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HIRLAM – High Resolution Limited Area Model

Evaluation of some HARMONIE-AROME cy46 data assimilation tunable settings

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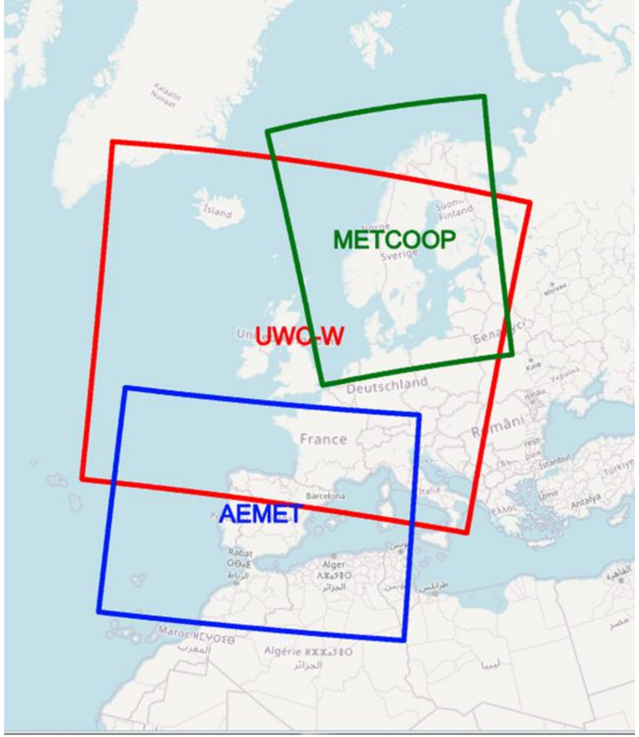
Outline

- CY46 evaluation runs
- Description of tunable settings
- Diagnostic methods
- Recommended adjustments
- Limitations revealed by BGOS and how to alleviate
- Summary and conclusions

Full report available here:

https://opensource.umr-cnrm.fr/attachments/download/6142/Tuning_report_jan25.pdf

Harmonie-AROME Cycle 46 evaluation runs



Extensive DA experiments have been carried out over 3 domains and 4 different seasons to evaluate the performance of the Cycle 46 as compared to the currently operational Cycle 43.

They have been run over a month period , with a 15 days spin-up period.

Observation usage was the same in both model versions and roughly corresponding to operational use in each domain.

For this tuning we use the results from the cy46 runs

- Description of tunable settings

Description of tunable settings

First guess Check

Tunable parameter L

First-guess check to reject observations due to Gross errors

$$\{[H(x_b]_i - y_i\}^2 / \sigma_{b,i}^2 > L \times \lambda, \quad (1)$$

where $\lambda = 1 + \sigma_{o,i}^2 / \sigma_{b,i}^2$ rejection limit and

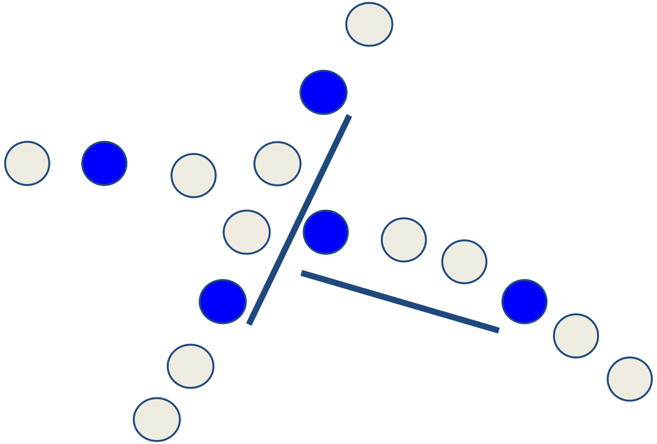
$\sigma_{o,i}$ and $\sigma_{b,i}$ - error standard deviations ($\sigma_{b,i}$ from errgrib-file)

By default L=25 → reject obs if $|y - Hx_b|$ > 5 times $\sqrt{\sigma_{b,i}^2 + \sigma_{o,i}^2}$

