HEXAGON | veripos

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Application Note

Quantum Tides

HEXAGON AUTONOMY & POSITIONING DIVISION
CONFIDENTIAL AND PROPRIETARY DATA

Contents

Introduction

This document outlines the functionality and performance characteristics of the Veripos Quantum Tides service.

Veripos provides a range of positioning services for a multitude of hydrographic applications. The primary service, Veripos Apex Pro, is a high-accuracy service that offers highly accurate and stable positions with real-time accuracies of 5 cm in 2D and in height. The positions derived using this service can be used to detect and estimate the variations of the actual sea surface from mean sea surface resulting in a tide observation.

The real-time observation of tidal variations using high-accuracy GNSS offers many benefits over conventional methods, i.e. the deployment of tide gauges or the use of tidal prediction software. The use of real-time tide information allows bathymetric data to be corrected in real-time and thus removing the requirement for post-processing. Real-time tide information also offers a better representation of the real tides compared to model based predictions. Major cost savings can be achieved on hydrographic projects if no tide gauges have to be deployed.

Quantum Tides

Description

Veripos Quantum Tides uses the highly stable and accurate positions from the Veripos PPP positioning services.

The Veripos Apex Pro is the premium positioning service offering centimetre level position accuracy globally. The service is based around a positioning technique known as PPP (Precise Point Positioning) where errors in the GNSS system are either independently corrected or modelled to a high degree of accuracy. Veripos Apex Pro delivers a high accuracy position using a proprietary PPP algorithm developed by Veripos that minimises or removes all of the main GNSS errors sources such as satellite orbit, satellite clock, troposphere, ionosphere and multi-path.

To carry out this absolute positioning technique orbit and clock correction information is broadcast for each and every GNSS satellite to allow removal of satellite-based error components. Use of multi frequency GNSS hardware at the user-end permits the calculation and removal of local ionosphere errors, whilst troposphere delays are estimated within the calculation. Other sources of error are also modelled, and these include effects of ocean loading, earth tides and phase windup. To obtain the high-accuracy solution, multi-path and GNSS receiver noise errors are minimised through use of carrier phase observables, which are precise to the millimetre level. In all, Veripos provides truly global and seamless high-accuracy positions, which are not only robust but effective in all areas of operation, including areas of ionosphere disturbance.

The high-accuracy PPP positions can be used to detect height variations relative to a vertical reference offshore. In order to derive tidal height variations, the real-time tide estimation process has to manage height variations caused by vessel motion and the error in the PPP position calculation.

The combined tide and position results are stored to file and/or serially interfaced to a Survey software package. Users can then compensate for the effects of tides in real-time and/or post processed methods.

Vertical Reference Terminology

Terminology used in this document.

Table 1: Terminology

Mean Sea Surface (MSS)	The MSS represents the height of the ocean surface (measured from the surface of a reference ellipsoid), averaged over a specific time interval (and corrected for ocean and earth tides). MSS models are developed based on data provided by altimetry satellites. The MSS is not an equipotential surface.
Mean Sea Level (MSL)	There are two interpretations: 1 - In geodesy, MSL usually means the local height, i.e. the vertical offset, of the global Mean Sea Surface above a level reference surface called the Geoid. 2 - In tidal analysis, MSL means the still water level averaged over a period of time such as a month or year so periodic changes in sea level due to, for example the tides, are also averaged out. MSL values are measured with respect to the level of benchmarks on land, and as such a change in an MSL can result from either a real change in sea level or a change in the height of the land on which the tide gauge is located (e.g. from isostatic rebound).
Geoid	The Geoid is a surface over which the gravity potential is constant (water does not "flow" on the Geoid but it remains in equilibrium). It also the equipotential surface of the Earth's gravity field which best fits, in a least squares sense, global MSS.
Dynamic Ocean Topography (DOT)	The difference between MSS and the Geoid. It originates from the fact that the major ocean circulation has a (more or less) time-invariant nonzero component (a component that does not average to zero over time).

