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Tuning of error statistics and quality control in Data Assimilation

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25th EWGLAM 30th SRNWP meeting, 25-28 September 2023, Reykjavik, Iceland

Outline

- **Introduction**
- **HARMONIE-AROME CY46 preparations**
- **Data assimilation tools**
- **Results**
- **Summary and future plans**

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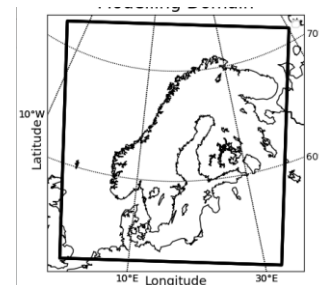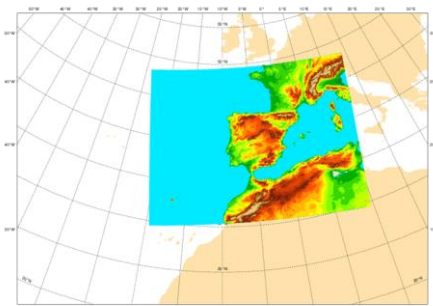
Introduction

- ACCORD research and development consortium consisting of 26 countries for convection-scale limited-area modelling.

- Sub-consortia of ALADIN, LACE and HIRLAM.

- HIRLAM flavour of common modelling framework is referred to as HARMONIE-AROME. It consists of quality assured modelling framework containing source-code and scripts prepared for operational use.

- Operational centers exists (AEMET, MetCoOp, UWC-W, ..)

- At present quality assurance evaluation runs for HARMONIE-AROME cy46 is on-going through a comparison with currently operational cy43.

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HARMONIE-AROME CY46 preparations

- Extended coordinated experiments are ongoing to quality assure HARMONIE-AROME cy46 through comparison with cy43.
- One-month parallel runs (with 2 weeks warm -up period) over the domains of the operational centres AEMET, MetCoOp and UWC-W for different seasons.
- Data assimilation (DA) feedback statistics from these runs are used to overhaul the several parameter settings of importance for the DA performance, such as error specifications, thinning distances and quality control rejection limits.
- Tuning-tools to be used in the processes have been prepared for commonly available ACCORD DA toolbox.

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ACCORD Data Assimilation tools

There is an **ACCORD ASSIMILATION TOOLS** repository at
https://github.com/Hirlam/AccordDaTools

- jbdiagnose: diagnose background error auto-correlations
- plotjbbal: diagnose background error cross-correlations
- plotvarbcpred: check the variational bias correction predictors
- dfscomp: impact on analysis of various observation types
- diacov: visualisation of background errors (partly 2D)
- clouddetect: investigate functionality of satellite infrared cloud detection

Next step:
- festat: derive background error statistics
- obstat: intercomparison of short-range forecast quality
- monitoring: tools for checking drops in obs availability/quality
- tuning: like Desroziers, Andersson&Jarvinen, Obstool etc.

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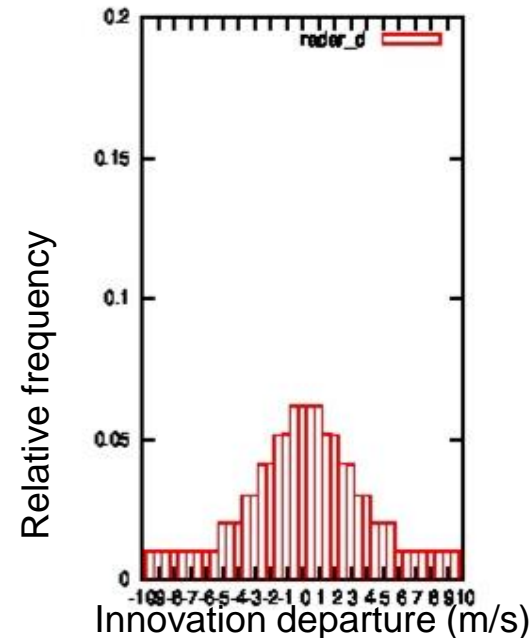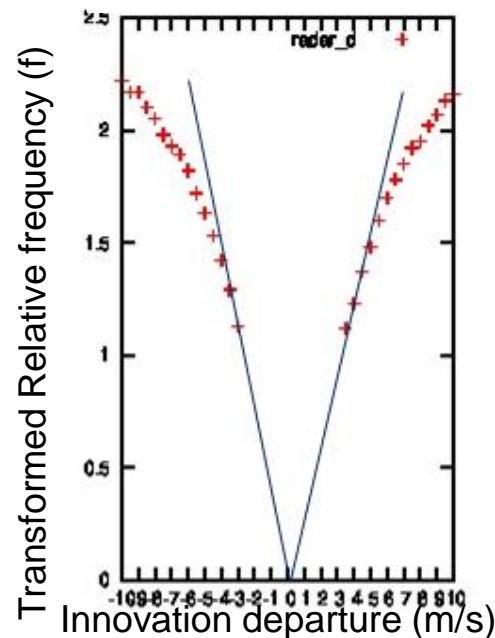
where $\lambda = 1 + \sigma_{o,i}^2/\sigma_{b,i}^2$, FgLim is the rejection limit and $[H(\boldsymbol{x}_b)]_i$ denotes the projection of the model state on y_i observation, where the potential observation bias has been accounted for. $\sigma_{o,i}$ and $\sigma_{b,i}$ are the standard deviation of the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

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

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

Example for radial winds:

Transformation formula:

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

Transformed Relative frequency (f) vs Innovation departure (m/s)

Relative frequency vs Innovation departure (m/s)

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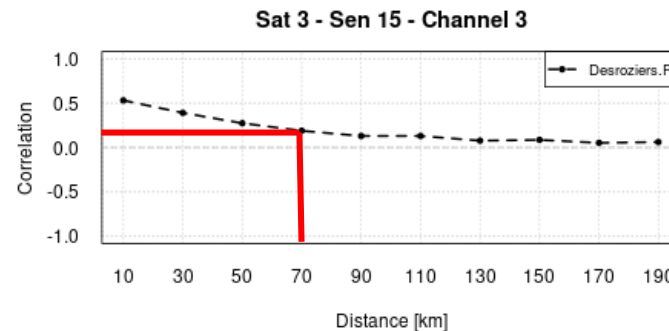
Number of data in each bin as function of distance between data pairs.

