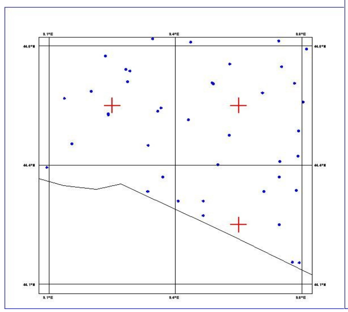
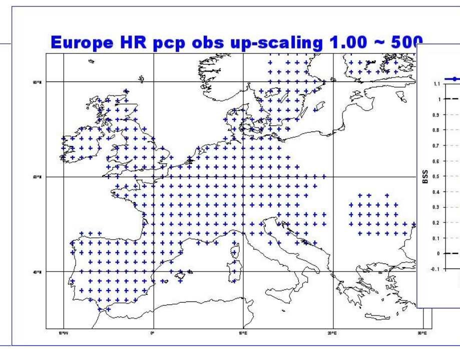
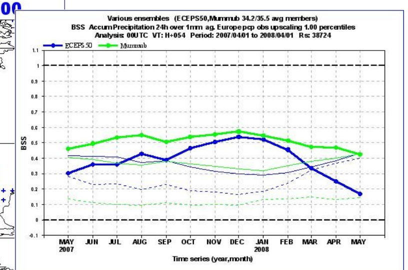
Introducing **observational uncertainty** in the scoring of a multi-model LAM EPS over the European area







Carlos Santos (csantos@inm.es), AEMET

Anna Ghelli, ECMWF (anna.ghelli@ecmwf.int)

José Antonio García-Moya (j.garcia-moya@inm.es), AEMET

The blind men and the elephant: road map

- Interpolation model -> HR obs
  Independency of realizations?
- Up-scaling HR obs -> model
  Representative?
- Considering obs uncertainty
  Consistency?
- Deconvolution method
  Sampling error?
- Sampling error estimate
  …
  …
- Object/Feature-oriented verification

This work

This work

- Interpolation model -> HR obs

  Independency of realizations?
- Up-scaling HR obs -> model

  Representative?
- **Considering obs uncertainty**

  Consistency?
- Deconvolution method

  Sampling error?
- Sampling error estimate

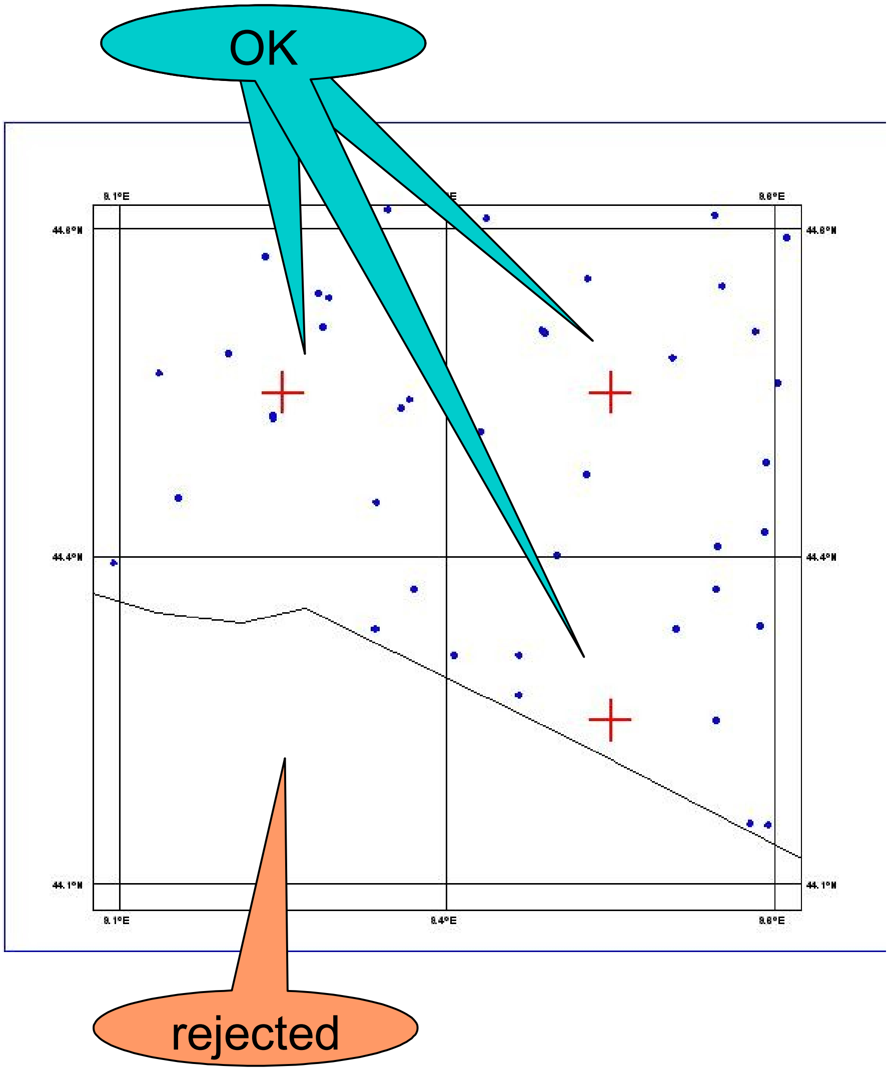
  …

  …
- Object/Feature-oriented verification

Obs Error

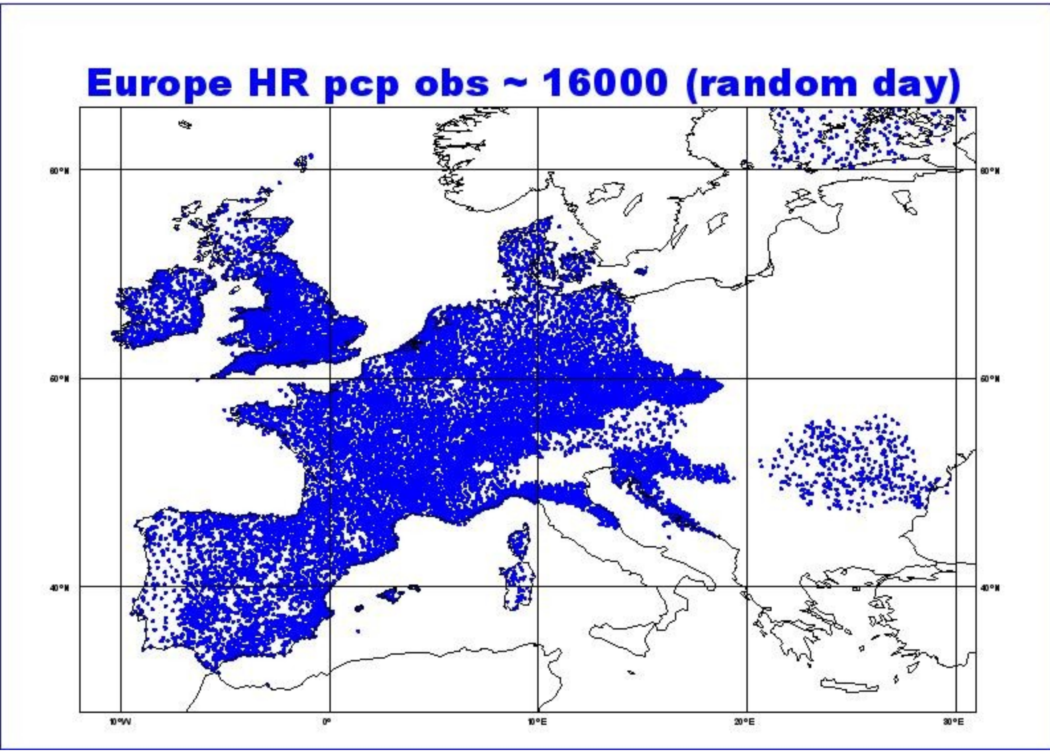
- Traditional assumption: Obs error << Model error
  - Introducing obs uncertainty could better represent actual performance
  - Obs error ~~<<~~ Model error
- Candille&Talagrand 2008 approach: Joint distribution framework extension
  - Met1: "Perturbed ensemble"
  - Met2: "Observational probability"
    - Worse reliability
    - Better resolution
    - Smaller Uncertainty term
    - Generally better BSS
    - Worse discrimination
- Collaboration ECMWF-AEMET
  - Following "Observational probability" Candille&Talagrand
  - Using up-scaled observations to build obs PDF
  - Results consistent with Candille&Talagrand
  - Better idea of ensemble performance?

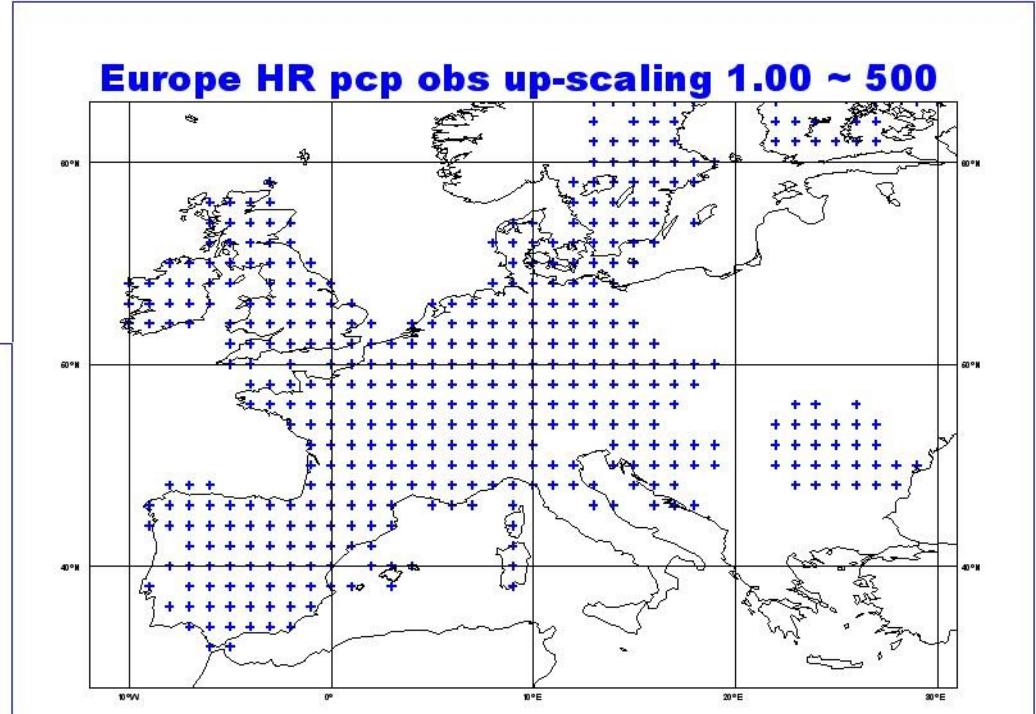
Up-scaling method

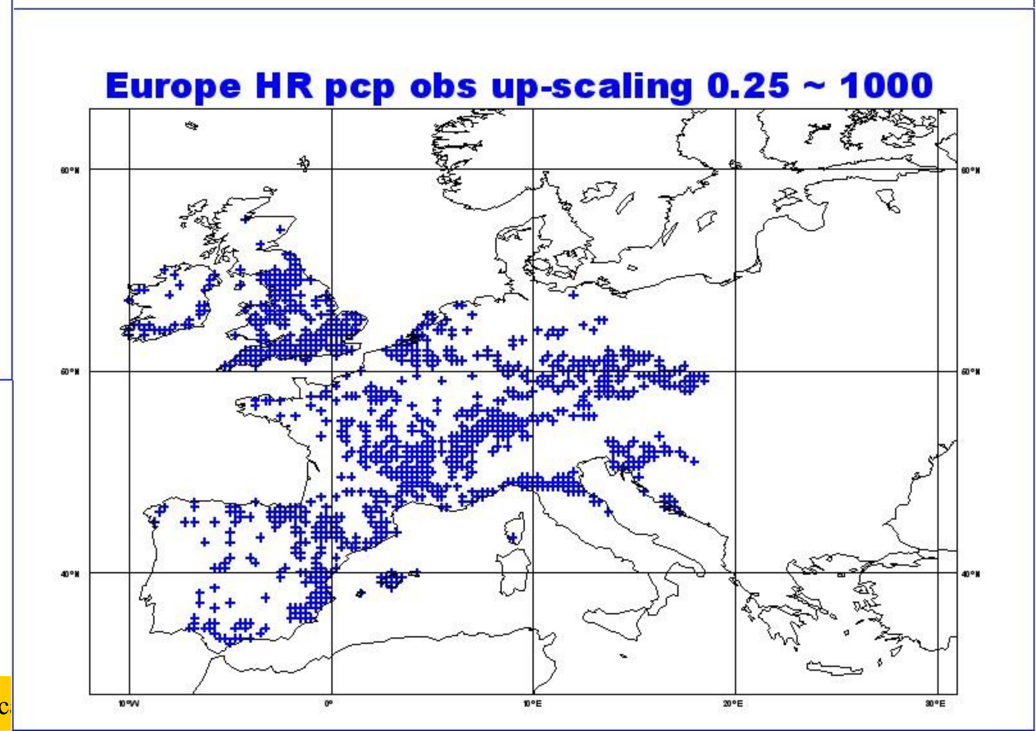


- Up-scaling Europe HR data
- Two up-scaling box sizes:
  - 1ºx1º
  - 0.25ºx0.25º
- Minimum number of obs:
  - #obs < 5 → grid point rejected
  - #obs >= 5 → grid point OK
- Two different representations of “truth”:
  - Average
  - Quantiles 10, 25, 50, 75, 90

Up-scaling method







Brier Score

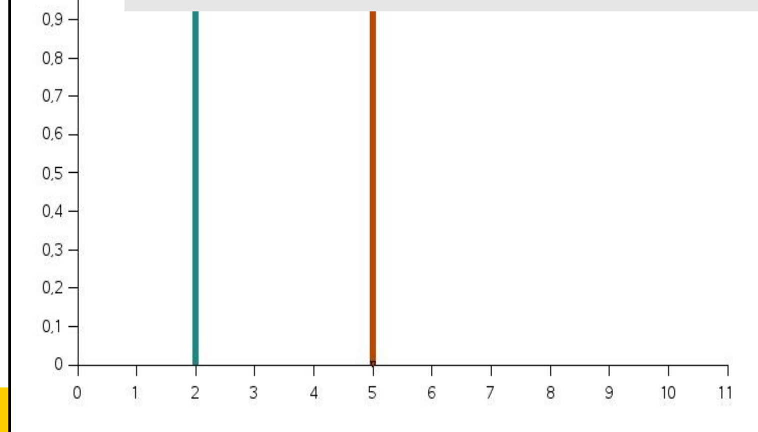
- How well fit fc and ob?

  p_i = forecast probability $\in$ [0,1]

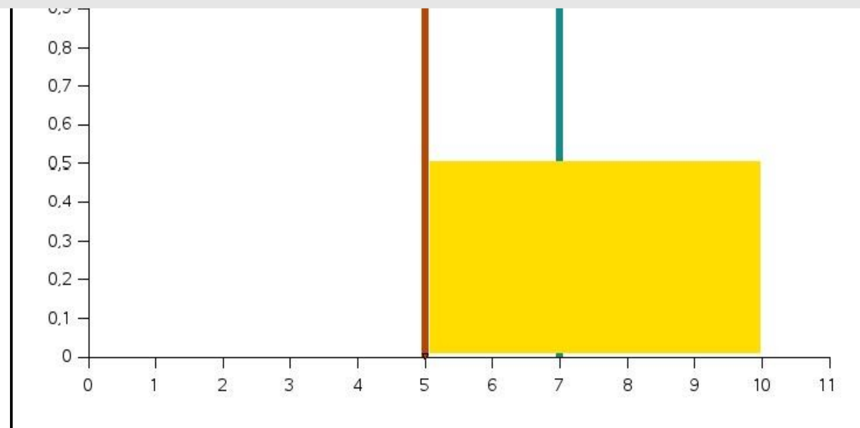
  p_{0i} = observation = {0,1}

$$0 \le \quad BS = \frac{1}{N}\sum_{i=1}^{N}(p_i - p_{0i})^2 \quad \le 1$$

$p_{0i}=P(X>t)=0$ if $X<t$



$p_{0i}=P(X>=t)=1$ if $X>=t$



Brier Score (extended)

- How well fit fc and ob?

  p_i = forecast probability $\in [0,1]$

  p_{0i} = observation $\cancel{= \{0,1\}}$ $\in [0,1]$

$$0 \le \quad BS = \frac{1}{N}\sum_{i=1}^{N}(p_i - p_{0i})^2 \quad \le 1$$

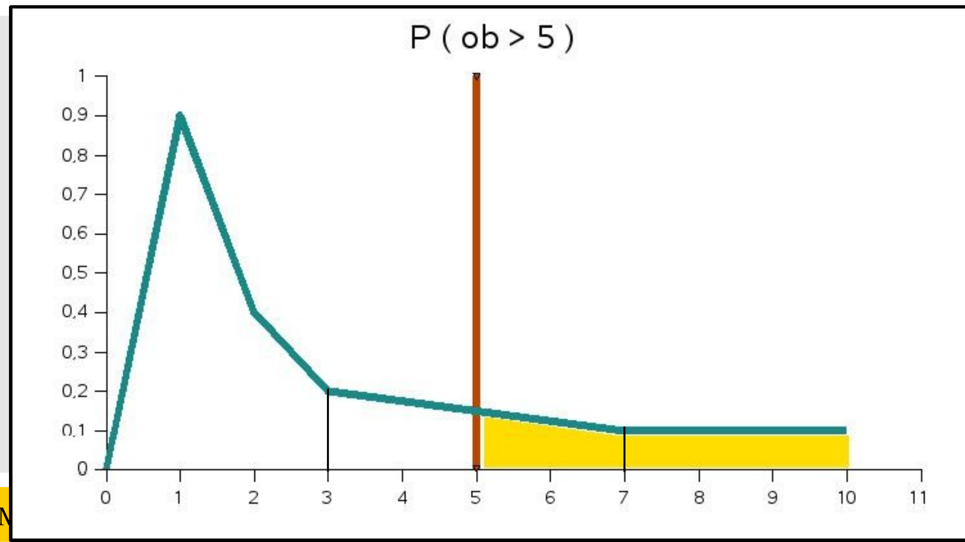
$q_j = \{\ 10,25,50,75,90 \mid P(X>q_j)=1-q_j\ \}$

given $q_{j-1} < t < q_j$

$P(X>q_{j-1} \mid q_{j-1}<t) \le P(X>t) \le P(X>q_j \mid q_j>t)$

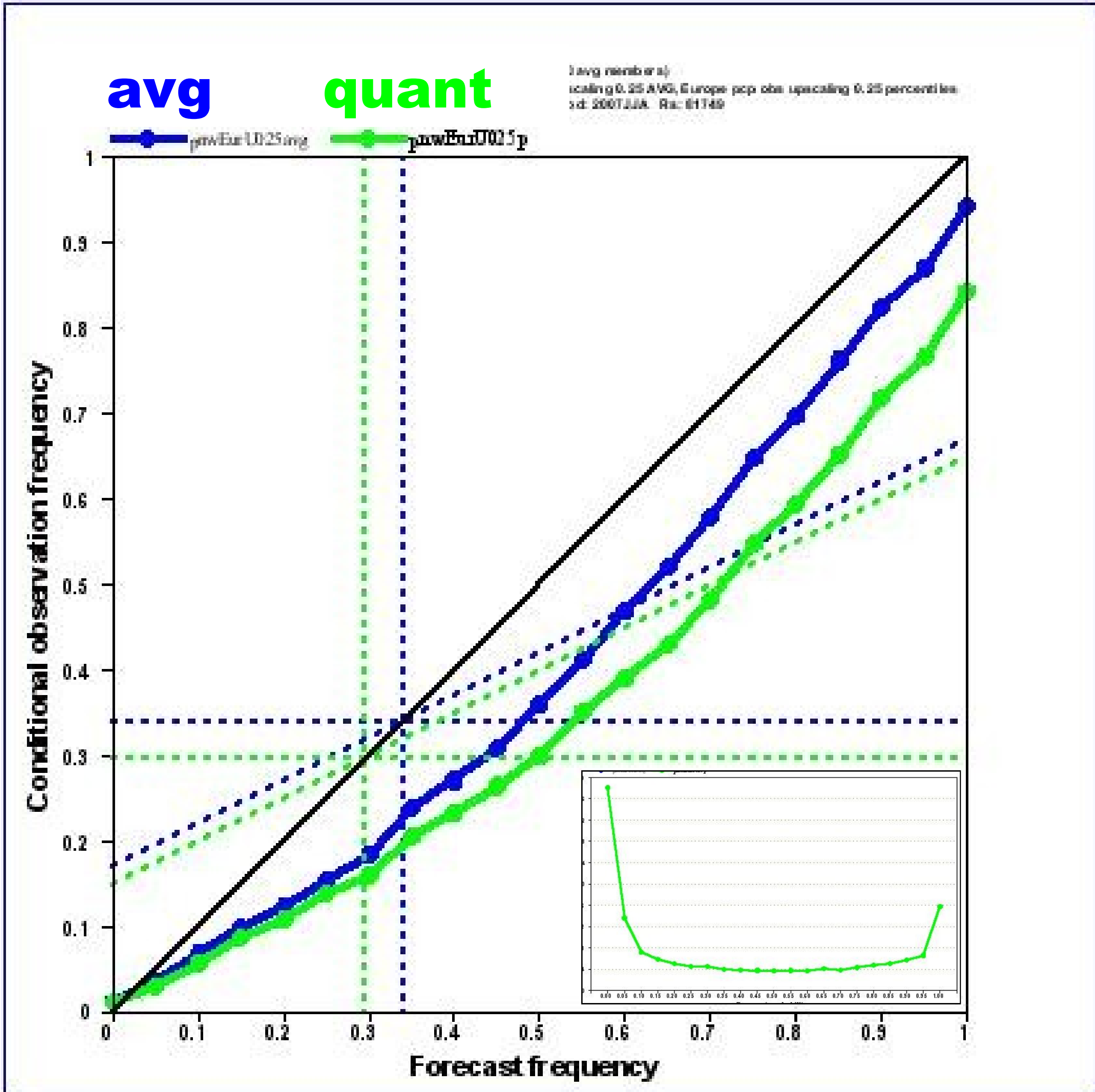
$P(X>t) \approx P(q_{j-1}<X<q_j \mid q_{j-1}<t<q_j)$

