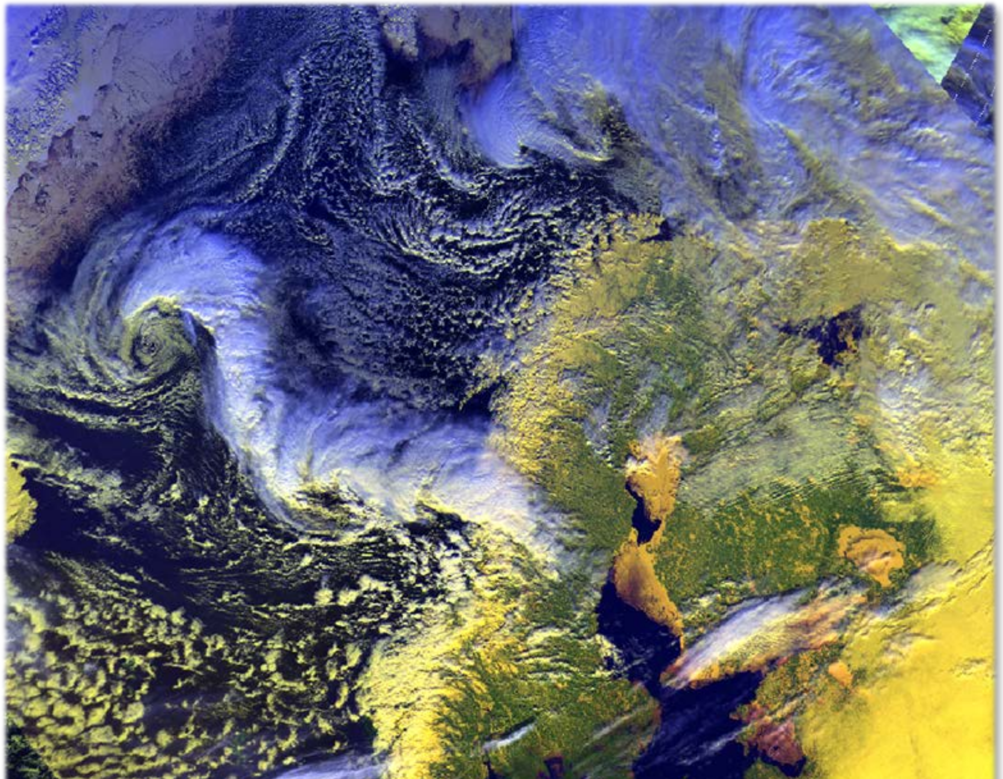


Polar lows

A challenge for predicting extreme polar weather

Trond Iversen

ECMWF

(MET Norway representative in WWRP-PPP SG

Contributions from

Linus Magnusson (ECMWF), Alex Deckmyn (KMI), Andrew Singleton, Harold McInnes, Inger-Lise Frogner, Jørn Kristiansen, Gunnar Noer, Hanneke Luijting (MET, Norway), Kai Sattler (DMI)

WWRP/THORPEX/ECMWF Workshop on Polar Prediction; June 2013

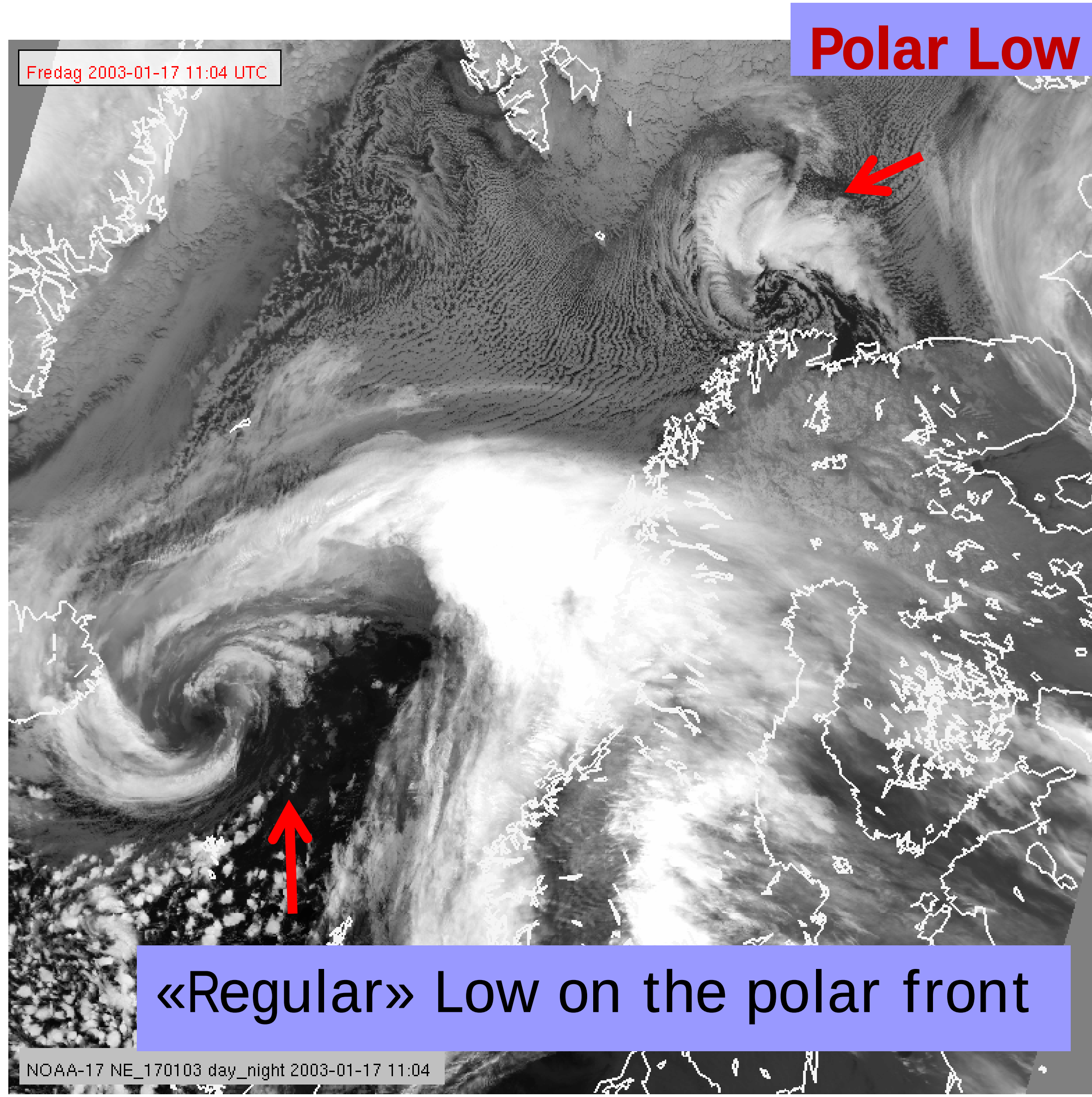
Contents

- **synoptics and mechanisms**
  - **IPY-Thorpex cases March 2008**
- flow index, climatology
- **predictability and available observations**
- examples of Forecast verification:
  - ECMWF, GLAMEPS, HarmonEPS
- **polar lows and climate change**
- Summary and challenges

Synoptics

The polar low:

- A small-scale, rapidly developing and fairly intense cyclone over ice-free ocean
- October - May
- Rapidly changing weather
- Gale or storm force winds
- Severe snow intensity

