Use of Real Time PPP to Derive Tide

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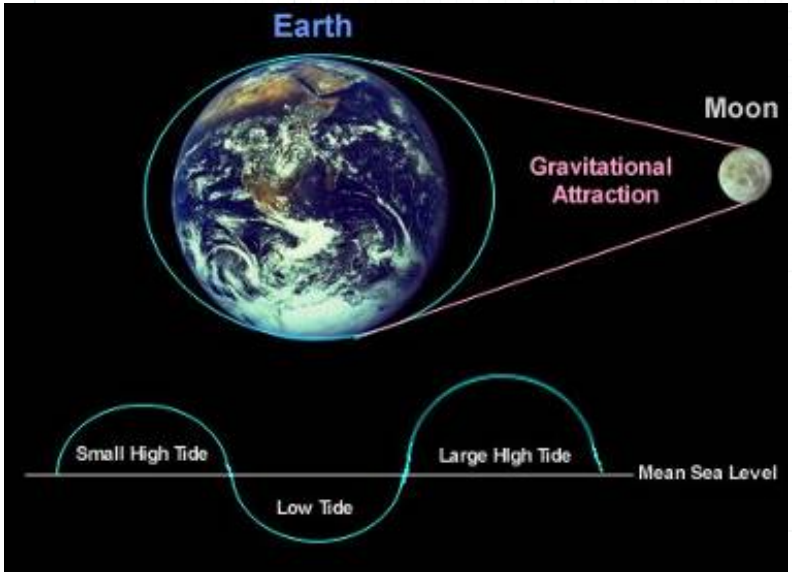
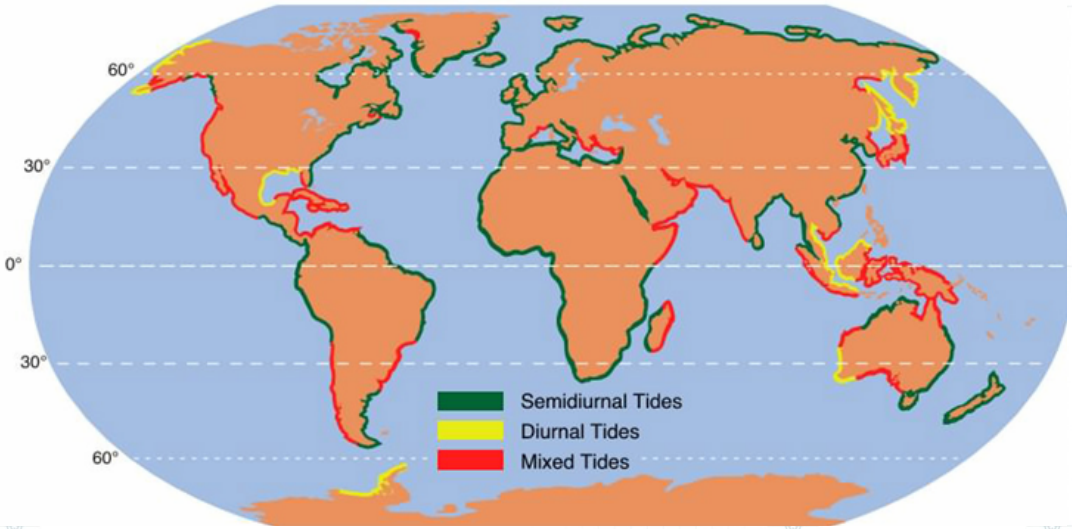
What is Tide?

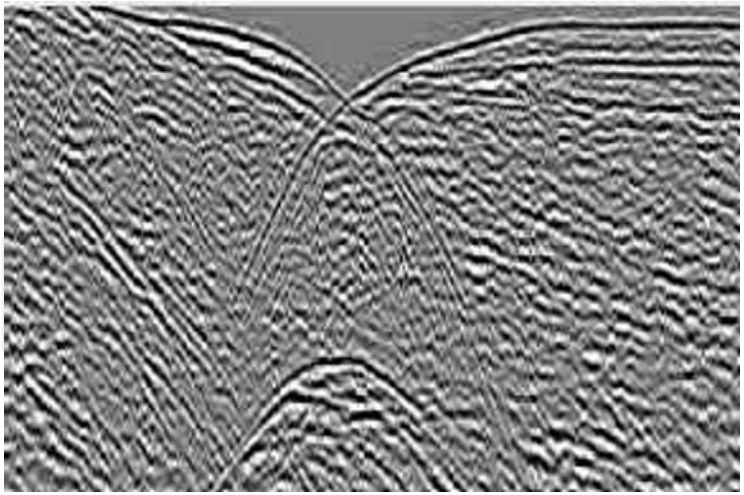
- Tide is the periodic rise and fall of the sea level under the gravitational pull of the moon and sun
  - Caused by attraction (gravity) of sun and moon
  - Normally twice per day (but not always)
  - Size of tide varies during the solar and lunar cycles
- Tides cause periodical variations in ‘equilibrium’ sea level called Mean Sea Surface





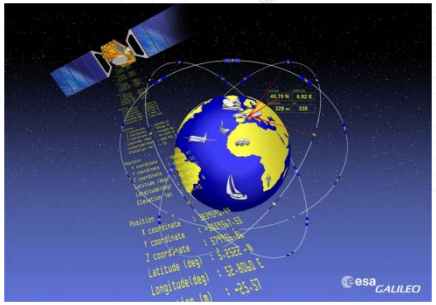
Applying Tides to Depth Data

- Why tide is important
  - Required for reduction of calculated depths
  - Generally referenced to surface of sea
    - Safe Navigation for Vessels
    - Design and Construction of Offshore Structures
    - Seismic Trace correlation to seabed depth
  - Always changing due to tide, and by different amounts in different places



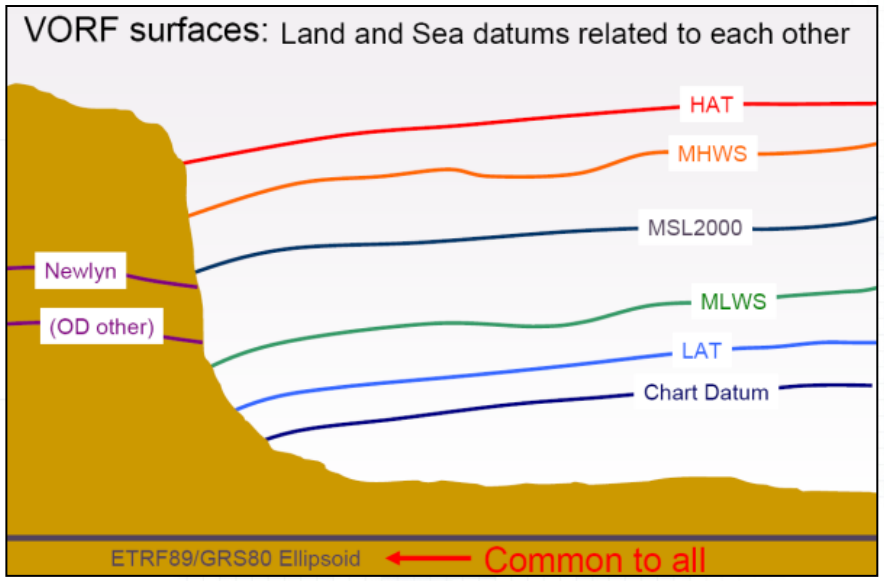
How to Measure Tide

- Tide gauges (measuring the depth at a location)
  - Most accurate
  - Sometime difficult to get data
- Predicting tides
  - Easy and repeatable
  - Doesn't account for environment (atmospheric effects, storm surges, etc.)
- Predicting tide by use of standard ports (tide tables)
  - More hassle and easier to make mistakes
  - Still doesn't account for environment
- Using GNSS
  - Includes environment effects (atmospheric effects, storm surges, etc.)
  - How to relate GNSS ellipsoid to chart datum – difficult



Vertical Datum

- Very complex – what datum do we use...



