Singular Vectors in Hirlam

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Outline

- Set-up of the singular vector computation

- Experience thus far
  (PhD project started 1 December 2006)

- Future work

The singular vector technique (1)

- Look for perturbations of the initial state, that grow fast during a certain forecast time.

- Employ a linear version of the nonlinear forecast model. So there is a way to determine how an initial perturbation $\varepsilon(0)$ evolves into a perturbation $\varepsilon(T)$ at forecast time T: $\varepsilon(T) = \mathbf{M}\,\varepsilon(0)$

- Define a norm to measure the size of perturbations. For the moment, the 'total energy' norm has been used.

- Find an efficient eigenvalue solver.

The singular vector technique (2)

- Given this 'total energy' norm:

$$(\varepsilon, \varepsilon) = \iiint u^2 + v^2 + \alpha T^2 \, d\Sigma \, dp + \iint \beta \ln ps^2 \, d\Sigma$$

look for perturbations ε(0) that maximize

$$\langle \varepsilon(T), \varepsilon(T) \rangle = \langle \mathbf{M}\,\varepsilon(0), \mathbf{M}\,\varepsilon(0) \rangle = \langle \mathbf{M}^*\mathbf{M}\,\varepsilon(0), \varepsilon(0) \rangle$$

→ Solve eigenspectrum of $\mathbf{M}^*\mathbf{M}$

propagator of the adjoint model

The singular vector technique (3)

- Passing the adjoint test is essential:

$$< M\, \varepsilon_1 , \varepsilon_2 > = < \varepsilon_1 , M^* \varepsilon_2 >$$

- Suitable environment for SV computation: 4d-var?

  - NL run, and TL+AD models are available
  - get rid of Jo (observations) part
  - remove other possibly problematic features

Experimental Set-up

- quite similar to Hirlam 4d-var configuration, e.g.,

  (i) tangent and adjoint model with lmfsp_vdif = true
  (ii) 6h forecast (optimization) period

- area size: NLON x NLAT x NLEV = 54x40x40, with
  0.5 x 0.5 degree resolution

- case 2006030503

- software is being tested at ECMWF (still some problems with
MPI environment).

case 2006030503
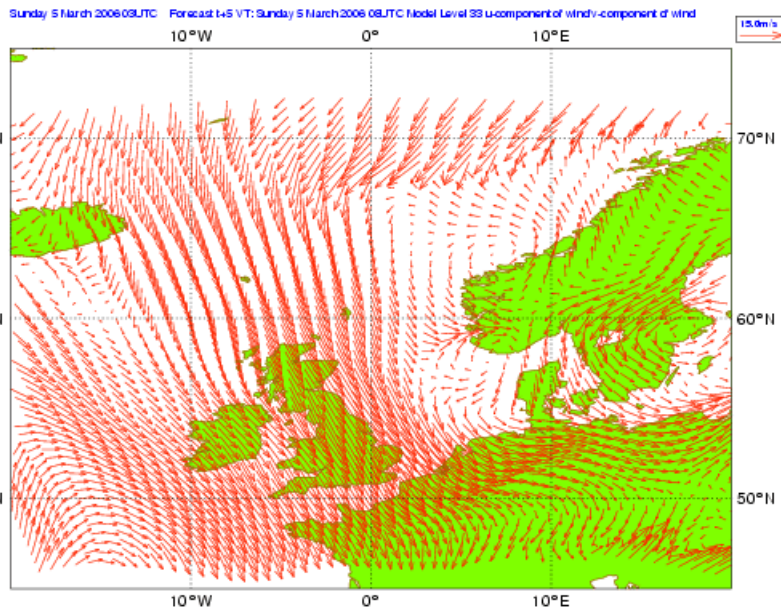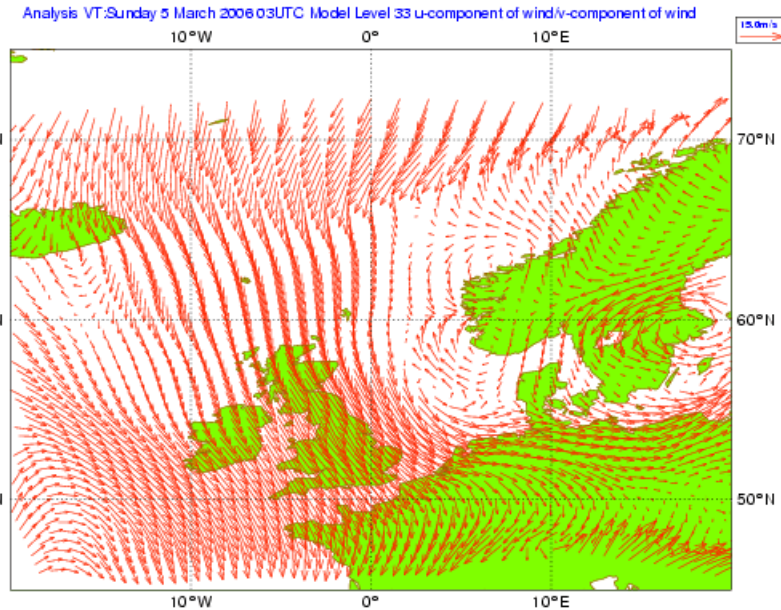
u- and v-component of wind

