Norwegian Meteorological Institute

24th ALADIN Workshop & HIRLAM ALL STAFF Meeting

7-10 April 2014
Bucharest, Romania

Problems (and Solutions? ...)

Jelena Bojarova & the HIRLAM Team

HIRLAM + ALADIN = HARMONIE

Devoted to Gert-Jan Marseille

&

All people who are not indifferent and
who are not afraid to question....

More About Problems....

No job
No money
No house
No husband

!

NO
PROBLEMS

Problem Number 1

An Attack:

*"HARMONIE DA with 3h RUC **does not help to improve** HARMONIE forecast. Why? Either the information content from previous observations is not captured by the system or the (unrealistic) small scale structures overwhelm the analysis increment already after 3 hours?"*

A disappointed DA scientists, Gert-Jan Marseille

A quick reaction:

*"In my view the problem is not related to small scale feature that the HARMONIE model cannot handle in the data assimilation, but related to systematic errors in the physics that make **data assimilation difficult or impossible**."*

A brave senior mathematician, Nils Gustafsson

In any case, the evidence is here :

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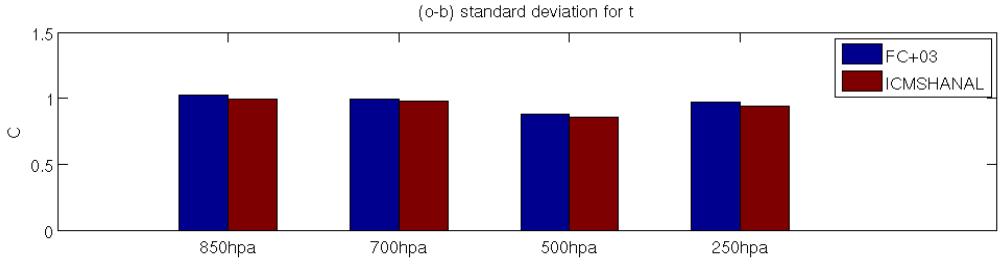

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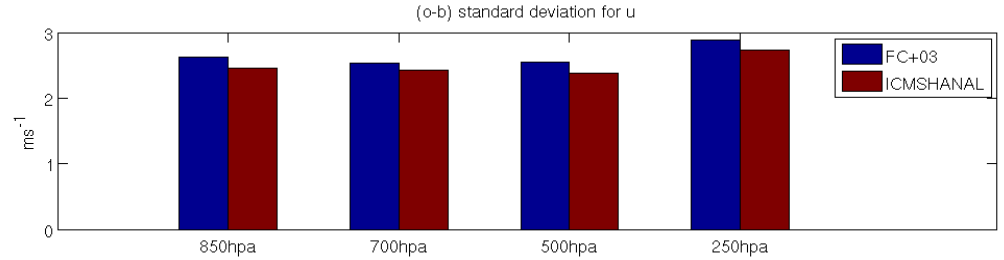

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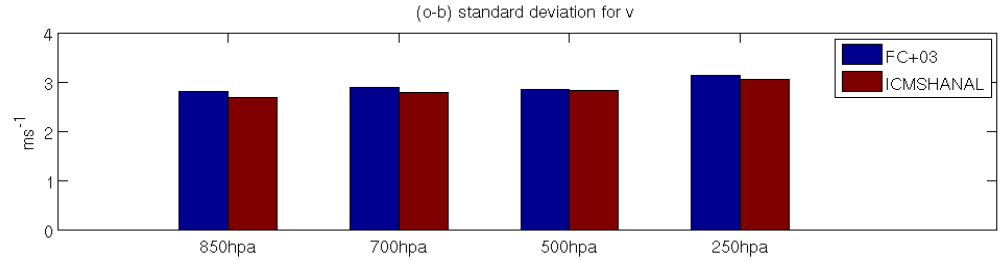


850hPa 700hPa 500hPa 250hPa

Analysis error verified against AIREP observations

HARMONIE FC+3

HARMONIE FC+3 + LSM ECMWF

HARMONIE AROME 3DVAR 3hRUC
ECJAN domain;
800x800, 2.5km,
conventional + scatterometer winds
(from Gert-Jan Marseille)

The truth lies always somewhere in between, doesn't it ?...

What is wrong essentially

→ 1) structure functions?
→ 2) unrealistic small scale structures?
→ 3) systematic errors (model biases) ?

Let's take a look at structure functions

Example, ECMWF 500 hPa kinetic energy spectra for different forecast lengths, when a T7999 (2.5 km) model is initialized from T1279 (16 km) data.

From Wedi et al. (2012)

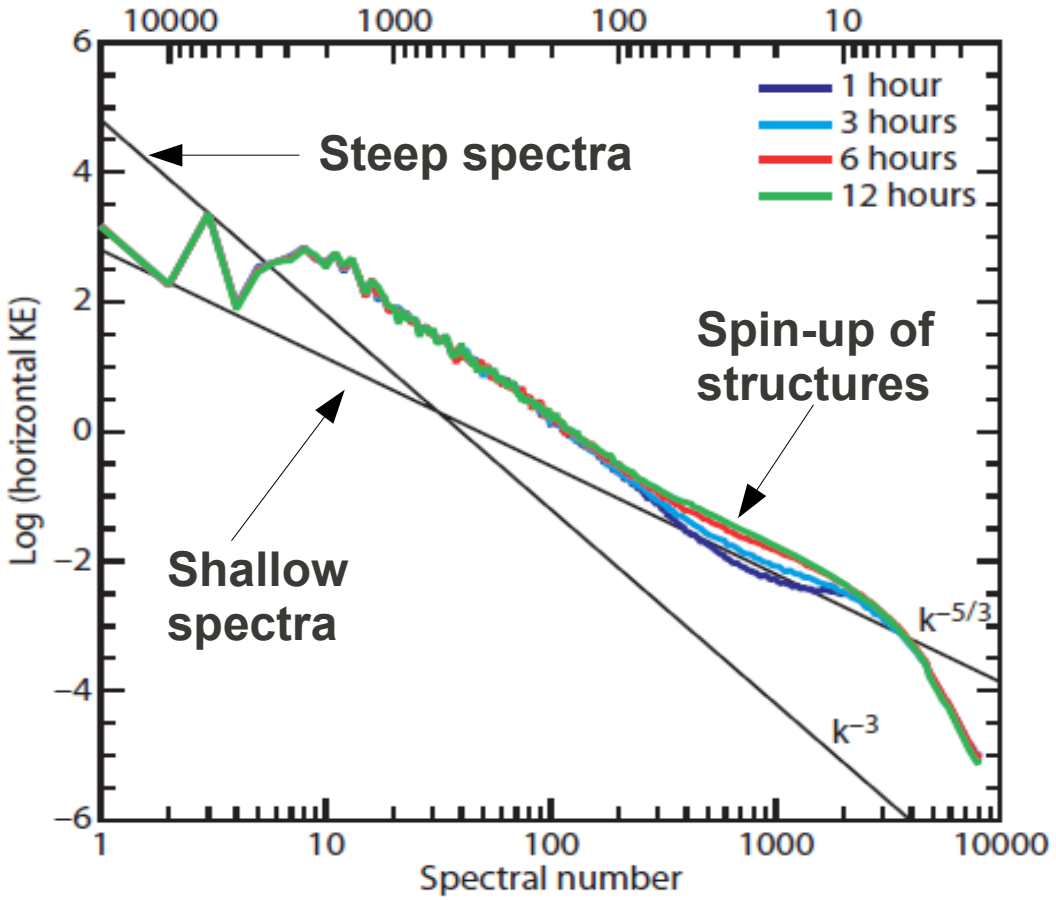


Figure 2 Global horizontal kinetic energy spectra at 500 hPa height for the first 12 hours of the T7999 (~2.5 km grid length) simulation against the total wavenumber (with the largest number corresponding to the truncation limit of the spherical harmonics series expansion, i.e. 7999).

Let's take a look at structure functions (2)

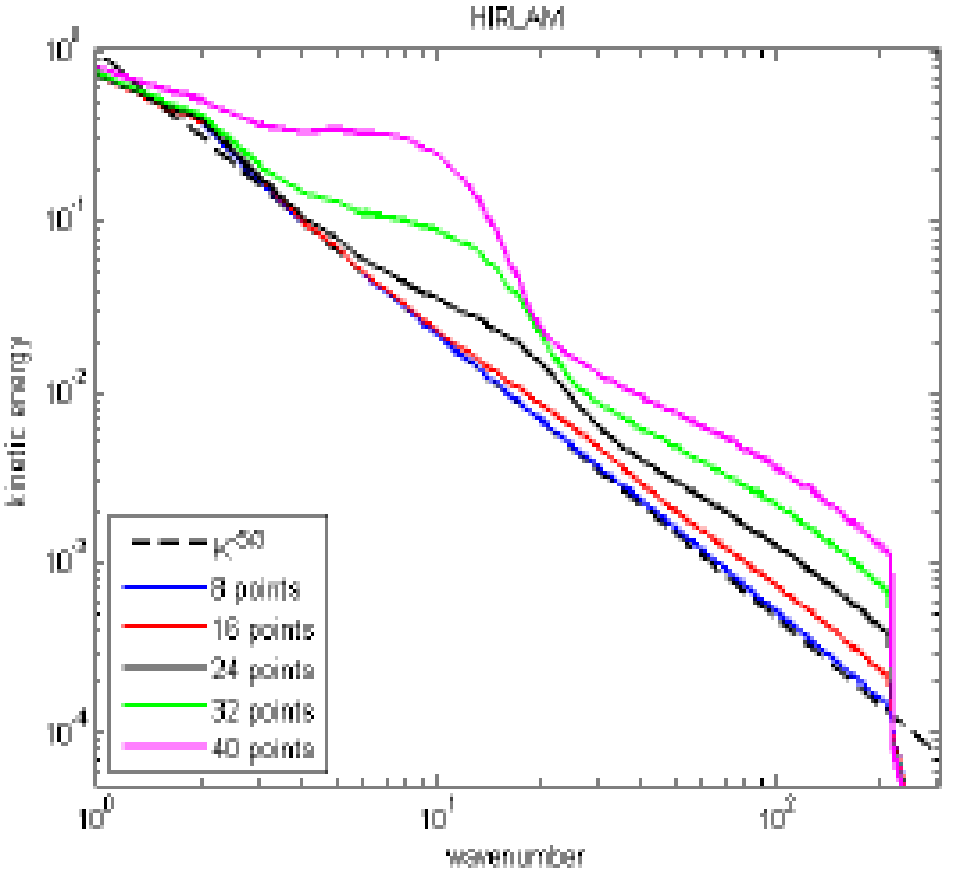
Calculation of spectra over a regional domain

- Extension zone to obtain bi-periodicity => aliasing effects

- "Mirroring" (cosine transforms), see AROME results in Ricard et al (2013)

- Use of gridpoint structure functions instead

$$f(s) = \text{Average}((u(x+s,t)-u(x,t))^2)$$



Example of aliasing effects in kinetic energy spectra due to the bi-periodization technique used in HIRLAM (simulation study by Blazica et al., 2013).

Note: A kinetic energy spectrum $k^{-5/3}$ corresponds to $f(s) \sim s^{2/3}$!

