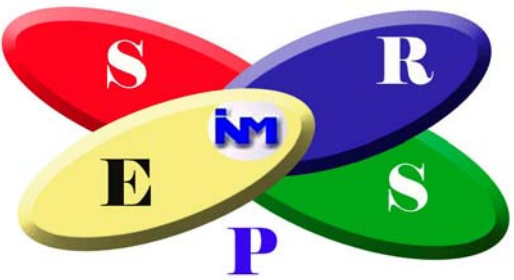


Multi-model Ensemble Prediction System at INM

José A. García-Moya
INM

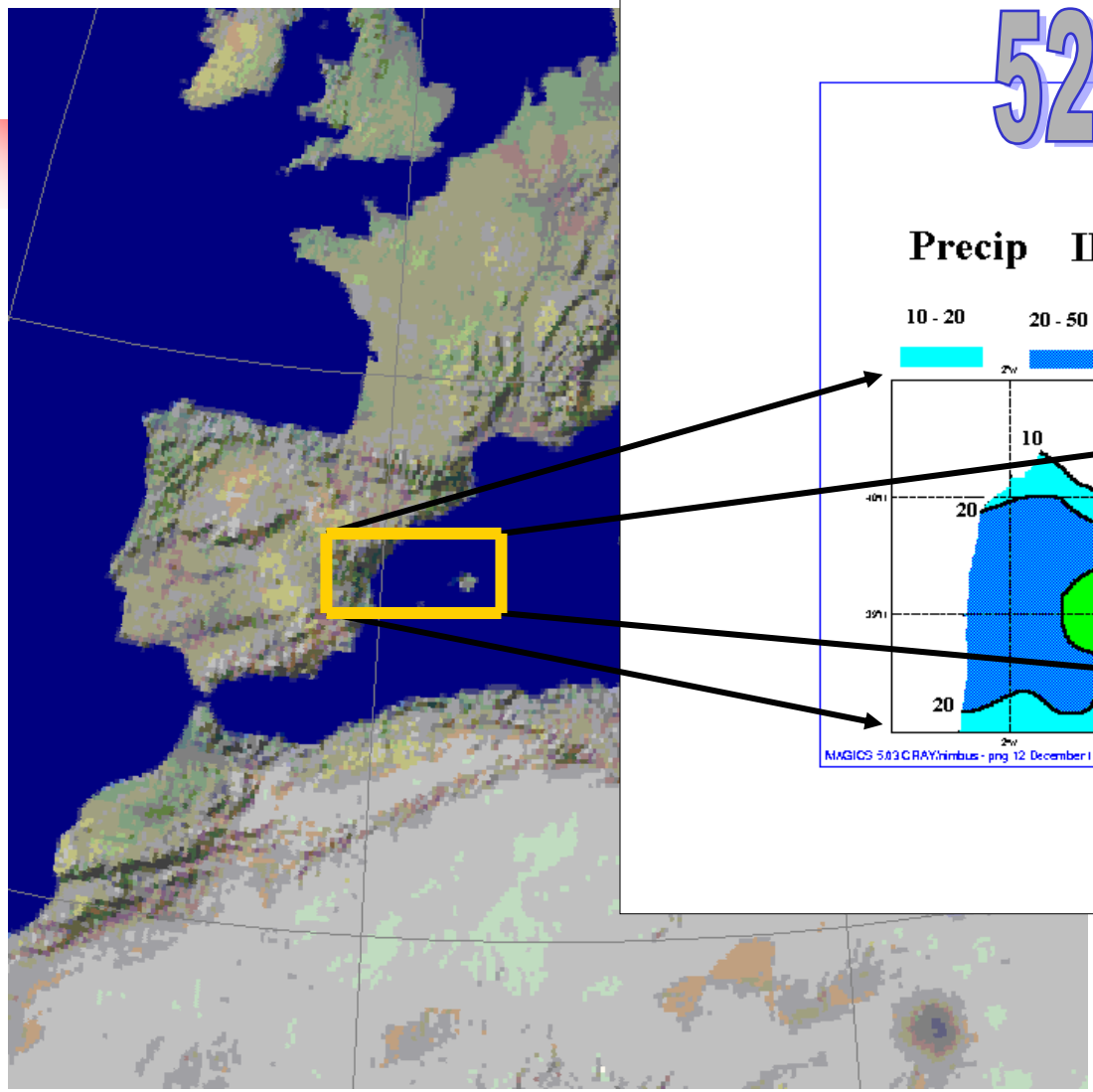
Joint COST Action 731 and NetFAM Workshop on Uncertainty in High-Resolution Meteorological and Hydrological Models

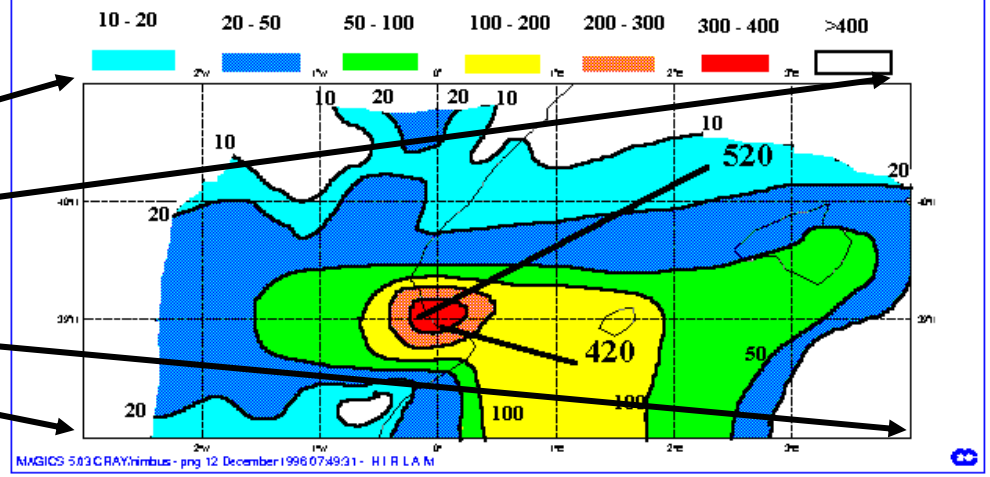
Vilnius, April 2006

Introduction

- Surface parameters are the most important ones for weather forecast.
- Forecast of extreme events (convective precip, gales,…) is probabilistic even for the short-range.
- Short Range Ensemble prediction can help to forecast these events.
- Forecast risk (Palmer, ECMWF Seminar 2002) is the goal for both Medium- and, also, "Short-Range Prediction" (quotation is mine).

520 mm/24 h




Precip INM 96091007 - 96091107
10 - 20
20 - 50
50 - 100
100 - 200
200 - 300
300 - 400
>400
10
20
20
10
10
520
20
20
420
50
20
100
100
MAGICS 5.03 CRAY/nimbus - png 12 December 1996 07:49:31 - H I R L A M

Errors in NWP models

- Due to the model formulation
  - Multi-model techniques
- Due to uncertainties in the initial state
  - Singular vectors, breeding
- Due to the parameterization schemes
  - Multi-physics
  - Stochastic physics techniques
- Special for LAM: Due to uncertainties at boundaries
  - From different deterministic global models
  - From a global ensemble

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

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

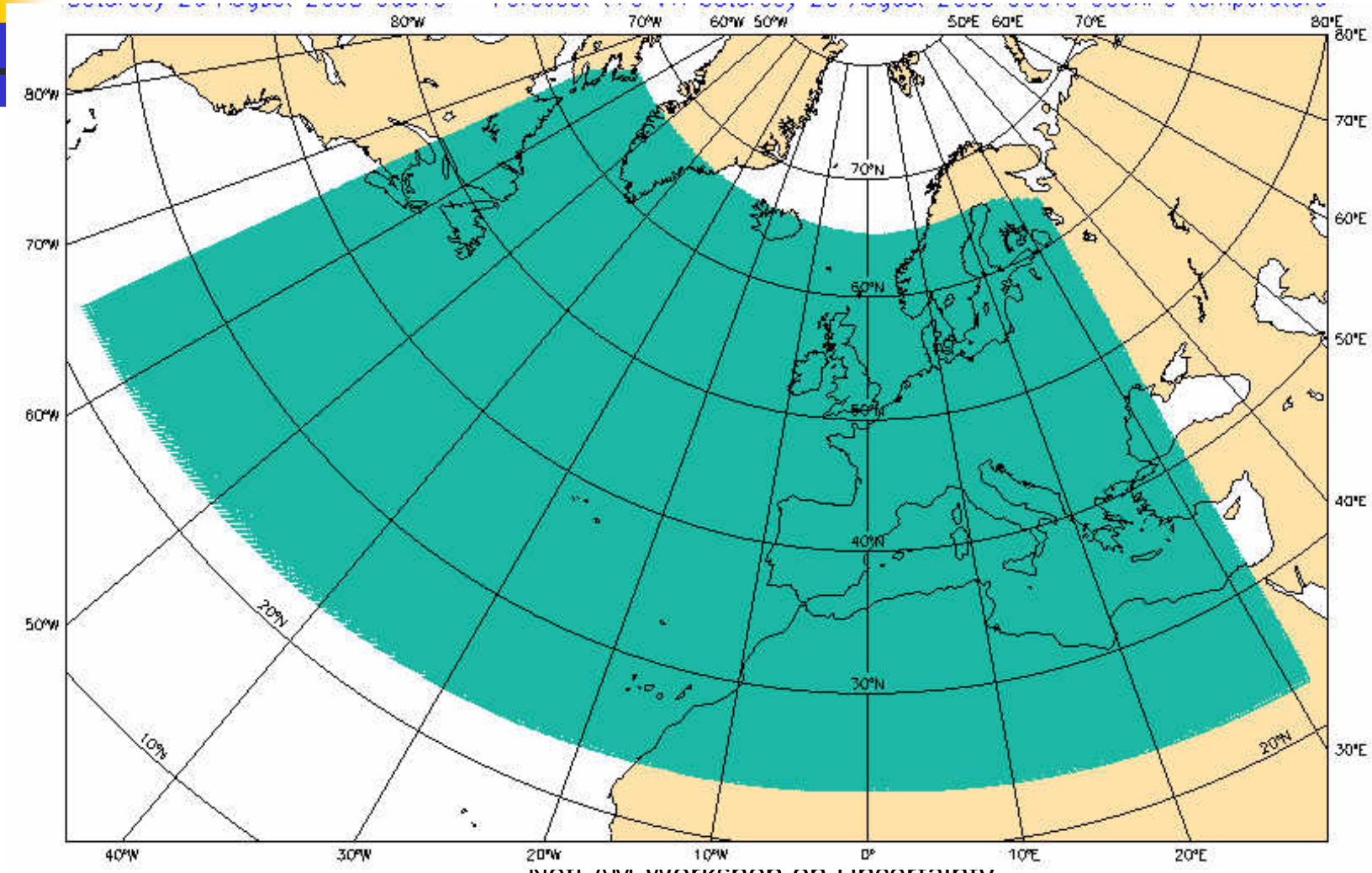
Road Map

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 verfication	
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



