



**Zied Ben Bouallegue and Susanne E. Theis (DWD), 2014**

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# Time lagged ensemble of precipitation forecasts over the Eastern Mediterranean

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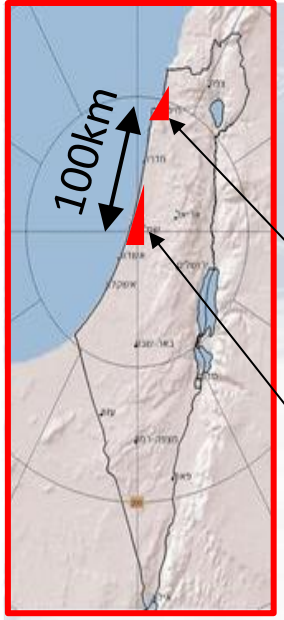
The Israel Meteorological Service, Israel

**COSMO User Seminar, Offenbach, February 2018**

# Motivation

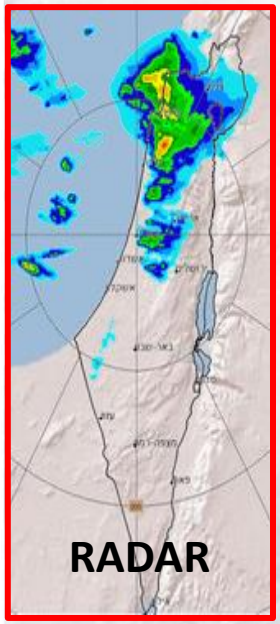



~10% of population

~35% of population

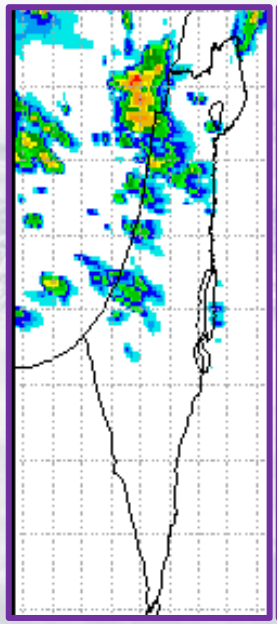
Precise precipitation forecast is needed

20170211
18-24Z

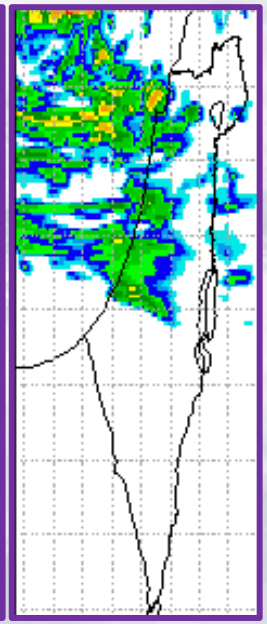




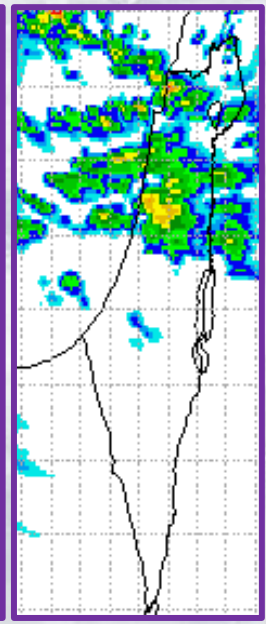
20170210 00Z
+48h



20170209 12Z
+60h



20170209 00Z
+72h

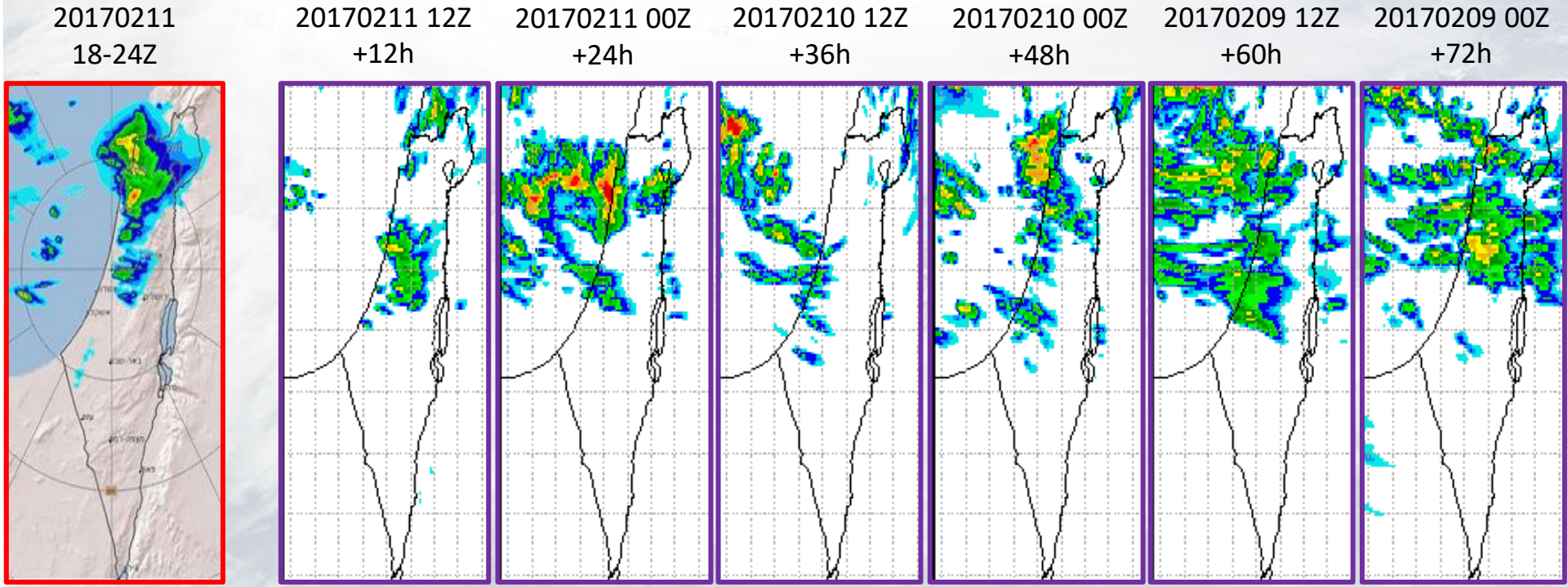


# Motivation

The last available run is not always better

How can we use the previous runs to improve our forecast?

Time Lagged Ensemble



# Outline

What is time lagged ensemble for precipitation?

What is the role of additional smoothing?

Precipitation verification using:

- Reliability
- ROC area
- FSS

⟹ Optimal smoothing radius

Typical spatial error

Optimal probability forecast

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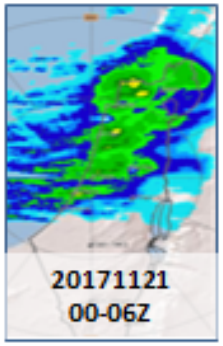
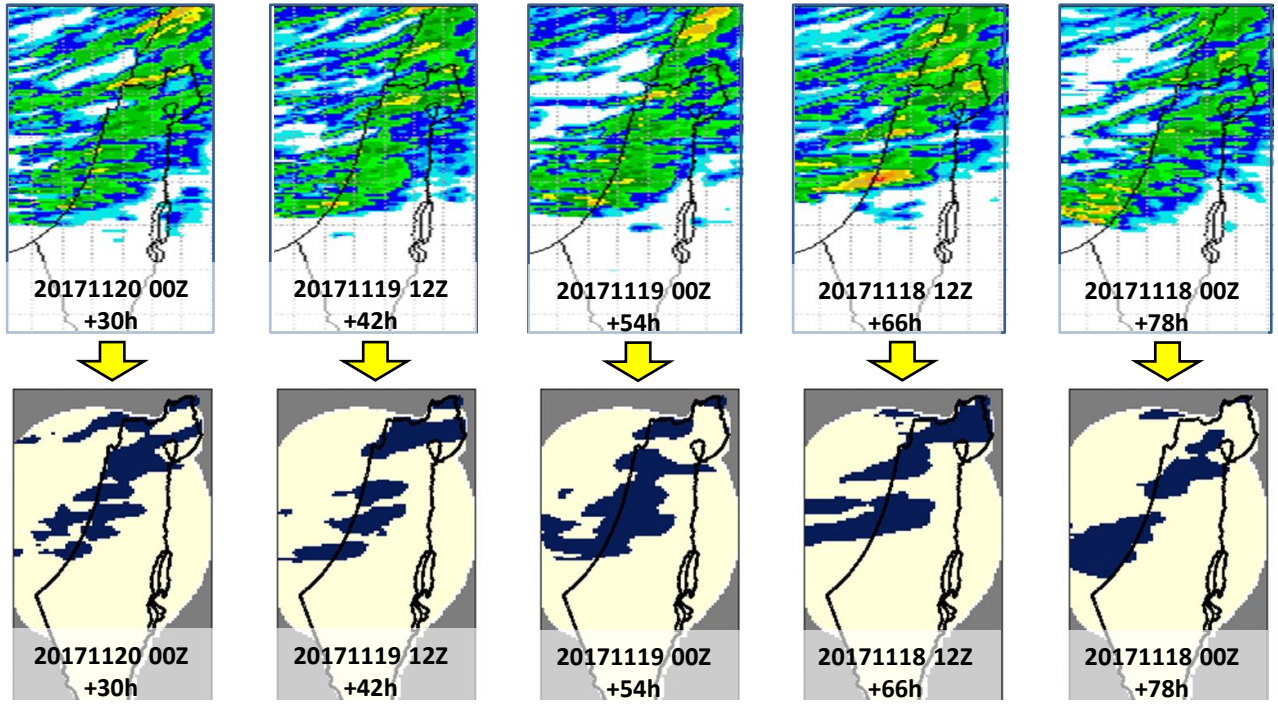
# Time Lagged Ensemble for precipitation

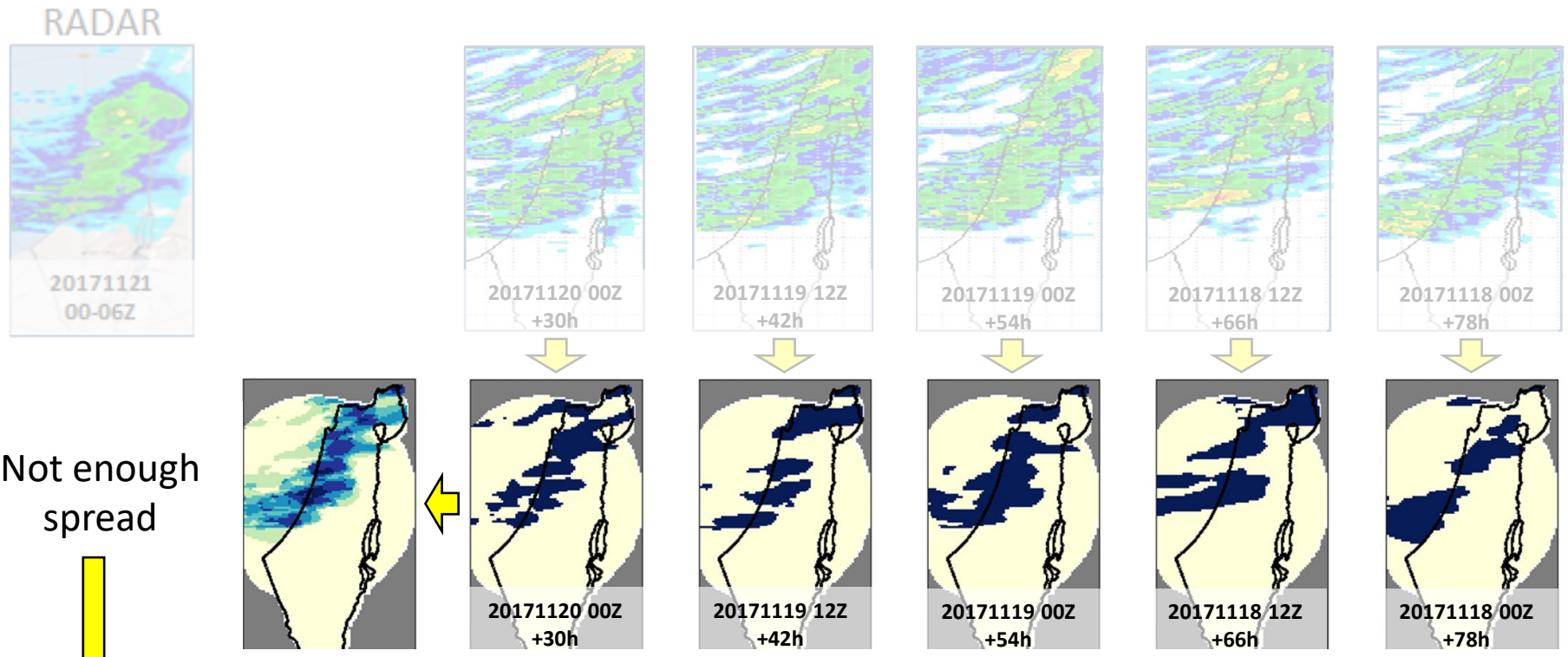
RADAR




>5 mm/6h



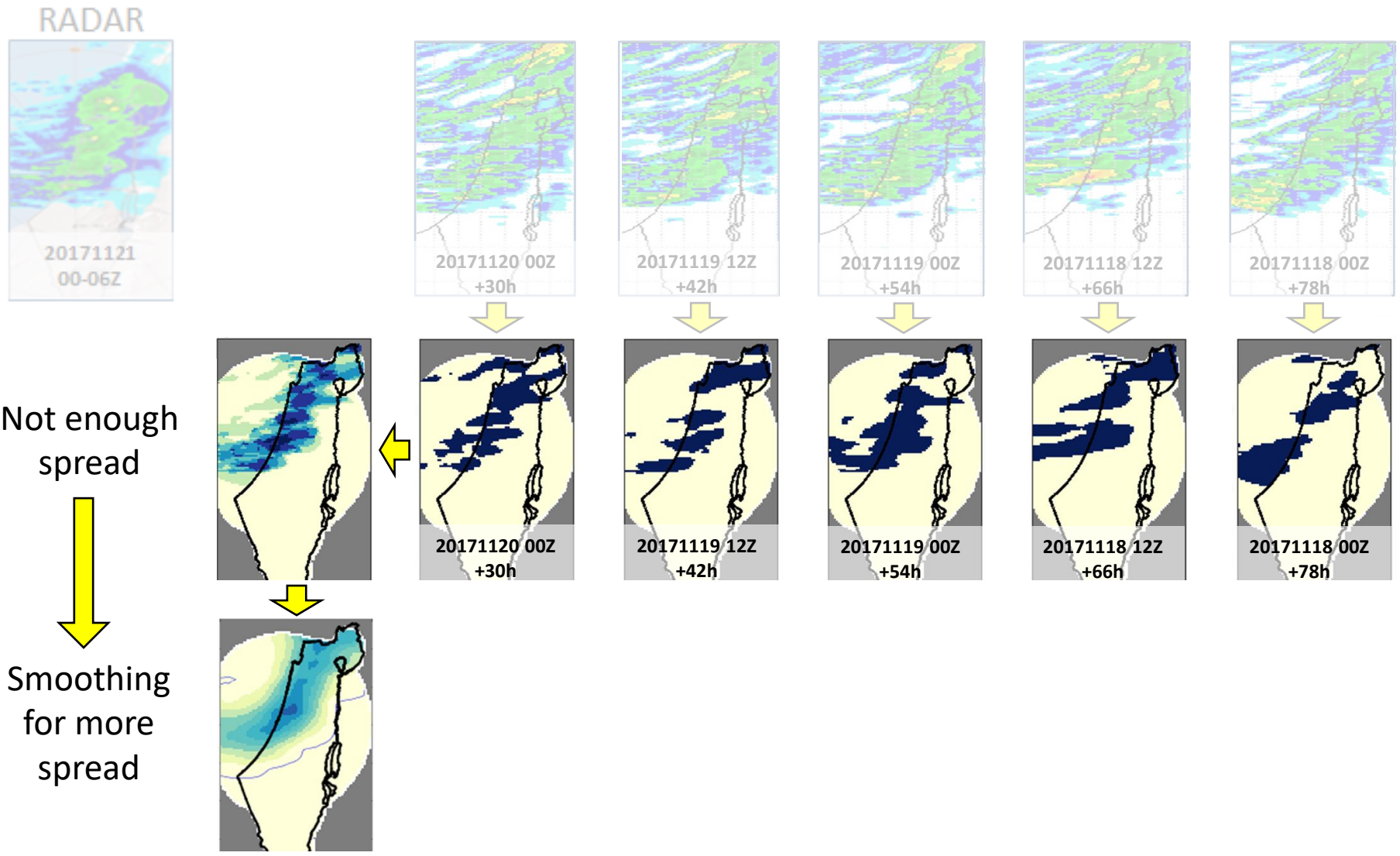
# Time Lagged Ensemble for precipitation



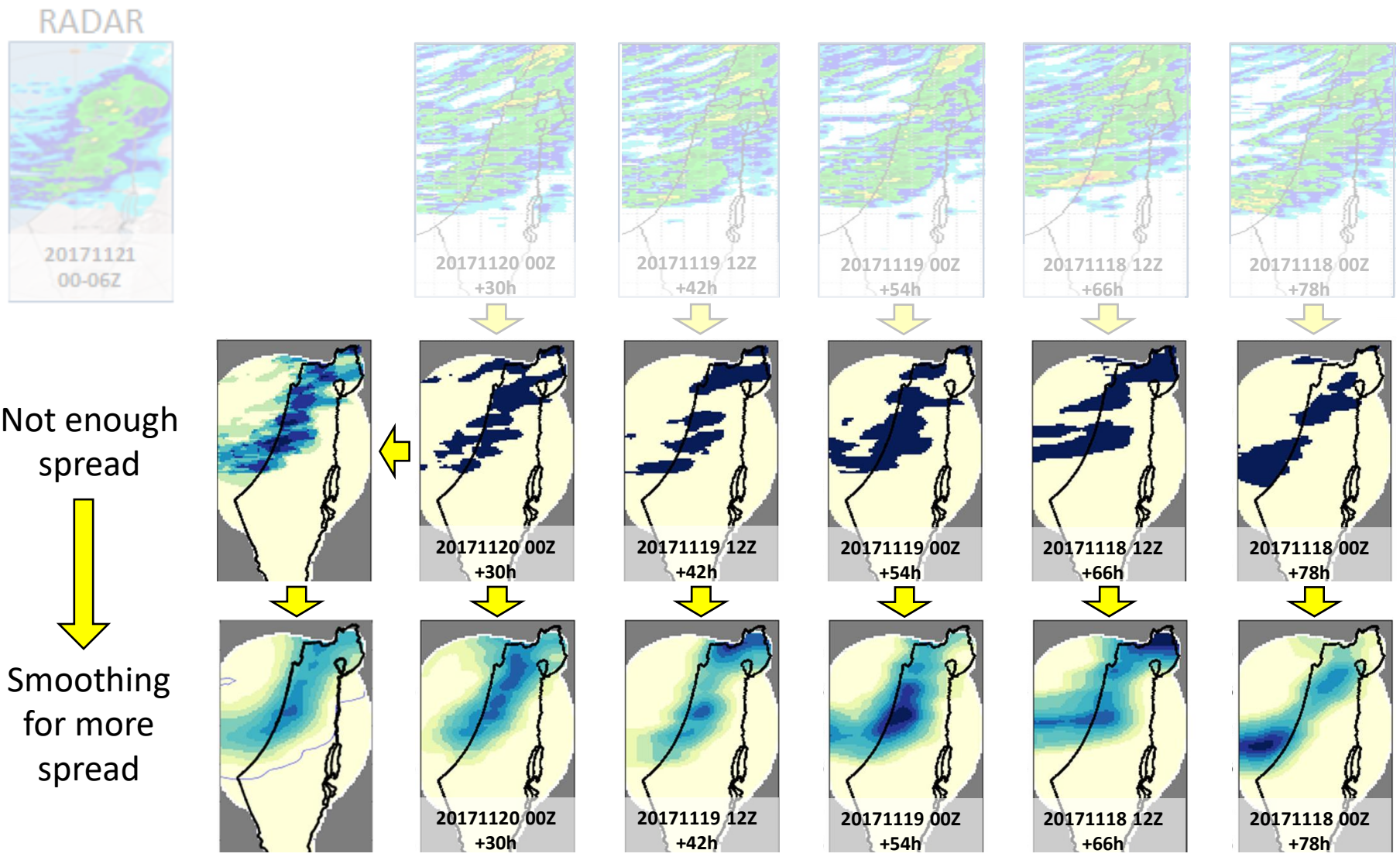

Not enough spread

Smoothing for more spread

# Time Lagged Ensemble for precipitation



# Time Lagged Ensemble for precipitation



# Outline

What is time lagged ensemble for precipitation?