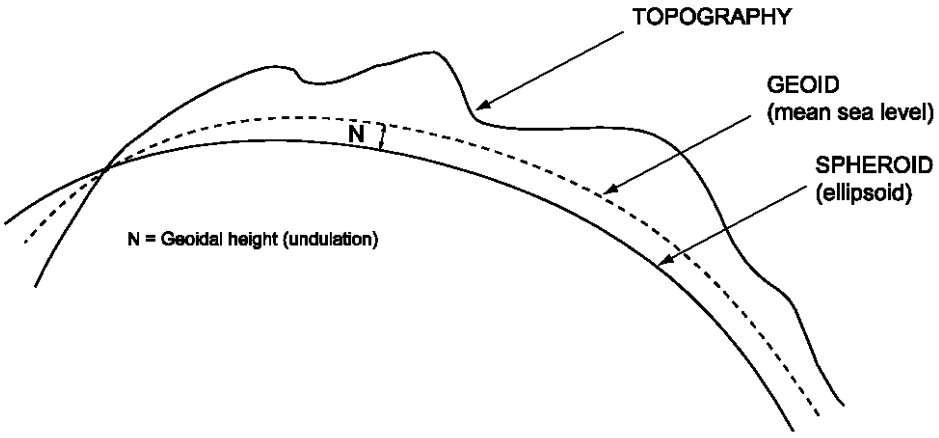

Figure 1: Geoid – Spheroid Separation

If oceans were static (no impact from current, wind and air pressure) then MSS and the Geoid would be the same surface (dotted line in the above figure). In reality there are ocean currents driven by winds and atmospheric heating and cooling, giving rise to differences in sea level around the world. The local differences between the Geoid and MSS are described by the Dynamic Ocean Topography (DOT). The DOT values approximately range between -2.5 m and +1.2 m. Geoid models such as EGM96 and EGM2008 can be considered an approximation of MSS to a 2-3 m level.

Tidal Estimations

QUANTUM Tides provides two real-time tide observations relative to different vertical references in Geoid Tide and MSS Tides formats. The diagram below illustrates the vertical measurements to be considered:

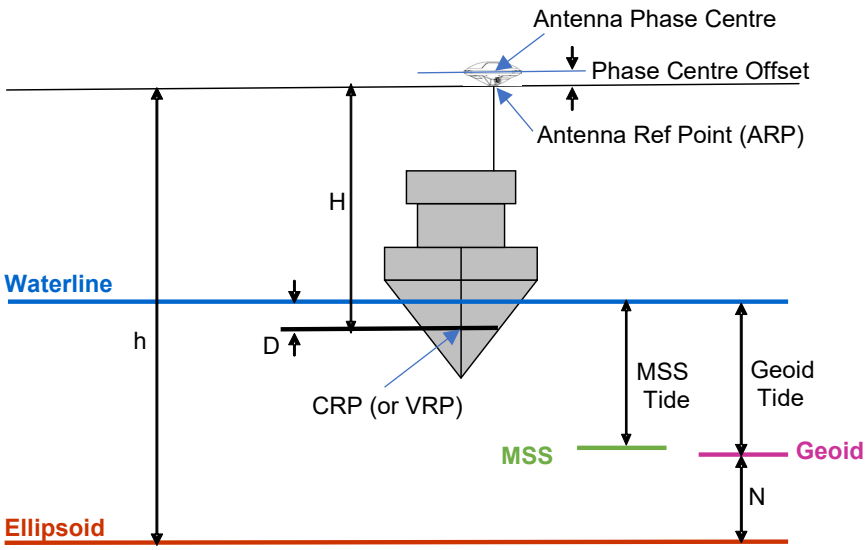

Figure 2: Geoid Tide and MSS Tide vertical measurements

Table 2: Figure 2 legend

Term	Definition
Antenna Phase Centre	The electrical phase centre of the GNSS antenna.
ARP	Antenna reference point (base of the antenna)
CRP (or VRP)	Central reference point (or Vertical reference point)
Phase centre offset	Vertical distance, ARP to the antenna phase centre
h	Vertical distance of the Antenna phase centre to Ellipsoid
H	Measured height (a manual measurement performed by dimensional control or tape measured). The measured value is the vertical distance from the vessel CRP to antenna ARP + phase centre offset.
N	Geoidal height or undulation. This value is based on either the EGM96 or EGM08 model.
D	Vertical distance of water line to the CRP, this will change as the vessel draft changes (e.g., change in vessel load).

Geoid Tides

The Geoid Tides calculation estimates the tide relative to Geoid (either EGM96 or EGM2008). Geoid Tides is available once PPP calculation convergence is complete, and the first averaging period is complete. The startup time for Geoid Tides is relatively short (approximately 30 minutes). The equation below details the Geoid Tide estimation.

Geoid Tide = (PPP height – GNSS antenna height above water line) – undulation

MSS Tides

Quantum MSS Tides removes the effects of tides using the Doodson filter period to determine the MSS. The filter takes 39 hours to complete this process, once the MSS is determined, the MSS Tide calculation determines the tides relative to the MSS.

The MSS Tides estimation is independent of uncertainties in Geoid models and does not require the antenna height above the waterline measurement. The MSS Tides observation is more accurate since the MSS vertical reference is centimetre accurate.

Discussion