2006020503

+5h forecast
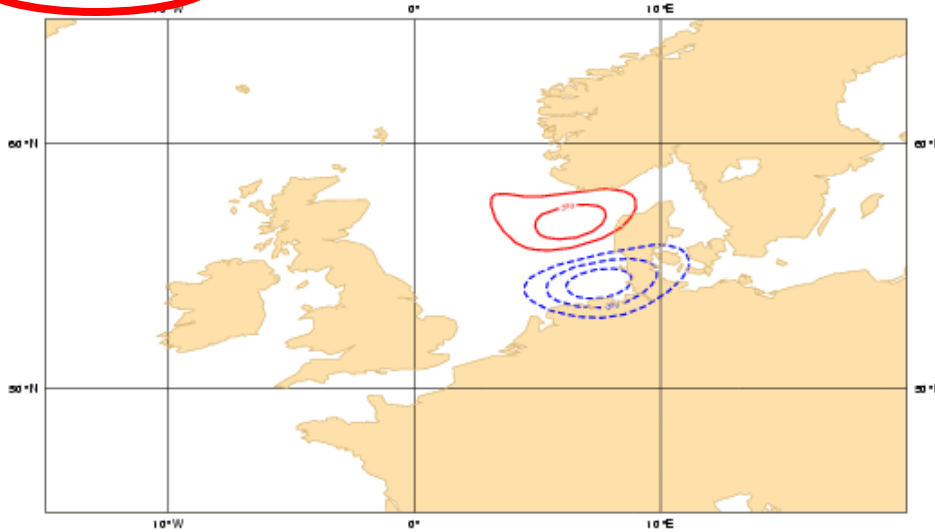
Eigenvalues of the SV operator

