AQ Forecast in Emilia-Romagna, Italy

An attempt to verify forecast with a probabilistic approach

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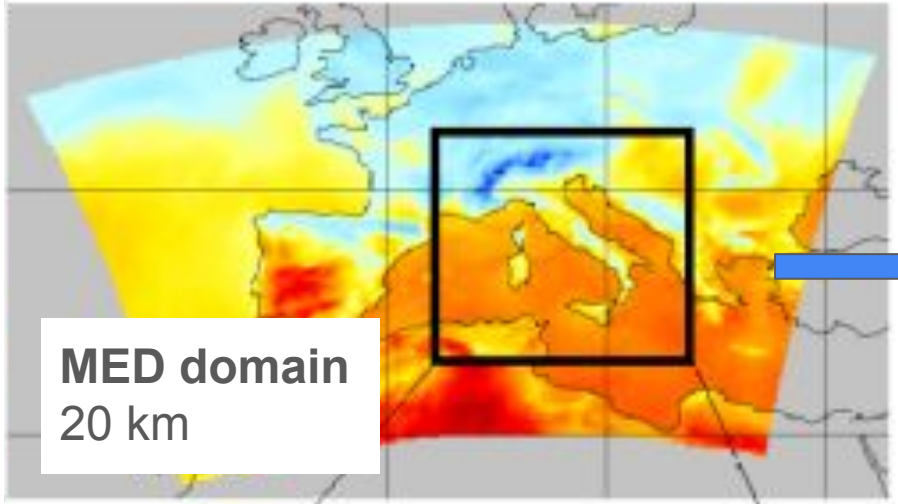
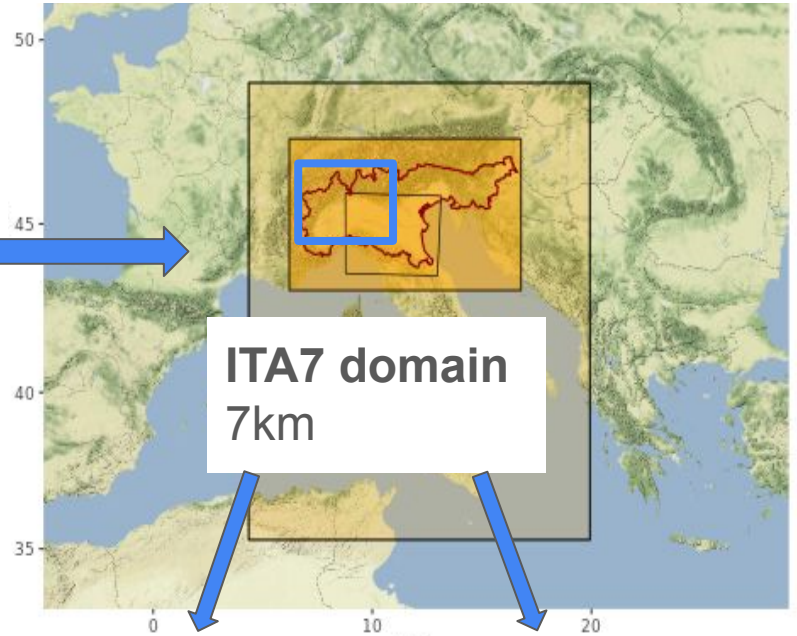
arpae emilia-romagna

FAIRMODE Technical Meeting Dublin, 7-9 October 2024

Operational forecasting @ Arpae NINFA kAIROS



MED domain
20 km



ITA7 domain
7km

CTM

CHIMERE + COSMO/ICON

Anaysis	**Forecast**
d_{-1}	$d_0 d_1 d_2$

hourly concentrations
PM_{10} $PM_{2.5}$ O_3 NO_2

Northern Italy + Slovenia
5 km

LIFE 15 IPE IT 013

EMR3 domain
3km

Forecast used to activate extra actions to reduce emissions during episodes of high PM concentrations (concentration > 50 µg/m^3)

reliability is required

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Post Processing: IBIS module

Adjusting quantitative CTM prediction with observed daily concentrations

Statistical bayesian model for real-time adjustment

Observed data model

$$Y_t(s) = Z_t(s) + \varepsilon_t(s) \qquad \varepsilon_t(s) \sim N(0, \sigma_\varepsilon^2)$$

Latent process

$$Z_t(s) = \beta_0 + \beta_1 X_t(B) + \rho Z_{t-1}(s) + \eta_t(s) \qquad s \in B$$

$$(\eta_{0,t}(s_1), \ldots, \eta_{0,t}(s_n)) \sim N\left[0, \sigma_\eta^2 S_\eta(\phi, \nu)\right] \qquad t = 1, \ldots, 14$$

autocorrelation
14 days

- β_0: global additive bias
- $\beta_1 X_t(B_s)$: global multiplicative bias
- $\rho Z_{t-1}(s)$: autoregressive term to model auto-correlation between PM_{10} measurements on successive days
- $\eta_t(s)$: local additive bias (spatially varying intercept process)

S. K. Sahu, A. E. Gelfand, and D. M. Holland. High-resolution space-time ozone modeling for assessing trends. Journal of the American Statistical Association, 102:1221–1234, 2007.
S. K. Sahu, S. Yip, and D. M. Holland. Improved space-time forecasting of next day ozone concentrations in the eastern us. Atmospheric Environment, 43:494–501, 2009.
K. S. Bakar and S. K. Sahu. spTimer: spatio-temporal Bayesian modeling using R. Journal of Statistical Software, 63(15):1–32, 2015.

