Norwegian Meteorological Institute

High Resolution Limited Area Model Hirlam

Upper-air data assimilation in HIRLAM status and plan

Roger Randriamampianina

28th ALADIN Workshop & HIRLAM All Staff Meeting 16-20/04/2018, Toulouse, France

outline

- Operational upper air data assimilation (UA-DA) systems in HIRLAM

- Data assimilation meetings (working week and video)

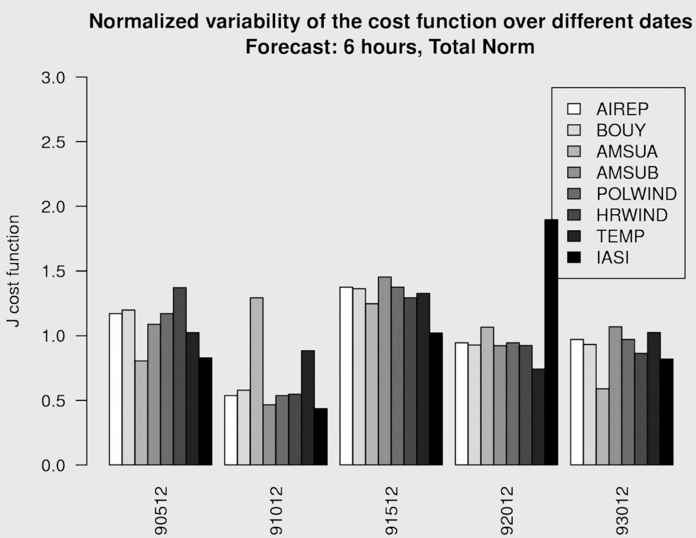
- Some development works related to UA-DA

- Local implementation

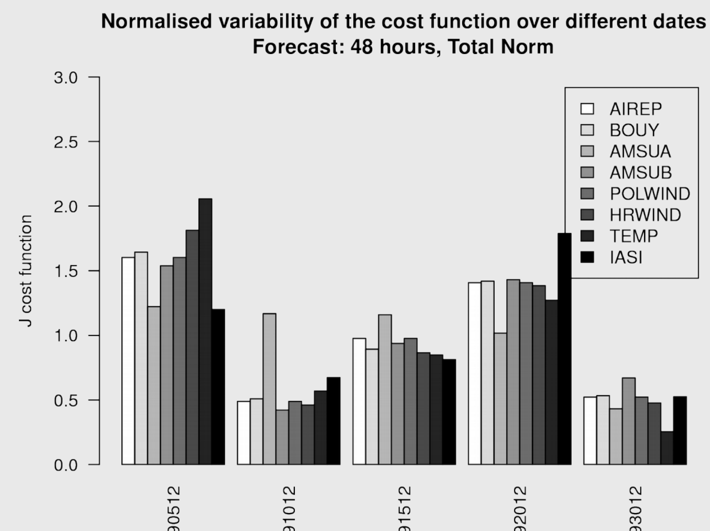
- Outlook

Operational upper air data assimilation (UA-DA) systems

- **Assimilation scheme:** 3D-VAR;
- **Cycling Strategy:** 3 hourly;
- **Conventional observations:** SYNOP, SHIP, BUOY, AMDAR, AIREP, ACARS, ModeS EHS, Pilots, TEMP;
- **Satellite radiances:** AMSU-A, AMSU-B/MHS, ATMS, IASI;
- **Satellite retrievals:** Scatterometer, GNSS ZTD, GPS RO, (geo **and polar**)AMV;
- **Radar observations:** Reflectivity;
- **Bias correction scheme:** Variational (VarBC).



Experiment run with AROME-MetCoOp Sensitivity of the forecast model to different observations



Data assimilation meetings

- **Working weeks** (minimum once per year each)
  – On the use of observations
  – On algorithmic issues

- **Video meetings** (two series per year)
  – The use of conventional observations and COPE
  – Radar data (pre-)processing
  – Retrievals (observations)
  – Algorithmic issues: 3DVar, 4DVar, ETKF, etc…
  – Radiance data assimilation

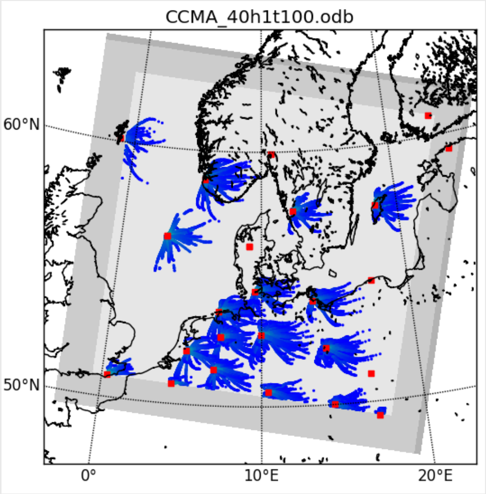
==> **Many thanks for the permanent high participation rates**

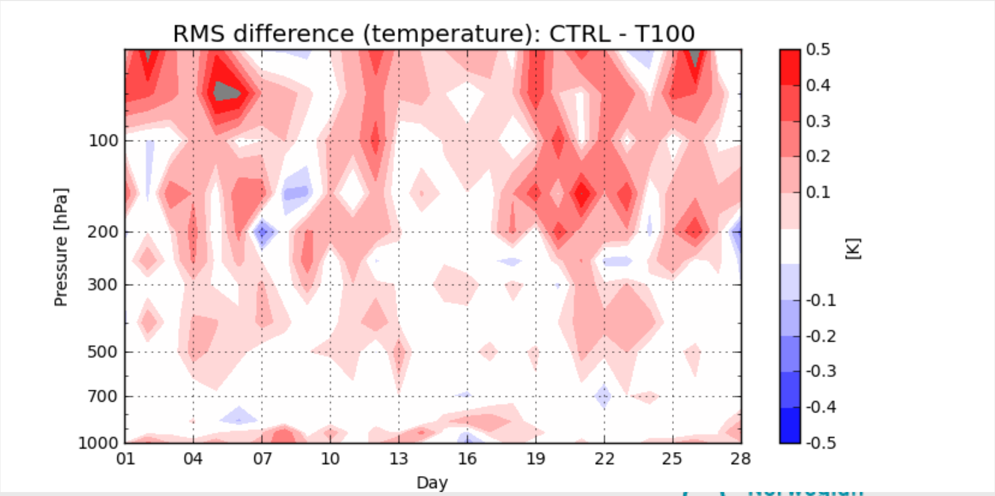
Wiki page: https://hirlam.org/trac/wiki/Meetings/Data_assimilation

Highlight of the progress – towards improved tools and schemes

Bator for all observations: use of Bator alone to read all observations (Eoin Whelan)

- Don't need Oulan anymore (40h1.1.1)
  - USEOBSOUL=0 in scr/include.ass
  - WMO/ECMWF/HIRLAM BUFR
  - Radiosonde drift information (from CY43)
  - New AMDAR template (thanks to Maria Monteiro)
  - Used operationally by MetCoOp
- More COPE & ODB2 in CY46?





