MFMC GBAS – Flight Trials and Performance Studies

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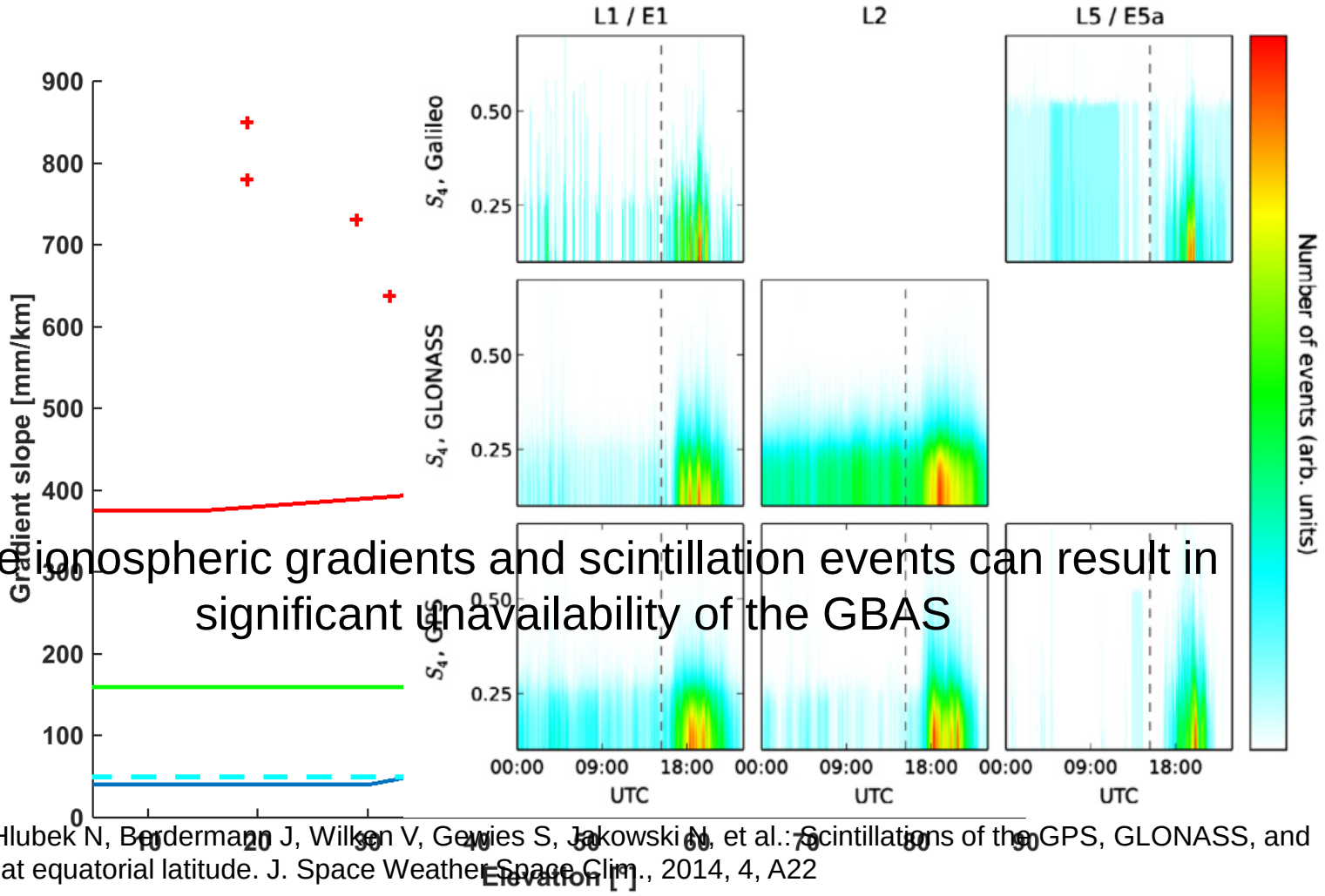
DLR

Multi-Frequency Multi-Constellation GBAS
Why? How?

- Protection against ionospheric gradient threat
- Ionospheric scintillation issues in high/low latitudes
- Weak constellations and required masking may have impact on performance

Motivation

Why?



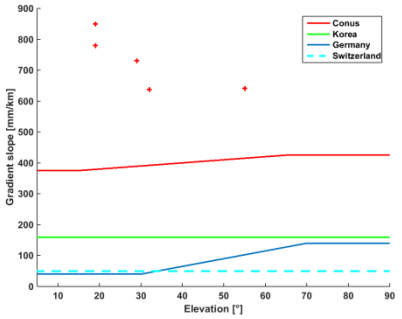
Large ionospheric gradients and scintillation events can result in significant unavailability of the GBAS

