Hirlam Singular Vectors
First results with CAPE-SVs

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Overview

- Singular Vectors Theory (For LAMs)
- Hirlam SVs for August 22, 2007 (Including CAPE-SV)
- Conclusions and future plans

Singular Vectors

Given the model

$$\dot{x} = g(x) \quad x(0) = x_0$$

The time evolution of small perturbations $\epsilon(0)$ of the initial condition $x(0)$ is given by

$$\epsilon(T) = M(0,T)\epsilon(0)$$

Singular vectors are those vectors $\epsilon(0)$ that maximize the ratio

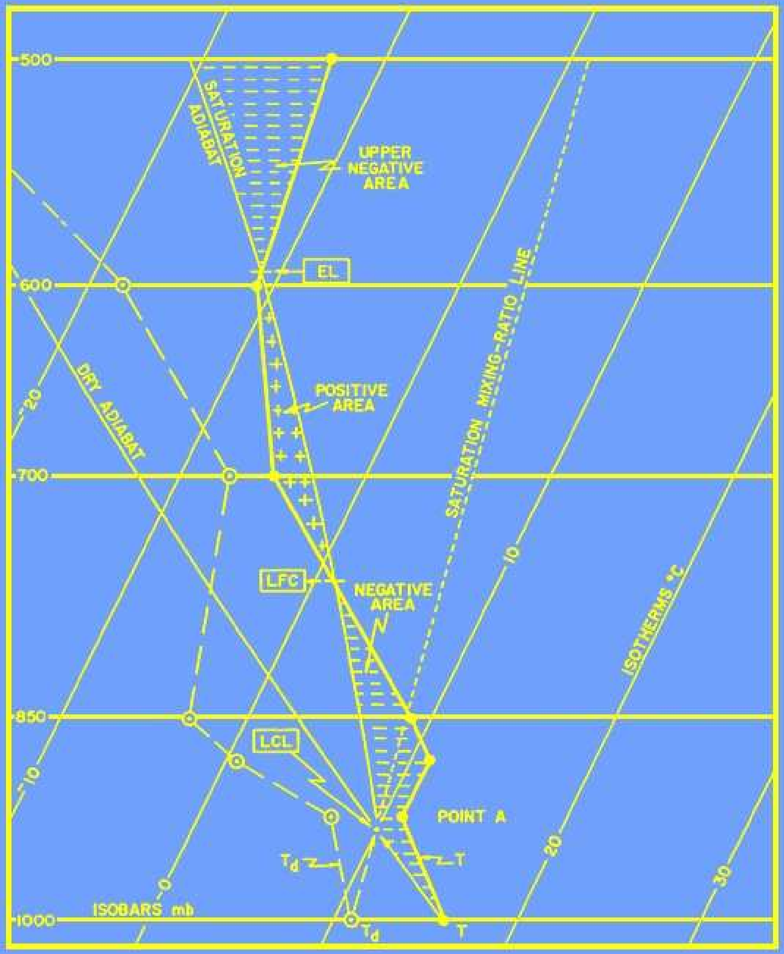
$$\frac{||P\epsilon(T)||^2_{C_1}}{||\epsilon(0)||^2_{C_0}}$$

for given projection P and norms $||\cdot||_{C_1}$ and $||\cdot||_{C_0}$.

Initial and final time norm

1. Ideal case: initial time norm is (approximation of) inverse of analysis covariance matrix
2. At ECMWF the (dry) total energy norm is the default initial and final time norm
3. For LAMs ??? (see case study)

Convective Available Potential Energy (CAPE)



Three ways to define parcel

- Surface-based parcel (Hirlam)
- Most unstable parcel (found in the lowest 500 hPa of the atmosphere) (Hirlam)
- Mean conditions in the lowest 50-100 hPa (ECMWF)

No consensus on how to define parcel. Mean conditions seem most appropriate to determine convection[1]