Cloud initialisation using SAF/NWC products

– Cloud initialisation: under implementation by **E. Gregow**, M. Lindskog, T. Landelius, S. Van de Veen & T Moene in CY38h1.2

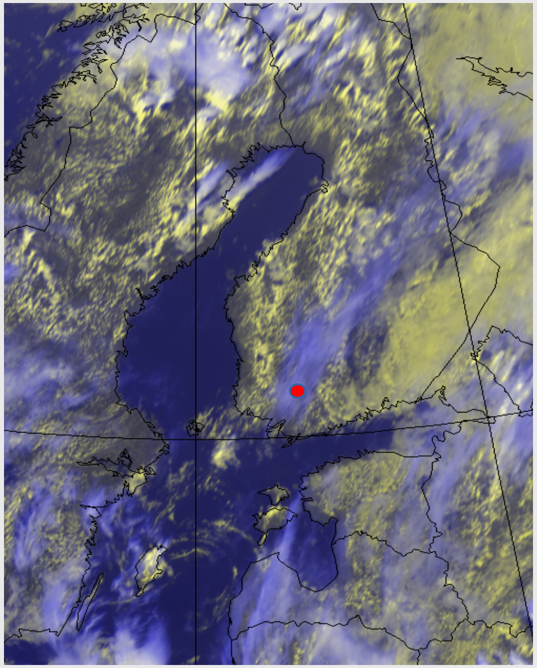
The different steps of the implementation of Van der Veen (2013) technique:

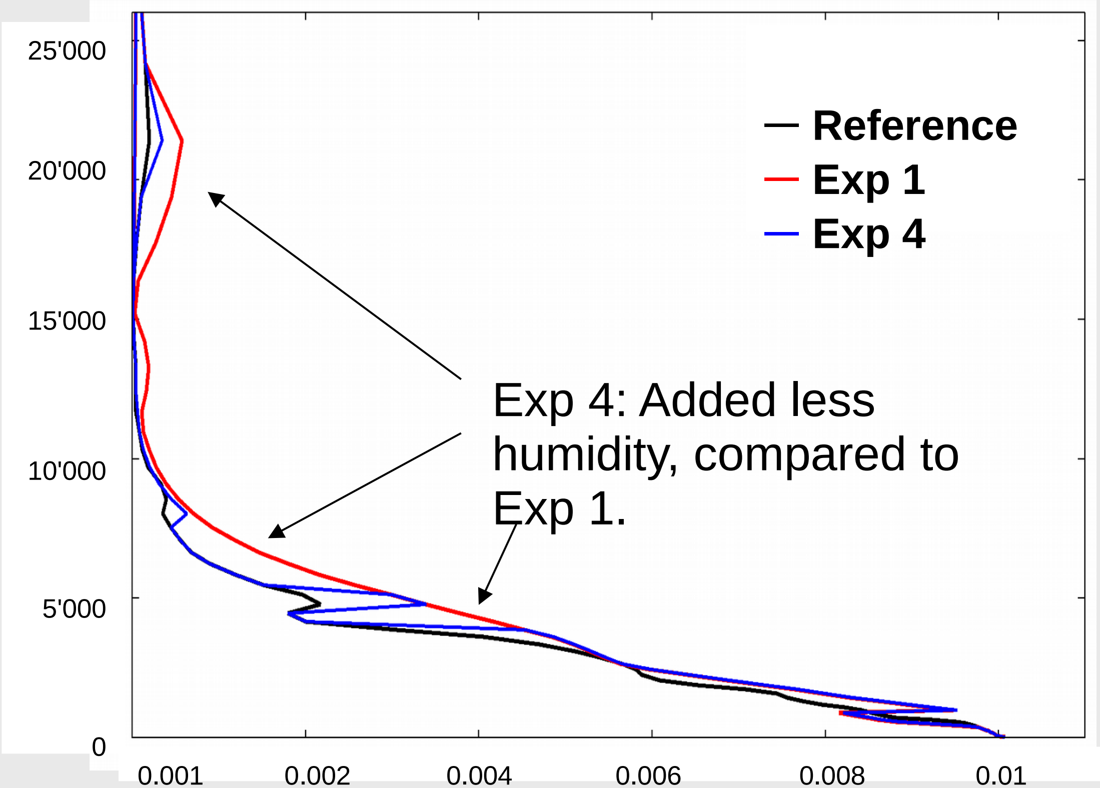
1 – Cloud-base from Synop data → Interpolated cloud-base field (“Van der Veen Method” method) (Exp 1);

2 – Cloud-base estimation: mean “climatological” cloud base (SMHI solution) (Exp 2);

3 – Exclude certain cloud classes from SAF product, and account for saturation of WV against ice (not only to water) in the upper-troposphere (Exp 3);

4 – Detection of the cloud layers and control of the humidity tendency (Exp 4);





==> More experiments have been conducted to find the best settings

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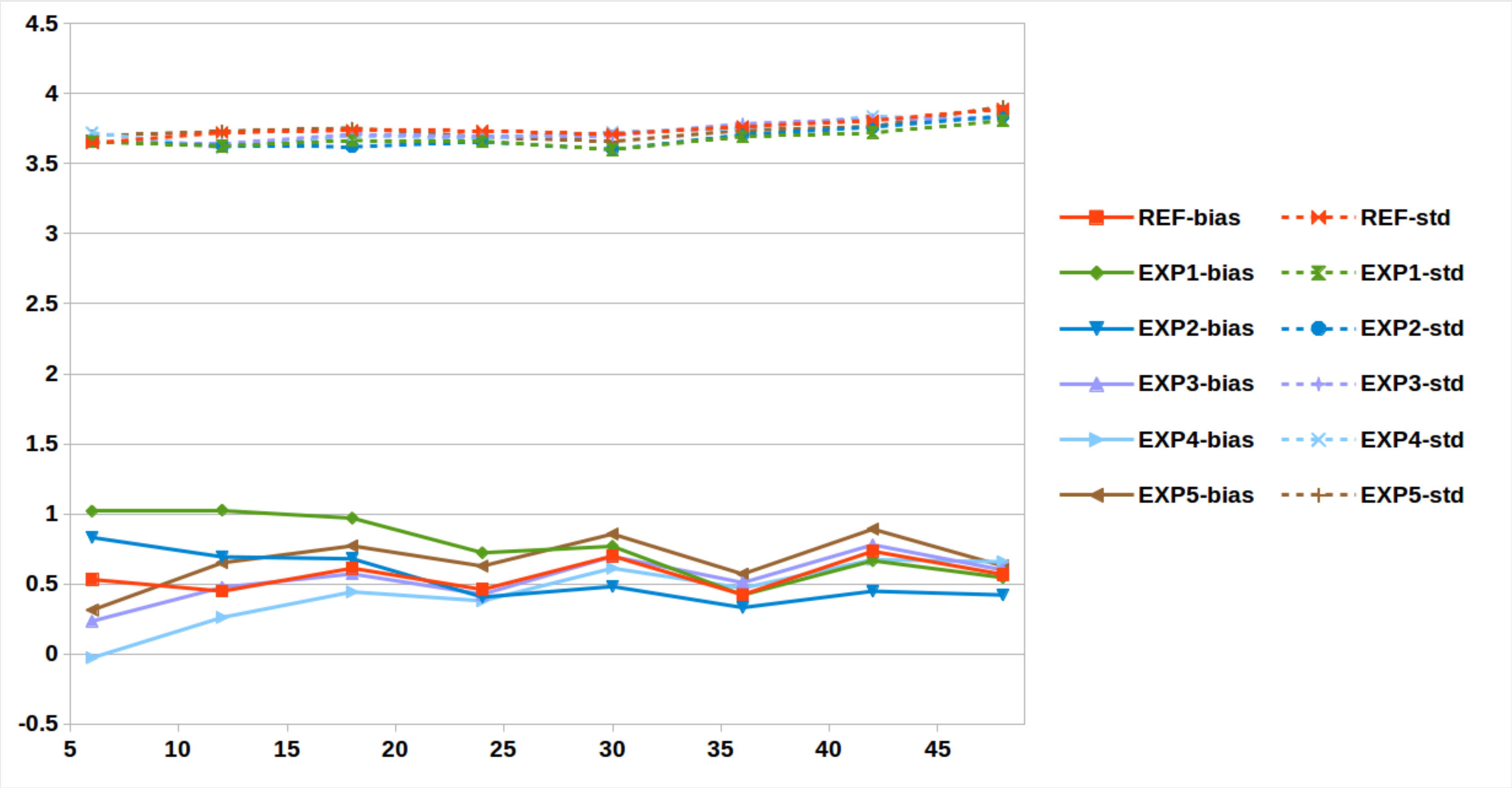
Highlight of the progress – initialisation

– Cloud initialisation: flexible solution ready for operational implementation by **E. Gregow**, M. Lindskog, T. Landelius, S. Van de Veen & T Moene in CY38h1.2



WebGraf: Verification of the total cloud cover; Ref Exp (red), MSG EXP1 (green), MSG-SWE EXP2 (dark-blue), MSG-SWEw4 EXP3 (purple), MSG-SWEw4-CldLay EXP4 (light-blue) and MESAN EXP5 (brown), for 1 week in July 2016. Number of observations 2'600-4'800.

