Overview of HIRLAM data assimilation activities On algorithmic developments and Use of Observations

Collected by Jelena Bojarova

The 34th EWGLAM and 19th SRNWP Meeting,
FMI, Helsinki, 8-11Oct. 2012

HARMONIE- HIRLAM-B programme

developments for convection-permitting scales

Powerful and flexible research tool
designed for synoptic scale systems

HIRLAM (HIgh Resolution Limited Area Model)

ECMWF IFS (Integrated Forecasting System)

ALADIN (Aire Limitée Adaptation Dynamique Développement InterNational)

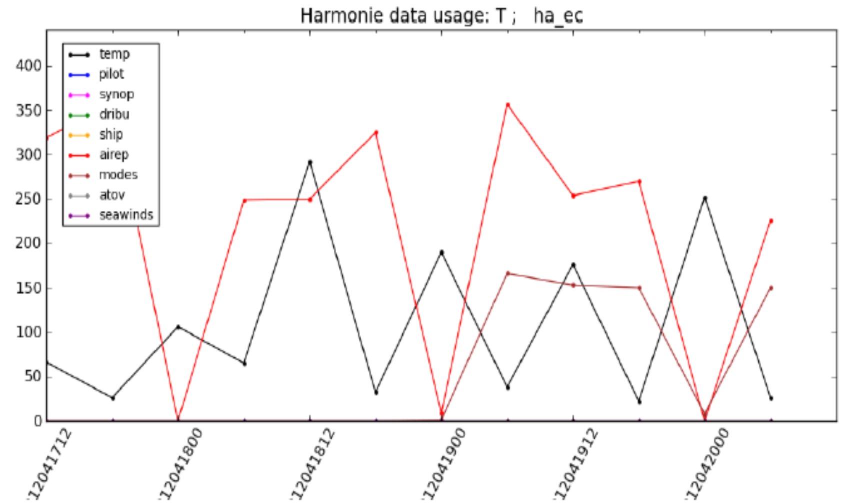
The goal: move operational activities here
but is still under development

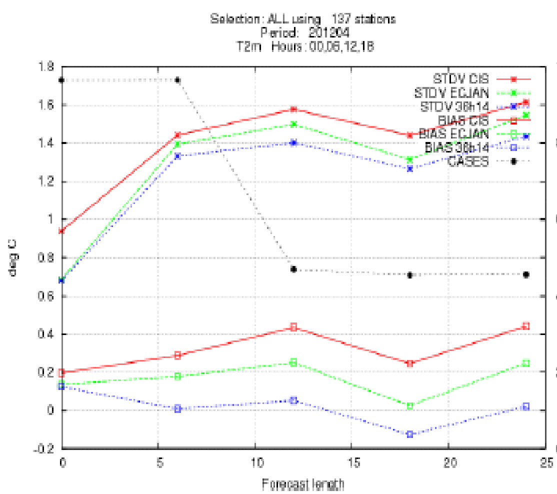
HARMONIE (***Hirlam Aladin*** Regional/Meso-scale Operational NWP In Europe)

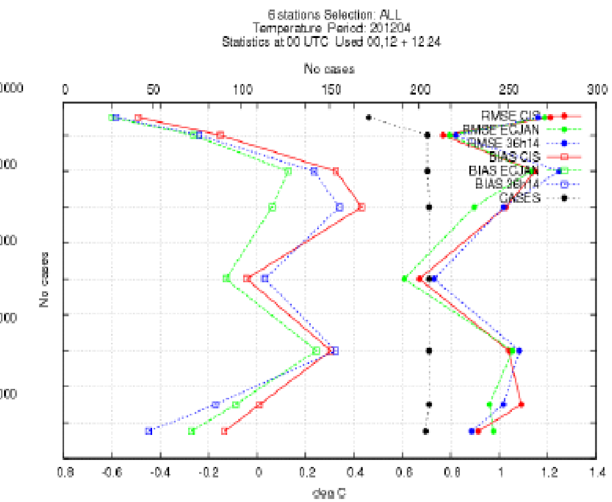
(Pre-)Operational HARMONIE at KNMI

ECJAN

Data usage: ModeS from 2012041906





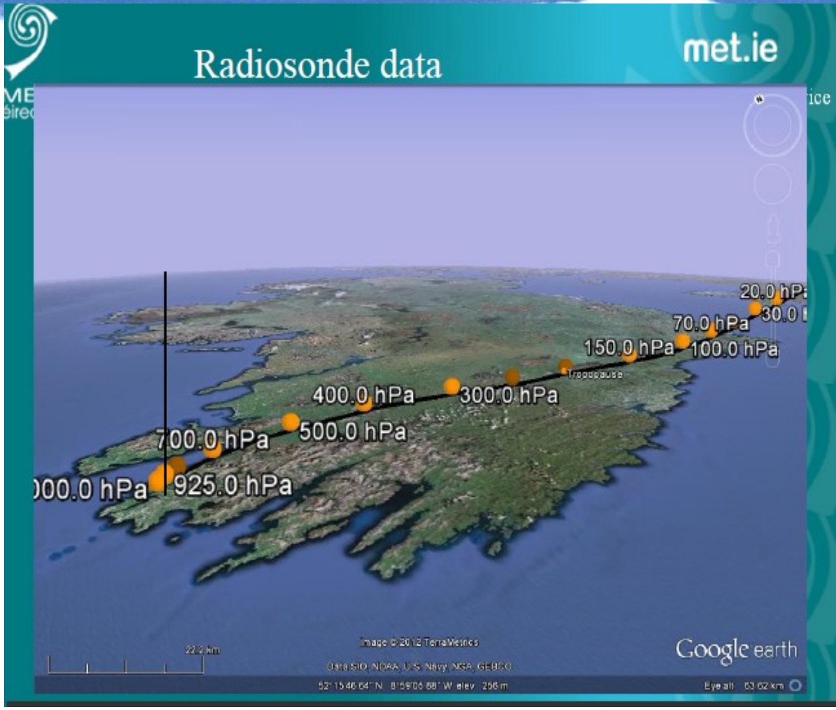


by Jan Barkmeijer and Siebren de Haan, KNMI

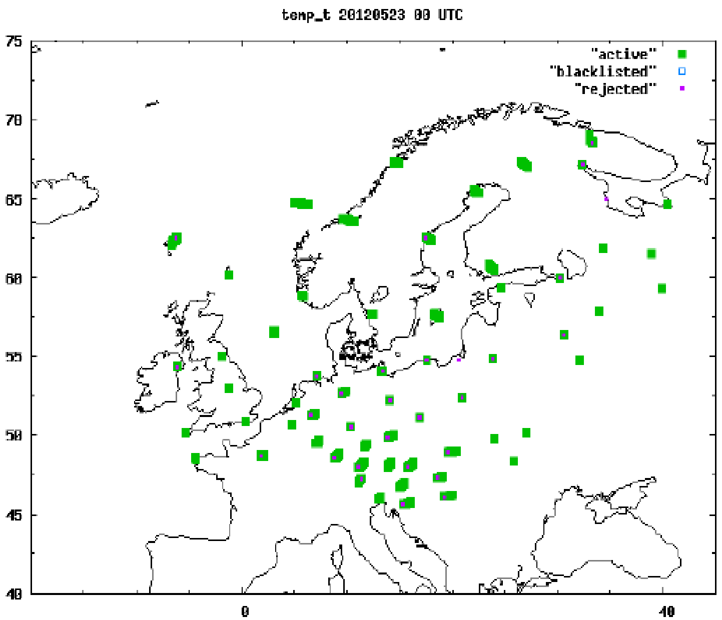
Improved use of the existing observational network

TAC data format → TDCF data format

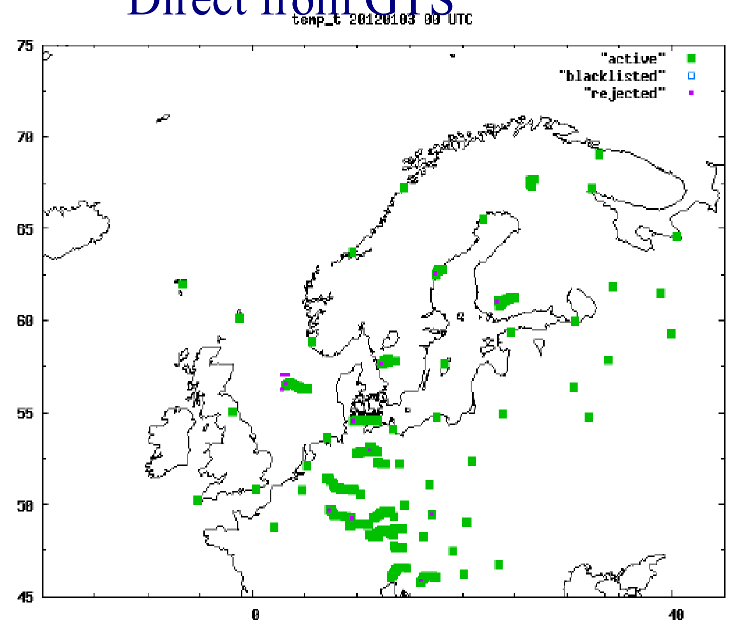
Higher resolution,
Better accuracy,
More Metadata



