Sonardyne
SOUND IN DEPTH

Absolute accuracy and repeatability… what can be expected?

Malik Chibah,
Subsea INS Manager, Sonardyne

Absolute accuracy and repeatability… what can be expected?

1. **Introduction**
2. Understanding characteristics of the positioning system
3. Planning and analysis
4. Real time considerations
5. What help is available to answer this question going forward?
6. Conclusion

Introduction

- Absolute accuracy and repeatability (for subsea positioning systems)….what can be expected?
- Very difficult question to answer!
- <u>Many</u> factors involved…it is not just a simple case of looking on a data sheet (can be misleading)
- Pragmatic approach:
  - Understanding characteristics of the positioning system
  - Planning and analysis
  - Real time considerations
  - What help is available to answer this question going forward?

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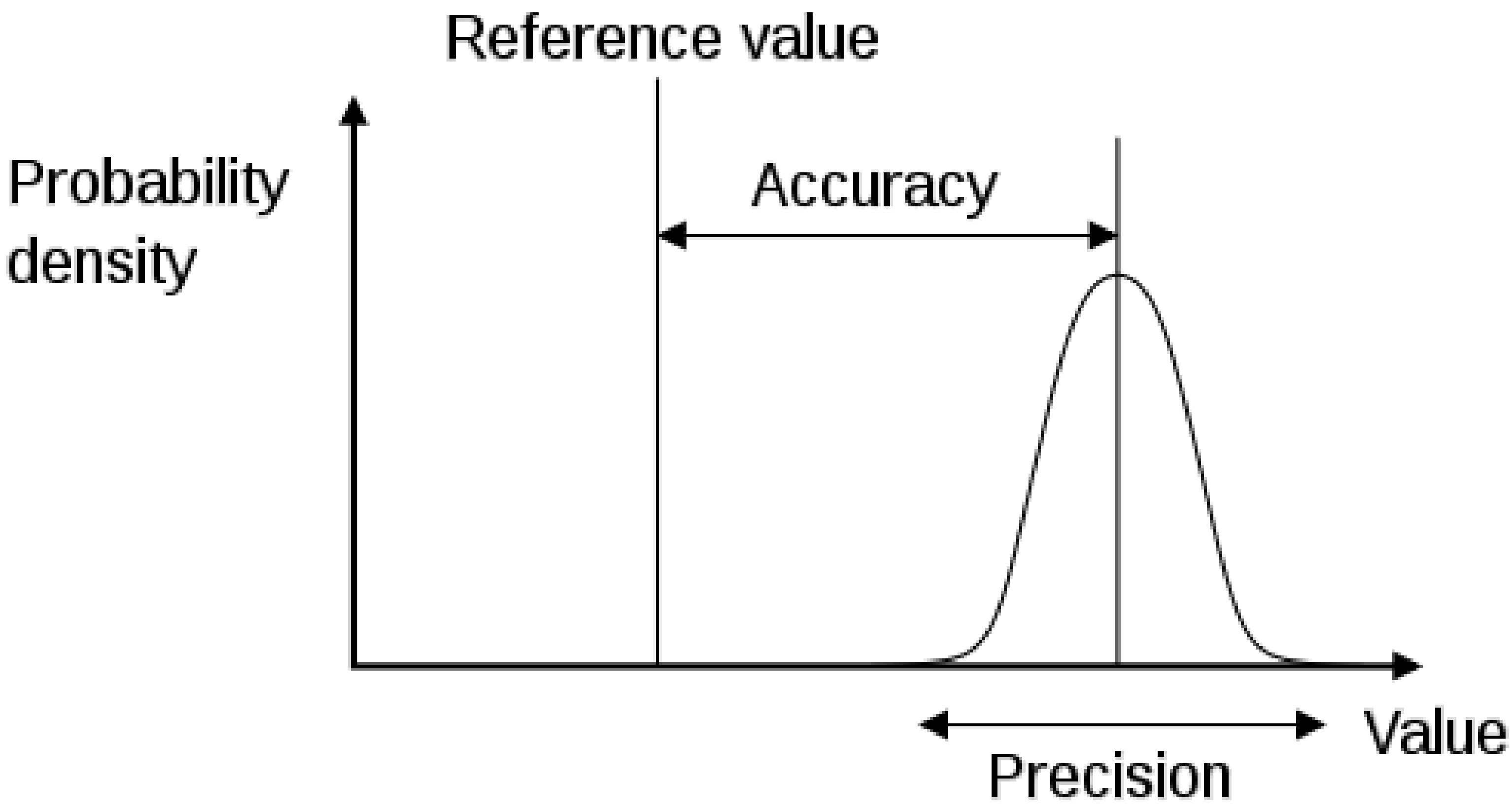
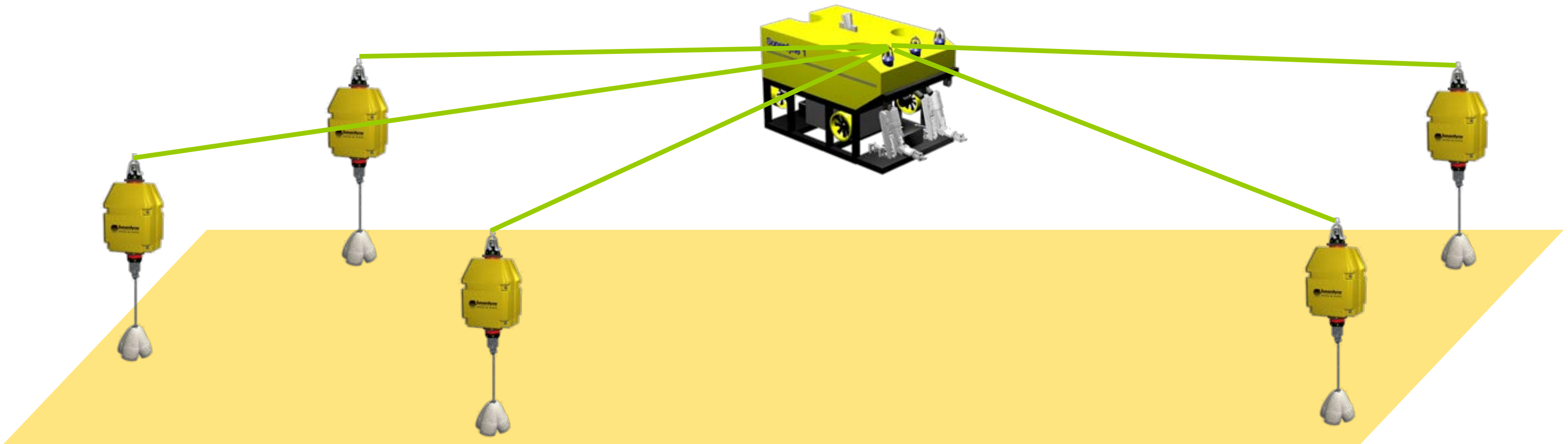
Accuracy and Precision in 1D



Characteristics of the Positioning System: **L**ong **B**ase **L**ine (LBL) Positioning

- Positioning relative to an array of seabed transponders deployed at fixed and known locations.
- Precision dependent upon: range precision
  array size & geometry
  depth sensor precision
- Accuracy dependent upon: range measurements,
  sound speed
  transponder positions (box in & calibration)

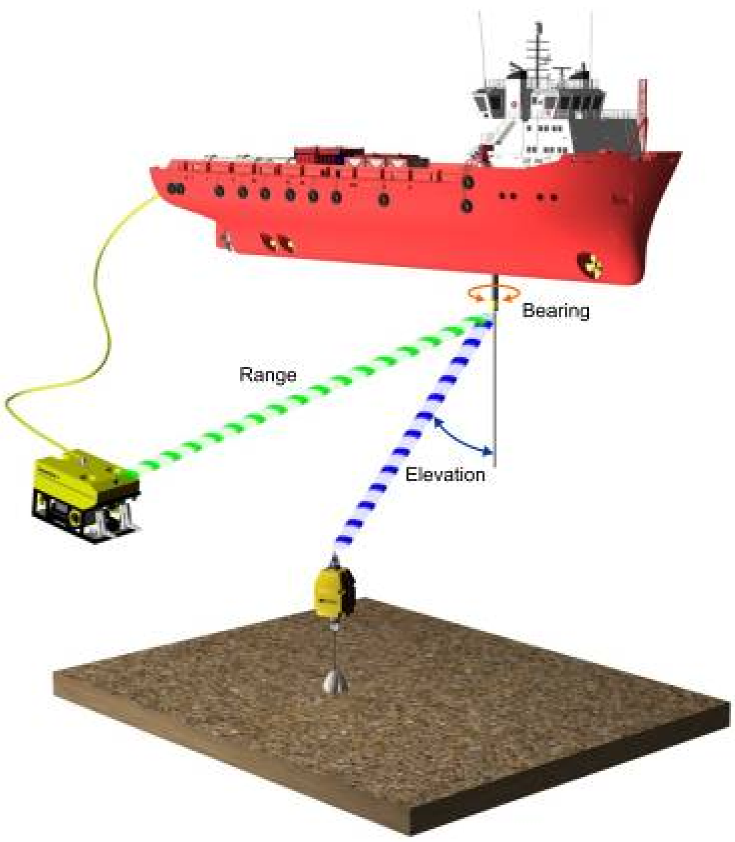


Characteristics of the Positioning System: Principal error sources in LBL

Random	Systematic	Mistake / Gross
Range 'jitter' due to in-band noise	Sound speed	Incorrect TAT applied in computation of range from timing observation
Transponder timing	Incorrect offsets	Multipath
	Un-calibrated or using in-correct calibration figures	Ray bending
	Float deflection	
	Tide	

The least squares stochastic model is concerned with random error only. Least squares does not *usually* account for systematic errors, however some gross errors should be rejected by the least squares process.

Characteristics of the Positioning System:
Ultra **S**hort **B**ase**L**ine (USBL) acoustic positioning



•Range and bearing measurement of transponder position relative to USBL transceiver

Accuracy decreases with depth:

1-2m per 1000m depth (dependant on SNR)

Modern strap-down inertial sensors (AHRS) improve accuracy:

-0.12% slant range (6m, 1DRMS) was achieved in 4950m water depth.

