NWP verification scheme
\`SLX´
(**S**tructure of **L**ocal e**X**tremes)

ASM 2019

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OUTLINE

- What is SLX ?
- Motivation for developing SLX
- Short summary of computational procedure
- Robustness to `hedging´
- Some examples
- Outlook

What is SLX $_{(1)}$?

- SLX is the short abbreviation for the name ` **S**tructure of **L**ocal e**X**tremes´
- SLX describes the degree of match between forecast and analysis of local extremes in these spatial fields, taking into account a neighborhood size to match the occurrence of local extremes .
- SLX is a generalization of a scheme (SWS ~ Significant Weather Score) , Sass and Yang 2012 , operational at DMI , comparing few extreme observation points with forecast field.

What is $SLX_{(2)}$?

- Neighborhood size may be chosen between 0 (point verification) and a maximum possible value depending on the size of the integration domain.

- The range of SLX is between 0 and 1. Higher values means higher quality, with 1 valid for a perfect forecast . The score function F_{SLX} determining SLX is a decreasing function with increasing difference of absolute value between forecast and observations.

- SLX is a weighted average between components describing match of minima and maxima, using analyses and forecasts of the field. Individual components illustrate specific properties of the forecast versus analysis.

Motivation for developing SLX ?

- In Weather Forecasting we are often confronted with the questions:

  What will be the extreme values of a given weather parameter today ?
  - and **where will the extremes be located geographically ?**

  In order to answer these questions based on NWP we need a scheme dedicated to measure the ability of the NWP model to predict local extremes.

- **Double penalty and SLX:**
  In view or the `double penalty´ issue when trying to verify local extremes on the grid scale the verification scheme needs to take into account the effect of spatial neighborhoods. SLX is a verification scheme taking into account these requirements.

Short summary of computational procedure ?

1) **Local maxima and minima:** Determine these, both in analysis and forecast, - and their locatition (index of field value) . In case of multiple occurrence of same maxima and minima , e.g. - zeros , the multiple location of the extremes are kept track of for repeated computations involving these points.

2) **Neighborhood size and the possibility to select sub-domains:** These options provide a large flexibility. One extreme is to achieve a computation of grid scale statistics over the entire domain.

SLX : Example of model domain not sub-divided . A boundary zone B is shown. Both local maxima and minima are identified , for both analysis and forecast (Max-ob, Min-ob, Max-fc, Min-fc). A comparison is carried between the extreme point and the points in the neighborhood.

