IGS Workshop 2014

Effects of the April 1st, 2014 GLONASS Outage on GNSS Receivers

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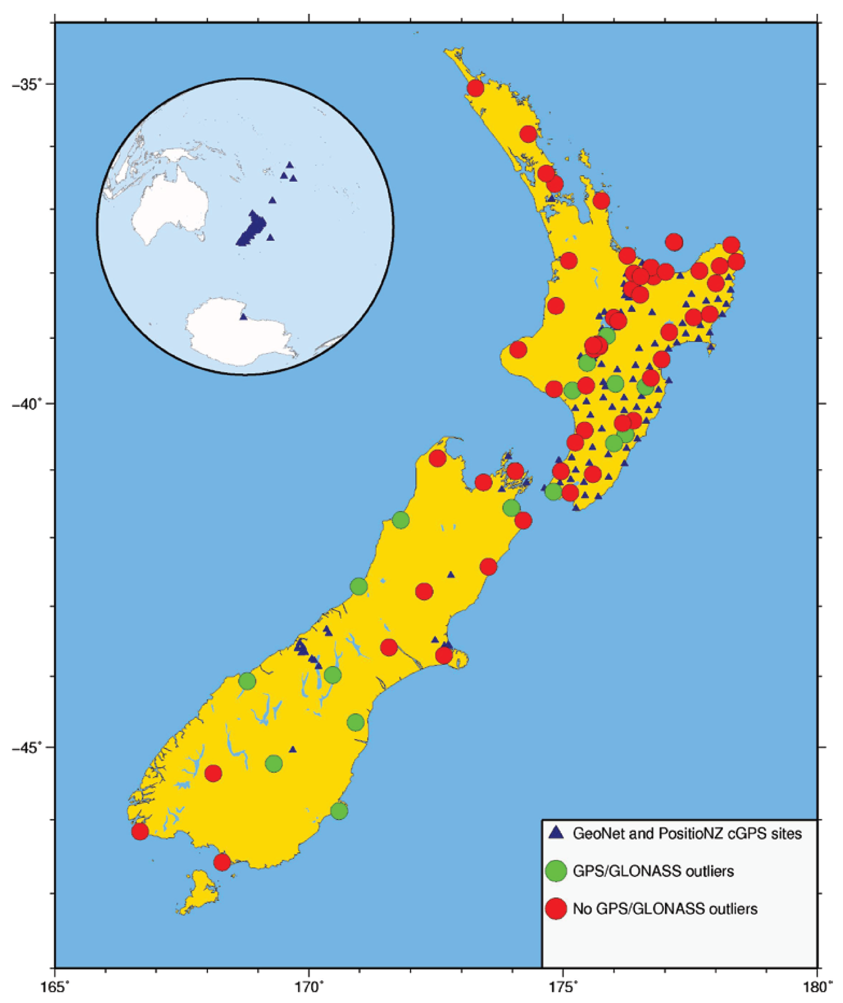
Overview:

The use of multi-constellation GNSS receivers has been assumed as a way to increase system integrity both by increased coverage during normal operations and fail-over redundancy in the event of a constellation failure. At approximately 21:00 UTC on April 1st the entire GLONASS constellation was disrupted as illegal ephemeris uploaded to each satellite took effect simultaneously. The outage continued for more than 10 hours as affected satellites broadcast navigation messages with incorrect application times.

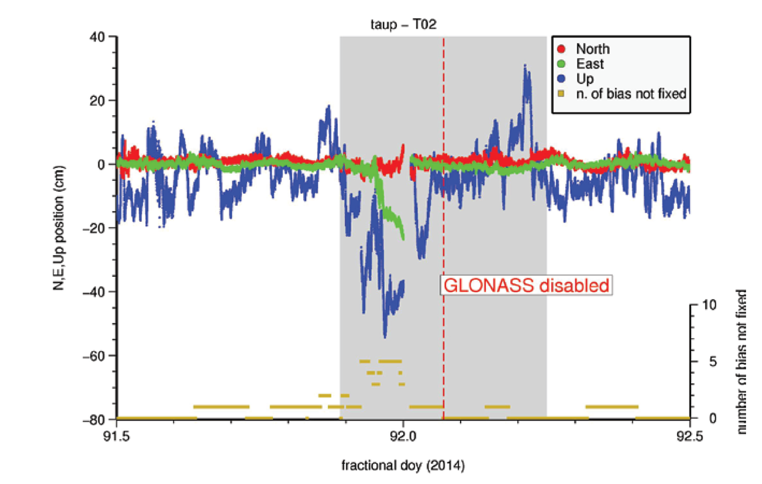
Although the ephemeris were incorrect, pseudoranges were correctly broadcast on both L1 and L2 frequencies and the carrier phases themselves were not affected; in the best case, GNSS receivers could be expected to continue to track all signals including GLONASS (as many did) and in the worst case to continue to at least track GPS and other constellations. However, in many cases Receiver Autonomous Integrity Monitoring (RAIM) failed to exclude the illegal GLONASS ephemeris while computing positions.

