`Forecasting spatial structure of local precipitation extremes´

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OUTLINE

- **Motivation for verifying local extremes in a NWP model domain**
- **From motivation to the creation of a novel spatial verification scheme**
- **Computational methodology of new scheme:**
- **A forecast example**
- **Characteristics of new scheme relative to FSS and SAL spatial schemes**
- **Additional information**
- **Contact and References**

MOTIVATION:

Figure 1a-b illustrate a challenging forecasting situation when NWP users experience significant spatial variability of precipitation (red area with observed maximum (ob-max), and blue area with observed minimum (ob-min) which could potentially be with zero precipitation). The grey `back-ground´ value represents intermediate precipitation amounts.

The observed local extremes occur within close distance geographically. The lighter red and blue areas represent forecast highest and lowest values, respectively .

It would be of great value, e.g. in the context of many types of outdoor activities, if both the wet extreme and the dry extreme could be forecasted with high accuracy , - regarding both absolute amount and spatial accuracy.

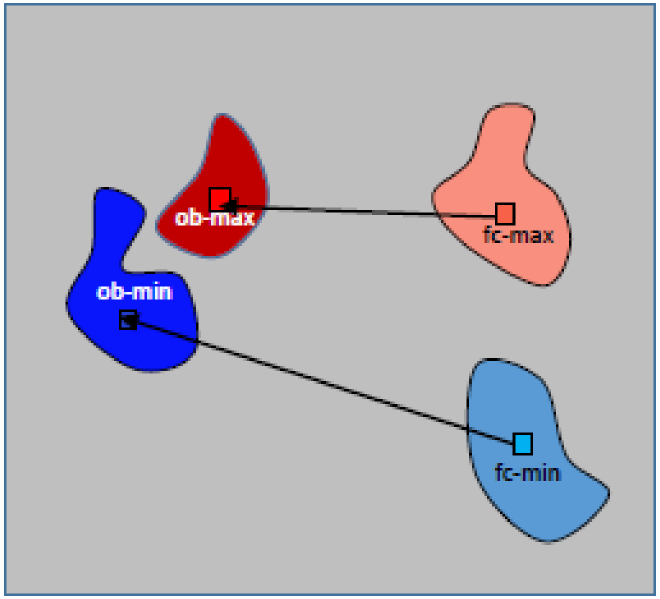


Fig.1a: non-optimal forecast with relatively long distance (represented by length of arrows) between forecasted and observed precipitation extremes (fc-max, ob-max, fc-min, ob-min)

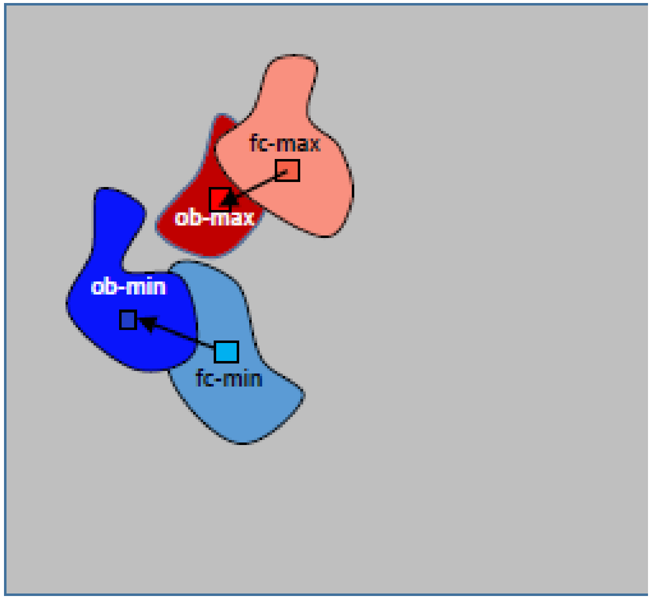


Fig.1b: Improved overlapping forecast with relatively short distance (represented by length of arrows) between forecasted and observed precipitation extremes (fc-max, ob-max, fc-min, ob-min)

