Choosing the optimal sub-ensemble of boundary conditions using the cluster analysis

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COSMO General Meeting, September 2020

Overview

Since 2020: Development of a new COSMO 2.5km resolution 20 members ensemble over the Eastern Mediterranean

Platform: ECMWF computer

BC: ECMWF 51 members ensemble (EC-ENS)

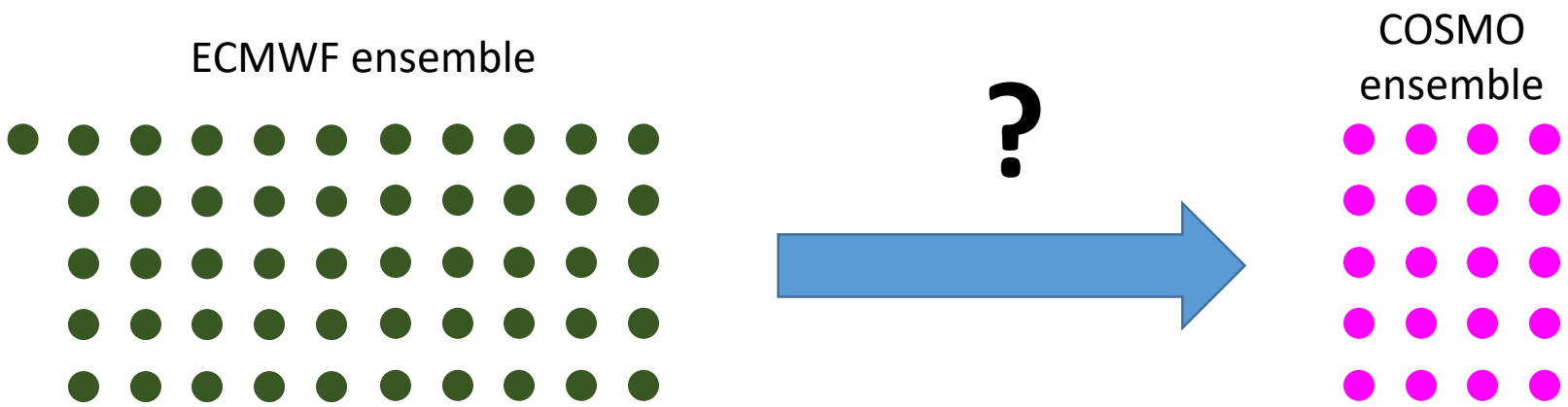
Goal: Ensemble which will is reliable and skillful

Sources of forecast uncertainty:

- Uncertainty in boundary conditions → use of driving ensemble (**EC-ENS**)
- Uncertainty in model physics → Stoch. Pert. of Param. Tendencies (**SPPT**), parameter perturbations (**PP**)
- Uncertainty in initial conditions → **KENDA** analysis perturbations.

Topic

1. **Which 20 EC-ENS members to choose?**
2. If we have time … Does SPPT benefits? Does PP benefits?



Method

Suggest 12 methods for selection of driving EC-ENS sub-ensemble (20 members)

Questions:

A. Choose **most different** (representative) 20 EC-ENS members or the **most close** to deterministic IFS?
B. Which atmospheric **fields** will define the "distance" between members?
C. Which **forecast range** will be used to calculated the distance?

The suggested methods are:

1. Most close to IFS, cape only, small domain, forecast range with maximum spread
2. Most close to IFS, cape and TCWV (50%-50%), small domain, forecast range with maximum spread
3. Most close to IFS, vorticity$_{500}$, larger domain, forecast range with maximum spread
4. Most close to IFS, vorticity$_{500}$ and MSL 50%-50%, larger domain, forecast range with maximum spread
5. Most close to IFS, Z_{500} and MSL 50%-50%, larger domain, forecast range=96h
6. Representative, cape only, small domain, forecast range with maximum spread
7. Representative, cape and TCWV (50%-50%), small domain, forecast range with maximum spread
8. Representative, vorticity$_{500}$, larger domain, forecast range with maximum spread
9. Representative, vorticity$_{500}$ and MSL 50%-50%, larger domain, forecast range with maximum spread
10. Representative, Z_{500} and MSL 50%-50%, larger domain, forecast range=96h
11. Representative, (*similar to LEPS*), fields: Z, QV, U, V at 500, 700, 850 hPa, larger domain, forecast range=96h
12. Random 20 members at each run

Focus on rain season: 22/12/2019-10/01/2020, 05/02/2020-16/02/2020

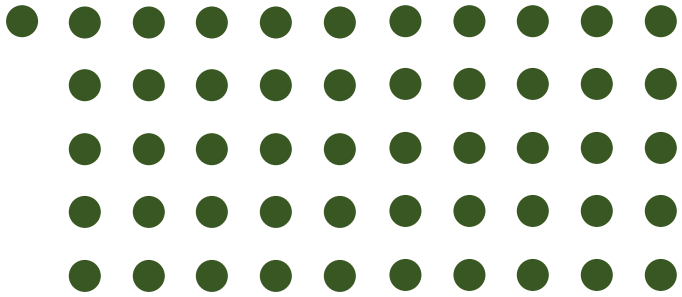
Twice daily COSMO runs (64 runs) of 51-members ensemble → allow testing methods without more runs!

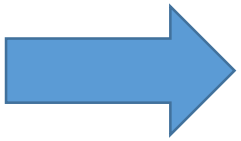
Verify the 12 methods and select the optimal one

Method: clarification

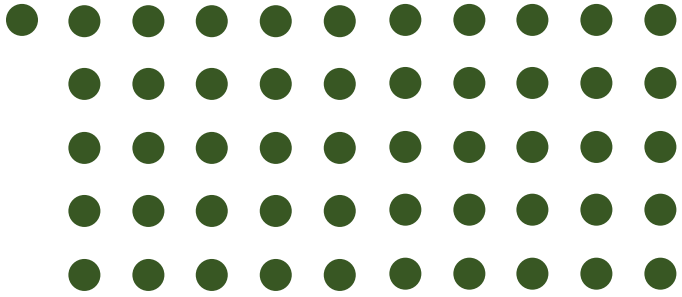
A. Run all 51 members

ECMWF ensemble

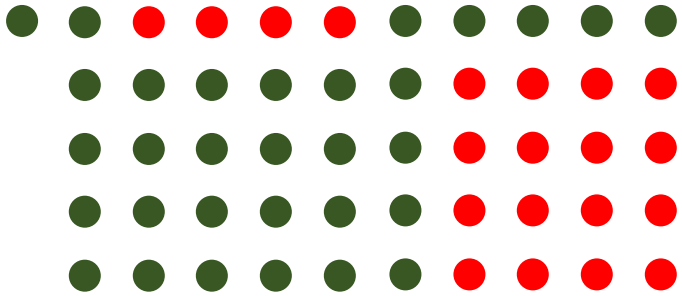


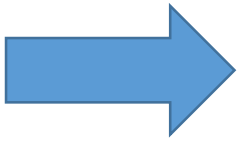


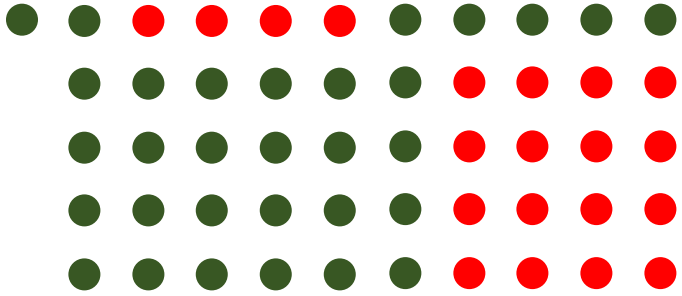
COSMO ensemble



B. Try method 1







Verify **those** and decide if this method is good

C. Try method 2,… and so on

Distance between EC-ENS members

For field F, height (or pressure) level L and forecast range t, we calculated the mean and standard deviation for all the grid points and 51 ensemble members. The **normalized field** at each grid point i,j of ensemble member m is:

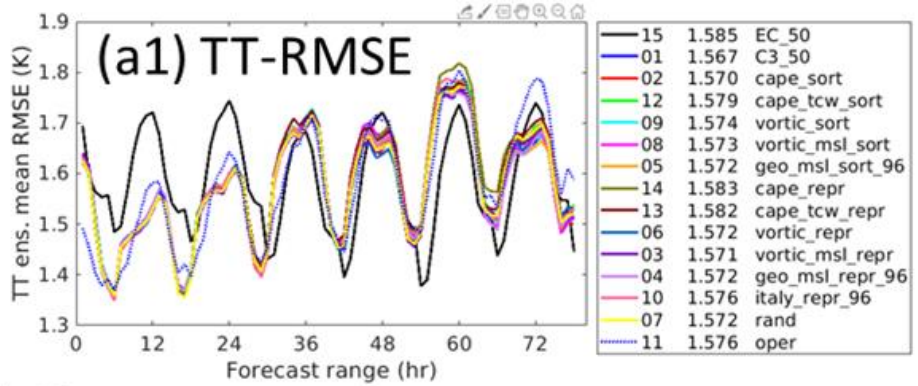
$$x_{i,j,m}(F,L,t) \rightarrow \hat{x}_{i,j,m}(F,L,t) = \frac{x_{i,j,m}(F,L,t) - \overline{x_{i,j,m}(F,L,t)}^{i,j,m}}{\sigma(F,L,t)}$$

