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Assimilation of ZTD data – error modelling

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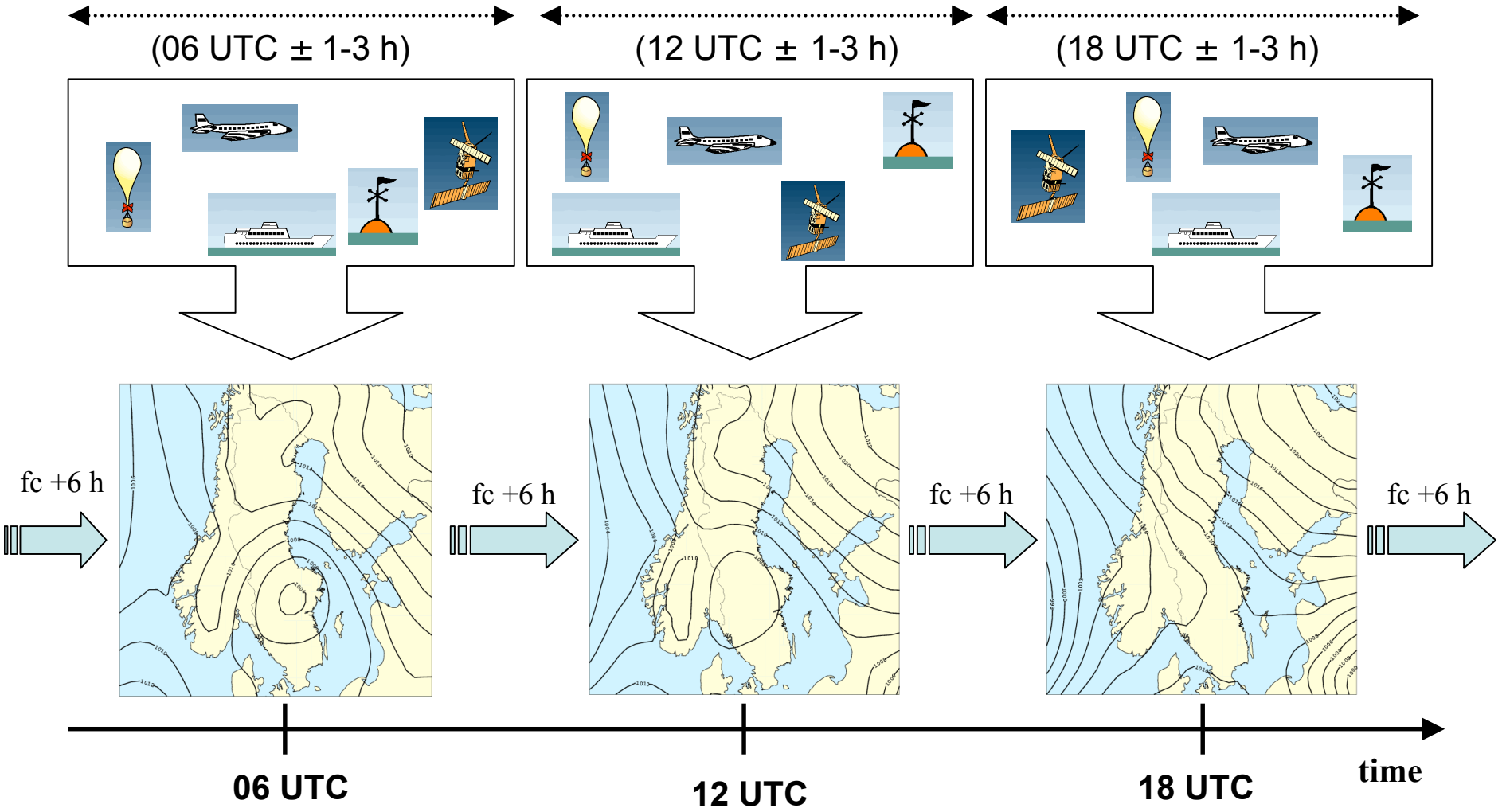
Intermittent data assimilation