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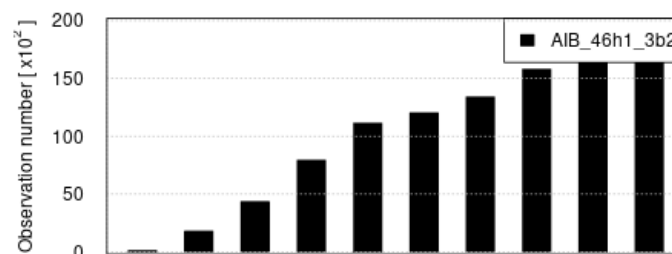
3- Desroziers

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

$$\vec{d}^o_{bi} = \vec{d}^o_{ai} + \vec{d}^a_{bi}$$
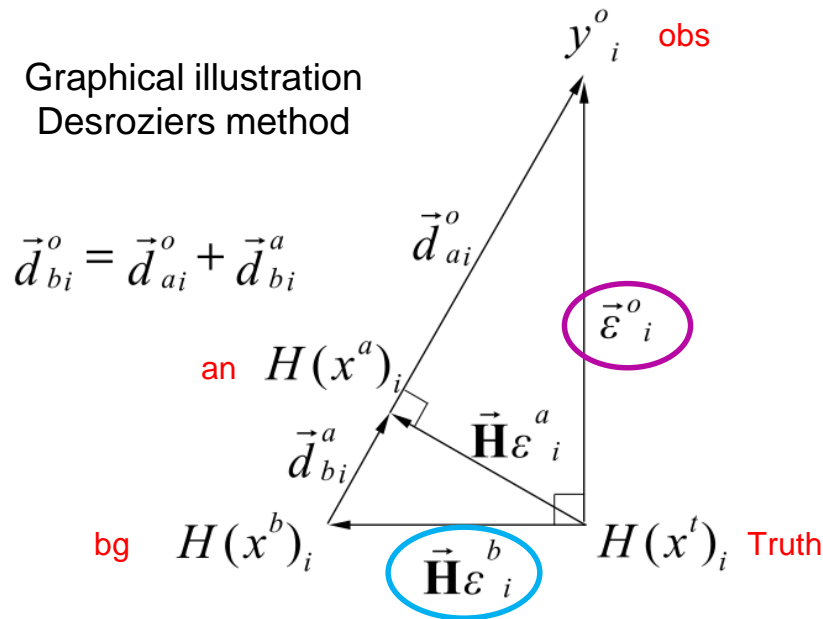
Example for ABO temperatures
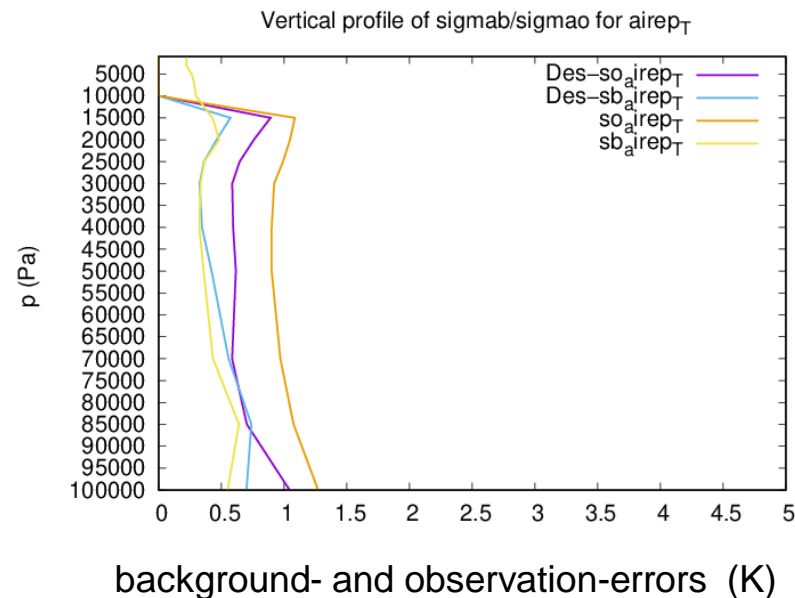
Vertical profile of sigmab/sigmao for airep$_T$

background- and observation-errors (K)

