AP 1:

- Vorwarnung vor kritischen Wetterlagen: Identifikation von kritischen Wetterlagen, Langfristvorhersagen von Stationsniederschlägen mittels klimatologischem Downscaling
- Ermittlung des Gebietszustands: Ermittlung der Gebietsbodenfeuchte (verteiltes Bodenmessnetz, Fernerkundung und Modell)
- Ermittlung des Schneezustands (Ausdehnung, Zustand, Mächtigkeit; verteiltes Bodenmessnetz, Fernerkundung und Modell)

Der Goldersbach

Zu AP 1

Aus dem Antrag:

“Die mathematische Einfachheit des empirischen Downscaling ermöglicht die Lokalisierung ganzer Ensemble-Vorhersagesysteme wie etwa die des ECMWF (EPS) oder des NCEP (MREF). Hieraus lassen sich dann stabile Wahrscheinlichkeitsverteilungen für das Auftreten von HW-relevanten Niederschlägen abschätzen. Aus diesen wiederum soll der Prototyp eines sehr einfachen, etwa 5-kategorialen Frühwarnsystems (kein, geringes, mittleres, hohes, volles Gefahrenpotenzial) aufgebaut werden.”

Ensemble prediction: A pedagogical perspective

Tim Palmer, Roberto Buizza, Renate Hagedorn, Andy Lawrence, Martin Leutbecher, Lenny Smith

The ECMWF Ensemble Prediction System (EPS) has featured extensively in the ECMWF Newsletter, including articles assessing the performance of the EPS, plans for EPS development, and applications to which the EPS has been used. For example, in ECMWF Newsletter No. 104, trends in EPS probability skill scores since 1994 were reviewed by Roberto Buizza. In this issue, the skill of the EPS in forecasting rainfall and potential vorticity is discussed by Mark Rodwell.

Despite the fact that the EPS brings additional value to ECWMF's dissemination products through its ability to assess flow-dependent weather risk, the EPS is a less straightforward tool to use than the more traditional deterministic forecast. Not surprisingly, therefore, conceptual questions are sometimes asked about the EPS. Here are some examples. What is the relationship between the spread and skill within the EPS? If the northern hemisphere RMS error of a typical ensemble member is routinely larger than that of the corresponding deterministic forecast, does this imply that this ensemble member is simply a degradation of the deterministic forecast? Should we be striving to reduce the RMS error of ensemble members relative to the deterministic forecast? Does it make a difference if we ask how many ensemble members are better than the deterministic forecast locally, compared with hemispherically? Are the baroclinically-tilted structures often seen in the EPS initial perturbations consistent with our knowledge of analysis error? Perhaps most important of all

