Norwegian Meteorological Institute

The 36th EWGLAM & the 21st SRNWP Meeting

29 September -2 October 2014
Deutscher Wetterdienst, Offenbach, Germany

Overview of the HIRLAM-B

the data assimilation activities

Jelena Bojarova on behalf of the HIRLAM Team

Hirlam + ALADIN = HARMONIE

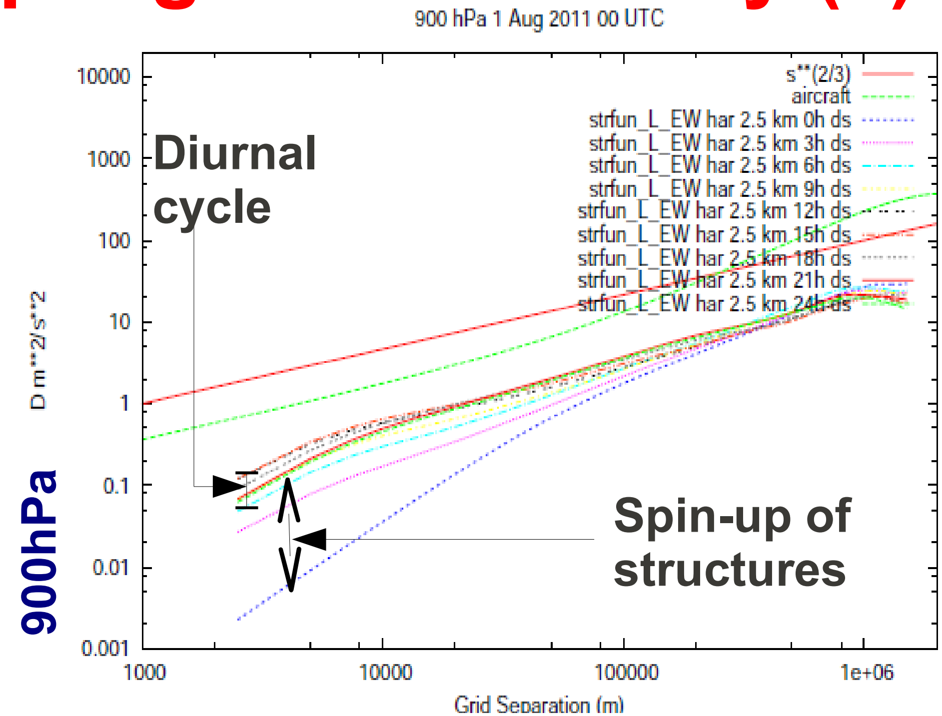

1. Structure functions
2. More high resolution observations
3. Overall tuning of the DA system
4. HARMONIE AROME 4DVAR
5. Consistent DA-EPS system
6. Unified variational data assimilation framework
Towards efficient data assimilation on meso-scales

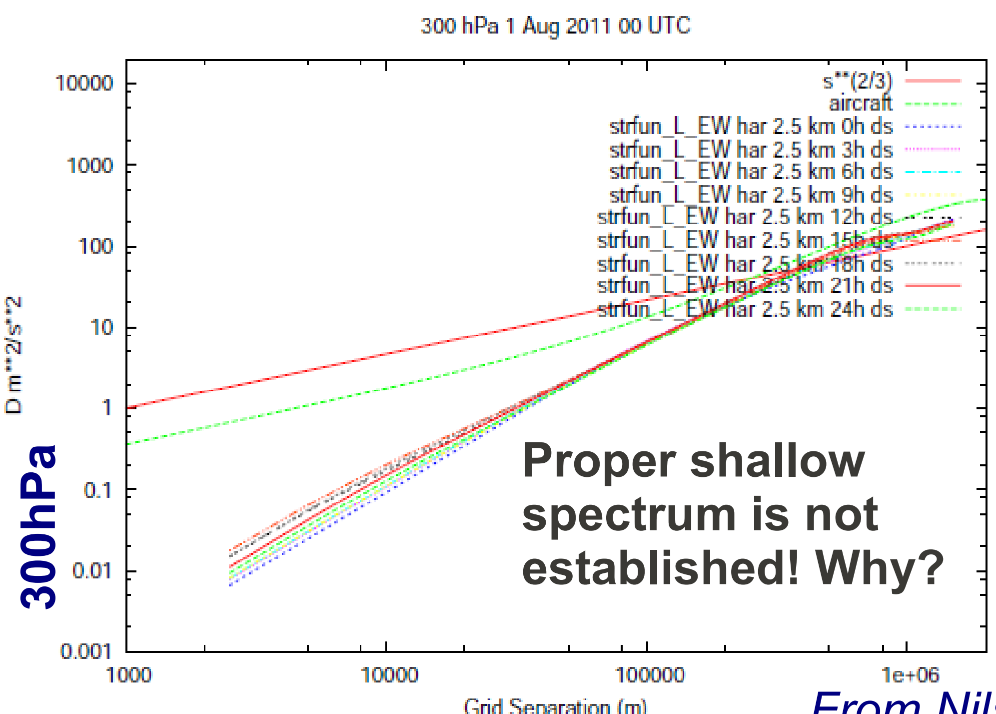
Structure functions: sampling of uncertainty (1)

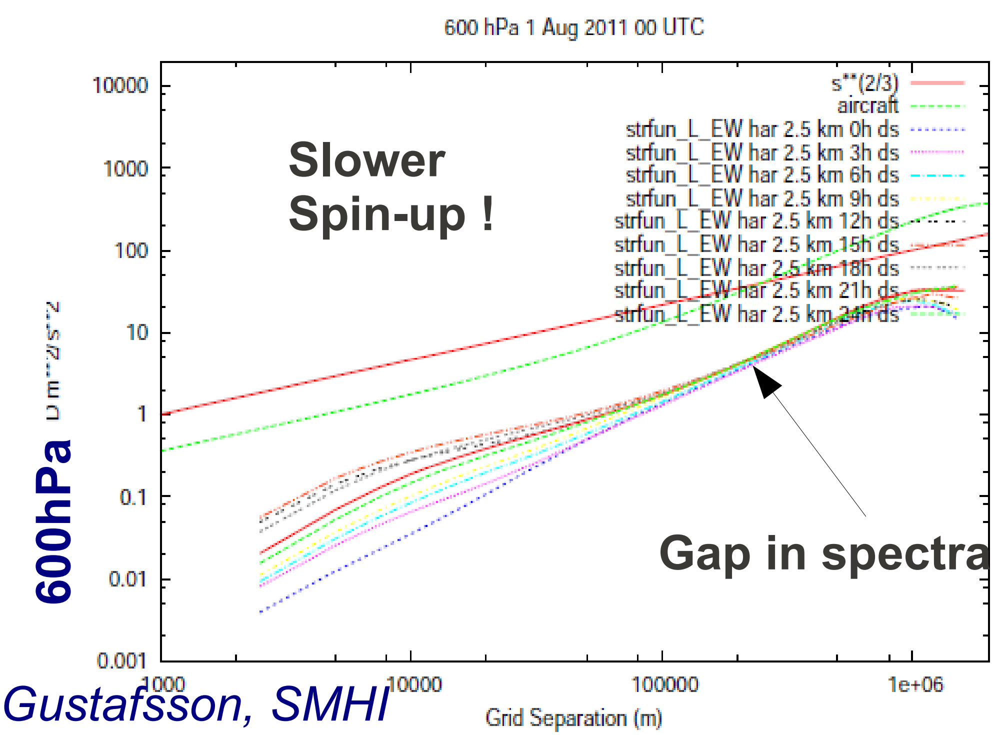
Downscaling experiment to generate background error statistics

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

Downscaling of the ECMWF perturbations







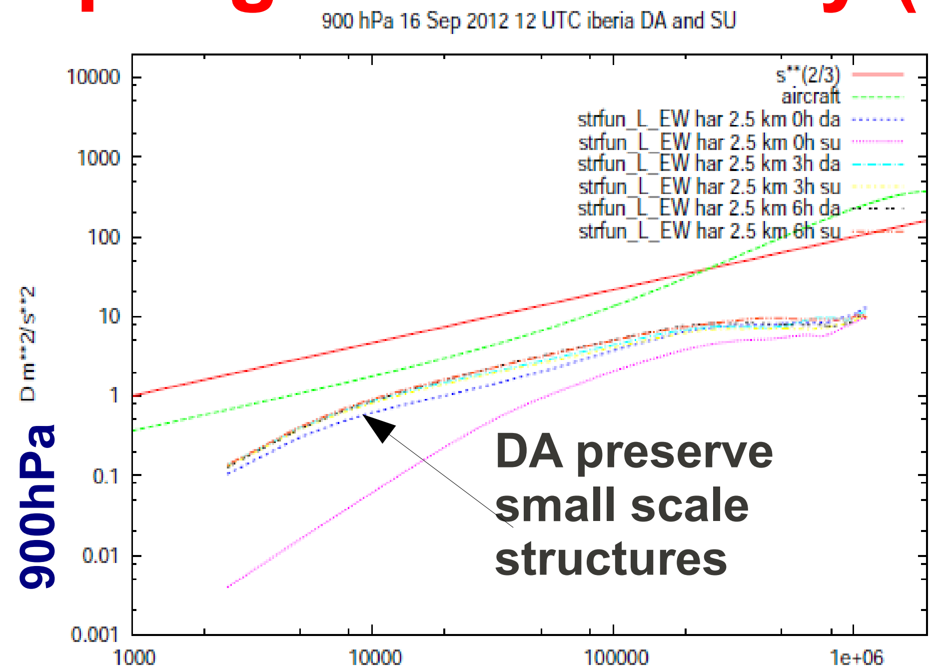
From Nils Gustafsson, SMHI

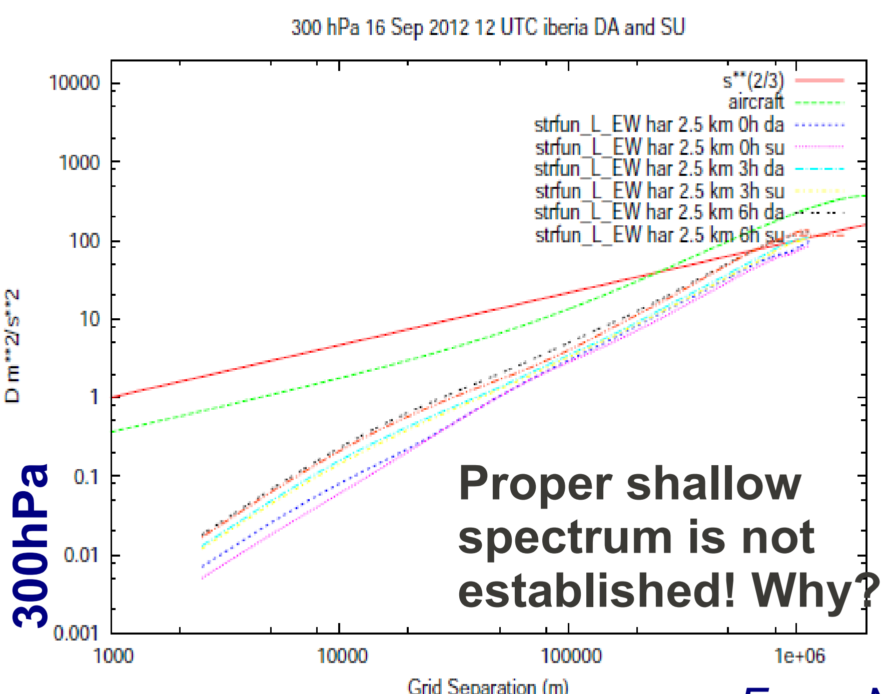
Structure functions: sampling of uncertainty (2)

