Daily and 3-hourly Quantitative Precipitation Estimation for ELDAS[1]

Franz Rubel, Katharina Brugger, Paul Skomorowski and Markus Kottek

Biometeorology Group, Department of Natural Sciences
University of Veterinary Medicine Vienna, Austria

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

[1] Adapted from presentation

Data - rain gauges

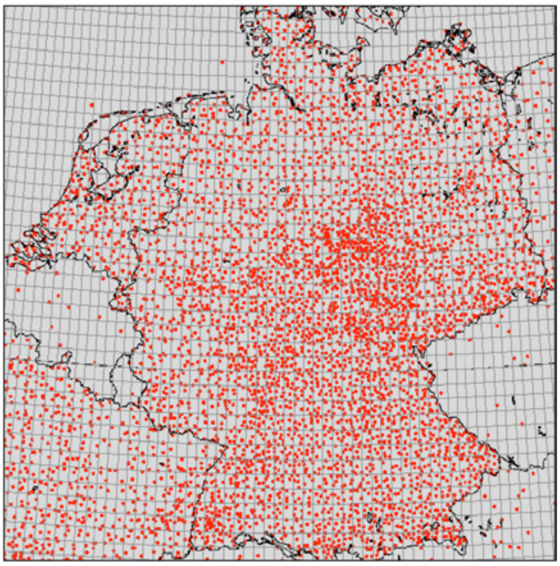
Total	**21,600**
Denmark	210
Sweden	740
Norway	670
Finland	400
Poland	1,190
Great Britain	2,900
Ireland	400
Netherlands	320
Germany	4,000
France	4,250
Spain	3,350
Austria	490
Switzerland	350
……………	…….

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°

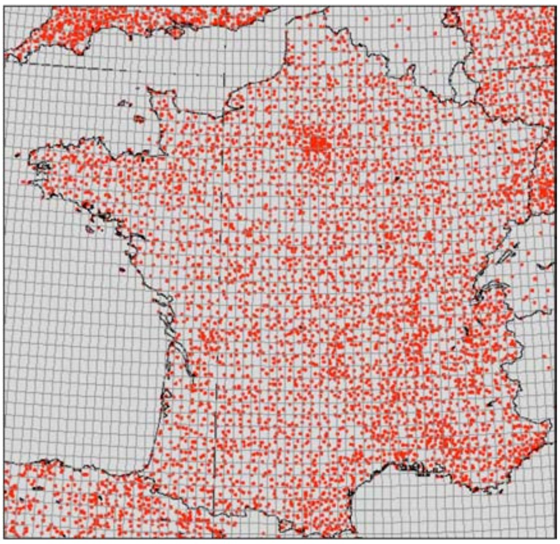


Number of climate precipitation gauges:

France 4,250

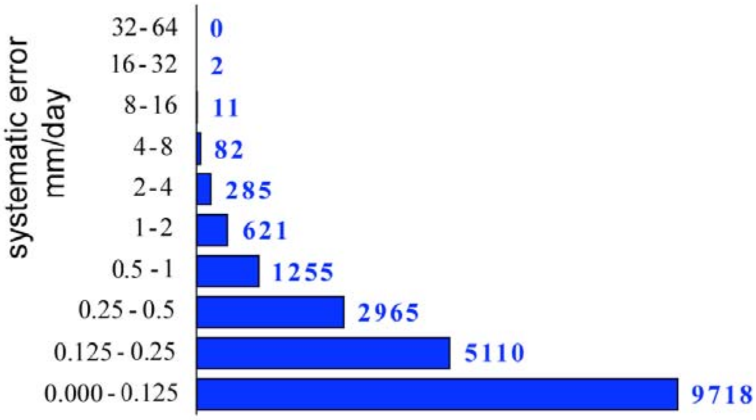
Provider and/or Contact person:
METEO-FRANCE
Jean-Christopher Calvet
Jean-Louis Roujean

Grid spacing 0.2°



Method - Precipitation Correction and Analysis Model (developed during FP4 projects NEWBALTIC I, II)

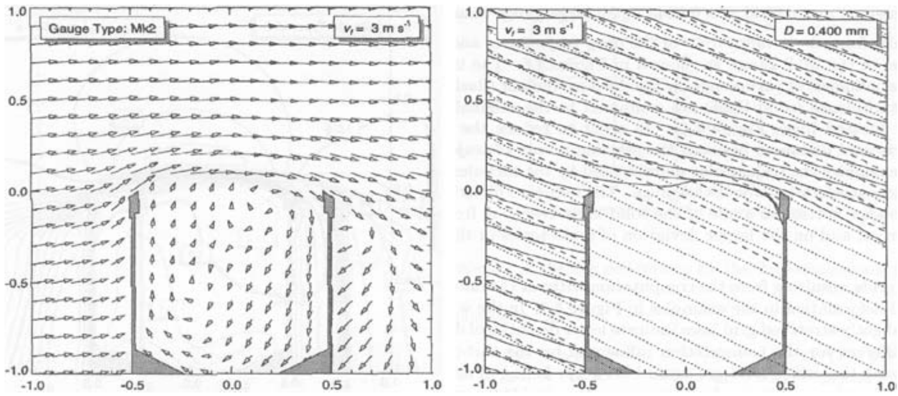
Daily gauge measurements have been corrected for systematic errors (wind induced errors, wetting and evaporation losses).



