# High-resolution ensemble prediction of a polar low development

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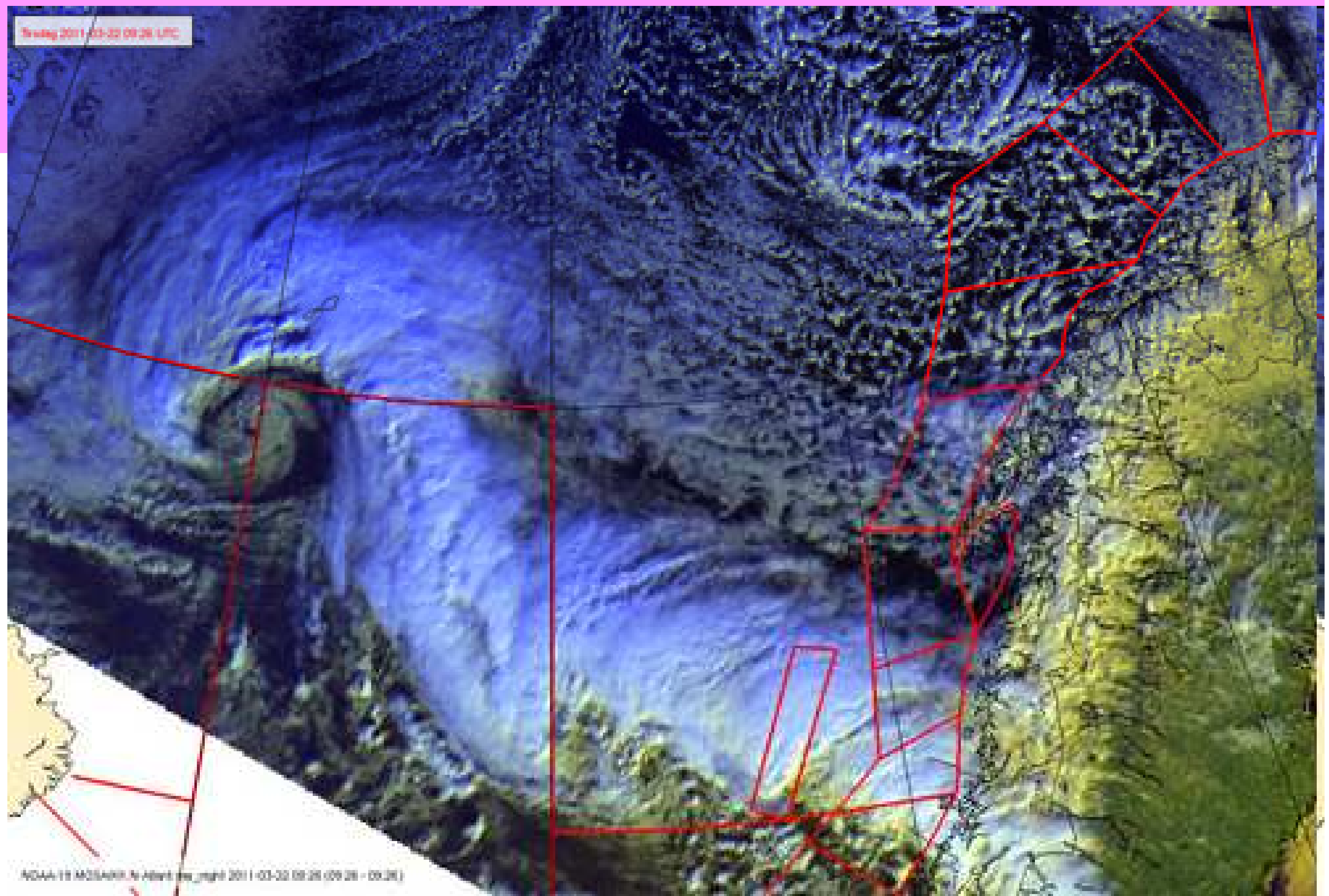
# Polar Lows

- Occur frequently but irregularly (on average 4-6 per winter month)
- Intense (strong winds and heavy precipitation)
- Short-lived (1–2 days)
- Meso-scale (100- to 600-km diameter)
- Unique to the Polar Regions
- Associated with cold air outbreaks
- Decays quickly after landfall
- Speed of 10–15 m $s^{-1}$



# Forecast challenges

- In situ observations are often too sparse for an adequate analysis of the atmosphere
- Only partly compensated by remote sensing data from polar orbiting satellites.
- The model representation of moist convection is crucial, e.g. resolution.
- The size and position of the model domain is important.

# Main goal of the study

- Forecasting potentially severe weather ranging from 12 hours to ~2 days.
- To show a **first example** of the feasibility of applying a high resolution EPS
  - A single case **3-4 March 2008**
  - A polar low in the Norwegian Sea off the coast of Northern Norway
  - **Well observed** during the IPY-THORPEX campaign.
- Each of the forecasts are initialized at **1800 UTC 2 March 2008**.

# A nested ensemble system

- A three-step nested EPS; TEPS->LAMEPS->UMEPS.
  - Each step produces a 21-member forecast ensemble
  - The horizontal resolution increases with each step.

**Step 1 TEPS:**

•A 21-member configuration of the ECMWF-EPS run at T399 (ca. 50 km) up to 72 hours lead time. Global.
•Initial state perturbations from singular vectors.
•Run at 00 and 12 UTC initial times.

