Properties of Singular Vectors using Convective Available Potential Energy as final time norm[1]

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Ole Vignes and Xiaohua Yang

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Overview

- Theory
  - Singular vectors
  - CAPE and SCAPE (semi) norms
- Case study (GLAMEPS period: 15 – 30 Aug. 2007 Including convective system in Finland on the 22nd)
  - Singular values
  - Structure TE-SVs versus CAPE-SVs
  - Test linearity assumption
- Conclusions and future plans

Singular vectors

> Singular vectors are initial condition perturbations that have maximum impact on a prescribed forecast aspect.

Assume forecast errors $\delta x(t_1)$ are linearly related to errors in the analysis $\delta x(t_0)$

$$\delta x(t_1) = \mathrm{M}(t_0, t_1)\delta x(t_0)$$

Singular vectors are those structures $\delta x(t_0)$ with $||\delta x(t_0)||_E^2 = 1$
That maximize

$$||P\delta x(t_1)||_C^2$$

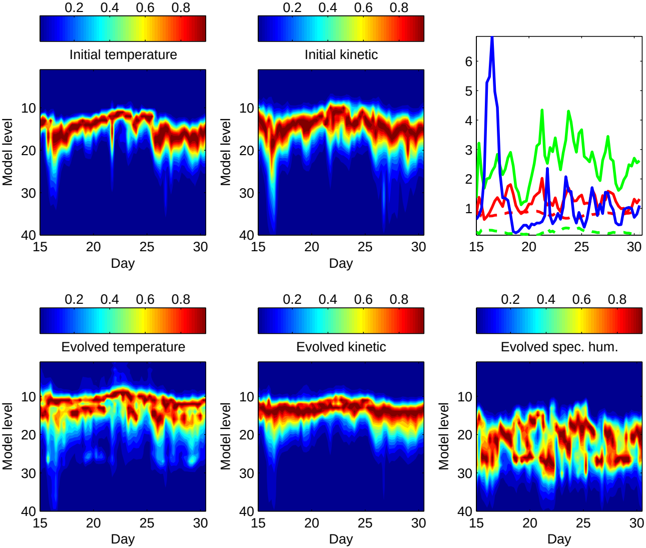
Where P is a projection operator.

Singular vectors and EPS

The ensemble members of the ECMWF EPS are constructed from total energy SVs and is currently the most successful global EPS.

- Can we use TE-SVs in short range EPS
- Is the tangent linear assumption valid at high resolutions
- Are there better (structured) methods to obtain i.c. perturbations

TE-SVs (OT=12h) GLAMEPS period



PhD thesis E. Hágel percentage outliers using TE-SVs in SREPS is too high near the surface (TE-SVs not suitable for SREPS)

High impact weather/Deep convection

One of the main objectives of LAM is accurately forecasting high impact weather. Almost all severe local storms are associate with deep convection and require three necessary ingredients:

1. A moist layer of sufficient depth
2. A steep enough lapse rate
3. Sufficient lift of a parcel to reach its level of free convection

In general the large scale flow creates the favorable thermodynamic environment (1 and 2) while the mesoscale provides the lift (3) needed to initiate convection. The requirements (1) and (2) can be understood in terms of CAPE (see Doswell III (1987)).
Can we construct EPS members that focus on predictability of CAPE?

CAPE and SCAPE semi norms

Let x_r denote the model state and $\mathcal{C}(x_r)$ the corresponding CAPE values. Perturbations δx of the model state x_r lead to CAPE perturbations $\delta\mathcal{C}$

$$\delta\mathcal{C} \approx \left.\frac{\partial\mathcal{C}}{\partial x}\right|_{x_r} \delta x \equiv C_{x_r}\delta x = \delta C$$

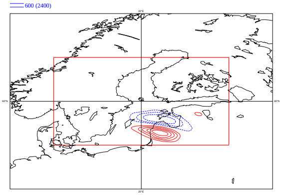
Then the CAPE (semi) norm is defined as

$$\sum_{i=1}^{nlon}\sum_{j=1}^{nlat} \delta C(i,j)^2 = (\delta C, \delta C)$$

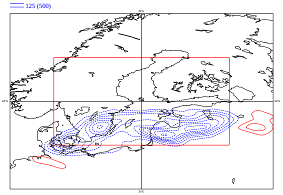
and CAPE-SVs maximize the sum of squared CAPE values inside a projection domain.

