Student Presentation, HYDRO 16

Swathe Services

rapidCAST: Analysis of spatio-temporal variability in high resolution sound speed measurements.

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Multi-beam bathymetric survey

- Rapid advance in Multibeam technology over the last decade
- Remaining unknown: Environmental Sound Speed (SS) variability (Gardiner & Slade, 2016)
- Inadequate SS knowledge can result in acoustic wave propagation and refraction errors (Cartwright, & Clarke, 2002)
- Accuracy standards vital in hydrographic surveying (IHO)

"By knowing too much about the water-column, one can objectively quantify the impact of not knowing enough" (Beaudoin *et al*. 2009)

Questions to be answered

- *Spatio-temporal sound speed variability in Plymouth Sound*
- *What is the effect of this sound speed variability on my data?*
- *How often should I take a sound speed profile?*

Plymouth Sound, UK

- Tidal range 2 – 6 metres
- Mean outflow 22.5 m3/s (Dyer 1997)
- Widely used section of waterway
- Shallow Survey data sets 2005 & 2015

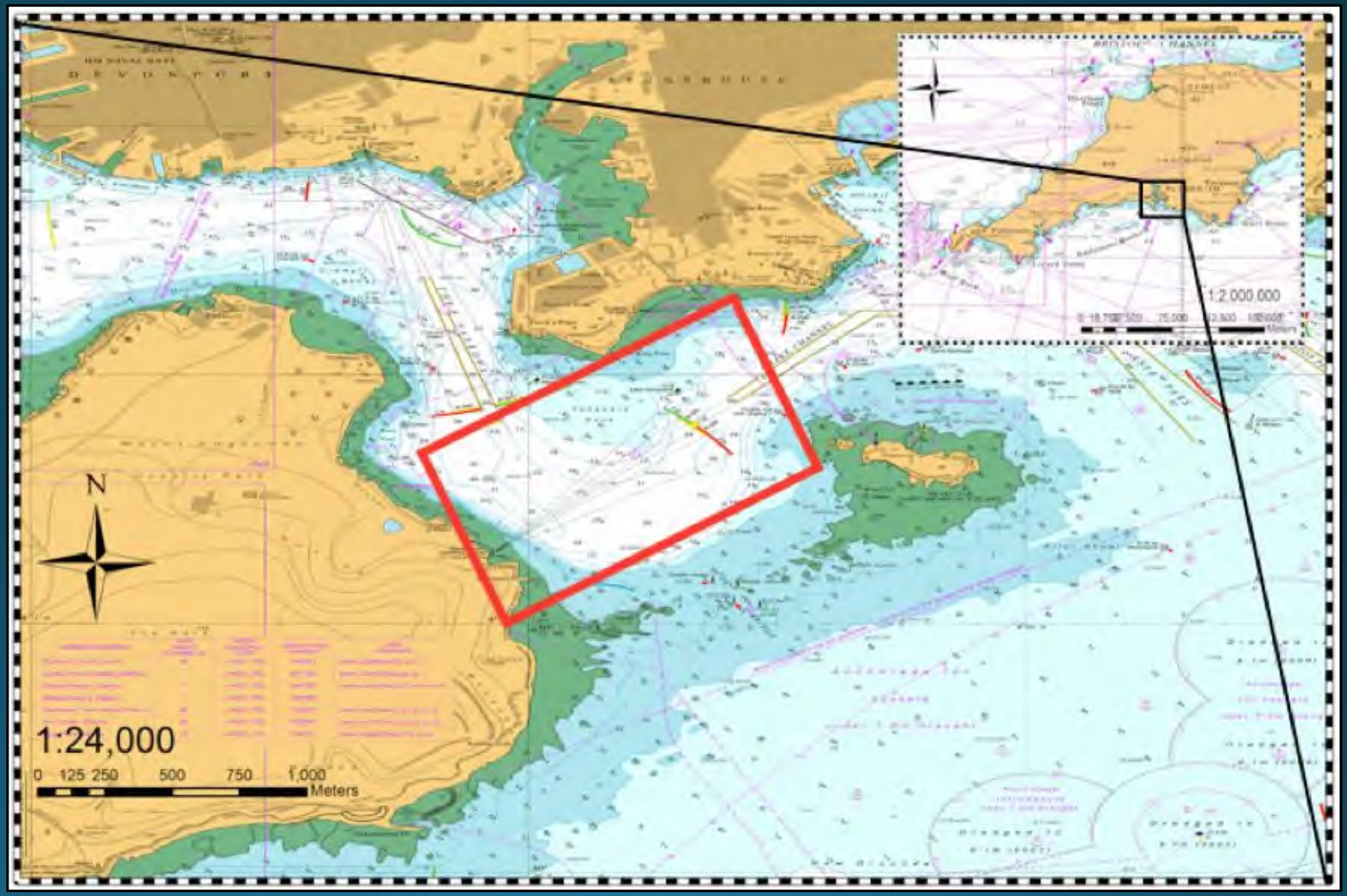


Figure 1: The area of study at the mouth of the Tamar estuary within Plymouth Sound.