-Deep water: Update rate ~5 sec @ 3000m

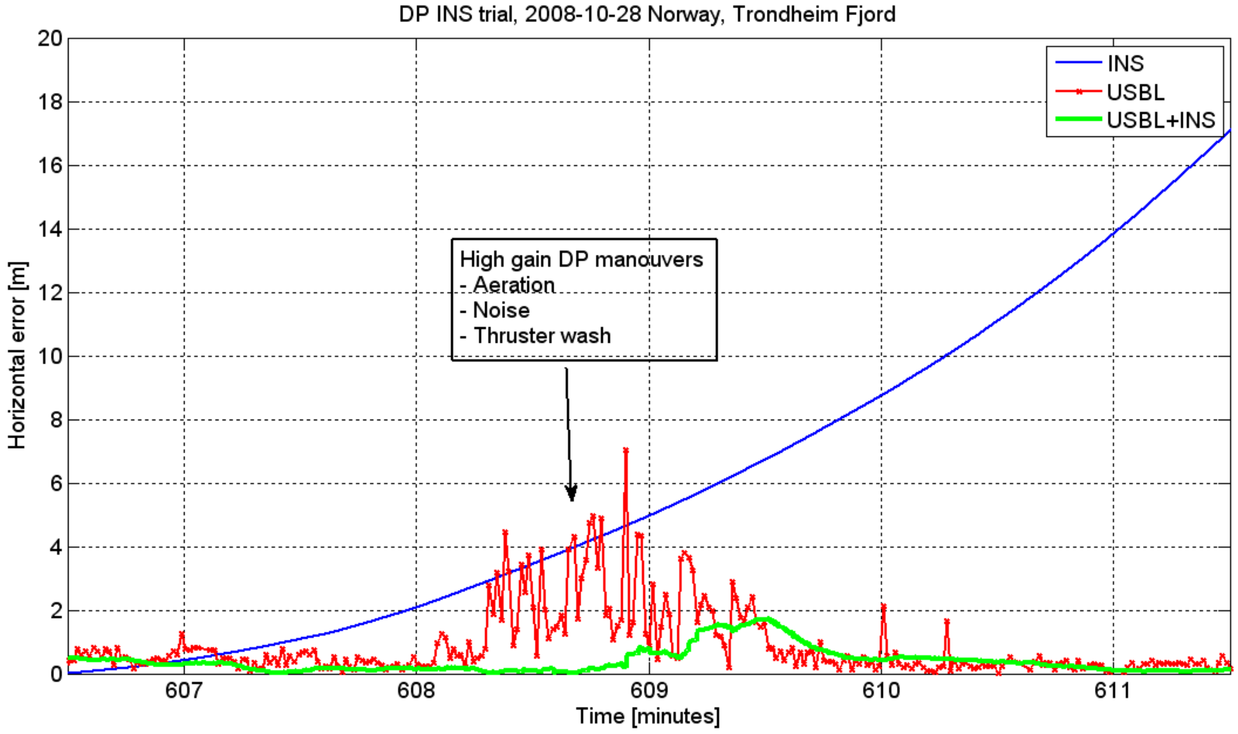
Characteristics of the Positioning System: Principal error sources in USBL

Random	Systematic	Mistake
Range 'jitter' due to in-band noise	**Sound speed**	Incorrect TAT applied in computation of range from timing observation
Transponder timing	**Incorrect offsets**	Multipath
Attitude or gyro sensor drift	**Un-calibrated or using in-correct calibration figures**	
Angle Measurement		

The observation model for the position solution is based on standard (random) error only.

Characteristics of the Positioning System: **A**coustically **A**ided **INS** (AAINS)?

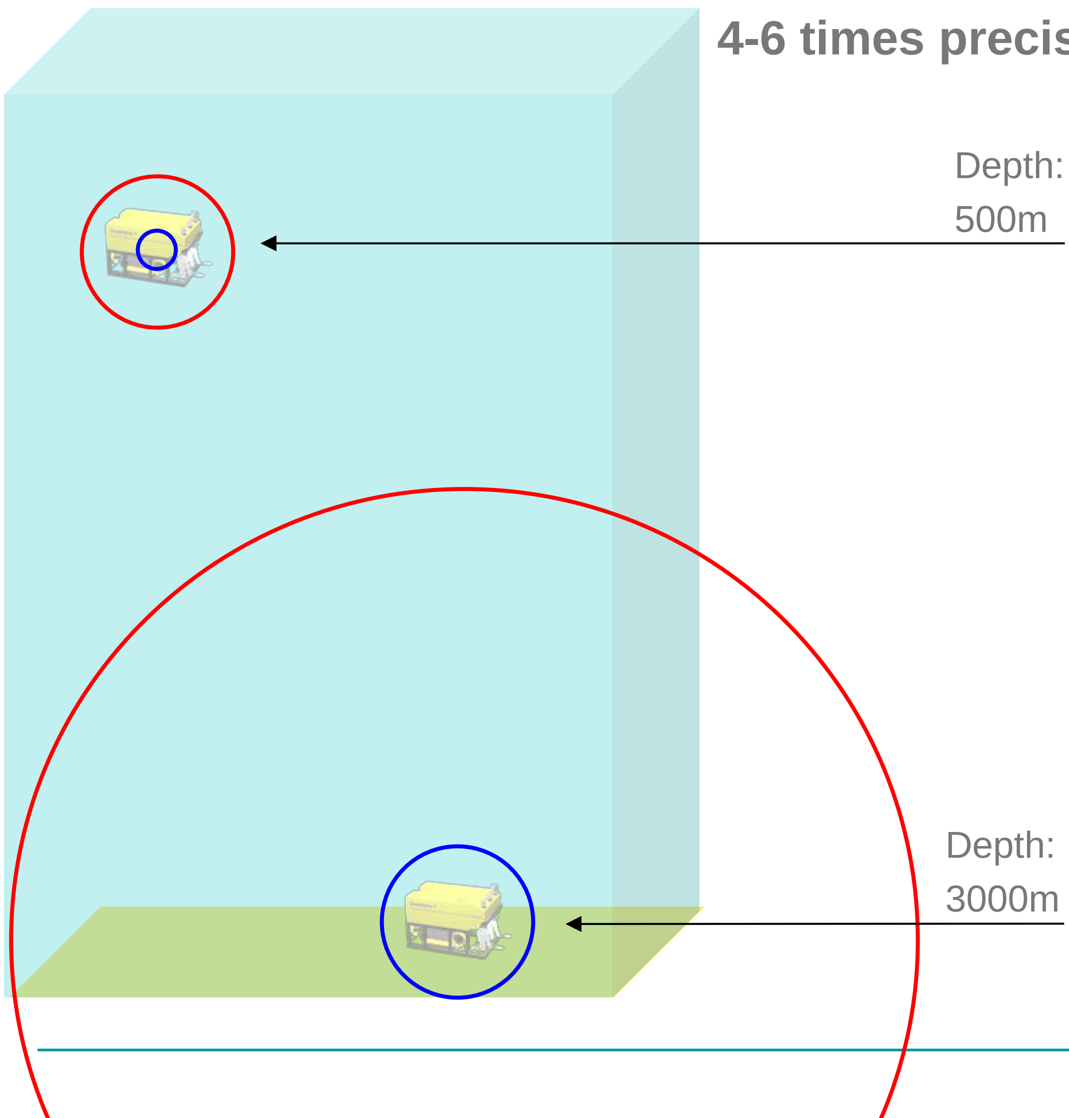
- INS:
  - Good <u>short term accuracy</u> but long term drift
  - Inherently self-contained and robust
  - High update rate
- Acoustics:
  - Good <u>long term accuracy</u>
  - Precision can degrade with depth and environment (SNR)
- AAINS:
  - Accuracy and robustness
  - 'Best of both worlds'



Characteristics of the Positioning System:
USBL vs. SPRINT (USBL & DVL) INS Precision

USBL + DVL Aided SPRINT INS:

4-6 times precision improvement over 'raw' USBL



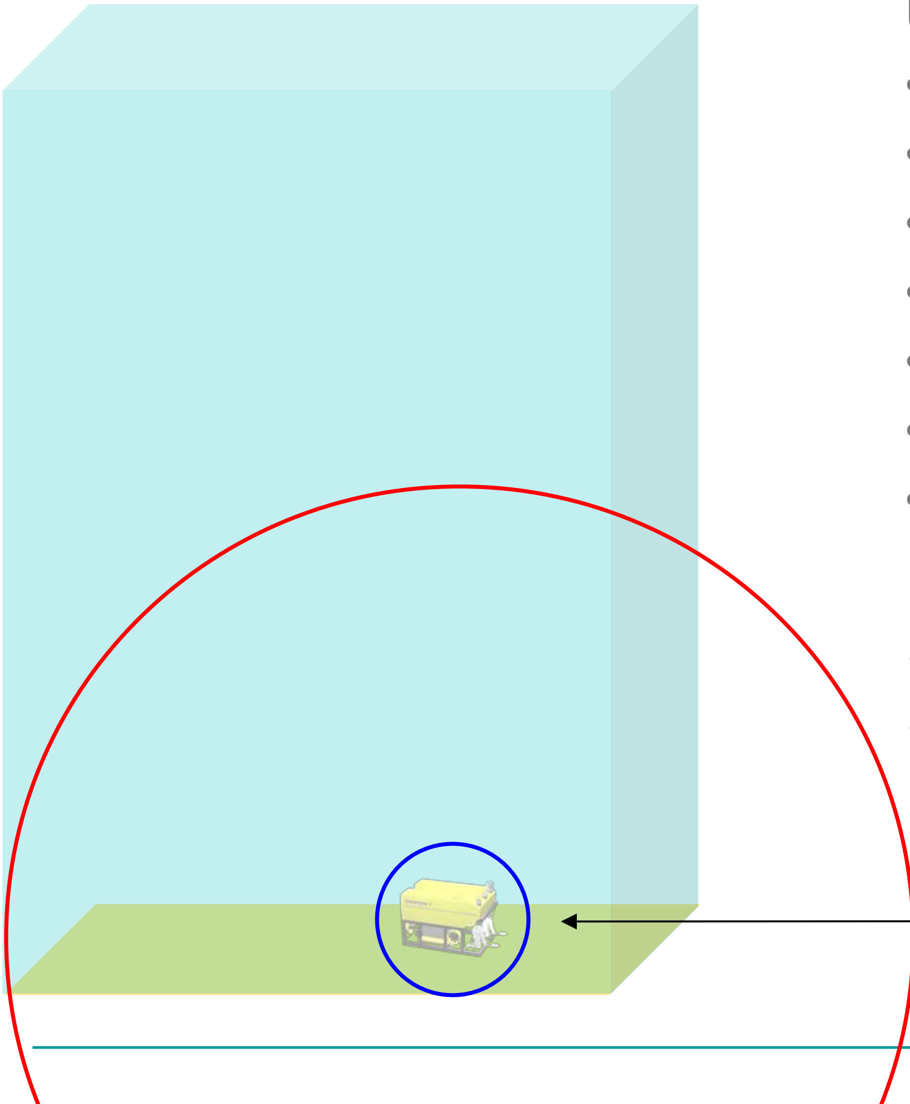
USBL ± 1m

SPRINT (USBL & DVL) ± 0.2m

USBL ± 6m

SPRINT (USBL & DVL) ± 1m

Characteristics of the Positioning System: USBL & SPRINT (USBL & DVL) INS: Systematic Errors



USBL Sources of Error:

- Blunder (Offset, Incorrect Survey Config.)
- DGPS (e.g. Loss of corrections)
- Sound Velocity Profile
- Multipath
- Vessel Attitude Sensor Quality
- Poor/Incorrect Calibration
- Etc.