Mean Lower Low Water
Mean Low Water
Mean Low Water Neaps
Mean Low Water Springs
Mean Sea Level (MSL)
Mean Tide Level

Approximate Lowest Astronomical Tide
Approximate Mean Low Water Springs
Approximate Mean Low Water Tide
Approximate Low Water
Approximate Mean Sea Level
Half Tide
Highest Astronomical Tide
Highest High Water Large Tide
Highest Normal High Water
Highest High Water
High Water Springs
Indian Spring High Water
Indian Spring Low Water
Lowest Astronomical Tide (LAT)
Lower Low Water Large Tide

Vertical Datum – Baltic Sea Example

5.4 Vertical Datum

Bathymetric survey data shall be in metres and reduced to Mean Sea level (MSL) European Vertical Reference Frame 2000/2007 (EVRF2000/2007). EVFR2000/2007 is referenced to height zero at Normaal Amsterdam Peil (NAP) defined through the height of 0.71599 metres at United European Levelling Network (UELN) bench mark 13600 (52° 22' 53" N, 4° 54' 34" E). Datum at NAP is mean high tide in 1684, (EPSG code 5129). Predicted tides for the Baltic Sea are unlikely to be representative of the corrections to variations in the sea level as most of the influence for sea level variation is as a result of atmospheric conditions and not from normal atmospheric effect. Due to this, a combined observed surge and tidal model shall be developed by Contractor from tidal observations from at least five stations during the survey.

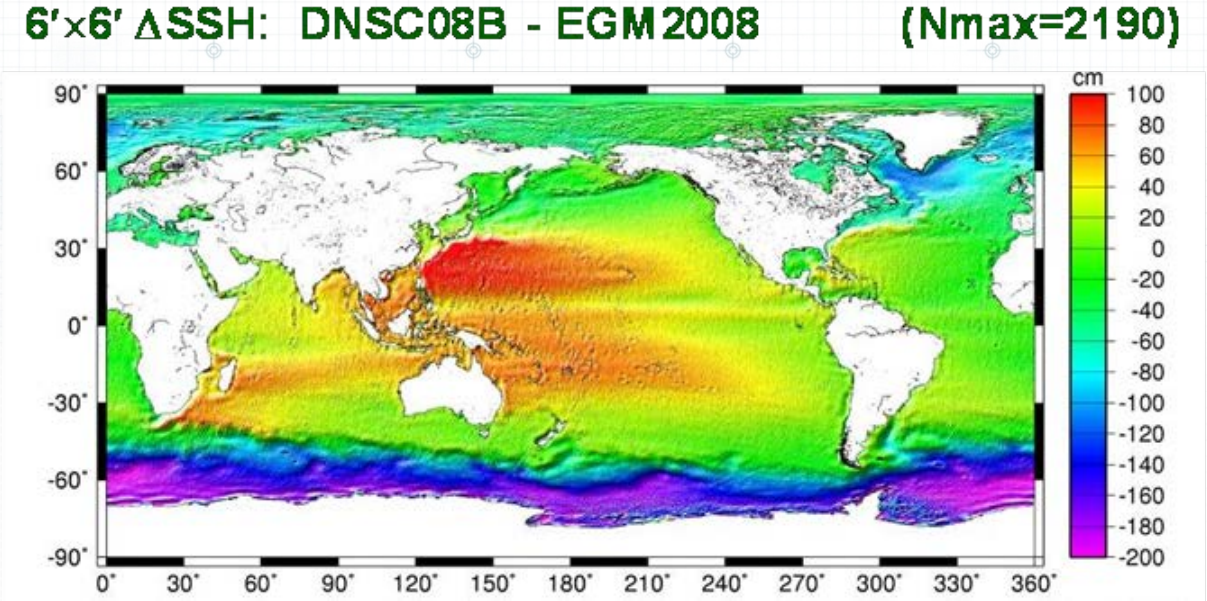
- Appears to be no published all-covering tidal model of the Baltic Sea, only piecemeal models and results at the tide gauges
- Tidal variation is minimal (cm range) whereas non-tidal variation (winds & air pressure) is several decimeters
- Also the 2 realizations of EVRS differ enormously in the Baltic area
  - Because epoch of EVRF2000 is 1960.0 and EVRF2007 has 2000.0
- EGM96 is not ideal for use in large areas of the open Baltic as many gravity surveys were only made after the model, therefore need to use EGM08
- Neither our clients or us could find a clear published relationship between MSS or EGM96/08 and EVRF2000/2007
- In end used DTU10 MSS model

Tide Terminology

- **Mean Sea Surface** represents mean state of the ocean and includes permanent effects of global currents
  - MSS models are developed based on data provided by altimetry satellites. It is not an equipotential surface
- **Mean Sea Level** (MSL) refers to a 'level' water surface, which you get if the sea was perfectly at rest
  - It coincides with an equipotential surface (e.g. the Geoid), MSL values are measured with respect to the level of benchmarks on land
- **Geoid** is an equipotential surface which would coincide exactly with the mean ocean surface of the Earth, if the oceans were in equilibrium, at rest, and extended through the continents
  - Approximated by Geoid Models as for example EGM96 and EGM2008
- **Dynamic Ocean Topography** (DOT) is difference between MSS & Geoid/MSL
  - It originates from the fact that the major ocean circulation has a (more or less) time-invariant non-zero component (i.e. a component that does not average to zero over time)

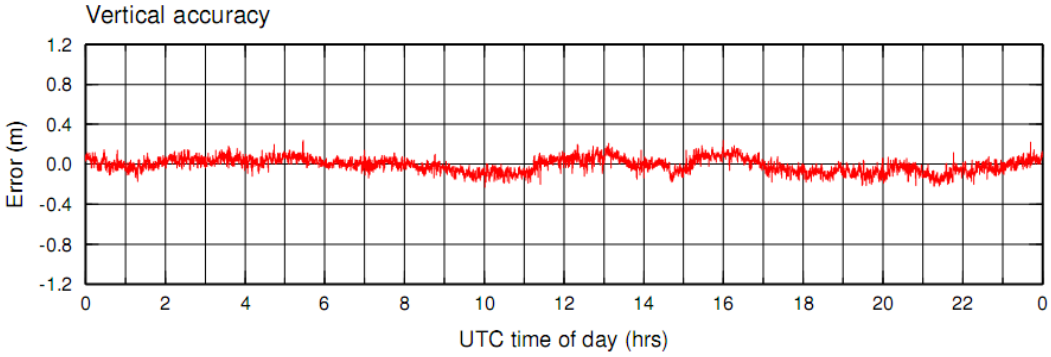
How Are Tides Determined

- If the oceans were static and not affected by winds and air pressure, then MSS and Geoid would be the same surfaces
- However, there are steady currents in the ocean, driven by winds and atmospheric heating and cooling, which give rise to differences in sea level around the world
- These local differences between the Geoid and MSS are described by the Dynamic Ocean Topography. The DOT values range between -2.5m and +1.2 m (approx)