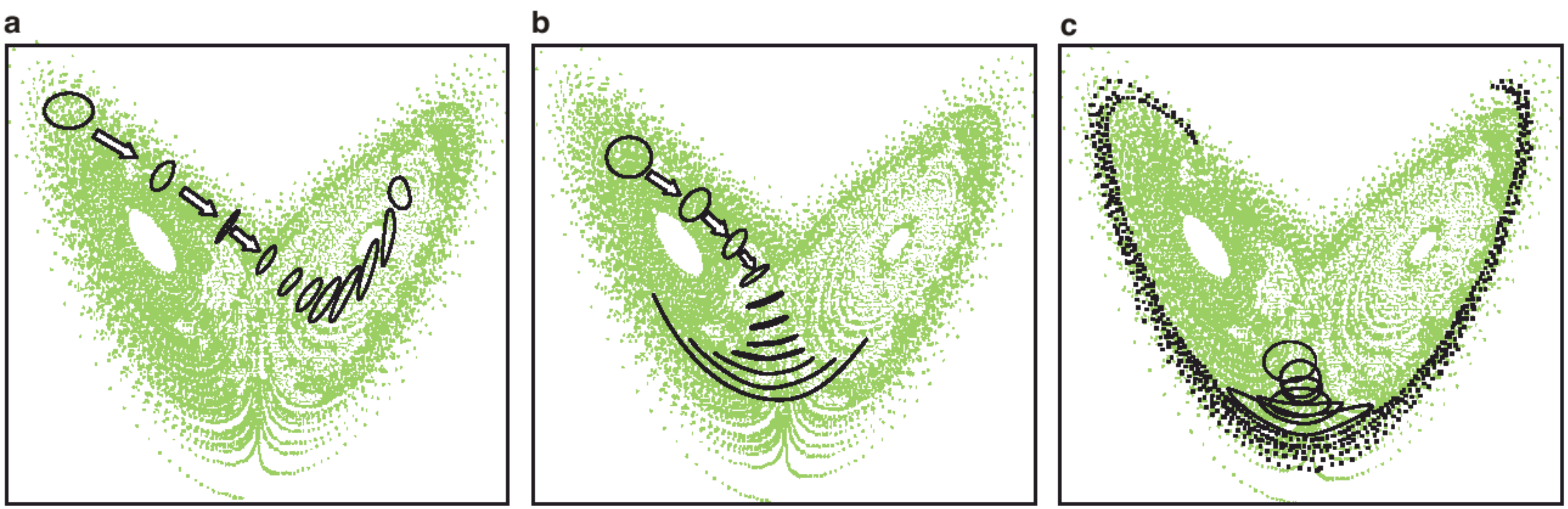
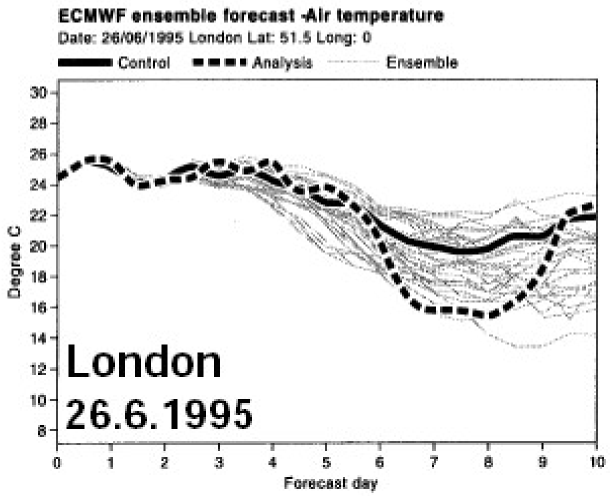
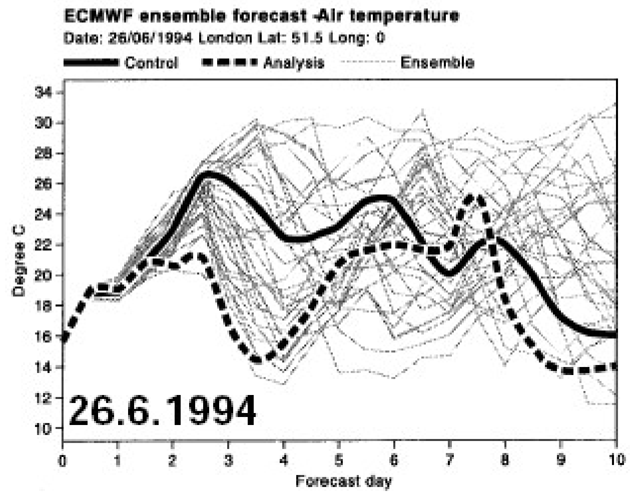


Figure 1 Scientific basis for ensemble forecasting. In a nonlinear system the growth of initial uncertainty is flow dependent – here illustrated with the Lorenz (1963) model. The set of initial conditions (black circle) is located in different regions of the attractor in (a), (b) and (c).

Mittelfristige Wettervorhersage: Beschreibung eines nichtlinearen chaotischen Systems





EPS, Ensembles

→ gute Vorhersagbarkeit

→ schneller Verlust der Vorhersagbarkeit

Hauptziel: Gütevorhersagen für mittelfristige Wettervorhersage, Streuungs-Güte (spread-skill) Beziehungen

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ECMWF ENSEMBLE PREDICTION SYSTEM

ECMWF produces a 51 member ensemble of 10-day forecasts every day, comprising 1 control integration and 50 perturbed integrations.

3.1 Control integration

The control integration is run at T_L255L40 resolution using the operational model cycle from the operational T_L511 analysis truncated at T_L255.

3.2 Perturbed initial conditions

Each member of the 50 perturbed integrations is run from perturbed initial conditions. These perturbations are constucted from fast-growing instabilities of the circulation, calculated from the dominant singular vectors of the forward tangent propagator of the linearised dynamics. Also included in the initial perturbations are more slowly growing structures associated with singular vectors evolved from 2 days earlier.

3.3 Perturbed integrations

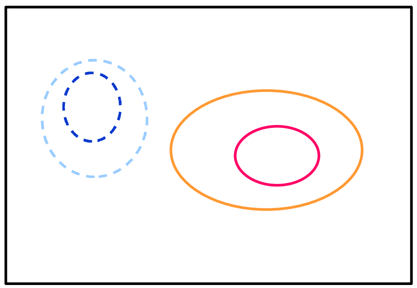
The 50 perturbed integrations are run with the same model cycle and resolution as the control integration but with the inclusion of a stochastic physics parametrisation. Each member of the 50 perturbed integrations is run with a set of randomly drawn realisations of the stochastic physics scheme.