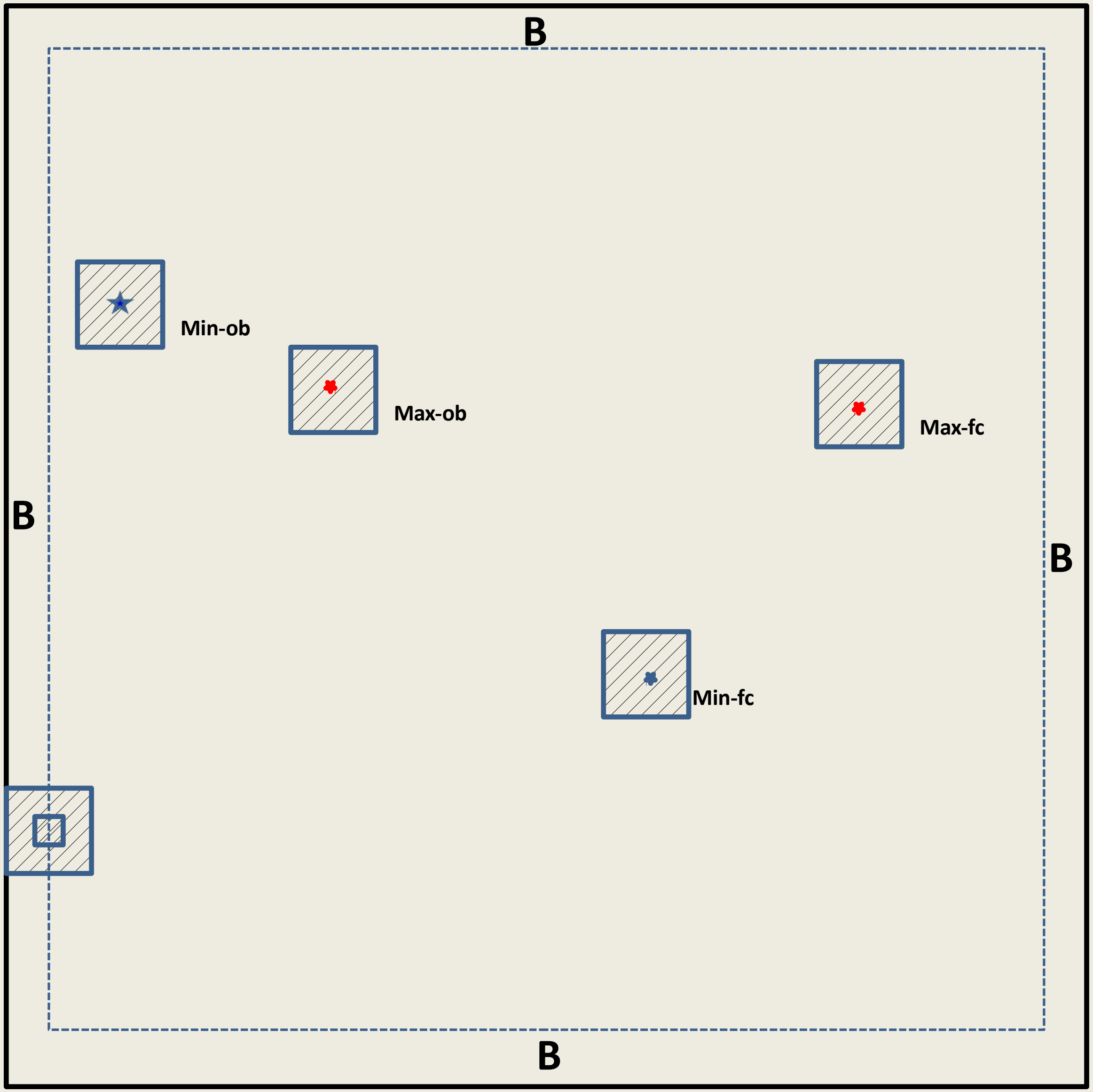


Fig1

SLX : **Example of 4 sub-domains. The SLX score is composed of four individual measures, i.e. Observation based and forecast based minima and maxima respectively. Average values are computed from scores in sub-domains.**