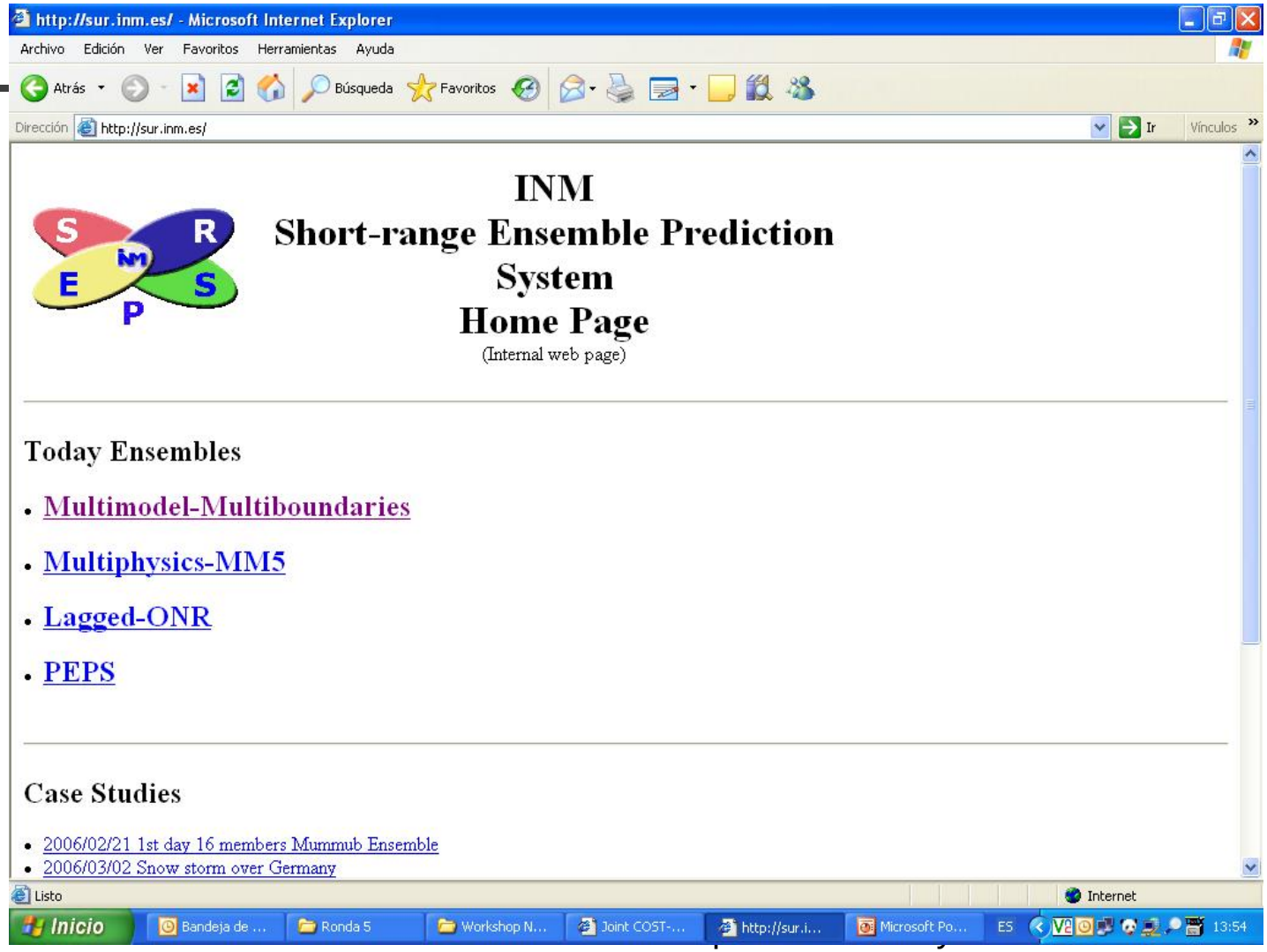
Monitoring in real time

- 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)**

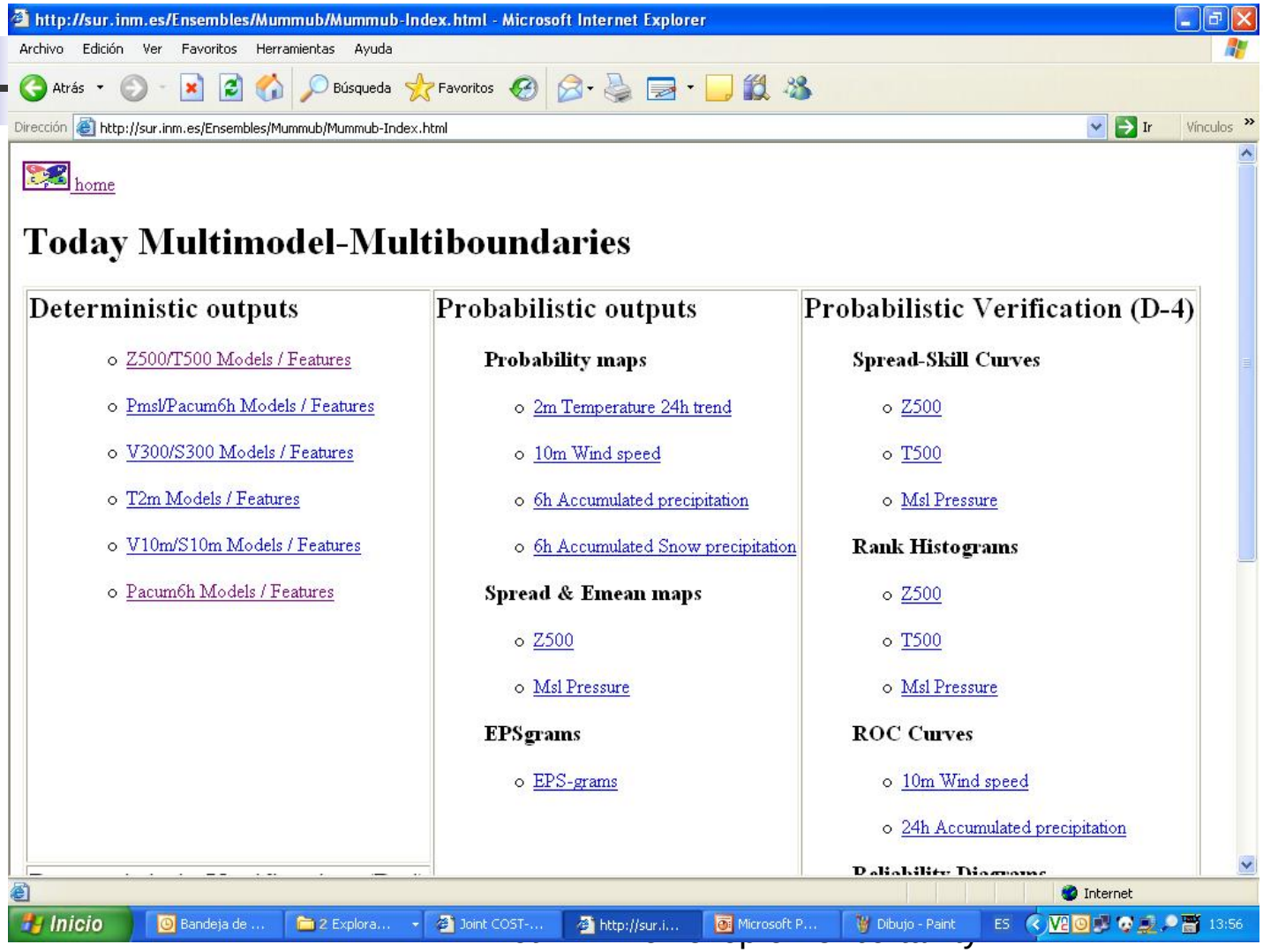
Different ensembles

- 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

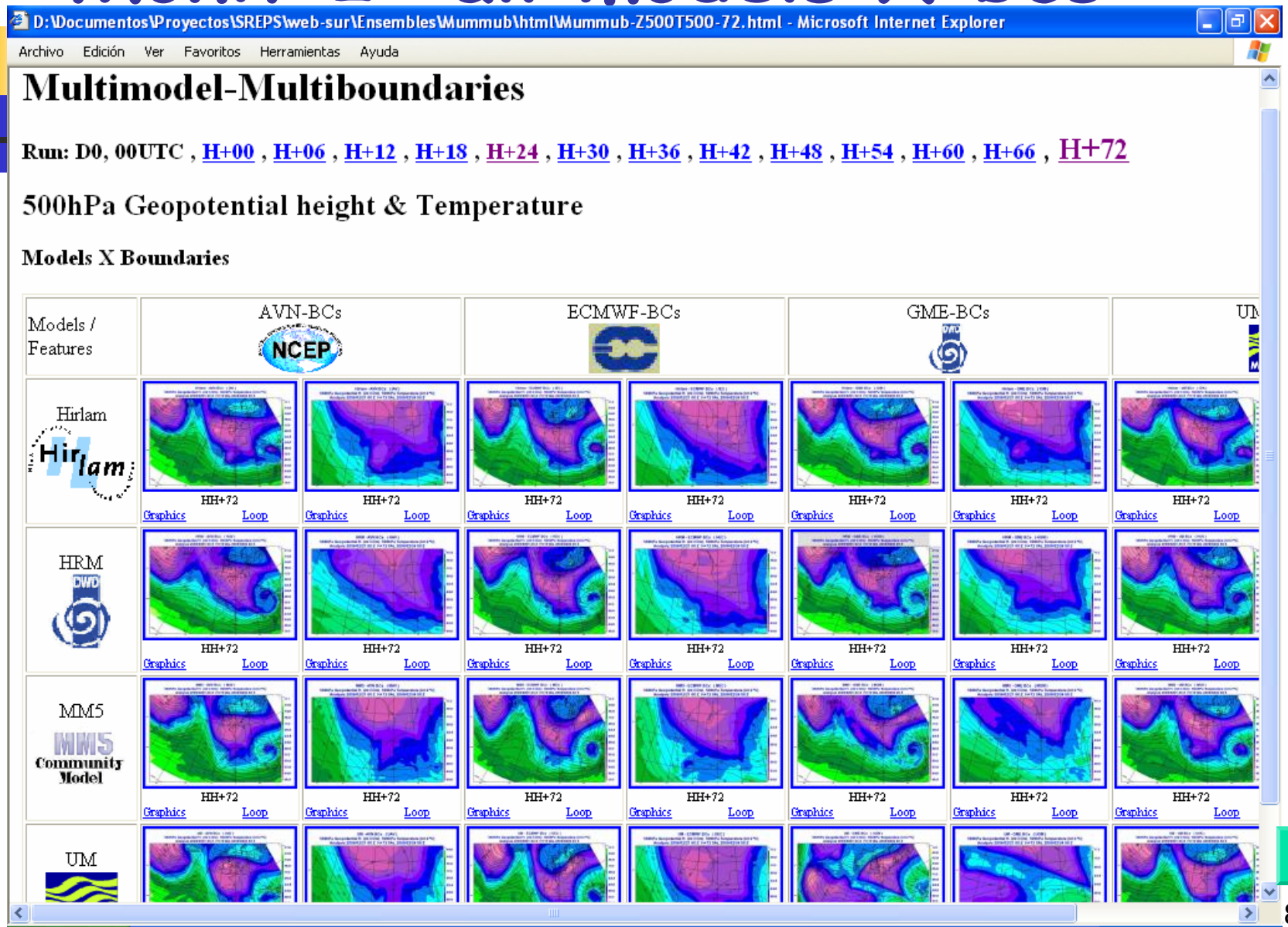
Intranet web server



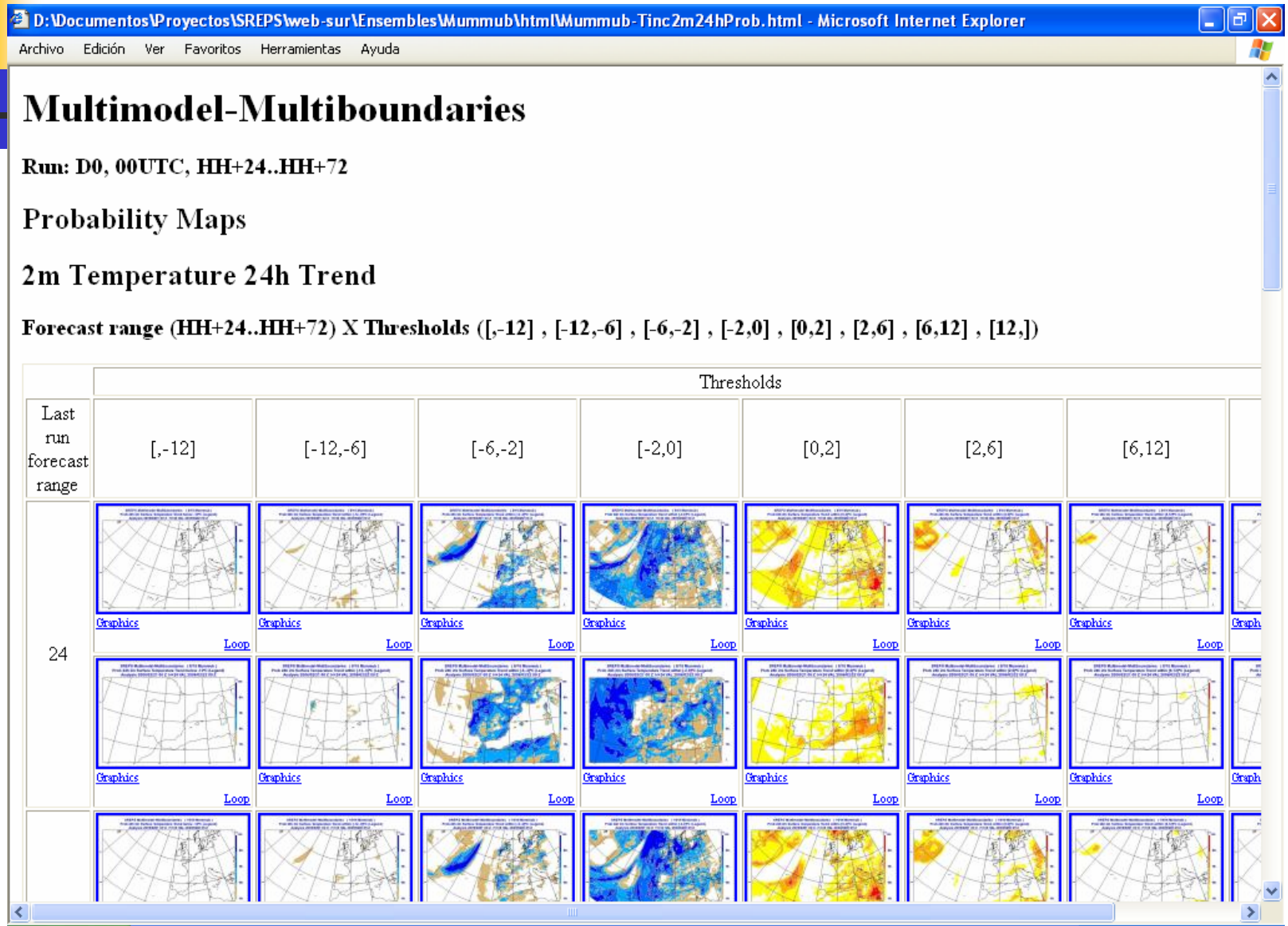
Monit 1: home


http://sur.inm.es/Ensembles/Mummub/Mummub-Index.html - Microsoft Internet Explorer
Archivo Edición Ver Favoritos Herramientas Ayuda
Atrás Búsqueda Favoritos
Dirección http://sur.inm.es/Ensembles/Mummub/Mummub-Index.html
Ir Vínculos
home
Today Multimodel-Multiboundaries
Deterministic outputs
Z500/T500 Models / Features
Pmsl/Pacum6h Models / Features
V300/S300 Models / Features
T2m Models / Features
V10m/S10m Models / Features
Pacum6h Models / Features
Probabilistic outputs
Probability maps
2m Temperature 24h trend
10m Wind speed
6h Accumulated precipitation
6h Accumulated Snow precipitation
Spread & Emean maps
Z500
Msl Pressure
EPSgrams
EPS-grams
Probabilistic Verification (D-4)
Spread-Skill Curves
Z500
T500
Msl Pressure
Rank Histograms
Z500
T500
Msl Pressure
ROC Curves
10m Wind speed
24h Accumulated precipitation
Internet
Inicio
Bandeja de ...
2 Explora...
Joint COST-...
http://sur.i...
Microsoft P...
Dibujo - Paint
ES
13:56

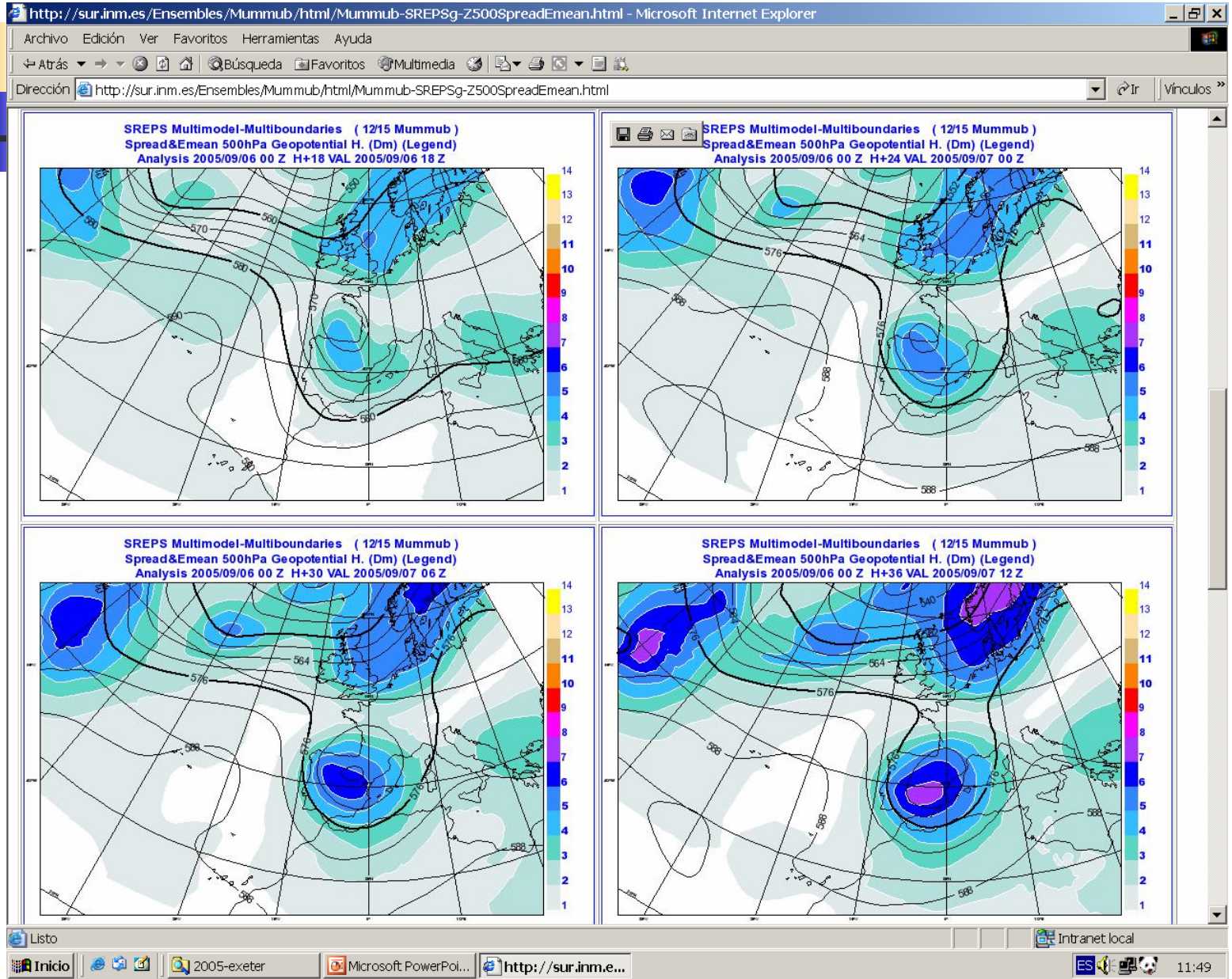
Monit 2: all models X bcs



Monit 3: All Prob 24h 2m T trend



Monit 4: Spread - Emean maps

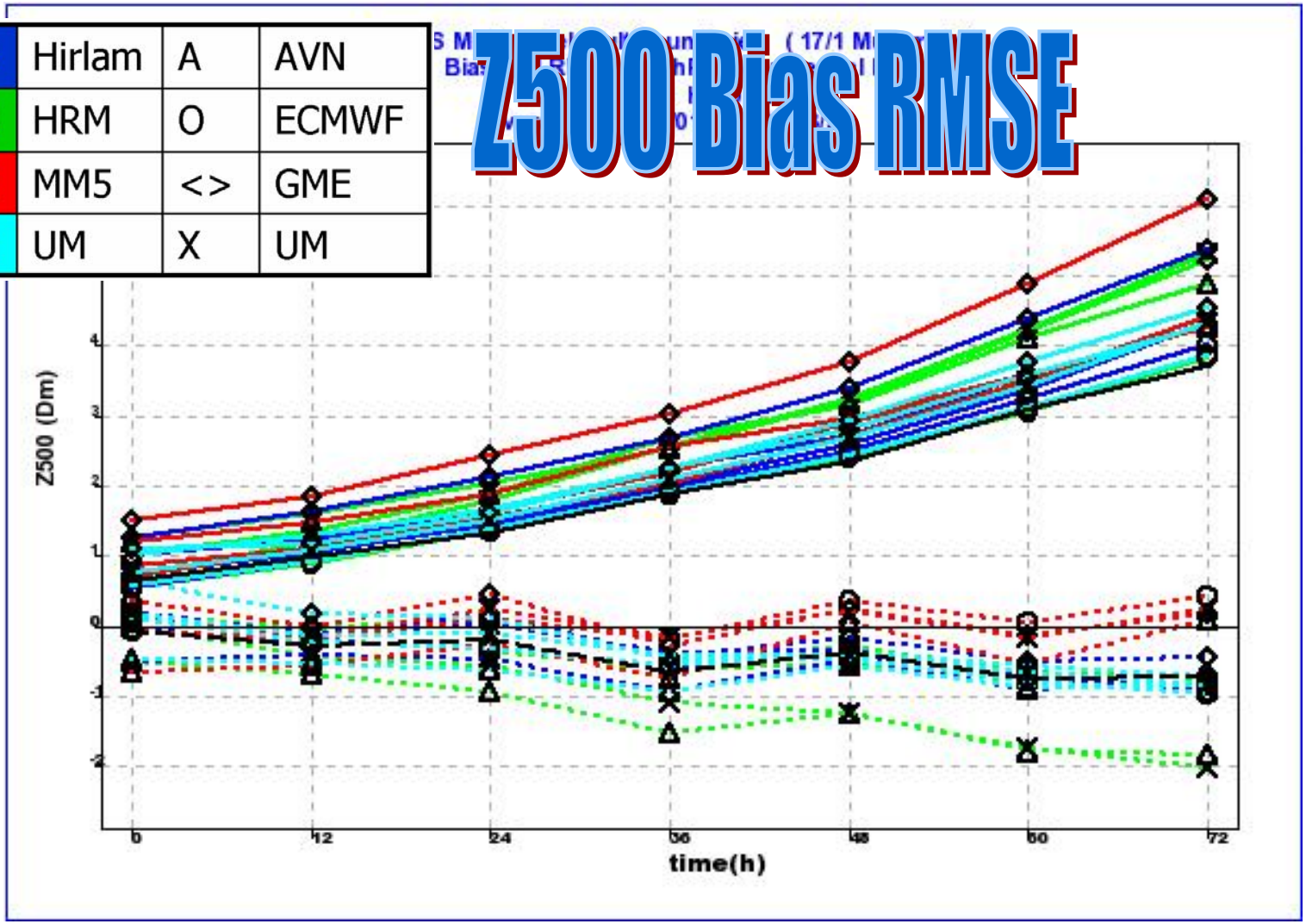


Validation

- 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)

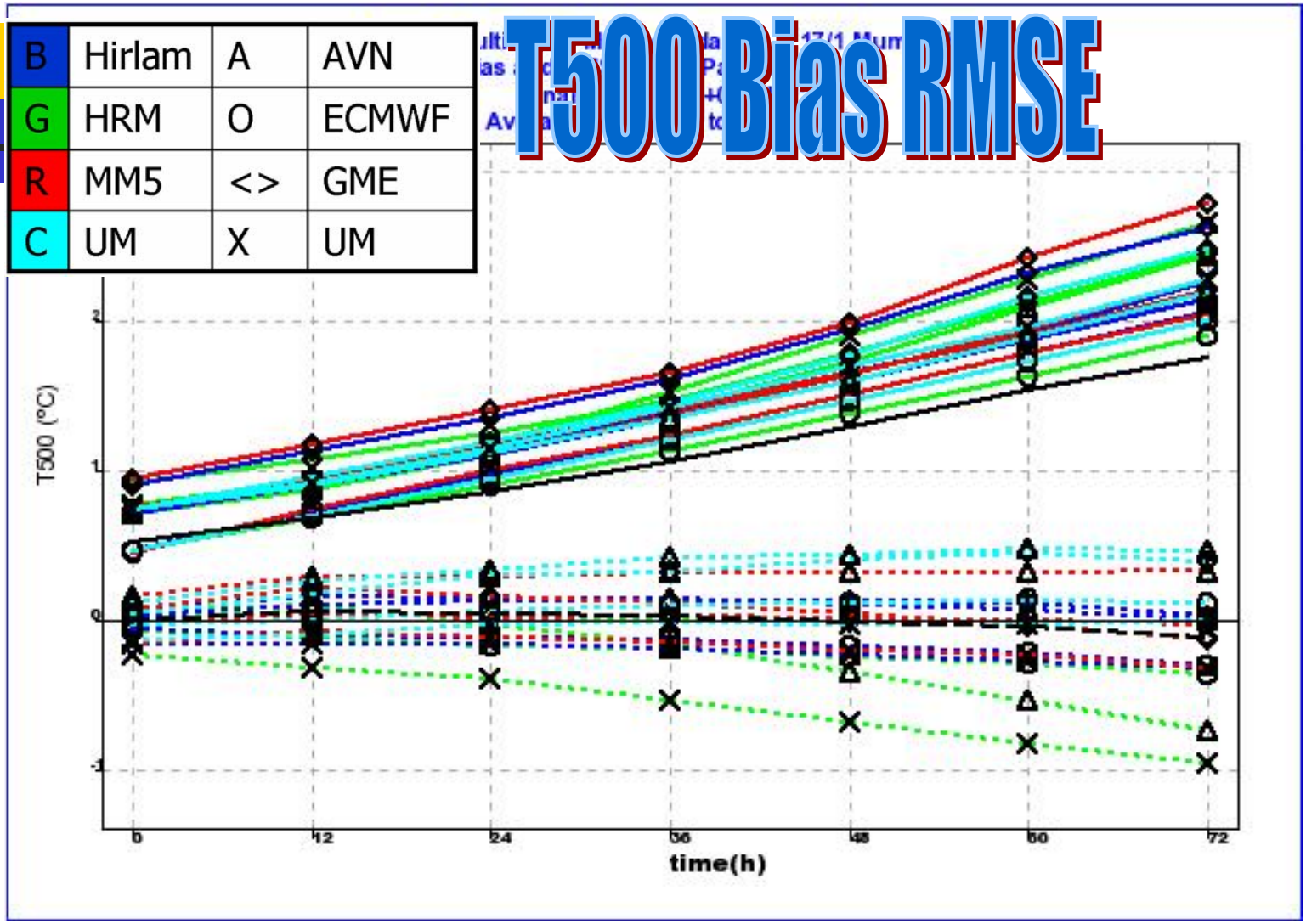
B	Hirlam	A	AVN
G	HRM	O	ECMWF
R	MM5	<>	GME
C	UM	X	UM