Sound Speed variability and its effect on bathymetric data

- SS variability causes acoustic waves to bend and refract
- Application of Sound Speed Profiles (SSPs) can account for refraction effects
- Allows for ray tracing computations
- Beaudoin *et al*. (2009). Uncertainty Wedge Analysis

Table 1: IHO minimum standards for hydrographic surveys, adapted to study site (IHO SP44, 5th Edition 2008).

Order	Special	1a
Maximum allowable Total Horizontal Uncertainty at 95% confidence level	2m	5m + 5% of depth
Derived THU for Study area	**± 2m**	**± 5.775m**
Maximum allowable Total Vertical Uncertainty at 95% confidence level	a= 0.25 m b= 0.0075 m	a= 0.5 m b= 0.013 m
Derived TVU for Study area	**± 0.276 m**	**± 0.539 m**
TVU equation derived from: $\pm\sqrt{[a^2 + (bxd)^2]}$ **Where a= constant depth error, b= factor of depth dependent error, and d= depth**		

Teledyne Oceanscience rapidCAST & Valeport SWiFT SVP

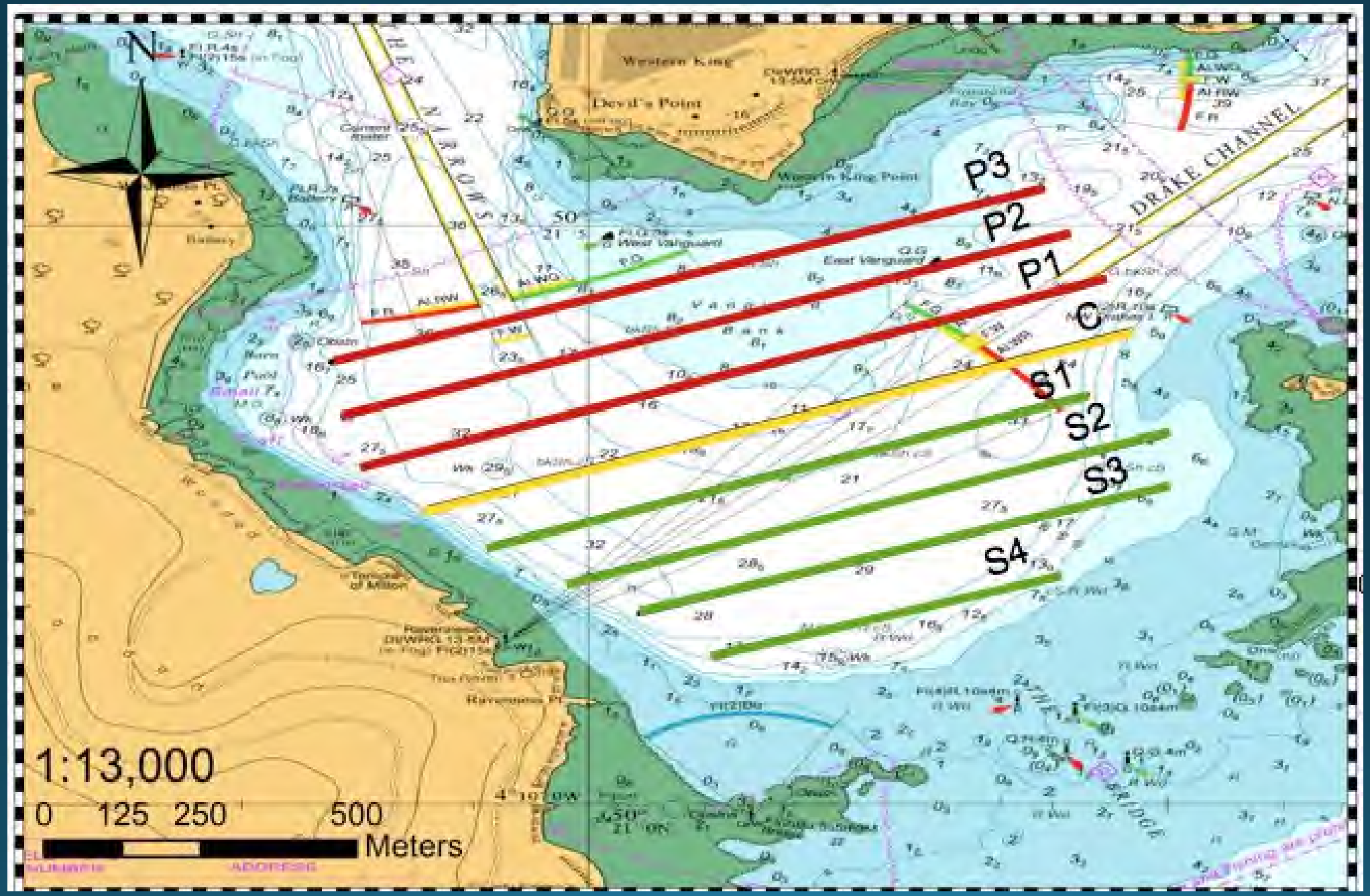


Figure 2. Illustrates the Survey lines that were run repeatedly during data collection.