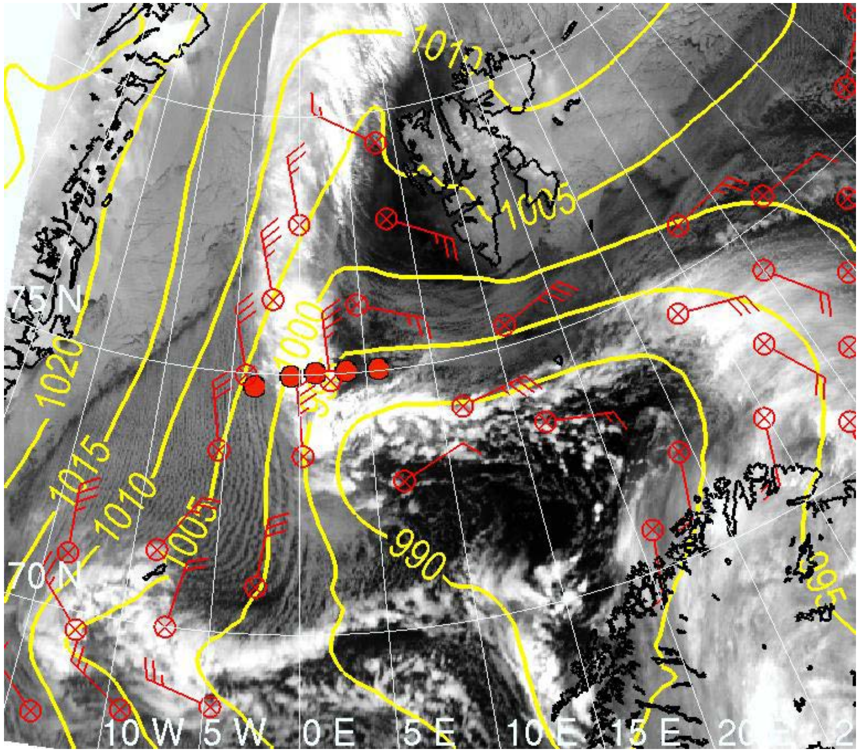


IPY thorpex flight campaign: *Kristjánsson et al. (2011: BAMS)*

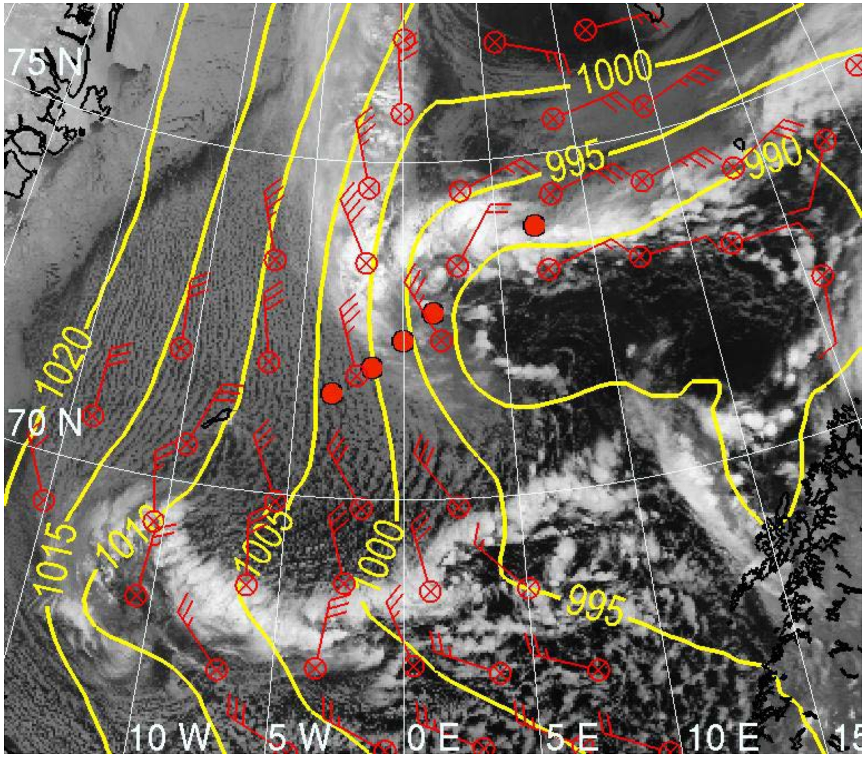
The 3-4 March Polar Low

Initial baroclinic phase

12:21 UTC on 3 March



16:01 UTC on 3 March

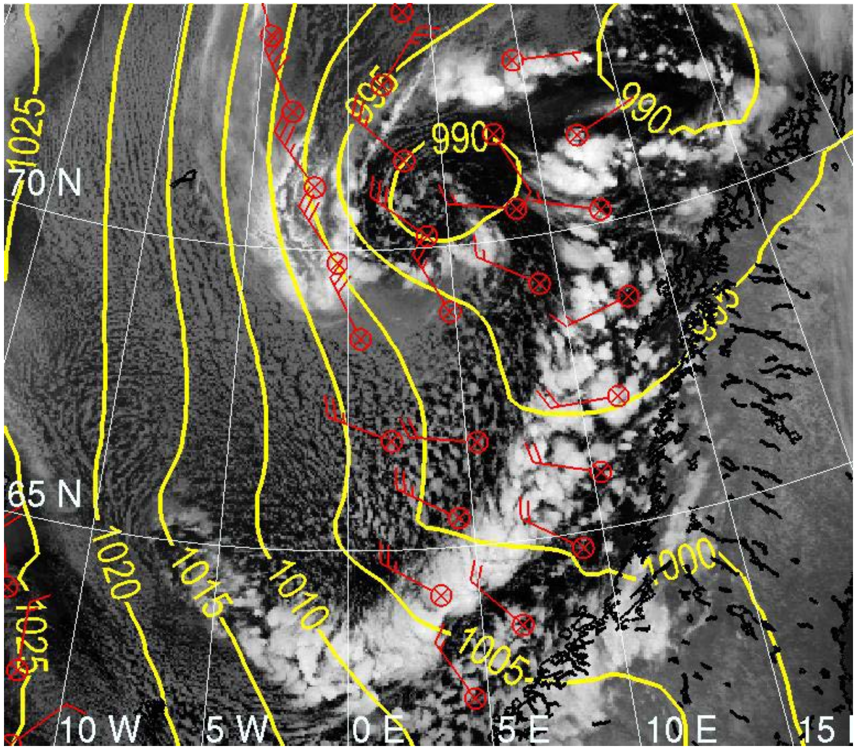


IPY thorpex flight campaign: *Kristjánsson et al. (2011: BAMS)*

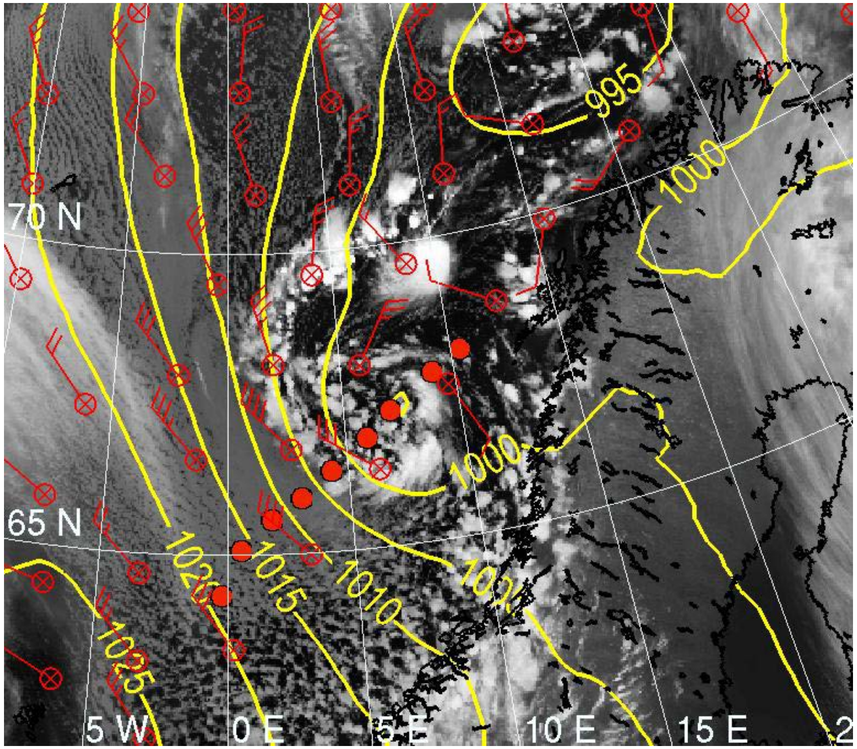
The 3-4 March Polar Low

Mature Convective Phase

03:07 UTC on 4 March

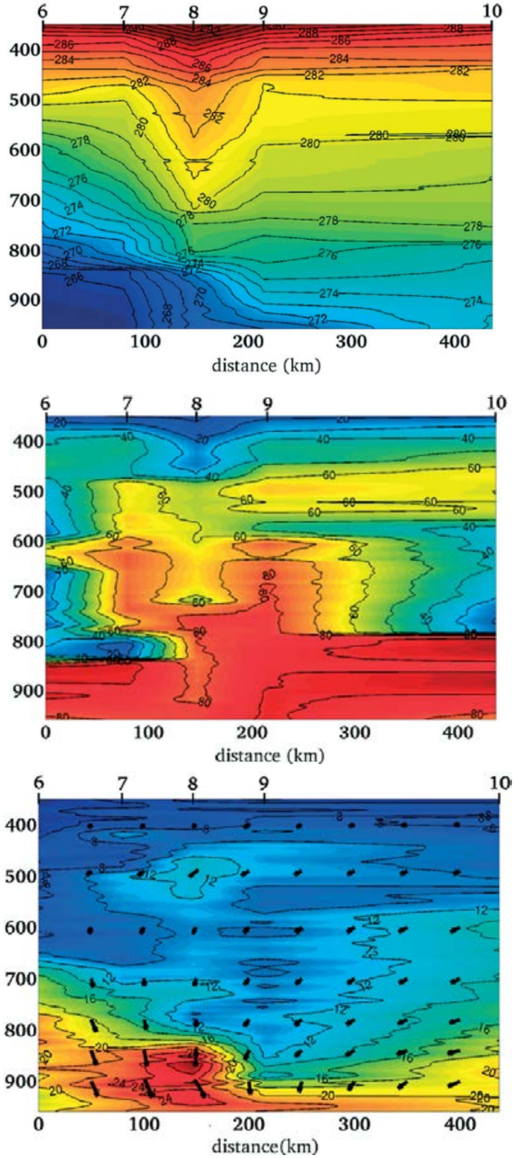


11:28 UTC on 4 March



Føre et al, 2011, QJRMS, 137

16:01 UTC on 3 March

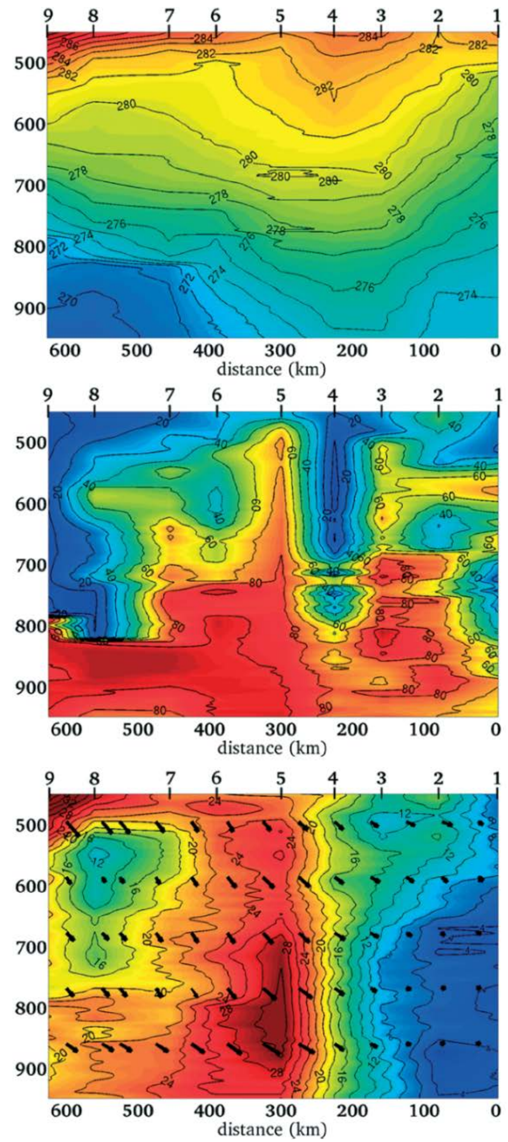


Pot Temp

Rel Hum

Wind

11:28 UTC on 4 March



Weather forecasters' awareness

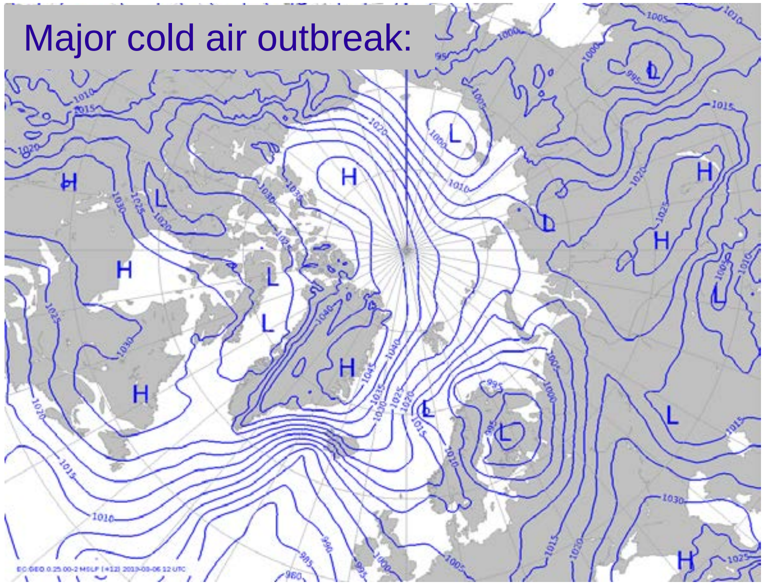
- **MCAO: Major Cold Air Outbreaks**
- **SST – T(500hPa) > 43 °C**
- **Potential Vorticity > 2 PVU**
- **Trough at 500 hPa**

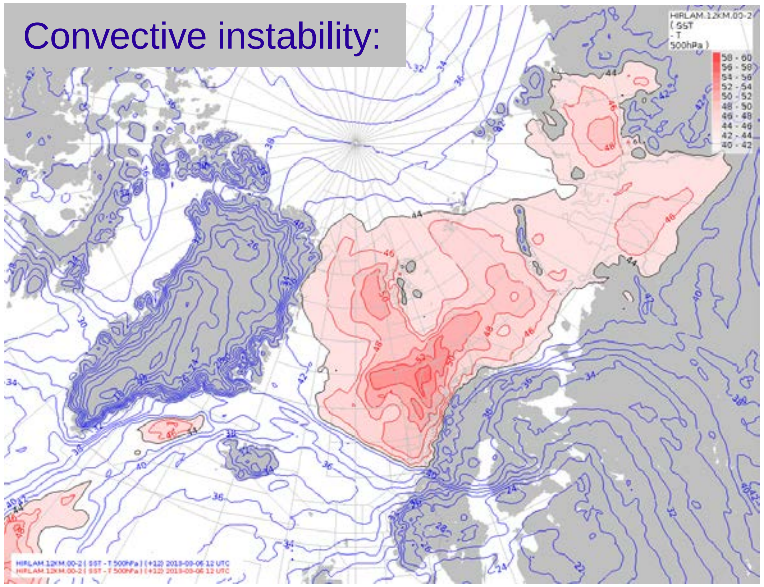
Areas with high potential for PL development

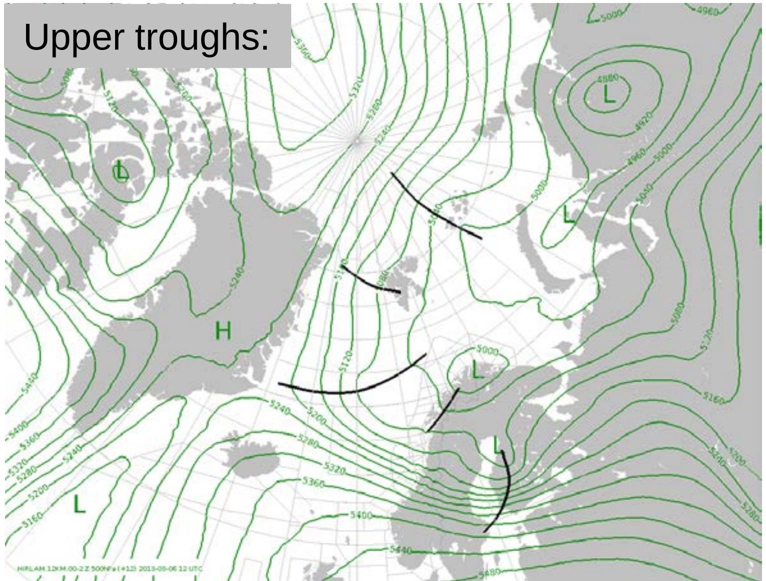
Aided by:

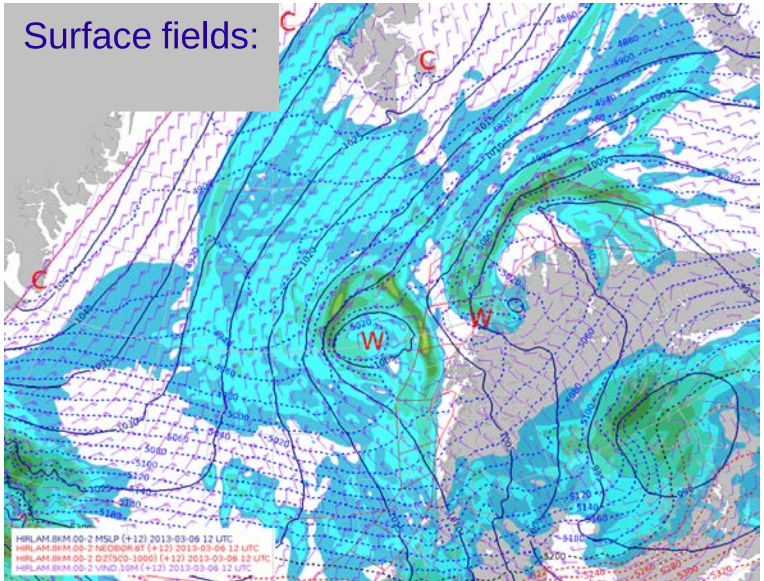
- **Satellite images**
- (High-res.) **model forecasts**
    - Experience: often not reliable

Useful model output:
1) «deterministic»


Major cold air outbreak:


Convective instability:

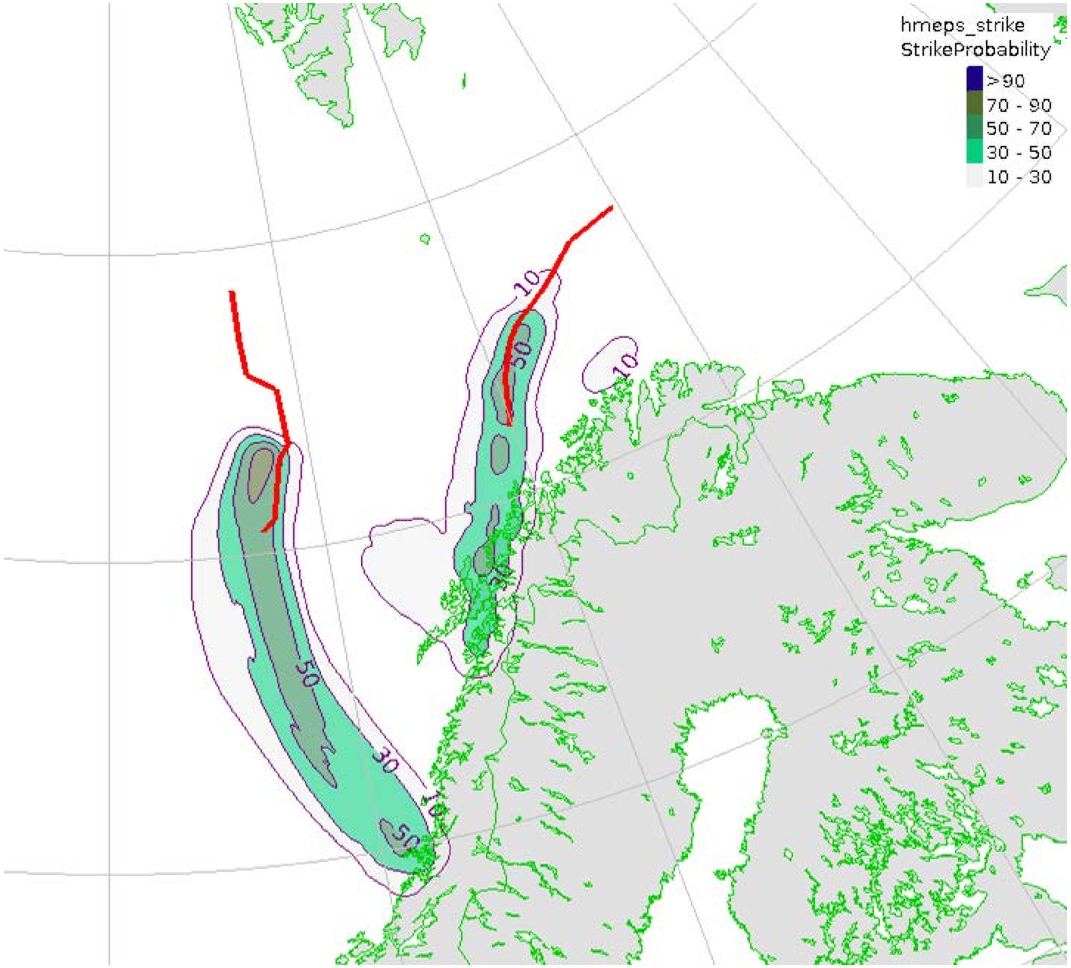

Upper troughs:


Surface fields:

Useful model output: 2) «probabilistic»

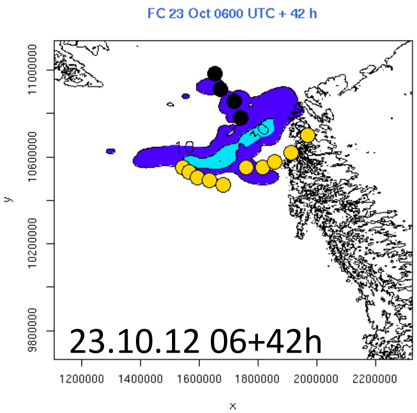
New (Barentswatch): **Tracking PL by High Res HarmonEPS:**

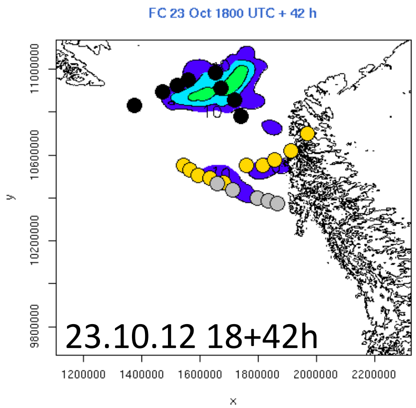
- 2,5km, L65 non-hydr. Harmonie/Arome EPS
- Dyn downscaling EC-EPS
- +42h, 06 & 18 utc
- 10 members + control
- Probabilities
  - Tracks
  - Wind speed
  - Precip. intensity

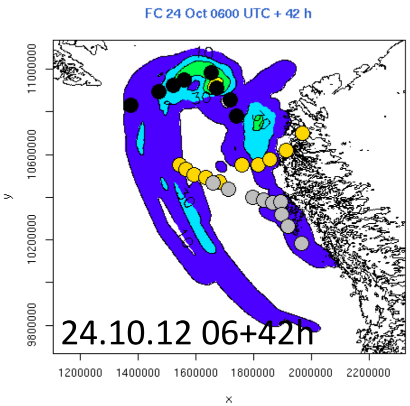


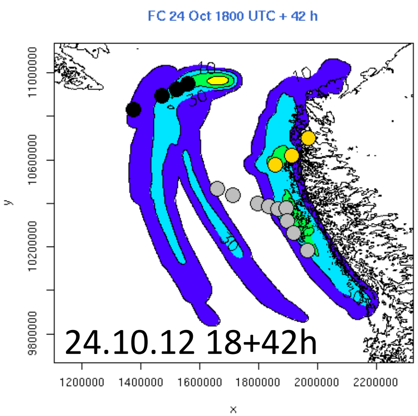
http://www.barentswatch.no/Tema/Sjotransport/Polarvar-og-istjenester/Varsler/

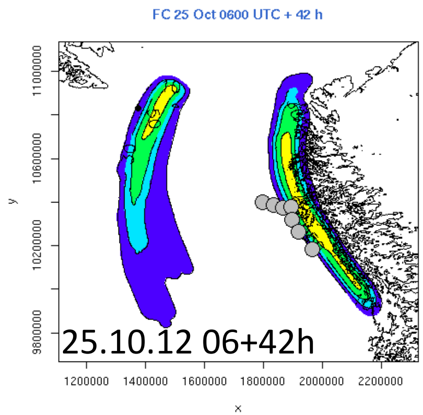
PL Strike Probability Maps, HarmonEPS



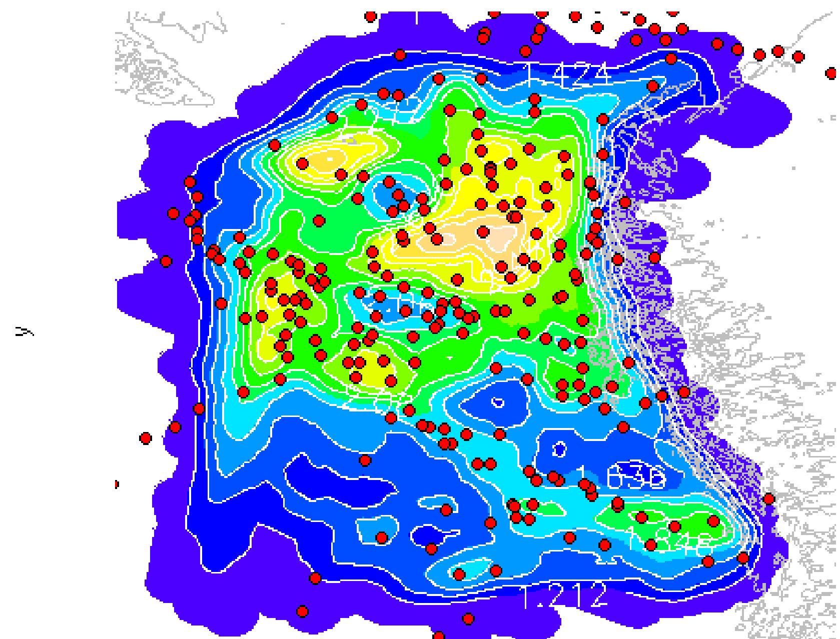








Statistics, Oct 2012 - April 2013



(J. Kristiansen, MET Norway)

