



Royal Netherlands
Meteorological Institute
*Ministry of Transport, Public Works
and Water Management*

GNSS&NWP@KNMI

Siebre de Haan



E-GVAP data is assimilated in HIRLAM 11km hourly update
Preparation for assimilation in HARMONIE ongoing
Development of Slant assimilation in progress

Slant Path Delay operator



STD operator

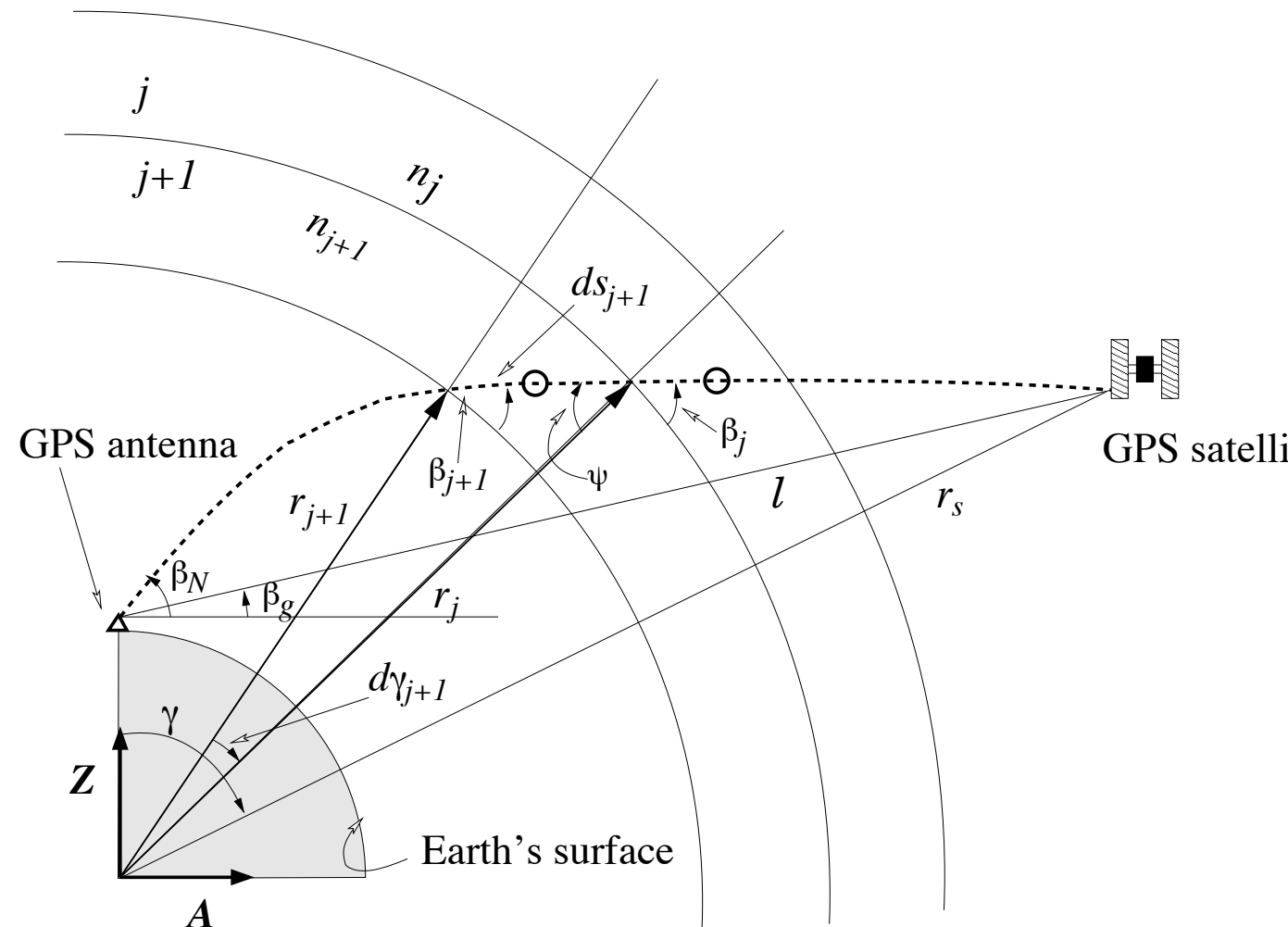
$$\begin{aligned}\tau &= \int_{H_a}^{r_s} n(s) ds - L \\ &= \int_{H_a}^{r_s} (n(s) - 1) ds + S - L \\ &= \int_{H_a}^{r_s} 10^{-6} \mathcal{N}(s) ds + S - L\end{aligned}$$

At low elevations S and L differ!

