# DATA ASSIMILATION OF GNSS ZTD FROM THE NGAA PROCESSING CENTRE

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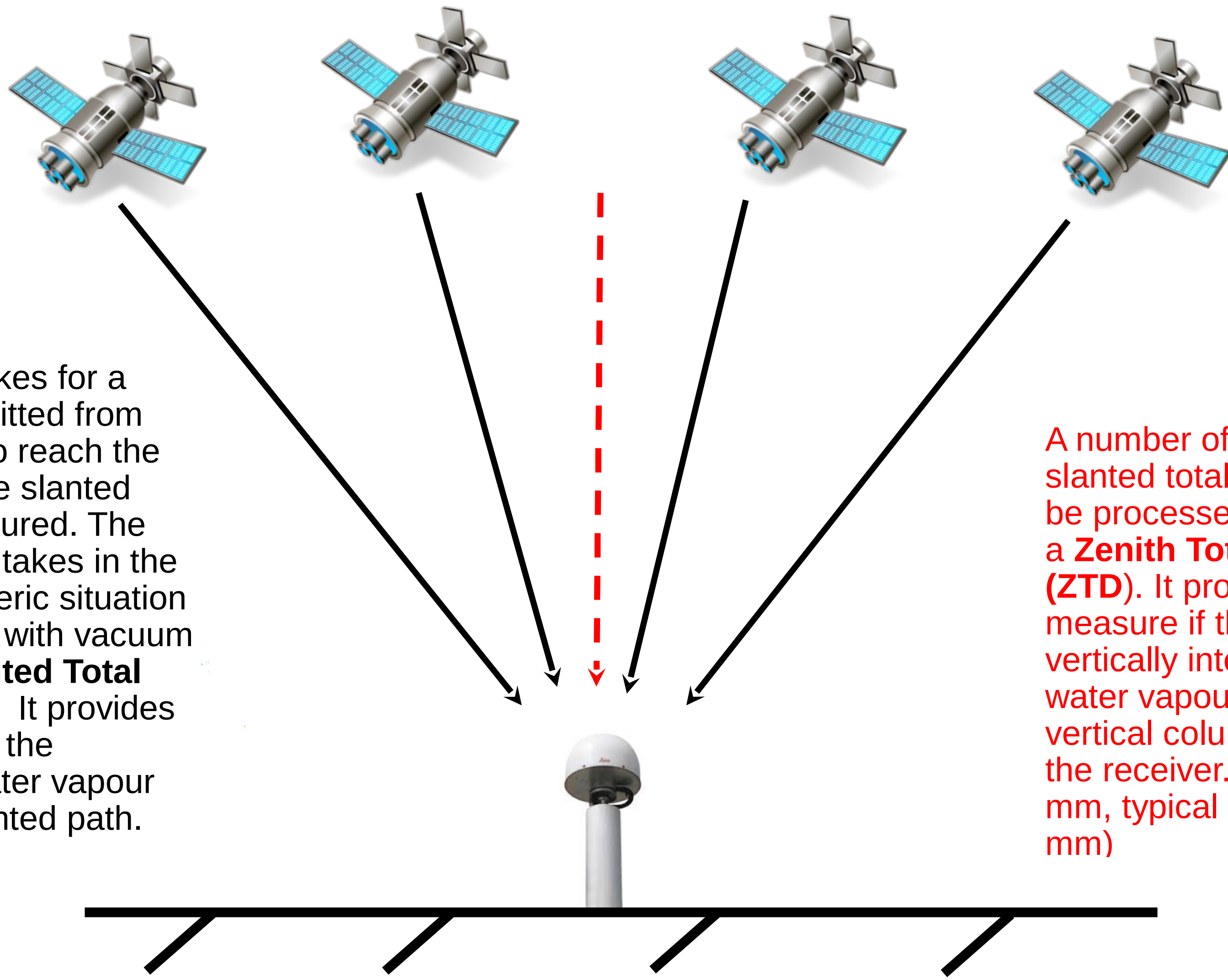
# *GNSS derived moisture*

SMHI

Global Navigation Satellite System

GPS, GLONASS, GALILEO, COMPASS



The time it takes for a signal transmitted from the satellite to reach the receiver in the slanted path is measured. The longer time it takes in the real atmospheric situation as compared with vacuum is called **Slanted Total Delay (STD)**. It provides a measure of the integrated water vapour along the slanted path.

A number of such slanted total delays can be processed to obtain a **Zenith Total Delay (ZTD)**. It provides a measure if the totally vertically integrated water vapour in a vertical column above the receiver. (unit: s or mm, typical value 2500 mm)

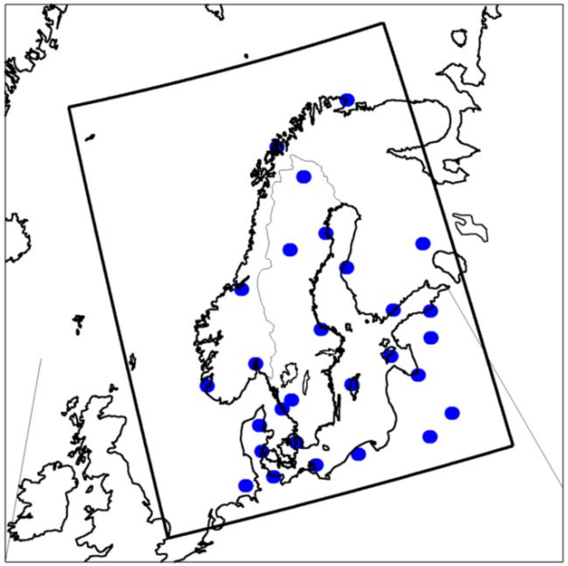
# MetCoOp

Meteorologisk institutt

FINNISH METEOROLOGICAL INSTITUTE

SMHI

- An operational km-scale NWP system based on AROME.
- Ensemble system with 10 ensemble members.
- Upper-air data assimilation based  3D-Var to obtain the best possible initial state for the atmosphere.
- Observation used are conventional types of in-situ measurements, radar reflectivities, satellite radiances (AMSU A, AMSU-B/MHS and IASI), advanced scatterometer surface winds and GNSS ZTD.



MetCoOp model domain and GNSS stations (28 stations from ROBH and METO processing centres).

