21˚ COSMO General Meeting
Rome, Italy
9-13 September 2019

Ensemble activities at arpae

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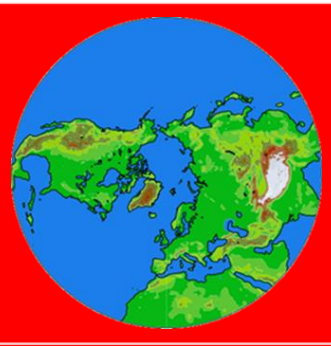
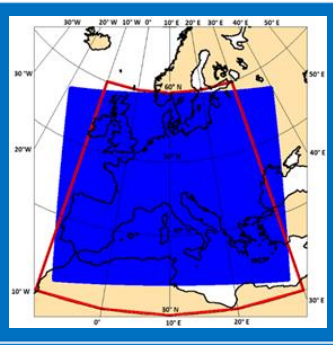
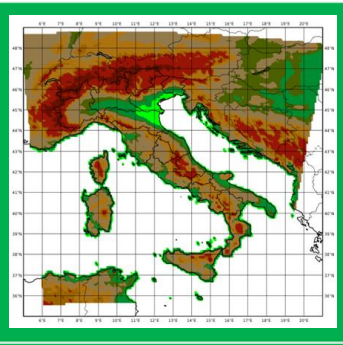
(1) Arpae-SIMC, (2) ECMWF, (3) DWD

OUTLINE

- The ensemble forecast systems
  - ECMWF ENS
  - COSMO-LEPS
  - COSMO-2I-EPS
- Ensemble products and their use by forecasters
- Verification activity → description of the experiments
  - 21 January – 30 April 2019
  - 23 May – 30 June 2019
  - Recent investigations
- Conclusions

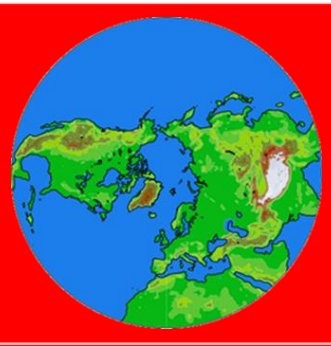
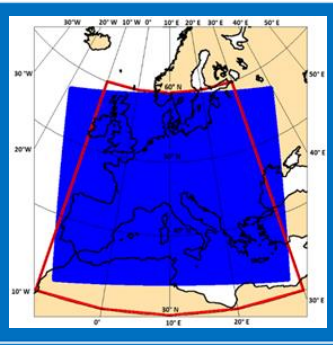
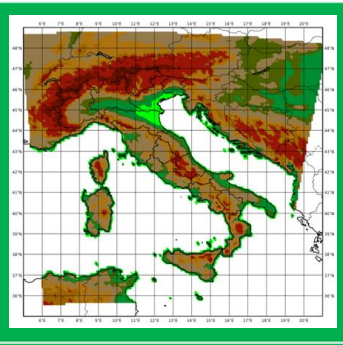
The ensemble forecast systems

OVERVIEW ON ECMWF ENS , COSMO-LEPS , COSMO-2I-EPS

MAIN TECHNICAL FEATURE \ ENSEMBLE SYSTEM	ECMWF ENS	COSMO-LEPS	COSMO-2I-EPS
Integration domain			
Horizontal resolution (km)	18	7	2,2
Vertical resolution (Model level)	91	40	65
Forecast range (hours)	240	132	51
Type of model	Hydrostatic model	Non-hydrostatic model	Non-hydrostatic model
Type of convection	Parameterized convection	Parameterized convection	Explicit convection
Ensemble size	51	20	20
Starting times (UTC)	00, 06, 12, 18	00, 12	21 -> 00

Ensemble systems whose products are available to forecasters

OVERVIEW ON ECMWF ENS , COSMO-LEPS , COSMO-2I-EPS

MAIN TECHNICAL FEATURE \ ENSEMBLE SYSTEM	ECMWF ENS	COSMO-LEPS	COSMO-2I-EPS
Integration domain			
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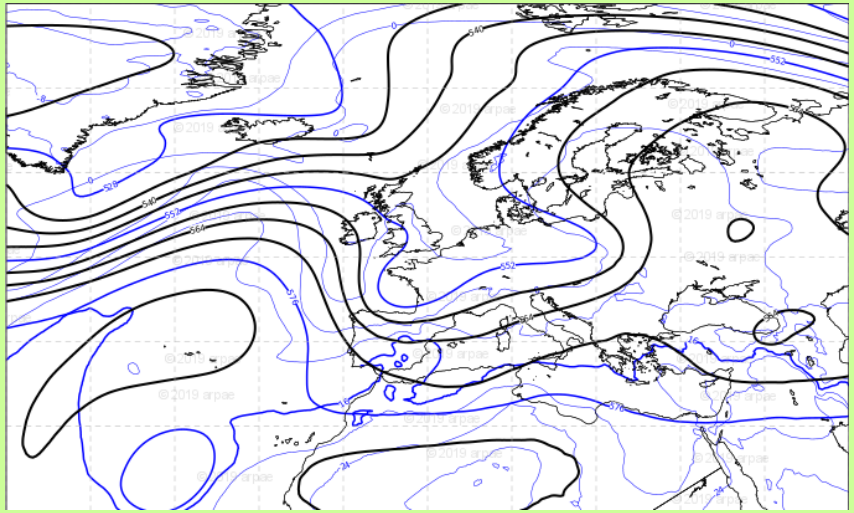
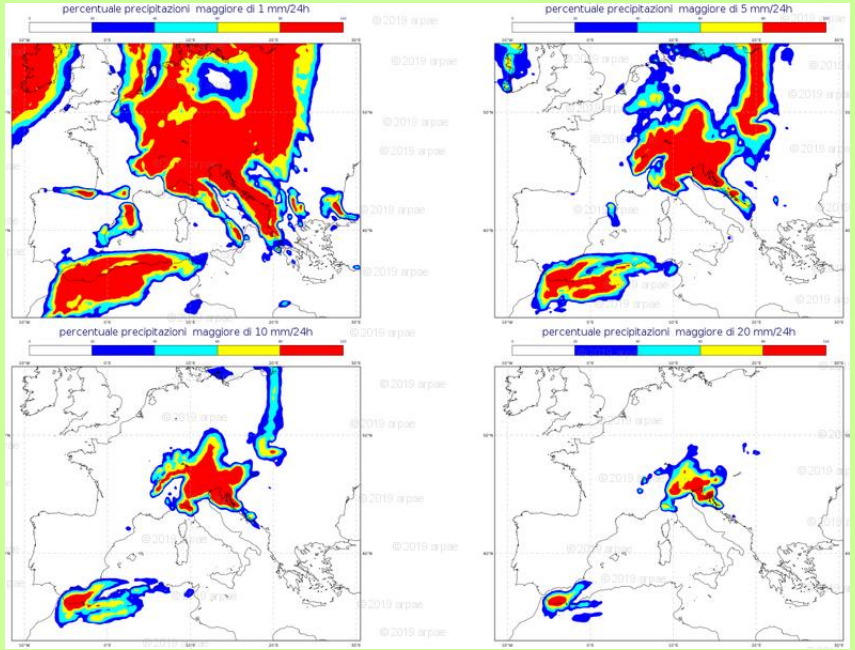
Ensemble systems involved in the verification activity

Ensemble products and their use in the operation room

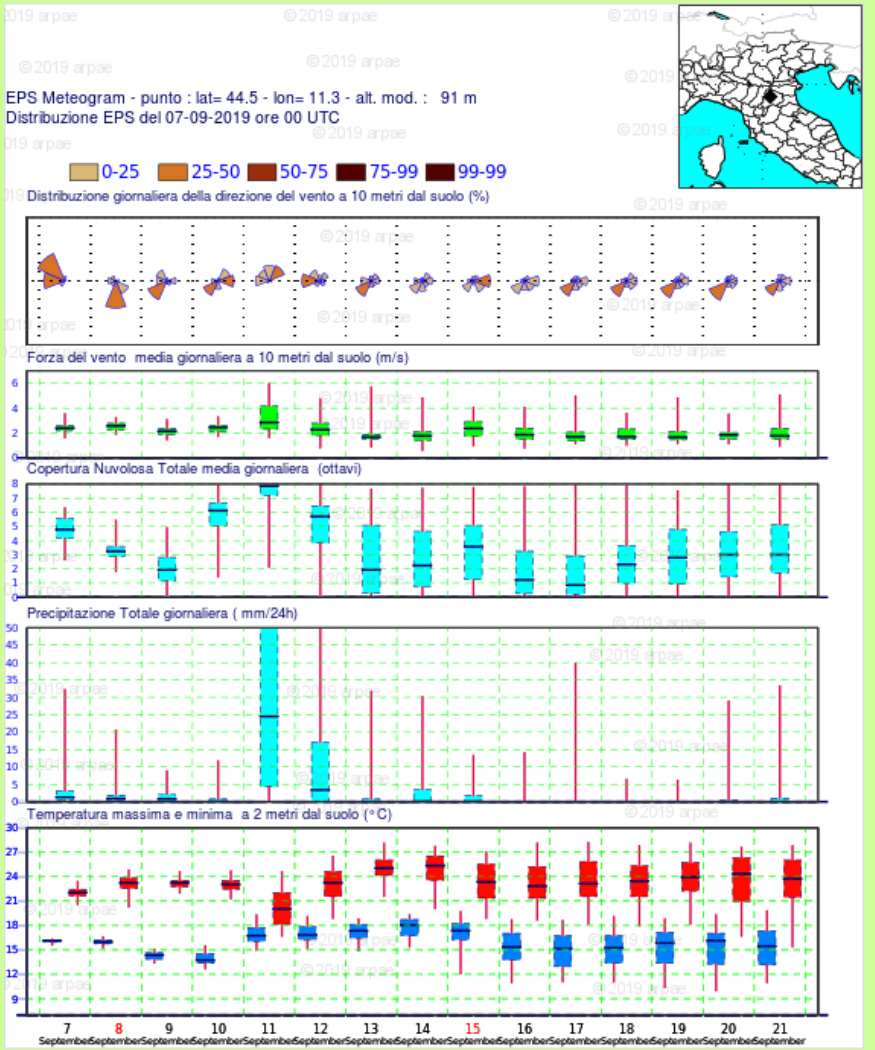
ECMWF ENS



Ensemble mean geopotential at 500 hPa

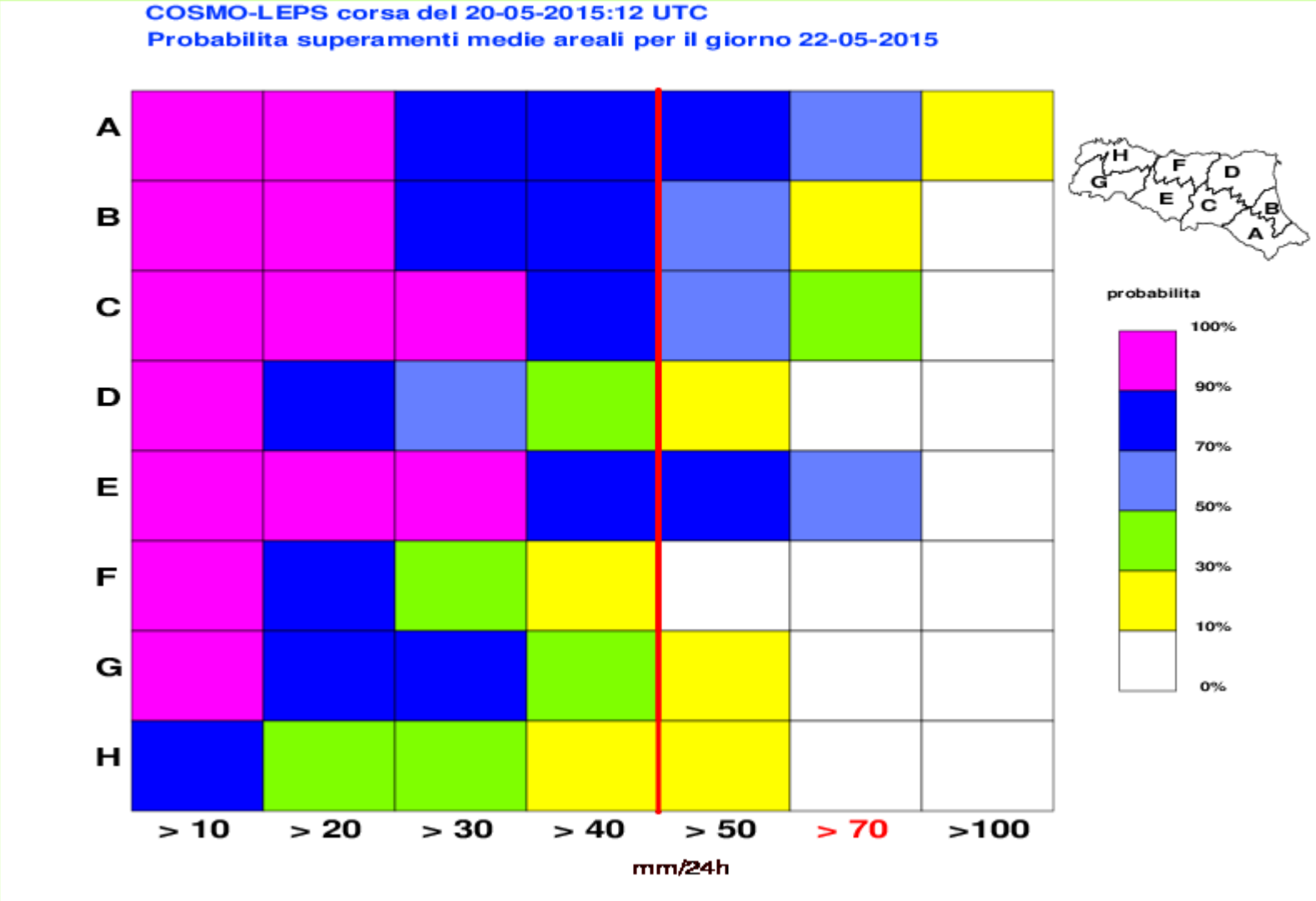


Probabilistic precipitation ordered by threshold



National Civil Protection Department Meteograms

COSMO-LEPS



Divide **Emilia-Romagna** into 8 "homogeneous" **alert areas** (average size ~3000 km2, 60 grid points per area).

For each COSMO-LEPS member, consider the corresponding areal means of **24-hour precipitation**.

Compute **exceedance probabilities for pre-defined thresholds**; colours "quantify" probabilities.