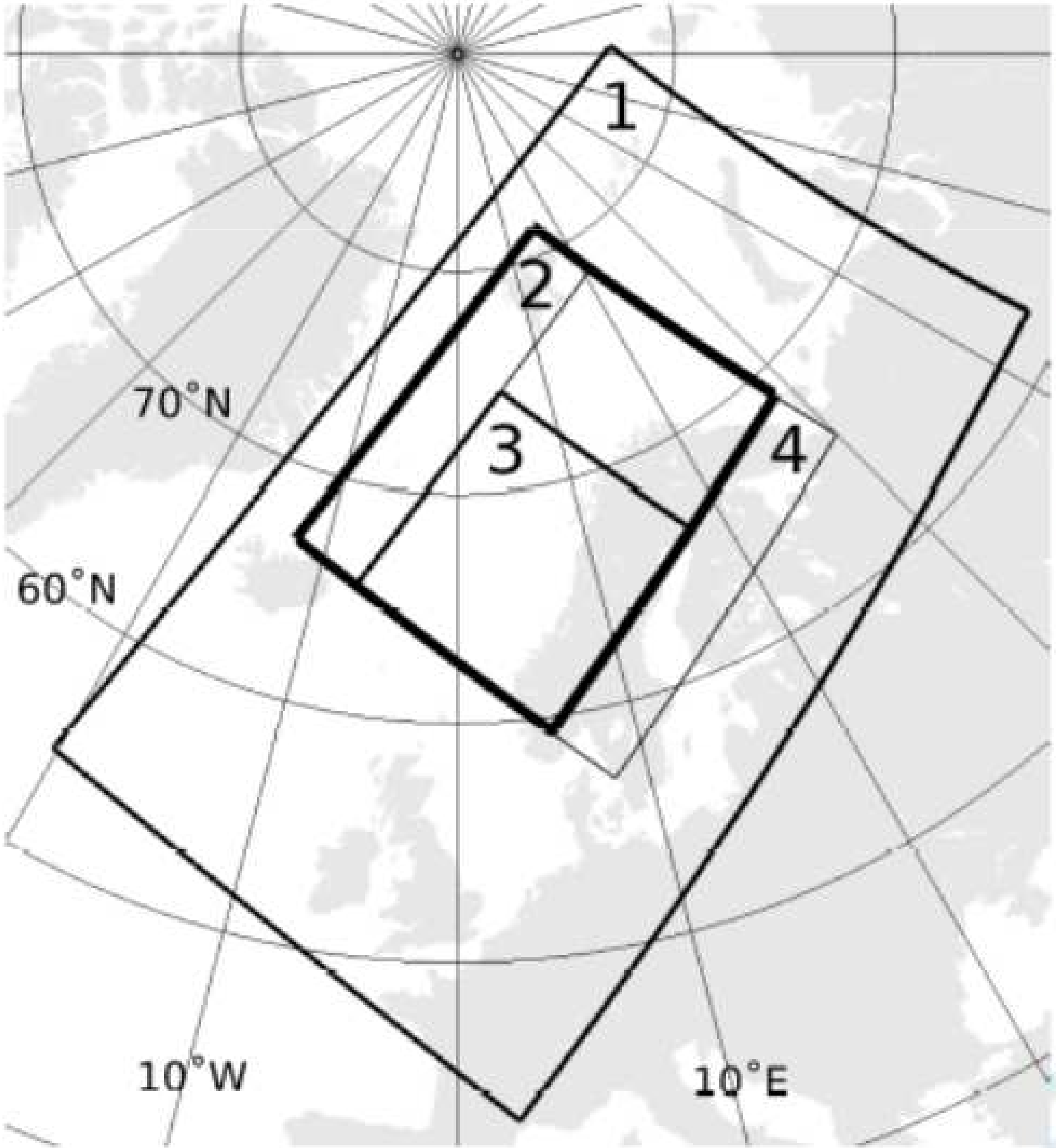
**Step 2 LAMEPS:**

•Quasi-hydrostatic HIRLAM at 12 km grid mesh. LAM.
•6-hourly 3DVar data assimilation for the control forecast.
•TEPS provids perturbed LBCs and initial state perturbations.
•Starting at 06 and 18 UTC and runs for 60 h.

**Step 3 UMEPS:**

•Non-hydrostatic Unified Model (UM) with 4-km grid resolution.
•Dynamical downscaling of each LAMEPS member.

# Model domains




**1** LAMEPS
**2** UMEPS-big (390*490 points)
**3** UMEPS-small (300*300 points)

The location of the domains was determined **subjectively** considering the development of the polar low.

Given their sizes, UMEPS-big and UMEPS-small should be optimally located with respect to the development of the polar low.

