ACCORD
A Consortium for COnvection-scale modelling Research and Development

Hirlam
High Resolution Limited Area Model

HIRLAM activities on Data Assimilation and Use of Observations

LACE
nwp central europe

RC LACE and DAsKIT working Days
22 to 24 September, 2021

ALADIN

Magnus Lindskog
HIRLAM PL for Data Assimilation and Use of Observations
and HIRLAM DA staff

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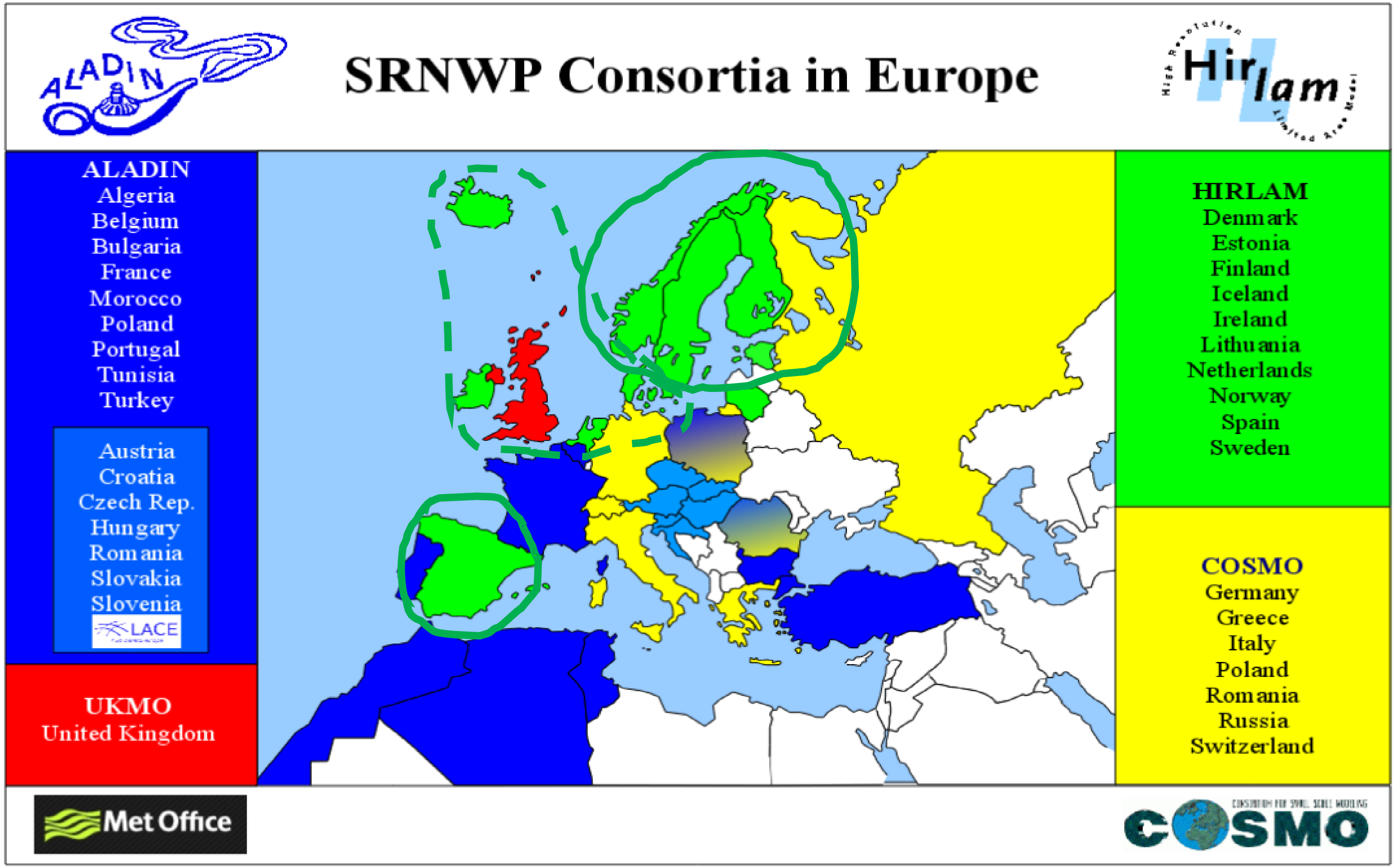
A Consortium for COnvection-scale modelling Research and Development

Structure

Hirlam
High Resolution Limited Area Model

- Introduction
- Algorithmic developments
- Background error statistics
- Observation handling
- Nowcasting
- Conclusions

Background



Operational centres

RCR

MetCoOp

AEMET

and

UWC-West

Taking large scale host model information into account

New approach under development and testing

Method

we define

$$\widetilde{x_b} = \mathbf{C}(\mathbf{B}+\mathbf{C})^{-1}x_b + \mathbf{B}(\mathbf{B}+\mathbf{C})^{-1}x_c$$

and

$$\widetilde{\mathbf{B}} = \mathbf{B}(\mathbf{B}+\mathbf{C})^{-1}\mathbf{C} = \mathbf{C}(\mathbf{B}+\mathbf{C})^{-1}\mathbf{B}, \qquad \widetilde{\mathbf{B}}^{-1} = \mathbf{B}^{-1} + \mathbf{C}^{-1}$$

then

$$J(x) = \frac{1}{2}(x-\widetilde{x_b})^{\mathrm{T}}\widetilde{\mathbf{B}}^{-1}(x-\widetilde{x_b}) + \frac{1}{2}(y-\mathbf{H}x)^{\mathrm{T}}\mathbf{R}^{-1}(y-\mathbf{H}x)$$

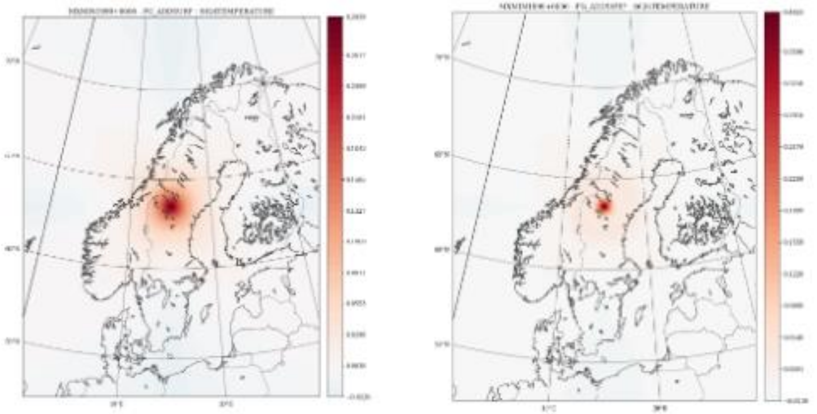
meaning that (at least theoretically) the minimization can be performed without the extra J_k term explicitly present, provided

- we pre-mix x_b and x_c into a new background term $\widetilde{x_b}$
- we use a modified background error covariance matrix $\widetilde{\ }$

Not necessarily any simpler for a completely general **C**.

Example of functionality

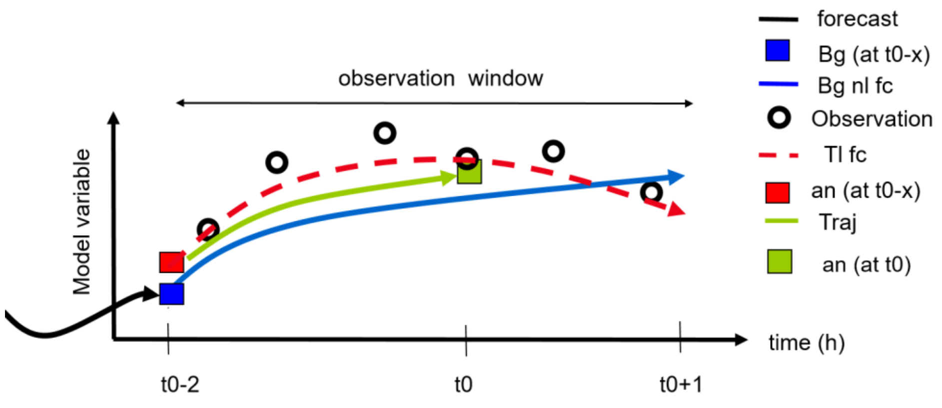
One single temperature observation +1K at 500 hPa, L24, $\rho(0) = 0.4$, $\rho(K-1) = 3$.



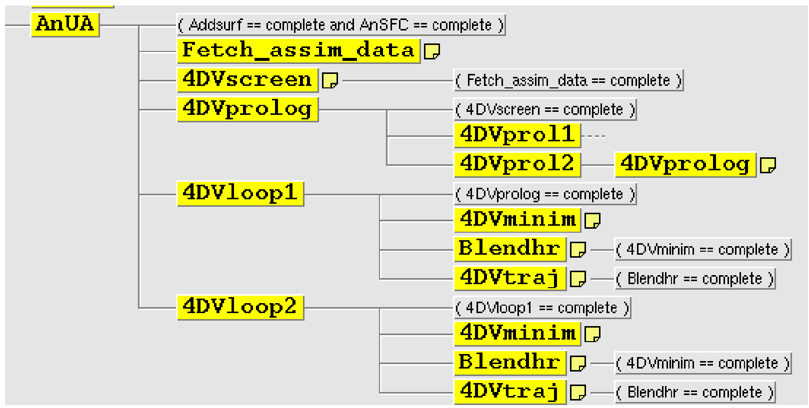
Left with original **B**, right with spectrally mixed $\widetilde{\mathbf{B}}$.