CASE 2006030500
Optimization time = 6h
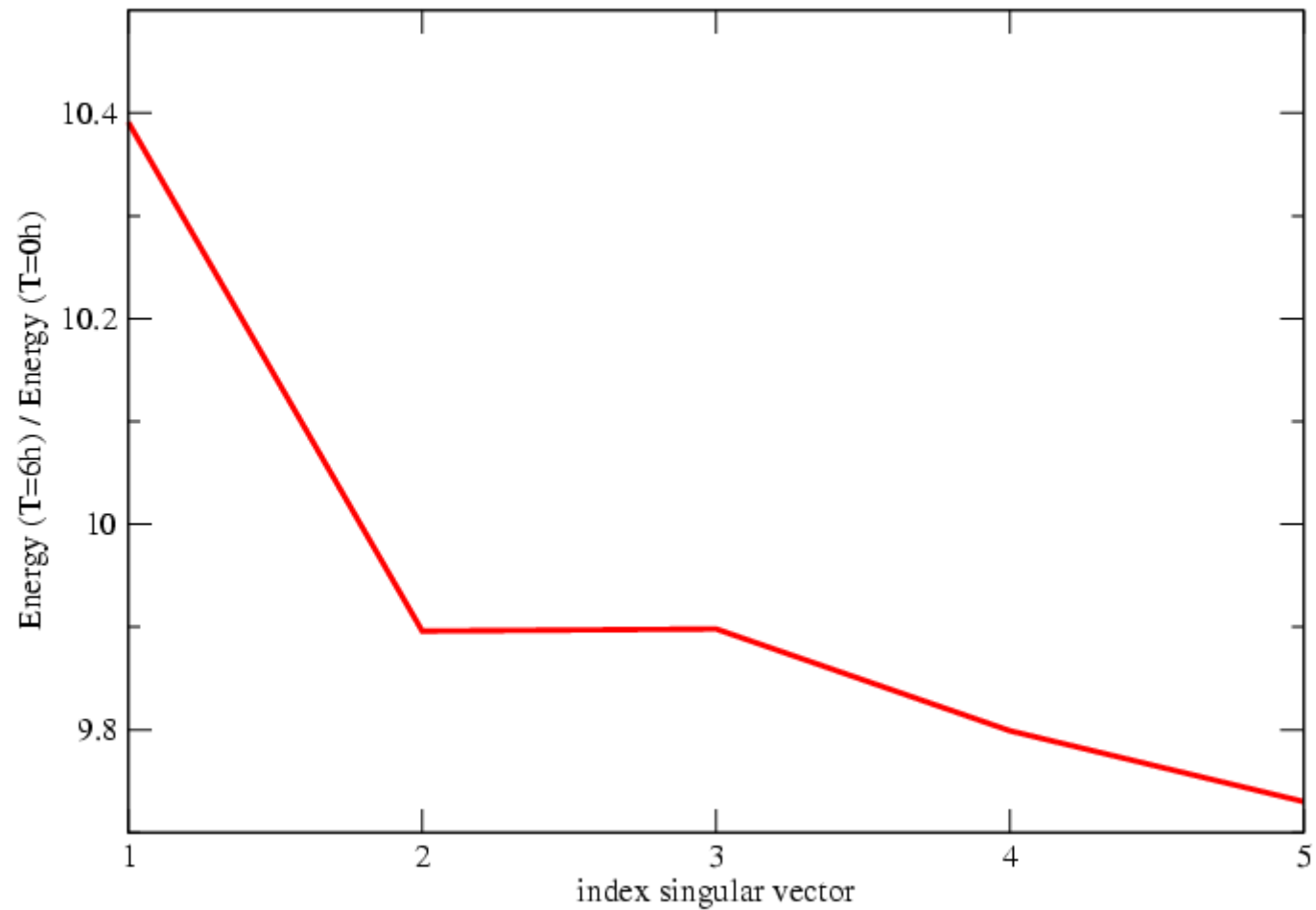
After 6h linear integration

Analysis VT:Sunday 5 March 2006 03UTC Model Level 27 temperature
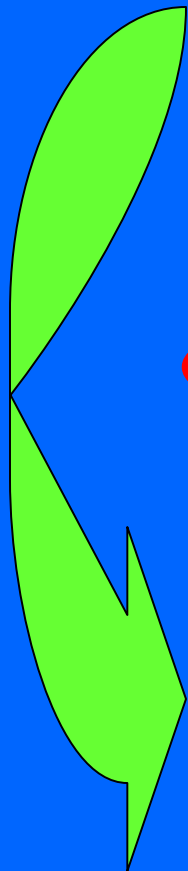
Analysis VT:Sunday 5 March 2006 03UTC Model Level 27 temperature