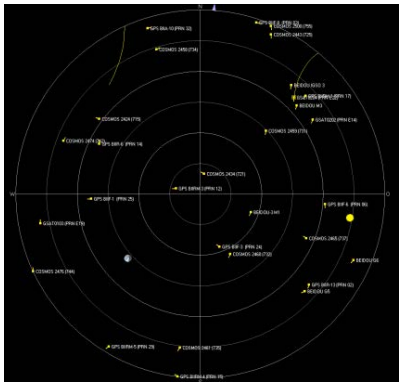
Graphic from: Hlubek N, Berdermann J, Wilken V, Gewies S, Jakowski N, et al.: Scintillations of the GPS, GLONASS, and Galileo signals at equatorial latitude. J. Space Weather Space Clim., 2014, 4, A22

Motivation

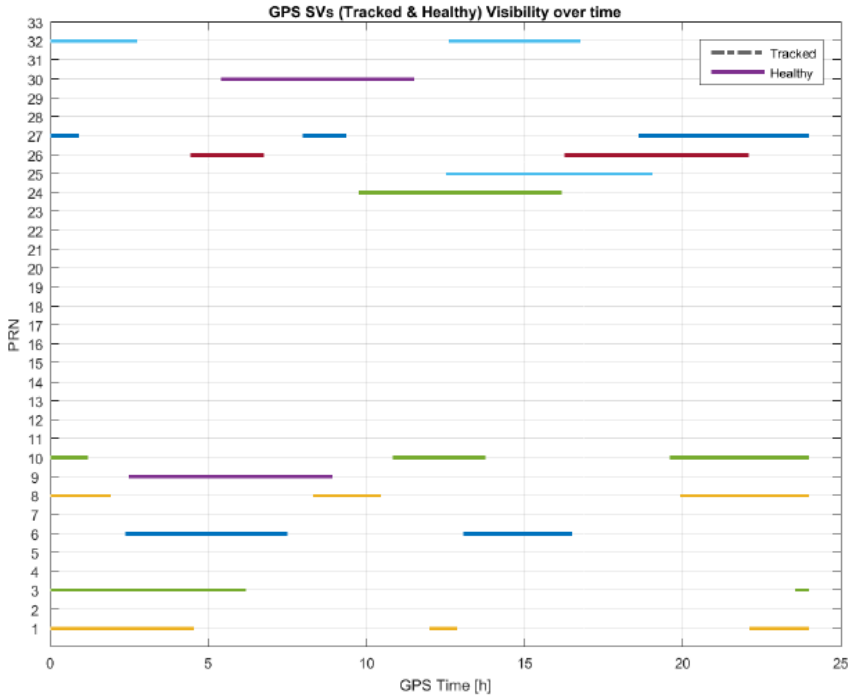
How?

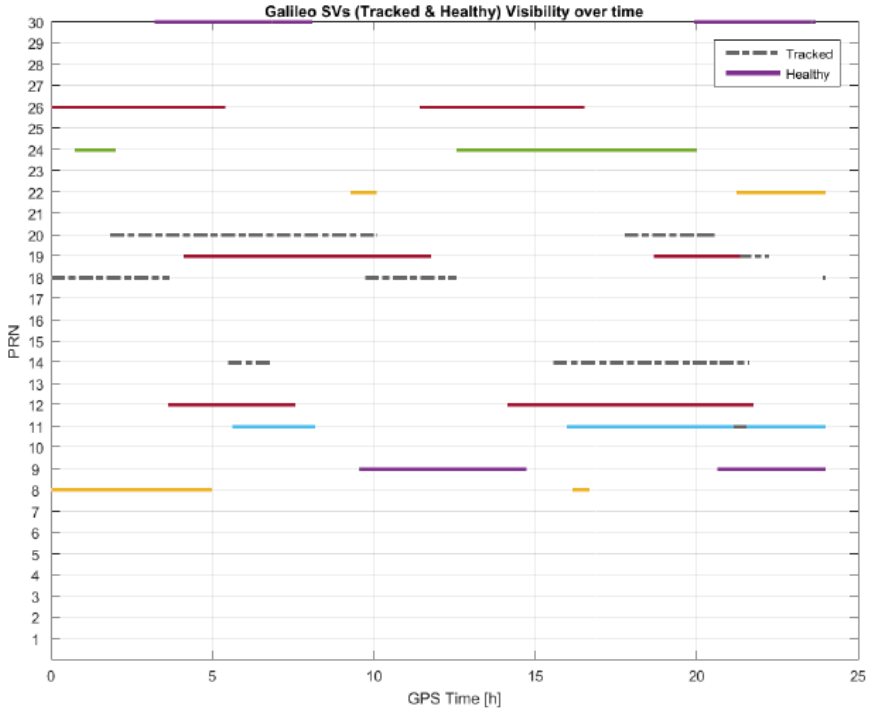
- Dual-frequency GBAS can tackle the ionospheric gradient problem
- Multi constellation GBAS can reduce the impact of scintillations on availability
- Quickly growing Galileo constellation (all satellites with E1/E5a)
- Currently 12 GPS Block IIF satellites with L1 and L5 operational, continuous launches all with second frequency





L5/E5a Satellite Status
(12 GPS Block IIF, 14 (9) Galileo)





