COntinuous
Mesoscale
Ensemble
Prediction
System
@ DMI

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Why short-range ensemble forecasting?

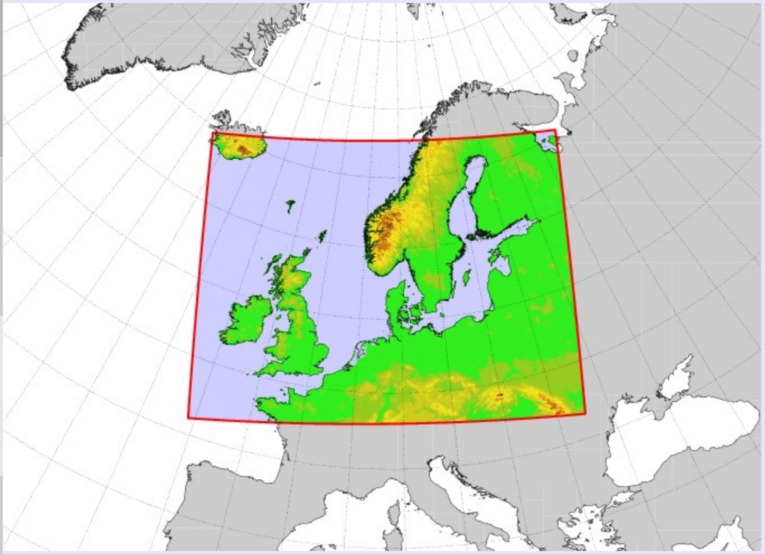
- Quantify uncertainty
  - Precipitation
  - Cloud cover
  - Cloud base
  - Visibility/fog
  - ...
- Predict high-impact weather
  - Cloud bursts/thunderstorms
  - Heavy snowfall/snowstorms
  - (Wind storms)

Sources of forecast uncertainty

- Initial conditions
- Lateral boundary conditions
- Forecast model

Present short-range DMI-EPS

	E05-EPS
Forecast model(s)	HIRLAM
Resolution	0.05°, 40 vertical levels
Members	25 (2 control, 23 perturbed)
Update period	6 hr (all members)
Initial and lateral boundary conditions	1 control 6 perturbations (SLAF)
Model perturbations	2 cloud schemes (STRACO + Kain/Fritsch-Rasch/Kristjansson), stochastic physics (SPPT)



Short-range DMI-EPS

	E05-EPS	COMEPS
Forecast model(s)	HIRLAM	HARMONIE-AROME HIRLAM
Resolution	0.05°, 40 vertical levels	2.5 km, 65 vertical levels 0.03°, 65 vertical levels
Members	25 (2 control, 23 perturbed)	24 (12 pert. HARMONIE + 12 pert. HIRLAM)
Forecast length	54 hr	42 hr
Update period	6 hr (all members)	1 hr (4 members)
Initial and lateral boundary conditions	1 control 6 perturbations (SLAF)	12 perturbations (SLAF)
Model perturbations	2 cloud schemes (STRACO + Kain/Fritsch-Rasch/Kristjansson), stochastic physics (SPPT)	HIRLAM: As E05-EPS HARMONIE: Turbulence, shallow convection, subgrid scale orography, ...

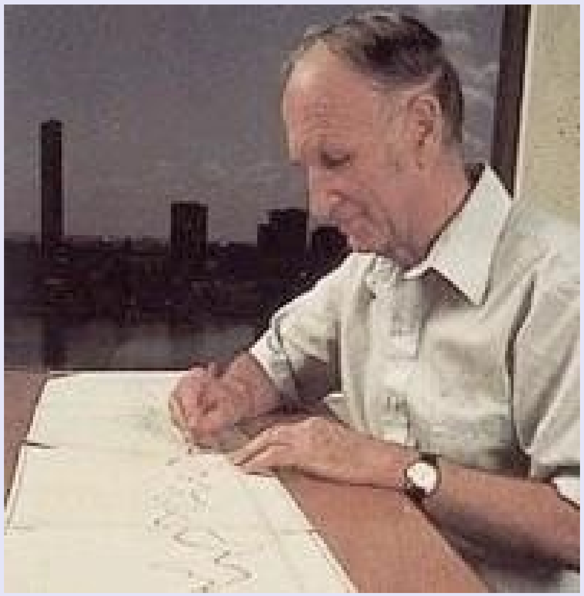
COMEPS domains

Hirlam-H03 (0.03°)

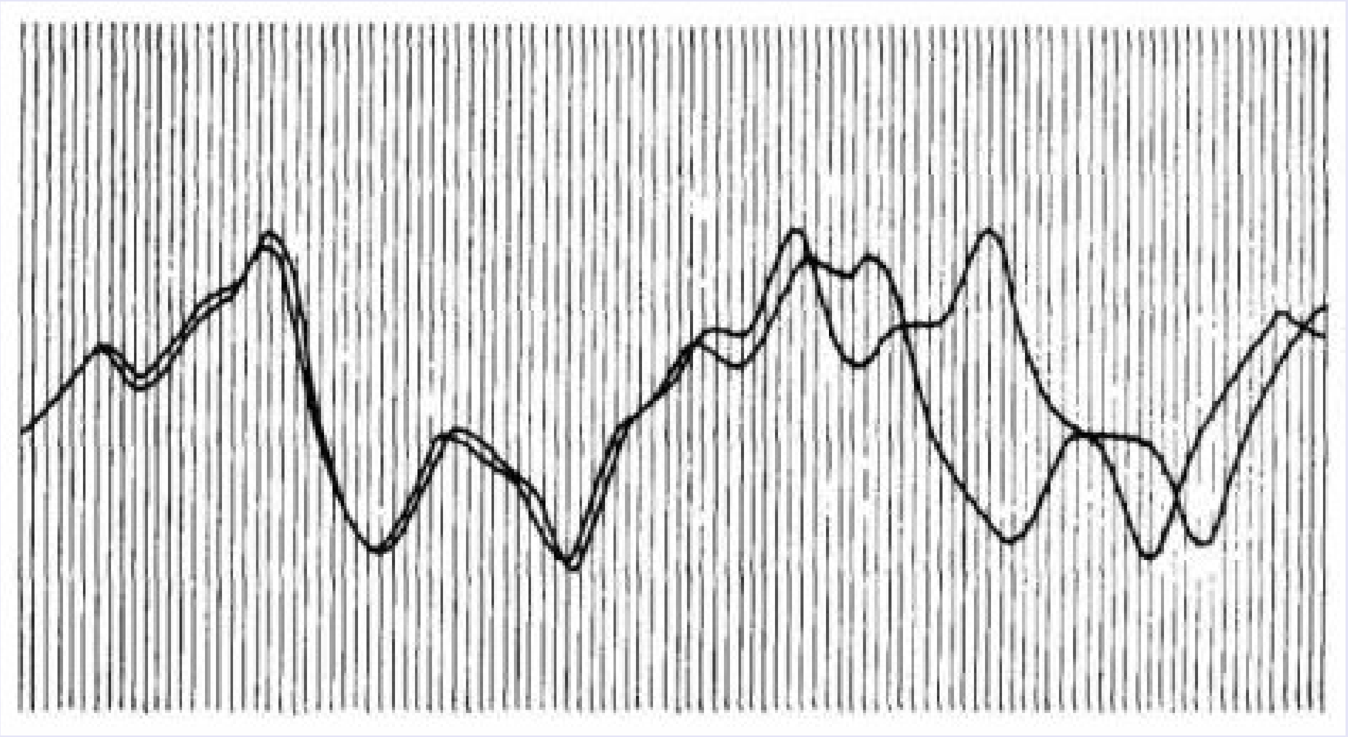
Harmonie-DKA (2.5 km)

North Sea wave model

Sensitivity to initial conditions

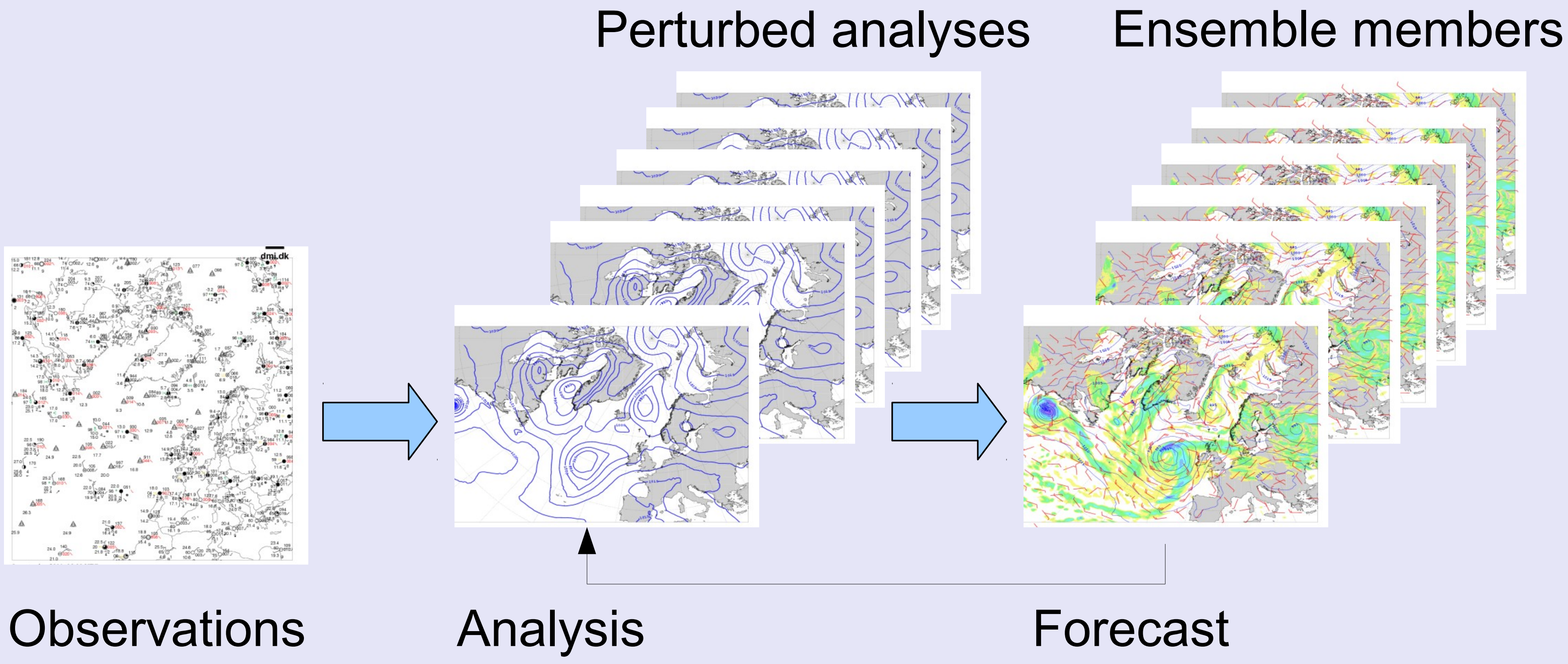


Edward Lorenz (1917-2008)



Ensemble prediction

- Few initial condition samples that best span the phase space



Initial condition perturbations

- Use ECMWF ensemble members
- Monte Carlo method/random sampling
- Systematic perturbations of control analysis
  - Singular vectors
  - Breeding method
  - Scaled Lagged Average Forecast (SLAF)
  - Ensemble Kalman filtering methods

SLAF

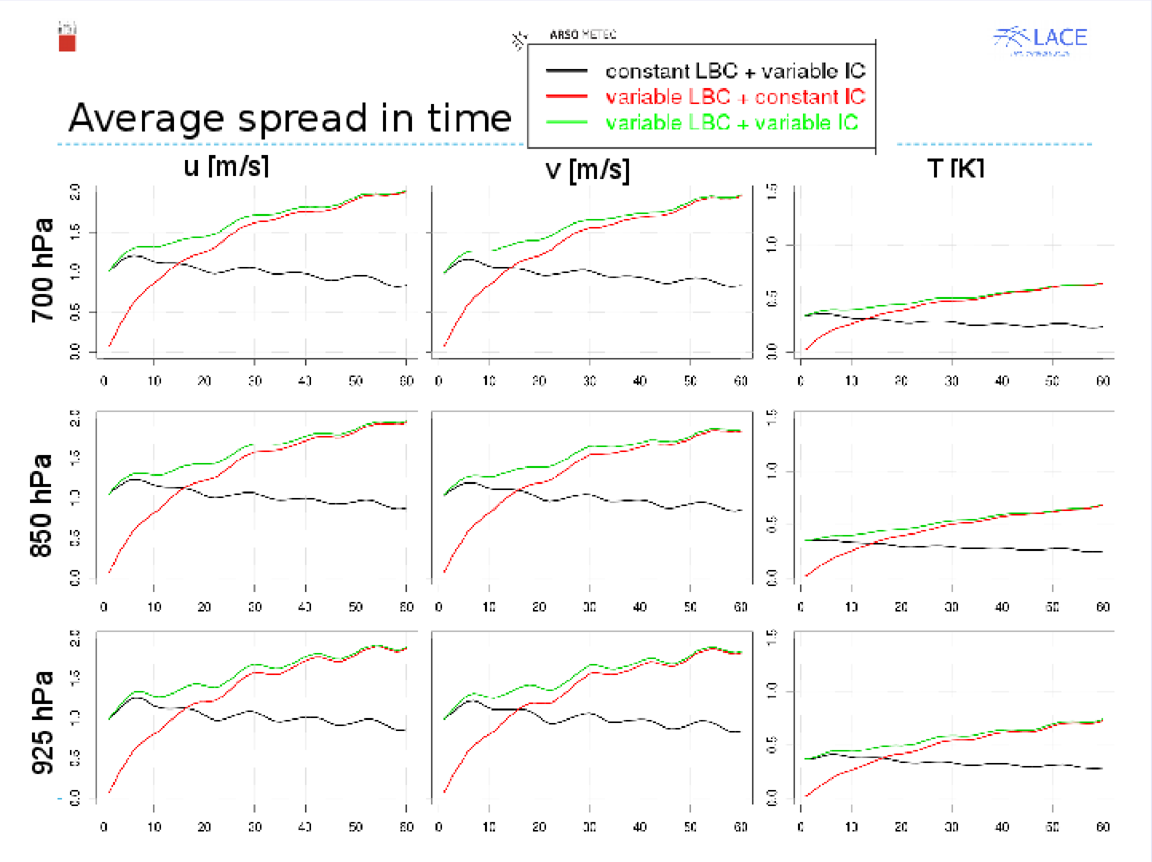
- Use forecast errors as perturbations
  - $IC_T^{(1,2)} = A_T \pm \alpha_1 \, (F_{T\text{-}12h}(t=12h) - F_{T\text{-}6}(t=6h))$
  - $IC_T^{(3,4)} = A_T \pm \alpha_2 \, (F_{T\text{-}18h}(t=18h) - F_{T\text{-}6}(t=6h))$
  - ...
  - $IC_T^{(11,12)} = A_T \pm \alpha_6 \, (F_{T\text{-}42h}(t=42h) - F_{T\text{-}6}(t=6h))$

A_T = Control analysis at time T
F_T = ECMWF forecast at time T
$\alpha_1, ..., \alpha_6$ = scaling parameters

- Time shift to perturb lateral boundaries
- Pros
  - Forecast error ~ uncertainty
  - Simple
- Cons
  - Number of perturbations is limited
  - No optimization regarding sampling of phase space

Importance of lateral boundary perturbations

Jure Cedilnik and Nedjeljka Zagar, ALADIN Workshop/HIRLAM All Staff Meeting 2017:



For forecast lengths > ~15h lateral boundary perturbations contribute more to the ensemble spread than initial condition perturbations!

Sampling model uncertainty

- Multi-model ensemble
  - Special case: “Poor man's ensemble” where the ensemble is a collection of available deterministic forecasts
- Multi-physics ensemble
- Stochastic physics
  - Stochastic perturbation of physics tendencies (SPPT)
  - Stochastic kinetic energy backscatter (SKEB)
- Stochastic parameter perturbations (SPP)

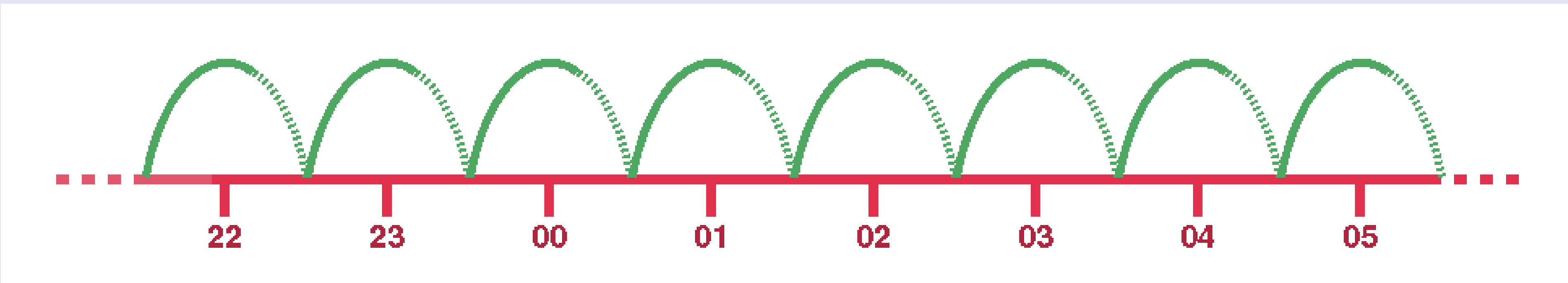
Ensemble update: Traditional EPS

Control	00Z						06Z		
mbr001	Ctl+P_a						Ctl+P_a		
mbr002	Ctl-P_a						Ctl-P_a		
mbr003	Ctl+P_b						Ctl+P_b		
mbr004	Ctl-P_b						Ctl-P_b		
mbr005	Ctl+P_c						Ctl+P_c		
mbr006	Ctl-P_c						Ctl-P_c		
...									

