Methods for Developing ASF Grids for Harbor Entrance and Approach

ILA 35 – Groton, CT

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HEA Navigation Concept

ASF corrected TOAs:

- To remove spatial component:
  - Use published grid, interpolate between grid points
  - Issues include grid density, regions of interest, and grid creation
- To remove temporal component:
  - Local monitor receiver, broadcast offsets over LDC
  - Issues include correlation distance, monitor averaging, multiple monitor interpolation

Goals for Today

Grid creation:

- Data collection and processing:
  - Static (stationary platform)
  - Dynamic (moving platform)
  - Review processing performed
- Methods for converting to a grid
  - Sample navigation performance

Data Collection in NY Harbor

Staten Island Reference Station

- Located at ESD NY (Fort Wadsworth)
  - LRSIIID, E-field ASF measurement system

Data Collection

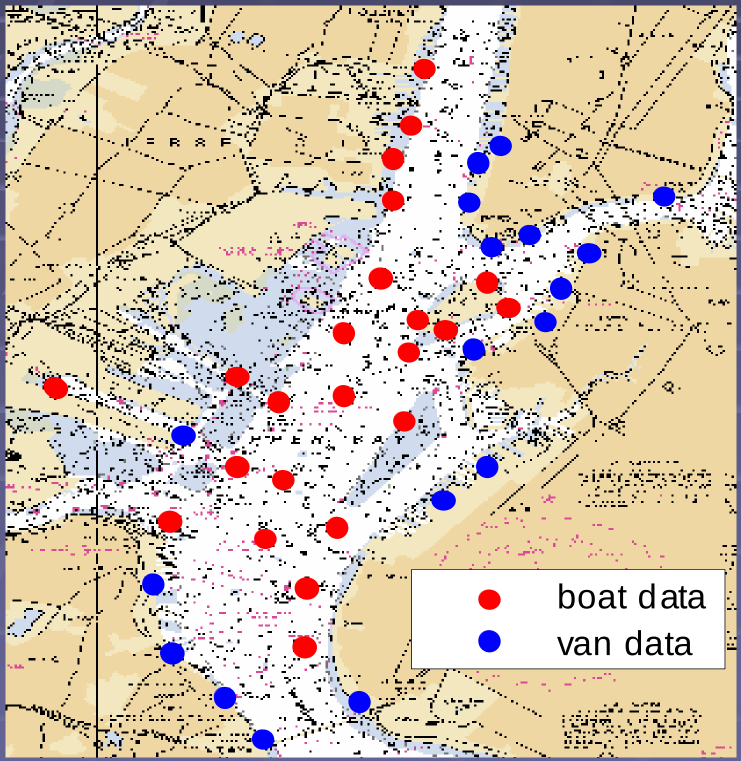
Phase 1 – May 2006

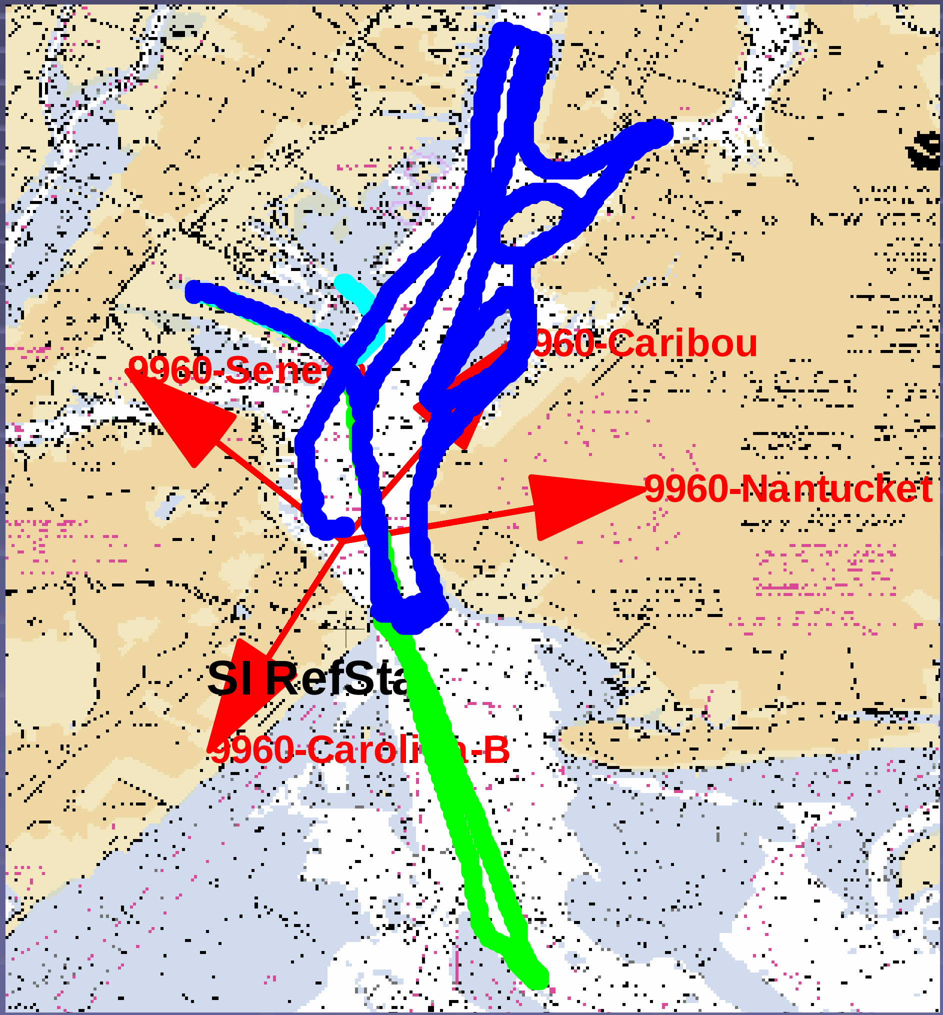
- Vessel
  - Slow circuit of harbor (5-6 kts)
  - 25 Static locations
- Van
  - 19 Static locations

Phase 2 – Aug 2006

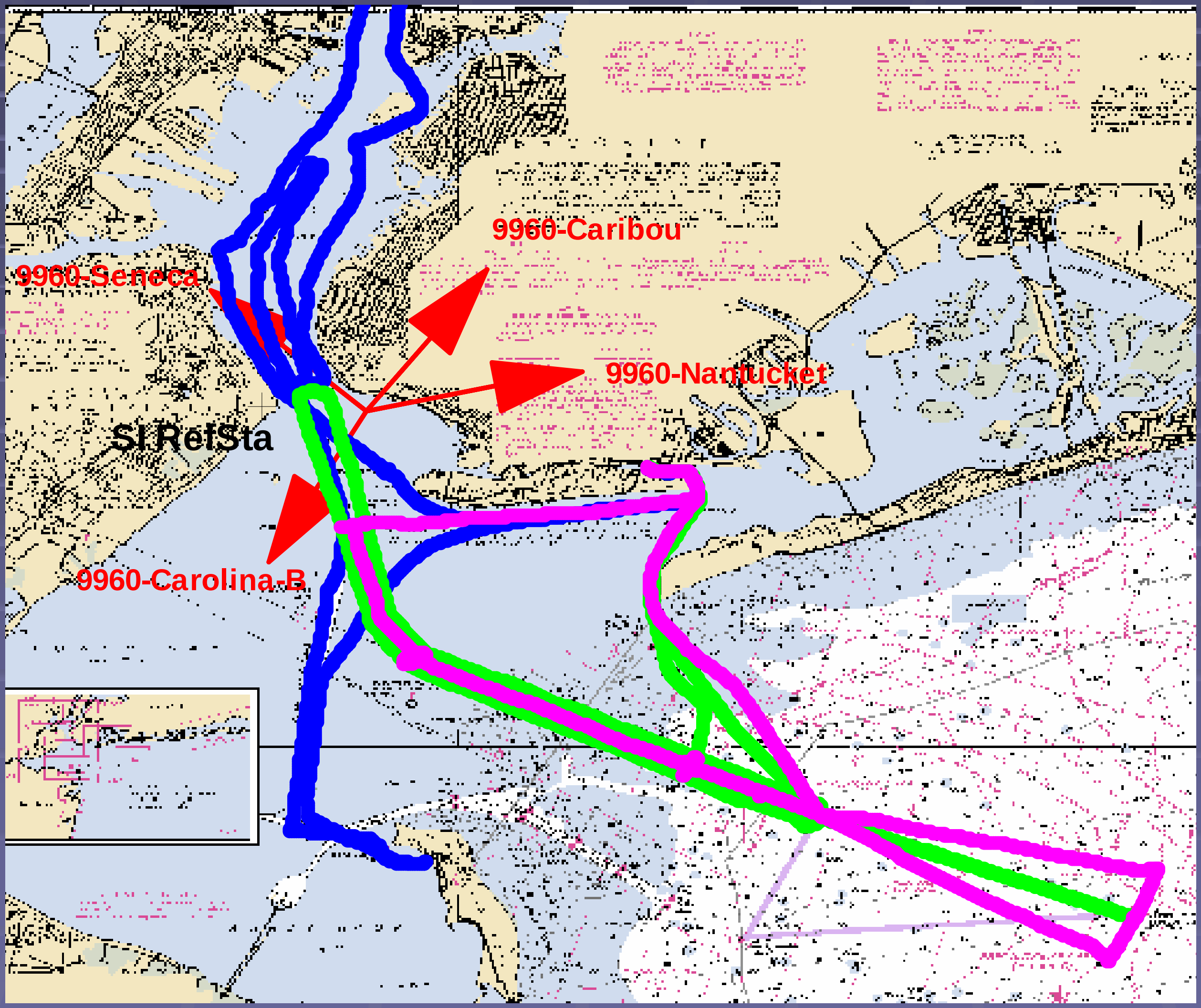
- Different vessel
  - Repeat upper harbor
  - 12 static locations
  - Continuous track in lower harbor