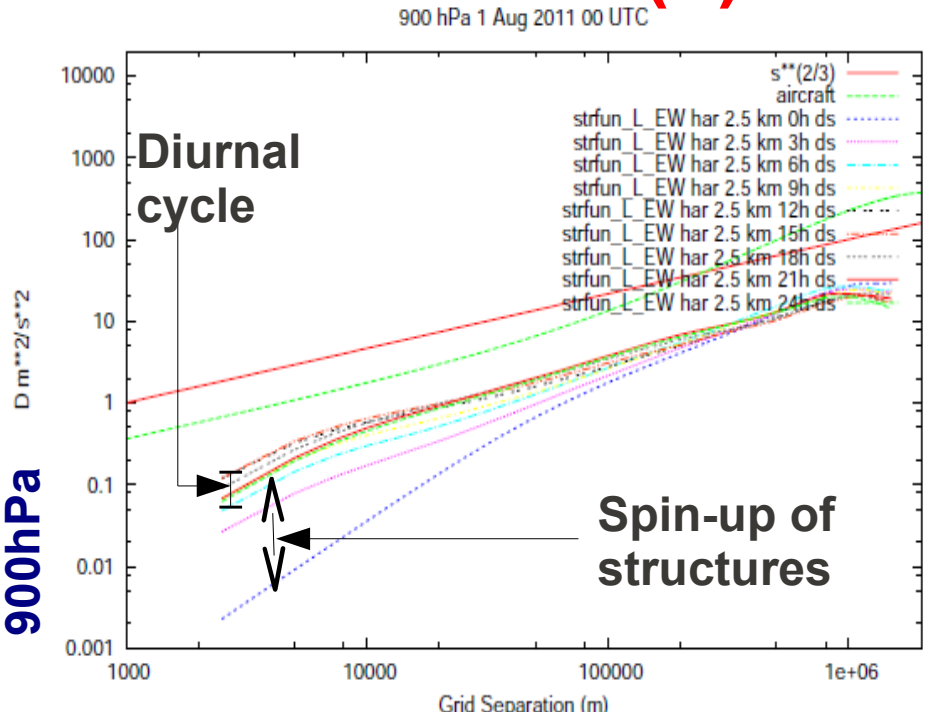
(from Nils Gustafsson & Slovenija University)

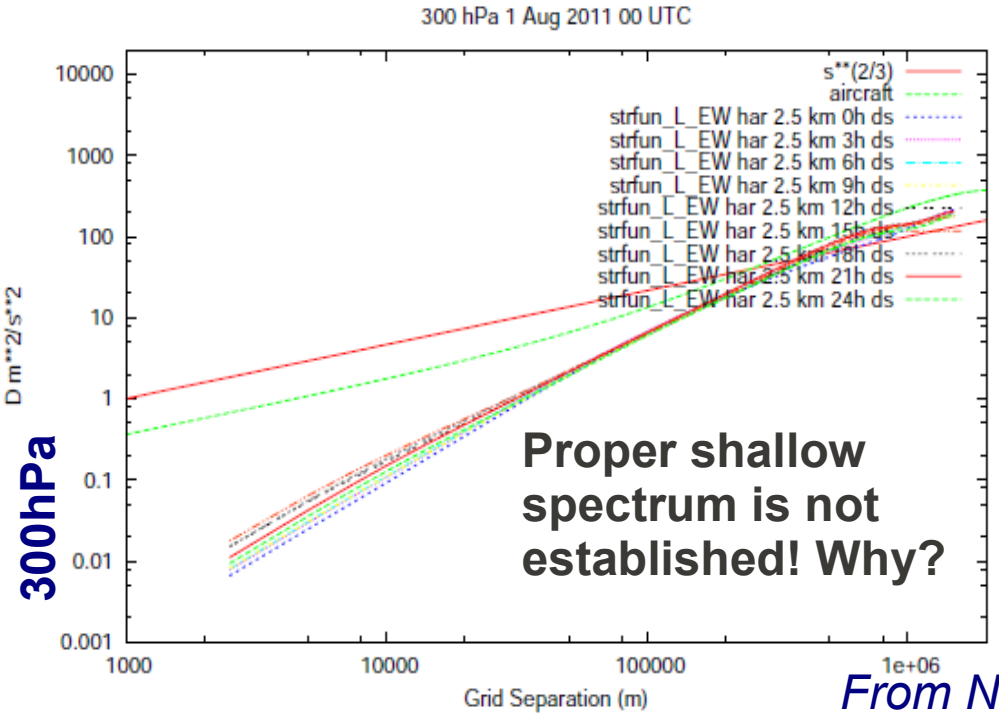
Let's take a look at structure functions (3)

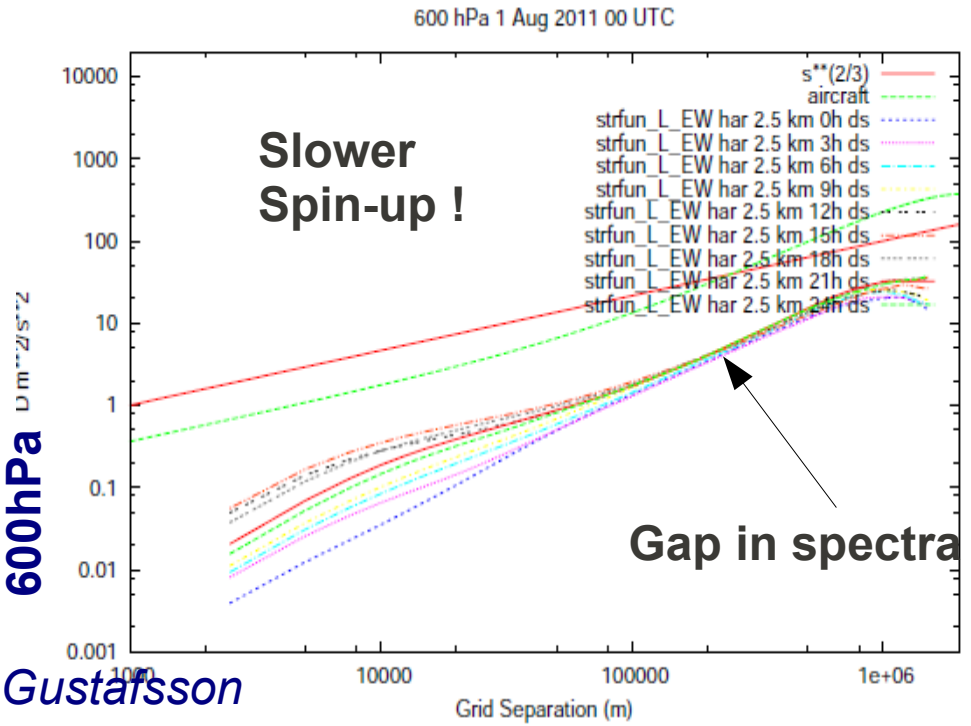
Downscaling experiment to generate background error statistics

HARMONIE AROME 65 lev **2.5**km
METCOOP25B, 960x750 gridpoints

Might be difficult to assimilate on meso-scale structures !







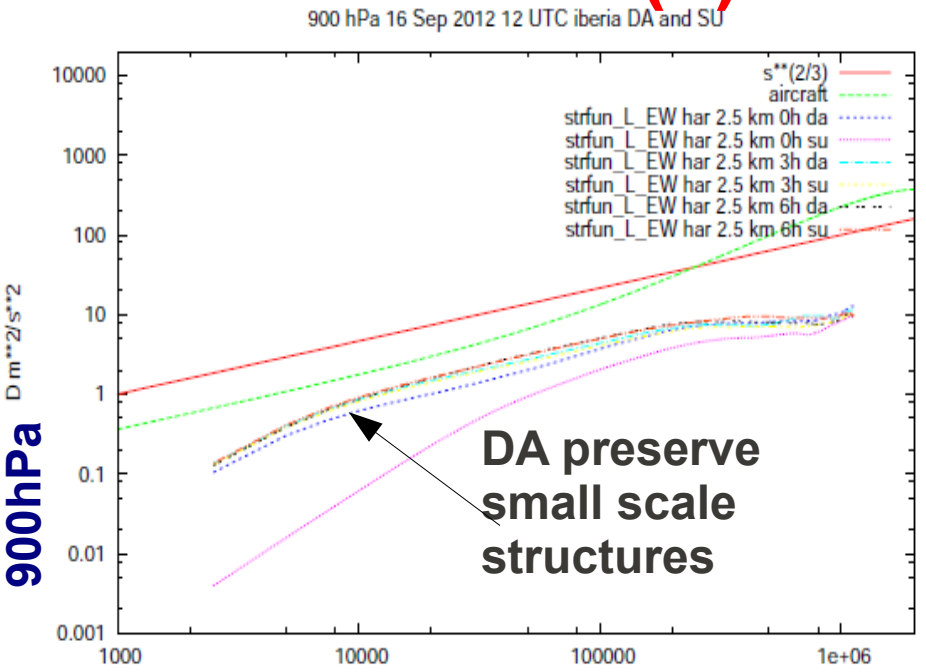
From Nils Gustafsson

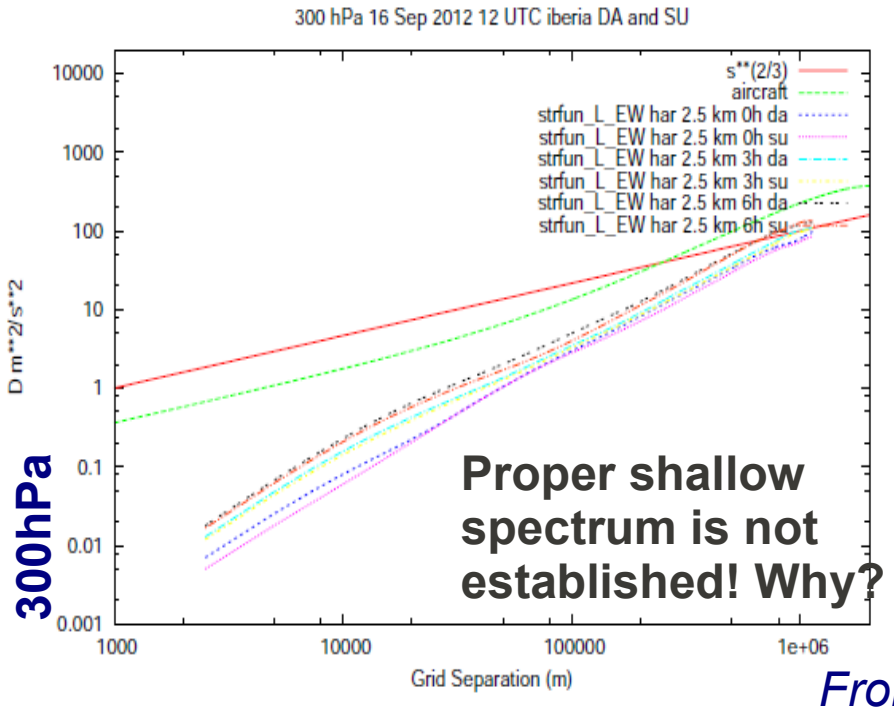
Let's take a look at structure functions (4)