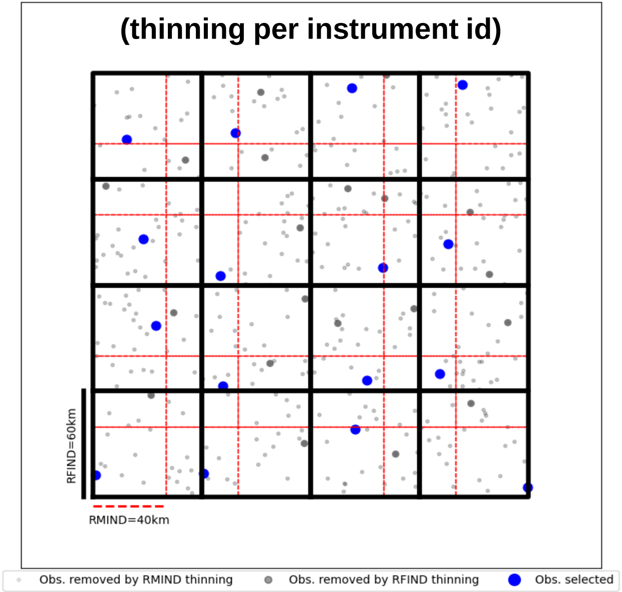
Description of tunable settings

Observation thinning

AMDAR and SHIP
(thinning per station id)



Satellite radiances



Tunable parameters RMIND (AMDAR) and RSHIDIS (SHIP)

Tunable parameters RFIND, RMIND

Description of tunable settings

Background and Observation error scaling

Relative weight of background and observations in minimisation of penalty function J:

$$J = J_b + J_o = \frac{1}{2}\delta\mathbf{x}^T\mathbf{B}^{-1}\delta\mathbf{x} + \frac{1}{2}(H\mathbf{x}^\mathbf{b} + \mathbf{H}\delta\mathbf{x} - \mathbf{y})^T\mathbf{R}^{-1}(H\mathbf{x}^\mathbf{b} + \mathbf{H}\delta\mathbf{x} - \mathbf{y})$$

stabal_cv.dat
stabal_bal.dat

Tunable parameters
REDNMC, REDNMC_Q

SIGMAO_COEFF(OBSTYPE)

but note that $\sigma_{o,i}$ and $\sigma_{b,i}$ in different spaces (unbalanced temperature relative to brightness temperature)

Background Errors in Observation Space (BGOS)

Application developed in the OOPS framework to compute background error standard deviation in observation space:

$$\sigma_b^o = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(HU\chi_i)^2}$$

where

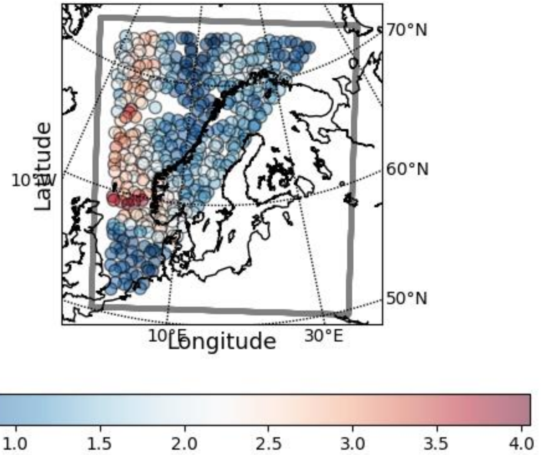
σ_b^o	bg error std in ob space
N	sample size

U is the series of transform applied to get a unit B matrix in minimization, H is the observation operator (tl or nl) and χ_i is the control vector (containing Gaussian errors) for the individual member i.

