CSP Precipitation Methodology

MARKUS KOTTEK

FRANZ RUBEL

markus.kottek@vu-wien.ac.at

Biometeorology Group, Department of Natural Sciences,
University of Veterinary Medicine Vienna, Veterinärplatz 1,
A-1210 Vienna, Austria

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CSP Precipitation

Objectives

- Development of a global scale daily precipitation product based on existing multi-satellite estimates and bias-corrected precipitation gauge analyses to provide the ONC, OFM and OLF.
- Improvement of the satellite estimates, the GPCP-1DD data, due to calibration with the bias-corrected rain gauge data based on about 6 000 synoptic stations worldwide, provided by the GPCC.

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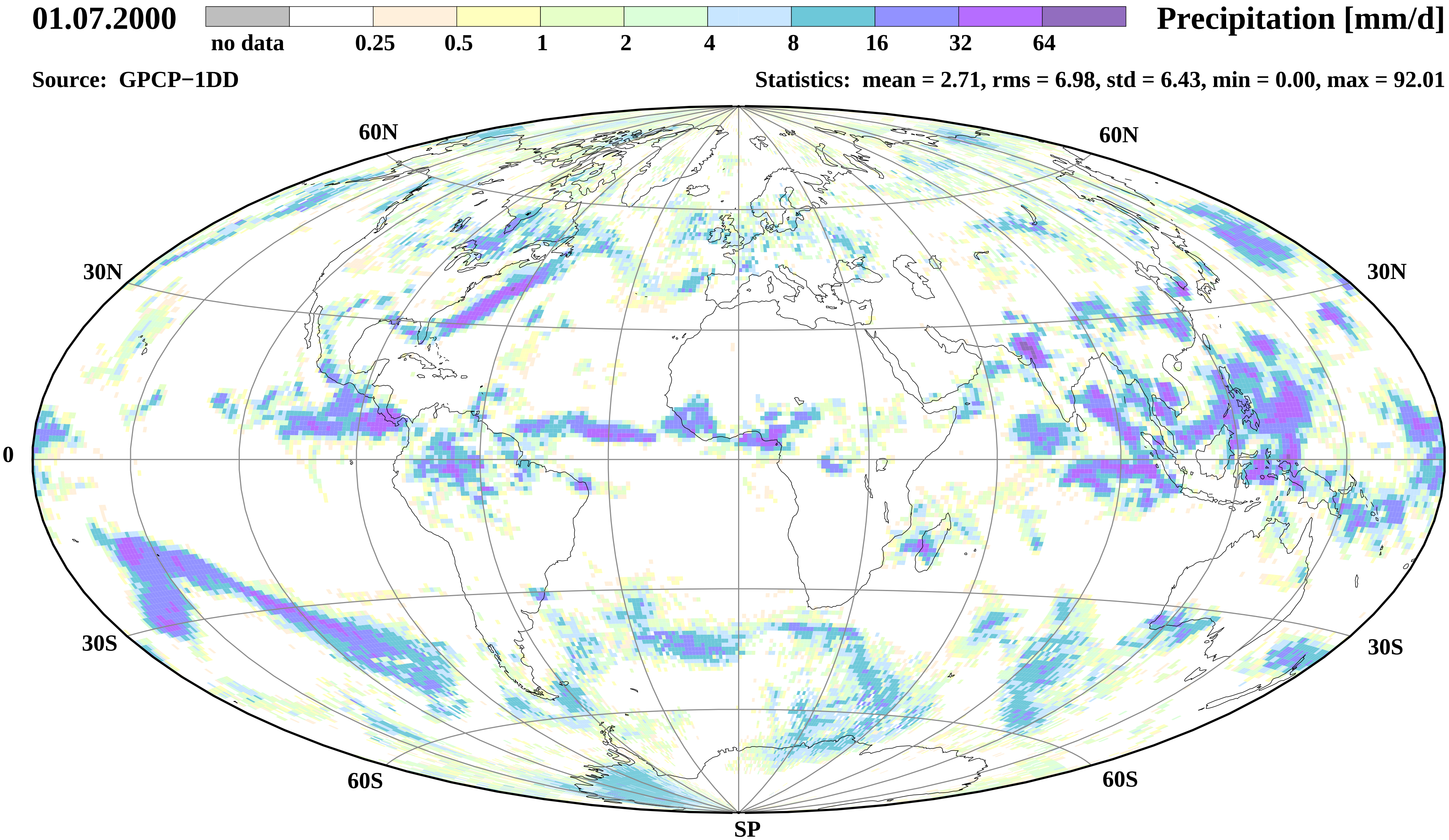

Fig. 1: GPCP-1DD (Global Precipitation Climatology Project - 1 Degree Daily) multi-satellite estimates of precipitation for July 2000.