Z500 Bias RMSE



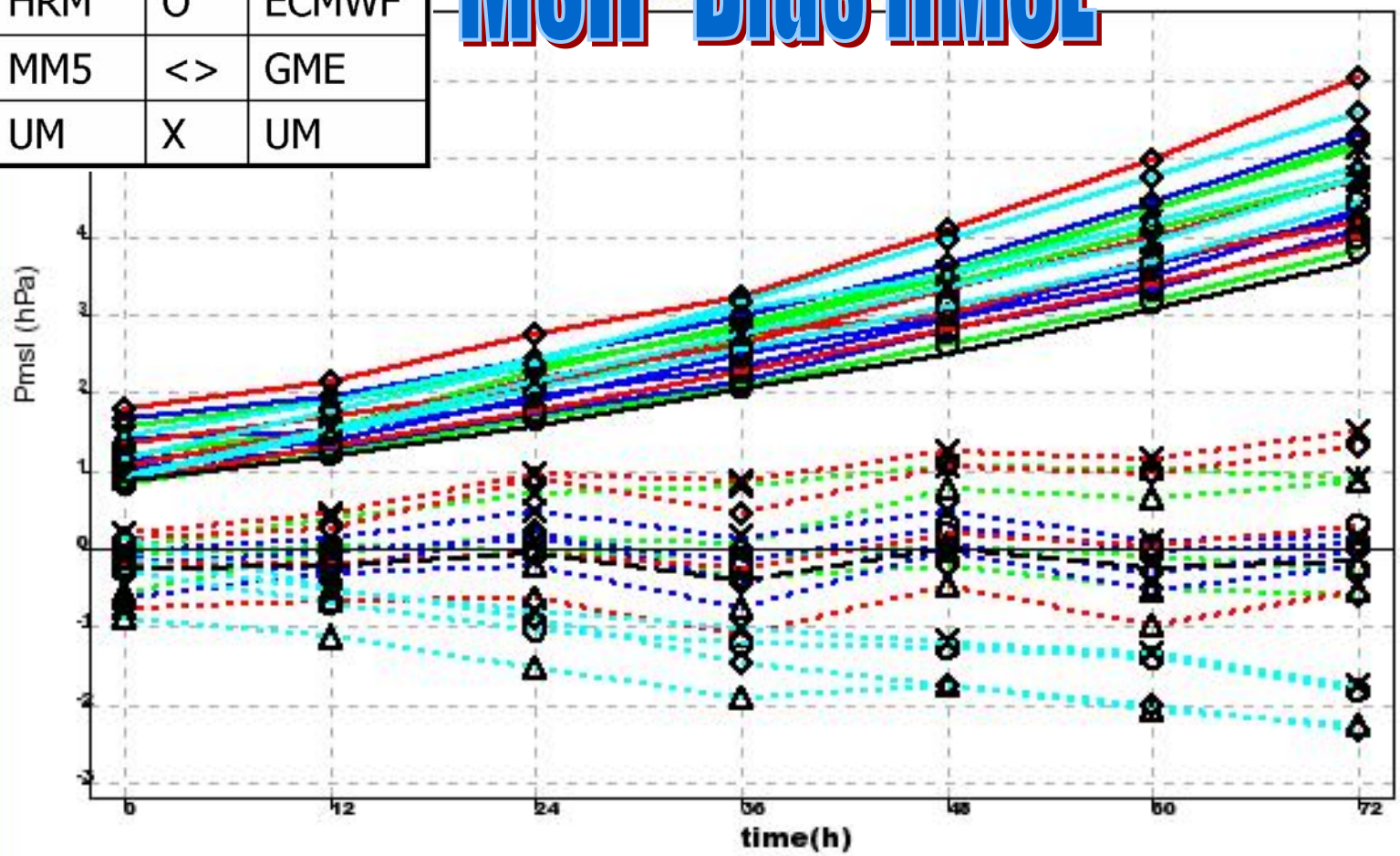
T500 Bias RMSE

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



MsIP Bias RMSE

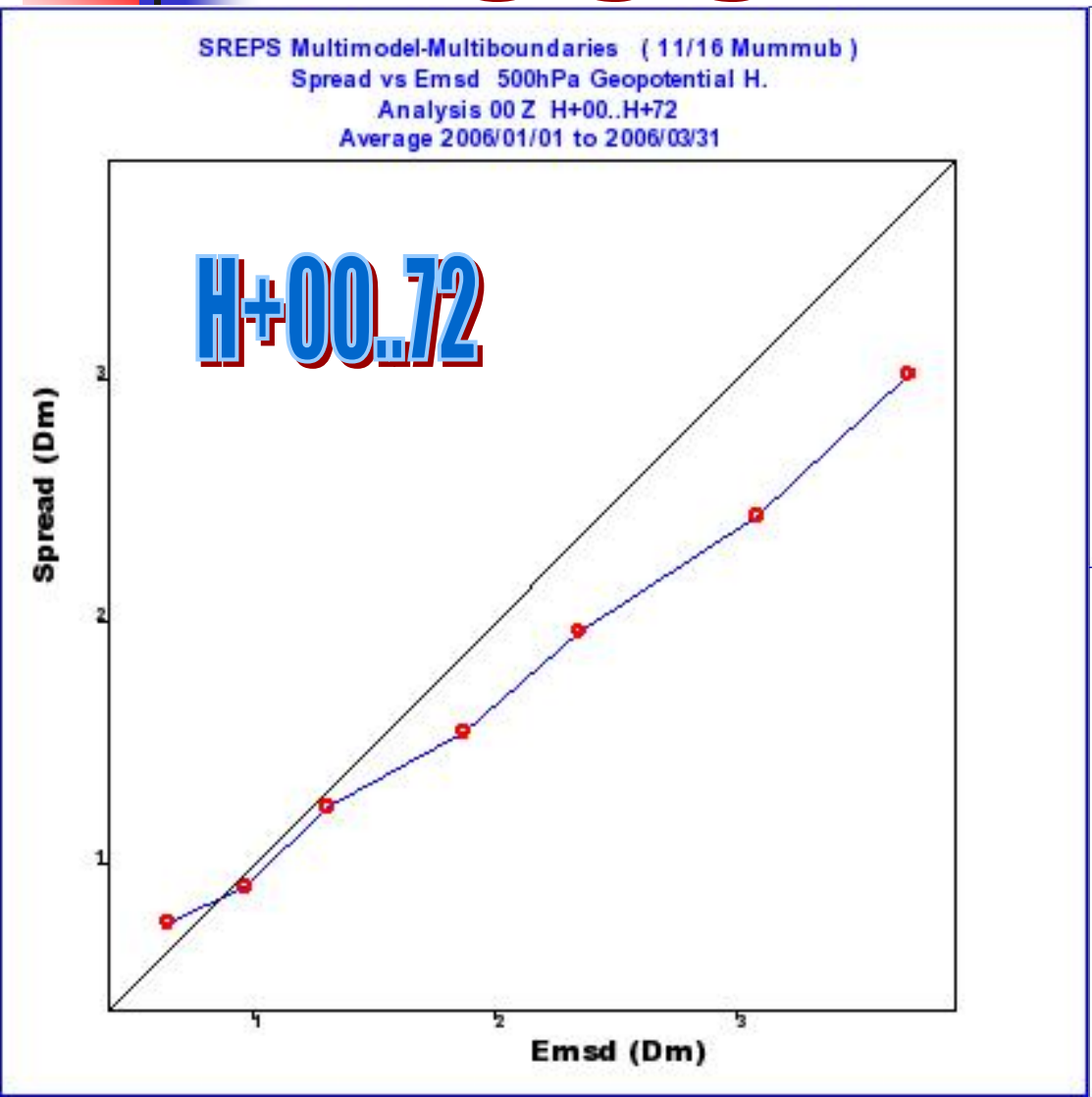
B	Hirlam	A	AVN
G	HRM	O	ECMWF
R	MM5	<>	GME
C	UM	X	UM

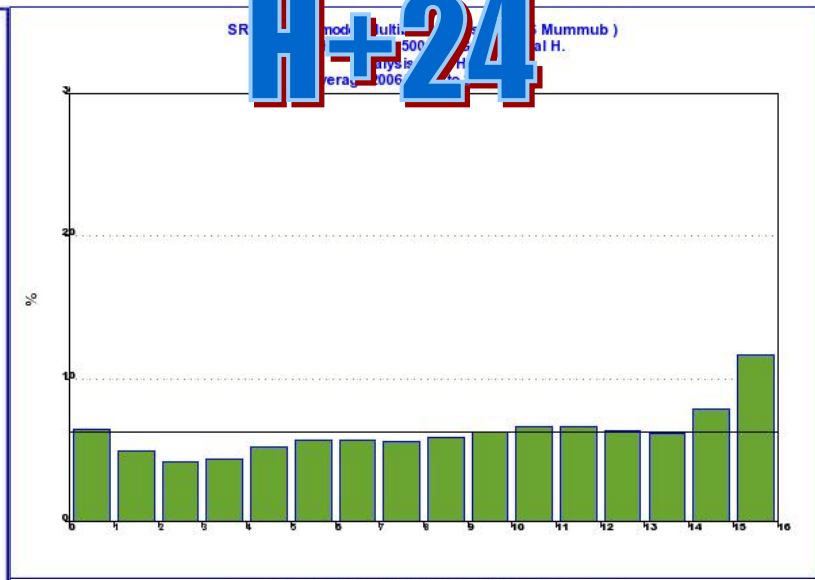


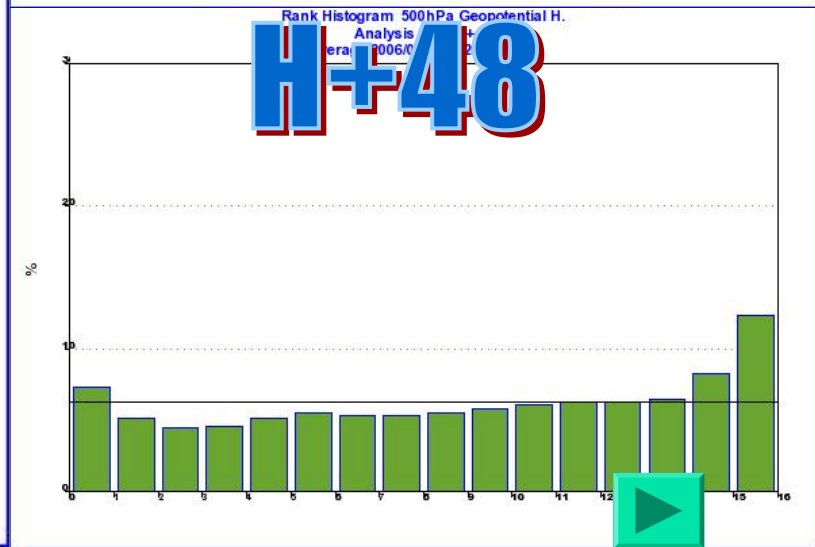
Probabilistic Verification

- 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

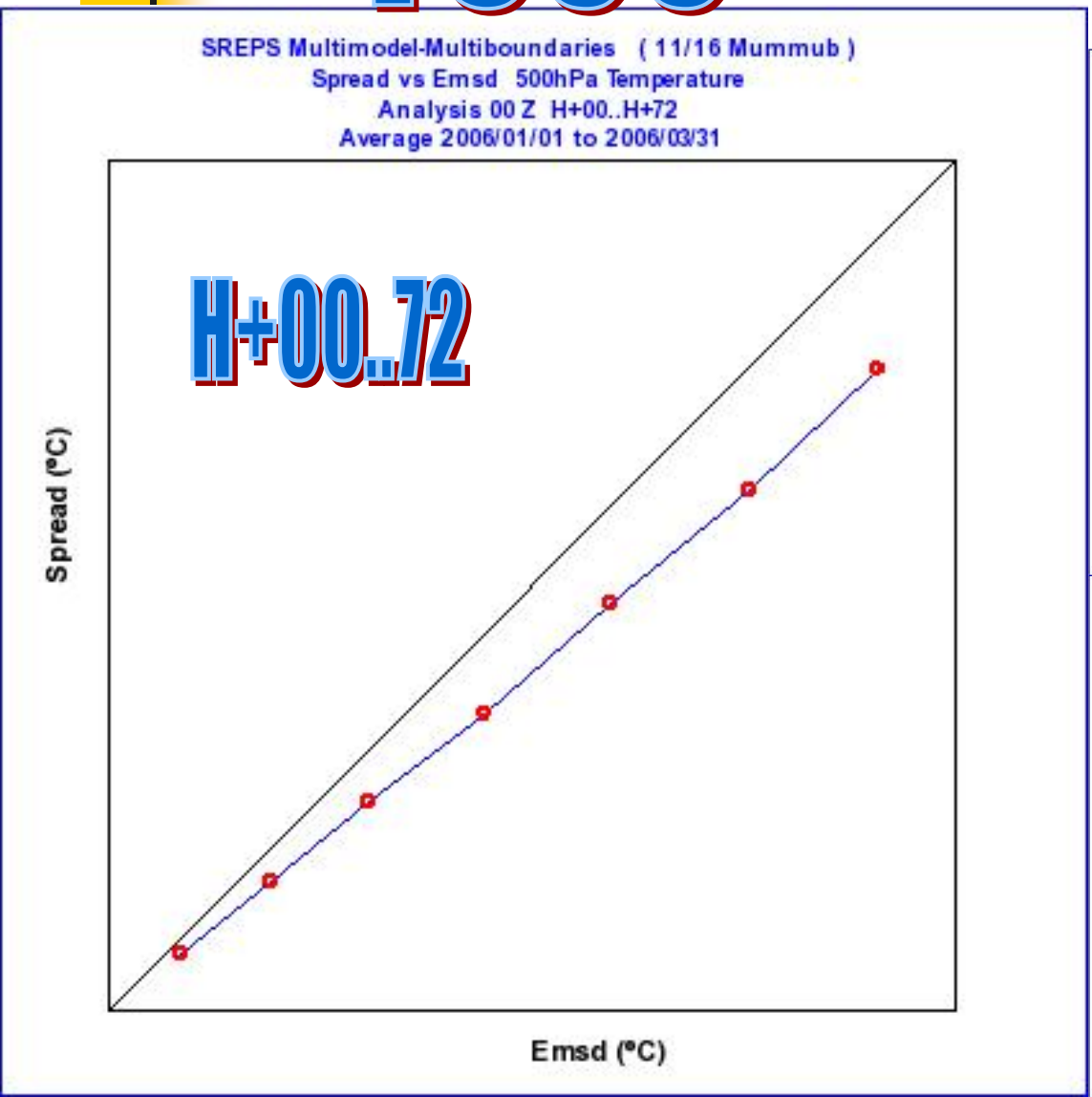
Z500


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
Spread (Dm)
Emsd (Dm)
1
2
3

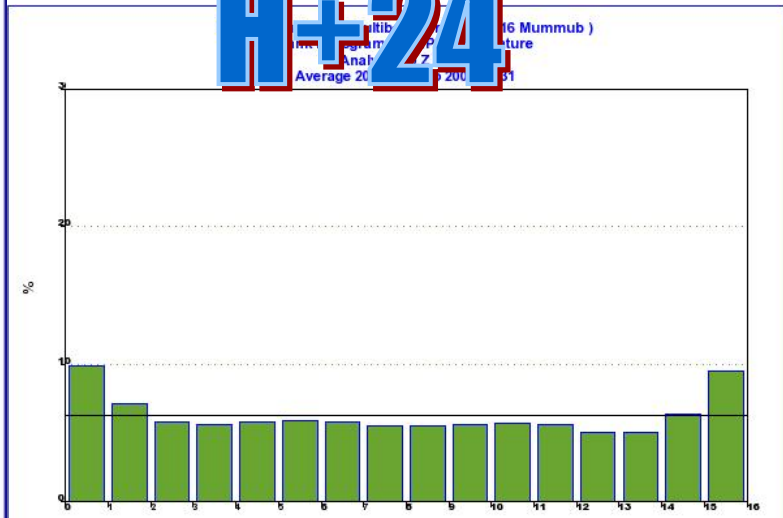

H+24
%


Rank Histogram 500hPa Geopotential H.
Analysis
H+48
%

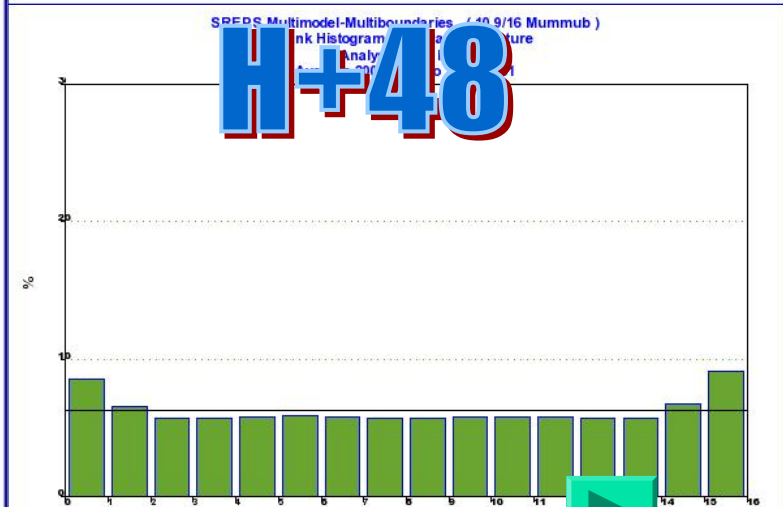
T500


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)

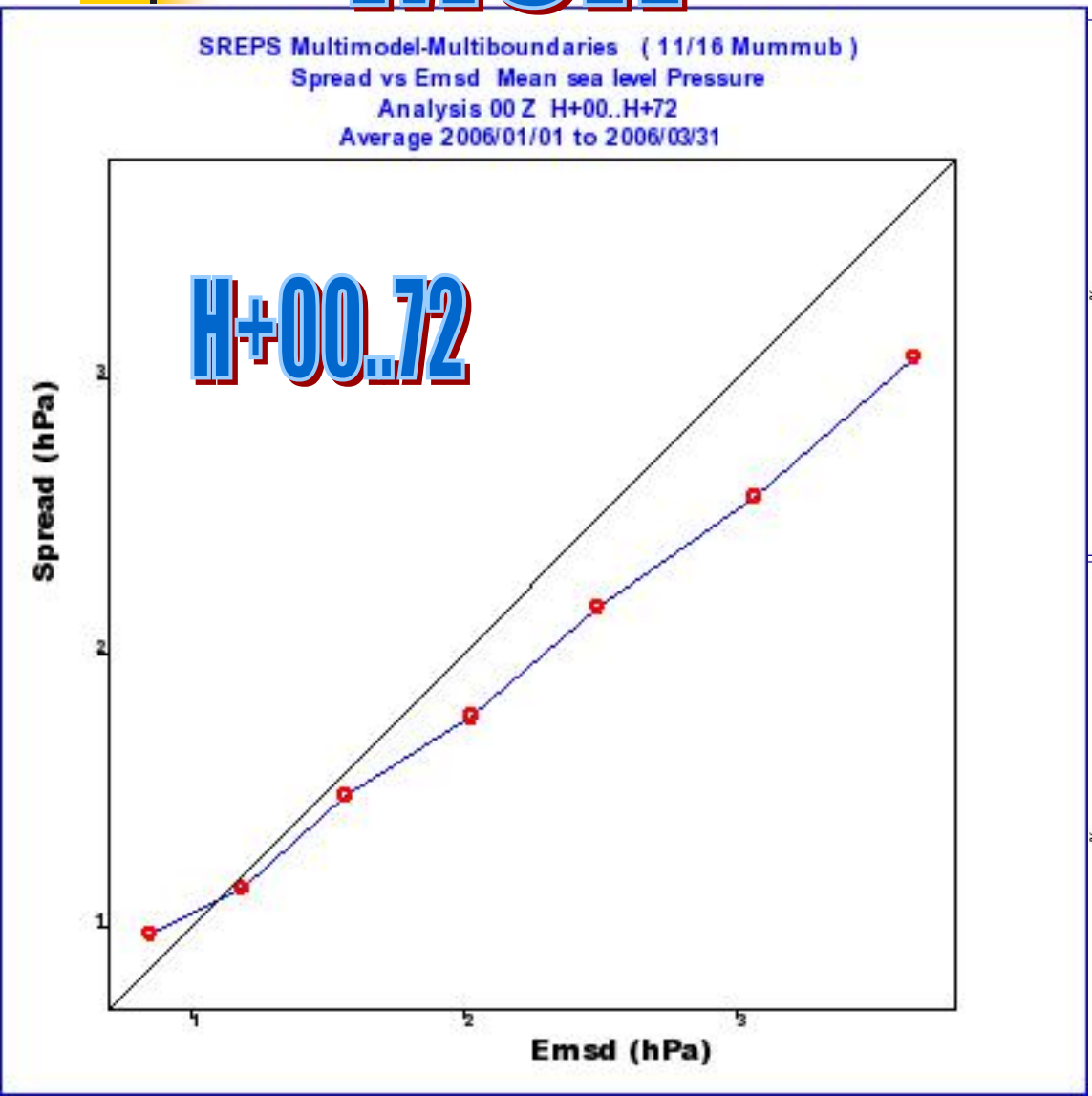
H+24

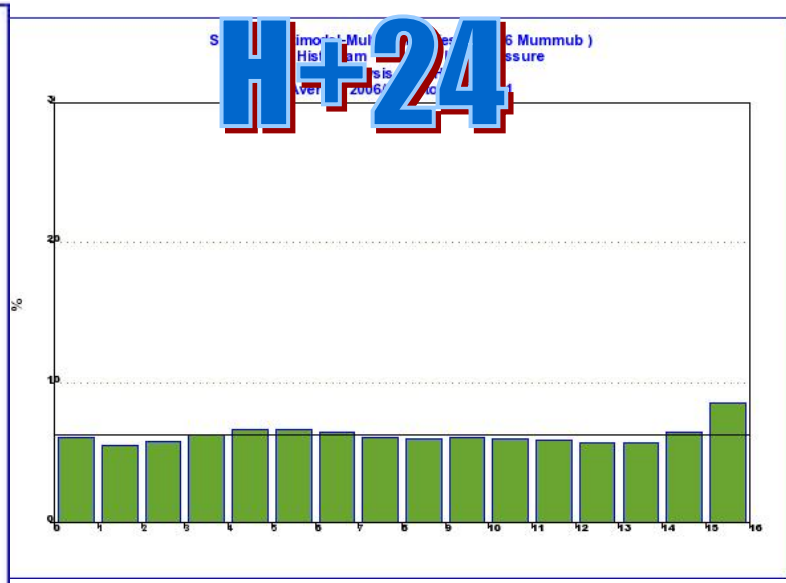

%

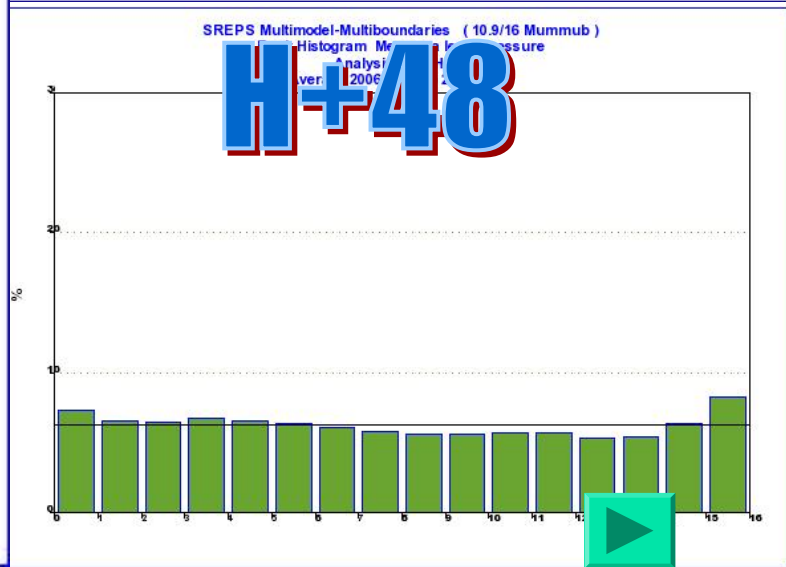
H+48


%

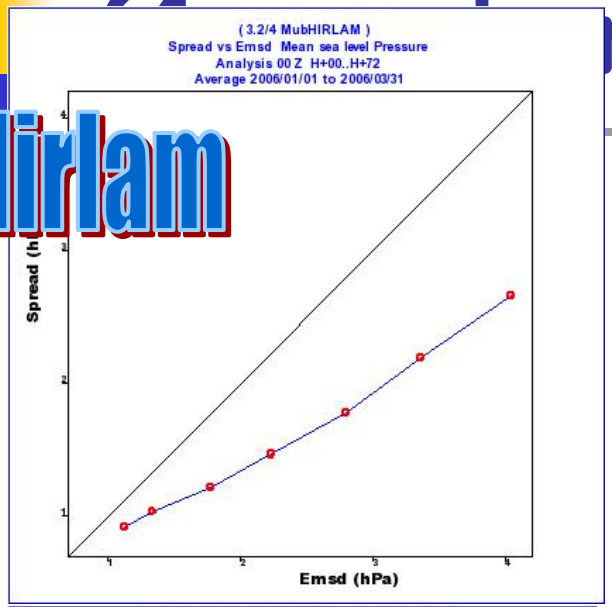
MsIP

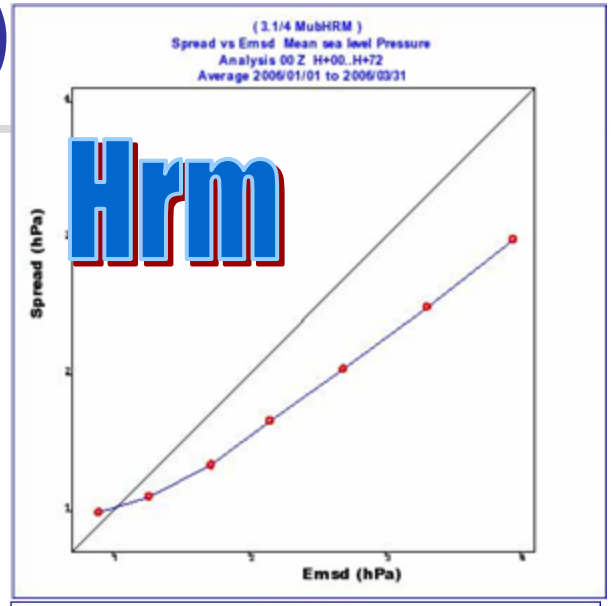

SREPS Multimodel-Multiboundaries (11/16 Mummub)
Spread vs Emsd Mean sea level Pressure
Analysis 00 Z H+00..H+72
Average 2006/01/01 to 2006/03/31
H+00..72
Spread (hPa)
Emsd (hPa)
1
2
3

