Combined Processing of GPS & BeiDou Measurements: Some First "Observations"

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Introduction

Geodetic science, as well as geospatial applications require reliable, rapid, precise and, ideally, real time positioning. Precise Point Positioning (PPP) has become an increasingly popular GNSS technique for precise receiver positioning.

In this poster presentation the traditional PPP methodology is used to compare GPS-only results with those derived from combined GPS and BeiDou measurement processing.

The BeiDou system (BDS) is a recent Regional Navigation Satellite System that is able to be used of precise positioning, navigation and timing services by users in the Asia-Pacific region. Some IGS research groups have generated BDS precise orbit and clock correction data, along with GPS and GLONASS.

Mathematical background

GNSS observation model of is presented in equation (1) $P_i = \rho + c(dt_r - dts) + T + Iono + b + \varepsilon_p$

$$L_i = \rho + c(dt_r - dts) + T + Iono - \lambda_i N_i + b + \varepsilon_l$$

where i equals to frequency index 1 and 2, P_i and L_i denotes raw code and phase observations, ρ is the geometric distance between satellite and receiver, c is the speed of light in vacuum, dtr is receiver clock error, dts satellite clock error, T is the tropopspheric error, Iono is the ionospheric error, b is the inter system bias(i.e. GPS and BDS), λ_i is the wavelength of the frequency L_i and lastly ε_p and ε_l are the modelled noise, such as code/phase noise, multipath errors. Traditional PPP model follows ionophere-free code(P_{IF}) and phase (L_{IF}) observations (2) to generate float solutions using the precise orbit and clock correction provided by the International GNSS Service (IGS) and satellite.

$$P_{IF} = \alpha_{IF} P_1 + \beta_{IF} P_2$$

$$L_{IF} = \alpha_{IF} L_1 + \beta_{IF} L_2$$

where α_{IF} and β_{IF} are $\frac{(f_1)^2}{(f_1)^2 - (f_2)^2}$ and $\frac{-(f_2)^2}{(f_1)^2 - (f_2)^2}$, respectively.

In this poster the inter system bias(i.e. b) is also estimated. For position estimation using traditional kalman filter, we consider the following linear equation (3).

$$y = Hx + v = H(x) + v$$

y is state vector of observations, H is a design matrix which consists of partial derivations of observations. The parameter v is the measurement errors and x is the parameter vector to be estimated (i.e. position, clock errors, intersystem bias and velocity).

$$y = H(x_o) + \frac{\partial H(x)}{\partial x} * \delta x + v$$

$$\delta y = H * \delta x + v$$

Kalman filter details are not included here as space constrains.

Data Set

This investigation focuses on the processing of 24 hours of L1 & L2 GPS and B1 & B2 BDS measurements from DOY 070, GPS week 1783. The orbit and clock correction files, provided by ESA, for GPS and BDS were downloaded from the IGS. RINEX data files from the GNSS station JFNG (China) and CUT0 (Australia) were used. GPS-only, BDS-only and combined GPS + BDS PPP processing has been carried out in order to investigate positioning accuracy as well as the impact of adding BDS observations when processing GPS. For the truth coordinate the AUSPOS online GPS processing service was used. For this data processing, a 10° cut-off elevation angle was applied. Antenna PCV, phase wind-up correction, earth rotation and solid earth tide correction model were all applied. Elevation-dependent observation weighting was applied, according to 1/ sin(e)^2 where e is the satellite elevation.

Result

Figure 1 shows the accuracy results from GPS-only, BDS-only, and GPS+BDS processing. Table 1 summarises the statistics (rejecting the first 30mins for convergence). RMS values were generated from the difference between truth coordinate and the PPP-estimated positions. STD refers to the spread of the estimated positioning solutions from the mean estimated position. It has been observed that the horizontal accuracy of GPS-only solutions outperformed the BDS-only and GPS+BDS for both stations, whereas the 3D accuracy varies. The GPS +BDS combination helps to improve the 3D accuracy for CUT0. Intersystem bias are plotted in Figure 2.

Table 2 shows the convergence behaviour of PPP positioning solutions. In this investigation it can be seen that the impact of adding BDS observations improves the convergence time for 50cm,20cm and 10cm horizontal accuracies for both stations.

However, for vertical convergence only CUT0 performs better for all convergence time categories. It should be noted that accuracy for GPS+BDS was not as good as for GPS-only. As a result, this analysis leasuggests further investigations into GPS and BDS intersystem bias, as well as other error sources such as quality of BDS's precise orbit and clock correction.

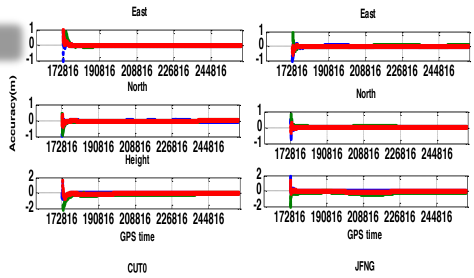

Figure 1: PPP results for CUT0 and JFNG station, DOY:070, Blue: GPS, Green: BDS, Red: GPS+BDS.

	CUT0			JFNG		
	GPS	BDS	GPS+ BDS	GPS	BDS	GPS+ BDS
2D	0.009	0.028	0.057	0.020	0.064	0.031
3D	0.28	0.142	0.013	0.032	0.175	0.058
RMS(3D)	0.053	0.175	0.068	0.037	0.202	0.068
STD(3D)	0.121	0.457	0.216	0.175	0.209	0.143

Table 1: Statistics from PPP results

	Convergence in meter	GPS (2D) (min)	GPS (H) (min)	BDS (2D) (min)	BDS (H) (min)	GPS+ BDS (2D) (min)	GPS+ BDS (H) (min)
CUTO	0.05	66	76	54	78.5	44	54
	0.1	44	56	50.5	74.5	39.5	46
	0.2	39	44.5	41	58	30	39.5
	0.5	7	29	30.5	40.5	5	6
JFNG	0.05	42.5	47	45.5	14.5	42	58.5
	0.1	36	44	42	13	25	46.5
	0.2	11.5	26	24	10	14.5	8
	0.5	8.5	4	7	7	4.5	4

Table 2: Convergence time

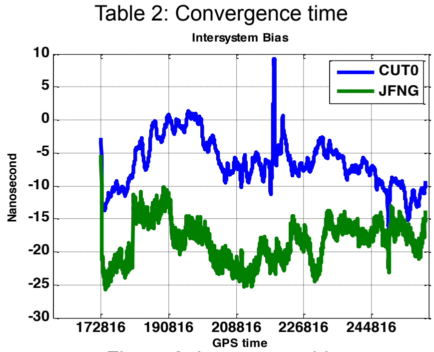

Figure 2: Intersystem bias

Concluding remark

In this poster presentation, preliminary GPS +BDS PPP results have been presented. It has been identified that further investigations into intersystem biases is required.