SMHI data



Direct from GTS



(by Eoin Whelan, The Irish Meteorological Sievice)

Short-term framework

for meso-scale DA

Implementation of the RUC setup ((pre-)operational at KNMI);
— 3h update frequency (1h dynamical "spin-up" problem)

High resolution high frequency observations
— conventional data : temp, synop, ships+
— ModeS (pre-operational at KNMI) +AMDAR (Bias Correction!)+
— RADAR, GPS, ASCAT (in progress) +
— screen level observations for UA DA (first priority) +
— "moist" observations (cloud initialisation + cloudy radiances) (research)

A *configuration of the observation network plays an important role for the efficiency of the RUC scheme, in particular reducing the "spin-up" problem: both upper air and lower troposheric observations should be present*

Assimilation of radar reflectivity data in HARMONIE (1)

Method from Météo-France: 1D Bayesian + 3DVAR [2, 3, 1]

- Reflectivity is not a model control parameter
- ⇒ Generate pseudo-observations from the model background (first guess): Profiles of relative humidity

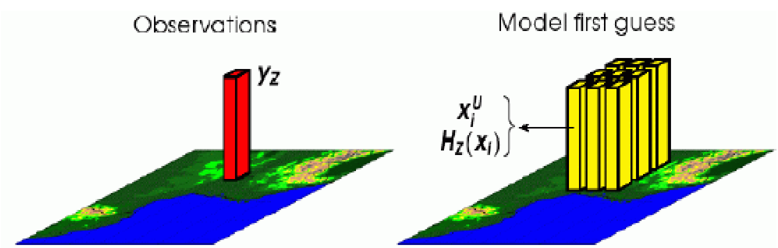
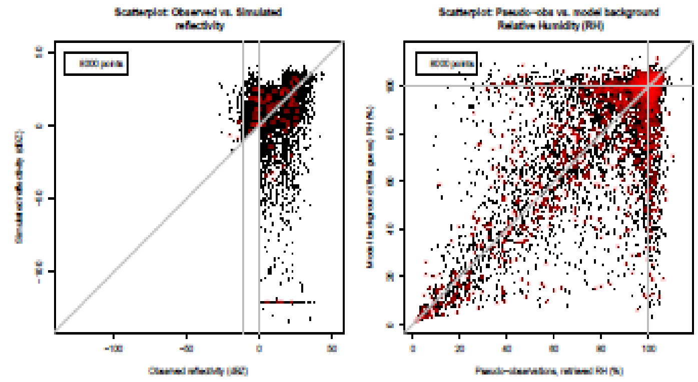


Illustration: Olivier Caumont

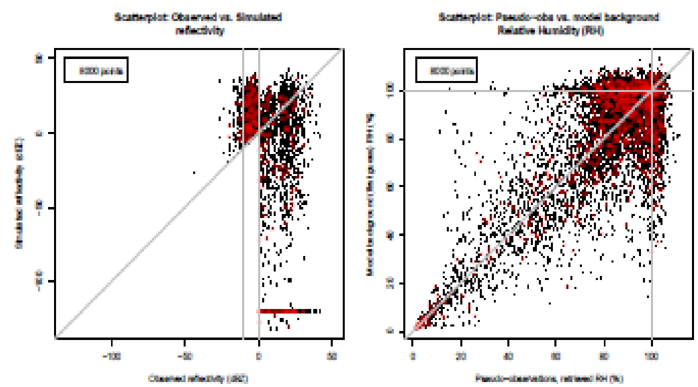
- Several neighboring columns of simulated reflectivity ($H_Z(x_i)$) are used to generate one single pseudo-obs. column of relative humidity (RH, x_i^U).

(*by Martin Sigurd Grønsleth and Roger Randriamampianina, met.no report*)



(a) 2011-09-06: Observed reflectivity (dBZ) vs. simulated reflectivity (dBZ), thinned to 8000 points.

(b) 2011-09-06: Relative humidity (RH) pseudo-observations (retrieved RH) (%) vs. model background (first guess) RH (%). Thinned to 8000 points.



(c) 2011-09-07: Observed reflectivity (dBZ) vs. simulated reflectivity (dBZ), thinned to 8000 points.

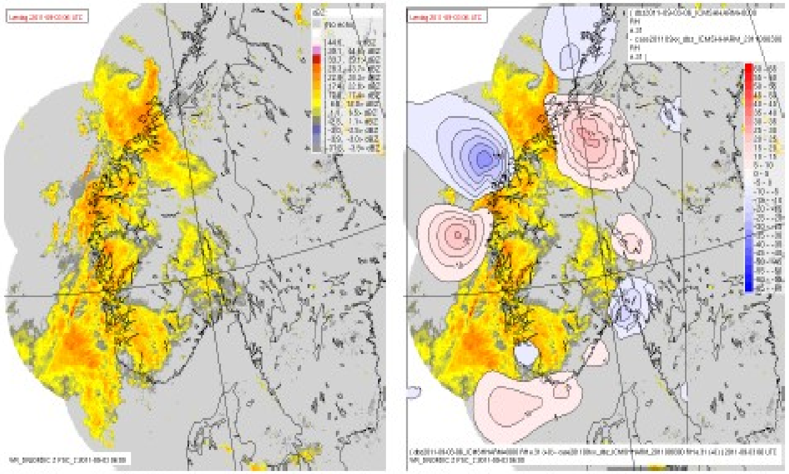
(d) 2011-09-07: Relative humidity (RH) pseudo-observations (retrieved RH) (%) vs. model background (first guess) RH (%). Thinned to 8000 points.

Figure 3.15: Scatter plot of (pseudo-)observation vs. (simulated) model background. Active values, i.e. after the 1D Bayesian inversion, are circled in red. Data from four cycles at 2011-09-06 (upper, heavy rain), and 2011-09-07 (lower, less rainy). See text for explanation.

Assimilation of radar reflectivity data in HARMONIE (2)

Case Study in a non-optimal setup

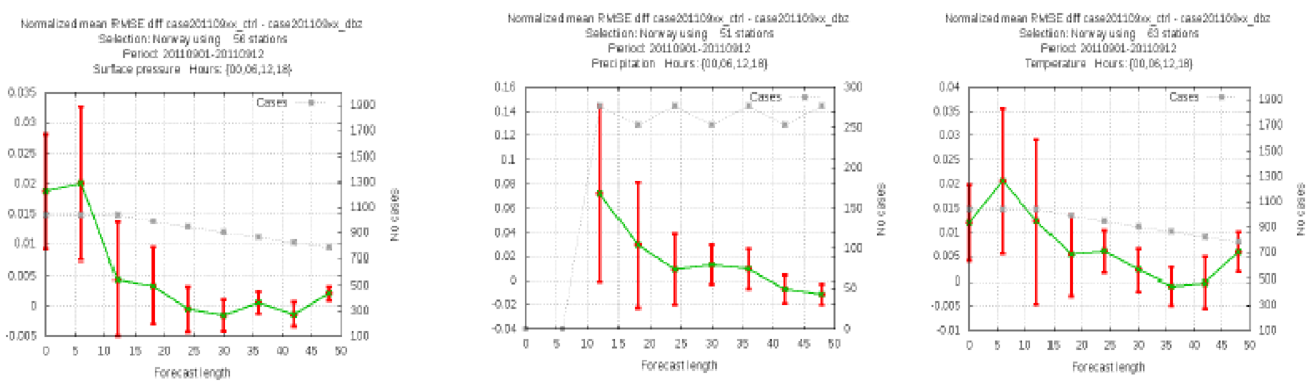
(small domain + 6h update frequency)
Positive impact on surface pressure, 12h accumulated precipitation and temperature scores for short forecast length



(a) Observed reflectivity at analysis time (Pseudo-CAPPI, *i.e.* reflectivity at about 500-700 m)

(b) Analysis minus first guess (model background) in relative humidity (RH) at model level 31

Figure 3.16: Analysis increments for HAR25EXP_RADAR. We can see that assimilation of radar reflectivity is increasing/decreasing relative humidity at appropriate places. Note that the pseudo-CAPPI plot does not reflect the full volume of observed reflectivity (which is used in the assimilation).