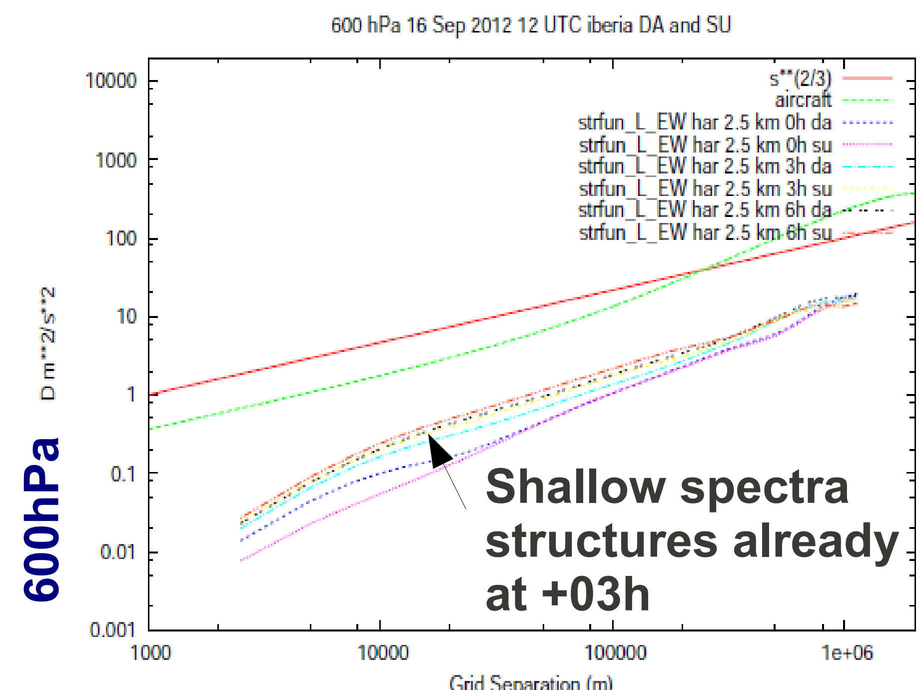
Comparison between kinetic energy spectra for downscaling ("cold SF") and data assimilation ("warm SF") fields

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

Concentrate on observations in the lower troposphere



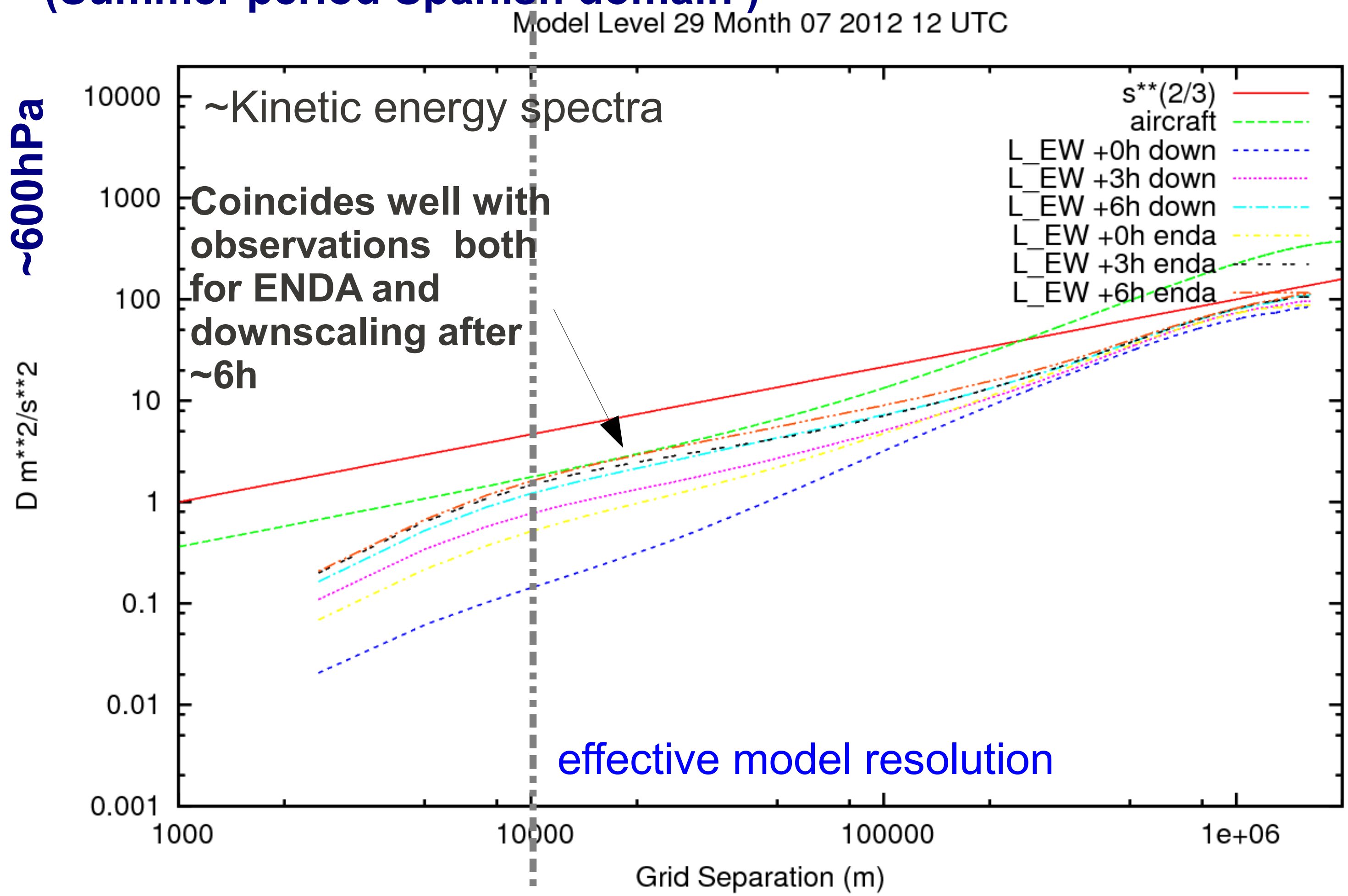




From Nils Gustafsson, SMHI

Structure functions: sampling of uncertainty (3)

HARMONIE ENDA system for generation of structure functions (Summer period Spanish domain)



Important to have turbulent motion and energy at initial time on appropriate scales. Spin-up properties depends **on the stability of boundary layer**.

From Nils Gustafsson & Magnus Lindskog, SMHI

Structure functions: sampling of uncertainty (4)

stat hor. f-plane balance between geop. and vort.

$$\phi^z_{mn} = \beta_z(m,\ n)\,\zeta^z_{mn},$$

$$\beta_z(m,\ n) = \frac{\mathrm{cov}(\phi^z_{mn},\ \zeta^z_{mn})}{\mathrm{var}(\zeta^z_{mn})} = \frac{\overline{\phi^z_{mn}\zeta^{z*}_{mn}}}{\overline{\zeta^z_{mn}\zeta^{z*}_{mn}}}.$$

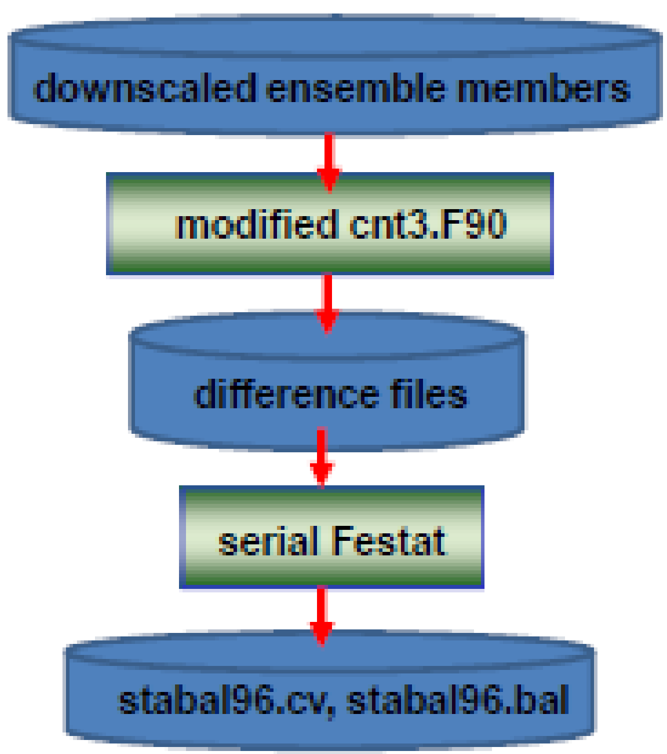
analytical hor. f-plane balance between geop and vort.

$$\Delta\phi(\mathbf{h},\ z) = f_0\zeta(\mathbf{h},\ z) \Leftrightarrow (\Delta\phi)^z_{mn} = f_0\zeta^z_{mn}$$

$$\Leftrightarrow \phi^z_{mn} = \frac{f_0}{\Delta_{mn}}\zeta^z_{mn},$$

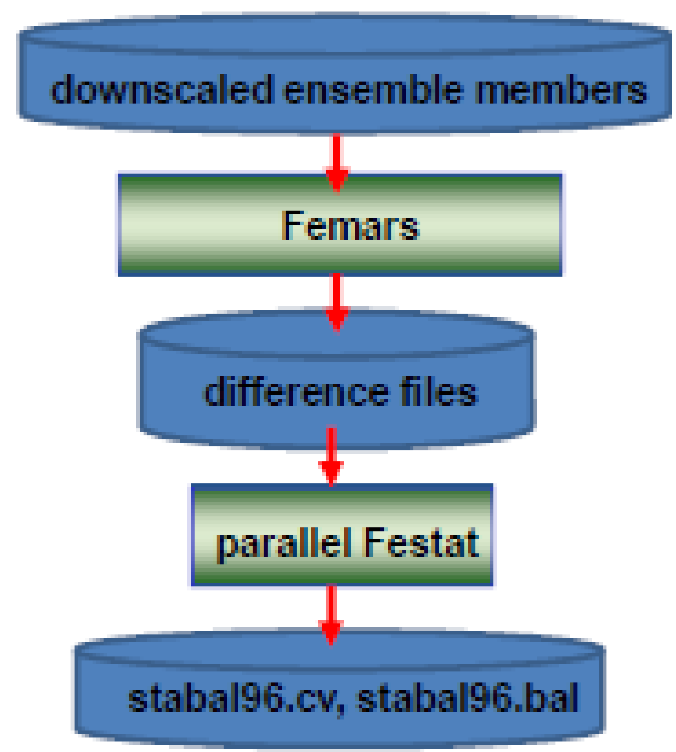
$$\Delta_{mn} = -\left(2\pi\frac{k^*}{N_s}\right)^2.$$