Rapid update EPS

Control	00Z	01Z	02Z	03Z	04Z	05Z	06Z	07Z	08Z
mbr001	Ctl+P_a						Ctl+P_a		
mbr002	Ctl-P_a						Ctl-P_a		
mbr003		Ctl+P_b						Ctl+P_b	
mbr004		Ctl-P_b						Ctl-P_b	
mbr005			Ctl+P_c						Ctl+P_c
mbr006			Ctl-P_c						Ctl-P_c
...				Ctl+P_d					
				Ctl-P_d					
					Ctl+P_e				

Hourly control analyses (traditional)



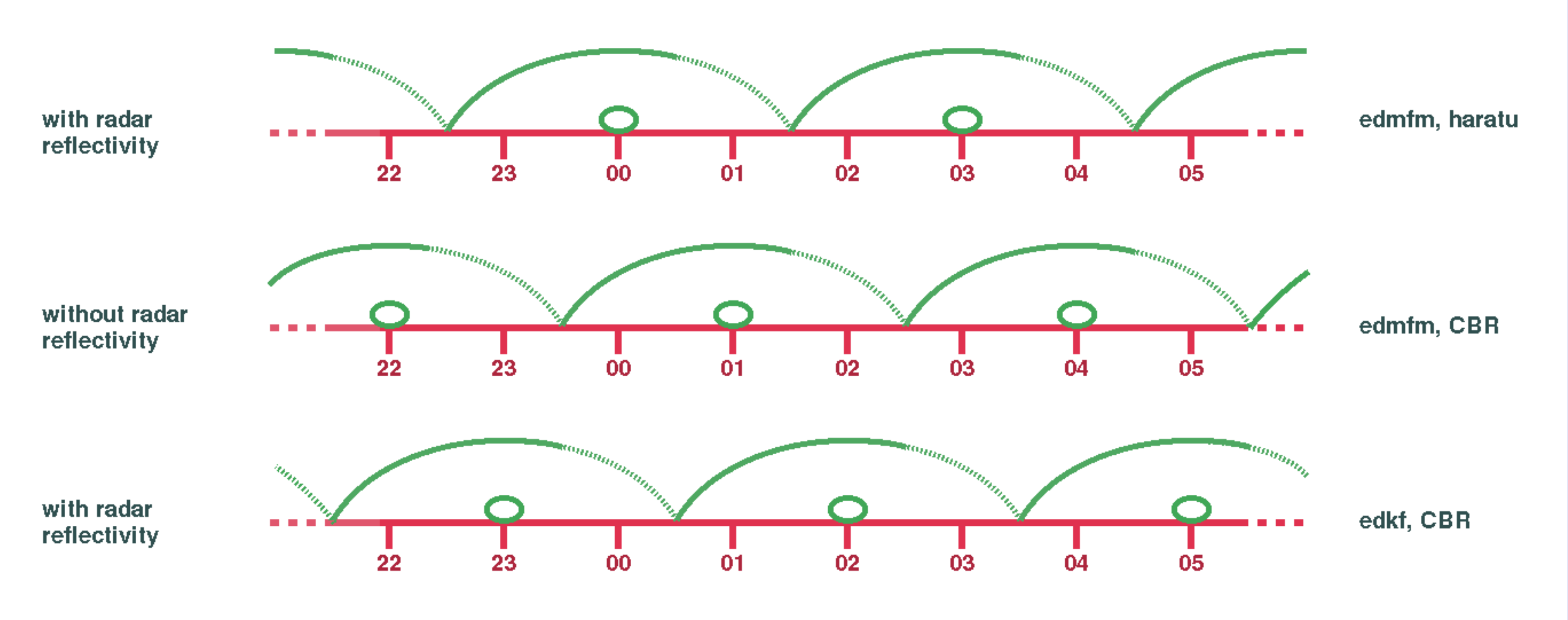
Cycling with hourly 3DVAR with observation data window of +/- 30 min

First guess produced from hourly cycling

Drawback:

- short observation data cutoff;
- spin-up effect;
- logistic difficulty with timely delivery

Hourly control analyses (COMEPS)



Hourly data assimilation of 3-hourly windowed 3DVAR in ***overlapping time windows***

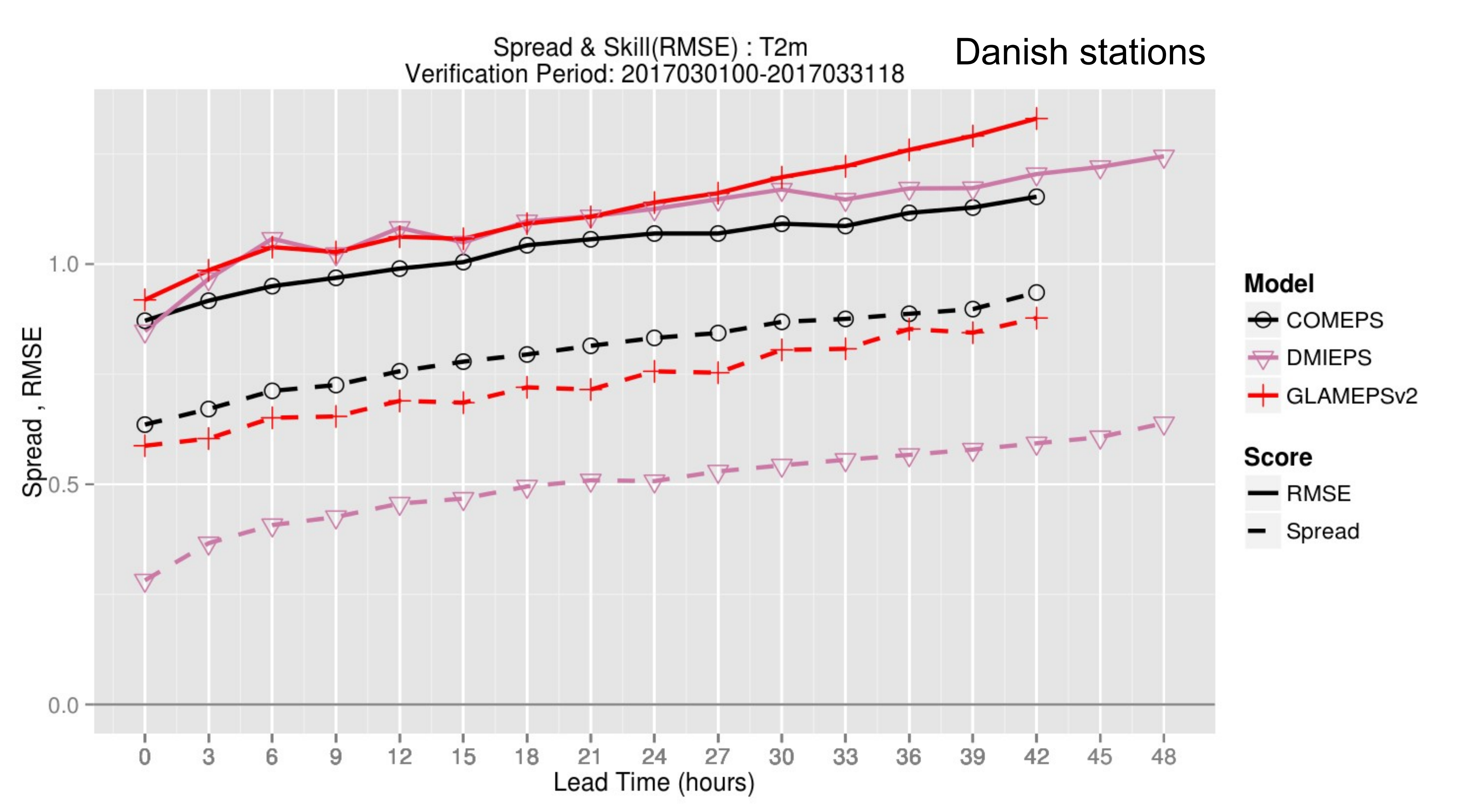
Benefit:

- Use of more observation data
- Varying setup in both use of observations and assimilation algorithm
- No problem of using the same observations repeatedly be consecutive analyses
- Easier to catch up in case of delays

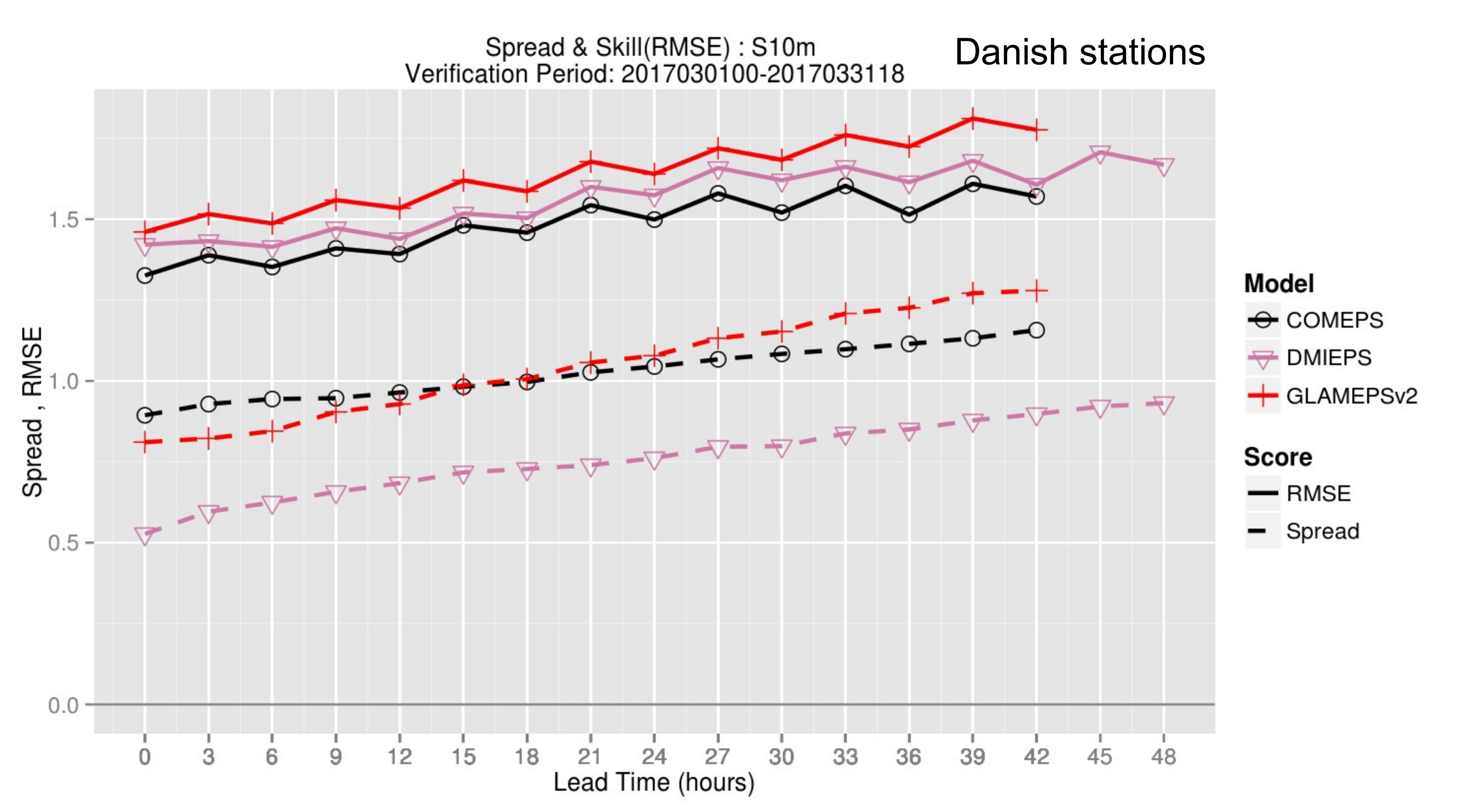
Properties of an ideal ensemble prediction system

- All ensemble members equally likely and
- Statistically indistinguishable from observations
- Ensemble spread = forecast error
- Forecast probabilities = observed frequencies (reliability)

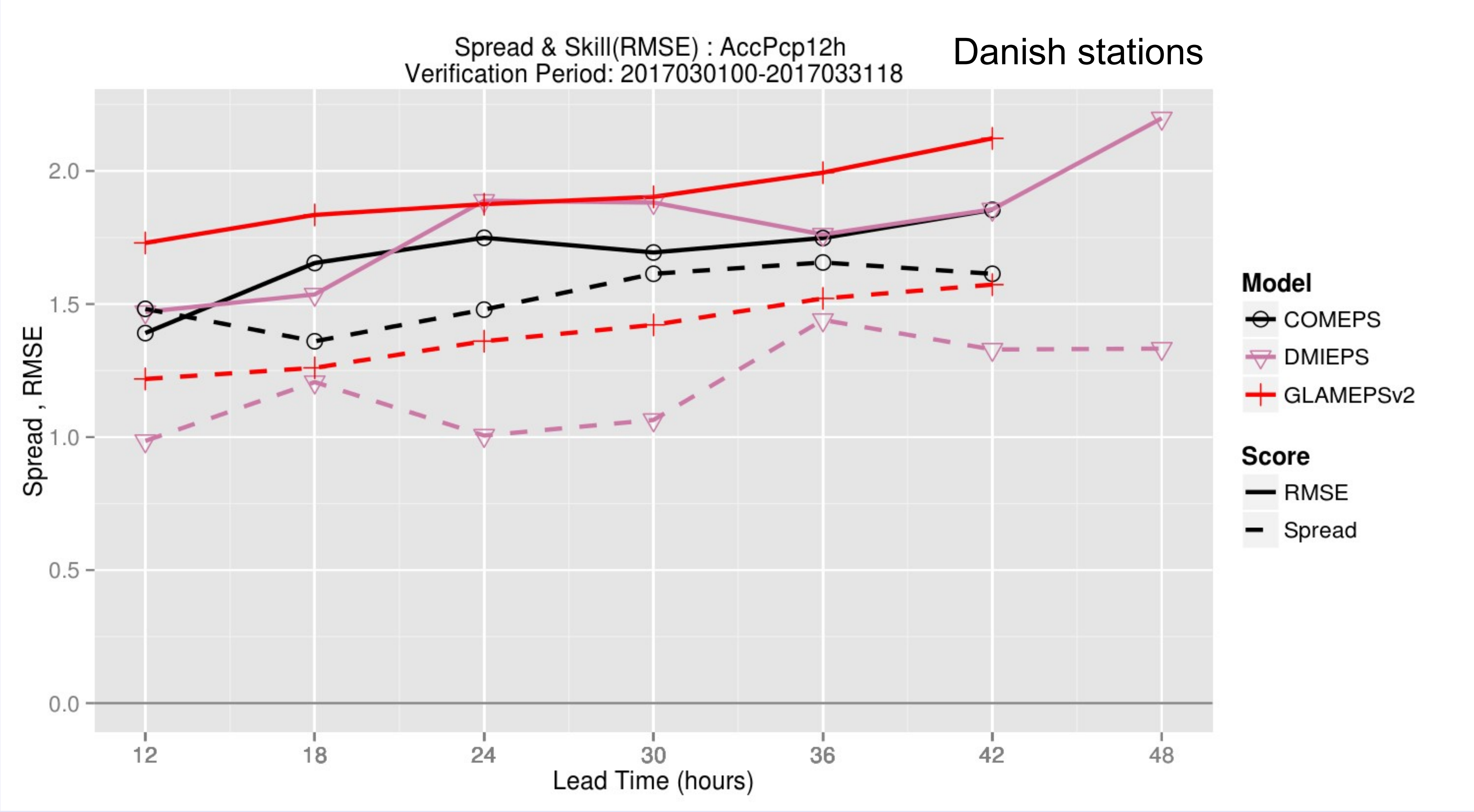
Verification, spread/error, T2m



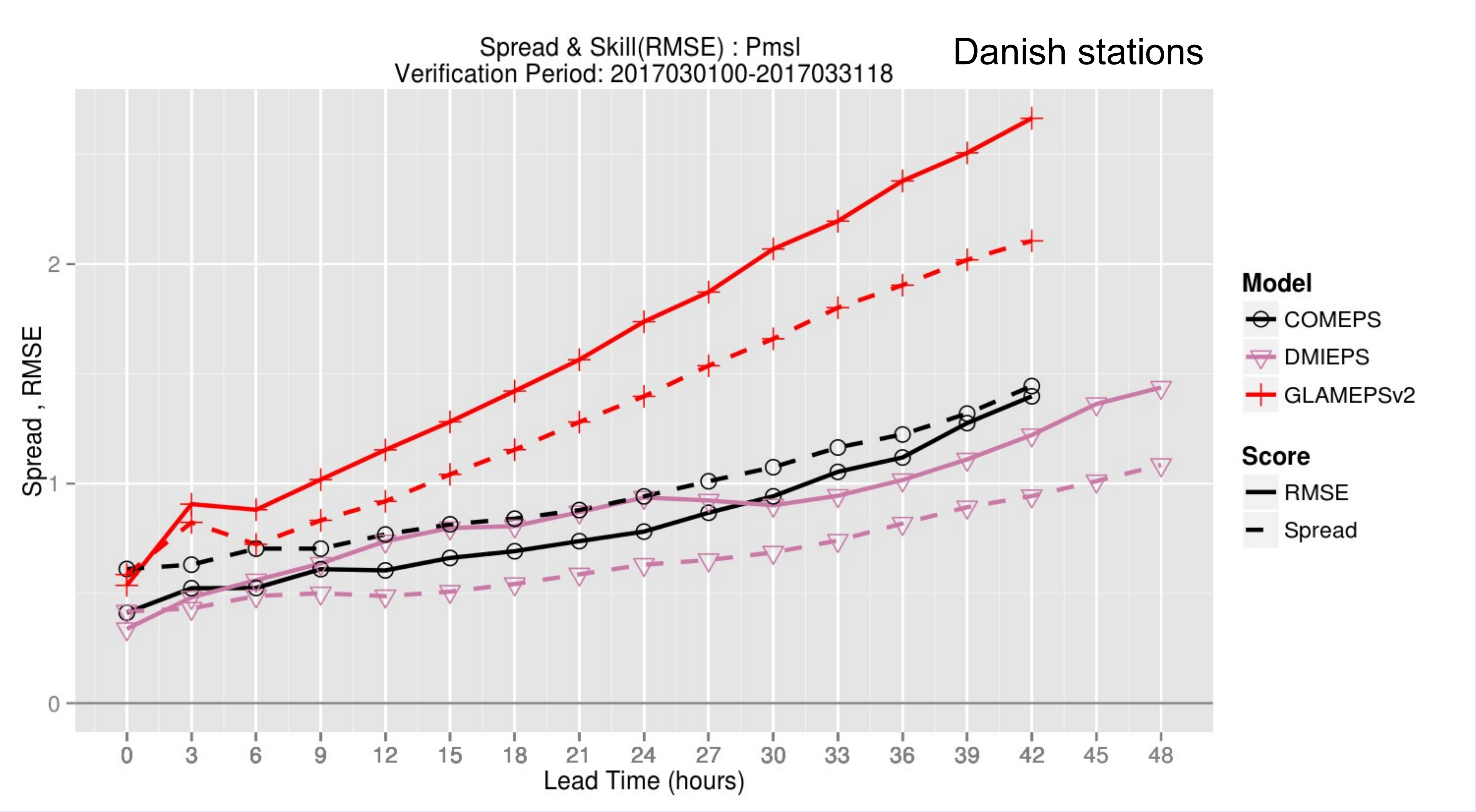
Verification, spread/error, 10m wind speed



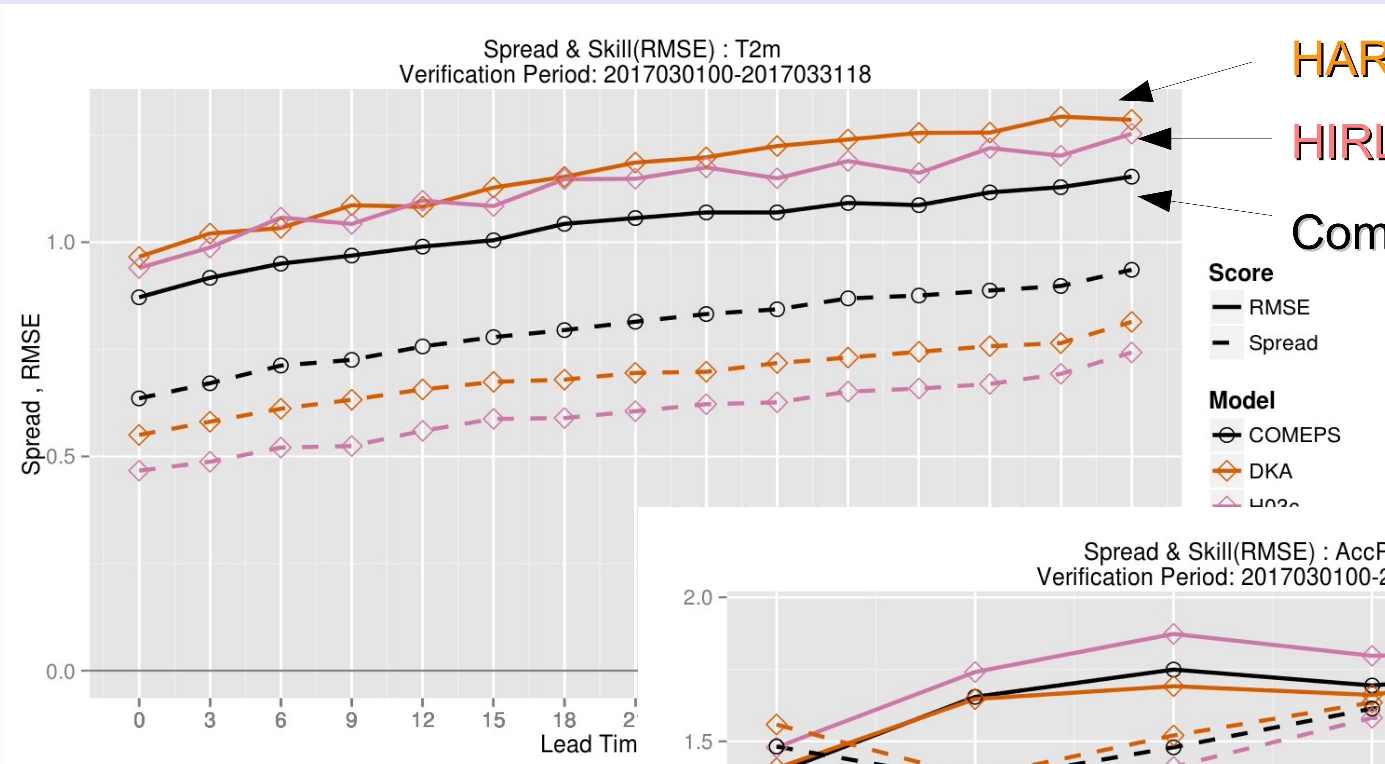
Verification, spread/error, precipitation

