Upper-air data assimilation in HIRLAM status and plan

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

![Normalized variability of the cost function over different dates](image1)

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

![Normalized variability of the cost function over different dates](image2)
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);

Exp 4: Added less humidity, compared to Exp 1.

More experiments have been conducted to find the best settings
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**

$$2J(x^k) = \int_{o} w^k \| x^k - x_o^k \|^2 + w_c^k \| Mx^k - x_*^k \|^2$$

Good progress reported through 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. Gustafsson¹, J. Bojarova², and O. Vignes²

\[
J(\delta x_{\text{var}}, \alpha) = \beta_{\text{var}} J_{\text{var}}(\delta x_{\text{var}}) + \beta_{\text{ens}} J_{\text{ens}}(\alpha) + J_0
\]

\[
\frac{1}{\beta_{\text{var}}} + \frac{1}{\beta_{\text{ens}}} = 1.
\]

\[
J_{\text{ens}} = \frac{1}{2} \alpha^T A^{-1} \alpha
\]

\[
B_{\text{ens}} = A \circ B_{\text{raw-ens}}
\]

Ensemble: 10 members of BRAND perturbations

Localisation: spectrum of unbalanced surface pressure

\[
\Rightarrow \begin{cases} 
YQ\%\text{LGP}=.\text{TRUE.} \\
YQ\%\text{LSP}=.\text{FALSE.}
\end{cases} \Rightarrow \begin{cases} 
YQ\%\text{LGP}=.\text{FALSE.} \\
YQ\%\text{LSP}=.\text{TRUE.}
\end{cases}
\]

Qtrans

Local dev

\[\Rightarrow \text{See Jelena's presentation for more details}\]
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

**=> 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);

0 1 2 3 4 5 6 7 8 9

One 1-hour cycling DA system

0 1 2 3 4 5 6 7 8 9

Two 2-hour cycling DA systems

0 1 2 3 4 5 6 7 8 9

Three 3-hour cycling DA systems

==> These systems have the same cost, but gain in observation usage, especially if 4DVar is used as DA
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)
Highlight of the progress – towards improved tools and schemes
== Frequent refresh with overlapped windows ==
(Xiaohua Yang)

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 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](image1.png)

![Spain](image2.png)

![Error reduction](image3.png)
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

Assimilation of ATOVS with surface, radiosonde and aircraft observations

Same ATOVS data in both cases

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.
- 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).

Galileo System.
Actually there are 18 satellite launched.
https://www.esa.int/
The humidity sensor of E-AMDAR is really valuable.

Preliminary comparison with Harmonie has been done.

For upper levels have better behaviour.

Try to understand the random bias of low levels.

All the E-AMDAR bulletin with q sensor in one-month
https://eucos.dwd.de/eamdar
Highlight of the progress – 3D-VAR: local implementation Dynamical emissivity and use of atlas in microwave radiance assimilation (Sigurdur Thorsteinsson & Roger Randriamampianina)

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