ION GNSS 2010

AUTONOMOUS ISOTROPY-BASED INTEGRITY USING GPS AND GLONASS

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SESSION E4: INTEGRITY MONITORING FOR NEXT GENERATION APPLICATIONS

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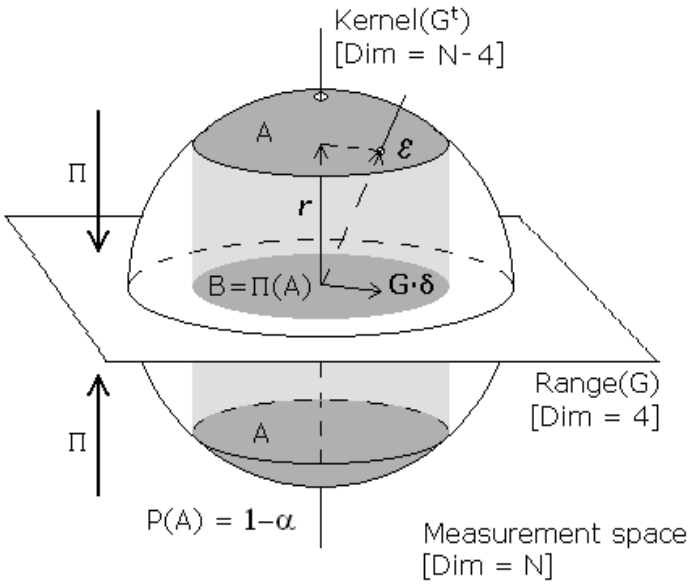
INNOVATING SOLUTIONS

OUTLINE

- IBPL: Isotropy-Based Protection Levels
- PPP: Precise Point Positioning
- Products for PPP
- Static IBPL results
- Kinematic IBPL results
- Long-term IBPL results
- Conclusions

THE IBPL ALGORITHM

- IBPS stands for Isotropy-Based Protection Level
- Applicable to standalone single-freq pseudorange-based user positioning
- RAIM only, no FDE applied
- Protection Level (PL) bounds the position error to a certain probability or confidence level $1-\alpha$
- α is the integrity risk
- Vector of least squares estimation residuals is used for characterization of the position error
- HPL=k·**r**·HDOP, k is a function of α
- It is assumed that the measurement error vector has an isotropic distribution in the measurement space
- Isotropy implies that the pointing direction of the error vector defines a uniform distribution in the measurement space
- No gaussianity assumed on individual errors