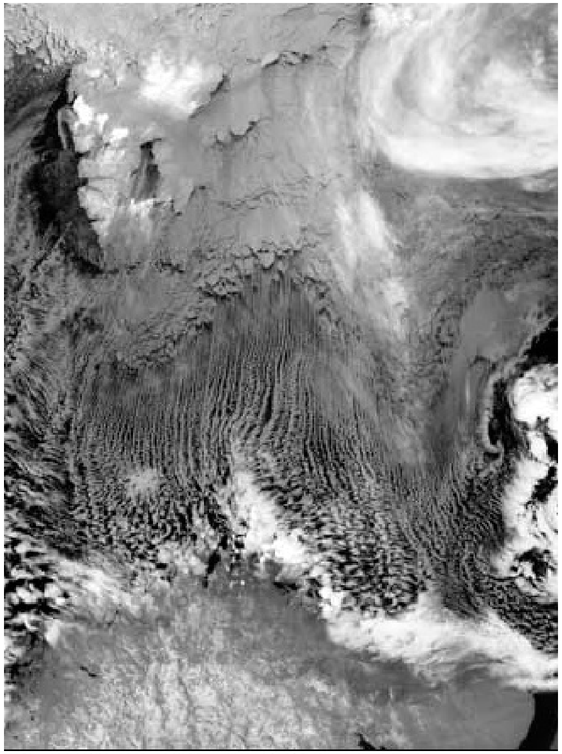


Figure 1 - NOAA 17 - 09:14 UT on December 21, 2003

Factors Limiting the Predictability of Polar Lows

Trigger mechanisms:

- Initial analysis of polar
    - Low-level baroclinic zones (e.g. «old occlusions»)
    - upper-level PV anomalies
- Resolution of sharp surface contrasts
    - SST, sea-ice, topography
- Resolution of associated ABL features:
    - low-level fronts and jets

Growth mechanisms:

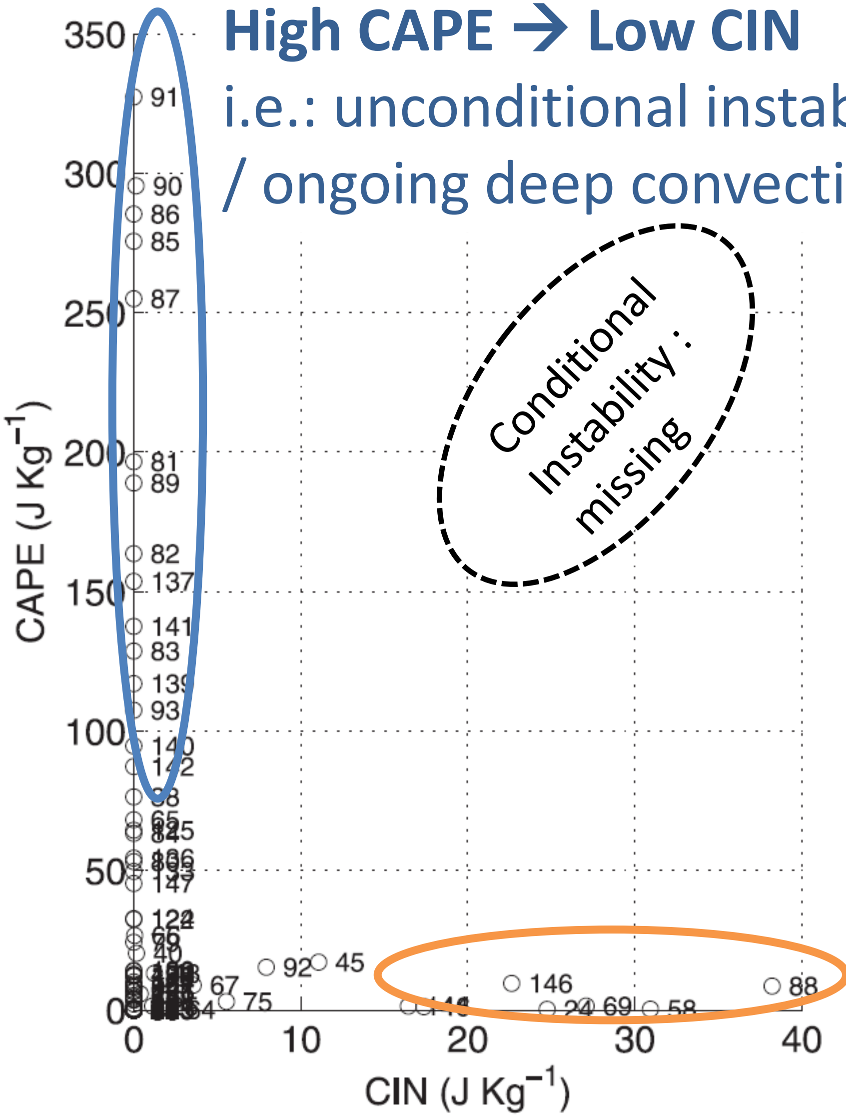
- Vertical fluxes in unstable, windy marine ABL
- deep convective cloud parameterizations
    - vertical profile of released latent heat
- Mixing processes in upper ocean:
    - SST-feedbacks
- Baroclinicity and APE-release

Growth mechanism: CISK, WISHE, …?

Linders and Sætra, 2010, J.A.S.

High CAPE → Low CIN

i.e.: unconditional instability / ongoing deep convection



High CIN → Low CAPE

Stably capped, unstable ABL, i.e. during cold air outbreaks

t_{CAPE}<1h; t_{PL}~>1d

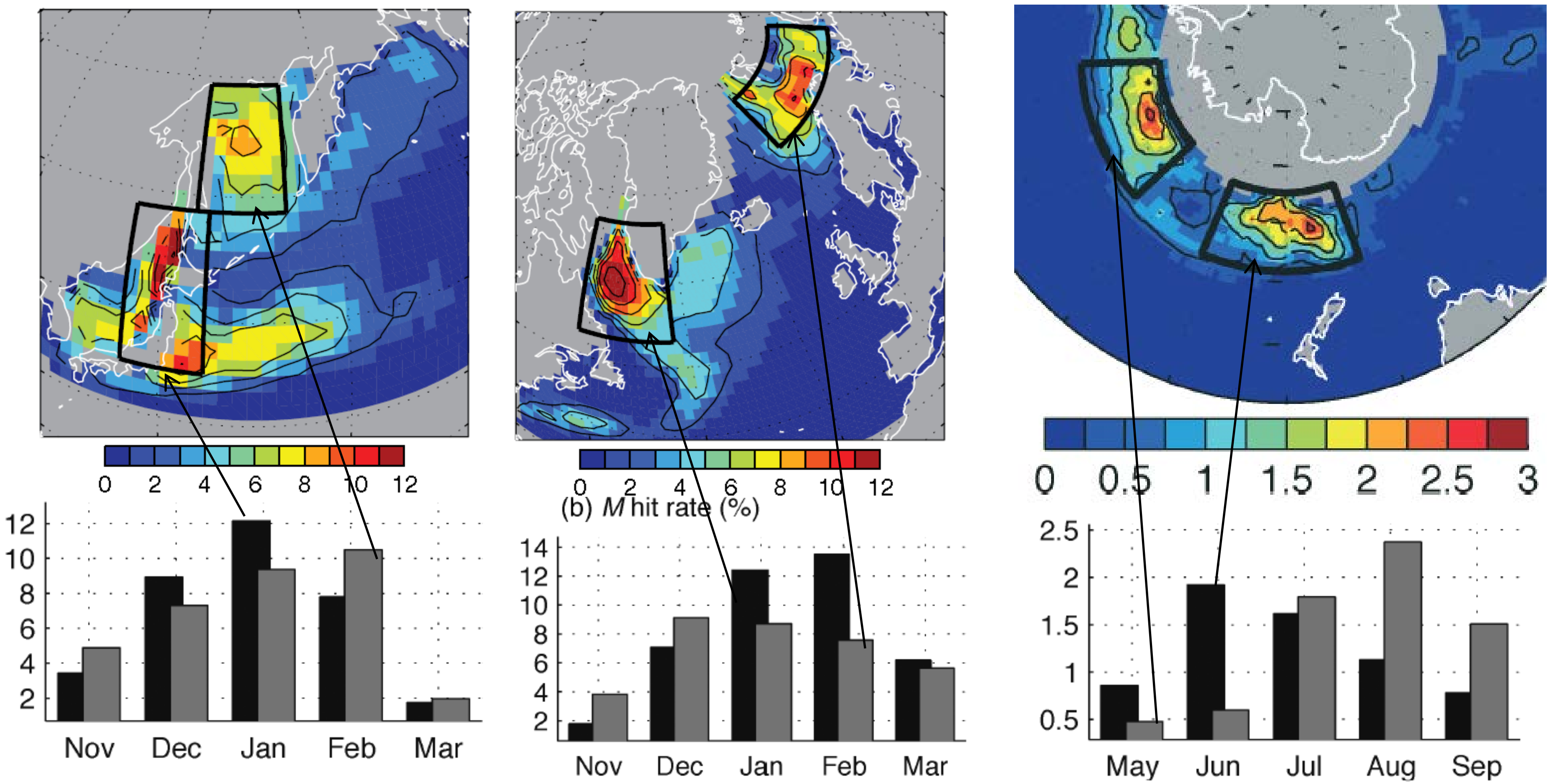
There is no CAPE-reservoir for PL kinetic energy.

Plausible energy source: Continuously replenished turbulent surface fluxes

Kolstad, 2011, QJRMS, 137

MCAO (M>3.4)-Hit Rate 1989-2010, ERA Interim

$$M = \frac{L}{Z}(\ln \theta_S - \ln \theta_{700}) \qquad L = 7 \times 10^5 \text{ m}$$



Additional requirement are needed for PLs to actually occur:

E.g.: upper-level PV anomaly: p_{2pvu} > 470 hPa

Aspelien et al, Tellus (2011), 63A, 564–584

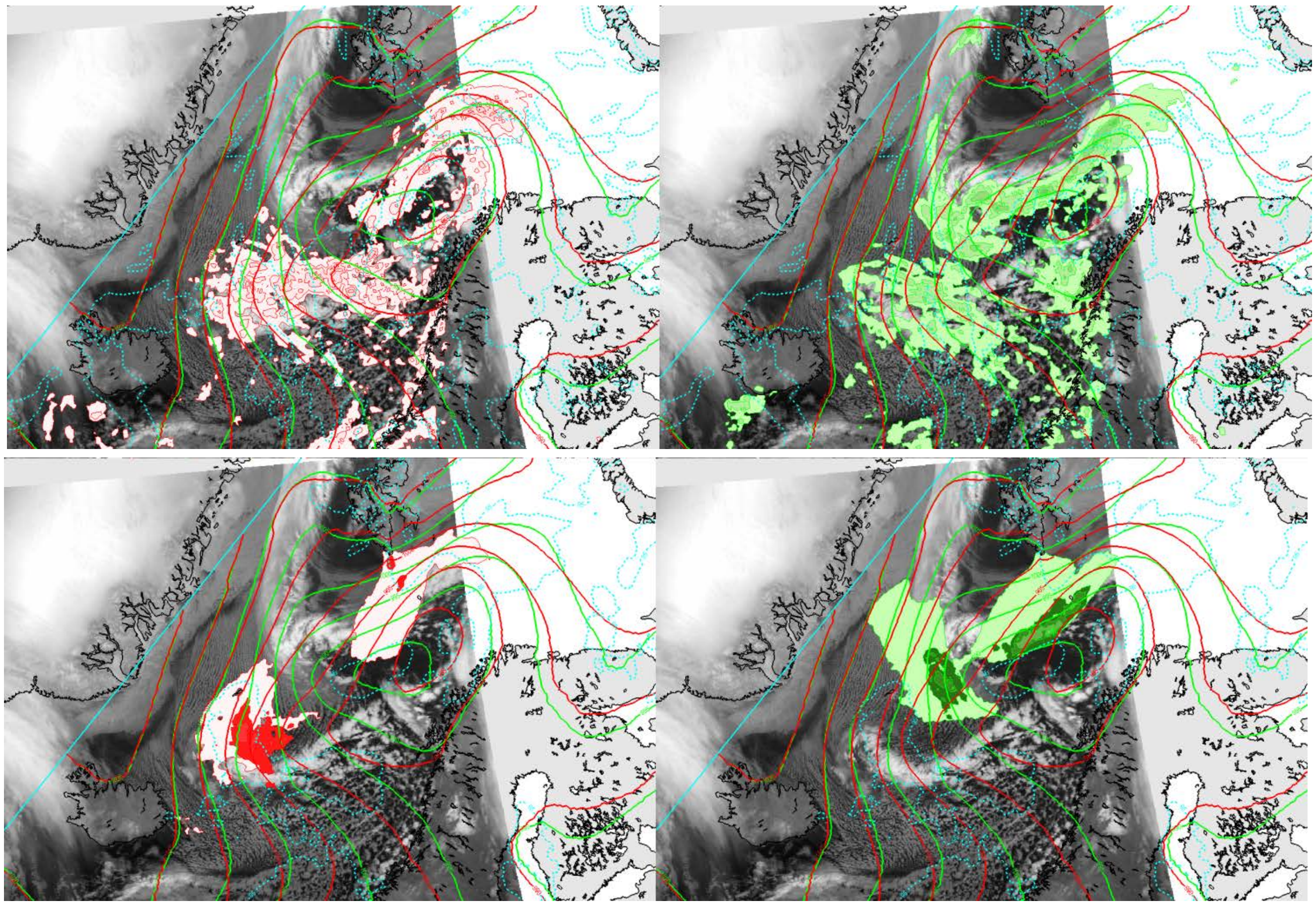
The Operational 42-member LAM-EPS at MET Norway during the IPY Thorpex Campaign: Polar Low(s) 03-04.03.2008

Progs, +47h, Val 03.03.2008 17 UTC

No Campaign data | **Incl. Campaign data**

Ens Mean mslp, Prob: Pr > 0.5mm/h (10%) & 1mm/h (10%)

Ens Mean mslp, Prob: ff10 > 15m/s (30%) & 20m/s (30%)



Campaign observations ➔ improved forecast

Aspelien et al, Tellus (2011), 63A, 564–584

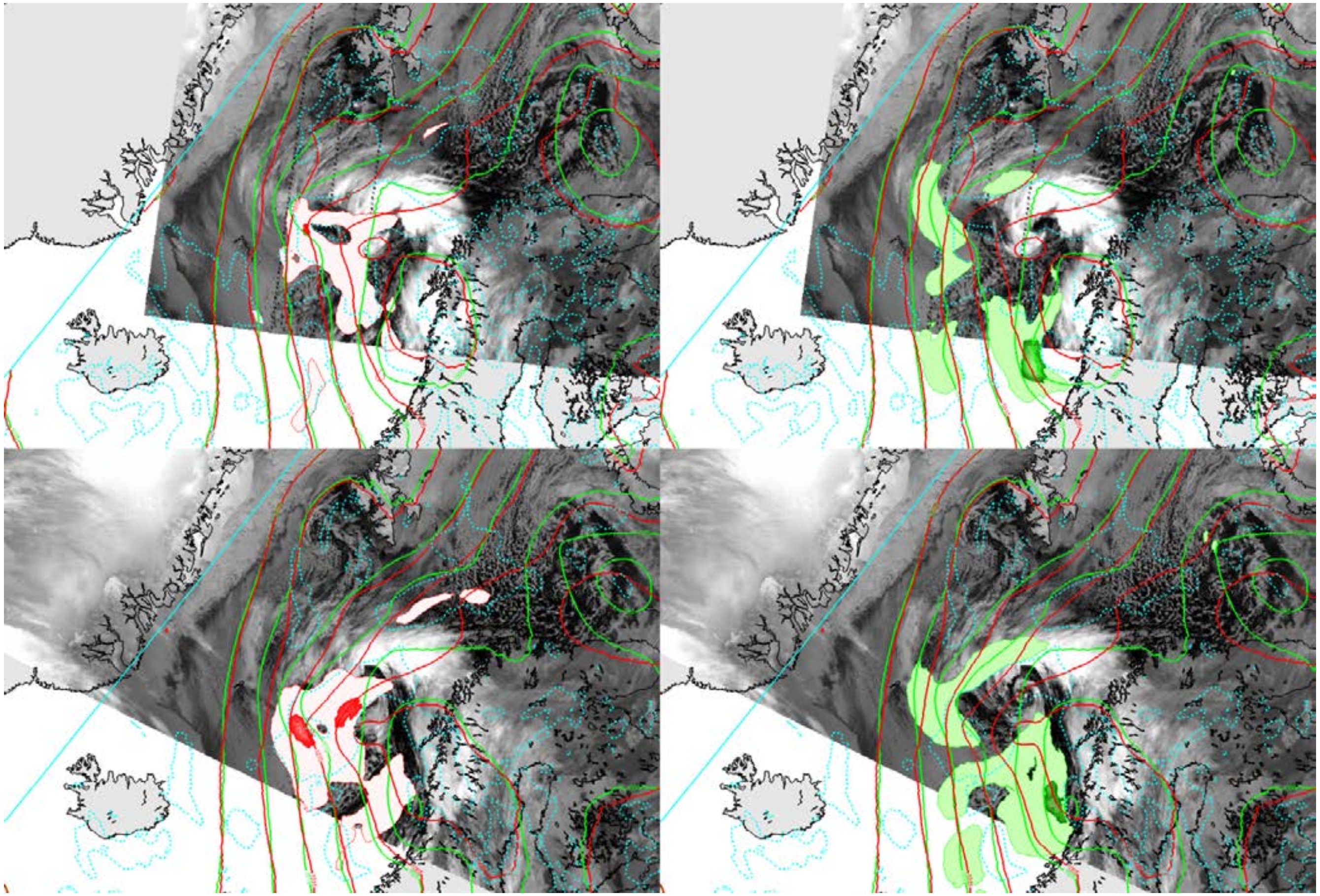
The Operational 42-member LAM-EPS at MET Norway during the IPY Thorpex Campaign: Polar Low(s) 16-17.03.2008

Ens Mean mslp, Prob: ff10 > 15m/s (30%) & 20m/s (10%)

No Campaign data | **Incl. Campaign data**

+18h
Val 16.03.2008
12 UTC

+24h
Val 16.03.2008
18 UTC



Campaign observations ➔ reduced forecast quality(!)

