Estimating the displacement in precipitation forecasts using the Fractions Skill Score

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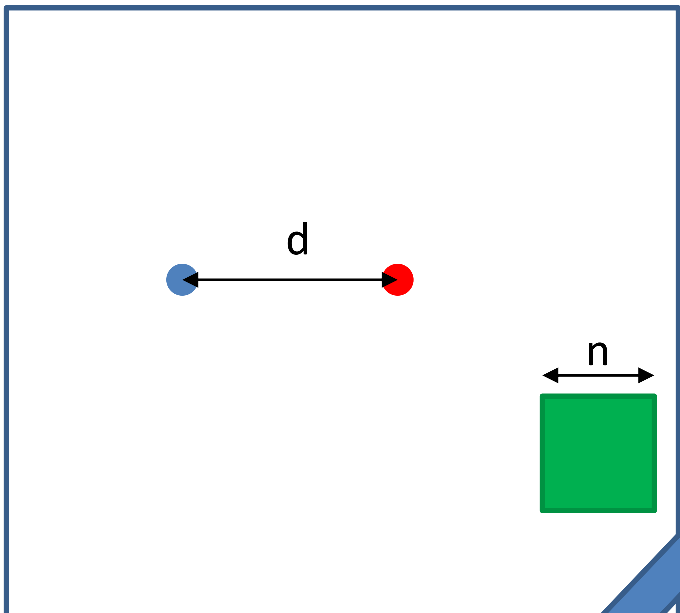
Fraction Skill Score (FSS)

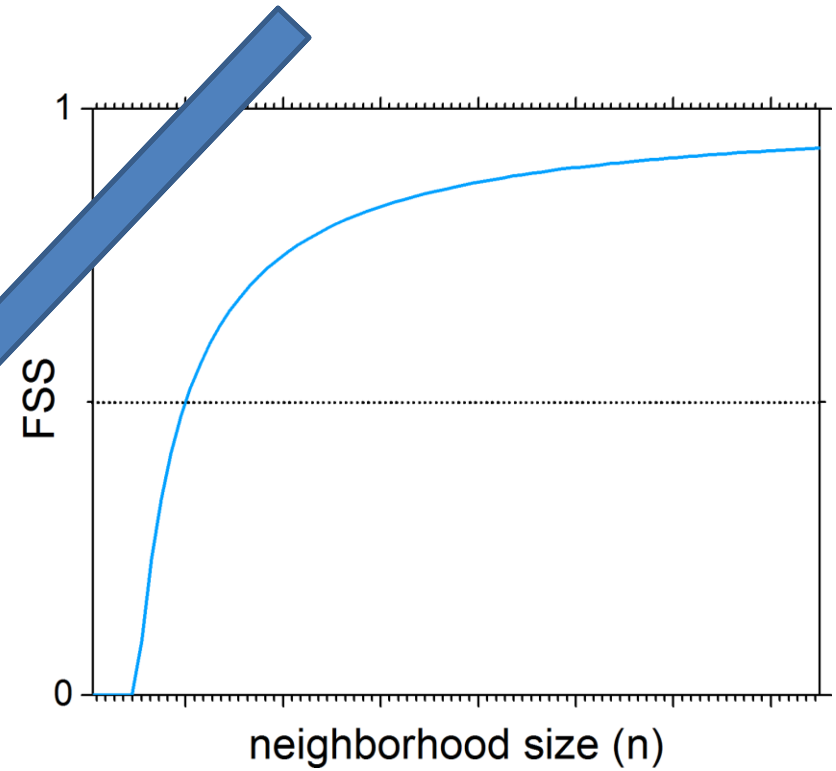
- FSS is a popular spatial verification method used for precipitation
- It can be classed as a **neighborhood approach method**
- In this study we focus on analyzing the ability of FSS to give a meaningful measure of spatial displacement of precipitation
- The use of spatial displacement as a verification measure is very appealing for forecast interpretation since it is easy to understand and mimics how we tend to judge fields by eye
- This ability has been hinted at in some previous studies/papers but never properly analyzed

FSS displacement

A simple idealized setup (Roberts, 2008, Skok, 2015):

$$FSS = 1 - d/n$$





$$d_{FSS} = (1 - FSS) \cdot n$$

FSS displacement -> If the FSS value is know at some neighborhood size the displacement can be determined exactly.

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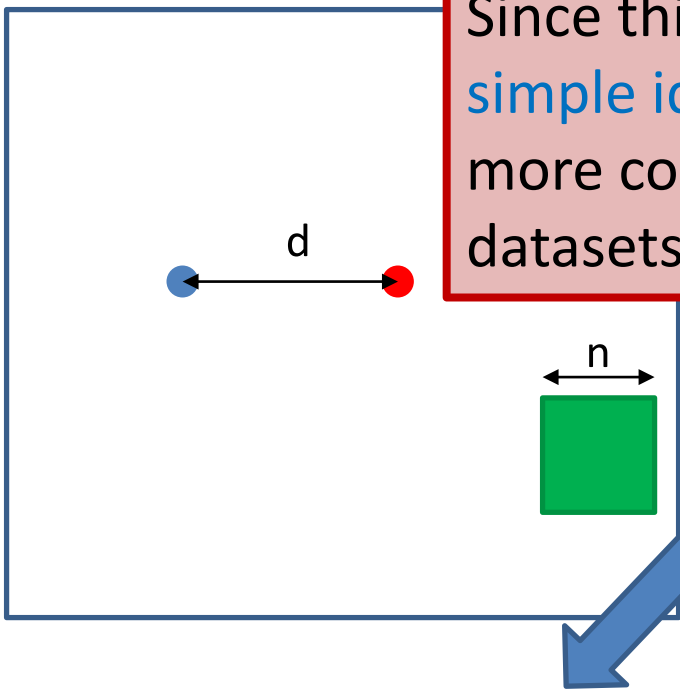
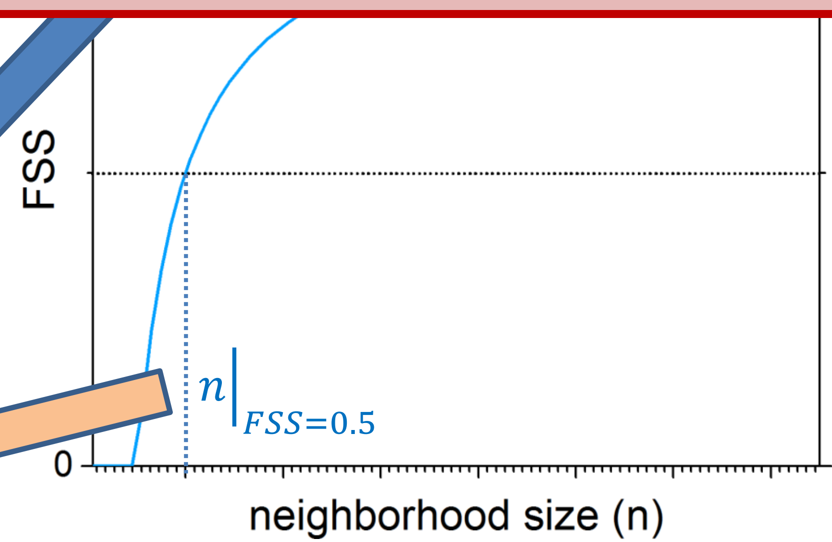
FSS displacement

