HEXAGON | veripos

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Application Note

Quantum Tides

HEXAGON AUTONOMOUS SOLUTIONS DIVISION
PROPRIETARY DATA

Contents

Overview

This application note outlines the functionality and performance characteristics of the Hexagon | 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 the 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, 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 Veripos positioning services.

Veripos Apex PRO is the premium positioning service, offering centimetre-level position accuracy globally. The service is based around a positioning technique known as precise point positioning (PPP), 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 error 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 the 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. To derive tidal height variations, the real-time tide estimation process must 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

Term	Definition
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 MSS 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 that 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 remains in equilibrium). It is 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 non-zero component (a component that does not average to zero over time).

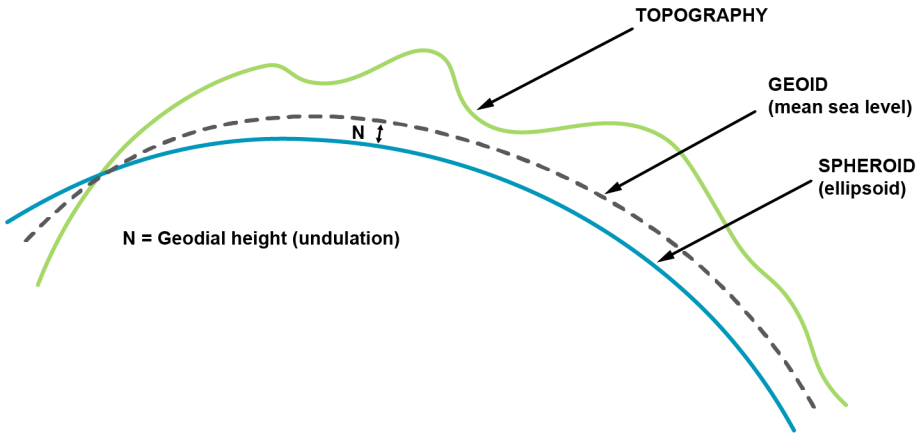

Figure 1 Geoid – Spheroid separation

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 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:

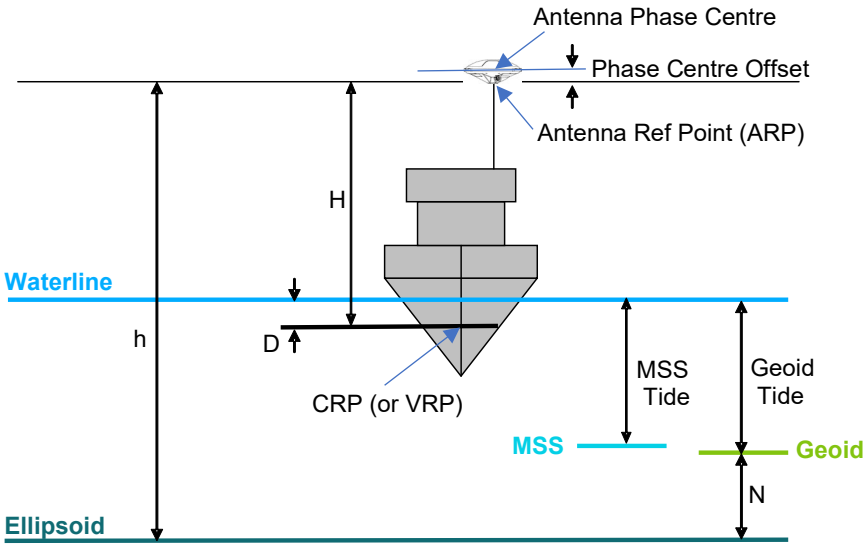

Figure 2 Geoid Tide and MSS Tide vertical measurements

Table 2 Figure 2 legend

Term	Definition
Antenna phase centre	The electrical phase centre of the GNSS antenna.
Antenna reference point (ARP)	Reference point of the antenna (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 the ellipsoid.
H	Measured height (a manual measurement performed by dimensional control or a tape measure). 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 the 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 the geoid (EGM96, EGM2008, or a USER defined value). Geoid Tides is available once the PPP calculation convergence and the first averaging period are complete. The startup time for Geoid Tides is relatively short (approximately 30 minutes). The equation below details the Geoid Tide estimation.