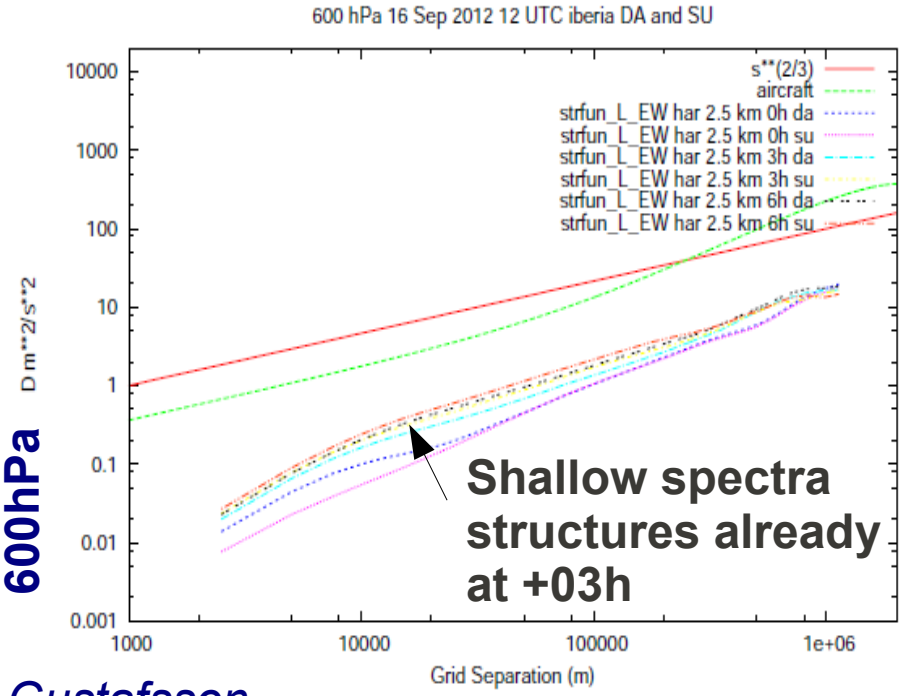
Comparison between kinetic energy spectra for downscaling ("cold SF") and data assimilation ("warm SF") fields

HARMONIE AROME 65 lev **2.5**km
IBERIA_2.5, 576x480 gridpoints

No chance to initialise convective scales from the upper troposphere observations





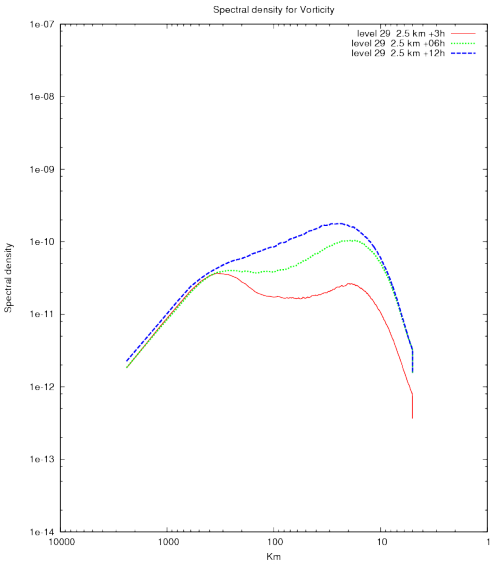


From Nils Gustafsson

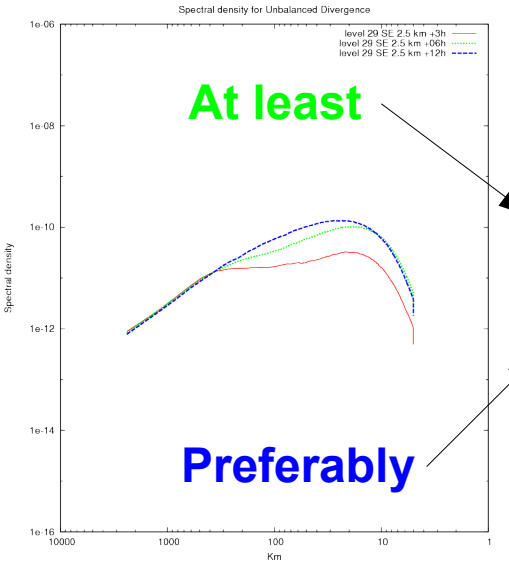
Let's take a look at structure functions (5)

FESTAT: spectral density at 900hPa based on different forecast lengths of the ensemble

Note: Most of energy is on large scales ! =>
Averaging ↔ smoothing ?



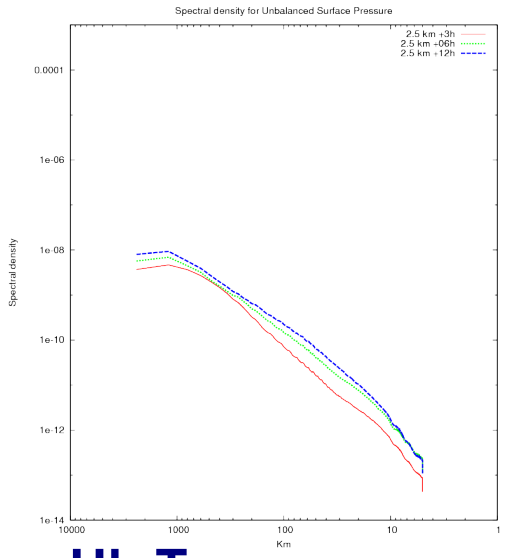
VOR



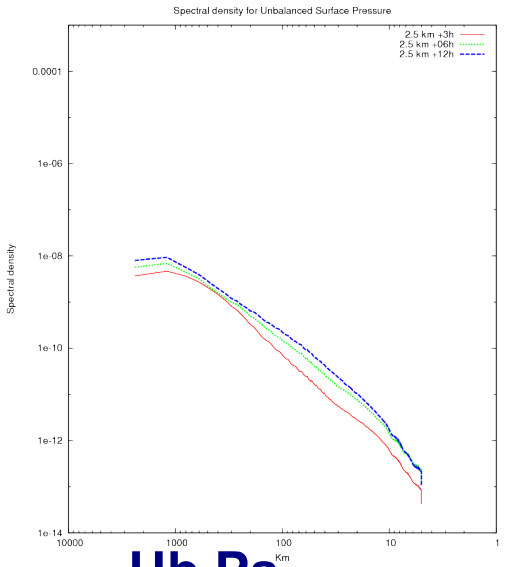
Ub. DIV

At least
+03h
+06h
+12h
Preferably

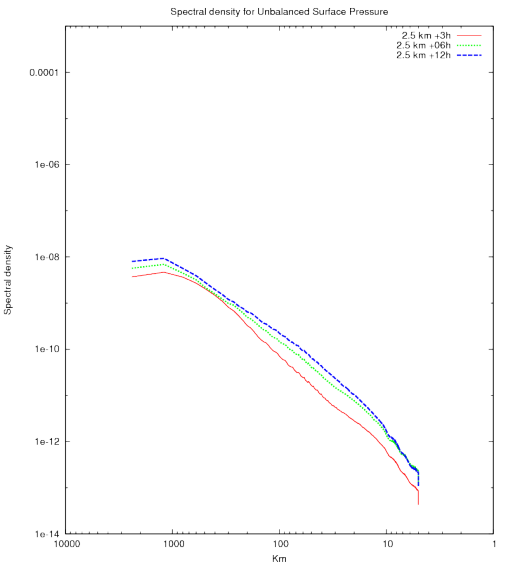
$$(VOR, DIV) \times k^{-2} \Rightarrow (u,v)$$



Ub T



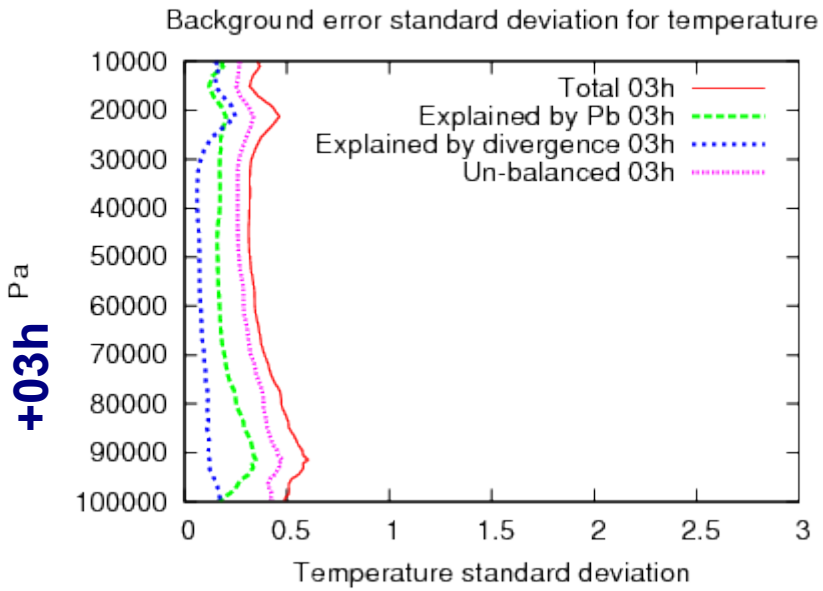
Ub Ps

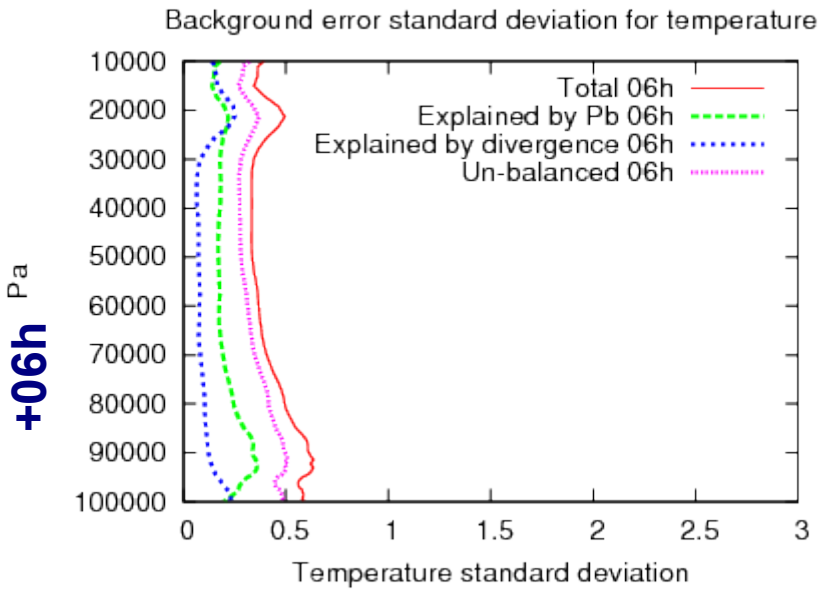


Ub Hum

From Nils Gustafsson

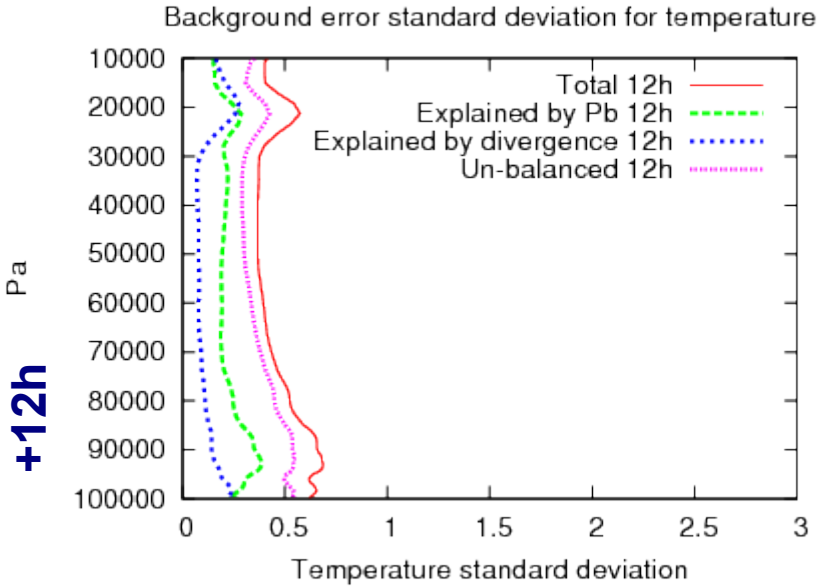
Let's take a look at structure functions (6)





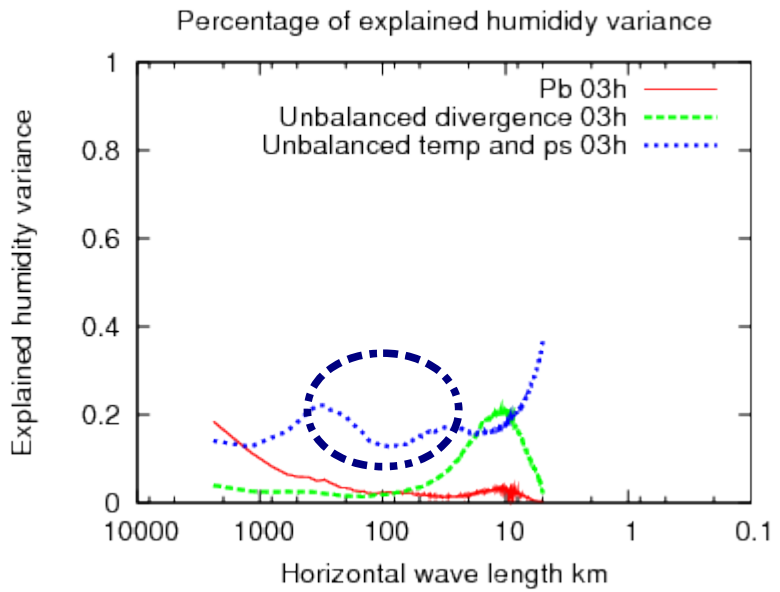
FESTAT: background error standard deviation for Temperature based on different forecast length ensemble

Balances seems to be less of a problem!