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

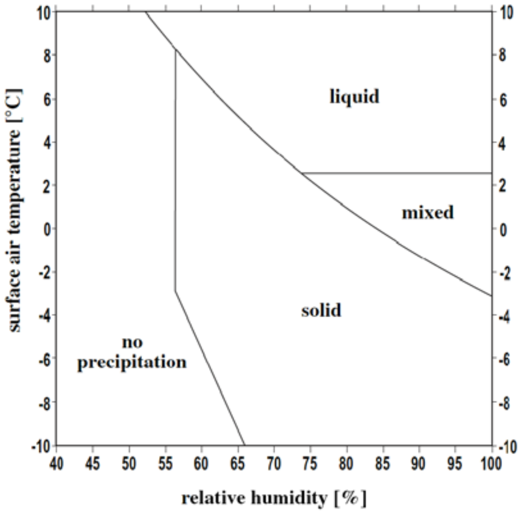
Frequency distribution 1 Jan. 2000

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 mm, free-stream velocity v=3 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:

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

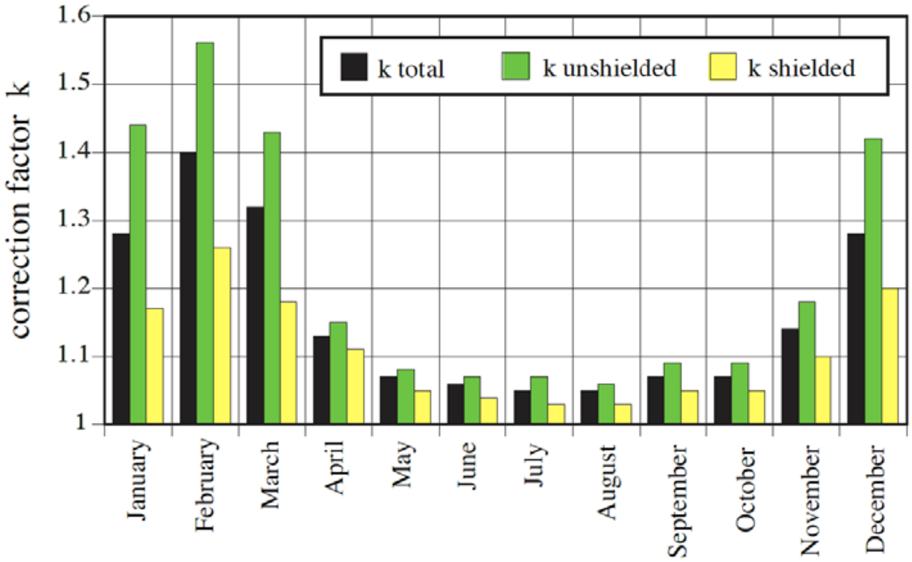
Solid precipitation:

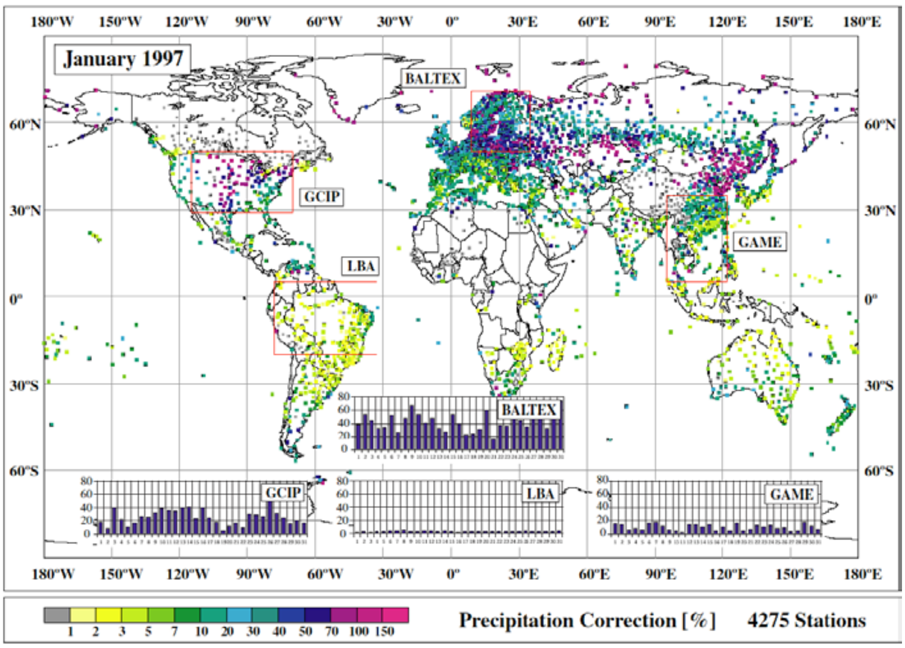
$$k = f\,(T, v)$$

Double Fence Intercomparison Reference (DFIR)

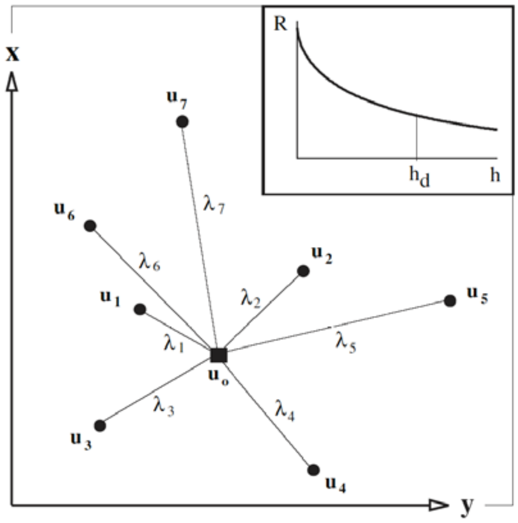
Gamserrugg (2074 m)

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 $Z(\mathbf{u}_o)$ is calculated from the following weighted mean:

$$\widehat{Z}(\mathbf{u}_o) = \sum_{i-1}^{n} \lambda_i \, Z(\mathbf{u}_i)$$

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:

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

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

$$\begin{vmatrix} \mathbf{R_{gg}} & 1 \\ 1 & 0 \end{vmatrix} \cdot \begin{vmatrix} \lambda_\mathbf{g} \\ \mu_g \end{vmatrix} = \begin{vmatrix} \mathbf{R_{go}} \\ 1 \end{vmatrix}$$

Co-Kriging of Satellite and Gauge Data

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

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

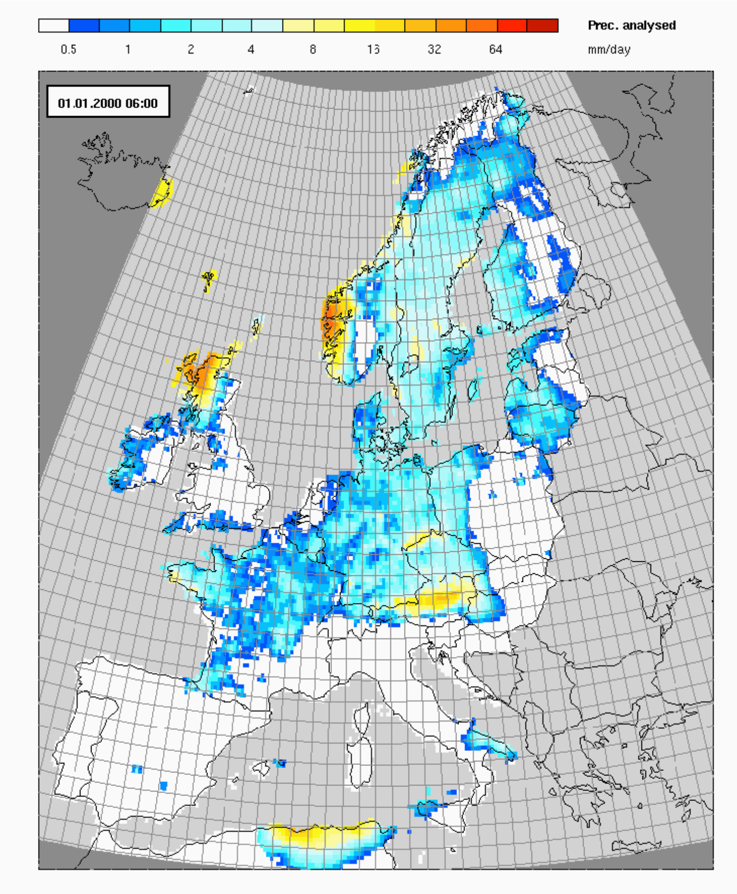
Solution:

$$\begin{vmatrix} \mathbf{R_{ss}} & \mathbf{R_{sg}} & 1 & 0 \\ \mathbf{R_{gs}} & \mathbf{R_{gg}} & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{vmatrix} \cdot \begin{vmatrix} \lambda_\mathbf{s} \\ \lambda_\mathbf{g} \\ \mu_s \\ \mu_g \end{vmatrix} = \begin{vmatrix} \mathbf{R_{so}} \\ \mathbf{R_{go}} \\ 0 \\ 1 \end{vmatrix}$$