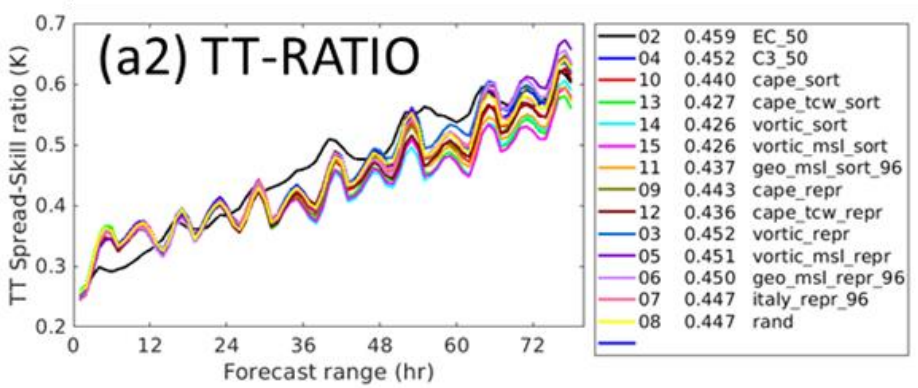
Taking into account all the grid points i,j , fields F, height levels L and forecast ranges t, the "distance" between 2 ensemble members m_1 and m_2 is:

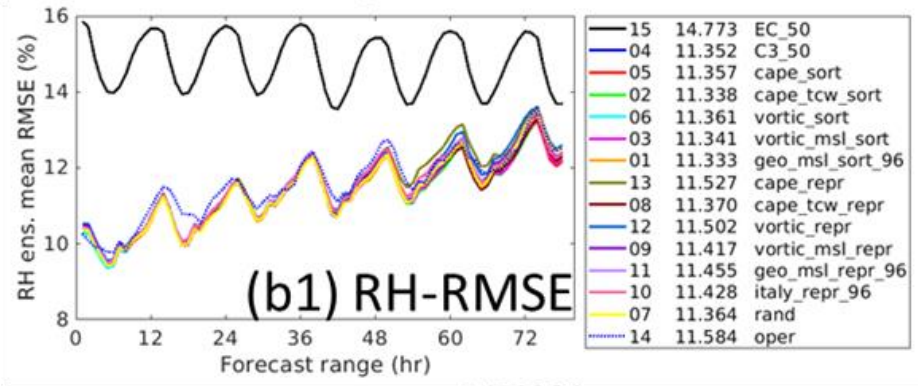
$$\Delta\hat{x}(m_1 \leftrightarrow m_2) = \sqrt{\frac{1}{N_i N_j N_F N_L N_t} \sum_{i,j,F,L,t} \left(\hat{x}_{i,j,m_1,F,L,t} - \hat{x}_{i,j,m_2,F,L,t}\right)^2}$$

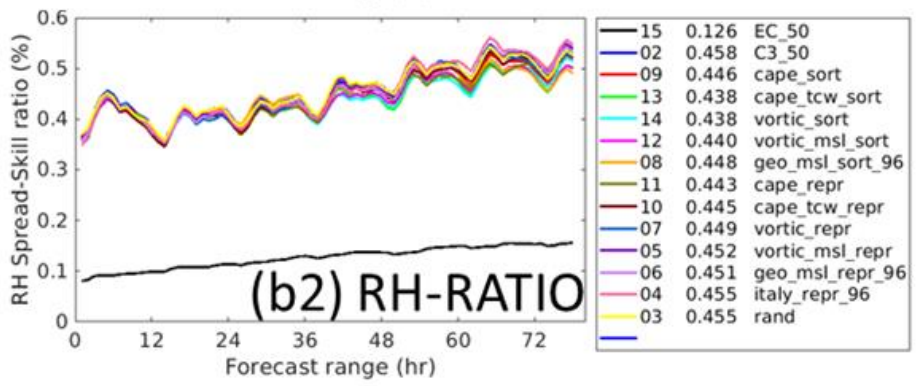
- *Molteni, F., Buizza, R., Marsigli, C., Montani, A., Nerozzi, F., Paccagnella, T., 2001: A strategy for High–Resolution Ensemble Prediction. Part I: Definition of Representative Members and Global Model Experiments. Quarterly Journal of the Royal Meteorol. Soc., No. 127, 2069-2094.*
- *Marsigli, C., Montani, A., Nerozzi, F., Paccagnella, T., Tibaldi, S., Molteni, F., Buizza, R., 2001: A strategy for High–Resolution Ensemble Prediction. Part II: Limited–area experiments in four Alpine flood events. Quarterly Journal of the Royal Meteorol. Soc., 127, 2095-2115. No. 12: April 2012 4 Predictability and Ensemble Methods 76*

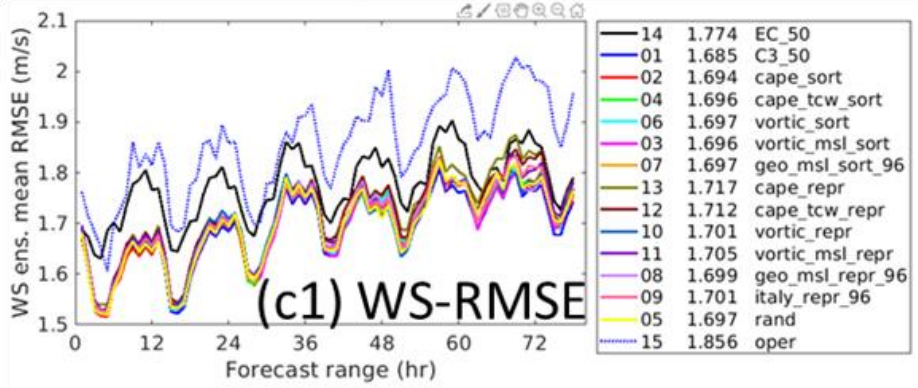
Verification of T_{2m}, RH_{2m}, WS_{10m} for all the methods

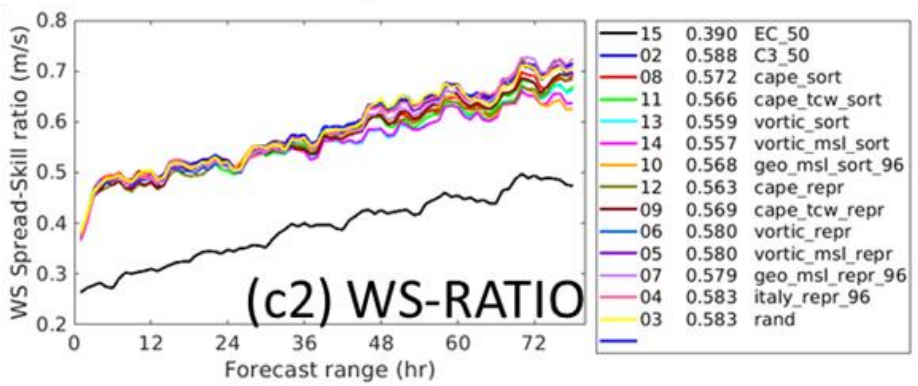












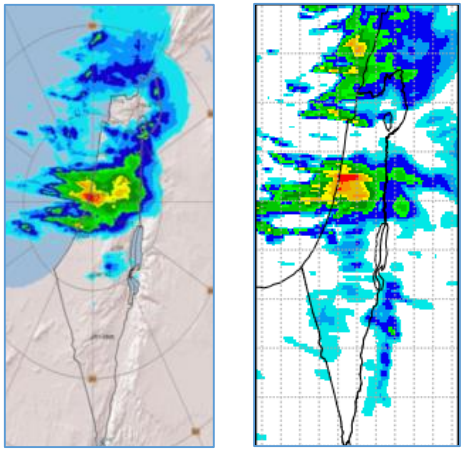
Unbiased RMSE and ensemble spread-RMSE ratio of twice daily COSMO-ENS forecasts for the **winter-period**: T_{2m} (a1,a2), RH_{2m} (b1,b2) and WS_{10m} (c1,c2). The verification was performed against 81 automatic weather stations

