Comparing three spatial verification schemes SAL, FSS, SLX : Similarities and differences

Bent Hansen Sass
Danish Meteorological Institue
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OUTLINE

- **SAL, FSS, SLX as spatial verification schemes**
- **Highlights from definition of the schemes**
- **Examples of differences and similarities**
- **Conclusions**

SAL, FSS , SLX
as `spatial verification schemes´ means that

Scores are defined from comparing full 2D fields of forecast and analysis, investigating the degree of similarity

Types of spatial methods: Neighborhood, Scale separation, Features based, Field deformation, Distance measures

Gilleland,E., Skok, G., Brown,G.B., Casati,B., Dorninger, M., Mittermaier, M.P., Roberts, N. and Wilson, L.J. 2020: A Novel Set of Geometric Verification Test Fields with Application to Distance Measures. *Mon. Wea. Rev.* **148**, 1653 - 1673

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`SLX´ verification scheme :

- *a novel scheme developed 2019-2020*
- *a publication is in review*
- *application: precipitation fields*
- *Input needed : decision on neighborhood size*
- *Prerequisite : A score function is defined*

SLX (Structure of Local EXtremes) measures:

i) how does the forecast match identified local maxima of the analysis

ii) how does the identified local maxima of the forecast agree with the analysis

iii) how does forecast match identified local minima of the analysis, and finally

iv) how does the identified local minima of the forecast agree with the analysis.

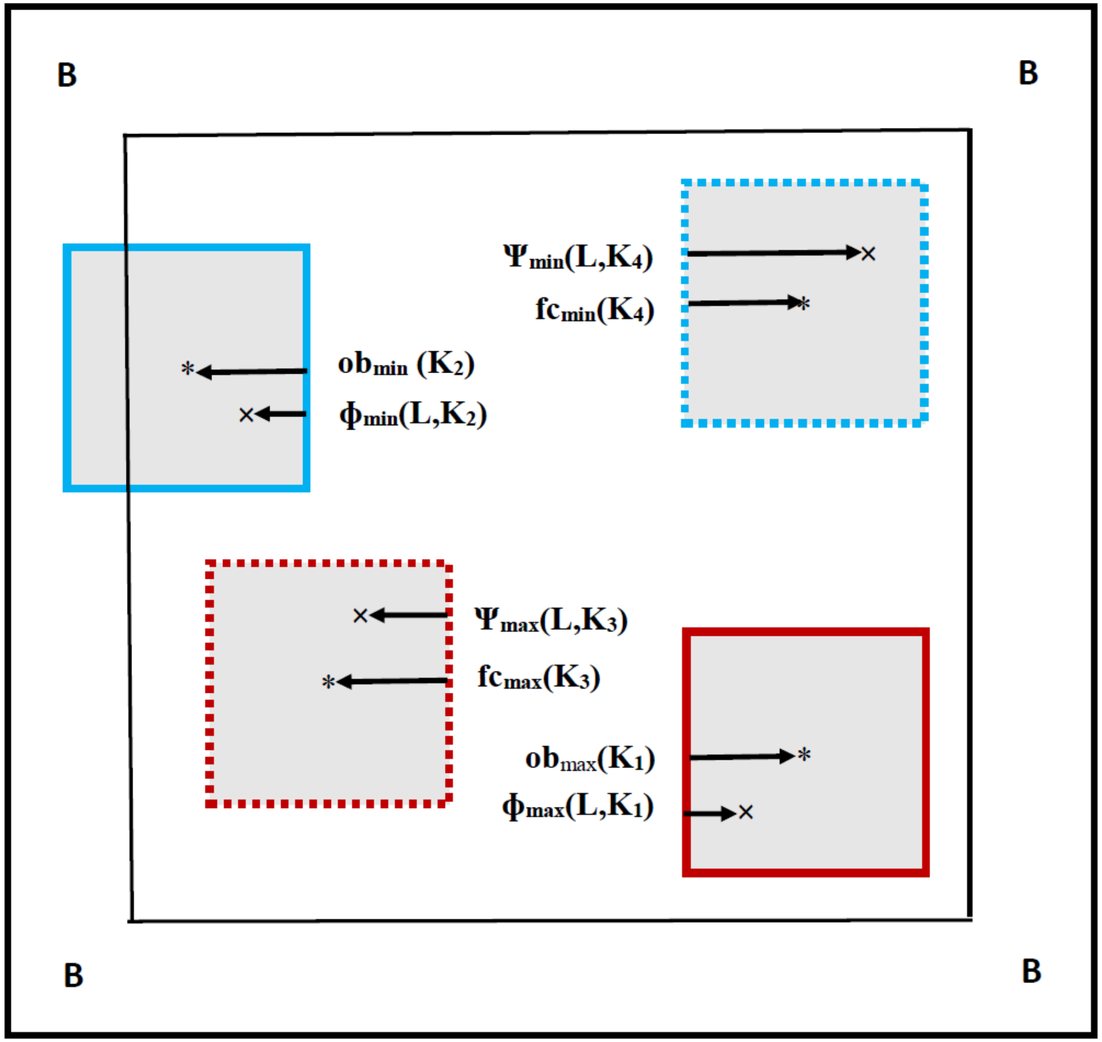
i) , ii) , iii) , iv) represent separate comparisons leading to scores defined in interval [0, 1] : SLX (ob_max), SLX (fc_max), SLX(ob_min), SLX(fc_min)