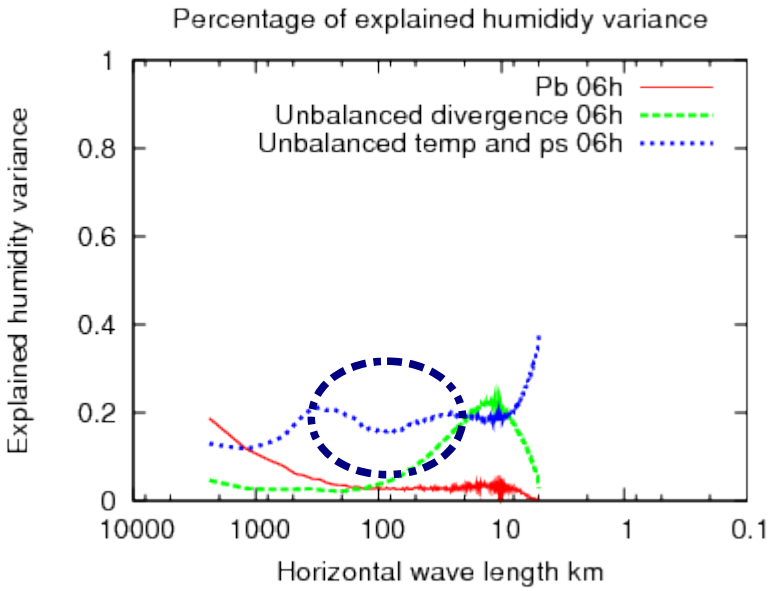


Let's take a look at structure functions (7)

+03h



+06h

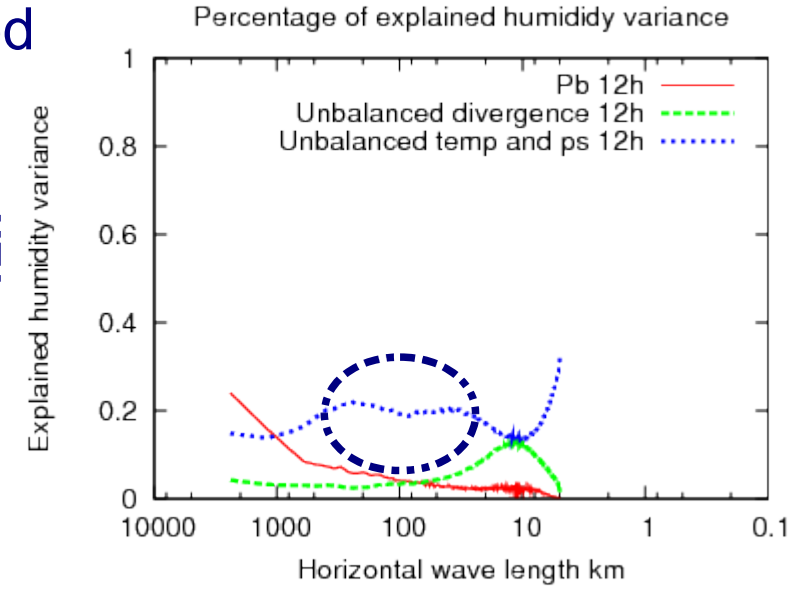


Spin-up + "Diurnal cycle"

FESTAT: The percentage of explained humidity variance at 900hPa.

Solution ?:
→ Go to "warm" structure functions
→ Take "spin-up" problems seriously
→ Take "diurnal cycle" into account performing DA

+12h

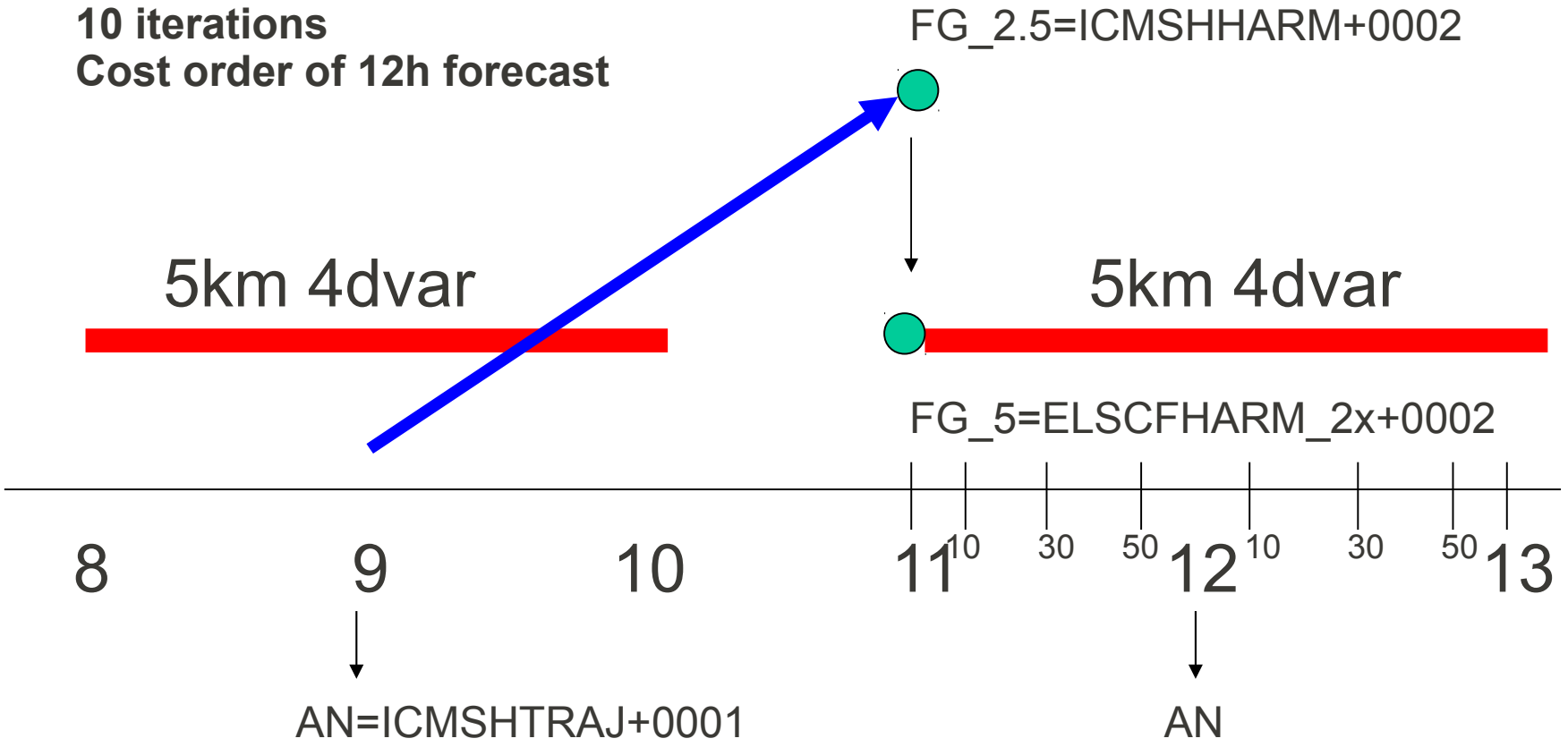


Most important: Go to flow-dependent structures !

HARMONIE AROME 4DVAR Prototype

(since 17 Jan 2014)

Hydrostatic ARPEGE TL/AD
2 h DA window
20 min observations time slot
Conventional + ModeS
Small domain 300x300
10 iterations
Cost order of 12h forecast



From Jan Barkmeyer & Magnus Lindskog et al

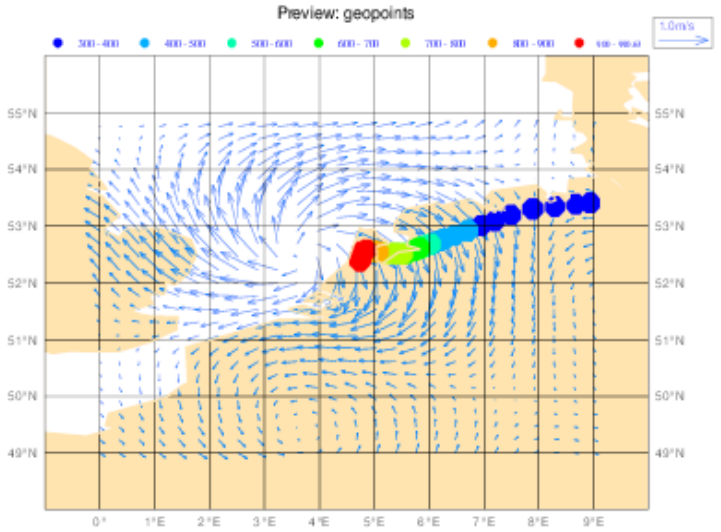
HARMONIE AROME 4DVAR Prototype (2)

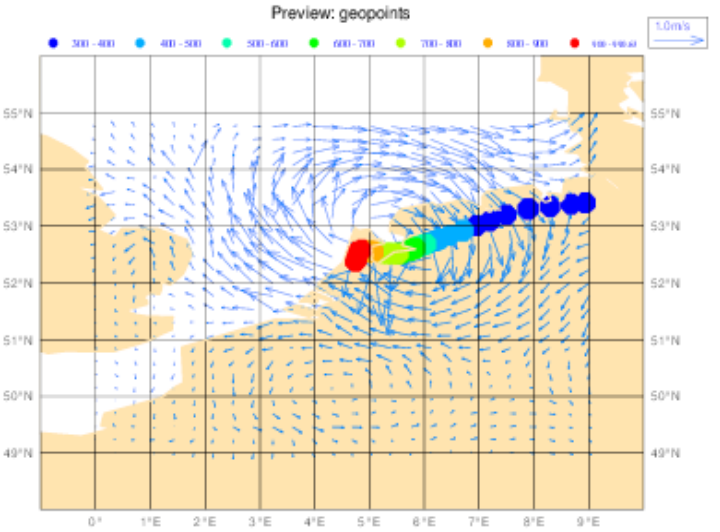
Increments
Lev 42
~1500m

T=0h (11 UTC)