temperature around 800 hPa
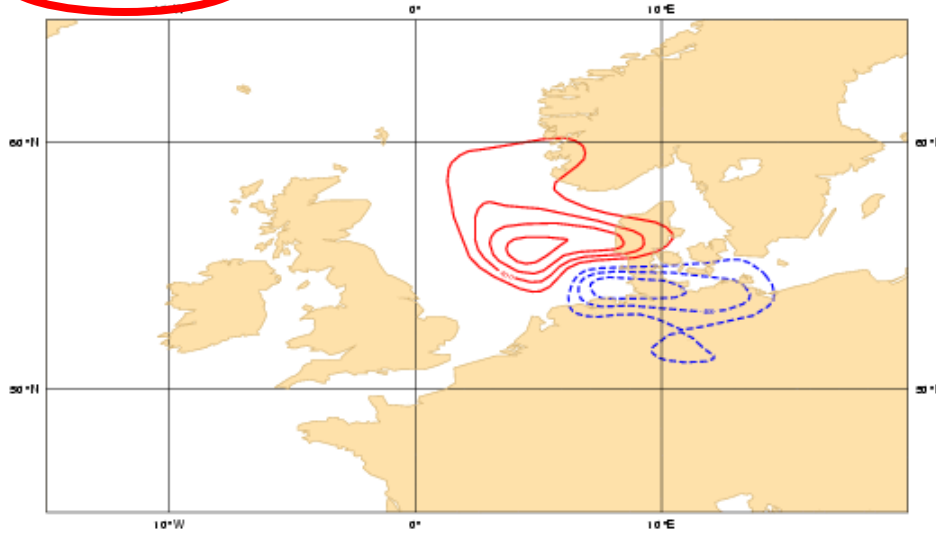
T=0h

T=6h
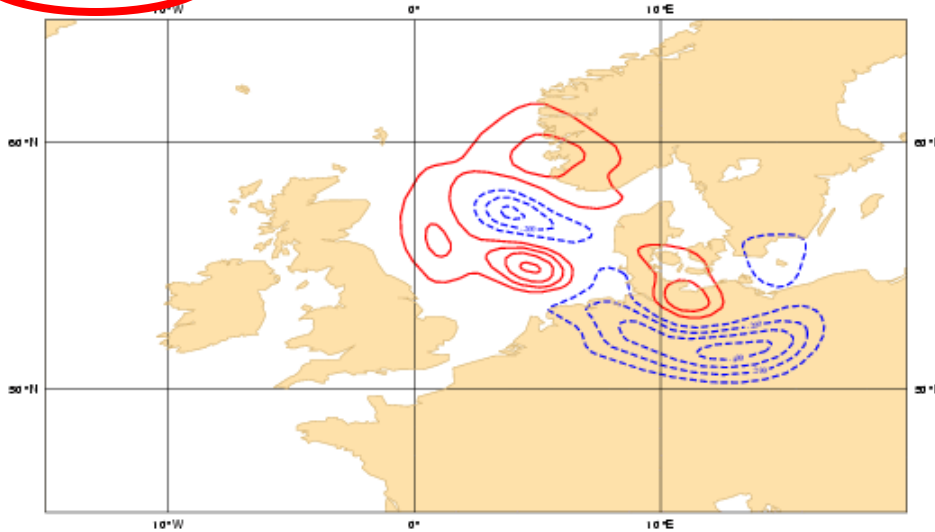
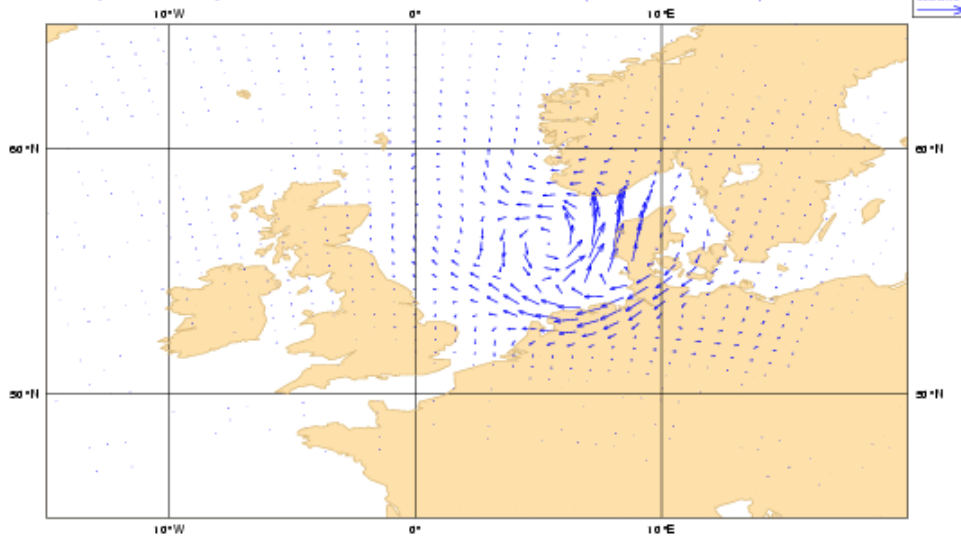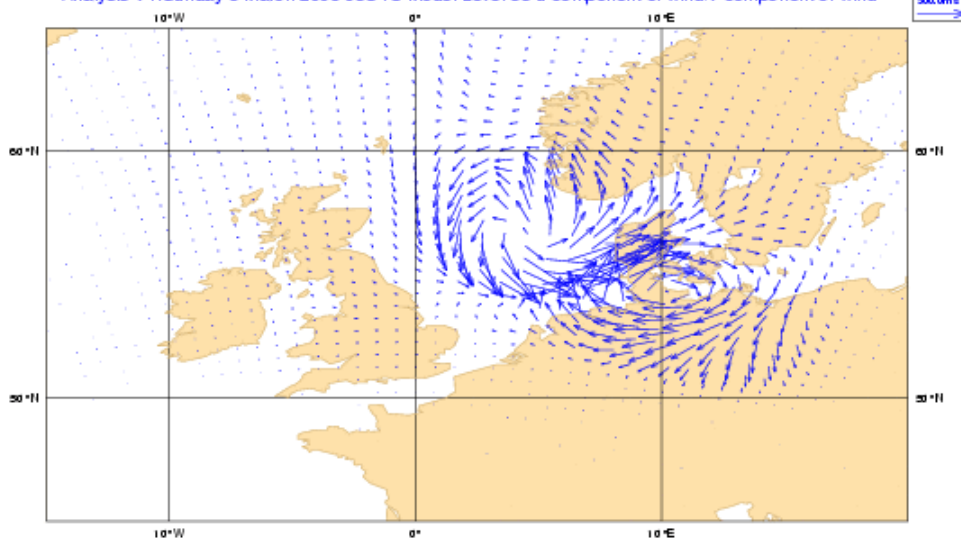Analysis VT:Sunday 5 March 2006 03UTC Model Level 33 temperature