$\qquad = (\ 1-q_j + 1-q_{j-1}\ )\ /\ 2 = 1-(q_j+q_{j-1})/2$



24h AccPcp	Observed	European HR	7-7UTC
	Ensemble forecast	00UTC t+54	6-6UTC
Ensembles	LAM 0.25º	AEMET multi-model SREPS	5models x 4BC = 20
	Global 0.50º	ECMWF EPS	1cont + 50pert = 51 (Singular Vectors)
Period	Apr2007-Jun2008		
Verification methods	Classical	Up-scaling average	0.25 1.00
	Candille&Talagrand “Observational probability”	Upscaling quantiles (10,25,50,75,90)	0.25 1.00
Scoring rules	ECMWF recommendations	BSS decomposition ROC, RV	

Reliability ↓ Resolution ↑ BS_{unc} ↓



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BrierRel=0.00618360484703
BrierRes=0.119171170058
BrierUnc=0.22455376174
Brier=0.111566196528
BSSrel=0.027537302422
BSSres=0.46929782367
BSS=0.503164873908

BaseRate=0.29562012991
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BrierUnc=0.155011260535
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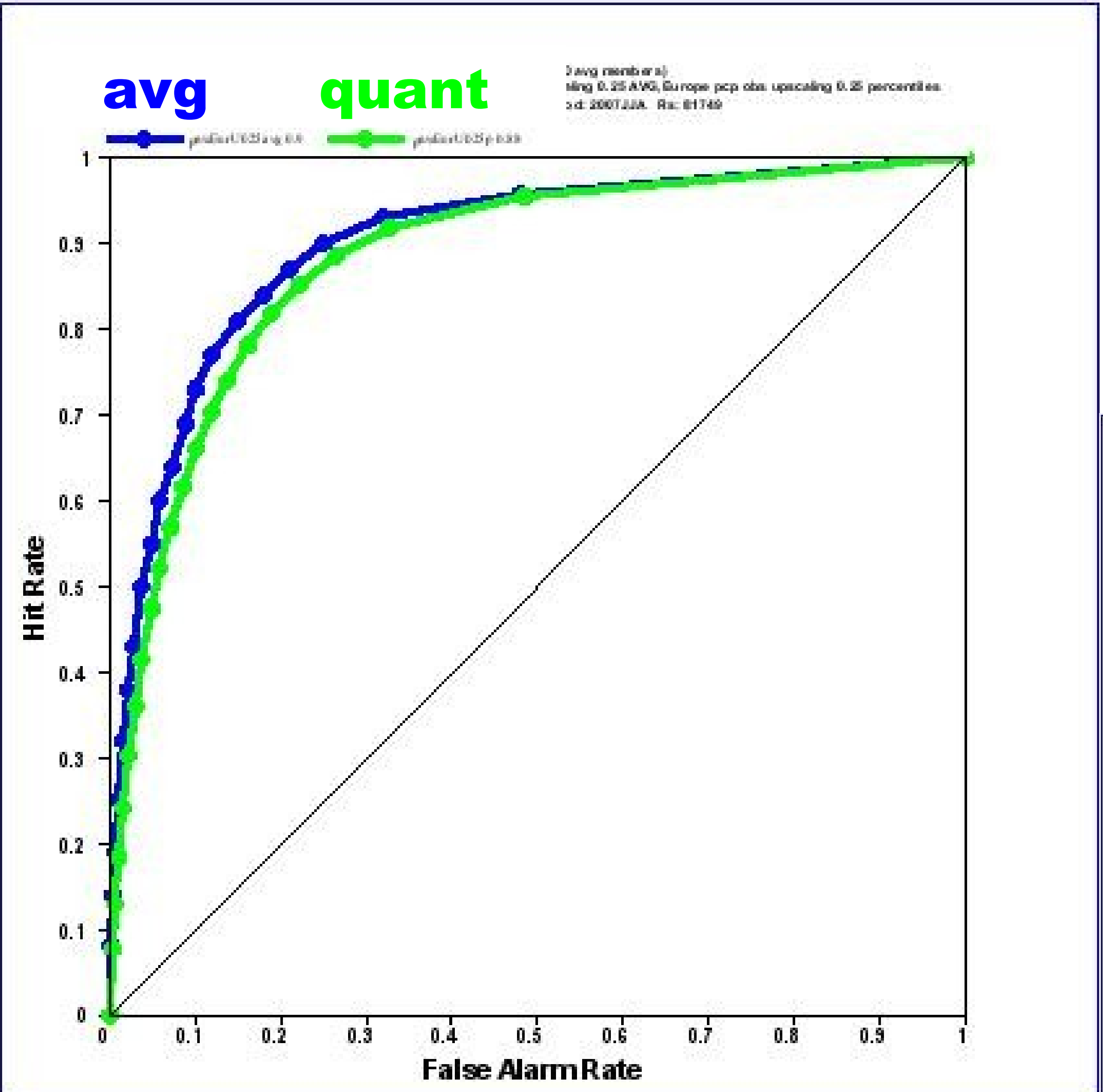
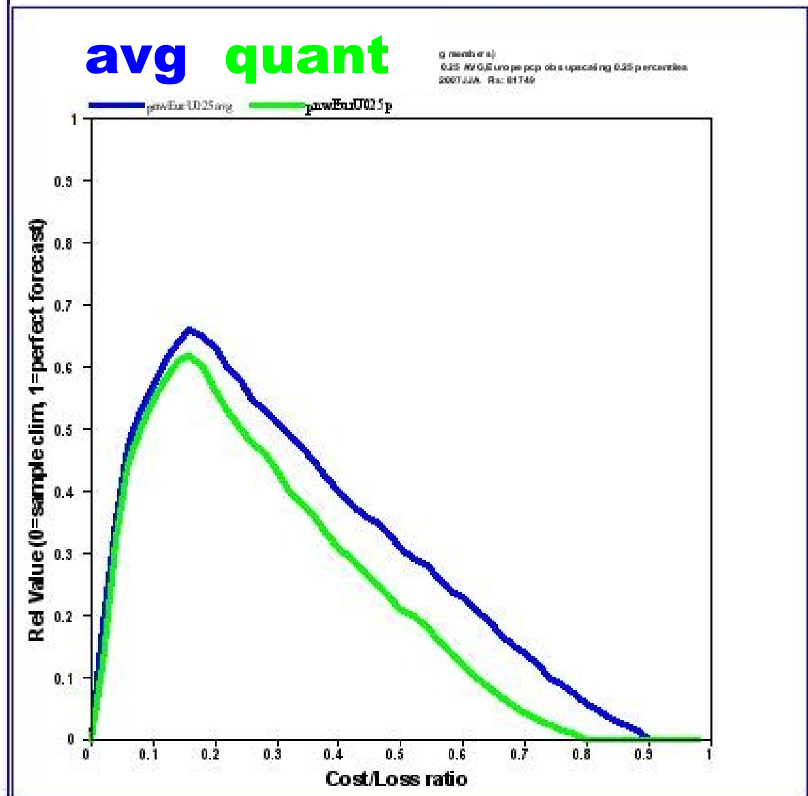
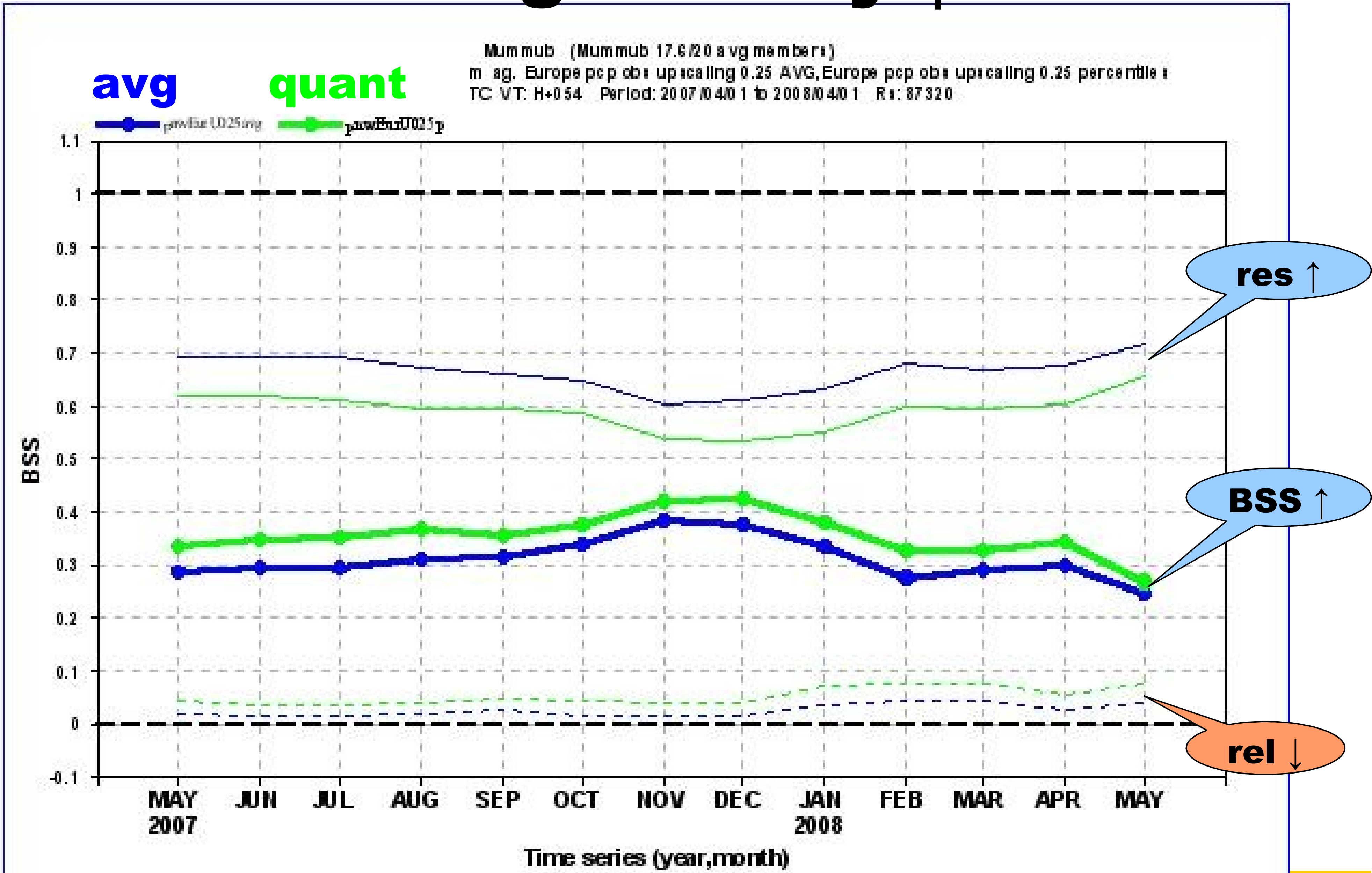
BSSrel=0.117017930373
BSSres=0.40546890137
BSS=0.477513168258