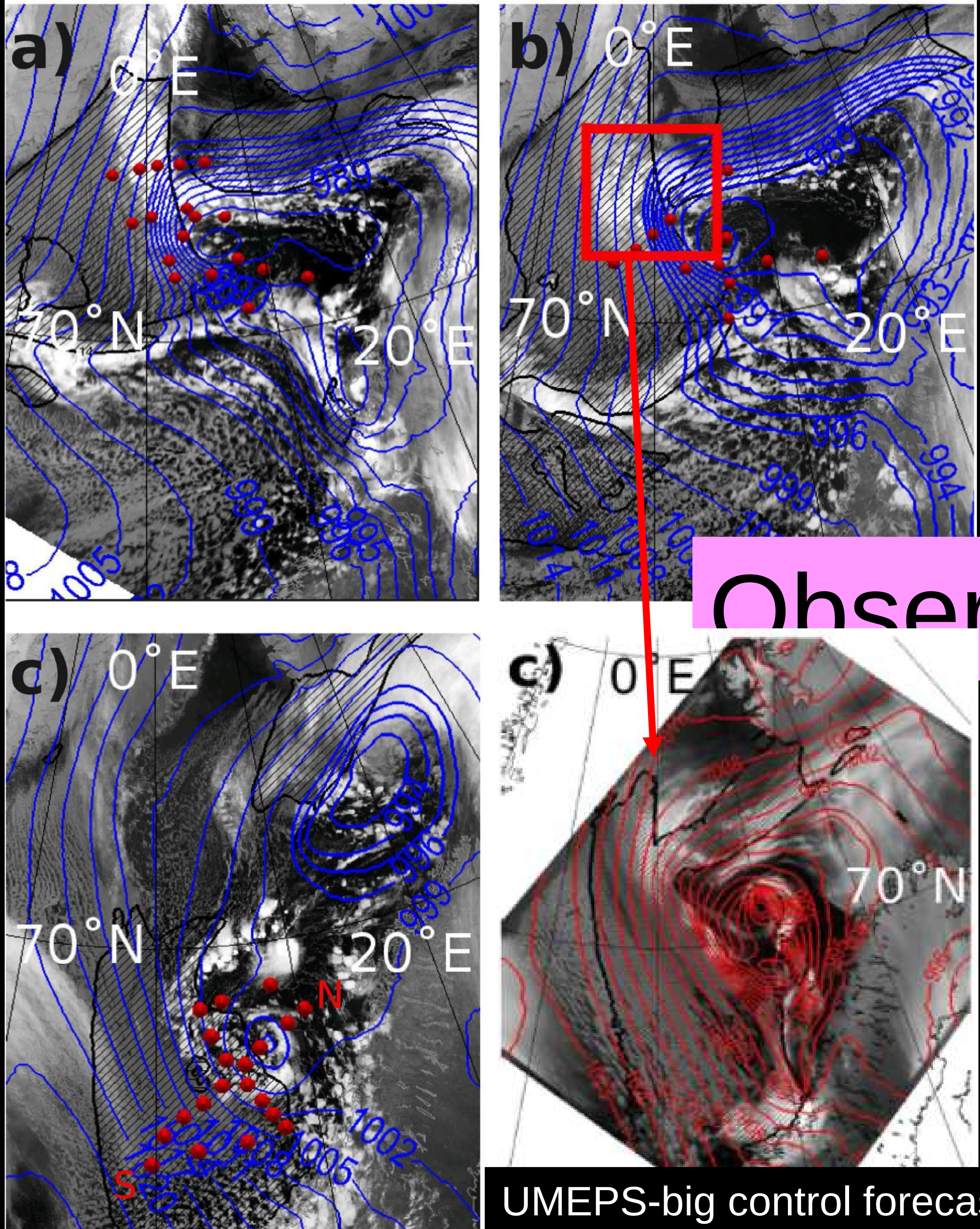
# Results

12 UTC

3 March

18 UTC

3 March




Observations

12 UTC

4 March

T+42

12 UTC

4 March

UMEPS-big control forecast

# MSLP

LAMEPS | UMEPS-small | UMEPS-big

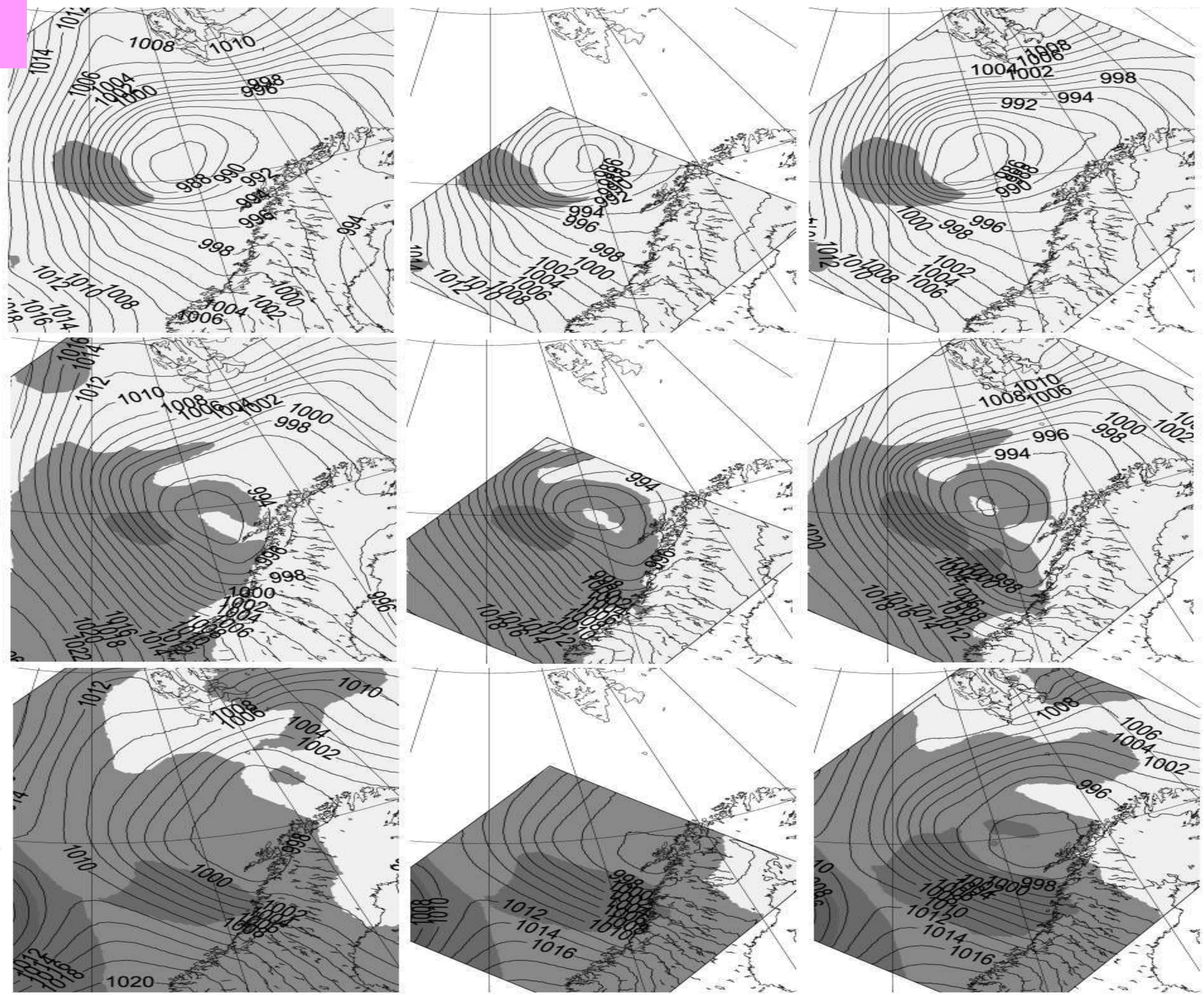
T+30

T+42

T+54

