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HIRLAM coupled to the ocean wave model WAM

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Outline

- Motivation: Why couple HIRLAM with an ocean wave model?
  - Improve simulations of Polar Lows through the description of surface roughness (and thereby the surface fluxes).
- The description of an experiment with a 3 month long forecast period.
- Results
  - General performance
    - Compared with observations
    - Compared against own analysis
  - Polar Lows

Momentum flux over the ocean is sea-state dependent!

- Short and steeper waves (young wind-sea) extract momentum more effectively from the atmosphere than swell.
- The momentum exchange between the atmosphere and ocean is sea-state dependent!
- Also the exchange of sensible and latent heat are dependent on the sea-state (still some debate on this).

Surface roughness over the ocean in HIRLAM

- Based on dimensional arguments, Charnock (1955) proposed the parameterization of surface stress over waves:

$$z_0 = \alpha u_*^2 / g$$

  - Combined with a logarithmic velocity profile it yields a drag coefficient that is increasing with the wind
  - For a given wind speed, the stress is always the same!

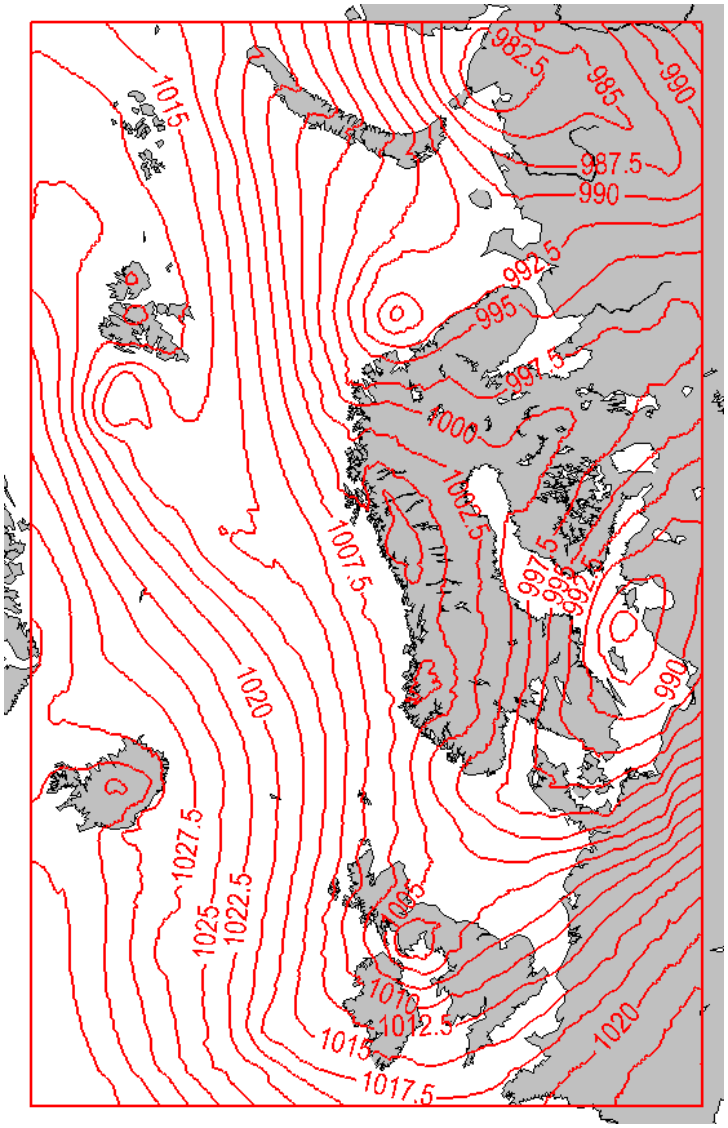
  - *In WAM the reformulation of the Charnock relation by Janssen (1991) is used to take the sea-state dependency into account.*

