Introduction to GNSS Positioning Corrections Systems

Position accuracy from all GNSS receivers, including those used in the CEE HydroSystems CEESCOPE™ echo sounders is quite poor in the absence of corrections signals to eliminate the error caused by atmospheric variation in the GNSS signal transmitted by the satellites. Understanding the corrections options available is important for equipment selection, and an overview is presented here.

Autonomous GNSS

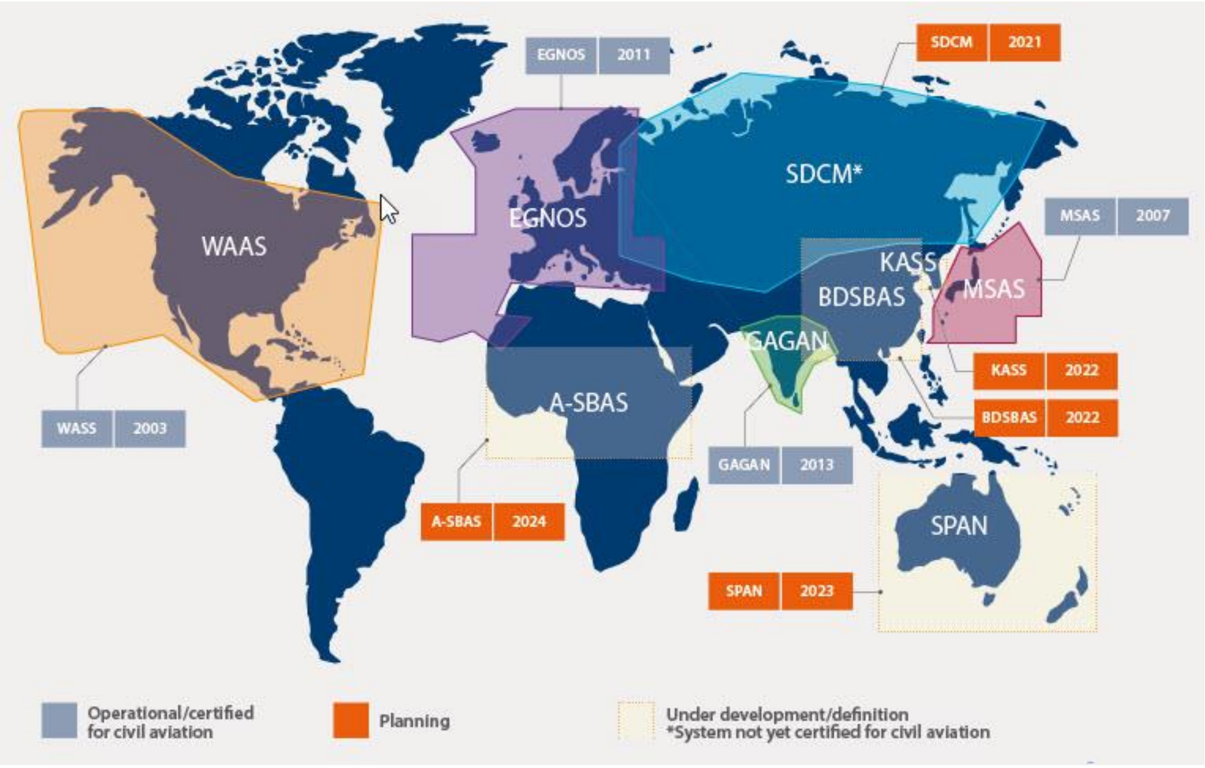
GNSS is the generic term used to describe the GPS and similar constellations of positioning satellites operated by various countries around the world. GNSS receivers receive position data from some or all of these satellite systems; position accuracy and resilience with sky view obstructions (trees, buildings) increases significantly as the available satellites increases. However, without any form of supplemental corrections, "autonomous" GNSS position provided by any GNSS receiver is poor. Simply by receiving the positioning satellite signals, even with many satellites in view, accuracy of only 3-5m is possible. This is due to several error sources, including distortion of the signal passing through the atmosphere as compared to the "ideal" path used in the position calculation.