Discrimination ↓

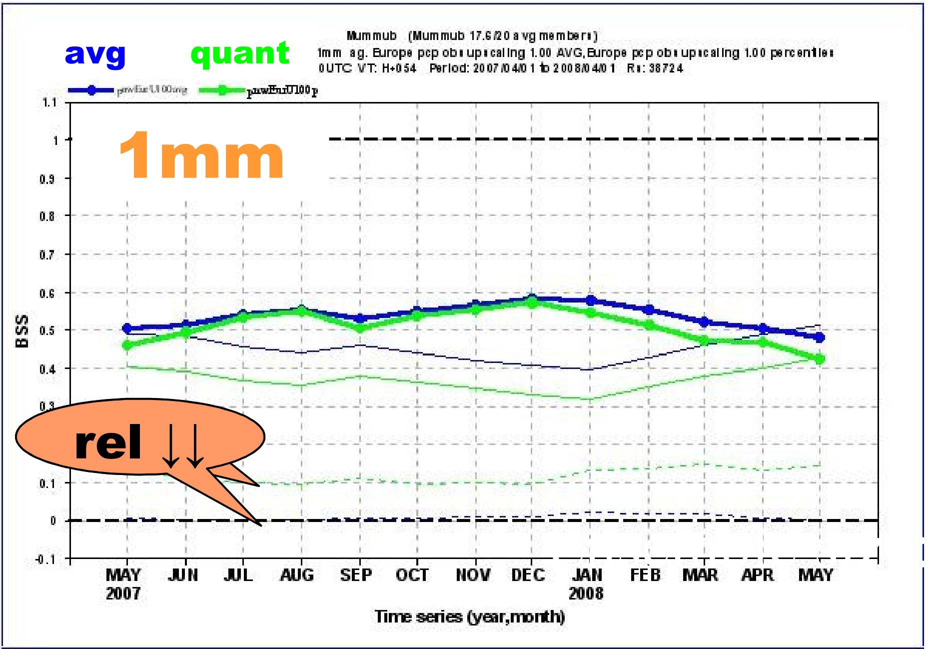


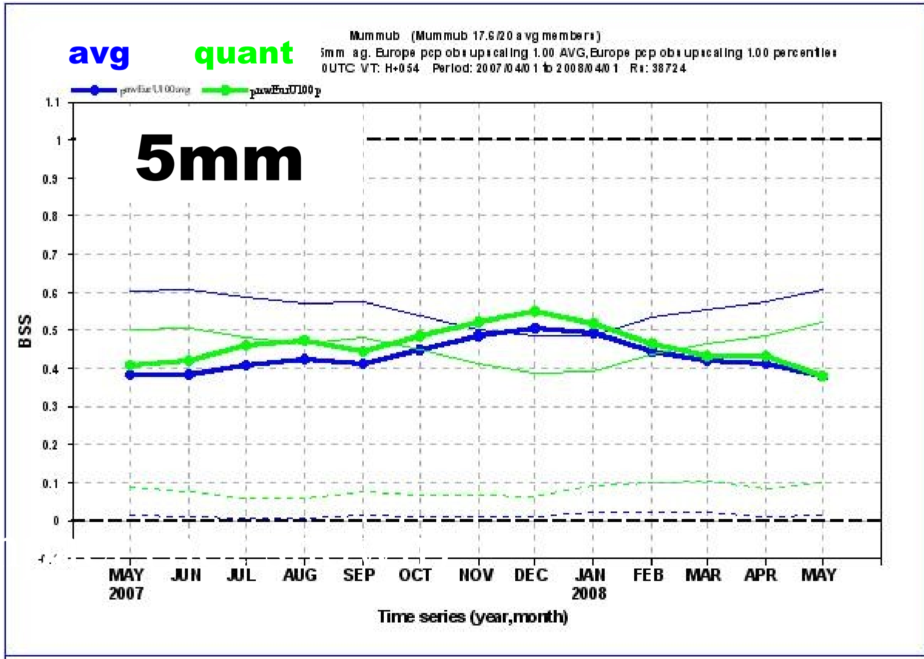


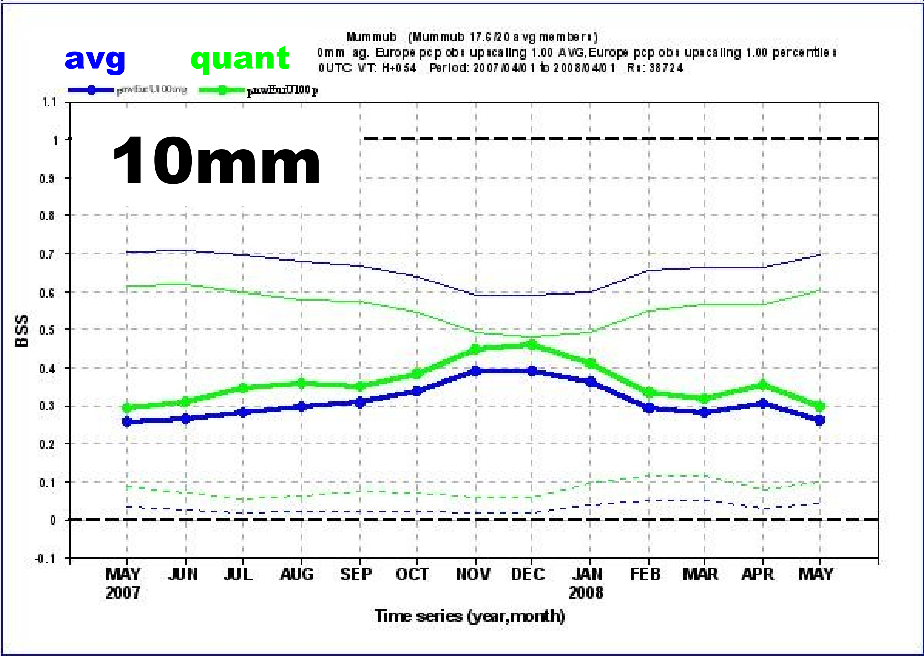
BSS generally ↑

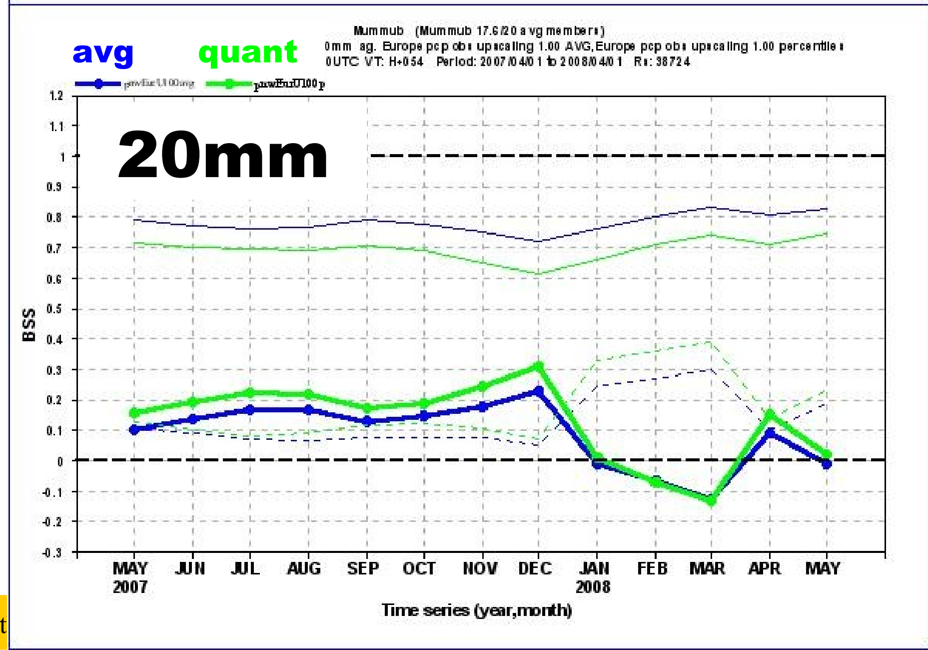


Rainfall threshold SREPS

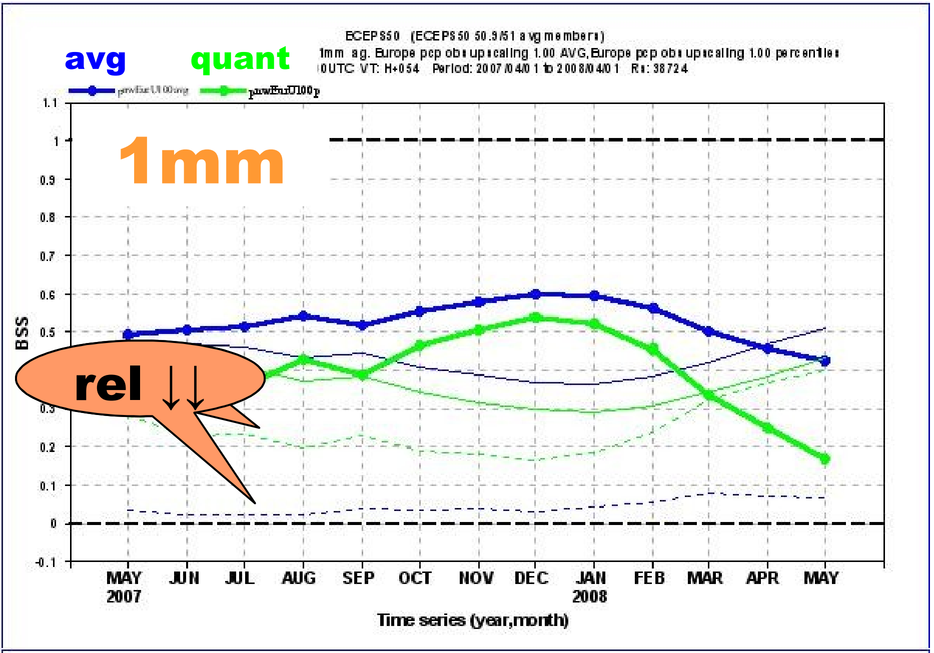


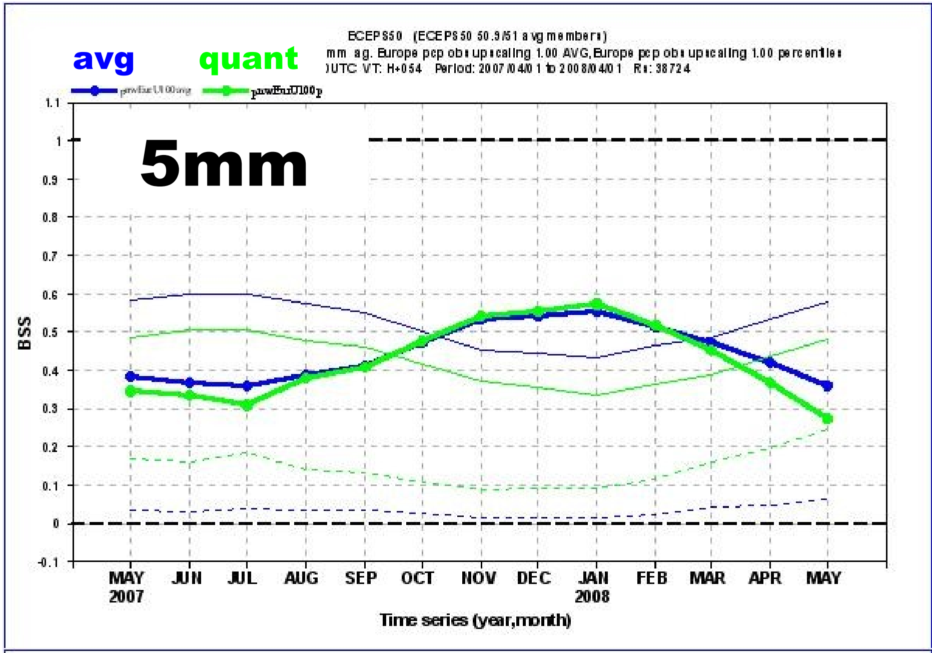


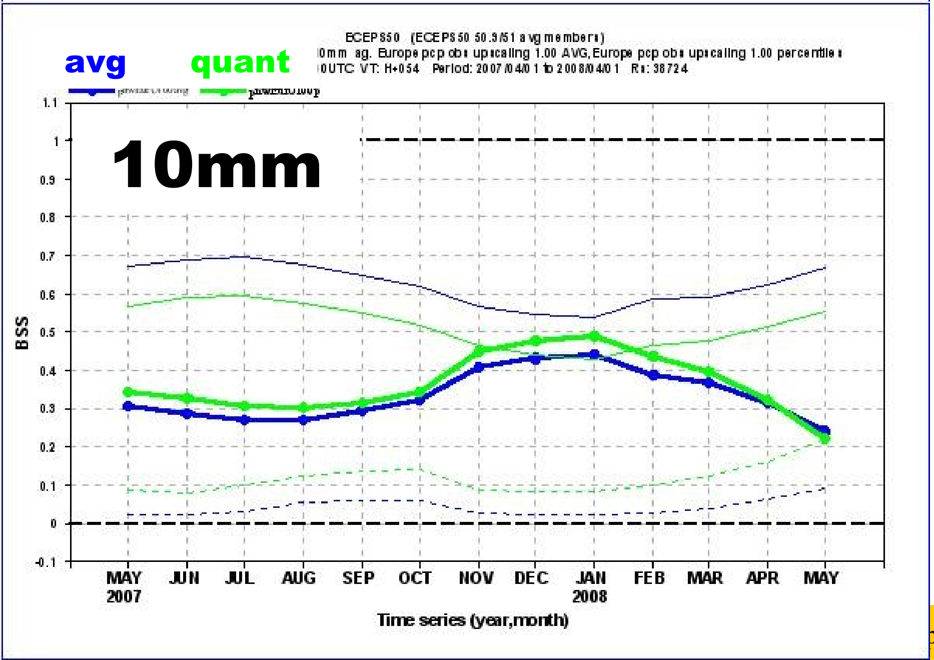


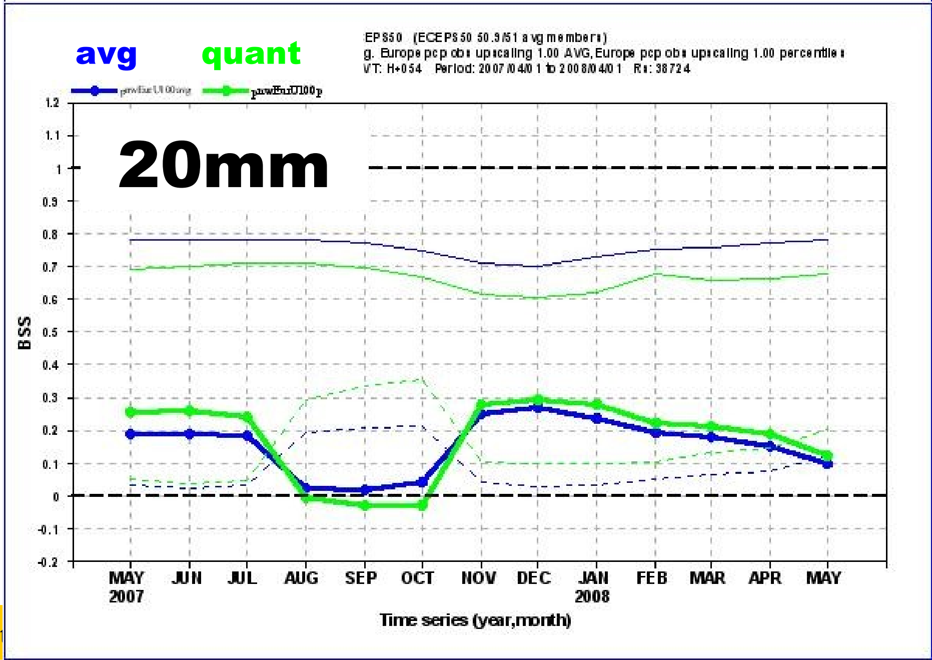


Rainfall threshold ECEPS

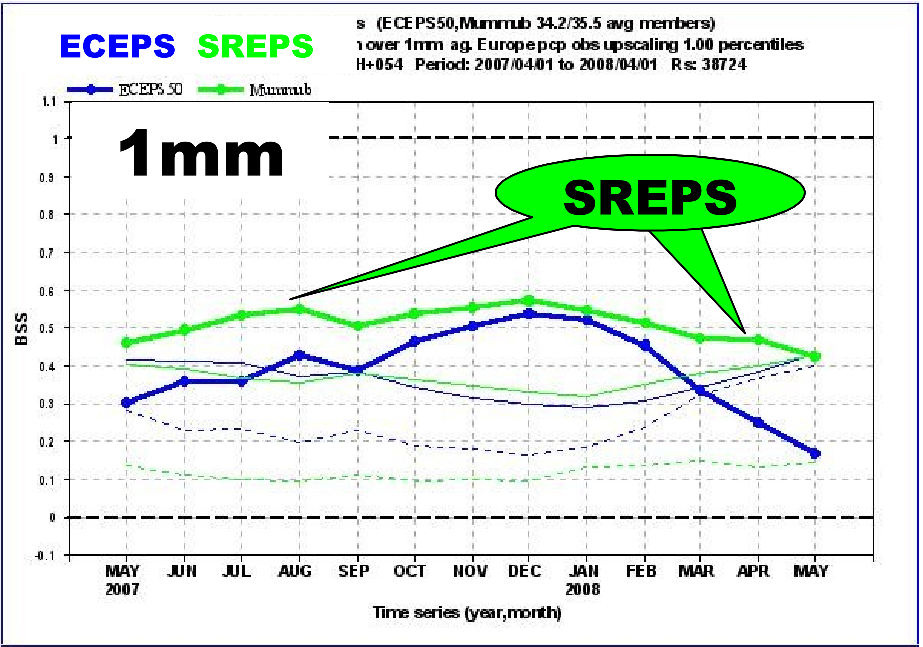


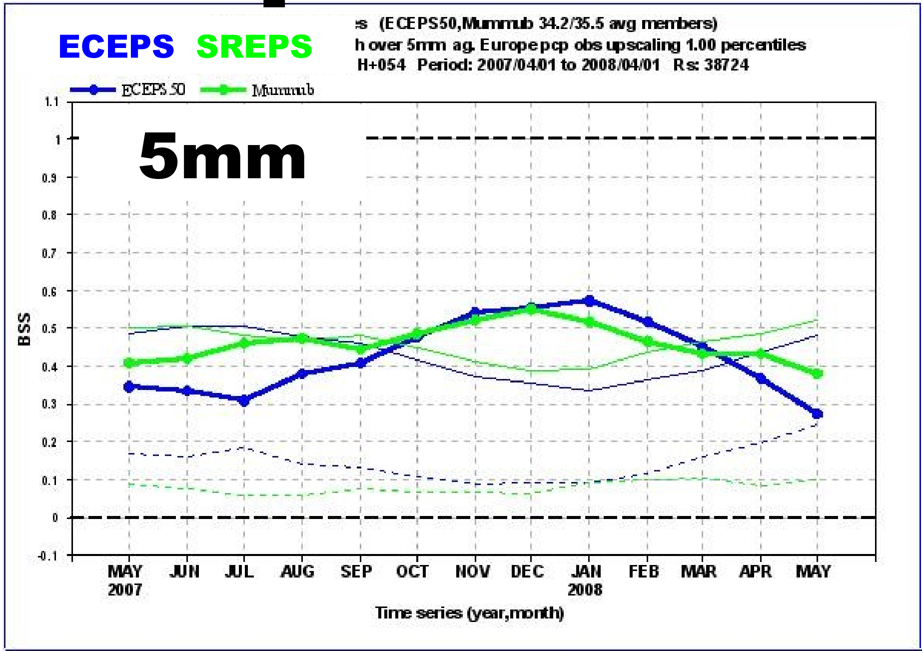


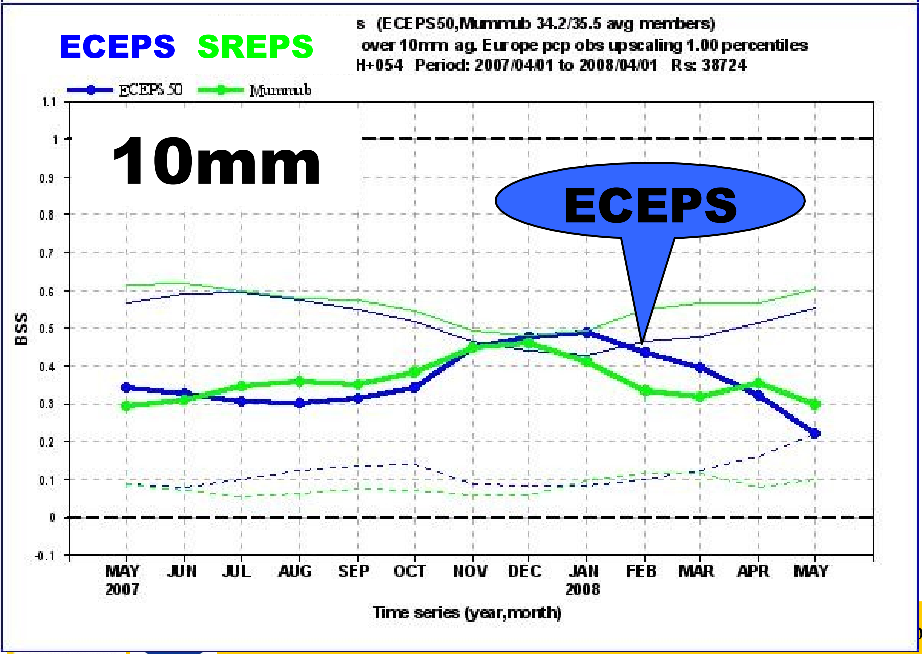


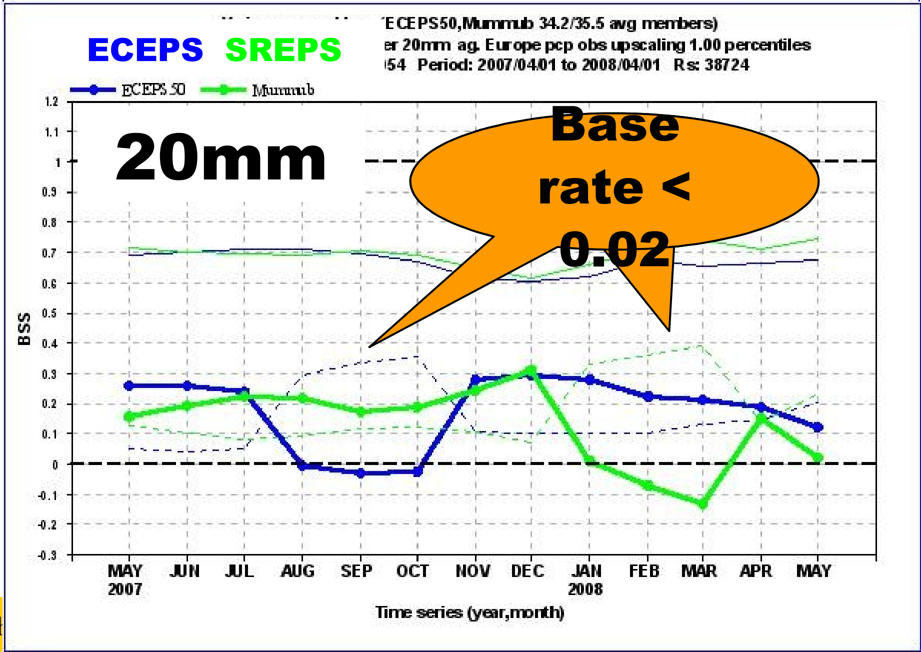


Model resolution quant









Conclusions

- Observational uncertainty method is compared w.r.t. classical for 24h AccPcp verification using Europe HR up-scaling
  - Once the rich information in the grid-box is available, it seems the most natural way to introduce it as observational uncertainty building a PDF
  - Up-scaling: average (certain), quantiles (uncertainty); 0.25º, 1.00º
  - Ensemble forecasts: AEMET Multi-model SREPS (LAM), ECMWF EPS (Global)

- Results are consistent with Candille & Talagrand "Observational probability":
  - Worse reliability, better resolution, BS_{unc} smaller
  - Generally better BSS
  - Worse discrimination

- Interesting results, impact on performance measures:
  - Rainfall threshold: worse BSS 1mm (known model bias), better BSS 5,10,20 mm
  - Model resolution (using up-scaling 1ºx1º): SREPS better in summer, quant improves SREPS advantages
  - Ensemble size: slight impact (not shown)
  - Using up-scaling 0.25ºx0.25º, bigger difference (not shown)

Thank you

csantos@inm.es
anna.ghelli@ecmwf.int
j.garcia-moya@inm.es

- European HR pcp data: many thanks to many ECMWF MS and Co-op States for making their climate network precipitation observations available for verification.

