Kazakh - Northern Block Single Frequency Long Baseline Adjustment

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Introduction

The following report is about a long baseline adjustment for a GPS survey performed in Kazakhstan by Stuart Engineering and Surveying (SESL) of Calgary. Apart from results of the survey, detailed information is provided with access to IGS RINEX data files, CORS precise ephemeris files and the NIMA EGM96 worldwide geoid model.

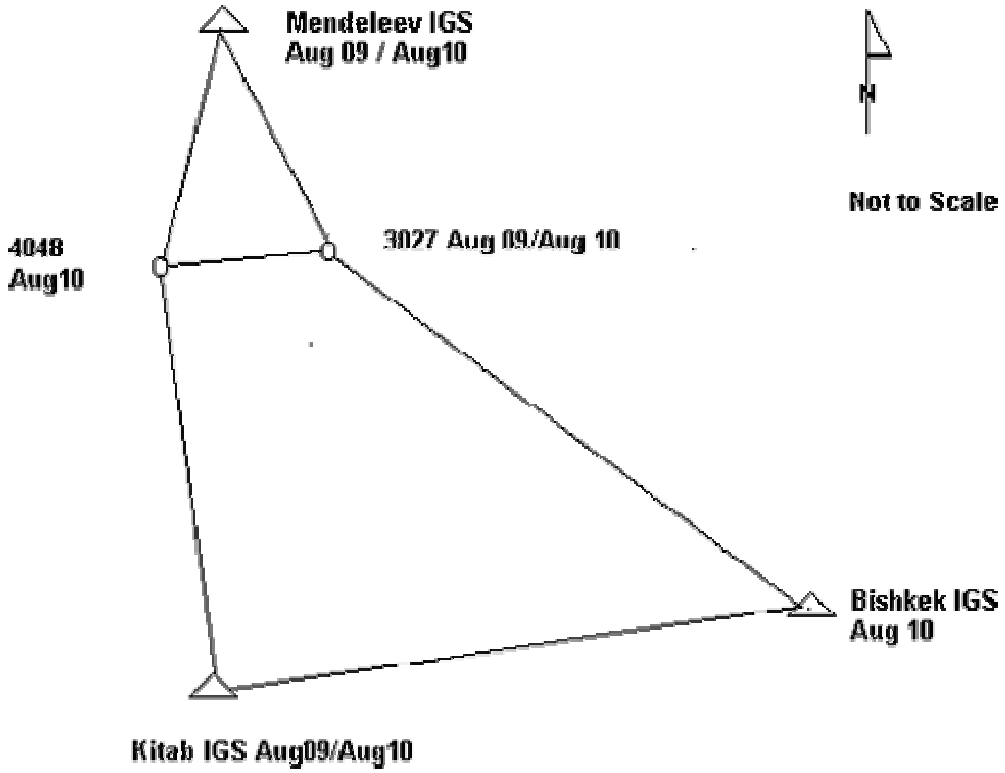

Figure 1: Adjustment of 3027 and 4048 from 3 IGS Stations

Network Adjustment

In the diagram above, the distance from unknown stations 3027 and 4048 is roughly 1000 km to a known station in Mendeleevo, Russia and 2000 km to IGS stations in Kitab, Uzbekistan and Bishkek, Kyrghyzstan.

Kazakh trig stations 3027 and 4048 were occupied with NovAtel single frequency receivers, and their coordinates were determined from an adjustment based on dual frequency data from IGS stations in Mendeleevo, Kitab, and Bishkek. Published coordinates for these stations are in ITRF94 which is considered aligned with WGS84 with the exception of crustal motion. Coordinates can be refined further by using yearly velocity of the crust from the last re-alignment of the ITRF and WGS84 framework in GPS week 873. This was not considered significant for this project.

Station	Published Latitude	Published Longitude	Published Ellipsoid Elevation (m)
Mendeleevo	56 01 38.924	37 13 24.910	254.98
Kitab	39 08 05.159	66 53 07.593	622.52
Bishkek	42 40 47.170	74 41 39.343	1714.22

Table 1: Published Coordinates of the 3 IGS Station Used in the Adjustment

In the network adjustment, Mendeleevo was held fixed with weighted coordinates of 0.10 m. Bishkek and Kitab were used as checkpoints. Trig stations 3027 and 4048 were considered unknowns. Data from August 9 and August 10 was used for 3027, while data for 4048 was only available on August 10.

Error Budget

In this network, it should be noted that the data collected on August 9 and August 10 at stations 3027 and 4048 was 6 hours of single frequency NovAtel data.

Research by Waypoint shows that with precise ephemeris in double difference code/phase processing, one can expect GrafNav/GrafNet to provide baseline accuracies of:

Single Frequency Baselines

Errors of 0.5 - 1.0 ppm with baseline length can be expected with single frequency GPS receivers, depending on ionospheric activity and time of observation. Six hours should be sufficient to obtain something in the order of 0.75 ppm or 75 cm on a 1000 km baseline.

Dual Frequency Baselines

Errors of 0.10 -0.20 ppm with baseline length can be expected using dual frequency. Six hours should be more than sufficient to obtain something in the order of 0.1 ppm or 10 cm on a 1000 km baseline.