A simple idealized se

The big question !!!

Since this recipe is strictly valid only for this simple idealized setup, how well does it work for more complicated idealized setups and for real datasets?

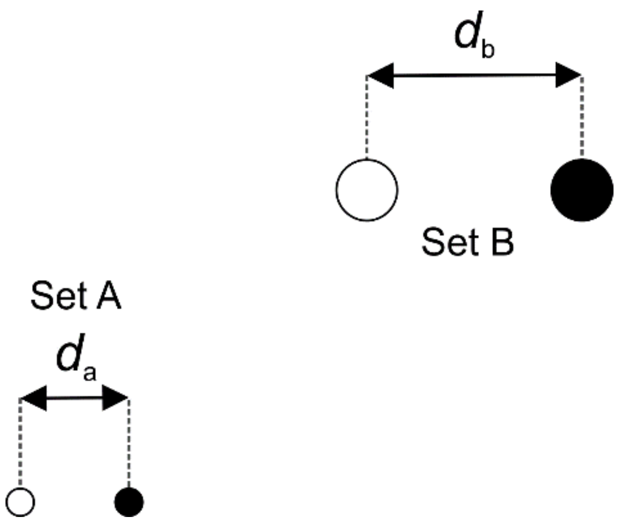




$$d_{FSS} = \frac{n|_{FSS=0.5}}{2}$$

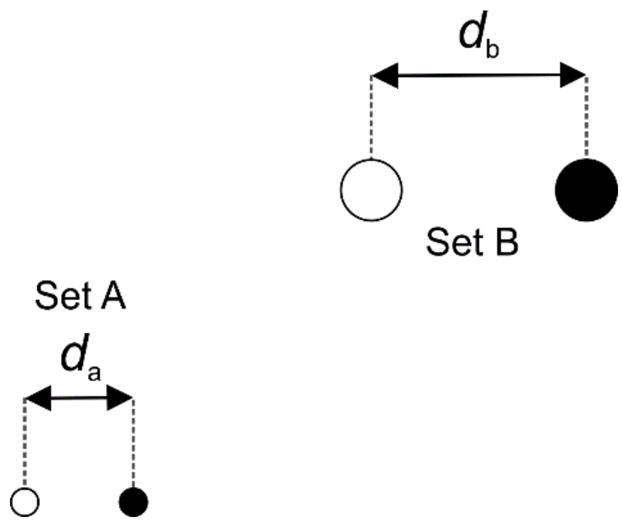
Usually the FSS value od 0.5 is used to determine the displacements -> we call this the **FSS=0.5 rule**. In this case the FSS displacements is half the neighborhood size.

Idealized setup 1: **Two separated sets**



$x = \frac{S_b}{S_a}$ with S being area size of precipitation

Idealized setup 1: **Two separated sets**



- An idealized setup with two separated sets is analyzed

$$d_{FSS} = \frac{d_a + x^2 d_b}{1 + x^2}$$

- If sets are the same size ($x = 1$)

$$d_{FSS} = \frac{d_a + d_b}{2}$$

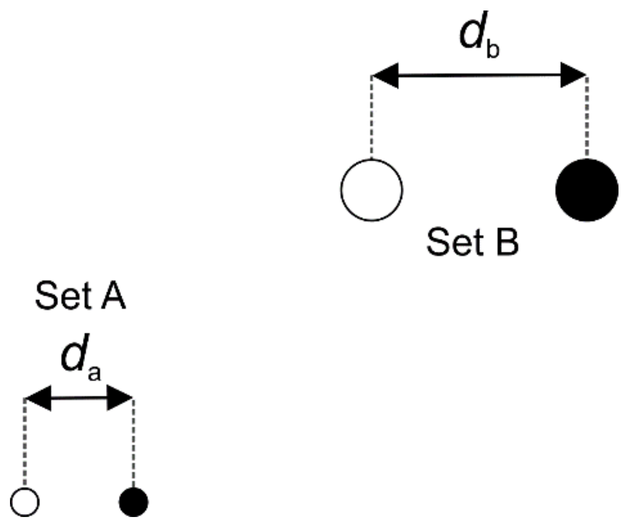
- If set B is quadruple size ($x = 4$)

$$d_{FSS} = \frac{d_a + \mathbf{16} \cdot d_b}{17}$$

$x = \frac{S_b}{S_a}$ with S being area size of precipitation

In this case the FSS gives a meaningful representation of the displacement with **larger areas havening an un-proportionally large effect**.

