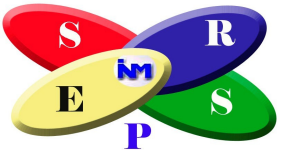


Multi-model Ensemble Prediction System at INM

José A. García-Moya
INM

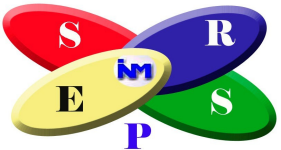
Hirlam-Aladin All Staff Meeting

Sofia, May 2006



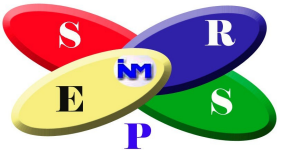
The team

- **José A. García-Moya.**
- **Carlos Santos** (Hirlam, verification & graphics, web server).
- **Daniel Santos** (MM5, Bayesian Model Average).
- **Alfons Callado** (UM & grib software).
- **Juan Simarro** (HRM, LM and Vertical interpolation software).



Thanks to...

- MetOffice
 - Ken Mylne, Jorge Bornemann
- DWD
 - Detlev Majewski, Michael Gertz
- ECMWF
 - Metview Team
- COSMO
 - Chiara Marsigli, Ulrich Schättler



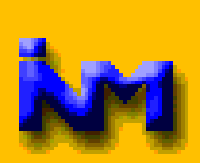
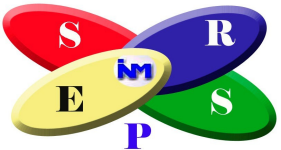
Introduction

- Multi-model ensemble technique seems to be very useful for probabilistic short-range forecast.
- Uncertainty due to errors in model formulation are taken into account.
- Results of the system are very promising in the first three months of pre-operational experience.
- Time lagged super-ensemble are still under development.



Multi-model

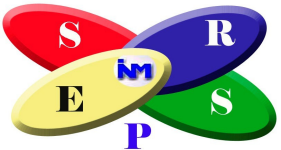
- Hirlam.
- HRM from DWD.
- MM5
- UM from UKMO.
- LM (Lokal Model) from COSMO



Multi-Boundaries

From different global deterministic models:

- ECMWF
- UM from UKMO
- AVN from NCEP
- GME from DWD



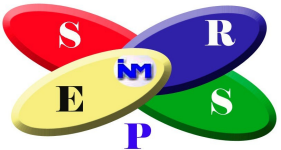
SREPS at INM

- 72 hours forecast four times a day (00, 06, 12 y 18 UTC).
- Characteristics:
 - 5 models.
 - 4 boundary conditions.
 - 4 last ensembles (HH, HH-6, HH-12, HH-18).
- 20 member ensemble every 6 hours
- Time-lagged Super-Ensemble of 80 members every 6 hours.



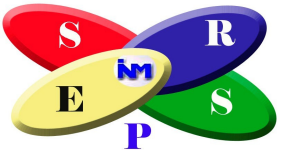
Current Ensemble

- 72 hours forecast twice a day (00 & 12 UTC).
- Characteristics:
 - 5 models.
 - 4 boundary conditions.
- Two 20 member ensemble every 24 hours



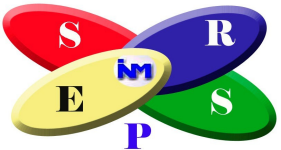
Road Map

2003-2004	Research to find best ensemble for the Short Range	
Jun 04 - Jun 05	Building Multimodel System	
Jun 05-Dec 05	Mummub n/16 members	Daily run non-operational
Mar 06	Mummub 16/16 members	Once a day
Jun 06	Mummub 20 members	Twice a day
July 06	Obs verification	
September 06	40 member lagged Super-ensemble	Twice a day
October 06	BMA Calibration	
January 07	Broadcast products	Experimental

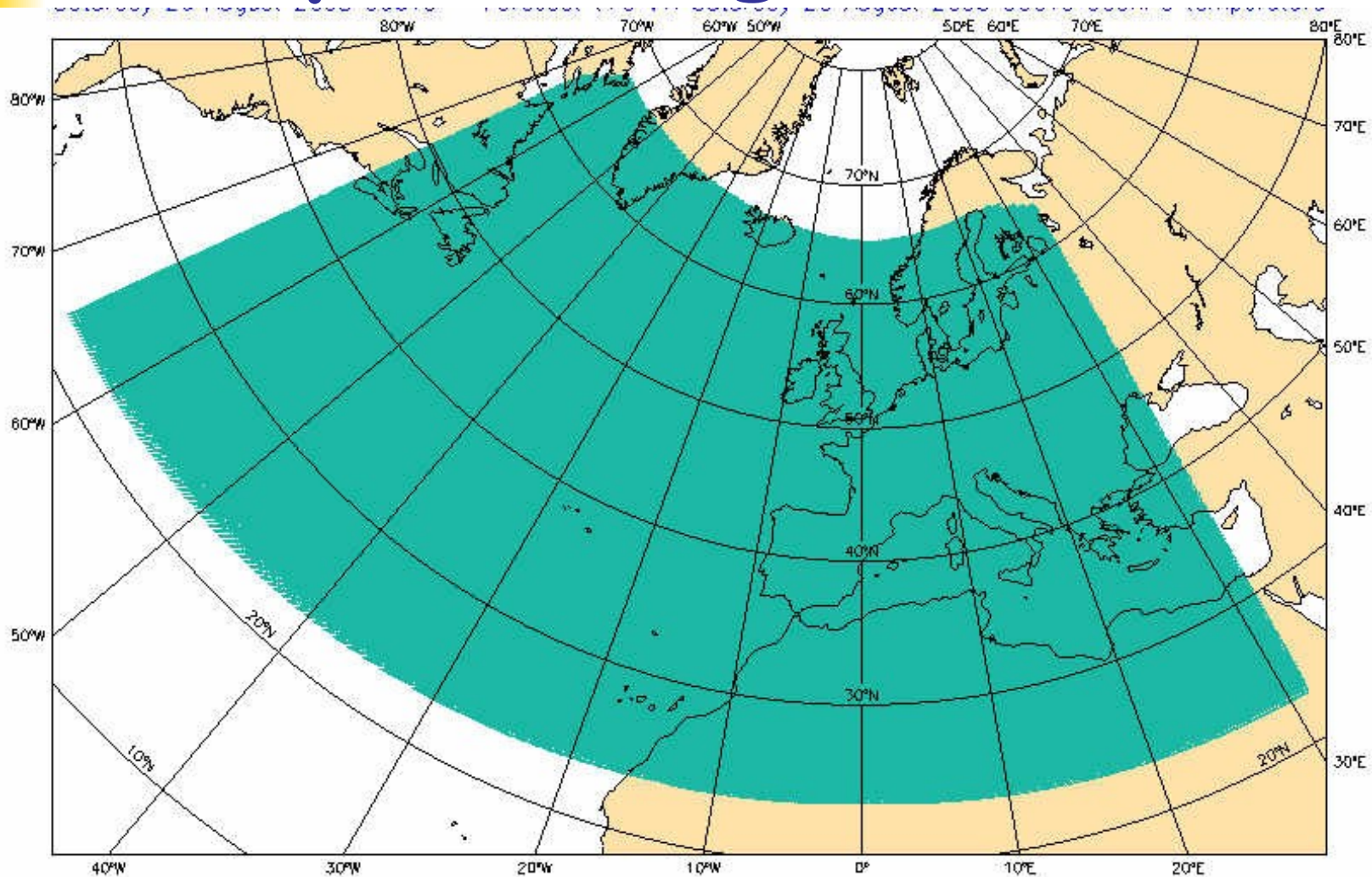


Post-processing

- Integration areas 0.25 latxlon, 40 levels
- Interpolation to a common area
 - ~ North Atlantic + Europe
 - Grid 380x184, 0.25°
- Software
 - Enhanced PC + Linux
 - ECMWF Metview + Local developments
- Outputs
 - Deterministic
 - Ensemble probabilistic



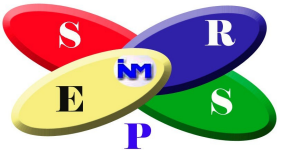
Post-processing II



May 2006

Hirlam-Aladin All Staff Meeting

11



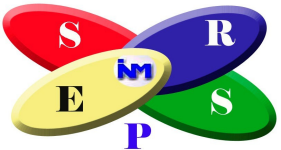
Monitoring in real time

- Intranet web server
- Deterministic outputs
 - Models X BCs tables
 - Maps for each couple (model,BCs)
- Ensemble probabilistic outputs
 - **Probability maps**: 6h accumulated precipitation, 10m wind speed, 24h 2m temperature trend
 - Ensemble mean & Spread **maps**
 - **EPSgrams (work in progress)**
- Verification: Deterministic & Probabilistic
 - Against ECMWF analysis
 - **Against observations (work in progress)**



Different ensembles

- Multi-model - Multi-boundaries
- Multi-physics
 - 5 members - MM5 with different options for the Physics
- Deterministic - Lagged
 - INM Hirlam deterministic model from the last three days (0.16 deg resolution and 40 vertical levels)
- PEPS



Intranet web server

The screenshot shows a Microsoft Internet Explorer browser window with the address bar set to <http://sur.inm.es/>. The page content includes the INM logo, the title "INM Short-range Ensemble Prediction System Home Page", and a note "(Internal web page)". Below this, there are two sections: "Today Ensembles" with links to "Multimodel-Multiboundaries", "Multiphysics-MM5", "Lagged-ONR", and "PEPS"; and "Case Studies" with links to "2006/02/21 1st day 16 members Murrub Ensemble" and "2006/03/02 Snow storm over Germany". The Windows taskbar at the bottom shows the system tray with the time 13:54 and the date May 2006.

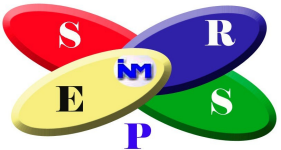
INM
Short-range Ensemble Prediction
System
Home Page
(Internal web page)

Today Ensembles

- [Multimodel-Multiboundaries](#)
- [Multiphysics-MM5](#)
- [Lagged-ONR](#)
- [PEPS](#)

Case Studies

- [2006/02/21 1st day 16 members Murrub Ensemble](#)
- [2006/03/02 Snow storm over Germany](#)



Monit 1: home

http://sur.inm.es/Ensembles/Mummub/Mummub-Index.html - Microsoft Internet Explorer

Archivo Edición Ver Favoritos Herramientas Ayuda

Dirección http://sur.inm.es/Ensembles/Mummub/Mummub-Index.html

home

Today Multimodel-Multiboundaries

Deterministic outputs	Probabilistic outputs	Probabilistic Verification (D-4)
<ul style="list-style-type: none">Z500/T500 Models / FeaturesPmsl/Pacum6h Models / FeaturesV300/S300 Models / FeaturesT2m Models / FeaturesV10m/S10m Models / FeaturesPacum6h Models / Features	<p>Probability maps</p> <ul style="list-style-type: none">2m Temperature 24h trend10m Wind speed6h Accumulated precipitation6h Accumulated Snow precipitation <p>Spread & Emean maps</p> <ul style="list-style-type: none">Z500Msl Pressure <p>EPSgrams</p> <ul style="list-style-type: none">EPS-grams	<p>Spread-Skill Curves</p> <ul style="list-style-type: none">Z500T500Msl Pressure <p>Rank Histograms</p> <ul style="list-style-type: none">Z500T500Msl Pressure <p>ROC Curves</p> <ul style="list-style-type: none">10m Wind speed24h Accumulated precipitation <p>Reliability Diagrams</p>

Inicio Bandeja de ... 2 Explora... Joint COST... http://sur.i... Microsoft P... Dibujo - Paint ES 13:56

Monit 2: all models X bcs

D:\Documentos\Proyectos\SREPS\web-sur\Ensembles\Wummub\html\Wummub-Z500T500-72.html - Microsoft Internet Explorer

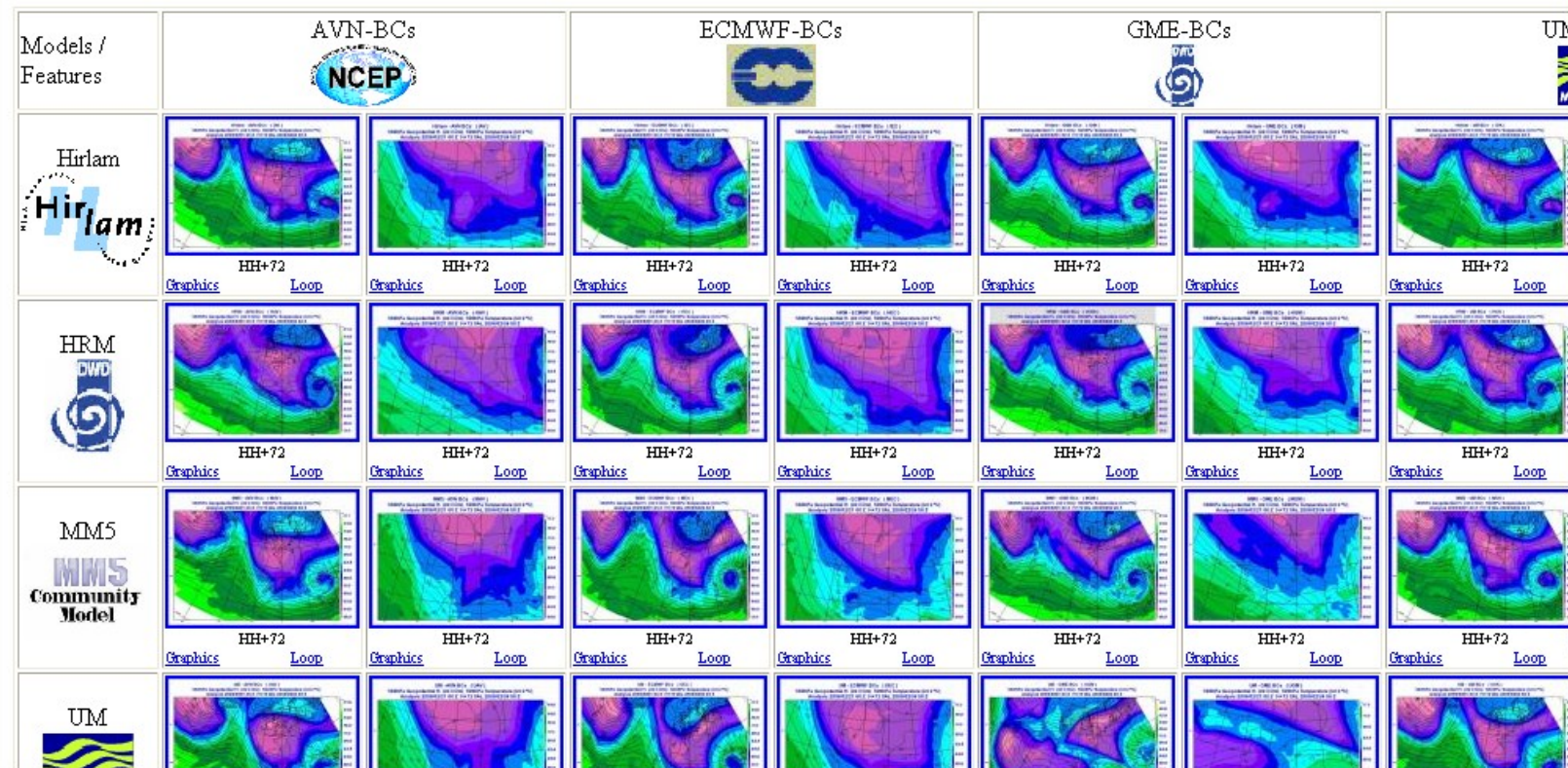
Archivo Edición Ver Favoritos Herramientas Ayuda

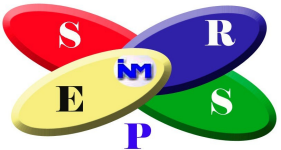
Multimodel-Multiboundaries

Run: D0, 00UTC , H+00 , H+06 , H+12 , H+18 , H+24 , H+30 , H+36 , H+42 , H+48 , H+54 , H+60 , H+66 , H+72

500hPa Geopotential height & Temperature

Models X Boundaries





Monit 3: All Prob 24h 2m T trend

D:\Documentos\Proyectos\SREPS\web-sur\Ensembles\Wummub\html\Wummub-Tinc2m24hProb.html - Microsoft Internet Explorer