Results Daily precipitation field

Features:

- Based on 21,600 observations
- Spatial resolution: 0.2° lat/lon
- Temporal resolution daily

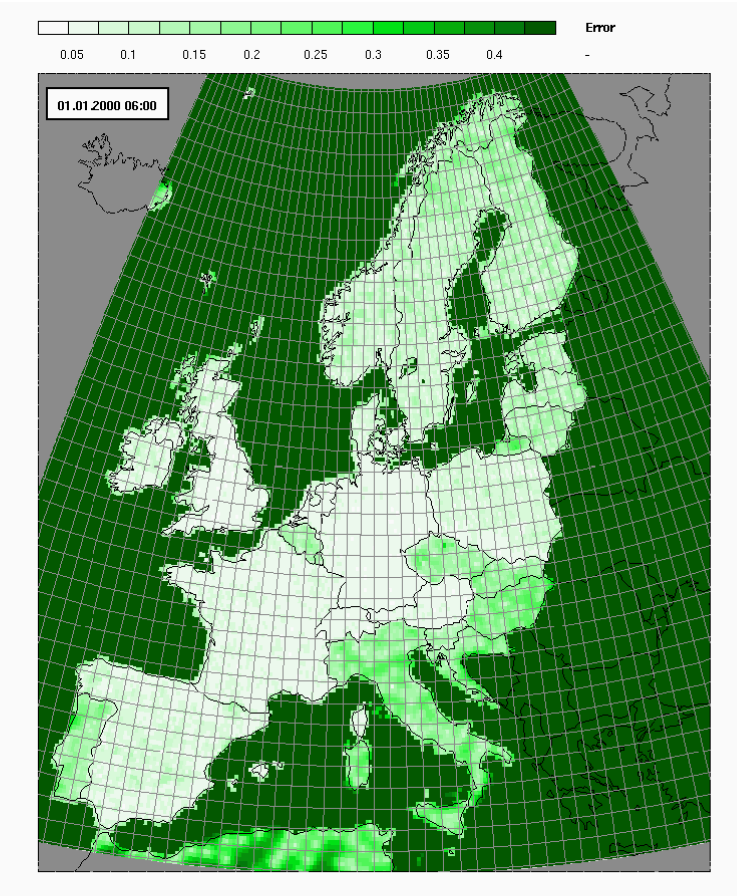


Results Interpolation error

Depends on:

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

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

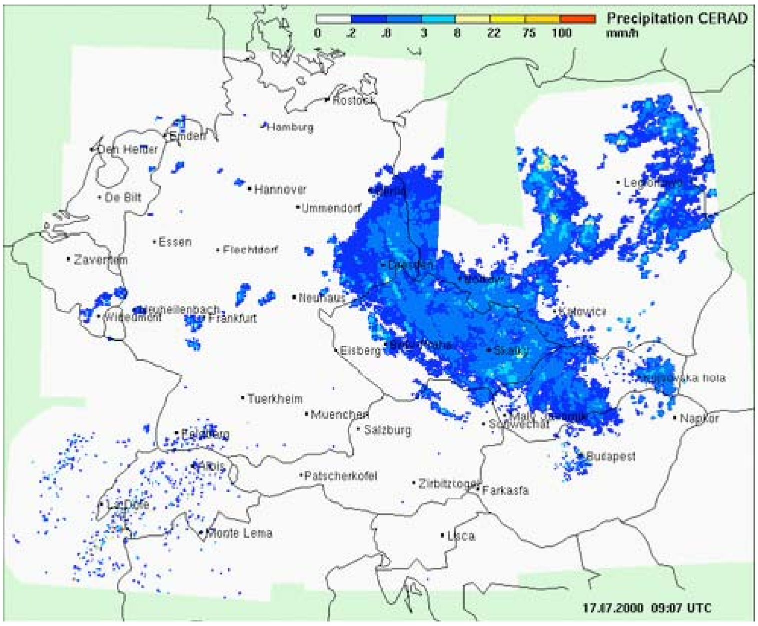


Deliverable II 0.2° 3-hrly precipitation analysis

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.



