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GNSS Modernisation and Its Effect on Surveying

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The Motivation

- Short range GNSS phase-based positioning is limited by multipath
  - Other errors spatially correlated
- This limits some RTK type applications
- GNSS phase multipath mitigation is extremely difficult today
  - Especially from very close reflectors
- GPS modernization and the new European GNSS – Galileo will provide reliable multiple signals for GNSS phase data processing

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Galileo possible frequency combinations and services

Frequency Combinations	Services (Types of Data)
L1 E5a	OS/CS/SOL
L1 E5b	OS/CS/SOL
L1 E6	OS/CS/SOL + CS/PRS
L1 E5a E5b	OS/CS/SOL
L1 E5a E6	OS/CS/SOL + CS/PRS
L1 E5b E6	OS/CS/SOL + CS/PRS
L1 E5a E5b E6	OS/CS/SOL + CS/PRS

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- GPS modernization and the new European GNSS – Galileo will provide reliable multiple signals for GNSS phase data processing
  - Most current solutions are effectively GPS L1 only
  - **Multipath error is frequency-dependent**

Most multiple frequency studies concentrate on ambiguity determination and ionospheric modelling

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The Questions

- How can the new signals be used to mitigate multipath?
- Will short range phase GNSS be more precise after GPS modernization and Galileo in FOC?

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The Route to The Answers

- Simulate multiple frequency GNSS data
  - No real data available today
- Process combinations
  - GPS: L1, L1+L2, L1+L2+L5
  - Galileo: L1+E5a+E5b
  - GPS+Galileo: L1+L2+L5+L1+E5a+E5b
- Compare with GPS L1 ONLY
  - **Assess impact of 'averaging'**

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Multipath Modelling

- Inputs
  - Reflector Positions (coordinates of four corners)
  - Relative Permittivity (RP)
  - Antenna Gain Pattern (AGP)
  - Phase Centre Variation (PCV)
- Computations
  - Reflection coefficient (from geometry, RP)
  - Phase shift of reflected signal (from geometry)
  - Polarization efficiency (from geometry, RP)
  - Gain ratio (from geometry, AGP)
  - Damping factor (from RC, PE, GR)
  - Correlation function (from chipping rate)
  - Phase error (from DF, CF, geometry)

Lau, L. and Cross, P. (2007) Development and Testing of a New Ray-Tracing Approach to GNSS Carrier-Phase Multipath Modelling. Journal of Geodesy, 81(11), pp. 713-732.

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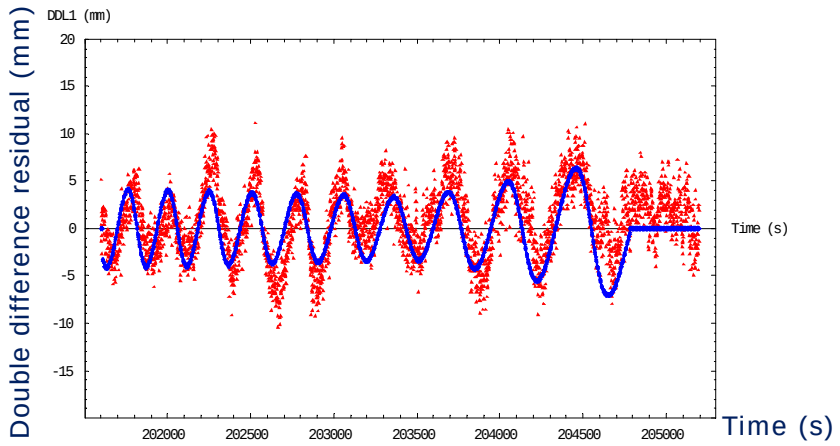
Validation of Simulator (1)



Real and simulated L1 DD residuals

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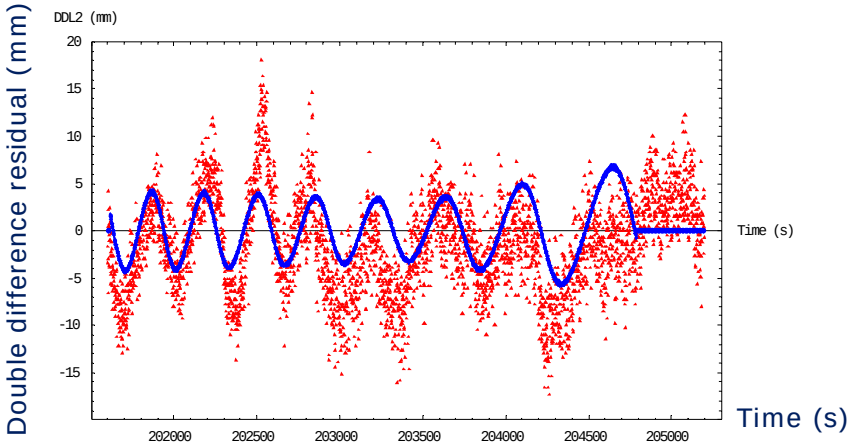
Validation of Simulator (2)