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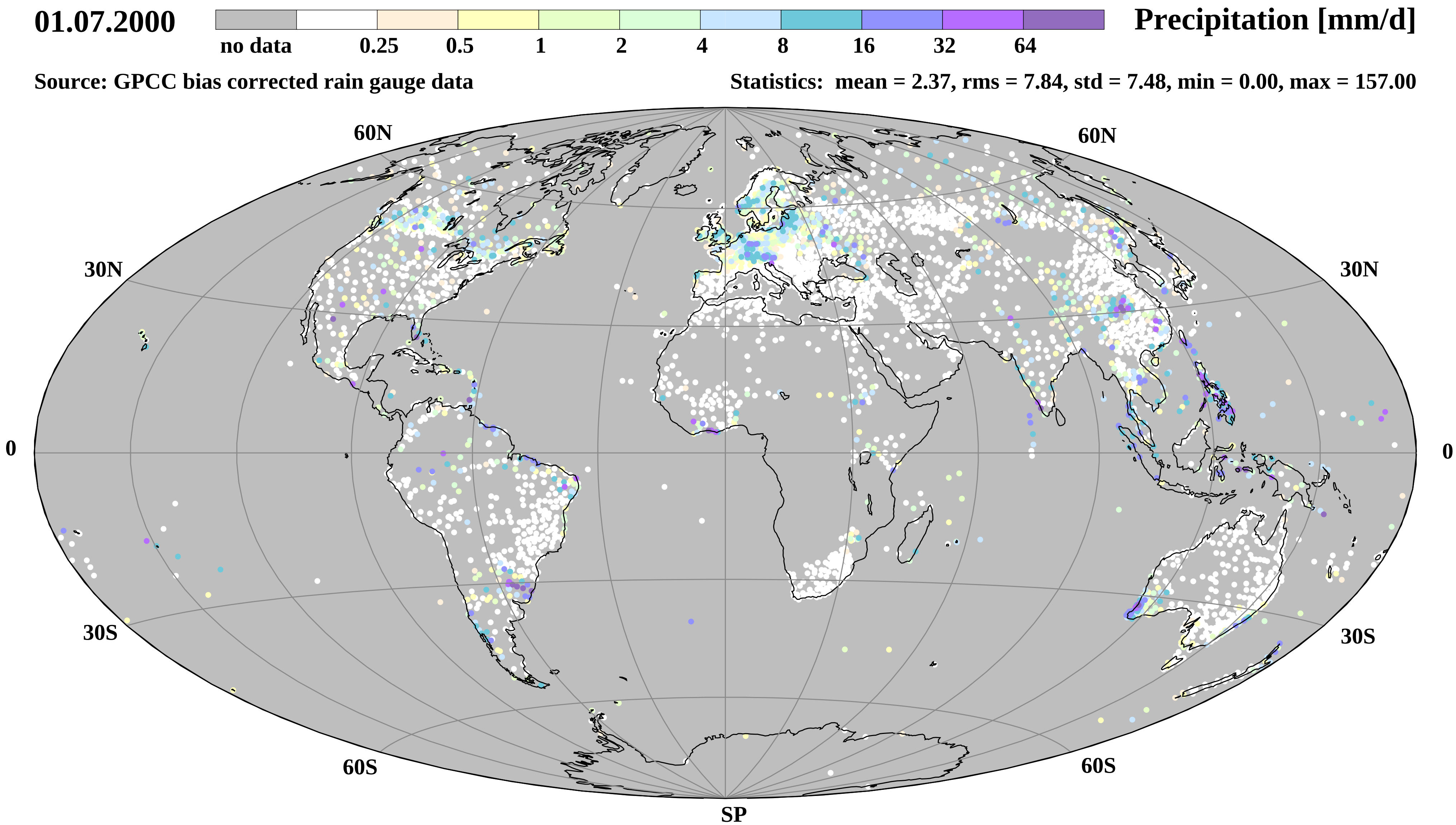

Fig. 2: GPCC (Global Precipitation Climatology Centre) bias-corrected rain gauge measurements for July 2000.

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Production process

– Interpolation of the GPCC bias-corrected rain gauge measurements to a global regular 1° longitude/latitude grid by *ordinary block kriging*.

– Merging of the GPCP-1DD multi-satellite estimates with the interpolated rain gauge measurements by *bivariate ordinary cokriging* to compute the CSP precipitation product.

– Verification of the CSP precipitation product over selected regions of the globe by the use of *skill scores*.

