GAST-D Monitoring Results from Post-processed Flight Trial Data: A Performance Evaluation of DLR´s GBAS Testbed

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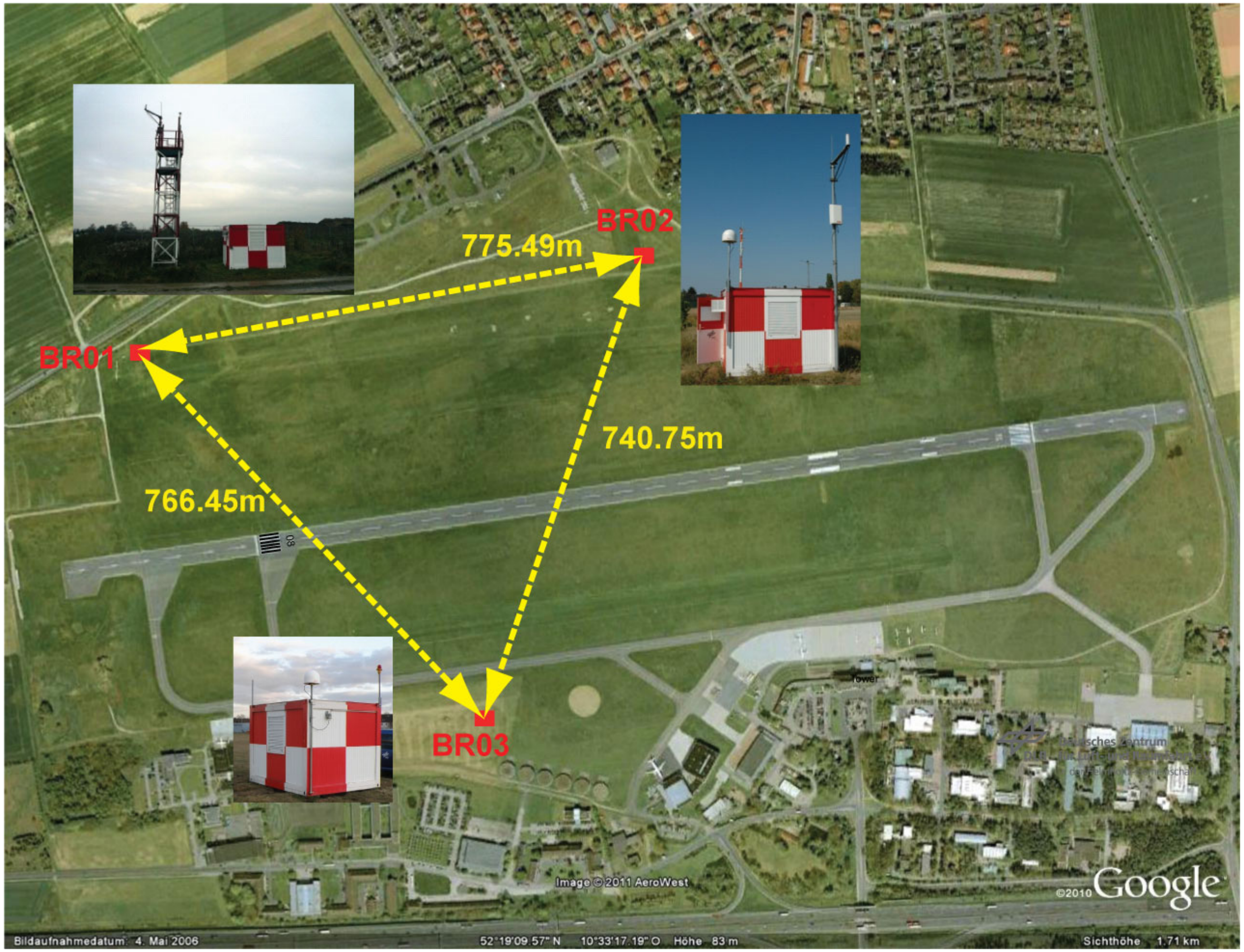
in der Helmholtz-Gemeinschaft

Overview

- Introduction of the GBAS Testbed
- 2009 Flight Trial Data
- Integrity Evaluation
- Monitoring Results
- Conclusion and Outlook

The DLR GBAS Testbed



Ground Subsystem Hardware

Outside Container

LEICA AR 25

Topcon Net-G3 Receiver

- EGNOS, GPS, GLONASS
- 2 Frequencies
- 20 Hz Sampling Rate

Inside Container

External Clock

TEMEX

Low Cost & Profile Frequency Rubidium Standard (LPFRS)

Improves short time stability

Airborne Subsystem Hardware

Topcon Net-G3 Receiver

- EGNOS, GPS, GLONASS
- 2 frequencies
- 20 Hz data sampling
- local data recording

Real time data transfer to ground processing facility via TCP/IP

VFW 614 ATTAS
"Advanced Technologies Testing Aircraft System"

Approach Speed 90knots (44 m/s)

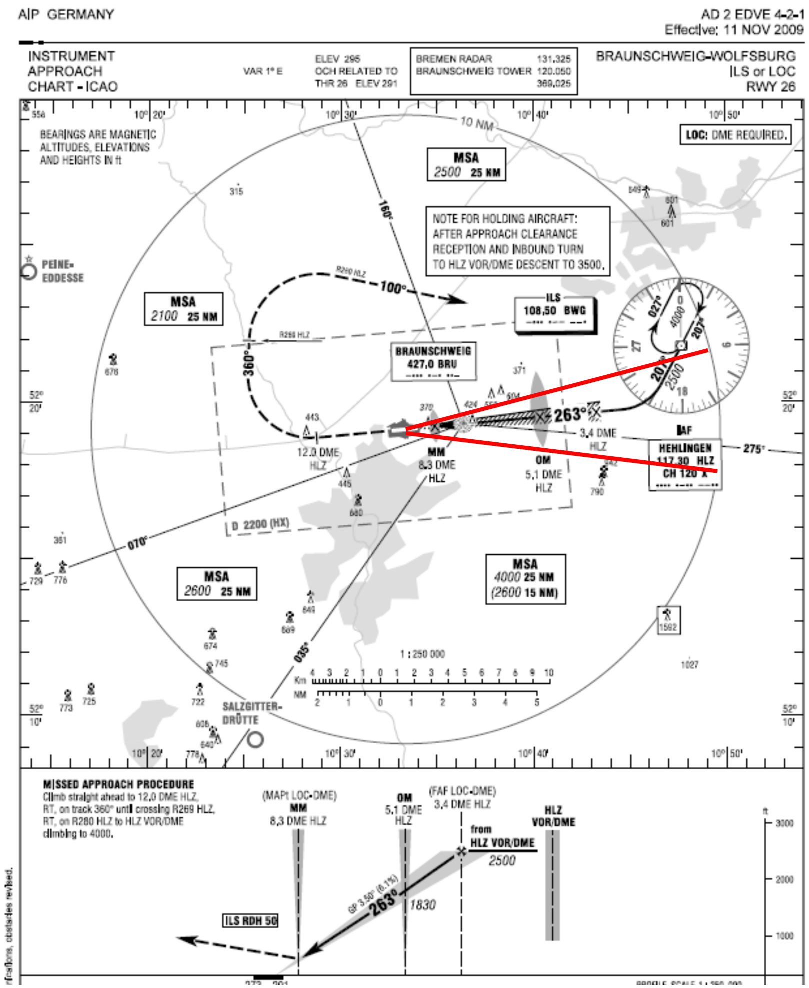
Flight Technical Error Autopilot σ <50 m