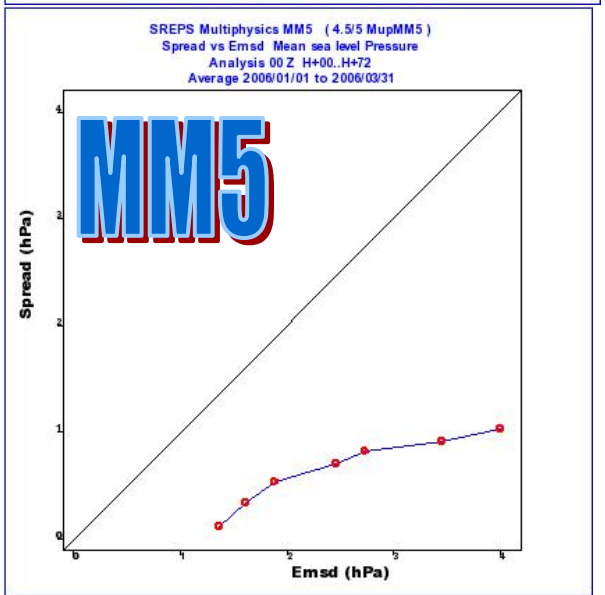

H+24
%
0
10
20

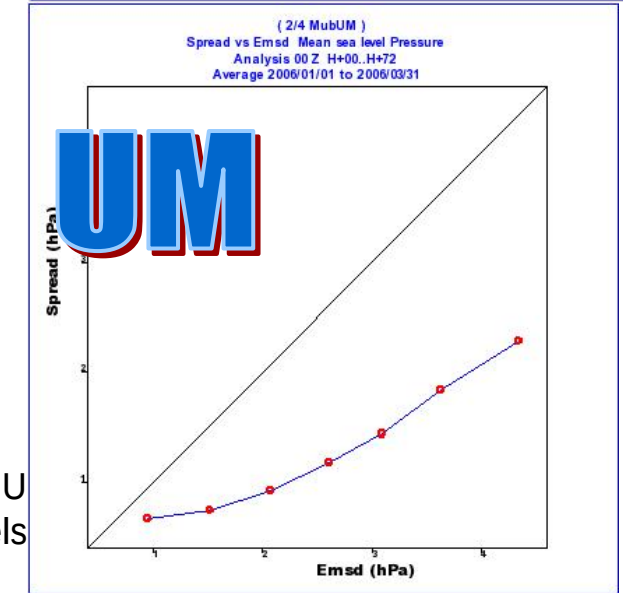

SREPS Multimodel-Multiboundaries (10.9/16 Mummub)
H+48
%
0
10
20

Single model Ensembles
(rs each)

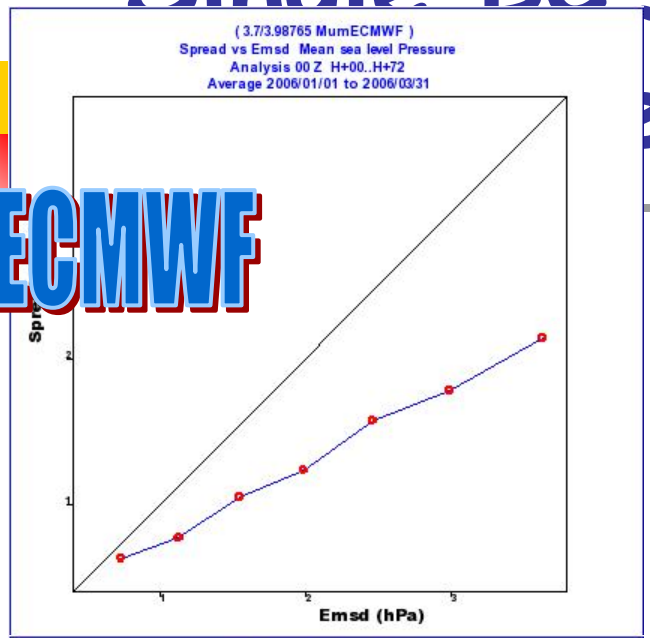




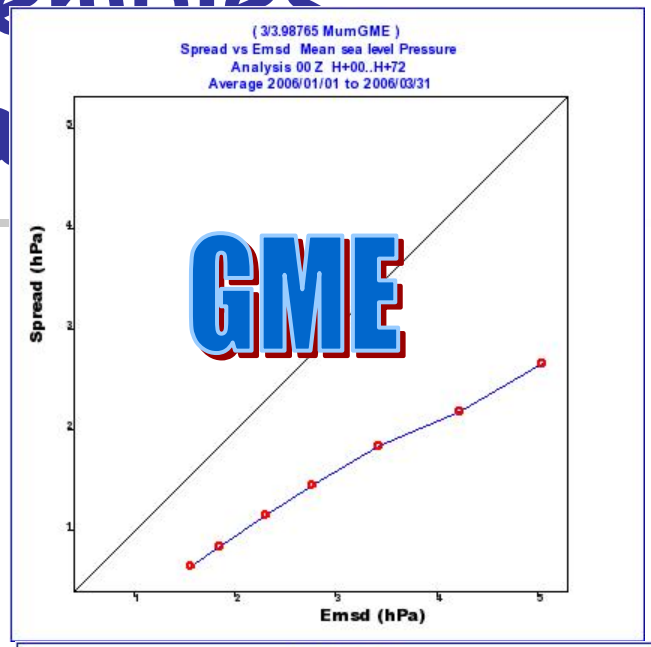




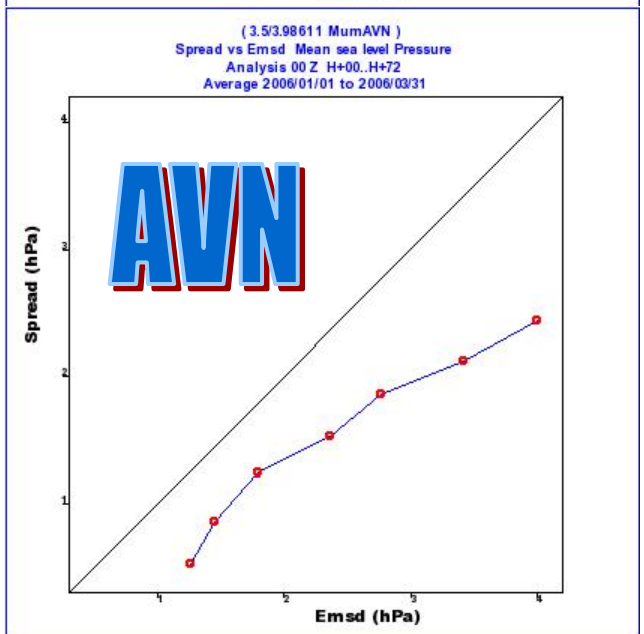
Single BC's Ensembles
ers ea



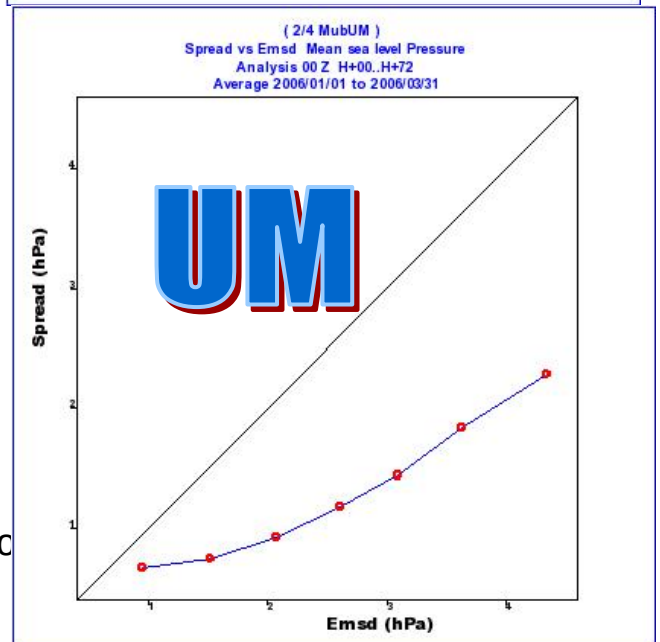
ECMWF



GME

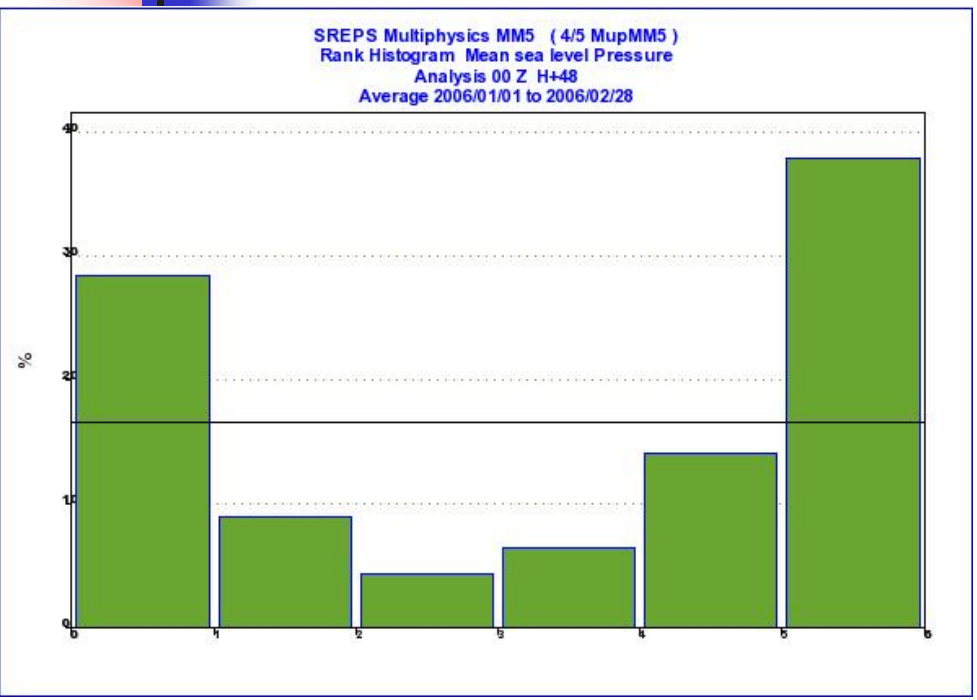


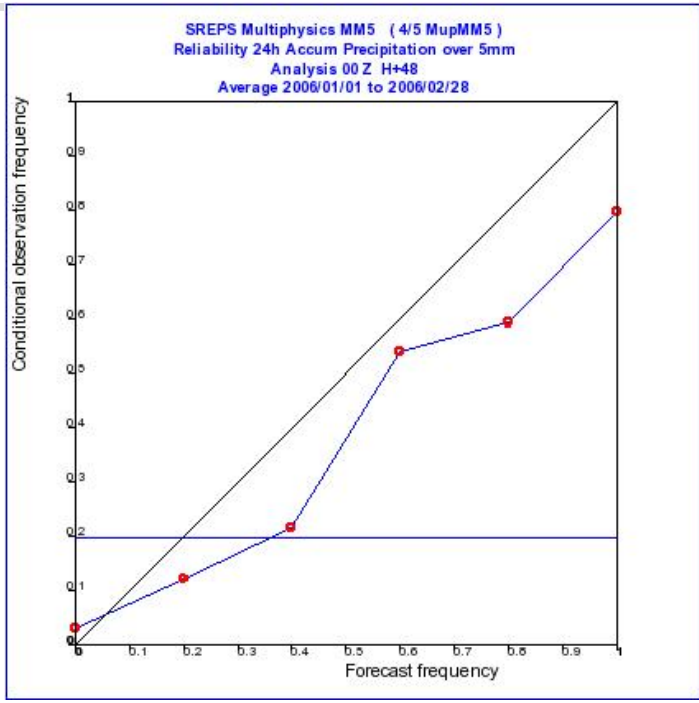
AVN



UM

MM5 Multi-physics (5 members)

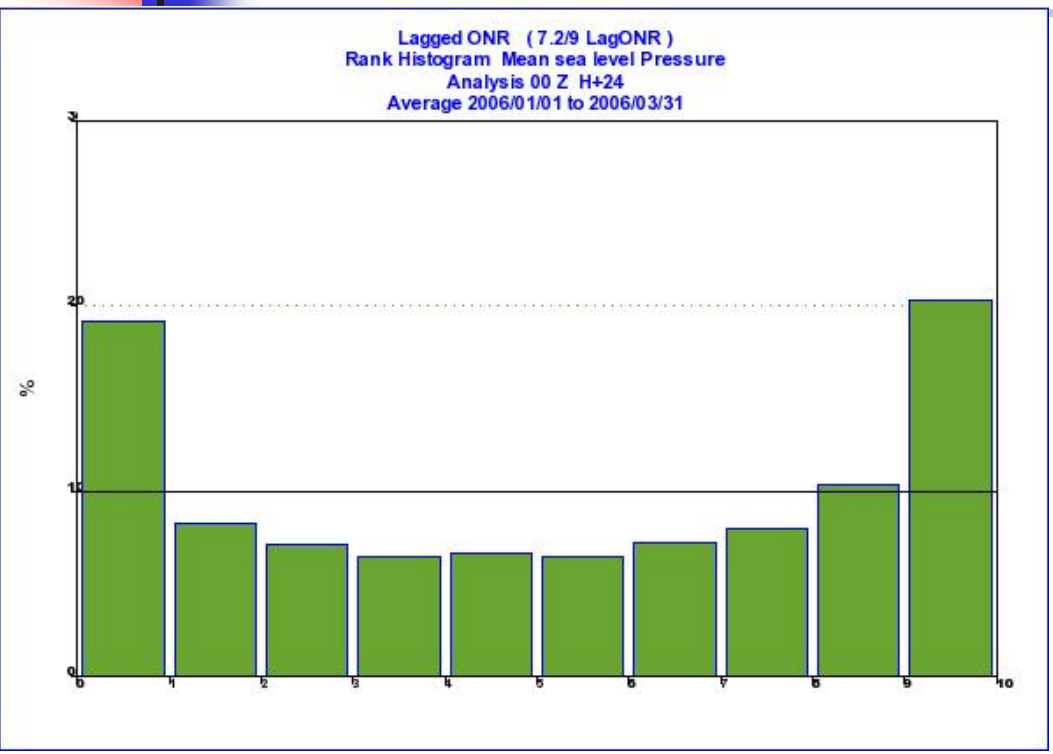


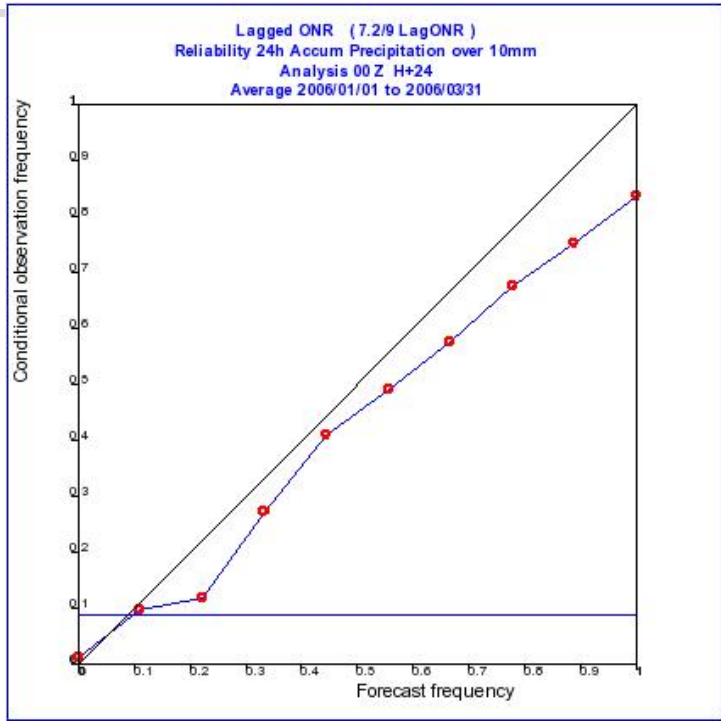


MslP H+48 Rank Hist.

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

Deterministic Hirlam Lagged Ensemble (9 members)



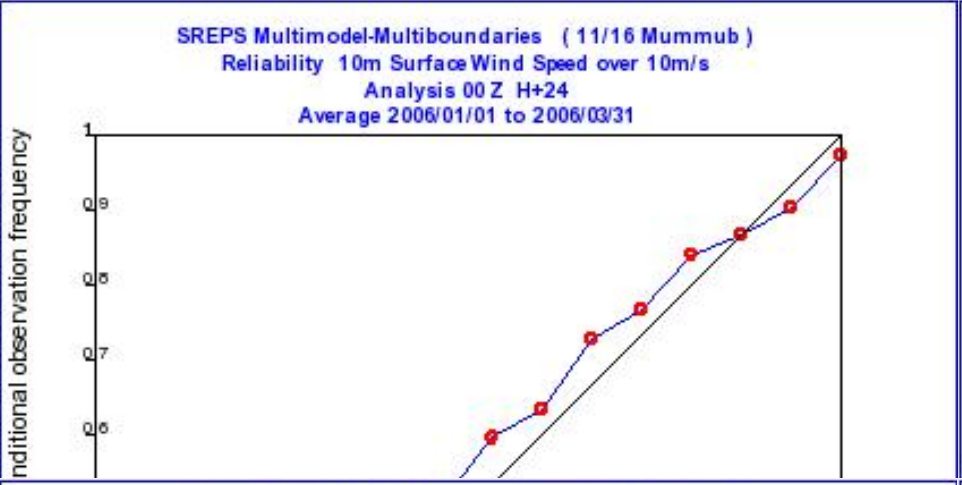


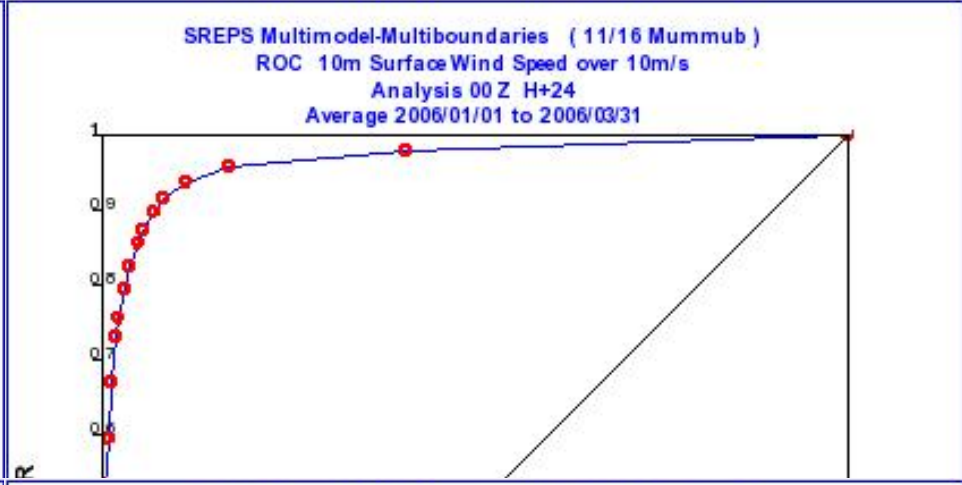
Mslp H+24 Rank Hist.