What is the role of additional smoothing?

Smoothing plays the role of additional ensemble members (although worse)

Weak smoothing→ not enough spread → many false alarms

Strong smoothing→ no sharpness → the forecast is not useful

**What is the optimal smoothing?**

# Outline

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# Outline

What is time lagged ensemble for precipitation?

What is the role of additional smoothing?

**Precipitation verification using:**

- Reliability
- ROC area
- FSS

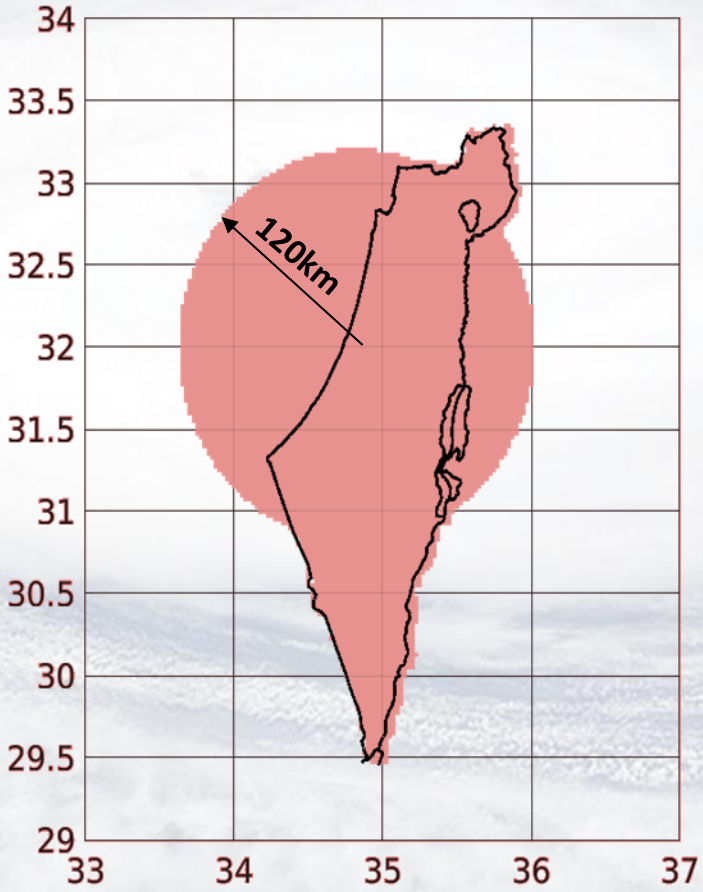
$\Rightarrow$ Optimal smoothing radius

Typical spatial error

Optimal probability forecast

# Verification domain

Period:
Dec-Feb 2017
Dec-Feb 2018



# Outline

What is time lagged ensemble for precipitation?

What is the role of additional smoothing?

Precipitation verification using:

- **Reliability**
- ROC area
- FSS

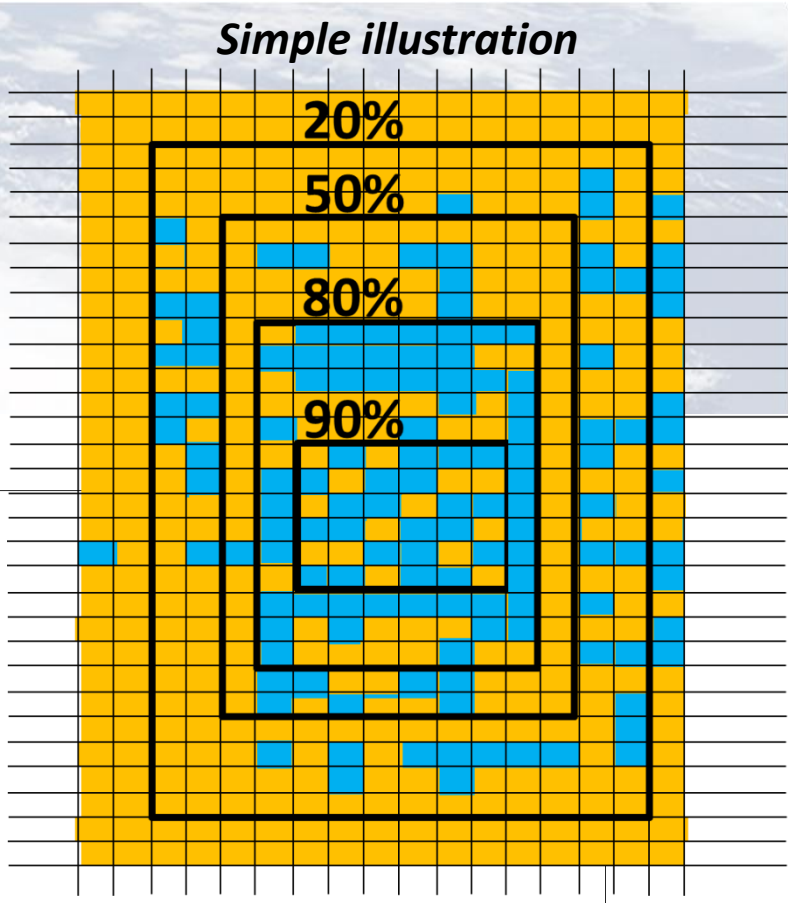
⇒ Optimal smoothing radius

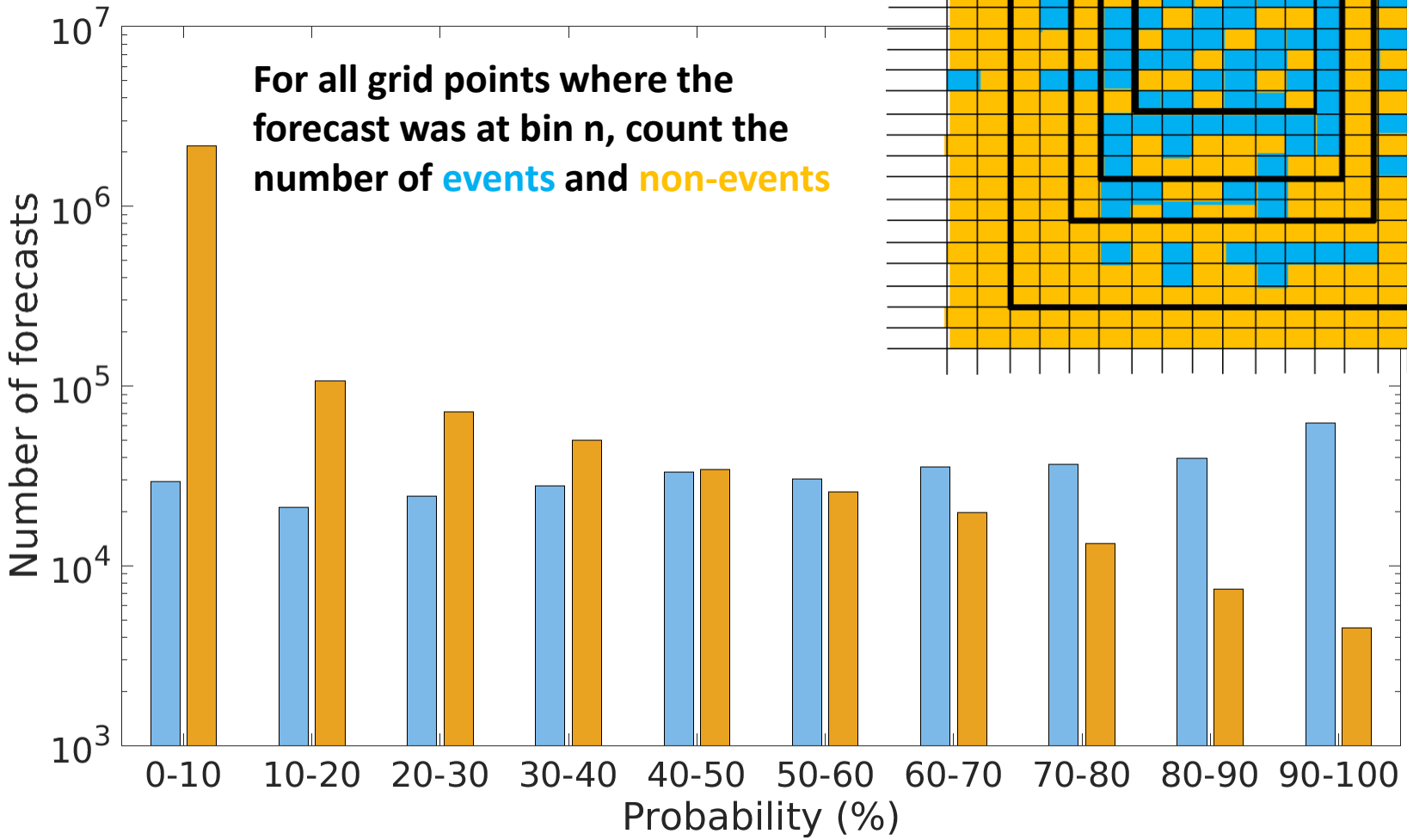
Typical spatial error

Optimal probability forecast

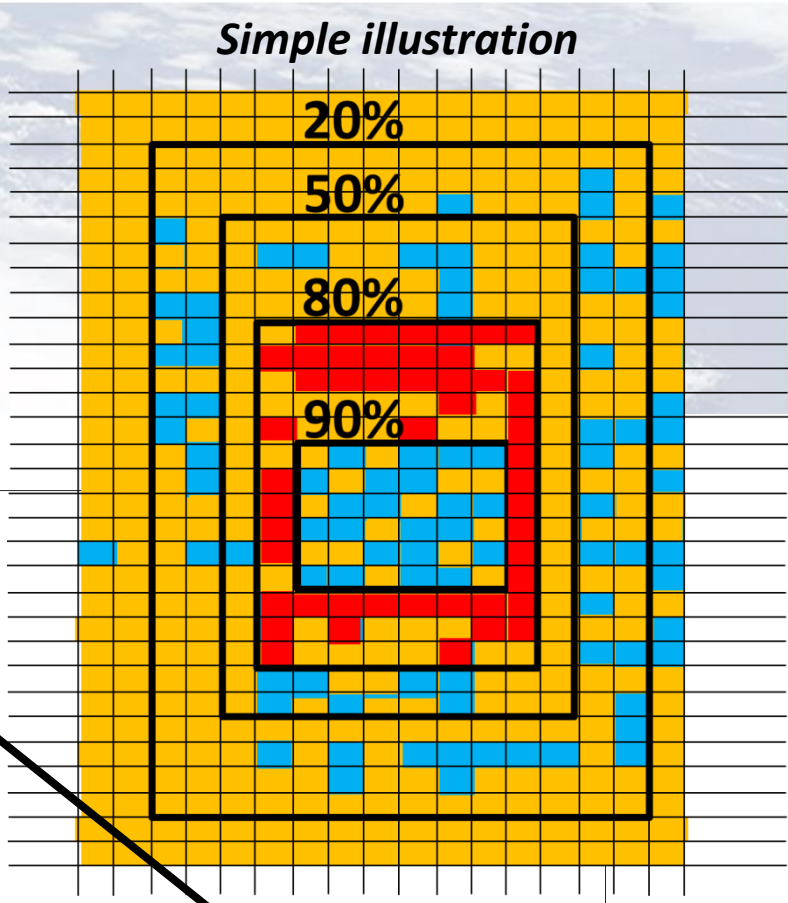
# **Reliability**: explanation

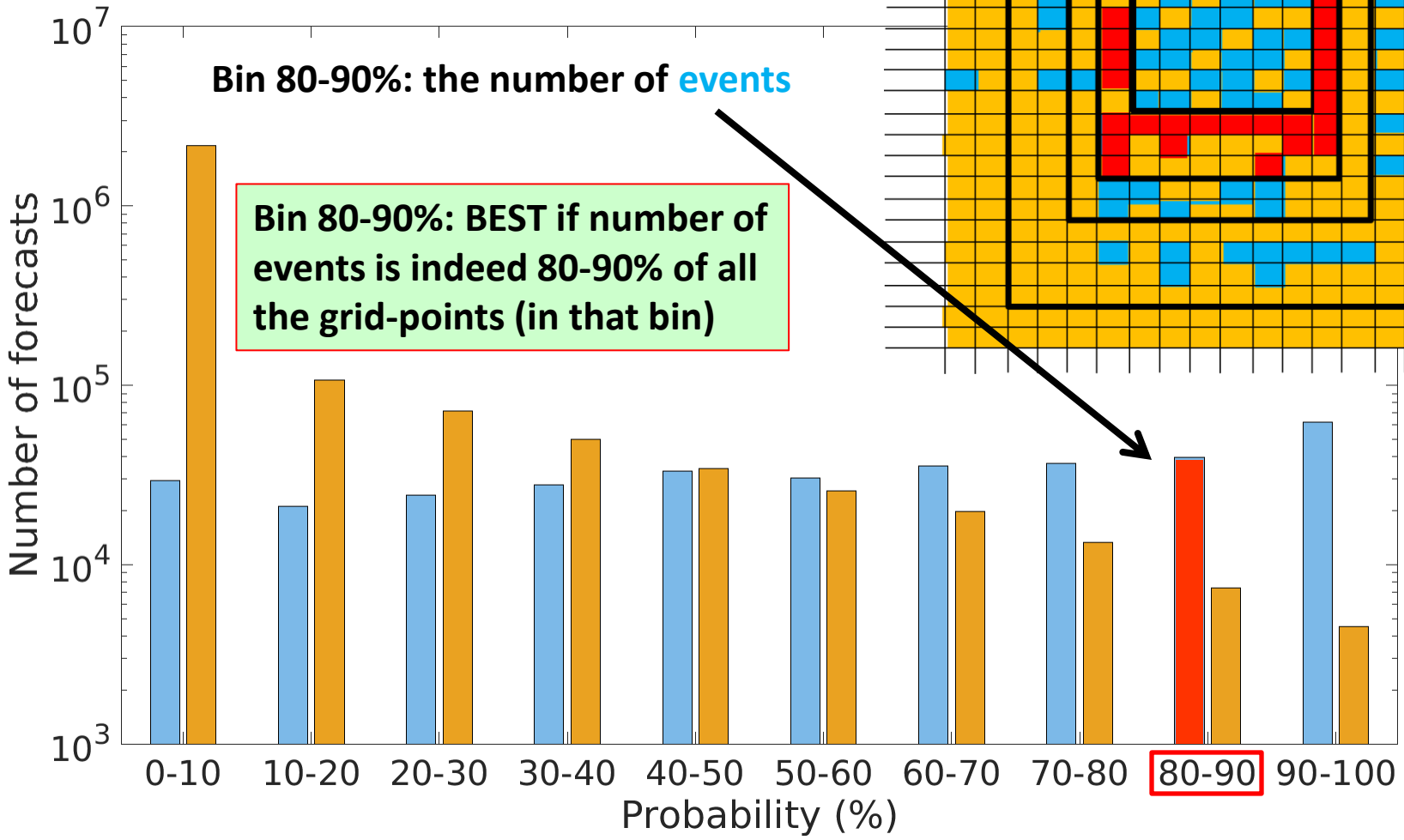
Example: Lead time ensemble for +18-24h
Smoothing radius: 20km
Event: >1mm/6h
Non-Event: <1mm/6h