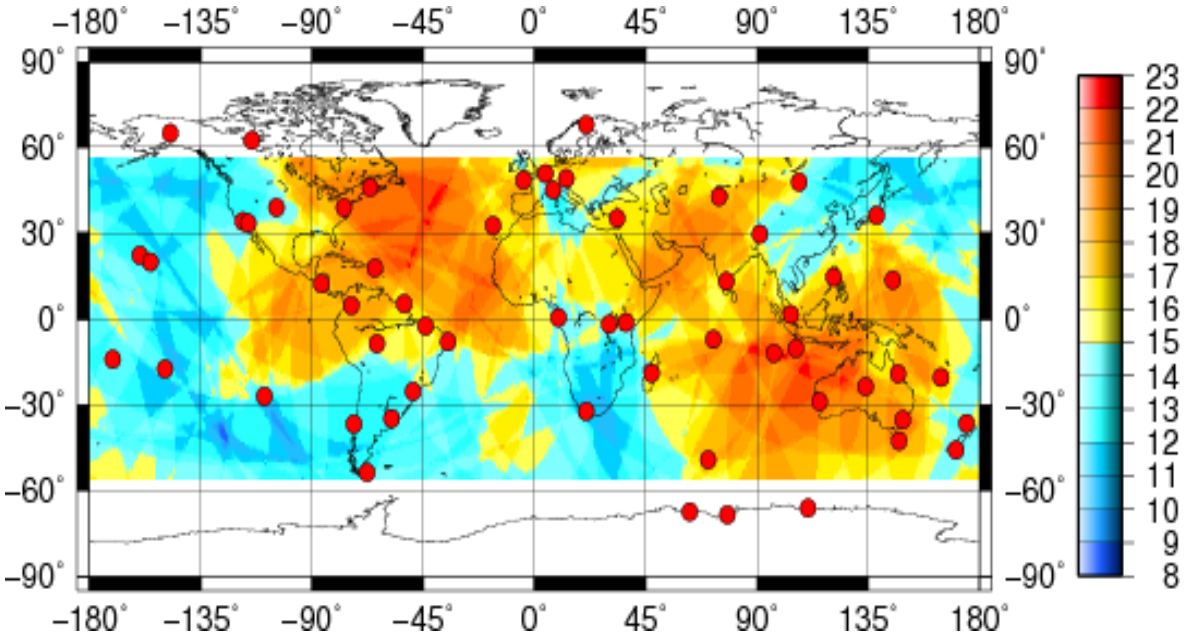


PRECISE POINT POSITIONING

- In order to validate the IBPL concept it is necessary to know the *true* receiver antenna position
- By true position we mean coordinates that are known to have an error several orders of magnitude smaller than the standard pseudorange-based position used in IBPL
- High-accuracy positioning at the cm-level can only be achieved combining pseudorange and carrier-phase measurements.
- Two main techniques are in used nowadays, the well-established RTK (Real Time Kinematics) and the relatively new PPP (Precise Point Positioning)
- PPP processes measurements from a single user receiver, using detailed physical models and corrections, and precise GNSS orbit and clock products
- PPP differs from other precise-positioning approaches like RTK in that no reference or base stations are needed in the vicinity of the user
- The PPP algorithm uses as input pseudorange and carrier phase observations from a dual-frequency receiver (iono-free)

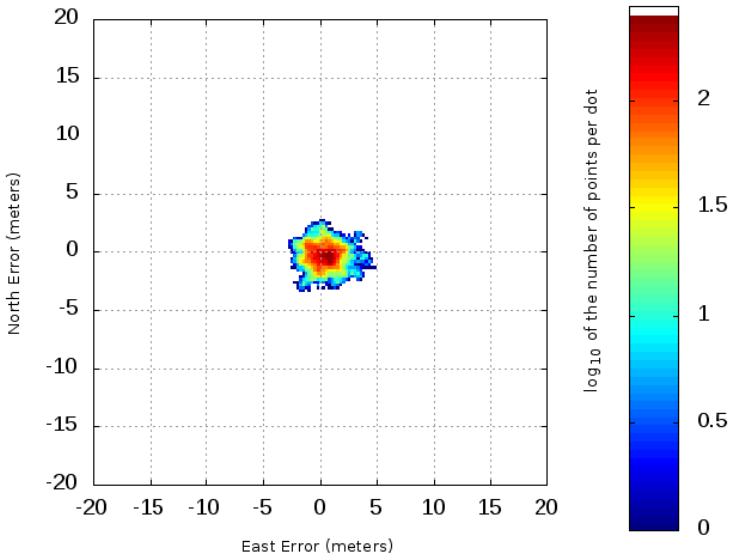
PRODUCTS FOR PPP

- Input *products* for PPP (sat orbits and clocks) are calculated beforehand by an offline process called ODTS (Orbit Determination & Synchronization)
- ODTS works in near-real time (30-min latency)
- IGS tracking network is used (NTRIP streams)
- GPS and GLONASS products generated
- Static and kinematic PPP supported, cm-to-dm level accuracy