MetCoOp

# GNSS from NGAA the processing centre

- Due to quality issues MetCoOp did not assimilate NGAA data but rather the few (28) stations over the MetCoOp domain processed by METO and ROBH processing centres.

- In June, 2015, Lantmäteriet (the Swedish mapping, cadastral and land registration authority) took over the NGAA data processing which includes two parts of work:

  1. Move and modify GIPSY solution to Lantmäteriet servers.
  2. Prepare a new Bernese solution.

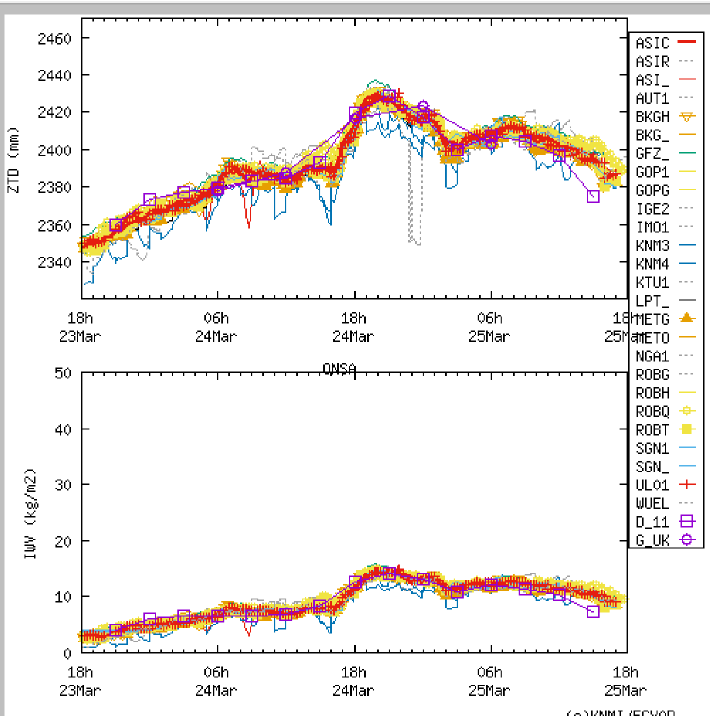
- Since 2016, Lantmäteriet send data to SMHI:
  - Sweden – 383 sites
  - Finland – 88
  - Denmark – 10
  - Norway – 192
  - IGS – 10

  In total 683 sites

- Both Bernese (v 5.2) solution (NGA1) and GIPSY (v 6.2) solution (NGA2) are uploaded to SMHI. Only Bernese solution are further uploaded to E-GVAP due to longer time delay (more than 1.5 hour) of the GIPSY solution caused by long waiting time of JPL ultra rapid orbit and clock product.

# NGAA at E-GVAP (egvap.dmi.dk)

## Onsala, Sweden (ONSA)




**HIRLAM(KNMI) AN - GPS ZTD**

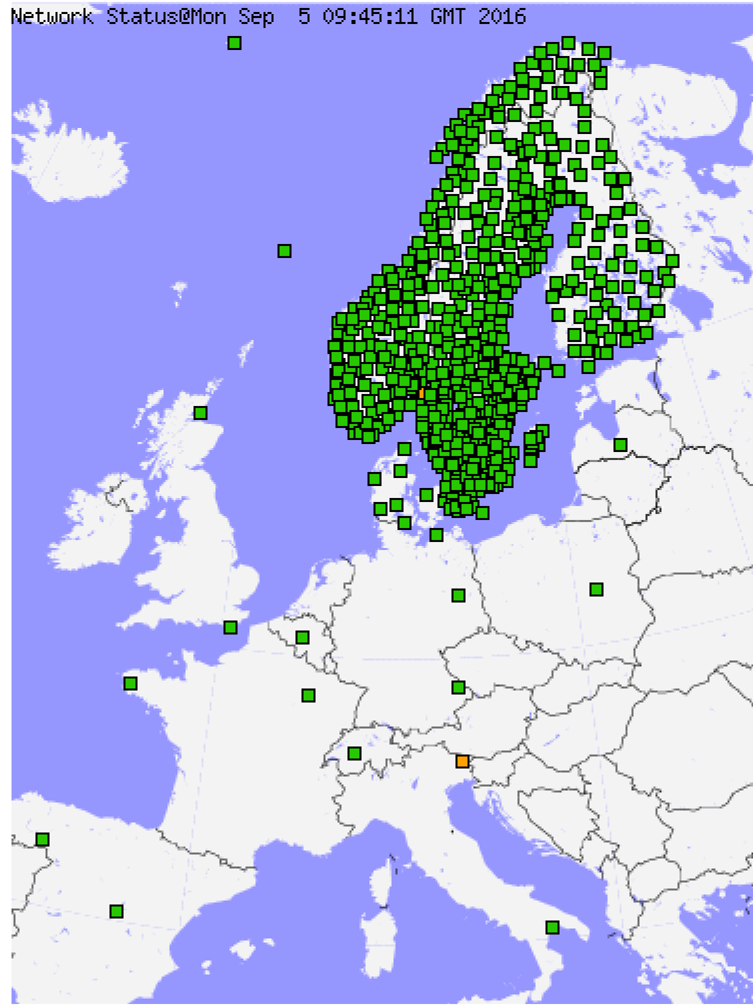
7day stat. 2017/03/09 - 2017/03/17

| AC | num | bias | RMS | stddev |
|---|---|---|---|---|
| ASIC | 56 | -3.3 | 8.9 | 8.2 |
| ASI | 56 | -2.8 | 9.0 | 8.6 |
| AUT1 | 56 | -2.2 | 9.2 | 8.9 |
| BKG | 56 | -0.0 | 8.4 | 8.4 |
| GFZ | 56 | 1.4 | 9.0 | 8.8 |
| GOP1 | 56 | -4.5 | 10.1 | 9.0 |
| GOPG | 56 | -4.0 | 10.1 | 9.2 |
| GUK | 52 | -0.7 | 7.3 | 7.2 |
| IMO1 | 56 | -3.0 | 9.6 | 9.1 |
| KNM3 | 56 | -3.2 | 10.4 | 9.9 |
| KNM4 | 56 | -11.7 | 17.0 | 12.2 |
| KTU1 | 56 | -4.2 | 10.0 | 9.0 |
| LPT | 56 | -3.7 | 10.1 | 9.3 |
| METO | 56 | -4.3 | 9.9 | 8.9 |
| ROBG | 56 | -2.2 | 9.0 | 8.7 |
| ROBH | 56 | -3.8 | 9.6 | 8.8 |
| SGN1 | 56 | -3.3 | 9.9 | 9.4 |
| SGN | 55 | -4.2 | 9.9 | 8.9 |
| **TEST** | | | | |
| ASIR | 56 | -1.6 | 9.4 | 9.2 |
| BKGH | 56 | -2.2 | 8.7 | 8.4 |
| IGE2 | 56 | -1.0 | 9.5 | 9.4 |
| METG | 56 | -3.8 | 9.3 | 8.5 |
| NGA1 | 56 | -4.4 | 9.2 | 8.1 |
| ROBQ | 56 | -0.8 | 9.8 | 9.8 |
| ROBT | 56 | -3.9 | 9.6 | 8.8 |
| WUEL | 56 | -4.9 | 10.9 | 9.8 |