Airborne Subsystem Hardware

Flight Trial Statistics and Setup

- Guidance through ILS
- GBAS Service Area and PAR
- Total of 30 approaches
- Evaluation based on DO253C

Date	No. approaches
2009/11/16	4
2009/11/26	1
2009/11/27	4
2009/12/07	6
2009/12/11	6
2009/12/14	2
2009/12/16	7



Airborne Architecture

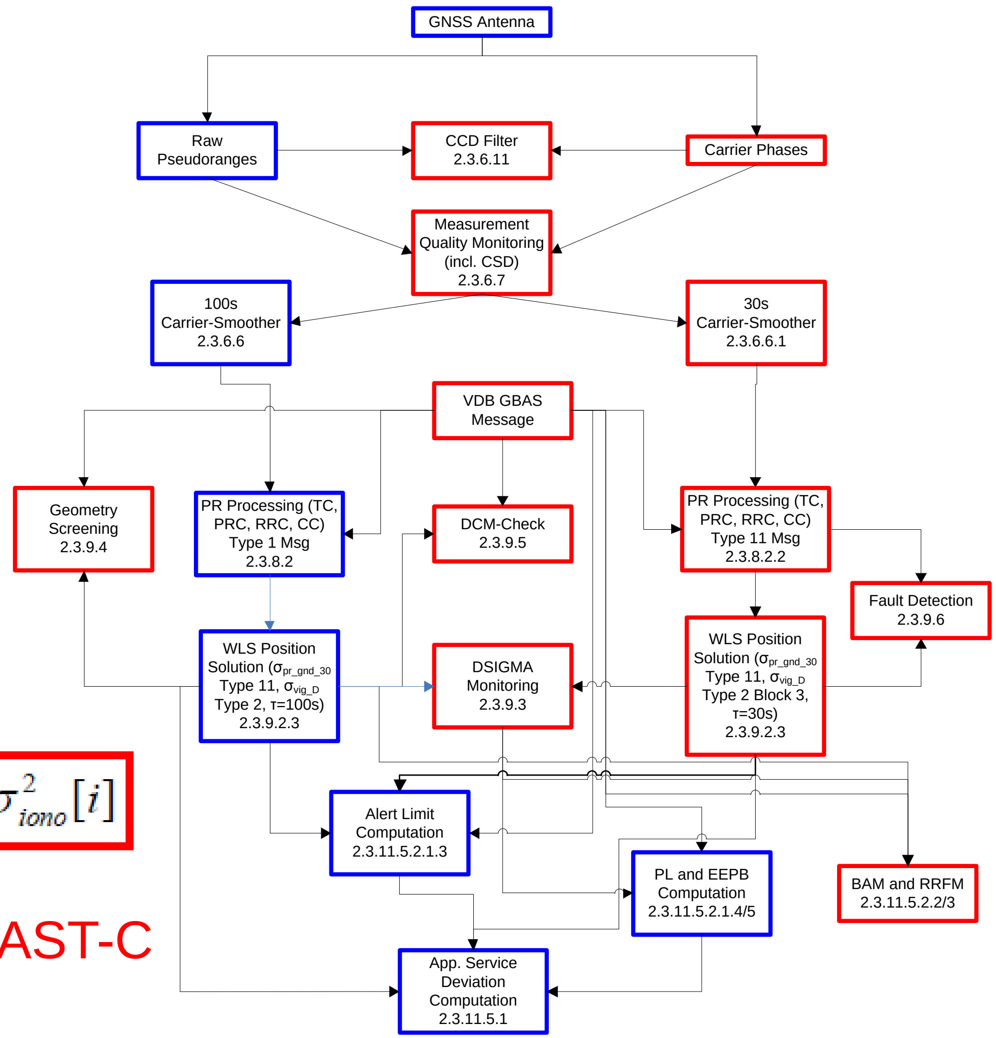
- Additional Monitors Implemented
- Geometry Screening in accordance with ATTAS FTE σ - S_{vert}< 4

- Nominal Protection Levels GAST-C vs. GAST-D

$$VPL_{Apr\_H0} = K_{ffmd}\sqrt{\sum_{i=1}^{N} s^2_{Apr\_vert,i}\,\sigma_i^2} + D_V$$