COSMO-LEPS

Day

Last run

Old runs

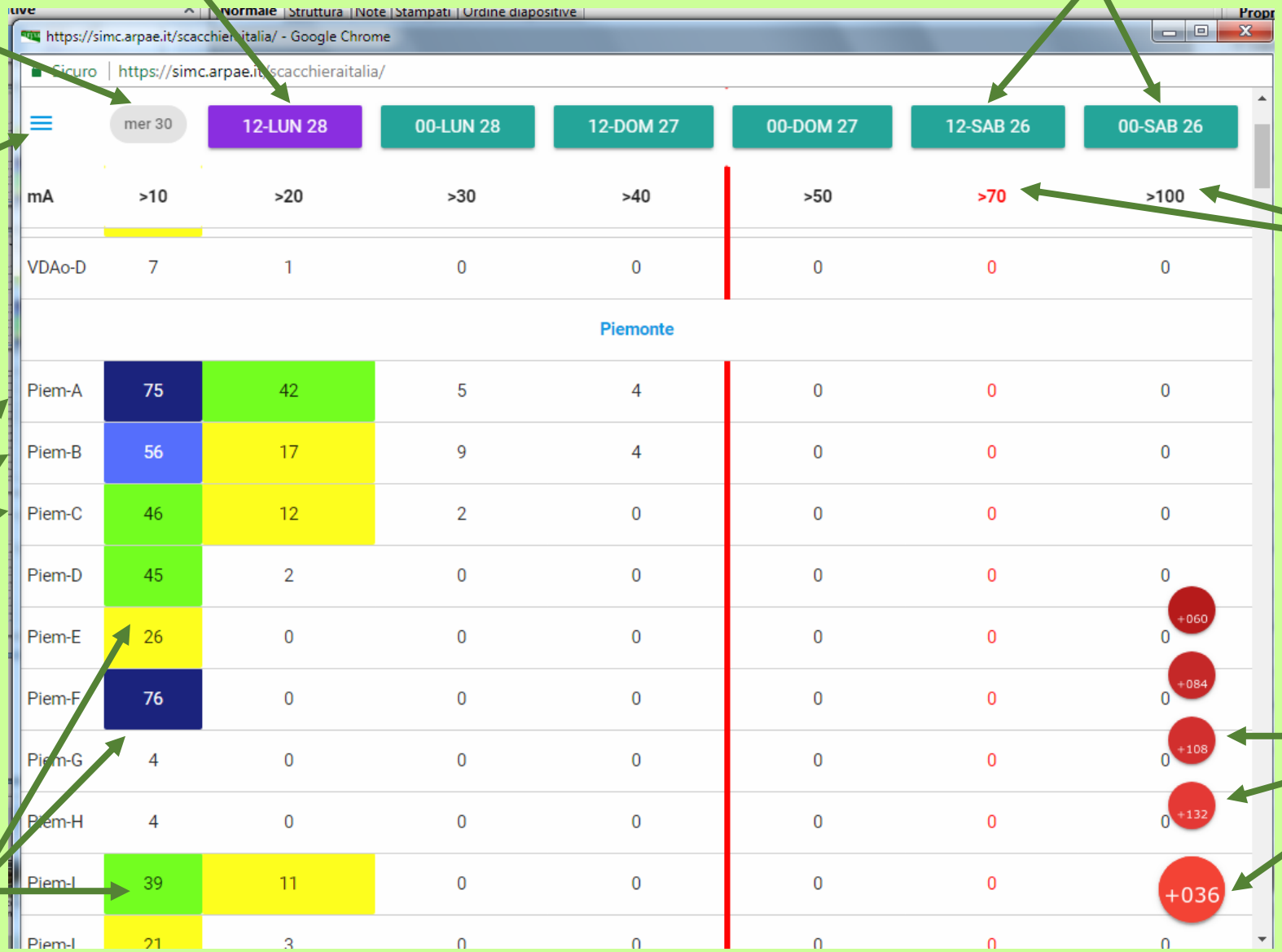
Select the region

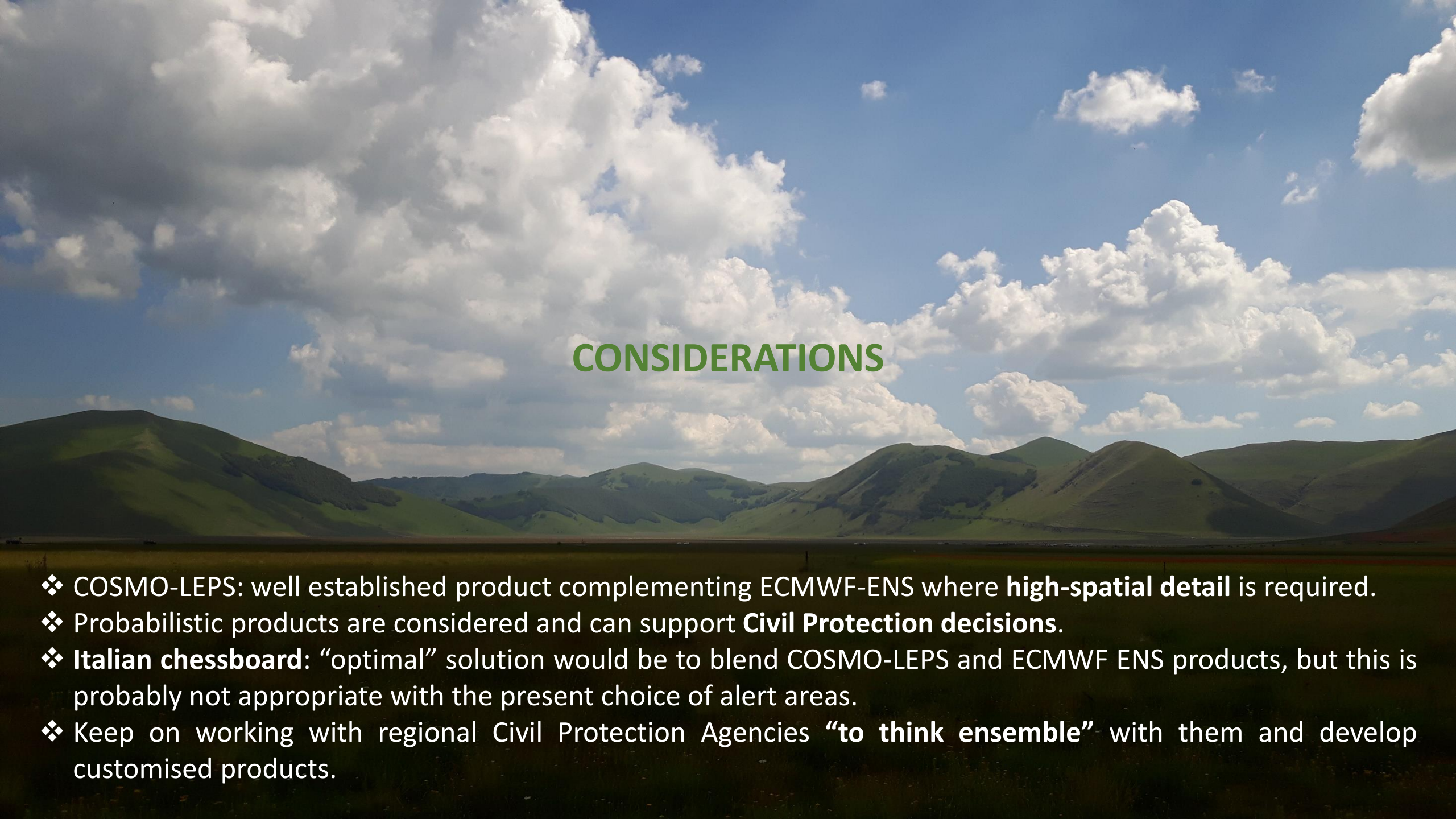
Thresholds

Alert areas

Probability of Exceeding thresholds

Deadlines





CONSIDERATIONS

- COSMO-LEPS: well established product complementing ECMWF-ENS where **high-spatial detail** is required.
- Probabilistic products are considered and can support **Civil Protection decisions**.
- **Italian chessboard**: “optimal” solution would be to blend COSMO-LEPS and ECMWF ENS products, but this is probably not appropriate with the present choice of alert areas.
- Keep on working with regional Civil Protection Agencies **“to think ensemble”** with them and develop customised products.

Verification activity

Description of the experiments

DESCRIPTION OF THE EXPERIMENTS

6h total precipitation verification

The intercomparison between the three ensemble systems is performed on the following two **periods**:

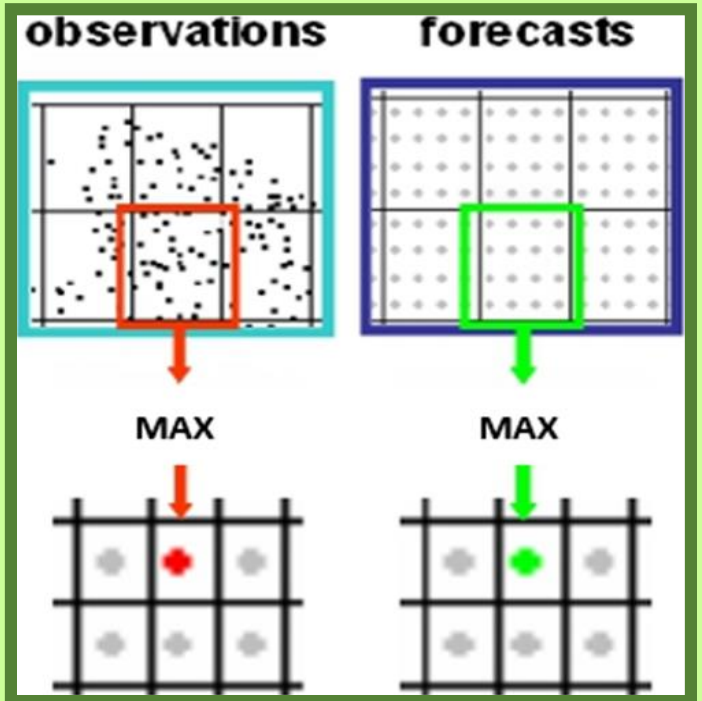
- **From 21 January to 30 April 2019**
- **From 23 May to 30 June 2019**

starting at **00 UTC** and with a forecast range of **48 hours** (post-processing frequency every 6 hours).

The systems are compared over the **Italian region**

Italian domain
Latitude: 35N – 48N
Longitude: 6E – 19E

DESCRIPTION OF THE EXPERIMENTS



The domain is divided in squared area **(0.25° x 0.25°)**;
the precipitation values of all stations and all model grid points falling in the same box are aggregated and processed.
The **maximum** value for the precipitation field in each **box** has been performed.

DPCN Observational network
5524 stations

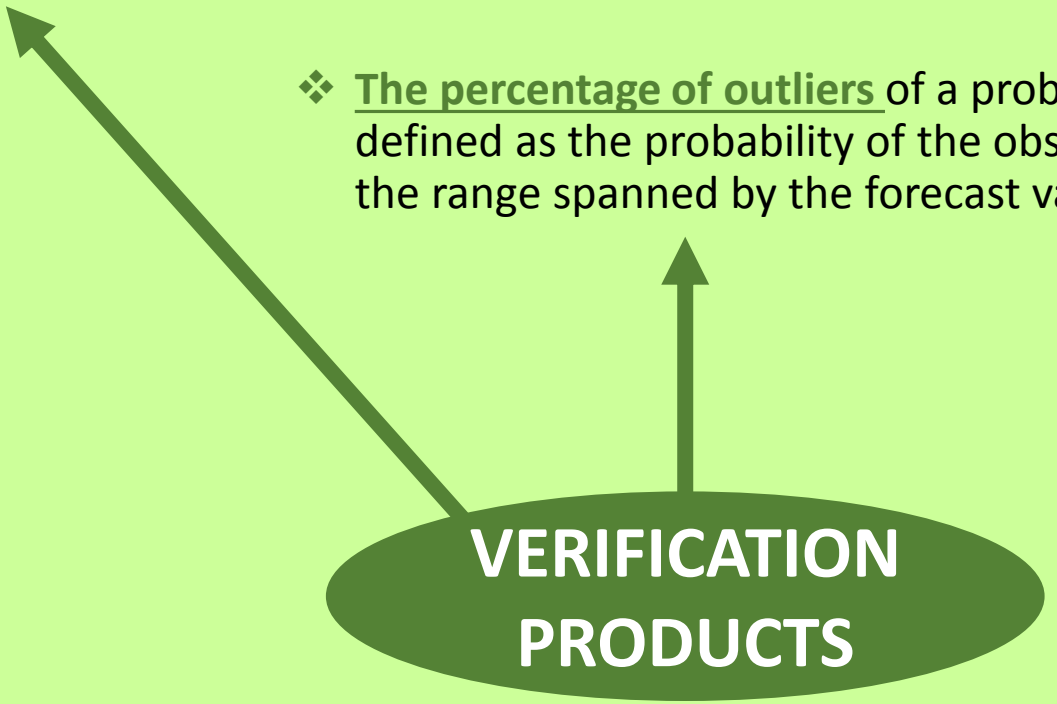
Alert purposes: the same method, but with DCPC **catchment area**

- **Ranked Probability Scores (RPS)** is an extension of the RMSE to the probabilistic world and to the multi-category events. RPS ϵ (0,1); The lower the RPS, the better the ensemble system.

$$RPS = \frac{1}{J-1} \sum_{m=1}^{J} (\sum_{j=1}^{m} f_j - \sum_{j=1}^{m} o_j)^2$$

❖ **Ranked Probability Scores (RPS)**

❖ **The percentage of outliers** of a probabilistic forecast system is defined as the probability of the observations lying outside the range spanned by the forecast values.



❖ **Ranked Probability Scores (RPS)**

❖ **The percentage of outliers**

❖ **Brier Score (BS)** is the mean square error of the probability forecast. The BS averages the squared differences between pairs of forecast probabilities and the corresponding binary observations, representing the occurence of the event. BS ϵ (0,1); the perfect forecast has BS=0.

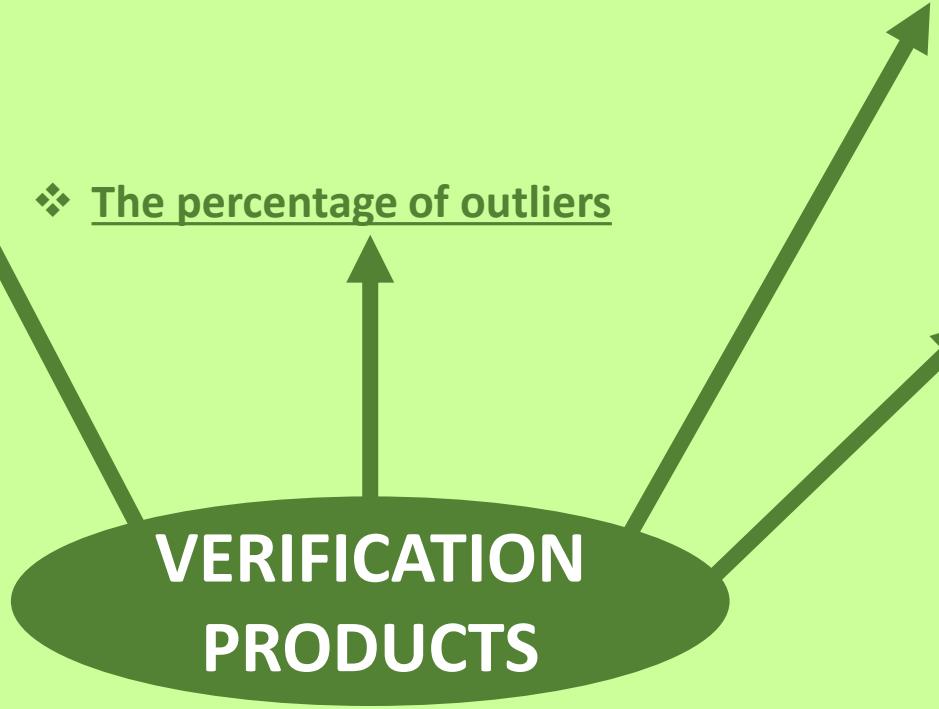
$$BS = \frac{1}{N}\sum_{i=1}^{N}(p_i - o_i)^2$$

VERIFICATION PRODUCTS

❖ **Ranked Probability Scores (RPS)**

❖ **Brier Score (BS)**

❖ **The percentage of outliers**



❖ **ROC Area**: the accuracy of probabilistic forecast can be evaluated using the Relative Operating Characteristic curves, which is obtained from contingency table; the area under the curve is used as a probabilistica score, its maximum value being 1, and a value of 0.5 indicating a no-skill forecast system.