Randriamampianina, Iversen and Storto, **2011, Q. J. R. Meteorol. Soc**.

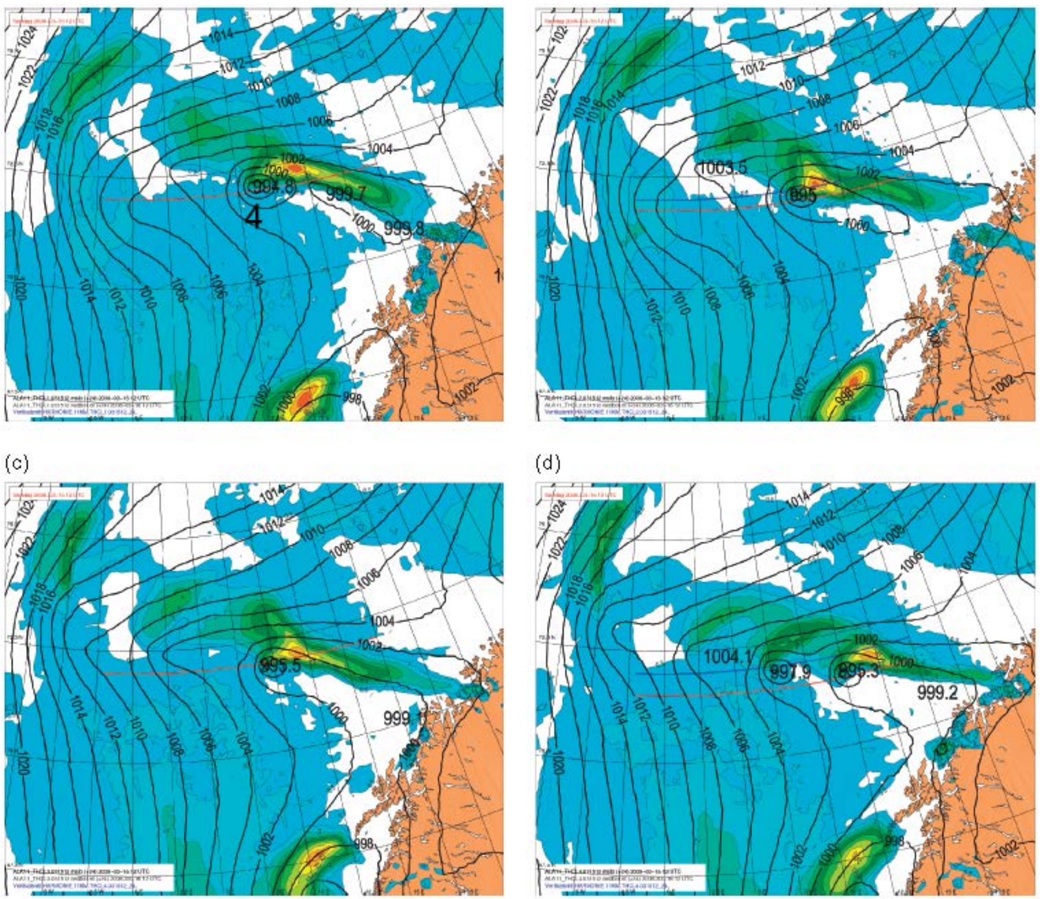
DOI:10.1002/qj.838

24h forecast, valid at 16.03.2008 12 UTC

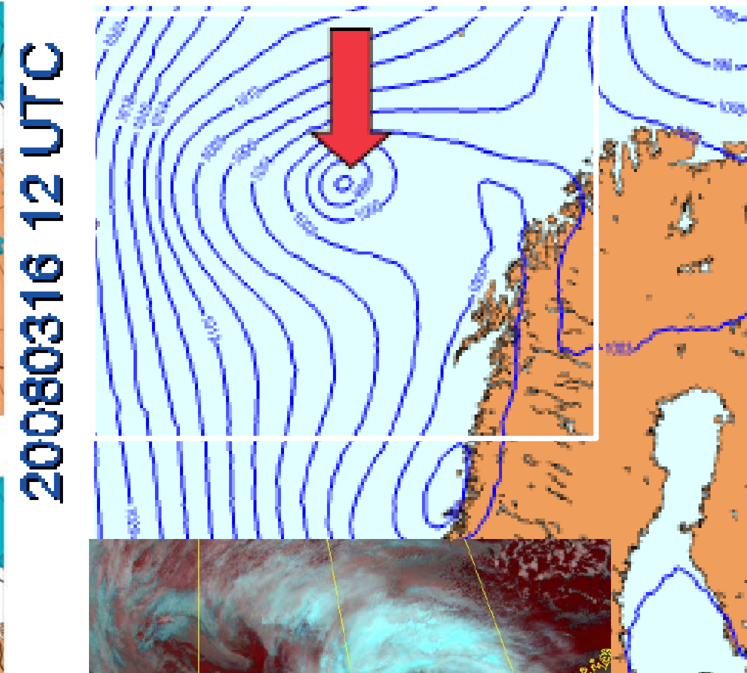
IASI-data | No IASI-data

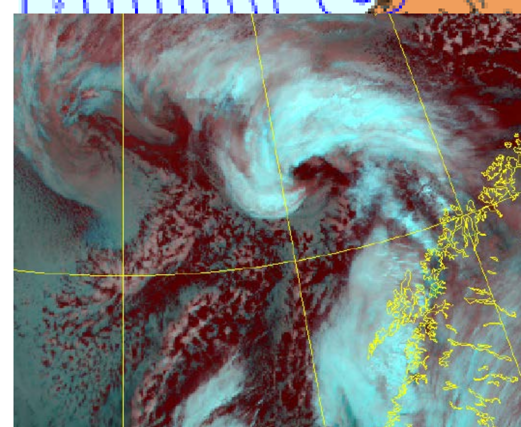
Campaign in-stu -data

No campaign in-stu -data



HARMONIE verifying analysis
16.03.2008 12 UTC
IASI & campaign data employed





NOAA-18, 16.03.2008 09:26

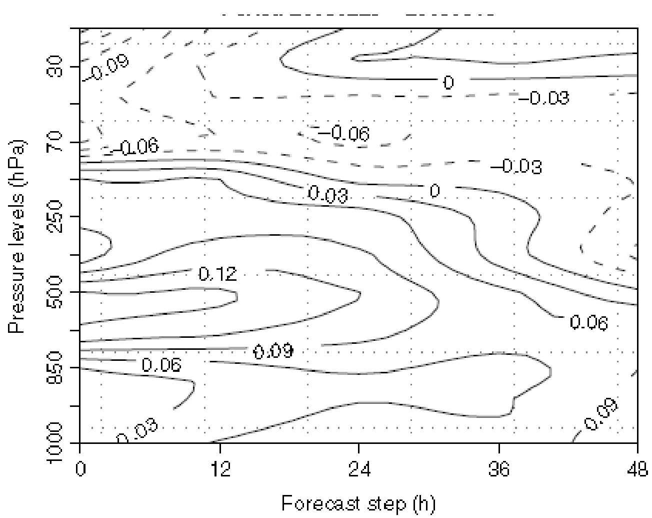
Campaign observations + IASI ➔improved forecast

Randriamampianina, Iversen and Storto, **2011, Q. J. R. Meteorol. Soc**.

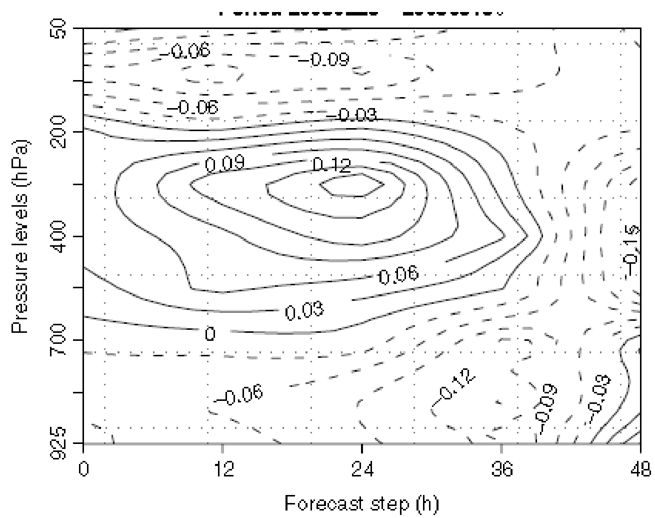
Impact of assimilating 41 IASI-channels data in analyses for HARMONIE/Aladin_11km_L60 forecasts of Z_{500}, 25.02-15.03.2008

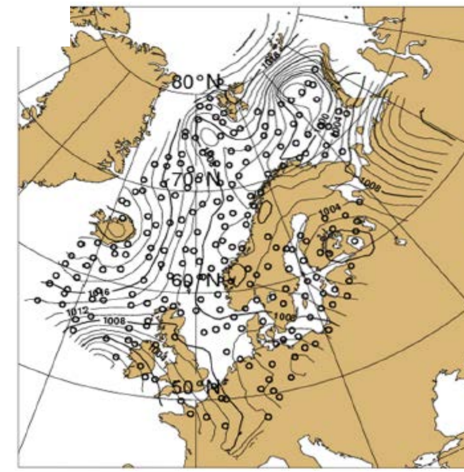
RMSE-reduction due to IASI-data, verif against ECMWF analyses

(a)

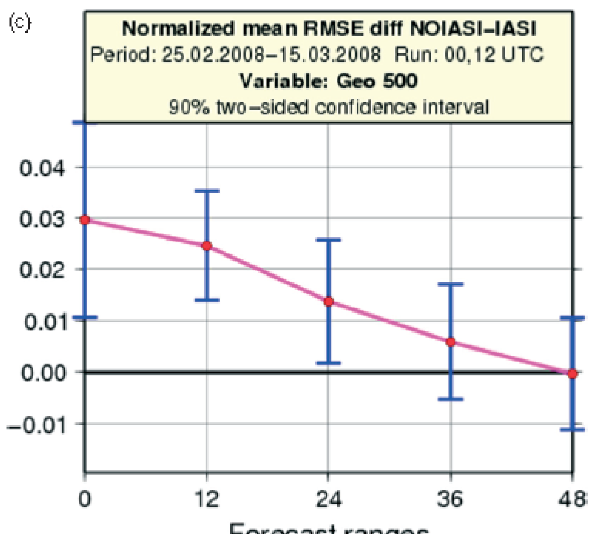


RMSE-reduction due to IASI-data, verif against observations

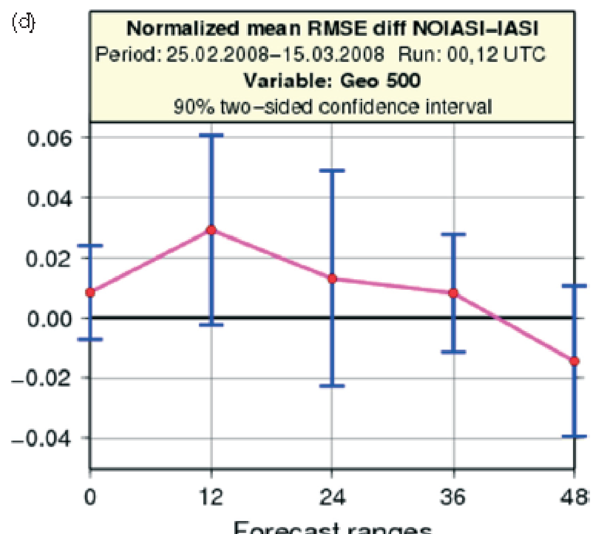




(c)



(d)

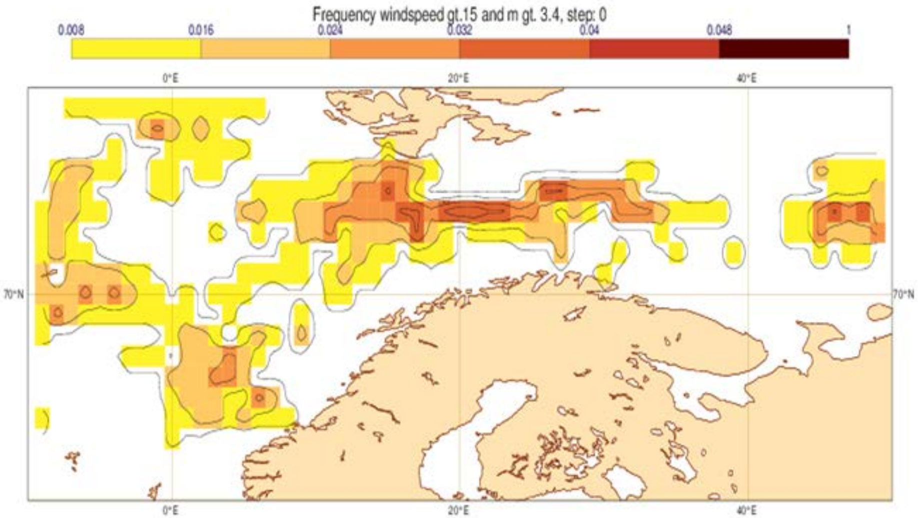


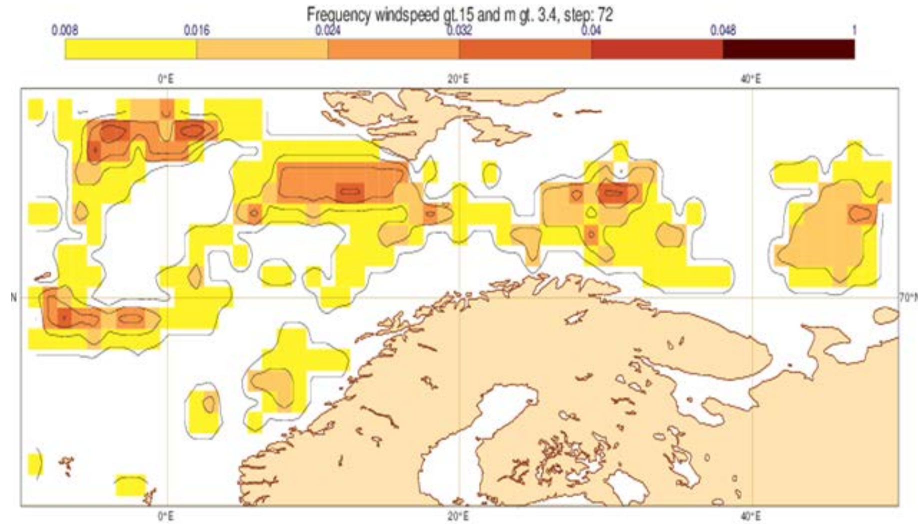
Normalized average & 90% two-sided confidence