Score function: 1 defines perfect match, 0 poor match between forecast and analysis in the neighborhood chosen.

Average computation for multiple extreme points

Also a weighted mean of the 4 score computations are carried out . This gives in total 5 outputs of a verification.

A spatial verification scheme `SLX´:



Setup for computing structure of local extremes. Local extremes $ob_{max}(K_1)$ and $ob_{min}(K_2)$ are identified, corresponding to observed maxima and minima of the respective fields (only one point of each type in the Figure). These values are compared, respectively, with forecasted maxima $\phi_{max}(L,K_1)$ and $\phi_{min}(L,K_2)$ valid for corresponding neighborhood(s) around the observed extremes, L is the tolerance defining the neighborhood size (see text). Similarly $fc_{max}(K_3)$ and $fc_{min}(K_4)$ correspond to forecasted local maxima and minima respectively, and $\Psi_{max}(L,K_3)$, $\Psi_{min}(L,K_4)$ correspond to observed extremes valid for the associated neighborhoods. A boundary zone of width B is included to allow computations using full neighborhood size close to the lateral boundaries.

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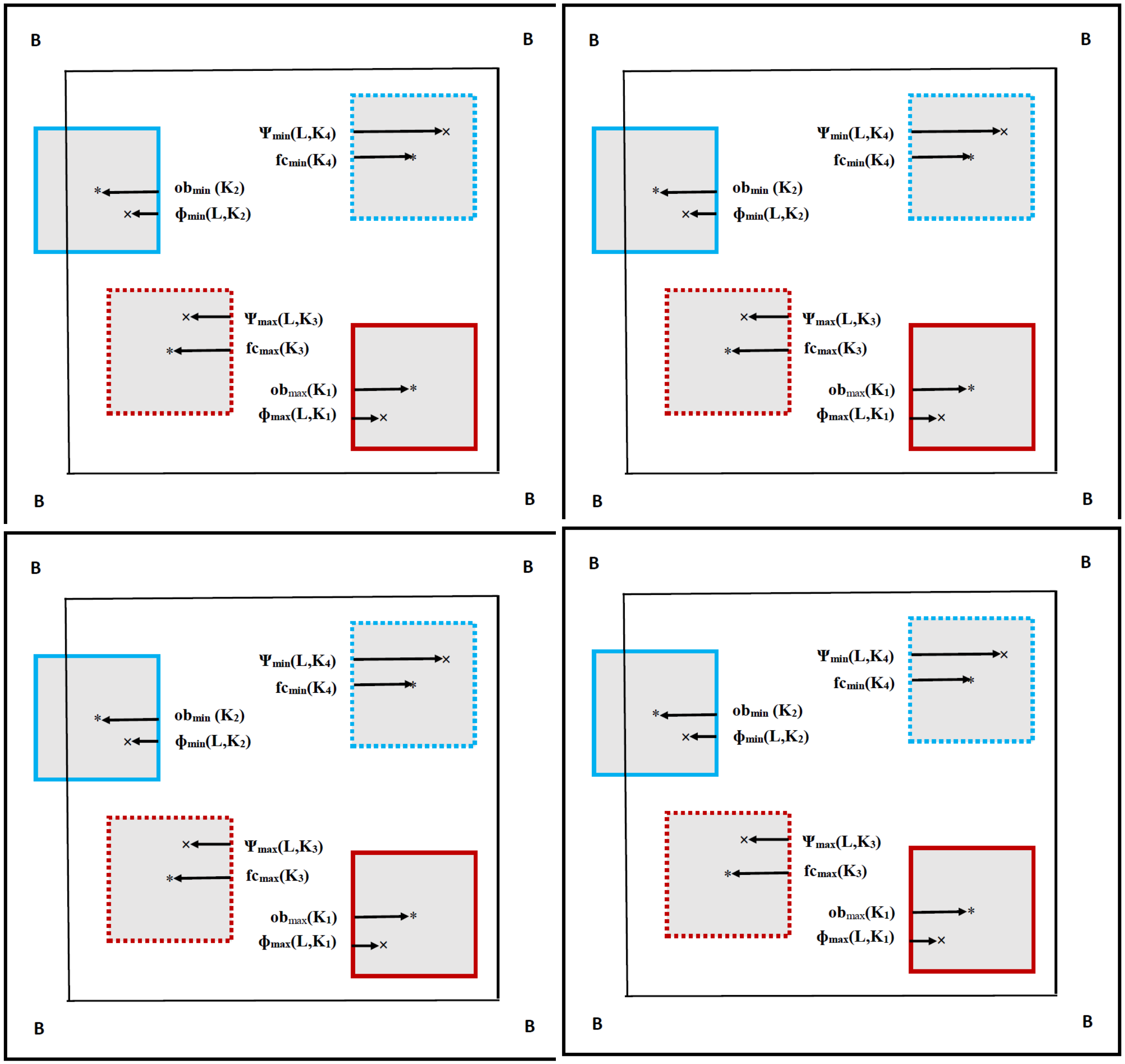
A spatial verification scheme `SLX´:
For large domains multiple sub-areas may be included