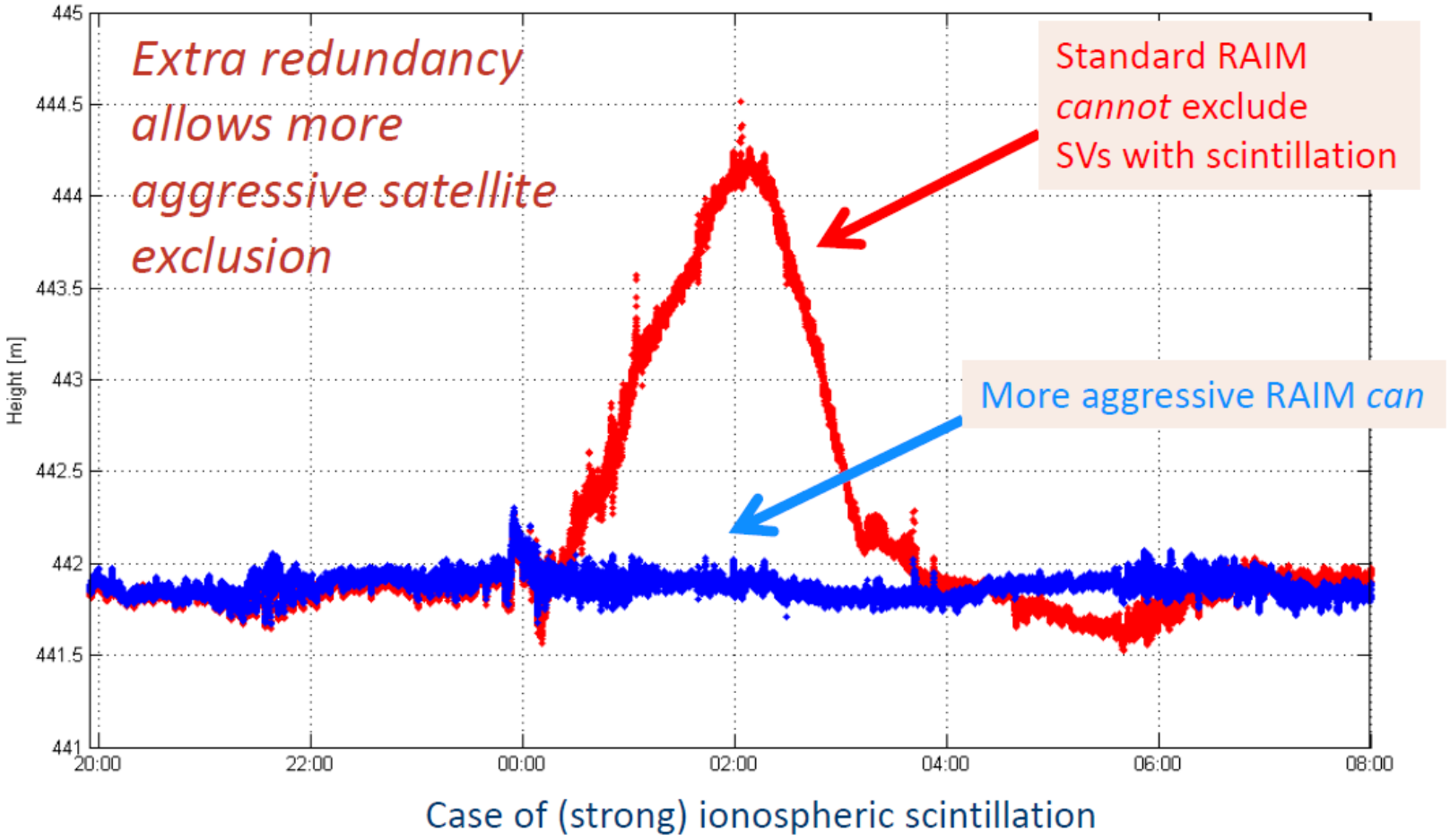


GNSS Positioning Technology

- Positioning is common technology used in offshore operations
- Augmentation data from service providers allows a higher level of accuracy & precision over standalone GNSS
  - Services range in accuracy from the metre level to the decimetre/centimetre level
  - Use of PPP (absolute) and RTK (relative) technologies
- New satellite constellations and modernisation of the current systems
  - GPS / GLONASS / Galileo /Compass
- Will see developments with new position solutions
  - Different levels of accuracy
  - Different combinations of satellite signals

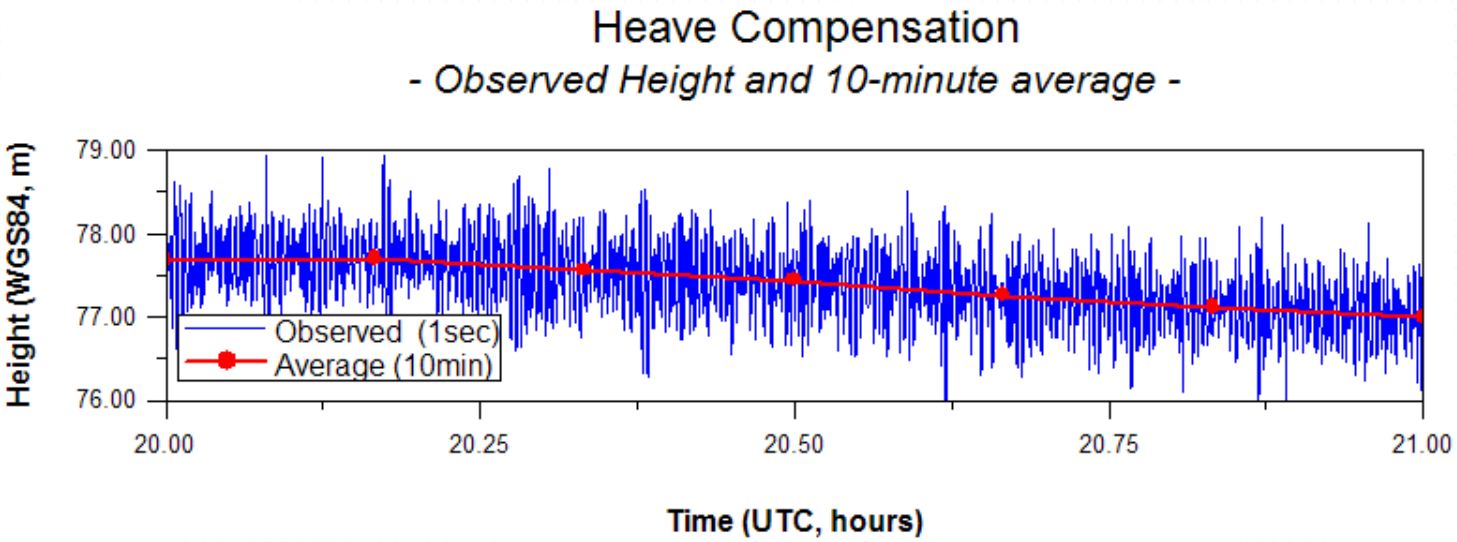


Multi-Constellation - Robustness



Using GNSS for Tide Estimation

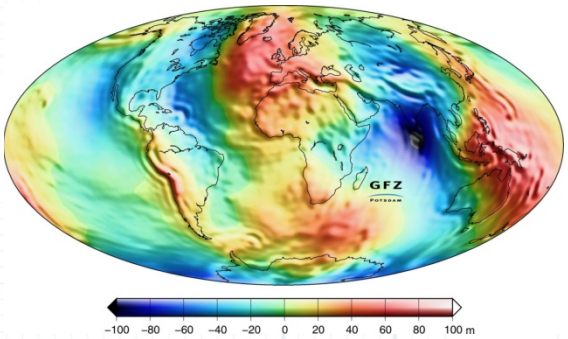
- Reduce the effect of heave, pitch and roll by averaging the high-accuracy heights or use direct measurements
- Ensure position is accurate (not converging or DGNSS)

