

Daily and 3-hrly Quantitative Precipitation Estimation for ELDAS

ECMWF/ELDAS Workshop on Land Surface Assimilation

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Deliverables (ELDAS workpackage 2001)

- I. 0.2-degree daily precipitation fields based on about 10,000 bias corrected rain gauge measurements and the corresponding fields of the estimation variance. Background fields (not used for the analysis) from ECMWF.

Model domain: Central and Northern Europe (selected regions)

- II. 0.2-degree 3-hourly precipitation fields disaggregated from daily fields using additional radar data (CERAD, BALTRAD).

Model domain: Central and Northern Europe (selected regions)

- III. 1.0-degree daily (1DD) satellite estimates (GPCP-1DD) calibrated with on-event bias corrected rain gauge data.

Model domain: Global

Deliverable I

0.2° daily precipitation analysis

Daily 0.2 degree precipitation fields based on about 10,000 bias corrected rain gauge measurements and the corresponding fields of the estimation variance.

Model domain: Central and Northern Europe (selected regions)

Status November 2004:

Number of collected precipitation gauges: 21,600

Model domain: Entire region of the European Union
Russia in preparation

Data - rain gauges

Total **21,600**

Denmark 210

Sweden 740

Norway 670

Finland 400

Poland 1,190

Great Britain 2,900

Ireland 400

Netherlands 320

Germany 4,000

France 4,250

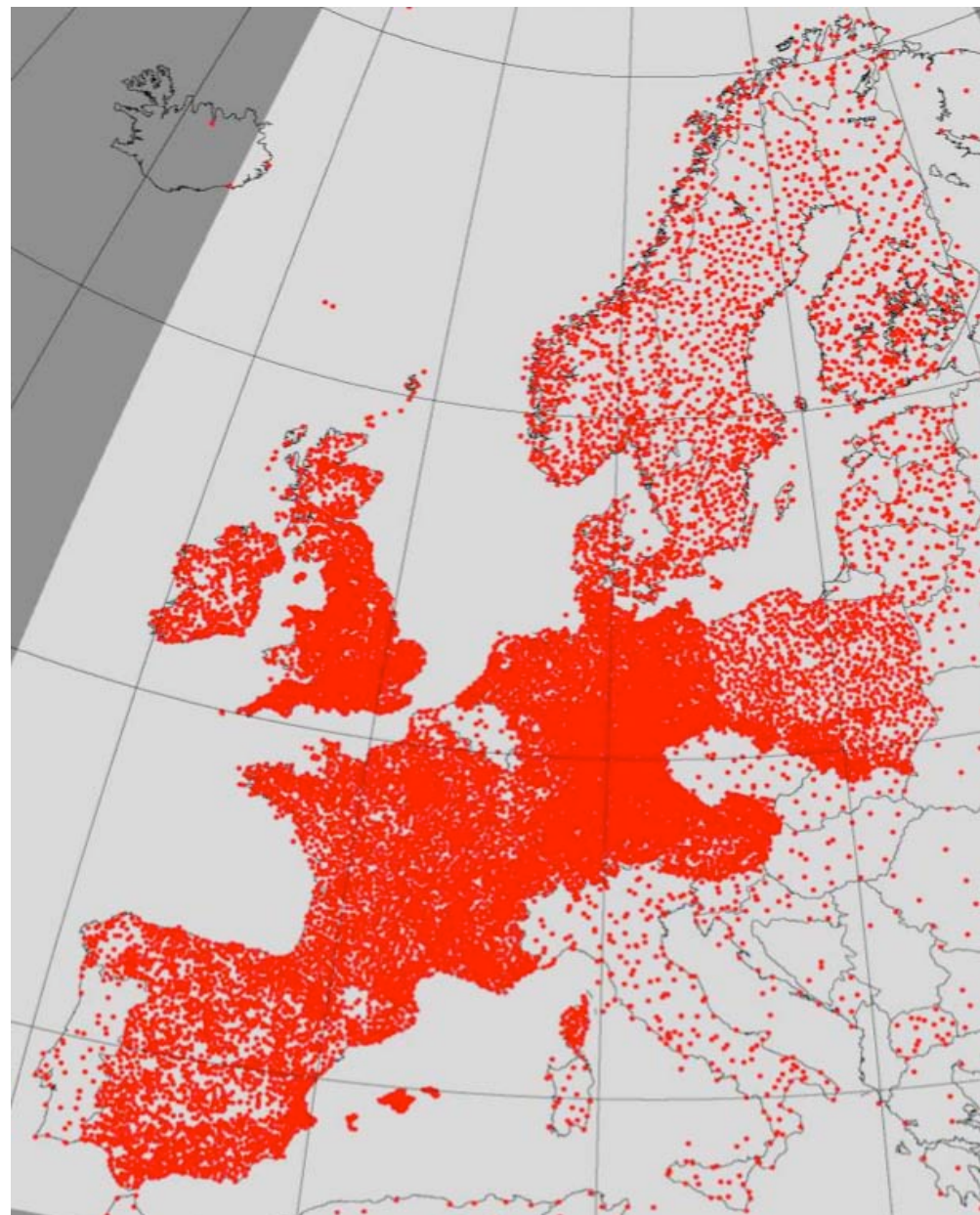
Spain 3,350

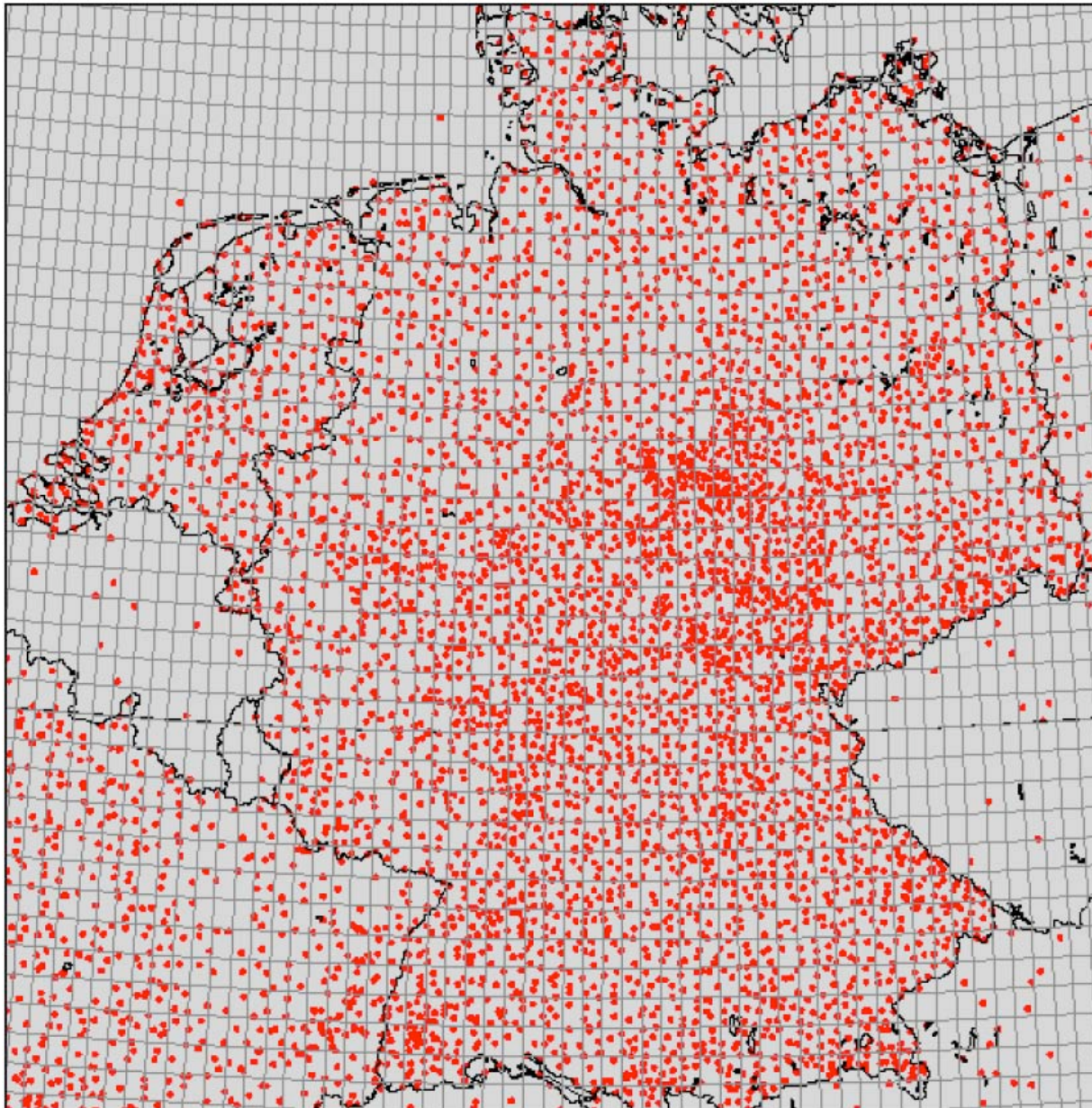
Austria 490

Switzerland 350

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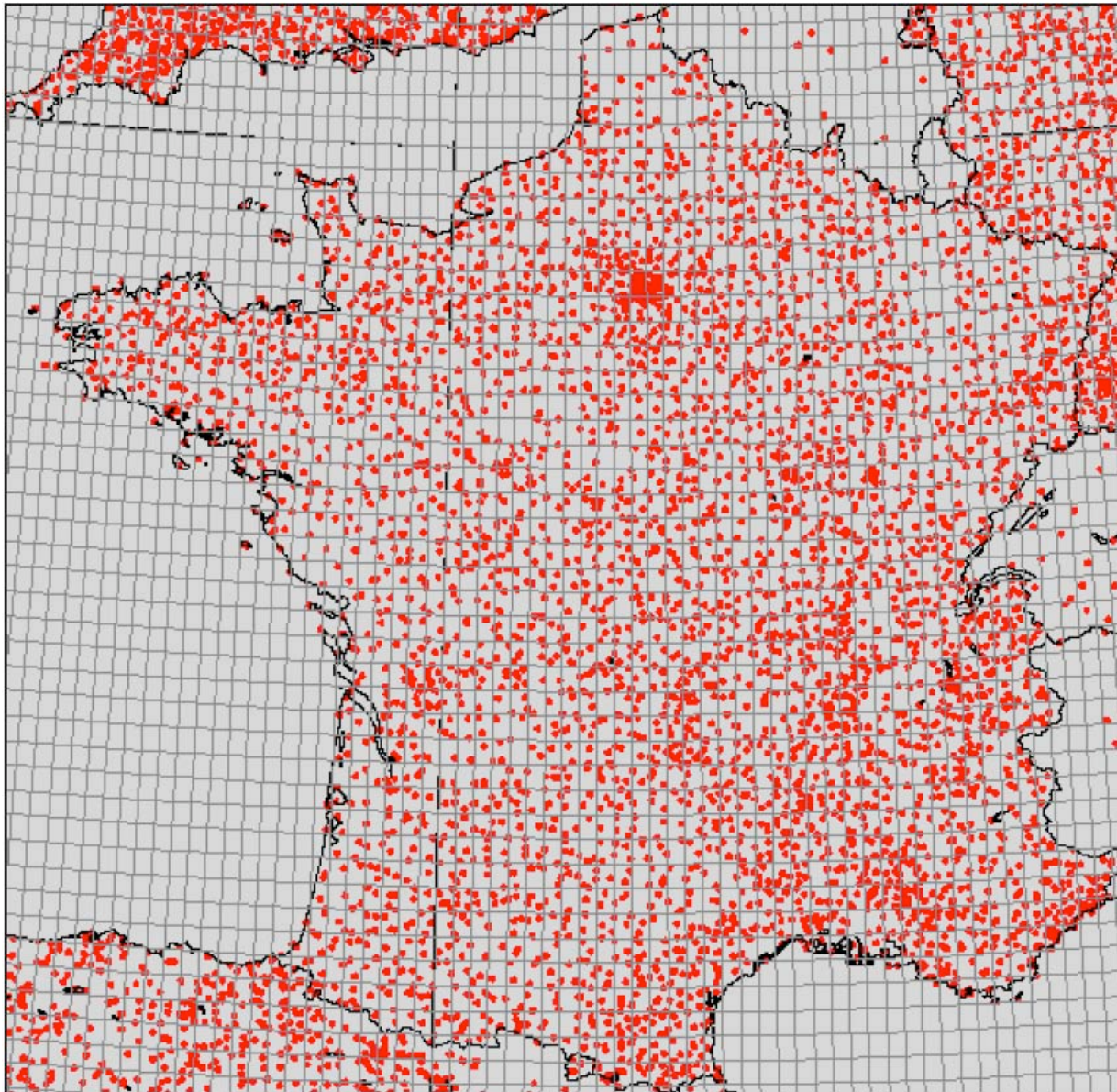
**Number of climate
precipitation gauges:**

Germany	4,000
The Netherlands	320

**Provider and/or
Contact person:**

DWD, Carola Craute
KNMI, Bart vd Hurk

Grid spacing 0.2°



**Number of climate
precipitation gauges:**

France 4,250

**Provider and/or
Contact person:**

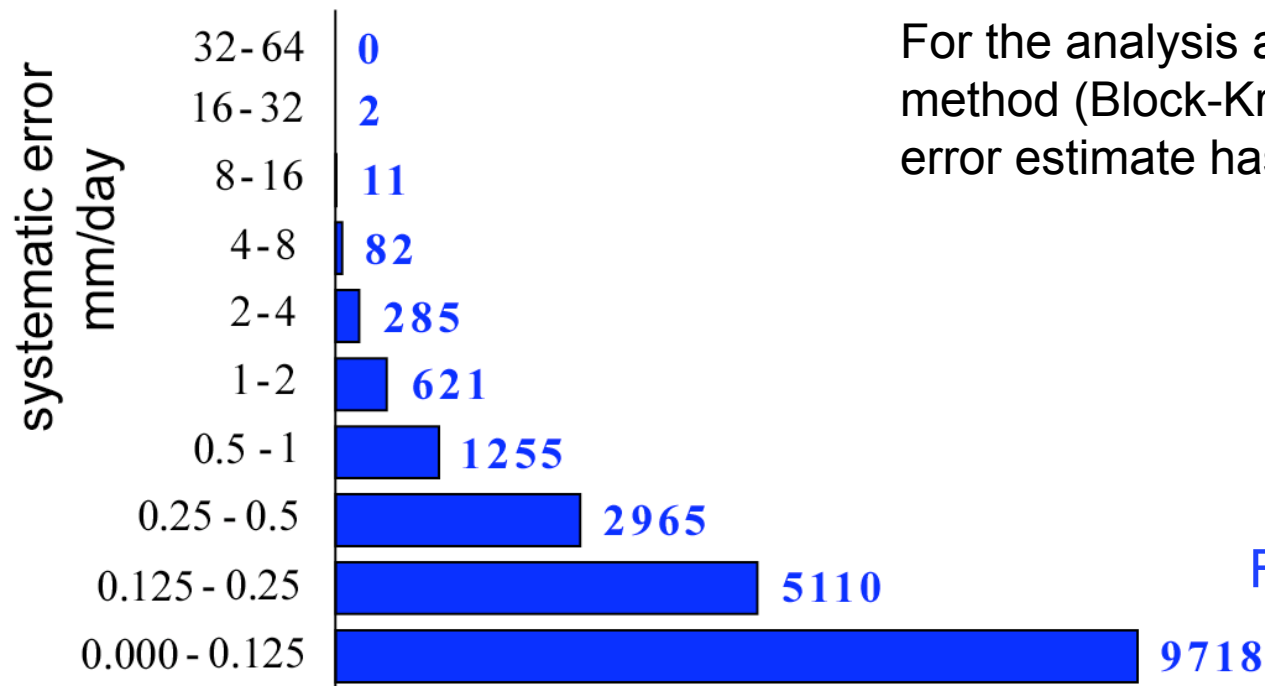
METEO-FRANCE
Jean-Christopher Calvet
Jean-Louis Roujean

Grid spacing 0.2°

Method - Precipitation Correction and Analysis Model

developed during FP4 projects NEWBALTIC I, II

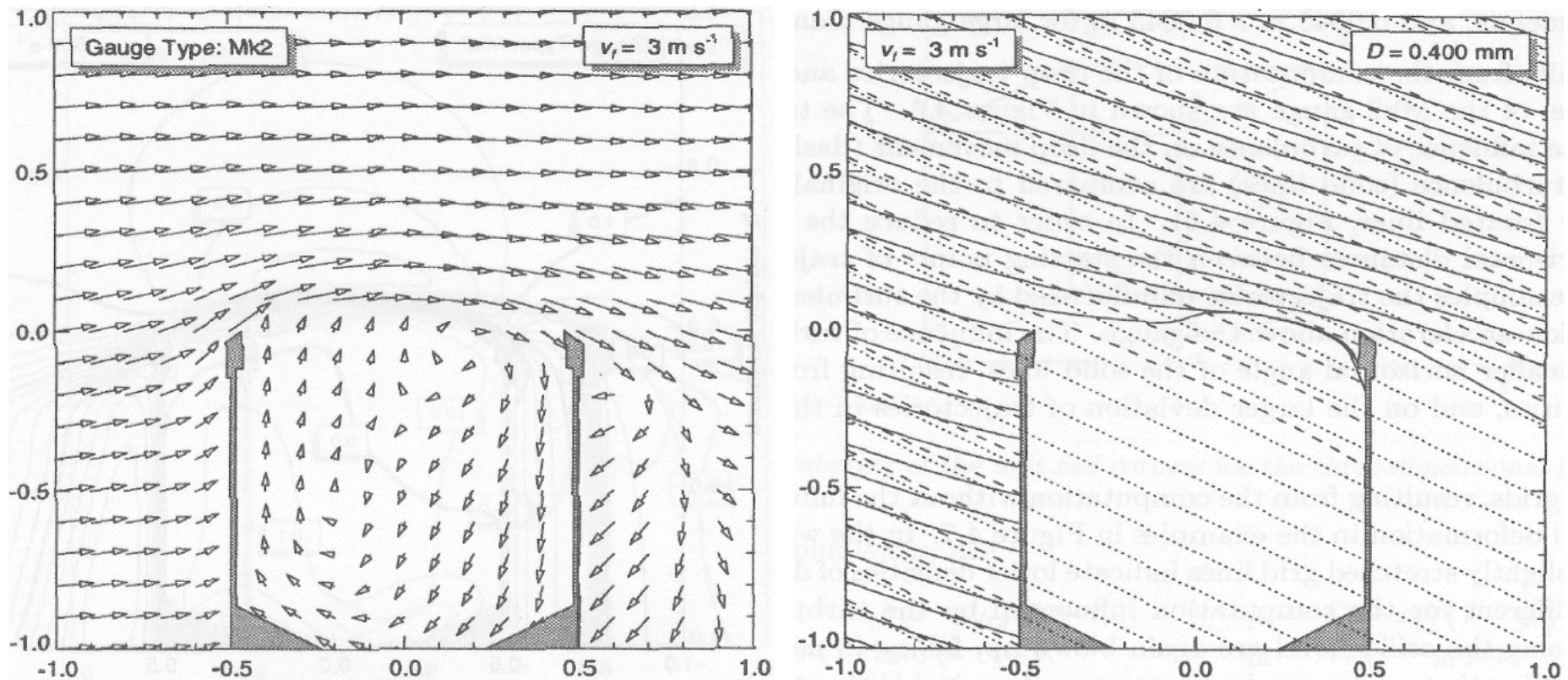
Daily gauge measurements have been corrected for systematic errors (**wind induced errors, wetting and evaporation losses**).



For the analysis an **Optimum Interpolation** method (Block-Kriging), which provides an error estimate has been applied.

