

RETICLE v2.0 – Recent Developments of DLR's Real-Time Clock Estimation (RETICLE) Engine

André Hauschild, DLR/GSOC



Knowledge for Tomorrow



Agenda

- Overview of RETICLE v2
- GNSS Clock Estimation Results
- Summary and Conclusion
- Recommendations



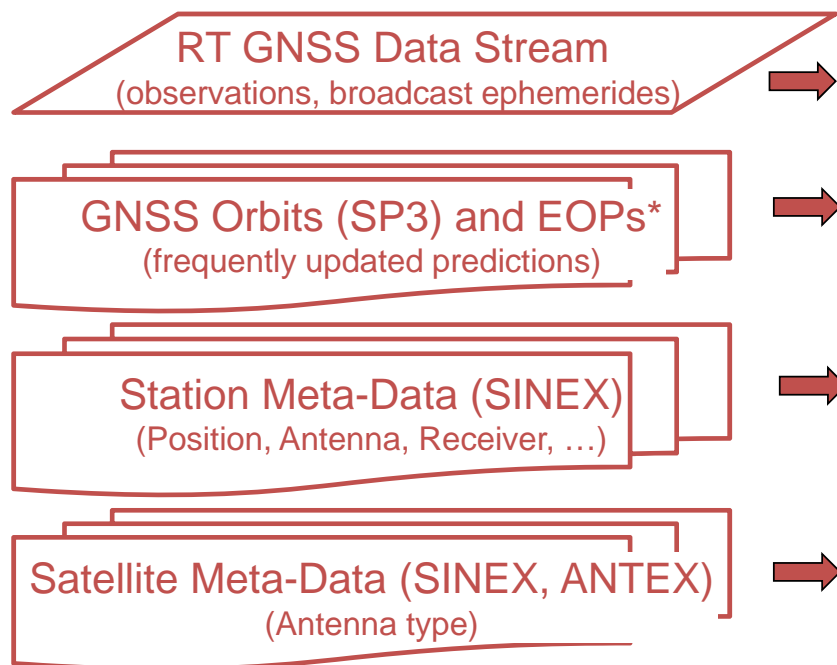
Brief History of RETICLE Development at GSOC

- Mid 2007: start of S/W development for v1.0
 - Single-threaded application, no parallelization, GPS only
 - Later addition of GIOVE and GLONASS
- Mid 2008: first operational real-time version
- End 2008: started participation in IGS Real-Time Pilot Project
 - One of the first real-time analysis centers to submit products
- Mid 2015: start of S/W development for v2.0
 - Multi-threading, designed for large network and multi-constellation
 - GPS, GLONASS, Galileo, BeiDou, QZSS