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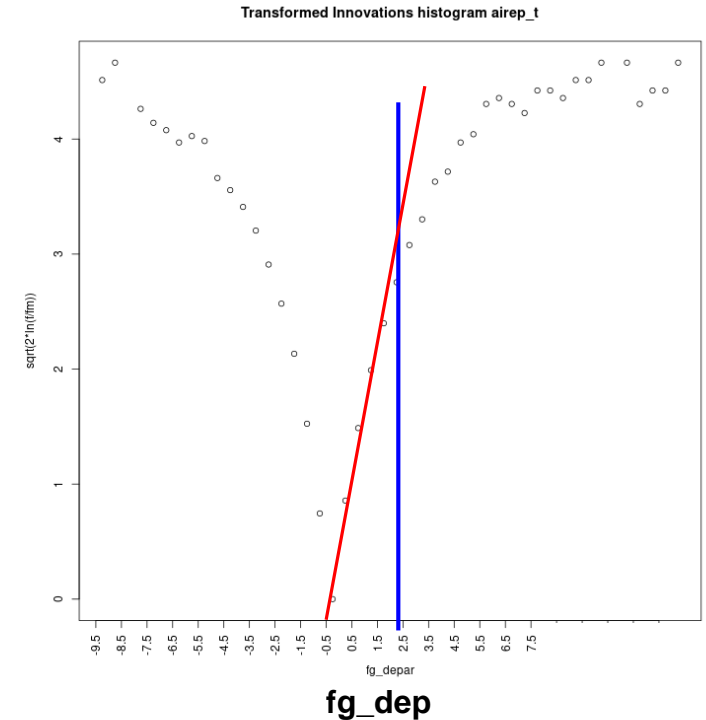- **Data assimilation tools**
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Currently used rejection limit
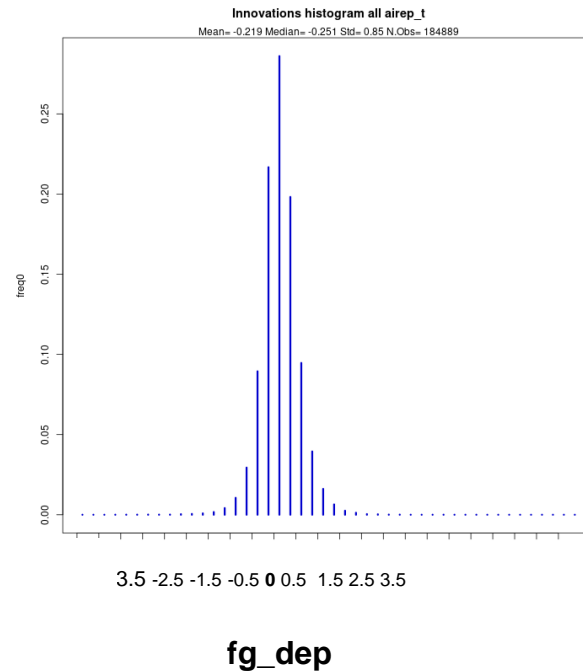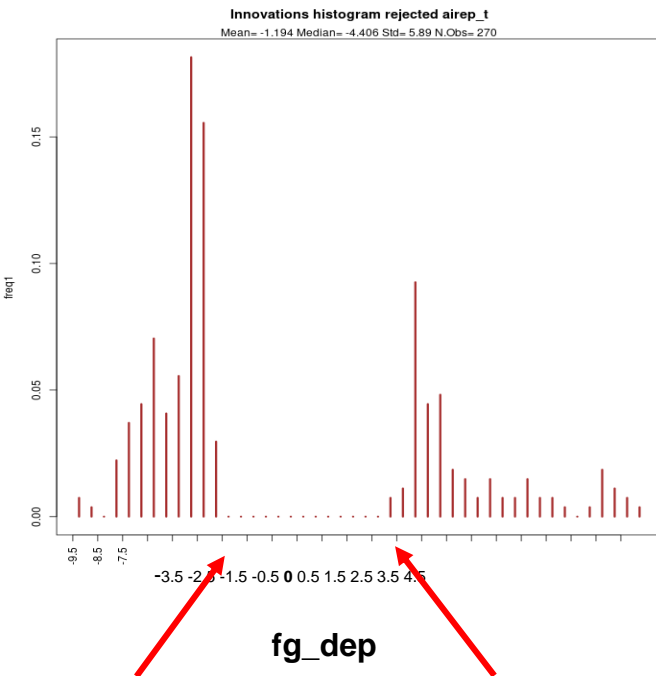
Desired rejection limit

The **currently used rejection limit** results in limit of first guess departure rejection around 2.5-3 K.

Estimated Limit of fg_dep: around 3.0 K, this means that **FgLim should be around 4,5 K**

Here the currently used rejections agrees approximately with diagnostically derived ones (4.0K).

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

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Obstype Rej. Lim.	Estimated AIB	Estimated MCP	Estimated UCW	Used sqrtRBGQC(2)
mhs	5	5	8	4

Similar fg_dep value at transform histogram . And estimated FgL is higher than used, then for MHS we could according to diagnosis be less restrictive and change RBGQC(2) =5 or 6

MCP
fgdep=8->FgL=5
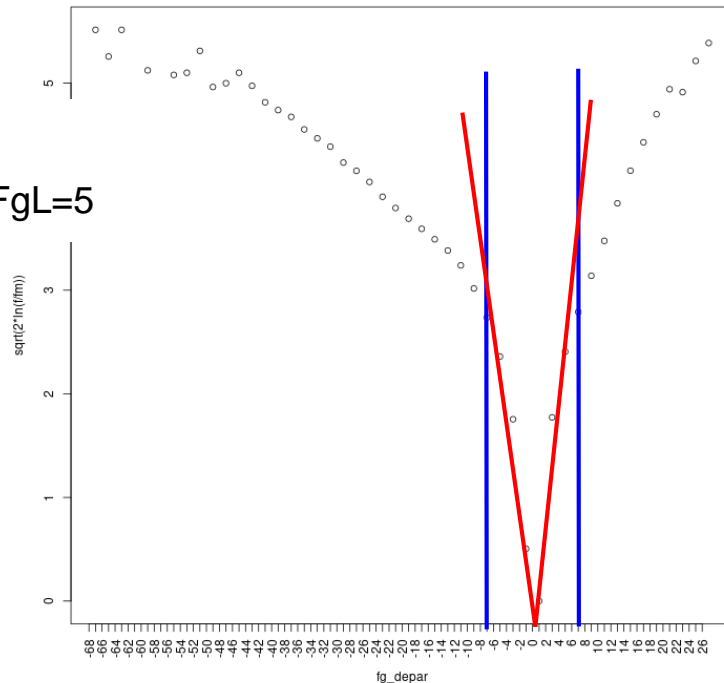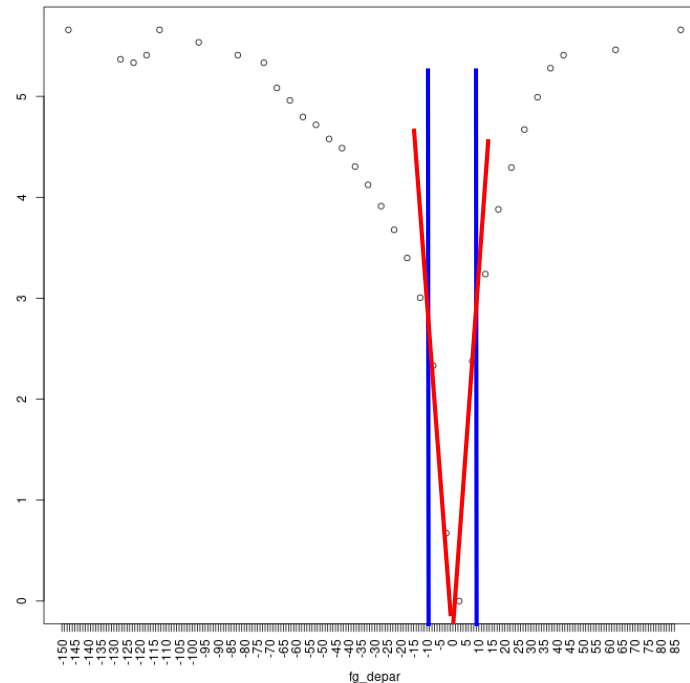
UCW
fgdep=10->FgL=8

