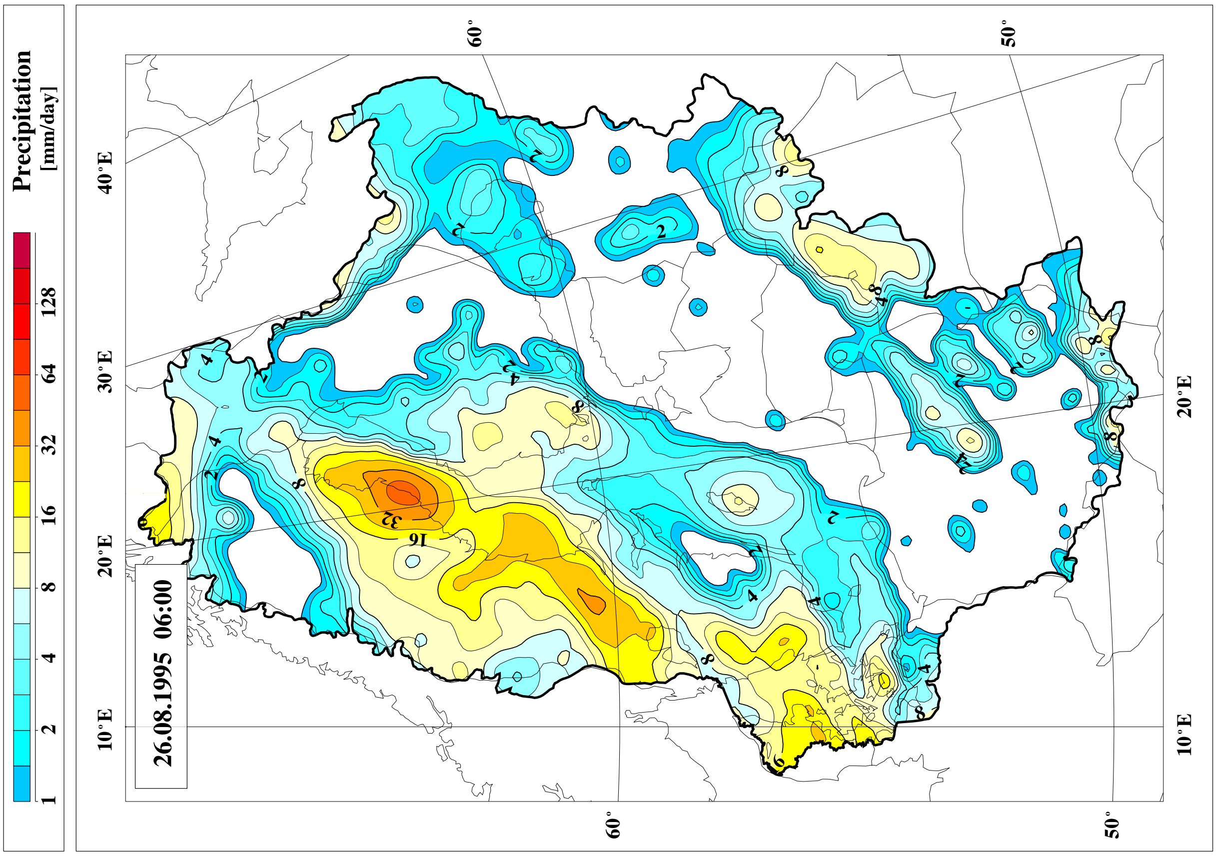
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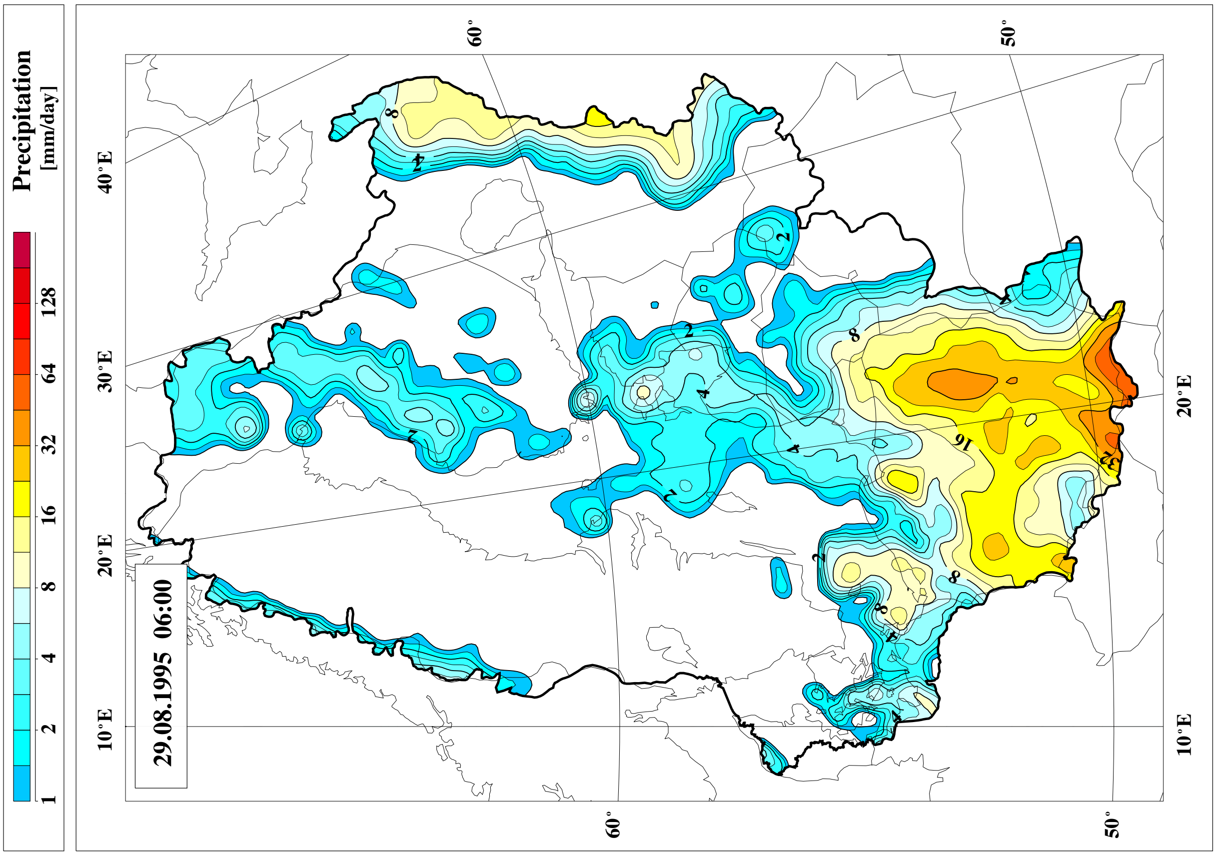
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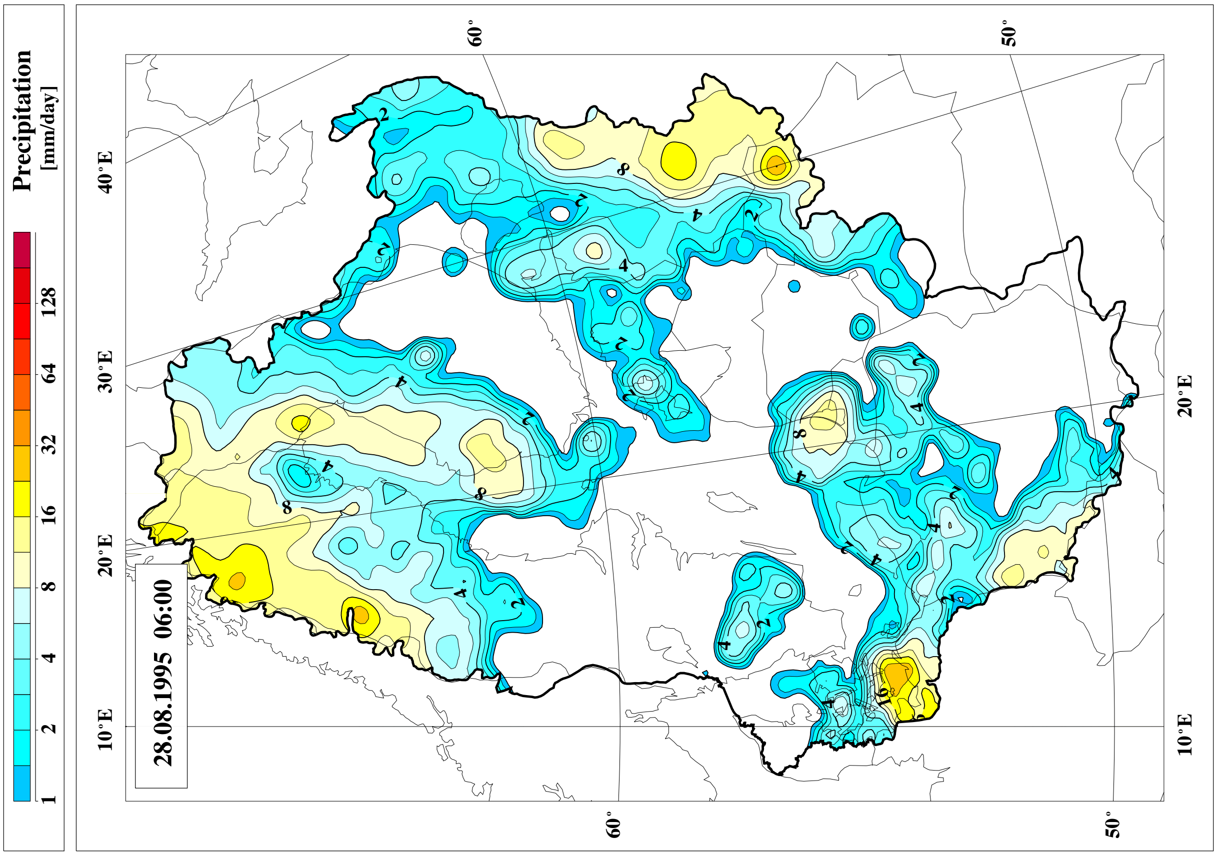
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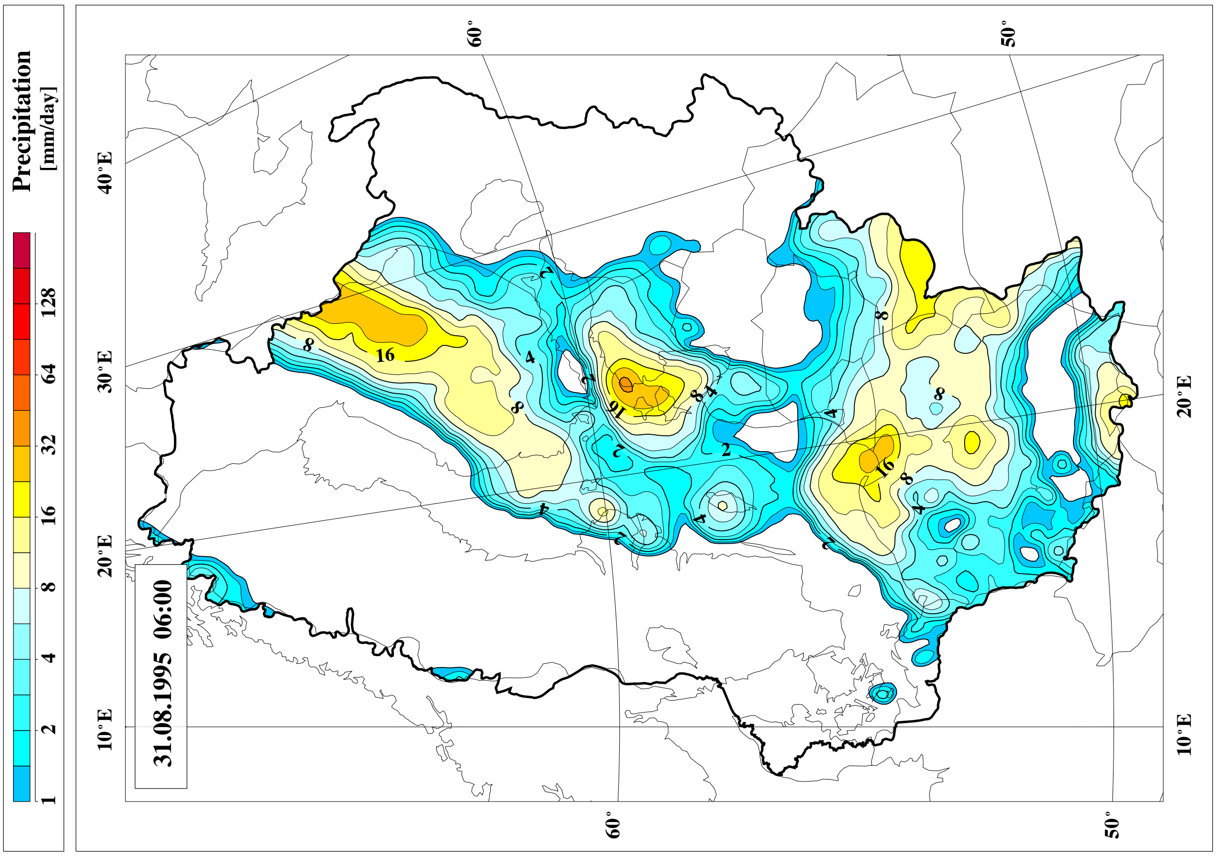
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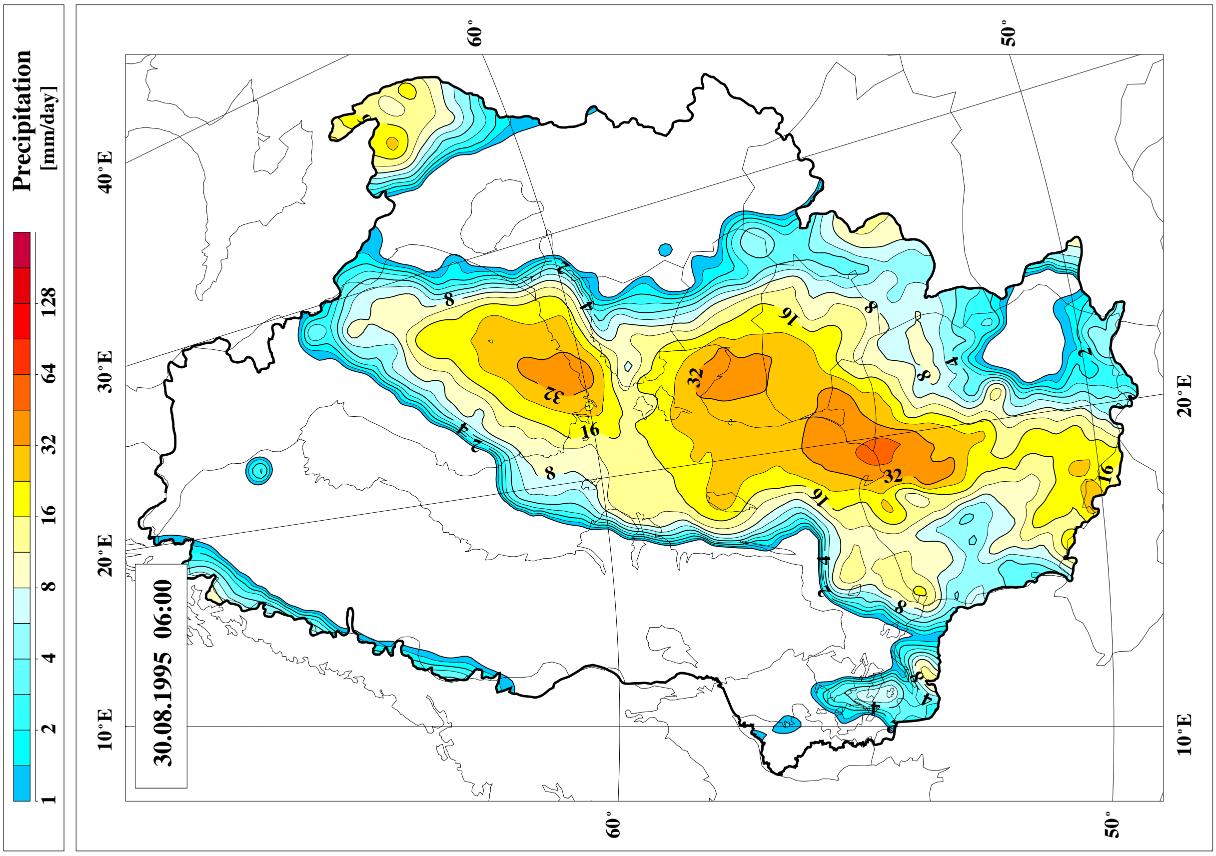
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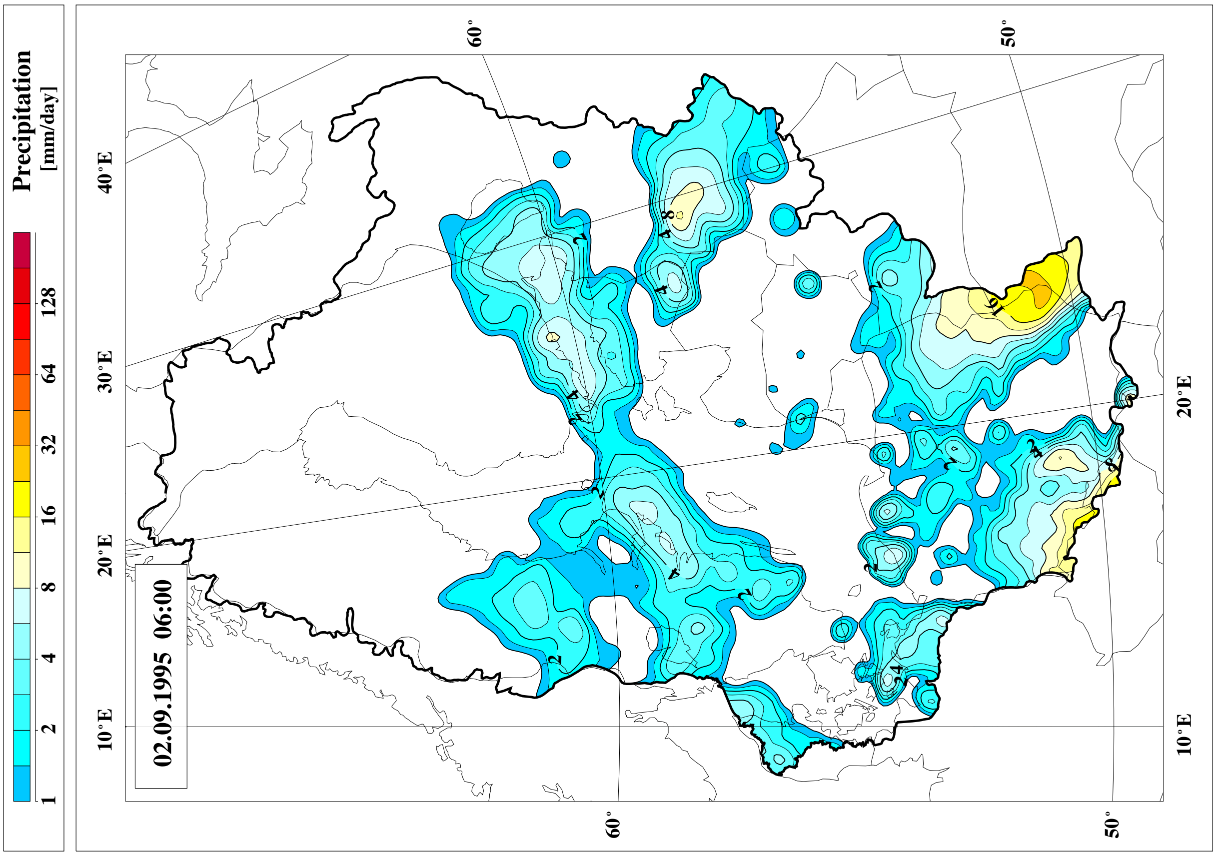
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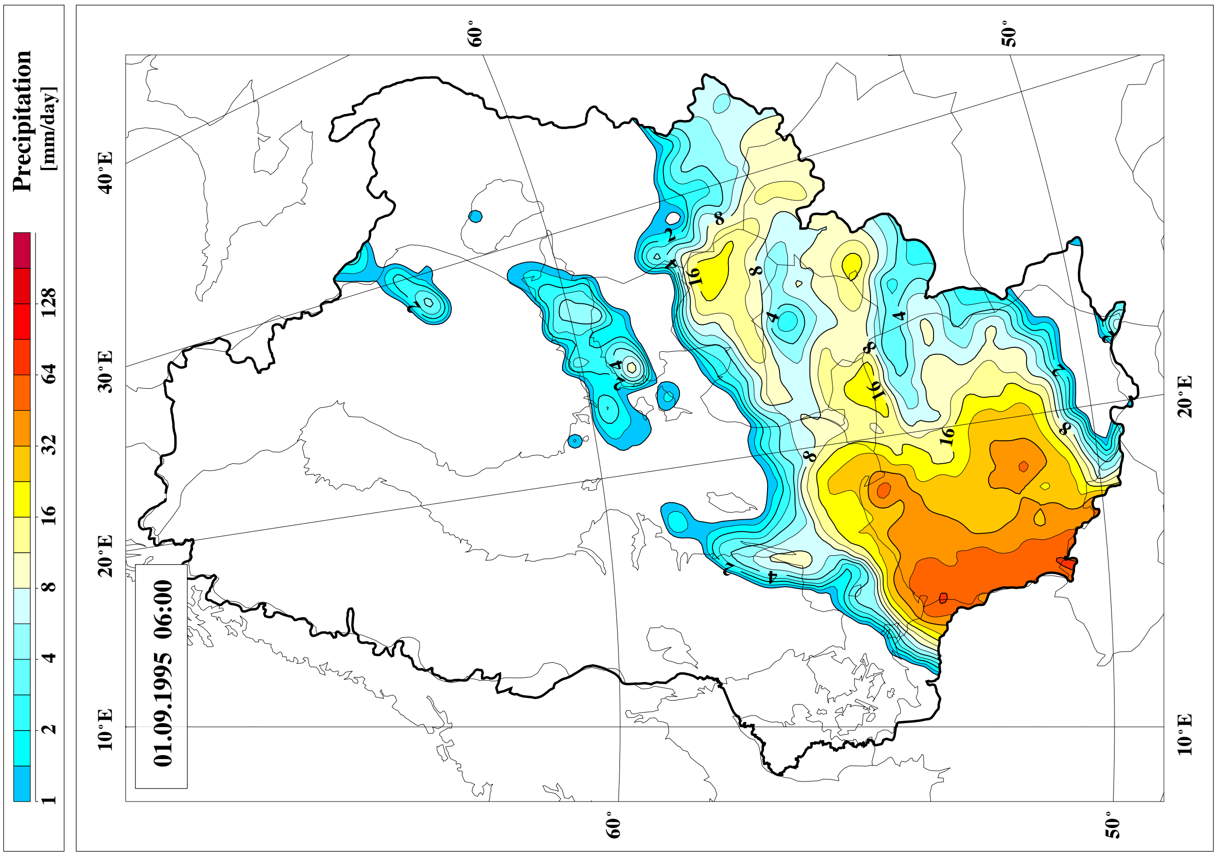
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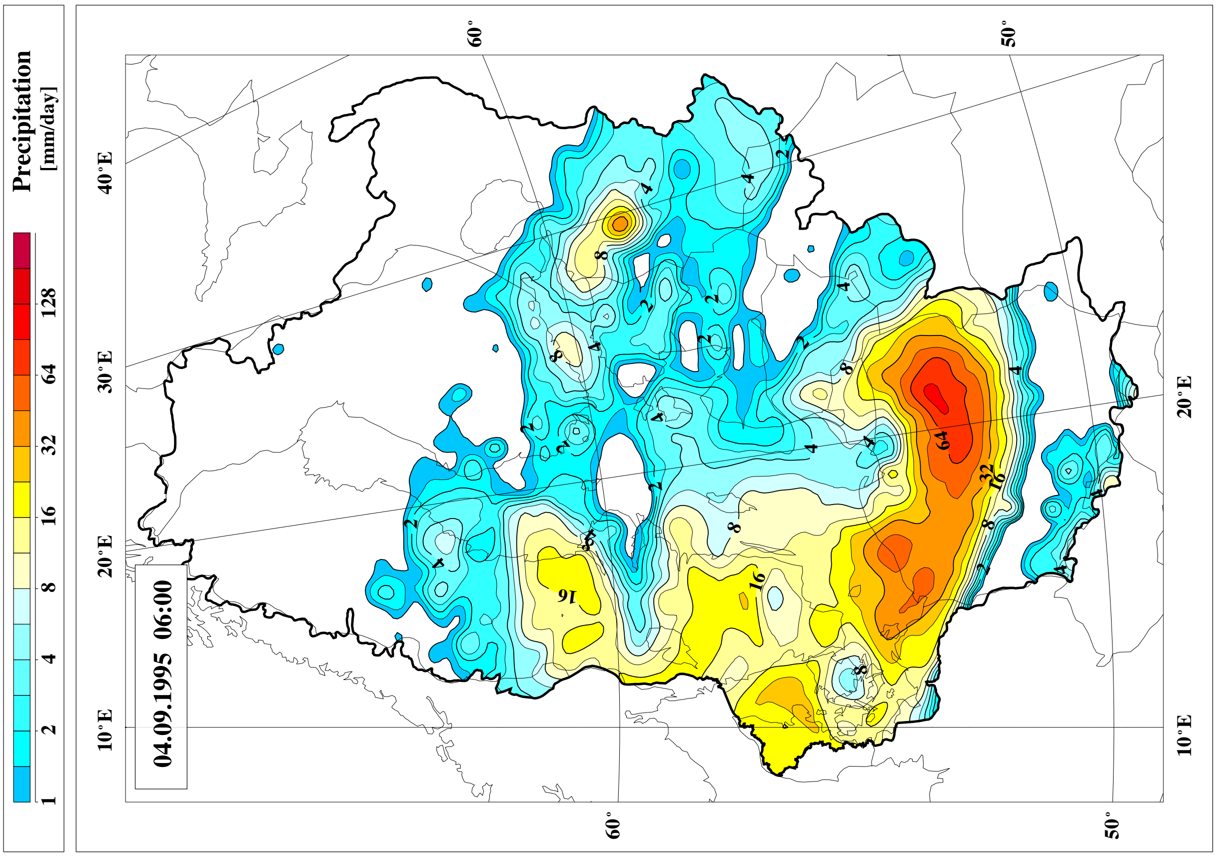
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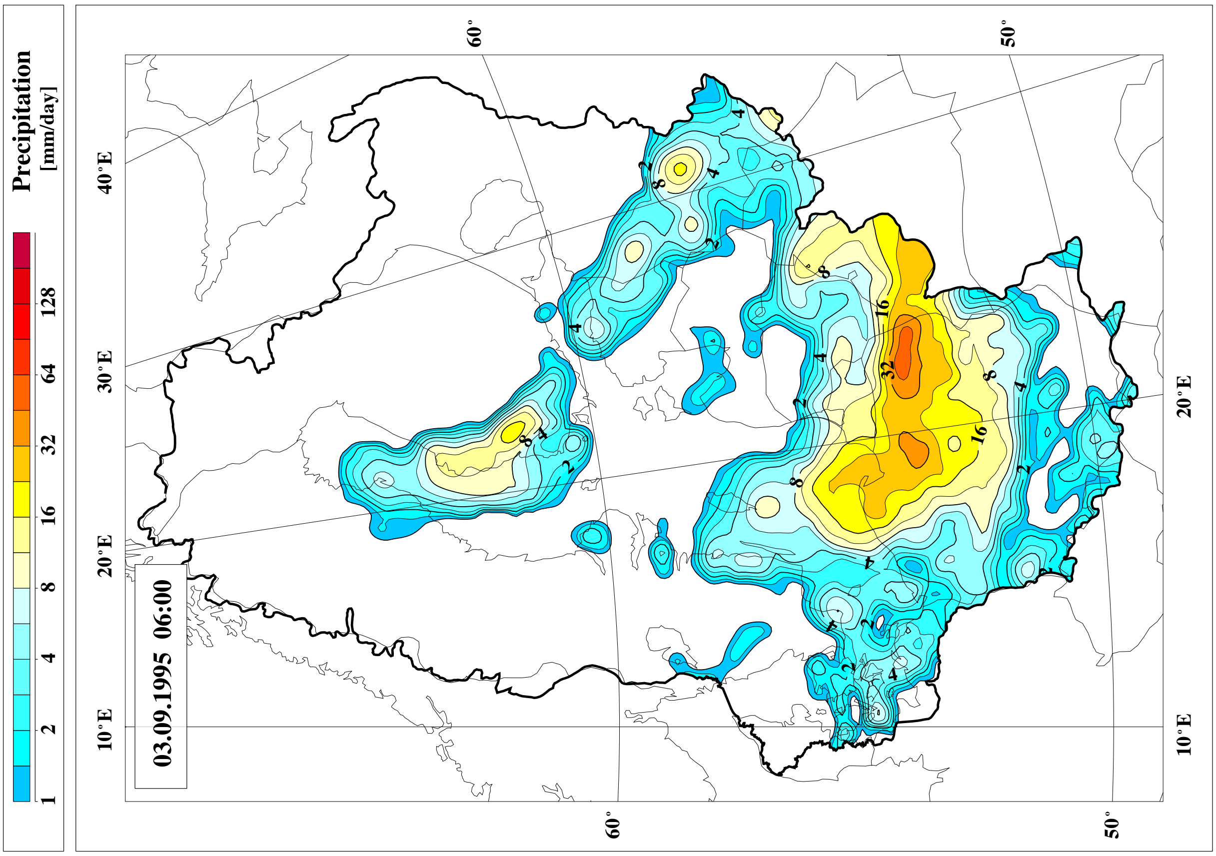
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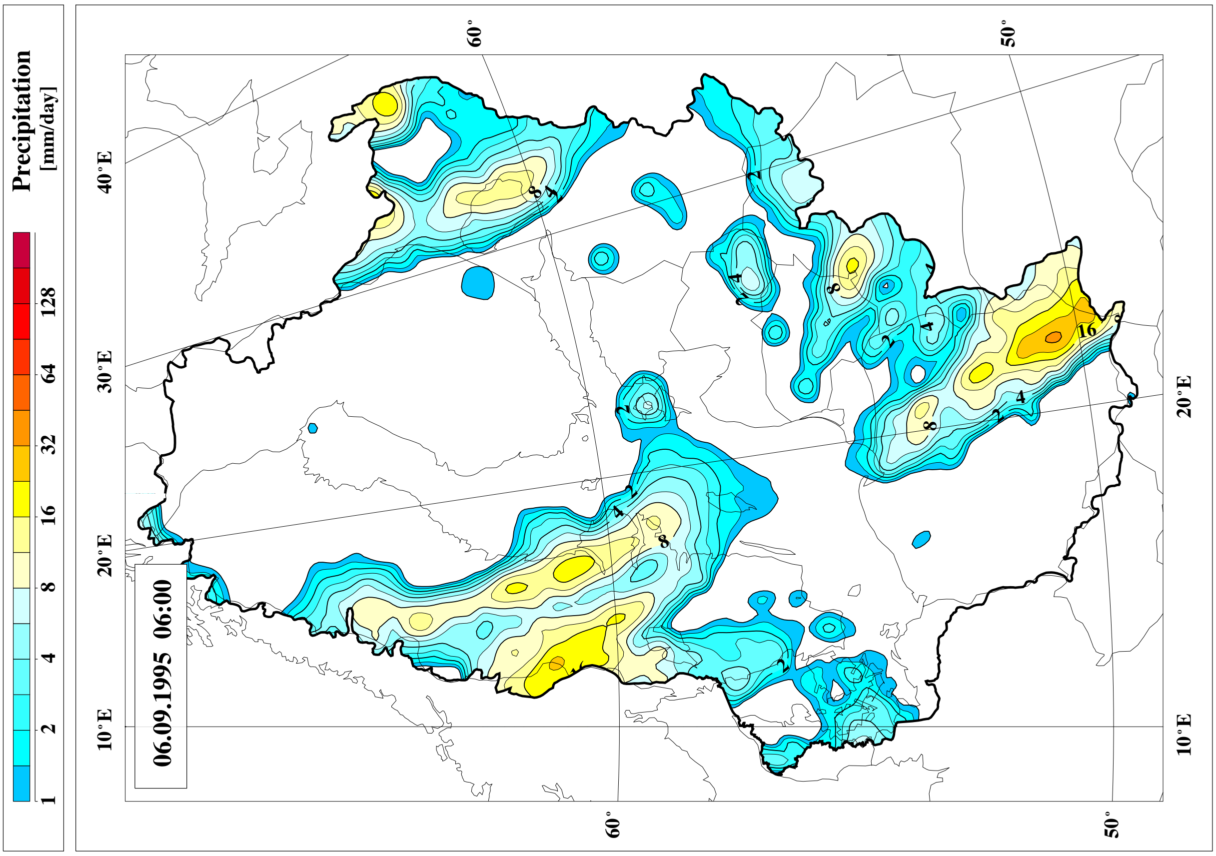
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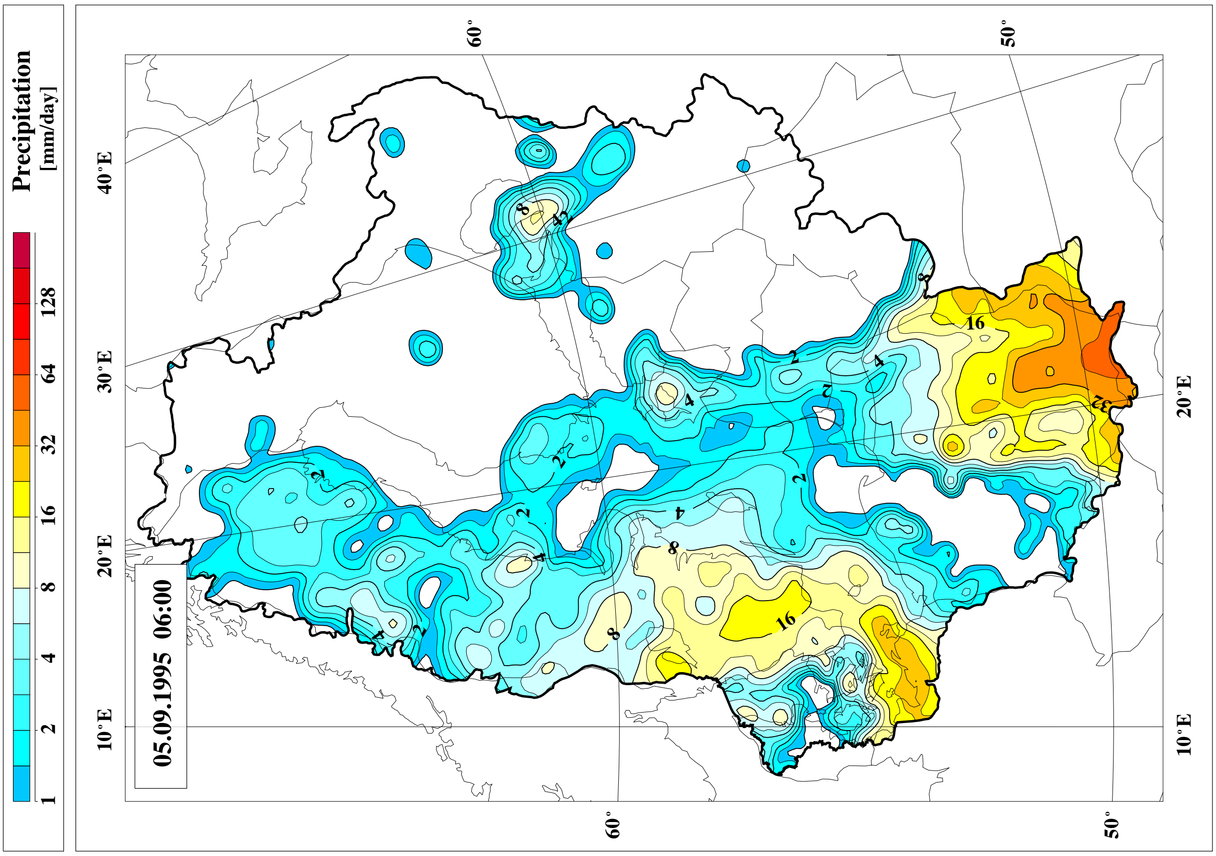
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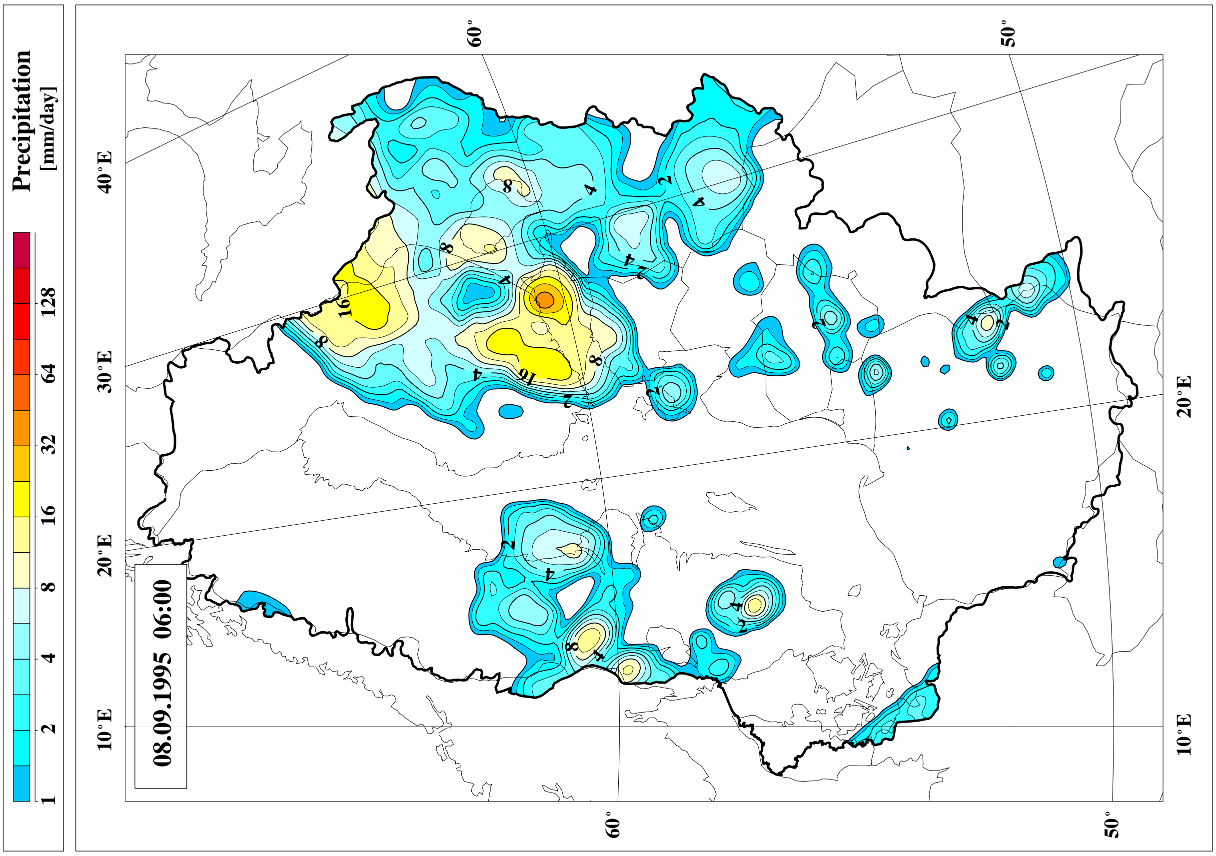
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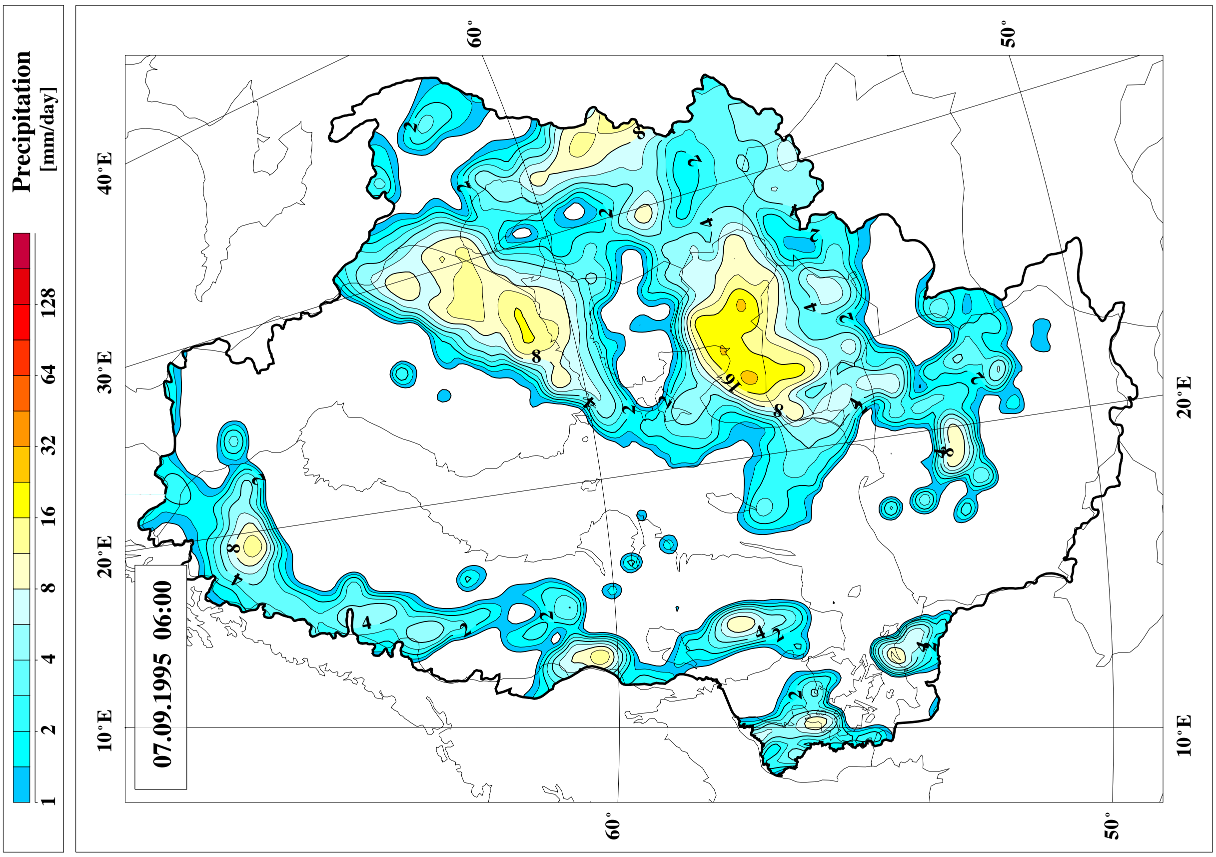
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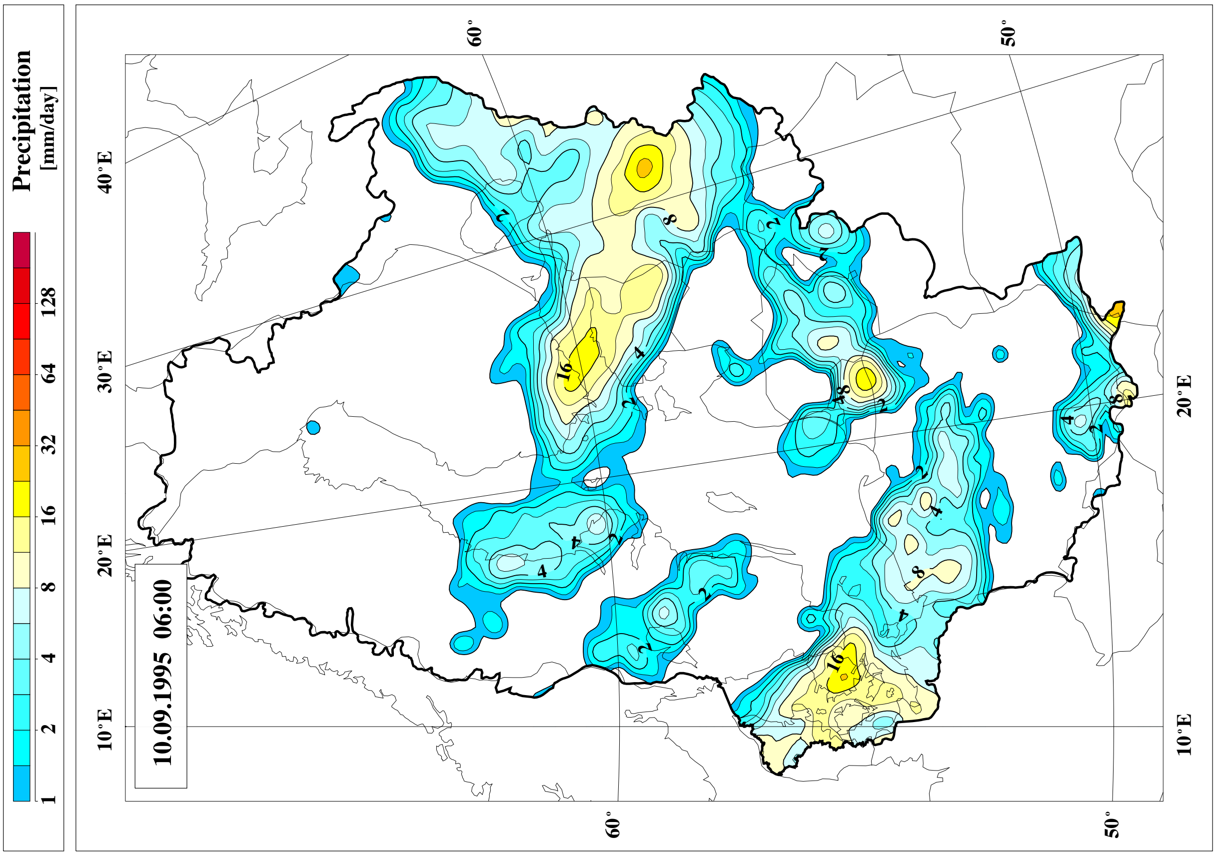
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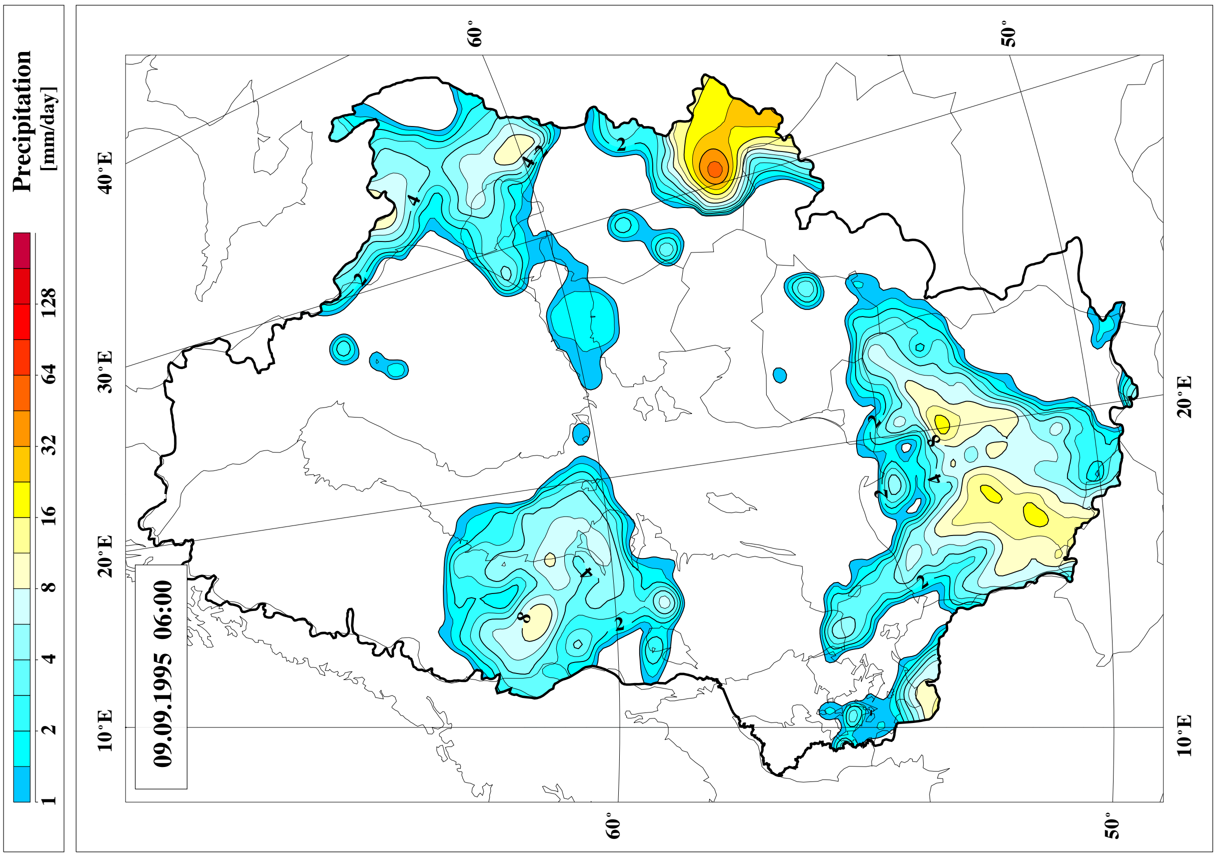