# **Reliability**: explanation



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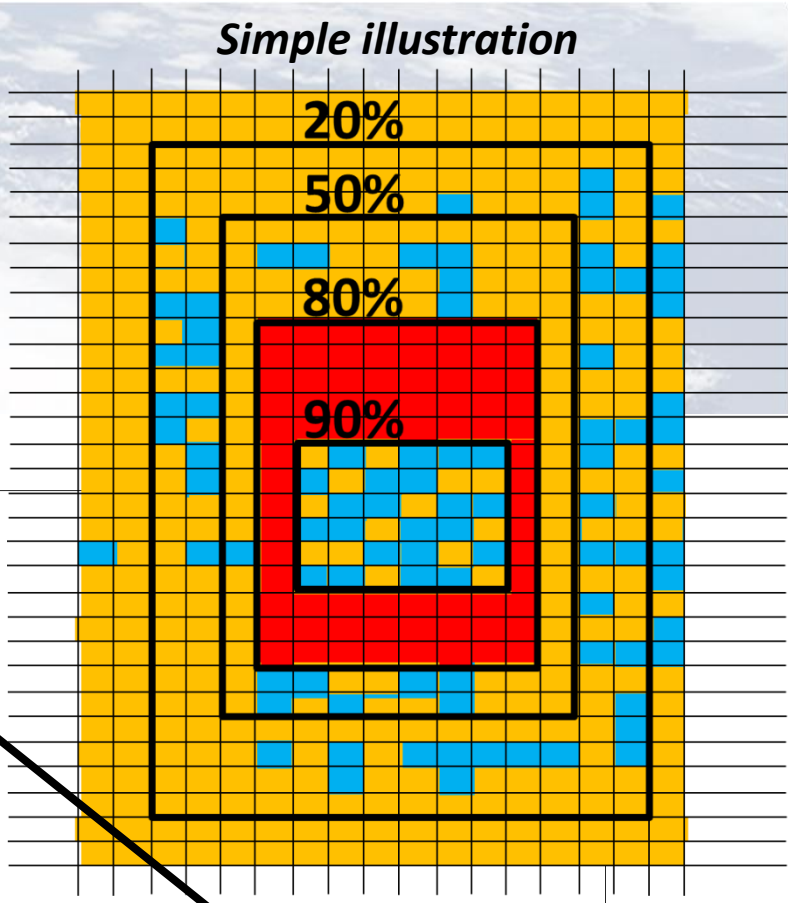
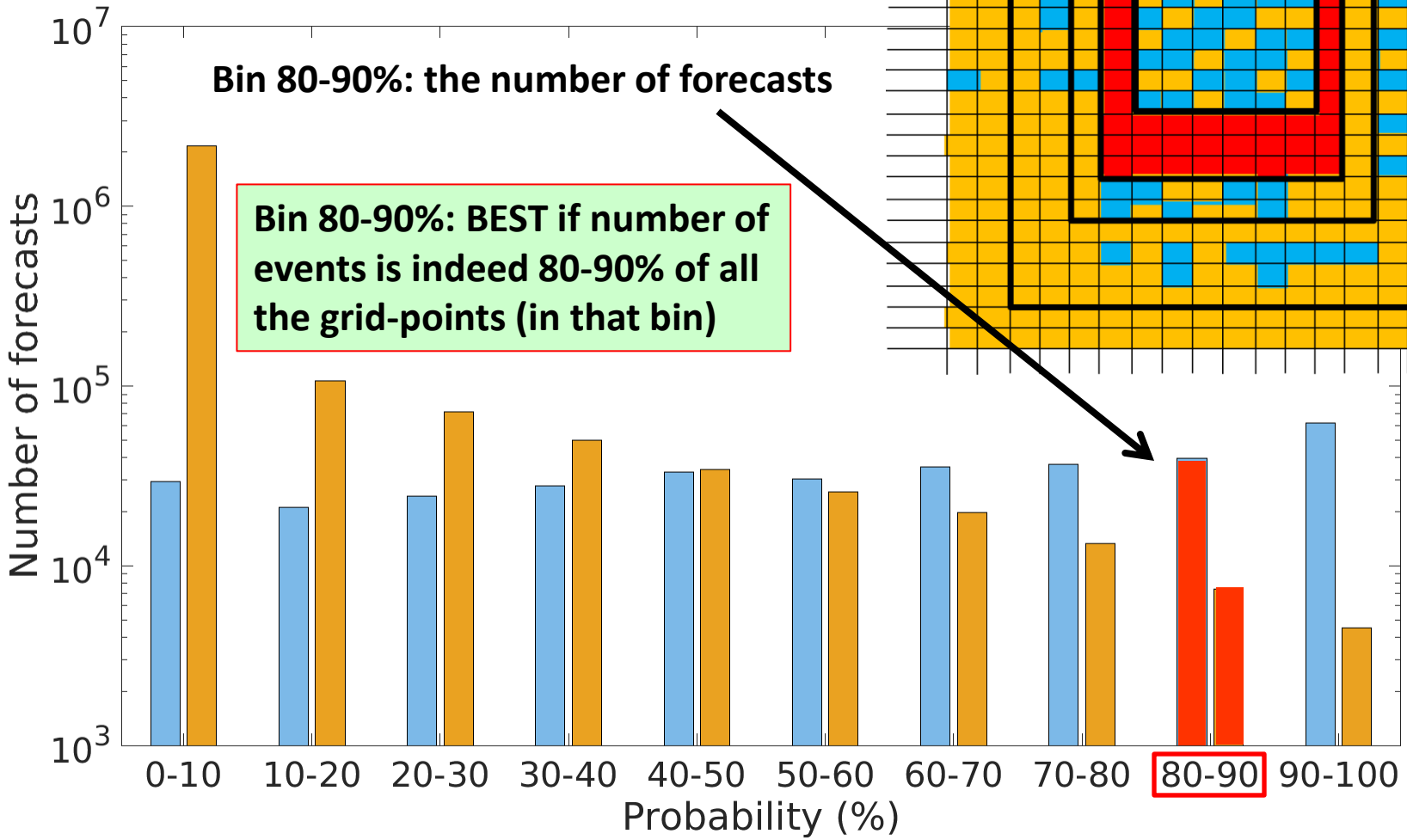
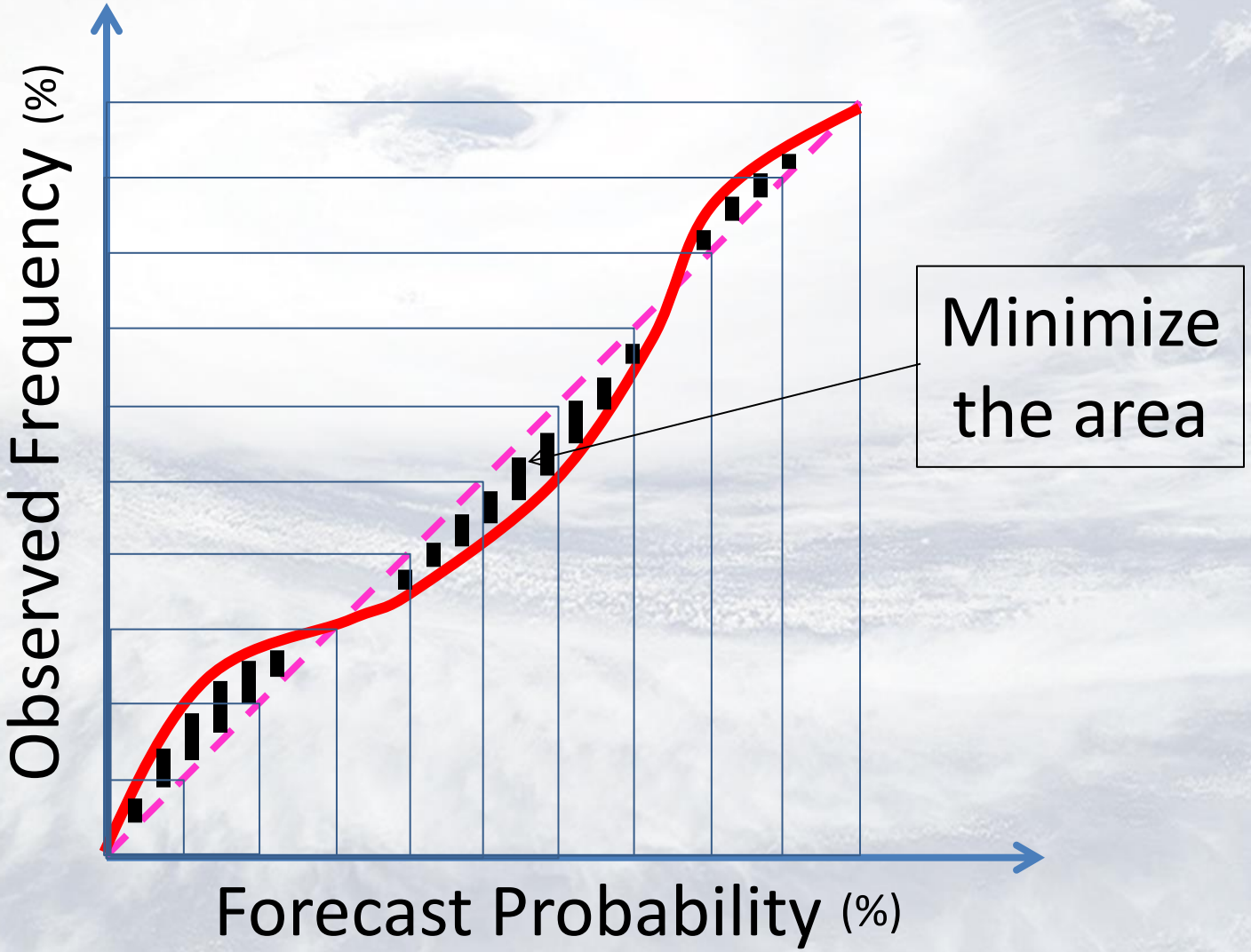


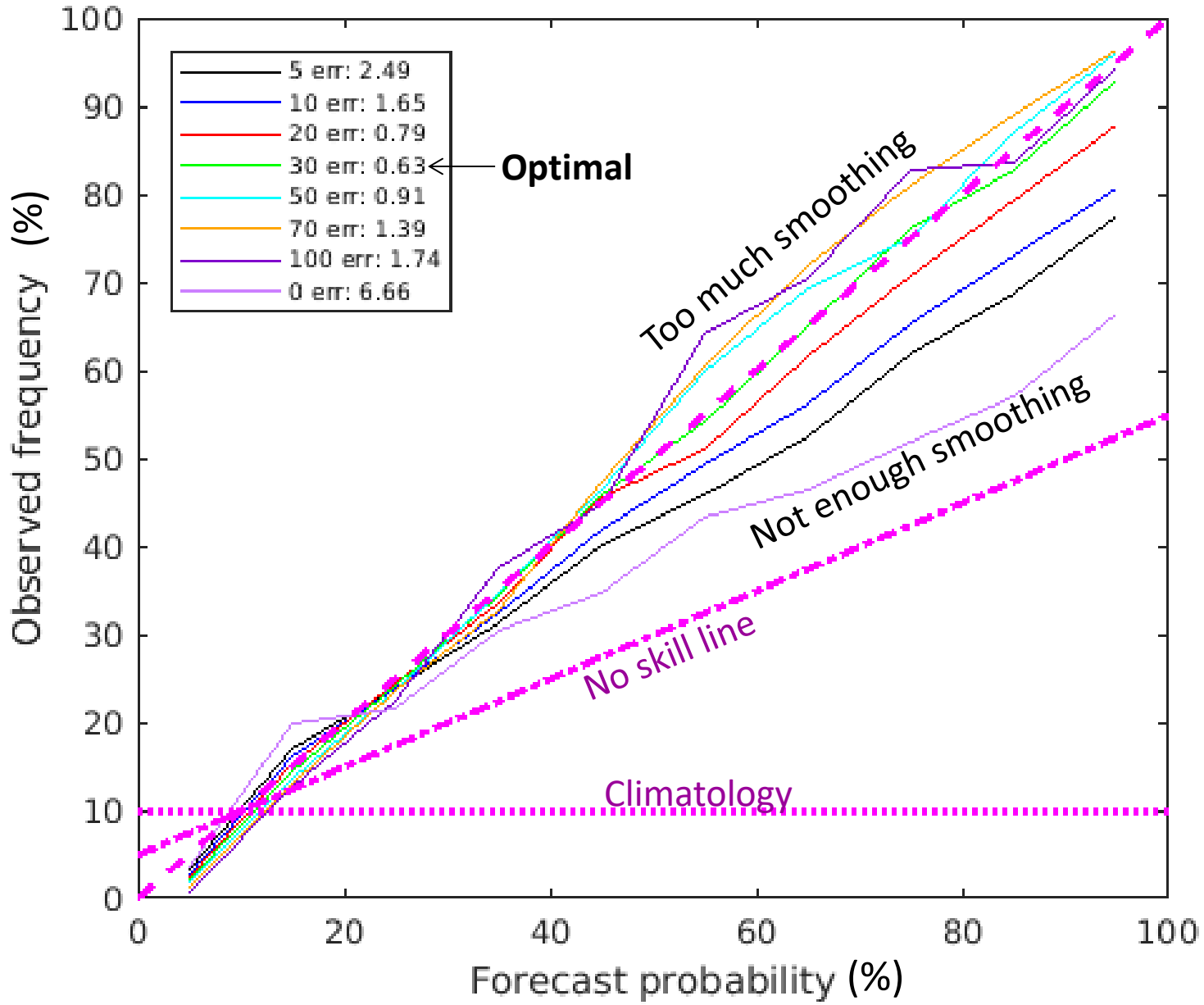
# Reliability diagram

**If for all occasions when forecast probability $P_k$ is predicted, the observed frequency of the event is $\overline{O_k} = P_k$ then the forecast is said to be reliable. Similar to bias for a continuous variable**



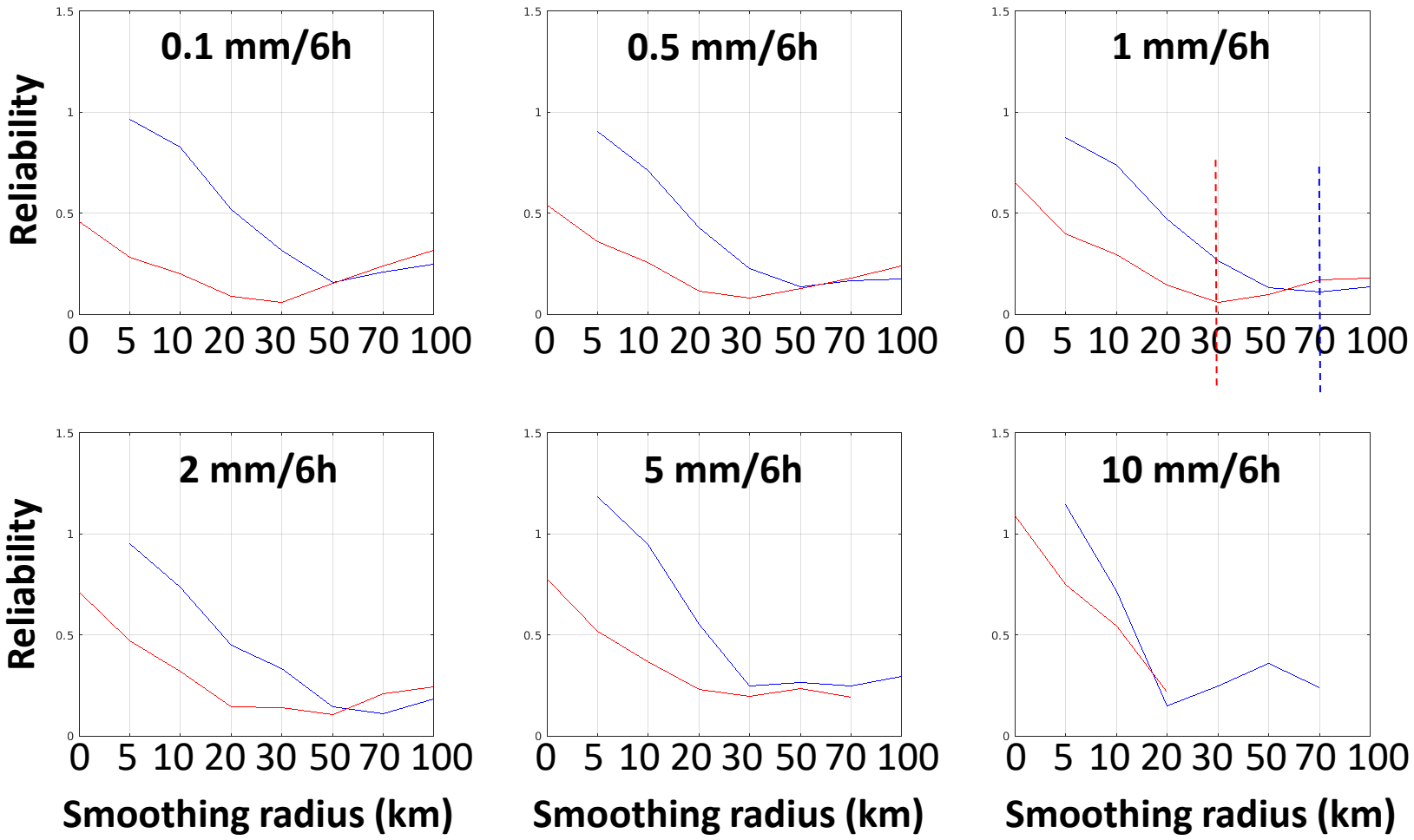
# Reliability diagram

Example: Lead time ensemble for +18-24h. Smoothing radius: 20km. Event: >1mm/6h



# Reliability vs. Smoothing radius

Example: +18-24h




Deterministic  Time-lagged ensemble

**Optimal smoothing radius vs. threshold and forecast range**

# Outline

What is time lagged ensemble for precipitation?

What is the role of additional smoothing?

**Precipitation verification using:**

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- **ROC area**
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⇒ Optimal smoothing radius

Typical spatial error

Optimal probability forecast

# From Reliability to ROC

- Reliability diagram – partitioning the data according to the forecast probability
- Suppose we partition according to observation – 2 categories, yes or no
- Look at distribution of forecasts separately for these two categories

⟹ **ROC** Measures "discrimination"

