

HIGH RESOLUTION PRECIPITATION ANALYSIS AND MODEL VALIDATION OVER COMPLEX TERRAIN

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Abstract: The VERA (Vienna Enhanced Resolution Analysis) method is applied to precipitation fields in order to assess its suitability for analysis and model validation with respect to this parameter. VERA is based on the variational principle and further allows the inclusion of supplemental knowledge of typical patterns of meteorological parameters (fingerprint) in the analysis process: in case there is a signal of the (predefined) fingerprint field detected in the data, the latter can be used for downscaling purposes. By evaluating spatial distributions of fingerprint weighting factors, the method can also be used in an “inverse approach” to get an assessment on how well a fingerprint model is reflected in observations. The suitability of the fingerprint technique for both the improvement of analysis quality and for model validation is investigated for different case studies.

Keywords: *VERA, fingerprint, precipitation analysis, MAP IOP-2b, local model validation, complex terrain*

1. THE FINGERPRINT CONCEPT IN VERA

Precipitation diagnosis and prognostics over mountainous terrain still poses a challenge due to the complex influence of topography. Both stratiform and convective precipitation usually show patterns that can hardly be resolved by an observing network. Similarly, the analysis and modelling of precipitation fields is subject to limitations that arise from the steep gradients which might occur in precipitation fields over mountain regions. The VERA analysis method (Bica et al. 2007; Bica et al. 2007a; Steinacker et al. 2006; Steinacker et al. 2000; Pöttschacher et al. 1996) is based on the variational principle applied to higher order spatial derivatives which are computed from overlapping finite elements. For a scalar quantity R the cost functional J (a weighted sum of squared spatial derivatives on two dimensions) is minimised:

$$J(R) = \iint_{\sigma} \sum_i \gamma_i [SD_i(R)]^2 d\sigma \rightarrow \text{Min} \quad \text{with} \quad R = R_S + cR_T \quad (1)$$

where γ_i stands for the weight of the different (i) spatial derivatives SD_i and σ denotes the area of the finite elements used for the derivation. This method minimises the curvature and/or gradient of scalar fields and the kinematic quantities of vector fields, respectively. The analysed variable R can be assumed to be composed of an unknown part R_S and a predefined part R_T that is due to orographic influence. The unknown factor c denotes a weighting factor that is to be determined in the course of the analysis process.

R_T (the “fingerprint”) is typically derived from physical a priori knowledge of patterns of meteorological fields over complex terrain (e.g. a thermal fingerprint simulating the effects of radiative heating or cooling over mountainous regions (Steinacker et al. 2006, Bica et al. 2007)). However, any other predefined field can be used, likewise.

For the analysis shown in Fig. 1, single observations (red diamonds) have been picked out from the 1D-field representing the “truth” (Fig. 2). The above equation has been used for interpolating the irregularly distributed observations to a regular 1D-grid under the constraints of minimised gradient and curvature. The latter can be easily identified from Fig. 1 (e.g. smooth curve between grid points 30 and 50).

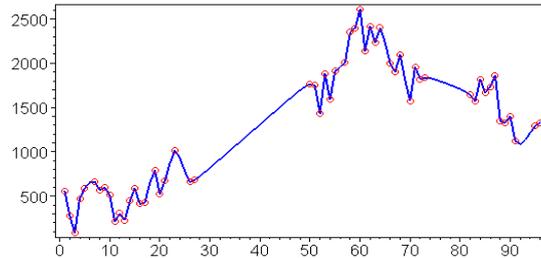


Figure 1: Analysis without fingerprint. The abscissa displays grid points indices, the ordinate the values of the analysed variables. Circles indicate observations which have been arbitrarily picked out from the “real” field shown in Fig. 2.

Let us now assume that the fingerprint is identical to the “true” field from Fig. 2. If this additional fingerprint information is included in the analysis, information can be transferred to data-sparse regions (e.g. grid points 30 to 50, Fig. 3) and the analysis error is reduced to zero.