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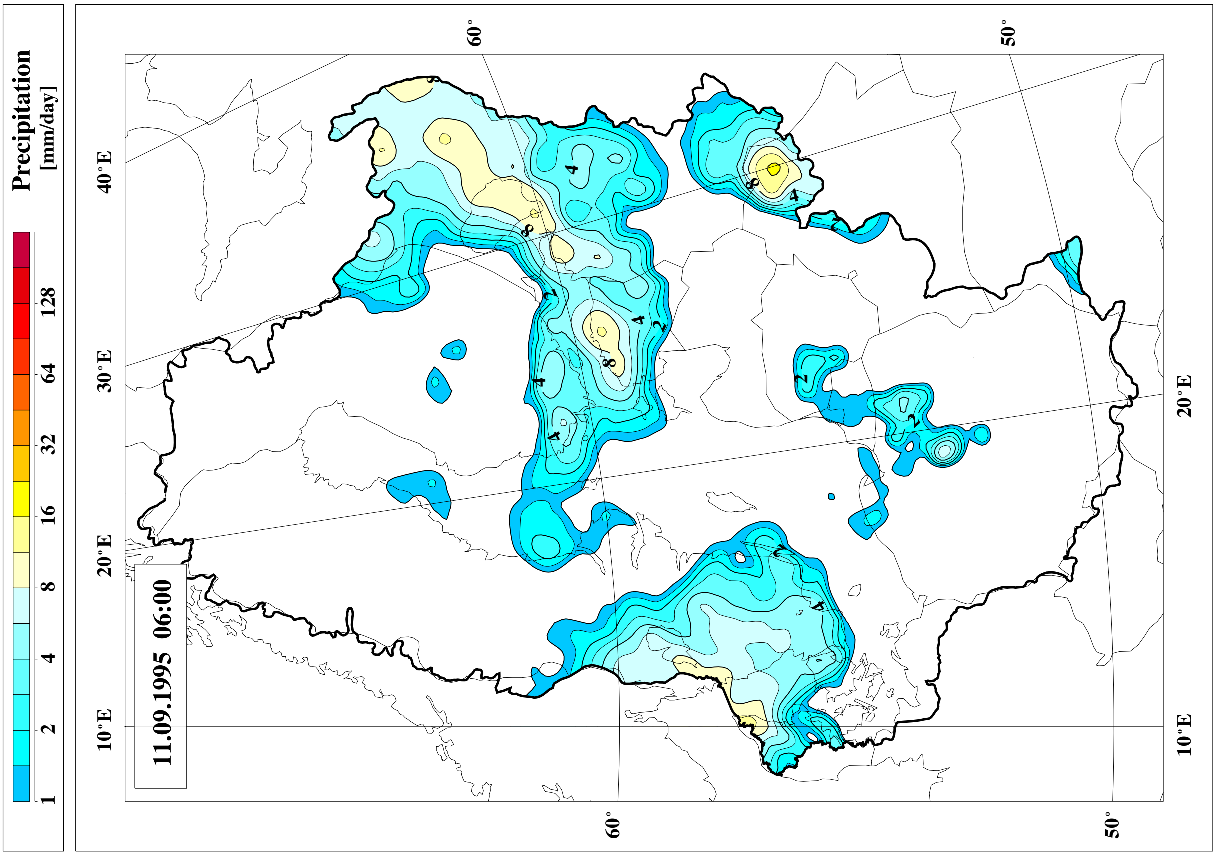
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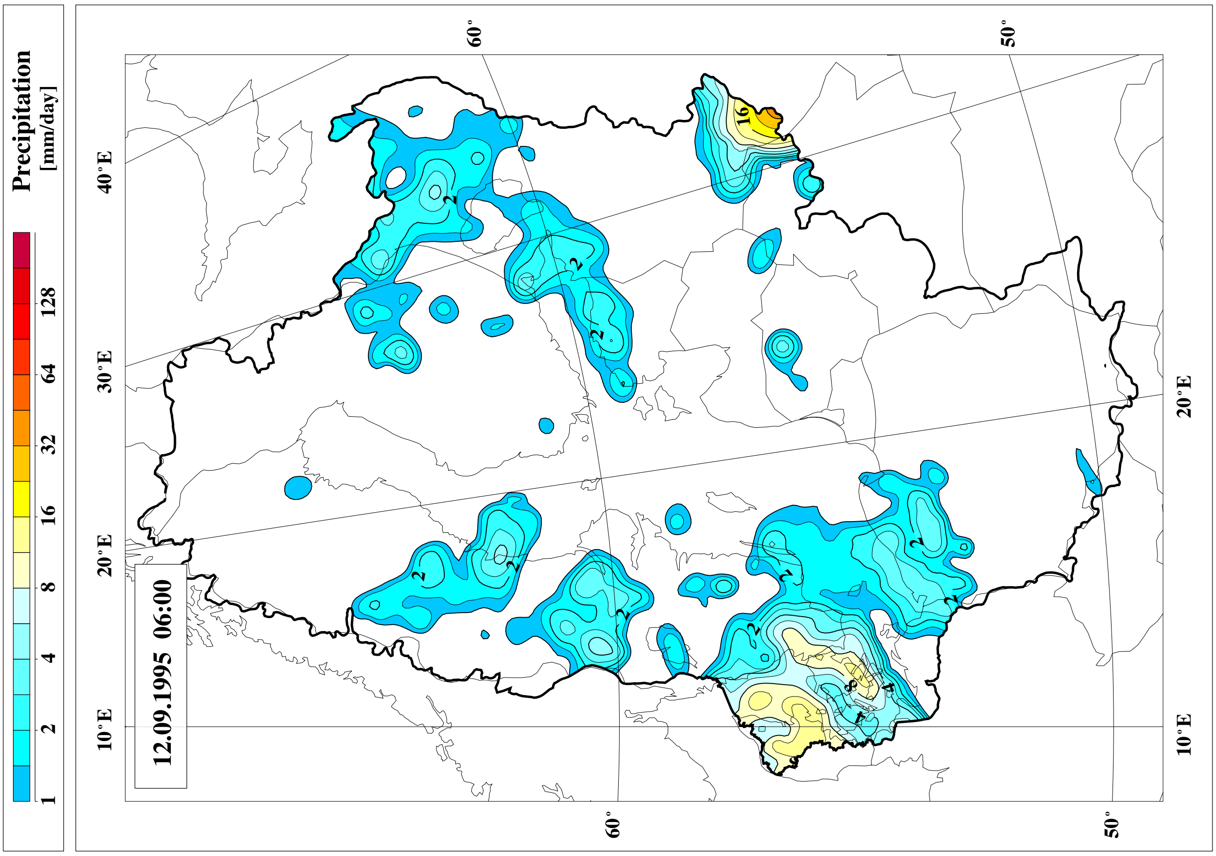
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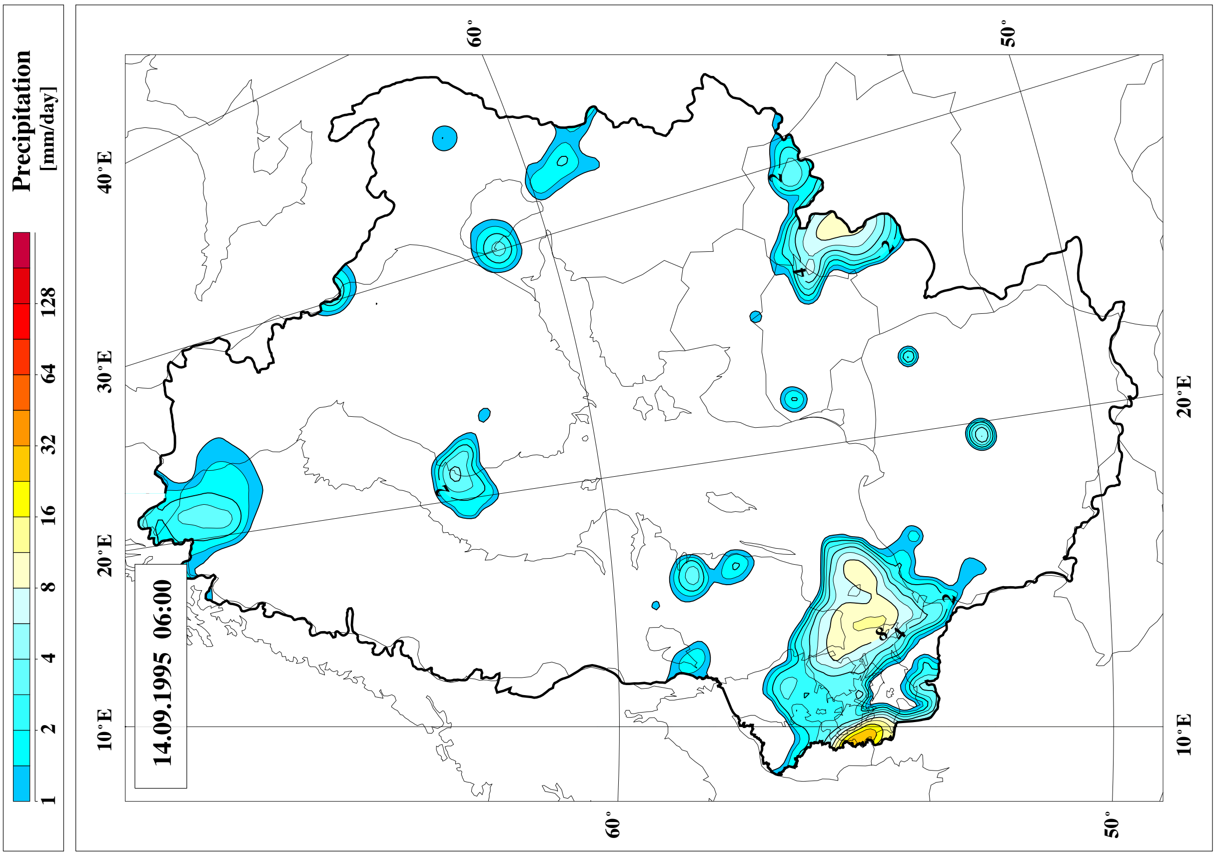
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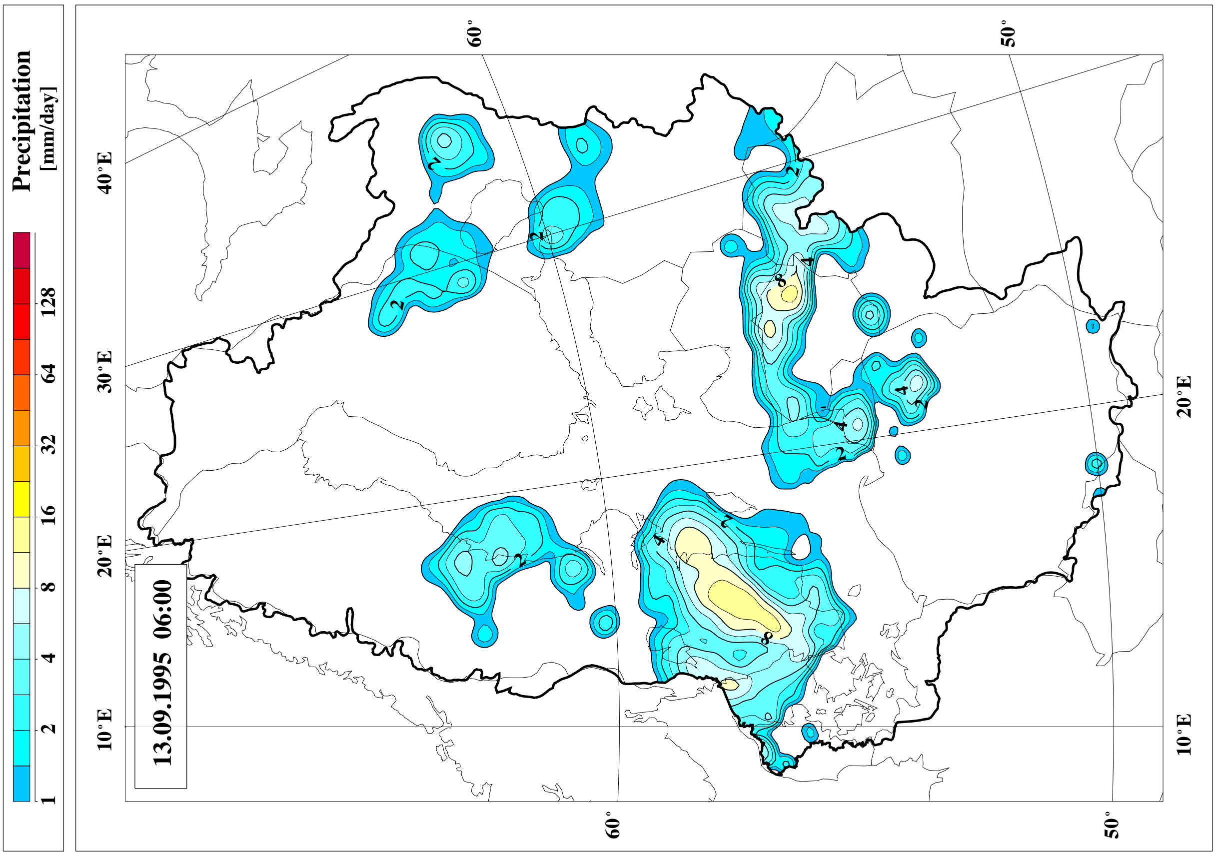
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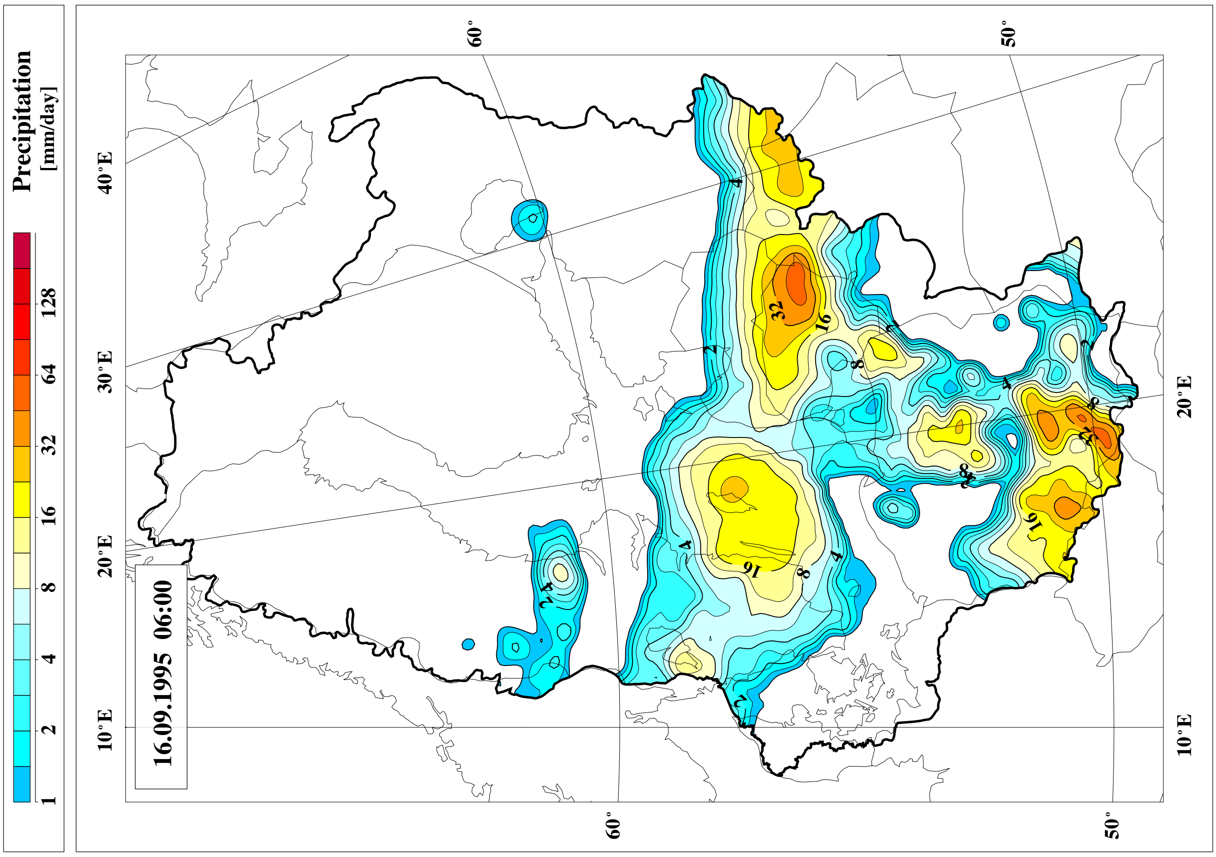
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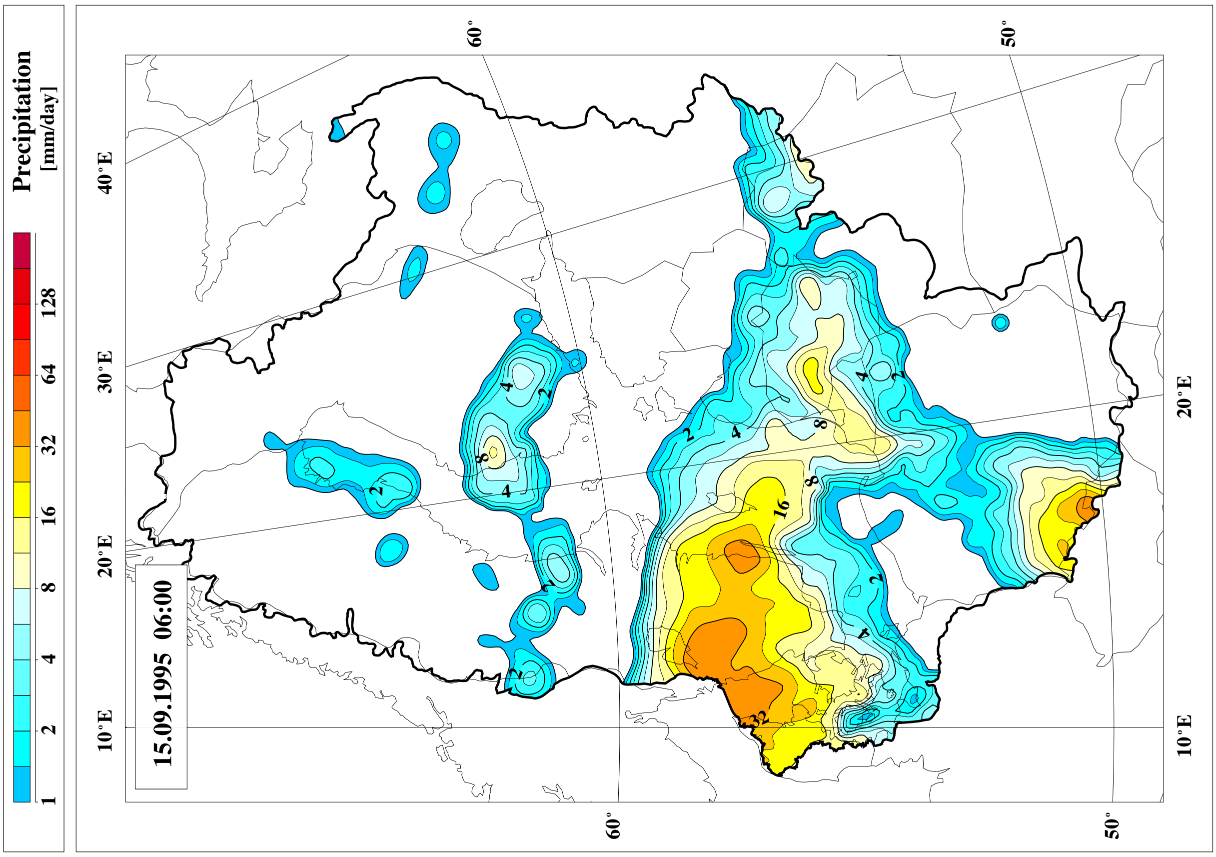
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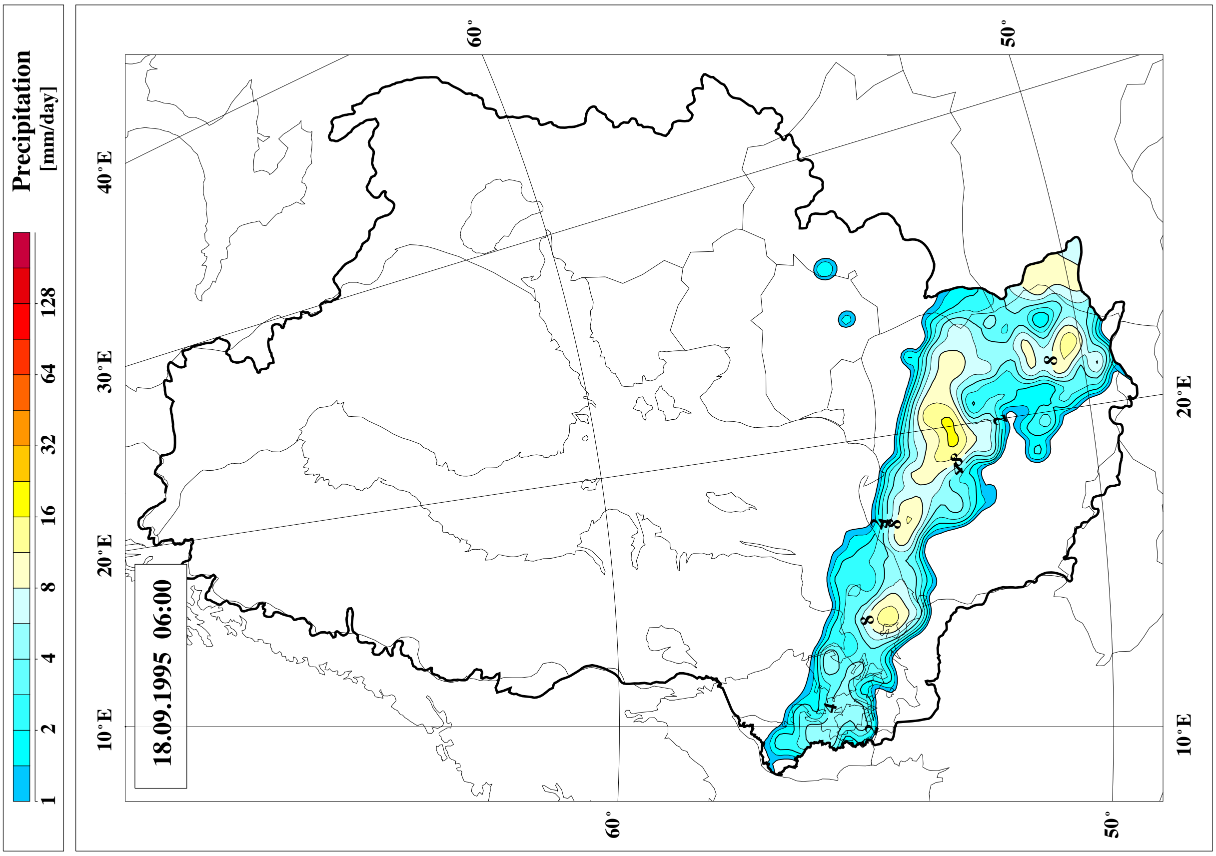
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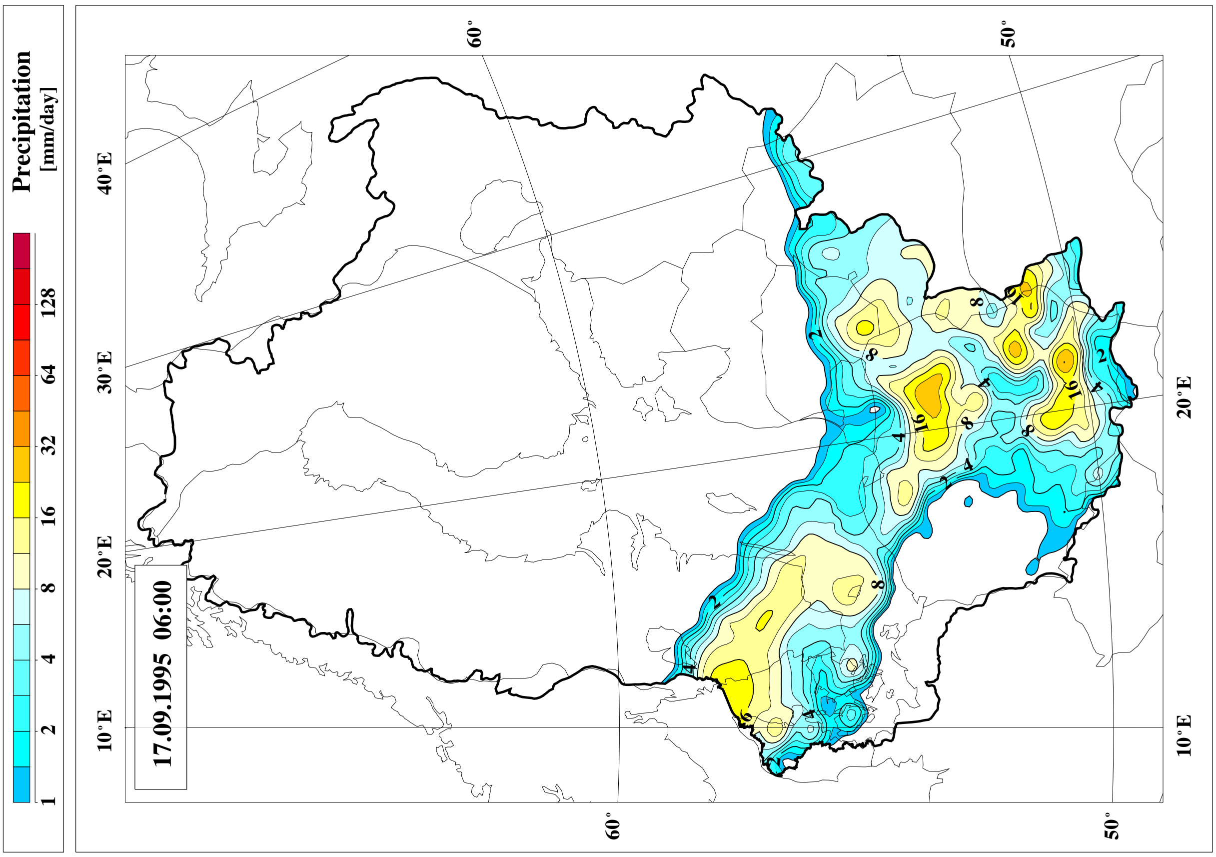
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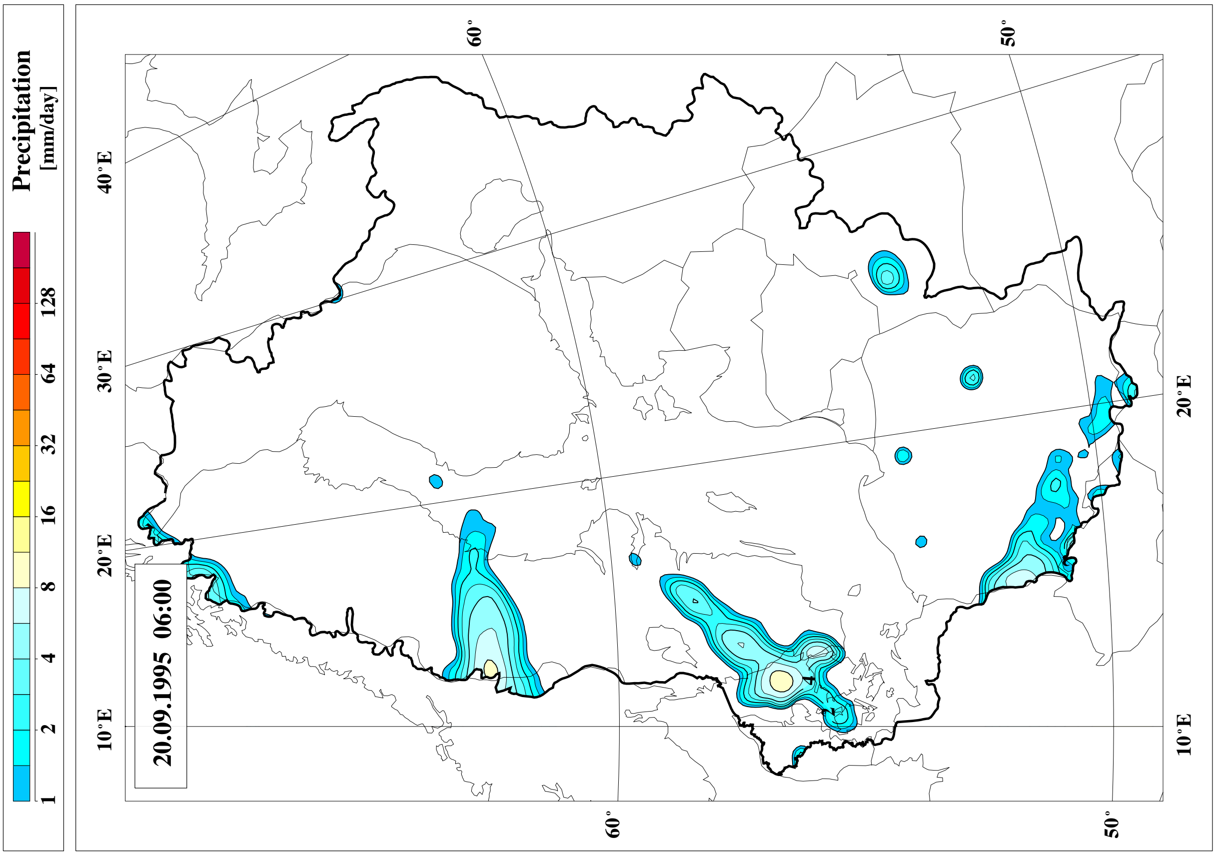
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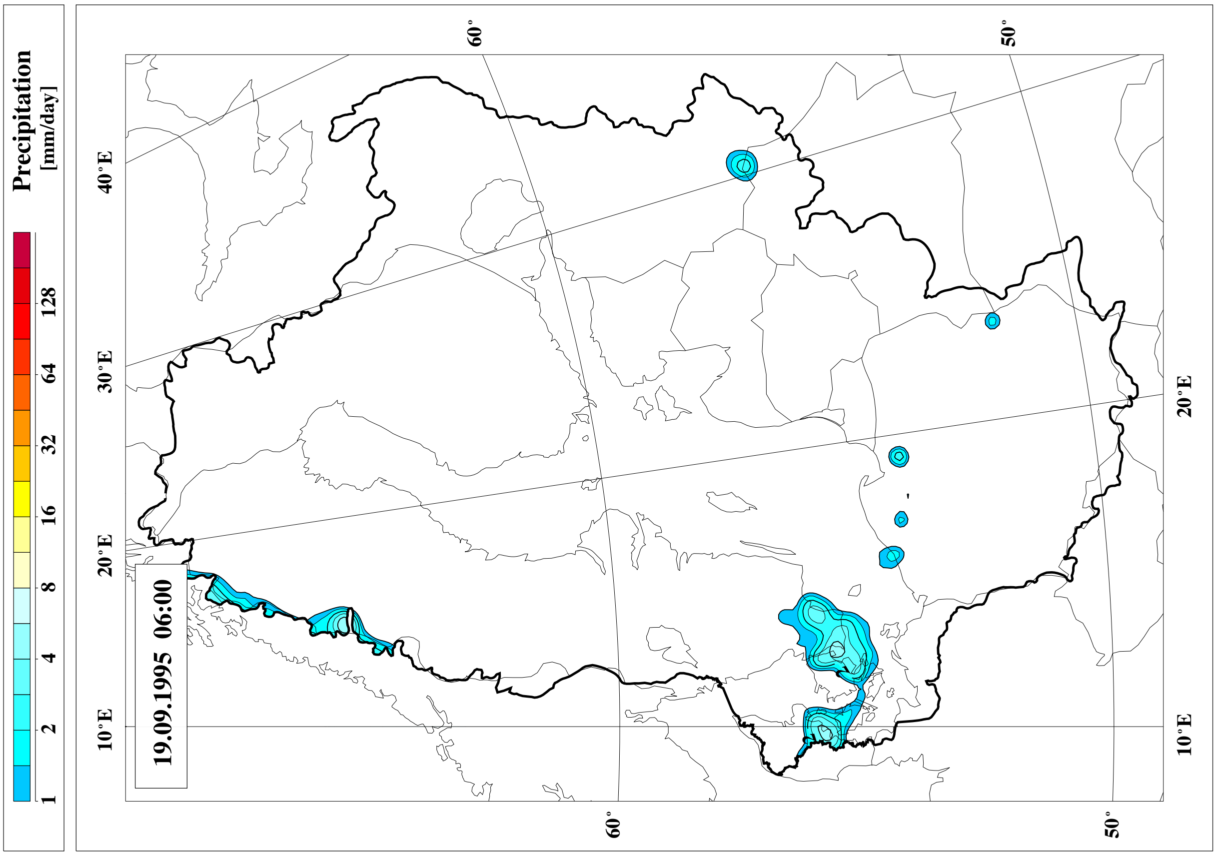
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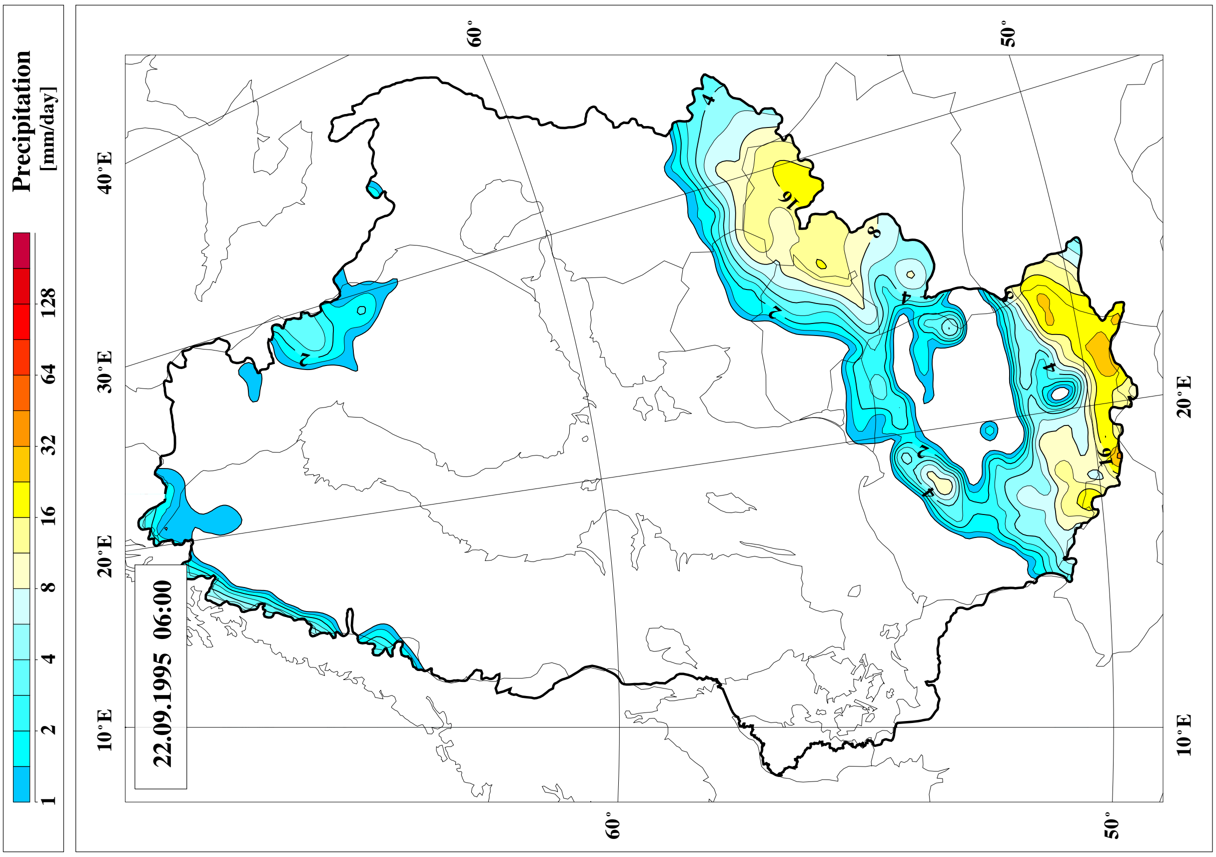
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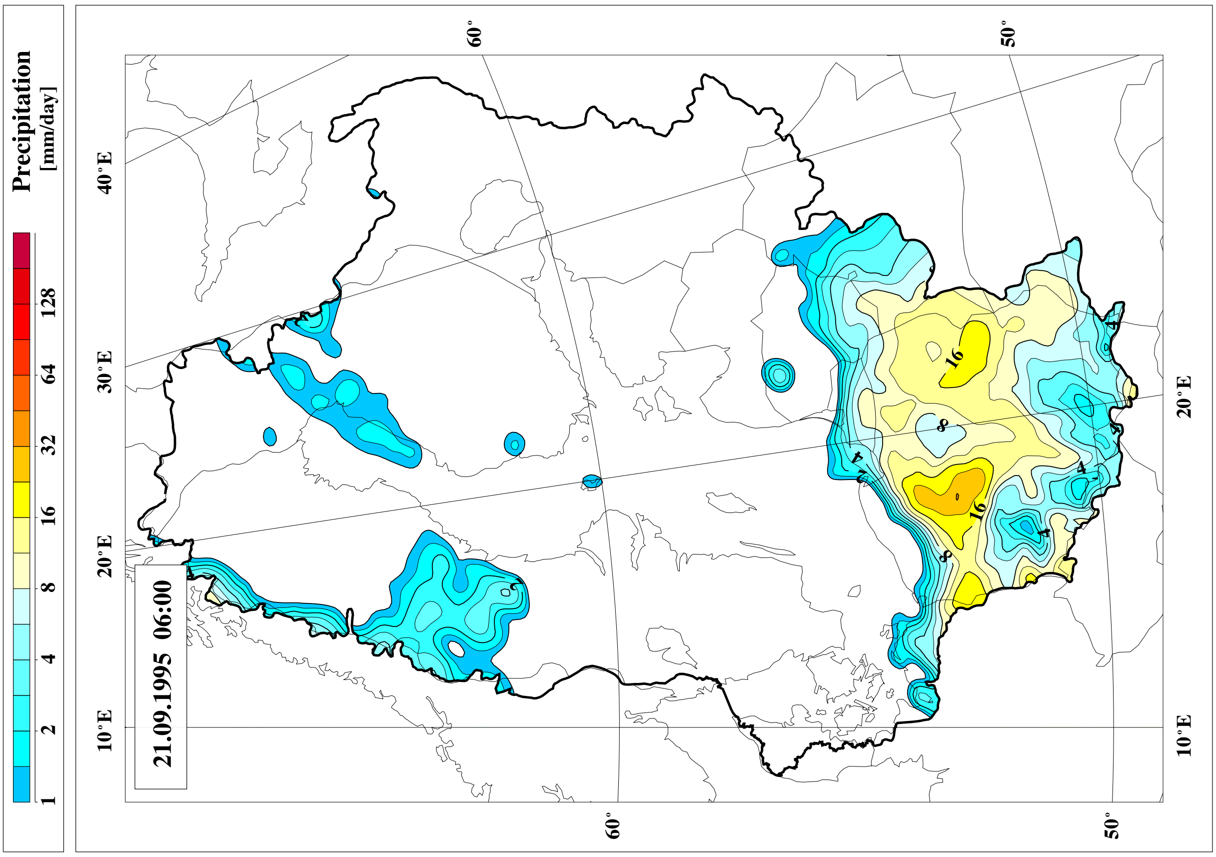
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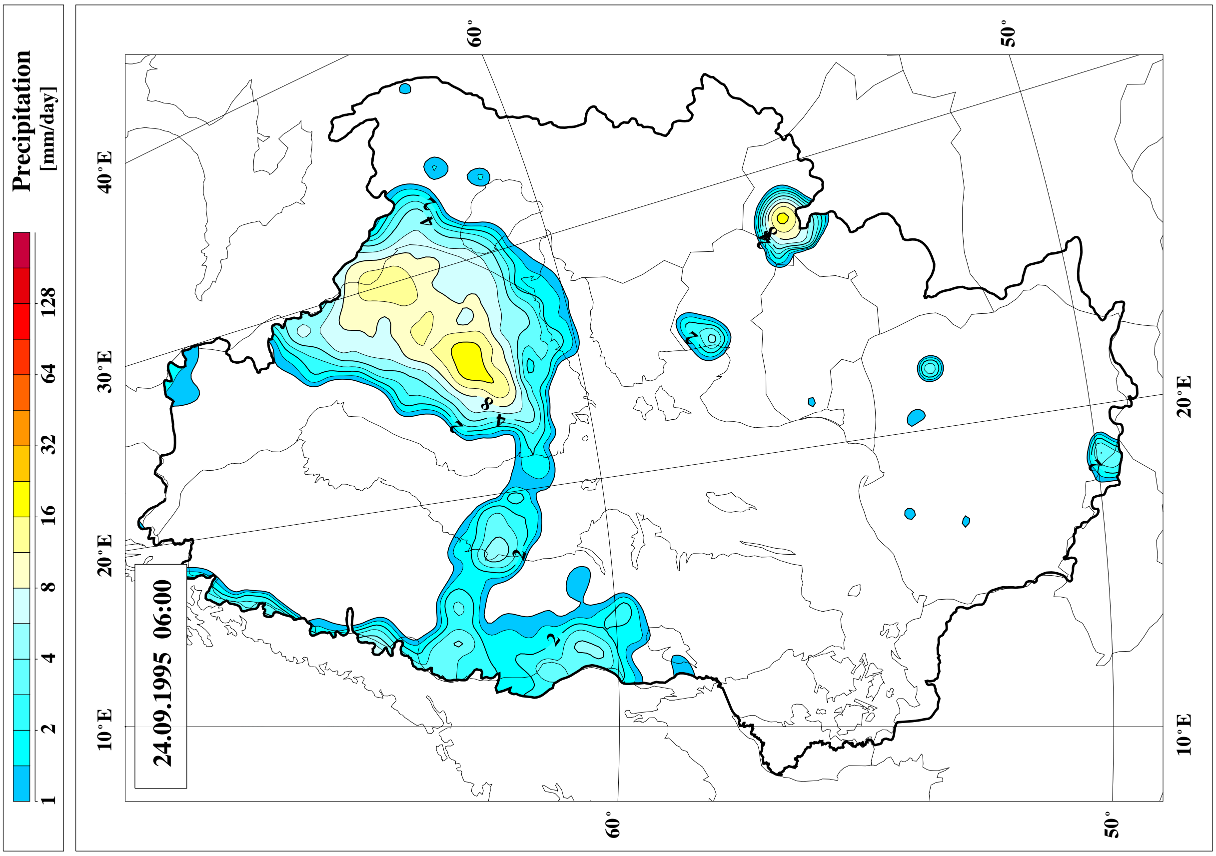
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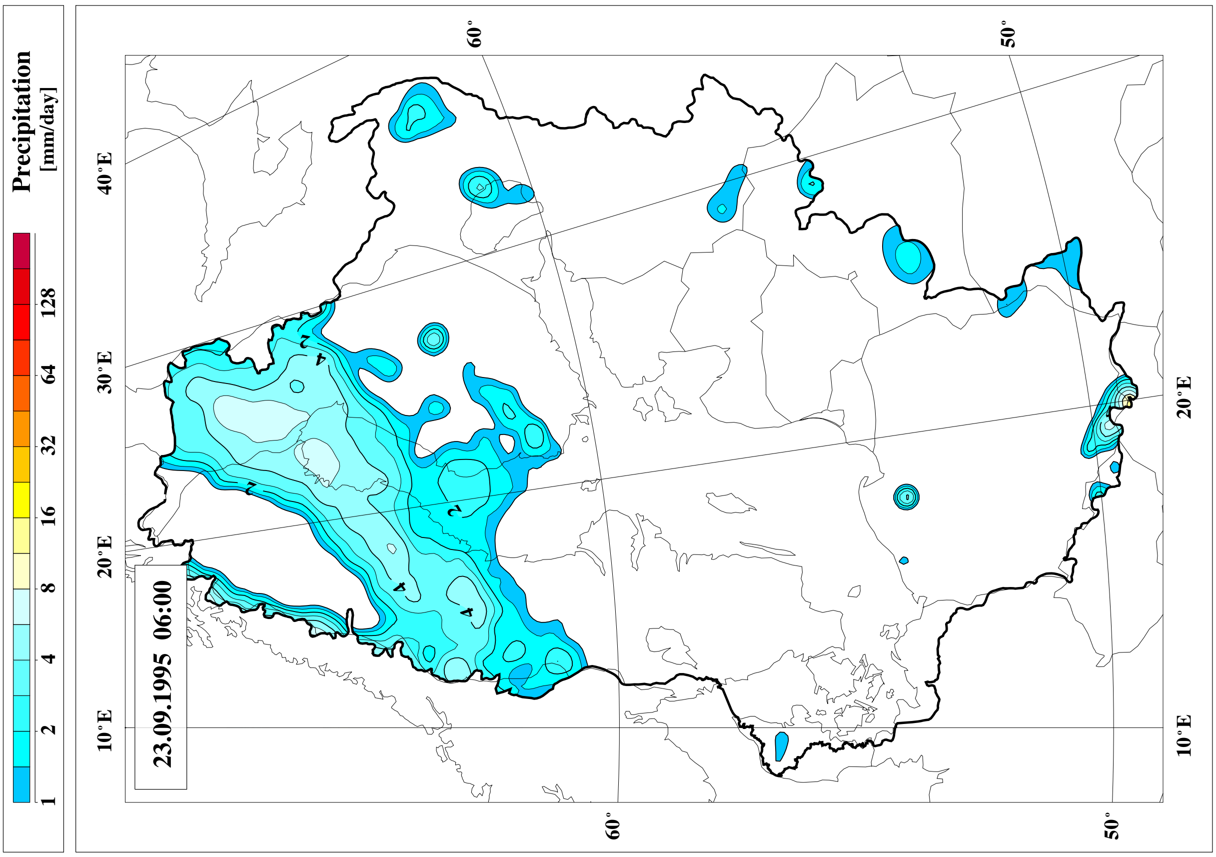
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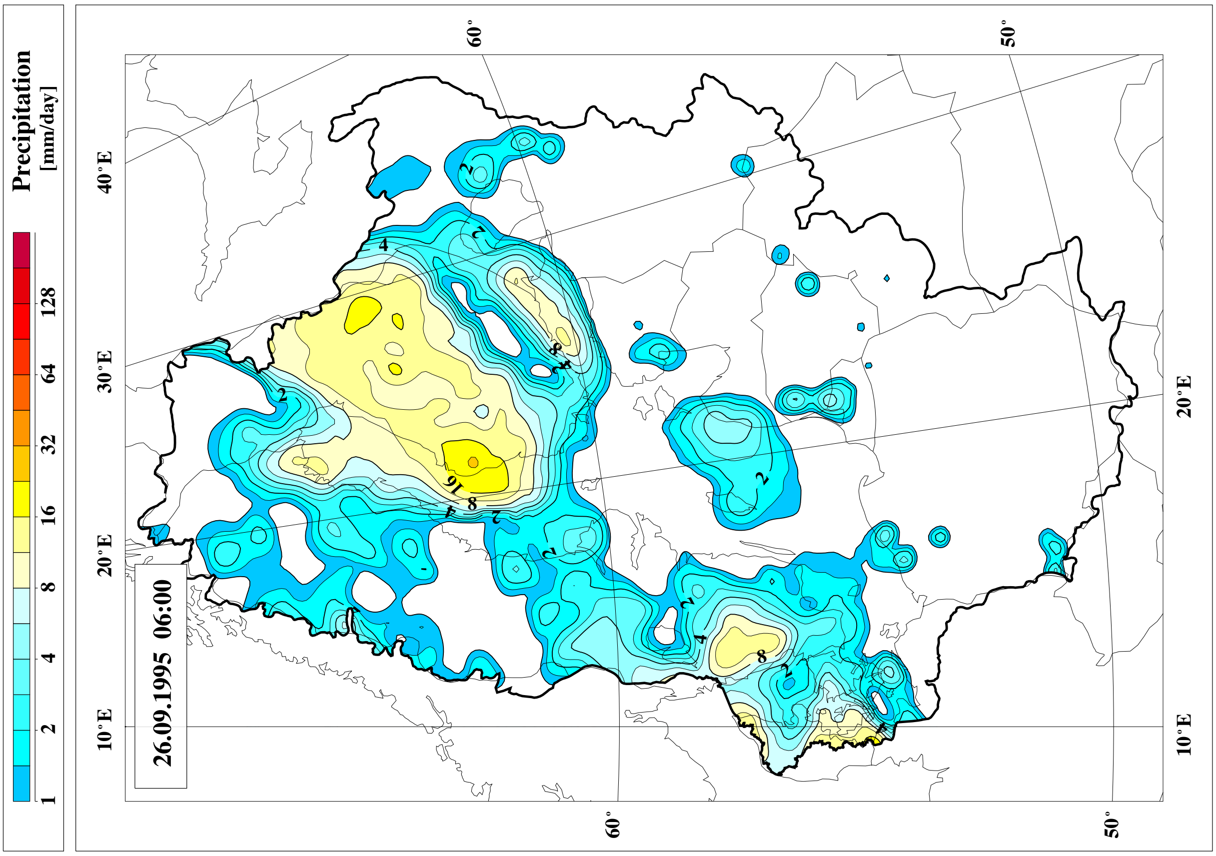