Real and simulated L2 DD residuals

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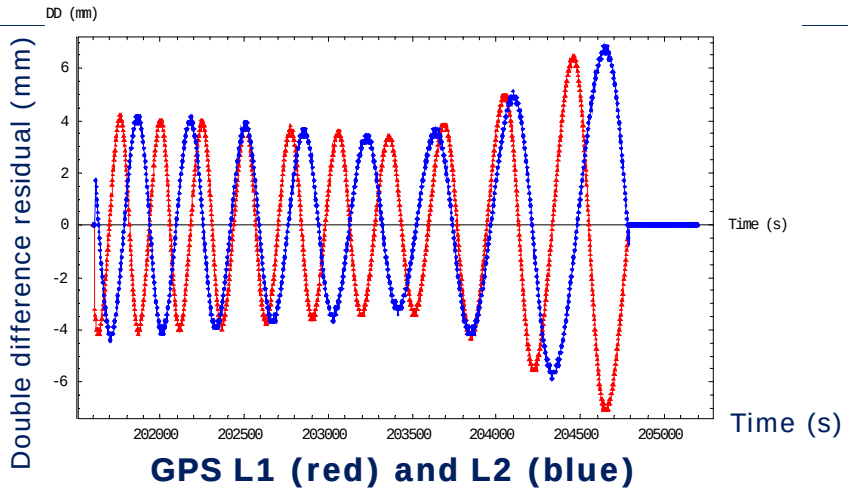
Simulated Multipath in Validation



GPS L1 (red) and L2 (blue)