❖ Ranked Probability Scores (RPS)

❖ Brier Score (BS)

❖ The percentage of outliers

VERIFICATION PRODUCTS

❖ ROC Area

❖ RMSE and bias

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1,N}^{N}(p_i - o_i)^2}, \qquad BIAS = \frac{1}{N}\sum_{i=1,N}^{N}(p_i - o_i).$$

❖ Ranked Probability Scores (RPS)

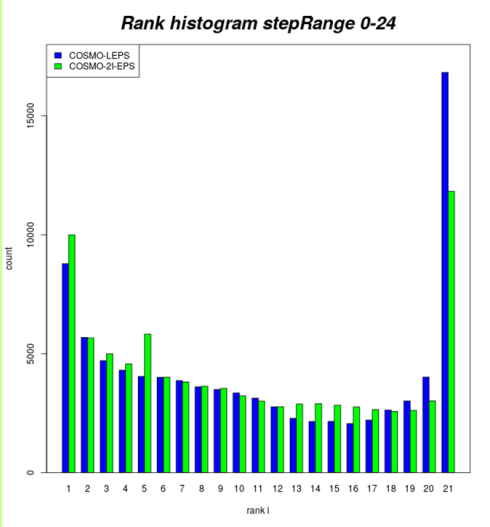
❖ Brier Score (BS)

❖ The percentage of outliers

VERIFICATION PRODUCTS

❖ ROC Area

❖ RMSE and bias



❖ The rank histogram is a diagnostic tool to evaluate the **spread of an ensemble**. The ensemble member forecasts are distributed so as to delineate ranges or **"bins"** of the predicted variable such that the probability of occurence of the observation within each bin is equal. The bins are determined by ranking the ensemble member forecasts from lowest to highest. The assumption underlying the rank is that the **probability** that the observation will fall in each bin is **equal**.

❖ Ranked Probability Scores (RPS)

❖ Brier Score (BS)

$$BiasScore = \frac{hits + false\ alarms}{hits + misses}$$

$$ProbabilityOfDdetection = \frac{hits}{hits + misses}$$

$$FalseAlarmRatio = \frac{false\ alarms}{hits + false\ alarms}$$

$$ThreatScore = \frac{hits}{hits + misses + false\ alarms}$$

		OBS	
		YES	NO
FCST	YES	hits	false alarm
	NO	misses	correct rejection

❖ The percentage of outliers

VERIFICATION PRODUCTS

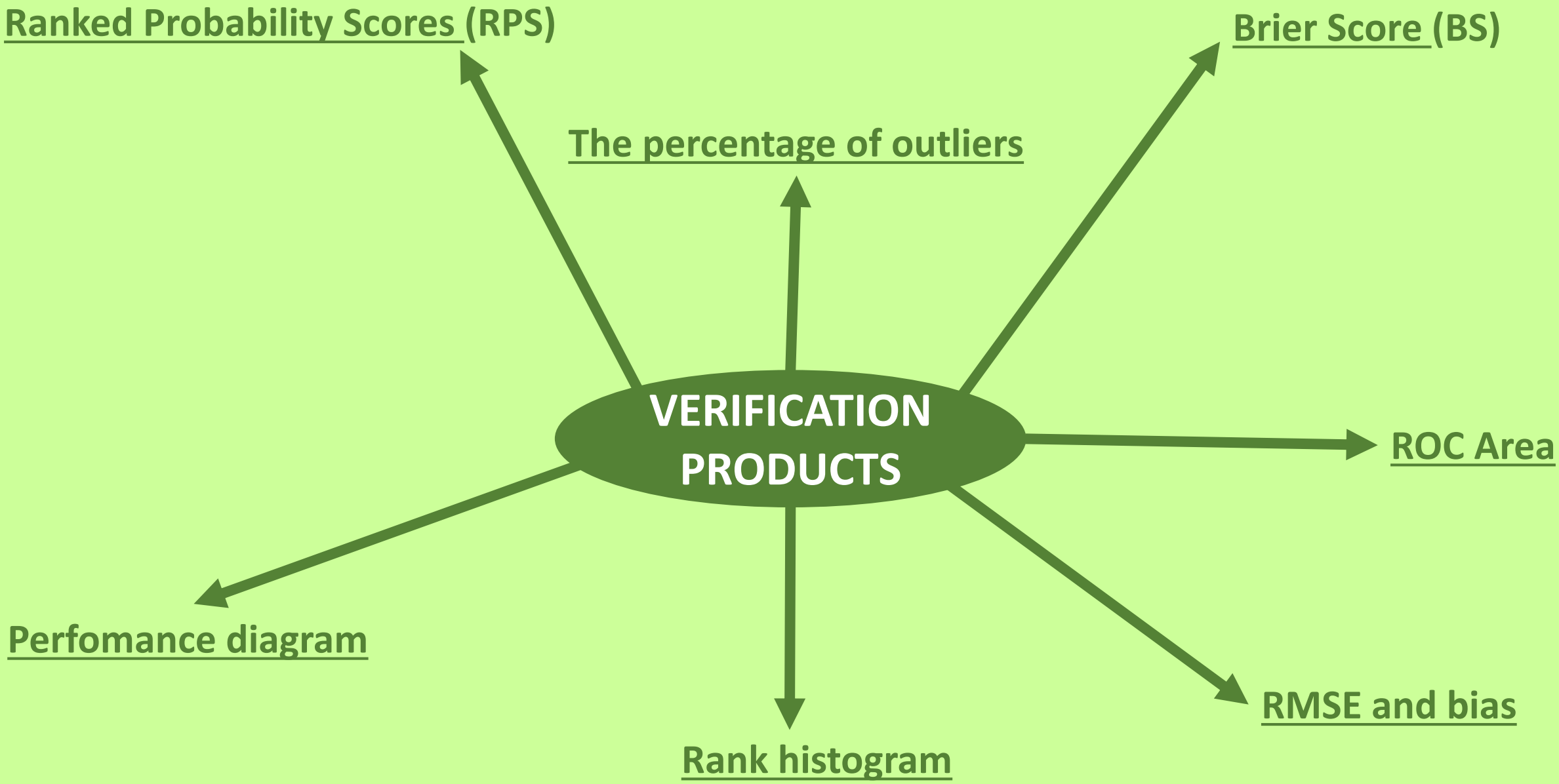
❖ ROC Area

❖ Perfomance diagram

It is possible to exploit the geometric relationship between four measure of dichotomous forecast performance: *Probability Of Detection* (POD), the *Success Ratio* (SR), *bias* and *Threat Score (TS)*. For good forecast, POD, SR, bias and TS approach unity, such that **a perfect forecast lies in the upper right of the diagram**.

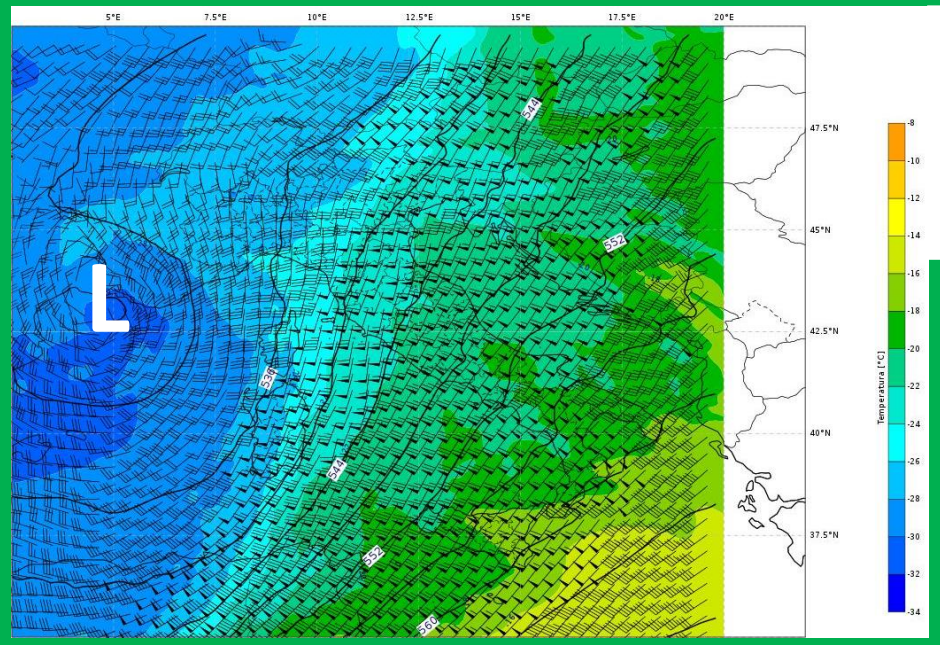
❖ RMSE and bias

❖ Rank histogram


Ranked Probability Scores (RPS)
Brier Score (BS)
The percentage of outliers
VERIFICATION PRODUCTS
ROC Area
Perfomance diagram
RMSE and bias
Rank histogram

1° Verification period:
21 January – 30 April 2019

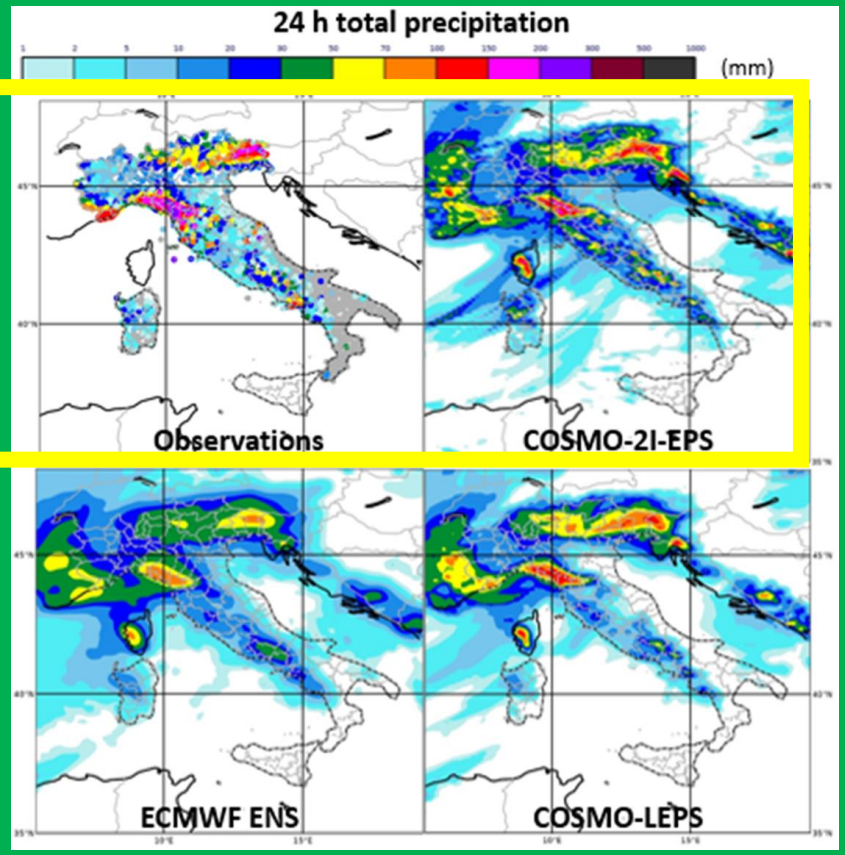
THE FLOOD IN EMILIA ROMAGNA AT THE BEGINNING OF FEBRUARY 2019



Analysis map from ECMWF of geopotential, temperature And wind at 500 hPa: ***2/02/19 12:00 UTC***

The entry of a trough on the western Mediterranean with the formation of a closed minimum on southern France have attracted relatively mild and strong south-western currents over Emilia Romagna, associated with rainfall and snowfall only on the highest peaks of the Apennines.

The precipitation predicted by COSMO-2I-EPS is the one closest to the observations both for distribution and intensity

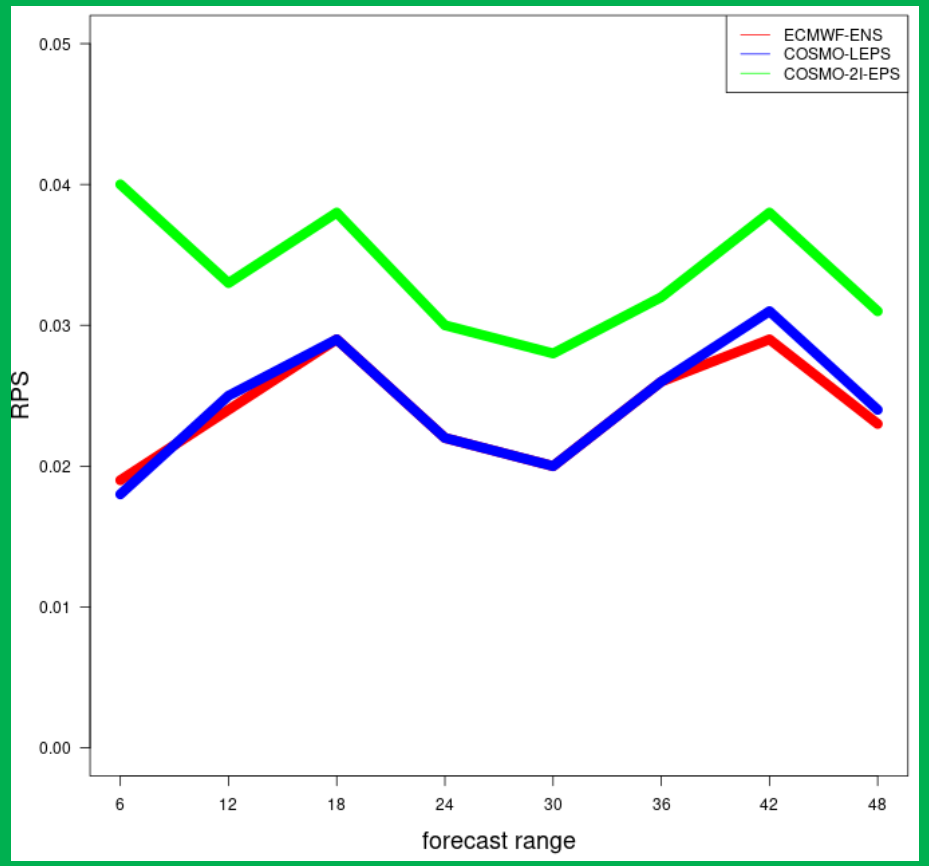


Maps of total precipitation cumulated over 24 hours (observations and forecasts) for 2 February 2019, as predicted by the first member of the three ensemble systems.

Radar reflectivity map:
2/02/2019 00:55 UTC

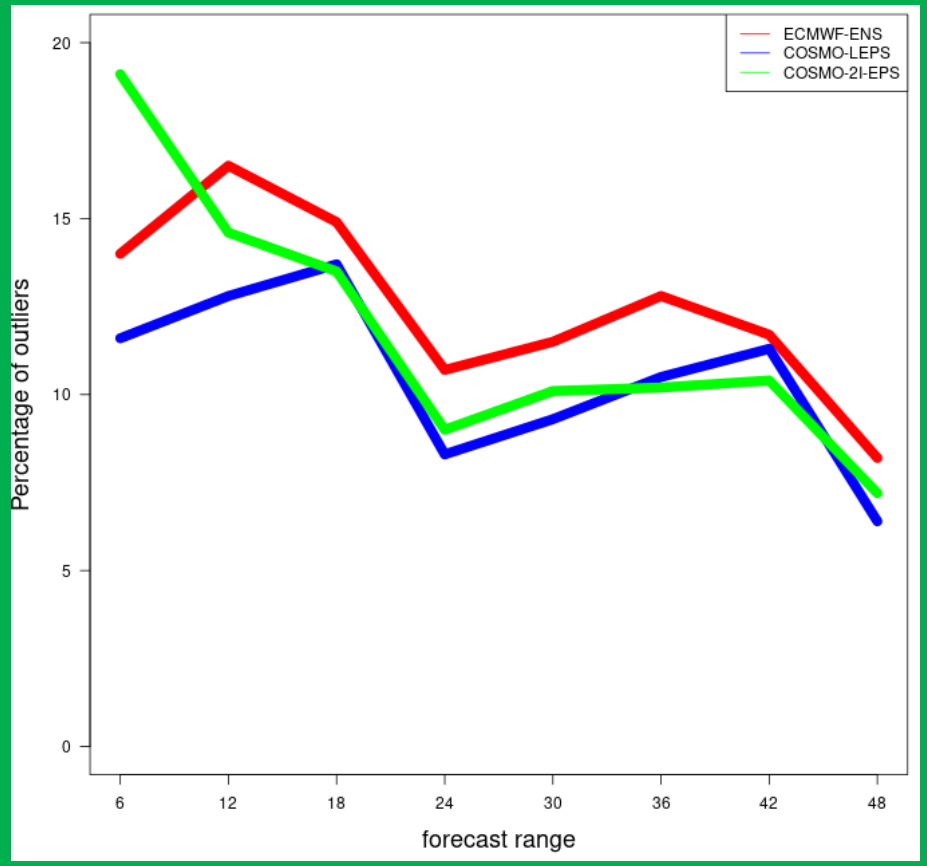
The havier precipitations have insisted on the Apennine ridge areas, due to the orographic lifting of the humid south-western currents.