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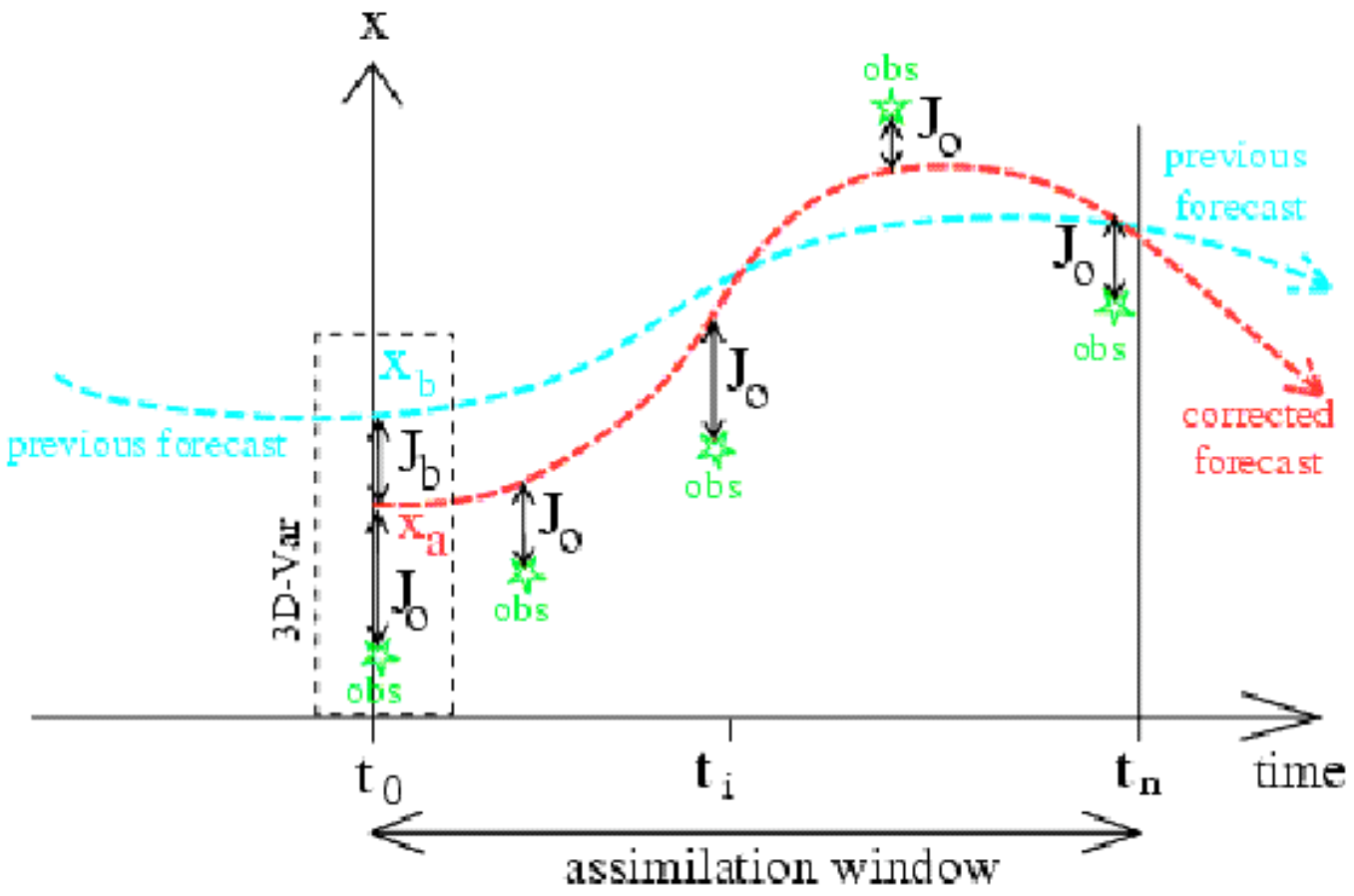
3- and 4-D variational assimilation