Overview of RETICLE

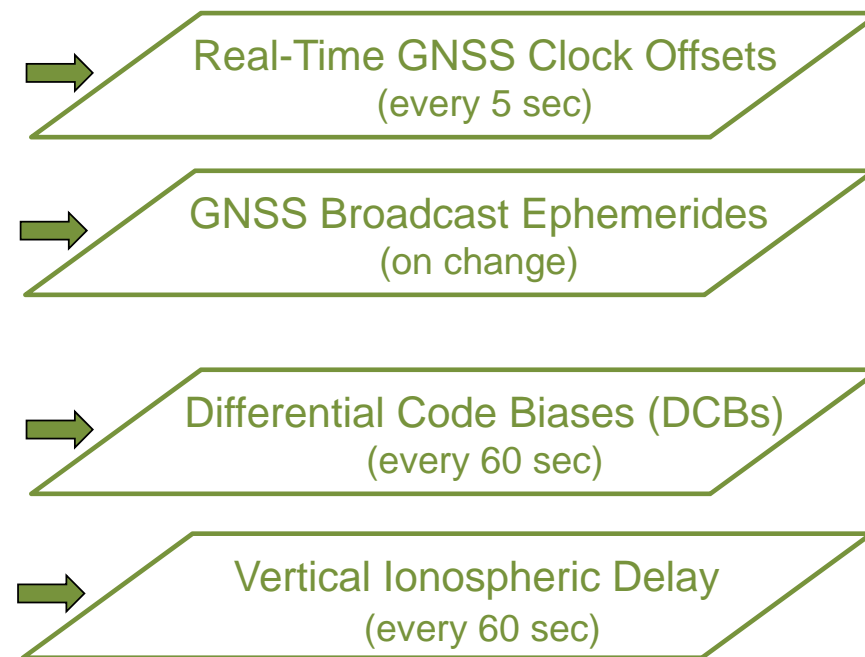
Inputs



* Earth-Orientation Parameters



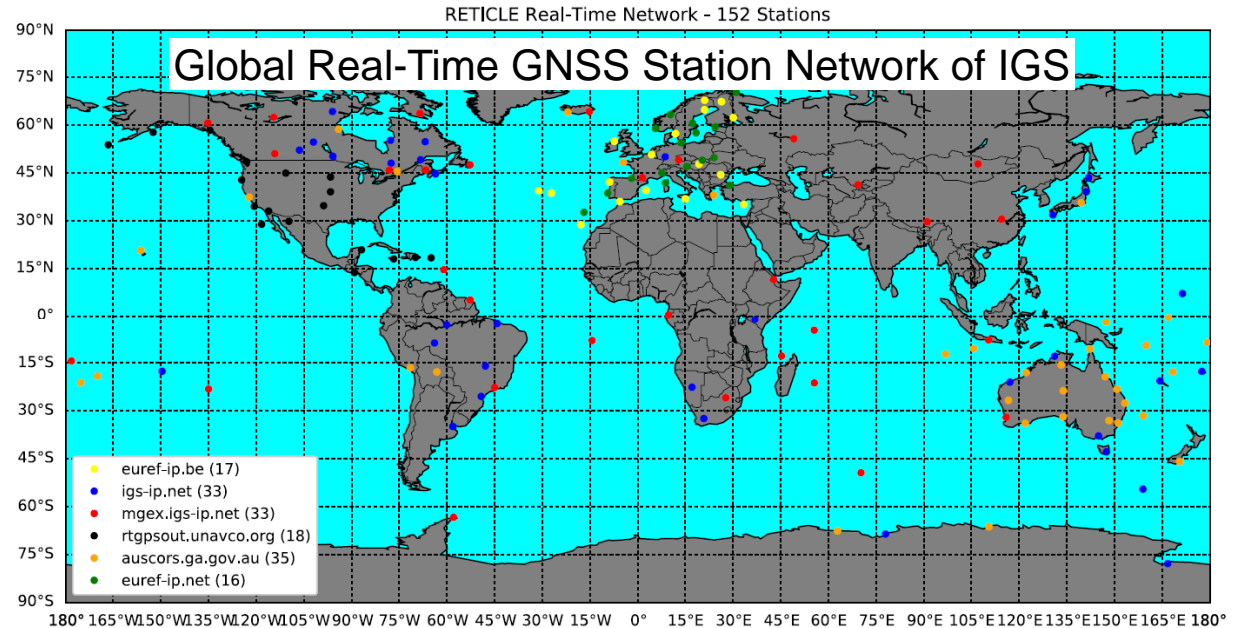
Outputs



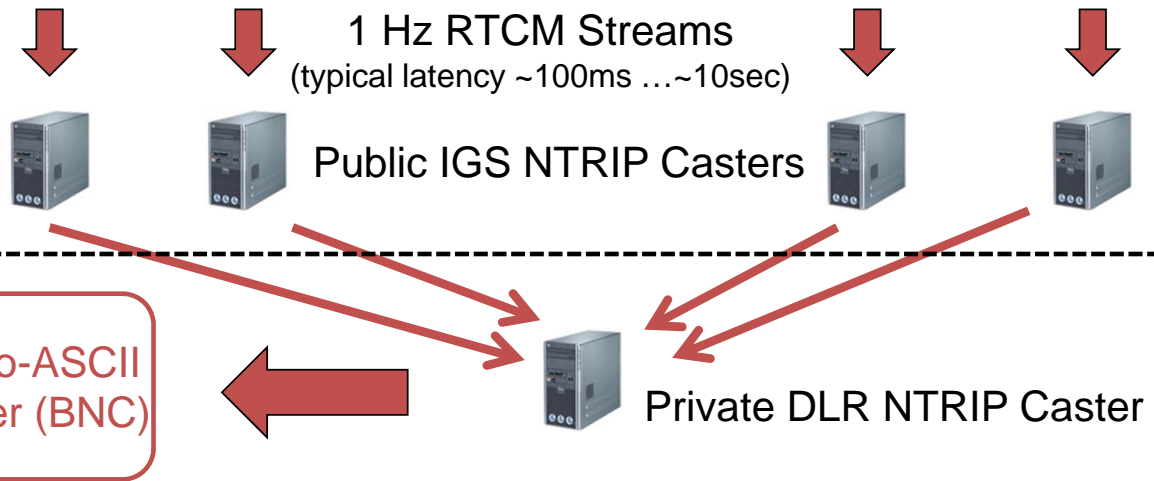
Overview of RETICLE – Inputs

RT GNSS Data Stream
(observations, broadcast eph.)

