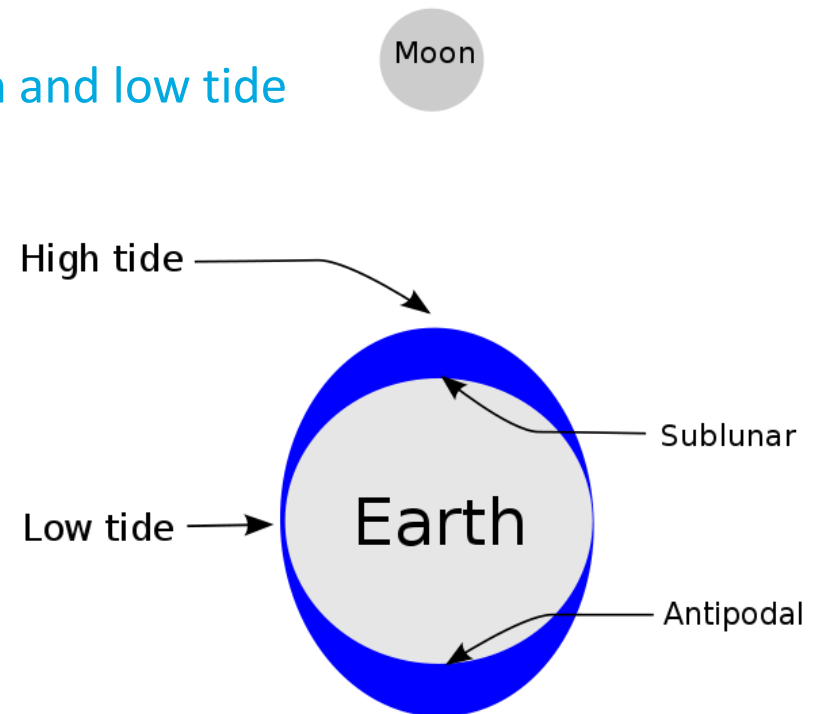


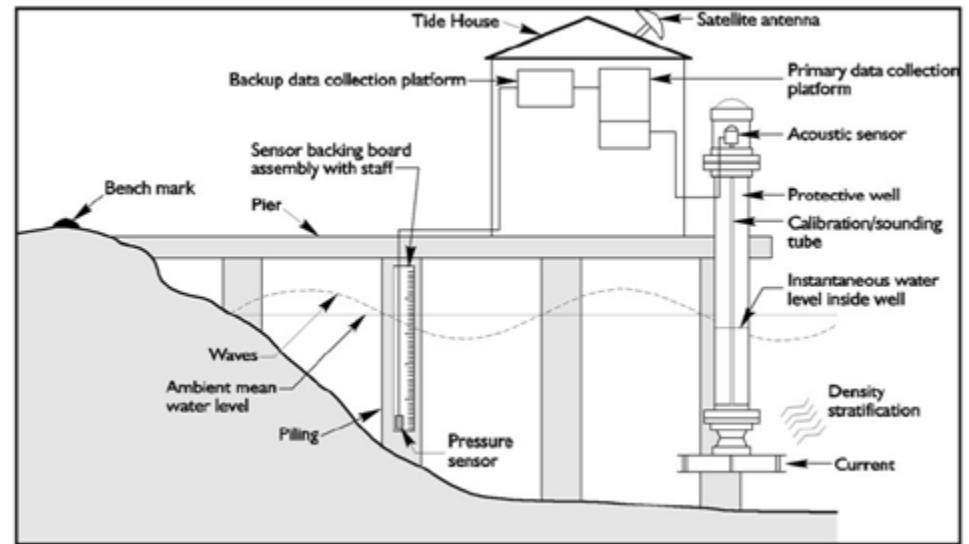
GNSS Technology for the Determination of Real-Time Tidal Information

- Tides are very long-period waves that move through the oceans in response to forces exerted by the moon and sun
 - Gravitational forces of the moon and sun create areas of high and low water on the earth's surface
 - As the earth rotates the location of high and low tide changes
 - The moon has the greatest effect on the water compared with the sun due to its proximity to the earth



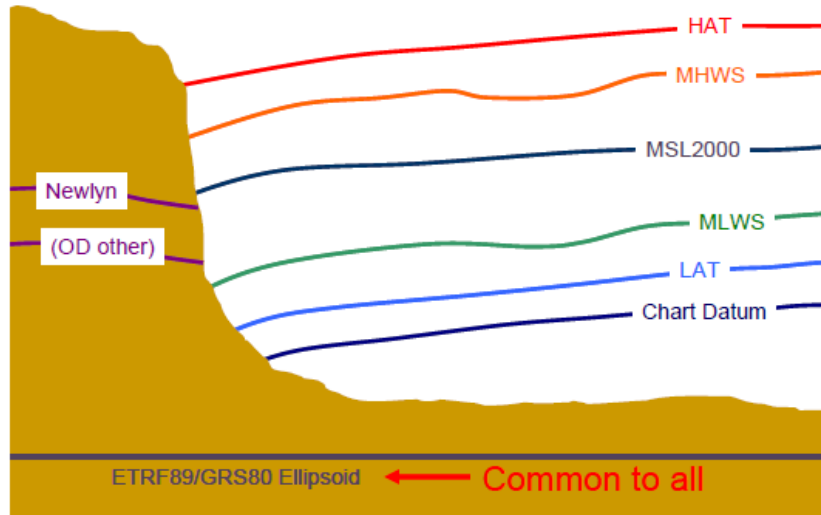
Onshore Tide Gauge Instrumentation

- Tide poles or tide staffs
- Mechanical Float and Stilling Well gauges (self-recording)
- Pressure gauges (bubbler gauges)
- Acoustic gauges
- Radar gauges