Old Procedure



Old Serial Festat

New Procedure



New Parallel Festat

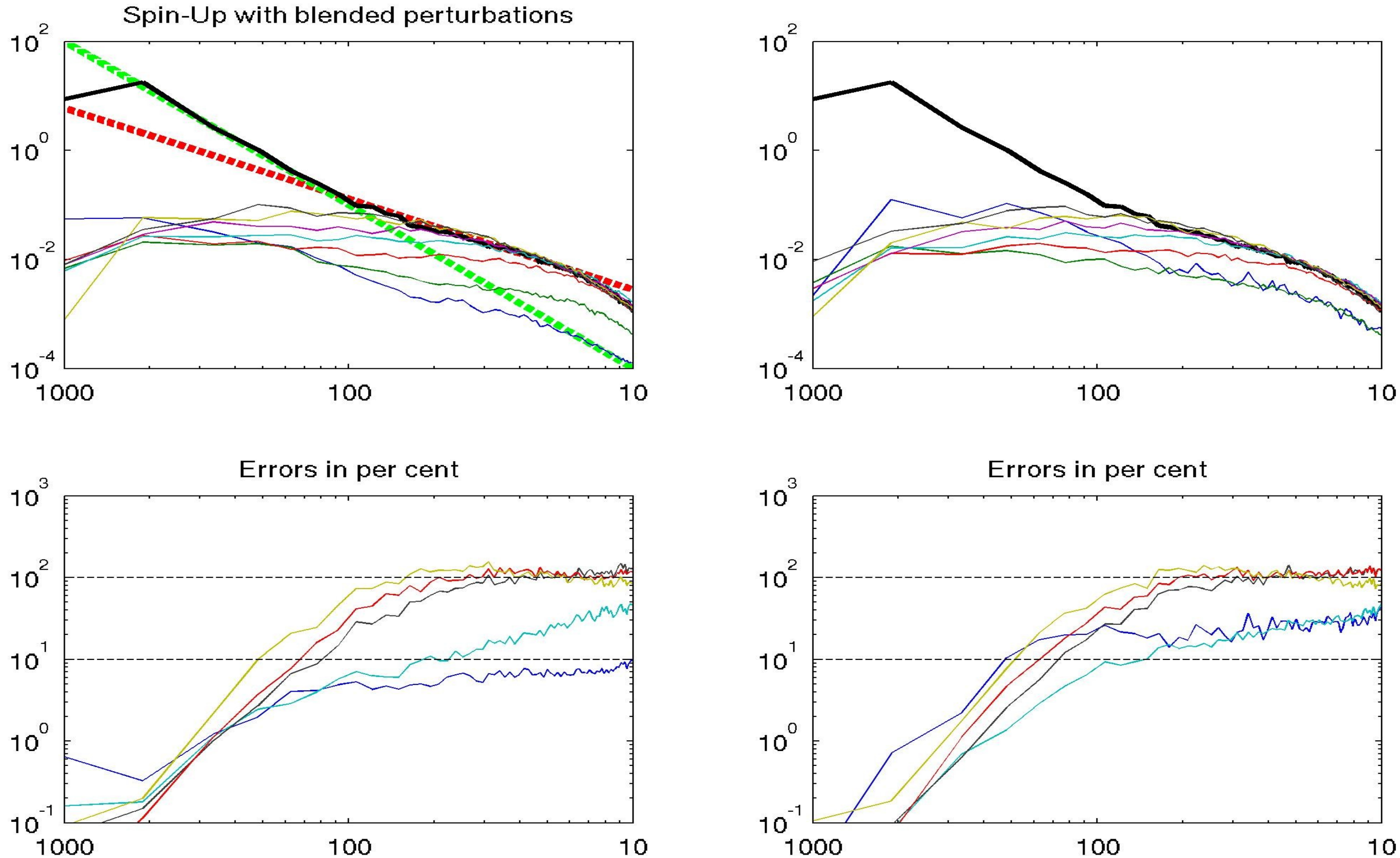
Thanks to MF Team !

From Magnus Lindskog, SMHI

Structure functions: sampling of uncertainty (5)

Error growth for the different size of initial perturbation

The development is non-linear already after 3 hours of model integration !



From Malte Müller, MET Norway

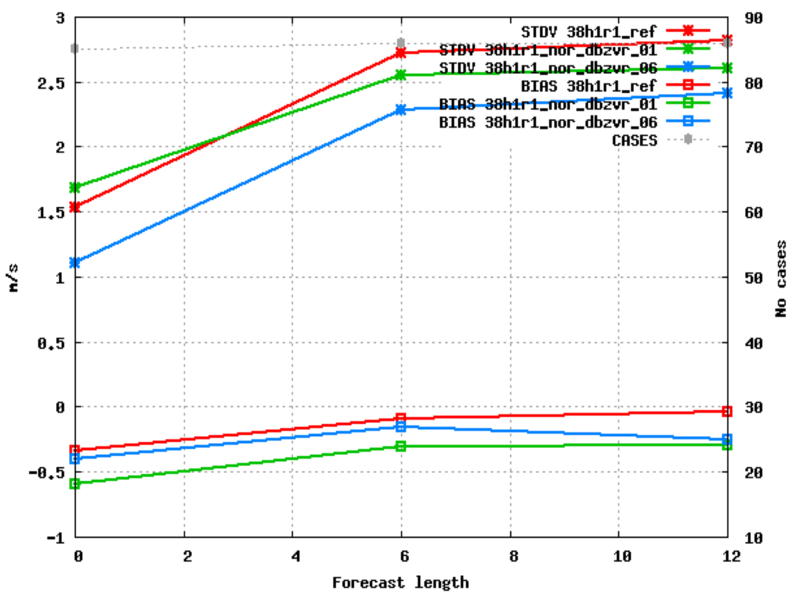
Need better insight into the error propagation mechanism:
→ Perturbing observations, what properties do we see?
→ How should we perturb in order to increase predictability?

Assimilation of radar data (1)

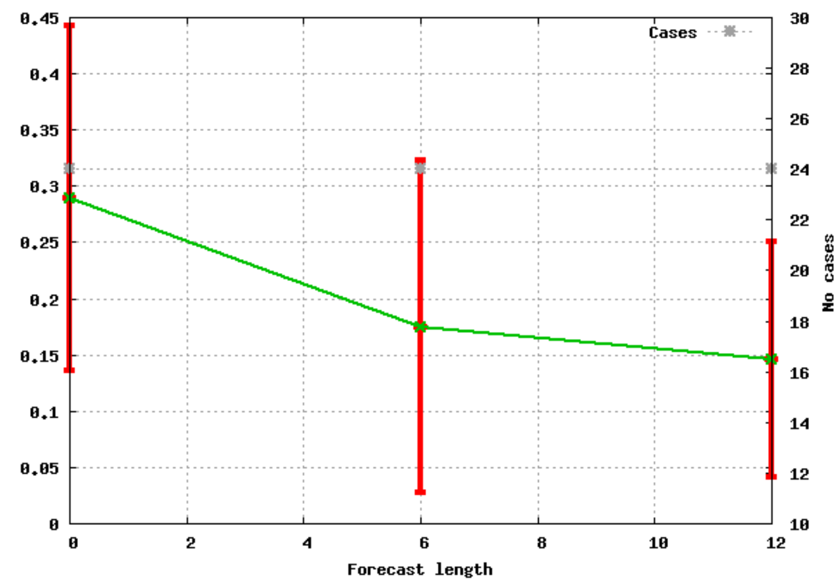
Root mean square error (RMSE) Radiosonde wind at 925hPa (~750m)
Summer experiment

Impact of the background error statistics
(preliminary results)

RMSE and BIAS



Difference (95% confidence)



Default model
Default model + radar
New model statistics + radar

New model statistics:
Perturbed observing network + varying physics parameterization + 12h model integration

From Malte Müller, MET Norway

The development of a robust technique to sample the model uncertainty on meso-scale is on-going

Assimilation of radar data (2)

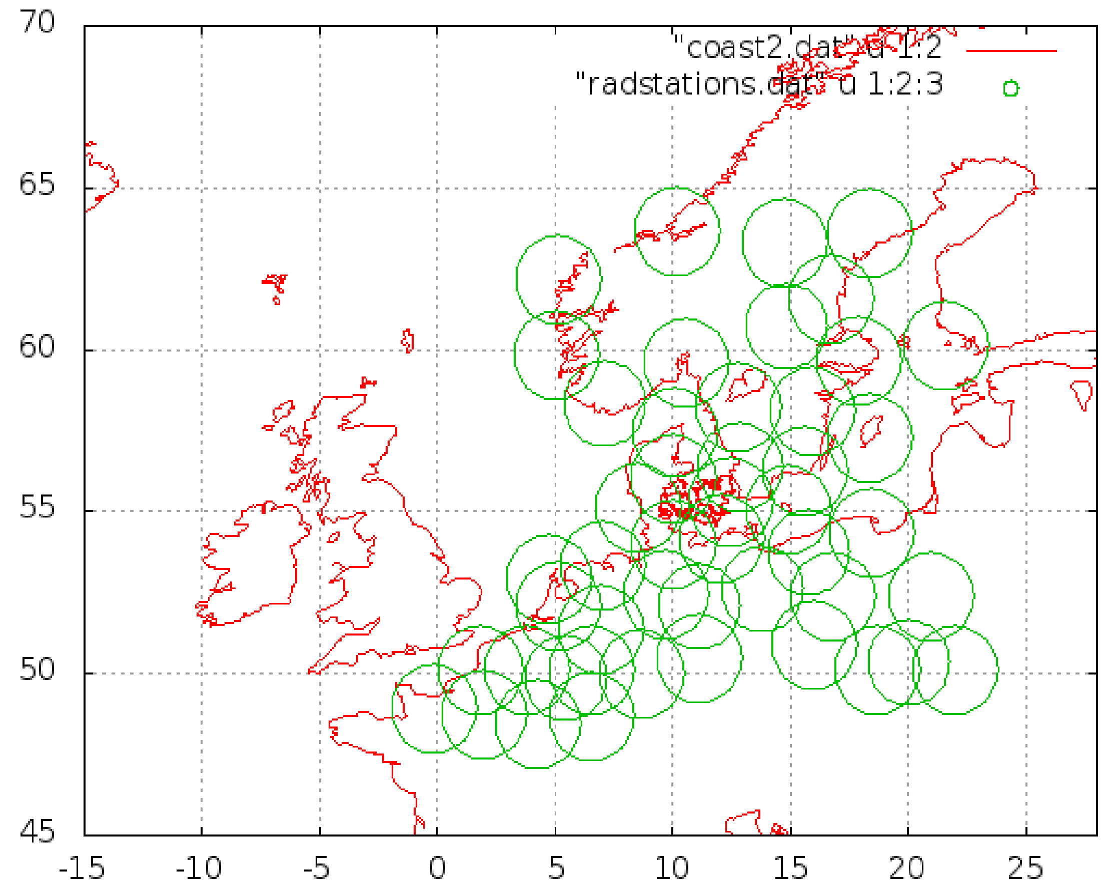
Radar data exchange experiment (DKA domain)

The BALTRAD QC Toolbox & Various local solutions at the NMSs

Harmonization and Transparency of local QC tools!