J_b measures the distance between the analysis and a background field

J_o measures the distance between the analysis and the observations

The minimum of J_b+ J_o is our analysis

$$J = J_b + J_o = \tfrac{1}{2}\left(\mathbf{x}-\mathbf{x}_b\right)^T \mathbf{B}^{-1}\left(\mathbf{x}-\mathbf{x}_b\right) + \tfrac{1}{2}\left(H\mathbf{x}-\mathbf{y}\right)^T \mathbf{R}^{-1}\left(H\mathbf{x}-\mathbf{y}\right)$$


x
obs
J_o
previous forecast
J_o
obs
x_b
previous forecast
J_b
J_o
obs
corrected forecast
x_a
J_o
obs
3D-Var
obs
t_0
t_i
t_n
time
assimilation window

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The moisture problem

Difficult quantity

- Large variations
- Small scale

Until now very few observations

- Radiosondes
- Very sparse coverage both spatially and temporally

Poor initialisation

- 2- or 3-D interpolation
- No feedback to pressure or wind fields

Many tuning parameters in the model

- The model is not ready for the new amounts of data
- New moisture information is wiped out by the dynamics

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Solutions to the moisture problem

Better initialisation

- …with feedback to (and from) other model variables

A new control variable for moisture

- Normalised relative humidity
- Gaussian error structure (but not at extremes)
- Results in removal of tuning parameters

4D-Var

- Better constructed from the start

Understanding the measurements

- Often complicated error characteristics
- Non-linear processes and errors
- Small scale

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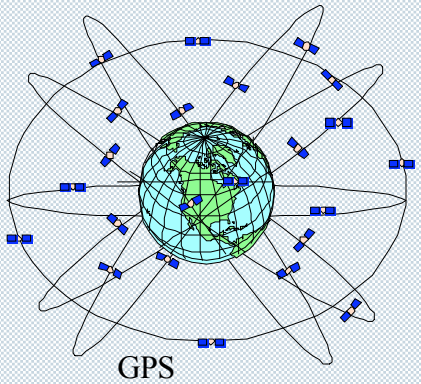
GPS moisture assimilation

"One person's noise is another person's signal"

Ground based GPS

Advantages:

- High resolution
- 55 to 60 stations every 15 minutes
- All weather, all the time
- Very cheap