Geoid Tide = (PPP reference point height – reference height above water line) – undulation

MSS Tides

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

The MSS Tides estimation is independent of uncertainties in geoid models and does not require the user-measured reference 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 models or a tide gauge measurement. Predicted tides models only calculate the predicted vertical movement of the sea surface caused by the 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 a high frequency (once per minute), which allows a very detailed sea surface variation pattern to be created.

Comparison of MSS Tides and tide gauge measurements has shown that 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 the measured reference height (above the waterline).
- Residual errors in the EGM model.
- Dynamic ocean topography (DOT).

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:

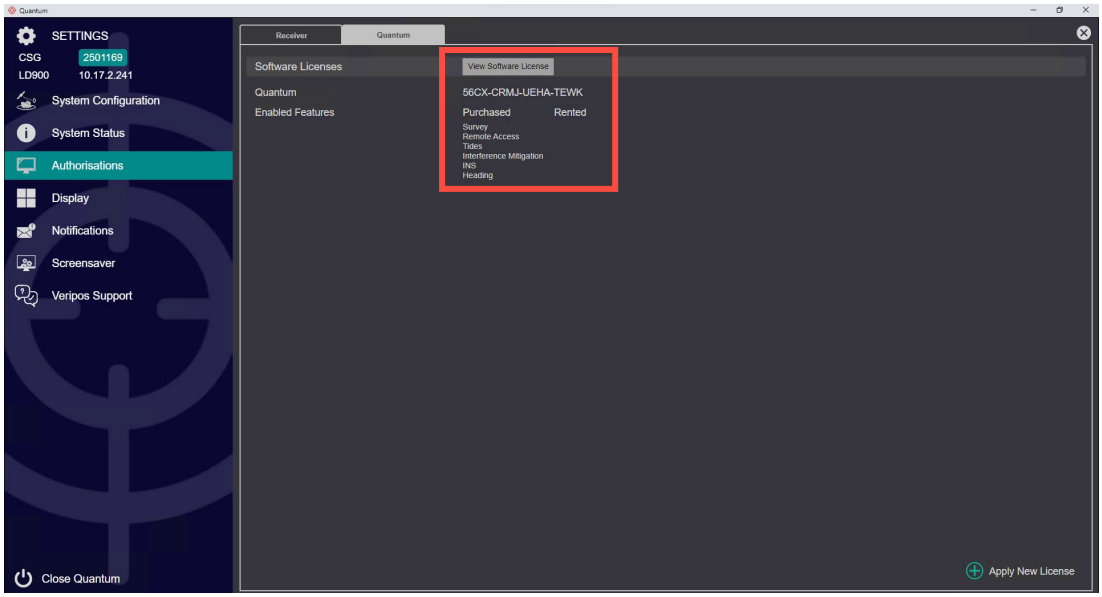

Figure 3 Quantum Tides license location

Quantum Tides configuration

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

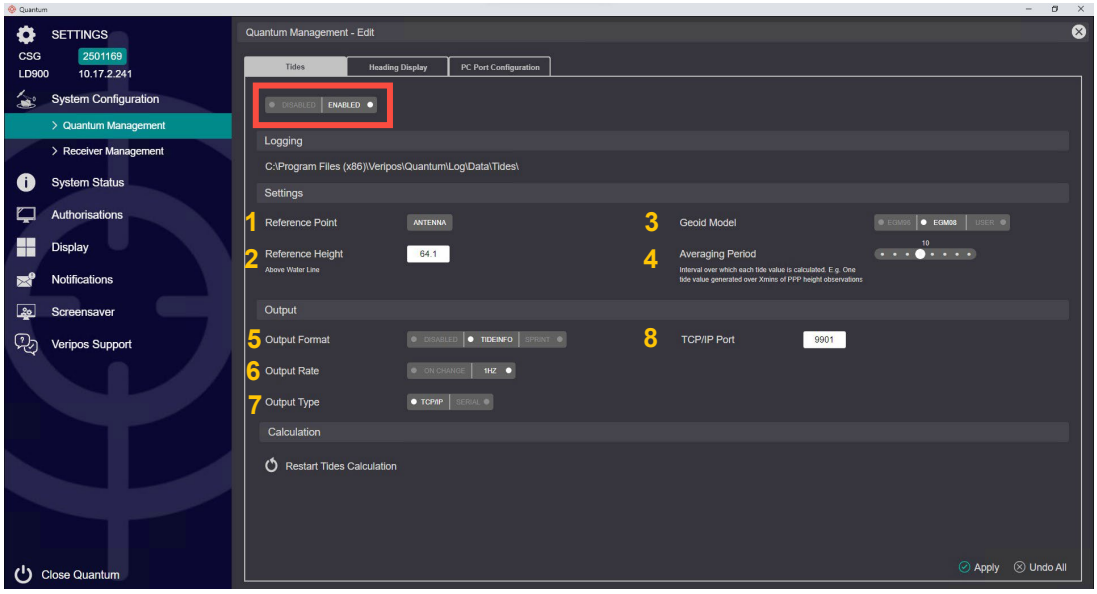

Figure 4 Enabling Tides within Quantum

The Logging directory is the PC directory where the Tides resultant files are stored. This can be either in Sprint or Tideinfo format. Note that 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. **Reference Point**: The reference point will usually be the antenna phase centre (APC). If the INS option is active, the user can set the reference point to either the antenna APC or the IMU centre of navigation (CON).
2. **Reference Height**: The reference height above the waterline. This value is only applied to the Geoid Tide estimation. This value is required to be updated regularly to reflect changes in vessel draft.
3. **Geoid Model**: Either EGM96, EGM08, or a USER defined value can be selected (or entered for the USER defined option). This selection is only applicable to the Geoid Tides calculation. Note: The geoid selection does not relate to the position output.
4. **Averaging Period**: The averaging period in which each tide value is calculated. Averaging is used to minimise the effects of vessel motion. The sliding scale ranges from 1–60 minutes. The averaging period can be set to match the vessel motion experienced.
5. **Output Format**: TIDEINFO or SPRINT formats are available. The default setting is DISABLED. Toggling Output Rate to either TIDEINFO or SPRINT.
6. **Output Rate**: This 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, e.g., one output every ten minutes. A 1HZ setting will create an output every second.
7. **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).
8. **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 needs 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 that the Tides computation is activated.

> **NOTE**
> Both the Geoid and MSS Tide computations are enabled by default.

