Comparison of ECMWF and HIRLAM wind forecasts in the Baltic Sea

Juha Kilpinen, AnnaKaisa Sarkanen, Pertti Nurmi and Sigbritt Näsman
Finnish Meteorological Institute (FMI)

- FMI news
  - New building (one floor for Finnish Marine Research Institute)
  - New supercomputer
- Meteorological visualisation applications (EGOWS 2005)
- Use and interpretation of medium and extended range forecast guidance (the title above)

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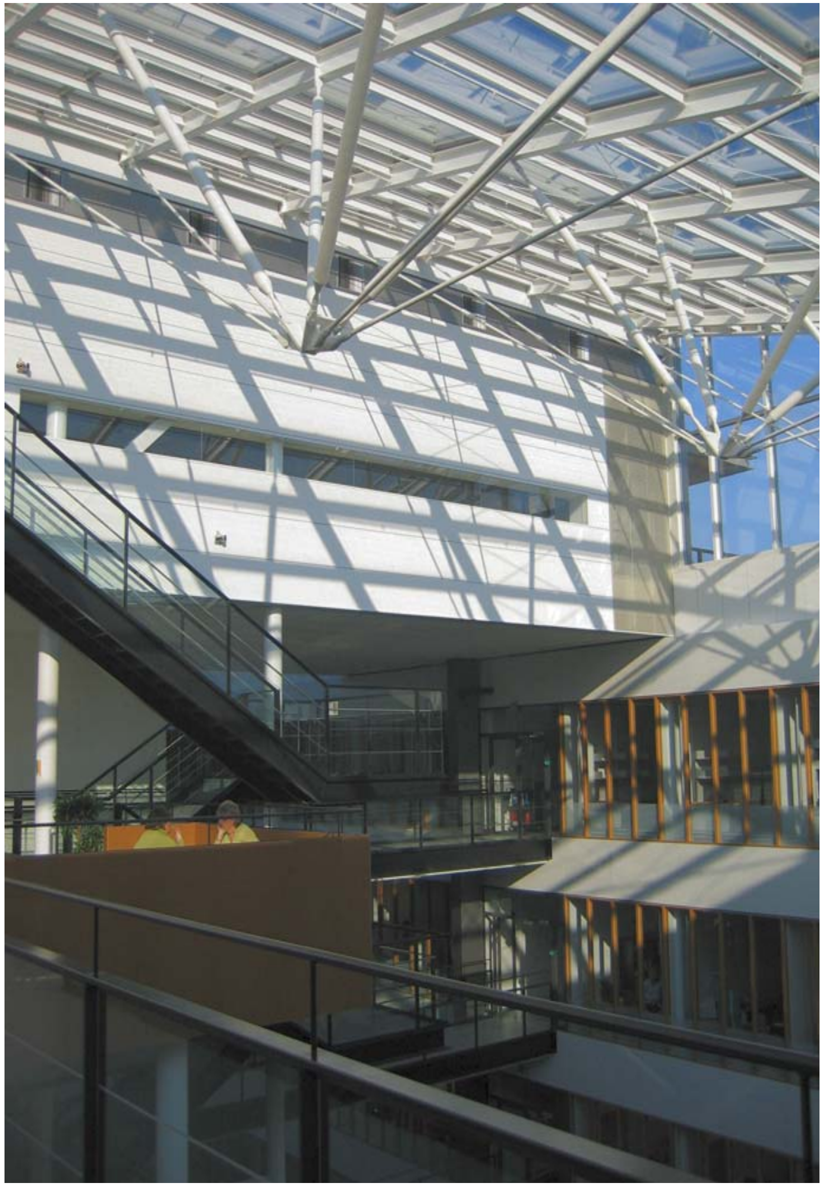

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New supercomputer

- SGI Altix 3700 BX2
  - 304 processors
  - 304 Gb of memory
  - 30 times faster than the previous IBM
  - HIRLAM and other applications (ECHAM5)

Meteorological visualisation applications

- Last EGOWS meeting in Exeter
  - http://www.metoffice.gov.uk/egows2005/programme.html

European Working Group on Operational Workstations (EGOWS) 2005

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Programme

Wednesday 22 June

Session 3a

Juha Kilpinen, Finnish Meteorological Institute
New features of the Grid Editor System (PDF, 9.2 Mb)

Mikko Strahlendorff, Finnish Meteorological Institute
The SISU-program. Renewing the weather service process at FMI (PDF, 404 kb)

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Comparison of ECMWF and HIRLAM wind forecasts in the Baltic Sea

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- This study is a part of two frameworks
  - evaluation of ECMWF EPS forecasts in FINLAND
  - evaluation of warning criteria for forecasting probability of near gale force wind in the Baltic Sea (Finland and Sweden issue near gale warnings and storm warnings for same areas, but with different criteria)
- Both ECMWF and HIRLAM data is used
- Period of data is one winter (~ September 2004 – April 2005)
- Observations from 21 coastal stations
- Both deterministic and probabilistic forecasts are verified
- Different methods for producing probability forecasts from deterministic data has been tested
- Different calibration methods has been tested and verified

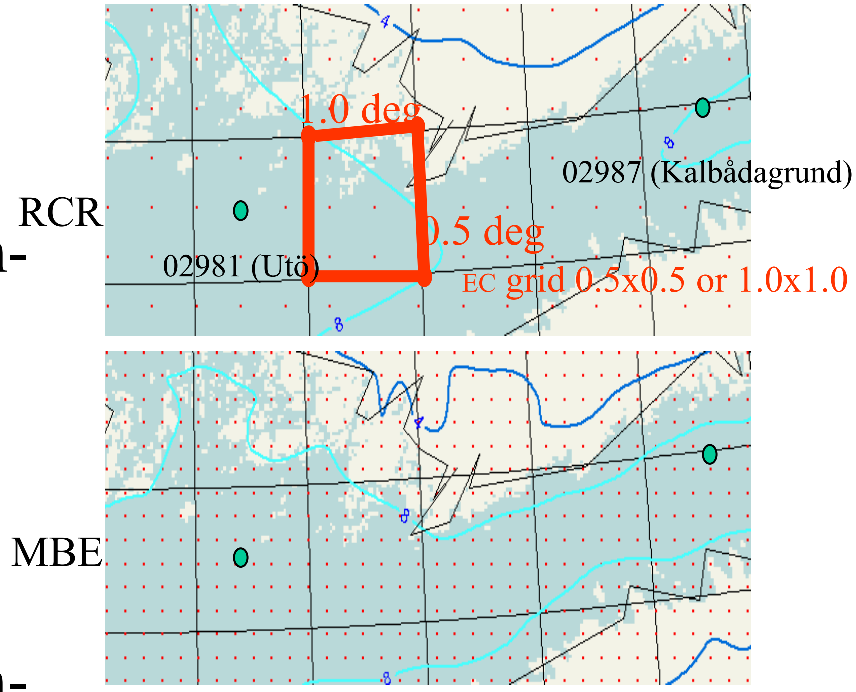
Data (ECMWF model data)

- ECMWF MARS data
  - u10m, v10m->speed10m
- Period 1.10.2004-30.4.2005 (Finnish stations)
- Period 1.10.2004-31.3.2005 (Swedish stations)
- Period 1.11.2004-31.3.2005 (Danish and Norwegian stations)
- forecasts valid at 00, 06, 12 and 18 UTC
- forecast lead time from +12h-+144h
- Operational data and Control data (interpolated to 0.5x 0.5 degree resolution)
- EPS data (interpolated to 0.5x 0.5 degree resolution)

Data (HIRLAM Model data)

- HIRLAM RCR
  - 10m wind speed & additional parameters
- Grid length about 22 km
- forecast lead time from +6h- +48h
- HIRLAM MBE
  - 10m wind speed & additional parameters
- Grid length 9 km
- forecast lead time from +1h- +24h

Different grids of HIRLAM (RCR (above) and BME)