(a) Surface pressure (PS)

(b) Precipitation (12 h accumulated)

(d) Temperature

(*by Martin Sigurd Grønsleth and Roger Randriamampianina, met.no report*

Quality control of radar data

is the core issue for the successful radar data assimilation.
(KNMI, DMI, SMHI, AEMET, met.no)

→ Poster "Quality control of polar weather radar data using the baltrad toolbox" *by Daniel Michelson et al.*

" Three bullets "

* the BALTRAD toolbox is an Open Source software framework for processing and improving the quality of weather radar data

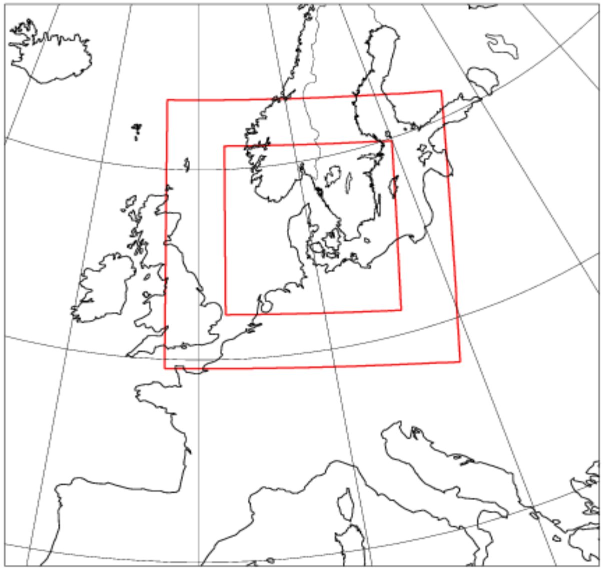
* the toolbox and its tools have been trialed at the European level using data from ~115 radars. HIRLAM community is investigating pros and cons of the BALTRAD Toolbox as a COMMON radar data QC tool

* the toolbox will be deployed by OPERA's Odyssey in support of NWP's needs.

Extended radar data impact studies

7-24 Aug 2010 (extended Danish domain)

are initiated by HIRLAM community in order to speed up the progress in implementing high-resolution high-frequency observations



3DVAR AROME HARMONIE RUC 3h

(conventional + radar data + ZTD GNSS + ASCAT winds + IASI (water vapour sensitive) + AMSU-a, AMSU-b)

Some information on the pre-processing of ZTD GNSS

→ "AEMET National poster" (by Jana Sanchez Arriola)

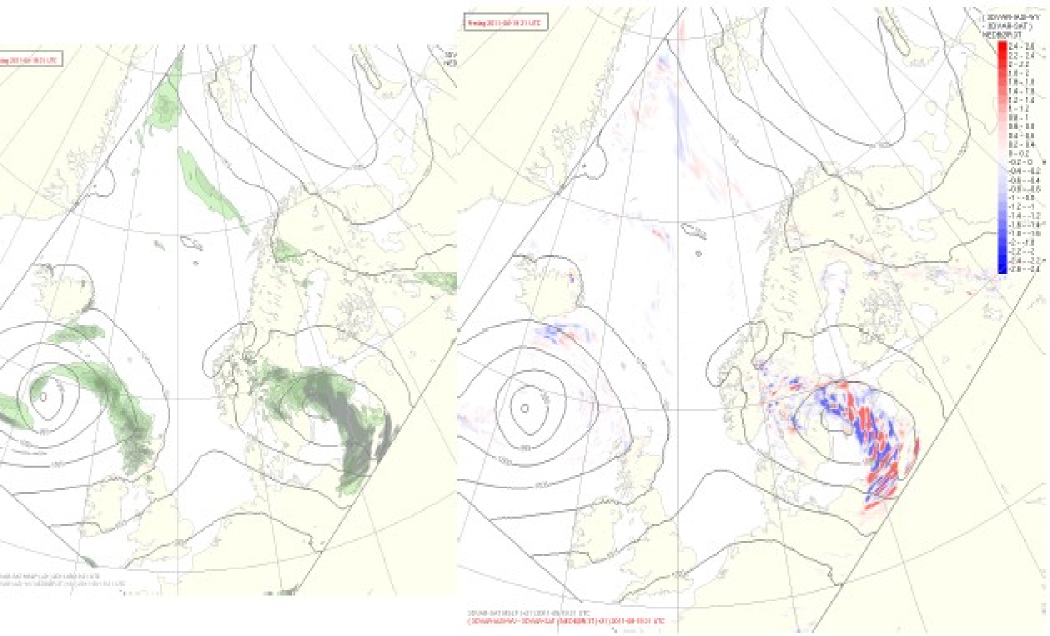
Assimilation of radiances in HARMONIE

Water vapour sensitive IASI channels

The moisture increments from water vapour sensitive IASI channels do not affect the total precipitation amount but impact the positioning of individual cells and bands

Channel number	Typical approximate peak level (hPa)
3448	250
3450	250
3452	300
3491	300
3506	300
3555	300
3575	300
3577	250
3580	250
3582	300
3589	300
3653	250
3658	300
3661	300
4032	250

Case 19 aug 21 utc



Research topic:

What is the optimal set of predictors assimilating radiances on meso-scale model ?

Harald Schyberg et al (met.no) in collaboration with Roger Randriamampianina

MSG cloud mask initialisation in HARMONIE (1)

(using cloud mask nowcasting SAF, MSC cloud top temperature and SYNOP cloud base height)

Relation between cloud amount and specific humidity:

$$q_m = q_s . ((1 - C) . \sqrt{N} + C) \qquad q_m = \min(q_m, C . q_s)$$

$$C = rh_{max} - (rh_{max} - rh_{min}) . \sin(\pi \frac{p}{p_s})$$

N: 3-D cloud cover

Preserve buoyancy when changing humidity (keep virtual T constant)

especially important in Harmonie!

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

Correction: $T = T_v / (1 + 0.61 q_m - q_l - q_i - q_r - q_s - q_g)$

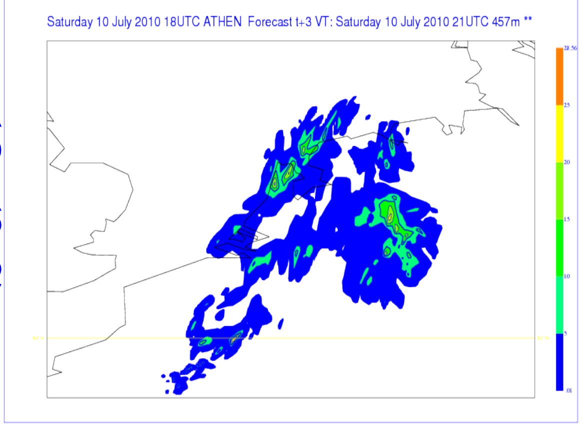
(by Sibbo van der Veen, KNMI)

Convection in HARMONIE

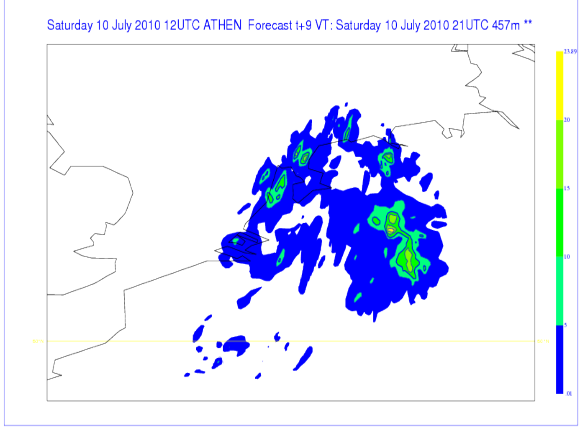
Severe thunderstorm 10 July 2010

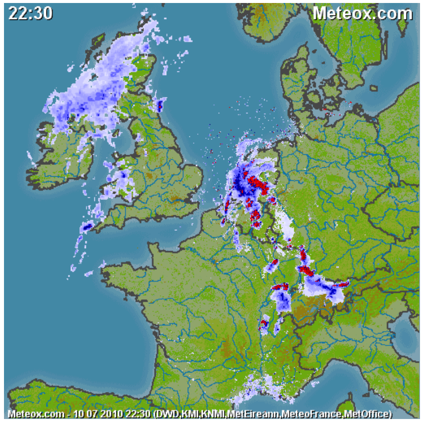
control

18+(3-2)