Idealized se



The difference between two neighborhood approaches (talk yesterday by Craig Schwartz)

- „smoothing radius" – the larger areas have the most influence on score value (the outliers are smoothed out)
- „search radius" - the influence of the smaller areas is increased (the outliers are strengthened – possible high sensitivity to noise)

$x = \frac{S_b}{S_a}$ with S being area size of precipitation

$$d_{FSS} = \frac{d_a + \mathbf{16} \cdot d_b}{17}$$

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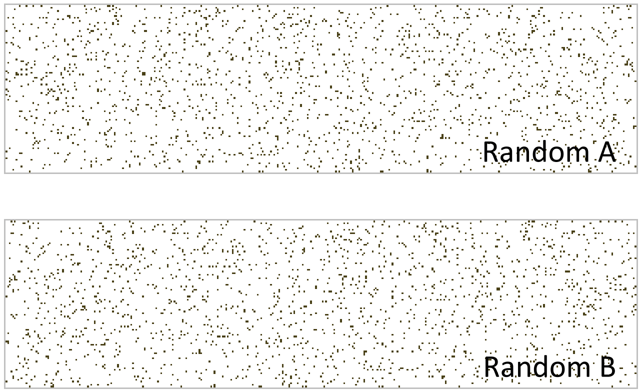
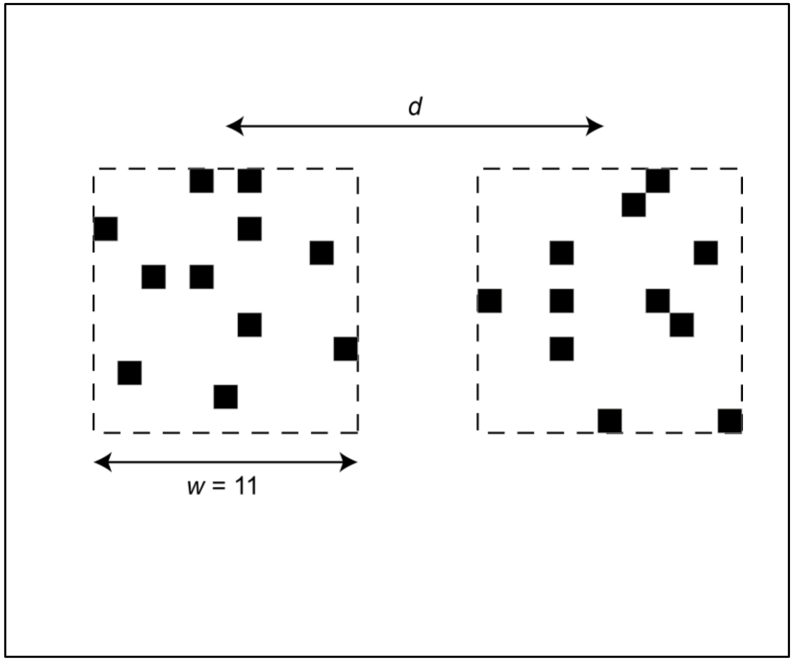
Idealized setups 2 & 3: **Random and envelope precipitation**



Random precipitation

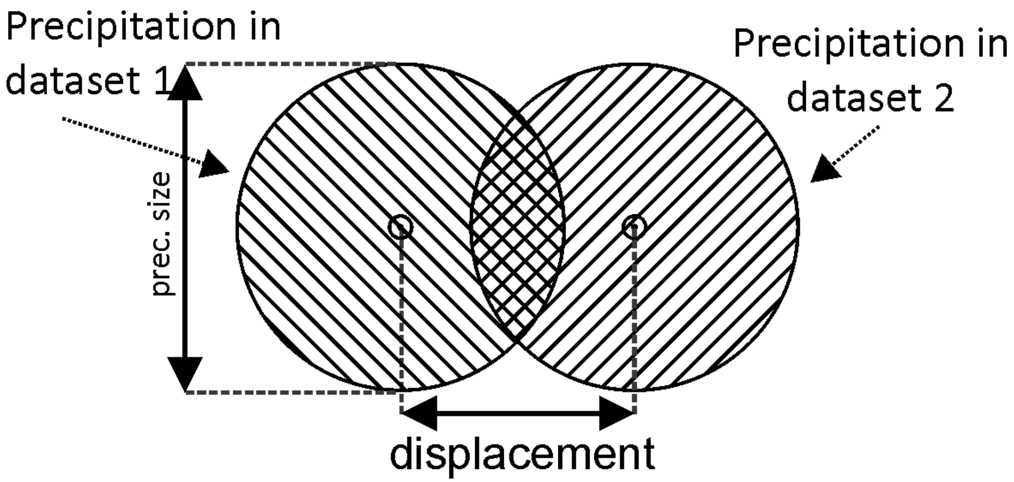
FSS displacements corresponds exactly to the average distance to the closest neighboring rainy pixel



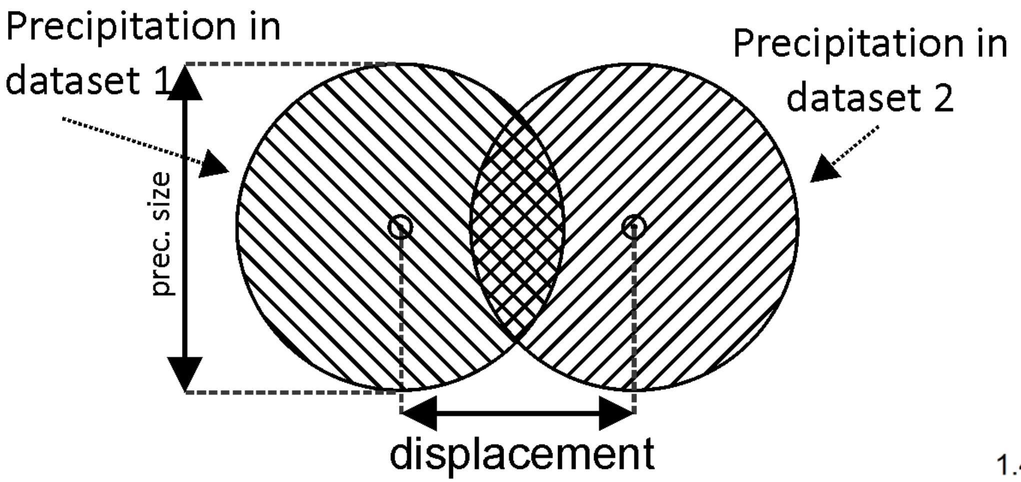
Envelopes of random precipitation

FSS displacement will correspond to envelope distance (if the envelopes are far apart) or inter-envelope displacement (if the envelopes overlap)