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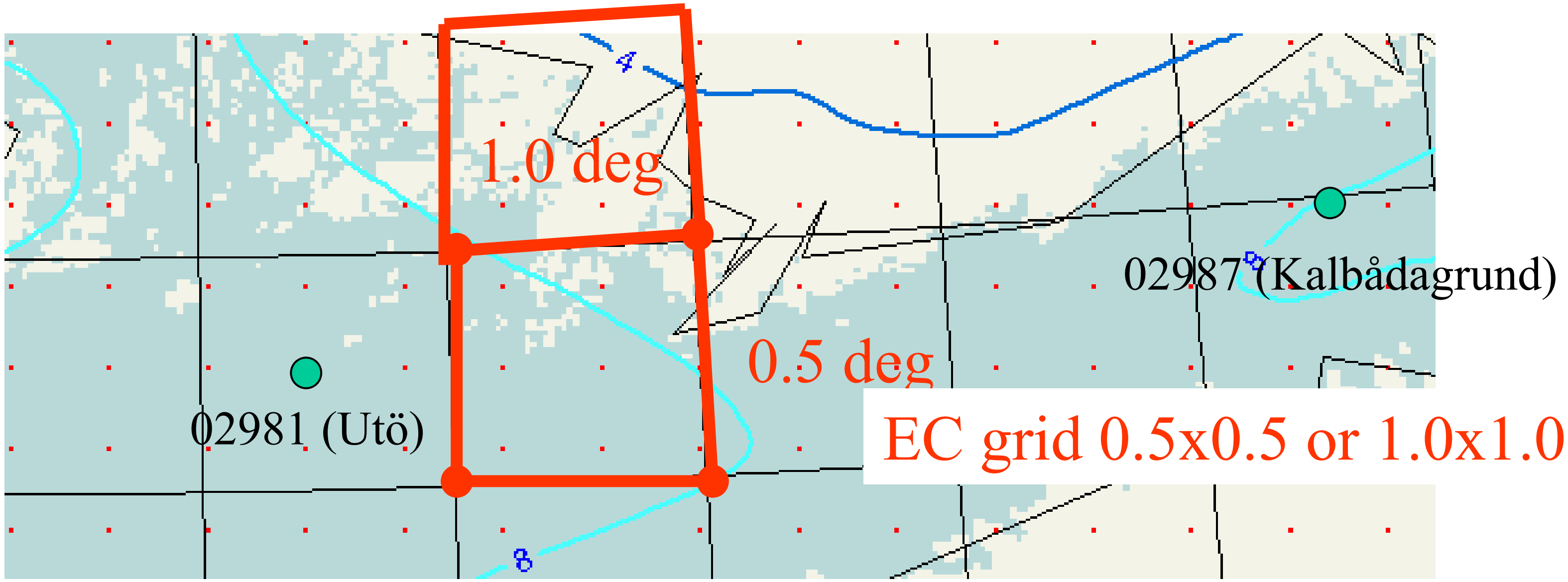
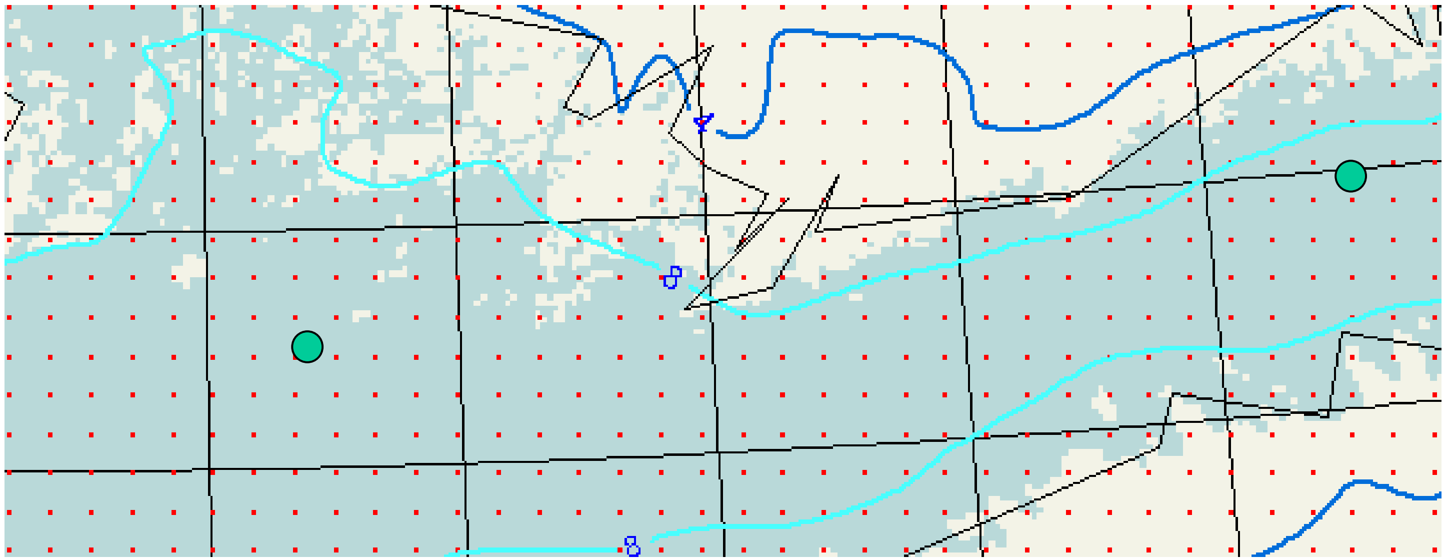
Different grids of HIRLAM (RCR (above) and BME)

RCR

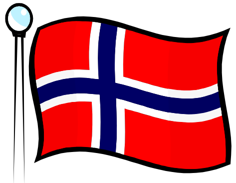


MBE

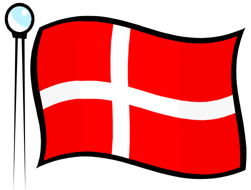


Observation stations:

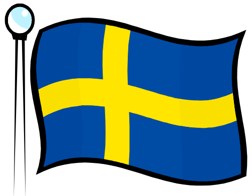
01427
01448
01467
01482



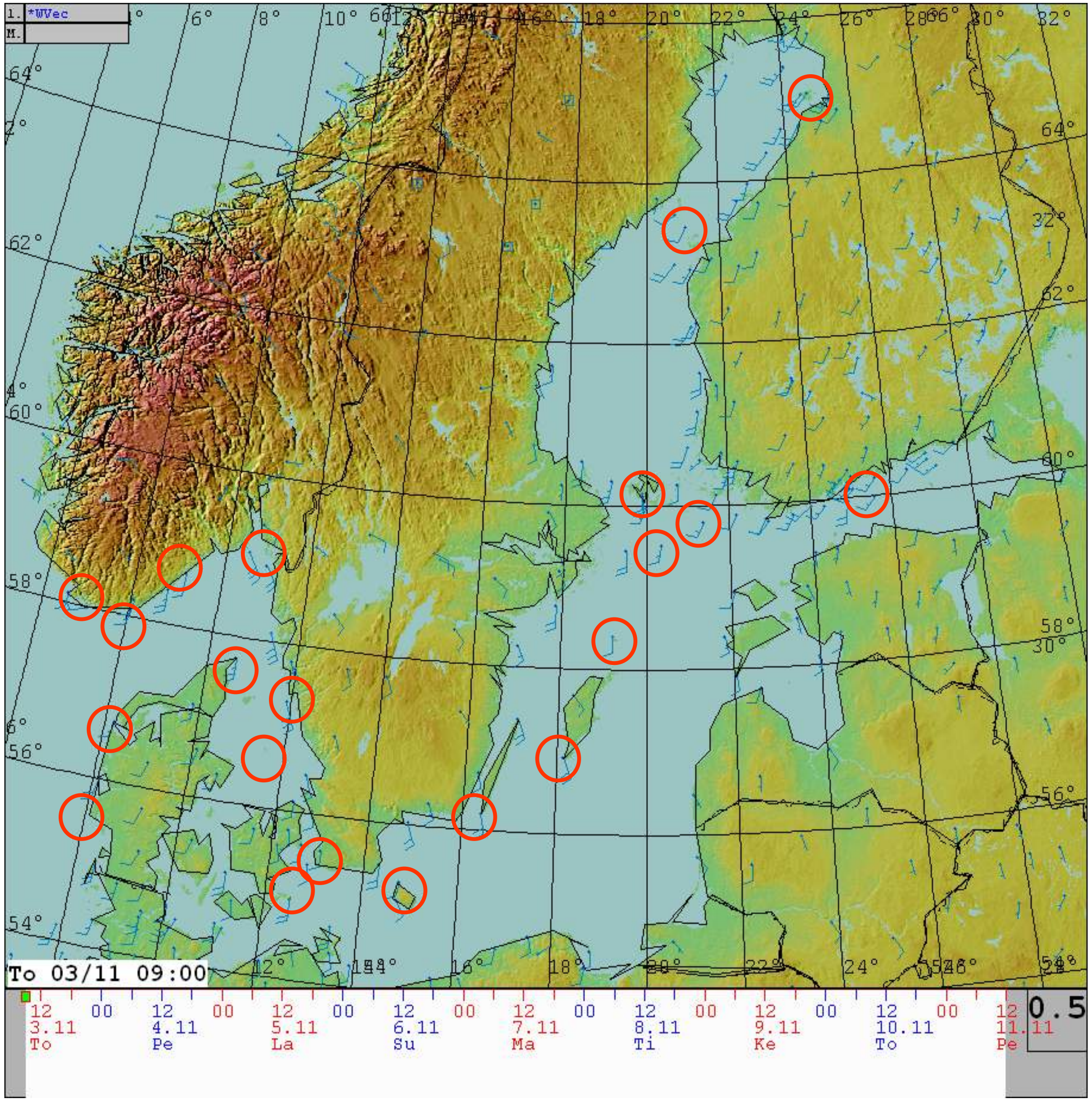
06081
06052
06041
06079
06179
06193



02517
02616
02644
02680
02584



02873
02910
02980
02981
02979
02987



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Stations

Hailuoto	02873
Valassaaret	20910
Nyhamn	02980
Utö	02981
Bogskär	02979
Kalbådagrund	02987

31 m

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32 m

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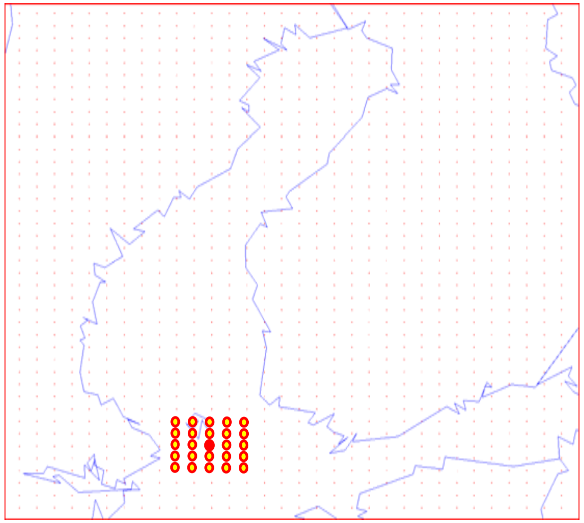
The methods for producing probabilistic forecasts for near gale force winds

- Deterministic data
- Method 1a: observed error distribution (dependent sample) is used to produce probability forecasts from operative deterministic forecasts ("error dressing")
- Method 1b: as above, but observed error distribution is approximated with Gaussian distribution (μ , σ)
- Method 2: as above but σ is derived from model "stability" (temperature difference of two model levels) with an empirical formula (by Håkan Hultberg, SMHI)
- Method 3: operational forecast is Kalman filtered and σ (a bi-product of Kalman filter) is used to estimate the probability (also Gaussian approximation)

The methods for producing probabilistic forecasts for near gale force winds

- Deterministic data (cont.)