model estimate

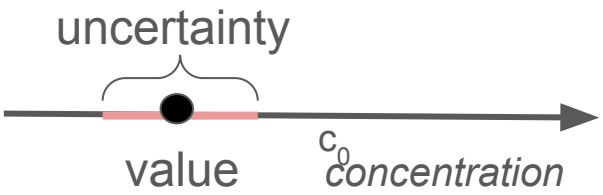
Trafic | **Background**

PM10
daily mean

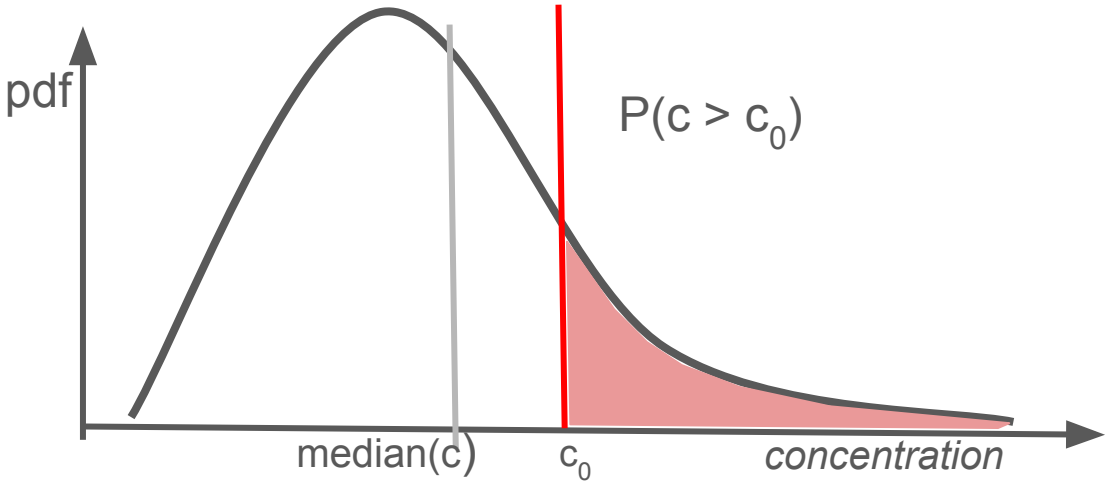
Probabilistic Prediction

For every prediction location a distribution of possible values

Deterministic approach



Probabilistic approach



Products

https://www.arpae.it/

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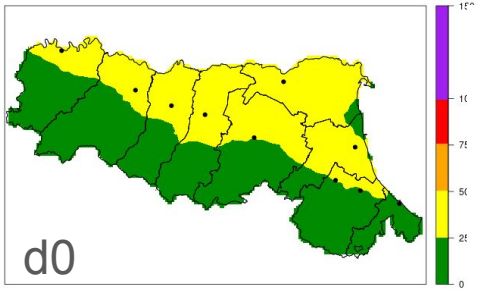
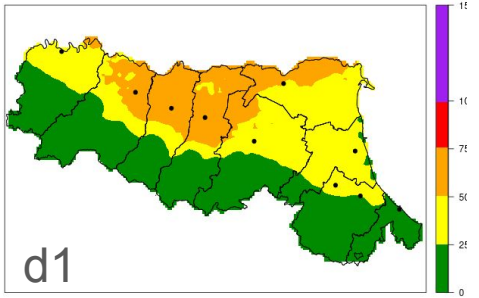
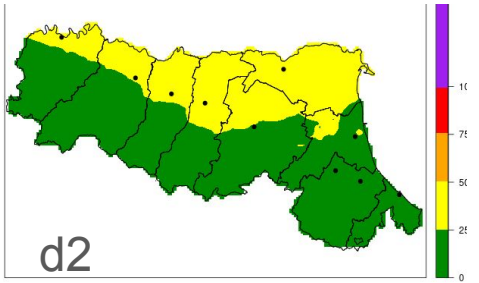
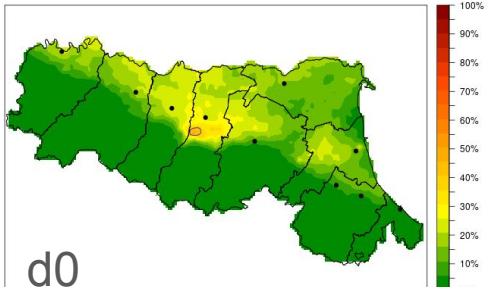
concentration

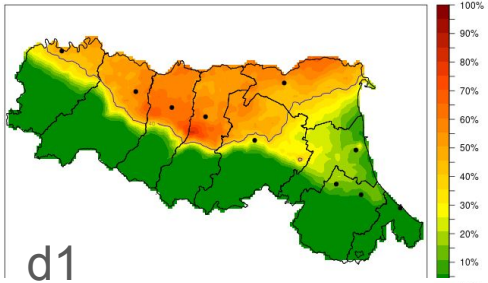


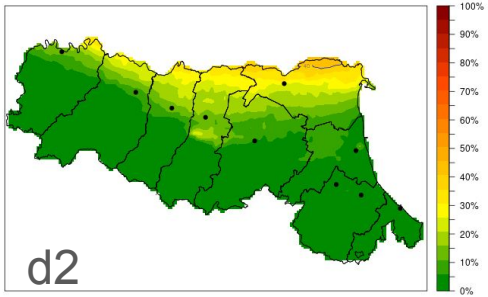




exceedance probability





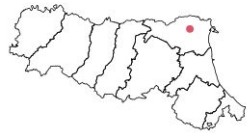


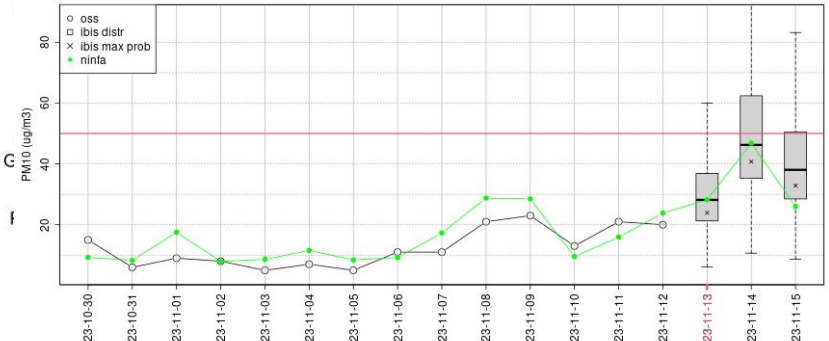
nome	prov	d0	d1	d2	P>50 d0	P>50 d1	P>50d2
CITTADELLA	PR	33	55	26	16	59	6
BADIA	PR	25	49	16	5	48	0
SARAGAT	PR	36	54	36	22	58	22
CASTELLARANO	RE	35	53	19	22	55	1
S. LAZZARO	RE	37	57	28	23	62	9
FEBBIO	RE	6	6	5	0	0	0
S. ROCCO	RE	35	53	36	19	56	22
REMESINA	MO	35	49	34	18	48	17
PARCO FERRARI	MO	38	53	30	26	56	11
GAVELLO	MO	31	52	42	14	52	33
PARCO EDILCARANI	MO	42	66	29	35	74	10
LUGAGNANO	PC	19	28	11	1	10	0
BESENZONE	PC	29	47	31	11	45	15
PARCO MONTECUCCO	PC	33	47	29	17	43	9
CORTE BRUGNATELLA	PC	6	5	5	0	0	0
PARCO RESISTENZA	FC	26	30	22	7	10	2
FRANCHINI-ANGELONI	FC	23	24	20	2	4	1
SAVIGNANO	FC	24	25	22	4	5	2
SAVIGNANO DI RIGO	FC	8	6	7	0	0	0