- RETICLE uses ~150 IGS RT network stations
 - Unification of stream to single access point
 - Conversion from raw (RTCM) to ASCII
- BKG's BNC decoder for RTCMv3 decoding
 - Output of OBS and NAV feed streams



Internet



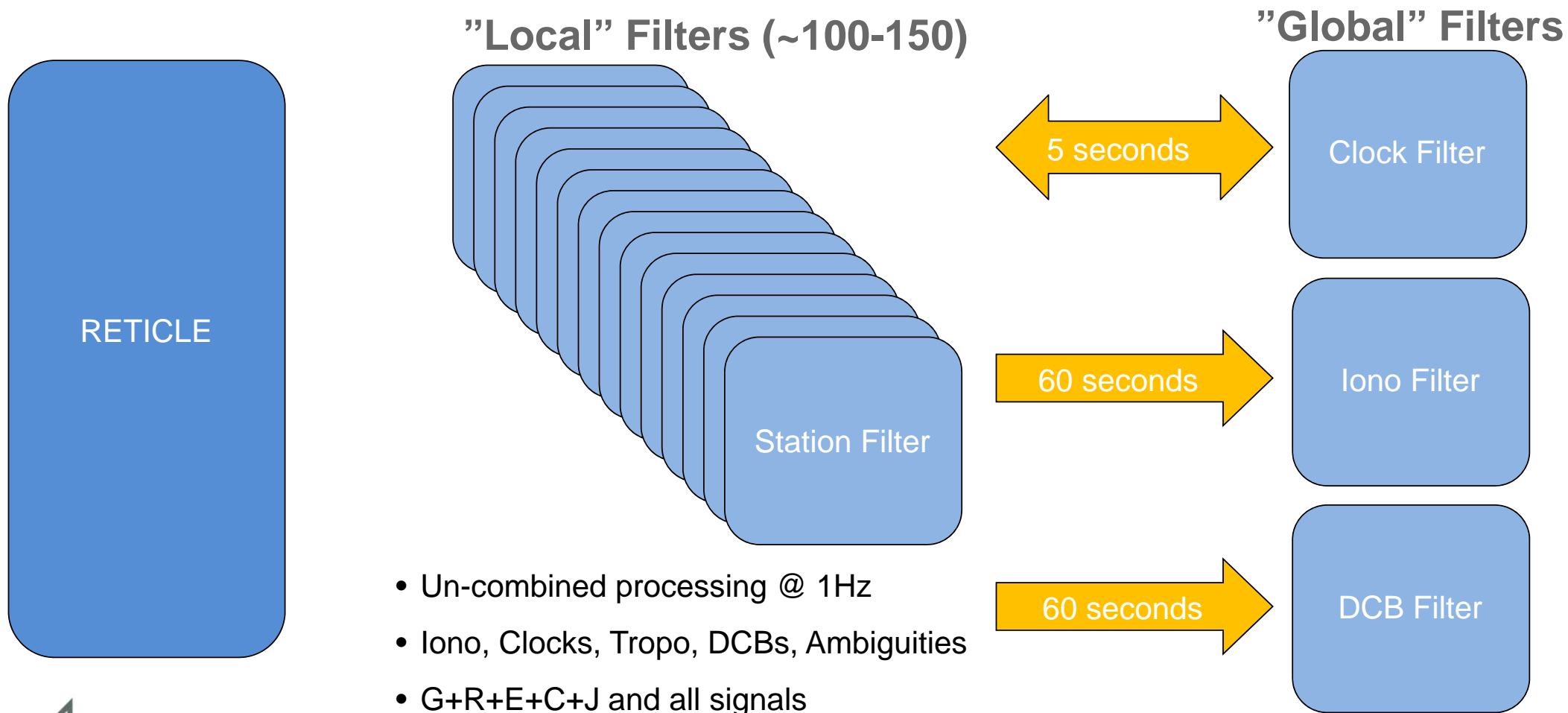
Overview of RETICLE – Core Algorithm

RETICLE

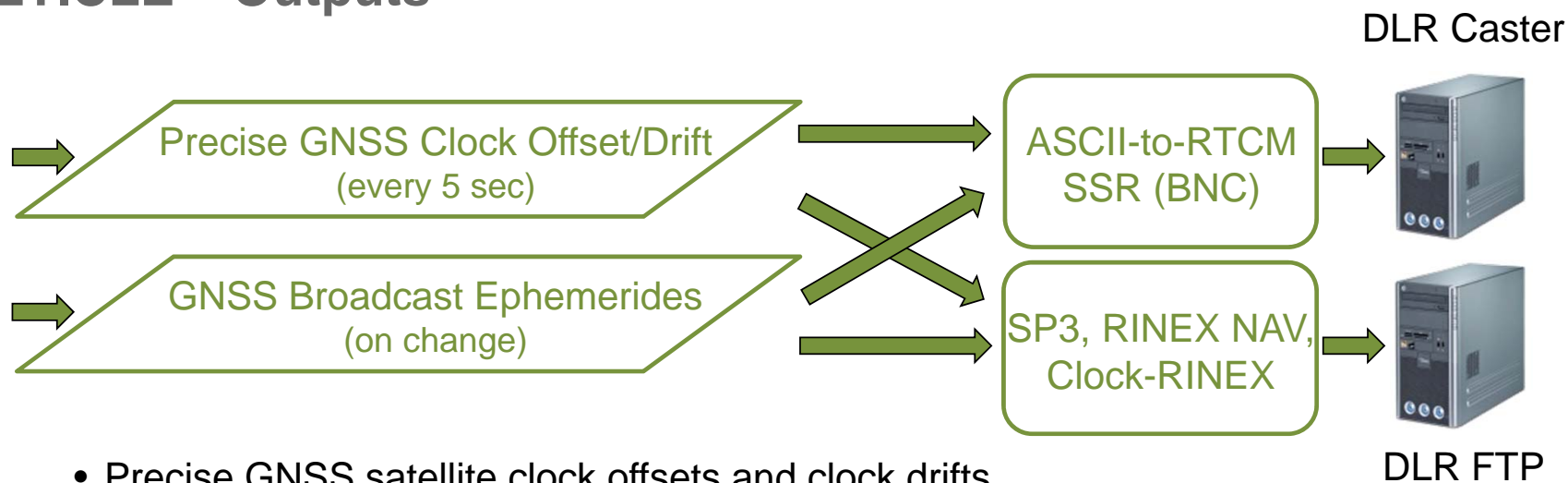
- Core algorithm based on federated Kalman-filter
- “Local” Kalman-filters for each individual station
- “Global” Kalman-filter for fusion of “local”-filter estimates
 - Estimates clock offset and drift every 5 seconds, iono + DCBs every 60 seconds
- Capable of processing a large station network (tested with up to ~150 stations)
- Capable of processing all GNSS (G+R+E+C+J) (~85 SVs)