There are fundamental differences between real-time GNSS tides estimations and predicted tides model or a tide gauge measurement. Predicted tides models only calculate the predicted vertical movement of the sea surface caused by gravitational effects of the sun and moon (primarily) and ignore atmospheric and storm surge effects. Predicted tides models produce a very smooth tidal curve. A tide gauge can observe tide at a much higher frequency and correct for atmospheric pressure effects but still may be affected by storm surges.

Quantum Tides provide the real-time total variation from a vertical reference (either MSS or an EGM model).

The benefit of estimating a real-time total variation from a vertical reference is that a single vertical correction can be applied to marine survey depth information. In addition, tides can be calculated at as high frequency (once per minute) which allows a very detailed sea surface variation pattern to be created.

Comparison of MSS Tides and tide gauges measurements have shown MSS Tides results are unbiased. Comparisons between Geoid Tides and tide gauges have shown errors. These errors are typically caused by one or more of the following:

- Errors in measured GPS antenna height (above the waterline)
- Residual errors in the EGM model
- Dynamic Ocean Topography

Quantum Tides Operation

The Quantum Tides service is integrated as a component within the Quantum application. Verify QC users of Tides should migrate to Quantum Tides for ongoing support. Verify QC is an end-of-life software product, please refer to this end-of-life bulletin.

Quantum Tides Licensing

Quantum Tides can be purchased or rented as an additional Quantum licensed feature. Once the Quantum Tides license is installed, the feature will be listed within the **Quantum Authorisations** menu:

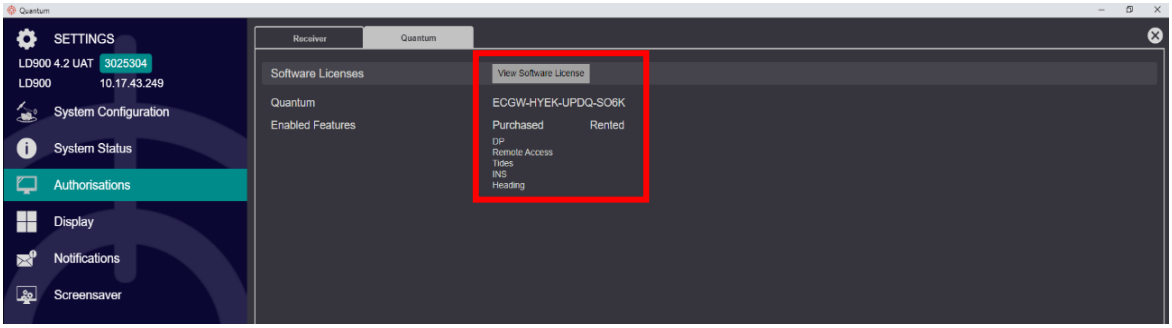

Figure 3: Quantum Tides license location

Quantum Tides Configuration

Once a valid license is applied, the Tides feature needs to be enabled within the **Quantum Management** menu:

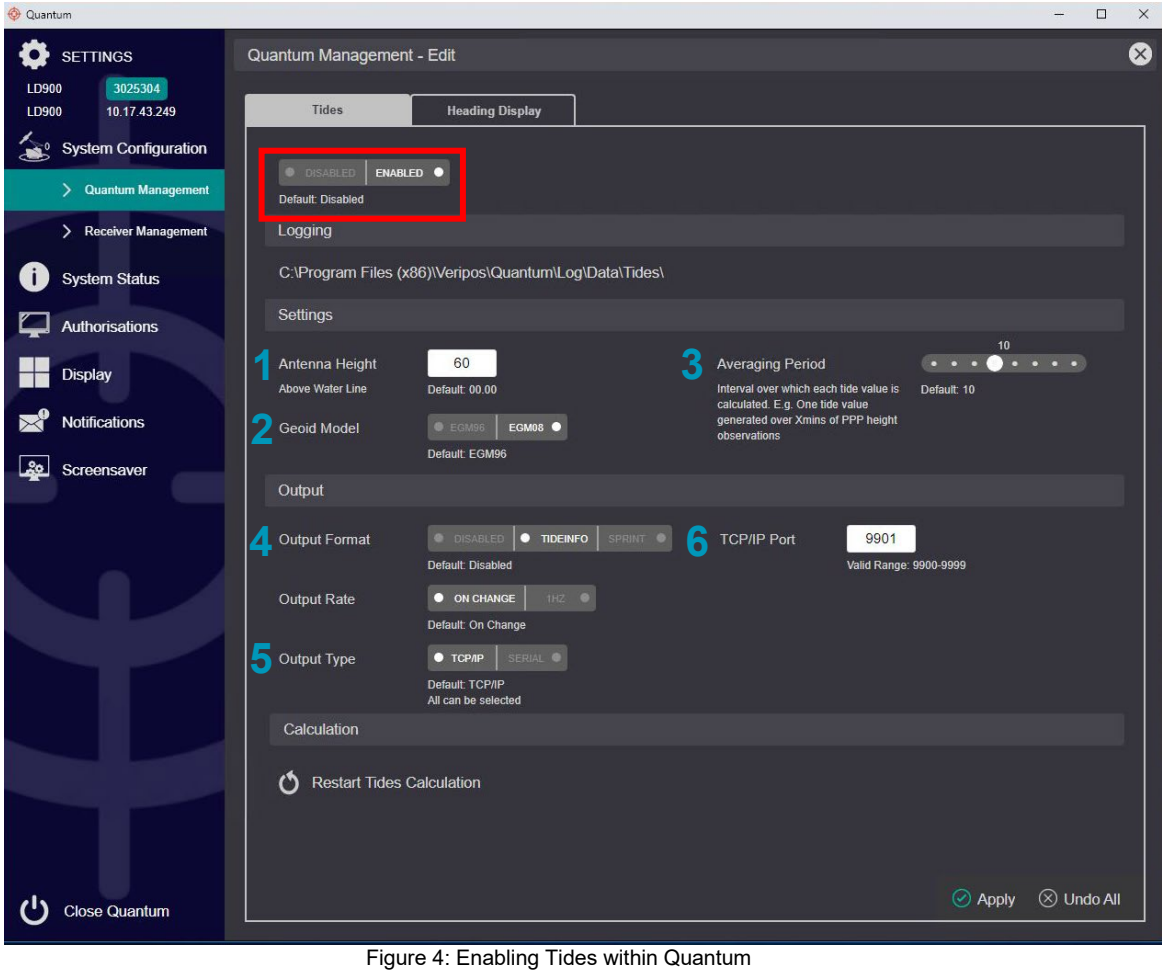

Figure 4: Enabling Tides within Quantum

The Logging directory is the PC directory where the tide resultant files are stored. This can be either in Sprint or Tidesinfo format. Note the tides logs (results) can also be interfaced to Survey software via serial or TCPIP socket. If the tides files are deleted from the Quantum logging directory, the MSS Tides calculation will be restarted. However, copying files will not disturb the tides calculations.

The tides configurable values within the Settings section are detailed here:

1. **Antenna Height**: The Antenna height above the waterline in metres. This value is only applied to the Geoid Tide estimation. This value is required to be updated regularly to reflect changes in vessel draft.
2. **Averaging Period**: The Averaging Period which each tide value is calculated. Averaging is used to minimise the effects of vessel motion. The sliding scale ranges from 1 to 60 minutes. The Averaging Period can be set to match the vessel motion experienced.
3. **Geoid Model**: Either the EGM96 or EGM08 can be selected here. This change will only be applicable to the GEOID Tides resultants. Note: the geoid selection does not relate to the position output.
4. **Output Format**: TIDEINFO or SPRINT formats are available. The default setting is DISABLED. Toggling Output Rate to either TIDEINFO or SPRINT will reveal the option to configure Output Rate, which can be toggled between ON CHANGE and 1HZ (one output per second). ON CHANGE will produce an output at the end of the averaging period EG every minute. A 1HZ setting will create an output every second.
5. **Output Type**: Either TCPIP or Serial output is available. If the TCPIP option is selected the resultant will be output via TCPIP socket (TCPIP client) at the Quantum systems IP address and the TCPIP port specified (this is the next configurable item). If the Serial output option is selected the user must also specify the Quantum PC serial port to be used and the serial configuration details (e.g. 9600,8, n,1).
6. **TCPIP Port**: This is the TCPIP port applicable for the TCPIP serial output configuration. The default value is port 9901.

Restart Tide Calculation: The MSS Tides calculation uses 39 hours of historic data which is used to determine the MSS. If the user requires to reset the Tides process (e.g. because the survey location has changed), they can select **Reset Tides Calculation** this will cause logged tides data to be deleted. The MSS tides calculation will therefore need to reconverge, over a 39-hour startup period. The tides logging process will also restart.

Quantum Tides Visualisation

Once the configuration is applied, the Sidebar will indicate the tides computation is activated.

Note: Both the Geoid and MSS Tide computations are enabled by default.