Precipitation verification

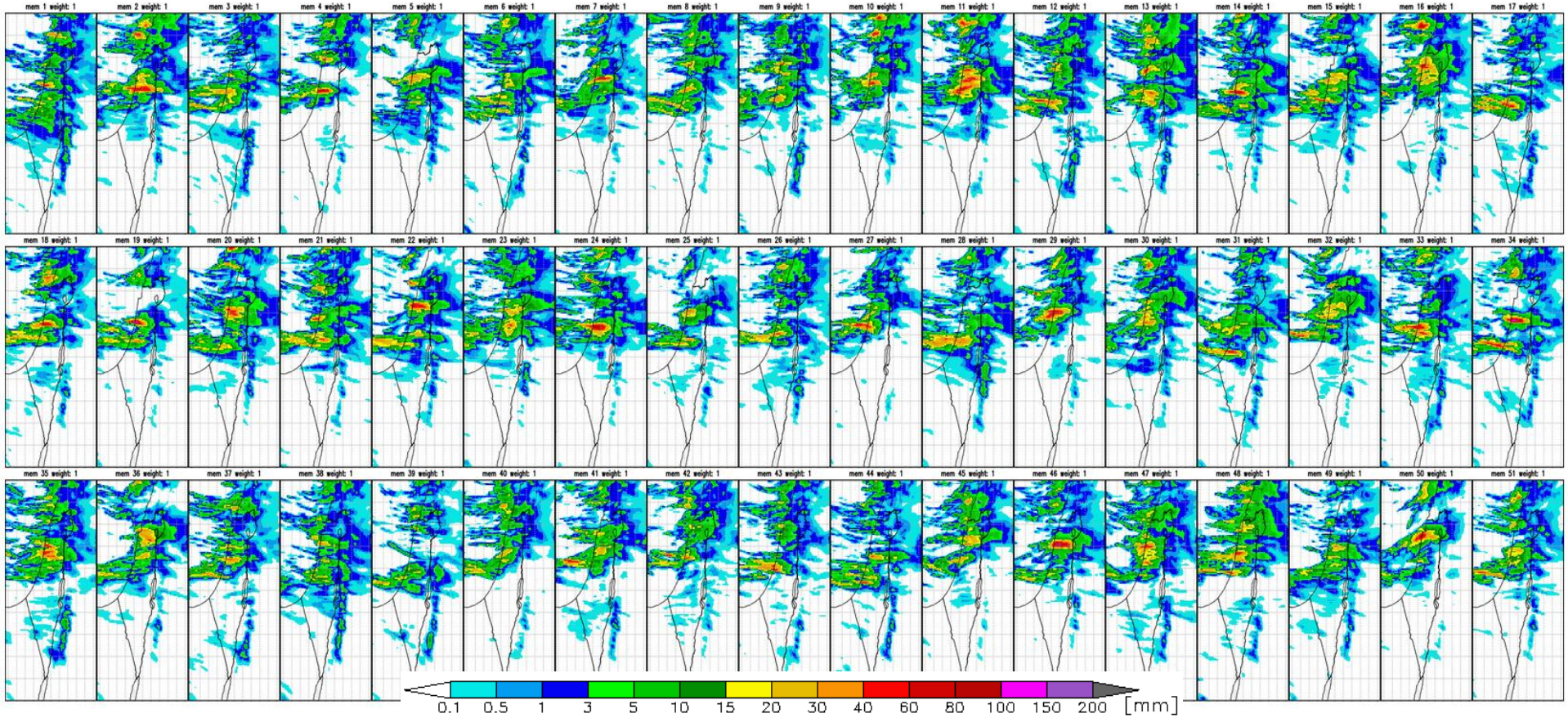
How good are the forecasts of objects locations?

Radar

COSMO deterministic

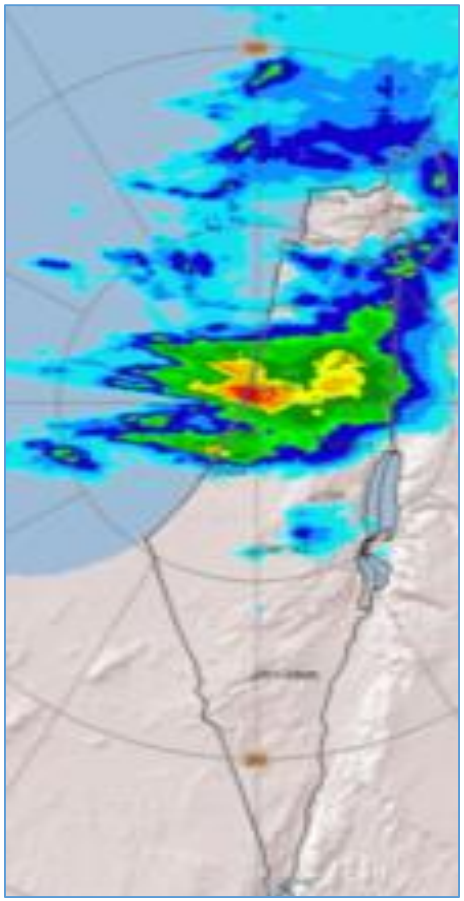


Example: “Tel-Aviv elevator disaster” 4/1/2020 6-12 UTC

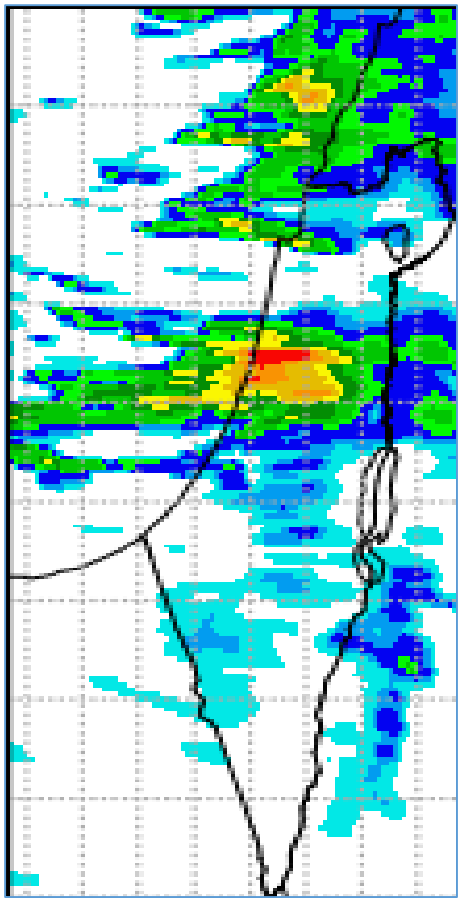


How good are the forecasts of objects locations?

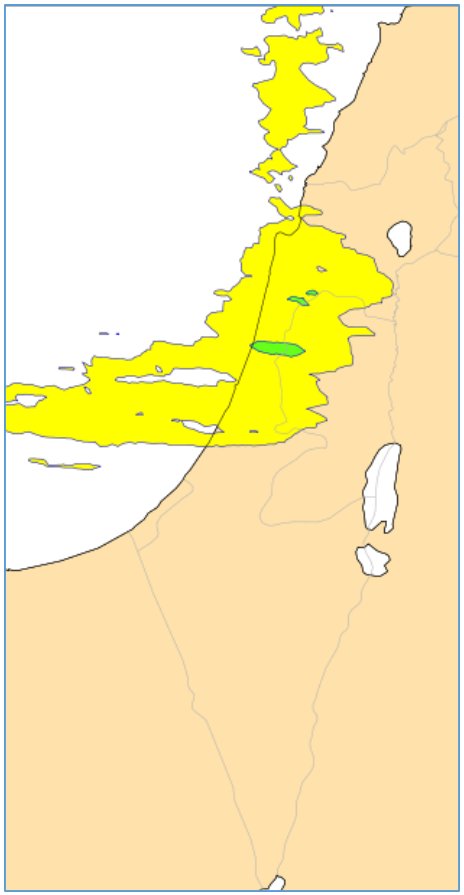
Radar + rain gauges

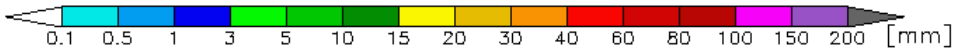


COSMO deterministic



COSMO 51-mem
Probability > 20 mm/6h





How good are the forecasts of objects locations?

- Deterministic COSMO precipitation forecasts are good - location errors around 30-40 km

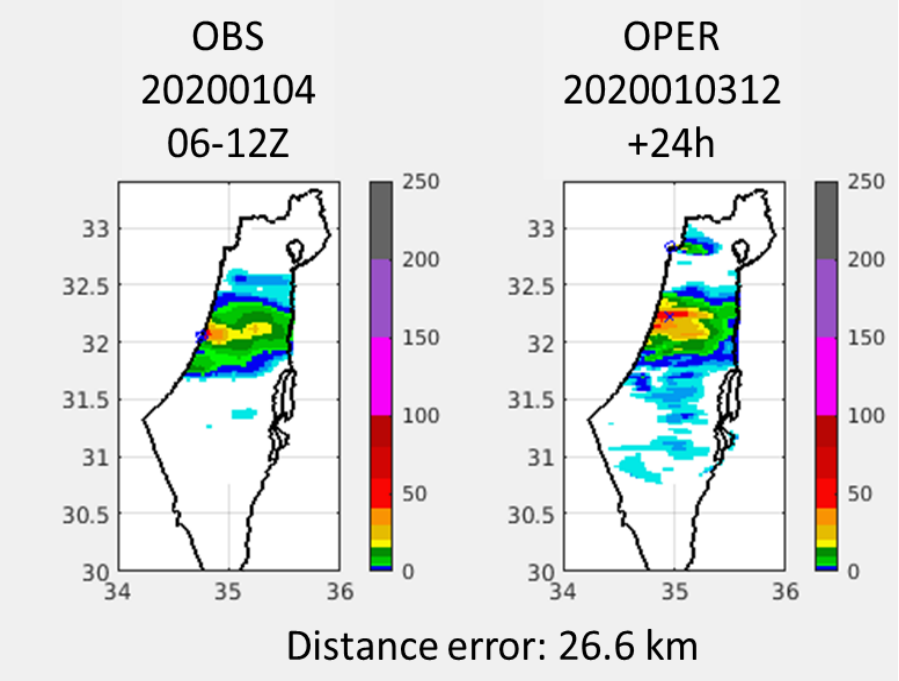
Khain, P, Levi, Y, Shtivelman, A, Vadislavsky, E, Brainin, E, Stav, N. Improving the precipitation forecast over the Eastern Mediterranean using a smoothed time-lagged ensemble. Meteorol Appl. 2020; 27:e1840. https://doi.org/10.1002/met.1840