The problem of scales

- ECHAM4 (T42) ~ 500 km
- EPS (T255) ~ 80 km
- GCMs are large-scale in space and time. They describe (at most) synoptic-scale atmospheric behavior.
- Hydrologic phenomena are small-scale. Their simulation requires (at least) daily meteorological input at the catchment scale.

downscaling

global/NA circulation g
(Z_{500}, T_{850}, Q_{850}, ...)

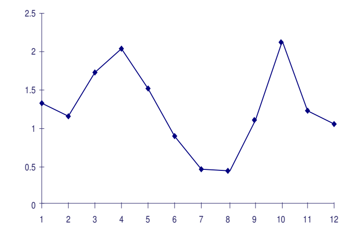


transfer function f

$$g \xrightarrow{f} l$$

$$l = f(g) + \varepsilon$$

local weather l



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minimize $\langle (l - f(g))^2 \rangle$!

linear regression: $f = \mathbf{R} = \mathbf{C}_{lg}(\mathbf{C}_{gg})^{-1}$ ($\mathbf{C}_{lg}$,... covariance) reduced model variability, $\mathbf{R}\mathbf{C}_{gg}\mathbf{R}^{\mathrm{T}}$, according to ...

$$\mathbf{R} = \mathbf{C}_{lg}(\mathbf{C}_{gg})^{-1} \quad \Rightarrow \quad \mathbf{R}\mathbf{C}_{gg}\mathbf{R}^{\mathrm{T}} = \mathfrak{C}\mathbf{C}_{ll} < \mathbf{C}_{ll}$$

with $\mathfrak{C} = \mathbf{C}_{lg}(\mathbf{C}_{gg})^{-1}\,\mathbf{C}_{gl}(\mathbf{C}_{ll})^{-1}$ canonical correlation matrix, $|\mathfrak{C}| < 1$

[i.e., the eigenvectors of $\mathfrak{C}$ are the canonical correlation patterns with corresponding eigenvalues (correlations) ≤ 1.]

My Grandmothers principle:

> *"If uncertain, don't do anything."*

⇒ Regression inappropriate for daily precipitation.

regression

via unconstraint error minimization

$$\min \langle (\boldsymbol{l} - \mathbf{L}\boldsymbol{g})^2 \rangle$$

analytic solution: $\mathbf{L} = \mathbf{R} = \mathbf{C}_{lg}(\mathbf{C}_{gg})^{-1}$

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expanded downscaling (EDS)

via constraint error minimization

$$\min \langle (\boldsymbol{l} - \mathbf{L}\boldsymbol{g})^2 \rangle$$

cond. upon

$$\mathbf{L}\mathbf{C}_{gg}\mathbf{L}^{\mathrm{T}} = \mathbf{C}_{ll}$$

No analytic solution. Via nonlinear optimization unique (?) solution **L** = **E**.

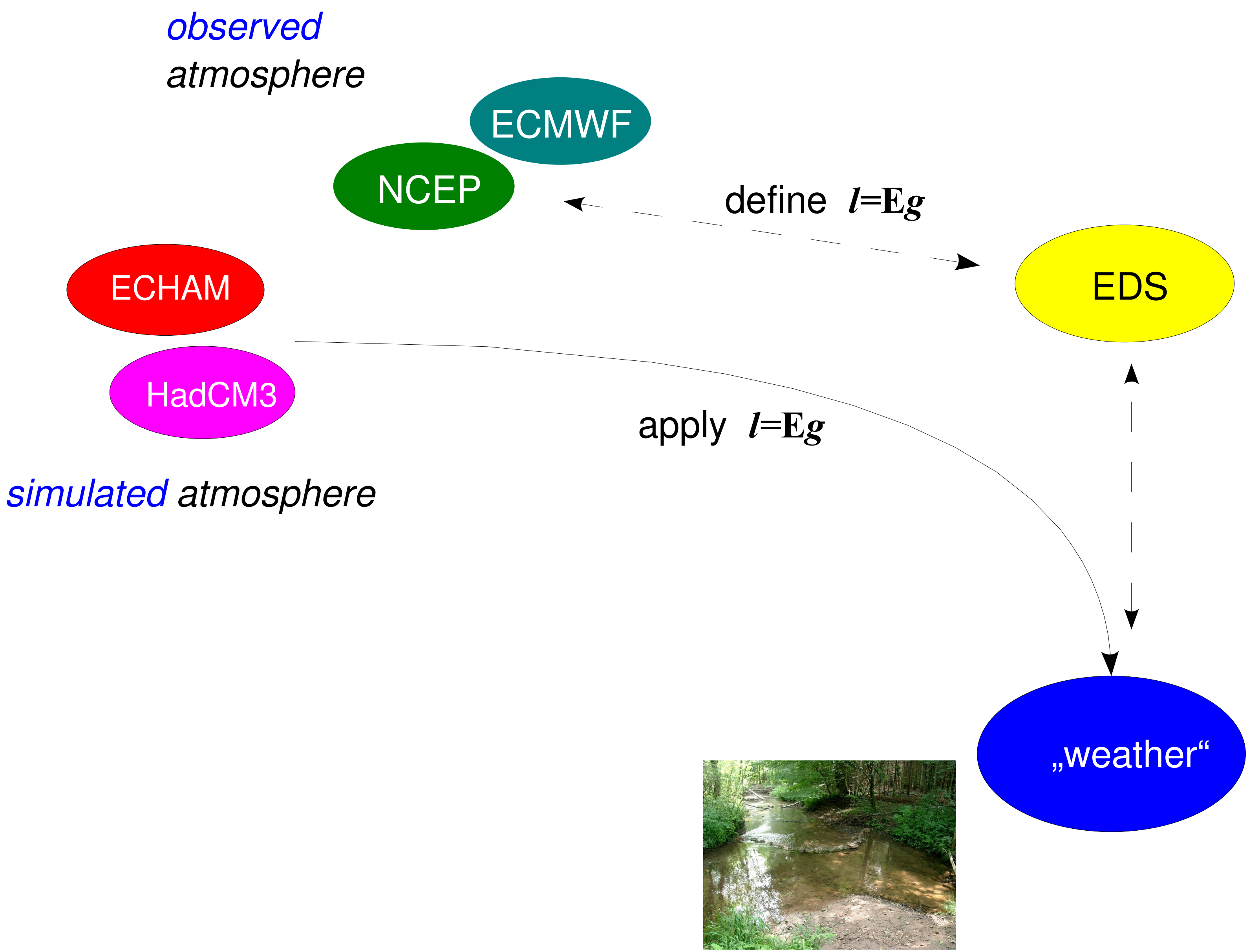
⇒ "Penrose regression problem"

