GPS Devices

Speed Sailing - Feature Comparison

Michael George (K888)

Issue 2.3 – 6th July 2010

1 Overview

1.1 Introduction

Ever since affordable GPS devices hit the market, windsurfers have been strapping the little marvels to their arms before going sailing. Many are curious to find out how fast they can sail and GPS speed ladders are common place at most clubs today.

Over the years, GPS technology has steadily improved and the number of devices on the market has increased massively. For those wishing to choose a device, it can seem a little daunting and I'm often been asked to explain technical terms or which device is best.

I've spent a fair bit of time studying GPS technology and decided to jot down some of the topics that I have learnt about. I have tried to avoid any detailed explanations about how GPS technology actually works but I have provided some good internet links throughout this document. I have tried to focus mainly on the topics that are relevant to speed sailors.

1.2 Basic Principals

Fundamentally, GPS devices calculate two things that interest speed sailors. They calculate our position (i.e. longitude, latitude and elevation) and speed (often referred to as "speed over ground", "course of ground" and "climb rate"). It is important to understand that these are two separate calculations and although they can influence other they are not as closely related as one might first expect.

Position is calculated using a relatively "simple" triangulation method. The positions of the satellites are known by the GPS and the time it takes for the signals to arrive at the GPS gives an approximate distance (ignoring atmospheric conditions and various other factors). This allows a receiver position to be calculated using the triangulation method.

Contrary to popular belief, speed is not derived from the distance and time between two position fixes. The GPS satellites are orbiting the Earth at high speeds and there is an observable Doppler effect on their signal frequencies. GPS receivers can therefore measure how fast the satellites appear to be moving towards (or away) from them. Since the GPS receiver already knows a lot about the satellites (position, speed and direction), they can determine their own speed using a mathematical approach called "least squares".

Civilian GPS (horizontal) position fixes are typically accurate to about 15 meters (50 ft) for 95% of the time. However, the advancement of technology means that today, civilian GPS fixes under a clear view of the sky are on average accurate to about 5 meters (16 ft) horizontally. Speeds are typically accurate to within 0.05 m/s (0.1 knots).

Note: Generally speaking, the speed information (Doppler derived) is more accurate than the positional information.

1.3 Common Misconceptions

I thought that I would add this section because I've heard all sorts of urban myths over the years.

Speeds on the device can be trusted
Whilst the speed on the device is usually very accurate, there are a number of factors that can result in a rogue value being reported (often referred to as a spike). Examining the track on a computer is usually required to give credibility to the observed readings.

One device faster than the other
I remember a couple of friends who both had the same Garmin model arguing that one of them always reported higher than the other. Wearing identical devices at the same time will always show a difference because the two devices are not synchronized.

Software shows the true speed
When examining older Garmin tracks (e.g. Geko, eTrex, Foretrex, etc) on a computer the reported speeds can be higher than the device reported on the screen (theoretically up to 2 or 3 knots higher). This is because the downloaded track is inaccurate, due to the precision of longitude and latitude being reduced to save memory (referred to as "grid effect"). Most Garmin devices do not save the Doppler based speed information so the computer software can only report speeds that are derived from the (inaccurate) positional data.

GPS is inaccurate at low speeds (walking)
Generally speaking, the error margins are the same no matter how fast you are travelling. If you are walking and the GPS reports 20 knots then it is clearly a "spike" but "spikes" can happen at any speed. This does not mean that the GPS is inaccurate at low speeds.

However, some independent testing has shown that the accuracy of Doppler derived speed accuracy can be noticeably better at higher speeds (>30knots).

GPS receivers work fine underneath neoprene
Some people put their GPS under their wetsuit, often because they do not have an aqua pack with an armband. This significantly affects the signal quality and it can result in poor quality results. I've seen a number of poor quality / erratic tracks from older Garmin models (e.g. Geko, eTrex and Foretrex) due to them being used under neoprene.

Waterproof / IPX7
The IPX7 standard basically means that a device can be left in 1m of water for 30 minutes. It is not enough to protect a device from you falling into the water and / or catapulting. All GPS devices need to be worn inside an aqua pack to keep them safe.

2 Choosing a Device

Before giving details about a few devices with which I've had hands-on experience, I'll describe a few features that may be mentioned later on. Some are good things to have and some are actually quite bad as they hide potential errors! See Appendix A for device lists.

Trip Computer and "Speed Genie"
Most devices offer some kind of trip computer which typically reports current speed, average speed, maximum speed, trip timer, and trip distance, etc. These are quite useful and some devices (e.g. GT-11 and GT-31) offer additional features such as the "Speed Genie" which reports speeds over a specific time period (e.g. 10 second average), shows speeds at the end of each run and allows the best runs to be recalled after a session.

Masking
Some devices (e.g. Garmin) apply masking so that if you're stationary and the unit is recording 0.1 or 0.2 knots it will display 0.0 on the screen. If you do a "stationary test" it will look as if the device doesn't wander but it is just hiding the actual error!

Smoothing
If the recorded speed suddenly changes, track smoothing will report the change more gradually on the screen. If it was a spike (possibly caused when changing from one satellite to another), a few knots may be added to your speed and it can be hard to spot!

Decimal Places
The number of decimal places may be deemed important when looking at peak speeds.

Allowed by GPSSS
If you wish to compete on GPS-Speedsurfing.com then you must use an approved device.

Recording Interval
Ideally a device should support 1 second recording, except when "grid effect" is an issue.

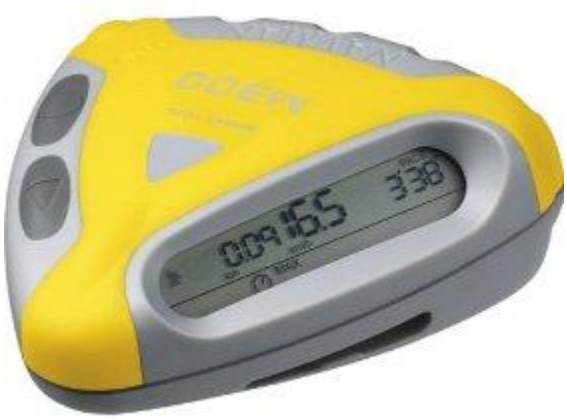
Grid Effect
"Grid effect" refers to lack of precision in positional data (longitude and latitude), which causes misleading speeds on a computer. Use 2s recording to minimize the effects!