- We would like the ensemble members to be as good as the deterministic COSMO

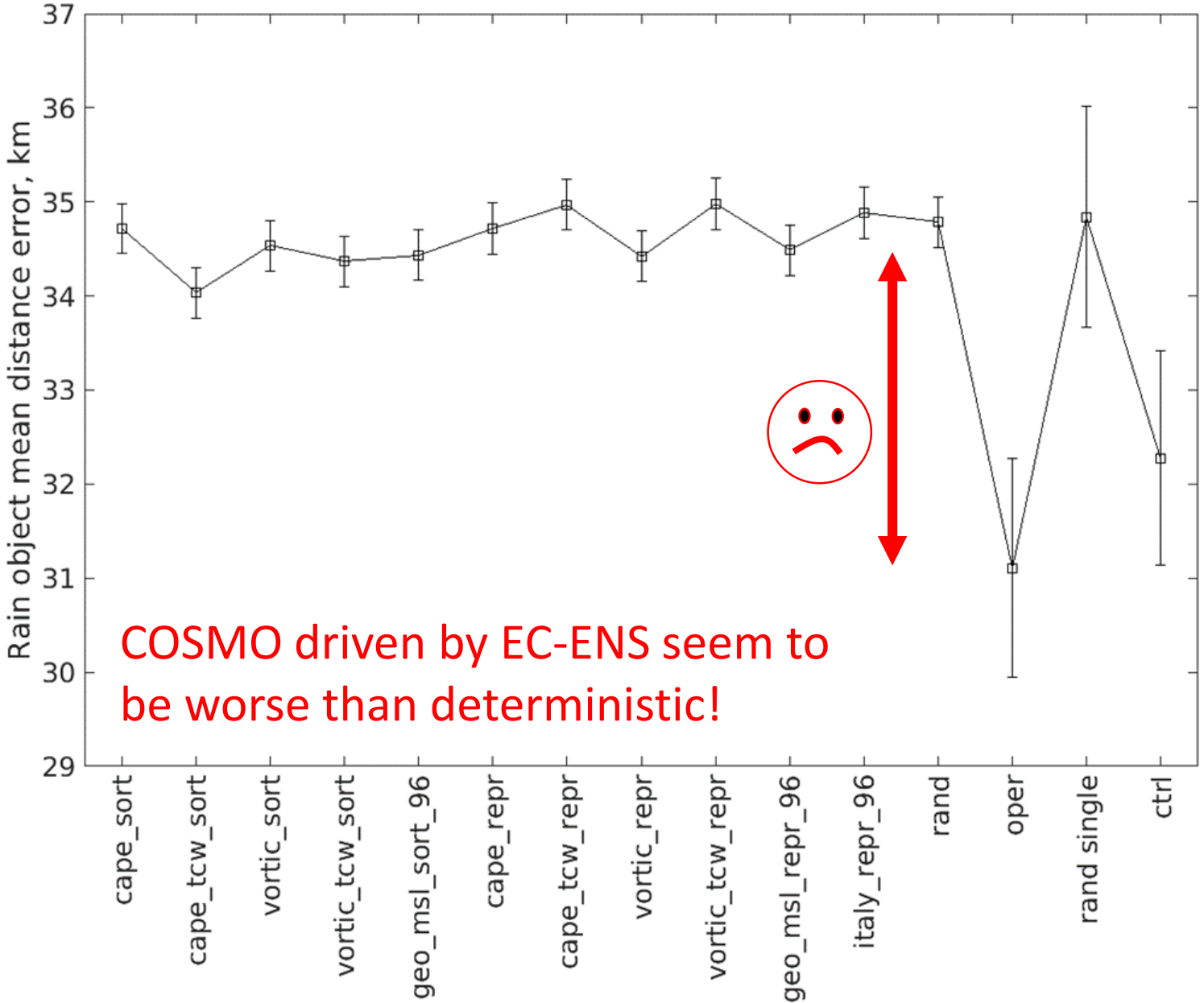
A quick method to evaluate the quality of precipitation objects prediction:

- Identification the local peaks in 2D precipitation map
- Search for one or two main peaks in both observed and simulated map
- For given forecast, identify the simulated peaks with the observed ones and calculate location errors

Example ("Tel-Aviv elevator disaster"):

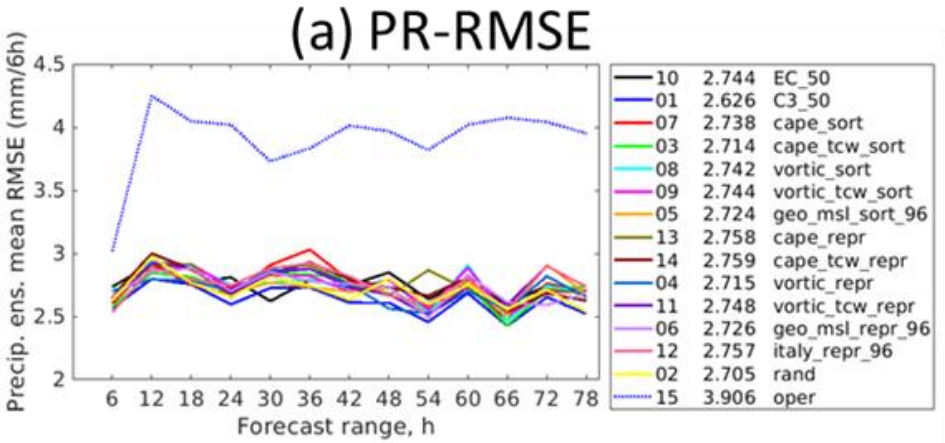


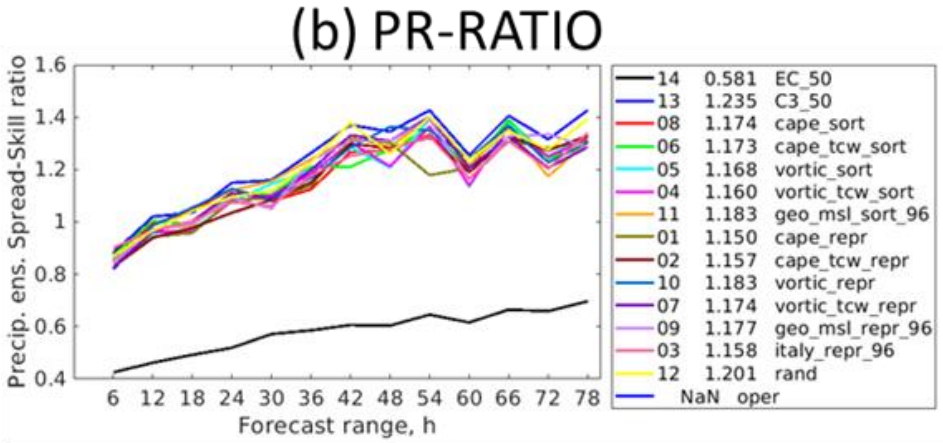
How good are the forecasts of objects locations?