50

Analysis VT:Sunday 5 March 2006 03UTC Model Level 33 temperature

200
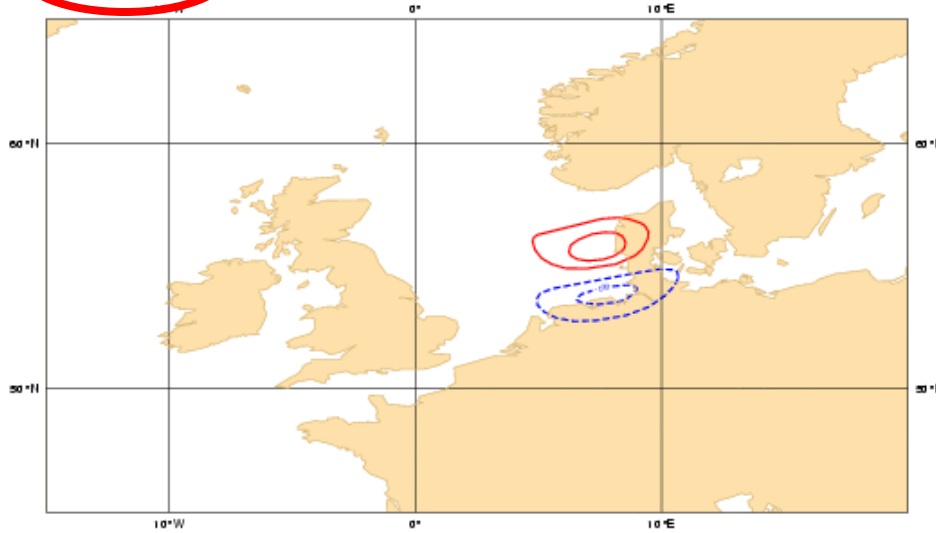
temperature around 950 hPa

T=0h

T=6h

Analysis VT:Sunday 5 March 2006 03UTC Model Level 33 u-component of wind/v-component of wind

Analysis VT:Sunday 5 March 2006 03UTC Model Level 33 u-component of wind/v-component of wind