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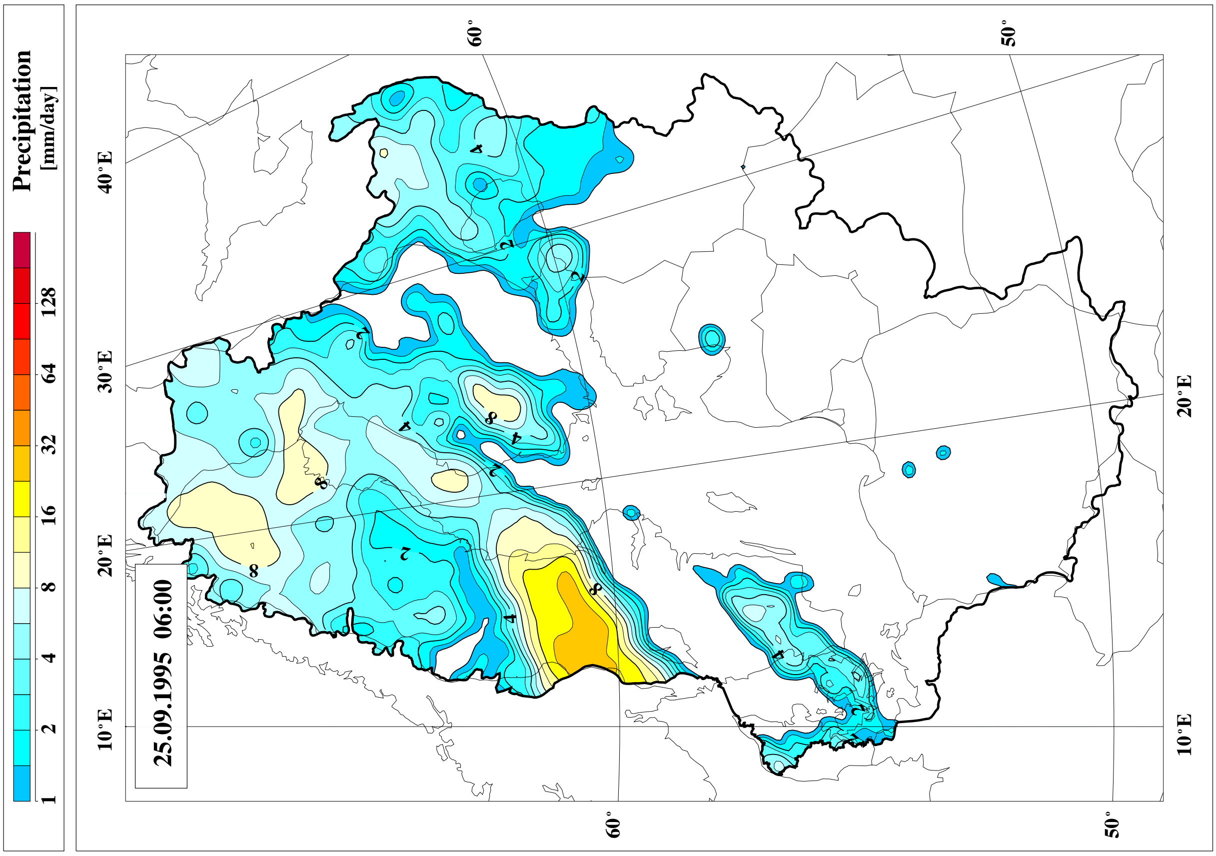
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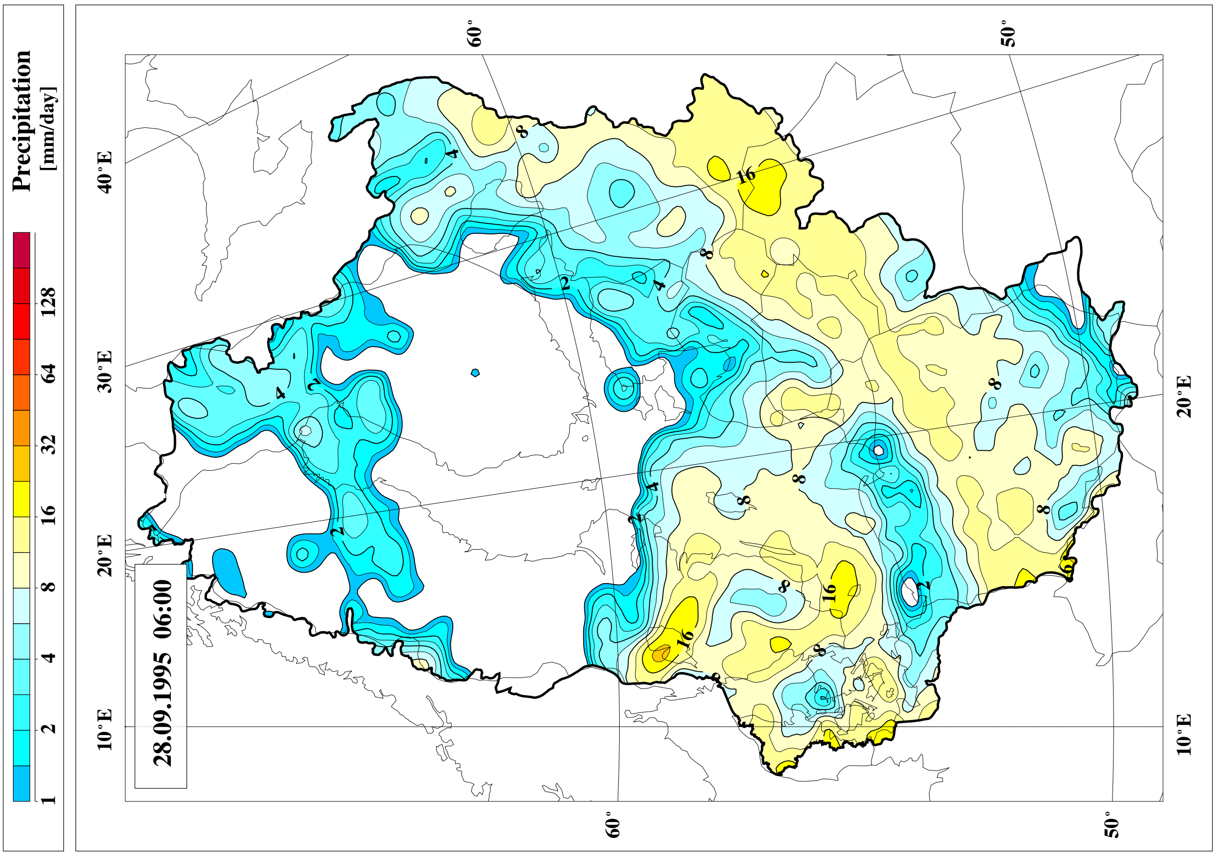
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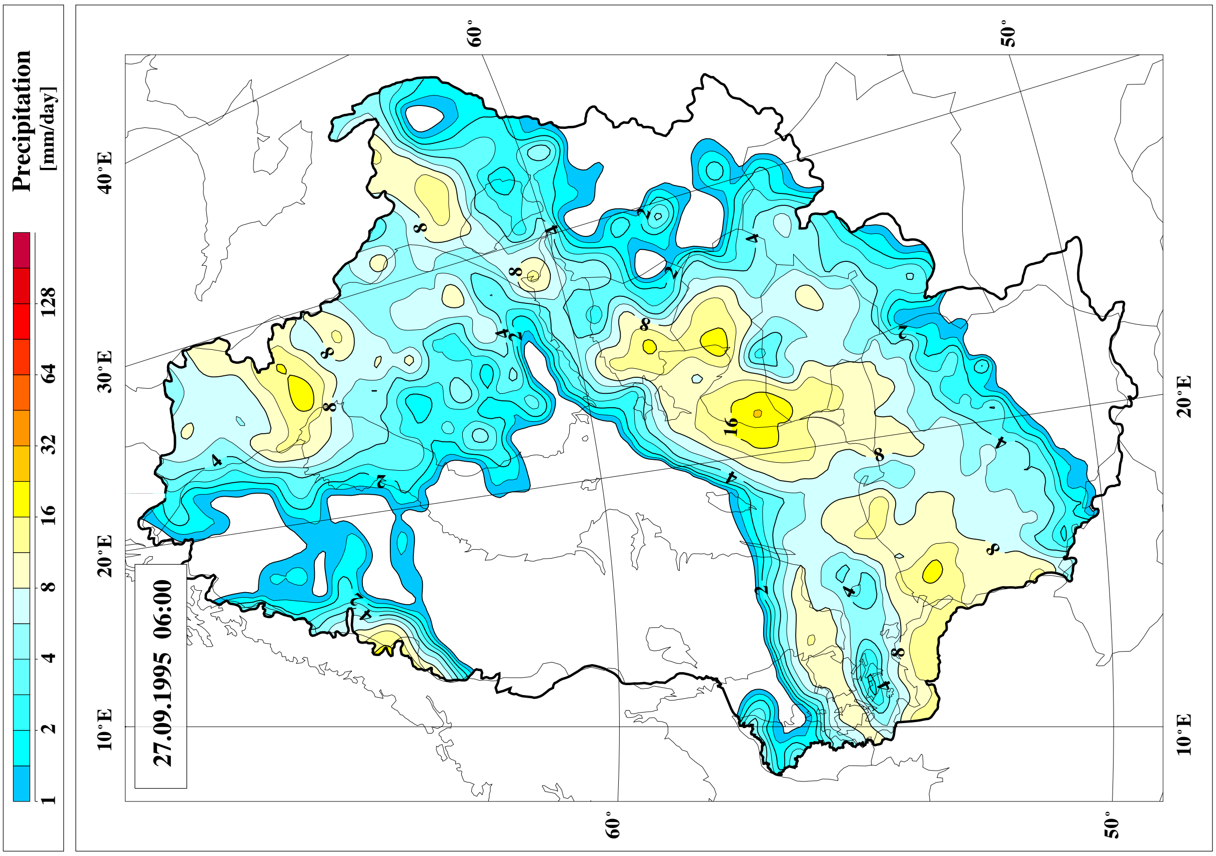
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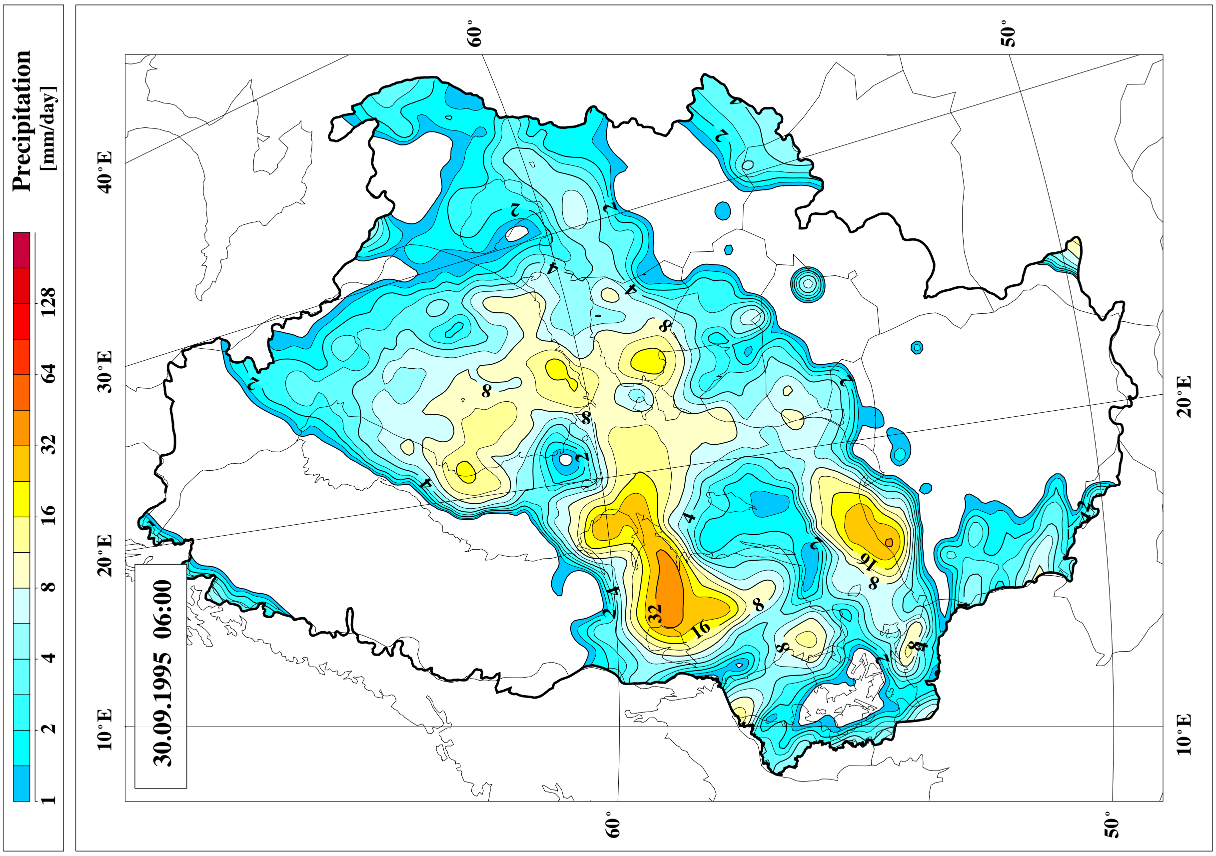
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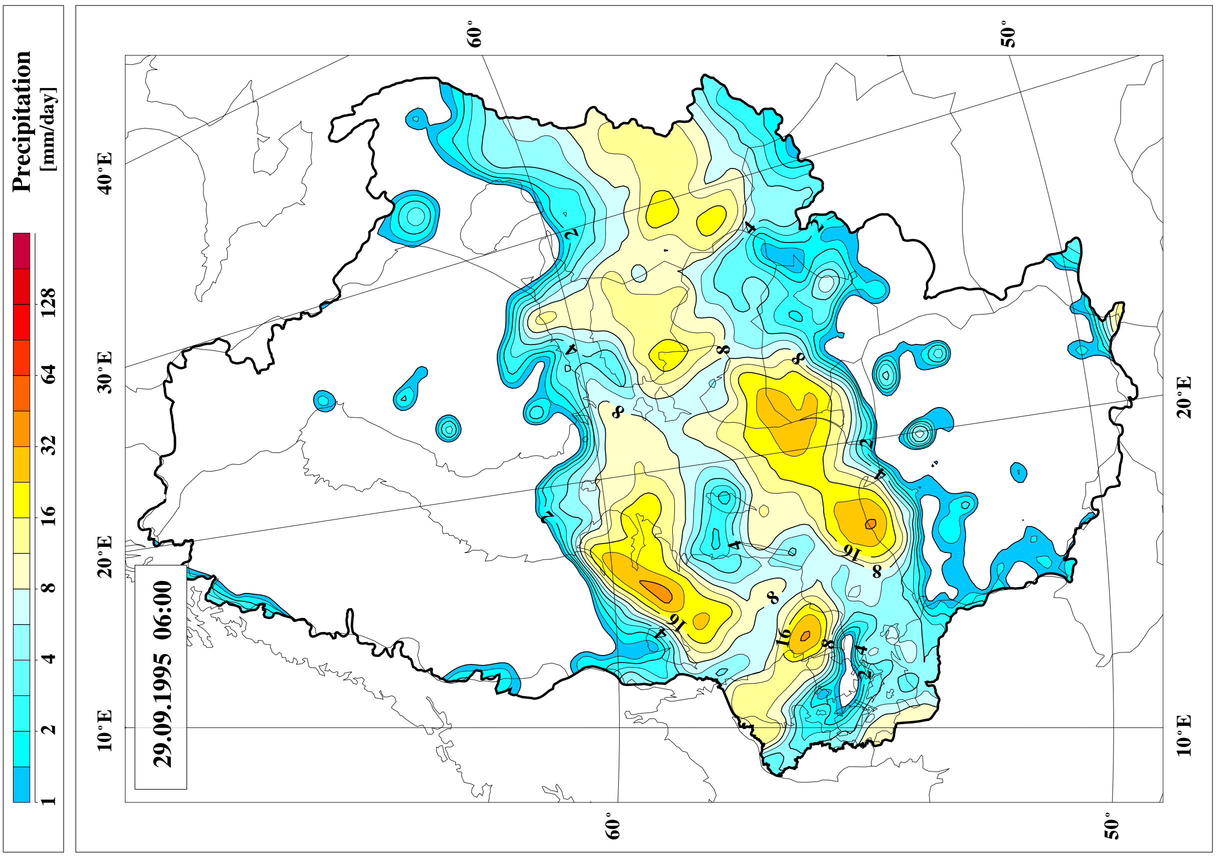
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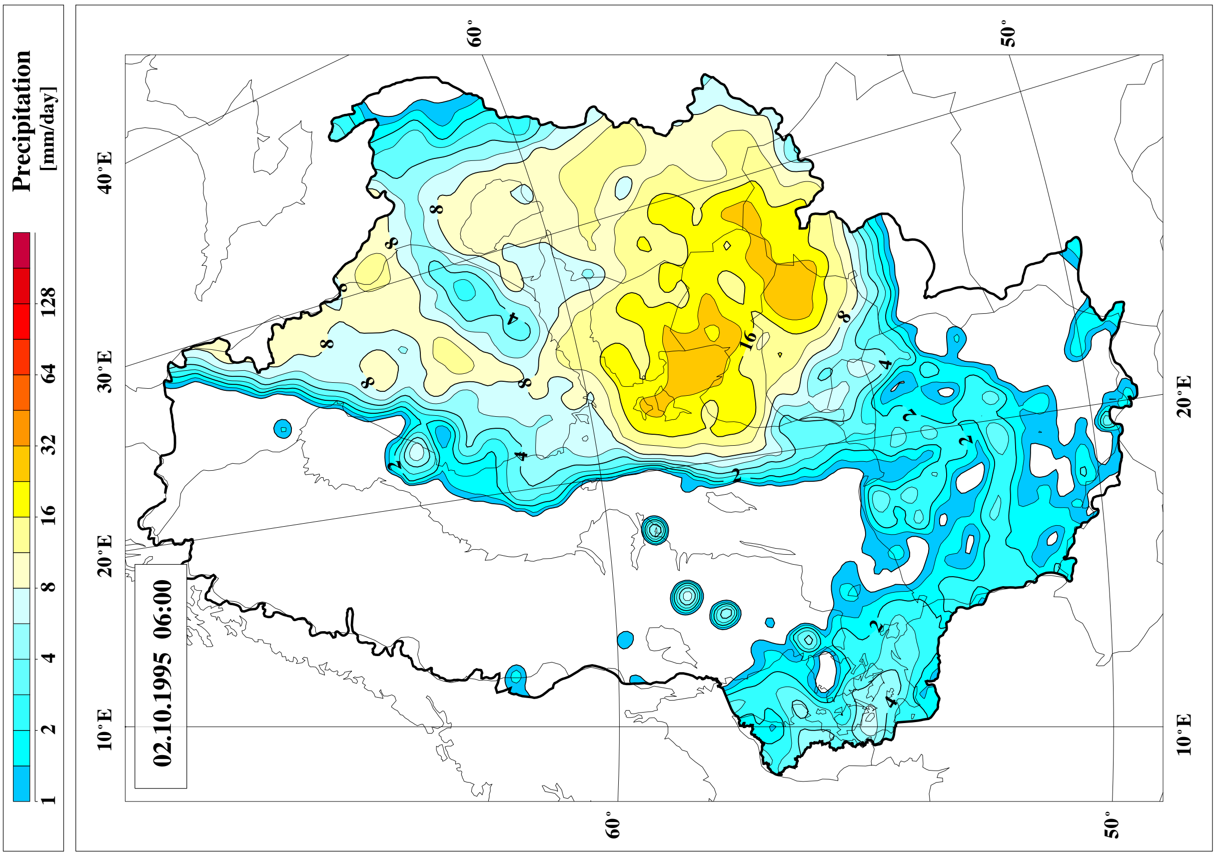
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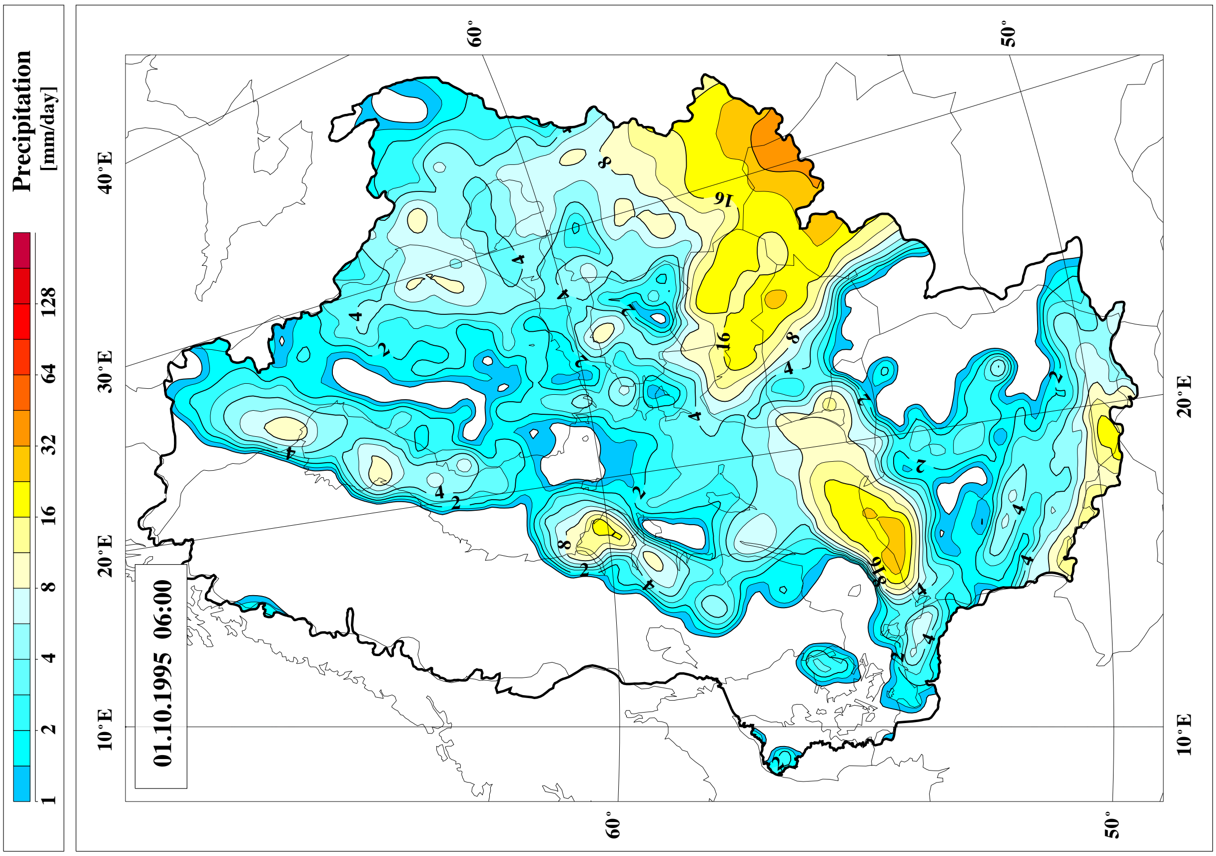
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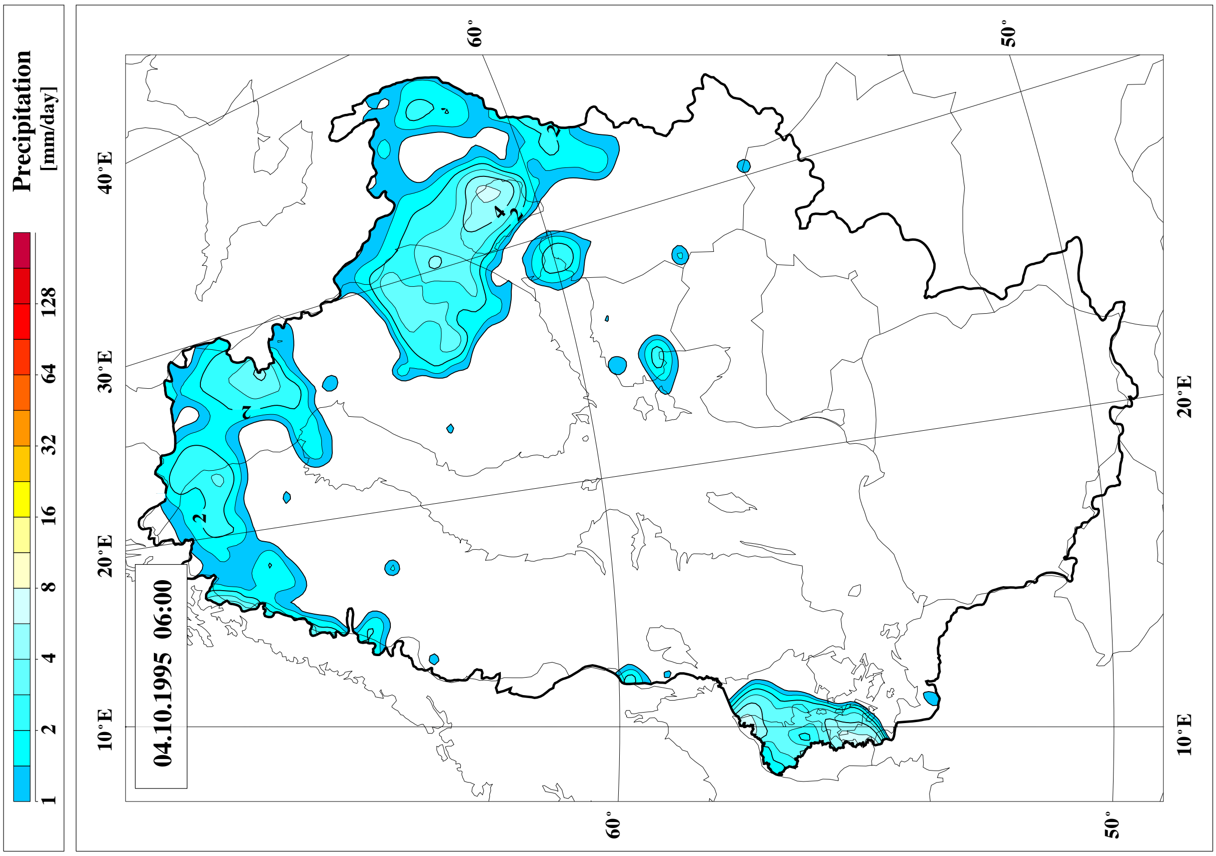
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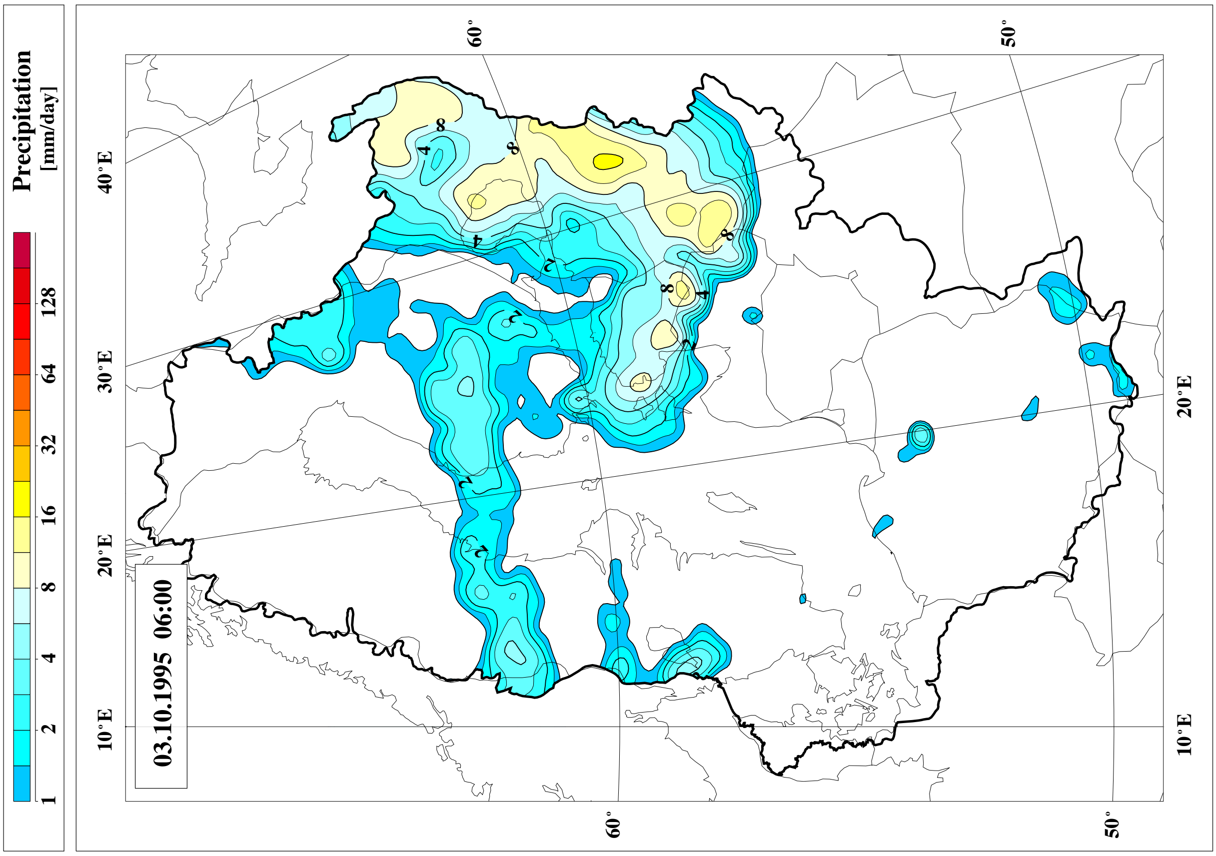
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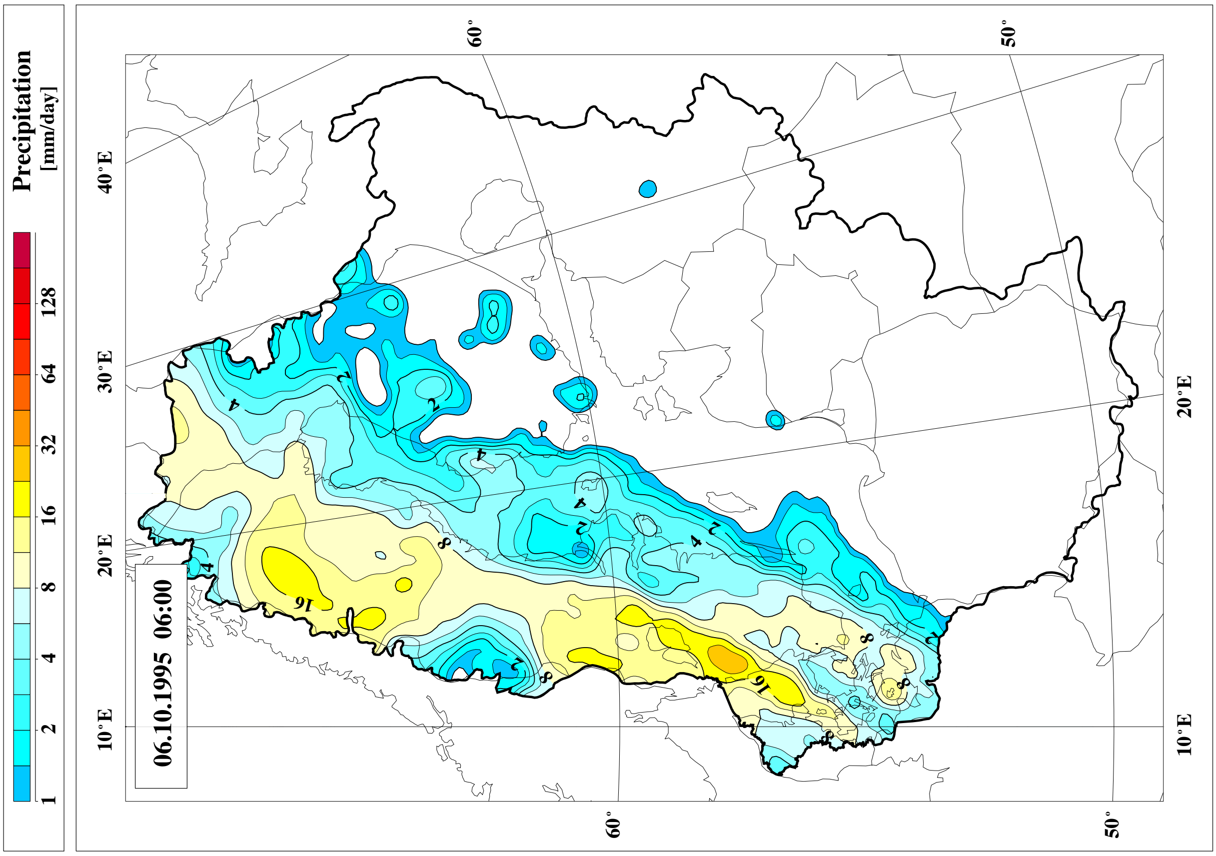
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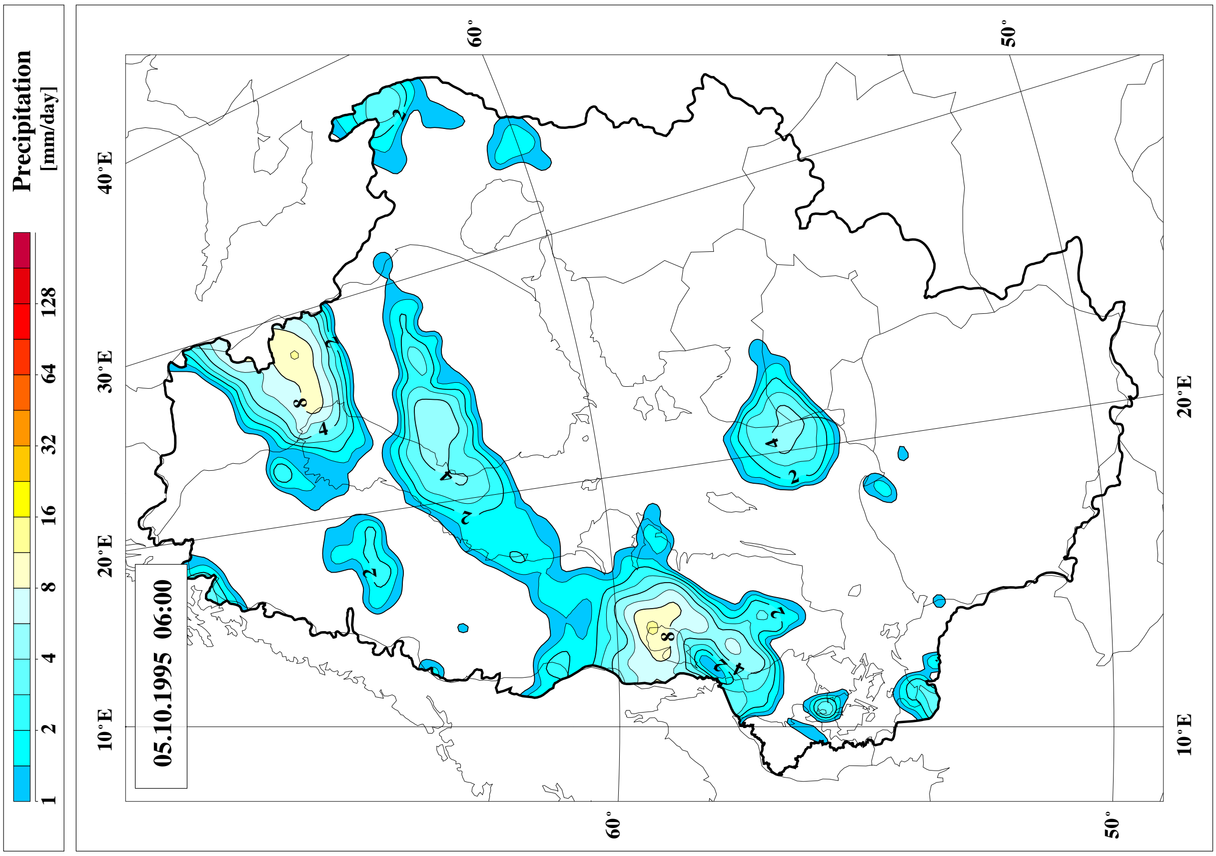
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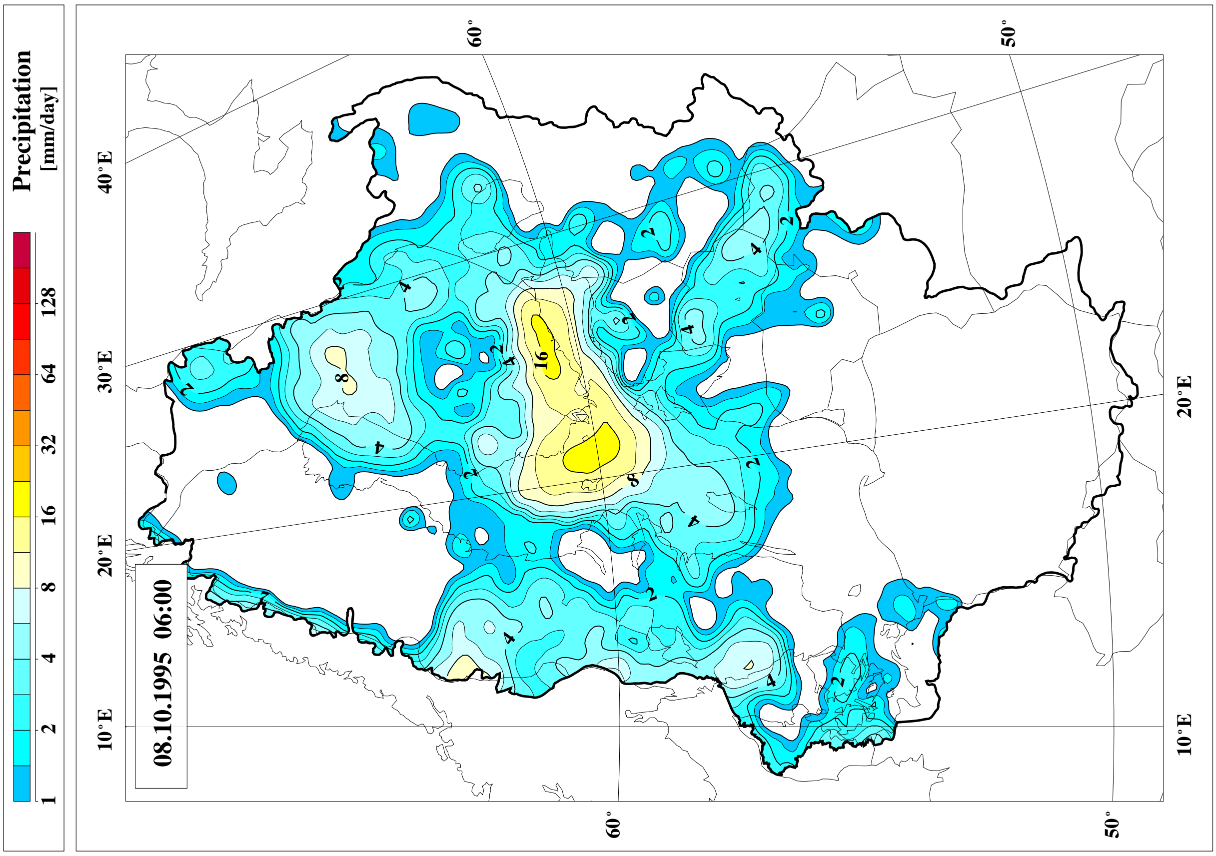
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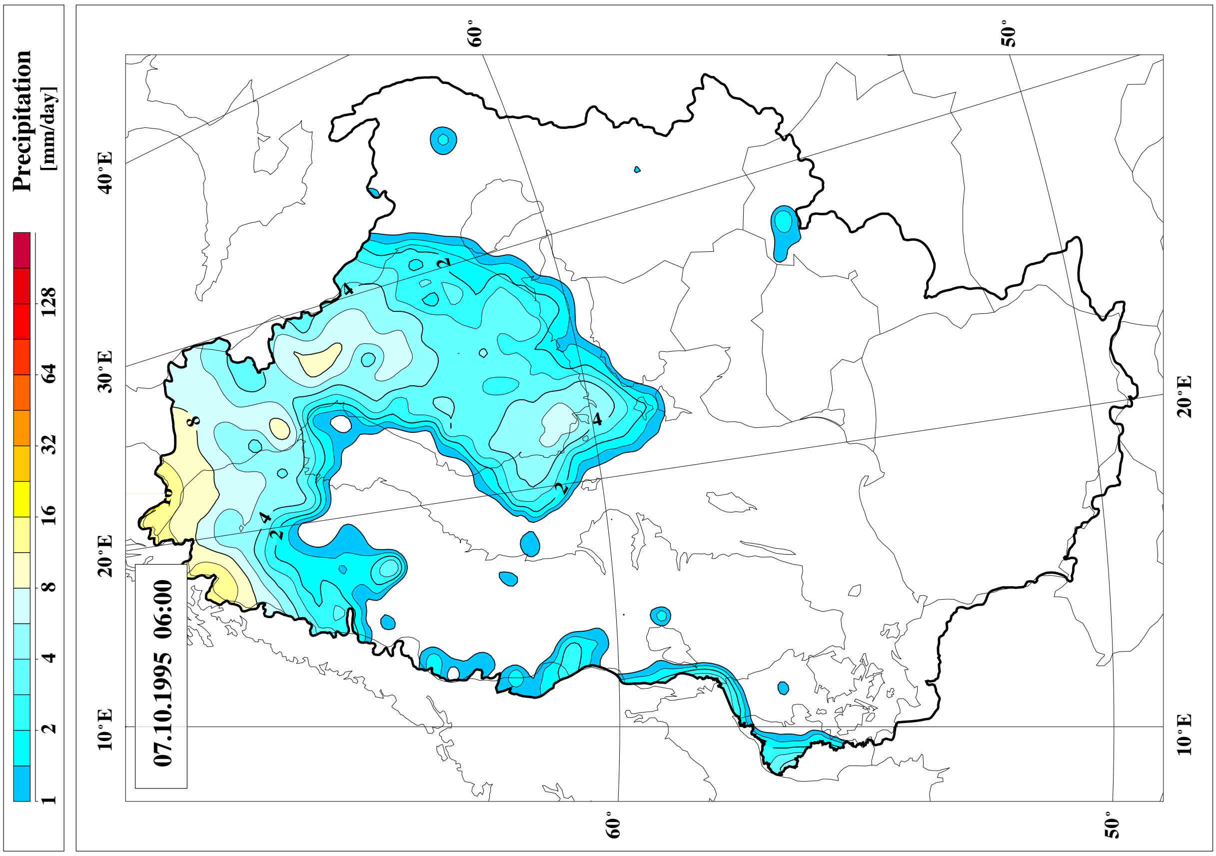
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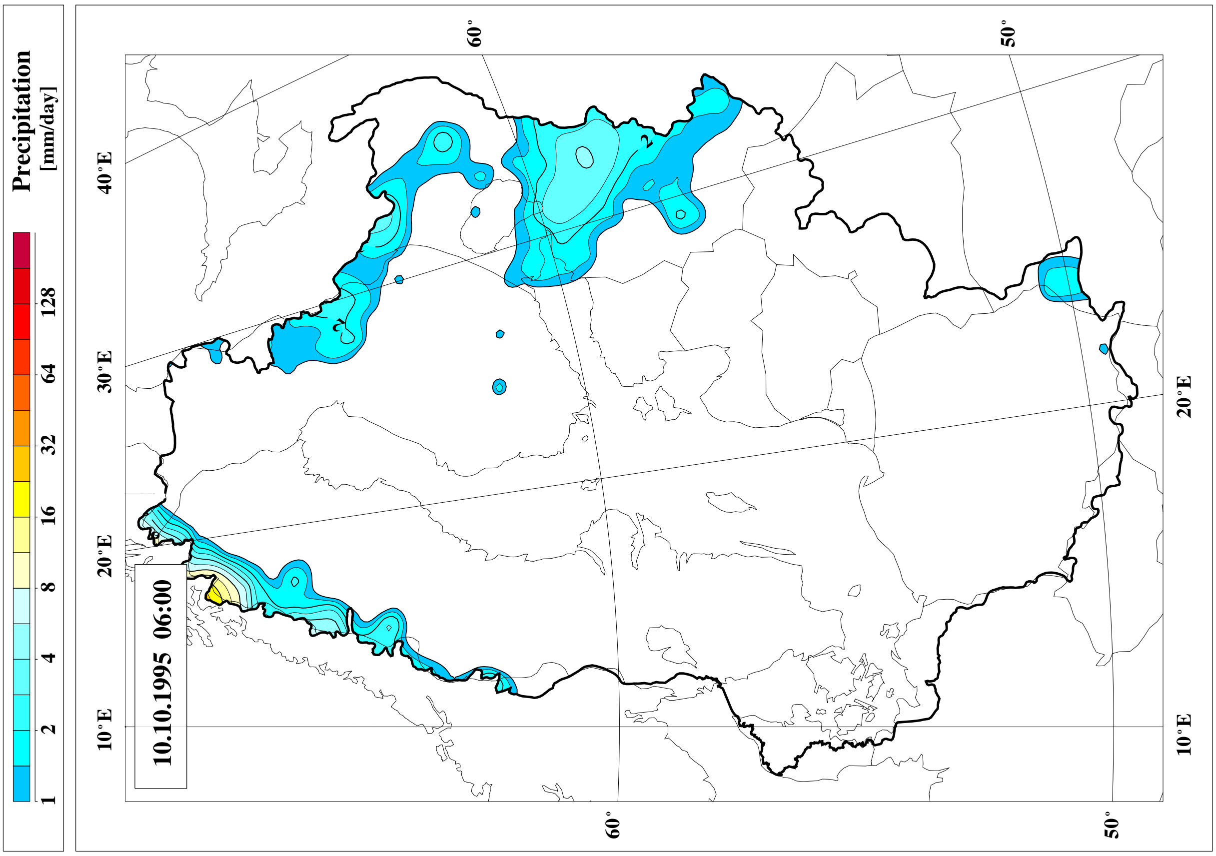
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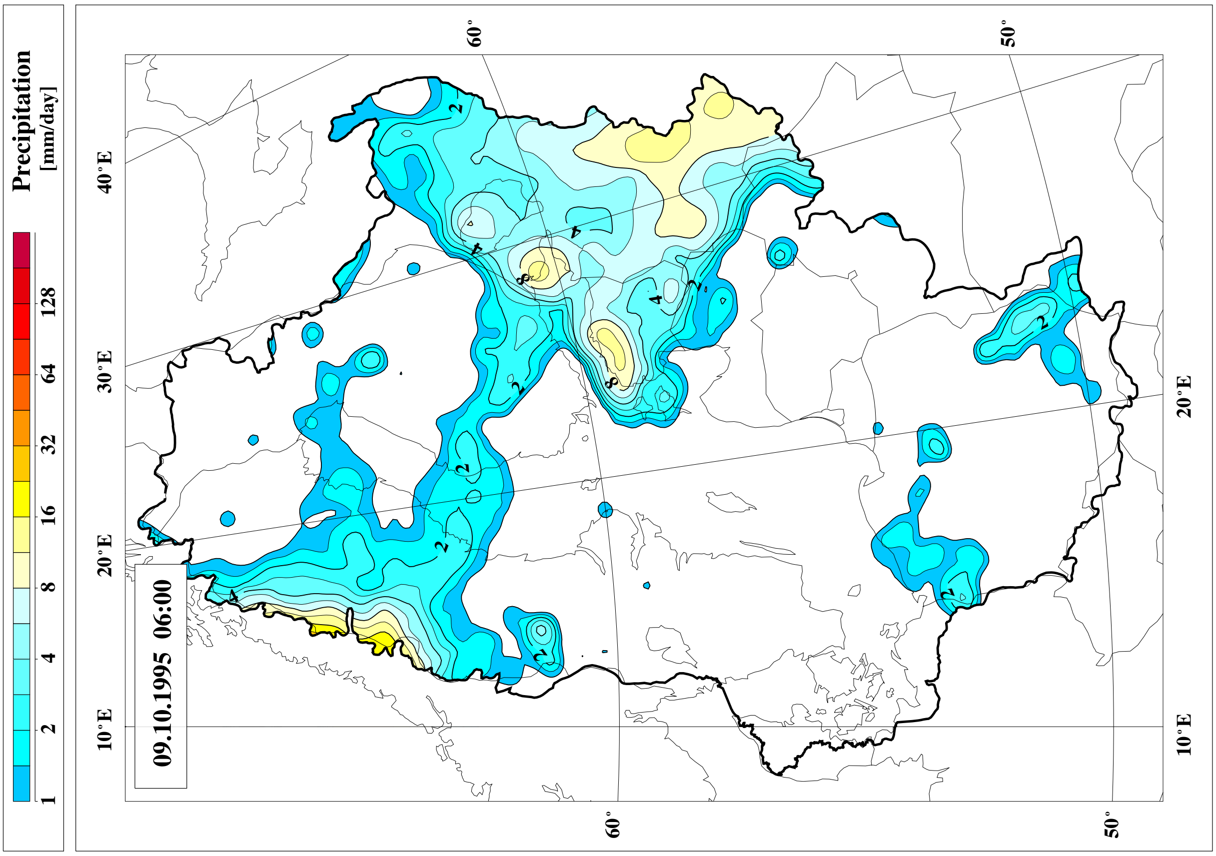