Ordinary block kriging

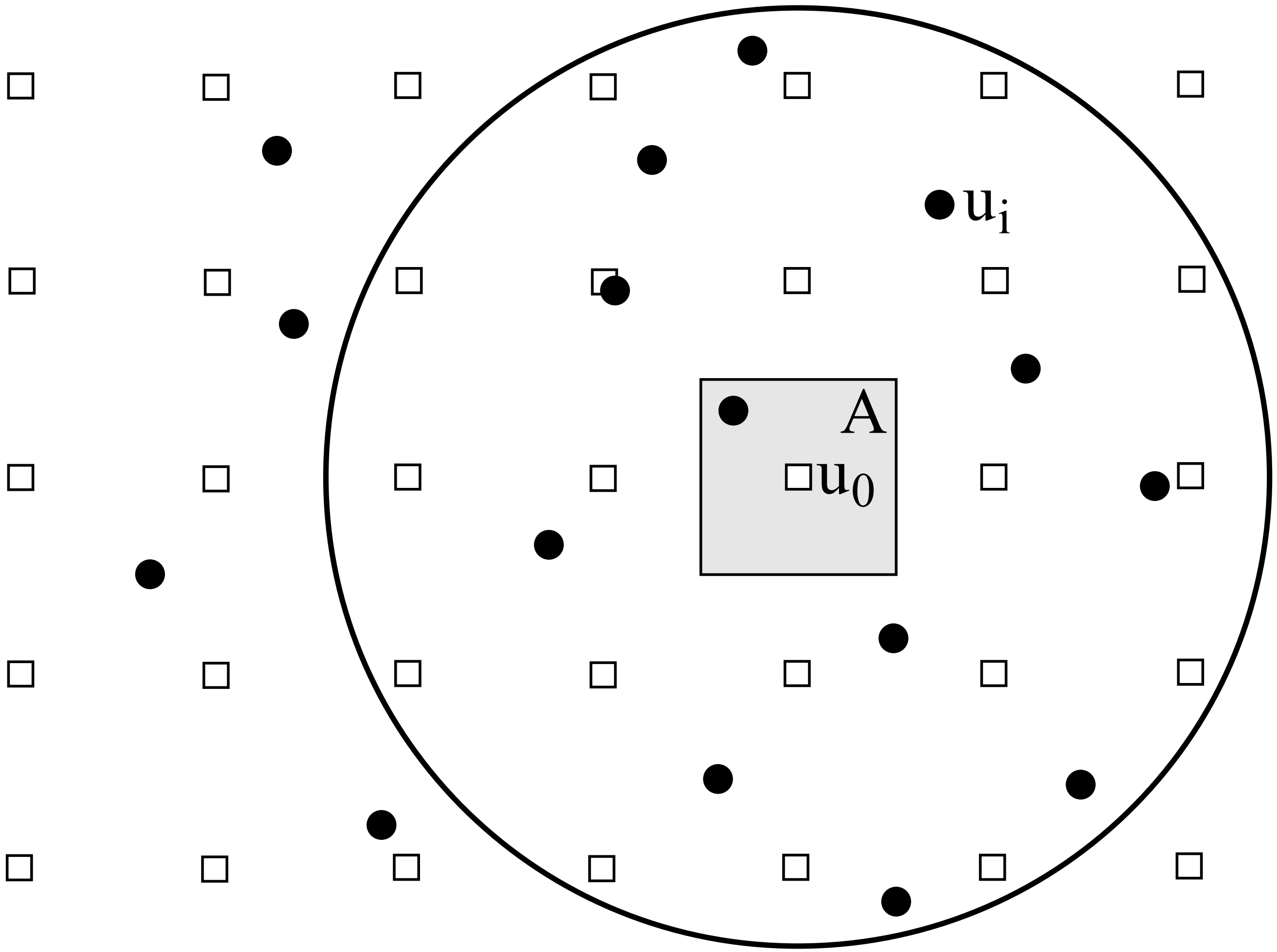

Fig. 3: For each area A, represented by a grid point $\mathbf{u}_0$, the $n = 24$ closest observations $Z_g(\mathbf{u}_i)$ within the decorrelation distance are used to estimate the value of the area averaged precipitation $\widehat{Z}(\mathbf{u}_0)$.

Ordinary block kriging

Assuming n contemporary gauge observations of the precipitation process $Z_g(\mathbf{u}_i)$, $\mathbf{u} \equiv (x, y)$, $i = 1, ..., n$, the areal averaged precipitation $\widehat{Z}(\mathbf{u}_0)$ can be estimated from the following linear combination

$$\widehat{Z}(\mathbf{u}_0) = \sum_{i=1}^{n} \lambda_{gi} Z_g(\mathbf{u}_i). \tag{1}$$

The weights λ_{gi} can be obtained under the condition of minimizing the estimation variance (mean square interpolation error)

$$\sigma_{\mathrm{E}}^2 = \mathrm{var}[Z(\mathbf{u}_0) - \widehat{Z}(\mathbf{u}_0)] = \mathrm{E}[(Z(\mathbf{u}_0) - \widehat{Z}(\mathbf{u}_0))^2]. \tag{2}$$

by the definition of correlation functions

$$R(\mathbf{u}_i, \mathbf{u}_j) = \frac{\mathrm{cov}[\mathbf{u}_i, \mathbf{u}_j]}{\sigma^2} = \frac{\mathrm{E}[Z(\mathbf{u}_i) \cdot Z(\mathbf{u}_j)] - m^2}{\sigma^2} \tag{3}$$

as covariance functions normalized with the variance $\sigma^2 = \mathrm{cov}[\mathbf{u}_i, \mathbf{u}_i]$.

Ordinary block kriging

The solution can be obtained by solving the following system of linear equations.

$$\begin{vmatrix} R(\mathbf{u}_1,\mathbf{u}_1) & \cdots & R(\mathbf{u}_1,\mathbf{u}_n) & 1 \\ \vdots & \ddots & \vdots & \vdots \\ R(\mathbf{u}_n,\mathbf{u}_1) & \cdots & R(\mathbf{u}_n,\mathbf{u}_n) & 1 \\ 1 & \cdots & 1 & 0 \end{vmatrix} \cdot \begin{vmatrix} \lambda_{g1} \\ \vdots \\ \lambda_{gn} \\ \mu_g \end{vmatrix} = \begin{vmatrix} R(\mathbf{u}_1,\mathbf{u}_0) \\ \vdots \\ R(\mathbf{u}_n,\mathbf{u}_0) \\ 1 \end{vmatrix}. \qquad (4)$$

$R(\mathbf{u}_i,\mathbf{u}_j)$ are the correlations between rain gauge observations at the locations $\mathbf{u}_i$ and $\mathbf{u}_j$, $R(\mathbf{u}_i,\mathbf{u}_0)$ are the correlations between the rain gauge observations at the locations $\mathbf{u}_i$ and the grid area integrated true precipitation process $Z(\mathbf{u}_0)$ and μ_g is the scalar Lagrangian multiplier.

Ordinary block kriging

The system (4) can be truncated by using the gauge-gauge correlation matrix $\mathbf{R}_{gg}$, the gauge-area correlation vector $\mathbf{R}_{g0}$ and the vector of weights to be estimated $\boldsymbol{\lambda}_g$:

$$\begin{vmatrix} \mathbf{R}_{gg} & \mathbf{1} \\ \mathbf{1}^\top & 0 \end{vmatrix} \cdot \begin{vmatrix} \boldsymbol{\lambda}_g \\ \mu_g \end{vmatrix} = \begin{vmatrix} \mathbf{R}_{g0} \\ 1 \end{vmatrix}. \tag{5}$$

Thus, if the correlations are known, the vector $\boldsymbol{\lambda}_g$ can be calculated from (5) and the linear combination (1) for the area averaged precipitation can be evaluated.