Transformation of MOTIVATION to a spatial verification scheme

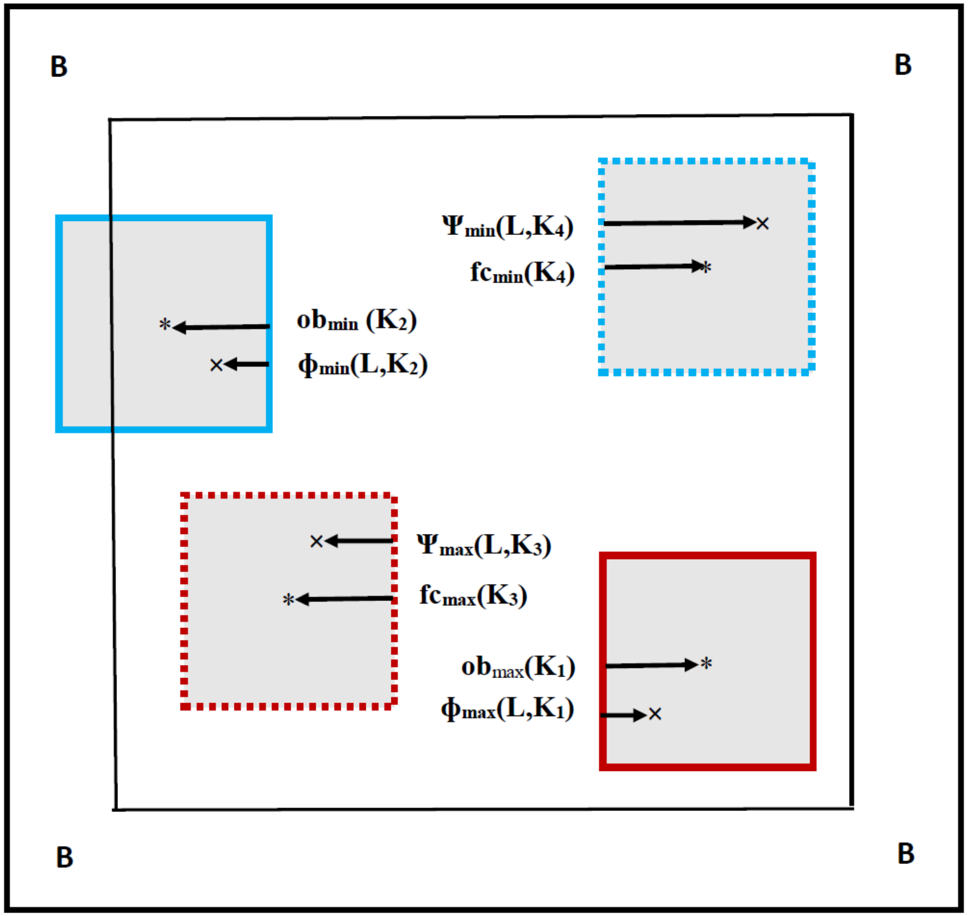


Fig.2 : Illustration of identified local extremes with neighborhoods of dimension L.
In case of multiple extreme points with ~ the same value
$1 \le K_1 \le M_1$, $1 \le K_2 \le M_2$ $1 \le K_3 \le M_3$, $1 \le K_4 \le M_4$,
M_1, M_2, M_3, M_4 are the number of extremes of each type

`SLX´

(Structure of Local EXtremes)

$ob_{max}(K_1)$ is maximum of the analysis field

$\phi_{max}(L,K_1)$ is forecasted maximum in neighborhood of dimension L around $ob_{max}(K_1)$