AUTONOMOUS Fix
Accuracy 3-5m
Receiver indicated quality code (1)

SBAS

In order to improve the GNSS position accuracy, errors due to the signal distortion in the path from the satellite down to the receiver antenna must be removed. As the atmospheric distortion will change with location, corrections must be specific to the location of the receiver. The closer the correction is made to the receiver, the higher the achievable accuracy. Recognizing the low inherent accuracy of uncorrected GNSS, free SBAS (Satellite Based Augmentation System) correction signals have been introduced, primarily intended for commercial aviation. The first of these was the WAAS (Wide Area Augmentation System) in the USA.

The various SBAS networks, available on any modern GNSS receiver are shown below.



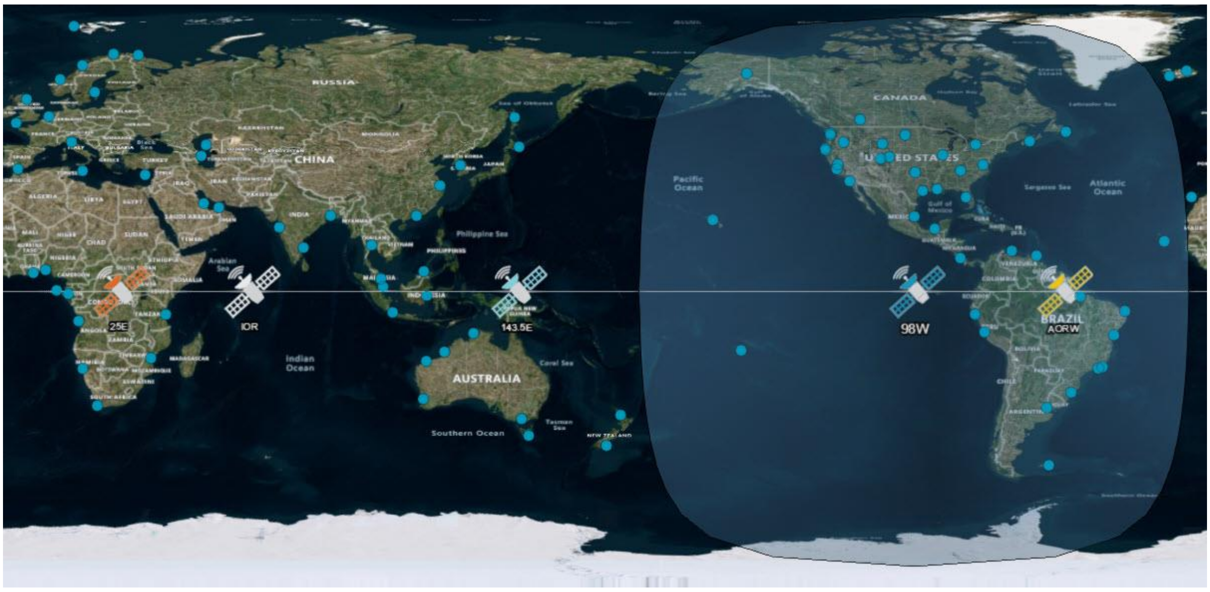
SBAS consists of a network of ground stations (for WAAS there are 38) that are continuously monitoring their position and comparing that computed position to the actual known position. The difference in these positions is caused by the system error at that location. The combined results from the ground stations in the network allow a variable correction to be computed and made available based on the GNSS receiver's (or aircrafts) position within the network. The correction signal is continuously available to compatible receivers in the network area from a separate geostationary satellite. The corrections satellite is at a low azimuth for higher latitudes and so a clear view of the sky towards the south (or north in southern hemisphere) is required.

Precise Point Positioning (PPP) L-Band Corrections

SBAS is useful for general positioning in regions with active systems however as SBAS operates on only the L1 (low precision) frequency it is incapable of survey-grade positioning, and it does not offer worldwide coverage. To improve accuracy possible with a single GNSS receiver, subscription-based PPP services are available as supplied by various GNSS manufacturers. These operate on the same principle as SBAS in that ground stations relay position corrections to a geostationary satellite which transmits corrections to operating receivers over the L-Band frequency, however measurements are made at a far greater precision and with worldwide coverage. Usually, a range of accuracy options are available depending on the service level / cost selected. Subscriptions are activated "over the air" with the activation signal sent to the operating receiver and are offered in short term (eg monthly) or long term (up to 5 years) periods. The three PPP services supported by CEE HydroSystems CEESCOPE™ echo sounders are as follows:

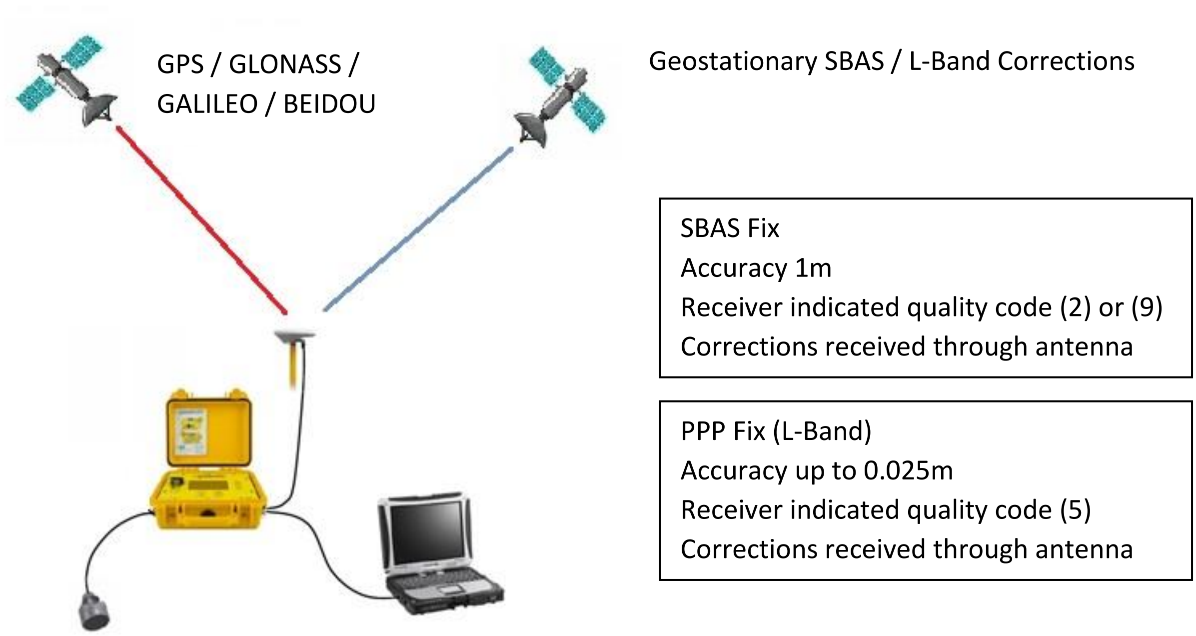
Hemisphere Atlas	0.08 – 0.5m horizontal
NovAtel TerraStar	0.02 – 0.5m horizontal / Up to 0.05m vertical
Trimble RTX	0.025m horizontal / 0.05m vertical

The TerraStar network of ground stations and the geostationary L-Band satellites are show below. It is notable that the ground stations are not equally spaced, and the further a GNSS receiver is from a ground station or group of stations, the lower the achievable accuracy.



The drawbacks of PPP operation, in addition to the subscription cost, are the reliance on receiving a signal from single corrections satellites that may be obscured by buildings or trees, and the need for a “convergence time” of up to 30 minutes before the position fix reaches the stated accuracy. The main benefit is the high accuracy possible without any need to set up a base station or receive third party corrections that need an active internet service, which may be problematic in remote locations.

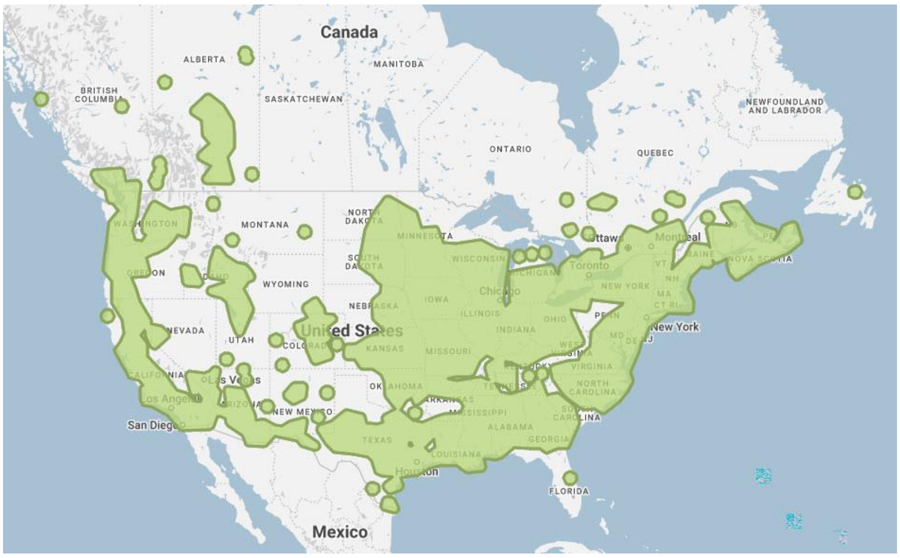
The PPP and SBAS system architecture is shown below.