($\delta x = U\chi$ $\quad J_b = \frac{1}{2}\delta x^T B^{-1}\delta x = \frac{1}{2}\chi^T\chi$)

Example

MHS channel 3 background error standard deviations in observation space 15 July 2022, 00 UTC. MetCoOp domain.



unit: K

(corresponding observation error standard deviation is 1.8 K)

Now we can compare bg errors with obs errors

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- Diagnostic methods

Diagnostic methods

1- Andersson&Järvinen Q. J . R. Meteorol. SOC. (1999). 125, pp. 691-122

AIM: To select appropriate check limits (FgLim) for background check. Assumption is that observations with errors outside Gaussian distribution are affected by Gross errors and should be removed prior to the data assimilation.

$$([H(\boldsymbol{x}_b)]_i - y_i)^2/\sigma_{b,i}^2 > \text{FgLim} \times \lambda$$

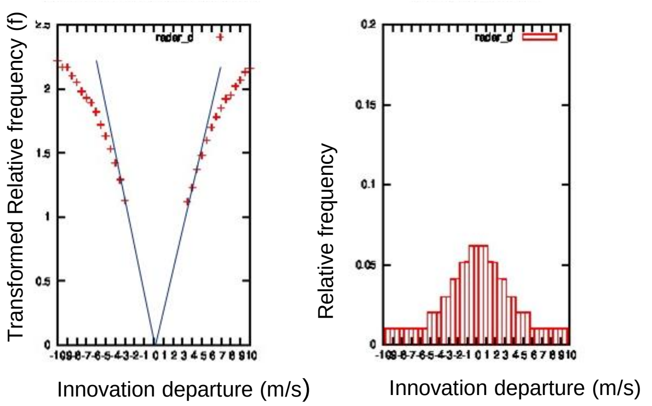
where $\lambda = 1 + \sigma_{o,i}^2/\sigma_{b,i}^2$, FgLim is the rejection limit and $[H(\boldsymbol{x}_b)]_i$ denotes the projection of the model state on y_i observation, where the potential observation bias has been accounted for. $\sigma_{o,i}$ and $\sigma_{b,i}$ are the standard deviation of the observation error and background error equivalent, respectively.

HOW: Plots histograms and transformed histograms of innovations to identify when distribution starts to deviate from Gaussian and where to put rejection limit.

Transformation formula:

$$\hat{f} = \sqrt{-2\ln[f/\max(f)]}$$

Example for radial winds:



Diagnostic methods

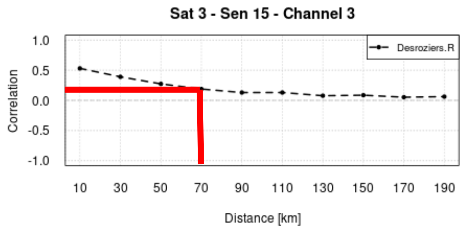
2- Obstool (based on P. Benachecks developments)

AIM: To set the thinning distances applied to high spatial density data in accordance with estimated observation error correlation length scales. The spatial thinning is applied both to limit data amounts and to compensate for our current lack of representation of spatial observation error correlations.

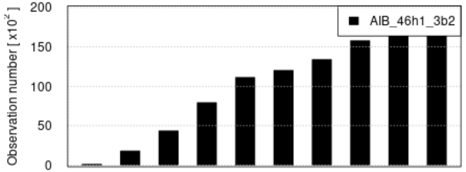
HOW: Based on DA feedback statistics files, innovations are separated into observation error correlations and background error correlations. From plots of the observation error correlation part, appropriate thinning distance is estimated with distance when the observation correlation drop to 0.2.

Example for satellite MHS channel 3 data

Derived observation error correlation as function of distance between data pairs.



Number of data in each bin as function of distance between data pairs.



