ITRF-scaled real-time broadcast corrections in regional datum

Lennard Huisman, Kadaster

Peter Teunissen, Curtin University

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Paris, France

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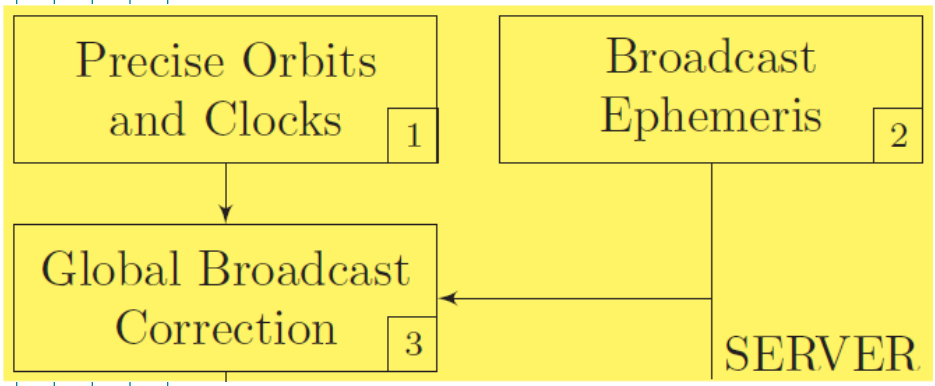
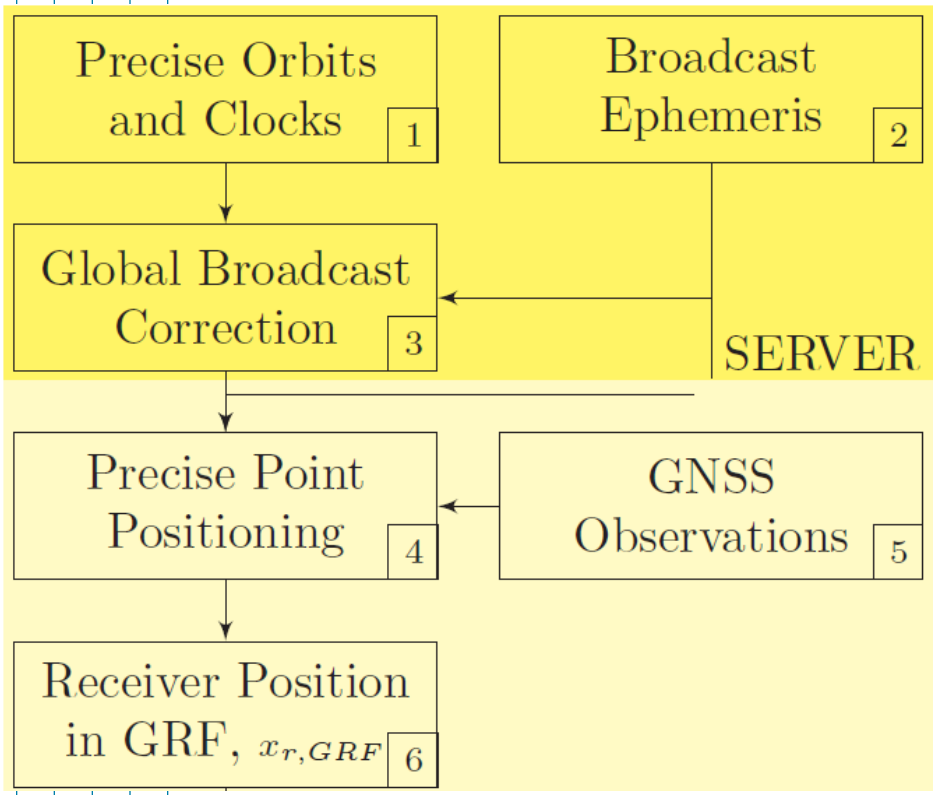
Outline

- Clock and Orbit corrections
- Global and Regional corrections
- Positioning results using products
- Proposed improved approaches

Real-Time Clock and Orbit Corrections



Real-Time Clock and Orbit Corrections



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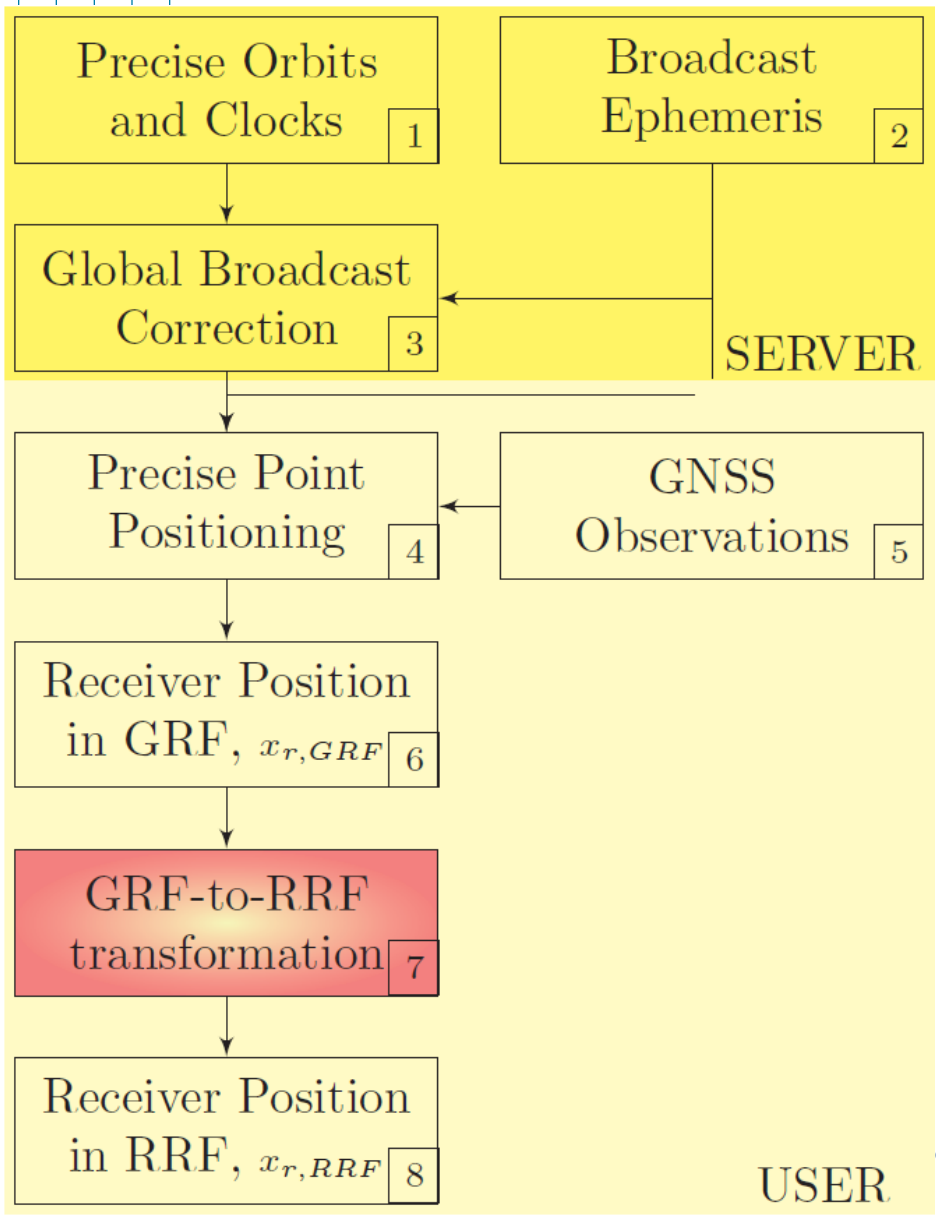
Real-Time Clock and Orbit Corrections



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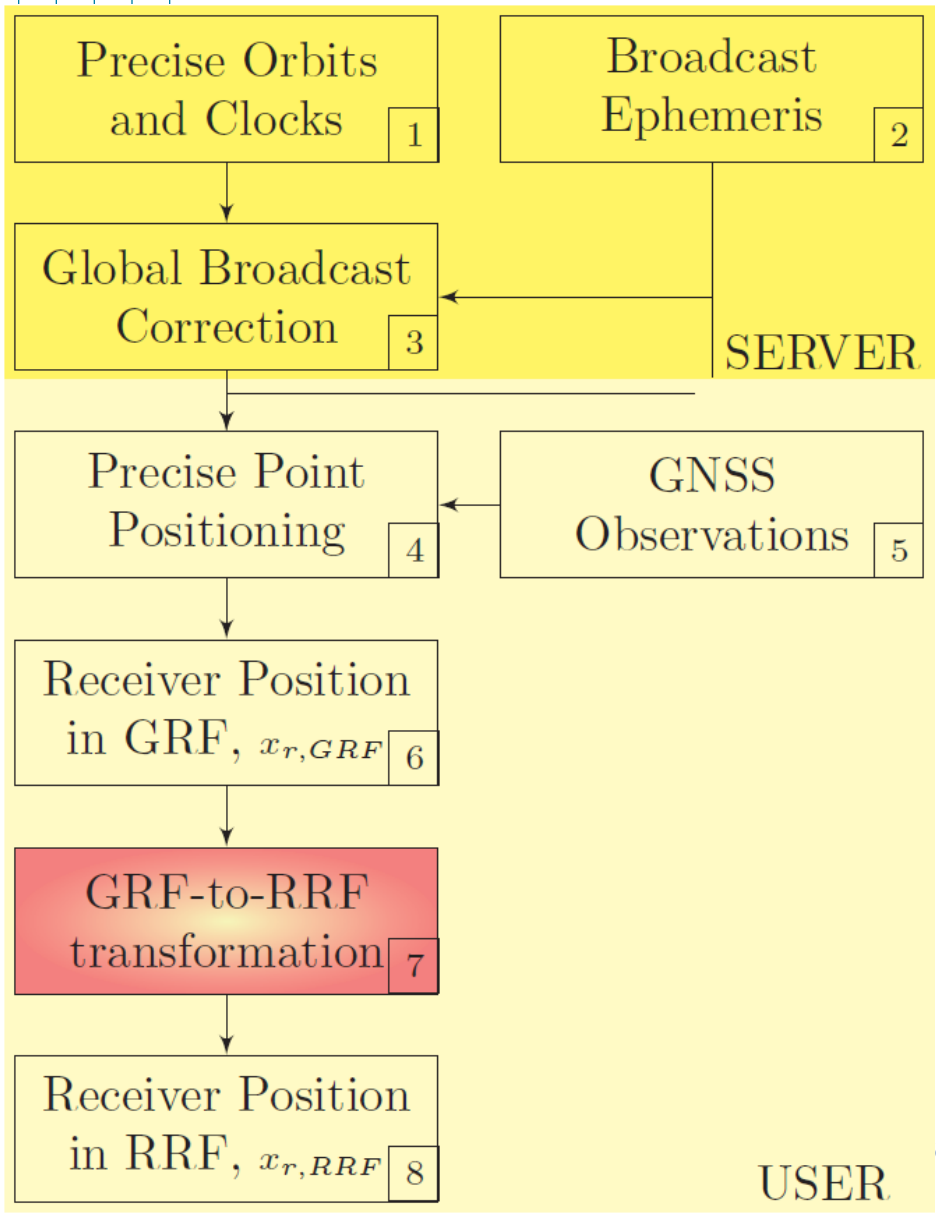
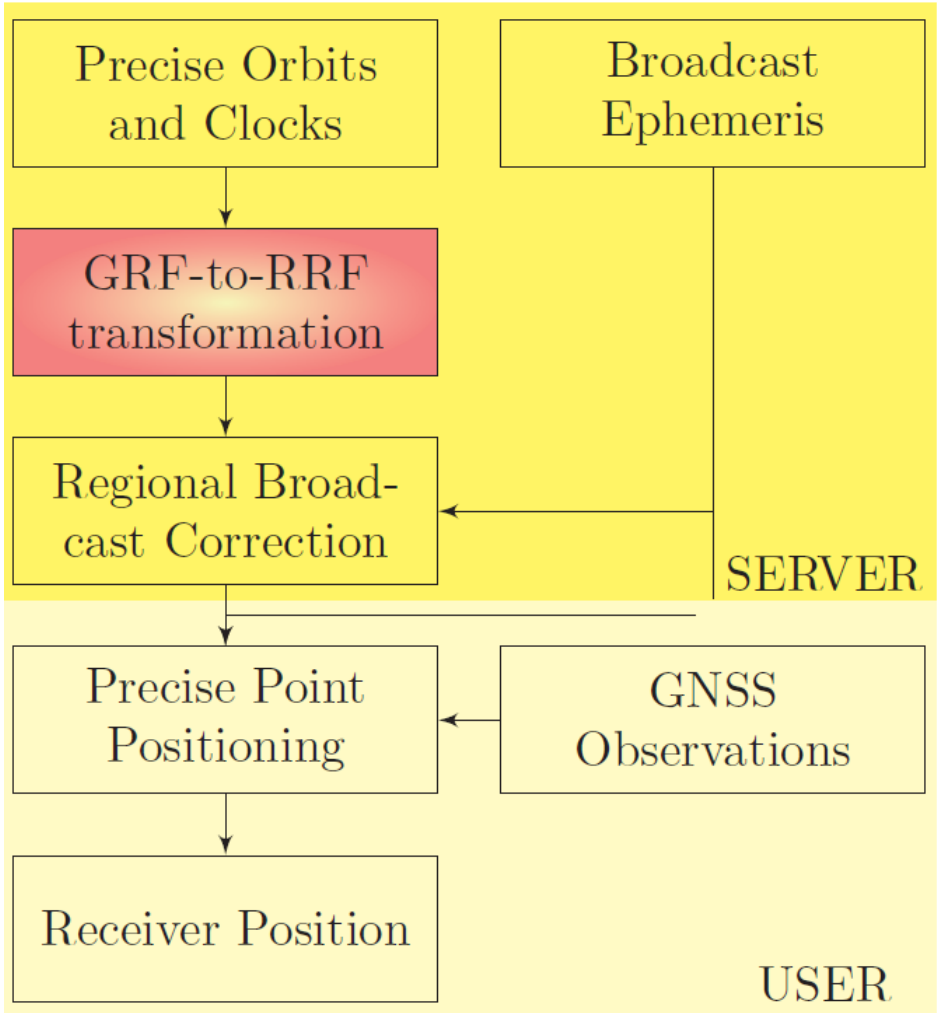
GBC