  Method 4: Uncertainty method (also called Neighbourhood method by e.g. Susanne Theis)
  - Spatial (Fig.) and/or temporal
  - neighbouring grid points
  - "Unc"

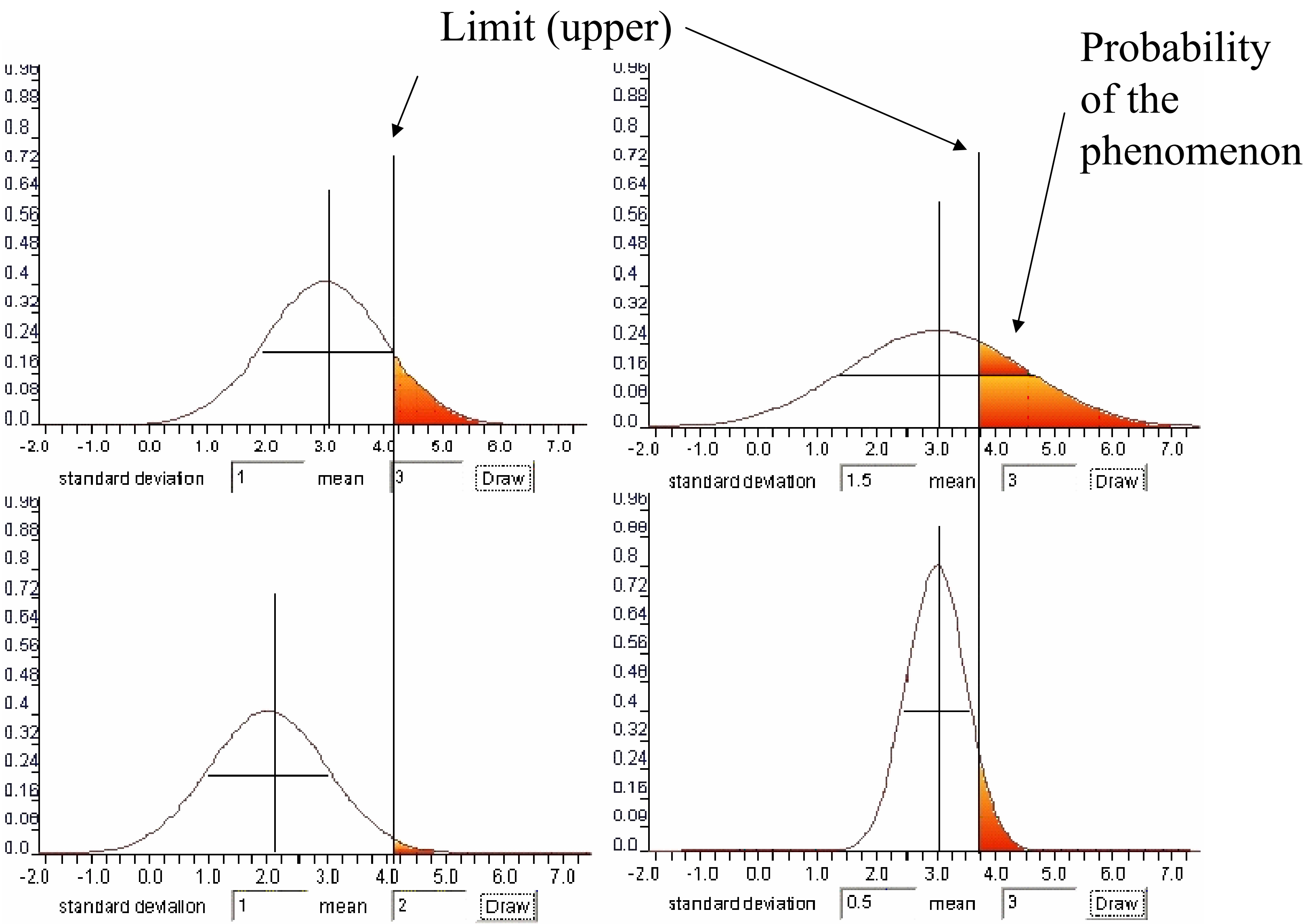


- EPS data (51 members): the probability of near gale wind (speed > 14 m/s or >13.9 m/s)

The methods for producing probabilistic forecasts for near gale force winds

- Calibrated EPS data: the calibration is made by Kalman filtering the EPS mean and then all EPS member are transformed with the same relationship to provide a new 51 member ensemble.
- Deterministic operative data: Kalman filtering of operative wind forecasts and application of Kalman filter residuals to provide the error distribution for probability of near gale. Also other alternatives exits but they have not yet been tested.

Some examples of theoretical pdf’s with different parameters



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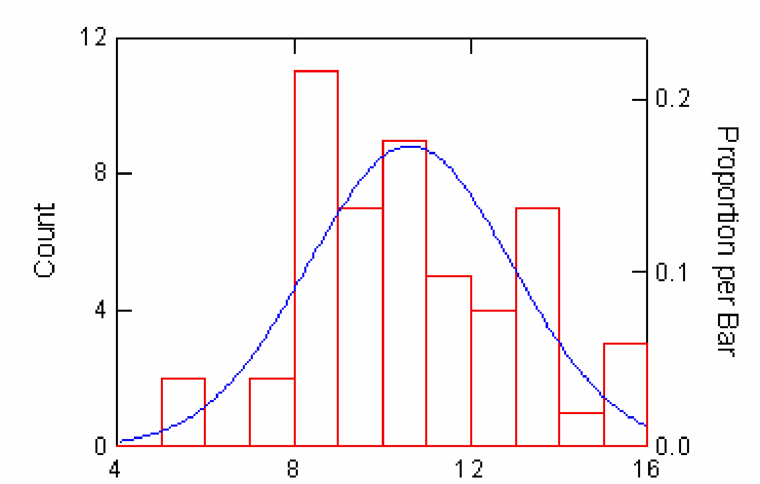
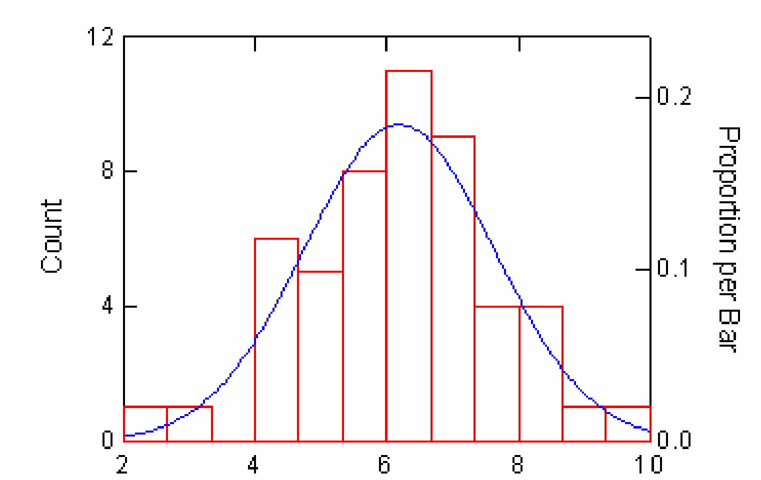
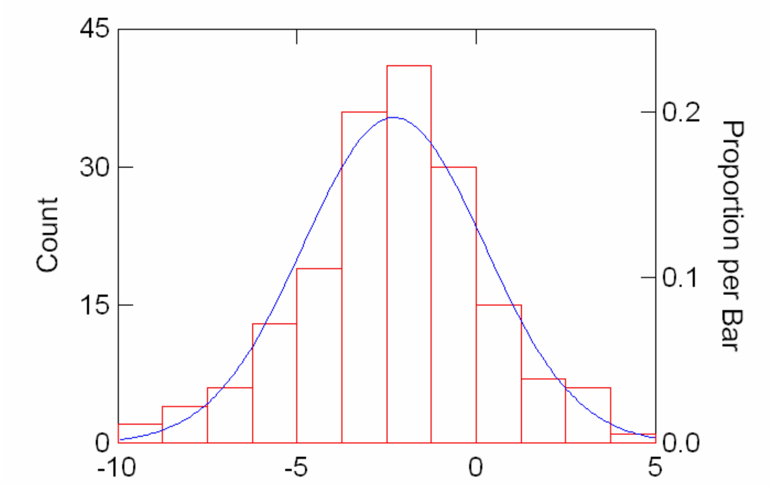
Examples of individual ensembles (station 02680 +24h (51 members))



day 49



day 83



Error distribution of Control forecasts (sample of 180 cases) and fitted Gaussian distribution

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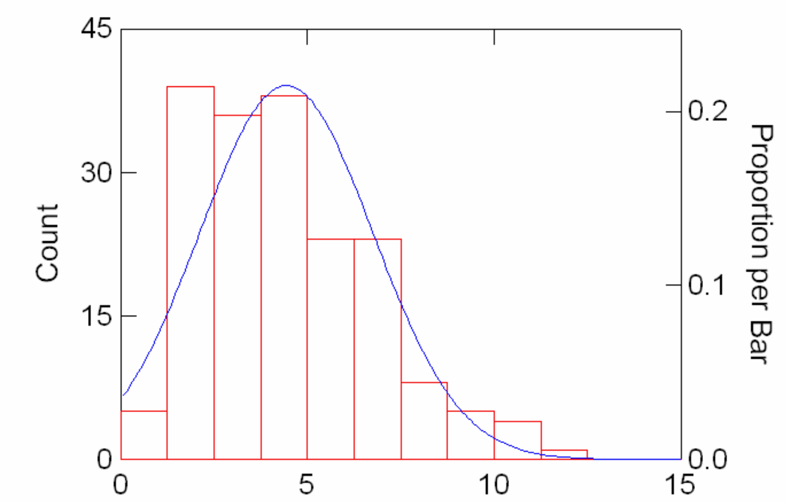
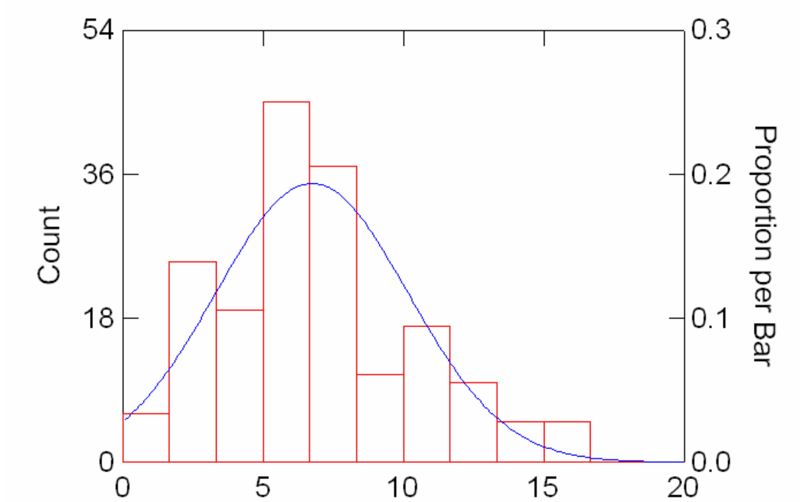
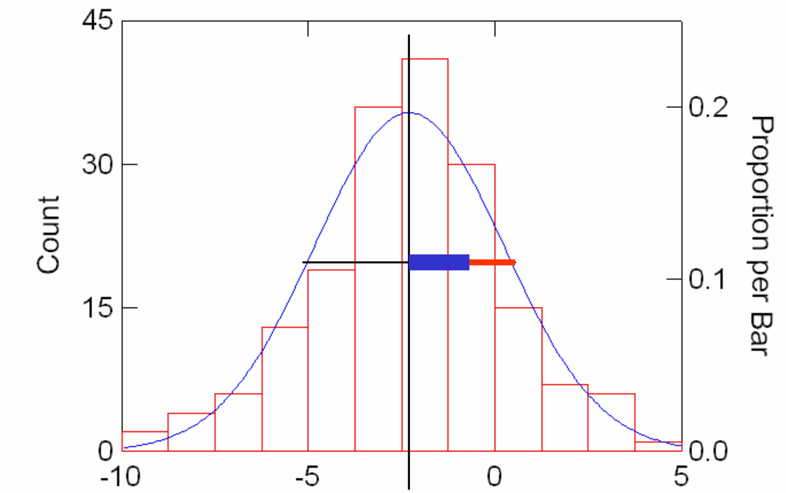
Examples of forecast/observation distributions (station 02680 +24h)