- Autonomous operation, minimize human interaction / maintenance
 - Automatic exclusion of unhealthy satellites
 - Handle changes in the real-time network (adding/removing stations)
 - Automated update of meta-data for stations and satellites



Overview of RETICLE – Core Algorithm



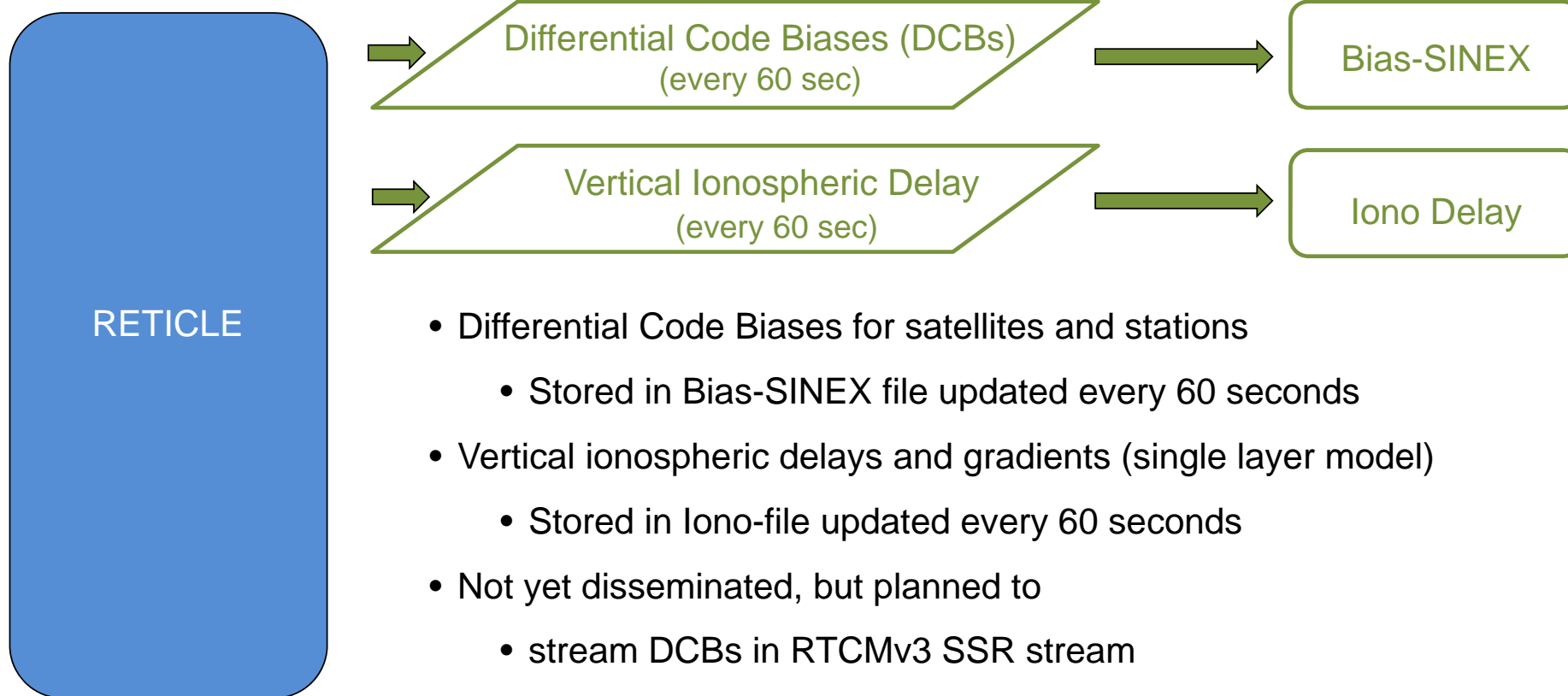
Overview of RETICLE – Outputs



- Precise GNSS satellite clock offsets and clock drifts
 - Update rate 5 seconds, latency ~ 8 seconds
- GNSS Broadcast Ephemerides
- File-based near real-time products updated every 5 minutes on FTP server
 - SP3 (sampling 10 min), Clock-RINEX (sampling 5sec), RINEX NAV
- RTCMv3 SSR streams for real-time users streamed to NTRIP caster
 - Generated with BNC