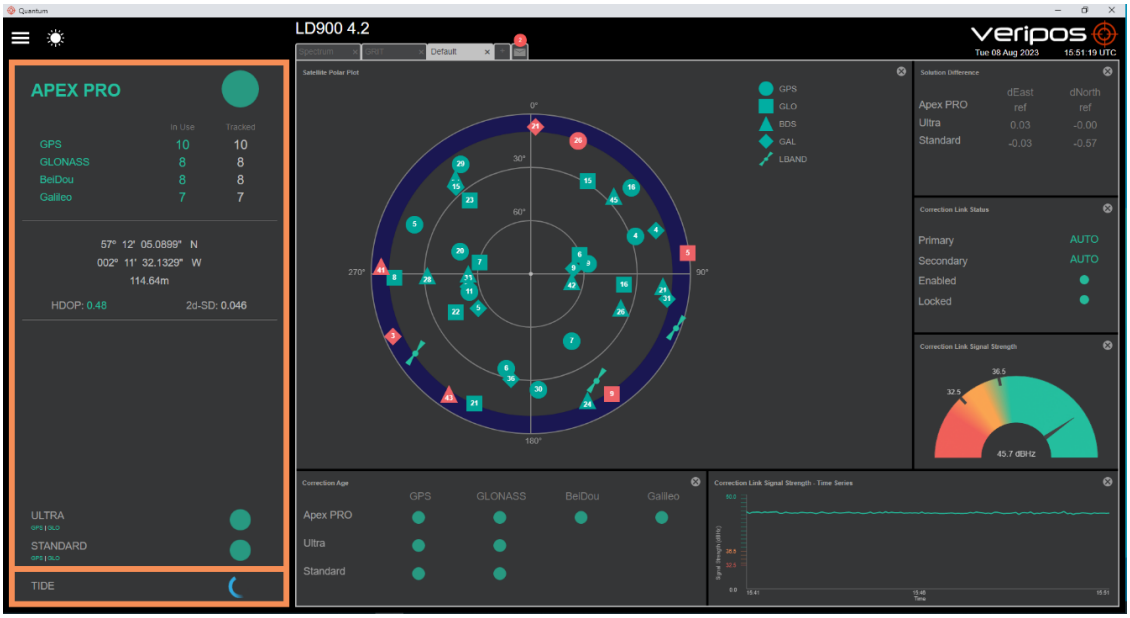

Figure 5: Tide status within sidebar

Within the sidebar, the blue 'turning' icon next to TIDE indicates the Tide computation is active and the hold-off period is active. Once the hold-off period is complete, the Tides indication will change to a green circle:

Figure 6: Tide computation active

Once there is a licensed and enabled tides calculation, tide specific Quantum tiles can be displayed. These tiles are highlighted below and explained in subsequent sections:

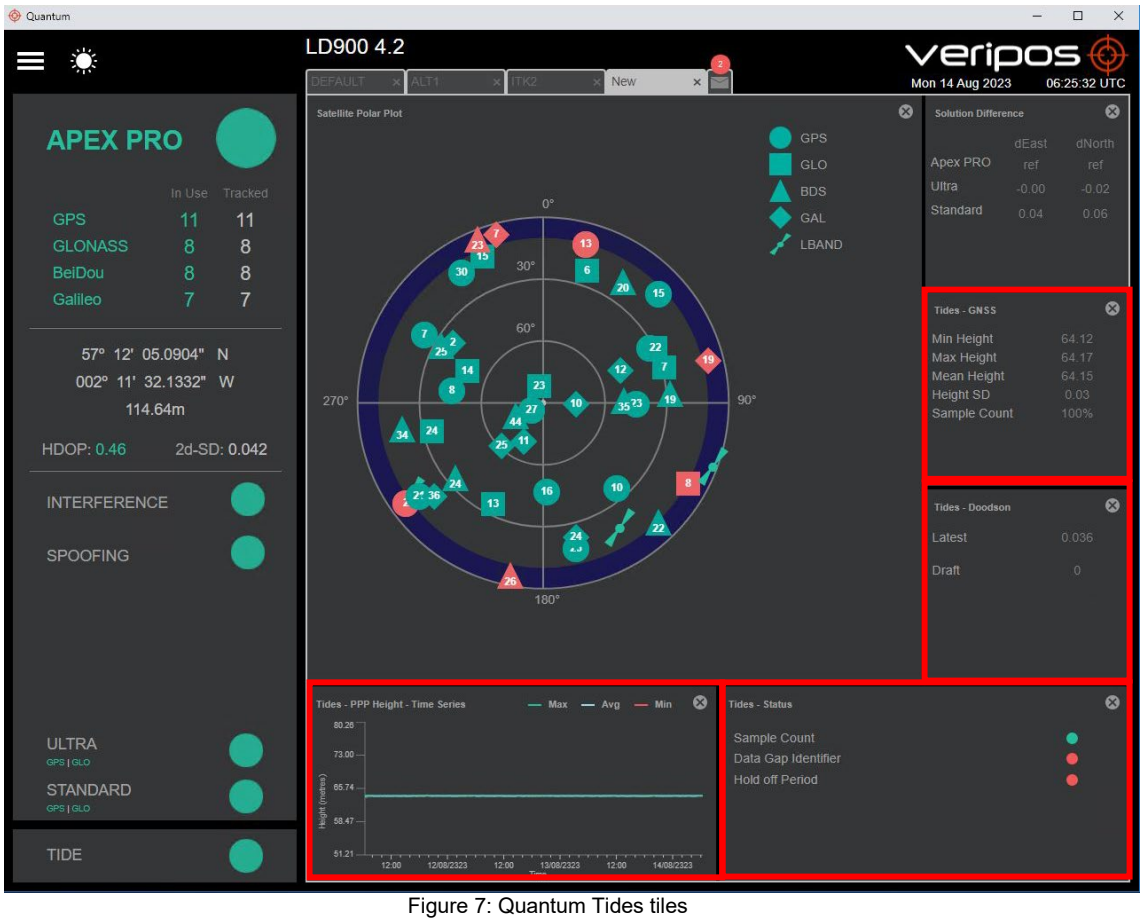

Figure 7: Quantum Tides tiles

Quantum Tile – Tides GNSS

GNSS PPP height calculation is core to both the MSS and Geoid tides computation. This tile tracks the minimum and maximum GNSS PPP height. The mean height (based on the averaging interval) and the Height SD are also indicated.

Quantum Tile – Tides PPP Height Time Series

This tile plots the minimum, maximum and the average PPP height (the tides averaging interval) computed over a three-day period:

- **Min Height** – Smallest position height in the last interval.
- **Max Height** – Largest position height in the last interval.
- **Mean Height** – Mean of the position heights within the last interval.
- **Height SD** – SD of the sample heights in the last interval.
- **Sample Count** – Percentage of available samples for the current interval.

Quantum Tile – Tides Status

The Tide Status tile displays the status of the Tides calculation. Status items are:

- **Sample Count** – Green (good) if sufficient samples during the last interval were used. Green status is active if the sample count is at least 50%. Red (bad) indicates there are insufficient samples.
- **Data Gap Identifier** – If a data gap is detected (missing PPP height measurements) the icon will be Green (bad) signalling that action is needed. The Red status is the good status.
- **Hold-Off Period** – A Green status is displayed when the 15-minute hold-off period is active. The Red status is displayed once the hold-off period is complete (desired status).

Quantum Tile – Tides Doodson

The Doodson tile displays the MSS Tides results.

- **Latest** – MSS tide is the tide above MSS estimated by the Doodson filter.
- **Draft** – The current Doodson value minus the Doodson value for the first record.

Appendix

Tides Output Formats

The TideInfo.txt file contains current system height and tide information at the Averaging Period as configured by the user. This file (or log output) contains comma delimited strings with variable length fields. Null fields indicate that no information is currently available; they should not be interpreted as 'zero'. Negative tide is low tide and positive tide is high tide respectively.