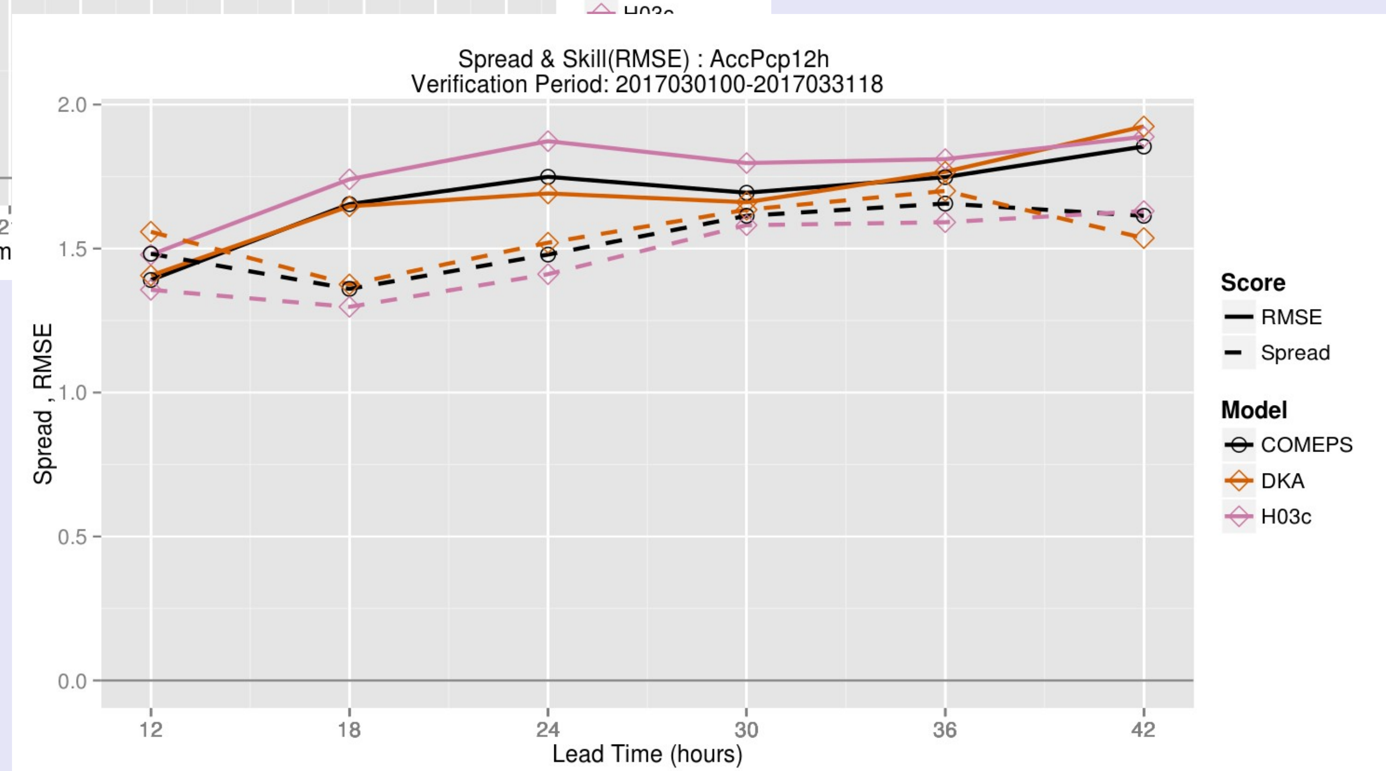


Verification, spread/error, MSLP

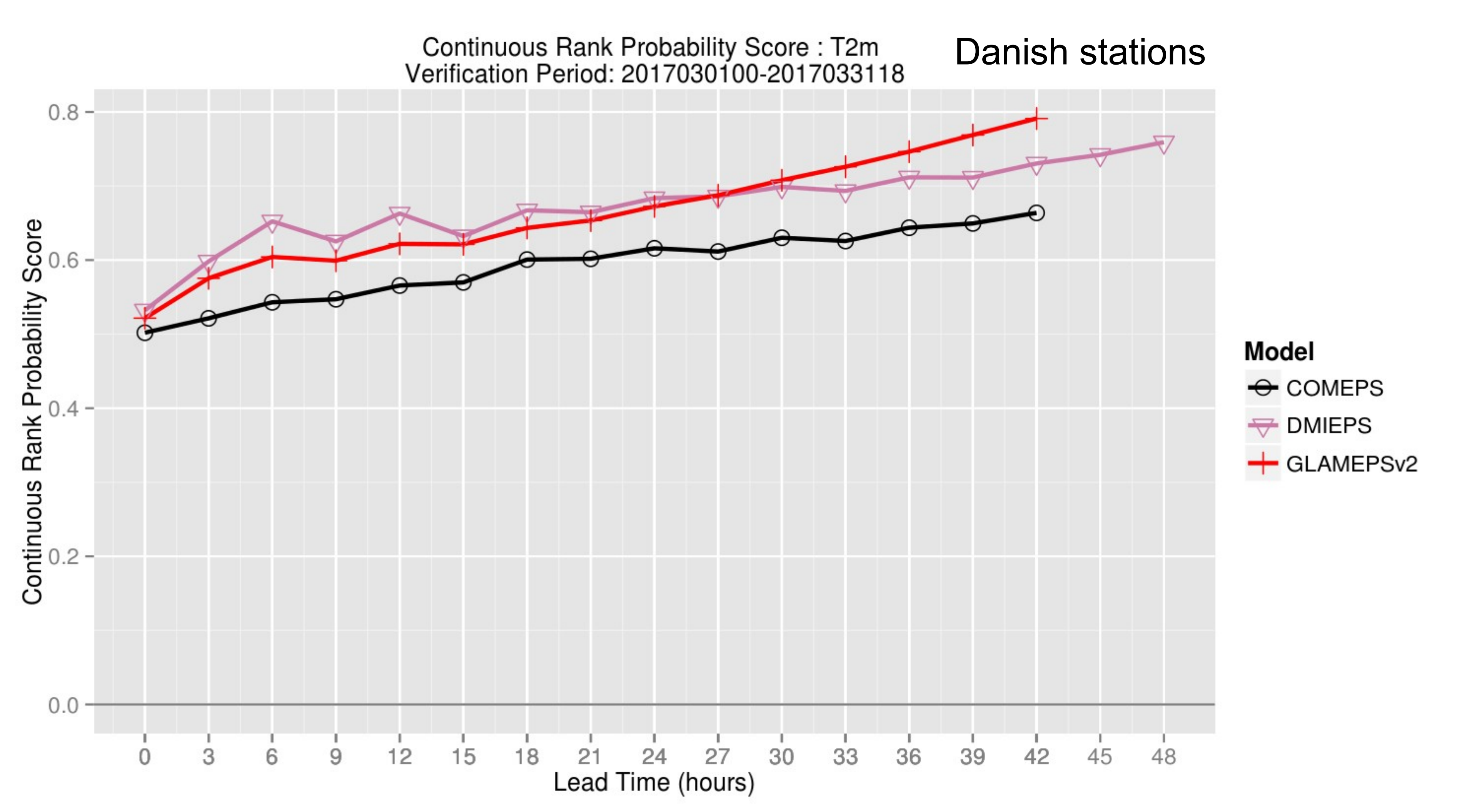


Verification, multimodel spread/error

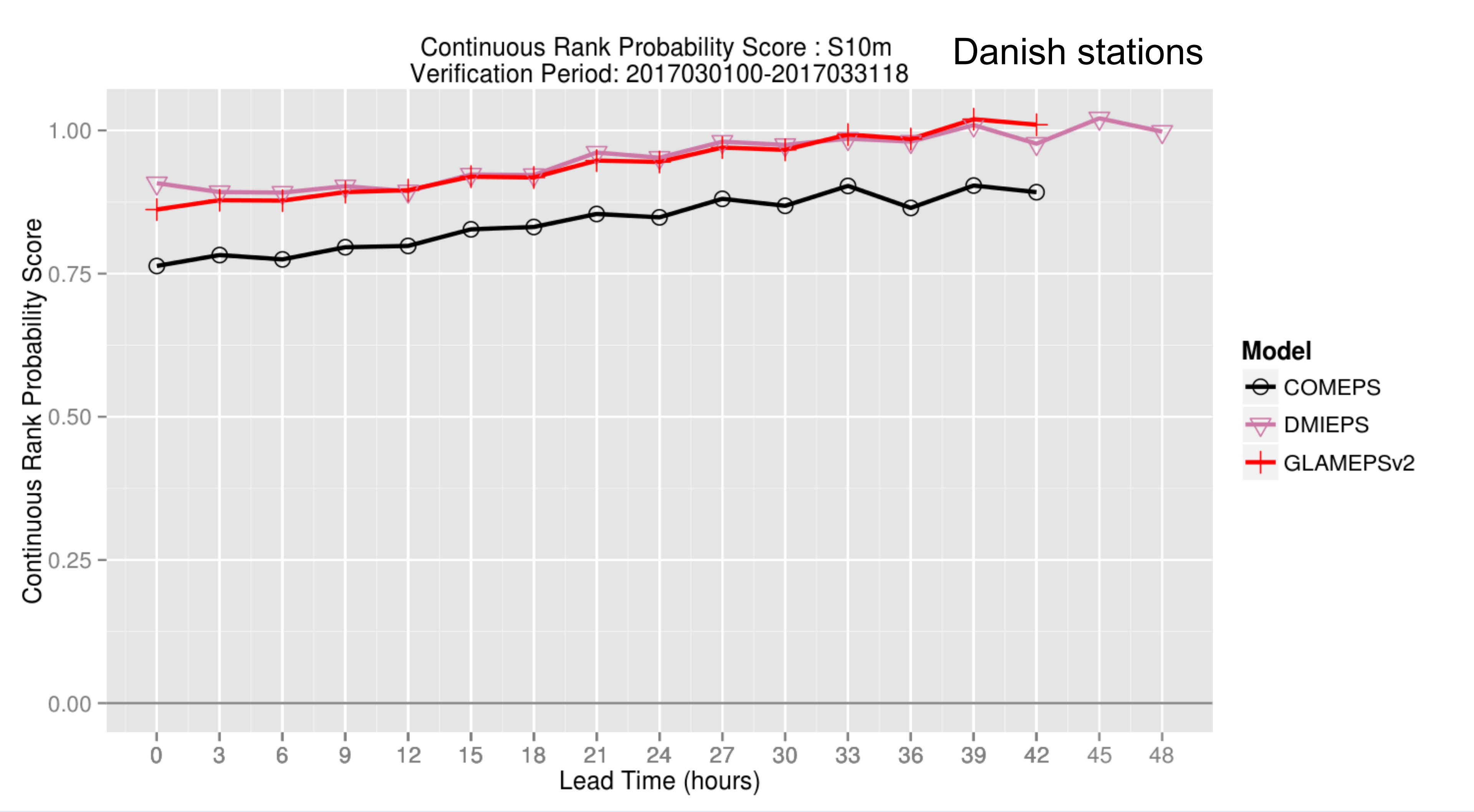




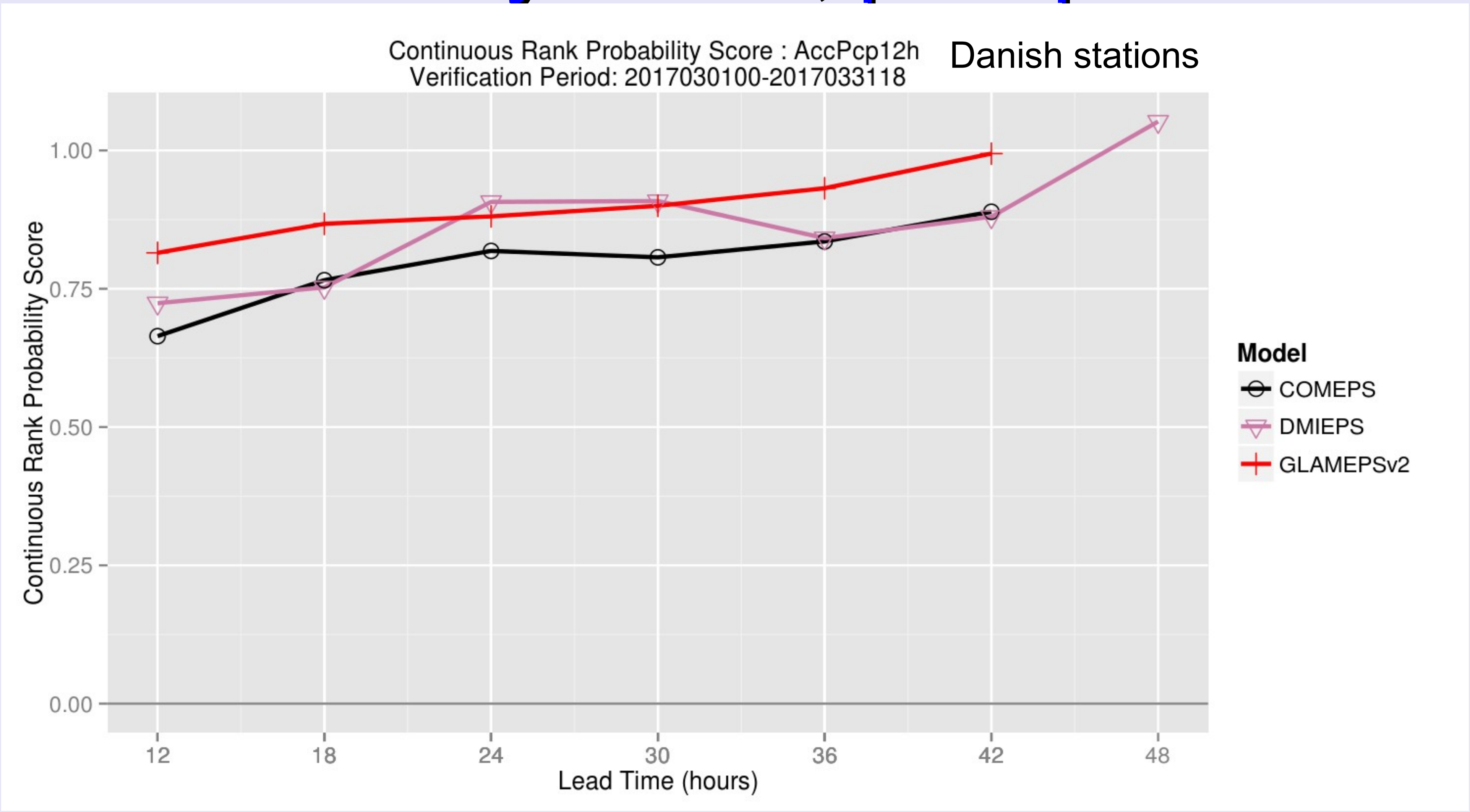
Verification, Continuous Rank Probability Score, T2m



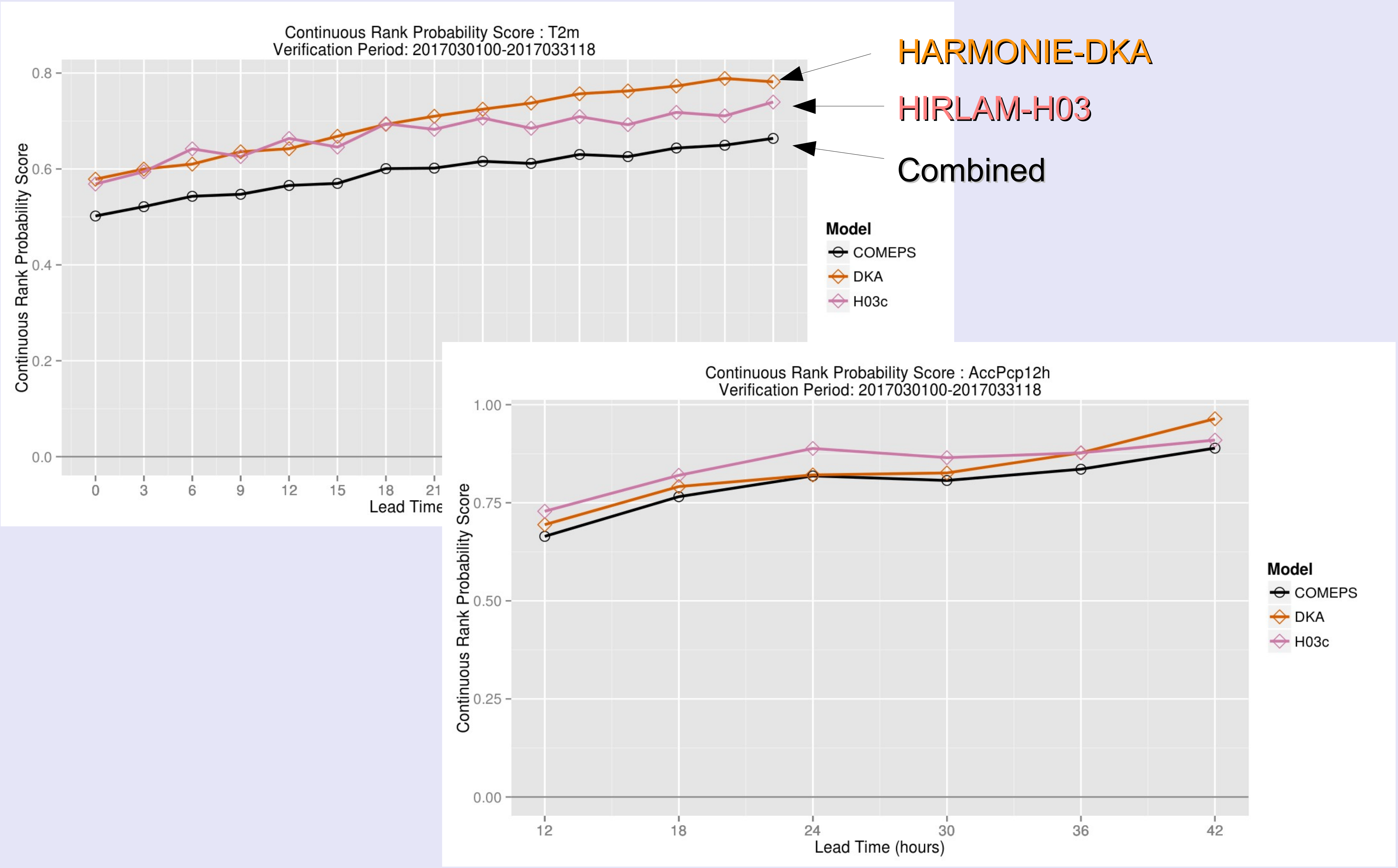
Verification, Continuous Rank Probability Score, 10m wind speed