$ob_{min}(K_2)$ is minimum of the analysis field

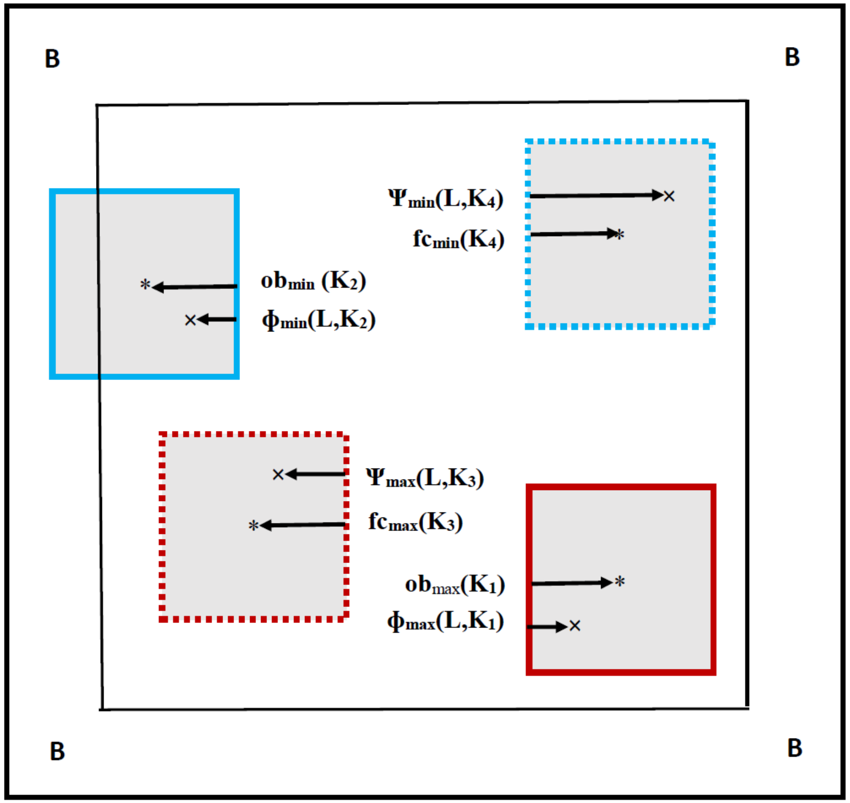
$\phi_{min}(L,K_2)$ is forecasted minimum in neighborhood of dimension L around $ob_{min}(K_2)$

$fc_{max}(K_3)$ is maximum of the forecast field

$\psi_{max}(L,K_3)$ is analyzed maximum in neighborhood of dimension L around $fc_{max}(K_3)$

$fc_{min}(K_4)$ is minimum of the forecast field

$\psi_{min}(L,K_4)$ is analyzed minimum in neighborhood of dimension L around $fc_{min}(K_4)$



A spatial verification scheme `SLX´:

A boundary zone of width B is included to allow computations using full neighborhood size close to the lateral boundaries.

Alternatively, full neighborhoods are not feasible close to the lateral boundary points

Example from Figure: $ob_{max}(K_1)$: Observed maximum , - K_1 identifies extreme point, i.e. multiple number of extremes may be accounted for up to M_1 – considered if highest values occur with almost identical values (small tolerance)

Maximum forecasted value in a neighborhood of dimension L:

$$\phi_{max}(L, K_1) = Max\{ \phi(i, j) \}, \; i \in [i_{K1} - L, , i_{K1} + L], \; j \in [j_{K1} - L, , j_{K1} + L]$$

i_{K1}, j_{K1} are coordinates of the related forecasted values in central point.

SLX

- a novel scheme developed 2019-2020

- ***current application: precipitation fields***
- ***input needed : decision on neighborhood size***
- ***prerequisite : A score function is defined***

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(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.

`SLX´ verification steps $_{(1)}$:

The steps of the verification process for the score component SLX_{ob_max} may be summarized as follows:

I) Choose the current dimension of neighbourhood size L to be used for a given computation

II) Determine the value (and positions in grid) of the observed maxima $ob_{max}(K_1.)$

III) Compute the forecasted maxima $\phi_{max}(L,K_1)$ in the neighbourhood(s) of the extreme point(s).