Highlight of the progress – initialisation

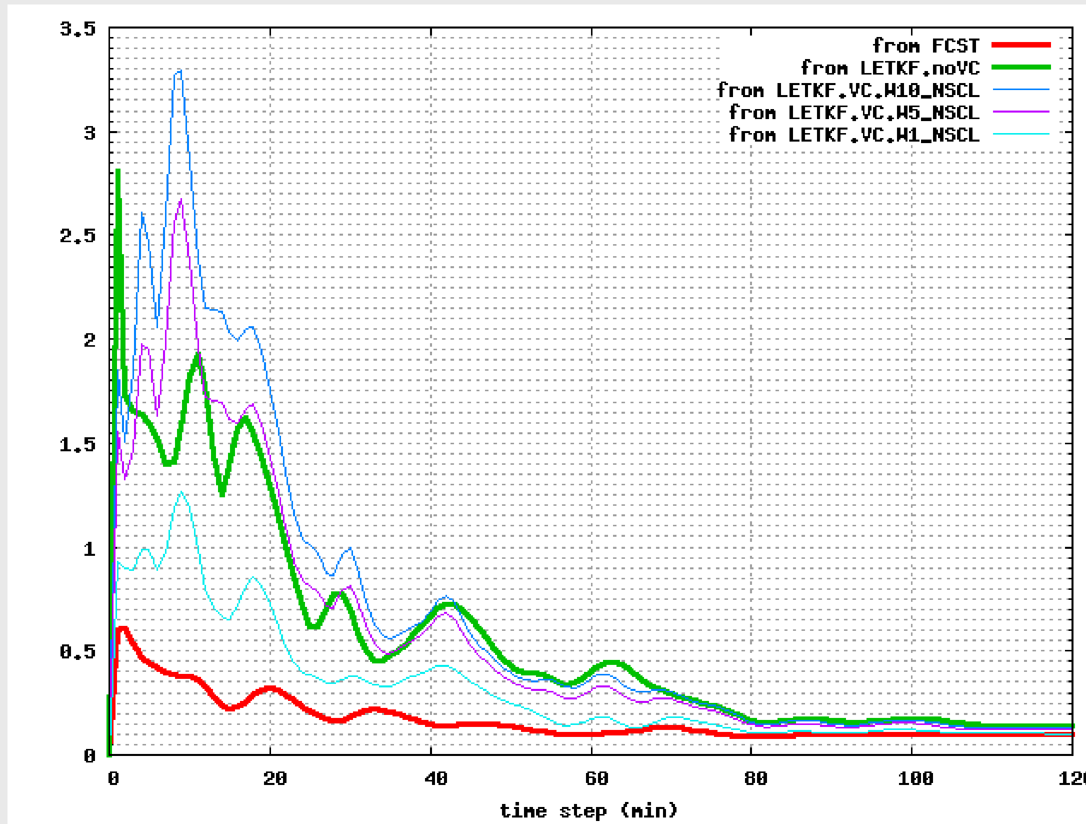
– Considering the variational constraints (VC) encoded in an operator M
M: Non-hydrostatic semi-implicit system: **Carlos Geijog**

$$2J(x^k) = \int_o^{\bar{\xi}} w_o^k \left\| x^k - x_o^k \right\|^2 + w_c^k \left\| Mx^k - x_\bullet^k \right\|^2$$

Good progress reported throuh the video meetings.

One can recognise an ECHKEVO diagnostic tool results here when using the VC scheme with LETKF.

See Carlos' presentation for more details



Highlight of the progress – towards improved tools and schemes
== 4DVar ==

Progress with 4DVar the scheme: (Jelena Bojarova, Nils Gustafsson, Jan Barkmeijer, Magnus Lindskog, Martin Ridal, and more …)

==> See minutes of Lanzarote meeting on wiki for more information about the decision related to 4DVar decision.

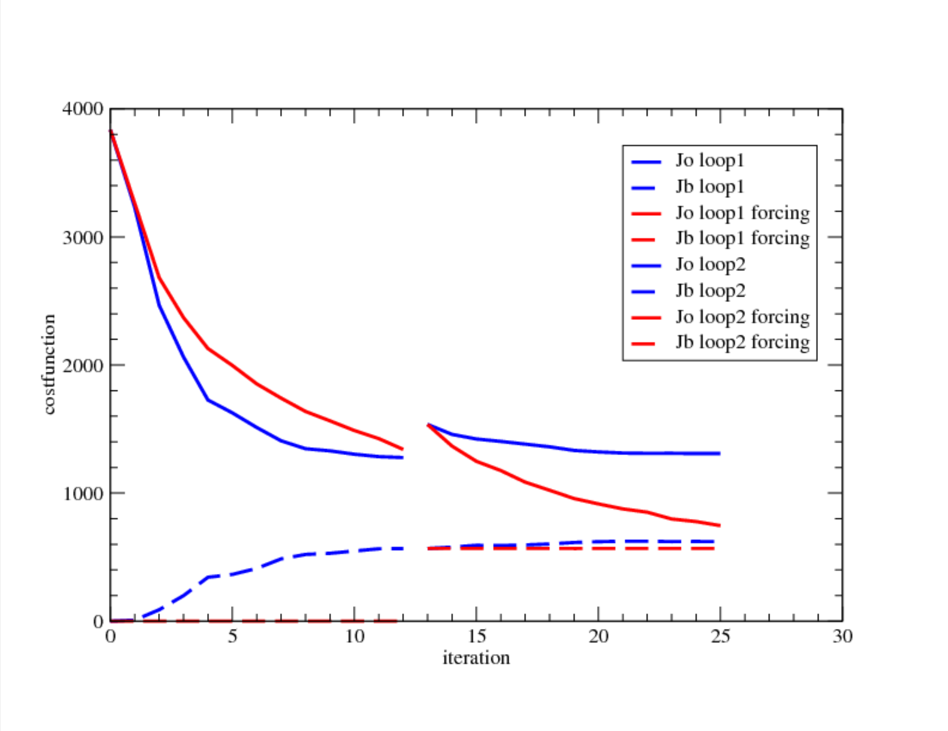
– Among others, use of humidity in spectral space in minimisation, do most of the development in CY40, etc …

Effort was devoted to have "all operational observations" available and treated in 4DVar.

On right: a comparison of two 4DVar minimization procedures:

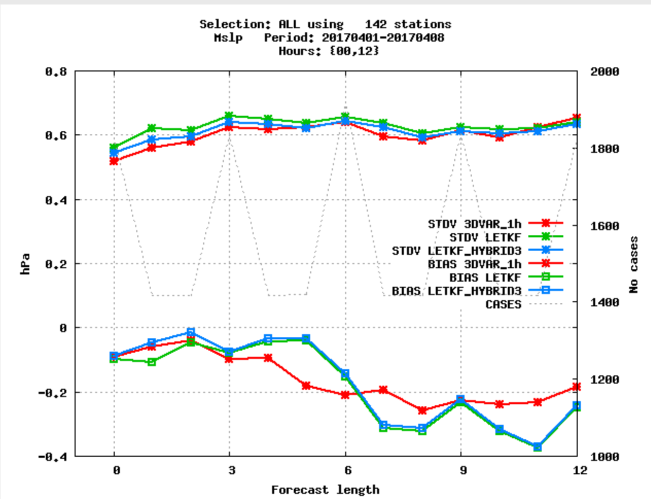
– Blue lines two default outer-loops

– Red lines two outer-loops using forcing with tendency in both the loops



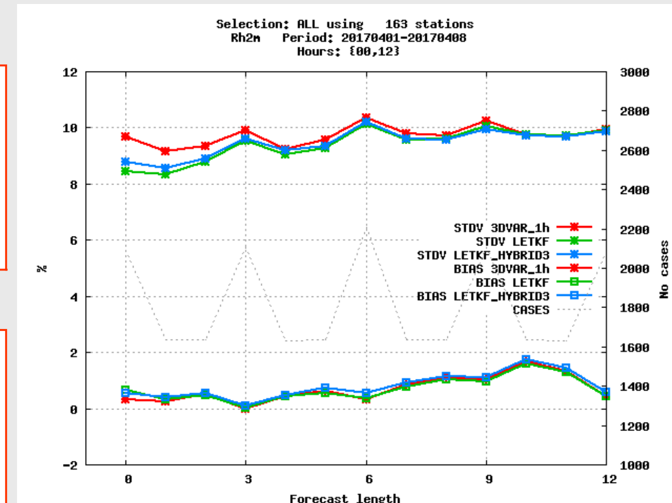
Highlight of the progress – towards improved tools and schemes
== LETKF ==
(Pau Eescriba & Jelena Bojarova)