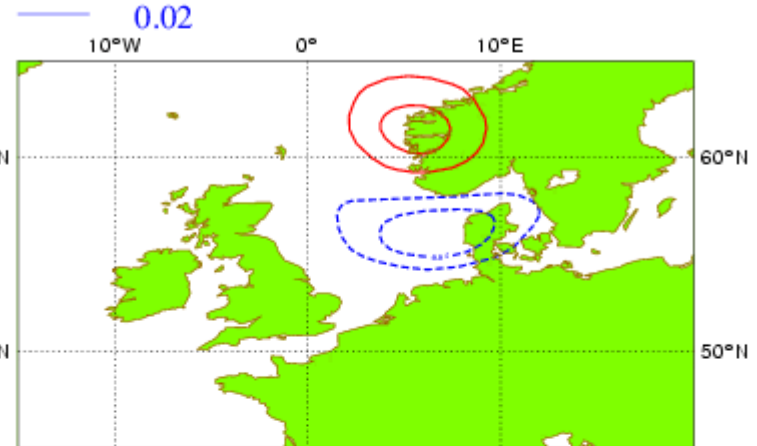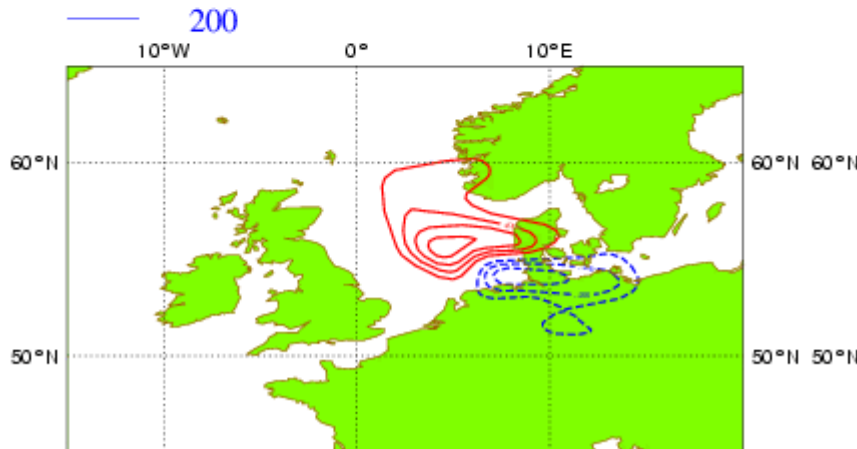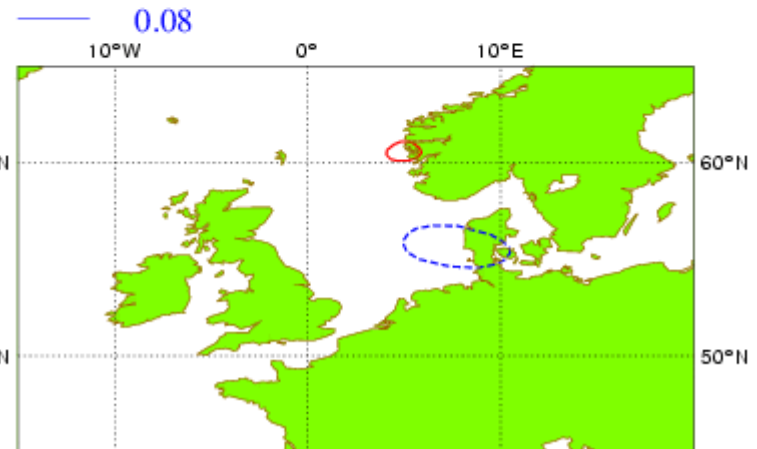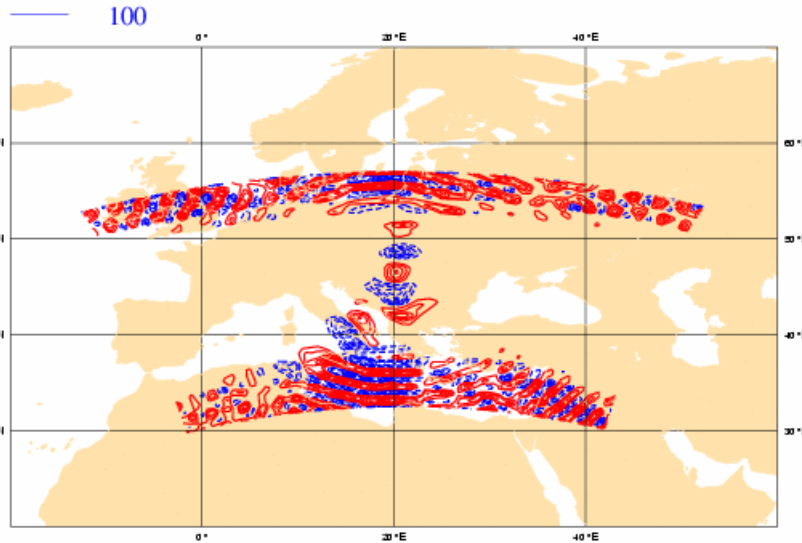u- and v- wind
at around 950 hPa