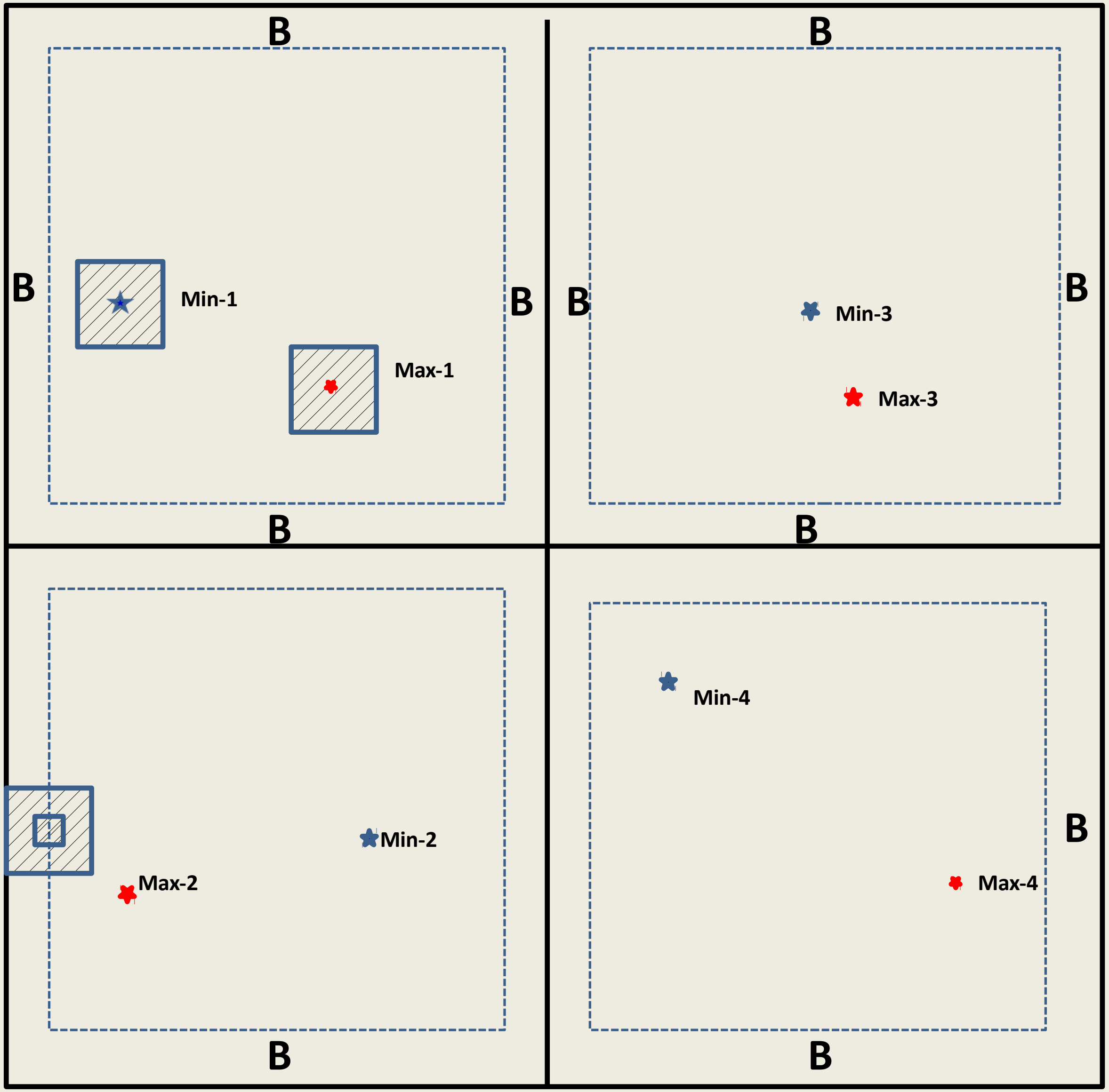
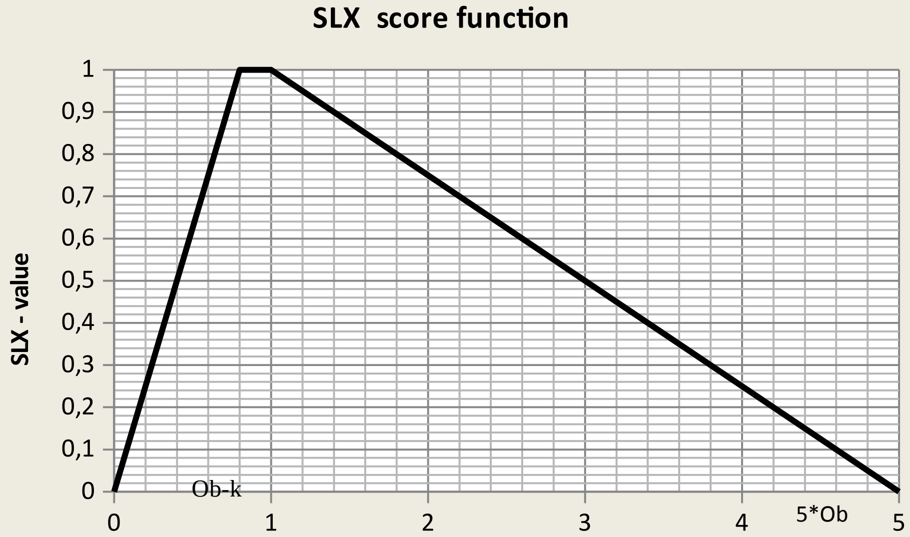


Fig2

F_{SLX}

Fig.3



- In each neighborhood a comparison is made between central point (extreme point) and the neighborhood points. The extreme value in the neighborhood will be selected as input to the score computation
- The score computation depends on the magnitude of this difference. Currently the piecewise linear and asymmetric function F_{SLX} of the Figure is used in verification of precipitation. Asymmetry has implications for the SLX value of some model states compared with a symmetric function.
- The final score SLX is a weighed average between the four components .

$$SLX = \frac{1}{4} (SLX_{ob\text{-}max} + SLX_{ob\text{-}min} + SLX_{fc\text{-}max} + SLX_{fc\text{-}min})$$

The score function could be chosen flexible depending on the User Community involved.

Hedging$_{(1)}$: SLX is robust

Fig 4 illustrates that SLX with a score function having decreasing values as forecast deviates increasingly from observations has desirable properties with regard to the impact of model bias. A forecast with a non-zero bias will give a smaller SLX-value than a scheme with zero bias, assuming the same range of forecast variability .