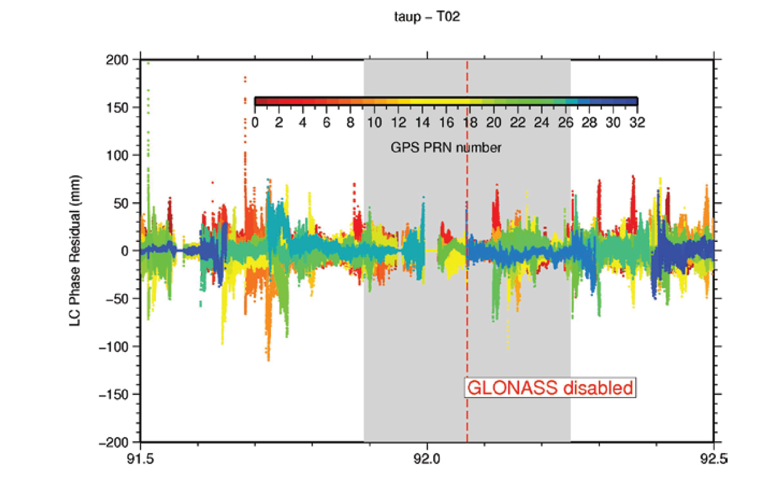
GeoNet

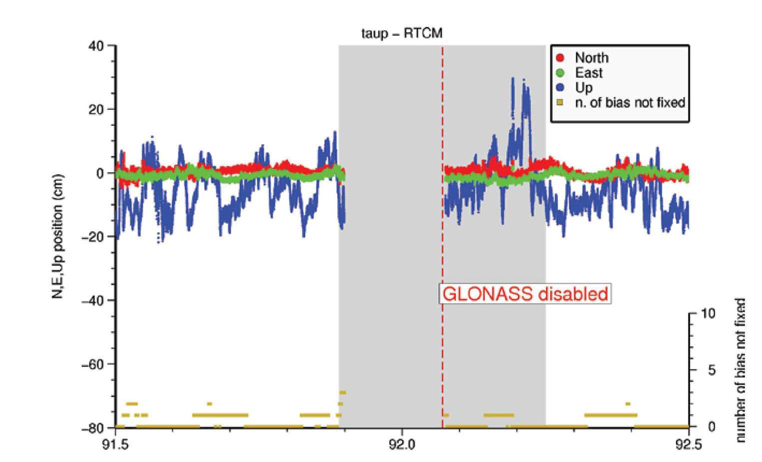


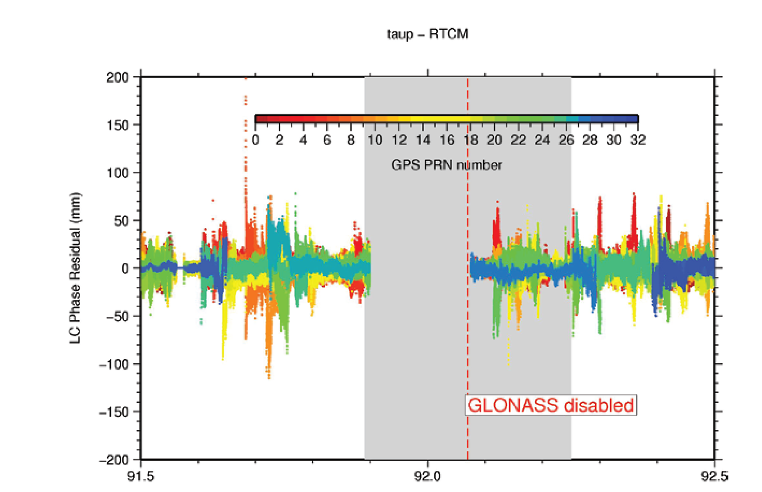
Observations from the GeoNet network in New Zealand indicate that a significant percentage of the 79 GLONASS-enabled receivers experienced total tracking failures during the outage period, which caused real-time streaming outages and data loss. Network operators disabled GLONASS tracking on a subset of receivers that were streaming RTCM messages. The receivers immediately returned to normal tracking behavior after GLONASS was disabled.