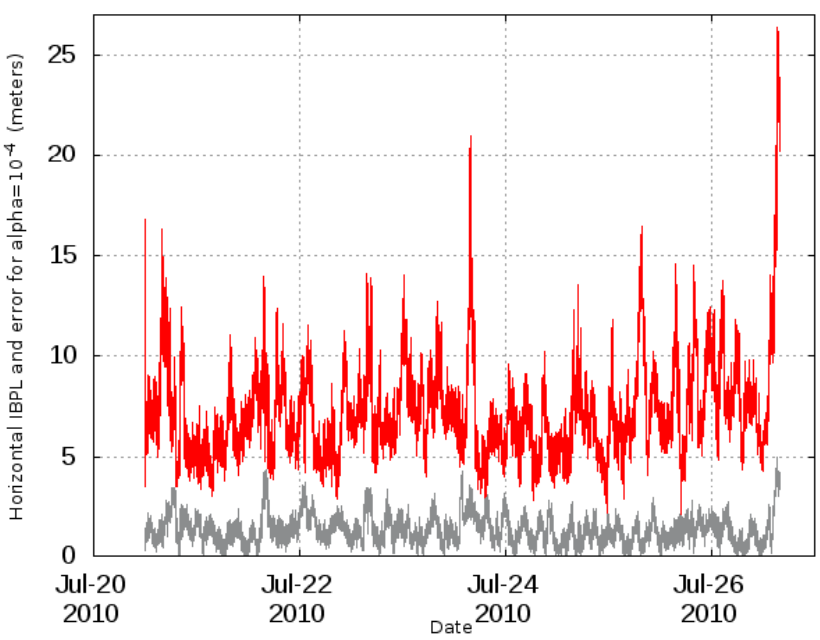
STATIC IBPL

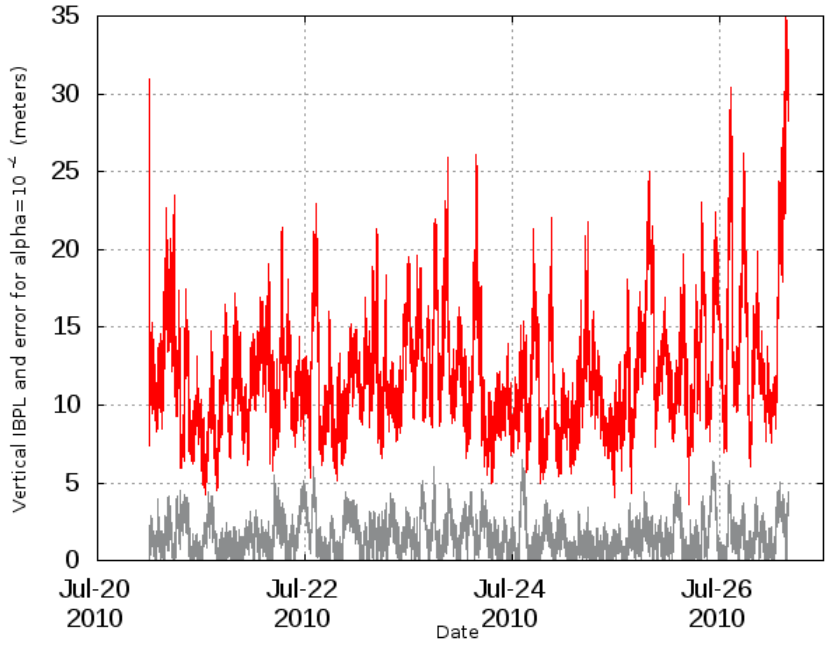
- Topcon Hyper dual-frequency GPS+GLONASS receiver
- Can be mounted on a tripod or on a magnetic base for a car roof
- 7-day data recording on GMV's roof near Madrid (open-sky)
- July 20-26, 2010 (20 GLONASS flying)



STATIC IBPL RESULTS (1)

- Protection Levels and error vs time for $\alpha = 10^{-4}$ (probability of integrity failure = 0.01%).