Number of satellites, HDOP information, SDOP information
Some devices save additional information which gives extra credibility to the track data.

Cables or SD Card?
Proprietary cables may be a problem if you need to download your track on a different computer and don't have your cable. Downloads via a serial cable can also be quite slow.

Writing the track data directly to an SD card makes it easier to analyze the track on a computer later on and avoids slow download speeds.

2.1 Navman M300 (Discontinued)



The Navman M300 was very popular between 2005 and 2007, partly due to promotions with new JP boards and their use at the Maui Speed Challenge.

Although the features were very basic and there was no way to link it up to a PC, it was a good way to gauge your speed in the early days of GPS speed sailing. Although they can be worn on your upper arm, it is better to use an aqua pack because the IPX7 standard is not adequate for windsurfing and the strap can also come undone whilst sailing.

The Navman masks out low speeds (showing 0.0 when stationary) and reports 10 second average speeds, rather than actual speeds. Prior to selling my own Navman M300, I confirmed that the reported speeds matched the 10s averages on my Locosys GT-11 and I also did some controlled tests to convince myself that it was reporting 10s averages.

Pros:

- Easy to use
- Not wildly prone to "spikes"
- Reported speeds are 10s averages

Cons:

- No peak speed (just 10s average)
- No decimal places over 20 knots
- Unable to download to PC
- Cannot ratify the speed results
- Cannot perform further analysis
- Not suitable for GPSSS

Links:

- Starboard Forum: Press Release: New Maui Speed Challenge Series
- Starboard Forum: Maui Speed Challenge Series: Race 1

2.2 Garmin Geko

Geko 101

Geko 201

Geko 301

This range was made popular due to the low price and availability. Although the 201 and 301 allow you to download your tracks to a PC, the biggest problem is the propensity to false readings ("spikes") and like all Garmin devices they only save positional data rather than the Doppler based speed data. The positional data exhibits the "grid effect" (discarding the lower precision bits for longitude and latitude) in order to save memory.

Masking and track smoothing are both evident with the device reporting 0.0 when stationary.

Tips: Ensure that track recordings are every 2 seconds, rather than in "auto" mode.

Pros:

- Cheap
- Simple button operations
- There is an NMEA out feature but it isn't feasible to use it when windsurfing!

Cons:

- Prone to "spikes"
- Only records position, not speed
- "Grid effect" (up to 2.39m)
- Uses proprietary Garmin cable
- Slow download (COM port)
- Runs 2 "AAA" batteries

Links:

- Garmin: Geko 101, Geko 201, Geko 301 (Product)

2.3 Garmin eTrex (early models) [Discontinued]

eTrex **Venture** **Legend** **Summit** **Vista**

This range was made popular due to the low price and availability. Although the eTrex models allow you to download your tracks to a PC, the biggest problem is the propensity to false readings ("spikes") and like all Garmin devices they only save positional data rather than the Doppler based speed data. The positional data exhibits the "grid effect" (discarding the lower precision bits for longitude and latitude) in order to save memory.

Note that there are two significant variants of the eTrex (Yellow), Camo and Summit. The differences relate to the software versions (2.x or 3.x). Only the 3.x software allows you to specify the recording interval whereas the 2.x software only supports "auto" mode.

Masking and track smoothing are both evident with the device reporting 0.0 when stationary.

Tips: Ensure that track recordings are every 2 seconds, rather than in "auto" mode.

Pros:

- Cheap
- Simple button operations
- There is an NMEA out feature but it isn't feasible to use it when windsurfing!

Cons:

- Prone to "spikes"
- Only records position, not speed
- "Grid effect" (up to 2.39m)
- Uses proprietary Garmin cable
- Slow download (COM port)
- Runs 2 "AA" batteries

Links:

- Garmin: eTrex (Yellow), Camo, Legend, Summit, Venture, Vista (Product)
- Garmin: eTrex Series (Specification)
- OpenStreetMap Wiki: Garmin/eTrex Series

2.4 Garmin Foretrex + Forerunner (early models) [Discontinued]

Foretrex 101

Foretrex 201

Forerunner

The Foretrex and Forerunner ranges are very similar but they provide slightly different features (i.e. trekking vs running). Although they can be worn on the wrist or upper arm, it is better to use an aqua pack because the IPX7 standard is not adequate for windsurfing and the strap can also come undone whilst sailing. As with the eTrex models, "spikes" and the "grid effect" are two of the biggest criticisms of these models.

The cables vary slightly for the different models. The Foretrex 101 uses a proprietary cable that plugs straight into the device whilst the Forerunner 101 has no PC connectivity. The Foretrex 201 and Forerunner 201 use the same proprietary cable as the Foretrex 101 but require an additional proprietary "cradle". The Forerunner 301 uses standard USB.

Masking and track smoothing are both evident with the device reporting 0.0 when stationary.

Tips: Ensure that track recordings are every 2 seconds, rather than in "auto" mode.

Pros:

- Small compact unit
- Simple button operations
- Large screen with good display choices for speed sailing
- Built in rechargeable battery (201 and 301)
- There is an NMEA out feature but it isn't feasible to use it!

Cons:

- Forerunner only has "auto" mode
- Prone to "spikes"
- Only records position, not speed
- "Grid effect" (up to 2.39m)
- Uses proprietary Garmin cable (101 and 201)
- Slow download (COM port)
- Runs 2 "AAA" batteries (101)

Links:

- Garmin: Foretrex 101, 201 + Forerunner 101, 201, 301 (Product)
- Garmin: Foretrex 101 + 201, Forerunner 101 + 201, 301 (Specification)

2.5 Garmin eTrex C (original colour models) [Discontinued]

Venture Cx **Legend C + Cx** **Vista C + Cx**

This range includes five models (Legend C, Vista C, Legend Cx, Venture Cx, Vista Cx) and offers several improvements over the original eTrex models. The colour screens are obvious but they also added a USB connector, micro SD card slot (x models – for additional maps) and an improved Garmin chipset. The new chipset means that TTFF (time to first fix) via AutoLocate is reduced from 5 minutes to 2 minutes and the "grid effect" is also gone. Like all Garmin devices, this range only saves positional data rather than the Doppler based speed data.