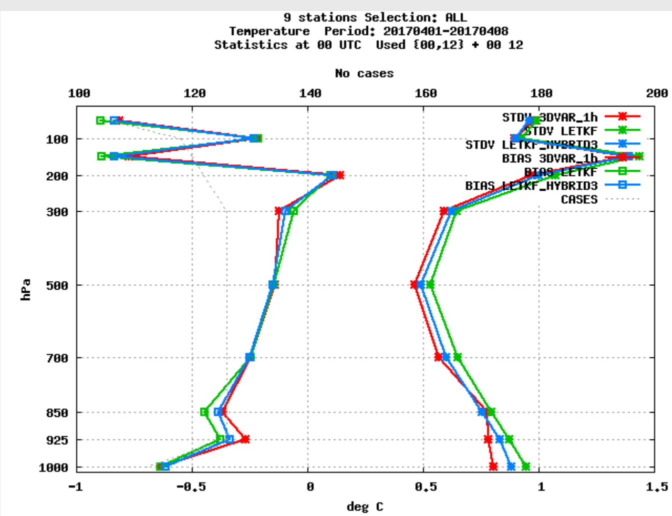
==> See minutes of the video meeting on Algorithmic issues for more details.



Comparing 3DVar, LETKF, and hybrid

Consistency of Hybrid in performance





Some raised questions, among others:

Why 3DVAR doesn't assimilate t2m and rh2m?

If algorithms is well tunned can hybrid outperform both schemes?

Assimilate Surface Pressure in HARMONIE to test Ps_bias_correction.x?

Highlight of the progress – towards improved tools and schemes
== EDA ==
(Inger-Lise Frogner & Roger Randriamampianina)

==> Inger-Lise will report about testing the EDA to produce perturbation for MEPS

Highlight of the progress – towards improved tools and schemes
== EnVar ==
(Jelena Bojarova)

Implementation as in

A hybrid variational ensemble data assimilation for the HIgh Resolution Limited Area Model (HIRLAM)

N. Gustafsson[1], J. Bojarova[2], and O. Vignes[2]

$$J(\delta \boldsymbol{x}_{\mathrm{var}}, \boldsymbol{\alpha}) = \beta_{\mathrm{var}} J_{\mathrm{var}}(\delta \boldsymbol{x}_{\mathrm{var}}) + \beta_{\mathrm{ens}} J_{\mathrm{ens}}(\boldsymbol{\alpha}) + J_{\mathrm{o}} \qquad (6)$$

$$\frac{1}{\beta_{\mathrm{var}}} + \frac{1}{\beta_{\mathrm{ens}}} = 1.$$

$$J_{\mathrm{ens}} = \frac{1}{2} \boldsymbol{\alpha}^T \mathbf{A}^{-1} \boldsymbol{\alpha}$$

$$\mathbf{B}_{\mathrm{ens}} = \mathbf{A} \circ \mathbf{B}_{\text{raw-ens}}$$

$$\underbrace{\boxed{\begin{array}{l}\text{YQ\%LGP=.TRUE.}\\ \text{YQ\%LSP=.FALSE.}\end{array}} \Rightarrow \boxed{\begin{array}{l}\text{YQ\%LGP=.FALSE.}\\ \text{YQ\%LSP=.TRUE.}\end{array}}}_{\text{Decision}} + \underset{\text{Local dev}}{\boxed{\text{Qtrans}}}$$

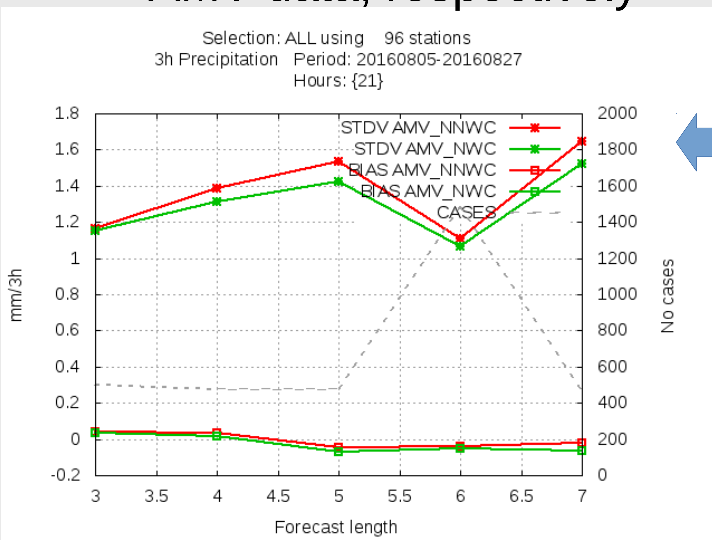
Ensemble : 10 members of BRAND perturbations

Localisation : spectrum of unbalanced surface pressure

==> See Jelena's presentation for more details

Highlight of the progress – towards improved tools and schemes
== Rapid refresh ==

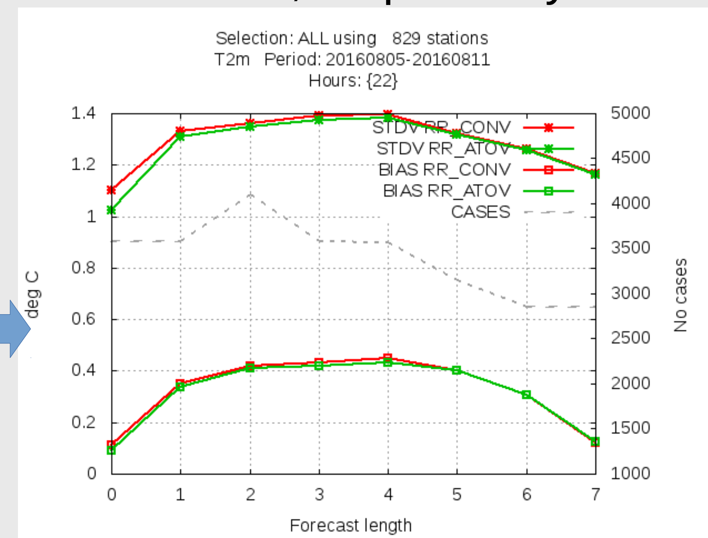
Impact of AMV: green and red lines are respectively runs with and without AMV data, respectively

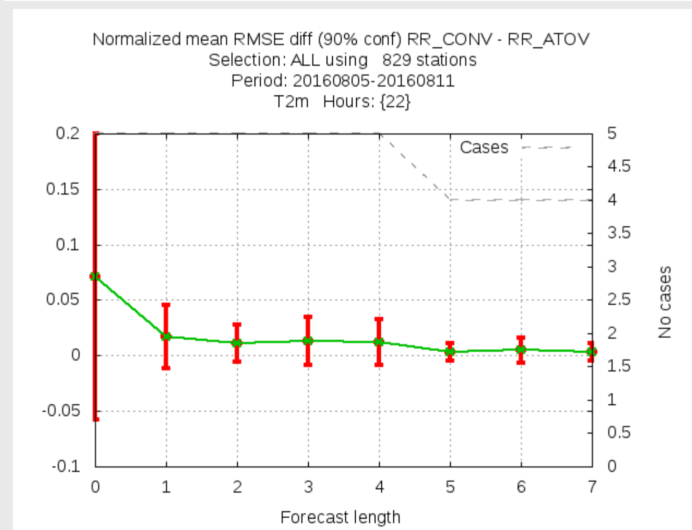


Geostationary Satellite based AMV

Polar orbiting Satellite based radiances

Impact of ATOVS: green and red lines are respectively runs with and without ATOVS data, respectively