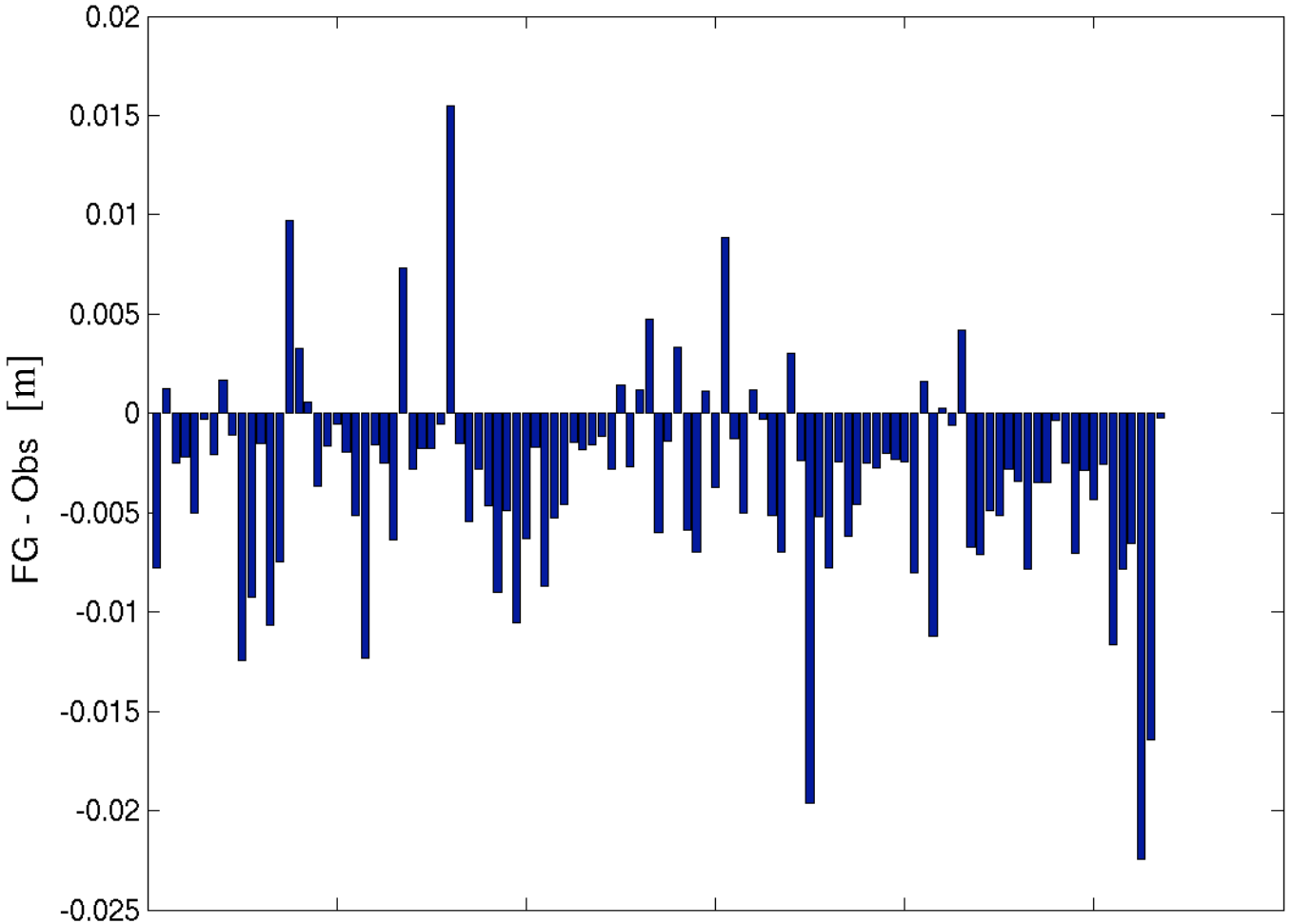


Disadvantages:

- Only columnar water vapour
- There is be a bias and correlated errors

First guess (6h forecast) – Observation

Average over 4 days



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Bias correction

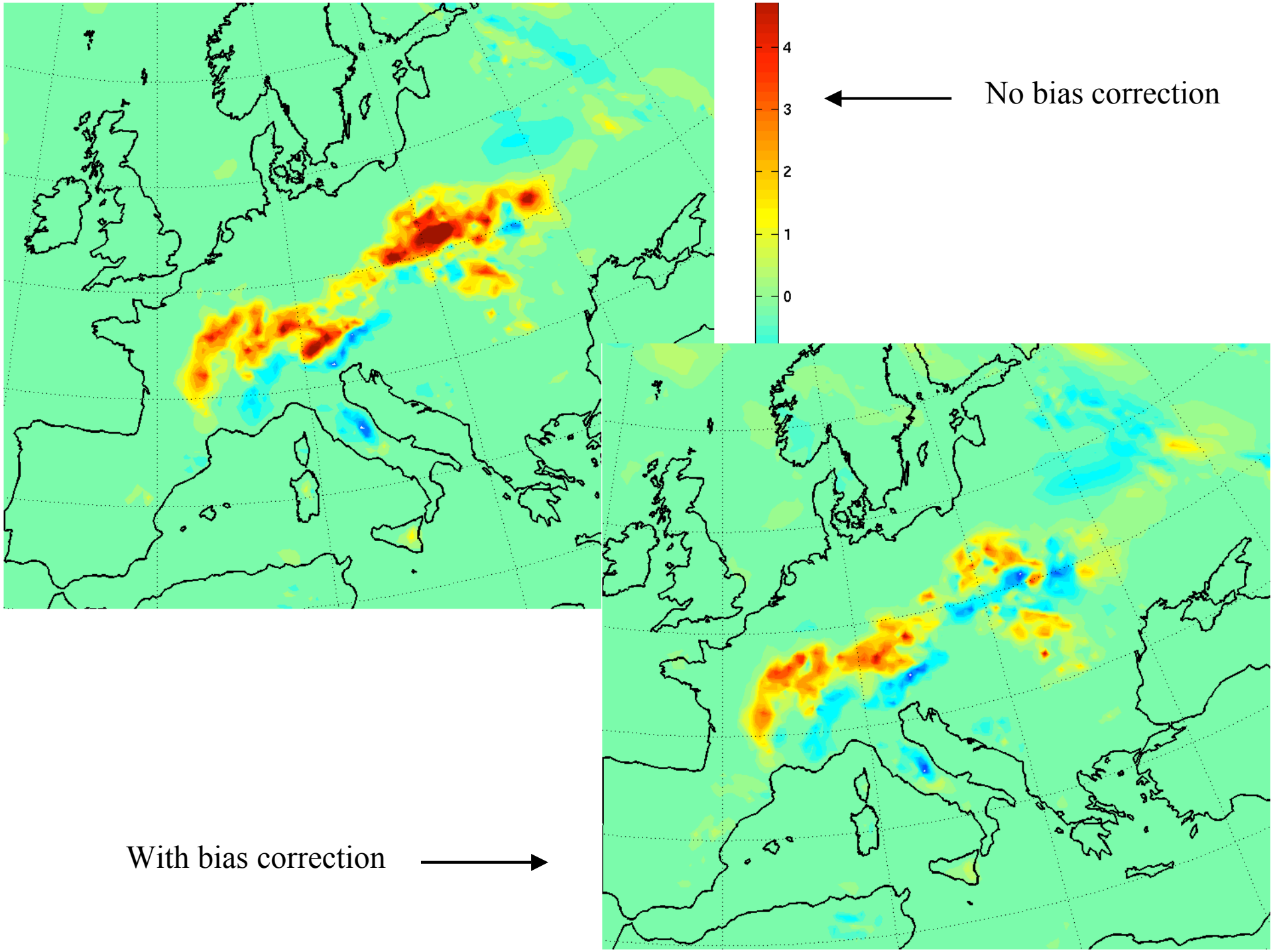
What causes the bias?