USBL Aided INS:

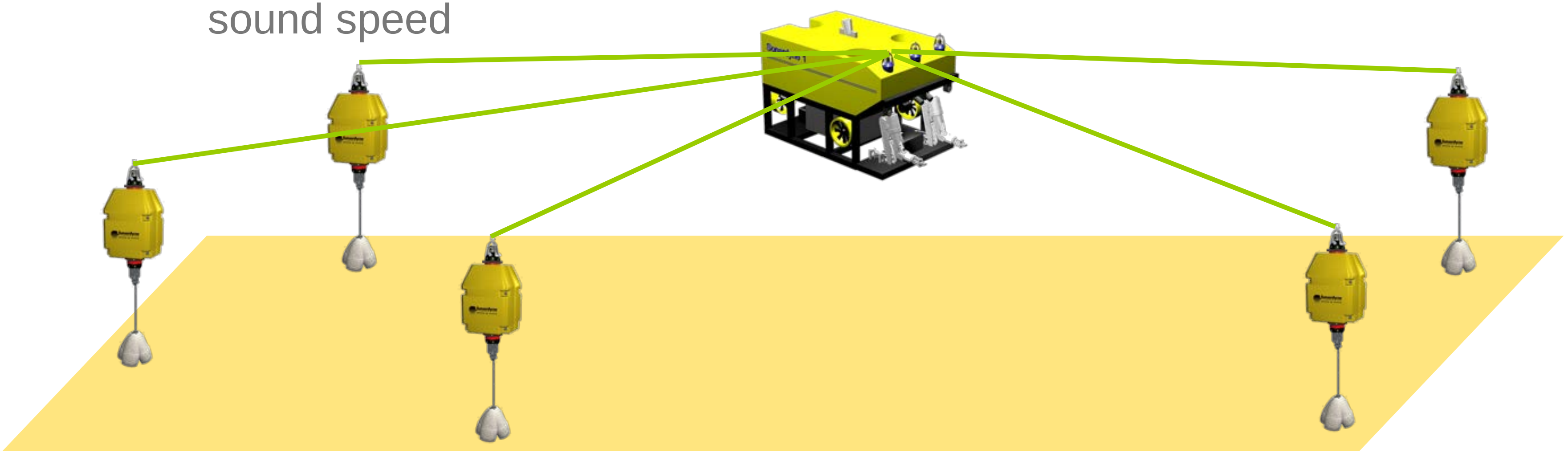
- Can reject short-term position outliers
- Will not resolve USBL systematic errors

Depth:
3000m

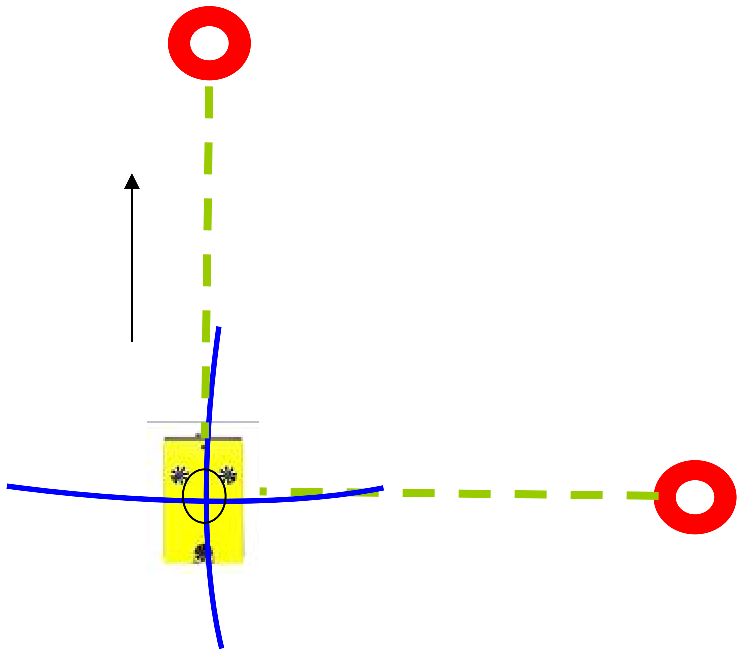
USBL ± 6m
SPRINT (USBL & DVL) ± 1m

Characteristics of the Positioning System: (SPRINT) LBL INS

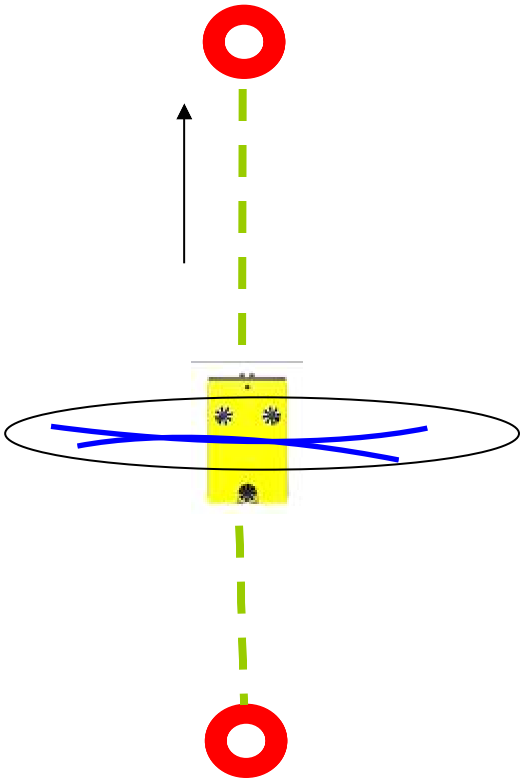
- Dramatically enhanced robustness over acoustics only:
  - Resilience to acoustic outages & outliers
  - High update rate
- Accuracy with 2 or more transponders:
  - Centimetre level (dynamic) similar to conventional static LBL (**)
  - Requires:
    - Good geometry
    - Excluding effect introduced by errors in transponder position/depth and sound speed