12 UTC

4 March

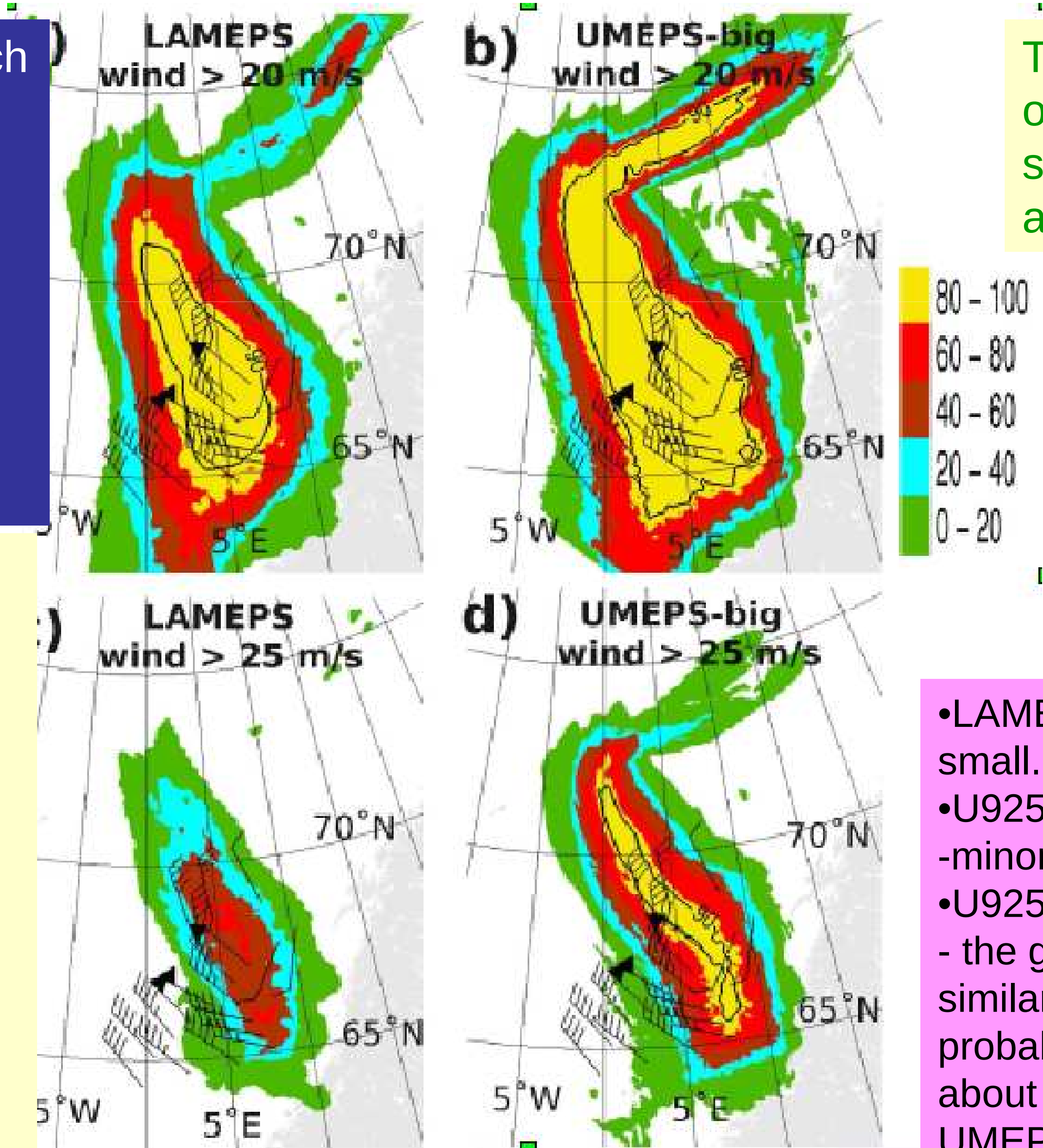


Ensemble mean – contour   Ensemble spread - shaded

# Probability for severe winds (925 hPa)

12 UTC 4 March

The difference between the forecast probabilities is largest at T+42 when the polar low is at its peak.