Masking and track smoothing are both evident with the device reporting 0.0 when stationary.

Tips: Ensure that track recordings are every 1 or 2 seconds, rather than in "auto" mode.

Pros:

- Simple button operations
- 1 second recording interval
- No discernable "grid effect"
- Fast download via USB cable

Cons:

- Only records position, not speed
- Does not record satellite info
- Does not record HDOP info
- Runs 2 "AA" batteries

Links:

- Garmin: eTrex Legend C, Vista C, Legend Cx, Venture Cx, Vista Cx (Product)
- Garmin: eTrex Legend C + Vista C, Legend Cx + Venture Cx + Vista Cx (Spec)

2.6 Garmin Forerunner + Edge (newer models)

Forerunner 205

Forerunner 305

Edge 205 + 305

Edge 605 + 705

The Forerunner (205 and 305) and Edge (205, 305, 605 and 705) models utilize the SiRF Star III chipset and are very capable GPS devices. Unlike the earlier eTrex and Foretrex models, there is no discernable grid effect and the quality of the positional data appears to be comparable to that of the Locosys GT-31. However, as is the case with most other Garmin models only the positional data (longitude, latitude and elevation) is recorded on the devices, thus limiting subsequent analysis on a computer.

Note: It has been observed that the positional data of a GT-31 (also SiRF Star III) is more reliable than the positional data of a GT-11 and very consistent with the Doppler based speed data. This implies that the positional data of the Forerunner and Edge is likely to be pretty good too… in the absence of more detailed testing.

Tips: Ensure that track recordings are every 1 second, rather than in "auto" mode.

Pros:

- 1 second recording interval
- High accuracy positional data
- No discernable "grid effect"
- 3.5 hours of memory
- Built in rechargeable battery
- Fast download via USB cable

Cons:

- Only records position, not speed
- Does not record satellite info
- Does not record HDOP info
- Forerunner requires proprietary Garmin cradle (USB)

Links:

- Garmin: Forerunner 205, 305 + Edge 205, 305, 605, 705 (Product)
- Garmin: Forerunner 205 + 305, Edge 205 + 305 (Specification)

2.7 Garmin eTrex H (high sensitivity models)

eTrex H

Legend H

Vista H

Legend HCx

Summit HC

Venture HC

Vista HCx

This range of 7 models incorporates the MediaTek high-sensitivity GPS chipset. The main advantage over the previous eTrex range is the TTFF (time to first fix) which is much better than the Garmin chipsets. It is not yet known whether these models exhibit the "grid effect" but other recent devices (e.g. eTrex [colour], Forerunner 205 / 305 and Edge models) do not. Like all Garmin devices, this range will probably only save positional data rather than the Doppler based speed data. You can easily spot models from this range because the black image of a globe is no longer printed on the casing!

The cables vary slightly for the different models. The H models use the (traditional) proprietary Garmin cable whilst the HC and HCx model use a standard USB cable.

Masking and track smoothing are likely to be evident with the device reporting 0.0 when stationary.

Tips: Ensure that track recordings are every 1 or 2 seconds, rather than in "auto" mode.

Pros:

- Simple button operations
- 1 second recording interval - tbc
- No discernable “grid effect” - tbc
- Fast download via USB cable (HC and HCx models)

Cons:

- Only records position, not speed
- Does not record satellite info
- Does not record HDOP info
- Uses proprietary Garmin cable (H models)
- Slow downloads (H models)
- Runs 2 "AA" batteries

Links:

- Garmin: eTrex H, Legend H, Vista H (Product)
- Garmin: eTrex Legend HCx, Summit HC, Venture HC, Vista HCx (Product)

2.8 Garmin Foretrex (newer models)

Foretrex 301 **Foretrex 401**

As far as speed sailing is concerned, little is known about the Foretrex 301 and 401 (yet). Garmin states that it contains a "high-sensitivity GPS receiver" but it is not the SiRF Star III or MTK chipset. The TTFF (time to first fix) is much better than the original Foretrex 101 and 201. It is not yet known whether these models exhibit the "grid effect" but other recent devices (e.g. eTrex [colour], Forerunner 205 / 305 and Edge models) do not. Like all Garmin devices, this range will probably only save positional data rather than the Doppler based speed data.

Masking and track smoothing will probably be evident with the device reporting 0.0 when stationary.

Tips: Ensure that track recordings are every 1 or 2 seconds, rather than in "auto" mode.

Pros:

- Small compact unit
- Simple button operations
- Large screen with good display choices for speed sailing
- 1 second recording interval - tbc
- No discernable "grid effect" - tbc
- Fast download via USB cable

Cons:

- Only records position, not speed
- Does not record satellite info
- Does not record HDOP info
- Runs 2 "AAA" batteries

Links:

- Garmin: Foretrex 301 and 401 (Product)

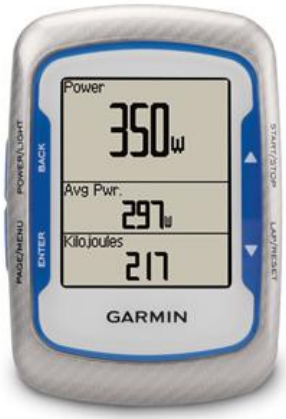
2.9 Garmin (unsuitable models)

Forerunner 110

Forerunner 405

Forerunner 405CX

Forerunner 310XT



Edge 500

The above models are based on SiRF III and SiRF IV (Forerunner 110) chipsets but the recording interval cannot be specified and defaults to "auto" mode.

A couple of the devices (Forerunner 310XT and Edge 500) are supposed to switch to "approximately 1 second recording" when connected to a power meter but there are reports that such recordings are erratic and do not record every second.

For this reason, the above devices are deemed unsuitable for speed analysis.

Links:

- Garmin: Forerunner 110, 310XT, 405, 405CX (Product)
- Garmin: Edge 500 (Product)

2.10 Locosys GT-11 / Scytex NAVi GPS / Amaryllo Trip Tracker [Discontinued]

The GT-11 (based on SiRF Star II chipset) was a revelation for speed sailors because it introduced a number of features that were previously unavailable on the Garmin devices.