RBC



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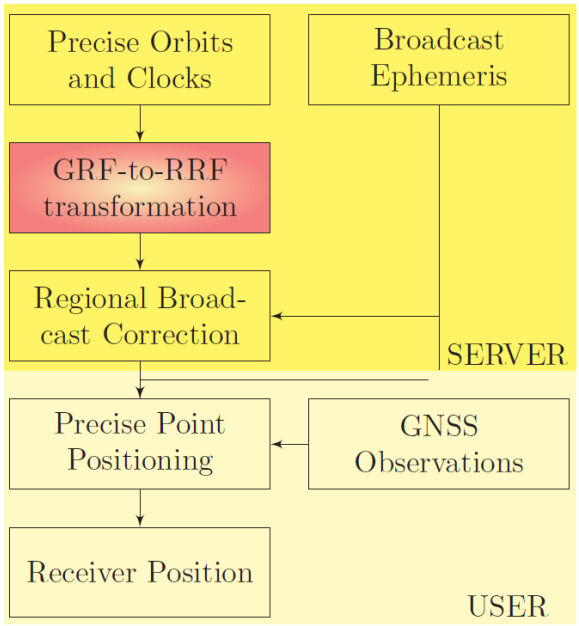
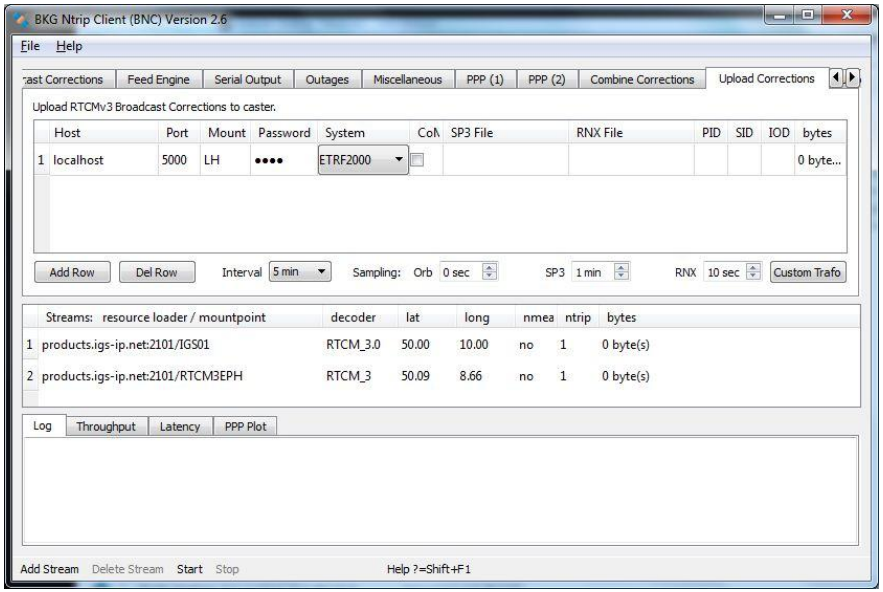
Case study – ETRS89



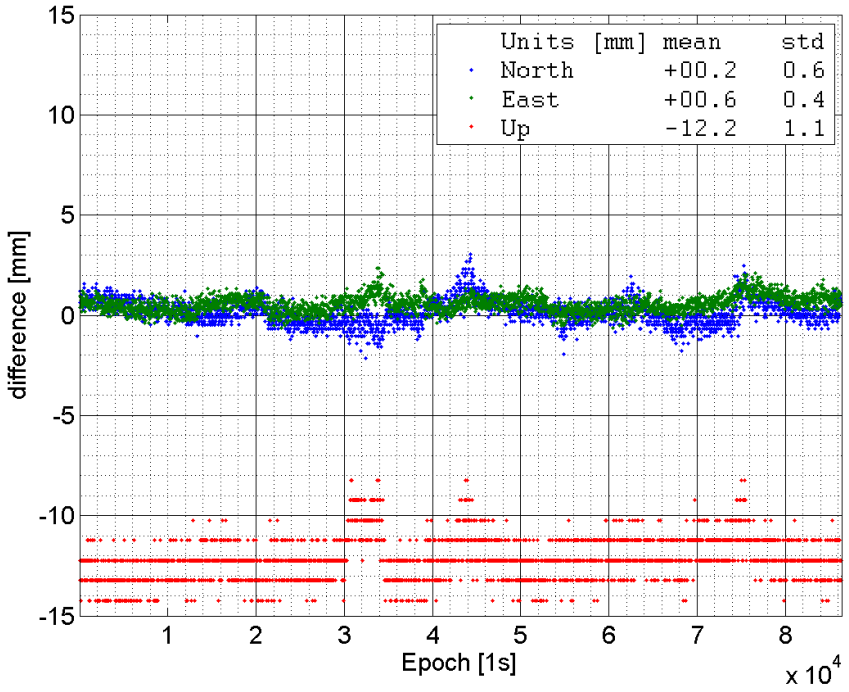


- Produced RBC in ETRF2000 using BNC 2.6 s/w and own Matlab implementation with IGS01 GBC as input
- Results shown for May 30th 2012, station WSRT, Netherlands

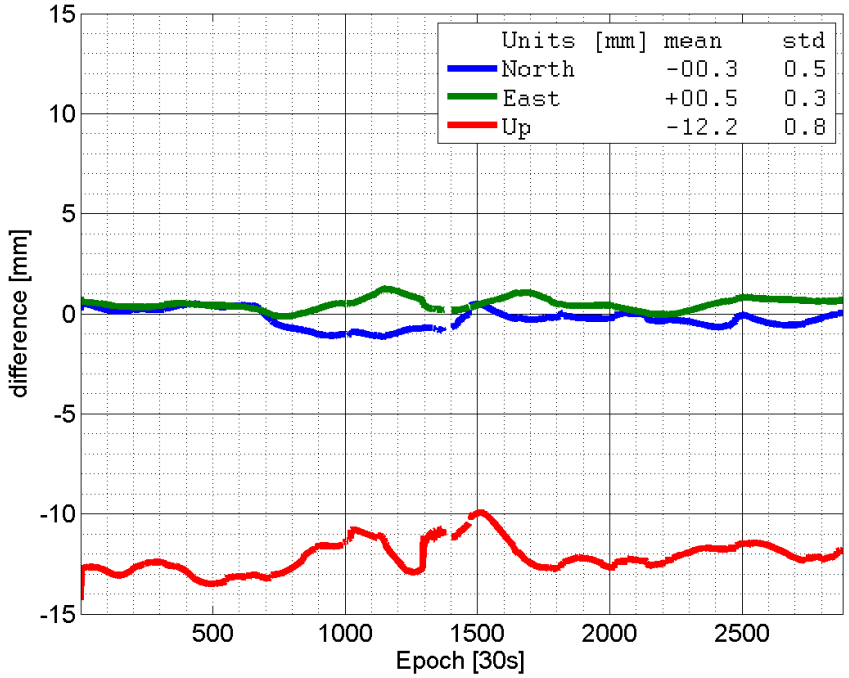
Case study – ETRS89

- Differences using GBC and RBC

SPP (BNC2.6)



SF-PPP (Matlab)



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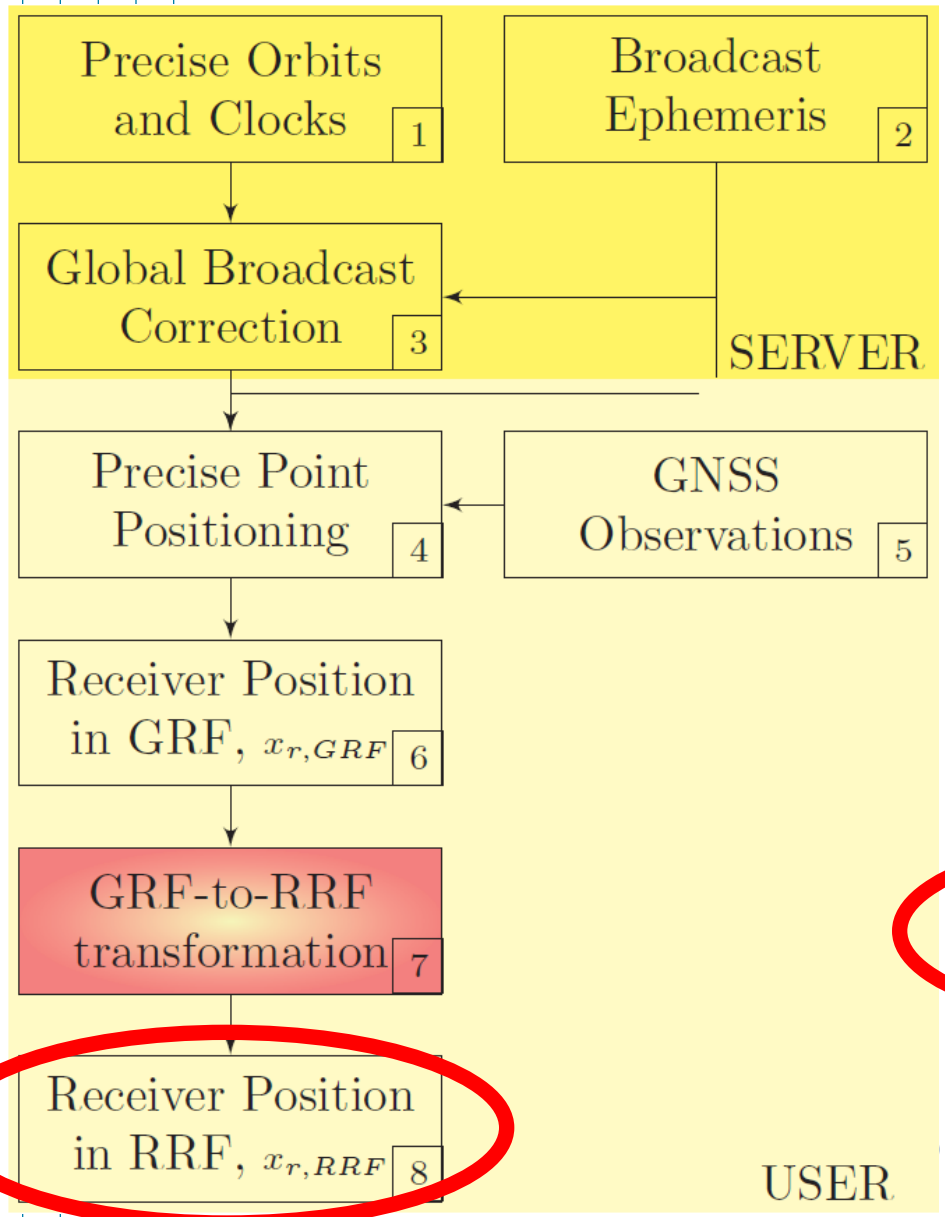
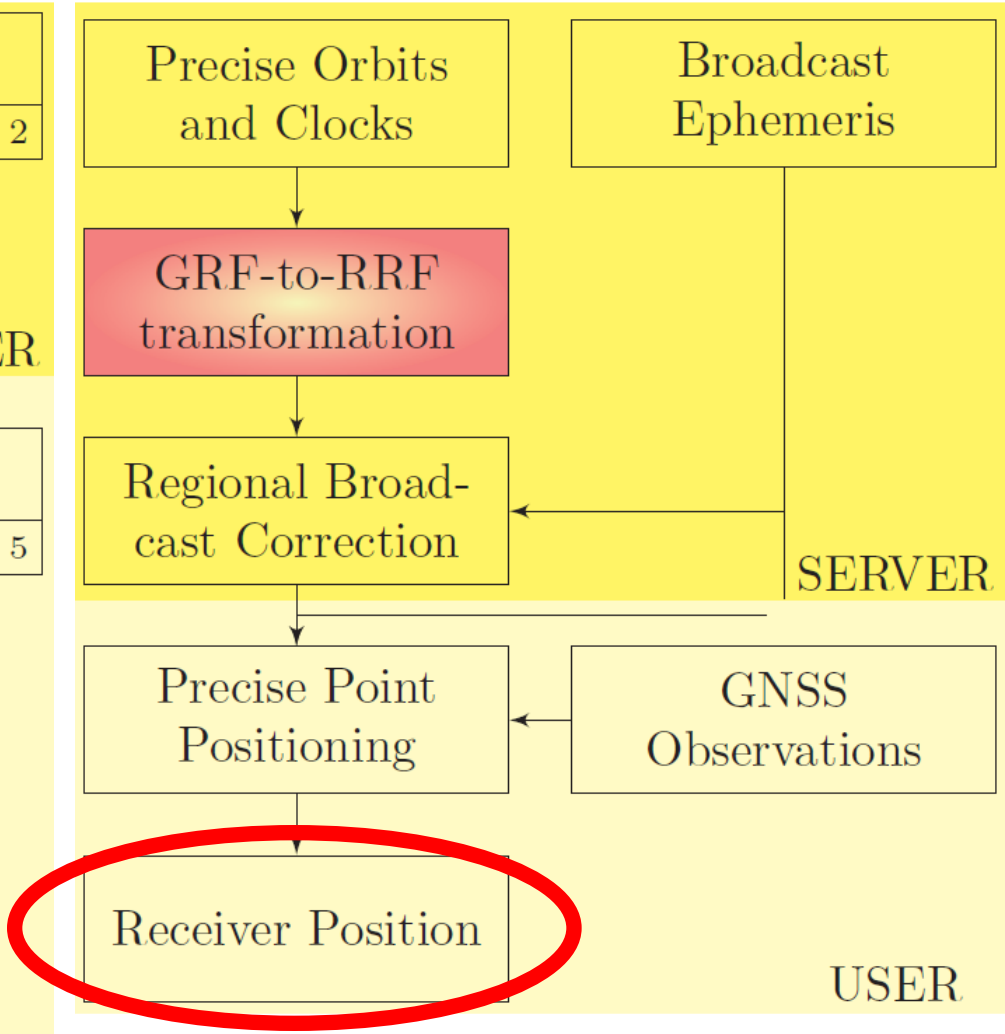
GBC