The common QC is essential for the progress in the radar data assimilation

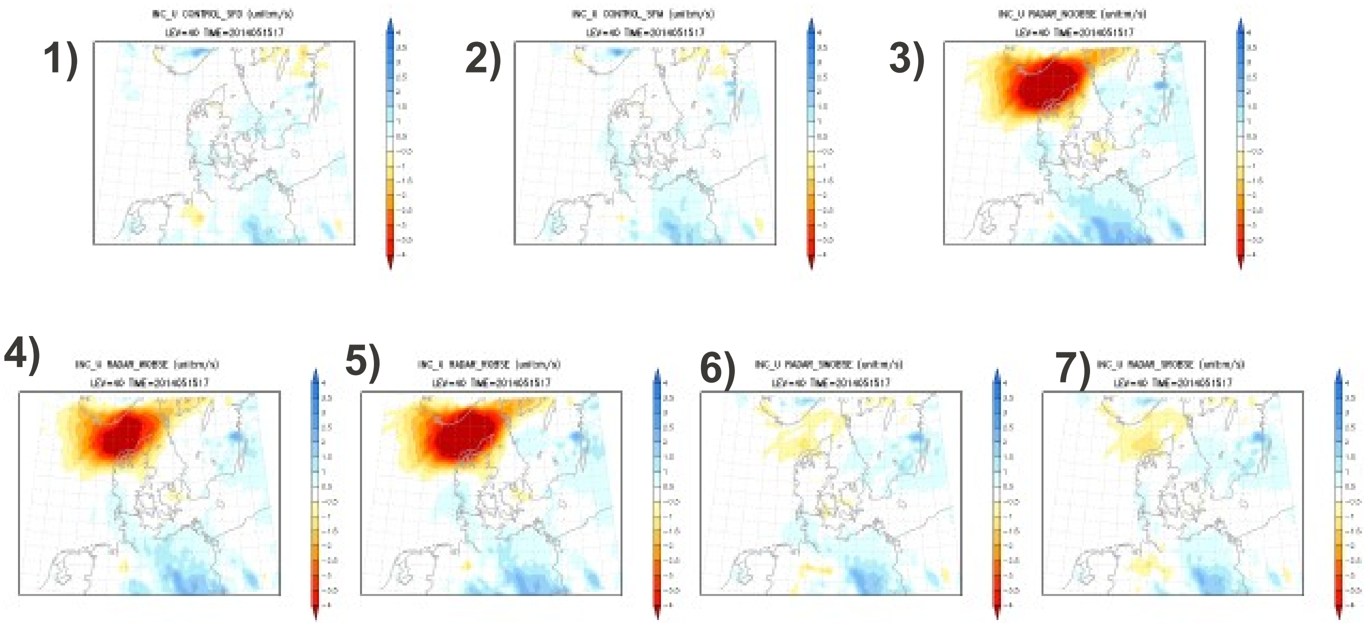
Important lessons to be learned on the local data exchange!



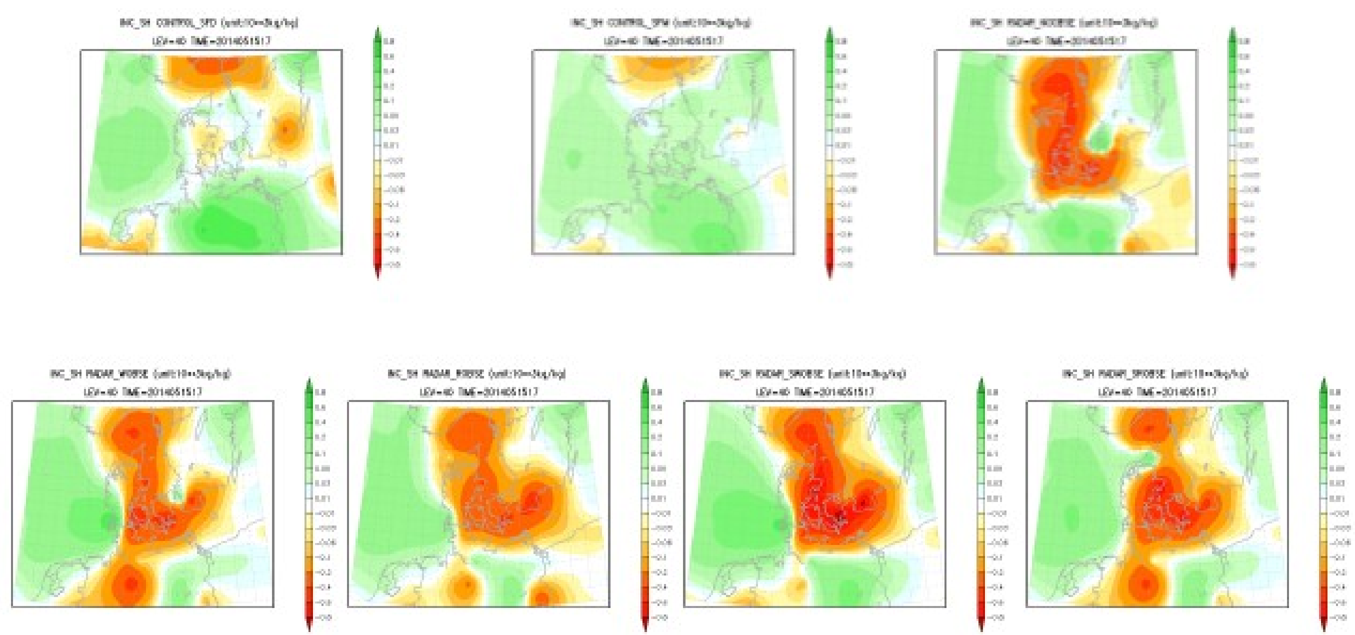
42 stations with reflectivities,
~20 with radial wind in addition;

From Mats Dahlbom, DMI

Assimilation of radar data (3)



U wind component an. increment 2014 05 17 ~850hPa



Specific humidity an. increment 2014 05 17 ~850hPa

Impact of observation error characteristics and structure functions on radar data assimilation

1) Default

2) Time-of-the-day str.func.

3) $OE_w = \frac{2}{250}D+1,\ OE_r = \frac{0.25}{160}D+0.15$

4) $OE_w = \frac{2}{250}D+2,\ OE_r = \frac{0.25}{160}D+0.15$

5) $OE_w = \frac{2}{250}D+1,\ OE_r = \frac{0.25}{160}D+0.30$

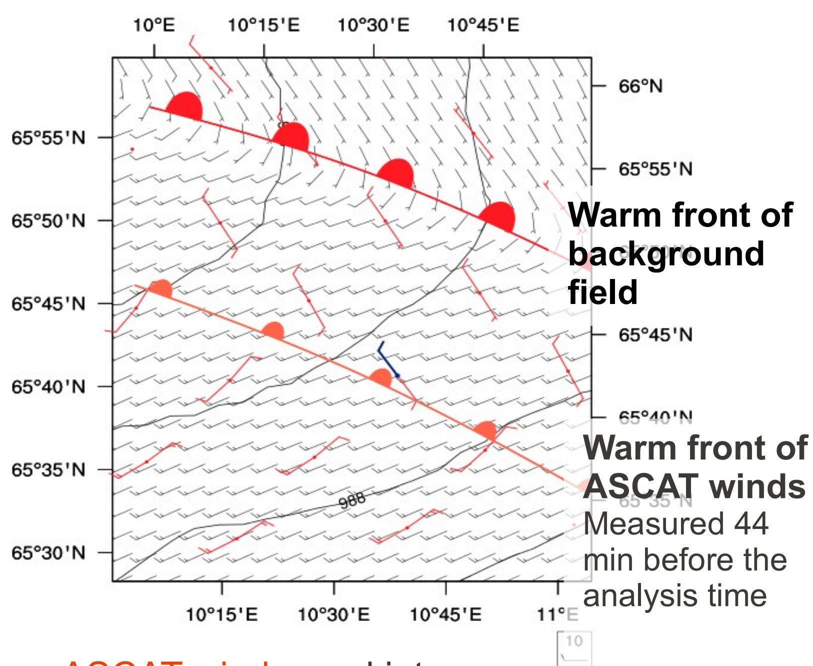
6) $OE_w = \frac{2}{200}D+1,\ OE_r = \frac{0.25}{160}D+0.15$

7) $OE_w = \frac{2}{250}D+1,\ OE_r = \frac{0.25}{100}D+0.15$

From Shiyu Zhuang, DMI

More high-resolution observations: scatterometer winds (1)

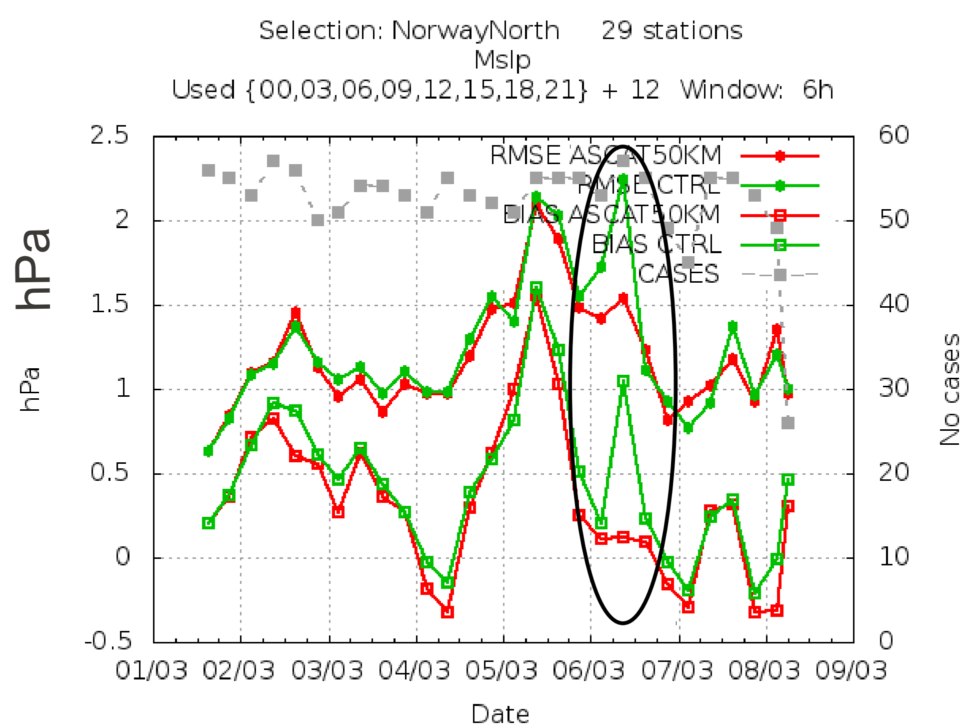
Time difference between the ASCAT measurement and the analysis time generates wrong ambiguity selections



ASCAT winds read into the model but rejected.
ASCAT winds used in DA.