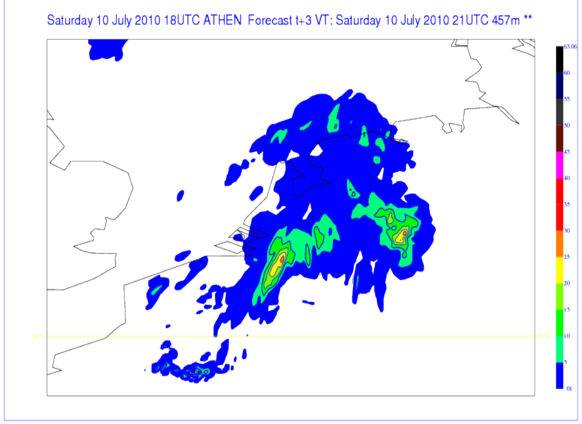


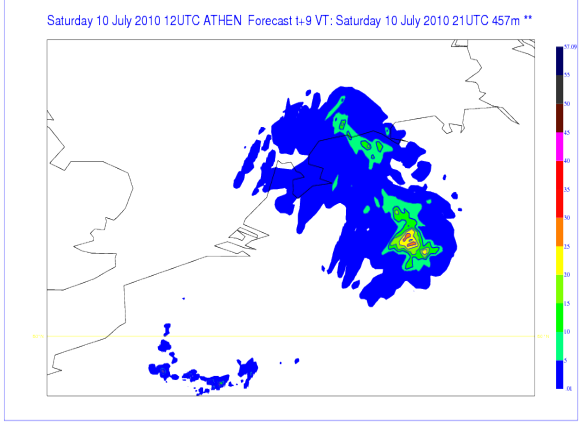
12+(9-8)





MSG

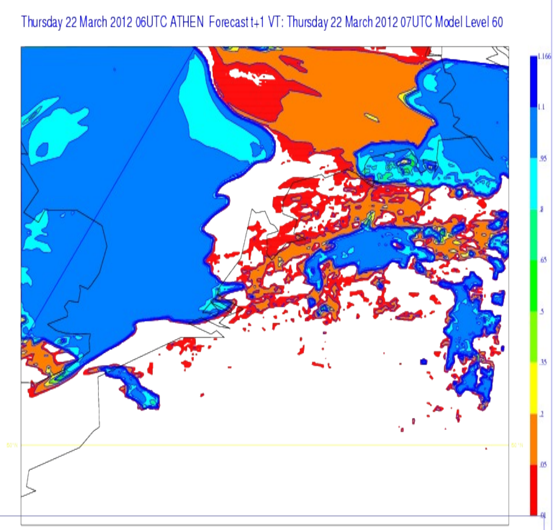


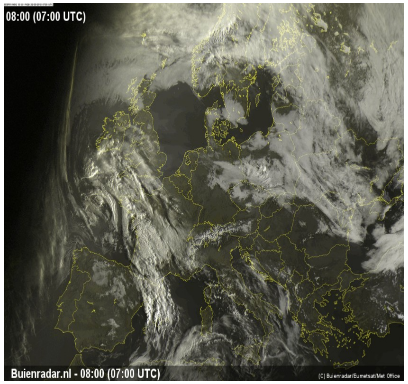


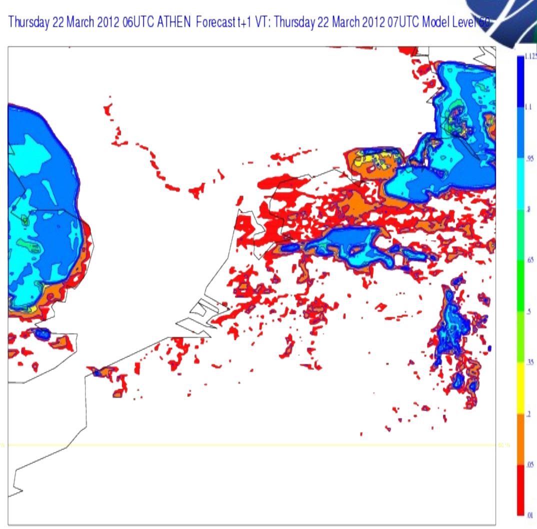
(by Sibbo van der Veen, KNMI)

Fog in HARMONIE

+1



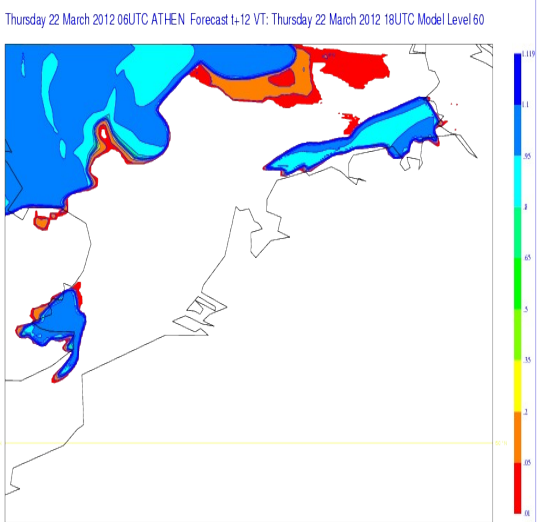


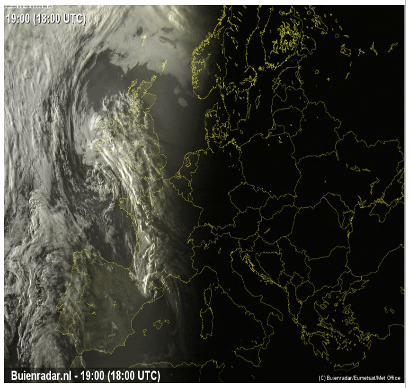


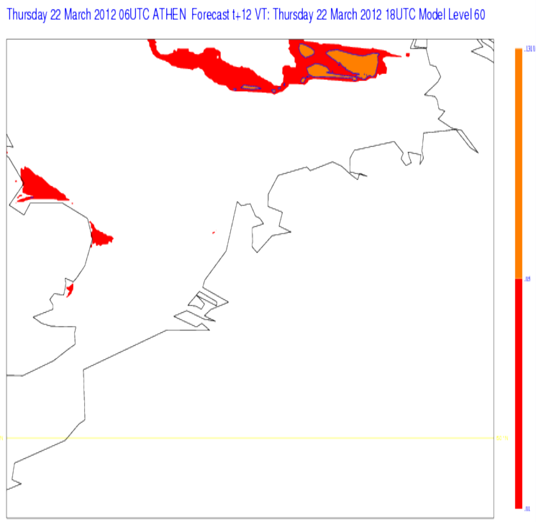
Control

MSG mask

+12







(by Sibbo van der Veen, KNMI)

Cloud mask initialisation in HARMONIE (2)

HIRLAM model

—improved forecast of cloud cover, precipitation, upper air temperatures and surface pressure

—worse bias of 2m temperature

HARMONIE model

—increased thunderstorm precipitation considerably

—was able to remove erroneous fog fields up to +24 forecast length

—"buoyancy correction" is very important

Research topic:

—How to integrate the methodology into variational data assimilation

Near-real time (15 minutes delay) CPP

- 2-D physical cloud properties:
  - Integrated cloud water [kg m^{-2}];
  - Average effective cloud drop size, r_e, [μm];
  - Cloud top temperature [K];
  - Cloud bottom temperature [K].

Meteosat Second Generation (MSG)

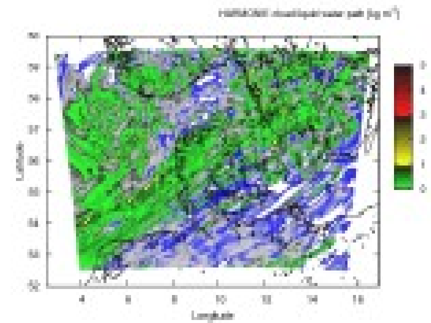
$$\mathcal{R}(x, y; \lambda, \theta_0, \theta, \phi; \rho(\theta_0, \theta, \phi), CWP, r_e) \quad (1)$$

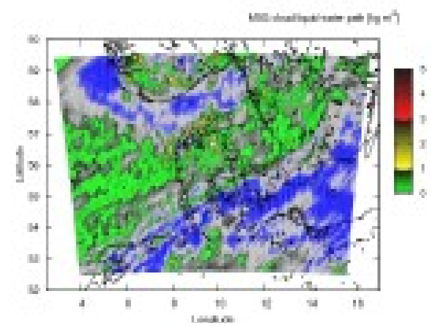
$$\mathcal{R}(x, y; \lambda = 810nm) \;+\; \mathcal{R}(x, y; \lambda = 1640nm) => \quad (2)$$

$$CWP(x, y) \;+\; r_e(x, y) \quad (3)$$

Nakajima & King (1990); Roebeling *et al.* (2006).