The "Speed Genie" is a mode that automatically displays what the sailor needs to see, thus avoiding the need for any button pressing. For example, during a run it will show the current speed but at the end of the run it will show the peak speed and 10 second average (during the run) plus the highest ones of the day. Off the water, it is also possible to review the top speeds (peak or 10 second average) without the need for a computer.

It also records more data than just the positional data (e.g. Doppler speed, satellites in view, HDOP – horizontal dilution of precision) and writes straight to a SD card, as well as the internal flash memory (serving as a useful backup).

Pros:

- 1 second recording interval
- Records "Doppler" speeds
- Records satellite information
- Records HDOP information
- No discernable "grid effect"
- Writes directly to SD card
- Writes directly to flash memory
- Built in rechargeable battery
- Charges via USB cable

Cons:

- Not the nicest of user interfaces
- Annoying "move long?" question
- Difficult to operate in aqua pack
- Fiddly to access the SD card

Links:

- Locosys: GT-11 (Product), GT-11 (Specification)

2.11 Locosys GT-31

The GT-31 utilizes the SiRF Star III which is claimed to have better accuracy for Doppler shift, amongst other improvements. It also has a quicker startup time and my own testing has shown that the positional data is far more reliable than that from a GT-11 (utilizing SiRF Star II but still good). It also calculates SDOP (speed dilution of precision) and saves it within the track data, giving even greater creditability to the speeds reported. Note: SDOP is only calculated / recorded when using firmware V1.2 B1405x or higher.

The "Speed Genie" has also been improved, allowing the user to configure which bits of information are displayed and there is also an (optional) audible readout after each run.

It has all of the benefits of the GT-11 plus more besides:

- Faster and more responsive than GT-11
- Improved accuracy and sensitivity over GT-11
- Very good TTFF (time to first fix) when the unit is switched on
- Less likely to lose the fix once it has it, thus resulting in better quality
- Doppler data (speed over ground) is slightly more accurate than GT-11
- Positional data is much more accurate than GT-11 (much closer to Doppler)
- Less "wander" occurs than on the GT-11 – often noticeable during course racing
- Records at exactly 1 second intervals, without occasional 0.999s / 0.998s (GT-11)
- Longer battery life than the GT-11
- No aliasing errors (a minor issue on the GT-11)
- The newer firmware adds "Delete All" and "Save All" options.
- No annoying "Move Long?" questions like the GT-11

Links:

- Locosys: GT-31 (Product), GT-31 (Specification)

3 Tips

3.1 Locosys GT-11

There are already sites that explain how to set up the GT-11 (see links below) so I will just list a few additional tips:

Setup:

- Set up the “Memory Card” and “Data Logger” so that you have a backup!
- Using the “Memory Card” option "On" ensures that all data is recorded, thus allowing people to work out the cause of any data errors. Additional data errors have been reported to occur when using “On-Fix” but it is yet to be proved.
  N.B. The “On” option also overrides the “Min Speed” setting (GT-11 + GT-31).
- A “Min Speed” of “1” (knot) in the “Data Logger” avoids any recordings whilst standing still but still captures all movement on the water.

Before Sailing:

- Ensure that the battery is fully charged because track quality is reduced when it is low. After 6 to 8 hours the speeds can still look ok but positional data can be poor.
- Switch on the GT-11 and chuck it on your dashboard whilst a fix is acquired.
- If the GT-11 asks "Move Long?" then it is asking if you have moved a significant distance (over 100 km) or a significant length of time has passed (days) since the last use. This is related to stale ephemeris or azimuth data and answering "yes" forces a cold start. It shouldn't really have to ask this question but when it does appear, just answer “Yes”.
- It is good to clear out readings in the trip meter, speed genie and data logger.
- Beware! If you format your card before the GT-11 creates a “new file” it will not create a file afterwards. Observant users may notice an “eject card” icon appear when this occurs. Once a file is created, the GT-11 will refuse to format the card.

After Sailing:

- Save the data logger to the SD card, just in case the SBN file was not saved.
  N.B. Expect a new (small) SBN file after saving the data logger to the SD card.
- If necessary, SBN files can be joined from the Windows “Command Prompt” using “copy /b input_file_1+input_file_2 output_file”. This works because the SBN format is made up of packets that have start / end sequences, packet length and payload length. Although joining files results in the header (username, serial, firmware, etc) being replicated in the middle of the file, it can simply be ignored by the software. GpsarPro, GPSResults and RealSpeed all handle joined files.

Links:

- Locosys: GT-11 (Downloads)
- Tom Chalko: GT-11 Setup Guide
- Basil Canibis: GT-31 Manual (GT-31 setup is almost identical to the GT-11)

3.2 Locosys GT-31

There are already sites that explain how to set up the GT-31 (see links below) so I will just list a few additional tips:

Setup:

- Set up the “Memory Card” and “Data Logger” so that you have a backup!
- Using the “Memory Card” option "On" ensures that all data is recorded, thus allowing people to work out the cause of any data errors. Additional data errors have been reported to occur when using “On-Fix” but it is yet to be proved.
  N.B. The “On” option also overrides the “Min Speed” setting (GT-11 + GT-31).
- A “Min Speed” of “1” (knot) in the “Data Logger” avoids any recordings whilst standing still but still captures all movement on the water.
- Specify the “Speed Genie” elements that you want to see within “Misc”.

Before Sailing:

- Ensure that the battery is fully charged.
- Switch on the GT-31 and chuck it on your dashboard whilst a fix is acquired.
- Use “Delete All” to clear out the trip meter, speed genie and data logger.

After Sailing:

- Use “Save All” to write the speed report and data logger to the SD card as backup.
  N.B. Expect a new (small) SBN file after saving the data logger to the SD card.
- If necessary, SBN files can be joined from the Windows “Command Prompt” using “copy /b input_file_1+input_file_2 output_file”. This works because the SBN format is made up of packets that have start / end sequences, packet length and payload length. Although joining files results in the header (username, serial, firmware, etc) being replicated in the middle of the file, it can simply be ignored by the software. GpsarPro, GPSResults and RealSpeed all handle joined files.

Links:

- Locosys: GT-31 (Downloads)
- Tom Chalko: GT-31 Setup Guide
- Basil Canibis: GT-31 Manual

4 Appendices

4.1 Appendix A – Device Features

These tables only list features that are of significance to speed analysis. Traffic lighting has been applied for basic guidance.