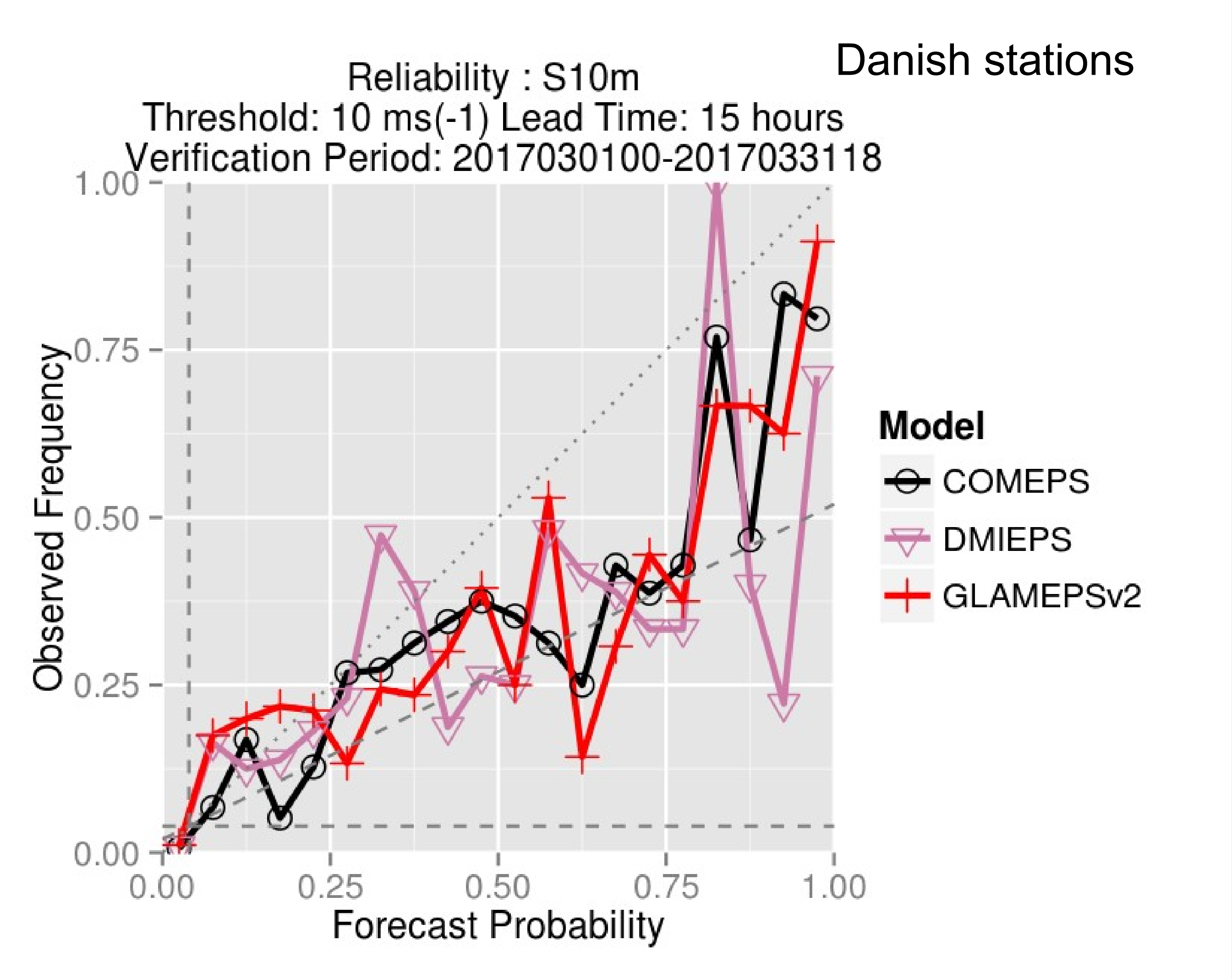
Verification, Continuous Rank Probability Score, precipitation



Verification, multimodel CRPS



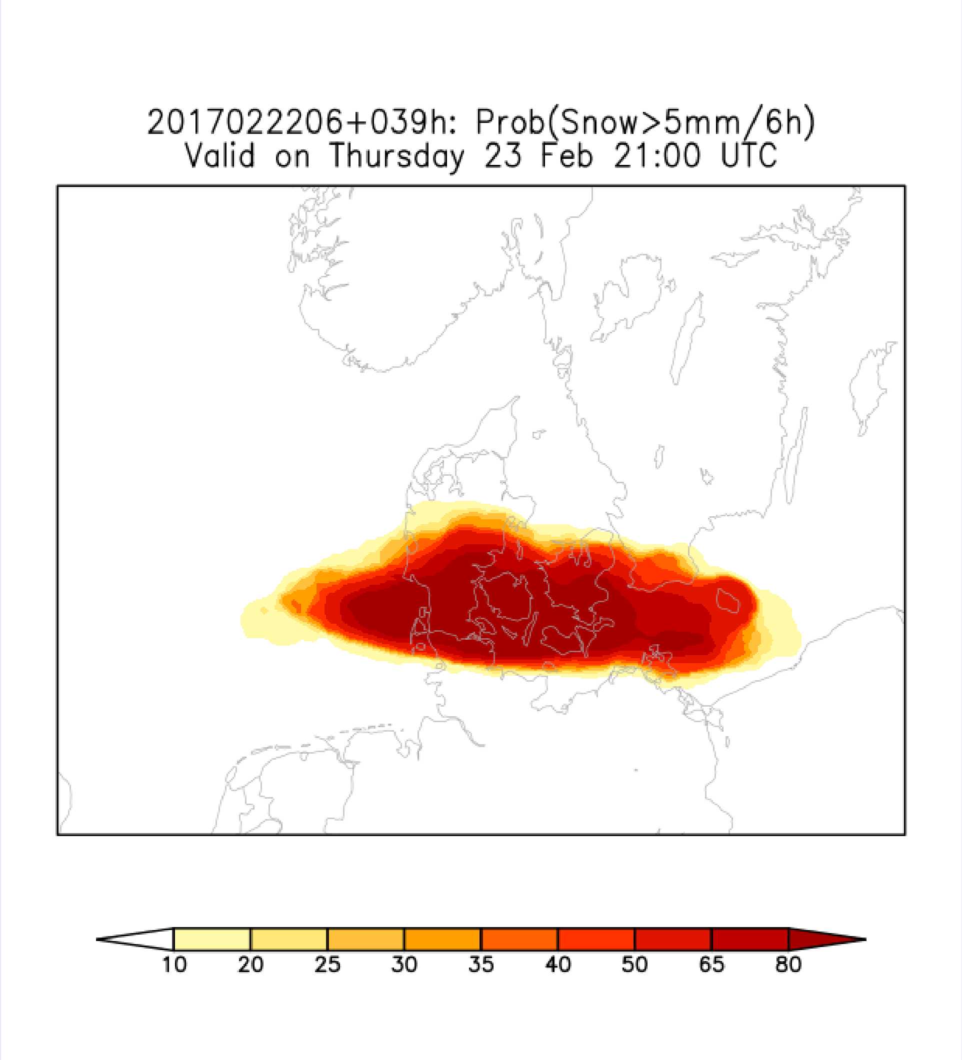
Verification, high wind speeds (>10 m/s)



Snowfall 23 Feb 2017

Snowfall 23 Feb 2017

E05-EPS



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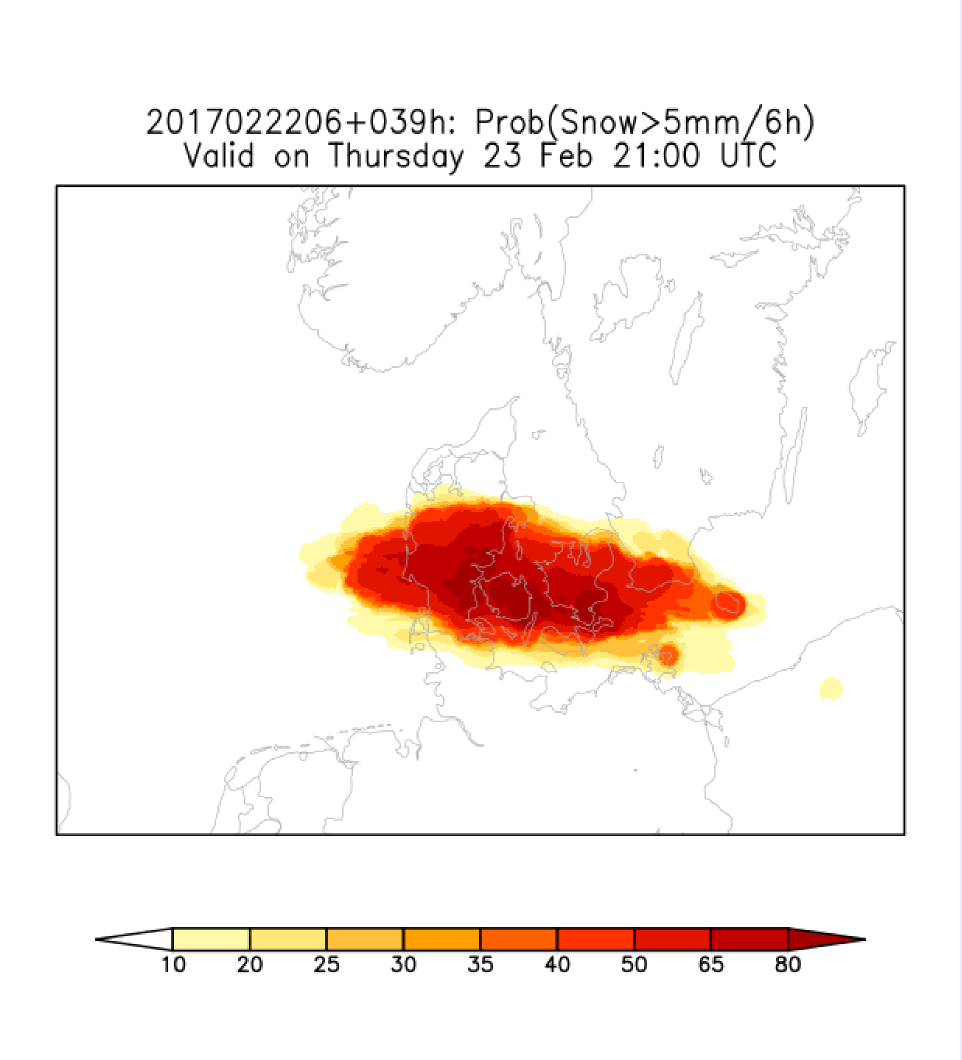

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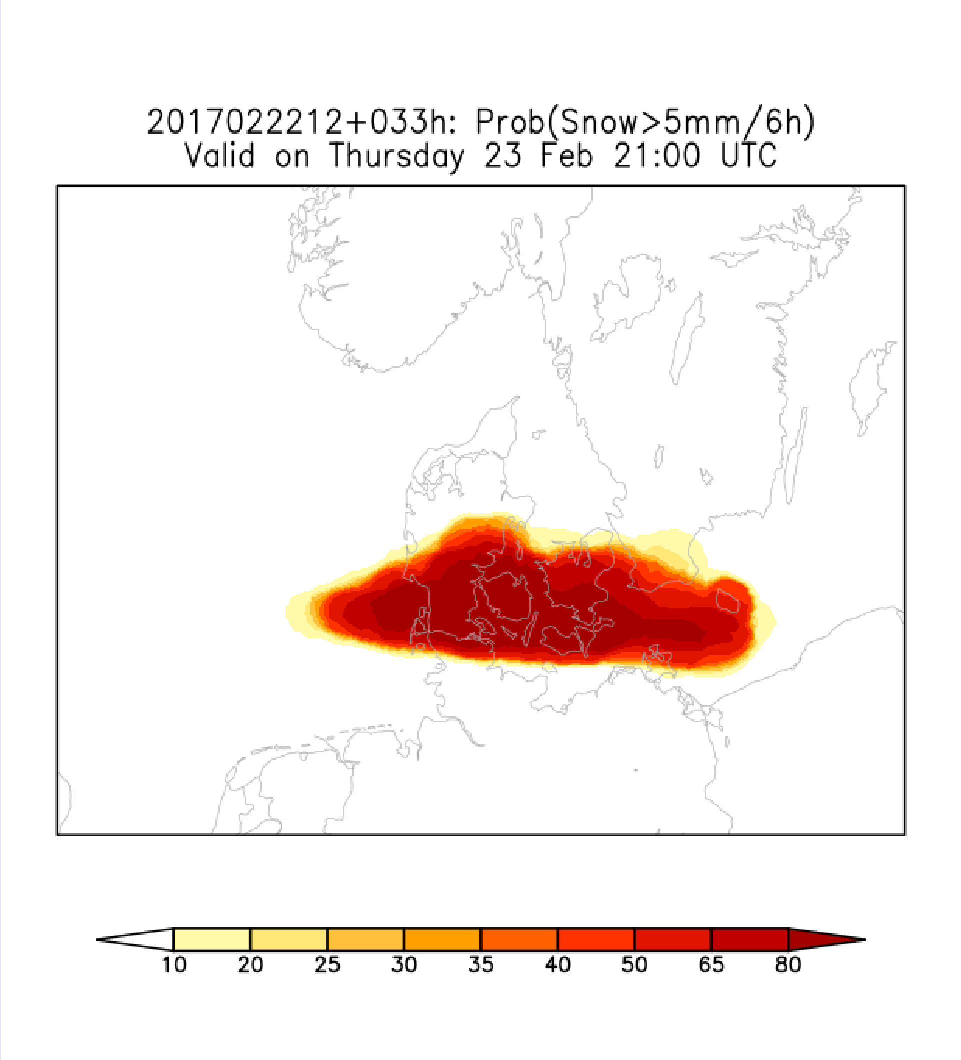

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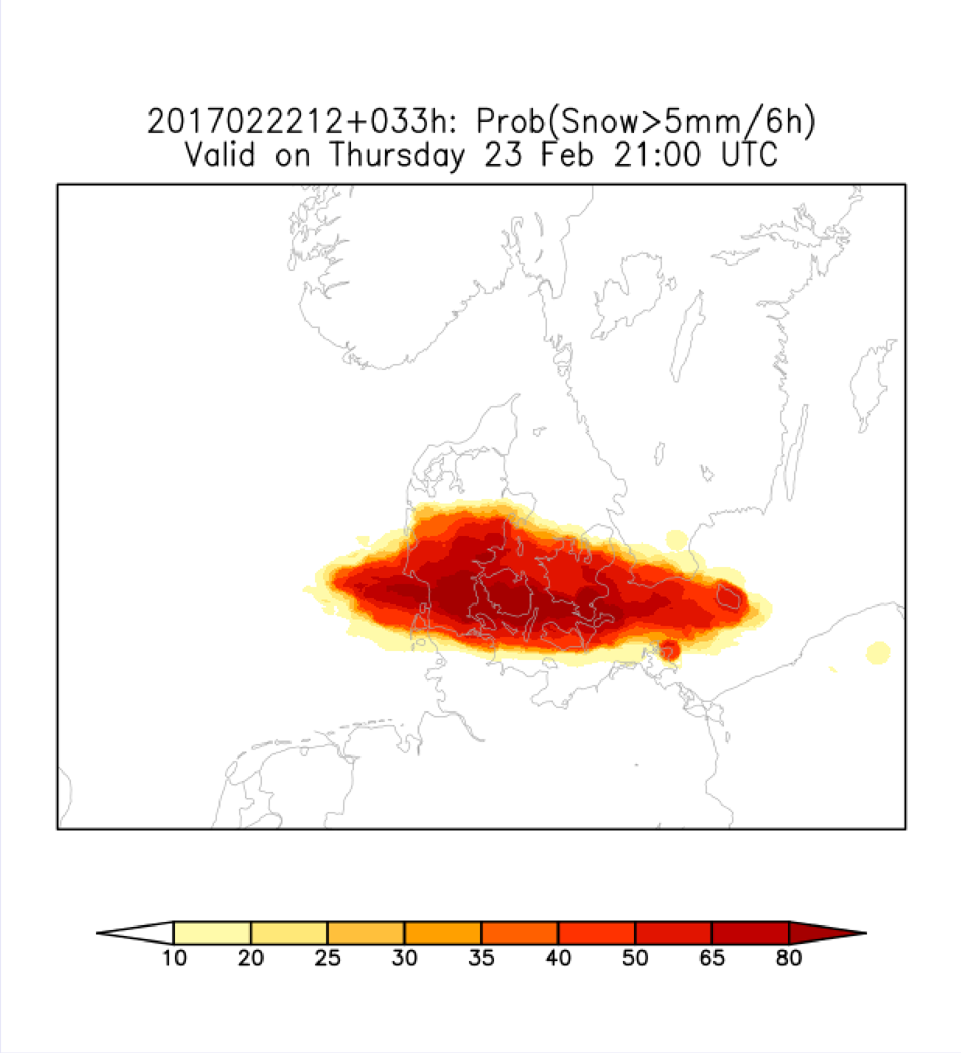

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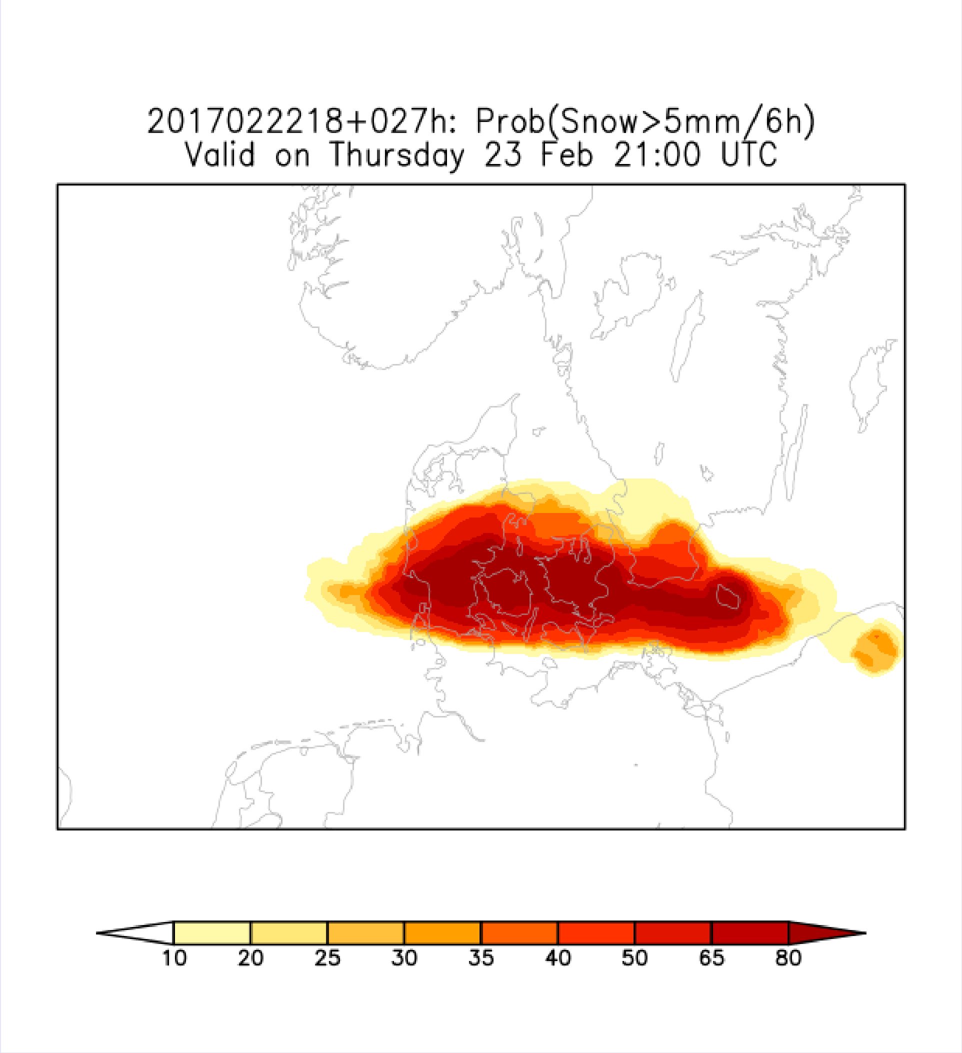