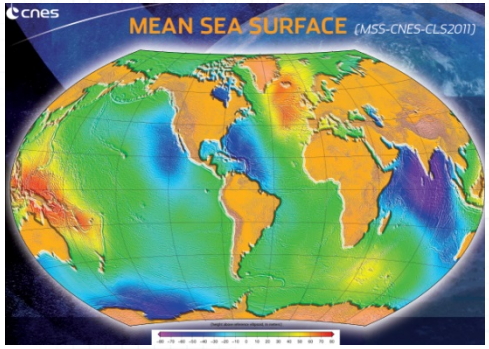


- After 39hrs de-tide the heights by using the Doodson filter derived MSS estimate
- Leave actual tidal reduction to client, i.e. antenna offsets, draft & squat

Using Geoid or MSS Models

- Geoid Model
  - Tide estimate available instantaneously
  - Accuracy dependent on Geoid model
  - Requirement for some regional requirements (e.g. German GCG2011) which links land and offshore
- MSS Model
  - Tide estimate available instantaneously
  - Global models available with improving resolution as more satellite data collected
  - Examples include DNSC08, CLS2011
    - DTU10 model has over 18 years worth of data
- Antenna height and relationship to sea surface is important





Doodson Filter

- Simple X0 filter designed to damp out the main tidal frequencies
- Using hourly values
  - 19 values either side of the central one
- Produces a MSS estimate
- Historically used at static tide gauges
- Can be used in a dynamic environment

MSL TIDAL OBSERVATIONS
(By 39 Hourly Observations / Doodson Filter)

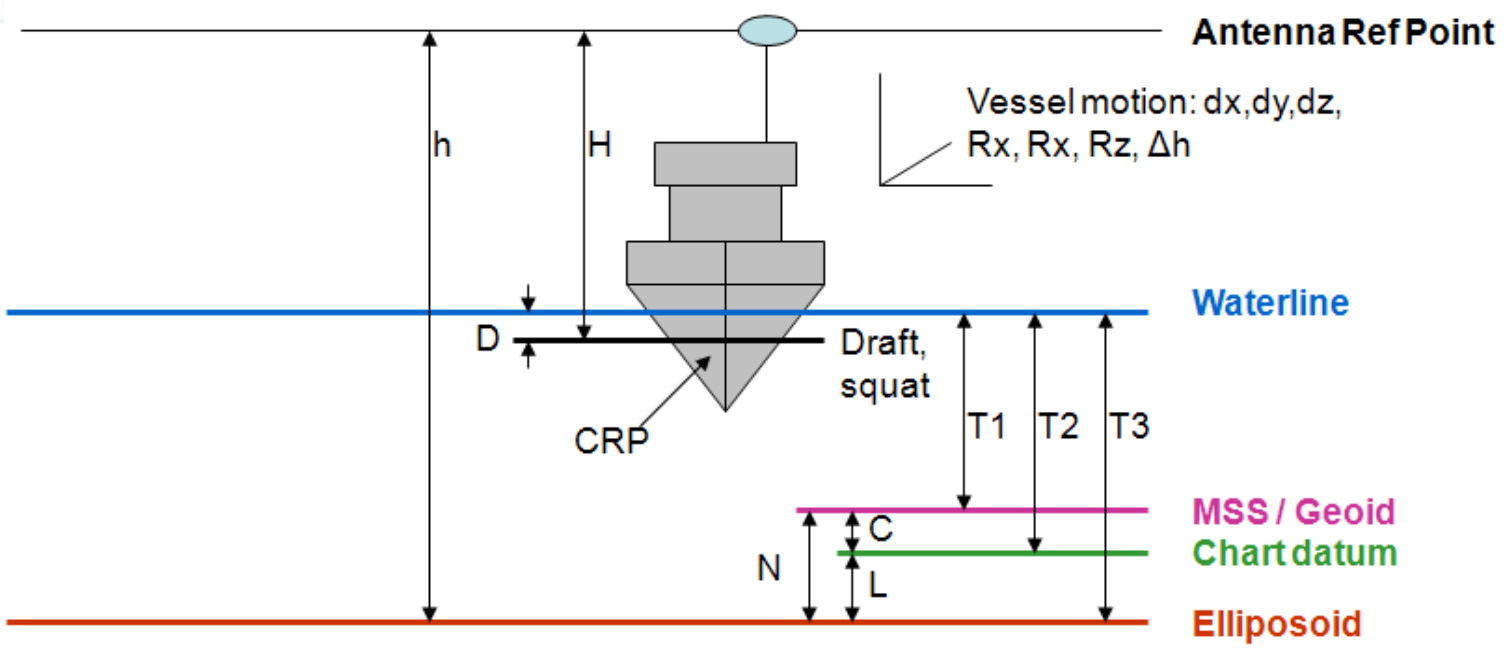
JOB No:
CLIENT:
PROJECT:

Diagram: The surveyor shall provide a diagram showing the points of reference and measurements.

Hour #	Date	Time	Observed Height (H)	Doodson Multiplier (M)	H x M
0				1	0
1				0	0
2				1	0
3				0	0
4				0	0
5				1	0
6				0	0
7				1	0
8				1	0
9				0	0
10				2	0
11				0	0
12				1	0
13				1	0
14				0	0
15				2	0
16				1	0
17				1	0
18				2	0
19				0	0
20				2	0
21				1	0
22				1	0
23				2	0
24				0	0
25				1	0
26				1	0
27				0	0
28				2	0
29				0	0
30				1	0
31				1	0
32				0	0
33				1	0
34				0	0
35				0	0
36				1	0
37				0	0
38				1	0
			Sum =	30	0
			MSL =	Σ (HM) / 30 =	0

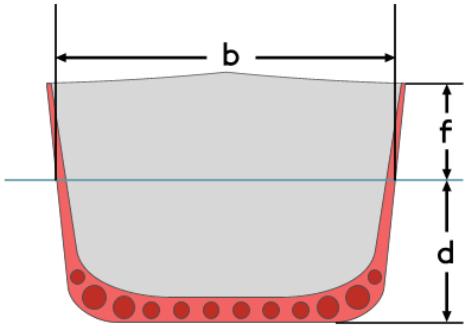
Reducing Antenna Height to Sea Surface

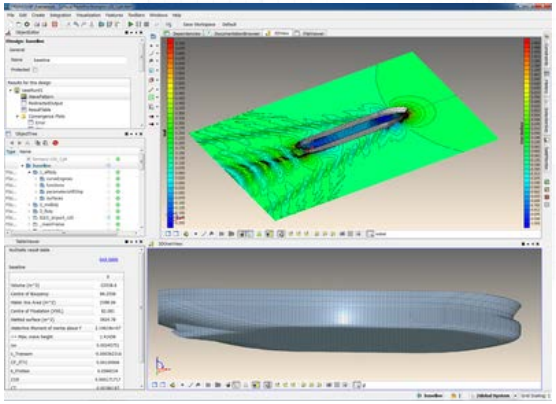
- The vertical offset between the vessel waterline and the GNSS antenna needs to be known
  - Incorrect offset can introduce bias into tide determination when using models
- Need to careful with vessel draft