RPS



- The **ECMWF** and **COSMO-LEPS** RPS is very similar
- The **COSMO-2I-EPS** one is the highest for the entire forecast range
- There is a slight **diurnal cycle**
- The COSMO-2I-EPS RPS is very high in the **first six hours** of the forecast range

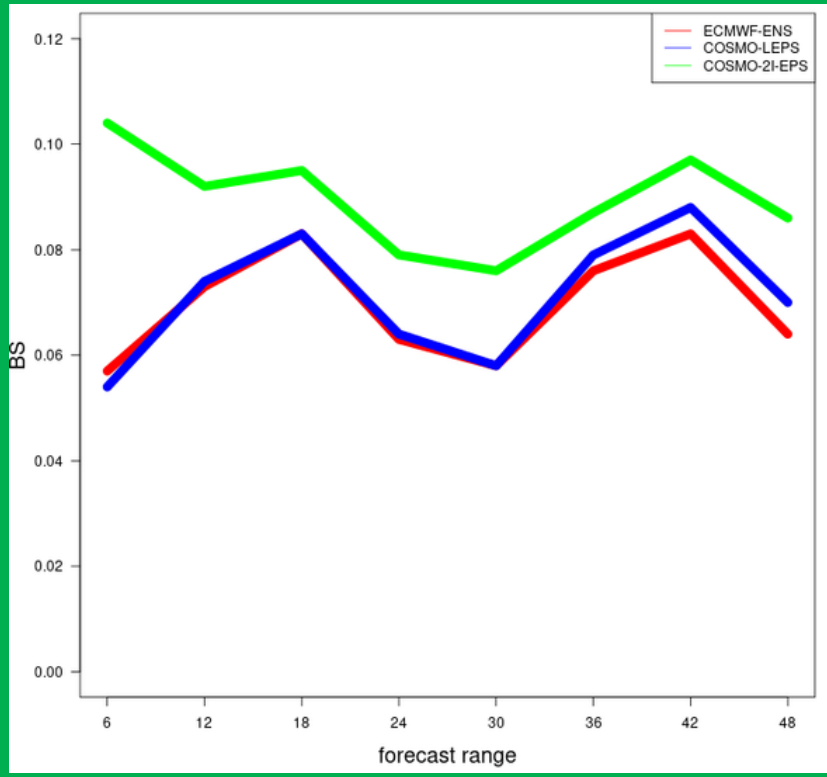
PERCENTAGE OF OUTLIERS



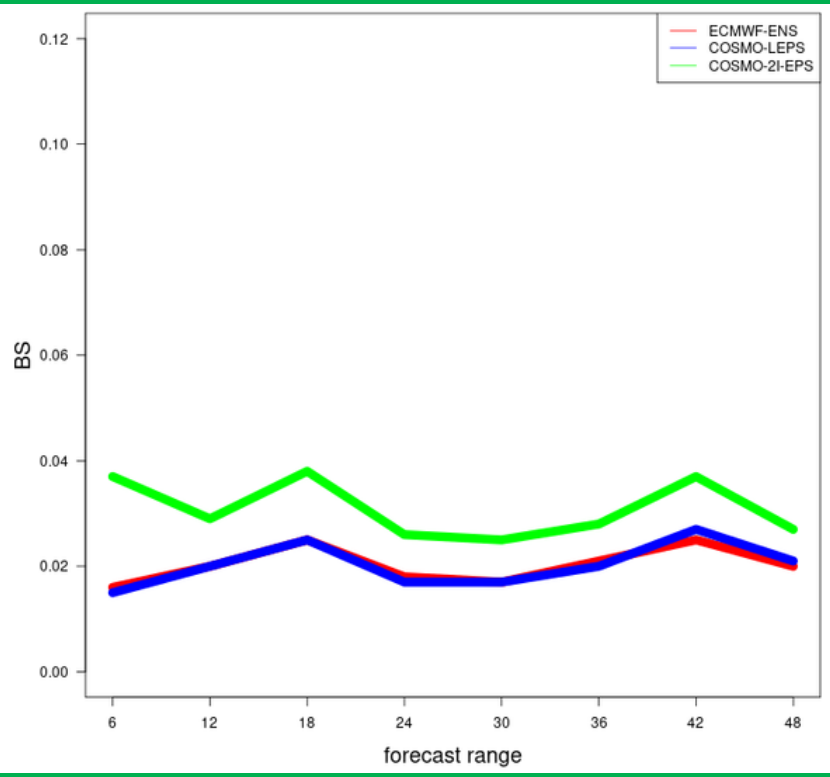
- **COSMO-based ensemble systems** have lower percentages of outliers than ECMWF ENS
- COSMO-2I-EPS has an unusually high percentage of outliers for the **first six hours** of the forecast range
- There is a slight **diurnal cycle**

BS

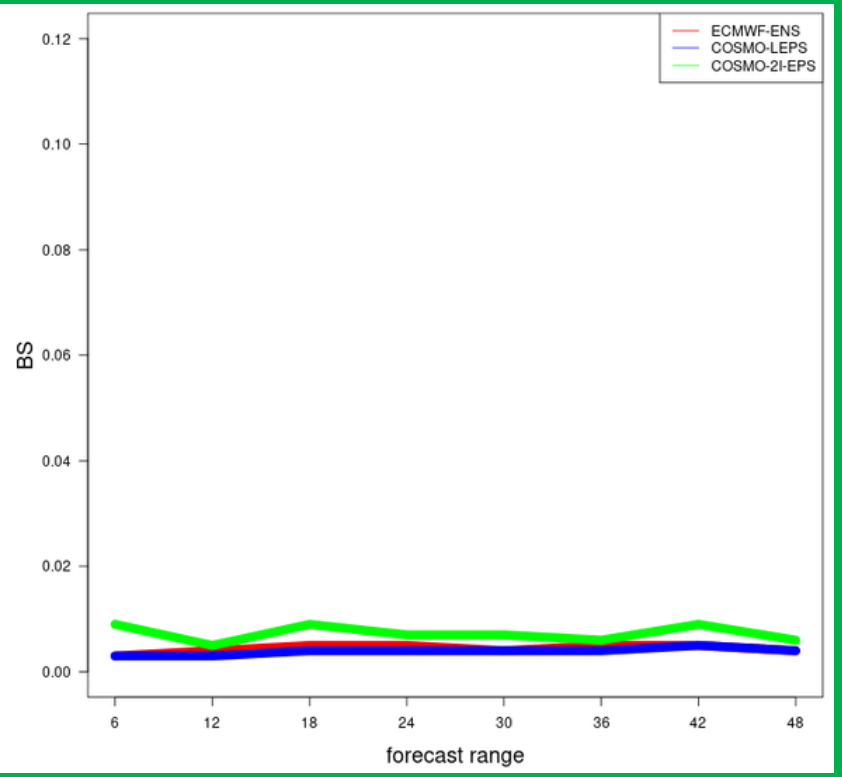
Threshold: 1mm



Threshold: 10 mm



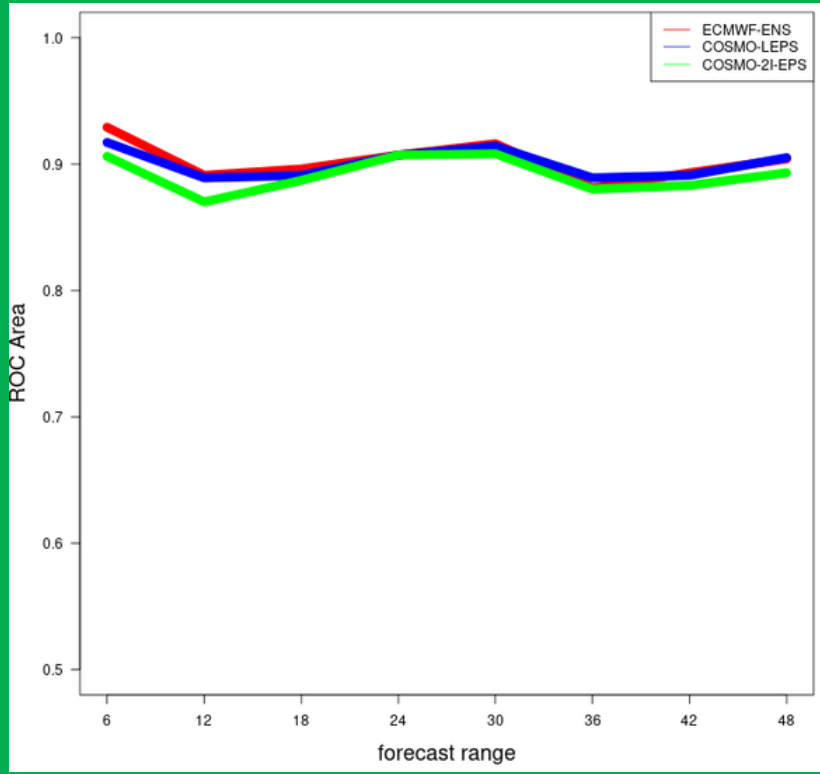
Threshold: 25 mm



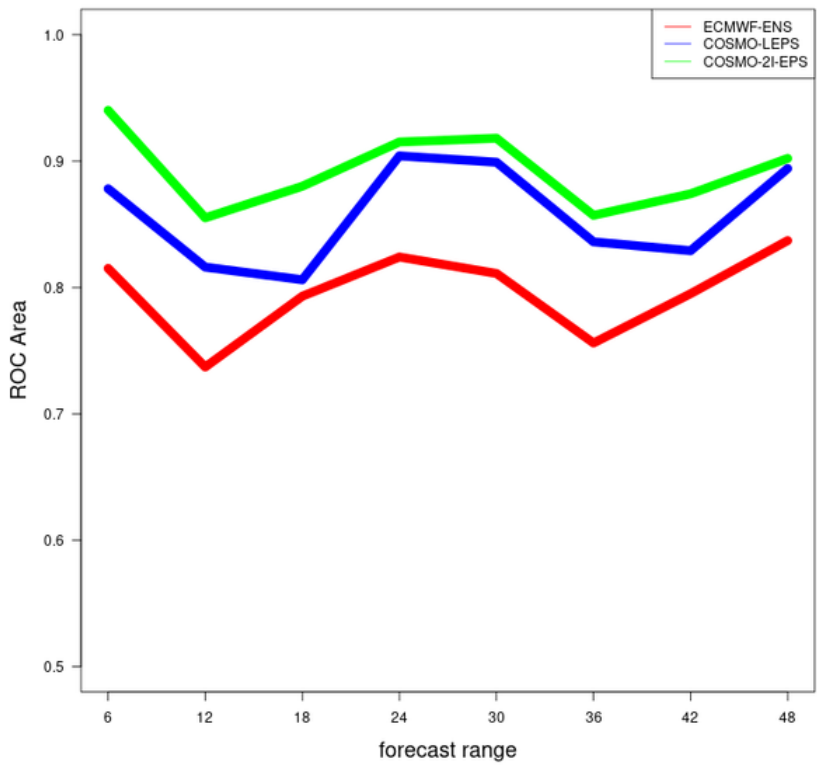
- The BS tends to decrease with increasing threshold, regardless of the ensemble systems
- For the **25 mm threshold**, the BS of the three ensemble systems is very similar and close to zero, so it does not represent a significant case
- For the **1 mm and 10 mm thresholds**, the BS of ECMWF and COSMO-LEPS are almost superimposed, while that of COSMO-2I-EPS is worse (being higher for the whole forecast range)
- The **daytime cycle** is less visible as the threshold increases
- The COSMO-2I-EPS **problem** persists in the first six hours of the forecast range