Concentrazione di PM10 (ug/m3) osservata e prevista

GHERARDI (FE) - FondoRurale

Emissione del 2023-11-13





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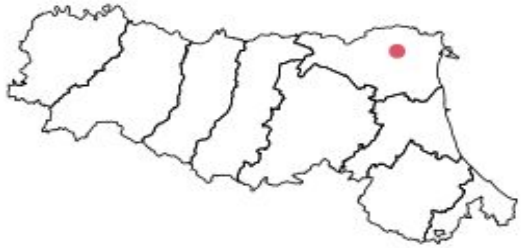
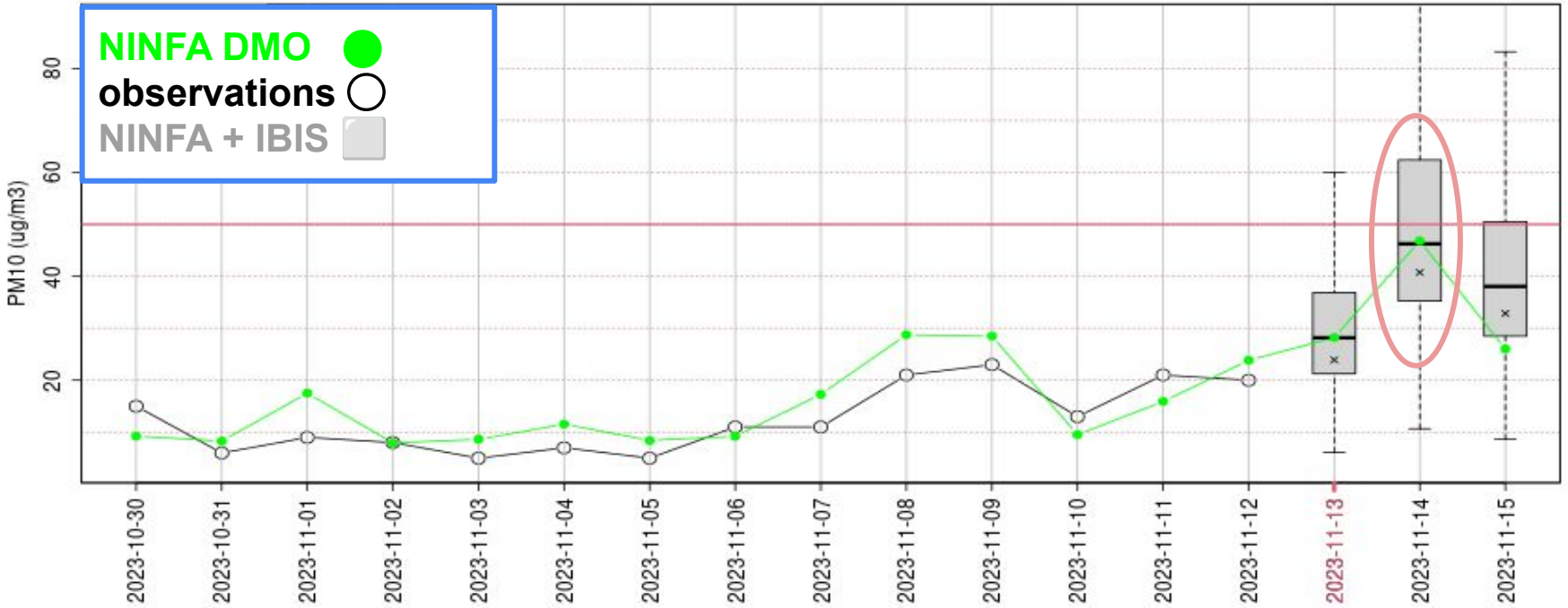
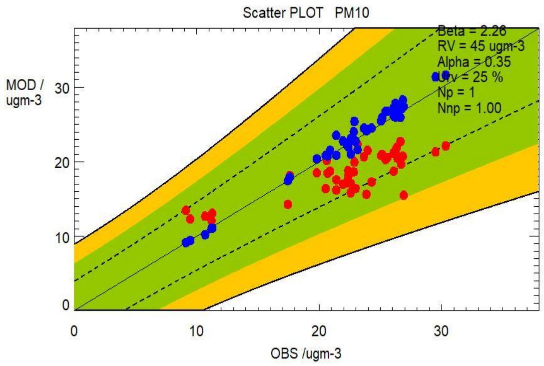
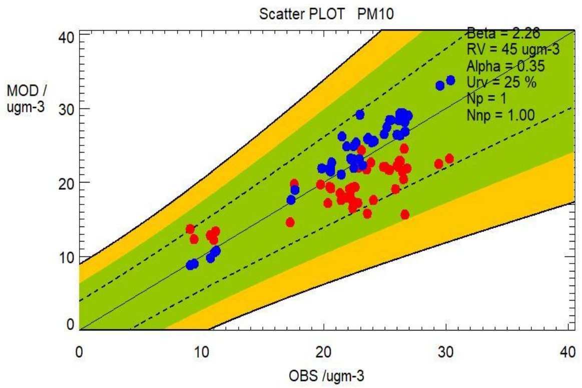
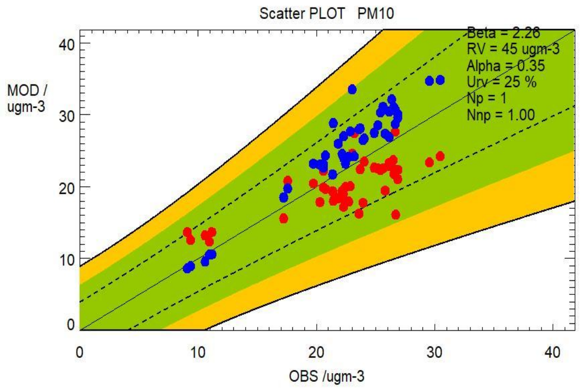








