Experience with operational LAMEPS at met.no

Trond Iversen

Acknowledgement:
Inger-Lise Frogner,
Marit H. Jensen,
Hilde Haakenstad,
Ole Vignes

Uncertainty in High-Resolution Meteorological and Hydrological Mod
Vilnius, Lithuania, 26-28 April 2006

Some publications

Frogner and Iversen (2001) "Targeted ensemble prediction for Northern Europe
and parts of the North Atlantic Ocean." *Tellus* 53A, 35-55.

Frogner and Iversen (2002) "High resolution limited area ensemble predictions based on low resolution targeted singular vectors." *Q. J. of the Royal Meteorol. Soc.*, **128**, 1321-1341

Frogner, Haakenstad and Iversen (2006) "Limited area ensemble predictions at the norwegian meteorological institute" *Q. J. of the Royal Meteorol. Soc.*, Accepted.

See upcoming ECMWF Newsletter.

Why ensemble prediction?

Heard in the corridor:

- ”I prefer deterministic models”
- ”People want to know if it’s going to rain, and not that it might possibly rain”
- ”We should use all resurces to produce ***The Best Model and the best forecasts***, not to produce a multitude of mediocre models and forecasts”

However:

- Weather prediction with quality better than climate statistics is not a deterministic problem!
- If we pretend it’s deterministic, we lose information that can be crucial to protect human lives and property
- Predictability generally decrease with decreasing scales

Why ensemble prediction?

Probabilistic products:

- The predictability of today's weather
- Romoval of unpredictable components by e.g. cluster averages
- Forecasts of risk of extreme events
- Forecasts beyond the predictability limit of pure atmospheric forecasts (monthly, seasonal, and longer)
- In a well calibrated EPS:

  Forecast errors due to initial state uncertainty can be separated from errors caused by model physics inaccuracy

Use of LAMEPS

- Forecasting (*)
- Storm-surge LAMEPS (*)
- Input to hydrological models (*)

Limited area ensemble forecasting in Norway - outline

- Ensemble forecasts using Norway's operational version of the HIRLAM model – **LAMEPS**
- Initial states and lateral boundary data are preturbed with a dedicated version of **EPS** from ECMWF - **TEPS**
- TEPS and LAMEPS combined gives **NORLAMEPS**
- Present focus: **precipitation, and extreme precipitation events**
- Other examples: Winds, waves, and storm surge

TEPS

- A dedicated version of EPS. Differences are
  - 20 + 1 ensemble members, as opposed to 50 + 1 for EPS
  - Target area Northern Europe and adjacent sea areas, as opposed to NH north of 30°N(*)
  - Runs to +96h, as opposed to +240h for EPS (**)
- Starts at 12 UTC every day
- Started at ECMWF in Feb. 2005.
- Operational since 5 April 2005.
- T255L40(~80 km), Since Feb 1st: T399L62(~55 km)

LAMEPS

- HIRLAM in ensemble set-up (6.2.0++; since 20th Feb: 6.4)
- Resolution: 0.2 deg (20km), 40 levels
  (to be improved: new computer in Summer 2006)
- Forecast Range: +60h
- 20 members + Control,
  Control based on Norwegian HIRLAM analysis
  20 Initial and open boundary perturbations from TEPS(*)
- Starts at 18UTC every day (fresh HIRLAM analysis),
  i.e. a 6 hour delay compared to TEPS and EPS
- Operational at met.no since 14 February 2005

NORLAMEPS

- Combines IFS TEPS and HIRLAM LAMEPS
    - A simple multimodel, multi- initial- state ensemble
    - 40 + 1 ensemble members
    - includes two different models (model uncertainty)
    - NORLAMEPS has better resolution than EPS
    - NORLAMEPS is designed for our area of interest
    - For day 1 – 3

Generation of perturbations

30 minutes

12 UTC

Running TEPS to +96h

20 + 1 members

2 hours

ECMWF

TEPS is automatically transferred to met.no

TEPS is made ready to run in the Norwegian model environment

19 UTC

TEPS is transferred to Trondheim

Generation of HIRLAM perturbations

LAMEPS running 18 UTC, to +60h

50 minutes

Combination of TEPS and LAMEPS - NORLAMEPS

00 UTC

Generation of probability products for customers

Verification methodology - 1

- Verify precipitation against "super-observations". (Ghelli and Lalaurette):
- All precipitation sites in Norway inside the verification area are aggregated using the method of Kriging
- Total precipitation (stratiform and convective) from LAMEPS, TEPS, EPS and NORLAMEPS are compared to these "super-observations"

Verification methodology – 2

- Distribution of precipitation in Norway is dominated by sharp gradients (*)
- We verify in sub-regions with grossly different precipitation climatology separately.
- Inside each sub-region precipitation climatology is fairly uniform
- Averages are calculated using weights reflecting the area of the sub regions

RESULTS FROM VERIFICATION

- Two periods:
  - Test-period: 45 days during 14 Feb. 2005 until 24 July
  - Operational: 14 Feb. 2005 until 19 Feb. 2006, seasonal
- Three verification sub-domains based on precipit. climatology
- Verification is done for
  - **LAMEPS 20 + 1 members**
  - **TEPS 20 + 1 members**
  - **EPS 50 + 1 members**
  - **NORLAMEPS 40 + 1 members**
- Parameter: 24 hours precipitation (from 06 to 06 UTC)
- Forecast lengths

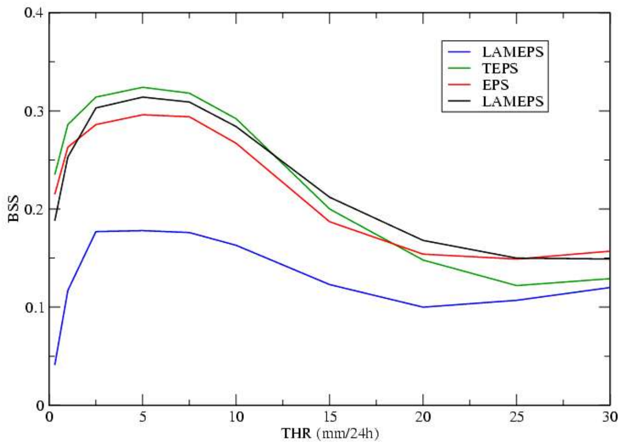
  LAMEPS (from 18 UT): +36 and +60 hours

  TEPS (from 12 UT): +42 and +66 hours

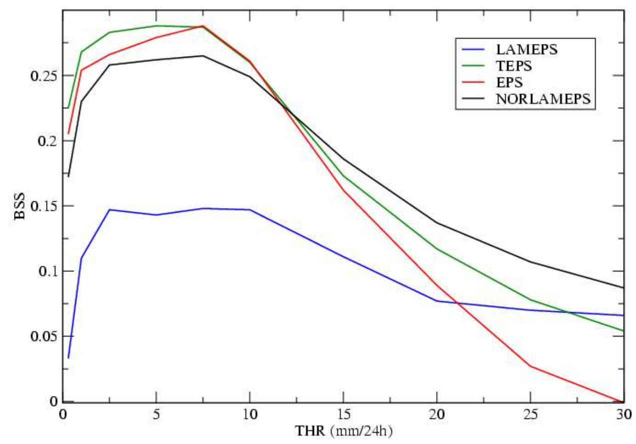
  EPS (from 12 UT): +42 and +66 hours

BRIER SKILL SCORE
all three regions

BSS (12/18h - 36/42h)

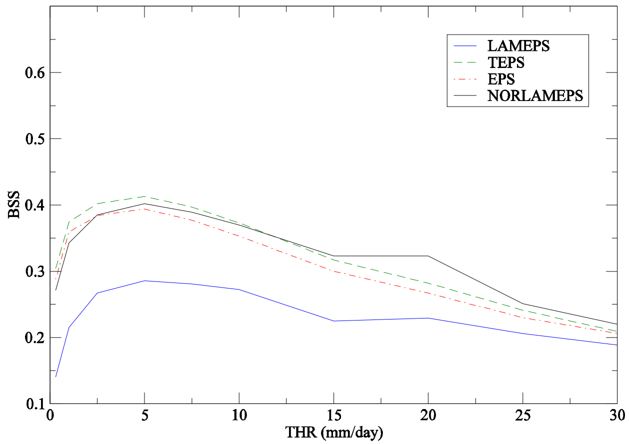


BSS (36/42h - 60/66h)

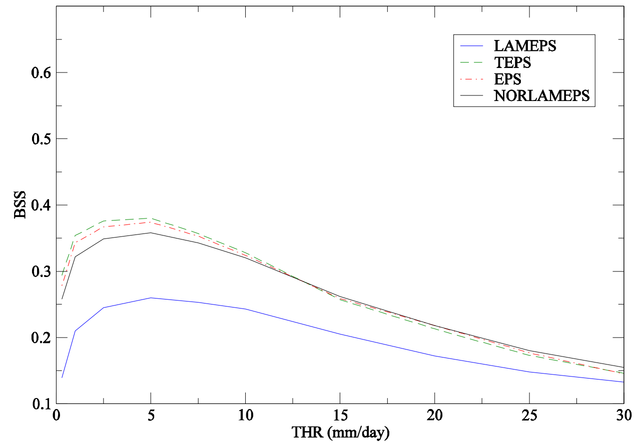


Test- period

BSS (12-36h)



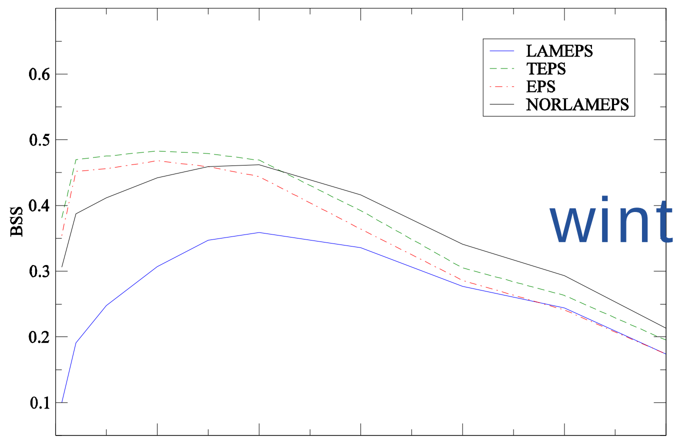
BSS (36-60h)



Annual average

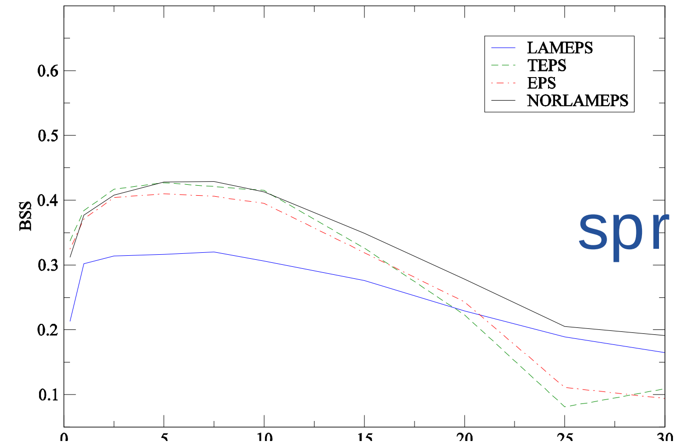
BRIER SKILL SCORE
area 1 west

Brier Skill Score (12-36h)
AREA1 - WINTER 2005/2006



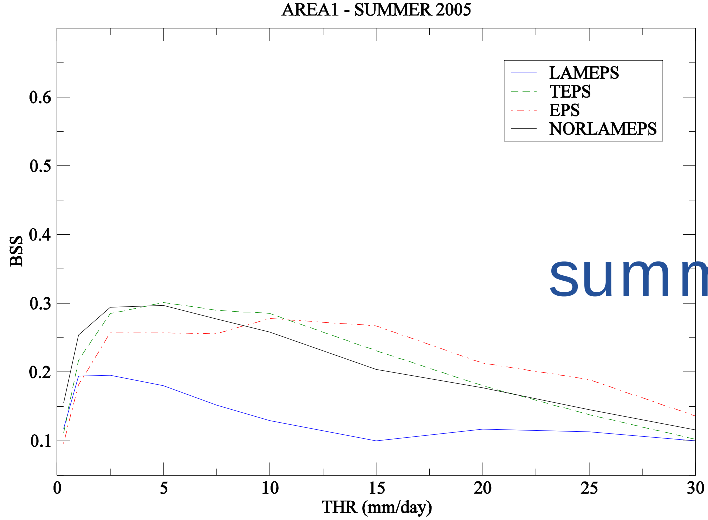
winter

Brier Skill Score (12-36h)
AREA1 - SPRING 2005



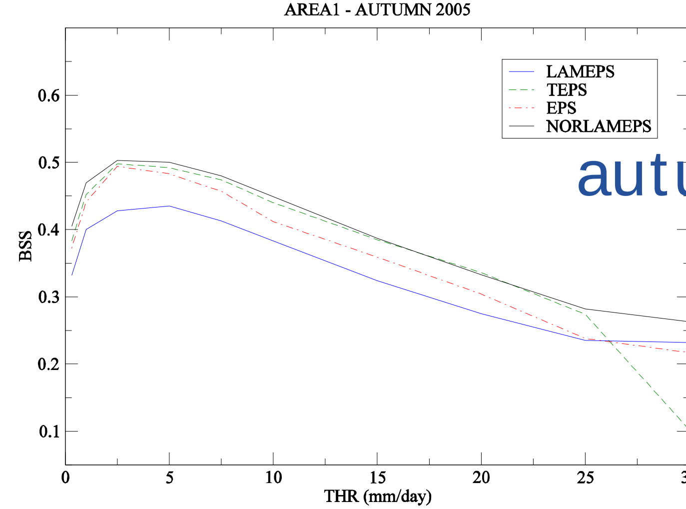
spring

Brier Skill Score (12-36h)
AREA1 - SUMMER 2005



summer

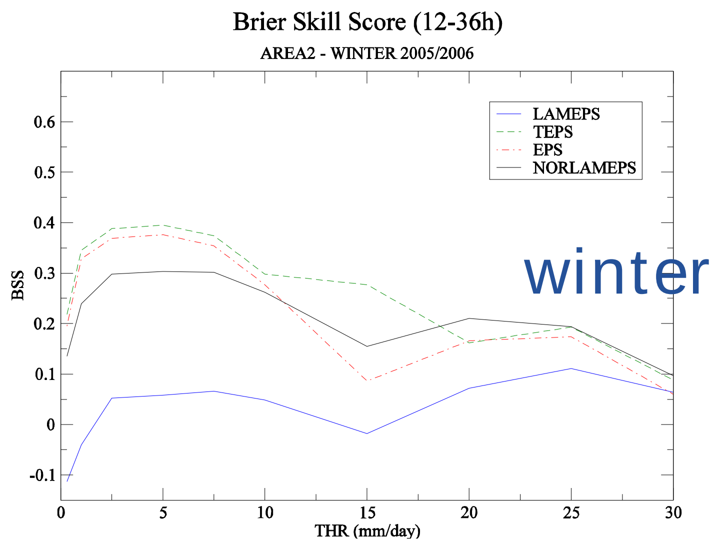
Brier Skill Score (12-36h)
AREA1 - AUTUMN 2005