RBC



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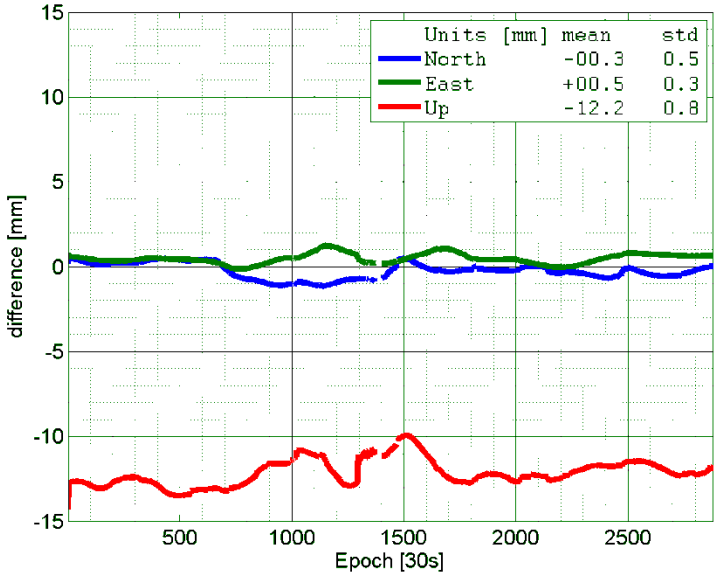
Observations have a different scale than the reference system

- Scale is main contributor
  - For ETRS89 at May30th 2012:
    - Scale = 1+ 2.333e-09
  - Effect on range of 20.000 km of ignoring scale in algorithm:
    - 0.047 meter
  - Effect on earth surface:
    - 0.015 meter
- Troposphere is second largest contributor, when ellipsoidal heights are used in a-priori ZTD computation



Scaling is main contributor

- Relation receiver-satellite range in GRF and RRF

$$\rho^s_{r,GRF} = \left\| x^s_{GRF} - x_{r,GRF} \right\|$$
$$= \frac{1}{\lambda} \left\| x^s_{RRF} - x_{r,RRF} \right\|$$
$$= \frac{1}{\lambda} \rho^s_{r,RRF}$$

- Parameters in red are affected

$$p^s_r = \rho^s_r - dt^s + dt_r + m^s_r \tau_r + I^s_{r,j}$$

$$\phi^s_r = \rho^s_r - dt^s + dt_r + m^s_r \tau_r - I^s_{r,j} + w_j M^s_{r,j}$$

Main conclusion of analysis

- Regional orbit corrections in ETRF2000, cause a location and time (geometry) dependent bias
- The bias is caused by the scale difference between ITRF and ETRF
- Bias is independent for positioning method (SPP / SF-PPP / DF-PPP (/ PPP-RTK?))

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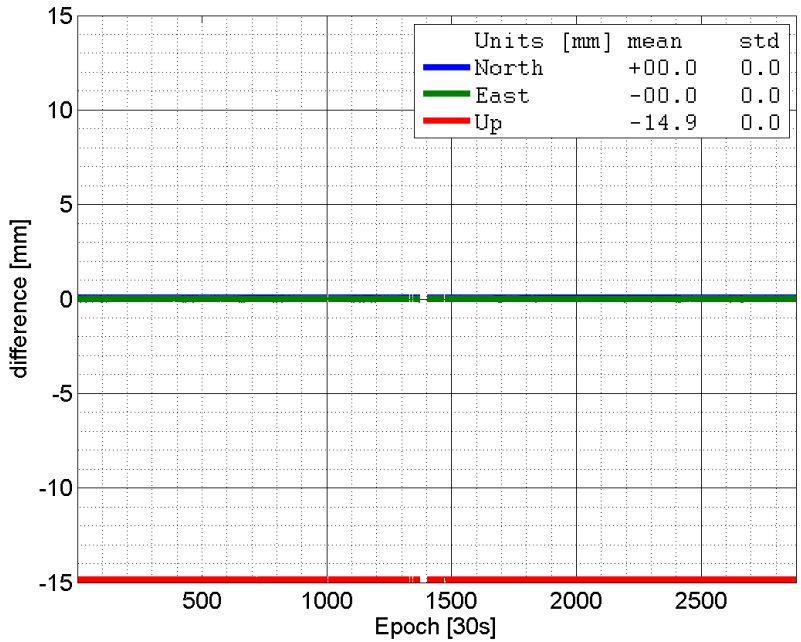
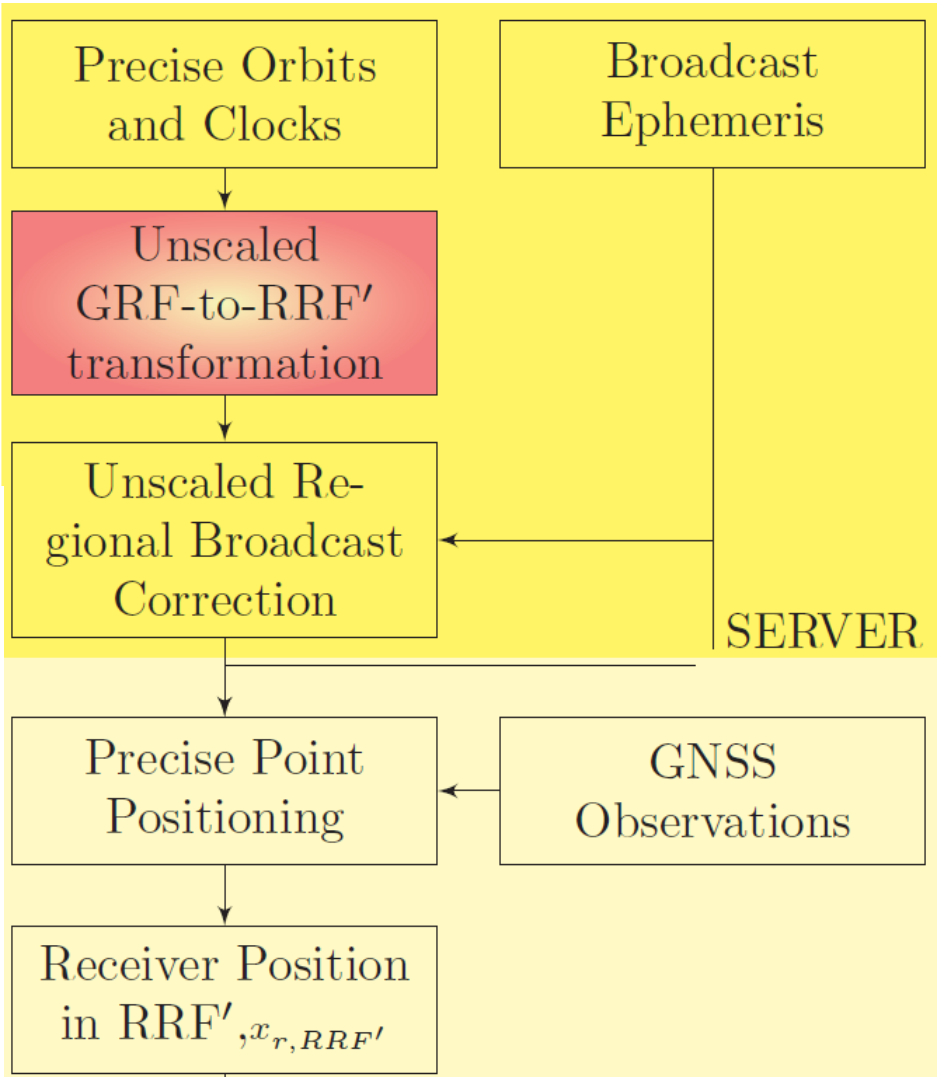
Observations have a different scale than the reference system

- How to deal with this without modifying PPP algorithm
  - Unscaled RBC
    - Ignore scale in transformation
  - ‘Scale-absorbed’ RBC
    - Adapt transformation parameters
- Both approaches allow for prediction of scale-induced error