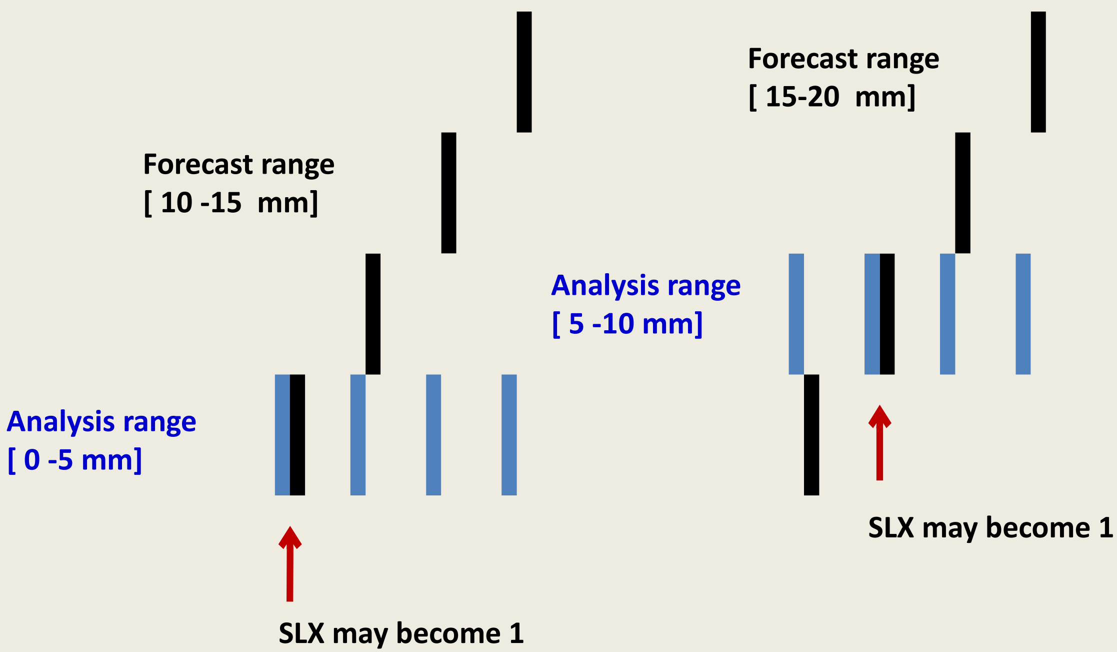


Fig.4 : SLX sensitivity to model bias

Hedging$_{(2)}$: SLX is robust

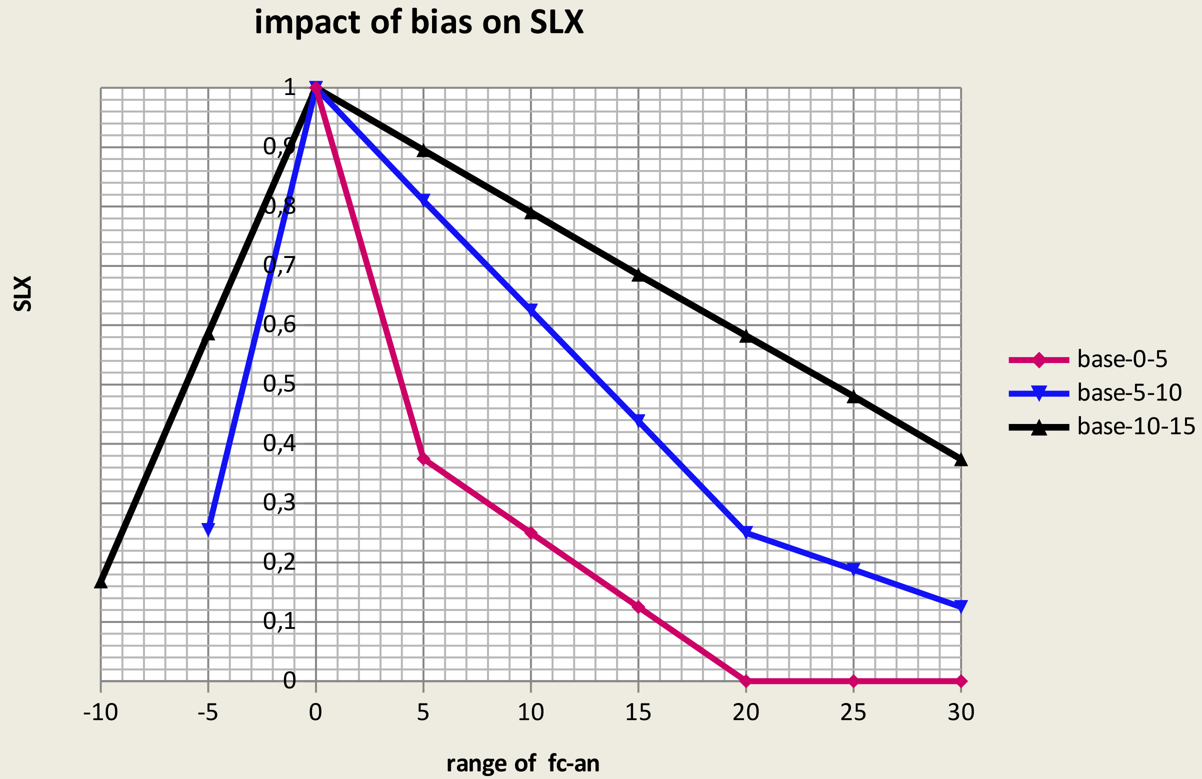


Fig.5 shows the impact of bias on the SLX score for the extreme values of forecasts and analysis fields occurring in the same neighborhood. (function F_{SLX} of Fig. 3 is used). The purple curve applies to analysis range 0 -5 mm, blue curve : 5- 10 nm, black curve 10-15 mm. The impact of bias is inherent ! If the bias of the fields is zero the fields can potentially give SLX=1

1. constant fields

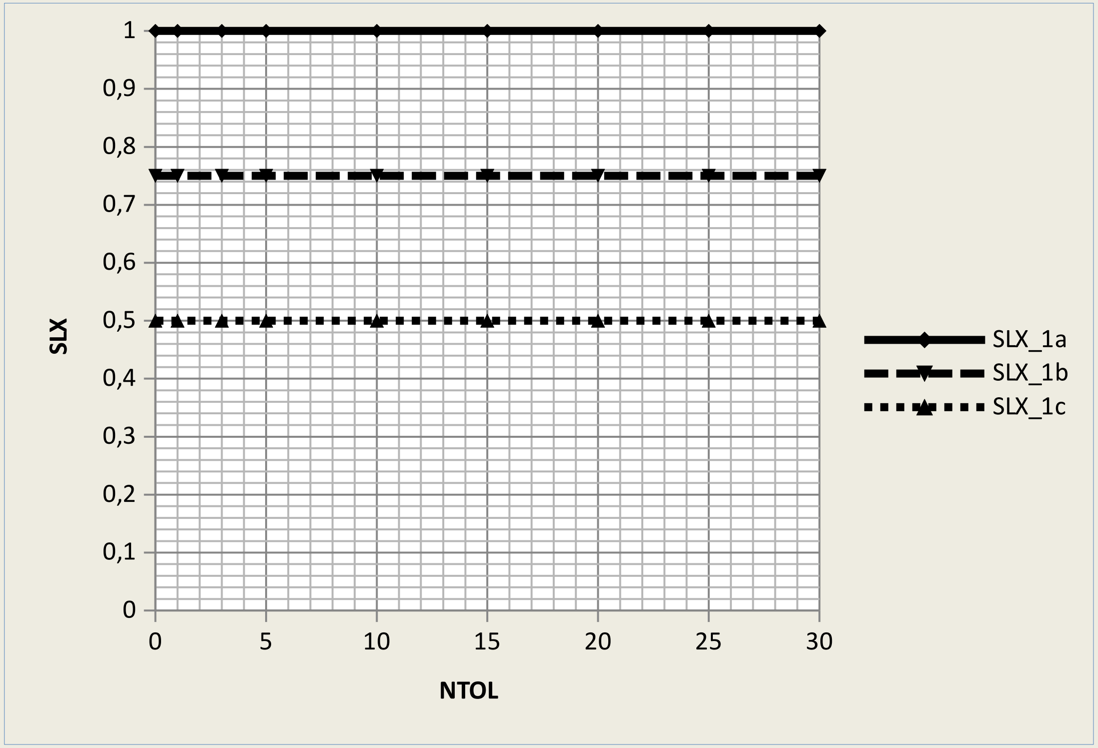


Fig.6

1a applies to ob=5 mm, fc= 5 mm , all SLX-cores are = 1.00
1b applies to ob=5 mm, fc=10 mm , all SLX--scores are = 0.75
1c applies to ob=5 mm, fc=15 mm , all SLX--scores are = 0.50

Idealized Test case :
Extreme 2-GRID noisy analysis and forecast

10	0	10	0	10
0	10	0	10	0
10	0	10	0	10
0	10	0	10	0
10	0	10	0	10

analysis

0	10	0	10	0
10	0	10	0	10
0	10	0	10	0
10	0	10	0	10
0	10	0	10	0

forecast

2-GRID NOISY fields, forecast
with correct values and amplitude of oscillation
But sfifted one grid point implying that
<u>no values are correct on the grid scale</u>

