Satellite positioning

How accurate is it?

Although GPS is the only satellite positioning system used in France, many products combining receiver and correcting signals are available on the market. In order to assess them, according to the purpose and conditions of use, ARVALIS – Institut du végétal measured their level of accuracy in various conditions.

Besides accuracy, the choice of a particular satellite positioning system should also be based on the constraints connected with its use (initialisation time, quality of reception in the presence of masks).

Global positioning systems (GPS), are used increasingly often by the agricultural industry. However, GPS on its own is sometimes not accurate enough for its intended use. This is why differential corrections (dGPS) are offered. The French market offers a wide selection of signals. The choice of a signal depends on its intended use (yield map, surveying, steering, variable rate application…) and therefore, on its accuracy. In order to have a better idea of what can be expected from satellite positioning, depending on conditions of use, type of equipment and differential correction, precision tests were set up in autumn 2006.

Accuracy drifts with time

The accuracy of GPS positioning depends on:

- the quality of the equipment used: a hill walking GPS will be less accurate than a professional receiver. This is due to the sensitivity of the receiver (clock…).
- the data that the antenna is capable of receiving.
- The GPS signal is sent on two wavelengths (L1 and L2). The mono frequency receivers only use L1. Dual frequency receivers are capable of using both data components, making positioning more stable and accurate.
- the presence of differential correction. This is sometimes only available for dual frequency receivers.

Omnistar's HP and John Deere's SF2 are the most accurate signals but are difficult to use where masks are present (woods, buildings…) due to signal loss.

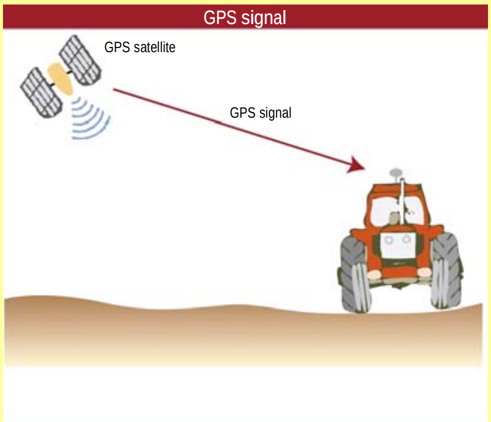
The accuracy of the correction drifts with time: two positions, established using the same fixed receiver 15 minutes apart will show a greater discrepancy than two positions established one minute apart. Calculating this drift helps to estimate the error that occurs between two passes of a machine, when GPS is used as a steering bar.

Two types of tests: static and dynamic

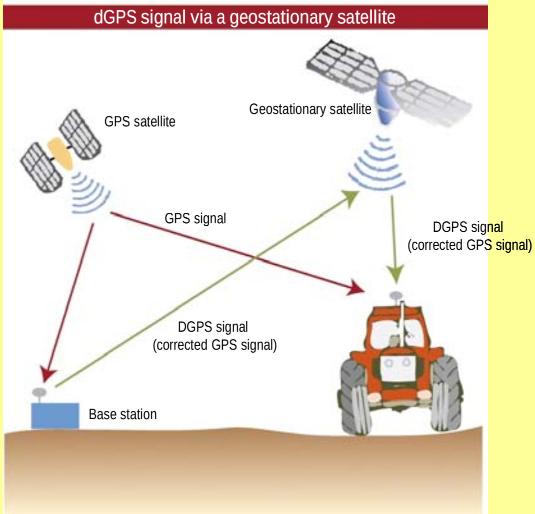
Dynamic measurements were recorded at a speed of 8 km/h, without any masks (mid field) over 45 minute periods roughly. Static measurements were also recorded but over longer periods of time (around one and a half hours) in various conditions (with a wood nearby, beside a building and in the middle of a field).

On its own, the GPS gives a 75 cm maximum error, 95% of the time between two passes 15 minutes apart *(figure 1)*. Except with the Garmin 76, which has a level of accuracy of over 2 m, using differential correction improves accuracy.

What is differential correction? (insert 1)



GPS (Global Positioning System): positioning system based on a network of 24 satellites which the US Defence Department started setting up in 1978 and which has been operational since 1994. Its users can obtain their position, their speed per hour, anywhere in the world, 24 hours a day.



dGPS (Differential Global Positioning System, or differential correction): this corrective technique is designed to minimise the sources of error which interfere with the transmission of the GPS signal (satellite positions, signal propagation in the atmosphere, the ionosphere…). Differential positioning is based on a network of fixed receivers (base station) the exact position of which is known. At any time, the difference between the fixed receiver's absolute coordinates and its measured coordinates is known. This difference helps to calculate the correction which must be applied to the coordinates measured on a mobile receiver (user) at the same moment in time. Corrections can be transmitted to the mobile receiver via a geostationary telecommunication satellite. This is the case for the Egnos, Omnistar VBS/HP/XP (Fugro) and StarFire 1 and 2 (John Deere) signals.