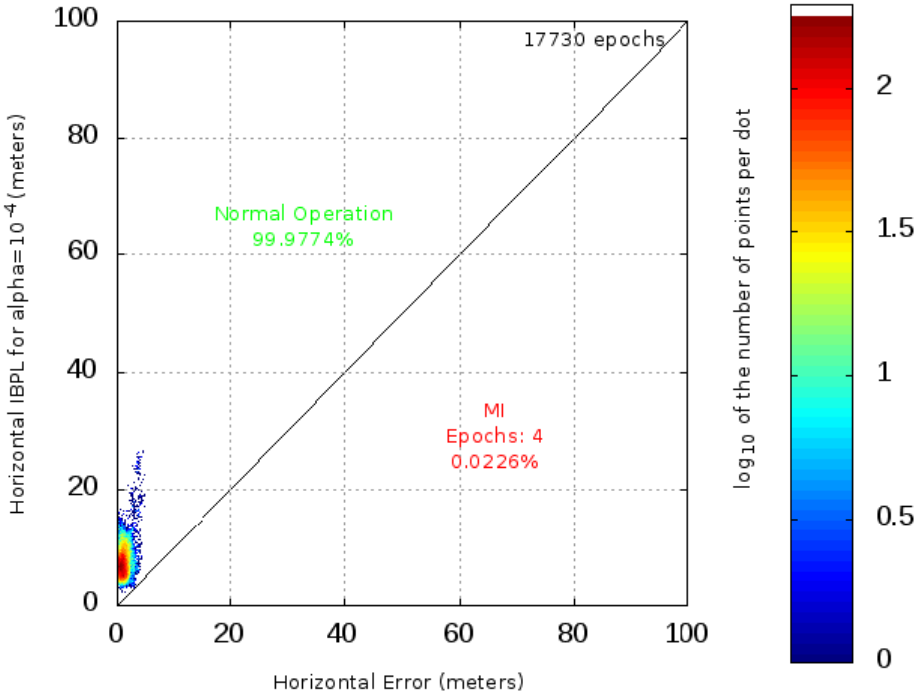


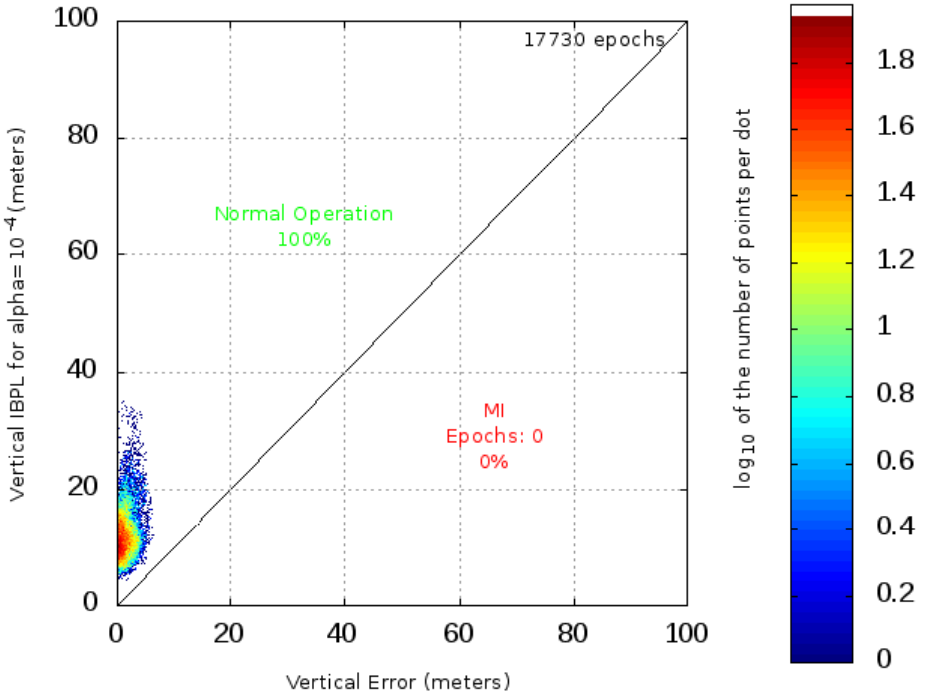


- PL is nearly always larger than the position error
- PL effectively overbounds the user error, within the given integrity risk

STATIC IBPL RESULTS (2)

- Stanford diagrams for $\alpha = 10^{-4}$

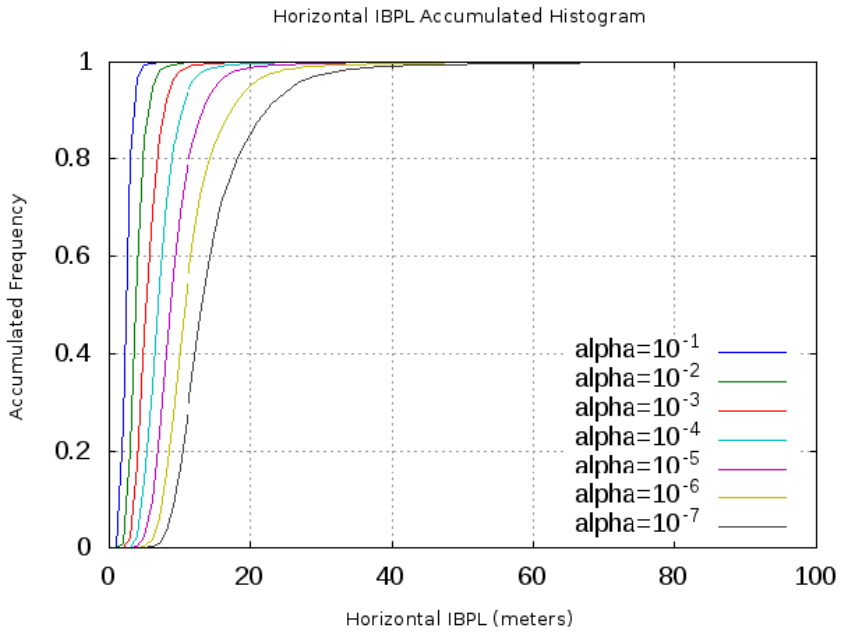


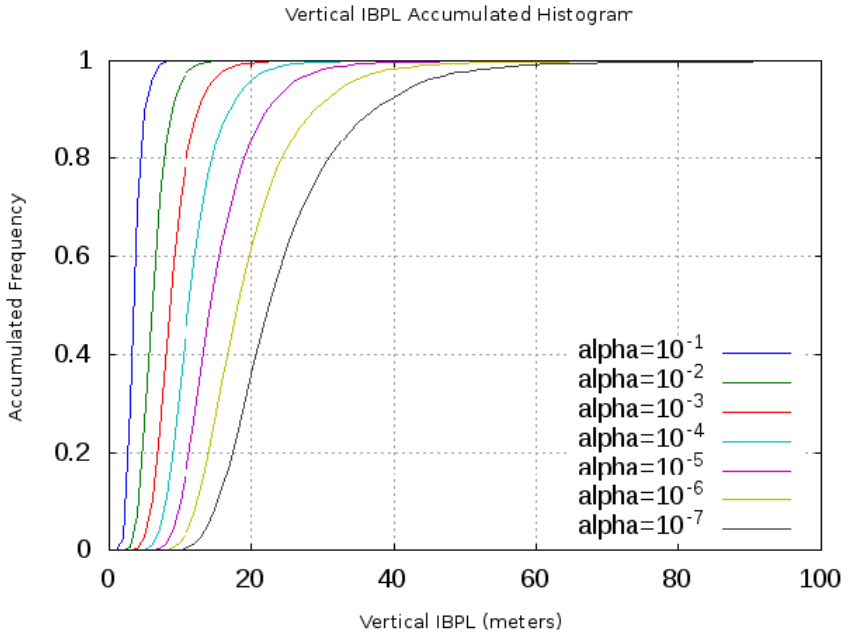


- Horizontal results show that integrity fails around 0.02% of the time, as compared to an a-priori failure probability of 0.01%
- No integrity failure is observed in the vertical component