Expanded downscaling, **E***, is the unique optimum linear model (in the l. sq. sense) that preserves local covariance.*

When driven by observed global fields it simulates realistic local variability on the daily scale.

When driven by changed global fields, e.g. in a climate scenario, the local variability might change accordingly.

EDS for climate scenarios



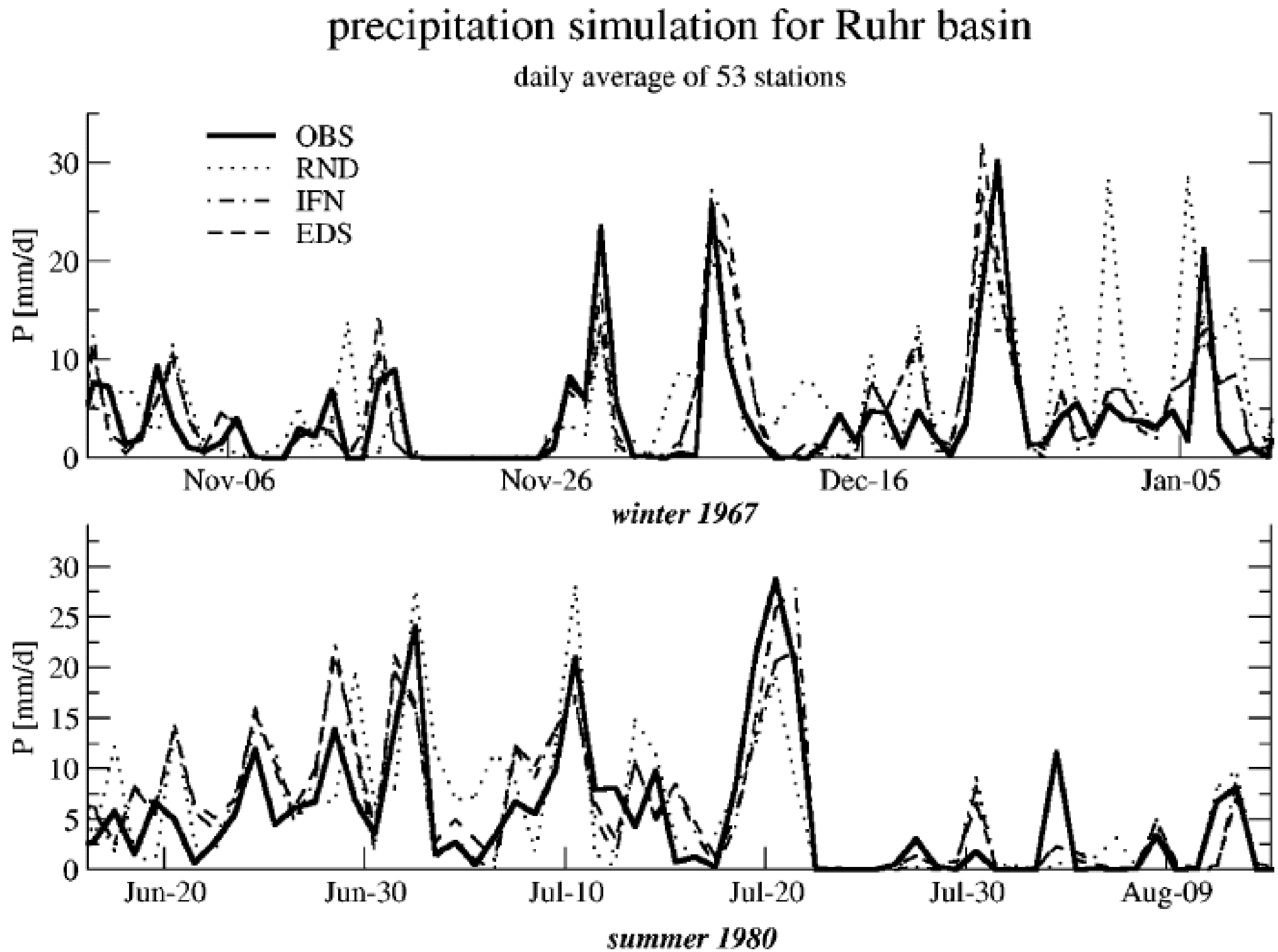
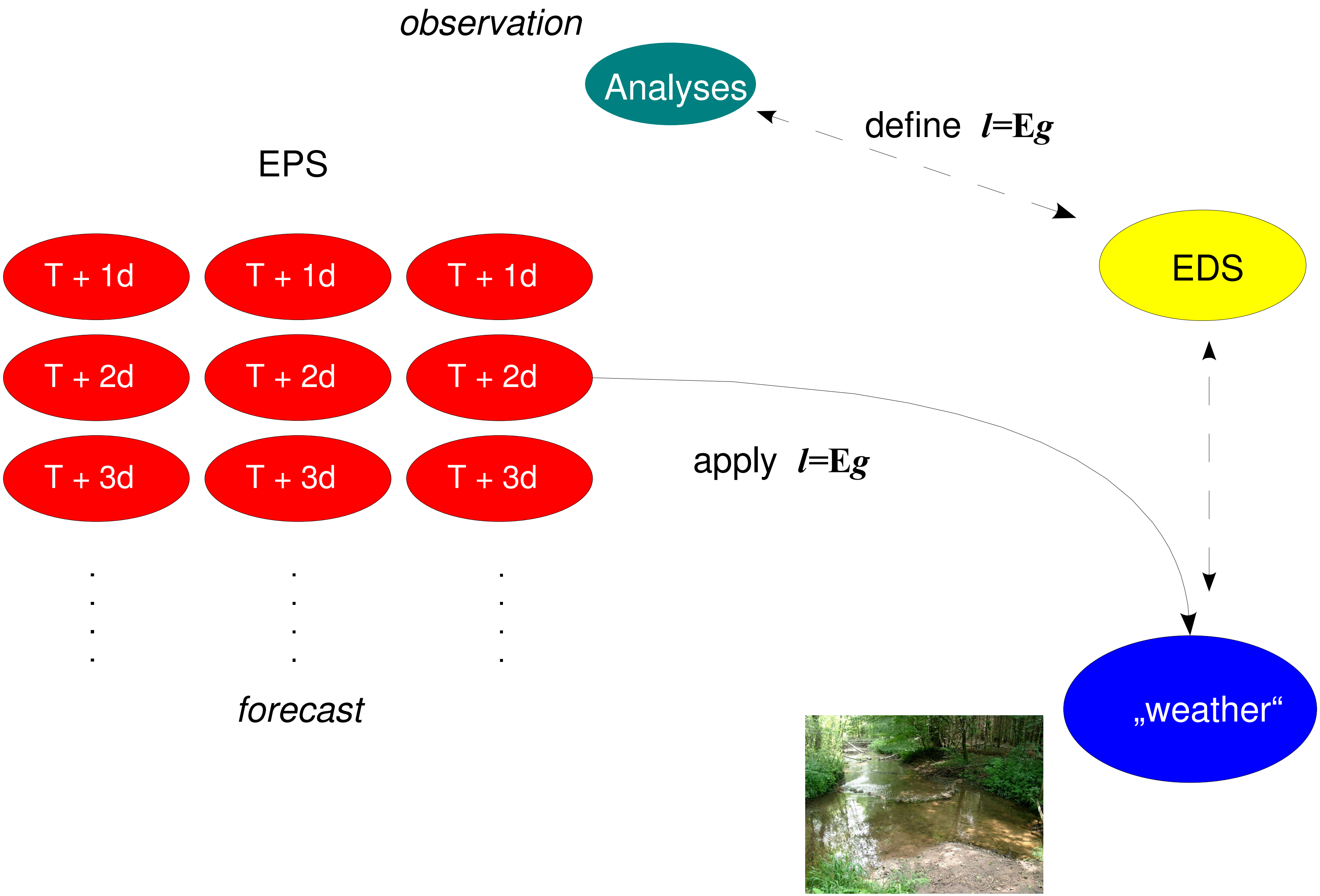