NH Polar Low Index «climatology», winter 2013

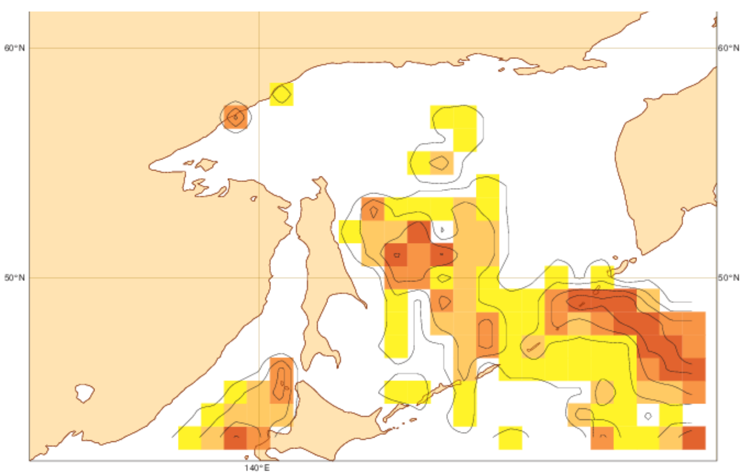
ECMWF T_L1279

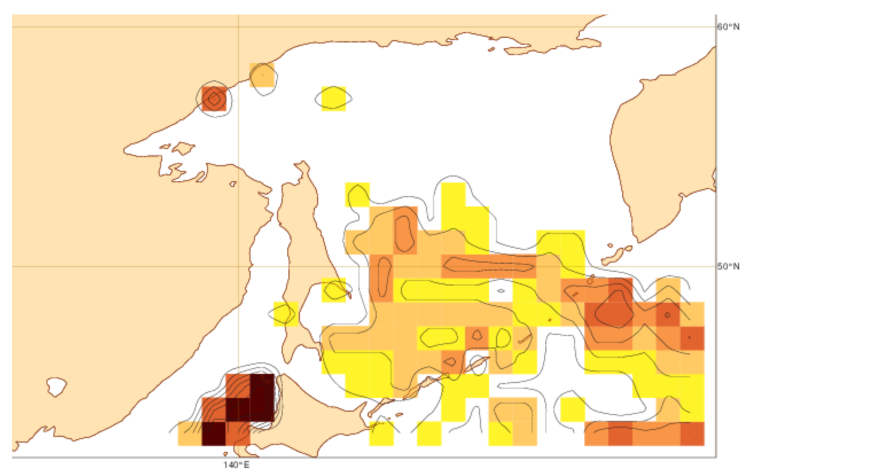
Linus Magnusson, ECMWF





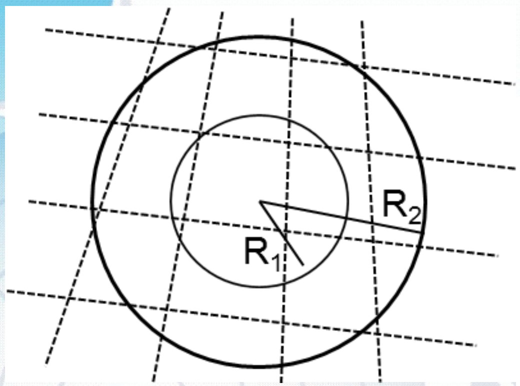
Analysis **+3D Prog**



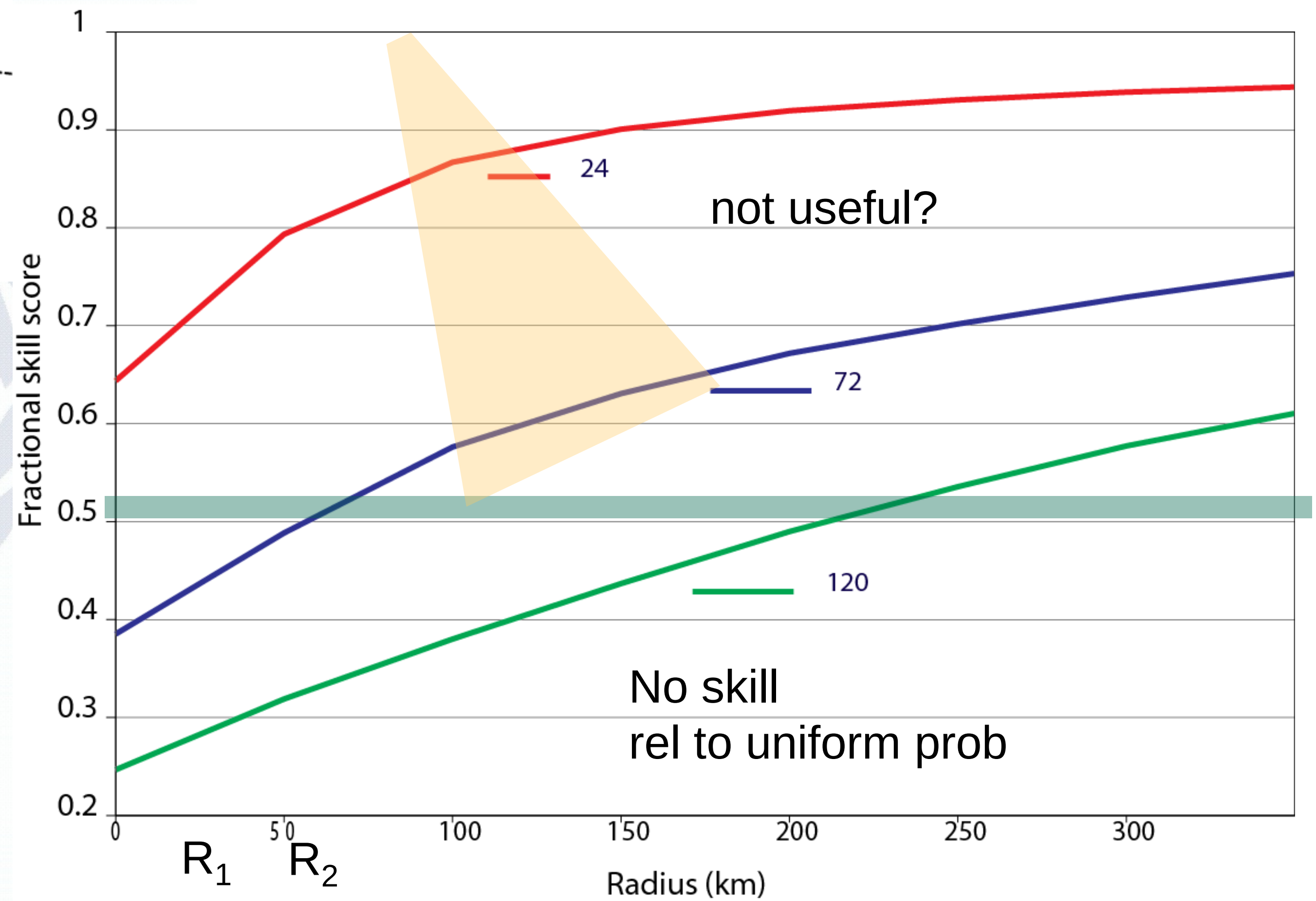


Fractions Skill Score for polar low index

EC deterministic, event = [SST-T_{500} >43K & ff10>15m/s]



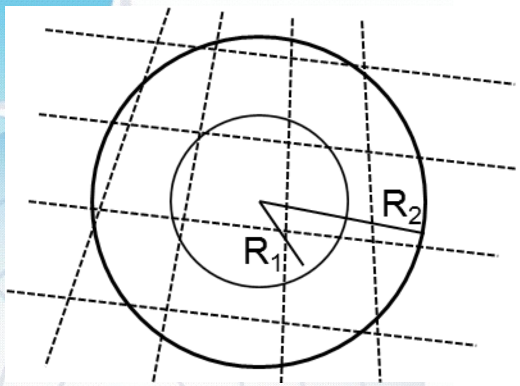
Norwegian & Barents Seas, winter 2012-13

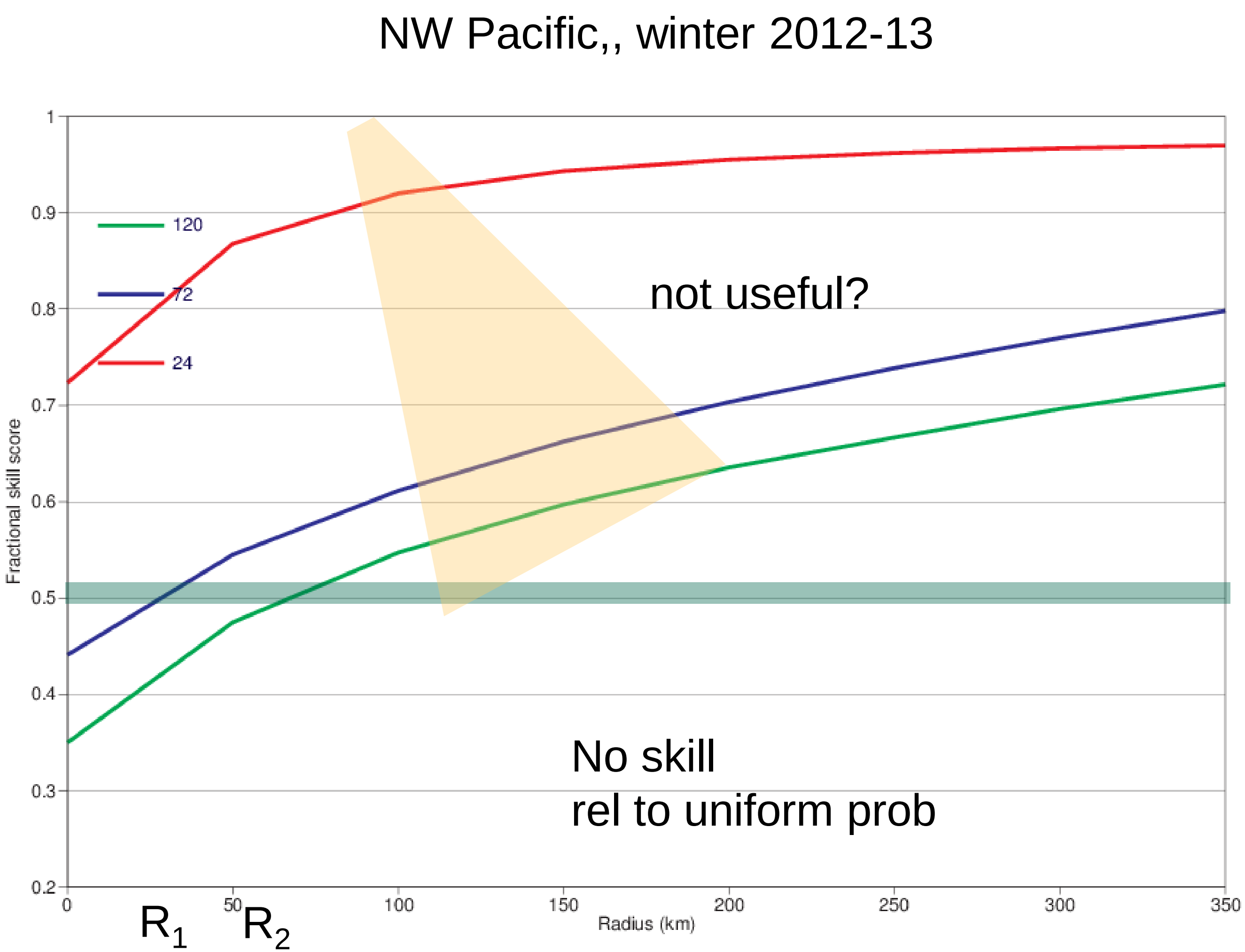


Linus Magnusson, ECMWF

Fractions Skill Score for polar low index

EC deterministic, event = [SST-T_{500} >43K & ff10>15m/s]





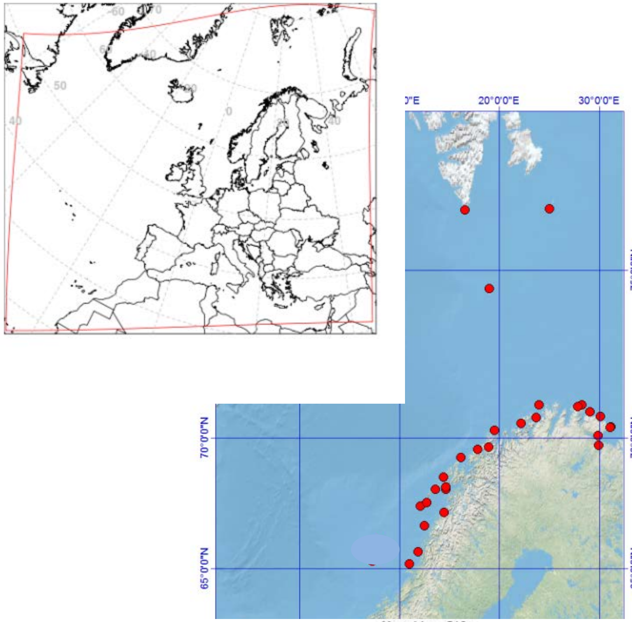
Linus Magnusson, ECMWF

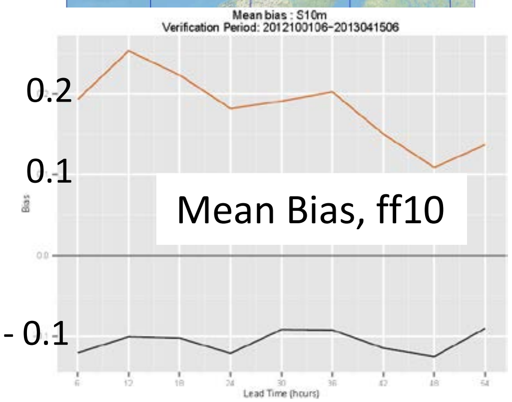
GLAMEPS; Verification against regular OBS

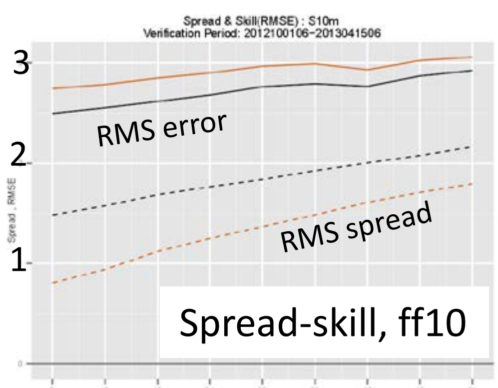
Relevant SYNOP-sites for Polar Lows in Nordic Seas

GLAMEPS (HIRLAM&ALADIN, 54 members, ~10 km) **& ECEPS:**

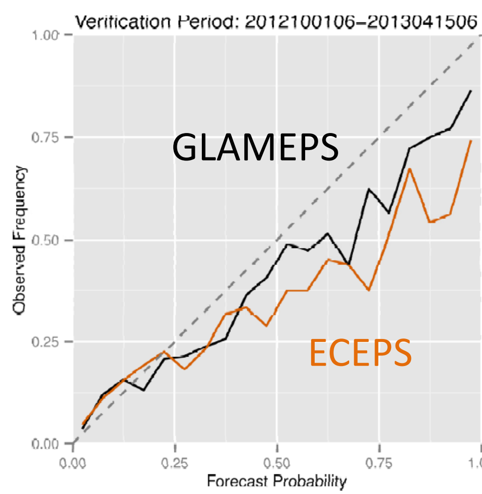
A. Singleton; A. Deckmyn; I-L. Frogner, K. Sattler – *see Iversen et al, (2011)*