STATIC IBPL RESULTS (3)

- Accumulated PL histograms for $\alpha = 10^{-1}$ to $\alpha = 10^{-7}$

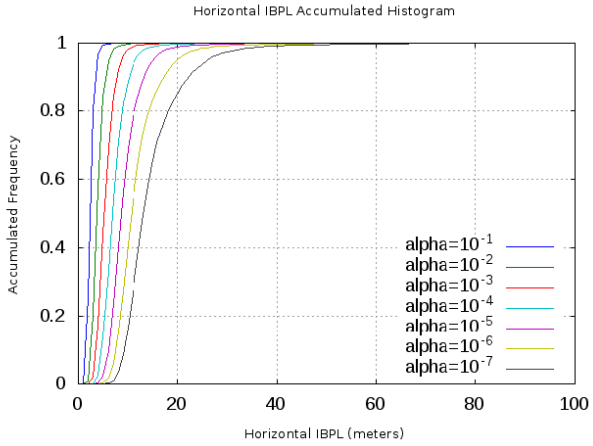


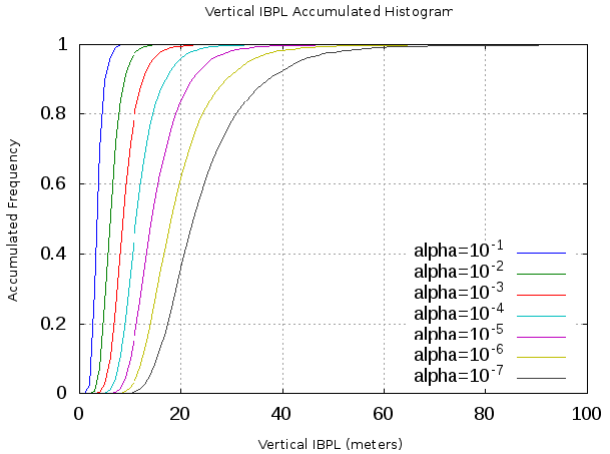


- Size of the PL increases as the integrity risk decreases

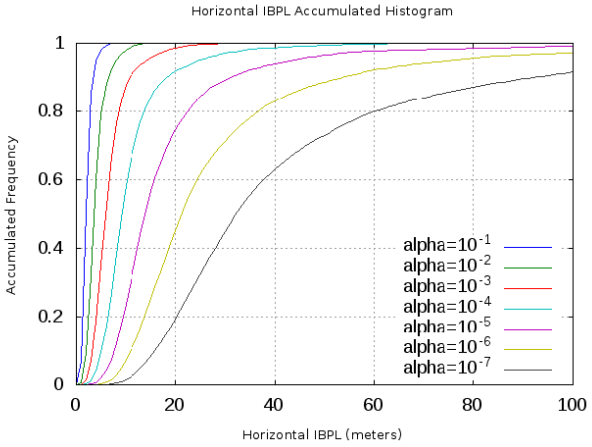
STATIC IBPL RESULTS (4)