Network RTK

To achieve very high accuracy position, including elevation results adequate to correct for changes in hydrographic survey water levels, an RTK (Real Time Kinematic) corrections solution is required. The RTK corrections may be supplied by a single local base station over a radio link (discussed later in the article) or through a wider network internet subscription service. While PPP solutions might be a fit for some survey scenarios, RTK is the corrections choice for most precision surveys where accurate position and elevation is needed. Usually for Hydrographic surveying, RTK is the only method that can adequately provide tide correction or properly monitor water level changes. Like the other corrections types discussed above, network RTK relies on a set of continuously operating ground stations. Unlike the PPP and SBAS systems, network RTK may be provided on local or state level by regional GNSS dealers and represents more of a patchwork of services. But as the base stations are closer to the operating receiver than for a wide area network, errors are lower and achievable accuracy is consistently higher.

An undisturbed connection to the internet and active subscription is required for network RTK as corrections are supplied from a specific IP address / web site. Most are paid services supplied by, for example, Trimble (VRS Now) or Hexagon Leica (SmartNet – coverage shown below).

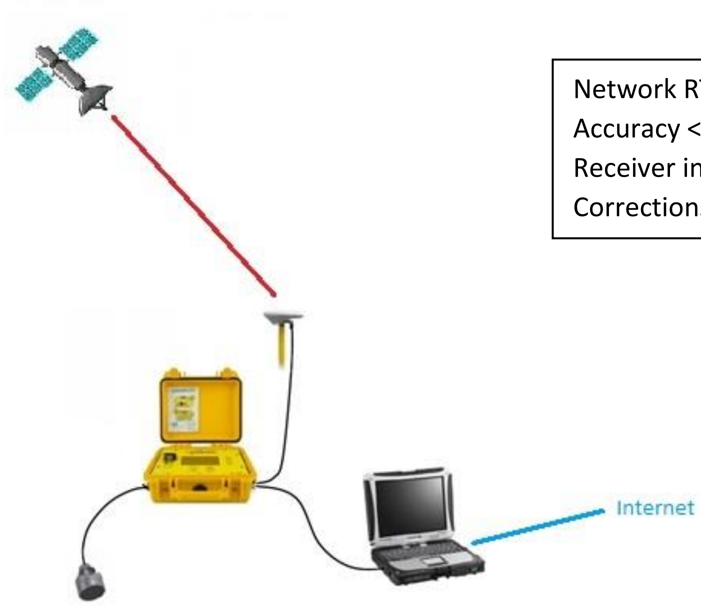


After logging in to the service, the user can select to receive corrections from a “drop down” list of nearby base stations, or for “Virtual Reference Station” (VRS) services, the closest base stations are used in combination to compute the error that would be expected at the exact position of the receiver, potentially improving accuracy as the receiver moves around. Some network RTK services are available free of charge, with users able to connect to single base stations operating locally.

The benefit of network RTK is simplicity and ease of use. The drawback is the availability of service. There needs to be a reliable internet connection available at all times, and an available service provider in the survey area. As can be seen above, network RTK simply might not be an option in many places with lower population or harsh terrain.

For standalone GNSS receivers, the SIM card is usually inside the rover, allowing a direct connection to the internet to receive network RTK. For the CEESCOPE™ echo sounders, the corrections are received by the connected PC, either via a SIM card in the PC, hotspot, or cell phone internet connection. The hydrographic acquisition software such as HYPACK or Hydromagic manages the real time transfer of corrections to the CEESCOPE™ through a built-in NTRIP client.

The network RTK architecture is shown below.