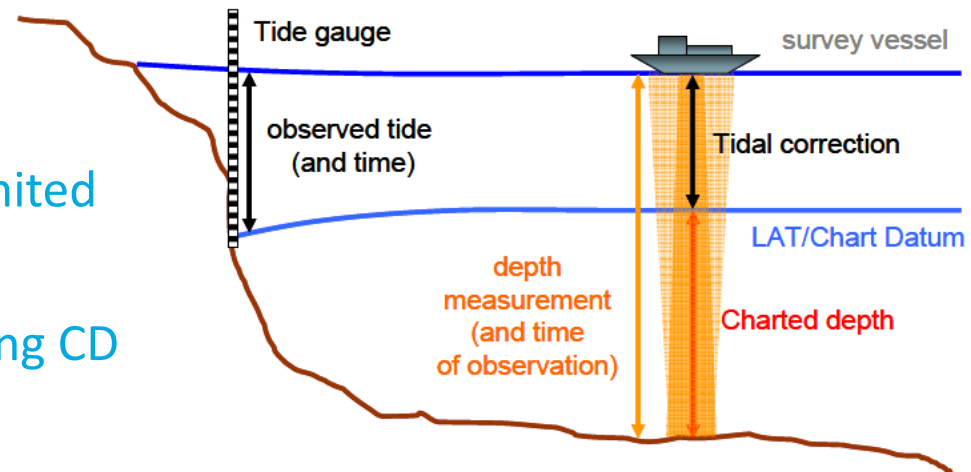
- Pressure sensor (not requiring a fixed datum)
 - Easiest use offshore
 - Robustness and validity of measured tide
 - Any acquisition problems only highlighted after recovery
 - High risk of loss of the instrument
- Tide gauges used indirectly through tidal predictions
 - Can't account for local environment (surge, atmosphere)
- Tidal prediction software (e.g. POLPRED)
 - Can't account for local environment (surge, atmosphere)
 - Only access regional portions of predicted tides per license
 - Easy to operate





- HAT/LAT – the highest and lowest levels respectively which can be predicted under average meteorological conditions
- MHWS/MLWS – the average of the height of two successive high waters during those periods of 24 hrs (approx. once per fortnight)
- MSL – the average level of the sea surface over a long period, normally 19 years
- CD – often defined as by the LAT observed over a certain time period. A common outcome from a survey is a chart showing depth of water below Chart Datum. The chart seeks to express the minimum depth of water available to the mariner for the purposes of navigation

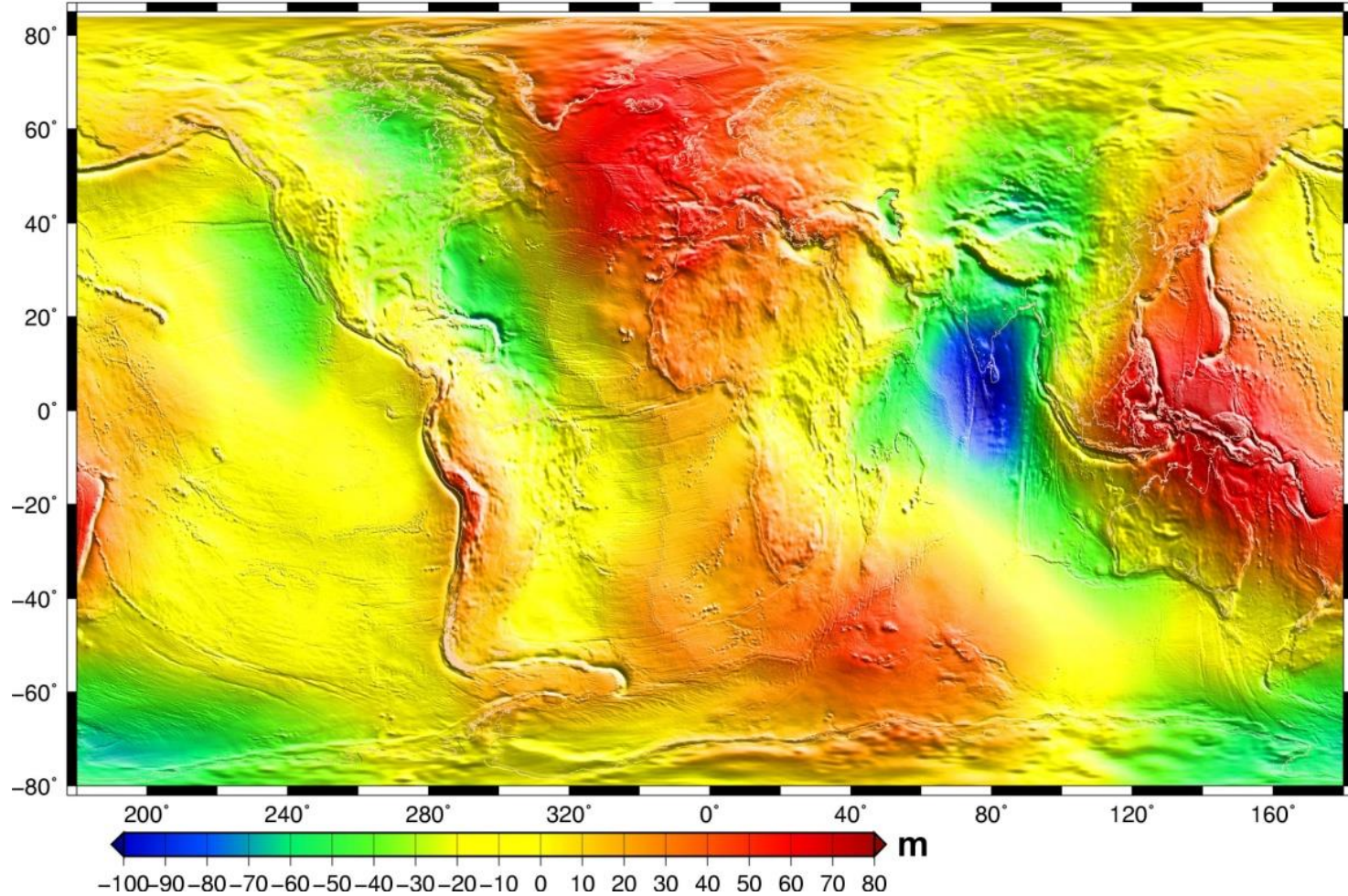
- Tidal correction must be applied to reduce the soundings to CD
- Coastal tide gauge and co-tidal charts
 - Co-tidal chart to correct the observed coastal tide variations for change in phase and amplitude of tide between the station and the survey vessel
- Drawbacks
 - Synchronised operations
 - Latency (two observation sets married together)
 - Accuracy (co-tidal charts have a limited resolution, paper product)
 - Inconsistency (survey practices using CD are poorly defined)



- Using satellites, we can measure sea level over almost the entire ocean
- Two kinds of measurement are needed to determine sea level
 - Position of sea surface (radar altimetry using two way travel time and precise tracking of the satellite)
 - Accurate measurements of the Earth's gravity field or height associated with Gravity to find the position of a level surface known as the geoid