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Diagnostic methods

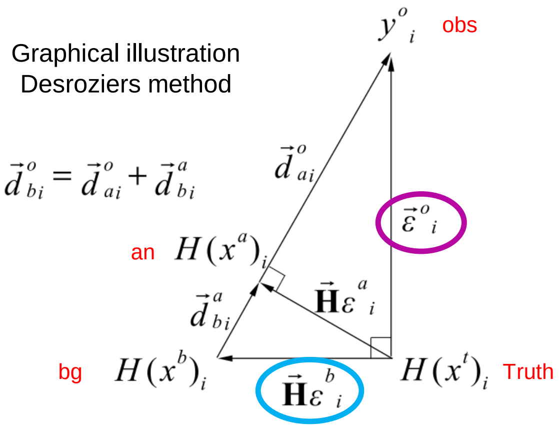
3- Desroziers

Q. J. R. Meteorol. Soc. (2005), 999, pp. 1–999

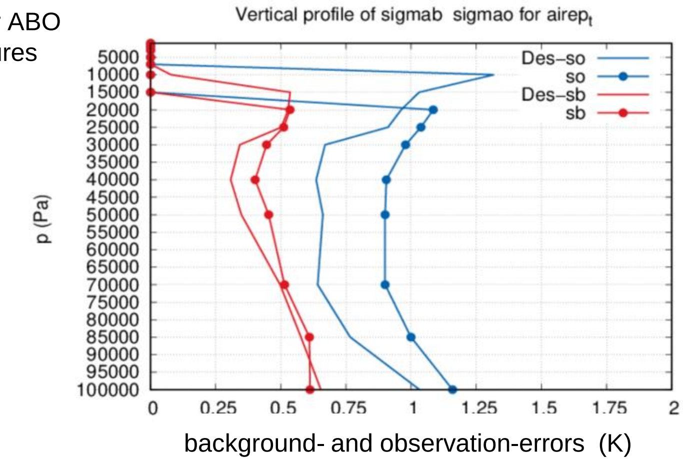
AIM: To compare used background- and observation-errors with theoretical ones calculated by Desroziers method and exploit if revisions of error standard deviation specifications needed.

HOW: Use DA feedback statistics of residuals and innovations from parallel cy46 evaluation experiments. Investigate plots of the current prescribe and the by Desroziers method suggested observation and background error values.

Graphical illustration Desroziers method



Example for ABO temperatures



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- Recommended adjustments

Recommended adjustments

Background check rejection limits

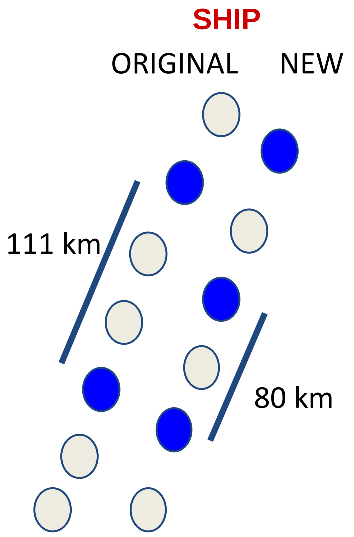
default is $5 \text{ times} \sqrt{\sigma_{b,i}^{2} + \sigma_{o,i}^{2}}$

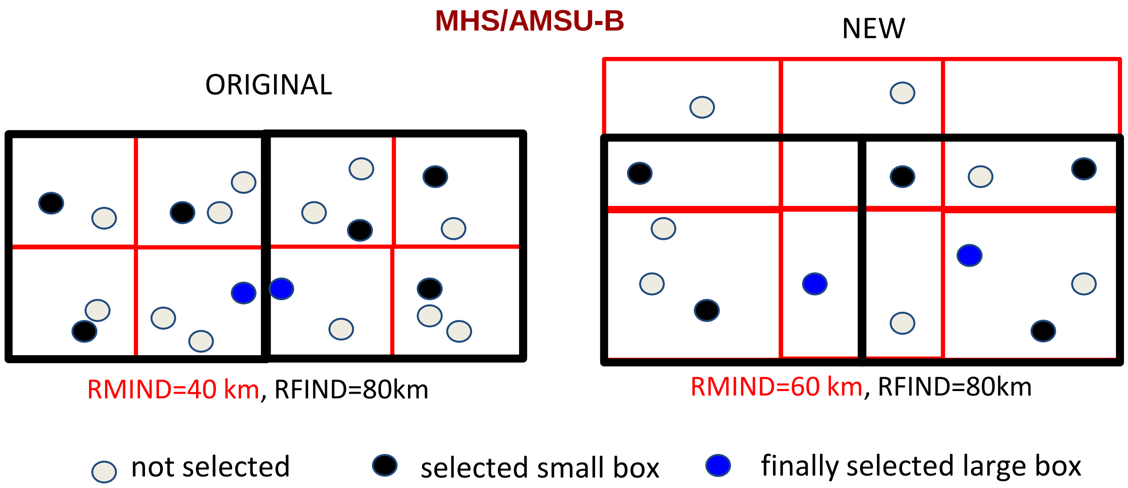
PARAMETER /CONFIGURATION	MetCoOp Before	MetCoOp After	UWC-W Before	UWC-W After	AEMET Before	AEMET After
GNSS ZTD	4	3	4	3	4	3
RADAR RH	4	3	4	3	4	3
MHS	4	3	4	3	4	3
ATMS	4	3	4	3	4	3
MWHS-2	4	3	4	3	4	3

General reduction of L value for these observations

Recommended adjustments

Thinning distances





Note that likelihood two close observations less with 60 km/80 km (overlapping boxes)!