Phase 1 Locations/Tracks





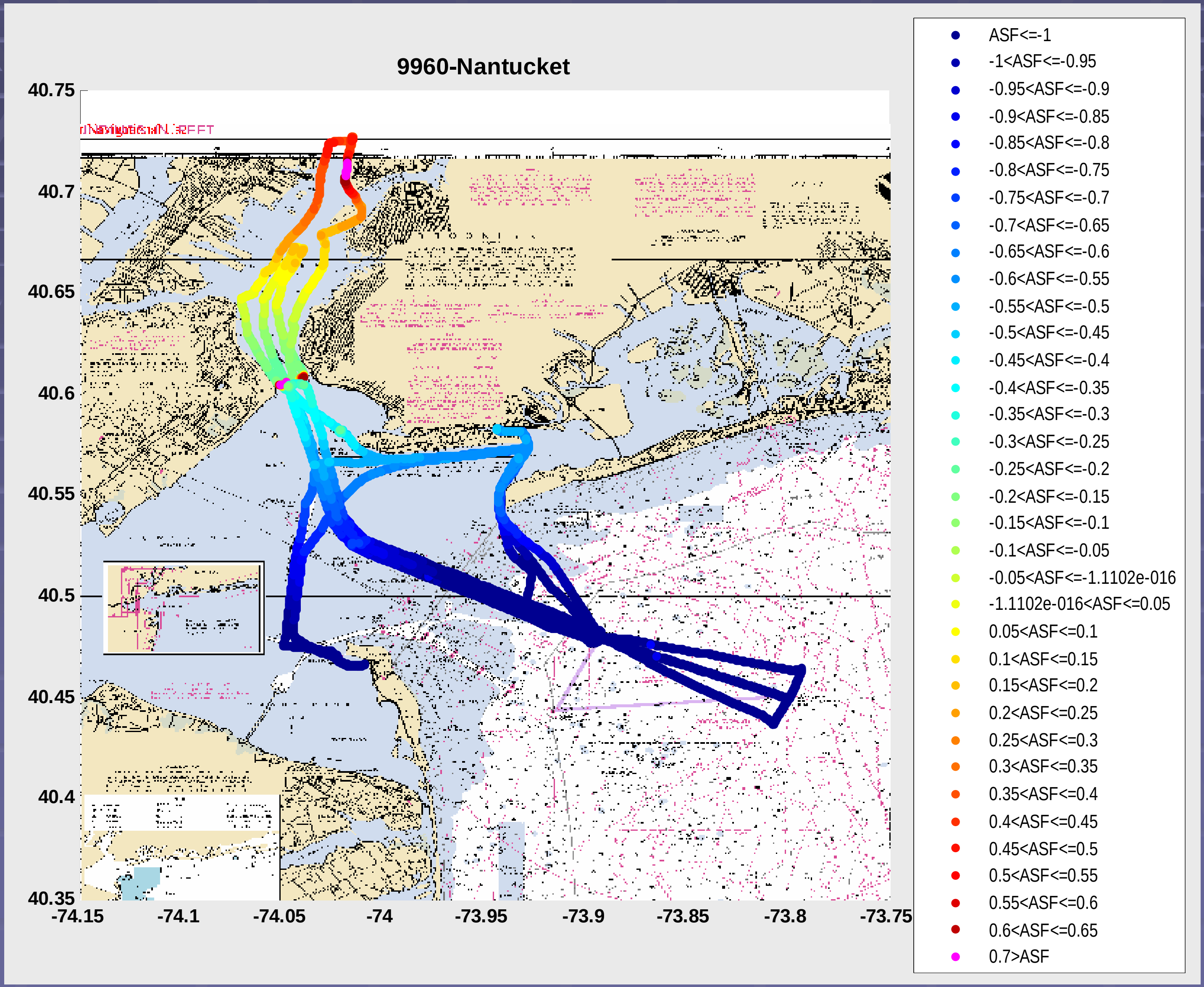
Phase 2 Tracks



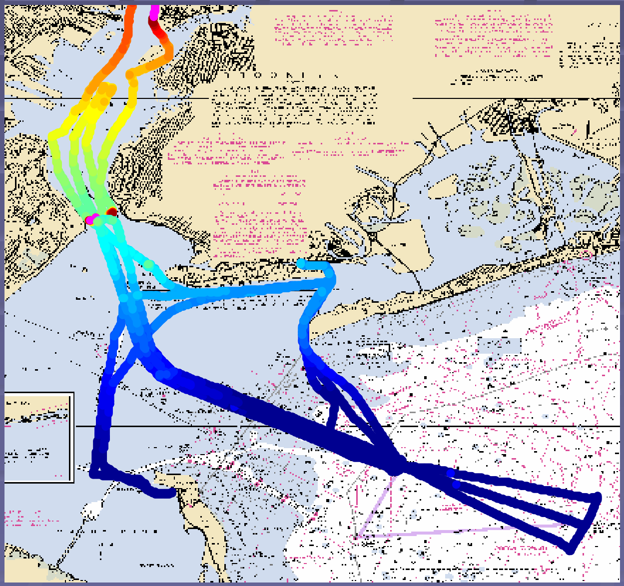
Data Processing

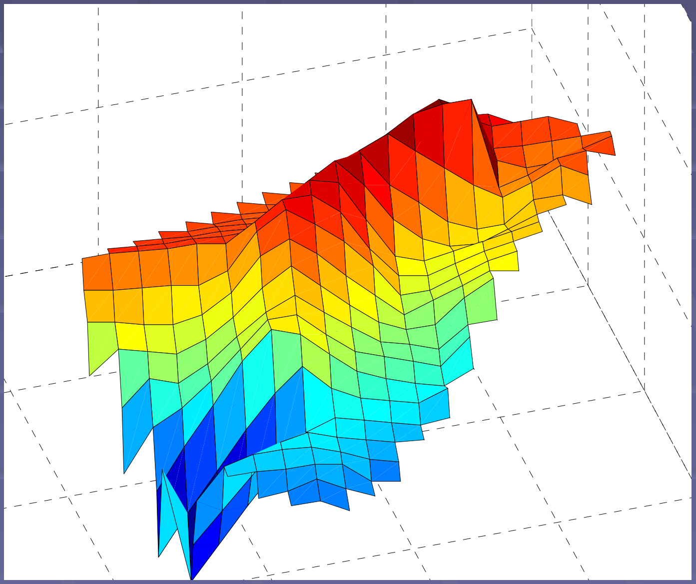
- TOAs processed to remove receiver filtering (and time lag)
- Precise track computed using L1/L2 GPS data post-processed with GrafNav s/w using CORS reference stations
- ASFs calculated using precise track position and unfiltered TOAs
- Relative ASFs calculated ($ASF_{boat} – ASF_{SI}$)