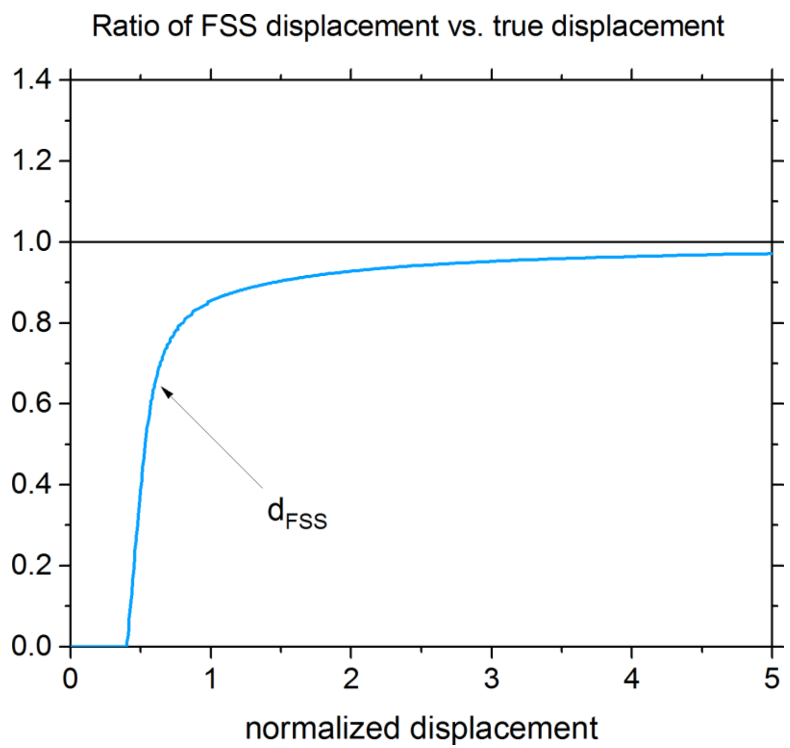
Idealized setup 5: **Overlapping precipitation**



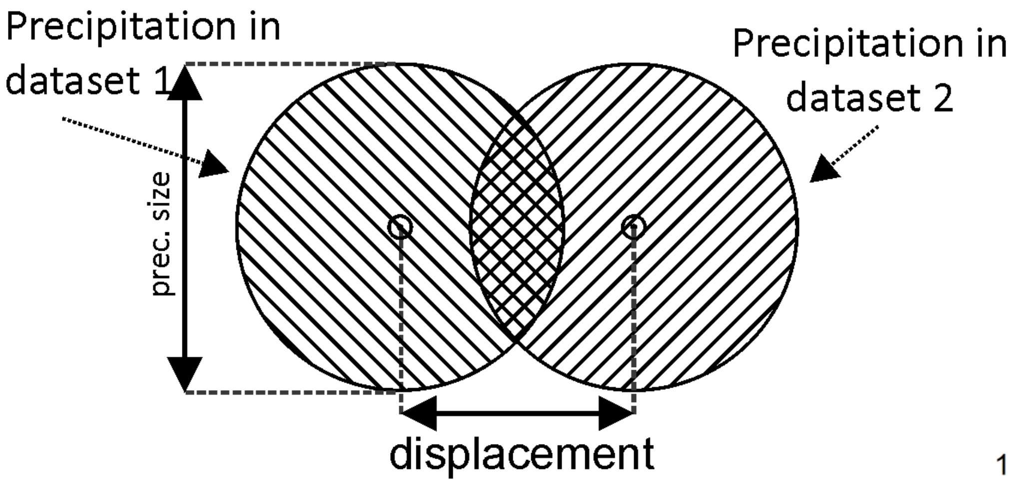
Idealized setup 5: **Overlapping precipitation**



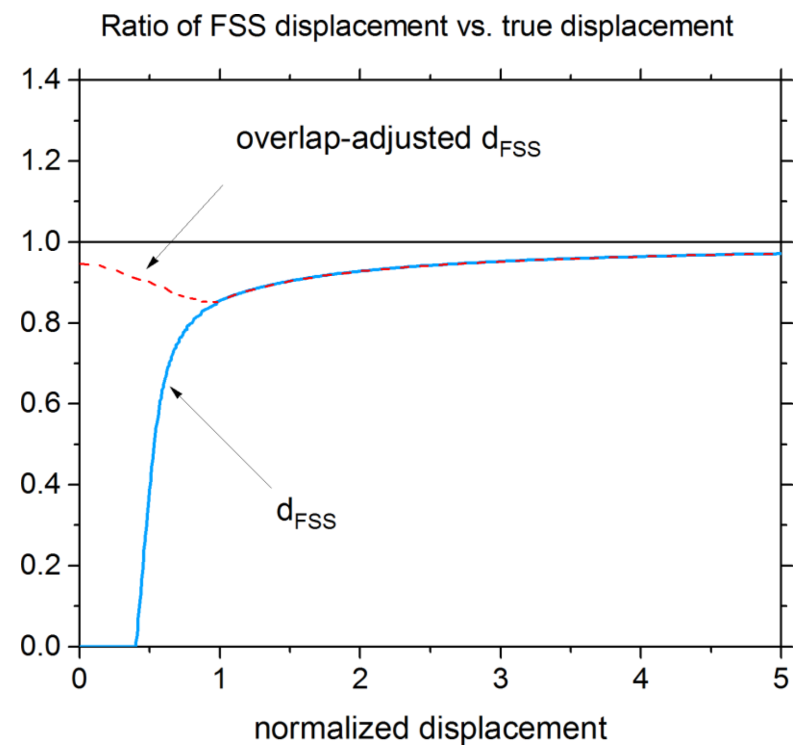
Simply using the $FSS = 1 - d/n$ equation **does not work** in case of significant **overlap** !!