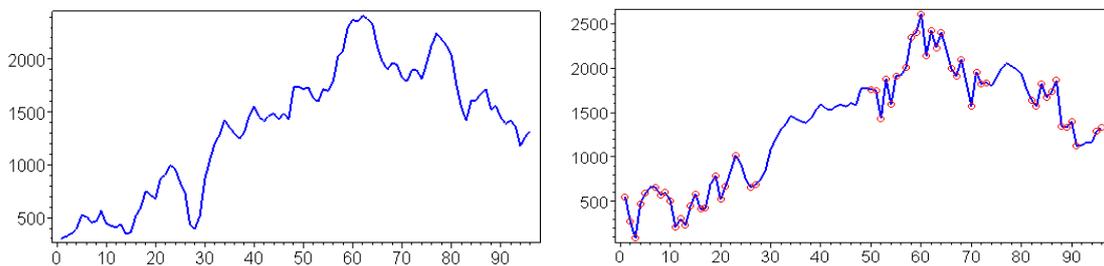


Figure 2 (left): Real topography. In our experiment, this field is identical to the fingerprint.

Figure 3 (right): Analysis with fingerprint.

A major advantage of the method is that one or more fingerprints can be included to the analysis with *variable weight*. That is, the weighting factor c from eq. (1) can be determined independently for different subdomains. Consequently, variable influence of the fingerprint field is obtained, too: in regions, where a very weak fingerprint signal can be detected in the data, c is close to zero. The positive effect of fingerprint use on the analysis quality has been documented in Steinacker et al. (2006) and Bica et al. (2007).

2. INVERSE APPLICATION OF THE FINGERPRINT TECHNIQUE

The fingerprint technique may be used in an “inverse approach” to get an assessment on how good a fingerprint model is reflected in real data. This information can be easily obtained if weighting factors $c_{i,j}$ are determined for an adequate number of subdomains in 2 or 3D and visualised or evaluated statistically.

A number of experiments have been carried out for the MAP IOP’s 2b and 8 as well as for the August 2005 flooding event. For the MAP IOP-2b case (19 to 21 September 1999) a simple fingerprint of linear increase of precipitation with height has been assumed. Fig. 4 shows a 2D-pattern of c -values over the LMTA (Lago Maggiore Target Area). If observations and fingerprint field are given on the same scale, regions with c close to 1 indicate that the fingerprint signal was detected in the data quite reliably. In this case, eq. (1) can be used to derive the following statements:

$c = 1$	fingerprint signal exactly found in data
$0 < c < 1$	weak signal found
$c = 0$	no signal found
$c < 0$	inverse signal found
$c > 1$	stronger signal found

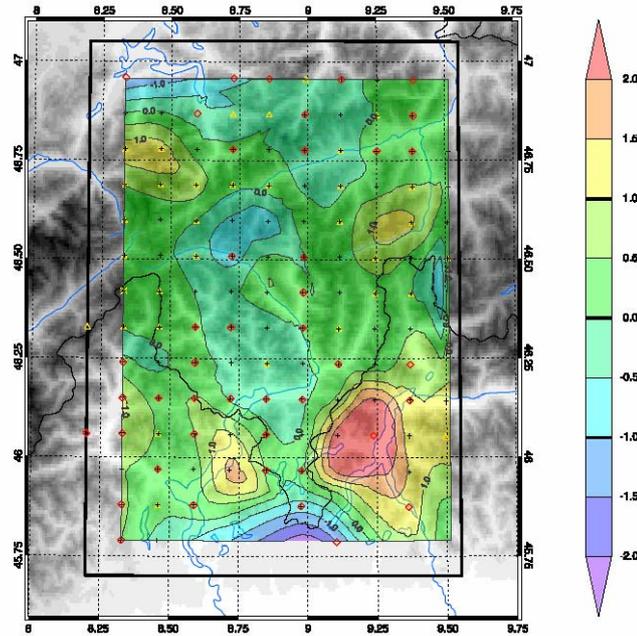


Figure 4: c -field of a simple fingerprint of linear increase of precipitation with height for the MAP IOP-2b case. Regions with c close to 1 indicate that the fingerprint signal was detected in the data.

3. SUMMARY AND OUTLOOK

Experiments have shown that the fingerprint technique in VERA can lead to a significant improvement of analysis quality under favourable preconditions. Moreover, VERA may be used in an “inverse approach” to facilitate local model evaluation in an innovative way. The classical statistical measures for model evaluation tend to be strongly influenced by the model’s resolution (Barstad and Smith, 2005, Smith and Barstad, 2004). A higher level of details in the model (i.e. higher resolution) usually degrades the accuracy in terms of mean error, RMSE and others. What is needed is a measure that

- facilitates model validation in an easy and reliable way,
- does not favour coarse resolution and
- is computationally efficient i.e. produces results in a reasonable amount of time.

The “inverse approach” in VERA appears to be suited for local model evaluation over complex topography with regard to the above aspects, however further investigations should be made in order to gain new and improved insight.

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