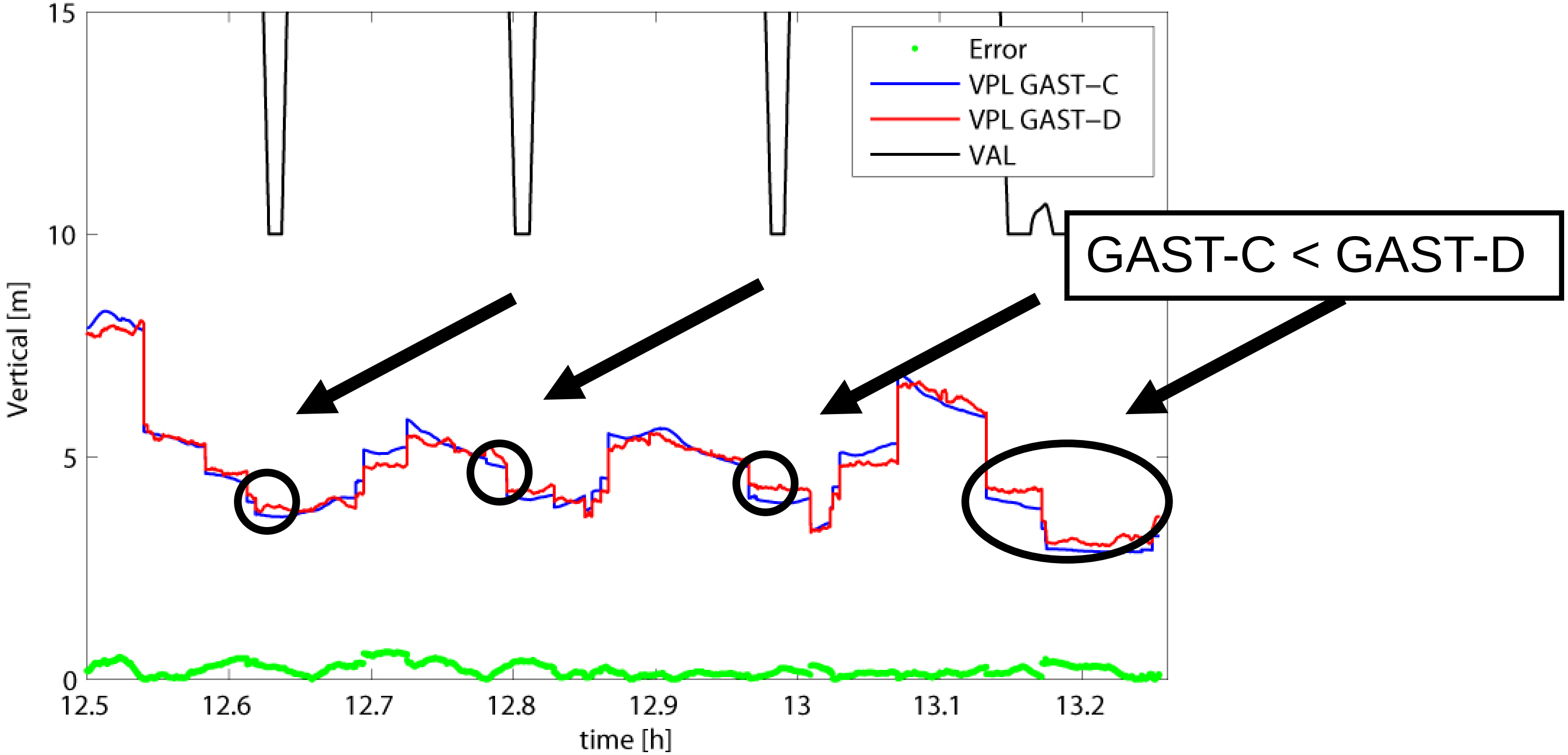
$$\sigma_i^2 = \sigma^2_{pr\_gnd\_x}[i] + \sigma^2_{tropo}[i] + \sigma^2_{pr\_air}[i] + \sigma^2_{iono}[i]$$

GAST-C < GAST-D GAST-D < GAST-C



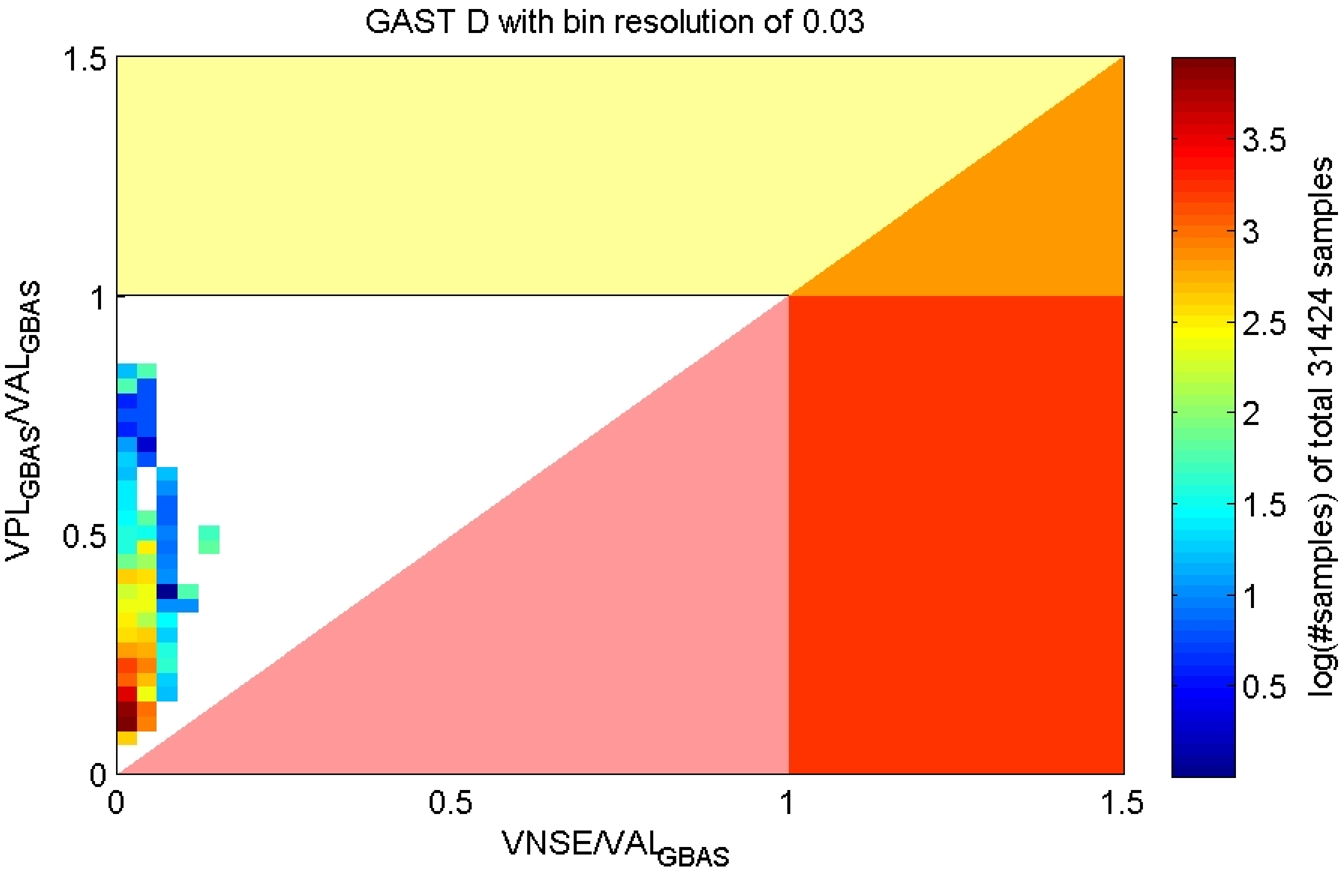
Protection Level Behavior

- Levels GAST-C vs. GAST-D
- Nov. 27 2009



Integrity Evaluation (Stanford Diagram)