`SLX´ verification steps $_{(2)}$:

IV) Insert the values $ob_{max}(K_1)$ as value = OB and $\phi_{max}(L,K_1)$ as a forecast to the score function *S* of Figure 3. The values and distance between the two determine the value between 0 and 1 of the score $S_{ob\_max}(K_1)$

V) The procedure is repeated when multiple extreme points are diagnosed , $1 \le K_1 \le M_1$ and the average of all computations is computed as the final value of the score (SLX_{ob_max})

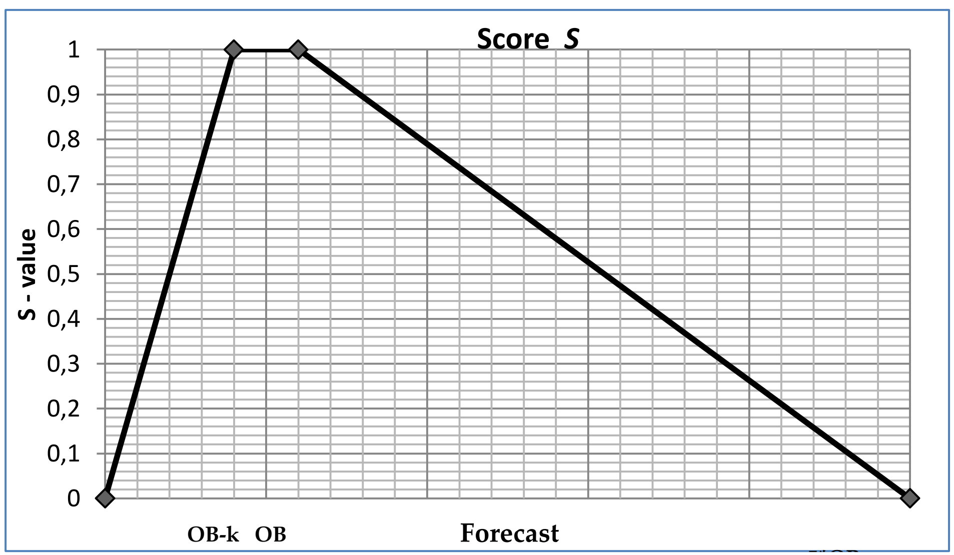

Fig.3 Example of score function *S* which is asymmetric (developed in collaboration with professional NWP users)

`SLX´ verification scheme :

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SLX (Structure of Local EXtremes) measures:

Using these steps for each type of extreme leads to four individual scores defined in interval [0, 1] : SLX (ob_max), SLX (fc_max), SLX(ob_min), SLX(fc_min)

A weighted score SLX is computed as a combined score.

$$SLX_{ob\_max} = \frac{1}{M_1} \sum_{K_1=1}^{M_1} S_{ob\_max}(K_1) \qquad SLX_{ob\_min} = \frac{1}{M_2} \sum_{K_2=1}^{M_2} S_{ob\_min}(K_2)$$