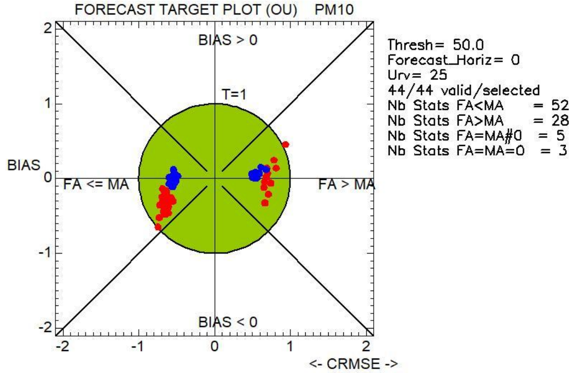


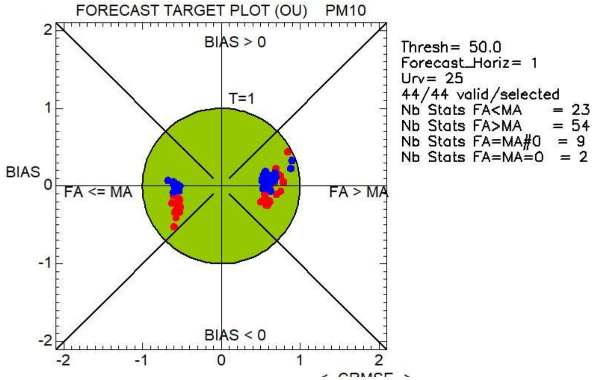
DMO

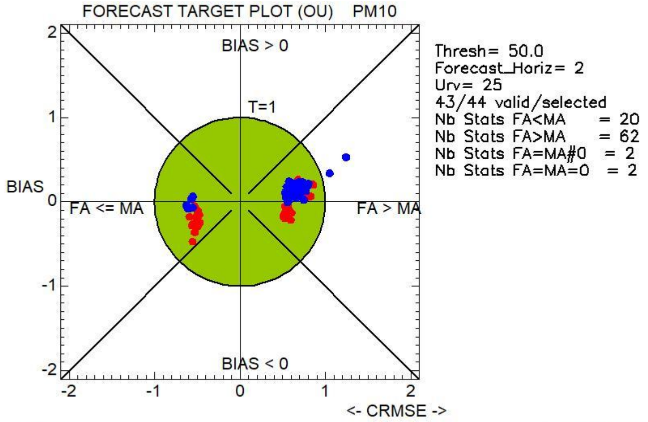
IBIS

NINFA DMO

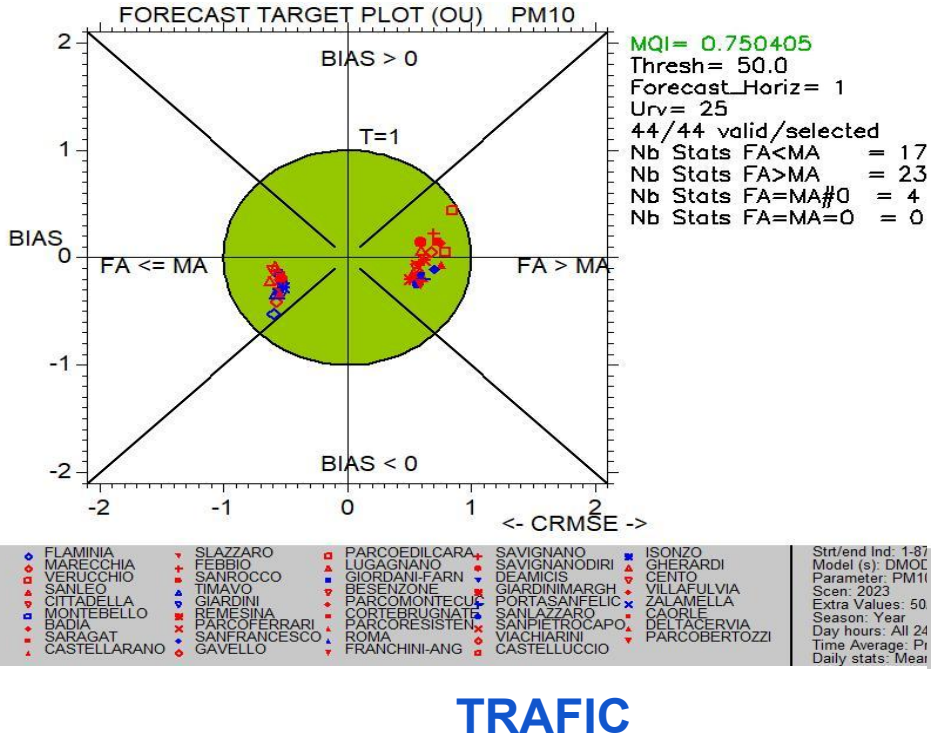
2023



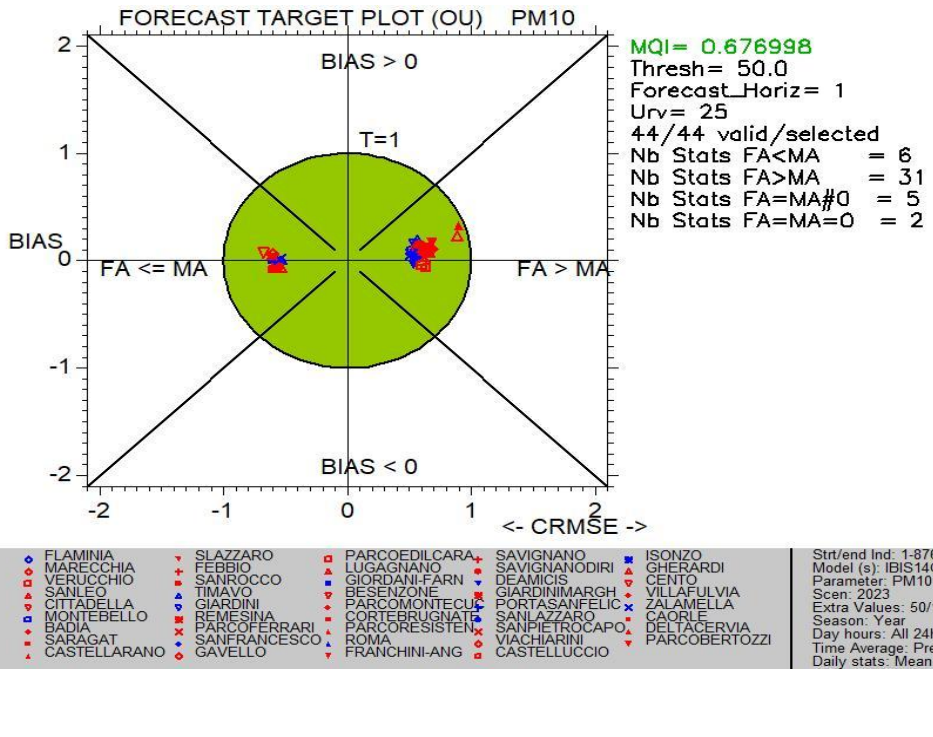




DMO



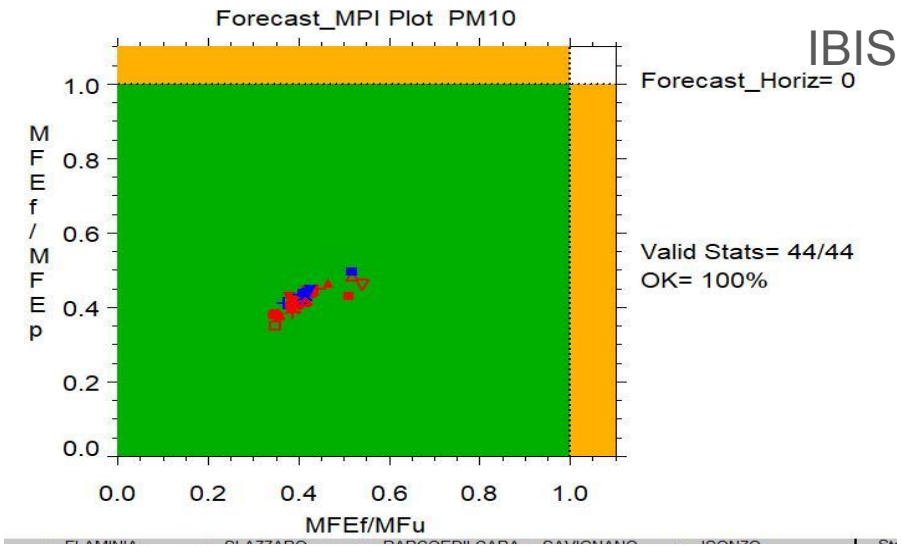
IBIS

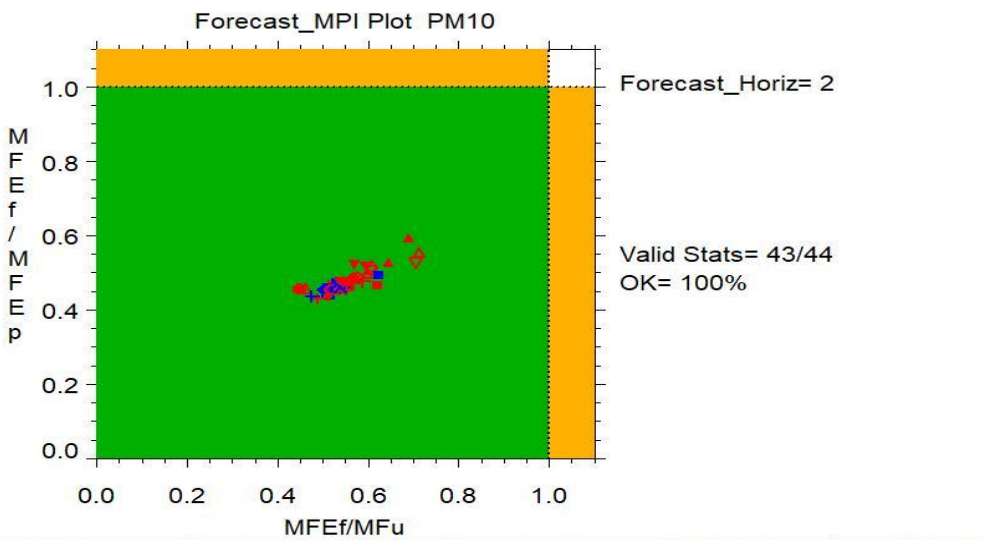


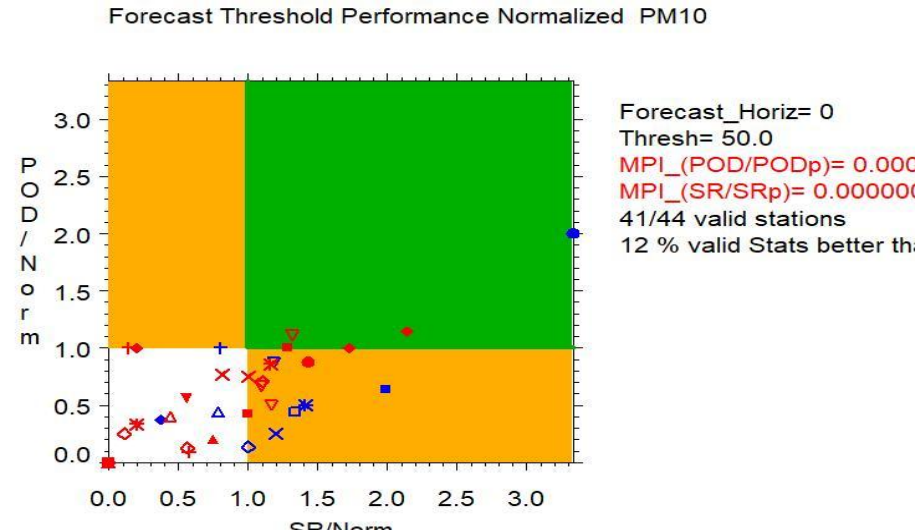
TRAFIC

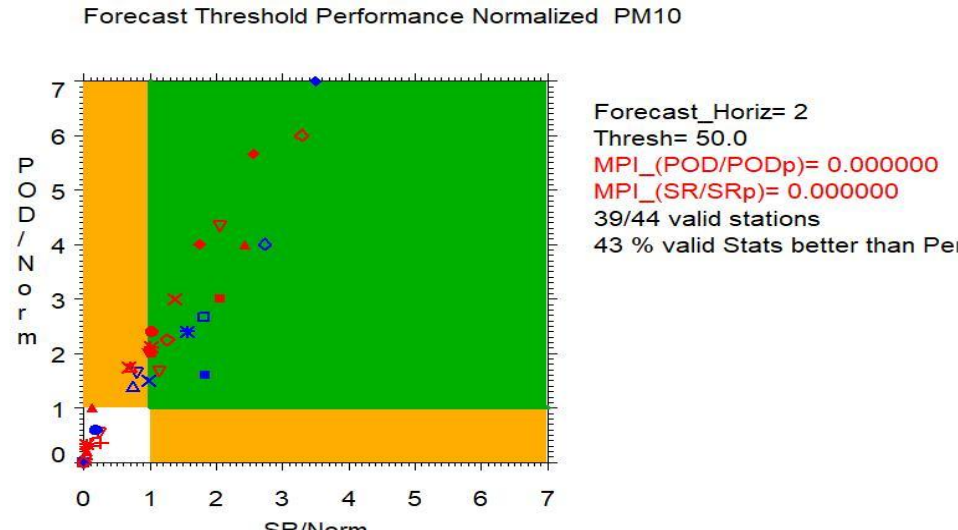
BACKGROUND

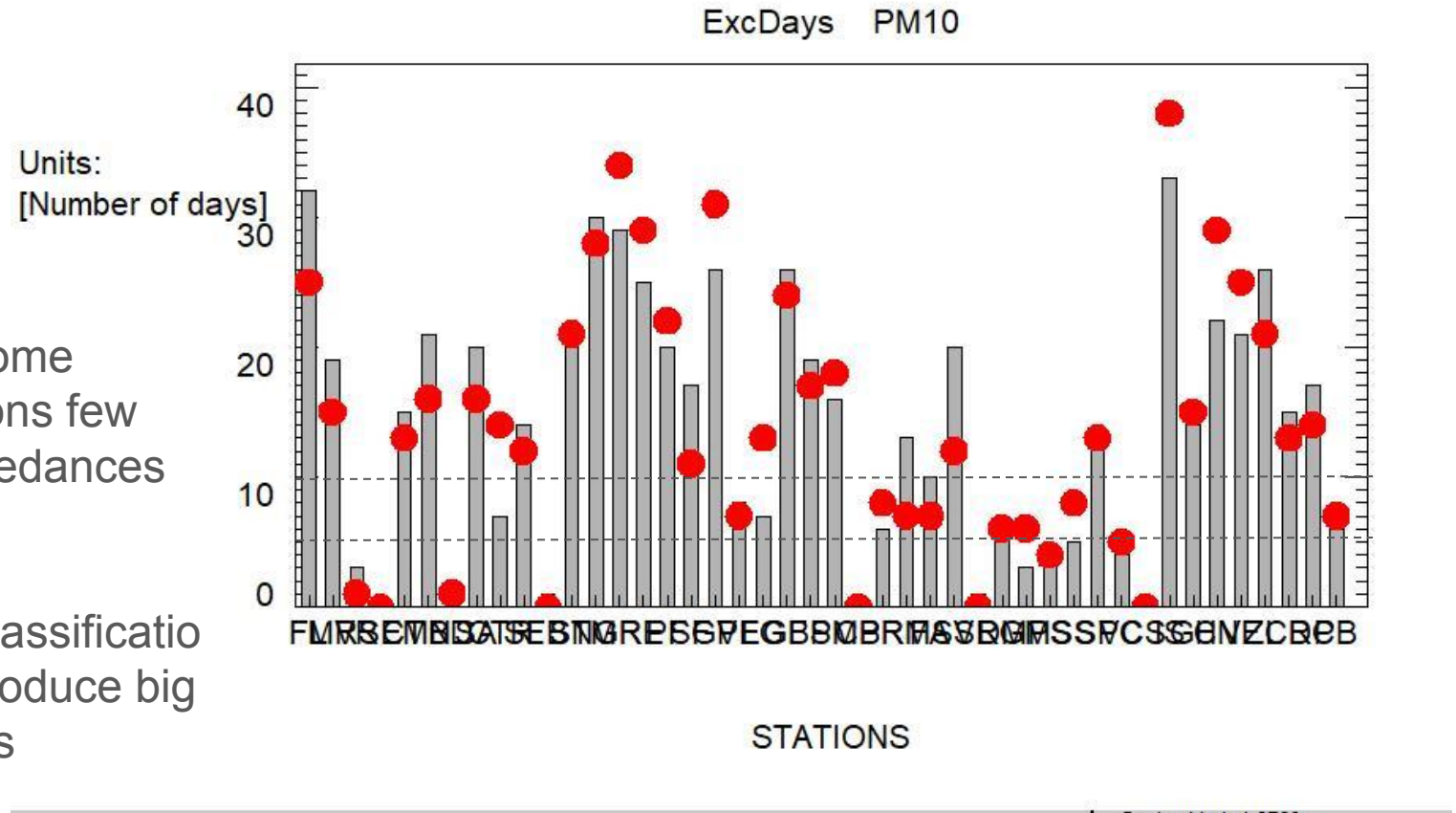
IBIS


Forecast_MPI Plot PM10
Forecast_Horiz= 0
Valid Stats= 44/44
OK= 100%
MFEf/MFEp