Detailed descriptions of this method can be found in the literature (e.g. Wackernagel, 1995).

Correlation functions

We assume that there exist n contemporary observations of precipitation process $Z(\mathbf{u}_i)$, $\mathbf{u} = (x, y)$ and $i = 1, ..., n$. Further, if there exist multiple realizations $t = 1, ..., T$ of this process $Z(\mathbf{u}_i)$, then the correlation can be defined as

$$R(\mathbf{u}_i, \mathbf{u}_j) = \frac{\sum_{t=1}^{T} [Z_t(\mathbf{u}_i) - m(\mathbf{u}_i)][Z_t(\mathbf{u}_j) - m(\mathbf{u}_j)]}{\sqrt{\sum_{t=1}^{T} [Z_t(\mathbf{u}_i) - m(\mathbf{u}_i)]^2 \sum_{t=1}^{T} [Z_t(\mathbf{u}_j) - m(\mathbf{u}_j)]^2}}. \tag{6}$$

where $m(\mathbf{u}_i)$ is the mean of the precipitation process at the location $\mathbf{u}_i$.

Assuming that the precipitation process is homogenous and isotropic within the model domain, the correlations depend only on the interstation distance ρ_{ij}; they are independent of the geographical locations and can be modeled by the use of exponential correlation functions.

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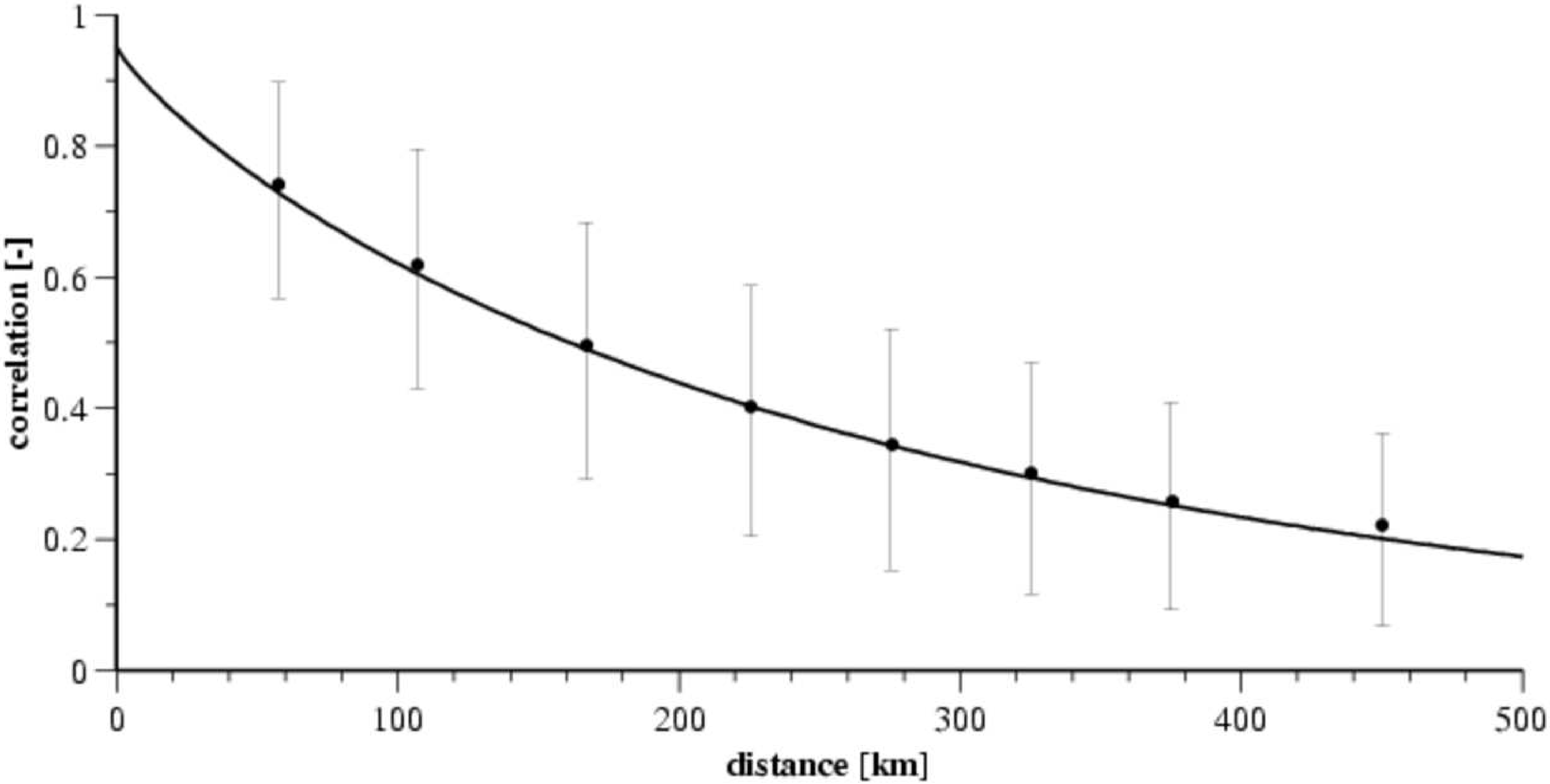

Fig. 4: Correlation coeffi cients estimated from 60 realizations of 12-hourly accumulated precipitation observations over Central Europe with standard deviations and fi tted correlation function $R(\rho) = 0.95 \exp[-0.008\,\rho^{0.86}]$.