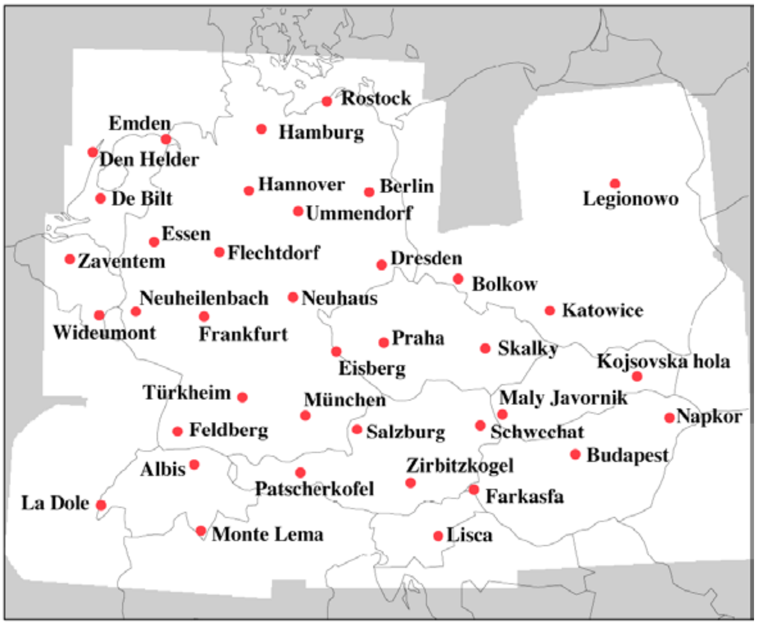
Data - operational weather radar networks

CERAD, the Central European Radar Network

Resolution 30 min 4 km

Maximum intensity product with 8 rain classes

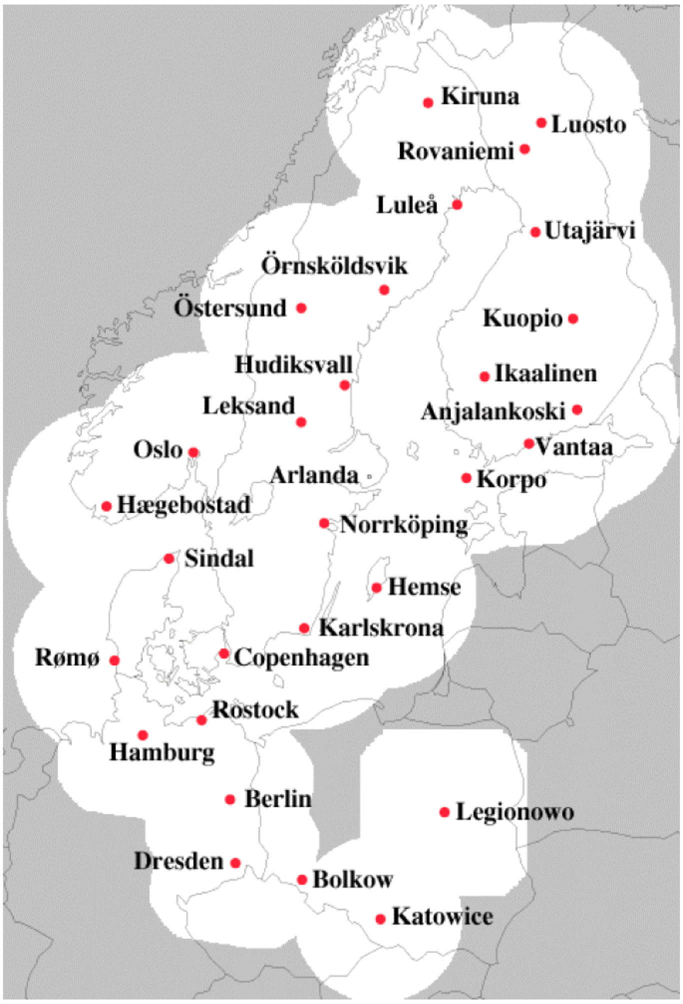
Provider: Technical University Graz, Austria Konrad Köck