The experiment

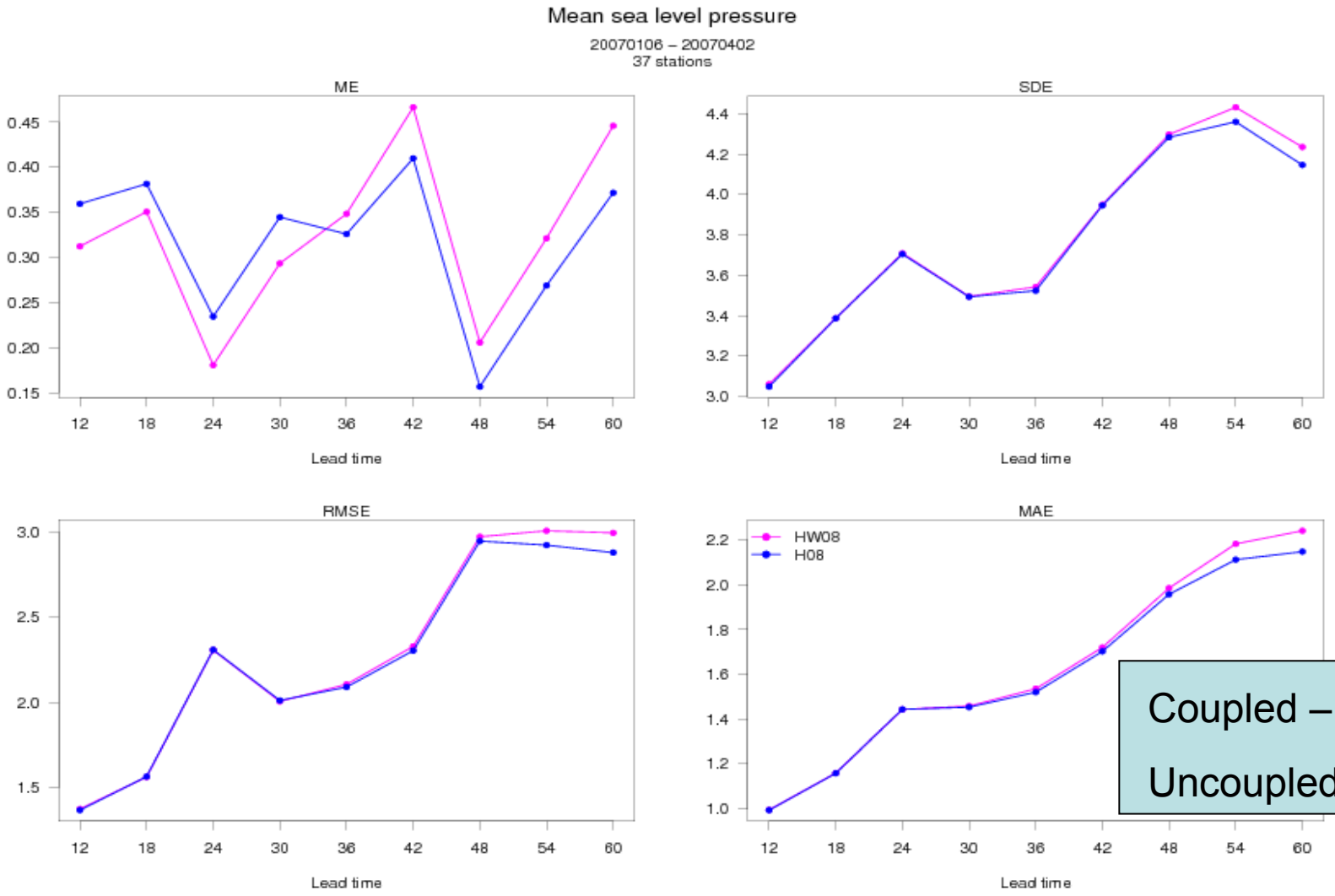
- A 3 month long experiment period (JFM 2007) with ***coupled*** and ***uncoupled*** forecasts.

- V10m and Z_0 are exchanged between the models on every HIRLAM time-step. WAM is put in as a subroutine.

- HIRLAM 7.1.3, 8km res., 60L
- WAM operational met.no version
- 00: +60h
- 06,12,18: +9h