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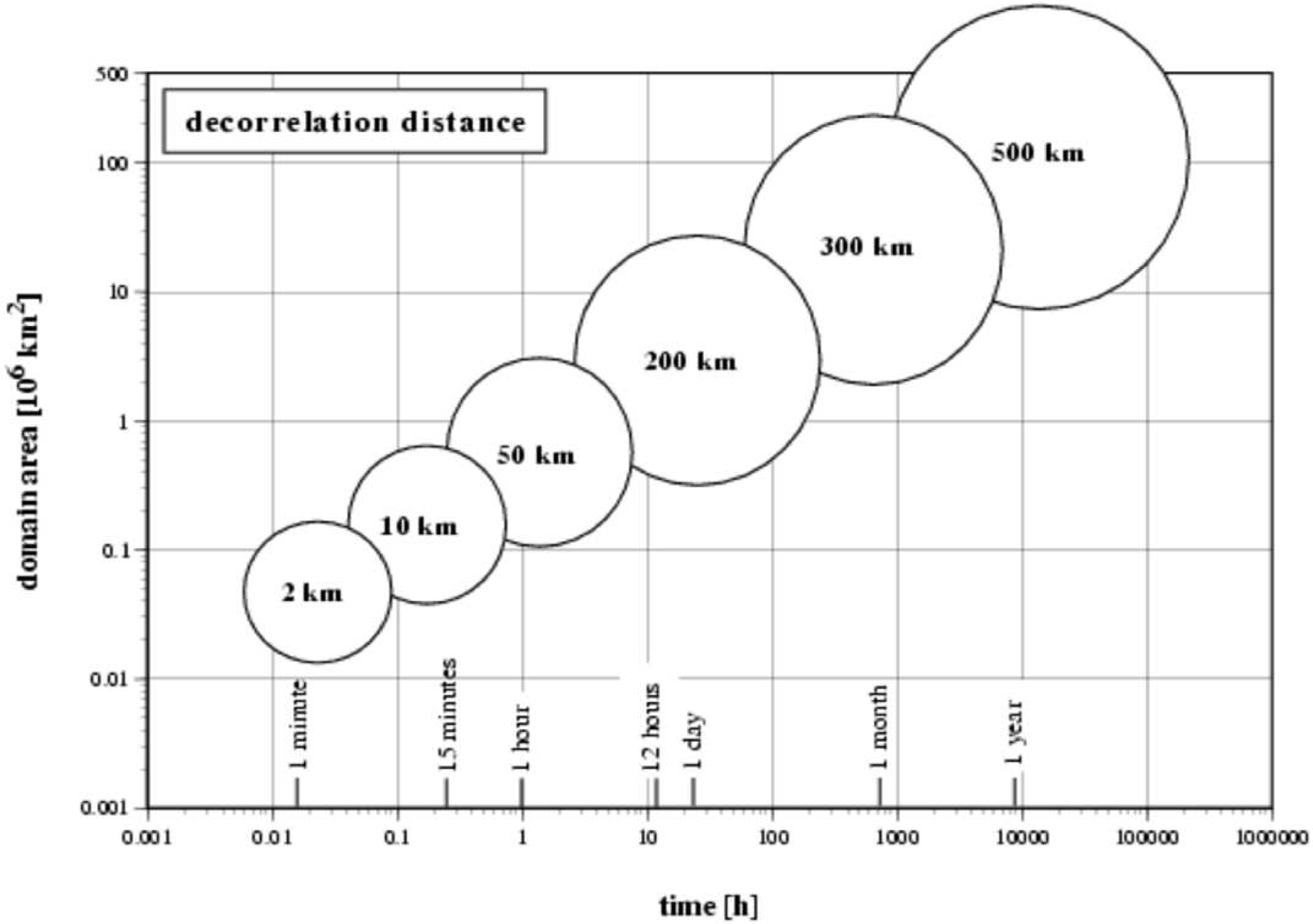

Fig. 5: Scale dependence of correlation function used for statistical analysis of precipitation represented by decorrelation distance for increasing spatial and temporal resolution.