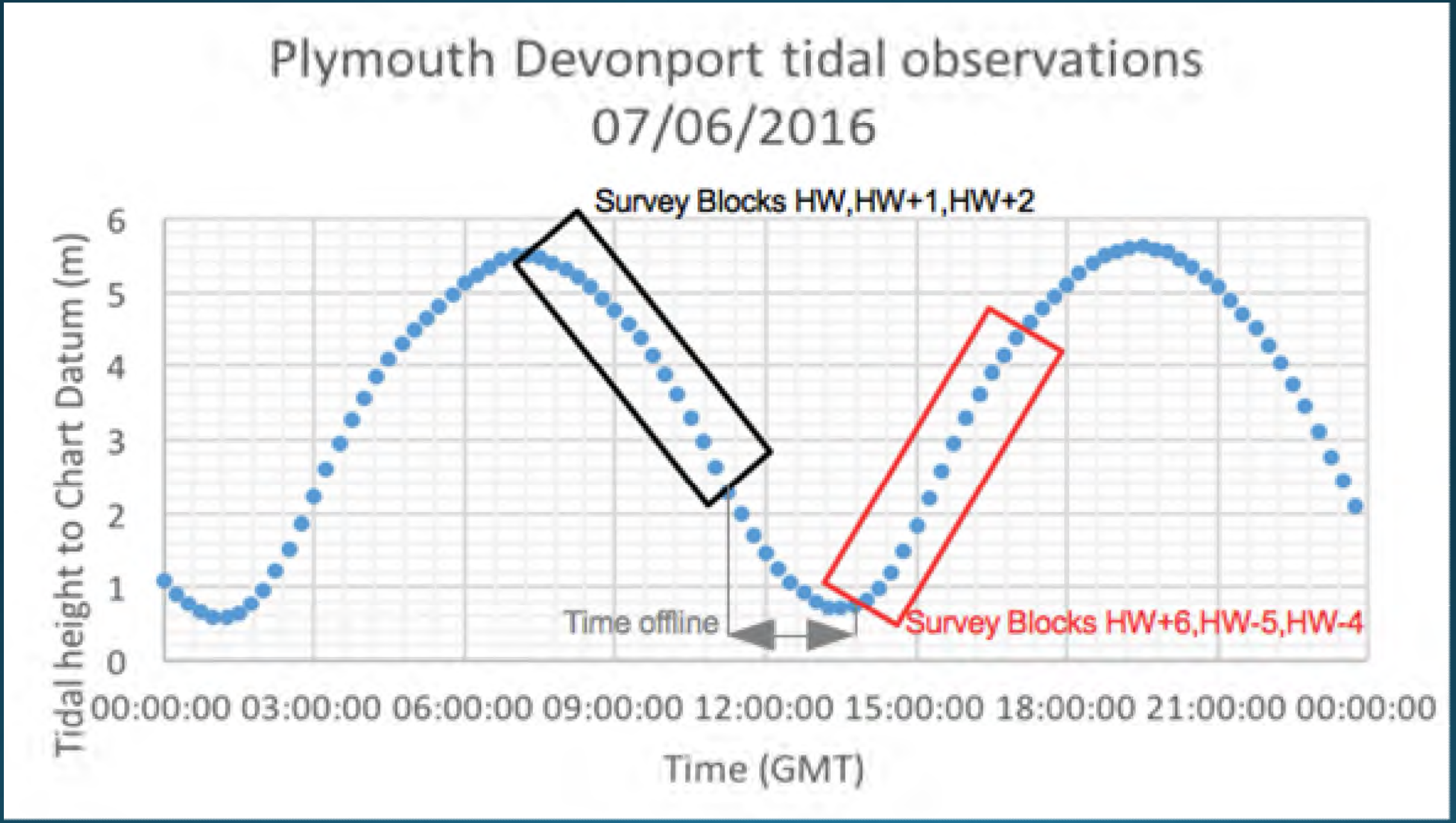


Figure 3. Data Acquisition periods showing survey blocks completed through the tidal cycle.