[1] http://www.spc.noaa.gov/exper/mesoanalysis/help/begin.html

CAPE Final time norm

Given a subroutine $\mathcal{C}$ that computes CAPE

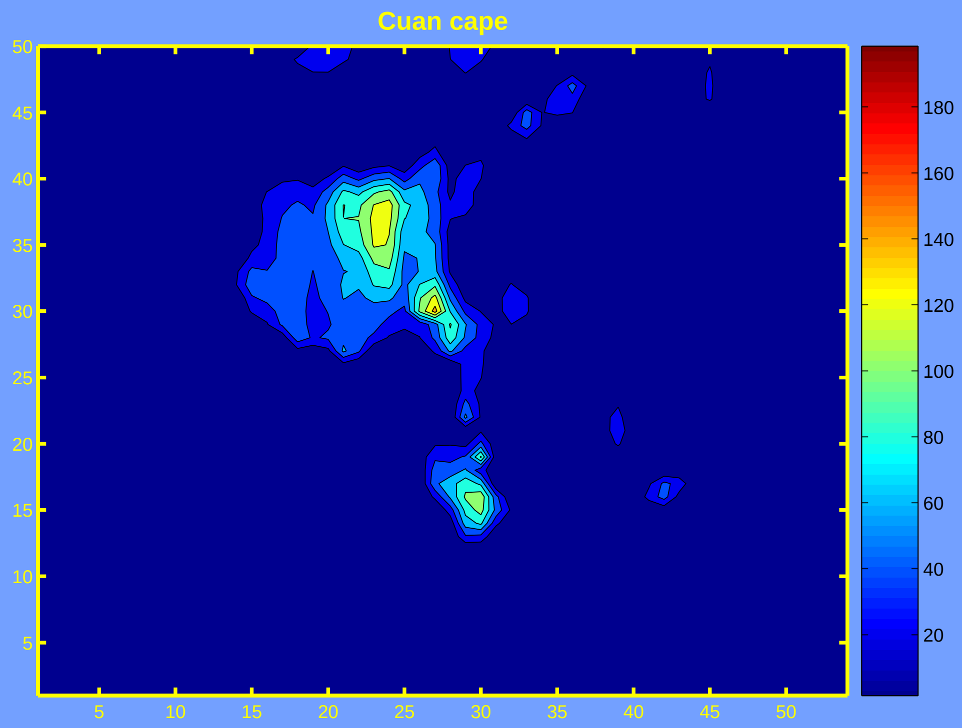
$$(T, q) \mapsto \mathcal{C}(T, q)$$

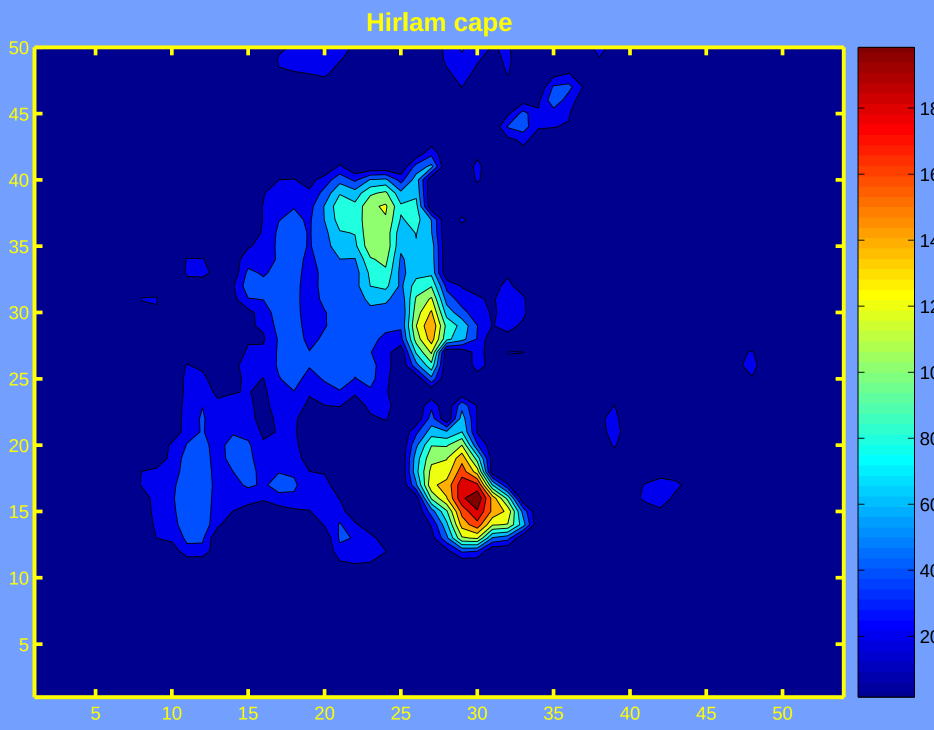
and the corresponding TL and AD -versions C, C^*.
We look for perturbations that maximize