Recommended adjustments

Background and observation error standard deviations in minimization

Decrease sigmao

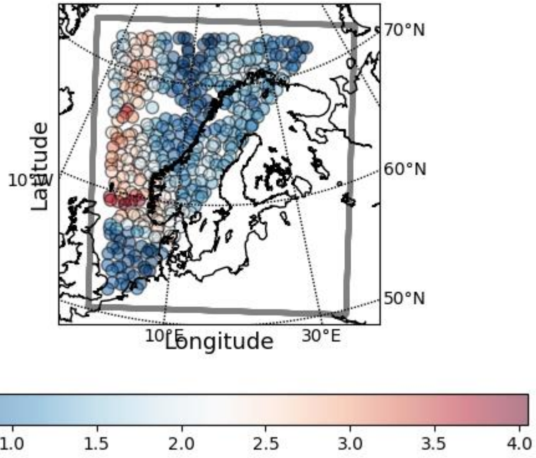
PARAMETER /CONFIGURATION	MetCoOp Before/After		UWC-W Before/After		AEMET Before/After	
REDNMC	0.6	0.63	0.9	0.85	0.9	0.85
SIGMAO_COEF TEMP T	0.90	0.81	0.90	0.81	0.90	0.81
SIGMAO_COEF TEMP u/v	0.90	0.81	0.90	0.81	0.90	0.81
SIGMAO_COEF SYNOP Z	1.0	0.9	1.0	0.9	1.0	0.9
SIGMAO_COEF ASCAT	0.9	0.86	0.9	0.86	0.9	0.86
SIGMAO_COEFF RADAR WIND	1.0	0.95	1.0	-	1.0	-

- Limitations revealed by BGOS and how to alleviate

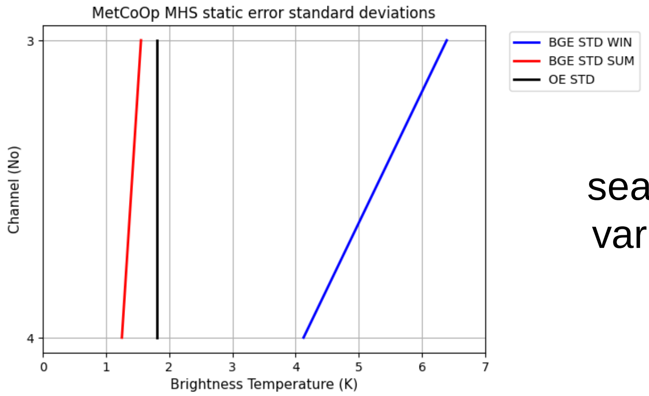
Limitations revealed by BGOS and how to alleviate

Application of BGOS revealed strong spatial and seasonal variation for **humidity sensitive satellite radiances** and **radar relative humiditiy** background errors in observation space (despite background errors in model space constant). See example below for MHS radiances.

spatial variation



MHS channel 3 background error standard deviations in observation space 15 July 2022, 00 UTC. MetCoOp domain.