Archivo Edición Ver Favoritos Herramientas Ayuda

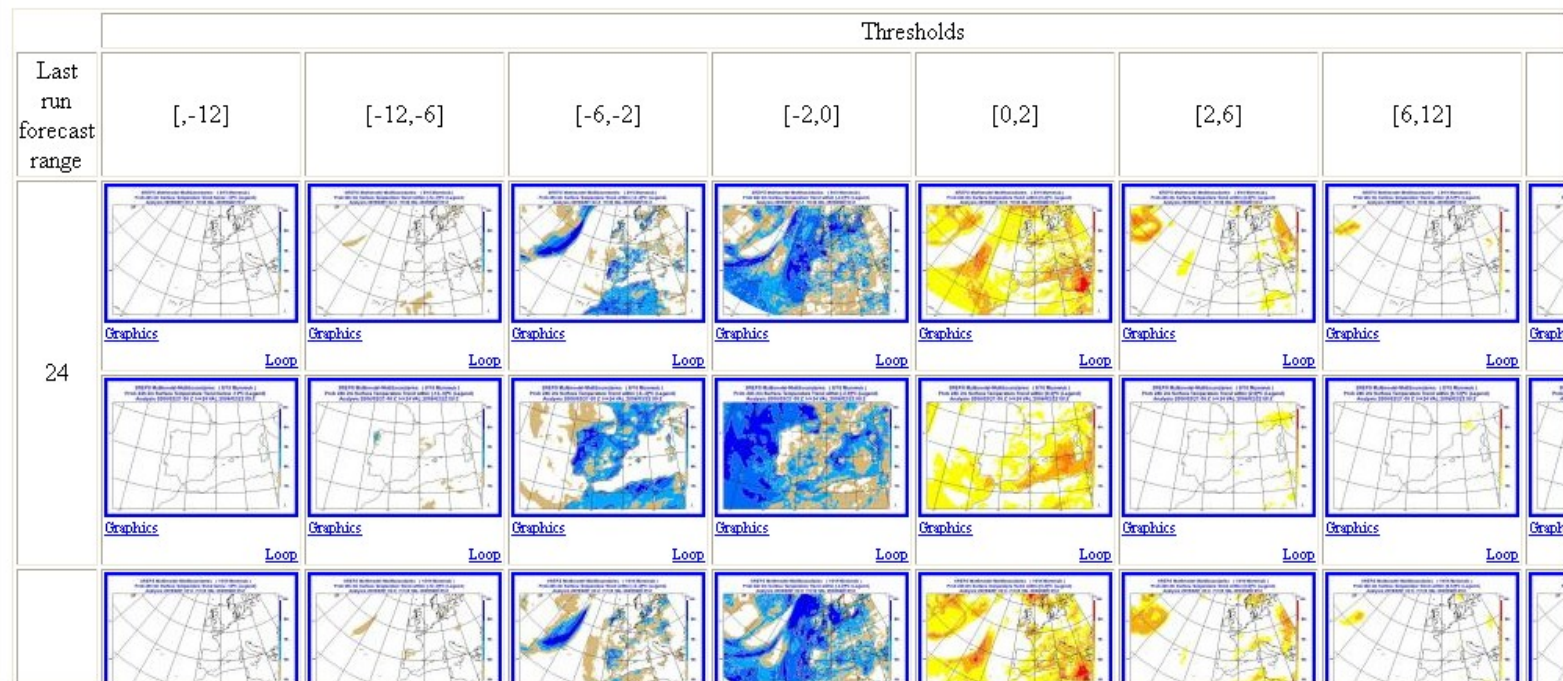
Multimodel-Multiboundaries

Run: D0, 00UTC, HH+24..HH+72

Probability Maps

2m Temperature 24h Trend

Forecast range (HH+24..HH+72) X Thresholds ([,-12] , [-12,-6] , [-6,-2] , [-2,0] , [0,2] , [2,6] , [6,12] , [12,])



Monit 4: Spread - Emean maps

<http://sur.inm.es/Ensembles/Mummub/html/Mummub-SREPSg-Z500SpreadEmean.html> - Microsoft Internet Explorer

Archivo Edición Ver Favoritos Herramientas Ayuda

Dirección <http://sur.inm.es/Ensembles/Mummub/html/Mummub-SREPSg-Z500SpreadEmean.html>

SREPS Multimodel-Multiboundaries (12/15 Mummub)
Spread&Emean 500hPa Geopotential H. (Dm) (Legend)
 Analysis 2005/09/06 00 Z H+18 VAL 2005/09/06 18 Z

SREPS Multimodel-Multiboundaries (12/15 Mummub)
Spread&Emean 500hPa Geopotential H. (Dm) (Legend)
 Analysis 2005/09/06 00 Z H+24 VAL 2005/09/07 00 Z

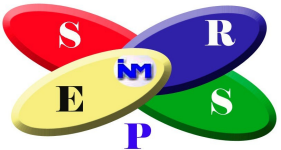
SREPS Multimodel-Multiboundaries (12/15 Mummub)
Spread&Emean 500hPa Geopotential H. (Dm) (Legend)
 Analysis 2005/09/06 00 Z H+30 VAL 2005/09/07 06 Z

SREPS Multimodel-Multiboundaries (12/15 Mummub)
Spread&Emean 500hPa Geopotential H. (Dm) (Legend)
 Analysis 2005/09/06 00 Z H+36 VAL 2005/09/07 12 Z

Listo Intranet local

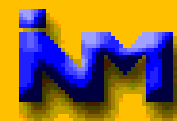
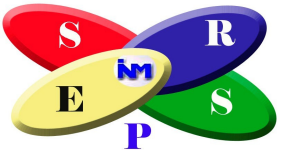
Inicio 2005-exeter Microsoft PowerPoi... <http://sur.inm.e...> ES 11:49





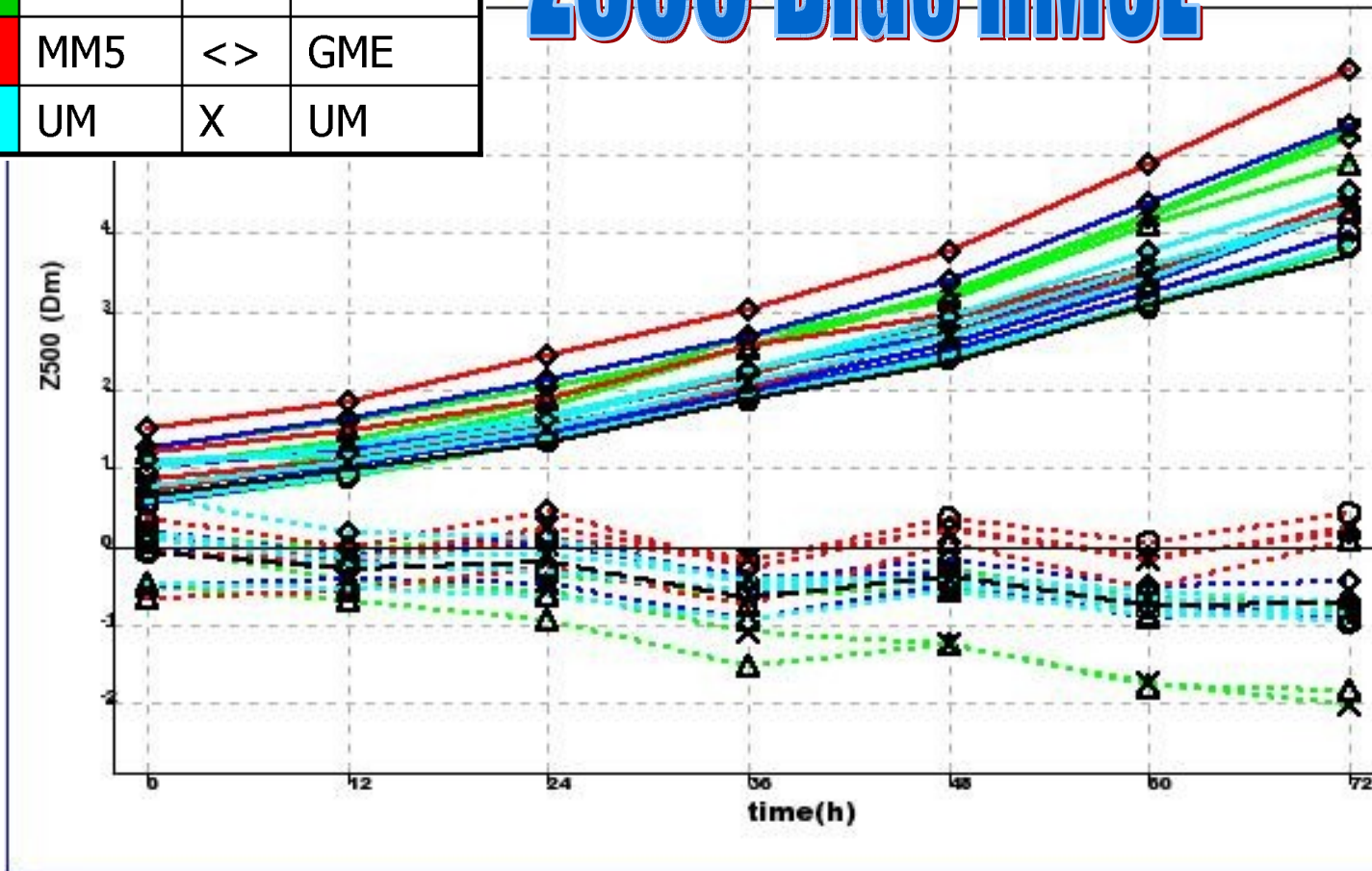
Validation

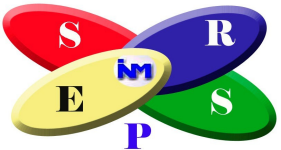
- **Observation (work in progress)**
- **ECMWF operational analysis as reference**
- Verification software
 - ~ ECMWF Metview + Local developments
- Deterministic scores
 - Bias & Rms for each member
- Probabilistic ensemble scores
 - Spread-skill
 - Rank histograms
 - Reliability diagrams
 - ROC curves
 - RV plots
- **~3 months verification (Jan-Mar, 2006)**



7500 Bias RMSE

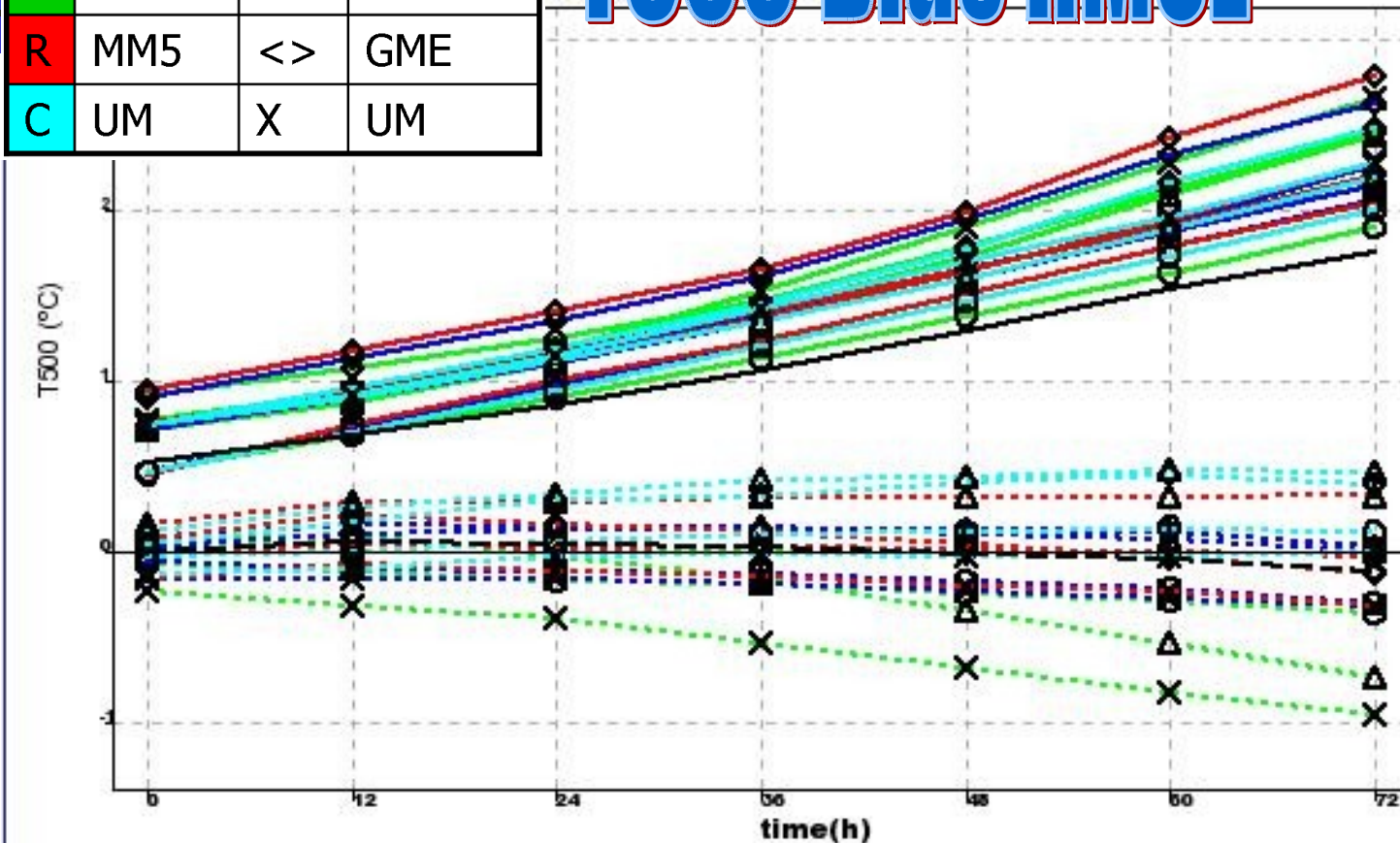
B	Hirlam	A	AVN
G	HRM	O	ECMWF
R	MM5	<>	GME
C	UM	X	UM

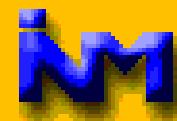
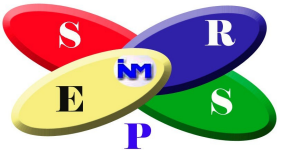




T500 Bias RMSE

B	Hirlam	A	AVN
G	HRM	O	ECMWF
R	MM5	<>	GME
C	UM	X	UM

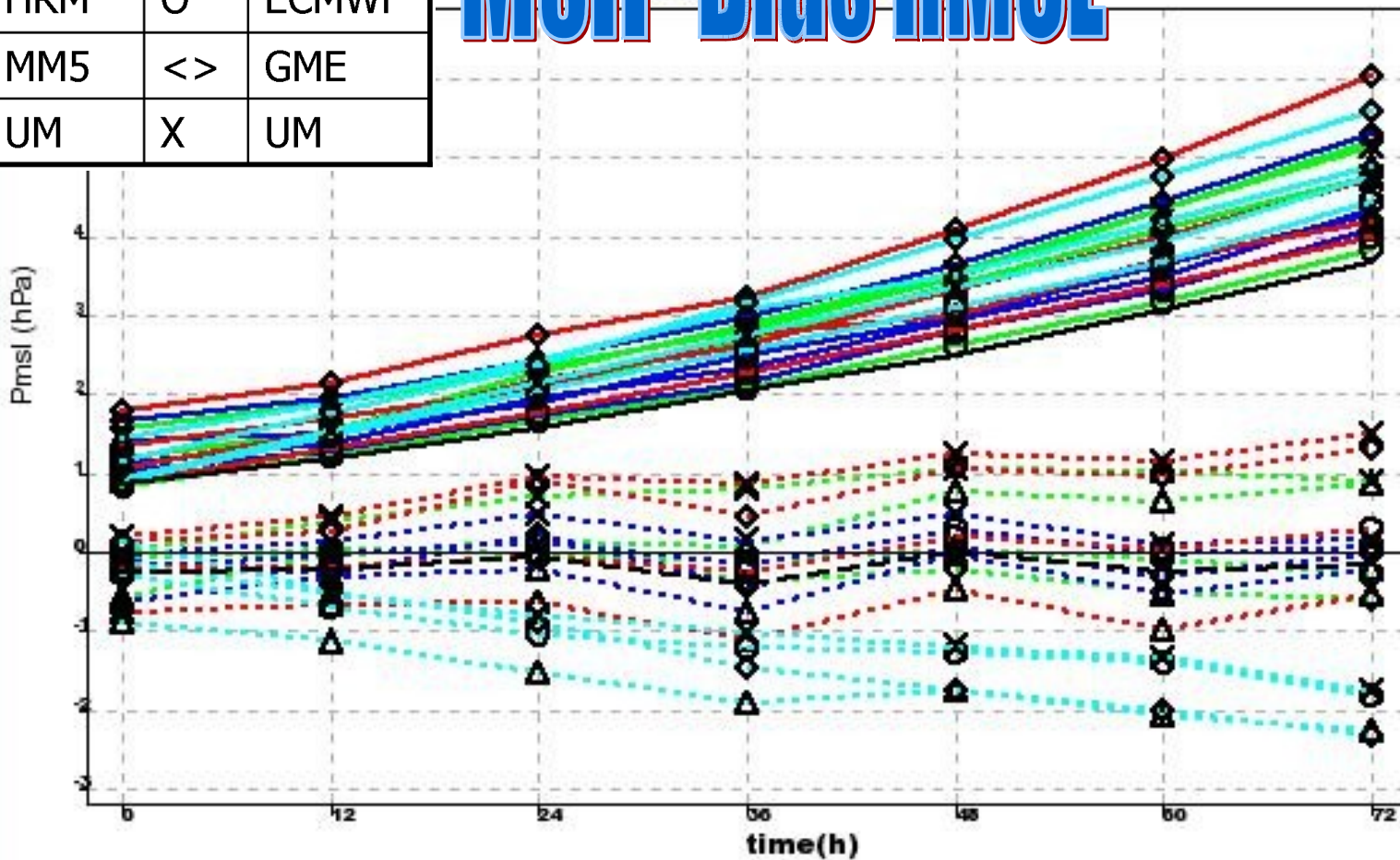




SEPC Multiscale Multiboundaries (47/1 Mumbur)