GPS Block IIF and Galileo status

Performance Metric: Availability

- Represented by protection levels:

$$VPL_{H0} = K_{ffmd} \cdot \sqrt{\sum_i (s_{vert,i}^2 \cdot \sigma_i^2)} + D_V + b_{other}$$

$$\sigma_i = \sqrt{\sigma_{gnd}^2 + \sigma_{air}^2 + \sigma_{iono}^2 + \sigma_{tropo}^2 + \sigma_{other}^2}$$

- Need to determine all the necessary parameters for the processing modes

- Analysis of extesive ground and flight data to establish expectable performance models

Data Collection

Airbus A320

Duration: *100 hours A320 since May 2015*
6 hours Dornier March 2015

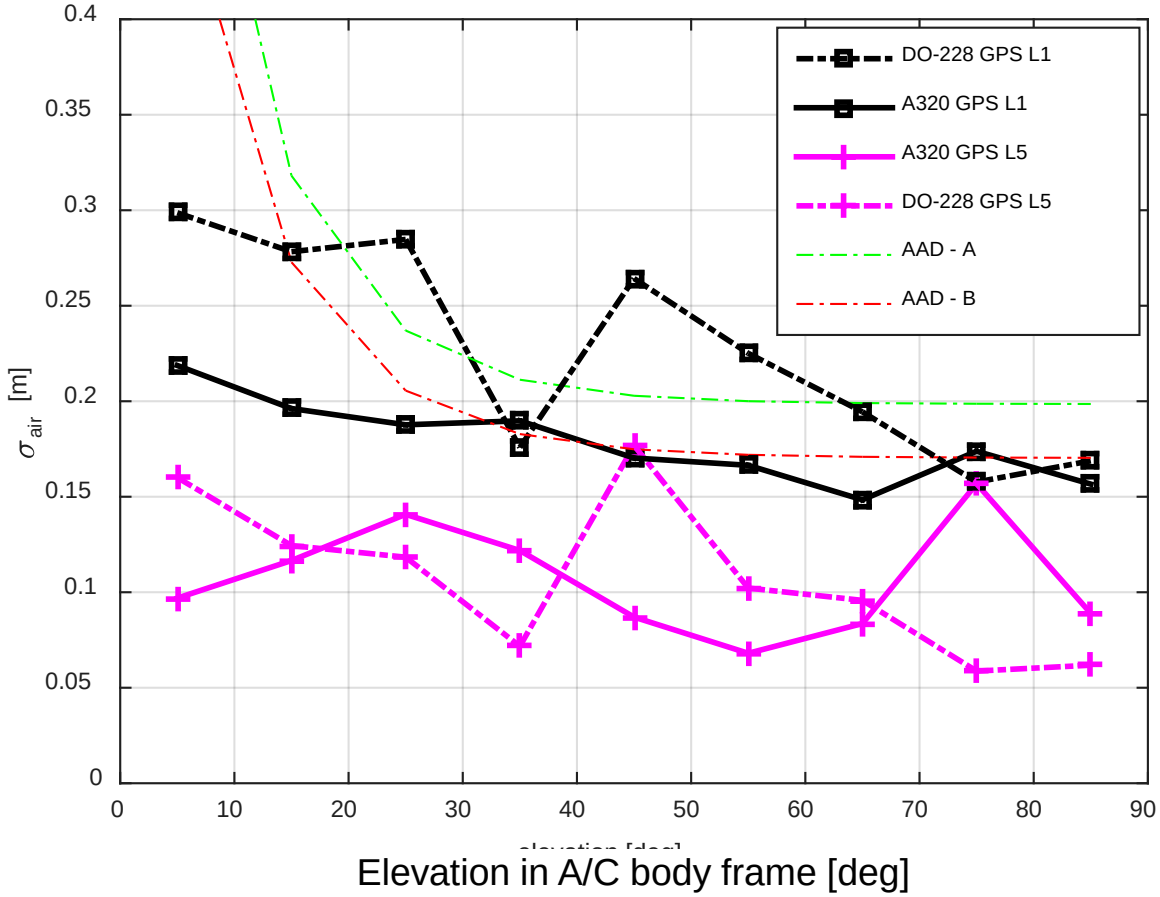
Receiver: *Javad Delta*
23 Mhz bandwidth
2 correlator spacings