Reduced thinning (a case of polar low):

RMSE and bias of mslp as timeseries



With ASCAT winds – 50 km thinning
Without ASCAT winds

From Teresa Valkonen, MET Norway

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

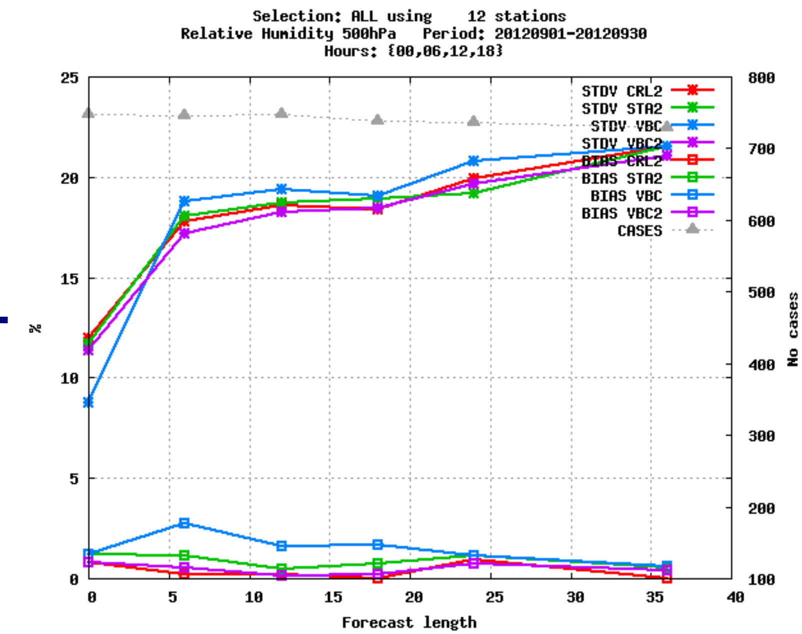
CRL2 "REDNMC=0.6 no GNSS"

VBC "First bad trial with GNSS"

STA2 "static bias correction with GNSS"

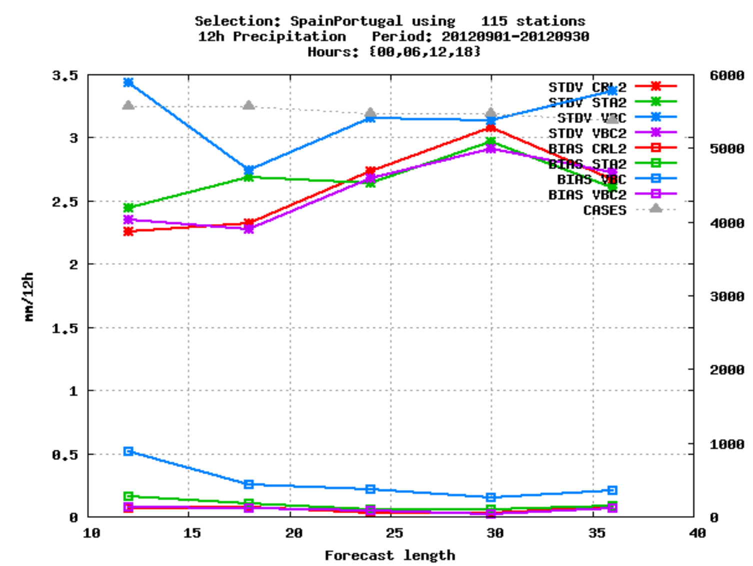
VBC2 "stiff VarBC with GNSS"

500h Spec.Hum



Persistent positive impact (finally!)

12h Accum. Precipitation



DO NOT OVERFIT!!!

Keep yourself away from the observations, if model is biased

From Jana Sanchez Arriola(AEMET), Sigurdur Thorsteinsson (IMO), Magnus Lindskog (SMHI)

Overall tuning of the DA system

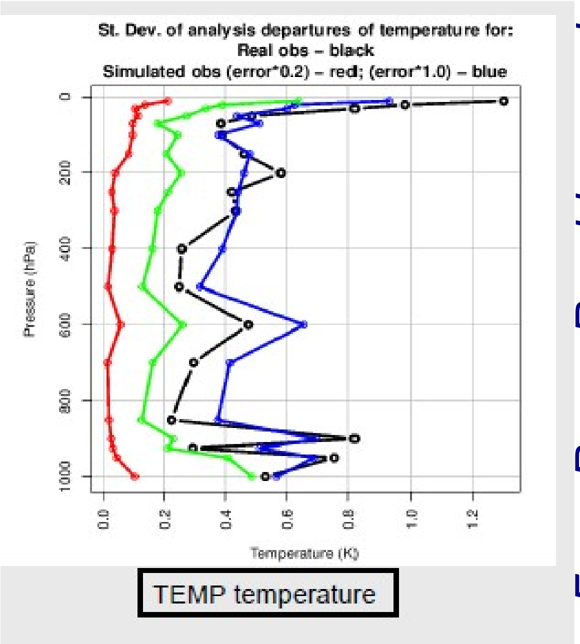
(efficient use of **combined** high-resolution observations)

OSSE setup
(tuning of simulated
obs. errors)

- VarBC
- Observation error characteristics
- Cyclic frequency
- Super-obbing/thinning versus effective model resolution
- Obs. errors correlation
- ...

Impact studies

Diagnostics



From Roger Randriamampianina, MET Norway

challenge

infeasible for a single one

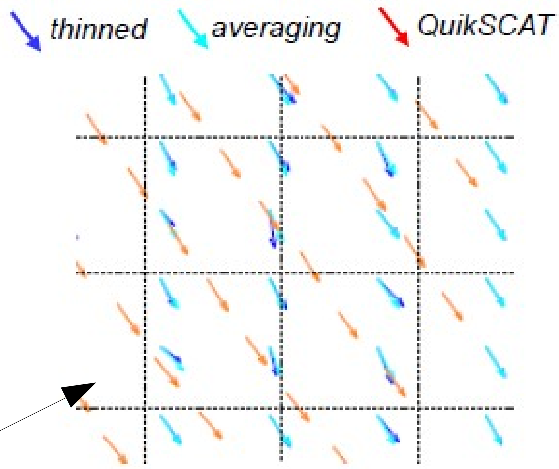
Coordinated use of combined efforts

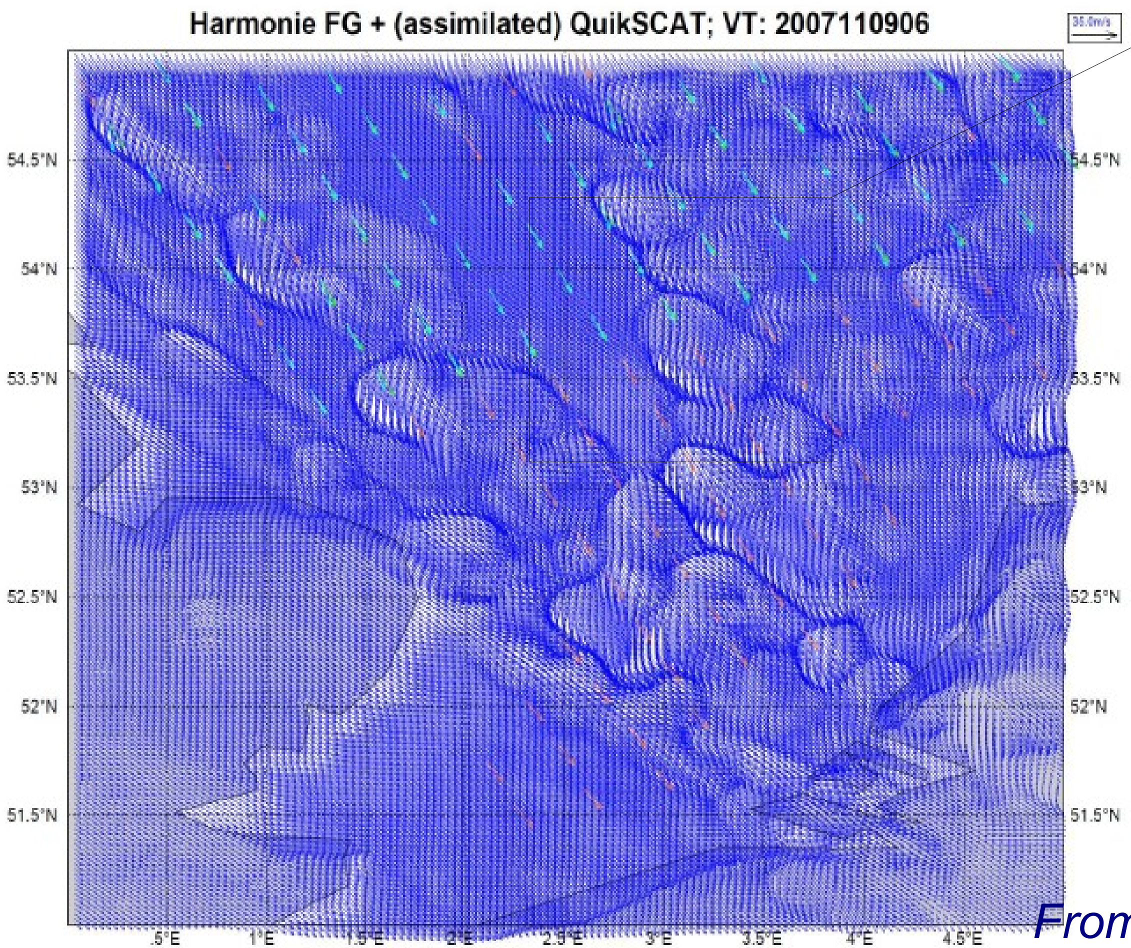
solution

achievable for the team

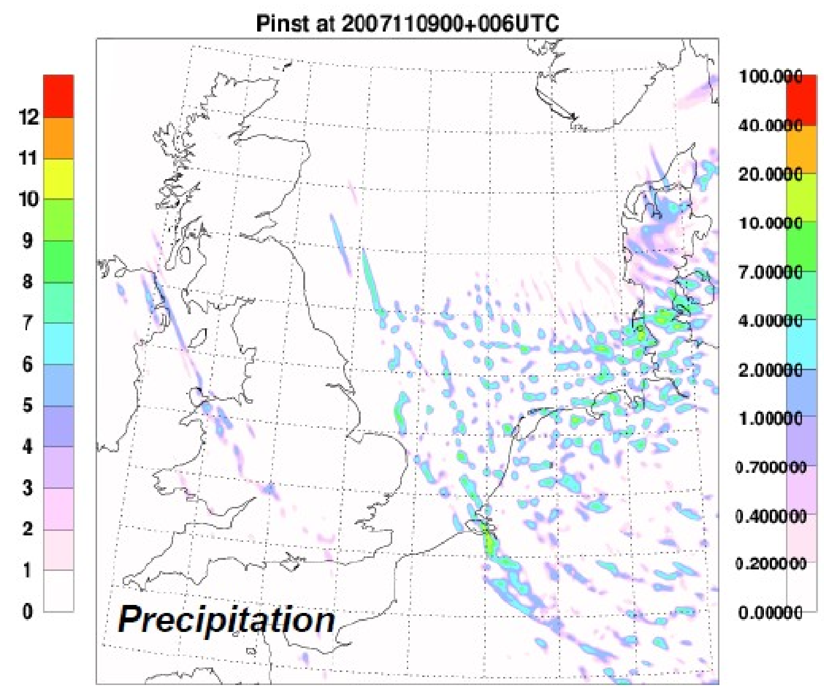
Scales for the deterministic analysis update