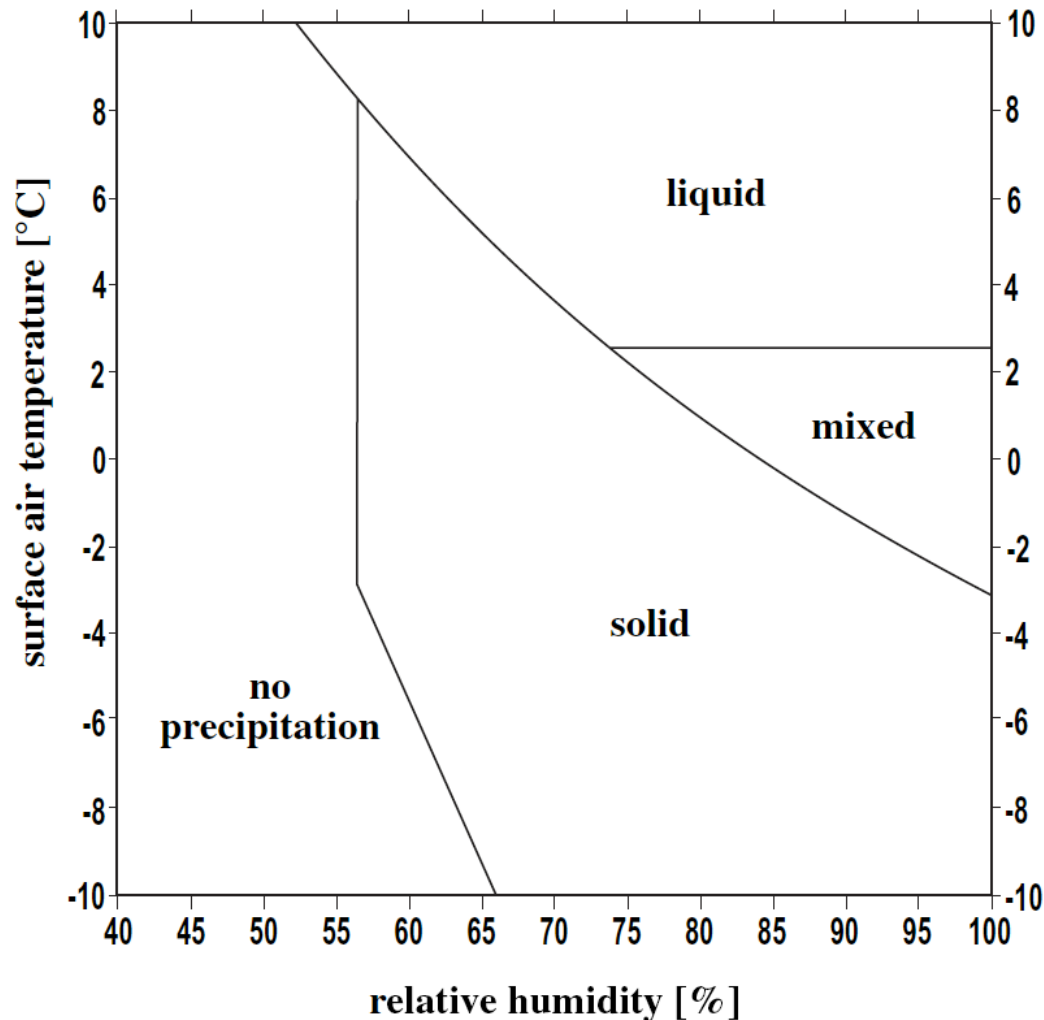
Frequency distribution
1 Jan. 2000

Motivation for correction of the aerodynamic error



Simulated velocity vectors (left) and trajectories (right) for the Mk2 gauge (Nespor, 1996). The distances were normalized by the diameter of the gauge orifice. Dotted lines represent undisturbed trajectories, solid lines trajectories influenced by turbulence (drop diameter $D=0.4 \text{ mm}$, free-stream velocity $v=3 \text{ m/s}$).

Correction of systematic measurement errors



The corrected value of the precipitation amount Z is estimated as

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

where the aerodynamic correction factor k depends on the type of precipitation.

Liquid precipitation:

$$k = f(Z_I, v)$$

Solid precipitation:

$$k = f(T, v)$$

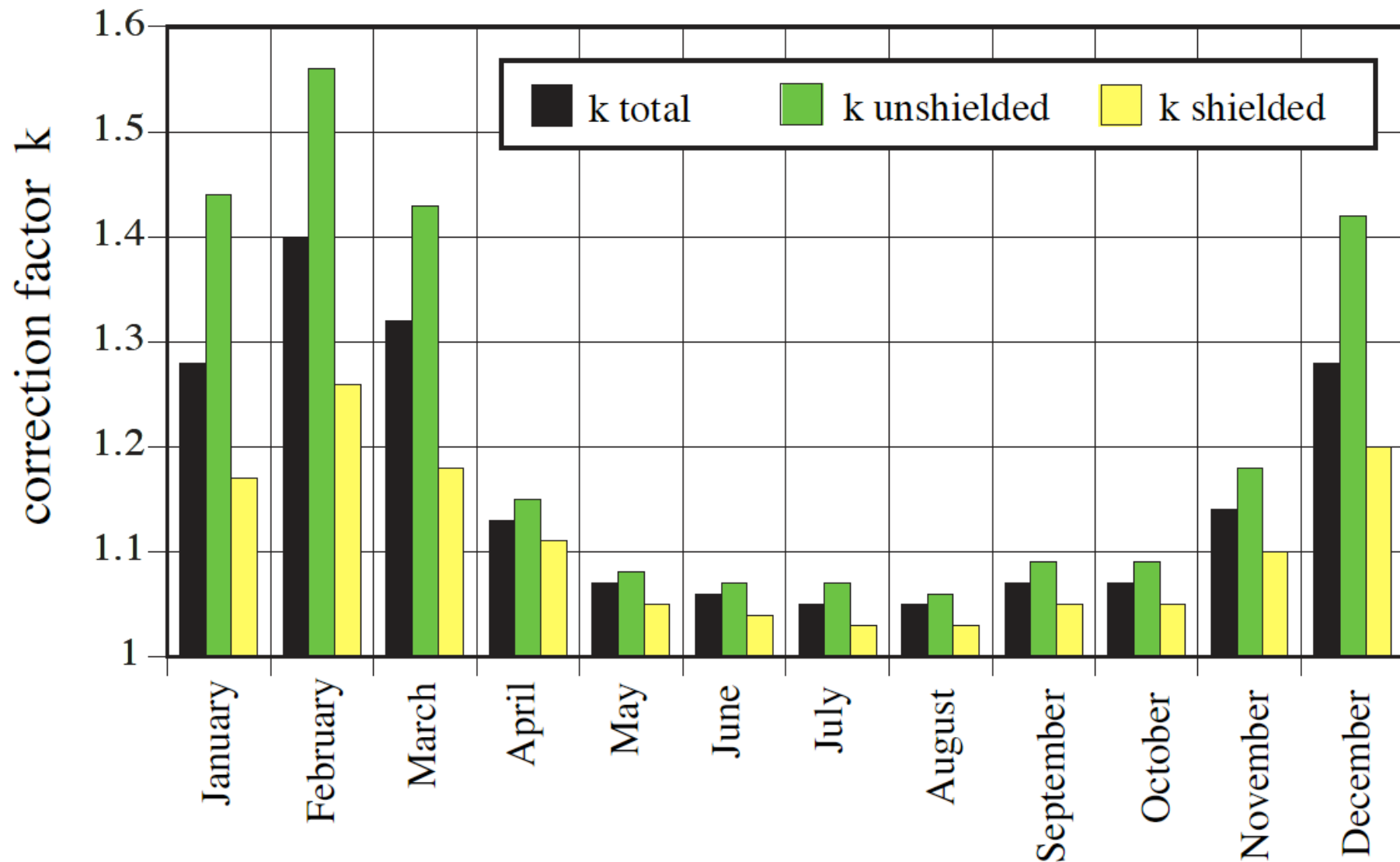
Double Fence Intercomparison Reference (DFIR)

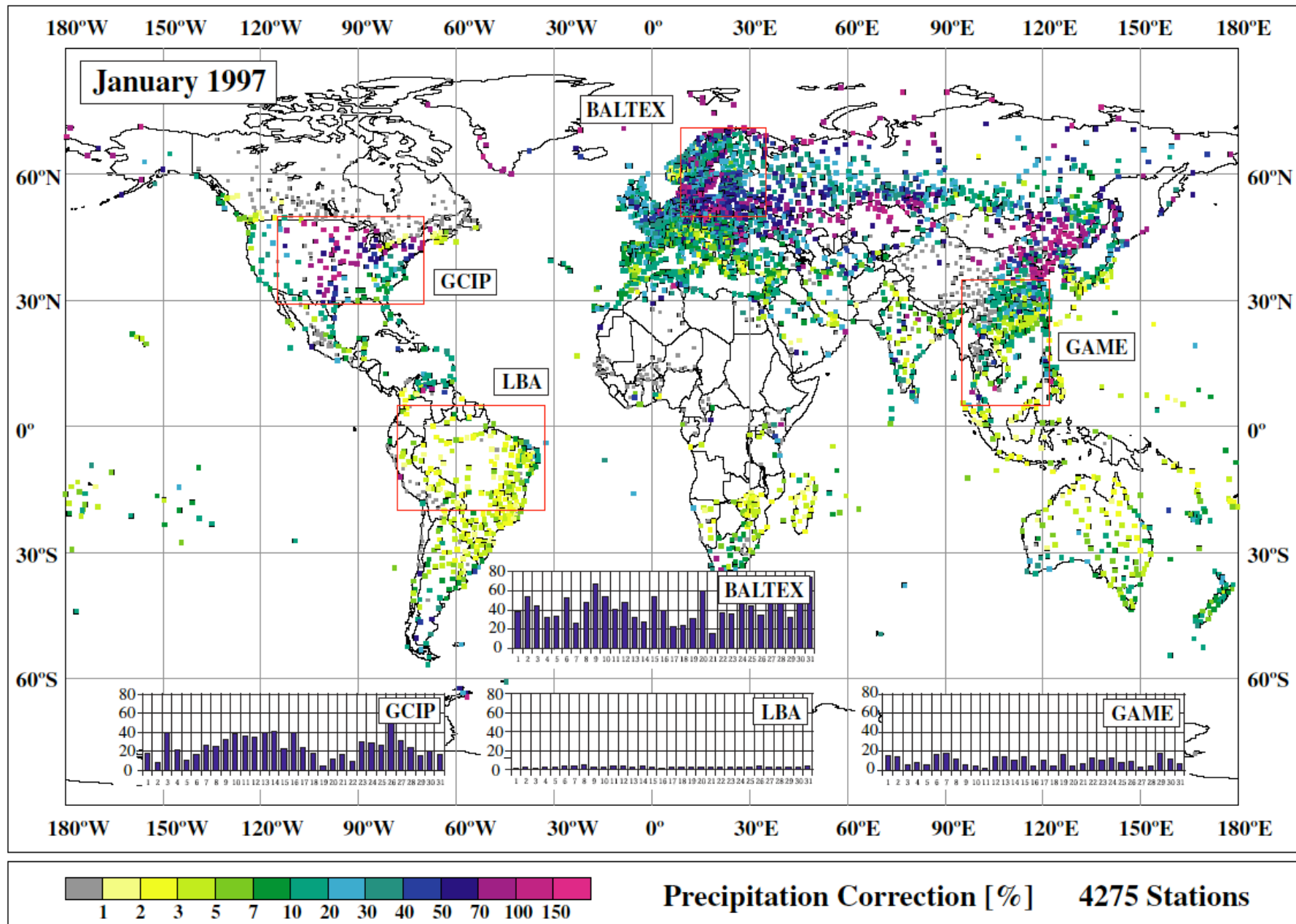
Gamserrugg (2074 m)