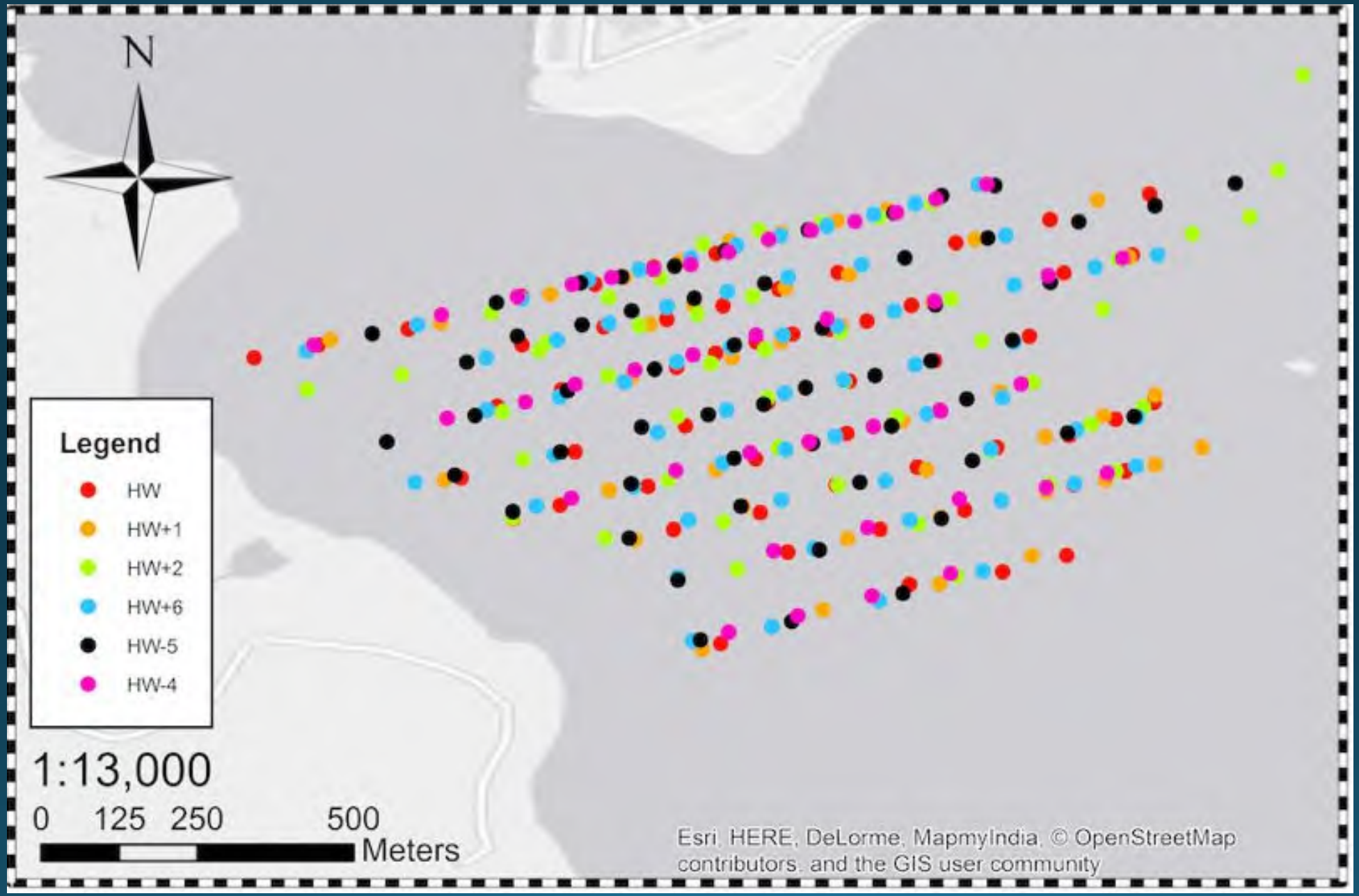
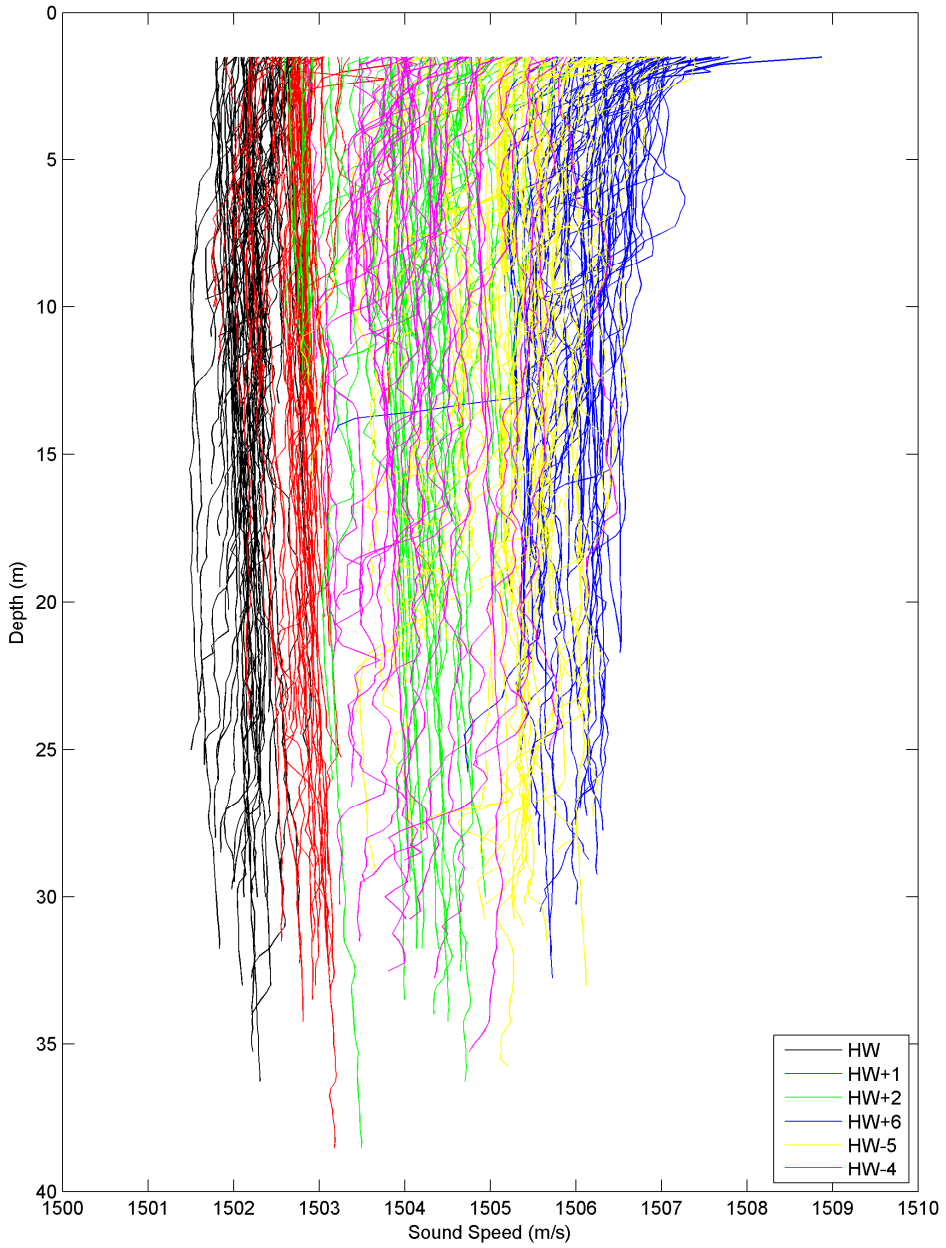