Distribution of EPS mean



Distribution of observations



Distribution of error

Error distribution of EPS mean forecasts (sample of 180 cases) and fitted Gaussian distribution BLUE line corresponds to mean spread of EPS mean

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Calibration of EPS forecasts

- Traditionally calibration of ensemble forecasts means that the probabilities are relabelled using the information in reliability diagram (a large sample of past forecasts and observations are needed)
- In this study Kalman filtering is used to calibrate ensemble mean forecasts (and also operative as well as control). Then every individual ensemble member is transformed with the state vector. This calibrates at least the "mean" of distribution and hopefully also the "spread".
- Kalman filtering is also used in traditional way to correct the deterministic forecasts and then to estimate the probabilities using observed error distribution

Verification measures

- For deterministic forecasts (operative, control and EPS mean, Kalman filtered operative)
  - Mean Error ME
  - Root Mean Squared Error, RMSE
  - Standard Deviation of Error, STD
- For probabilistic forecasts (”Error Dressing/classical”, EPS, calibrated EPS (with Kalman filter), Kalman filtering, “Stability” method, “Uncertainty” method)
  - (Brier Score), Brier Skill Score, ROC curve, ROC area
- Some comparisons with HIRLAM data (mostly probabilistic scores)
- SPREAD in this content is mean of standard deviation of ensemble mean (51 members)

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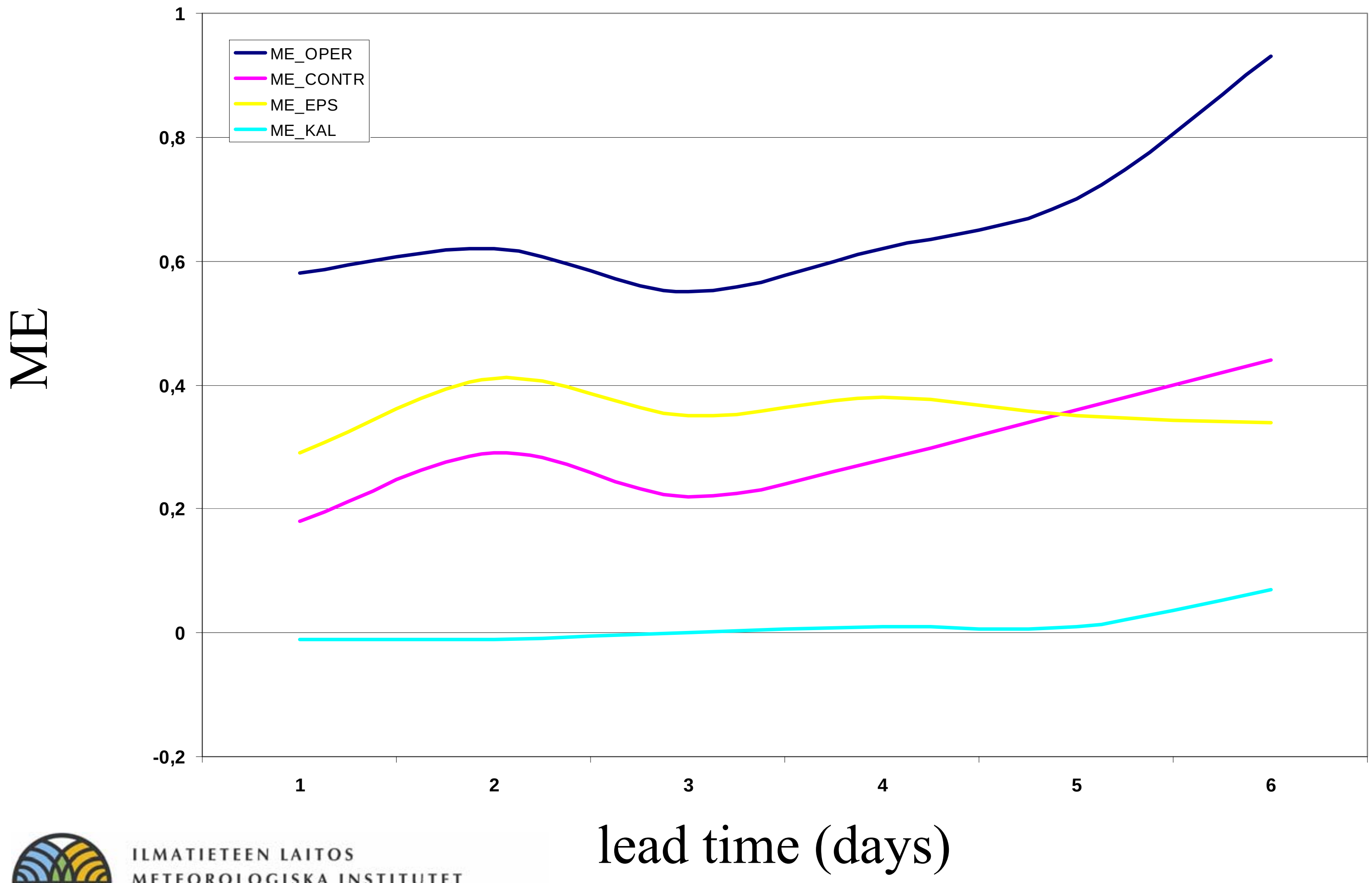
Results: Deterministic forecasts

Pooled results from 21 stations (00 UTC, 1 = +12h, …)



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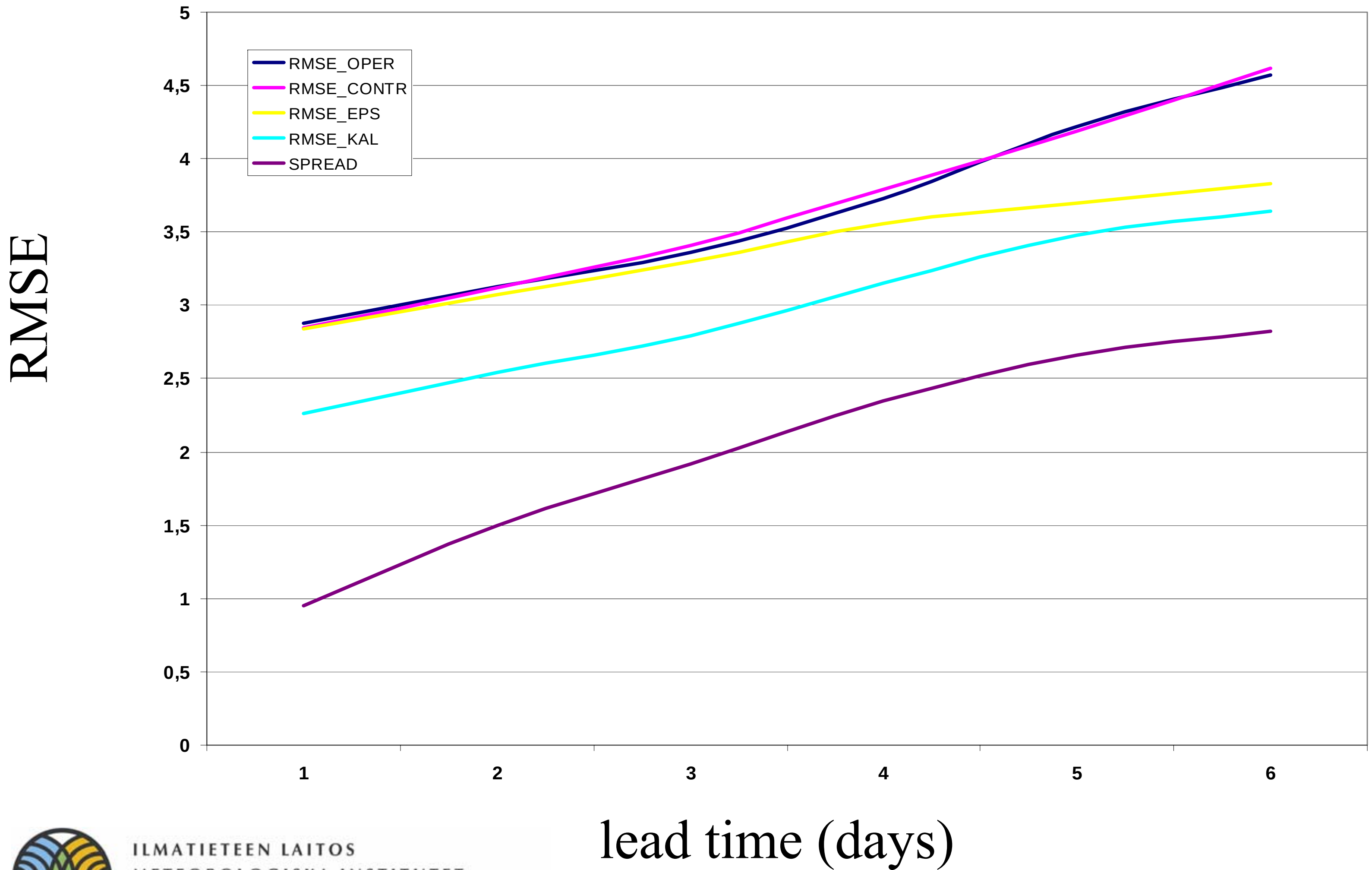