Antenna: Antcom multiband

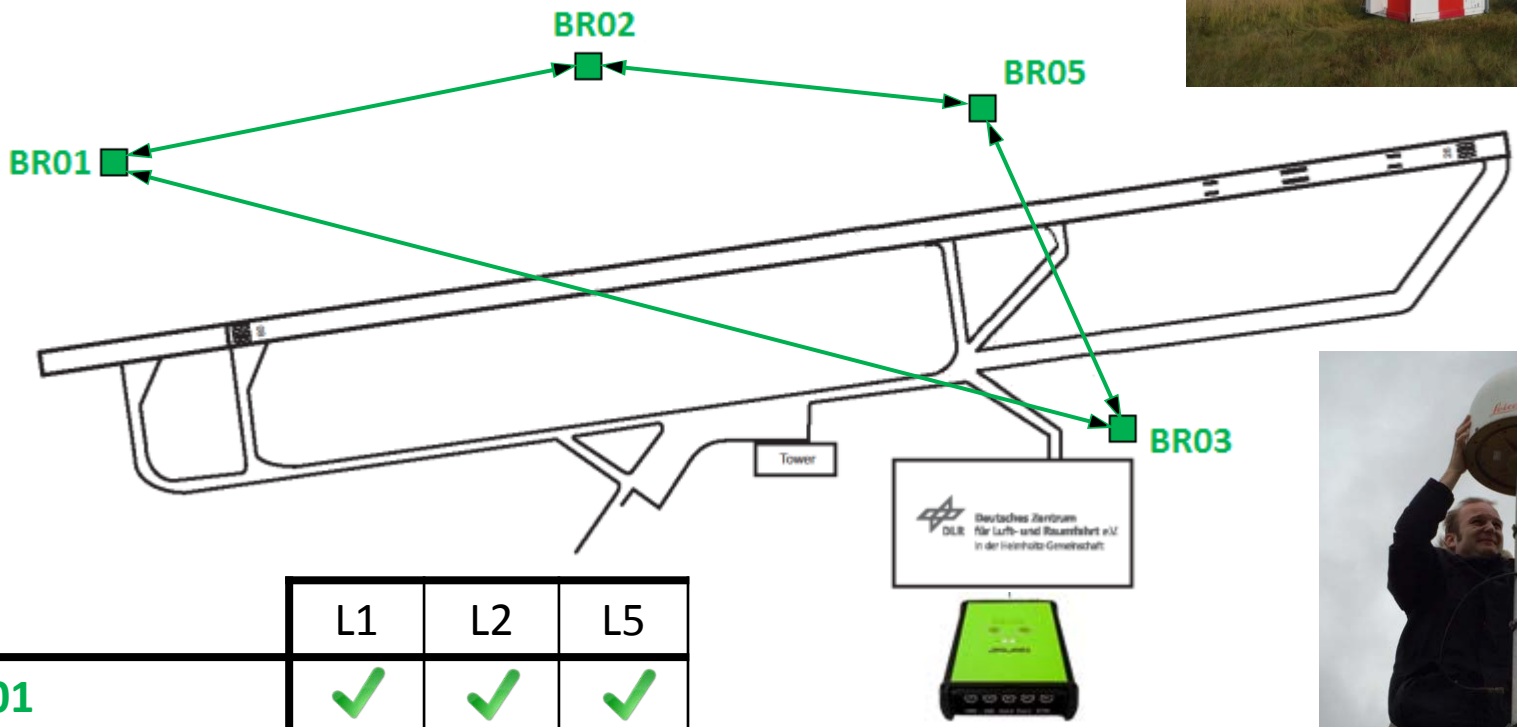
Dornier DO-228

Towards MFMC GBAS – Performance Assessments

$Sigma_{air}$



DLR Ground Facility
Braunschweig Airport



	L1	L2	L5
BR01	✓	✓	✓
BR02	✓	✓	✓
BR03	✓	✓	✓
BR05	✓	✓	✓

Javad Delta Receivers with
GPS (L1/L2/L5) + Galileo (E1/E5a) + Glonass + BDS
Connected to Leica AR25 choke ring antennas

Evaluating Performance of GPS L5 and Galileo E1/E5a
Using Ground Measurements

- Improved performance of the Galileo signals

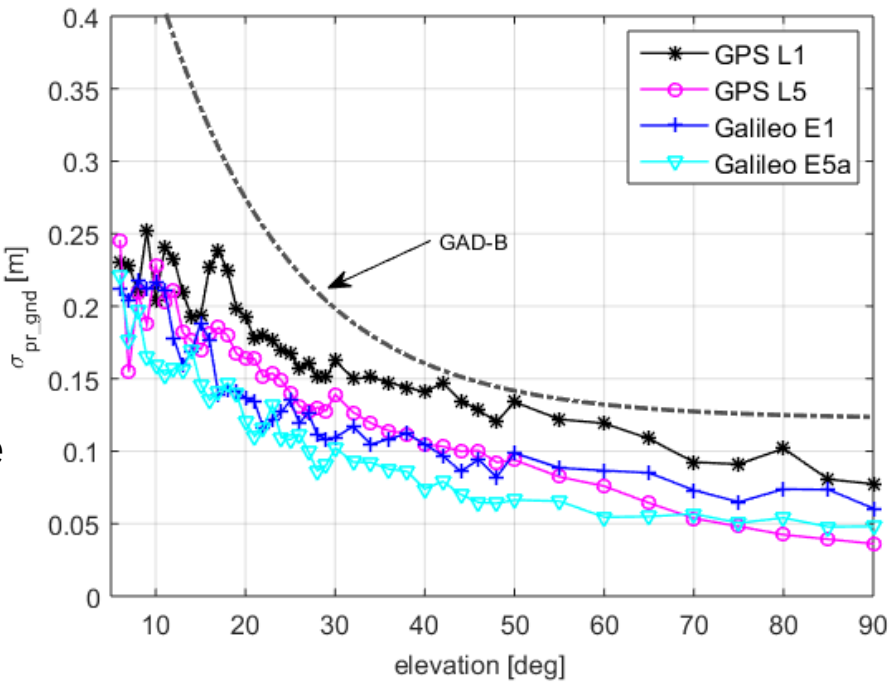
- RX configuration:
  - 0.1 chips correlator spacing (L1/E1)
  - 1 chip correlator spacing (L5/E5a)