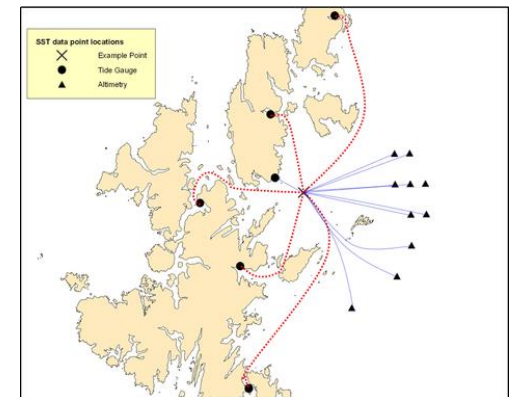


- Relationship between local vertical levels (CD, LAT or MSL) and the ellipsoid (GNSS)
- Two kinds of surface models can be used worldwide
 - **Geoid** – equipotential surface of the Earth's gravity field tending to coincide with MSL. Coincidence is exact if the oceans and the atmosphere were in a complete state of equilibrium
 - **MSS** – derived from altimetry, the height of the free surface of the oceans. Average level of ellipsoid corresponding to observation period of the model.
 - Altimetry values only valid a respectable distance from the coast ~10km
 - Integrate Geoid models in to the calculations
 - Affected by currents, wind and atmosphere – Dynamic Ocean Topography (DOT)
 - DOT mathematically corresponds to the difference between the Geoid and the MSS
 - Globally, changes in DOT are generally between -2 m and +2m



Vertical Offshore Reference Frame (VORF)

- Offshore reference frames represented as a continuous surface relative to ETRF89 (GRS80)
 - Use GNSS to precisely determine ellipsoidal height of each tide gauge
 - Tide gauge observations used to derive ellipsoidal height of MSL at tide gauge
 - Satellite altimetry measures MSL of open oceans from space >> ellipsoidal height of MSL at tide gauge **AND** in open oceans now known
 - Geoid to derive DOT (MSL – Geoid) >> use DOT to interpolate between open ocean and tide gauge >> gives continuous MSL surface
 - Use tidal modelling to derive other surfaces
 - 17 times denser than either the MSS or EGM08 surfaces

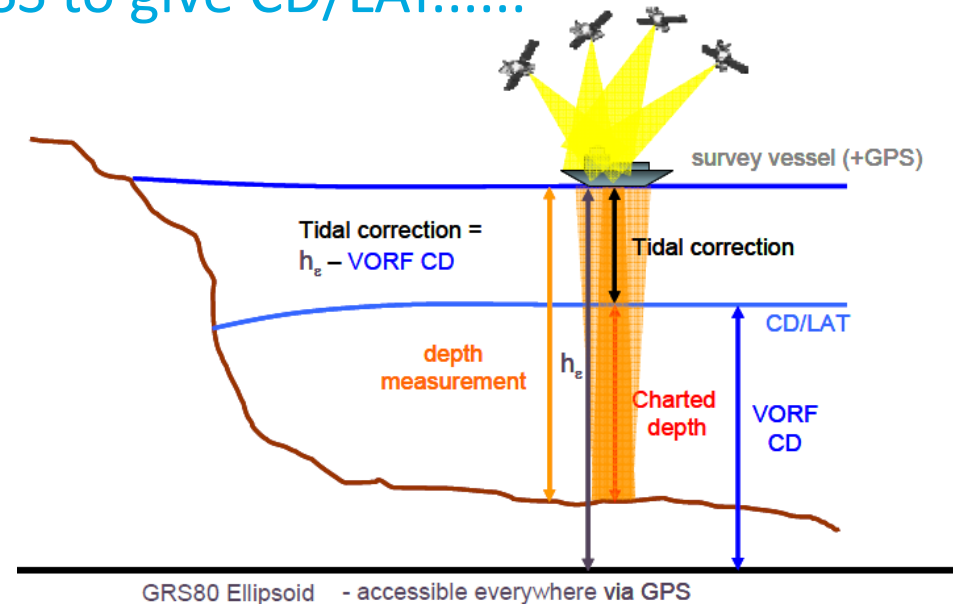


- Survey vessel equipped with GNSS delivers ellipsoidal height at an accuracy $\sim 10\text{cm}$ (1σ)
- GNSS enables calculation of the ellipsoidal height of the echo sounder (h_ϵ) (assuming corrections for offsets and attitude)
- Lat/Long used to query VORF/MSS to give CD/LAT.....