MFEf/MFu
0.0
0.2
0.4
0.6
0.8
1.0


Forecast_MPI Plot PM10
Forecast_Horiz= 2
Valid Stats= 43/44
OK= 100%
MFEf/MFEp
MFEf/MFu
0.0
0.2
0.4
0.6
0.8
1.0

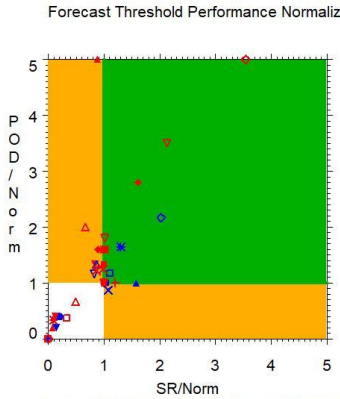

Forecast Threshold Performance Normalized PM10
Forecast_Horiz= 0
Thresh= 50.0
MPI_(POD/PODp)= 0.000
MPI_(SR/SRp)= 0.00000
41/44 valid stations
12 % valid Stats better th
POD/Norm
SR/Norm
0.0
0.5
1.0
1.5
2.0
2.5
3.0

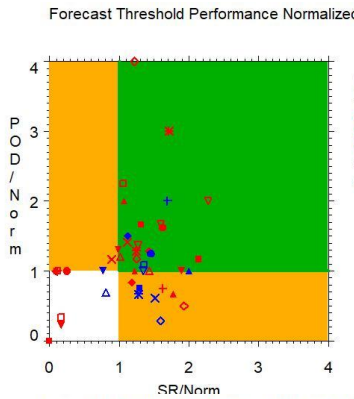

Forecast Threshold Performance Normalized PM10
Forecast_Horiz= 2
Thresh= 50.0
MPI_(POD/PODp)= 0.000000