# **ROC**: explanation

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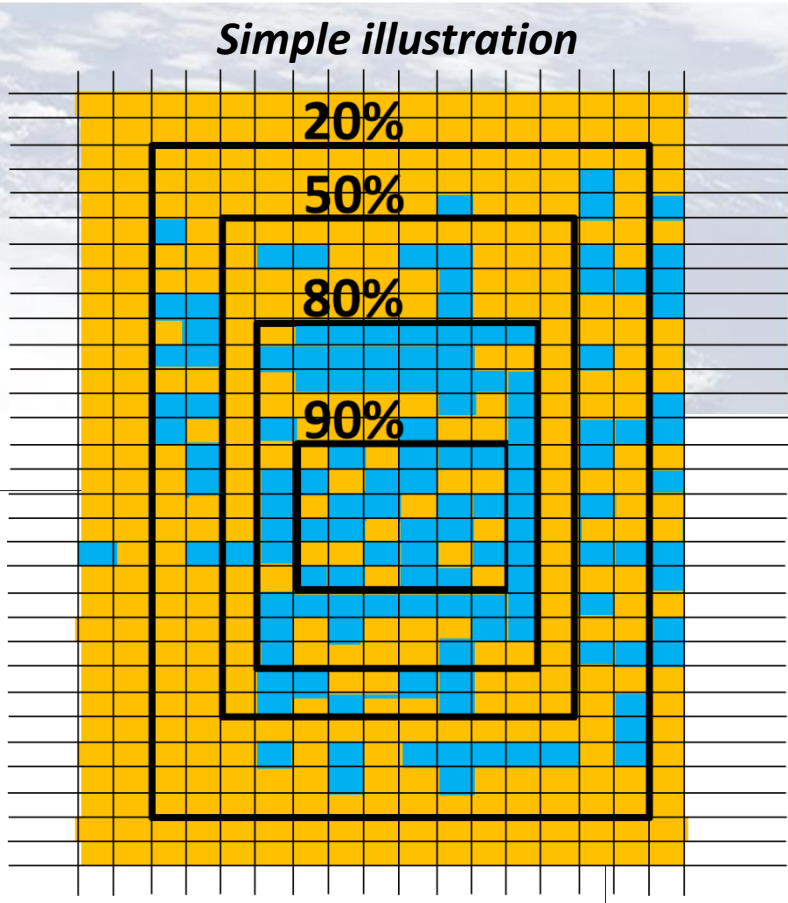
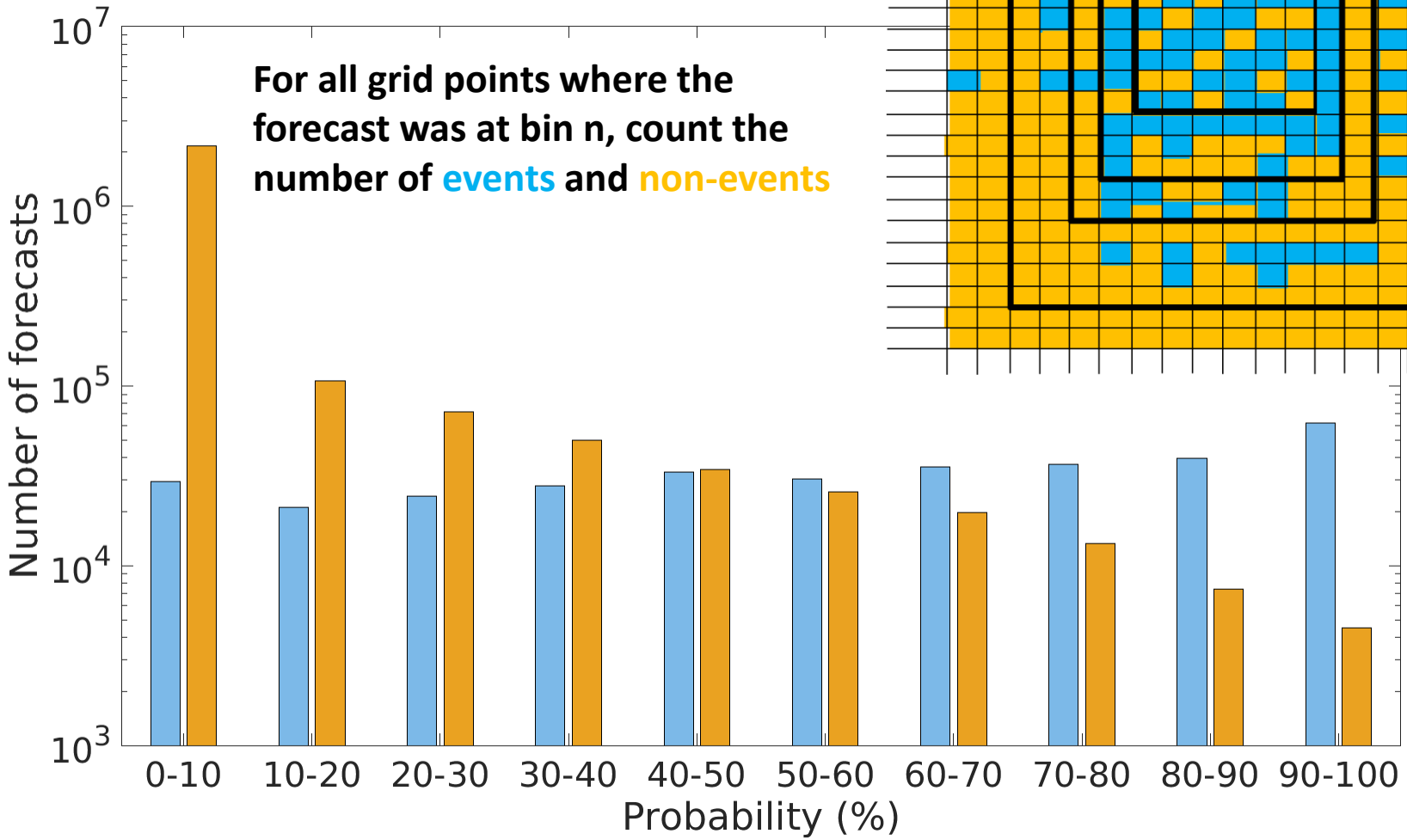
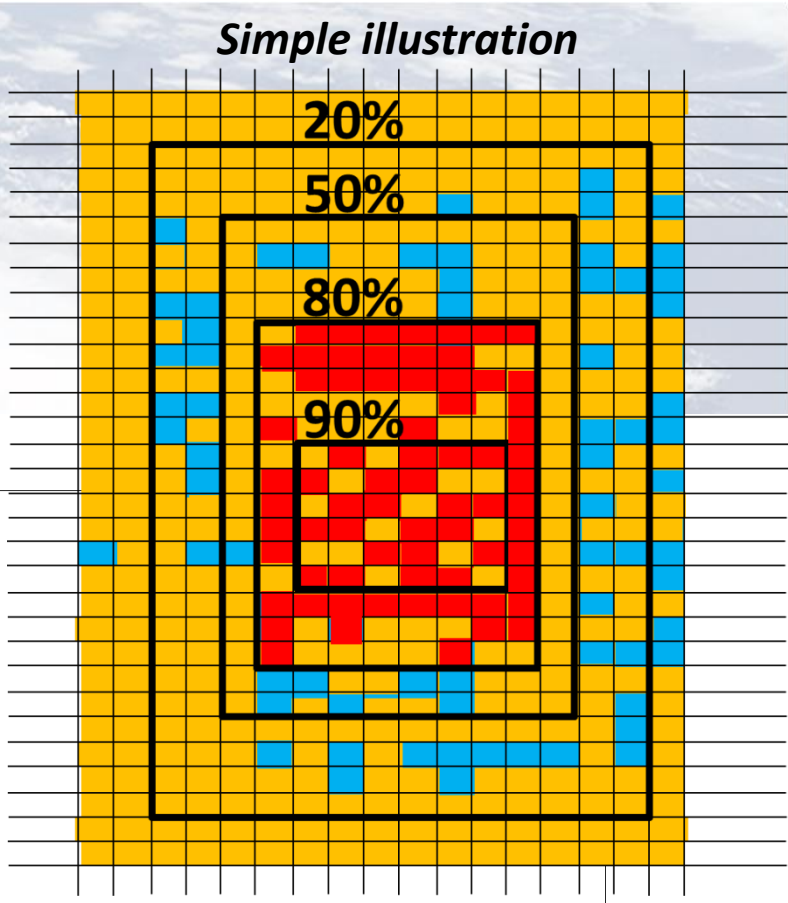


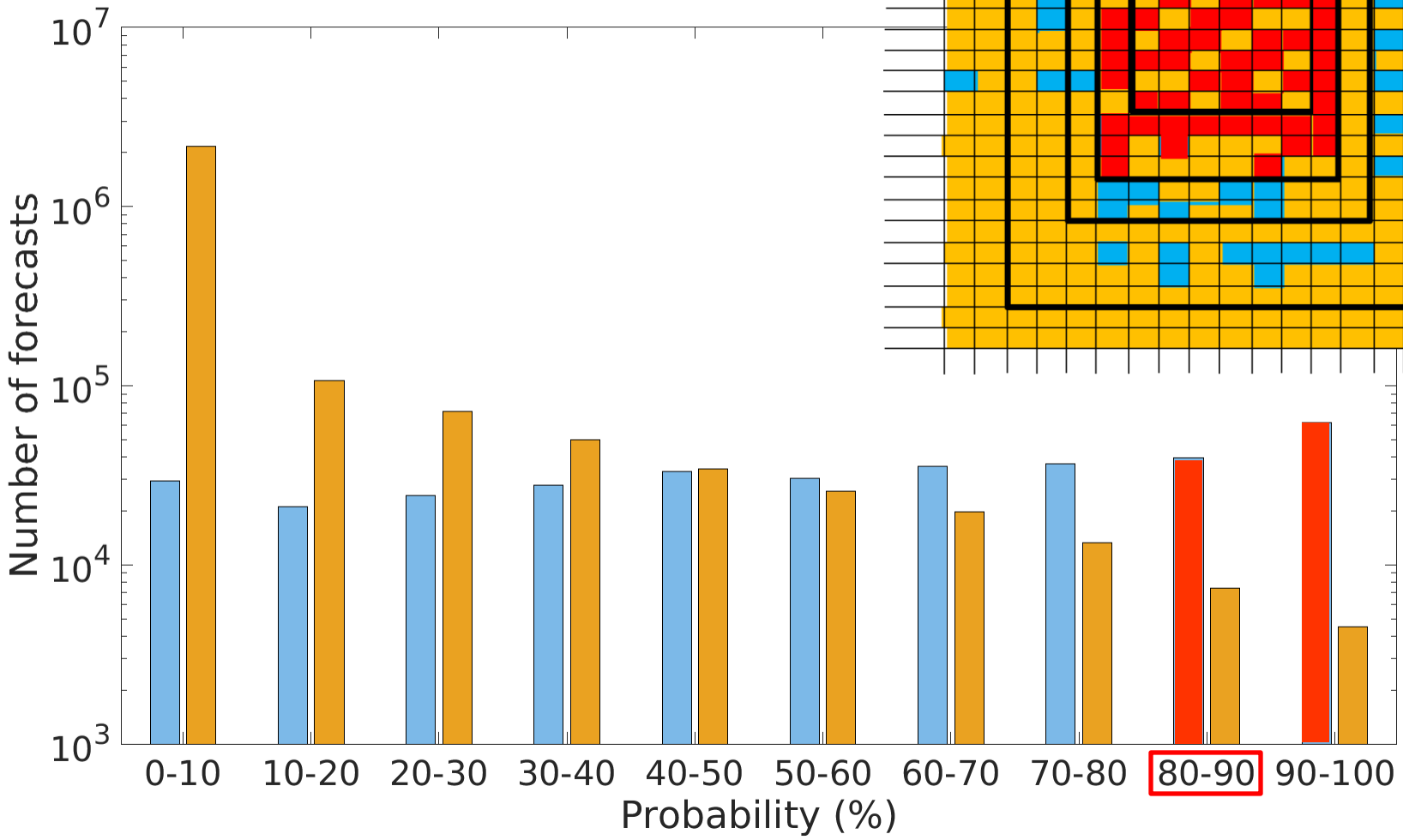



# **ROC**: explanation

**Hit Rate**
(for bin n)

$$H_n = \frac{\sum_{i=n}^{10} Y_i}{\sum_{i=1}^{10} Y_i}$$



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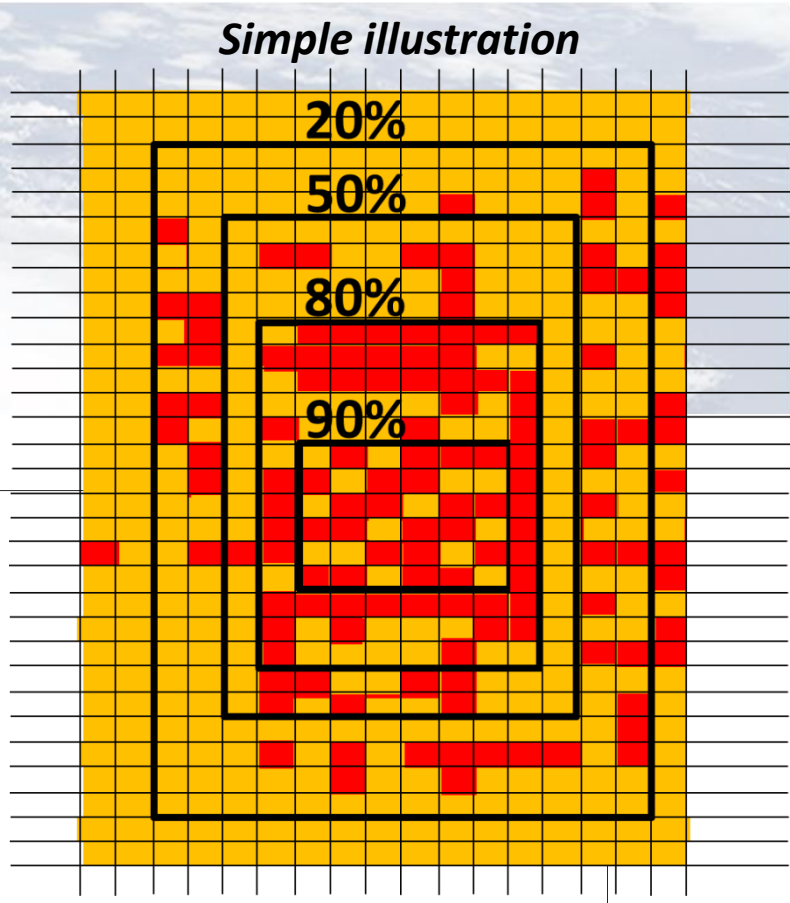