Comparing HARMONIE with 2D cloud MSG cloud water path





Beta version

For Northwestern Europe:
https://hirlam.org/portal/oprint/WebgraF/OBSCPP/OBS/?choice_ind=NORDIC

(Kristian Pagh Nielsen, DMI)

Surface DA : improved spatialisation tool

(MESCAN, EURO4M in collaboration with MF)

Introduction of more realistic correlation function in CANARI:

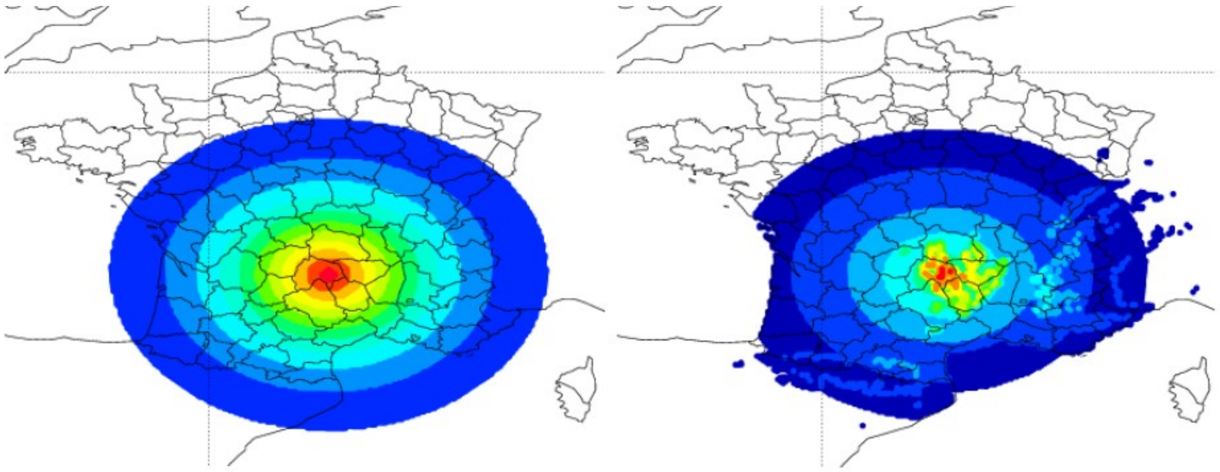
Old:

$$Corr_{CAN}(r) = e^{-0.5\frac{r}{d_1}}$$

New:

$$Corr_{MES}(r, d_p, d_z) = 0.5\left[e^{-\frac{r}{d_2}} + \left(1 + \frac{2r}{d_2}\right)e^{-2\frac{r}{d_2}}\right] \cdot F_p(d_p) F_z(d_z)$$

after Häggmark et al, 2000, Tellus, 52A, 2-20.



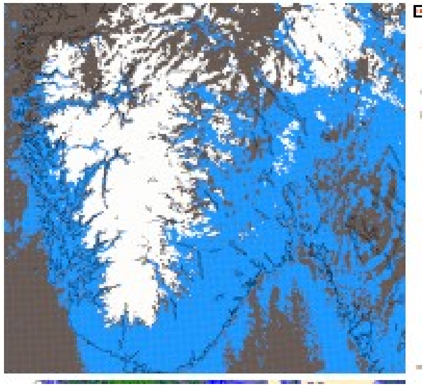
The new anisotropic correlation function creates more realistic analysis increments (right Figure) by accounting for height difference and land-sea mask.

(by Tomas Landelius, SMHI)

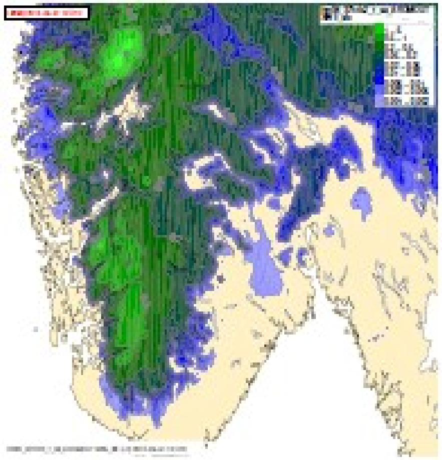
Surface DA in Nordic Conditions

(snow data assimilation)

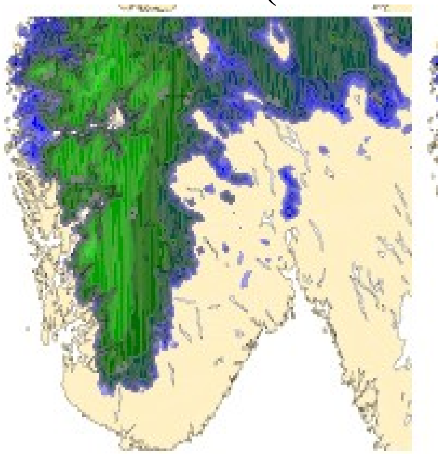
50 % snow probability map
(met.no product)



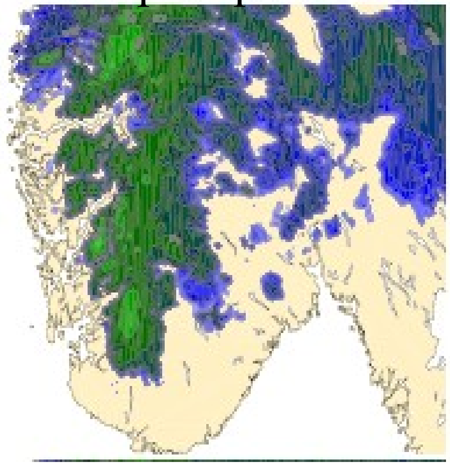
HARMONIE control



snow/no snow (SWE< 25kg/m^2)



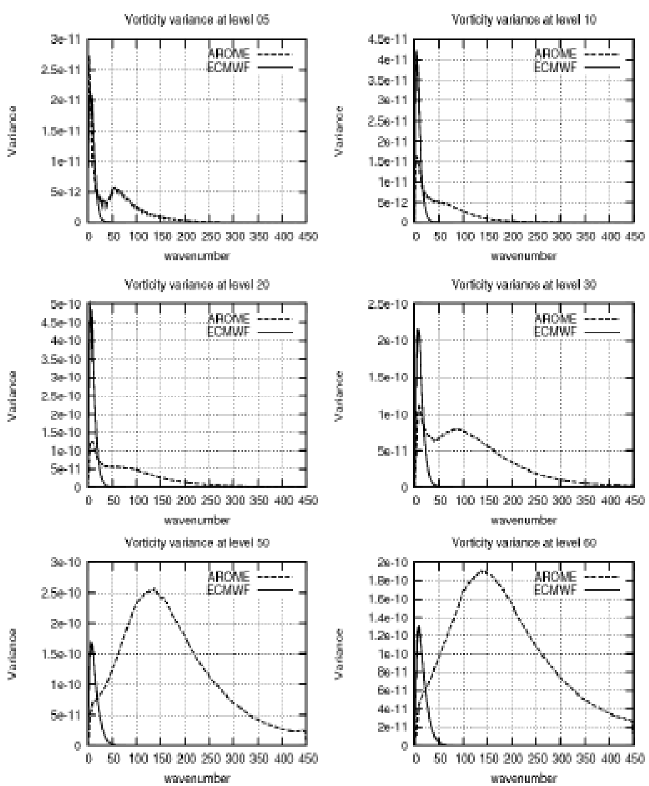
Local precipitation stations



(by Mariken Homleid and Mari-Anne Killie, met.no)

Large-scale error constraint in LAM

in collaboration with MetCoOp project

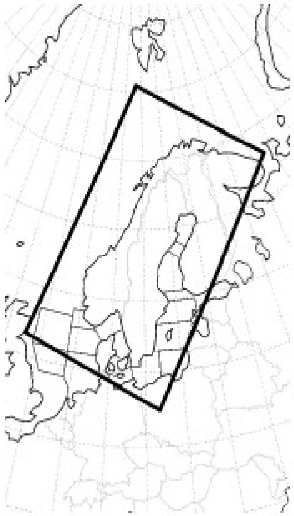


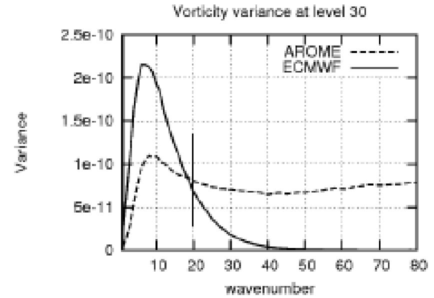
Adjust model state to host model and observations