Unscaled RBC

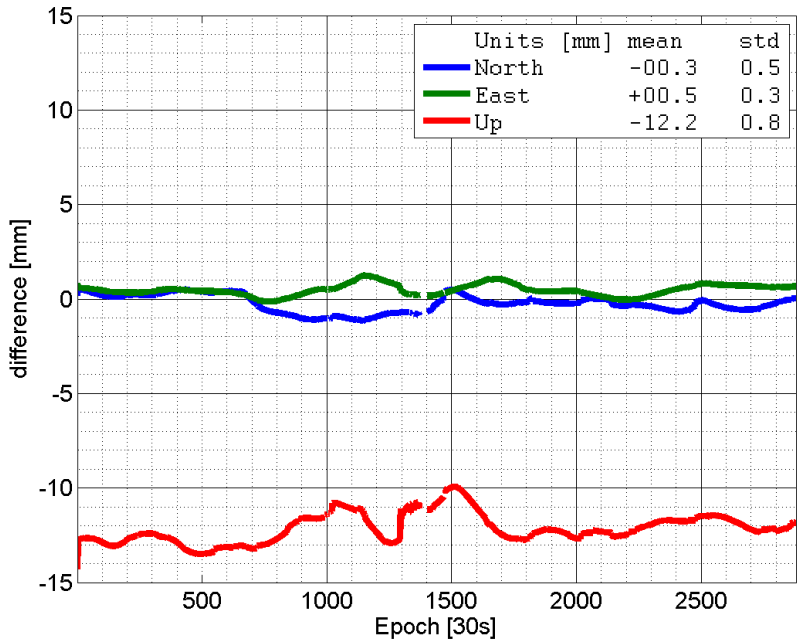
- Results

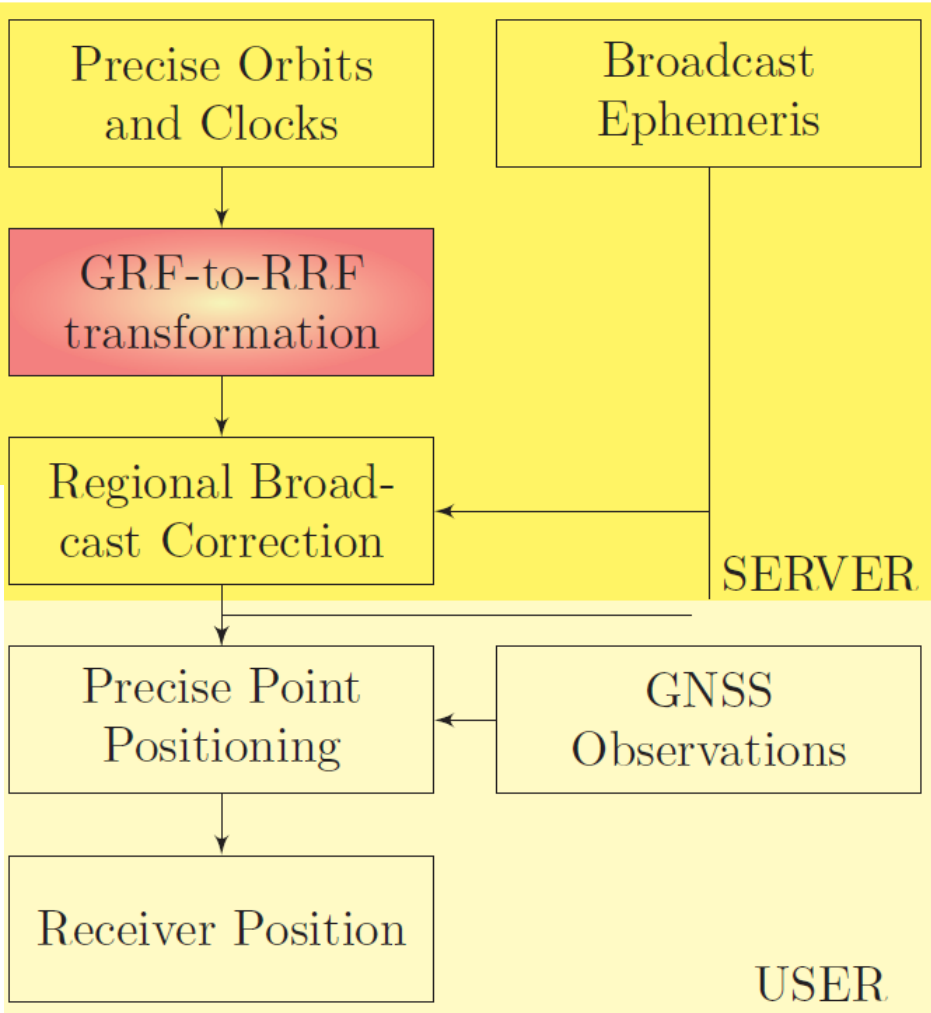




Existing RBC

- Results





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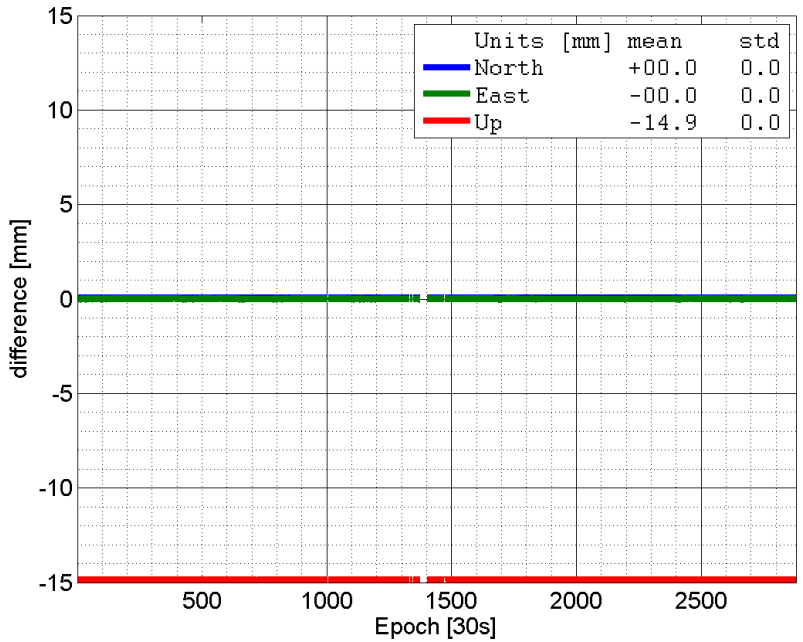
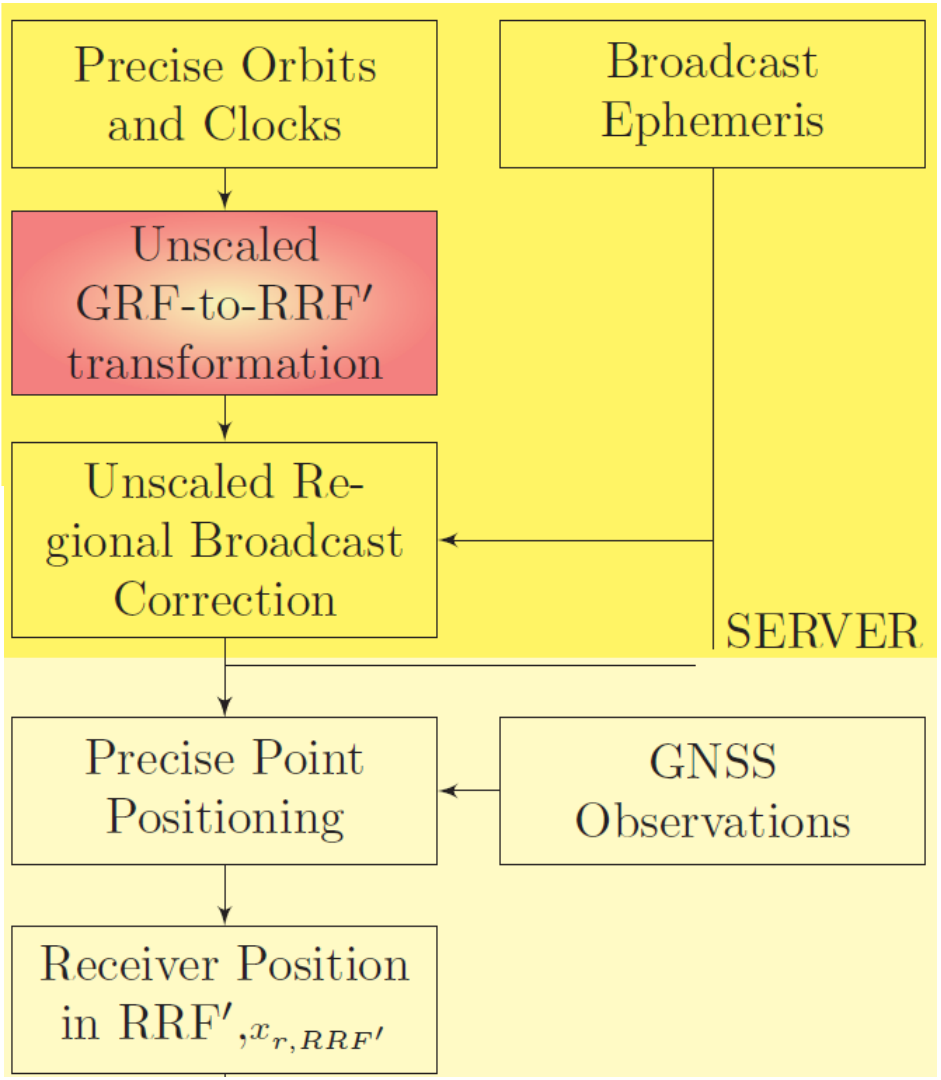
Unscaled RBC