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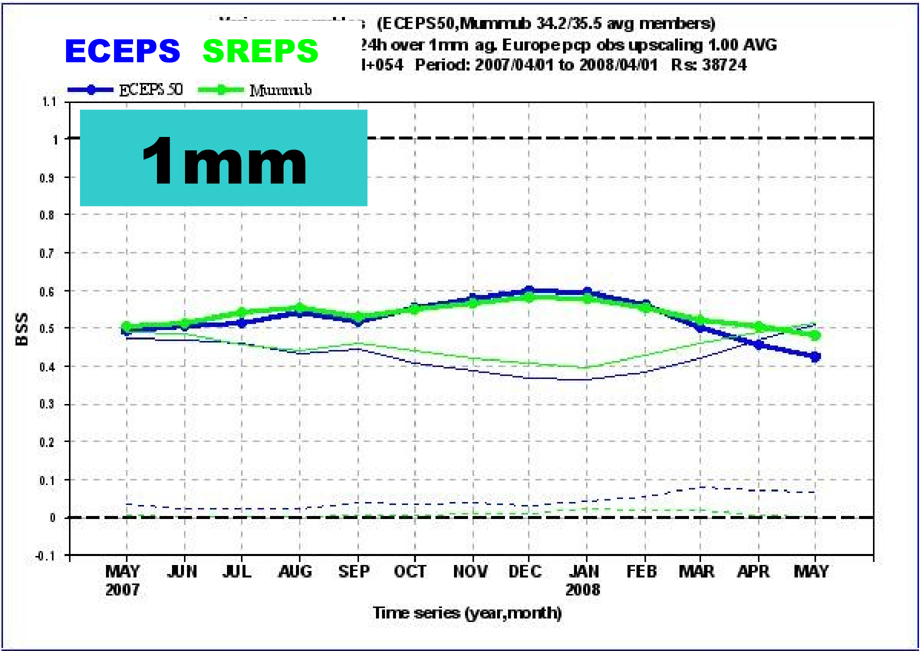
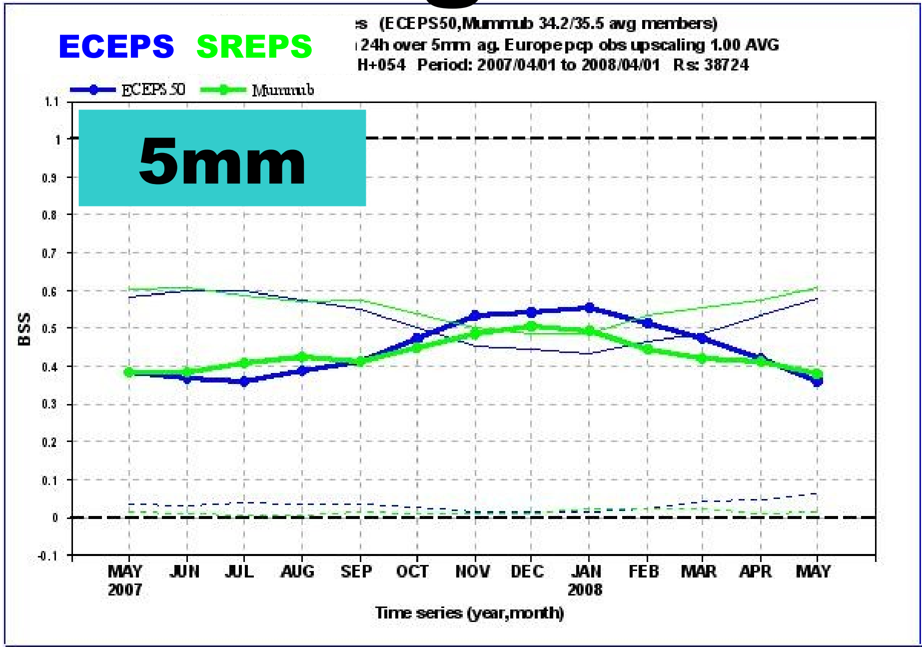
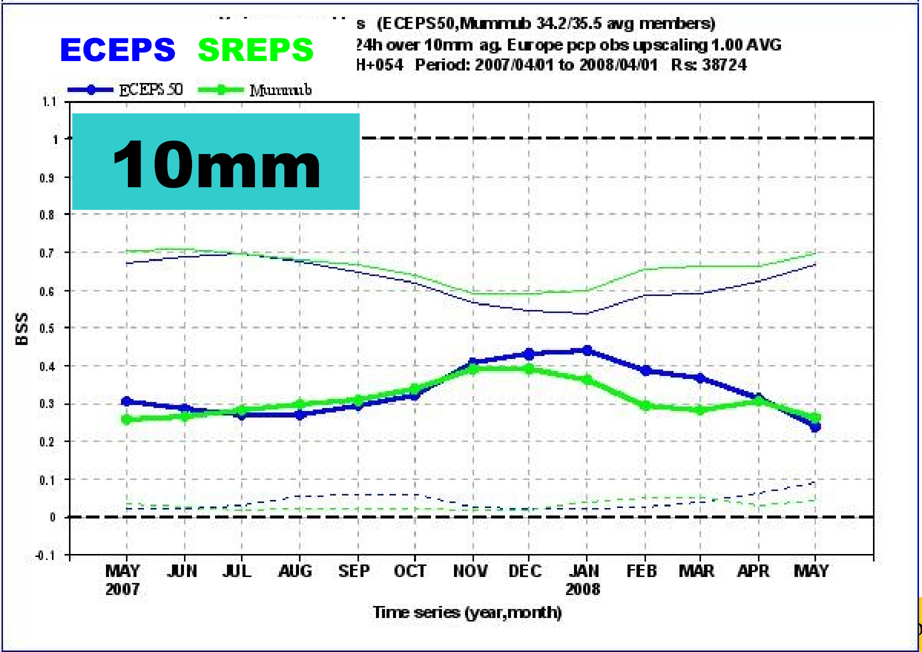
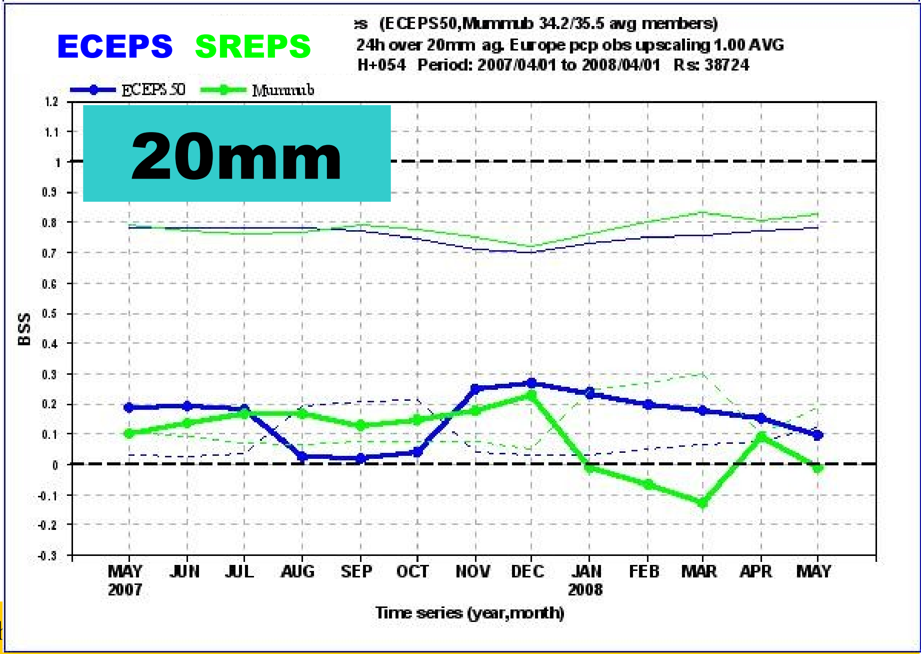
Bonus slides

Model resolution avg

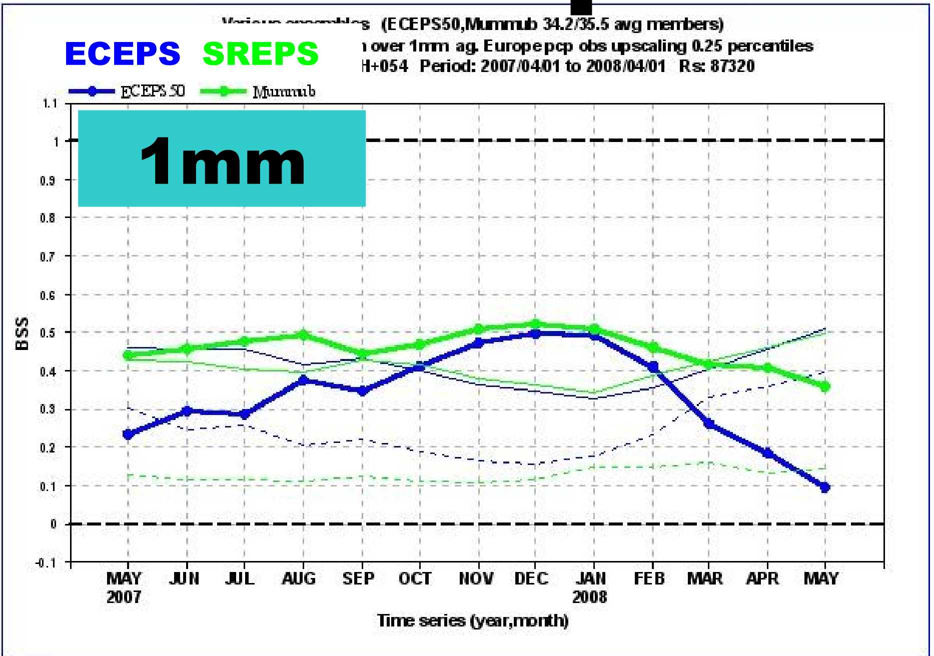


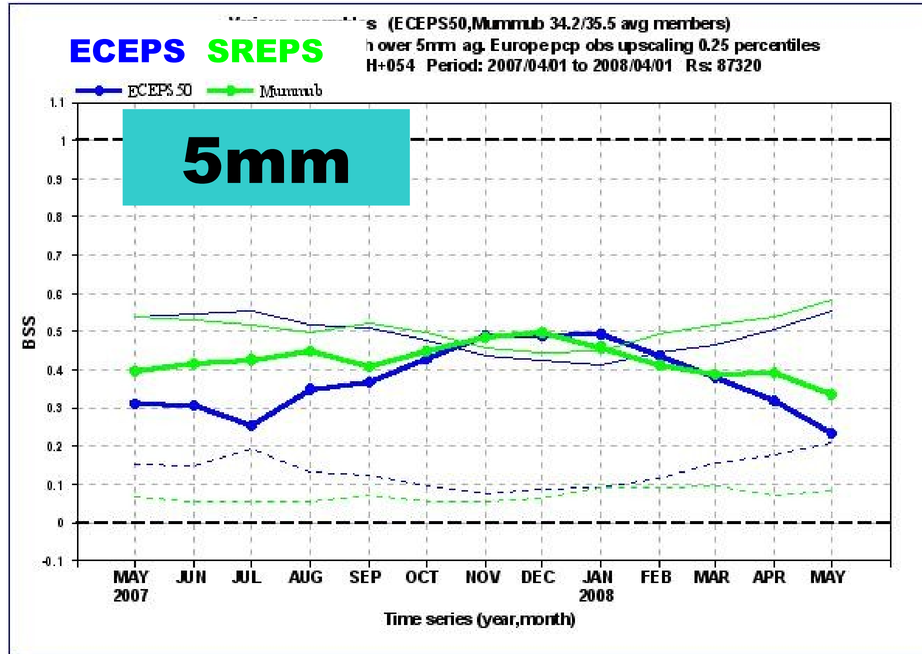


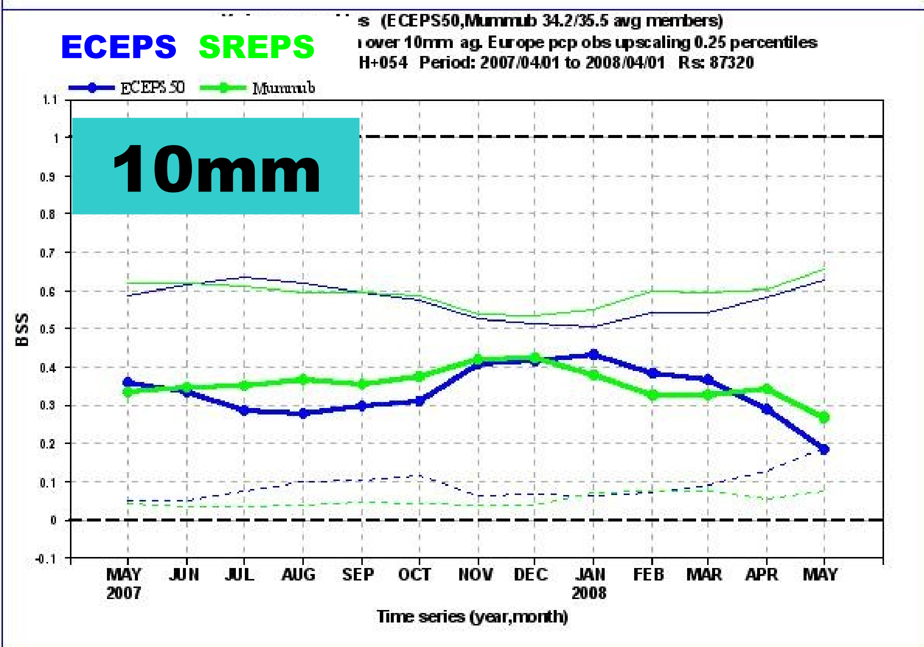


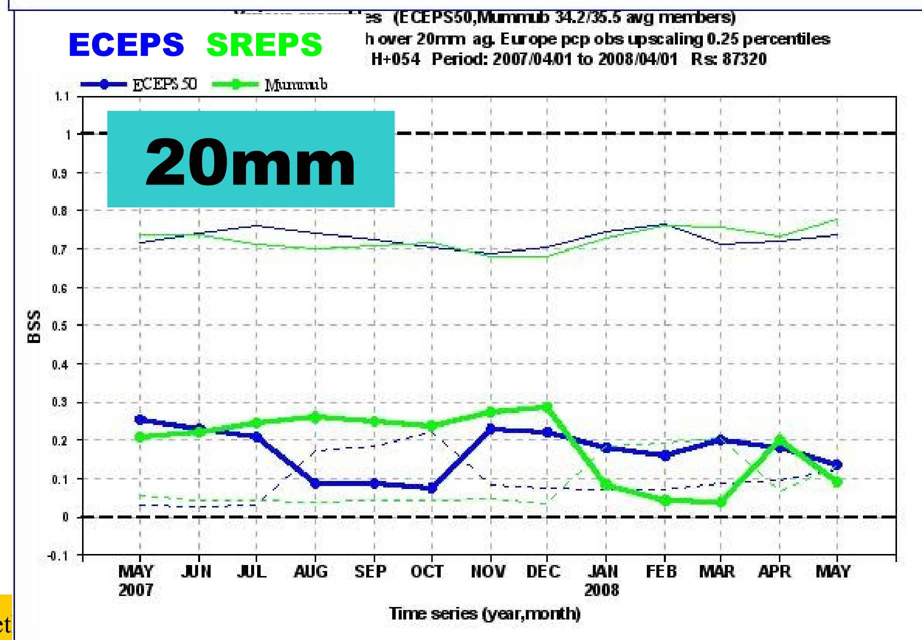


Up-scaling box size

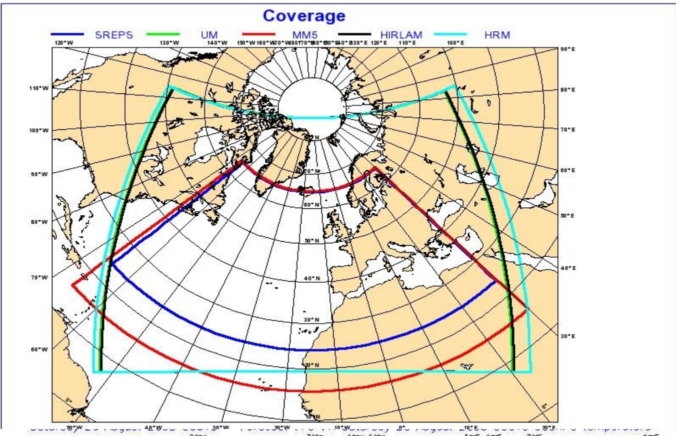


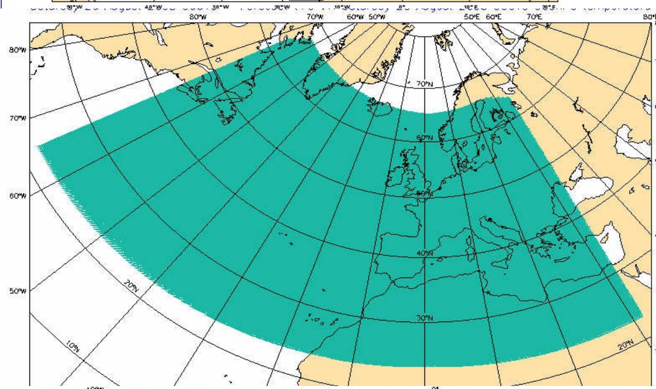


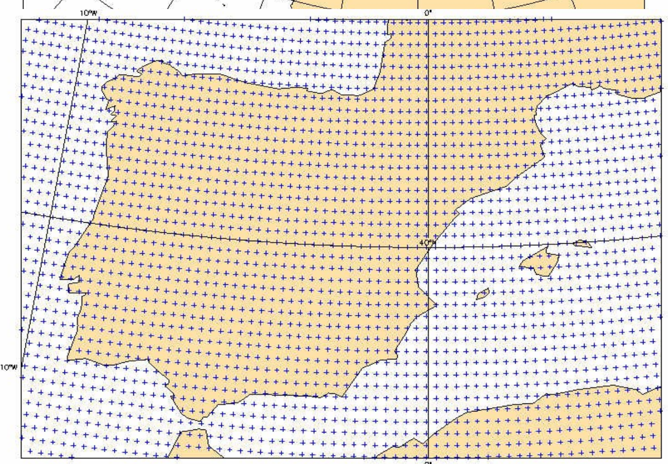


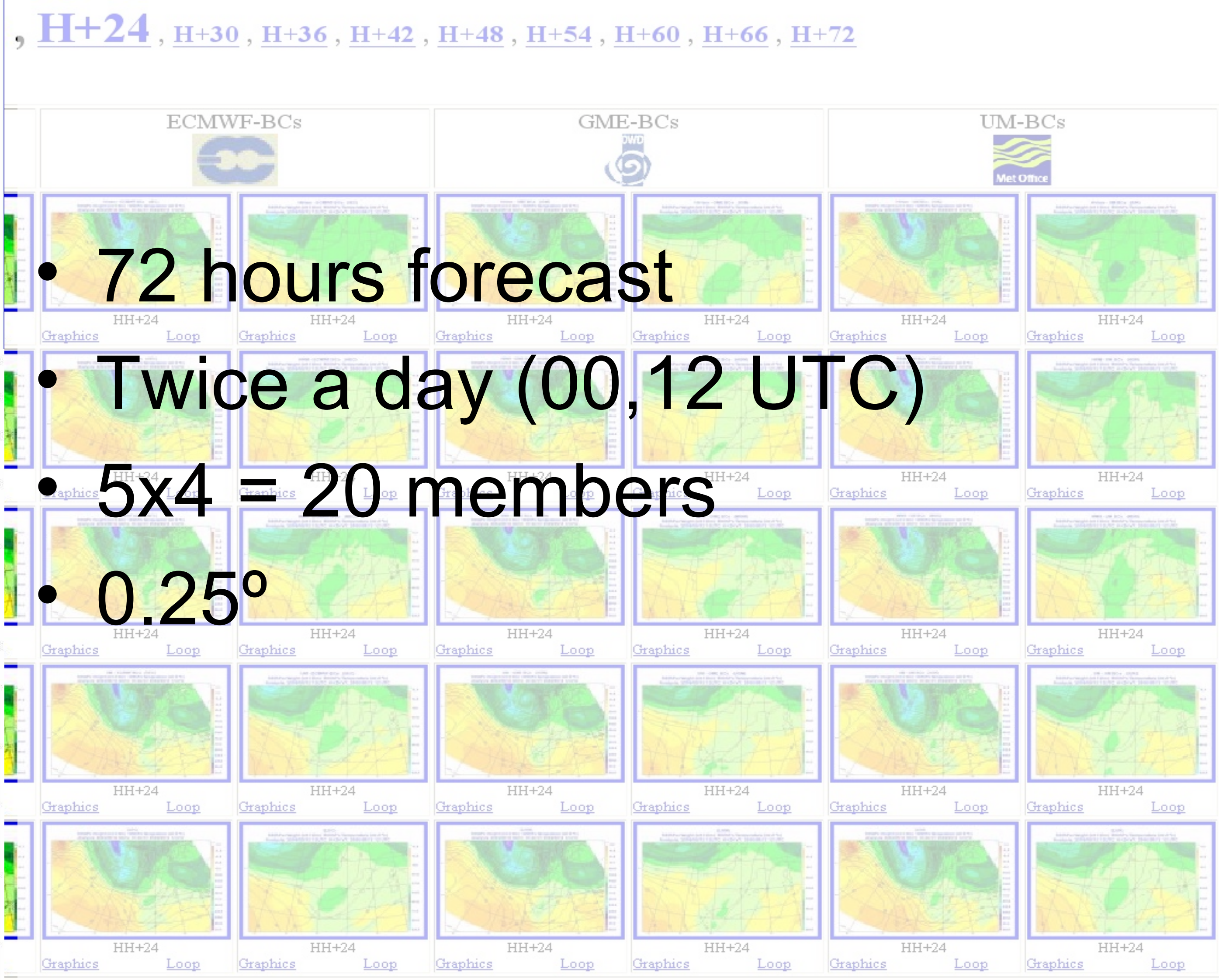


AEMET Multi-model LAM SREPS









- 72 hours forecast
- Twice a day (00,12 UTC)
- 5x4 = 20 members
- 0.25º

Brier Score Decomposition

$$\mathrm{BS} = E[(p-p_0)^2] = \underbrace{E[(p-p'(p))^2]}_{\text{Reliability}} - \underbrace{E[(p'(p)-p_c)^2]}_{\text{Resolution}} + \underbrace{E[p_0^2]-p_c^2}_{\text{Uncertainty}}$$