- Service area, all approaches



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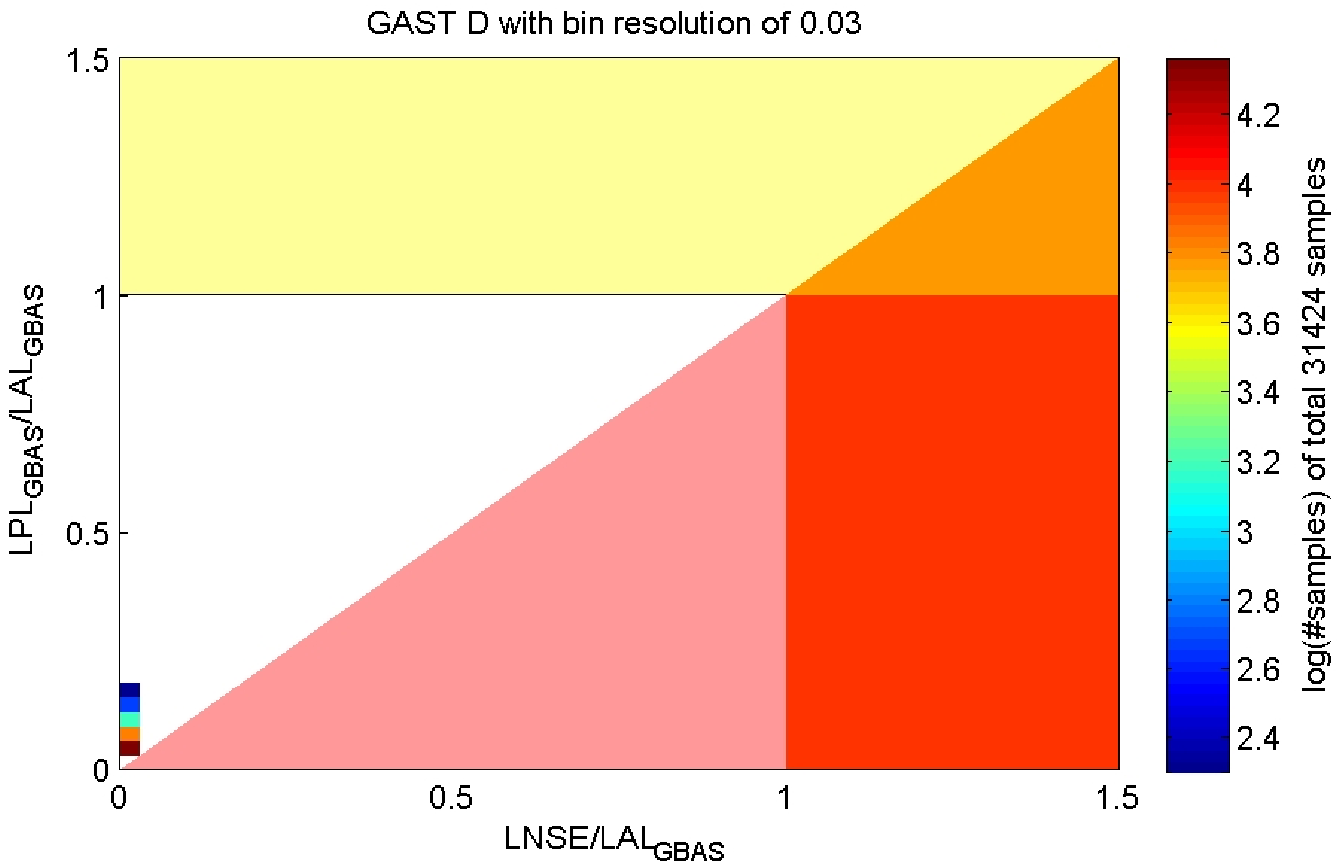
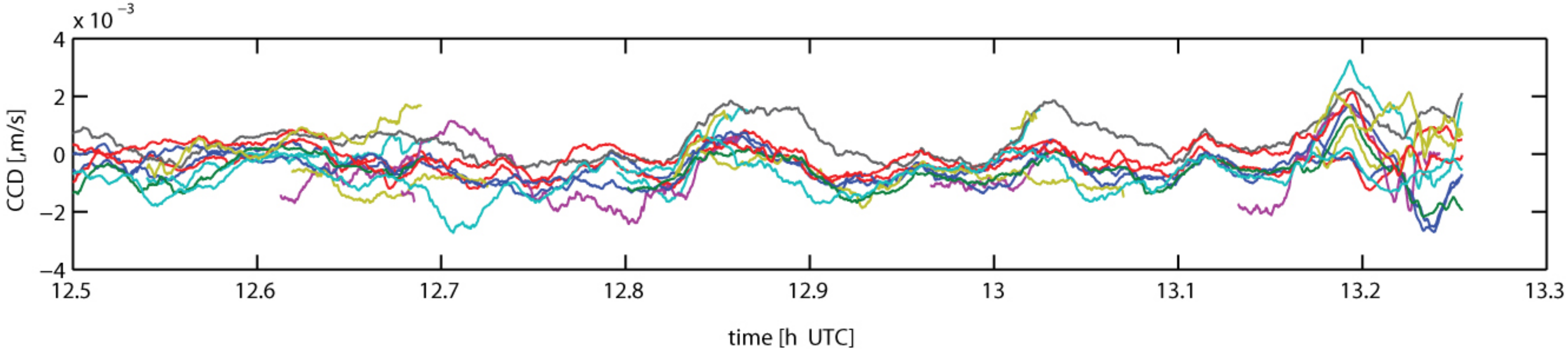