- Different software
- Other differences in the processing, cut off angles…
- Antenna position and surroundings
- NWP model

Until we know it must be the modelled

Many different correction approaches

- Diurnal cycles
- Monthly means
- Slowly varying stochastic error
- …


4
3
2
1
0
No bias correction
With bias correction

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The observation operator - H

Calculates a model equivalent of the observed quantity

- Transformation from spectral- to grid point space
- Vertical and horizontal interpolation to the observation point

In our case: A model ZTD at the station position

- ZHD from the ground pressure
- ZWD through integrated water vapour
- ZTD = ZHD + ZWD

The goal is to assimilate as raw data as possible

- Rinex data?

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Error structures of the model – the B matrix

Determines how an observation is spatially distributed

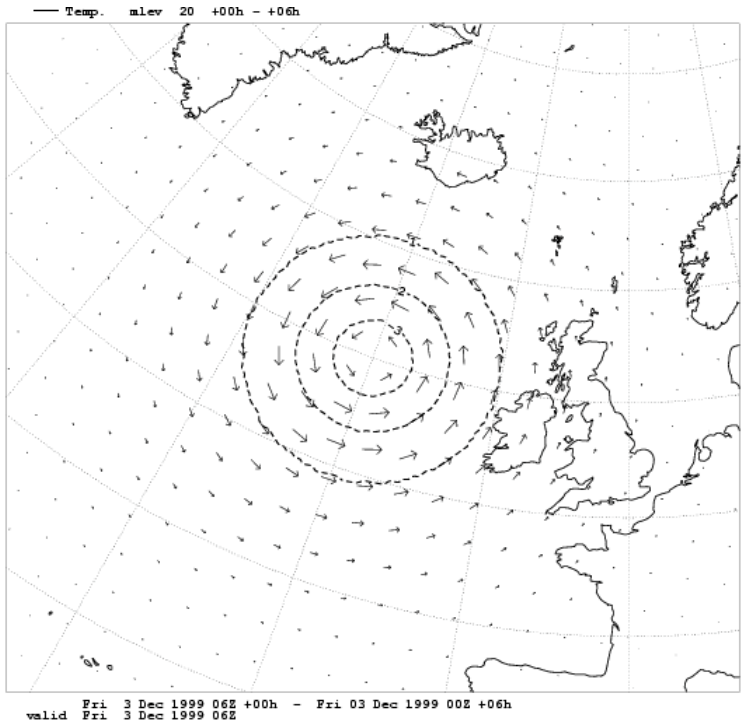
- Balance of the mass- and temperature fields
- Often assumed isotropic and homogeneous