T=0h

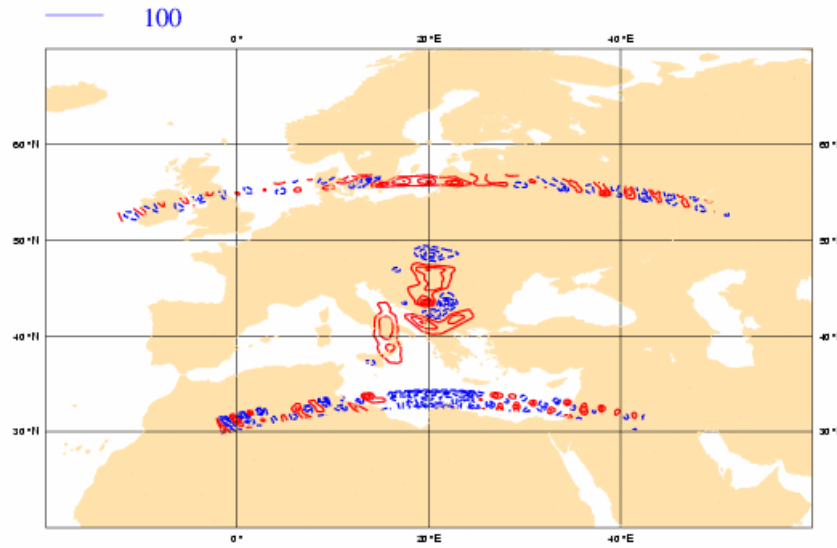T=6h

HIRLAM (0.5°) vs. ECMWF (2.0°)

Unexpected results for the 'Edit Hagen' case

After 6h linear integration

Analysis VT:Wednesday 28 June 2006 15UTC Model Level 33 temperature
100

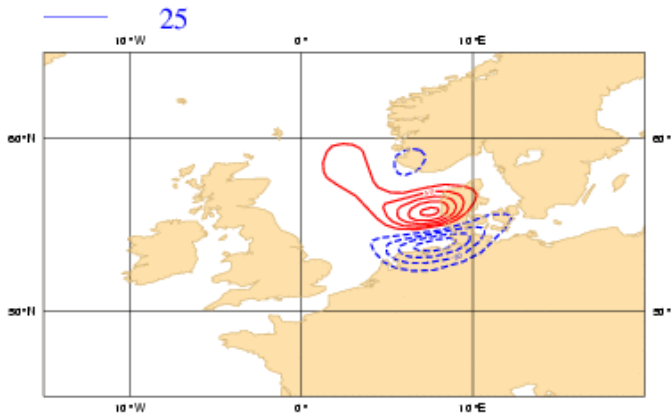Analysis VT:Wednesday 28 June 2006 15UTC Model Level 33 temperature
100

An inconsistency in the treatment of spectral arrays led to an asymmetry of the defining operator for SVs.
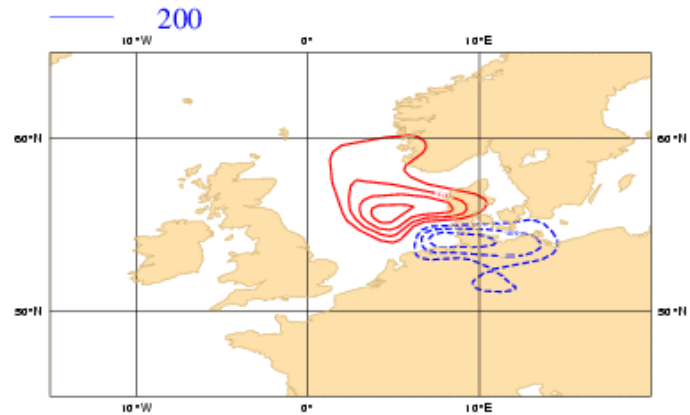
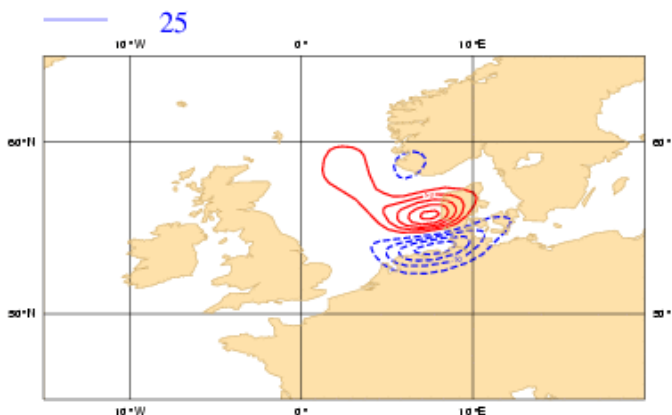**T950   for   T=0h   T=6h**

