Regional Cooperation for
Limited Area Modeling in Central Europe

LACE
nwp central europe

Assimilation of GNSS ZTD in AROME 3DVAR

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Outline

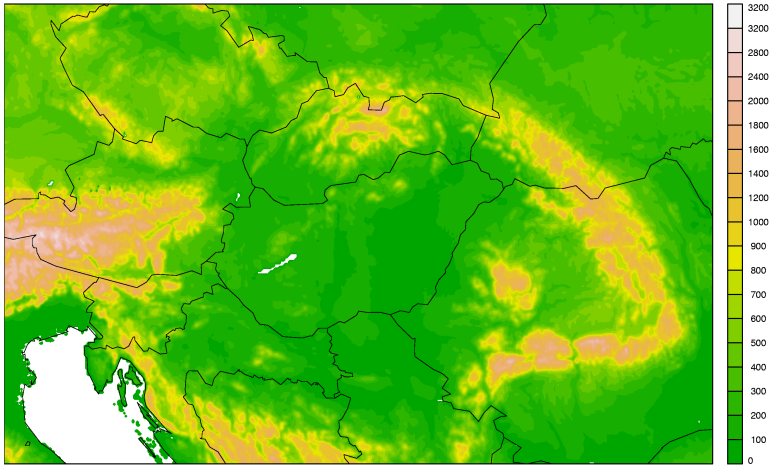
- Description of AROME DA system at OMSZ
- GNSS ZTD observations and pre-processing
- bias correction developments
- Problems and plans

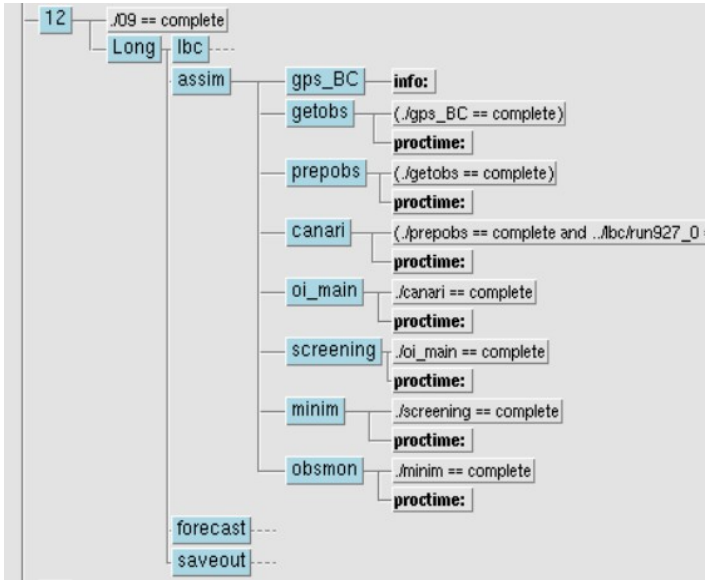
Operational AROME NWP and DA systems

- AROME
  - 2.5km horizontal, 60L vertical
  - cy38t1_bf03
  - 8 runs/day up to 48 hours
  - 1 hourly coupling IFS global

- Operational DA system
  - 3 hourly RUC
  - Operational OI_main, 3DVAR
  - AROME EDA B matrix
  - Observations:
    SYNOP (Z,T2,U10,H2)
    AMDAR (T,U,Q)
    Mode-S MRAR (Slovenia, T,U)
    TEMP (Z,T,U,Q)

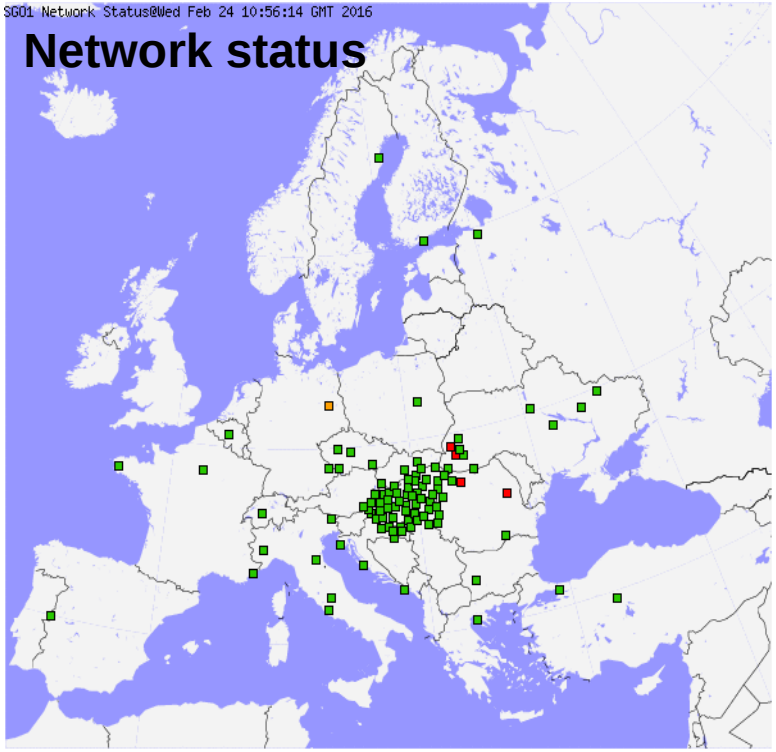
- **Experimentally added GNSS ZTD on the top of operational DA system**