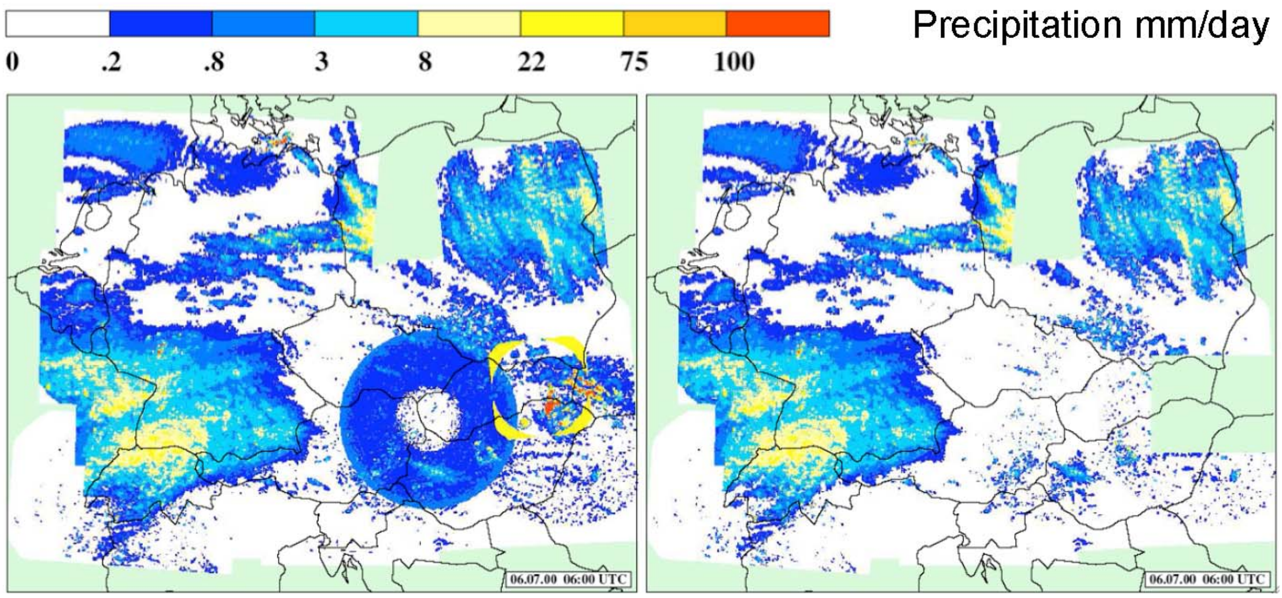
BALTRAD The Baltic Radar Network

Resolution 15 min 2 km

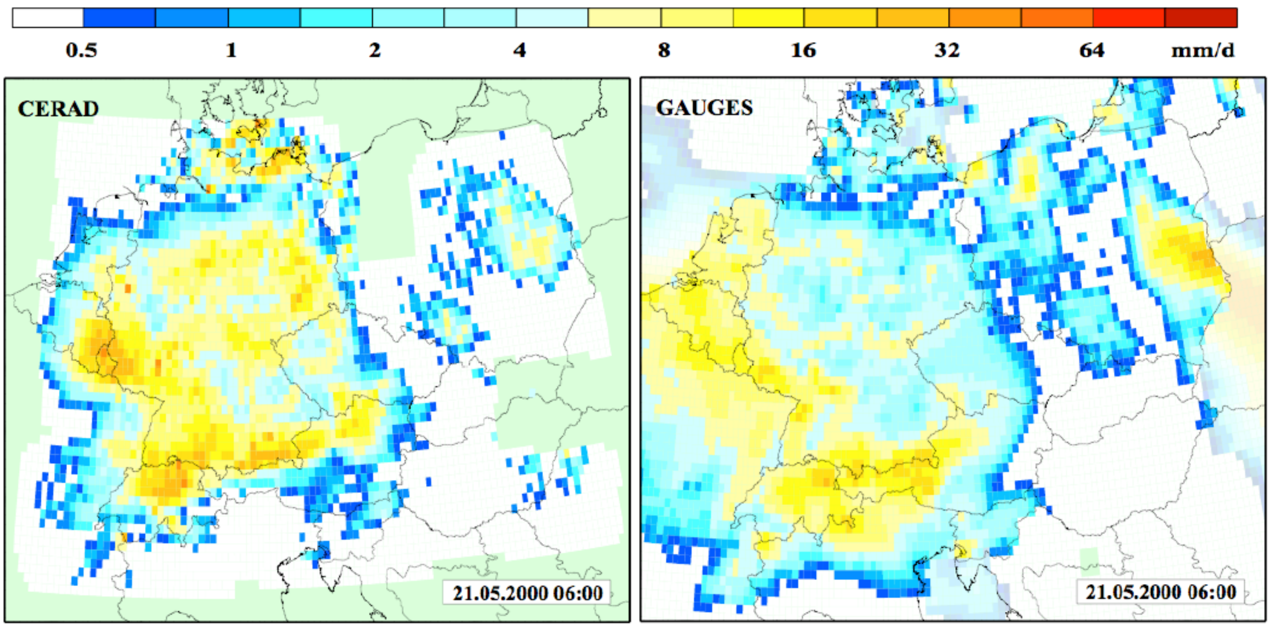
Provider:
SMHI, Sweden Daniel Michelson



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

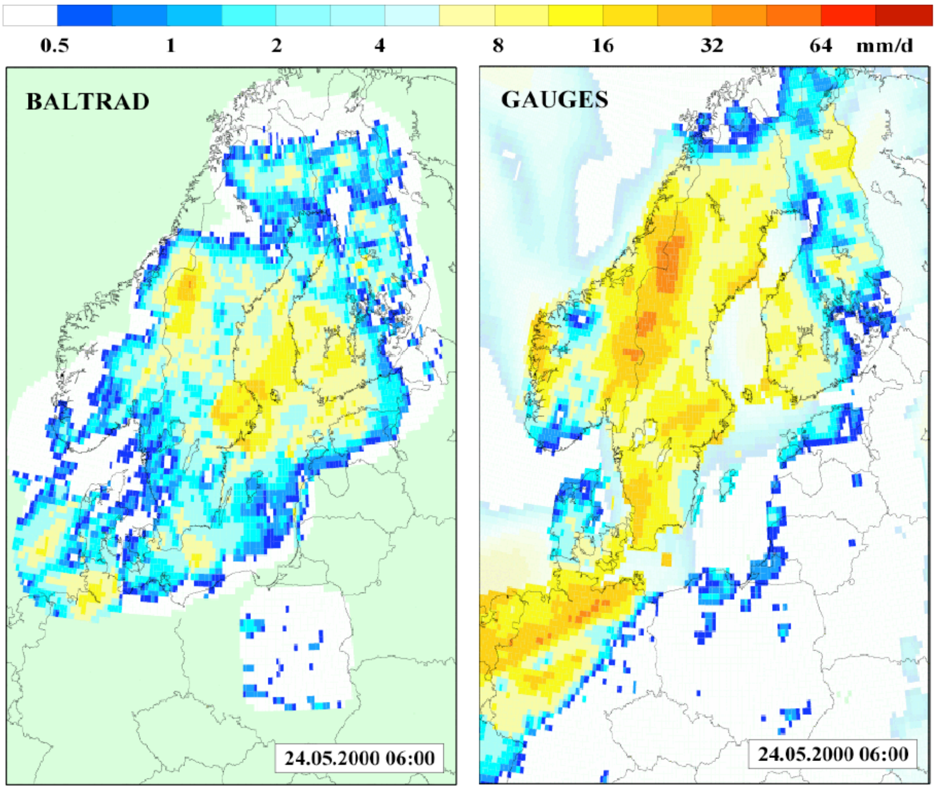
Comparison -daily precipitation BALTRAD vs gauges in mm/day