MPI_(SR/SRp)= 0.000000
39/44 valid stations
43 % valid Stats better than Per
POD/Norm
SR/Norm
0
1
2
3
4
5
6
7

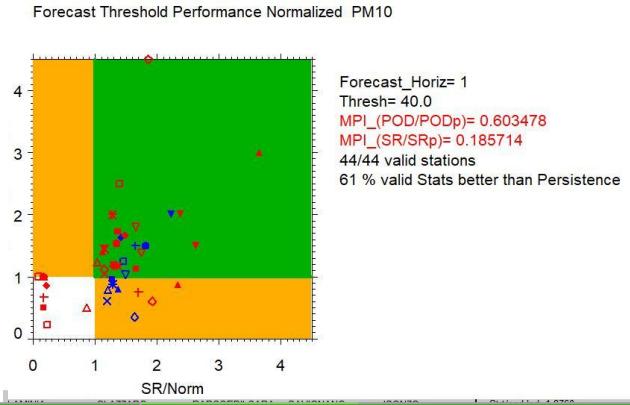


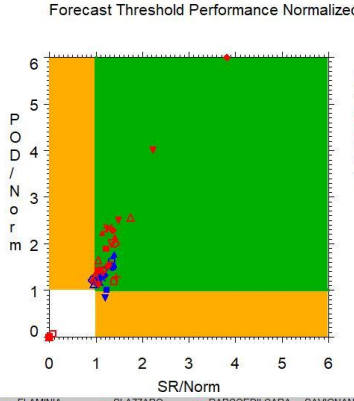
for some stations few exceedances

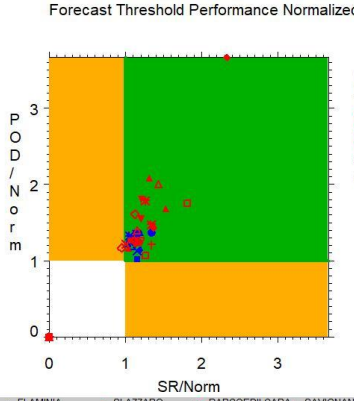
few misclassifications produce big errors











Threshold	% valid station better than persistence	
	IBIS	DMO
50	44	45
45	55	55
40	61	61
35	77	59
30	86	30

decreasing threshold increases performance with respect to persistance

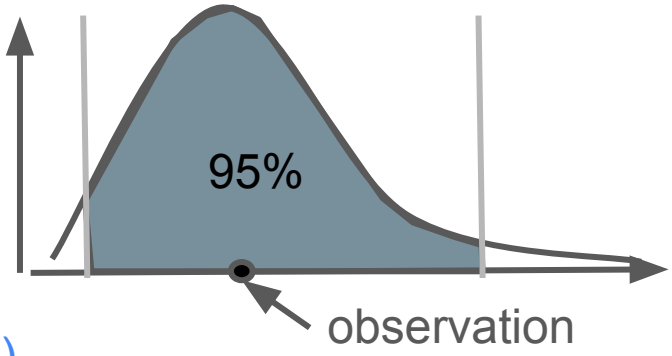
What about probability?