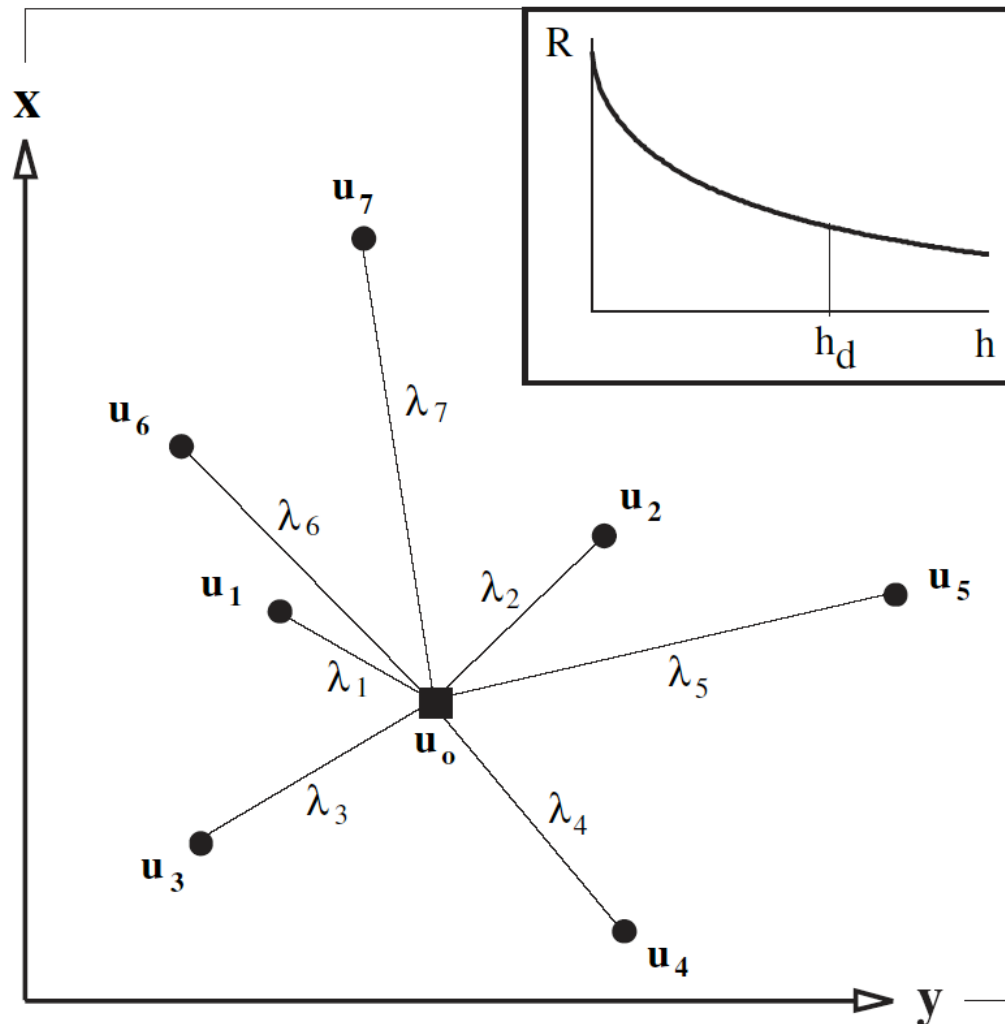
Photo: Blumer, F. R., Swiss Federal Institute of Technology

Average aerodynamic correction factors for BALTEX, 1996





Method - Ordinary Block Kriging (OI without background)



Statistical analysis of rain gauge data:

The precipitation value at the location of the grid point $Z(u_o)$ is calculated from the following weighted mean:

$$\hat{Z}(u_o) = \sum_{i=1}^n \lambda_i Z(u_i)$$

The weights λ_i are obtained by minimizing the mean square error. The analyzed fields are model independent; ordinary block-kriging (O.I. without a first guess field and area averaged) is used.

The weights λ_i can be obtained under the condition of minimizing the estimation variance (mean square interpolation error) from the following system of linear equations:

$$\begin{vmatrix} R(\mathbf{u}_1, \mathbf{u}_1) & \dots & R(\mathbf{u}_1, \mathbf{u}_n) & 1 \\ \dots & \dots & \dots & 1 \\ R(\mathbf{u}_n, \mathbf{u}_1) & \dots & R(\mathbf{u}_n, \mathbf{u}_n) & 1 \\ 1 & \dots & 1 & 0 \end{vmatrix} \cdot \begin{vmatrix} \lambda_1 \\ \dots \\ \lambda_n \\ \mu \end{vmatrix} = \begin{vmatrix} R(\mathbf{u}_1, \mathbf{u}_o) \\ \dots \\ R(\mathbf{u}_n, \mathbf{u}_o) \\ 1 \end{vmatrix}$$

Or in short form by using the gauge-gauge correlation matrix $\mathbf{R}_{gg}$ and the gauge-area correlation vector $\mathbf{R}_{go}$:

$$\begin{vmatrix} \mathbf{R}_{gg} & 1 \\ 1 & 0 \end{vmatrix} \cdot \begin{vmatrix} \lambda_g \\ \mu_g \end{vmatrix} = \begin{vmatrix} \mathbf{R}_{go} \\ 1 \end{vmatrix}$$

Co-Kriging of Satellite and Gauge Data

Will be applied to merge precipitation analysis from rain gauge data and satellite estimates (deliverable III).

$$\hat{Z}(\mathbf{u}_o) = \sum_{j=1}^{n_s} \lambda_{rj} Z_s(\mathbf{u}_j) + \sum_{i=1}^{n_g} \lambda_{gi} Z_g(\mathbf{u}_i)$$

Solution:

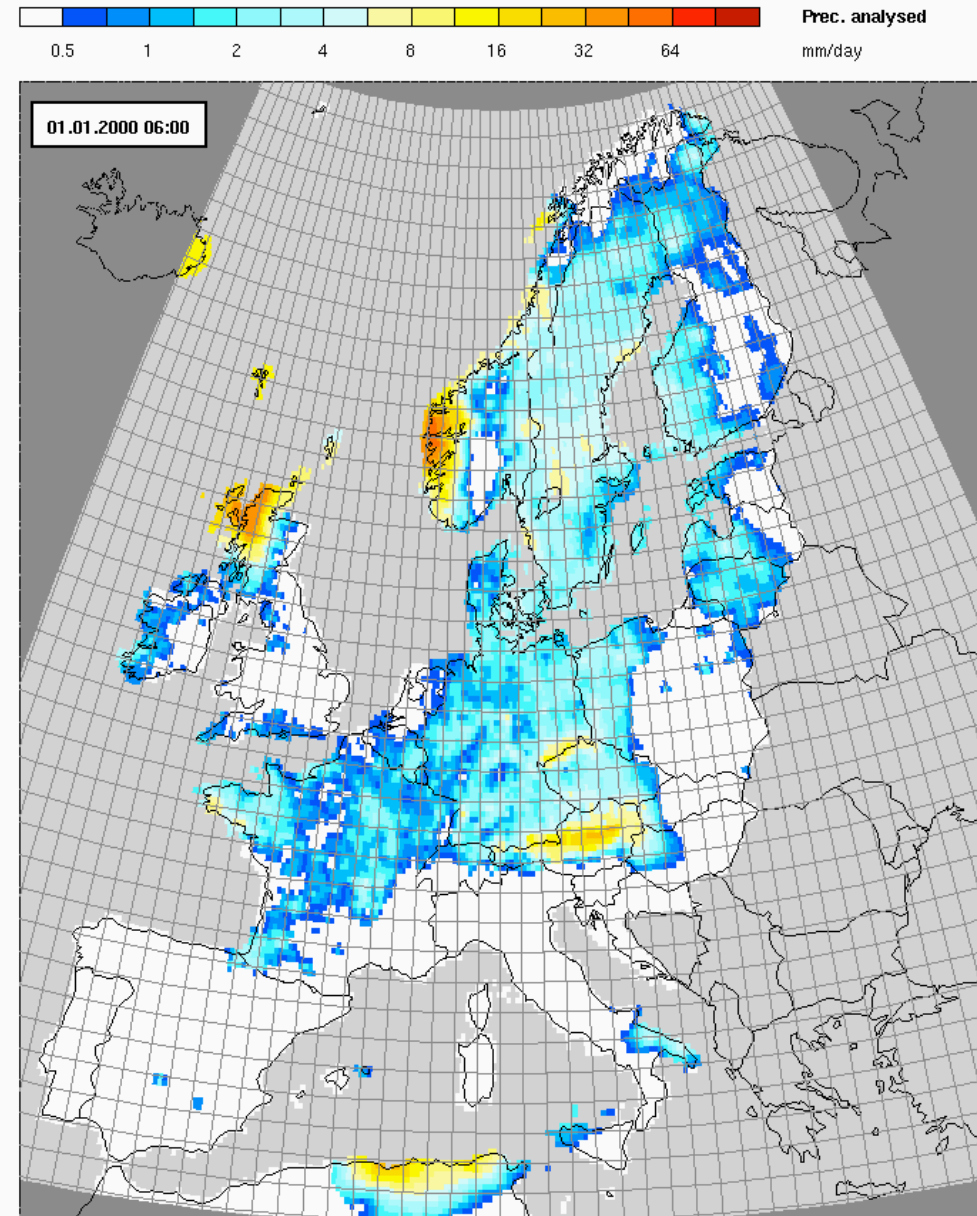
$$\begin{vmatrix} \mathbf{R}_{ss} & \mathbf{R}_{sg} & 1 & 0 \\ \mathbf{R}_{gs} & \mathbf{R}_{gg} & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{vmatrix} \cdot \begin{vmatrix} \lambda_s \\ \lambda_g \\ \mu_s \\ \mu_g \end{vmatrix} = \begin{vmatrix} \mathbf{R}_{so} \\ \mathbf{R}_{go} \\ 0 \\ 1 \end{vmatrix}$$