ROC Area

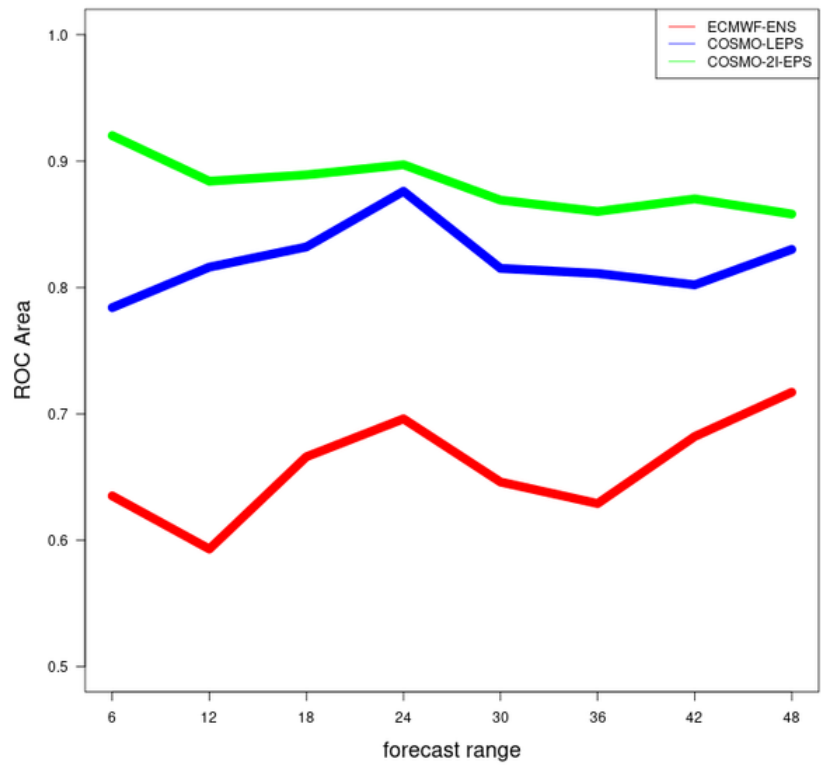
Threshold: 1mm



Threshold: 10 mm

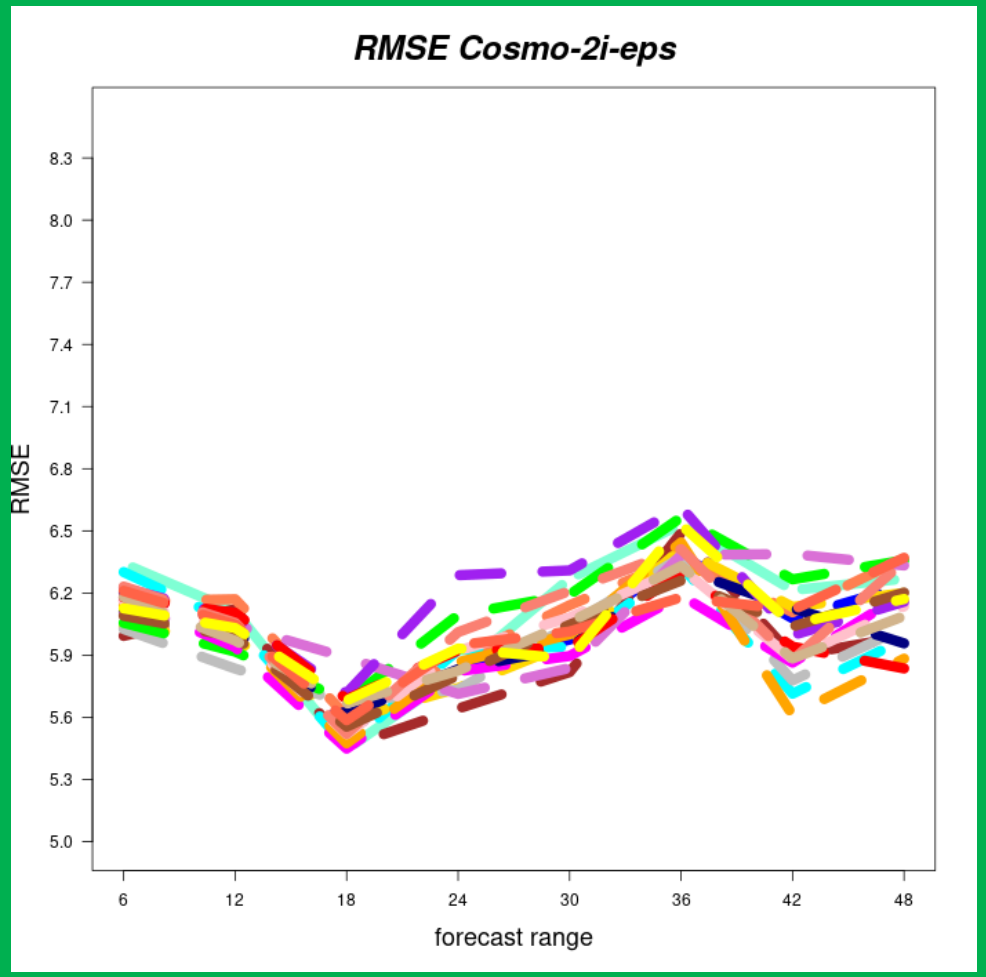


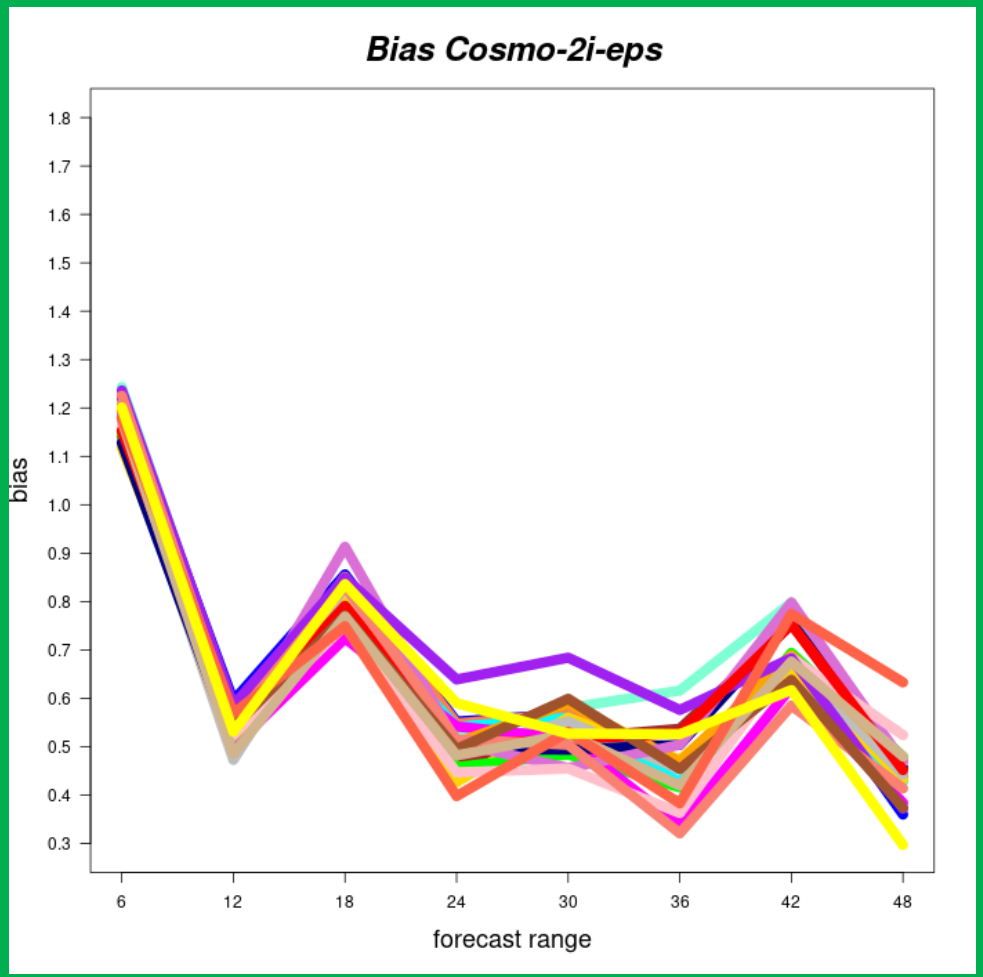
Threshold: 25 mm



- The ROC Area of **ensemble systems with parametrized convection** tends to decrease - and therefore to worsen - with the increase of the threshold; instead the ROC area of **COSMO-2I-EPS** remains stable at high values

RMSE & BIAS COSMO-2I-EPS

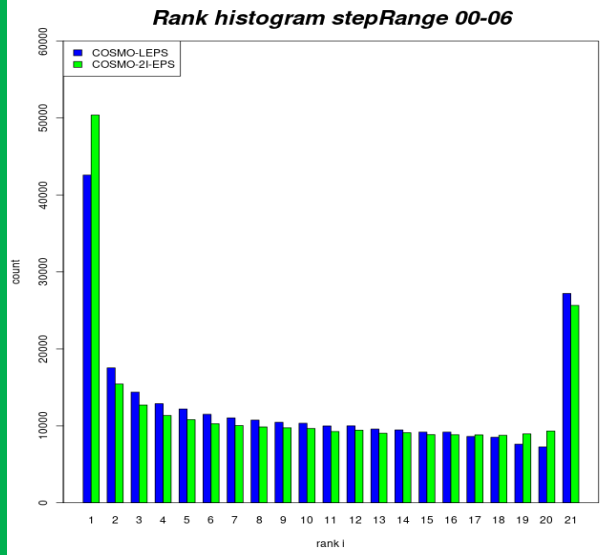


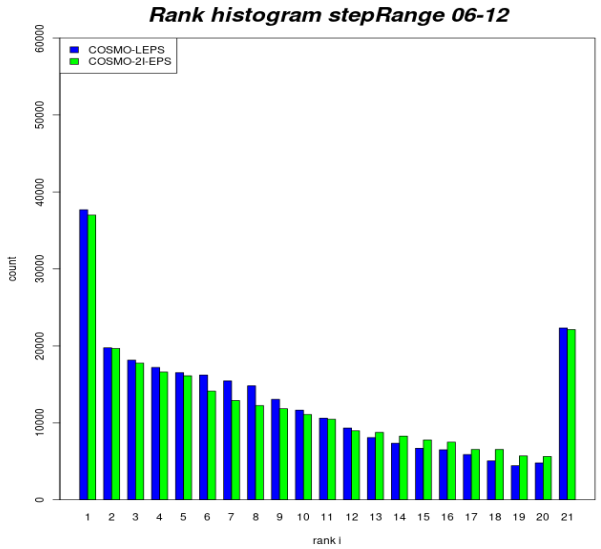


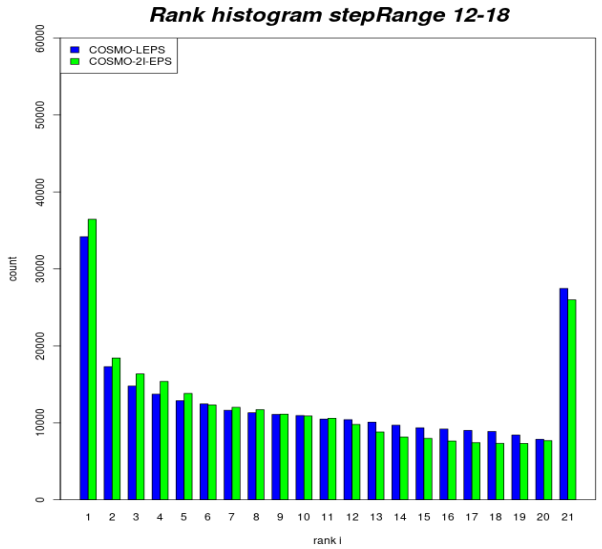
Each color indicates one of the twenty COSMO-2I-EPS members

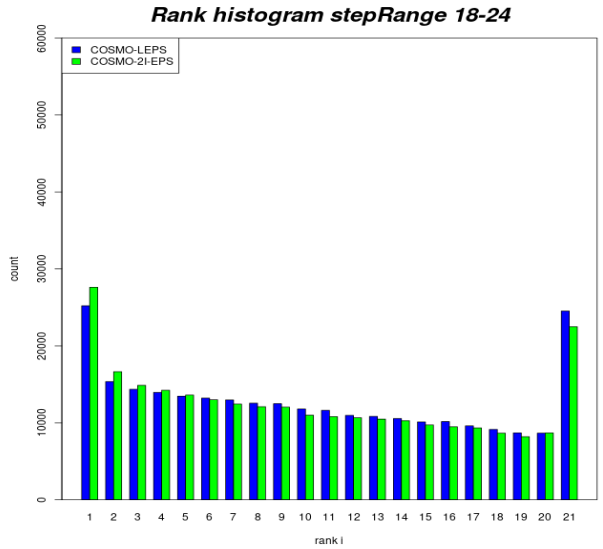
- The **RMSE** tends to increase slightly with the forecast range if +6, +18, +42 hours of the forecast range are excluded
- The **problem** on the first six hours is visible from the RMSE values and even more from those of the bias
- The **bias** tends to decrease slightly with the forecast range if the weak daytime cycle is excluded (+ 18h, + 42h)

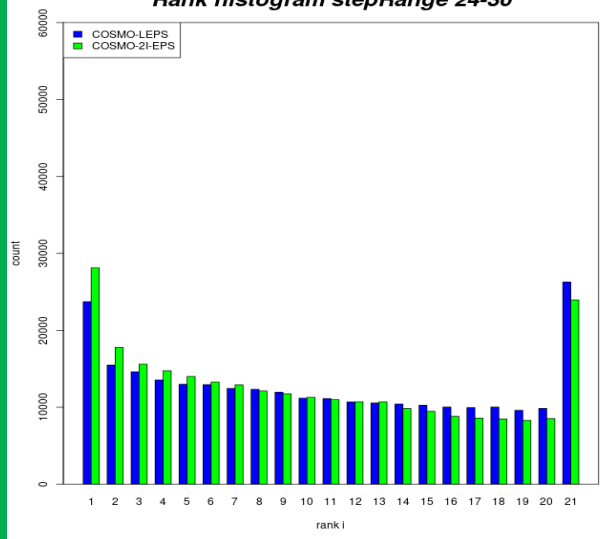
RANK HISTOGRAM COSMO-LEPS vs COSMO-2I-EPS

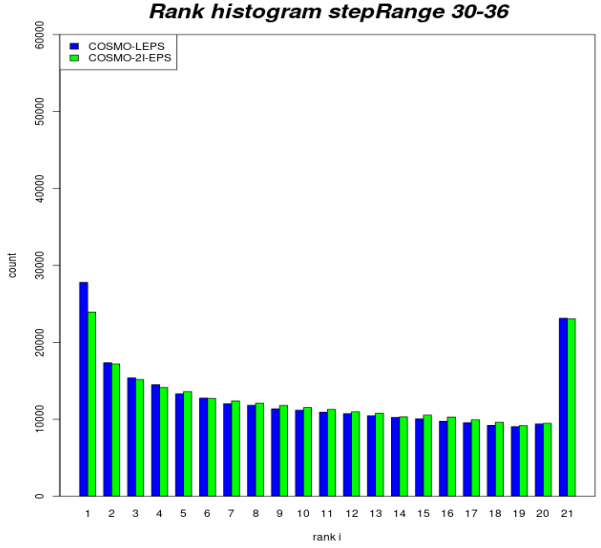


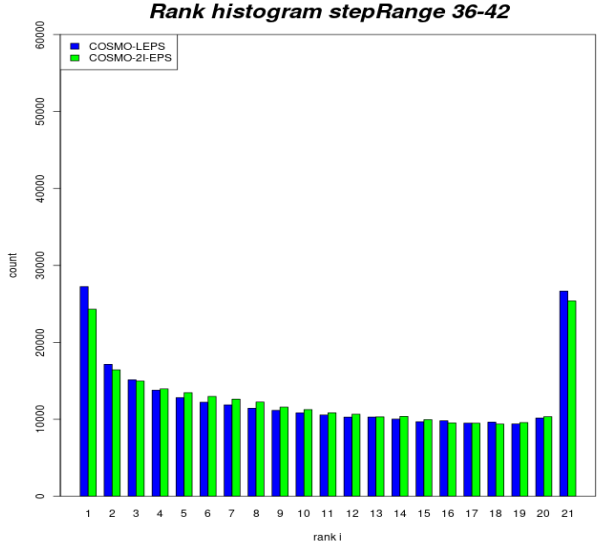


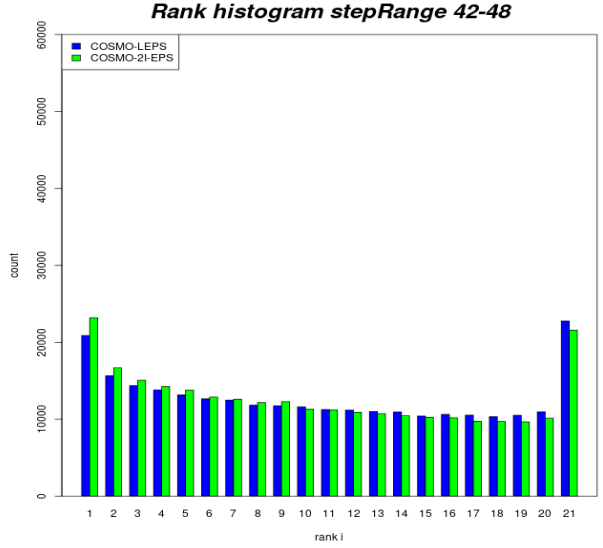












- ✓ The U-shape of the rank histograms indicates the **subdispersion** of both ensemble systems
- ✓ This subdispersion is stronger in the **last bin** of the most intense precipitation for **COSMO-LEPS** and in the **first bin** of the lighter precipitation for **COSMO-2I-EPS**