→ 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; **What are the meaningful scales for deterministic analysis update?**





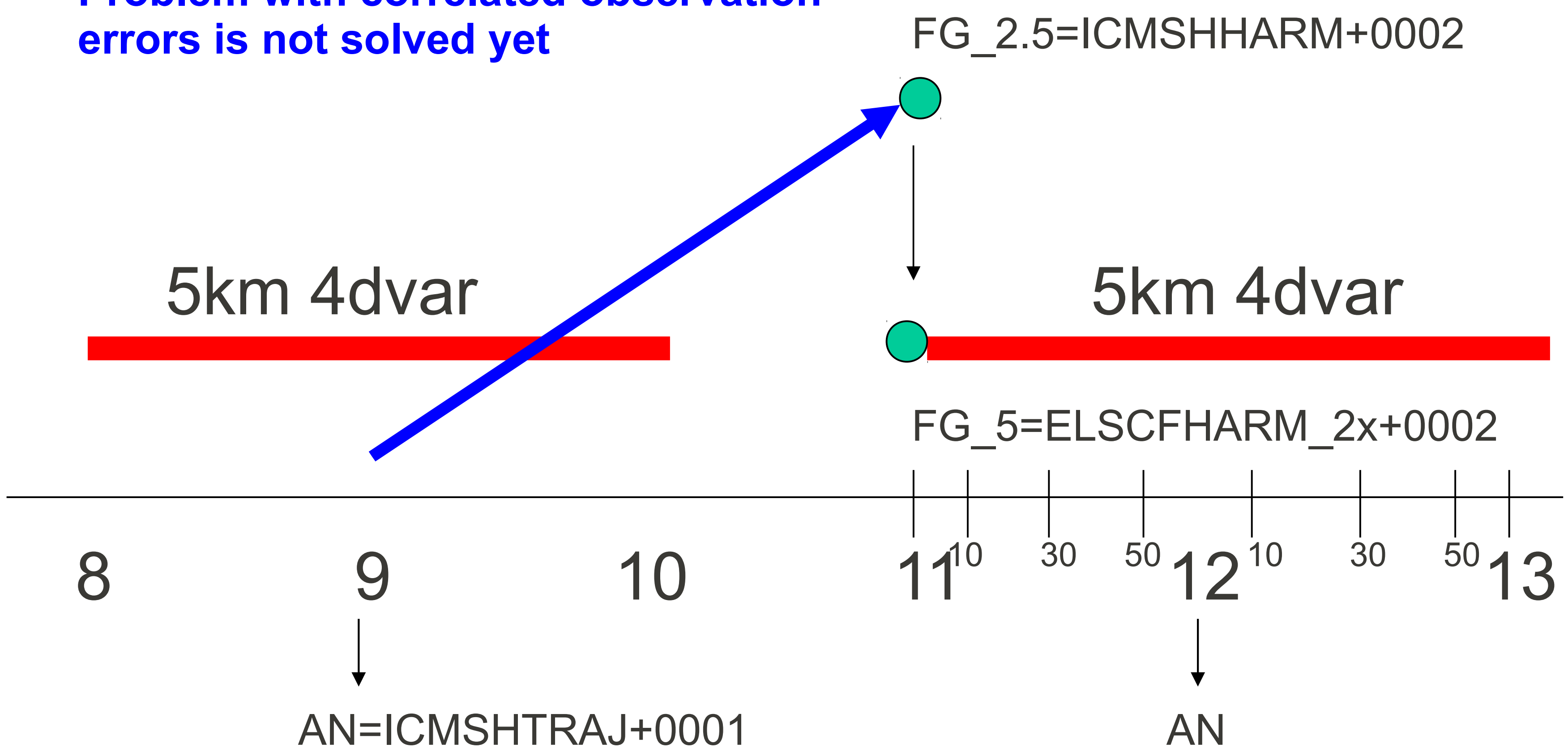
QuickSat footprint is about 50km^2



From Gert-Jan Marseille & Wim de Rooy (KNMI)

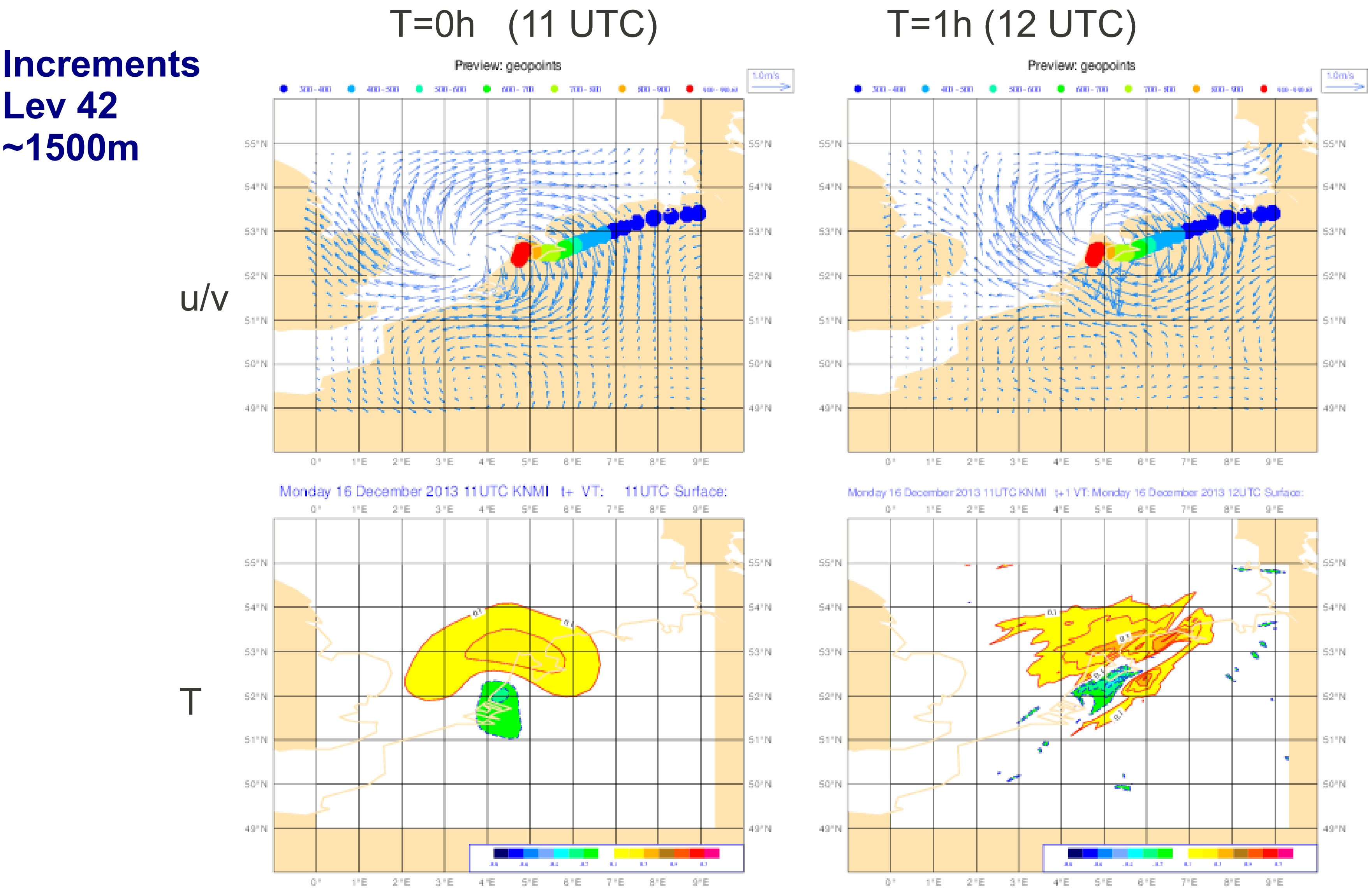
HARMONIE AROME 4DVAR Prototype
(since 17 Jan 2014)

Hydrostatic ARPEGE TL/AD
2 h DA window **(soon even shorter)**
20 min observations time slot
Conventional + Mode-S, radar data **(ZTD GNSS on the way)**
Cost order of 12h forecast
Problem with correlated observation errors is not solved yet



From Jan Barkmeyer (KNMI) & Magnus Lindskog (SMHI) et al

HARMONIE AROME 4DVAR Prototype (2)

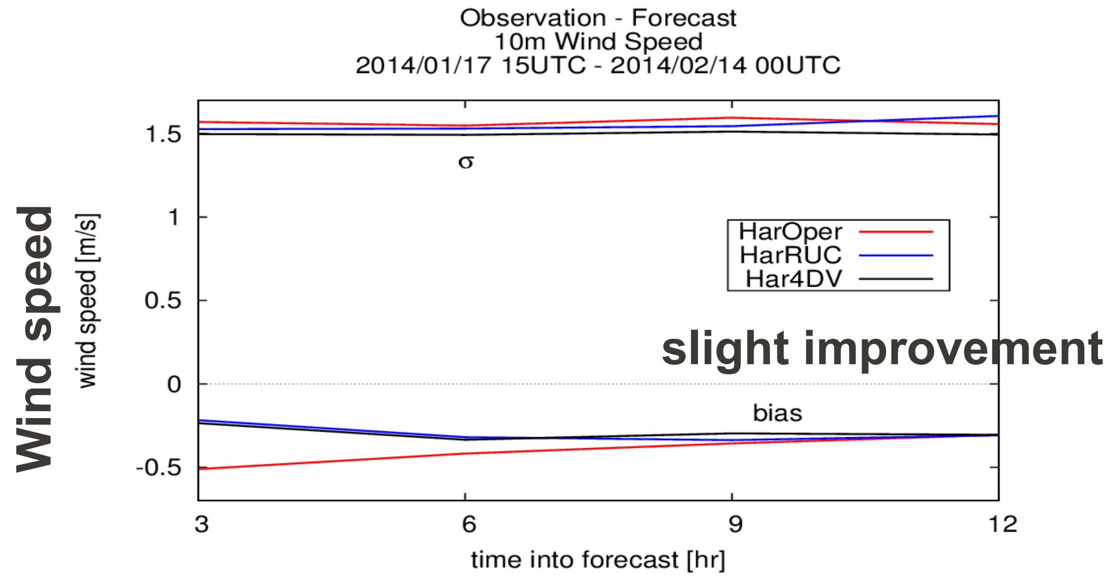


Problem with the small scale noise still remains when interpolating increment to high-resolution