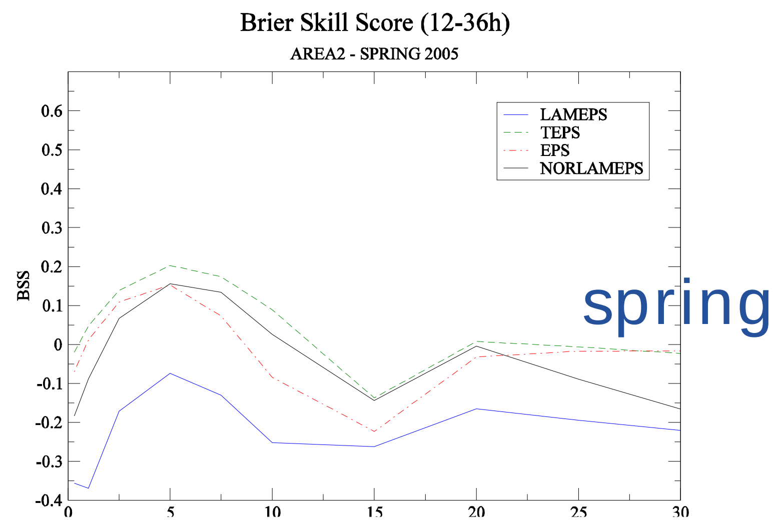


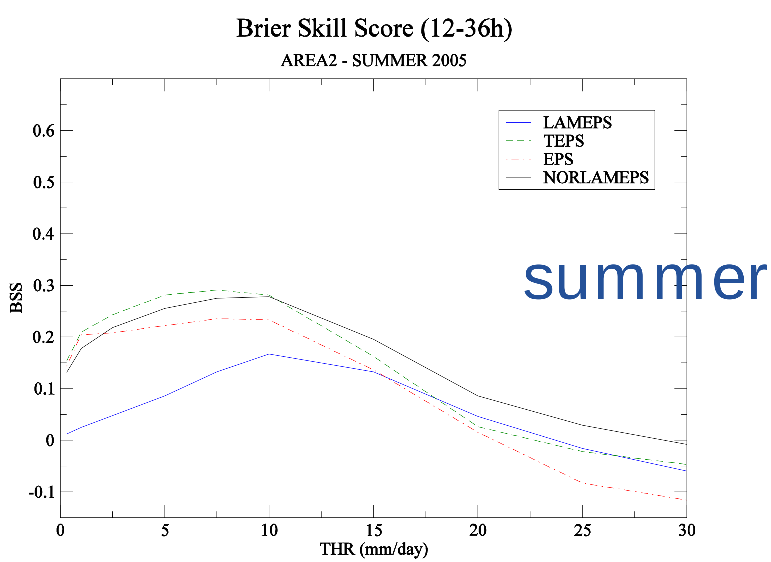
autumn

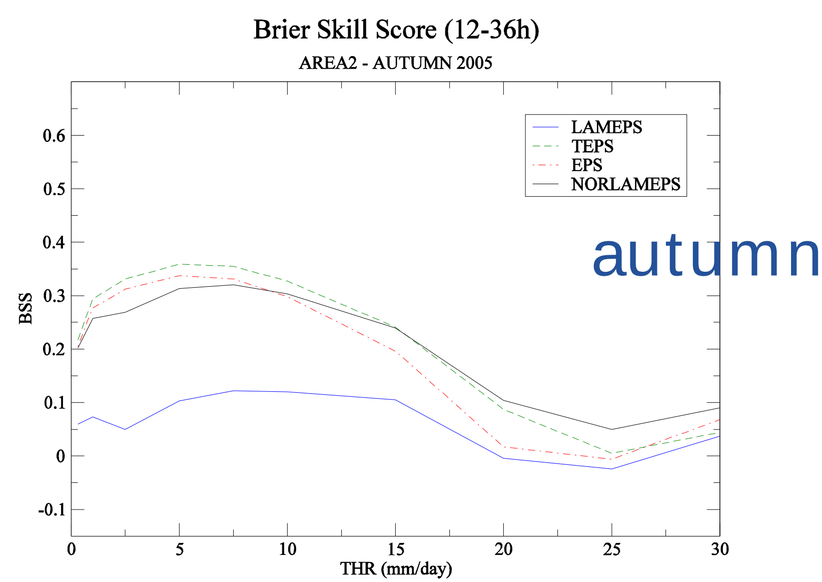
BRIER SKILL SCORE

? Ea



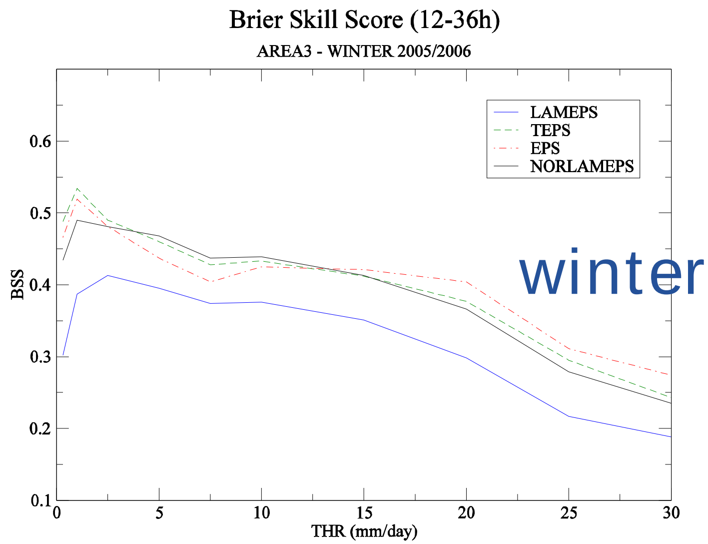


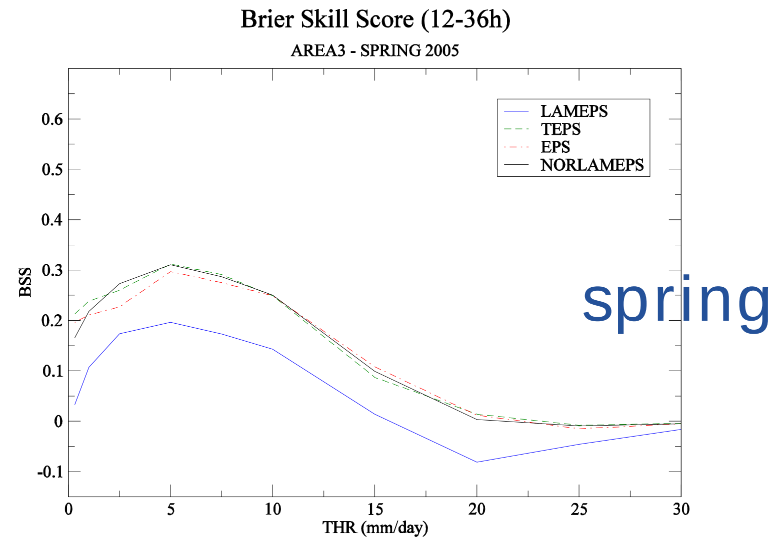


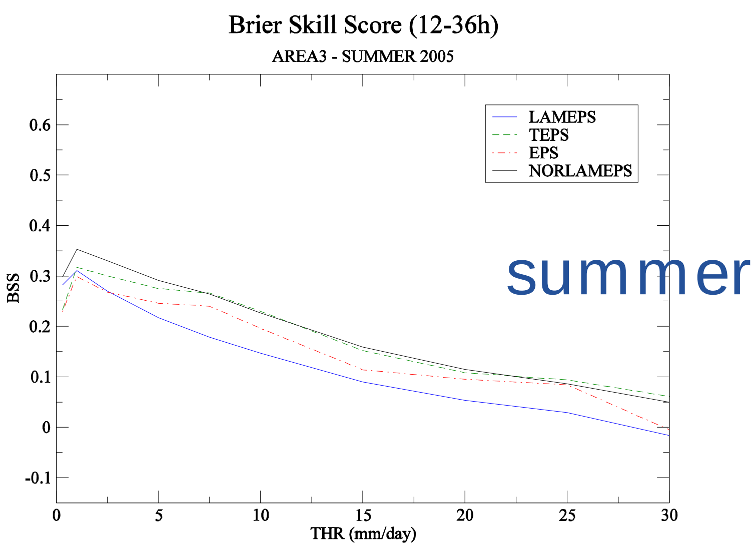


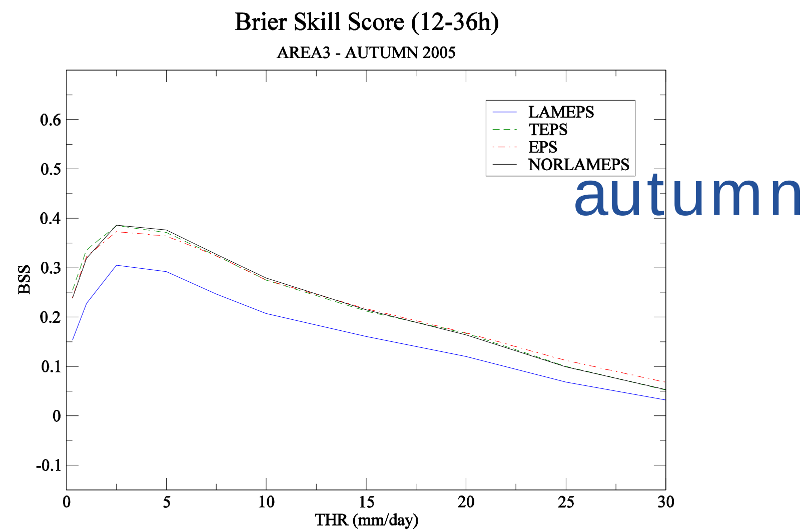
BRIER SKILL SCORE

Nc

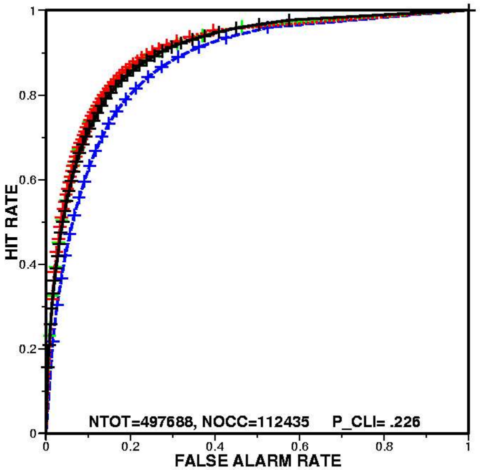




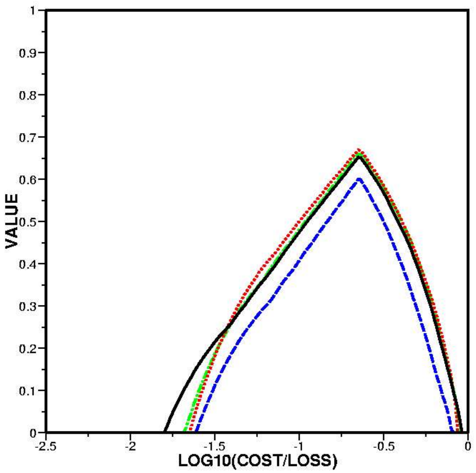


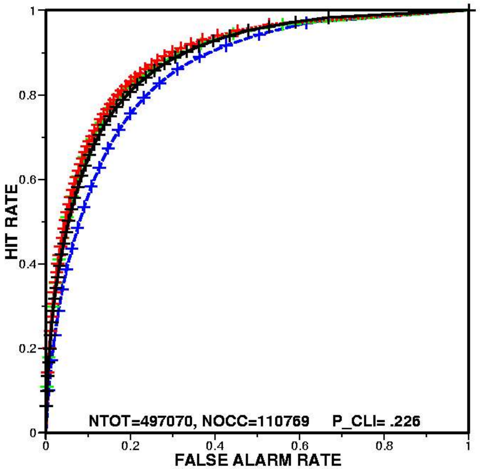


ROC and Value(C/L), all three regions
LOW THRESHOLD: 5 mm/24h

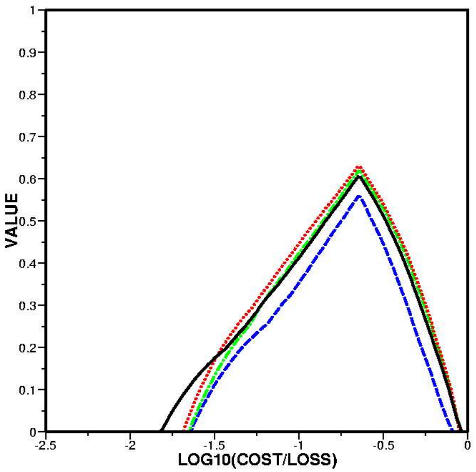


PRECIP, + 36h, THR = 5.00
DASH: lameps (AREA= .872)





PRECIP, + 60h, THR = 5.00
DASH: lameps (AREA= .854)

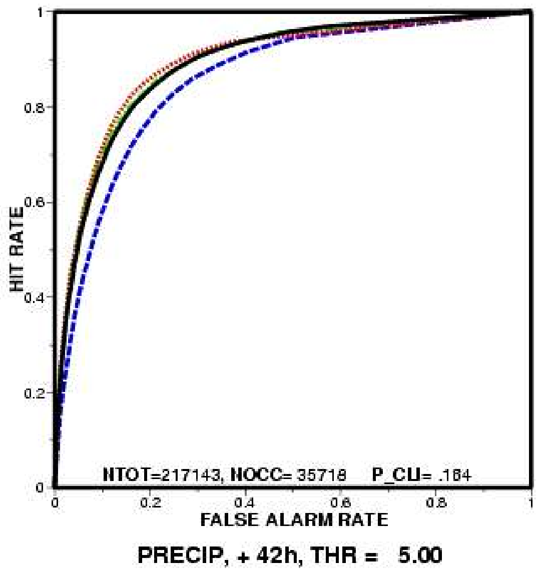


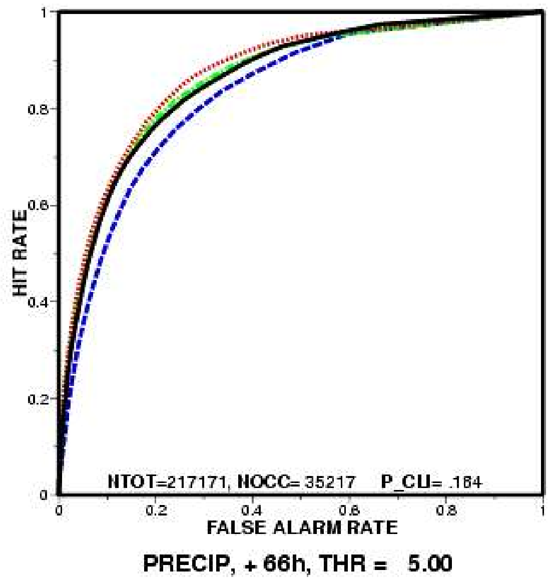
- Annual average

LAMEPS
TEPS
EPS
NORLAMEPS

ROC and Value(C/L), all three regions

LOW THRESHOLD: 5 mm/24h





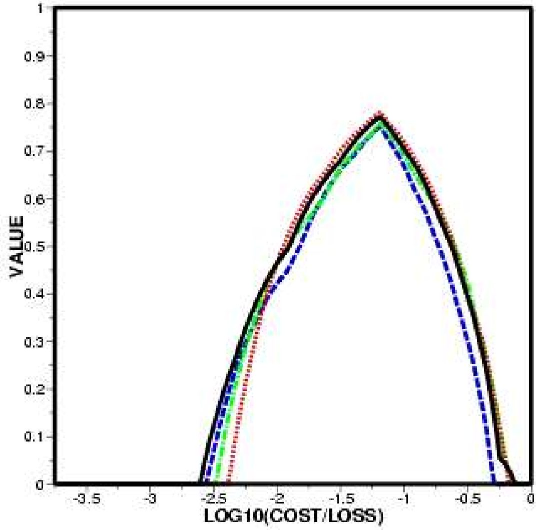
Test period

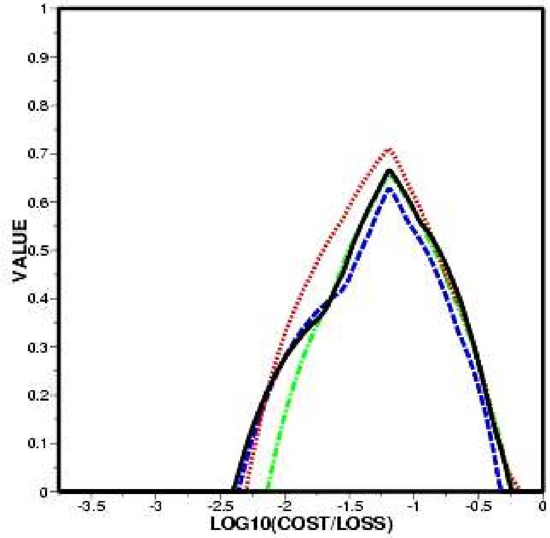
LAMEPS

TEPS

EPS

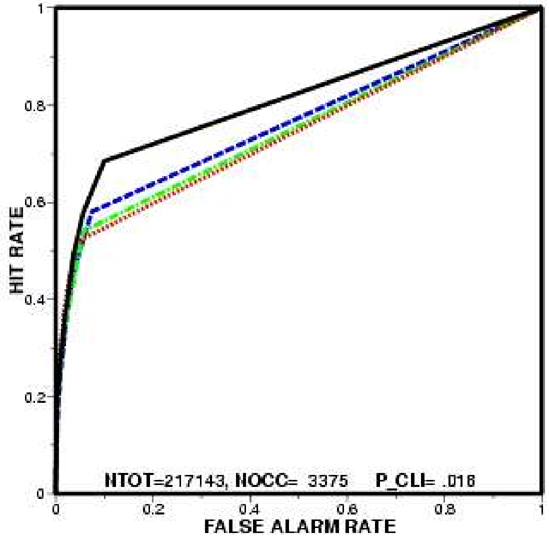
NORLAMEPS



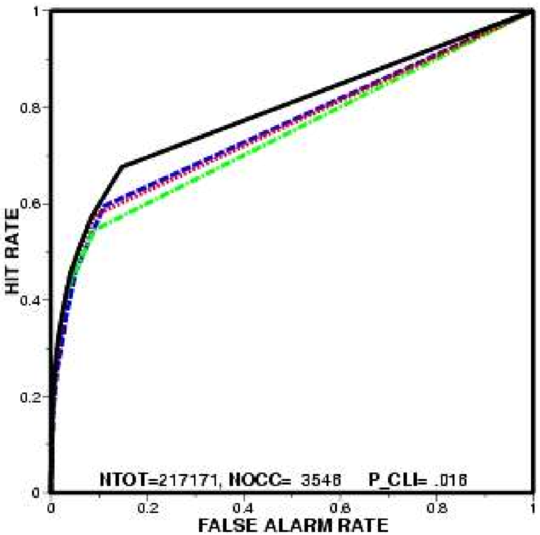


ROC and Value(C/L), all three regions

MEDIUM THRESHOLD: 20 mm/24h



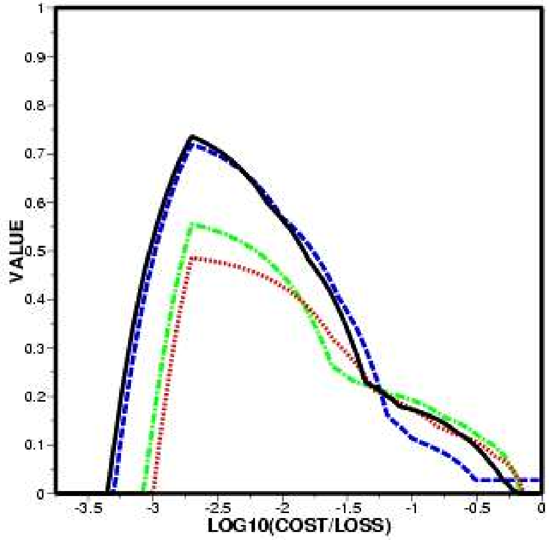
PRECIP, + 42h, THR = 20.00

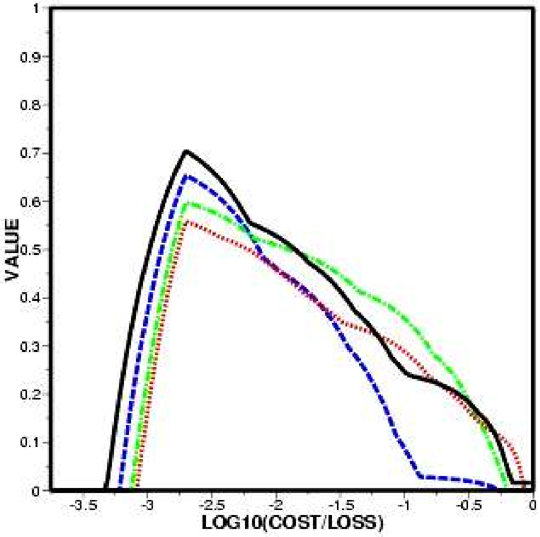


PRECIP, + 66h, THR = 20.00

Test period

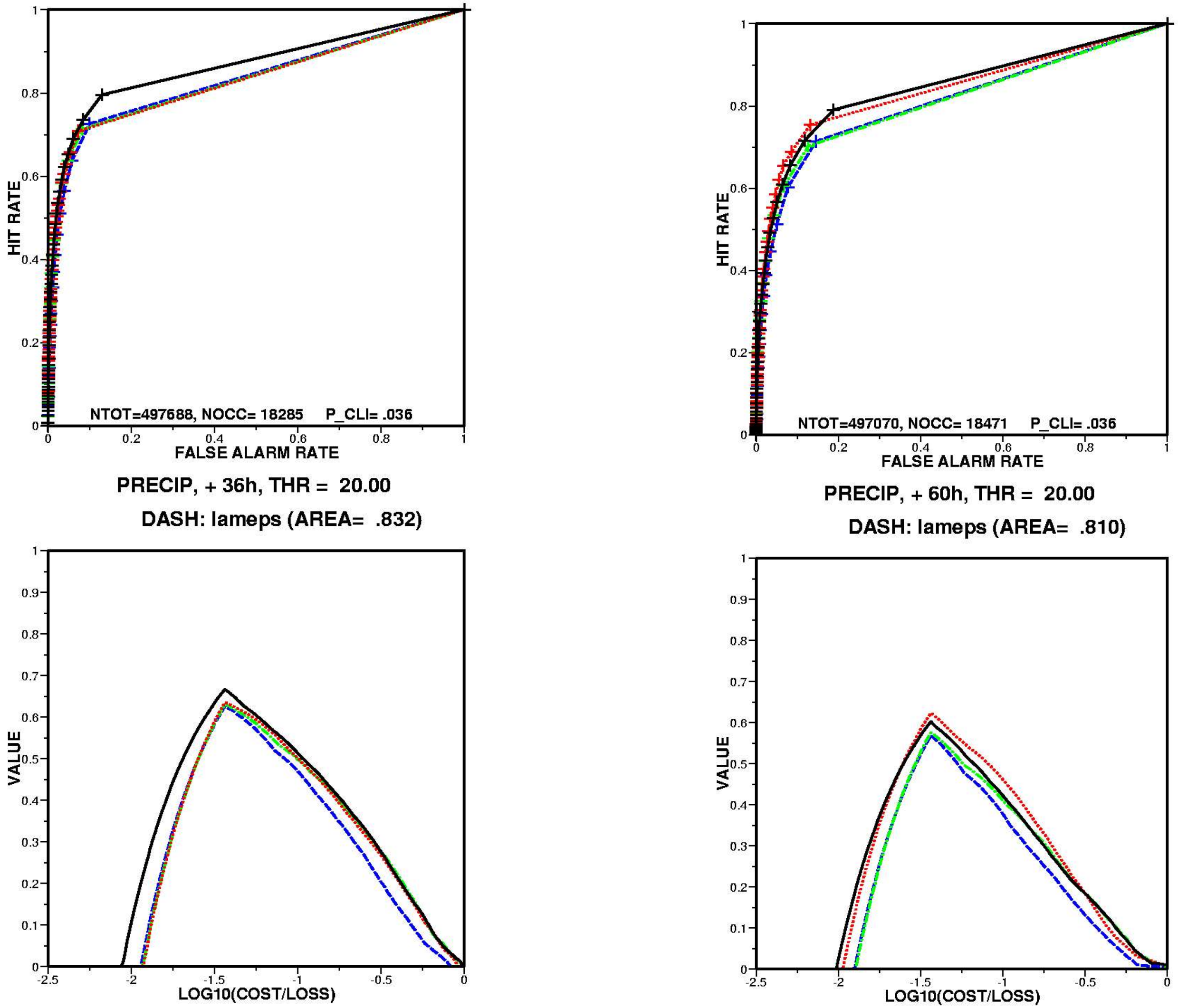
LAMEPS
TEPS
EPS
NORLAMEPS





ROC and Value(C/L), all three regions

MEDIUM THRESHOLD: 20 mm/24h

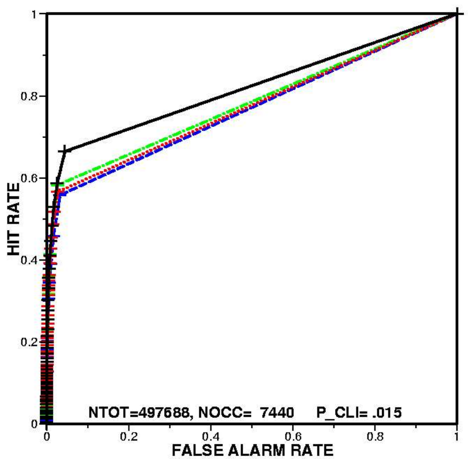


Annual average

LAMEPS
TEPS
EPS
NORLAMEPS

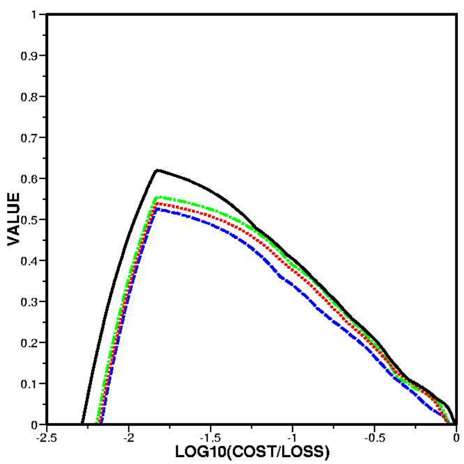
ROC and Value(C/L), all three regions

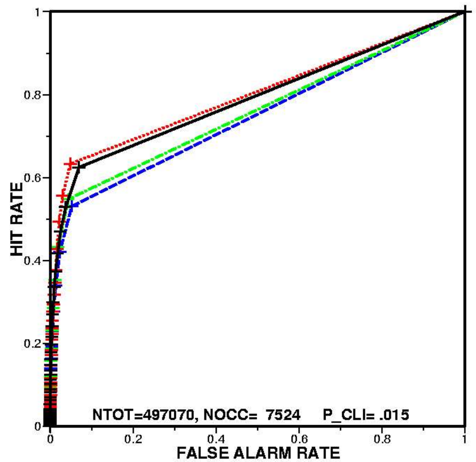
HIGH THRESHOLD : 30 mm/24h



PRECIP, + 36h, THR = 30.00

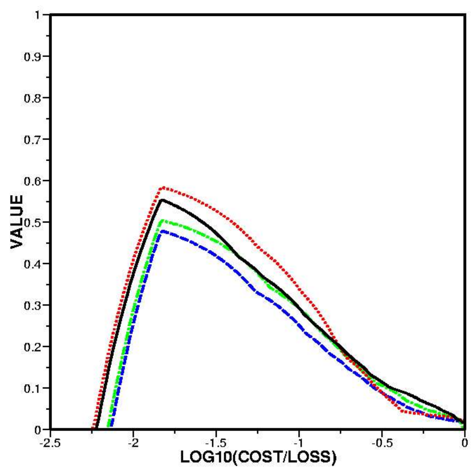
DASH: lameps (AREA= .767)