Idealized setup 5: **Overlapping precipitation**



Simply using the $FSS = 1 - d/n$ equation **does not work** in case of significant **overlap** !!



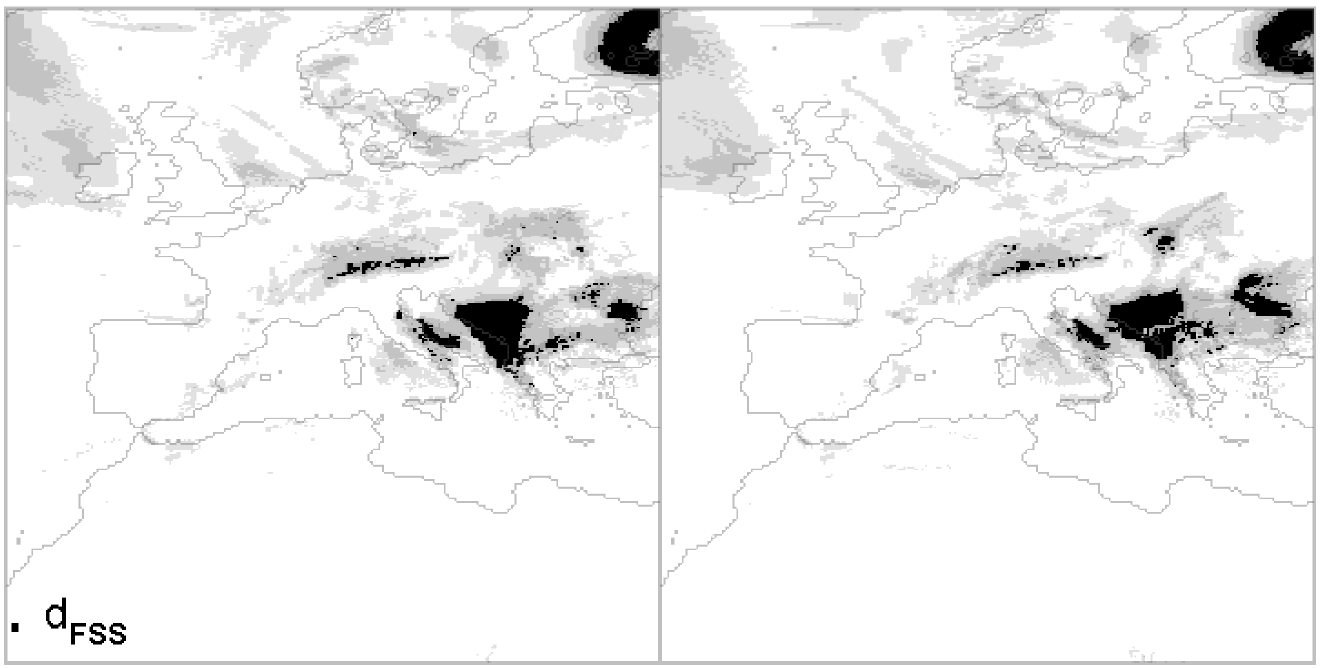
A special overlap-adjustment needs to be made which takes into the account the portion of overlapping area.

After applying the adjustment the **results are much better !!!**

Real cases 1: ECMWF operational forecasts

6h hourly precipitation starting at 00 UTC. 2% frequency threshold used.