It shows that phase multipath is **frequency-dependent**

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Validation of Simulator

- **Good agreements of simulated multipath data with real multipath data**

Extrapolate

- **Multipath errors in the future GPS and Galileo multiple-frequency data**

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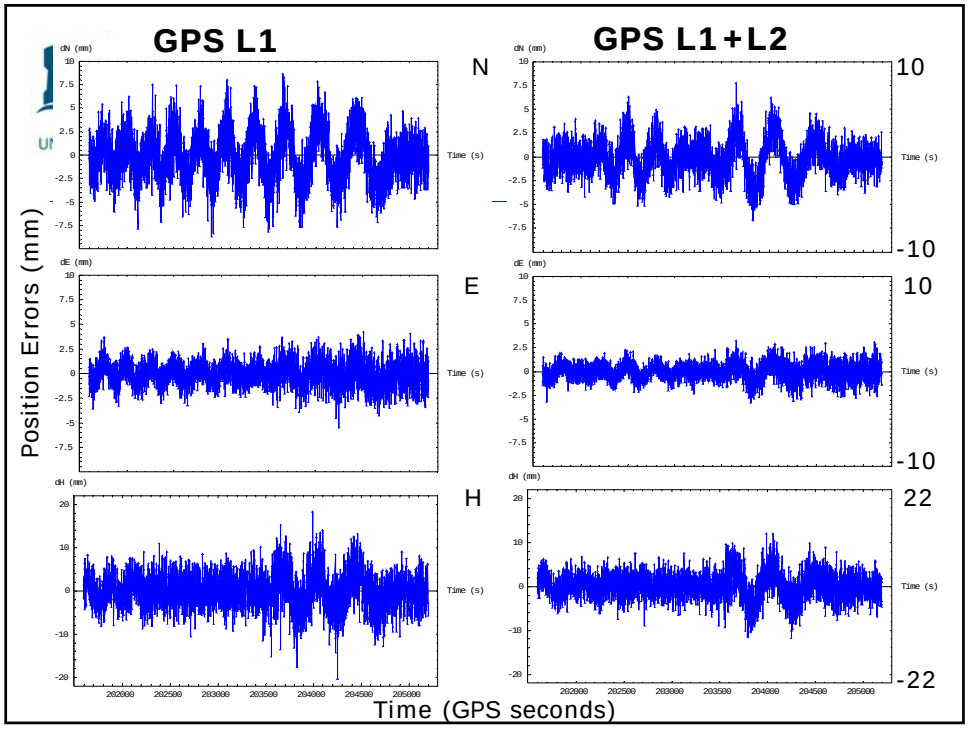
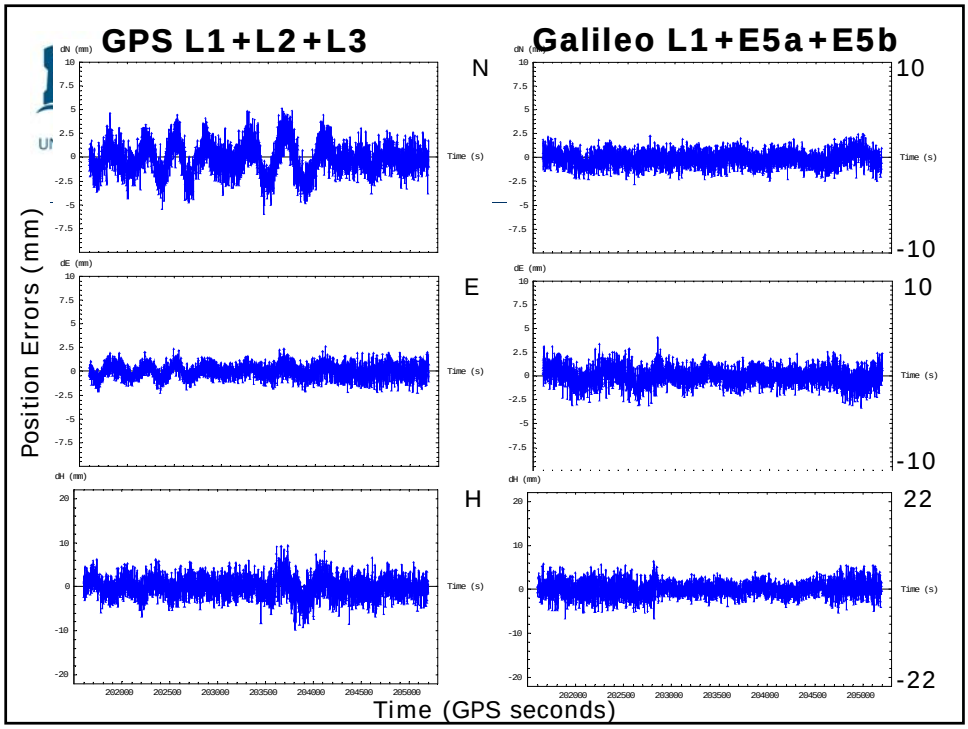
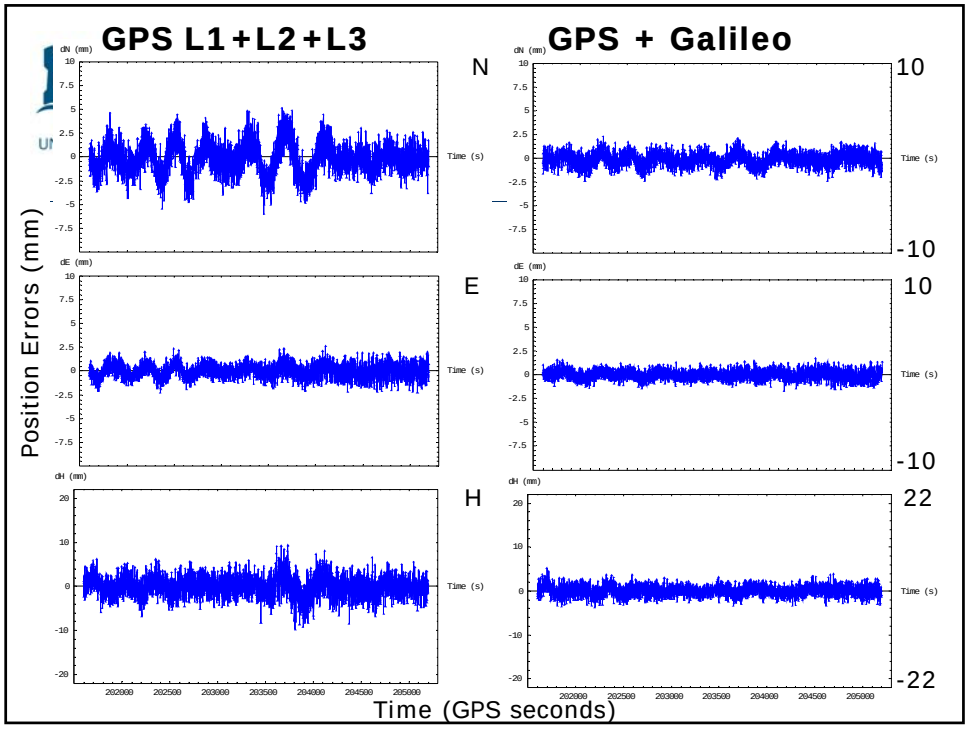
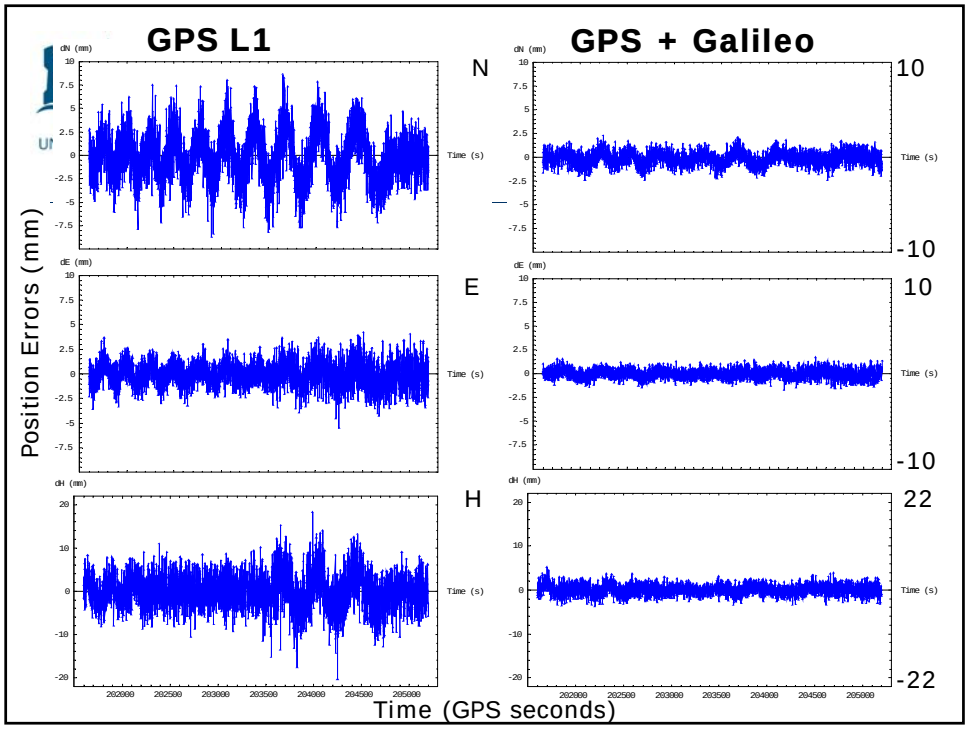
GNSS Data Processor