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

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DOMAINS COMPARISON

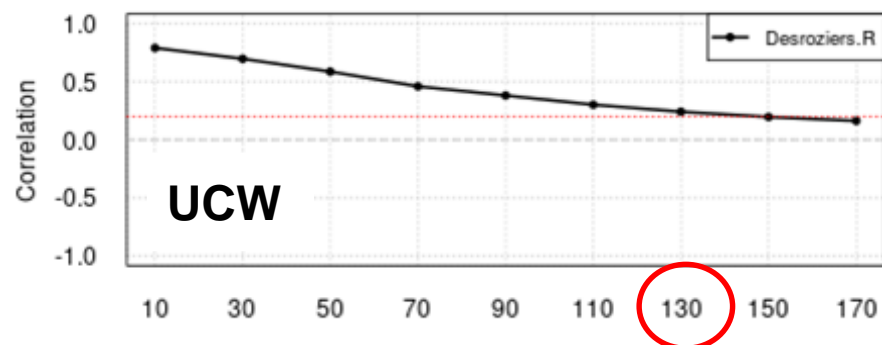## Thinning Distances   mhs

Example ongoing work

Sat 223 - Sen 15 - Channel 4 — AIB

Sat 223 - Sen 15 - Channel 4 — MCP
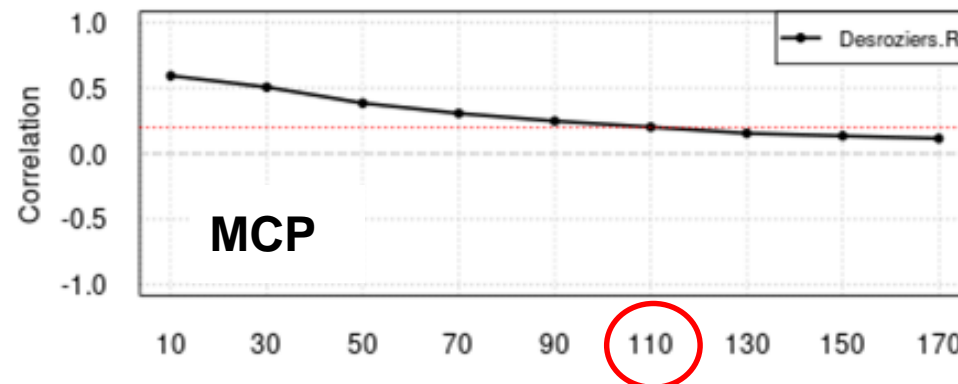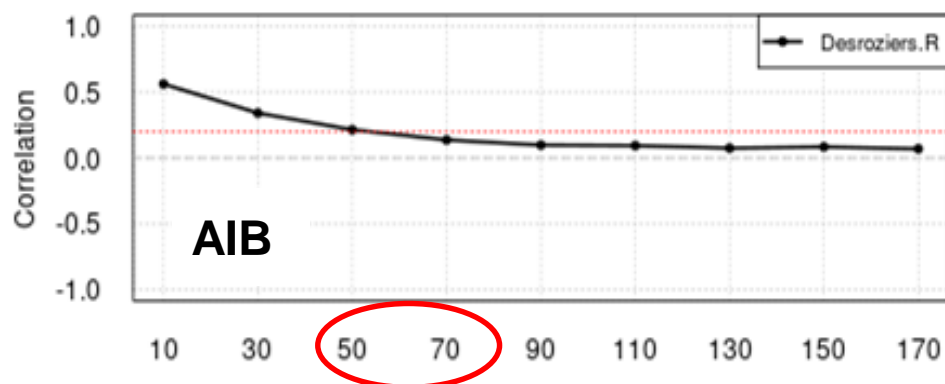
Sat 223 - Sen 15 - Channel 4 — UCW

AIB: round 60 km is the correct distance to be used.
MCP: round 110 km is the correct distance to be used.
UCW: round 130 km is the correct distance to be used.

The thinning distance that is being used is 80 km.

Also need to:
- look at data coverage maps and as well compare with some additional runs without thinning applied to data when deriving the diagnostics. Now few data at short distances due to current thinning.
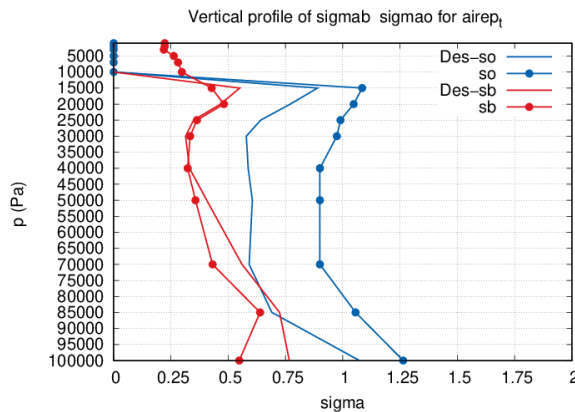- compare with other satellites and try to understand differences.