O. Vignes

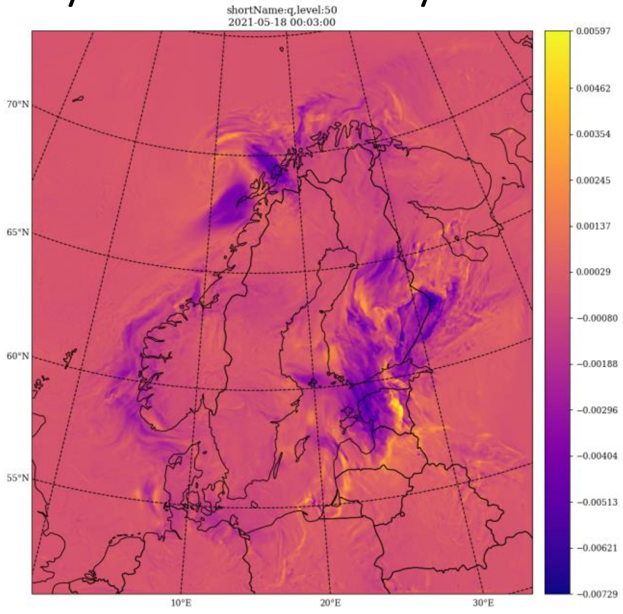
HARMONIE-AROME 4D-VAR



Bg (after lsm)
anbeg
An



Humidy model level 50 analysis increments



- Daily runs in MetCoOp (planned at AEMET)
- Encouraging results
- Optimized for operational use/same ready time as 3D-Var
- Open-MP, possibility to run parts with single precision
- Adaptations for use in nowcasting

J. Barkmeijer et al.

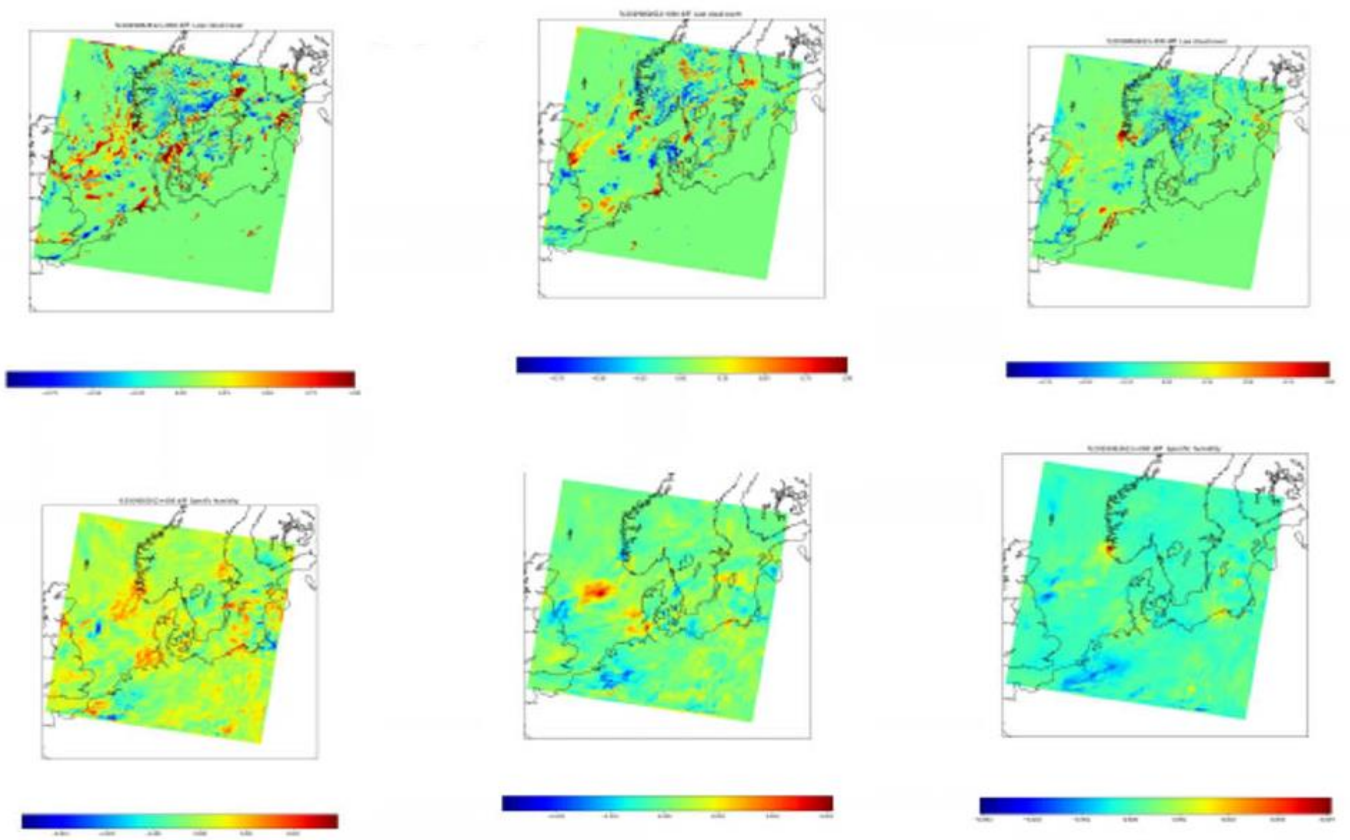
HYBRID EN-VAR

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

BREND (500 km) *BREND (100 km)* *EDA (100 km)*

Low level cloud increments

Humidity-increments at 700 hPa



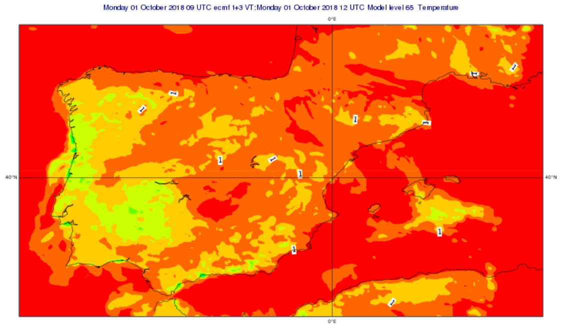
- 20+1 ensemble members
- Compare EDA, BRAND, BREND
- Visualisation of structures

J. Bojarova

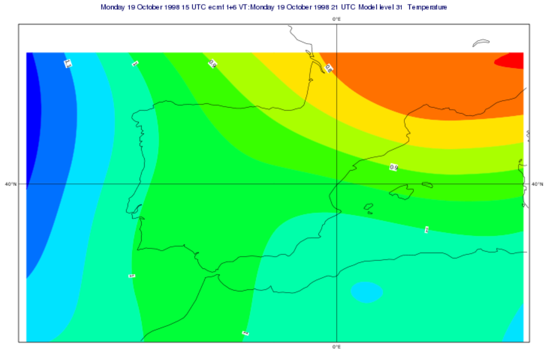
LETKF

$$J(x) = (x - x^b)^T (P^b)^{-1} (x - x^b) + (y^o - H(x))^T R^{-1} (y^o - H(x))$$

- Exploiting potential for future use of LETKF ensemble in screening background check
- Extended periods, smoothening, filtering, flow-dep. BGOS, …
- First results below from a 10 member LETKF ensemble an from that standard deviations calculated for one particular time and shown here for temperatures .



Temperature standard deviation at lowest model level as derived from ensemble

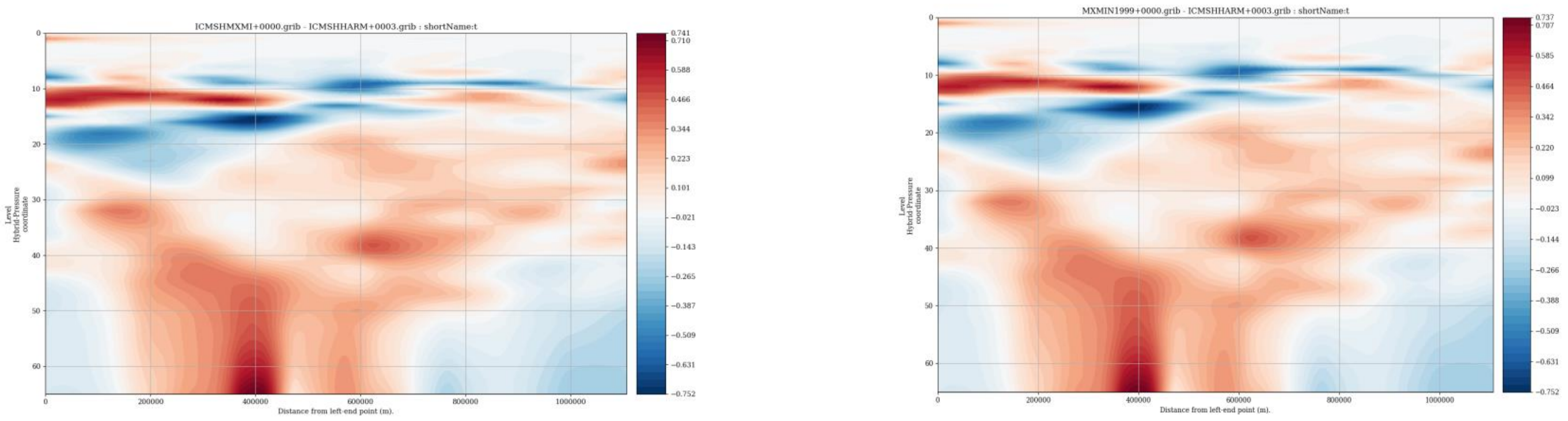


Temperature standard deviation at lowest model level From ERRGRIB FILE.

P Escribà

OOPS

OOPS version DA with conv obs. producing results comparable with MASTERODB version.



Cross section of OOPS increment (left) vs MASTERODB temperature increment right).
Conventional types of observations used.

R. Stappers

General Procedure
(2 steps)

- **Downscale** ECMWF EDA (ELDA) forecasts with 2.5 km HARMONIE-AROME (Typically 4 ensemble members launched from ECMWF EDA analyses 00,12 UTC and with ECMWF EDA on lateral boundaries. This is done for a (representative) summer and winter period. +6h forecasts differences from these forecasts are used to generate background error statistics. (if no previous B matrix available).

- Then (usually for same periods) the statistics generated above are used for generating **HARMONIE-AROME EDA** forecasts (cycled runs with 3h da cycle for the winter and the summer period) with perturbed observations. Again 4 perturbed ensemble members and statistics generated from +6h forecast differences. ECMWF EDA as LBC and SST perturbations from ECMWF (no surface nor physics perturbations).

- In re-analysis project CERRA we do have a procedure for keeping a large number of forecast differences from summer/winter on disc and re-run festat with different amount of contributions from summer winter dependent on season (and also differences from latest days using a small ensemble).