4.1.1 Navman

Device	Cable	Chipset	Mask?	Speed Genie?	SD Card?	Display D.P.s	Allowed GPSSS?	Recording Interval	Track Memory	Grid Effect?	Doppler Speed?	Num Sats?	HDOP Info?	SDOP Info?	Overall
Navman M300	n/a	?	Y	N	N	0	N	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

4.1.2 Garmin Geko

Device	Cable	Chipset	Mask?	Speed Genie?	SD Card?	Display D.P.s	Allowed GPSSS?	Recording Interval	Track Memory	Grid Effect?	Doppler Speed?	Num Sats?	HDOP Info?	SDOP Info?	Overall
Geko 101	n/a	Garmin	Y	N	N	1	N	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Geko 201	Garmin (Serial)	Garmin	Y	N	N	1	Y	2 sec	10,000 (5.5 h)	Y	N	N	N	N	
Geko 301	Garmin (Serial)	Garmin	Y	N	N	1	Y	2 sec	10,000 (5.5 h)	Y	N	N	N	N	

4.1.3 Garmin eTrex (early models) [Discontinued]

Device	Cable	Chipset	Mask?	Speed Genie?	SD Card?	Display D.P.s	Allowed GPSSS?	Recording Interval	Track Memory	Grid Effect?	Doppler Speed?	Num Sats?	HDOP Info?	SDOP Info?	Overall
eTrex 2.x	Garmin (Serial)	Garmin	Y	N	N	1	N	Auto	2,047	Y	N	N	N	N	★
eTrex Camo 2.x	Garmin (Serial)	Garmin	Y	N	N	1	N	Auto	2,047	Y	N	N	N	N	★
eTrex Summit 2.x	Garmin (Serial)	Garmin	Y	N	N	1	N	Auto	2,047	Y	N	N	N	N	★
eTrex Venture	Garmin (Serial)	Garmin	Y	N	N	1	Y	2 sec	2,047 (1.1 h)	Y	N	N	N	N	★
eTrex 3.x	Garmin (Serial)	Garmin	Y	N	N	1	Y	2 sec	10,000 (5.5 h)	Y	N	N	N	N	★★
eTrex Camo 3.x	Garmin (Serial)	Garmin	Y	N	N	1	Y	2 sec	10,000 (5.5 h)	Y	N	N	N	N	★★
eTrex Summit 3.x	Garmin (Serial)	Garmin	Y	N	N	1	Y	2 sec	10,000 (5.5 h)	Y	N	N	N	N	★★
eTrex Legend	Garmin (Serial)	Garmin	Y	N	N	1	Y	2 sec	10,000 (5.5 h)	Y	N	N	N	N	★★
eTrex Vista	Garmin (Serial)	Garmin	Y	N	N	1	Y	2 sec	10,000 (5.5 h)	Y	N	N	N	N	★★

Note that there are two variants of the eTrex (Yellow), Camo and Summit. The differences relate to the software version (2.x or 3.x).

4.1.4 Garmin Foretrex + Forerunner (early models) [Discontinued]

Device	Cable	Chipset	Mask?	Speed Genie?	SD Card?	Display D.P.s	Allowed GPSSS?	Recording Interval	Track Memory	Grid Effect?	Doppler Speed?	Num Sats?	HDOP Info?	SDOP Info?	Overall
Forerunner 101	n/a	Garmin	Y	N	N	1	N	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Forerunner 201	Garmin (Serial)	Garmin	Y	N	N	1	N	Auto	3,000	Y	N	N	N	N	★
Forerunner 301	USB	Garmin	Y	N	N	1	N	Auto	5,000	Y	N	N	N	N	★
Foretrex 101	Garmin (Serial)	Garmin	Y	N	N	1	Y	2 sec	10,000 (5.5 h)	Y	N	N	N	N	★★
Foretrex 201	Garmin (Serial)	Garmin	Y	N	N	1	Y	2 sec	10,000 (5.5 h)	Y	N	N	N	N	★★

4.1.5 Garmin eTrex C (original colour models) [Discontinued]

Device	Cable	Chipset	Mask?	Speed Genie?	SD Card?	Display D.P.s	Allowed GPSSS?	Recording Interval	Track Memory	Grid Effect?	Doppler Speed?	Num Sats?	HDOP Info?	SDOP Info?	Overall
eTrex Legend C	USB	Garmin+	Y	N	N	1	Y	1 sec	10,000 (2.7 h)	N	N	N	N	N	★★★
eTrex Vista C	USB	Garmin+	Y	N	N	1	Y	1 sec	10,000 (2.7 h)	N	N	N	N	N	★★★
eTrex Legend Cx	USB	Garmin+	Y	N	Y*	1	Y	1 sec	10,000 (2.7 h)	N	N	N	N	N	★★★
eTrex Venture Cx	USB	Garmin+	Y	N	Y*	1	Y	1 sec	10,000 (2.7 h)	N	N	N	N	N	★★★
eTrex Vista Cx	USB	Garmin+	Y	N	Y*	1	Y	1 sec	10,000 (2.7 h)	N	N	N	N	N	★★★

* - Although the “x” devices support micro SD cards, they cannot be written to during your session.

4.1.6 Garmin Forerunner + Edge (newer models)

Device	Cable	Chipset	Mask?	Speed Genie?	SD Card?	Display D.P.s	Allowed GPSSS?	Recording Interval	Track Memory	Grid Effect?	Doppler Speed?	Num Sats?	HDOP Info?	SDOP Info?	Overall
Forerunner 205	Garmin (USB)	SiRF Star III	Y	N	N	1	Y	1 sec	13,000 (3.5 h)	N	N	N	N	N	★★★
Forerunner 305	Garmin (USB)	SiRF Star III	Y	N	N	1	Y	1 sec	13,000 (3.5 h)	N	N	N	N	N	★★★
Edge 205	USB	SiRF Star III	Y	N	N	1	Y	1 sec	13,000 (3.5 h)	N	N	N	N	N	★★★
Edge 305	USB	SiRF Star III	Y	N	N	1	Y	1 sec	13,000 (3.5 h)	N	N	N	N	N	★★★
Edge 605	USB	SiRF Star III	Y	N	Y*	1	Y	1 sec	16,383 (4.5 h)	N	N	N	N	N	★★★
Edge 705	USB	SiRF Star III	Y	N	Y*	1	Y	1 sec	16,383 (4.5 h)	N	N	N	N	N	★★★

* - Although the Edge 605 + 705 devices support micro SD cards, they cannot be written to during your session.