GeoNet - Track Results



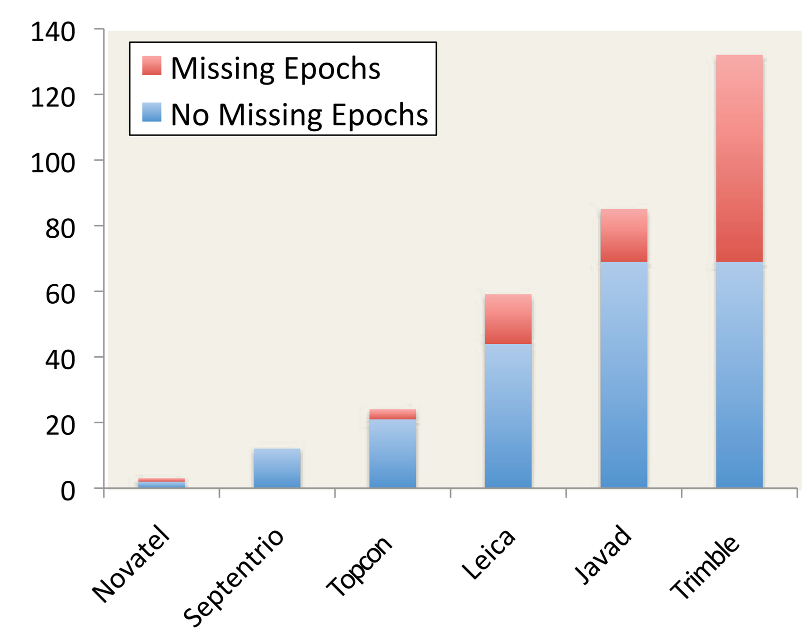






These figures show processing results from the station TAUP in New Zealand's Geonet. The upper two figures show processing results from the raw T02 files. The lower two figures show the processing results from data collected via RTCM streams. The outage affected the RTCM processing up to the time when GLONASS tracking was disabled.