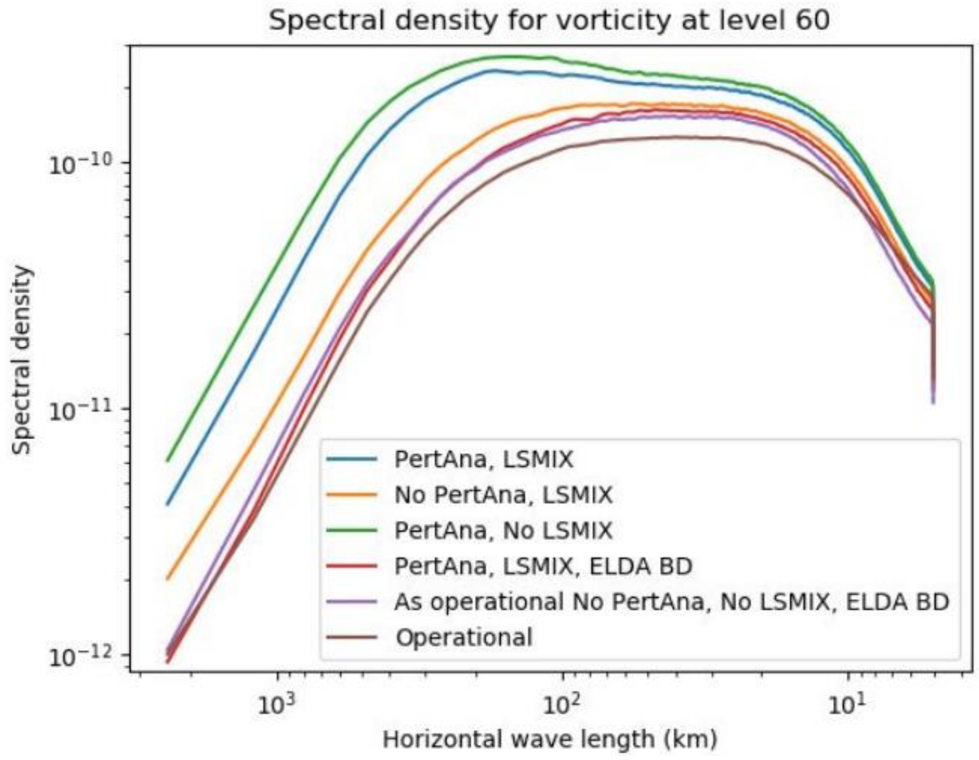
(done when new cycles or major changes in modelling system)

(note +6h fc differences used to represent +3h background errors, avoid spin-up effects in statistics LSMIX=.false.)

R. Azad, M Ridal, E. Whelan et al.

Exploiting the use of an operational ensemble for B matrix calculations

- Default procedure (brown) uses ECMWF ENDA
- Operational ensembles uses IFS ENS
- IFS ENS contains larger scale perturbations than EDA.
- ECMWF will output (but not archive or disseminate) hourly data up to +18h from their EDA suite (aka ELDA) with the introduction of 47r3 in October.



USE OF ECMWF ENDA WHEN GENERATING B-MATRIX RESULTS IN TOO BROAD SCALES

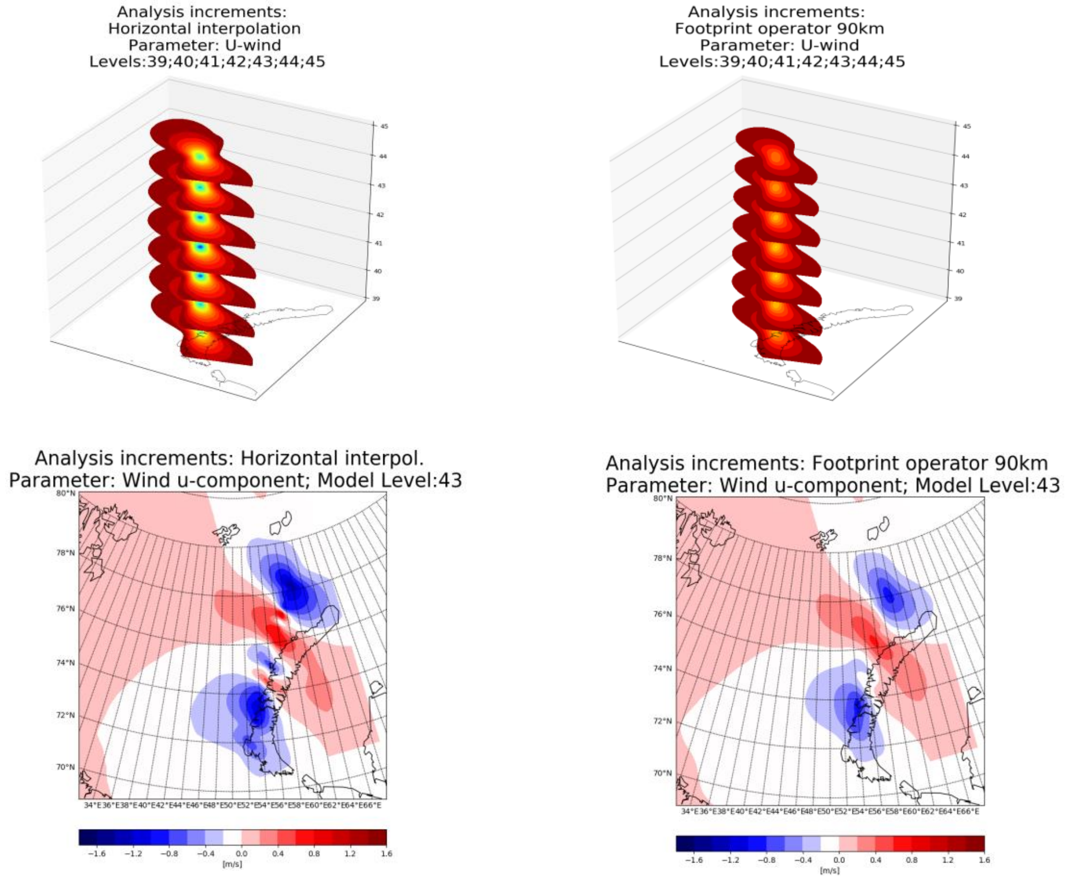
U. Andrae, I.-L. Frogner and M. Lindskog

Observation handling

Supermodding-A **footprint operator** to average within footprint of observation and to better handle scale differences between observation and model

Supermodding – A special footprint operator for mesoscale data assimilation using scatterometer winds by **Máté Mile**, **Roger Randriamampianina**, **Gert-Jan Marseille**, Ad Stoffelen, QJRMS: 20 January 2021, https://doi.org/10.1002/qj.3979.

Aeolus winds

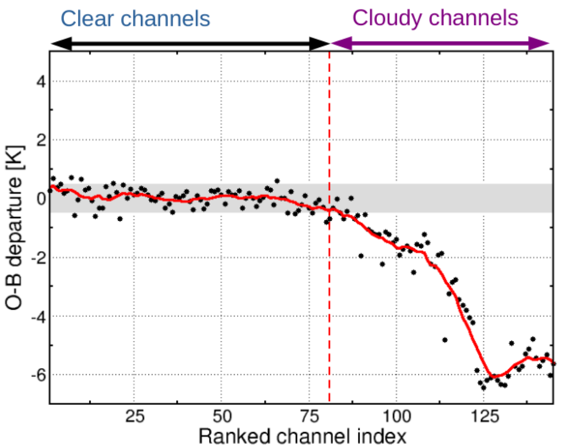


- First developed for ASCAT
- Applied to ASCAT, Aeolus and satellite data
- Less fit to observations and smother analysis increments

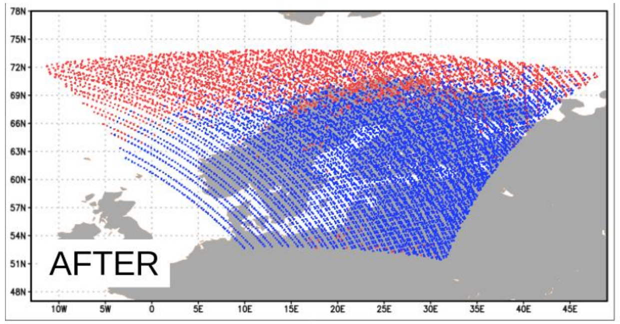
M. Mile et al.

Improved cloud detection for satellite radiances

Properly working



Stratospheric channel cloudy
Stratospheric channel clear



General idea

McNally and Watts cloud detection (2003):

– Take a large number of channels from the 15 µm (long-wave IR sounding band

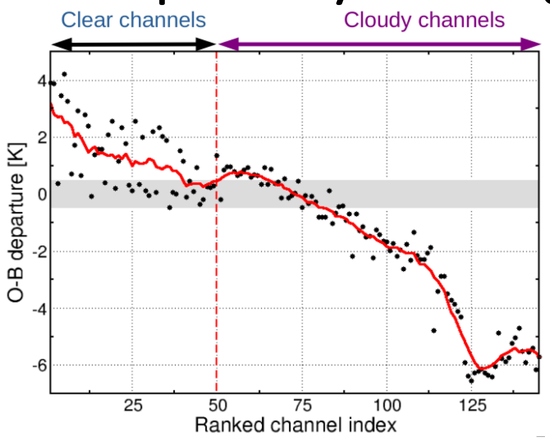
– Rank O-B departures in vertical and apply a smoothing filter

– Find the ”breaking point” that marks the distinction between clear and cloud-affected channels

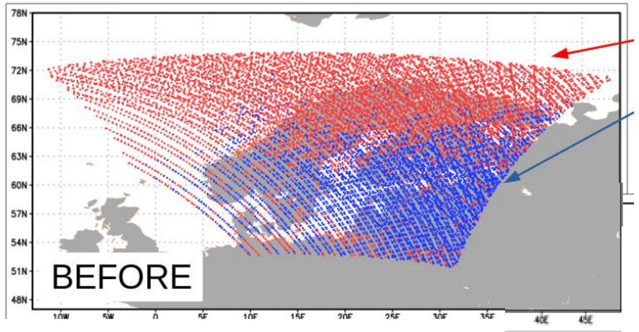
- Carefully select channels to be used in cloud detection.
- Let all these data through bias correction (in active or passive mode)