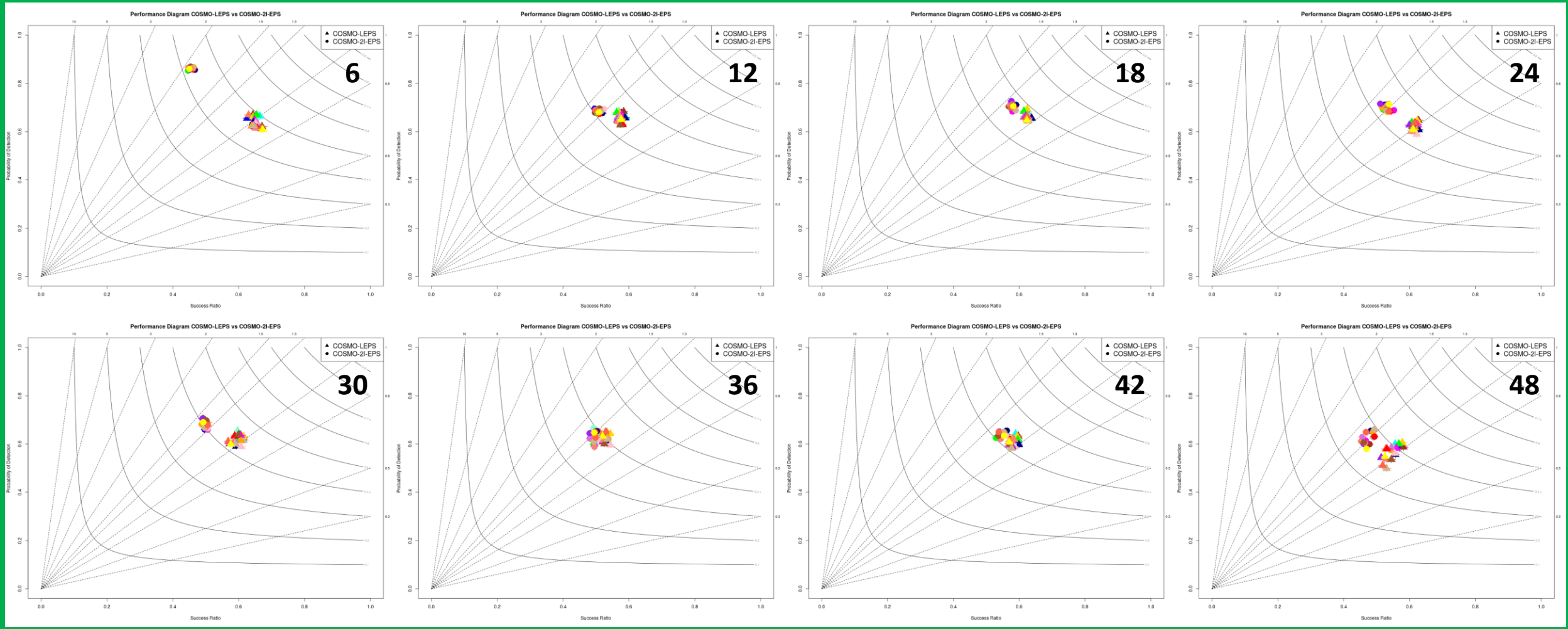
PERFORMANCE DIAGRAM

COSMO-LEPS VS COSMO-2I-EPS

Threshold 1mm

COSMO-LEPS

COSMO-2I-EPS



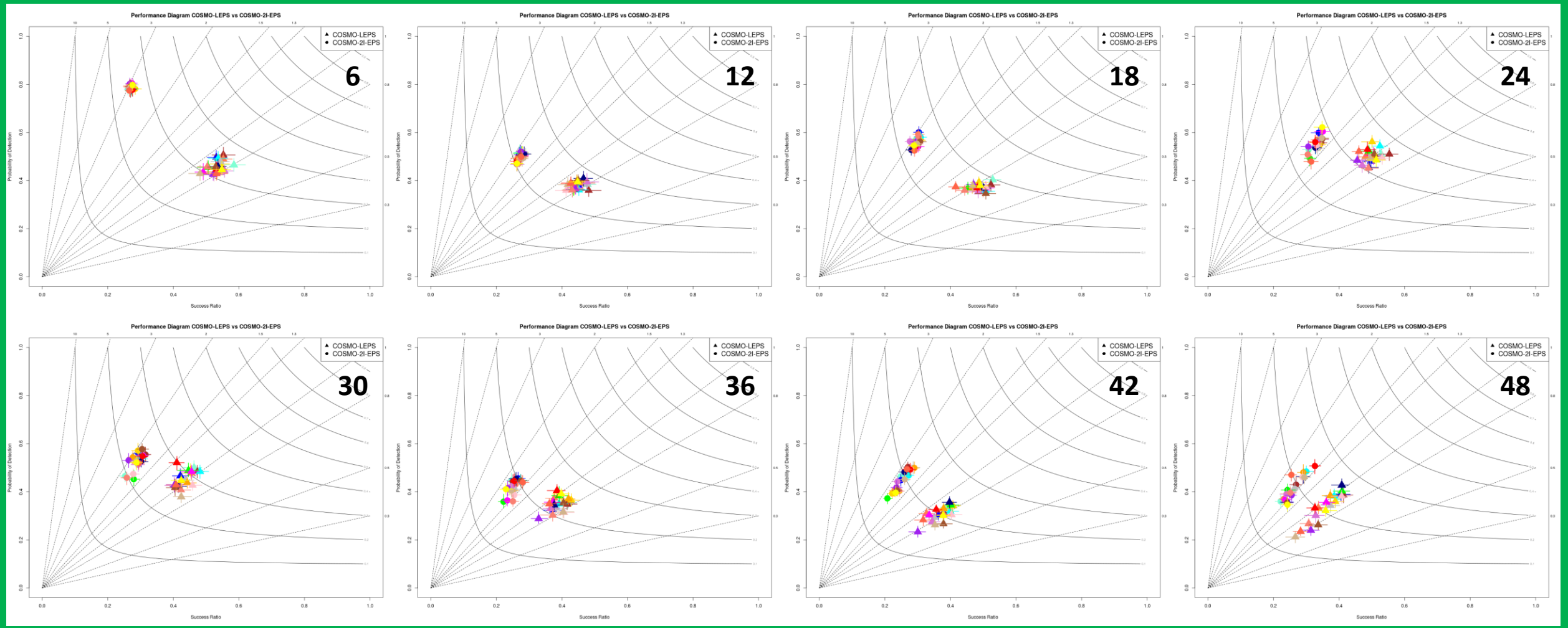
PERFORMANCE DIAGRAM

COSMO-LEPS VS COSMO-2I-EPS

Threshold 10mm

COSMO-LEPS

COSMO-2I-EPS



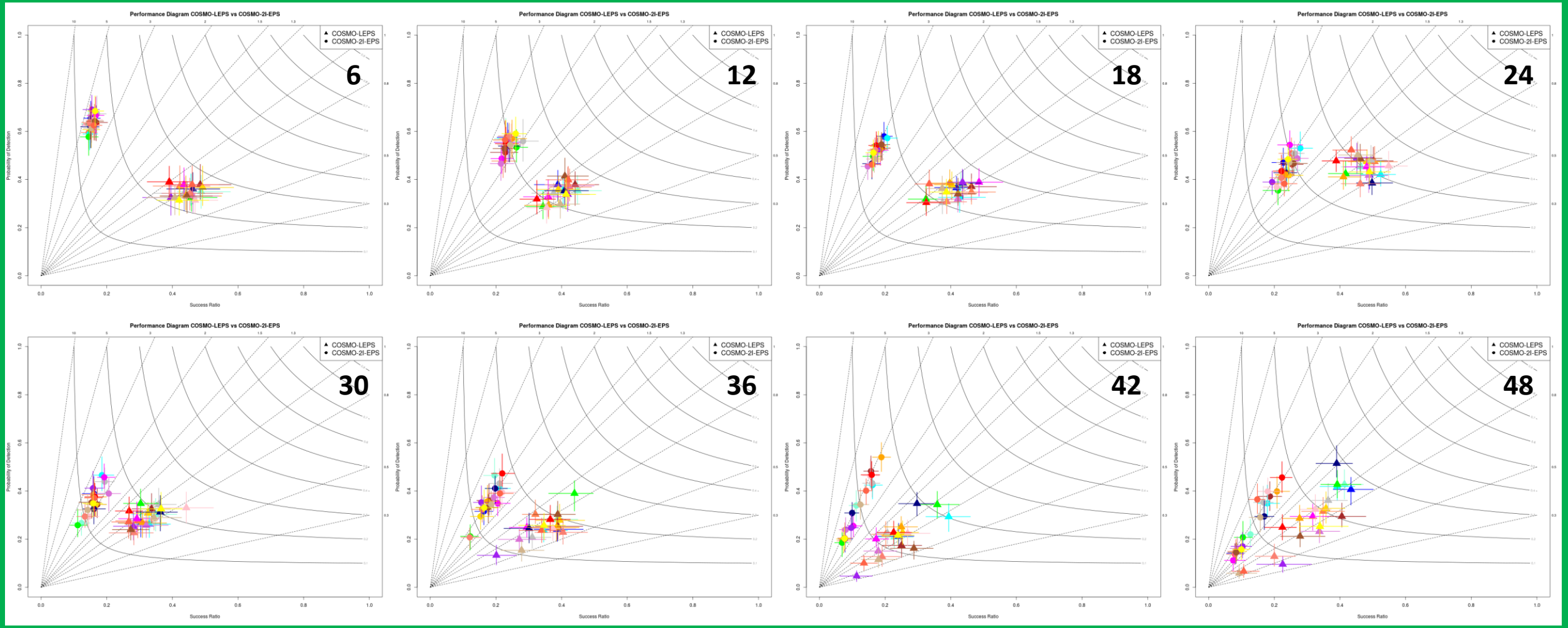
PERFORMANCE DIAGRAM

COSMO-LEPS VS COSMO-2I-EPS

Threshold 25mm

COSMO-LEPS

COSMO-2I-EPS



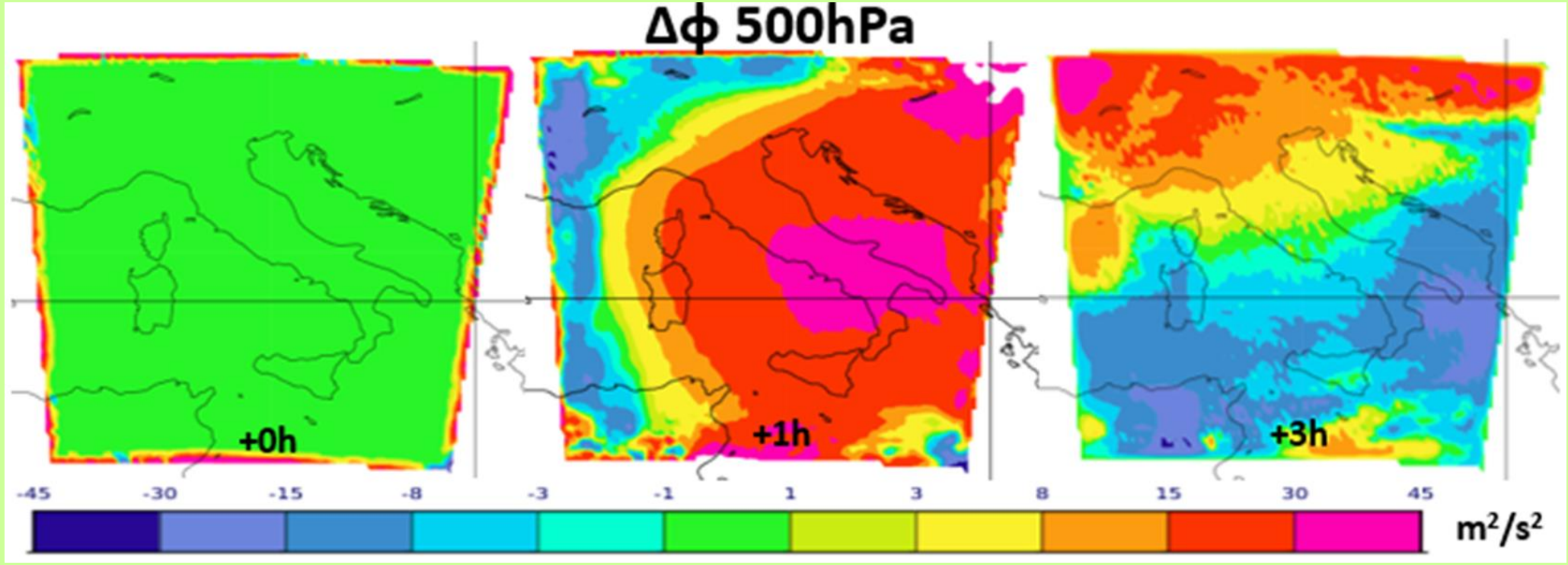
Considerations:

- the **clouds** of both ensemble systems tend to move to the **lower left** and to **open**, increasing the threshold and the forecast range
- the **problem** of COSMO-2I-EPS in the first six hours is evident

Recent investigations

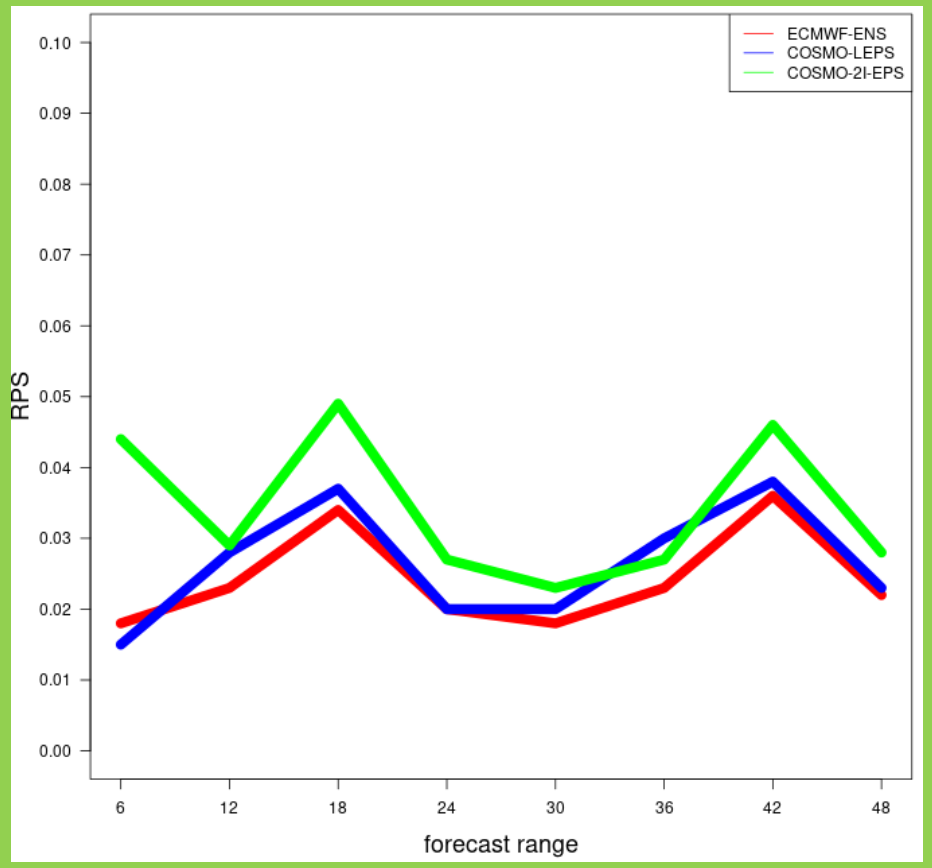
RECENT INVESTIGATIONS

To solve the problem that COSMO-2I-EPS seems to have in the first 6 hour of the forecast range, **the first boundary condition of COSMO-2I-EPS was changed from AM to KENDA**.
This test was made for the run of **22 May 2019**.
The results are meaningful for the **geopotential at 500hPa**.
In the images below the geopotential difference is plotted for the same COSMO-2I-EPS run inizialized once with the first boundary condition from AM and once from KENDA.
At zero time on the edge of the domain a considerable variation of geopotential was observed with respect to the case with boundary condition from AM.
In the following three hours this variation of geopotential spreads within the domain.