Extra term in cost-function

$$J(x)=J_b+J_o+\underbrace{(x-x_{ls})^T V^{-1}(x-x_{ls})}_{J_k}$$

Truncate Jk information at K=20



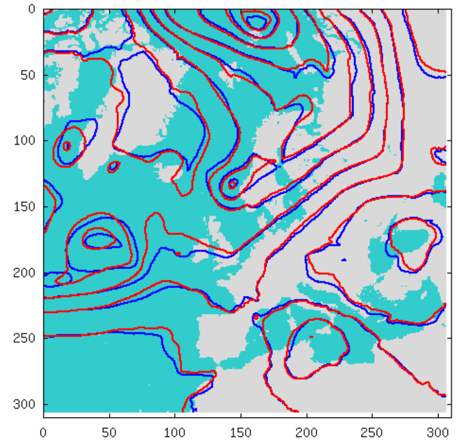


AROME 2.5 km;
Host model
ECMWF

by Per Dahlgren, SMHI

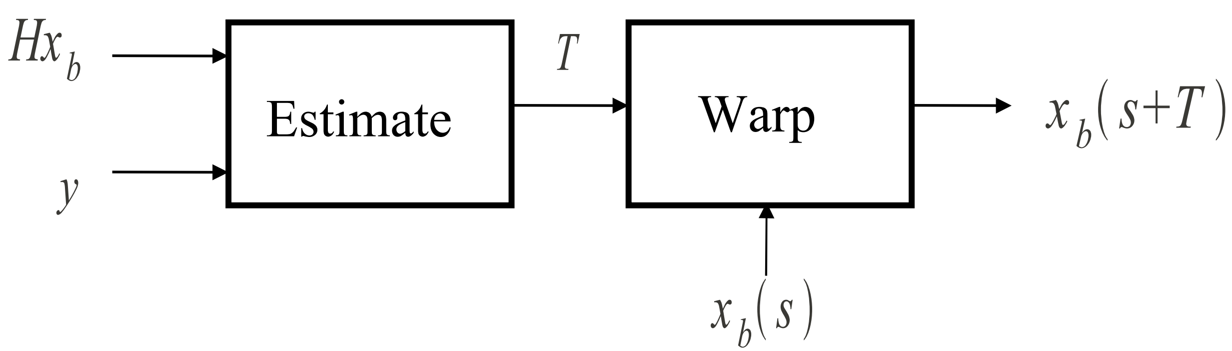
Correction of non-additive errors (1)

research with H IRLAM model



Handling – two step method

Estimate the phase error (displacement field) and warp the first guess.

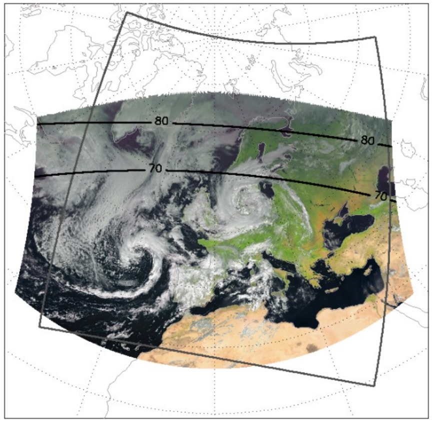


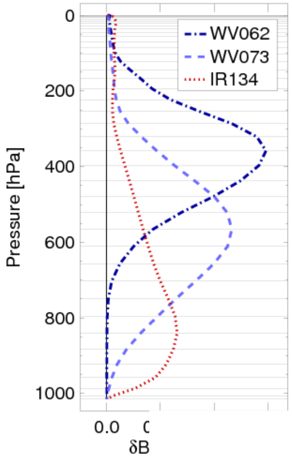
Minimize the additive error using standard VAR-method.

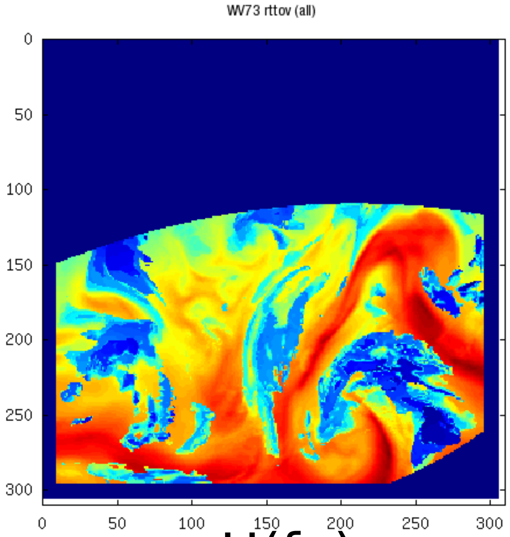
by Tomas Landelius & Magnus Lindskog, SMHI

Correction of non-additive errors (2)

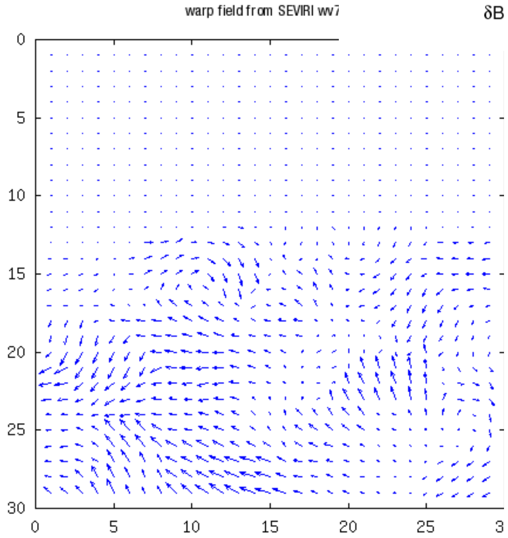
Example: SEVIRI data (WV 073)



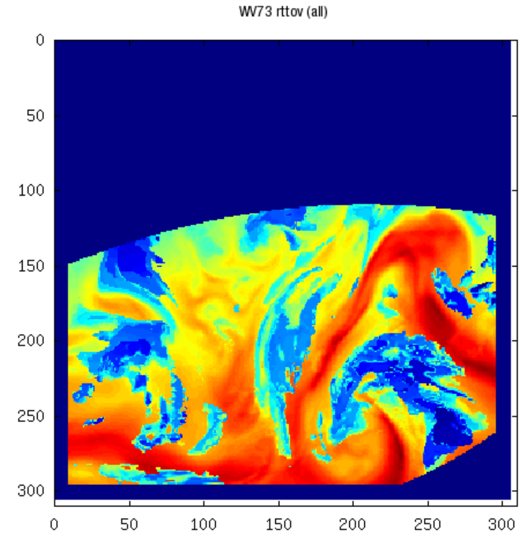




H(fg)



Estimated T



SEVIRI

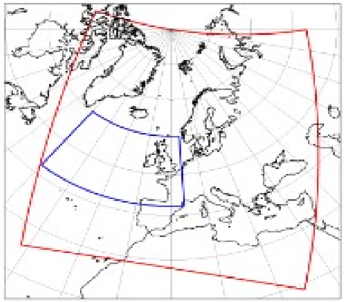
by Tomas Landelius & Magnus Lindskog, SMHI

Correction of non-additive errors (3)

Balances

- The warped field is introduced as pseudo-observations and used to modify the original background field in a full-scale data assimilation with HIRLAM variational data assimilation and its balance constraint.
- The resulting field is then used as background field in the following standard 3D-Var, when a full set of observations are assimilated

A Case study with simulated observations, 20090113 12 UTC



HIRLAM C22 domain

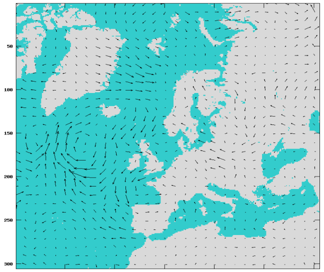
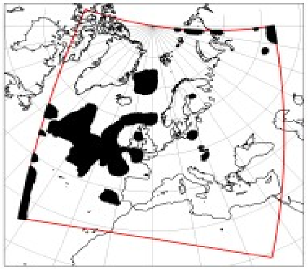


Fig. 2. Estimated phase errors for the 12 hour forecast from 20090113:00 UTC.

Displacement field



Pseudo observations

- Better balance in initial state and better quality of short range forecast when the phase error correction through warping is introduced in the form of pseudo observations .