seasonal variation

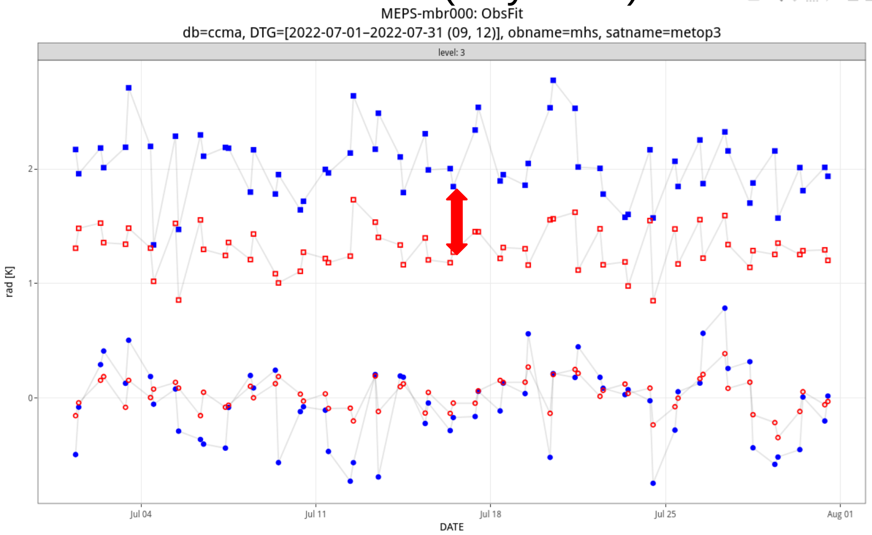
Background errors in MHS channel 3-4 observation space with standard operational MetCoOp B matrix
Black curve observation error, Blue winter background error in MHS ch 3-4 space and Red summer background error in MHS ch 3,4 space.

Limitations revealed by BGOS and how to alleviate

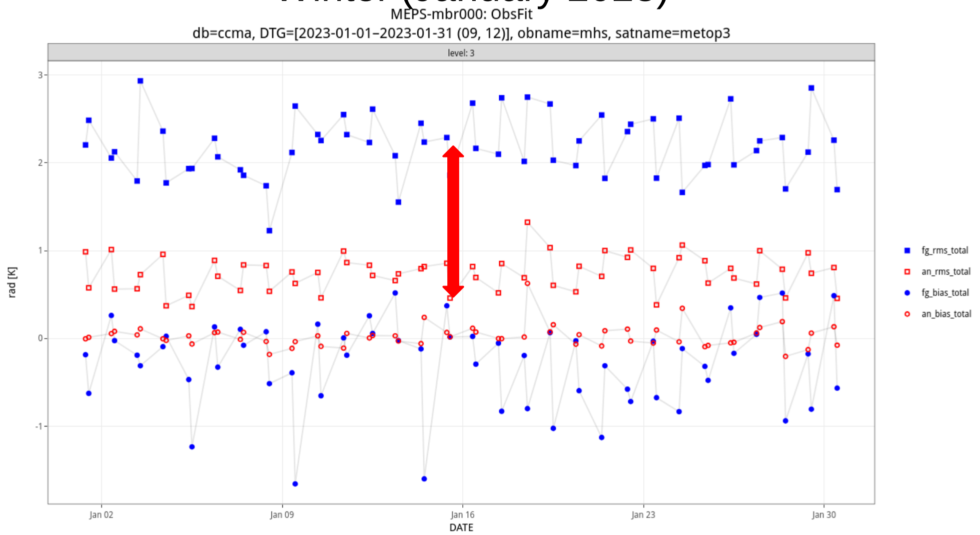
MetCoOp operational observation monitoring

Metop C MHS channel 3 observation fit statistics time-series

Summer (July 2022)



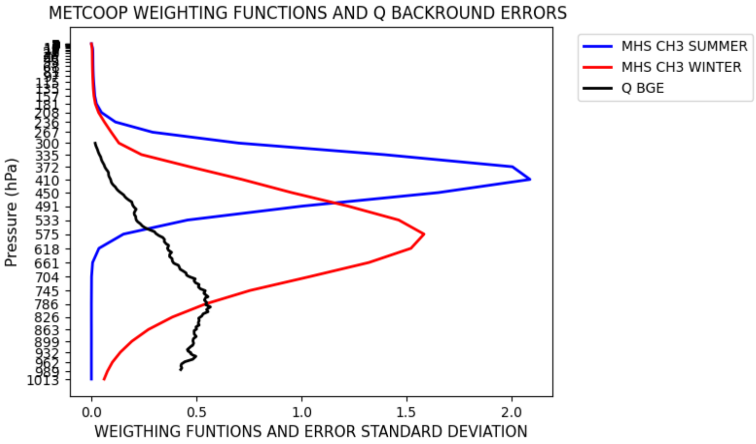
Winter (January 2023)



More weight to MHS observations during winter than during summer!