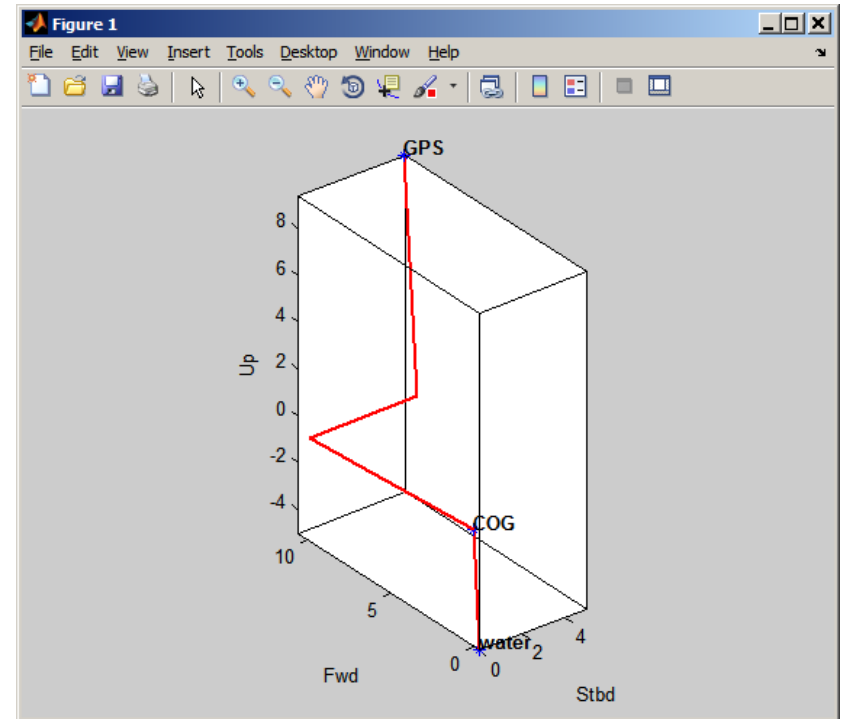
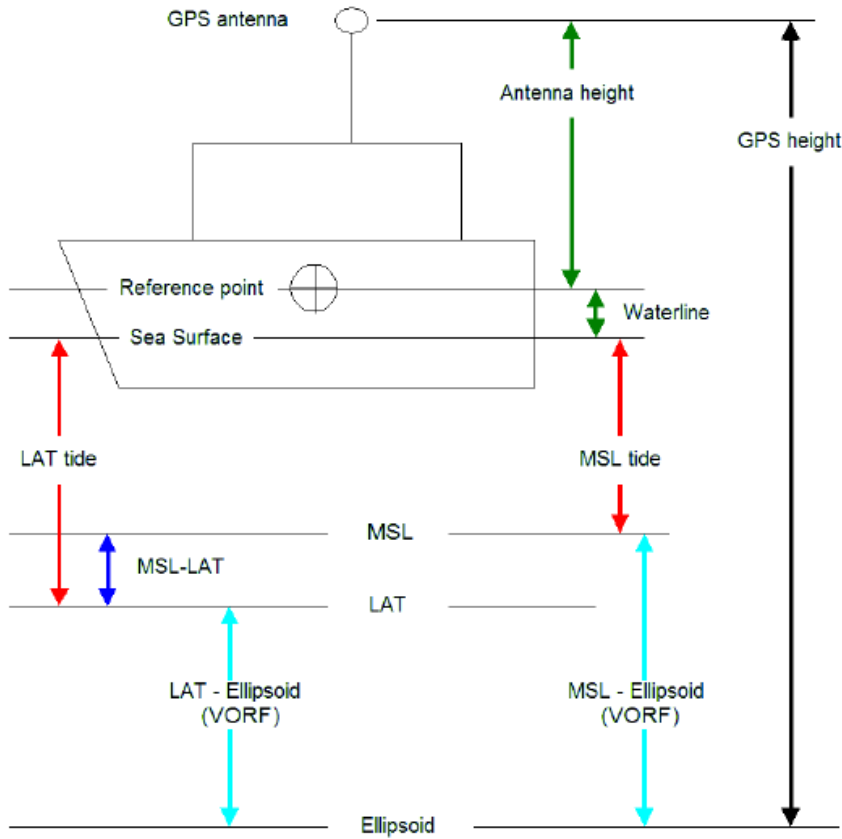
$$\Delta tide = h_\epsilon - h_{VORF\ MSL}$$

- Gains

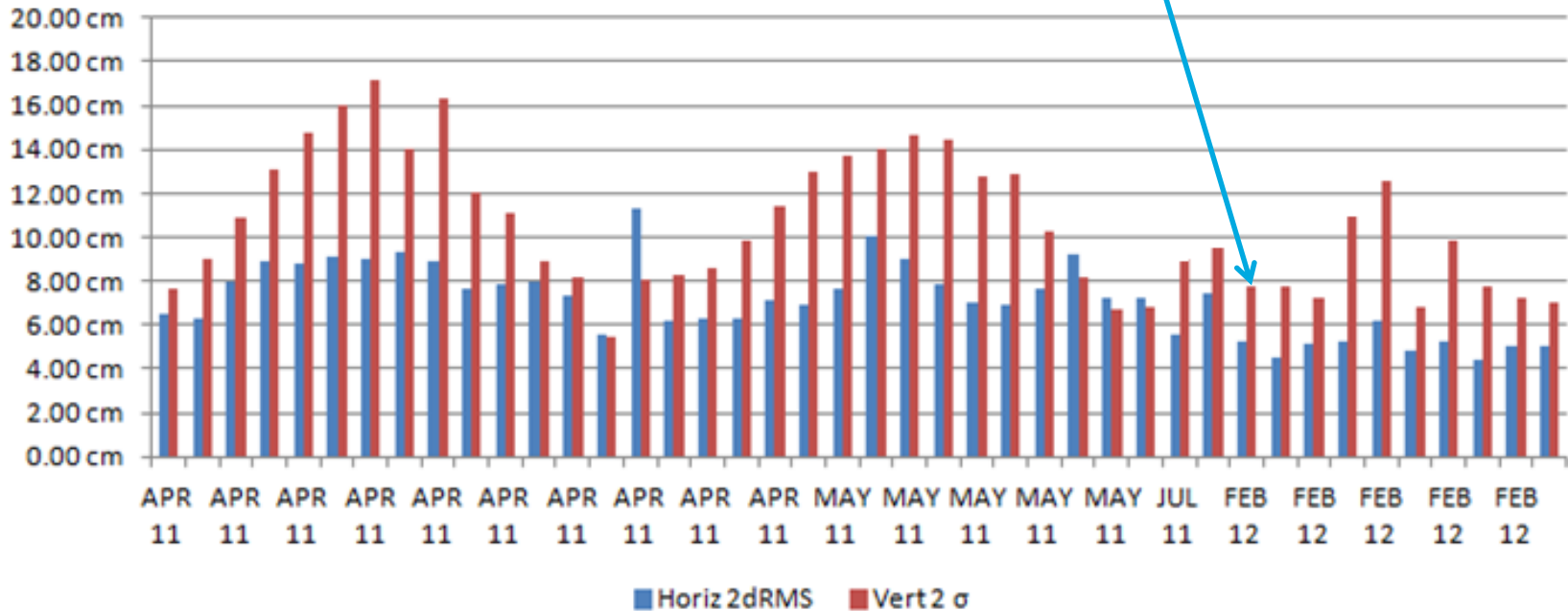
- No reliance on tide gauges
- Consistency (all contractors using same reduction methods)
- QC (error budget controlled by GNSS and bathymetry – both user based)
- Speed (data available on board the ship)



Relating Antenna Height to Sea Surface



- Correctors for GLONASS constellation (C2)
- Improved GNSS PPP algorithms (*iCORE*)
- GPS & GLONASS improved convergence time



- C-Nav C2 vertical accuracy is significantly more precise than the legacy C1 (GPS only service)
- Upgrade included implementation of proprietary network of C-Nav3050 equipped reference stations
 - Improved modelling using homogeneous network of receivers
- New PPP algorithms
- 10.3 cm ± 2.4 cm (2σ)