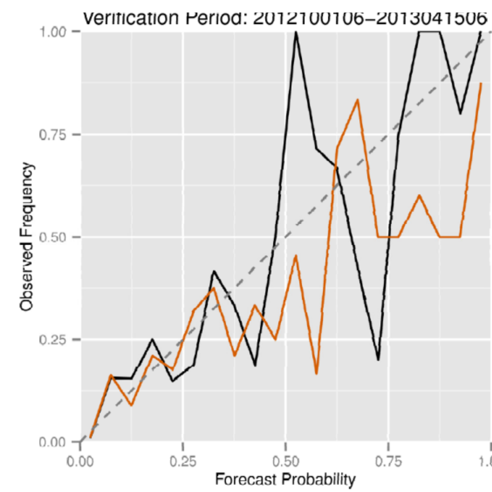




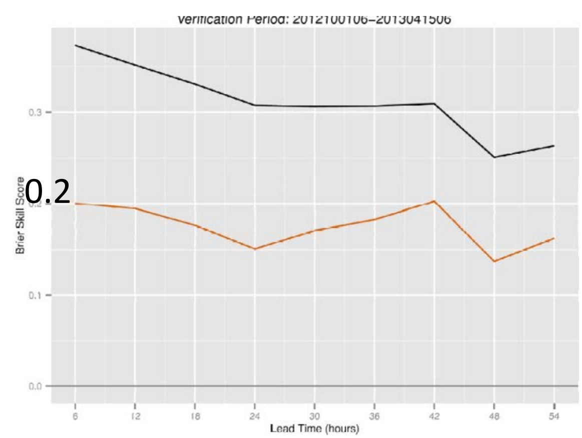
REL;t+42,ff10>10m/s



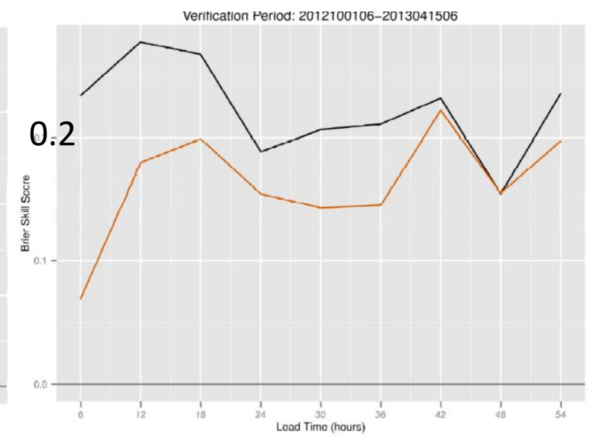
REL;t+42,ff10>15m/s



BSS; ff10>10m/s

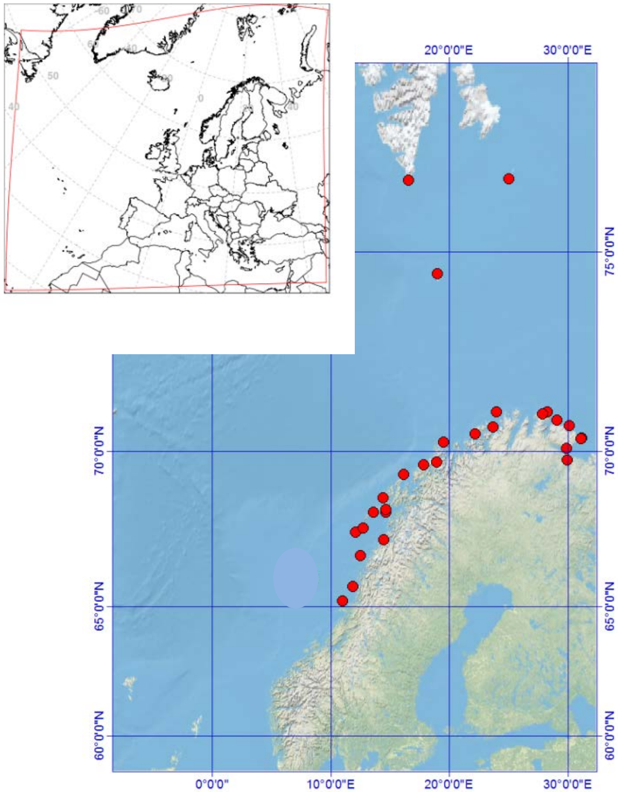


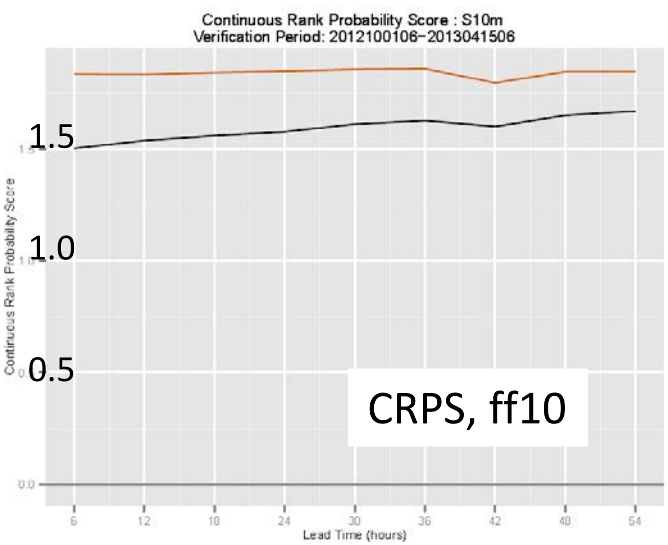
BSS; ff10>15m/s



GLAMEPS & ECEPS

A. Singleton; A. Deckmyn; I-L. Frogner, K. Sattler – *see Iversen et al, (2011)*





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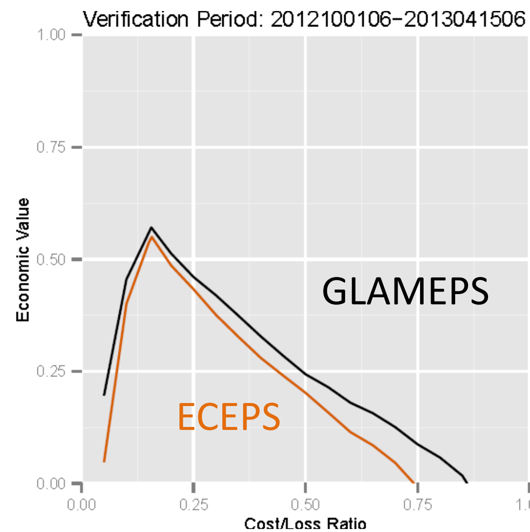
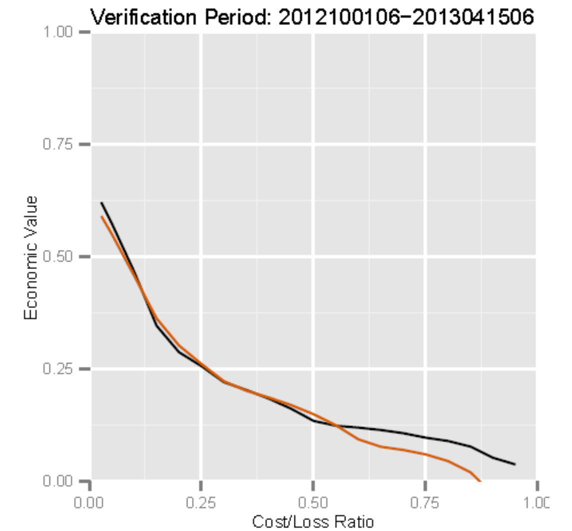
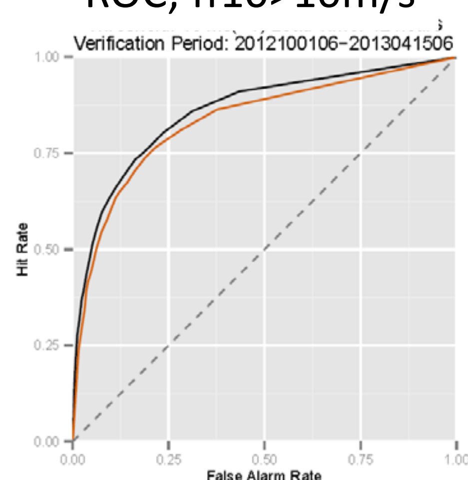


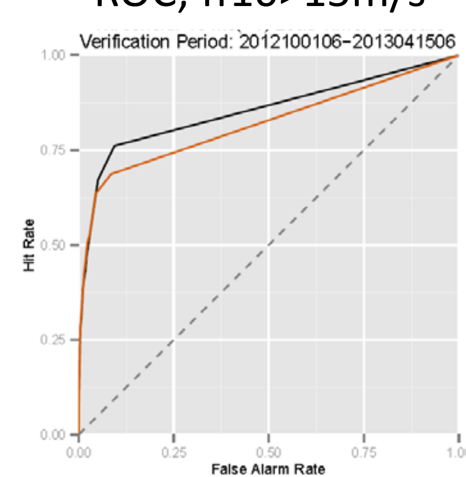
Value;t+42,ff10>15m/s



ROC; ff10>10m/s



ROC; ff10>15m/s

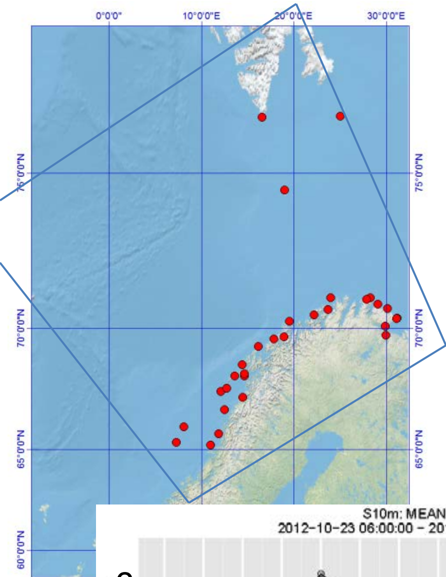


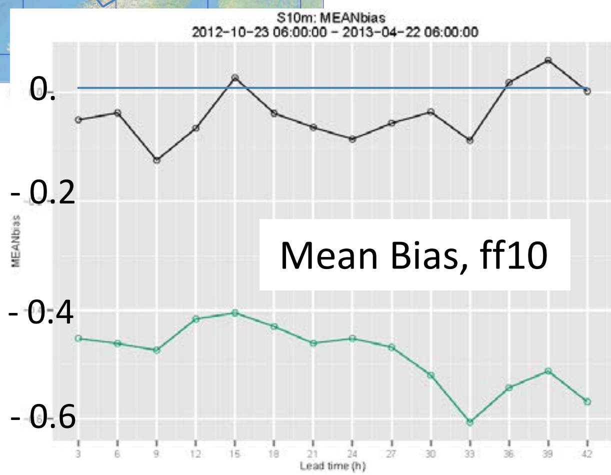
HarmonEPS: Verification against regular OBS

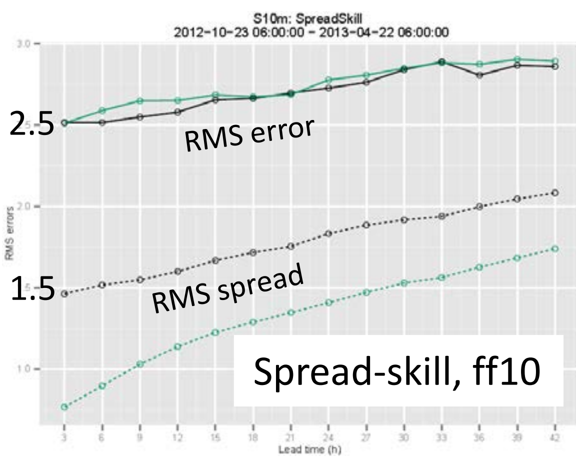
Relevant SYNOP-sites for Polar Lows in Nordic Seas:

HarmonEPS_11 Norway (11 members, 2.5km, 60 lev) & **GLAMEPS_54**

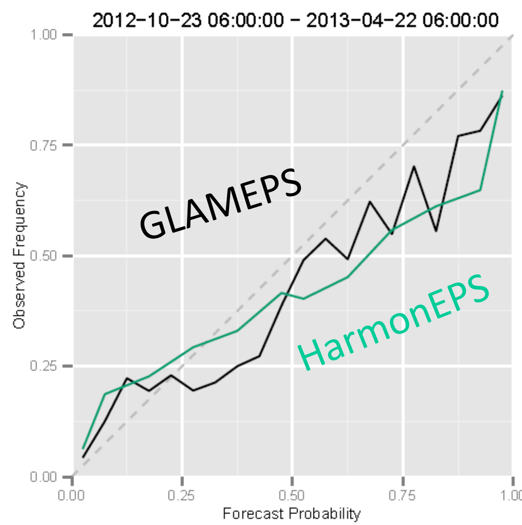
T. Aspelien, J. Kristiansen, A. Singleton, H. McInnes



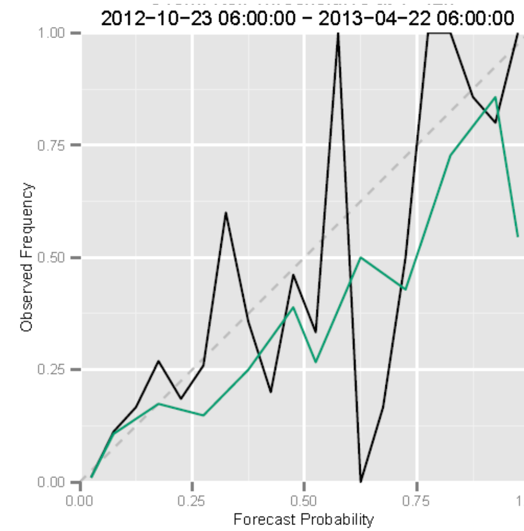




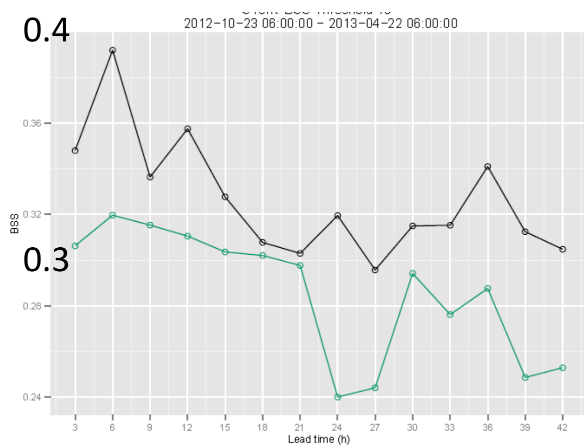
REL;t+42,ff10>10m/s



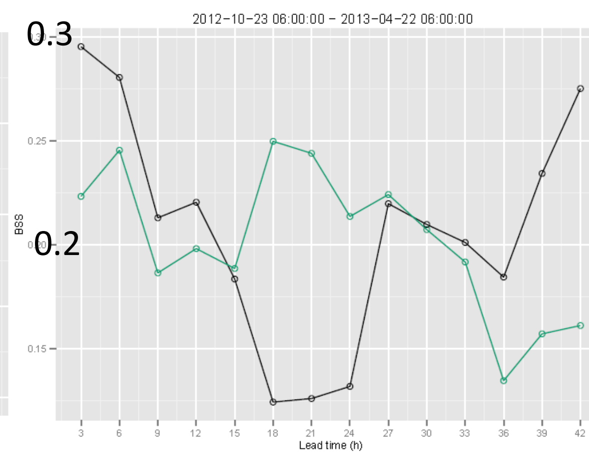
REL;t+42,ff10>15m/s



BSS; ff10>10m/s

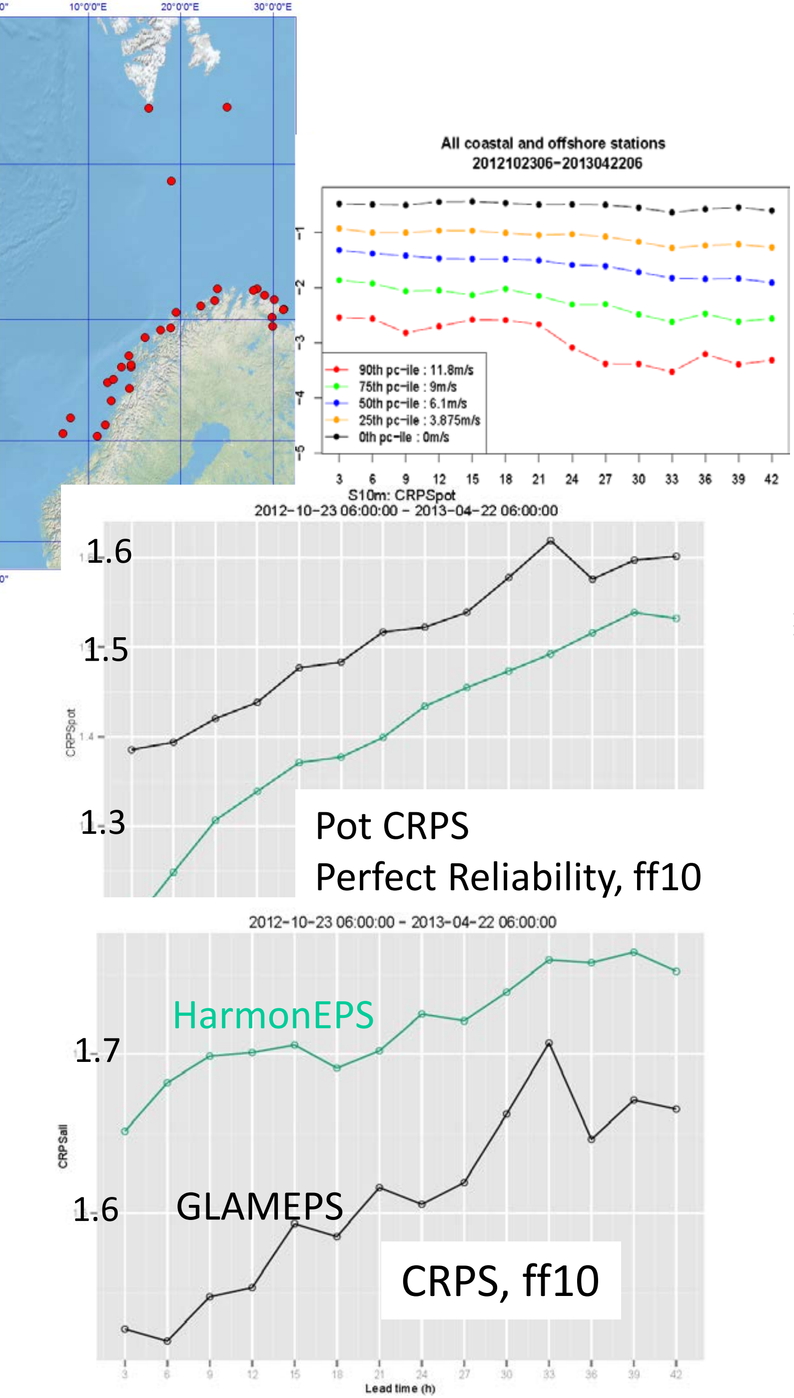


BSS; ff10>15m/s

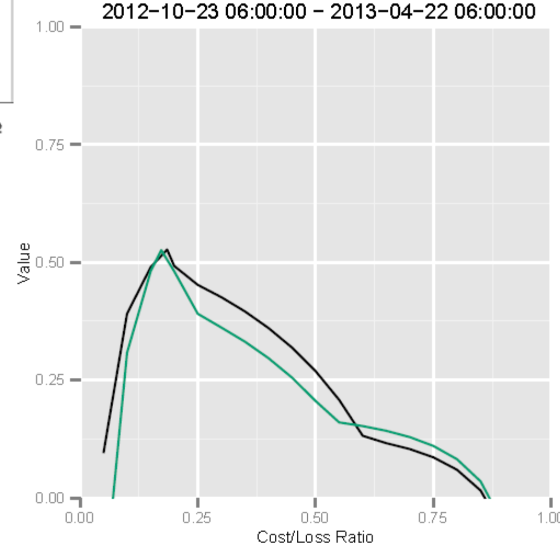


HarmonEPS_11 & GLAMEPS_54

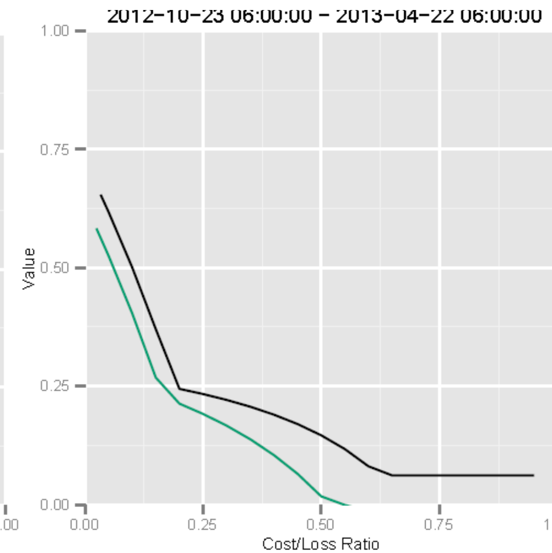
T. Aspelien, J. Kristiansen, A. Singleton, H. McInnes