- Multipath and noise on Galileo E1 is lower than on GPS L1, especially at low elevation
  - BOC(1,1) modulation
  - Wider transmission bandwidth

- Galileo E5a shows lower multipath and noise than Galileo E1
  - BPSK(10) signal
  - Higher chip rate
  - Higher signal power

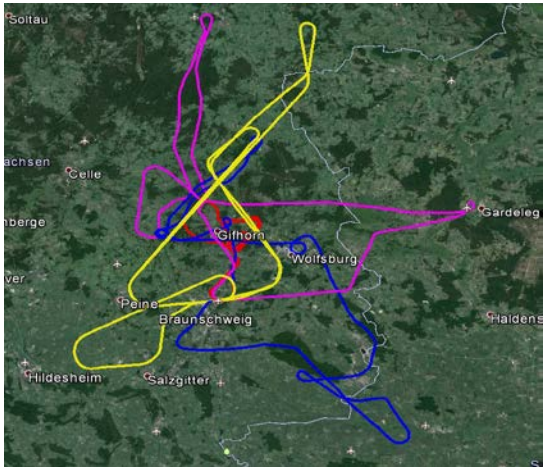
10 GPS Block IIF , 4 Galileo

40 days of data – 100 sec smoothing constant



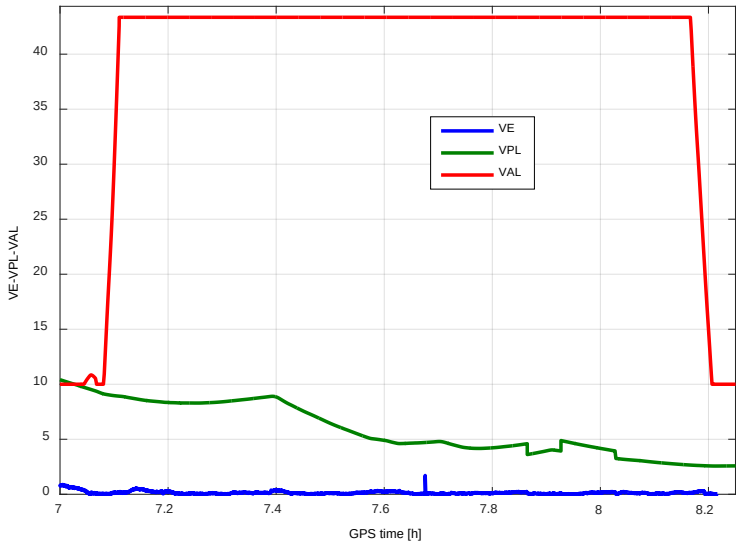
Paper presented at ITM 2015 : M-S Circiu et. Al – “Evaluation of GPS L5, Galileo E1 and Galileo E5a Performance for Multi Frequency Multi Constellation GBAS”

Dual-Frequency Dual-Constellation GBAS
Flight Trials

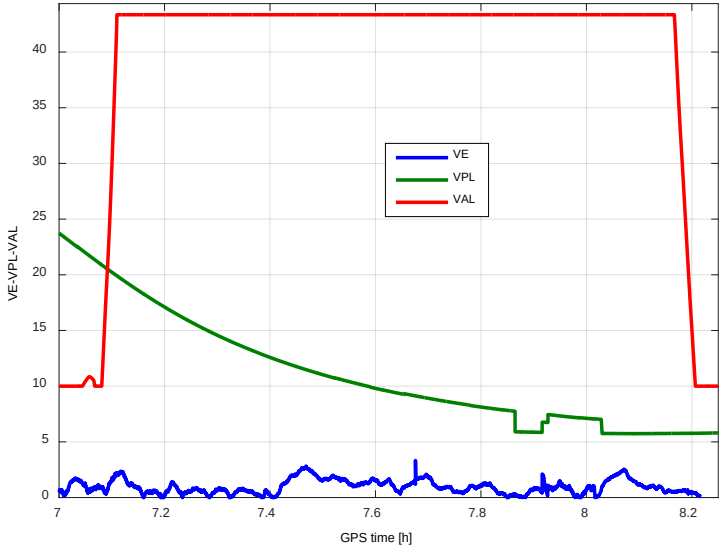


- 4 flights in March 2015 with Dornier DO-228 (6h total)
- Satellite visibility: 5-7 dual frequency (GPS+Gal)