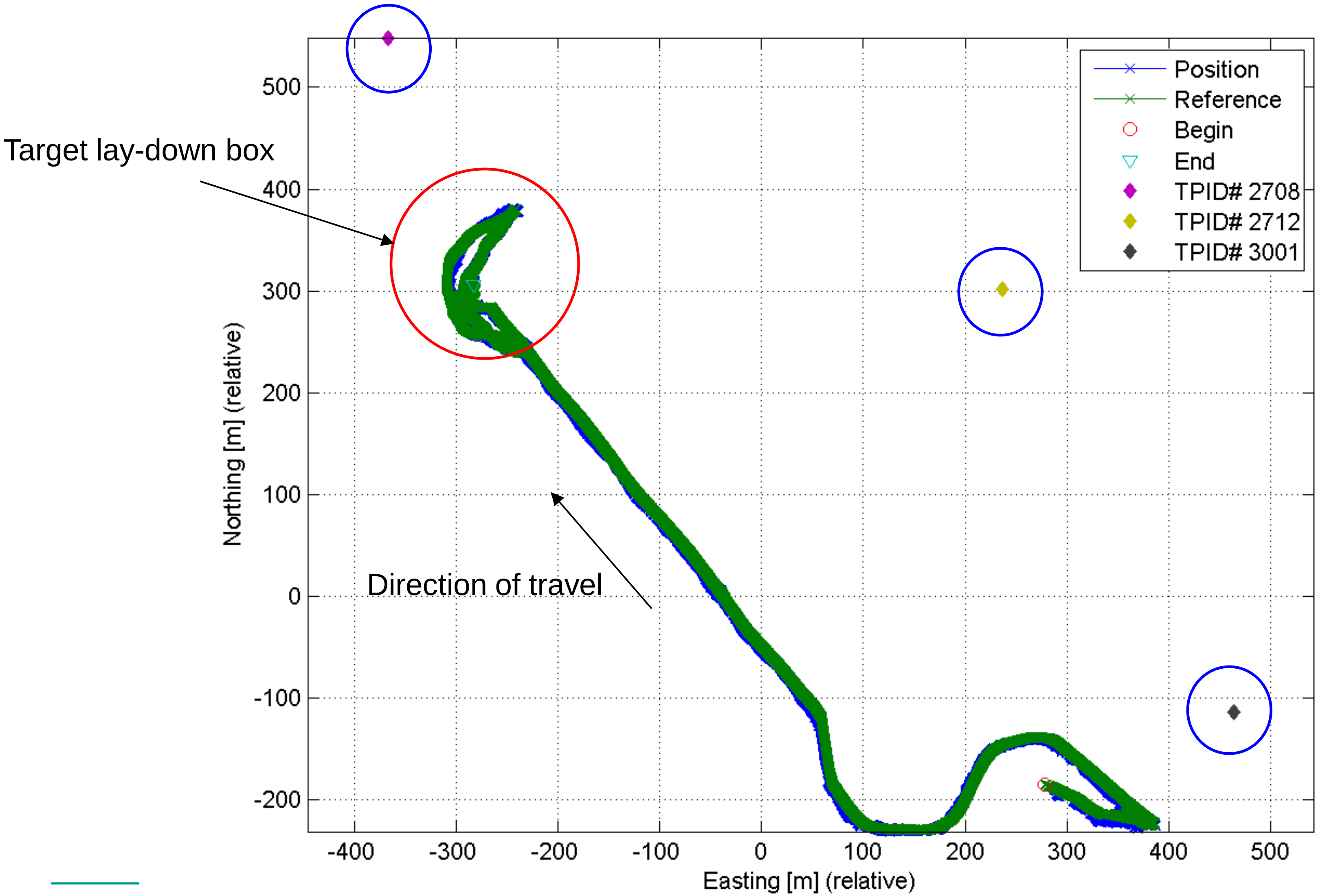
- Good geometry



- Poor geometry



Characteristics of the Positioning System: Sparse LBL Case Study: Umbilical Lay



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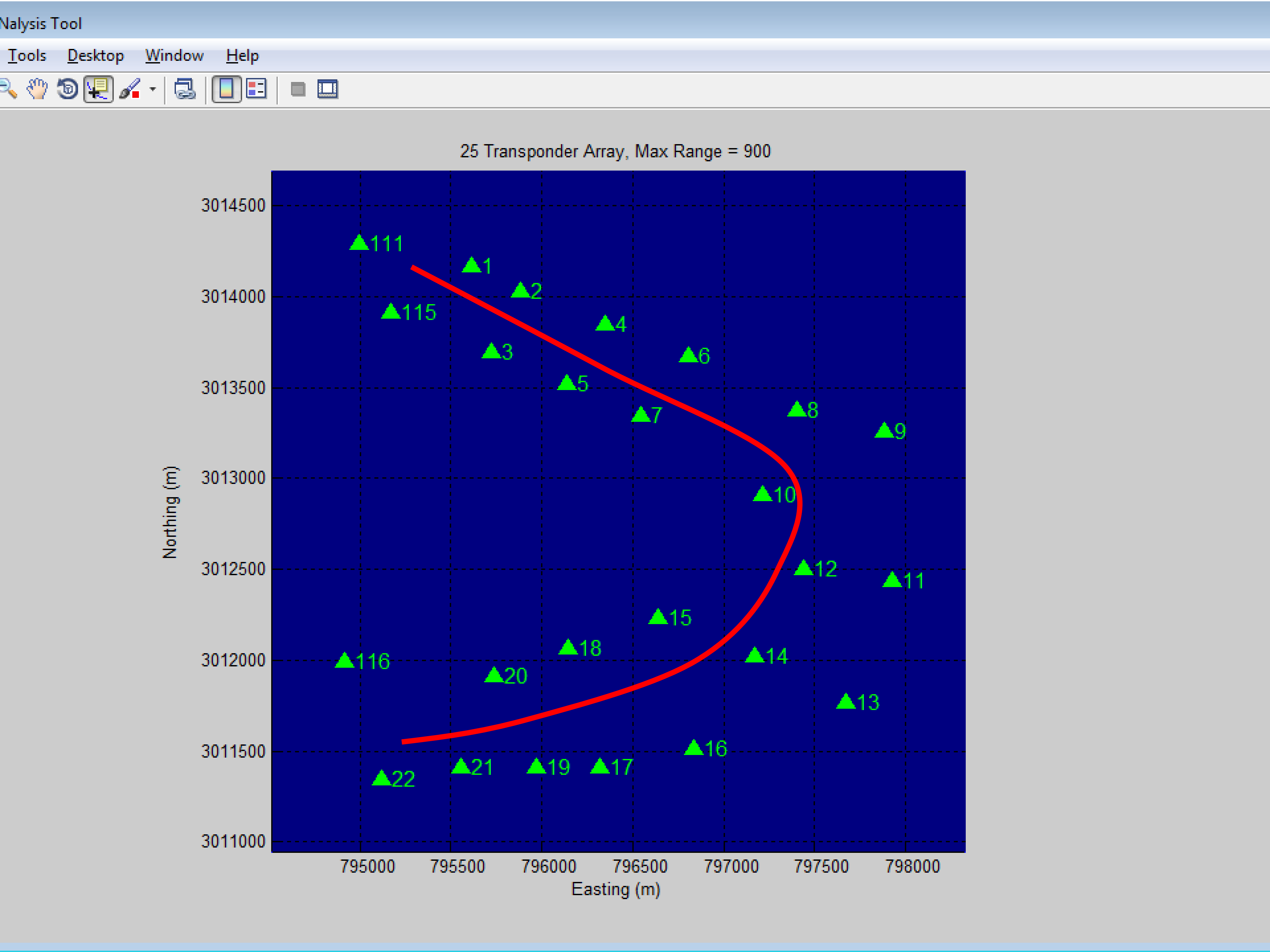
Nalysis Tool
Tools
Desktop
Window
Help
25 Transponder Array, Max Range = 900
Northing (m)
3014500
3014000
3013500
3013000
3012500
3012000
3011500
3011000
795000
795500
796000
796500
797000
797500
798000
Easting (m)
111
1
2
115
4
3
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18
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116
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13
16
21
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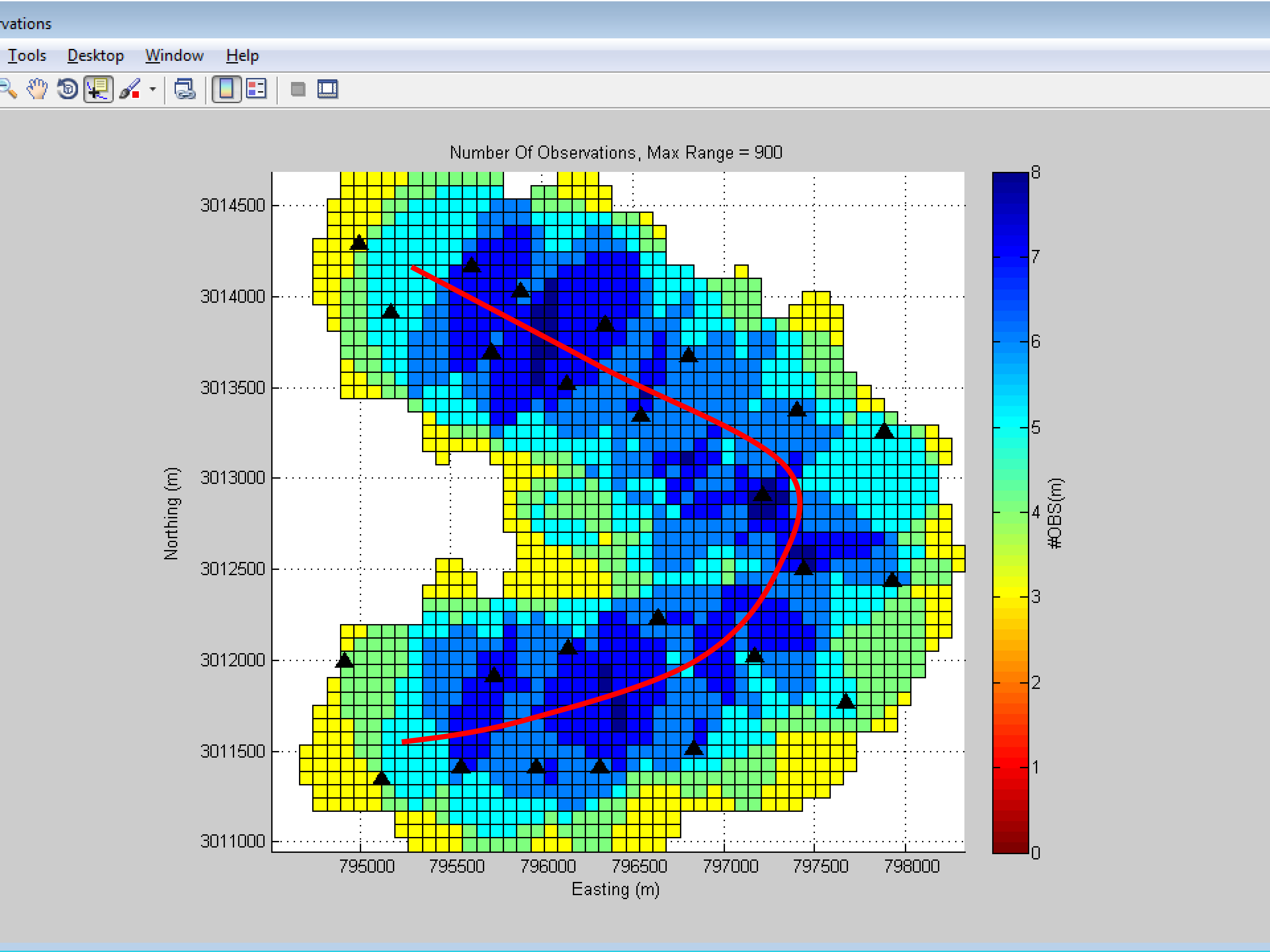
17
22



vations
Tools
Desktop
Window
Help
Number Of Observations, Max Range = 900
3014500
3014000
3013500
3013000
3012500
3012000
3011500
3011000
Northing (m)
795000
795500
796000
796500
797000
797500
798000
Easting (m)
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7
6
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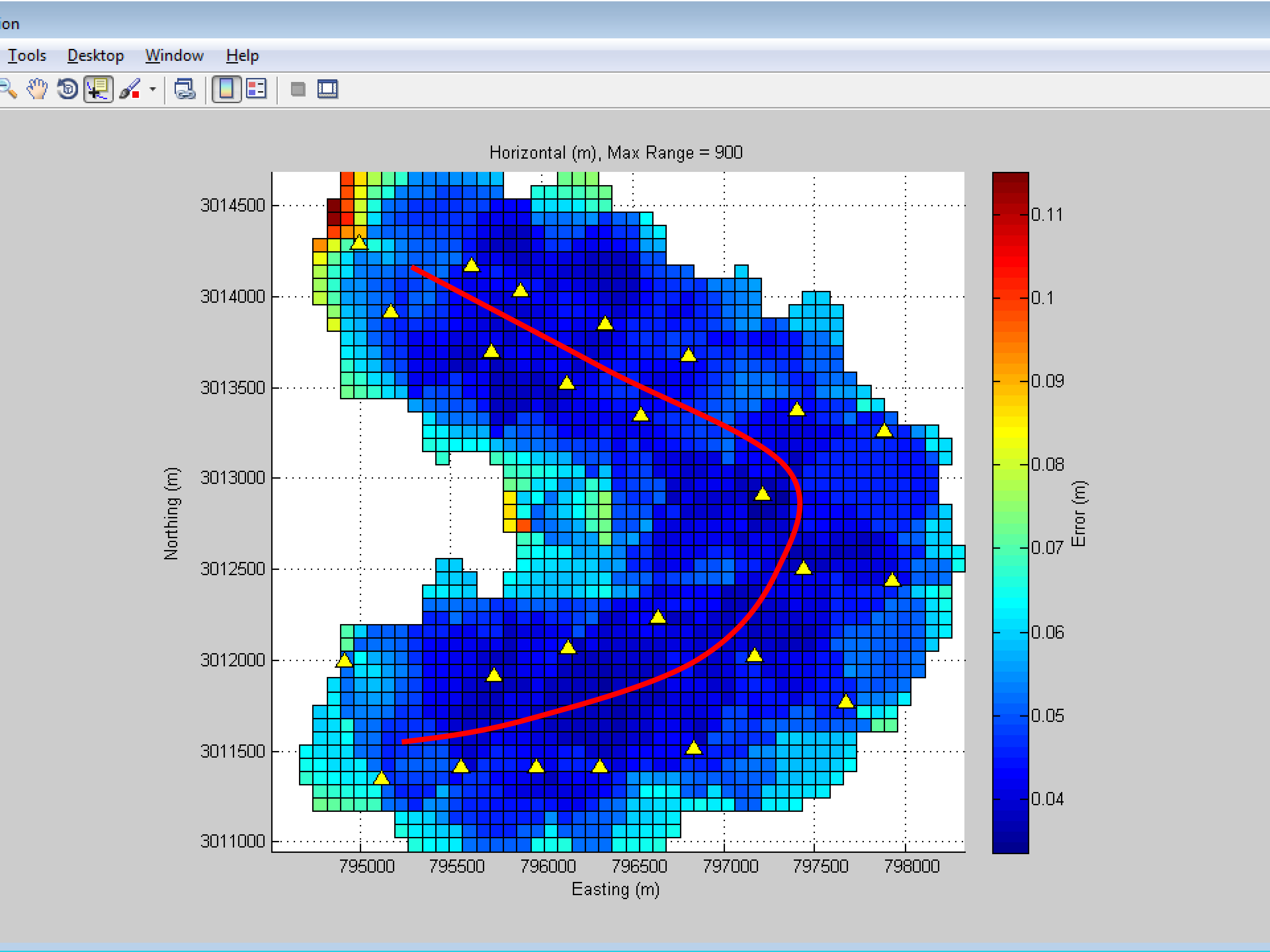
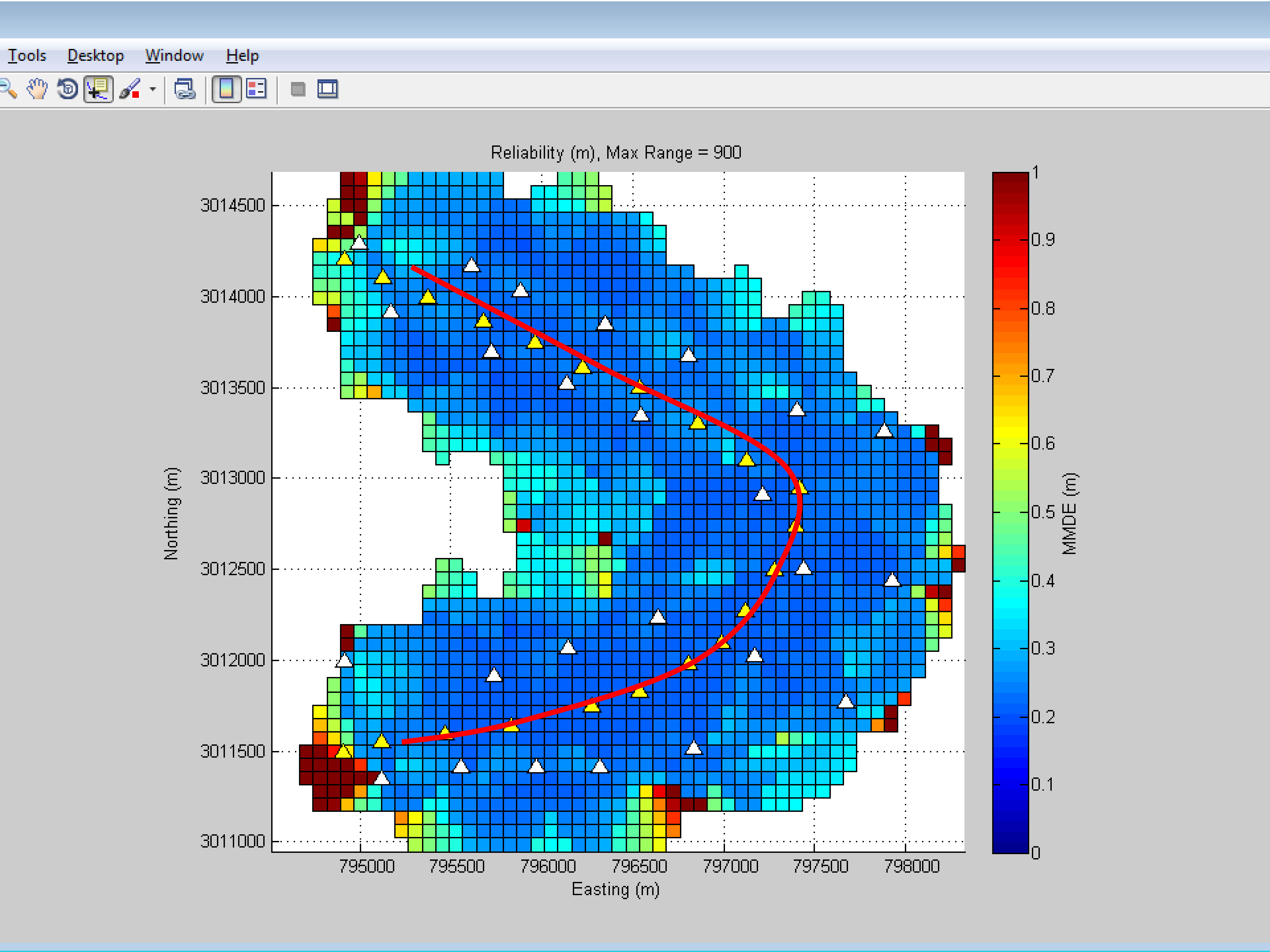
3
2
1
0
#OBS(m)