Vessel Measurements

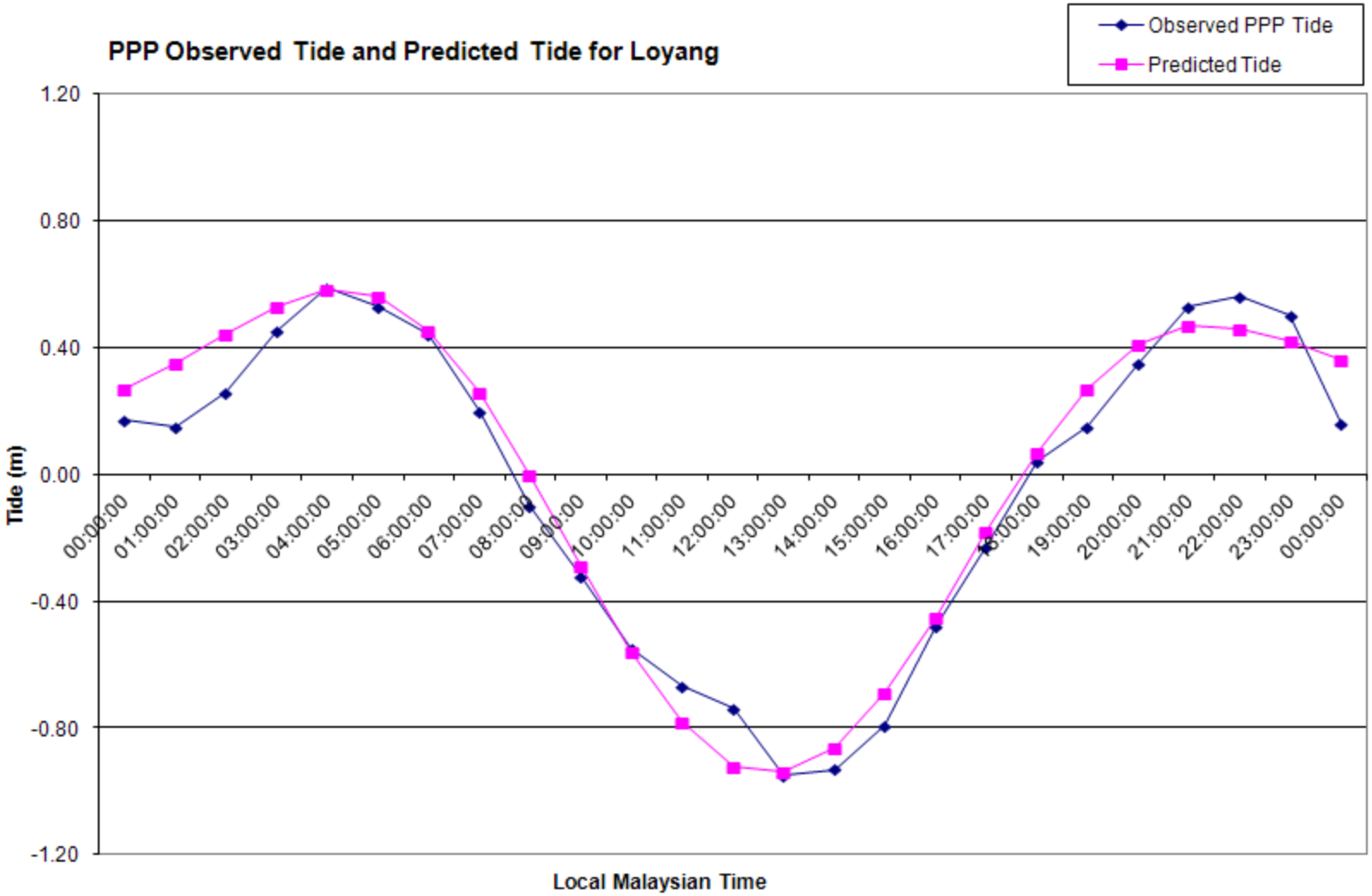
- Draft is important measurement
  - Relate GNSS height to the sea surface
  - Tends to be a dynamic value – use sensors such as laser or radar to measure
  - Affected by vessel operations
- Vessel Squat and its effects on tides is something that is being investigated
  - Impacted by vessel speed





Offshore Results

PPP and Predicted Tides



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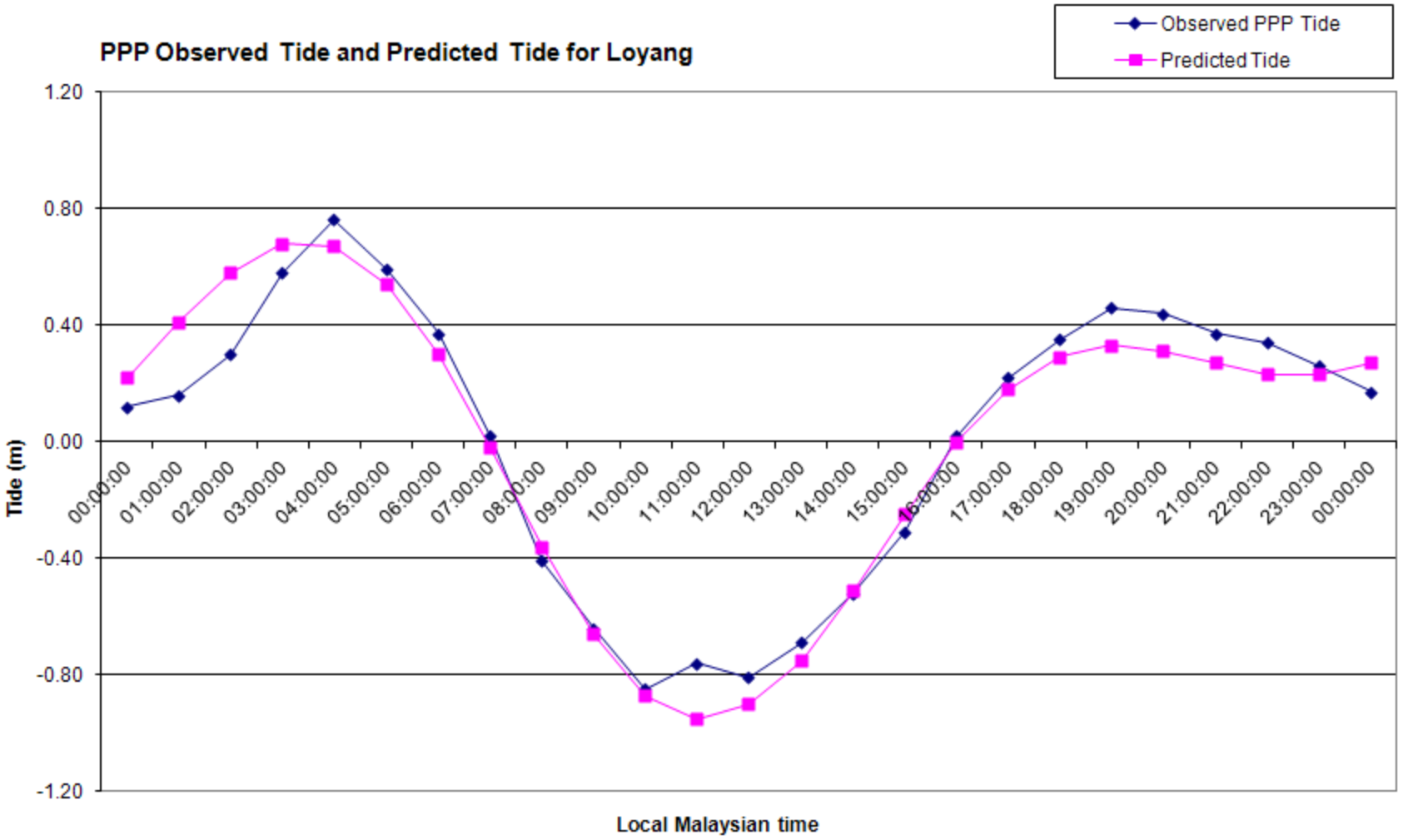