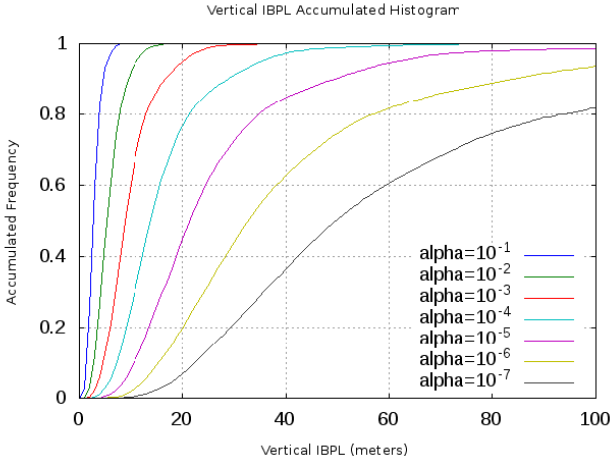
- GPS+GLONASS





- GPS-only





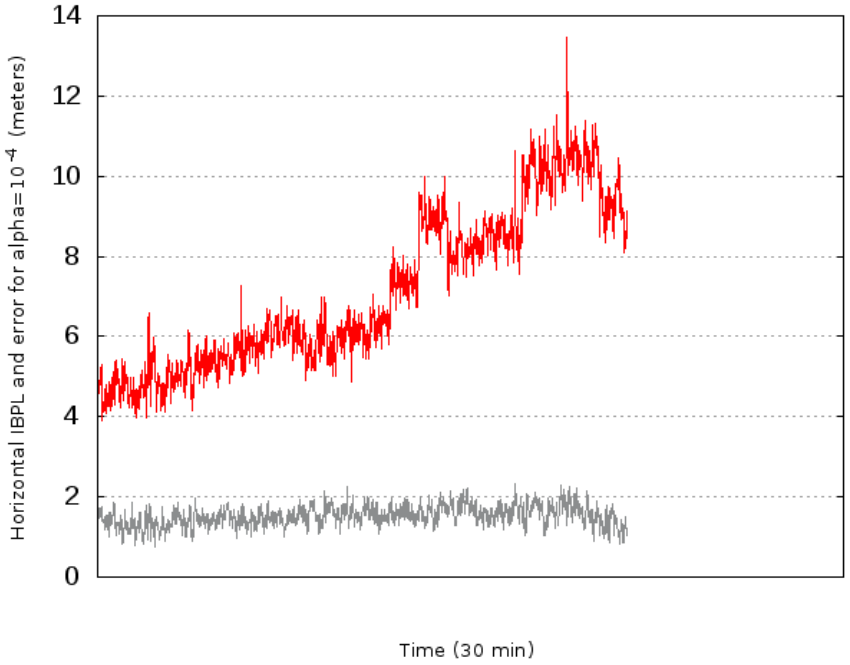
- PL size decreases a lot when adding GLONASS

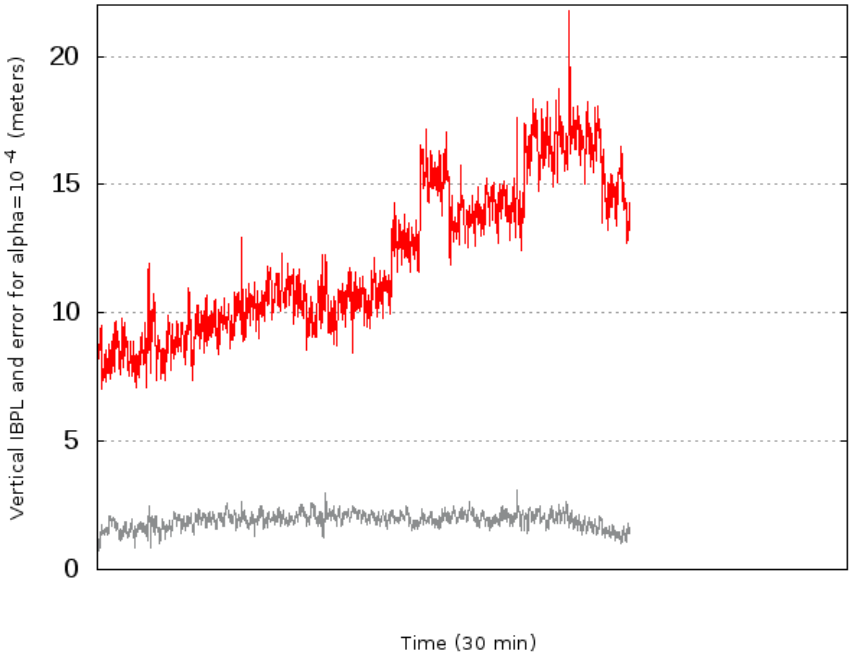
KINEMATIC IBPL

- 30-min open-sky tour, countryside near GMV offices
- Around 2.5 km
- July 23, 2010

KINEMATIC IBPL RESULTS (1)

- Protection Levels and error vs time for $\alpha = 10^{-4}$ (probability of integrity failure of 0.01%).