PRECIP, + 60h, THR = 30.00

DASH: lameps (AREA= .746)



Annual average

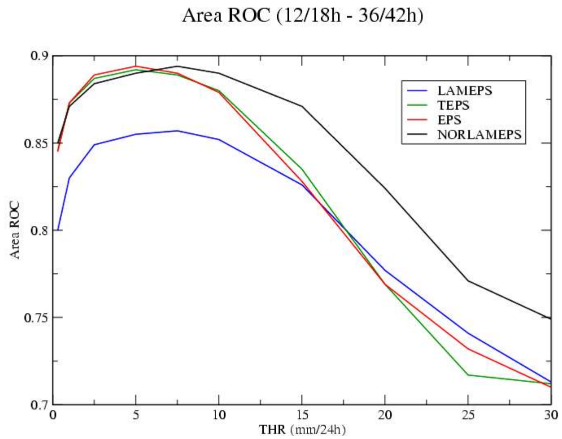
LAMEPS

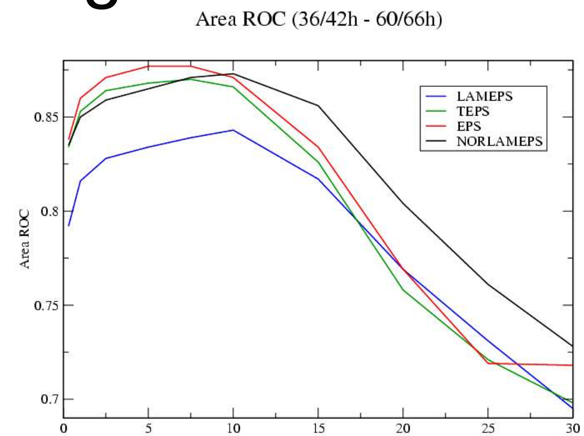
TEPS

EPS

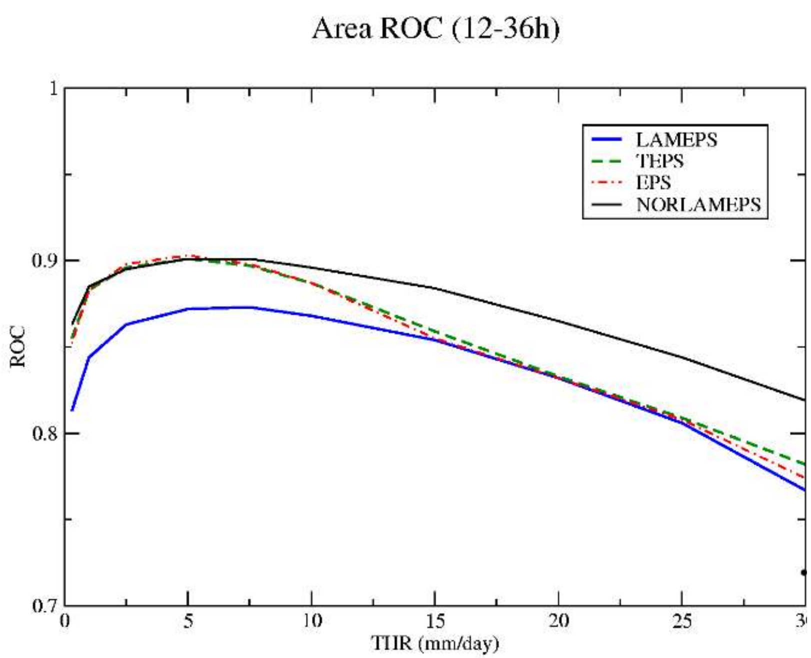
NORLAMEPS

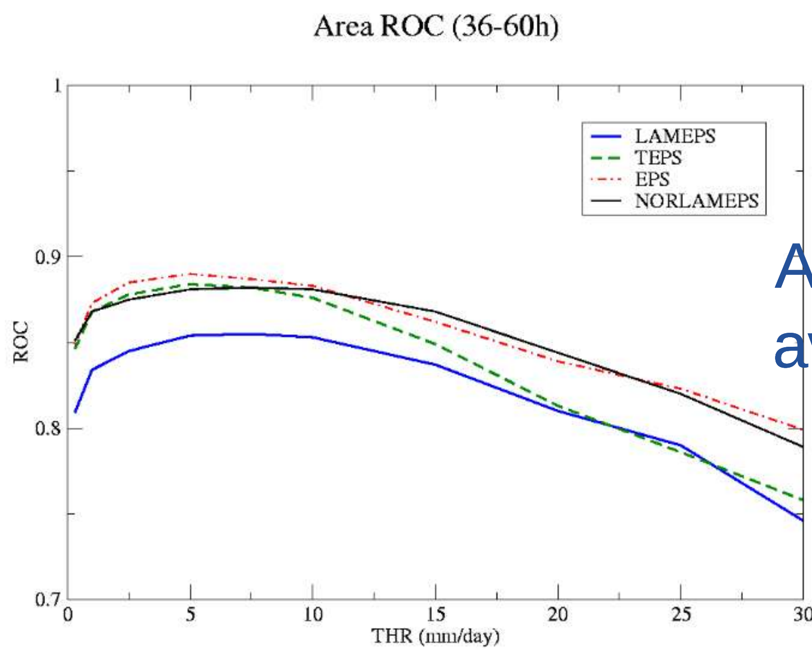
Area under ROC- curve all three regions





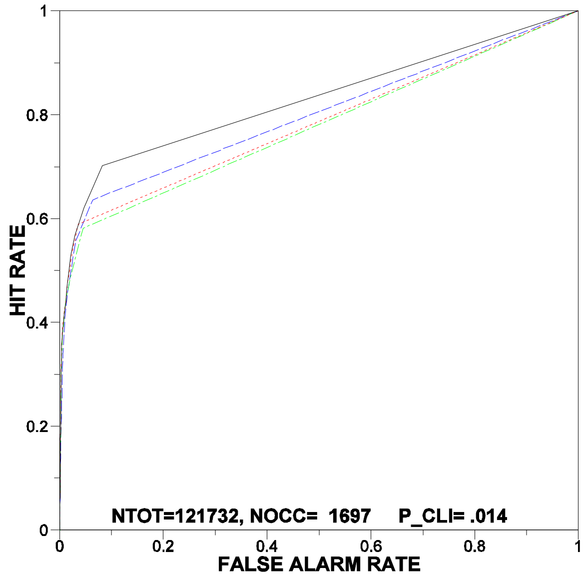
Test- period



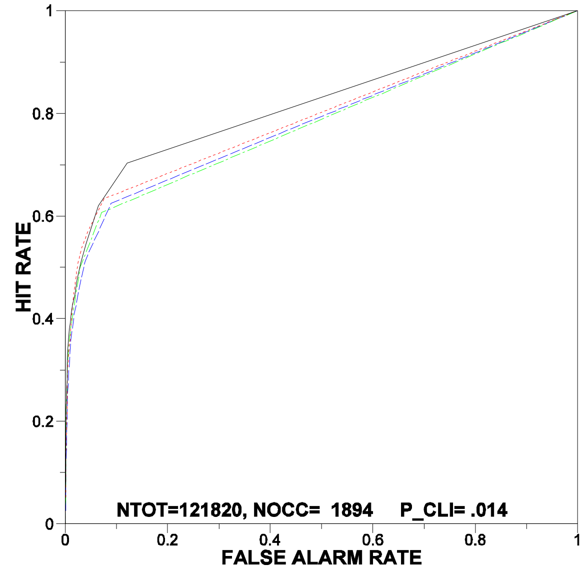


Annual average

MEDIUM THRESHOLD: 20 mm/24h



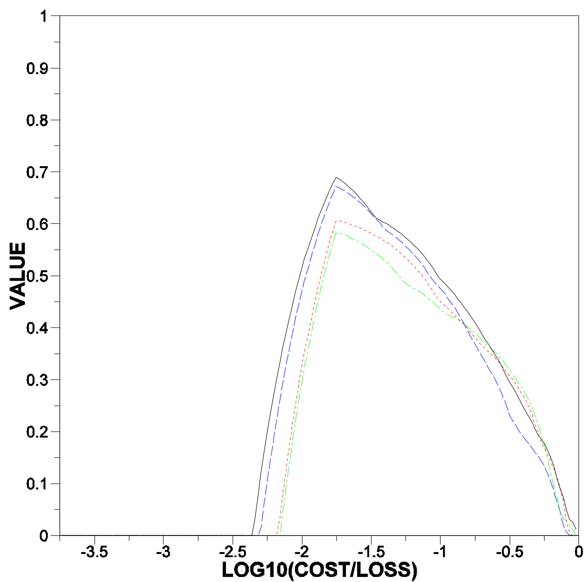
PRECIP, + 42h, THR = 20.00

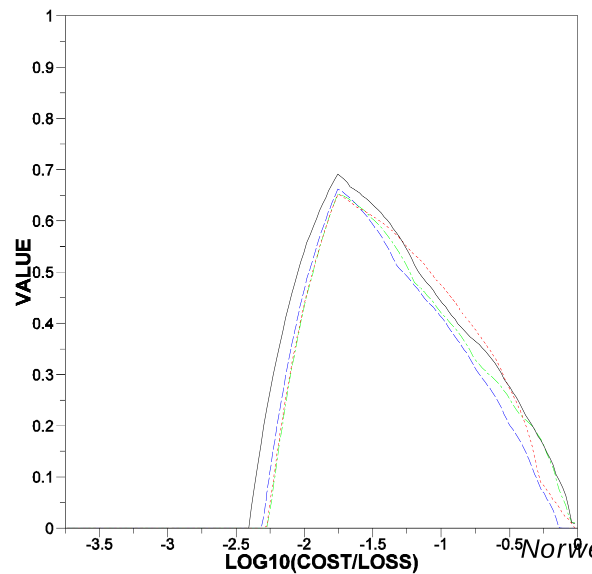


PRECIP, + 66h, THR = 20.00

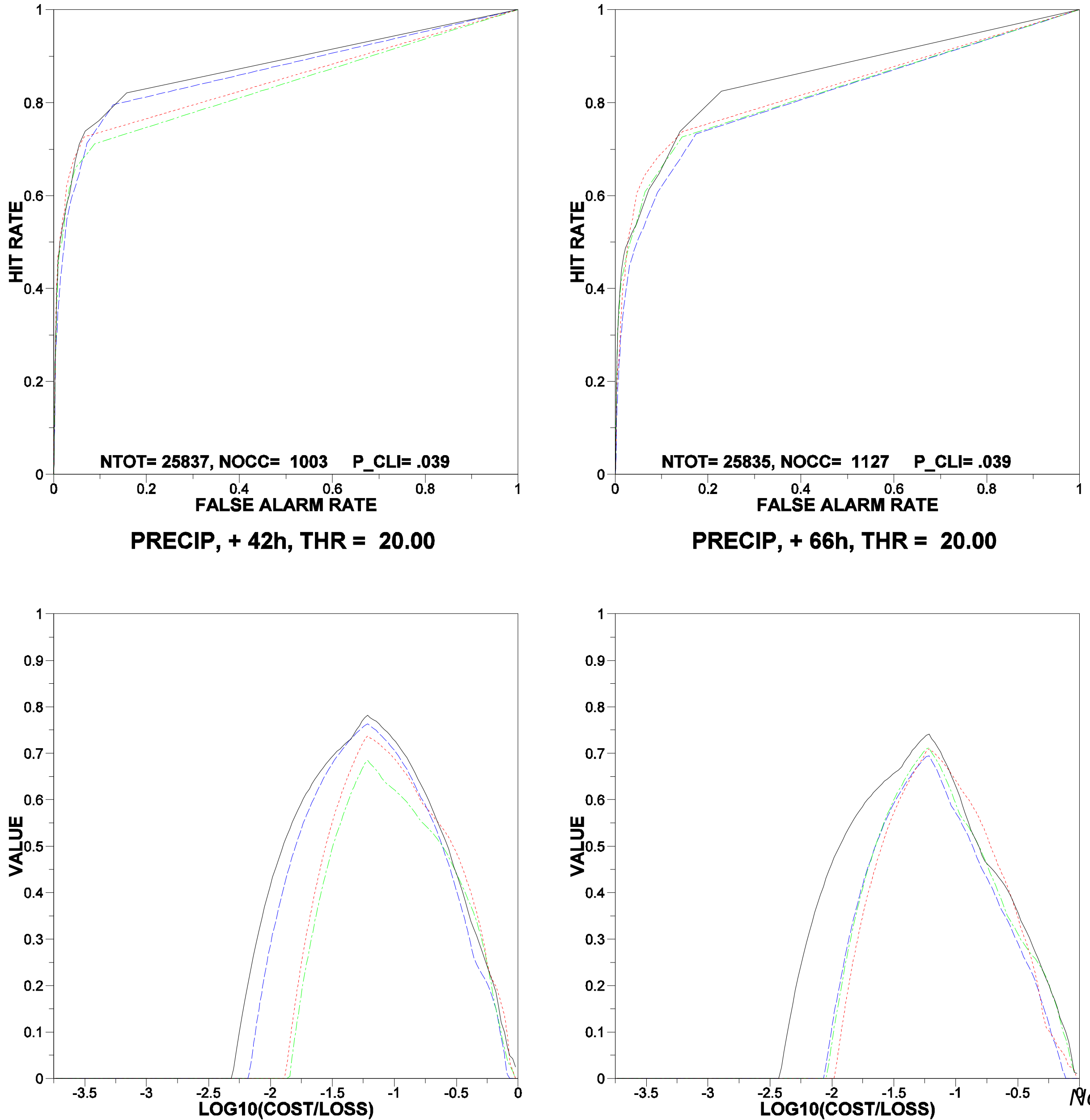
Spring

LAMEPS
TEPS
EPS
NORLAMEPS





MEDIUM THRESHOLD: 20 mm/24h

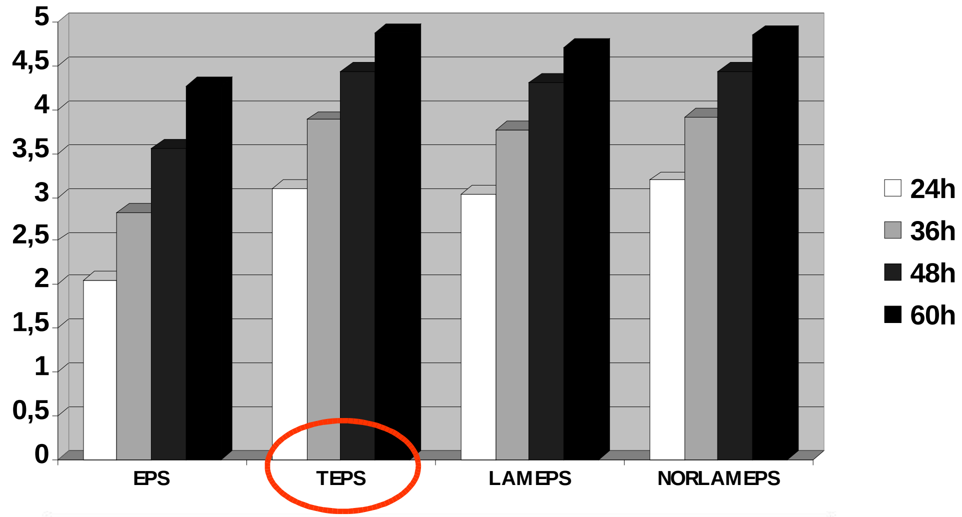


Spring
Area 1

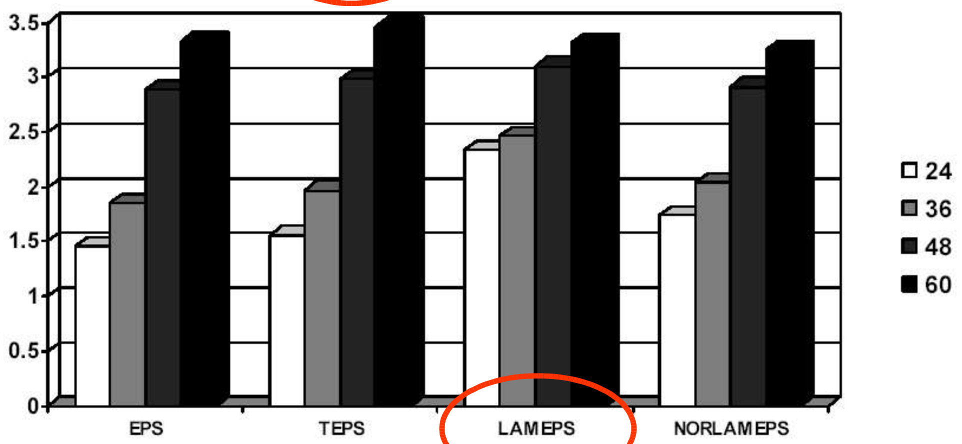
LAMEPS
TEPS
EPS
NORLAMEPS

Rms Spread around ensemble mean and rms error of ensemble mean for the 45-day test-period

MSLP



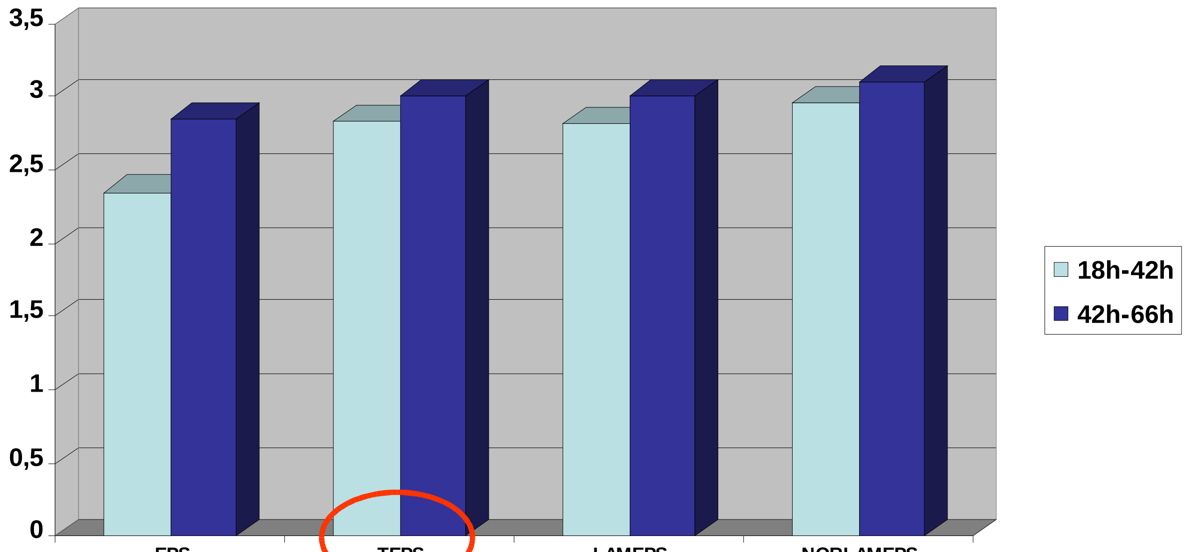
Spread



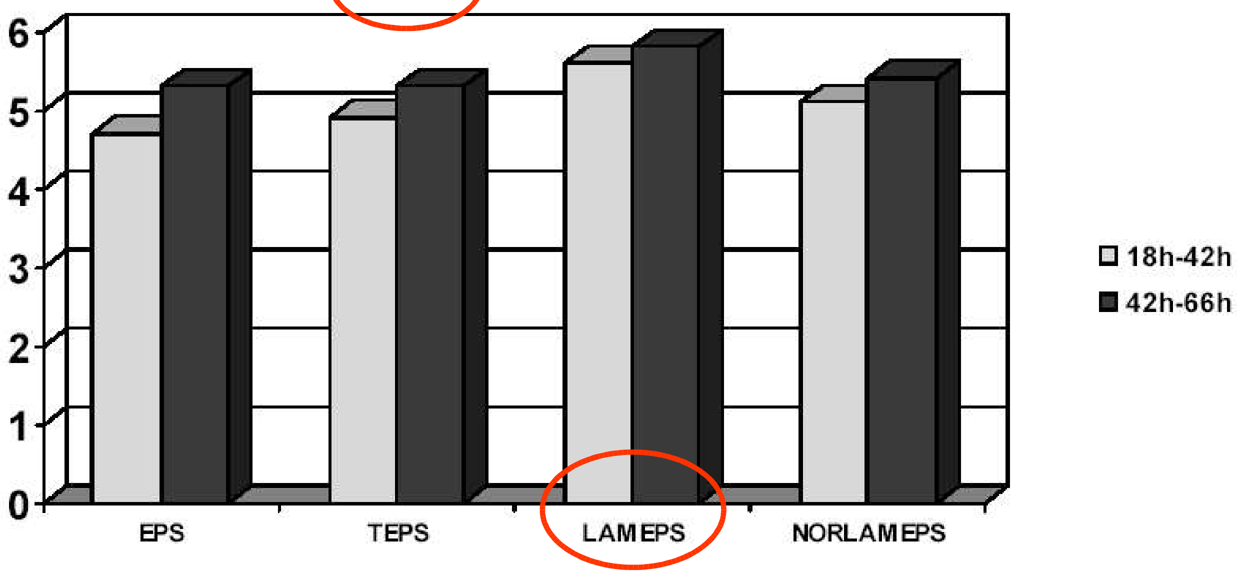
Error

Rms Spread around ensemble mean and rms error of ensemble mean for the 45-day test-period

PRECIP.