Overview of RETICLE – Outputs



- Differential Code Biases for satellites and stations
 - Stored in Bias-SINEX file updated every 60 seconds
- Vertical ionospheric delays and gradients (single layer model)
 - Stored in Iono-file updated every 60 seconds
- Not yet disseminated, but planned to
 - stream DCBs in RTCMv3 SSR stream
 - generate Real-Time GIM based on vertical delays



Overview of RETICLE – Results

- Orbit predictions
 - IGS ultra-rapid predictions for GPS and GLONASS
 - DLR ultra-rapid predictions for Galileo
- Clock accuracy assessment with SISRE (1)
 - Reference product DLR MGEX final orbit/clock
- Consistent clock reference signals
 - GPS C1C/C2W, GLO C1C/C2P, GAL C1X,C5X
- Typical SISRE rms
 - GPS: 7-8 cm
 - GAL: 9-11 cm
 - GLO: ~decimeters
- GLONASS clocks are biased (FDMA inter-channel biases), but stable

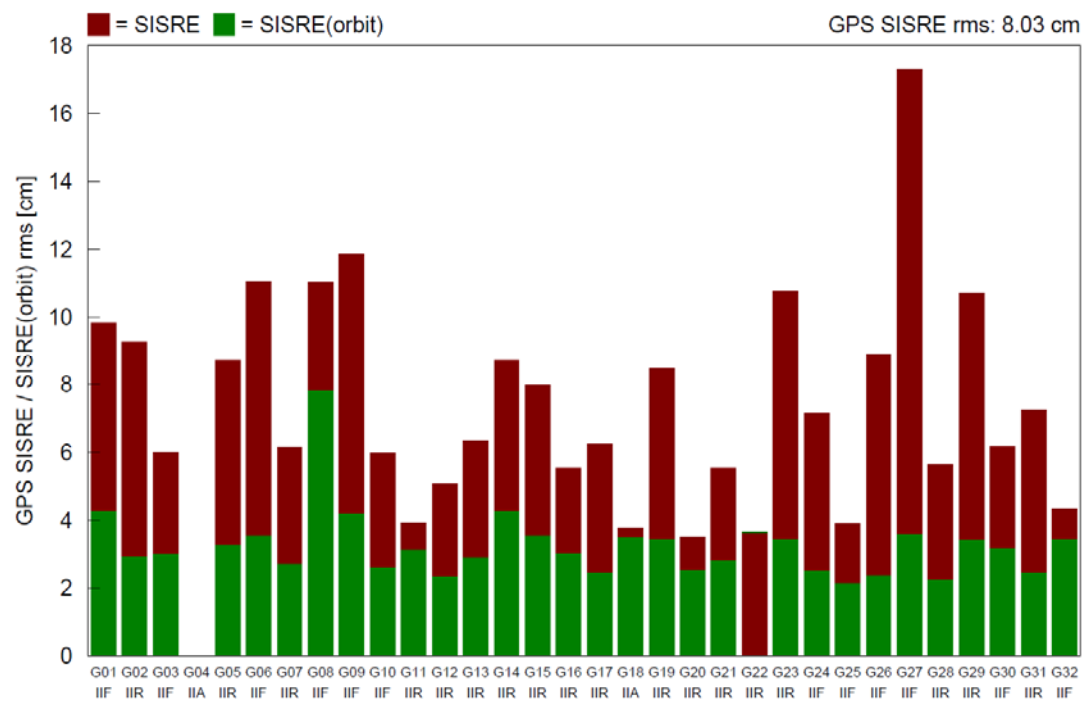
| Date | SISRE rms [cm] | | |
|-------------|----------------|-------|-------|
| | GPS | GLO | GAL |
| 19-Oct-2018 | 7.26 | 41.92 | 10.77 |
| 20-Oct-2018 | 7.41 | 49.50 | 13.67 |
| 21-Oct-2018 | 7.66 | 57.60 | 11.58 |
| 22-Oct-2018 | 7.44 | 71.34 | 10.93 |
| 23-Oct-2018 | 8.03 | 85.17 | 9.90 |
| 24-Oct-2018 | 7.47 | 89.96 | 9.50 |
| 25-Oct-2018 | 8.40 | 95.94 | 7.88 |