Code Carrier Divergence Monitor - Nov. 27 2009



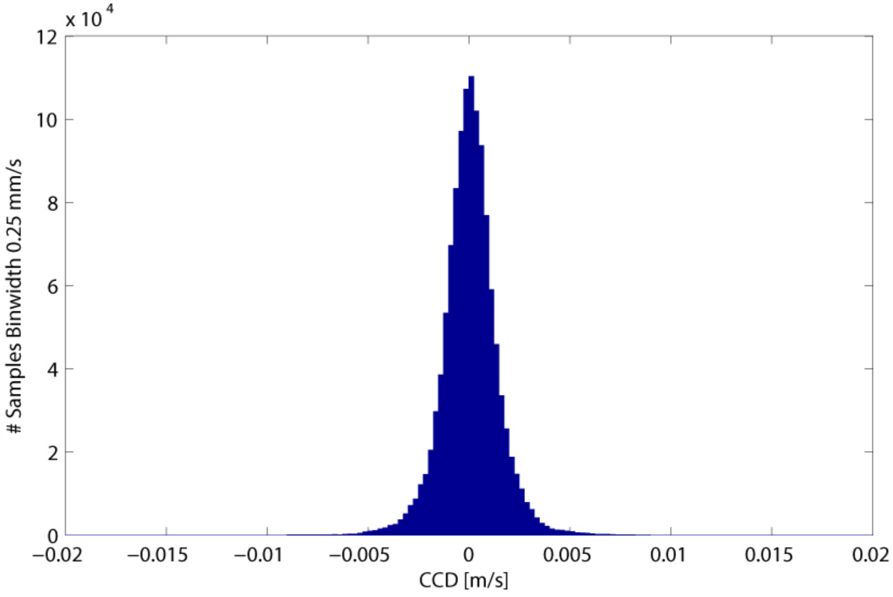
- Two step fliter

$$Z_n = (1-\alpha)Z_{n-1} + \alpha \Delta CMC_n$$

$$D_n = (1-\alpha)D_{n-1} + \alpha Z_n$$

$$\alpha = 0.5\, s/100\, s = 1/200$$

- Threshold 12.5 mm/s
- Threshold is in mm in DO253C



Differential Correction Magnitude Check - Nov. 27 09

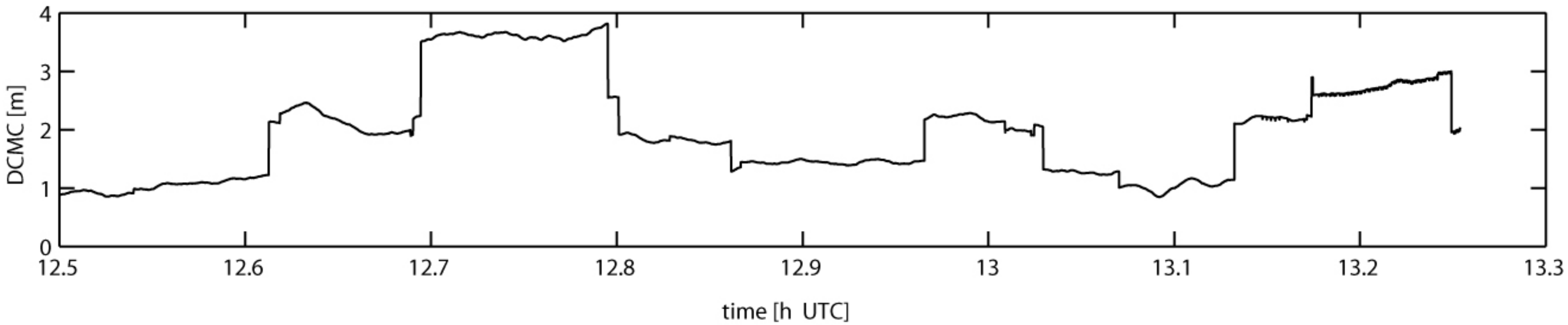
- Differential correction magnitude in position domain

$$\delta PR_i = PRC_i + RRC_i(t - t_{apl}) + TC_i$$

$$\vec{x} = S\delta PR$$

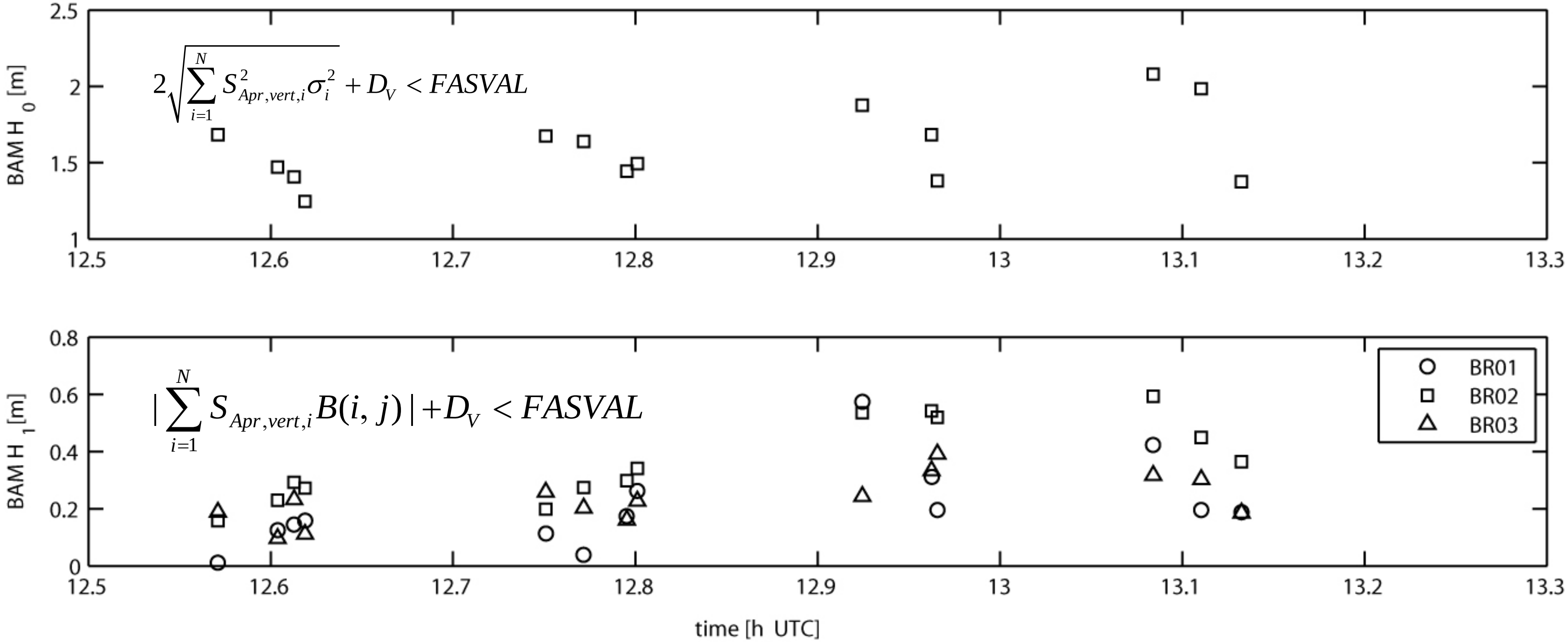
$$DCM_H = \sqrt{x_1^2 + x_2^2}$$

- In DO253C with satellite clock bias
- Threshold 200m



Bias Approach Monitor

- Compares 66% position uncertainty and B-Values in position domain to FASVAL (10m) when transitioning to PAR or geometry change occurs