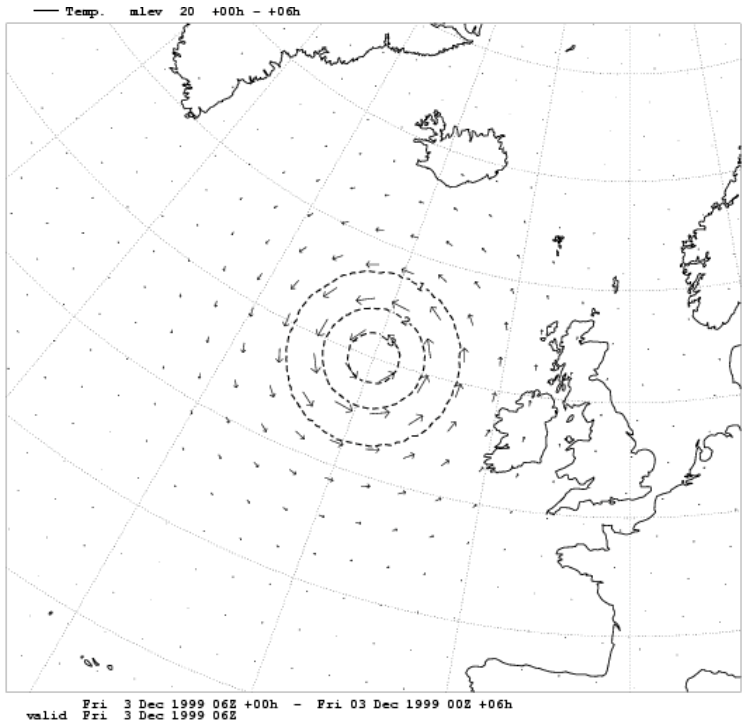
The NMC-method

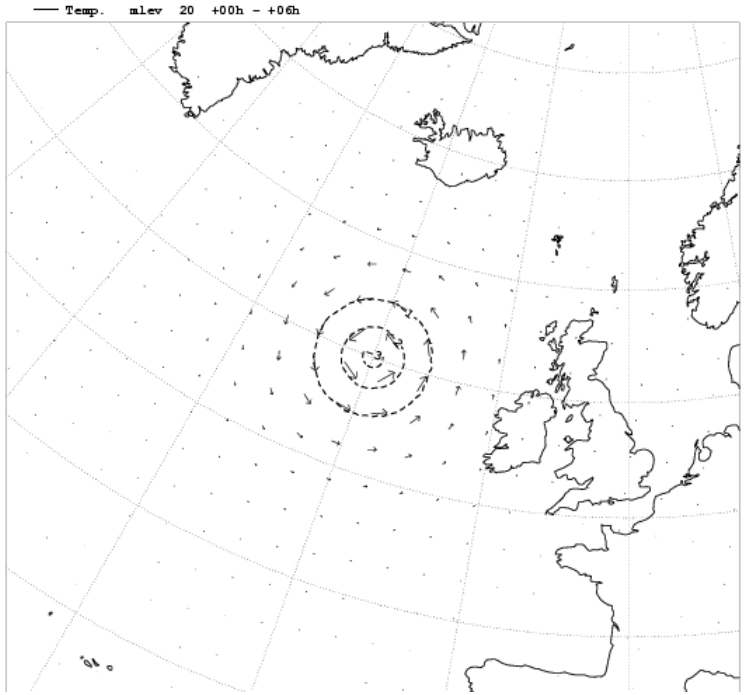
- 48-24 h forecast (valid at the same time)
- Originally a “temporary solution”
- Test with 36-18 h forecast
- Different resolutions (44, 33, 22 km)