Fig. 1. Precipitation simulation for the Ruhr basin, for typical time spans. For winter 1967 (upper panel) it is evident that fast fluctuations of RND (dots, they are stochastic) are uncorrelated to the observations (OBS, heavy line), whereas larger clusters are better reproduced. IFN (dashed-dots) and EDS (dashed) perform satisfactory on both temporal scales, but in most cases IFN is bigger. The summer 1980 simulation (lower panel) appears more erratic. The heavy event around July 20 is reproduced quite well by IFN, and too weak by EDS and especially RND. Precipitation is shown as the average over.

EDS applications

- **EUROTAS** - **EUR**opean river flood **O**ccurence and **T**otal risk **A**ssessment **S**ystem
- **DFNK** - German research network natural disasters
- **SHYDEX** - Scenarios of hydrologic extremes (DFG project)

EDS for OPAQUE



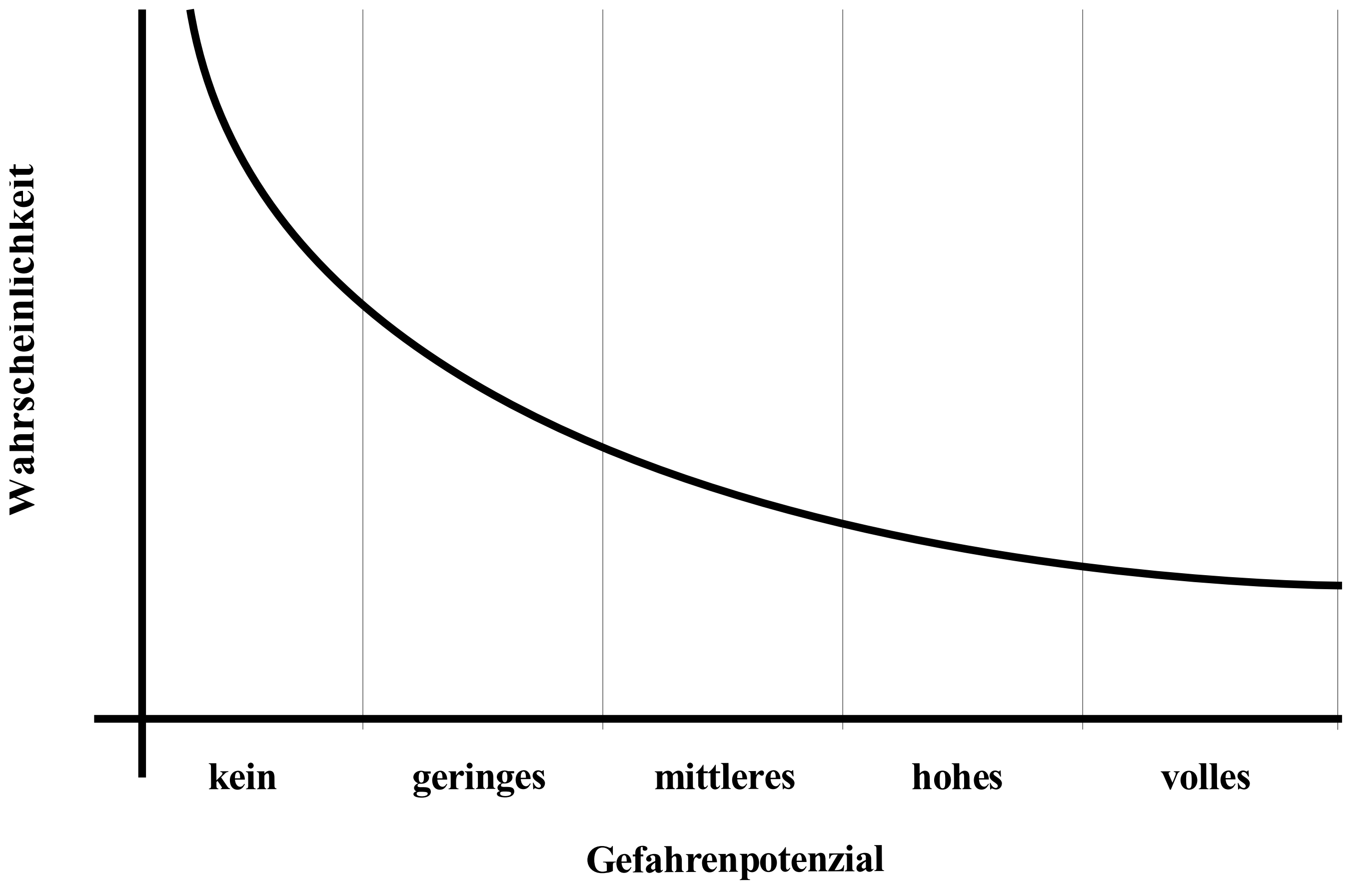
Benötigte Felder für OPAQUE:

Z_{500}, T_{850}, $Q_{850,}$ ... (0.5° x 0.5° lat/long grid ??) aus

- Operational archive, analysis
- Operational archive, EPS, Perturbed forecast

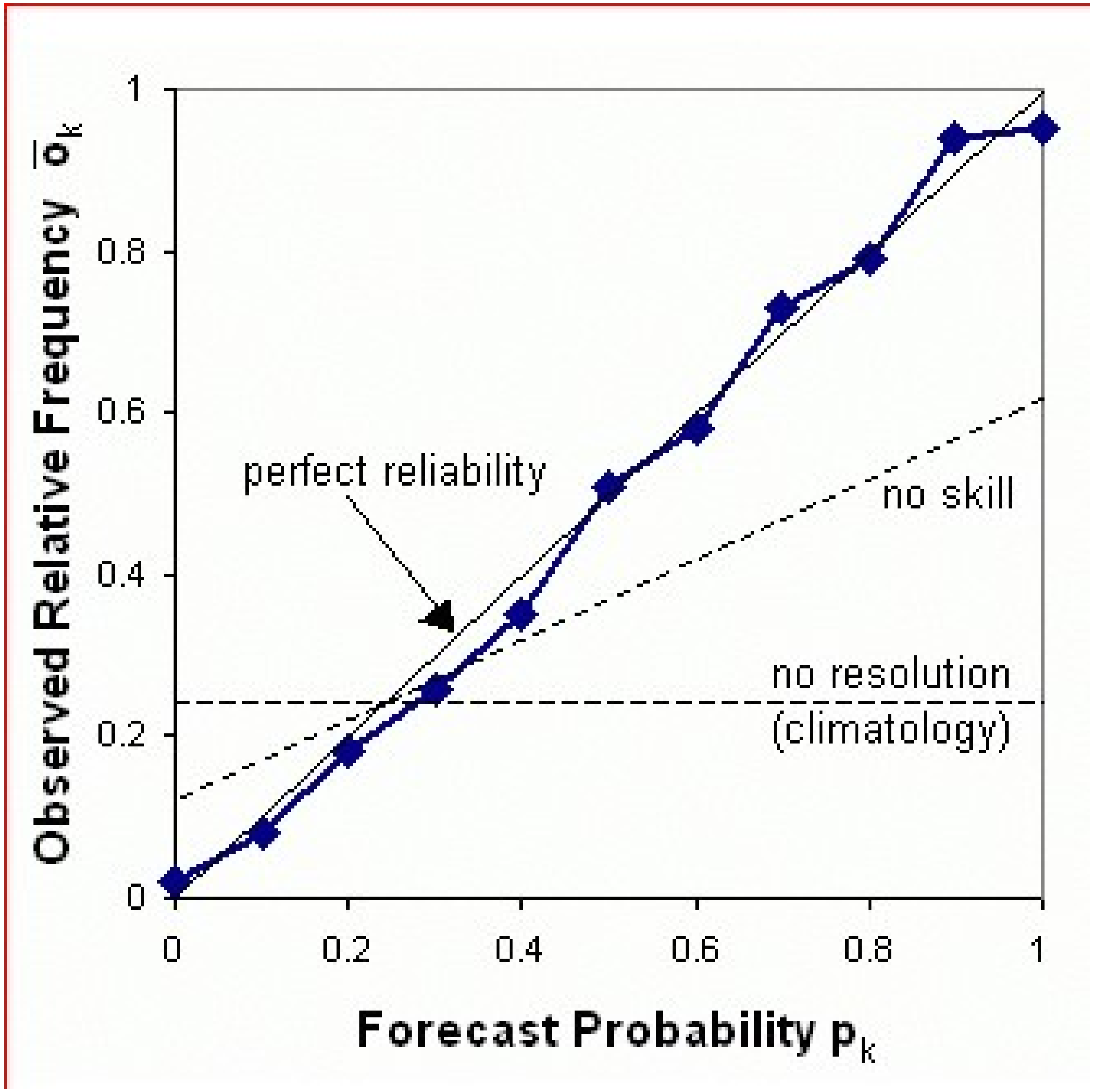
???