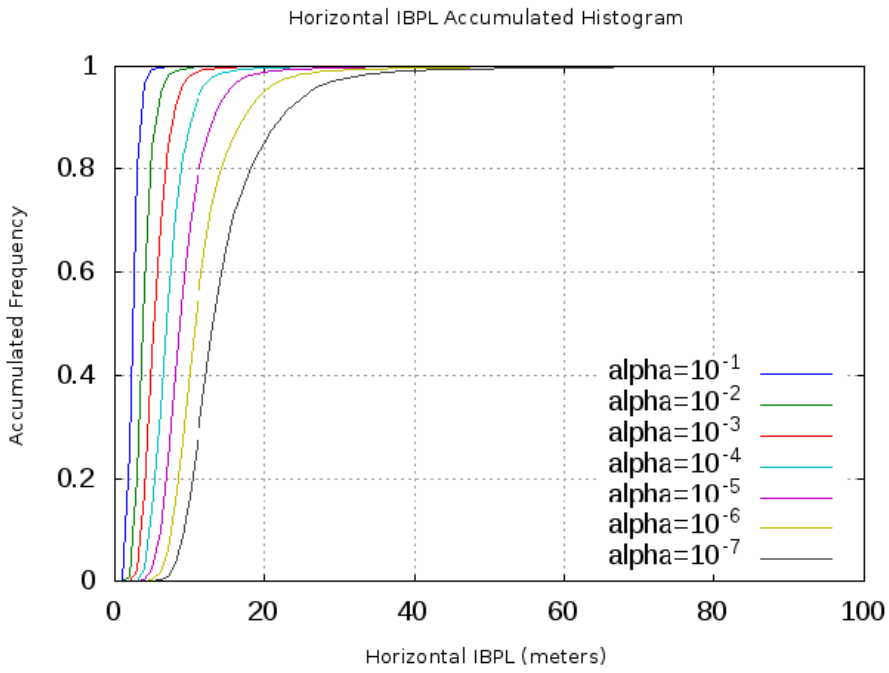


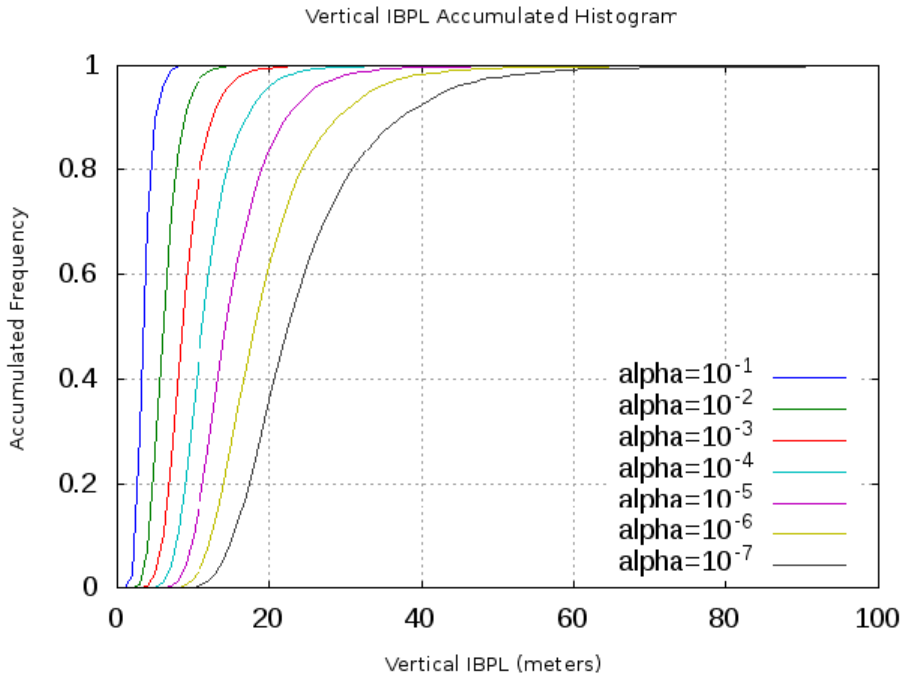


- PL is always larger than the position error
- No integrity failure is observed in the horizontal or vertical components
- PL effectively overbounds the user error, within the given integrity risk

KINEMATIC IBPL RESULTS (2)