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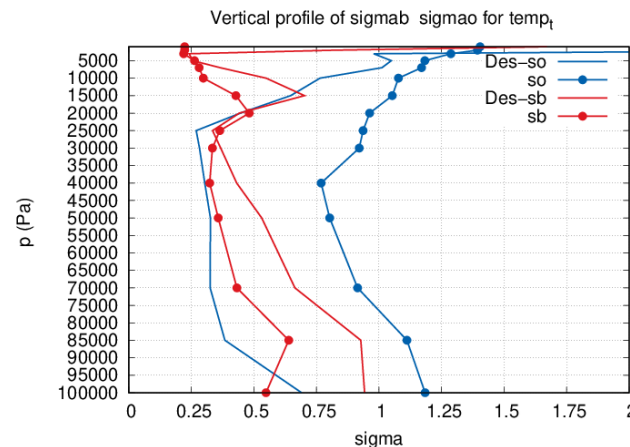A Consortium for COnvection-scale modelling
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Blue-observation, red-background. Dots currently used and full Desroziers diagnosed.

Airep

Vertical profile of sigmab sigmao for airep$_t$

Vertical profile of sigmab/sigmao ratio for airep$_t$

Temp

Vertical profile of sigmab sigmao for temp$_t$
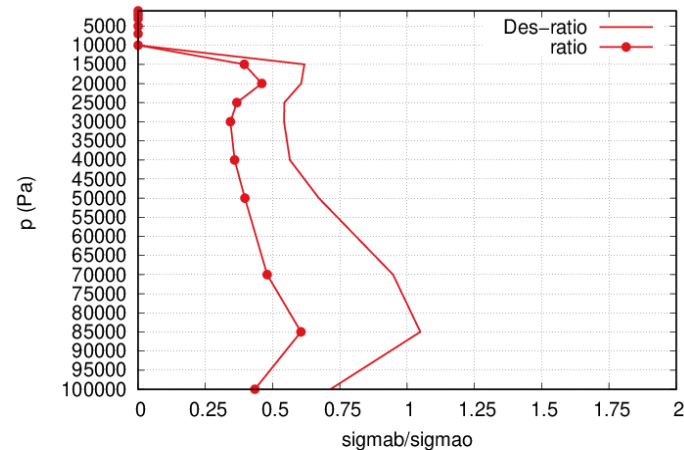
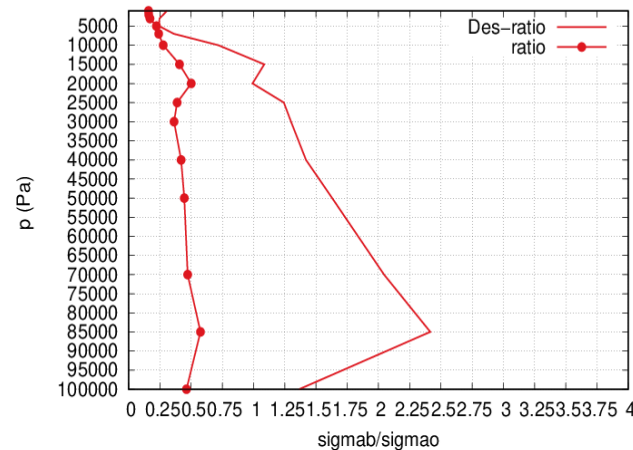Vertical profile of sigmab/sigmao ratio for temp$_t$

SIGMAO AND SIGMAB VALUES

Slight **increase** in **sb** desirable according to Desroziers (both for AIREP and TEMP, consistent)

More substantial **decrease** in **so** for both AIREP and TEMP (a bit more for TEMP).

Used RATIO sb/so is lower than Des one for AIREP and TEMP. Ratio suggested by Desroziers is 0.75-1.5.

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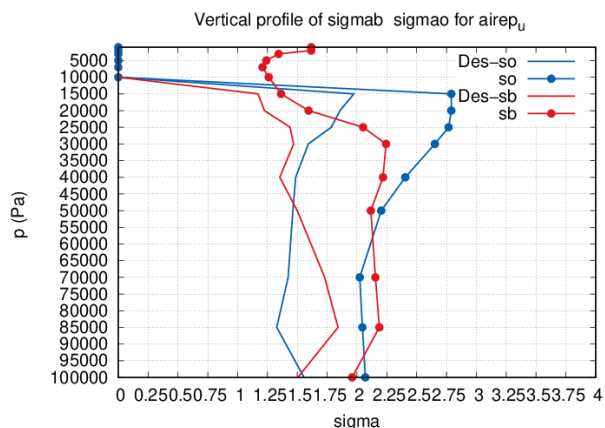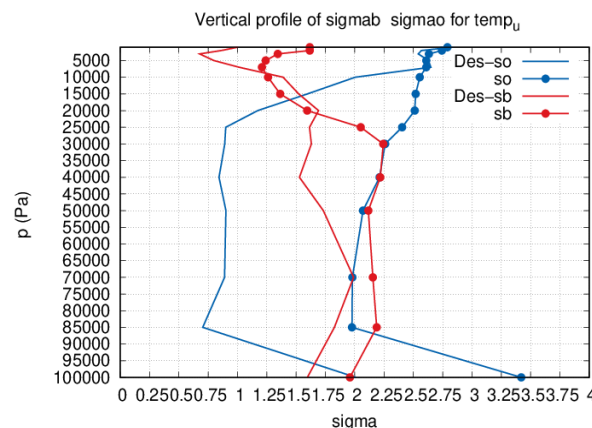A Consortium for COnvection-scale modelling Research and Development