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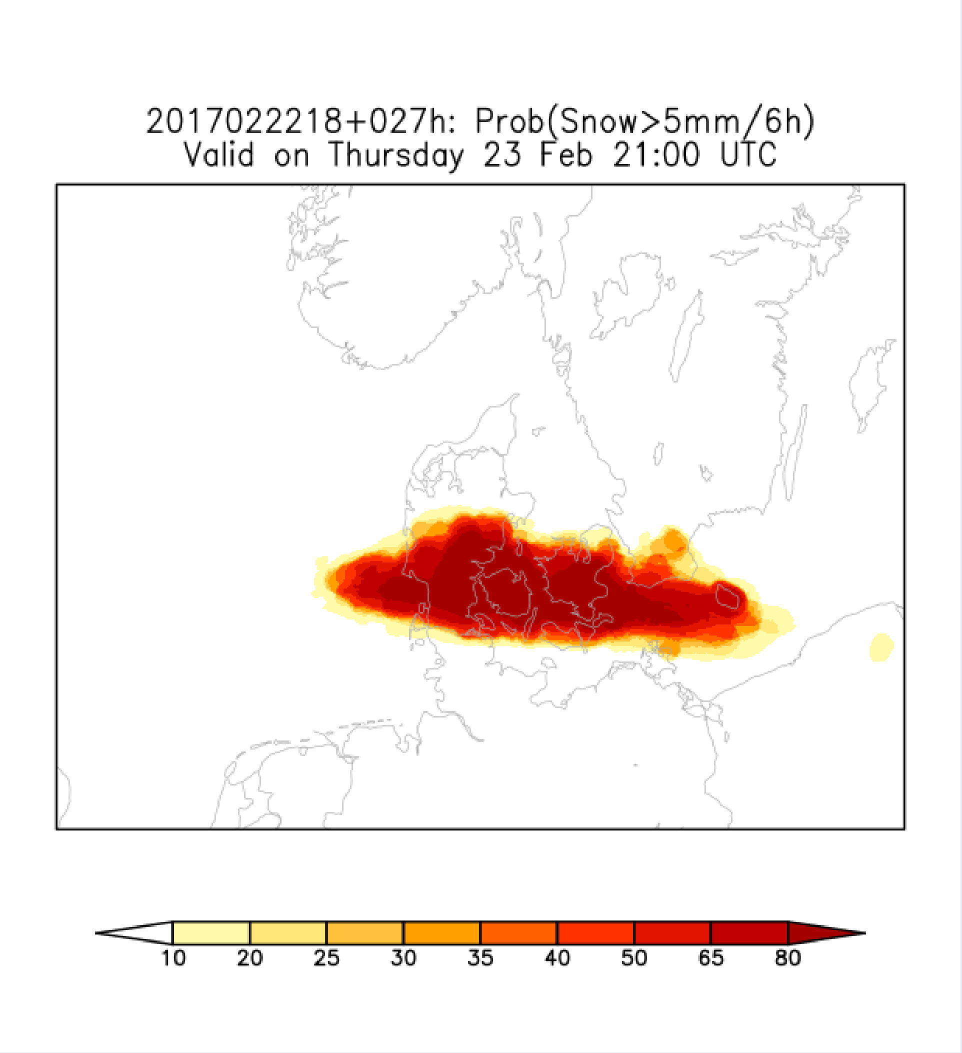

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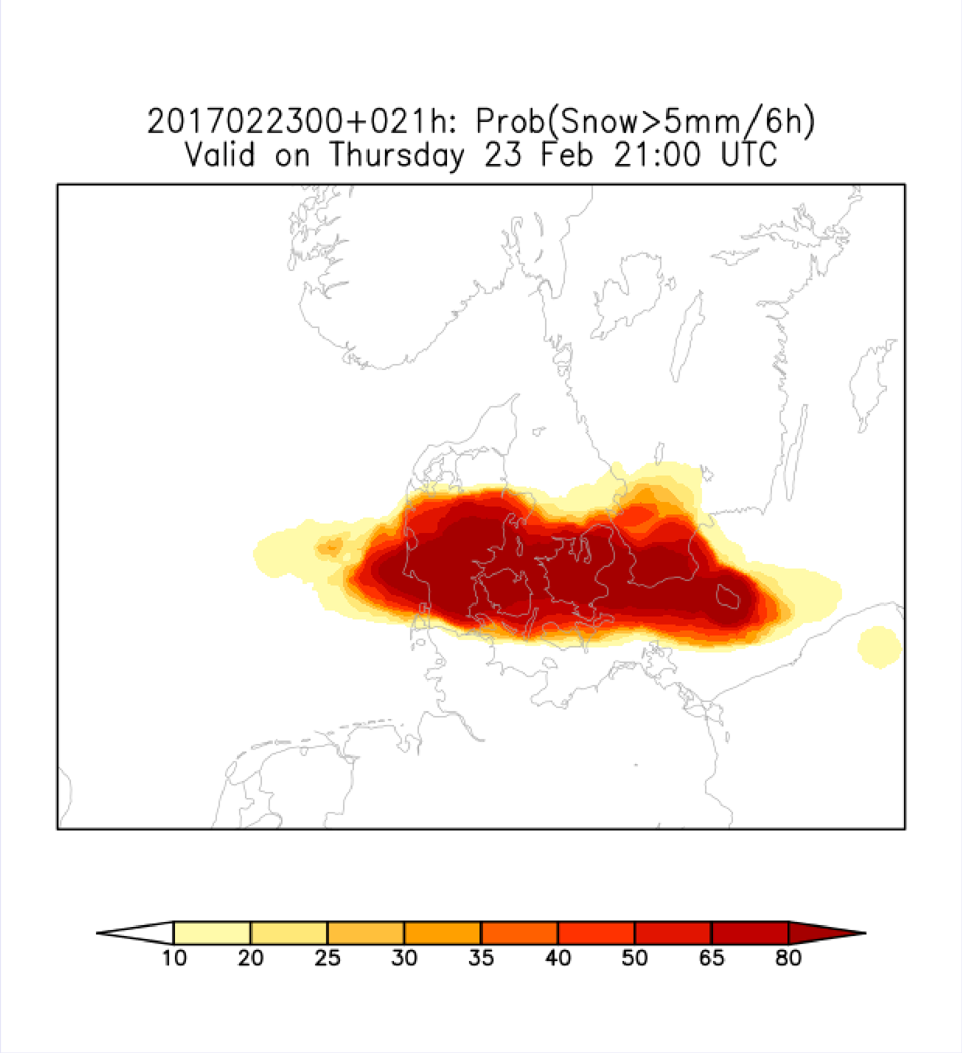

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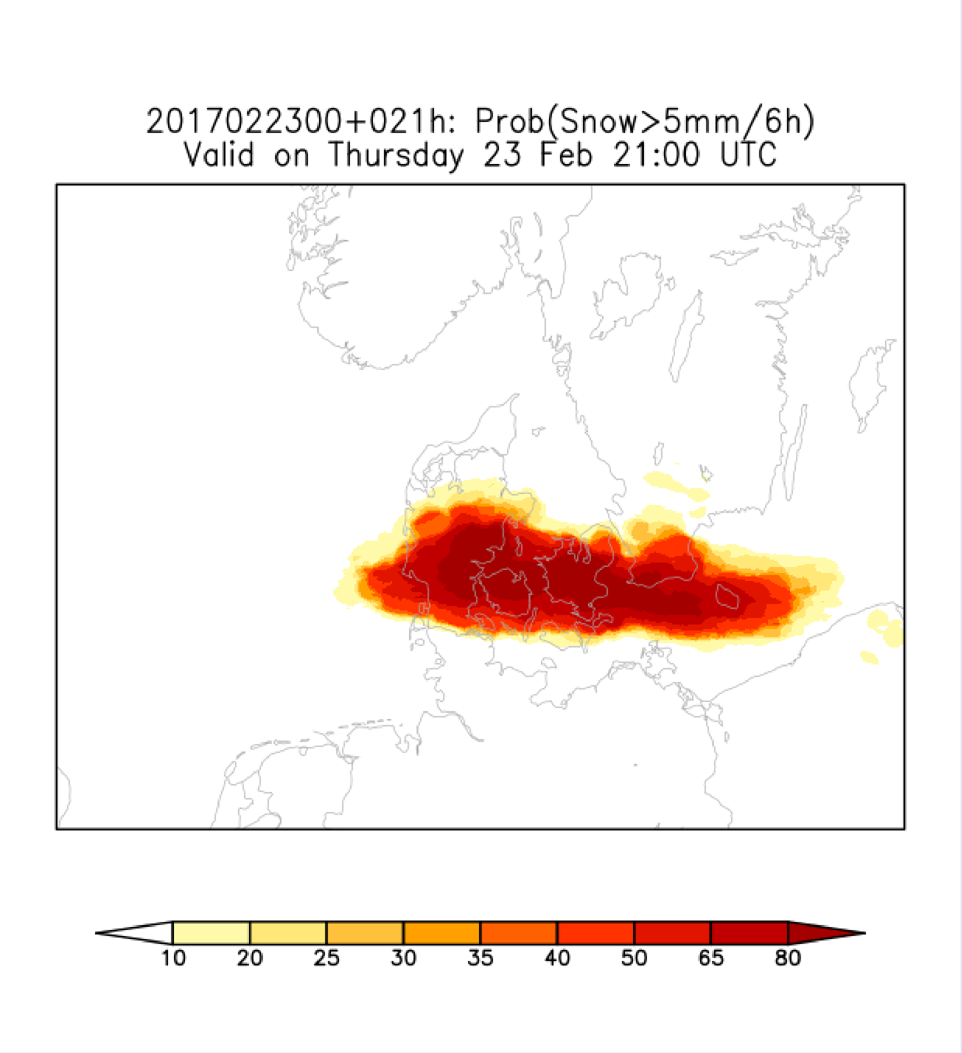

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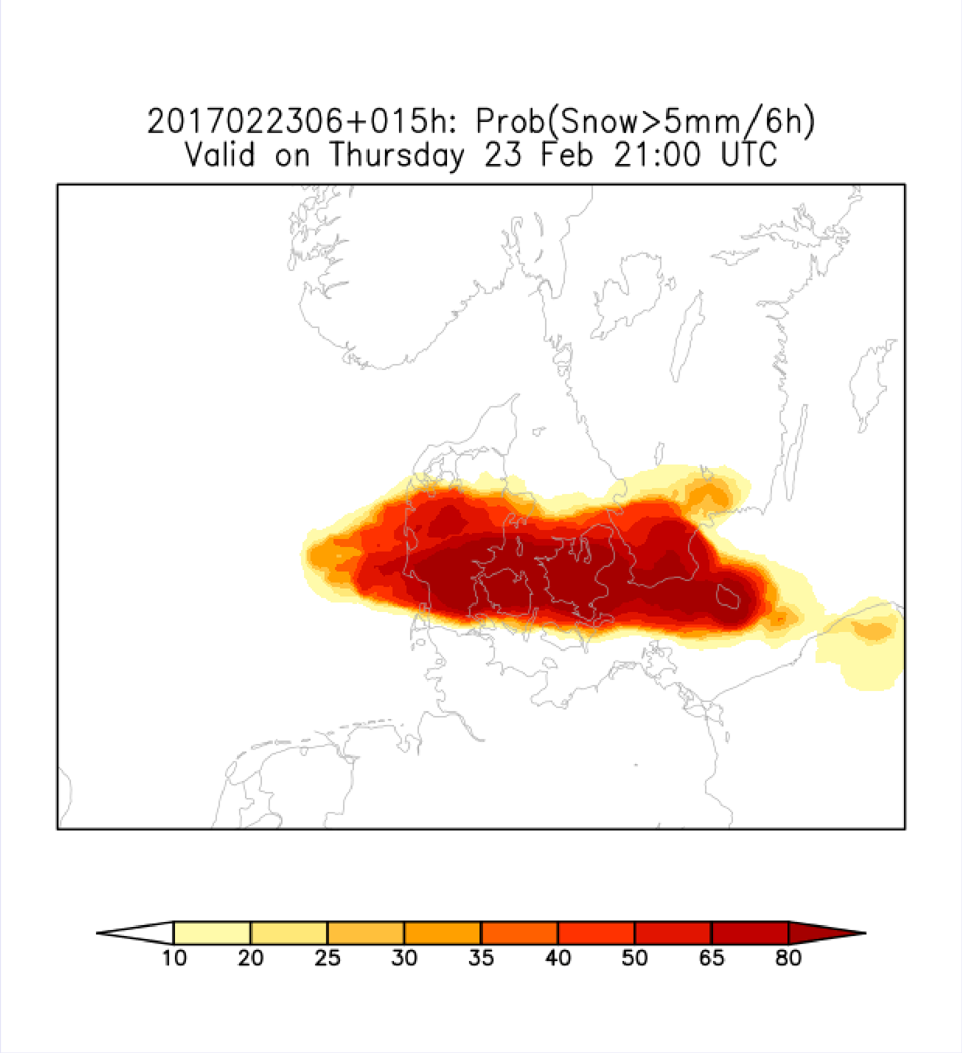

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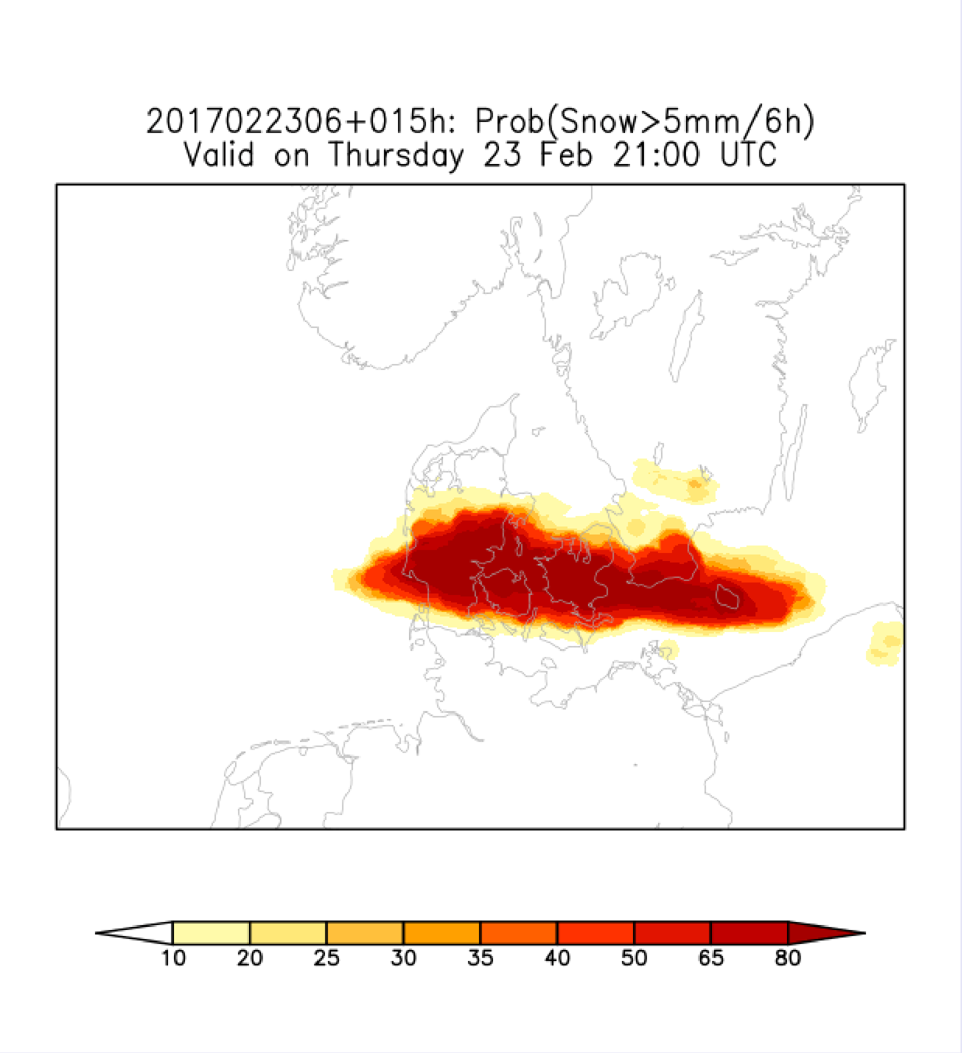

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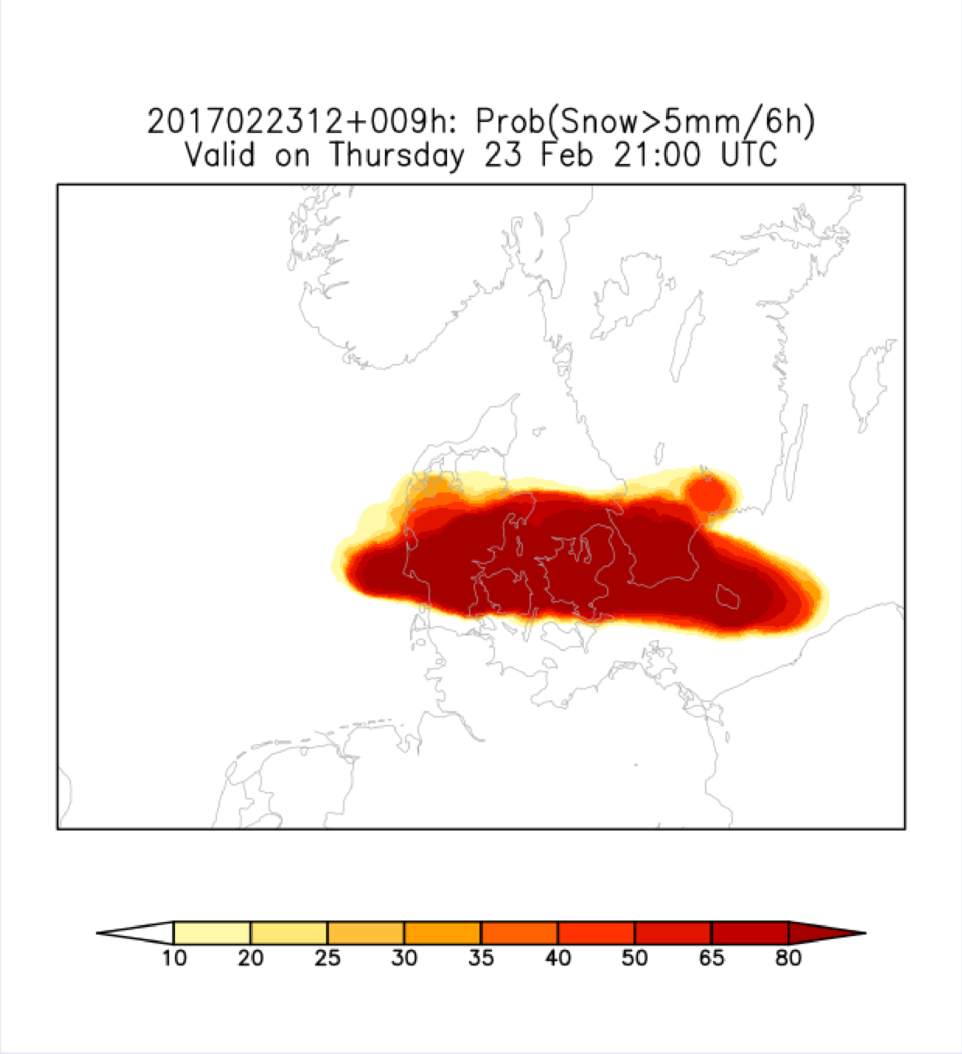