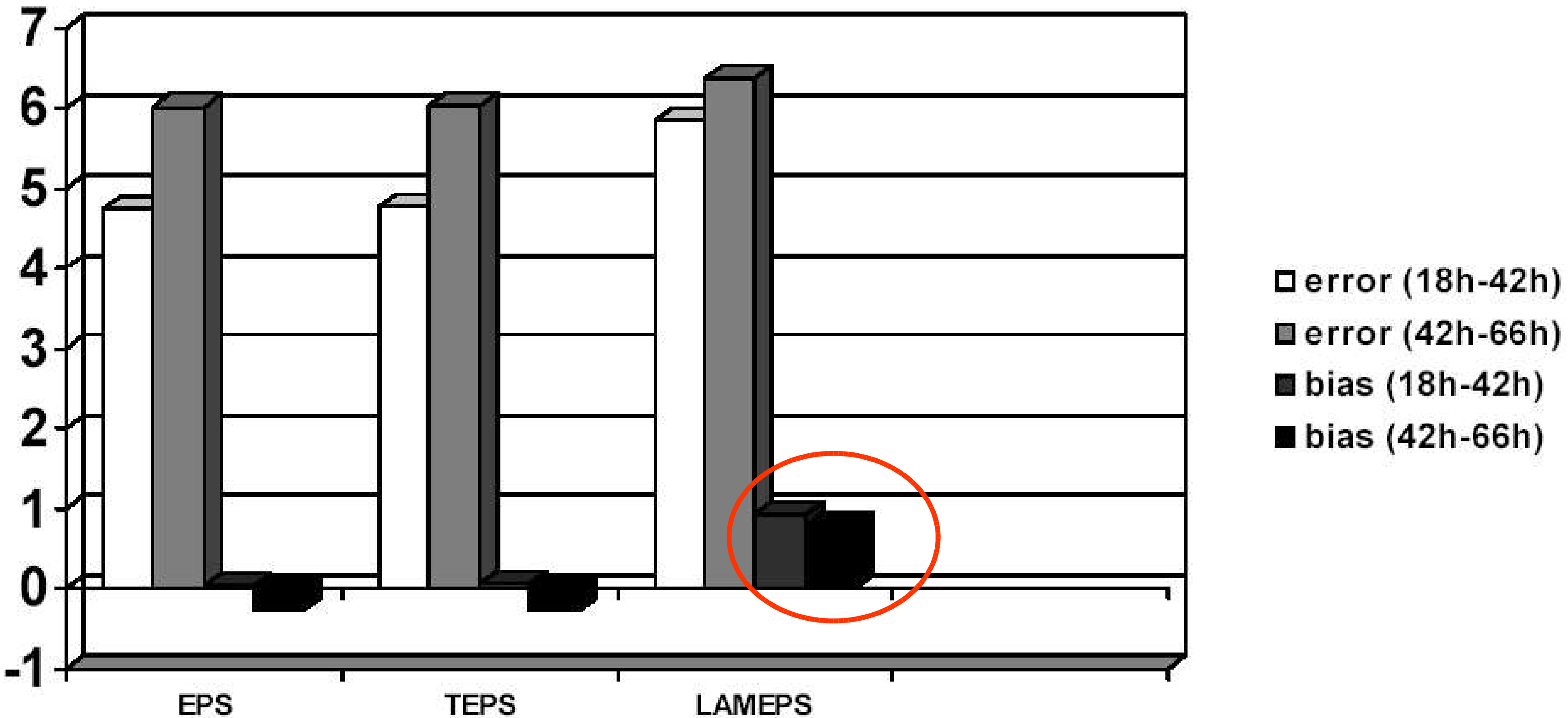
Spread



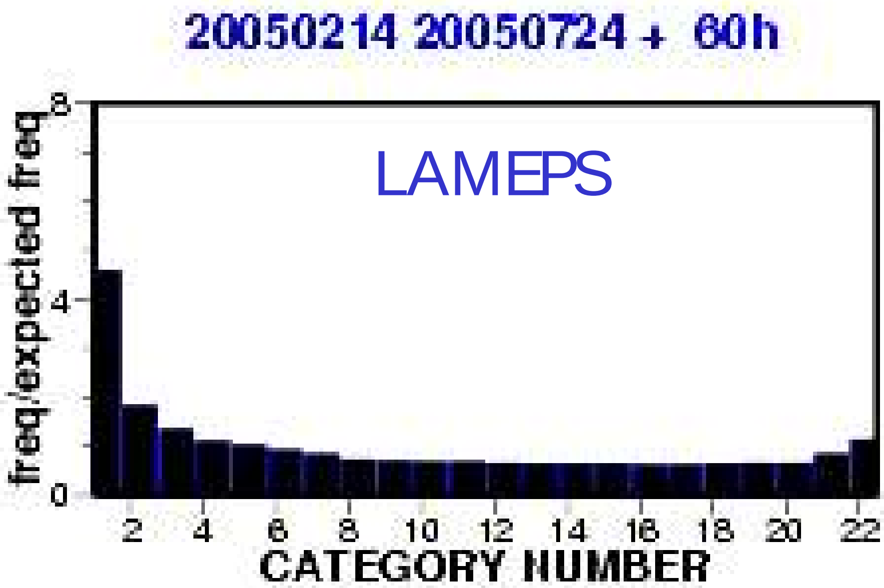
Error

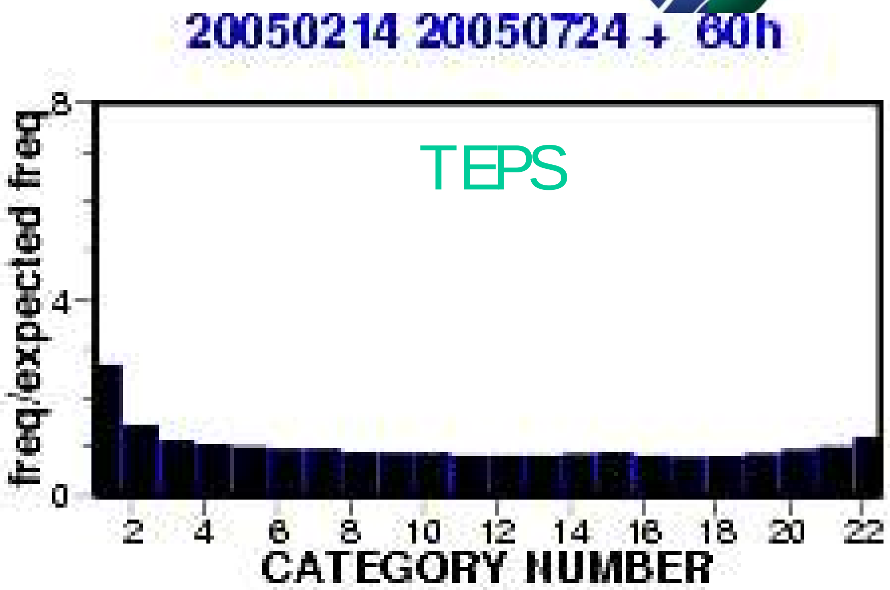
Rms error and bias error of control forecast for the 45- day test- period

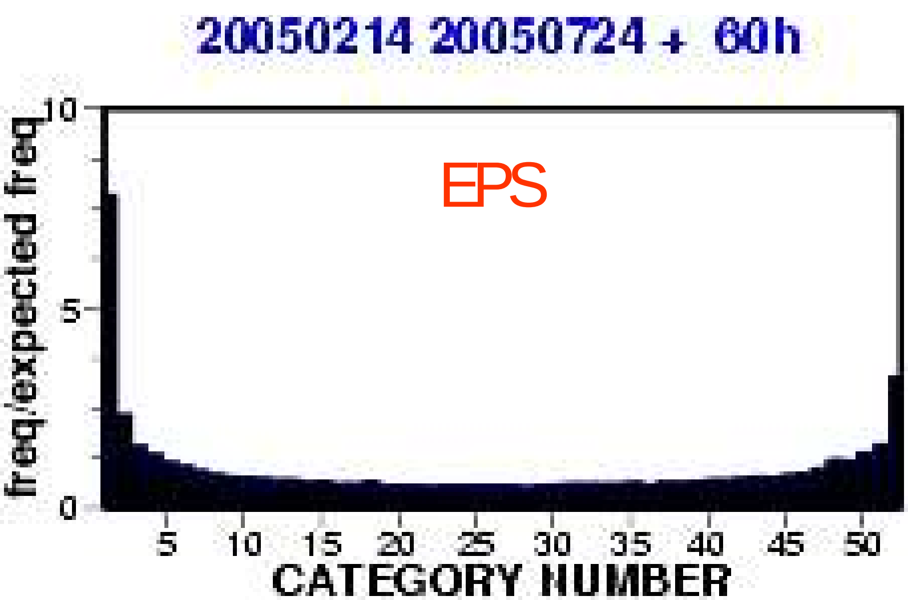
PRECIP.

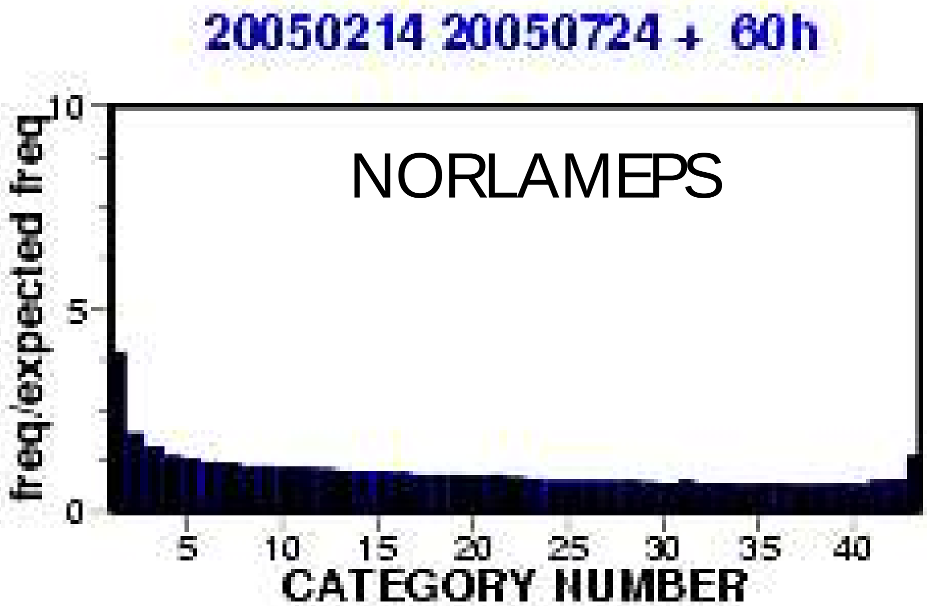


Rank histograms (test period)