$$\frac{||C\epsilon(T)||^2}{||\epsilon(0)||^2_{C_0}}$$

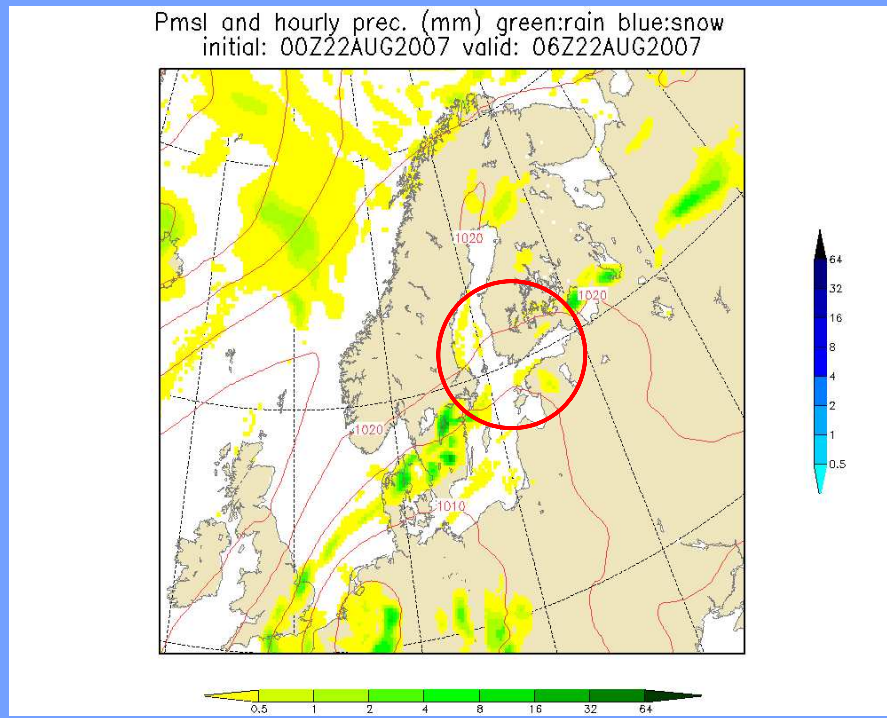
Here C and C^* are derived from an approximate CAPE-calculation used in the operational ECMWF-model using an automatic code generation tool.

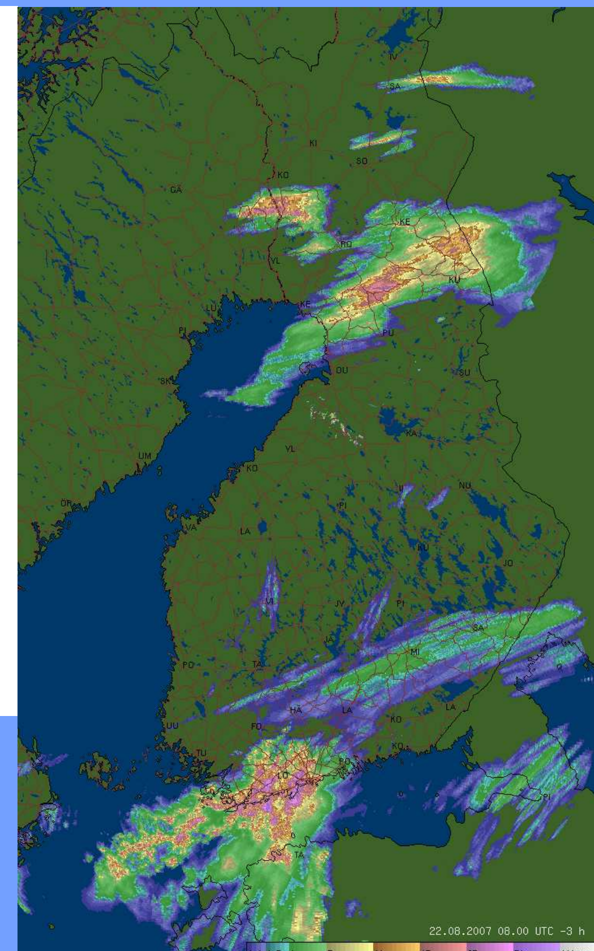
Hirlam CAPE vs ECMWF CAPE at 2006-03-05





Aug. 22, 2007 6UTC: Forecast and measurements





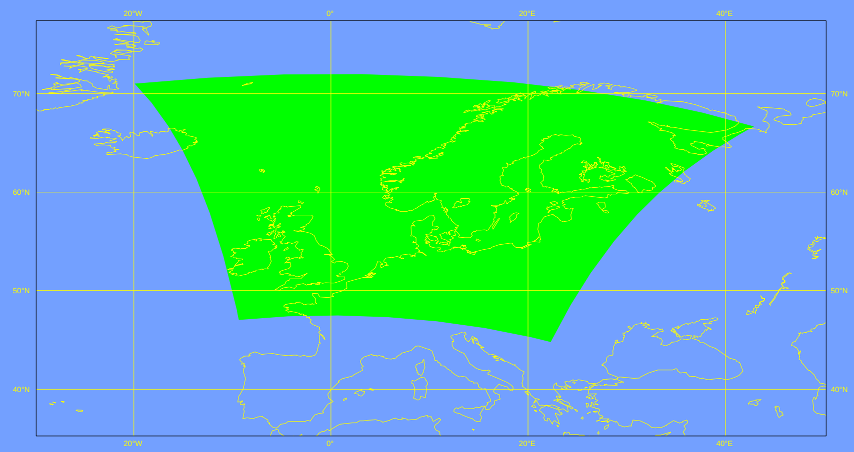
Hirlam failed to forecast this thunderstorm in any cycle verifying at the same time

Could a Hirlam EPS have anticipated this storm?