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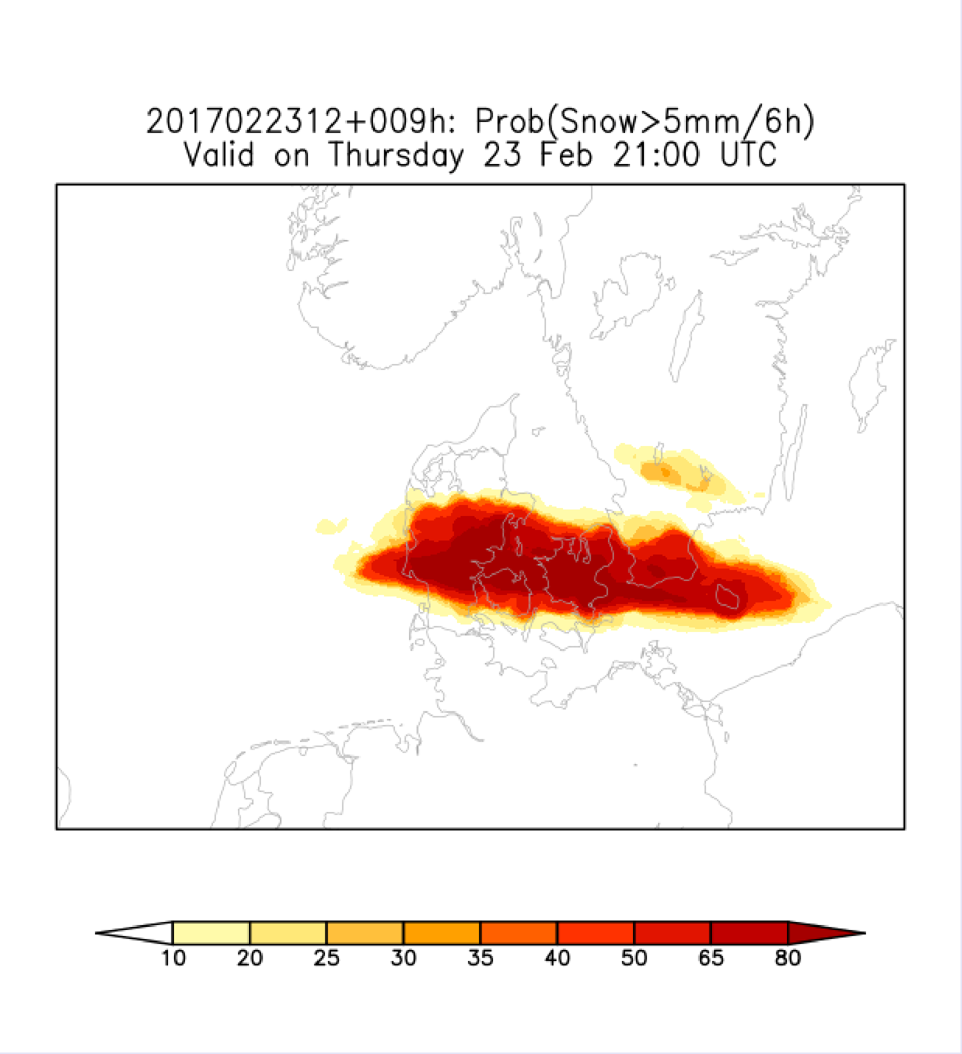

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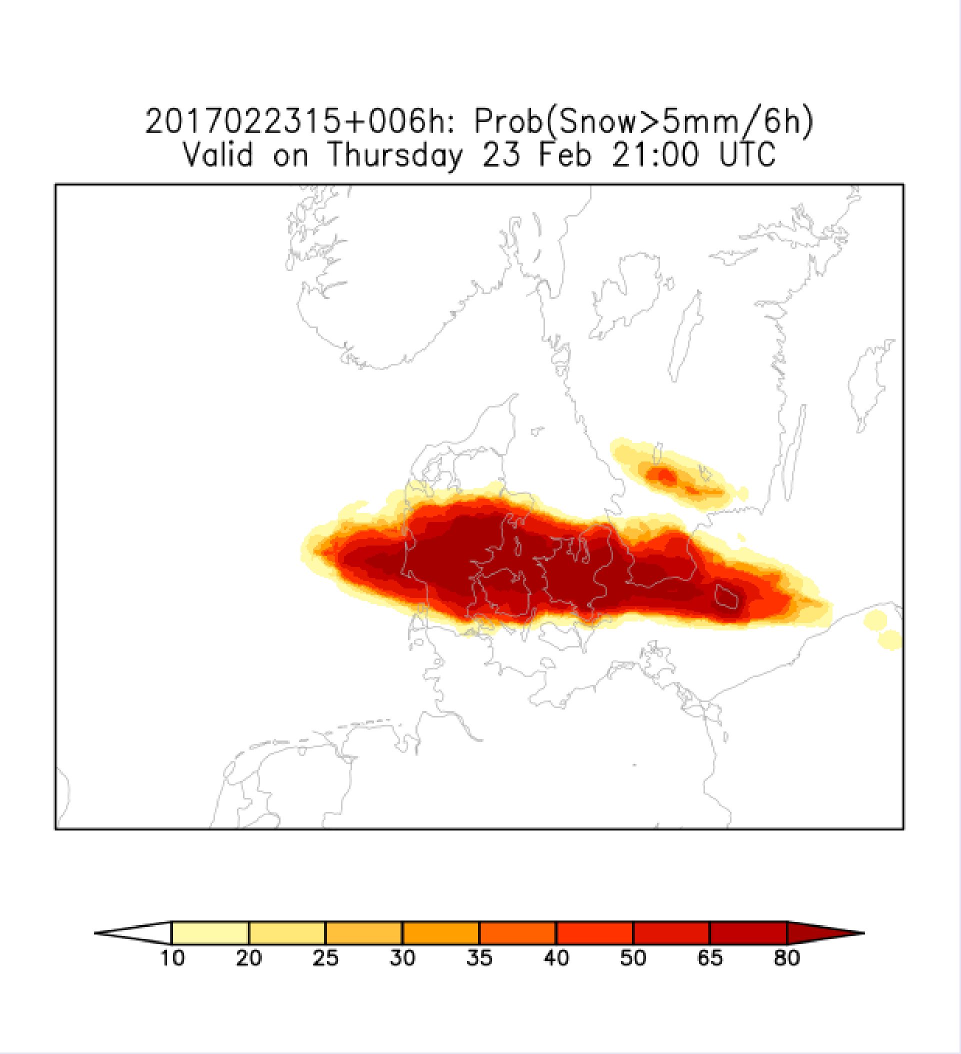
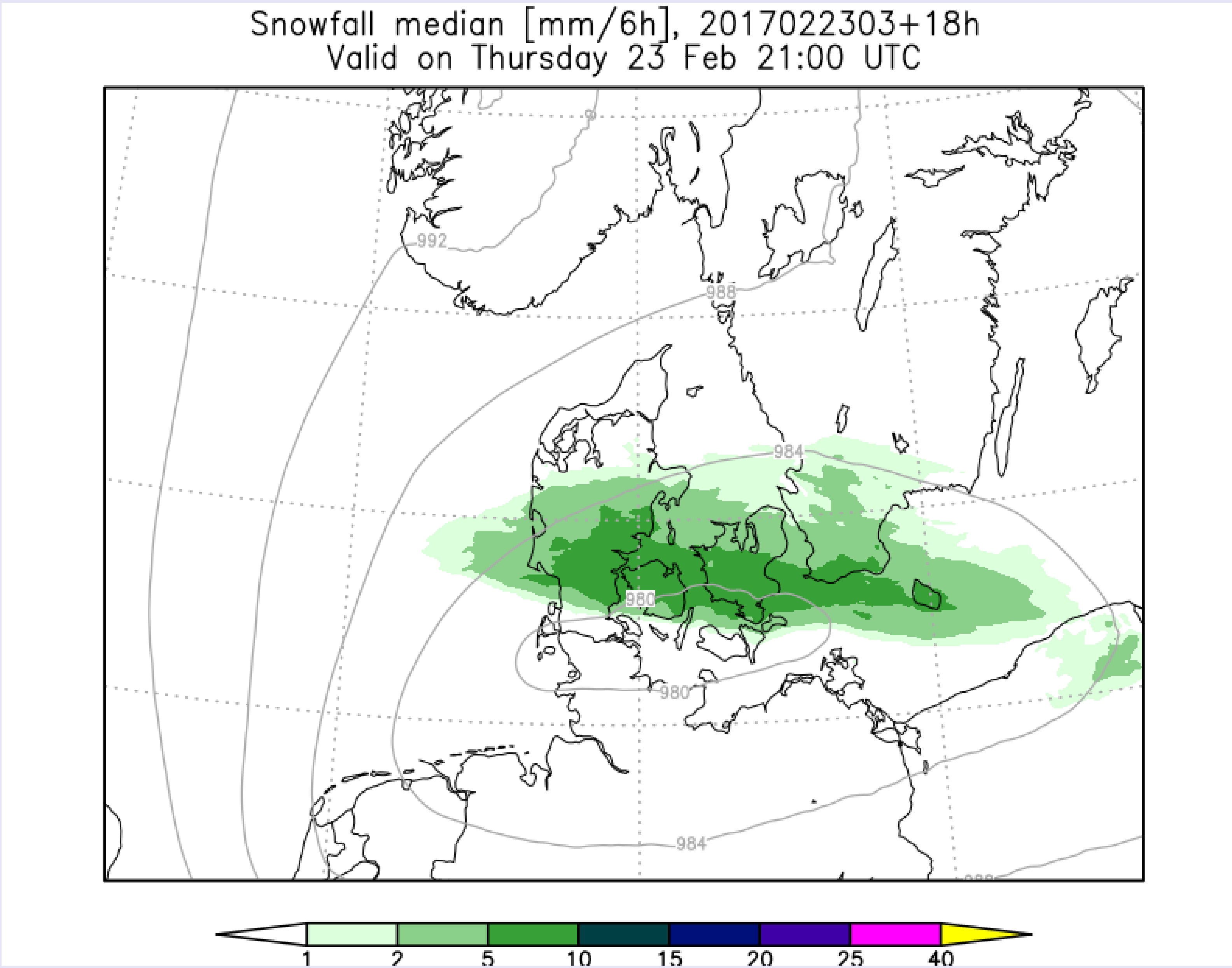
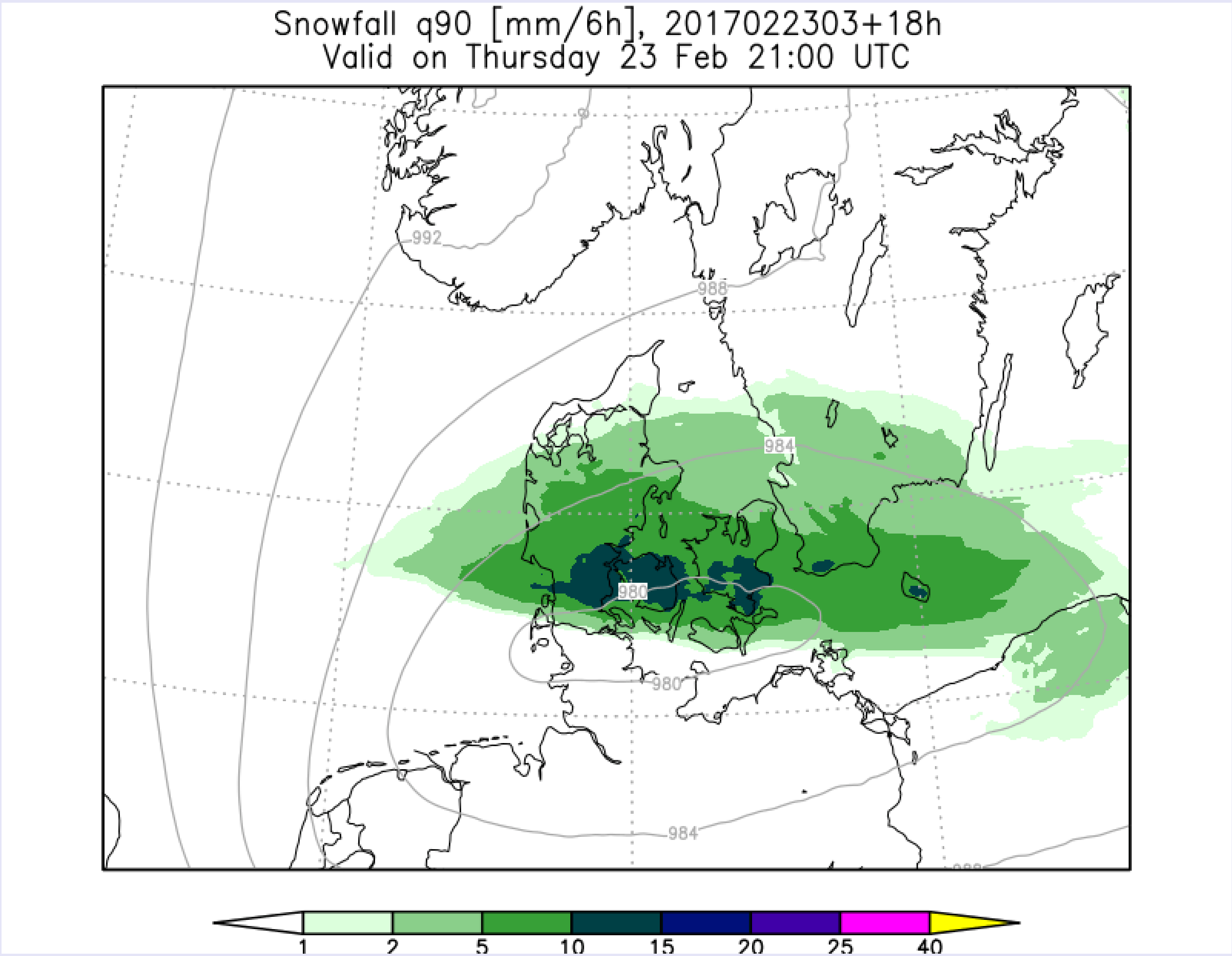