**Graphical location of the site**

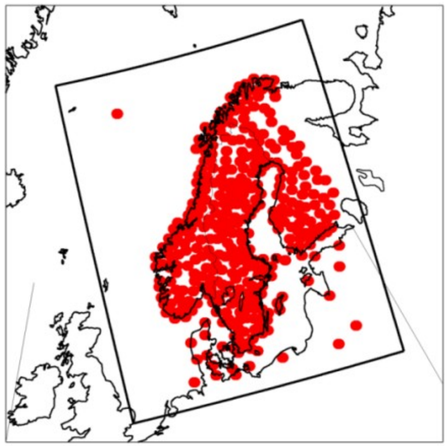
| | |
|---|---|
| **latitude** | |
| **longitude** | |
| **altitude** | |

## The NGA1 data sent to E-GVAP

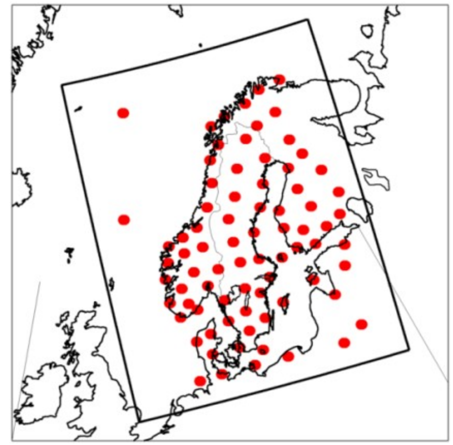


# Observation handling components

## Spatial thinning of observations



Before spatial thinning



Spatial thinning ~100 km
(~80 stations)

## Variational Bias Correction

Linear predictor model:

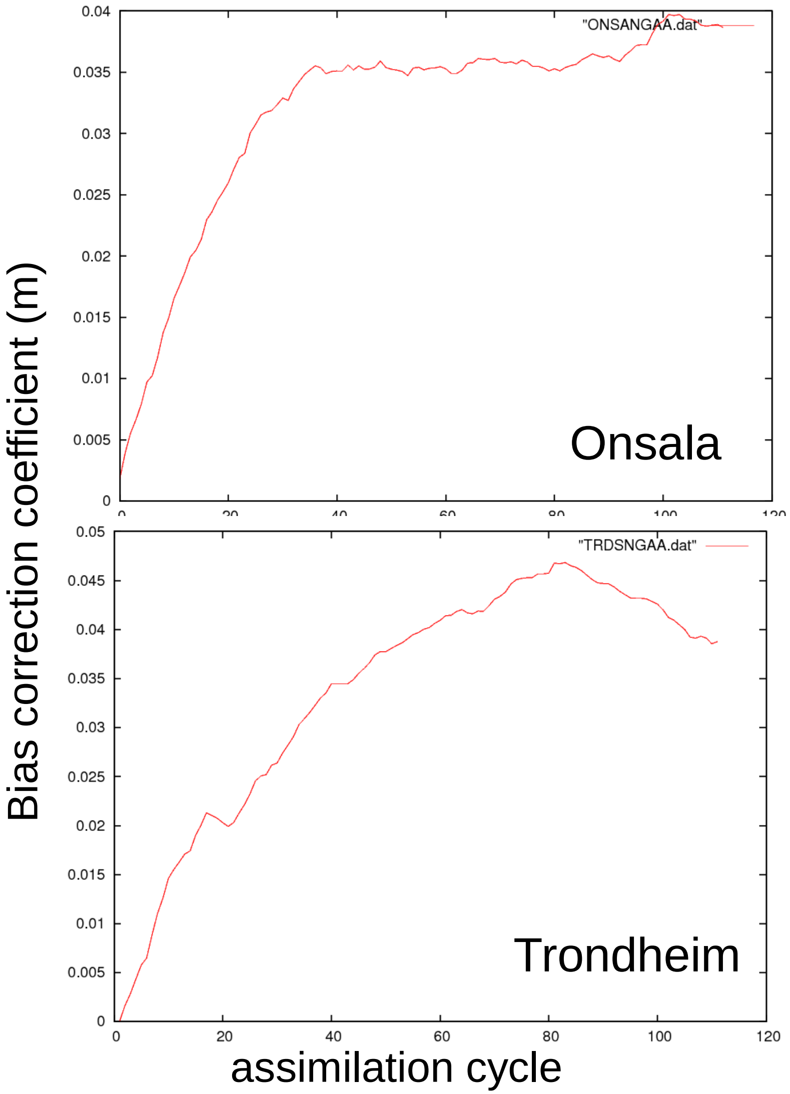
$$b(x,\beta) = \sum_{i=0}^{Np} \beta_i p_i(x)$$

Modified cost function:

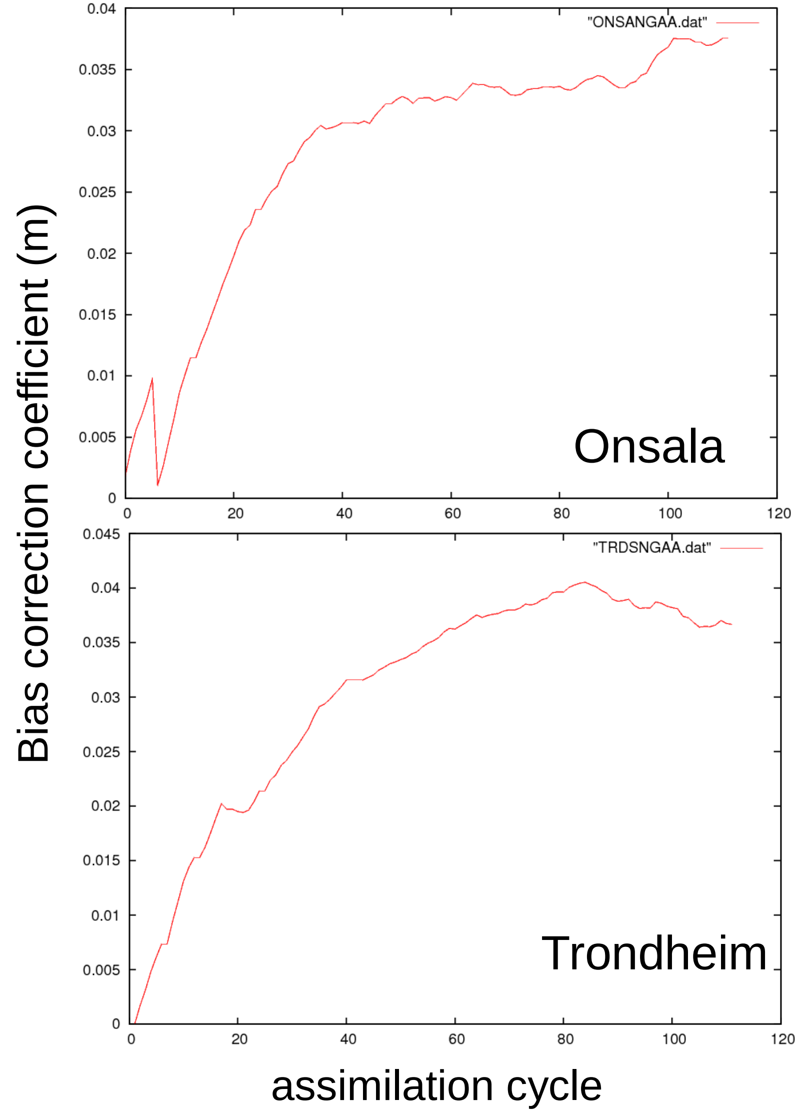
$$J(x,\beta) = \frac{1}{2}(x - x^B)^T B^{-1}(x - x^B) + \frac{1}{2}(\beta - \beta^B)^T B_\beta^{-1}(\beta - \beta^B) + \frac{1}{2}(Hx + b(x,\beta) - y)^T R^{-1}(Hx + b(x,\beta - y))$$

# Spin-up of NGAA GNSS VARBC-coefficients 20160215-20160229

## NGA1




## NGA2



# Four one-month parallel data assimilation and forecast experiments for June 2016

- **Impact of introducing NGAA GNSS ZTD**

  **Operational, NGA1 GNSS usage, NGA2 GNSS usage**
  **(all runs with ~80-100 km thinning distance and one VARBC predictor)**

- **Impact of different VARBC predictor choices**

  **offset , offset and 1000-300 hPa thickness, offset and TCWV**
  **(all runs with ~80-100 km thinning distance and NGA1)**

- **Impact of modifying thinning distance**

  **NGA1 observation usage ~80-100 km thin. dist. , NGA1 observation usage 40 km thin. dist.**

- **Impact of modified background error statistics (B matrix)**

  **Original and modified B (both runs with ~80-100 km thinning distance and NGA1)**

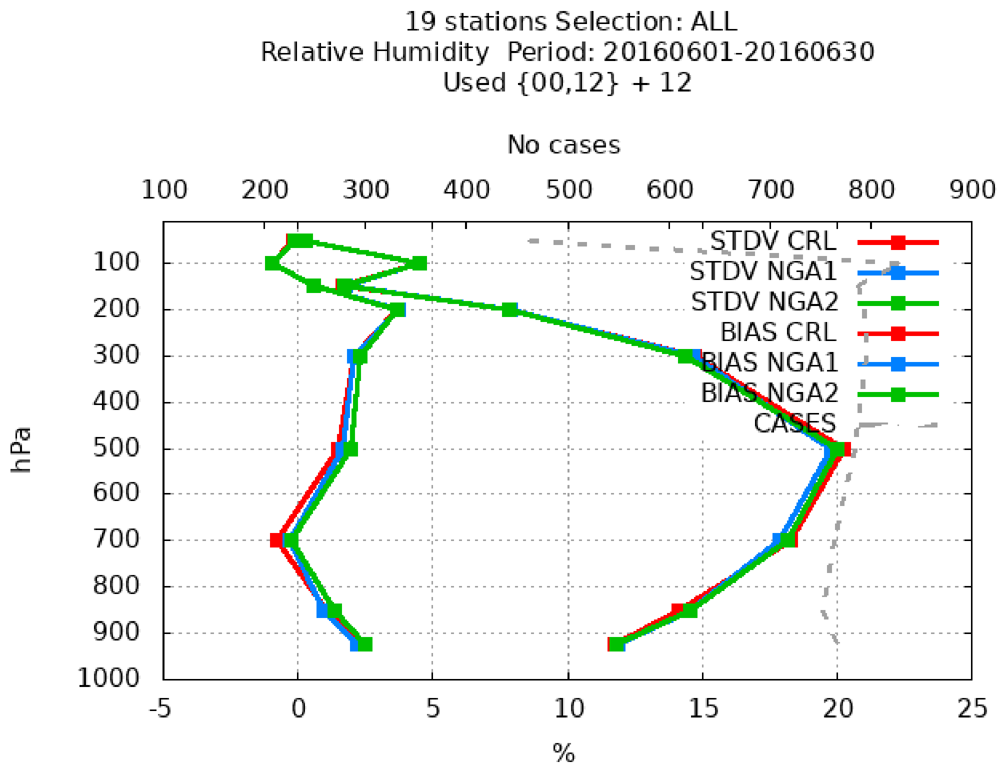
  **B-matrix derived using cy40h1.1 (MetCoOp) and ECMWF ensemble (EDA) with cubic grid of ~20 km**