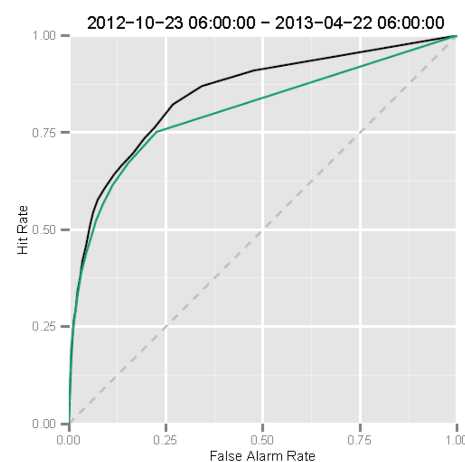
Value;t+42,ff10>10m/s



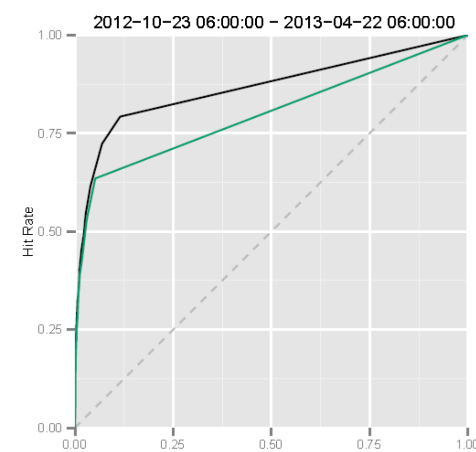
Value;t+42,ff10>15m/s



ROC; ff10>10m/s



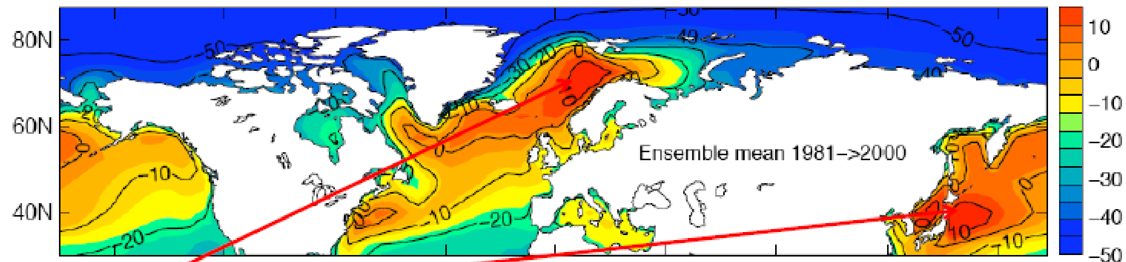
ROC; ff10>15m/s



Kolstad and Bracegirdle, 2007, Clim Dyn:

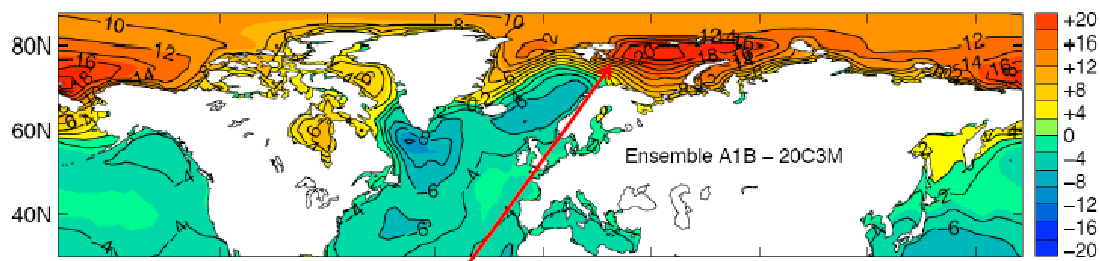
Marine cold-air outbreaks in the future: an assessment of IPCC AR4 models

Where do we find polar lows today?



Red: Marine cold air outbreaks => polar lows

Polar Lows in the Future



Blue: Fewer polar lows than now

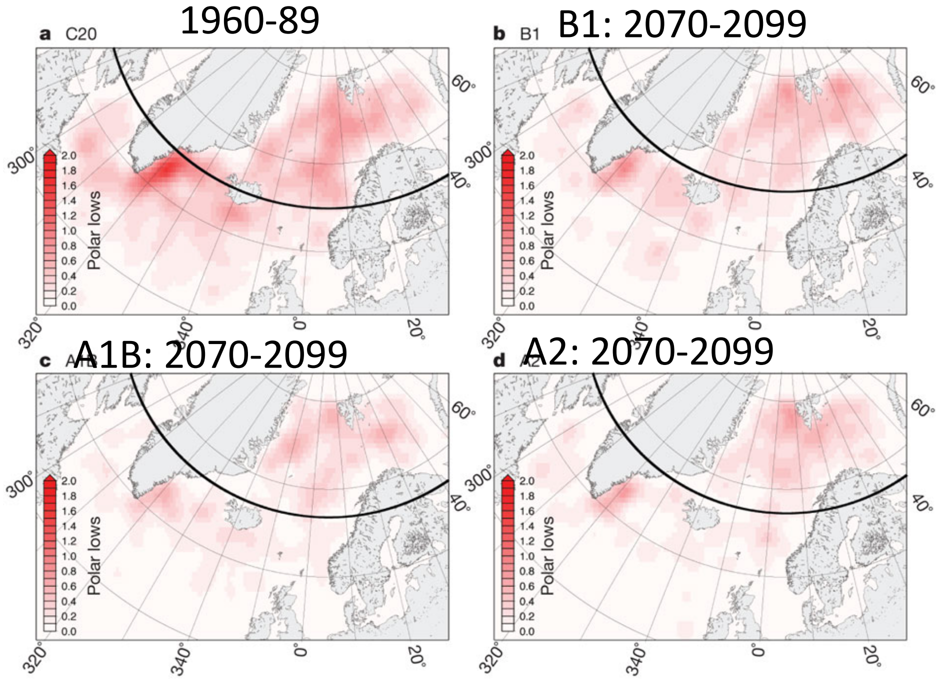
Red: More numerous polar lows than now

Note increase in the Barents Sea

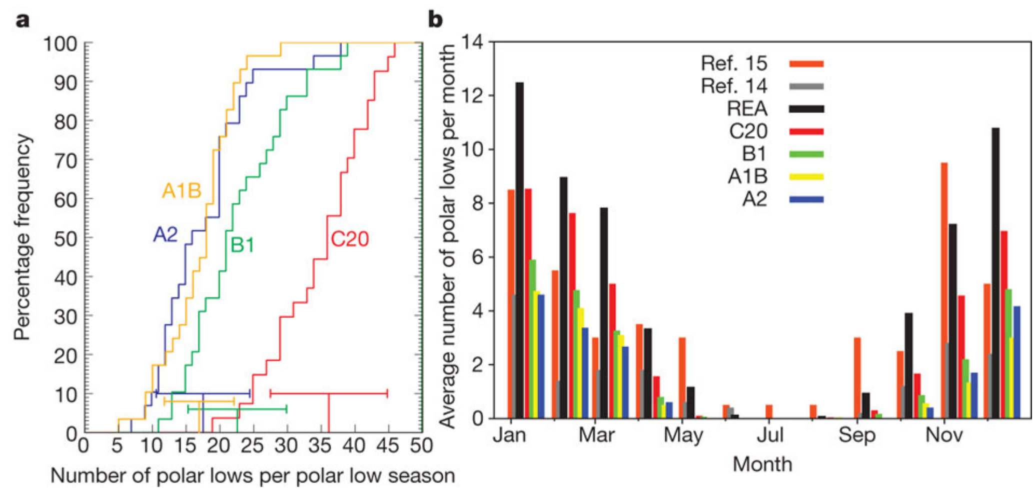
Downscaled IPCC AR4 projections

M Zahn & H von Storch, 2010

Nature **467**, 309-312 (2010) doi:10.1038/nature09388



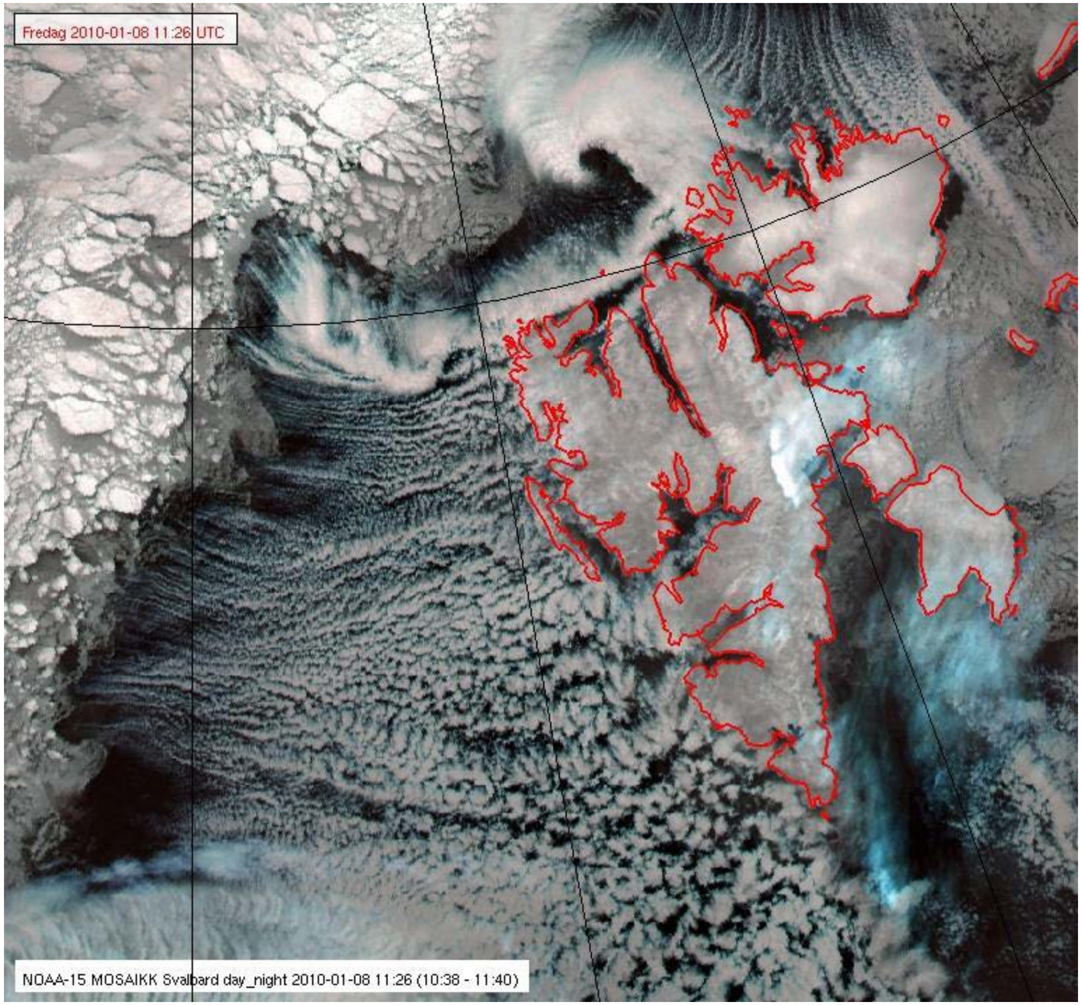
Projected
Polar low density distribution.



Number of polar lows per polar low season and the seasonal cycle.

First (?) PL to occur N of Spitsbergen

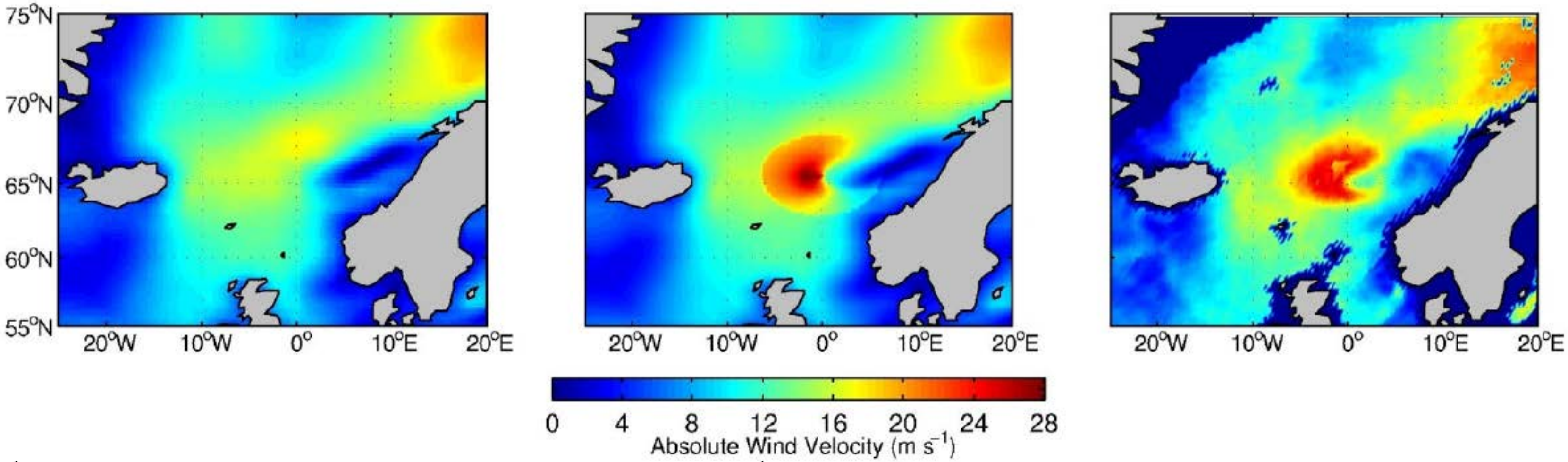
8 Jan 2010

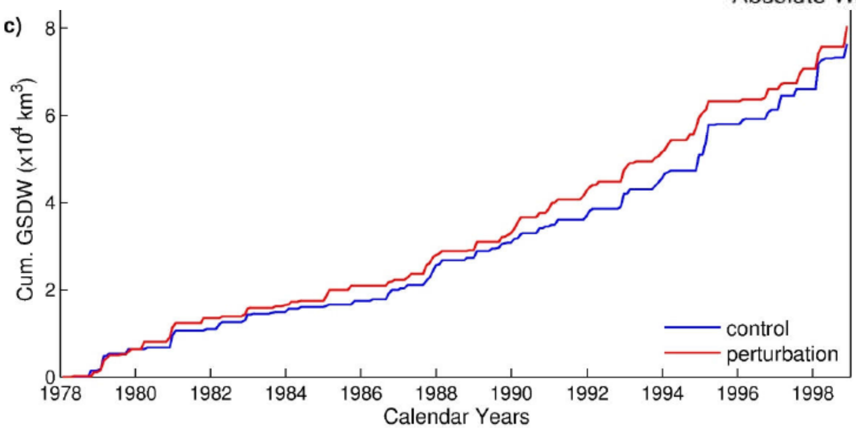


Condron & Renfrew (2012), *Nature Geoscience*

‘Missing’ polar lows enhance deep-water formation in the Nordic Seas

a) Standard ERA-40 data; **b)** ERA-40 + PL parameterized; **c)** satellite data (SSM/I)





The cumulative volume of GSDW formed in the Control (blue) and Perturbation (red) experiments. The total production of Greenland Sea Deep Water increases by 4.1 x 10^3 km^3 (5.3 %) in the experiment with parameterized PL.