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Results: Deterministic forecasts

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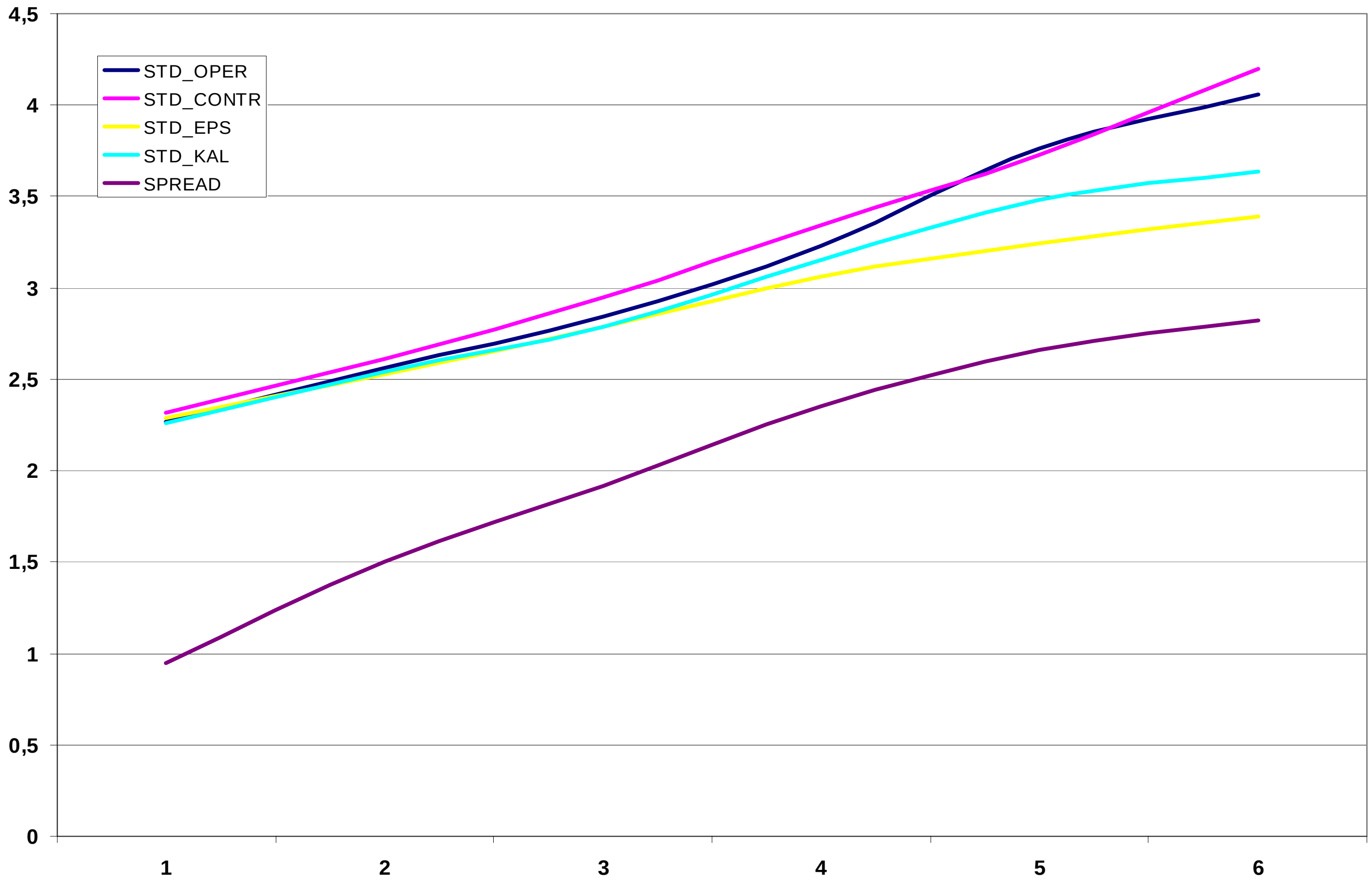

STD

lead time (days)

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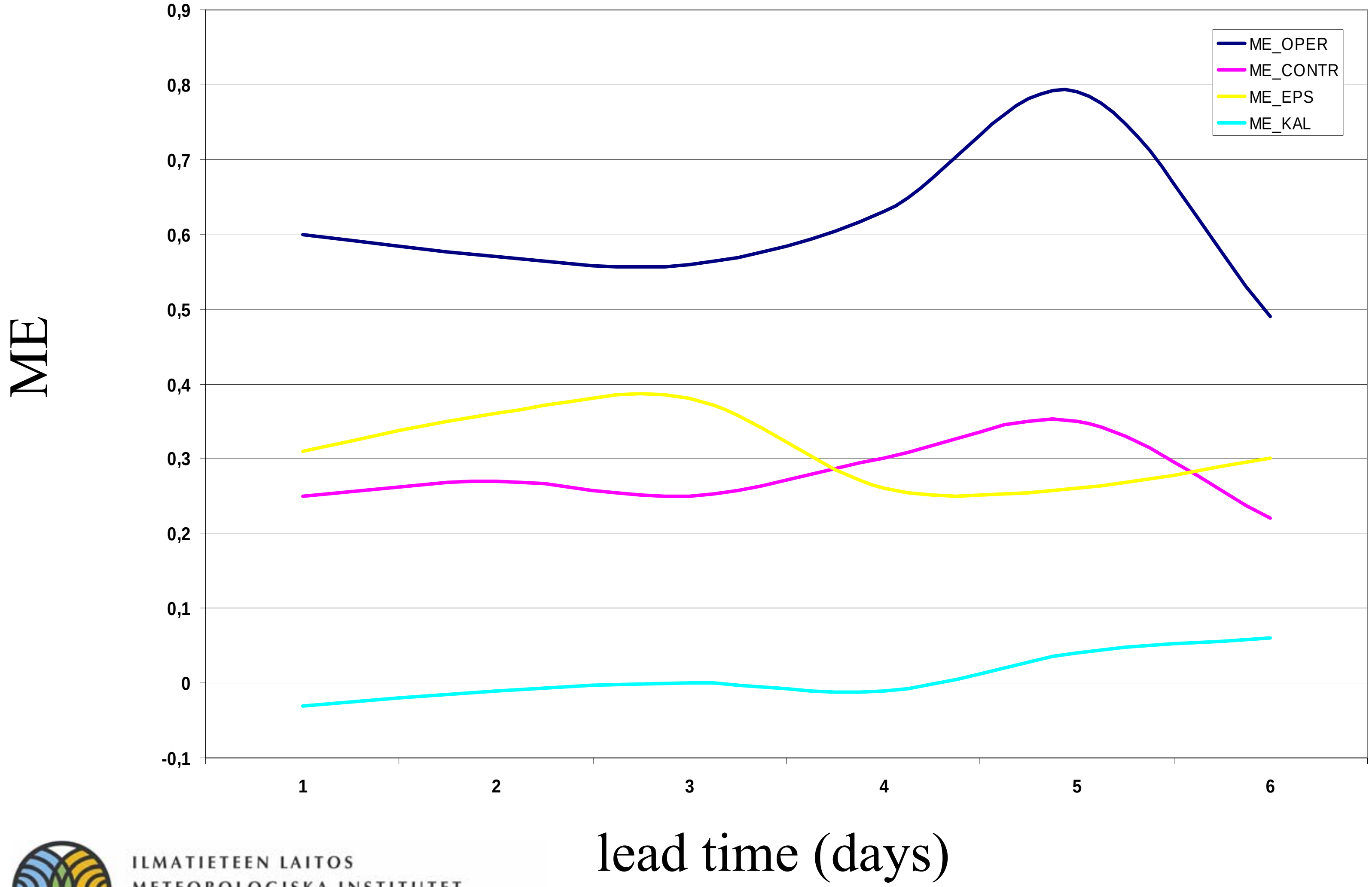
Results: Deterministic forecasts

Pooled results from 21 stations (12 UTC)



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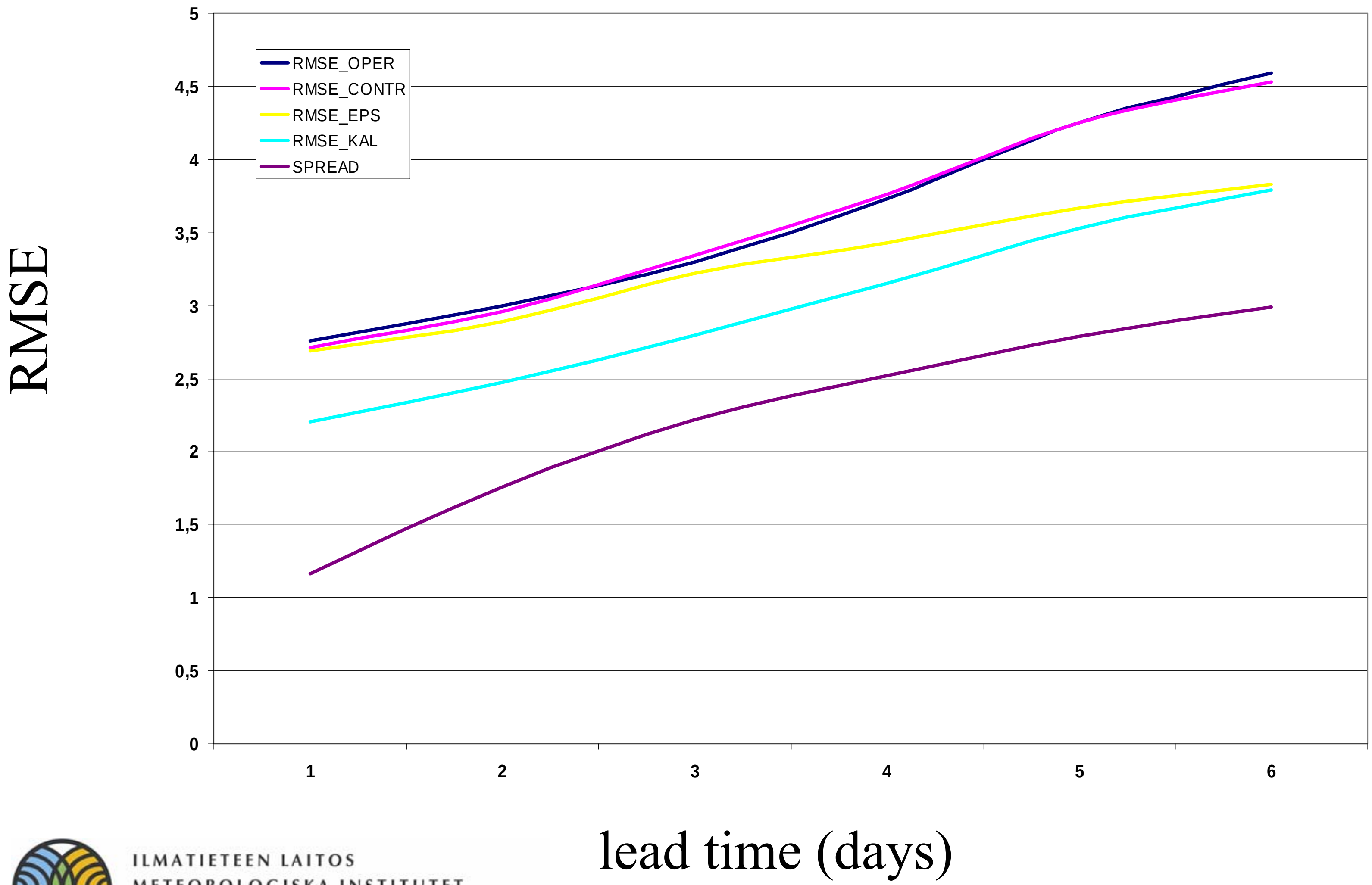
Results: Deterministic forecasts