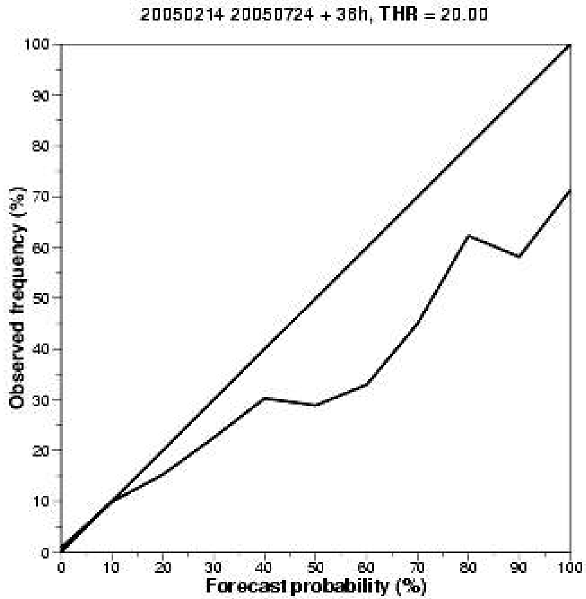




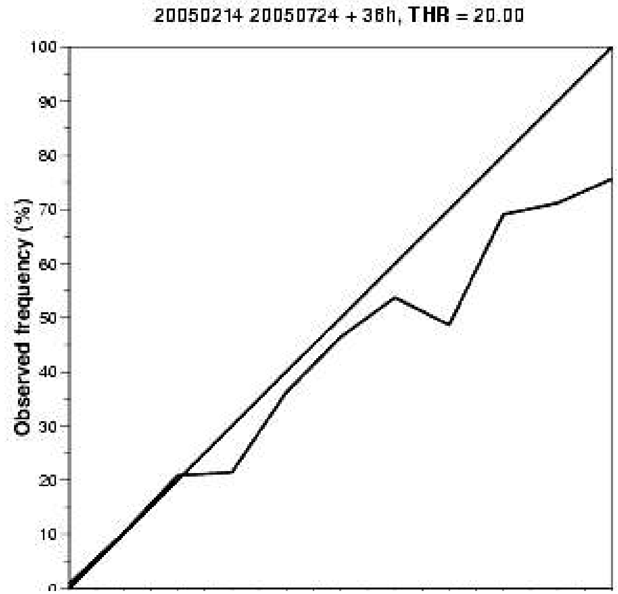




Reliability diagrams 20mm. 36h

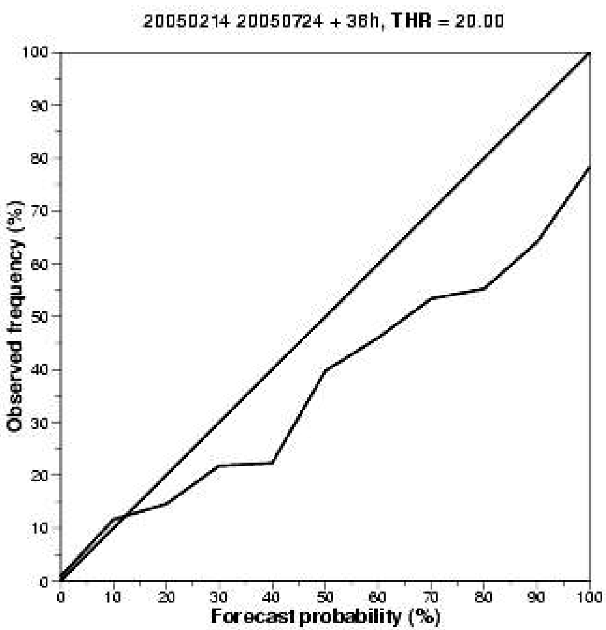


LAMEPS

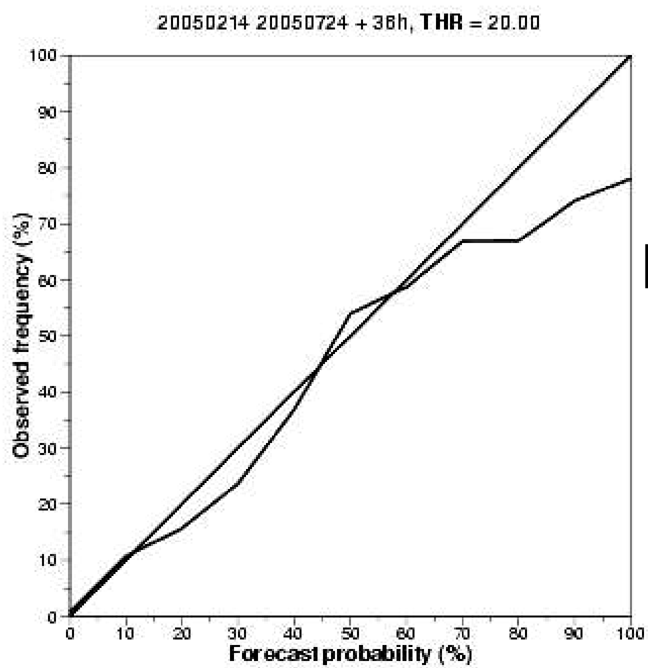


TEPS

Test Period

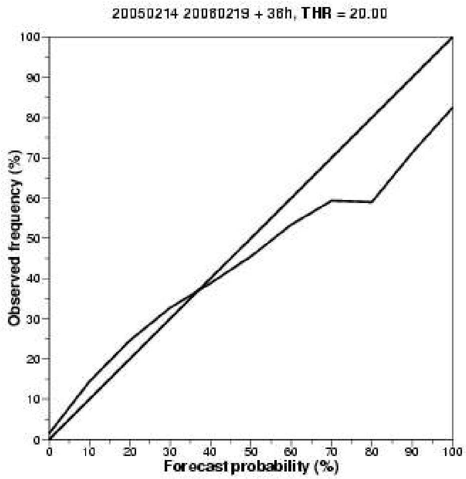


EPS

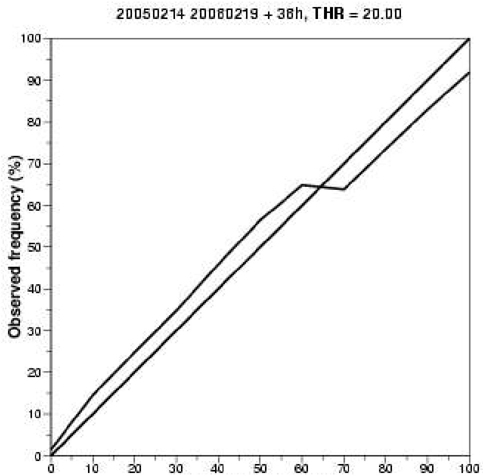


NORLAMEPS

Reliability diagrams, 20mm, 36h

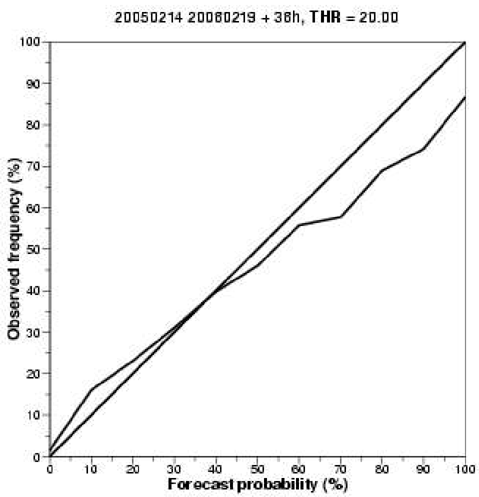


LAMEPS

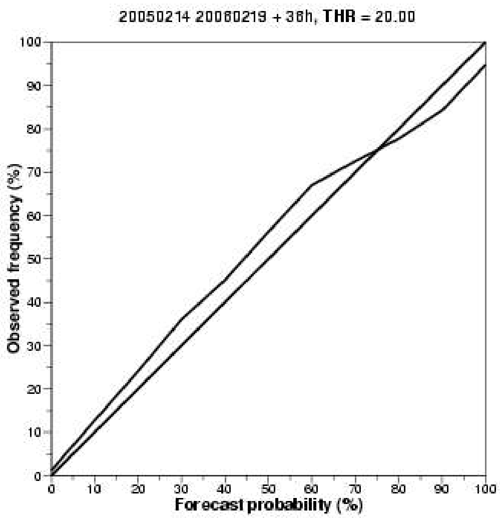


TEPS

Annual average

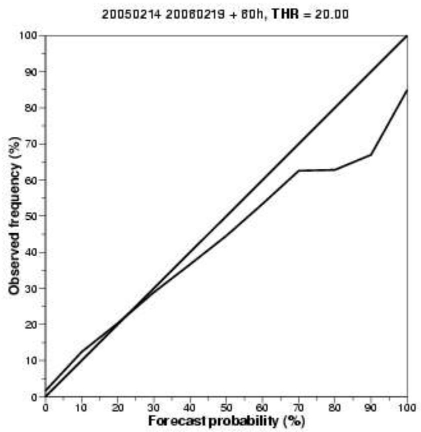


EPS

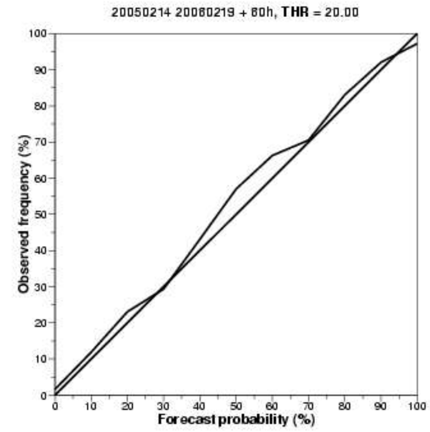


NORLAMEPS

Reliability diagrams, 20mm, 60h

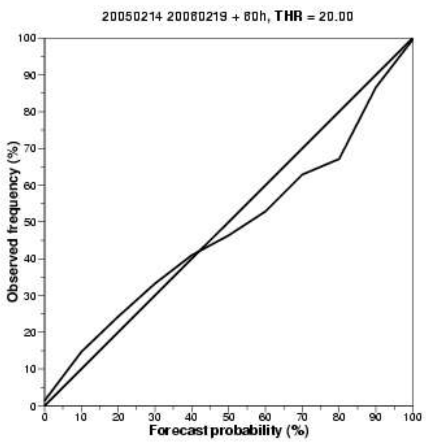


LAMEPS

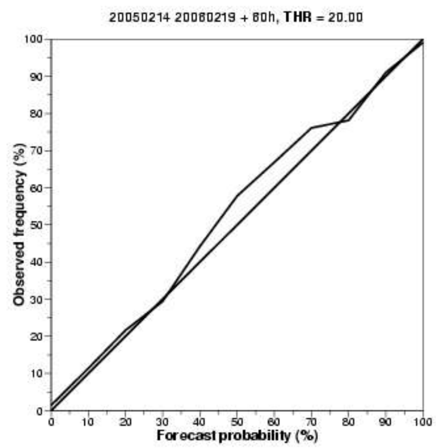


TEPS

Annual average



EPS



NORLAMEPS

Future developments

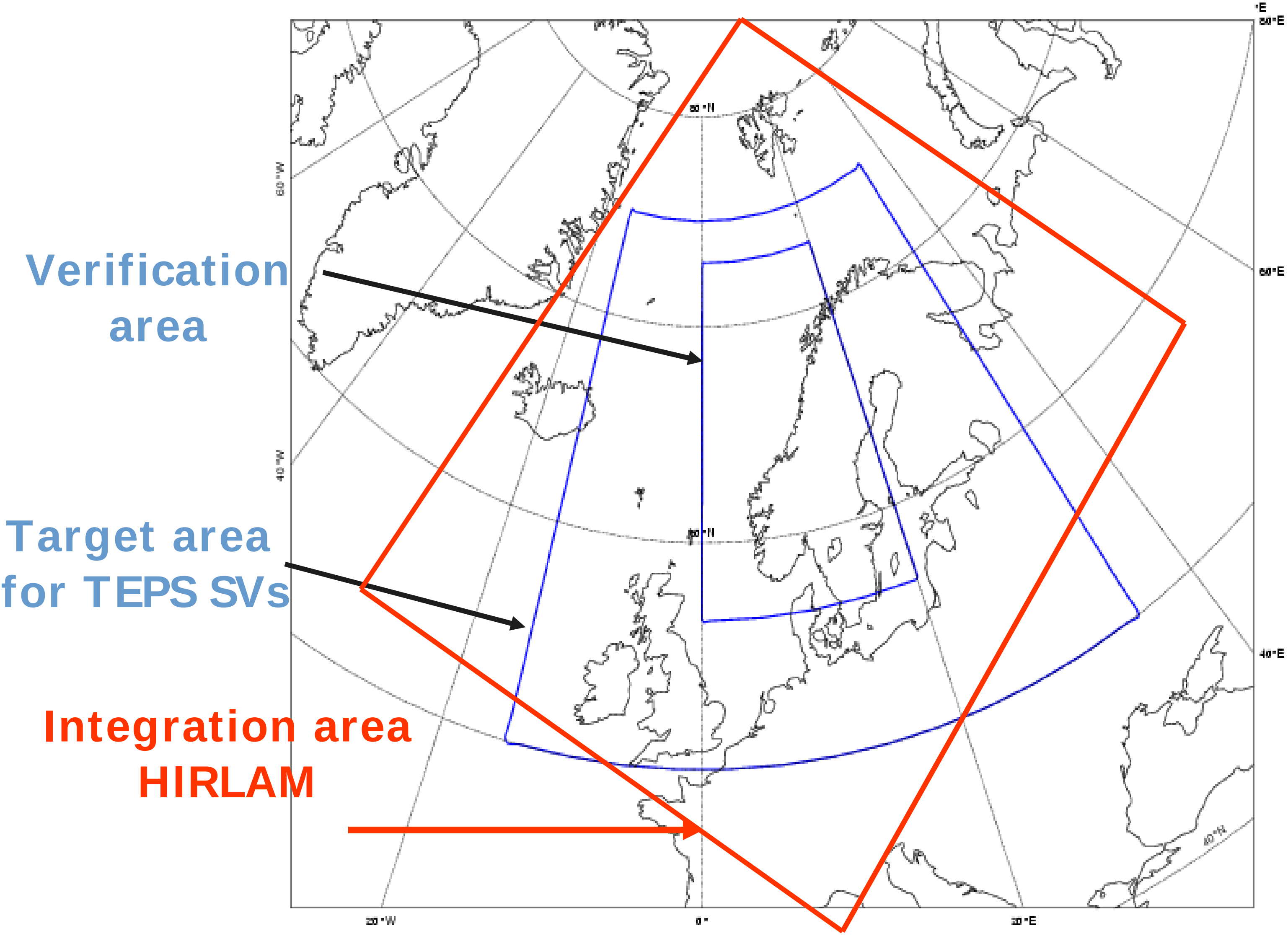
- Include perturbations of model physics in LAMEPS
- HIRLAM should be improved
- Increase the time resolution of the boundary fields (now every 6 hour)
- Expand system to more parameters: temperature, wind, ...
- Develop more probability products
- Compute meso-scale initial perturbations within HIRLAM-domain
- Incease resolution (0.1 degrees)
- Non-hydrostatic downscaling

Test LAMEPS on a new configuration for TEPS

- A system that combines targeted SVs and hemispheric SVs (Martin Leutbecher, ECMWF)
  - 10 leading targeted singular vectors
  - 40 leading hemispheric singular vectors computed in the subspace orthogonal to the targeted singular vectors
  - Ensemble size 20 + 1
  - Initial perturbations constructed with (revised) Gaussian sampling
- Results in increased spread for TEPS after day 2, without increasing the error of the ensemble mean
- We wish to test LAMEPS on this revised TEPS system

Thank you for your attention

AREAS USED

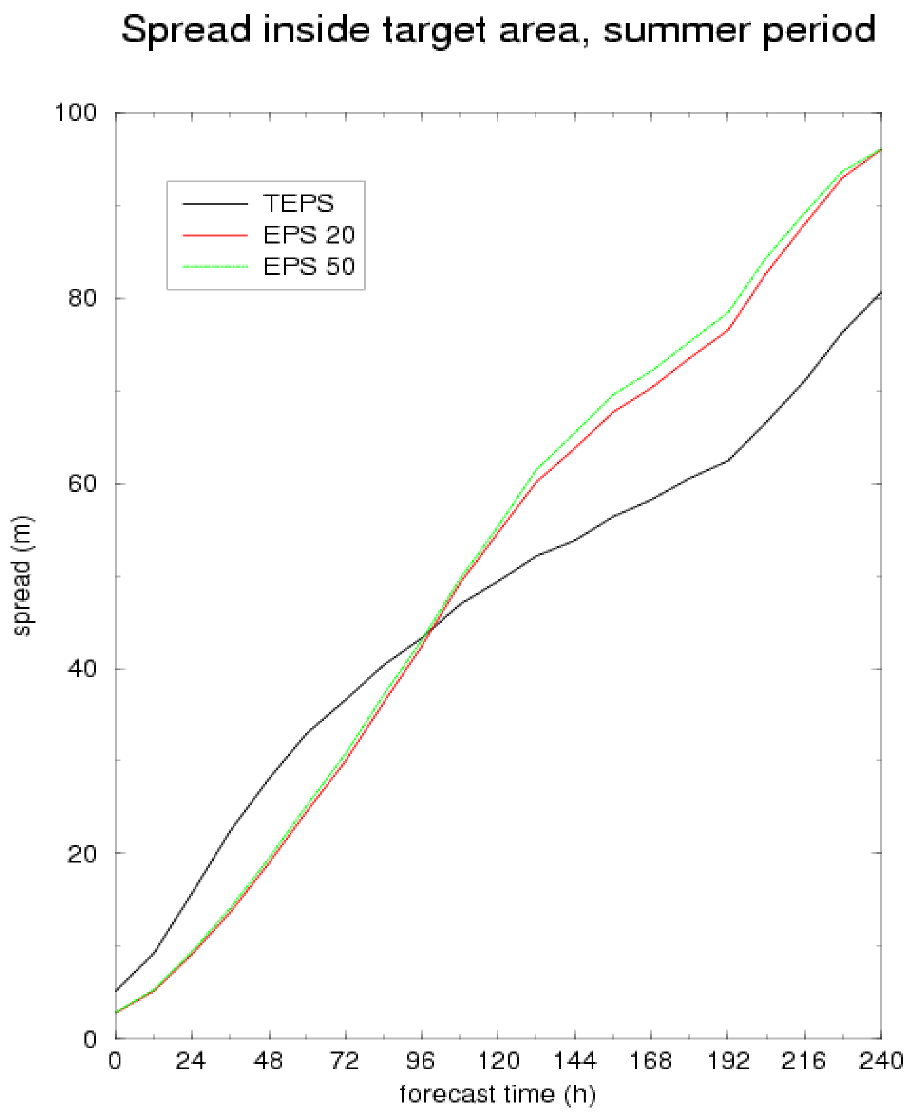


Verification area
Target area for TEPS SVs
Integration area HIRLAM

Comparison of TEPS and operational EPS, selected periods in 1997.

Spread =
Average RMS of z 1000hPa around ensemble mean

$$spread = \frac{1}{I}\sum_{i=1}^{I}\sqrt{\frac{1}{N\cdot D}\sum_{n=1}^{N}\sum_{d=1}^{D}(e_{ind} - p_{id})^2}$$



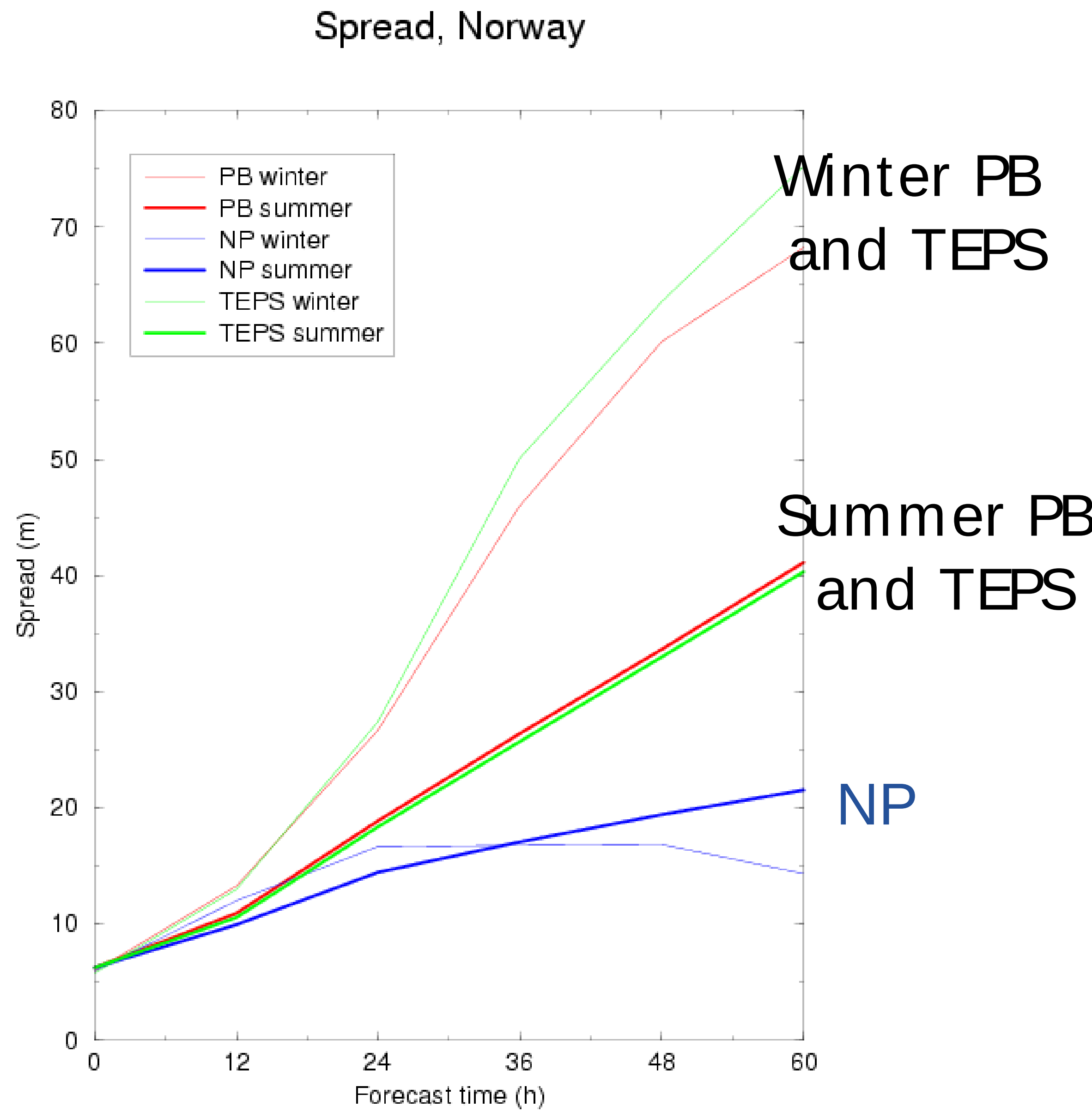
PB:

LAMEPS based on perturbed initial and boundary data

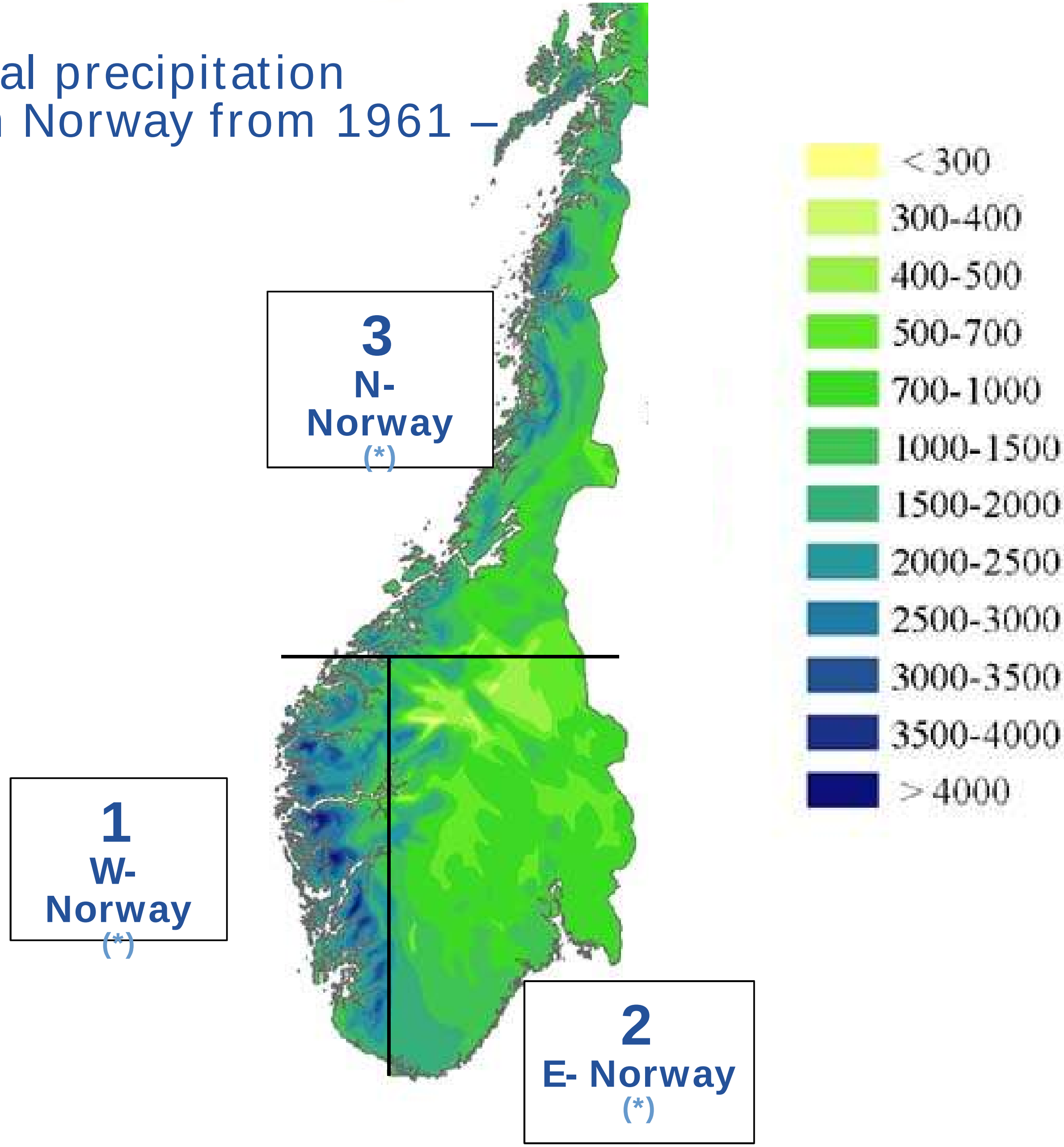
NP:

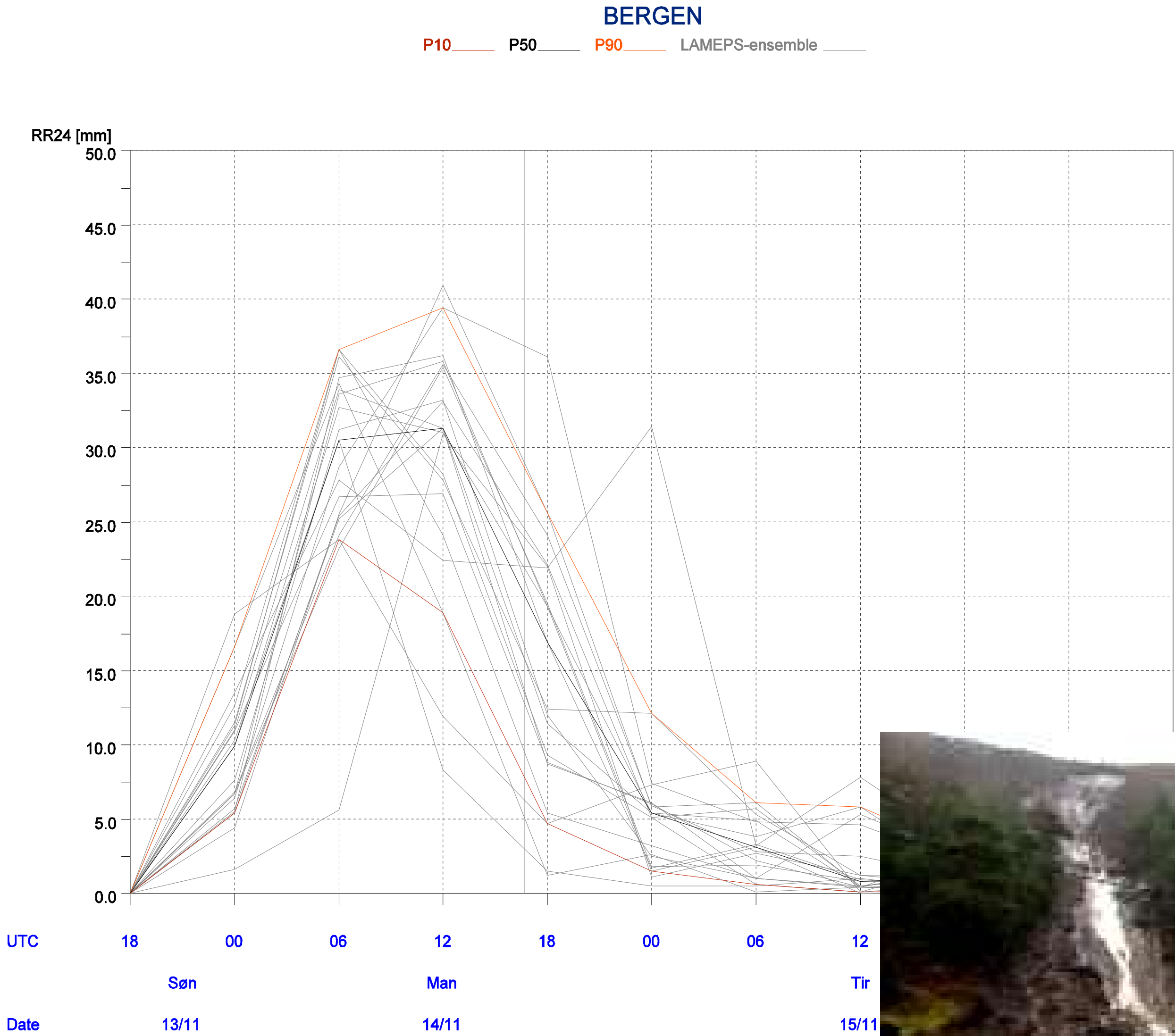
LAMEPS based on perturbed initial data only

Results for a few dates in 1997

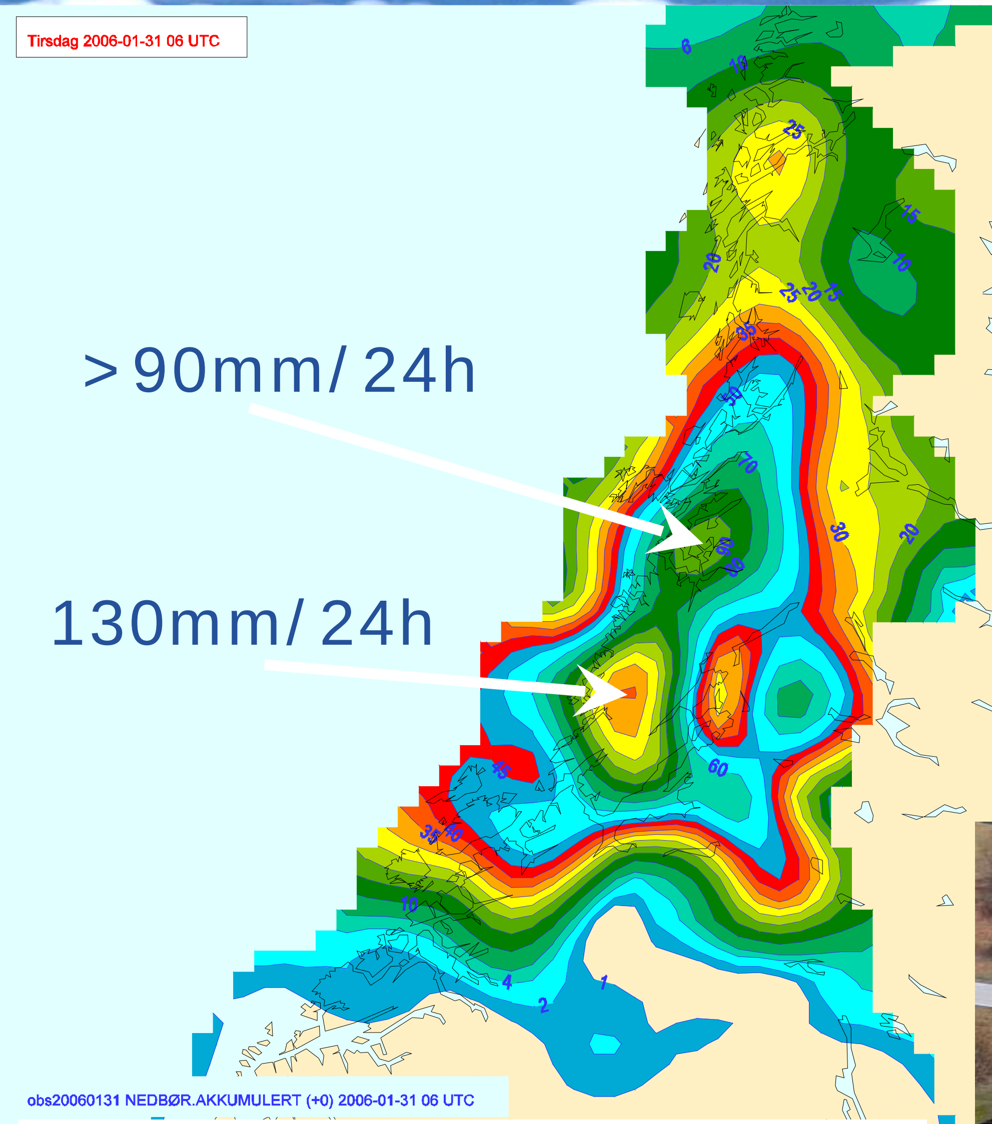


Average annual precipitation amounts in Norway from 1961 – 90 (mm).





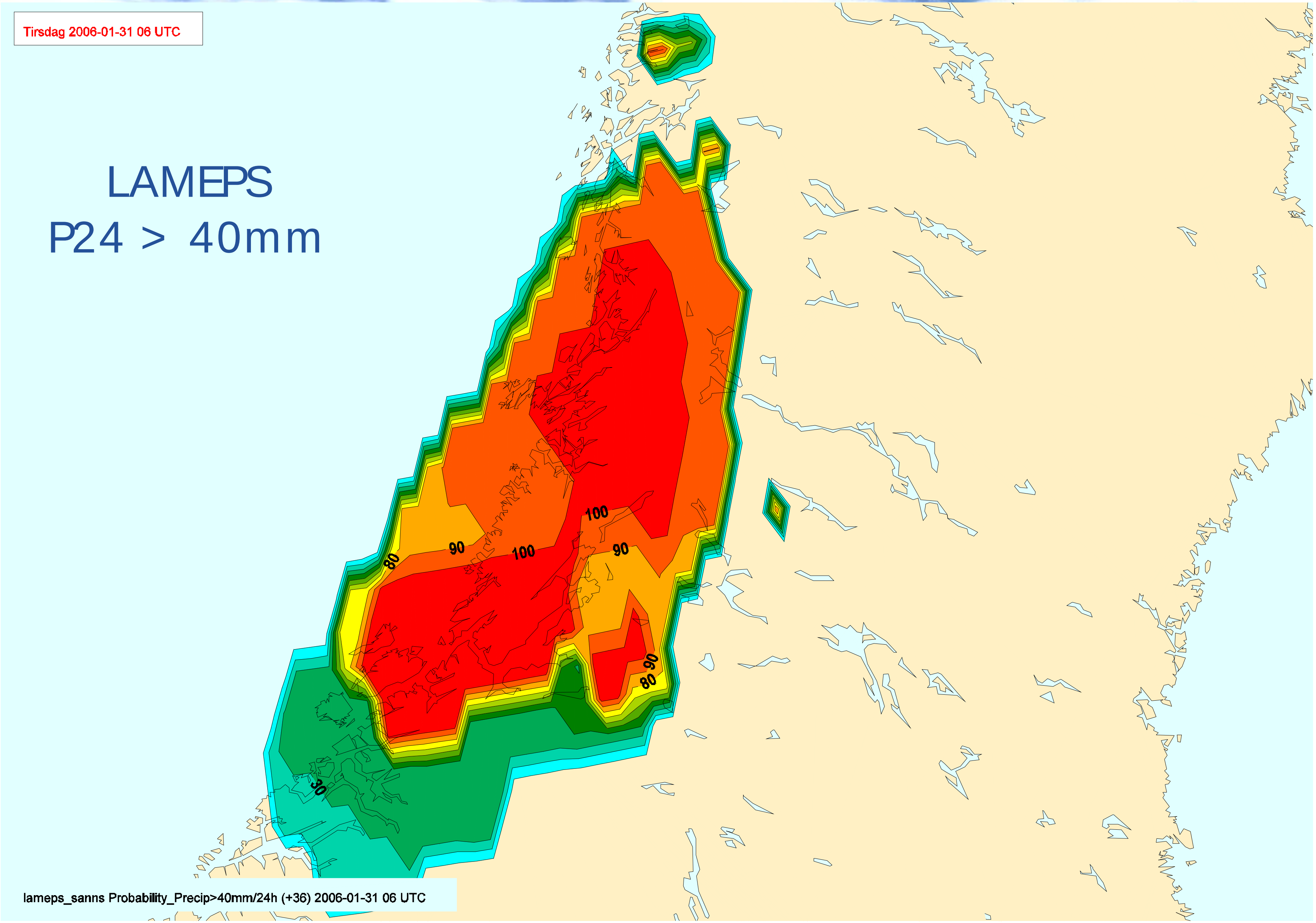
Bergen, November 2005



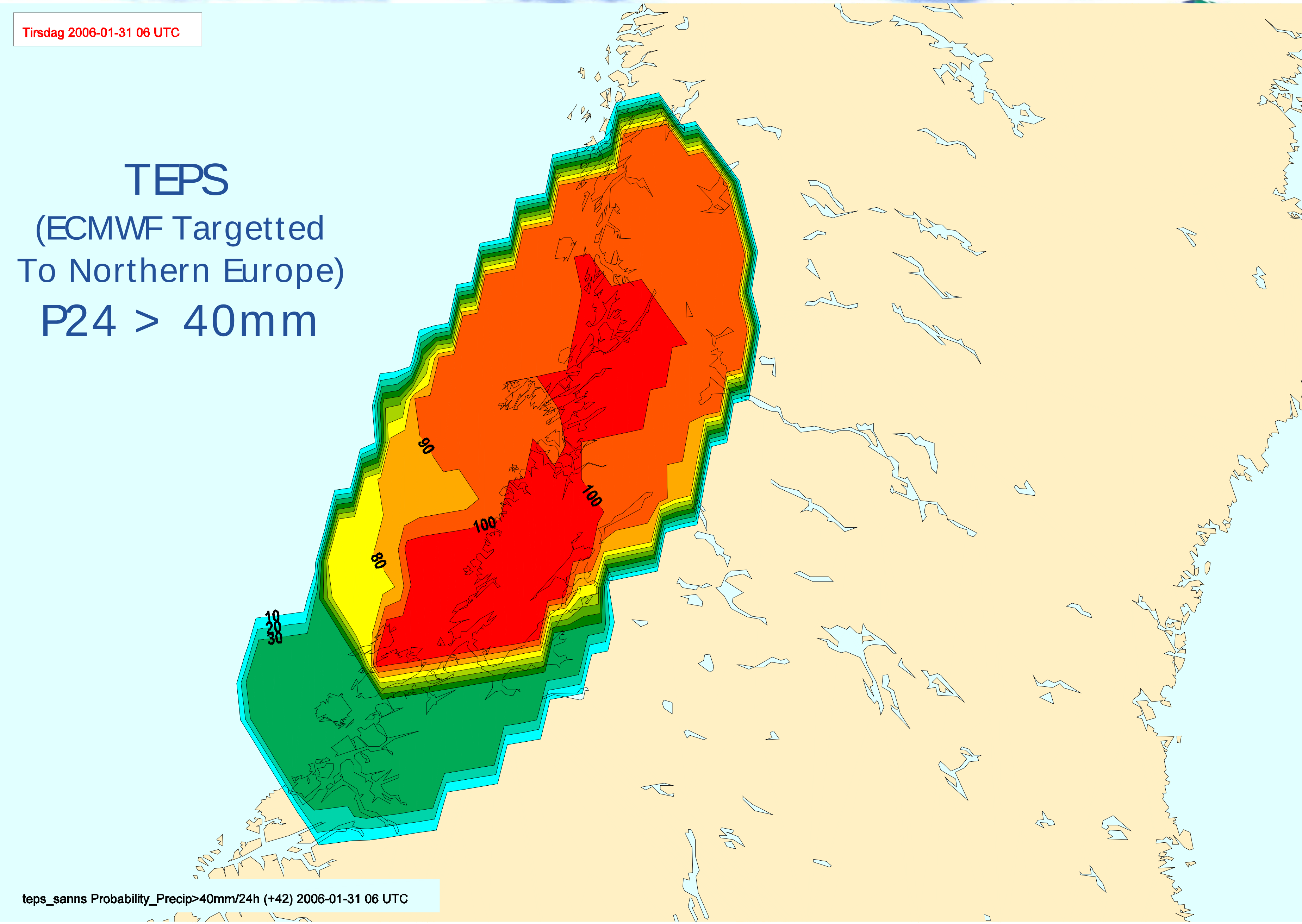
"100 year precipitation event" in the middle part of Norway

30-31. January 2006

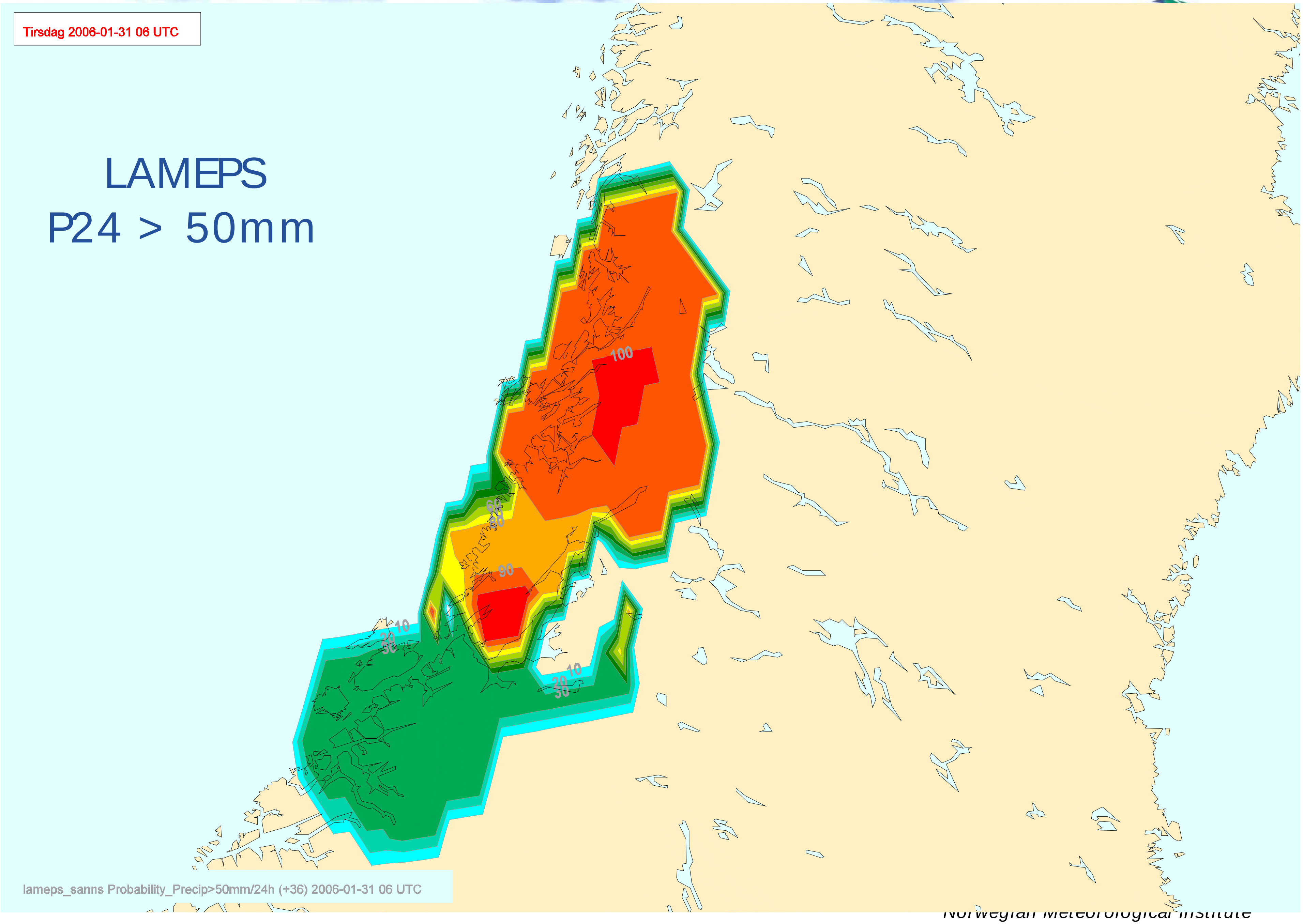
LAMEPS
P24 > 40mm



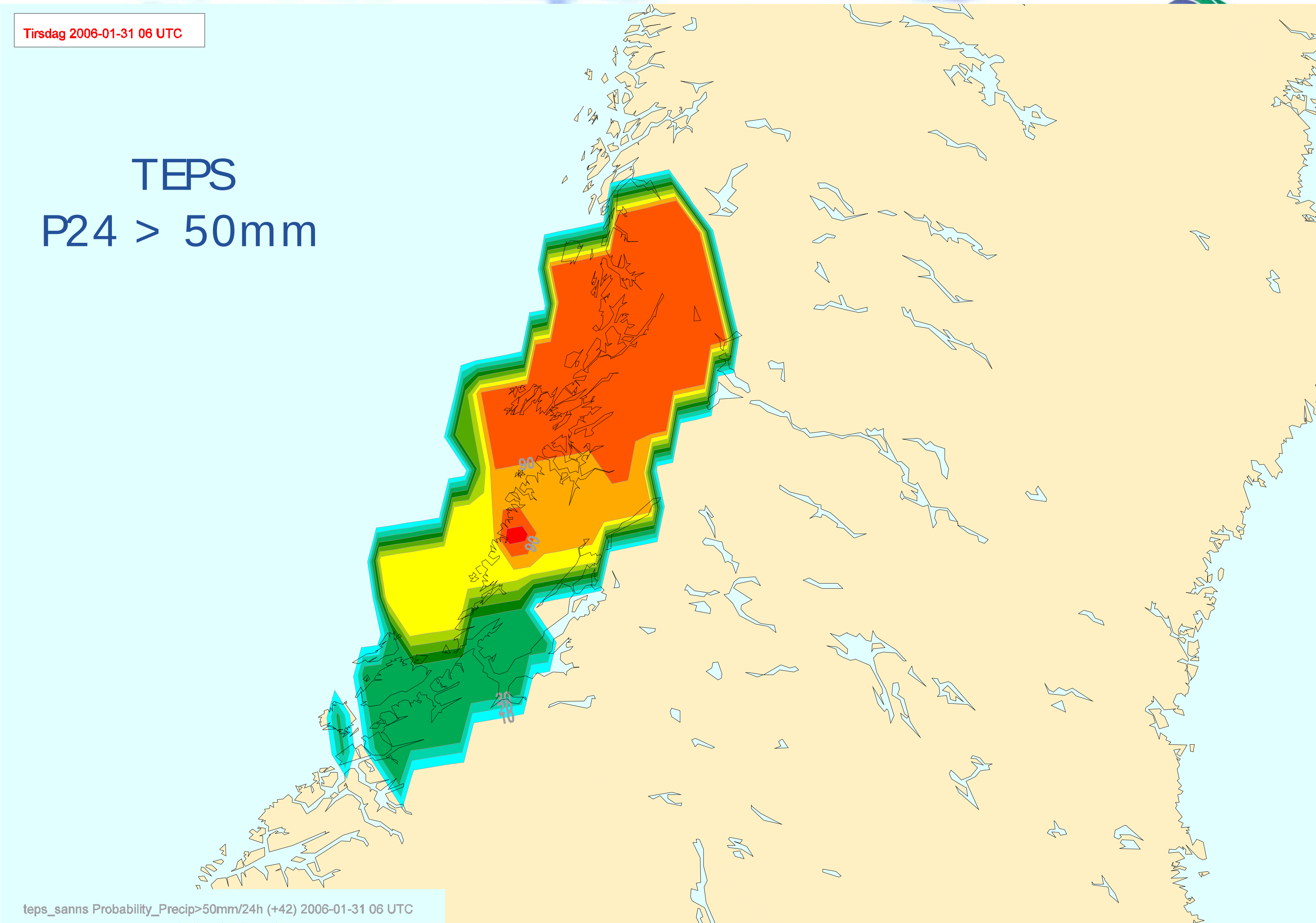
TEPS
(ECMWF Targetted To Northern Europe)
P24 > 40mm