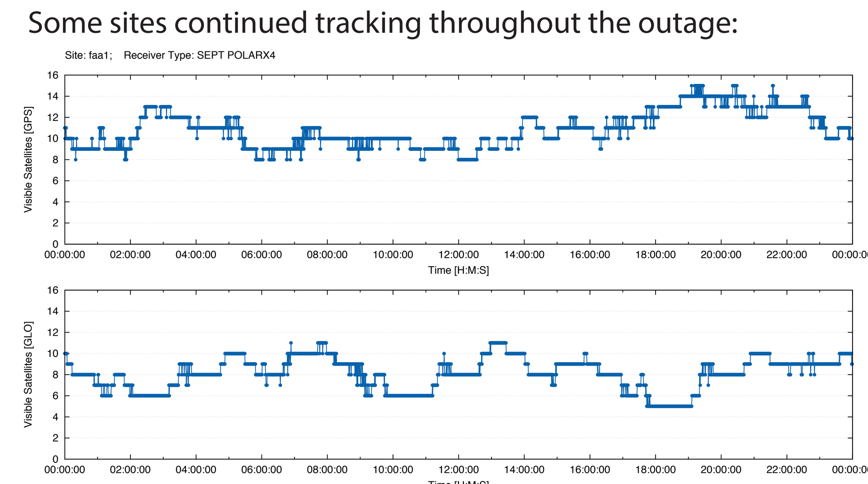
Receivers



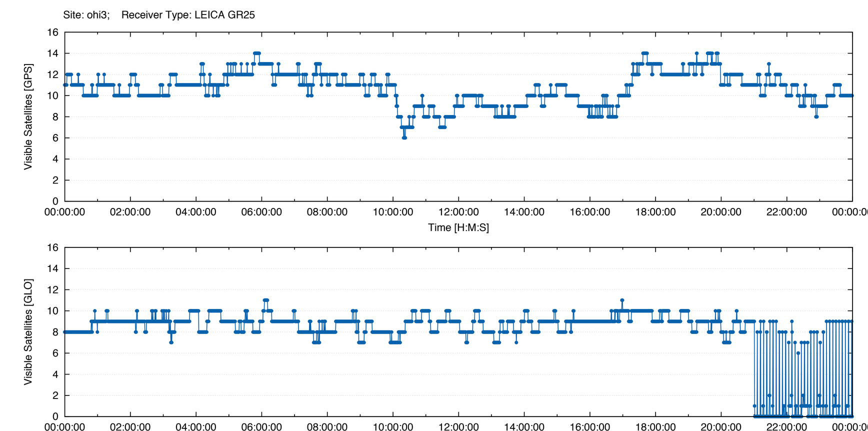
Sites were flagged as missing epochs if the predicted number of epochs did not match the number recorded in the UNAVCO archive. The results have been organized by receiver make.

Visible Satellites

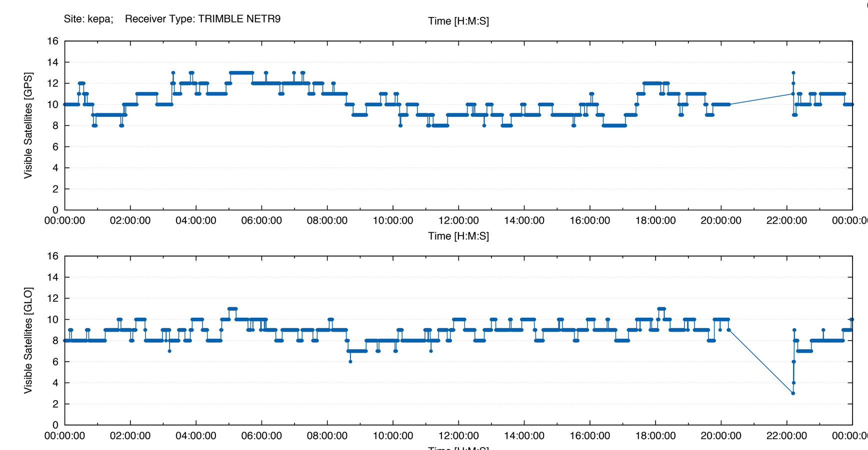
Some sites continued tracking throughout the outage:



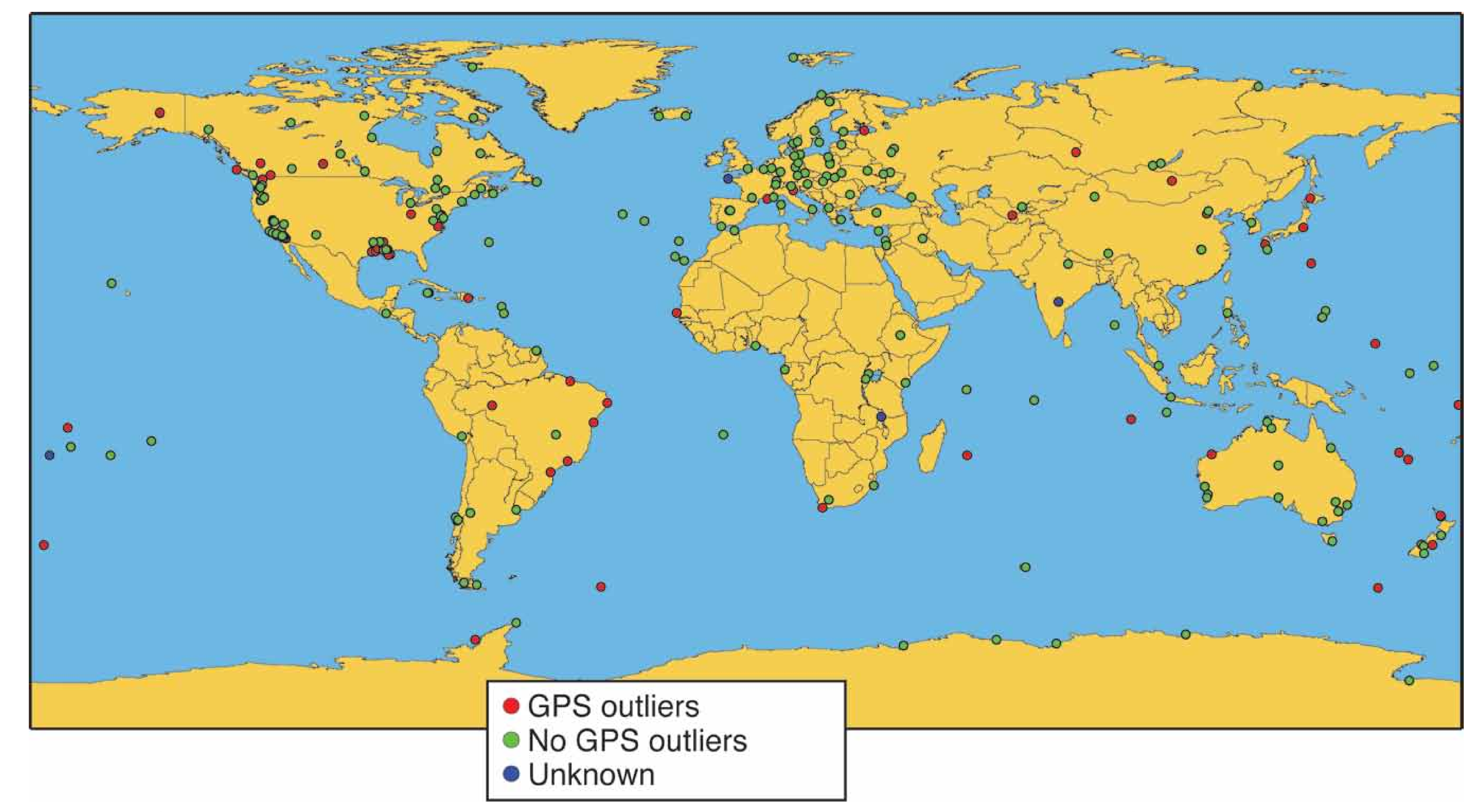
Some sites exhibited tracking problems only with GLONASS:



While other sites had complete tracking failures on all satellites:

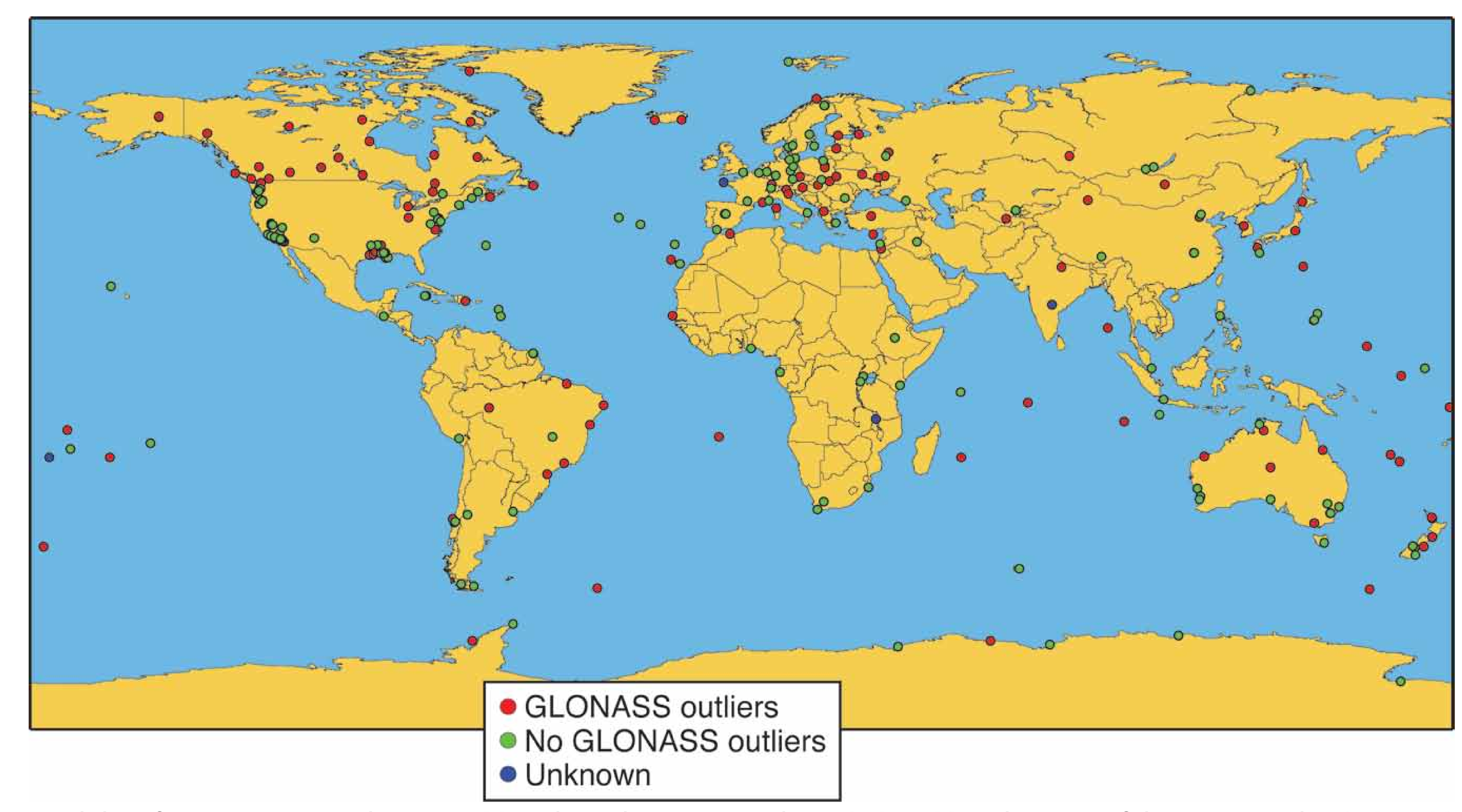


GPS Outliers

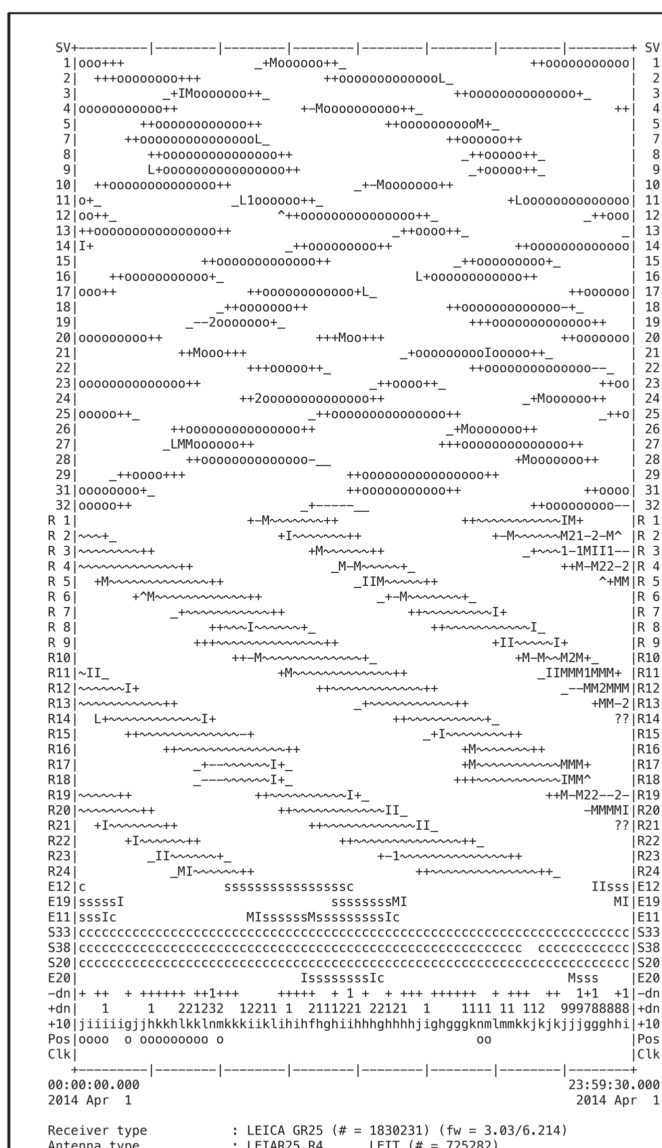


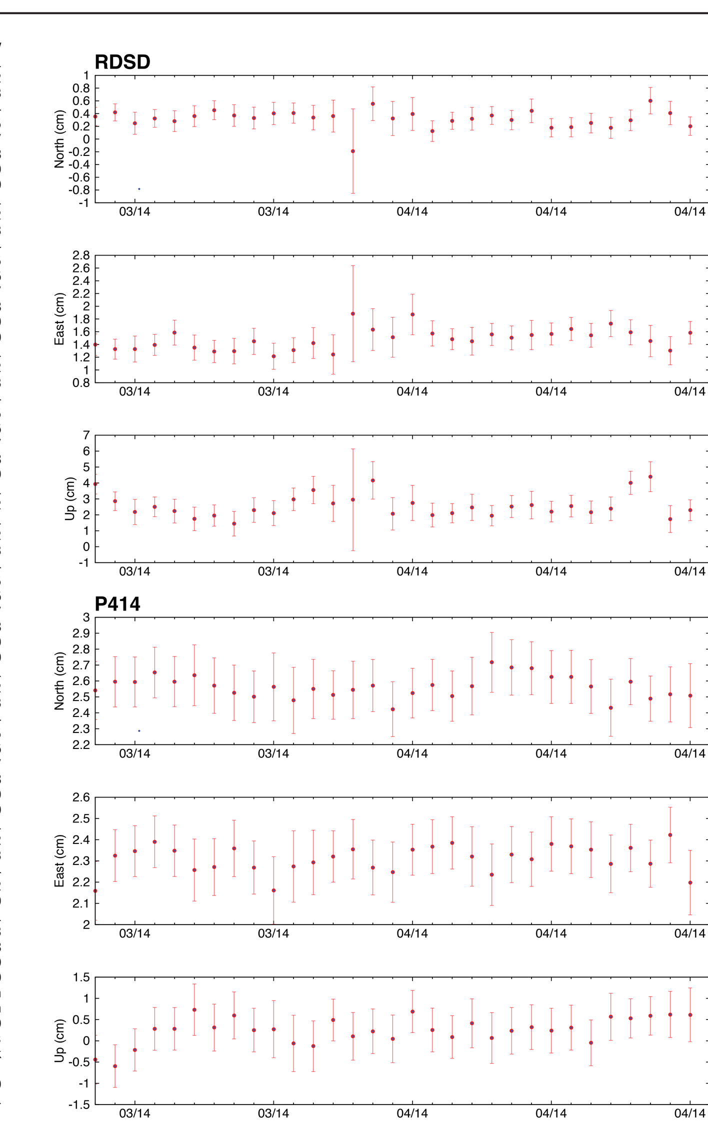
Aggregated data from 316 sites in the UNAVCO archive that were tracking GLONASS at the time of the outage. The GPS outlier flags were determined from missing epochs and by manual inspection of visible satellites figures. We found that 67 of the 316 sites (21%) had some problems tracking GPS during the outage.

GLONASS Outliers



Aggregated data from 316 sites in the UNAVCO archive that were tracking GLONASS at the time of the outage. The GLONASS outlier flags were determined from missing epochs and by manual inspection of visible satellites figures. We found that 131 of the 316 sites (41%) had some issue tracking GLONASS during the outage.