Blue-observation, red-background. Dots currently used and full Desroziers diagnosed.
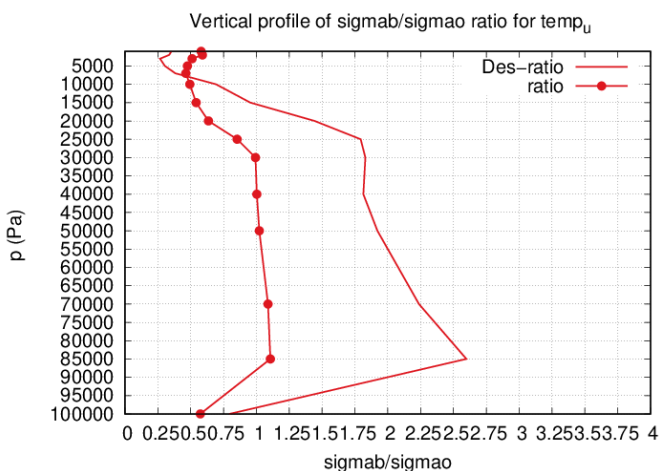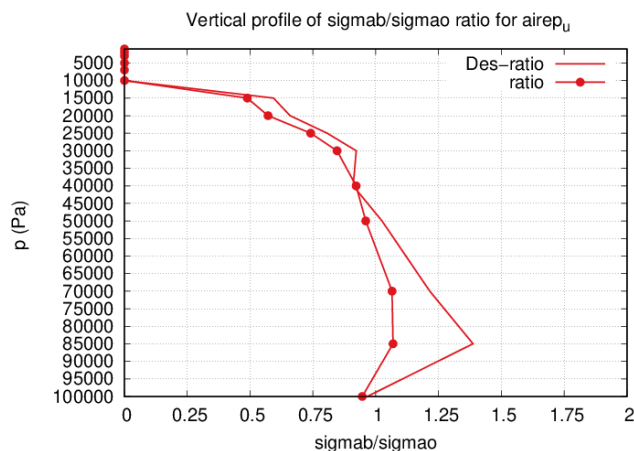
Airep

Temp

SIGMAO AND SIGMAB VALUES

A **decrease** in **sb** desirable according to Desroziers (both for AIREP and TEMP, consistent)

Note **Des sb** around 1.5 m/s suggested both according to AIREP and TEMP.

A **decrease** of **so** desired according to statistics, consistent with temperature for AIREP TEMP

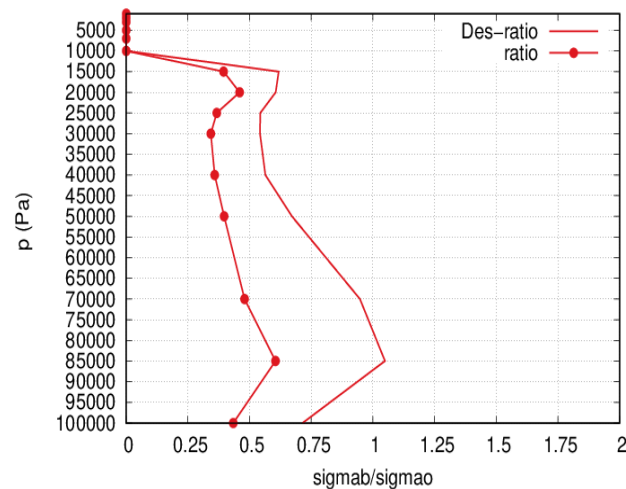**Used RATIO sb/so** for AIREP is in accordance with Desroziers.

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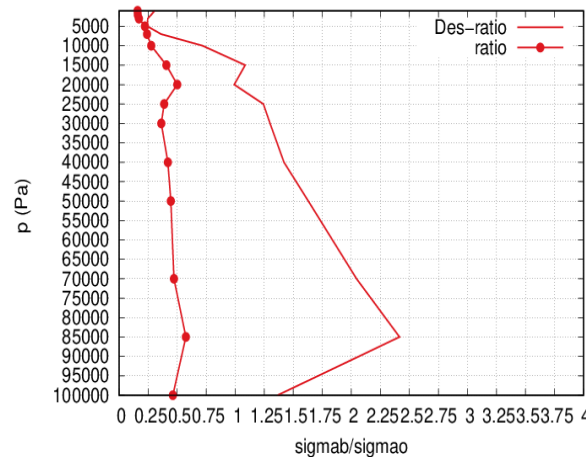
Airep

Temp

T

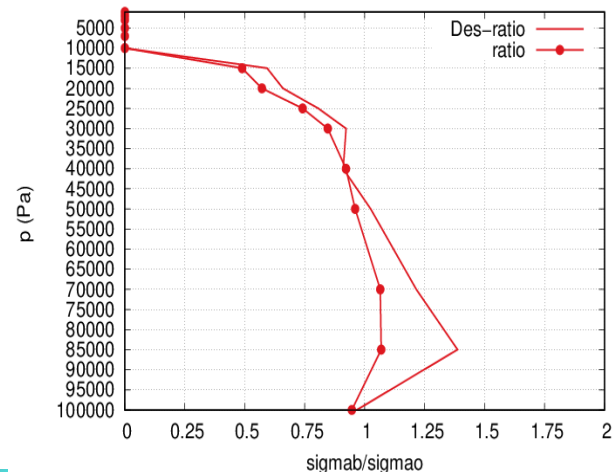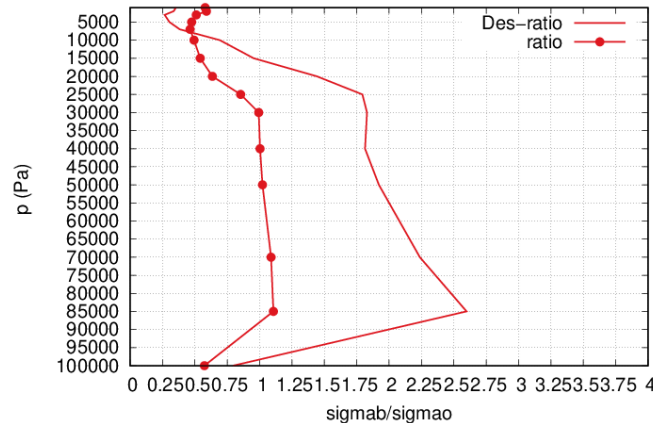Vertical profile of sigmab/sigmao ratio for airep$_t$