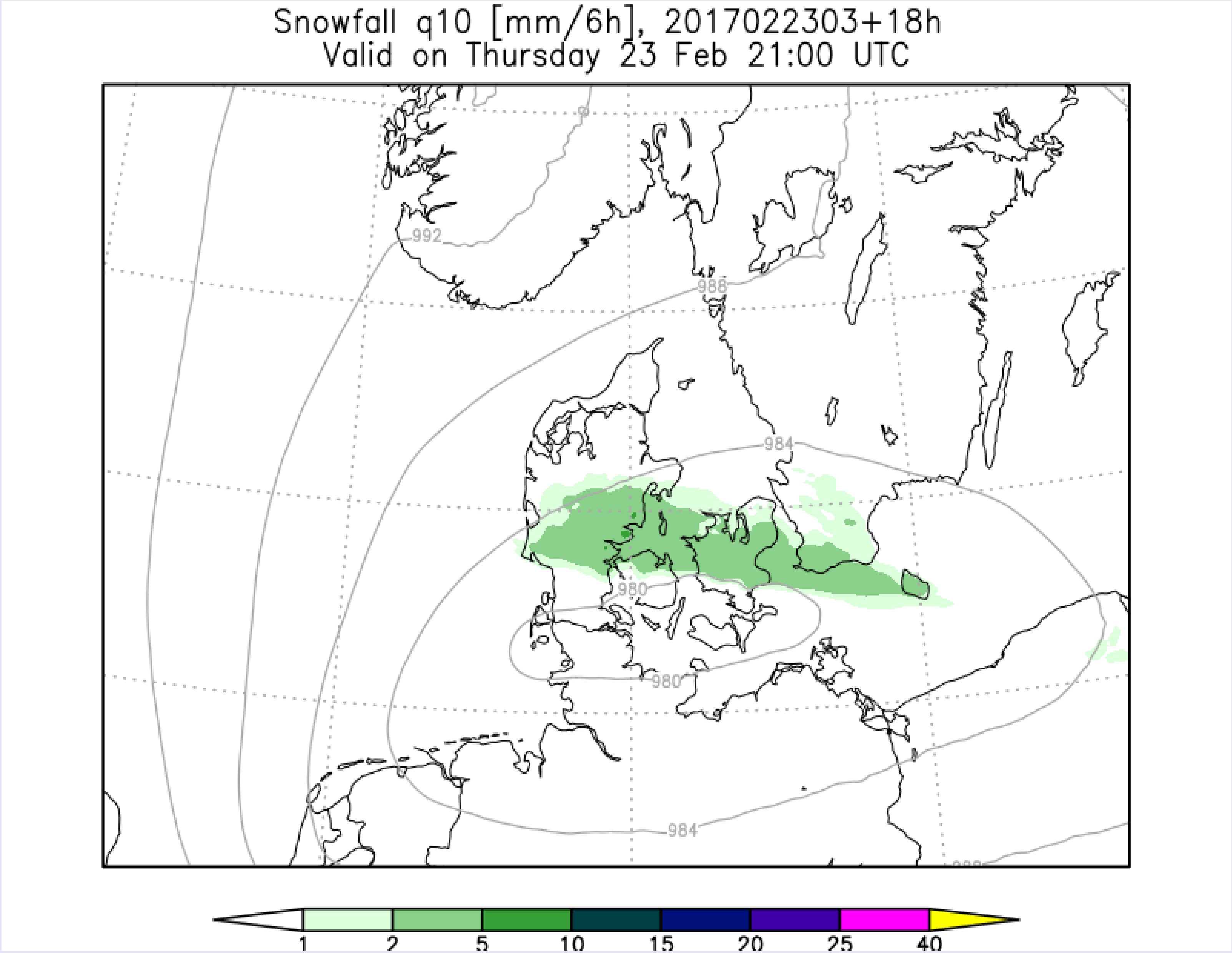
Snowfall median



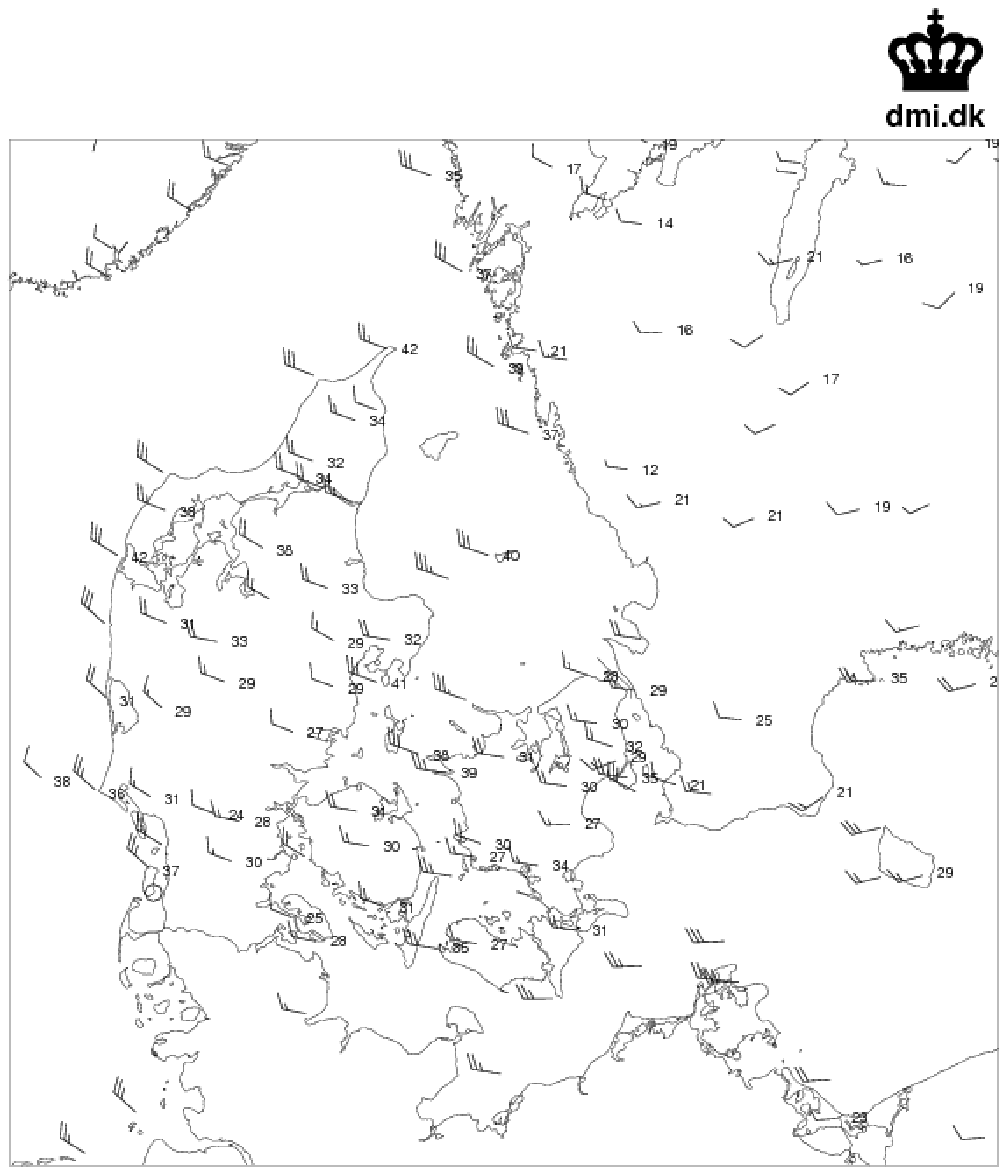
Snowfall 90th percentile



Snowfall 10th percentile



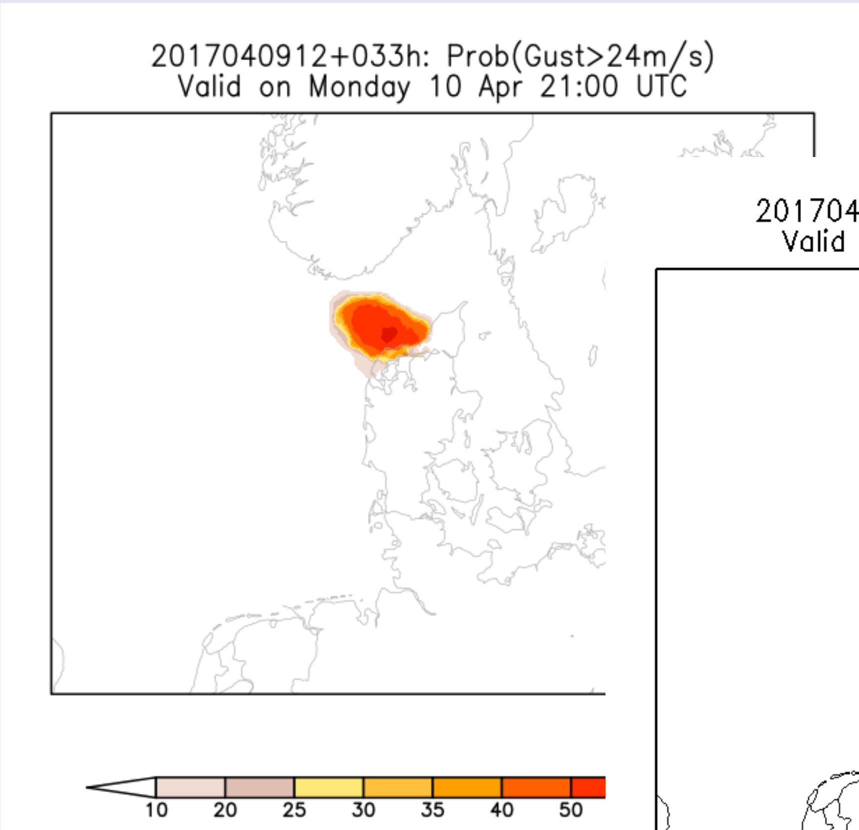
Wind gust 10 Apr 2017



10. april 2017, 21:00 UTC
Vind, Vindstød,

Wind gust 10 Apr 2017

E05-EPS



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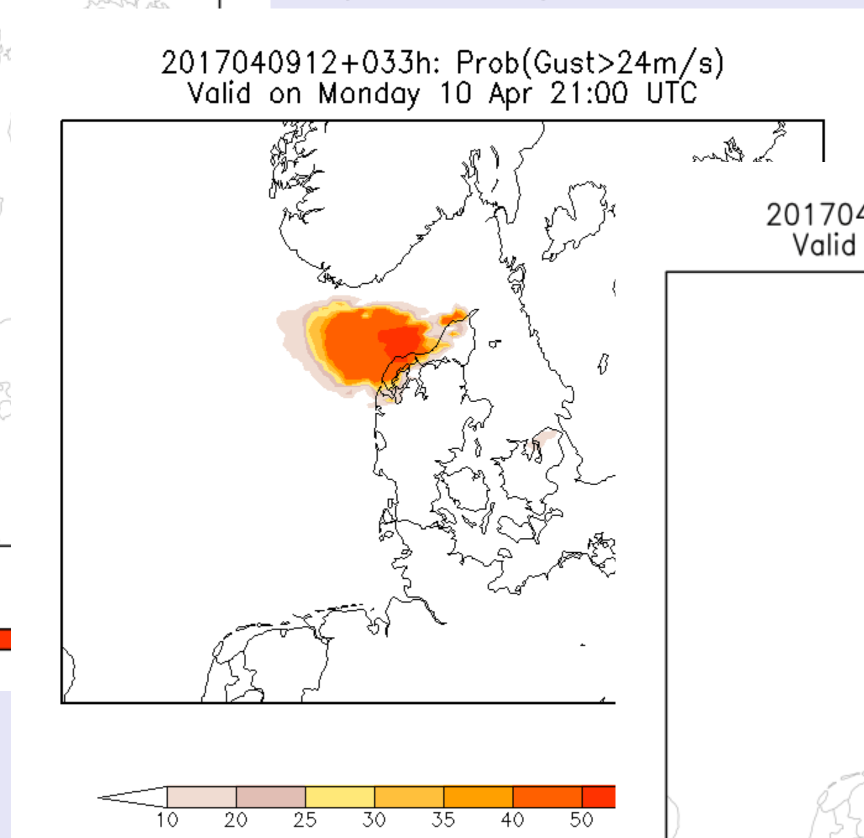

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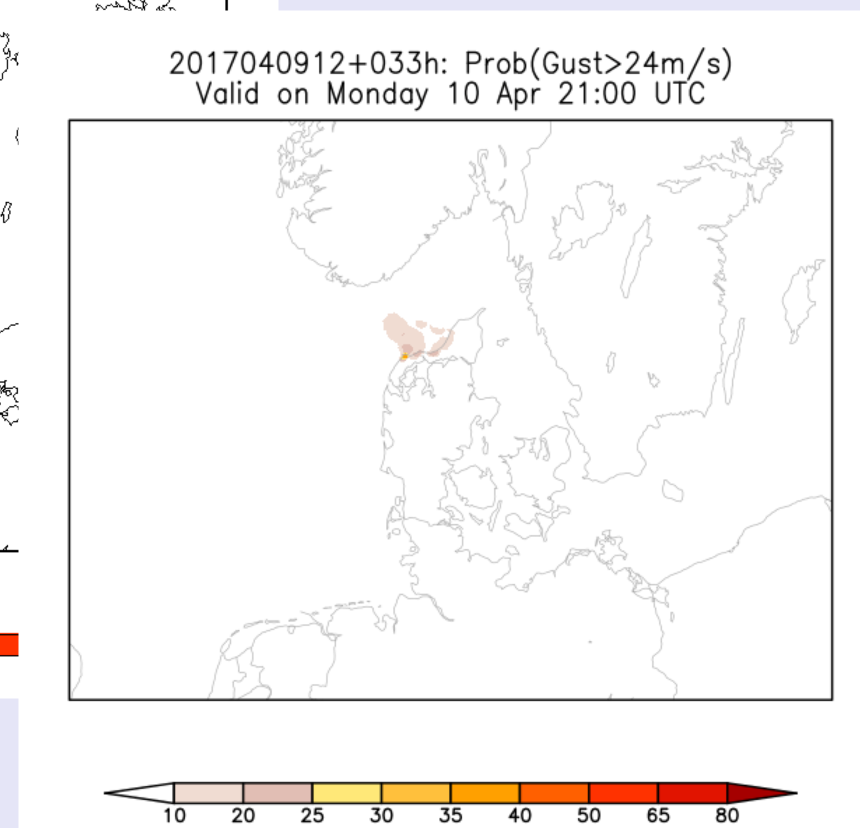

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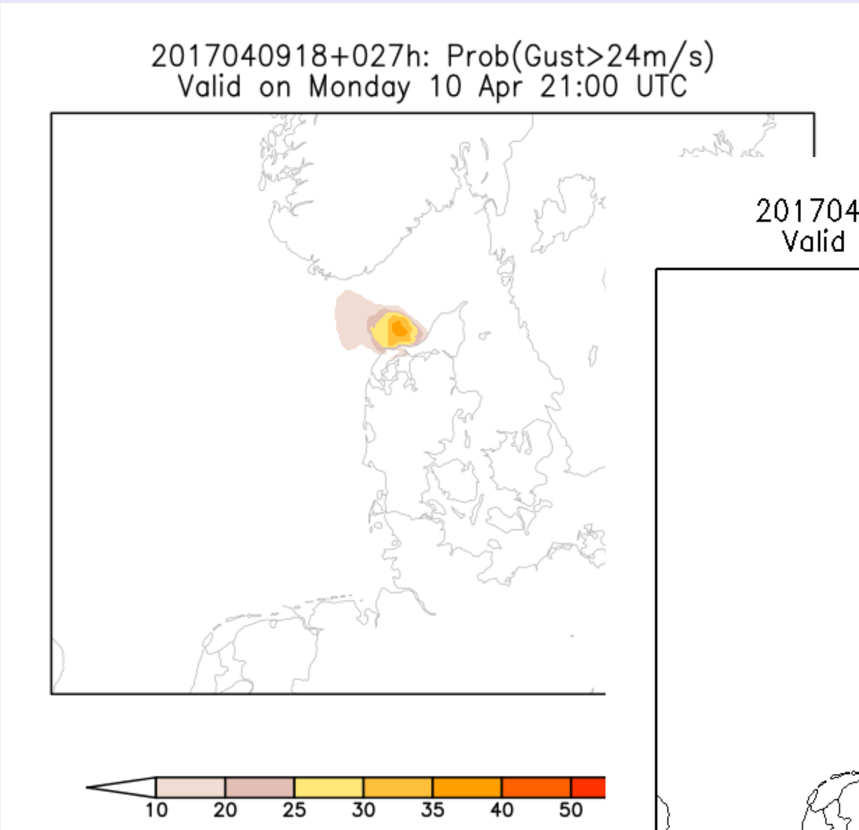

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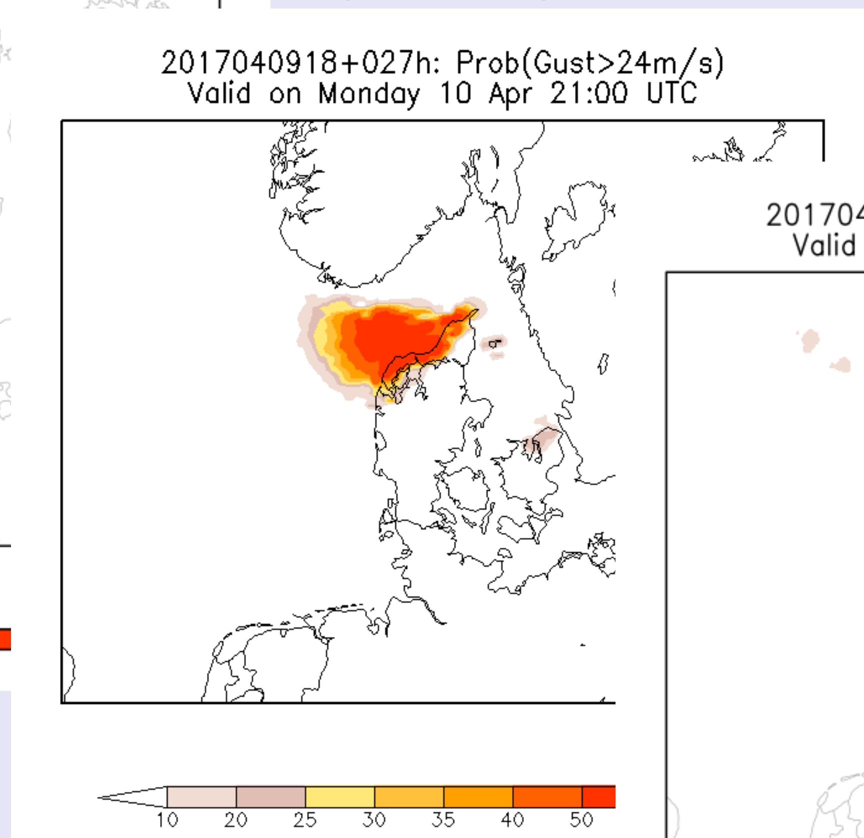

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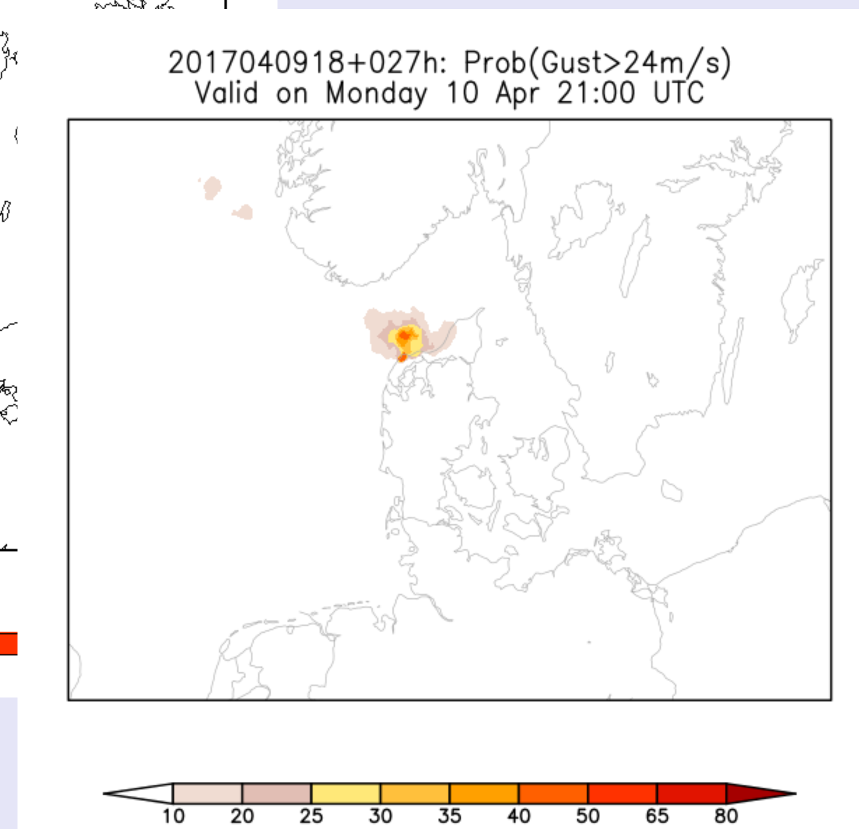

Wind gust 10 Apr 2017

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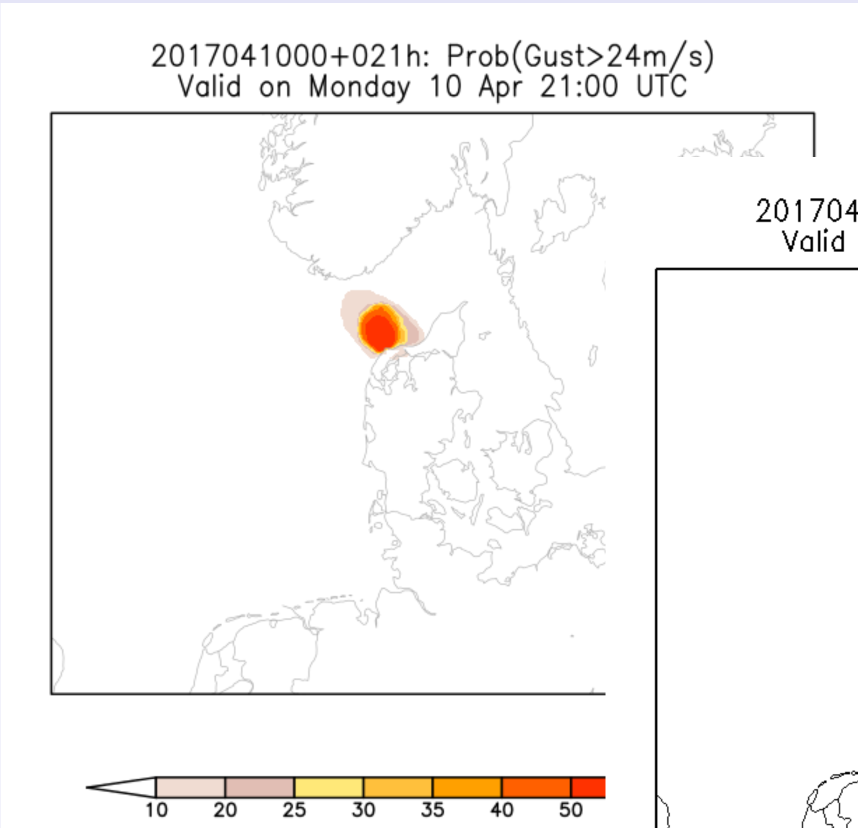

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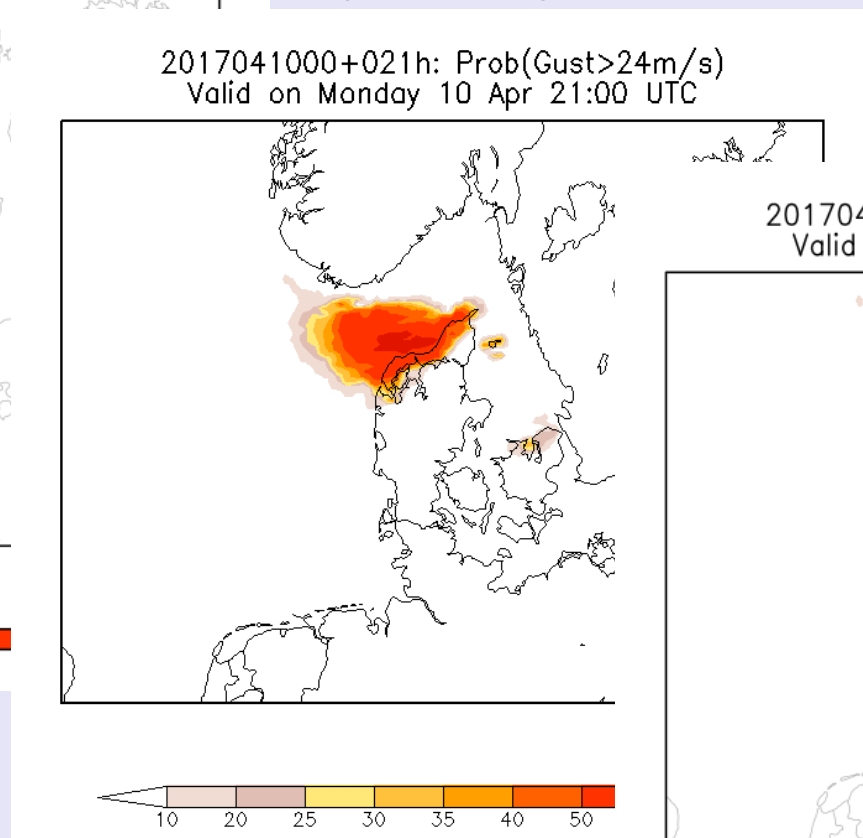