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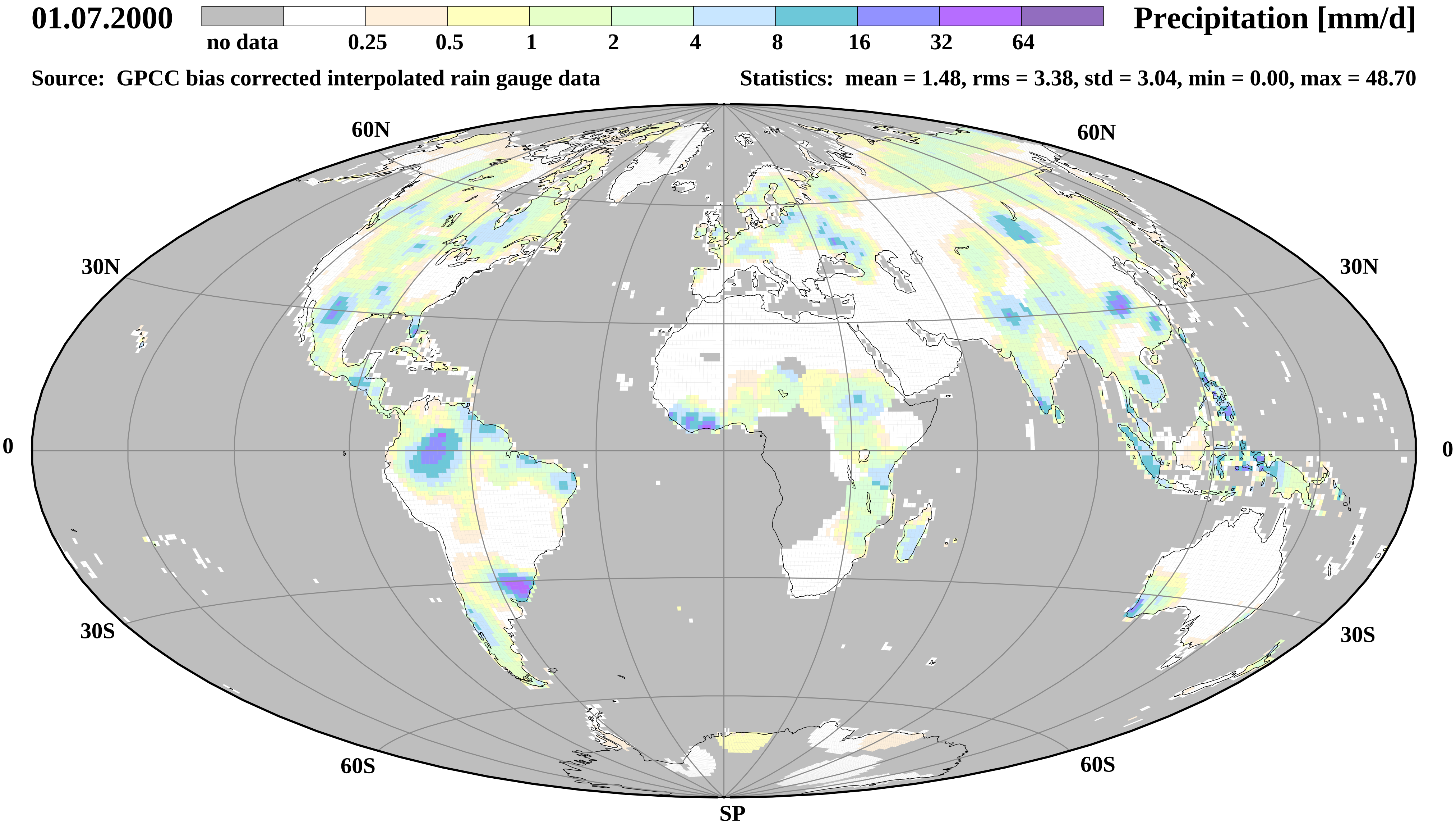

Fig. 6: GPCC (Global Precipitation Climatology Centre) bias-corrected and interpolated rain gauge measurements for July 2000.

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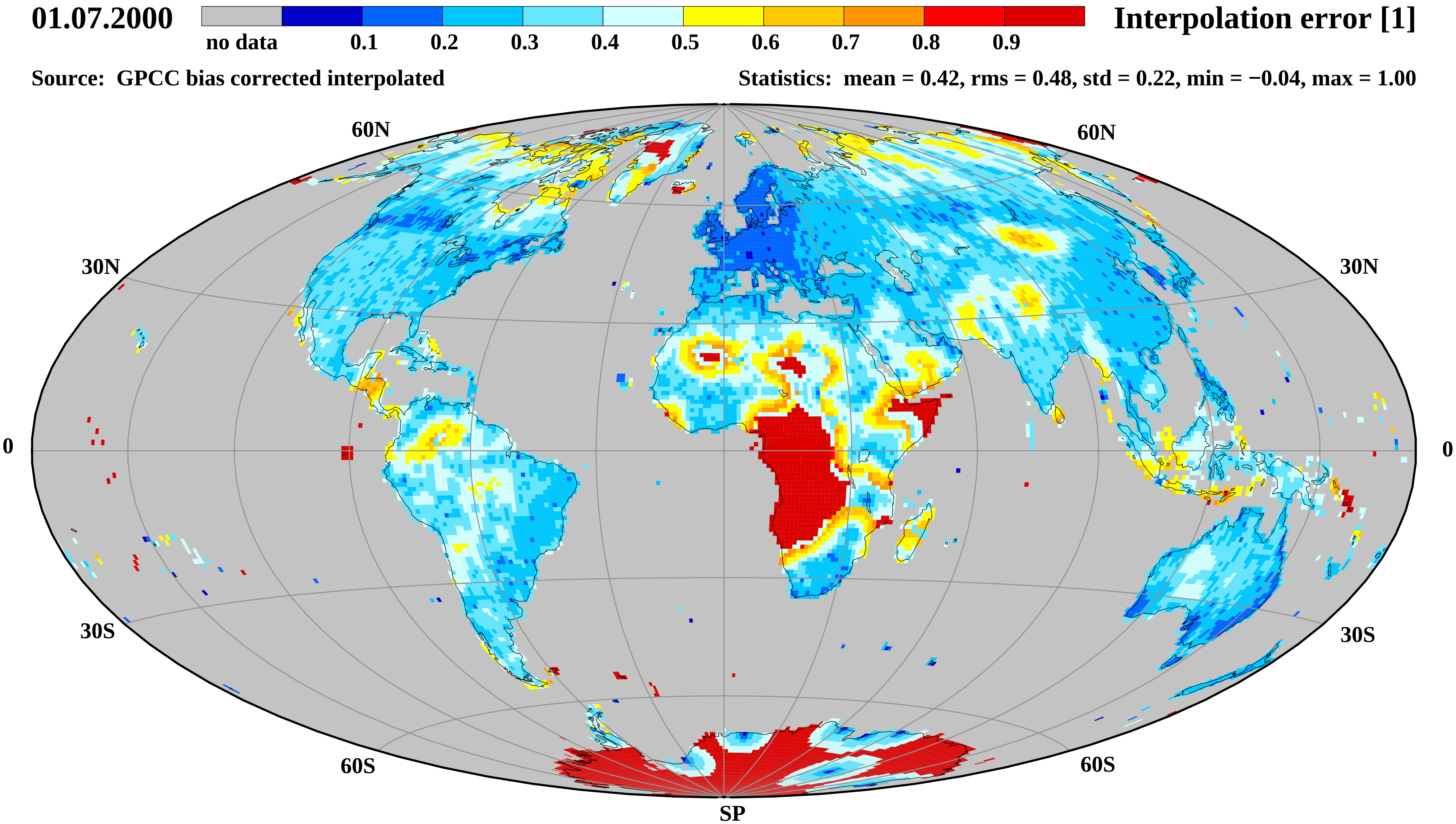

Fig. 7: Interpolation error for GPCC bias-corrected rain gauge measurements, July 2000.