Pooled results from 21 stations (12 UTC)



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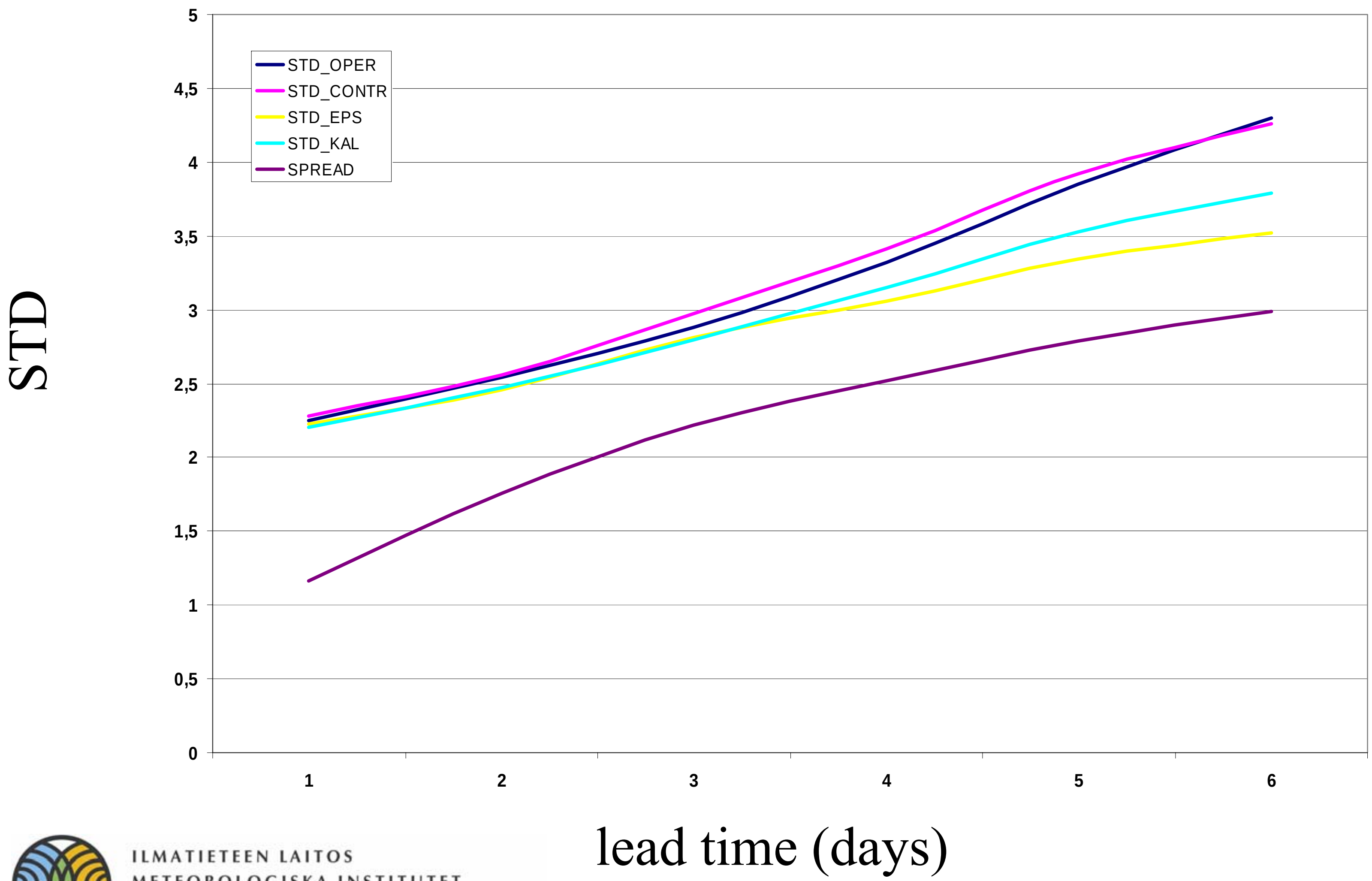
Results: Deterministic forecasts

Pooled results from 21 stations (12 UTC)



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Probabilistic FCs: ROC

Relative Operating Characteristic

- To determine the ability of a forecasting system to discriminate between situations when a signal is present **(here, occurrence of near-gale)** from no-signal cases **("noise")**
- To test model performance relative to a specific threshold
- Applicable for probability forecasts and also for categorical deterministic forecasts
  - ⇨ Allows for their comparison

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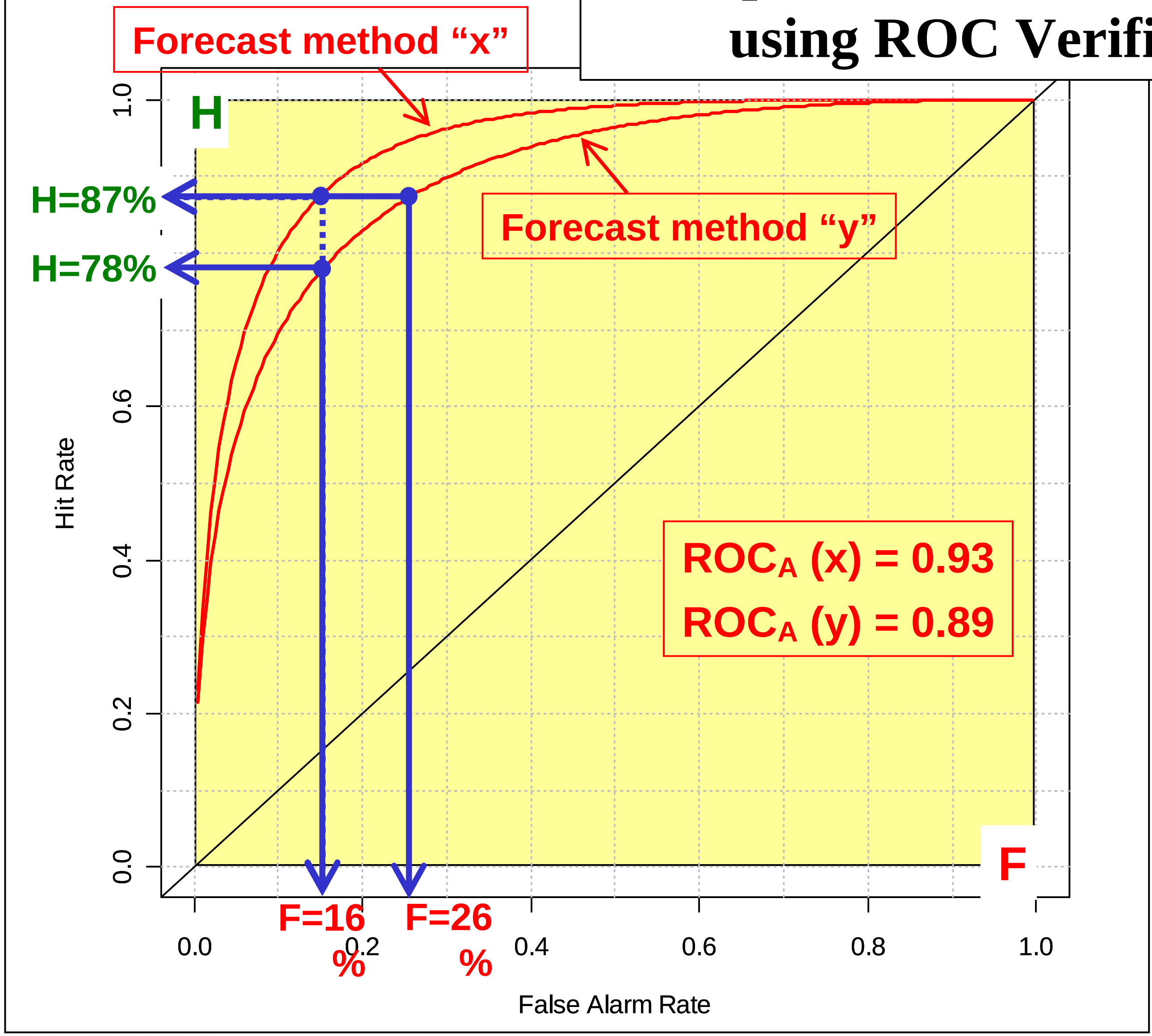
Example of Decision-Making using ROC Verification