Can we say anything about model performance in predicting probability of exceedance?

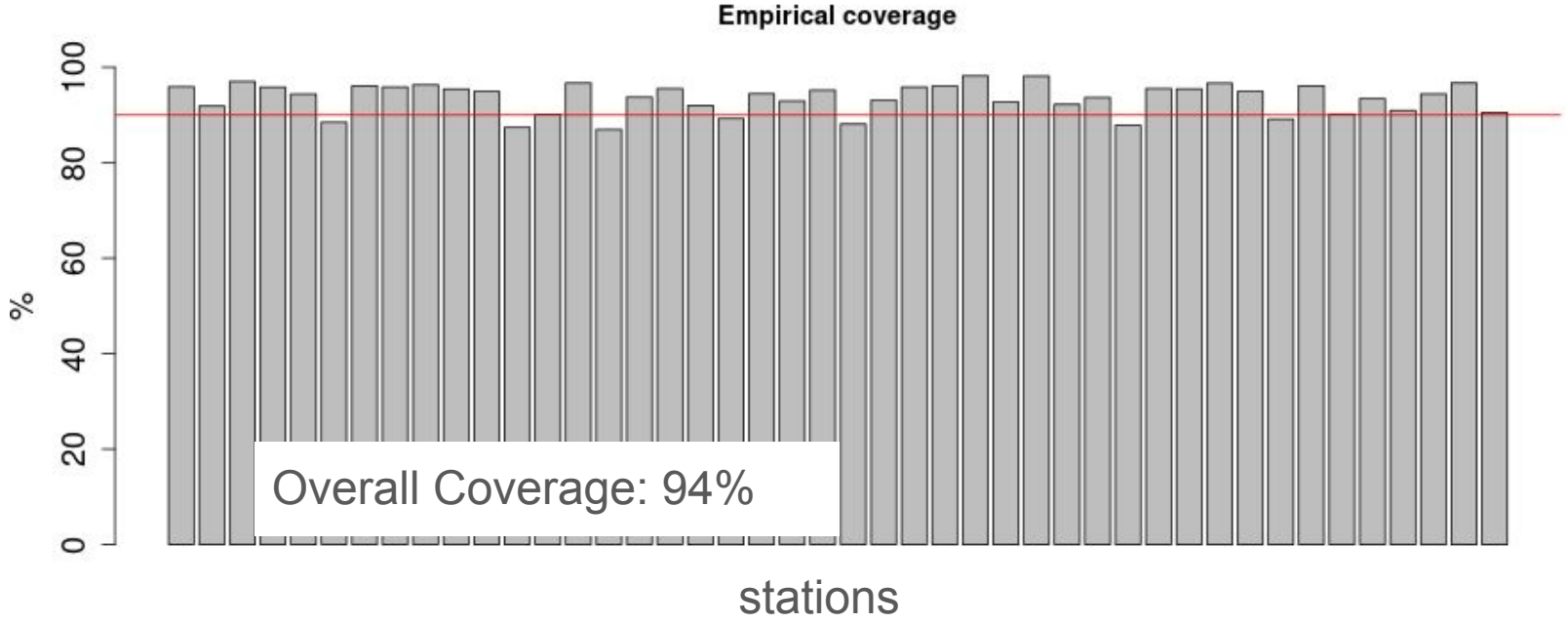
tentative probabilistic verification

Empirical coverage

How good is model in explaining variability?



how many times is the observation in the credible range of prediction, i.e. 95%
percentile(0.025) < observation < percentile(0.975)

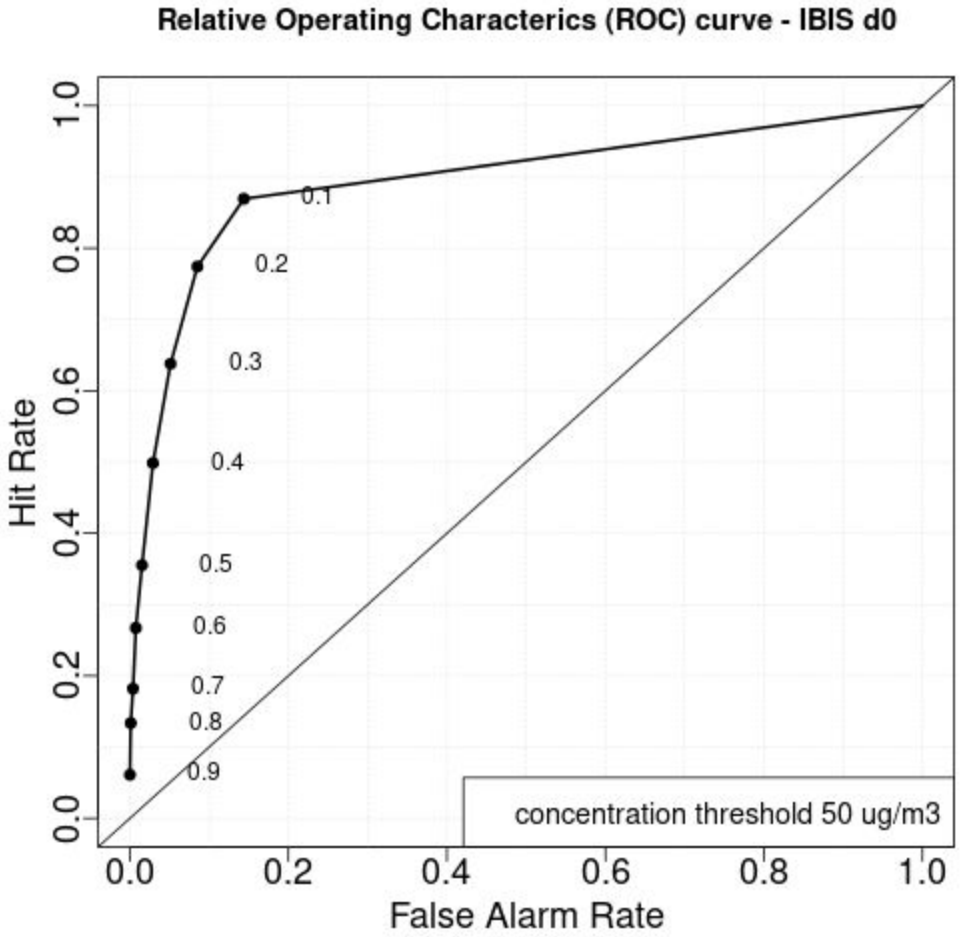


Relative Operating Characteristic

probabilistic prediction can be converted to deterministic for each probability threshold