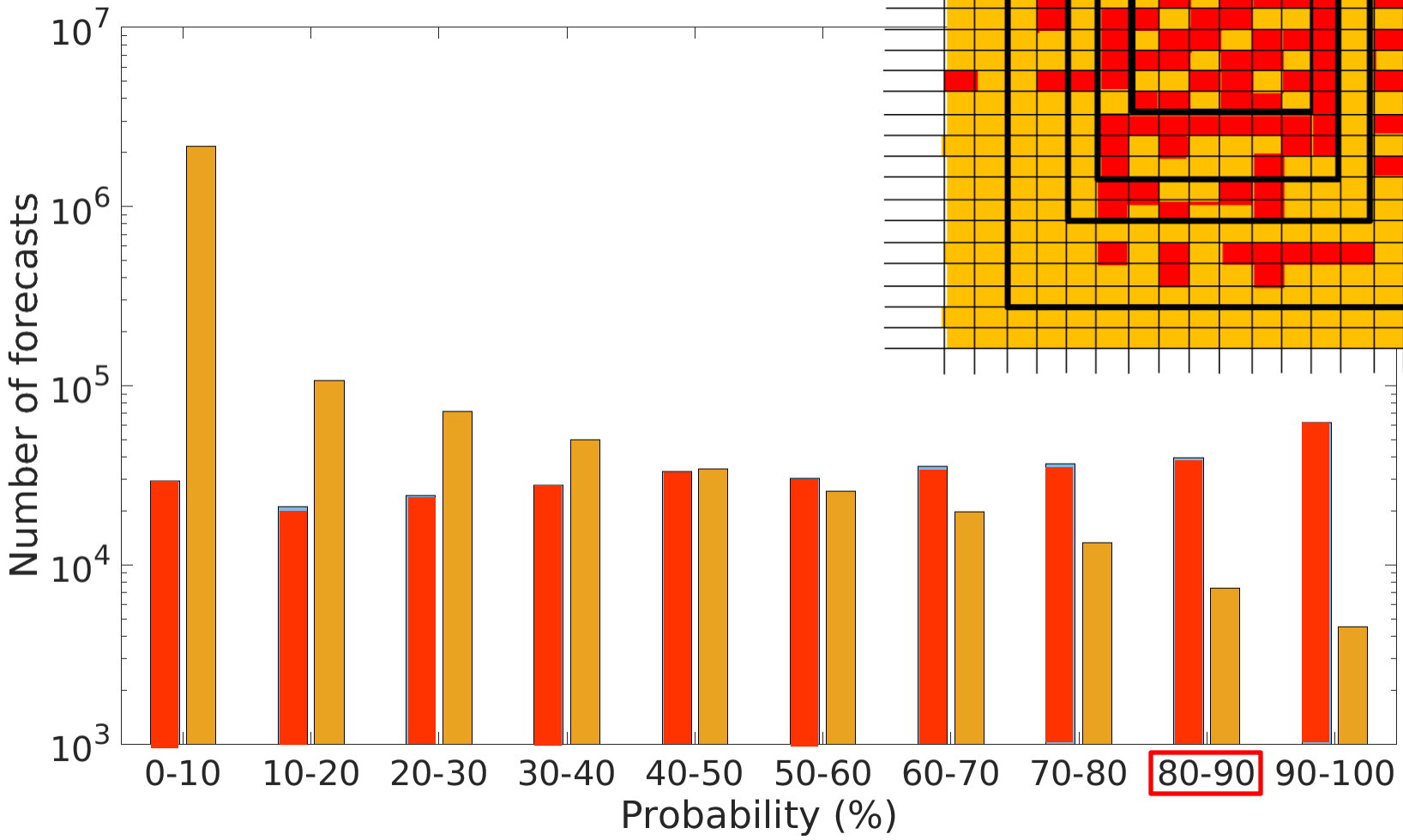

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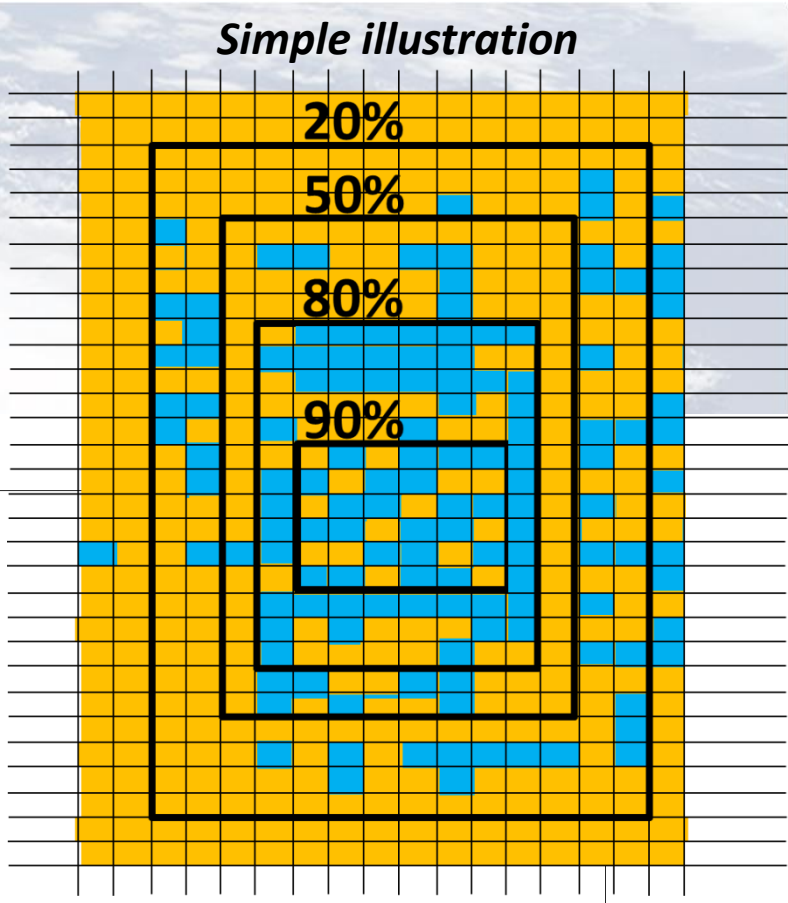
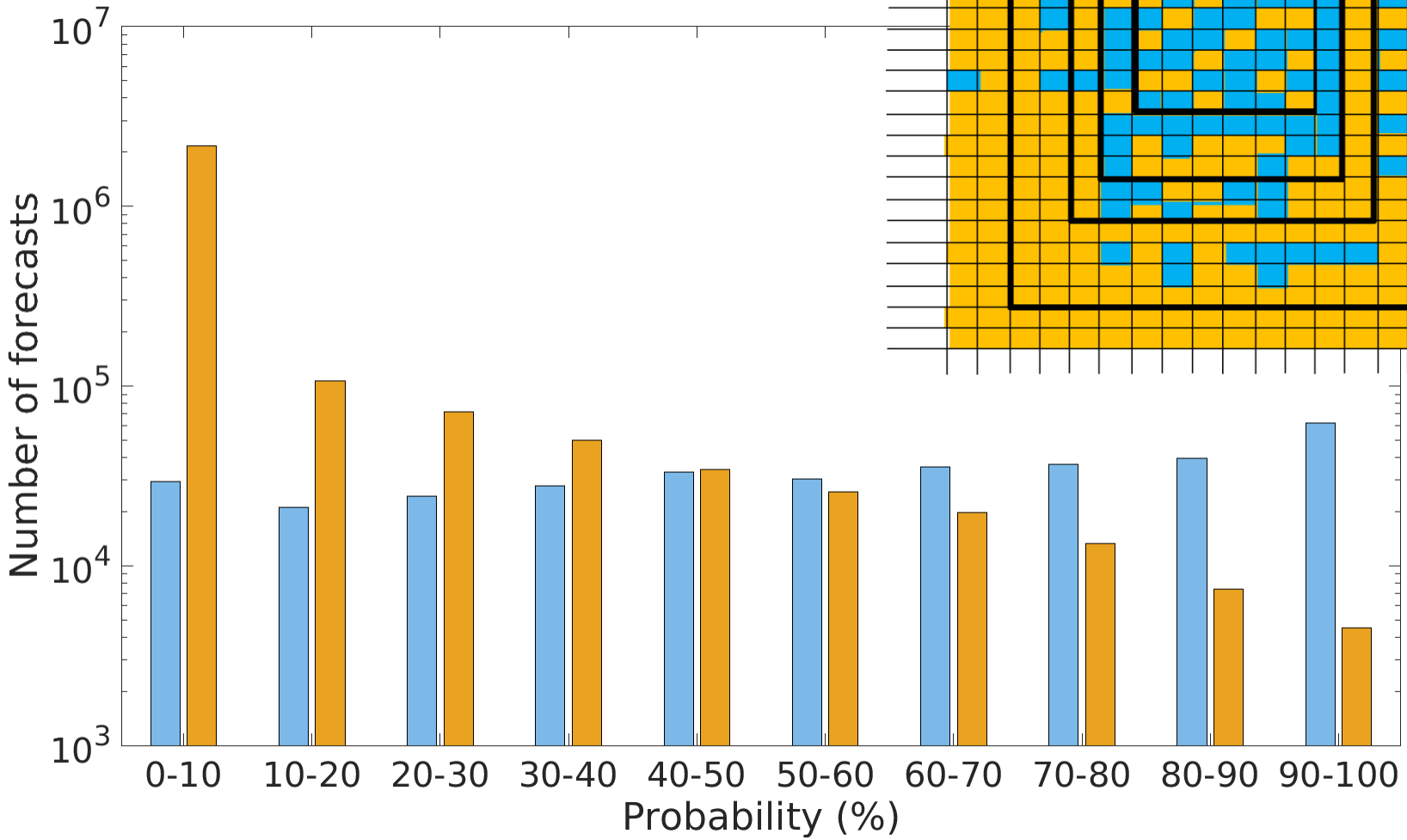
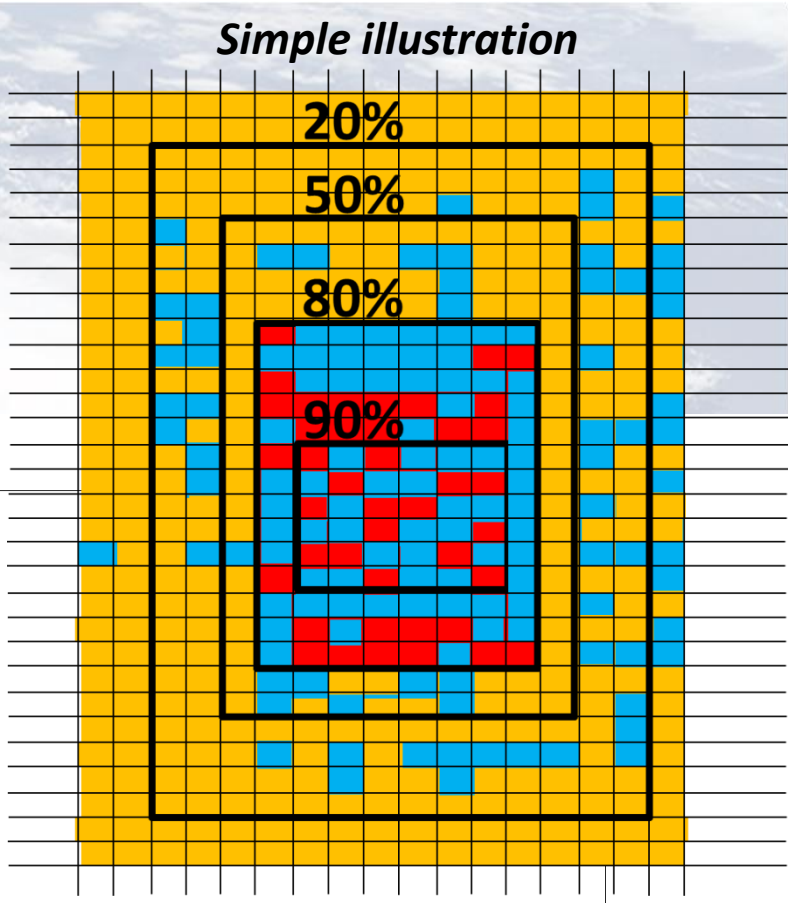


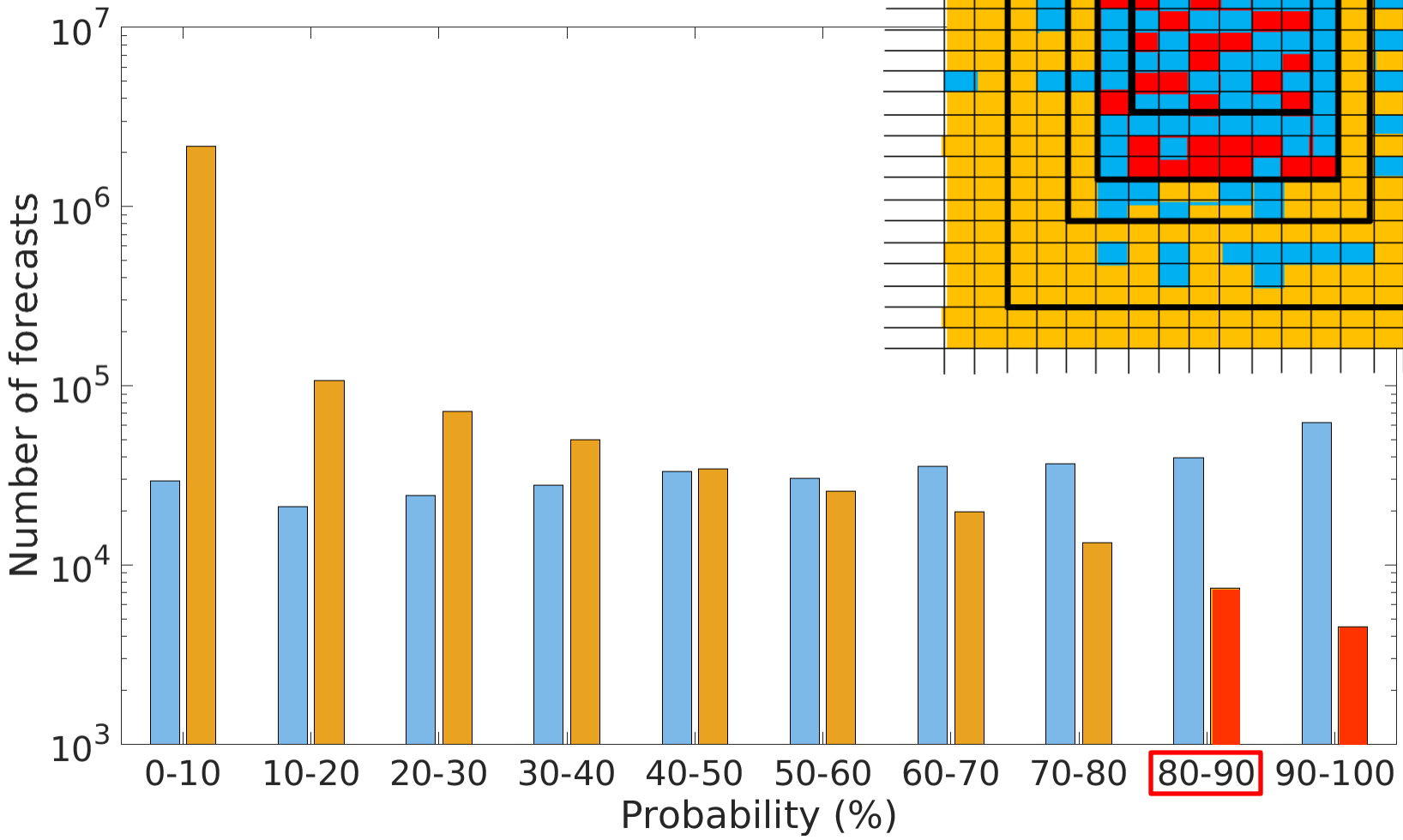



# **ROC**: explanation

**False Alarm**
(for bin n)

$$F_n = \frac{\sum_{i=n}^{10} N_i}{\sum_{i=1}^{10} N_i}$$



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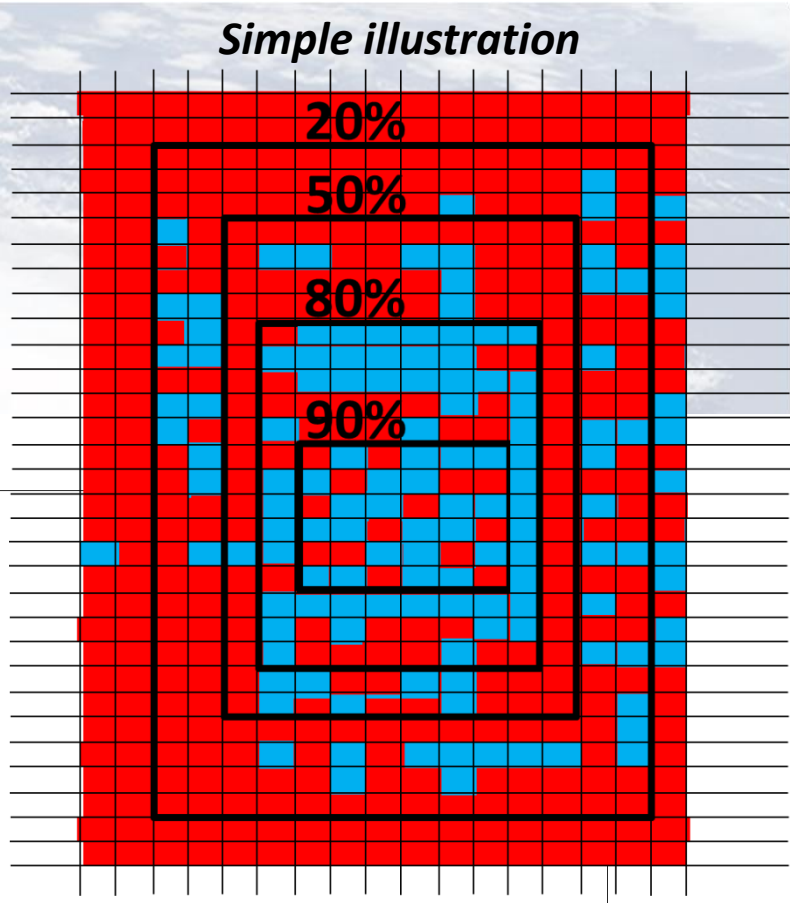
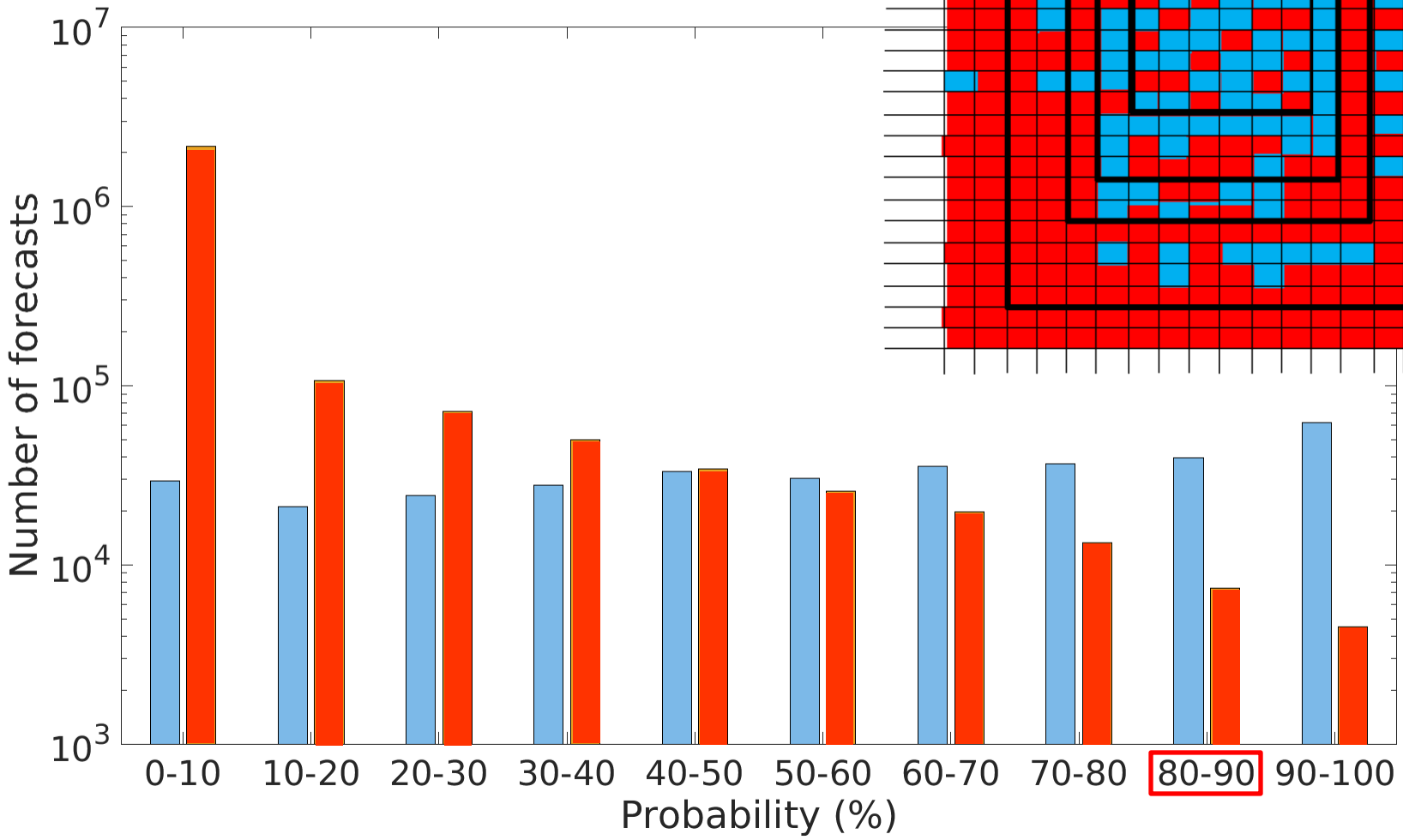
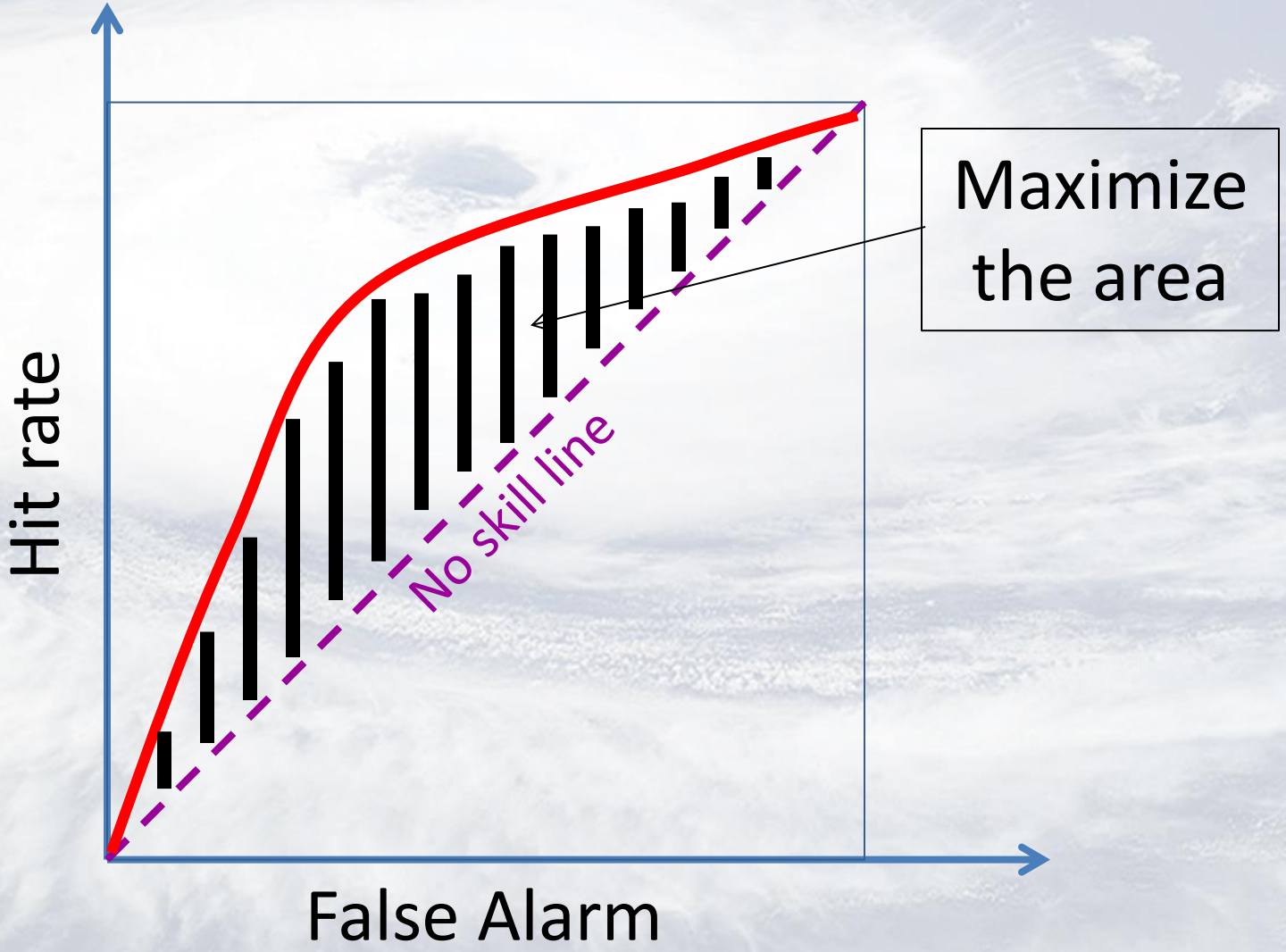