(1) Montenbruck O, Steigenberger P, Hauschild A (2018) *Multi-GNSS signal-in-space range error assessment —methodology and results*. Adv Space Res 61(12):3020–3038

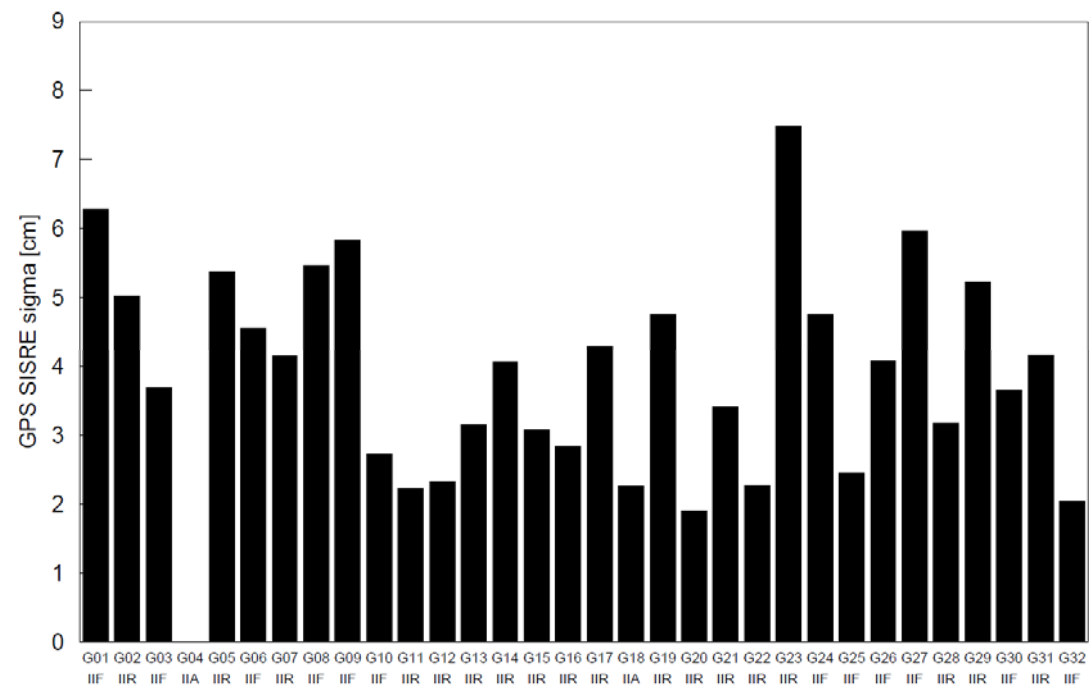


Overview of RETICLE – Results

GPS SISRE Mean

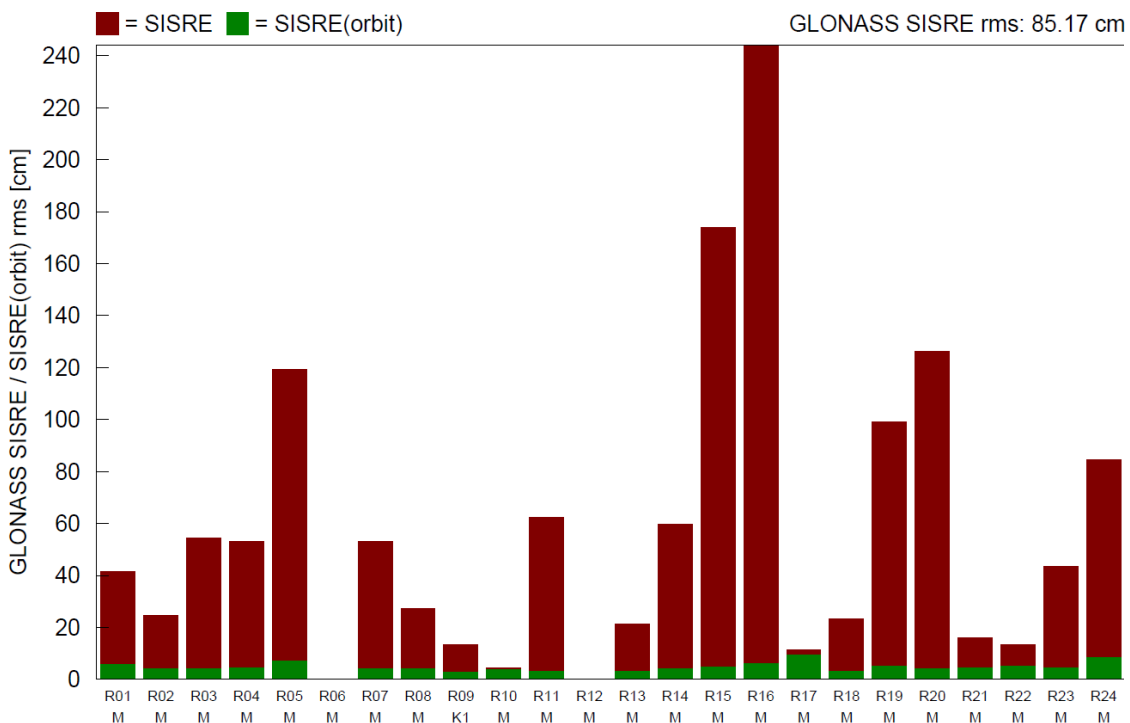


GPS SISRE StdDev

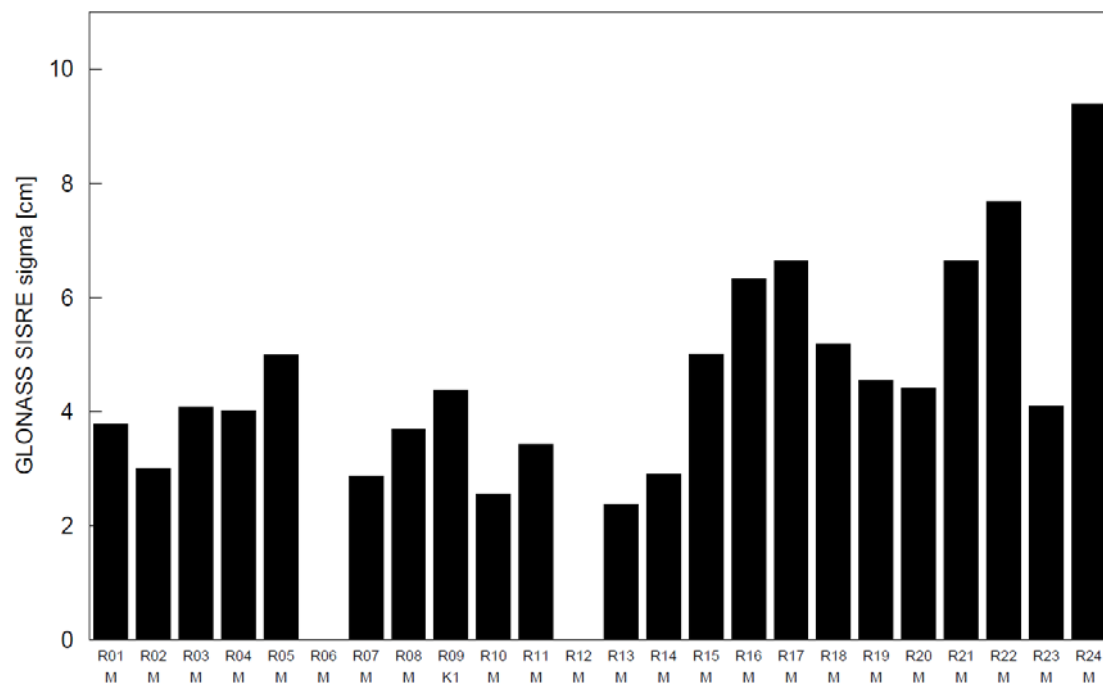


Overview of RETICLE – Results

GLONASS SISRE Mean

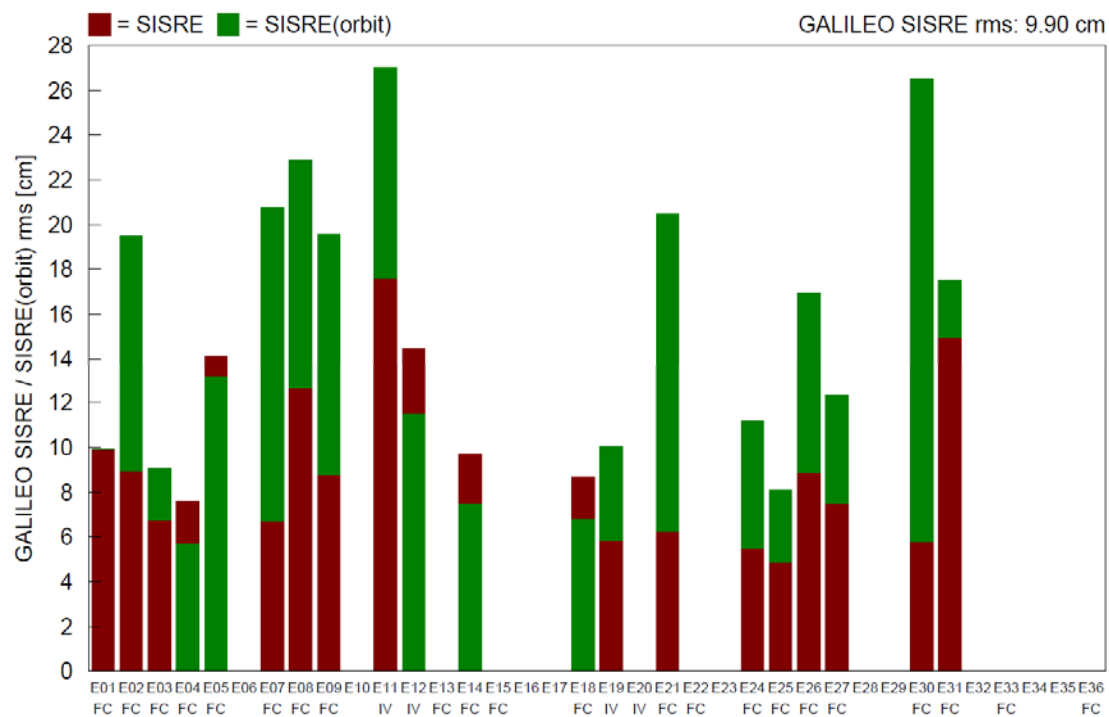


GLONASS SISRE StdDev

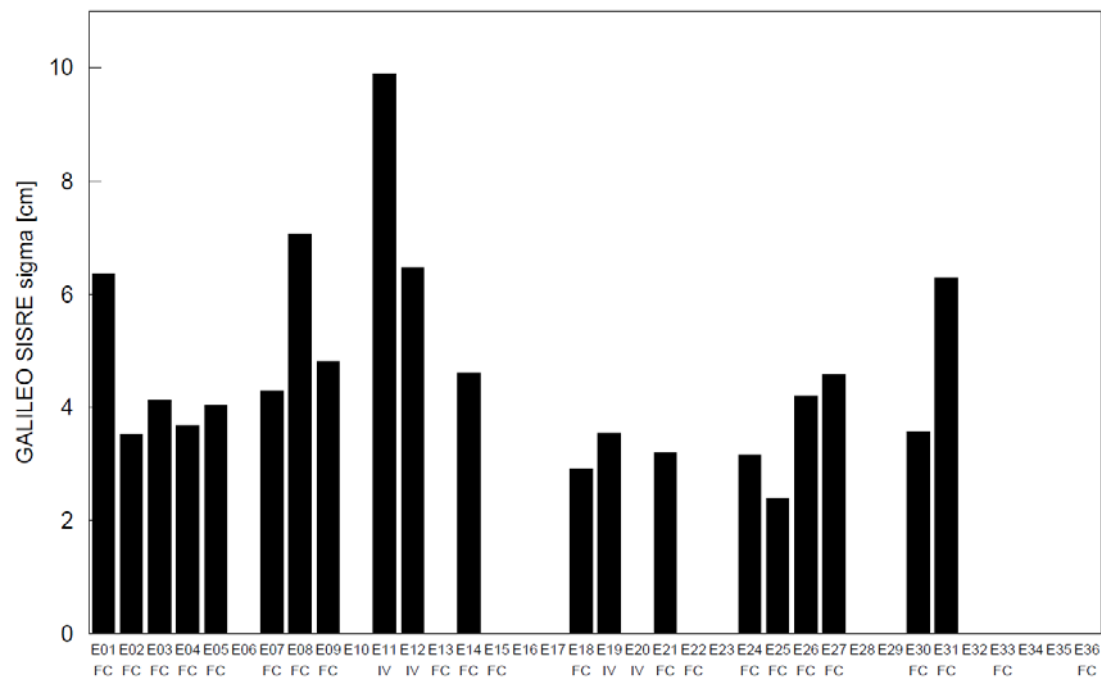


Overview of RETICLE – Results

Galileo SISRE Mean



Galileo SISRE StdDev



Summary and Conclusions

- New multi-GNSS version of RETICLE