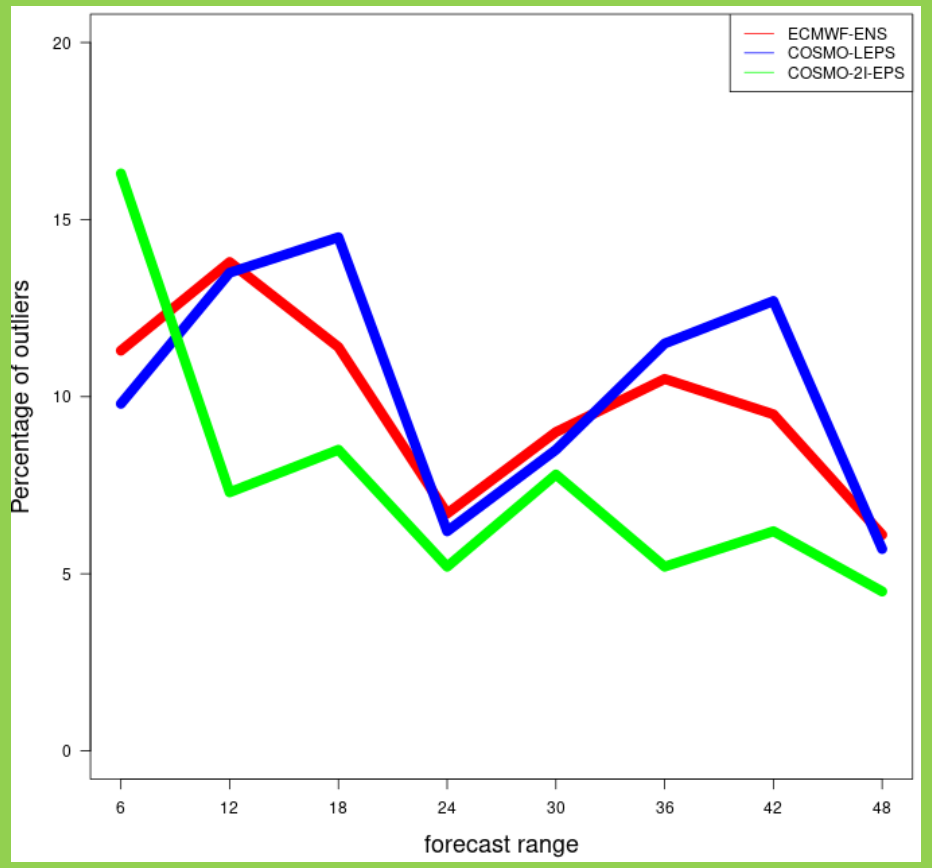

2° Verification period:
23 May – 30 June 2019

RPS



- With respect to the previous case, the COSMO-2I-EPS RPS tends to **improve** and get closer to the results of the other two ensemble systems
- There is a slight **diurnal cycle**
- COSMO-2I-EPS still shows RPS so high in the **first six hours**

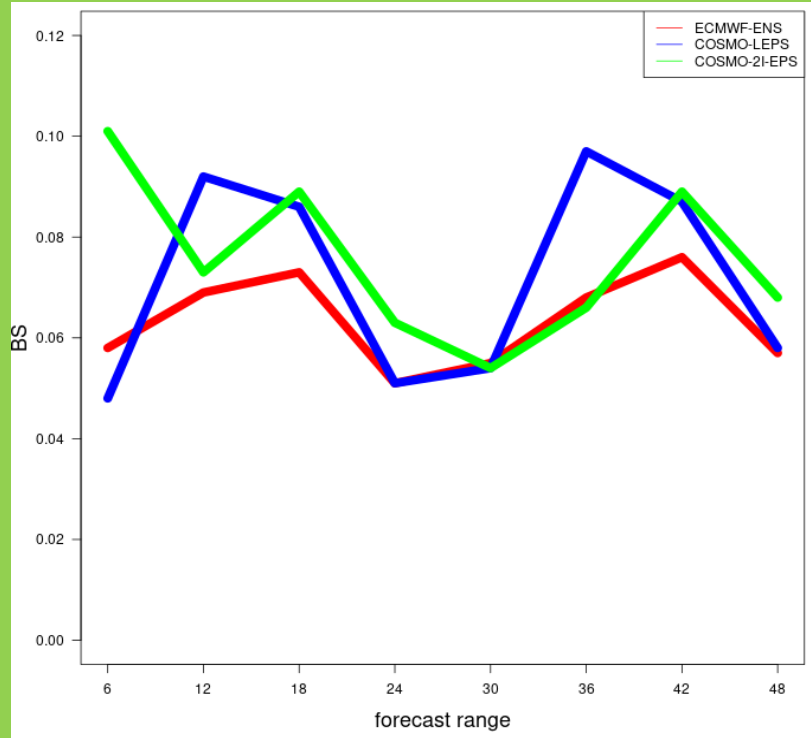
PERCENTAGE OF OUTLIERS



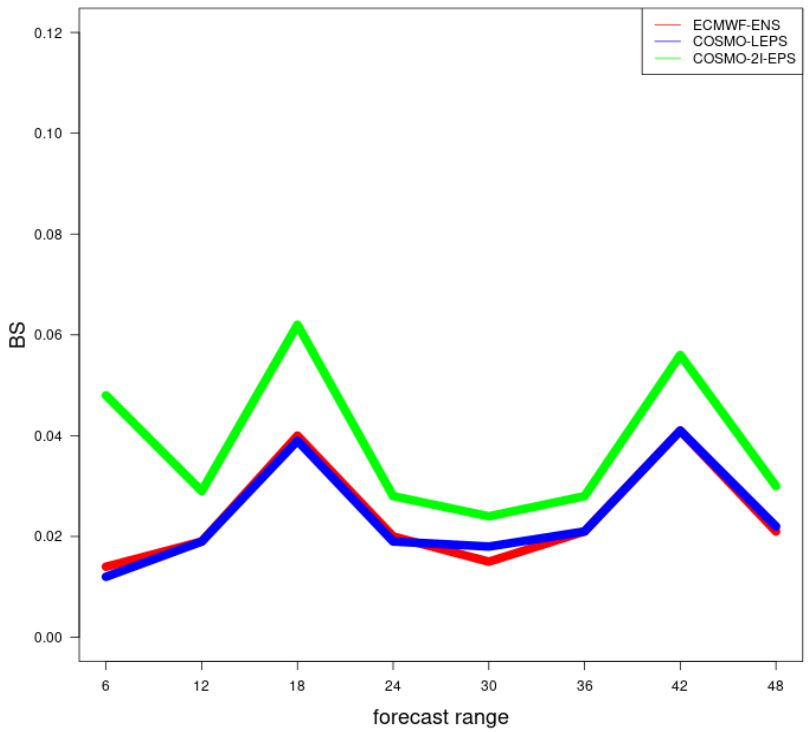
- Also the percentage of outliers of COSMO-2I-EPS **decreases** becoming always the lowest, except in the first six hours where the **problem** persists
- The ensemble system with parameterized convection has a rather accentuated **daytime cycle**

BS

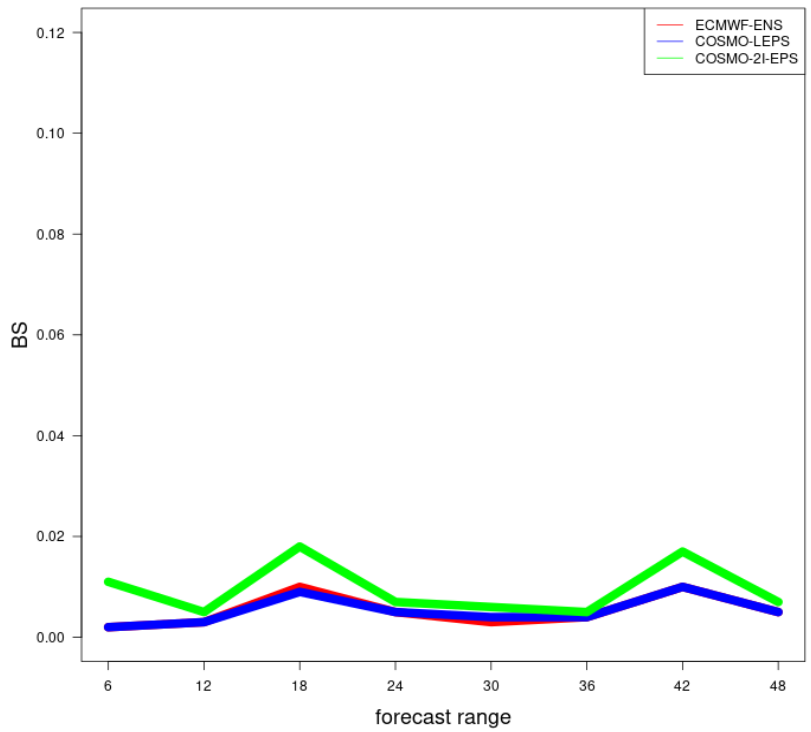
Threshold: 1mm



Threshold: 10mm



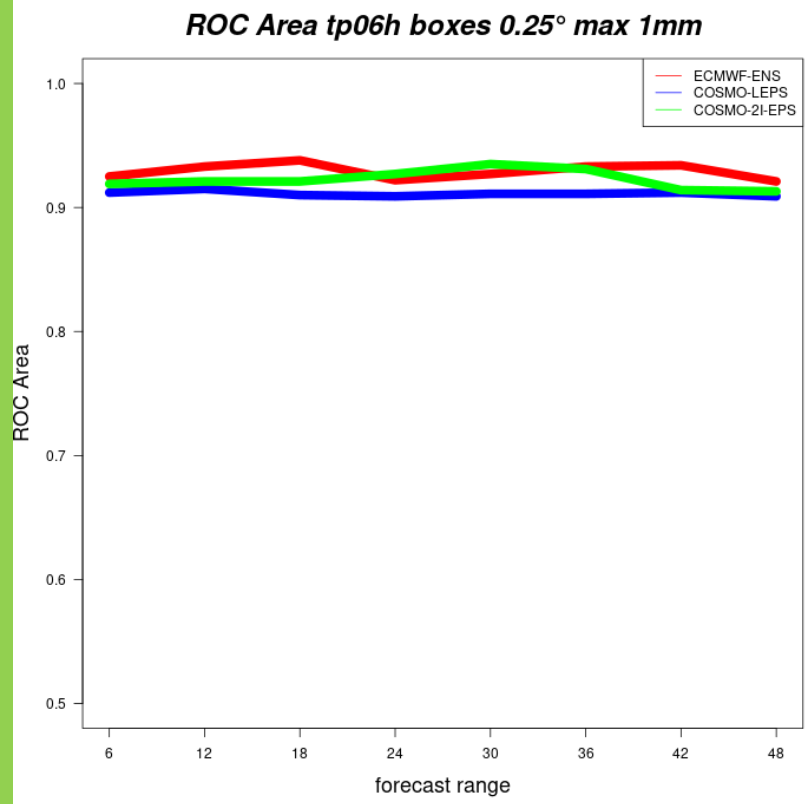
Threshold: 25mm



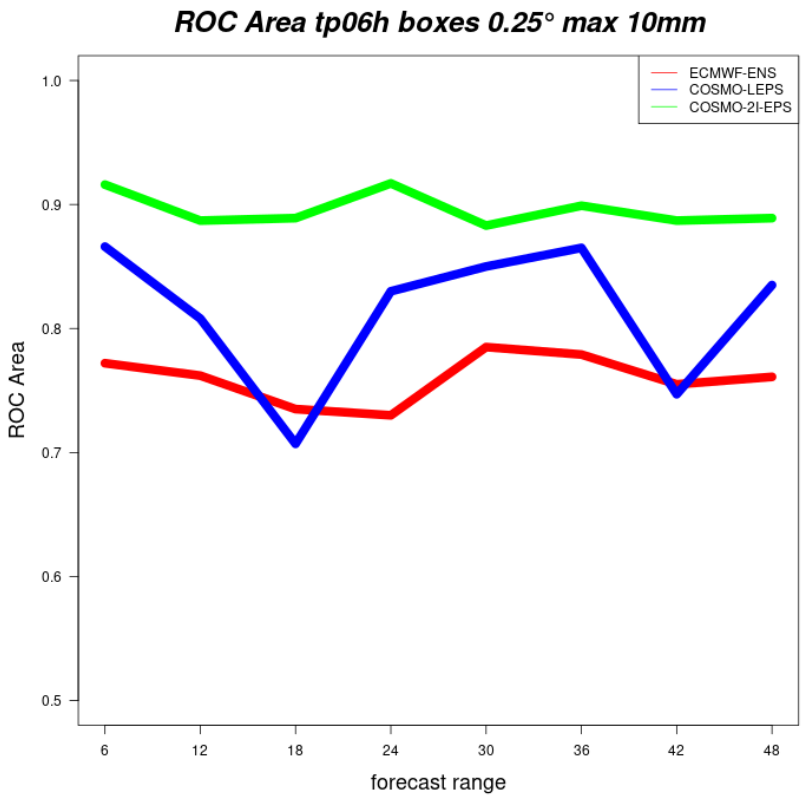
- The BS tends to decrease with increasing threshold, regardless of the ensemble systems
- For the **25 mm threshold**, the BS of the three ensemble systems is very similar and close to zero, so it does not represent a significant case
- For the **10 mm thresholds**, the BS of ECMWF and COSMO-LEPS are almost superimposed, while that of COSMO-2I-EPS is worse (being higher for the whole forecast range)
- For the **1 mm thresholds**, the BS of COSMO-2I-EPS is significantly improved compared to the previous case
- The **daytime cycle** is stronger than the January – April case and it becomes less visible as the threshold increases
- The **COSMO-2I-EPS problem** persists in the first six hours of the forecast range