Bivariate ordinary cokriging

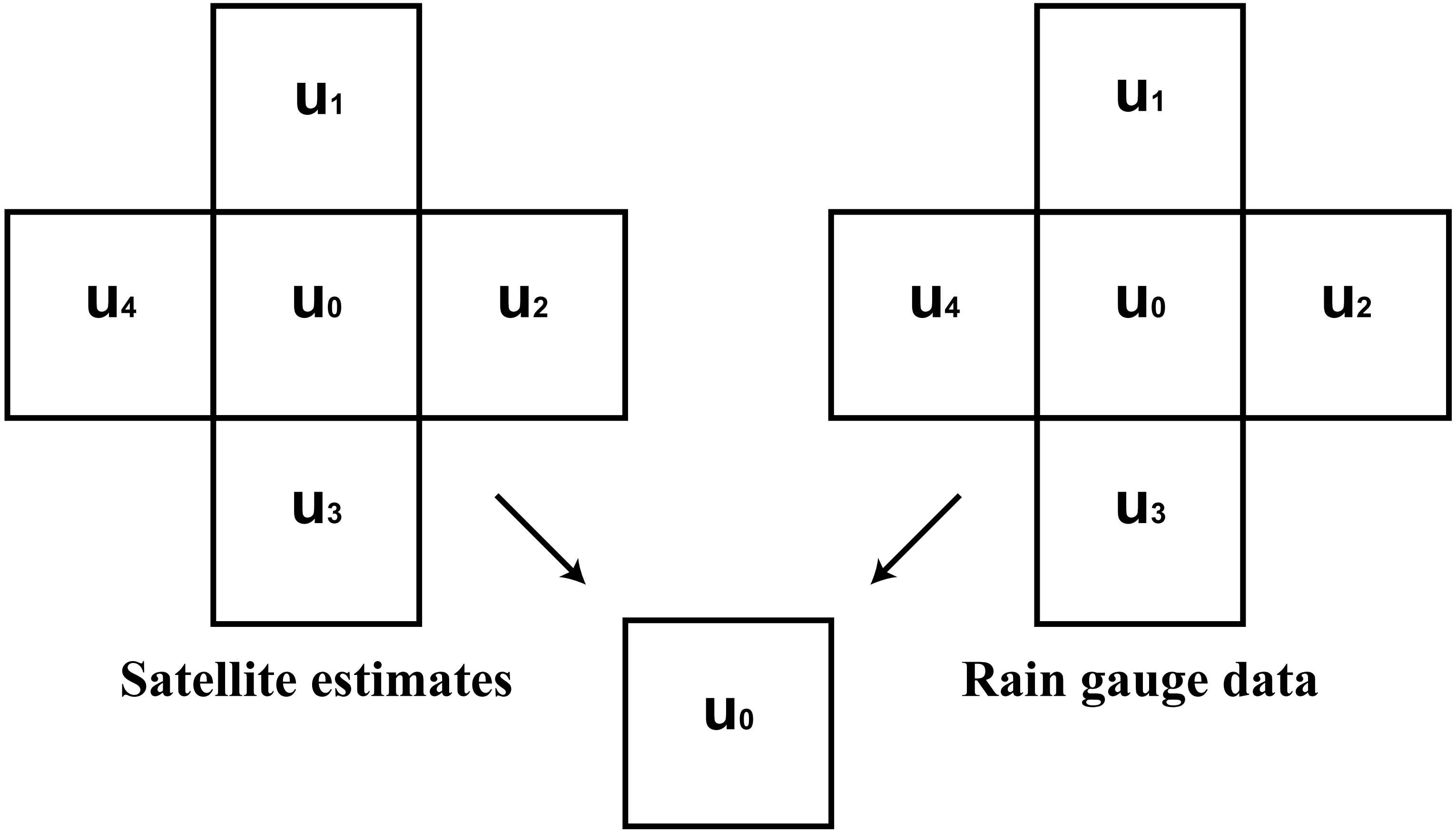

Fig. 8: Schematic representation of the confi guration of the data included in the cokriging system.