$$where \quad \left\{ \begin{array}{l} p'(p) = P(p_0 = 1 | p) = E[p_0](p) = cond\ obs\ frequency \\ p_c = P(p_0 = 1) = E[E[p_0](p)] = E[p_0] = base\ rate \end{array} \right\}$$

$$\mathrm{BS} = \frac{1}{n}\sum_{i=1}^{N}(p_i - o_i)^2 = \underbrace{\frac{1}{n}\sum_{i=1}^{I} n_i (p_i - \bar{o}_i)^2}_{\text{Reliabilty}} - \underbrace{\frac{1}{n}\sum_{i=1}^{I} n_i (\bar{o}_i - \bar{o})^2}_{\text{Resolution}} + \underbrace{\bar{o}(1-\bar{o})}_{\text{Uncertainty}}$$

$$where \quad \left\{ \begin{array}{l} \bar{o}_i = p(o = 1 | p_i) = \dfrac{1}{N_i}\displaystyle\sum_{k \in N_i} o_k \\ \bar{o} = \bar{\bar{o}}_i = p(o = 1) = \dfrac{1}{n}\displaystyle\sum_{i=1}^{I} n_i o_i \end{array} \right\}$$

Brier Score Decomposition (extended)

$$\mathrm{BS} = E[(p-p_0)^2] = \underbrace{E[(p-p'(p))^2]}_{\text{Reliability}} - \underbrace{E[(p'(p)-p_c)^2]}_{\text{Resolution}} + \underbrace{E[p_0^2]-p_c^2}_{\text{Uncertainty}}$$

$$where \quad \begin{cases} p'(p) = P(p_0=1|p) = E[p_0](p) = cond\ obs\ frequency \\ p_c = P(p_0=1) = E[E[p_0](p)] = E[p_0] = base\ rate \end{cases}$$

$$\mathrm{BS} = \frac{1}{n}\sum_{i=1}^{N}(p_i-o_i)^2 = \underbrace{\frac{1}{n}\sum_{i=1}^{I} n_i(p_i-\bar{o}_i)^2}_{\text{Reliabilty}} - \underbrace{\frac{1}{n}\sum_{i=1}^{I} n_i(\bar{o}_i-\bar{o})^2}_{\text{Resolution}} + \underbrace{\cancel{\bar{o}(1-\bar{o})}}_{\text{Uncertainty}}$$

$$where \quad \cancel{\begin{cases} \bar{o}_i = p(o=1|p_i) = \dfrac{1}{N_i}\sum_{k\in N_i} o_k \\ \bar{o} = \bar{\bar{o}}_i = p(o=1) = \dfrac{1}{n}\sum_{i=1}^{I} n_i o_i \end{cases}}$$

(M)CT and Joint Distribution

		ob	
		1	0
P(X) = 0/n	1	a_0	b_0
P(X) = 1/n	1	a_1	b_1
P(X) = 2/n	1	a_2	b_2
...			
P(X) = n/n	1	a_n	b_n

p_i	n_i	$\bar{o}_i$
0	a_0+b_0	$a_0/(a_0+b_0)$
1/n	a_1+b_1	$a_1/(a_1+b_1)$
2/n	a_2+b_2	$a_2/(a_2+b_2)$
n/n	a_n+b_n	$a_n/(a_n+b_n)$

(M)CT and Joint Distribution

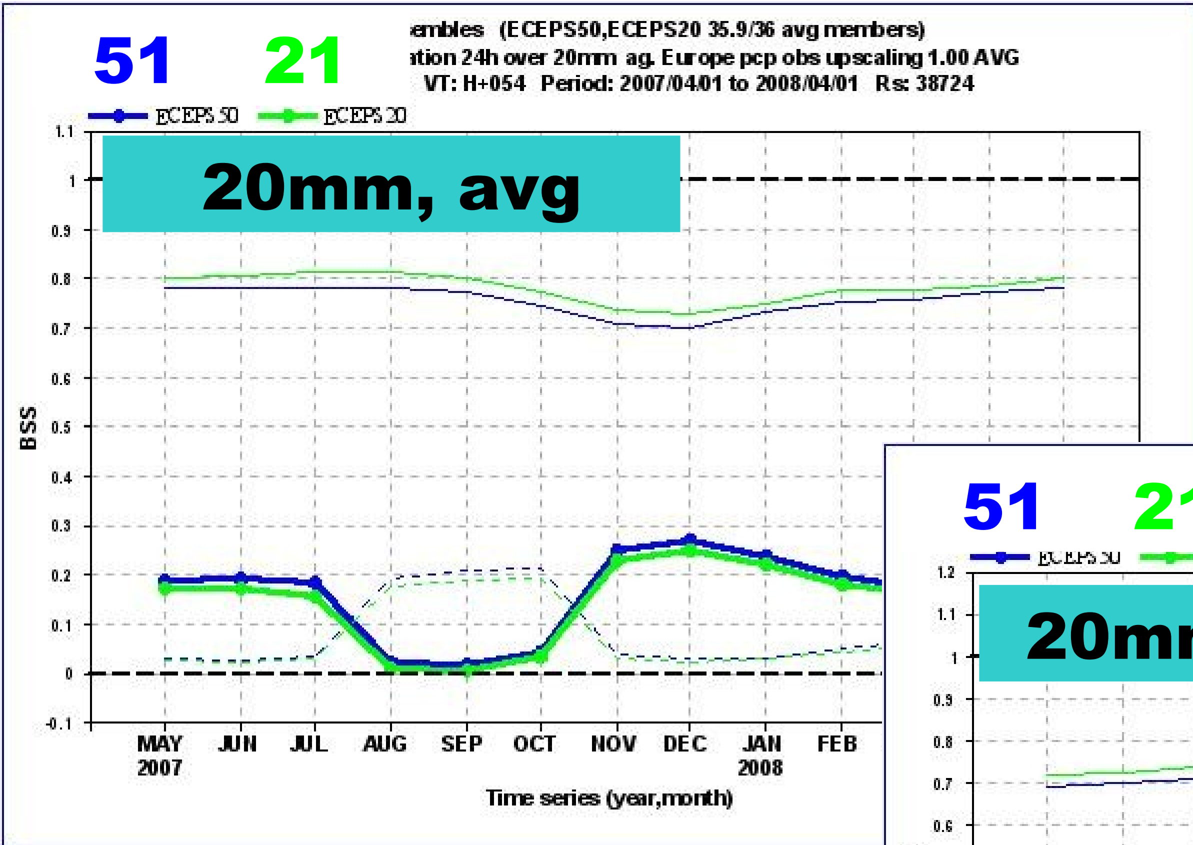
		ob	
		0 ($o < t$)	1 ($o \geq t$)
P = 0/n	1	b_0	a_0
P = 1/n	1	b_1	a_1
P = 2/n	1	b_2	a_2
...			
P = n/n	1	b_n	a_n

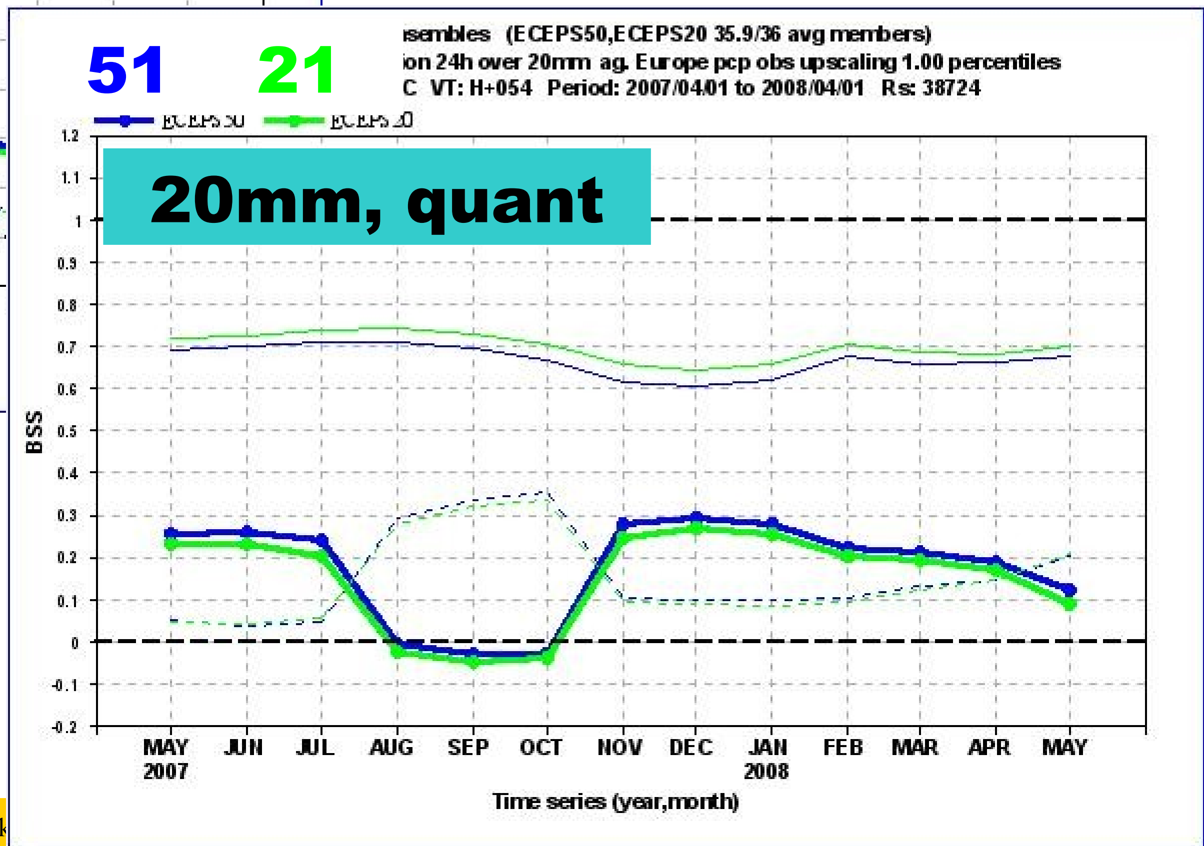
p_i	n_i	$\bar{o}_i$
0	a_0+b_0	$a_0/(a_0+b_0)$
1/n	a_1+b_1	$a_1/(a_1+b_1)$
2/n	a_2+b_2	$a_2/(a_2+b_2)$
...		
n/n	a_n+b_n	$a_n/(a_n+b_n)$

		ob					
		0	q_{10}	q_{25}	q_{50}	q_{75}	q_{90}
P = 0/n	1	$a_{0,0}$	$a_{0,10}$	$a_{0,25}$	$a_{0,50}$	$a_{0,75}$	$a_{0,90}$
P = 1/n	1	$a_{1,0}$	$a_{1,10}$	$a_{1,25}$	$a_{1,50}$	$a_{1,75}$	$a_{1,90}$
P = 2/n	1	$a_{2,0}$	$a_{2,10}$	$a_{2,25}$	$a_{2,50}$	$a_{2,75}$	$a_{2,90}$
...							
P = n/n	1	$a_{n,0}$	$a_{n,10}$	$a_{n,25}$	$a_{n,50}$	$a_{n,75}$	$a_{n,90}$

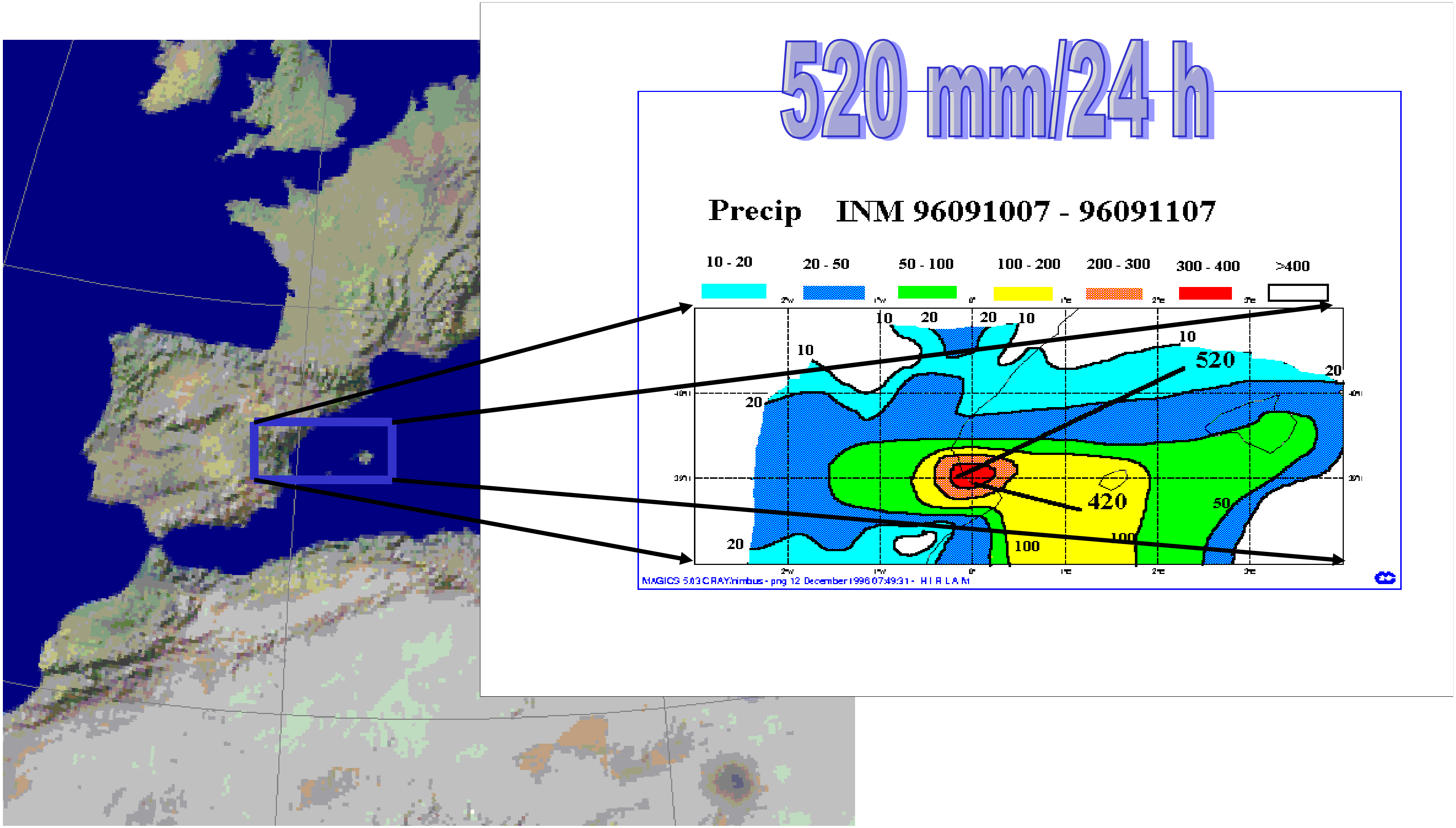
p_i	n_i	$\bar{o}_i$
0	$\sum a_{0,q}$	$\sum (o_q a_{0,q}) / \sum a_{0,q}$
1/n	$\sum a_{0,q}$	$\sum (o_q a_{1,q}) / \sum a_{1q}$
2/n	$\sum a_{0,q}$	$\sum (o_q a_{2,q}) / \sum a_{2,q}$
...		
n/n	$\sum a_{0,q}$	$\sum (o_q a_{n,q}) / \sum a_{n,q}$

Ensemble size ECEPS

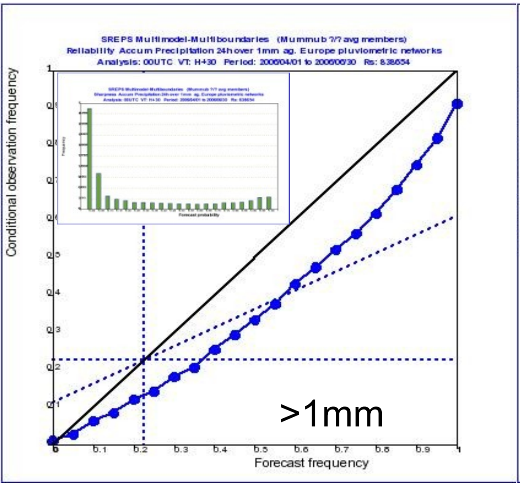


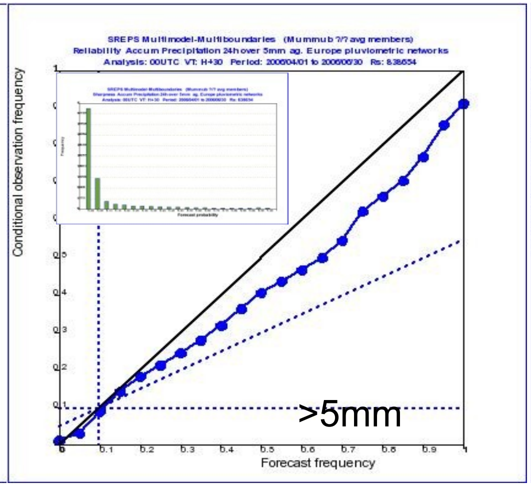


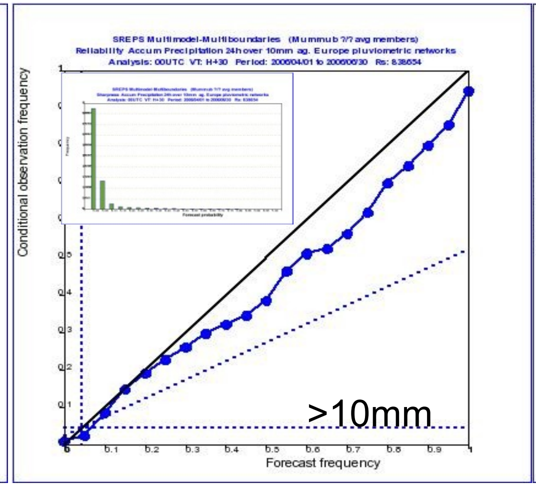
Why an EPS for SR?