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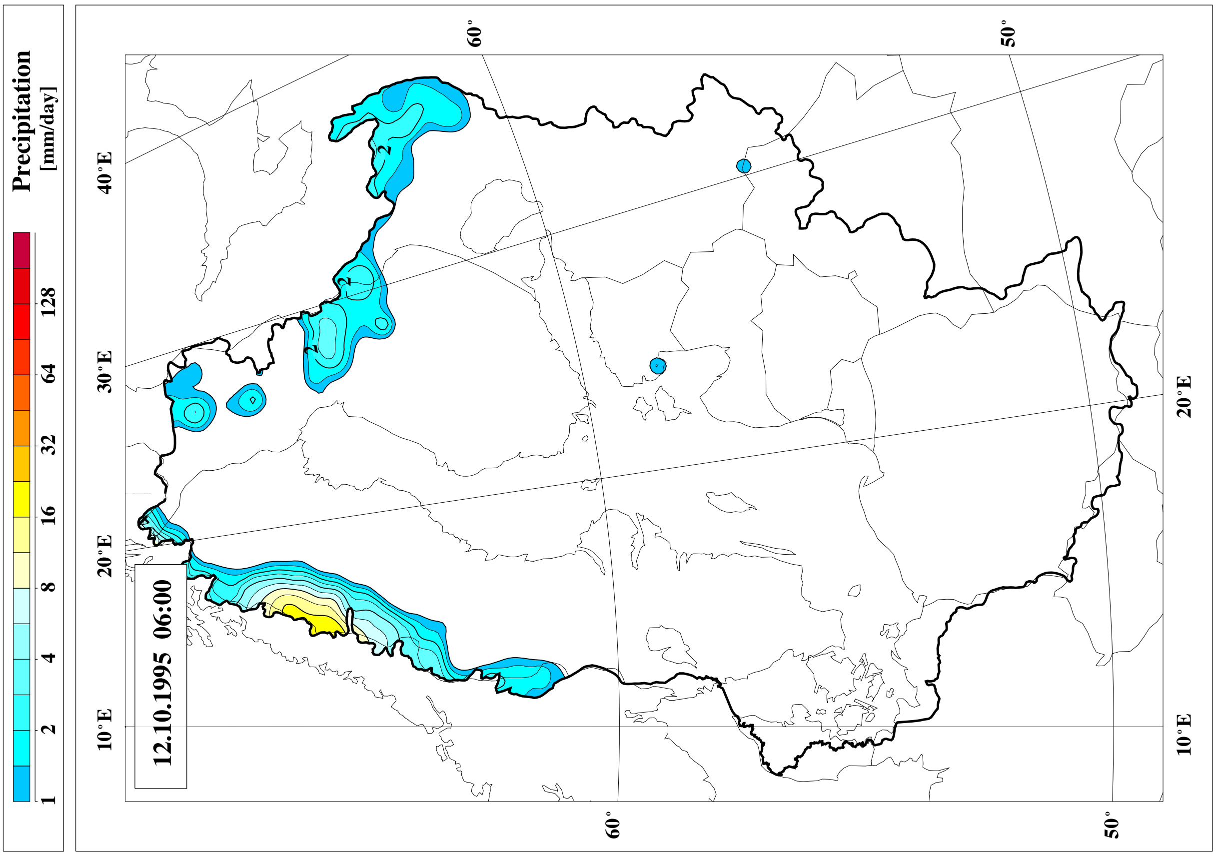
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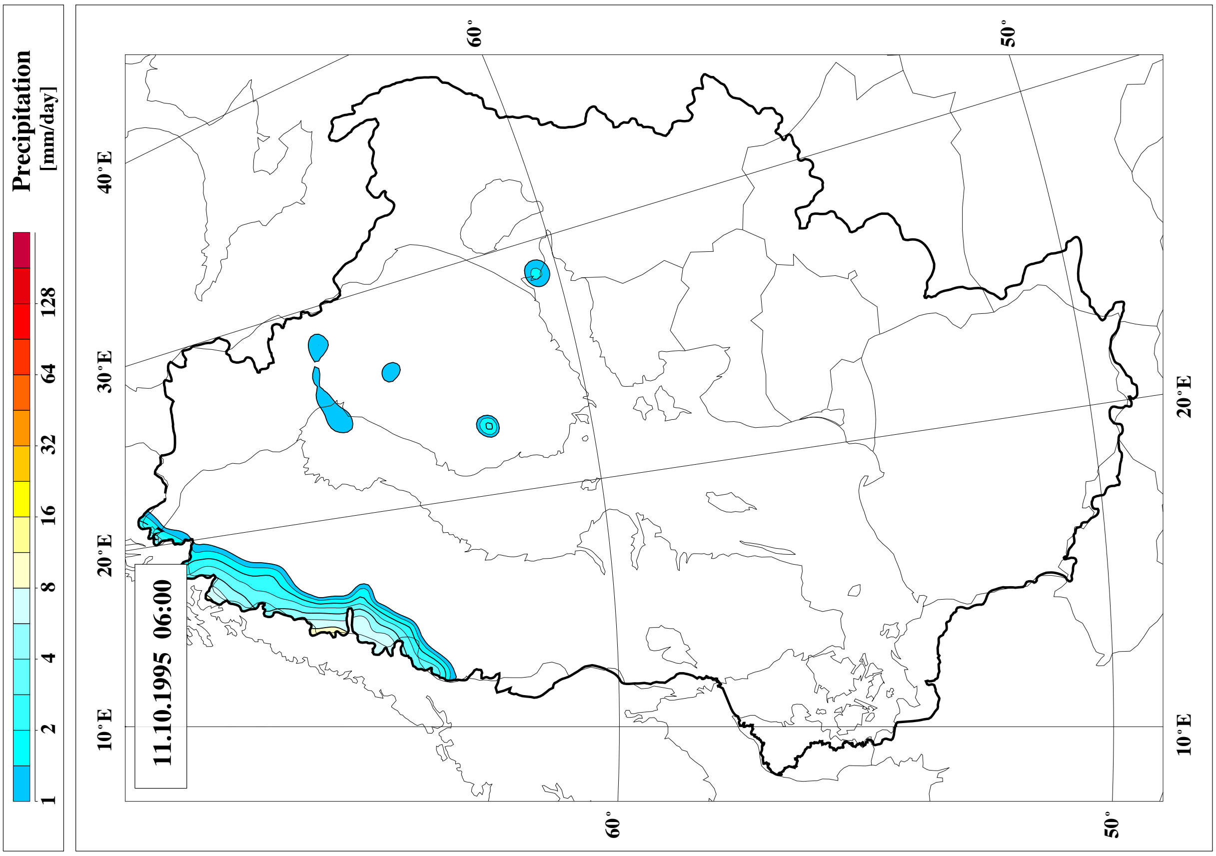
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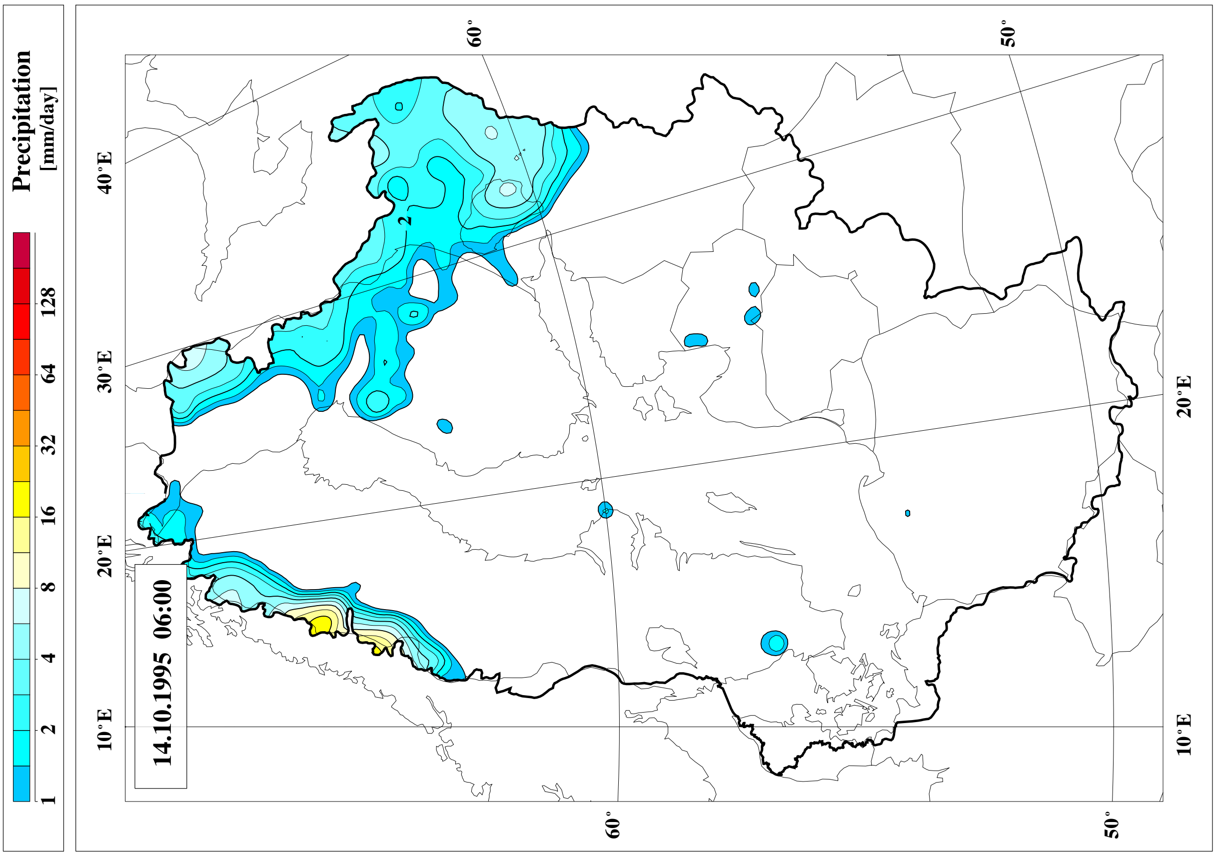
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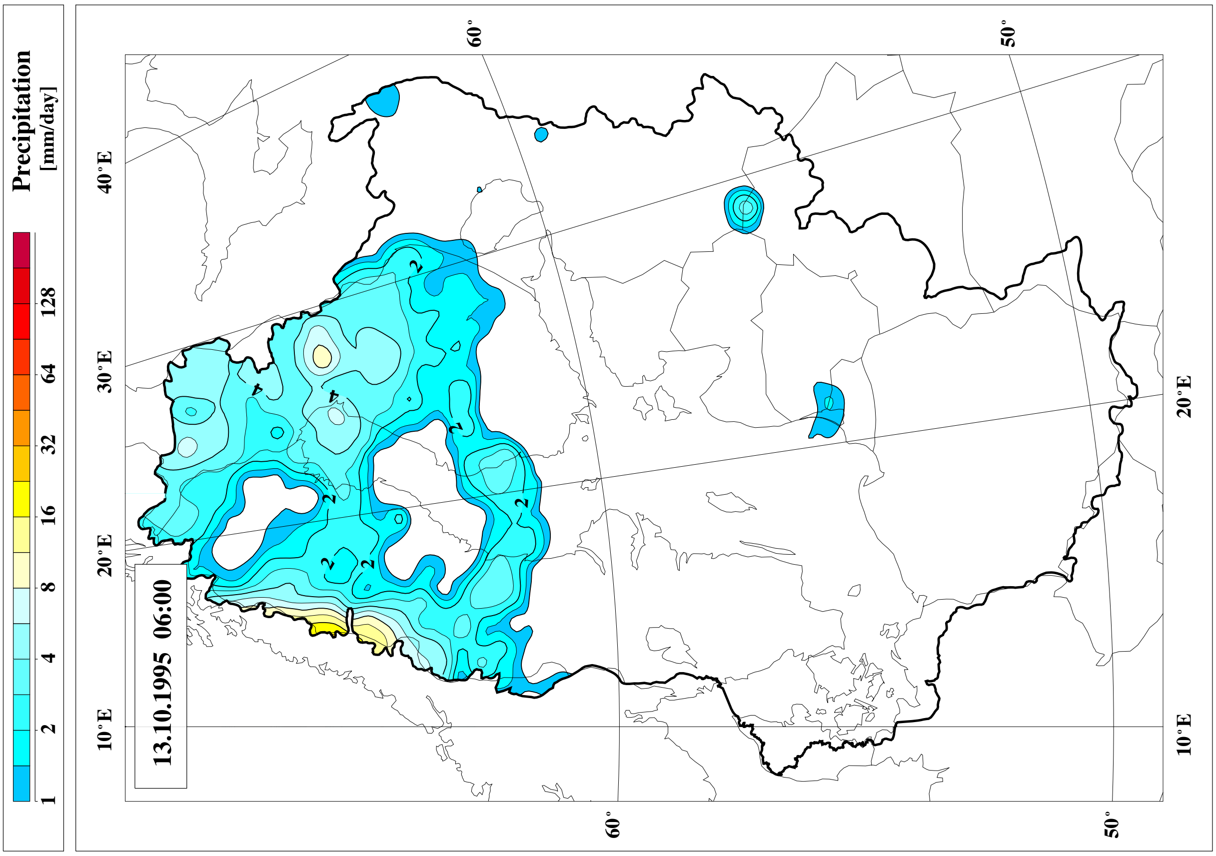
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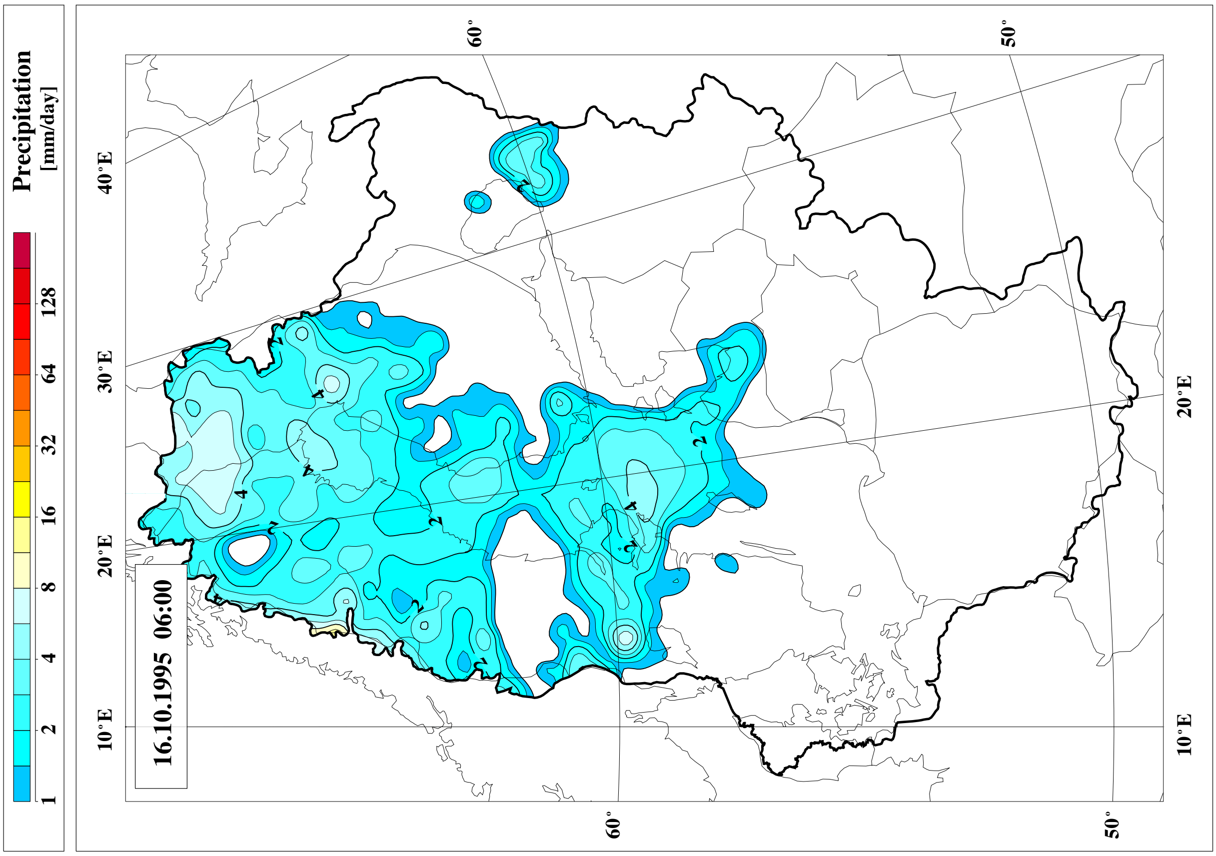
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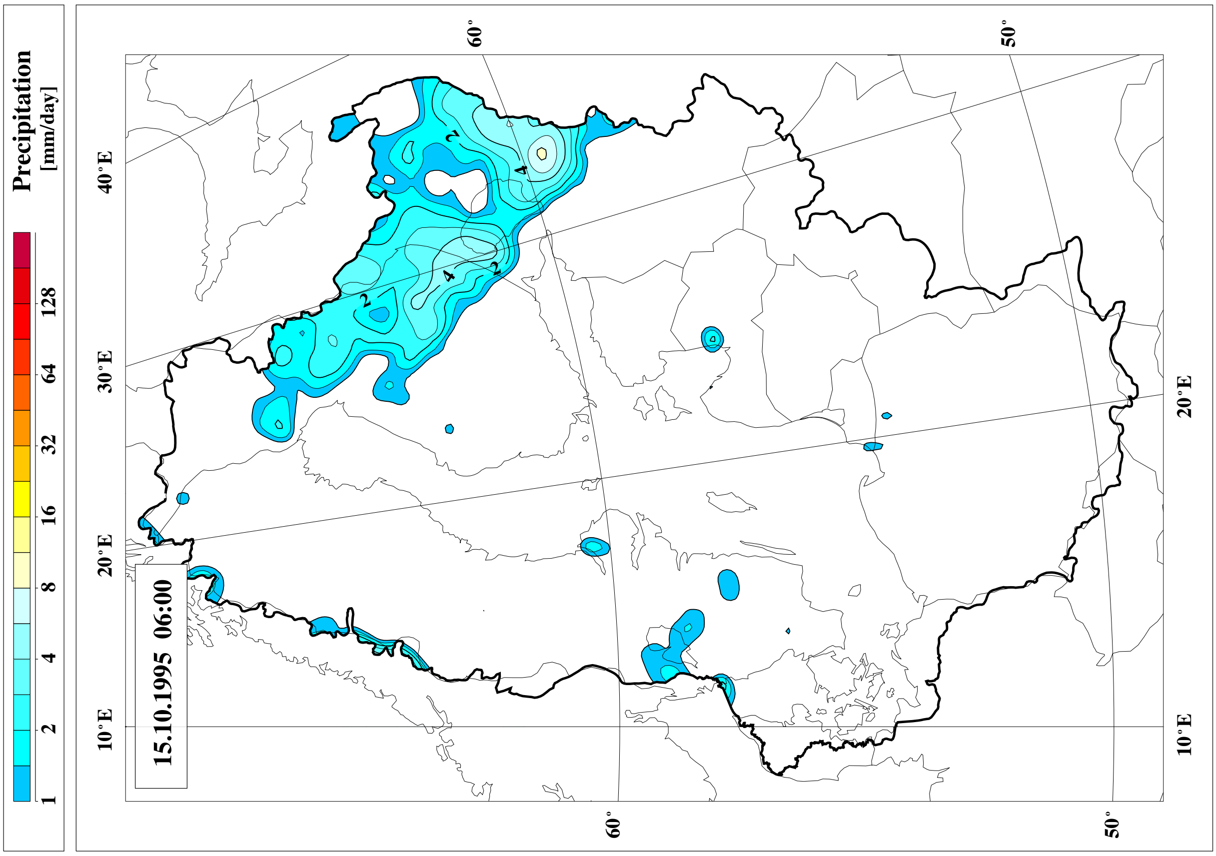
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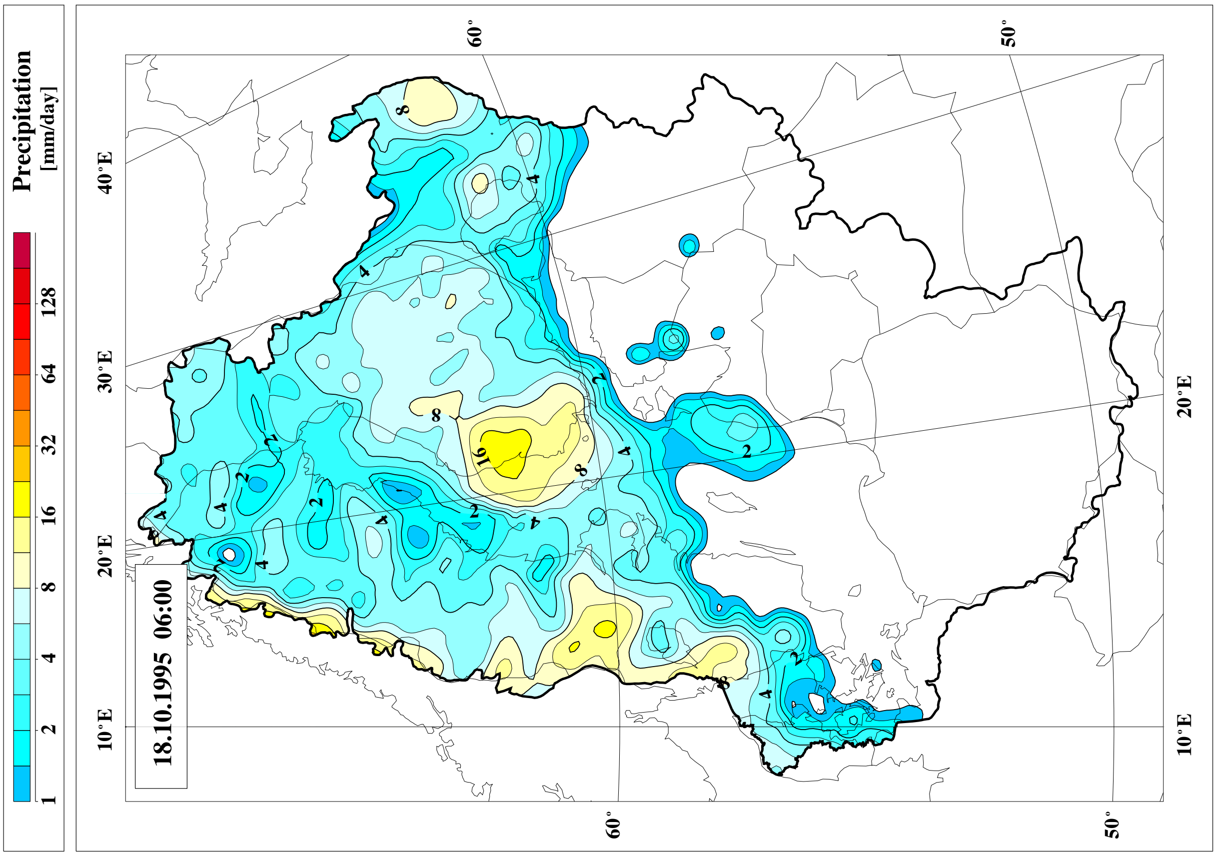
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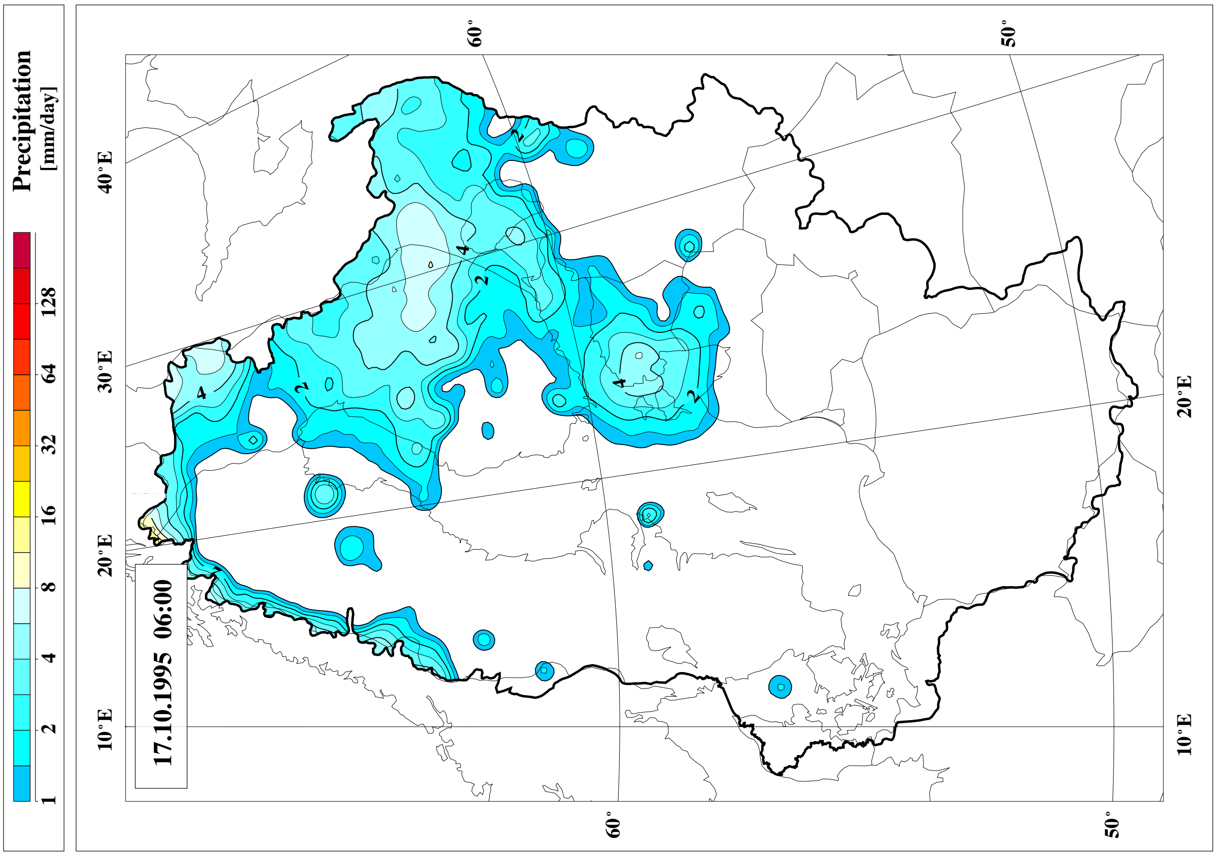
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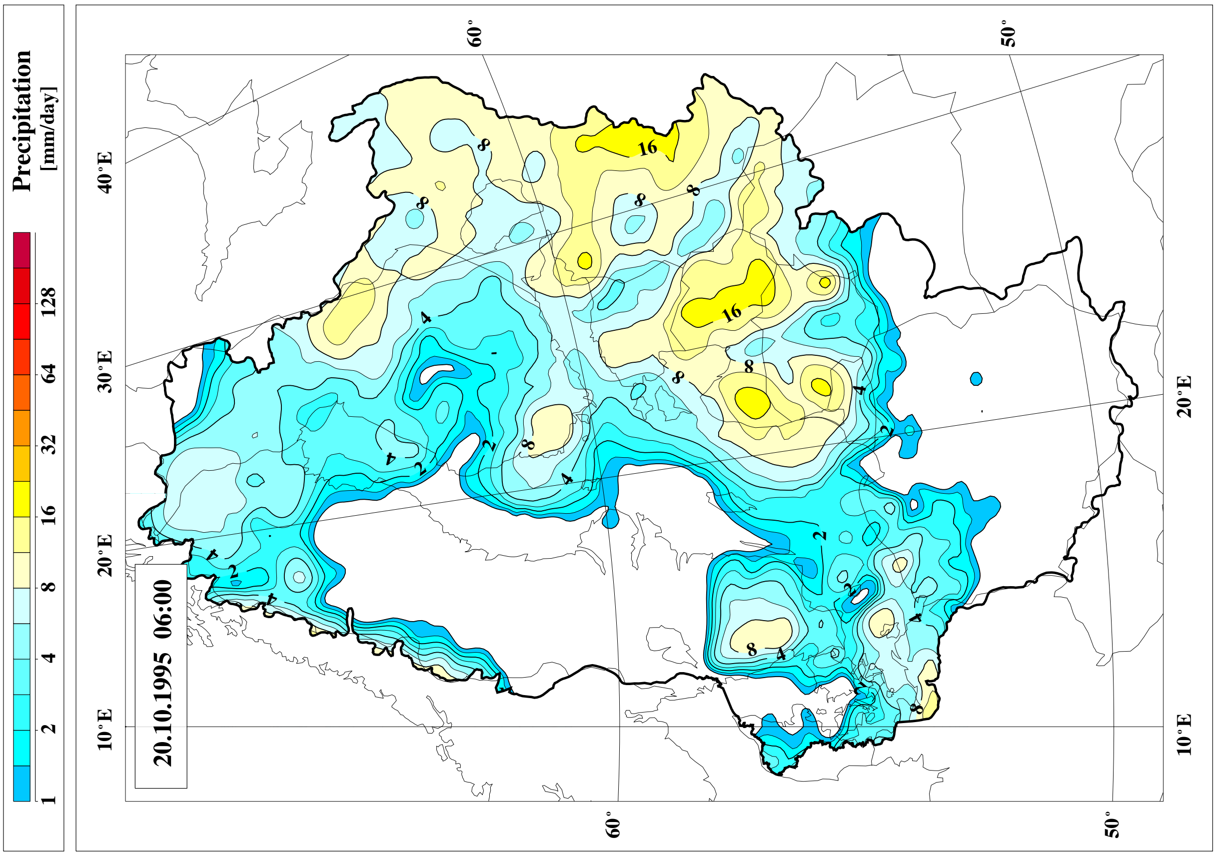
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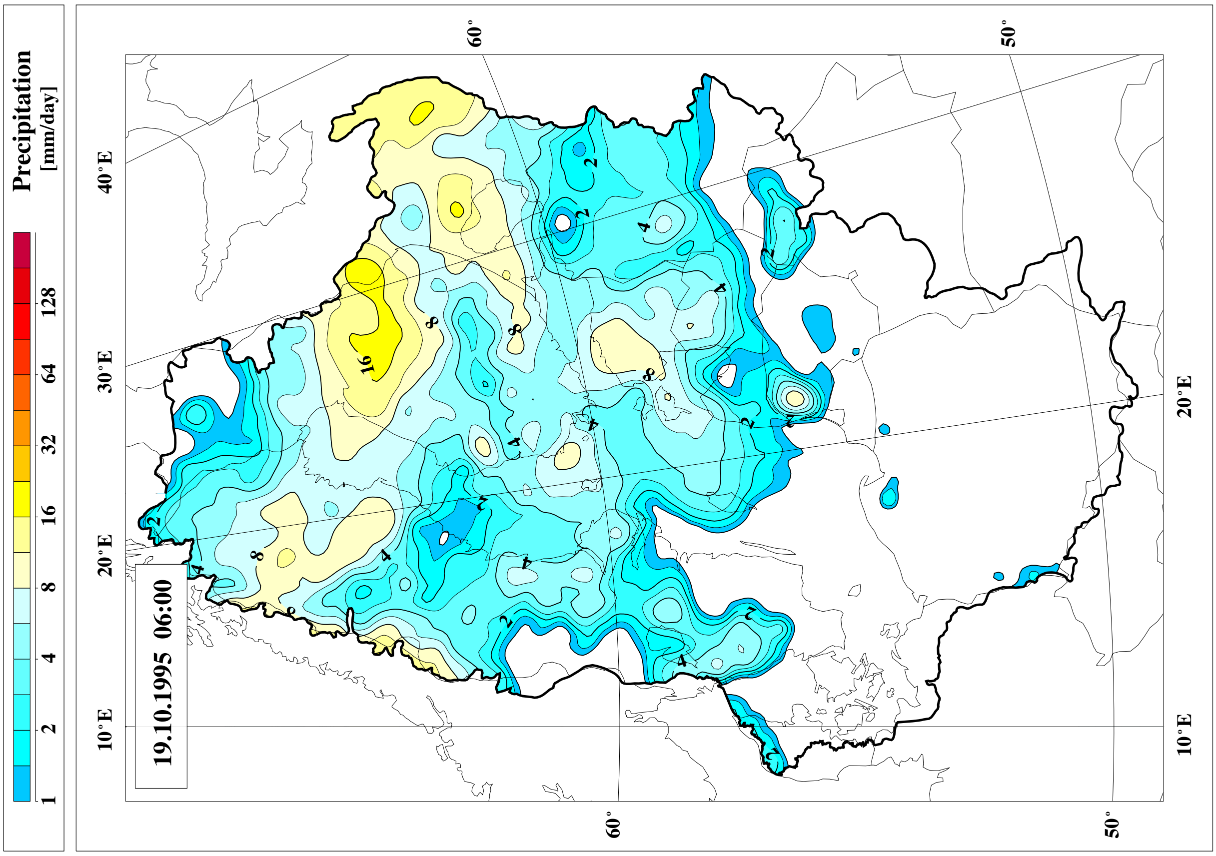
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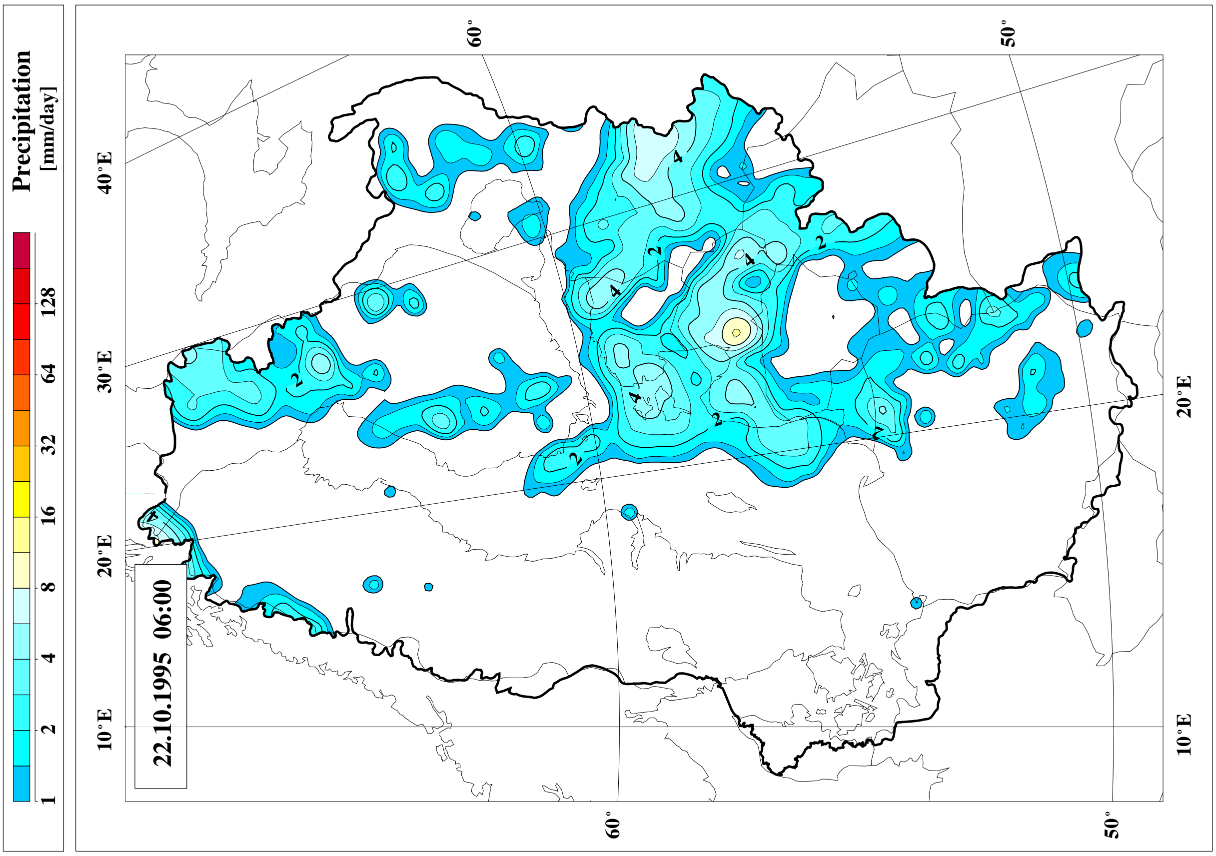
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[mm/day]
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20°E
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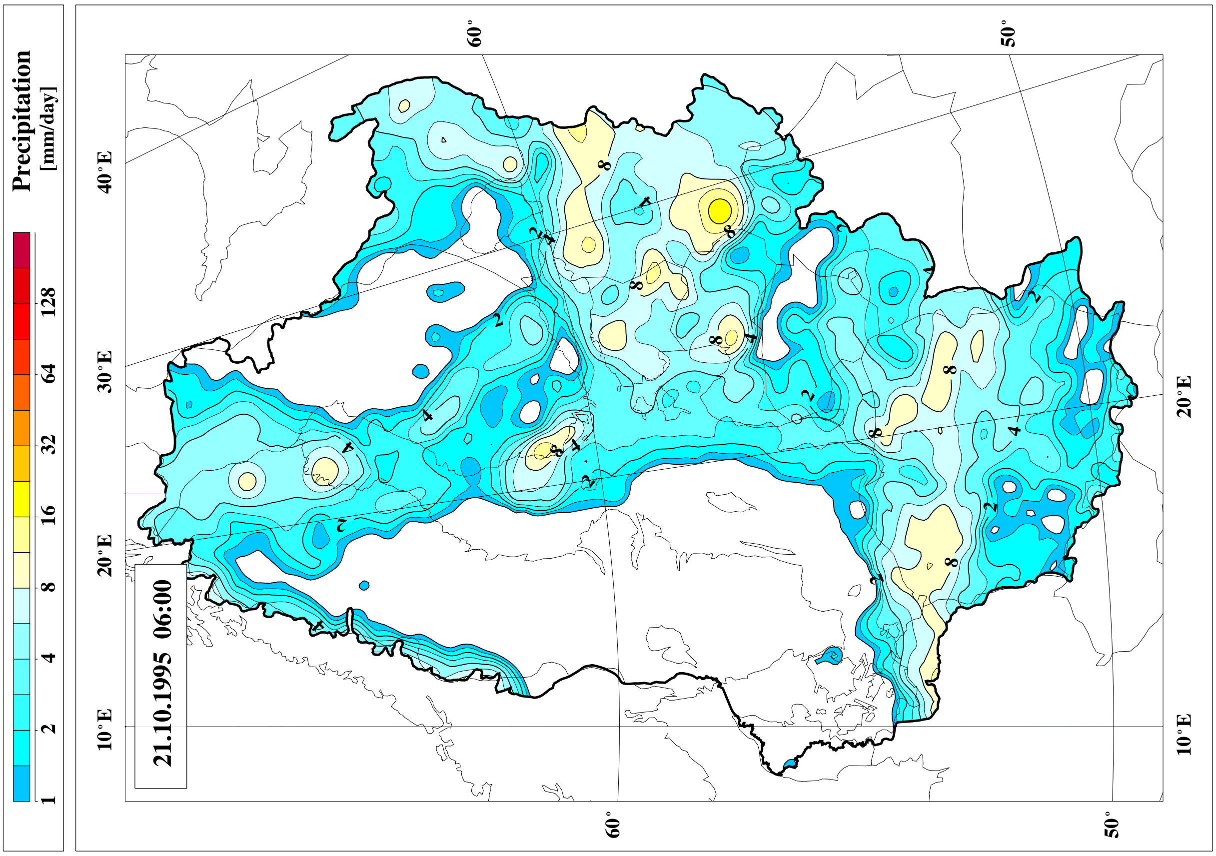
40°E
60°
50°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[mm/day]