Beispielvorhersage: Niederschlag t + 3d



EPS → EDS
Vorhersage

Verification



the marquee should be hired if there is more than a 10% chance of rain. However, if the party was just for friends from the pub, then perhaps it was only necessary to hire the marquee if the chance of rain exceeds 70%.

The value of the EPS against the deterministic control for such binary decision making is assessed routinely at ECMWF in the form of Potential Economic Value (Figure 6). Here the

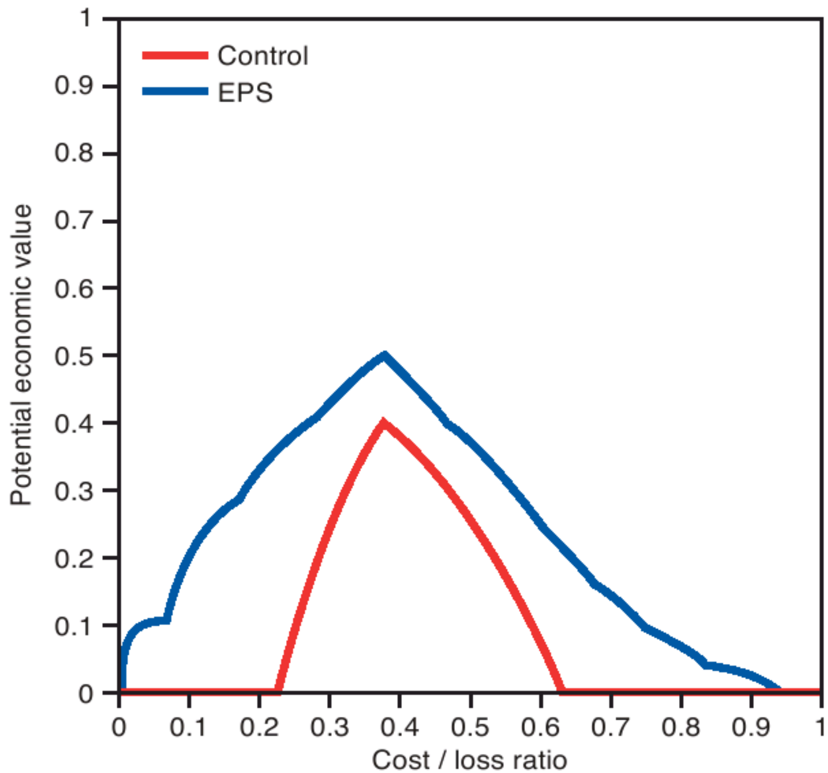


Figure 6 Potential economic value for the ECMWF EPS control and the EPS itself based on six-day forecasts of whether or not it will rain (24-hour precipitation exceeding 1 mm, August–October 2005, Europe). The potential economic value ranges between 0 (climatological forecast) and 1 (perfect forecast). For users with either low cost/loss ratio, or high cost/loss ratio, the control itself has no value for decision making (over and above decisions made with knowledge of the climatological frequency of rain).

EPS versus deterministic forecasts for weather trading

Not all decisions are simple binary decisions. Consider a simple gambling game – perhaps not so different to that played by energy traders – where you are betting on the Heathrow temperature seven days from now. Should you just bet on one temperature, or spread your bets across a range of temperatures, e.g. in proportion to the EPS-based probability of occurrence? Assume the "casino" you are betting against has determined the payout for a correctly-forecast temperature, based on a Gaussian distribution whose mean is the ECMWF high-resolution forecast of Heathrow temperature, and whose standard deviation is taken from past error statistics of the high-resolution forecast. This is the so-called Weather Roulette problem first posed by Leonard Smith (London School of Economics) and Mark Roulston (Pennsylvania State University). The gamble starts on the first of January with an initial stake of £1. All the winnings are reinvested. Based on day 7 forecasts, Figure 7(a) shows that, after a year, the gambler using the EPS will have made more than $£10^{30}$ against the casino! It turns out that the EPS gambler will win against the casino at all forecast ranges, though the payout is largest at about day 6–7.

Suppose the gambler had access to the high-resolution deterministic. Could he improve his strategy by combining the high-resolution deterministic forecast with the EPS. Figure 7(b) shows that for lead-times up to 4 days, a betting system based on an optimal blend of high-resolution and EPS probabilities leads to a positive return when played against odds based solely on the EPS. However, after about day 4 there appears little extra value in adding the high-resolution deterministic forecast to the EPS. (*Rodwell*, 2005, discusses the potential impact of adding the high-resolution deterministic forecast to the EPS in terms of precipitation.)

Der Goldersbach