==> Positive impact of retrievals (AMV)

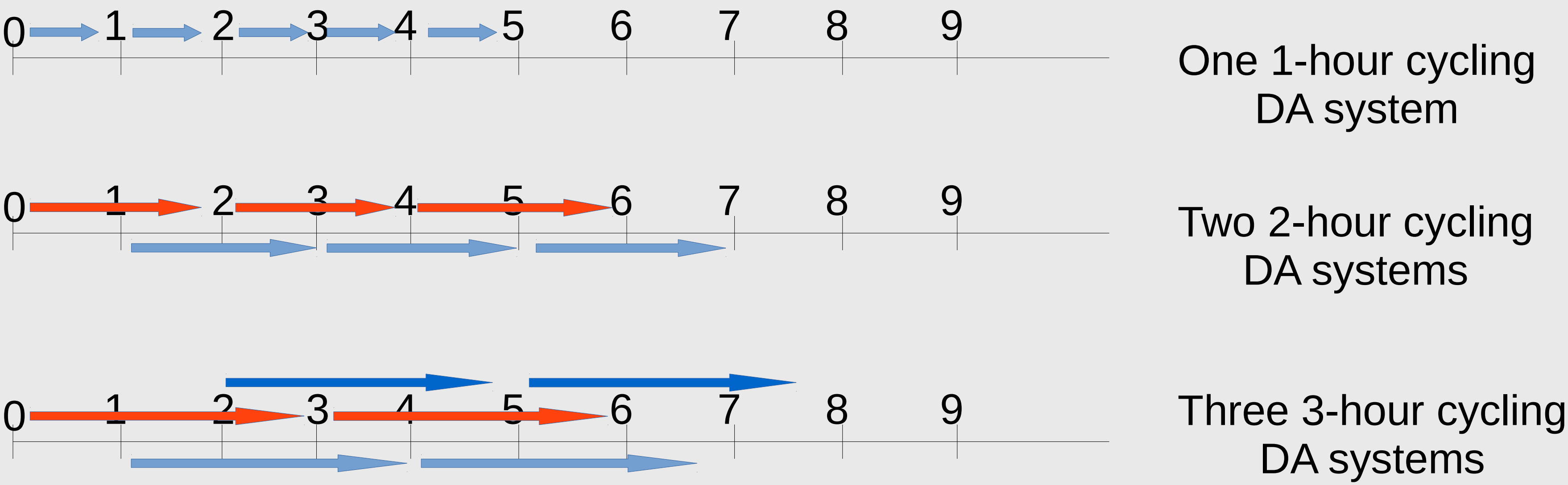
==>Very small impact of radiance observations sometime rather positive than neutral, sometime rather negative than neutral

==>15 min seems too short to get necessary polar orbiting based observation to be appropriately processed and assimilated

Highlight of the progress – towards improved tools and schemes
== Rapid Update Cycling ==

Possible solutions:
– Make the VarBC more flexible in handling of different sets of observations, including missing data in some update time (assimilation time);

– Use cycling data assimilation with (partially) overlapping windows (Yang et al. 2017);



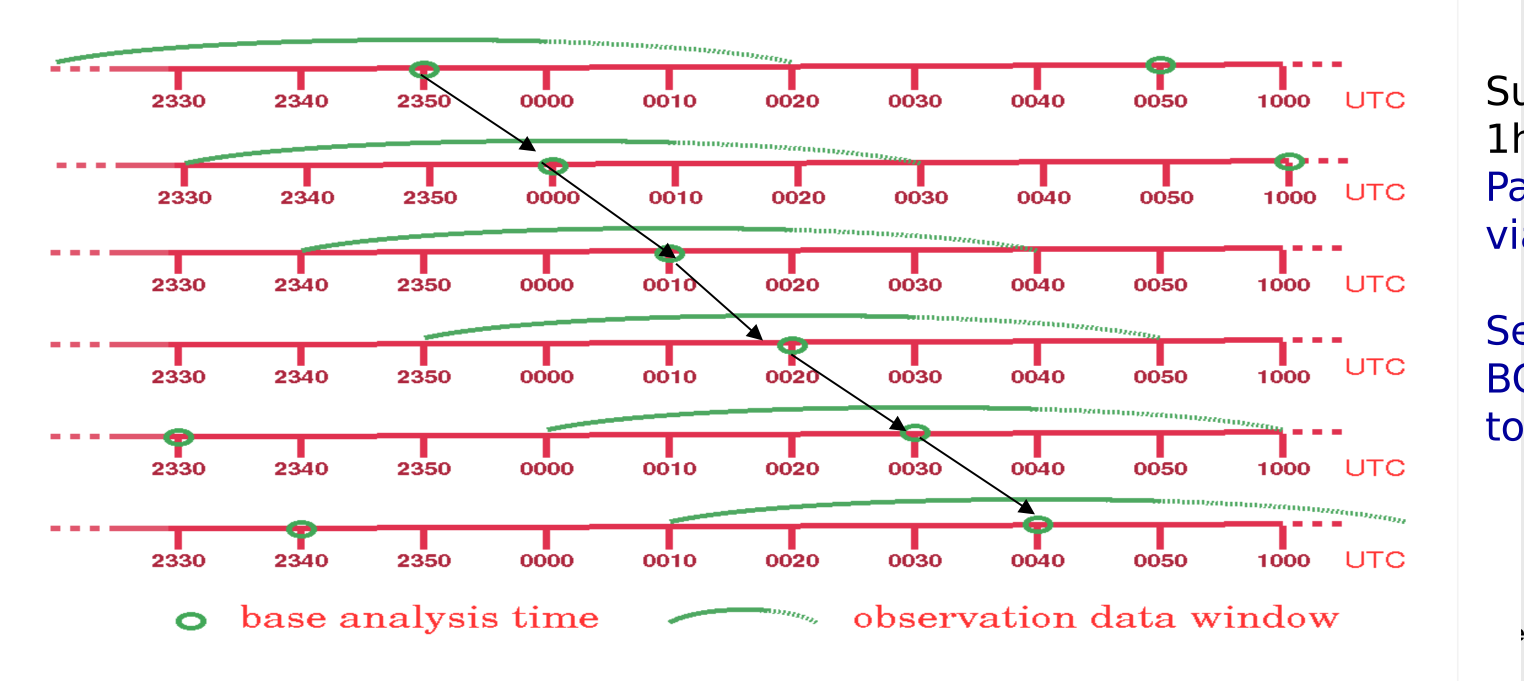
==> These systems have the same cost, but gain in observation usage, especially if 4DVar is used as DA

Highlight of the progress – towards improved tools and schemes
== Frequent refresh with overlapped windows ==
(Xiaohua Yang)

In operational DMI-COMEPS@2.5 km, an ensemble of 3DVAR data assimilation along time has been developed for Harmonie control members, modelling uncertainty in observation and in model errors. The ensemble consists of parallel assimilation suites with hourly shift using partially overlapped window with 3 h interval. A time lagged EPS is constructed therein.

The configuration strategy is now extended to nowcasting range with sub-km resolution to construct frequently refreshing 3DVAR analysis. The scheme enables frequent assimilation of short cutoff radar data, with a view to address concerns on moistures spin-up, better utilisation of observation, temporal correlation of data, better operational robustness.

Approaches to connect adjacent cycles with partial overlapping is in development. (Xiaohua Yang)



Sub-hourly suite
1h to 2h window
Partial connection
via surface DA

Separation of
BG/FG in VAR
to be considered?