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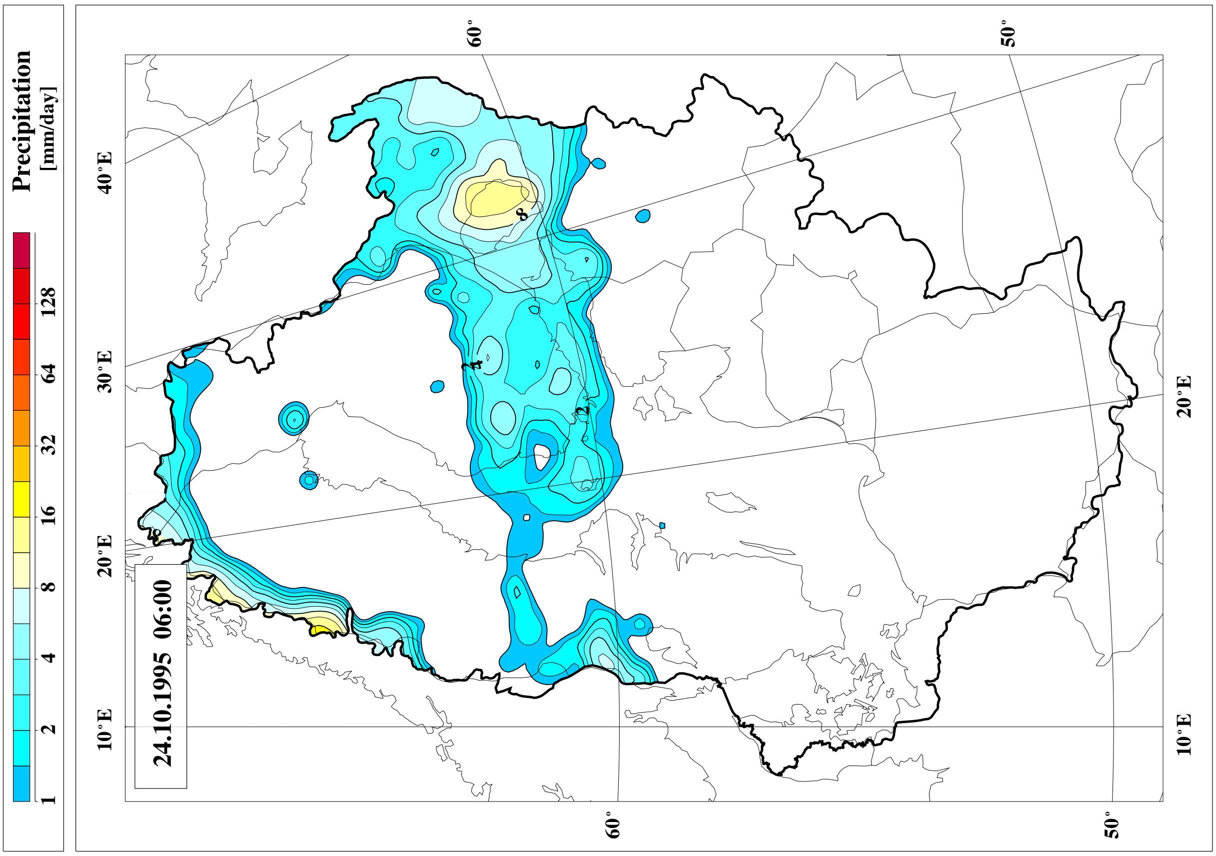
50°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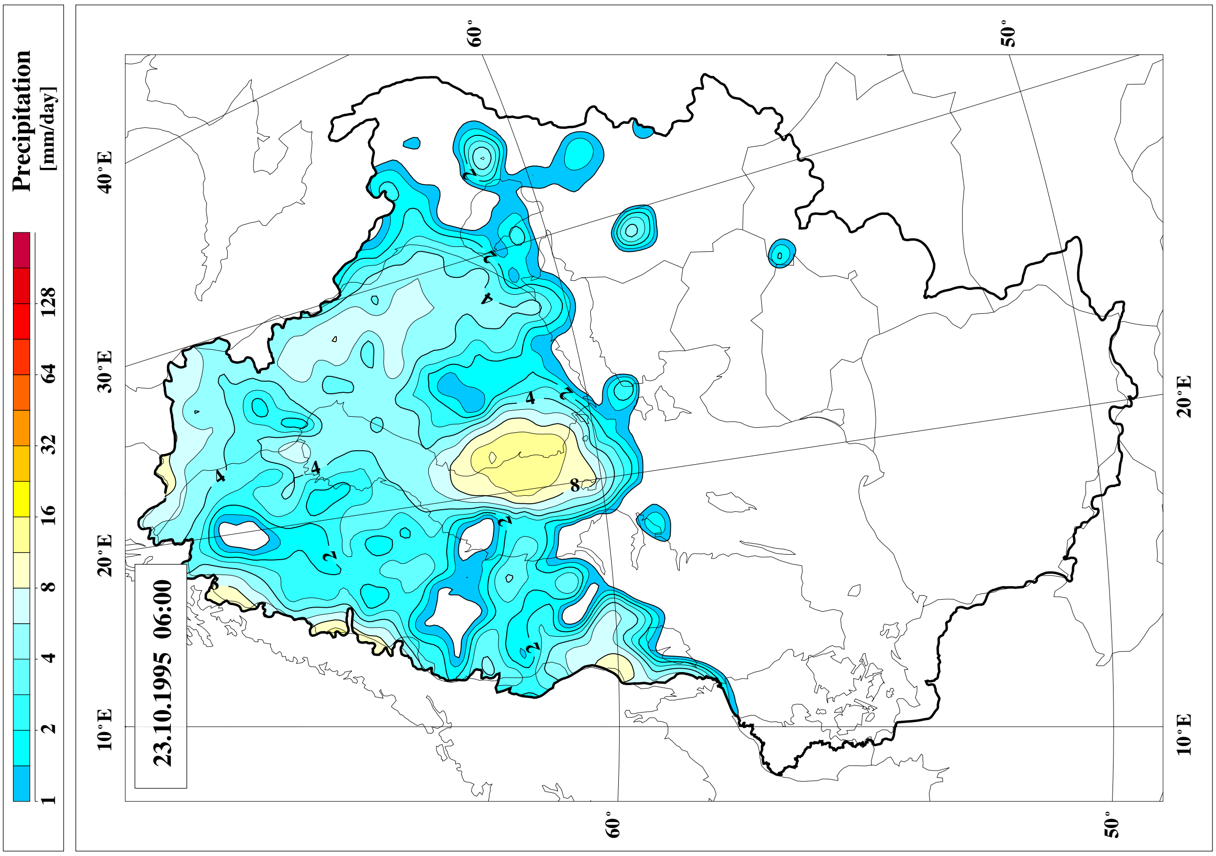
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[mm/day]
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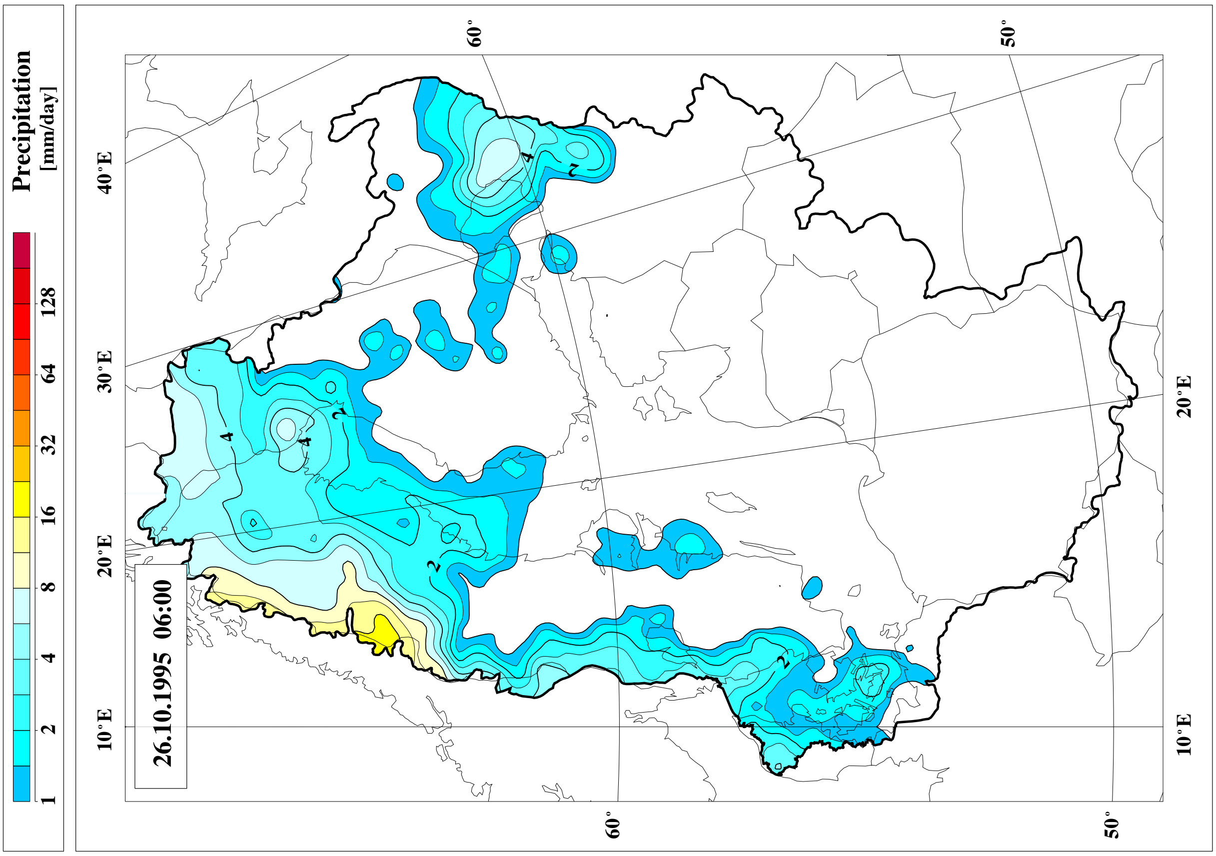
128
23.10.1995 06:00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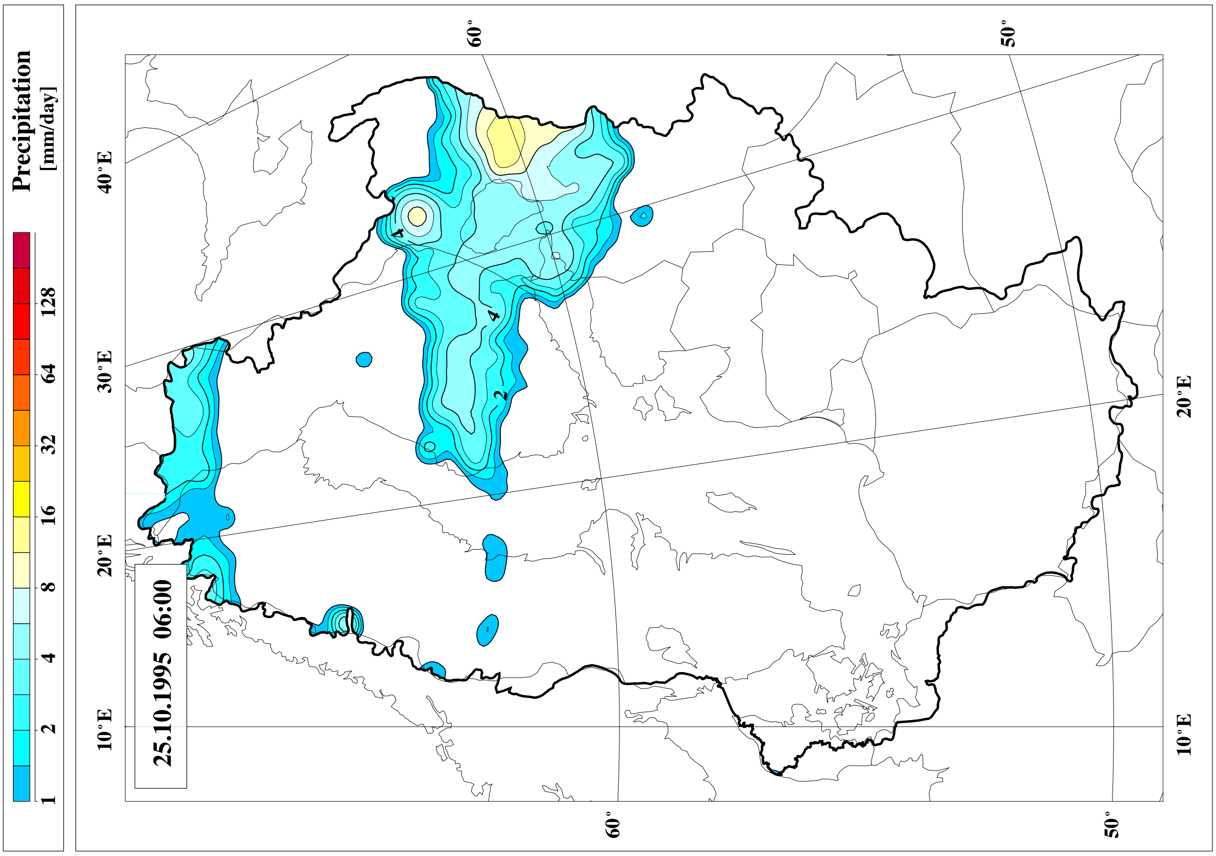
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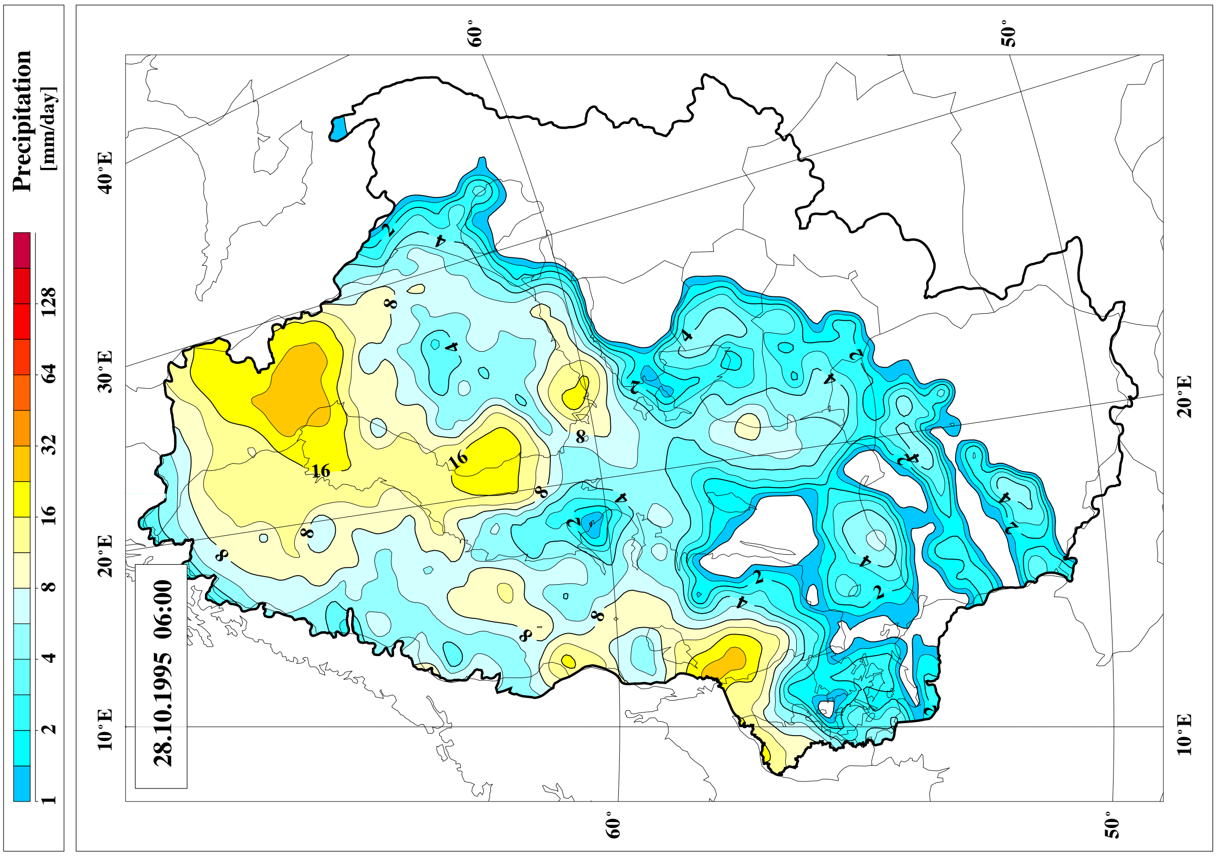
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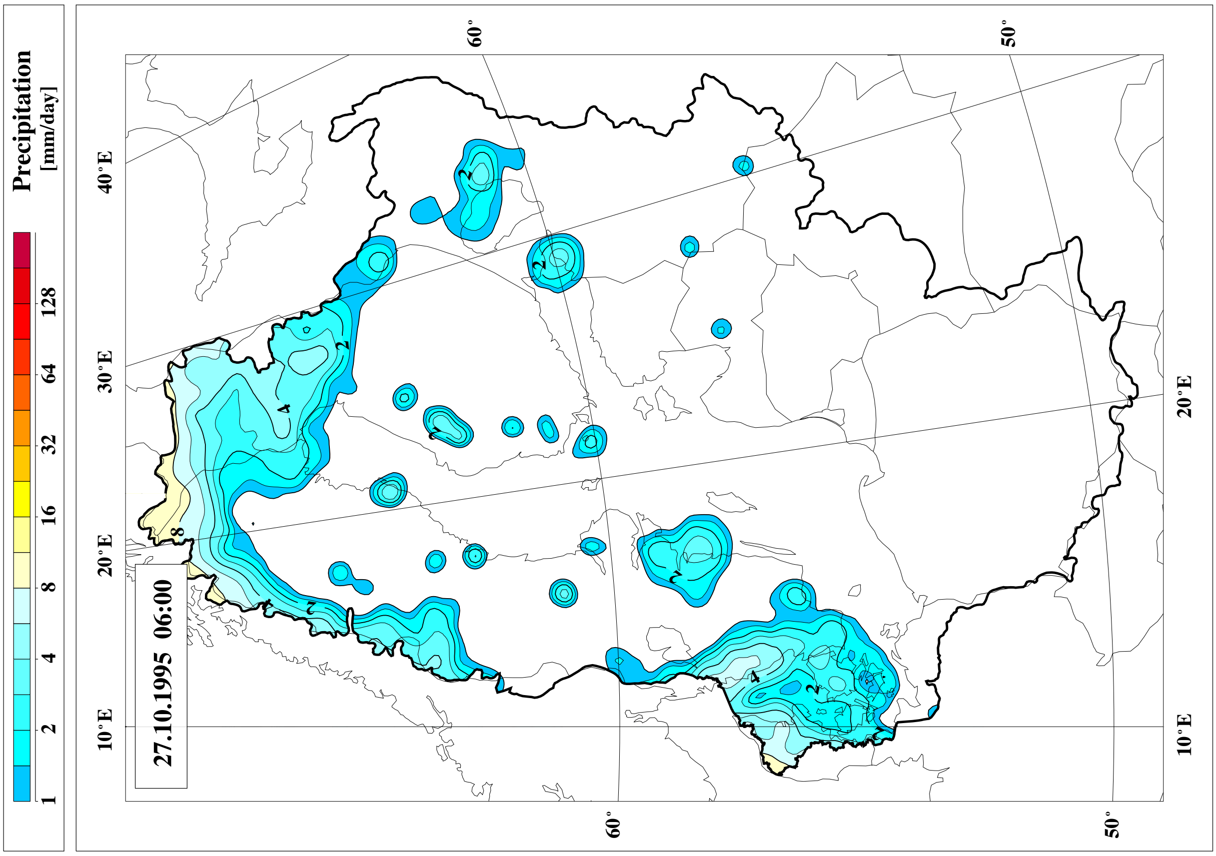
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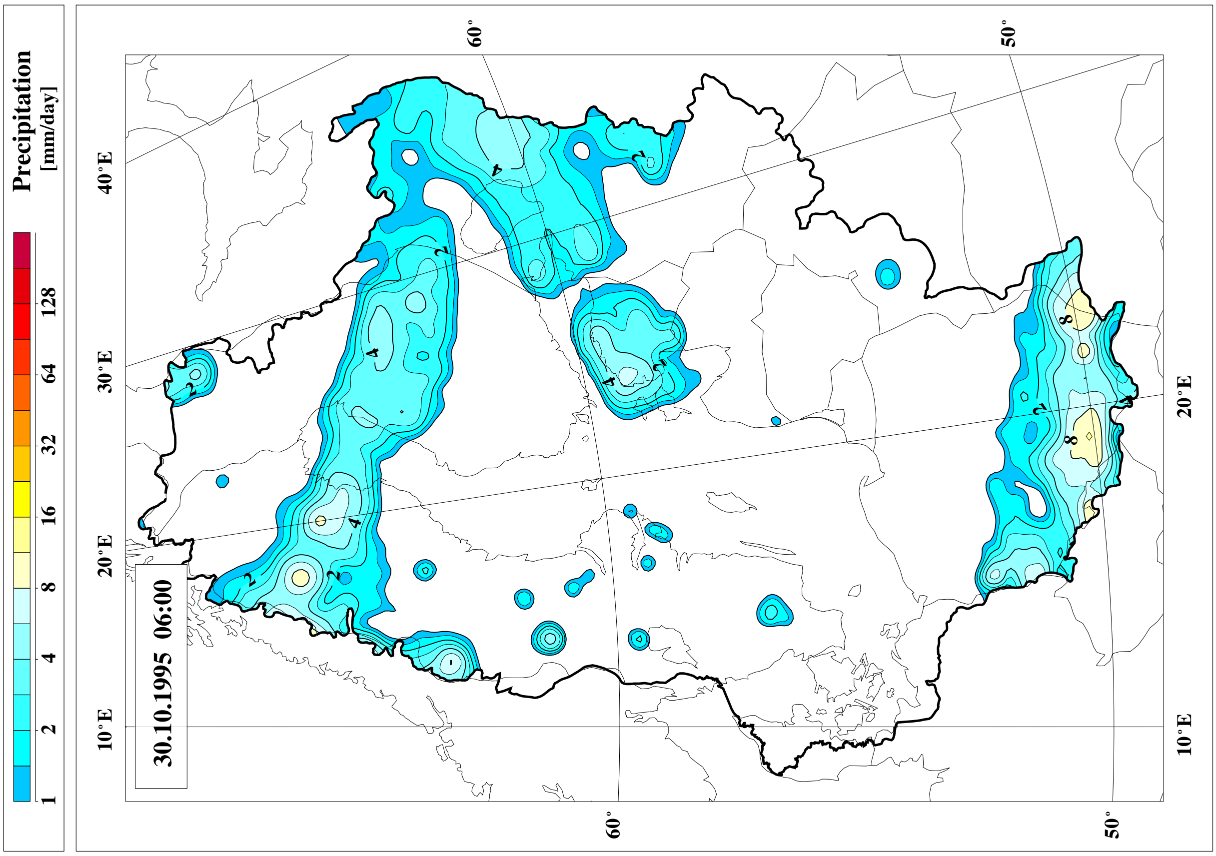
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[mm/day]
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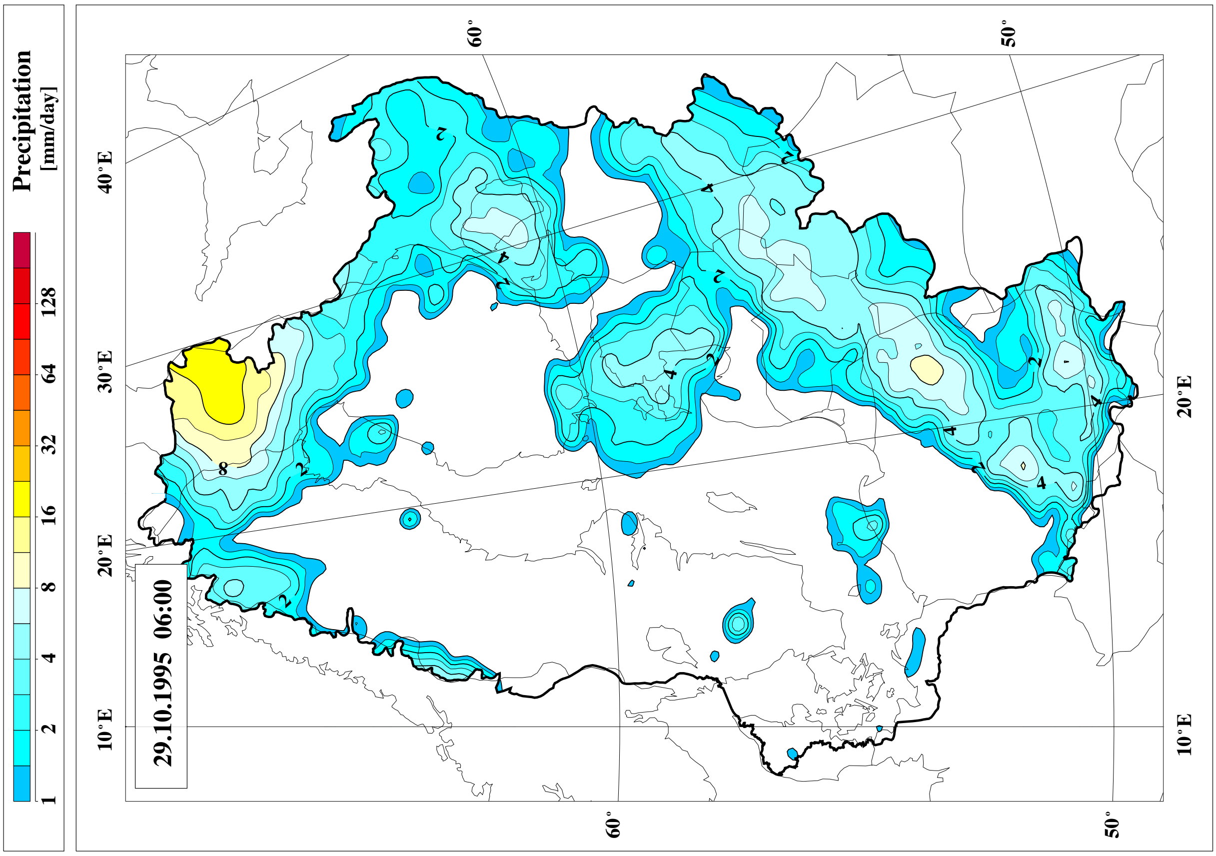
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128
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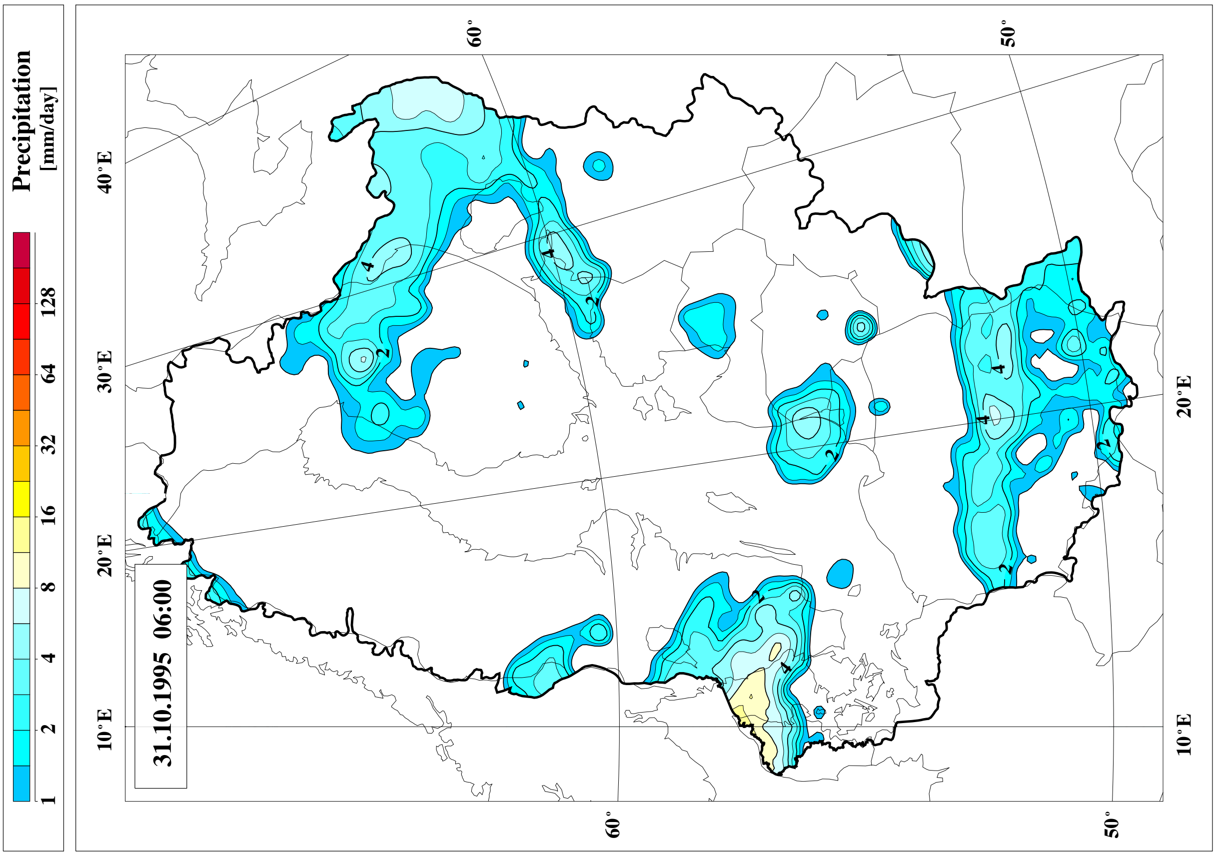
50°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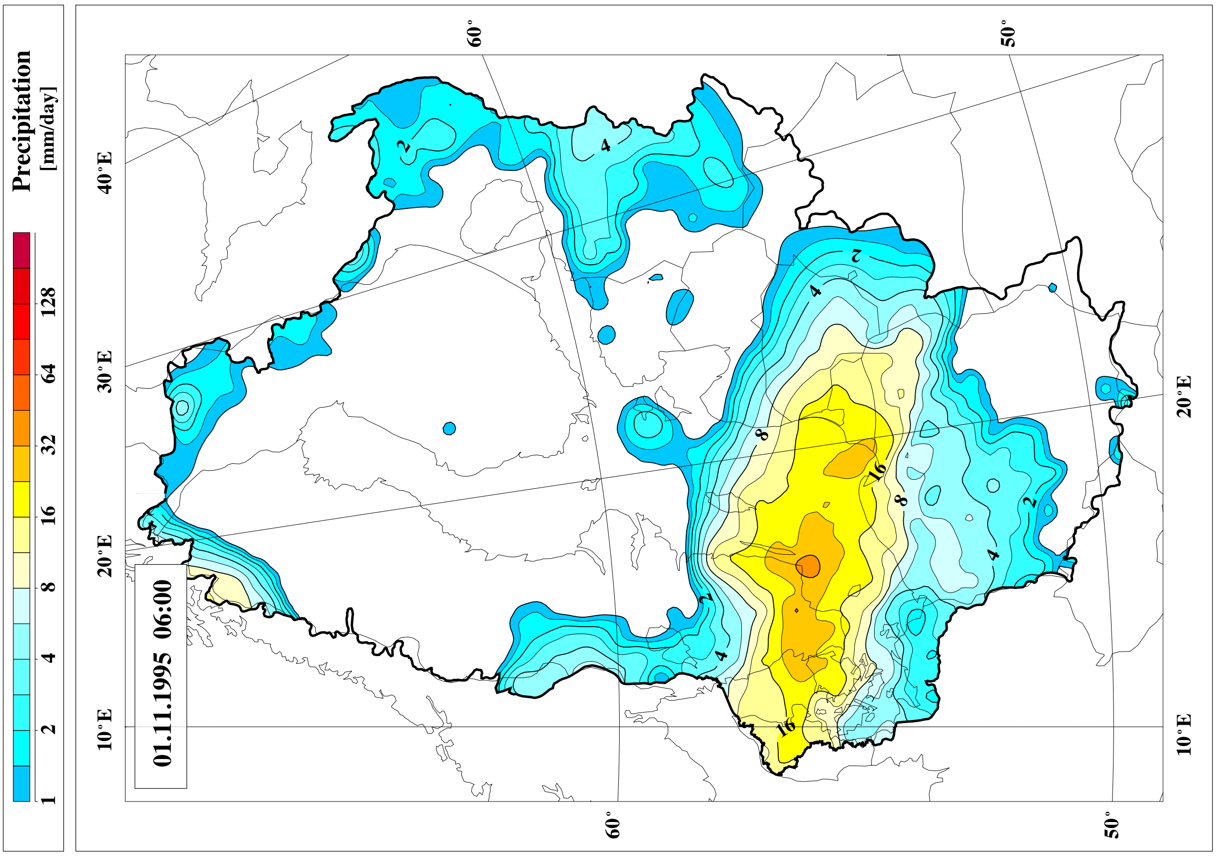
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Precipitation
[mm/day]
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10°E
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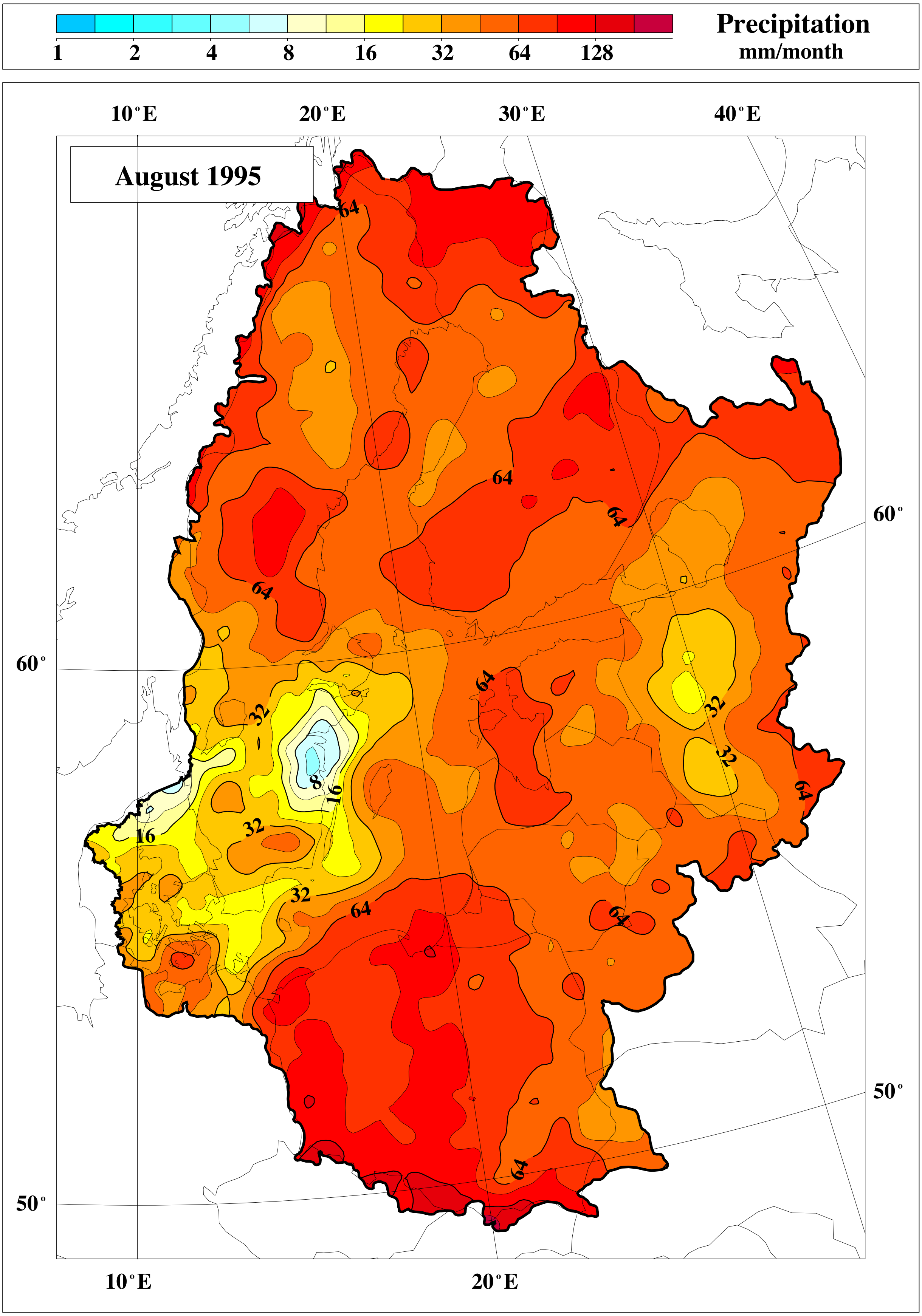
6 MONTHLY BALTIC DRAINAGE PRECIPITATION

