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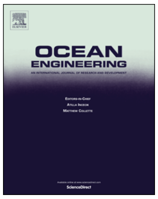

Online kinematic GNSS data processing for small hydrographic surveys

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ABSTRACT

Free access online GNSS (Global Navigation Satellite System) data processing services are becoming popular since only a single GNSS receiver can do the job. These services are user friendly and easy to use. Thus, no training and a GNSS software package purchase are needed. This means less cost to users. Currently, three online GNSS data processing services provide kinematic data processing option. In this study, GNSS data collected for hydrographic surveying is processed using these online services and positioning precision of these services are compared. The results indicate that with 1 s data, decimeter to meter precision can be achieved for both horizontal and vertical coordinates.

1. Introduction

To this date, there are six online GNSS (Global Navigation Satellite System) data processing services (OPUS, APPS, SCOUT, CSRS-PPP, GAPS and AUSPOS) freely available to users to our knowledge. Detailed information about these services may be obtained by accessing their respective website URLs given in Table 1. Online processing services deliver solutions to users without any cost, and with unlimited access. Only access to the Internet and an email address are needed to make use of these services (Ghoddousi-Fard and Dare, 2006). Although some of these services accept most proprietary receiver binary format files, some still require RINEX (Receiver Independent Exchange Format) file or compressed RINEX files. With just one GNSS receiver, the observations are collected and then postprocessed based on differential methods using either reference stations or precise point positioning using globally available precise satellite orbit and clock data, and processing results are returned to the user via e-mail (Ebner and Featherstone, 2008). Among these online services only three of them (APPS, CSRS-PPP and GAPS) provide kinematic data processing option.

Hydrographic surveying deals with measurement of depth at known locations, typically for the purpose of creating depth maps of water bodies. In the past, locations of depth soundings were determined using shore-based surveying or dead-reckoning navigation techniques. However, since the development of precise satellite based survey methods (i.e., GNSS), locations of depth measurements are more commonly determined using RTK (Real Time Kinematic) GPS (Global Positioning System). Using RTK GPS for hydrographic surveying is similar to other applications, in that a base station is set up over a known point on land, and a rover receiver is used to measure the positions of unknown points using corrections transmitted from the base station via radio transmission. The rover on the vessel combines the data from the base with its own observations and determines its corrected 3D position in real time (Ghilani and Wolf, 2007).

Echosounders measure depth of water by transmitting a sonar pulse from a transducer into the water column and measuring the amount of time it takes for that pulse to return to the transducer. Travel distance through the water column is then calculated by applying the velocity of sound through water, which varies with salinity, pressure, and temperature. In hydrographic surveying, it is crucial to have an accurate velocity measurement at the survey area, which can be measured using either bar check or velocity profiling methods. The bar check method is essentially a determination of velocity by taking a series of measurements through water to a known depth. Velocity profiling uses a cable mounted sensor that directly measures the velocity of sound waves through water passing between a transmitter and receiver in the sensor housing as the unit is lowered through the water column. In this study, bar checks were used to calculate the appropriate velocity, and were performed at approximately hourly intervals.

By combining RTK GNSS horizontal and vertical coordinates with echosounding techniques and practices, a user can expect to obtain XYZ coordinates of the bottom of a small body of water with accuracies approaching one decimeter. Achieving the same level of precision is investigated by using online kinematic GNSS data processing services; namely, CSRS PPP, GAPS and APPS.

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2. Theory of precise point positioning

The position of a standalone receiver tracking dual frequency GNSS signals can be determined using undifferenced code and phase observations as

$$C_{1,2} = \rho_r^s + c(dt_r - dt^s) + dI_{1,2} + dT + e(C_{1,2})$$
$$P_{1,2} = \rho_r^s + c(dt_r - dt^s) - dI_{1,2} + dT + \lambda_{1,2}N_{1,2} + e(P_{1,2}) \quad (1)$$

where

$C_{1,2}$ code observations of L_1 and L_2 pseudoranges, respectively
$P_{1,2}$ phase observations of L_1 and L_2 carrier phases, respectively
ρ_r^s true geometric distance between receiver and satellite
c speed of light in vacuum (299,792,458 m/s)
dt_r receiver clock error from GNSS time
dt^s satellite clock error from GNSS time
$dI_{1,2}$ ionospheric terms on L_1 and L_2 signals, respectively
dT tropospheric effect
$\lambda_{1,2}$ wavelengths of L_1 and L_2 signals, respectively
$N_{1,2}$ integer phase ambiguities relevant L_1 and L_2 signals
$e(C_{1,2})$ measurement errors of $C_{1,2}$ code observations
$e(P_{1,2})$ measurement errors of $P_{1,2}$ phase observations.