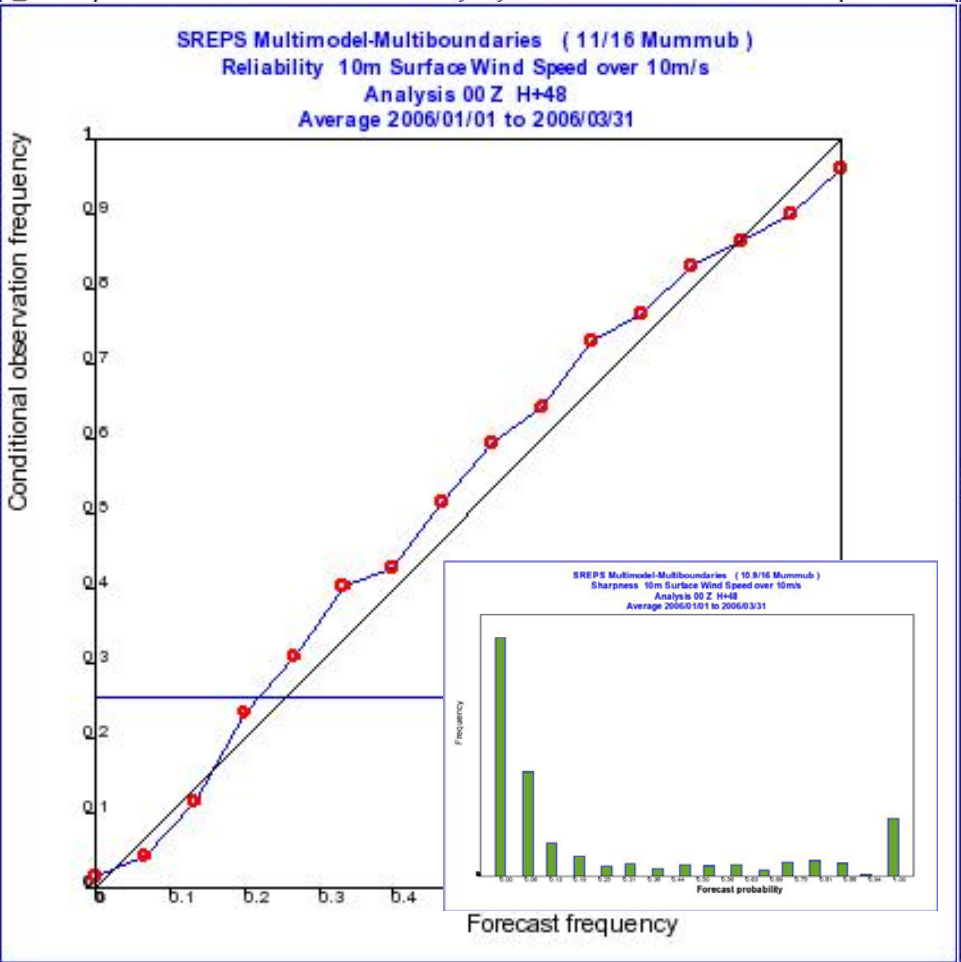
24 h. Acc. Precip H+24 > 5 mm.

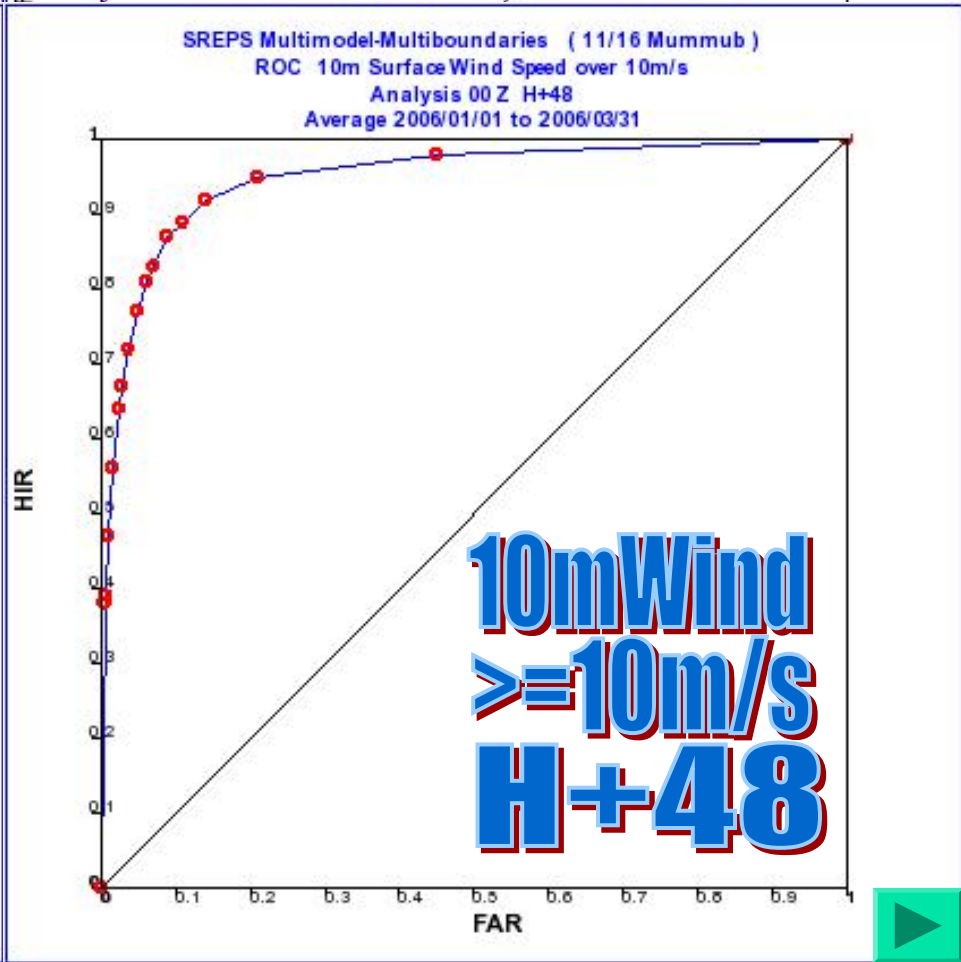
Surface parameters

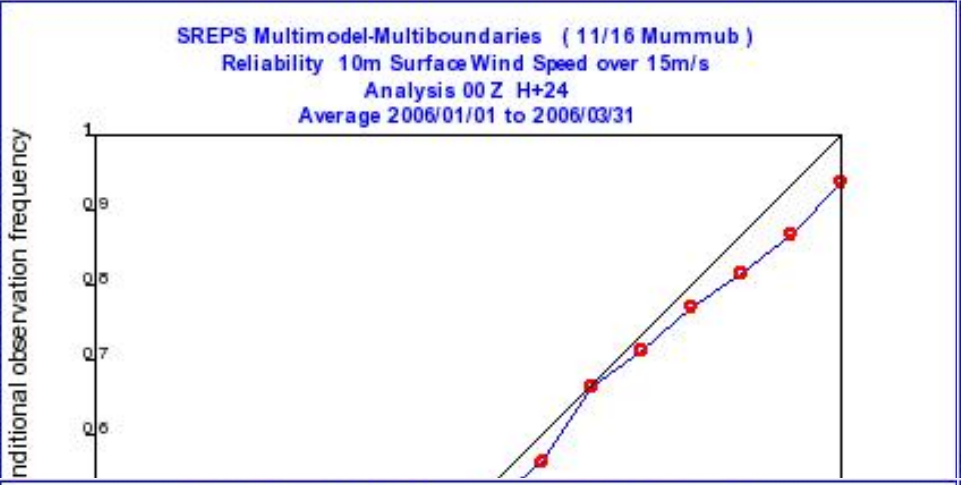
- Parameters
  - 10m Wind Speed
    - Thresholds: 10m/s, 15m/s
  - 24h Accumulated Precipitation
    - Thresholds: 1mm, 5mm, 10mm, 20mm
- Scores
  - Reliability diagrams
  - ROC curves
  - RV plots
- Forecast lengths:
  - H+24, H+48

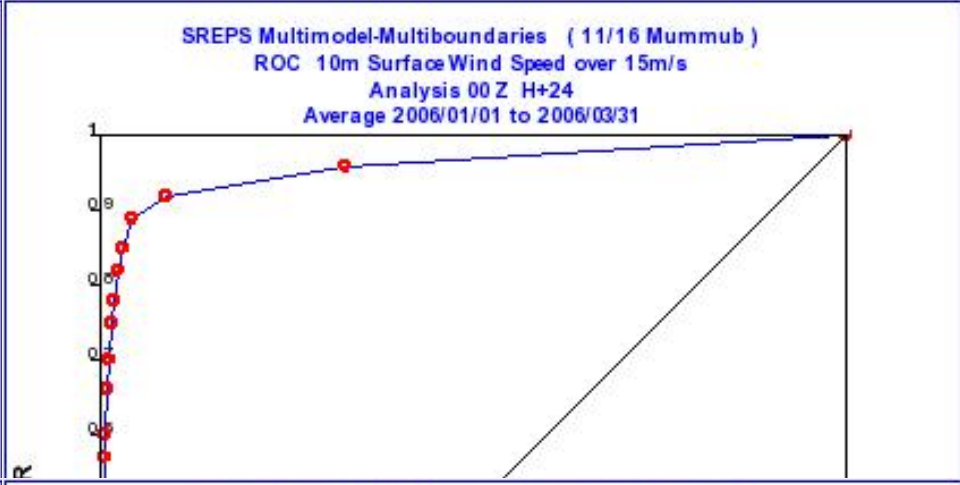

SREPS Multimodel-Multiboundaries (11/16 Mummub)
Reliability 10m Surface Wind Speed over 10m/s
Analysis 00 Z H+24
Average 2006/01/01 to 2006/03/31
nditional observation frequency

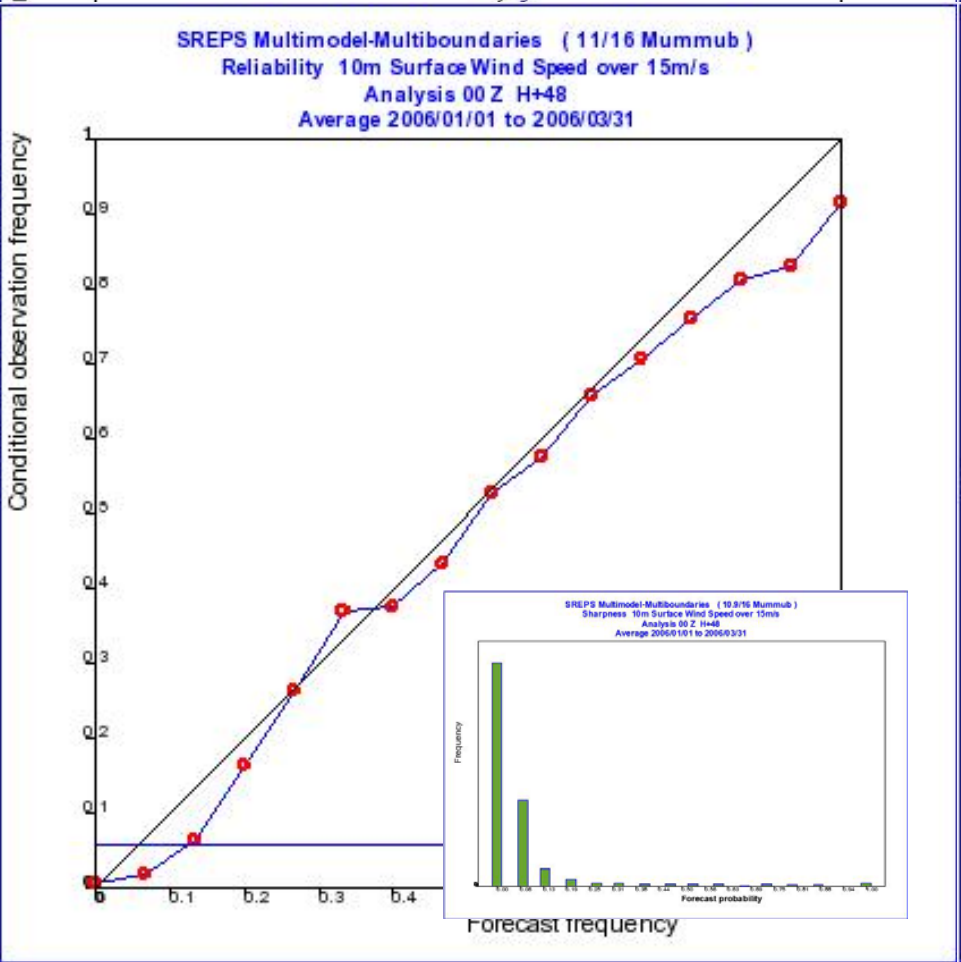

SREPS Multimodel-Multiboundaries (11/16 Mummub)
ROC 10m Surface Wind Speed over 10m/s
Analysis 00 Z H+24
Average 2006/01/01 to 2006/03/31

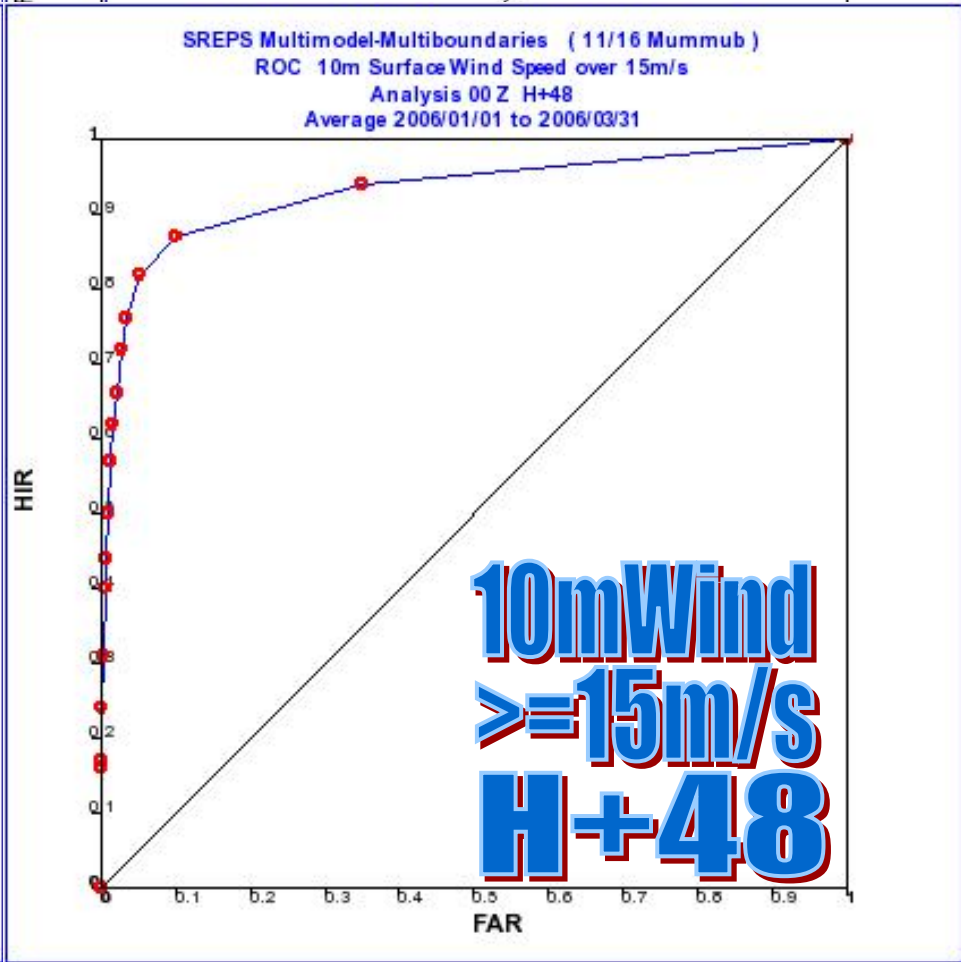

SREPS Multimodel-Multiboundaries (11/16 Mummub)
Reliability 10m Surface Wind Speed over 10m/s
Analysis 00 Z H+48
Average 2006/01/01 to 2006/03/31
Conditional observation frequency
Forecast frequency
SREPS Multimodel-Multiboundaries (10.9/16 Mummub)
Sharpness 10m Surface Wind Speed over 10m/s
Analysis 00 Z H+48
Average 2006/01/01 to 2006/03/31
Frequency
Forecast probability


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
FAR
10mWind
>=10m/s
H+48


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
nditional 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