Results

Daily precipitation field

Features:

- Based on 21,000 observations
- Spatial resolution: 0.2° lat/lon
- Temporal resolution daily



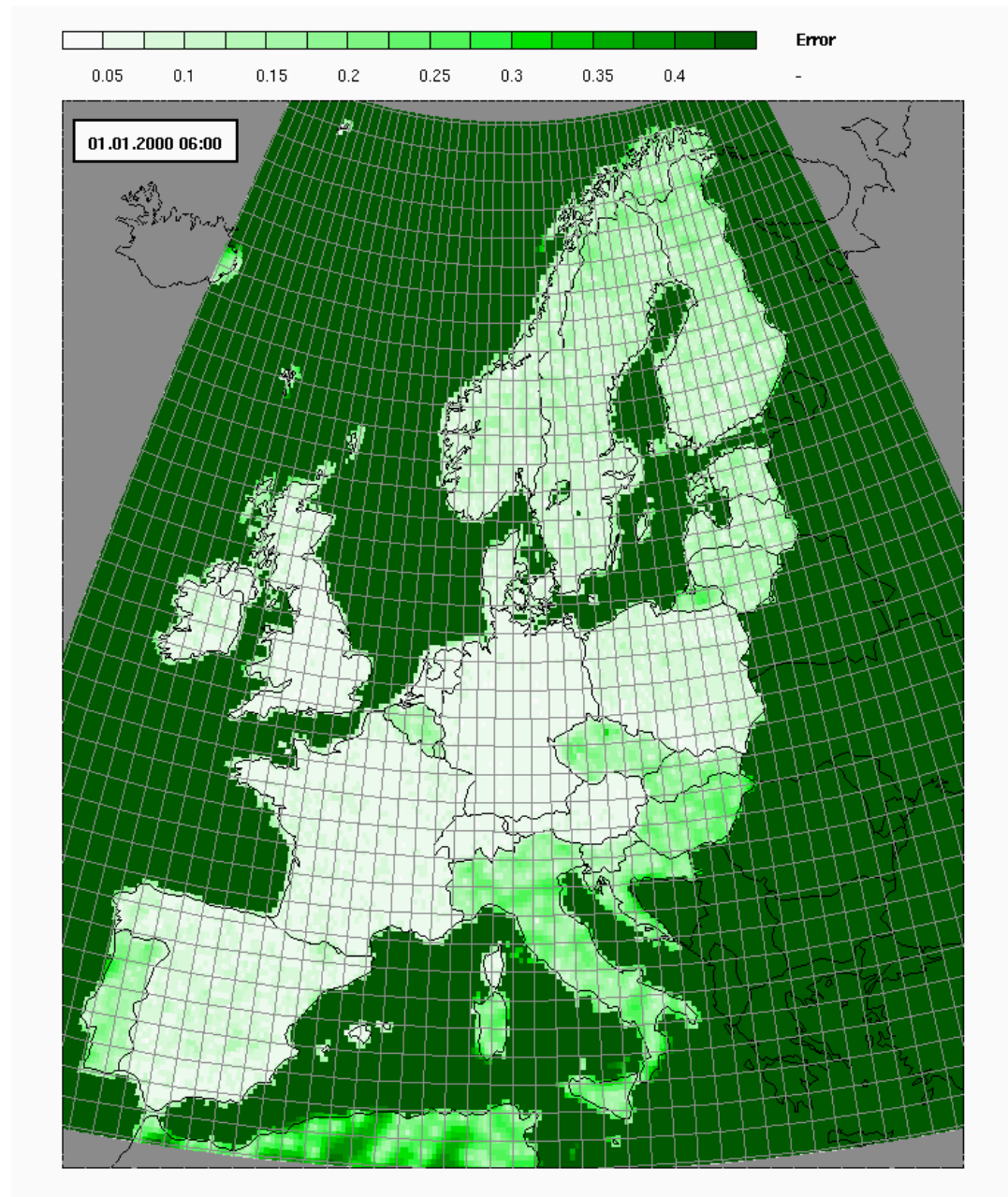
Results

Interpolation error

Depends on:

- Grid distance
- Station density
- Spatial correlation (ACF)

The ELDAS land/sea mask has been applied and extended to Eastern Europe.



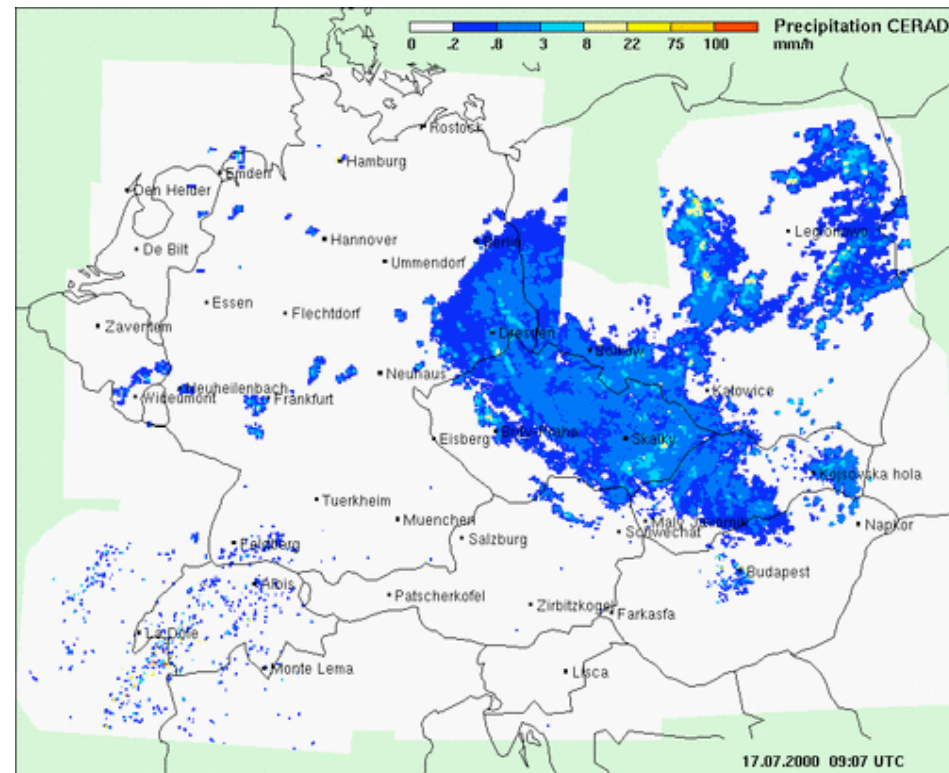
Deliverable II

0.2° 3-hrly precipitation analysis

0.2-degree 3-hourly precipitation fields disaggregated from daily fields using additional radar data (CERAD, BALTRAD).

Model domain:
Central and Northern Europe

Software to visualize radar data on their original projection has been developed for CERAD and BALTRAD, respectively.



Data - operational weather radar networks

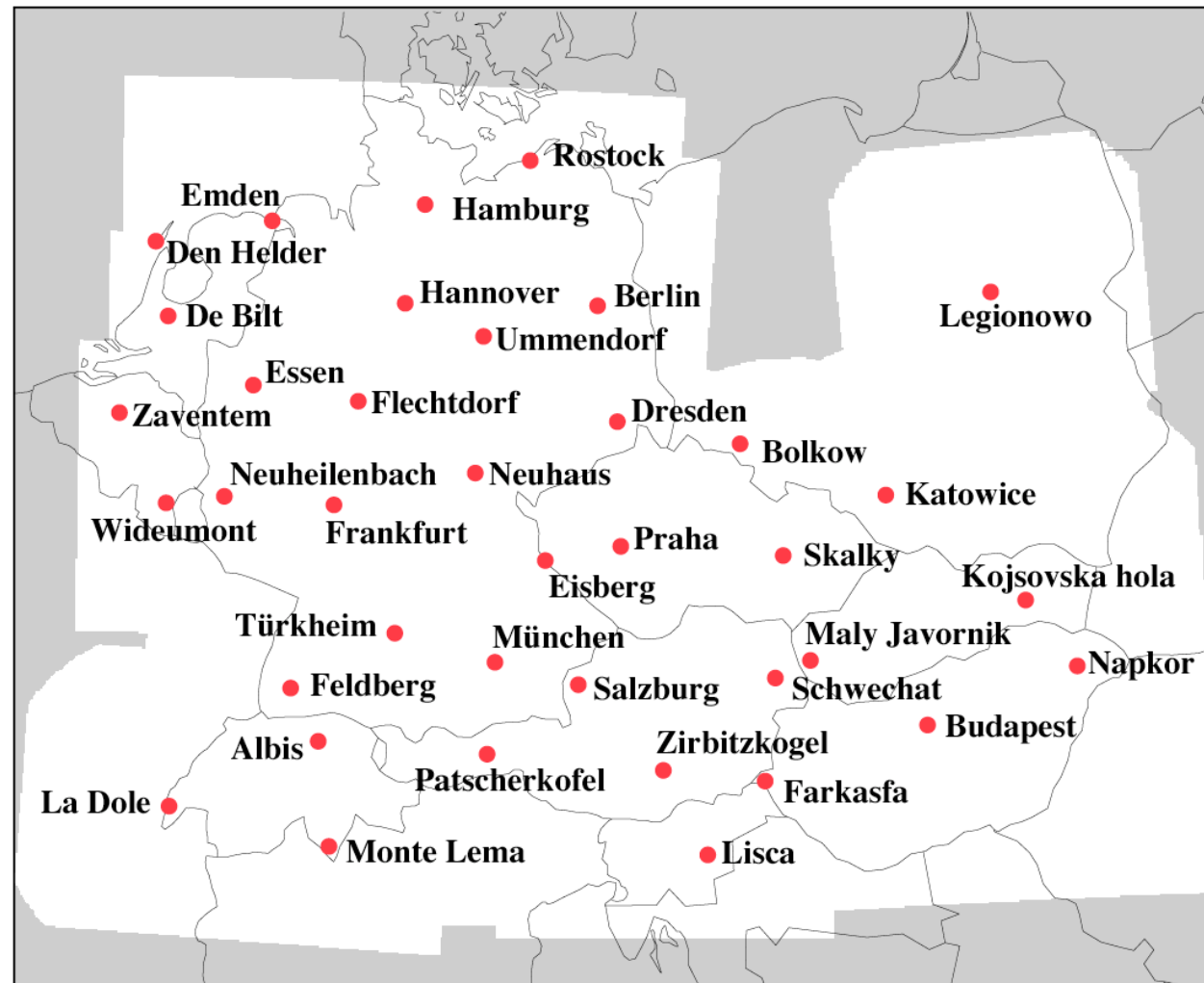
CERAD, the Central European Radar Network