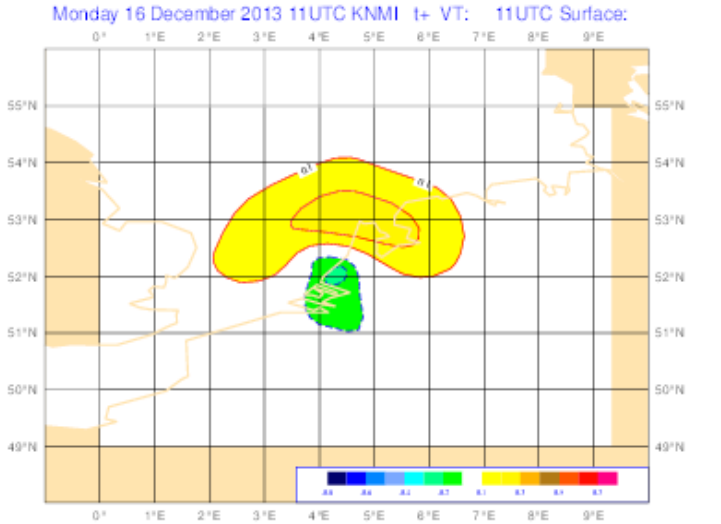
T=1h (12 UTC)

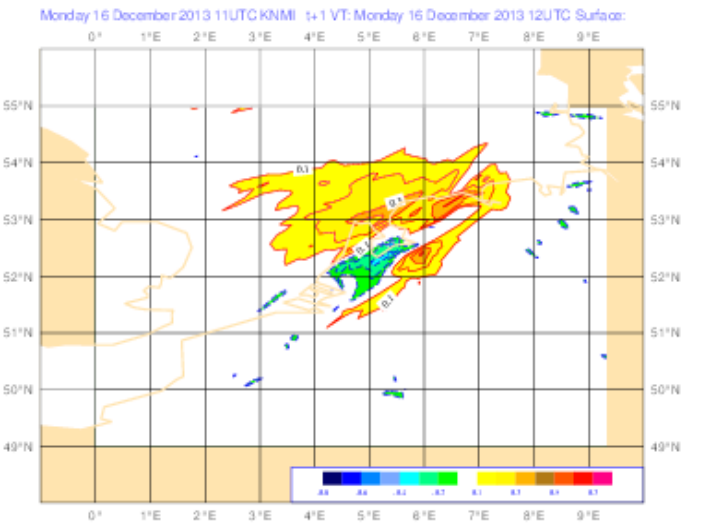
u/v





T





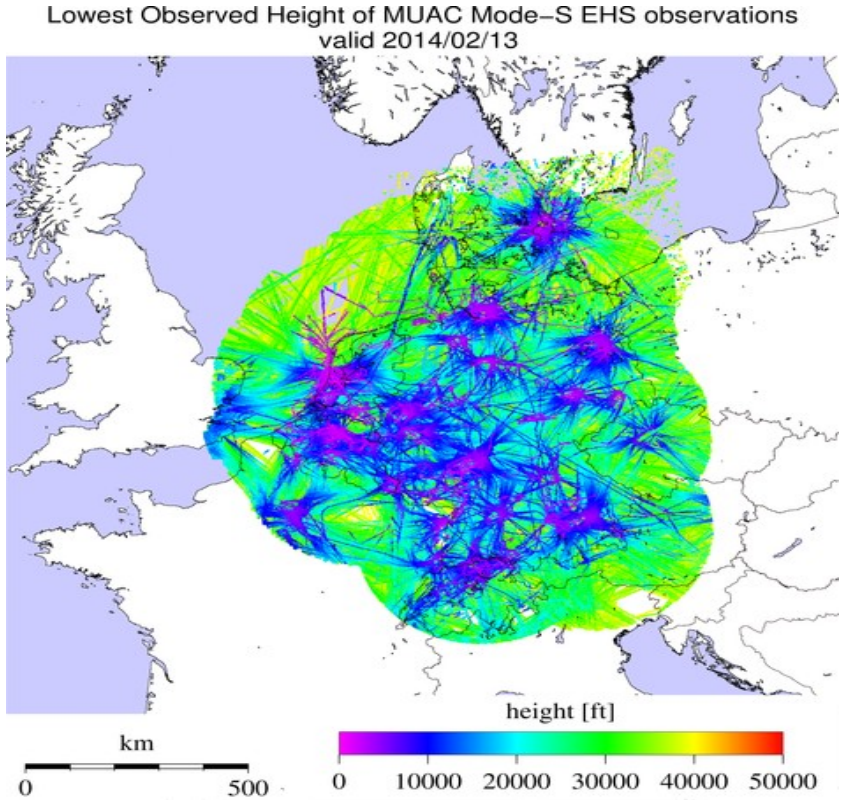
Problem with the small scale noise interpolating increment to high-resolution is not solved yet!

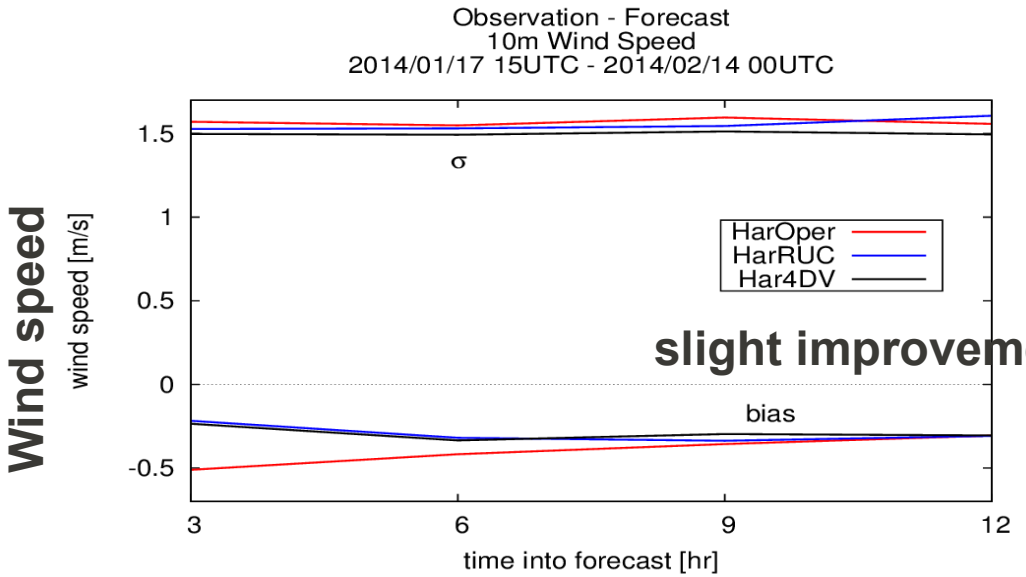
HELP, PLEASE!!!

HARMONIE AROME 4DVAR Prototype (3)

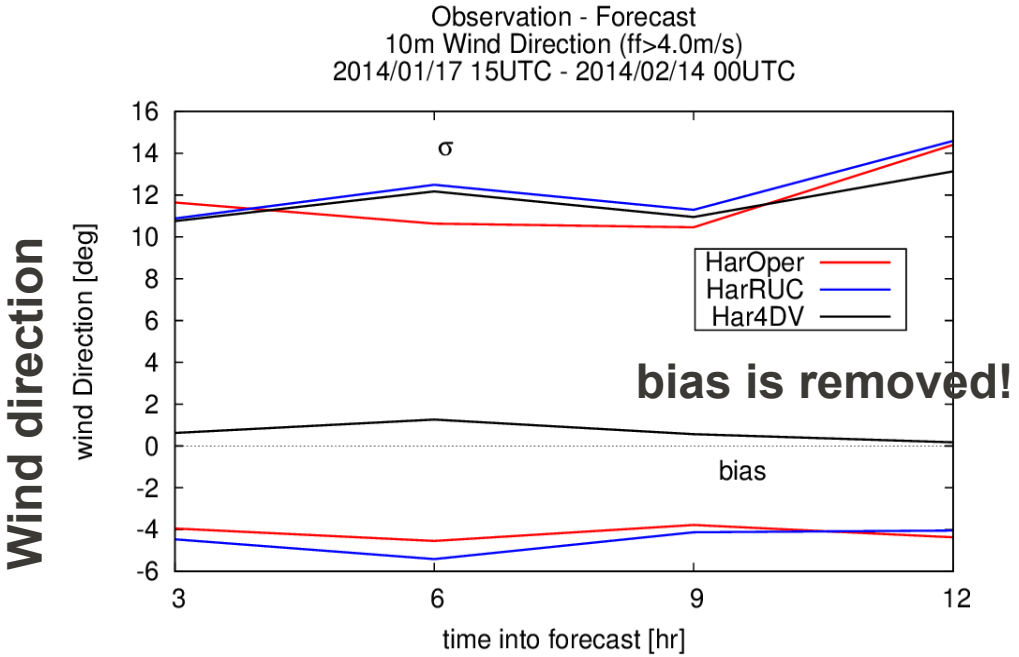
Impressing one month period verification results
(17 Jan – 14 Feb 2014)

HarOper : 3h 3DVAR + HIRLAM LBC
HarRUC : 3h 3DVAR + EC LBC + ModeS
Har4DV : 2h 4DVAR + ModeS





10 m wind verification

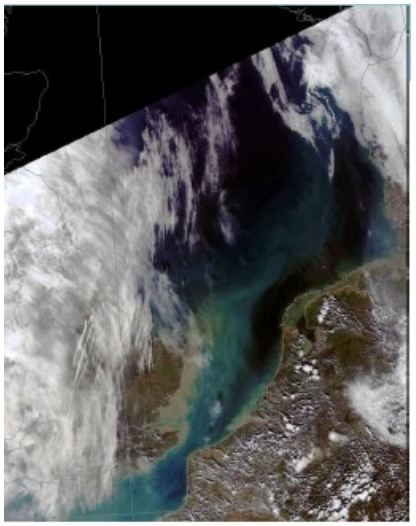


From Jan Barkmeyer & Siebren de Haan

HARMONIE AROME 4DVAR Prototype (4)

Jan Barkmeyer & Sibbo van der Veen

Satellite image

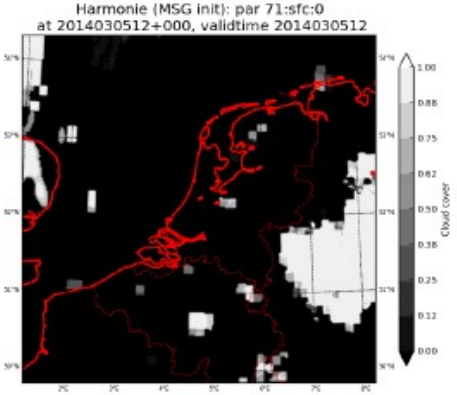


Even more impressing results!

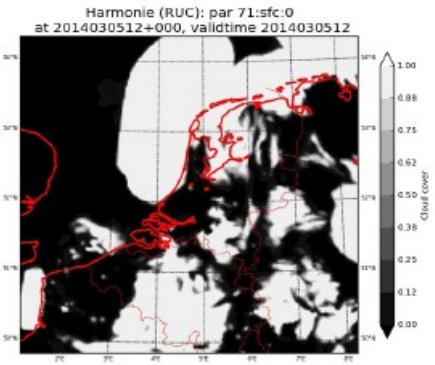
The Fog over sea problem is significantly reduced in HARMONIE AROME 4DVAR assimilation

Flow-dependent structure functions even with a very crude TL/AD model helps!