Precipitation – standard verification

Spread-Skill

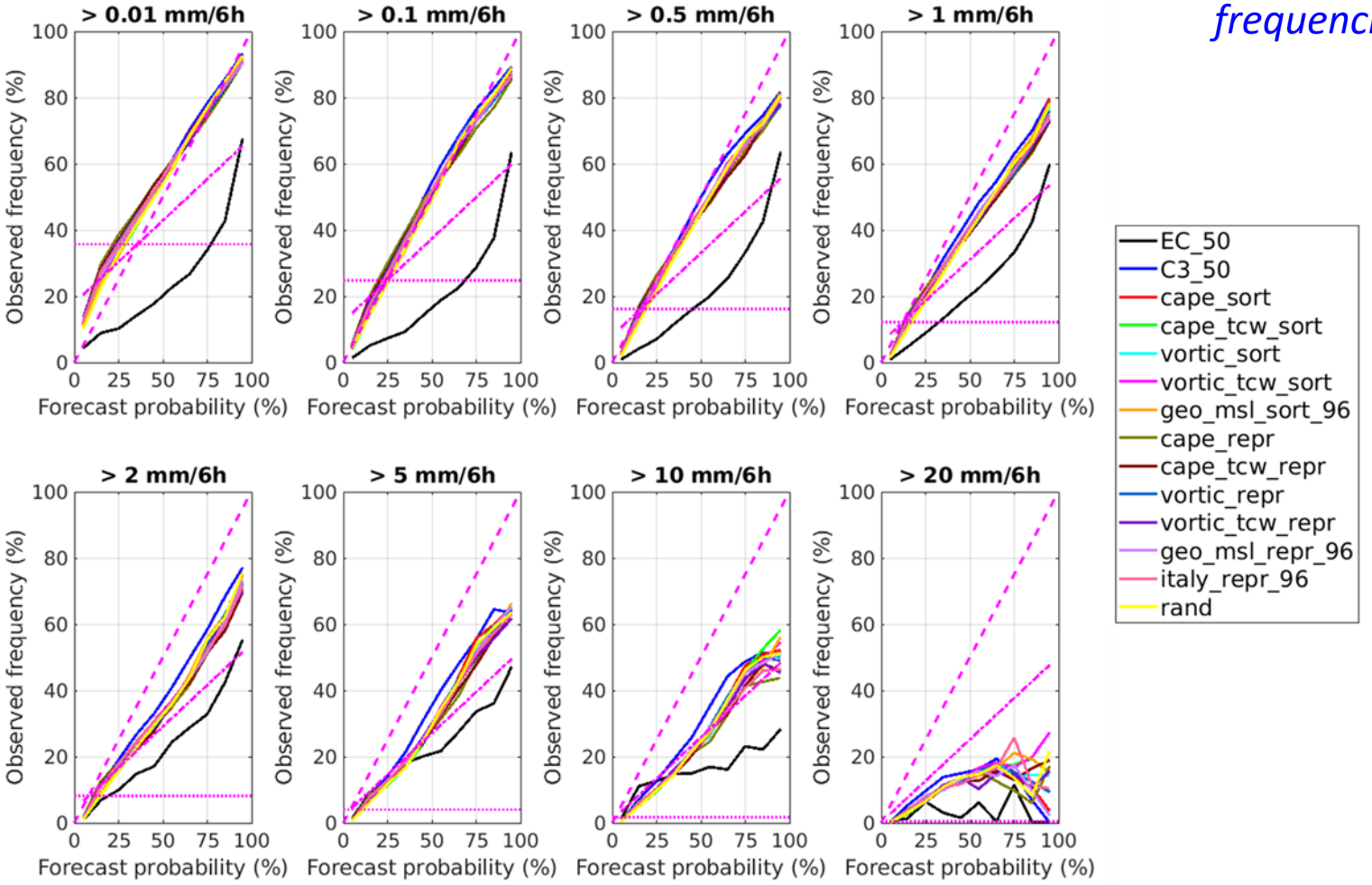




Precipitation – standard verification

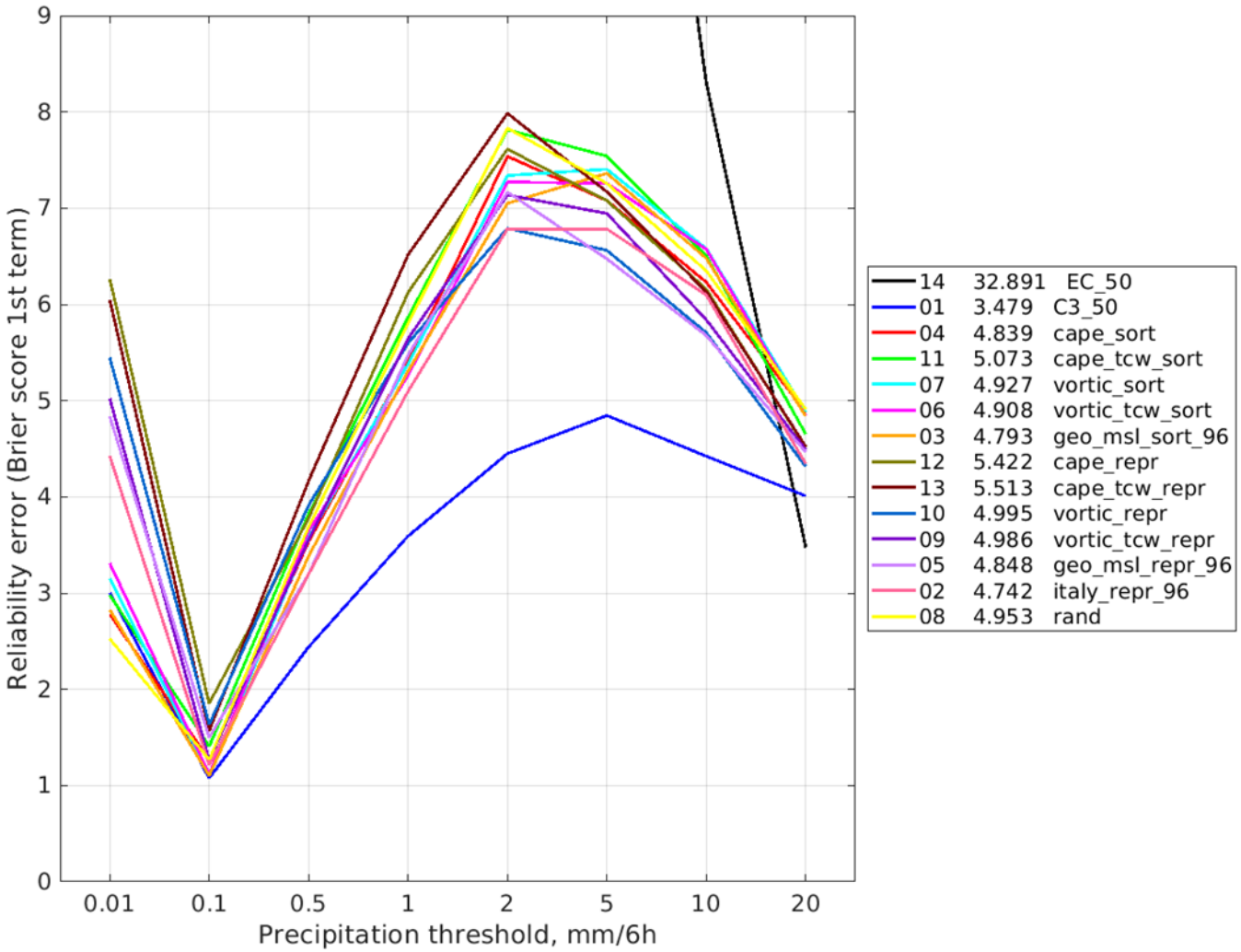
Reliability diagrams

Do the predicted probabilities of events correspond to their observed frequencies?



Precipitation – standard verification

Reliability diagrams: area from diagonal

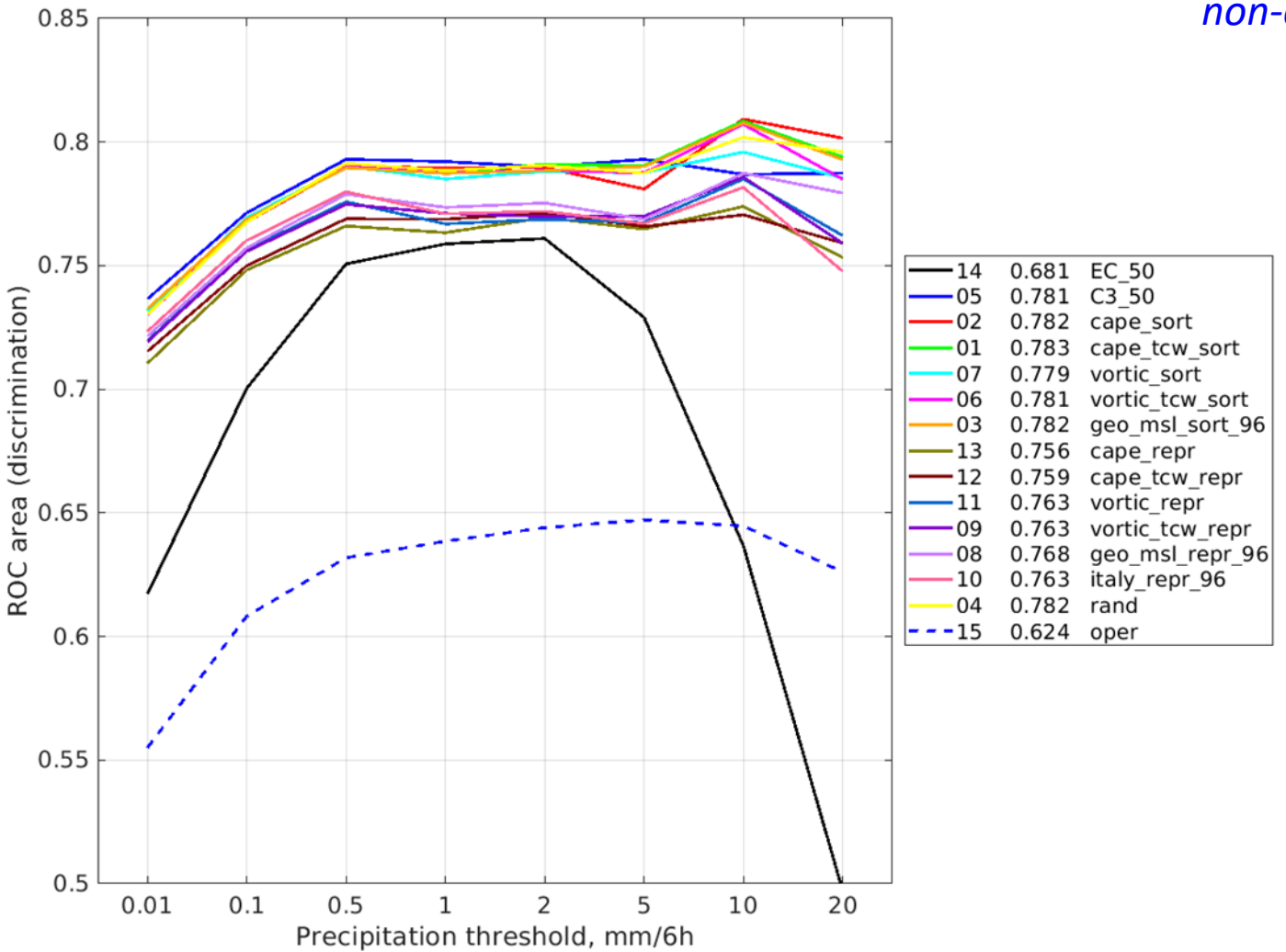


Do the predicted probabilities of events correspond to their observed frequencies?