4.1.7 Garmin eTrex H (high sensitivity models)

Device	Cable	Chipset	Mask?	Speed Genie?	SD Card?	Display D.P.s	Allowed GPSSS?	Recording Interval	Track Memory	Grid Effect?	Doppler Speed?	Num Sats?	HDOP Info?	SDOP Info?	Overall
eTrex H	Garmin (Serial)	MTK	Y	N	N	1	?	1 sec	10,000 (2.7 h)	N?	N	N	N	N	★★★
eTrex Legend H	Garmin (Serial)	MTK	Y	N	N	1	?	1 sec	10,000 (2.7 h)	N?	N	N	N	N	★★★
eTrex Vista H	Garmin (Serial)	MTK	Y	N	N	1	?	1 sec	10,000 (2.7 h)	N?	N	N	N	N	★★★
eTrex Legend HCx	USB	MTK	Y	N	Y*	1	?	1 sec	10,000 (2.7 h)	N?	N	N	N	N	★★★
eTrex Summit HC	USB	MTK	Y	N	N	1	?	1 sec	10,000 (2.7 h)	N?	N	N	N	N	★★★
eTrex Venture HC	USB	MTK	Y	N	N	1	?	1 sec	10,000 (2.7 h)	N?	N	N	N	N	★★★
eTrex Vista HCx	USB	MTK	Y	N	Y*	1	?	1 sec	10,000 (2.7 h)	N?	N	N	N	N	★★★

* - Although the “x” devices support micro SD cards, they cannot be written to during your session.

4.1.8 Garmin Foretrex (newer models)

Device	Cable	Chipset	Mask?	Speed Genie?	SD Card?	Display D.P.s	Allowed GPSSS?	Recording Interval	Track Memory	Grid Effect?	Doppler Speed?	Num Sats?	HDOP Info?	SDOP Info?	Overall
Foretrex 301	USB	?	Y	N	N	1	?	1 sec?	10,000 (2.7 h)	N?	N	N	N	N	★★★
Foretrex 401	USB	?	Y	N	N	1	?	1 sec?	10,000 (2.7 h)	N?	N	N	N	N	★★★

4.1.9 Garmin (unsuitable models)

Device	Cable	Chipset	Mask?	Speed Genie?	SD Card?	Display D.P.s	Allowed GPSSS?	Recording Interval	Track Memory	Grid Effect?	Doppler Speed?	Num Sats?	HDOP Info?	SDOP Info?	Overall
Forerunner 110	Garmin (USB)	SiRF Star IV	Y	N	N	1	N	Auto	?	N?	N	N	N	N	★
Forerunner 405	Garmin (USB)	SiRF Star III	Y	N	N	1	N	Auto	?	N?	N	N	N	N	★
Forerunner 405CX	Garmin (USB)	SiRF Star III	Y	N	N	1	N	Auto	?	N?	N	N	N	N	★
Forerunner 310XT	Garmin (USB)	SiRF Star III	Y	N	N	1	N	~1 sec	?	N?	N	N	N	N	★★
Edge 500	USB	SiRF Star III	Y	N	N	1	N	~1 sec	?	N?	N	N	N	N	★★

4.1.10 Locosys / Scytex / Amaryllo

Device	Cable	Chipset	Mask?	Speed Genie?	SD Card?	Display D.P.s	Allowed GPSSS?	Recording Interval	Track Memory	Grid Effect?	Doppler Speed?	Num Sats?	HDOP Info?	SDOP Info?	Overall
Locosys GT-11	USB	SiRF Star II	N	Y	Y*	2	Y	1 sec	28,672 (8.0 h)	N	Y	Y	Y	N	
Scytex NAVi GPS	USB	SiRF Star II	N	Y	Y*	2	Y	1 sec	28,672 (8.0 h)	N	Y	Y	Y	N	
Amaryllo T. Tracker	USB	SiRF Star II	N	Y	Y*	2	Y	1 sec	28,672 (8.0 h)	N	Y	Y	Y	N	
Locosys GT-31	USB	SiRF Star III	N	Y	Y*	2	Y	1 sec	16,384 (4.5 h)	N	Y	Y	Y	Y	

* - Logging to SD card means that tracks of any length can be recorded and are not limited by the memory of the “data logger”.

n.b. The Locosys GT-11, Scytex NAVi GPS and Amaryllo Trip Tracker are all the same device but with different names.

4.2 Appendix B – "Doppler Speed"

One of the inspirations for the GPS system came when the Soviets launched the first Sputnik in 1957. A team of U.S. scientists led by Dr. Richard B. Kershner were monitoring Sputnik's radio transmissions. They discovered that, due to the Doppler effect, the frequency of the signal being transmitted by Sputnik was higher as the satellite approached, and lower as it continued away from them. They realized that since they knew their exact location on the globe, they could pinpoint where the satellite was along its orbit by measuring the Doppler distort. Conversely, they realised that by knowing the positions of multiple satellites and monitoring the observed Doppler shifts they could pinpoint their own location on the globe.

Most GPS use doppler for speed calculation. The velocity computation is hardly affected by position computation, sometimes not at all. Computation of velocity and computation of position are often two separate processes but manufacturers tend to keep their approaches a closely guarded secret. Estimated velocity aids in predicting of where the next position calculation will converge, but position plays little role in the calculation of velocity.

This Doppler based speed is often only displayed on the screen rather than stored on the device itself.

There are numerous articles on the web about the use of Doppler so here are a few links:

- GPS Determination of Course and Speed by Tom Clark
- MicroSAT GPS Sensor by Datron
- Comment from Senior SiRF Engineer – right at the bottom of the thread
- GPSSS Discussion about Velocity Computation – some comments from Garmin

Tom Chalko has also written a couple of technical papers with speed sailing in mind:

- High Accuracy Speed Measurement using GPS
- Estimating Accuracy of GPS Doppler Speed Measurement using SDOP

4.3 Appendix C – "Spikes"

A word "spike" is commonly used when referring to an invalid reading on the GPS.