If a linear combination model is used,

$$L_{IF} = \frac{f_1^2}{f_1^2 - f_2^2}L_1 - \frac{f_2^2}{f_1^2 - f_2^2}L_2 \quad (2)$$

in which L represents both code (C) and phase (P) observations, the frequency-dependent ionospheric terms can be eliminated from Eq. (1). On the other hand, precise orbit and clock information that come from rapid and final orbit solutions of satellites can be considered as known parameters in the observation equations. In this case, the ionosphere-free (IF) observation equations become

$$C_{IF} = \rho_r^s + cdt_r + dT + e(C_{IF})$$
$$P_{IF} = \rho_r^s + cdt_r + dT + \lambda_{IF}N_{IF} + e(P_{IF}) \quad (3)$$

where λ_{IF} is the wavelength of the combined phase and N_{IF} is the non-integer ambiguity of ionosphere-free combination. The linearized adjustment model of Eq. (3) and its solution procedures can be found in e.g. Kouba and Heroux (2001). Normally, before the use of IF observation equations in the adjustment model, they should be corrected for additional systematic effects such as satellite antenna, phase wind-up, relativistic effect and site specific corrections due to ocean loading, solid tides, etc.

Table 1
URLs of online GNSS data processing services.

Service	URL
OPUS	http://www.ngs.noaa.gov/OPUS/index.jsp
APPS	http://apps.gdgps.net/
SCOUT	http://sopac.ucsd.edu/scout.shtml
CSRS-PPP	http://webapp.geod.nrcan.gc.ca/geod/tools-outils/ppp.php
GAPS	http://gaps.gge.unb.ca/
AUSPOS	http://www.ga.gov.au/bin/gps.pl

3. Applications and results

Triple frequency GNSS receivers (Leica GX1230) and a hydrolite single beam echosounder are used to collect the measurements. The hydrolite, manufactured by Seafloor Systems, Inc., is a single beam echo sounder with the transducer attached to the bottom of a GNSS rover rod, which takes point soundings at a rate of 6 Hz and sends the data through a Bluetooth connection to the GNSS data collector. Since RTK corrections supply elevation values for the transducer (after applying an offset for the height of the rod), this provides a relatively user friendly configuration for small hydrographic surveys. Measurements for this study are taken in Turkey Creek in Brevard County, Florida (Fig. 1). The survey area for this study was centered on the Florida East Coast (FEC) railway bridge crossing the creek, and extended about 100 m to the east, and approximately 150 m west of the bridge. This is considered an ideal location for the RTK and Hydrolite setup due to shallow (< 5 m depth) and calm inland waters, where conditions and depth favor a smaller boat and survey setup.

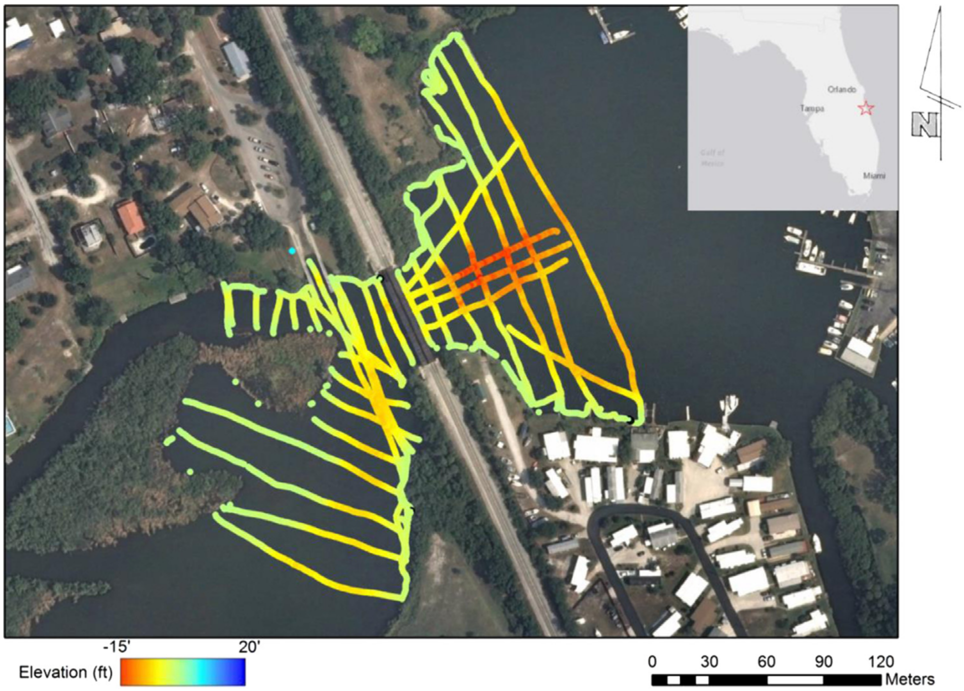

Fig. 1. Aerial photo of project site. Colored lines show locations of depth measurements, with color scale representing elevation of points in feet (aerial image from Labins.org). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)