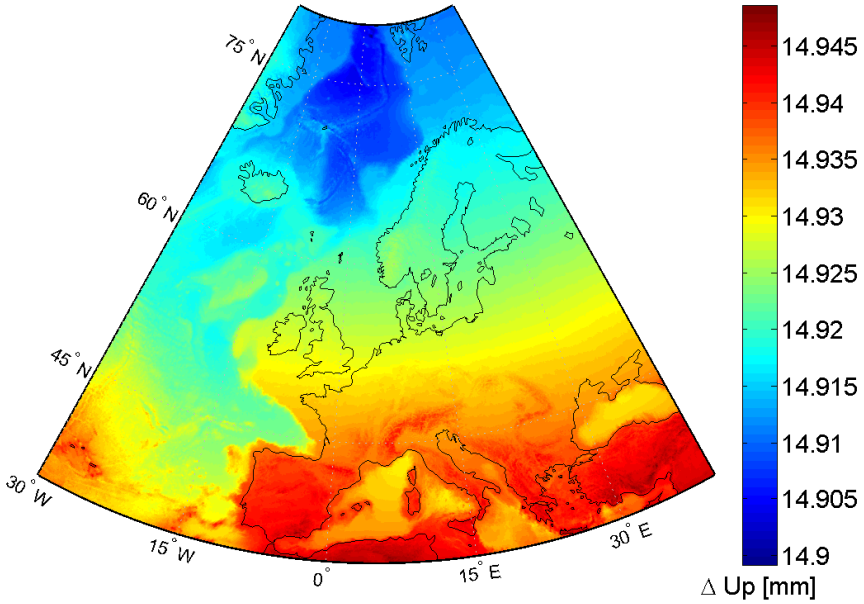
- Results

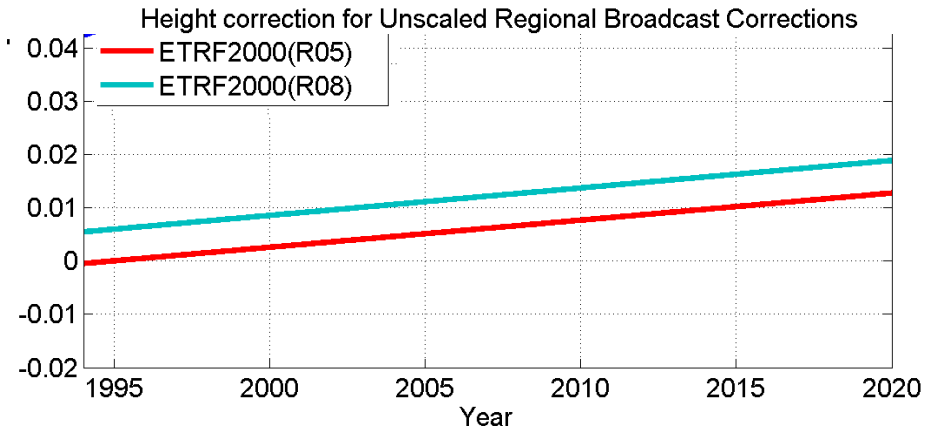




Unscaled RBC

- Prediction of scale-induced biases





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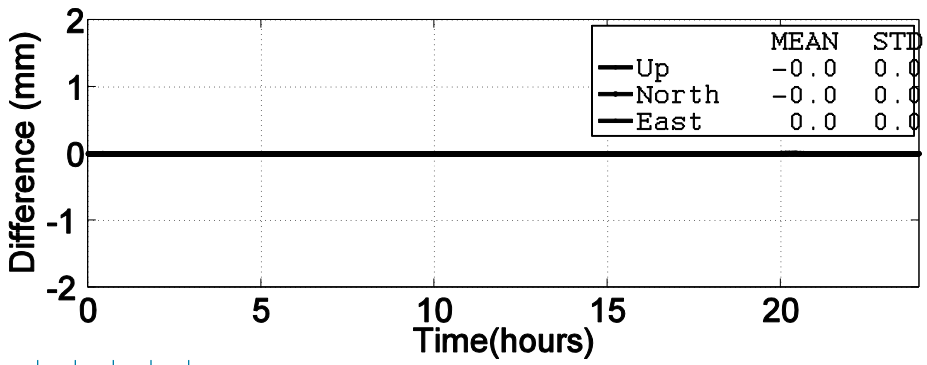
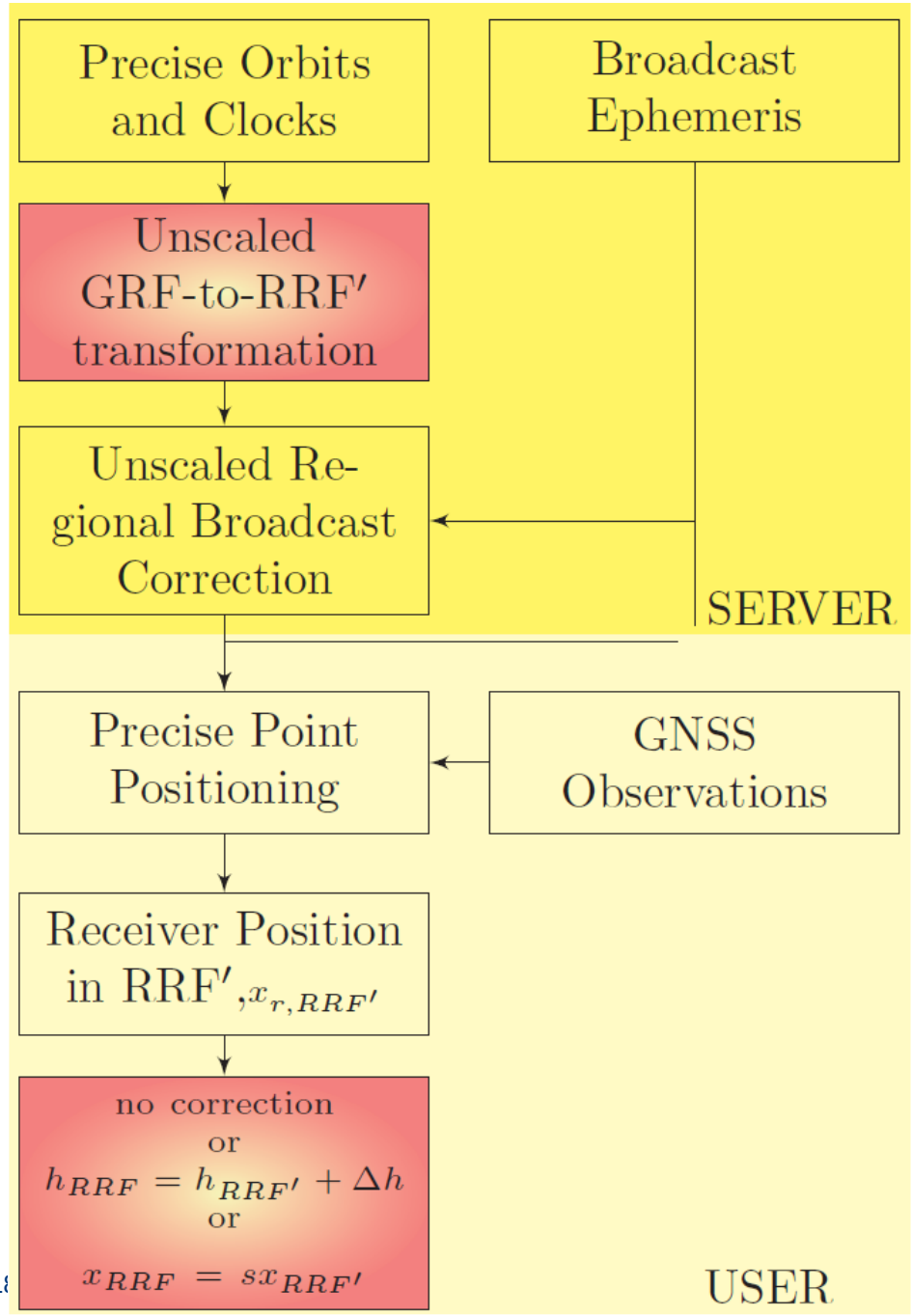
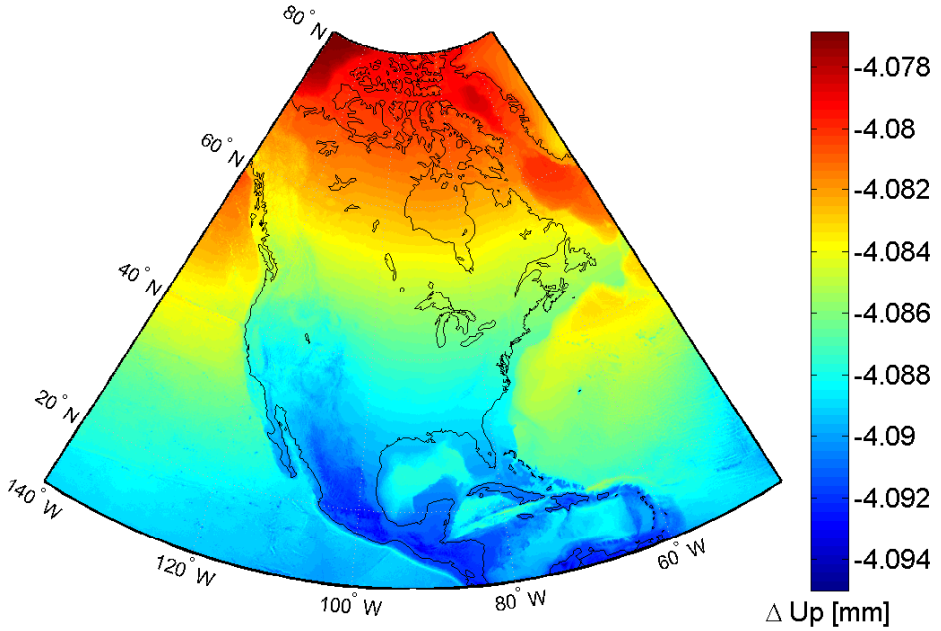
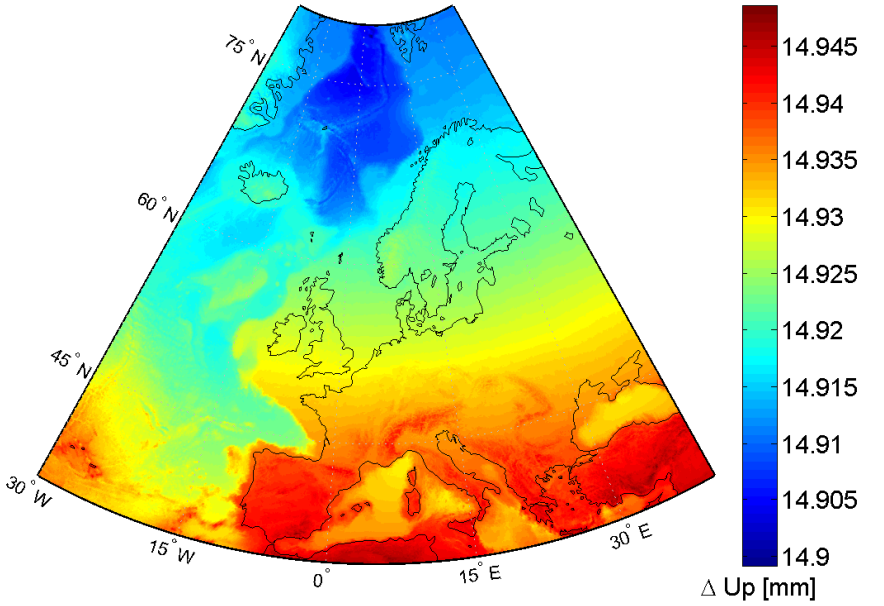
Unscaled RBC

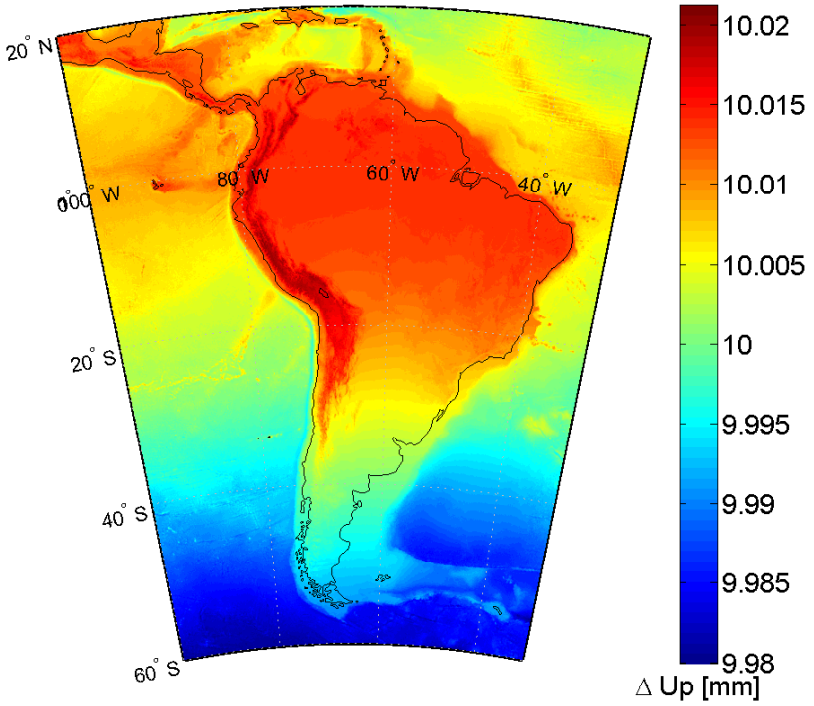
- Results

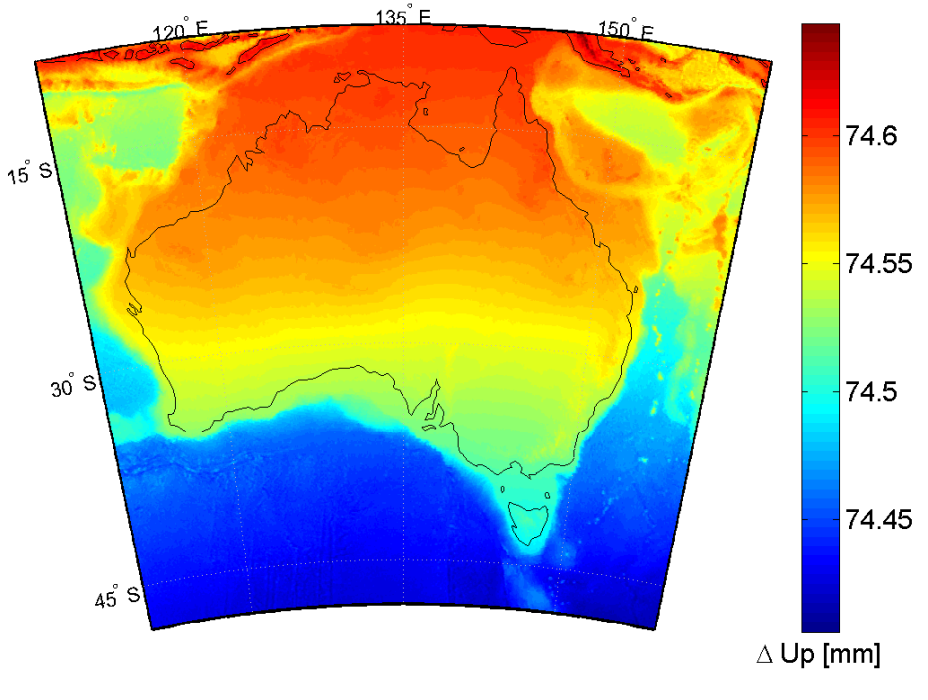





80° N
60° N
40° N
20° N
140° W
120° W
100° W
80° W
60° W
-4.078
-4.08
-4.082
-4.084
-4.086
-4.088
-4.09
-4.092
-4.094
Δ Up [mm]


75° N
60° N
45° N
30° W
15° W
0°
15° E
30° E
14.945
14.94
14.935
14.93
14.925
14.92
14.915
14.91
14.905
14.9
Δ Up [mm]


20° N
0°
80° W
60° W
40° W
20° S
40° S
60° S
10.02
10.015
10.01
10.005
10
9.995
9.99
9.985
9.98
Δ Up [mm]


120° E
135° E
150° E
15° S
30° S
45° S
74.6
74.55
74.5
74.45
Δ Up [mm]

Main conclusion Unscaled approach

- Leaving scale out of transformation causes location indepedent height bias only
- Height bias is at same level as varying bias caused by existing approach
- Advantage:
  - Bias can be computed for any epoch and any location, hence can be corrected if user does not want to ignore it

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‘Scale-absorbed’ transformation parameters

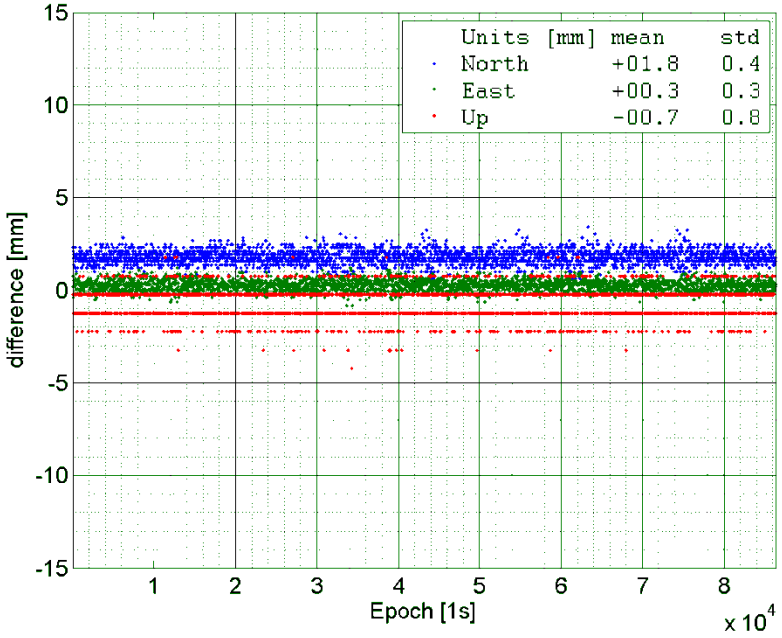
- Can we come-up with a transformation that minimizes the scale-induced bias on the server side?