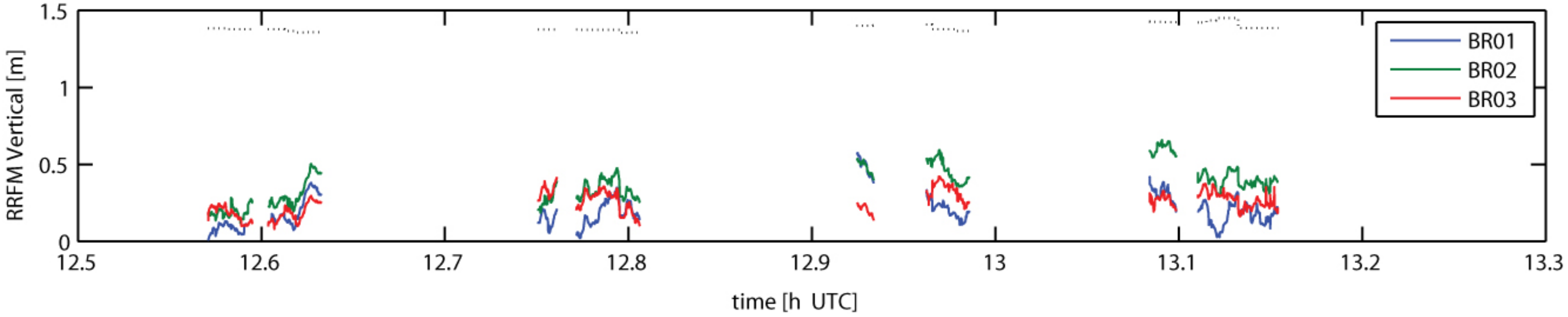
Reference Receiver Fault Monitor - Nov. 27 2009

- B-values mapped into position domain

$$\left|\sum_{i=1}^{N} S_{Apr,vert,i} B(i,j)\right| + D_V < T_{B,air,vert} \qquad T_{B,air,vert} = K_{ffd,B}\sqrt{\sigma^2_{B_{vert}} + \sigma^2_{D_V}}$$

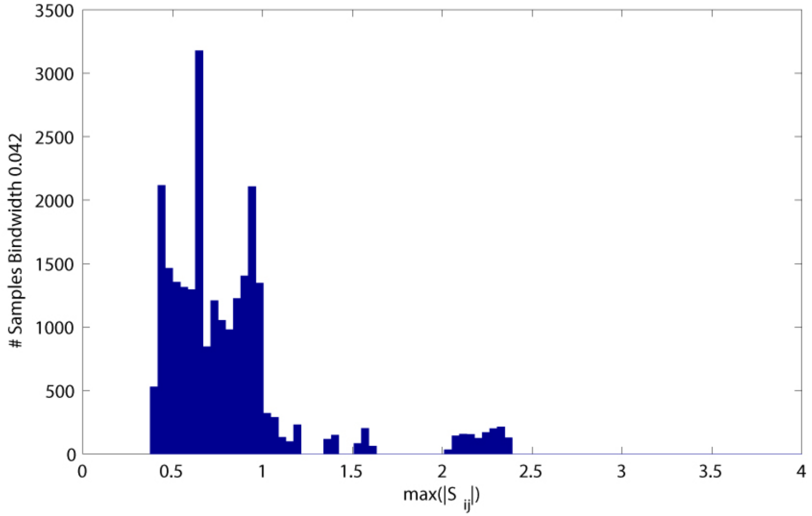
$$\left|\sum_{i=1}^{N} S_{Apr,lat,i} B(i,j)\right| + D_L < T_{B,air,lat} \qquad T_{B,air,lat} = K_{ffd,B}\sqrt{\sigma^2_{B_{lat}} + \sigma^2_{D_L}}$$

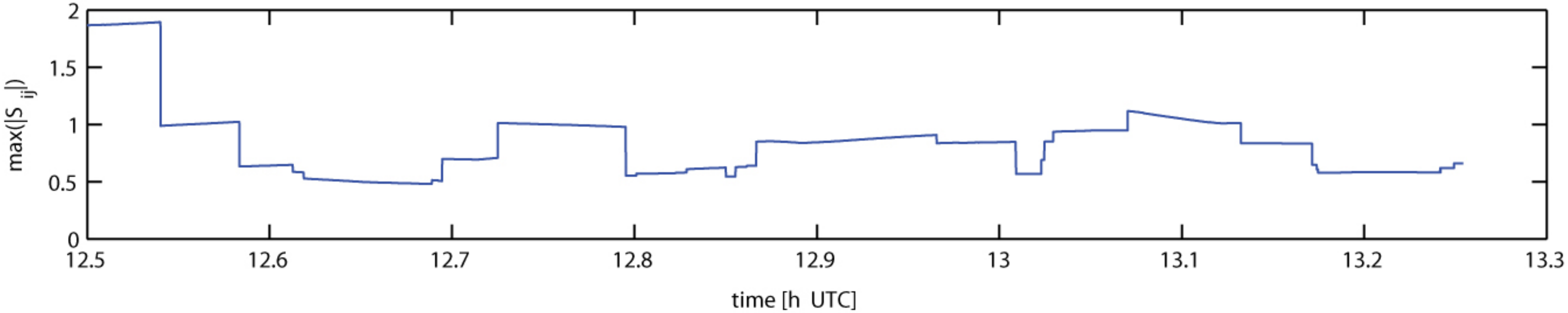
- $K_{ffd,B}$=5
- Only while inside PAR



Maximum Element of Pseudoinverse

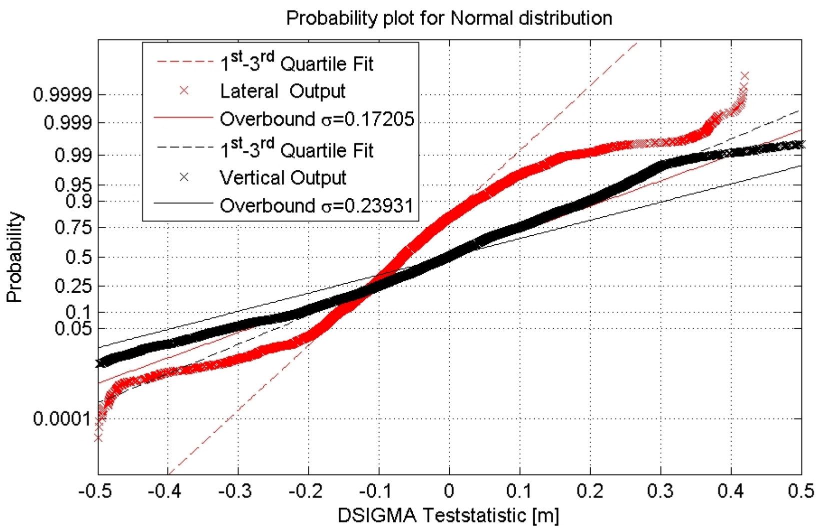
- Geometry needs to be screened to avoid positioning with maximum undetectable range error of 1.5m
- Here, limited to 4 but could be increased accoording to FTE
- Maximum S_{ij} observed during all flight trials was 2.43