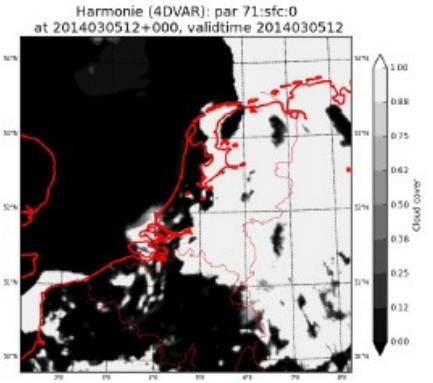
Cloud mask initialisation



HarRUC



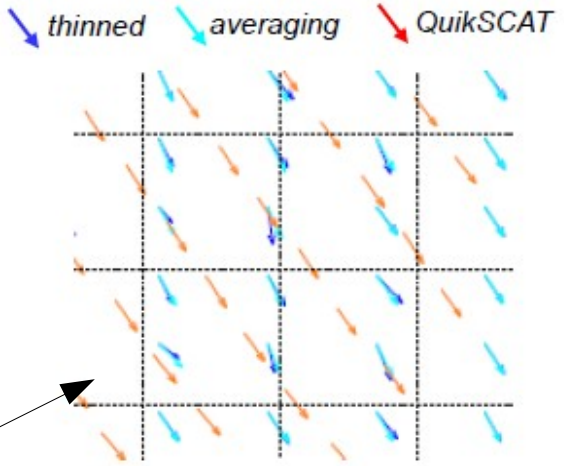
Har4DV



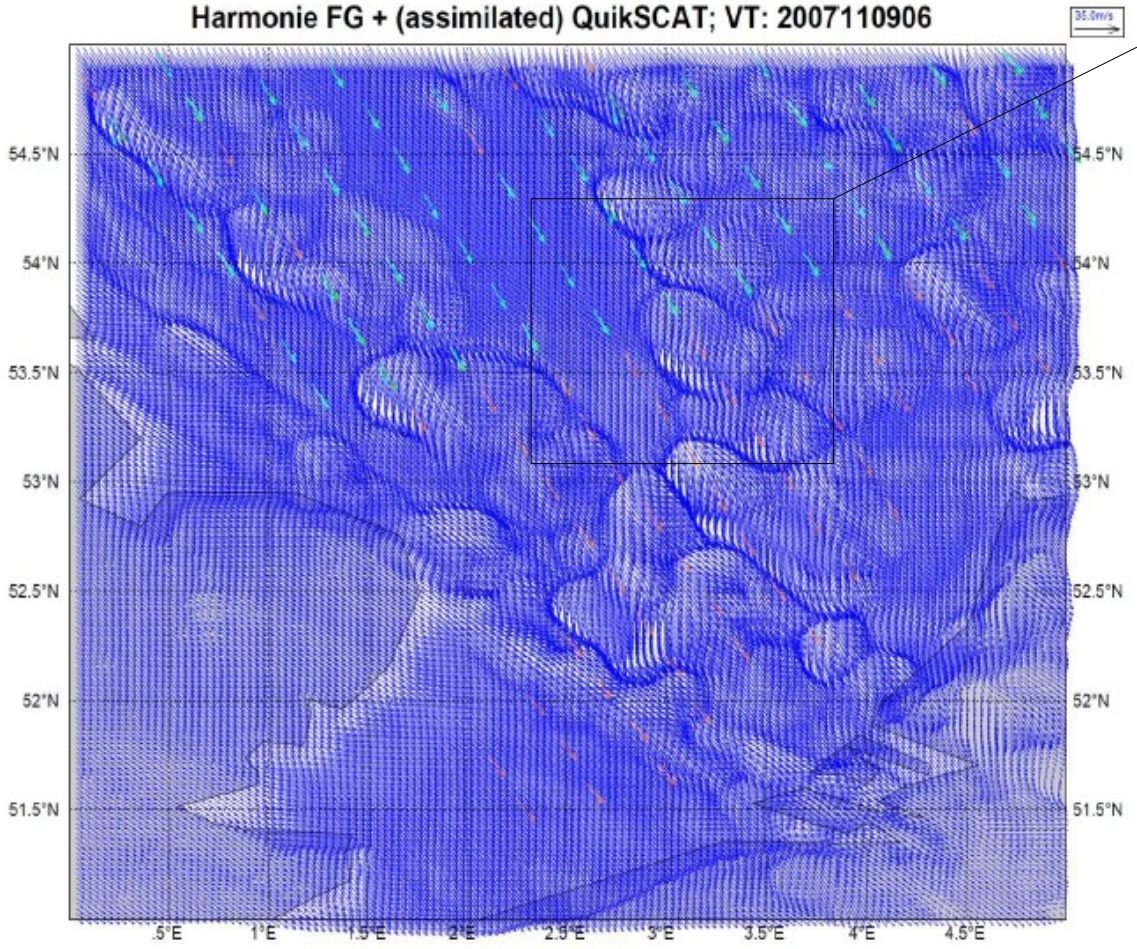
Proof of Pudding lies in the Eating!

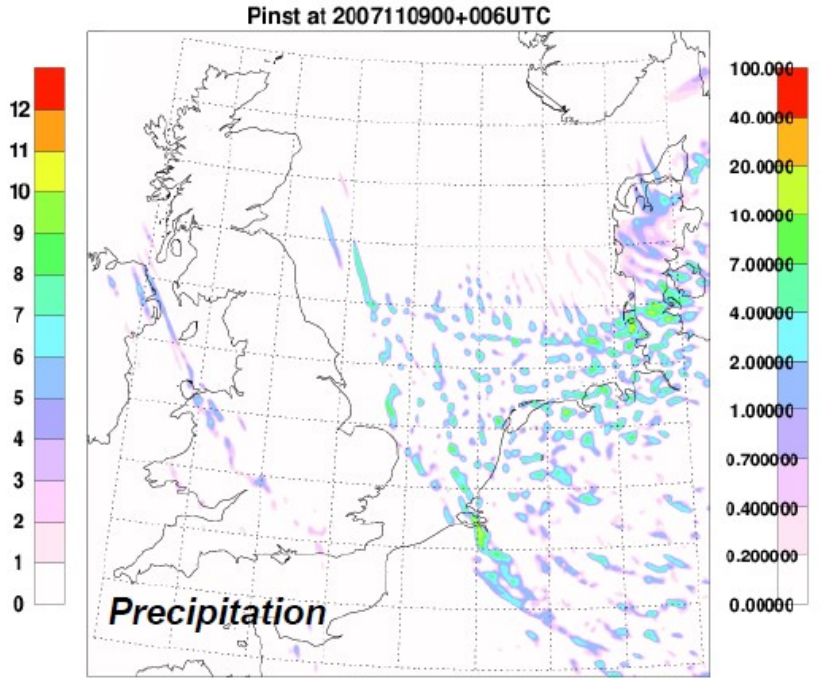
Do small scale structures verify ? (1)

→ Averaged HARMONIE fields compare well with observations;
→ **HARMONIE AROME 2.5** small scales structures are probably realistic, **but are they real**?
→ Nature and NWP model <=> two realisations of a stochastic process; **Point-by-point comparison is not possible!**



QuickSat footprint is about 50km^2





From Gert-Jan Marseille & Wim de Rooy

Does small scale structures verify ? (2)

Not everything is so bad as it looks like :

Smooth ASCAT surface wind product is able to improve forecast quality of temperature and relative humidity of the large scale environment:
→ In Teresa Valkonen Presentation

Where should we go now ?

→ 1. Improve observation operator => **Integrate do not interpolate !**
→ 2. Direct assimilation of backscatering/radiances instead of retrievals => **advanced forward observation operator!**
→ 3. More data => Treat correlated observation errors appropriately instead of thinning;
Most important: More high-resolution observations in high-update frequency DA scheme!

Very big question

→ Control small scales motion / control large scale environment ?
→ Mimic small scale variability / assimilate structures?
→ Does inherited stochasticity exist in the NWP models?

More high resolution data : ZTD GNSS (1)

One month verification period

01/09 – 30/09 2012 (HYMEX)

AROME 2.5 IBERIA_2.5 65 level **CY38**

3h RUC 3DVAR Conventional + ZTD GNSS

CRL2 "REDNMC=0.6 no GNSS"

VBC "First bad trial with GNSS"

STA2 "static bias correction with GNSS"

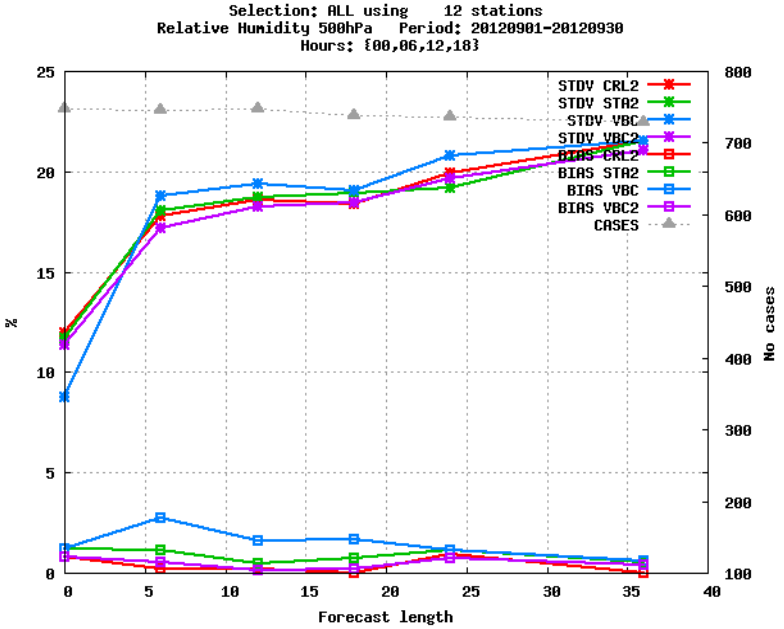
VBC2 "stiff VarBC with GNSS"

Persistent positive impact (finally!)

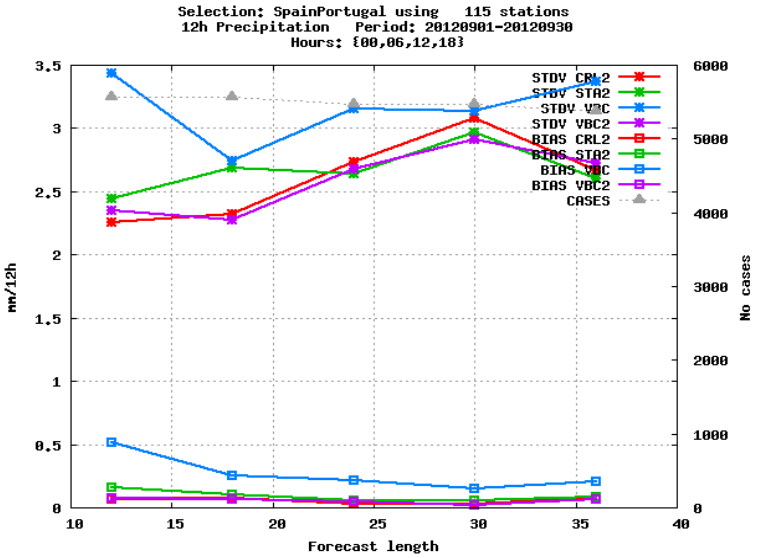
DO NOT OVERFIT!!!