Figure 4: Total casts distribution over the survey area colour coded by survey block.



Prediction:
SS reduction at lower tidal period

Observed: Sound speed increase from HW to HW+6, decreasing thereafter

- Minimum: 1501.483 ms^{-1} at HW
- Maximum: 1508.876 ms^{-1} at HW+6
- Range 7.393 ms^{-1}

Figure 5: All Sound Speed Profiles colour coded by survey block.

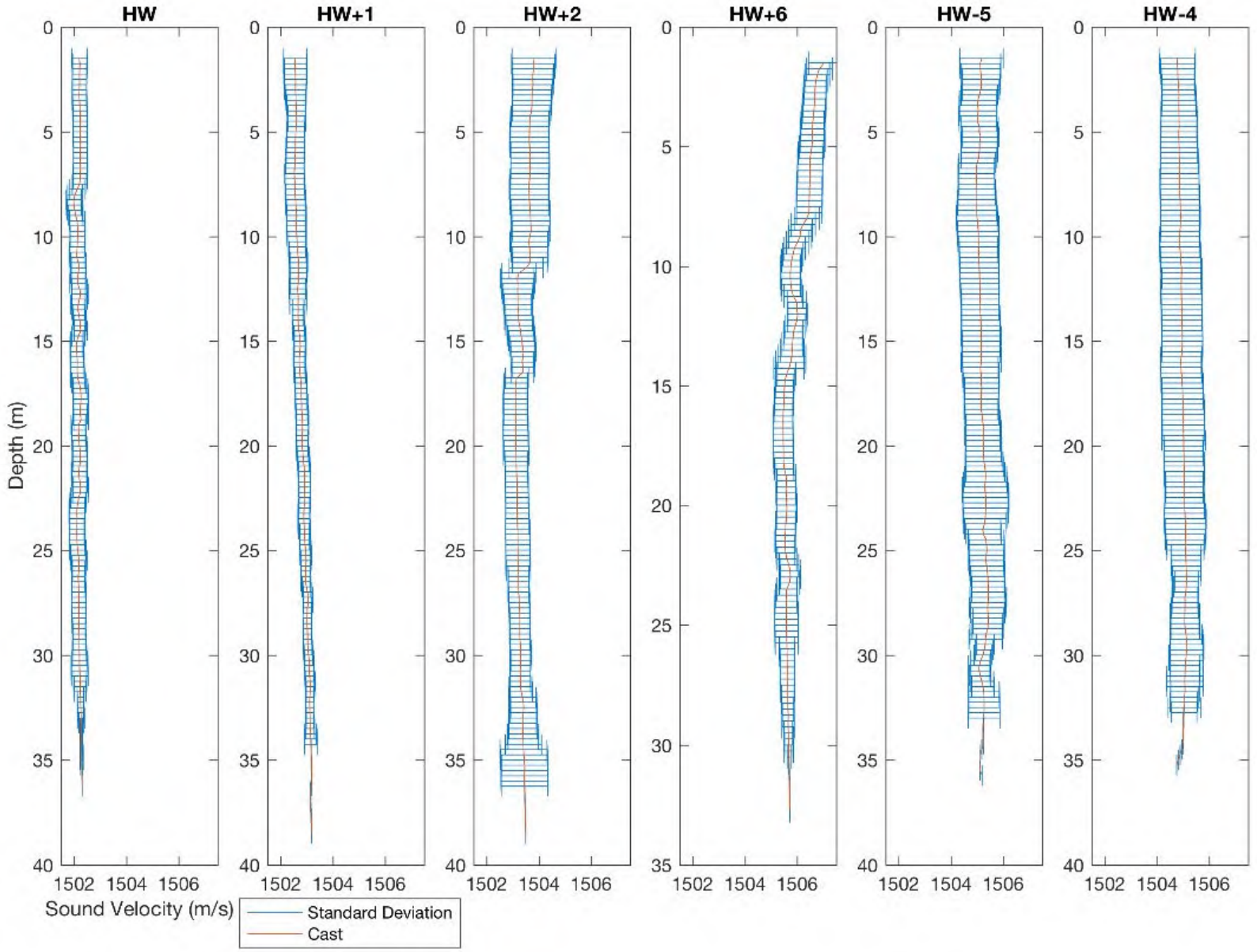


Figure 6: Block variance (Deepest cast compared to all other profiles within block)

Table 2. Measured sound speed uncertainty contributions by block split into vertical and Horizontal error budget contribution.

Block	Sound Speed (m s^{-1})			Maximum Vertical Error (m)		% of error budget	Maximum Horizontal Error(m)		% of error budget
IHO Special order				±0.276			±2.000		
	Min	Max	Range						
HW	1501.48	1502.92	1.5	-0.07	+0.09	**32%**	-0.21	+0.26	12%
HW+1	1501.73	1504.86	3.13	-0.04	+0.16	**36%**	-0.11	+0.45	14%
HW +2	1502.59	1506.17	3.58	-0.13	+0.08	**38%**	-0.37	+0.24	15%
HW+6	1503.18	1508.87	5.69	-0.11	+0.22	**59%**	-0.30	+0.62	23%
HW-5	1502.78	1507.39	4.61	-0.16	+0.14	**54%**	-0.46	+0.38	21%
HW-4	1502.86	1506.48	3.62	-0.14	+0.15	**52%**	-0.39	+0.46	21%
November HW-3	1493.92	1503.07	9.15	-0.12	+0.74	**155%**	-0.36	+2.14	63%