c) 2014-05-14 1 day forecast FSSn1=0.75 dFSS=4



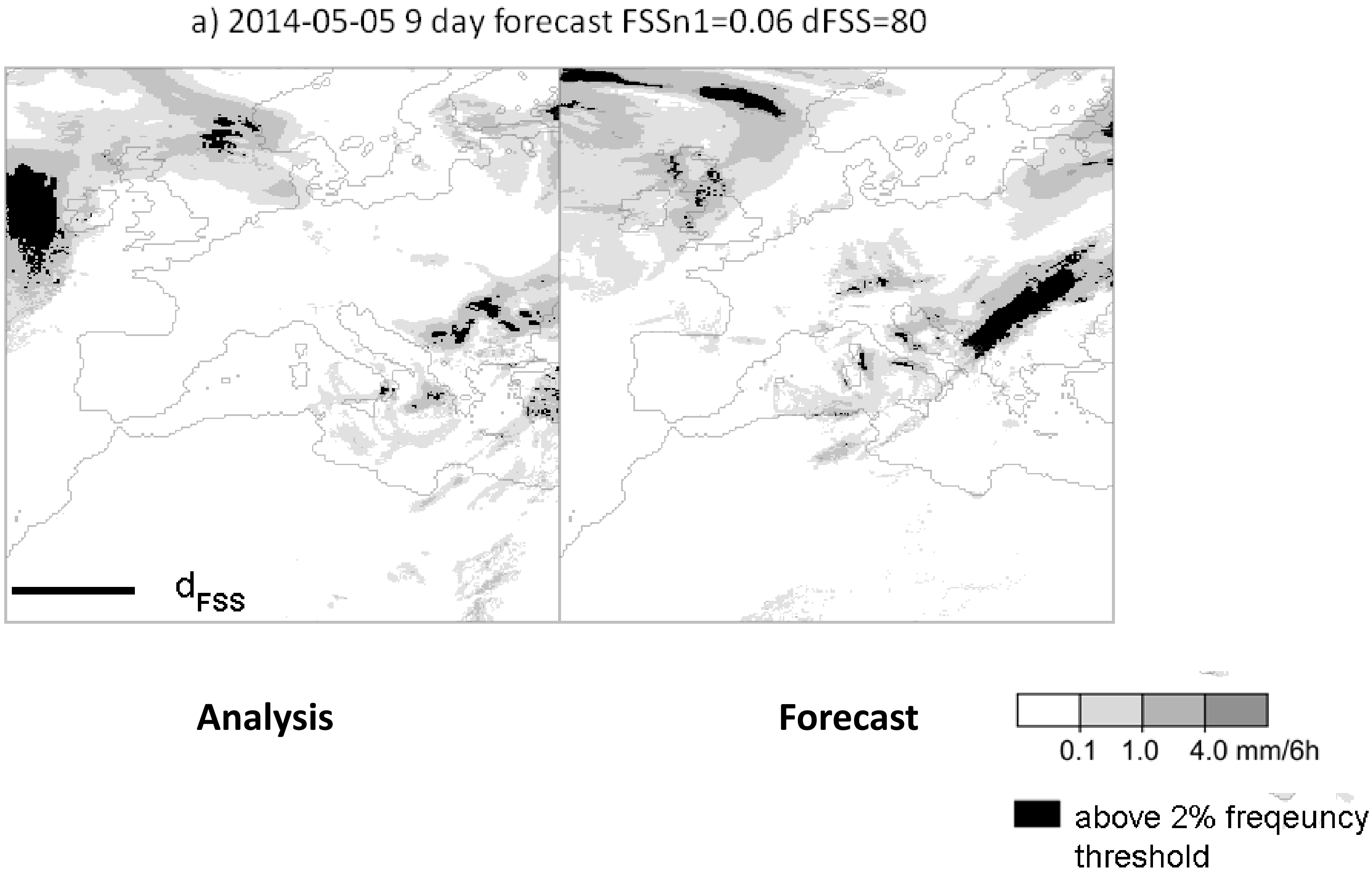
Analysis **Forecast**

0.1 1.0 4.0 mm/6h

above 2% freqeuncy threshold

Real cases 1: ECMWF operational forecasts

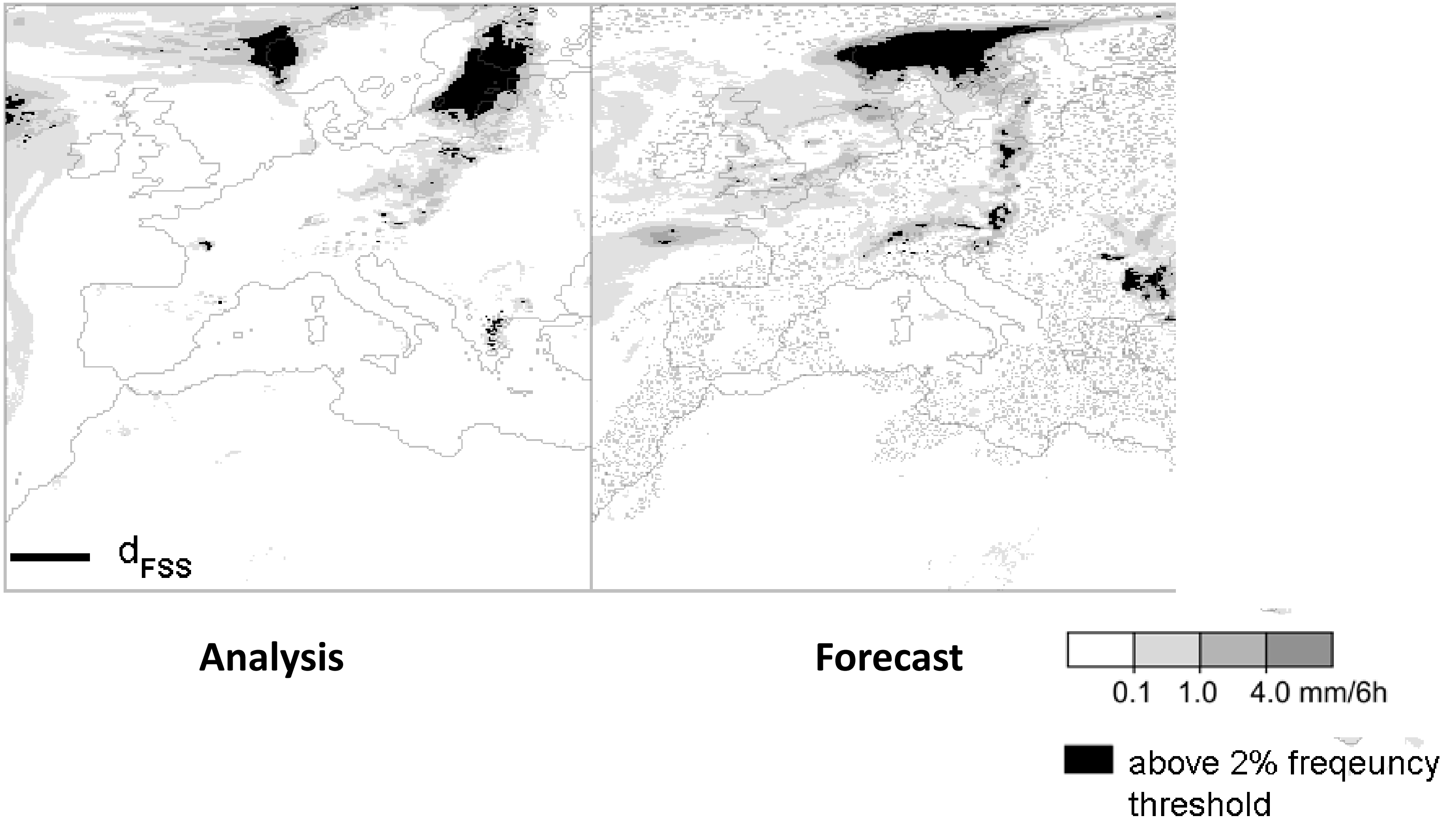
6h hourly precipitation starting at 00 UTC. 2% frequency threshold used.