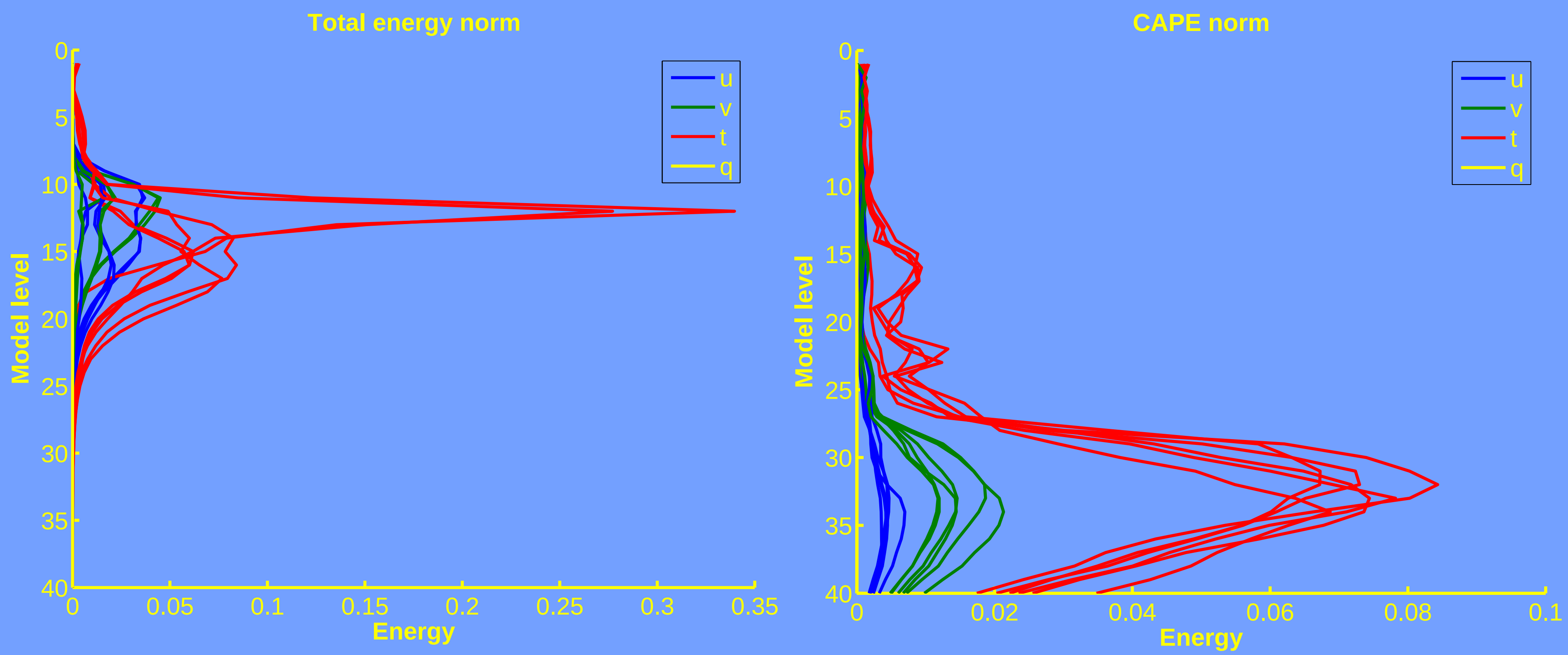
(Pictures from T. Iversen)