Future plans

- Application of pseudo observation approach to real data in the form of SEVIRI radiances and in that context investigate optimal superob averaging sacels.
- Investigate how ensemble approaches can be utilised to handle phase errors.
- Transfer of developments from HIRLAM to HARMONIE framework.

by Tomas Landelius & Magnus Lindskog, SMHI

Correction of non-additive errors (4)

Field alignment technique assimilating radar data reflectivities in HARMONIE is implemented.
→ "National AEMET poster" (by Carlos Geijo)

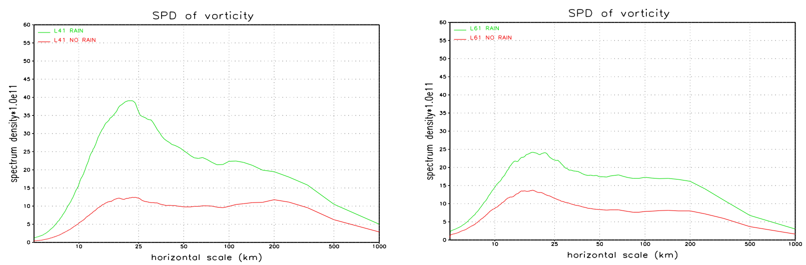
Research topic: the real challenge is how to extend the methodology to the multivariate framework

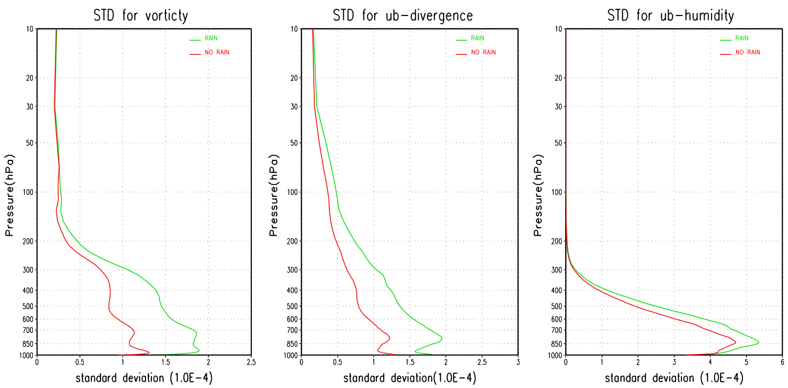
Weather regime dependency

diagnosis of structure functions(rain/dryness)

Horizontal spectra

Dominance in meso-scale for rain cases





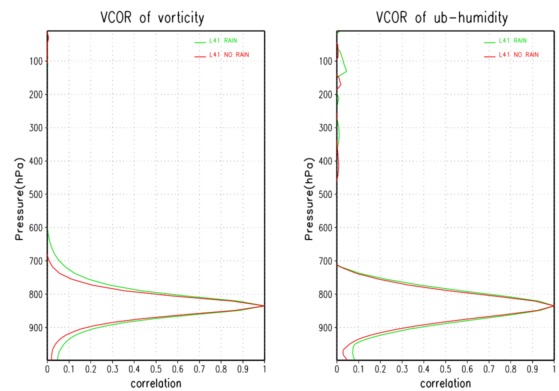
Standard deviation

Vorticity/Divergence/Humidity: larger for rain than for dryness

Vertical correlation

Vorticity: wider for rain than for dryness

Humidity: nearly neutral



Statistic sampling data collecting

Rain/Dryness cases are separated from 201006-201008 Harmonie ensemble 6h forecast data set according to corresponding precipitation measurements

(*by Shiuy Zhuang, DMI*)

Ensembles for HIRLAM Hybrid variational ensemble data assimilation

Considerations:

* We need a **rich** ensemble to describe flow-dependent assimilation increments!

* Can we afford an ensemble size of ~100?

* With a smaller ensemble size, can we improve for the Hybrid by adding lagged members?

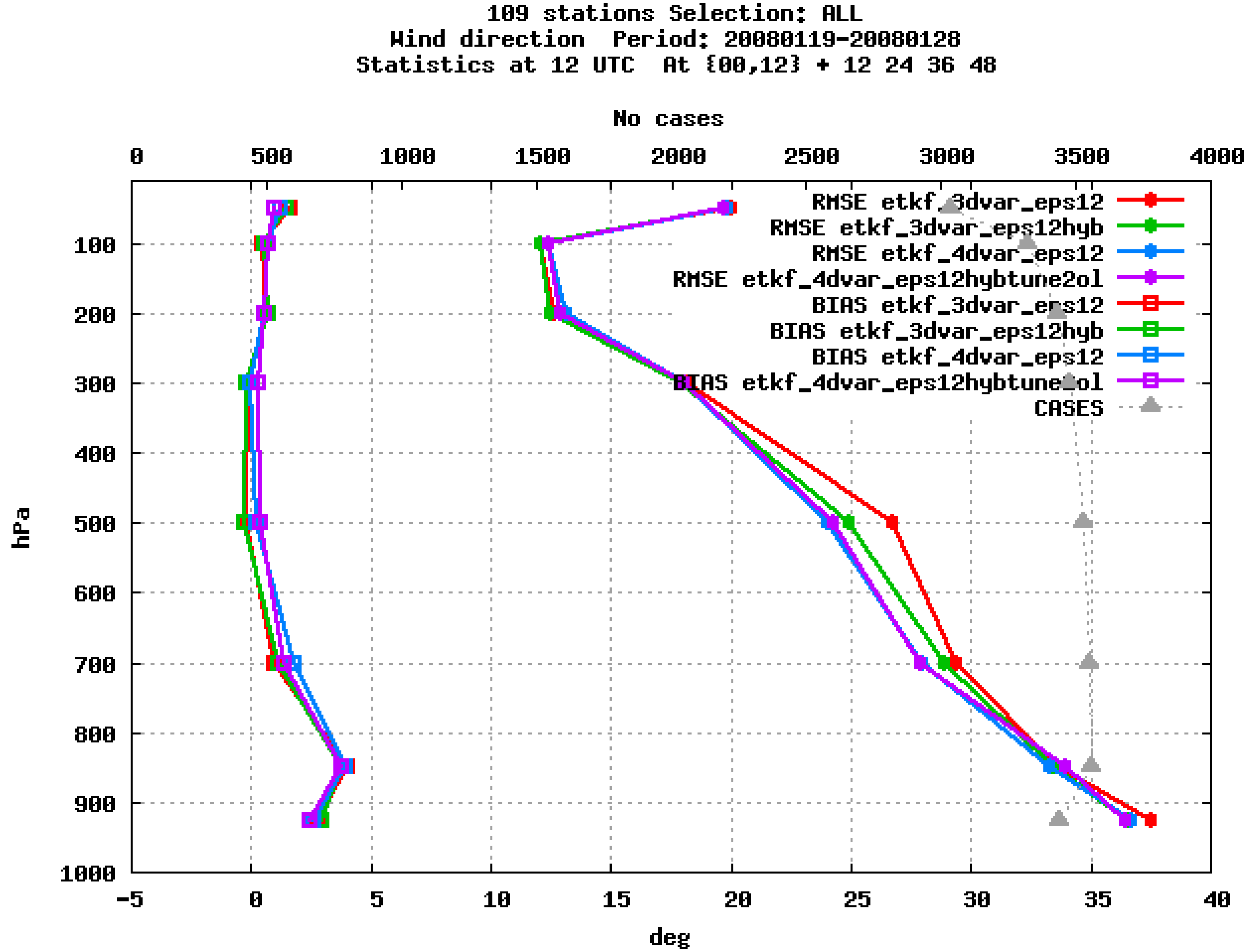
* Lagged initial time and/or lagged valid time (to describe timing errors)?

* We also need LBC perturbations!

Experiments for a short winter period 17 – 28 January 2008

- **3D-Var, 3D-Var Hybrid (50% static – 50% EPS-ETKF 12 members)**
- **4D-Var, 4D-Var Hybrid (50%-50%)**
- **4D-Var Hybrid (75%, 25%, inflated EPS spread)**
- **4D-Var Hybrid (50%, 50%), add lagged ensemble (+9h in addition to +3h, correct valid time)**
- **4D-Var Hybrid (50%, 50%), add ensemble with lagged valid time (+2h) for possibly correction for timing errors**
- **4D-Var Hybrid (50%, 50%), increased number of members to 20**