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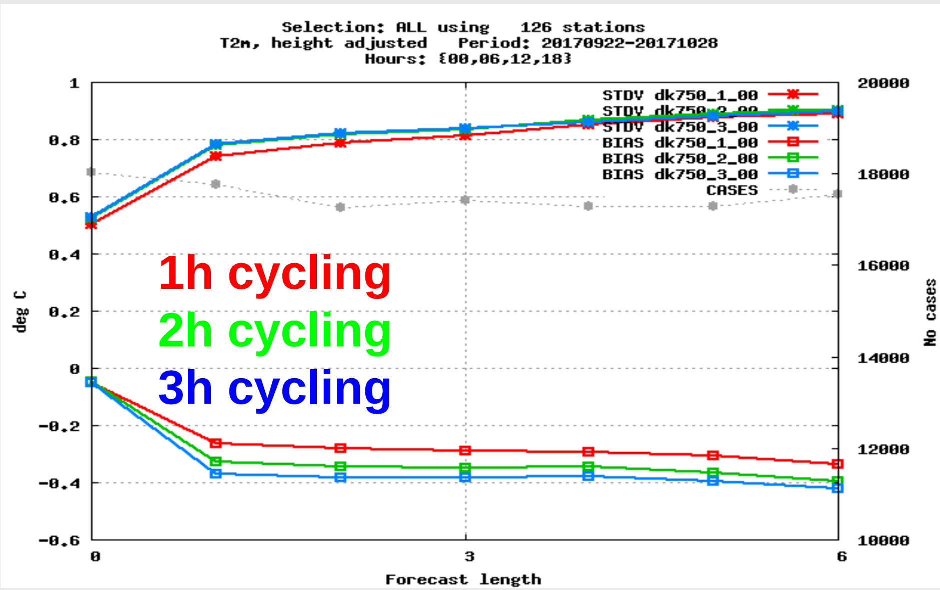
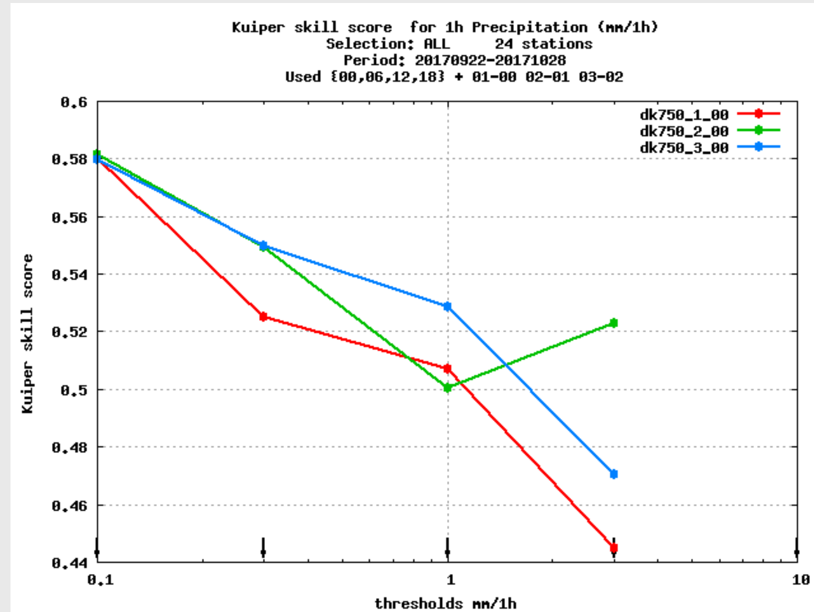
Highlight of the progress – towards improved tools and schemes
== Frequent refresh with overlapped windows ==
(Xiaohua Yang)

Std & bias T2m



KSS Rain

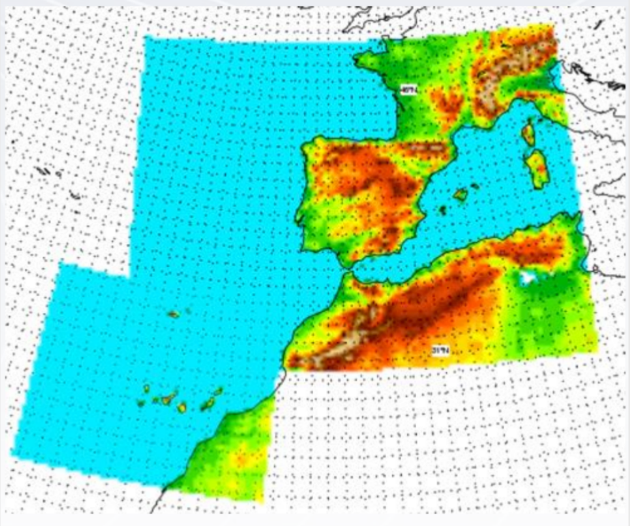


Findings about assimilation data window & cycling frequency

1h cycling clearly advantageous for dry surface parameters like MSLP/T2m
But for cloud and precipitation, 1h cycling is less optimal compared to 2h/3h

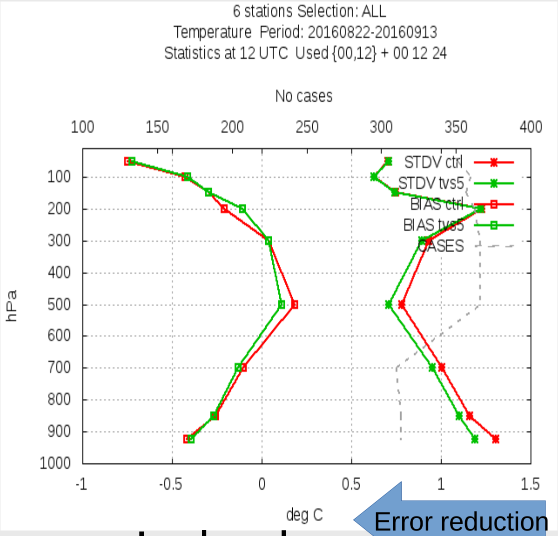
Towards use of satellite observations in all HIRLAM centres

Task: Implement 3D-VAR DA with with satellite observations

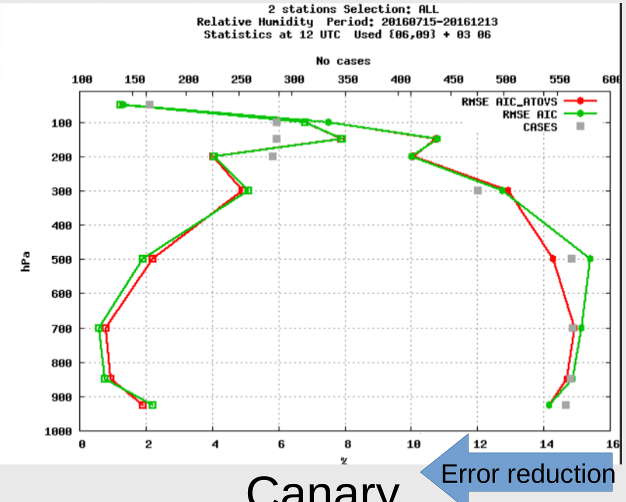


Iceland: Use conventional and ATOVS observations
(Sigurdur Thorsteinsson (IMO) and Roger Randriamampianina)

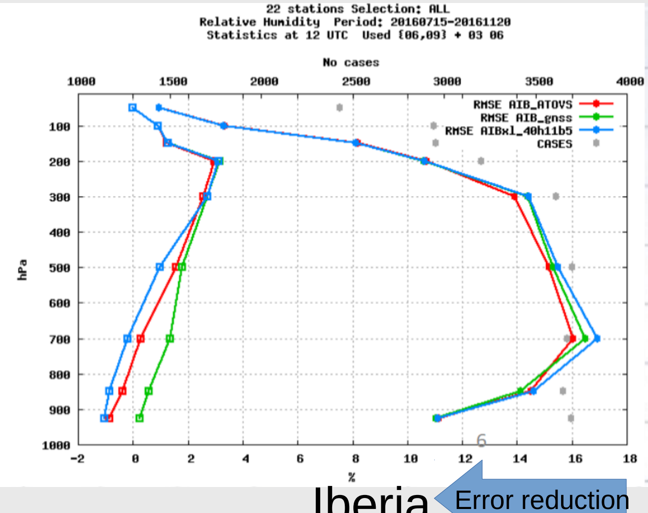
Spain: Use conventional, ATOVS and GNSS ZTD observations by
(Maria Diez, Jana Arriola and Joan Campins AEMET)