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
Forecast frequency
SREPS Multimodel-Multiboundaries (10.9/16 Mummub)
Sharpness 10m Surface Wind Speed over 15m/s
Analysis 00 Z H+48
Average 2006/01/01 to 2006/03/31
Frequency
Forecast probability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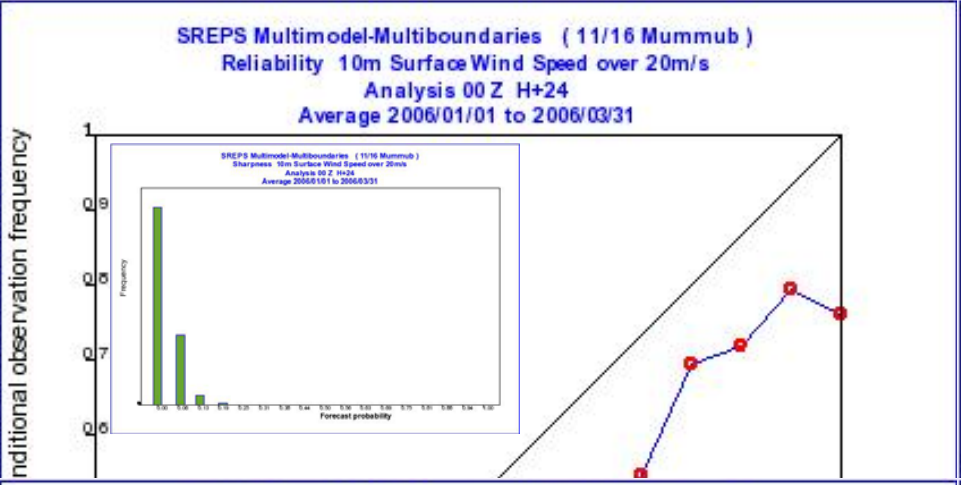
ROC 10m Surface Wind Speed over 15m/s
Analysis 00 Z H+48
Average 2006/01/01 to 2006/03/31
HIR
FAR
10mWind
>=15m/s
H+48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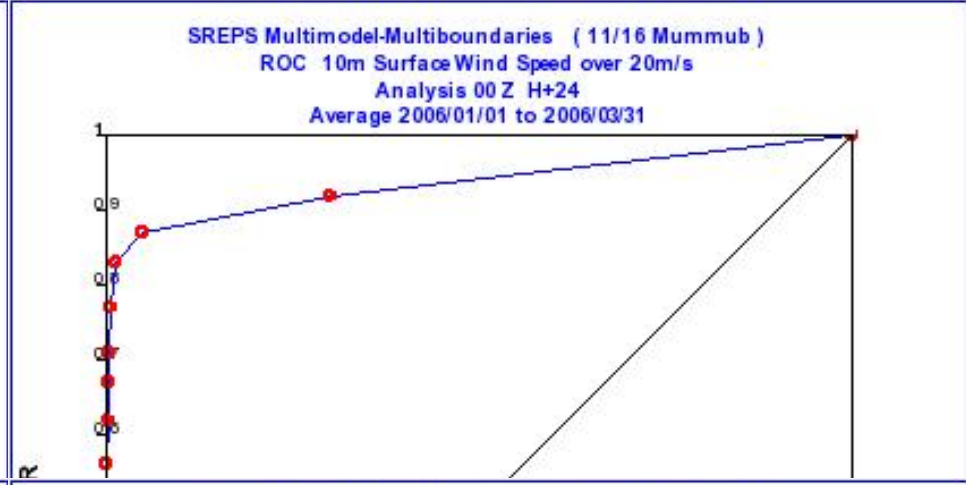
Reliability 10m Surface Wind Speed over 20m/s
Analysis 00 Z H+24
Average 2006/01/01 to 2006/03/31
nditional observation frequency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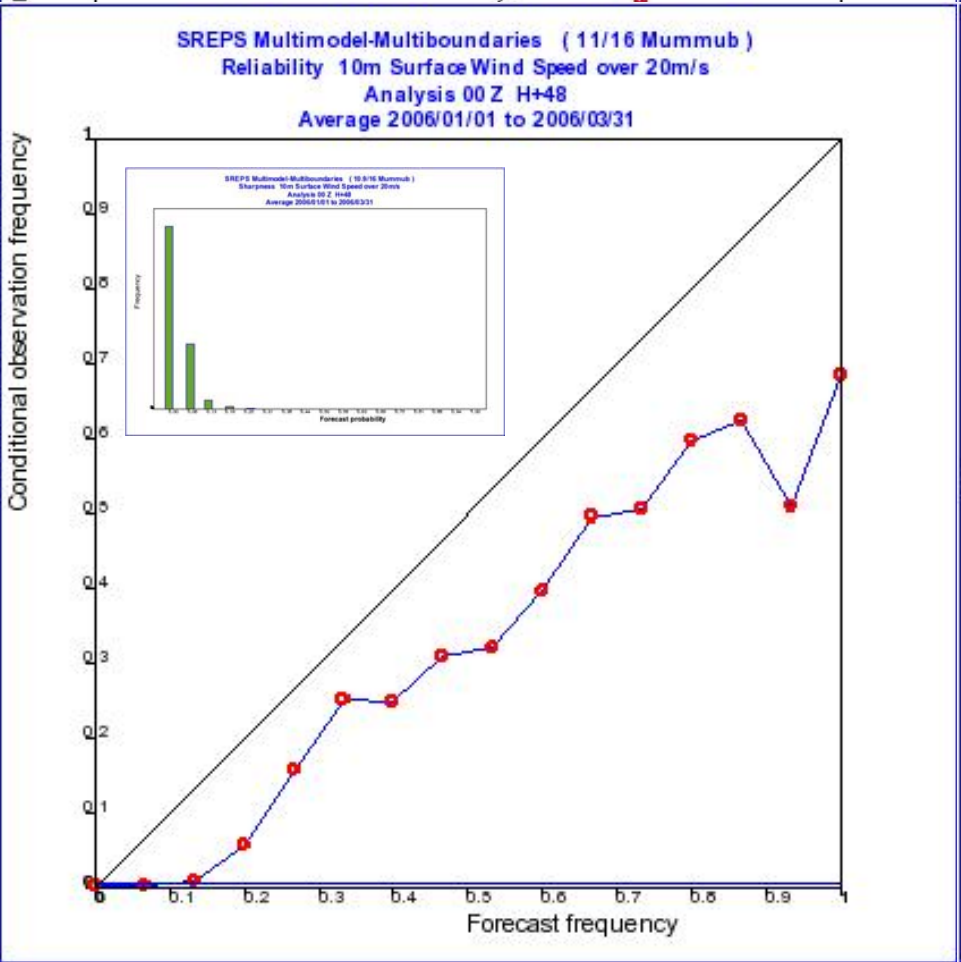
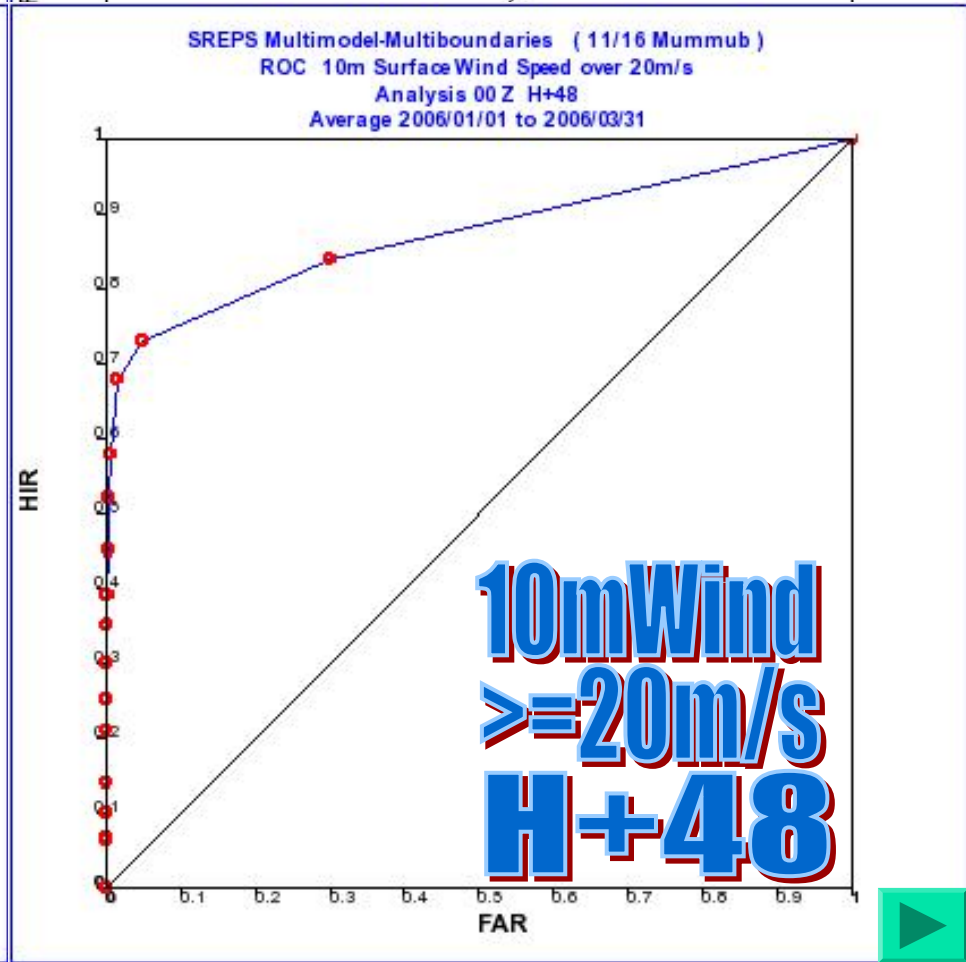
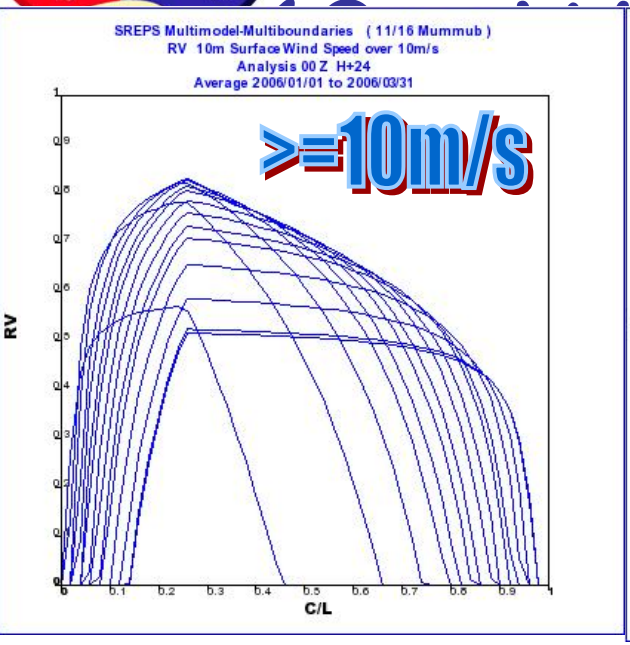
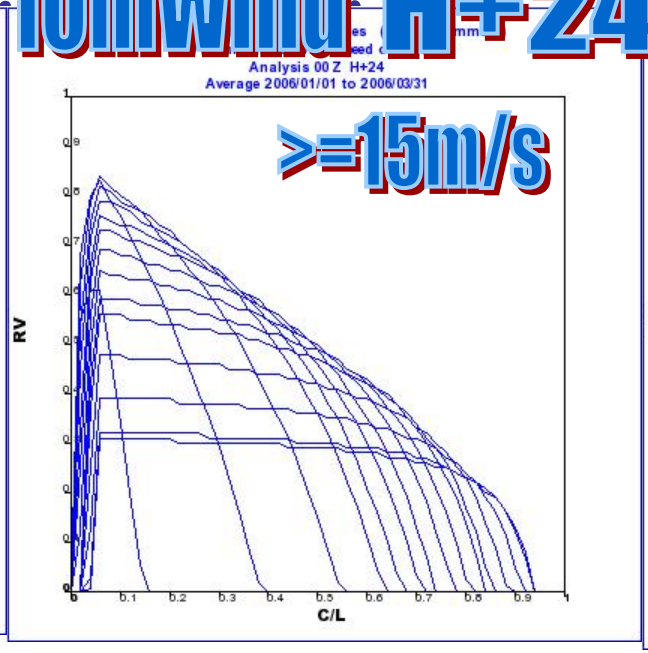
ROC 10m Surface Wind Speed over 20m/s
Analysis 00 Z H+24
Average 2006/01/01 to 2006/03/31

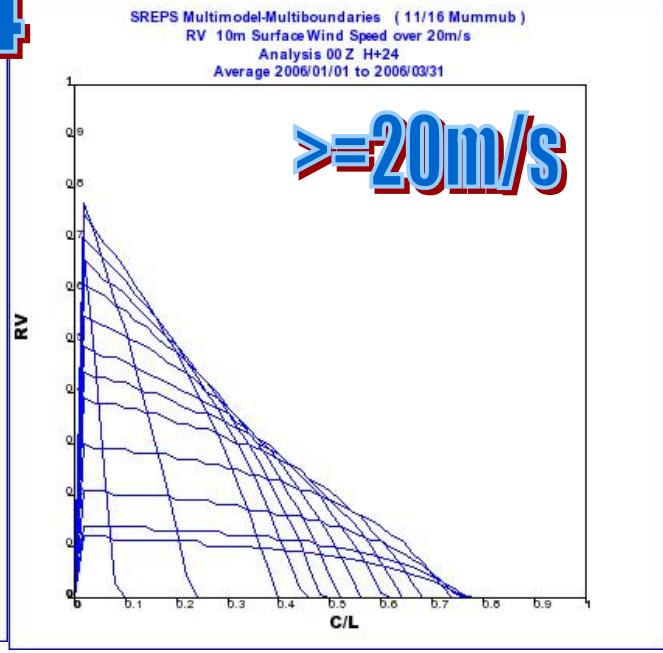

SREPS Multimodel-Multiboundaries (11/16 Mummub)
Reliability 10m Surface Wind Speed over 20m/s
Analysis 00 Z H+48
Average 2006/01/01 to 2006/03/31
Conditional observation frequency
Forecast frequency


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
FAR
10mWind
>=20m/s
H+48

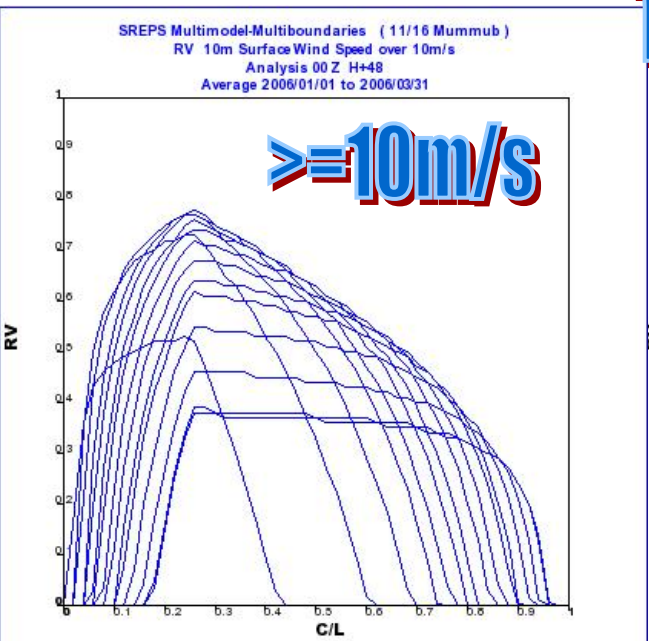
10mWind H+24

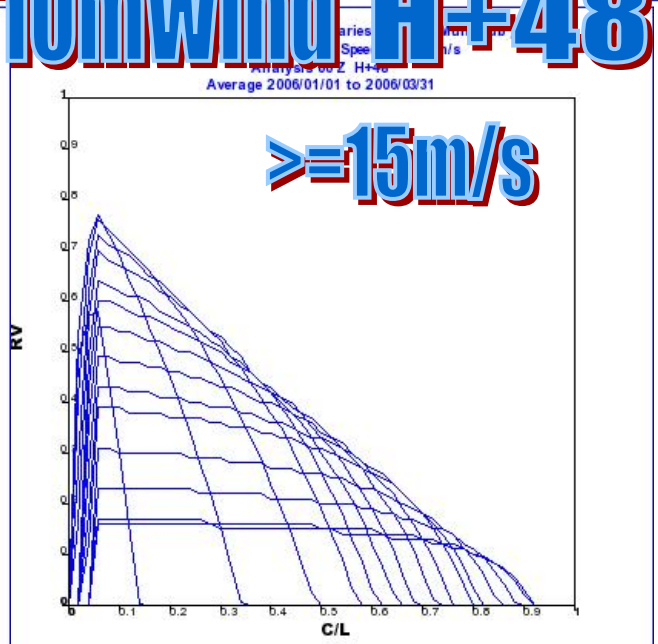


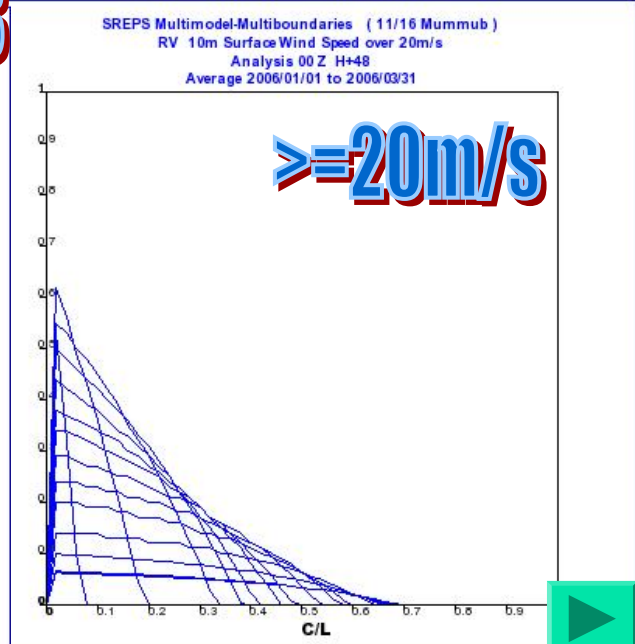


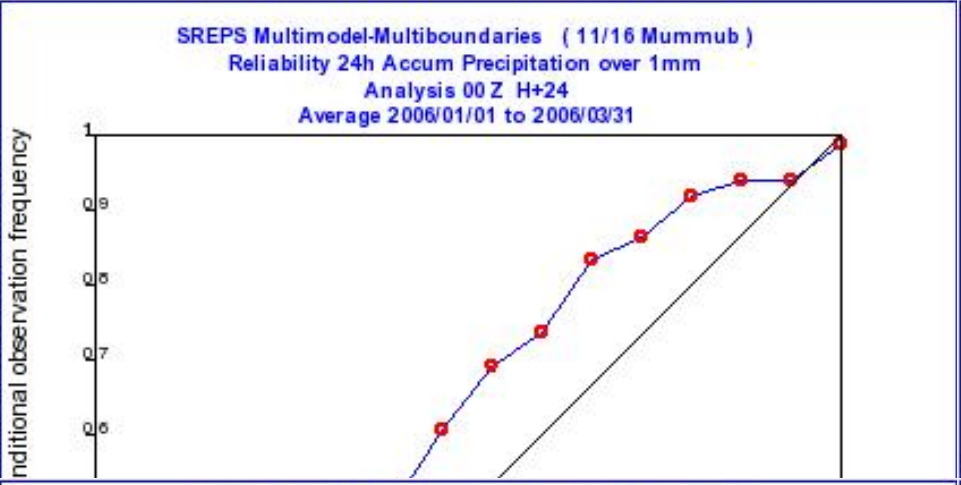


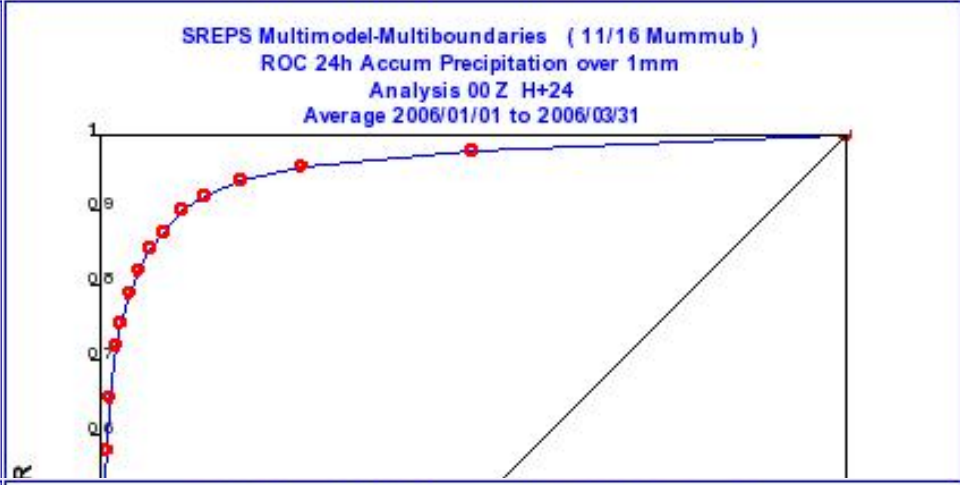
10mWind H+48








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
nditional observation frequency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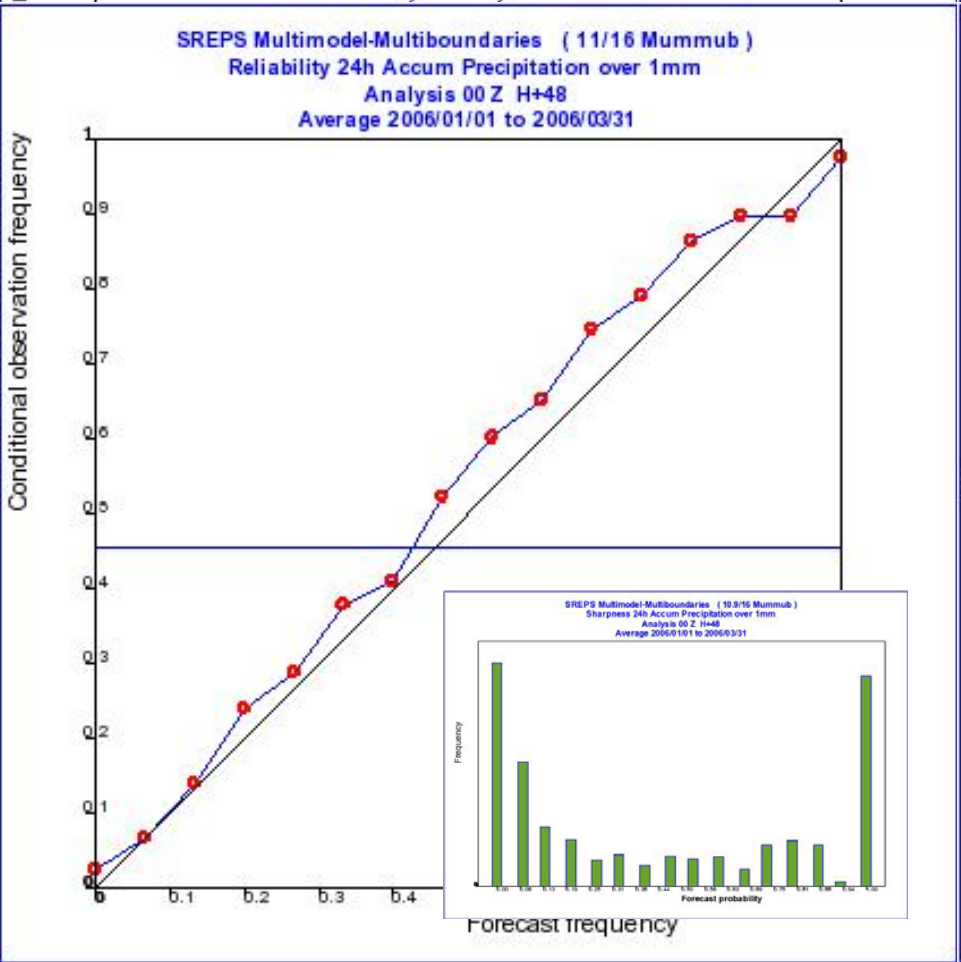
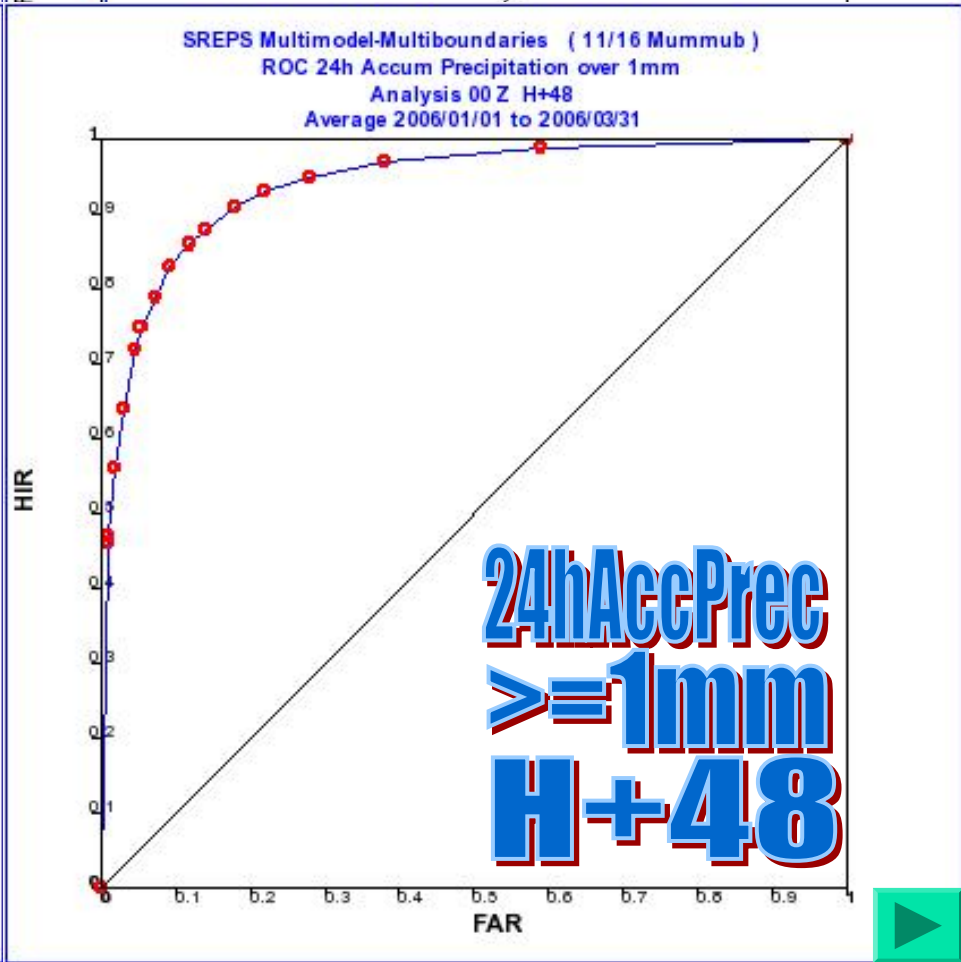
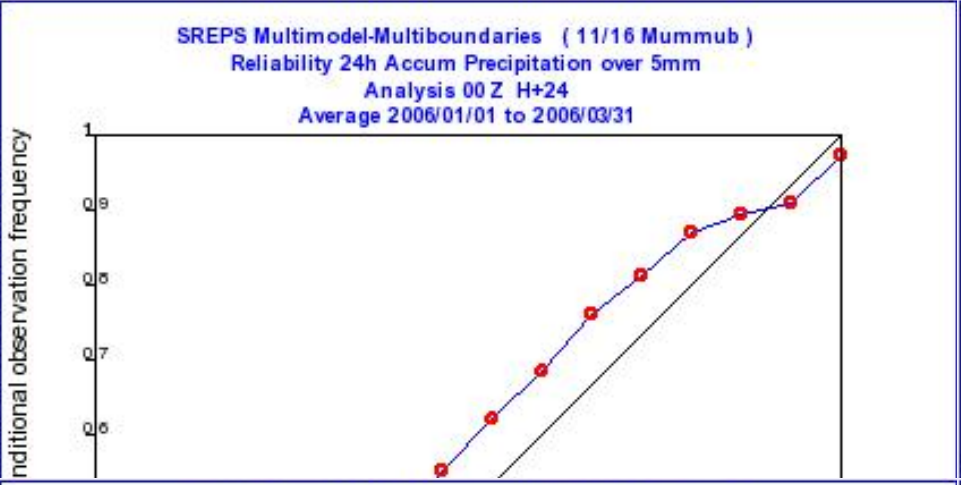
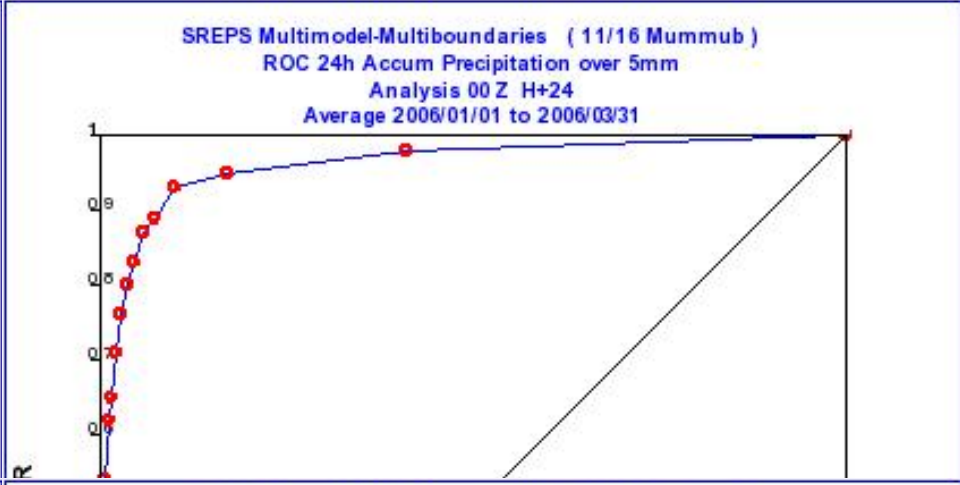
ROC 24h Accum Precipitation over 1mm
Analysis 00 Z H+24
Average 2006/01/01 to 2006/03/31