Systematic 2-grid structure of difference between forecast and analysis

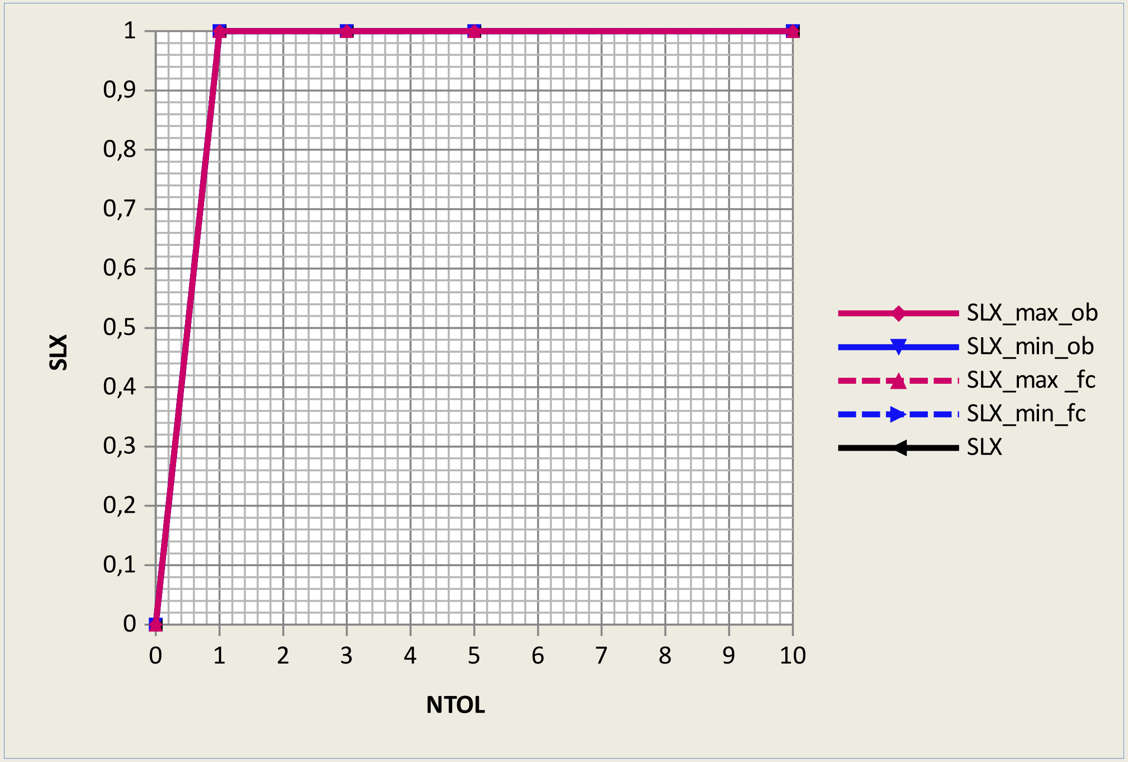


Fig.8

Analysis field consists of a regular 2-grid variation between 0 and 10 mm
Forecast field similar but shifted 1 grid point giving no agreement between fields on the scale of single grid points, but perfect match for neighborhood comparisons at larger scales (NTOL > 0)

Systematic 2-grid structure of difference between forecast and analysis, with half amplitude of variability in forecast field.