Refractivity between layers:

$$N(h; H_k \leq h < H_{k-1}) = N_k \left(\frac{N_{k-1}}{N_k} \right)^{\frac{h - H_k}{H_{k-1} - H_k}},$$

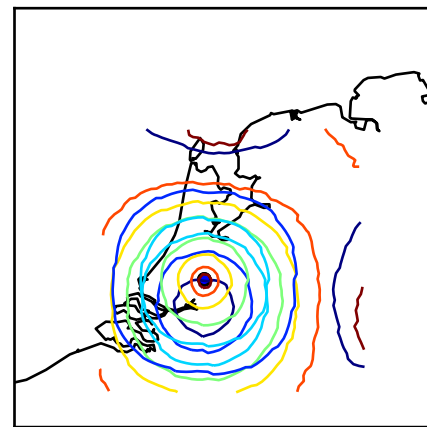
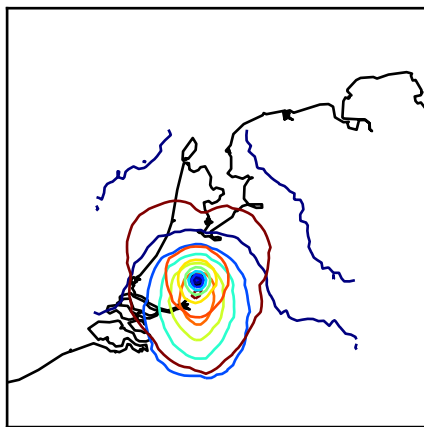
Simplified Tangent Linear and Adjoint





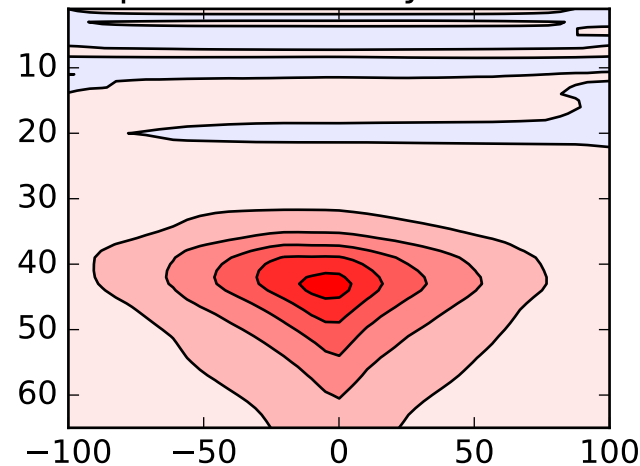
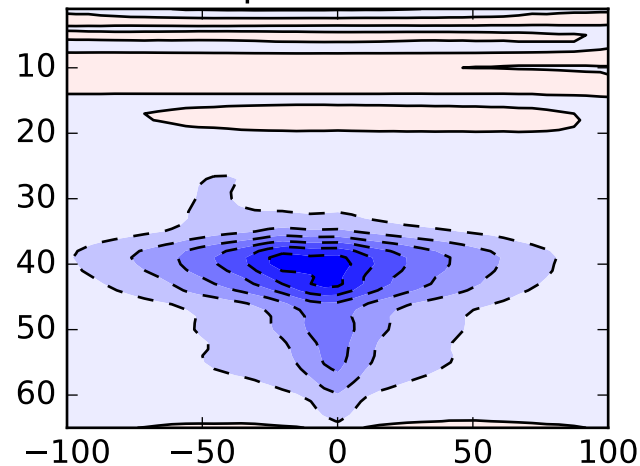
Single observation

- ♦ 5 degrees elevation
- ♦ point south
- ♦ Obs > model
- ♦ q increases
- ♦ T decreases



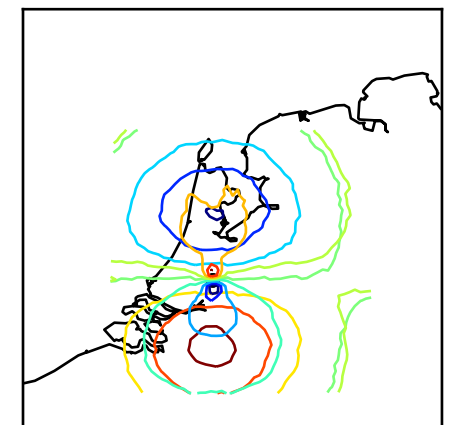
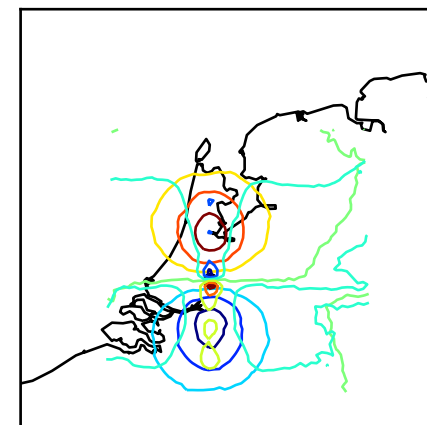
Temperature 0.052