Some of the earlier GPS units were particularly susceptible to "spikes", especially the early Garmin models (e.g. Geko, eTrex, Foretrex 101 / 201 and Forerunner 101 / 201 / 301).

"Spikes" may occur for a number of reasons:

- Poor signal – may be caused by a windsurfer wearing the GPS under neoprene
- New satellites – fix on to new satellites may cause the readings to suddenly jump
- Multi-path – signals bouncing of nearby buildings / walls may cause bad readings

When they occur, it can often be associated with falling into the water too!

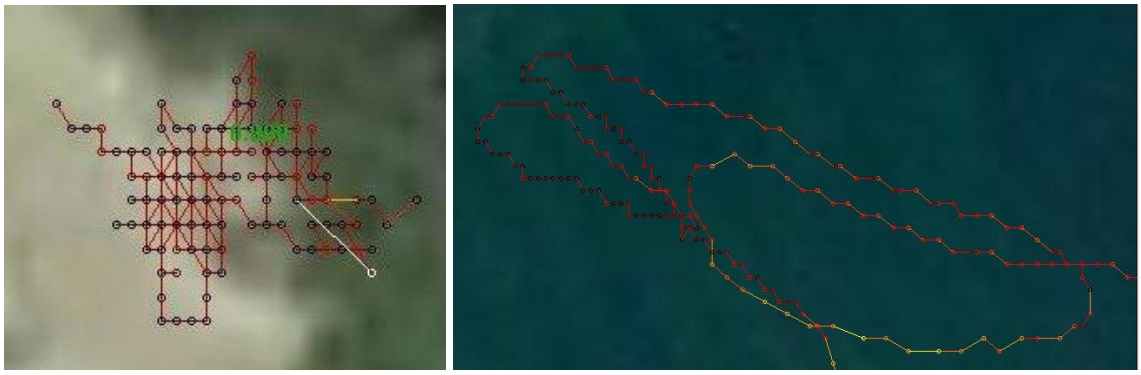
I stumbled across a video clip on YouTube which clearly shows a big spike between 01:00 and 01:02. The device being used was a Garmin GPSMAP 60CSx (SiRF Star III):

- Spike of 37.67 Knots @ 01:00 - 01:02

4.4 Appendix C – "Grid Effect"

The term "grid effect" was coined by Andrew Daff (GPSSS forums) after zooming into Foretrex and Geko tracks using GPSResults and RealSpeed. It is known to occur on all of the earlier Garmin models (e.g. Geko, eTrex, Foretrex 101 / 201 and Forerunner 101 / 201 / 301) due to them discarding some of the precision from longitude and latitude values when recording track points. Garmin have confirmed that this is to save memory space. The effect is that all track point positions are aligned to the nearest point on a grid where the cell size is up to 2.39m, dependant on your position on the globe.

The two screenshots below illustrate typical symptoms:



- The first track was recorded over a very small area and clearly shows the grid
- The second track was recorded over a larger area and clearly shows a zig-zag

On devices that only record their position (not speed) and "grid effect" is evident, the software calculated speeds are therefore somewhat inaccurate. For this reason, the GPSSS rules state that such devices should be configured to record at 2 second intervals (rather than 1 second), thus halving the potential error. Even so, there is still the possibility that the speeds reported by the software may be up to 2 or 3 knots higher than they should be!

Later models from Garmin like the Legend C and Edge 205 do not exhibit the "grid effect" because the longitude and latitude is no longer truncated. Testing shows that the 1 second track points from the newer Garmin models is significantly better than the older models but still not as good as the Doppler derived data from the GT-11.

Speeds over longer periods of time (or longer distances) are affected to a lesser degree.

A couple of threads exist on GPSSS which discuss the "grid effect" in more detail:

- "A better GPS" – describes the 2.39m Grid
- "Edge 205" – describes the Grid Effect

Manfred Fuchs (author of GPSResults) also published some enlightening test results.

4.5 Appendix D – File Formats

There are a number of common file formats for GPS tracks.

4.5.1 GPS Exchange Format (.GPX)

This is the format of choice when using Garmin devices. Most GPS software is capable of loading GPX files.

Link: GPX: the GPS Exchange Format

4.5.2 NMEA 0183 (.TXT)

The NMEA format can potentially include more information than is typically found in the GPX format (e.g. speed, satellites, HDOP, etc). Some GPS devices provide an "NMEA out" feature which enables the data to be captured in real-time but it requires a laptop or PDA to be connected whilst sailing!

Links: NMEA 0183 (Wikipedia) and a GPSSS discussion about NMEA

4.5.3 SiRF Binary Data Set No. 2 (.SBN)

The SBN format is native SiRF binary data. It is relatively efficient (more compact than NMEA) and is written directly to the SD card of a GT-11 or GT-31. It is worth noting that Locosys have extended the record structure slightly, allowing additional information to be recorded (including SDOP).

Although the GT-11 and GT-31 offer various format choices for the "Memory Card" feature, the "SBN" format should be chosen in preference to any others (e.g. NMEA).

Link: SiRF Binary Protocol Reference Manual

4.5.4 SiRF Binary Packed (.SBP)

The SBP format is used by the "Data Logger" of the GT-11 and GT-31. Each record is just 32 bytes in size (much smaller than an SBN record) but still contains all of the data that is required for speed sailing analysis.

The SBP file serves as a useful backup, just in case the SBN file is not written to the card.

Link: Navilink Protocol

4.6 Appendix E – Chipsets

The chipset dictates how well the GPS device will function and how accurate it is.

Comparison of GPS chips - http://www.gpspassion.com/fr/articles.asp?id=143&page=2

Manfred Fuchs (author of GPSResults) also published some interesting test results.

4.6.1 Garmin

The early Garmin chipset(s) appeared to be quite susceptible to "spikes" and so it is important that any "peak speeds" be verified on a computer.

Popular Devices: Garmin Geko, eTrex, Foretrex 101 / 201 and Forerunner 101 / 201 / 301

4.6.2 SiRF Star II

Accuracy is not considered to be an issue, only sensitivity. The SiRF II chip provides a very high level of Doppler shift accuracy.