Typical ASF Data



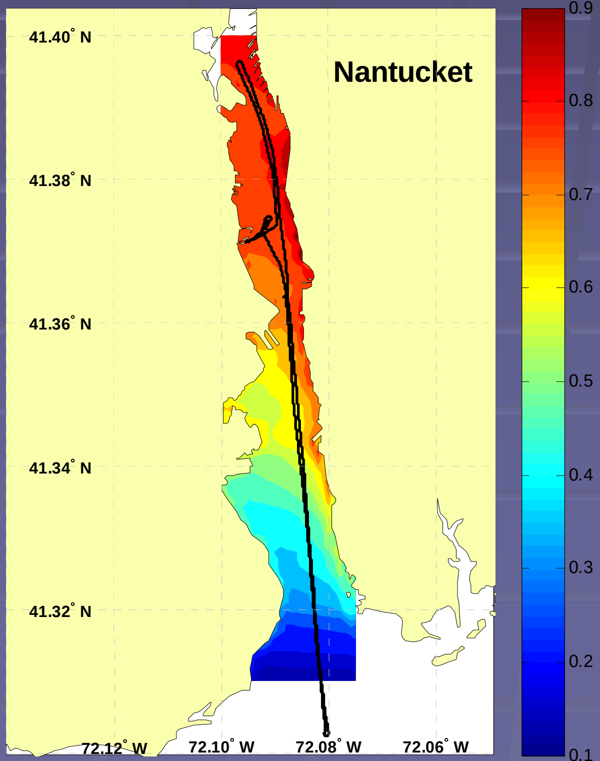
Grid Development

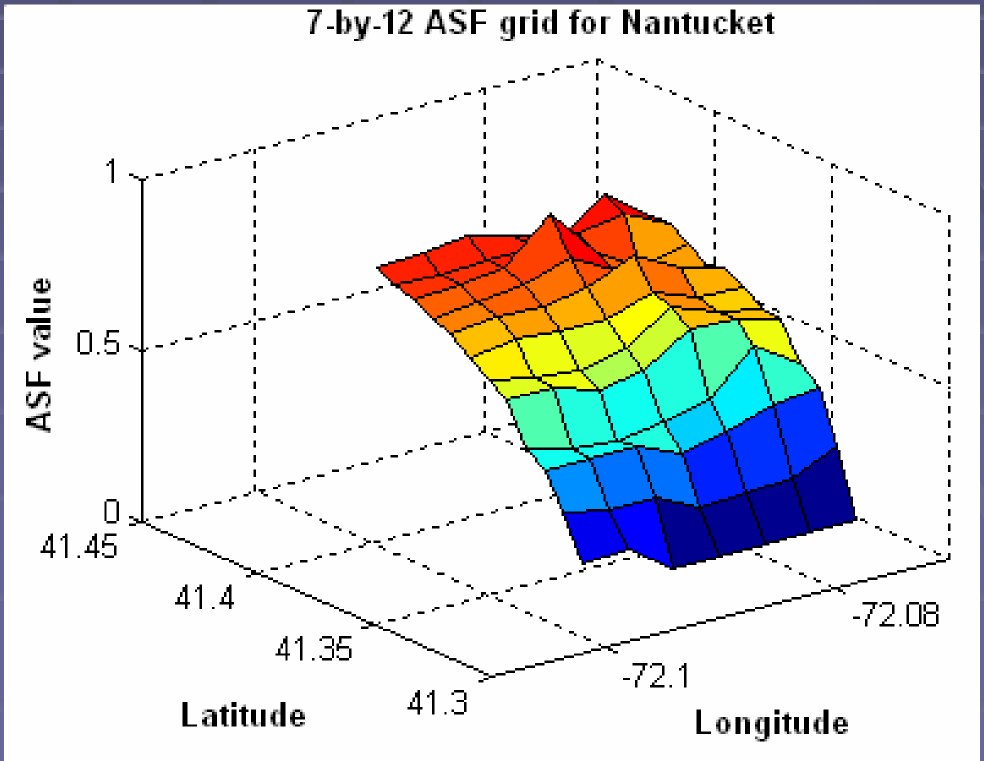




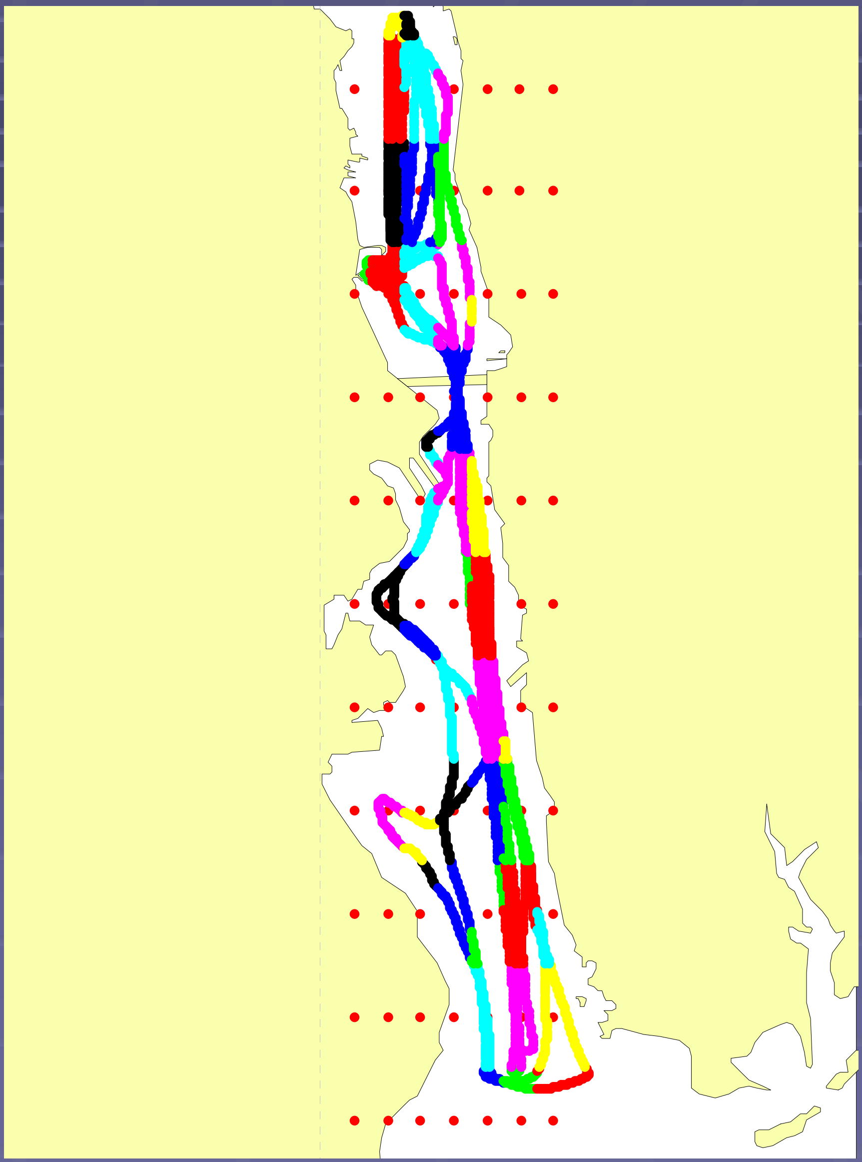
Our History

- ION June 2004 – 500 m spacing BALOR grid on the Thames River
  - Not accurate enough in practice



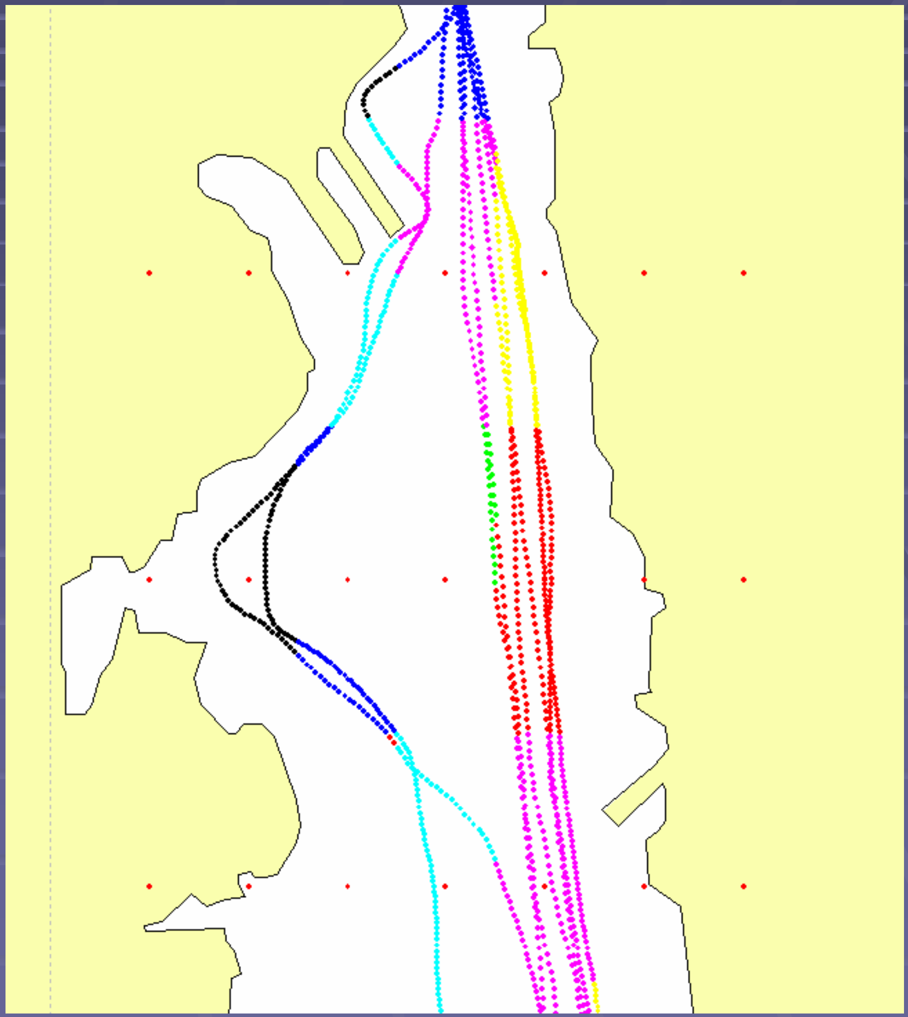


- ION Jan 2005 – survey data on the Thames River; naïve grouping; median chosen as ASF value
- Better, but still has issues



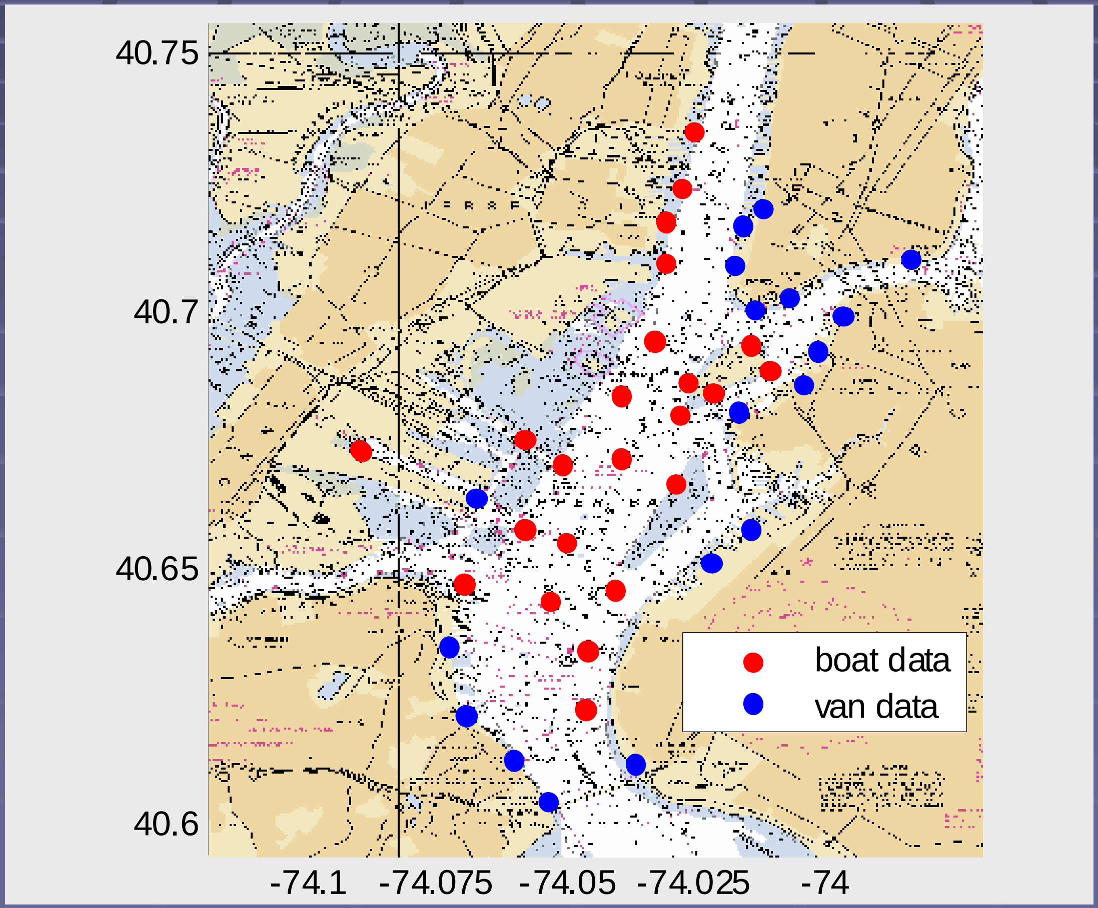
Weaknesses of Prior Work

- Some ASF values are missing (no data)
- No explicit correlation over adjacent grid points
- Geometry of data is not significantly used