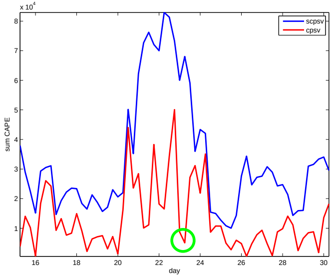
CAPE and SCAPE semi norms

CAPE field evolved CAPE-SV



CAPE field evolved SCAPE-SV



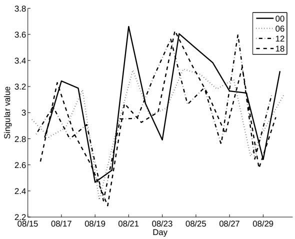


The SCAPE-SVs maximize the sum of CAPE (inside the projection domain)

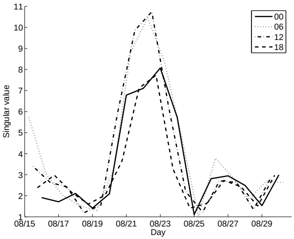
- CAPE-SVs maximize CAPE RMSE
- SCAPE-SVs maximize the CAPE bias

SCAPE-SVs are easier to calculate because there is no need to solve and eigenvalue problem

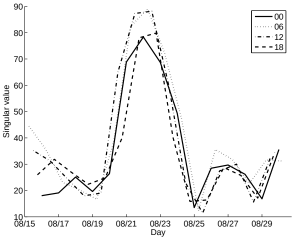
Singular values



TE-SV

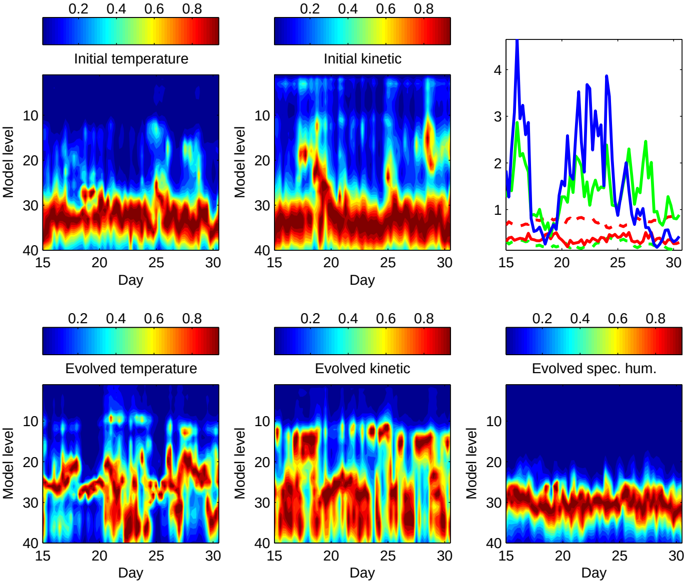


CAPE-SV

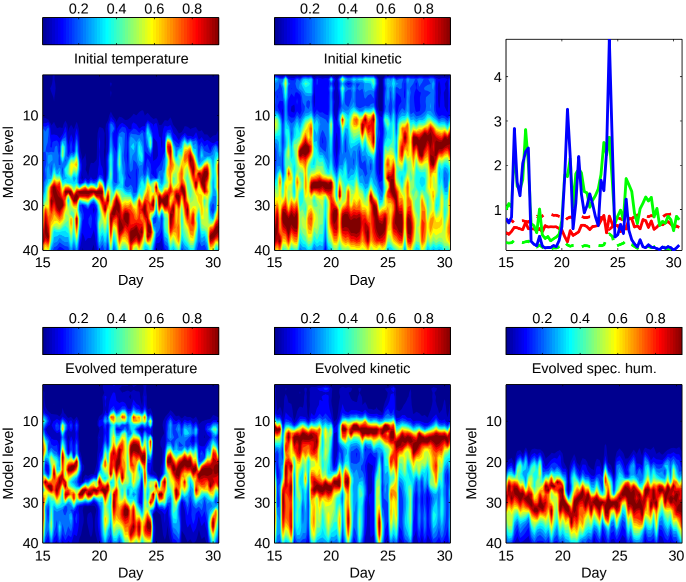


SCAPE-SV

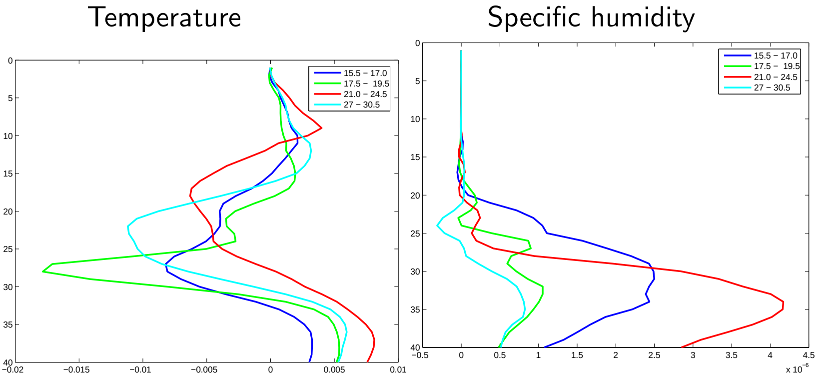
CAPE-SV GLAMEPS period



SCAPE-SV GLAMEPS period



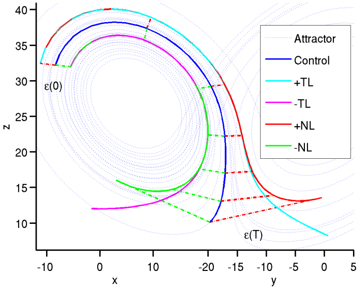
Averaged vertical profiles of q and t

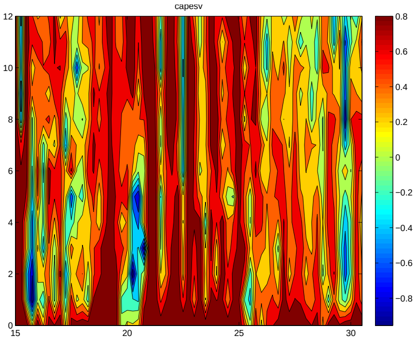


SCAPE-SVs are beneficial to all three necessary ingredients for deep convection

- Sufficient moisture in lower troposphere
- A steep enough lapse rate
- Sufficient lift of a parcel to reach the LFC (CIN decrease).

Similarity index (Is the TL assumption valid?)

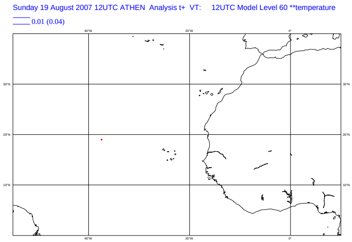


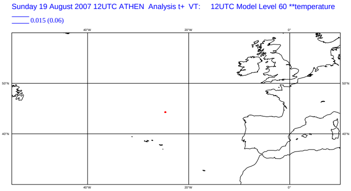


CAPE SV scaling: max Temp perturbation 0.5 K

Rapid loss of linearity for some days while almost perfect results at other days.

Twin experiment T perturbation level 60 (7.3beta3)



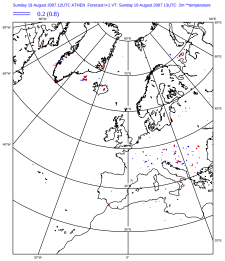


Exp a Exp b c d

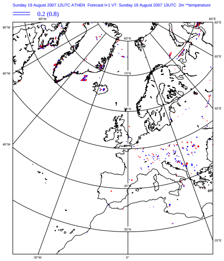
Starting from ECMWF analysis but without DFI.