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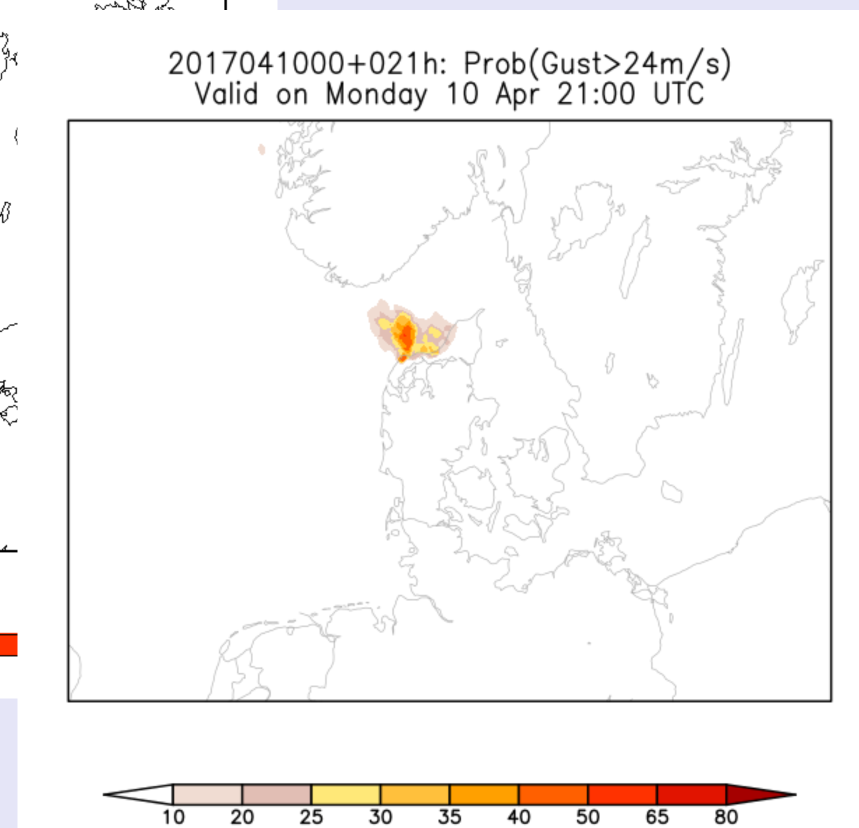

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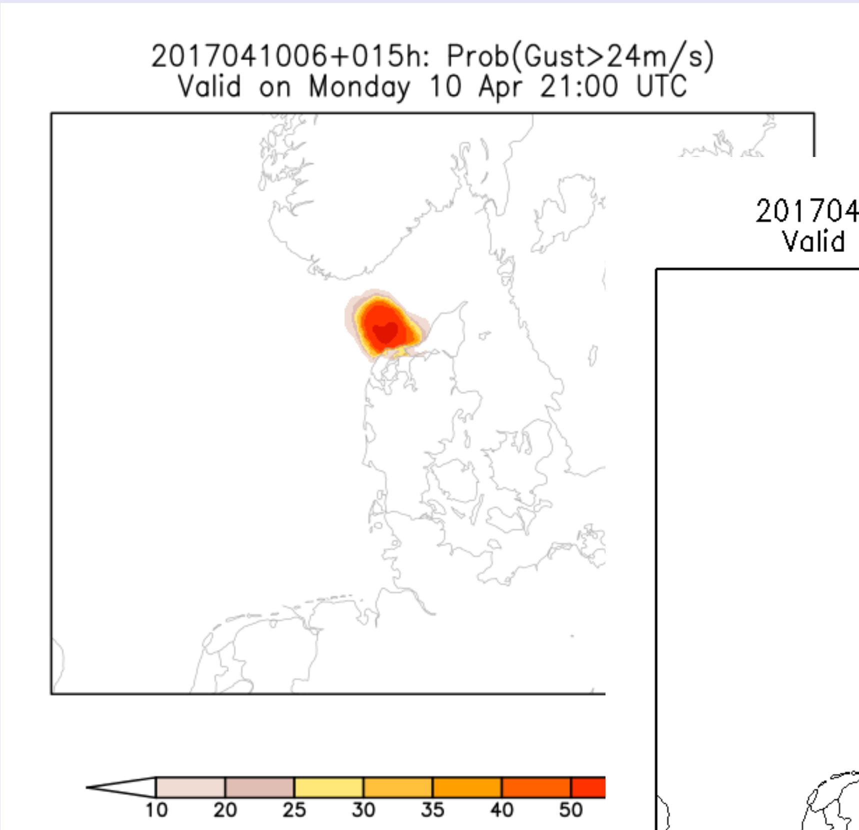

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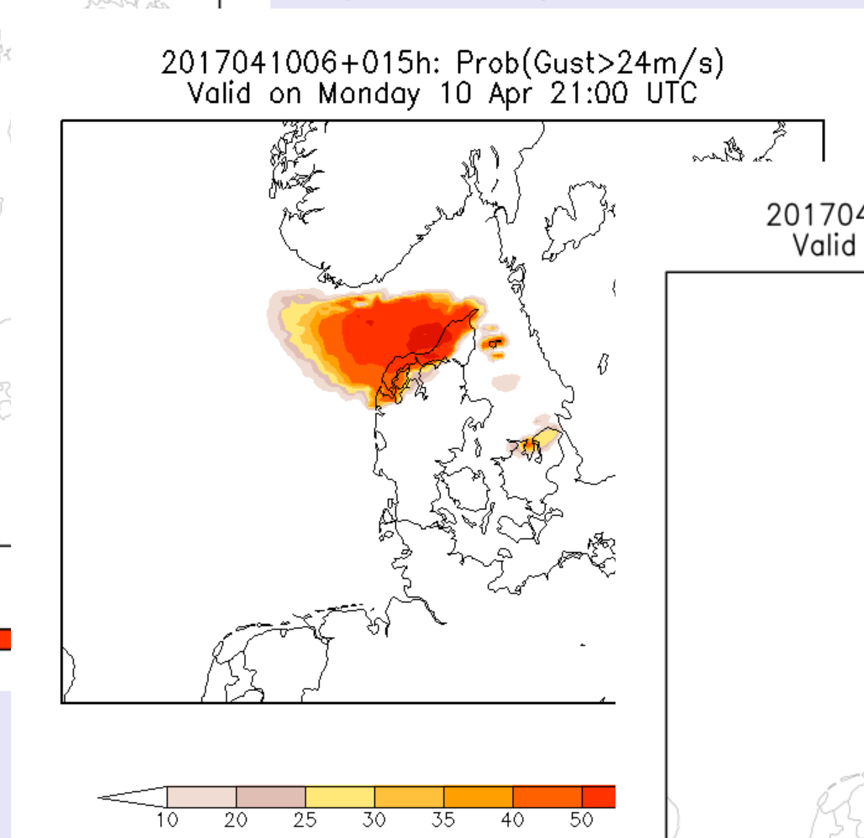

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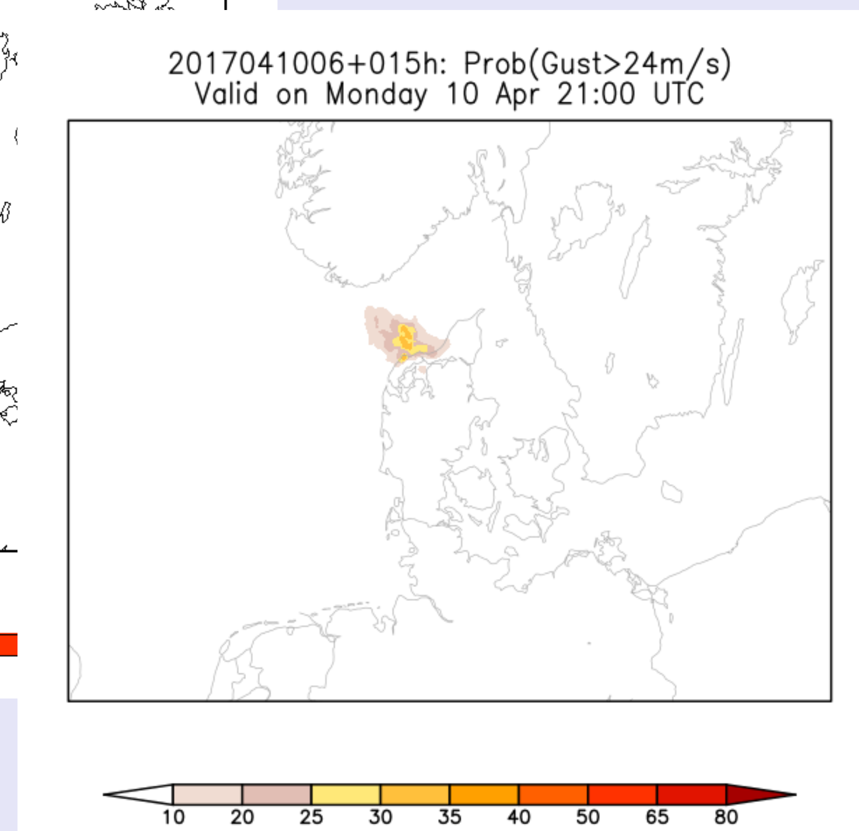

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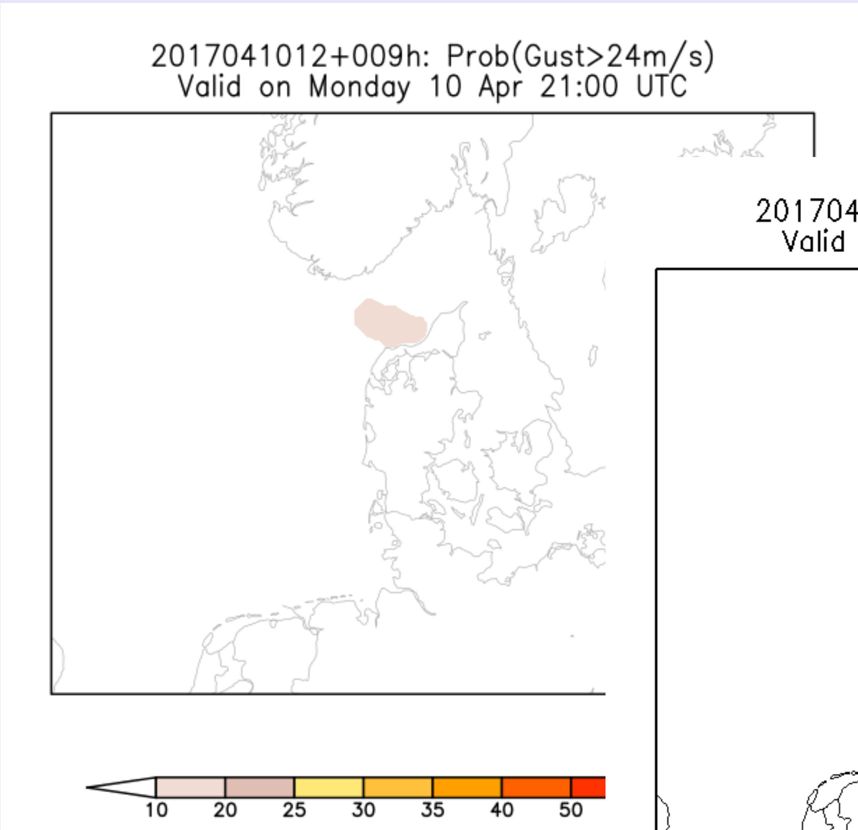

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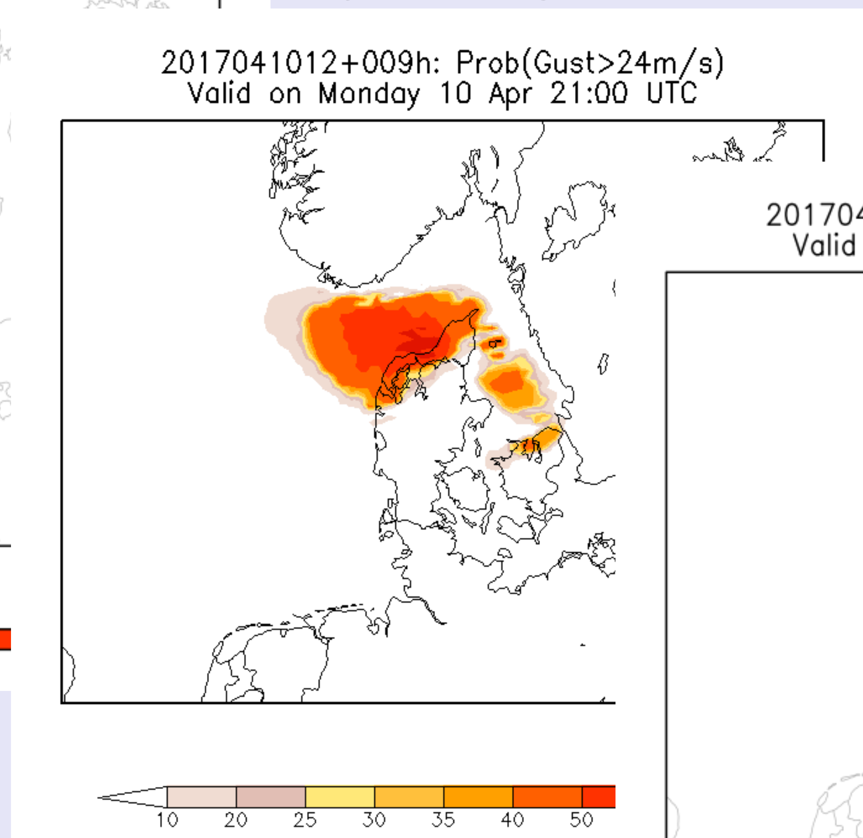

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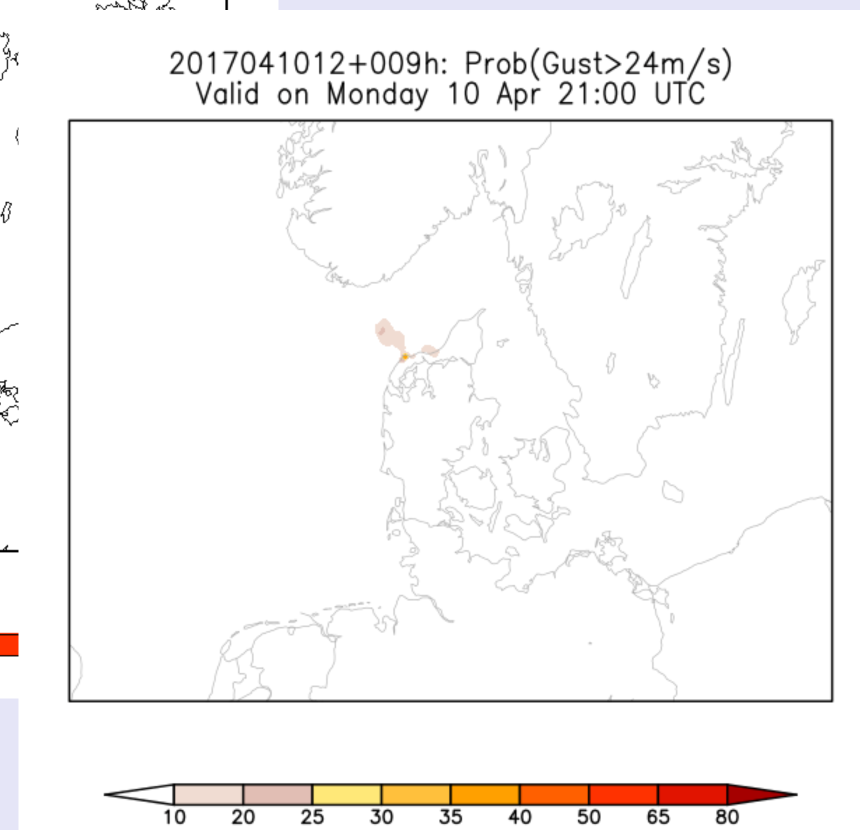
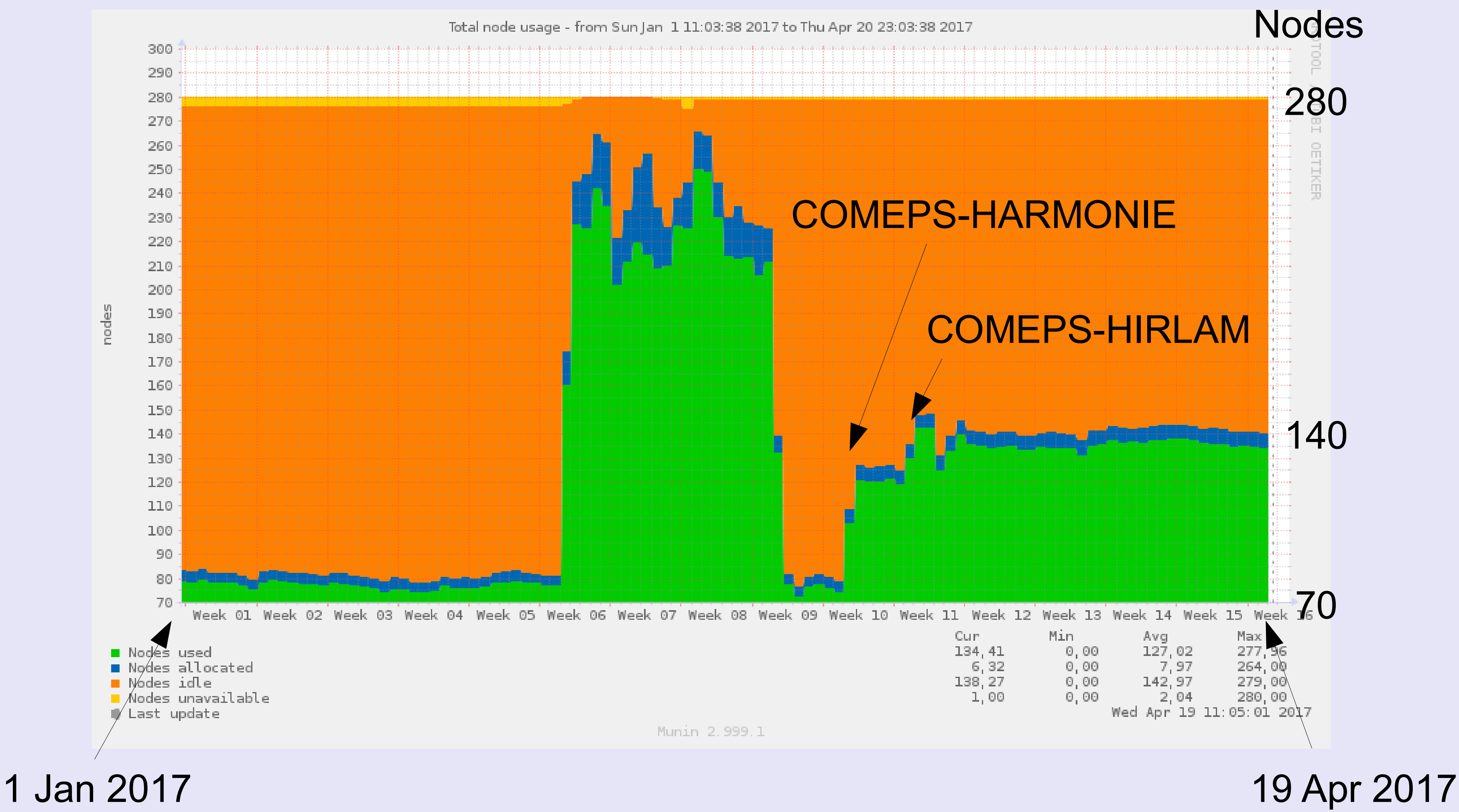


thor compute node usage



Outstanding issues

- Presentation in NinJo
- Use on dmi.dk
- Run interesting cloud burst cases
- Study different types of initial and lateral boundary condition perturbations
- Surface perturbations (SRNWP focus area)
- Verification of ensemble forecasts of high-impact weather

Concluding remarks

- COMEPS runs in real-time, see forecasts on http://varulven.dmi.dk/~hf/vejr/COMEPS
- Meteorological performance is promising
- Formal operationalization is expected this spring
- Present HIRLAM 5km EPS will continue over the summer