Bivariate ordinary cokriging

The linear combination for cokriging of satellite estimates $Z_s(\mathbf{u})$ and rain gauge data $Z_g(\mathbf{u})$ can be written as

$$\widehat{Z}(\mathbf{u}_0) = \sum_{j=1}^{n_s} \lambda_{sj}\, Z_s(\mathbf{u}_j) + \sum_{i=1}^{n_g} \lambda_{gi}\, Z_g(\mathbf{u}_i). \tag{7}$$

The weight vectors $\boldsymbol{\lambda}_s$ and $\boldsymbol{\lambda}_g$ that need to be estimated can be computed from the following system of linear equations.

$$\left|\begin{array}{cccc} \mathbf{R}_{ss} & \mathbf{R}_{sg} & \mathbf{1} & \mathbf{0} \\ \mathbf{R}_{gs} & \mathbf{R}_{gg} & \mathbf{0} & \mathbf{1} \\ \mathbf{1}^\top & \mathbf{0}^\top & 0 & 0 \\ \mathbf{0}^\top & \mathbf{1}^\top & 0 & 0 \end{array}\right| \cdot \left|\begin{array}{c} \boldsymbol{\lambda}_s \\ \boldsymbol{\lambda}_g \\ \mu_s \\ \mu_g \end{array}\right| = \left|\begin{array}{c} \mathbf{R}_{s0} \\ \mathbf{R}_{g0} \\ 0 \\ 1 \end{array}\right|. \tag{8}$$

Bivariate ordinary cokriging

$\mathbf{R}_{ss}$ is the satellite-satellite correlation matrix, $\mathbf{R}_{gg}$ the gauge-gauge correlation matrix and $\mathbf{R}_{sg} = \mathbf{R}_{gs}^{\top}$ the satellite-gauge crosscorrelation matrix.

Since the true area integrated precipitation is unknown, the satellite-area correlation vector $\mathbf{R}_{s0}$ and the gauge-area correlation vector $\mathbf{R}_{g0}$ are approximated from $\mathbf{R}_{ss}$ and $\mathbf{R}_{gg}$ (Krajewski,1987).

Analogous to the ordinary block kriging equation (5) the weight vectors $\boldsymbol{\lambda}_s$ and $\boldsymbol{\lambda}_g$ can be obtained from the cokriging equation (8) if the correlations $\mathbf{R}_{ss}$, $\mathbf{R}_{gg}$ and $\mathbf{R}_{sg}$ are known.

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Operational scenario

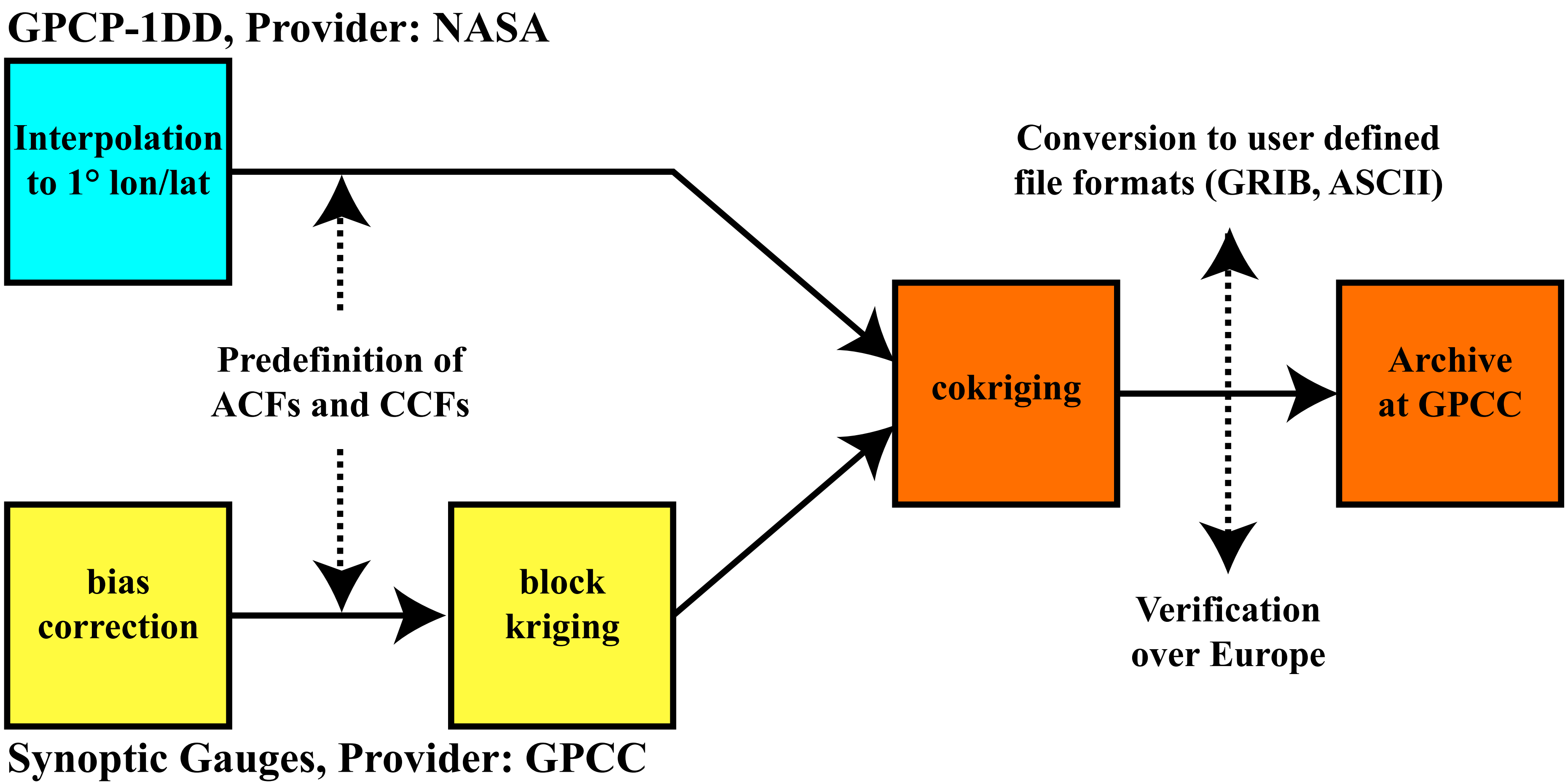

Fig. 9: Schematic representation of the operational scenario, propably performed at the GPCC.

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