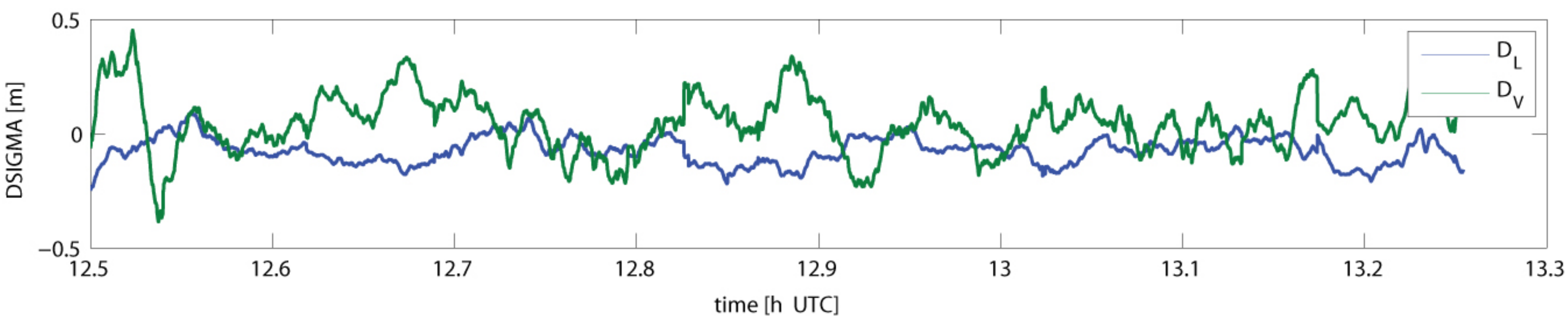




DSIGMA Monitor Statistics (D_V -Vertical)

- Difference between 30s and 100s smoothed position
- Muphy and Harris (2006): σ=0.22m
- Additional Ionosphere monitor required -> Double Difference Phase





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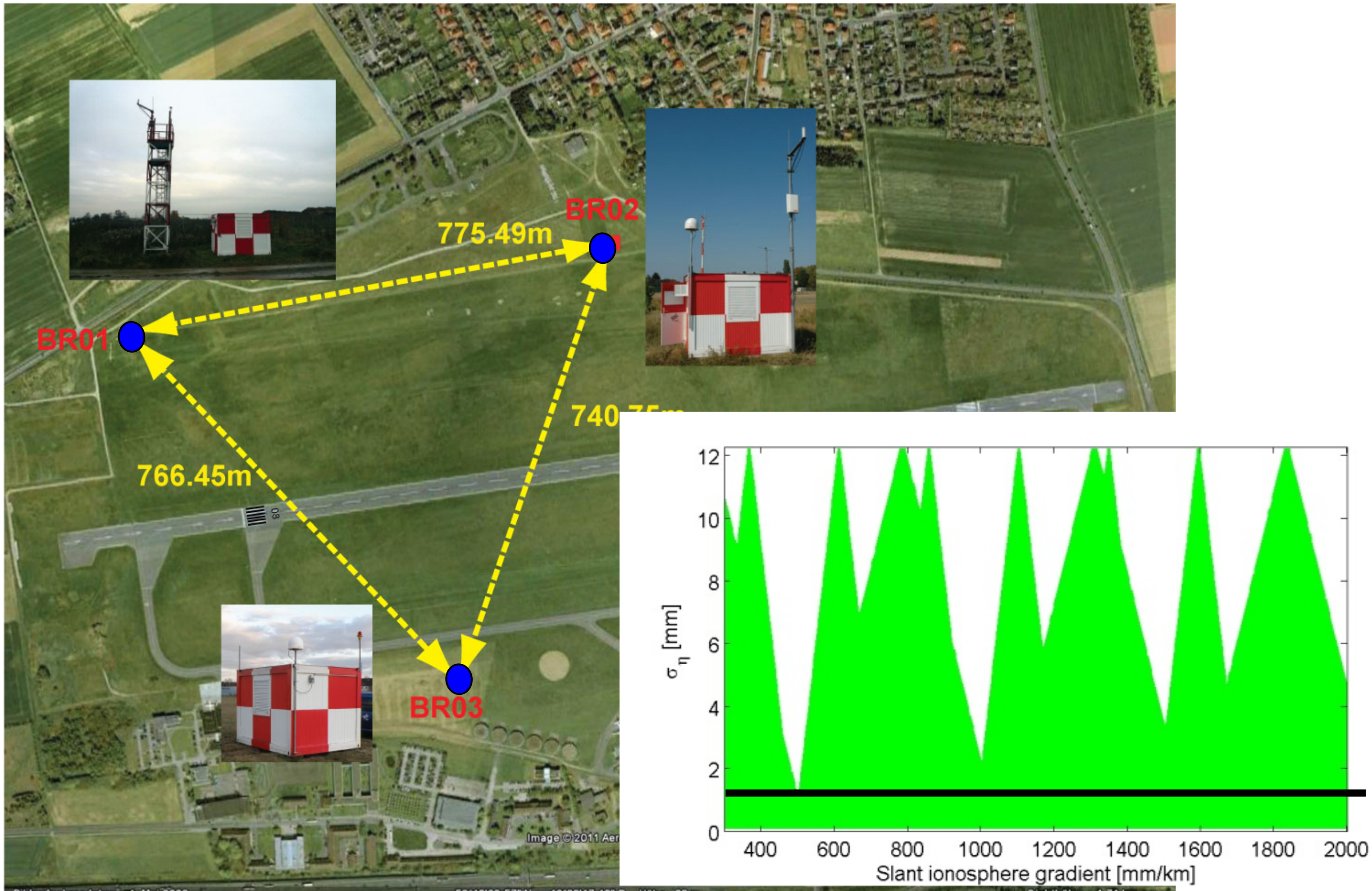
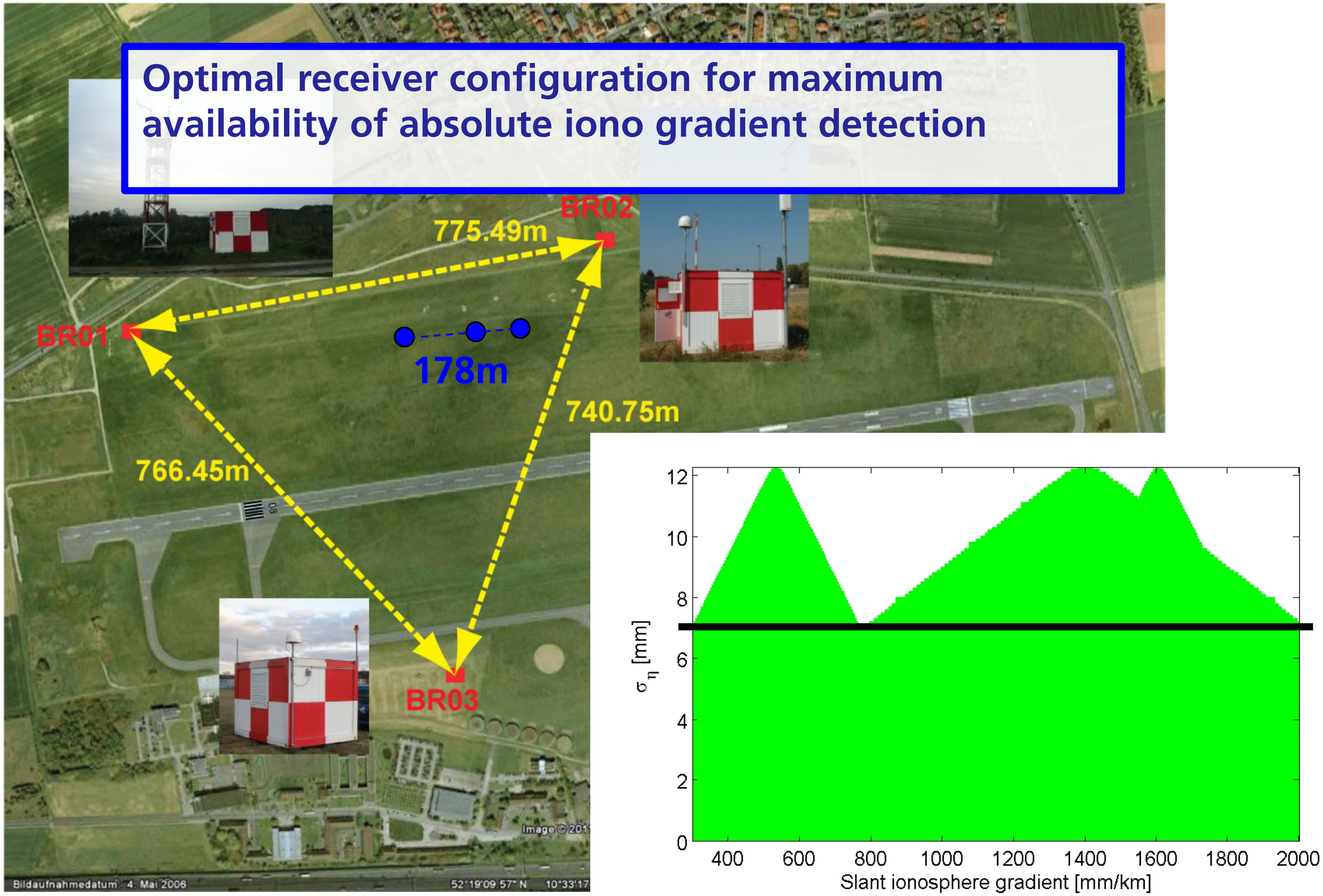
Optimal absolute iono gradient monitoring network