Keep yourself away from the observations, if model is biased

500h Spec.Hum



12h Accum. Precipitation



Jana Sanchez Arriola, Sigurdur Thorsteinsson & Magnus Lindskog

More high resolution data : ZTD GNSS (2)

Model Biases

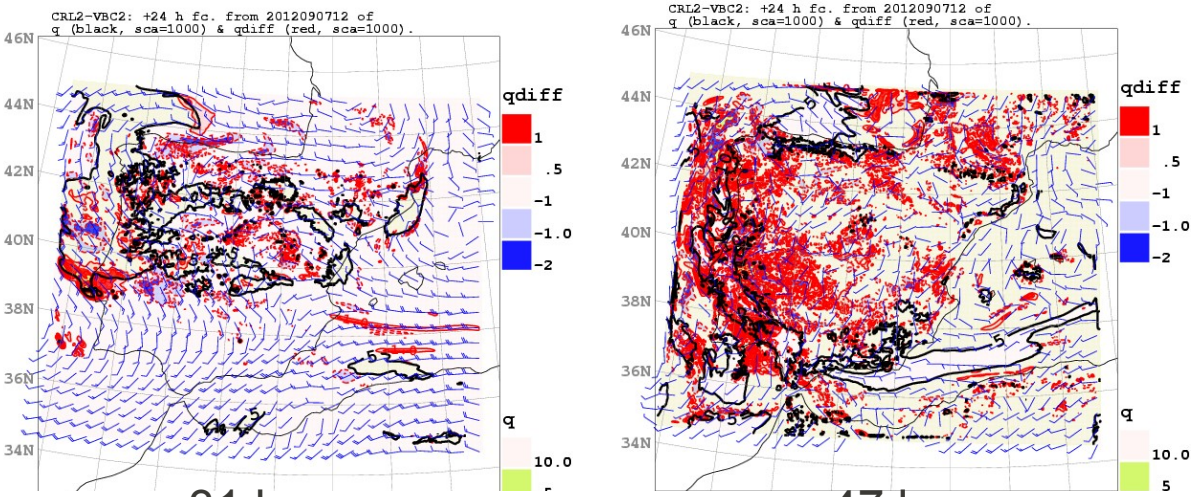
VarBC scheme for ZTD GNSS (offset only) improves forecast skills. How? =>

GNSS help to dry out a too wet model

Model Is BIASED! => it is **difficult to assimilate observations** in the biased model efficiently. Coming close to the observations distorts the climate of biased model and degrade the forecast quality.

+24h forecast differences valid 08 Sept 2012 12 UTC

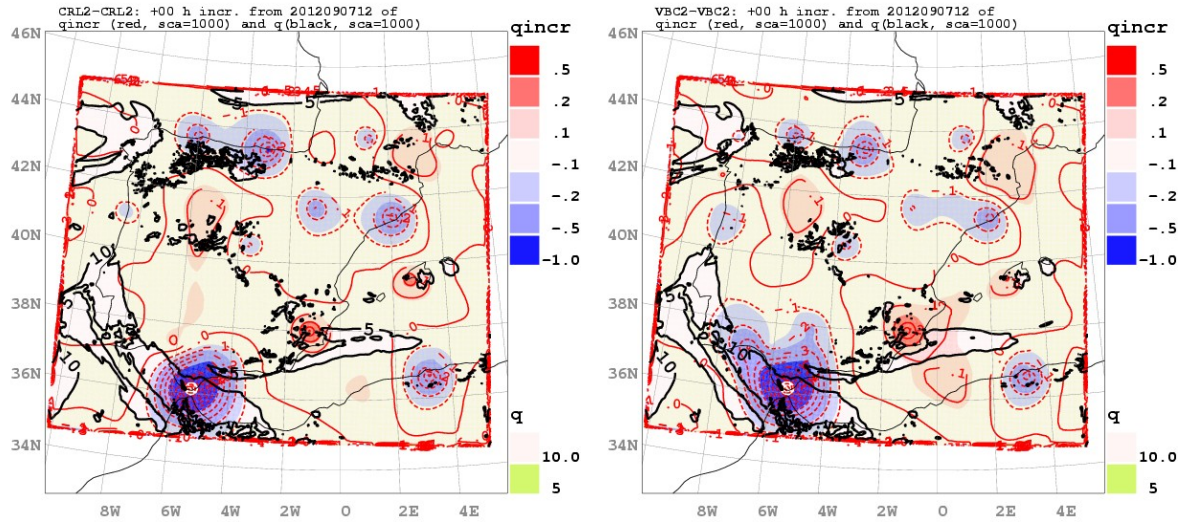
CRL2-VBC2



31 lev 47 lev

Spec. Humidity

analysis increment valid 08 Sept 2012 12 UTC lev 47



CRL2 **VBC2**

Most important: Joint efforts addressing common problems by physics and data assimilation scientists are needed in order to make a progress!

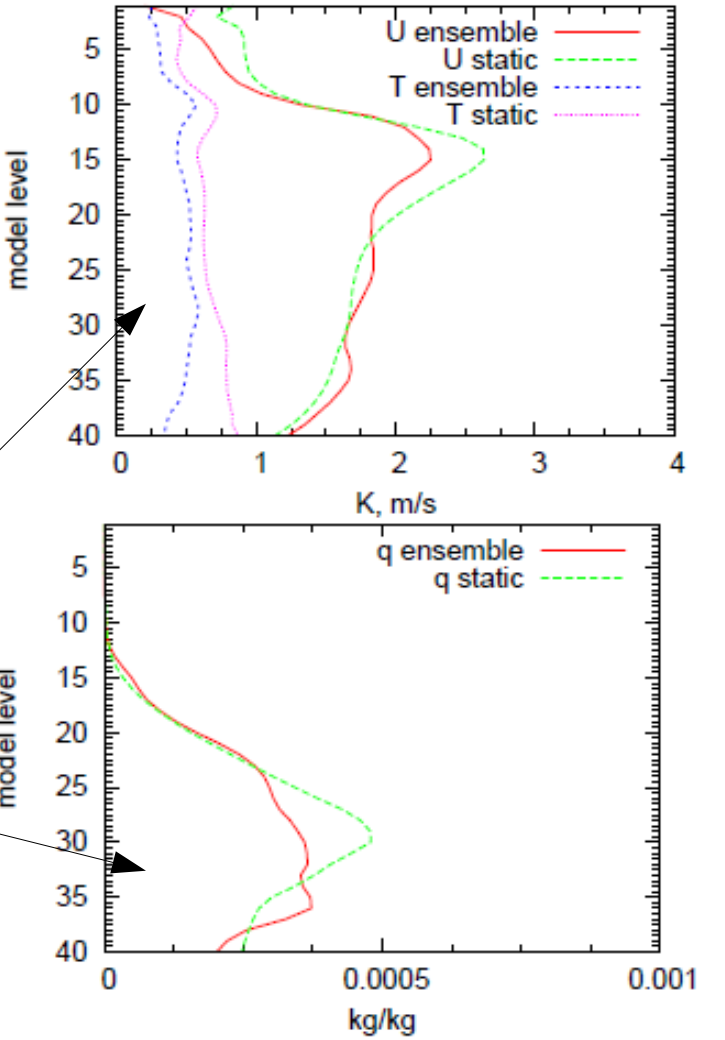
Flow-dependent structure functions (1)

Domain averaged flow-dependent structure functions

HIRLAM experience :
ETKF based rescaling scheme with 20 ensemble members for randomly selected case

→ Surprisingly good correspondence between domain averaged flow-dependent and climatological structure functions for **wind** and **temperature** model state components.

→ As expected, the flow-dependent structures for **humidity** differ from the climatological ones.



Thank You for BGOS, Ulf!

Spatial distribution of the ensemble variance for T at level 30

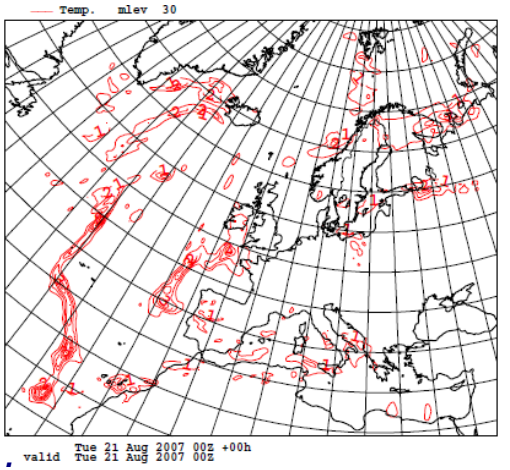


Fig. 7. Vertical profiles of climatological (static) and area averaged ensemble based background error standard deviations for one randomly selected case 22 January 2008 12UTC+06h. Top: U-component of wind (ensemble red curve, static green curve) and temperature (ensemble blue curve, static pink curve). Bottom: Specific humidity (ensemble red curve, static green curve).

ETKF Family Corporation

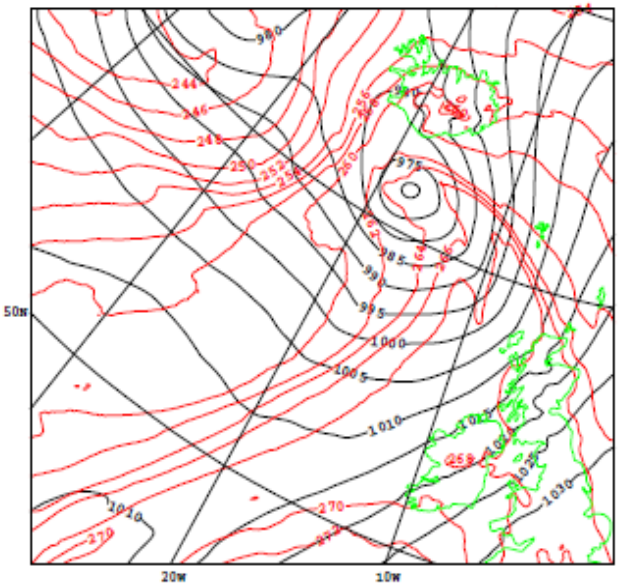
Flow-dependent structure functions (2)

Single simulated observation experiments

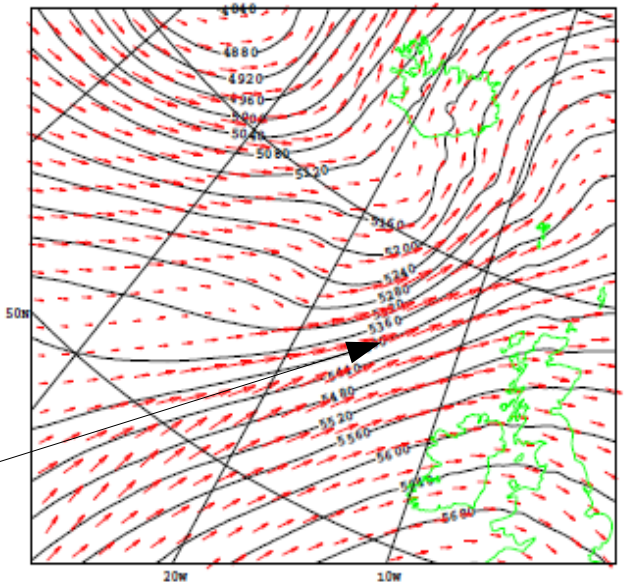
58° N, 15° W; 500hPa
5 hours into assimilation window
du =10m/s; dv = 5m/s

Flow-dependent inhomogeneous forecast error statistics are crucially important for conditioning of small scale structures by the large scale flow situation

Flow situation
(background state)