Real cases 1: ECMWF operational forecasts

6h hourly precipitation starting at 00 UTC. 2% frequency threshold used.

d) 2014-06-12 9 day forecast FSSn1=0.12 dFSS=49

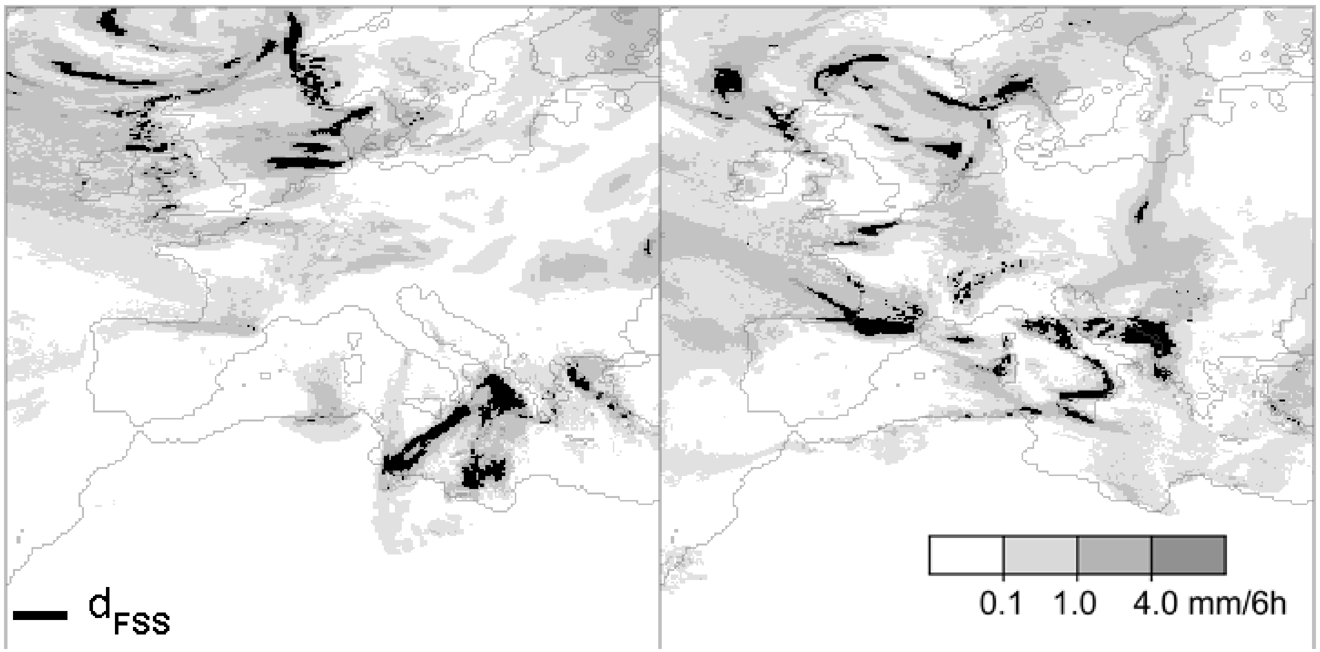


Analysis **Forecast**

Real cases 1: ECMWF operational forecasts

6h hourly precipitation starting at 00 UTC. 2% frequency threshold used.

g) 2014-12-11 9 day forecast FSSn1=0.05 dFSS=30



Analysis **Forecast**

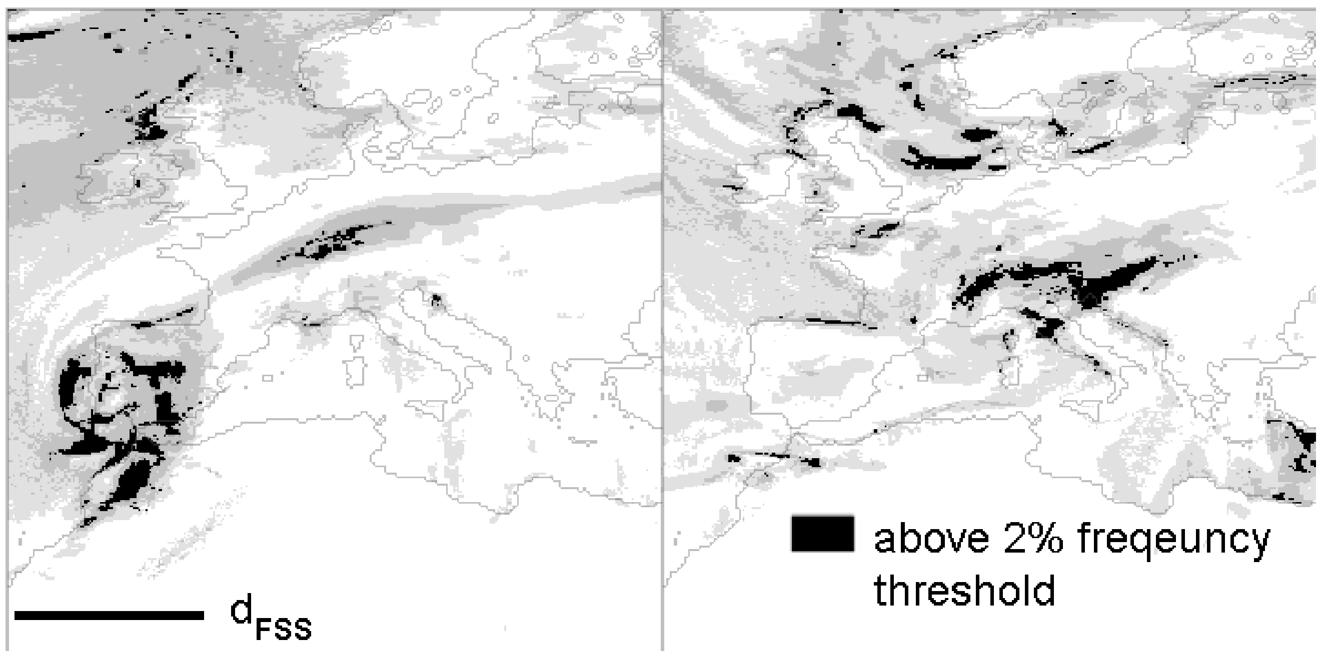
0.1 1.0 4.0 mm/6h

above 2% freqeuncy threshold

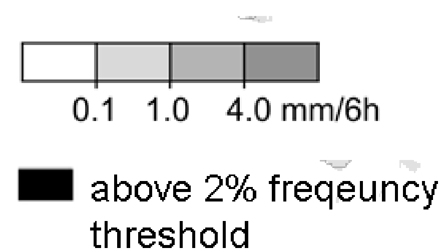
Real cases 1: ECMWF operational forecasts