Single-frequency L5/E5a GPS and Galileo

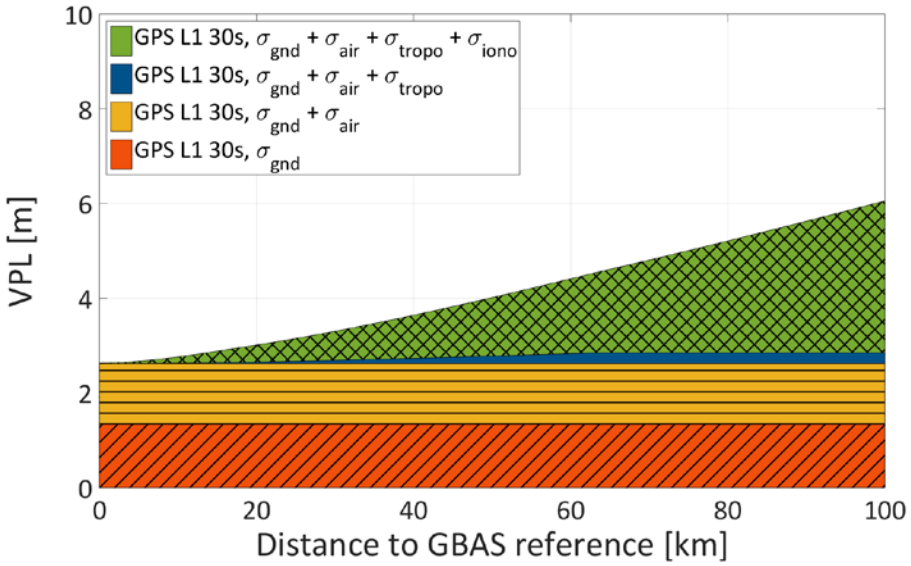


Dual-frequency L1/E1+L5/E5a GPS and Galileo

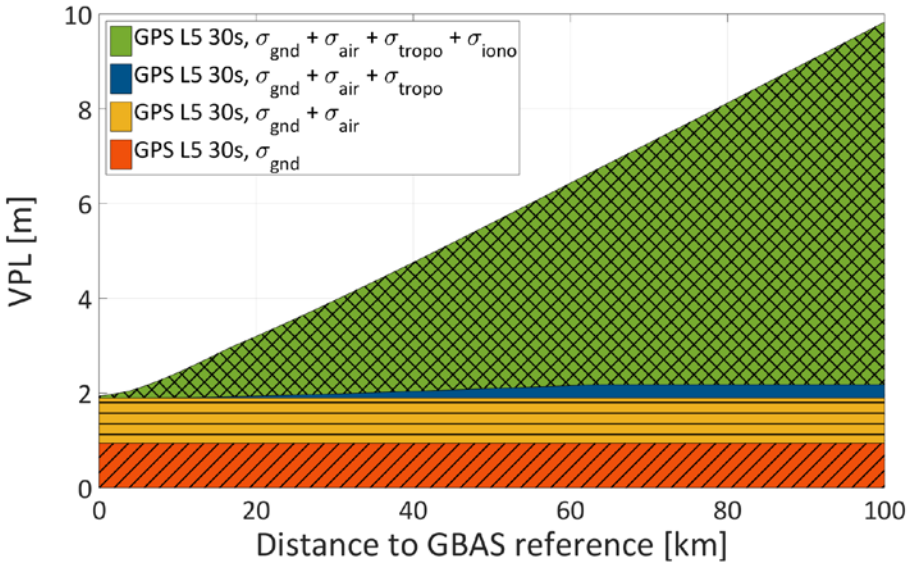


Protection Levels

Contribution of Different Sigma Terms