Precipitation – standard verification

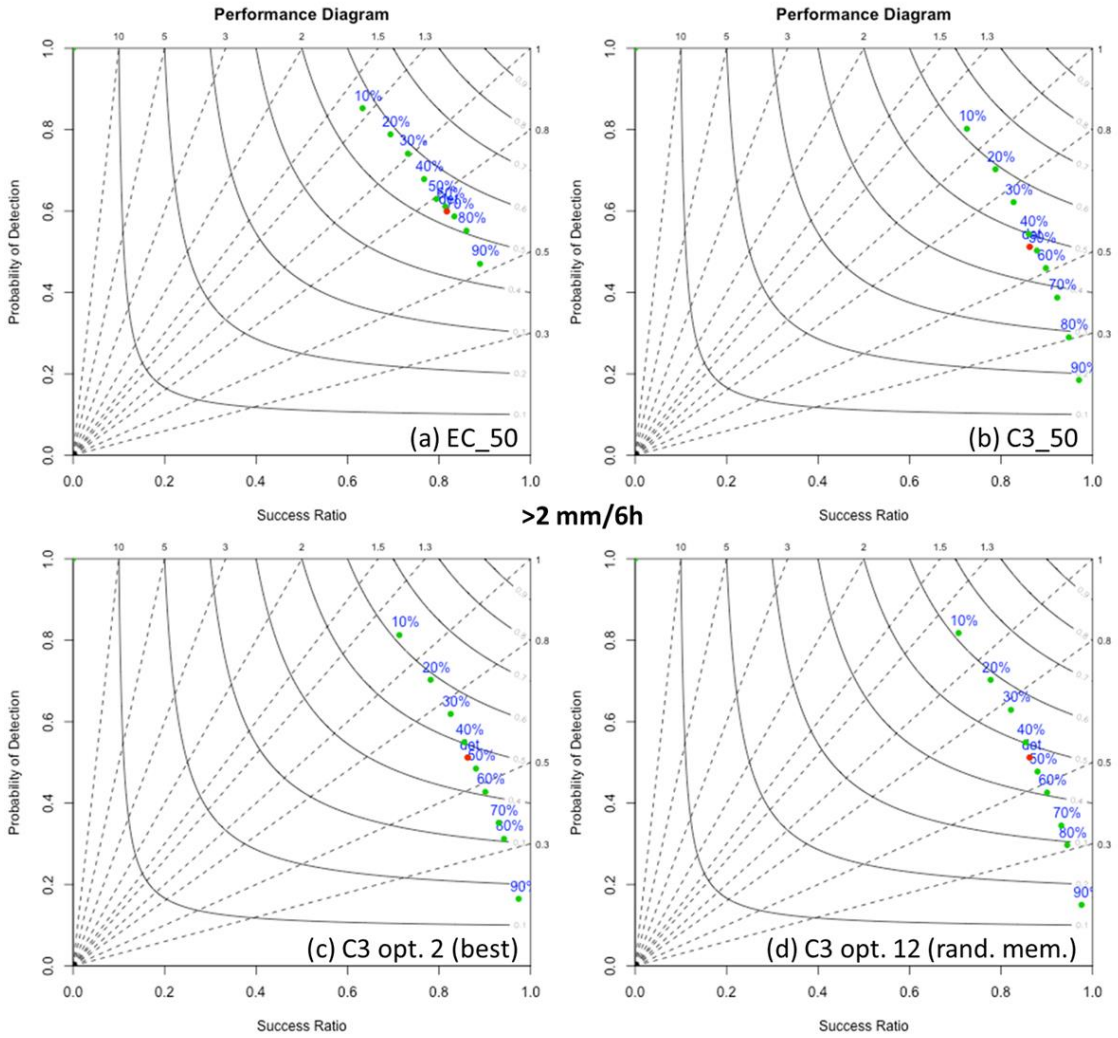
ROC area

Ability to discriminate between events and non-events



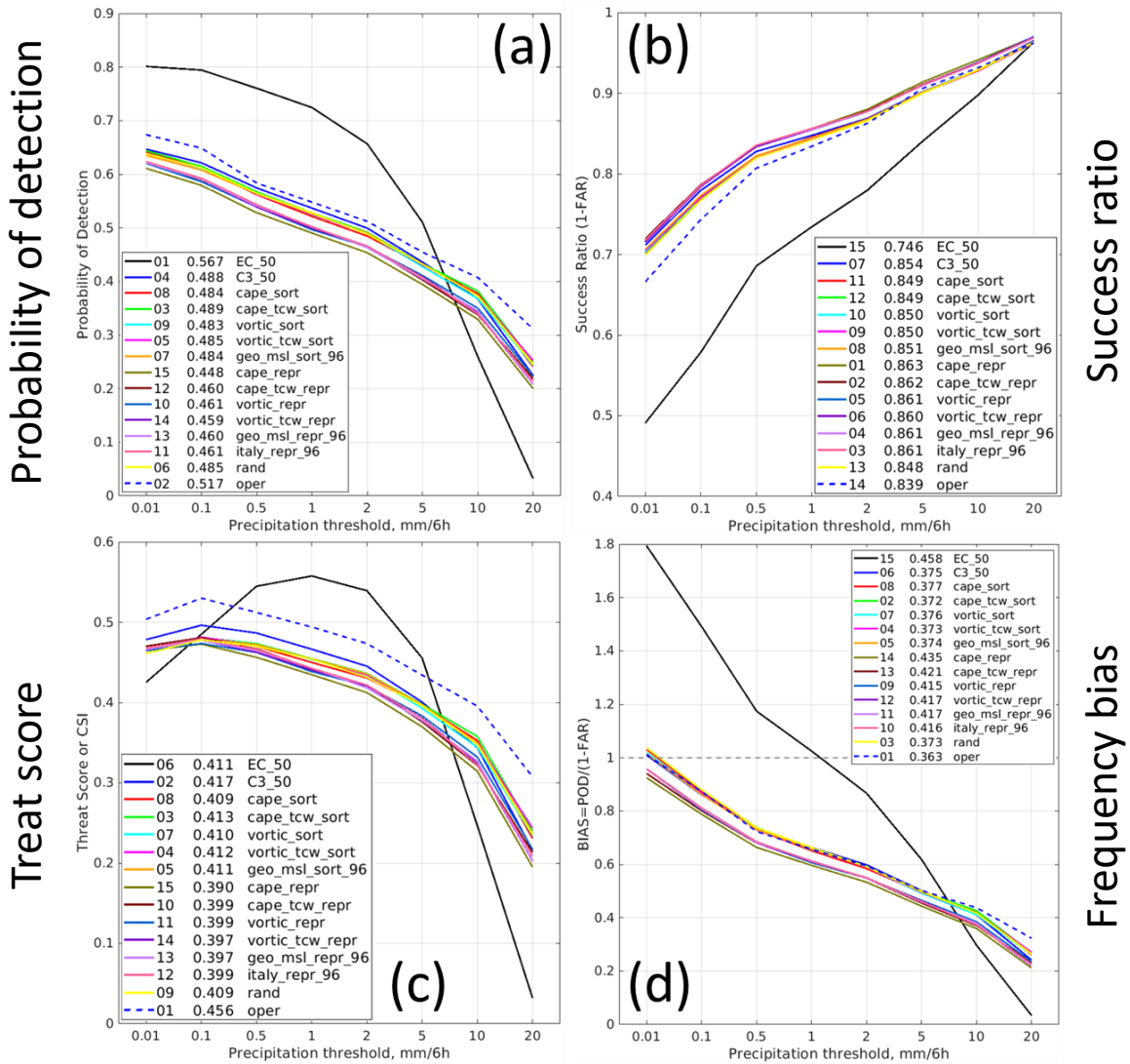
Precipitation – standard verification

Performance diagrams



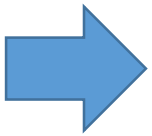
Precipitation – standard verification

Performance diagrams - averages



Precipitation – and the winner is …

	Method	ODE Objects distance error of ensemble members	Spread-skill ratio	Brier Score Mean squared probability error	Reliability Do the predicted probabilities of events correspond to their observed frequencies?	ROC Ability to discriminate between events and non-events	TS or CSI General performance according performance diagram	Frequency bias frequency of forecast events vs. frequency of obs. events	TOT
1	cape_sort	8	8	2	3	2	5	6	**34**
2	cape_tcw_sort	1	6	4	10	1	1	1	**24**
3	vortic_sort	6	5	5	6	6	4	5	**37**
4	vortic_tcw_sort	2	4	6	5	5	2	3	**27**
5	geo_msl_sort_96	4	11	3	2	3	3	4	**30**
6	cape_repr	7	1	12	11	12	12	12	**67**
7	cape_tcw_repr	11	2	11	12	11	7	11	**65**
8	vortic_repr	3	10	10	9	10	8	7	**57**
9	vortic_tcw_repr	12	7	7	8	8	11	10	**63**
10	geo_msl_repr_96	5	9	8	4	7	10	9	**52**
11	italy_repr_96	10	3	9	1	9	9	8	**49**
12	rand	9	12	1	7	4	6	2	**41**

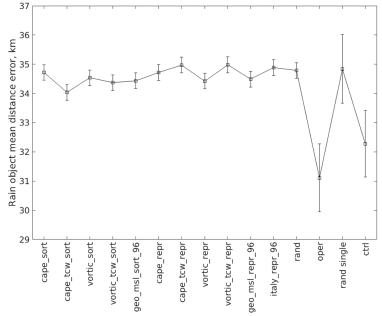


How to choose the optimal 20 EC-ENS members?