## Results from parallell data assimilation experiments

### Impact of introducing NGAA GNSS ZTD

### Time-averaged verification scores over MetCoOp domain

Bias and RMSE for +12 hour relative humidity forecasts



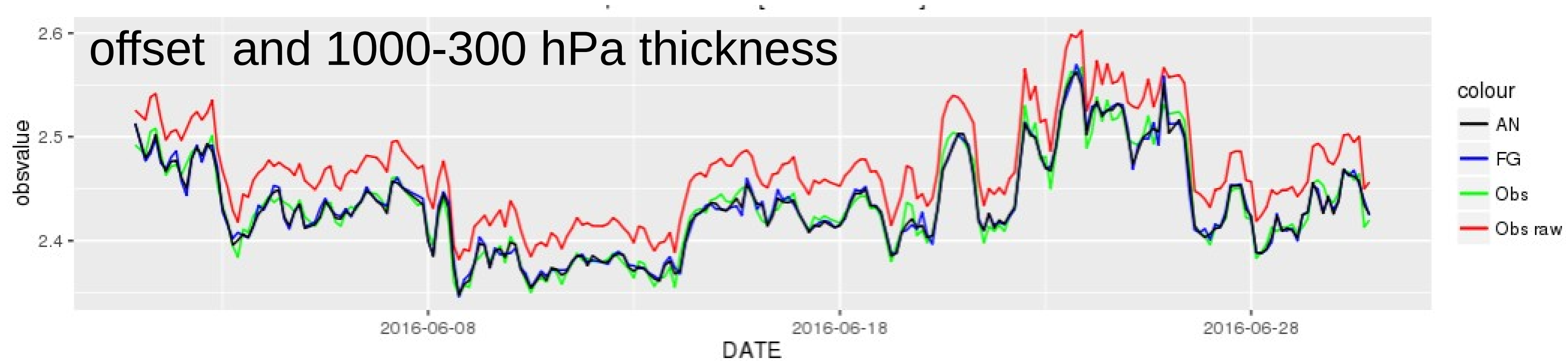

— Operational
— NGA1
— NGA2

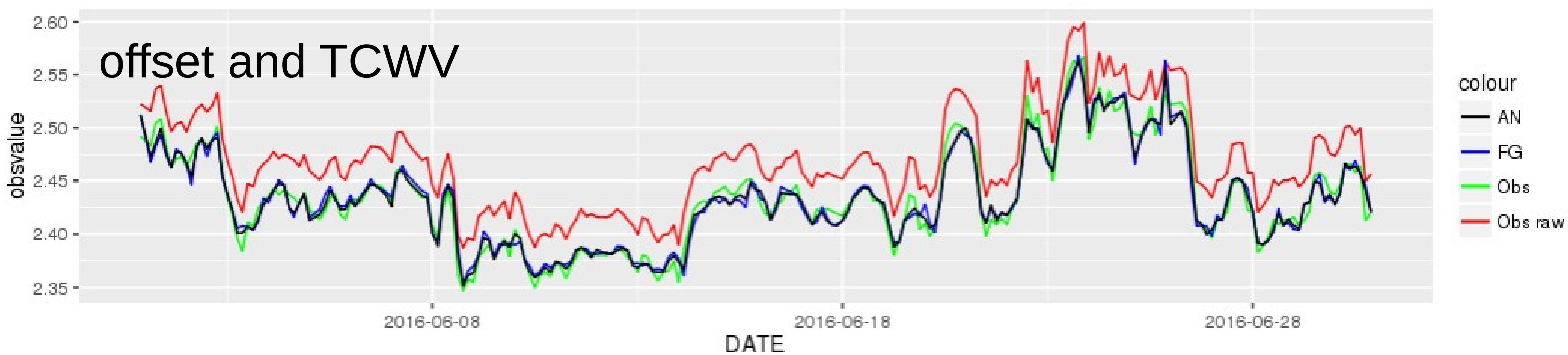
Introduction of NGAA with Bernese (NGA1) solution was more beneficial.