Gauges	31.18
BALTRAD	1.15
RMSE	3.85
Correlation	0.56

Results for 2000

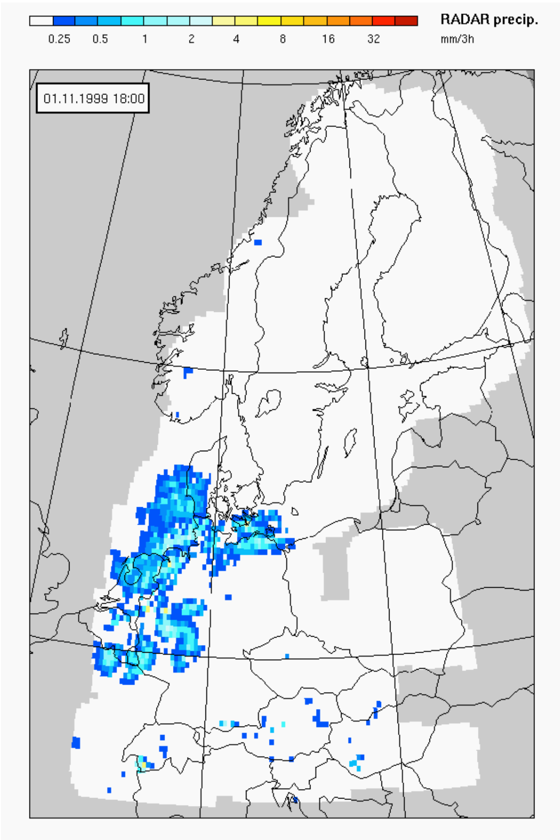
BALTRAD underestimates surface precipitation

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 semiautomatic 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 simples 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