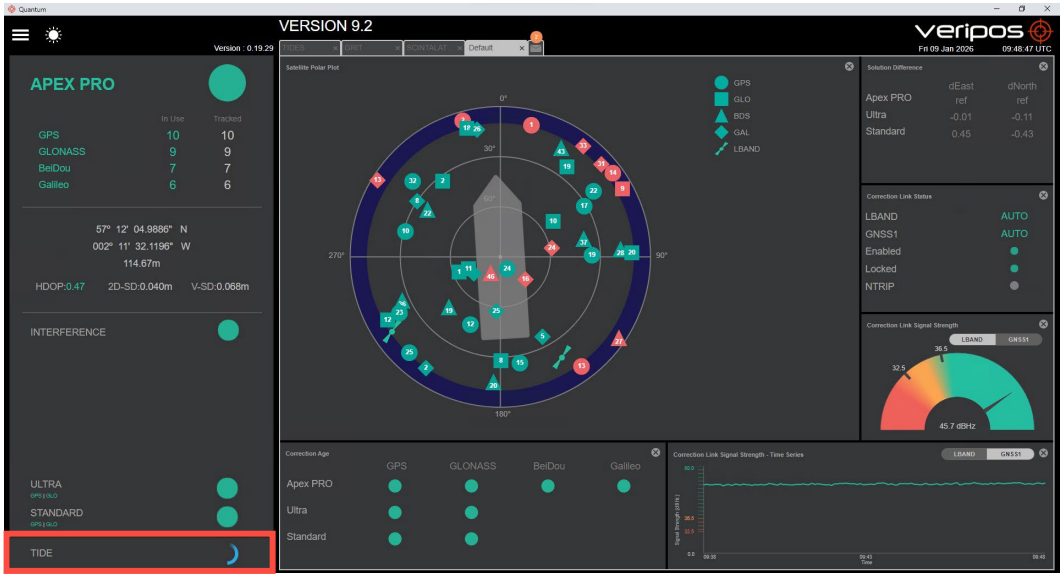

Figure 5 Tide status within sidebar

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:

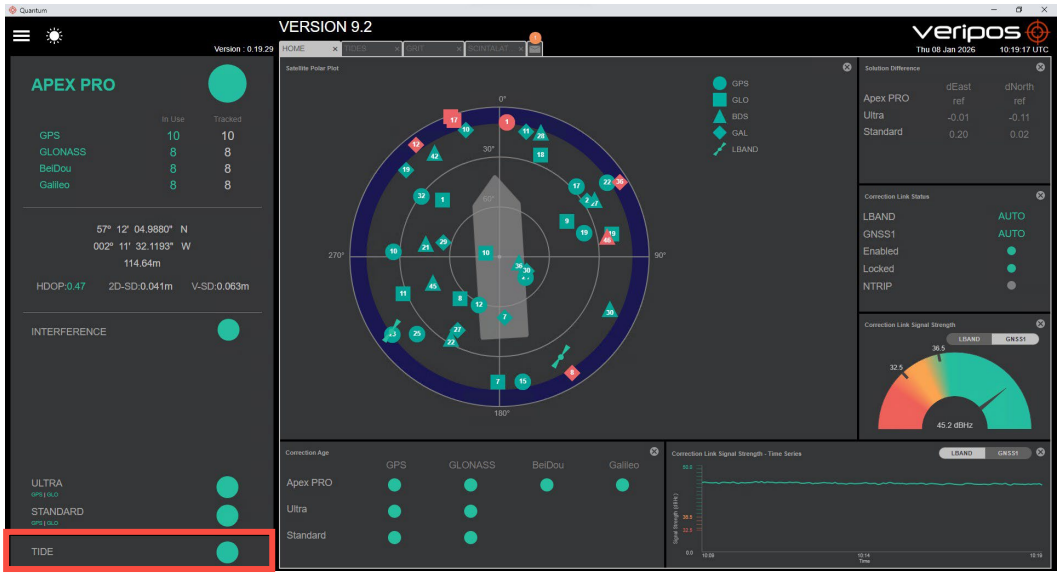

Figure 6 Tide computation active

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:

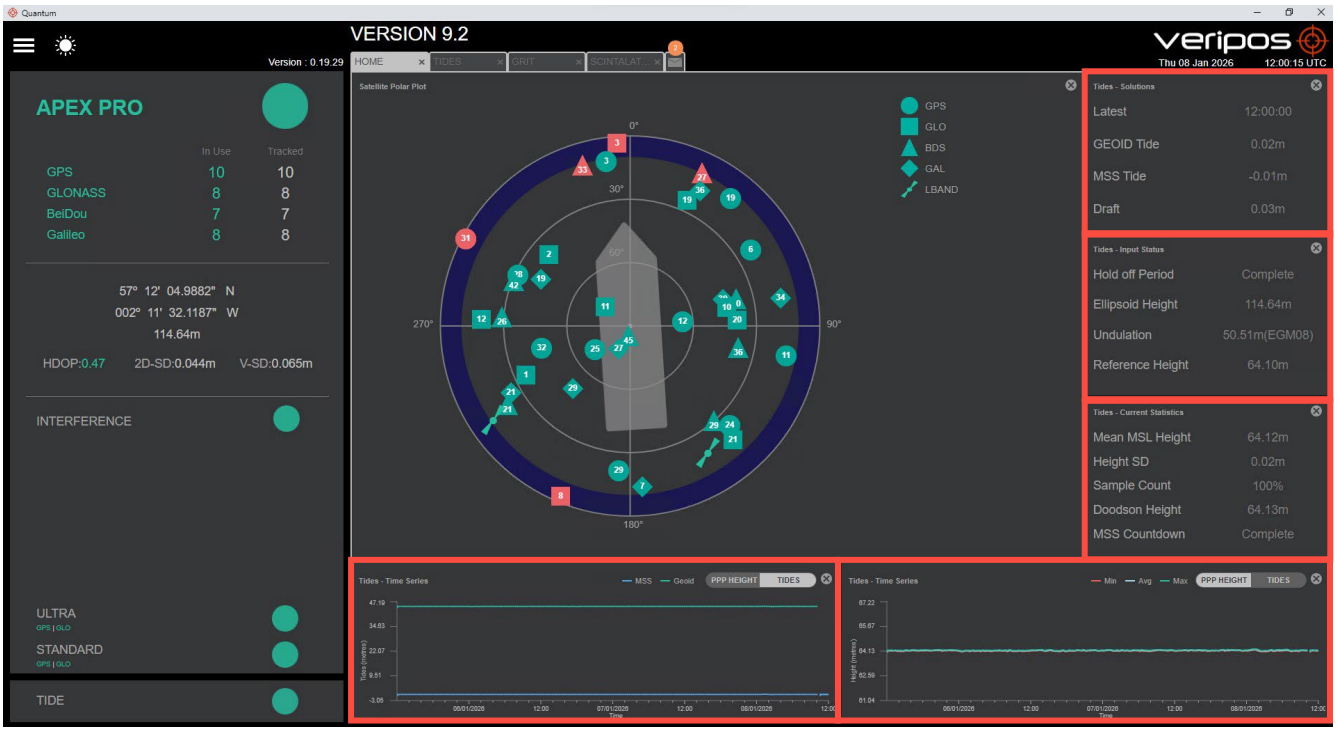

Figure 7 Quantum Tides tiles

Quantum tile – Tides - Input Status

The Tides Input Status view displays the following information:

- **Hold off Period**: Hold off period countdown (15 minutes to complete).
- **Ellipsoid Height**: Height of reference point above the reference ellipsoid.
- **Undulation**: Separation between the reference ellipsoid and the geoid model, with the geoid model used in brackets.
- **Reference Height**: Height of the reference point above the waterline, set by the user.

Quantum tile – Tides - Current Statistics

The Current Statistics view displays the following information:

- **Mean MSL Height**: Height of the reference point above the waterline.
- **Height SD**: Standard deviation of the reference point height.
- **Sample Count**: Percentage of data samples received during the averaging period.
- **Doodson Height**: MSL height of reference point.
- **MSS Countdown**: MSS Tide Doodson filter convergence countdown (39 hours to complete).

Quantum tile – Tides - Time series

This view has two selectable plot options: TIDES and PPP HEIGHT.

The PPP HEIGHT plot displays the minimum, maximum and the average height of the reference point, plotted over a 72-hour period:

- **Min**: Smallest reference point height in the last interval.
- **Max**: Largest reference point height in the last interval.
- **Avg**: Mean reference point height within the last averaging interval.