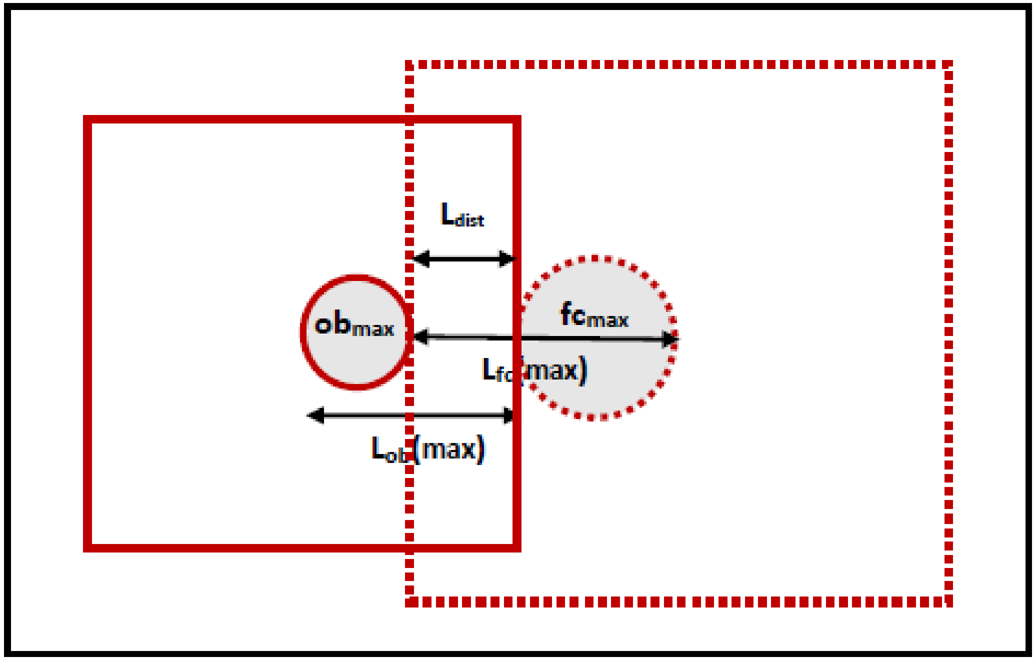
$$SLX_{fc\_max} = \frac{1}{M_3} \sum_{K_3=1}^{M_3} S_{fc\_max}(K_3) \qquad SLX_{fc\_min} = \frac{1}{M_4} \sum_{K_4=1}^{M_4} S_{fc\_min}(K_4)$$

$$\mathbf{SLX} = \tfrac{1}{4}\left(SLX_{ob\_max} + SLX_{ob\_min} + SLX_{fc\_max} + SLX_{fc\_min} \right)$$

” Understanding SLX with multiple extreme points ”

Average computation:

All extreme points are considered with equal weight in a neighborhood computation. The Figure illustrates situation for maxima. For minima an important option exists to look for a value closet to a specified value V_{min} which may be larger than zero. This tends to prevent the score related with minima to become close to 1 in situations with large dry areas.



$$SLX_{ob\_max} = \frac{1}{M_1} \sum_{K_1=1}^{M_1} S_{ob\_max}(K_1)$$

Fig. 4

Relation between neighborhood and score components : If $ob_{max} = fc_{max}$ in grey colored areas and zero values apply outside, then $S_{ob\_max} = S_{fc\_max}$ is zero for $L < L_{dist}$, which is the separation distance between ob_{max} and fc_{max} precipitation areas. $L_{ob}(max)$ is a neighborhood size above which S_{ob_max} becomes 1. $L_{fc}(max)$ is a neighborhood size above which S_{fc_max} becomes 1.