MSIP Bias RMSE

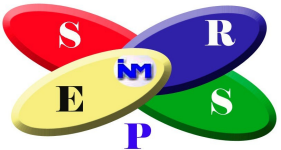
B	Hirlam	A	AVN
G	HRM	O	ECMWF
R	MM5	<>	GME
C	UM	X	UM





Probabilistic Verification

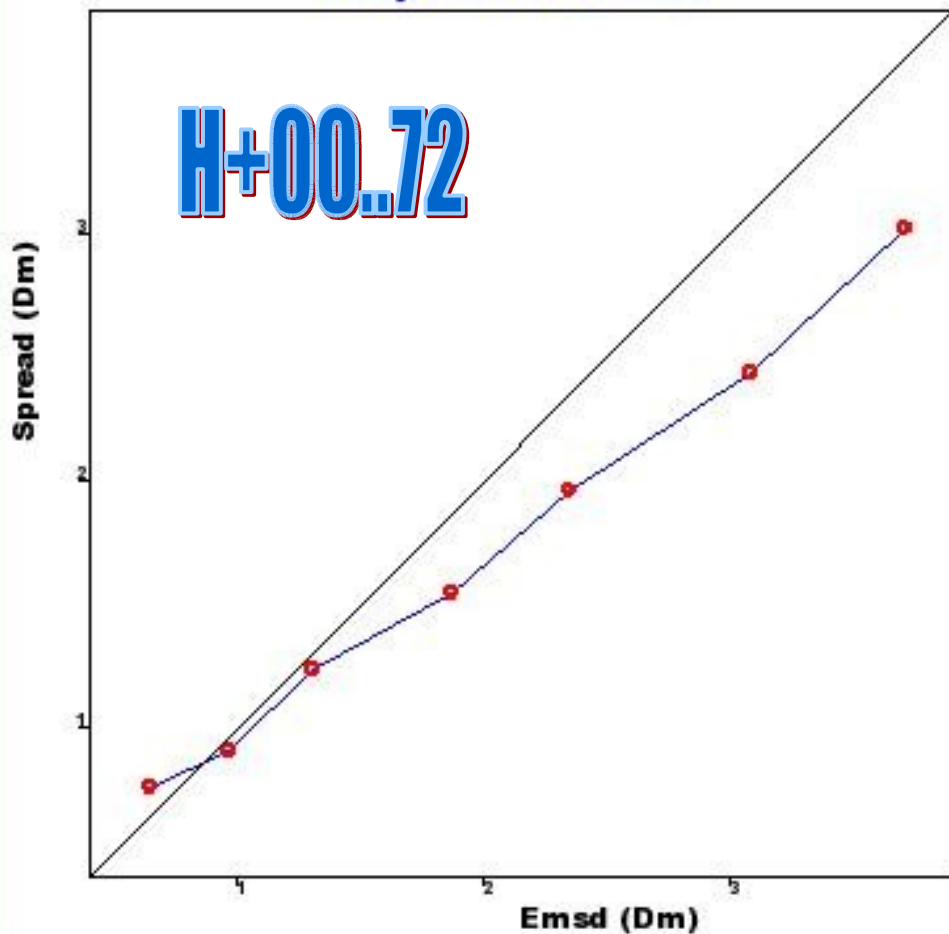
- Parameters
 - Z500, T500, Msl Pressure
- Scores
 - Spread-skill diagrams (Spread vs Ensemble Mean Error)
 - H+00 to H+72
 - Rank histograms
 - H+24, H+48



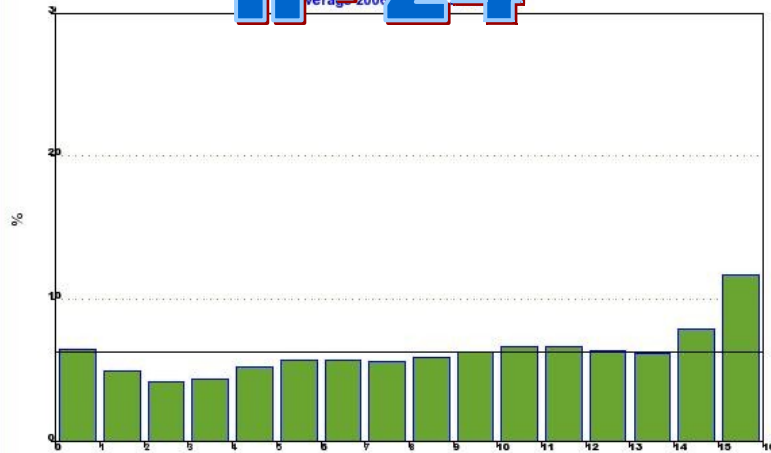
Z500

SREPS Multimodel-Multiboundaries (11/16 Mummub)
 Spread vs Emsd 500hPa Geopotential H.
 Analysis 00 Z H+00..H+72
 Average 2006/01/01 to 2006/03/31

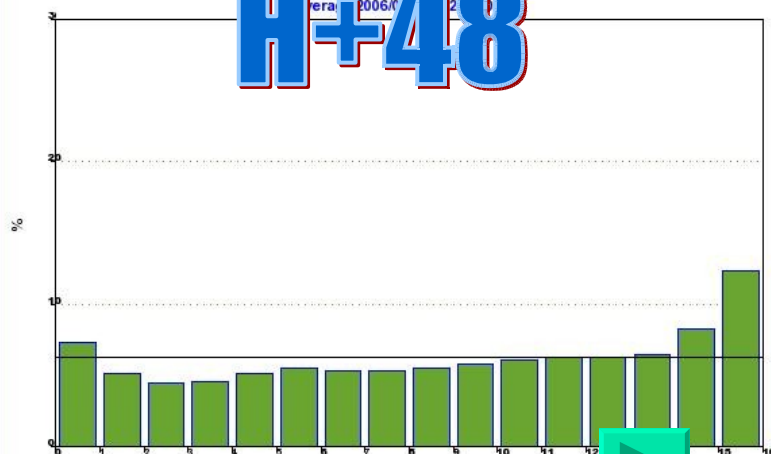
H+00..72

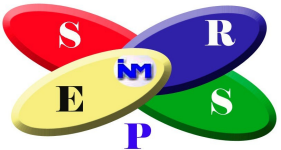


SR mod Multi (11/16 Mummub)
H+24
 Analysis 500hPa Geopotential H.
 Average 2006/01/01 to 2006/03/31



Rank Histogram 500hPa Geopotential H.
 Analysis 500hPa Geopotential H.
 Average 2006/01/01 to 2006/03/31
H+48





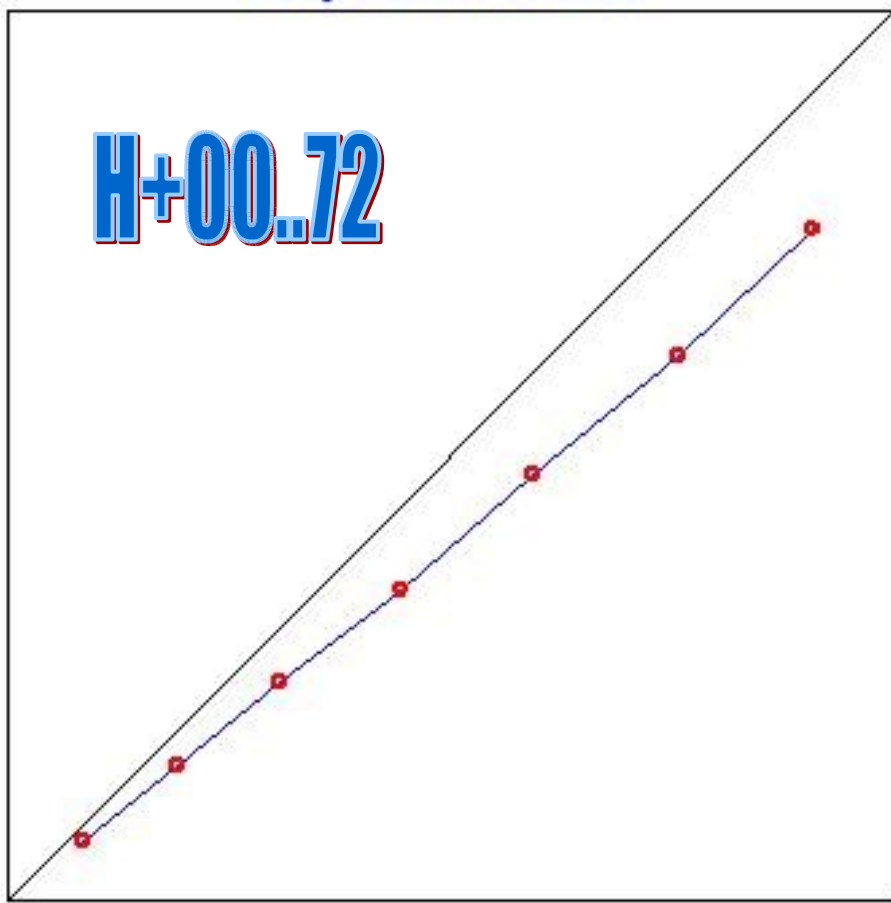
T500



SREPS Multimodel-Multiboundaries (11/16 Mummub)
 Spread vs Emsd 500hPa Temperature
 Analysis 00 Z H+00..H+72
 Average 2006/01/01 to 2006/03/31

H+00..72

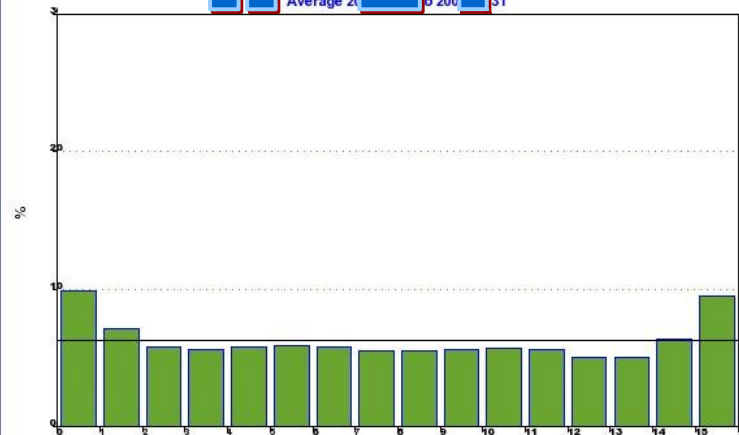
Spread (°C)



Emsd (°C)

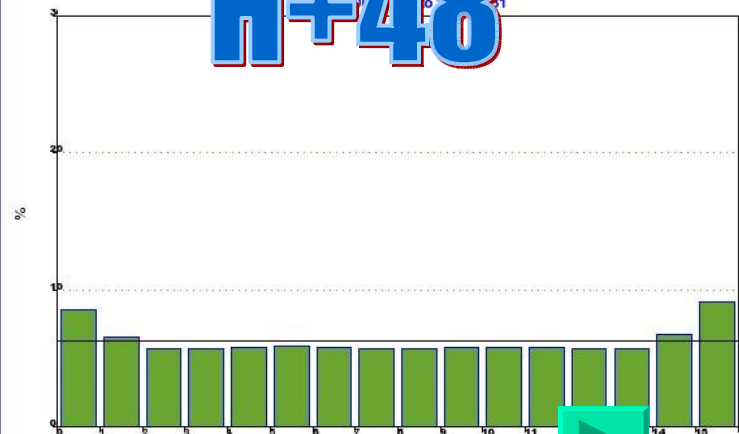
H+24

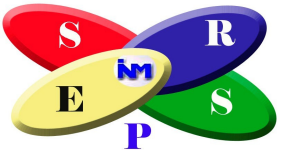
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 Link Histogram of Spread vs Emsd 500hPa Temperature
 Analysis 00 Z H+00..H+72
 Average 2006/01/01 to 2006/03/31



H+48

SREPS Multimodel-Multiboundaries (11/16 Mummub)
 Link Histogram of Spread vs Emsd 500hPa Temperature
 Analysis 00 Z H+00..H+72
 Average 2006/01/01 to 2006/03/31





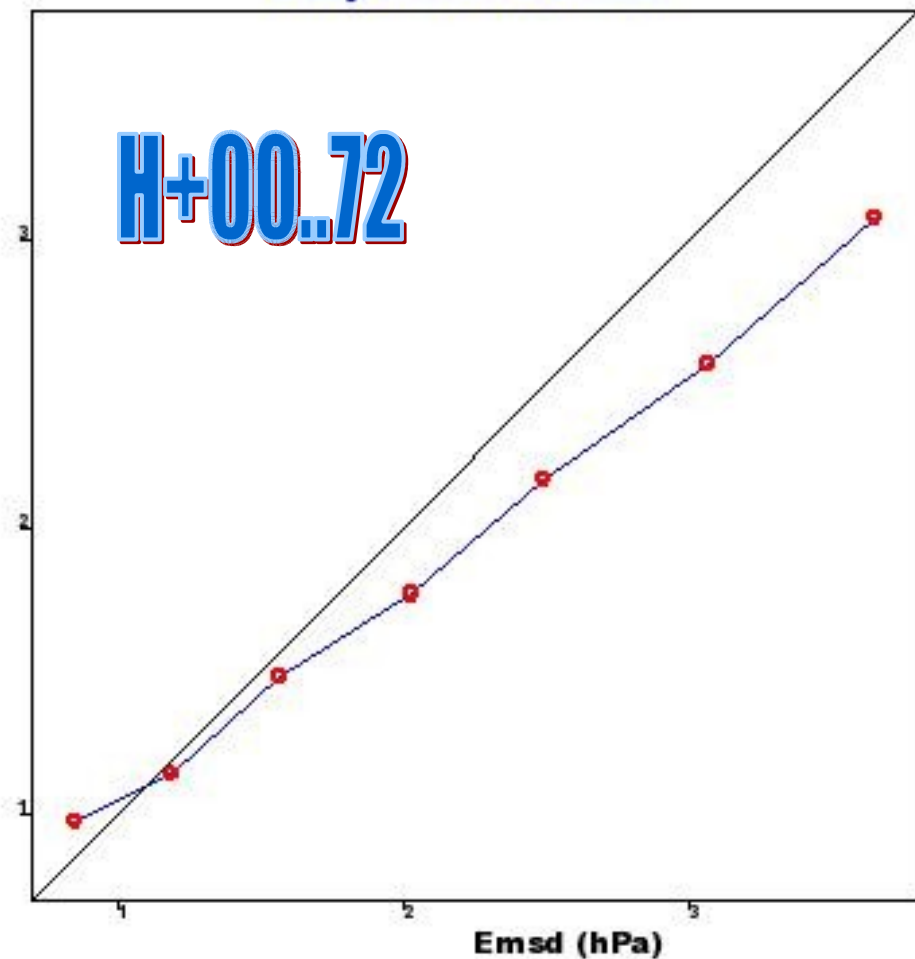
MSIP



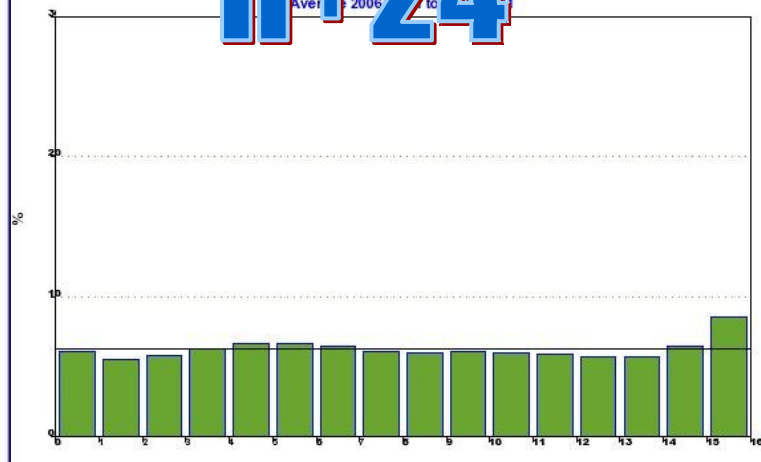
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 Spread vs Emsd Mean sea level Pressure
 Analysis 00 Z H+00..H+72
 Average 2006/01/01 to 2006/03/31