R. Eresmaa

Sub-optimally working



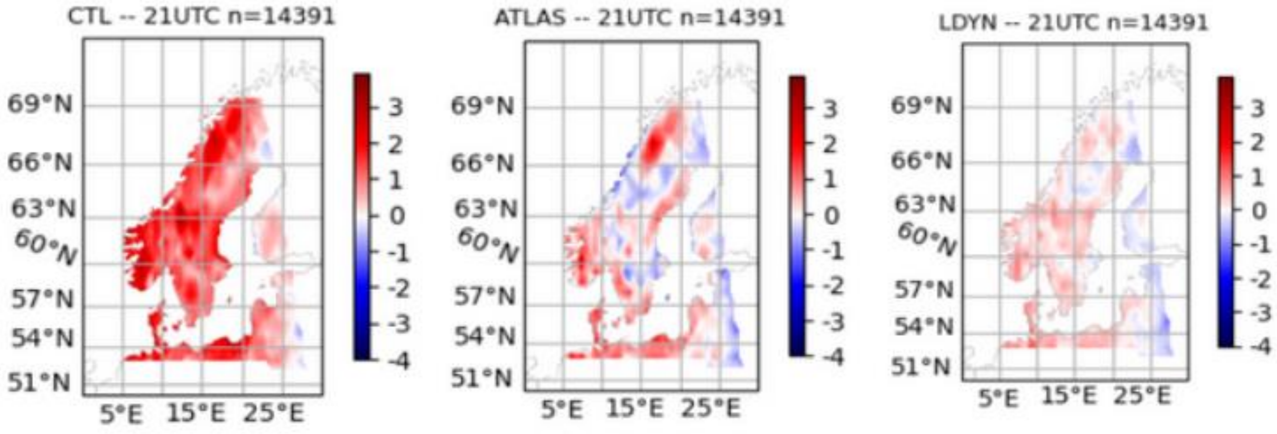
Stratospheric channel cloudy
Stratospheric channel clear



Observation handling

Exploring an improved use of low-peaking channels using emissivity Atlases or dynamical emissivity estimates

Maps of FGd AMSU-A Channel 4 (52.8 GHz) using different surface schemes - 09/06/2021 (21UTC)



On-going experiments

S. Guedj, R. Stappers, J. Blyverket

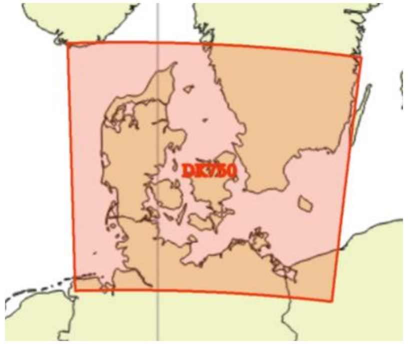
Observation handling

Some more achievements and on-going work in the area of satellite data assimilation (and other)

- More satellites (Metop-C, FY-3D, SNPP, NOAA20, Meteosat, HY-2B and soon FY3E) and types instruments (ATMS, SEVIRI, MWHS-2) at various institutes.
- Alternative cycling procedure for VARBC coefficient under evaluation.
- Procedure to updating also upper-air skin temperature in between CANARI and upper-air.
- First all-sky assimilation in cy 46.
- Exploitation of various types of observations: Aeolus HLOS, ASCAT, GNSS RO using SPIRE data, GNSS slant delays, Mode-S, RADAR winds, ..
- Surface pressure from Crowdsource observations
- T2m,RH2m in MetCoOp nowcasting framework (both for surface using Pysurfex and upper-air)

M Diez, J. Campins, I Martinez, F. Silva, V. Costa, E Whelan, M Dahlbom, B. Amstrup, R. Eresmaa, S. Thorsteinsson, X. Yang, D. Schönach, E. Gregow, J. Bojarova, M. Ridal, P. Medeiros, S. Guedj, R. Stappers, J. Blyverket, R. Randriamampianina , M. Mile, R. Azad, S. Hagelin, S. Haan, G.-J. Marseille, H. Körnich, H. Schyberg, A. Dybbroe, M. Lindskog et. al.

Observation handling



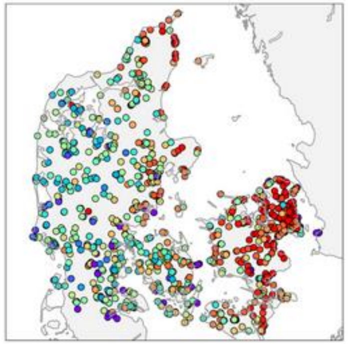
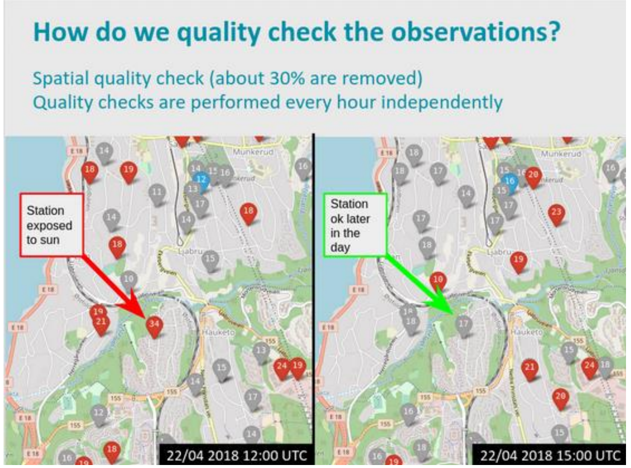


Illustration domain
And one your of data
10 May, 2018
8.30-9.30 UTC

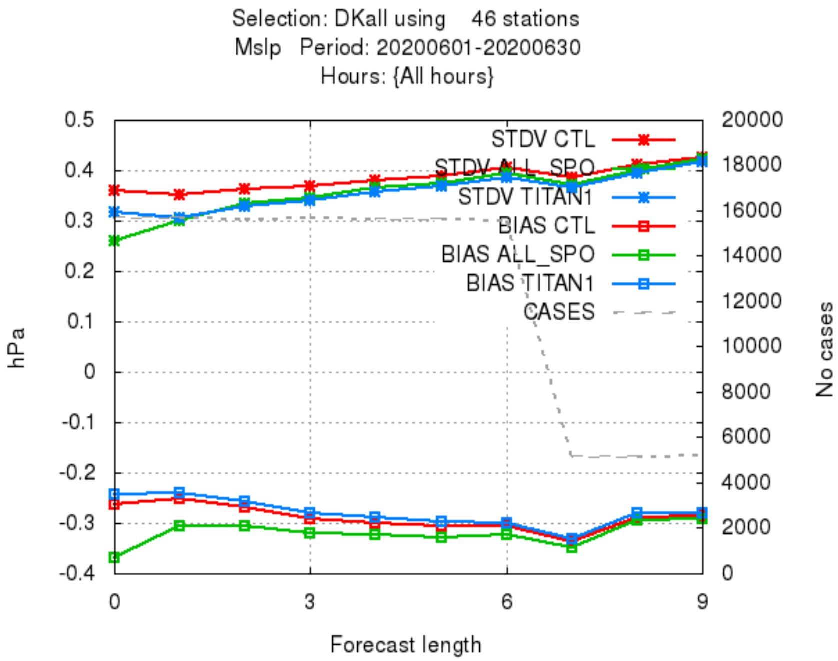
TITAN QC FUNTIONALITY



Plausibility, FirstGuess, Fraction, Sct, Buddy, Climatology, Redundancy, BlackList, DomainCheck, NoMeta

Surface pressure from smartphones

Verification scores from a one-month parallel exp.



Standard deviation and bias for surface pressure forecasts as function of forecast range for three runs. Red is control with no SPOs, green is all SPOs with no QC, blue is QC with TITAN (no thinning, no bias correction but with inflated obs. errors).

K. Hinz, , T. Aspelien, T. Snipen

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Observation handling

Hirlam High Resolution Limited Area Model

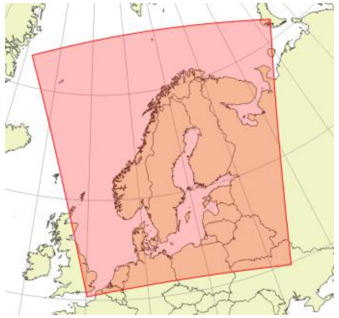
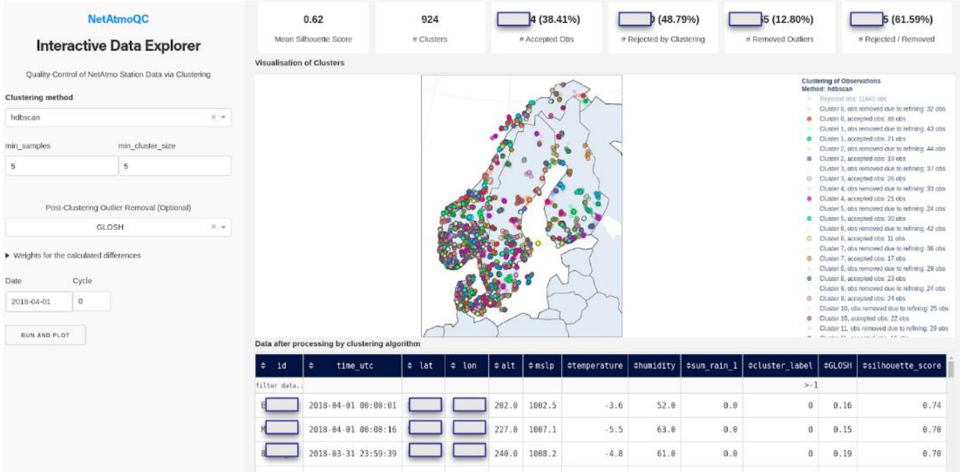


Illustration domain

QC using Unsupervised Machine Learning (ML)



Find clusters of similar obs. Accept obs. with highest degree of confidence belonging to a cluster. Reject obs. that looks like outliers or just do not belong to any cluster.