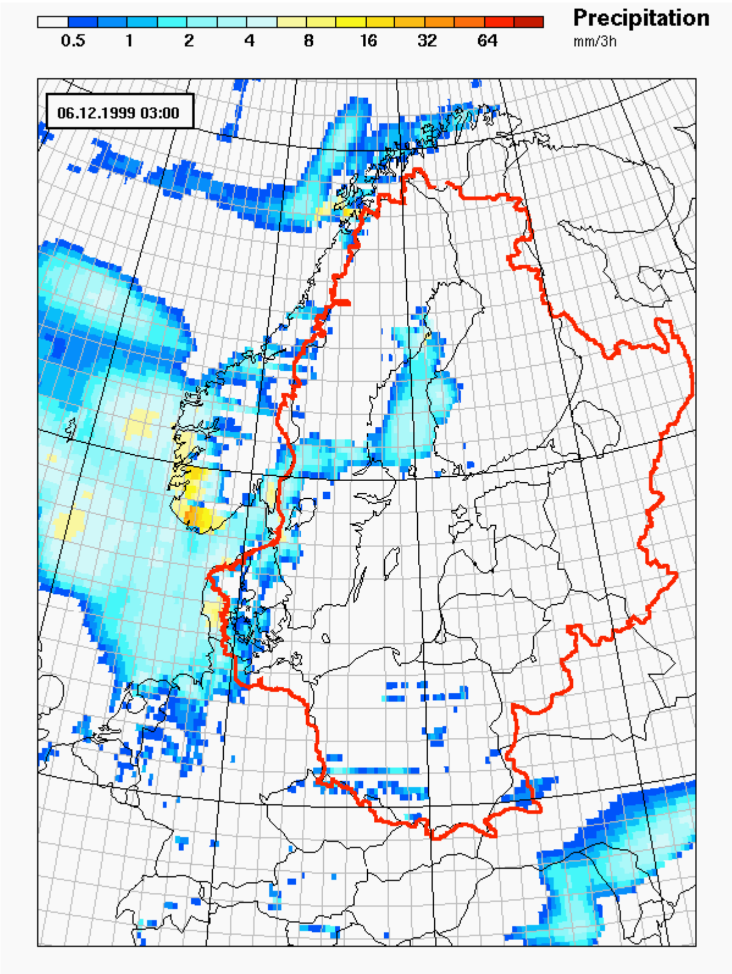
Input Data: BALTRAD, 2km 15min
CERAD, 4km 30min
Gauges, 21,000

Daily Background: ECMWF T511 exp.

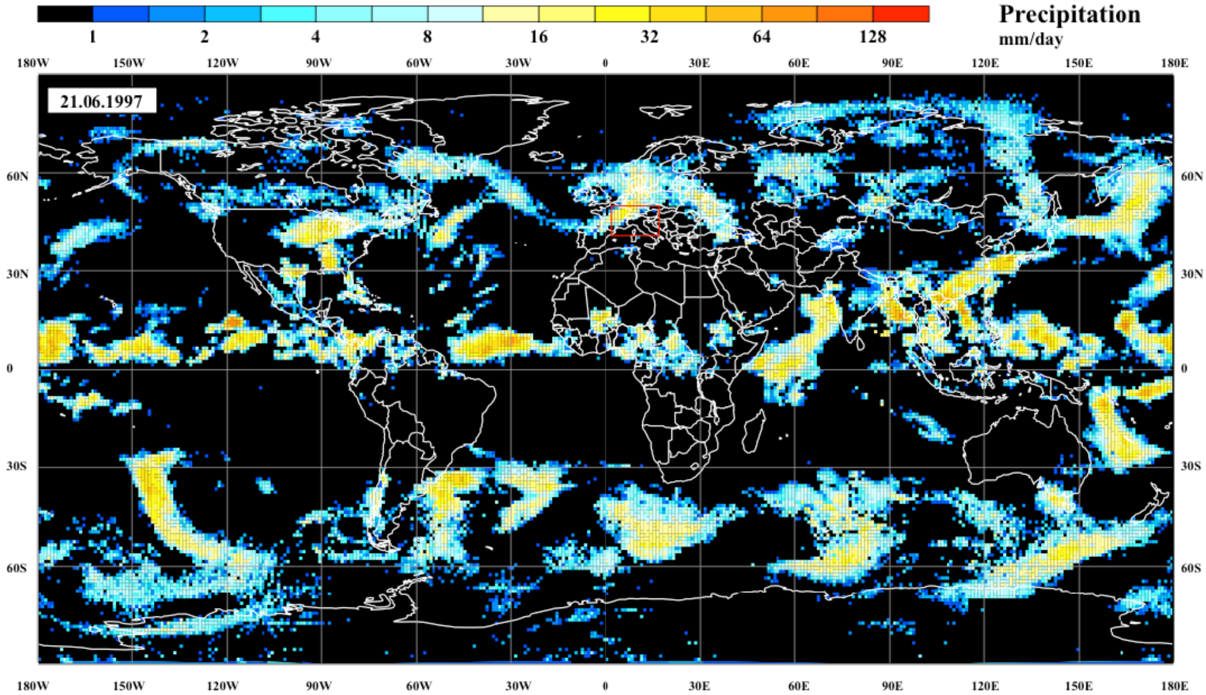
Run Addition: Error fields and flags

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

Predicted - GPCP satellite estimates vs. Observed - MAP rain gauge analysis

	Observed yes	Observed no	
Predicted yes	37 % h...hits	10 % f...false	47 %
Predicted 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

Predicted - ECMWF 6-30 hour forecasts vs. Observed - MAP rain gauge analysis

	Observed yes	Observed no	
Predicted yes	48 % h...hits	10 % f...false	58 %
Predicted 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