# Results from parallell data assimilation experiments

## Impact of different VARBC predictor choices

### Time-series of GNSS ZTD from Onsala receiving station

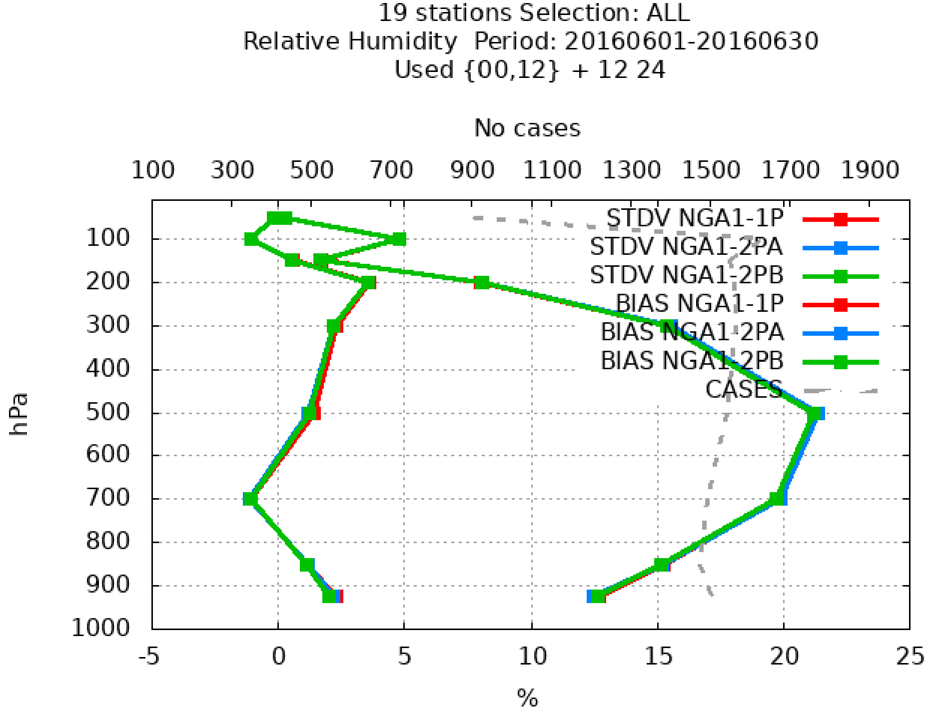



## Results from parallell data assimilation experiments

### Impact of different VARBC predictor choices

### Time-averaged verification scores over MetCoOp domain

Bias and RMSE for +12,24 hour relative humidity forecasts



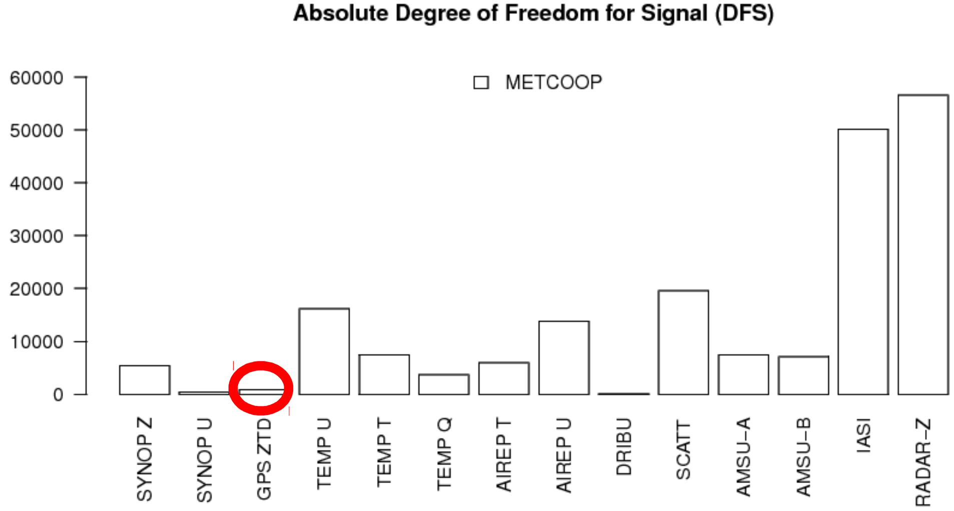

— Offset
— Offset + 1000-300 hPa
— Offset + TCWV

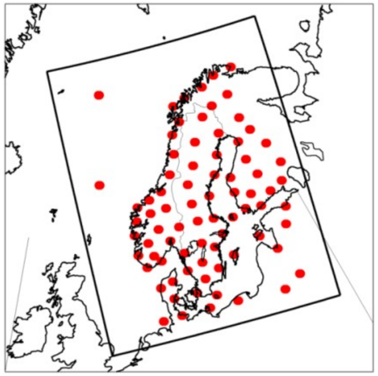
Small impact of introducing one more predictor in GNSS VARBC.

# Results from parallell data assimilation experiments

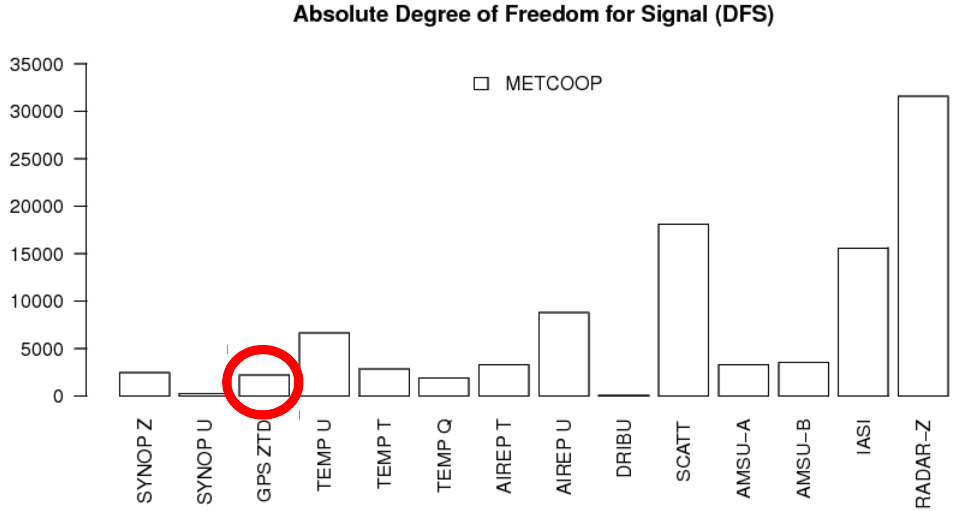
SMHI

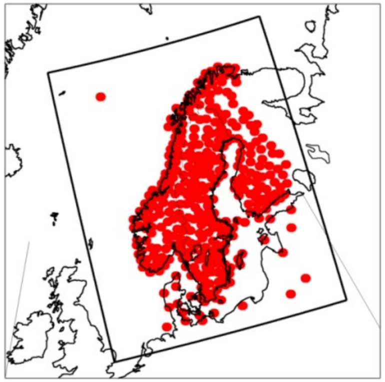
**Effect of modified GNSS ZTD thinning distance on Impact on analysis separated into observation types (20160612-20160616)**



80-100 km (~80 stations)



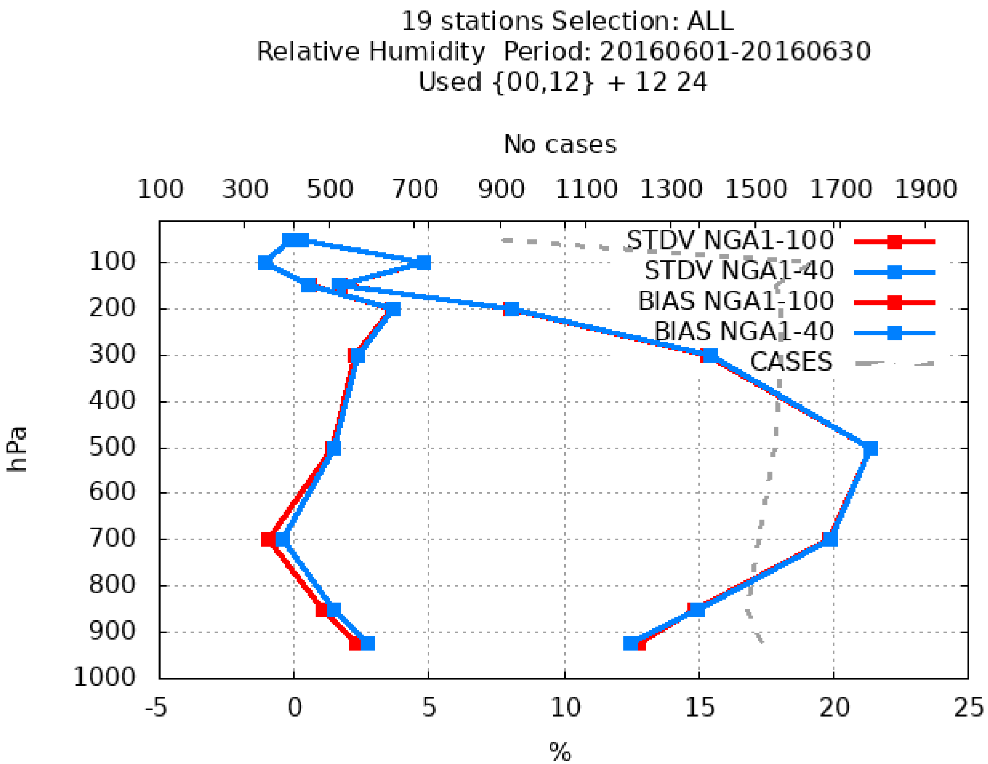
40 km (~330 stations)