Spread (hPa)

H+00..72

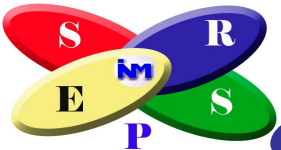


H+24



H+48

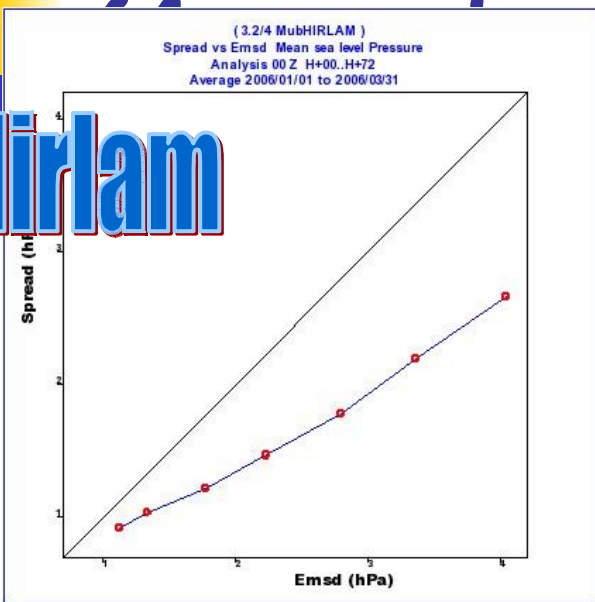




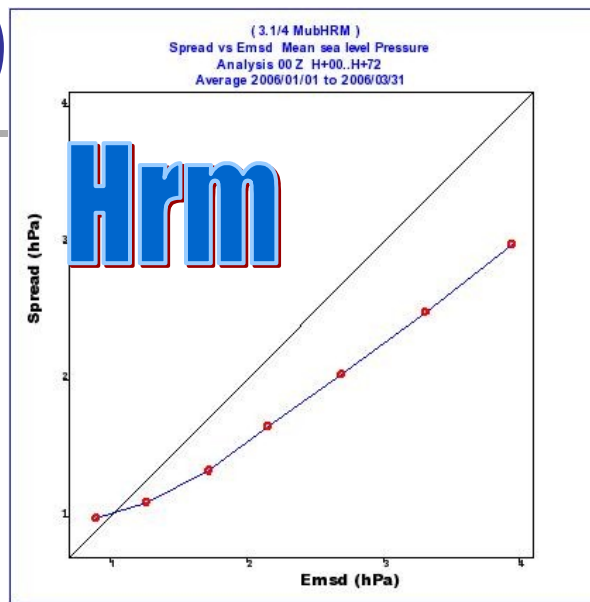
Single model Ensembles

(3 members each)

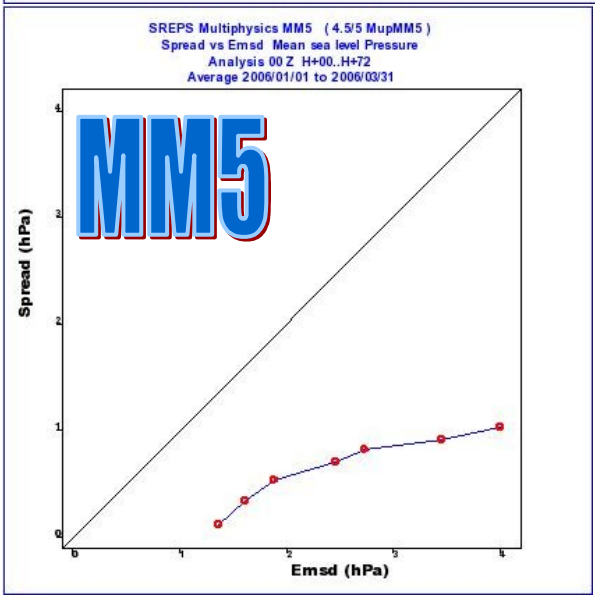
Hirlam



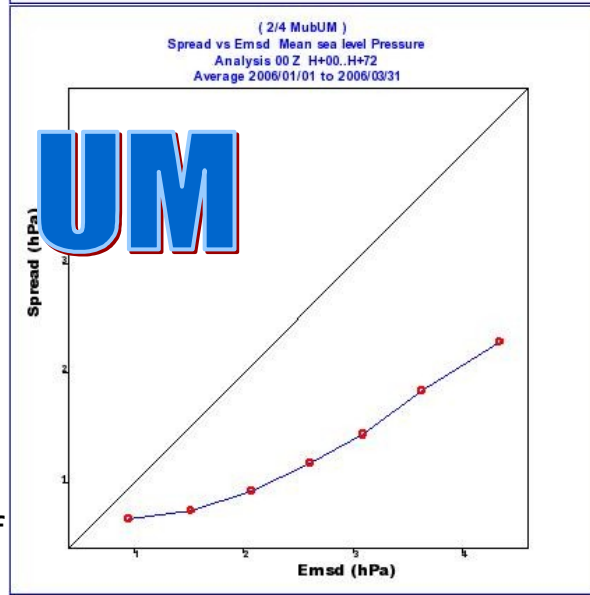
Hrm



MM5

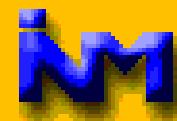
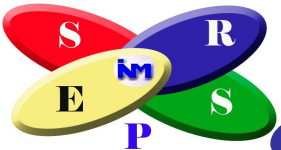


UM



Hirlam-Aladin All Staff

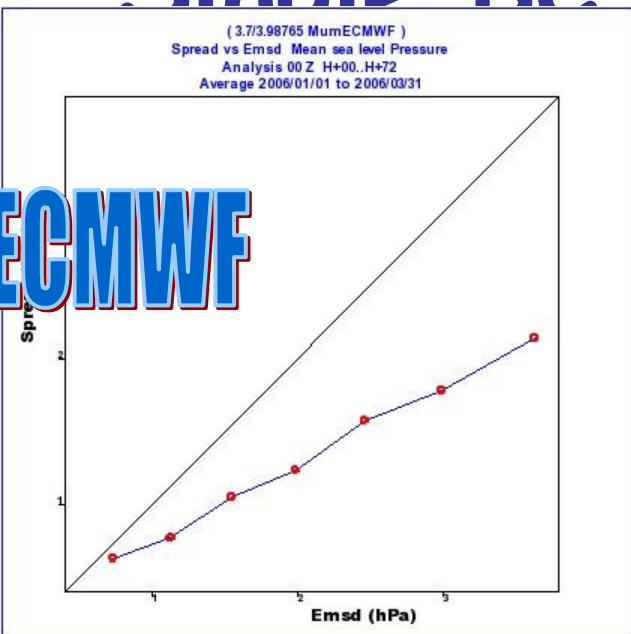




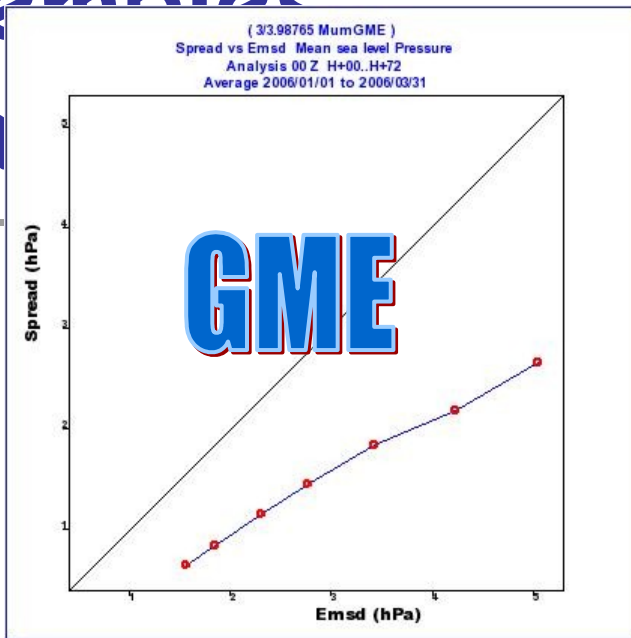
Single BC's Ensembles

ers ea

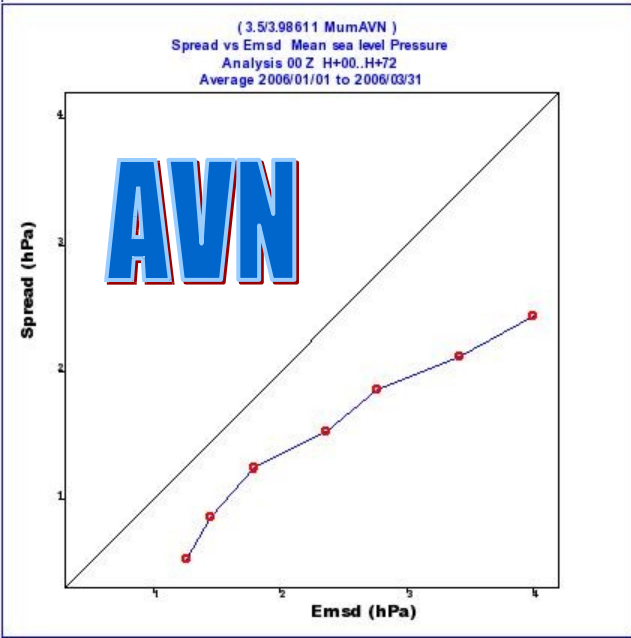
ECMWF



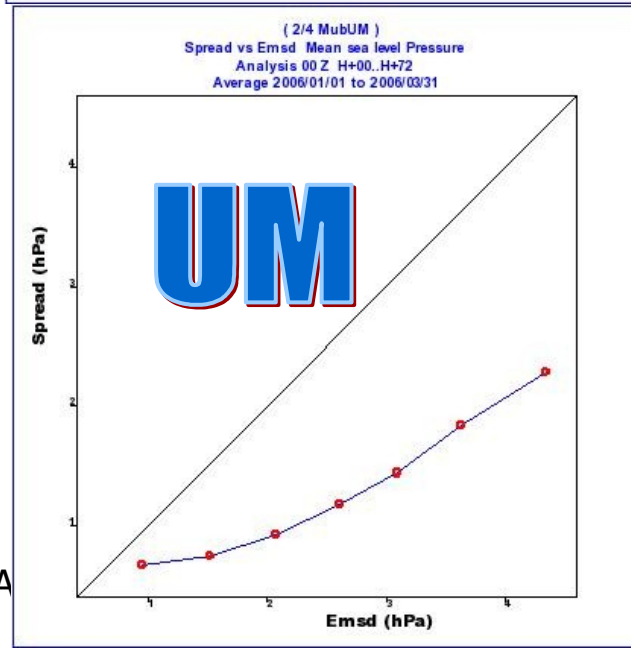
GME



AVN

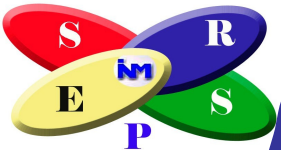


UM



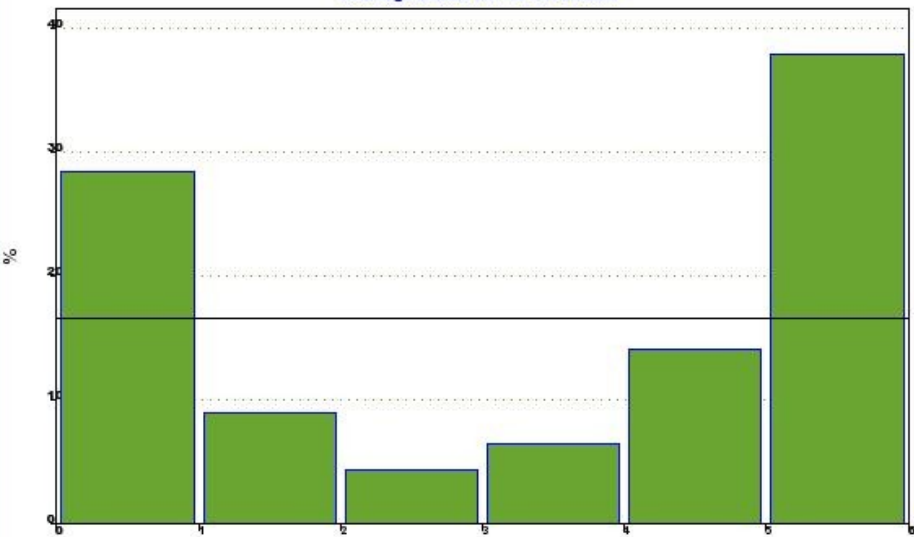
Hirlam-Aladin A



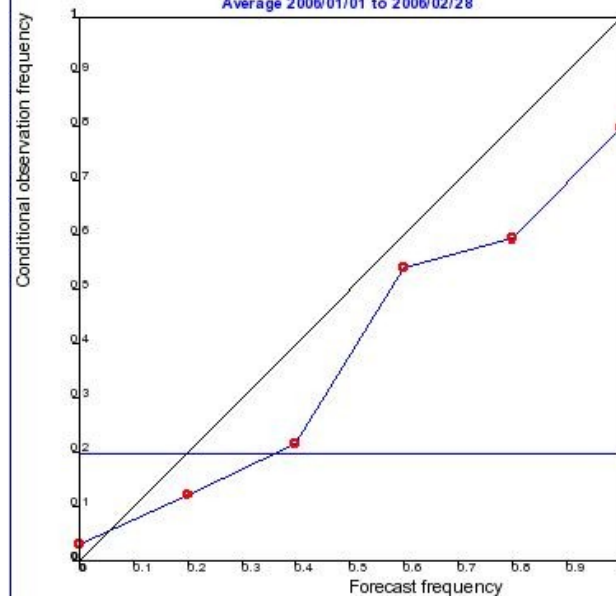


MM5 Multi-physics (5 members)

SREPS Multiphysics MM5 (4/5 MupMM5)
Rank Histogram Mean sea level Pressure
Analysis 00 Z H+48
Average 2006/01/01 to 2006/02/28



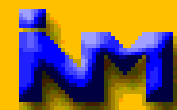
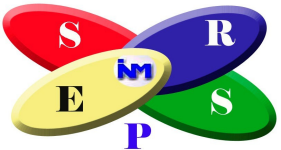
SREPS Multiphysics MM5 (4/5 MupMM5)
Reliability 24h Accum Precipitation over 5mm
Analysis 00 Z H+48
Average 2006/01/01 to 2006/02/28