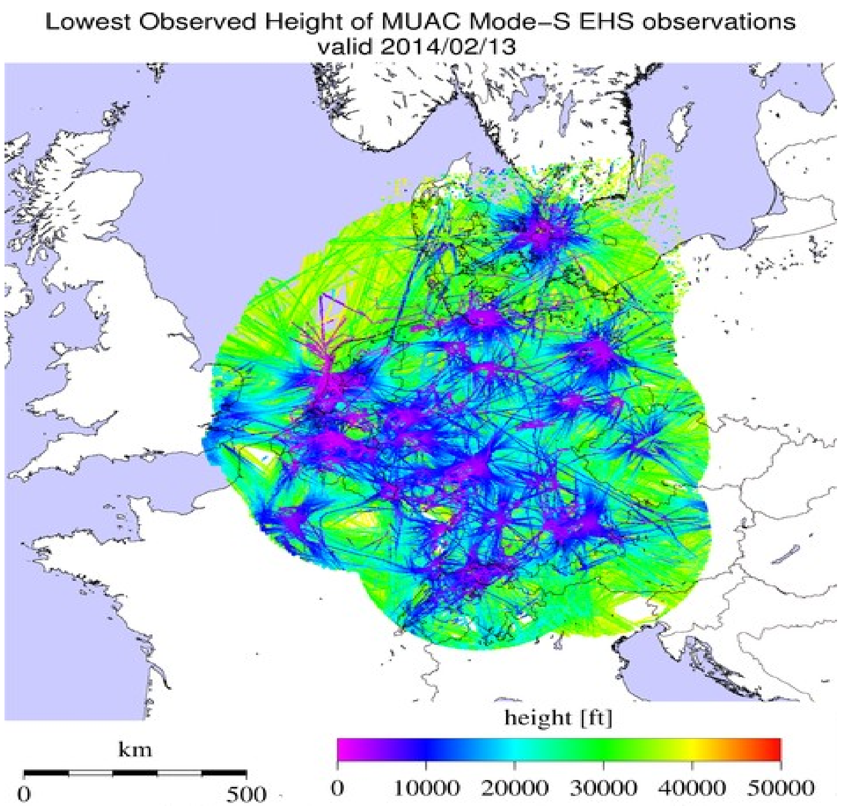
HARMONIE AROME 4DVAR Prototype (3)

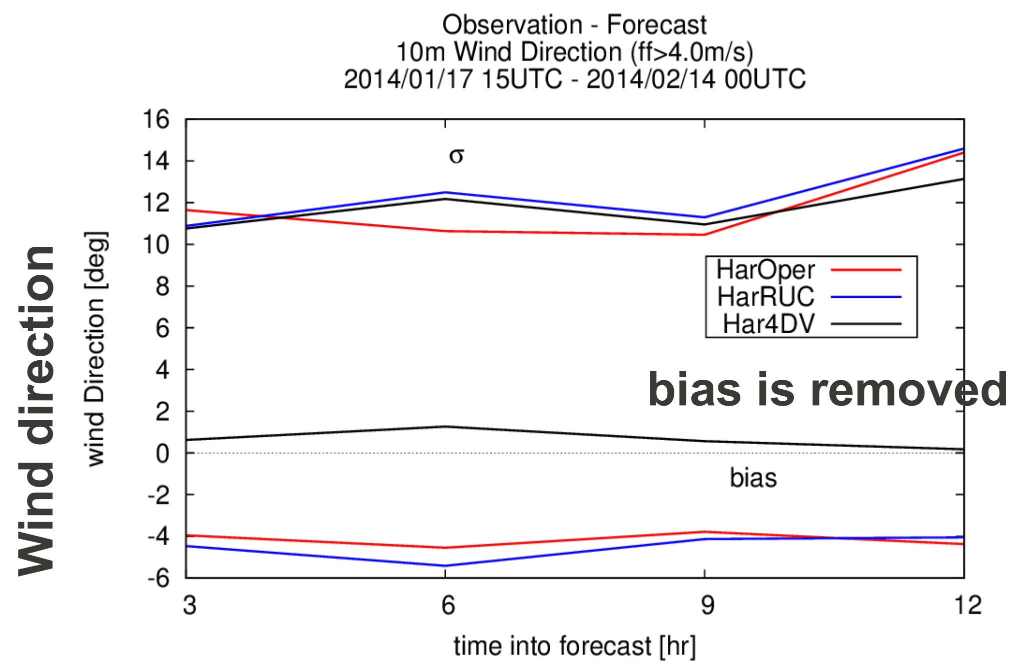
Impressing one month period verification results
(17 Jan – 14 Feb 2014)

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



10 m wind verification



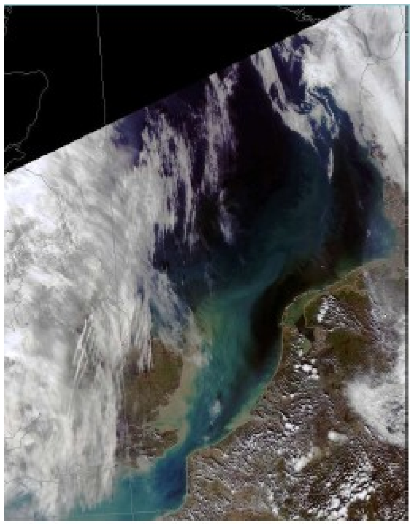


From Jan Barkmeyer & Siebren de Haan

HARMONIE AROME 4DVAR Prototype (4)

From Jan Barkmeyer & Sibbo var der Veen (KNMI)

Satellite image

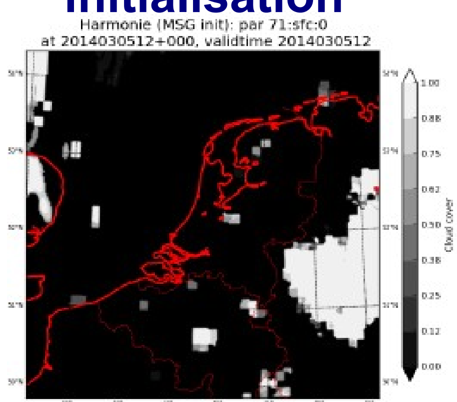


Even more impressing results!

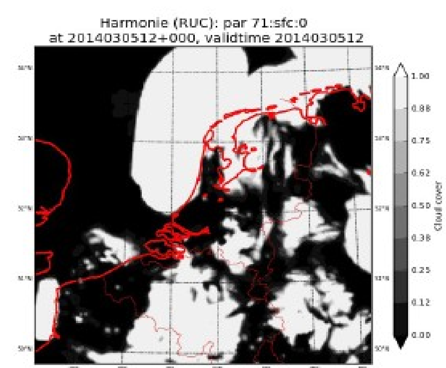
The Fog over sea problem is significantly reduced in HARMONIE AROME 4DVAR assimilation

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

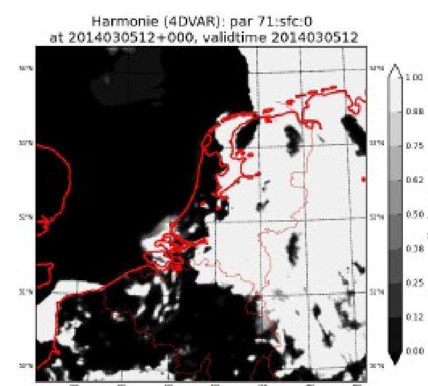
Cloud mask initialisation



HarRUC



Har4DV



Proof of Pudding lies in the Eating!

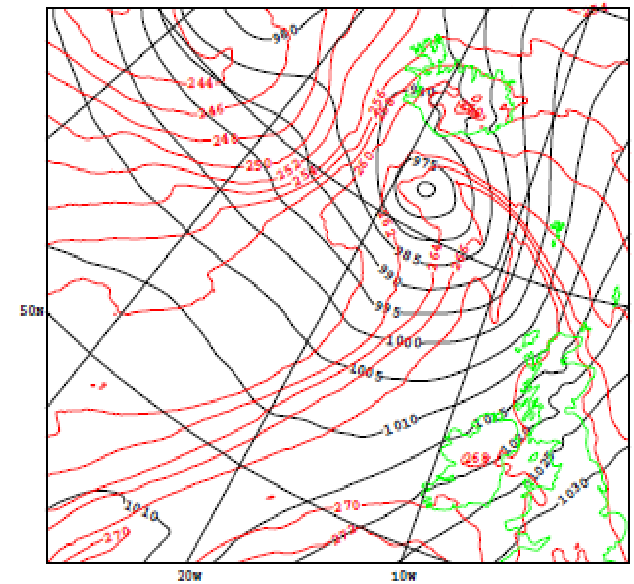
Flow-dependent structure functions (1)

Single simulated observation experiments

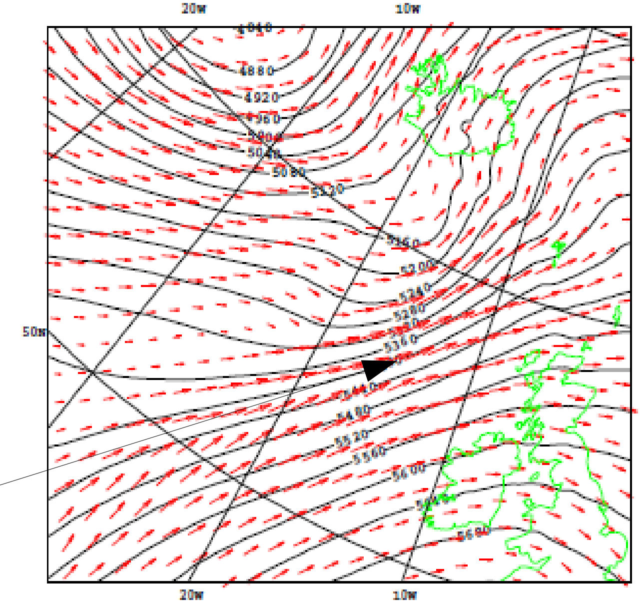
58° N, 15° W; 500hPa
5 hours into assimilation window
du =10m/s; dv = 5m/s

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

From Nils Gustafsson (SMHI) & Jelena Bojarova (MET Norway)