Ensemble assimilation

- A number of 6 h forecasts with different initial conditions
- Observation are perturbed randomly
- Perturbed boundaries from a similar exp. at ECMWF
- Will resolve shorter length scales (to avoid representation errors)







Operational NMC method (44 km)

NMC method 22 km

Ensemble assimilation 22 km

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Error struct. of the measurements – the R matrix

The true ZTD error is not known

- Only “formal” errors from the processing
- Observation errors must be assumed or estimated

Correlated errors makes the matrix non-diagonal

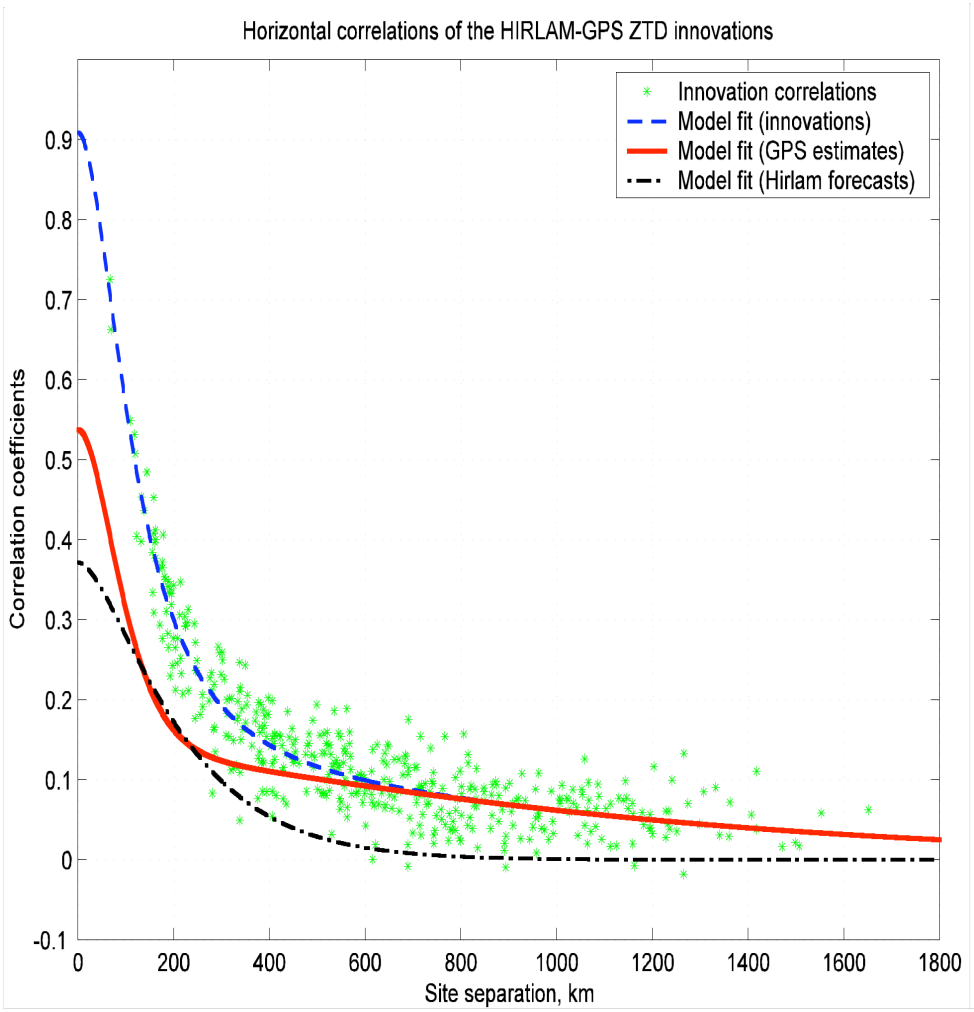
- Very costly to invert
- Needs to be rewritten and/or transformed