LAMEPS
P24 > 50mm

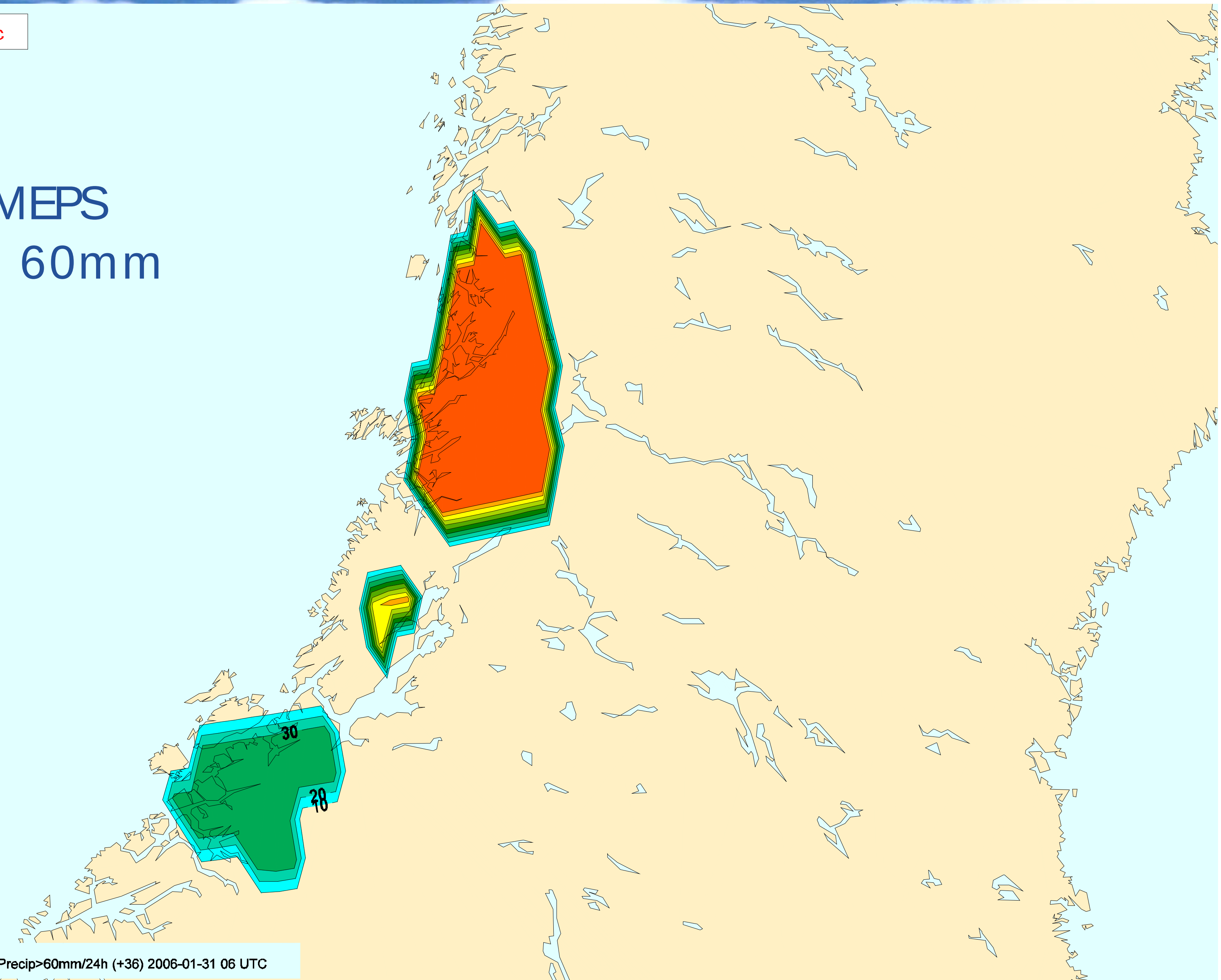


TEPS
P24 > 50mm



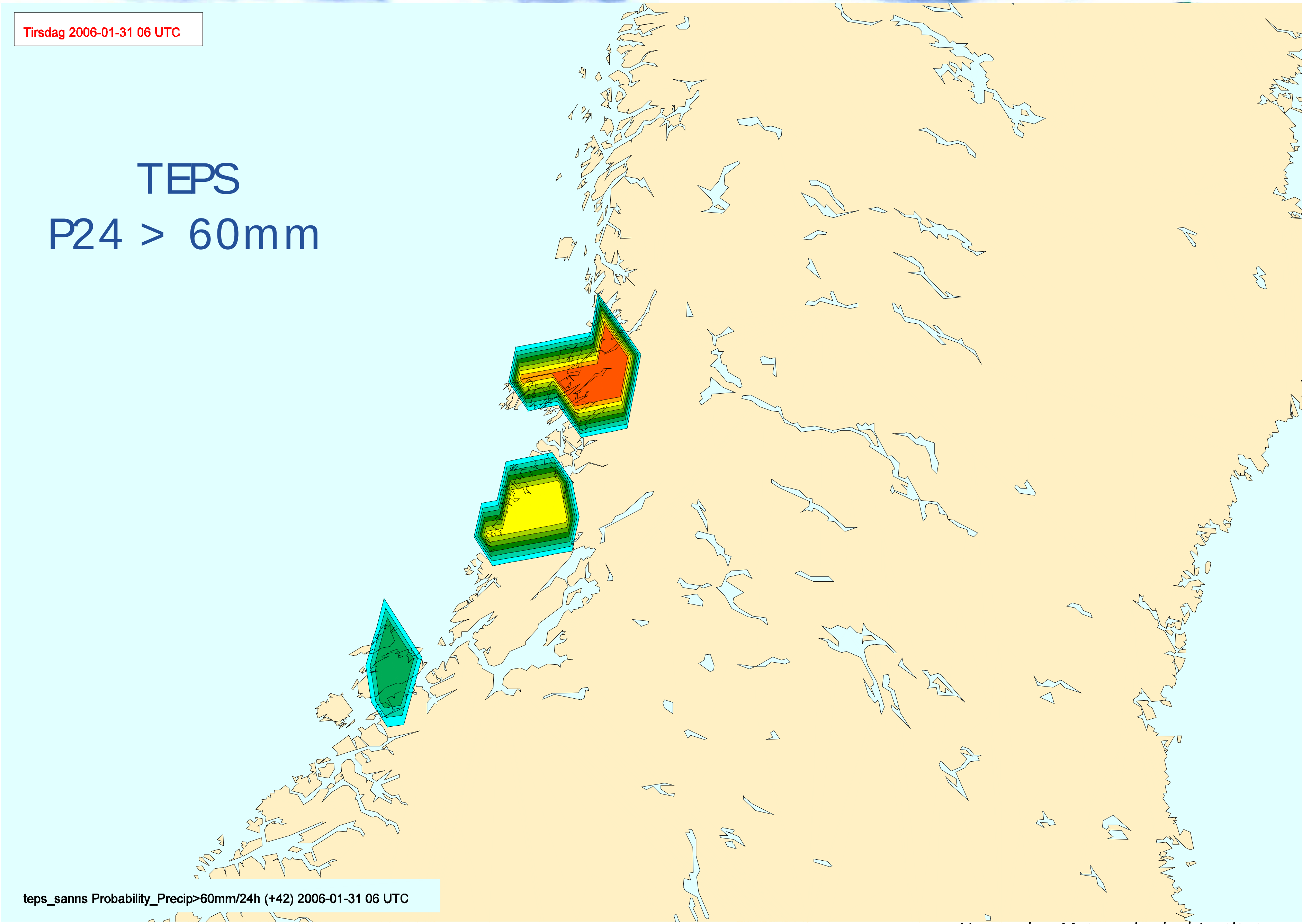
Tirsdag 2006-01-31 06 UTC

LAMEPS
P24 > 60mm

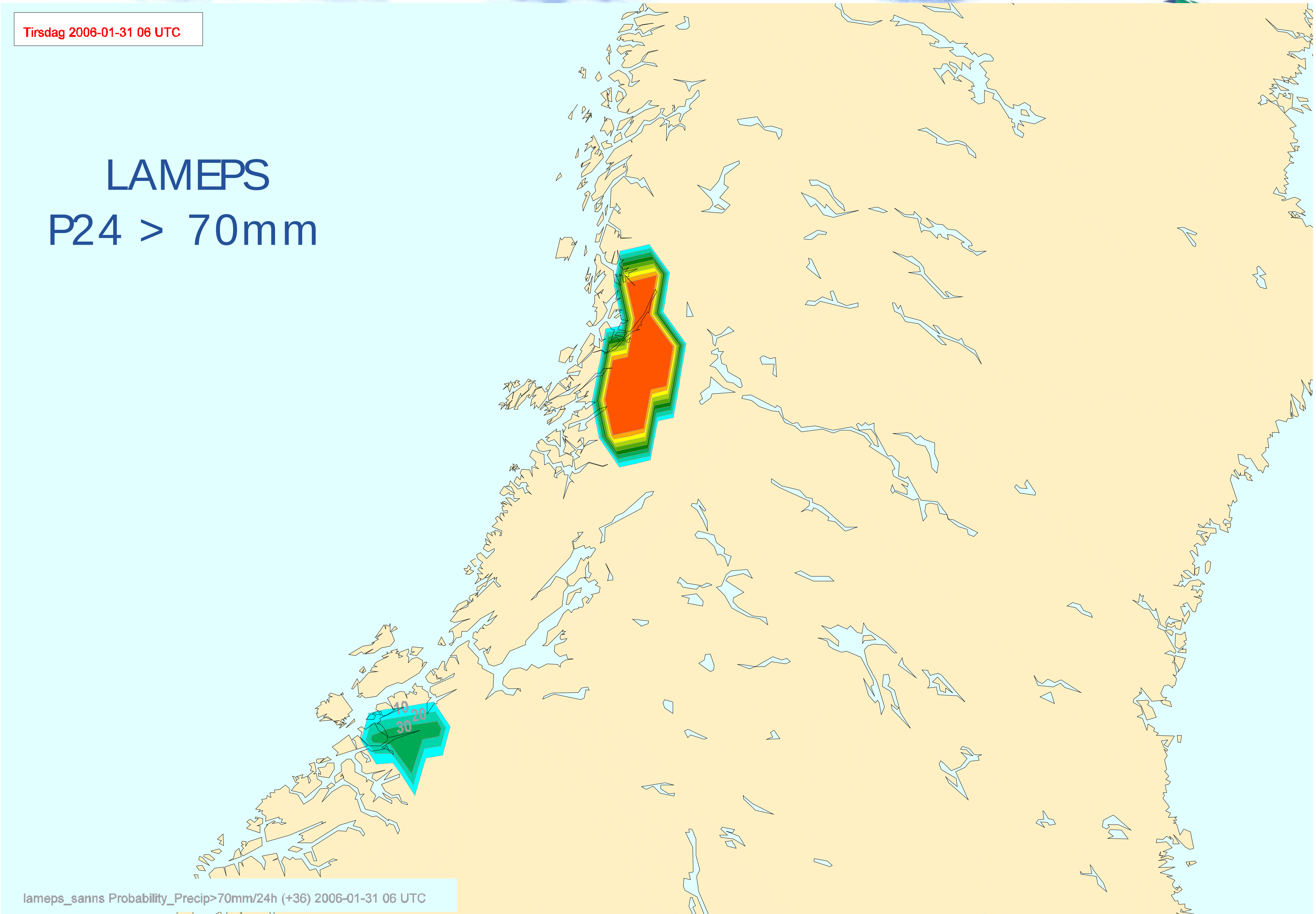


lameps_sanns Probability_Precip>60mm/24h (+36) 2006-01-31 06 UTC

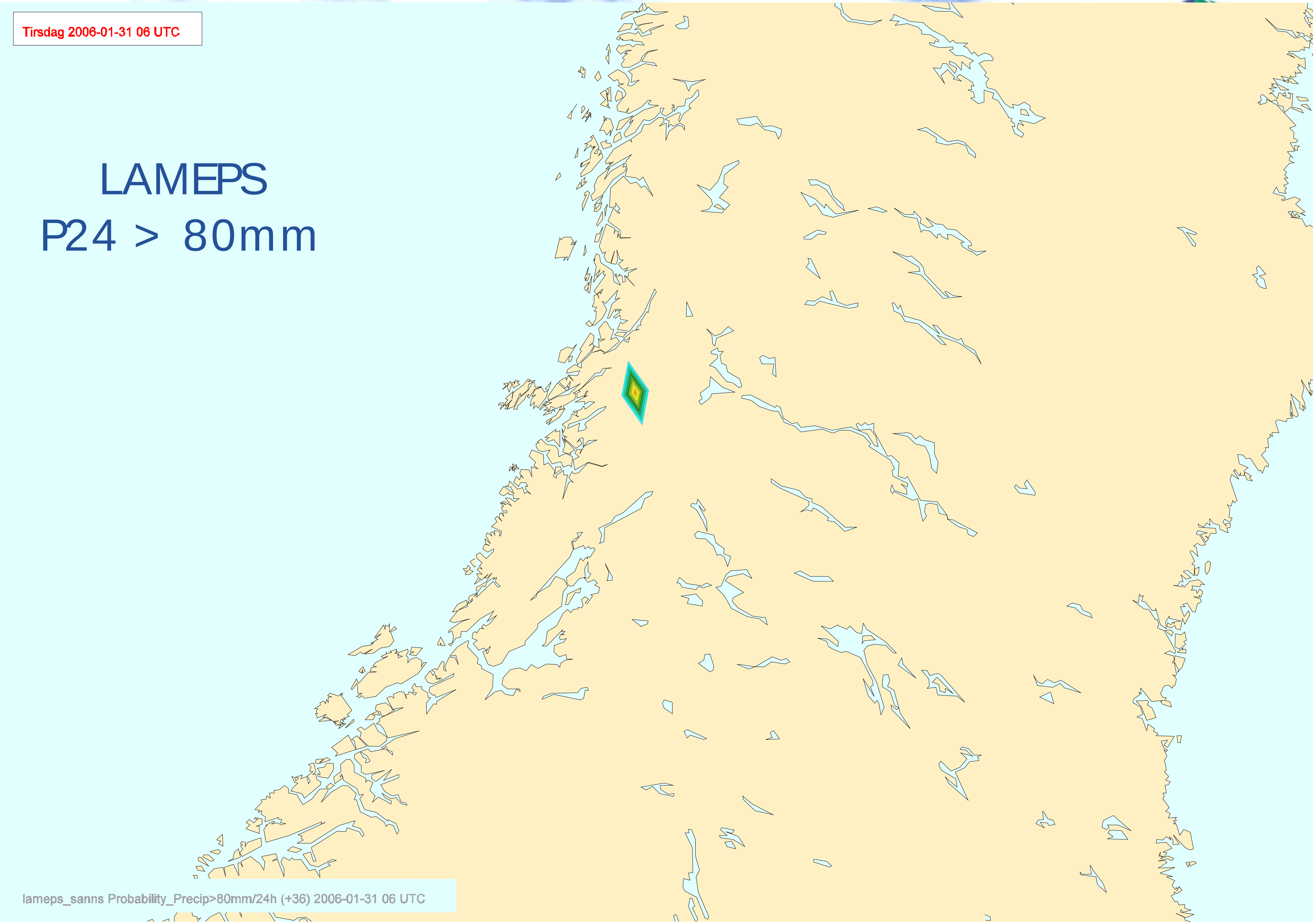
TEPS
P24 > 60mm



LAMEPS
P24 > 70mm



LAMEPS
P24 > 80mm



Examples of use of LAMEPS

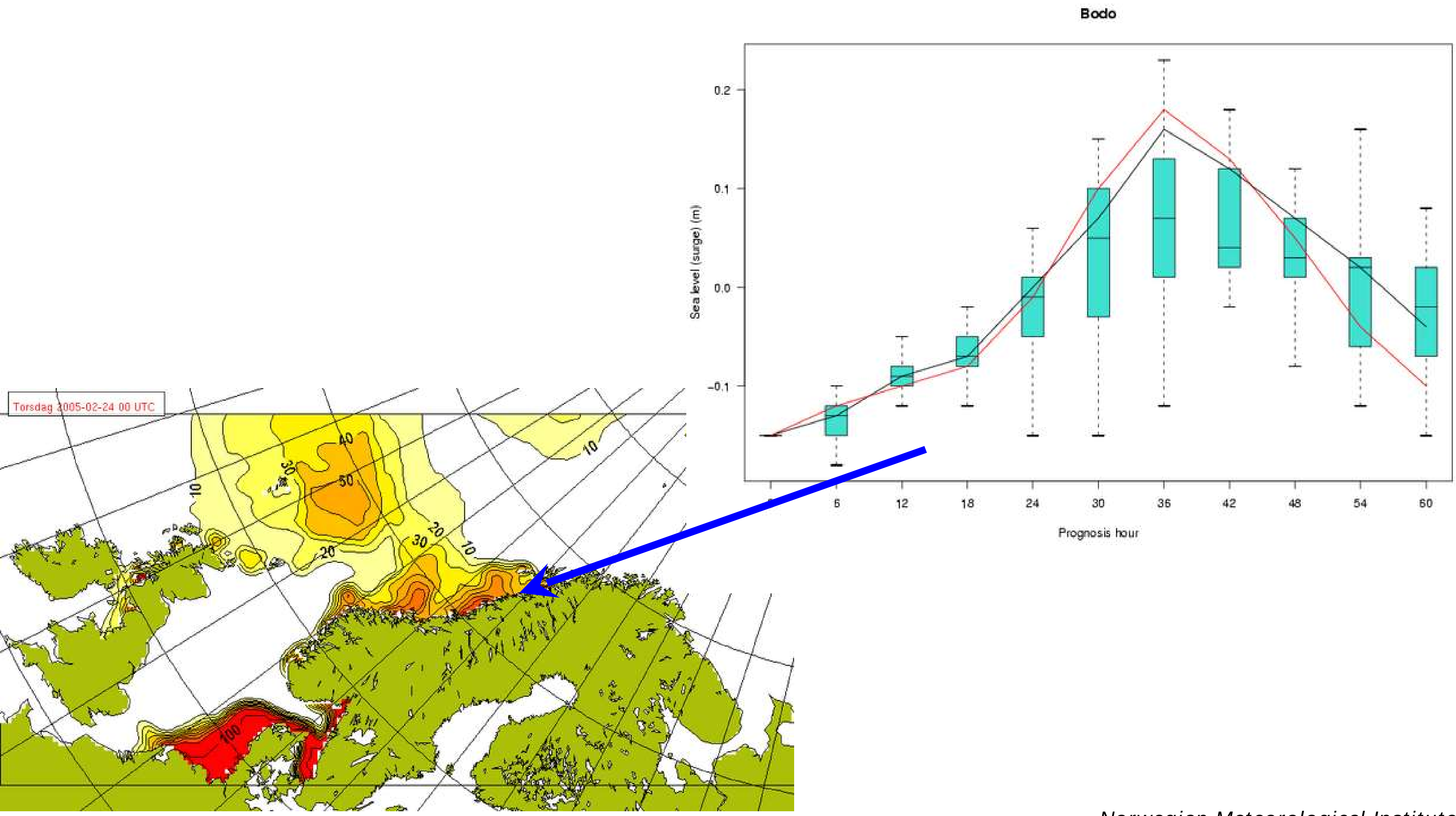
- Ensemble of hydrological models –
  one time series for each ensemble member as input to the hydrological models (customers)