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
Forecast frequency
Frequency
Forecast probability


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
FAR
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
nditional observation frequency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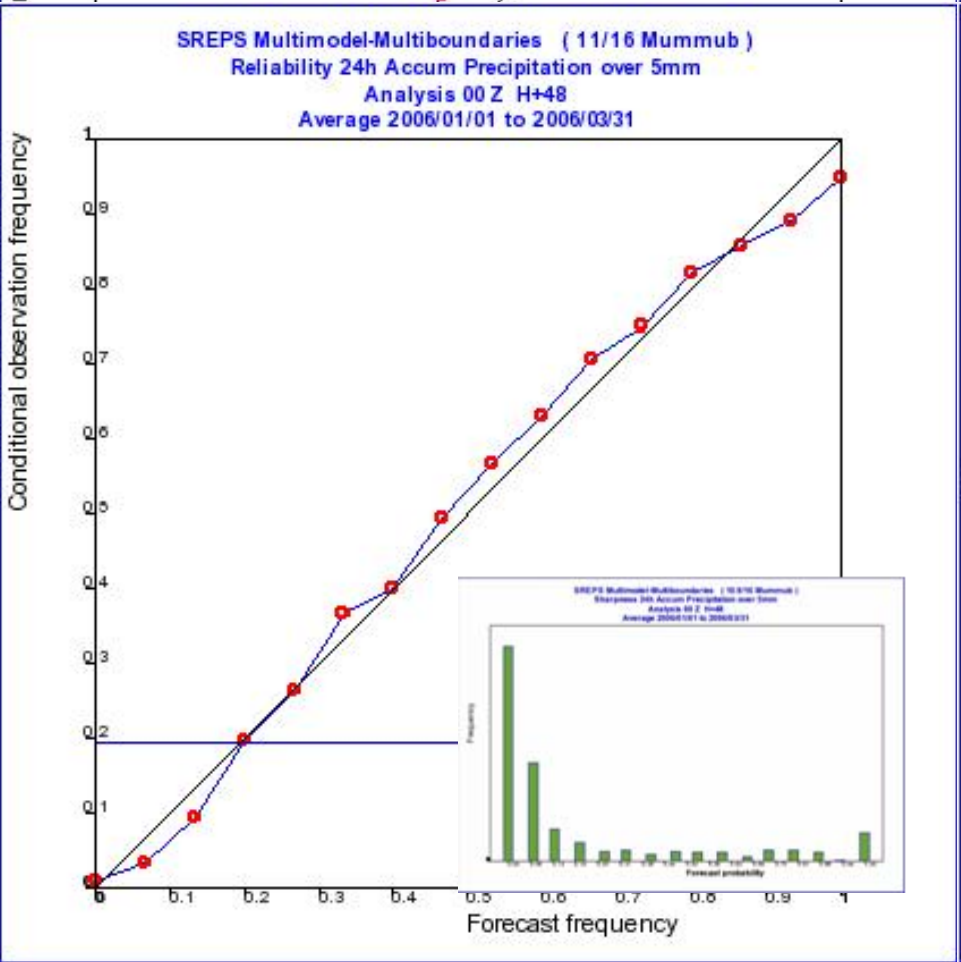
ROC 24h Accum Precipitation over 5mm
Analysis 00 Z H+24
Average 2006/01/01 to 2006/03/31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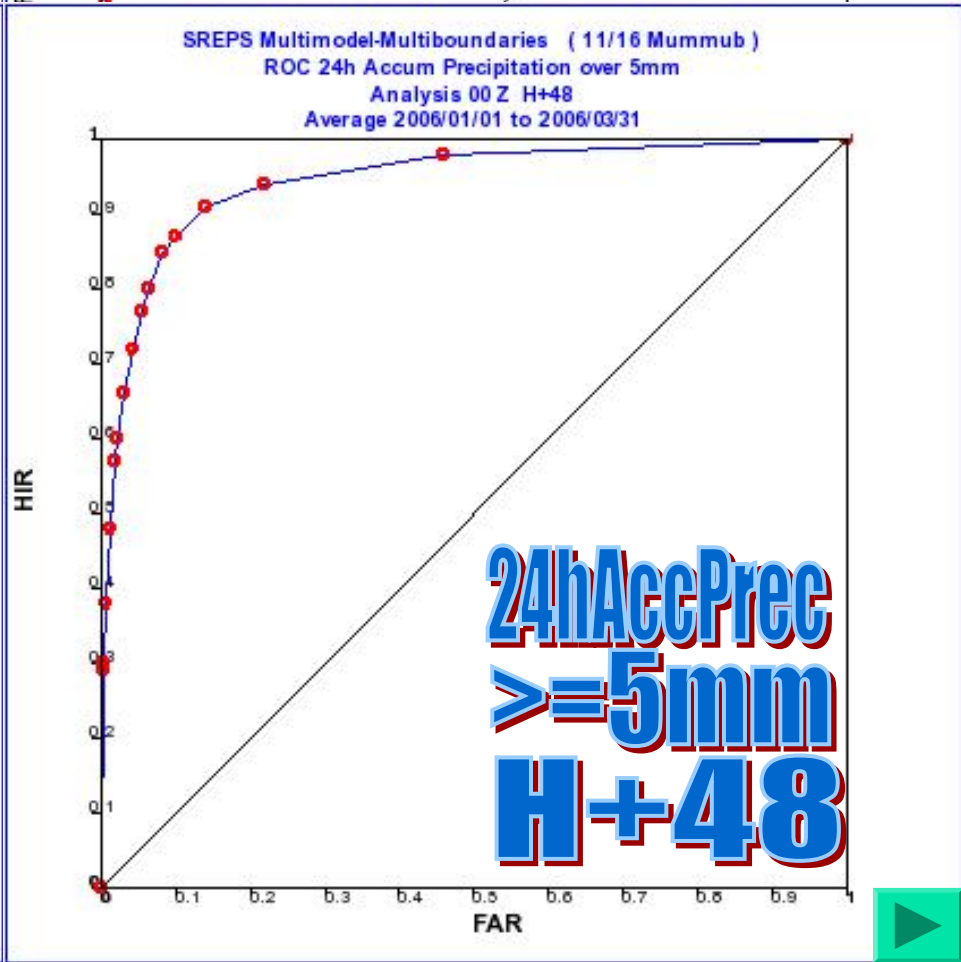
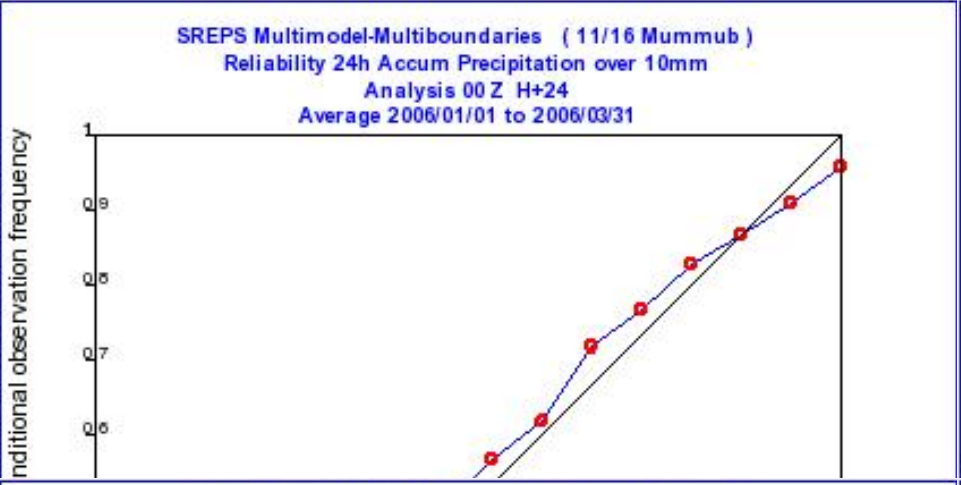
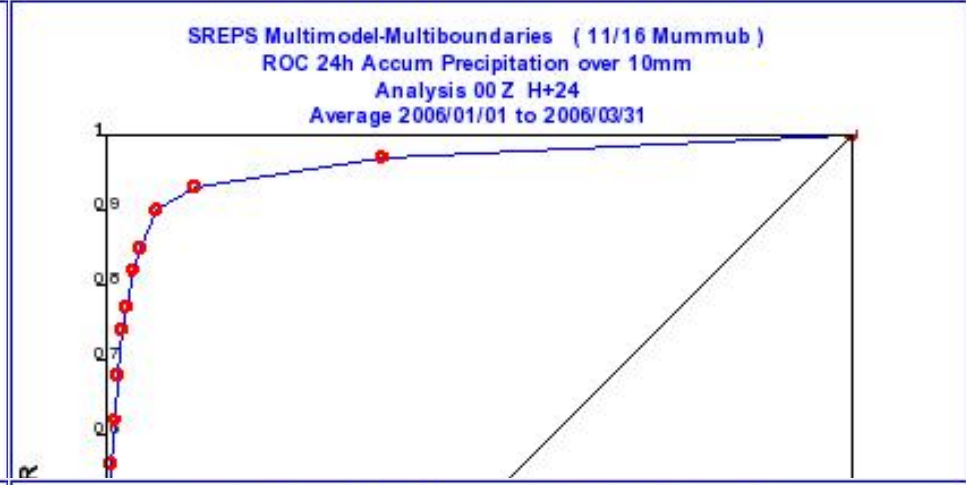
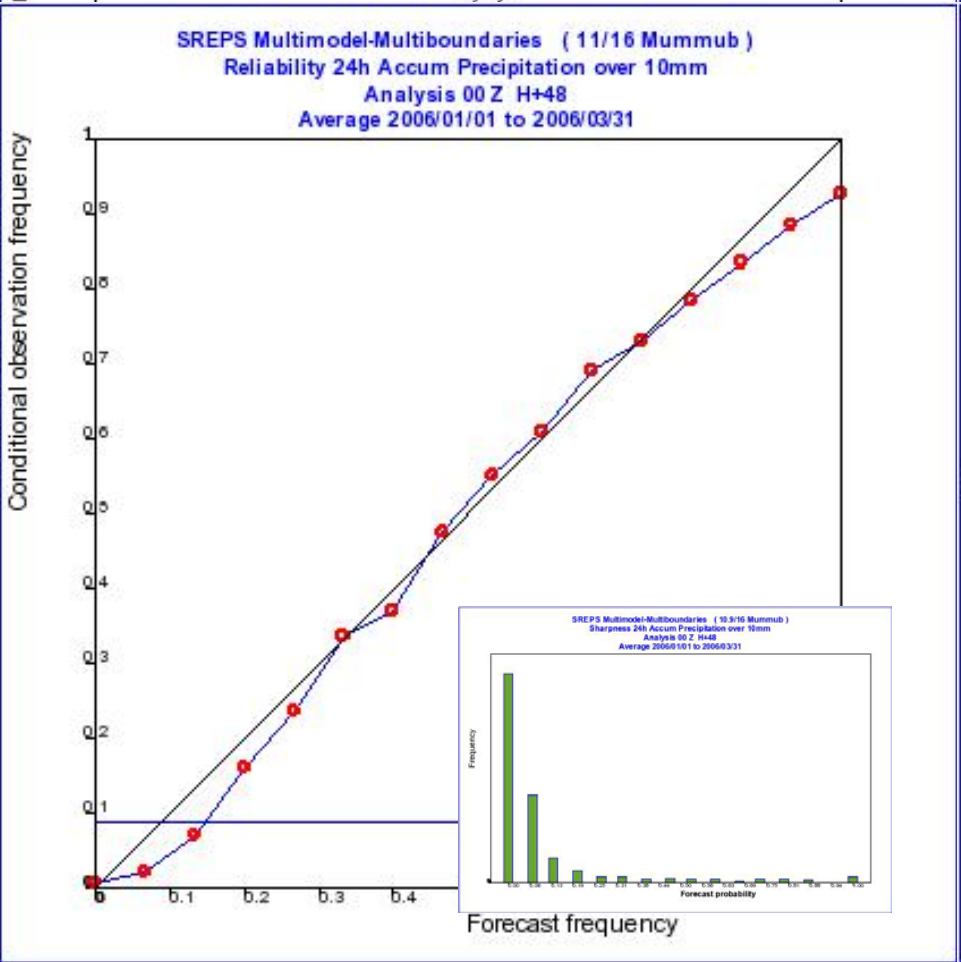
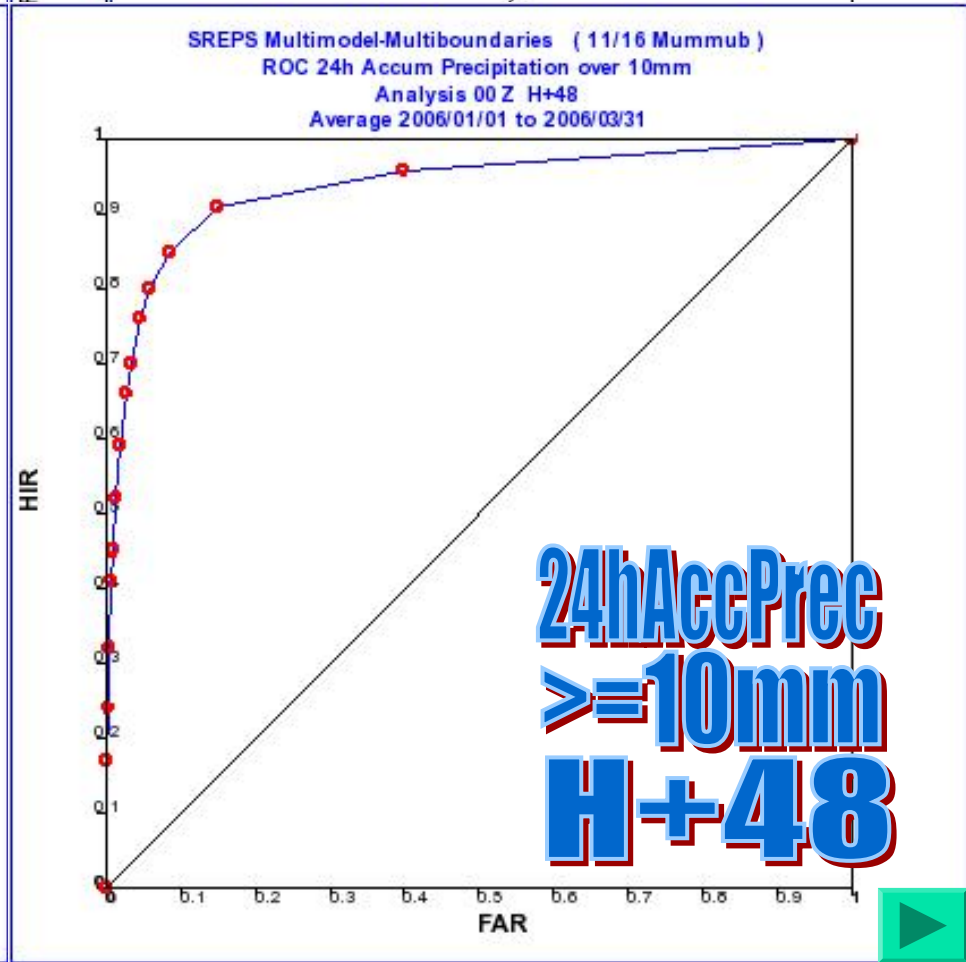
Reliability 24h Accum Precipitation over 5mm
Analysis 00 Z H+48
Average 2006/01/01 to 2006/03/31
Conditional observation frequency
Forecast frequency