Iceland



Canary

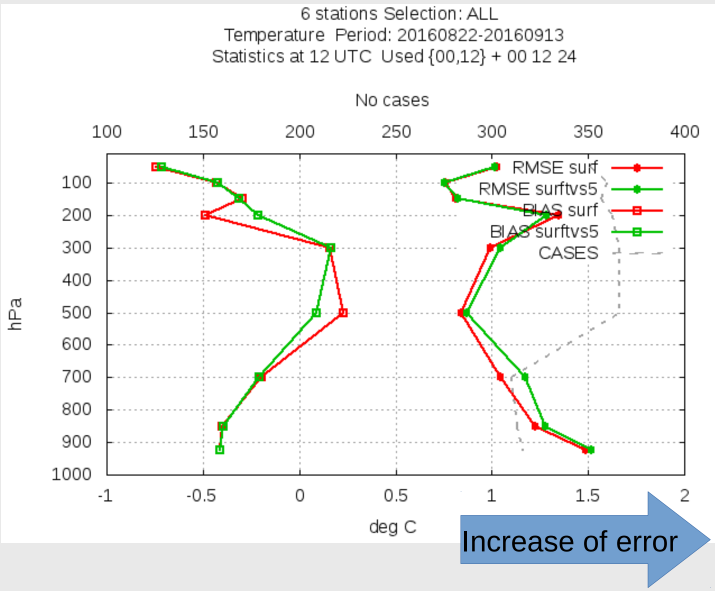


Iberia

Do we always get positive impact?

(Sigurdur Thorsteinsson & Roger Randriamampianina)

Assimilation of ATOVS with surface observations only



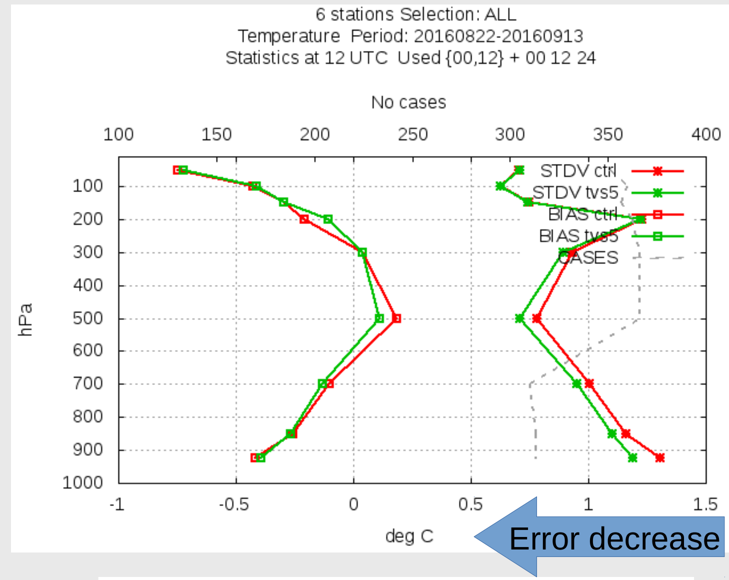
Negative impact of ATOVS

Icelandic IGA 3DVar study

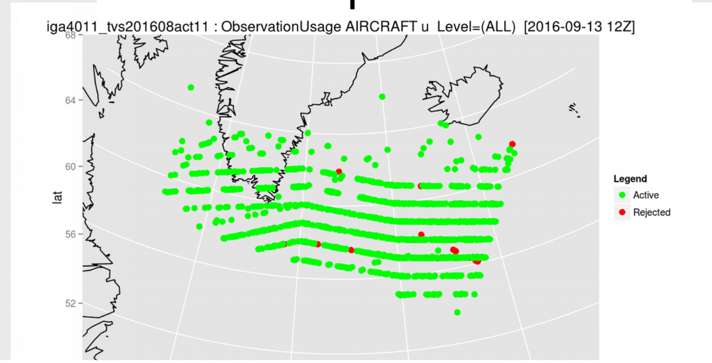
==> Radiance assimilation needs good 'anchoring' observations

Same ATOVS data in both cases

Assimilation of ATOVS with surface, radiosonde and aircraft observations



Positive impact of ATOVS

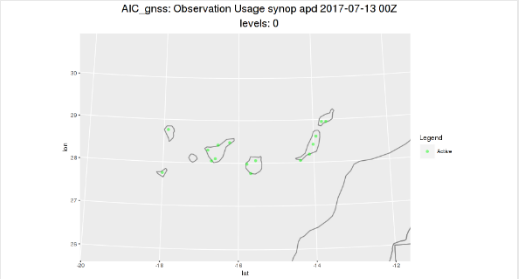


Many observations from trans-Atlantic flights

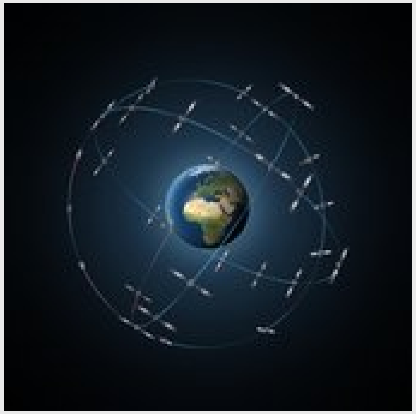
Do we always get positive impact?

(Maria Diez, Jana Sanchez, Joan Campins)

– Domain mainly sea area and the land part has complex orography.
– Sharp and high mountains.
Teide and Caldera de Taburiente.



Map of GNSS stations

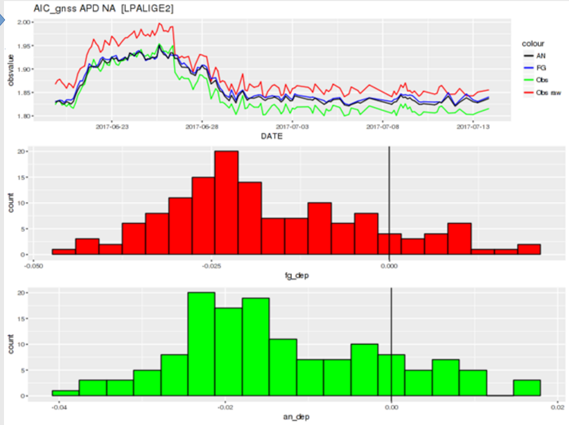


Galileo System.

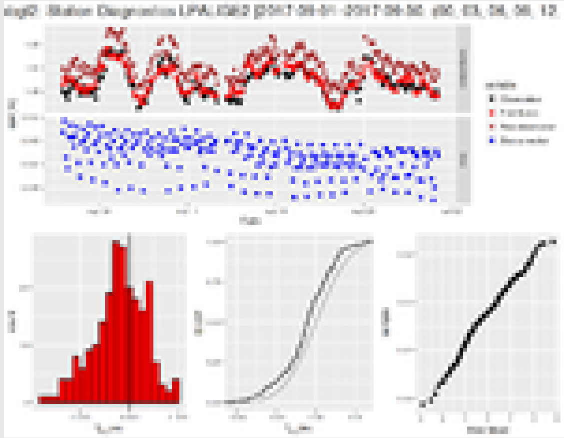
Actually there are 18 satellite launched.

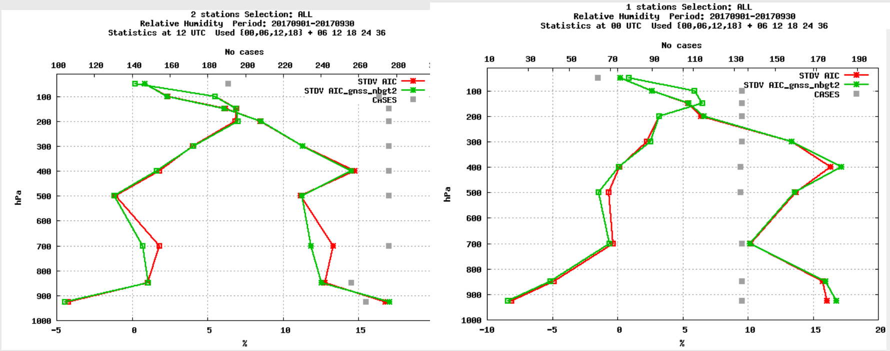
[***https://www.esa.int/***](https://www.esa.int/)

– Problems with the calibration of VARBC, with the default setup.