Results from parallell data assimilation experiments

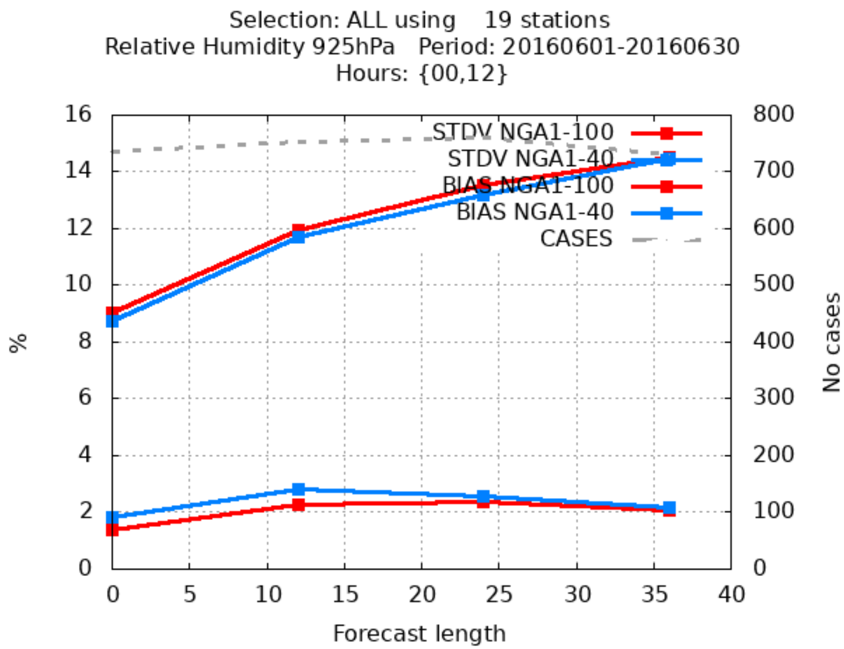
# Impact of introducing modified GNSS ZTD thinning distance

## Verification scores over MetCoOp domain

Relative humidity for +12,24




Relative humidity at 925 hPa.



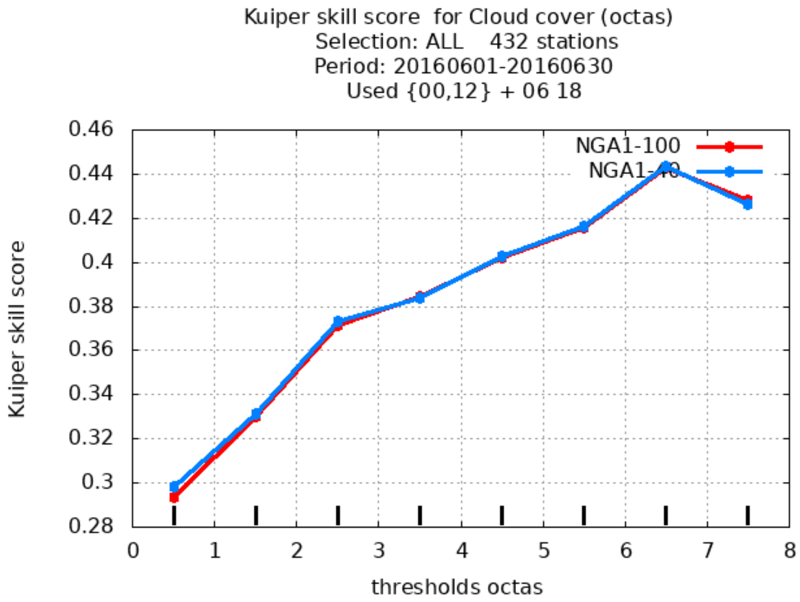

Larger bias and smaller standard deviation at lowest levels for NGA1-40, otherwise neutral.

# Results from parallell data assimilation experiments

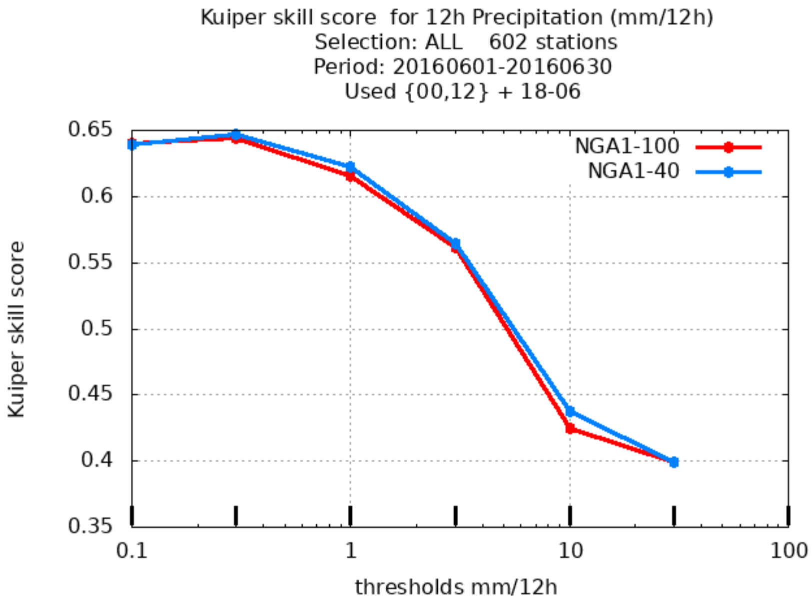
## Impact of introducing modified GNSS ZTD thinning distance