# ROC diagram



# ROC diagram

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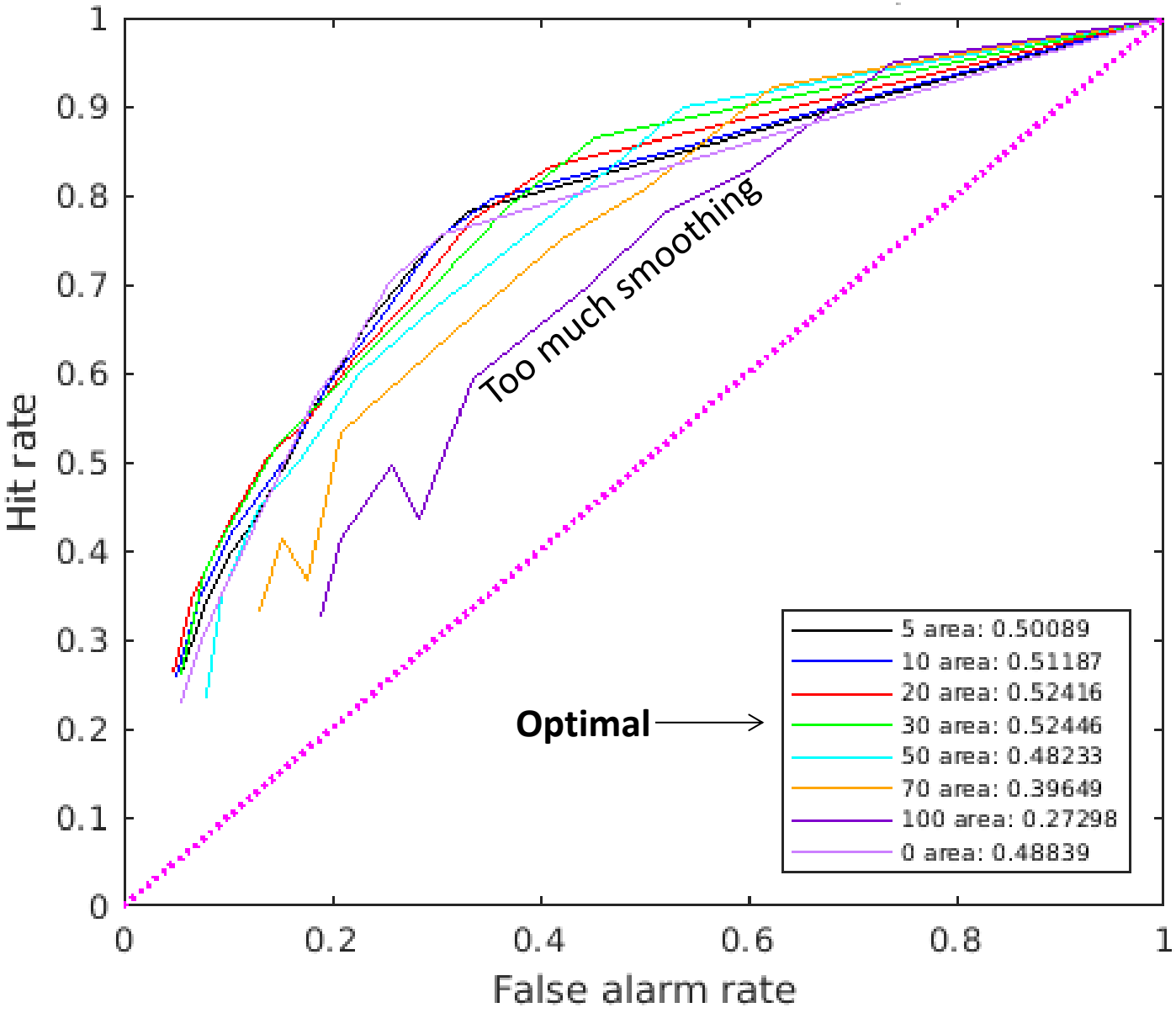
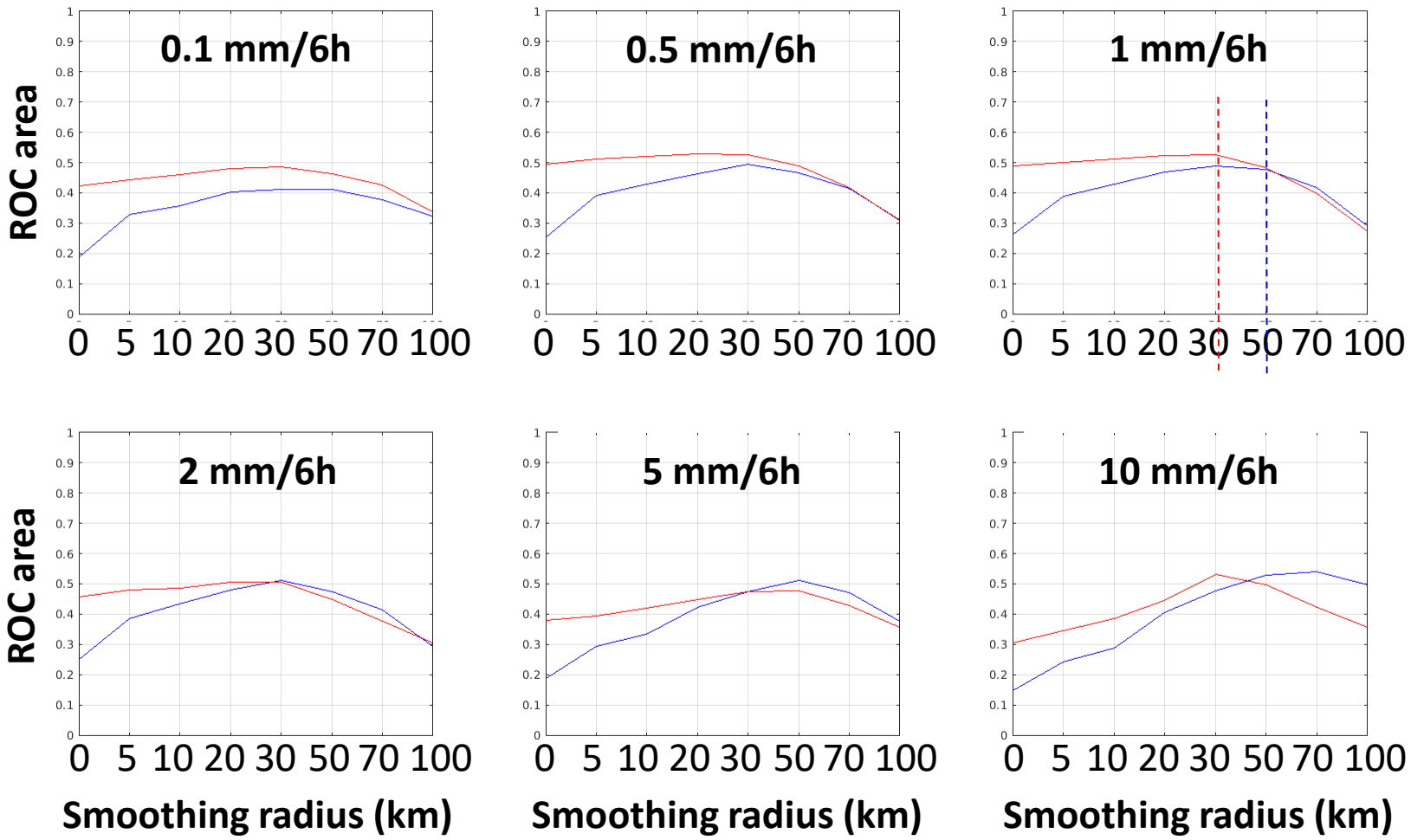


# ROC area vs. Smoothing radius

Example: +18-24h




Deterministic  Time-lagged ensemble

**Optimal smoothing radius vs. threshold and forecast range**

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$\Rightarrow$ Optimal smoothing radius

Typical spatial error

Optimal probability forecast

# Fractional Skill Score (FSS)

For every threshold and every smoothing radius:

Brier score: $$FBS(Tr,R) = \frac{1}{N}\sum_{i,j}\left(M_{i,j} - O_{i,j}\right)^2$$

Worst Brier score: $$FBS_{worst}(Tr,R) = \frac{1}{N}\sum_{i,j}\left({M_{i,j}}^2 + {O_{i,j}}^2\right)$$

Fractional Skill Score: $$FSS(Tr,R) = 1 - \frac{FBS(Tr,R)}{FBS_{worst}(Tr,R)}$$

$M_{i,j}$ - forecast probability to path the threshold

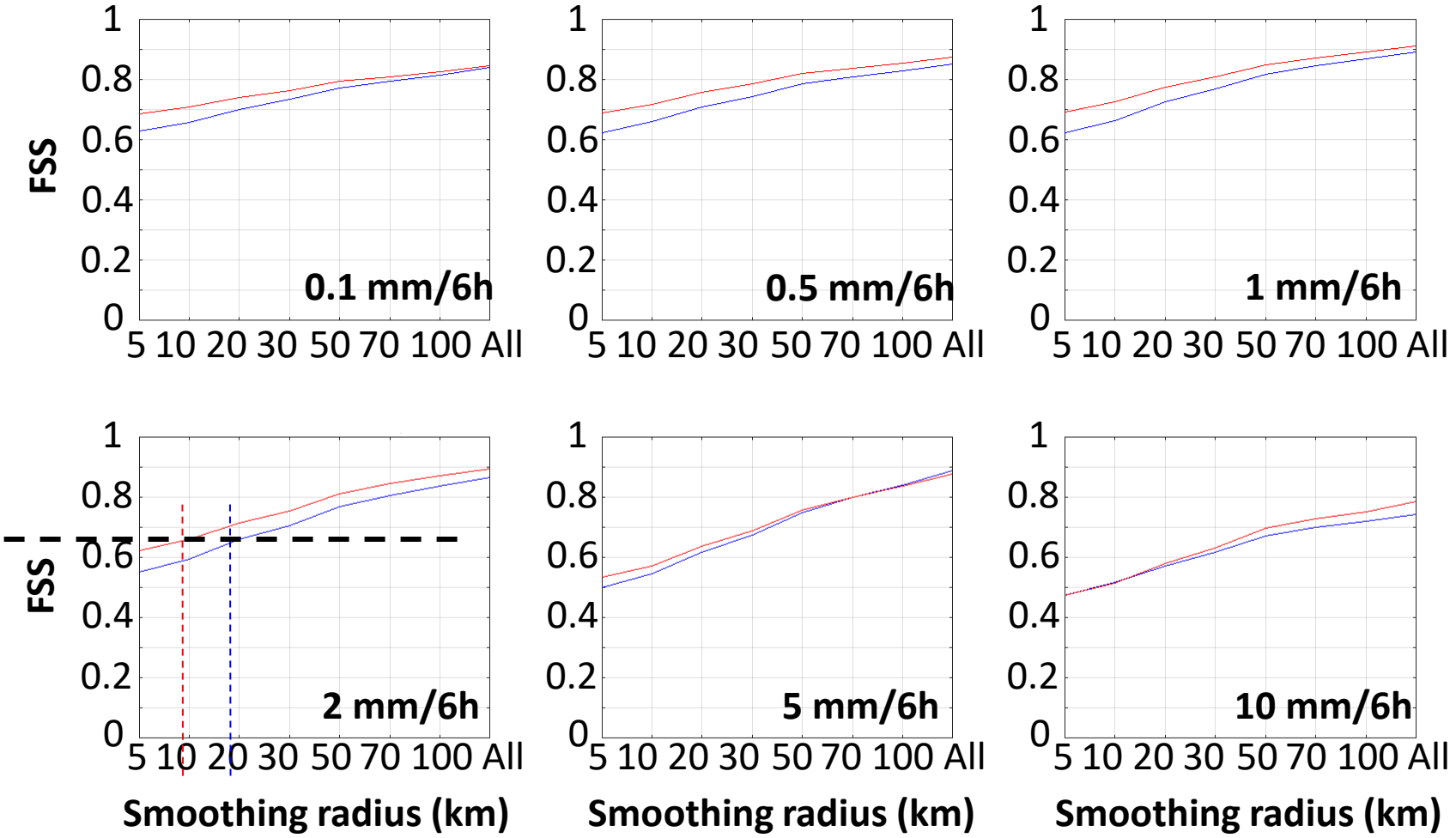
$O_{i,j}$ - fraction of observations in surrounding R which passed the threshold

| $FSS$=1 | $FSS$=0 |
|---|---|
| BEST | WORST |

***Roberts and Lean (2008), Ebert (2008)***

# FSS vs. Smoothing radius

Example: +18-24h

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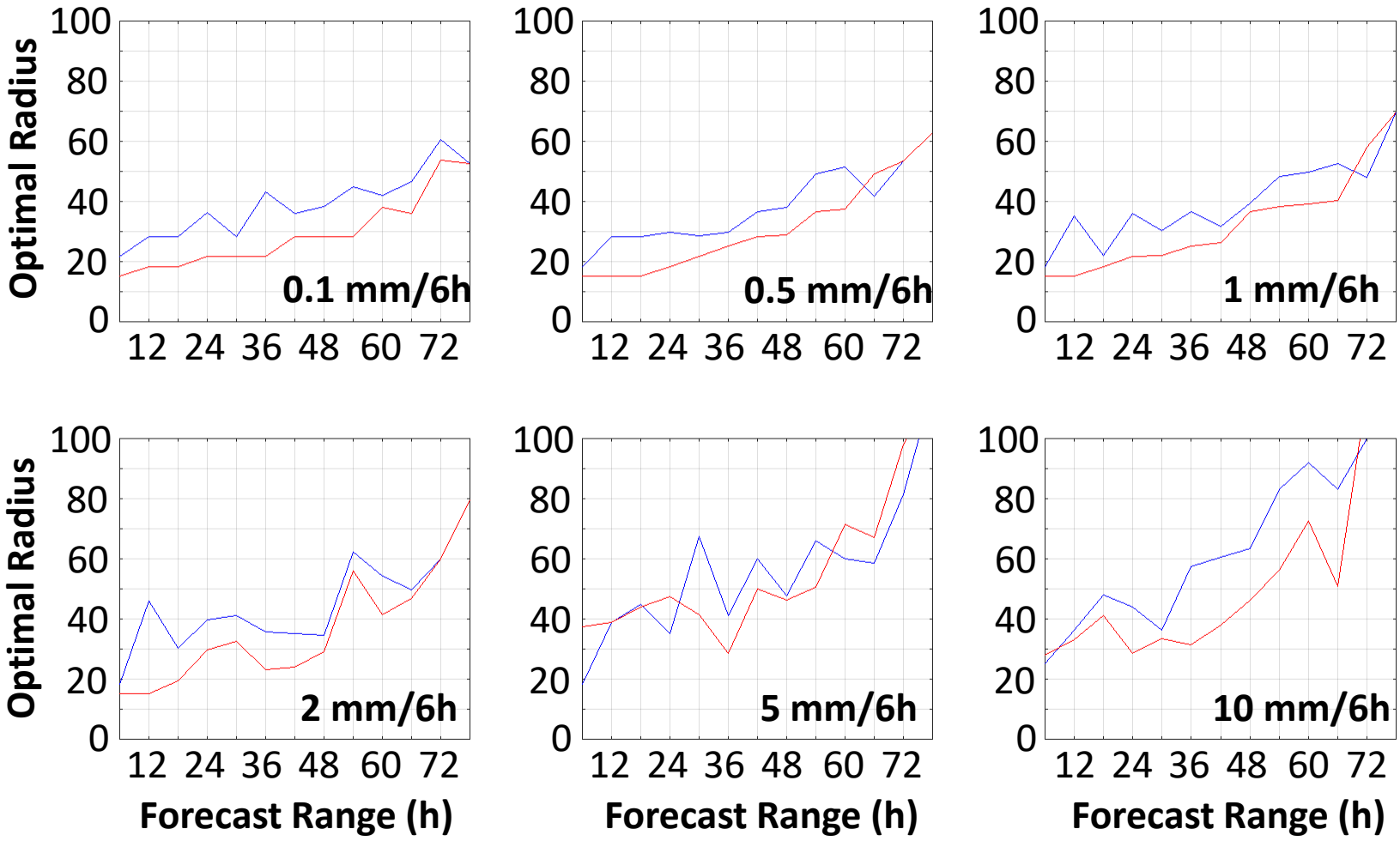
# Optimal Smoothing radius vs. Forecast range