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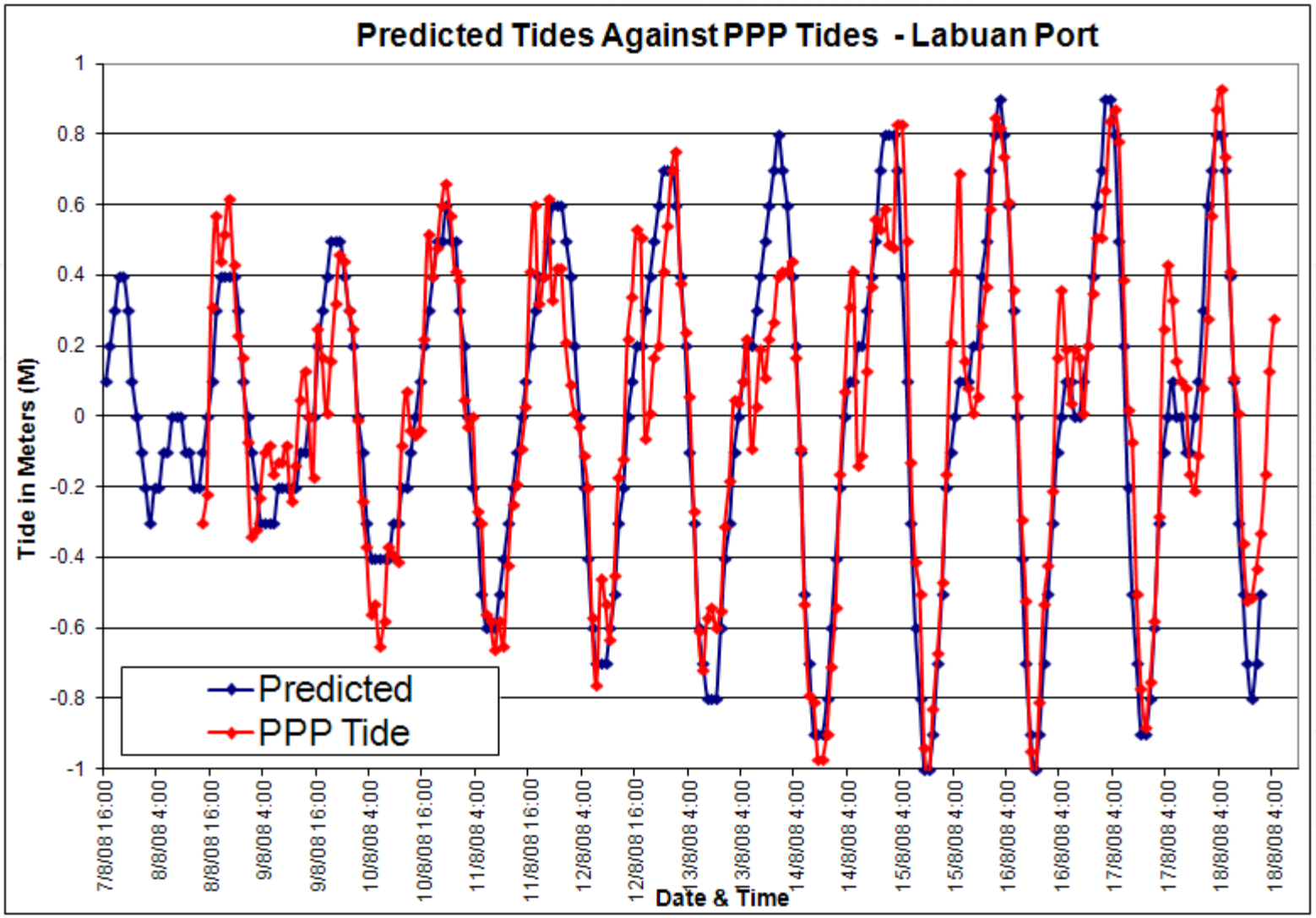

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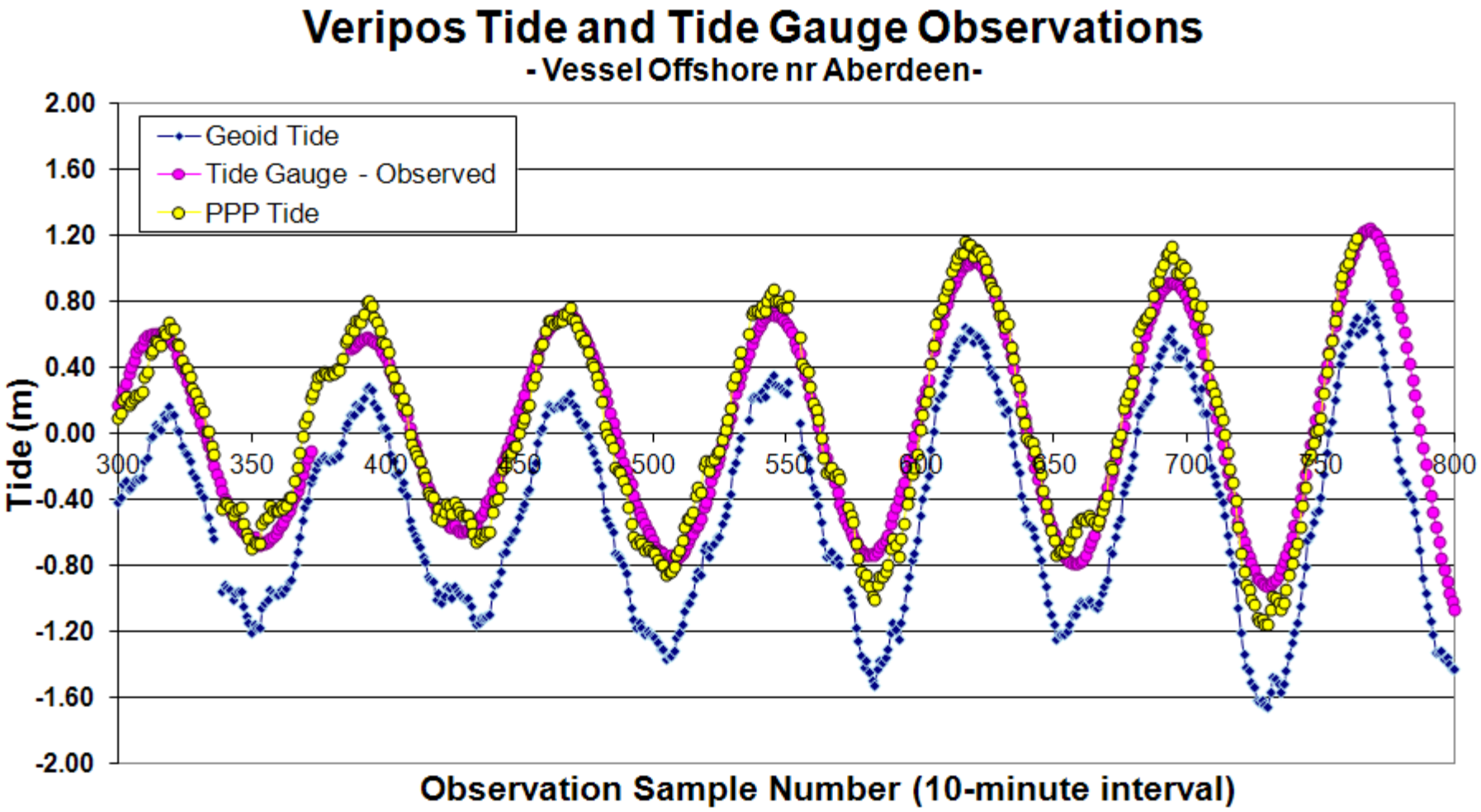