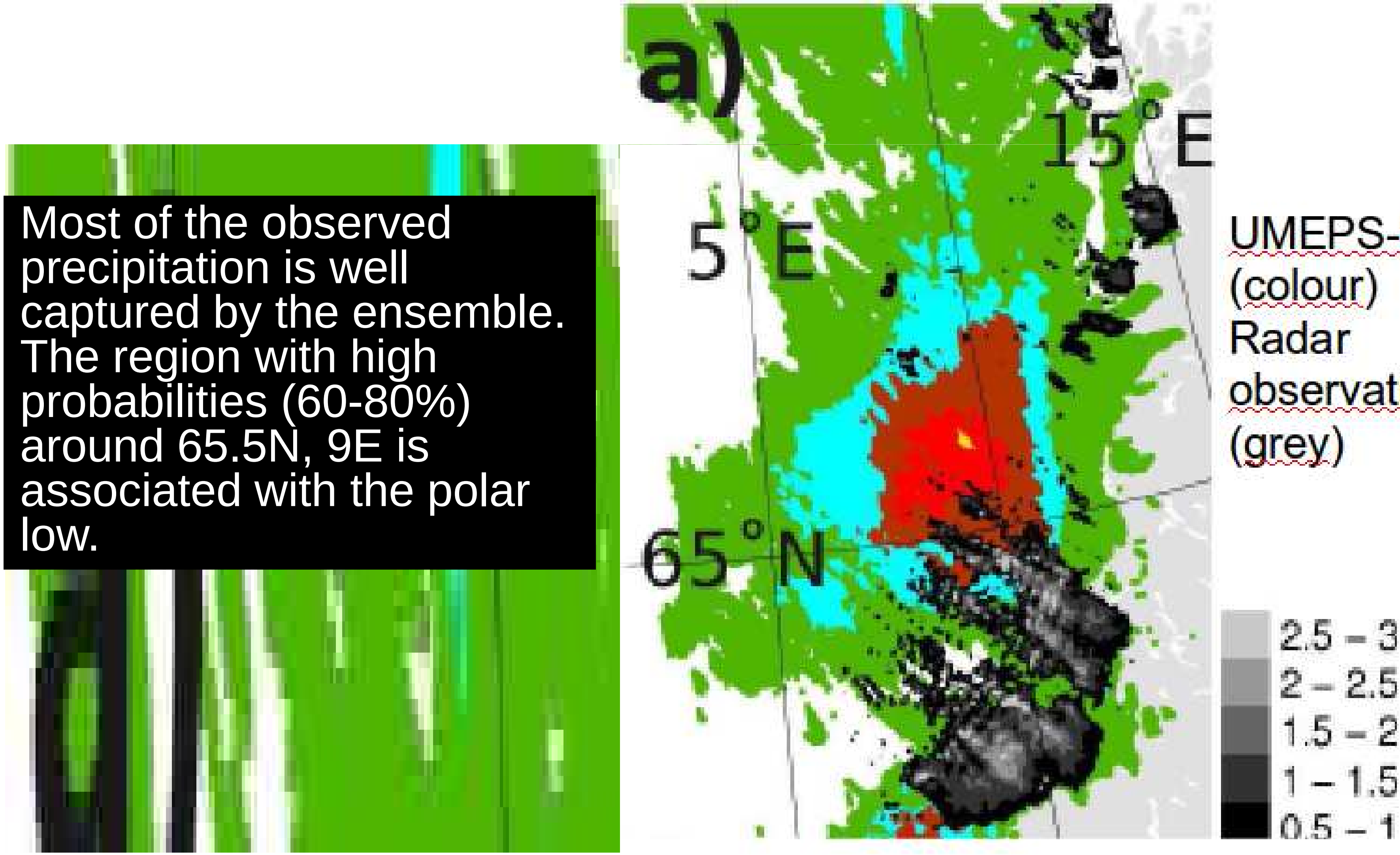



The dropsonde observations are shown as wind arrows.

All members have wind speeds > 20 m/s over a large spatial region around the observed wind maxima. UMEPS-big has generally higher probabilities than LAMEPS.