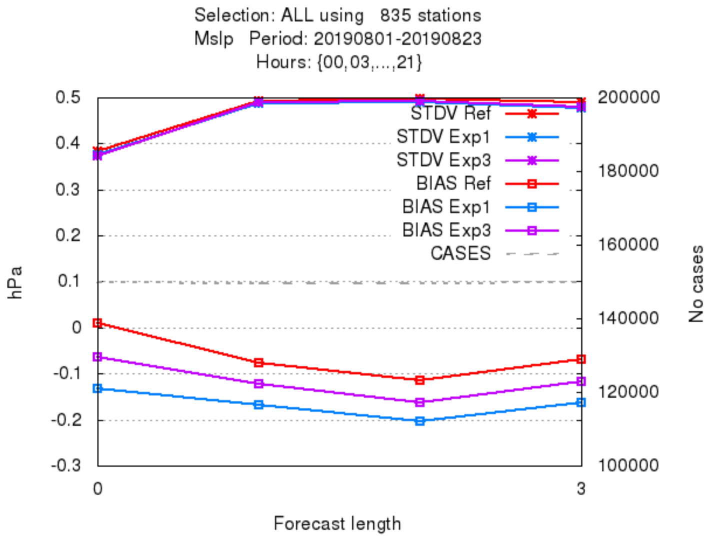
$$d_{i,j} = w_s.d_{s;i,j} + \sum_{\Lambda} \sqrt{w_\Lambda^2.(\Lambda_j - \Lambda_i)^2}$$

Distance and data characteristics taken into account.

Surface pressure from NetAtmo stations

Verification scores from a three-week parallel exp.

Ref- No Netatmo
Exp1-Netatmo with basic prior to model QC
Exp3-Netatmo with ML QC



VARBC, thinning and inflation applied to NetAtmo data.
Further tuning and optimisation planned.

E. Gregow, M. Ridal, P. Medeiros, R Stappers, J. Bojarova et al.

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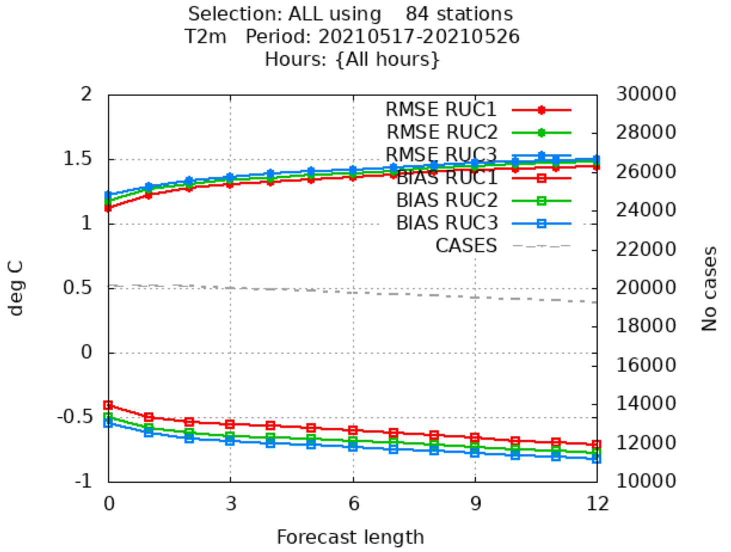
Nowcasting

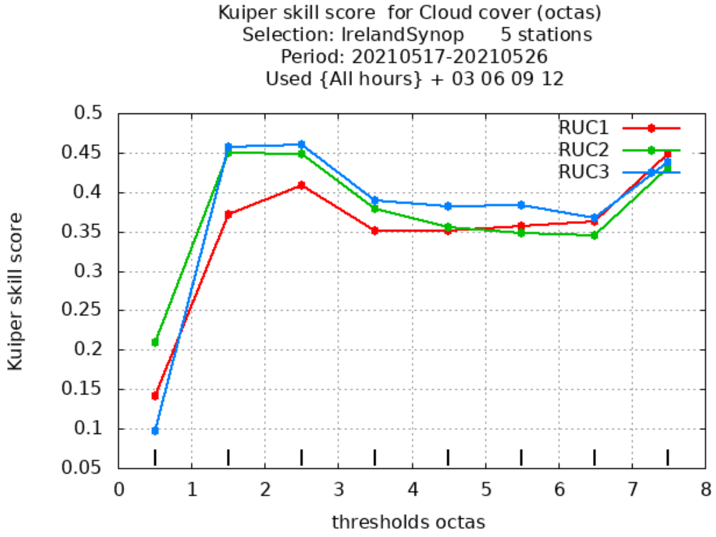
Hirlam

Comparing

1h/2h/3h DA-cycles

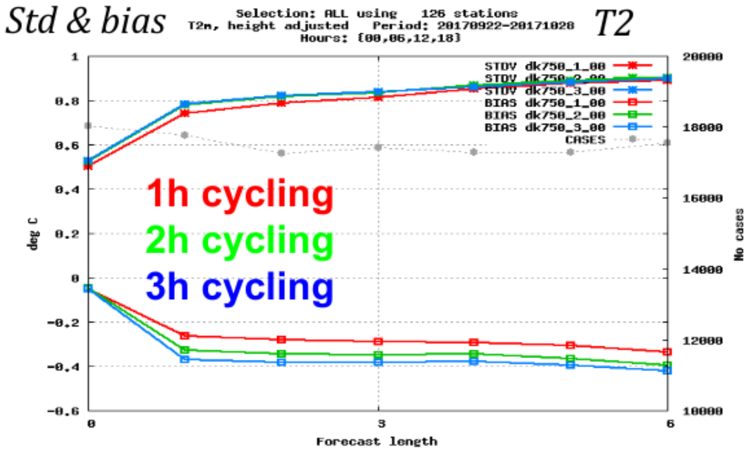
Spring

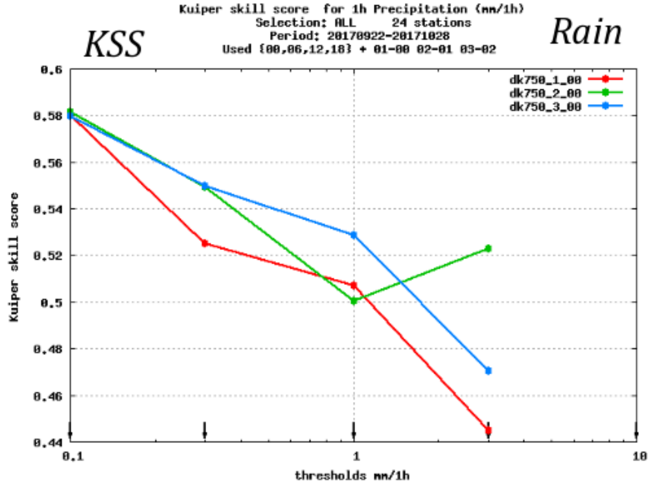




for short spring and longer autumn period

Autumn





Scores for dry/moist-variables better/worse with 1h-cycling as compared with 2/3.

E. Harney and X. Yang

On-going work and plans

- Exploiting and optimizing time-filtering through initialisation approaches (Incremental Analysis Update and Variational Constraint).
- Enhanced handling of host model information.
- Overlapping window 4D-Var.
- Improved use of cloud products through use of optical thickness and ML.
- Various studies of spin-up and sensitivity to observation usage etc.
- Framework for sub-hourly studies is being set-up.

C. Ceigo, G., S. v. Veen, E Gregow, T. Landelius, K, C. Pederssen, O. Vignes, M. Dahlbom, J. Bojarova, J. Barkmeijer, B. X. Yang,
U. Andrae, S. d. Haan, E. Harney, I. Ansper, A. Lerner et al.

Conclusions

- An operationally feasible HARMONIE-AROME 4D-Var available.
- Important progress in radiance data assimilation.
- Encouraging results with crowdsource observations.
- 1h-da cycling remains a challenge.
- OOPS has been compiled and run with conventional types of observations.

Extra material

Taking large scale host model information into account

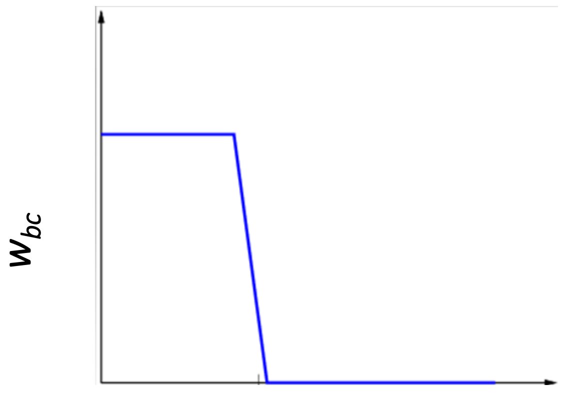
So far two main approaches tried, LSM and J_k

Large Scale Mixing (LSM) before UA DA

$$x_{mix}(m,n,l) = w_{bc} x_{ecmwf}(m,n,l) + (1 - w_{bc}) x_{harmonie}(m,n,l)$$

x-model state,m,n-hor. wave num.,l-level, w_{bc}-mixing weight

Illustration for one particular vertical level



Note: w_{bc}-mixing weight varies with height and goes to 0 at surface

J_k – term in cost function

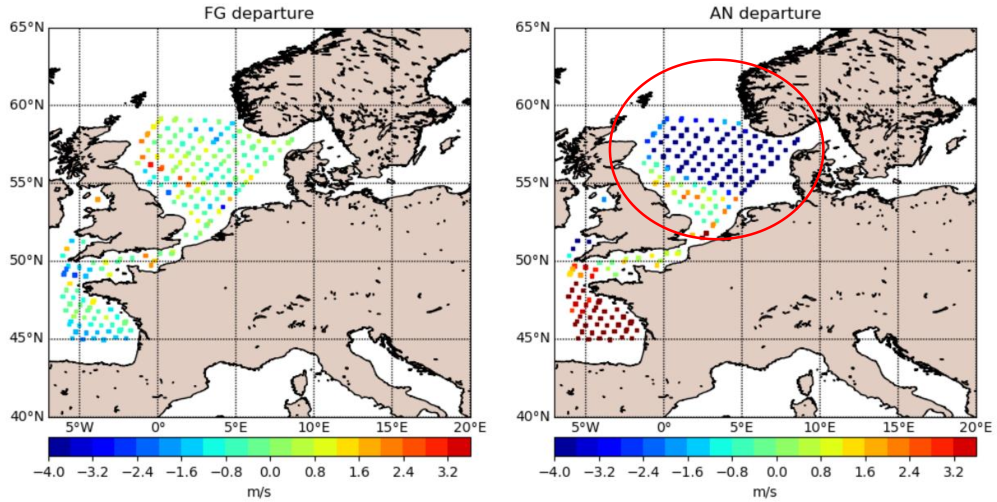
To account for the coupling model state, an extra penalty term is added

$$\min_x J(x) = J_b + J_o + J_k$$
$$= \frac{1}{2}(x - x_b)^T \mathbf{B}^{-1}(x - x_b) + \frac{1}{2}(y - \mathbf{H}x)^T \mathbf{R}^{-1}(y - \mathbf{H}x) + \frac{1}{2}(x - x_c)^T \mathbf{C}^{-1}(x - x_c)$$

where

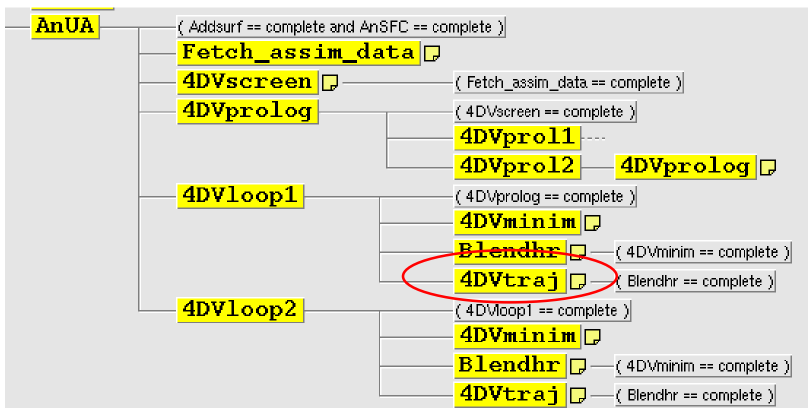
- x_b is the background state, **B** the background error covariance matrix
- y is the observations vector, **R** its error covariance matrix, **H** observation operator
- x_c is the coupling model state, **C** the coupling model error covariance matrix