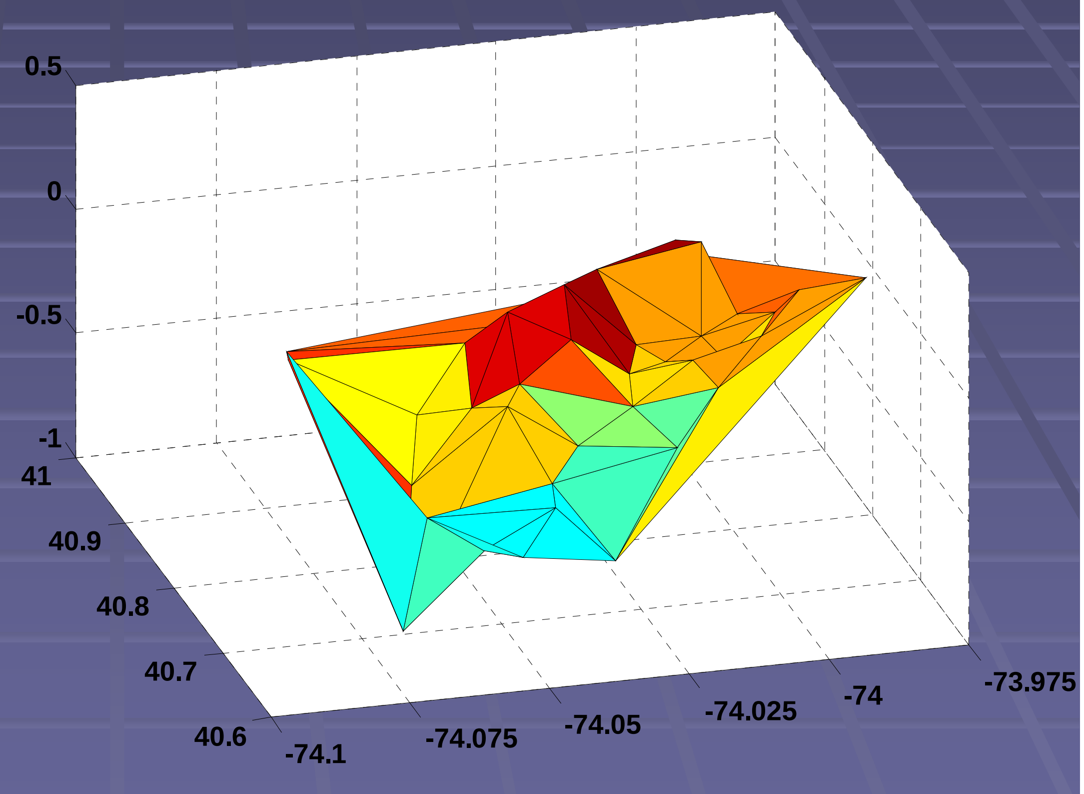
Grid Creation – Static Data

- On-land and on-water locations



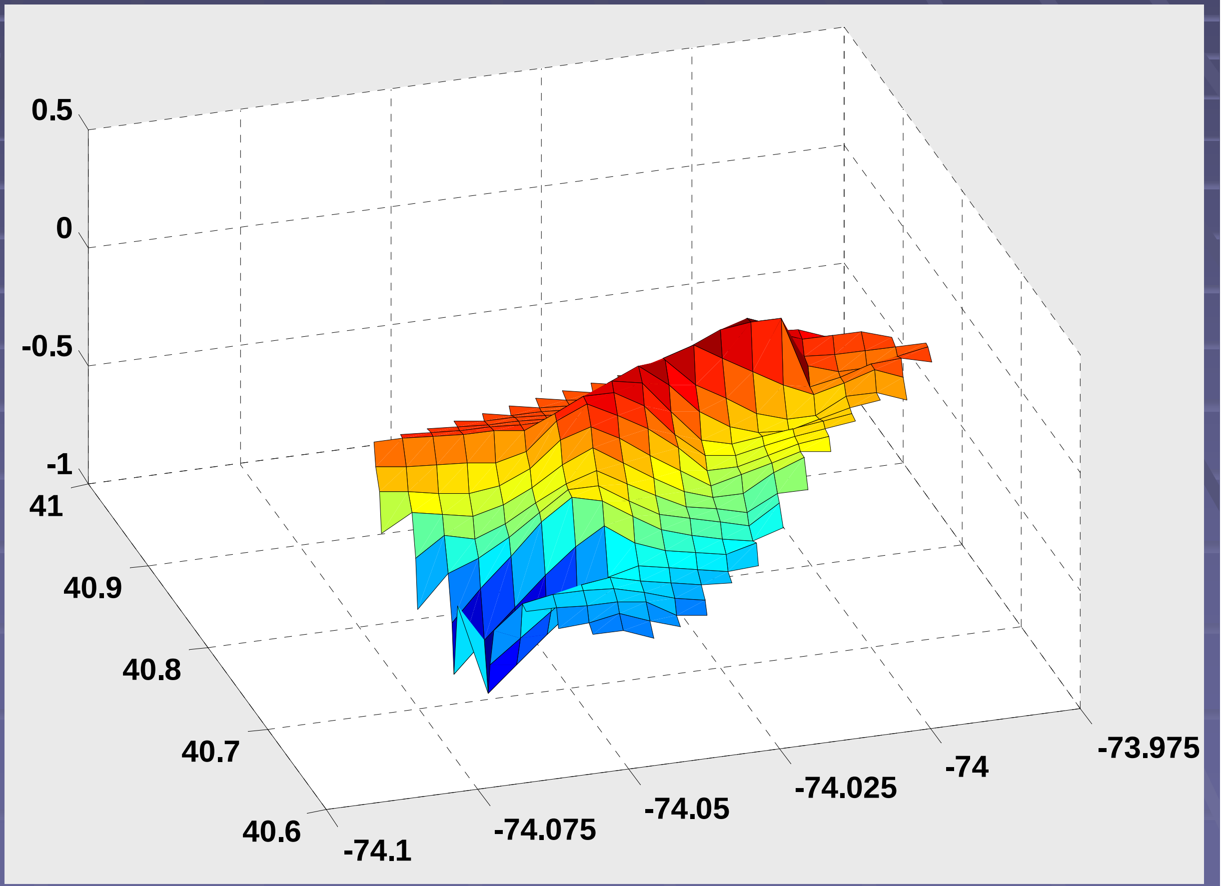
Grids from Static Data

- Average to remove noise
- Use triangular interpolation on non-uniform grid
- Delaunay triangle surface