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
FAR
24hAccPrec
>=5mm
H+48

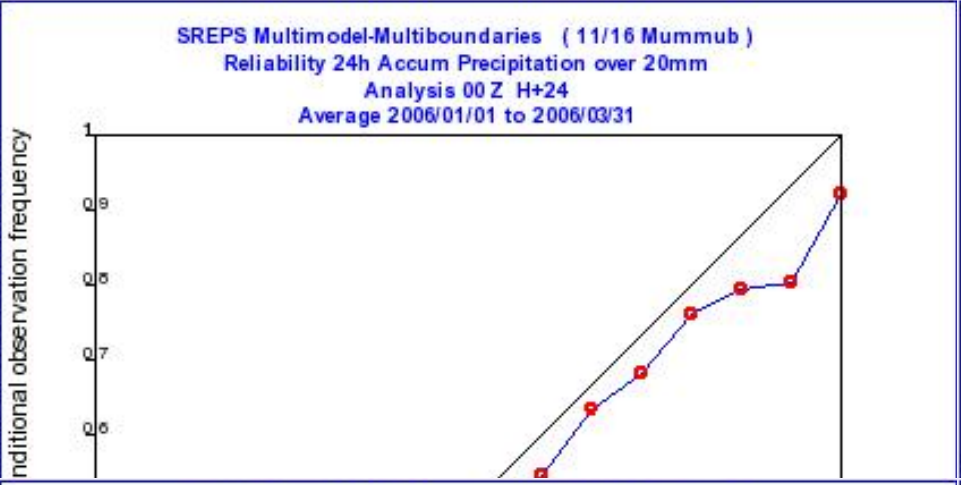


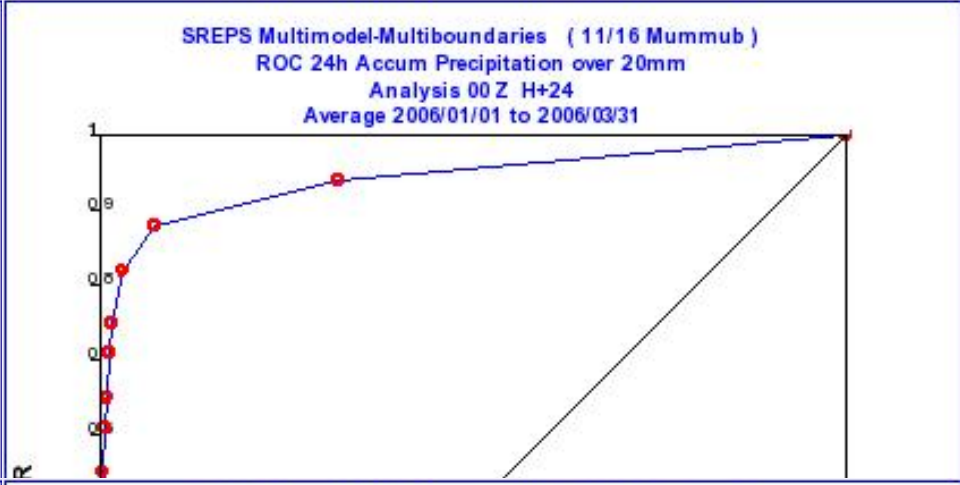






24hAccPrec
>=10mm
H+48


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
nditional observation frequency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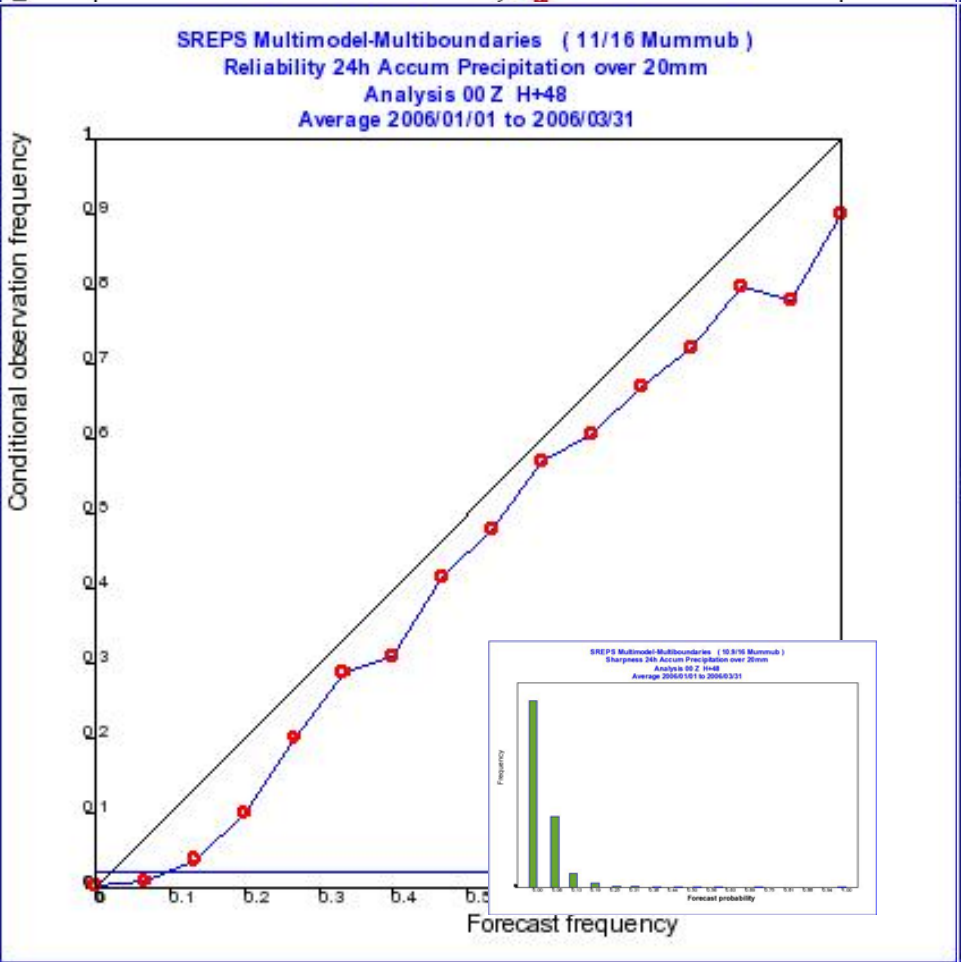
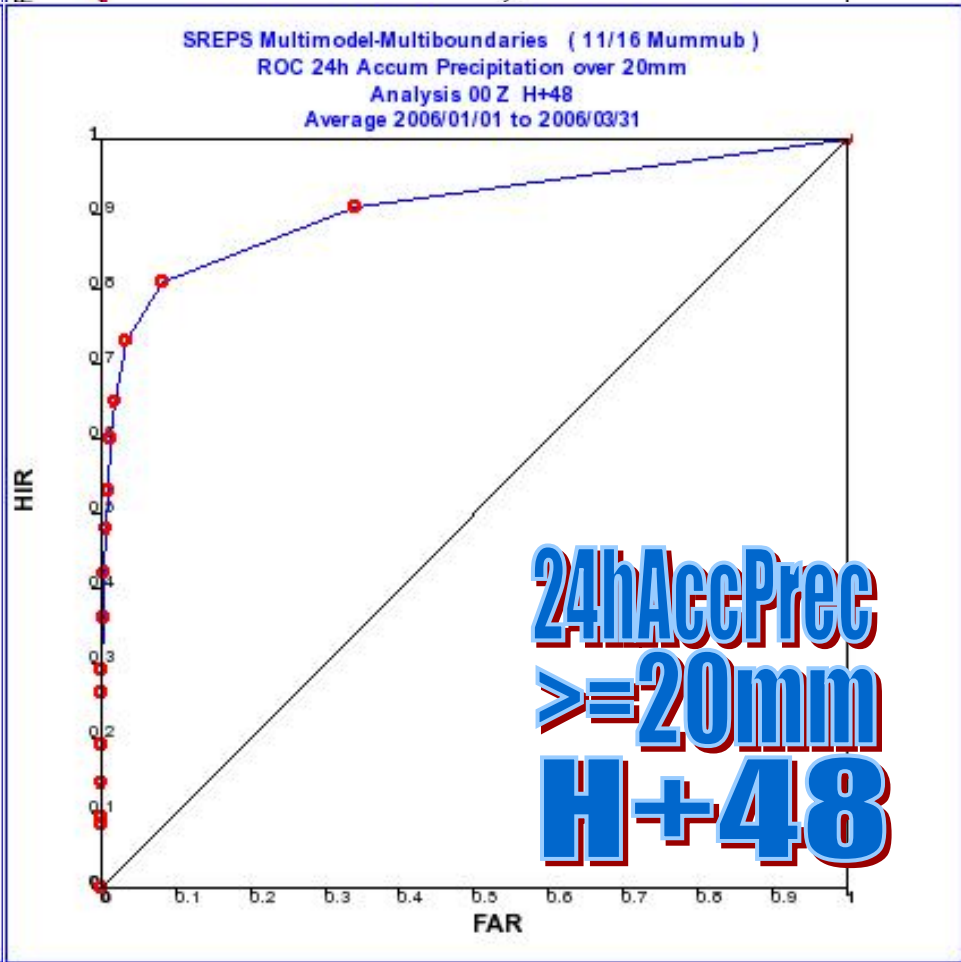
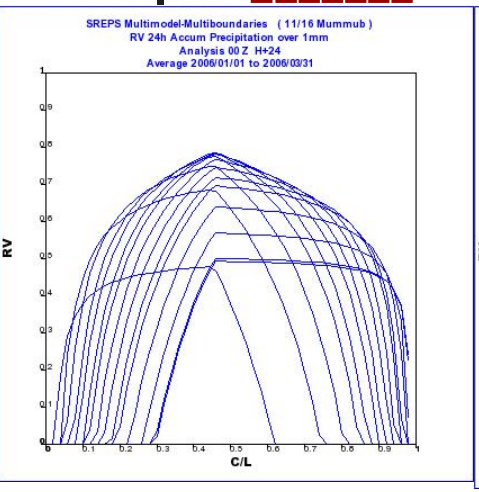
ROC 24h Accum Precipitation over 20mm
Analysis 00 Z H+24
Average 2006/01/01 to 2006/03/31


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
Forecast frequency

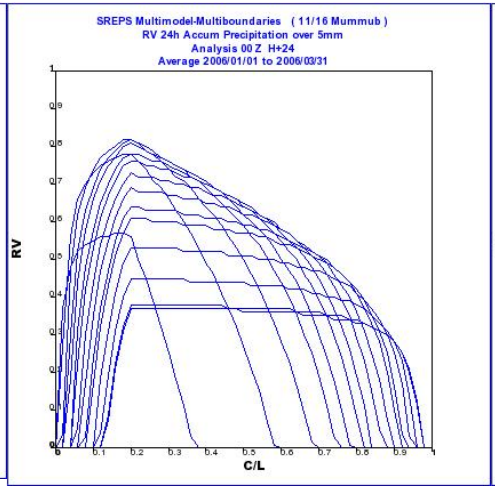

SREPS Multimodel-Multiboundaries (11/16 Mummub)
ROC 24h Accum Precipitation over 20mm
Analysis 00 Z H+48
Average 2006/01/01 to 2006/03/31
HIR
FAR
24hAccPrec
>=20mm
H+48

24h AccPrec H+24

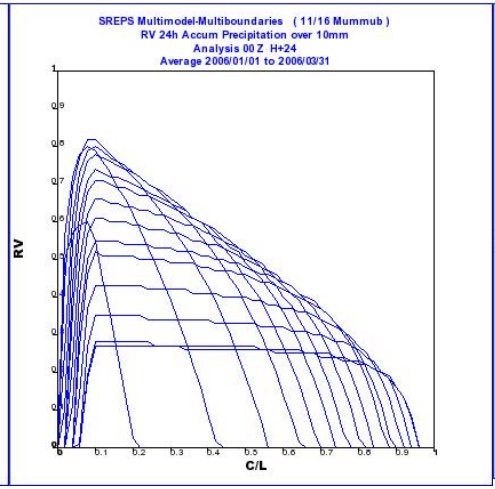
>=1mm



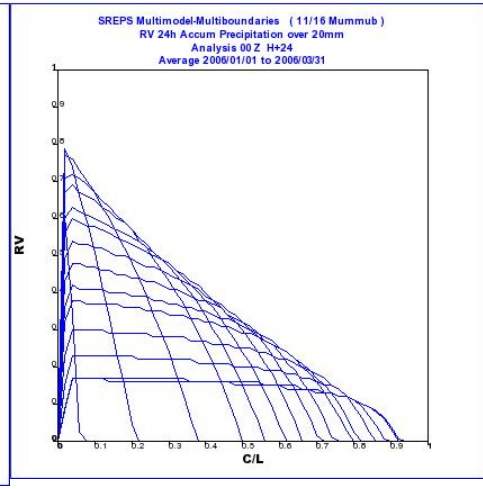
>=5mm



>=10mm

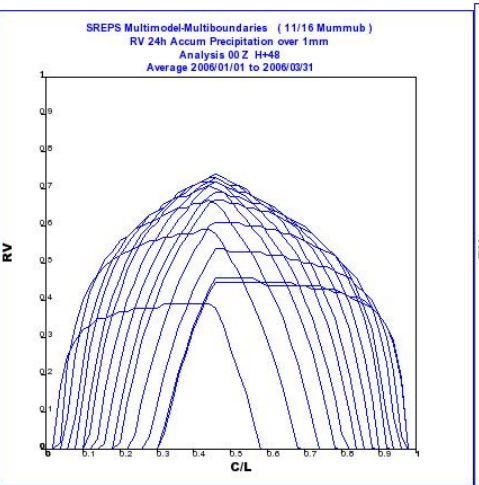


>=20mm



24h AccPrec H+48

>=1mm



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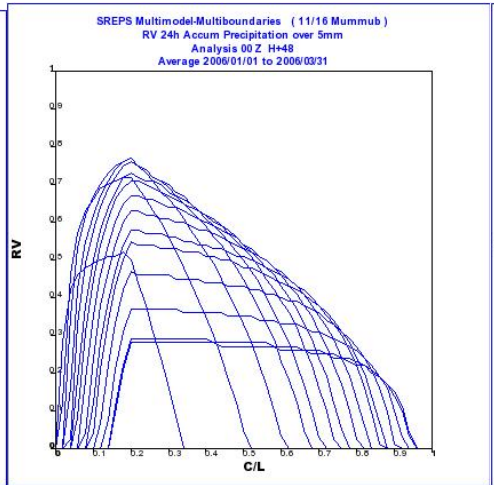
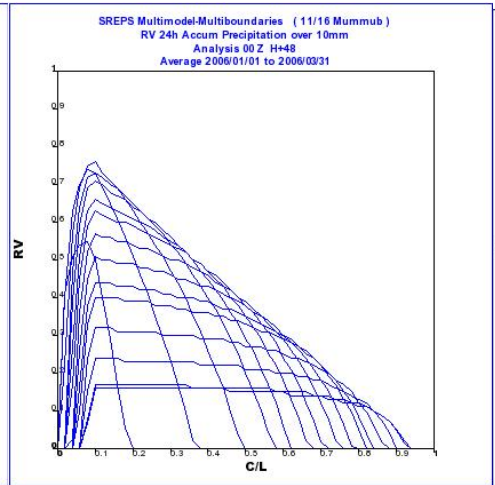
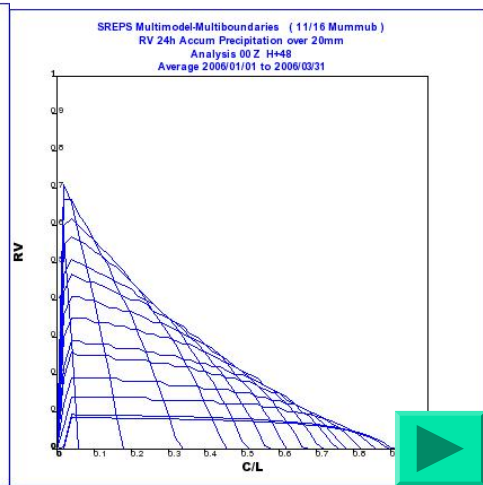


>=10mm



>=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)

Prometeo

SREPS/INM could be combined eventually with PROMETEO

PROMETEO is a statistical downscaling method described in

Clustering methods for statistical downscaling in short-range weather forecast
J.M. Gutiérrez, R. Cano, A.S. Cofiño, and M.A. Rodríguez
Monthly Weather Review, 132(9), 2169-2183 (2004)

PROMETEO

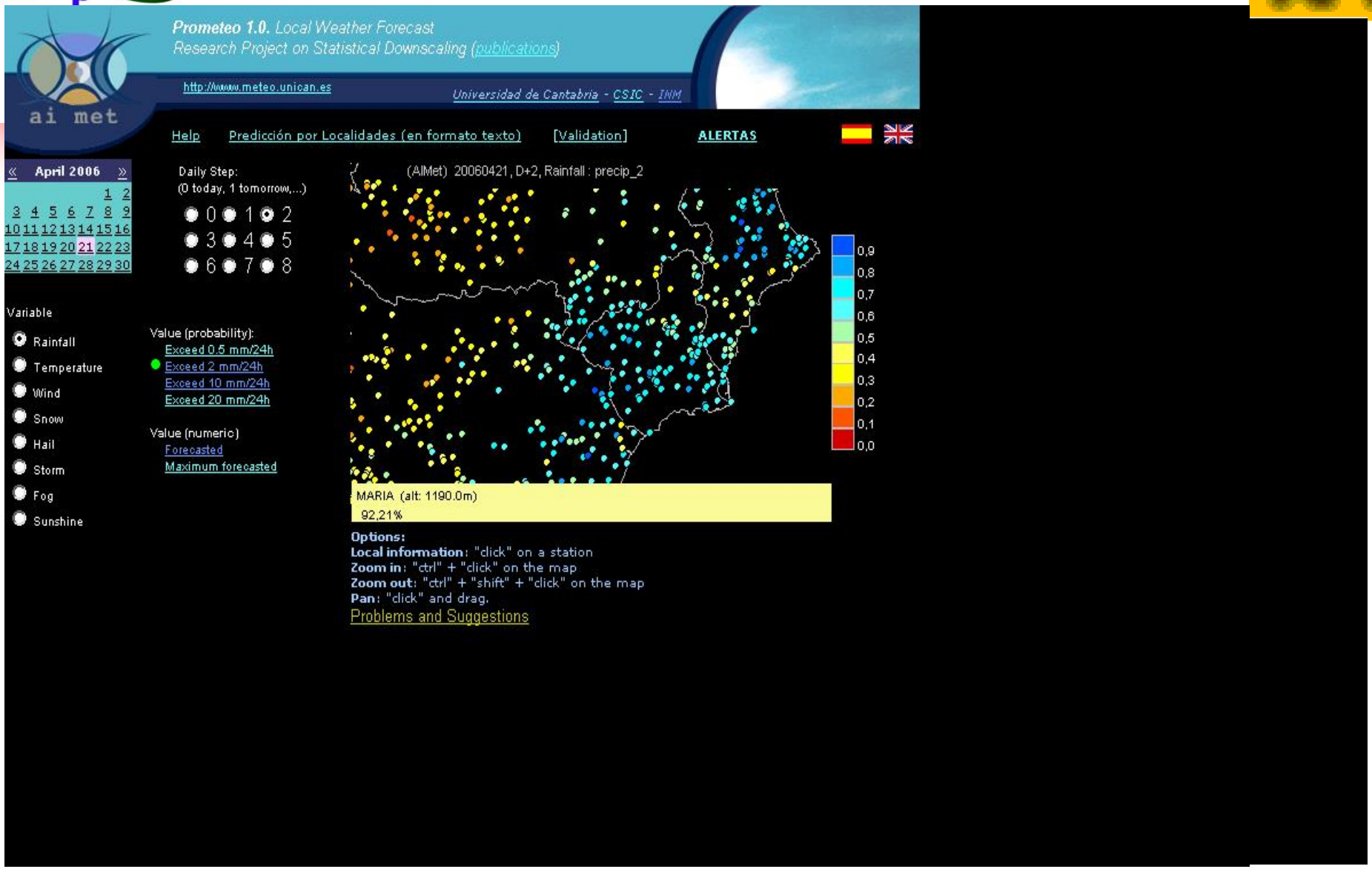
i. Seeks from ERA-40 fields the 25 closest analogues to the deterministic forecasts of the ECMWF, with projections from 1 to 9 days.
ii. PDFs are produced for each predictand and observatory of the Spanish Thermopluviometric network
iii. Predictands are: Precipitation, temperature, sunshine, wind gusts and meteors (snow, storm, hail, fog).
iv. Stations used are around 3000 pluviometric stations, 2000 thermometric stations and 200 station for sunshine and wind gusts.

Prometeo II

Some displays of Prometeo outputs follow:

- Probabilistic forecast from one ECMWF deterministic forecast (Day 2, when Precipitation exceeds 2mm)
- Zoom and details for one station
- Set of forecasts for one station and one date
- Example of validation for two years

Input could be probabilistic forecasts instead of deterministic forecasts.


Prometeo 1.0. Local Weather Forecast
Research Project on Statistical Downscaling (publications)
http://www.meteo.unican.es
Universidad de Cantabria - CSIC - INM
ai met
Help
Predicción por Localidades (en formato texto)
[Validation]
ALERTAS
April 2006
Daily Step:
(0 today, 1 tomorrow,...)
0 1 2
3 4 5
6 7 8
Variable
Rainfall
Temperature
Wind
Snow
Hail
Storm
Fog
Sunshine
Value (probability):
Exceed 0.5 mm/24h
Exceed 2 mm/24h
Exceed 10 mm/24h
Exceed 20 mm/24h
Value (numeric)
Forecasted
Maximum forecasted
(AlMet) 20060421, D+2, Rainfall : precip_2
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
MARIA (alt: 1190.0m)
92,21%
Options:
Local information: "click" on a station
Zoom in: "ctrl" + "click" on the map
Zoom out: "ctrl" + "shift" + "click" on the map
Pan: "click" and drag.
Problems and Suggestions

Predicción para la estación: MURCIA/ALCANTARILLA (altitud 89.0m)

Realizada el lunes 24/04/2006

ROC Area | Otoño | D+5 | Precipitación >10mm

(AlMet) rca, Otoño, D+5, NULL : precip_10

Precipitacion	Superar 0.5 litros/24h									
	Superar 2 litros/24h									
	Superar 10 litros/24h									
	Superar 20 litros/24h									
	Prevista									
	Máxima prevista									
Temperatura	Mínima prevista									
	Máxima prevista									
Viento	Superar 25 Km/h									
	Superar 50 Km/h									
	Superar 80 Km/h									
Nieve	Ocurrencia									
Granizo	Ocurrencia									
Tormenta	Ocurrencia									
Niebla	Ocurrencia									
Insolacion	Superar 25%									
	Superar 50%									
	Superar 75%	12 %	16 %	52 %	48 %	53 %	60 %	44 %	63 %	44 %
	Previsto (en %)	41,0	54,0	84,0	80,0	84,0	86,0	82,0	87,0	80,0
	Maxima prevista (en %)	84,0	81,0	88,0	87,0	88,0	88,0	88,0	91,0	86,0