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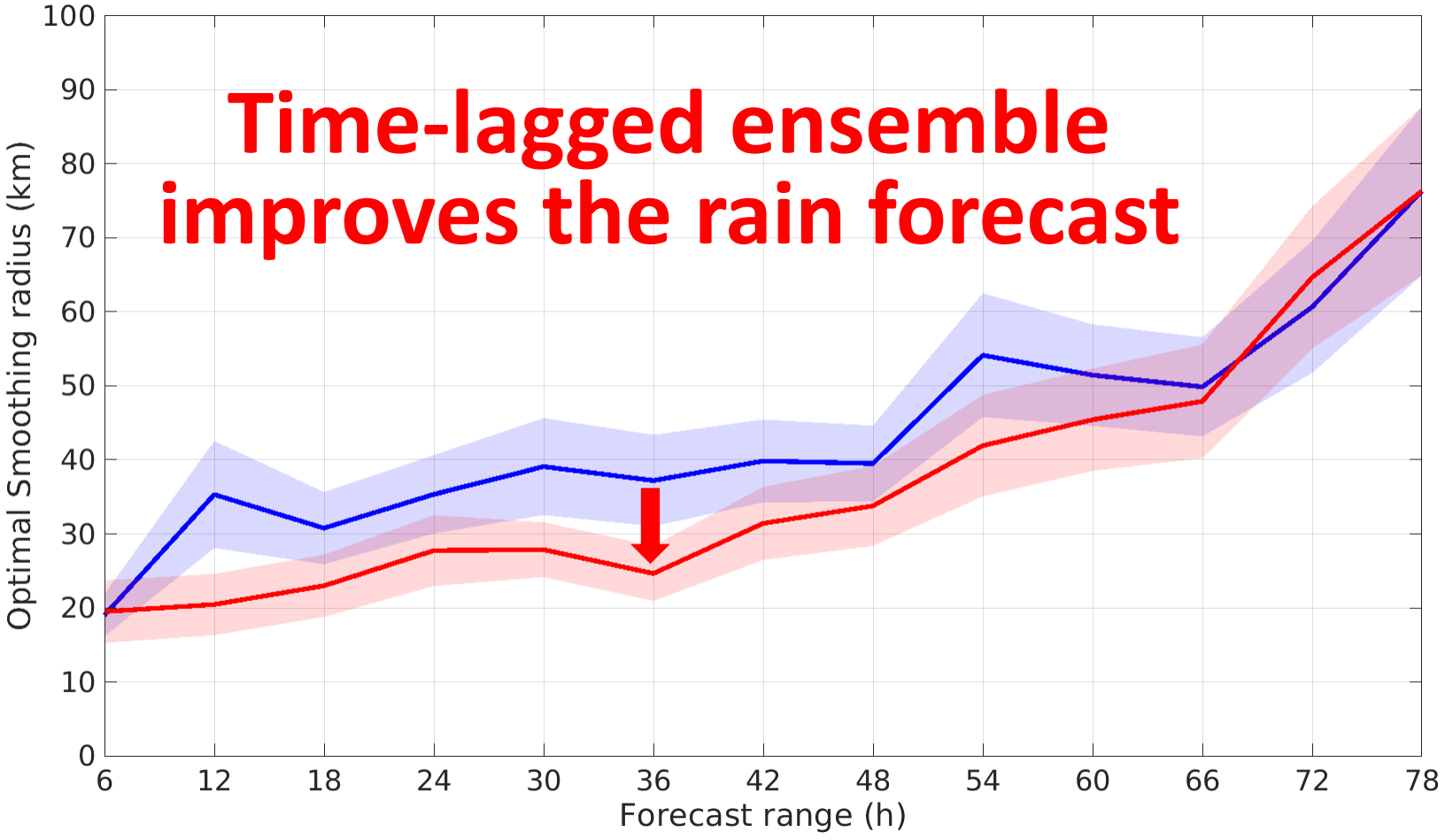
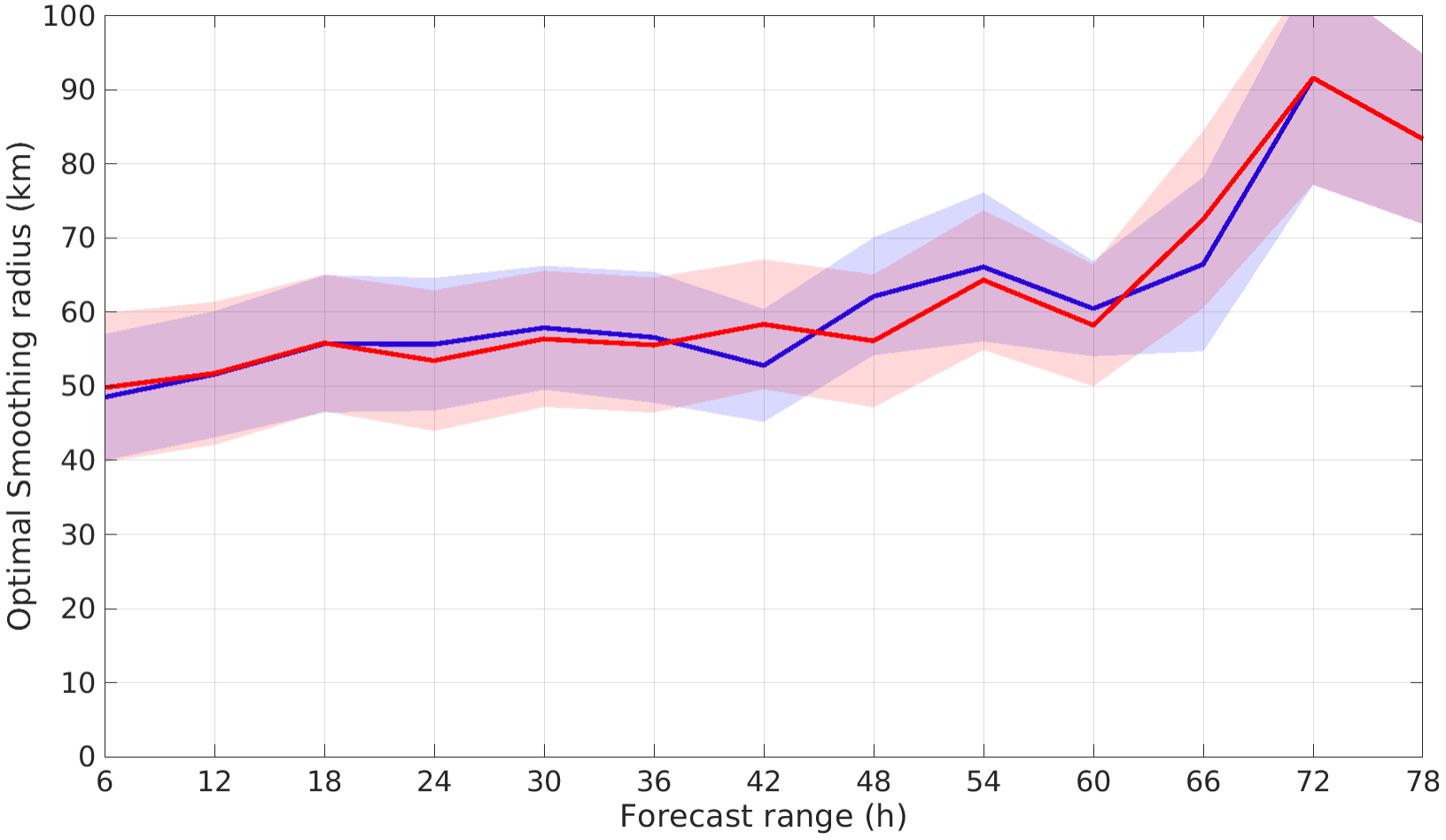
# Typical Spatial Error vs. Forecast range for COSMO-2.8km (avg. over thresholds)

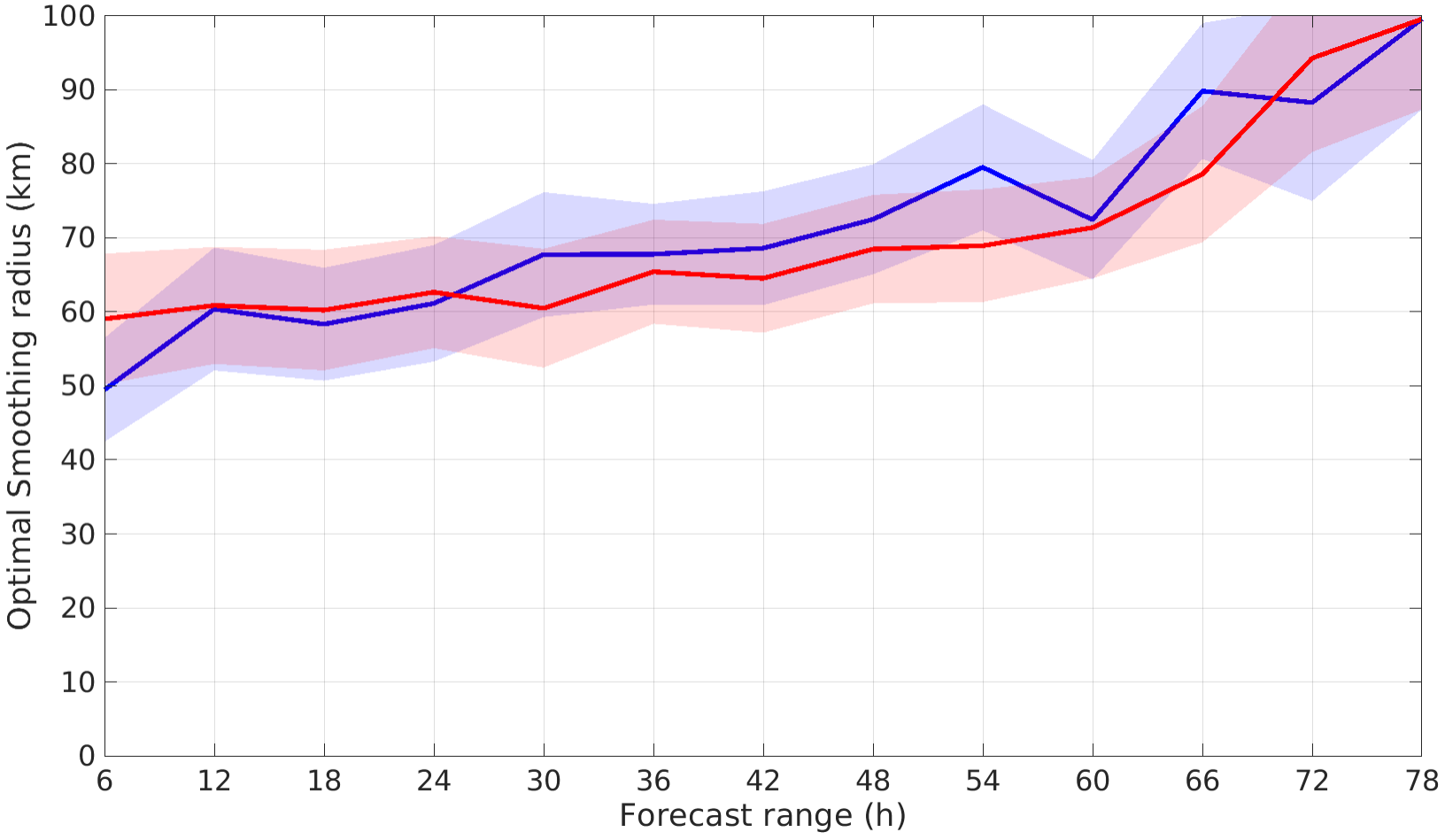


# Typical Spatial Error vs. Forecast range for IFS-9km (avg. over thresholds)



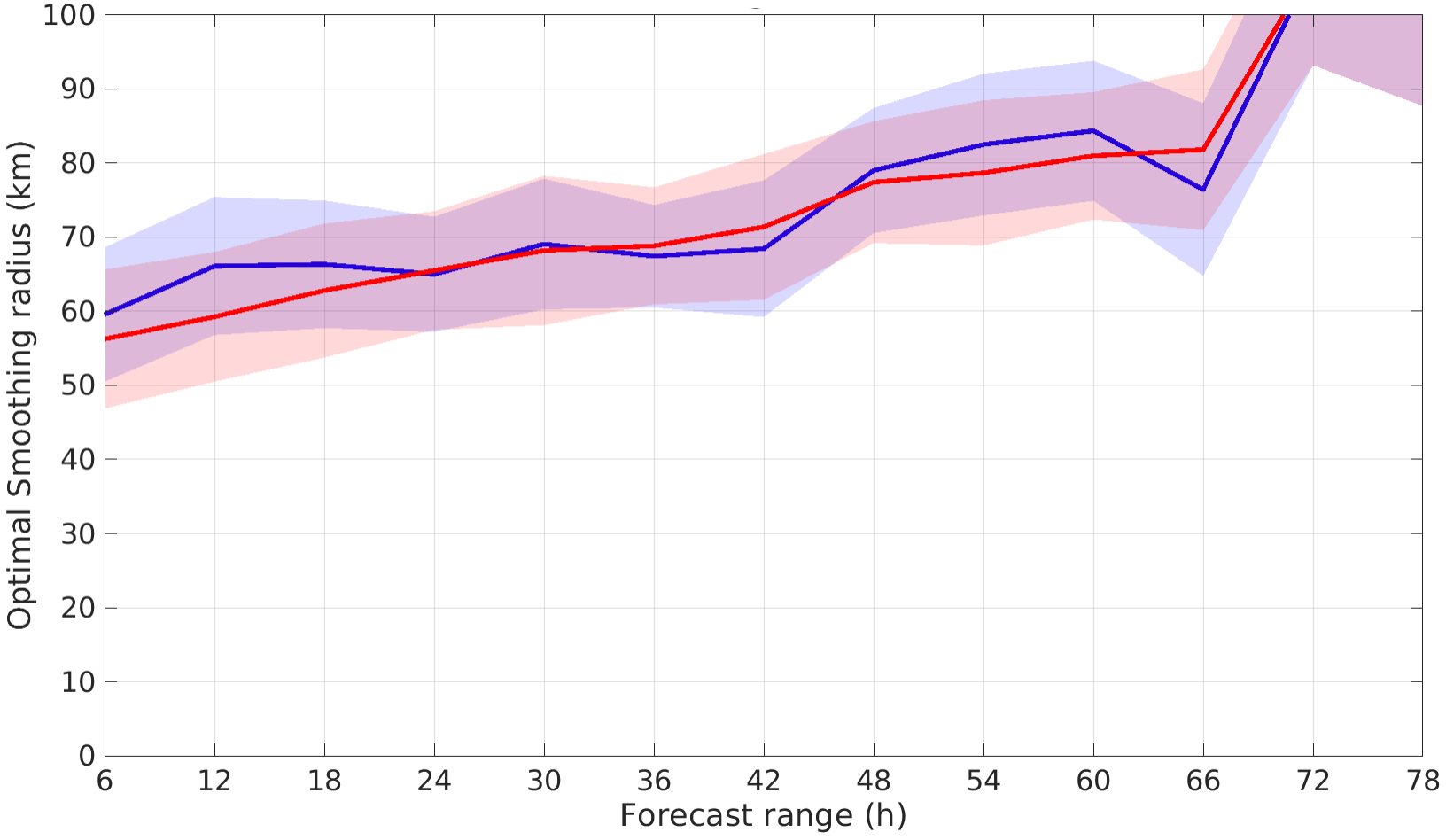

Deterministic  Time-lagged ensemble

# Typical Spatial Error vs. Forecast range for ICON-25km (avg. over thresholds)




Deterministic  Time-lagged ensemble

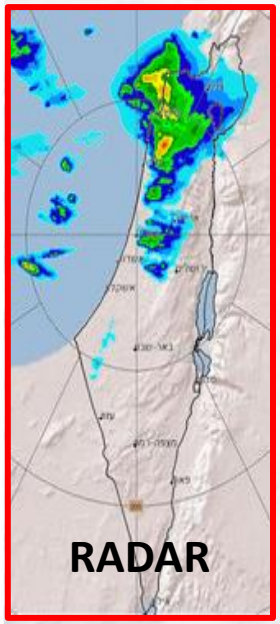
# Typical Spatial Error vs. Forecast range for GFS-25km (avg. over thresholds)




Deterministic  Time-lagged ensemble

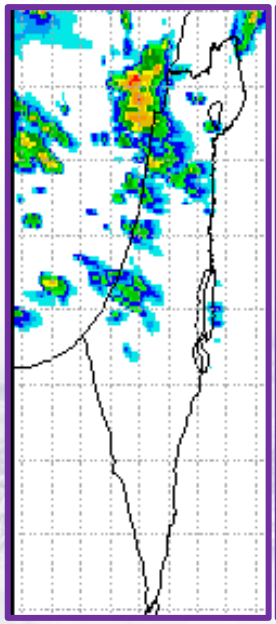
# Summary

20170211
18-24Z





20170210 00Z
+48h



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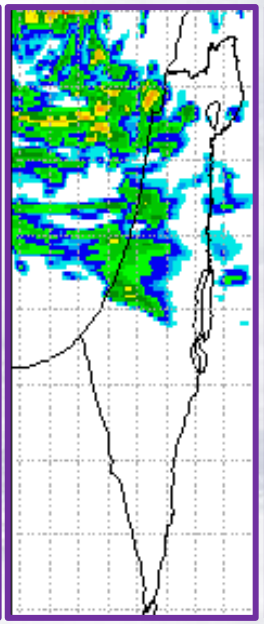

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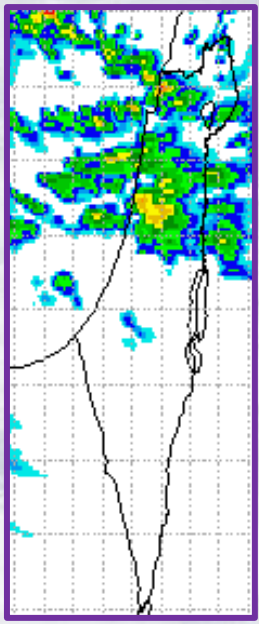
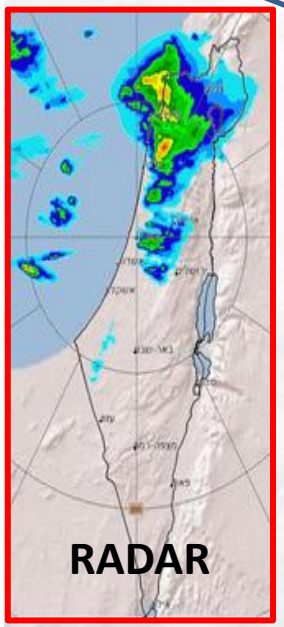
+72h

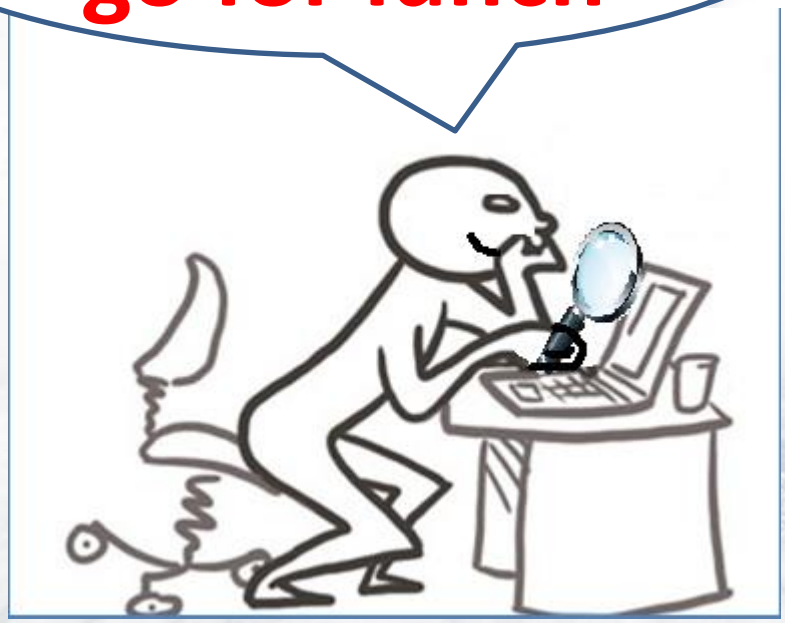


# Summary

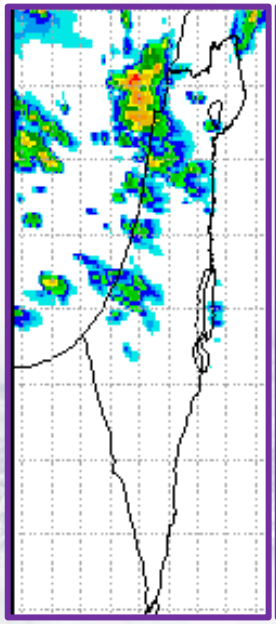
**The forecast can wait – let's go for lunch**