Specific humidity 1.1e-04



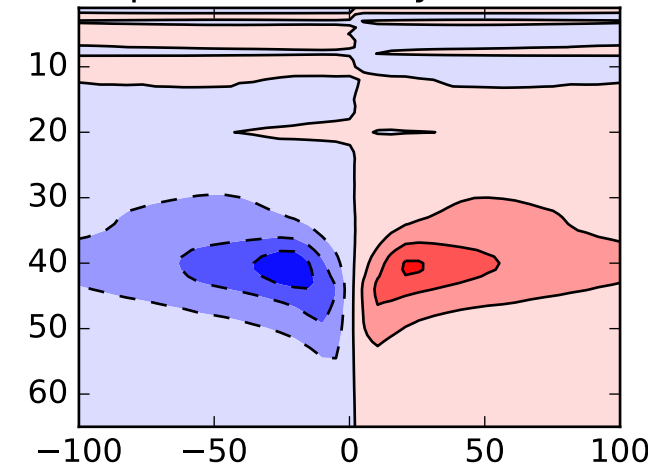
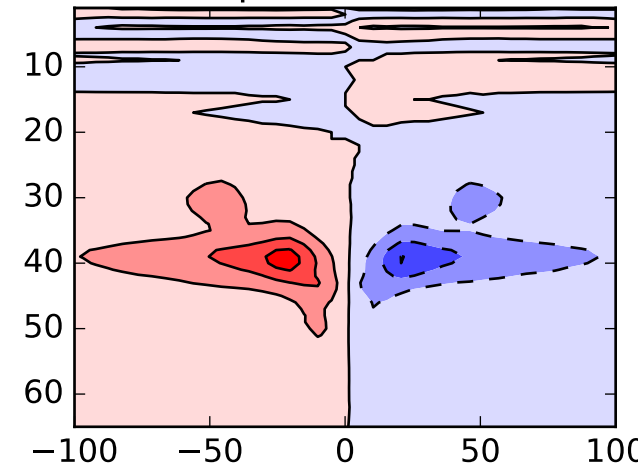
Double observation

- ♦ 5 degrees elevation
- ♦ point south (Obs < model)
- ♦ pointing north (Obs > model)



Temperature 0.0208

Specific humidity 3.0e-05

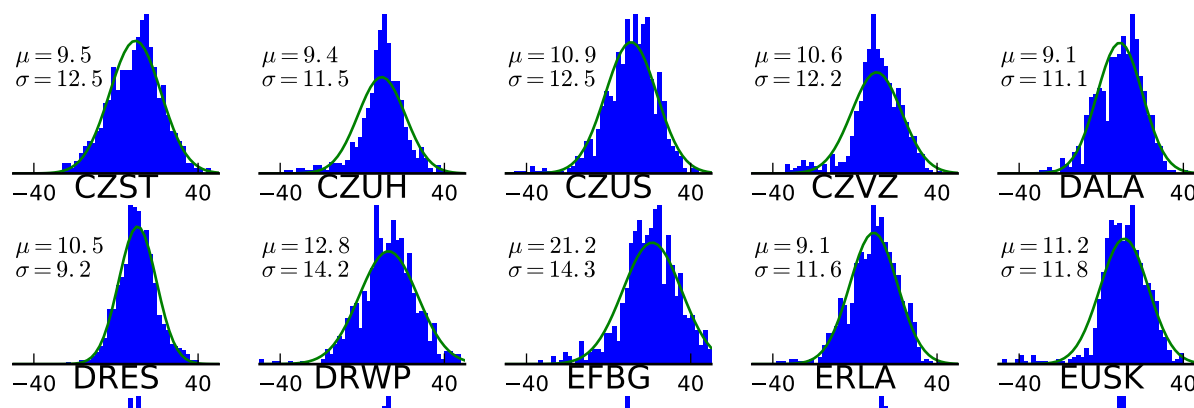
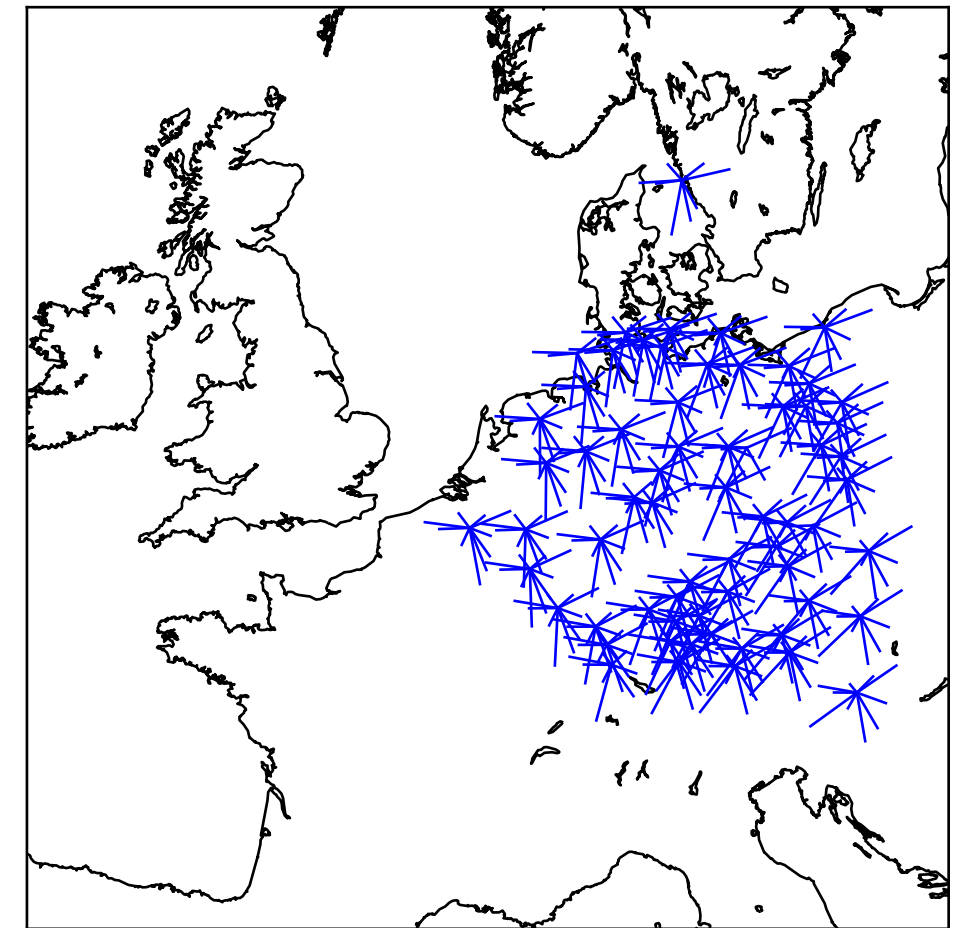