- Approach:
  - Grid of points covering the region to which the RRF applies
  - Estimate a 6-parameter (3x translation, 3x rotation, NO scale) transformation between the GRF and the RRF

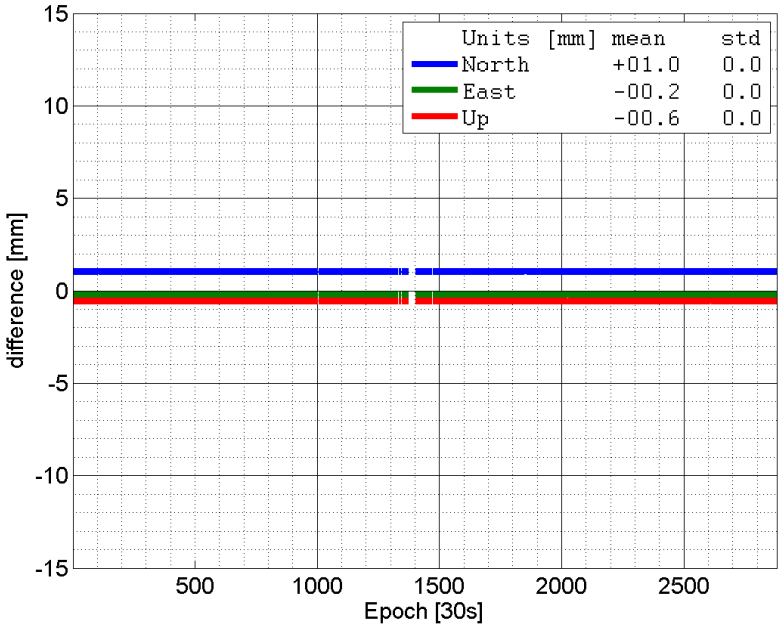
‘Scale-absorbed’ transformation parameters

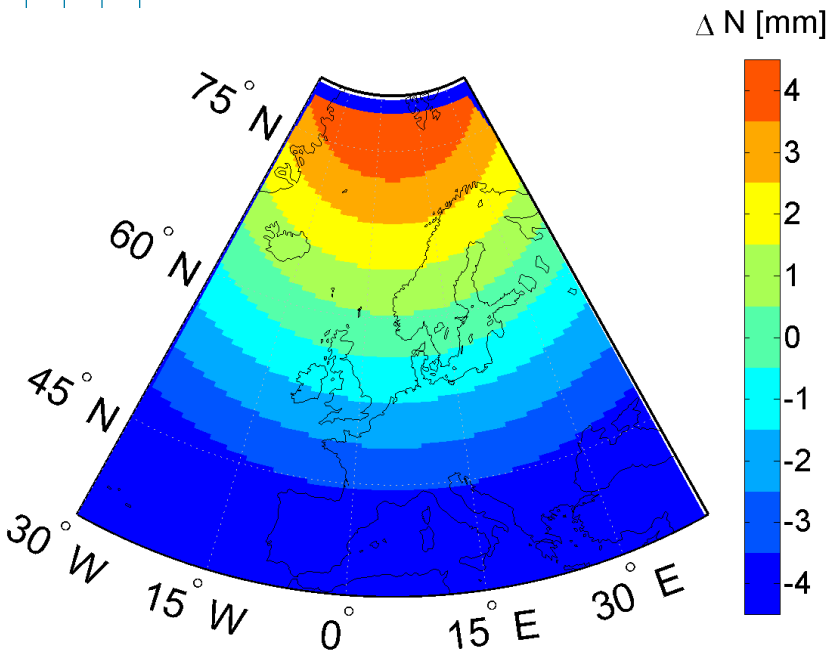
- Results

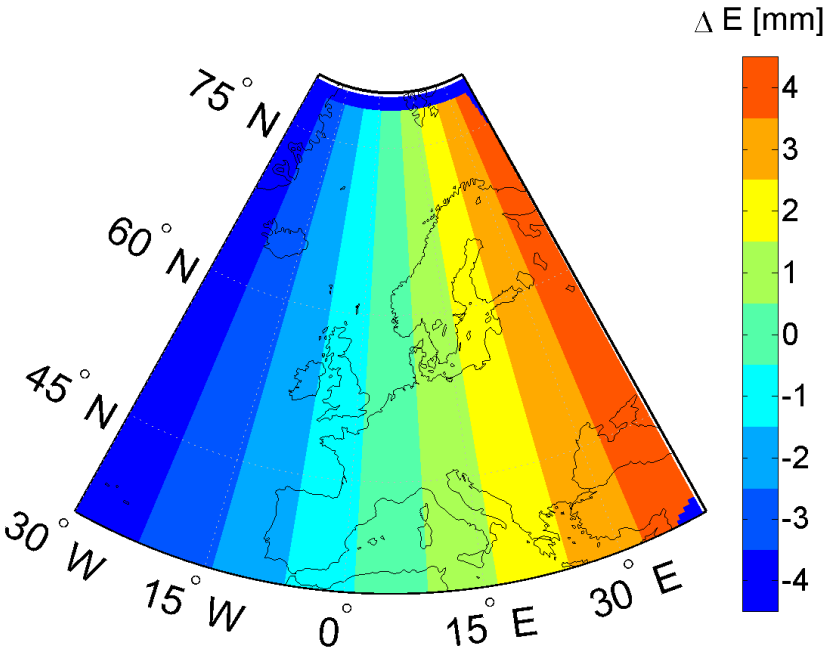
SPP (BNC2.6)

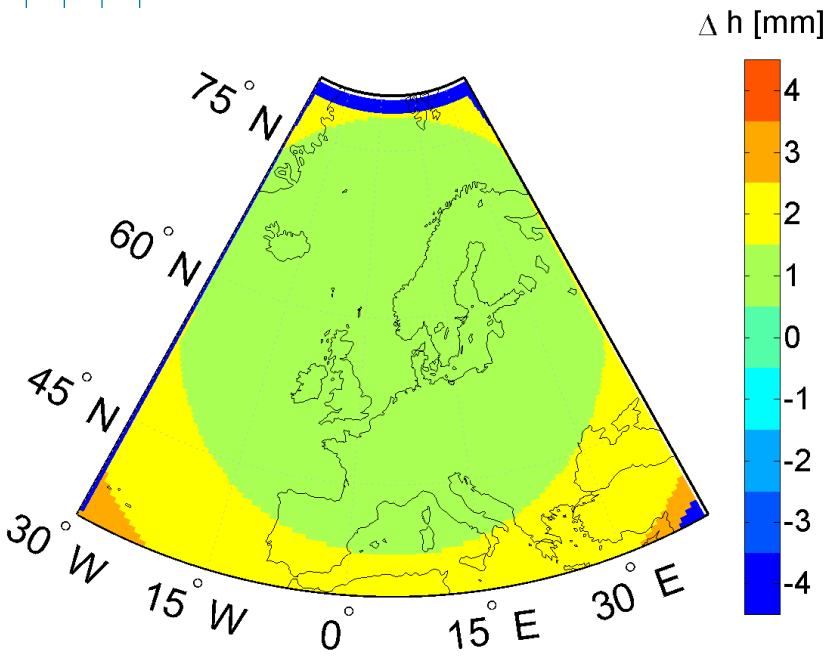


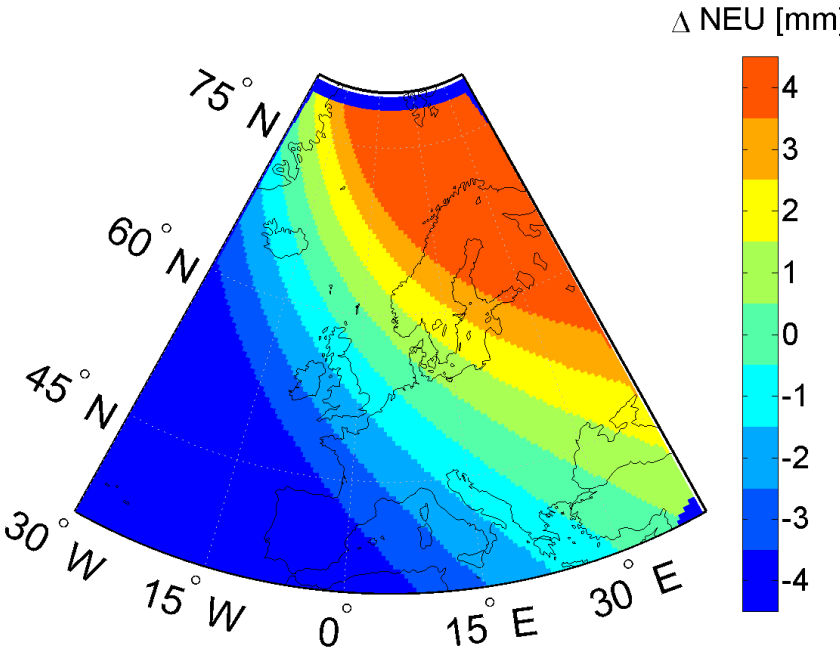
SF-PPP (Matlab)