In addition to the daily precipitation fields, both the areal distribution and the total amount of the monthly precipitation input into the Baltic Sea drainage basin are of interest. They are both computed from daily fields (Fig. 4) rather than from monthly gauge values. This guarantees that gauges which do not measure continuously all month long are also included in the analysis. Fig. 5 shows the areal distribution of the monthly precipitation fields for the PIDCAP months August, September and October 1995.

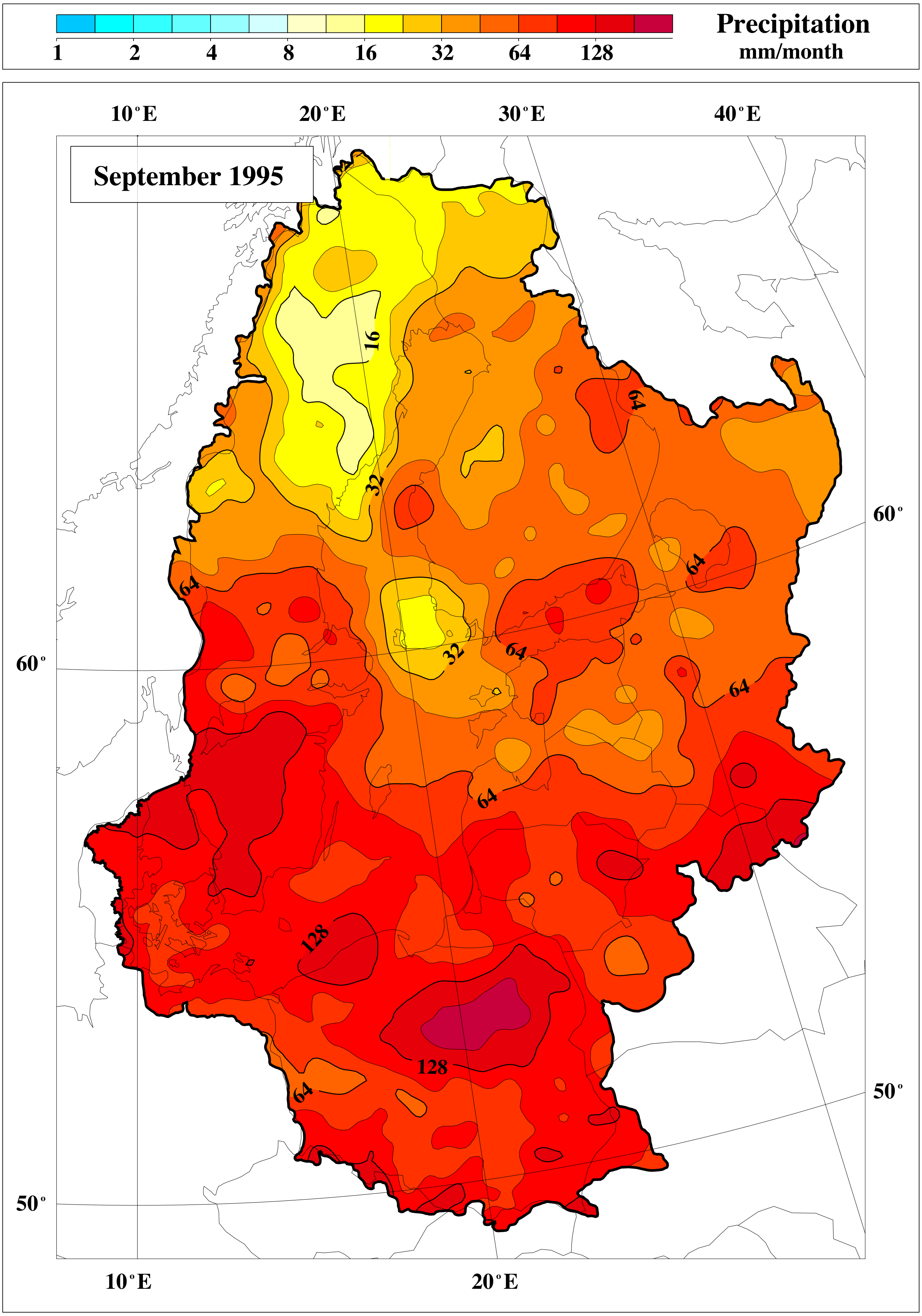
The areal precipitation distribution in August has a mean value of 59 mm. The maxima are registered in the mountainous parts of the catchment, with values exceeding 128 mm. The minimum with values lower than 8 mm is located in southern Sweden. In September the total freshwater input into the catchment is 73 mm, with low values in the North and high values in the South. In contrast to this, October is characterized by an opposite precipitation distribution with mean of 51 mm.