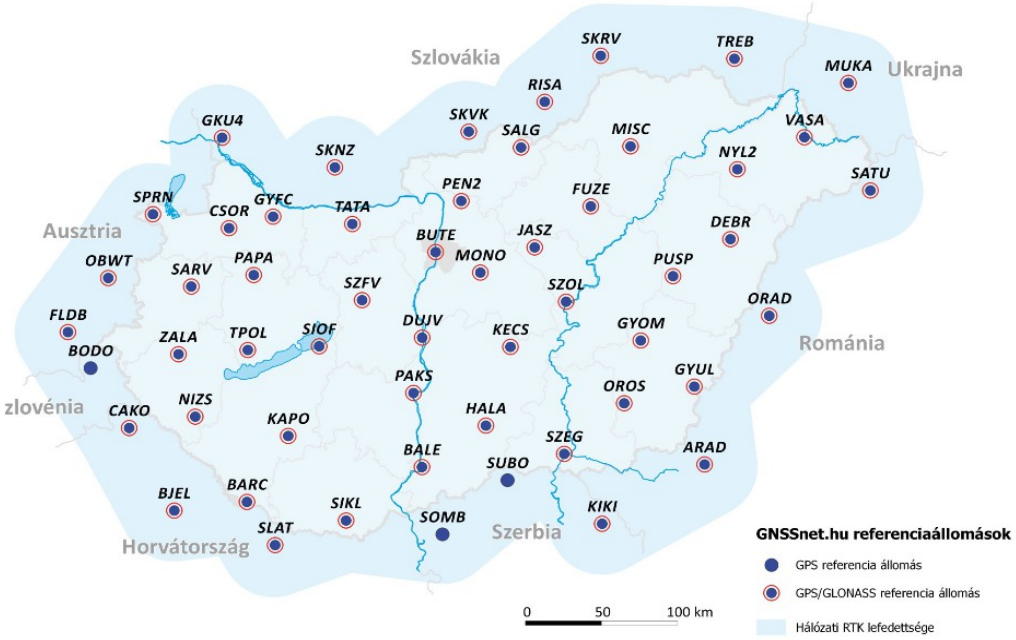


GNSS ZTD observations

- In previous experiments Hungarian GNSS ground-based receiver network so called SGO1 was used.