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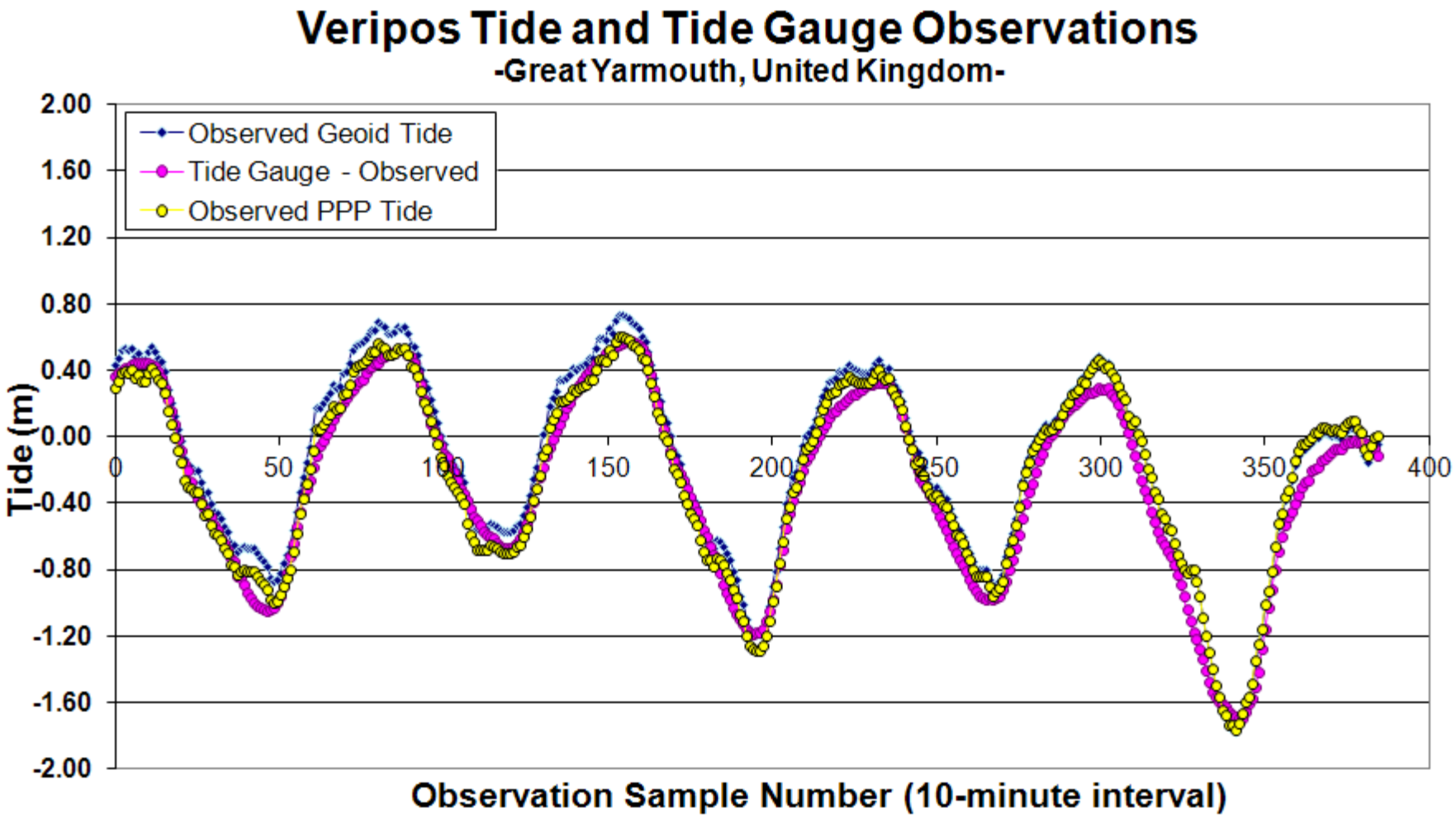
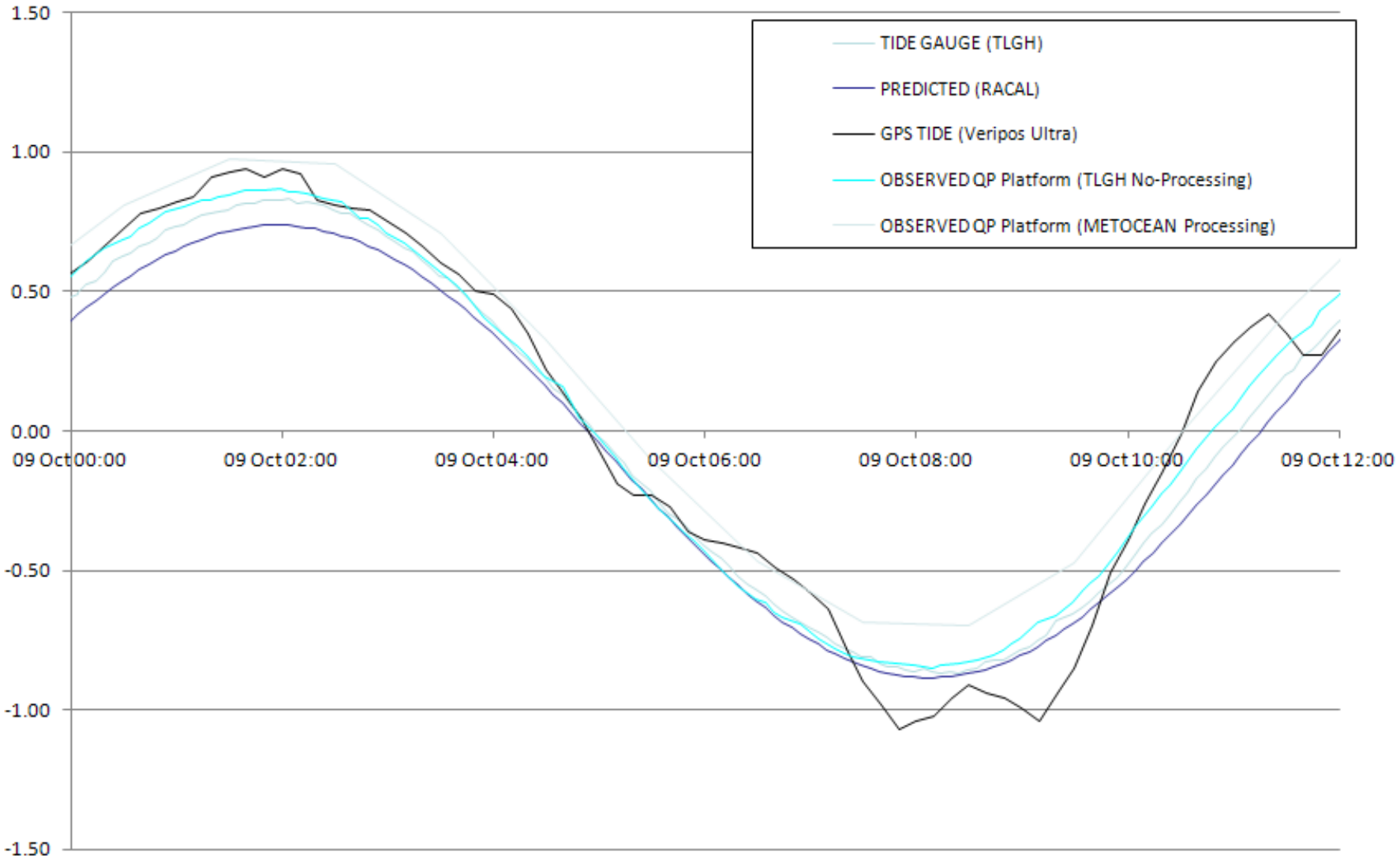
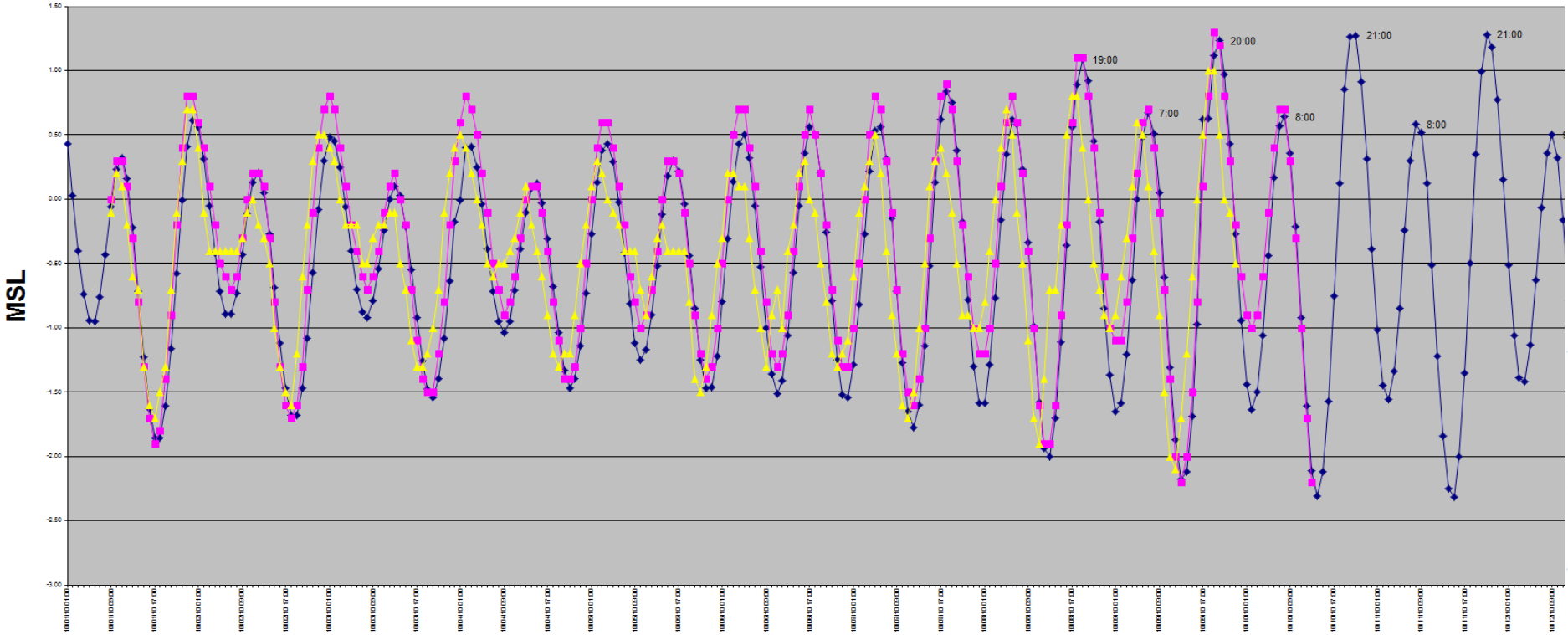