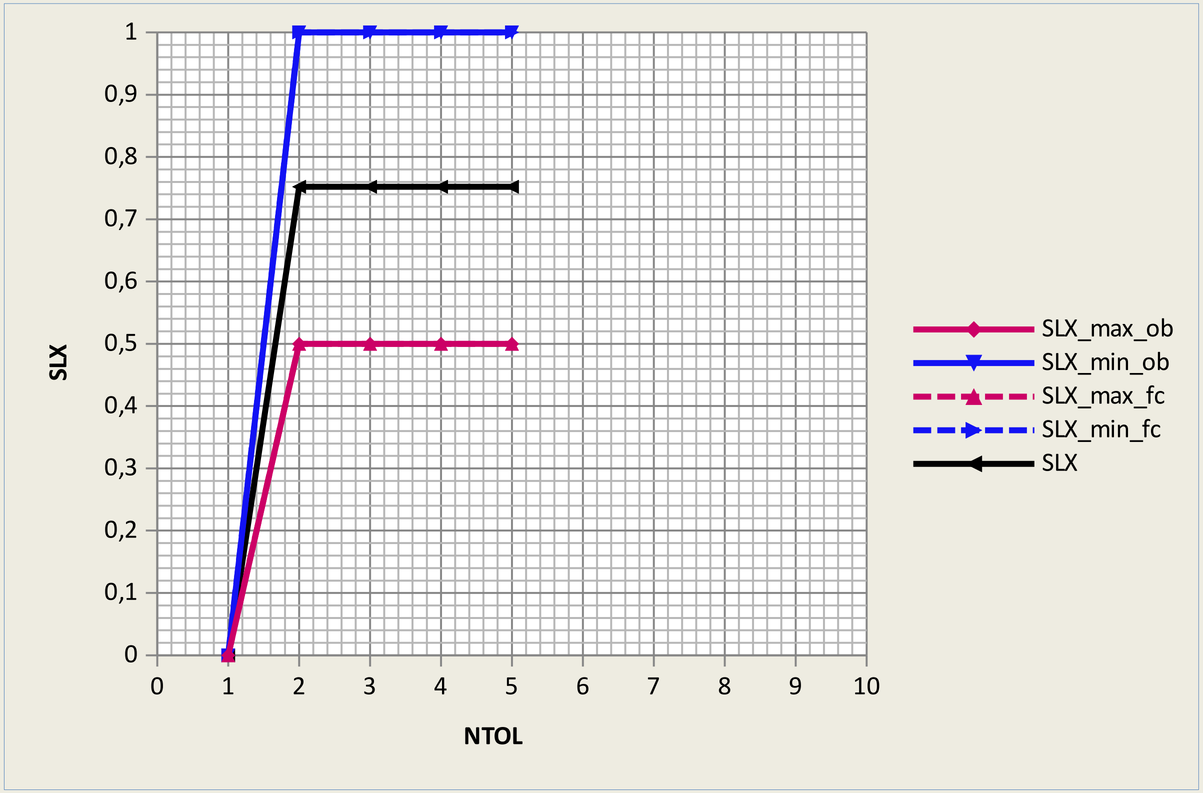


Fig.9

Analysis field regular 2-grid variation between 0 and 10 mm. Forecast field similar but shifted 1 grid point giving no agreement between fields on the scale of single grid points. Amplitude of forecast variation half that of analysis.

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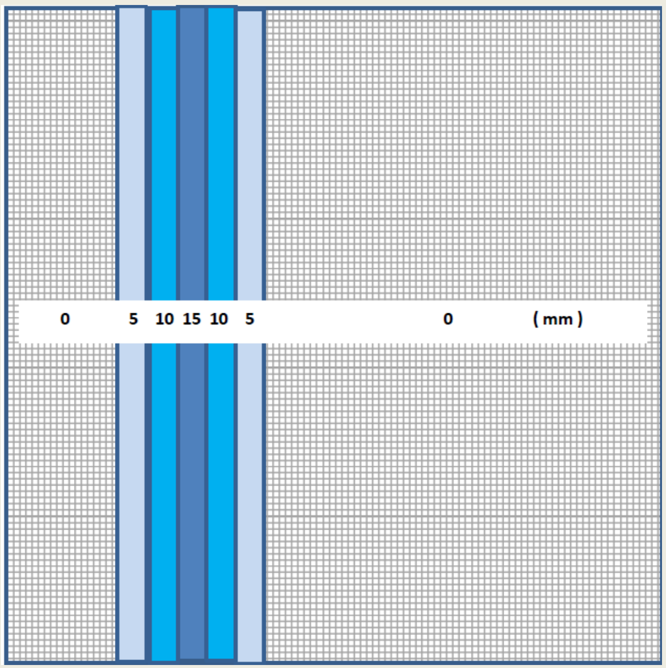
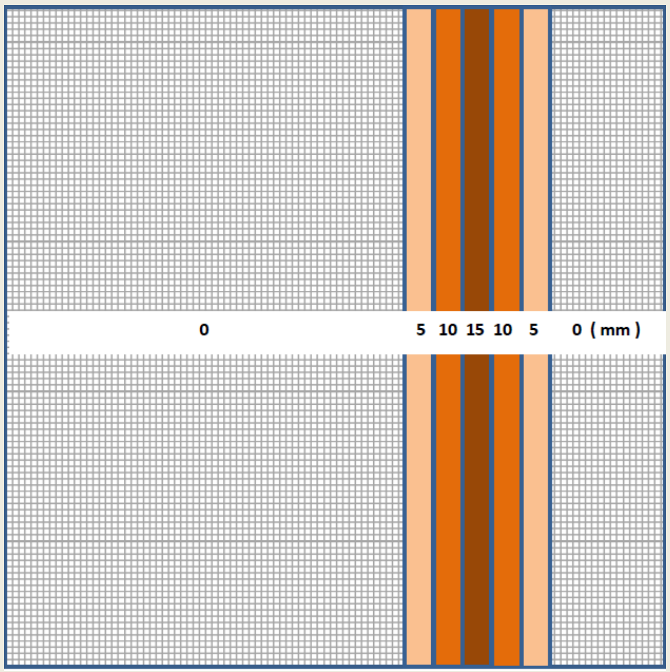
Displaced parallel precipitation bands



Analyzed precipitation



Forecasted precipitation

Fig.10 Effect of a displaced precipitation band : Forecast and analyzed precipitation bands are parallel 9 points across and displaced 10 grid points. Fields have zero values ouside precipitation bands. This provides some additional complexity when comuting scores related with zero value forecast or analysis. Both forecast and analyzed minima may get large errors when choosing a point in the area where analyzed or forecasted precipitation respectively are high.