SV Experimental setting

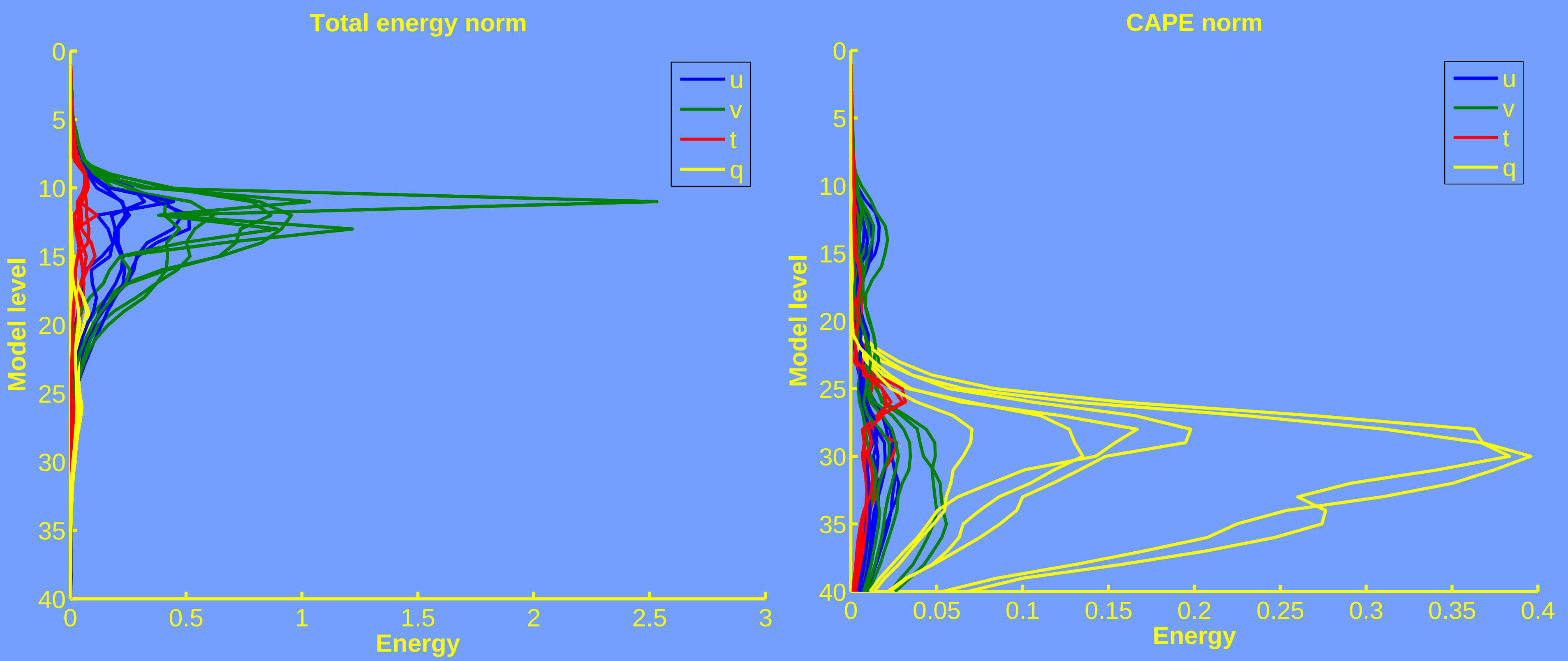
- Resolution: $0.5° \times 0.5°$
- Start 21 Aug 2007 15 UTC
- Optimization time: 12 h
- Dry total energy norm at initial time
- Cape/TE-norm at final time
- Adjoint model uses Meteo France simplified physics:
  - Condensation
  - Vertical diffusion