PMSL
T700



Z500
V500

Position of simulated observation V500

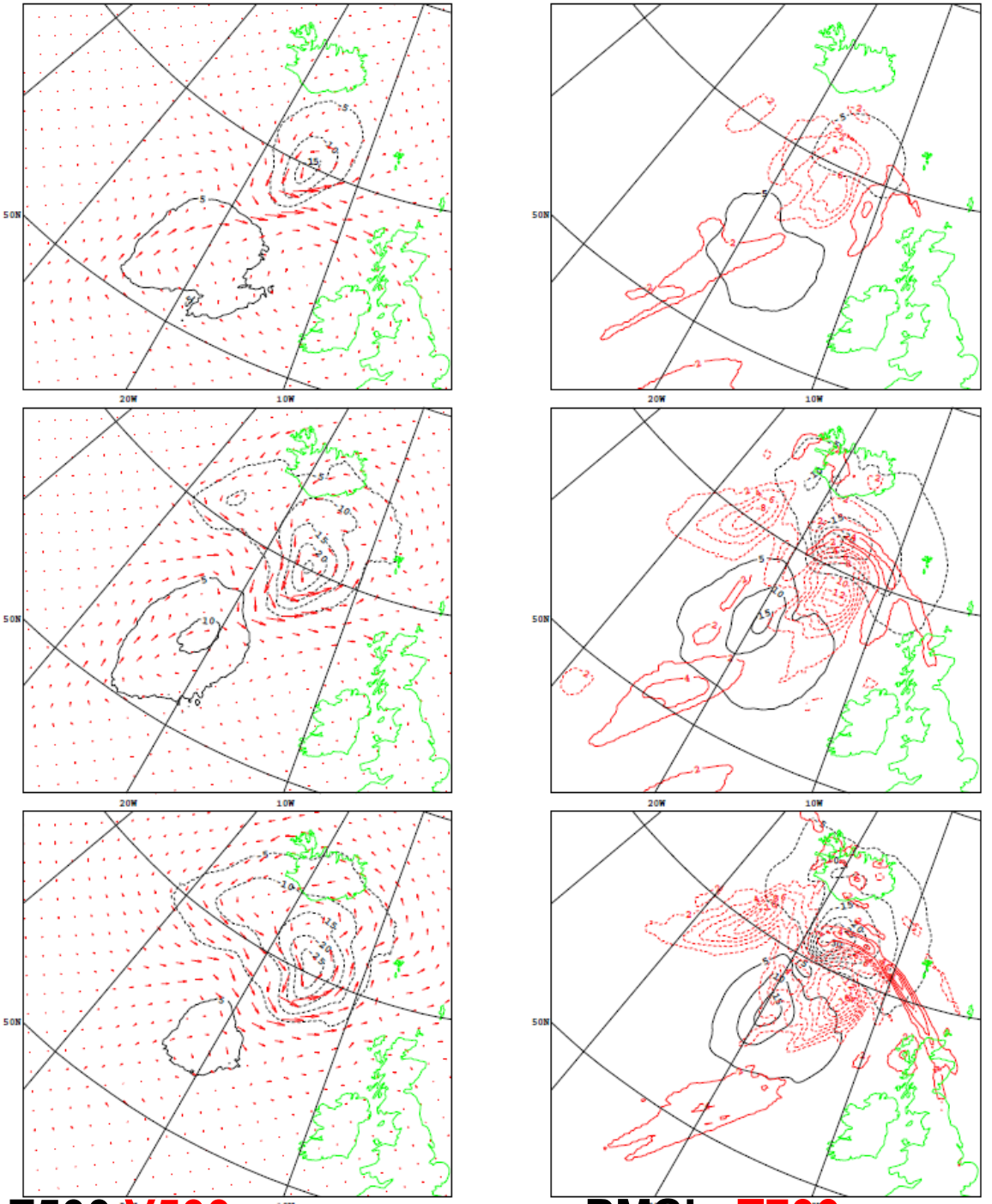
Flow-dependent structure functions (3)

4D-Var :=> TL model

4D-Var Hybrid :=> Ensemble constraint at initial time + TL model

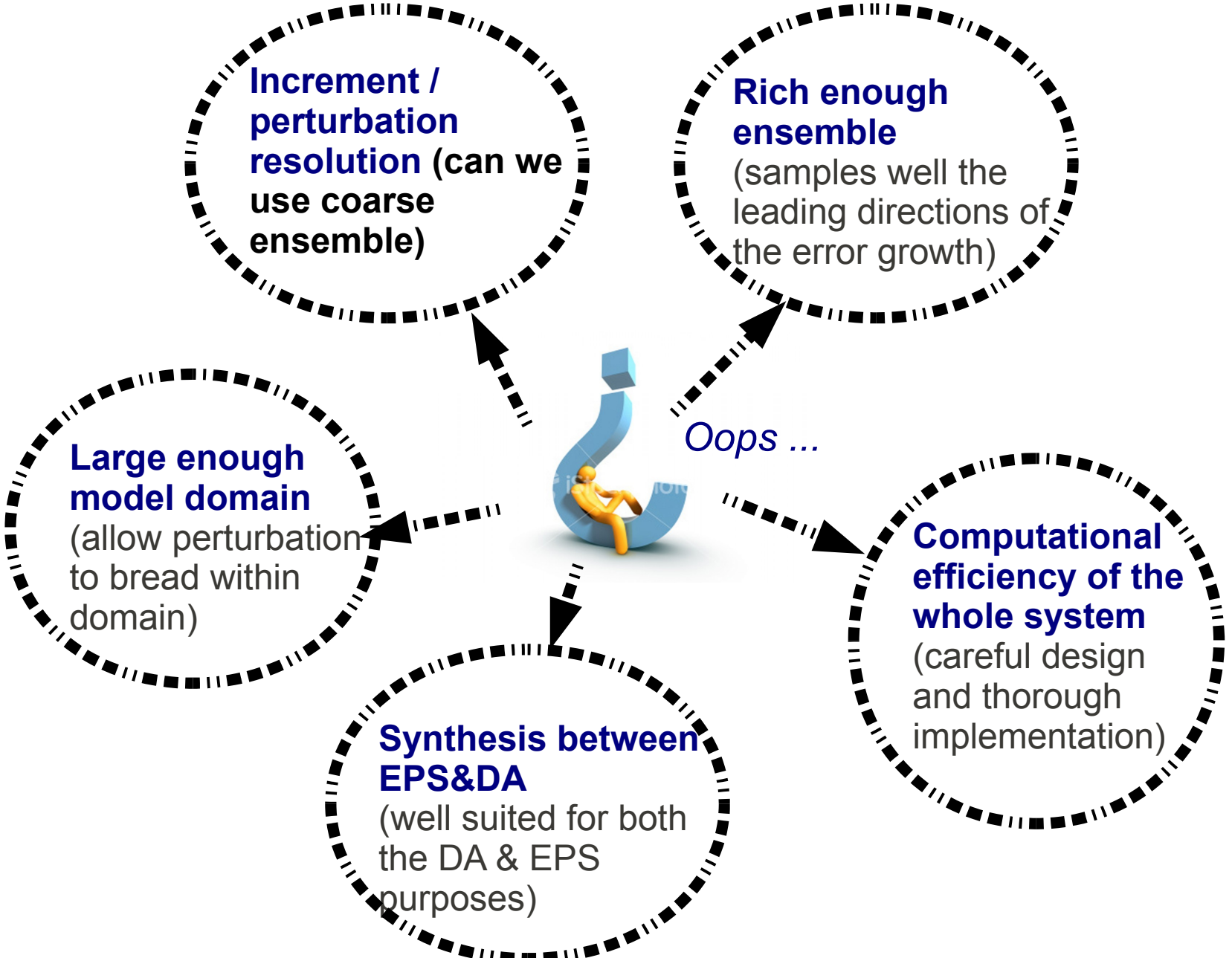
4D-En-Var

=> Ensemble constraint at initial time + 4-D ensemble evolution

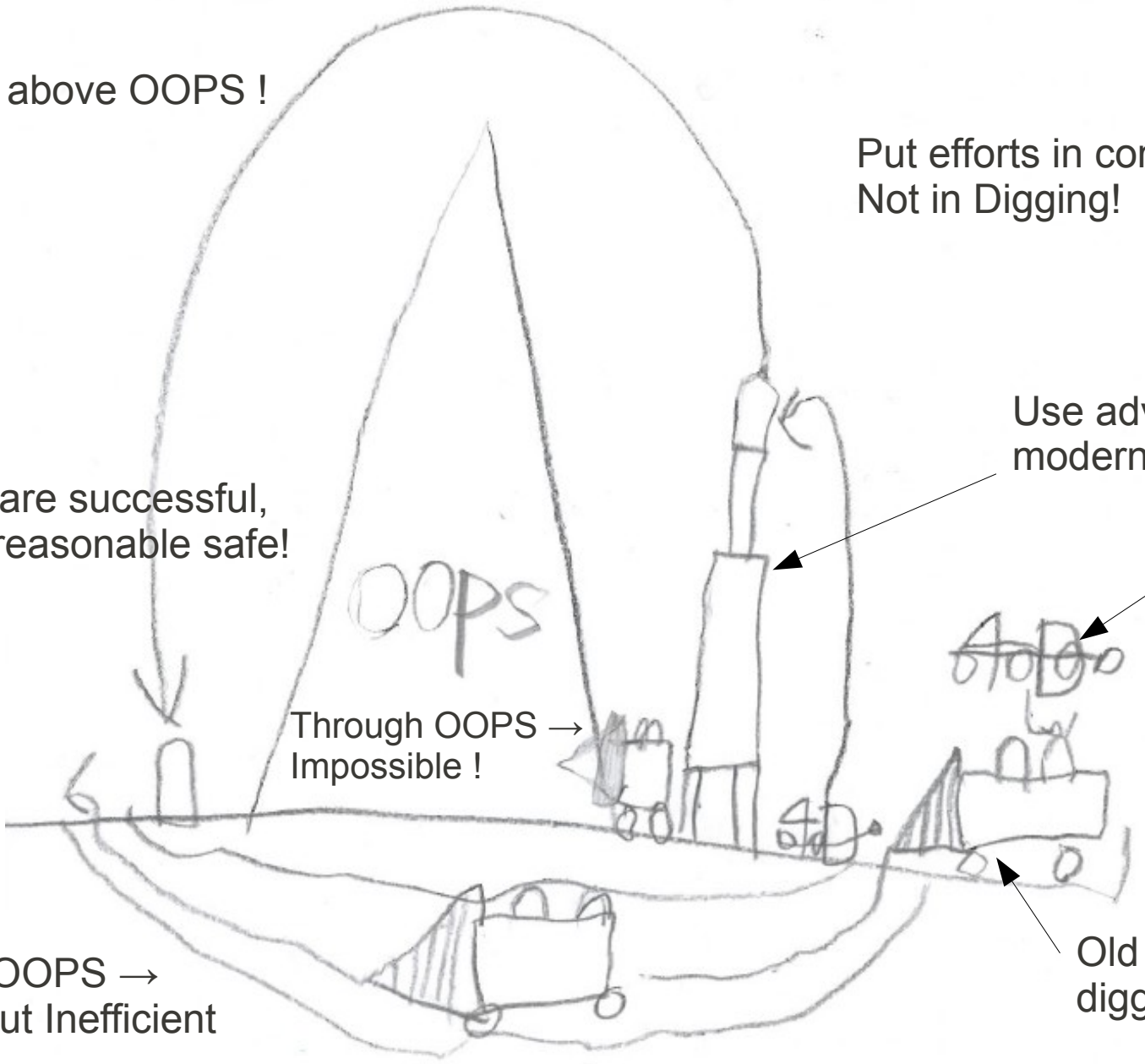


Z500, V500 PMSL, T700

New problem : LAM perturbations



Perspective of new generation: *Mamma, why do You all the time think only about problems? … You should concentrate yourself on solutions!*



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