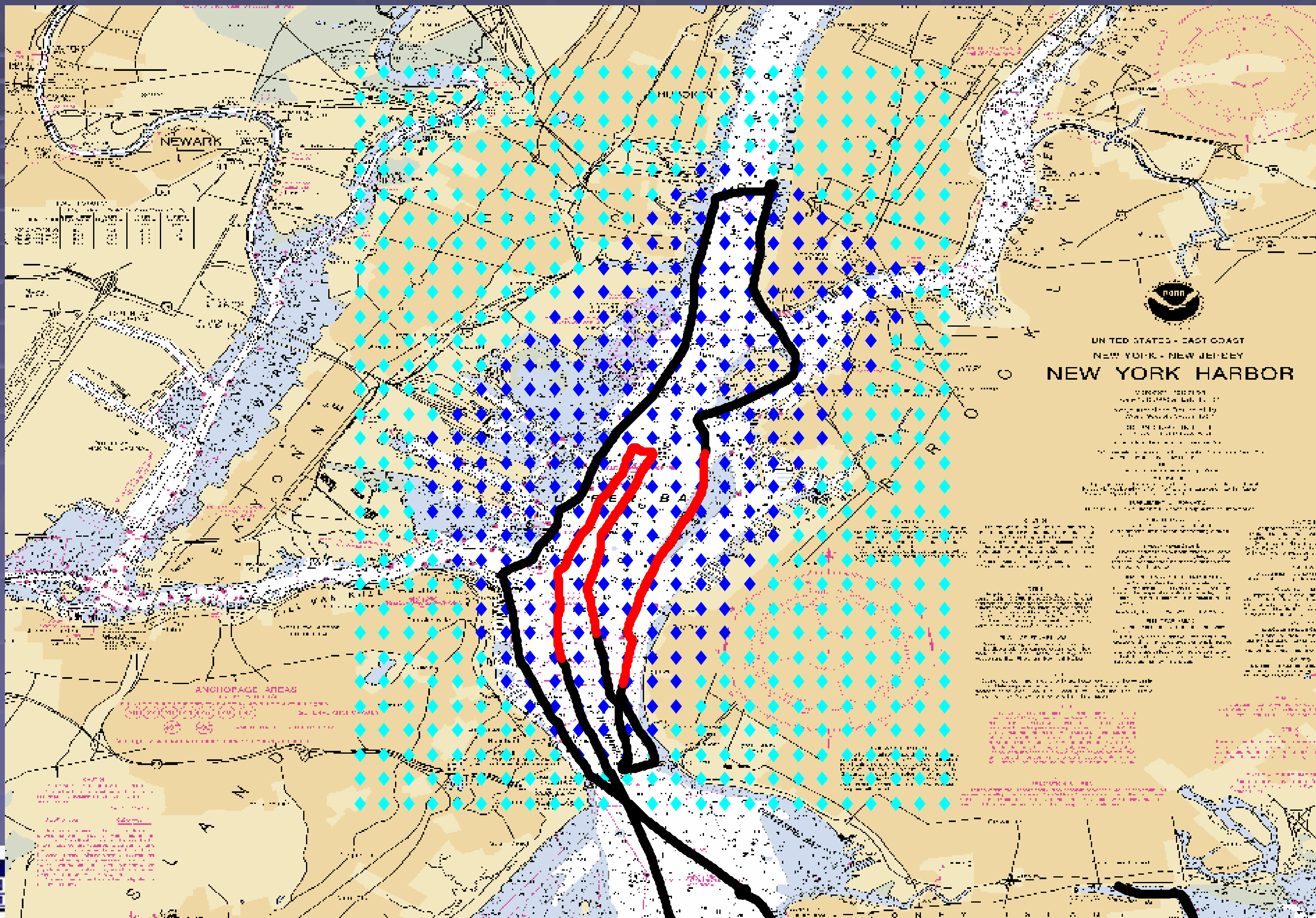


Uniform Static Grids

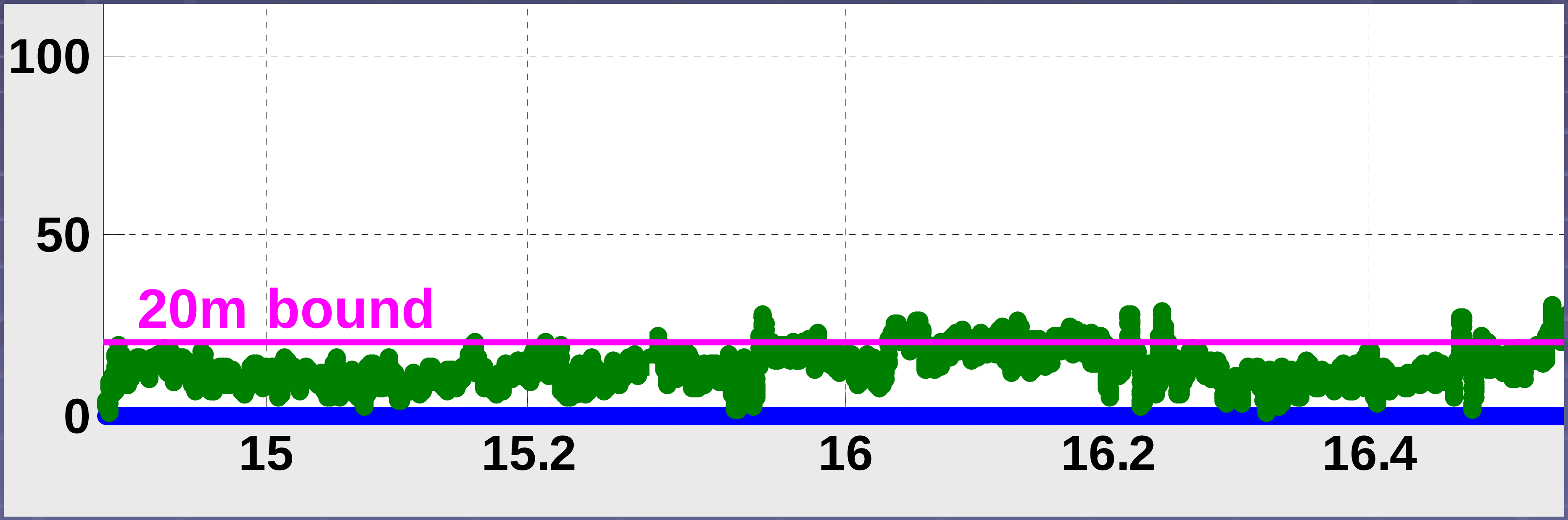
- Interpolate to a uniform grid
- Methods:
  - Interpolation between points
  - Have also tried Universal Kriging



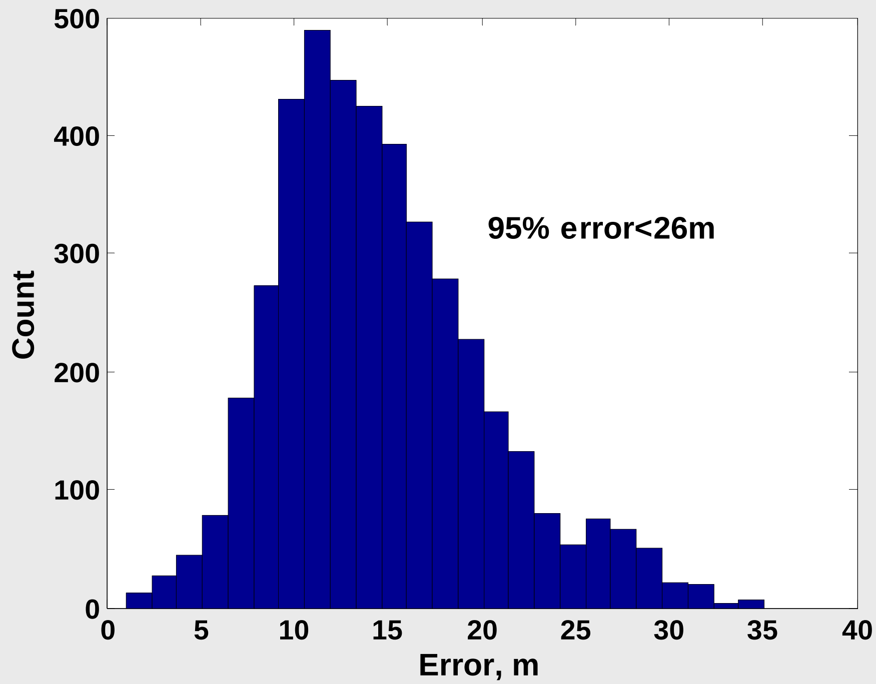
Static Grid Performance Trial



Position Error Results



Statistics


500
400
300
200
100
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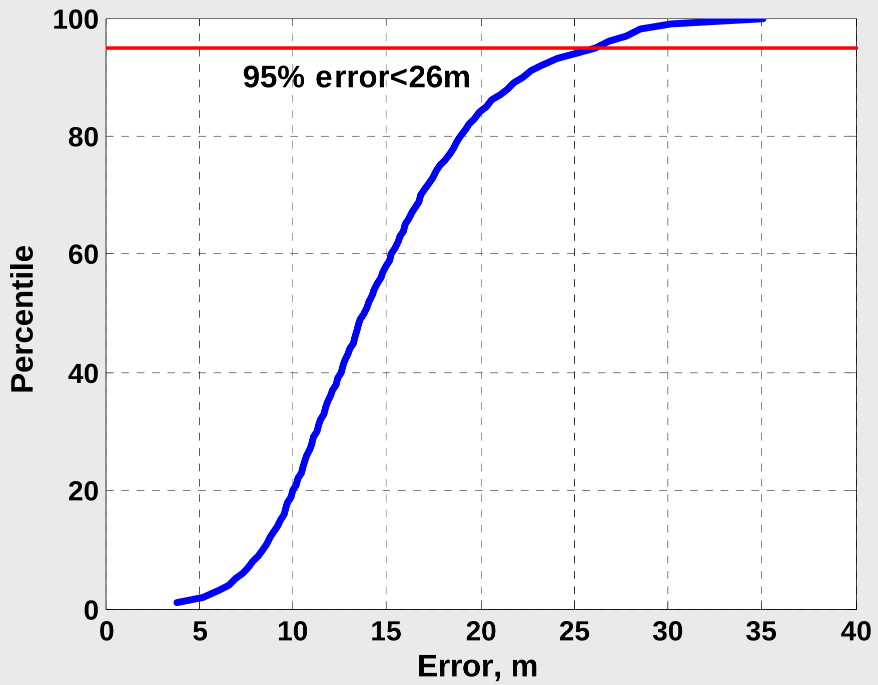
Count
0
5
10
15
20
25
30
35
40
Error, m
95% error<26m


100
80
60
40
20
0
Percentile
0
5
10
15
20
25
30
35
40
Error, m
95% error<26m

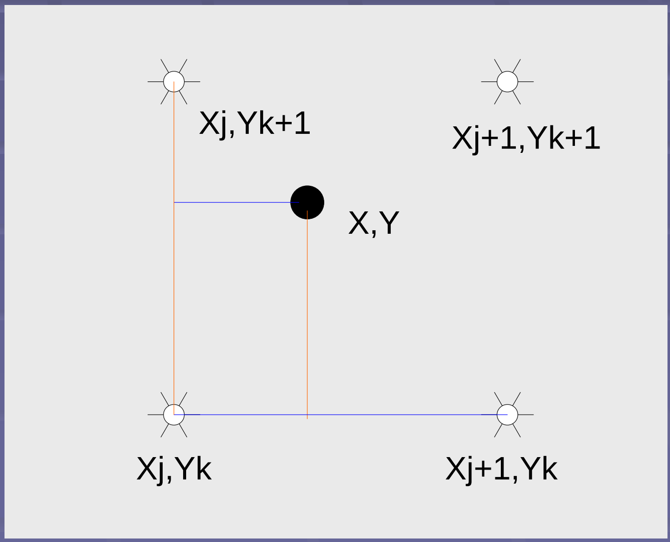
Grid Creation – Dynamic Data

- Recall standard linear interpolation:
  - Given a function at grid points, we can interpolate a general $F(x, y)$ by

$$\begin{aligned} F(x,y) \quad &= \quad (1-a)(1-b)F(x_j, y_k) + a(1-b)F(x_{j+1}, y_k) \\ &\quad + b(1-a)F(x_j, y_{k+1}) + abF(x_{j+1}, y_{k+1}) \end{aligned}$$

with

$$a = \frac{x - x_j}{x_{j+1} - x_j} \quad \text{and} \quad b = \frac{y - y_k}{y_{k+1} - y_k}$$



“Inverse Interpolation”