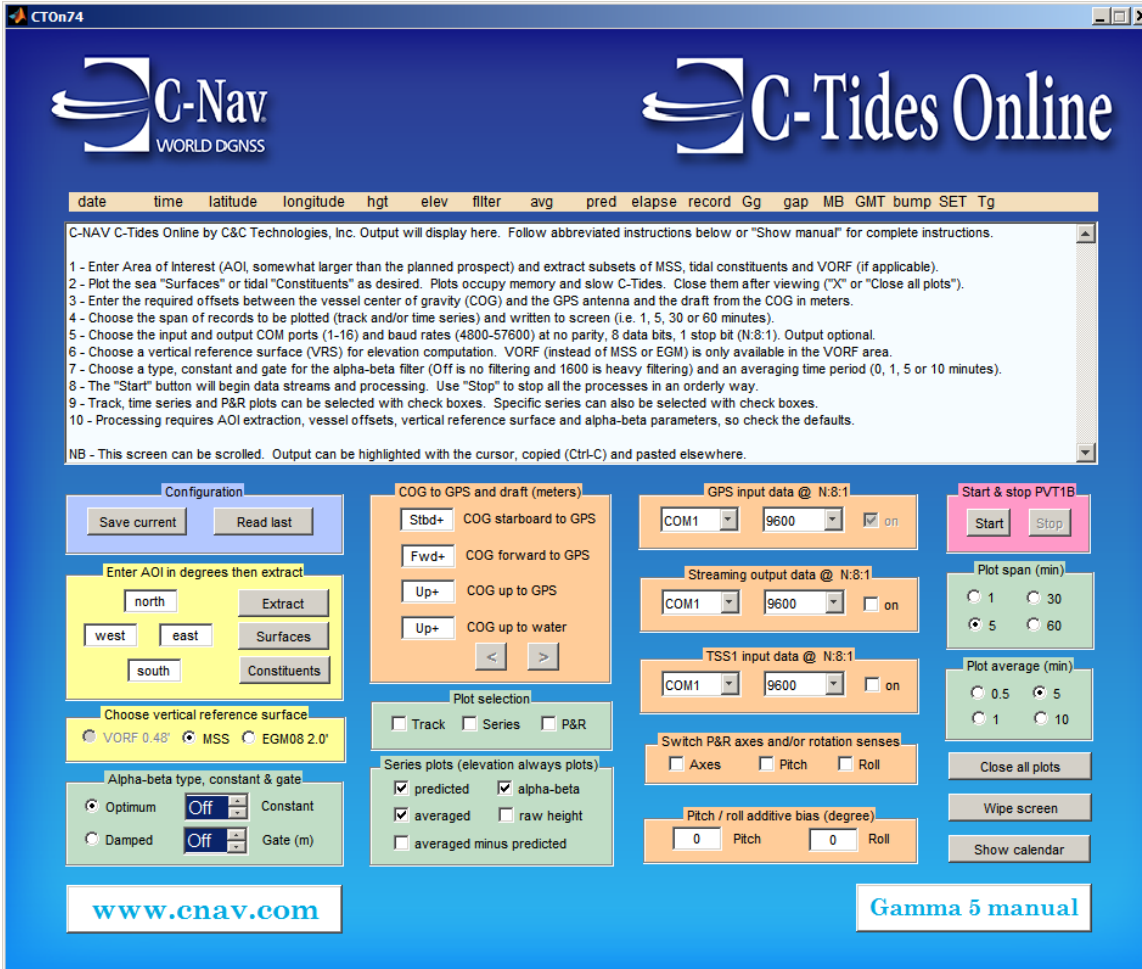
Station: CRCS Singapore	Observed Mean Position
Latitude: 1.330909528	Latitude: 1.330909442
Longitude: 103.951987028	Longitude: 103.951987105
Height: 51.597	Height: 51.601

Horizontal Statistics (meters)	Vertical Statistics (meters)
Minimum deviation: 0.000	Minimum deviation : -0.265
Maximum deviation: 0.087	Maximum deviation : : 0.185
2dRMS: 0.051	2 σ: 0.101
Mean: 0.026	Mean: 0.004
Standard Deviation: 0.026	Standard Deviation: 0.056

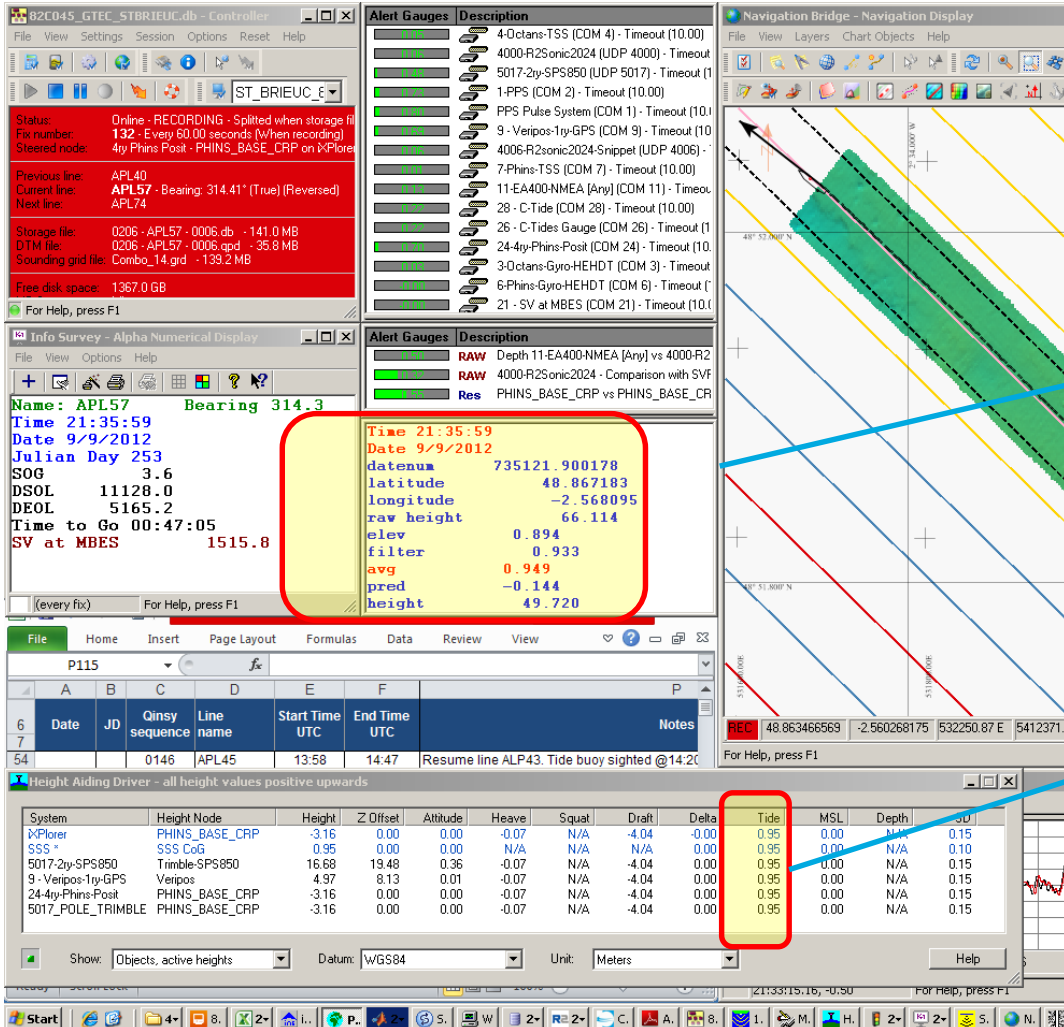
Station CRCS Kalvåg	Observed Mean Position
Latitude: 61.767820250	Latitude: 61.767820158
Longitude: 4.879132750	Longitude: 4.879132926
Height: 62.873	Height: 62.898