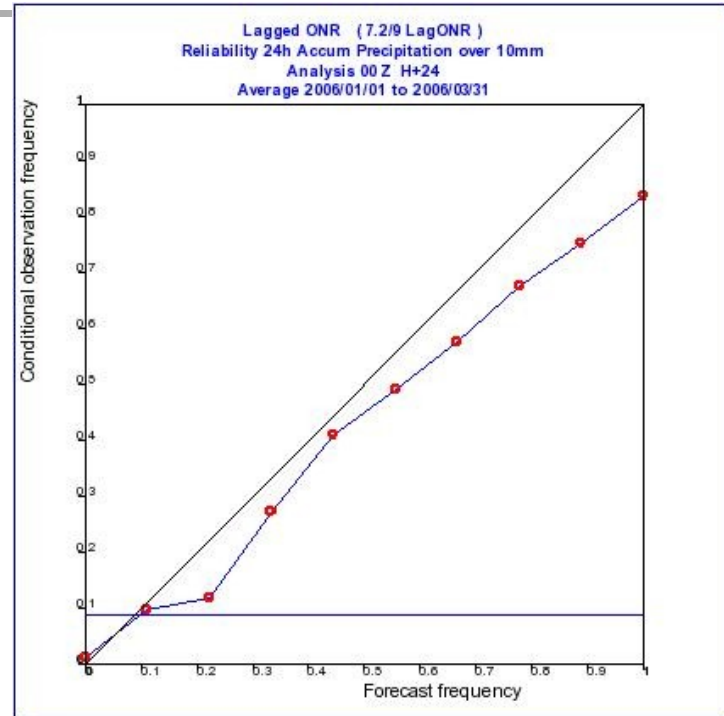
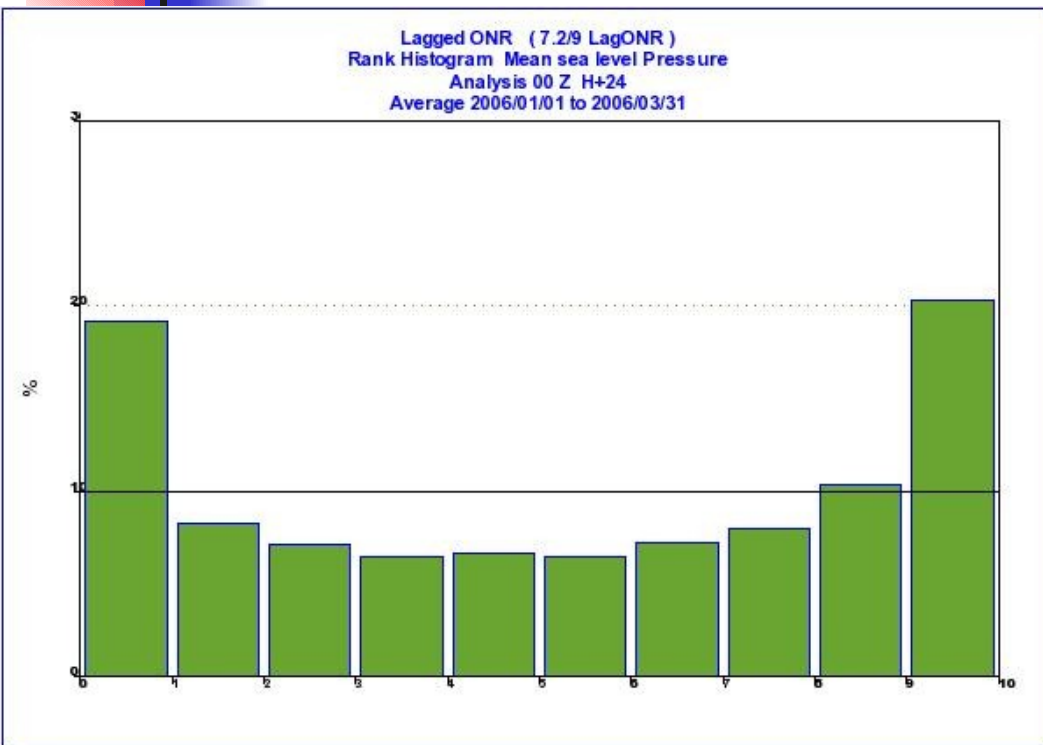
Mslp H+48 Rank Hist

24 h. Acc. Precip H+48 > 5 mm.





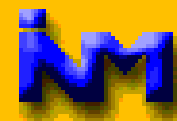
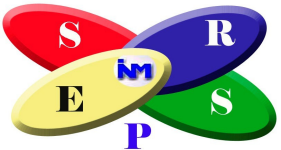
Deterministic Hirlam Lagged Ensemble (9 members)



Mslp H+24 Rank Hist

**24 h. Acc. Precip
H+24 > 5 mm.**





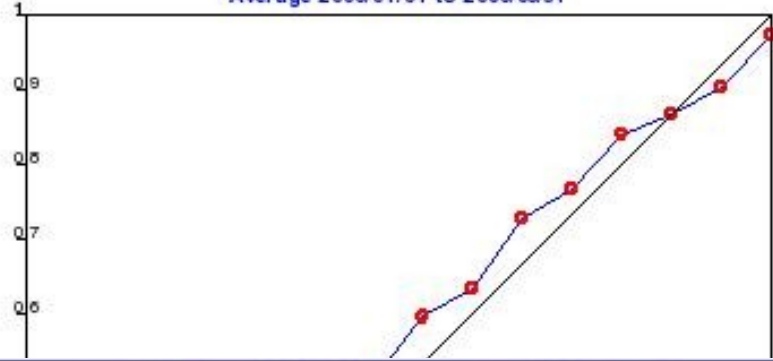
Surface parameters

Parameters

- 10m Wind Speed
 - Thresholds: 10m/s, 15m/s
- 24h Accumulated Precipitation
 - Thresholds: 1mm, 5mm, 10mm, 20mm
- Scores
 - Reliability diagrams
 - ROC curves
 - RV plots
- Forecast lengths:
 - H+24, H+48

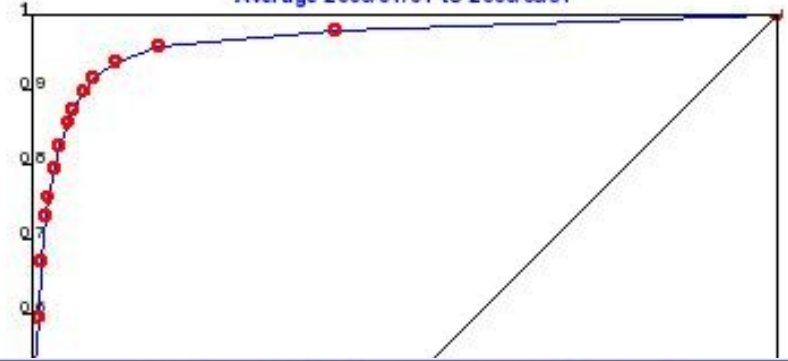
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 Reliability 10m Surface Wind Speed over 10m/s
 Analysis 00 Z H+24
 Average 2006/01/01 to 2006/03/31

Conditional observation frequency



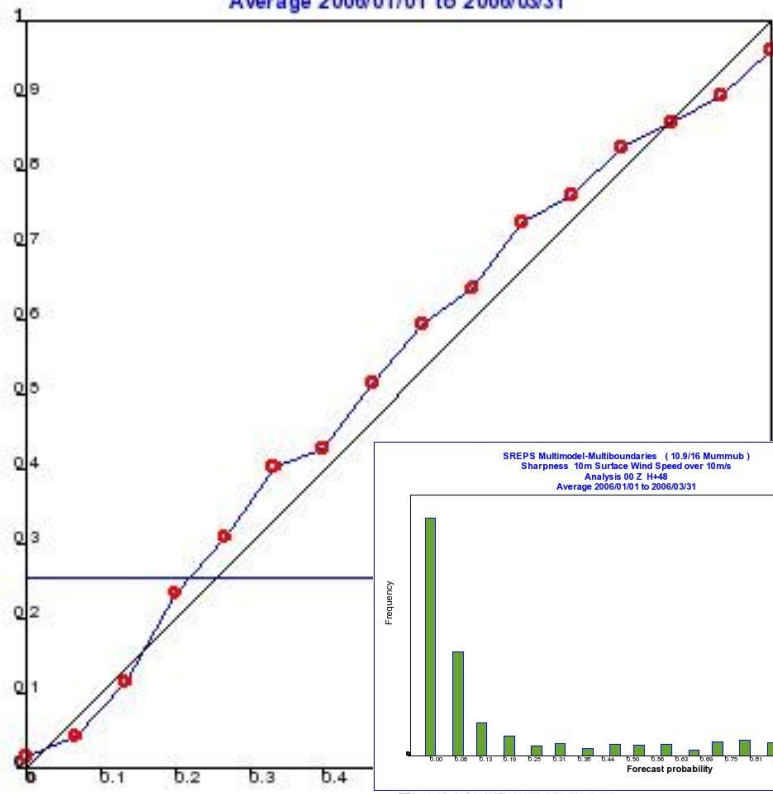
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 ROC 10m Surface Wind Speed over 10m/s
 Analysis 00 Z H+24
 Average 2006/01/01 to 2006/03/31

R



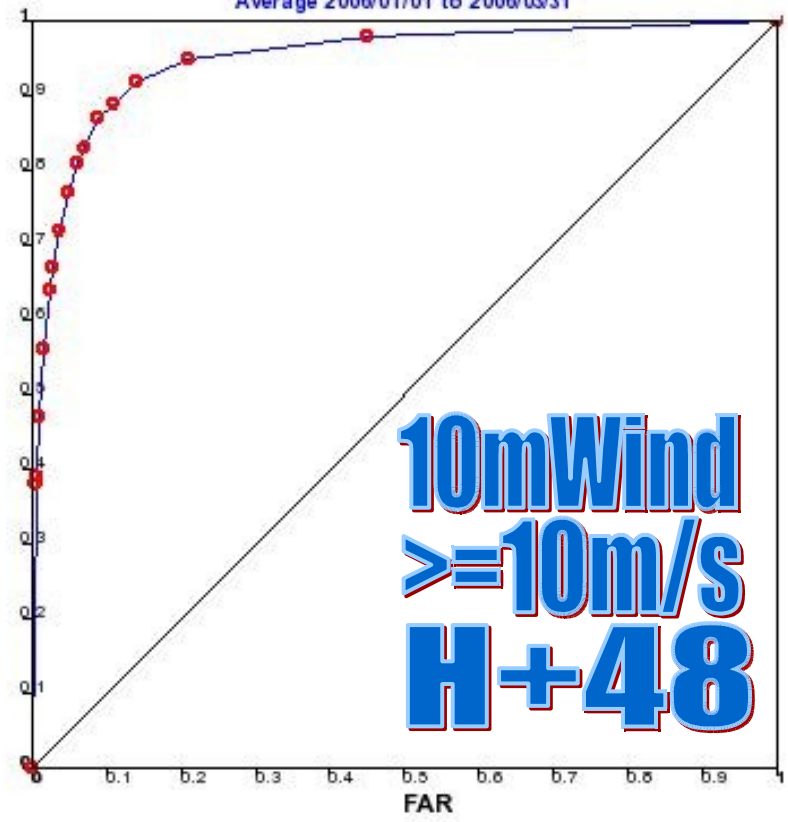
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 Reliability 10m Surface Wind Speed over 10m/s
 Analysis 00 Z H+48
 Average 2006/01/01 to 2006/03/31

Conditional observation frequency



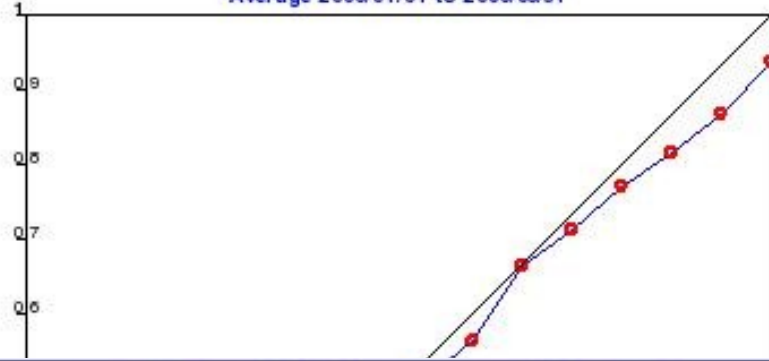
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 ROC 10m Surface Wind Speed over 10m/s
 Analysis 00 Z H+48
 Average 2006/01/01 to 2006/03/31

HIR



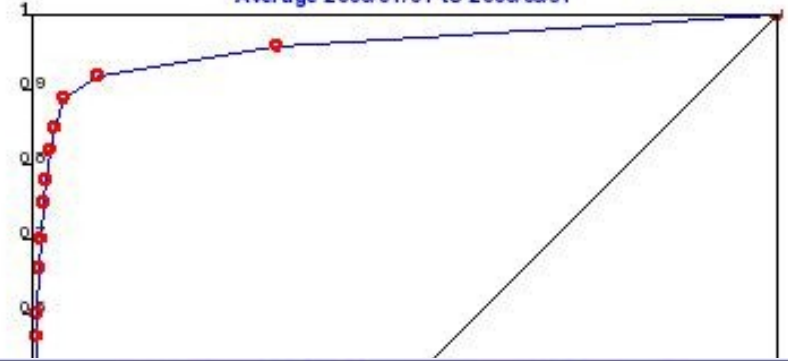
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 Reliability 10m Surface Wind Speed over 15m/s
 Analysis 00 Z H+24
 Average 2006/01/01 to 2006/03/31

Conditional observation frequency



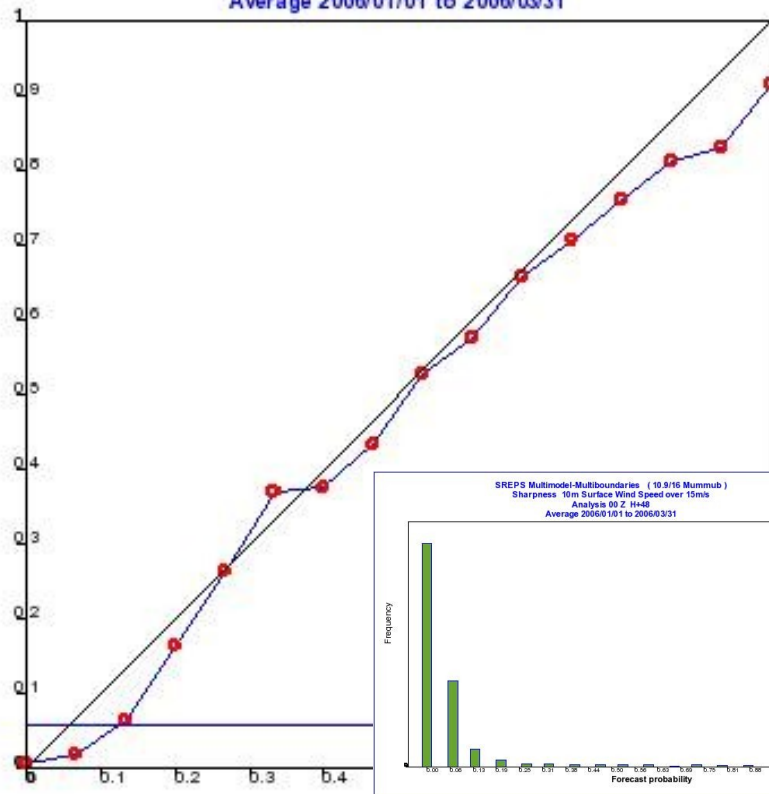
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 ROC 10m Surface Wind Speed over 15m/s
 Analysis 00 Z H+24
 Average 2006/01/01 to 2006/03/31