## Time-averaged verification scores over MetCoOp domain
## Kuiper skill score

Cloud cover



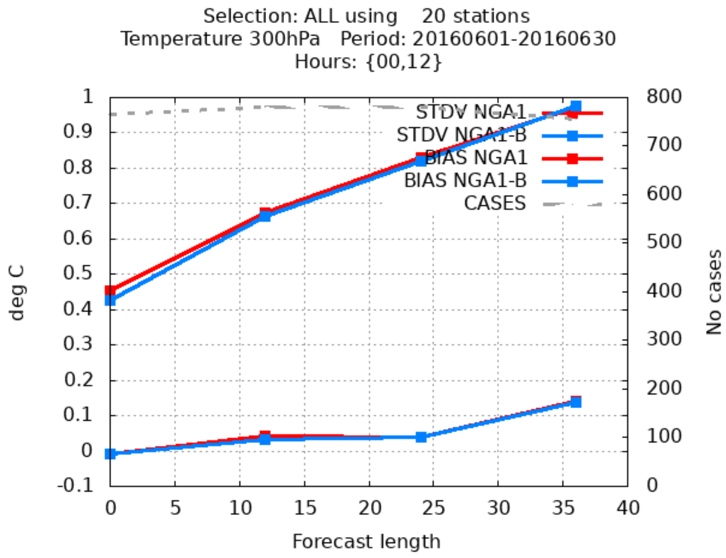

Precipitation 12h

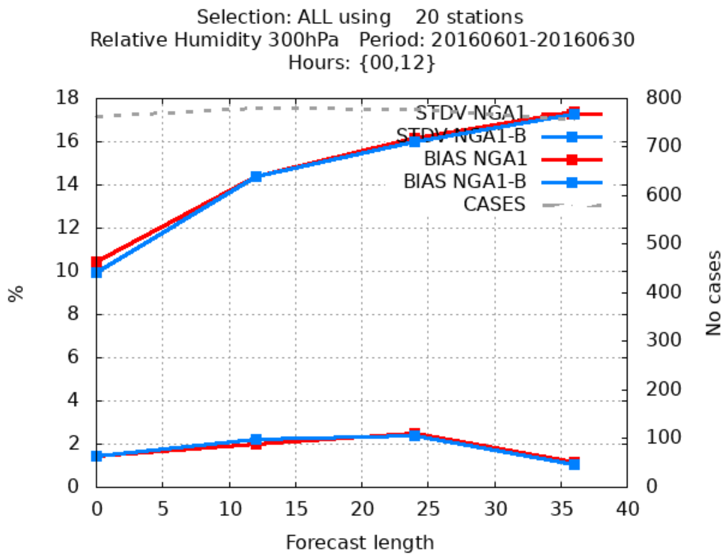


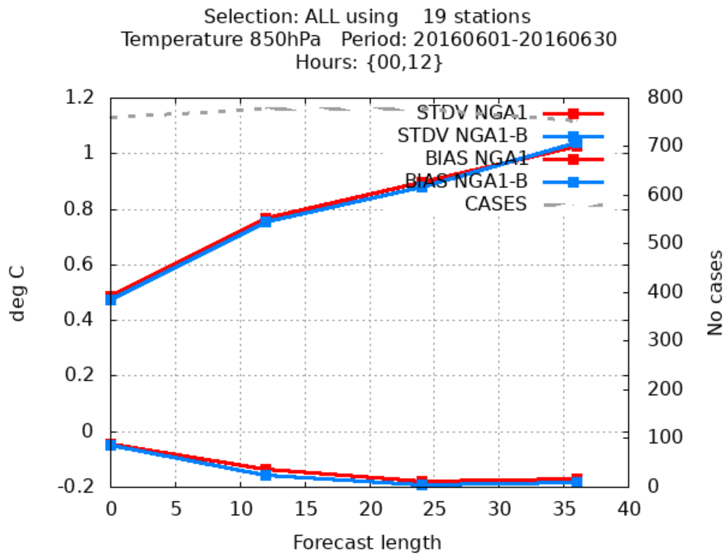

Slightly better precipitation forecasts for NGA1-40.

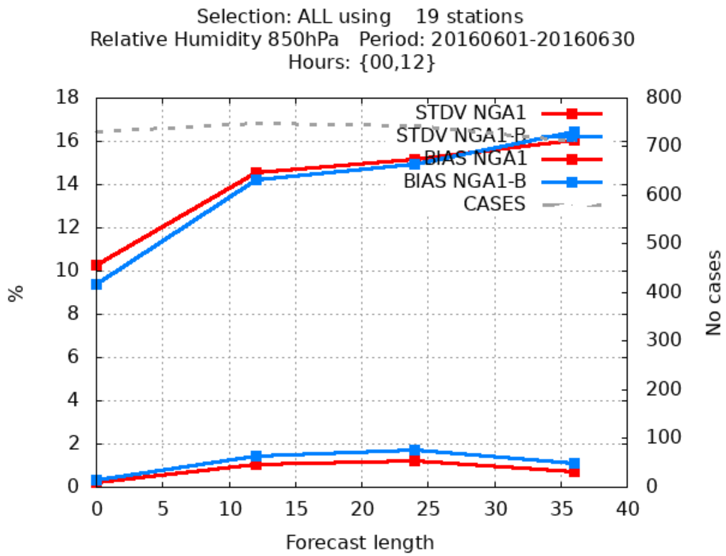
# Results from parallell data assimilation experiments

## Impact of modified background error statistics (B matrix)



## Conclusions and future plans

SMHI

•GNSS ZTD from the NGAA processing centre is now of a good quality and these are planned to be introduced in the MetCoOp operational data assimilation (now in pre-op).

•We have earlier demonstrated that use of GNSS ZTD observations together with a variational bias correction do improve the short range weather forecasts. The findings of the present study indicate however that it is enough to use one predictor, in the form of a constant offset.

•Rather encouraging  results were obtained with a reduced  thinning distance. The introduction of many different sources of humidity information seem to alleviate problems earlier noticed related to use of variational bias correction and small GNSS ZTD thinning distances. Some further investigations of low level biases are however needed.

•Within the data assimilation a clear interaction of GNSS ZTD with other types of humidity observation was noticed.

•The benefit of GNSS ZTD observations can be enhanced by improving various aspects of the NWP data assimilation in general, demonstrated here by modifying the B-matrix.