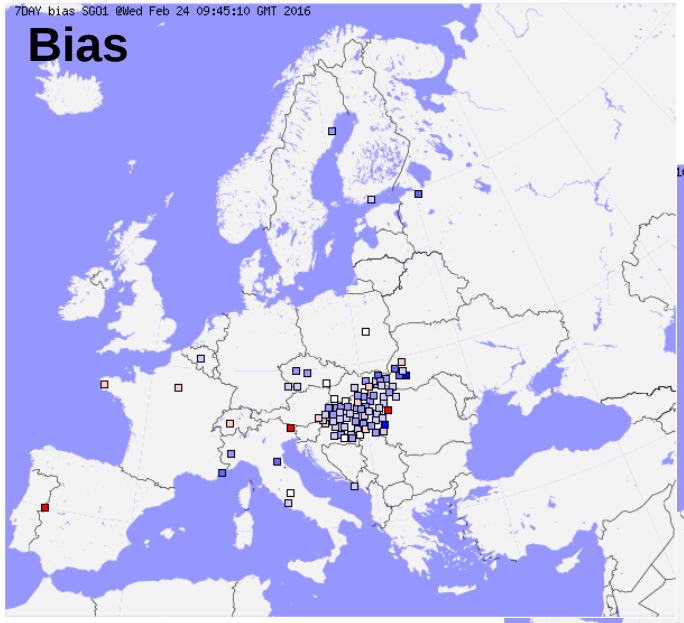
SGO1 E-GVAP network from E-GVAP portal



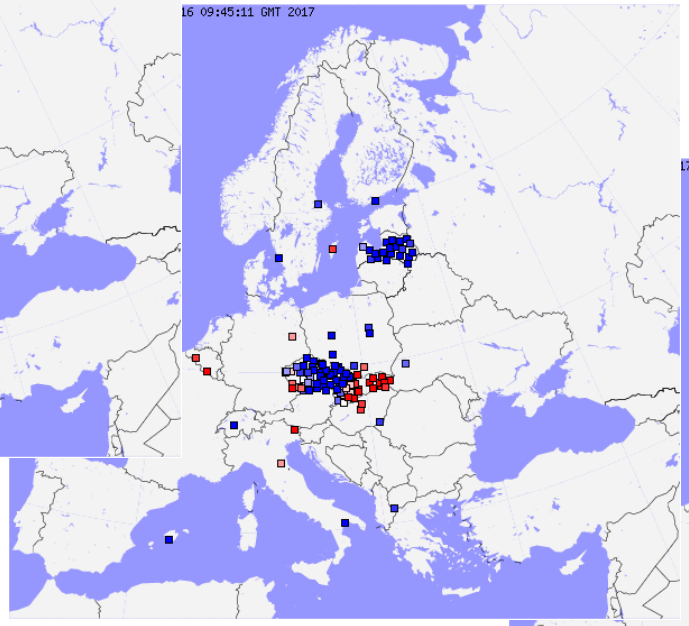
Reference stations in SGO1 network, 35+19 stations

GNSS ZTD observations

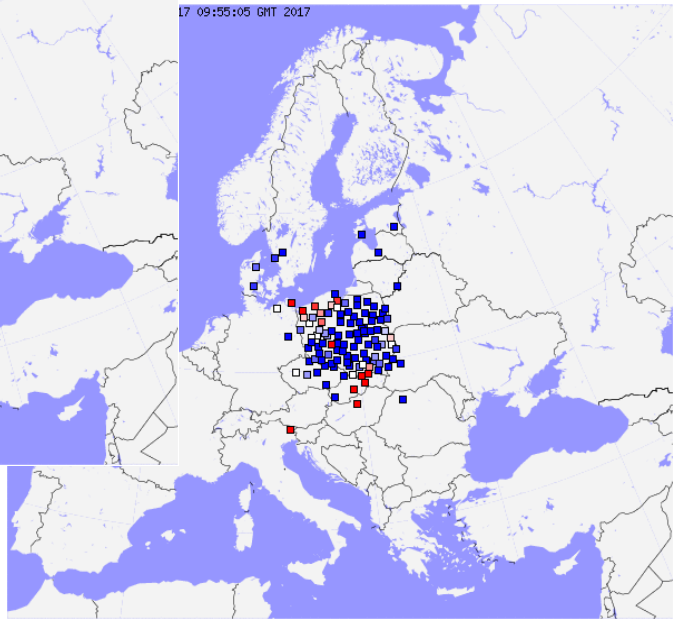
- Extend the use of ZTD observations with **SGO1**, **GOP1** and **WUEL** E-GVAP networks.