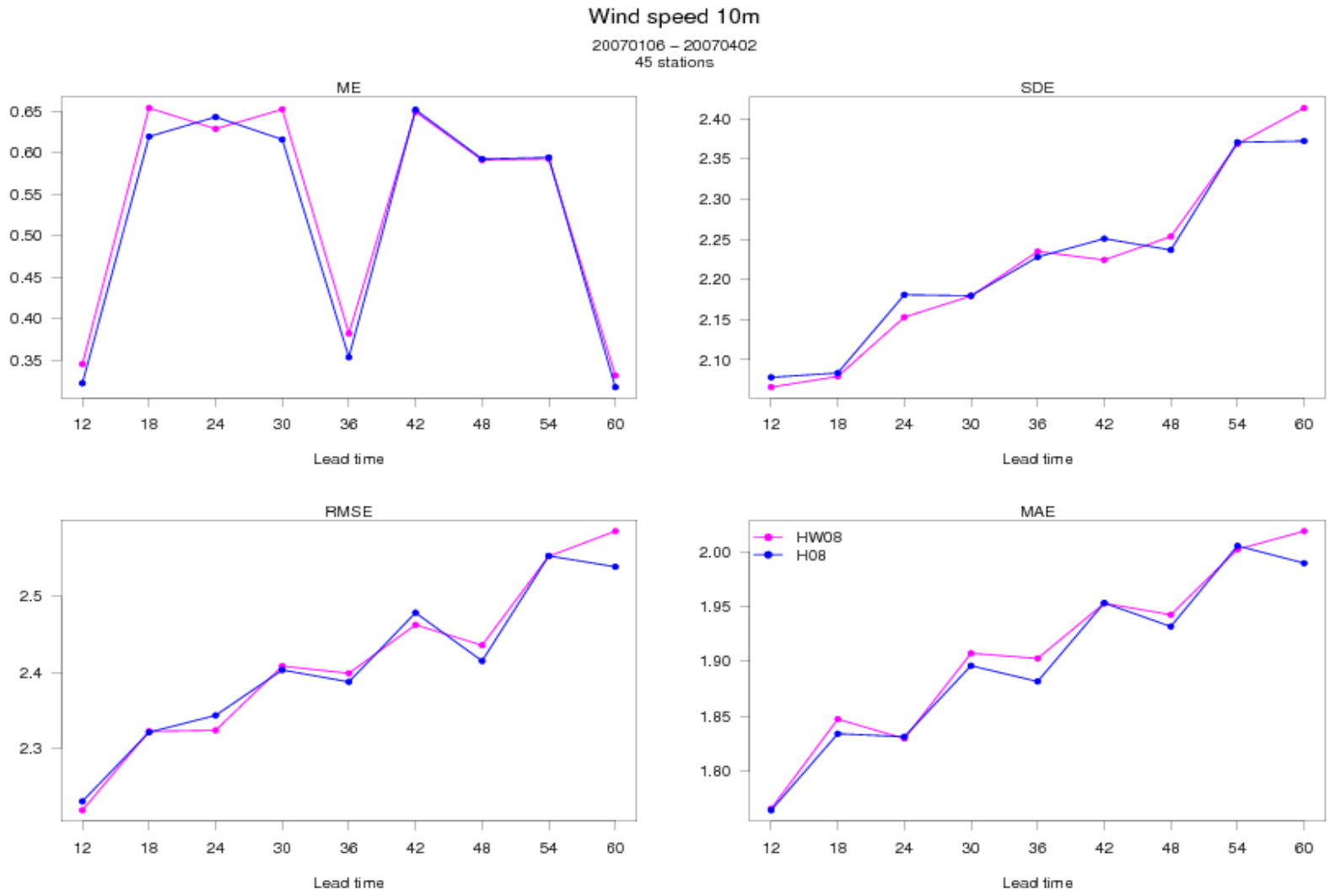
Comparison with Norwegian synop stations, MSLP:



Coupled – red

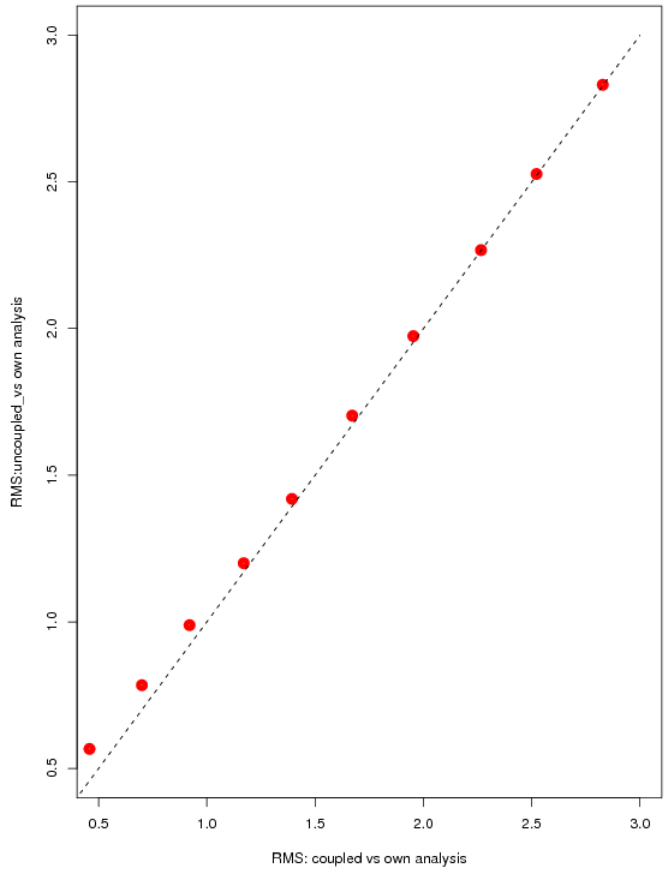
Uncoupled - blue

Comparison with Norwegian synop stations, Wind 10m:

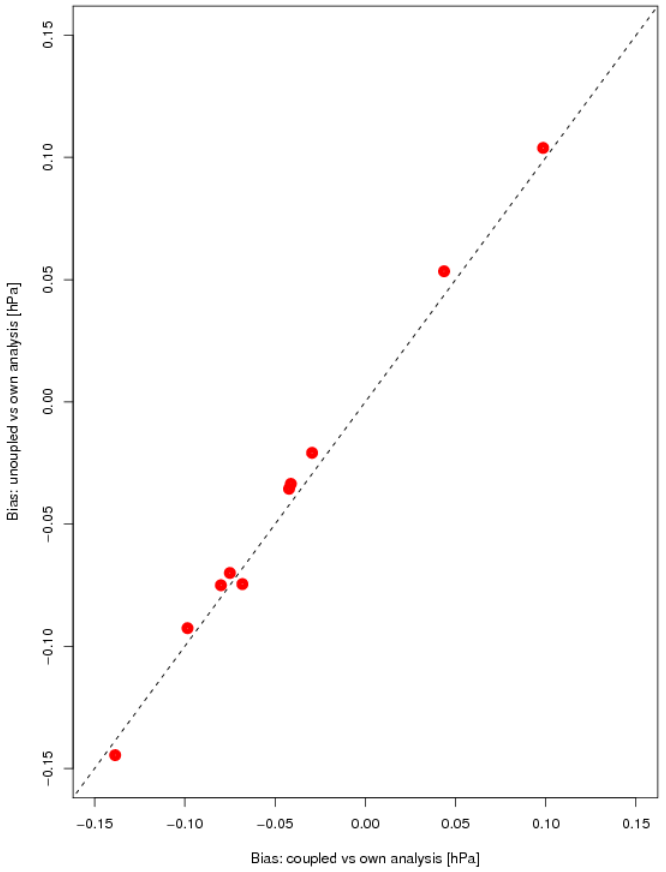


Comparison with own analysis of MSLP:

RMSE



BIAS



UNCOUPLED

COUPLED HIRLAM - WAM

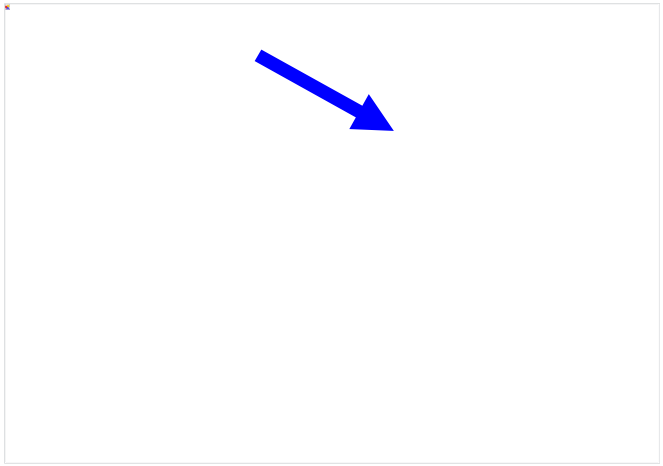
Polar Lows

- *”A polar low is a small, but fairly intense maritime cyclone that forms poleward of the main baroclinic zone. The horizontal scale of the polar low is approximately between 200 an 1000 kilometres and surface winds near or above gale force”*
  - Turner, Rasmussen and Carleton in: *Polar Lows. Mesoscale Weather systems in the Polar Regions* (Ed: Rasmussen and Turner) from 2003