Benchmark

- 10 days for (static) bias correction
- STD mapped by sine of elevation
- Selection of 'good' sites
 - ♦ reasonable Obs minus Background
 - ♦ not below orography
 - ♦ thinning to minimal 50km
- Selection of data
 - ♦ 10 minute window
 - ♦ one obs. per satellite
 - ♦ lowest elevation
- 10 days of forecasting

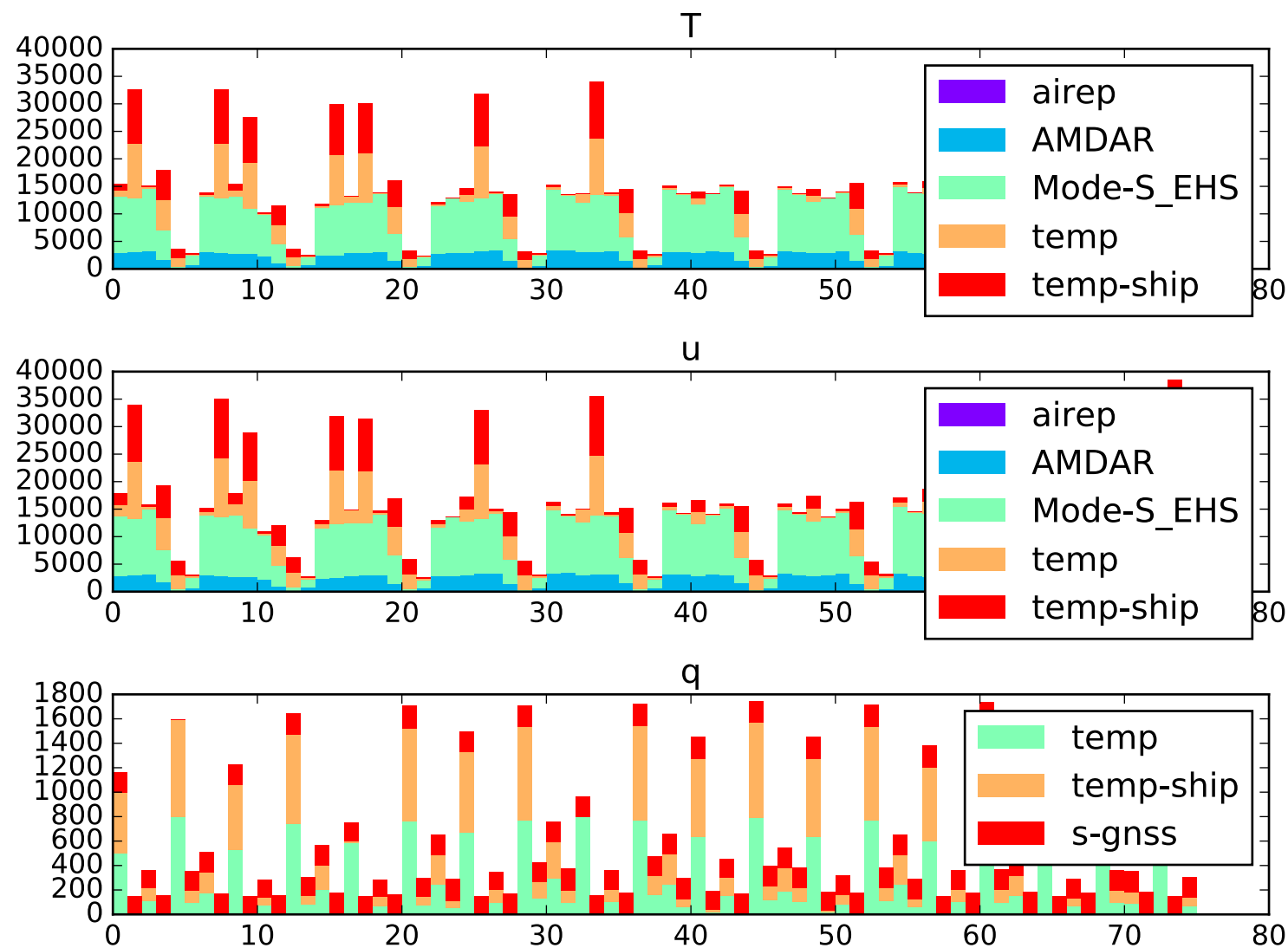
Screened observations



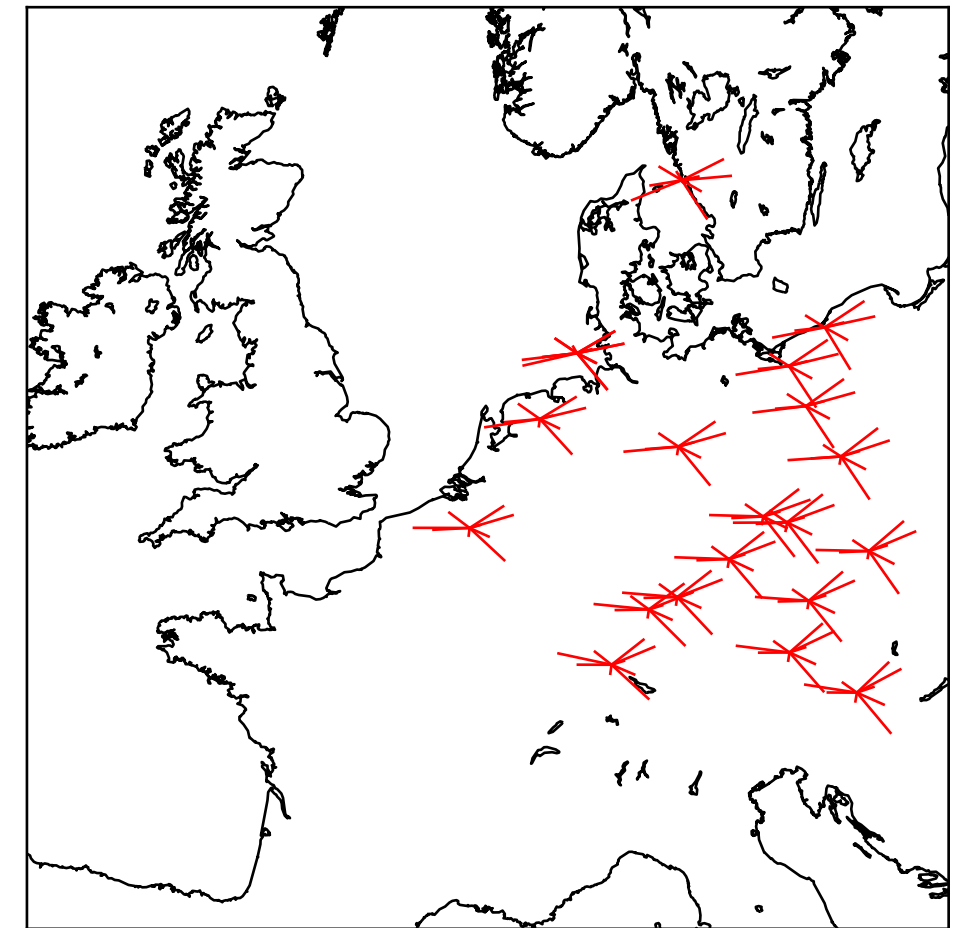


Data assimilated

- ◆ STD : 5% (150-200 obs per cycle)
- ◆ TEMP
- ◆ AMDAR
- ◆ Mode-S EHS (1-2%)