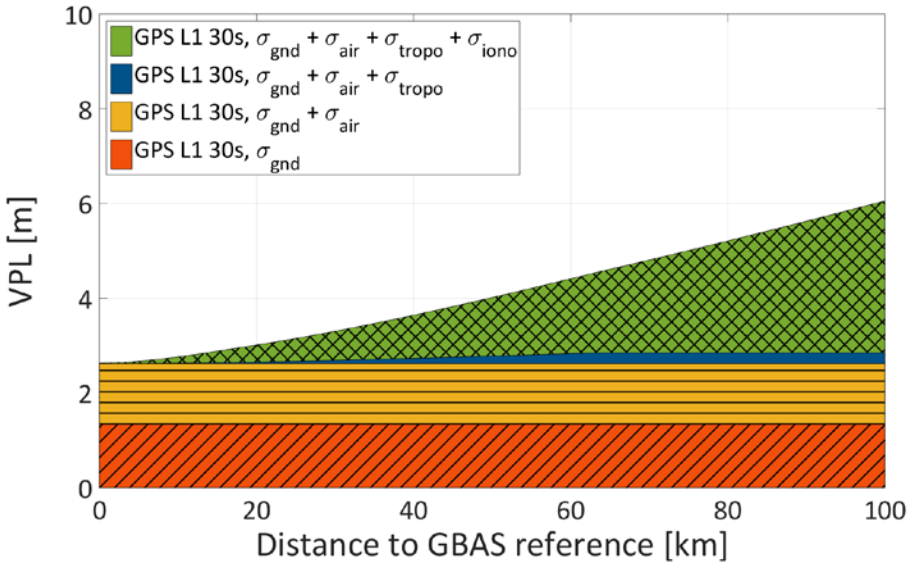


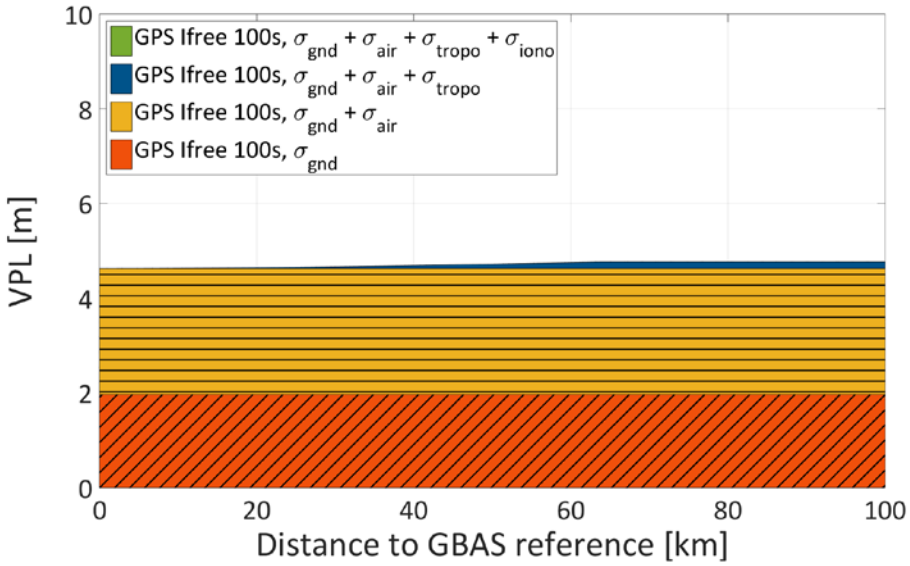
GPS L1 30s (GAST D)



GPS L5 30s

Protection Levels
Contribution of Different Sigma Terms



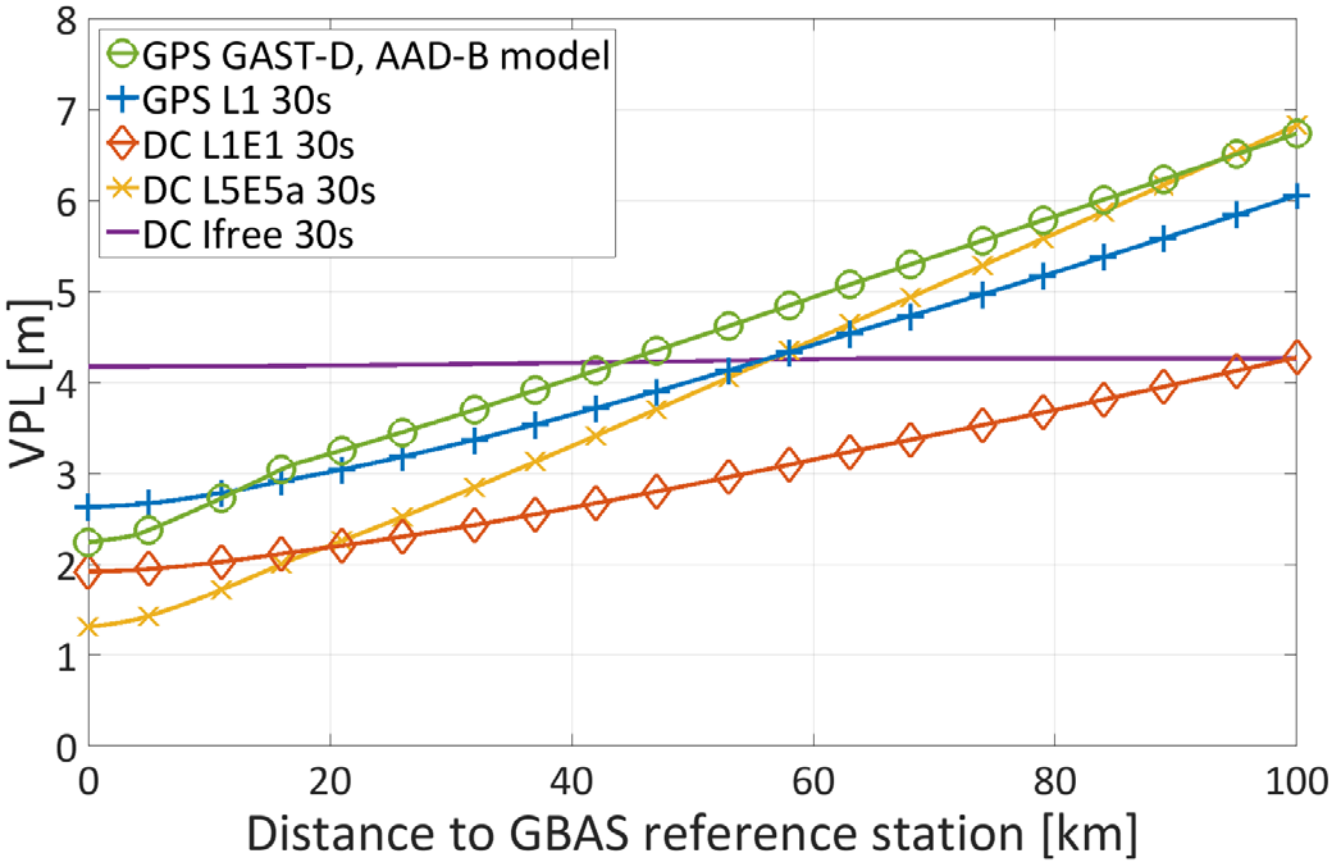


GPS L1 30s (GAST D)