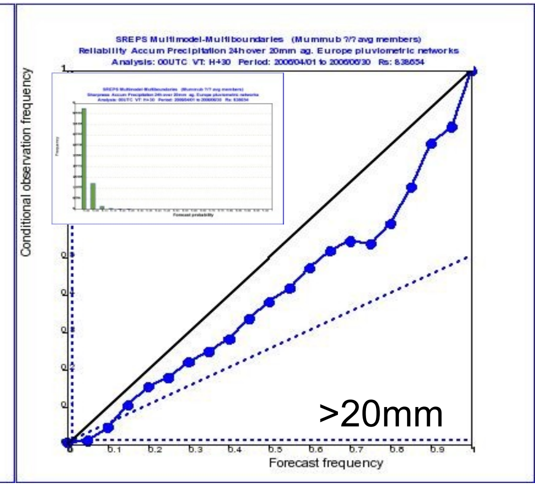


HR pcp observations





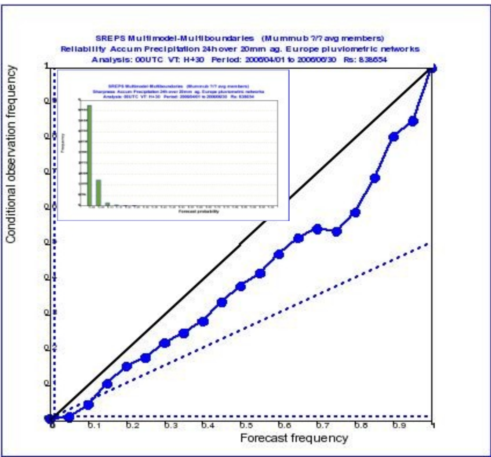




Reliability

Pcp>20mm

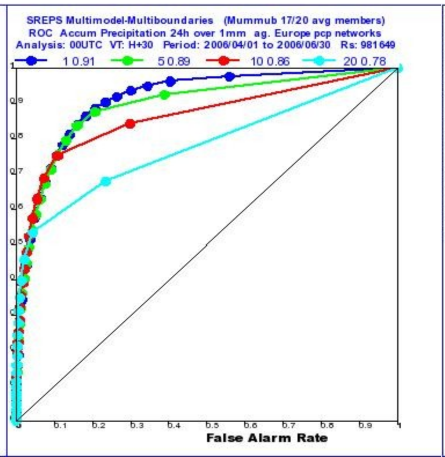
T+30



ROC

Pcp>1,5,10,20mm

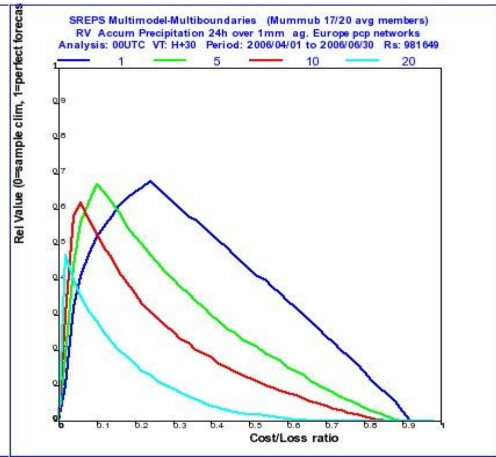
T+30



RV

Pcp>1,5,10,20mm

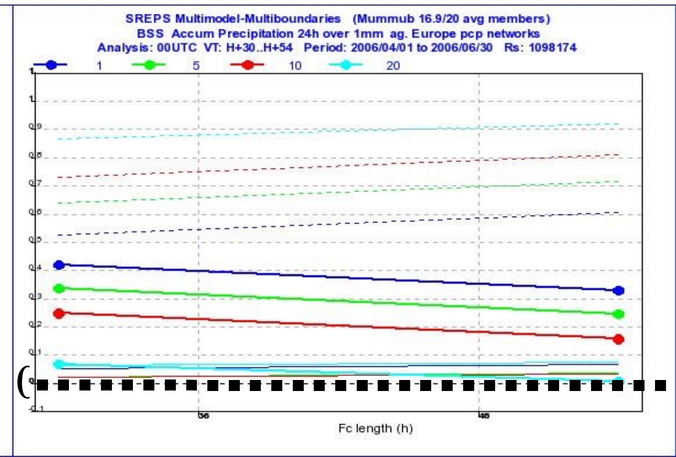
T+30



BSS

Pcp>5mm

T+30,54



Brier score y Brier skill score

Score	Cómputo	Significado	Rango	Perf
Brier	$BS=\frac{1}{N}\sum_{i=1}^{N}(p_i-o_i)^2$	Análogo al RMSE Diferencia entre predicción probabilística [0,1] y observación del evento binario {0,1}	[0,1]	0
Brier skill score	$BSS=1-\frac{BS}{BS_{ref}}$	Análogo al RMSE_SS Comparación con BS de referencia (persistencia, climatología, climatología muestral…)	(-∞,1]	1

Tabla contingencia determinista

- Caracteriza completamente la distribución conjunta de una predicción para un evento binario (X) sobre un total de N casos

fc(X)={1,0}

ob(X)={1,0}

		ob		
		1	0	
fc	1	a Aciertos	b falsas alarmas	a+b
	0	c Fallos	d negativos correctos	a+d
		a+c	b+d	a+b+c+d = N

Tabla de contingencia: derivados

- Con la tabla de contingencia se construyen numerosos scores derivados

		ob		
		1	0	
fc	1	a	b	a+b
	0	c	d	a+d
		a+c	b+d	a+b+c+d = N

Base Rate	s	(a + c) / n
HitRate	H	a / (a + c)
False Alarm Rate	F	b / (b + d)
False Alarm Ratio	FARatio	b / (a + b)
Proportion Correct	PC	(a + d) / n
…		

Scores comunes

		Ob	
		1	0
Fc	1	a	b
	0	c	d

Score	Cómputo	Significado	Rango	Perf
Proportion correct	$PC=\frac{a+d}{N}$	No es realmente indicativo	$(-\infty,\infty)$	0
Base rate	$s=\frac{a+c}{N}$	Mide la tasa del evento o “sample climatology”	[0,1]	-
Hit rate	$H=\frac{a}{a+c}$	SIs: se predice el evento y se da	$[0,\infty)$	1
False alarm rate	$F=\frac{b}{b+d}$	NOs: se predice el evento pero no se da	$[0,\infty)$	0
True skill score	$TSS=\frac{a}{a+c}-\frac{b}{b+d}$	Mide la habilidad para separar Sis y Nos, compara H y F	[-1,1]	0
Frequency bias index	$FBI=\frac{a+b}{a+c}$	Mide la proporción entre evento predicho y evento observado	$[0,\infty)$	1

Tablas de contingencia probabilísticas

- En un EPS (o una PDF) tenemos una probabilidad de predicción del evento binario:

$$P(X)=\frac{\sum_{i=1}^{N} fc_i(X)}{N} \quad donde \quad fc_i(X)=\{1,0\} \;\Rightarrow\; P(X)\in[0,1]$$

  - Es decir, casos favorables entre posibles, e.g. si 15 de 50 miembros dan T>15ºC, entonces P(X)=0.3
- La respuesta de un EPS de N miembros frente a un evento binario puede caracterizarse particionando la probabilidad de predicción en N intervalos
- Es decir, la distribución conjunta del EPS para el evento binario queda descrita en N Tablas de Contingencia

Tablas contingencia
PDF=

		ob	
		1	0
P(X) = 0/n	1	a_0	b_0
	0	c_0	d_0
P(X) = 1/n	1	a_1	b_1
	0	c_1	d_1
P(X) = 2/n	1	a_2	b_2
	0	c_2	d_2
...			
P(X) = n/n	1	a_n	b_n
	0	c_n	d_n

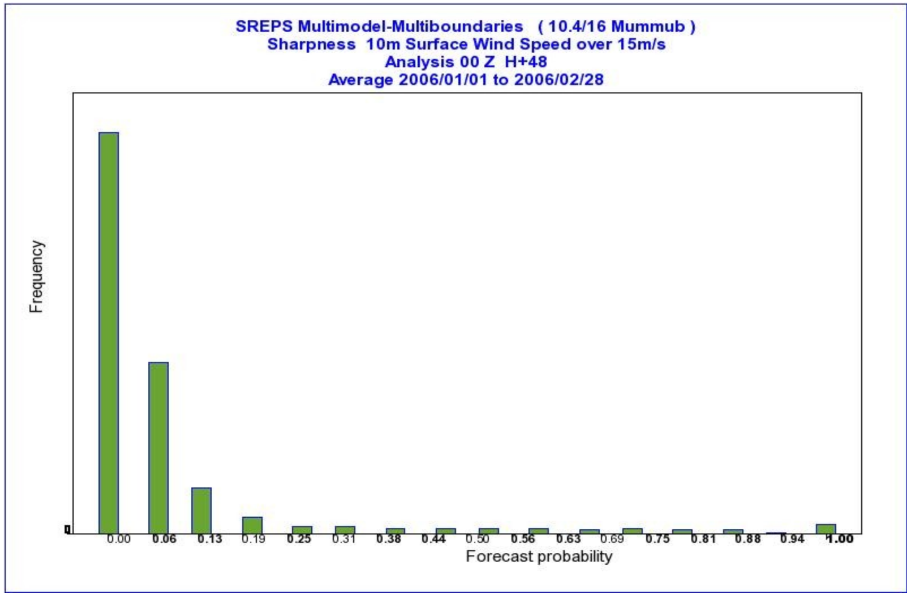
p_i	n_i	o_i
0	a_0+b_0	$a_0/(a_0+b_0)$
1/n	a_1+b_1	$a_1/(a_1+b_1)$
2/n	a_2+b_2	$a_2/(a_2+b_2)$
n/n	a_n+b_n	$a_n/(a_n+b_n)$

Sharpness

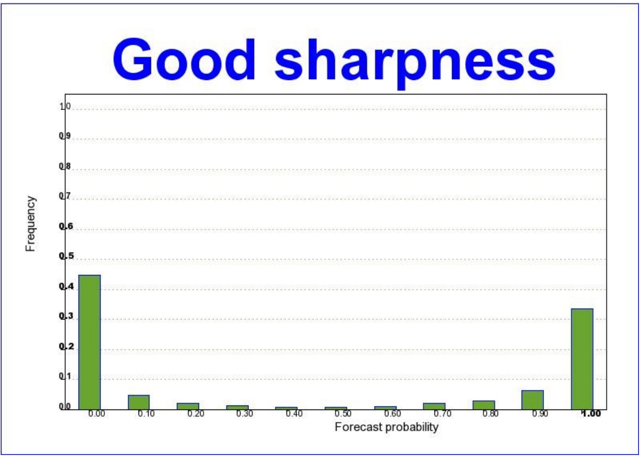
- Frecuencia de predicción por intervalos de probabilidad: depende del sistema de predicción **a priori,** sin contar con las observaciones
- Basada en distribución marginal de predicciones: distribución de frecuencias de intervalos de probabilidad n_i

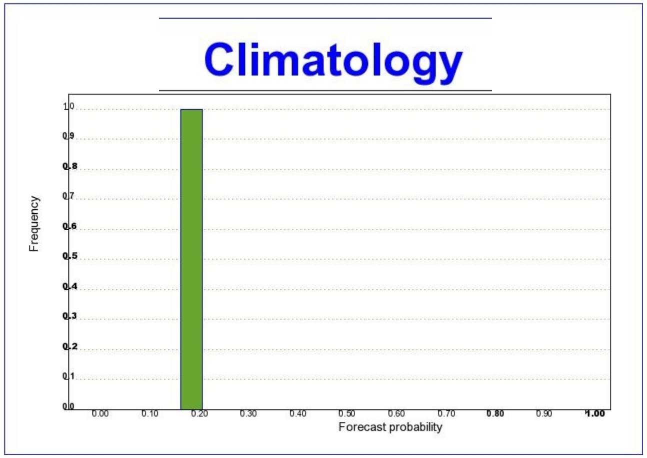
$$\begin{pmatrix} p_i = \dfrac{i}{N} \\ n_i(p_i) = a_i + b_i \end{pmatrix} \quad i = 0 \ldots N$$

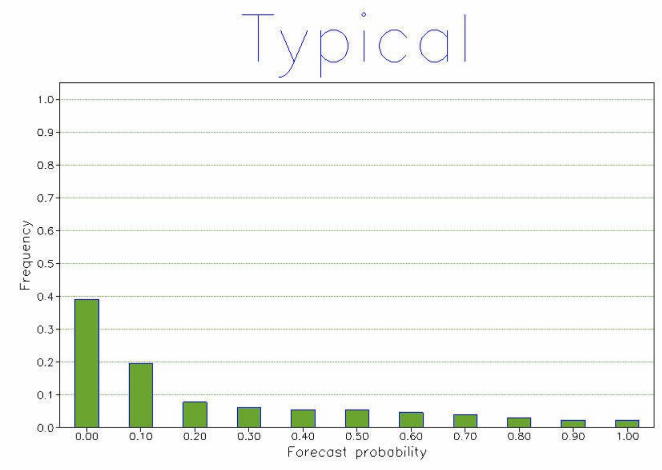
- **Sharpness histogram**
  - $(p_i , n_i(p_i))$ $i = 0 \ldots N$
  - Forma de U ~ buena resolución
  - Forma plana ~ sistema ambiguo

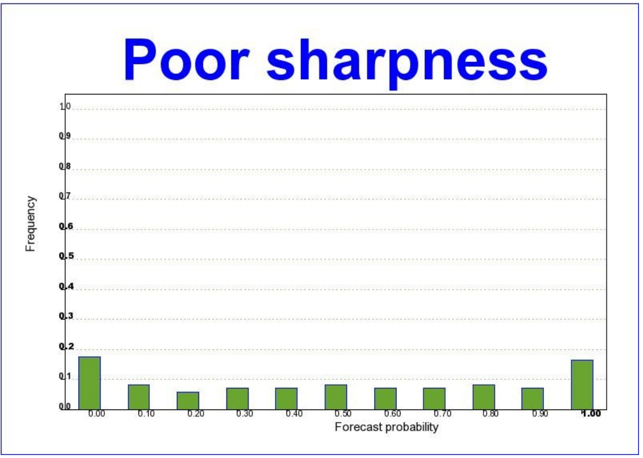


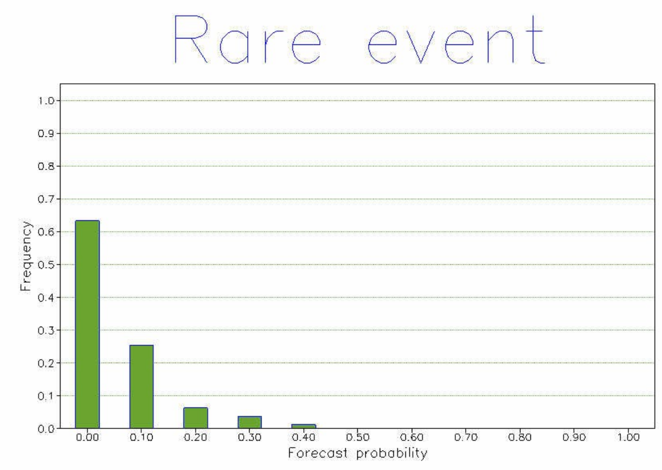
Sharpness


Good sharpness
Frequency
Forecast probability


Climatology
Frequency
Forecast probability


Typical
Frequency
Forecast probability

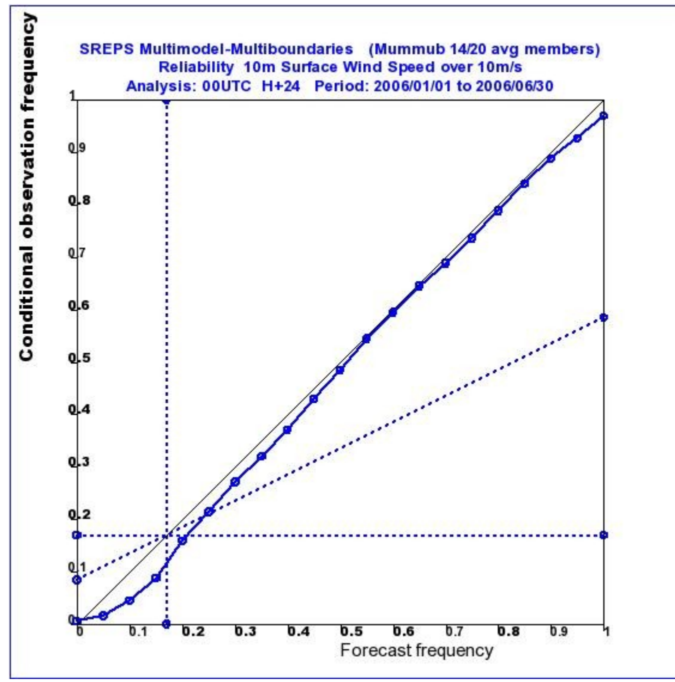

Poor sharpness
Frequency
Forecast probability


Rare event
Frequency
Forecast probability

Reliability

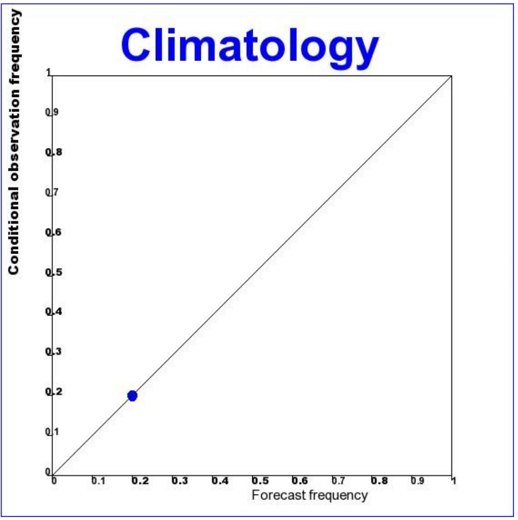
- Frecuencia de observación de X condicionada a la frecuencia de predicción por intervalos de probabilidad: Si predecimos X con probabilidad P, estadísticamente X debería darse aproximadamente en un %P de esos casos. Mide la **fiabilidad**
- Basada en distribución conjunta: intervalos de probabilidad p_i y las observaciones condicionadas $o(p_i)$:

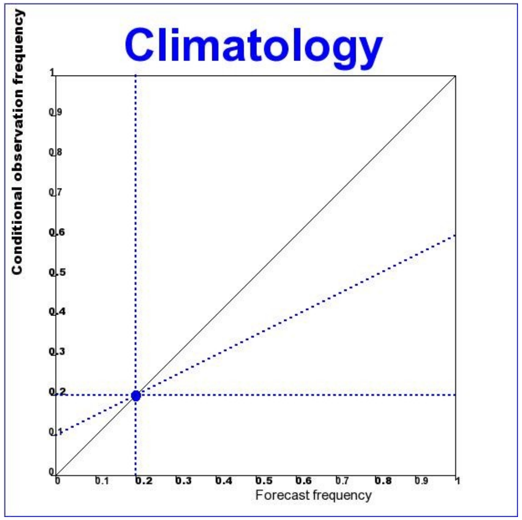
$$\left(\begin{array}{c} p_i = \dfrac{i}{N} \\ \bar{o}_i(p_i) = \dfrac{a_i}{a_i + b_i} \end{array} \right) \quad i = 0 \ldots N$$