R



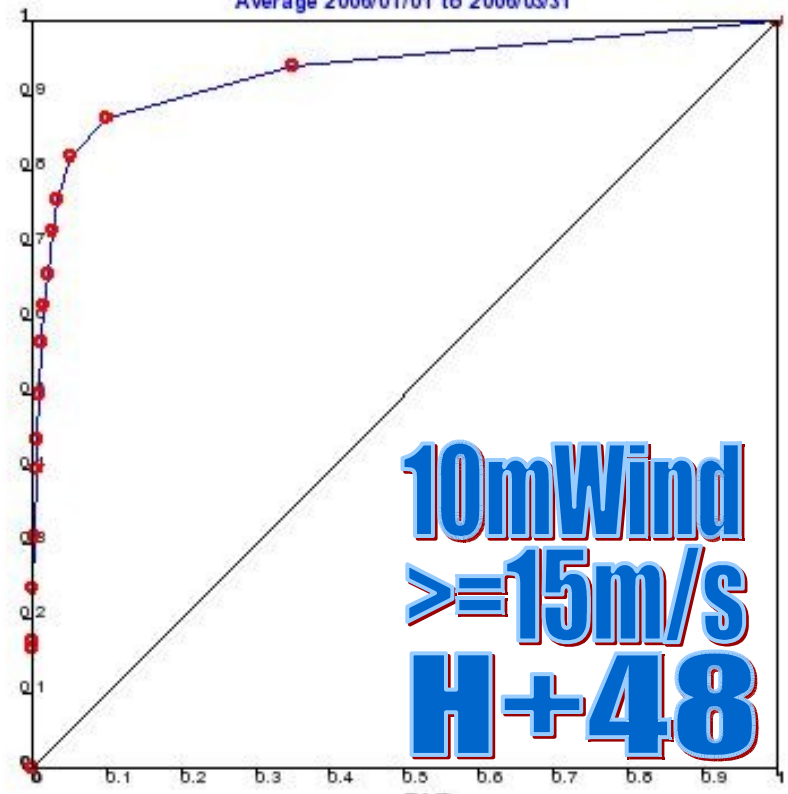
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 Reliability 10m Surface Wind Speed over 15m/s
 Analysis 00 Z H+48
 Average 2006/01/01 to 2006/03/31

Conditional observation frequency



SREPS Multimodel-Multiboundaries (11/16 Mummub)
 ROC 10m Surface Wind Speed over 15m/s
 Analysis 00 Z H+48
 Average 2006/01/01 to 2006/03/31

HIR

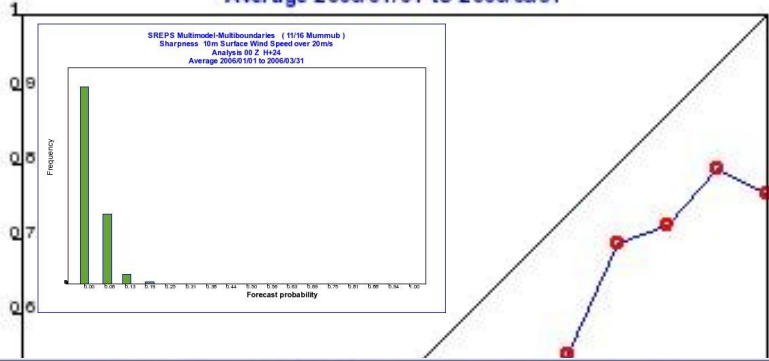


**10m Wind
 >= 15m/s
 H+48**

FAR

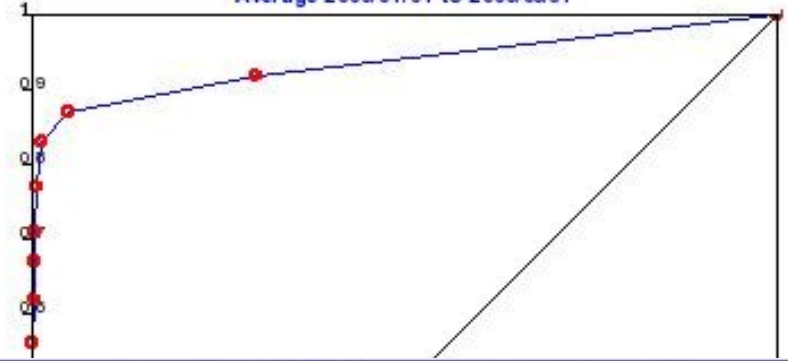
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 Reliability 10m Surface Wind Speed over 20m/s
 Analysis 00 Z H+24
 Average 2006/01/01 to 2006/03/31

Conditional observation frequency



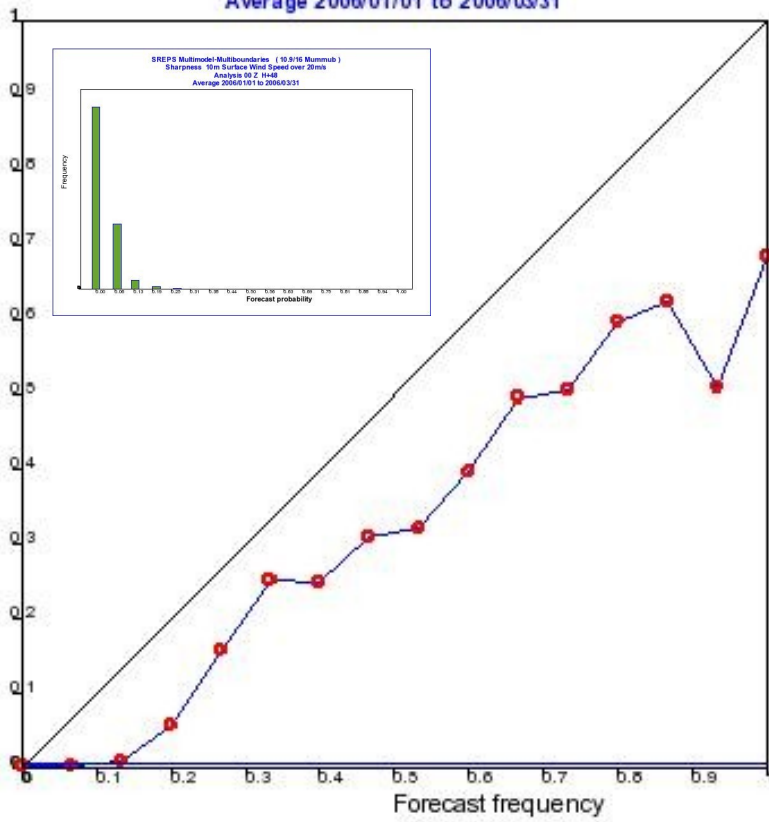
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 ROC 10m Surface Wind Speed over 20m/s
 Analysis 00 Z H+24
 Average 2006/01/01 to 2006/03/31

ROC



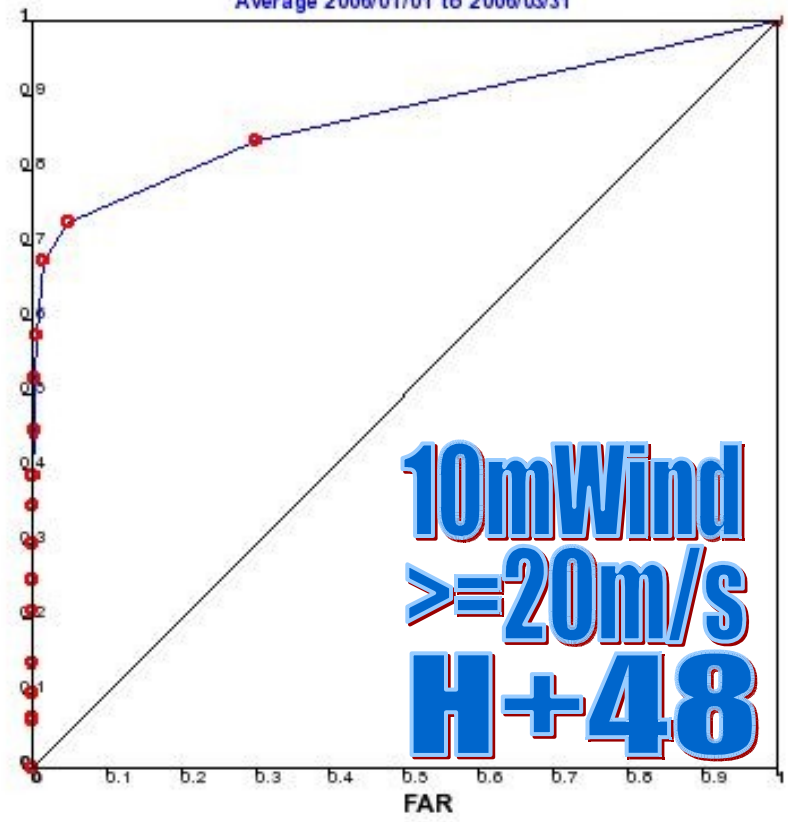
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 Reliability 10m Surface Wind Speed over 20m/s
 Analysis 00 Z H+48
 Average 2006/01/01 to 2006/03/31

Conditional observation frequency

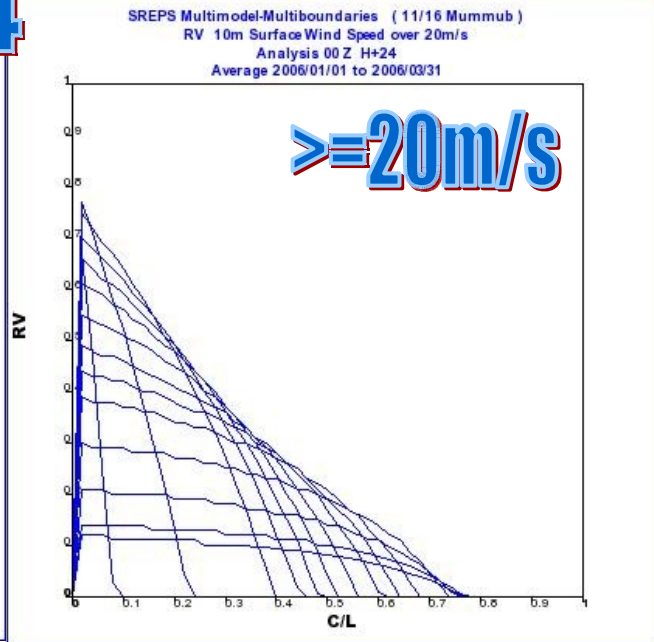
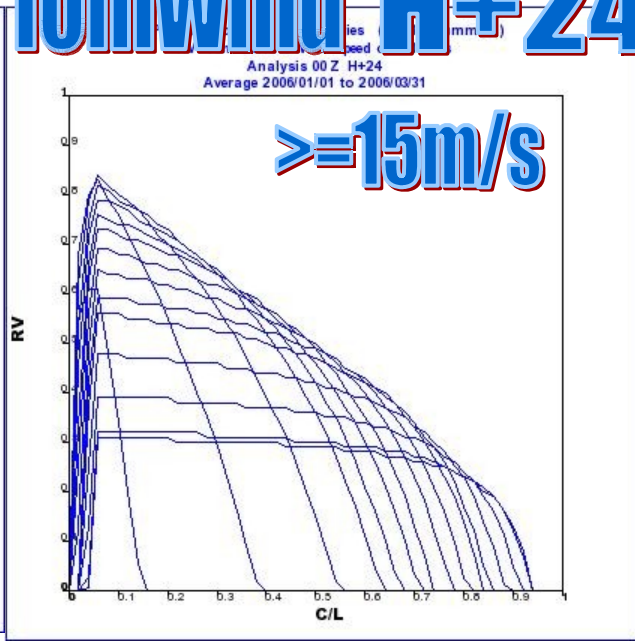
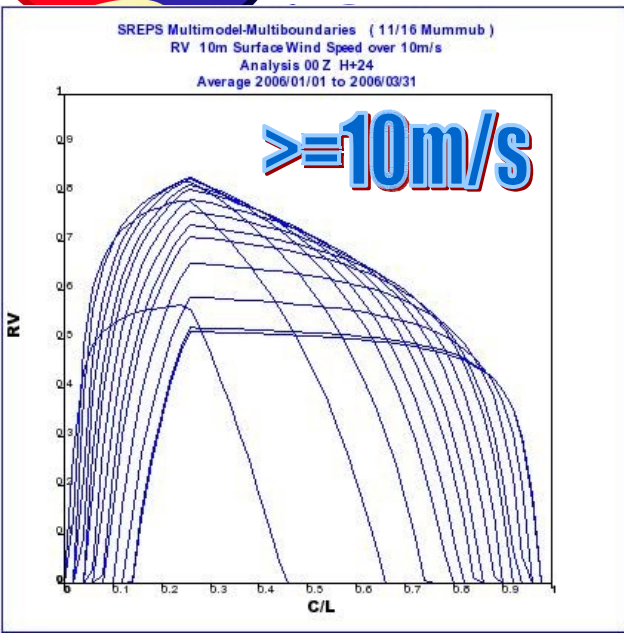


SREPS Multimodel-Multiboundaries (11/16 Mummub)
 ROC 10m Surface Wind Speed over 20m/s
 Analysis 00 Z H+48
 Average 2006/01/01 to 2006/03/31

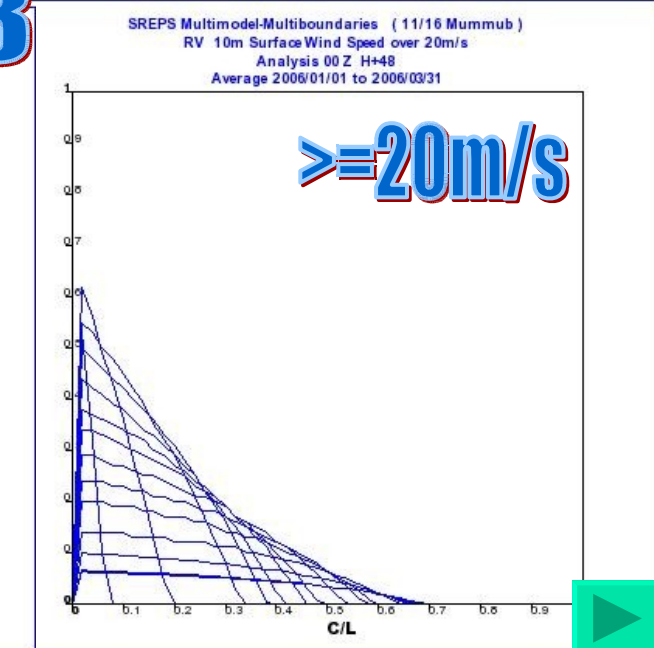
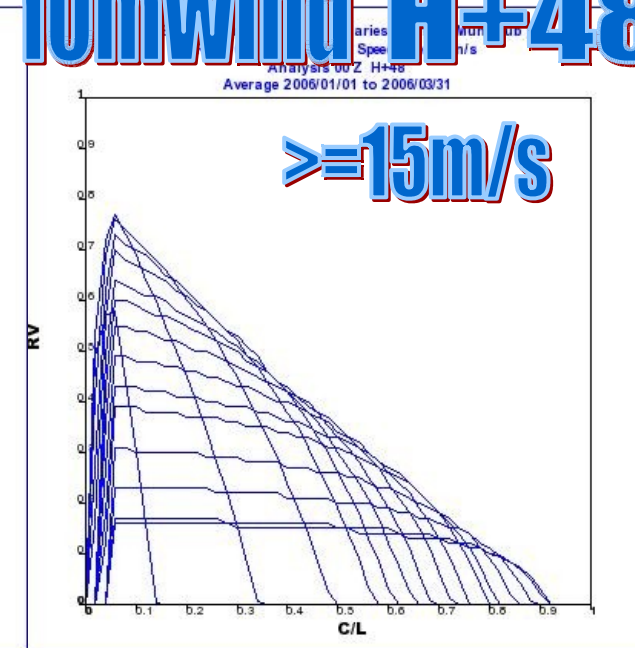
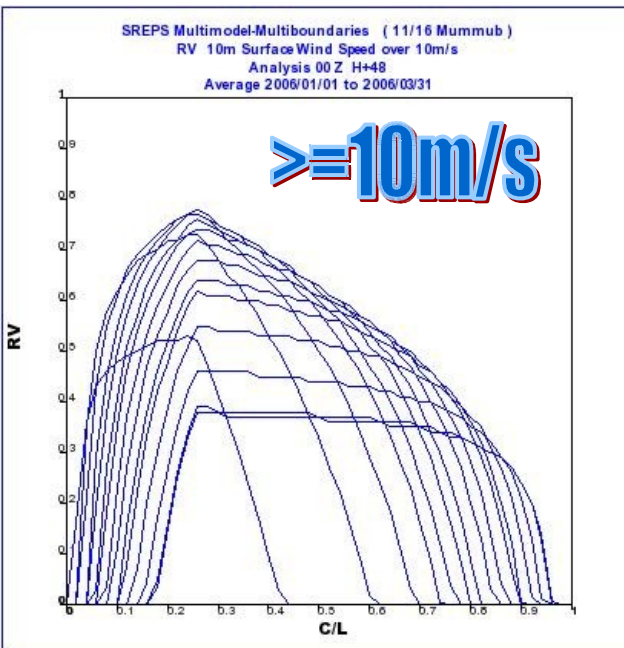
HIR