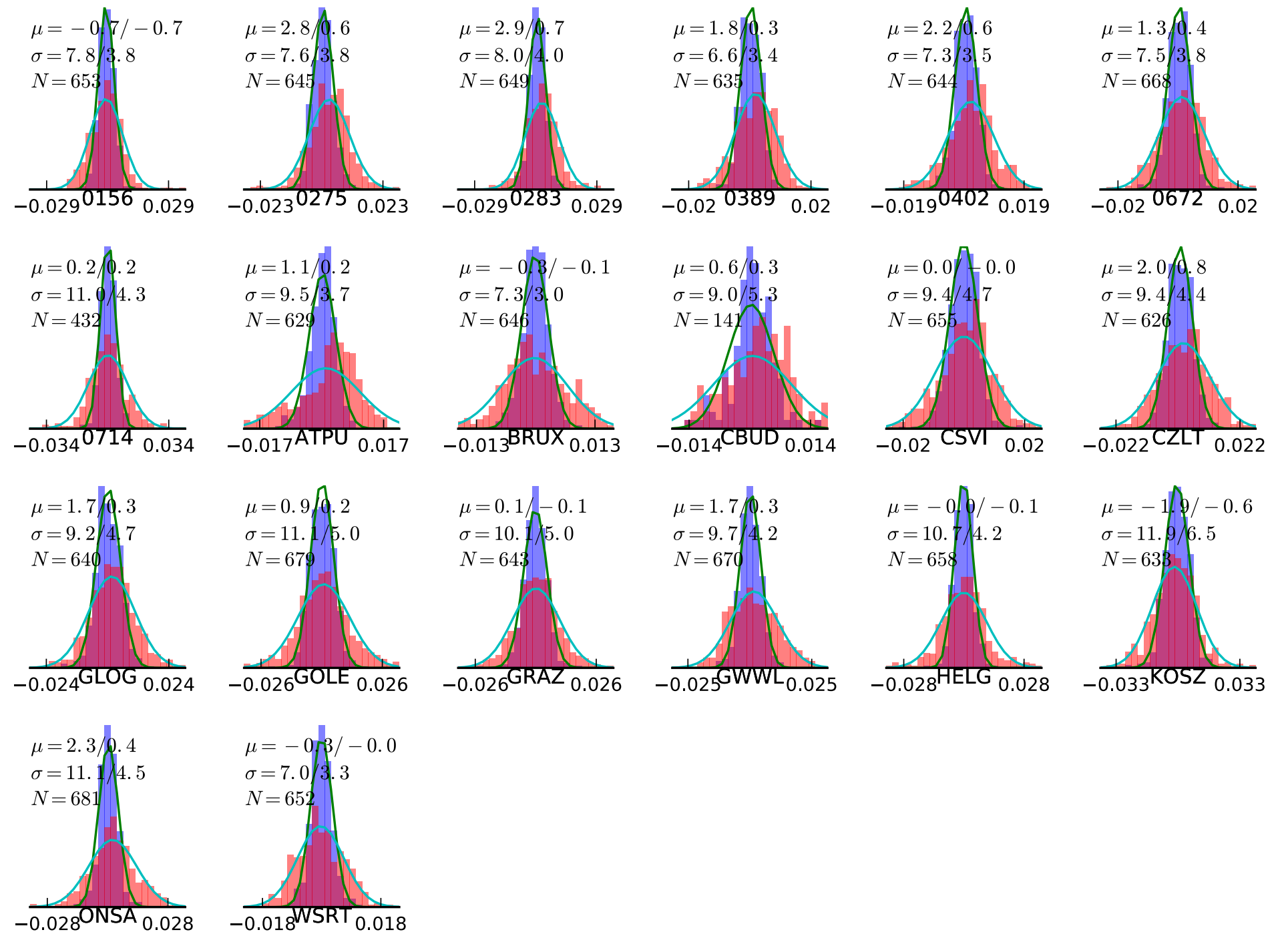
Used observations



O minus B



20 sites



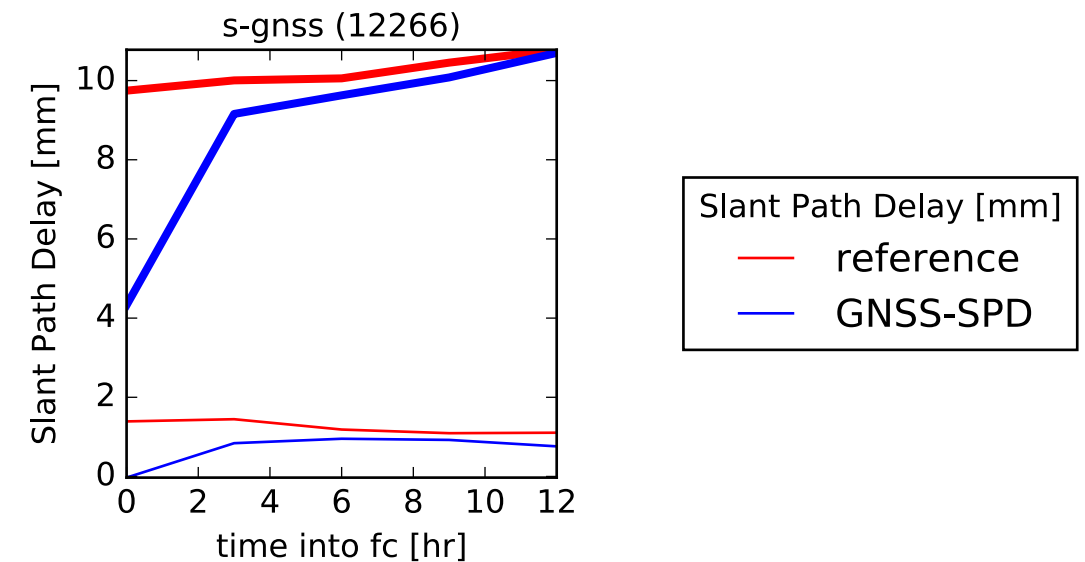


STD

- ♦ positive impact over whole forecast
- ♦ bias correction works sub-optimal
 - ❖ too short time window?
- ♦ all observations show very good statistics