Locosys quote a RMS steady state of 0.1m/s (0.2 knots).

Popular Devices: Navi GT-11 / Scytex NAVi GPS / Amaryllo Trip Tracker

4.6.3 SiRF Star III

The new chip is much more sensitive and is able to pick up and use very weak signals.

For example, there may be only 6 satellites in the sky and two of them may be very low on the horizon. The GT-11 may not pick them all up and only get 3 or 4 signals which would make the tracks invalid on GPSSS. The GT-31 would probably pick up all 6 satellites and produce data that is still valid and useful.

The biggest benefits are a much improved startup time, handling of weak signals and general accuracy (especially the positional data).

Popular Devices: Garmin Edge, Garmin Forerunner 205 / 305, Navi GT-31

5 Glossary

Some of these phrases haven't been mentioned in my document but are still included because they can give a little insight into the inner workings of GPS technology.

- *Almanac* - The GPS almanac is a set of data that every GPS satellite transmits, and it includes information about the state (health) of the entire GPS satellite constellation, and coarse data on every satellite's orbit. When a GPS receiver has current almanac data in memory, it can acquire satellite signals and determine initial position more quickly.
- *DGPS (Differential Global Positioning System)* - An enhancement to Global Positioning System that uses a network of fixed, ground-based reference stations to broadcast the difference between the positions indicated by the satellite systems and the known fixed positions. Requires different receiving equipment but increases positional accuracy to from around 15 meters to around 3-5 meters.
- *Ephemeris data* - Ephemeris data is a set of parameters that can be used to accurately calculate the location of a GPS satellite at a particular point in time. It describes the path that the satellite is following as it orbits Earth. To accurately calculate your location, ephemeris data is only usable for a limited time (a few hours or less). Up-to-date data is needed to minimize error that results from minor variations in a satellite's orbit.
- *GPX* - GPS eXchange Format, commonly used for Garmin tracks
- *HDOP (Horizontal Dilution of Precision*) - Allows one to more precisely estimate the accuracy of GPS horizontal (latitude/longitude) position fixes by adjusting the error estimates according to the geometry of the satellites used. Loosely related to the number of satellites in view but also influenced by their positions.
- *IPX7* – This designation means the GPS can withstand accidental immersion in one meter of water for up to 30 minutes. This standard is insufficient when speed sailing so it is recommended that you use your GPS in an aqua pack.
- *Kalman Filter* - produces estimates of the true values of measurements and their associated calculated values by predicting a value, estimating the uncertainty of the predicted value, and computing a weighted average of the predicted value and the measured value.
- *Latitude* - Location on Earth, north or south of the equator. Lines of Latitude are the imaginary horizontal lines shown running east-to-west (or west to east).
- *Least squares* - Standard approach to the approximate solution of over-determined systems, i.e. sets of equations in which there are more equations than unknowns.
- *Longitude* - Used in cartography and global navigation for east-west measurement. Constant longitude is represented by lines running from north to south.
- *Masking* - When stationary but the unit is recording 0.1 or 0.2 knots it will display 0.0 as the speed. If doing a stationary test it looks as if the GPS doesn't wander but all it is doing is hiding the actual error.
- *NMEA* - National Marine Electronics Association.

- *PLL (Phase Locked Loop)* - Control system that tries to generate an output signal whose phase is related to the phase of the input "reference" signal. Keeping the input and output phase in lock step implies keeping the input and output frequencies in lock step. Consequently, a phase-locked loop can track an input frequency. Whilst this is necessary for a GPS to “lock” on to the satellite signals, it is also used to determine the Doppler shift.
- *SA (Selective Availability)* - GPS includes a (currently disabled) feature called Selective Availability (SA) that adds intentional, time varying errors of up to 100 meters (328 ft) to the publicly available navigation signals. This was intended to deny an enemy the use of civilian GPS receivers for precision weapon guidance. It was ended in 2000, improving the precision of civilian GPS from about 100m to about 15m - 20m.
- *SBN (SiRF Binary)* – File format generated by Locosys GT-11 and GT-31.
- *SBP (SiRF Binary Packed)* - File format generated by Locosys GT-11 and GT-31.
- *SD Card (Secure Digital Card)* - Non-volatile memory card format developed by Panasonic, SanDisk, and Toshiba for use in portable devices.
- *SDOP (Speed Dilution of Precision)* - SDOP is a very useful and practical parameter for determining accuracy of GPS “Doppler speed” measurement.
- *SiRF Star II* –GPS microcontroller chip manufactured by SiRF Technology. Superseded by the SiRF Star III.
- *SiRF Star III* – High sensitivity GPS microcontroller chip manufactured by SiRF Technology.
- *Smoothing* - When the GPS switches to better satellites it may use track smoothing to avoid any sudden jumps in the readings. However, it can give you a few false extra knots and can be hard to detect.
- *Spikes* – Spurious readings. Older GPS units are generally more prone to spikes.
- *TTFF (Time To First Fix)* - Time taken for a GPS receiver to acquire an initial position and speed. The overall time taken is dictated by whether it is a cold, warm or hot start and the GPS chipset being used.
- *WAAS* - System of satellites and ground stations that provide GPS signal corrections, giving you even better position accuracy. Only available in North America and Hawaii. Increases positional accuracy from < 15m (95% typical) to < 3m (95% typical). Intended for air navigation, including precision approaches.
- *WGS 84 (World Geodetic System)* – Reference coordinate system used by GPS. It comprises a standard coordinate frame for the Earth, a standard spheroidal reference surface (the datum or reference ellipsoid) for raw altitude data, and a gravitational equipotential surface (the geoid) that defines the nominal sea level.

6 Links

The web is full of good articles about GPS technology but to save you some searching, here are a couple of links that explain the basic principals:

- Trimble - How GPS Works
- Wikipedia - Global Positioning System

7 History

1.0	2010-05-19	Initial version.
2.0	2010-05-26	Additional Garmin models, covers all popular ranges. 50% bigger!
2.1	2010-06-06	Minor tweaks and a few additional comments
2.2	2010-06-27	Mentioned GT-11 card formatting “gotcha” and possible “wander”
2.3	2010-07-06	Confirmation that Forerunner 201 + 301 only support “auto” mode