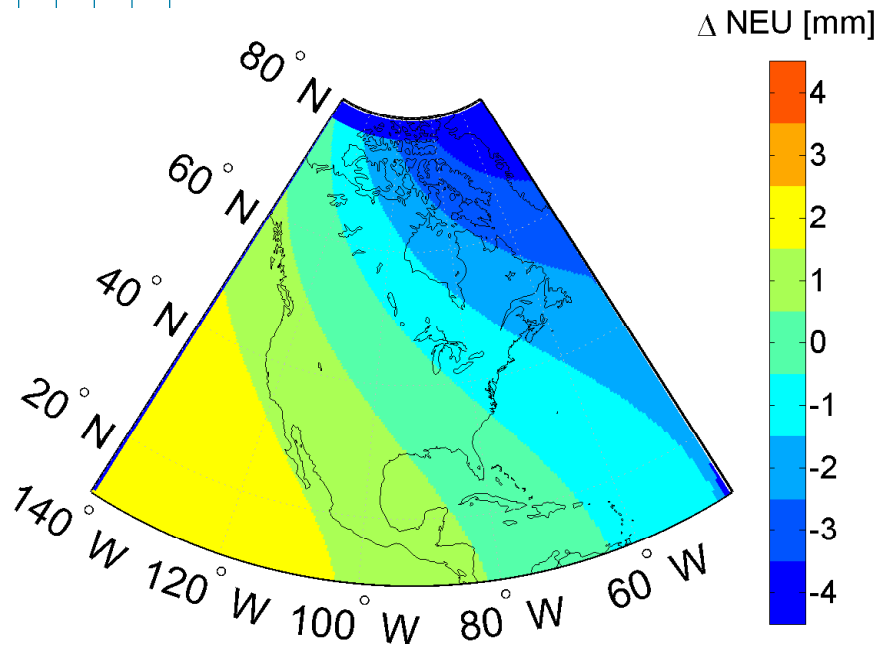


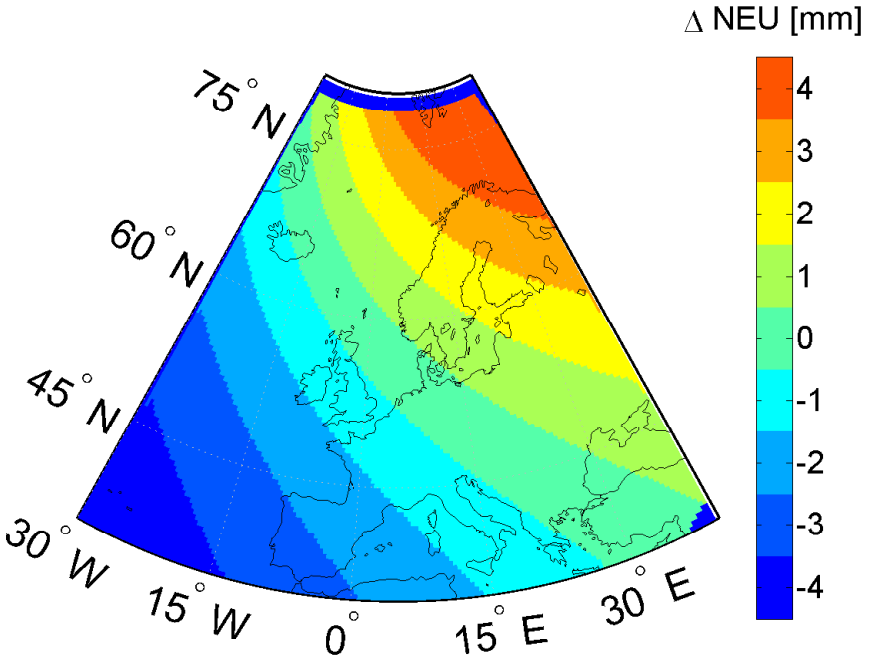

Δ N [mm]
75° N
60° N
45° N
30° W
15° W
0°
15° E
30° E
4
3
2
1
0
-1
-2
-3
-4

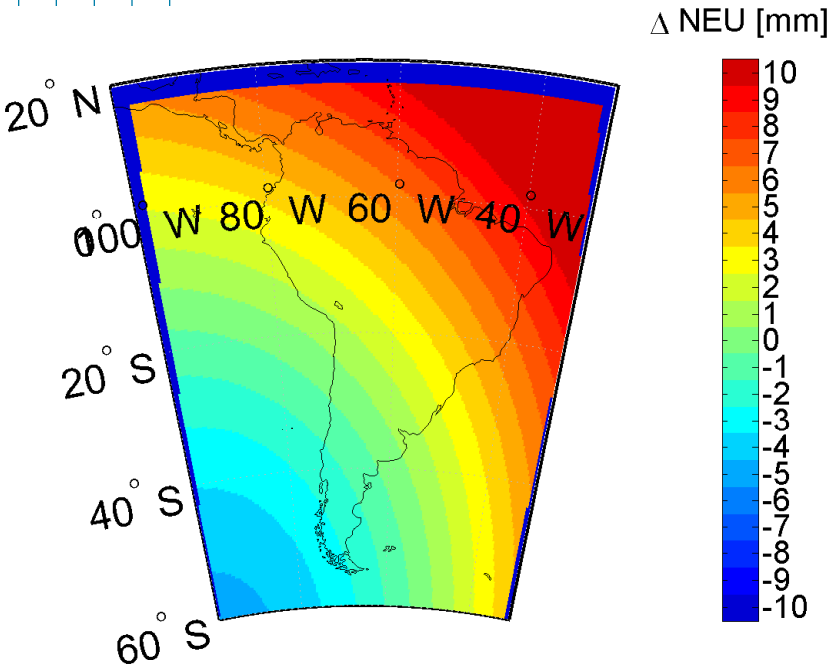

Δ E [mm]
75° N
60° N
45° N
30° W
15° W
0°
15° E
30° E
4
3
2
1
0
-1
-2
-3
-4

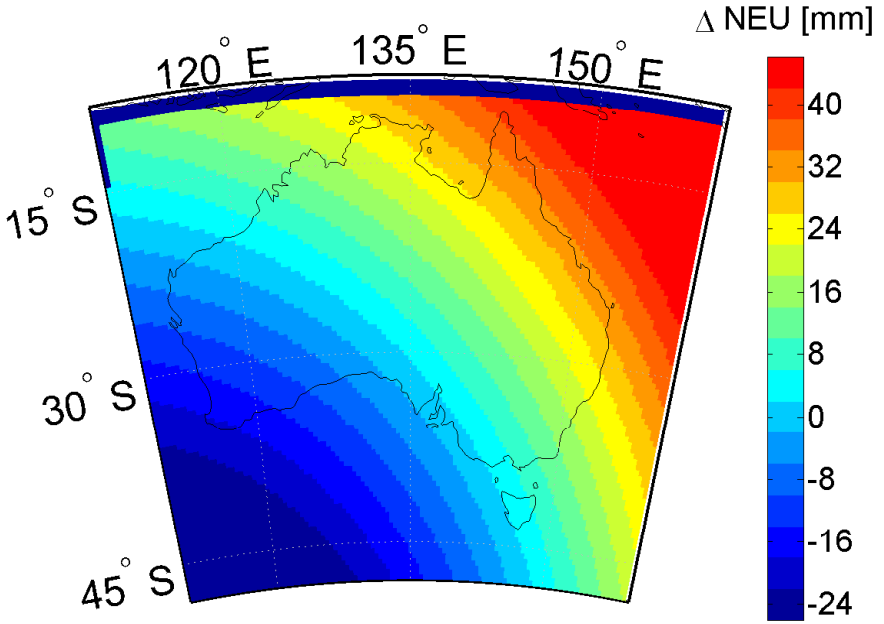

Δ h [mm]
75° N
60° N
45° N
30° W
15° W
0°
15° E
30° E
4
3
2
1
0
-1
-2
-3
-4


Δ NEU [mm]
75° N
60° N
45° N
30° W
15° W
0°
15° E
30° E
4
3
2
1
0
-1
-2
-3
-4


Δ NEU [mm]
80 ° N
60 ° N
40 ° N
20 ° N
140 ° W
120 ° W
100 ° W
80 ° W
60 ° W
4
3
2
1
0
-1
-2
-3
-4


Δ NEU [mm]
75 ° N
60 ° N
45 ° N
30 ° W
15 ° W
0 °
15 ° E
30 ° E
4
3
2
1
0
-1
-2
-3
-4


Δ NEU [mm]
20 ° N
0 °
100 ° W
80 ° W
60 ° W
40 ° W
20 ° S
40 ° S
60 ° S
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10


Δ NEU [mm]
120 ° E
135 ° E
150 ° E
15 ° S
30 ° S
45 ° S
40
32
24
16
8
0
-8
-16
-24

Main conclusions scale absorbed approach

- Computation of transformation between ITRF and ETRF without scale causes region dependent constant biases in all position components
- Bias small in central europe, larger at edges (upto 7 mm, current approach 14 mm)
- Bias can be computed a-priori, hence can be corrected if user does not want to ignore it

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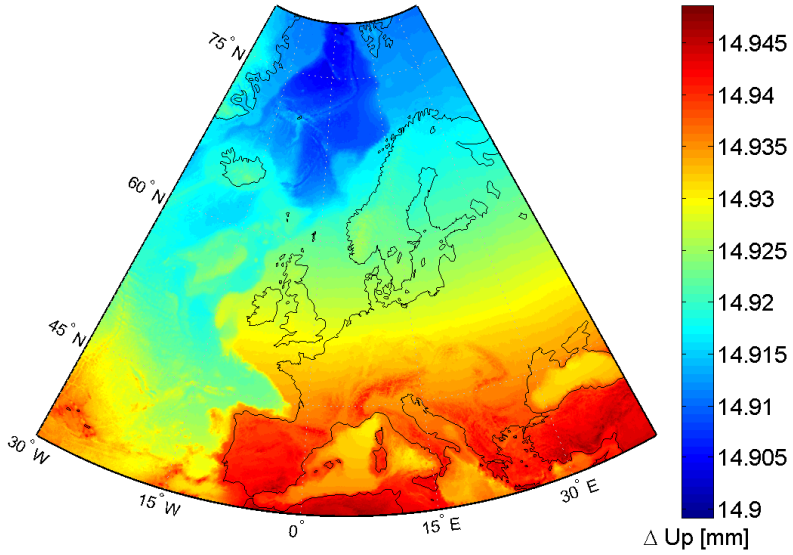
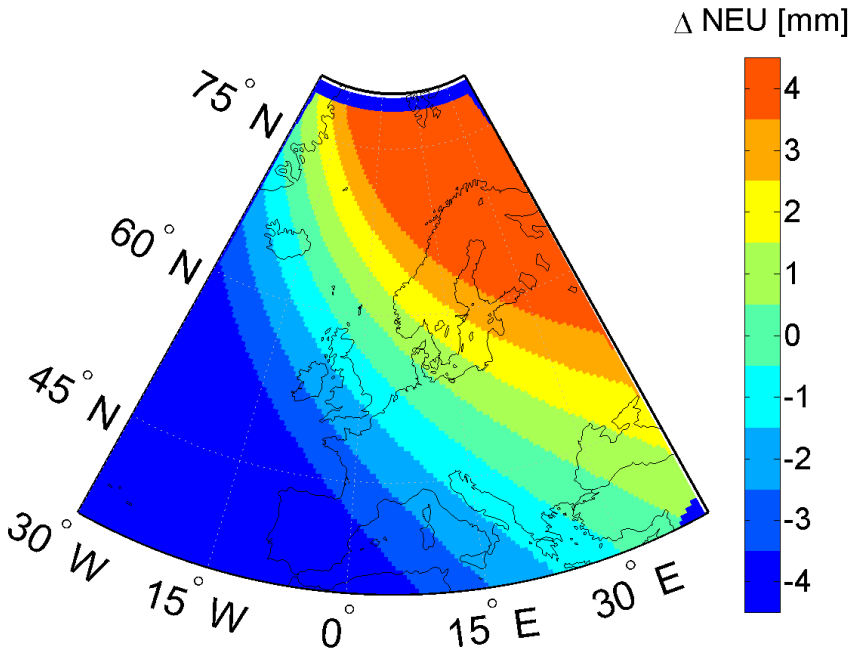
Scale-induced biases of both approaches

Correction type	Unscaled	Scale Absorbed
ETRF200(R08)	14.9 mm	-7 mm - +7 mm





Conclusions

- Existing approach causes satellite-receiver geometry dependent biases

- Leaving scale out of the transformation causes regional dependent bias(es) that
  - Are at the same level as biases of current approach (unscaled) or less (scale-absorbed)
  - can be a-priori computed → so a user can still correct for these bias(es)

Recommendation

- Since transformation of orbits to a regional reference frame causes location dependent biases caused by scale:
  - Do not create a regional product by applying a transformation
    - User applies transformation (GBC-approach)

  Or

  - Leave scale out of the transformation (unscaled approach) so that a user can choose to ignore the height bias or correct for it afterwards

Thank you for your attention

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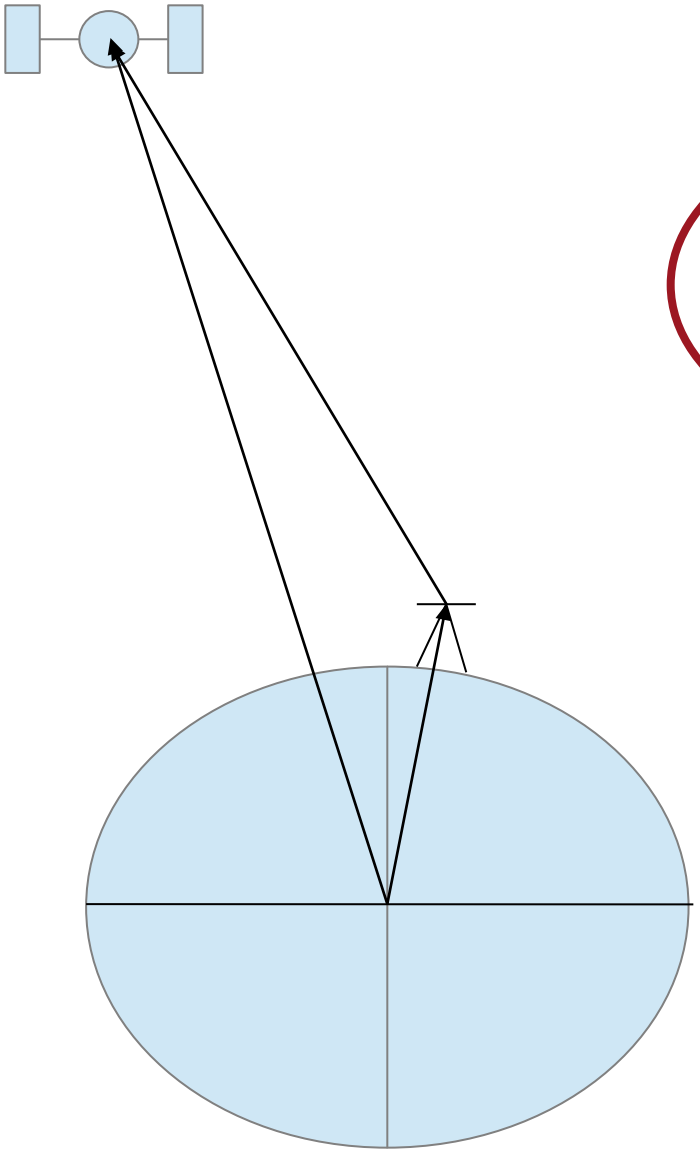