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Fractions skill score FSS

requires input on neighborhood size(s) and precipitation threshold(s)/percentile(s) used for the computation of FSS

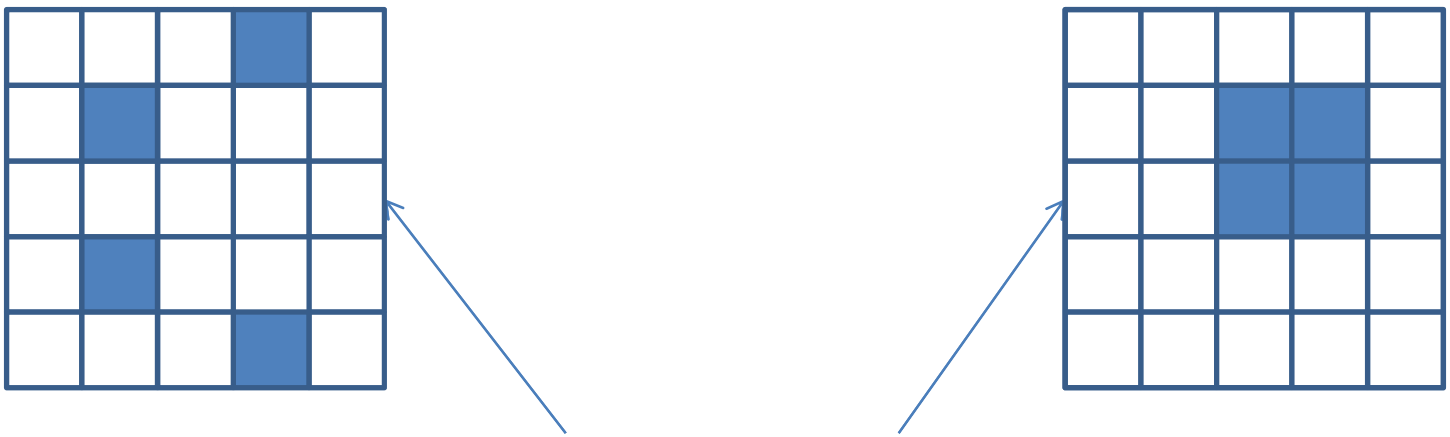
Precipitation smaller than the threshold

Precipitation larger than the threshold

Verification over
5*5 grid points

OBSERVED

FORECAST



Scattered versus coherent precipitation field. However , in both cases the fraction of the grid points with in the total box of 25 points is 4 / 25 = 16 % . The fracctions skill score **FSS** is considered perfect If the fractions are identical