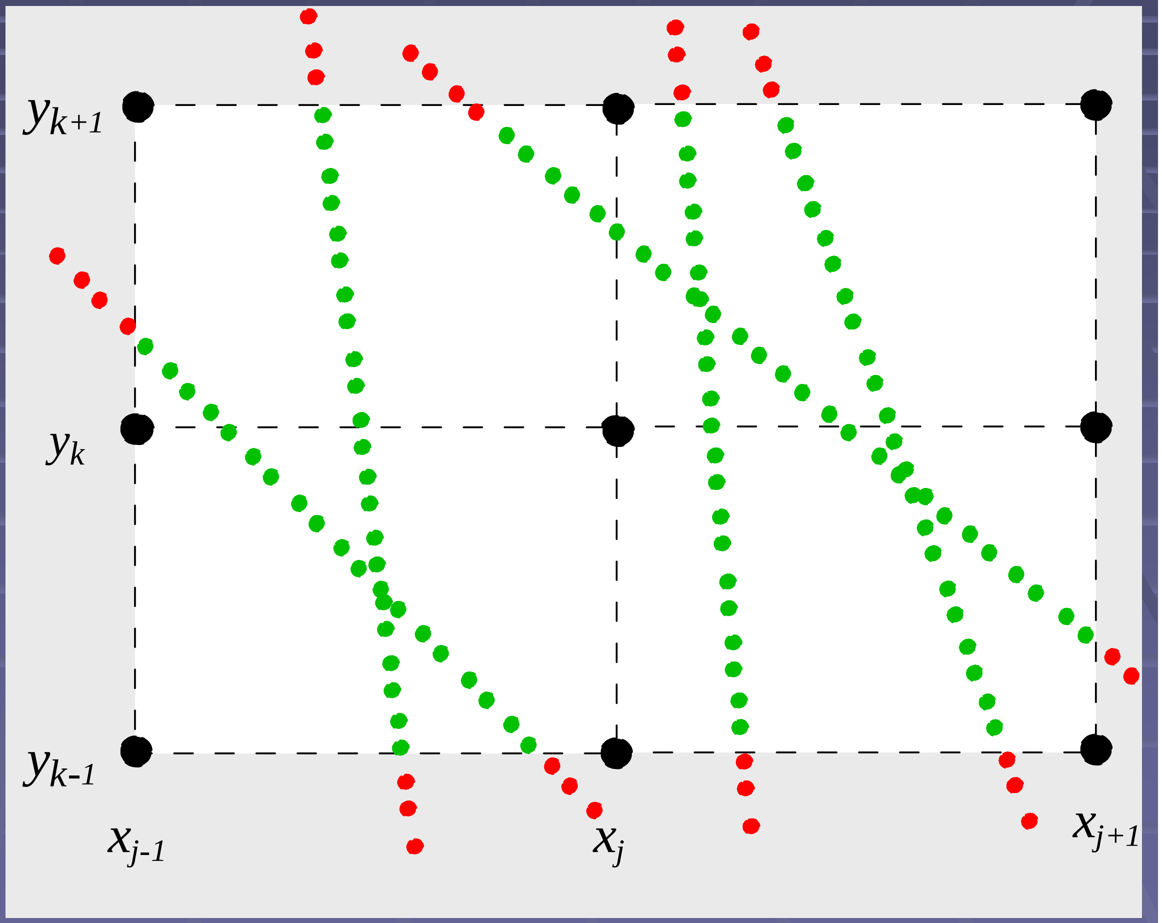
- Turn the equations around:

$$
\begin{aligned}
&(1-a)(1-b)F(x_j, y_k) + a(1-b)F(x_{j+1}, y_k) \\
&+ b(1-a)F(x_j, y_{k+1}) + abF(x_{j+1}, y_{k+1}) \qquad = \quad F(x, y)
\end{aligned}
$$

  - a, b, and $F(x, y)$ are known
  - so each data point yields a linear equation in 4 unknowns
  - solve large set of simultaneous linear equations to get grids

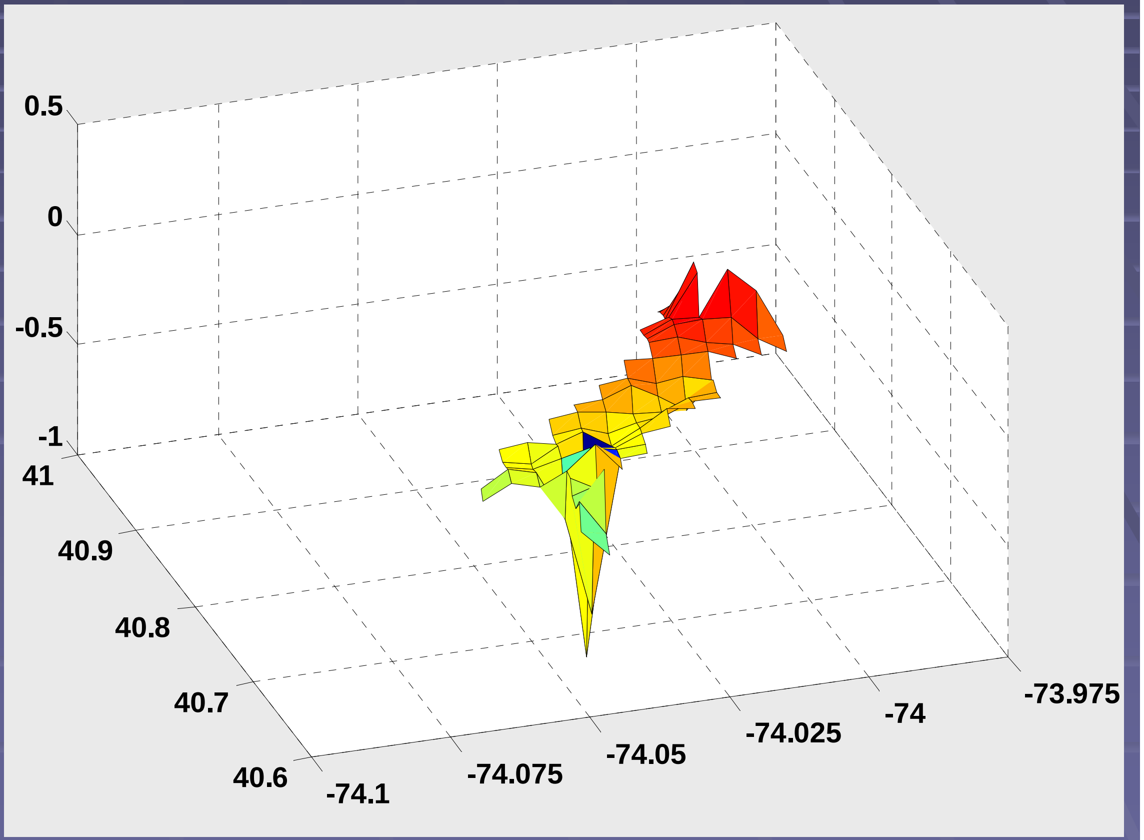
Advantages of New Scheme

- Geometry of data is used
- Implicit correlation over adjacent grid points
- Fewer ASF values are missing