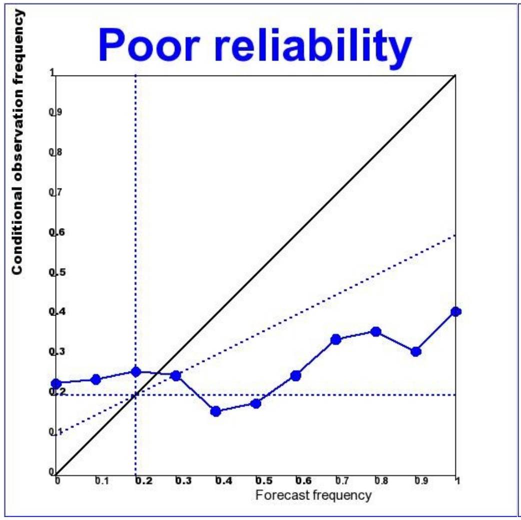


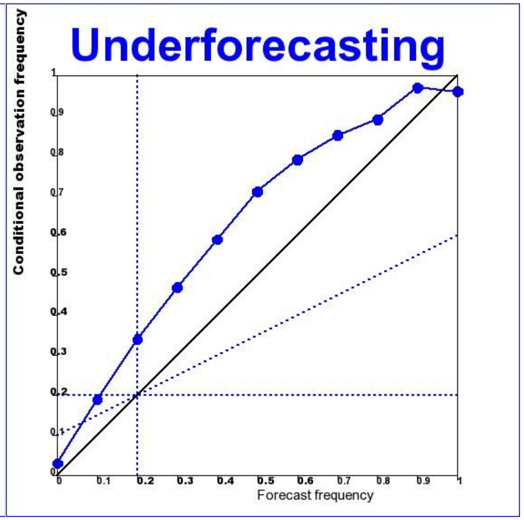
- **Reliability diagram**
  - (p_i , $o_i(p_i)$) i = 0…N
  - Proximidad a la diagonal ~ fiabilidad

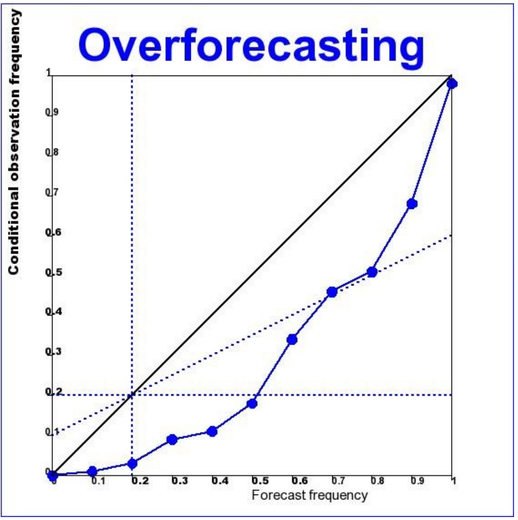
Reliability

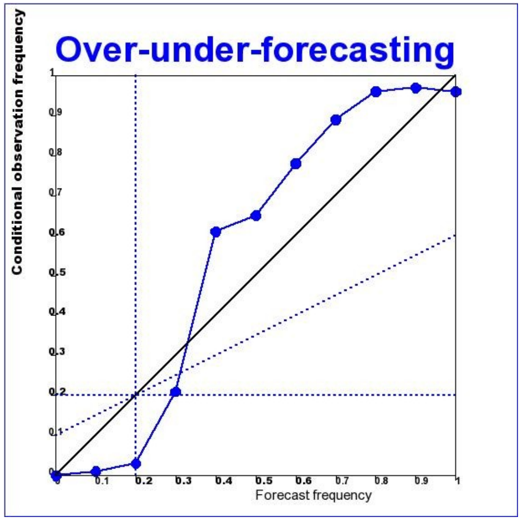


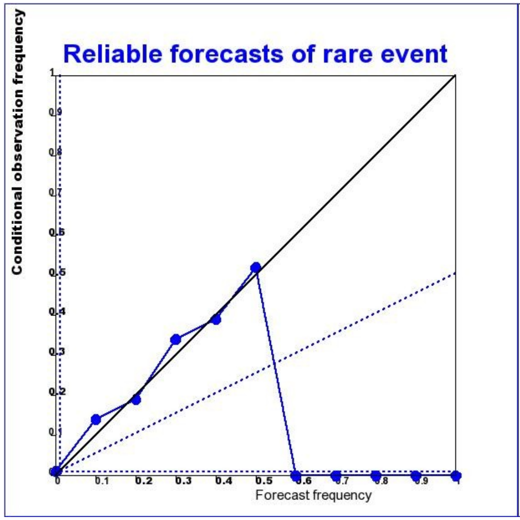


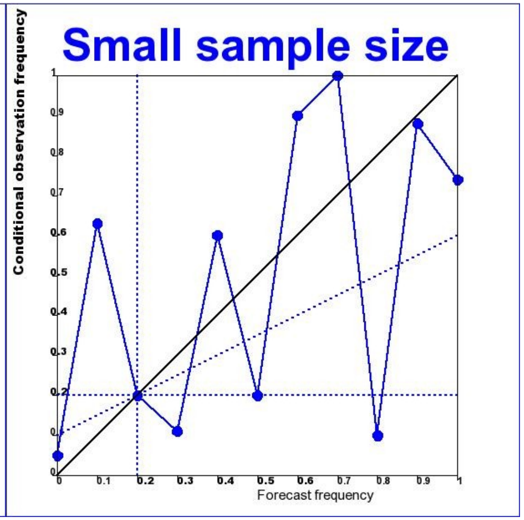












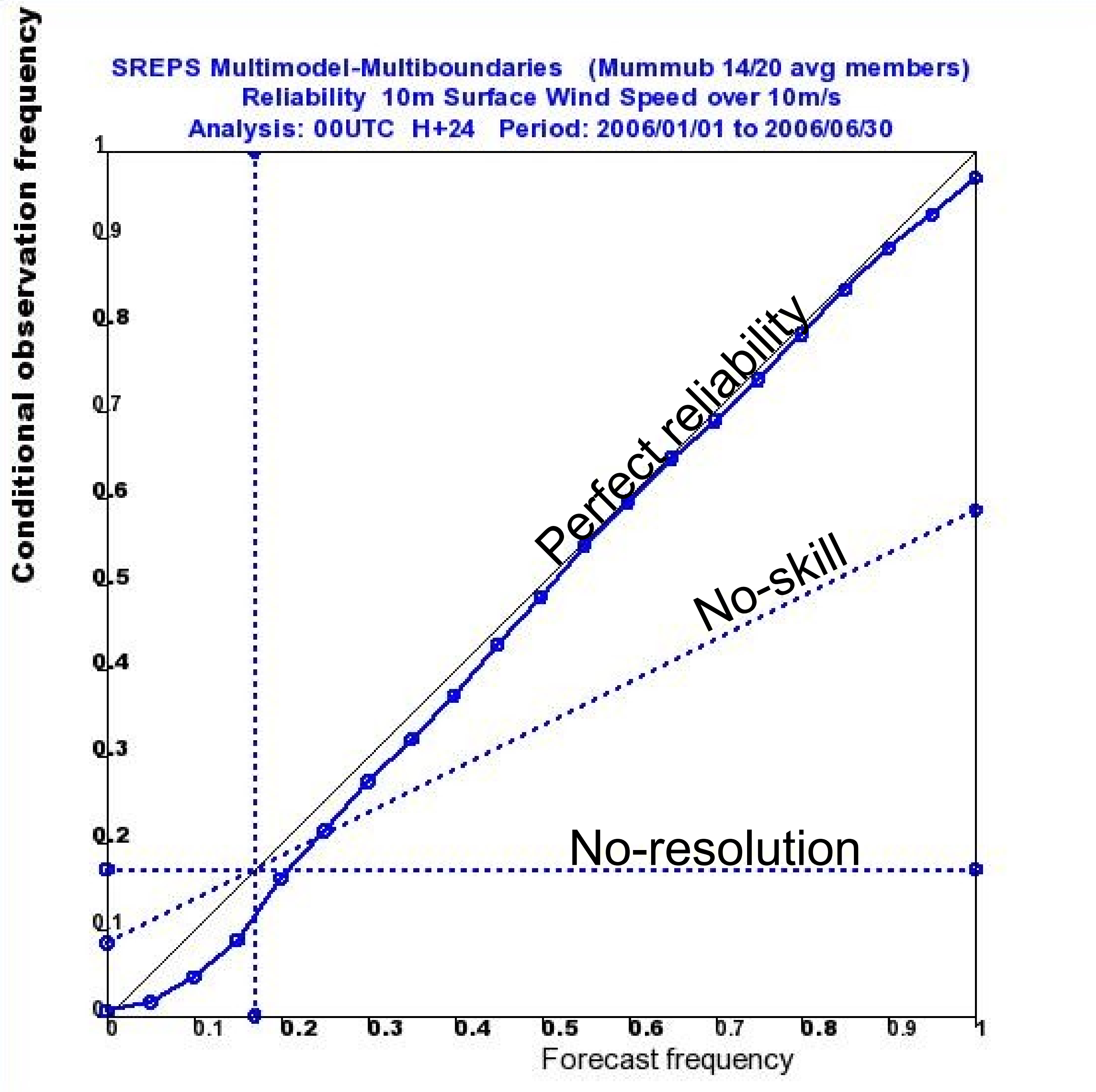
Brier Score Decomposition

$$BS = \underbrace{\frac{1}{n}\sum_{i=1}^{I} n_i (p_i - \bar{o}_i)^2}_{\text{Reliabilty}} - \underbrace{\frac{1}{n}\sum_{i=1}^{I} n_i (\bar{o}_i - \bar{o})^2}_{\text{Resolution}} + \underbrace{\bar{o}(1-\bar{o})}_{\text{Uncertainty}}$$

Reliability	**Resolution**	**Uncertainty**
[0,1]	[0,s(1-s)]	[0,0.25]
Cercanía entre ocurrencias observadas y las probabilidades de predicción	Discernimiento 0: ambiguo, todas las probabilidades con la misma frecuencia s(1-s): tajante, probabilidades con frecuencias 0 ó 1	Cercanía de ocurrencia del evento al 50% 0: no se da 0.25: se da 50%

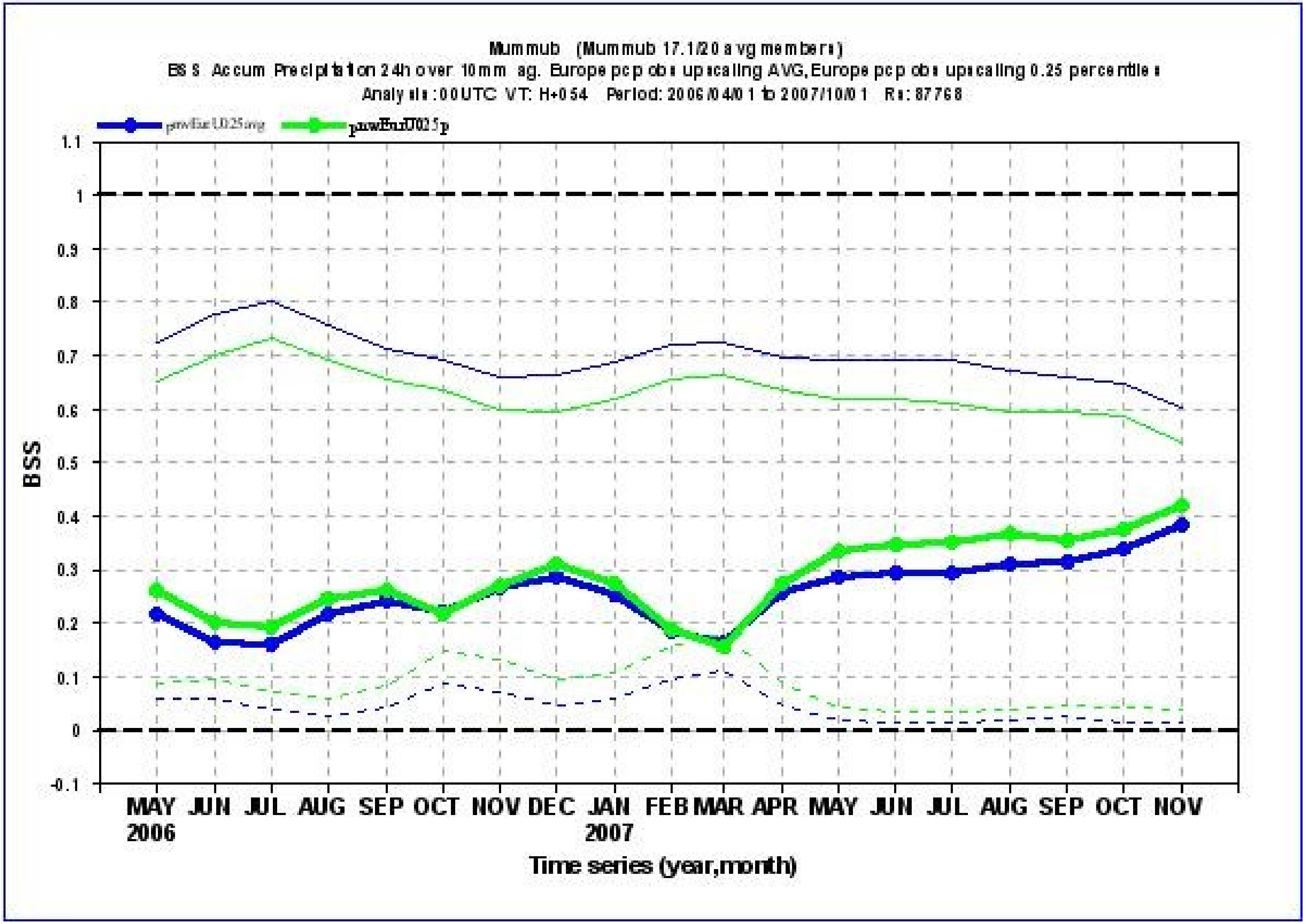
I: número total de intervalos de probabilidad

$$\bar{o}_i = p(o=1 \mid p_i) = \frac{1}{N_i} \sum_{k \in N_i} o_k$$


SREPS Multimodel-Multiboundaries (Mummub 14/20 avg members)
Reliability 10m Surface Wind Speed over 10m/s
Analysis: 00UTC H+24 Period: 2006/01/01 to 2006/06/30
Conditional observation frequency
Forecast frequency
Perfect reliability
No-skill
No-resolution
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Brier Skill Score Decomposition

$$BSS = 1 - BSS_{rel} - BSS_{res}$$

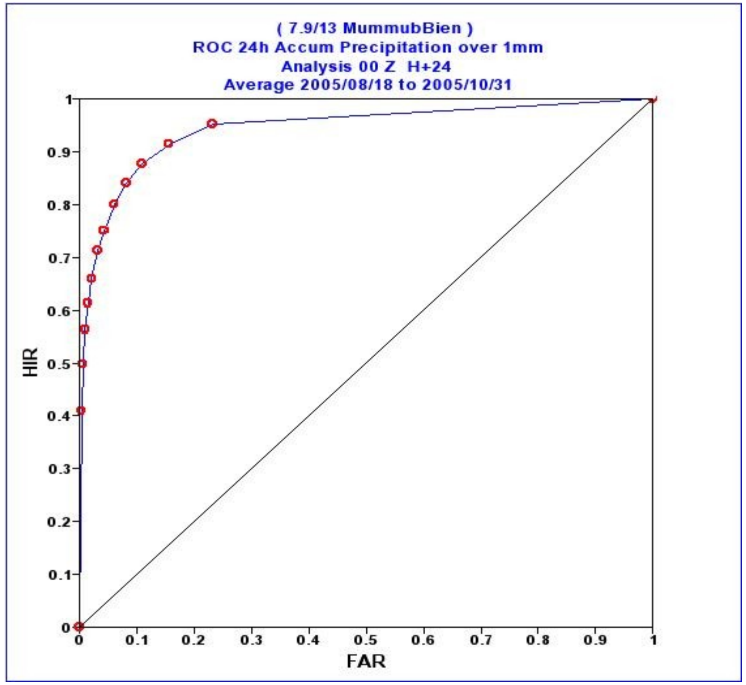


Discrimination

- Basado en Teoría de la Detección de la señal X, para describir la predicción condicionada por observación. Por intervalos acumulados de probabilidad, la relación H vs F mide la **capacidad discriminativa** del sistema de predicción, su capacidad de discriminar entre la ocurrencia o no del evento.
- Basada en acumulaciones de la distribución conjunta: tasas de aciertos H_i y falsas alarmas H_i:

$$\left(\begin{array}{l} H_i = \dfrac{a_i}{a_i + c_i} \\ F_i = \dfrac{b_i}{b_i + d_i} \end{array} \right) \quad i = 0 \ldots N$$

- **ROC curve**
  - (F_i , H_i)   i = 0…N
  - Mayor ROCArea ~ Mejor discriminación del evento binario
  - ROCArea > 0.5 aporta información
  - Cierta relación con la resolución



Tablas contingencia PDF>=

		ob	
		1	0
P(X) = 0/n	1	a_0	b_0
	0	c_0	d_0
P(X) = 1/n	1	a_1	b_1
	0	c_1	d_1
P(X) = 2/n	1	a_2	b_2
	0	c_2	d_2
...			
P(X) = n/n	1	a_n	b_n
	0	c_n	d_n

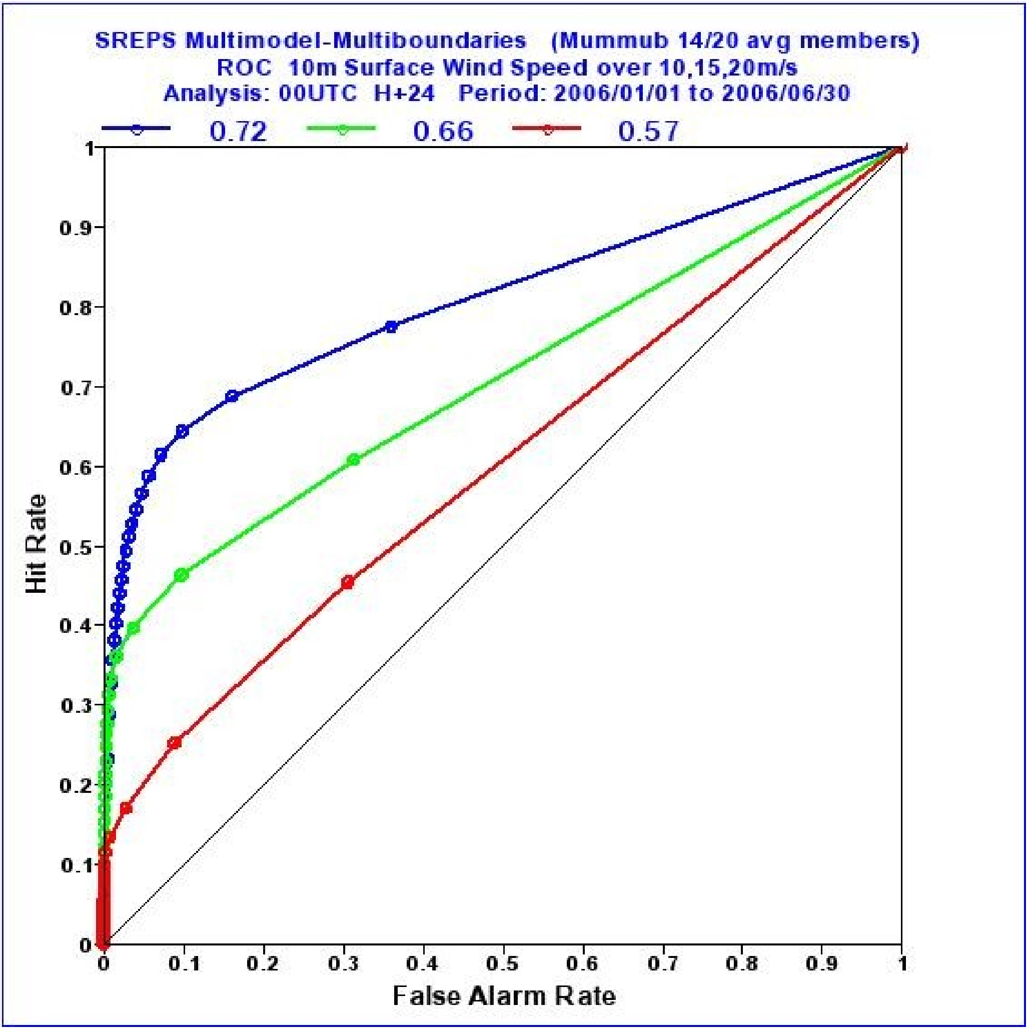
		ob	
		1	0
P(X) >= 0/n	1	A_0	B_0
	0	C_0	D_0
P(X) >= 1/n	1	A_1	B_1
	0	C_1	D_1
P(X) >= 2/n	1	A_2	B_2
	0	C_2	D_2
...			
P(X) >= n/n	1	A_N	B_N
	0	C_N	D_N