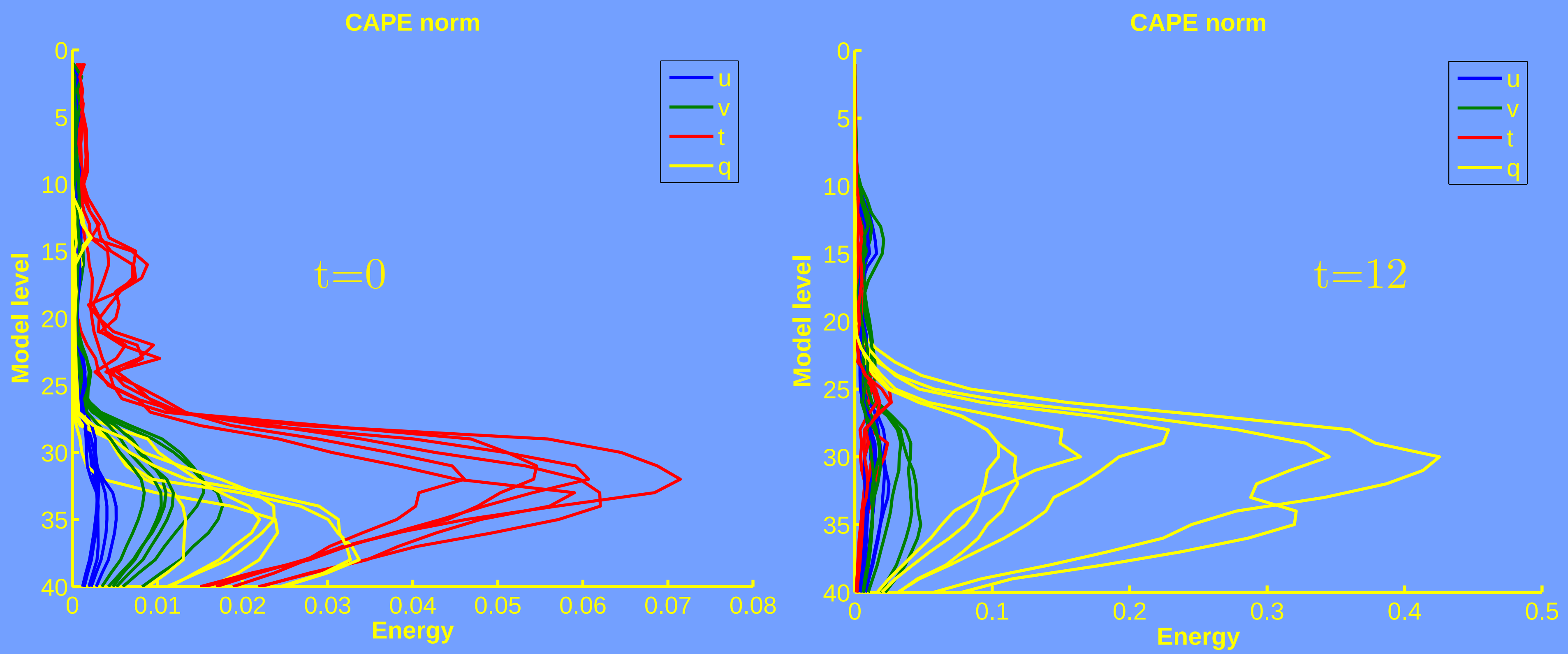
Vertical Energy distribution t=0



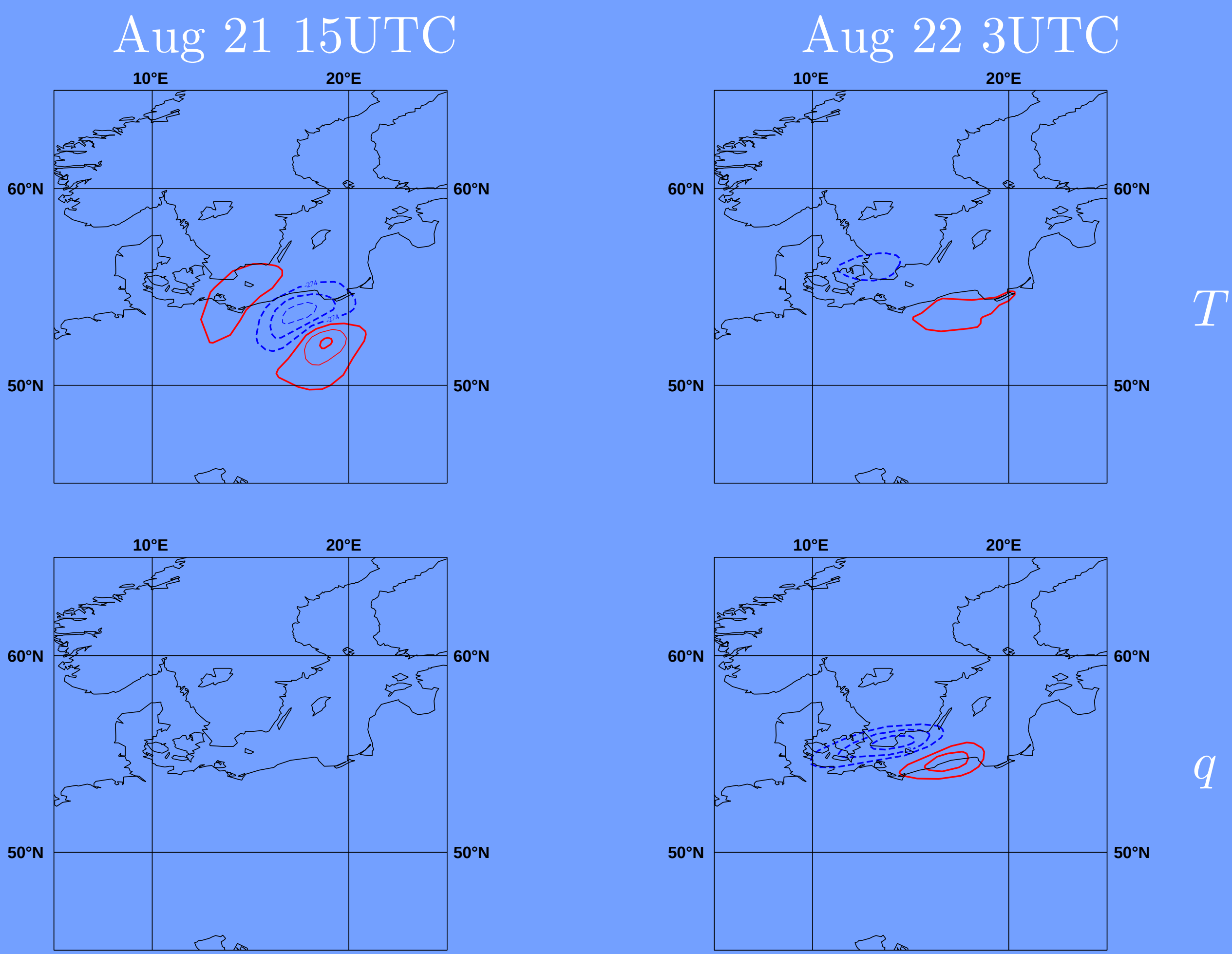
Vertical Energy distribution t=12h