Six signals on trial *(insert 2)*

Egnos (European geostationary Navigation Overlay Service), a free signal, was developed by the European Space Agency. Designed to assess the positioning quality of the future Galileo system, it can also be used as differential correction for a GPS. Currently broadcast by three geostationary satellites, it is still in its trial phase, resulting in frequent loss or absence of signal for variable periods of time (from a few minutes to several hours). Fugro signals are by subscription. Omnistar VBS (Virtual Base Station) uses a mono frequency antenna and does not require any initialisation time. The Omnistar HP (High Performance) uses a dual frequency antenna. It requires some initialisation time, necessary for achieving optimum accuracy, varying between 10 minutes if it is static, and 45 minutes on the move. This signal can be lost when getting closer to masks (woods, building…) if there is a 30-second break in reception, and will then require a reset. John Deere offer two signals (StarFire 1 and StarFire 2) dedicated to the dual frequency antenna of the same name. StarFire 1, or SF1, is free and is a lesser version of the StarFire 2 signal. StarFire 2, or SF2, is by subscription. In order to reach their optimum level of accuracy, both signals require a 30 to 45 minute initialisation time. The system is operational as soon as it is switched on but with a lower level of accuracy. As with the Omnistar HP system, coming close to a mask will result in loss of signal.

In order to assess each of the differential corrections available on the French market, they were tested simultaneously at the Boigneville research station (South of Paris).

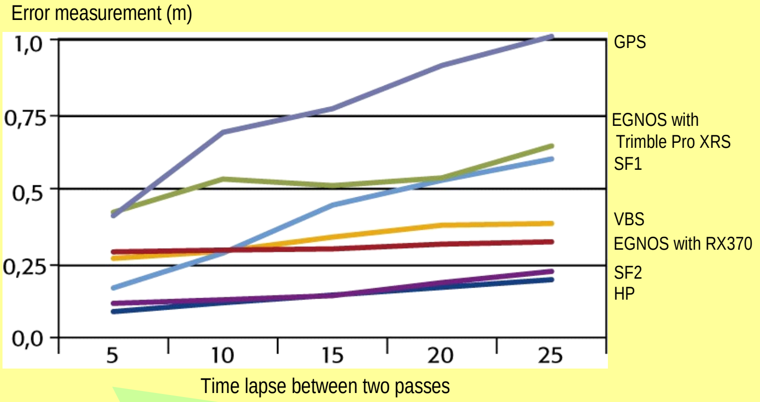
Static measurements to assess the accuracy of the systems help to evaluate their stability over time.

The Egnos signal improves GPS accuracy (by around 50 cm). However, the performance of Egnos is extremely variable (from 10 cm to over 20 m). This is due to the fact that it is still in its trial phase. It will be the subject of a new study once it becomes more stable. The VBS and Egnos signals recorded by the Tee Jet - LH Agro RX370 antenna showed a 30 cm error 95% of the time. The SF1 signal performs differently. It is more accurate for passes recorded 5 minutes apart, but it reaches a 60 cm error 95% of the time when passes are 15 minutes apart. The Omnistar HP and John Deere SF2 signals are the most accurate and present similar performance and accuracy levels: a 14 cm error 95% of the time between two passes 15 minutes apart. In a stationary position, the signals should show a lower level of accuracy than in dynamic tests as the GPS no longer benefits from the direction information, and also due to the variety of measurement conditions, including when measurements are recorded in the presence of obstacles *(figure 2 and table 1).*