Resolution 30 min
4 km

Maximum intensity
product with 8 rain
classes

Provider

Technical University
Graz, Austria
Konrad Köck



BALTRAD

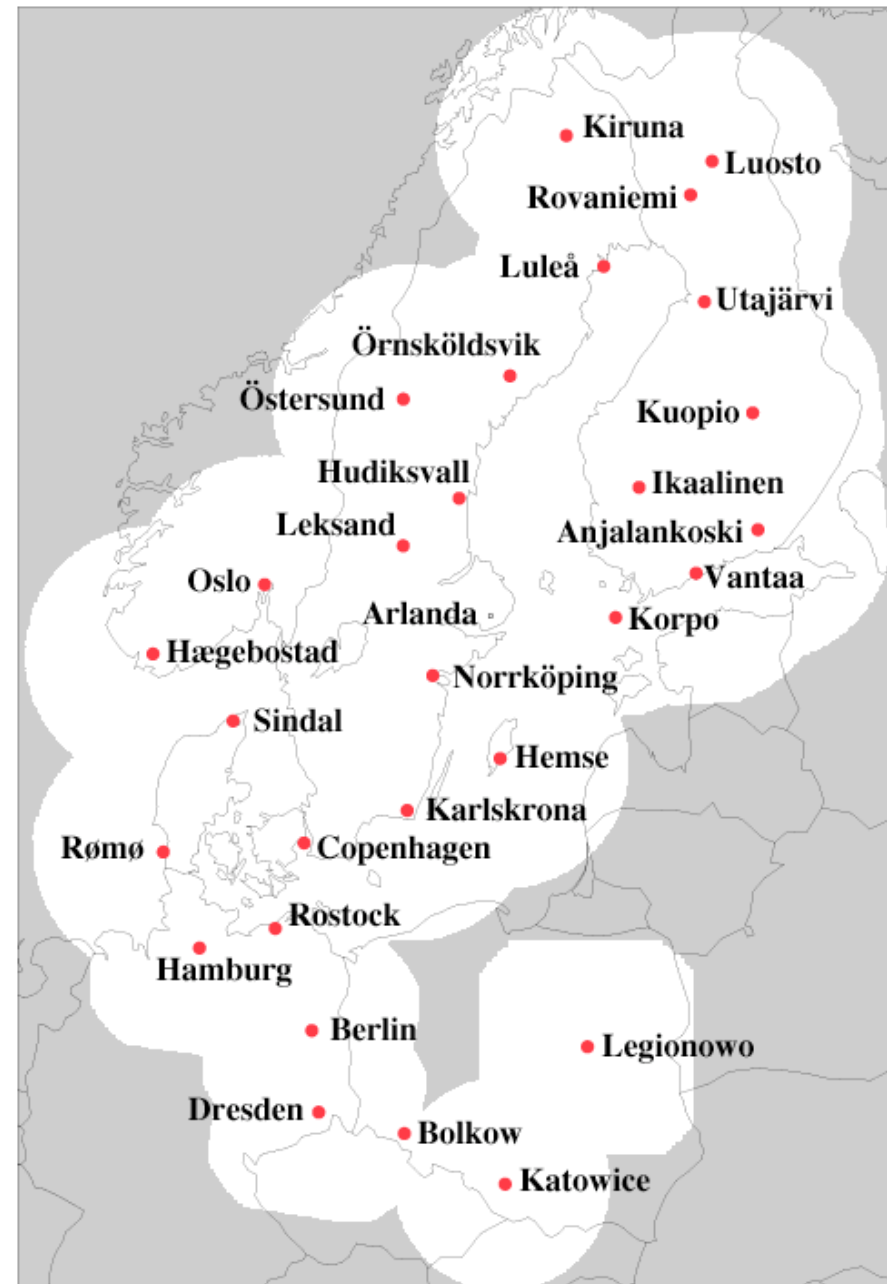
The Baltic Radar Network

Resolution 15 min
2 km

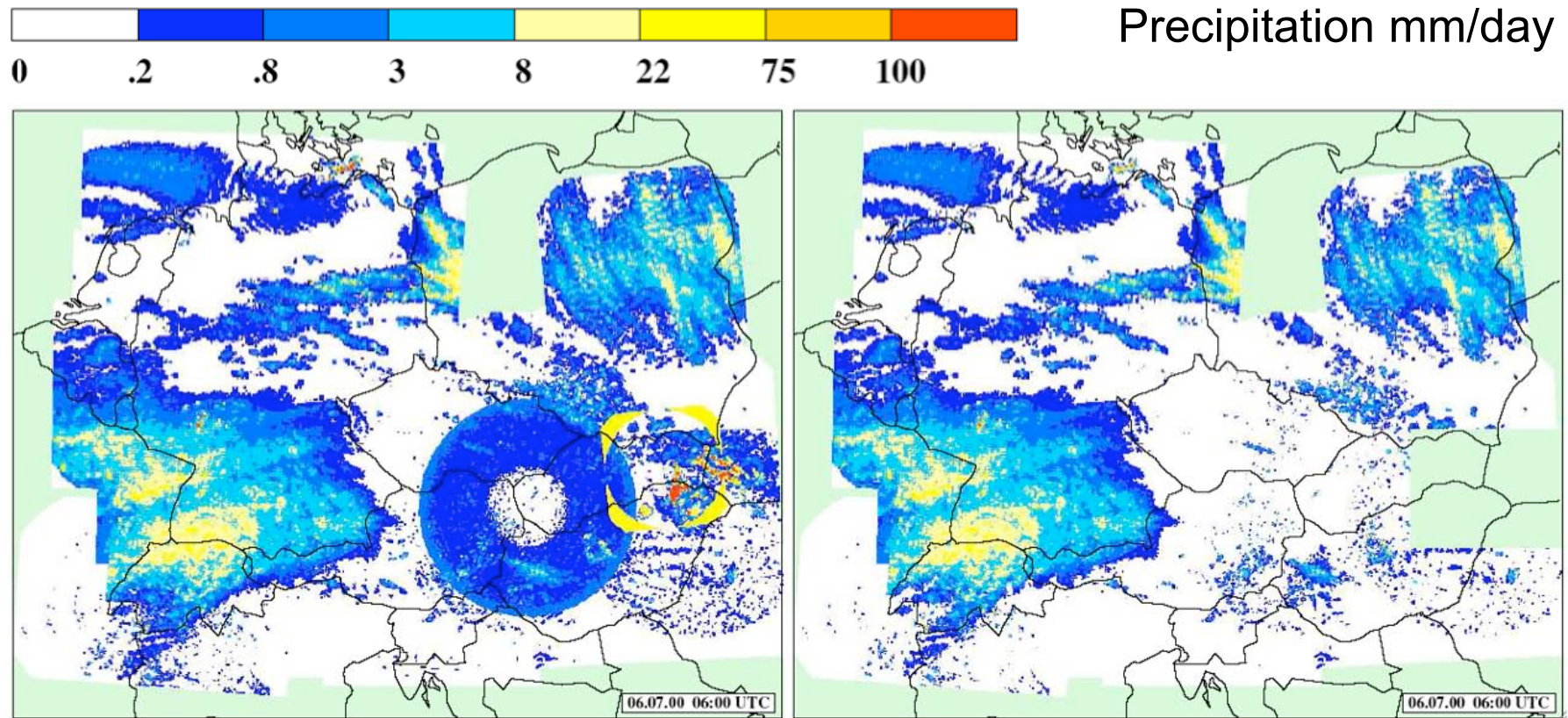
Provider

SMHI, Sweden

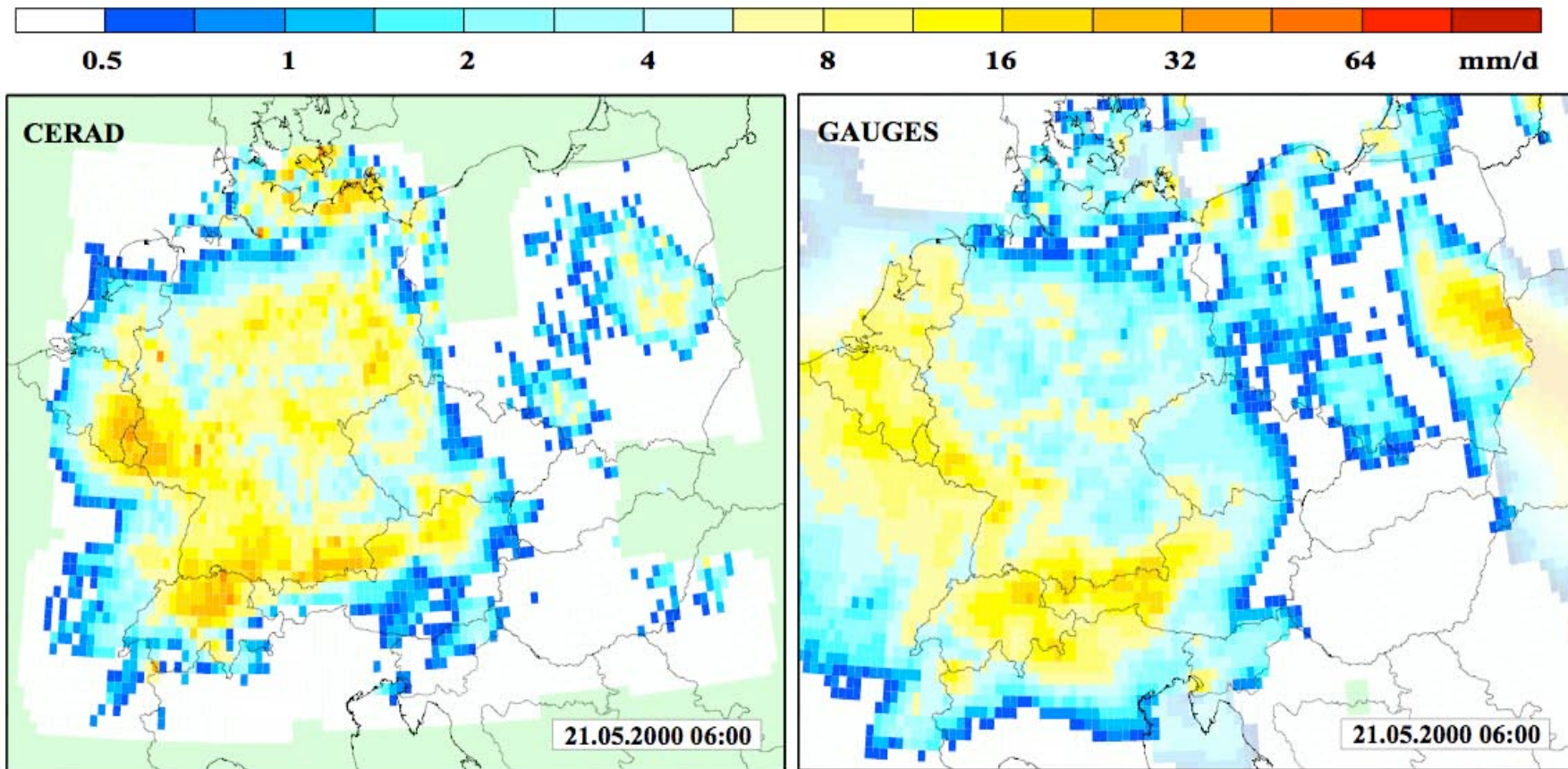
Daniel Michelson



Method - Error reduction of CERAD



Accumulated radar precipitation in mm/day, original (left) and corrected (right). Radar specific uncertainties are for example artefacts, ground and sea clutter, missing pictures, etc.



Results for 2000

Gauges 3.79 mm/d

	uncorr.	corr.
Radar precipitation	5.81	3.61
RMS error	10.71	4.92
Rank-order correlation	0.48	0.62

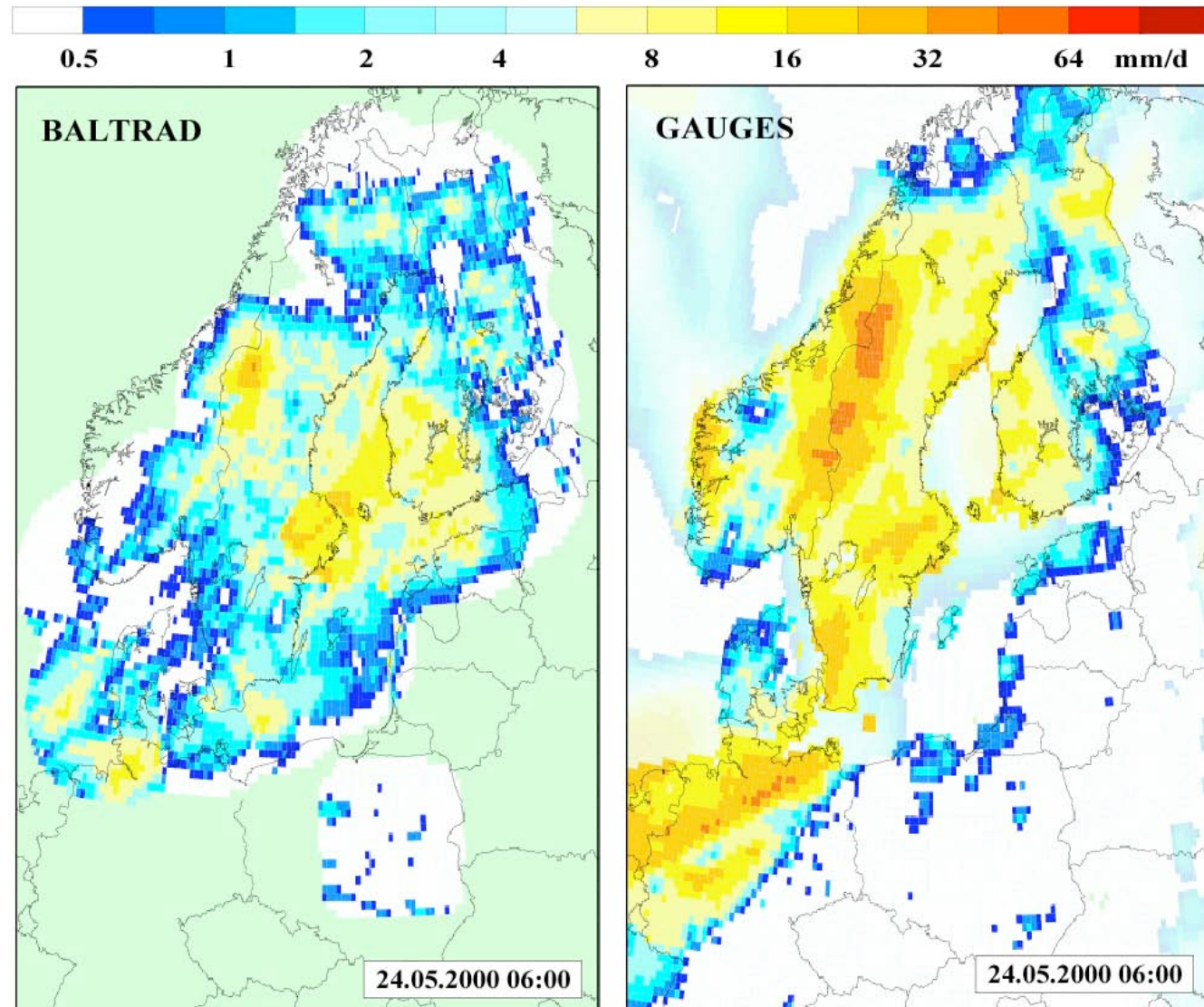
Comparison - daily precipitation BALTRAD vs gauges in mm/day

Gauges 3.18
BALTRAD 1.15
RMSE 3.85
Correlation 0.56

Results for 2000

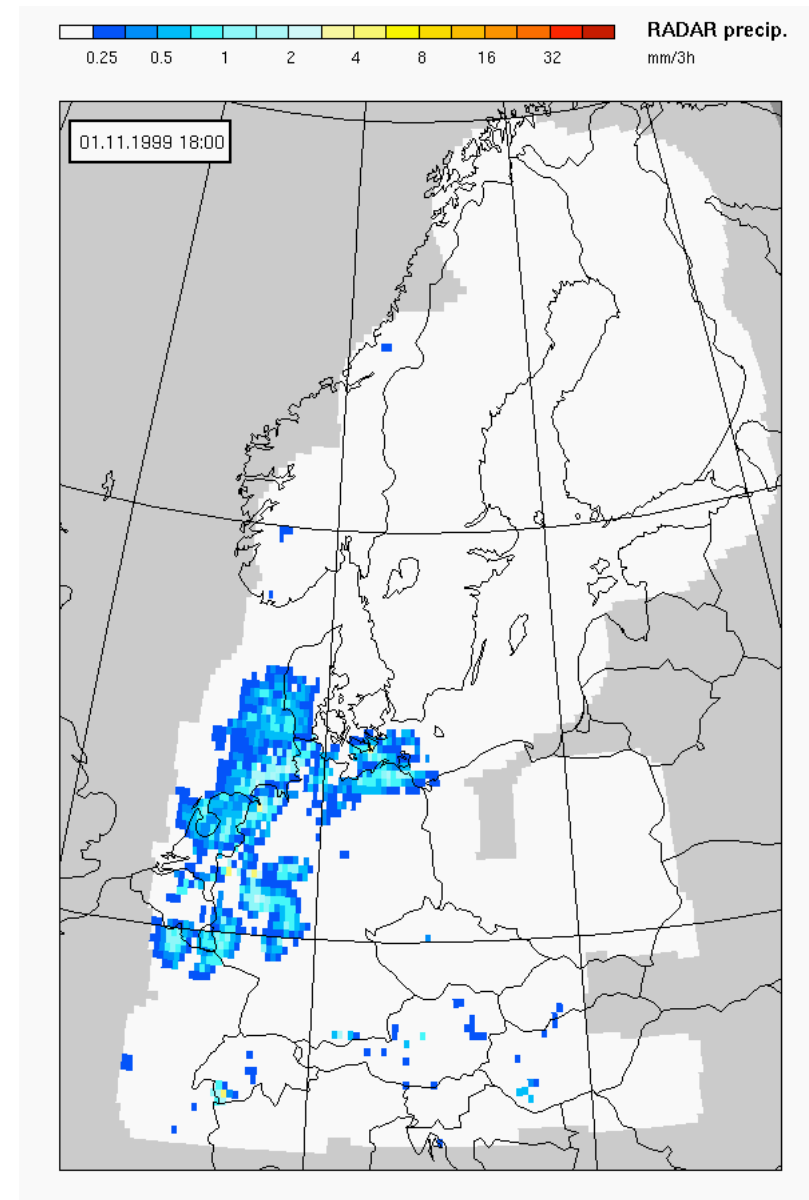
BALTRAD under-
estimates surface
precipitation

Gauges 2.40
BALTRAD 0.76



Merged CERAD / BALTRAD fields on the 0.2° grid

Operational BALTRAD and CERAD data have been accumulated to 3-hourly precipitation sums and interpolated to the 0.2° ELDAS grid. For overlapping grid areas the maximum value has been applied.



Results - merged CERAD/BALTRAD data, adjusted with daily precipitation gauge analyses

- Quantitative 3-hourly precipitation estimates derived from two international weather radar networks, CERAD and BALTRAD, have been merged and interpolated to the same 0.2° grid. Radar specific errors in CERAD have been reduced by a semi-automatic procedure.
- A total number of 21,600 daily precipitation observations have been corrected for systematic measurement errors and analysed on a 0.2° grid.
- The simplest possible method, linear temporal interpolation was used to adjust the 3-hrly radar fields with daily gauge analyses.