Fig. 6 shows the time series of the daily precipitation sums averaged over the whole catchment. The accuracy of the analysis is much lower over the open sea, in Fig. 7 the splitted time series for land and sea areas respectively are plotted. In the project NEWBALTIC, the analysis from land grid areas are usually taken for model verifications (Yang et al. 1998). The splitted time series indicate, that in most cases the precipitation part over land exceeds the one over sea. In certain cases, especially on days with high amount of precipitation, this picture reverts. The mean values over land/sea grid areas are 61/48 mm in August, 74/69 mm in September and 53/44 mm in October.

Figure 5 Page 60 - 62: Areal distribution of monthly precipitation within the Baltic drainage basin, obtained from daily objectively analyzed precipitation fields. Dates are August, September and October of the PIDCAP year 1995. Units in mm/month.



Precipitation
mm/month
1
2
4
8
16
32
64
128
August 1995
10°E
20°E
30°E
40°E
60°
50°
64
32
16
8



1
2
4
8
16
32
64
128
Precipitation
mm/month
September 1995
10°E
20°E
30°E
40°E
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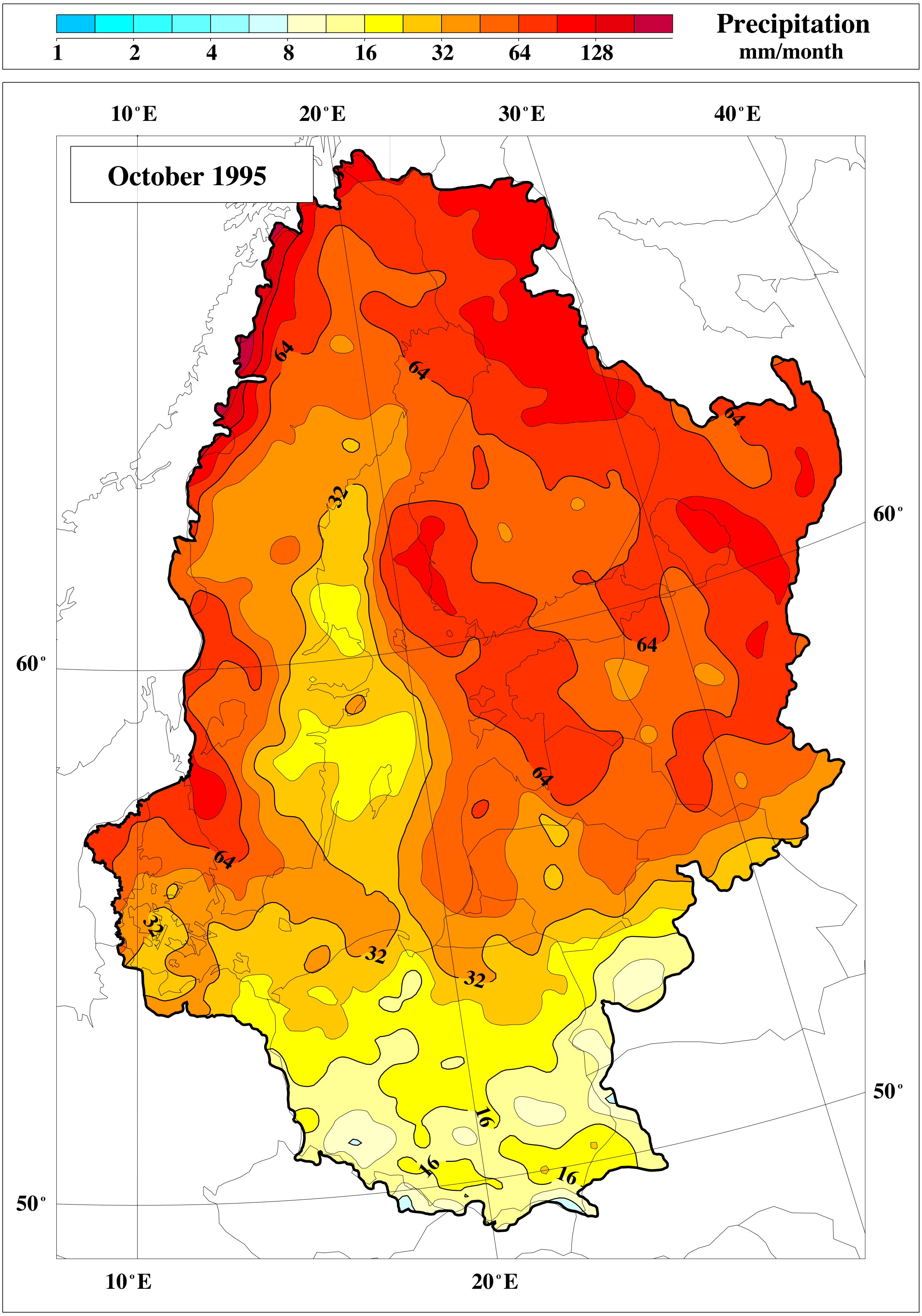
16
32
64
128


Precipitation
mm/month
1
2
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8
16
32
64
128
October 1995
10°E
20°E
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40°E
60°
50°
64
32
16

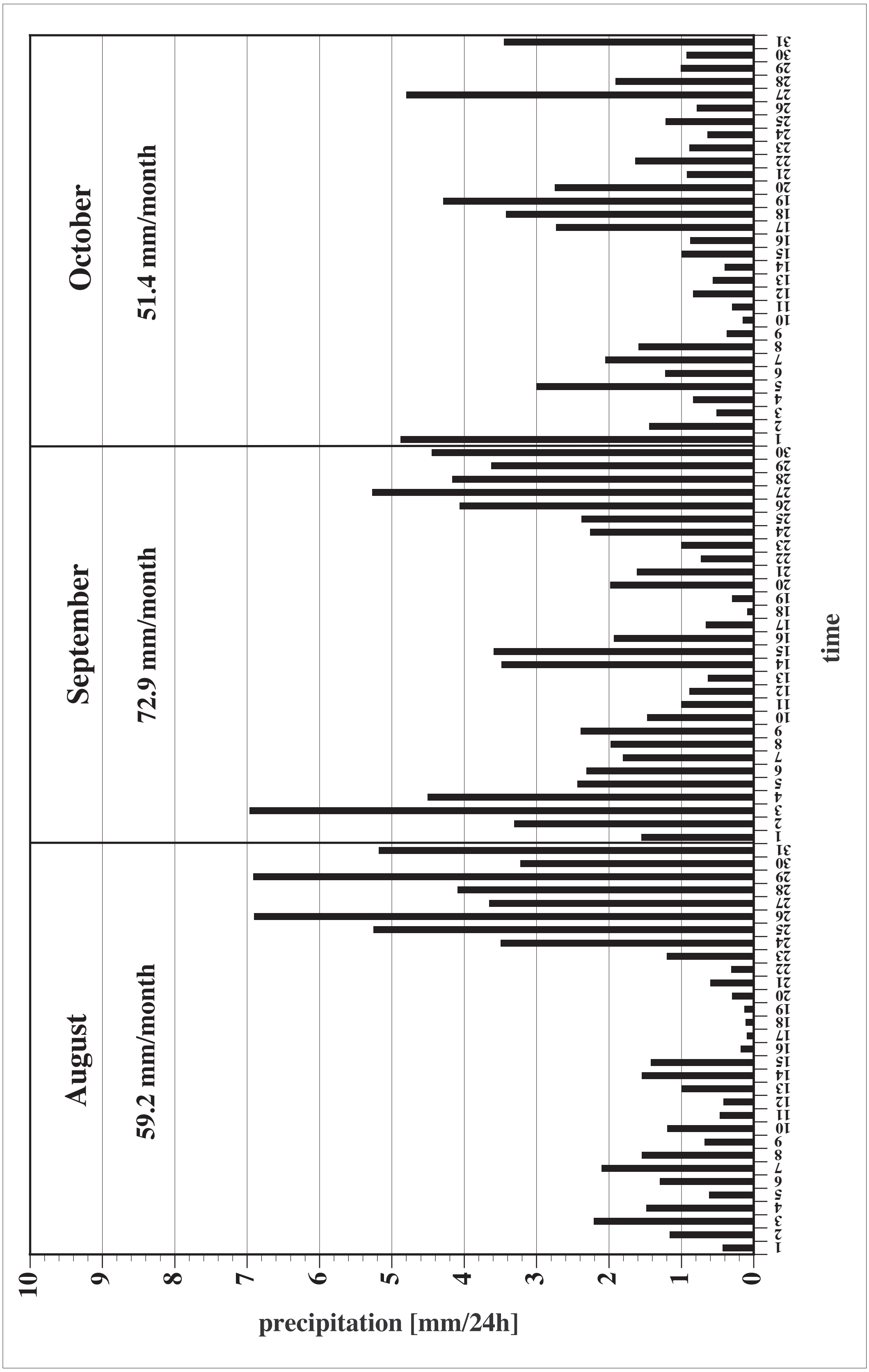


Figure 6 Daily precipitation sums averaged over the Baltic Sea drainage basin, calculated from objectively analyzed precipitation fields (Fig. 4), for the PIDCAP period of 1 August to 31 October 1995. Units are in mm/day. The monthly precipitation input into the Baltic drainage is 59.2 mm in August, 72.9 mm in September and 51.4 mm in October.

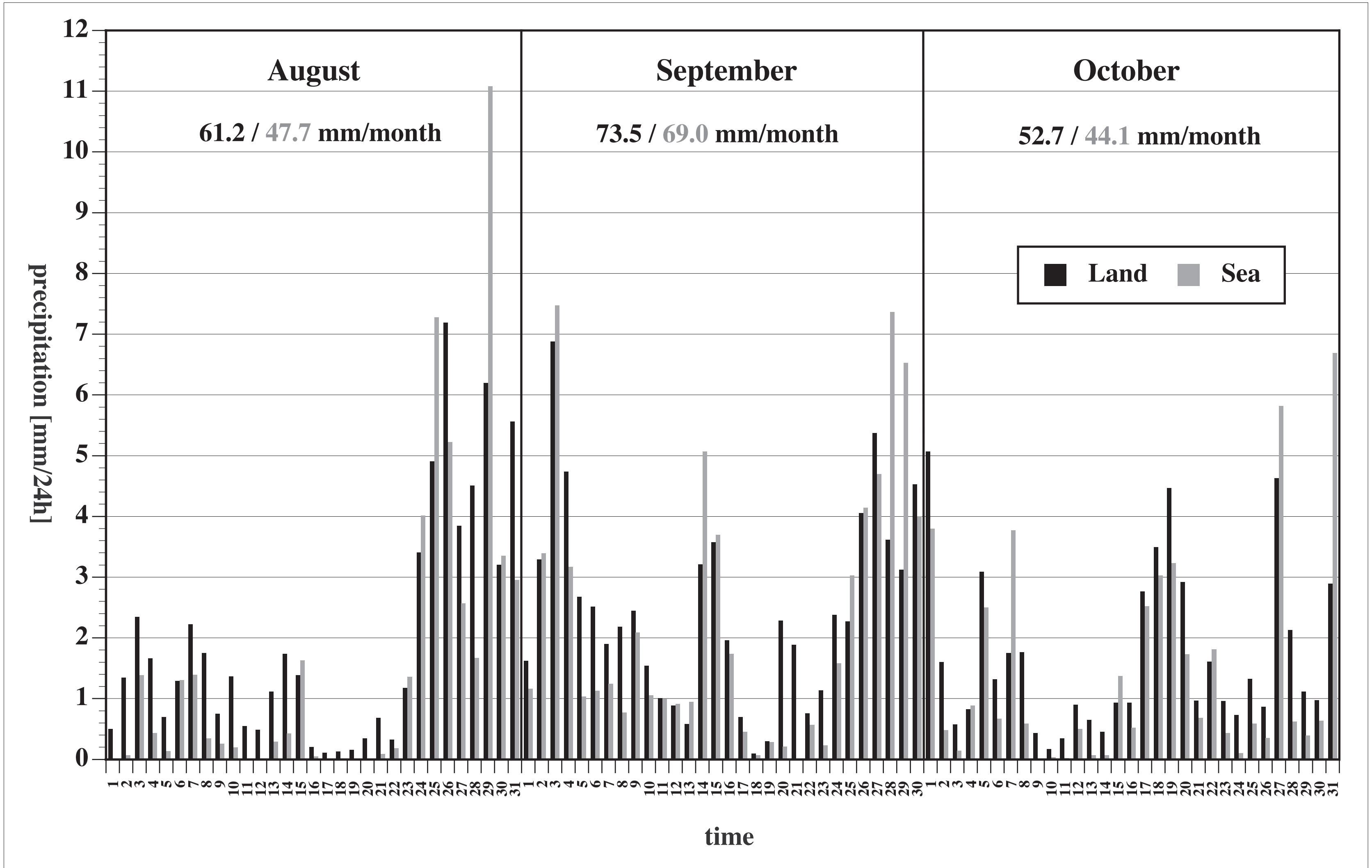


Figure 7 Daily precipitation sums averaged over land (black) and sea (grey) grid areas of the Baltic Sea drainage basin, calculated from precipitation fields (Fig. 4), for the PIDCAP period of 1 August to 31 October 1995. Units are in mm/day. The freshwater input over land is 61.2 mm in August,73.5 mm in September and 72.7 mm in October. Corresponding values over sea are 47.7 mm, 69.0 mm and 44.1 mm.

7 COMPARISON WITH EARLIER ANALYSES

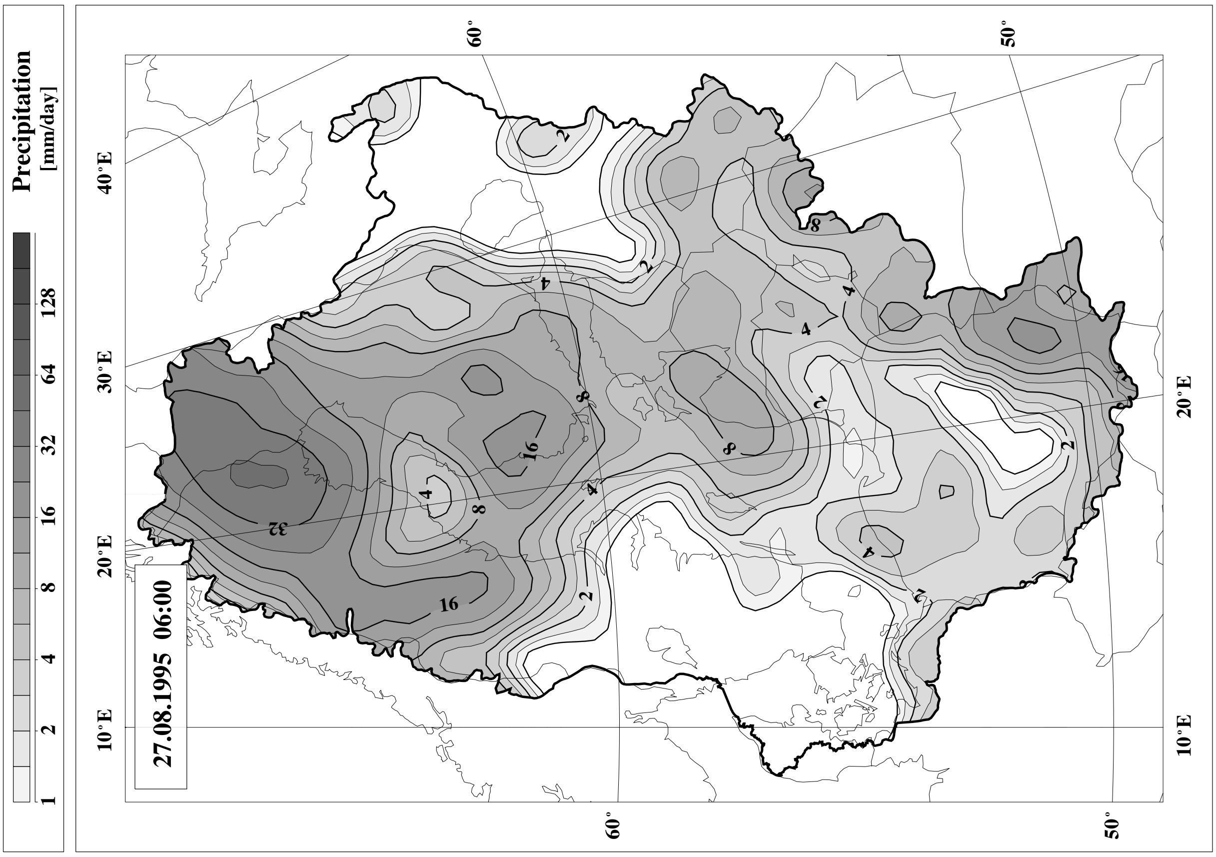
PIDCAP was defined in 1996 (Isemer 1996a). In the same year, before any data had been collected by the BMDC, the *PIDCAP Quick Look Precipitation Atlas* (Rubel 1996) became available. It gave the working groups participating in PIDCAP a first overview on precipitation events. This first precipitation analysis was based on SYNOP data only; the used grid was those of the German EM model (resolution 55 km).

What are the improvements of the new higher resolution analysis available now in the present atlas? It is clear, that the ten times higher data density analyzed on a finer grid gives more detailed pictures. Are the now analyzed fields more realistic compared with the former ones? To answer this question, in Fig. 8 the daily fields on the coarse resolution of 55 km are plotted against each other; again the 27 August 1995, 06:00 UTC was chosen. No statistical measures are given, the reader may form an opinion by visually comparing the pictures. Taking into account the spatial autocorrelation of precipitation events on different scales (Rubel 1996b, Hantel et al. 1997), it should not surprise that there is a relatively good agreement. Nevertheless, in some cases of small scale convection over limited regions, deficits due to the low data density of the synoptic network are found.

The following pictures (Fig. 9) show the corresponding comparison of the monthly precipitation fields. Again, it was found that the higher data density results in an almost negligible improvement. The values of the catchment averaged monthly precipitation sums calculated from low/high resolution analysis are 55/59 mm in August, 71/73 mm in September and 47/51 mm in October. This comparison confirms the reliability of the coarse resolution analysis from synoptic data only given in the *PIDCAP Quick Look Precipitation Atlas*. Differences are mainly caused by the correction of the raw gauge measurements (Rubel and Hantel 1998).

Figure 8 Page 66: Daily precipitation on the grid of the German EM-model (horizontal resolution 55 km), calculated from twice daily objectively analyzed fields based on 400 synopic gauges (left, see Rubel 1996), and averaged from the corresponding daily field based on 4 000 corrected rain gauges (right, see Fig. 2). Date: 27 August1995, 06:00 UTC. Units in mm/day.