OLD

NEW

Alternative initial SV norm

"Error in analysis T level75 2007031721 "
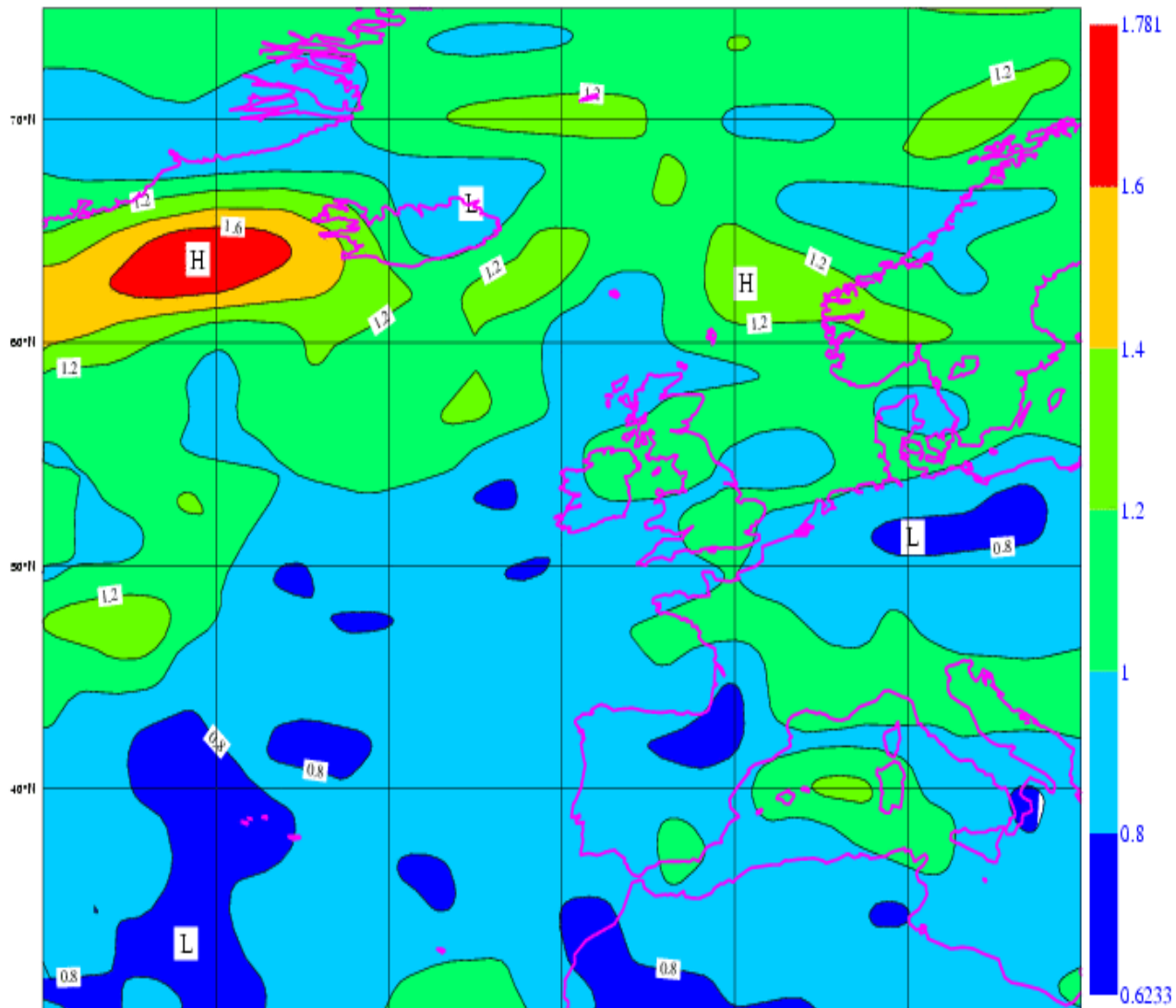
Future Plans

- Extend the SV computation to determine also

  (i)   fast-growing tendency perturbations **f:**

$$dx/dt = Hirlam(x) + \mathbf{f}$$

  (ii) and optimal boundary perturbations.

- Incorporate analysis error statistics in the SV computation

- Apply Hirlam SVs in ensemble forecasting. This will require info on the allowed amplitude of the initial perturbations (preferably from Hirlam 3d/4d-var).