GPS L1/L5 100s Ifree

Comparison and Trade-Off Studies

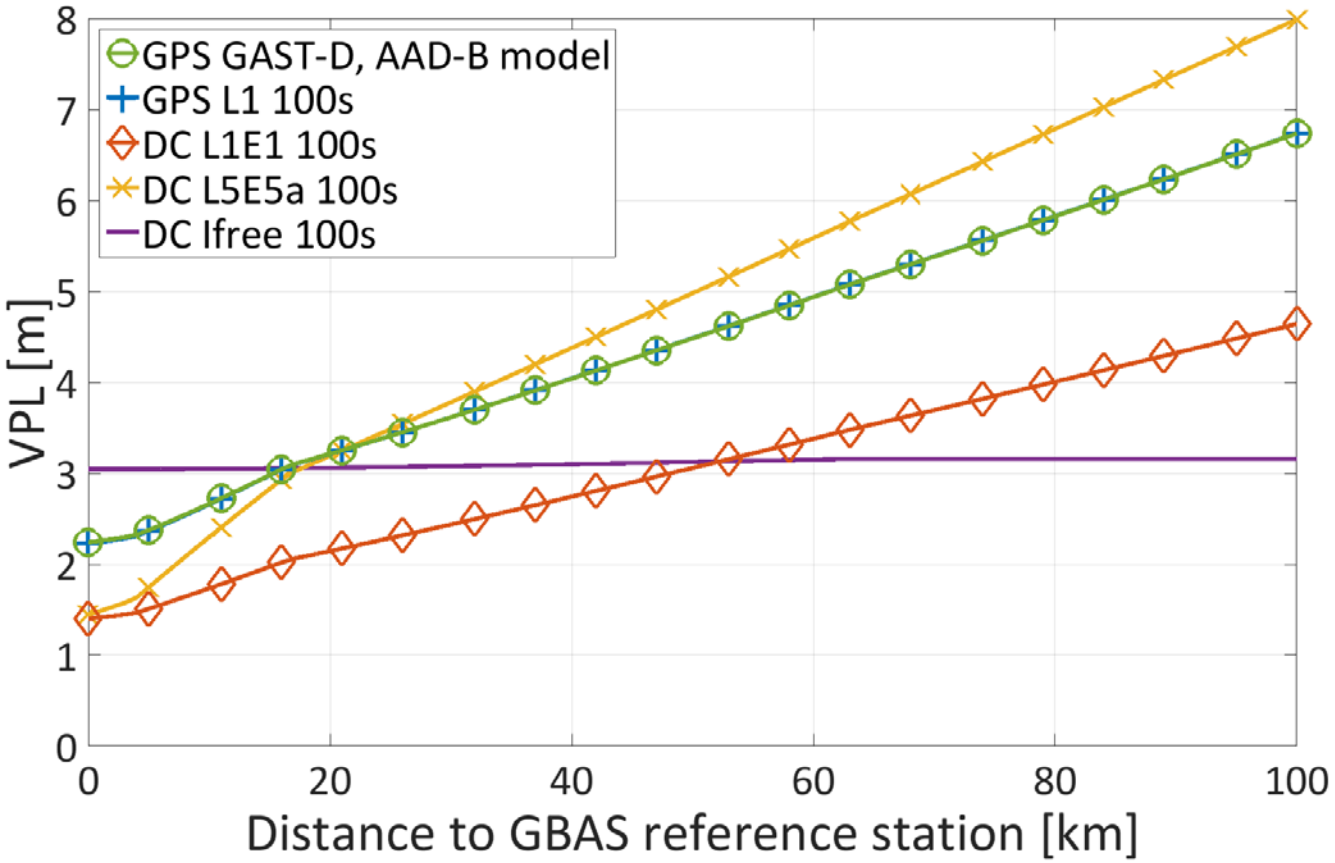
30s Smoothing Constant



- 'Nominal Performance of Future Dual-Frequency Dual-Constellation GBAS' In press, *August 2016, IJAE*

Comparison and Trade-Off Studies

100s Smoothing Constant



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Conclusions

- Dual frequency and multi constellation GBAS can resolve many of the current GBAS issues
- More data and investigations needed for suitable models covering all aircraft, receivers, antennas etc.
- No solution to all problems
- No defined way ahead concerning different modes
- Trade-off is a difficult task

Thank you for your attention!

Questions?