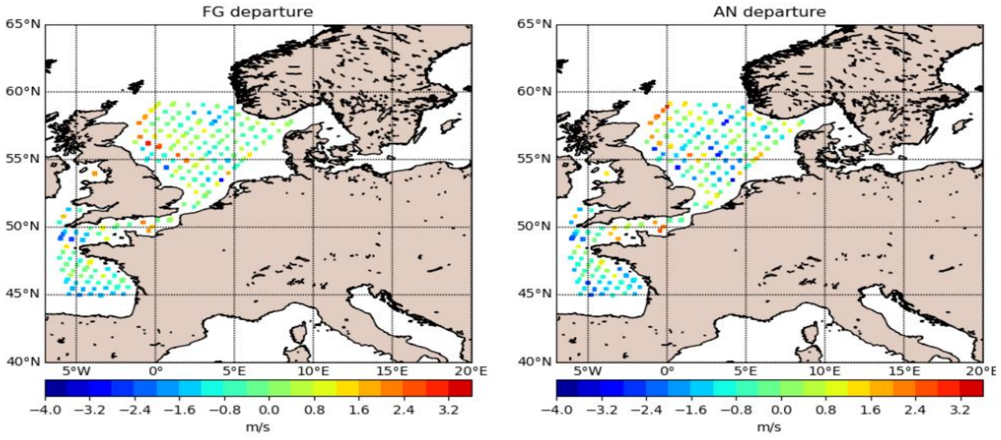
HARMONIE-AROME 4D-VAR ASCAT ISSUE



With problem

ASCAT data that belongs to timeslot are wrongly handled in trajectory run since with trajectory settings observation operator requires some diagnostical quantities obtain only after model is integrated one time step.



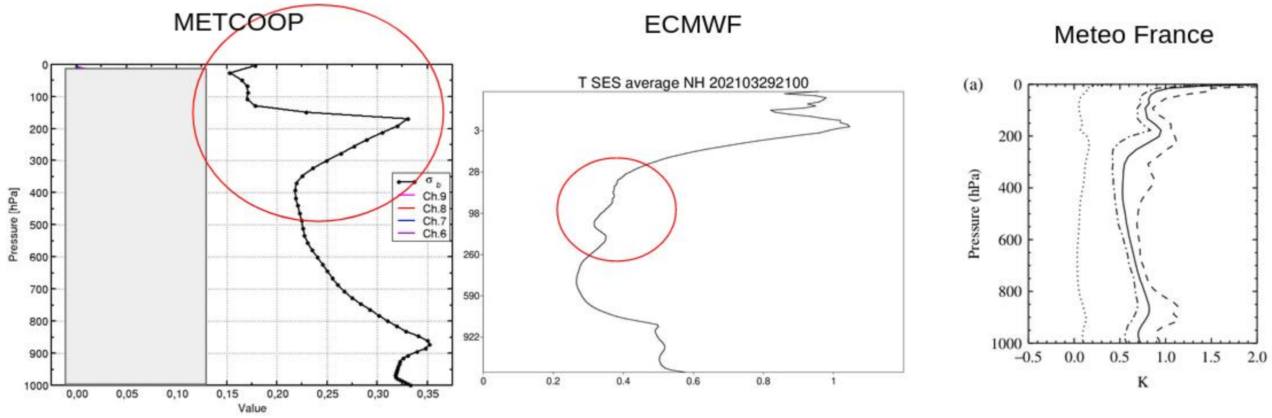


With problem fixed (not solved)

Make timeslot 1 very short in combination with
Excluding ASCAT data from timeslot 1 (mfblacklist.b or Bator)
With help from Christophe Payan we think that we are close to a solution.

Background error statistics

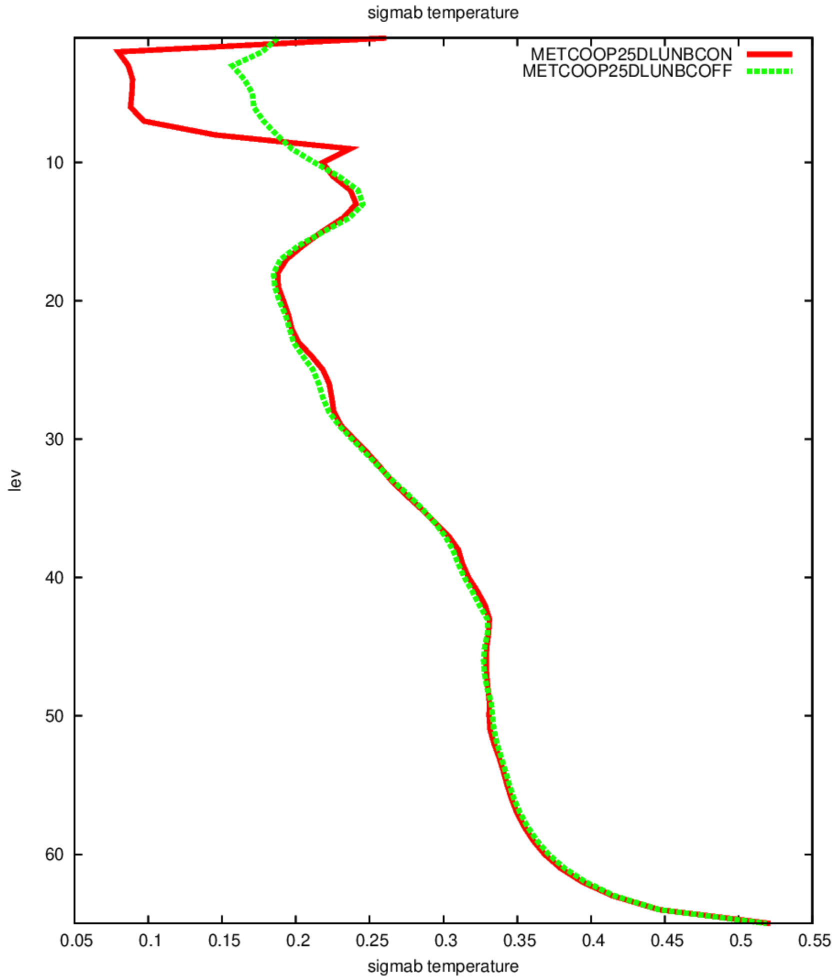
Issue



Spurious unbalanced temperature background error standard deviations has been found in MetCoOp system. Drop of errors at highest model levels and not seen in profiles from ECMWF and Météo France.

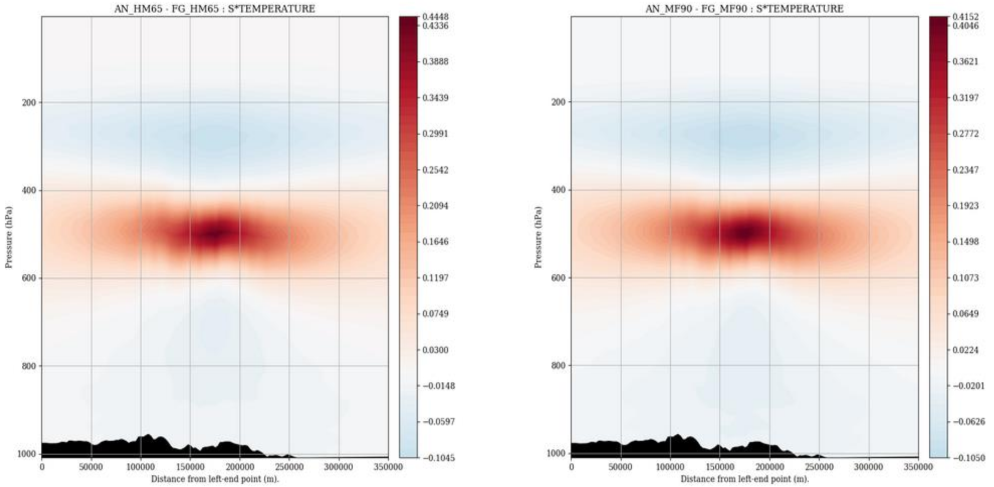
The reason was found to be use of LUNBC option in HARMONIE-AROME forecast model set-up, used mainly for stability reasons. The **solution** (or fix) is that we will turn off LUNBC when deriving background error statistics.

Issue



Tools

1. Interpolation of background error statistics.
using stabal.cv and stabal.bal.
To be made available.



2. jbdiagnose.x

Tool to extract information regarding standard deviations and balances in ascii format from stabal.cv and stabal.bal

jbdiagnose.F90, jbdiagnose.pdf

3 Scripts for Plotting of information extracted from Jb-diag

https://github.com/Hirlam/Plot-jbdiag

Short Summary

- A Supermodding approach developed and adopted to several types of observations.
- More satellites (Metop-C, FY-3D, SNPP, NOAA20, Meteosat, HY-2B and soon FY3E) and types instruments (ATMS, SEVIRI, MWHS-2) at various institutes.
- Encouraging steps towards improved handling of satellite radiances.
- Radar wind data assimilation studies at AEMET.
- Aeolus HLOS.
- GNSS RO using SPIRE data .
- GNSS slant delays data assimilation experiments in close collaboration with LACE.
- Several recent examples of assimilation of Crowd-source observations.
- Increasing use of Mode-S.