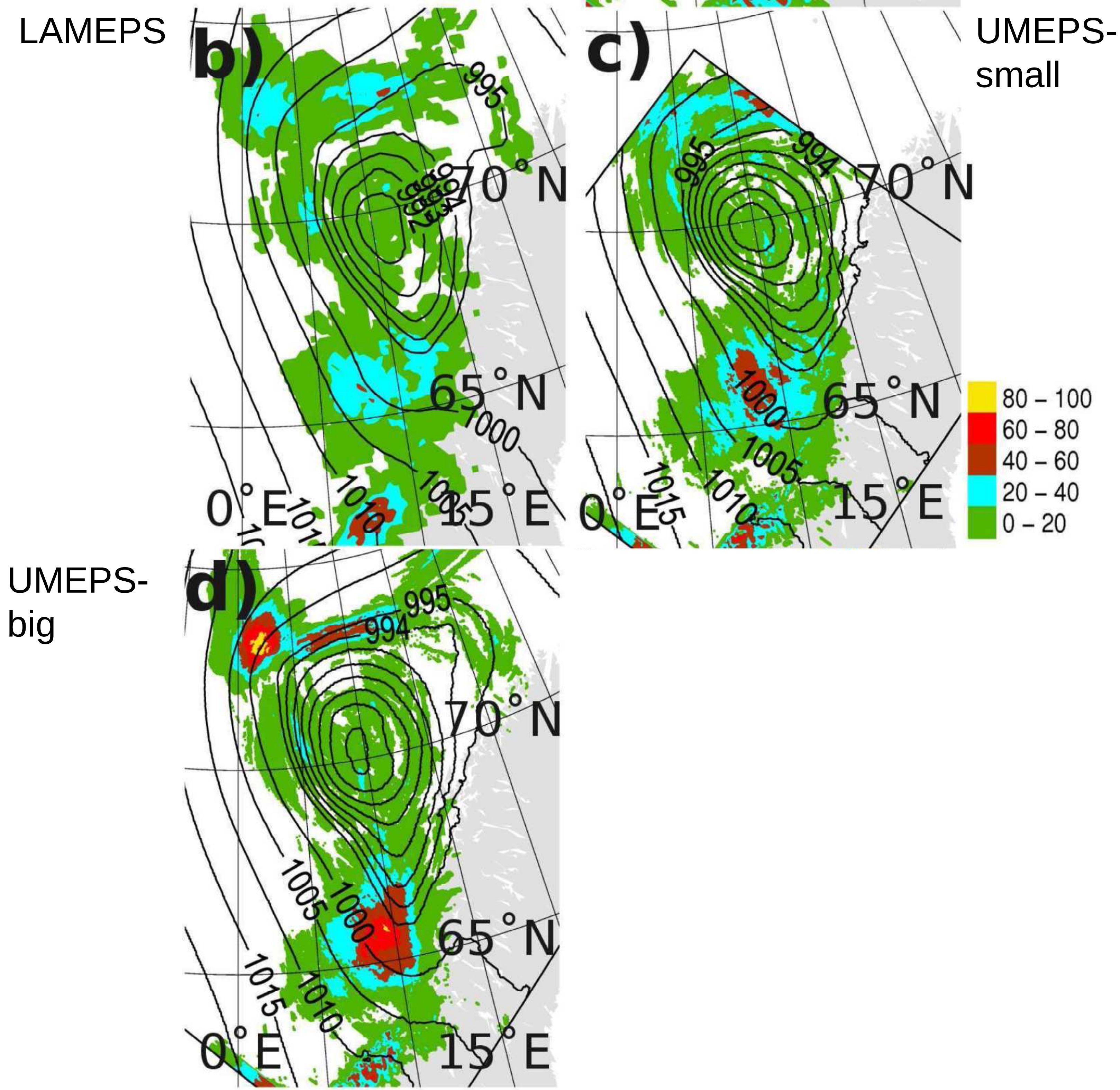
- LAMEPS vs UMEPS-small.
- U925>20m/s
-minor differences
- U925>25m/s
- the general pattern is similar but the probabilities are generally about 0.25 larger UMEPS-small.

# Probability for precipitation
# 2.5 mm/3h; 0900-1200 UTC 4 March




Most of the observed precipitation is well captured by the ensemble. The region with high probabilities (60-80%) around 65.5N, 9E is associated with the polar low.

UMEPS-big (colour)
Radar observations (grey)


LAMEPS
b)
995
70°N
65°N
1000
0°E
15°E
1010
c)
UMEPS-small
995
994
70°N
65°N
1000
1005
1010
1015
0°E
15°E
80 – 100
60 – 80
40 – 60
20 – 40
0 – 20
UMEPS-big
d)
995
994
70°N
65°N
1005
1000
1015
1010
0°E
15°E