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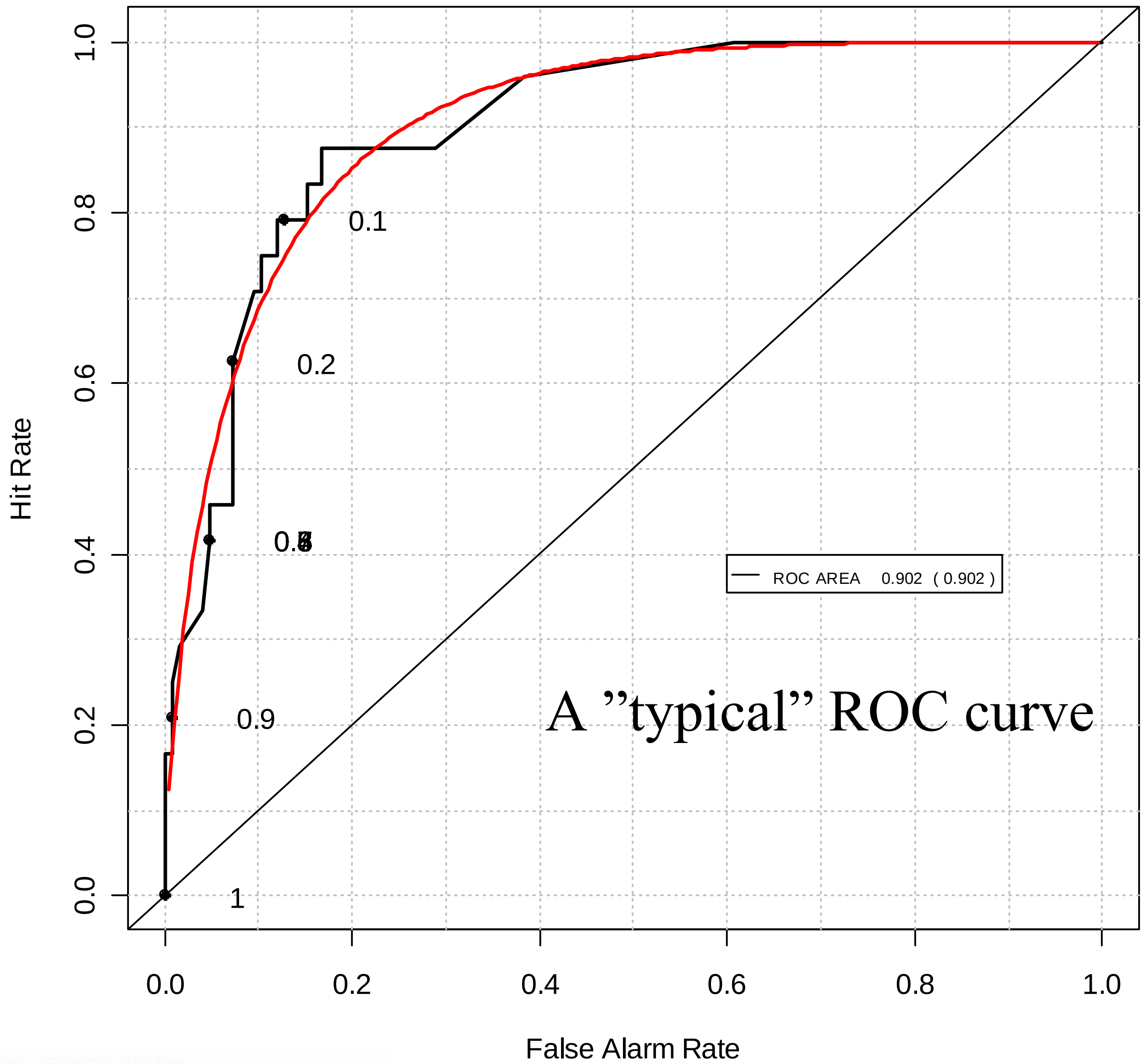
”Dressing” method: station 06079 +24h



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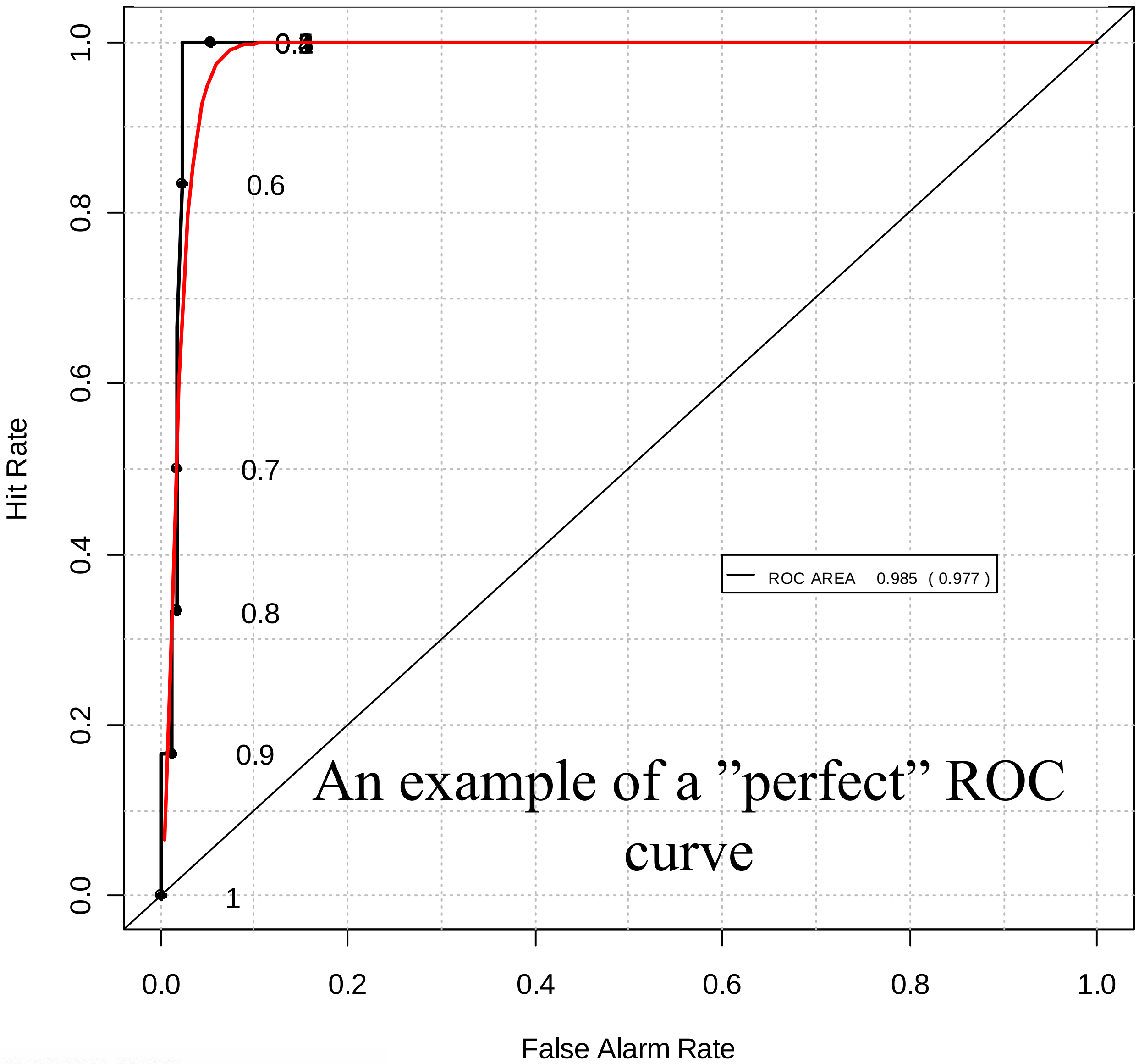
”Dressing” method: station 02584 +24h



Comparison of methods; station_02981_ +24 hrs

	HIRLAM				ECMWF		
	MBE Dr	MBE Stb	MBE Unc	RCR Unc	Dr	EPS	Kal
ROC_A	.91	.84	.90	.85	.98	.88	.95
BSS	.47	.12	.43	.34	.57	.44	.54

No. of events: ~ 25 /130

No. of events: ~ 30 /210

Dr - **"Dressing" of dependent sample**

Stb - **"Stability" method**

Unc - **"Uncertainty area" method**

EPS - **EPS 51 members**

Kal - **Kalman filter EPS**

Brier Score: $BS = (1/n)\ \Sigma\ (p_i - o_i)^2$

Brier Skill Score: $BSS = [1 - BS / BS_{ref}]$

Range: - oo to 1

Perfect score = 1

- MSE in probability space
- Sensitive to large forecast errors !
- Careful with limited datasets !
- Influenced by sample climatology
  - Different samples not to be compared