Can missing PL-driven ocean mixing also influence the seasonal forecast quality?

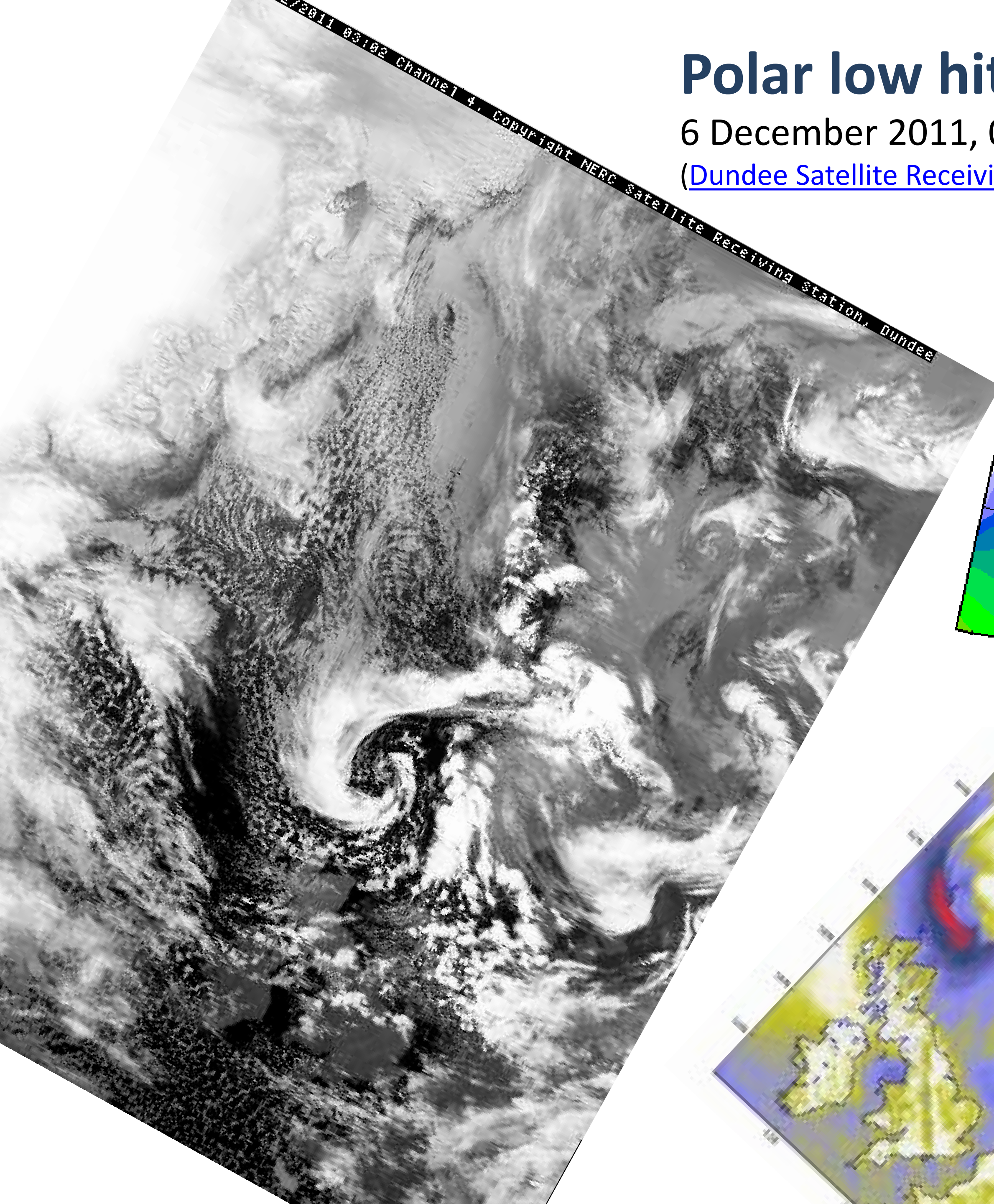
Challenges concerning Polar Lows and predictability

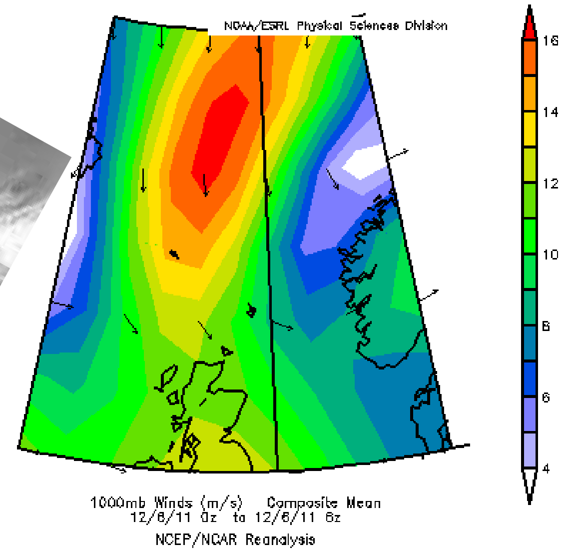
- Why are some PLs badly forecasted and others not?
  - Need to understand PLs that are not forecasted
  - Campaign data or target observations: not adequate
- What are the main missing components?
  - Conventional observations
  - Remote sensing observations
  - Methods for initial conditions and uncertainty →ens spread
  - Spatial resolution: do we need convection-perm NWP?
  - Is parameterized deep convection adequate→ens spread
  - Sea-ice, SST, and their uncertainties →ens spread
  - Contrasts: very stable and very unstable ABL→ens spread
- Potential for coupled atmosphere – upper ocean EPS?
  - PL-induced upper-ocean mixing: positive feedback
- Methods for more realistic for ensemble perturbations
  - Initial, boundary and model perturbations!
- Adequate data for calibration and verification

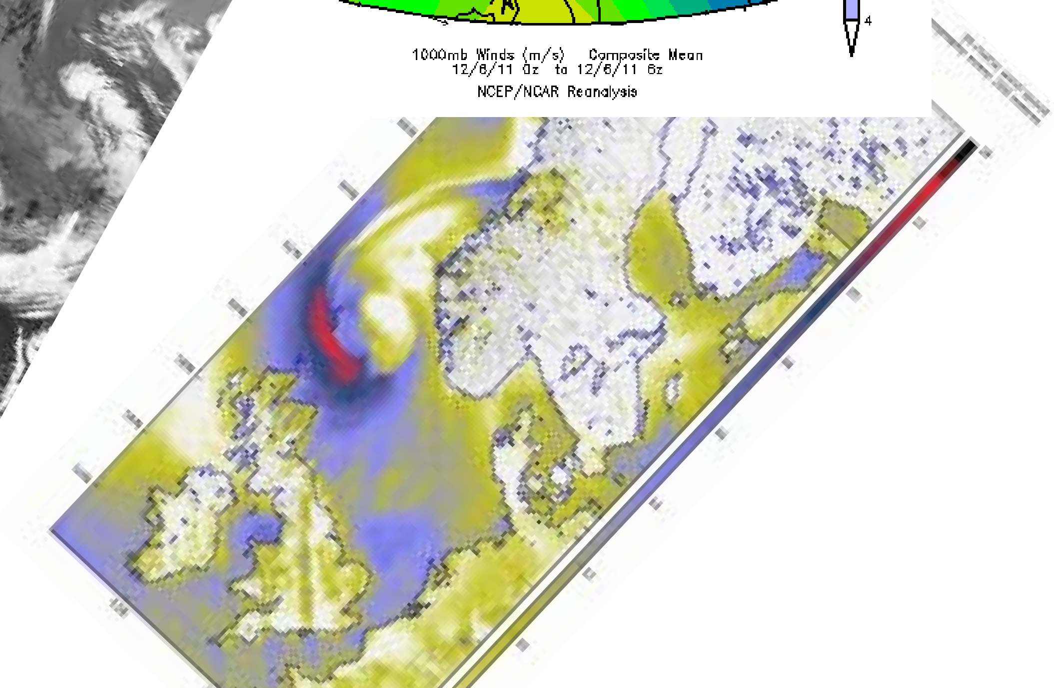
Polar low hits the UK

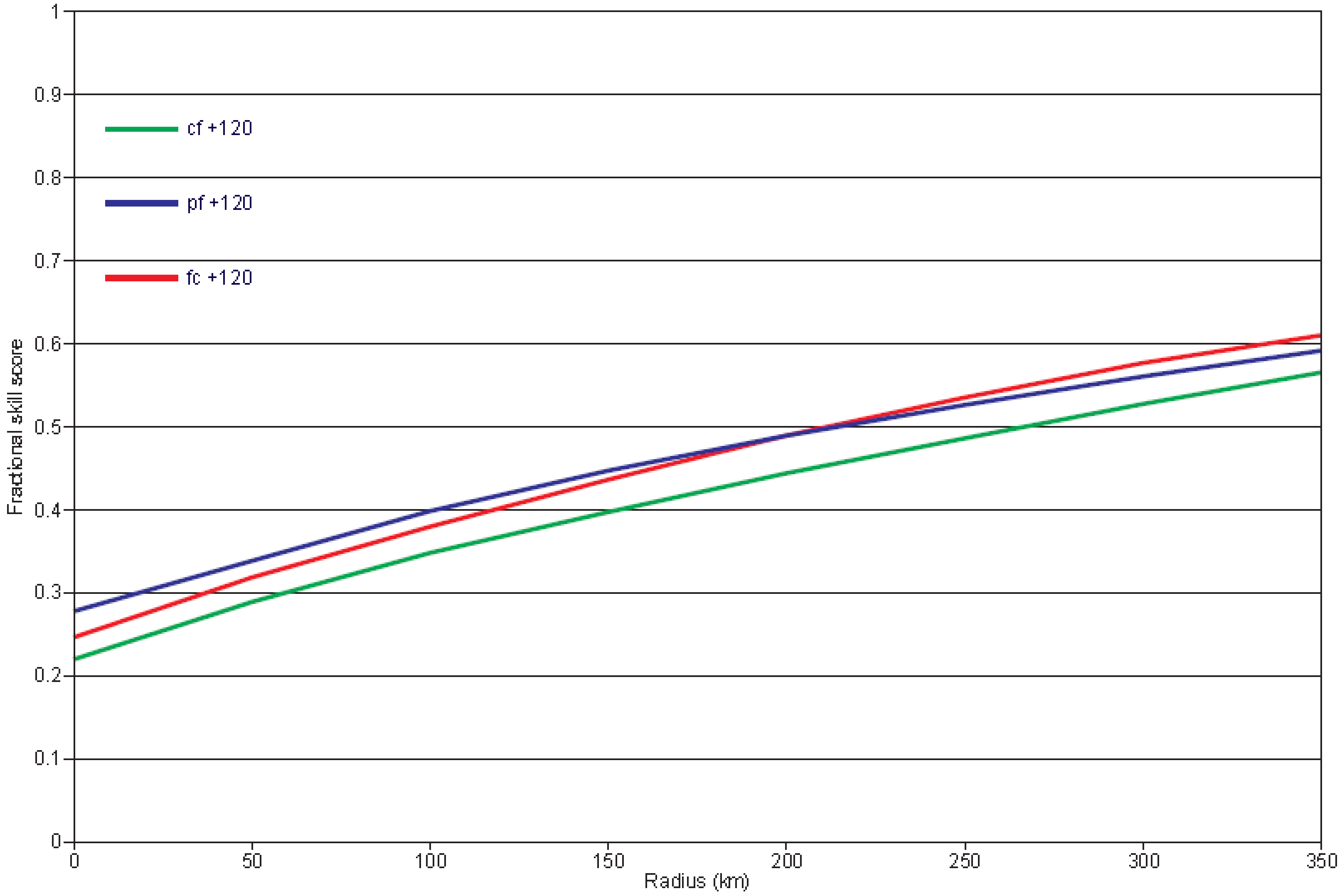
6 December 2011, 03:02.

(Dundee Satellite Receiving Station)









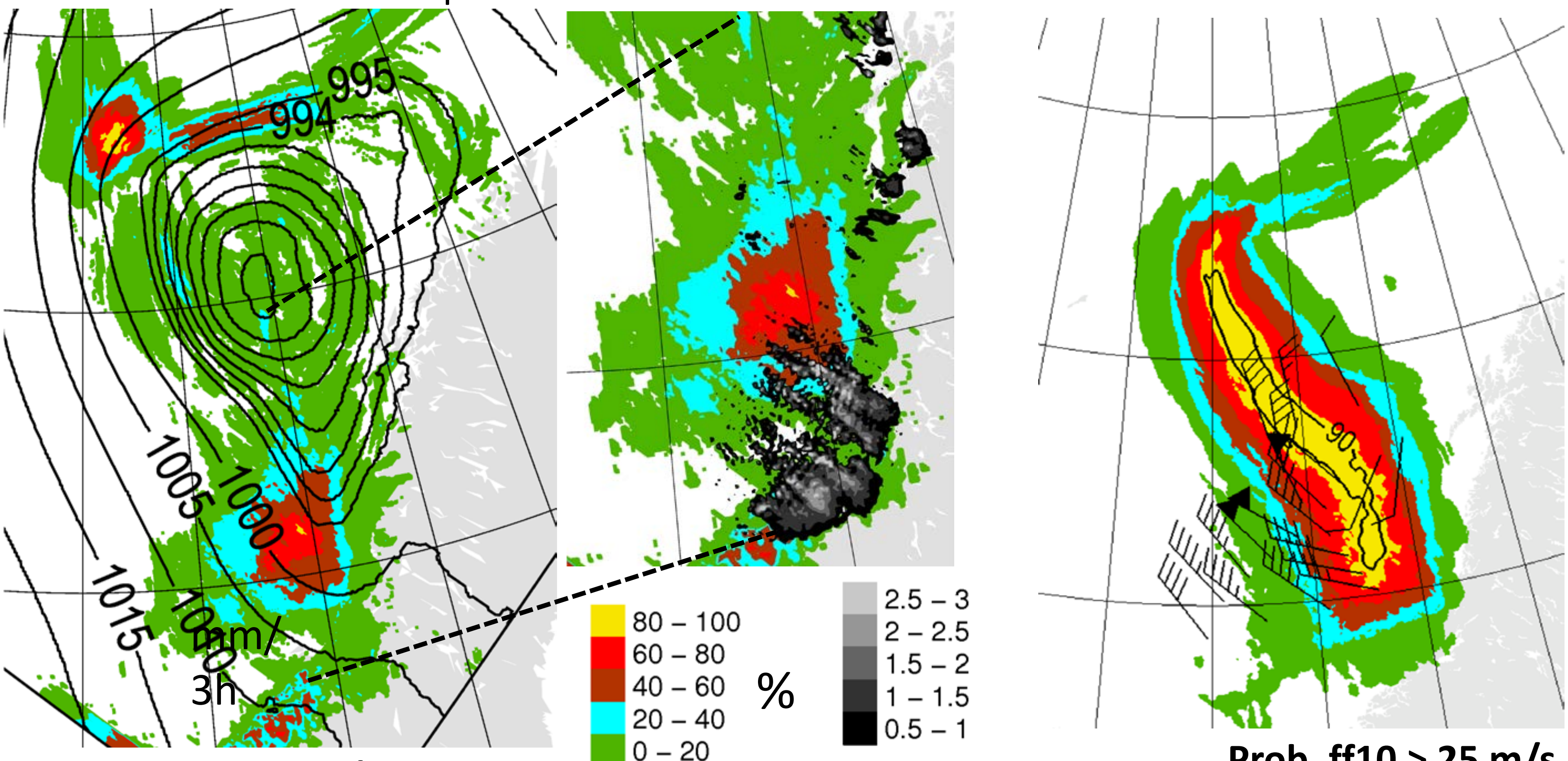
cf +120
pf +120
fc +120
Fractional skill score
Radius (km)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
50
100
150
200
250
300
350

Kristiansen et al, *Tellus (**2011**), 63A, 585–604*

3hPrec t+39-42h, valid 0900-1200 UTC 04 March 2008
925hPa wind speed t+42h, valid 1200 UTC 04 March 2008

met.no/UKMetOffice, UM4km, non-hydrostatic 20+1 member eps

Lines: ensemble mean mslp at t+42h



Prob, Pr > 2.5 mm/3h **Radar:mm/3h** **Prob, ff10 > 25 m/s**