Results

ELDAS precipitation product

Period: Oct. 1999 - Dec. 2000

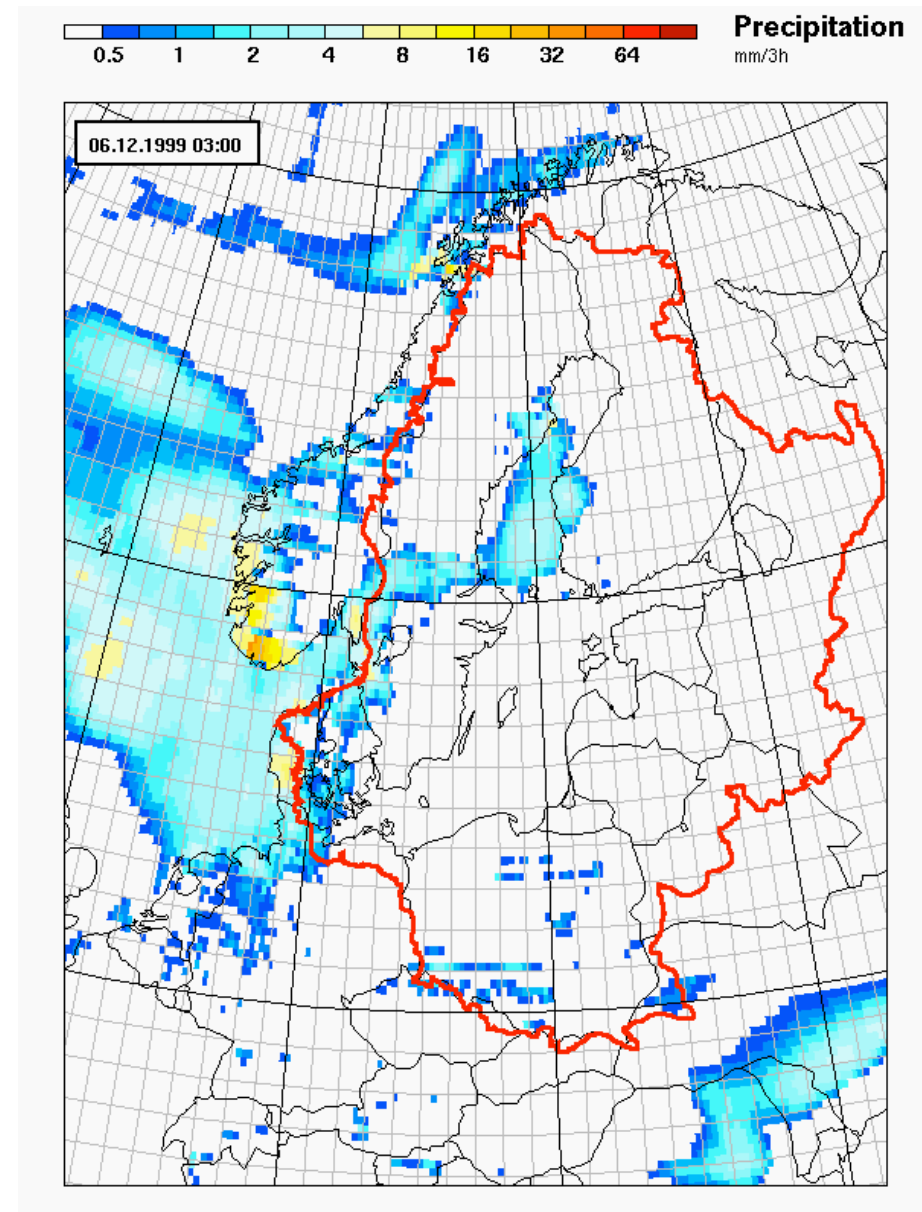
Input Data: BALTRAD, 2km 15min
CERAD, 4km 30min
Gauges, 21,000 daily

Background: ECMWF T511 exp. run

Addition: Error fields and flags

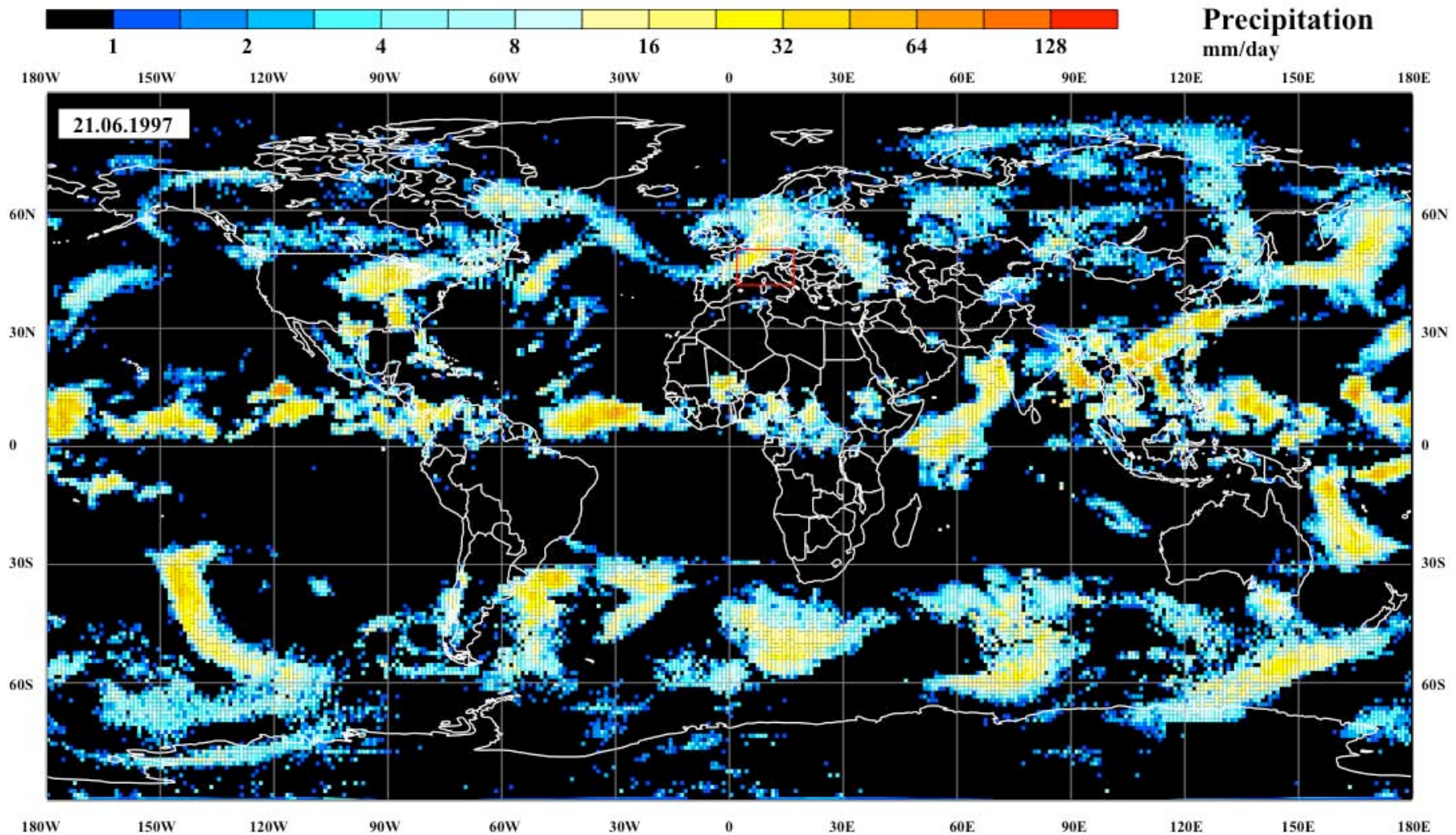
Resolution: 3-hourly / 0.2 degree

Region: Central & Northern Europe



Deliverable III

Global 1° daily precipitation fields, calibrated with gauges



Verification - GPCP-1DD vs. ECMWF Precipitation

		Observed - MAP rain gauge analysis		
		yes	no	
Predicted - GPCP satellite estimates	yes	37 % h...hits	10 % f...false	47 %
	no	24 % m ... misses	29 % z ... zero	53 %
		61 %	39 %	100 %

Continuous statistics

Observed	3.58
Estimated	3.76
Mean error	0.18
Mean absolute error	3.44
RMS error	6.20
Rank-order correlation	0.51

Categorical statistics

Hit rate, HR	0.66
Critical success index, CSI	0.52
Prob. of detection, POD	0.60
False alarm ratio, FAR	0.21
Bias score, BIAS	0.78
True skill statistics, TSS	0.36

		Observed - MAP rain gauge analysis		
		yes	no	
Predicted - ECMWF 6-30 hour forecasts	yes	48 % h...hits	10 % f...false	58 %
	no	13 % m ... misses	29 % z ... zero	42 %
		61 %	39 %	100 %

Continuous statistics

Observed	3.56
Estimated	2.43
Mean error	-1.13
Mean absolute error	2.70
RMS error	5.39
Rank-order correlation	0.67

Categorical statistics

Hit rate, HR	0.77
Critical success index, CSI	0.68
Prob. of detection, POD	0.80
False alarm ratio, FAR	0.18
Bias score, BIAS	0.96
True skill statistics, TSS	0.54

Verification - GPCP-1DD vs. ECMWF Precipitation

True skill statistics (TSS) for GPCP and ECMWF operational daily precipitation products as function of analyzed mean precipitation in the MAP model domain.

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

Summary

Precipitation products

- The first version of the GPCP-1DD product merged with daily, bias corrected, gauge measurements will be presented at the next **GEOLAND meeting** in Toulouse, France, in Dec. 2004.
- The experimental versions of the ELDAS precipitation fields in both resolutions, daily and 3-hourly, have been stored in **GRIB format in the ECMWF MARS** archive.
- The final version of 0.2° daily data is available, but has not yet been transmitted to ECMWF.
- Daily precipitation fields in **ASCII file format** will be archived and distributed by the **Global Precipitation Climatology Centre (GPCC)**.
- A distribution by the **British Academic Data Service (BADC)** is planned.

Acknowledgements

Remote sensing data

Daniel Michelson (SMHI) - BALTRAD

Konrad Köck (TU-Graz) - CERAD

George Huffman (NASA) - GPCP-1DD

Precipitation gauge data

C. Graute (BMDC), B. vd Hurk (KNMI), P. Viterbo (ECMWF), A. Menochet (BADC), U. Gjertsen and E. Førland (DNMI), P. Le Moigne and J. Noilhan (Meteo France), B. Navascues and E. Rodriguez Camino (INM), B. Rudolf and P. Otto (GPCC), T. Sheridan and A. Murphy (Met Eireann), J.-C. Calvet and J.-L. Roujean (France), T. Fuchs (EU Scientific Officer ELDAS)

Model data

P. Viterbo (ECMWF), L. Haimberger (ECMWF & IMGW)

Outlook

What do we need for an operational application of radar-gauge analysis in NWP ?

- 1) About 5 times more online precipitation gauges than currently available via GTS
- 2) A European radar network based on existing international networks