Limitations revealed by BGOS and how to alleviate

The reason for spatial and seasonal variation for MHS



MHS channel 3 summer condition weighting functions
MHS channel 3 winter condition weighting functions
MetCoOp vertical profile of seasonally and spatially averaged used vertical profile of unbalanced background error specific humidity profile.

In cold and try conditions (winter-time) the radiative transfer weighting function peak lower in the atmosphere and where the seasonally averaged humidity standard deviations are larger. Then, in cold conditions/winter-time we have larger background errors in observation space and therefore larger impact of observations.

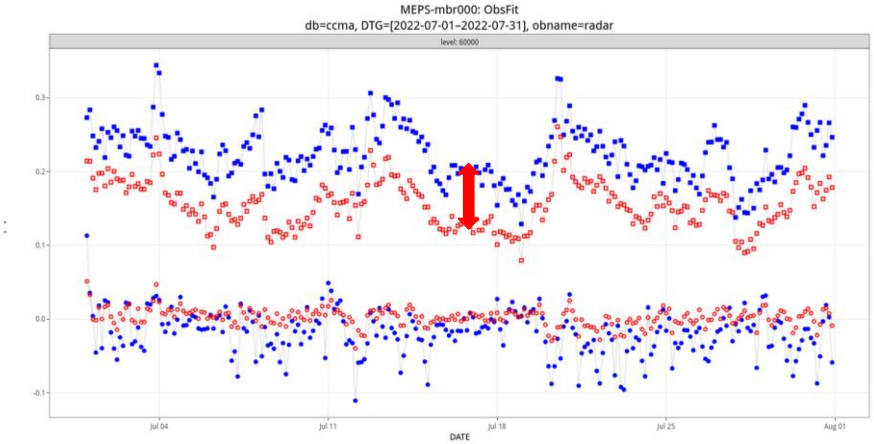
Limitations revealed by BGOS and how to alleviate

And same for Radar RH

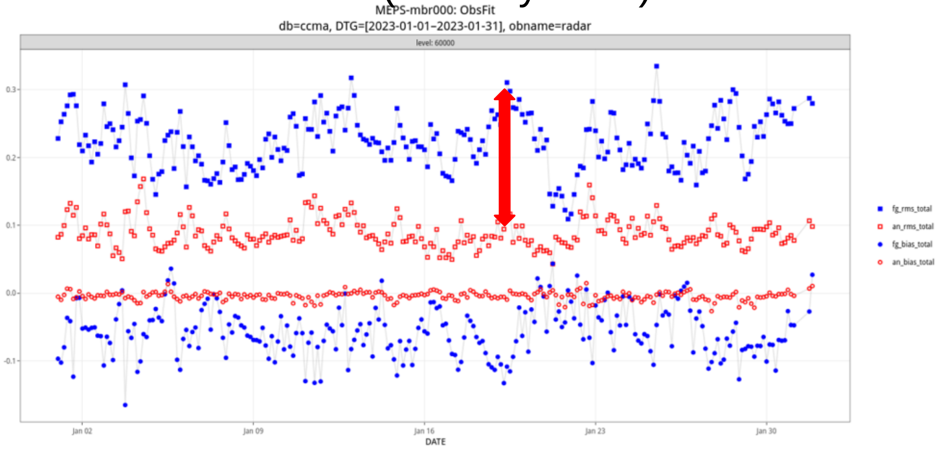
MetCoOp operational observation monitoring

RADAR relative humidity observation fit statistics time-series

Summer (July 2022)



Winter (January 2023)



Now the reason is again that bg error standard deviations are specified in terms of climatological profiles for unbalanced specific humidity. When they are transformed into errors in the space of Relative Humidity, the errors will be larger when the temperature is high in cold areas and during wintertime (them saturation water vapor smaller).

Note larger impact in winter! rms of ob-an is much smaller in winter

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Limitations revealed by BGOS and how to alleviate

How to alleviate this artefact on humidity analysis??