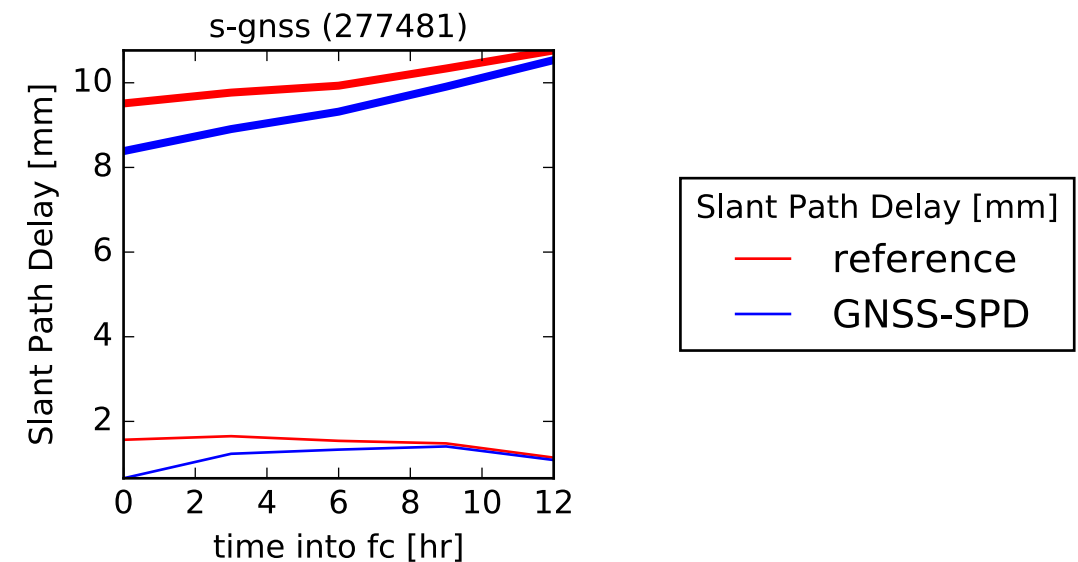
Period 2013051712-2013052618

all assimilated observations



Period 2013051712-2013052618

all observations

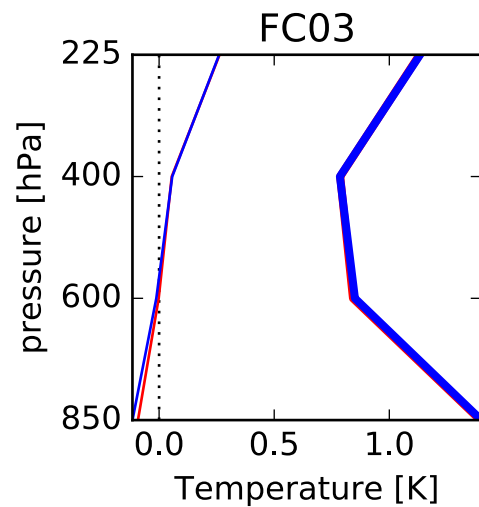
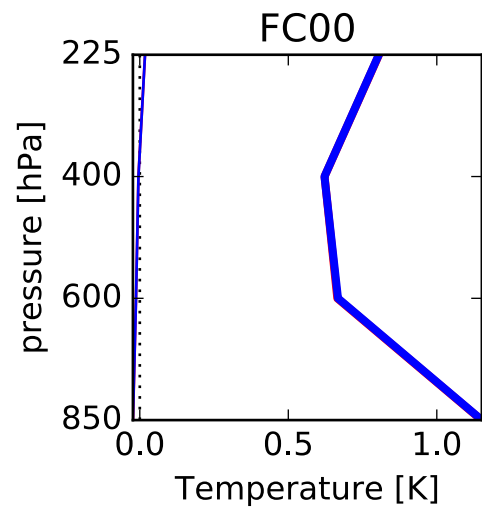


Impact on T,q

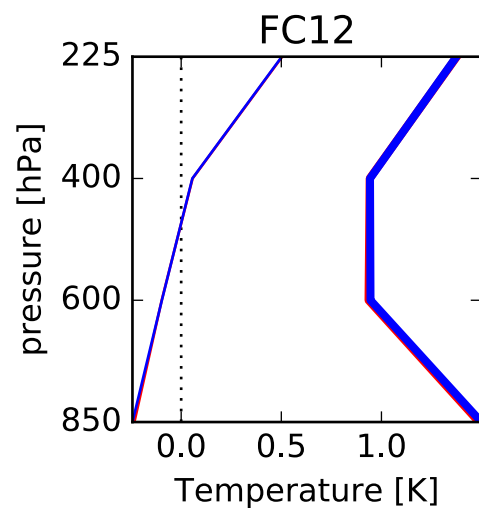
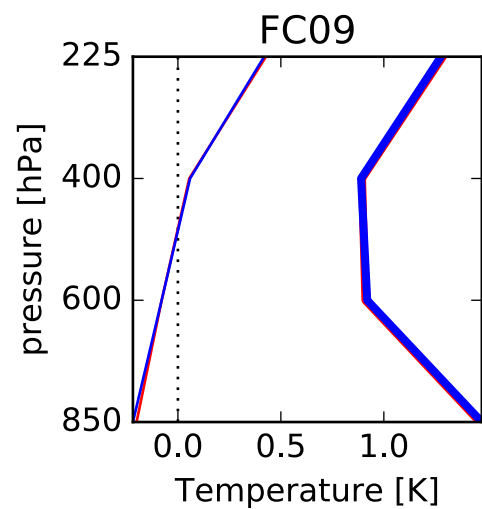