- Standard double difference model
  - Atmospheric models not turned on
- Separate equations for each frequency
  - No frequency weighting
  - Assume multiple frequency data will have similar noise
- Single epoch ambiguity solutions
- Standard least squares solutions
  - No rejection of data
  - Leads to positions and residuals


GPS L1
GPS L1+L2
Position Errors (mm)
N
E
H
Time (s)
10
-10
22
-22
Time (GPS seconds)


GPS L1+L2+L3
Galileo L1+E5a+E5b
Position Errors (mm)
N
E
H
Time (s)
10
-10
22
-22
Time (GPS seconds)


GPS L1+L2+L3
GPS + Galileo
Position Errors (mm)
N
E
H
Time (GPS seconds)


GPS L1
GPS + Galileo
Position Errors (mm)
N
E
H
Time (GPS seconds)

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Summary: Statistical results

System	3D pos. error		95% 3D pos. error	Max. 3D pos. error
	Mean	SD		
GPS Single	4.3	2.5	9.1	21.8
GPS Dual	3.1	1.9	6.8	13.1
GPS Three	2.5	1.4	5.2	10.6
Galileo Three	1.8	1.0	3.8	7.7
Galileo+GPS	1.3	0.6	2.5	5.2

Unit: mm

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Conclusions

- Realistic multipath simulator
- **GPS**: Use of multiple frequency data leads to significant averaging of the multipath error in least-squares estimation
  - Dual is about 28% better than single
  - Triple is about 19% better than modernized dual
- **GPS + Galileo**: About **70%** improvement when compared with GPS single-frequency data
- Robust solution for RTK multipath