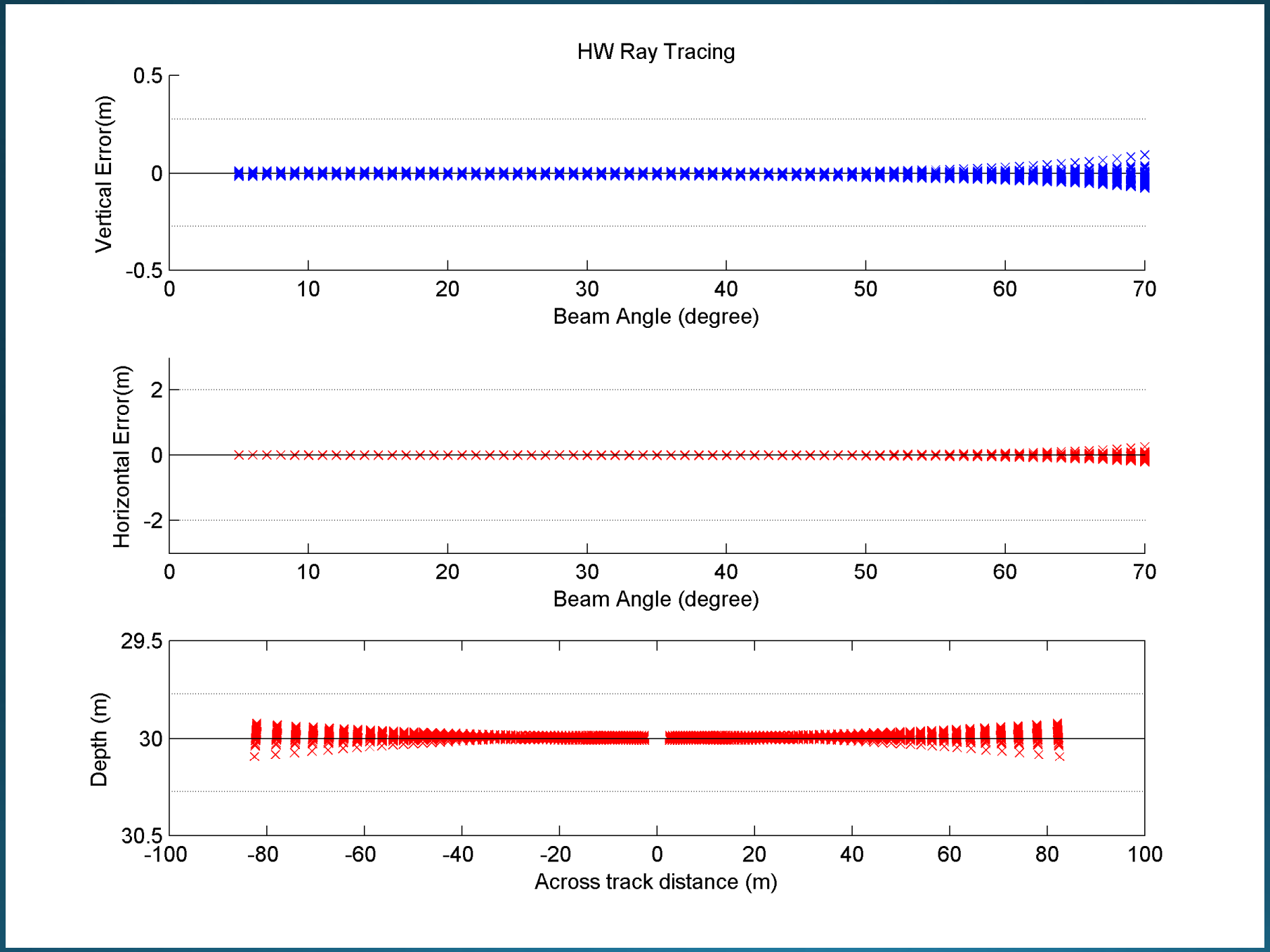


Figure 7. Ray Tracing for HW (Dashed lines represent IHO special order limits.) errors