ZTD spatial error correlation model

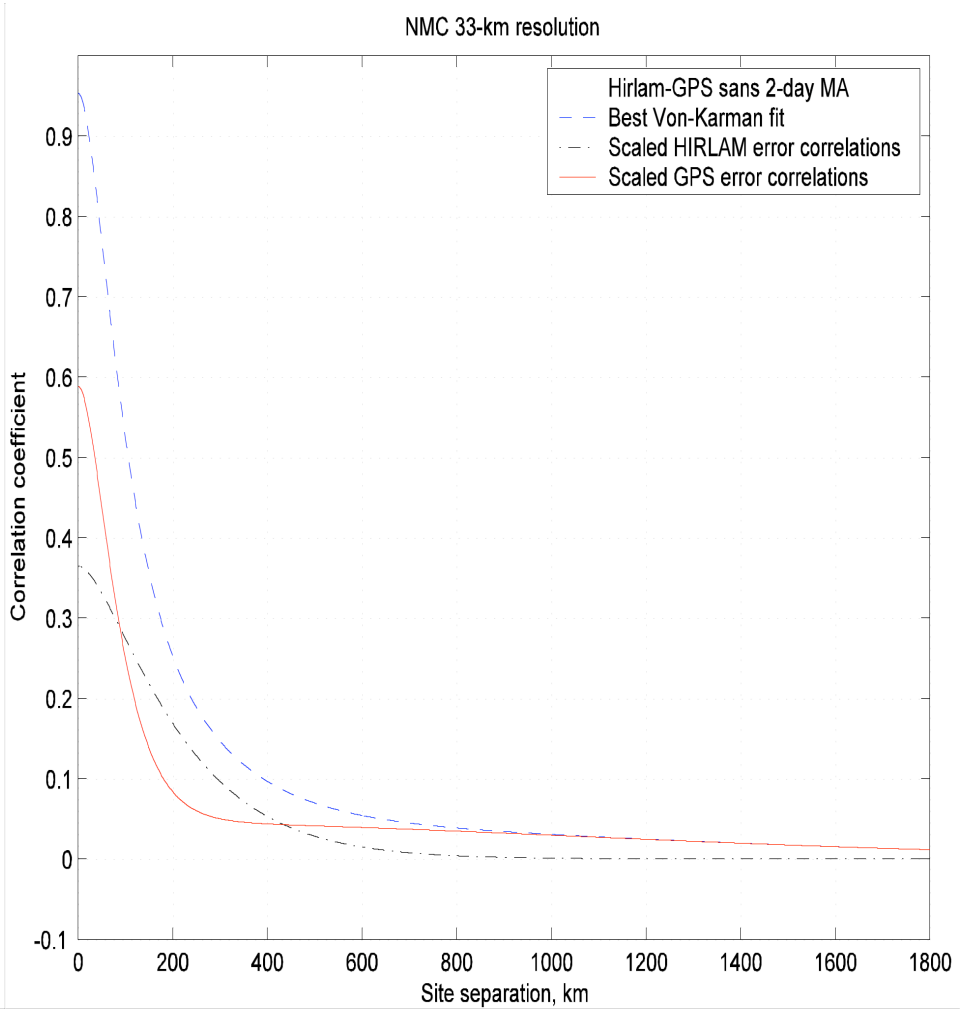
- Derived using other observations
- Derived from model – observation differences
- The effect of the bias correction

Spatial correlation functions for ZTD (fg-obs) using the NMC-method (33 km)

Uncorrected data



Bias corrected data



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The assimilation sequence

The ZTD data is processed before entering the model

- E.g. hourly means
- A first quality control (or blacklist)

Preprocessing

- Data screening (quality control)
- Bias reduction

Observation operator

- Calculates ground pressure at the observation location
- Model profiles are adjusted to correct height
- A model ZTD is calculated

The minimisation

- Calculate residuals: $Hx_b - y$
- Variational quality control
- Various transforms and normalisations
- The adjoint calculations is applied to get the model state variables

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Summary

Moisture is a difficult quantity to assimilate

- Historically very few observations
- Large variation

The bias problem

- What is the cause of the bias?
- How can we eliminate it as early as possible?

Observation operator

- We want to assimilate as raw data as possible
- Process the ZTD data in the obs. operator?

Error structures

- Model structure functions
- Observation error correlations