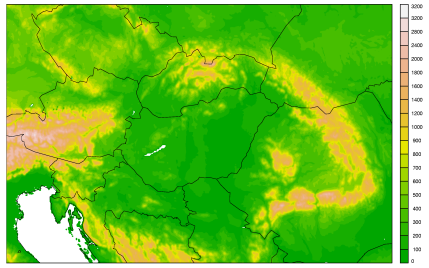
SGO1 – E-GVAP bias



GOP1 – E-GVAP bias



WUEL – E-GVAP bias



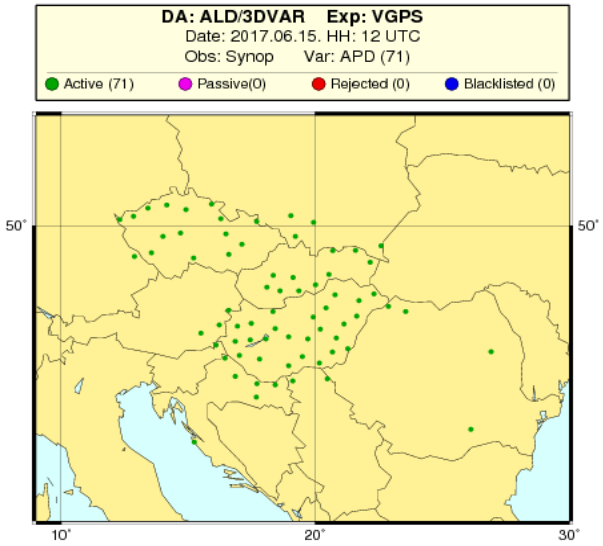
GNSS ZTD observations

- Access to E-GVAP ftp server of Metoffice (from H. Vedel E-GVAP PM)
- Training period and pre-selection procedure
  - File format conversion: the name of the GNSS stations should reflect the name of the E-GVAP networks

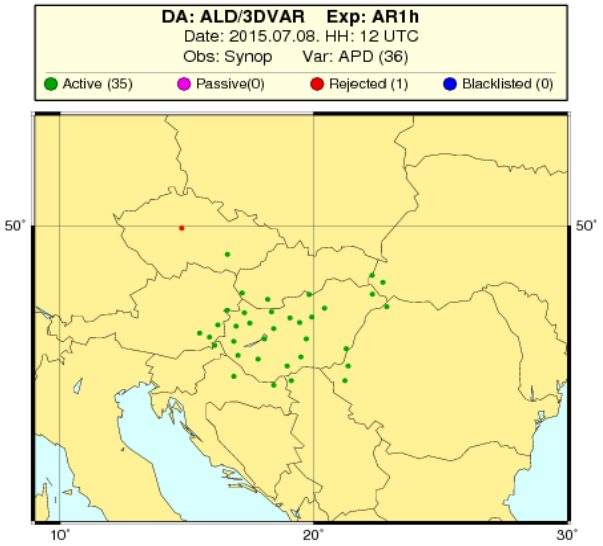
    e.g. DEBR → DEBRSGO1
- Selection tests, main requirements:
  - Biasmax: 15mm
  - Stdvmax: 15mm
  - Thinning: 40km
  - Sigmao: stdev_10days
- Examined 3 E-GVAP networks include several duplicated, triplicated stations. During the pre-selection procedure the best is put to the whitelist

GNSS ZTD observations

- These two additional E-GVAP networks brought roughly 30% more ZTD observations in our DA system (domain).
- Active GNSS stations of experiments using 3 networks and only 1 (SGO1) network from obsmonitor: (Not a fair comparison, just for illustration)



Observation monitoring (3 networks)



Observation monitoring (only SGO1)

Bias correction for GNSS

- Static bias correction is performing well in the experiments, but an operational use would be uneasy (regular updates of whitelist, sigmao-s and bias information).
  - 15 days long training period to select trusted stations and to calculate bias
- Variational bias correction is more promising, but it requires certain developments
  - Whitelist is still needed

    Zero static bias removal, update of metadata and sigmao-s
  - The suitable predictors for GNSS VARBC(?)