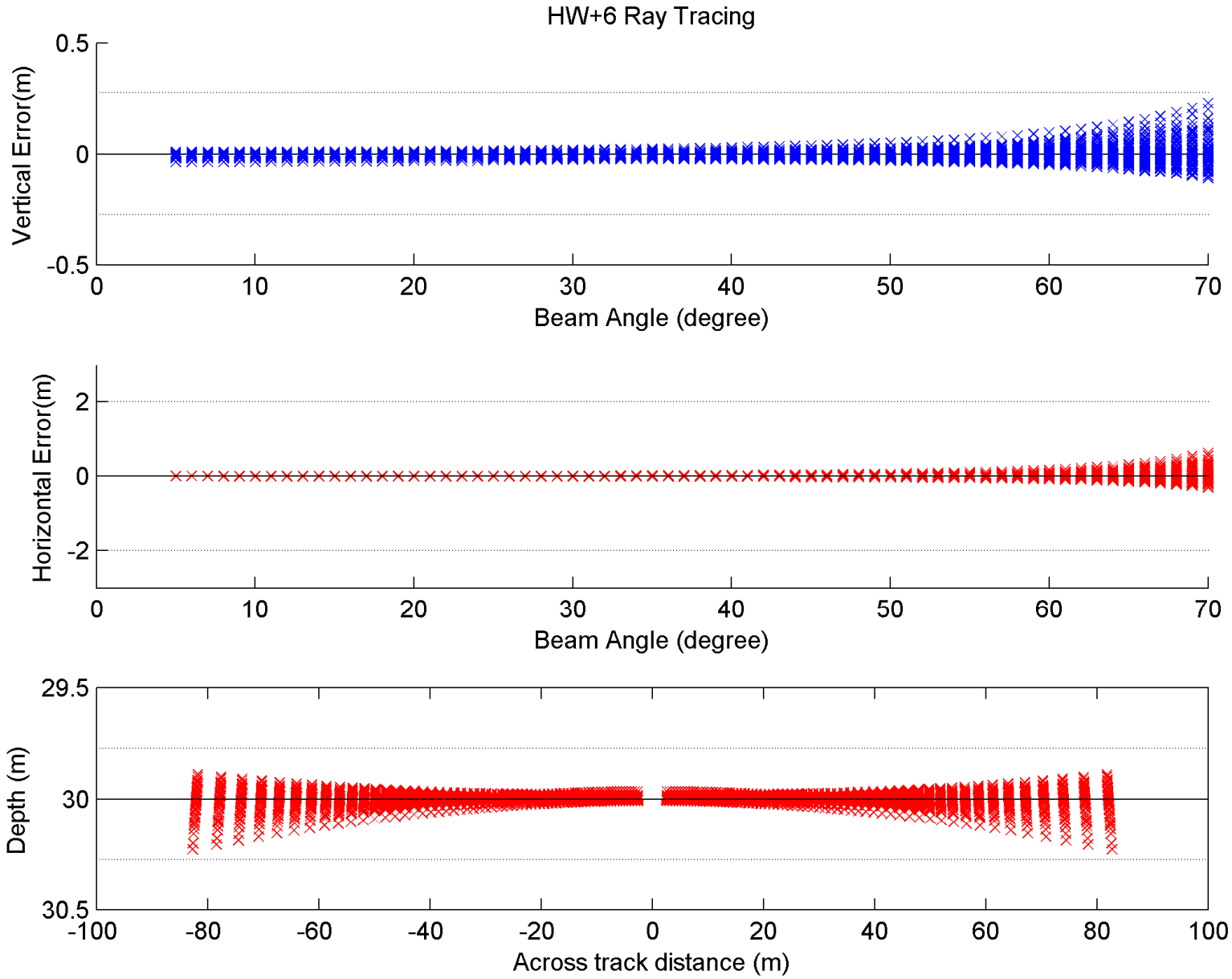


Figure 8. Ray Tracing for HW+6 (Dashed lines represent IHO special order limits.) errors

