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• GPS-only, Galileo-only, and GPS + Galileo combined processing solutions

• Galileo MGEX product analysis
  • CODE – Center for Orbit Determination in Europe
  • TUM – Technische Universität München
  • CNES – Centre National d’Etudes Spatiales

• Galileo E1/E5b & E1/E5 processing solutions

• Combined GPS L1/L5 & Galileo E1/E5a processing analysis

• GAPS v5.9.1 & v6.0.0 overview
GENERAL PROCESSING STRATEGY

• Preliminary analysis of the functionality of the Galileo GNSS
  • *Limited number of observable satellites*
    • PRNs 11, 12, 14, 18, 19, 22, & 26
    • Two more successfully launched on Sept. 11th
    • PRN 20 E1 transmission only
  • *Limited periods of simultaneous observability*
    • 4-5 satellites for up to 5 hours
  • *IGS MGEX orbit and clock products still experimental*

• UNB’s GPS Analysis and Positioning Software (GAPS) PPP engine
  • [http://gaps.gge.unb.ca](http://gaps.gge.unb.ca)
  • Modified to utilize Galileo observables
  • *Galileo-only & Galileo + GPS combined processing options*
  • *Use of IGS MGEX products to align reference frames and time systems*
  • *Estimation of Inter-System Biases to account for residual Galileo biases*
GENERAL PROCESSING STRATEGY

- **Stations**
  - IGS MGEX stations BRST (France), UNB3 (Canada), & USN8 (USA)

- **Observation periods**
  - DOY 190 & 200 of 2015
  - 4-5 hours of GPS & Galileo simultaneous observability

- **Observables**
  - Galileo E1/E5a, E1/E5b, & E1/E5
  - GPS L1/L2 & L1/L5
  - Carrier-phase & pseudorange iono-free combinations

- **Processing Parameters**
  - Static mode processing
  - Elevation angle cutoff: 3°
  - VMF1 (ECMWF) a priori NAD prediction model and Vienna mapping functions
  - Tropospheric gradients **NOT** estimated
  - IGS ANTEX antenna calibrations
\(4\) GPS satellites
- GPS C1C/C2W & L1C/L2W
- Within 1.3 cm (on average)

\(4\) Galileo satellites
- Galileo C1X/C5X & L1X/L5X (BRST & UNB3)
- C1C/C5Q & L1C/L5Q (USN8)
- MGEX CODE orbits and clocks
- Within 9.7 cm (on average)

\(4\) Galileo & 4 GPS satellites
- GPS C1C/C2W & L1C/L2W
- Galileo C1X/C5X & L1X/L5X (BRST & UNB3)
- C1C/C5Q & L1C/L5Q (USN8)
- MGEX CODE orbits and clocks
- Within 4.6 cm (on average)
Galileo-Only Product Discrepancy from IGS Combined Weekly Solutions

- 4 Galileo satellites
- Galileo C1X/C5X & L1X/L5X (BRST & UNB3)
- C1C/C5Q & L1C/L5Q (USN8)

Station and Product Source

BRST CODE Residuals

BRST TUM Residuals
BRST CNES Residuals

- 4 Galileo satellites
- Galileo C1X/C5X & L1X/L5X (BRST & UNB3)
- C1C/C5Q & L1C/L5Q (USN8)
- 4 Galileo satellites
- Galileo C1X/C7X & L1X/L7X (BRST & UNB3)
- C1C/C7Q & L1C/L7Q (USN8)
- MGEX CODE orbits and clocks
- Within 6.9 cm (on average)

- 4 Galileo satellites
- Galileo C1X/C8X & L1X/L8X (BRST & UNB3)
- C1C/C8Q & L1C/L8Q (USN8)
- MGEX CODE orbits and clocks
- Within 7.3 cm (on average)
• 4 GPS & 4 Galileo satellites
• GPS C1C/C2W & L1C/L5X
• Galileo C1X/C5X & L1X/L5X
• MGEX CODE orbits and clocks
• Within 6.5 cm (on average)

BRST 190 Residuals

UNB3 200 Convergence

• 4 GPS & 4 Galileo satellites
• GPS C1C/C2W & L1C/L5X
• Galileo C1C/C5Q & L1C/L5Q
• MGEX CODE orbits and clocks
• Within 270.0 cm (on average)
CONCLUSIONS

- **Galileo + GPS processing**
  - Interoperability and interchangeability of system observables validated
  - Slight degradation of positional solution
    - Perhaps attributed to use of MGEX products

- **Galileo-only processing**
  - Achievable at decimetre-level accuracy (static)

- **IGS MGEX product validation**
  - CODE and TUM products far superior to CNES

- **Galileo E5b and E5**
  - Results suggest minor improvement in positional solution
  - Further investigation of C8X/C8Q multipath improvement needed

- **Room for improvement**
  - More observable satellites, better positioning
    - Improved satellite geometry
    - Increased redundancy
  - Improved product generation
    - Currently the largest error contributor
GAPS v5.9.1 Overview

GAPS “Advanced” user submission page

Option to estimate/not estimate NAD
User-selection of NAD prediction model and mapping functions
User-selection of orbit and clock products to be used
Option to estimate/not estimate tropospheric gradients
User-selection of RINEX v3.x observables to be used
Option to use GPS L5
Option to use GPS L2C
Option to use custom user antenna calibration files
GAPS v5.9.1 Overview

GAPS “Basic” user submission page

- Allows for quick and easy submission of observation files
- For users who frequently use GAPS’ default processing options:
  - IGS Final products
  - GPS C1W/C2W & L1W/L2W observables
  - NAD estimation
  - NO tropospheric gradient estimation
  - UNB3m NAD prediction model & Vienna mapping functions
  - IGS ANTEX antenna calibrations
User-selection of system(s) to be used

User-selection of Galileo Phase observables, including E5a, E5b, or E5

User-selection of Galileo orbit and clock products to be used

Galileo ISB

Galileo PRNs used in solution