- Accumulated PL histograms for $\alpha = 10^{-1}$ to $\alpha = 10^{-7}$



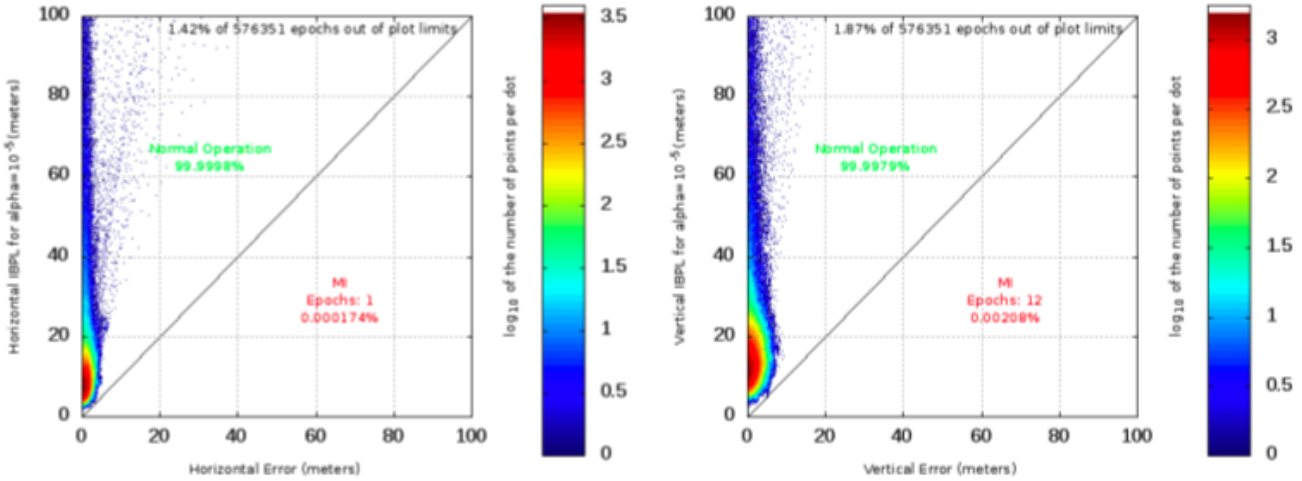


- Pattern and PL sizes similar to static IBPL

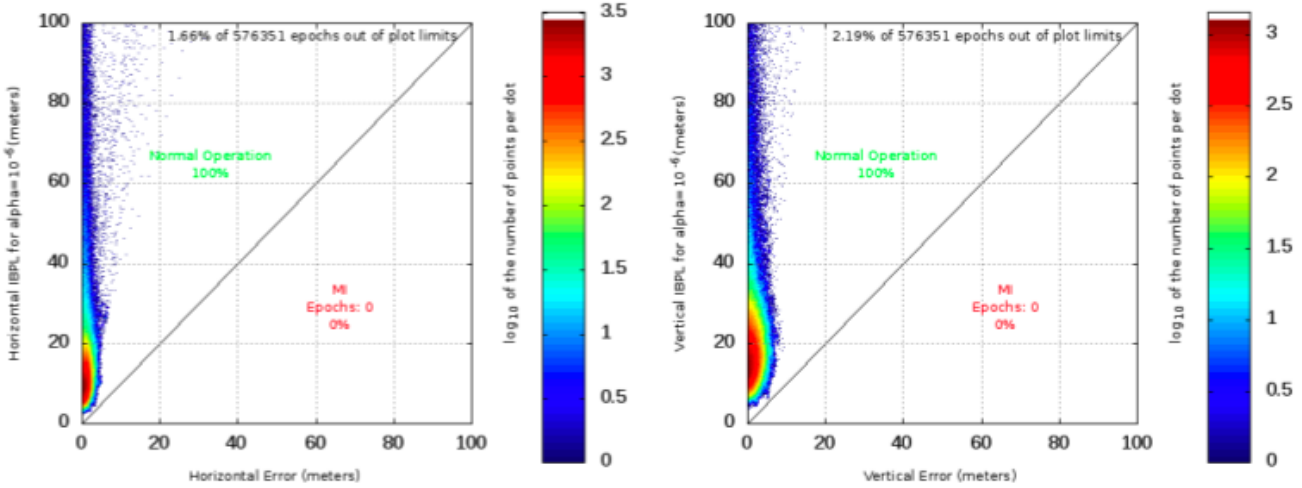
LONG-TERM IBPL RESULTS (STATIC)

- Processing 200 days of WTZR data @ 30 sec (500000+ samples)

- $\alpha = 10^{-5}$

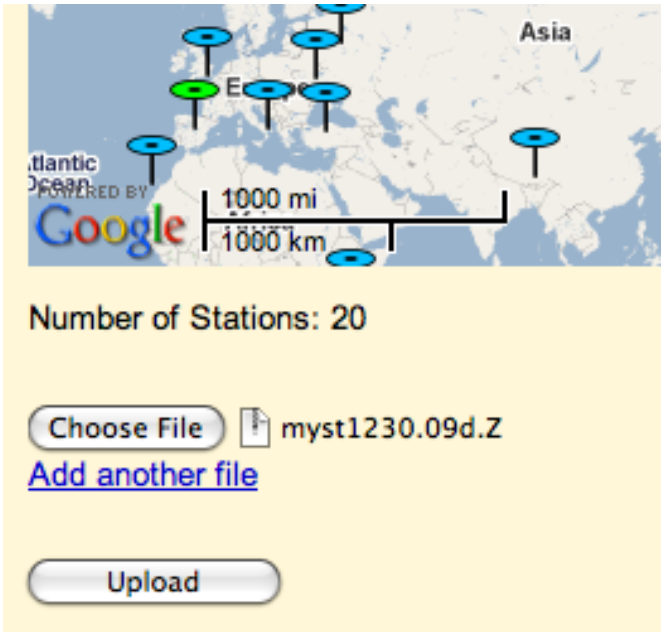


- $\alpha = 10^{-6}$



magicGNSS

- ***magicGNSS*** is a web application for GNSS data processing featuring high-precision and integrity
- Register for a 1-month free trial account
- Upload and process your own dual-frequency station data (RINEX observation files)
- Try IBPL/PPP online!
- **magicgnss.gmv.com**



CONCLUSIONS AND FUTURE WORK

- IBPL provides autonomous integrity for stand-alone pseudorange-based positioning
- GPS+GLONASS real data processing shows much reduced PL sizes vs GPS-only
- PPP is an effective and convenient way of validating IBPL performance (*true* position)
- Open-sky GPS+GLONASS results show promising performances
- IBPL/PPP can be applied to static and kinematic scenarios
- IBPL/PPP can be tested online at magicgnss.gmv.com
- Tests in urban and other difficult environments still to be done
- IBPL might be applicable to carrier-phase cm-level positioning (RTK, PPP) for precise-positioning integrity; to be studied in the future

Thank you!

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