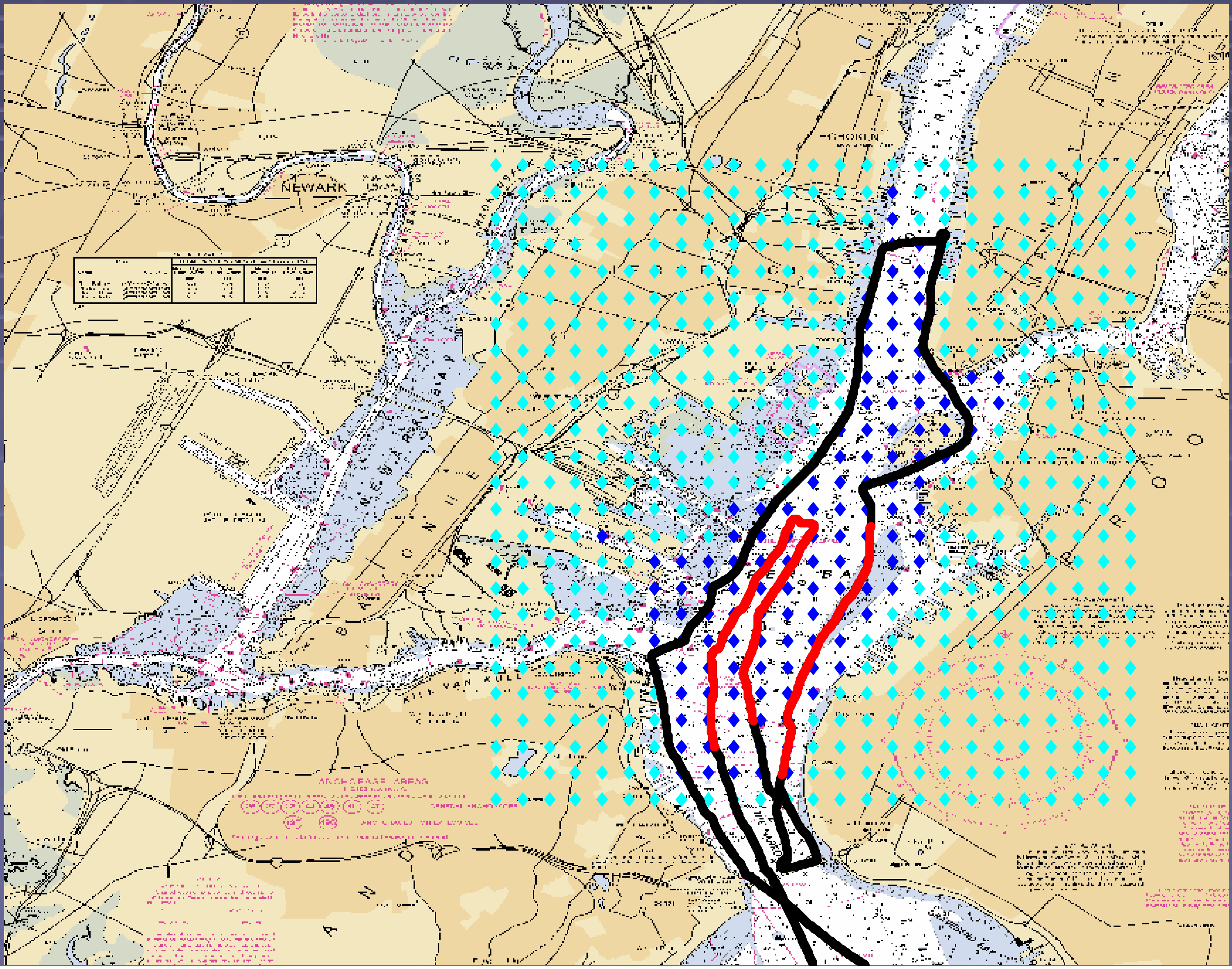


Sample Grid - Nantucket

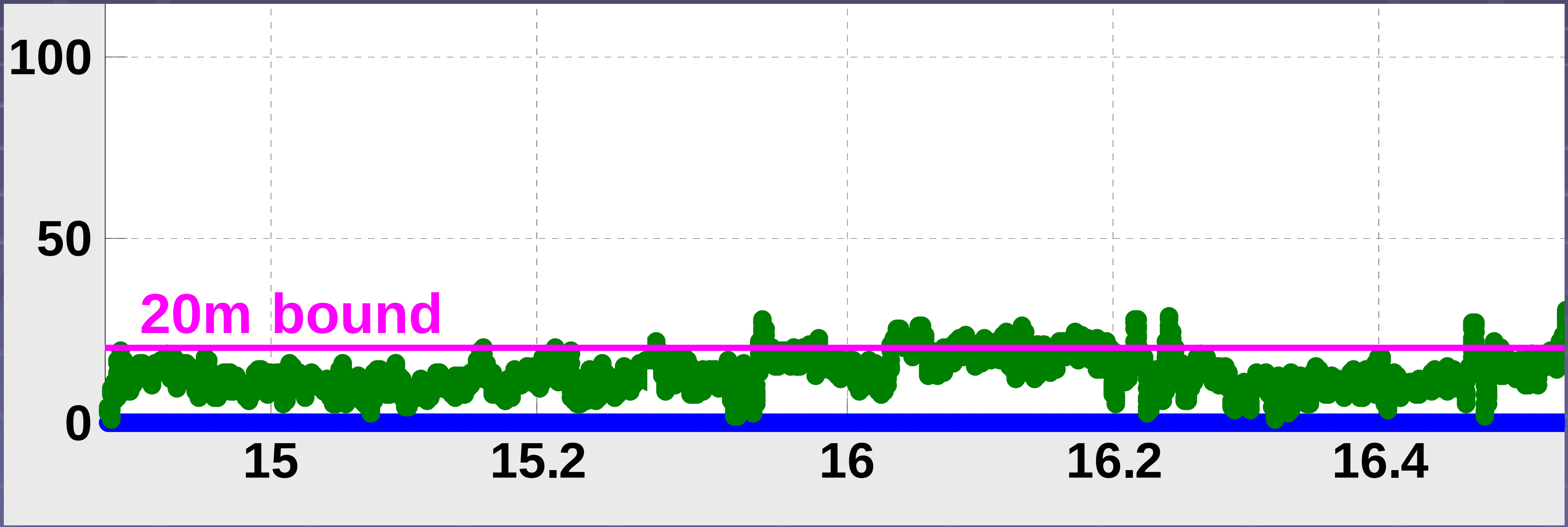
- Skip grid points with only a few equations (noise averaging)