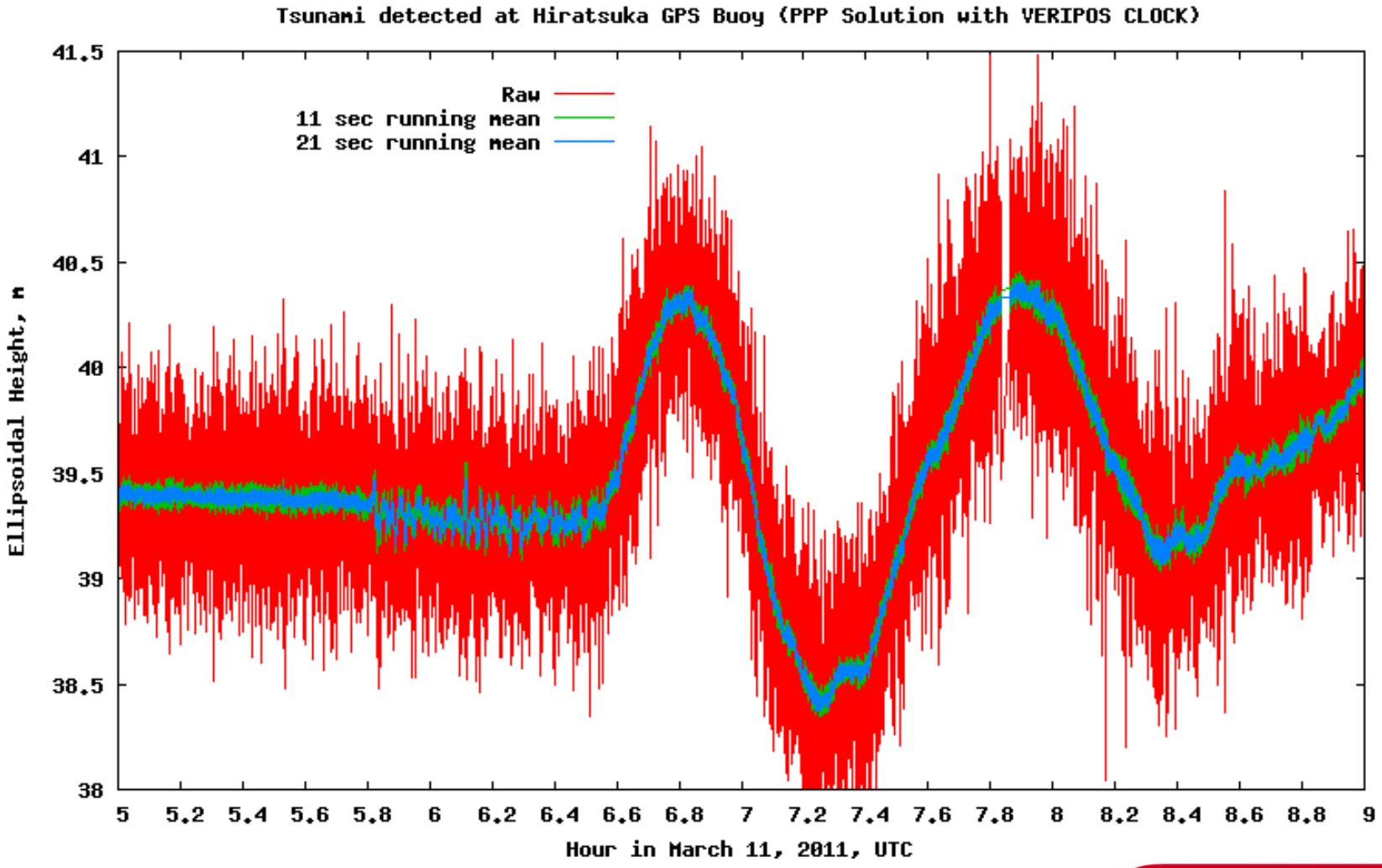
Offshore Results – Far East



Offshore Results v Tide Guage



Tsunami Monitoring – Japan Earthquake March 2011



Conclusions

- Important to understand relationship between vertical datum to ensure ellipsoidal height can be transformed
- Things are gradually getting better…
  - Less complex
  - Real-time reducing post-processing requirement
  - Improved accuracy
- Standardised approach in the future?

VERIPOS

Positioned for Success