Vertical Energy distribution moist CAPE-SV

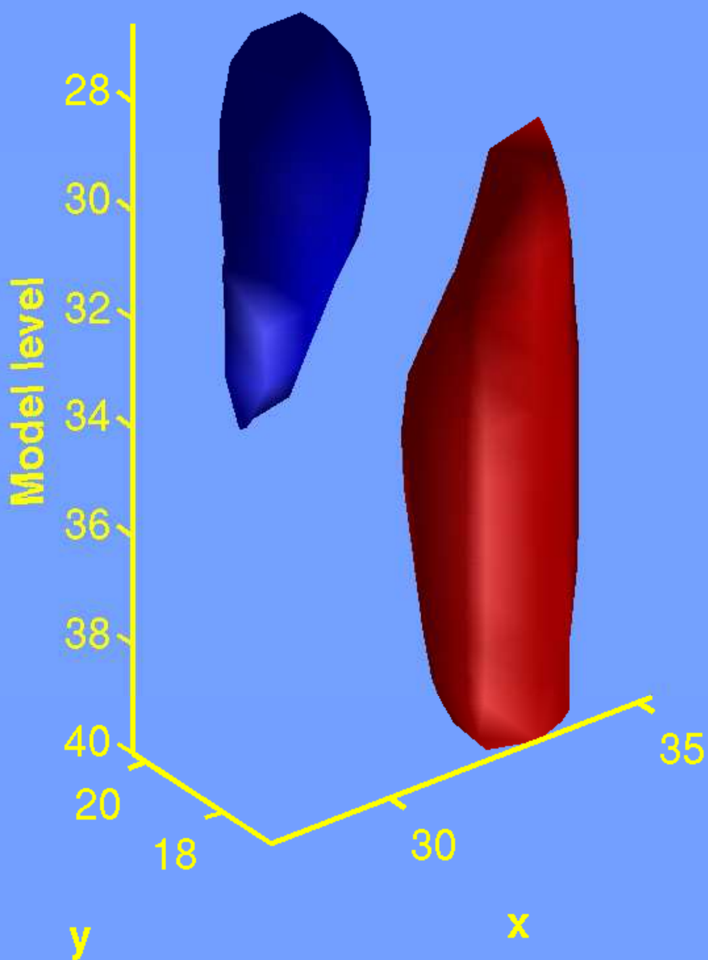


Leading CAPE-SV at level 30 (850 hPa)