Example of forecast verification scores for a first winter case



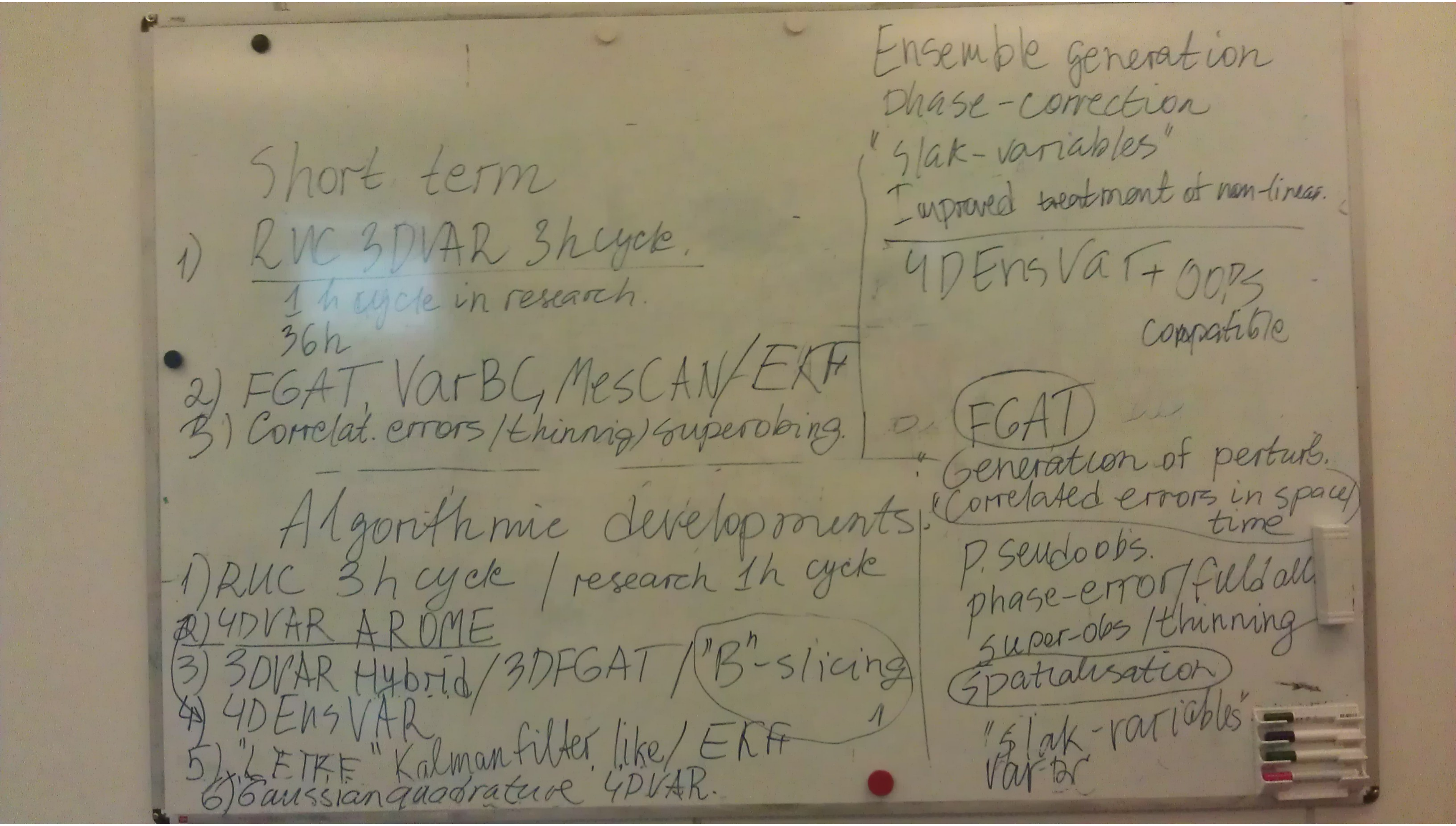
(by Gustafsson&Bojarova Family Corporation)

Experiments for 17 – 28 January 2008 (too short period) - Subjective summary of forecast verification scores

	3dvar -> 3dvar hybrid	3dvar -> 4dvar	4dvar -> 4dvar hybrid	Inflate pertur-bations	Lagged initial time	Lagged valid time	12-> 20 memb
PMSL Europa	+	++	0	-	0	0	+
PMSL Scand	++	+++	0	0	0	0	0
Precip Scand	+	++	0	++	+	++	+
TT prof	+	++	+	0	0	0	0
FF prof	++	++	0	-	-	0	+
RH pprof	+	0	+	+	0	0	+
Total	8 +	11 +	2+	1+	0	2+	4+

Working Week on flow-dependent methods for meso-scale DA

24-28 Sept. 2012, Copenhagen, DMI



Long term algorithmic developments:

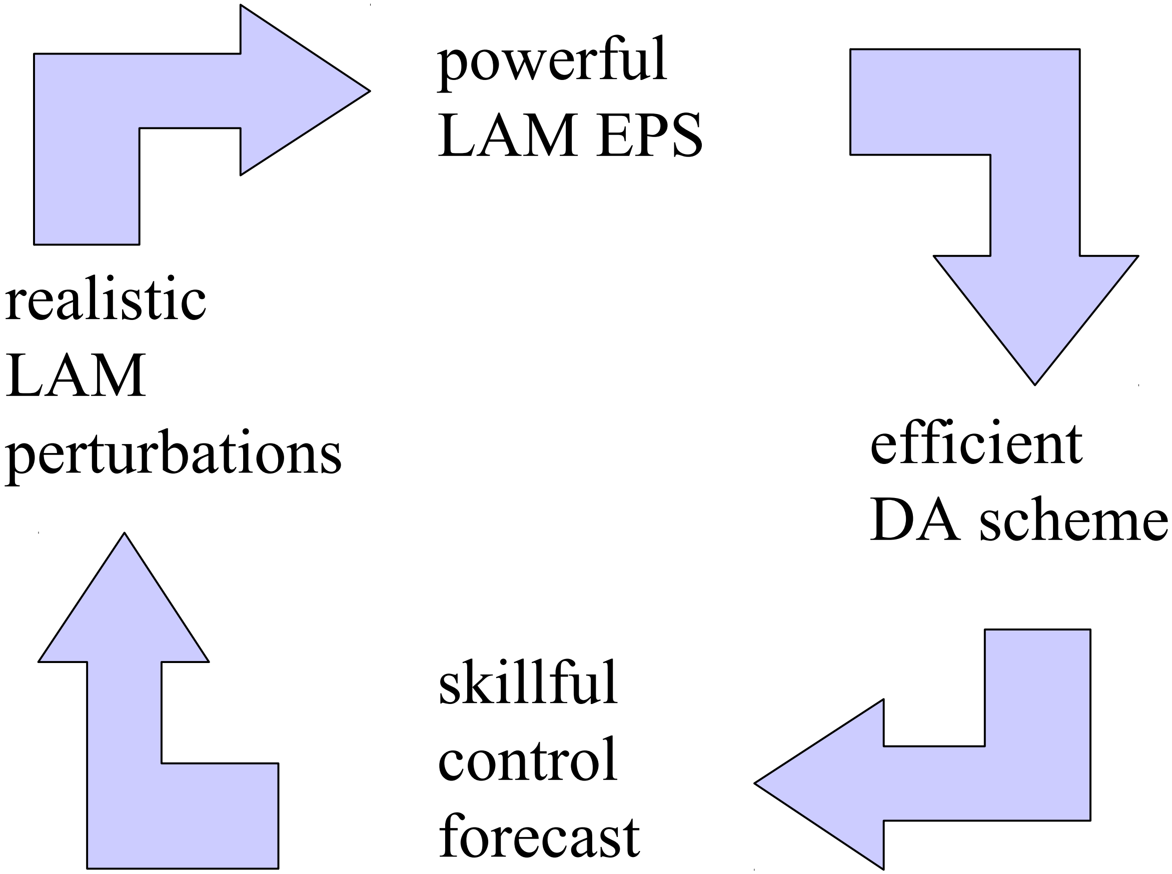
1) critical mass of “team” work is needed to assure the progress;

2) 4D-Ens-VAR framework is proposed as a long perspective “algorithmic investment”

* 4DVAR (ECMWF non-linear and diabatic simplified physics) and Hybrid ensemble variational data assimilation should be seen a “realisations” of 4D-Ens-VAR

3) Long term core data assimilation developments should consistently fit into OOPS/IFS paradigm

Solution in long term perspective



Transversary issue: interaction of initialisation/dynamics/physics/model error

Problem: too slow progress implementing “new” types of observations in the HARMONIE system

Working Week on the flow-dependent methods for meso-scale DA
Copenhagen, DMI, the 24th -28th of September

The factors which should speed up progress in Use of Observations

1) “Global” and “stable” pre-processing solutions (COPE on the long perspective)
2) More strict “phasing” procedure with the DA&UO experts involved
3) Two sided “phasing”: HARMONIE developments are phased into cycles evolution
4) Common/joint pre-processing software for as large number of observations as possible
5) Higher level of ambitions in the operational collaboration

The Project Leader on DA&UO should became more experienced and create high level of communication between staff members in HIRLAM consortium

Solution for long term perspective (2)

The theoretical basis of the variational data assimilation is violated in presence of the systematic bias and the flow-dependent representativity error

This is the common situation assimilation remote sensing observations

Assimilate structures instead of point observations