(*)

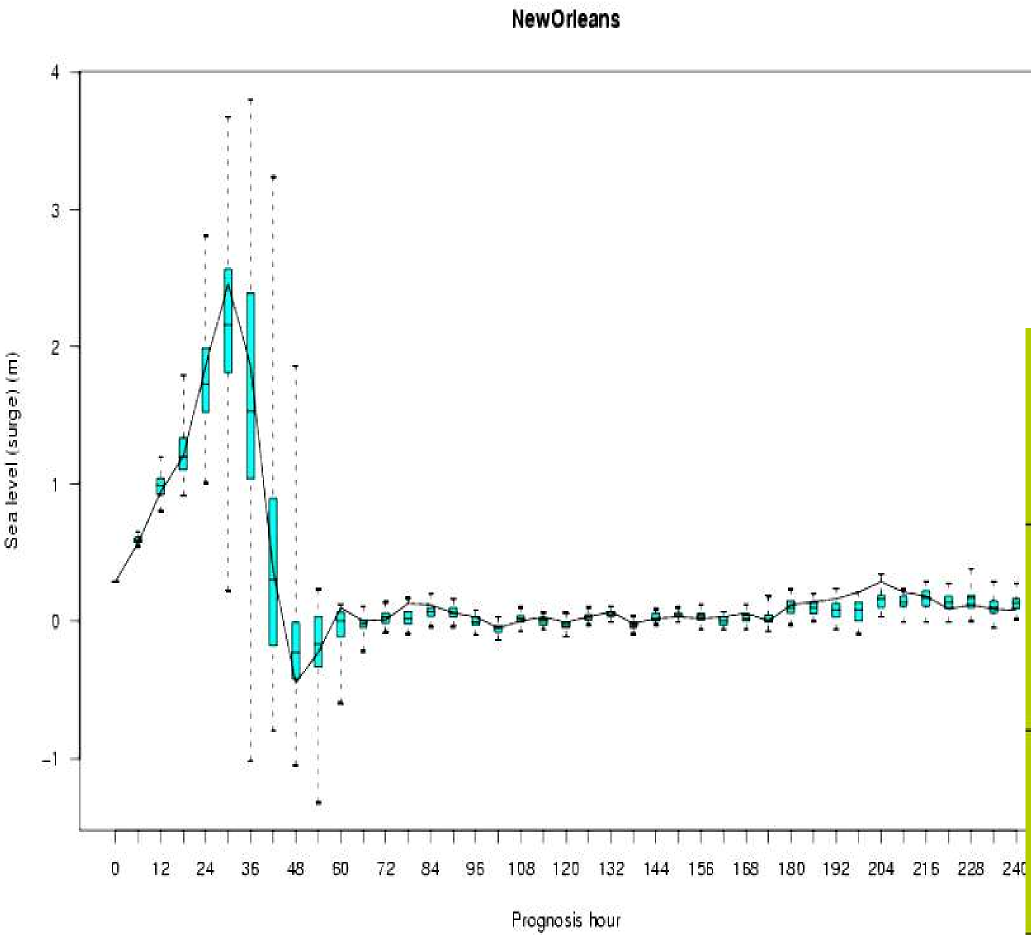
Area: Selbusjøen 615moh

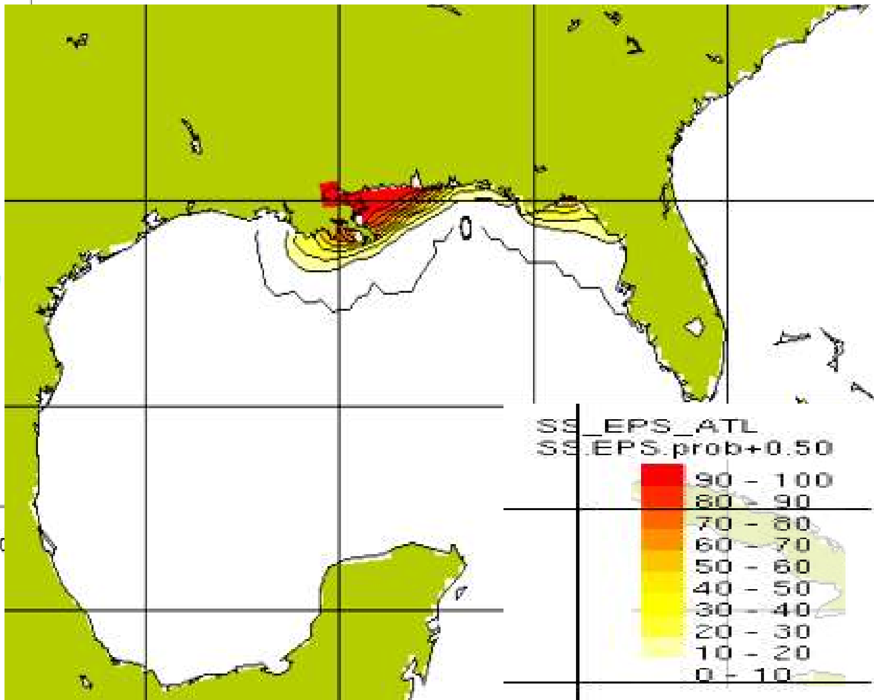
Time	T2m	dT/dz	R6
18+ 0	7.4	-1.3	0.0
18+ 6	1.0	-0.7	0.0
18+12	1.7	-0.8	1.5
...			
...			
18+54	3.3	-0.6	1.5
18+60	5.1	-0.7	0.3

Storm-surge LAMEPS
in operational routine at met.no

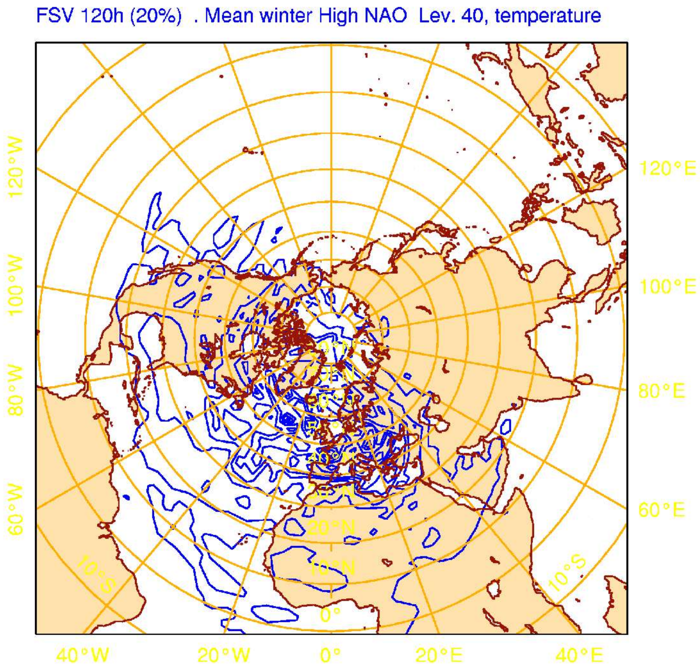


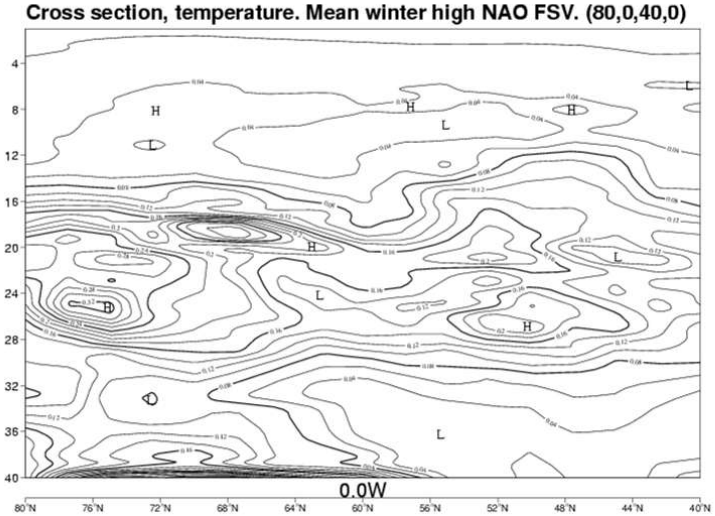
Something else….
EPS storm- surge Katarina



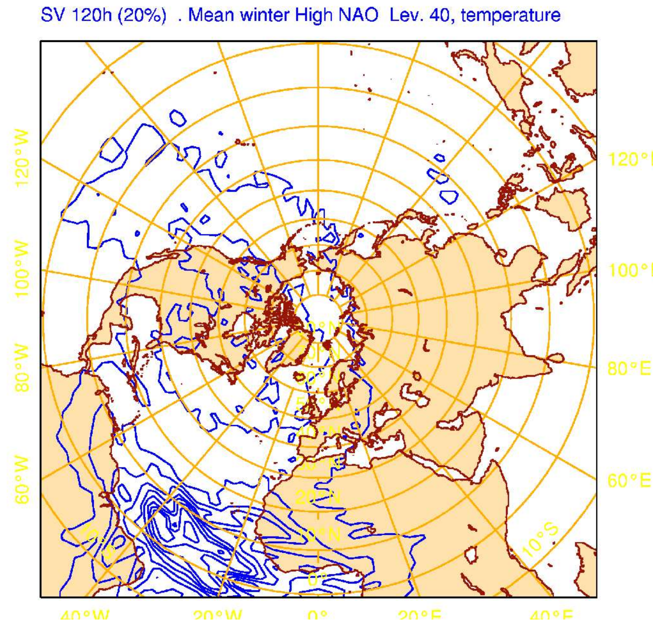


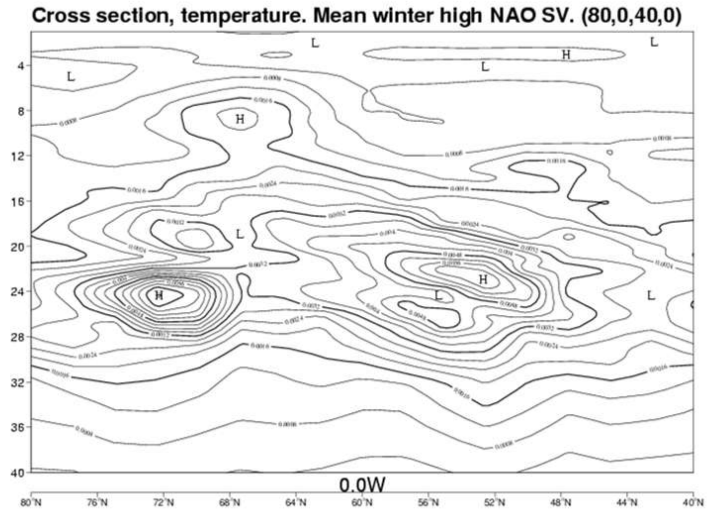
Forcing Singular Vectors Winter, High NAO

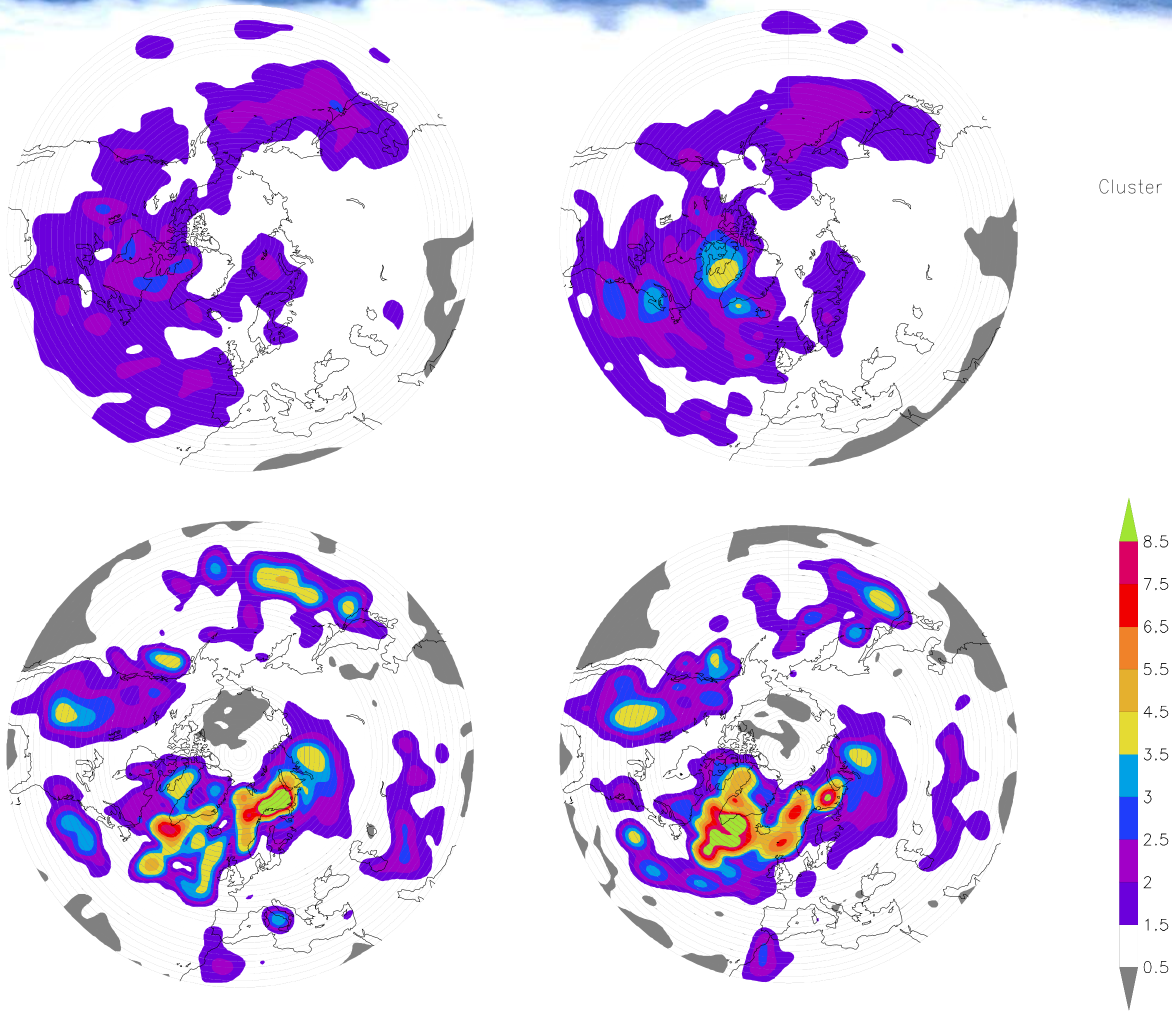


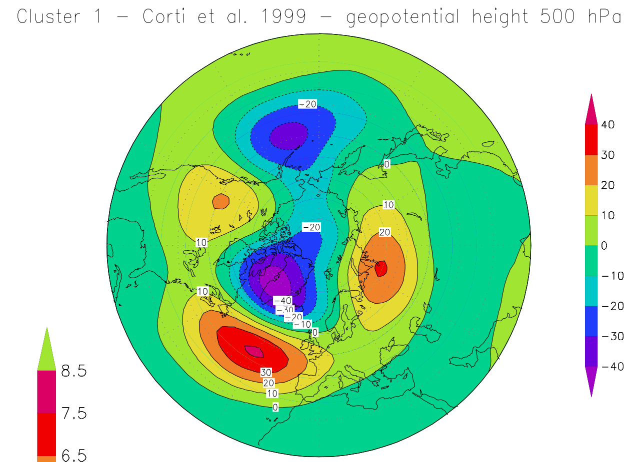


Singular Vectors
Winter, High NAO









COWL- pattern

Figure 4: Normalized root mean square of the optimal forcing perturbation patterns for the 15%most
and least (right) sensitive cases of the 223 cases shown in Figure 3. The temperature forcing patterns
model level 39 (top) and at model level 60 (bottom) are shown. The patterns are normalized with the
respective spatially averaged root mean squares.
From top left to bottom right the averages used are 6.02, 8.01, 1.91, and 2.66* . Note the nonlinear s

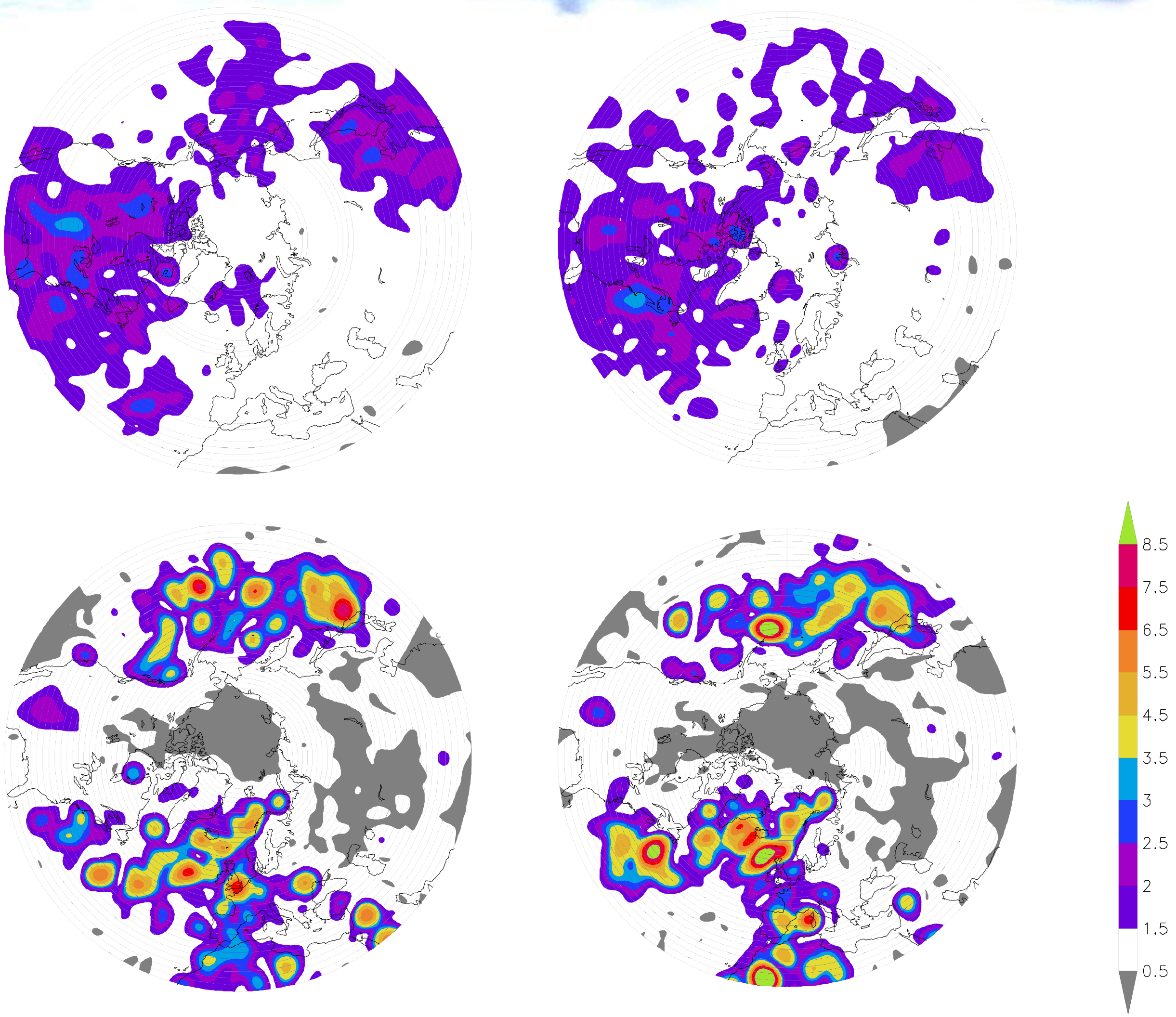


Figure 5: Same as Figure 4, but for perturbations of the initial state.
From top left to bottom right the averages used are 0.42, 0.60, 0.12, and 0.20 K.
Note the nonlinear scaling.