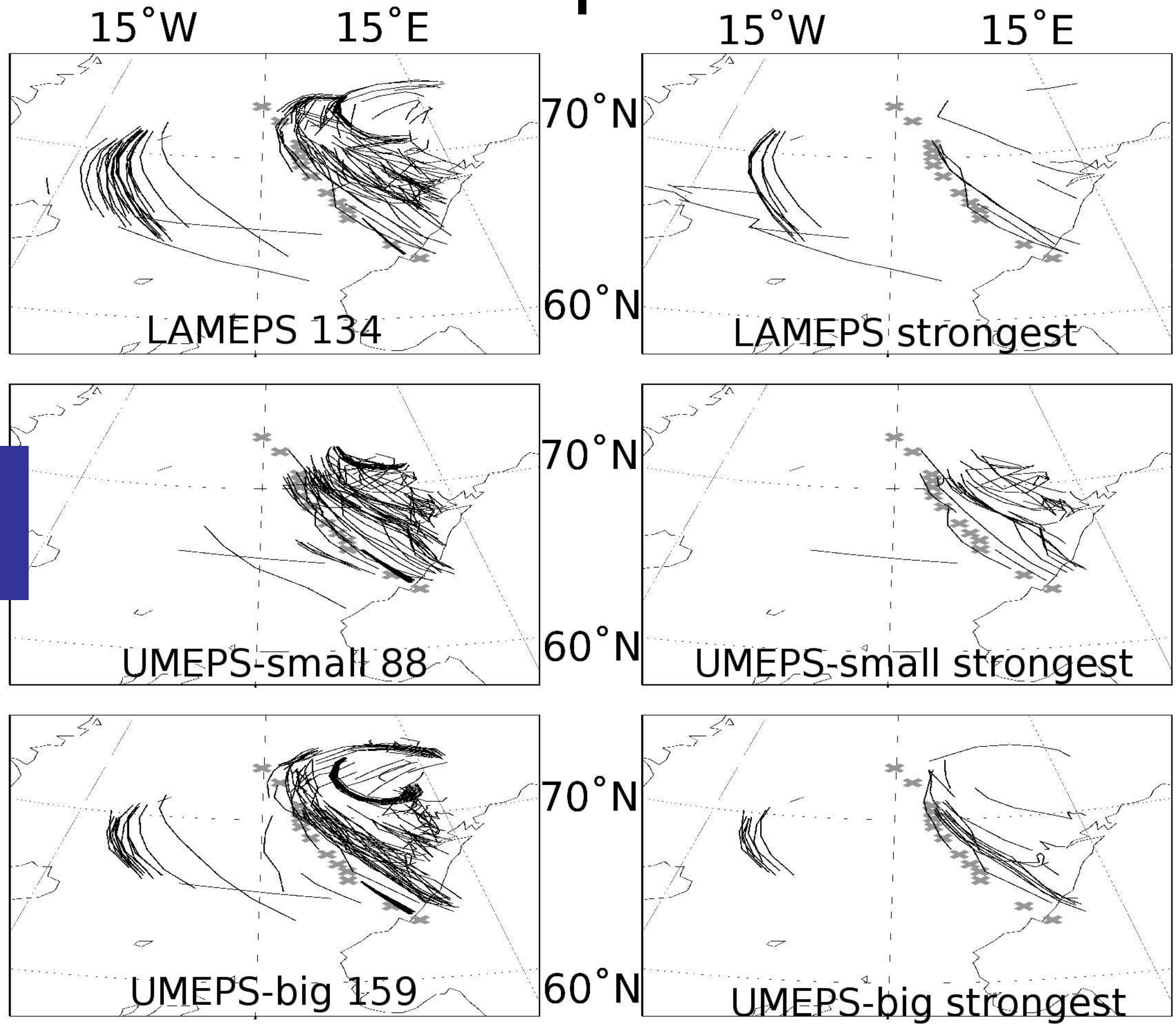
# Tracking polar lows

- Motivation
  - more easily identify and compare the polar low(s) of the different ensemble members and to calculate strike probability maps.
  - The tracking method is based on the algorithm of Hodges.
- Refined to deal with several smallscale vortices.

The term track refers to the trajectory of an individual storm, not the average path of many storms.

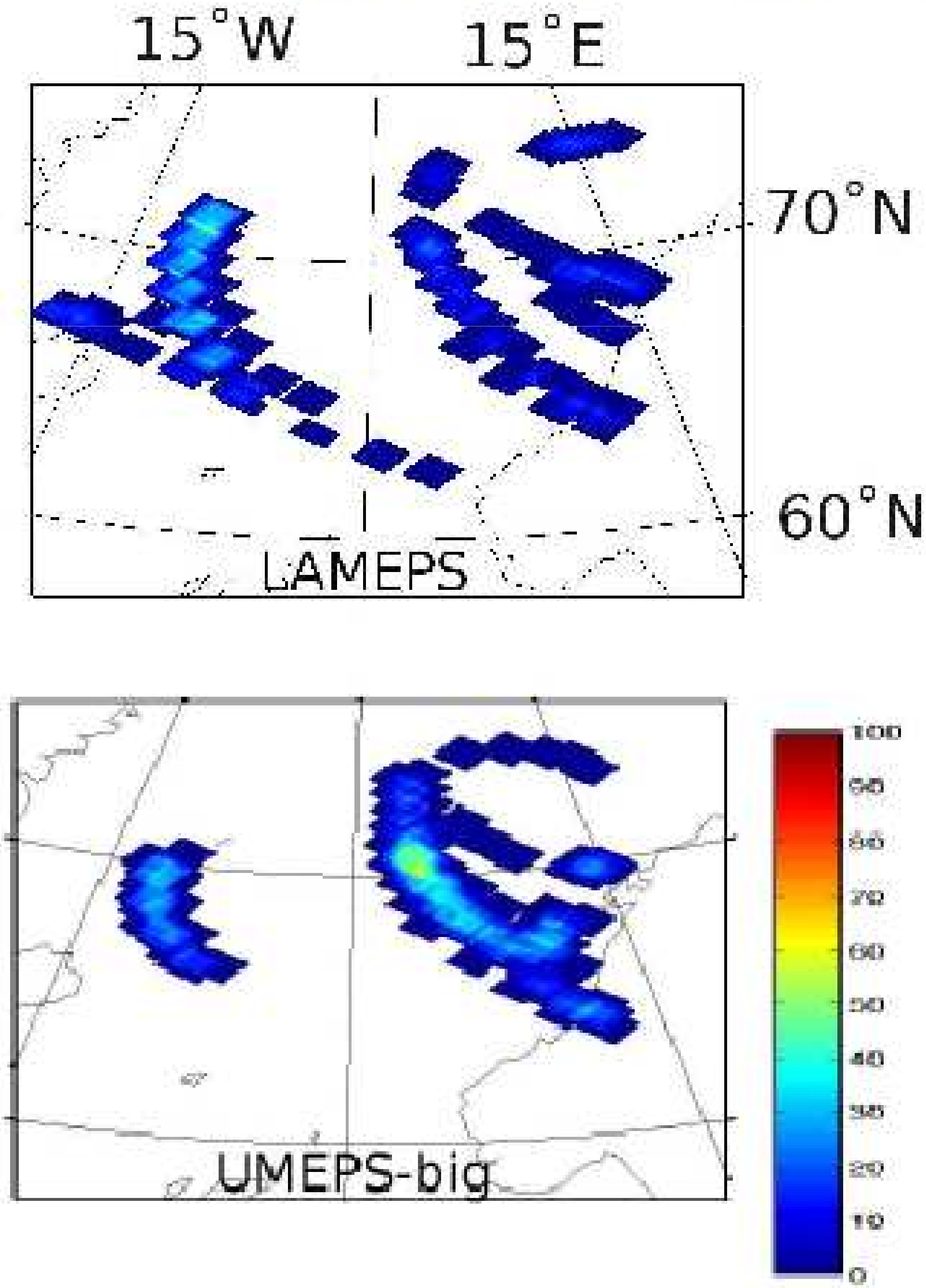
•Polar lows are usually not present in the analysis => more challenging to employ the tracking algorithm