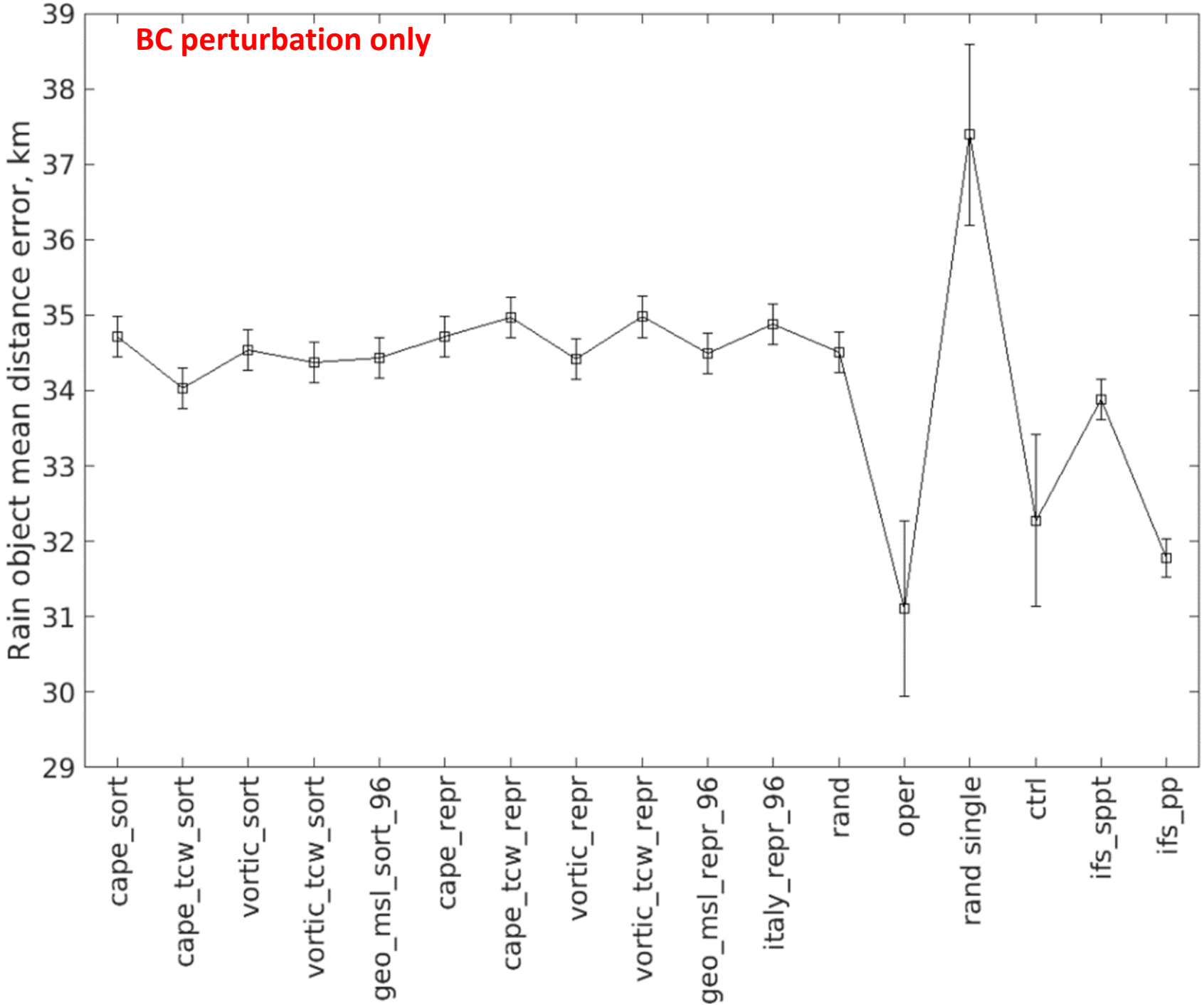
Method 2: Choose EC-ENS members most close to IFS using CAPE and TCWV (50%-50%) over small domain, use the forecast range with maximum spread

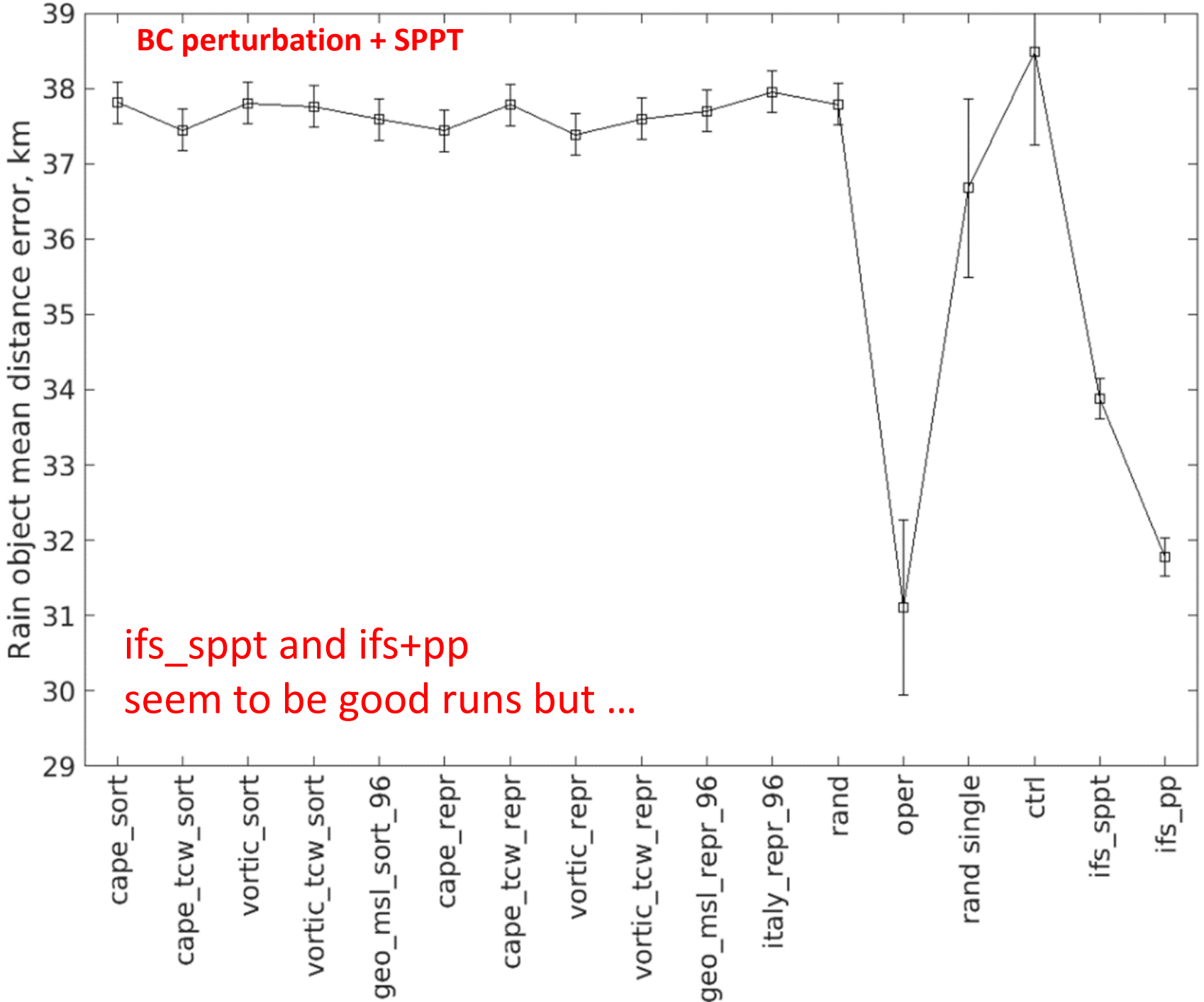
Few more slides?