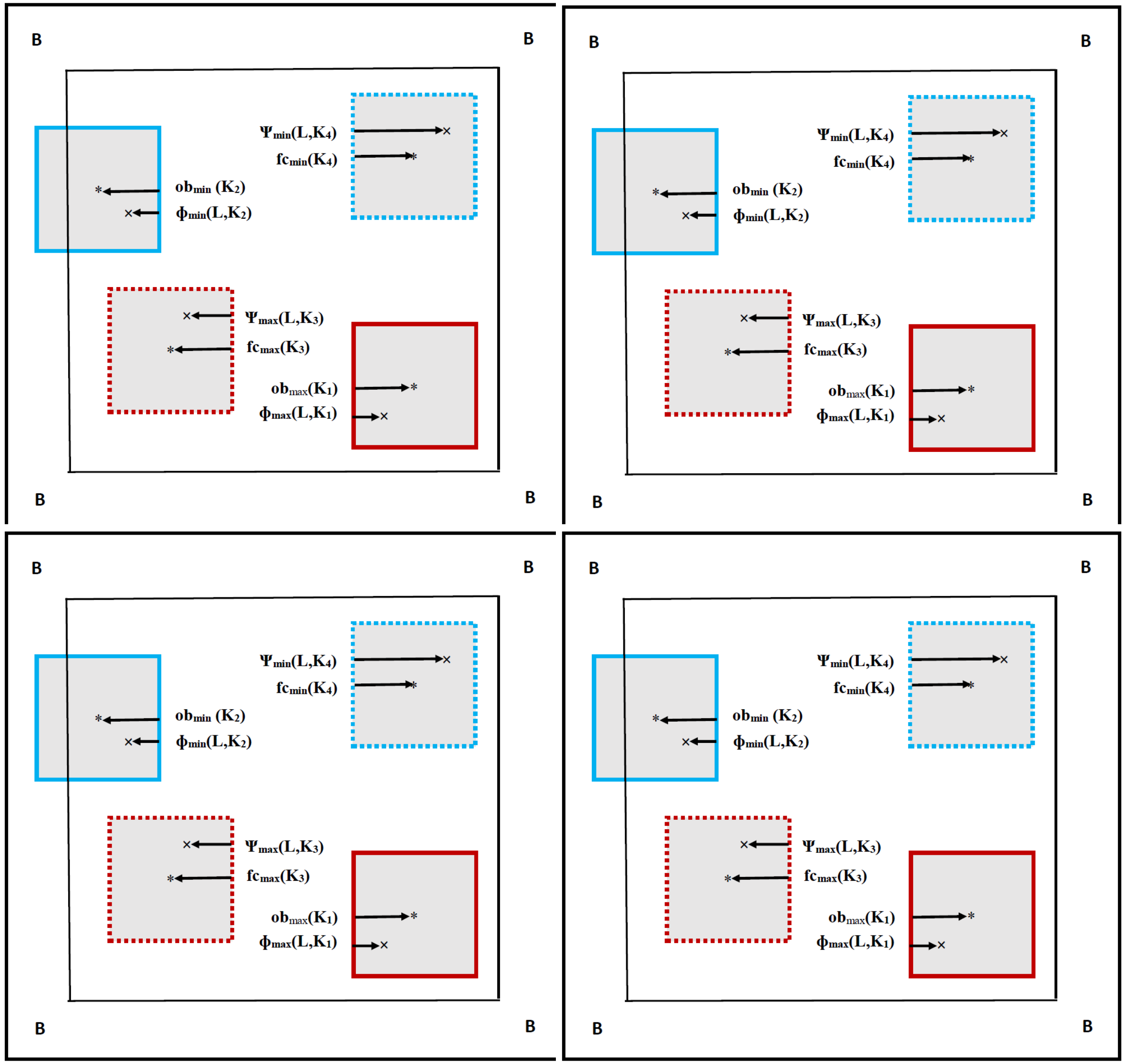


Fig.5 For large domains multiple sub-areas may be included that can be treated with separate or combined statistics.