– Updated the predictor only at 12 UTC and 00 UTC and decrease the value of nbg = 2. The VARBC in more stable





Impact: Verification

Improve scores of RH around 700 hPa at 12 UTC.

Lack of Radiosondes in this area at 00 UTC (Only 1).

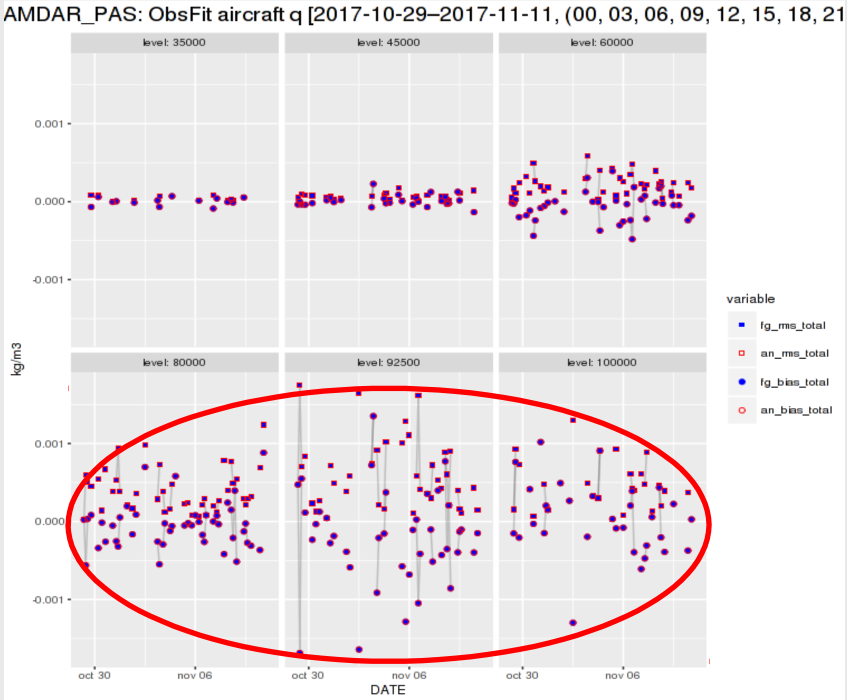
Highlight of the progress – 3D-VAR: local implementation (Maria Diez)

- The humidity sensor of E-AMDAR is really valuable.
  - Preliminary comparison with Harmonie has been done.
  - For upper levels have better behaiviour.

All the E-AMDAR bulletin with q sensor in one-month

[***https://eucos.dwd.de/eamdar***](https://eucos.dwd.de/eamdar)

Try to understand the random bias of low levels.

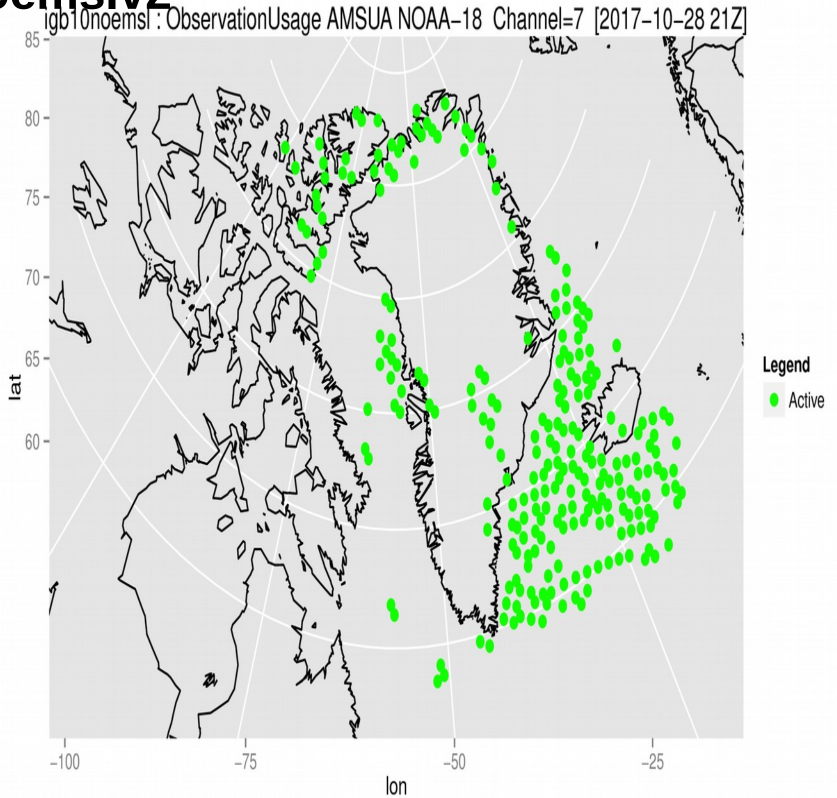


Highlight of the progress – 3D-VAR: local implementation

Dynamical emissivity and use of atlas in microwave radiance assimilation

(Sigurdur Thorsteinsson & Roger Randriamampianina)

noemslv2 ch. 7 2017-10-28 21Z



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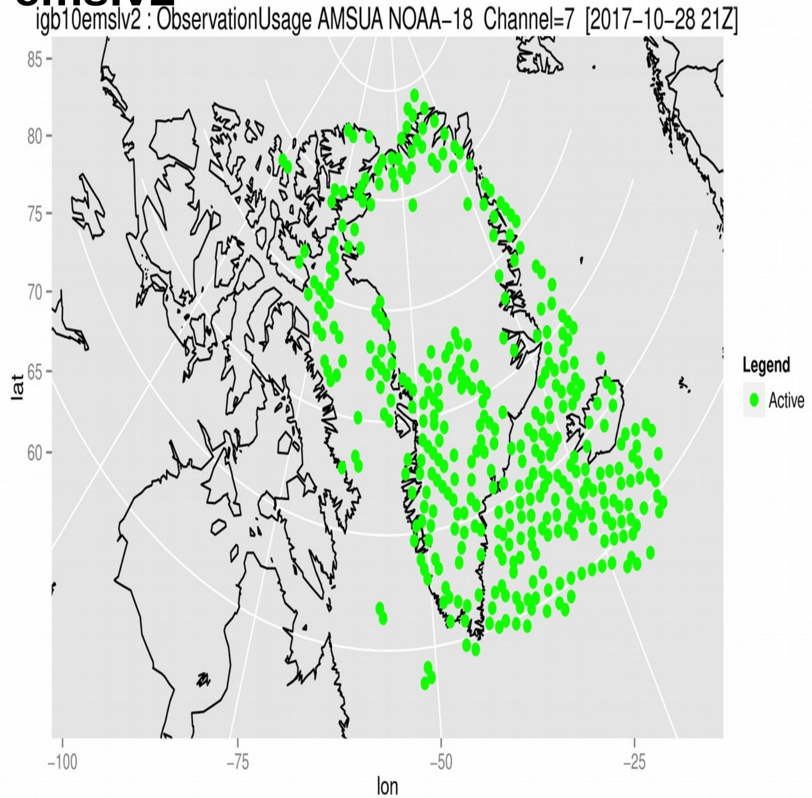

More ATOVS over sea ice and land ice

==> Many thanks to Philippe Chambon and Florian Suzat

Ongoing work; See Sigurdur's presentation for more details

Outlook – Just few of them ...

– Continue the local implementation of more observations …;

– Implementation of new observation types (ex. All-Sky radiances, Aeolus HLOS);

– Accounting for observation footprint in DA;

– Testing on DA schemes relevant for nowcasting;

– Working with initialisation schemes: LHN, back & forth nudging, use of variational constraint, IAU;

– Continue developing the LETKF, 4D-VAR and EnVar schemes;

– Bator for all observations and at the same time develop COPE to handle all observations;

– Diagnose B computation by checking Hirlam and MF/Aladin ways of computation;

– Better accounting of large scale information in initialisation and data assimilation;

– ….

Thank you