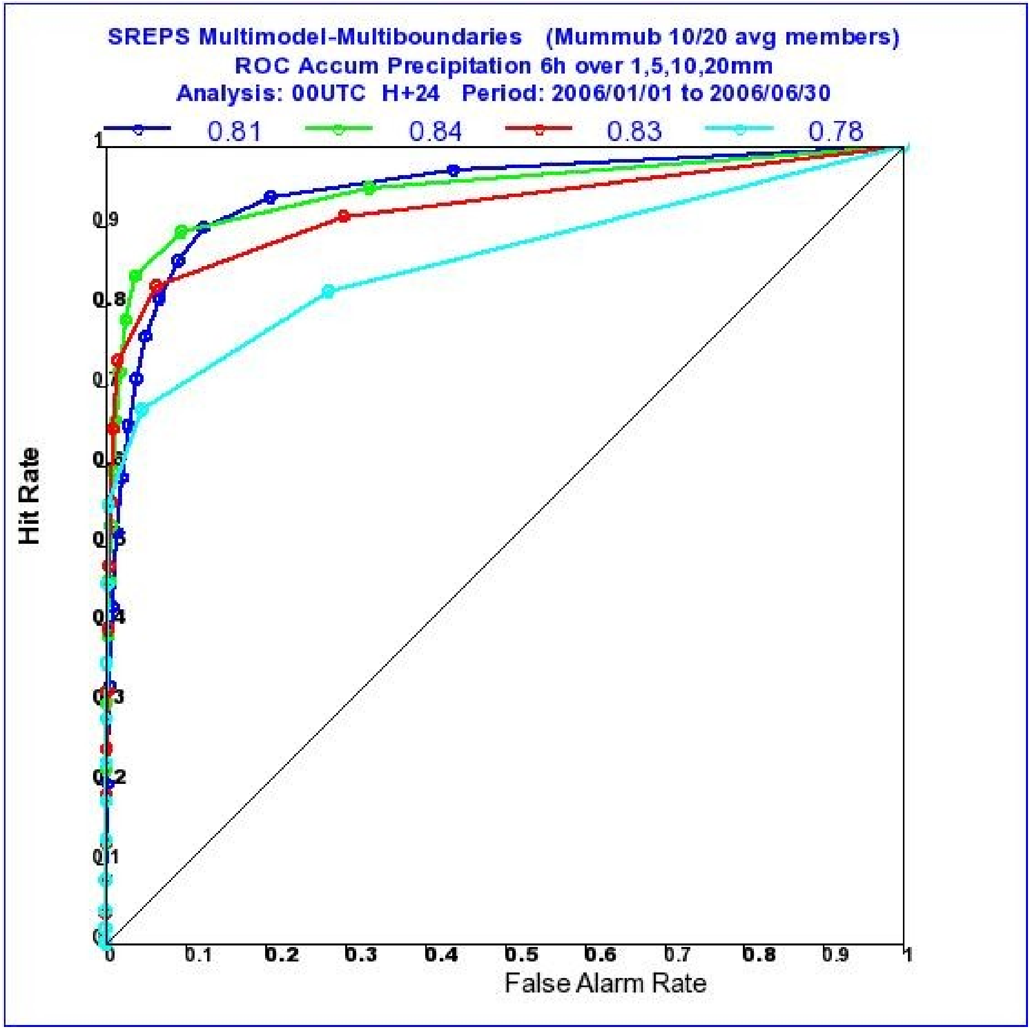
Tablas contingencia PDF>=

		ob	
		1	0
P(X) >= 0/n	1	A_0	B_0
	0	C_0	D_0
P(X) >= 1/n	1	A_1	B_1
	0	C_1	D_1
P(X) >= 2/n	1	A_2	B_2
	0	C_2	D_2
...			
P(X) >= n/n	1	A_N	B_N
	0	C_N	D_N

H_0	F_0
H_1	F_1
H_2	F_2
H_n	F_n

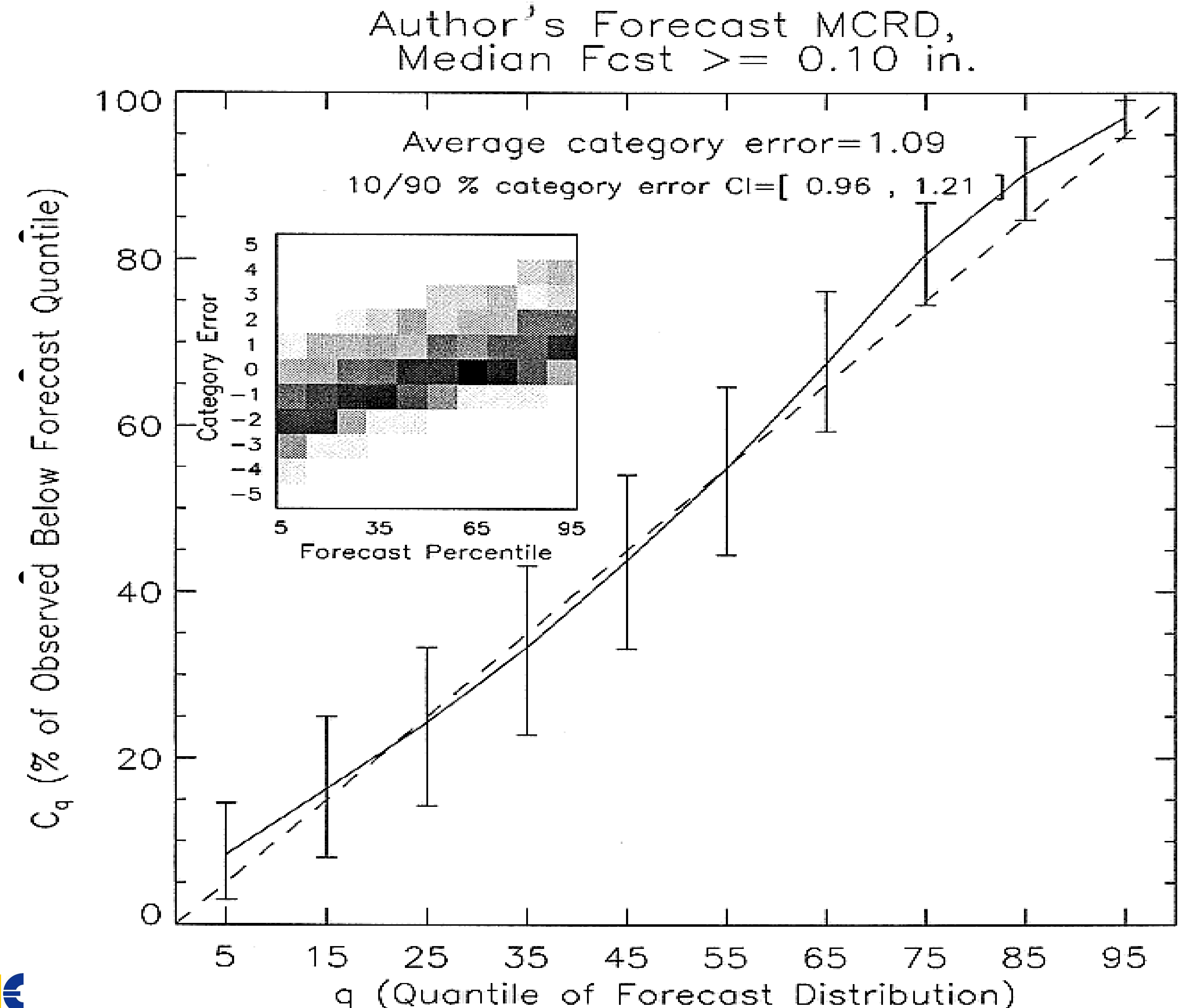
Discrimination





Muestreo

- Toda medida se debe mostrar junto al grado incertidumbre asociado
- Las medidas de verificación son estimadores estadísticos del valor verdadero (poblacional), calculados con muestras finitas de pares (fc,ob)
- Recomendable: barras de error, intervalos de confianza


Author's Forecast MCRD,
Median Fcst >= 0.10 in.
Average category error=1.09
10/90 % category error CI=[0.96 , 1.21]
Category Error
Forecast Percentile
5
35
65
95
5
4
3
2
1
0
−1
−2
−3
−4
−5
C_q (% of Observed Below Forecast Quantile)
q (Quantile of Forecast Distribution)
0
20
40
60
80
100
5
15
25
35
45
55
65
75
85
95

Problemas

- Extremo ≠ Severo
- Poca frecuencia → under-sampling, scores típicos inútiles
- No se investiga
- Aún no hay métodos maduros

- Group of experts in verification methods for extreme events
  - Use of EPSs
  - Confidence intervals on scores
  - New scores not sensitive to vanishing sample rates (very rare events) e.g. EDS
  - Feature-oriented, fuzzy verification methods (Ebert, Casati) might show a more realistic information about performance (by better representation of actual pcp), e.g. SAL decomposition

Brier Score Decomposition

$$BS = \underbrace{\frac{1}{n}\sum_{i=1}^{I} n_i (p_i - \bar{o}_i)^2}_{\text{Reliabilty}} - \underbrace{\frac{1}{n}\sum_{i=1}^{I} n_i (\bar{o}_i - \bar{o})^2}_{\text{Resolution}} + \underbrace{\bar{o}(1-\bar{o})}_{\text{Uncertainty}}$$

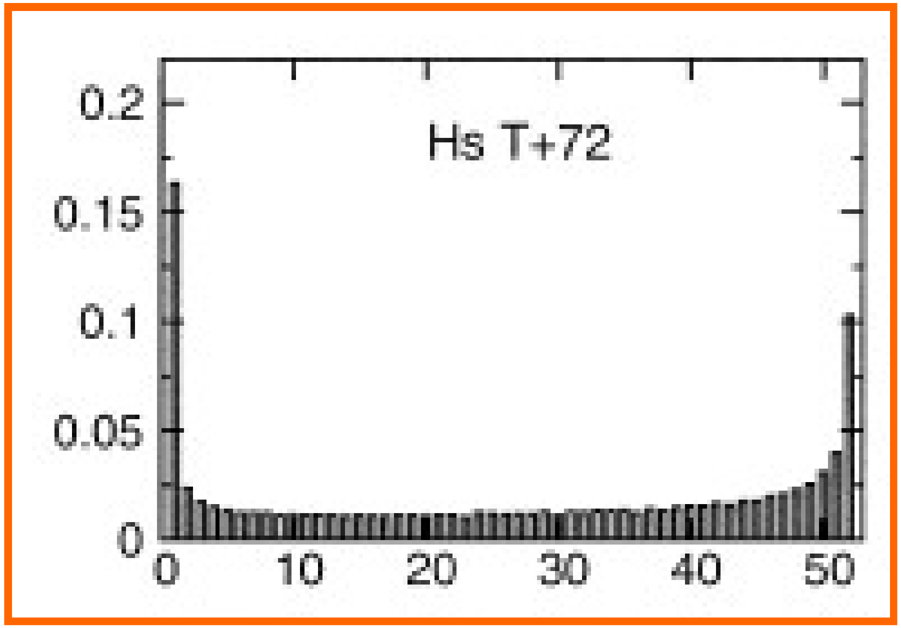
Reliability	**Resolution**	**Uncertainty**
[0,1]	[0,s(1-s)]	[0,0.25]
Cercanía entre ocurrencias observadas y las probabilidades de predicción	Discernimiento 0: ambiguo, todas las probabilidades con la misma frecuencia s(1-s): tajante, probabilidades con frecuencias 0 ó 1	Cercanía de ocurrencia del evento al 50% 0: no se da 0.25: se da 50%

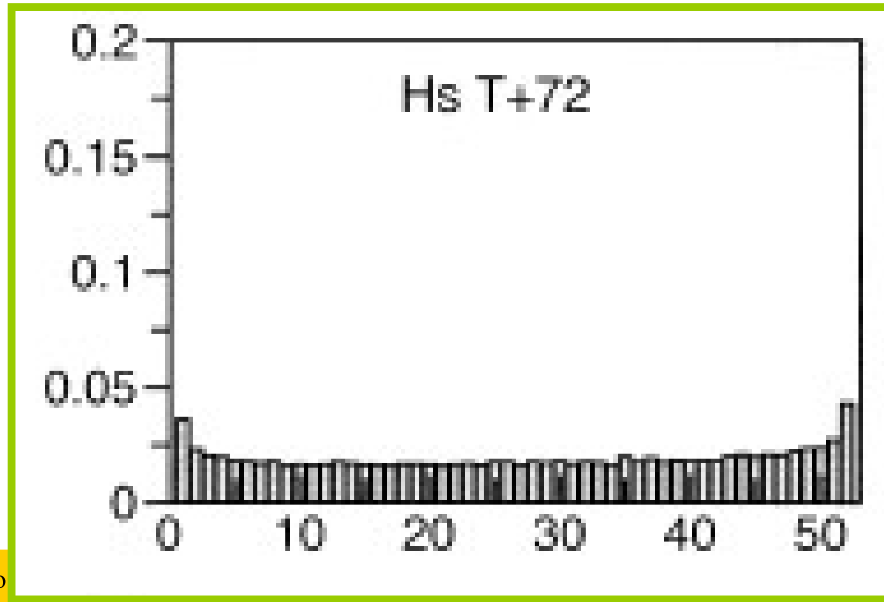
I: número total de intervalos de probabilidad

$$\bar{o}_i = p(o=1 \mid p_i) = \frac{1}{N_i} \sum_{k \in N_i} o_k$$

Obs Error

- Saetra-Hersbach approach
  - Estimation of obs error
  - Gaussian noise
  - Convolution PDF fc * PDF ob
- Results
  - Rank histogram are very sensitive to obs error, they don’t distinguish errors of different magnitudes
  - Taking into account obs error, the measure of ensemble under-dispersion is smoother





CT and Joint Distribution

		ob	
		1	0
P(X) = 0/n	1	a_0	b_0
	0	c_0	d_0
P(X) = 1/n	1	a_1	b_1
	0	c_1	d_1
P(X) = 2/n	1	a_2	b_2
	0	c_2	d_2
...			
P(X) = n/n	1	a_n	b_n
	0	c_n	d_n

p_i	n_i	$\bar{o}_i$
0	a_0+b_0	$a_0/(a_0+b_0)$
1/n	a_1+b_1	$a_1/(a_1+b_1)$
2/n	a_2+b_2	$a_2/(a_2+b_2)$
n/n	a_n+b_n	$a_n/(a_n+b_n)$

Obs Error

- Traditional assumption:

Obs error << Model error

- W.r.t. traditional measures, introducing obs uncertainty could improve the measure of actual performance.

Obs error ~~<<~~ Model error

Obs Error

- Candille&Talagrand approach
  - Met1: “Perturbed ensemble”
  - Met2: “Observational probability”
  - Joint distribution framework extension
- Results “Observational probability“
  - Taking into account obs error shows:
  - Worse reliability
  - Better resolution
  - More uncertainty
  - Generally better BSS
  - Worse discrimination

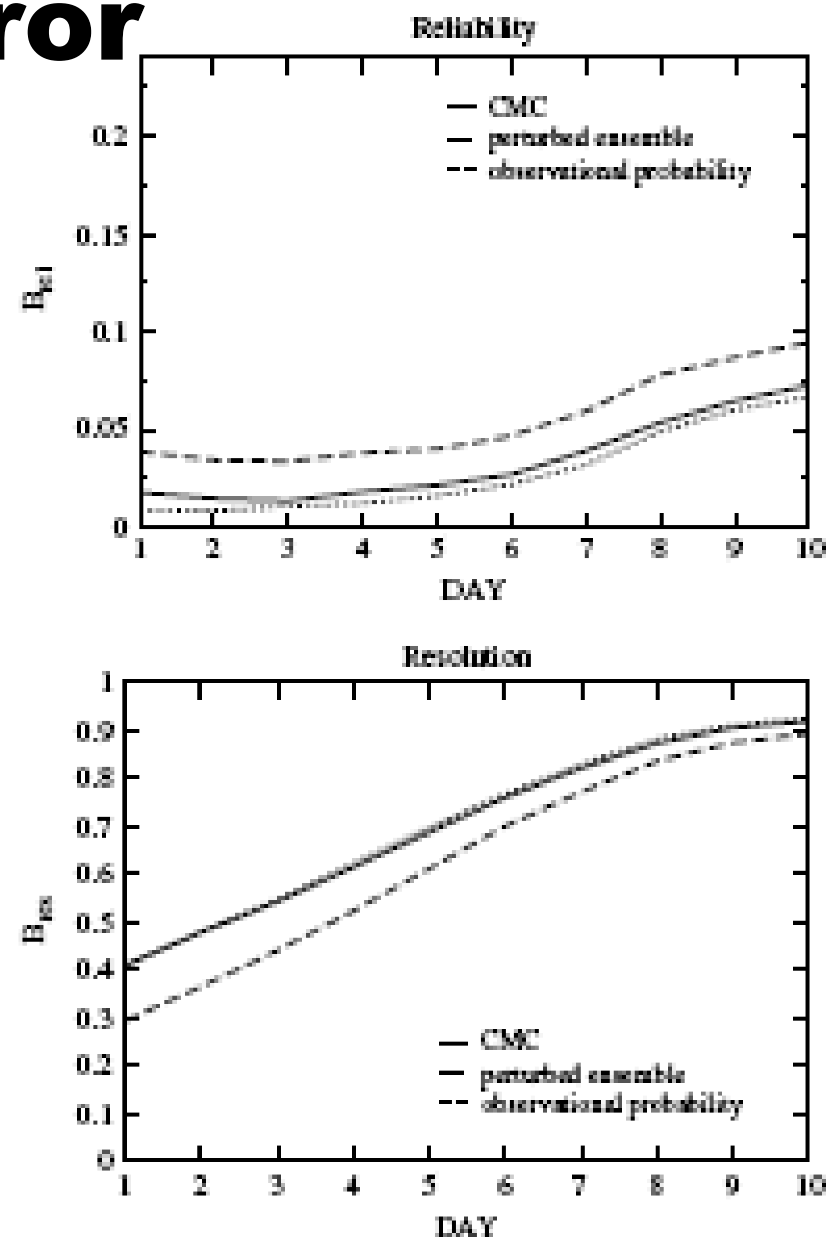


Figure 9. Variations with lead time of the reliability and resolution components of the Brier skill score. The curves are as in Figure 8.

Obs Error

- Collaboration ECMWF-AEMET
  - Following “Observational probability” Candille&Talagrand
  - Using up-scaled observations to build obs PDF
  - Joint distribution framework extension

- Results
  - Consistent with Candille&Talagrand
  - Better idea of ensemble performance?