 - Capable of processing GPS, GLONASS, Galileo, Beidou and QZSS
 - Un-combined observations, parallel processing
- Uses fixed predicted input orbits
 - GPS and GLONASS from IGV ultra-rapid product
 - Galileo from new DLR ultra-rapid product
 - Precise orbits for BeiDou and QZSS pending
- User access to products via
 - RTCMv3 SSR streams at DLR/GSOC caster
 - SP3, clock-RINEX and RINEV NAV files at DLR/GSOC FTP server
- Next steps: phase biases for PPP-AR and ionospheric corrections



RT-WG Needs and Recommendations (in order of urgency)

1. Need multi-GNSS ultra-rapid orbits

- Is the IGV (GPS+GLONASS) already official or still “experimental”?
- Include Galileo, BeiDou and QZSS in an official IGS ultra-rapid product

2. Need better quality control of GNSS broadcast ephemerides

- Accumulated RINEX NAV files and SW/RCV generated RTCMv3 streams
- Correct satellite health status is REALLY important!!

3. Need to get out of dead-end road with RTCM SSR messages

- No progress in phase-bias and iono/tropo SSR message standard
- Use a self-defined IGS format or other alternative for stream R/T corrections?

4. Need more multi-GNSS stations in North(!)-America, Russia and China

- Mostly GPS-only stations of UNAVCO in USA

Extremely urgent



Still very urgent