Network adjustments should provide some increase in accuracy due to redundant solutions at each point. GrafNet will weight the coordinates of the fixed points and provide a weighted average

solution for the coordinates at the unknown points. Weighting of the solutions is largely a function of the baseline lengths. In the adjustment of the northern Kazakh block, the tie to Mendeleevo is given the most weight since it is the shortest line.

Adjusted Coordinates and Error Estimates

Adjustment of the network above provided the following residuals and coordinates:

Output Vector Residuals (XYZ Cartesian, ECEF)

From Sta	To Sta	Rx (m)	Ry (m)	Rz (m)	PPM	Dist (km)
Bish	Kitab	0.0083	0.0037	0.0050	0.0	765.9
Mendel	Bish	0.0951	-0.3296	0.1048	0.1	3019.9
Mendel	Kitab	0.2274	-0.2288	0.0958	0.1	2853.3
Bish	4048	-0.4878	-0.2764	0.1570	0.3	2020.5
Kitab	4048	0.1909	-0.3421	0.2030	0.2	1819.9
Mendel	4048	0.3043	0.4231	-0.0482	0.5	1052.4
Bish	3027	-0.3910	-0.4498	0.1136	0.3	1999.6
Kitab	3027	0.0637	-0.3716	0.0236	0.2	1812.2
Mendel	3027	0.0171	0.6786	-0.1666	0.7	1064.0
4048	3027	-0.0801	-0.1395	0.0526	4.6	37.1
Kitab	3027	-0.2183	-0.1406	0.2246	0.2	1812.2
Mendel	Kitab	-0.5906	0.2072	0.3338	0.2	2853.3
Mendel	3027	0.2221	0.3446	-0.1906	0.4	1064.0
RMS		0.2825	0.3436	0.1595		

Output Station Coordinates (Lat/Long/Ht)

Station ID	Latitude	Longitude	Height (Ellipsoid)
Bish	42 40 47.17923	74 41 39.33210	1714.078 (check pt)
Kitab	39 08 05.16560	66 53 07.58486	622.2378 (check pt)
Mendel	56 01 38.92400	37 13 24.91000	254.9800 (held fixed)
4048	51 09 53.37911	50 55 28.92113	93.6803 (adjusted value)
3027	51 21 43.35870	51 21 09.17765	38.1217 (adjusted value)

Residuals indicate that global accuracies of 50 - 75 cm can be expected at the stations of interest (i.e. 3027 and 4048). This falls within the single frequency error budget as described above. Also, it

can be seen that the check points at Kitab and Bishkek (dual frequency IGS stations) agree with the published values (Table 1) to 20 - 30 cm over the 3000 km distance from the Mendeleevo IGS station held as a fixed point in the adjustment. Once again, this is consistent with the expected error budget with respect to dual frequency data.

It should be noted that the elevations determined are ellipsoidal. It is not certain at this time what the best method of establishing orthometric heights may be. Geoid modeling is expected to produce global orthometric heights only at the metre level in this region.

Check Ties to Published Data in the Southern Kazakh Block

Checks on the above coordinates and their accuracy estimates may be performed at any time in the future by observing or obtaining data sets (preferably dual frequency) at any of the northern block stations. Data could then be downloaded for Mendeleevo, along with CORS orbital data. Three to six hours of dual frequency data would be sufficient to perform a final check on the global precision of the above network.

As a final note, checks were performed on the single frequency Novatel data collected on July 28th at station 0014 in the southern Kazakh block previously surveyed by SESL. Station 0014 was originally coordinated in 1993. The tie to the known geodetic station 0014 was in the order of 30 cm horizontally using Mendeleevo as a base station. The closure with Kitab, at a distance of some 1700 km, was sub-metre horizontally. Both ties however, show a vertical misclosure of approximately -5.8 m to the coordinates derived in 1993. This could be a function of the re-adjustment of the WGS84 ellipsoid to align with the ITRF94 framework, although this is speculation.

The coordinates obtained for station 0014 from the tie to the Mendeleevo IGS station were:

Station	Latitude	Longitude	Ellipsoid Elevation (m)
Mendeleevo	56 01 38.924	37 13 24.910	254.98 (published)
0014 (year 1997)	46 24 20.084	53 26 08.053	-37.65
0014 (year 1993)	46 24 20.088	53 26 08.070	-31.68 (published)

Table 3: Check Tie Coordinates to Station 0014

It can be seen that the horizontal agreement to previous work is excellent. The vertical clearly misties with the earlier work, however it should be noted that OSU91A model gives a geoid undulation of -17.99 m at this point. This would provide us with an orthometric height at point 0014 of -19.66 m, which agrees within 2.37 metres of the published TCO Baltic elevation of -22.03 m.

Using the more recent EGM96 geoid model provides an even better tie. This model obtains an undulation of -17.26 metres at point 0014, giving us an orthometric height of -20.39 m or a tie of 1.64 m to the local Kazakh datum.

Addendum July 1998

In 1998, one year following the publication of this report, Stuart Engineering returned to Kazakhstan with Trimble dual frequency receivers this time. Personal communication with SESL engineers indicates that the agreement between the results published above and the coordinates given by dual frequency long baseline determination in 1998, agree within 0.50 m.