# ”Polar low” paths T+0 to T+60




X = Observed polar low

# Strike Probability Maps




- The forecast probability that a polar low will pass within a 48*48 km² region from a given location during the next 60 h.
- The forecast probability is based on the strongest track from each of the EPS members.

# Conclusions

- Both LAMEPS and UMEPS have the potential to give a warning of extreme weather 1-2 days ahead.
- UMEPS forecast the highest probabilities of strong wind speeds and intense precipitation.
  - This supports the basic assumptions behind dynamical downscaling.
- The added value (UMEPS vs LAMEPS) is sensitive to both domain size and domain location.

- The tracking identified different clusters, one of which was co-located with observed polar low.
- UMEPS-big gave a good estimate of the observed polar low trajectory
- Strike probabilities may be useful for forecasters on duty.
- Polar low path tracks and forecast strike probability maps are also of high potential value for the public user.

# Challenges

- An EPS needs to be run regularly for verification and for understanding its performance.
  - Difficult to obtain sufficient data with an on demand system for all the prepared domains.
- Moreover, there may not always be an optimal choice of domain.
  - The selection of model domain may itself introduce uncertainty in the forecasts.

# Future plans

- Continued work towards an operational high res EPS.
- Prepare *a priori* up to 4 domains to be selected from on a given day
- A good global or large regional ensemble forecast is needed to guide the choice of domain.
- UMEPS cannot be expected to improve complete failures in the coarser resolution forecasts.

- Investigate
  - the initial state perturbations with respect to spatial scale and error growth rate
  - sensitivity to spin-up time
  - a combination of different parameterization schemes/different models among the members to improve the ensemble forecast distributions

# Tracking polar lows

•The average number of tracks is, 2 to 5 times higher with a weaker threshold (2×10-5 s-1) than a stronger (1×10-4 s-1).

•Still, there are 6-10 tracks pr member!

•For the low vorticity threshold (2×10-5 s-1) the number of tracks increases slightly when the interval is reduced from 200-1000 km to 200-600 km.

•When the vorticity threshold is high (1×10-4 s-1) the number decreases when the interval is reduced.

•The atmospheric processes are generally observed over a broad spectrum of length scales and the filtering may not properly separate the different features unless as shown here, only the stronger vortices are retained.

cost function:

- Results for the average number of tracks per ensemble member in UMEPS-big:
  - Filtering intervals; 200-600 km and 200-1000 km
  - Vorticity thresholds; 2×10-5 and 1×10-4 s-1
  - vorticity fields; vor850 and vor925 hPa

| Experiment | Parameter | Vorticity threshold | Filtering interval | Average number of detected tracks |
|---|---|---|---|---|
| 1 | vor850 | 2x10-5 | 200-1000 | 24 |
| 2 | vor850 | 1x10-4 | 200-1000 | 9 |
| 3 | vor850 | 2x10-5 | 200-600 | 30 |
| 4 | vor850 | 1x10-4 | 200-600 | 6 |
| 5 | vor925 | 2x10-5 | 200-1000 | 22 |
| 6 | vor925 | 1x10-4 | 200-1000 | 10 |
| 7 | vor925 | 2x10-5 | 200-600 | 28 |

# Additional criteria

- The average number of tracks is smallest with vor850, 200-600 km and 1×10-4 s-1.
- However, vor925 tend to identify the systems earlier in the forecasts. The average number of tracks is then 8 pr member.
- Further objective criteria were introduced to reduce the number further.
  - (1) No land requirement: to exclude false disturbances over land the track must start over sea.
  - (2) Strong surface winds: the 10 m wind speed must exceed 13.9 m/s (moderate gale).
  - (3) Static stability: the temperature differences between the sea surface temperature (SST) and the temperature at 500 hPa must exceed 43 K.
  - In both (2) and (3) the criterion is evaluated within a 1° radius from a given track location and must be fulfilled over at least 20 % of the track time steps.
- These criteria resulted only in a reduction of 4-5 tracks in total.
  - Interestingly, as in Zahn and Storch (2008), the number of tracks were reduced in LAMEPS (not shown) suggesting a sensitivity to the spatial resolution of the model.
- Since there are several tracks per ensemble member, we have also selected the track with strongest mean vorticity.