Fractions skill score FSS

[Roberts, N.M. and Lean, H.W. 2008: Scale selective verification of rainfall accumulations from high-resolution forecasts of convective events. *Mon Wea. Rev.* , **136**, 78-97]

$$\mathrm{MSE}_{(n)} = \frac{1}{N_x N_y} \sum_{i=1}^{N_x} \sum_{j=1}^{N_y} [O_{(n)i,j} - M_{(n)i,j}]^2.$$

$$\mathrm{MSE}_{(n)\mathrm{ref}} = \frac{1}{N_x N_y} \left[\sum_{i=1}^{N_x} \sum_{j=1}^{N_y} O^2_{(n)i,j} + \sum_{i=1}^{N_x} \sum_{j=1}^{N_y} M^2_{(n)i,j} \right].$$

$$\mathrm{FSS}_{(n)} = \frac{\mathrm{MSE}_{(n)} - \mathrm{MSE}_{(n)\mathrm{ref}}}{\mathrm{MSE}_{(n)\mathrm{perfect}} - \mathrm{MSE}_{(n)\mathrm{ref}}} = 1 - \frac{\mathrm{MSE}_{(n)}}{\mathrm{MSE}_{(n)\mathrm{ref}}}$$

MSE_n *is mean square error between observed and forecasted fractions of an event , computing this over all grid points in the model domain*

MSE_{nref} *is the mean square error of the worst possible forecast serving as a reference to produce relative skill*

n *represents the number of grid boxes used to compute the fractions of observed event*

Nx *and* ***Ny*** *are the number of grid points in the x – and y dimension of the model domain*

O *stands for observed fraction,* ***M*** *stands for forecasted fraction.*

FSS *is the resulting fractions skill score.*

`SAL´ verification scheme

[Wernli ,H., Paulat, M. 2008: SAL - A Novel Quality Measure for the Verification of Quantitative Precipitation Forecasts. *Mon.Wea.Rev*., **136**, 4470-4486]

***Prerequisite : Requires definition of precipitation objects*]**

For **SAL** computations are uniquely defined from the values of the forecast- and analysis fields, provided that some precipitation objects have been defined. These objects would normally contain some grid points with significant amount of accumulated precipitation. The scores in **SAL** consists of 3 parts :

Structure : **S** , Amplitude: **A** and Location: **L** The components describe scaled mean features over the grid and thus do not explicitly focus on specific features in a localized area of the grid.

SAL:
Structure , Amplitude and Location

Structure component

$$V_n = \sum_{(i,j)\in \mathcal{R}_n} R_{ij}/R_n^{\max} = R_n/R_n^{\max},$$

$$V(R) = \frac{\sum_{n=1}^{M} R_n V_n}{\sum_{n=1}^{M} R_n}.$$

$$S = \frac{V(R_{\text{mod}}) - V(R_{\text{obs}})}{0.5[V(R_{\text{mod}}) + V(R_{\text{obs}})]}.$$

- The structure *S* compares the volumes of normalized precipitation objects.
- A scaled volume is computed
- The scaling with $R_n{}^{\max}$ reduces the weight of each object if the precipitation maximum $R_n{}^{\max}$ inside the object is large.
- The normailzed difference of V (R) between model and observations is computed
- ***S* becomes large if model predicts large scale precipitation in a situation where in reality small scale convection occurs.**

SAL:
Structure , Amplitude and Location

Amplitude component

$$A = \frac{D(R_{\mathrm{mod}}) - D(R_{\mathrm{obs}})}{0.5[D(R_{\mathrm{mod}}) + D(R_{\mathrm{obs}})]}.$$

$$D(R) = \frac{1}{N} \sum_{(i,j) \in \mathcal{D}} R_{ij},$$

- The amplitude A of SAL corresponds to a normalized difference of the domain averaged precipitation values .
- *D*(*R*) is the domain average of R, and R_{ij} are all the grid point values . R_{mod} applies to model while R_{obs} applies to observed average
- *A is in the interval between -2 and +2*

SAL:
Structure , Amplitude and Location

Location component

$$L_1 = \frac{|\mathbf{x}(R_{\text{mod}}) - \mathbf{x}(R_{\text{obs}})|}{d},$$

$$r = \frac{\sum_{n=1}^{M} R_n |\mathbf{x} - \mathbf{x}_n|}{\sum_{n=1}^{M} R_n}. \qquad R_n = \sum_{(i,j)\in \mathcal{R}_n} R_{ij}.$$

$$L_2 = 2\left[\frac{|r(R_{\text{mod}}) - r(R_{\text{obs}})|}{d}\right].$$

Total $L = L_1 + L_2$

- The location L consists of two components L_1 and L_2. d is the largest distance between two boundary points of the domain. x *(R)* is the centre of mass of the total precipitation field.
- The second term L_2 *computes the averaged distance between the centre of mass of the total field and the individual objects.*
- R_n *is the integrated precipitation in object bumber n*

.