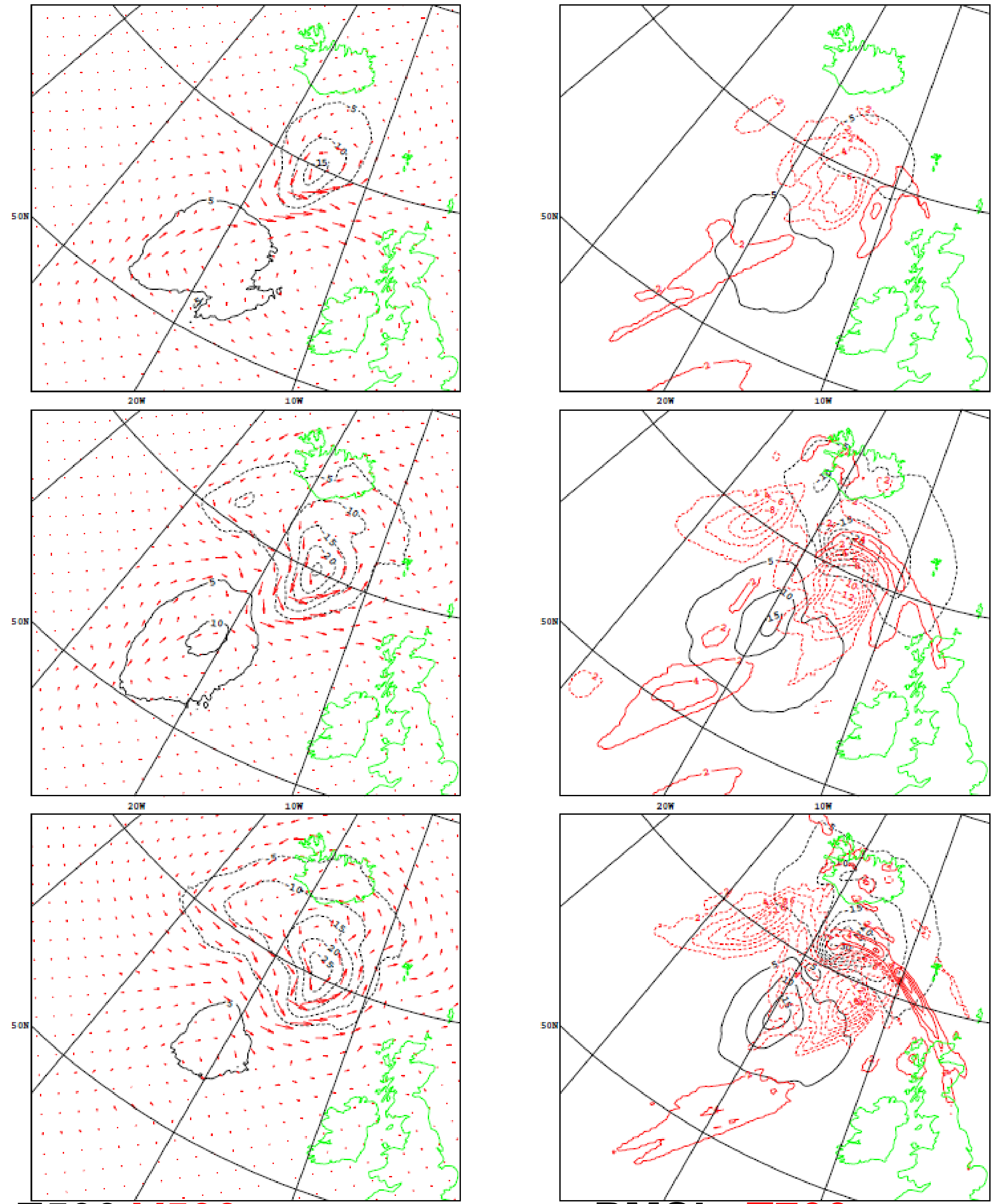
Flow-dependent structure functions (3)

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**

Unifying HARMONIE DA algorithmic developments

- Large scale error constraint:

  → ***Jk*** as additional regularization term
  J= Jb+Jk+Jo (with preconditioning).

  (Per Dahlgren, SMHI)

- Clouds mask initialisation: $T_v = T(1+0.61 q_m - q_l - q_i - q_r - q_s - q_g)$

  → constant virtual temperature constraint for adjusted temperature/humidity profiles **as a weak constraint** via Lagrangian multiplier

  (Sibbo van der Veen, KNMI)

- Phase-error correction via field alignment:

  → extended control vector space (initially as 2D field) + regularization constraint + displacement **transform operator, displacement TL, displacement AD**

  (Carlos Geijo, AEMET, Tomas Landelius et al (SMHI))

- Quadrature methods (linearization):

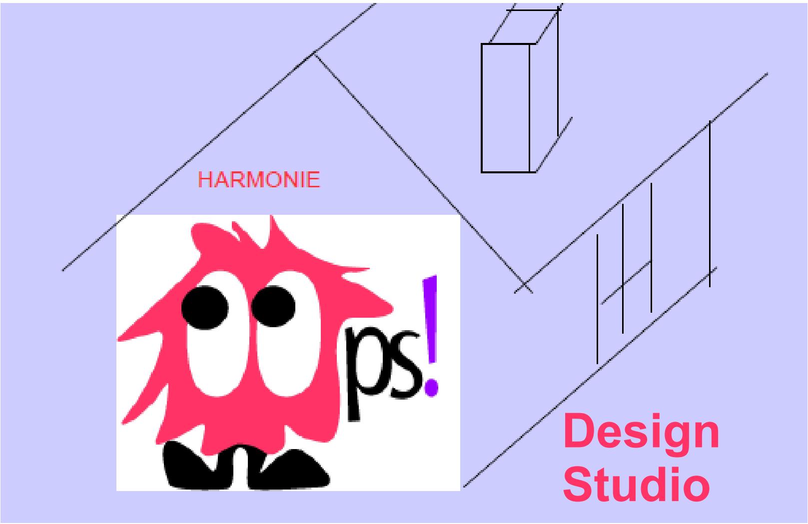
  → GQ-4DVAR, re-linearization of obs. operator

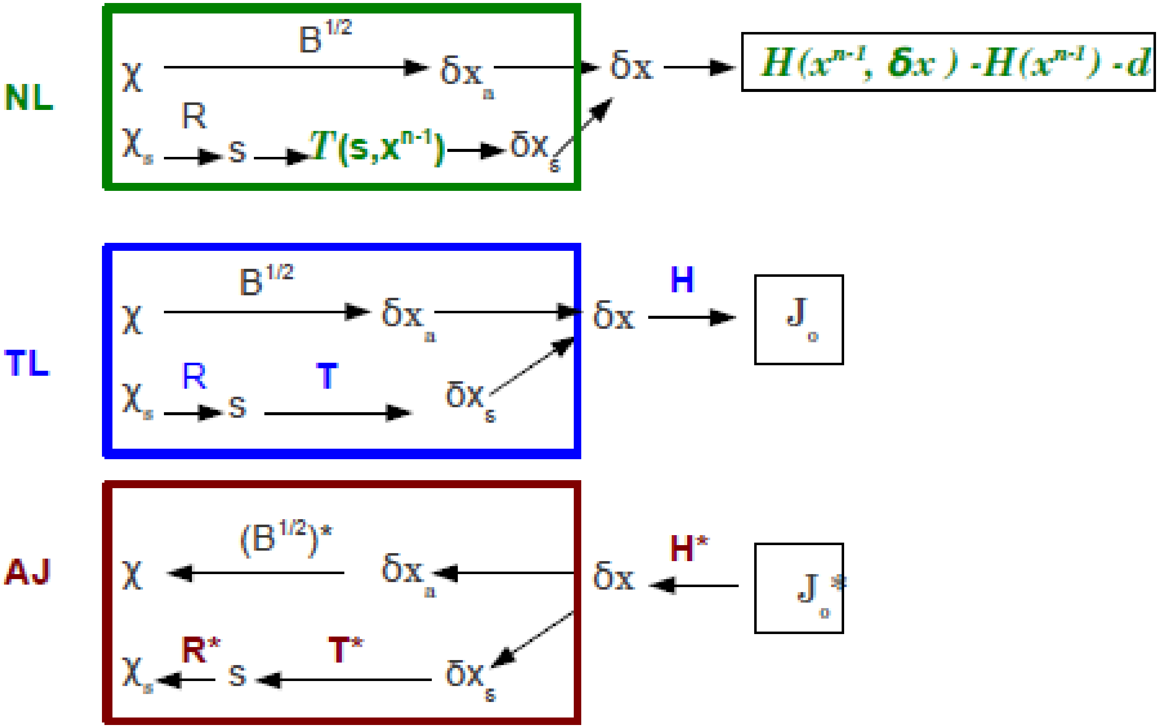
  (Roel Stappers, MET Norway)

and flow dependent background error statistics (*"Nils&Jelena"*), etc., etc., long term work planned within OOPS (***Jk*** more urgent)

Towards the unified variational data assimilation framework on meso-scales

(advantages of the OOPS design studio + inner/outer loop device =>
solution to a general non-linear minimization problem)

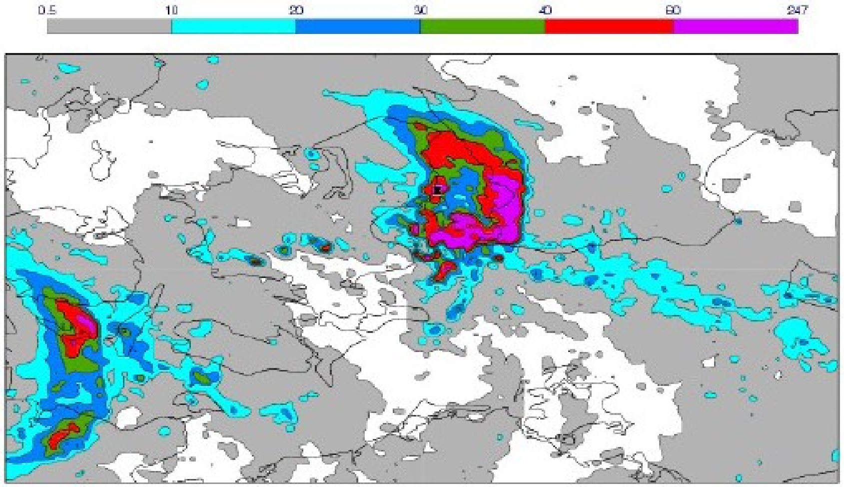




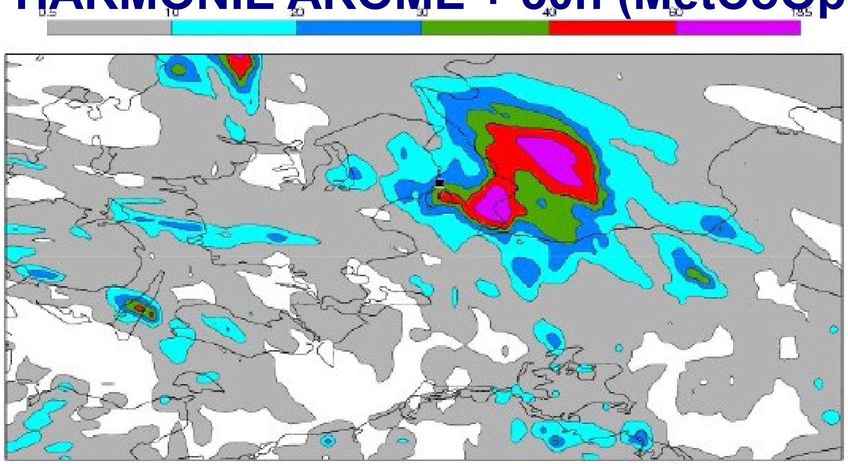
We plan to integrate the stand-alone developments into the unified variational data assimilation framework **first in form of pre-processors** and later on as **the part of joint cost-function**...

Keep going !

Radar data 31.08 00UTC - 12UTC



HARMONIE AROME + 30h (MetCoOp)



12 h accumulated rainfall

Good news : The HARMONIE AROME is often capable to predict convective precipitation events;

Worse "news": The quality of the short-term forecasts in the operational runs is not satisfactory : **coupling strategy and data assimilation to be blamed**

The best news: There is a lot of space for improvements !!!


Keep Going ...
everything will be okay
in the end ...
if it's not okay,
it's not the end
Unknown
Thank You for your attention!