Displaced parallel precipitation bands (10 and 20 points)

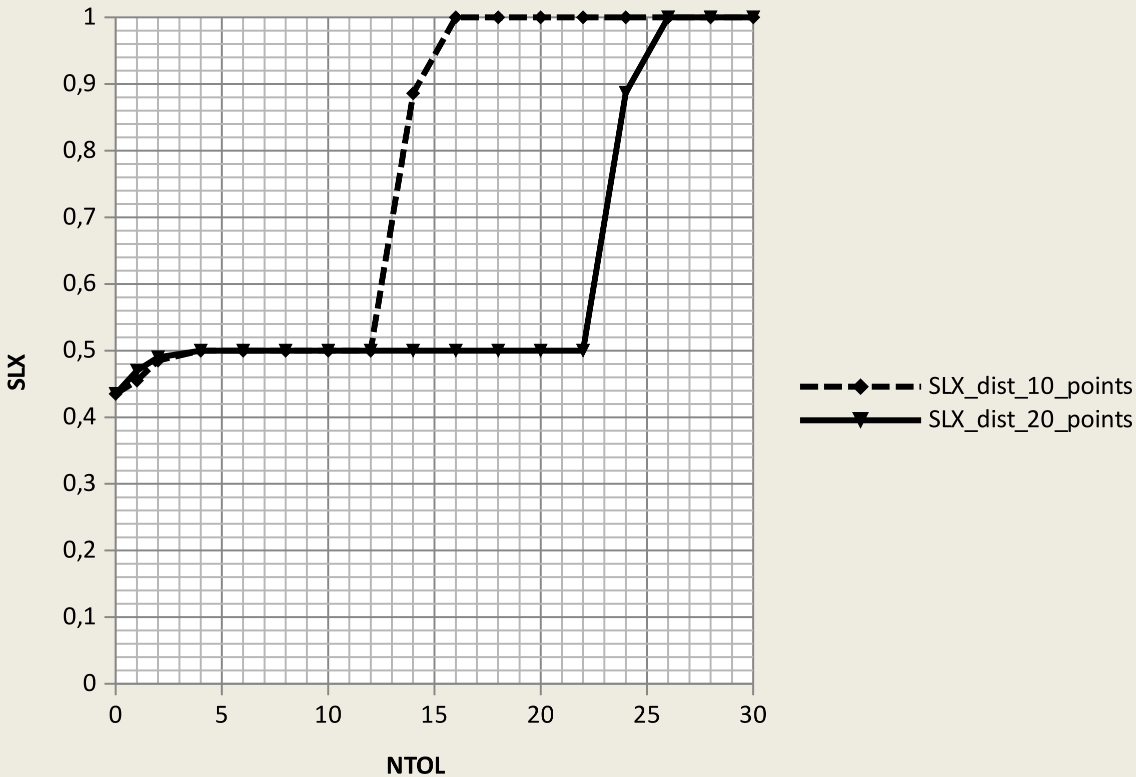


Fig.11: **Combined score `SLX´ shown for two different separations,10 and 20 repectively, between the two precipitation bands.**

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OUTLOOK

- The SLX scheme has been illustrated by only few idealized cases Many more cases are investigated as part of a test procedure.
- The scheme will be documented in a report /article
- It is suggested to test and use SLX in the HARP verification package.
- Precipitation is one of the difficult parameters to verify due to the frequent occurrence of zeros . This tends to give high values of the part of SLX comparing minima. - It is possible to generalize /modify the concept of minima, e.g. minima may optionally be defined relative to a non-zero value. This option is currently being tested.
- It will be easy to apply the scheme to other parameters.

- The scheme, developed in R, runs fast on small problem sizes (one or few seconds of execution time). Run time depends on the need of SLX to involve multiple extreme points.

- Generalisation to ensembles: Immediate possibility could be to compute SLX with input based on highest and lowest values of the entire ensemble and the possibility to test ensemble median as a single forecast.

References:

Sass, B.H., and Yang, X, 2012: A verification score for high resolution NWP: Idealized and pre-operational tests , HIRLAM Tech. Rep. no. 69, 28pp [available from www.hirlam.org]

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