Vertical profile of sigmab/sigmao ratio for temp$_t$

u

Vertical profile of sigmab/sigmao ratio for airep$_u$

Vertical profile of sigmab/sigmao ratio for temp$_u$

RATIO VALUES

Statistics **suggest increase in sigmab/sigmao** as compared to currently used.
(REDNMC=0.9)

It seems from previous slide that this should mainly be handled by revisions of sigmao.

Consistent signal in temperatures and winds. Make potential adjustment of background easier.

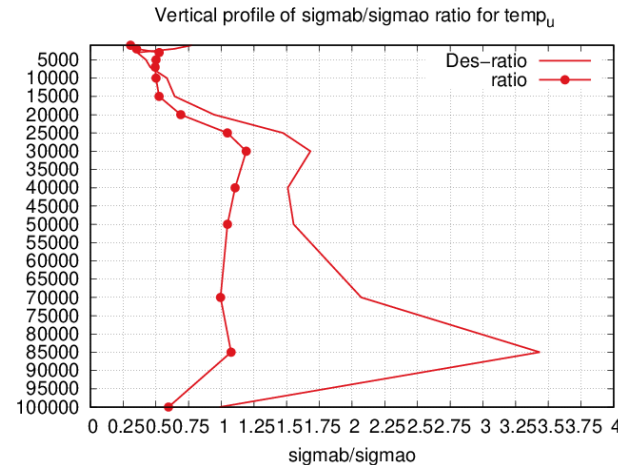This study has to be done with other domains and all the periods.

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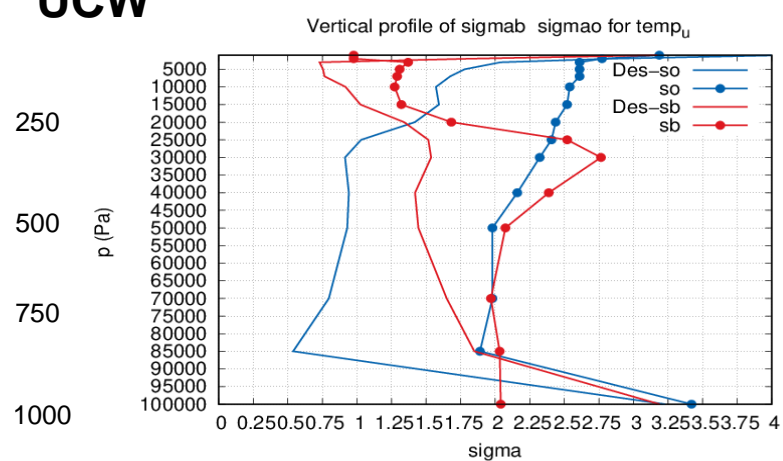A Consortium for COnvection-scale modelling
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3 Results Desroziers

u TEMP

Blue-observation, red-background. Dots currently used and full Desroziers diagnosed.