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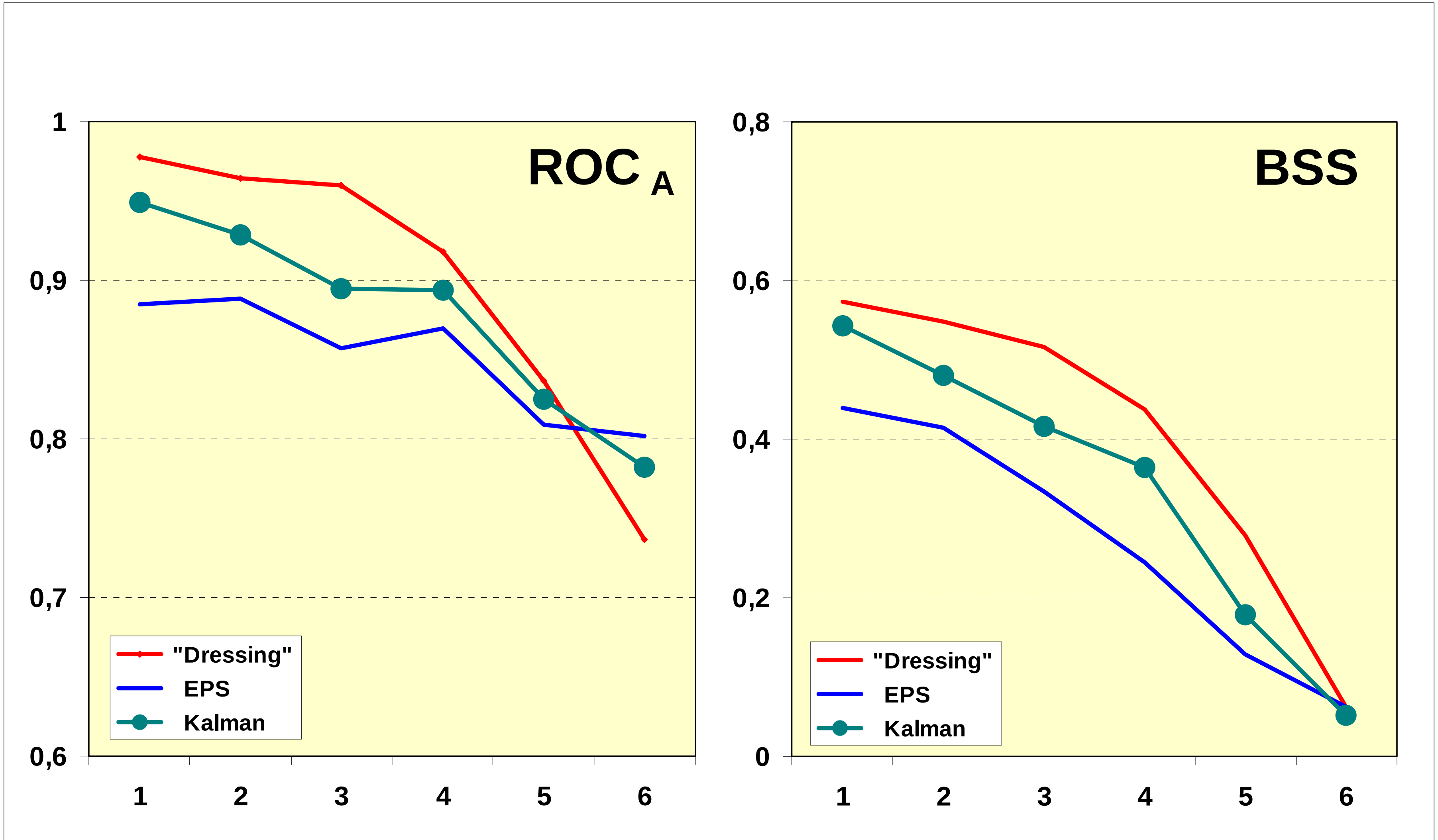
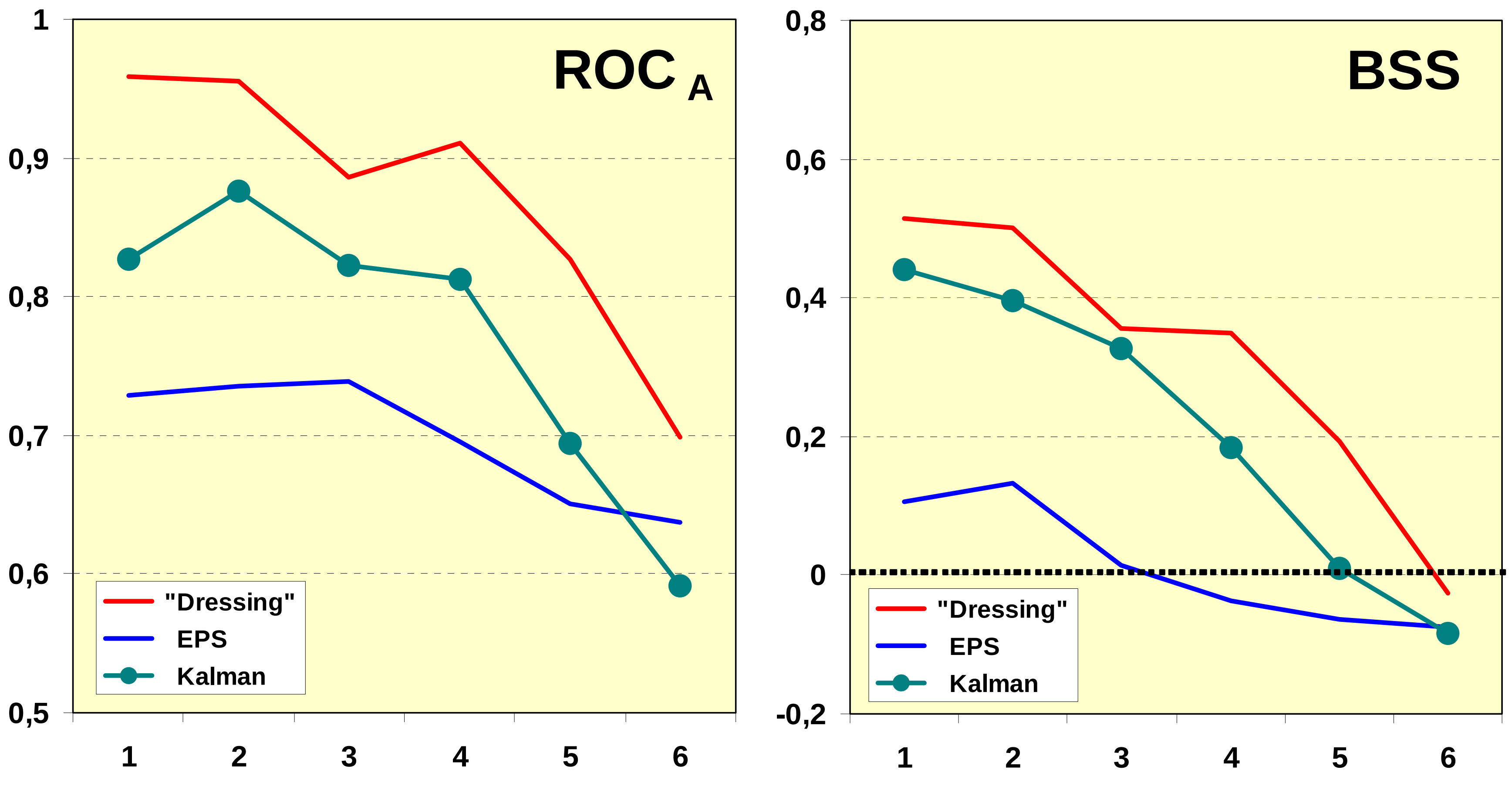
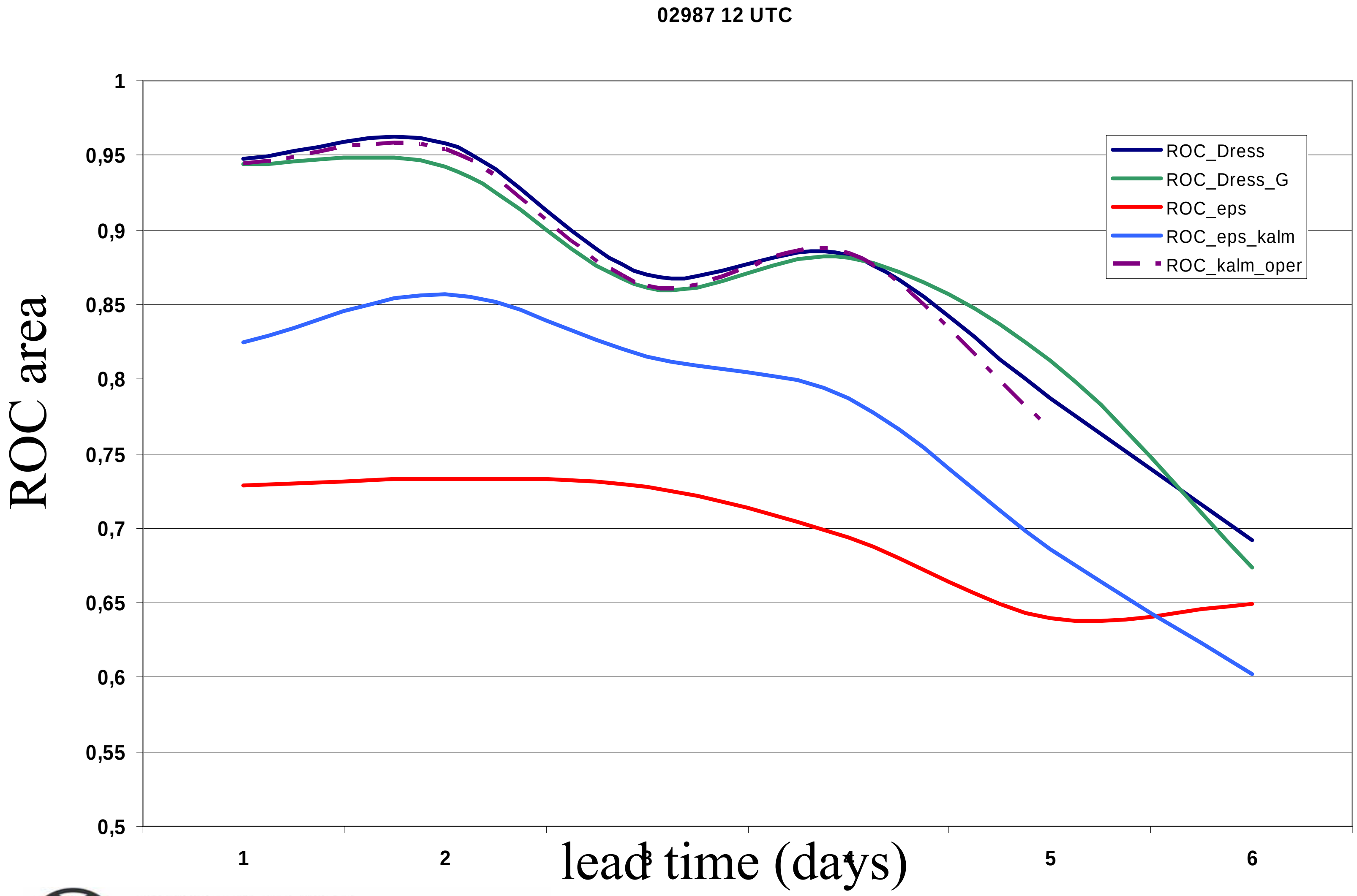
ROC Area & BSS w.r.t. to FC lead time; station_02981



ROC Area & BSS w.r.t. to FC lead time; station_02987



Results: Probability forecasts



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Conclusions

- Inhomogeneous observations a problem for verification
- EPS forecasts are slightly under dispersive
- The biases depend on station (height of anemometer etc.)
- Kalman filtering is able reduce biases and produce better probability forecasts for most stations in terms of ROC curve ROC area and Brier Skill Score
- "Dressing" of dependent sample: quality level hard to reach

THANK YOU