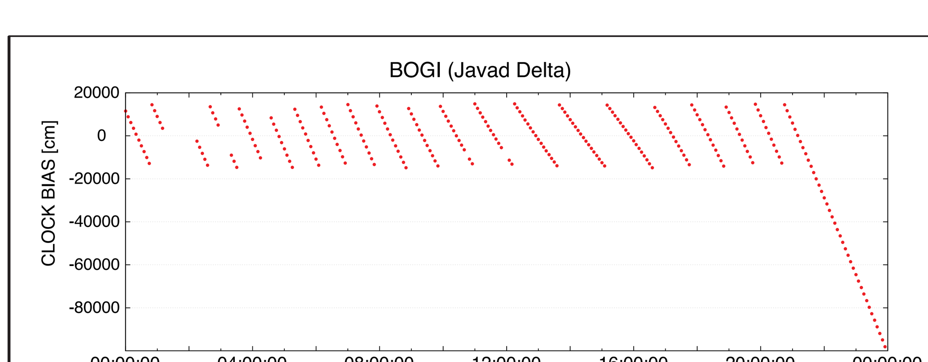




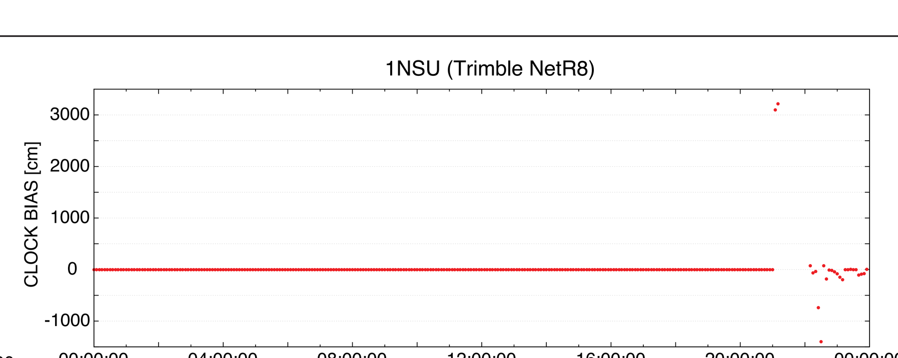
Far left: Example Teqc QC plot from the site OHI3. At ~21:00 UTC GLONASS tracking starts to show missing epochs and an increase in Ionospheric and multipath slips.

Upper left: Daily position solutions from the PBO Analysis Center Coordinator (ACC) for site RDSD (Trimble NetR9) located in Dominican Republic. The GLONASS outage had a negative impact on the daily position time series at sites where a significant portion of a given days GPS observations were lost.

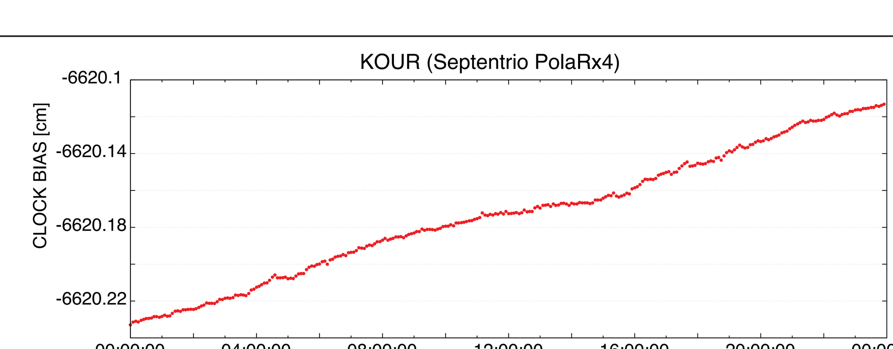
Lowerleft: Daily position solutions from the PBO Analysis Center Coordinator (ACC) for site P414 (Trimble NetR9) located in southern Washington state. At sites where only a small portion of the days data were lost due to the outage, the daily time series were unaffected.



Clock bias estimates as computed by GIPSY-OASIS for the station BOGI on day 91 of 2014. Clock steering on this Javad Delta receiver stopped functioning correctly following the beginning of the outage at 21:00 UTC. The clock steering vdid not recover until the receiver was rebooted on day 92.



Clock bias estimates as computed by GIPSY-OASIS for the station 1NSU on day 91 of 2014. Clock steering on this Trimble NetR8 receiver exhibited large outliers following the beginning of the outage at 21:00 UTC. The increased clock noise did not stop until the end of the GLONASS outage on the following day.



Clock bias estimates as computed by GIPSY-OASIS for the station KOUR on day 91 of 2014. The internal clock at this station is slaved to an external H-maser and the receiver does not apply any clock steering. This Septentrio PolaRx4 receiver continued to function nominally throughout the outage. We observed nominal tracking of GPS and GLONASS at the majority of sites where a superior external reference was used instead of the internal clock.

Summary:

By analyzing data collected from 316 GLONASS enabled sites in the UNAVCO archive and 79 sites in GeoNet we have observed that GLONASS & GPS tracking at a significant number of sites was impacted by the outage. Receiver type did seem to play a role in determining the probability of tracking failures. It is likely that failure of Receiver Autonomous Integrity Monitoring (RAIM) was the primary cause for tracking interruptions at affected sites. Manufactures are working on improving RAIM and updates should be available in future firmware releases. Despite the effects from the outage the heterogeneous nature of the IGS network helped to ensure stable orbit and clock products througout the GLONASS outage.