UCW
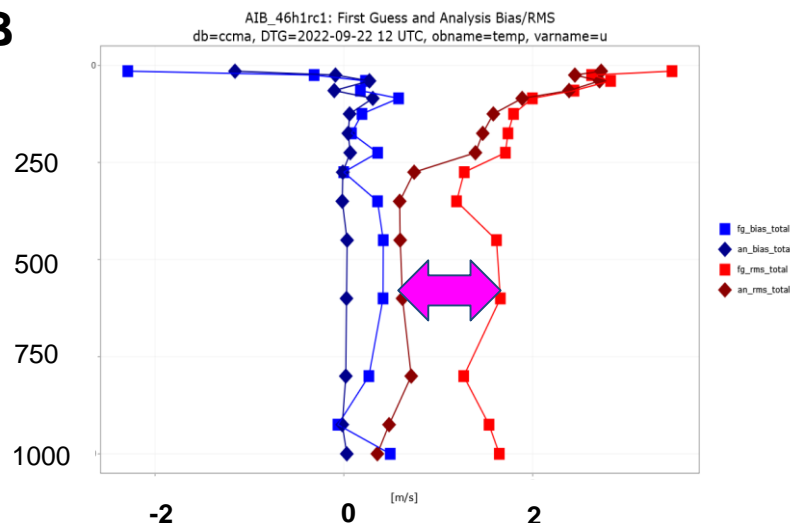

AIB

Consistent currently used values between domains.
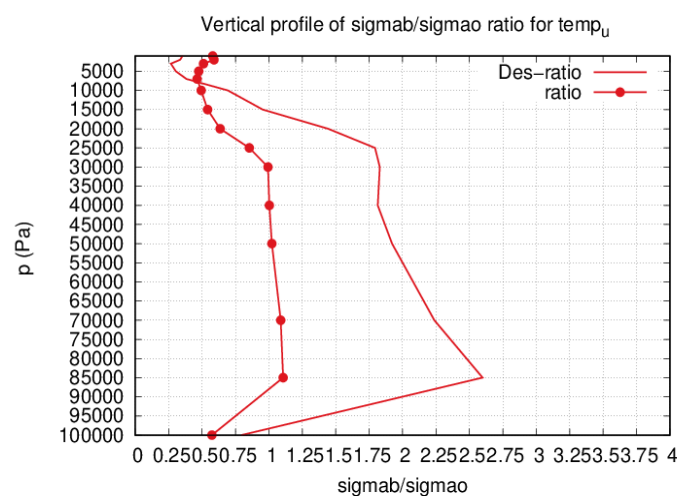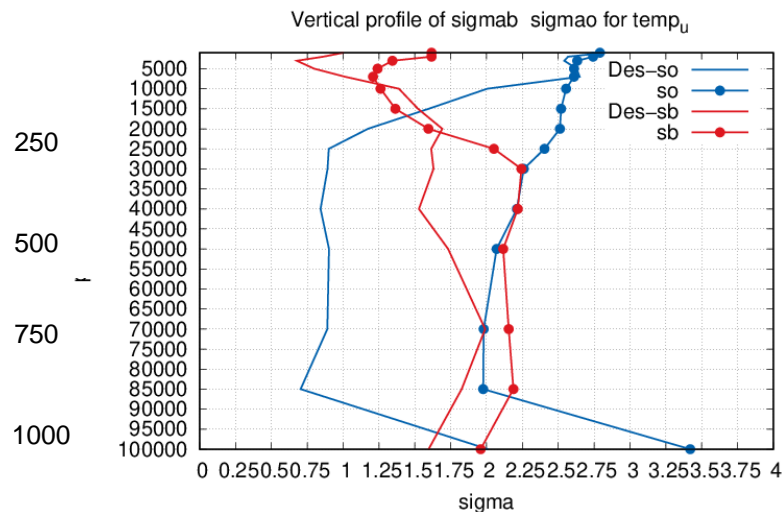
Also diagnosed ones (reduce sigmao).

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3 Results

DOMAINS COMPARISON
u TEMP

AIB

AIB_46h1rc1: First Guess and Analysis Bias/RMS
db=ccma, DTG=2022-09-22 12 UTC, obname=temp, varname=u

MCP

val46h1rc1_spring: First Guess and Analysis Departure
db=ccma, DTG=2023-05-05 12 UTC, obname=temp, varname=u

UCW

CY46 Feb 2022: First Guess and Analysis Bias/RMS
db=ccma, DTG=2022-02-22 12 UTC, obname=temp, varname=u
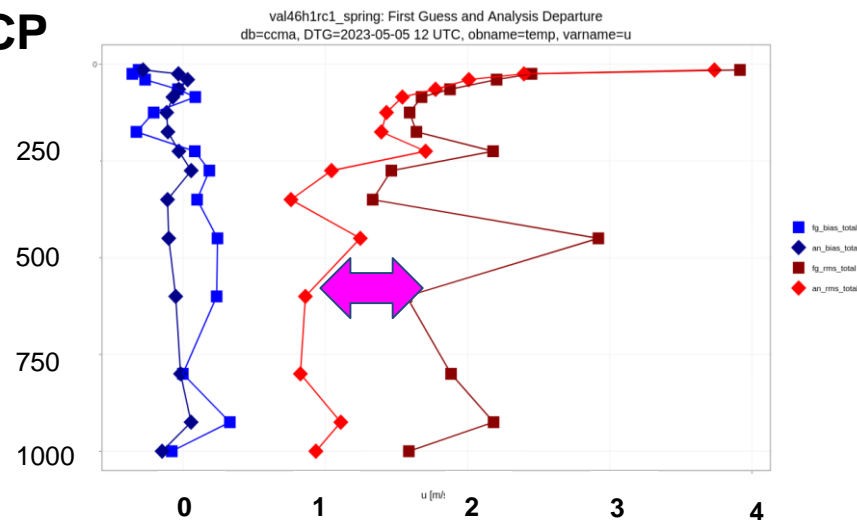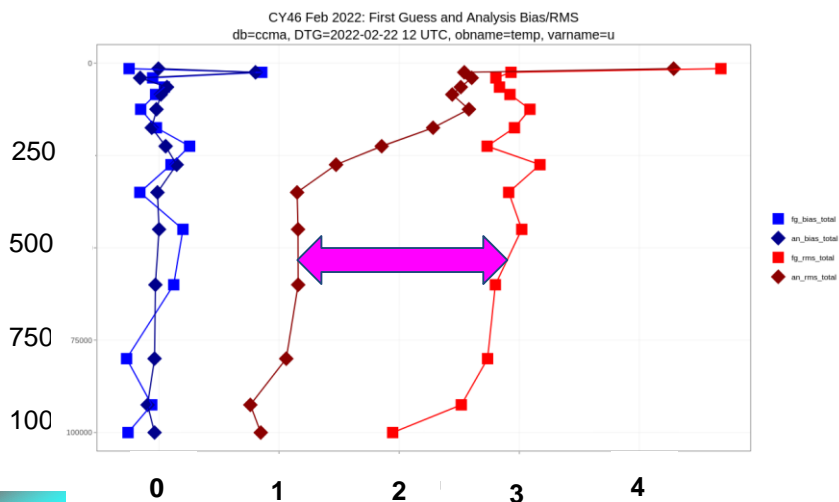
Example from one cycle of **TEMP u** observation fit statistics.
Confirmation that **AIB** and **UCW** similar statistics in previous slide results in **similar fit to observation values**: Difference rms(ob-bg) and rms(an-ob).
Note different scales on x-axis

MCP to be looked more into in detail in next step.

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Summary and future plans

- **Extended HARMONIE-AROME Cy46 parallel experiments over three different domains for different seasons are being used for tuning of DA functionality. Here we used samples from three weeks for each domain.**

- **The Tuning-tools used are being aimed for ACCORD DA tools repository, as well as other quite useful ones that are available (satellite inter-channel correlation tool).**

- **Some care needs to be taken and some improvements are still needed:**
  - **Each tuning method is associated with assumptions and weaknesses.**
  - **A longer term goal is to make the tuning and parameter estimation more automatic and minimize manual intervention.**

- **So far, preliminary results from the tuning exercise indicate a reasonably well tuned DA system.**

- **We have however identified some potential revisions of DA parameters to be made in HARMONIE-AROME and differences between domains to be further investigated.**

- **A summary report of our findings about the three domains, will be provided.**

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THANK YOU!!

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