Small positive impact on RH bias
No impact on T

Period 2013051712-2013052618
all observations



pressure [hPa]

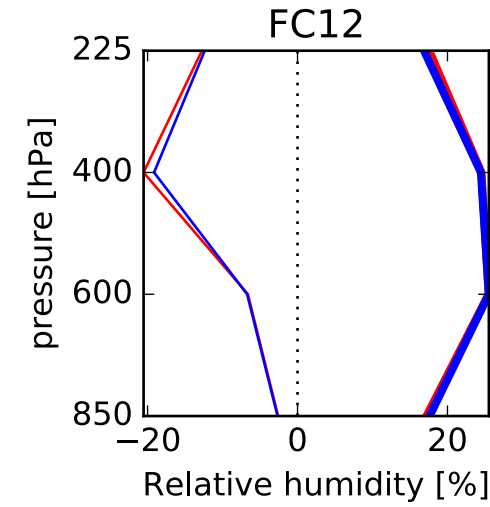
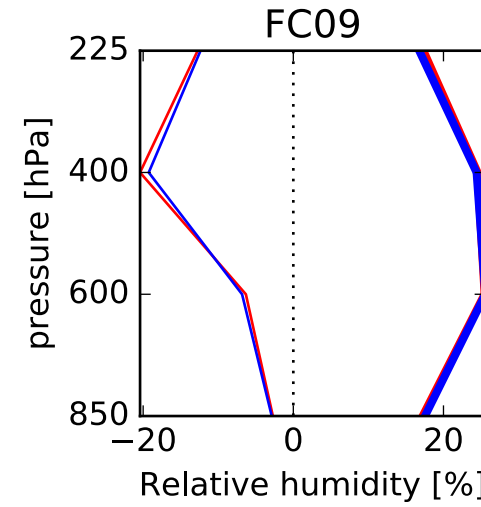
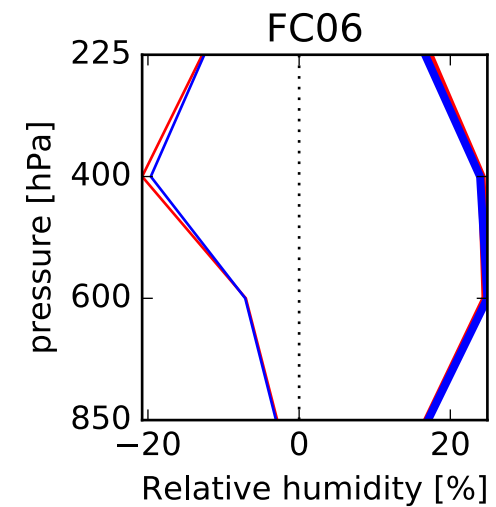
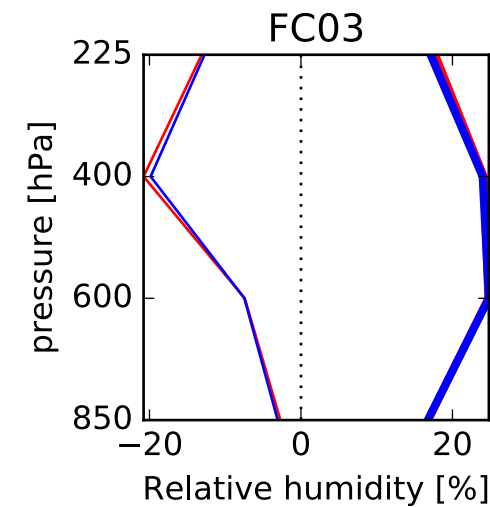
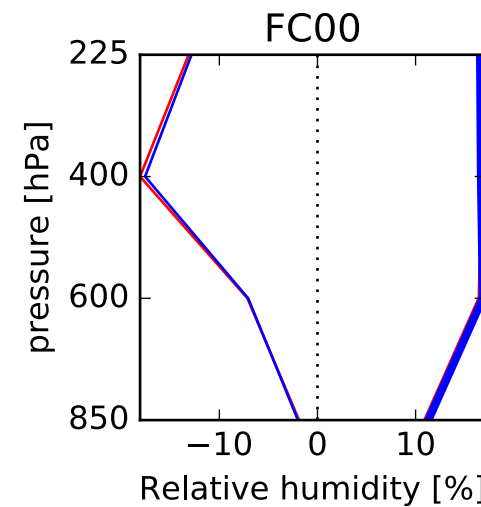


number
4473372

Mode-S_EHS T
— reference
— GNSS-SPD

1790132
1089015
836750

Period 2013051712-2013052618
all observations



number
6592
6624
5365
7060

temp rh
— reference
— GNSS-SPD



Next steps

- ♦ longer run
- ♦ more data
 - ❖ thinning to 20-30 km
 - ❖ 4DVAR?
- ♦ case studies