ion
Tools Desktop Window Help
Horizontal (m), Max Range = 900
Northing (m)
3014500
3014000
3013500
3013000
3012500
3012000
3011500
3011000
Easting (m)
795000
795500
796000
796500
797000
797500
798000
Error (m)
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04


Tools Desktop Window Help
Reliability (m), Max Range = 900
Northing (m)
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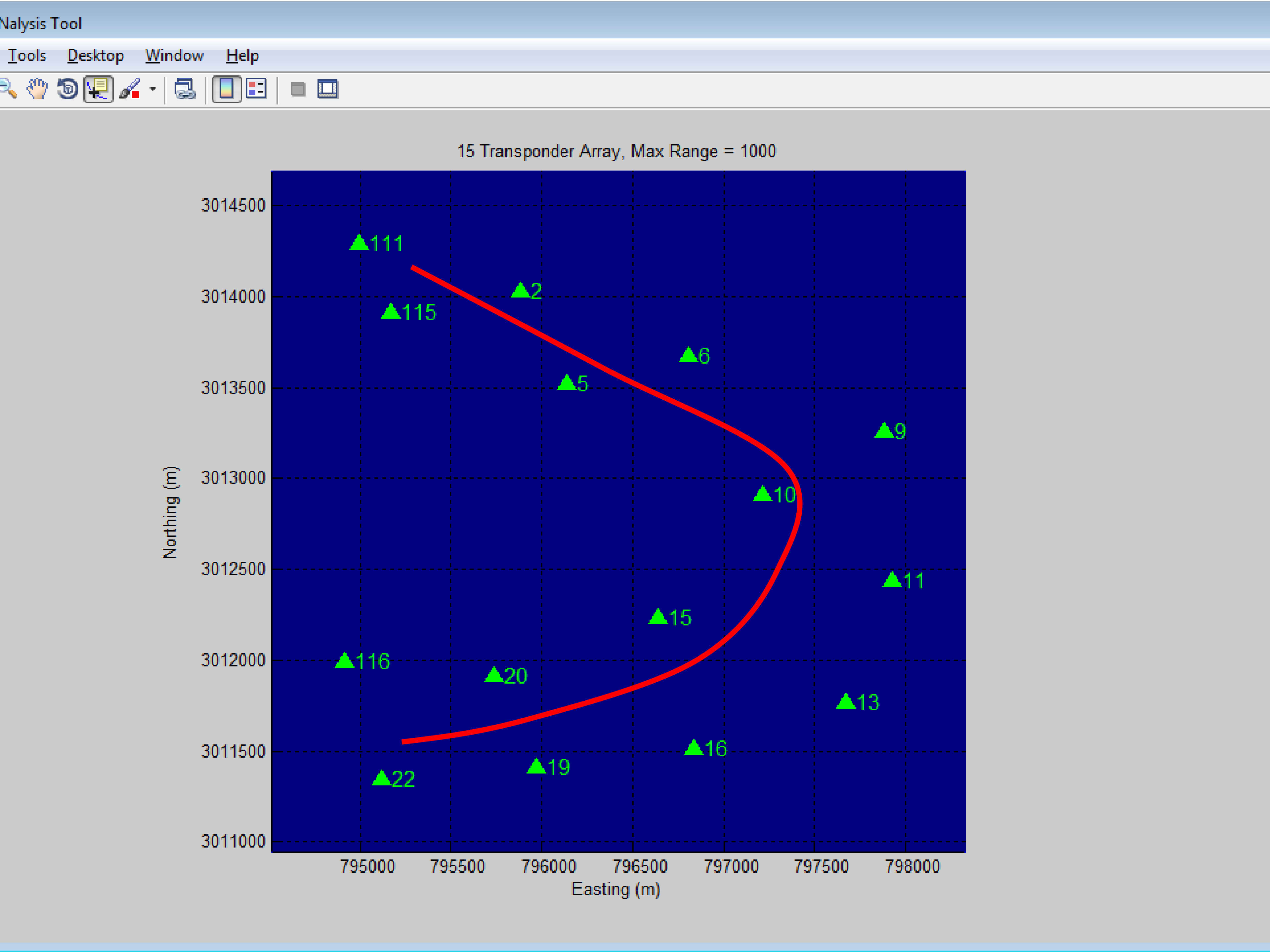
3014000
3013500
3013000
3012500
3012000
3011500
3011000
795000
795500
796000
796500
797000
797500
798000
Easting (m)
MMDE (m)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

- Conclusion
  - The corridor array is well designed and meets the positioning requirement of 1.5m (3 sigma) with adequate redundancy, geometry, precision and reliability.
- However, wouldn't it be nice if…
  - the positioning requirement could be met with less seabed equipment
  - and for this **sparse** array to be calibrated using traditional baseline collection and network adjustment?
  - Array could be sparser still….