- $\mathbf{x}_n$ *is the centre of mass of object n and* $\mathbf{x}$ *is the centre of mass of the entire field*
- The range of L is between 0 and 2.

SAL:

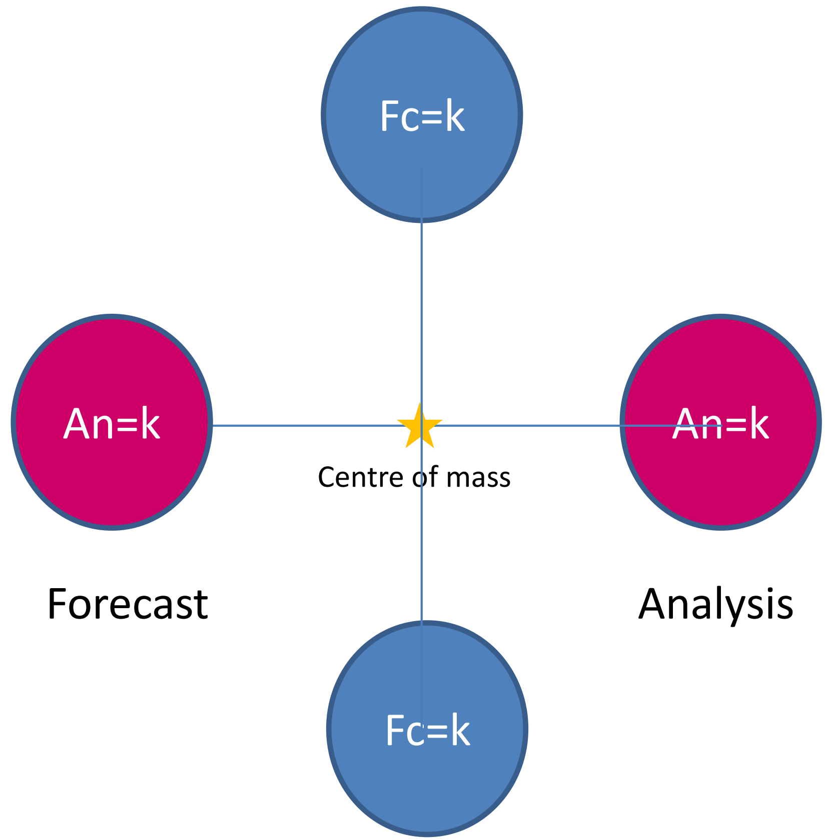
Structure , Amplitude and Location

CASE 1 : illustation of Location component :
with S = A = 0 ,

With only one precipitation object L > 0

SAL:

Structure , Amplitude and Location



CASE 2 with S = A = L = 0 , 2 symmetrically placed objects relative to a centre on mass, hence L becomes 0 , BUT the forecast and analysis fields are NOT the same !

CHARACTERISTICS	FSS	SAL	SLX
Main characteristics of scheme	Identify which scales can be resolved	Identify large-scale features, e.g. bias and variability of fields	Identify match of forecast and analysis around extreme values
Number of score components	1	3	5
Type of spatial scheme	N	F	N + F
Dimensions (0-D, 1-D, 2-D) of input parameters in normal tests.	2-D N- size and define Threshold/ percentile	0-D Uniquely defined once objects are fixed	1-D N-size + define Score-function between 0 and 1
Sensitivity to forecast bias	YES	YES	YES
Research oriented score	YES	YES	(YES)
User oriented score	(NO)	(YES)	YES
Easy interpretation	YES ?	YES/ NO ?	YES

N=Neighborhood , F= Features based

Conclusions

- The spatial verification schemes FSS, SAL, SLX are all quite different in design
- The schemes complement each other when used in verification of NWP

Merci beaucoup pour l'attention