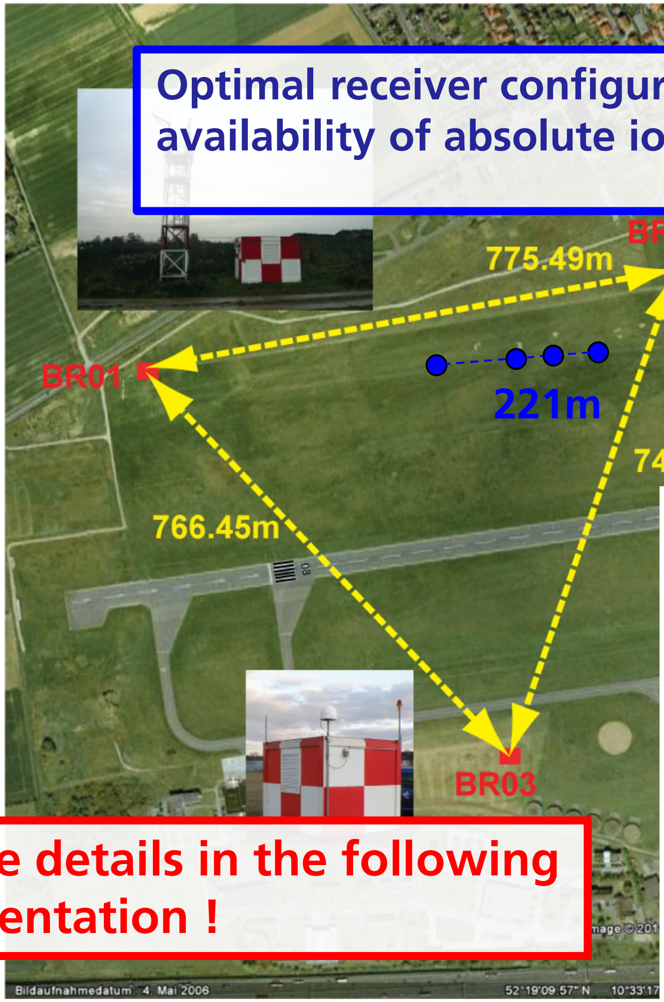
σ_η is phase noise of receiver &antenna

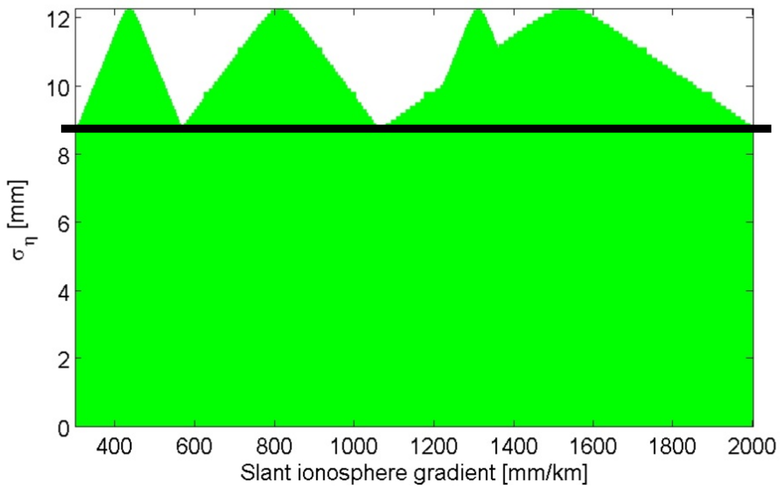
Optimal absolute iono gradient monitoring network



Optimal absolute iono gradient monitoring network

Optimal receiver configuration for maximum availability of absolute iono gradient detection





More details in the following presentation !

Summary

- GAST-D capability of testbed positive
- Monitors and system performed within nominal limits

For 2011-2012:

- Real time functionality ☑
- Absolute ionosphere gradient monitor set up
- Initial Autoland Trials with ATTAS (VWF614) or ATRA (A320)

Thank you for your attention.

You are invited to visit the GBAS Display at the DLR Booth.