    0: constant

    1: thickness 1000hPa – 300hPa

    3: skin temperature

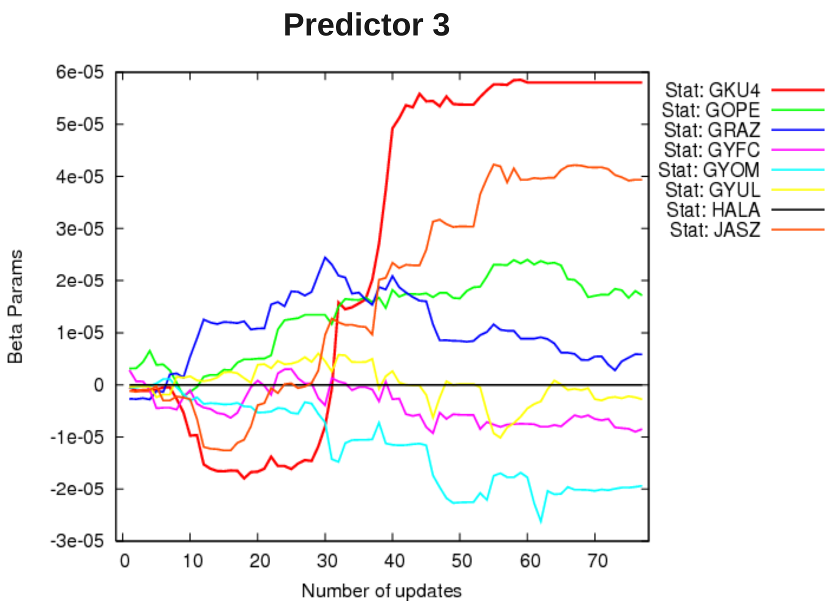
    4: TCWV

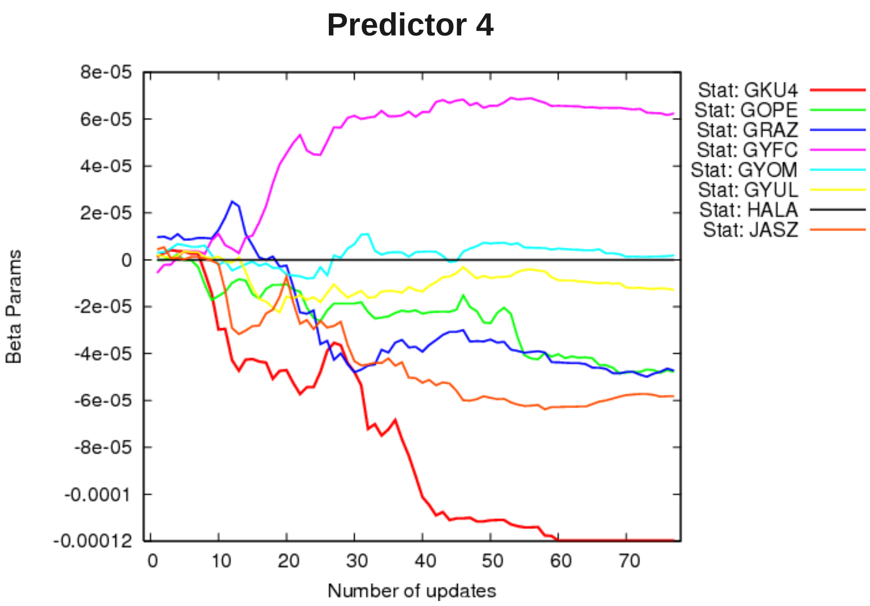
Bias correction for GNSS

- More predictors in VARBC SFCOBS
  - In routine varbc_pred.F90 the number of predictors was increased.
    - npredcs_sfcobs(4)=(/0,1,3,4)
    - SUBROUTINE predictors_sfcobs
      - Add pred(1,), pred(3,) and pred(4,) similarly to radiance VARBC
  - In routine varbc_sfcobs.F90 nparam variable was also increased (from 1 to JPMXNP)
  - Adopt HOP, HOPTL, HOPAD according to new VARBC_PRED_SFCOBS calls

```
ix=13
class=sfcobs
key=DEBRSGO11101280F 47  21
label=SFCOBS     statid=DEBRSGO1 subtype=110 varno=128 ppcode=0 lat= 47 lon=21
ndata=1
npred=4
predcs=0 1 3 4
param0=-3.483E-05  6.877E-05 -7.215E-05  1.490E-04
params=-1.568E-05  7.522E-05 -5.629E-05  1.511E-04
hstgrm=0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
```

Bias correction for GNSS





ix=13
class=sfcobs
key=DEBRSGO11101280F 47 21
label=SFCOBS   statid=DEBRSGO1 subtype=110 varno=128 ppcode=0 lat= 47 lon=21
ndata=1
npred=4
predcs=0 1 3 4
param0=-3.483E-05 6.877E-05 -7.215E-05 1.490E-04
params=-1.568E-05 7.522E-05 -5.629E-05 1.511E-04
hstgrm=0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

Problems

- After implementing new predictors and more observations from E-GVAP networks two issues were observed.
  - Passive assimilation with the use of variational bias correction (original aim is to do experiments with GNSS bias initialization)
  - Convergence issues in minimization which does not depend on bias correction or GNSS networks, but more on cases or periods what we selected
- Preliminary results, any comments are welcome!