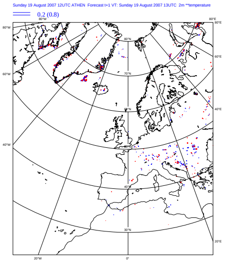
Twin experiments T2m differences at fc+1h

a) Max T diff 4.8 (init 0.1)

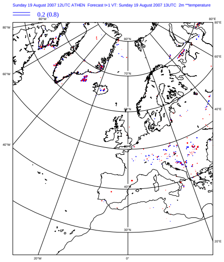


b) Max T diff 5.9 (init 0.1)





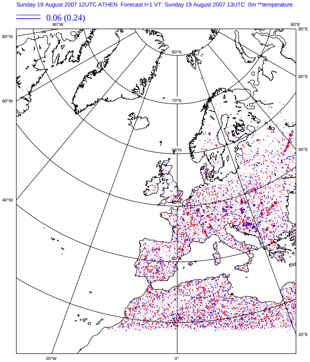
c) Max T diff 3.3 (init 1)



d) Max T diff 4.7 (init 0.01)

Twin experiment Max temperature differences fc+1h

Level	a	b	c	d	nophys
60	0.3	0.4	0.4	0.4	0.15
T2M	4.8	5.9	3.3	4.7	-
T surface	3.0	3.8	3.4	2.9	0



using 100 contourlines

Conclusions

- TE-SVs for short EPS
  - TE-SVs using short OT are situated in the higher troposphere and are probably inappropriate i.c. perturbations for SREPS
- CAPE-SVs
  - CAPE-SVs are situated in the lower troposphere and can inform about instabilities for unstable thermodynamic profiles.
  - This makes them a suitable candidate for SREPS focussing on predictability of high impact weather.
  - The impact of CAPE-SVs on convective precipitation is twice as large compared to TE-SVs (Not shown preliminary result)
- Optimal perturbations (SCAPE-SVs)
  - The SCAPE-SVs are obtained by one backward integration of the adjoint model (Faster/Simpler).
  - We can select shorter optimization times for norms related mesoscale aspects of the forecasts
  - Each member is unique: this information can be used to gradually improve the norms

Future research

- Study the impact of CAPE-SVs on precipitation
- Investigate the loss of linearity
- Other indices (Lifted index,CIN, etc.) to derive final time norms to construct EPS-members that focus on particular forecasts aspects