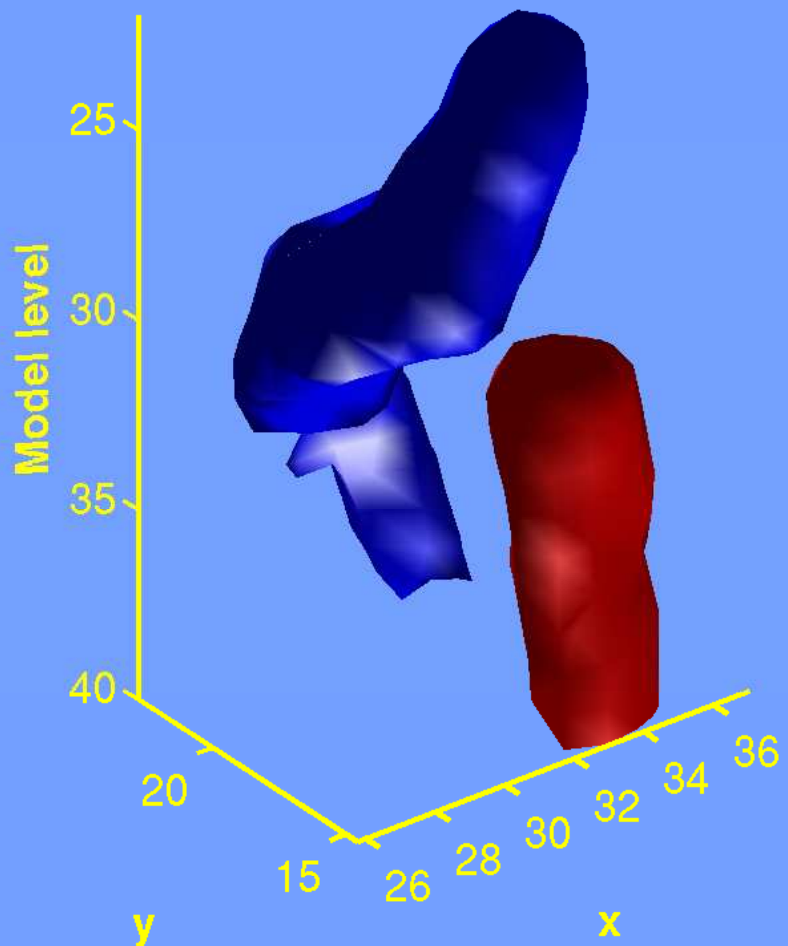


3D structure of leading evolved CAPE-SV

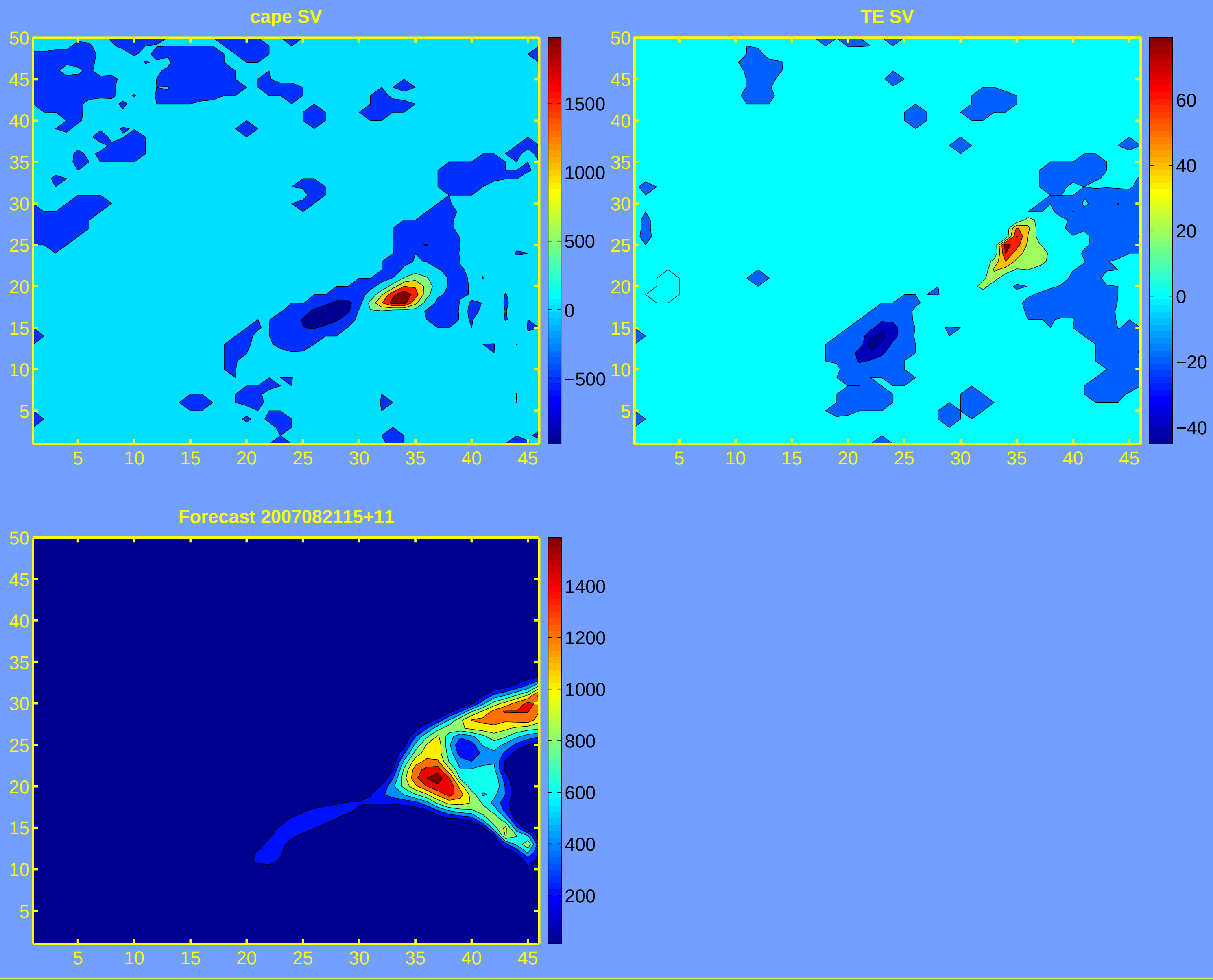
50 % Energy contour q



50 % Energy contour T



CAPE of leading evolved CAPE/TE-SV



Conclusions

From this case study

- All SVs indicate that CAPE in the region south west of Finland was sensitive to perturbations in the initial condition
- An EPS based on CAPE-SVs would have shown a large spread in CAPE and related variables in this region
- The SVs were optimized for 3UTC. The storm moved in to Finland from the south west at 6UTC Therefore it is likely that a Hirlam-EPS could have anticipated the storm

In general

- For predicting deep convection total energy does not appear to be an appropriate final time norm.
- For local area models the choice of the initial but especially the final time norm is still an open issue

Future research

- Extend SV-code to allow for forcing SVs calculations (Fastest growing tendency perturbations)

- Can a CAPE-SV/EPS system identify the August 22nd storm (Sibbo)
- What is the relative role of IC and model errors
- What is the difference between model parameter perturbations and tendency forcing perturbations
- What is the effect of using other stability indices as final time norm. Should CIN be included in the CAPE computation? How?