Horizontal Statistics (meters)	Vertical Statistics (meters)
Minimum deviation: 0.000	Minimum deviation : -0.138
Maximum deviation: 0.112	Maximum deviation : 0.182
2dRMS: 0.065	2σ: 0.094
Mean: 0.032	Mean: 0.025
Standard Deviation: 0.033	Standard Deviation: 0.042

- Stream and process C-Nav3050 PVT1B data
- Instantaneous Tide relative to to MSS (Global), VORF MSL (UK), or EGM08
- Real-time tide output not dependent on 39-hour time delayed estimate
- Real-time attitude input
- Allows for tidal reduction (antenna offsets, draft changes) at any point in operation
- Output formats: time series plots, RS232 streams, ASCII log files, or difference contours



Real Time Bathymetry Reduction using C-Tides Online



The screenshot displays the C-Nav software interface with several key components:

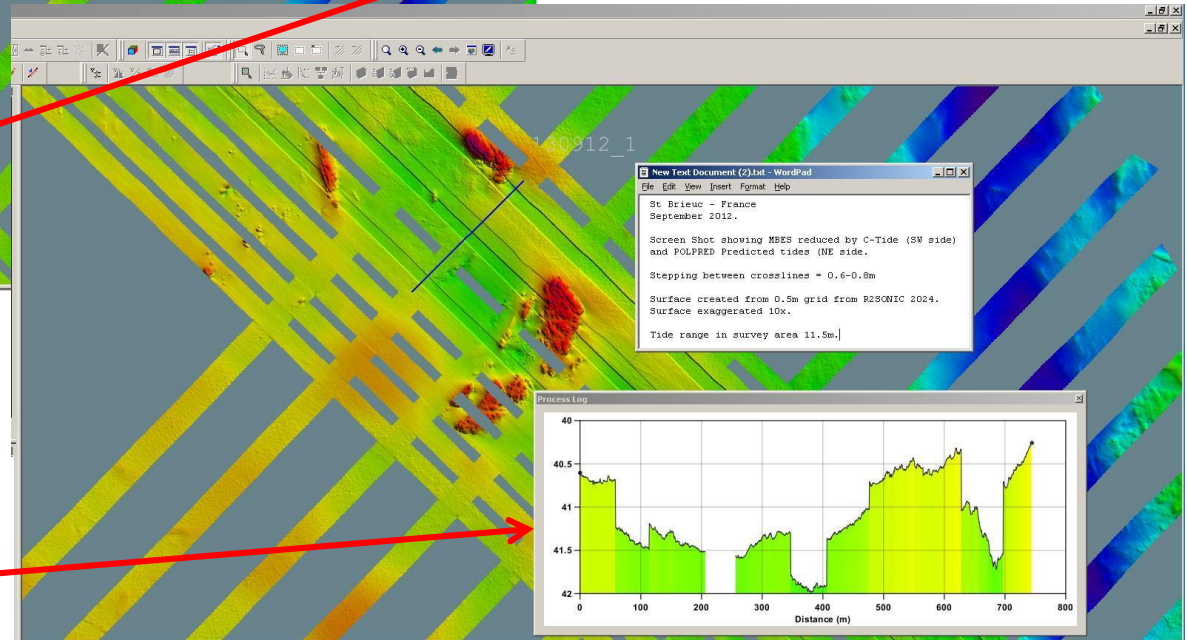
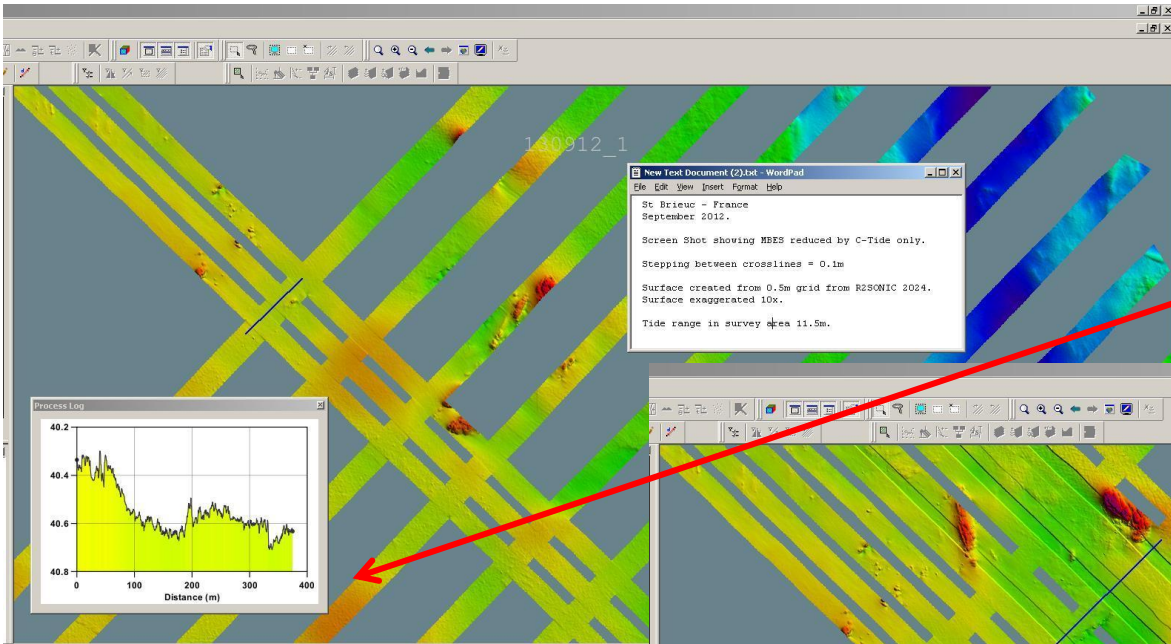
- Alert Gauges (Top Left):** A list of system alerts such as "4-Octans-TSS (COM 4) - Timeout (10.00)", "4000-R2sonic2024 (UDP 4000) - Timeout", and "5017-2ty-SPS850 (UDP 5017) - Timeout (1)".
- Status Window (Middle Left):** Shows recording status: "Online - RECORDING - Splitting when storage full". It lists the fix number (132), steered node (4ty Phins Post - PHINS_BASE_CRP), and storage file information.
- Info Survey - Alpha Numerical Display (Bottom Left):** Displays real-time survey data for APL57, including bearing (314.3), date (9/9/2012), and coordinates.
- Navigation Bridge - Navigation Display (Right):** A map showing a green shaded area representing bathymetry data. A blue arrow points from this area to the "Data from C-Tides Driver" label.
- Alert Gauges (Middle Right):** Shows raw and resolved data for "Depth 11-EA400-NMEA [Any] vs 4000-R2" and "PHINS_BASE_CRP vs PHINS_BASE_CR".
- Table (Bottom):** A table titled "Height Aiding Driver" with columns for System, Height Node, Height, Z Offset, Altitude, Heave, Squat, Draft, Delta, Tide, MSL, Depth, and SD. The "Tide" column is highlighted with a red box, and a blue arrow points from this box to the "Height from C-Tides Driver" label.