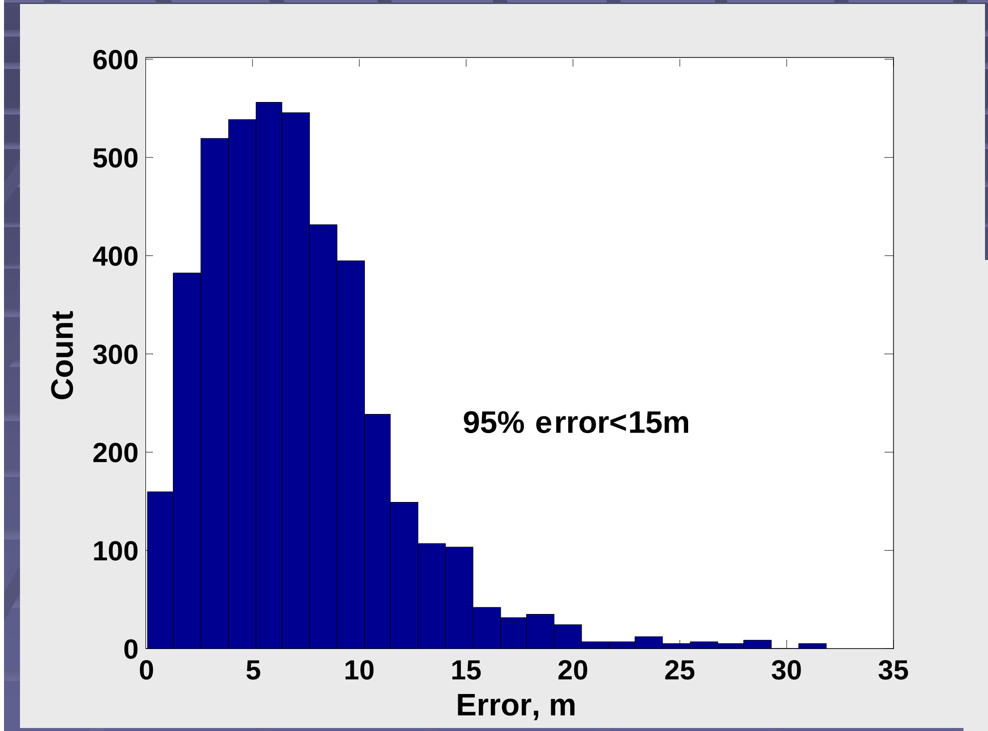
Dynamic Grid Performance Trial



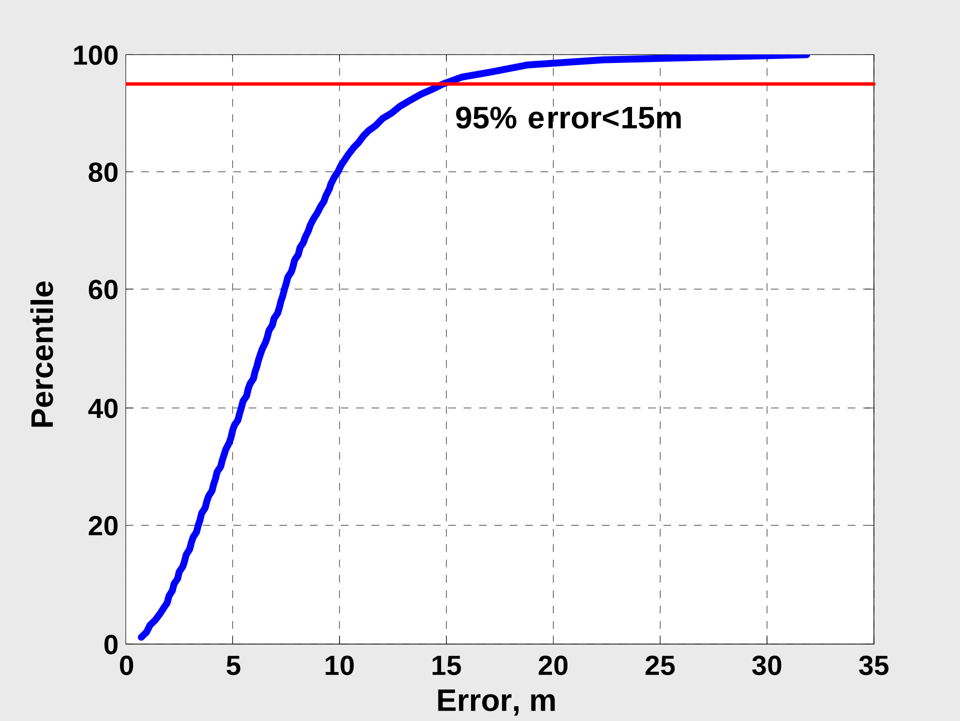
Inverse interp. Grid results



Statistics



600
500
400
300
200
100
0
Count
0
5
10
15
20
25
30
35
Error, m
95% error<15m

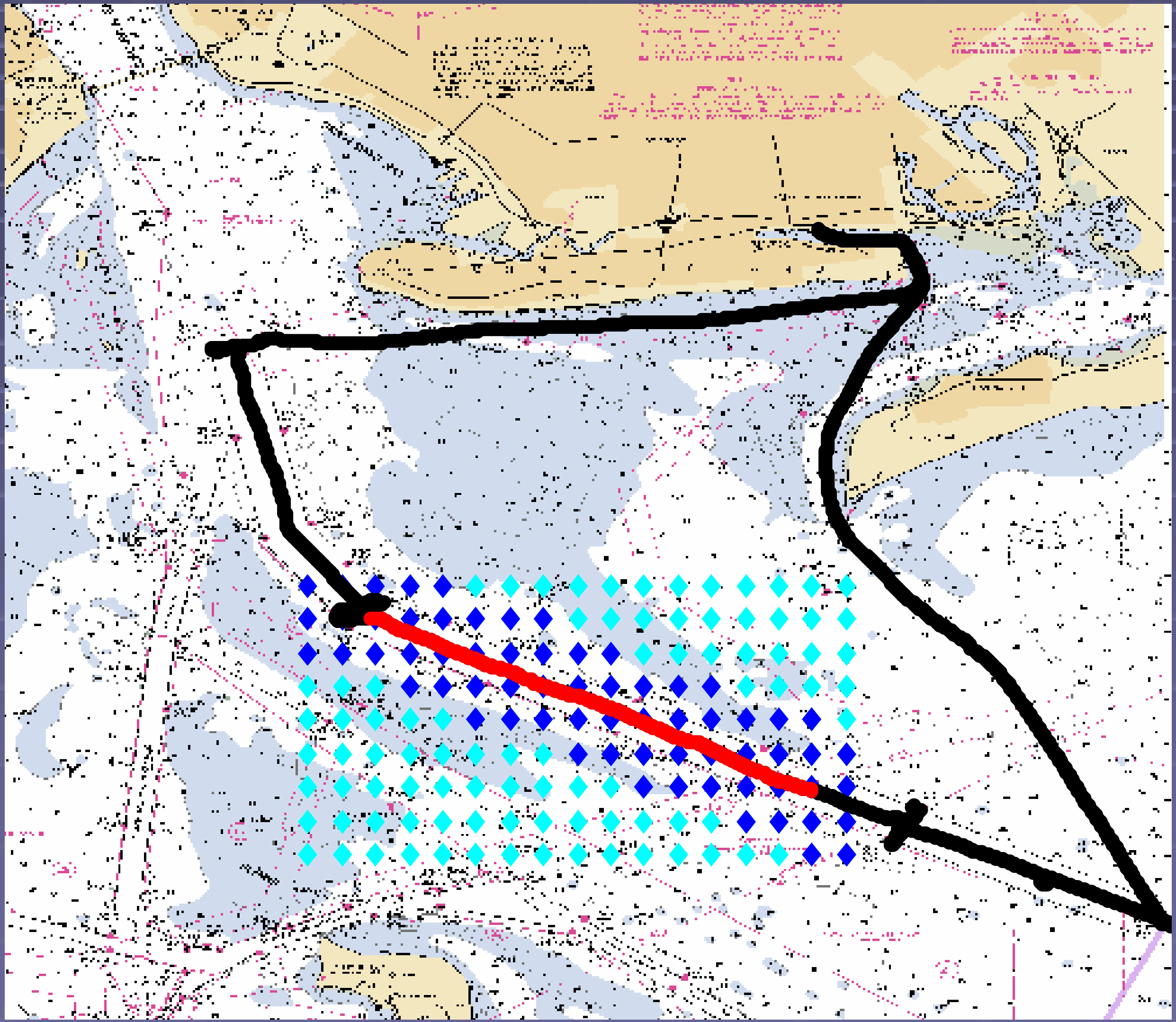


100
80
60
40
20
0
Percentile
0
5
10
15
20
25
30
35
Error, m
95% error<15m

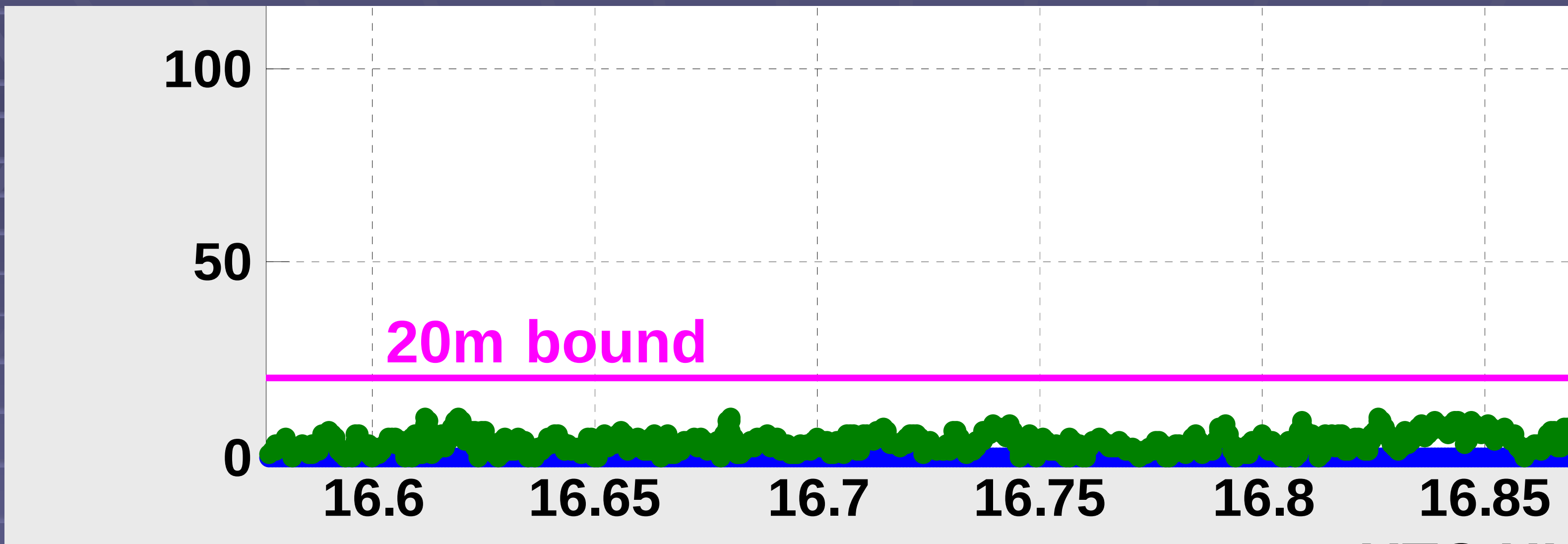
Lower Channel Test

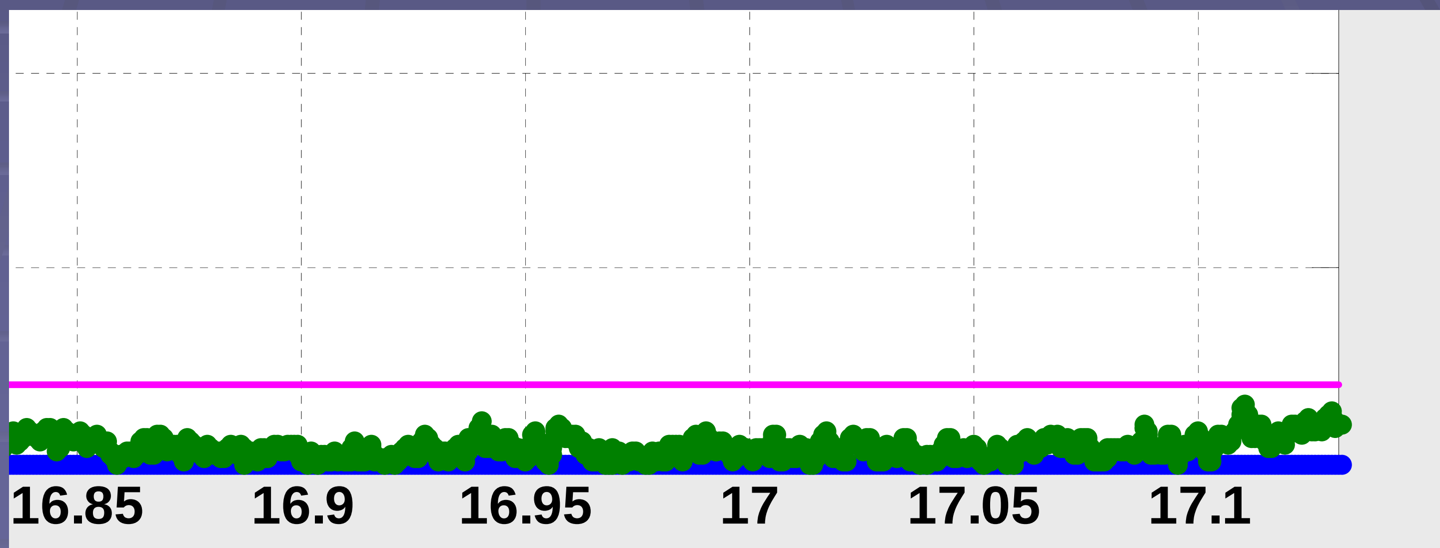
Created the Grid from One Day's
Data and Testing on a
Track from the Next

Lower Channel grid

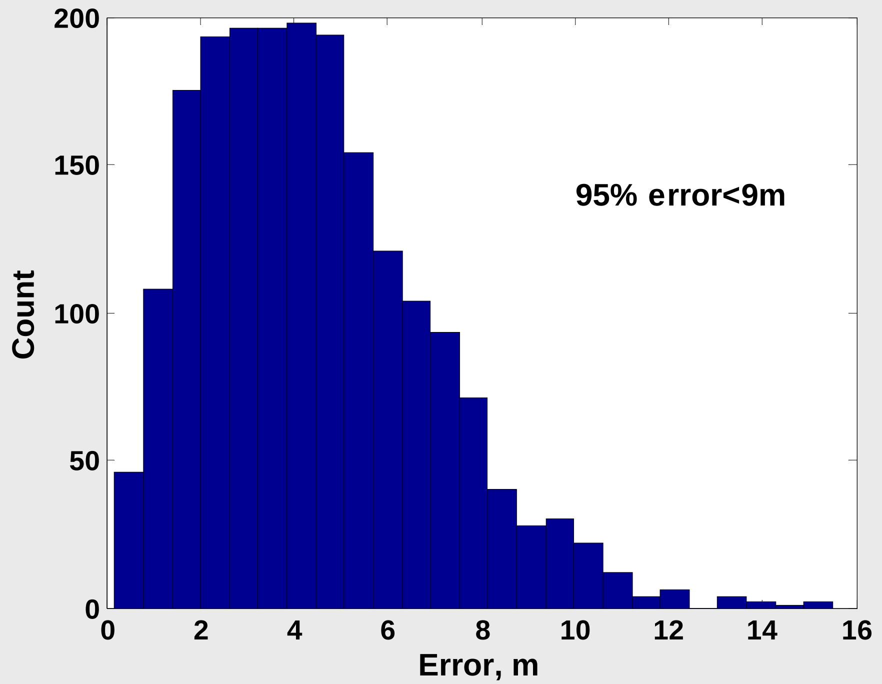


Lower Channel results





Statistics


200
150
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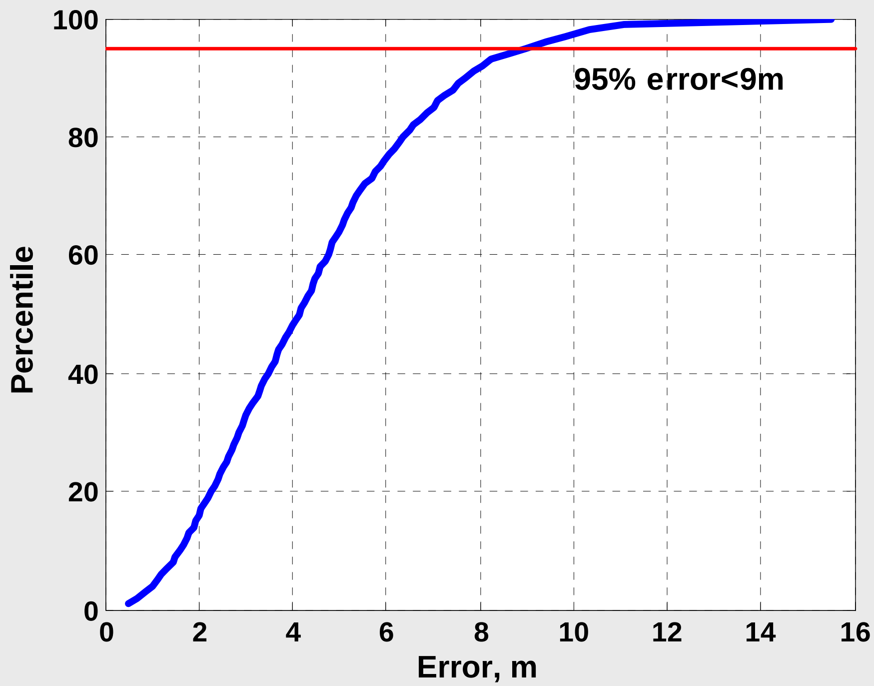
50
0
Count
0
2
4
6
8
10
12
14
16
Error, m
95% error<9m


100
80
60
40
20
0
Percentile
0
2
4
6
8
10
12
14
16
Error, m
95% error<9m

Conclusions

- Inverse Interpolation technique appears to be the best at this point
- Leads to collecting data by continuous survey of harbors – covering as much of navigable area as possible
- 20m accuracy possible with fairly sparse grid (500m spacing)

Questions?