Nalysis Tool
Tools Desktop Window Help
15 Transponder Array, Max Range = 1000
Northing (m)
3014500
3014000
3013500
3013000
3012500
3012000
3011500
3011000
Easting (m)
795000
795500
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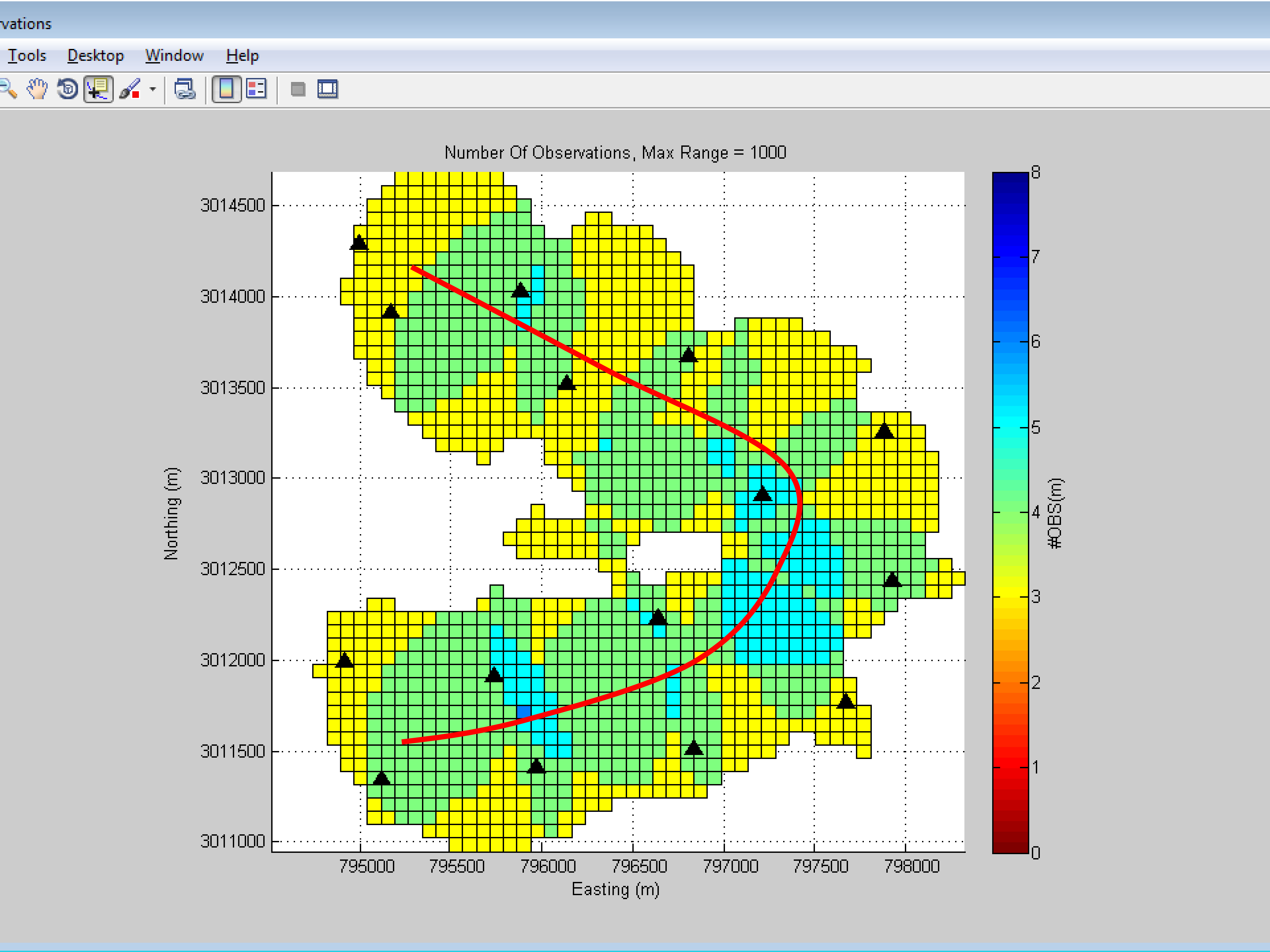
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Number Of Observations, Max Range = 1000
3014500
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Northing (m)
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Easting (m)
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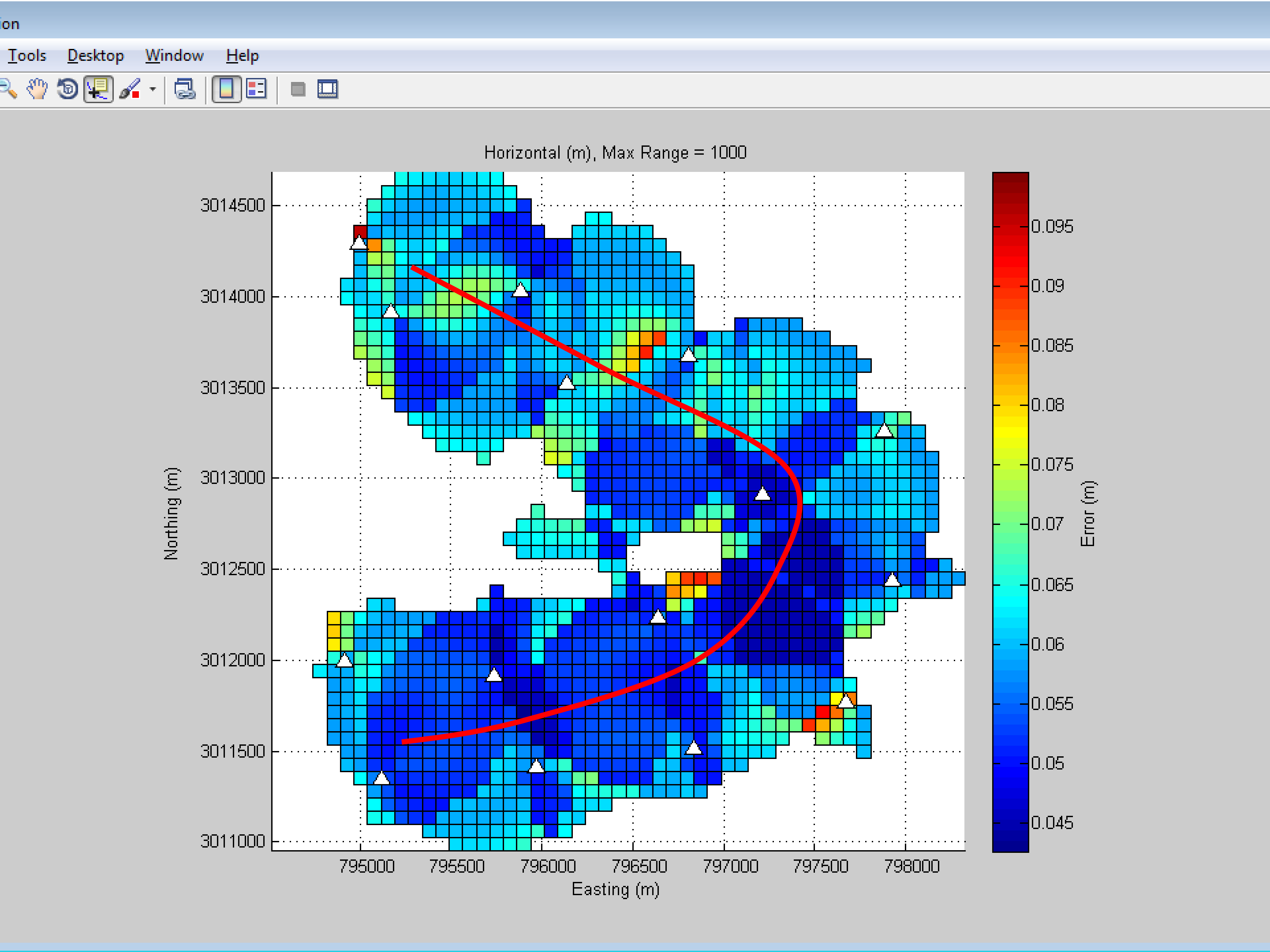
#OBS(m)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Tools Desktop Window Help
Horizontal (m), Max Range = 1000
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3012000
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3011000
Northing (m)
795000 795500 796000 796500 797000 797500 798000
Easting (m)
0.095
0.09
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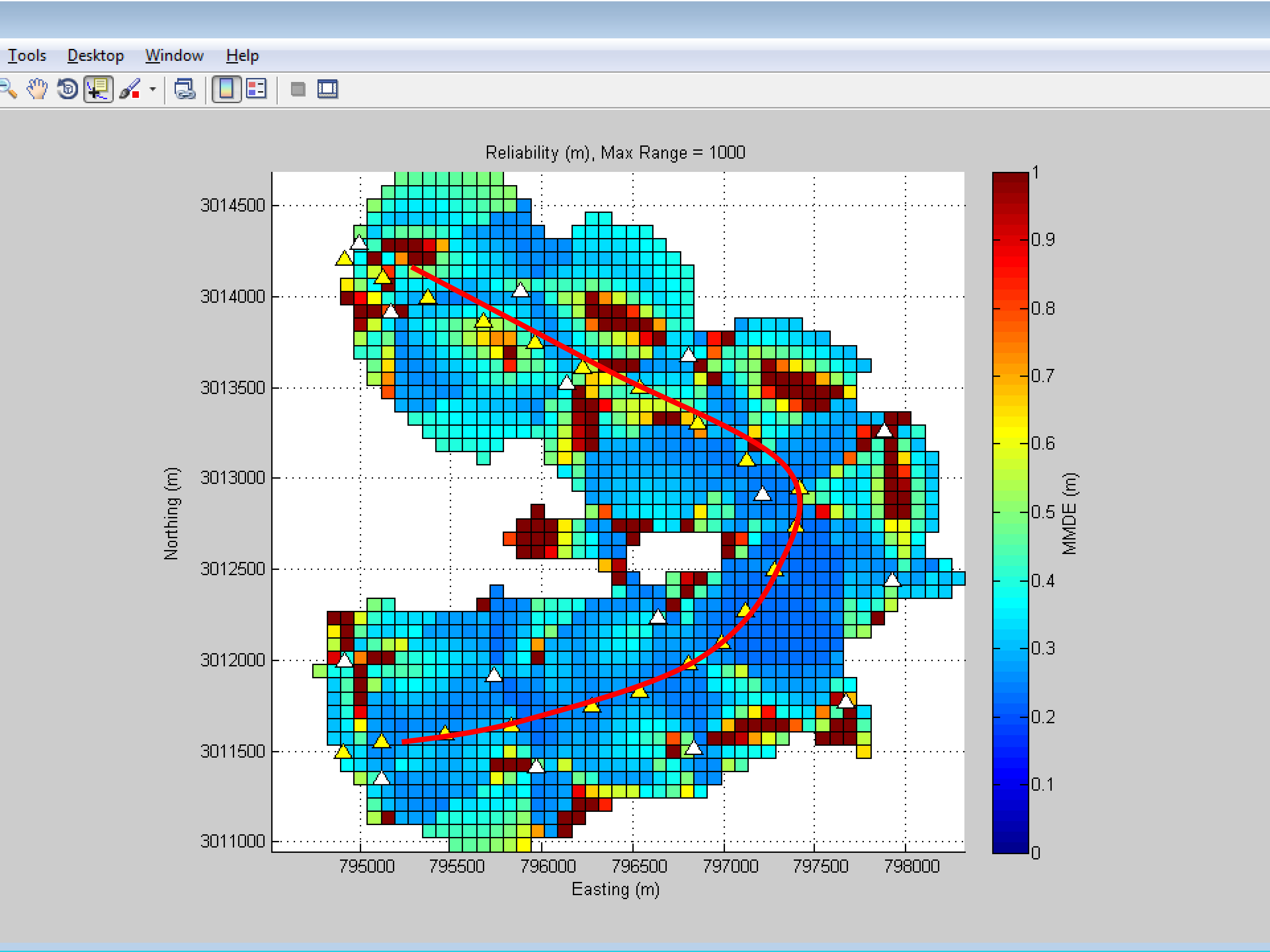
0.08
0.075
0.07
0.065
0.06
0.055
0.05
0.045
Error (m)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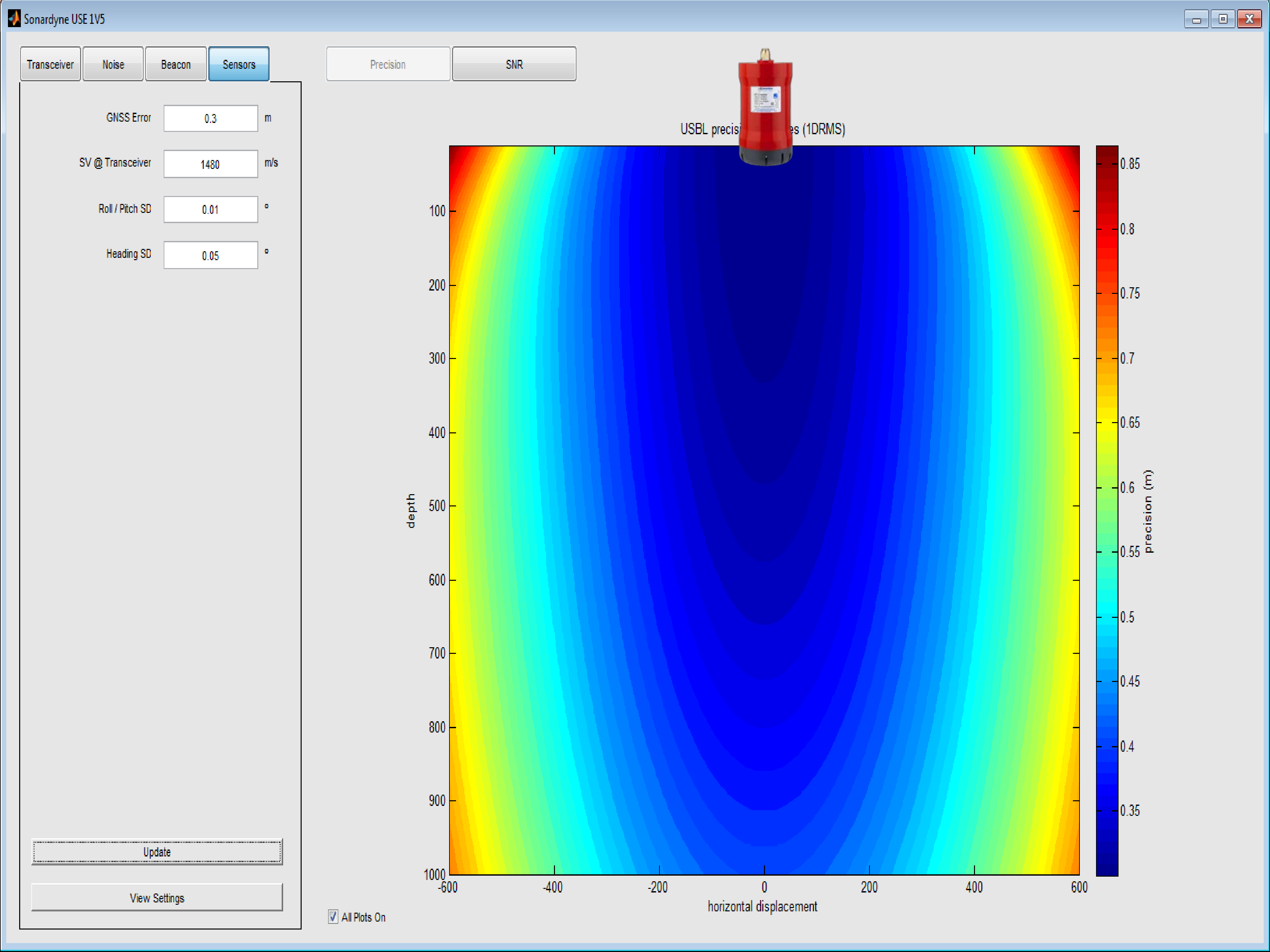
Desktop
Window
Help
Reliability (m), Max Range = 1000
3014500
3014000
3013500
3013000
3012500
3012000
3011500
3011000
Northing (m)
795000
795500
796000
796500
797000
797500
798000
Easting (m)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
MMDE (m)