Data from C-Tides Driver

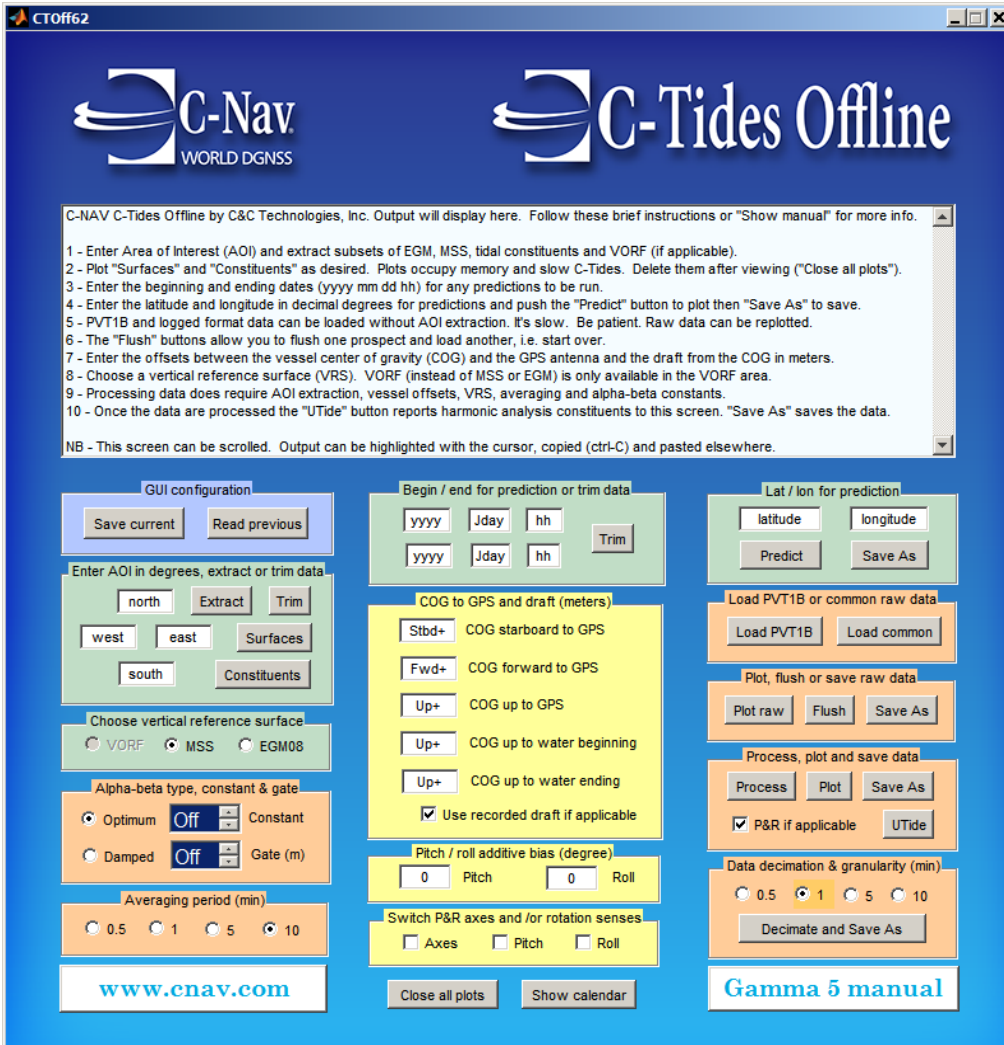
Height from C-Tides Driver

Real Time Bathymetry Reduction using C-Tides Online

- MBES data reduced using C-Tides
- Cross section across overlapping swath lines
- Stepping ~ 10cm



- MBES data reduced using C-Tides and POLPRED
- Stepping up to 1m



C-NAV C-Tides Offline by C&C Technologies, Inc. Output will display here. Follow these brief instructions or "Show manual" for more info.