Network RTK Fix
Accuracy <0.01m / 0.015m vertical
Receiver indicated quality code (4)
Corrections received through hotspot / phone

Local Base Station “Base / Rover” RTK

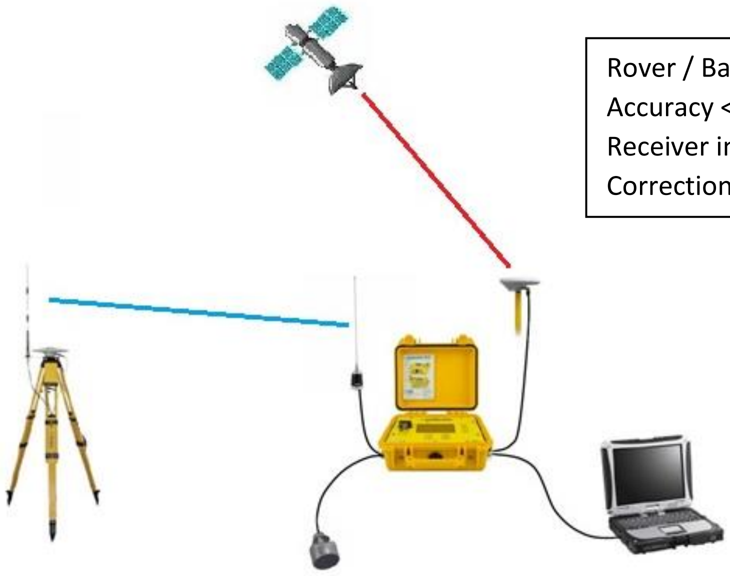
If network RTK is not available, or the survey environment calls for a dedicated source of very high precision corrections, then a local RTK base station is used. The base station consists of a second RTK GNSS receiver that is configured as a “Static Base Station”. The base receiver is programmed with the exact coordinates of its location, and as it continuously receives the GNSS position signal it compares the computed position with the known position. The difference in these two positions will reflect an error very close to the error in the nearly “rover” receiver position data. The correction to eliminate this error is computed and then is transmitted to the rover over a radio, usually in the 450MHz or 900 MHz frequency range.

The base station may have a built-in radio incorporated into the receiver for short range (<1 mile) operation, or a separate high-power radio may be connected to greatly extend the range. The rover will usually have a built-in receive radio. In the case of the RTK CEESCOPE™ a 403-470MHz UHF receive radio is integrated into the system, allowing direct connection to practically any base station.

The base station location must have been accurately surveyed beforehand, or located on an existing benchmark with published position and elevation data.

The benefit of the base / rover RTK setup is the flexibility to operate in any location without the requirement for a paid corrections service. The corrections are also entirely within the control of the surveyor and as the base station will usually be close to the rover receiver, accuracy achieved can be very high. The drawback is the requirement for a second GNSS receiver base station hardware and the time needed to set this up.

The base / rover RTK architecture is shown below:



Rover / Base RTK Fix
Accuracy <0.01m / 0.015m vertical
Receiver indicated quality code (4)
Corrections received through UHF radio

CEESCOPE™ Setup for GNSS (RTCM) Corrections

The CEESOPE™ is offered in two configurations, non-RTK and RTK. The corrections source may be modified by the user in the “RTCM” menu and different options will appear depending on the GNSS receiver inside. If the corrections selected (RTCM menu) are not available, for example the L-Band satellite is not in view or the radio parameters are incorrect, a “RTCM Error” will indicate.

Non-RTK: The non-RTK CEESCOPE™ is usually based on the Hemisphere range of GNSS receivers, with the available corrections as follows:

ATLAS — In most cases, select “Atlas” as the RTCM source. A lifetime Atlas BASIC 0.5m service is included in the CEESCOPE™ to provide a robust correction. If a higher quality subscription correction service (H-10) is active, then this will operate instead.

SBAS — If there is trouble receiving ATLAS corrections, the source may be downgraded to SBAS (if available at the location).

RTK: The Trimble or NovAtel RTK CEESCOPE™ has several options:

SBAS: If not using RTK, SBAS is selected as the best differential corrections option.

Internal Radio: If connecting to a base station, the frequency and radio modulation is entered to allow the radio in the CEESCOPE™ to communicate directly with the base radio.

Network: The corrections will pass to the CEESCOPE™ through the Ethernet (LAN) cable from the acquisition PC. An NTRIP client must be available to forward the corrections.

TerraStar: RTX — If a subscription is active, the relevant PPP service will be an available option.

Note that the RTK CEESCOPE™ can also log raw GNSS measurements for post processing