Forecast Example : Convection over parts of Denmark

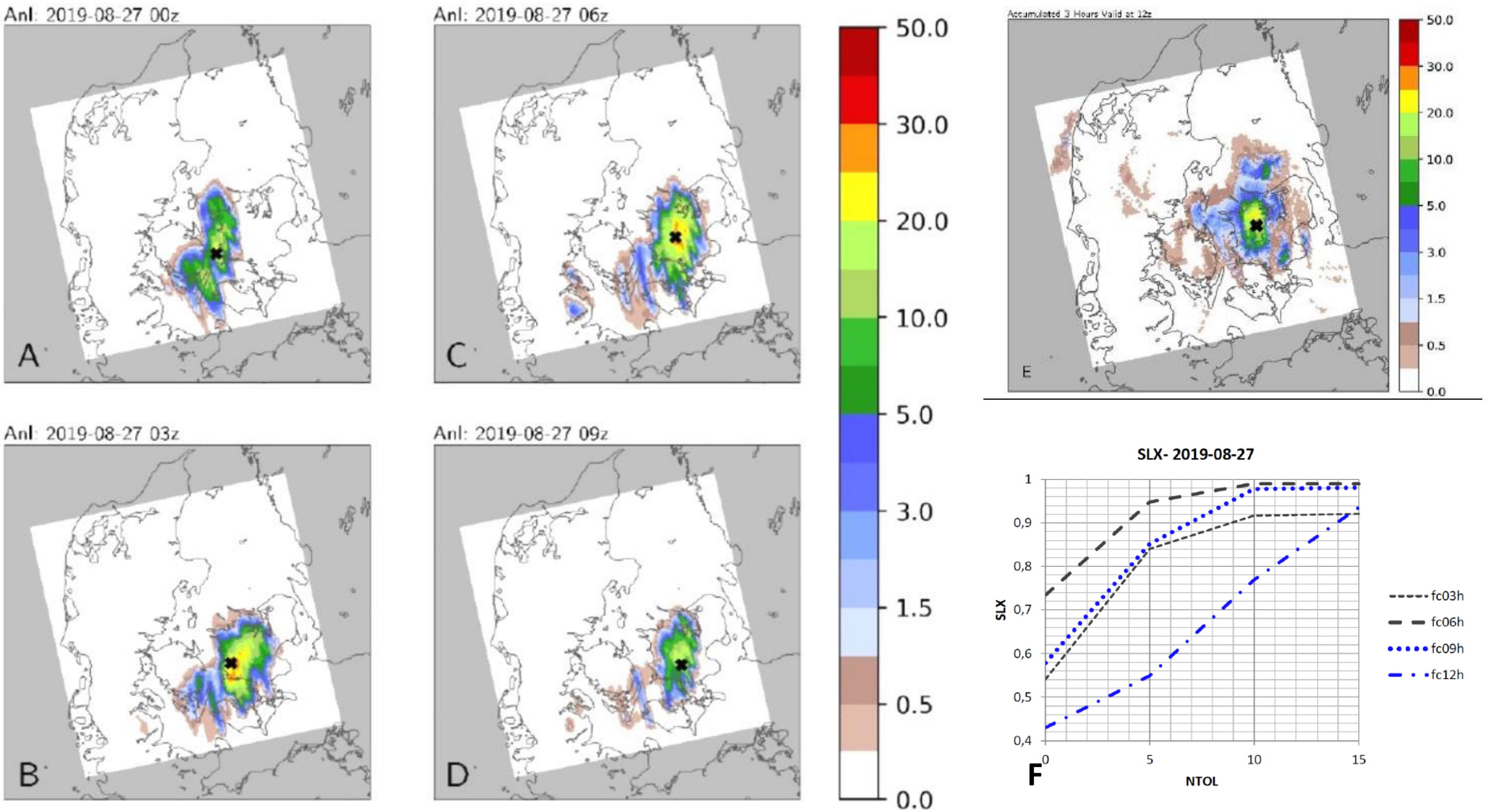


Fig. 6 Forecasted accumulated precipitation (kg/m^2) valid from 9 UTC -12 UTC 27 August 2019 over the light squared areas of dimensions 325 km*325 km. Figure A, B, C and D apply to forecasts starting at 00 UTC , 03 UTC , 06 UTC and 09 UTC respectively. Figure E shows the corresponding analyzed field of precipitation 9-12 UTC 27 August 2019. The black crosses indicate the maxima. Fig. 6 F shows the resulting combined scores of SLX , from four forecasts starting at different origin times.

Basic comparisons with Fractions Skill Score (FSS) and SAL (Structure , Amplitude and Location)

CHARACTERISTICS	FSS	SAL	SLX
Main characteristics of scheme	Predict fractions correct , - 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

N=Neighborhood , F= Features based

Additional information

- An early version of the idea of verifying local extremes has been opertaional in DMI for several years (Sass and Yang 2012) . Some other relevant references are provided in the last slide. A publication on SLX is under review in an international journal.

- The scheme has been tested in many idealized cases and in a simulation of pre-operational conditions.

- The scheme has been prepared for operational use. An operational precipitation analysis in DMI makes this feasible from 2021.

Contact information and References

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