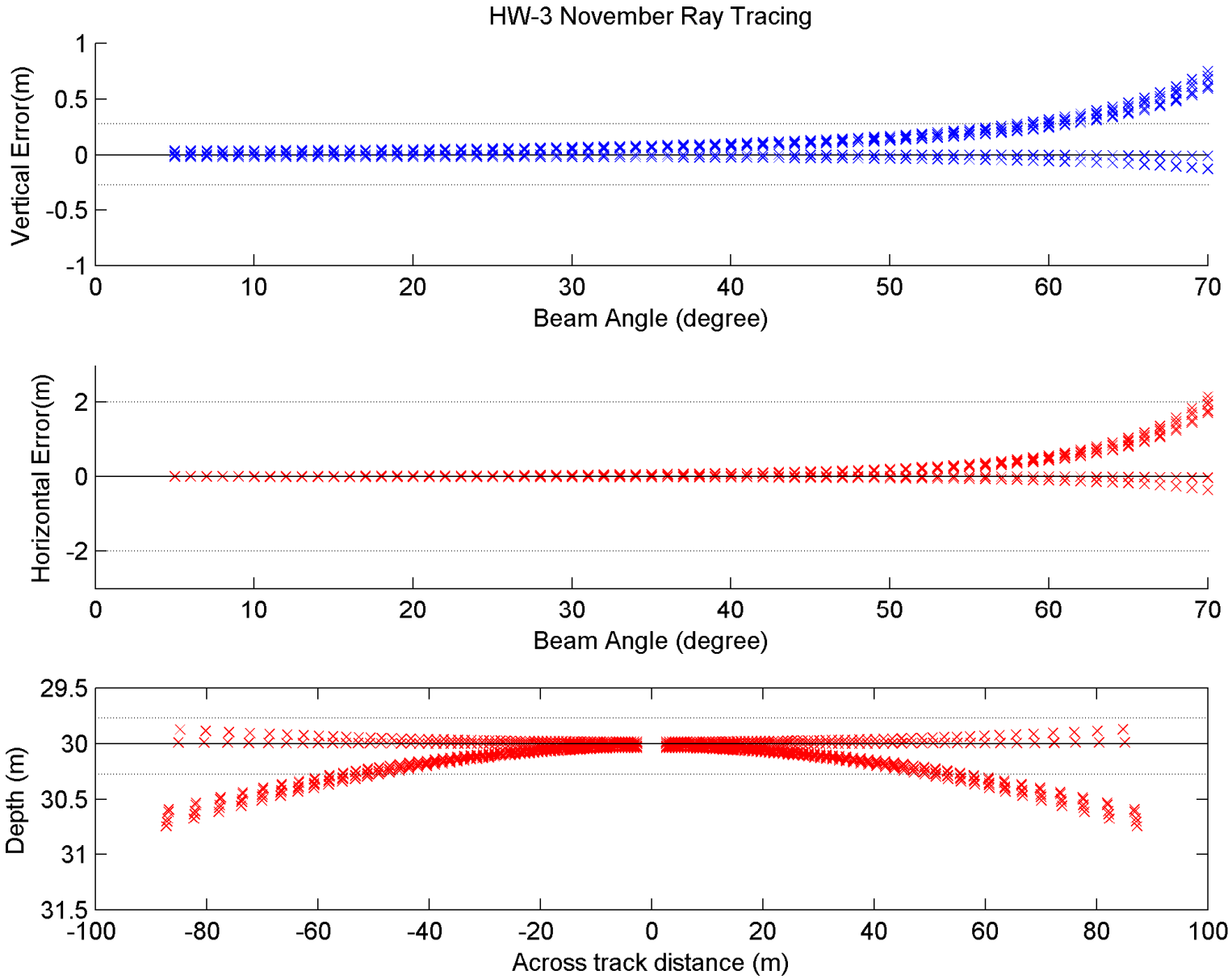


Figure 9. Ray Tracing errors for November Transect. (Dashed lines represent IHO special order limits.)

Conclusions

What is the effect of this variability on my data?

- June data
  - IHO Special Order not exceeded
  - Sound Speed variability had significant contribution to error budgets
  - 30%-59% TVU
  - Implications for volume calculations
- November data
  - Exceeds both THU and TVU error budgets for special order
  - Magnitude of error should be detected immediately

Conclusions

How often should I take a sound speed profile?

- Higher frequency casts reduce uncertainty values
- Prior knowledge of the temporal and spatial oceanographic variability and controlling factors
- Traditional "static cast" technique is balancing act
- Rapid and automated collection is practical and feasible
- **Better to have data you don't need than to not have data you do need!**

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- Dr Tim Scott, Plymouth University
- Mr Iain Slade, Fugro Academy

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