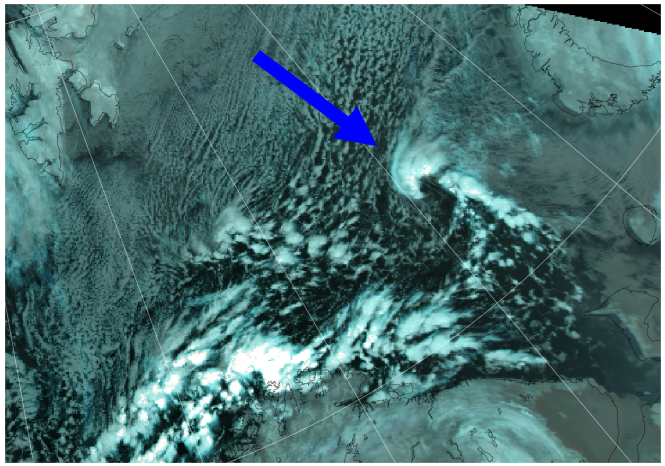
- *”…a polar low is a small-scale synoptic or subsynoptic cyclone that forms in the cold air mass poleward of the main baroclinic zone and/or major secondary frons.* ***It will often be of convective nature but baroclinic effects may be important…”***
  - Rasmussen in Polar and Arctic Lows (Ed: Twitchell, Rasmussen and Davidson) from 1989

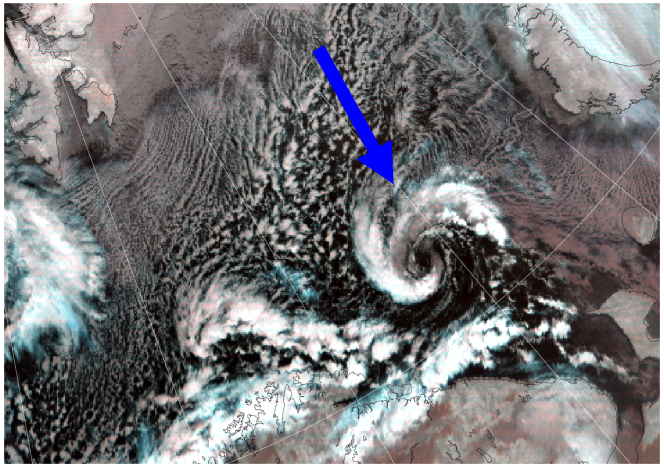
The Polar Low 21.January 2007:

03.22UTC 21. January

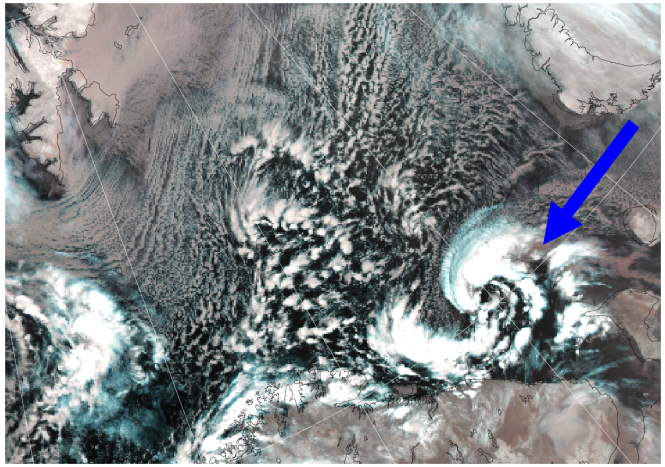


06.23UTC 21. January



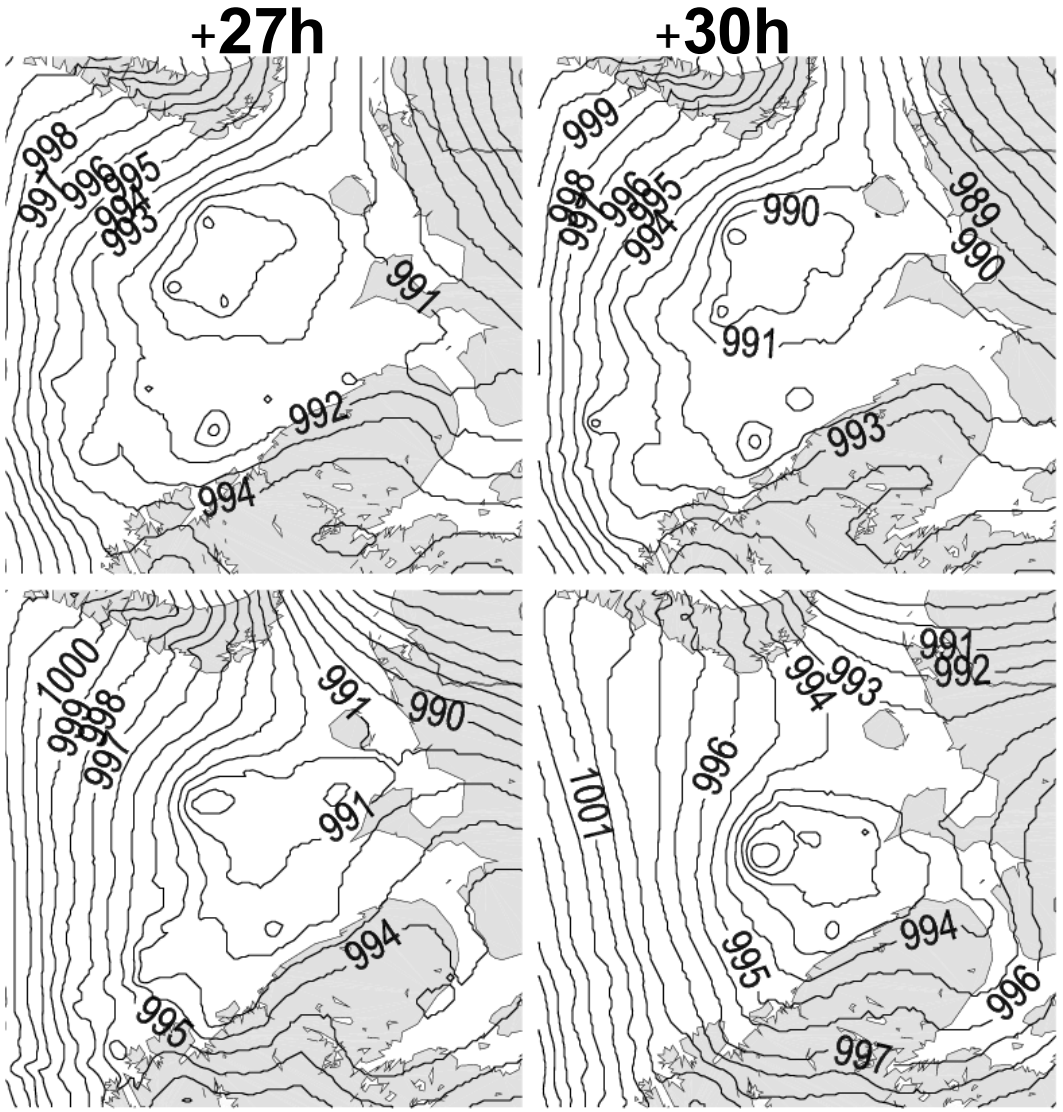


15.53UTC 21. January



01.31UTC 21. January

Uncoupled +24 to +48h forecast:



Forecast start: 20.01.2007

Windspeed?

~20m/s

Release of sens. and lat. heat?