Impact of accuracy drift on field work

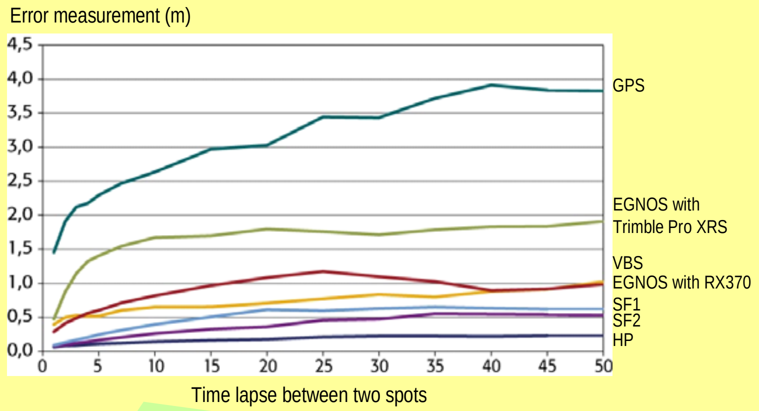
The forward speed of a tractor depends on the type of work being carried out: it is higher during a treatment than during sowing. Therefore, for a given field, the time required for a round trip will be shorter with treatment work If less time is required for a round trip, the maximum error will be lower, and vice versa. In other words, when sowing, the differential correction must be more accurate and more stable over time than for a treatment.

Error progression between two passes for a 5 minute round trip (600 m covered at 8 km/h in the best possible conditions) *(fig. 1)*



When conditions are good (no obstacle on the ground, optimum number of satellites…), differential corrections improve GPS accuracy. The best signals have a level of accuracy of less than 20 cm 95% of the time.

Progression of maximum error recorded with the system left switched on, in one spot, for 3 hours (average of mid field trials, alongside a wood, beside a building) *(fig. 2)*



When conditions are more restricting (presence of obstacles), the levels of accuracy measured for each differential correction are not as good as those recorded mid field (figure 1).

Accuracy of the signals 15 minutes after they started working *(tab. 1)*

Signals	Maximum error recorded 95% of the time	Area error (%) 28 m tool (e.g.: spreader)	Area error (%) 4 m tool (e.g.: drill)
GPS only	3 m	8	60
Egnos	1.70 m	5	35
Egnos with RX370 antenna	1 m	3	17
Omnistar VBS	65 cm	2	15
John Deere SF1	50 cm	1	8
Omnistar HP	16 cm	0.4	3
John Deere SF2	30 cm	0.7	5

The Omnistar HP signal for example has a 16 cm accuracy level 15 minutes after it started working (95% of the time).In the field, this level of accuracy results in a 0.4% area inaccuracy in the case of 28 m-wide spreading work and 3% in the case of 4 m-wide sowing.

Good conditions of use are a first step towards accuracy

The choice of a signal is primarily determined by its intended uses. High performance signals (Omnistar's HP and John Deere's SF2) seem to be essential for sowing, whereas a submetric signal such as John Deere's SF1 or Omnistar's VBS can be good enough for wide spreading applications. The second consideration is the characteristics of the farm: if the fields are surrounded by potential masks (woods, hedges, buildings…), there is no point in investing in a highly accurate signal such as Omnistar's HP and John Deere's SF2, as they would be difficult to use due to signal loss and the time required to reset the system. Conditions of use are determining for accuracy. Even with a highly accurate system, errors of several metres can occur if the satellite constellation is inadequate and initialisation is not perfect.

Three factors help make the best possible use of a system.

- satellite constellation (number, spread…): four satellites must be picked up in order to obtain a GPS position. Accuracy improves from seven satellites upwards.
- presence of obstacles likely to mask some GPS satellites or cause dGPS signal loss.
- weather conditions (fog, rain…) can deteriorate signal quality.

Absolute accuracy is lower

Those results represent relative accuracy levels, i.e. compared to a virtual reference fixed when the system is started up. In the absolute, the level of accuracy diminishes, as the aim is to find again the exact geographical coordinates of a spot or a line followed earlier. Even considering only the most accurate signals, on average, the Omnistar HP has a 45 cm accuracy level and the John Deere SF2 has a 1 m accuracy level. With those kinds of figures, it is impossible to find again a given spot exactly. This means that it is impossible to carry out spot fertiliser spreading in the autumn expecting to follow exactly the same course again at sowing time. In this case, the level of accuracy required is around one cm! Only a RTK system can guarantee this level of accuracy.

With three different receivers for Egnos *(insert 3)*

The measurements were carried out using:

- Trimble Ag332 (dual frequency receiver) for the Egnos and Omnistar HP/XP signals,
- Trimble PRO XRS (mono frequency receiver) for the GPS and Omnistar VBS,
- SF1 and SF2 signals were received using John Deere antennas,
- the Egnos signal, which is widely used because it is free of charge, was received using two other receivers: a Garmin 76 (hill walking GPS) and a Tee Jet – LH Agro RX 370 antenna.

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