20170
18-24Z

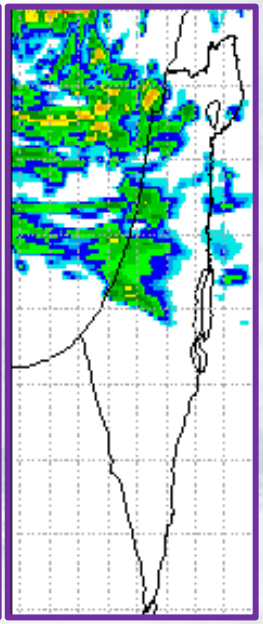


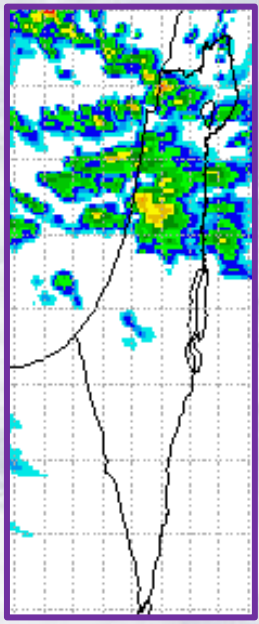
20170210 00Z
+48h



20170209 12Z
+60h



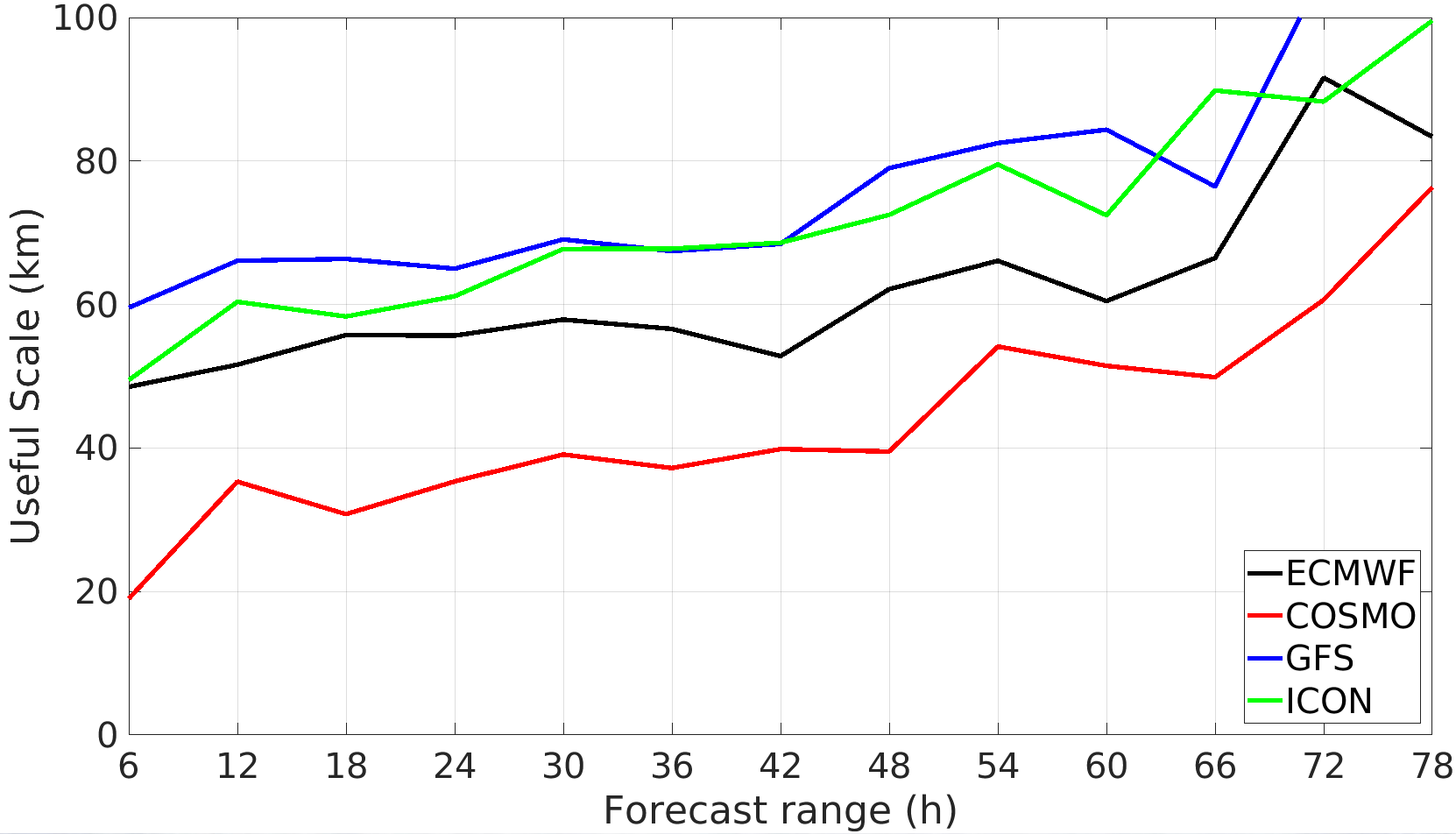
20170209 00Z
+72h

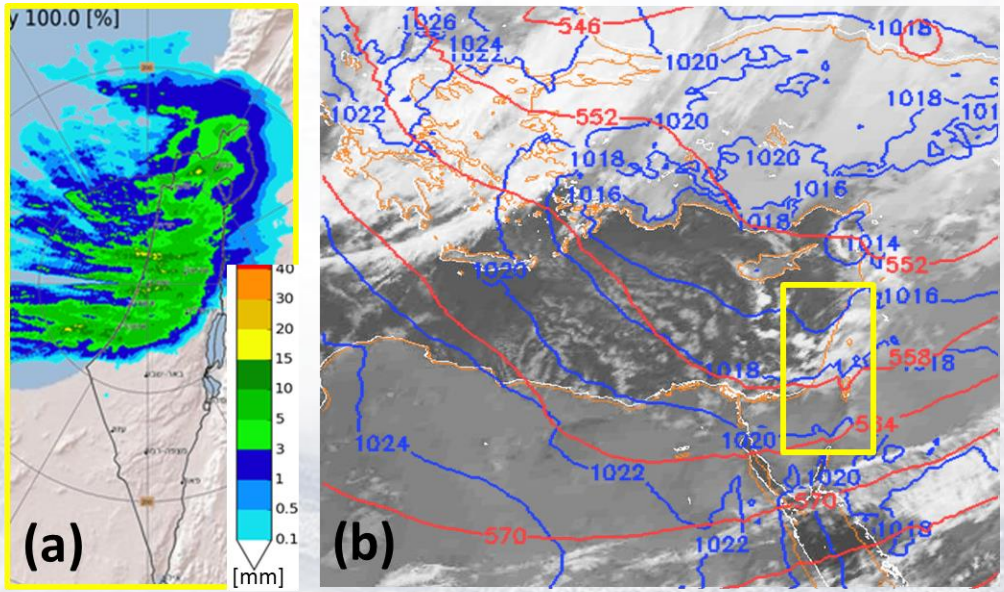


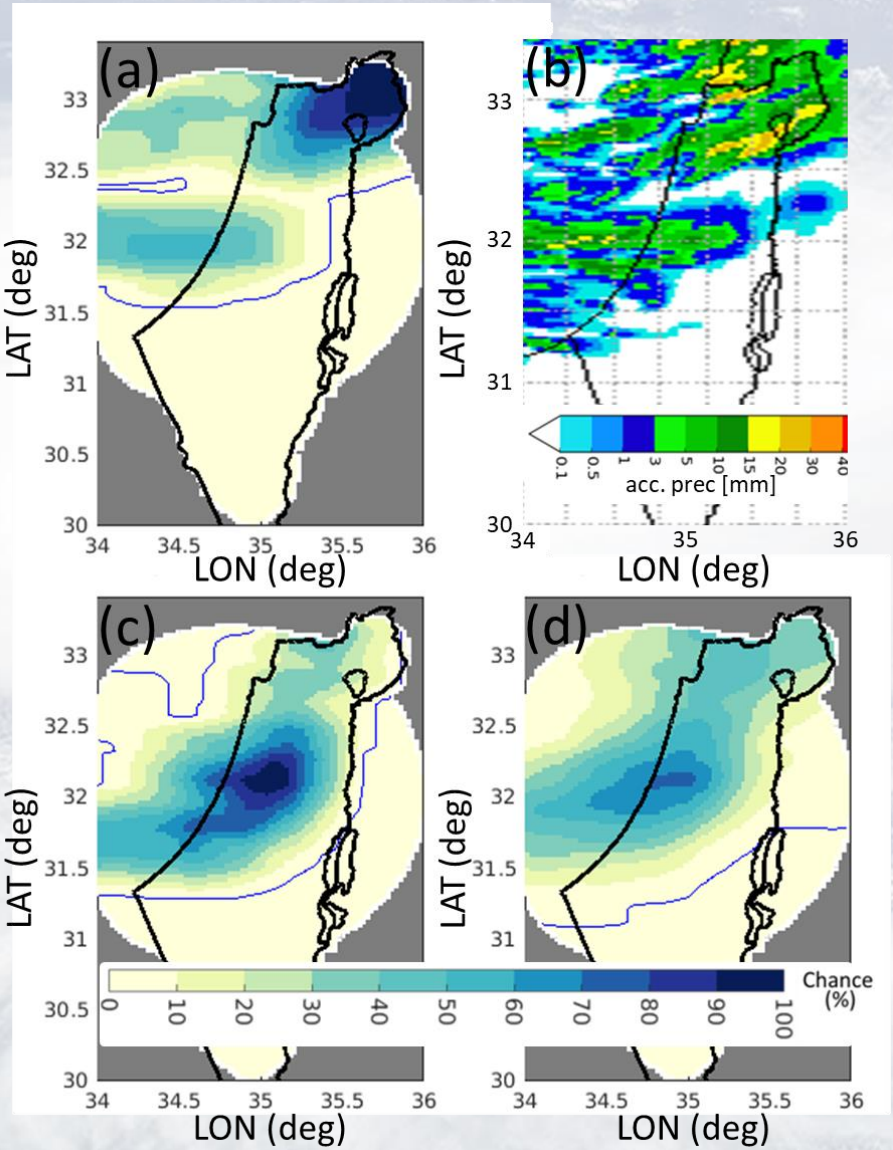
Thank you for your attention !

(Some additional slides …)

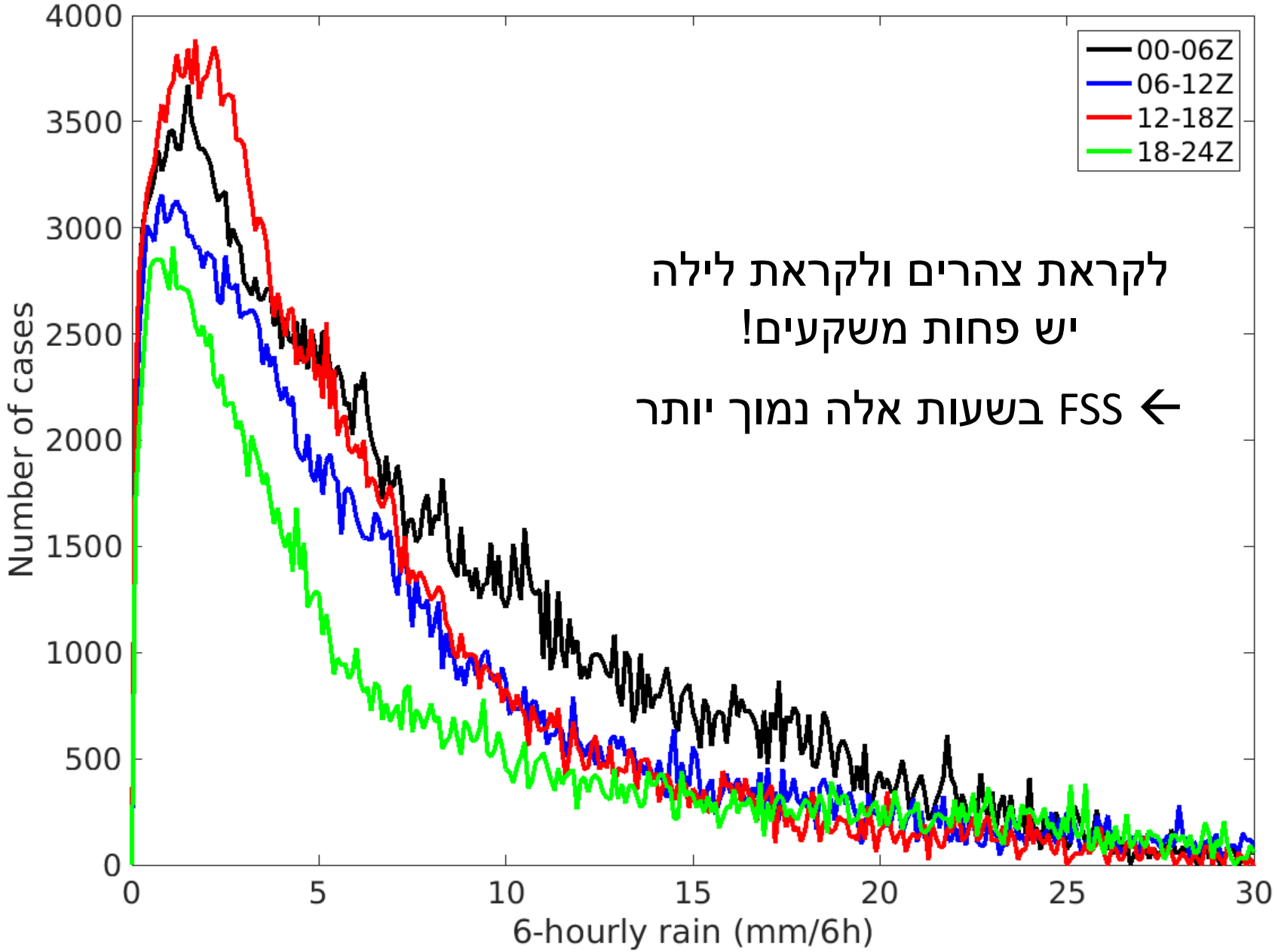
# Typical Spatial Error vs. Forecast range for deterministic runs




y 100.0 [%]
40
30
20
15
10
5
3
1
0.5
0.1
[mm]
(a)
(b)
1026
1024
546
1020
1018
1022
552
1016
1014
570


(a)
(b)
(c)
(d)
LAT (deg)
LON (deg)
33
32.5
32
31.5
31
30.5
30
34
34.5
35
35.5
36
0.1
0.5
1
3
5
10
15
20
30
40
acc. prec [mm]
0
10
20
30
40
50
60
70
80
90
100
Chance
(%)

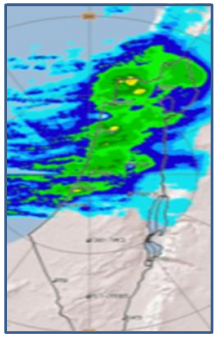
# חוב מתחילת ההרצאה – למה הציון מזגזג כתלות בטווח התחזית?

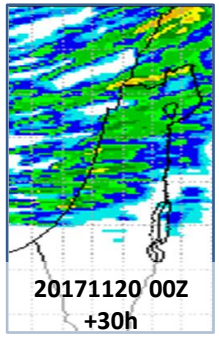


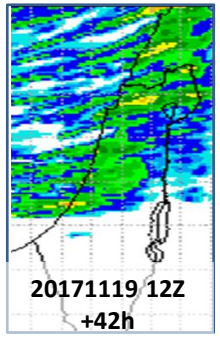

לקראת צהרים ולקראת לילה
יש פחות משקעים!

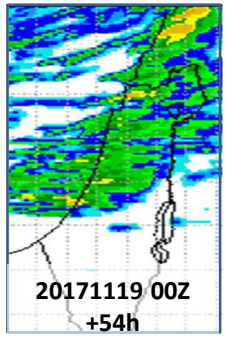
← FSS בשעות אלה נמוך יותר

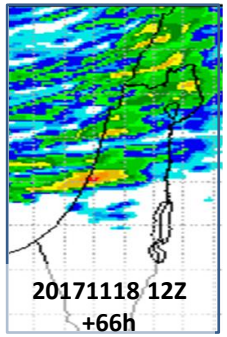
# Time Lagged Ensemble for precipitation

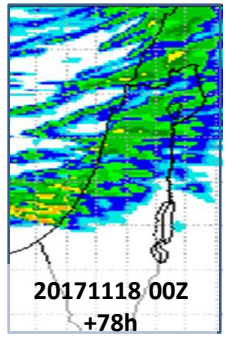


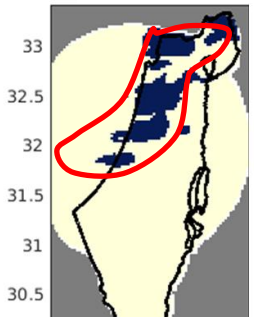


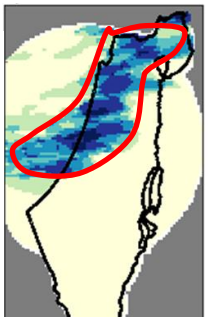



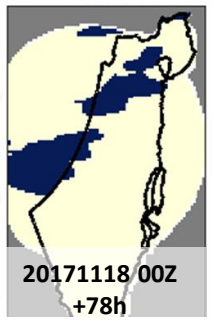



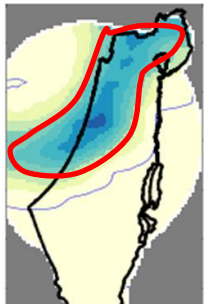



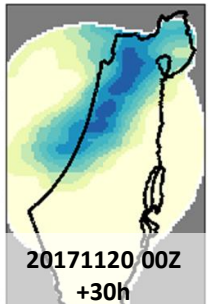



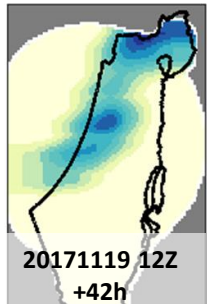


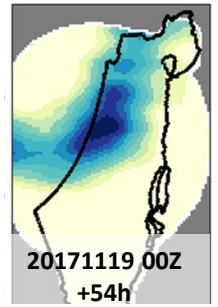


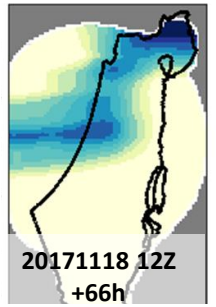


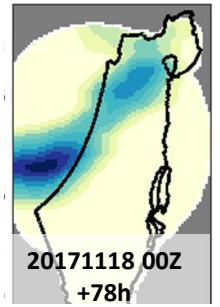





# Reliability

1. Decide number of categories (bins) and their distribution:
   - Depends on sample size, discreteness of forecast probabilities
   - Should be an integer fraction of ensemble size for e.g.
   - Don't all have to be the same width – within bin sample should be large enough to get a stable estimate of the observed frequency.
2. Bin the data
3. Compute the observed conditional frequency in each category (bin) *k*
   - $\textit{obs. relative frequency}_k = \textit{obs. occurrences}_k \;/\; \textit{num. forecasts}_k$
4. Plot observed frequency vs forecast probability
5. Plot sample climatology ("no resolution" line) (The sample base rate)
   - $\textit{sample climatology} = \textit{obs. occurrences} \;/\; \textit{num. forecasts}$
6. Plot "no-skill" line halfway between climatology and perfect reliability (diagonal) lines
7. Plot forecast frequency histogram to show sharpness (or plot number of events next to each point on reliability graph)

$$\frac{1}{N}\sum_{k=1}^{K} n_k \left(p_k - \bar{o}_k\right)^2$$

If for all occasions when forecast probability $p_k$ is predicted, the observed frequency of the event is $\bar{o}_k = p_k$ then the forecast is said to be reliable. Similar to bias for a continuous variable

# ROC area

- Reliability diagram – partitioning the data according to the forecast probability
- Suppose we partition according to observation – 2 categories, yes or no
- Look at distribution of forecasts separately for these two categories

# Construction of ROC curve

- From original dataset, determine bins
  - Can use binned data as for Reliability diagram BUT
  - There must be enough occurrences of the event to determine the conditional distribution given occurrences – may be difficult for rare events.
  - Generally need at least 5 bins.
- For each probability threshold, determine HR and FA
- Plot HR vs FA to give empirical ROC.
- Use binormal model to obtain ROC area; recommended whenever there is sufficient data >100 cases or so.
  - For small samples, recommended method is that described by Simon Mason. (See 2007 tutorial)

# Time Lagged Ensemble for precipitation