if $p > p_{Th}$ => X=1 yes

else X=0 no

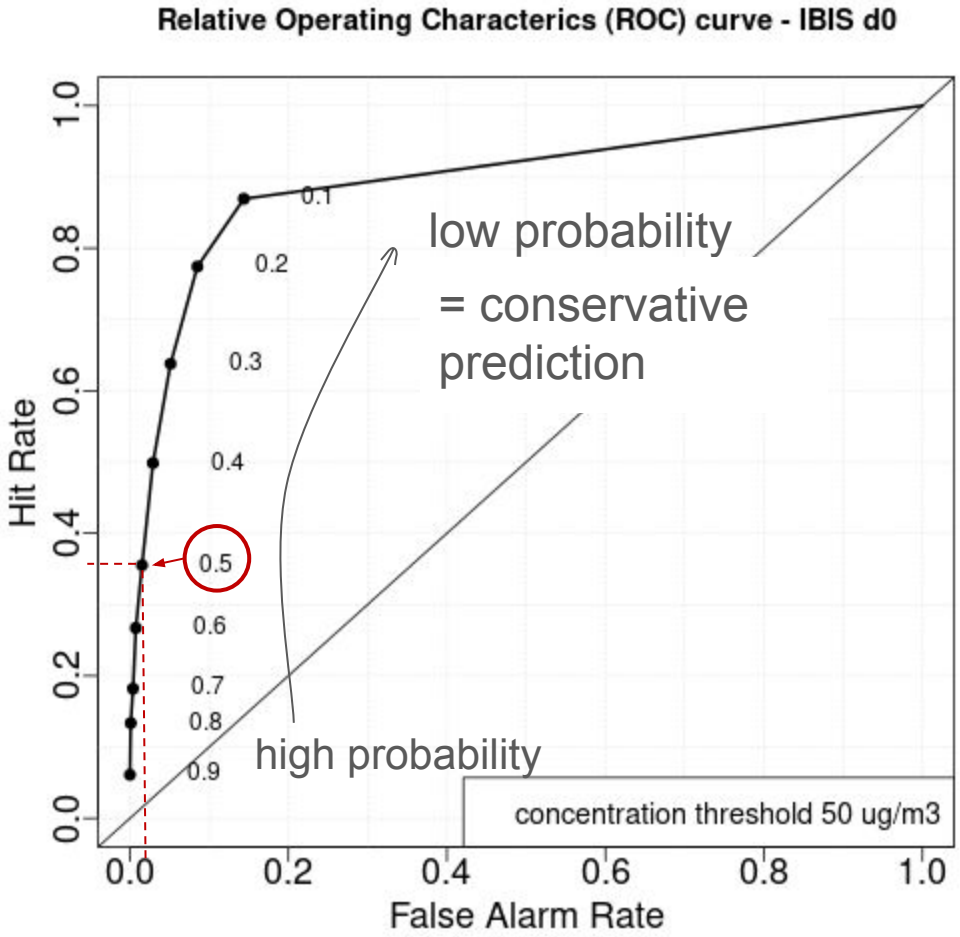


Relative Operating Characteristic

probabilistic prediction can be converted to deterministic prediction for each probability threshold

if $p > p_{Th}$ => X=1 yes
else X=0 no

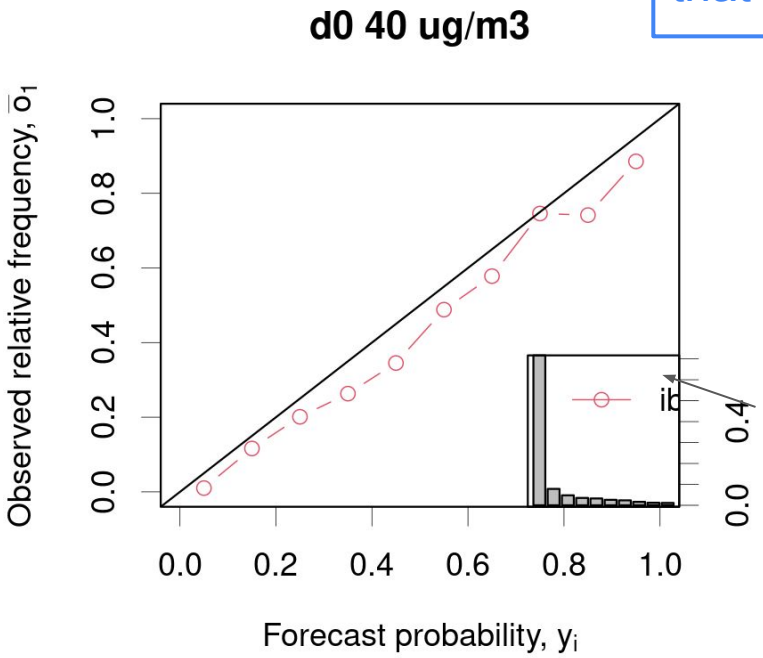
event X: exceedance



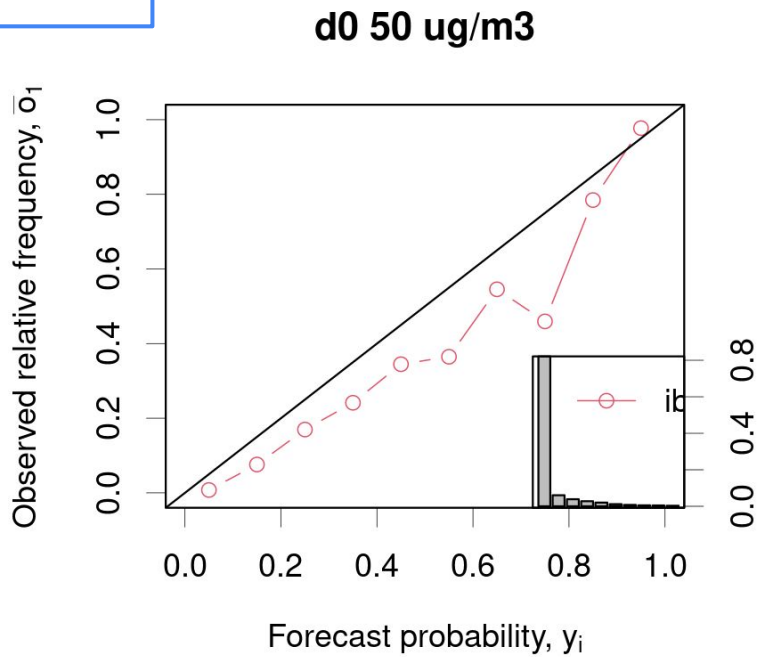
Reliability Diagram

shows relation between probability of event occurrence (predicted) and observed frequency of that event

perfect prediction: points on the bisector



Sharpness histogram: the frequency of forecasts in each probability bin (histogram) shows the sharpness of the forecast



Outcome

- The AQ forecast NINFA DMO satisfy the requirements
- The statistical post processing IBIS contributes to reduce quantitative bias
- The performance categorical prediction of exceedance depends on threshold
- A probabilistic approach is evaluated
- Open question: is it a probabilistic forecast worth for episode warning?

Thank you for your attention

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