ROC Area

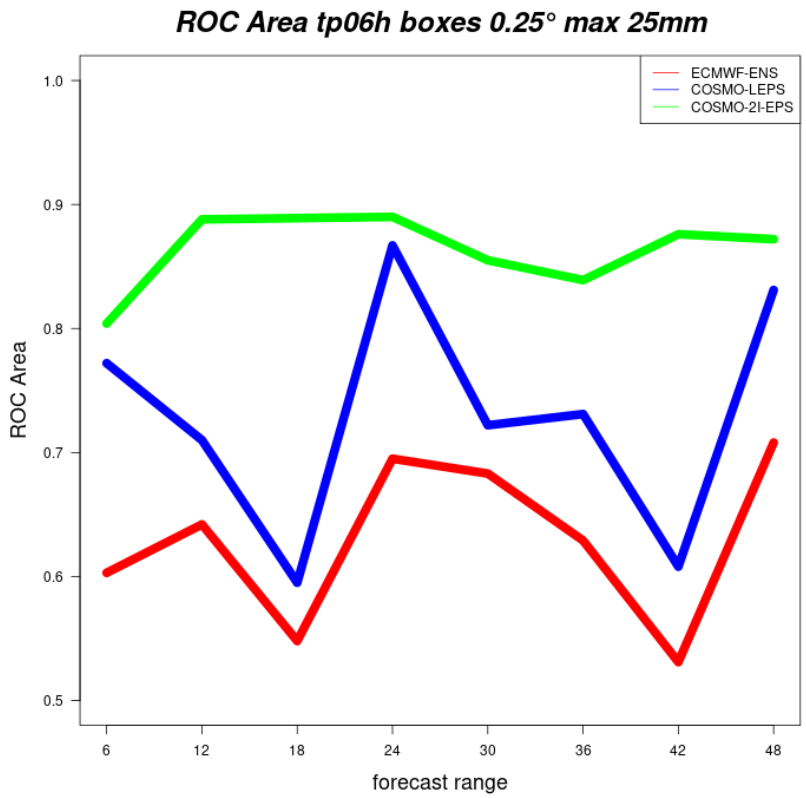
Threshold: 1mm



Threshold: 10mm

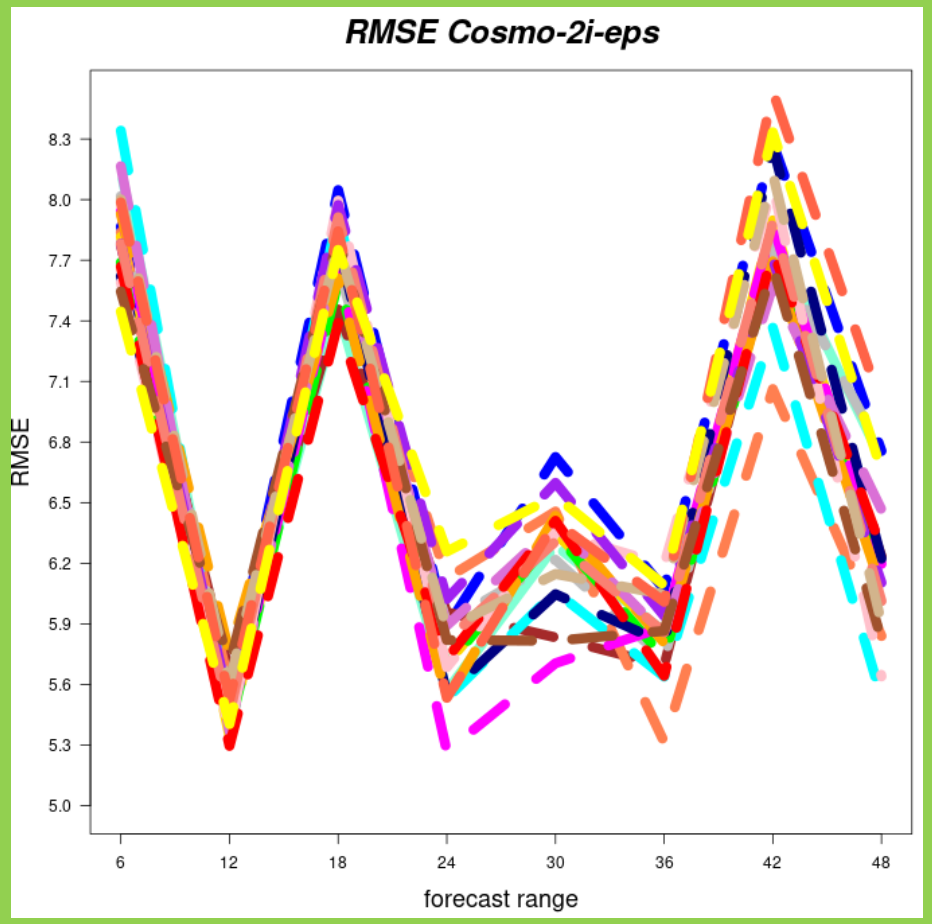


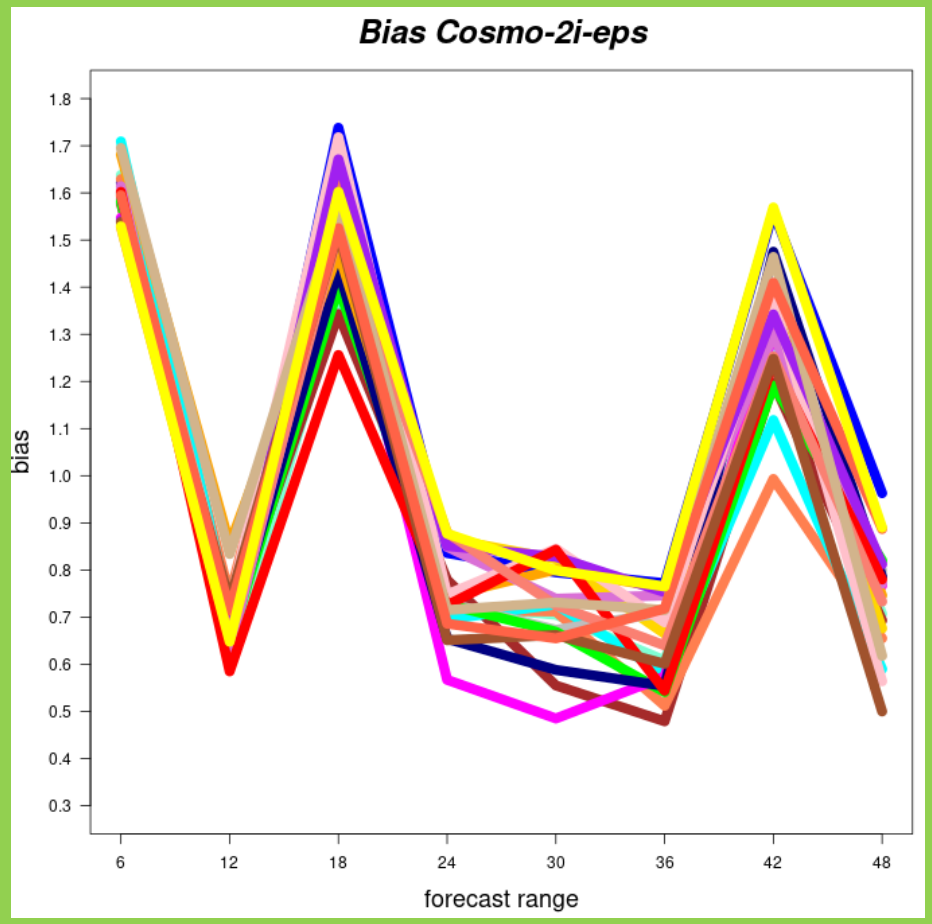
Threshold: 25mm



- The ROC Area of **ensemble systems with parametrized convection** tends to decrease - and therefore to worsen - with the increase of the threshold; instead the ROC area of **COSMO-2I-EPS** remains stable at high values
- Overall, the ROC Area values are lower and therefore **worse** than in the previous case

RMSE & BIAS COSMO-2I-EPS





Each color indicates one of the twenty COSMO-2I-EPS members

- The **RMSE** tends to increase slightly with the forecast range if +6, +18, +42 hours of the forecast range are excluded
- The **problem** on the first six hours is visible both from the RMSE values and from those of the bias
- The **bias** tends to decrease slightly with the forecast range if the daytime cycle is excluded (+ 18h, + 42h)
- In general the **daytime cycle** is stronger than the January – April case

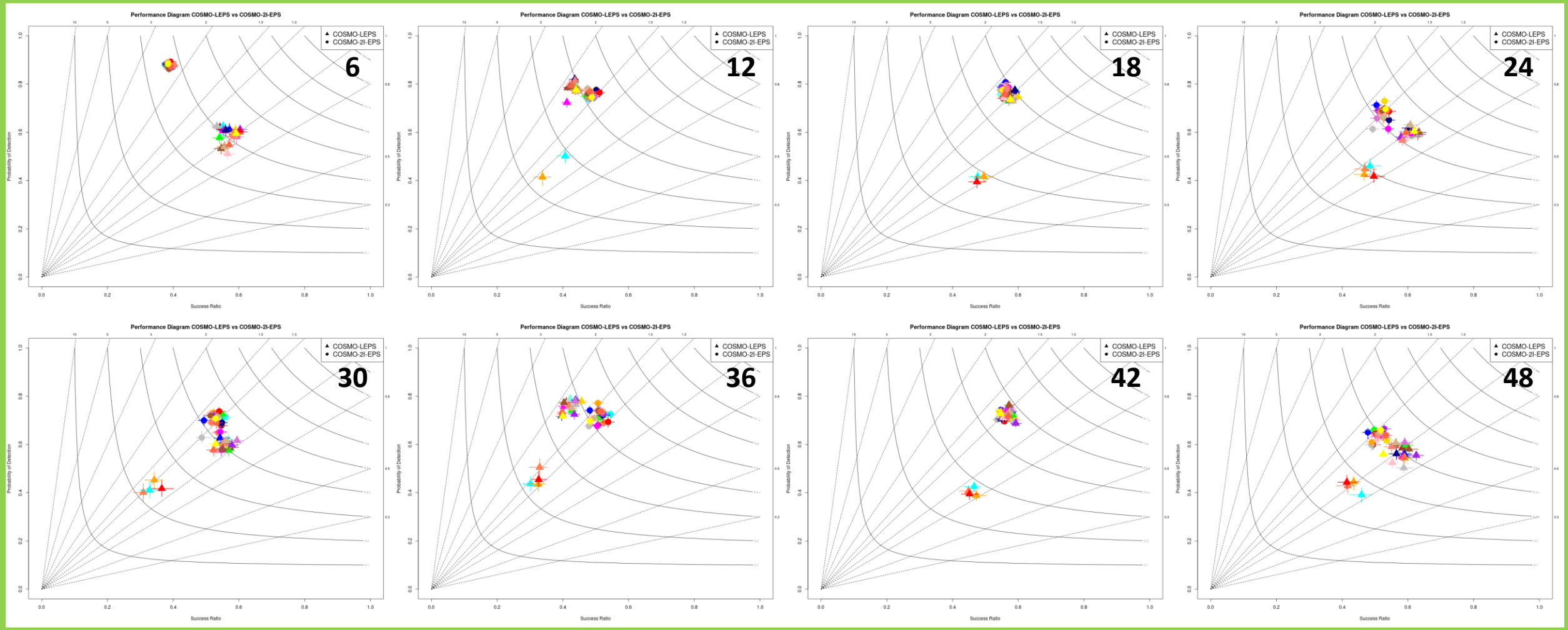
PERFORMANCE DIAGRAM

COSMO-LEPS VS COSMO-2I-EPS

Threshold 1mm

COSMO-LEPS

COSMO-2I-EPS



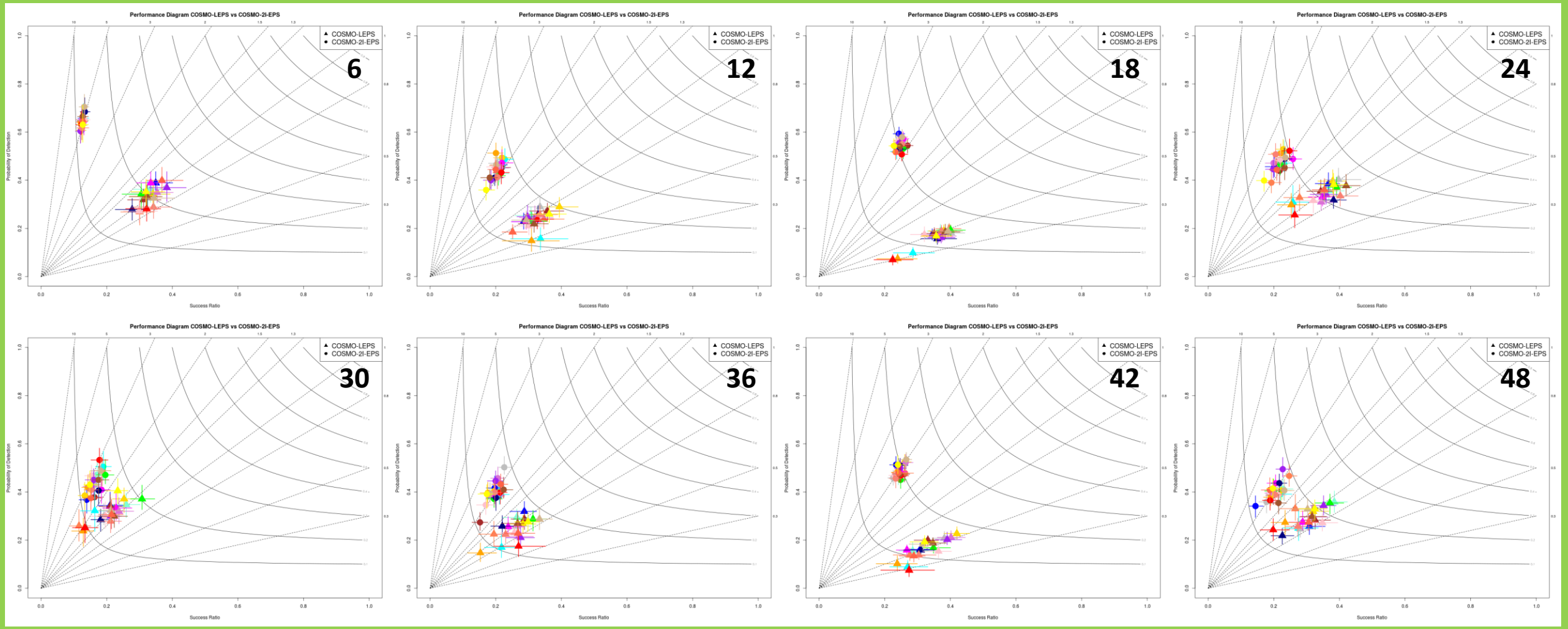
PERFORMANCE DIAGRAM

COSMO-LEPS VS COSMO-2I-EPS

Threshold 10mm

COSMO-LEPS

COSMO-2I-EPS



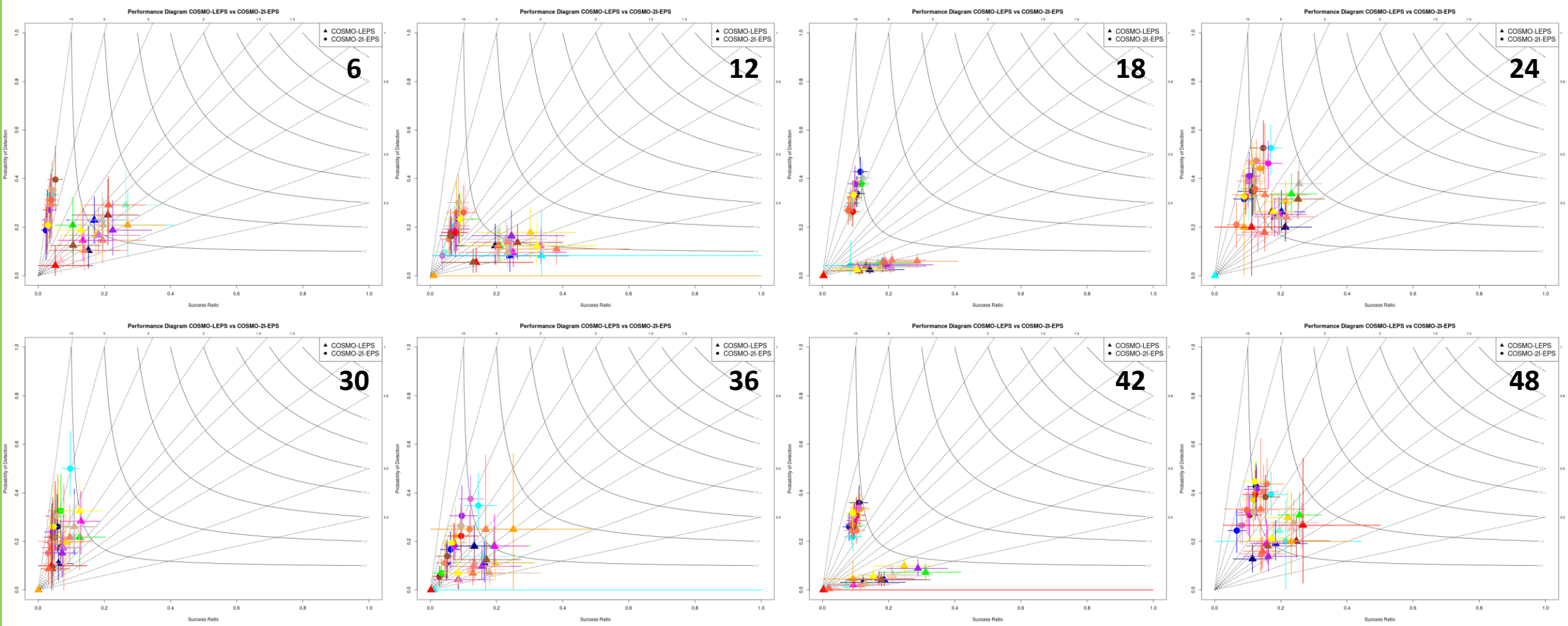
PERFORMANCE DIAGRAM

COSMO-LEPS VS COSMO-2I-EPS

Threshold 25mm

COSMO-LEPS

COSMO-2I-EPS



Considerations:

- Compared to the previous case, the clouds of both ensemble systems tend to be moved **lower down to the left** and to be **more open**, even for the 1mm threshold

CONCLUSIONS

CONCLUSIONS

How did **COSMO-2I-EPS** behave in the two verification periods?
Is there an improvement or a deterioration?

Score	1° period	Better or worse?	2° period
RPS	X	better	~
% outliers	~	better	OK
BS	X	better	~
ROC Area	OK	=	OK
RMSE	OK	worse	~
Bias	OK	worse	~
Rank histogram	OK		
Performance diagram	~	worse	X

- ✓ In the two periods analyzed some scores improve others worsen, probably due to **different statistics** and **different climatology**
- ✓ **The problem for the first six hours has not been solved**

Thanks for the attention