The TIDES plots show the Doodson Tides and Geoid results, plotted over a 72-hour period:

- **MSS Tide**: MSS Tides result (referenced to the MSS).
- **GEOID Tide**: Geoid Tides result (reference to the geoid).

Quantum tile – Tides - Solutions

The Tides Solutions view displays the following information:

- **Latest**: The UTC timestamp of the latest tides result.
- **GEOID Tide**: Geoid Tides result (referenced to the geoid).
- **MSS Tide**: MSS Tides result (referenced to the MSS).
- **Draft**: The variation of Doodson height since the start of the current averaging period.

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	[-]	$ApexTide or $UltraTide (dependent on active PPP calculation). $ApexTide is applicable to both APEX and APEX PRO calculation types.
1	yyyymmdd	[-]	UTC date stamp - year, month and date.
2	UTC Time	hh:mm:ss	UTC time stamp – hour, minute and second.
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	numerical	User-selected period (in seconds) over which the reference point heights are averaged.
5	Sample Count	numerical	Number of reference height samples included to derive the reference height average. A minimum of 50% of the defined Averaging Period is required to produce a valid sample count. This count remains constant throughout each epoch, updating only at the end of each new averaging period. The sample count will increase every epoch if set to 1 Hz.
6	Latitude	dddmm.mmmm	degrees, minutes and decimal minutes.
7	Latitude Hemisphere	c	N or S.
8	Longitude	dddmm.mmmm	degrees, minutes and decimal minutes.
9	Longitude Hemisphere	c	E or W.
10	Mean Height	hh.hh (metres)	Mean of the reference point height, calculated over the averaging period.
11	Mean of Height SD	hh.hh (metres)	Mean of the reference point height SD during the averaging period. This provides an indication of the quality of the reference point height.
12	SD of Heights	hh.hh (metres)	Standard deviation of the reference point height during the averaging period. This is an indication of the variation of the height due to vessel motion and position quality.

Content	Format	Unit	Notes
13	Minimum of Heights	hh.hh (metres)	Minimum of the reference point height during the averaging period.
14	Maximum of Heights	hh.hh (metres)	Maximum of the reference point height during the averaging period.
15	Doodson	hh.hh (metres)	Estimated reference point height above Mean Sea Surface.
16	MSS Tide	hh.hh (metres)	Local tide based on the Mean Sea. First available after 39 hours.
17	Geoid Tide	hh.hh (metres)	Local tide relative to user selected Geoid (see field 22). Available after 15 minutes 'hold-off' period.
18	Reference Height	hh.hh (metres)	User entered height of the reference point 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 vessel draft, calculated as the current Doodson value minus the Doodson value for the first record.
21	Vertical Bias	hh.hh (metres)	The vertical bias between MSS Tide and Geoid Tide.
22	Geoid Model	-	EGM96, EGM08 or USER.

Tideinfo example:

```
<$UltraTide,20070228,21:40:00,28,600,600,5236.2830,N,00143.5184,E,5.74,0.08,0.07
<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 MSS Tide with the opposite sign compared to 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	Date of month.
3	Month	MM	Month in the year.
4	Year	YYYY	Year.
5	MSS Tide	hh.hh (metres)	MSS Tide based on the Mean Sea Surface derived from the Doodson filter. First available after 39 hours. Set as 99999.99 when no reference height 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
```

Acronyms

Table 5 Acronym list

Term	Description
APC	Antenna phase centre
ARP	Antenna reference point
CON	Centre of navigation
CRP	Central reference point
DOT	Dynamic ocean topography
GNSS	Global navigation satellite system
GPS	Global Positioning System
MSL	Mean sea level
MSS	Mean sea surface
PPP	Precise point positioning
UTC	Coordinated Universal Time
VRP	Vertical reference point

Support

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

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

Documentation

Technical documents, along with firmware and software downloads, can be found on the Veripos Support website.