6h hourly precipitation starting at 00 UTC. 2% frequency threshold used.

h) 2014-12-14 9 day forecast FSSn1=0.03 dFSS=104

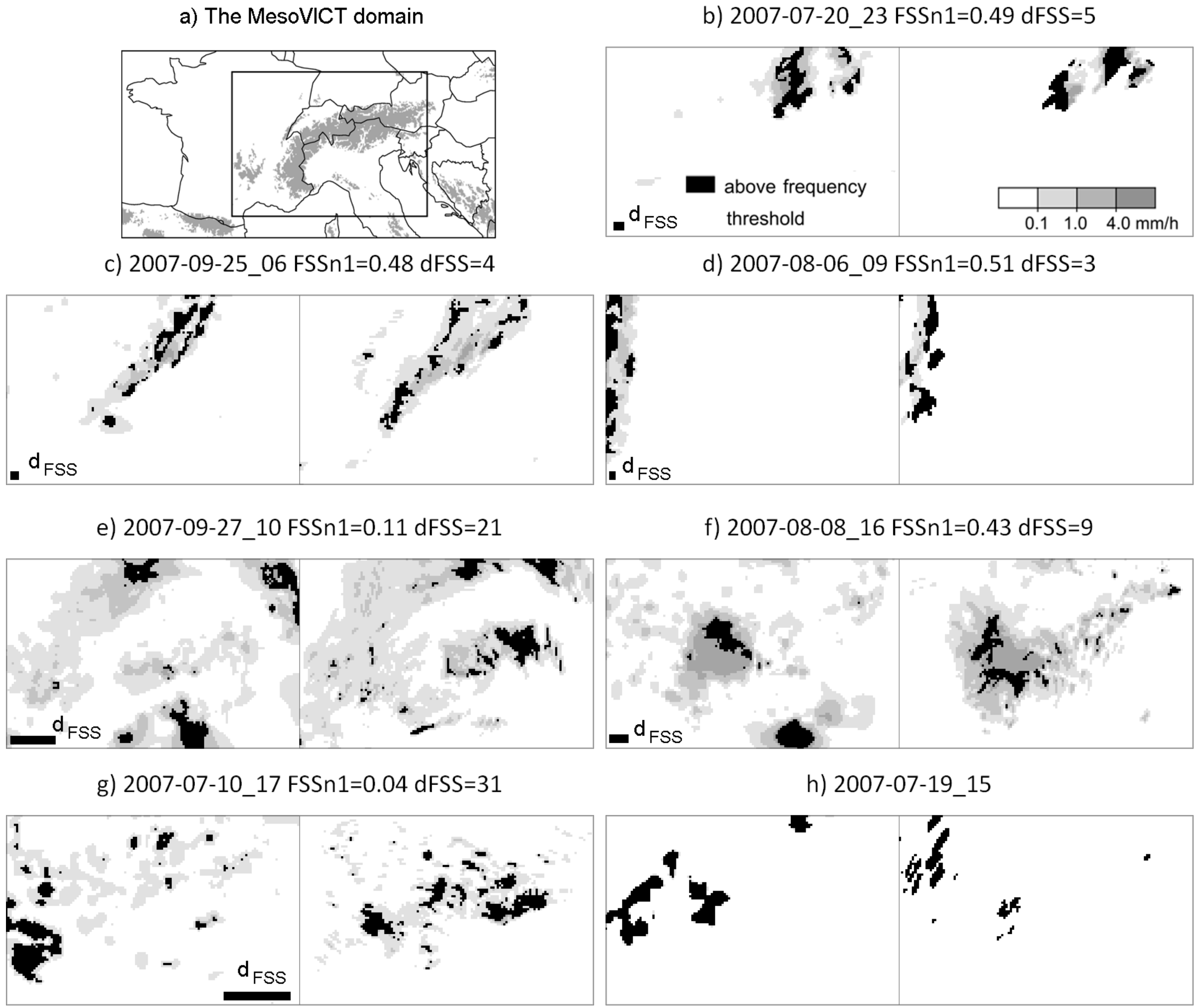


Analysis **Forecast**



Real cases 2: MesoVICT cases

1h hourly precipitation. 5% frequency threshold used.



Conclusions

- The FSS **can indeed be used** to determine spatial displacement in a meaningful way.
- The displacement provided by the FSS is directly related to the true displacements of precipitation but with larger precipitation objects having an unproportionally large influence.
- It is recommended that the user should use a frequency (percentile) threshold unless biases are known to be small (the methodology can tolerate some bias but not too much)

Conclusions

- The **overlap-adjusted variant** of the FSS displacement should be used
- The computational cost in calculating d_{FSS} is proportional to $N \cdot \log[\sqrt{N}]$ (using Faggian et al., 2015 approach for the fast fraction calculation + bisection for finding $n|_{FSS=0.5}$). N is the number of grid points in the domain.
- The d_{FSS} measure provides only one aspect of verification – it is not the whole story
- A paper will be submitted very soon
- Planning to provide optimized R code for calculation of d_{FSS} (also to SpatialVx ???)

Thank you !!