- 1 - Enter Area of Interest (AOI) and extract subsets of EGM, MSS, tidal constituents and VORF (if applicable).
- 2 - Plot "Surfaces" and "Constituents" as desired. Plots occupy memory and slow C-Tides. Delete them after viewing ("Close all plots").
- 3 - Enter the beginning and ending dates (yyyy mm dd hh) for any predictions to be run.
- 4 - Enter the latitude and longitude in decimal degrees for predictions and push the "Predict" button to plot then "Save As" to save.
- 5 - PVT1B and logged format data can be loaded without AOI extraction. It's slow. Be patient. Raw data can be replotted.
- 6 - The "Flush" buttons allow you to flush one prospect and load another, i.e. start over.
- 7 - Enter the offsets between the vessel center of gravity (COG) and the GPS antenna and the draft from the COG in meters.
- 8 - Choose a vertical reference surface (VRS). VORF (instead of MSS or EGM) is only available in the VORF area.
- 9 - Processing data does require AOI extraction, vessel offsets, VRS, averaging and alpha-beta constants.
- 10 - Once the data are processed the "UTide" button reports harmonic analysis constituents to this screen. "Save As" saves the data.

NB - This screen can be scrolled. Output can be highlighted with the cursor, copied (ctrl-C) and pasted elsewhere.

GUI configuration

Save current Read previous

Enter AOI in degrees, extract or trim data

north Extract Trim

west east Surfaces

south Constituents

Choose vertical reference surface

VORF MSS EGM08

Alpha-beta type, constant & gate

Optimum Constant

Damped Gate (m)

Averaging period (min)

0.5 1 5 10

www.cnav.com

Begin / end for prediction or trim data

yyyy Jday hh Trim

yyyy Jday hh

COG to GPS and draft (meters)

Stbd+ COG starboard to GPS

Fwd+ COG forward to GPS

Up+ COG up to GPS

Up+ COG up to water beginning

Up+ COG up to water ending

Use recorded draft if applicable

Pitch / roll additive bias (degree)

0 Pitch 0 Roll

Switch P&R axes and /or rotation senses

Axes Pitch Roll

Close all plots Show calendar

Lat / lon for prediction

latitude longitude

Predict Save As

Load PVT1B or common raw data

Load PVT1B Load common

Plot, flush or save raw data

Plot raw Flush Save As

Process, plot and save data

Process Plot Save As

P&R if applicable UTide

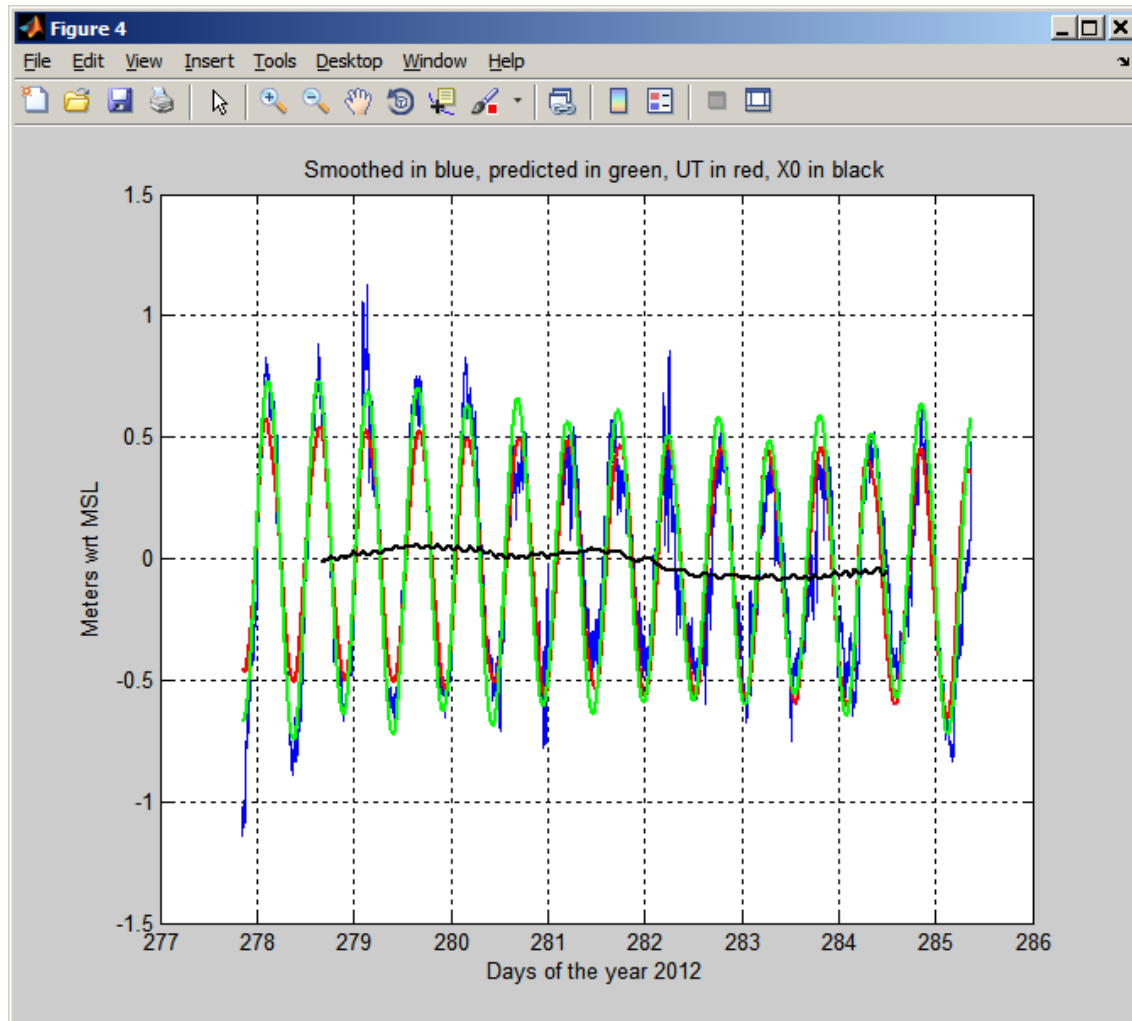
Data decimation & granularity (min)

0.5 1 5 10

Decimate and Save As

[Gamma 5 manual](#)

- Process C-Nav3050 recorded binary data or C-Tides Online data
- Processed tide relative to MSS (Global), VORF MSL (UK) or EGM08
- Allows for tidal reduction (antenna offsets, draft and squat)
- Tidal predictions for any Area of Interest in any time period
- Doodson X0 filter derived MSS estimate
- Tidal harmonic analysis using GNSS data to derive tide constituents using UTide





C-Nav[®]

POSITIONING SOLUTIONS