Problems with passive assimilation

- Doing coldstart initialization i.e. active assimilation of GNSS VARBC is working properly
- Passive assimilation experiments and VARBC (warmstart tests)

```
!---------------------- SYNOP CONSTANT DATA SELECTION ----------------------

if (OBSTYP = synop) then

   if VARIAB in (t2m,rh2m) then
      if (soe < 10.0 ) then fail(CONSTANT); endif;
   endif;

   if VARIAB in (u10m, v10m) then
      if (SPECIFIC > 0.0 ) then
         if CODTYP in (11, 14, 16) then fail(CONSTANT); endif;
         if (RLSMASK > 0.) then fail(CONSTANT); endif;
       end if;
      if (STALT >= 0.) and (abs(STALT - MODORO) > 200.0) then fail(CONSTANT); endif;
   endif;

   if VARIAB in (rh, q) then
      if (PRESS <= 300.) then fail(CONSTANT); endif;
   endif;

  if (VARIAB = rh2m) then
      !if (CODTYP in (21, 22, 23, 24)) then fail(CONSTANT); endif;
      !if (RLSMASK < 0.5) then fail(CONSTANT); endif;
      if (STALT >= 0.) and (abs(STALT - MODORO) > 200.0) then fail(CONSTANT); endif;
  endif;

  if (CODTYP = pgps) then fail(EXPERIMENTAL);endif;

endif;
```

- fail(EXPERIMENTAL) → no updates in VARBC files
- VARBC source code was backphased by Xin in 2014, but passive assimilation with VARBC was never tested!

Problems with convergence in minimization

- When GNSS ZTD is used in 3DVAR the convergence is occasionally blocked during the search of the minimum.

```
GREPCOST - ITER,SIM,JO,JB,JC,JQ,JP   0   0  2096.82772658    0.00000000000    0.00000000000    0.00000000000    0.00000000000
GREPCOST - ITER,SIM,JO,JB,JC,JQ,JP   1   1  1765.34627801    1.99277457275    0.00000000000    0.00000000000    0.00000000000
GREPCOST - ITER,SIM,JO,JB,JC,JQ,JP   2   2  1298.38025947   23.8575076639     0.00000000000    0.00000000000    0.00000000000
GREPCOST - ITER,SIM,JO,JB,JC,JQ,JP   3   3  1057.65965942   63.8816815556     0.00000000000    0.00000000000    0.00000000000
GREPCOST - ITER,SIM,JO,JB,JC,JQ,JP   4   4  872.583215435   99.4824133646     0.00000000000    0.00000000000    0.00000000000
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GREPCOST - ITER,SIM,JO,JB,JC,JQ,JP   9   9  524.271878571   206.440022058     0.00000000000    0.00000000000    0.00000000000
GREPCOST - ITER,SIM,JO,JB,JC,JQ,JP  10  10  498.562979062   219.441548034     0.00000000000    0.00000000000    0.00000000000
GREPCOST - ITER,SIM,JO,JB,JC,JQ,JP  11  11  468.356539359   236.439733460     0.00000000000    0.00000000000    0.00000000000
GREPCOST - ITER,SIM,JO,JB,JC,JQ,JP  12  12  441.686852361   257.122765213     0.00000000000    0.00000000000    0.00000000000
GREPCOST - ITER,SIM,JO,JB,JC,JQ,JP  13  13  443.582698848   249.372152512     0.00000000000    0.00000000000    0.00000000000
GREPCOST - ITER,SIM,JO,JB,JC,JQ,JP  14  14  442.659503795   247.638751460     0.00000000000    0.00000000000    0.00000000000
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GREPCOST - ITER,SIM,JO,JB,JC,JQ,JP  16  16  423.674143577   260.413849440     0.00000000000    0.00000000000    0.00000000000
GREPCOST - ITER,SIM,JO,JB,JC,JQ,JP  17  17  414.964686649   270.556944107     0.00000000000    0.00000000000    0.00000000000
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GREPCOST - ITER,SIM,JO,JB,JC,JQ,JP  19  20  409.771451210   271.367502629     0.00000000000    0.00000000000    0.00000000000
GREPCOST - ITER,SIM,JO,JB,JC,JQ,JP  20  21  405.947555758   274.724118641     0.00000000000    0.00000000000    0.00000000000
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GREPCOST - ITER,SIM,JO,JB,JC,JQ,JP  22  23  402.349929098   277.772602866     0.00000000000    0.00000000000    0.00000000000
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GREPCOST - ITER,SIM,JO,JB,JC,JQ,JP 999 999  403.172654631   276.912647448     0.00000000000    0.00000000000    0.00000000000
```

- line-search blocked on dxmin
- Increase of sigmao can help to avoid it.

Future issues and an operational introduction

- Fix passive assimilation and convergence issues
- Find appropraite bias predictors and test bias initialization
- Station pre-selection and whitelist updates
- Sigmao tuning
- Operational implementation

Thank You for your attention!