Tideinfo Format

Table 3: Tideinfo format information

Content	Format	Unit	Notes
0	TalkerID	[-]	$UltraTide or $ApexTide (dependent on active PPP calculation).
1	yyyymmdd	[-]	Identifies year, month and day for which all information in the string is valid.
2	Time (UTC or GPS)	hh:mm:ss (UTC) or sssssssss (GPS)	Identifies time in UTC or GPS for which all information in the string is valid.
3	Sequence Number	numerical	Sequential number incrementing by 1 for each averaging period. Maximum is 99999999 after which an automatic reset back to 1 takes place.
4	Averaging Period		User selected period over which Veripos Apex or Ultra heights are numerical averaged in seconds. Minimum is 60, maximum is 3600.
5	Sample Count	numerical	Number of Veripos Apex or Ultra height samples that were included to derive the antenna height average. Minimum is 50% of 'Averaging Period'. The sample count will increase every epoch if set to 1 Hz.
6	Latitude	dddmm.mmmm	degrees, minutes and Location where height and tide information is valid. decimal minutes.
7	Latitude Hemisphere	c	N or S.
8	Longitude	dddmm.mmmm	degrees, minutes and Location where height and tide information is valid. decimal minutes.
9	Longitude Hemisphere	c	E or W.
10	Mean Height	hh.hh (metres)	Mean of the Veripos Apex or Ultra heights during the 'Averaging Period'.
11	Mean of Height SD	hh.hh (metres)	Mean of the Height SDs associated with the Veripos Apex or Ultra heights during the 'Averaging Period'. This is an indication of the quality of the Veripos Apex or Ultra heights.
12	SD of Heights	hh.hh (metres)	Standard deviation of the Veripos Apex or Ultra heights during the 'Averaging Period'. This is an indication if the variation of the height due to vessel motion and position quality.
13	Minimum of Heights	hh.hh (metres)	Minimum of the Veripos Apex or Ultra heights during the 'Averaging Period'.
14	Maximum of Heights	hh.hh (metres)	Maximum of the Veripos Apex or Ultra heights during the 'Averaging Period'.
15	Doodson	hh.hh (metres)	Estimated antenna height above Mean Sea Surface from the Doodson filter. First available after 39 hours.

16	MSS Tide	hh.hh (metres)	Local tide based on the Mean Sea Surface derived from the Doodson filter. First available after 39 hours.
17	Geoid Tide	hh.hh (metres)	Local tide relative to user selected Geoid (see field 22). Available instantaneously after 'hold-off' time.
18	Antenna Height	hh.hh (metres)	User entered height of the antenna above the waterline.
19	Geoid Separation	hh.hh (metres)	Local offset between the user selected Geoid and the WGS84 reference ellipsoid.
20	Draft	hh.hh (metres)	The vertical bias detected between MSS Tide and Geoid Tide. Calculated as Antenna Height minus Doodson plus Draft.
21	Vertical Bias	hh.hh (metres)	The vertical bias detected between MSS Tide and Geoid Tide. Calculated as Antenna Height minus Doodson plus Draft.
22	Geoid Model	-	EGM96 or EGM08.

Tideinfo example:

```
$UltraTide,20070228,21:40:00,28,600,600,5236.2830,N,00143.5184,E,5.74,0.08,0.
07,5.66,5.82,5.45,0.29,0.02,5.72,44.84,0.00,0.27,EGM96*2B
```

Sprint Format

The SPRINT_Tides.txt file contains the current UltraTide with the opposite sign compared to the MSS Tide contained in the TideInfo.txt and Doodson.txt files. This file (or log output) contains comma delimited strings with variable length fields. Null fields indicate that no information is currently available; they should not be interpreted as 'zero'. Negative tide is high tide and positive tide is low tide respectively.

Table 4: Sprint format information

Content	Format	Unit	Notes
0	Hours	HH	Hours in the day (UTC). Time for which all information in the string is valid.
1	Minutes	MM	Minutes in the day (UTC). Time for which all information in the string is valid.
2	Day	DD	Day in the month.
3	Month	MM	Month in the year.
4	Year	YYYY	Year.
5	UltraTide	hh.hh (metres)	Local UltraTide based on the Mean Sea Surface derived from the Doodson filter. First available after 39 hours. Set as 99999.99 when no UltraTide value is available.
	*	c	Fixed end delimiter (real time output only).
		cc	Checksum (real time output only).

Sprint Tides example:

```
12,20,22,09,2006,-0.88
```

Support

To help answer questions and/or diagnose any technical issues that may occur, the Veripos Support website is a first resource.

Remaining questions or issues, including requests for test subscriptions or activation resends, can be directed to Veripos Support.