10mWind H+24

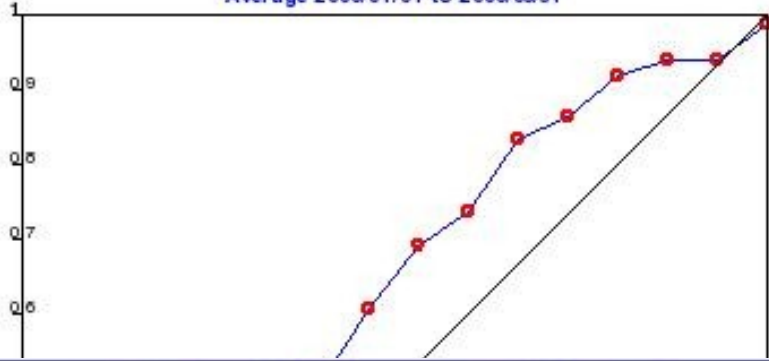


10mWind H+48



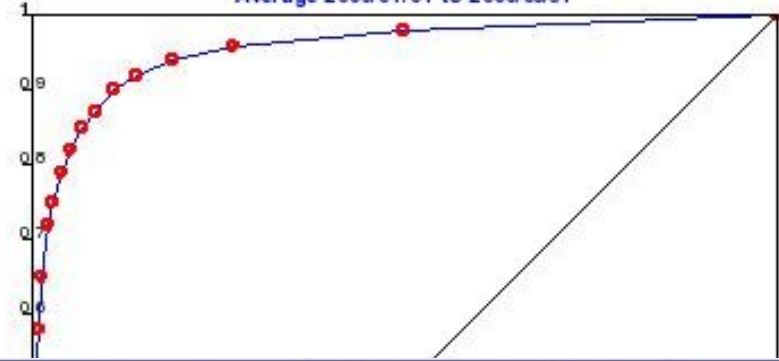
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 Reliability 24h Accum Precipitation over 1mm
 Analysis 00 Z H+24
 Average 2006/01/01 to 2006/03/31

Conditional observation frequency



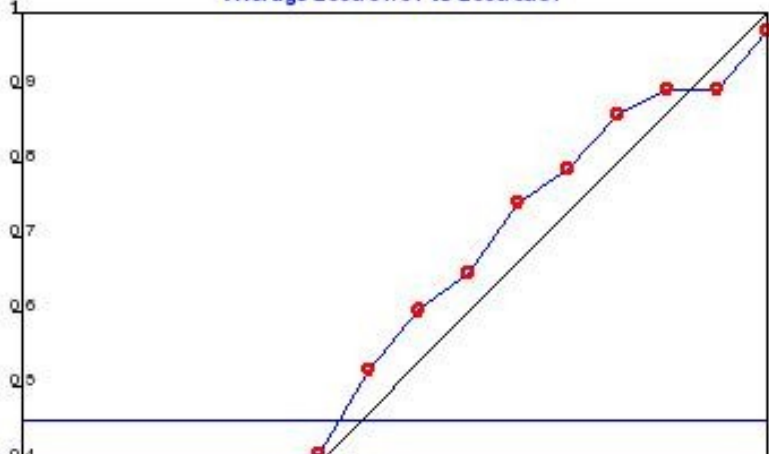
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 ROC 24h Accum Precipitation over 1mm
 Analysis 00 Z H+24
 Average 2006/01/01 to 2006/03/31

R



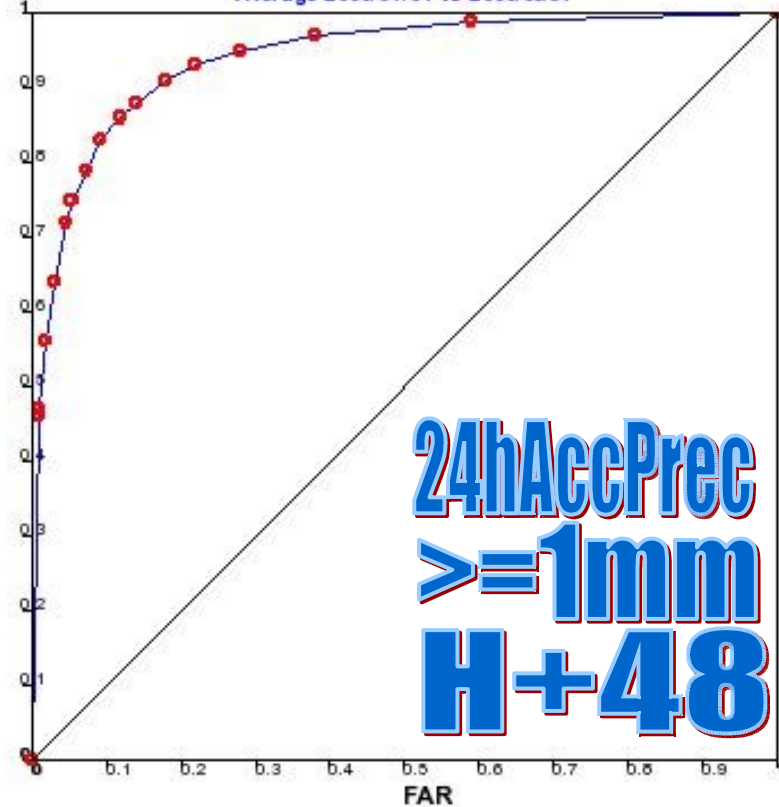
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 Reliability 24h Accum Precipitation over 1mm
 Analysis 00 Z H+48
 Average 2006/01/01 to 2006/03/31

Conditional observation frequency

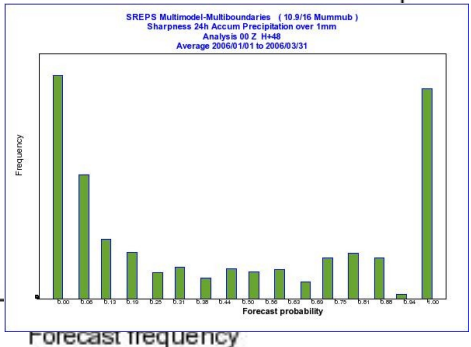


SREPS Multimodel-Multiboundaries (11/16 Mummub)
 ROC 24h Accum Precipitation over 1mm
 Analysis 00 Z H+48
 Average 2006/01/01 to 2006/03/31

HIR

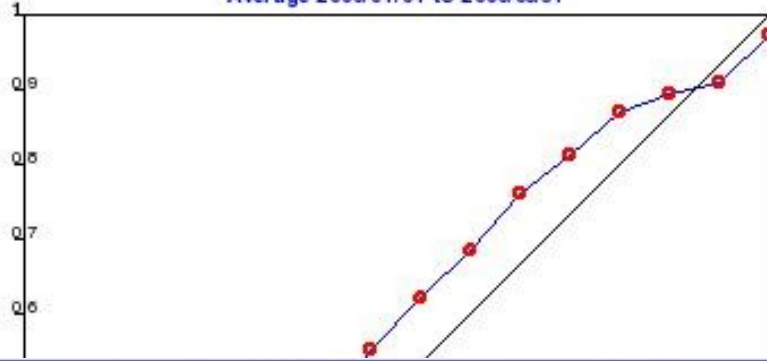


**24hAccPrec
 >=1mm
 H+48**



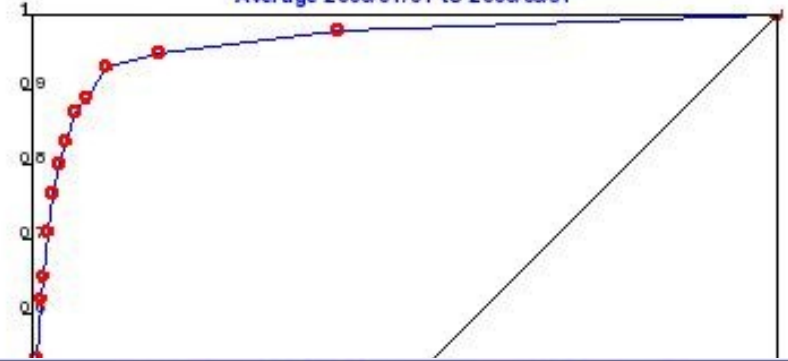
SREPS Multimodel-Multiboundaries (11/16 Mummub)
Reliability 24h Accum Precipitation over 5mm
Analysis 00 Z H+24
Average 2006/01/01 to 2006/03/31

Conditional observation frequency



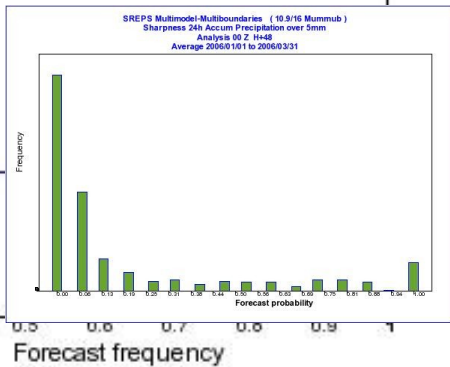
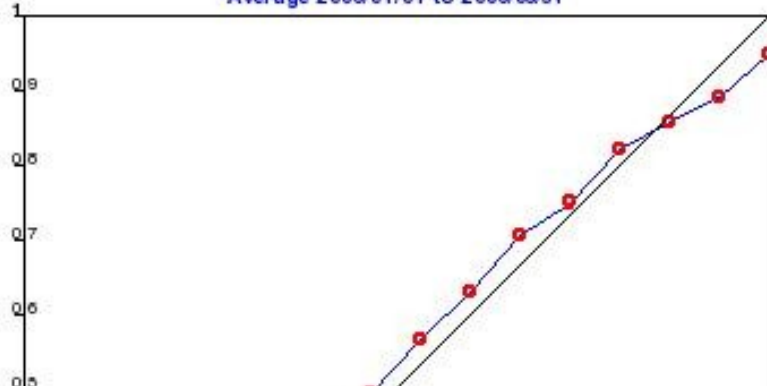
SREPS Multimodel-Multiboundaries (11/16 Mummub)
ROC 24h Accum Precipitation over 5mm
Analysis 00 Z H+24
Average 2006/01/01 to 2006/03/31

R



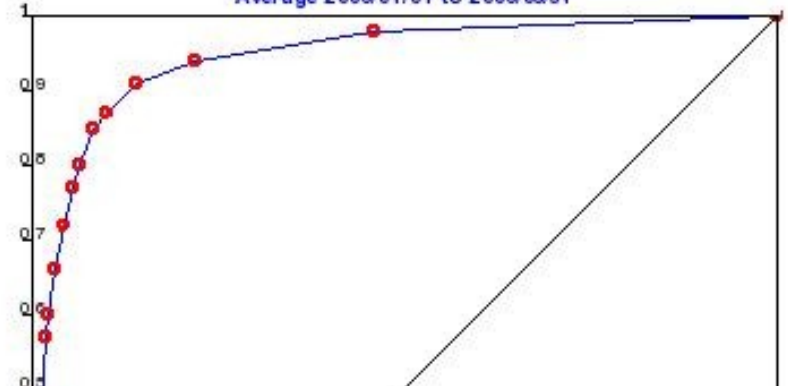
SREPS Multimodel-Multiboundaries (11/16 Mummub)
Reliability 24h Accum Precipitation over 5mm
Analysis 00 Z H+48
Average 2006/01/01 to 2006/03/31

Conditional observation frequency



SREPS Multimodel-Multiboundaries (11/16 Mummub)
ROC 24h Accum Precipitation over 5mm
Analysis 00 Z H+48
Average 2006/01/01 to 2006/03/31

HIR



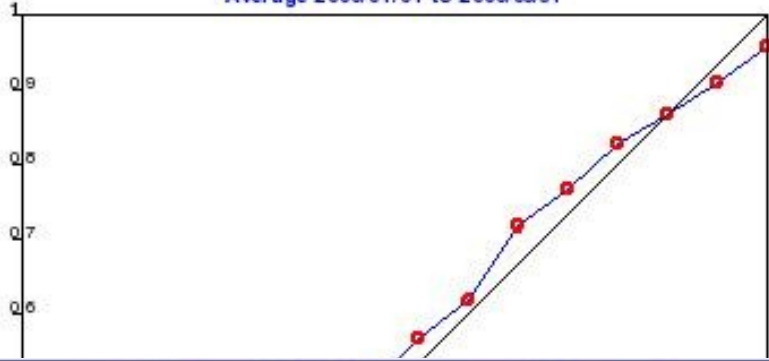
**24hAccPrec
>=5mm
H+48**

FAR



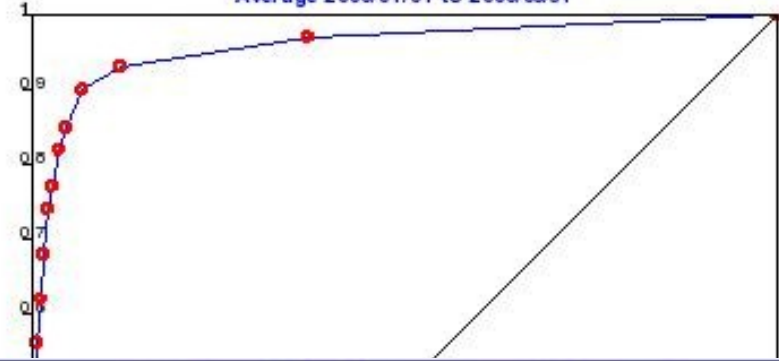
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 Reliability 24h Accum Precipitation over 10mm
 Analysis 00 Z H+24
 Average 2006/01/01 to 2006/03/31

Conditional observation frequency



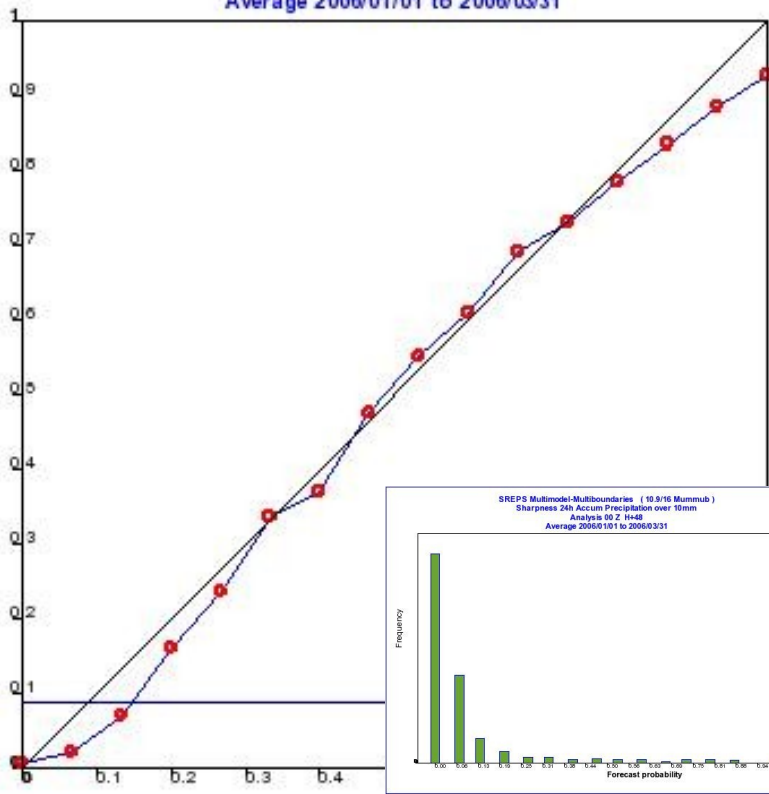
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 ROC 24h Accum Precipitation over 10mm
 Analysis 00 Z H+24
 Average 2006/01/01 to 2006/03/31