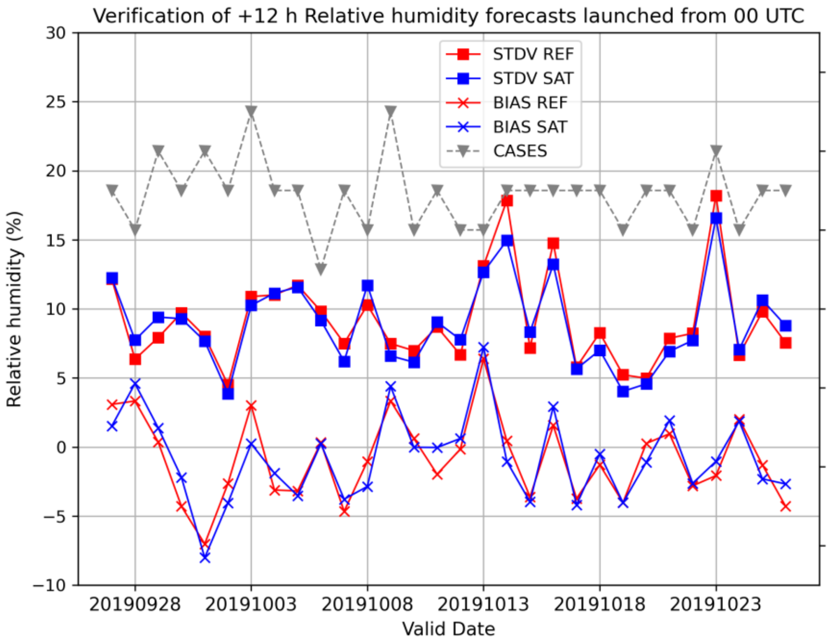
will be covered in more detail

Improved use of clear-air radiances (more data)

FY-3C/D MWHS2 AND METOP-C MHS/AMSU-A

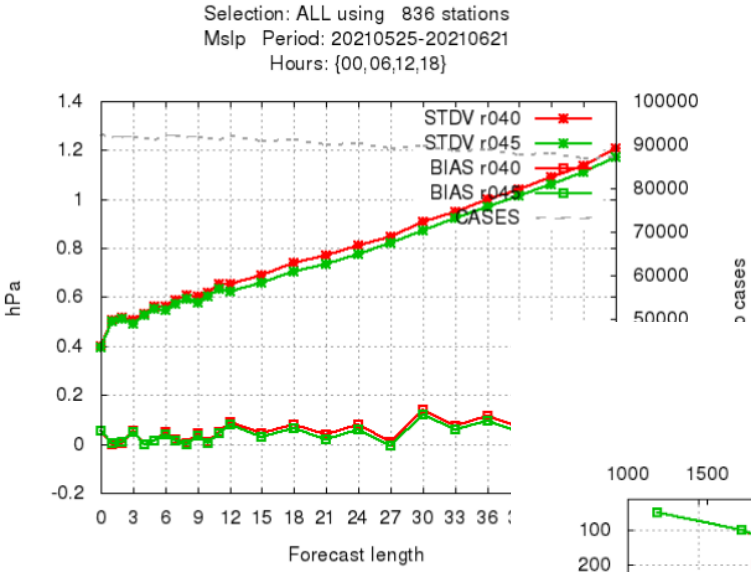
Lindskog, M., A. Dybbroe, R. Randriamampianina. 2021: Use of Microwave Radiances from Metop-C and Feng Yun-3 C/D Satellites for a Northern European Limited-area Data Assimilation System. Adv. Atmos. Sci., https://doi.org/10.1007/s00376-021-0326-5.

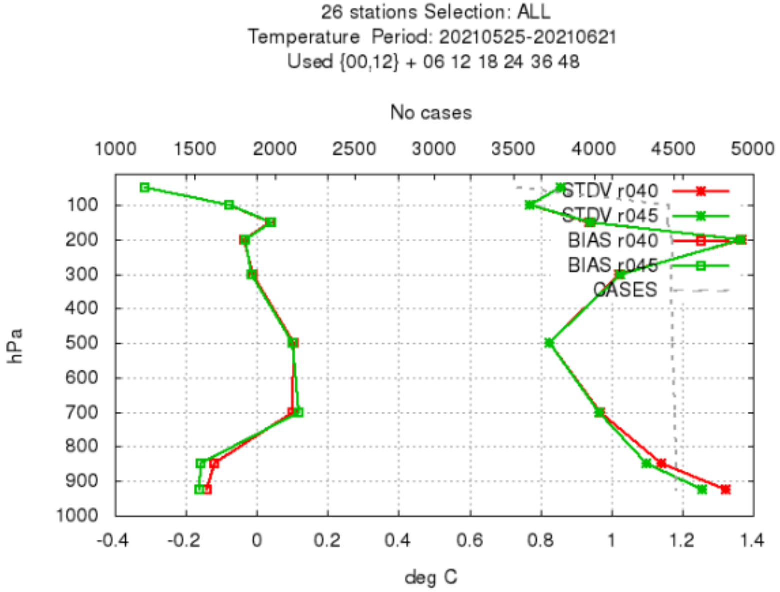
REF and **SAT** for verification against radiosondes.



Verification period: 27 Sep - 27 Oct 2019.

Suomi-NPP and NOAA-20 ATMS

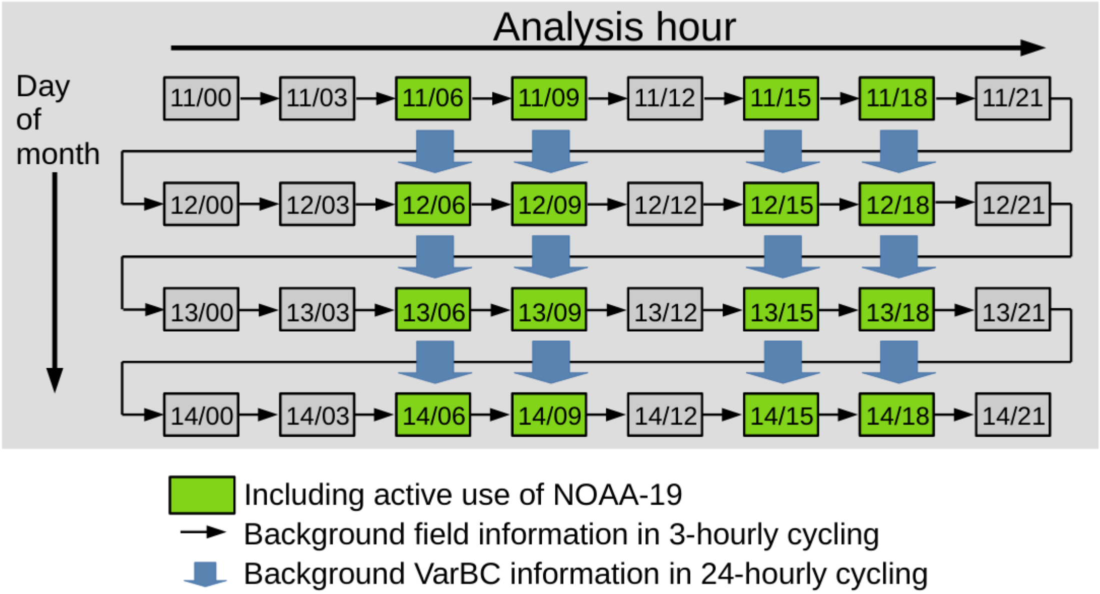




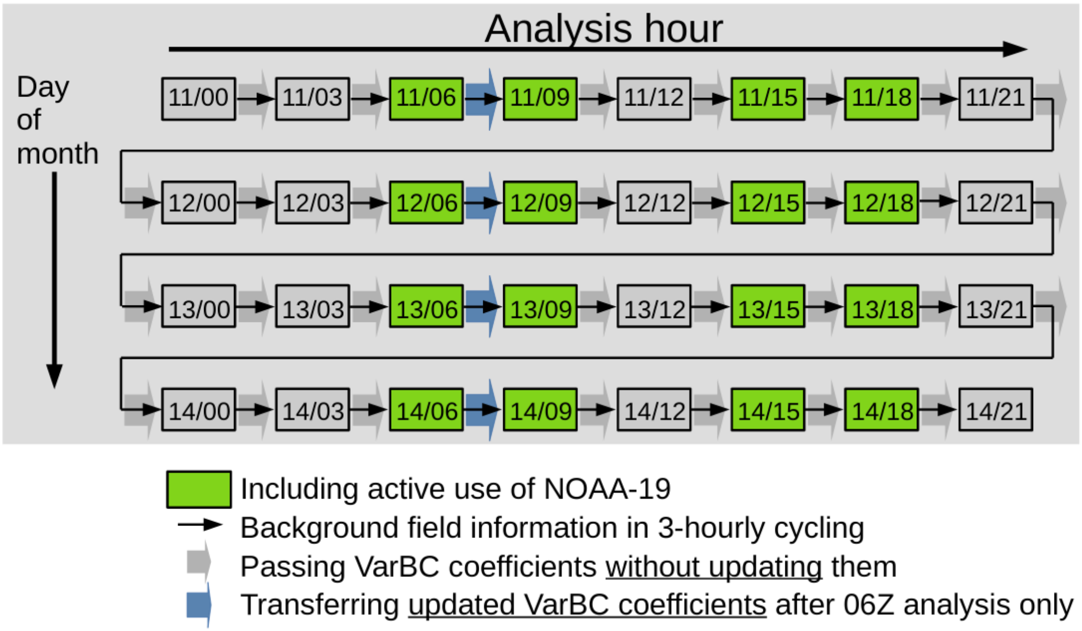
REF and **with ATMS**

Variational bias correction of satellite data

Current



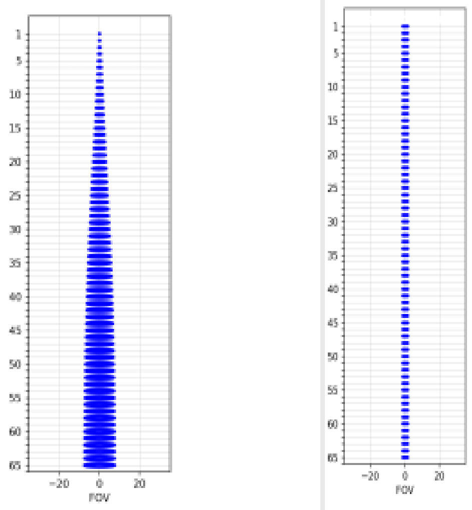
Refined



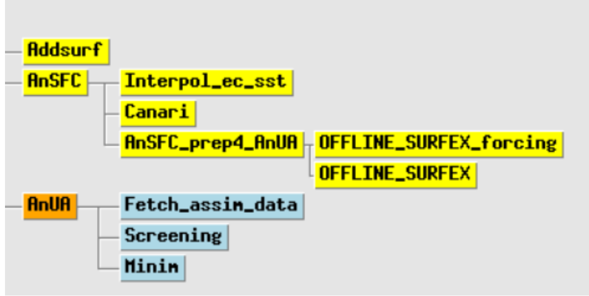
- Under evaluation
- Updating times for each satellite provided by namelist to varbc code (not LISTE_LOC)
- Updating time when best coverage of data