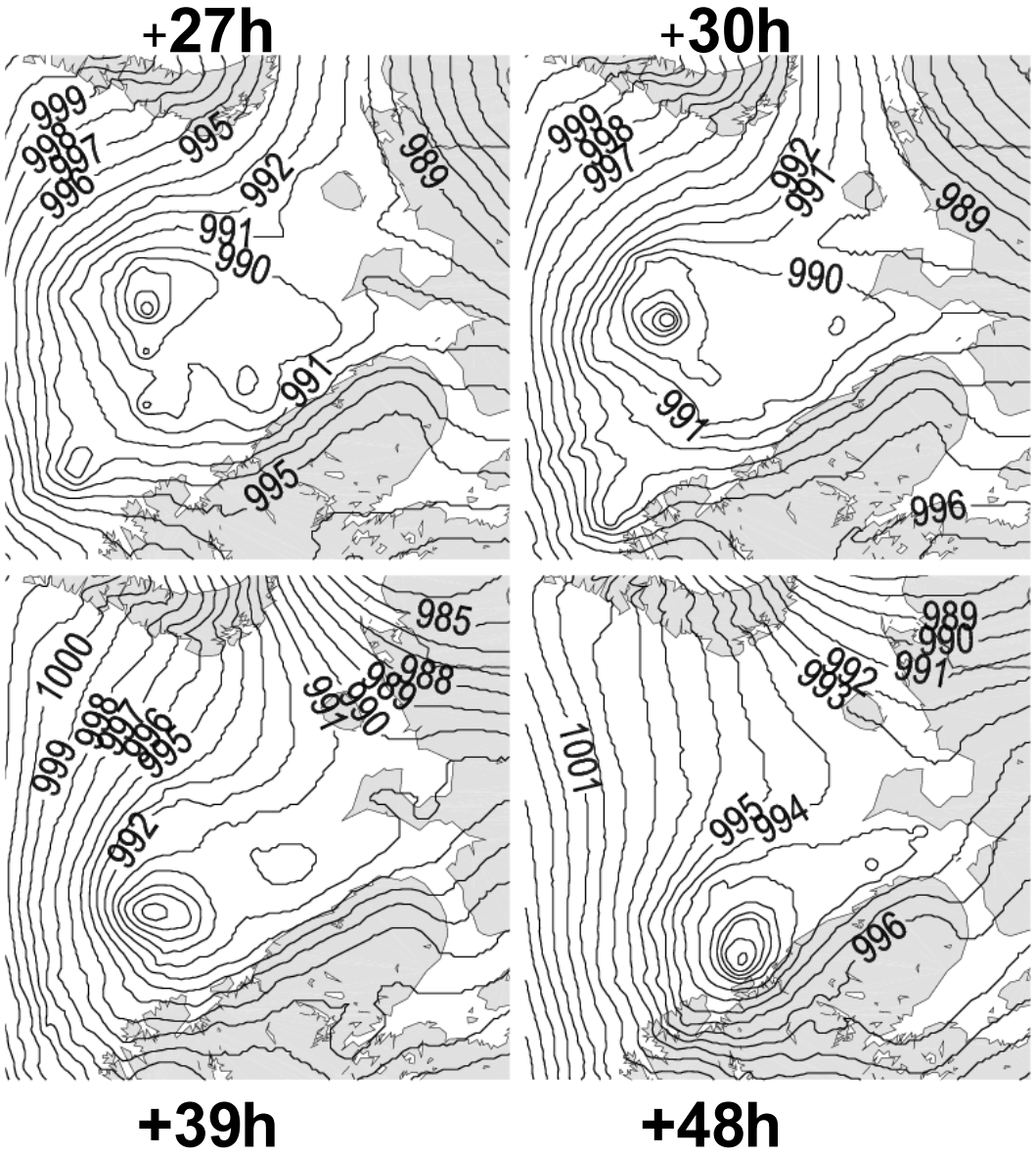
LH+SH associated with the simulated low is at a maximum ~325W/m2

The uncoupled forecast (+0 to +24) from 21.01 00UTC?

There are only minor signs of the polar low!

Is the polar low present in any of the analysis?
No.

Coupled +24 to +48h forecast:



Forecast start: 20.01.2007

Windspeed?

Max ~20m/s

Release of sens. and latent heat?

LH+SH associated with the simulated low is at a maximum ~400W/m2

The coupled forecast (+0 to +24) from 21.01 00UTC?

The polar low is present after a few hours forecast.

Is the polar low present in any of the analysis?

No, but the polar low appear after just a few hours forecast.

Additional comments:

- The coupled system show (in average) ~20% higher surface roughness over the ocean.

- The coupled system show (in average) 4.4% higher release of SH from the ocean to the atmosphere. But 1.4% less release of LH. And in combination the coupled system show (in average) 0.1% less heat release (LH+SH) from the ocean to the atmosphere.

- Coupled and uncoupled are more or less equal in quality on other reported polar lows in the period.

Summary:

- HIRLAM is coupled to the wave model WAM and an experiment over 3 winter months has been performed.
- Only minor impacts is found on the general performance of the model (MSLP, FF10m, T2m and precipitation). Can this be improved by a re-tuning of HIRLAM?
- An increased roughness length over the ocean is found, with increased release of sensible heat and decreased release of latent heat.
- A (possibly) positive impact on simulating Polar Lows is found.

Moist and heat fluxes

- Assuming a logarithmic vertical distribution, the exchange coefficient for heat (and moist) becomes

$$C_H = \sqrt{C_D}\left(\kappa / \ln\left(10 / z_T\right)\right)^2$$

- Sea state dependent trough C_D if z_T is constant
- This is still debated! Observations of fluxes show very large scatter