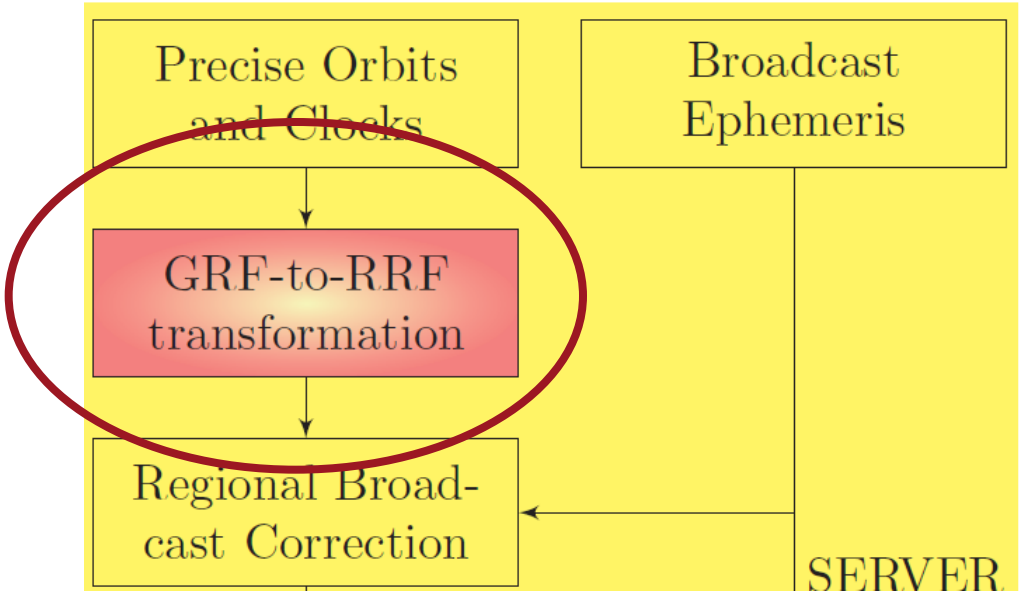

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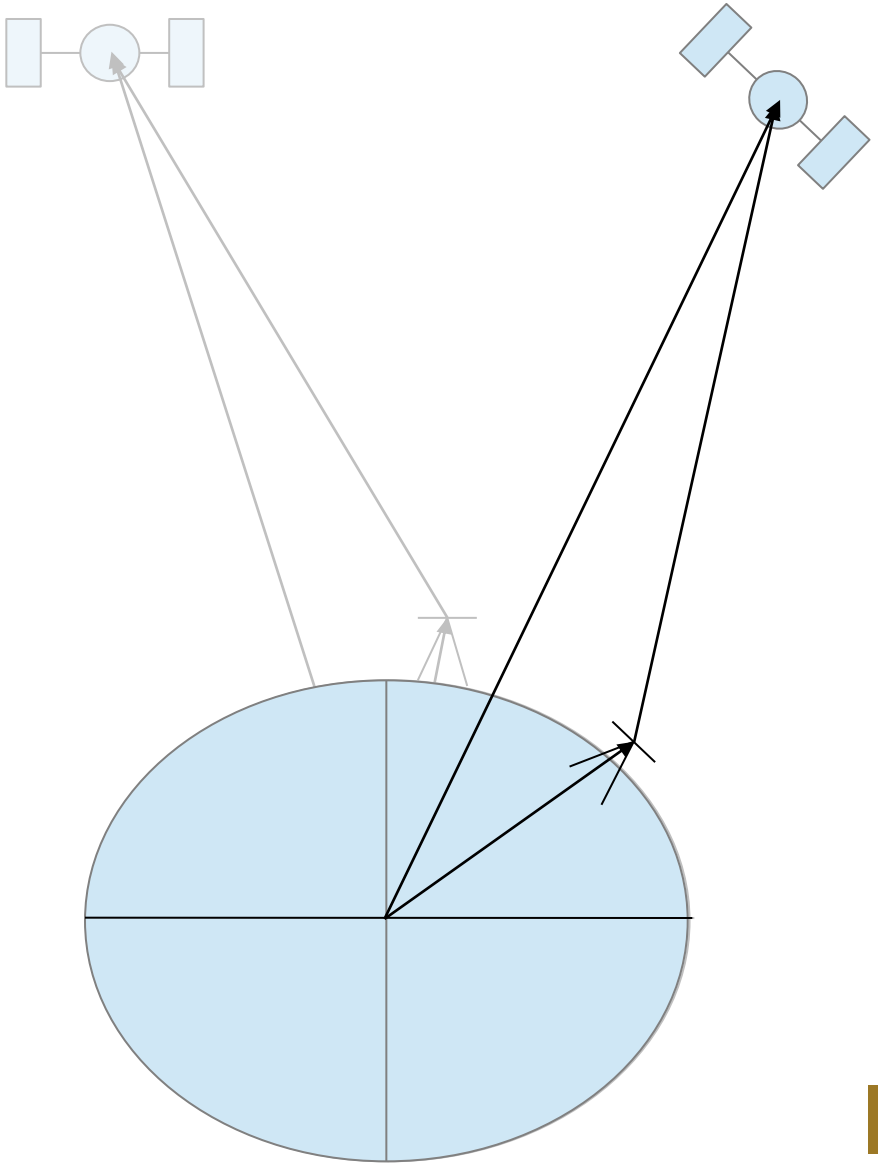
Rotation



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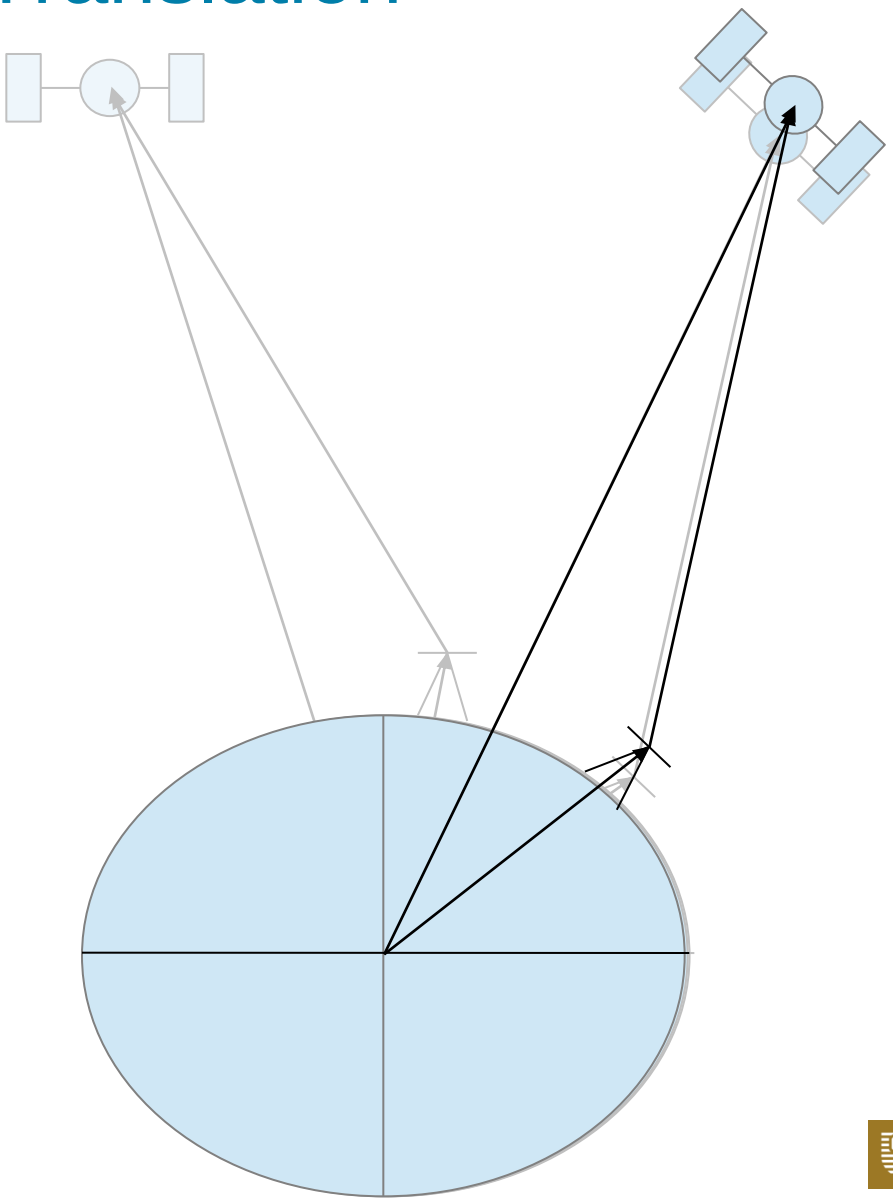
Translation



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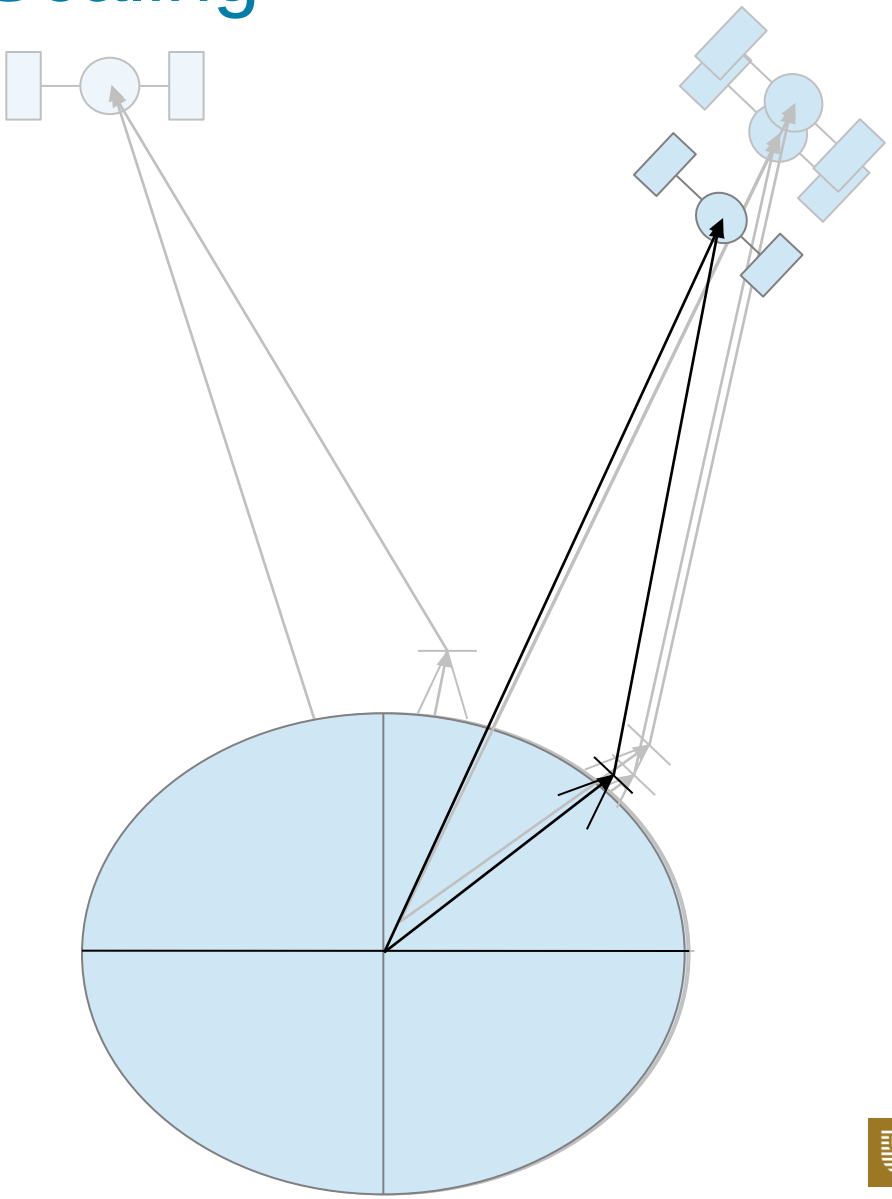
Scaling



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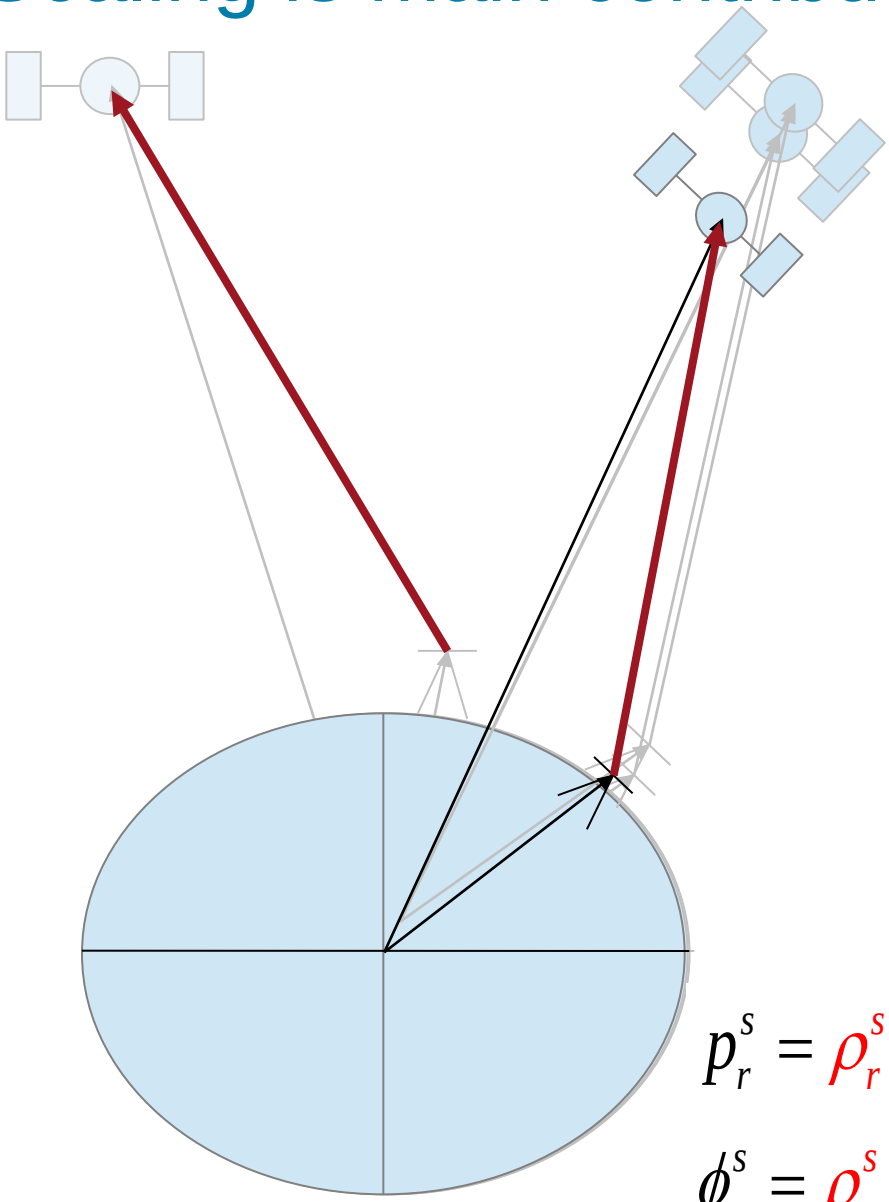
Scaling is main contributor



- Relation receiver-satellite range in GRF and RRF

$$\rho^s_{r,GRF} = \left\| x^s_{GRF} - x_{r,GRF} \right\|$$

$$= \frac{1}{\lambda} \left\| x^s_{RRF} - x_{r,RRF} \right\|$$

$$= \frac{1}{\lambda} \rho^s_{r,RRF}$$

- Parameters in red are affected

$$p^s_r = \rho^s_r - dt^s + dt_r + m^s_r \tau_r + I^s_{r,j}$$

$$\phi^s_r = \rho^s_r - dt^s + dt_r + m^s_r \tau_r - I^s_{r,j} + w_j M^s_{r,j}$$