R



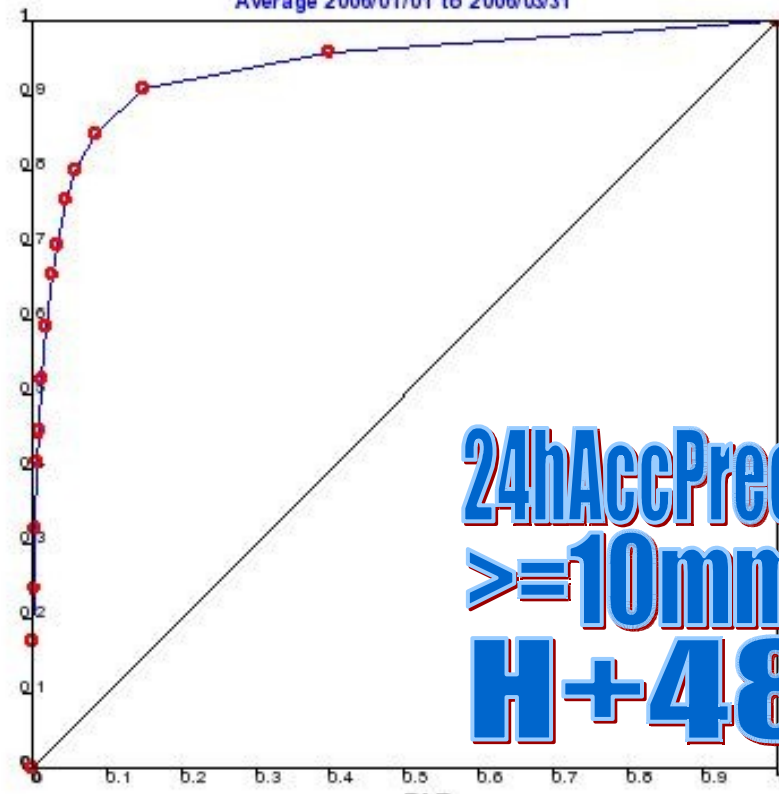
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 Reliability 24h Accum Precipitation over 10mm
 Analysis 00 Z H+48
 Average 2006/01/01 to 2006/03/31

Conditional observation frequency



SREPS Multimodel-Multiboundaries (11/16 Mummub)
 ROC 24h Accum Precipitation over 10mm
 Analysis 00 Z H+48
 Average 2006/01/01 to 2006/03/31

HIR

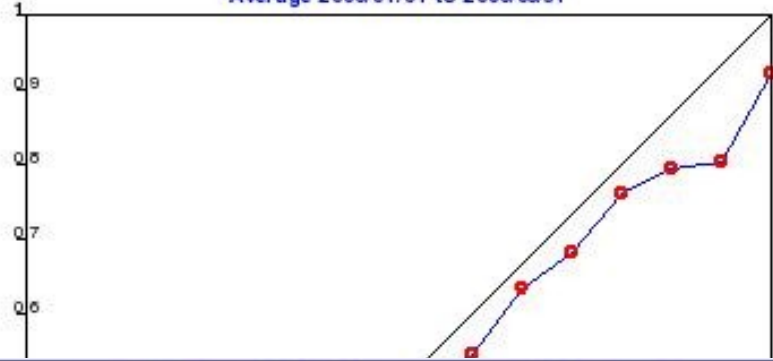


**24hAccPrec
 >=10mm
 H+48**



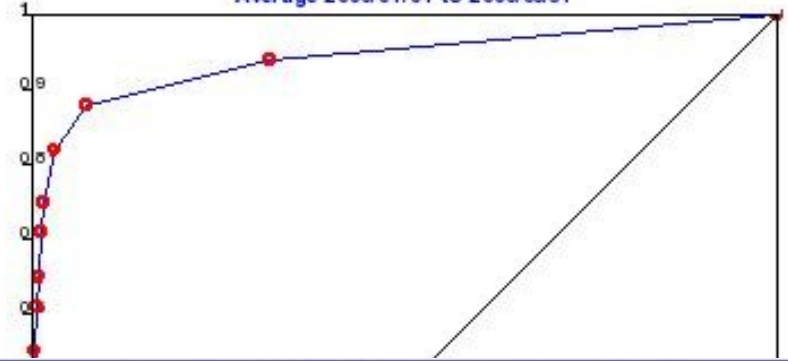
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 Reliability 24h Accum Precipitation over 20mm
 Analysis 00 Z H+24
 Average 2006/01/01 to 2006/03/31

Conditional observation frequency



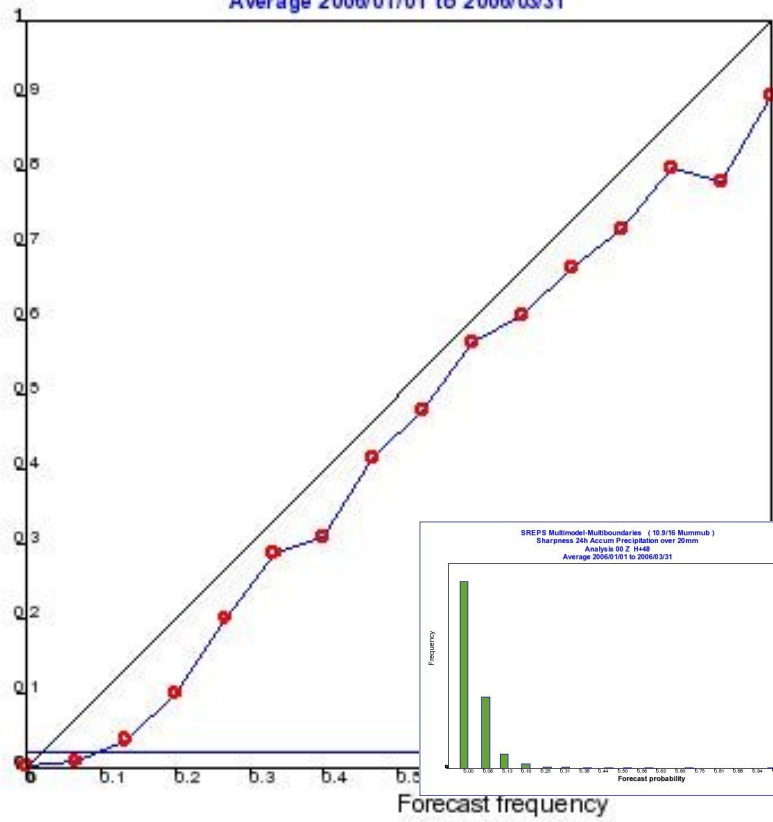
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 ROC 24h Accum Precipitation over 20mm
 Analysis 00 Z H+24
 Average 2006/01/01 to 2006/03/31

R



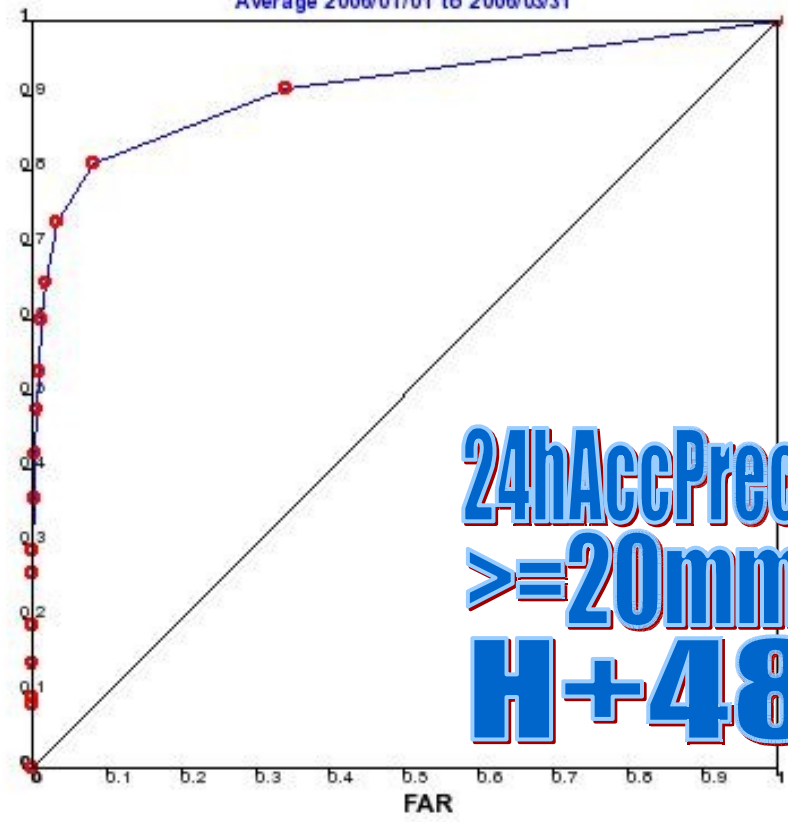
SREPS Multimodel-Multiboundaries (11/16 Mummub)
 Reliability 24h Accum Precipitation over 20mm
 Analysis 00 Z H+48
 Average 2006/01/01 to 2006/03/31

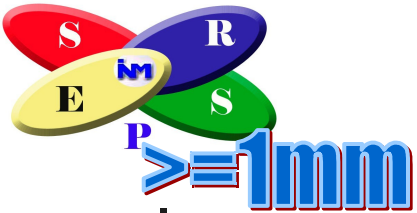
Conditional observation frequency



SREPS Multimodel-Multiboundaries (11/16 Mummub)
 ROC 24h Accum Precipitation over 20mm
 Analysis 00 Z H+48
 Average 2006/01/01 to 2006/03/31

HIR



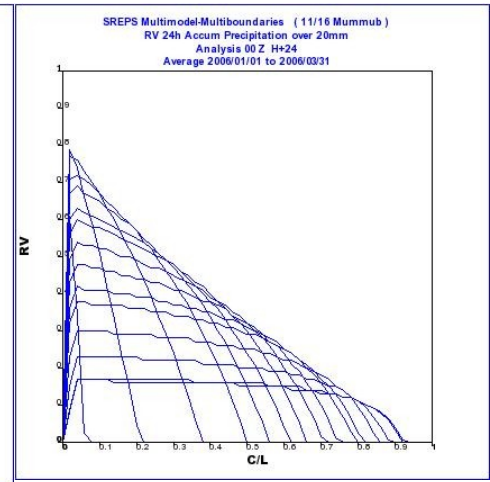
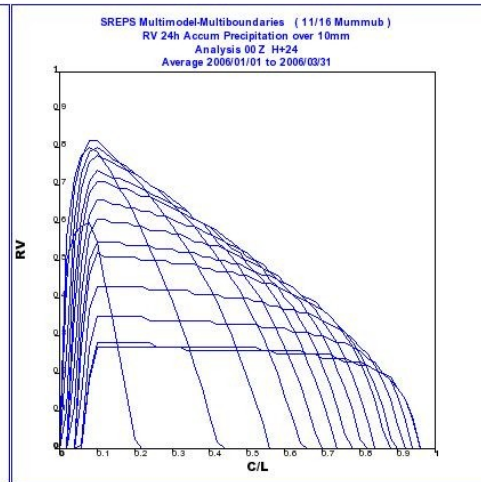
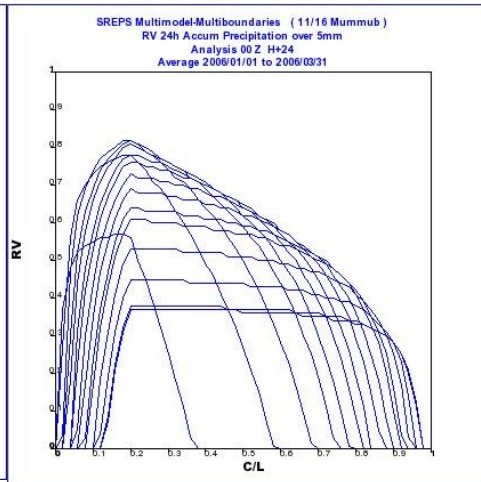
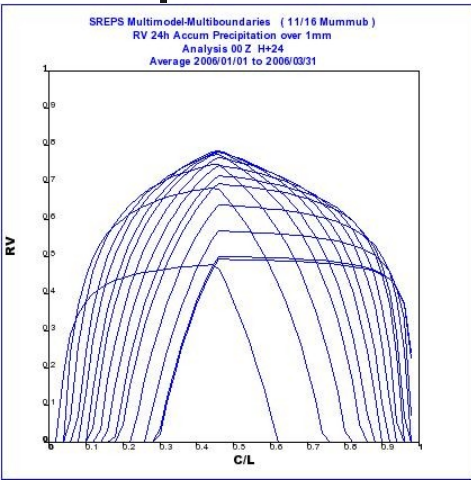


24h AccPrec H+24

>=5mm

>=10mm

>=20mm



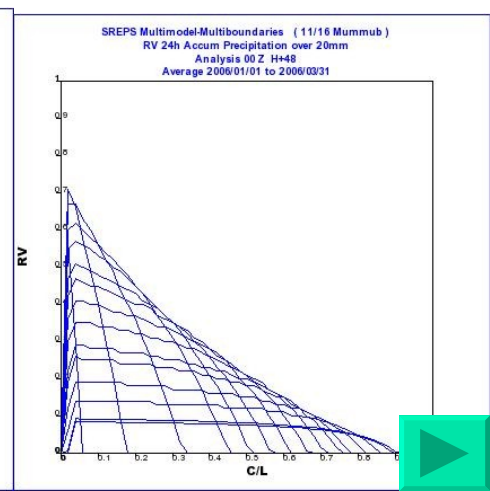
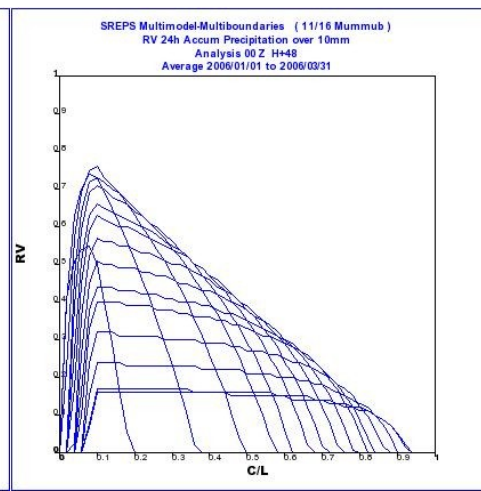
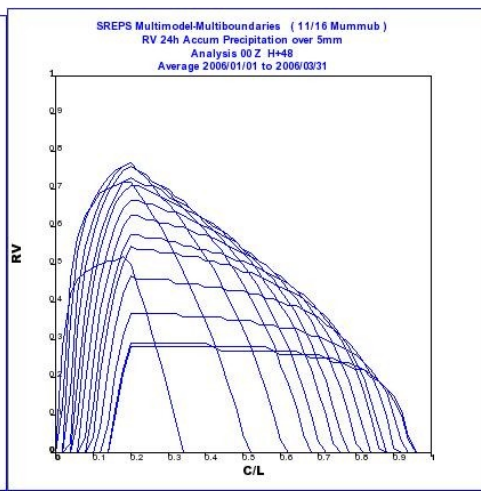
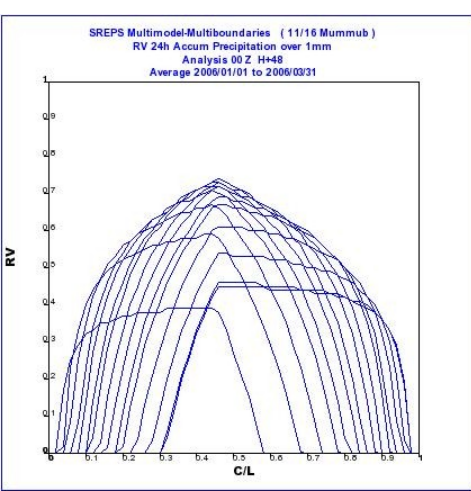
24h AccPrec H+48

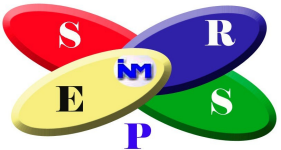
>=1mm

>=5mm

>=10mm

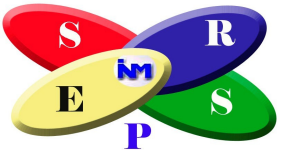
>=20mm





Conclusions for Multi-model

- Advantages:
 - Better representation of model errors (SAMEX and DEMETER).
 - Consistent set of perturbations of initial state and boundaries.
 - Better results (SAMEX, DEMETER, Arribas et al., MWR 2005).
- Disadvantages:
 - Difficult to implement operationally (different models should be maintained operationally).
 - Expensive in terms of human resources.
 - No control experiment in the ensemble.



Coming Future

- Bias removal
- **Calibration: Bayesian Model Averaging**
- **Verification against observations**
- Time-lagged 40 members twice a day
- More post-process software (clustering)