Figure 9 Page 67 - 69: Monthly precipitation on the grid of the German EM-model (horizontal resolution 55 km), calculated from twice daily objectively analyzed fields based on 400 synoptic gauges (left, see Rubel 1996), and averaged from the corresponding monthly fields based on 4 000 corrected rain gauges (right, see Fig. 5). Dates are August, September and October of the PIDCAP year 1995. Units in mm/month.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27.08.1995 06:00
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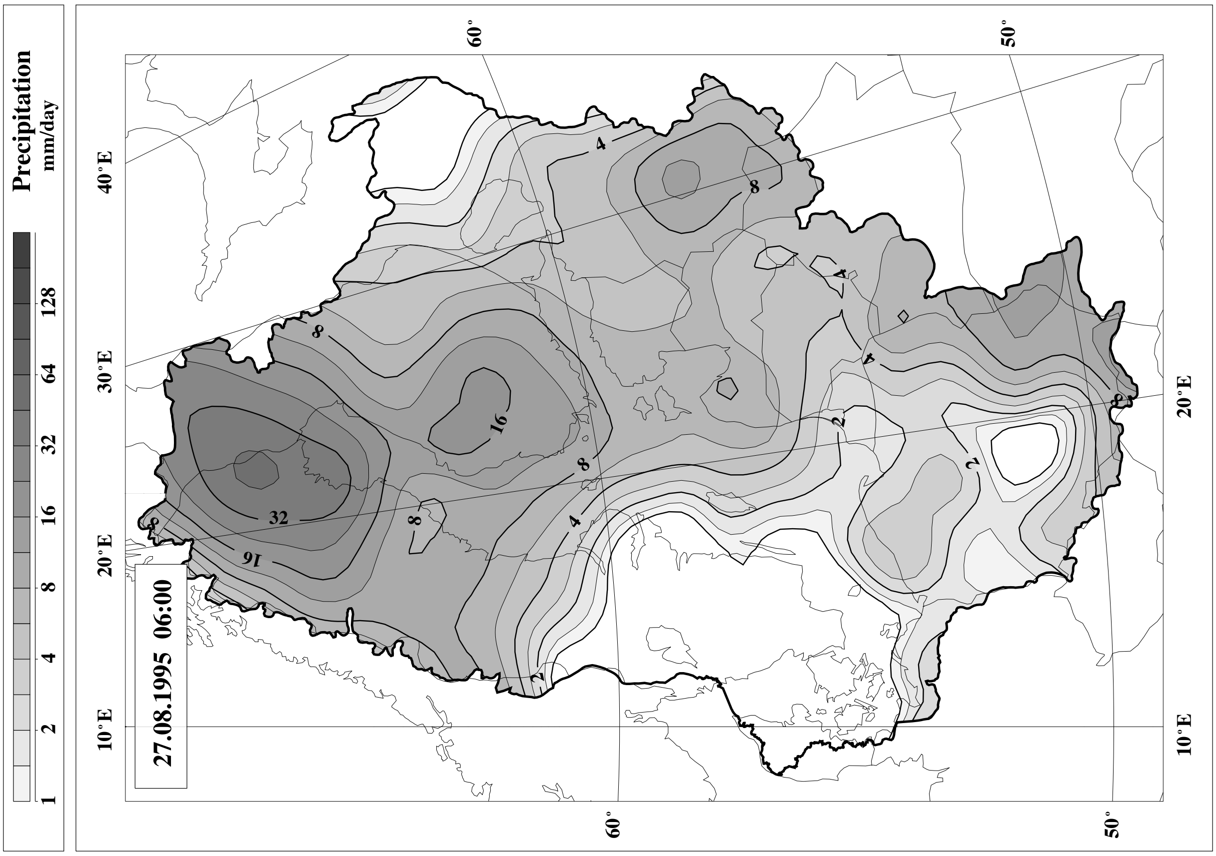
Precipitation
mm/day
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27.08.1995 06:00
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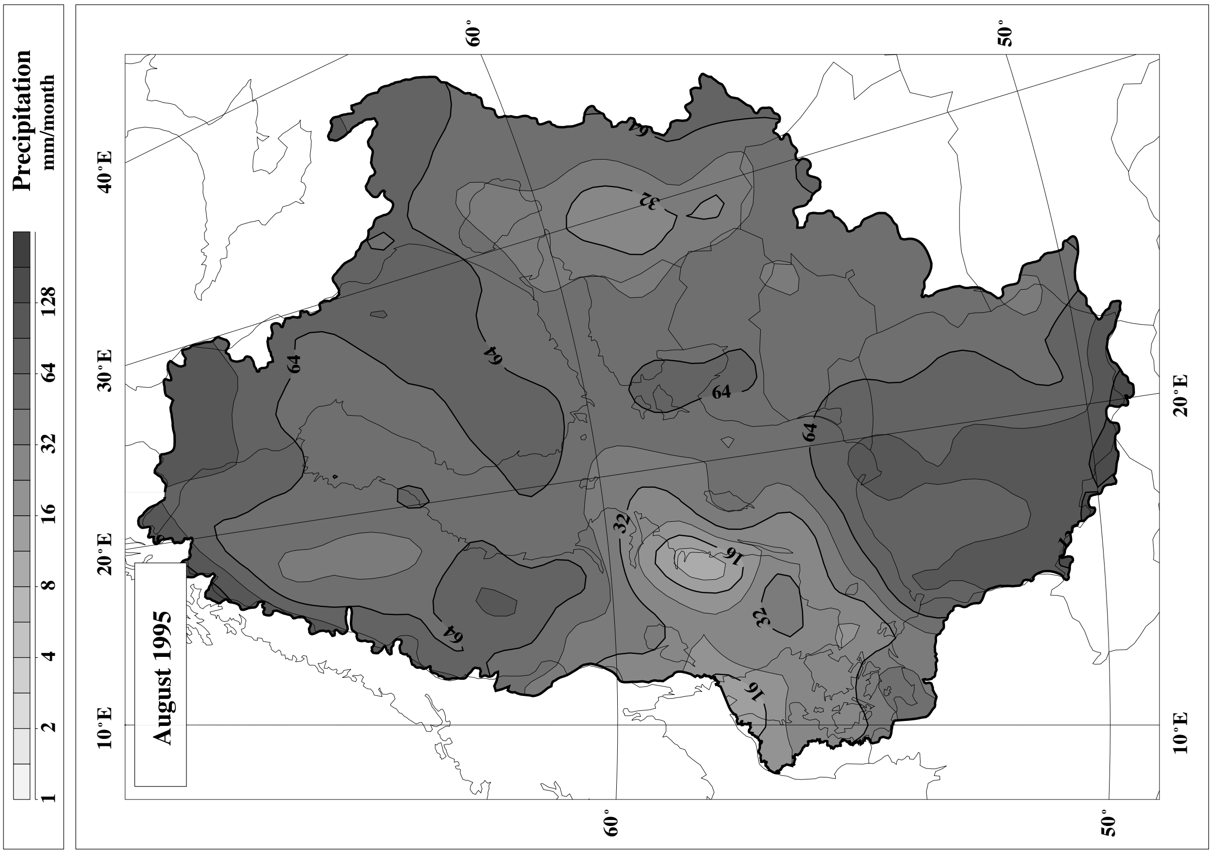
Precipitation
mm/month
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August 1995
10°E
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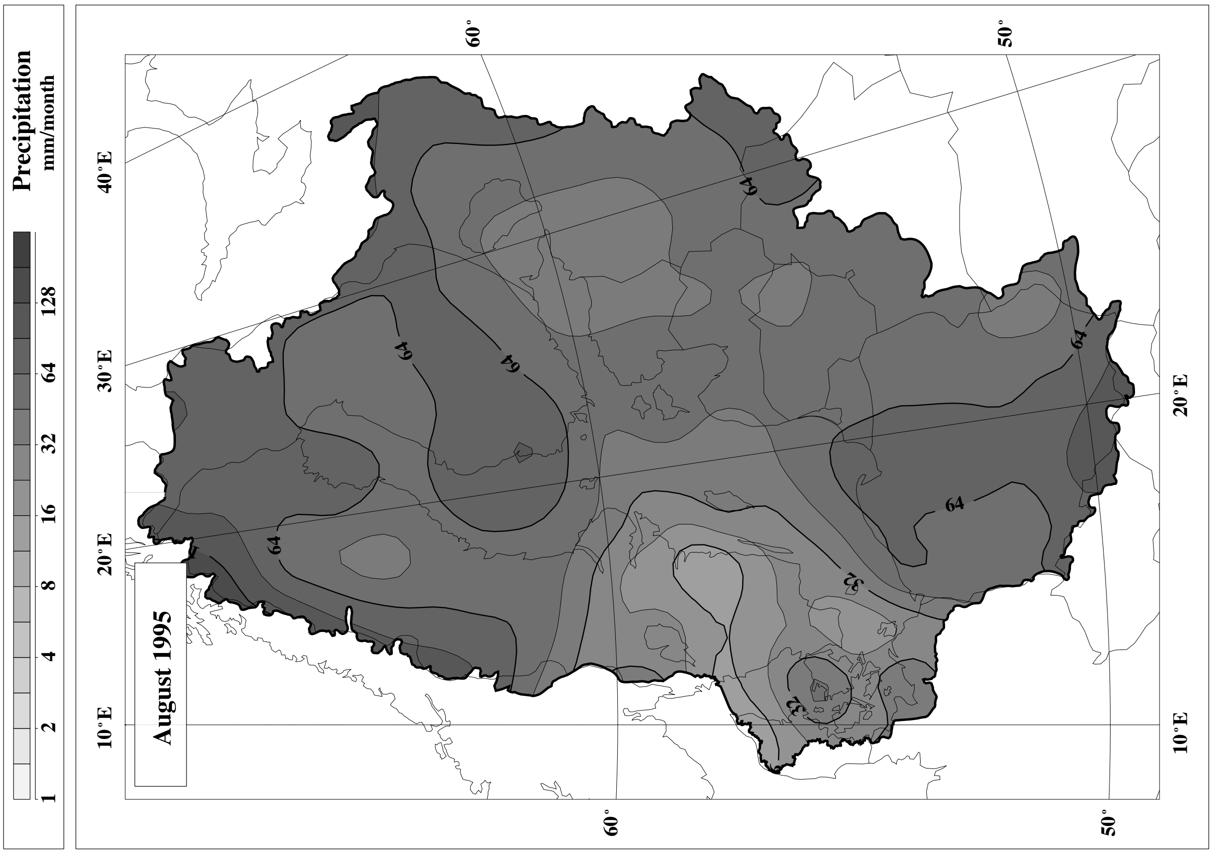
Precipitation
mm/month
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August 1995
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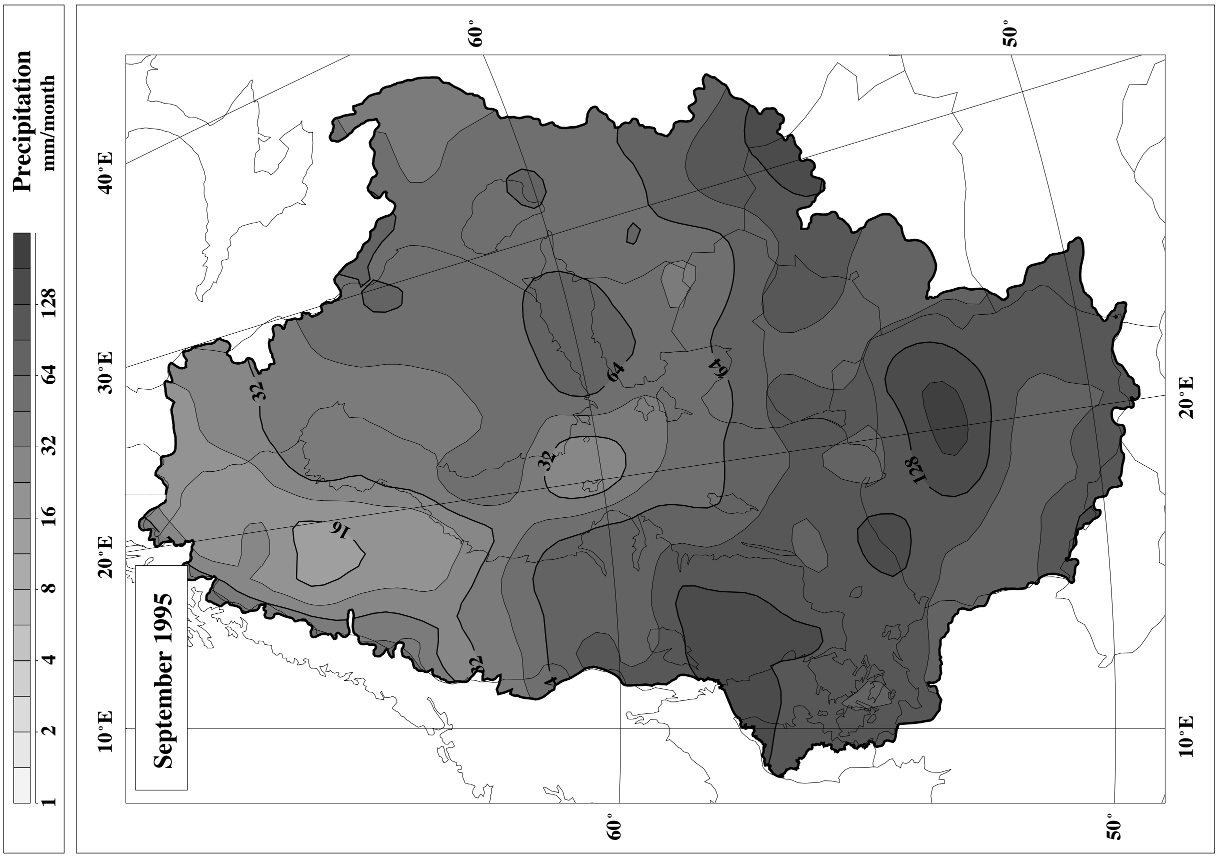
Precipitation
mm/month
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September 1995
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20°E
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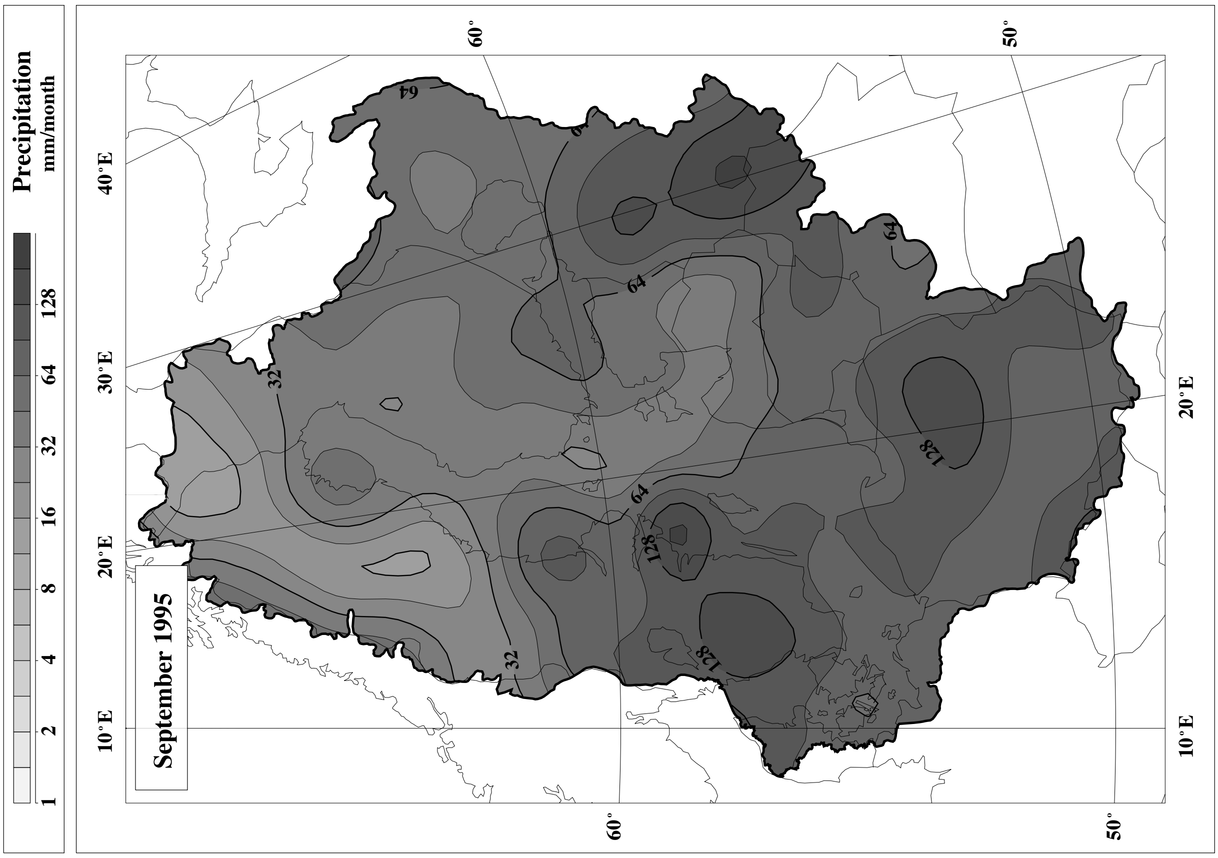
Precipitation
mm/month
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128
September 1995
10°E
20°E
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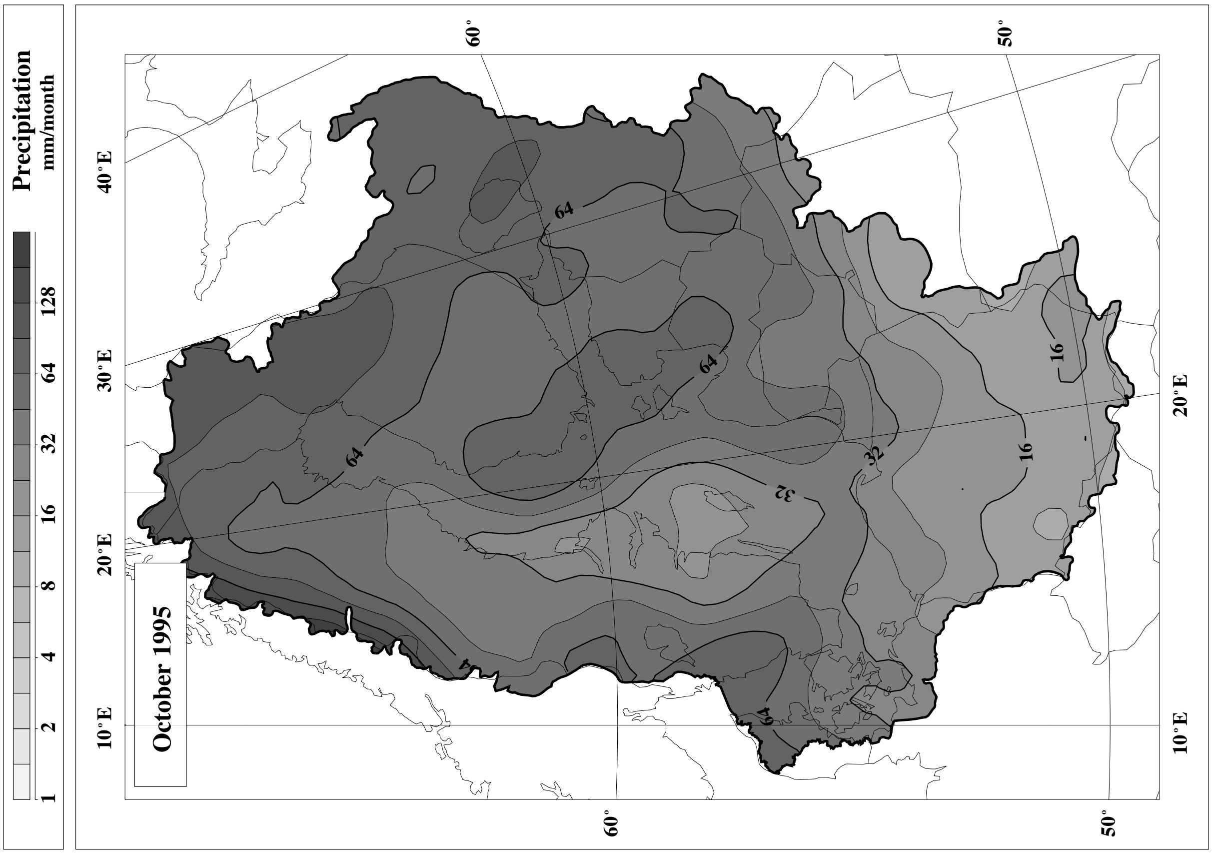
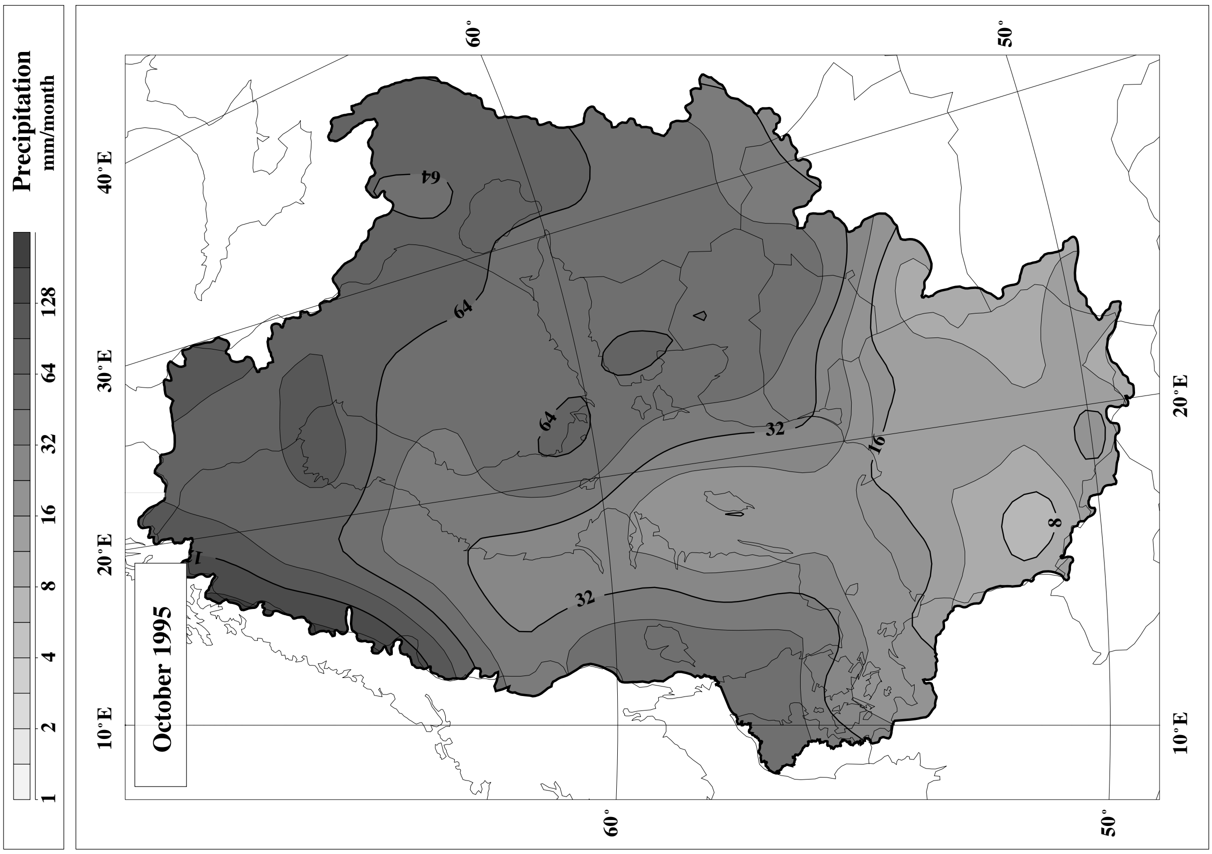
60°
50°


Precipitation
mm/month
1
2
4
8
16
32
64
128
October 1995
10°E
20°E
30°E
40°E
60°
50°
64
32
16


Precipitation
mm/month
1
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October 1995
10°E
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50°
64
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16
8

8 COMPARISON WITH NWP MODEL FORECASTS

In accordance to the *PIDCAP Quick Look Precipitation Atlas*, which contains comparisons between analysed precipitation fields with corresponding forecasts from the ECMWF model, here comparisons with mesoscale NWP models are shown.

It is not goal of this atlas to present a detailed model verification of the hydrological cycle of NWP models (Rubel et al. 1993, Hantel et al 1995). A first inter-comparison of models used in NEWBALTIC is forthcoming (Yang, et al. 1998). In order to nevertheless demonstrate the usefulness of the precipitation analysis for a verification, 3 model forecasts calculated from re-analysis in NEWBALTIC have been chosen. The first is the REMO, a derivative of the German DM (DWD, 1995), running at the GKSS Research Centre in a weather forecast mode (Karstens et al. 1996, Raschke et al. 1998). The second is also the REMO running at the MPI Hamburg in climate mode (Jakob et al. 1997). The third model is the Danish HIRLAM (Sass and Yang 1997).

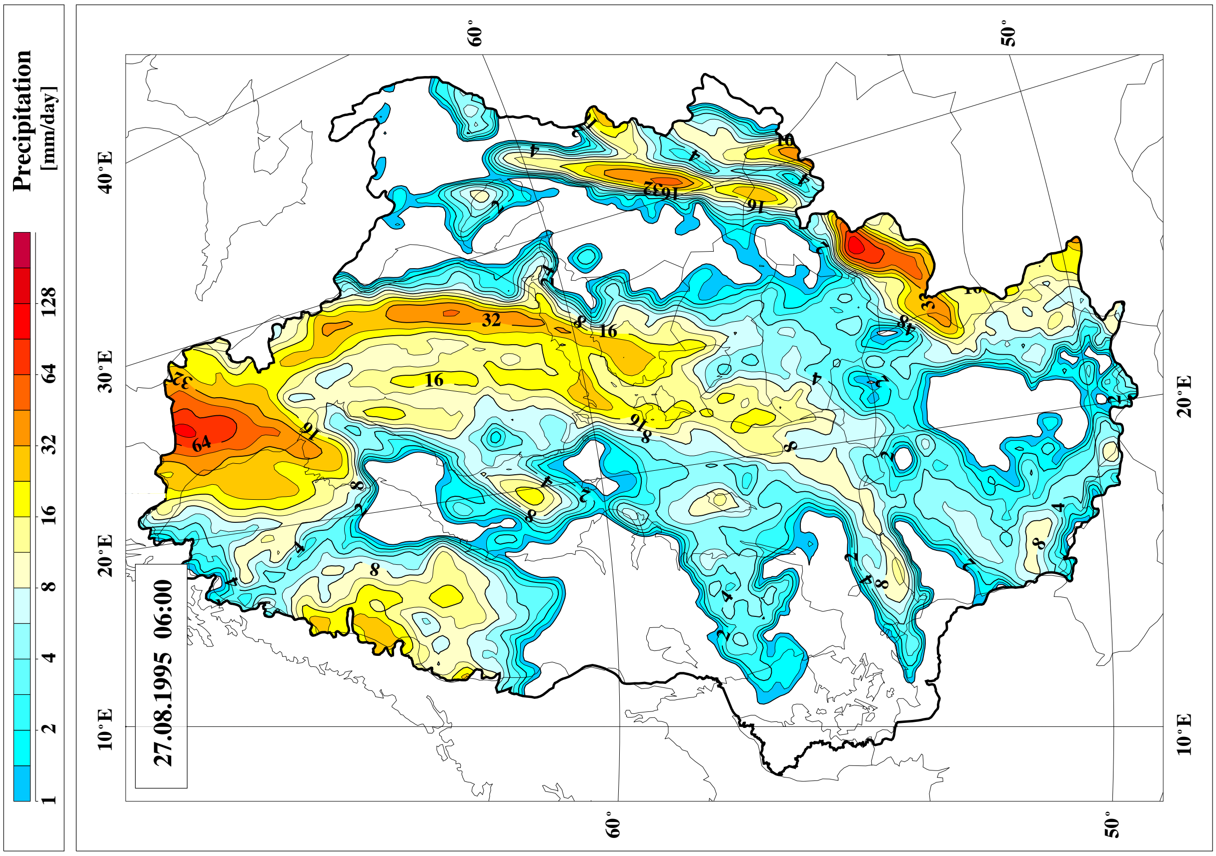
Fig. 10 shows the comparison between the analysis (left), based on corrected rain gauges, and the REMO forecast (right) accumulated from 6 hour to 30 hour forecasts from GKSS Research Centre. These daily precipitation field show a good agreement, except the predicted rain band in the east of the catchment which could not be analyzed from observations. Remarkable is the higher variance in the modelled precipitation fields.

The next picture shows the comparison between the monthly precipitation fields in the drainage basin (Fig. 11). Again, the analysis is based on corrected rain gauges (left), the forecast is from REMO running at MPI Hamburg (right).

The last comparison shows time series of analyzed areally averaged daily precipitation sums plotted against predictions (6 to 30 hour forecasts) from the Danish HIRLAM (Fig. 12). Particularly for September 1995, a very good agreement was found, while in August and October 1995 the overestimation of events with low precipitation is indicated. Monthly analyzed/modelled values are 61/75 mm in August, 74/74 mm September and 53/65 mm in October.

Figure 10 Page 71: Comparison of daily precipitation fields analyzed (left) from corrected rain gauges against predicted (right) with REMO (GKSS). Date: 27 August1995, 06:00 UTC. Units in mm/day.

Figure 11 Page 72: Comparison of monthly precipitation fields for October 1995, analyzed (left) from corrected rain gauges against predicted (right) with REMO (MPI). Units in mm/month.


Precipitation
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27.08.1995 06:00
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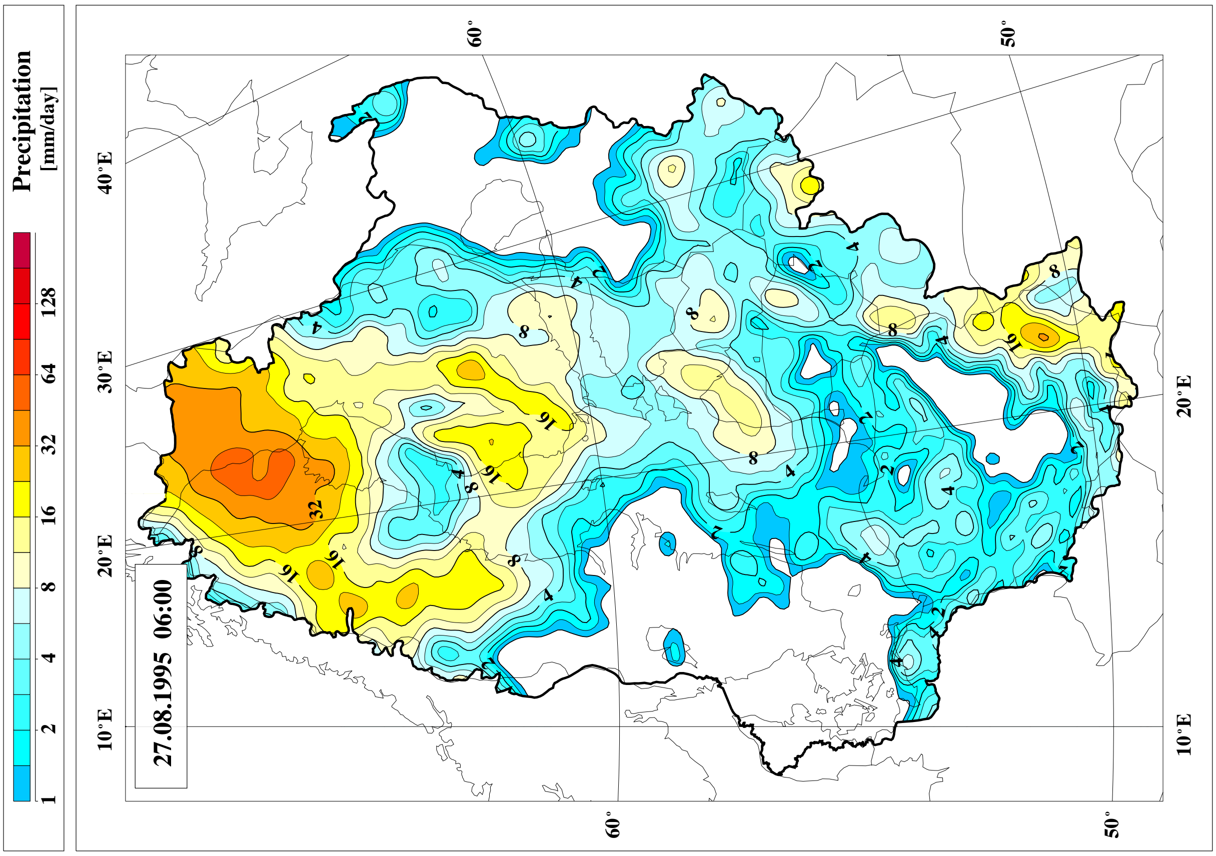
20°E
30°E
40°E
60°
50°


Precipitation
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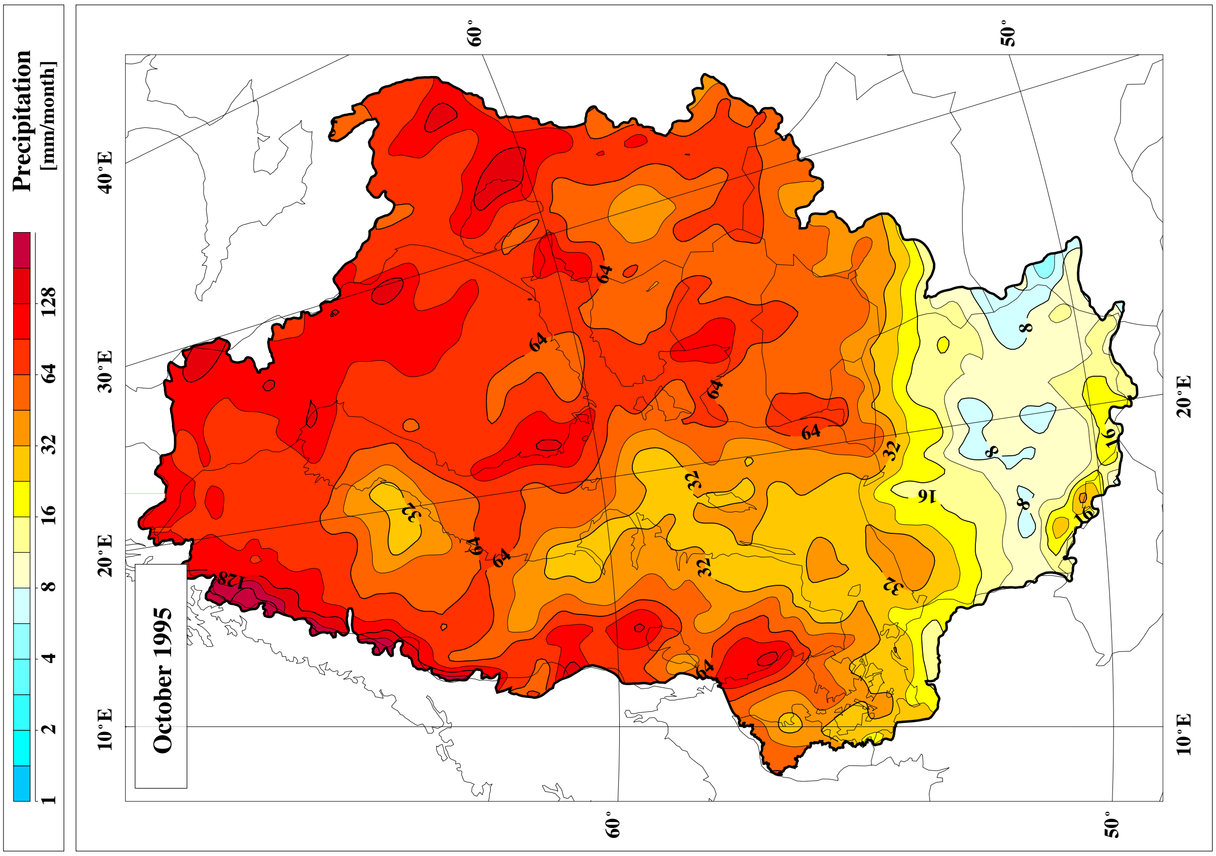
Precipitation
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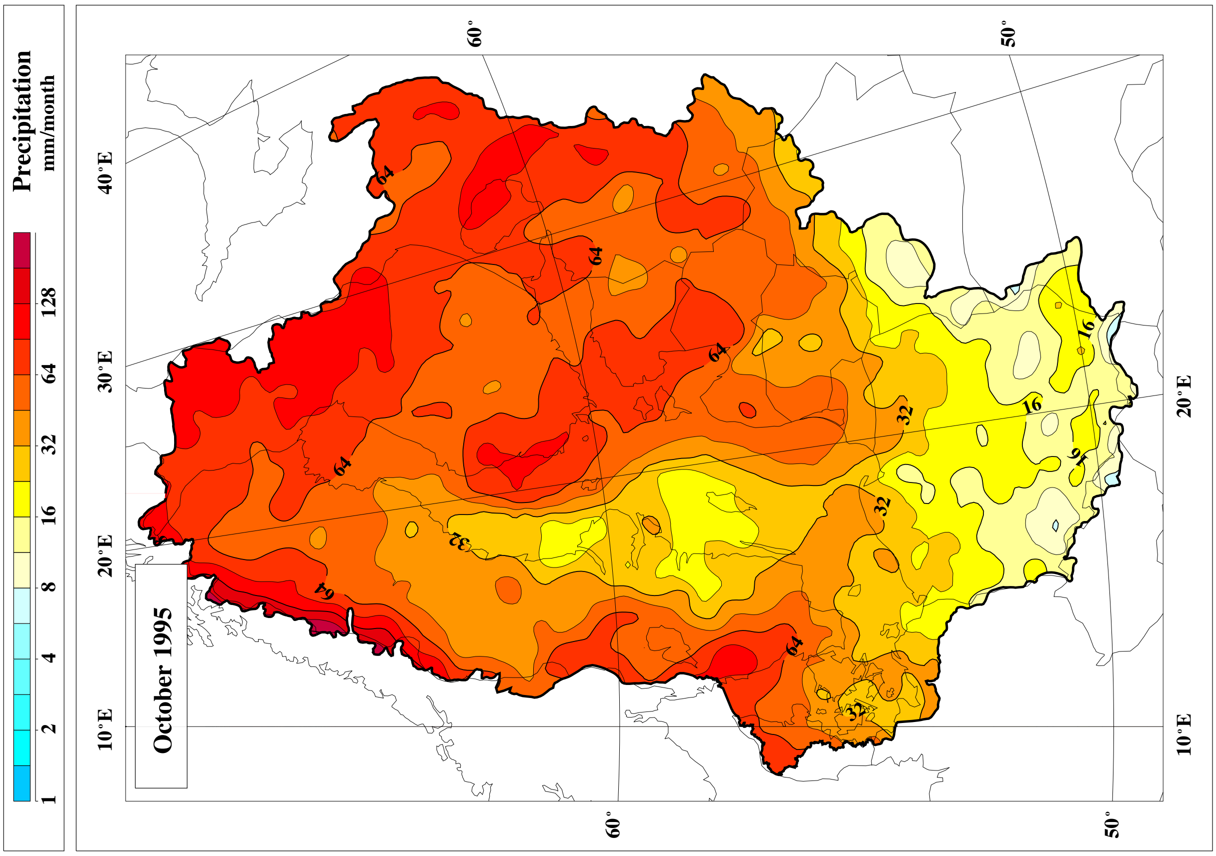
Precipitation
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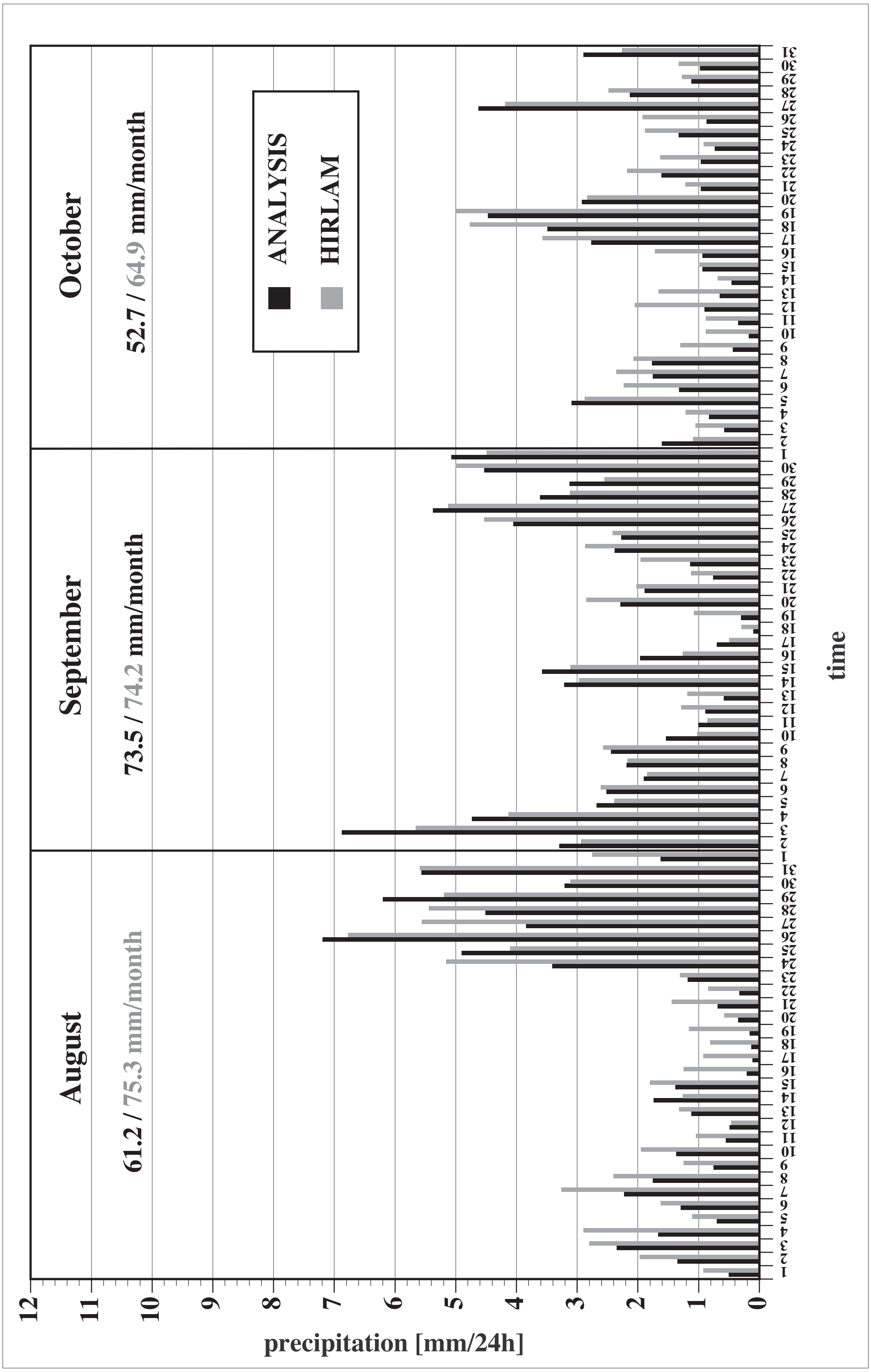

Figure 12 Daily precipitation sums averaged over land grid areas of the Baltic Sea drainage basin, analyzed from corrected rain gauges (black) and predicted from Danish HIRLAM (grey), for the PIDCAP period of 1 August to 31 October 1995. Units in mm/day. The freshwater input over land is 61.2 (75.3) mm in August,73.5 (74.2) mm in September and 52.7 (64.9) mm in October.

9 CONCLUSIONS

The present *Ground Truth Precipitation Atlas* was compiled following the concept of the formerly published *Quick Look Precipitation Atlas*. Again, for the analysis a statistical method known as ordinary block kriging (optimum interpolation without a modelled first guess field) was used. With this method, the areally averaged precipitation is estimated from the irregularly spaced observations, by minimizing the mean square interpolation error. Improvements compared to the former analyses are:

- Use of the extended data base collected by the BMDC;
- correction of the raw rain gauge measurements; and
- implementation of a mesoscale analysis grid with 18 km horizontal resolution.

The results have been presented in form of daily precipitation maps (corresponding to the available data base) for the whole BALTEX model domain. Further, the areal distribution of the monthly precipitation input into the Baltic drainage basin has been calculated from these daily precipitation fields. Averaging over all grid points within the catchment gives areally averaged monthly precipitation values for the three months of the PIDCAP period (for the fourth month no data from the BMDC are available). Additionally, the temporal distribution of the areally averaged precipitation values has been presented in form of time series. These are given for the whole catchment area, for land areas and for sea areas, respectively. Intercomparisons with fields from the *Quick Look Precipitation Atlas* indicate that the density of the synoptic network in Europe is sufficient for large scale analysis (55 km resolution). The reliability of the monthly precipitation fields calculated in the former atlas has been shown. In the last chapter, the usefulness of the presented precipitation analysis to validate NWP model forecasts has been demonstrated by comparisons with the German REMO and the Danish HIRLAM.

Future developments within NEWBALTIC II will consider the non-Gaussian probability density function of precipitation by a non-linear analysis schema. Additionally, radar data from NORDRAD will be included. The application of the improved analysis scheme in the *Main BALTEX Experiment 1999-2001* is planned.

Acknowledgments

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