Introducing seasonally dependent B

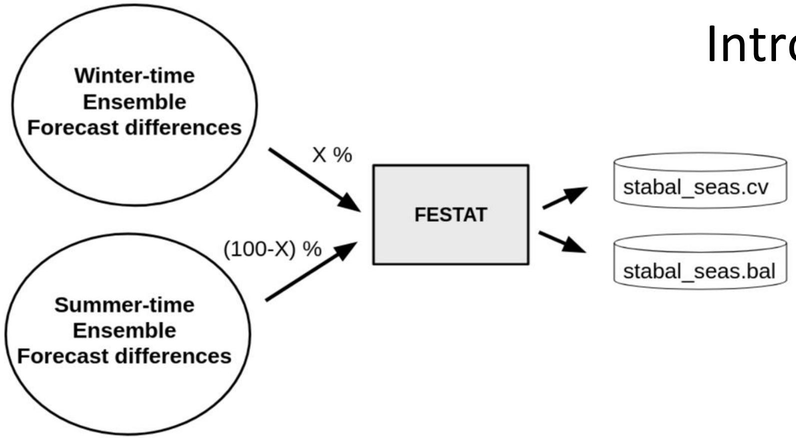
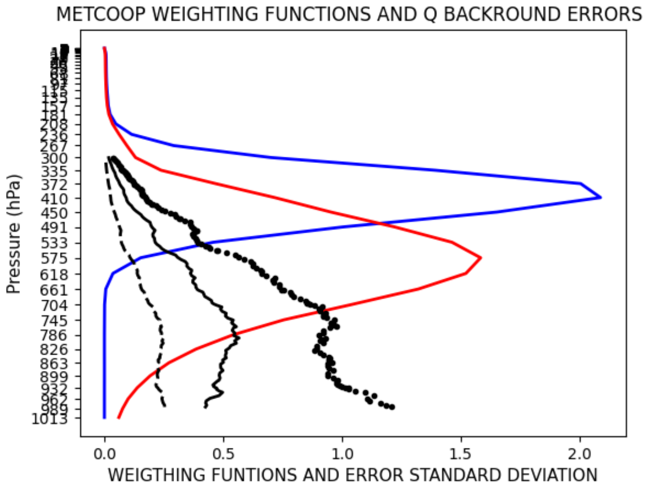


Figure C1. Illustration of proposed mix of seasonal input data for FESTAT. Winter: X=100 and seas=win, Summer X=0 and seas=sum, Autumn, Spring: X=50 and seas=aut, spr.

(Change of humidity control variable and ensemble based background errors also solve)

Limitations revealed by BGOS and how to alleviate

First illustration effect of introducing seasonally dependent B



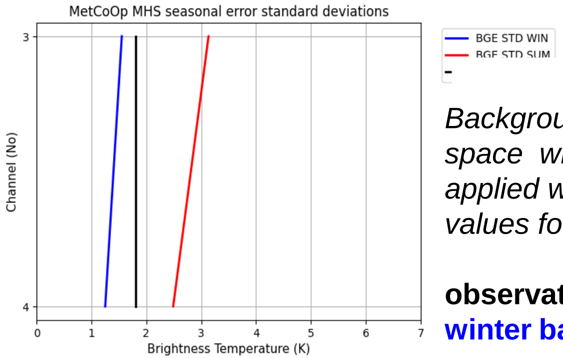
MHS channel 3 summer condition weighting functions

MHS channel 3 winter condition weighting functions

All season humidity background error

Winter humidity background error

Summer humidity background error



Background errors in MHS channel 3-4 observation space when a seasonally dependent B matrix was applied with summer errors for summer case and winter values for winter case.

observation error

winter background error in MHS ch 3-4 space

summer background error in MHS ch 3-4 space.

Summary and conclusions

- HARMONIE-AROME Cycle 46 has been subject to an extensive evaluation of tunable settings for the three operational domains.
- After a detailed analysis, we conclude that everything looked good but just some minor revisions were proposed.
- The application of BGOS revealed a weaknesses due to our current handling of humidity in data assimilation.
- This work resulted in preparation of tuning tools to be available on ACCORD DA tools.

Thank you for your atention!

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