Planning and Analysis: USBL Performance Prediction

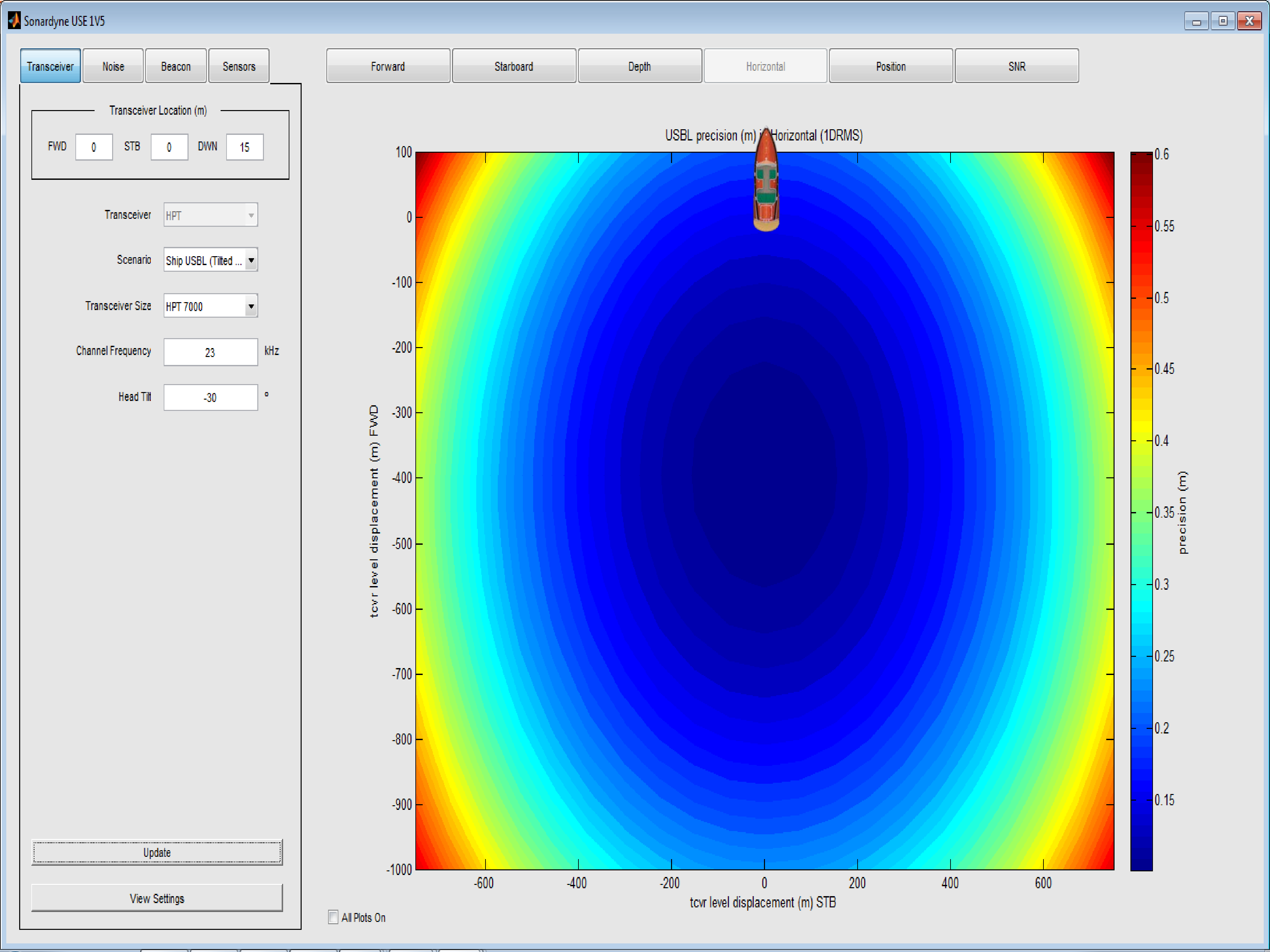
- Time and again we are asked to comment on:
  - the accuracy and precision of USBL
  - can system performance be improved over existing installation
- Answering the above is not just a simple case of looking on a data sheet
- As with all navigation systems capability and switch on performance are very different and if any assumptions change (environment, constellation, array) then performance will likely be affected

Planning and Analysis: USBL Performance prediction – The Customer Deliverable

- If you want to know USBL performance, we need to know the following…
  - Scenario & Tilt of USBL head
  - Transceiver Type
  - Frequency
  - Transceiver location relative to noise
  - **Noise**
  - Area of interest (depth and layback)
  - Transponder type
  - Source level
  - Signal type
  - **Roll Pitch Heading**
- Otherwise assumptions can be made but these may be incorrect



Sonardyne USE 1V5
Transceiver
Noise
Beacon
Sensors
GNSS Error
0.3
m
SV @ Transceiver
1480
m/s
Roll / Pitch SD
0.01
°
Heading SD
0.05
°
Update
View Settings
Precision
SNR
USBL precisi
es (1DRMS)
depth
100
200
300
400
500
600
700
800
900
1000
-600
-400
-200
0
200
400
600
horizontal displacement
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
precision (m)
All Plots On



Sonardyne USE 1V5
Transceiver
Noise
Beacon
Sensors
Forward
Starboard
Depth
Horizontal
Position
SNR
Transceiver Location (m)
FWD
0
STB
0
DWN
15
Transceiver
HPT
Scenario
Ship USBL (Tilted ...
Transceiver Size
HPT 7000
Channel Frequency
23
kHz
Head Tilt
-30
°
Update
View Settings
All Plots On
USBL precision (m) in Horizontal (1DRMS)
100
0
-100
-200
-300
-400
-500
-600
-700
-800
-900
-1000
tcvr level displacement (m) FWD
-600
-400
-200
0
200
400
600
tcvr level displacement (m) STB
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
precision (m)

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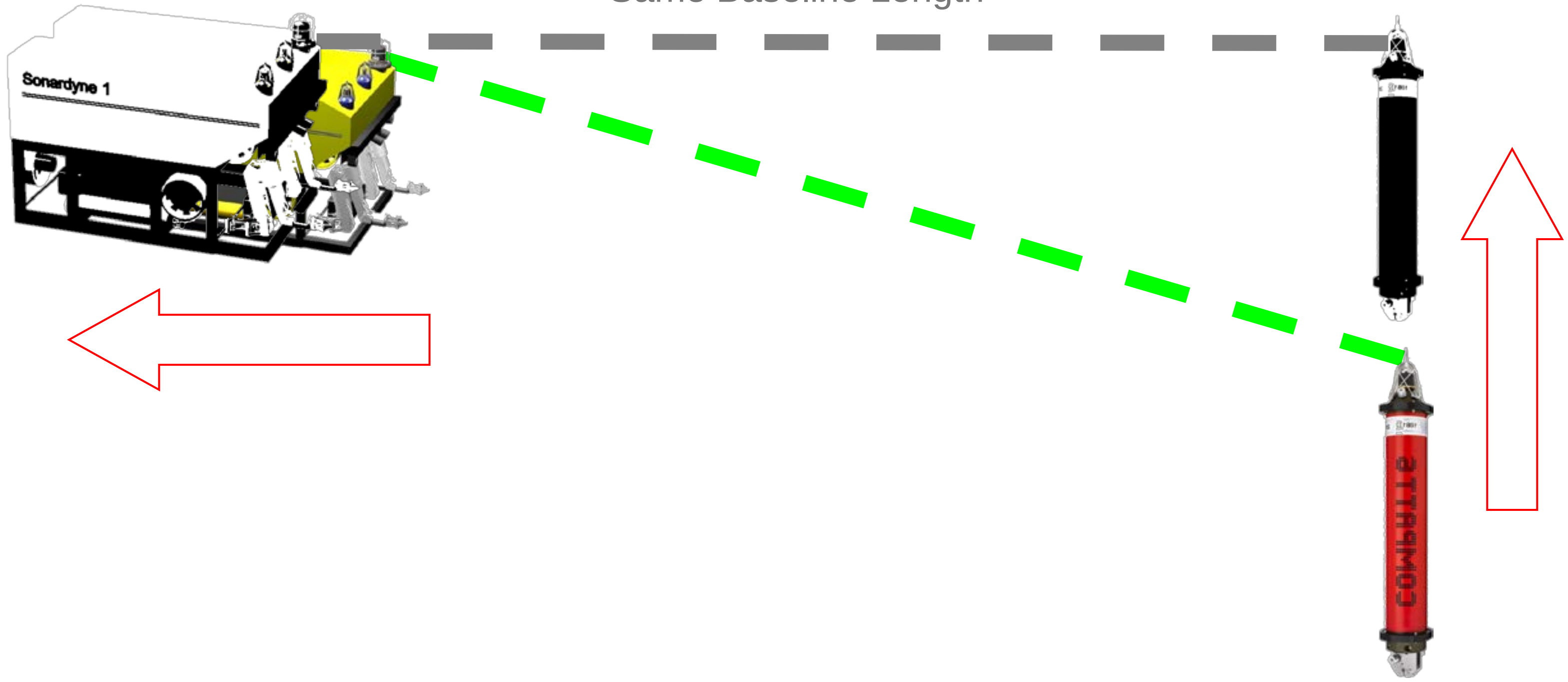
Real Time Considerations

- Analysis and planning predominantly uses assumptions with random errors
- Ensure that analysis and planning assumptions are still valid for real time system by avoiding:
  - Blunders
  - Systematic Errors
- Good Practice:
  - Training
  - Installation & Configuration
  - Real Time Monitoring
  - Verification

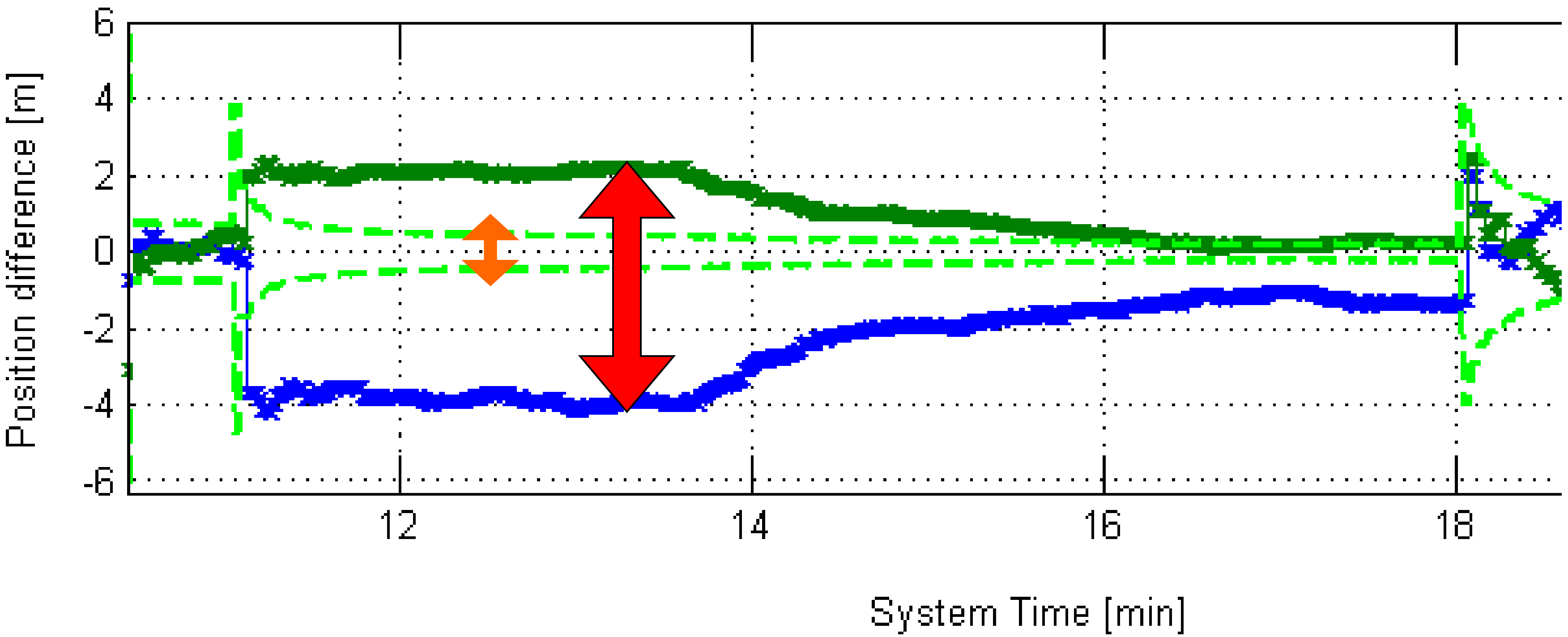
Real Time Considerations:
LBL INS: Effects of Depth Errors