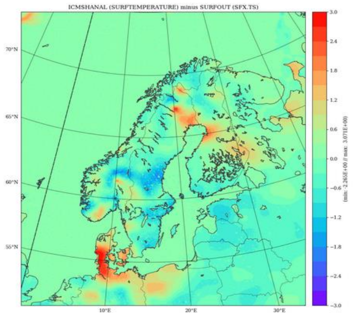
Towards Improved use of clear-air radiances

2. Footprint operator instead of horisontal interpolation

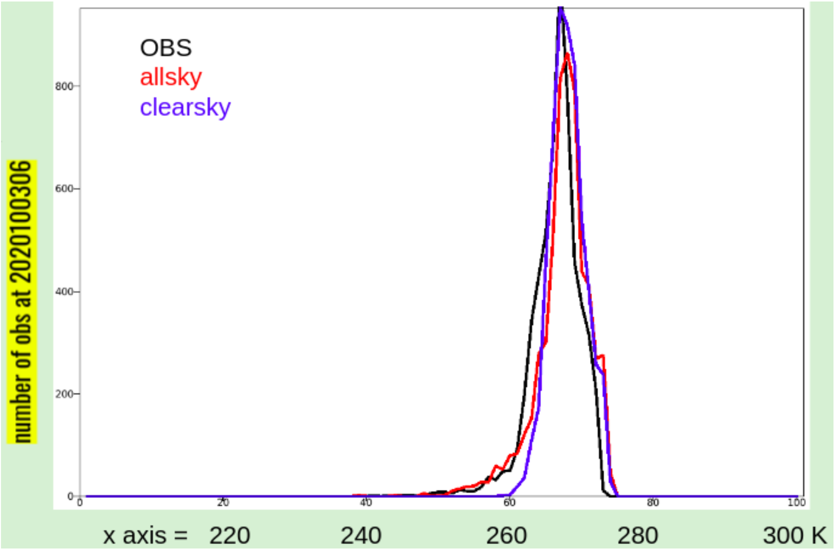


1. Updating UA fields with surface temperatures from CANARI





A first step towards all-sky use of radiances



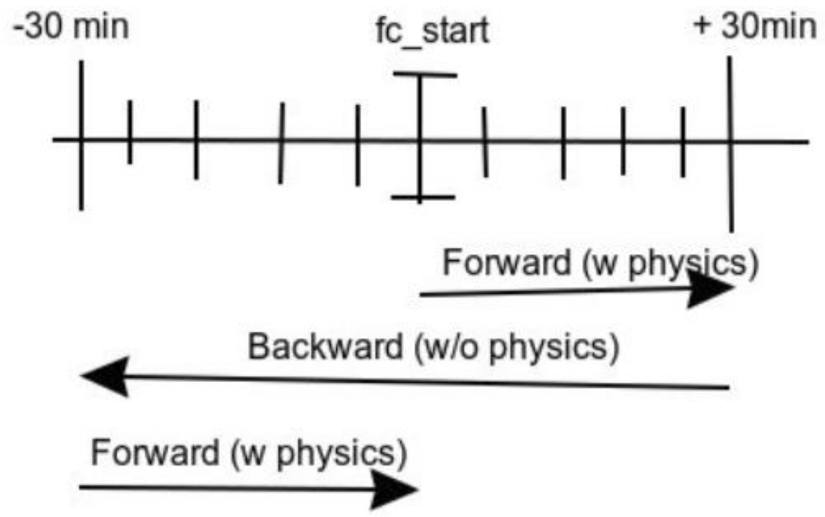
Spectra of clearsky (blue) and all-sky (red) Tb as well as the observed (black) Tb for ch 5 for one particular cycle.

The work is started in Harmonie CY46 and with MHS observations. In the IFS all-sky approach the radiance observation operator rttov is replaced by rttov_scatt which provides the model counterpart of the radiance observations in clear, cloudy and rainy conditions. The new observation type for all-sky is 16 and the code type used is 215.

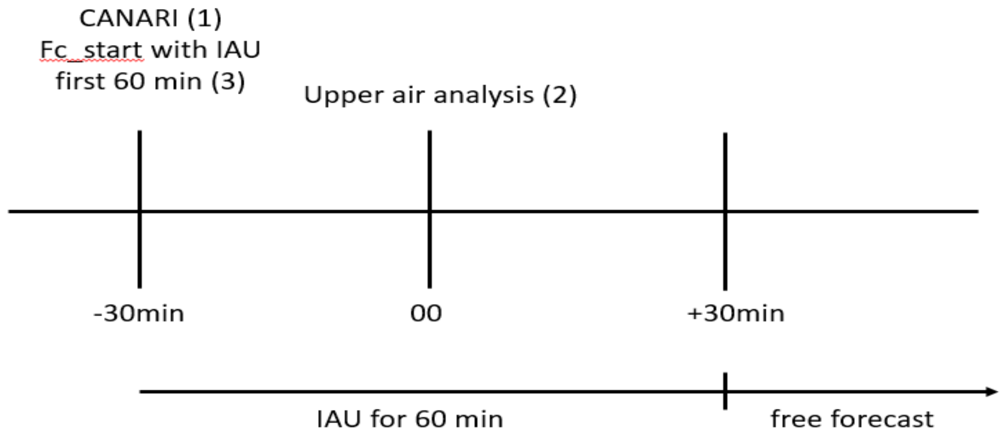
Work in close collaboration with Météo-France.

Incremental analysis update (IAU)

Backward adiabatic



Centered



Application of adiabatic backward DFI in MetCoOp nowcasting.
Plan to apply DFI centered but will require some re-organisation of tasks.

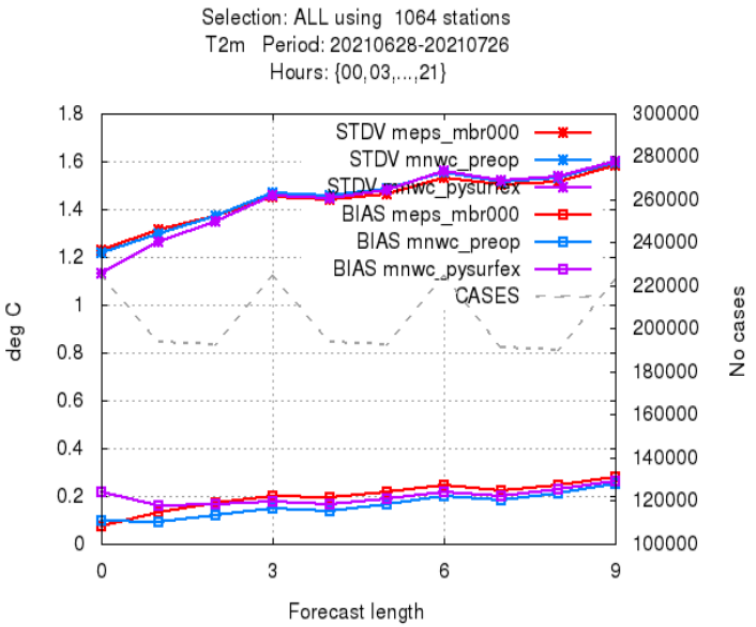
A Consortium for COnvection-scale modelling Research and Development

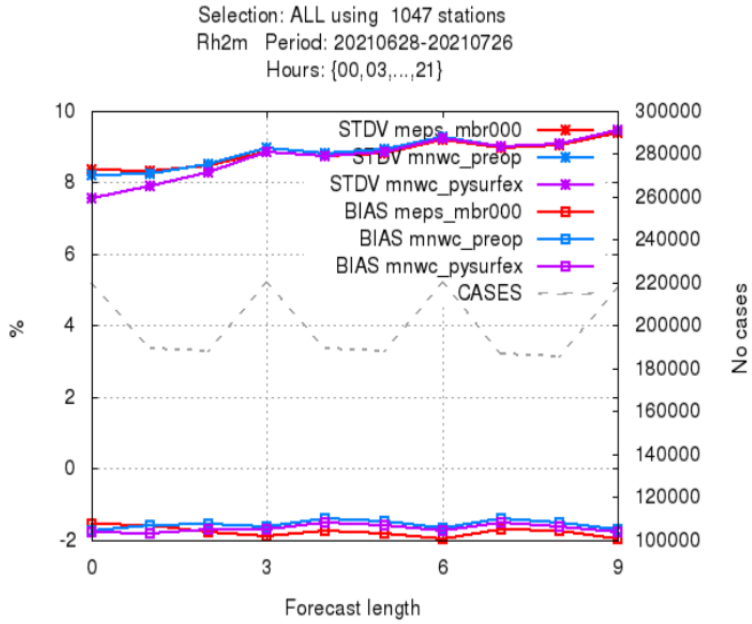
ACCORD
A Consortium for COnvection-scale modelling Research and Development

Nowcasting

Hirlam
High Resolution Limited Area Model

MetCoOp Nowcasting version using Netatmo data





Verification of MNWC-Pysurfex (purple) during July 2021 (purple lines) MetCoOp operational system MEPS-mbr000 (red) and MNWC_preop (blue).