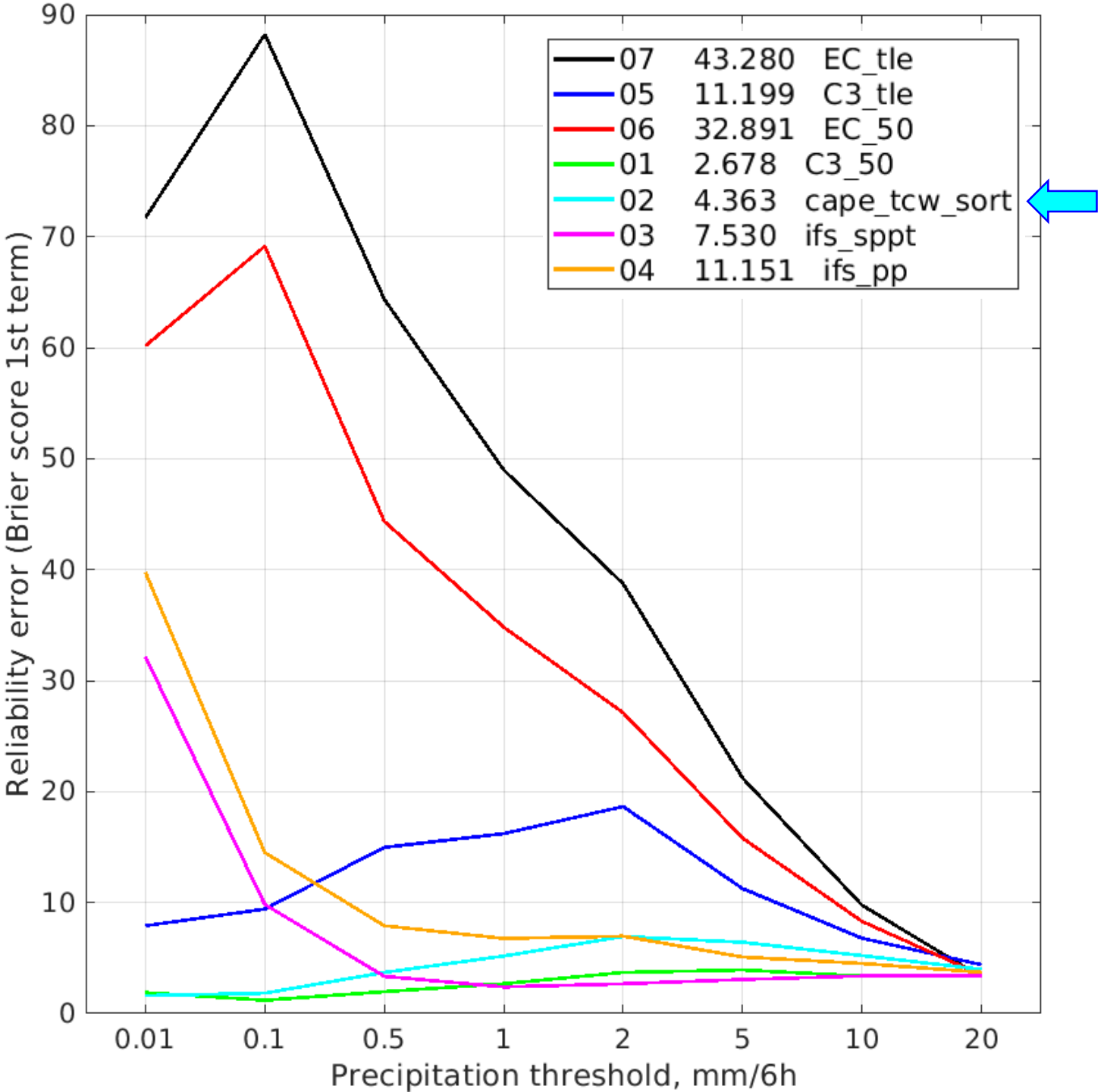
We found the optimum method
but
the members are not brilliant…

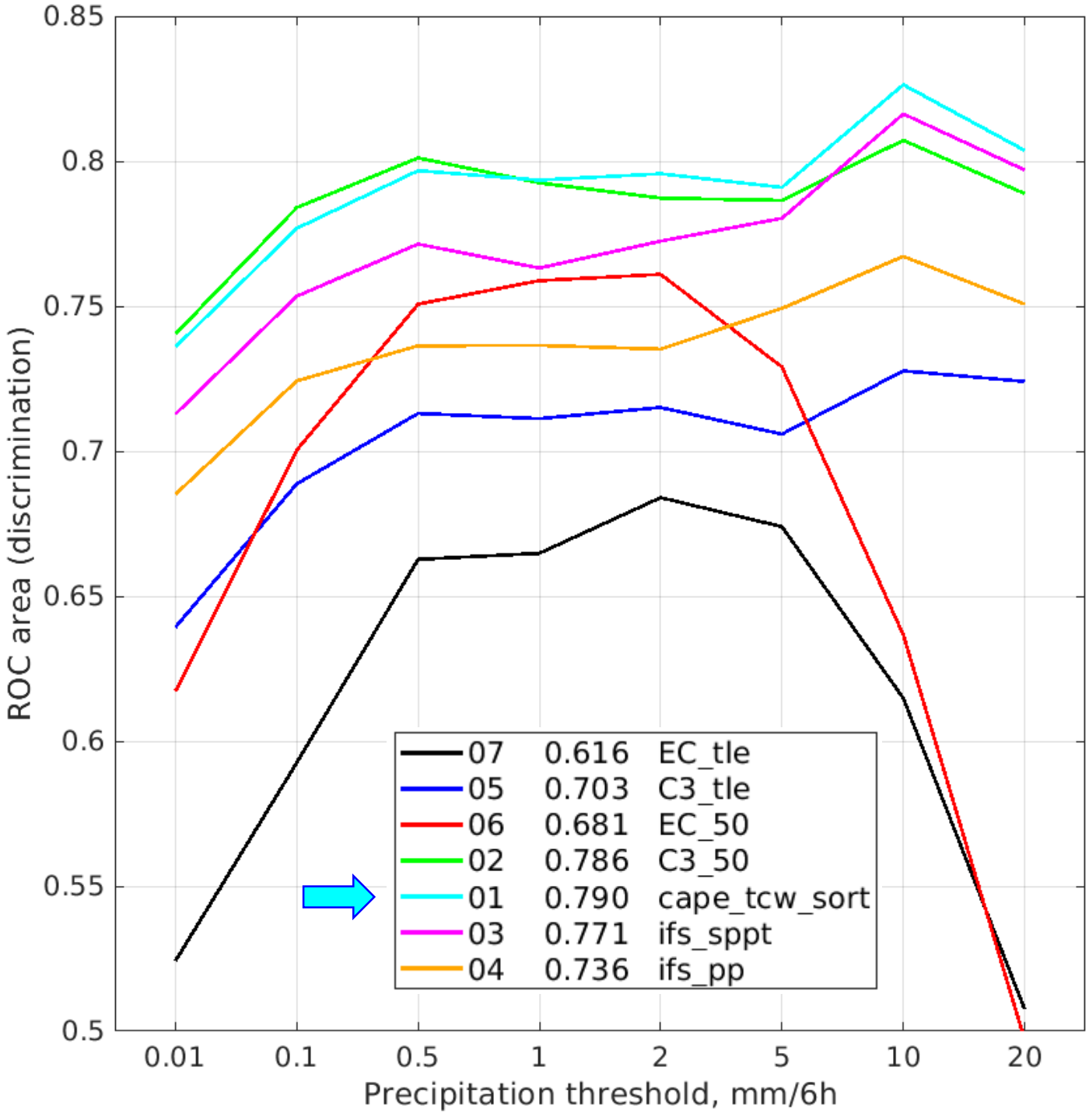


Does the chosen ensemble benefits?


BC perturbation only
Rain object mean distance error, km
39
38
37
36
35
34
33
32
31
30
29
cape_sort
cape_tcw_sort
vortic_sort
vortic_tcw_sort
geo_msl_sort_96
cape_repr
cape_tcw_repr
vortic_repr
vortic_tcw_repr
geo_msl_repr_96
italy_repr_96
rand
oper
rand single
ctrl
ifs_sppt
ifs_pp


BC perturbation + SPPT
Rain object mean distance error, km
39
38
37
36
35
34
33
32
31
30
29
ifs_sppt and ifs+pp
seem to be good runs but …
cape_sort
cape_tcw_sort
vortic_sort
vortic_tcw_sort
geo_msl_sort_96
cape_repr
cape_tcw_repr
vortic_repr
vortic_tcw_repr
geo_msl_repr_96
italy_repr_96
rand
oper
rand single
ctrl
ifs_sppt
ifs_pp


07 43.280 EC_tle
05 11.199 C3_tle
06 32.891 EC_50
01 2.678 C3_50
02 4.363 cape_tcw_sort
03 7.530 ifs_sppt
04 11.151 ifs_pp
Reliability error (Brier score 1st term)
Precipitation threshold, mm/6h
0
10
20
30
40
50
60
70
80
90
0.01
0.1
0.5
1
2
5
10
20


ROC area (discrimination)
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.01
0.1
0.5
1
2
5
10
20
Precipitation threshold, mm/6h
07 0.616 EC_tle
05 0.703 C3_tle
06 0.681 EC_50
02 0.786 C3_50
01 0.790 cape_tcw_sort
03 0.771 ifs_sppt
04 0.736 ifs_pp

Conclusion:

Although the single COSMO members are worse
(in objects locations)
their “ensemble scores” are better!

Possible explanation:

the story might be more complicated than just forecasting the location of the main objects?!

Summary

Since 2020: Development of a new COSMO 2.5km resolution 20 members ensemble over the Eastern Mediterranean

Platform: ECMWF computer

BC: ECMWF 51 members ensemble (EC-ENS)

Discussed:

- Method to choose 20 EC-ENS members
- The difficulties to have benefit in precipitation forecast

Plan: KENDA