- If Depth is incorrect in a calibrated C6 position used for aiding:
  - **The INS depth will still be at the correct depth as it will be using the ROV mounted sensor so the depth error will translate into a horizontal depth error**



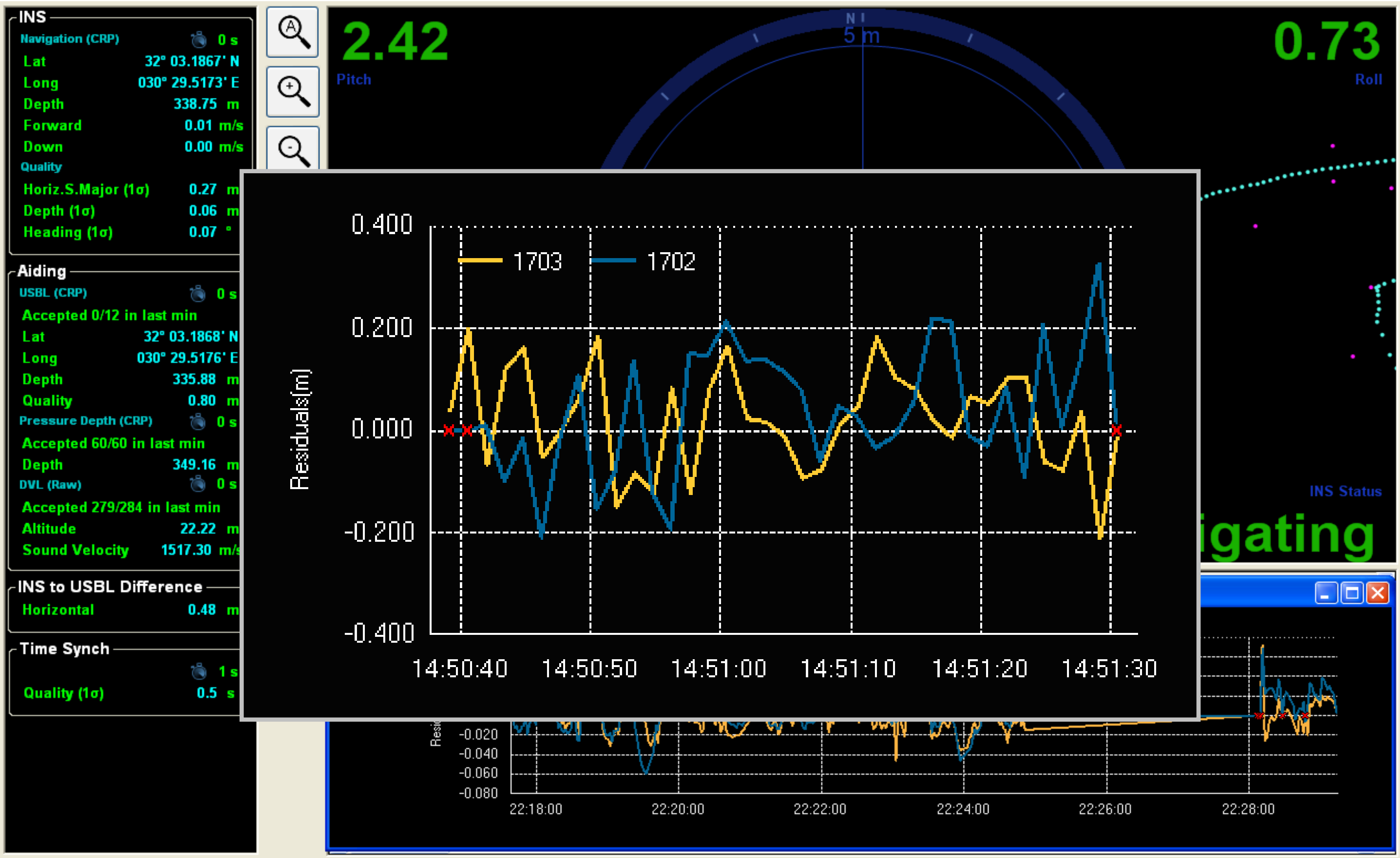
Real Time Considerations:
LBL INS: Effects of Sound Velocity Error

- 2 x transponder Sparse LBL & DVL INS (good geometry, 50-500m baselines)
- Plot shows difference between Sparse LBL & DVL INS and RTK GPS ‘truth’



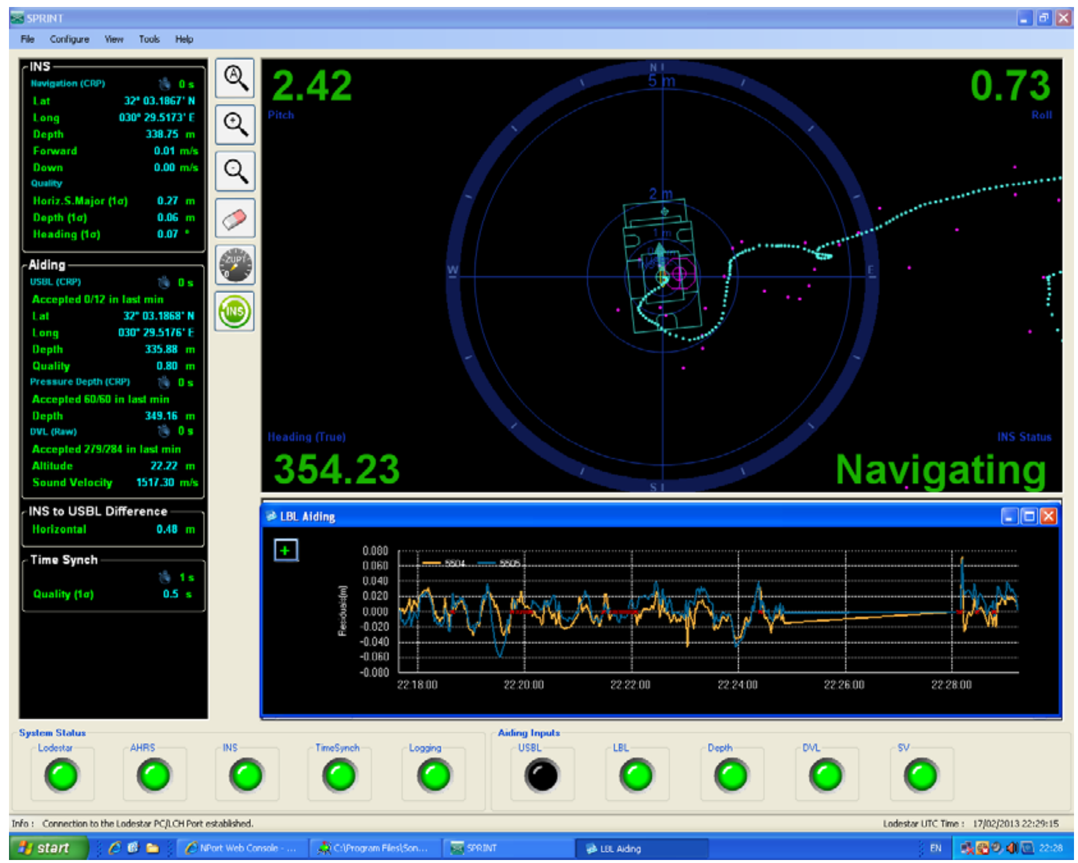
- Simulated systematic range error (sound velocity incorrect by 1m/s):
  - **Very poor accuracy (2-4m error)**
  - Loss of INS integrity (accuracy worse than INS position uncertainty)

Real Time Considerations:
LBL INS: Monitoring Errors with Real Time Residuals



Real Time Considerations:
Independent Verification: USBL vs. LBL

- Positioning checks with independent references:
  - USBL ➔ GPS (Surface)
  - LBL ➔ Transponder Array (Seabed)
  - Possible in SPRINT using Sparse array



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What Help is Available?
Sonardyne Survey Support Group

The primary role of the Group is to support survey and construction customers in the most efficient use of Sonardyne systems in all operational stages from field planning through to post operation analysis.

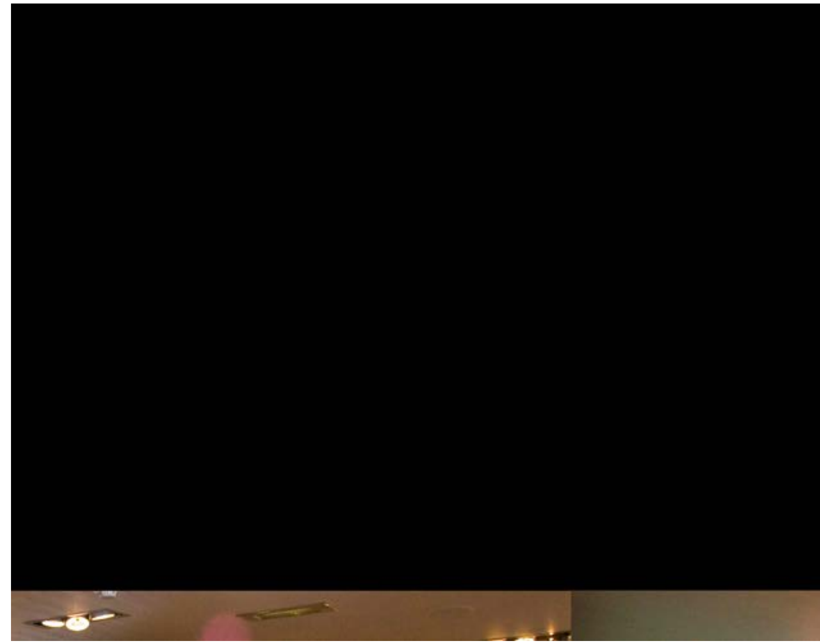
Through the following…

- Training and Workshops
- Product and System Awareness
- Equipment and System Optimisation
- Onshore and Offshore Support
- **LBL, USBL & Inertial analysis and modelling**
- **Field Planning**

Mail: **survey.support@sonardyne.com**

What Help is Available?
Workshops

- Acoustic Positioning Concepts
- Autonomous Monitoring Transponder
- iUSBL
- LBL
- Life of Field
- Metrology
- USBL & GyroUSBL
- CASIUS
- LBL Box-in
- Structure Placement
- Inertial
- **Performance Prediction & Errors**



Topics of discussion are flexible

Everyone is invited or can be tailored and run for your company

Free of charge

Mail: **survey.support@sonardyne.com**

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Conclusion

- It is possible to reasonably determine expected absolute accuracy and repeatability (beyond simple ‘data-sheet’ statistics).
- But:
  - Careful planning & analysis must be performed
  - Real time operation must strive to identify & avoid errors which invalidate the planning & analysis
- Resources are available to assist: Sonardyne Survey Support Group

Questions?

For more information please visit

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