PETERSON INTEGRATED GEOPOSITIONING

Differential Loran – 2004 Progress & 2005 Plans

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Funded by Federal Aviation Administration, Mitch Narins, Program Manager

International Loran Association, October 2004

-Note- The views expressed herein are those of the authors and are not to be construed as official or reflecting the views of the U.S. Coast Guard, the U. S. Federal Aviation Administration, or the U.S. Departments of Transportation and Homeland Security.

Outline

- Goals for FY05
  - Navigation
  - Time
- Program for FY05
  - Seneca LDC tests
    - Data Communications
    - Required Hardware
  - Establish timing base stations
- ASF Surveys
  - Software to planj, execute, & analyze surveys
  - Boston Harbor examples
- Comparison of 9th pulse and EUROFIX modulation

Goals for FY05

- Establish differential Loran navigation and timing capability on a 24/7 testing basis in selected areas in NE US
- Develop procedures & working knowledge necessary to establish differential Loran in an area

Program for FY05

- Establish timing base stations at
  - USCG Loran Support Unit
  - Volpe National Transportation Systems Center, Cambridge, MA
  - USCG Loran Monitor, Sandy Hook, NJ
  - US Naval Observatory, Washington, DC
- Complete marine navigation surveys
  - Boston Harbor
  - New York/Chesapeake/Delaware

Basic Issues

(* acknowledged/not covered)

- Communications network
- Base station density
- Surveys
  - Boundaries of the survey*
  - Survey density and level of redundancy
  - Seasonal variations
  - Grid density
  - Format of grid*
  - Absolute or relative TOA's*
  - Source of ground truth
  - Data integrity check

Seneca Loran Data Channel (LDC) tests

- Tasks to accomplish
  - Testing Time & Frequency Equipment (TFE) at LSU
    - Testing is mainly for new features of TFE version 11 which includes but is not limited to LDC
  - Establish communications to LDC computer at Seneca, base stations at Volpe & Sandy Hook, etc.
- On air from Seneca Spring 2005

Data Communications

- Presently use Loran operational network for LORIPP monitor network
  - No access from Internet
  - Limited bandwidth
  - Can’t use for test differential Loran due to operational nature
- Effort underway @ LSU to define new operational network
  - 1-2 years away
- Interim solution is Internet based communications
  - Established connections – USNO, LSU, PIG, TSC, etc.
  - Wireless, cable modem, dedicated landline (Volpe, Sandy Hook, Seneca)

Software tools for planning & executing surveys

- Uses raster scanned NOAA charts
  - Convert from BSB to .tif then to 8 bit bitmap
  - Registers lat/lon to pixel & colormap
- Planning
  - Point & click
  - Saves path as lat/lon file for execution phase
  - Saves screens
- Executing
  - Effectively multiple NMEA input ECDIS with same GUI & file format as planning software

42 21.773 N 071 02.648 W Total path 29.0 NM

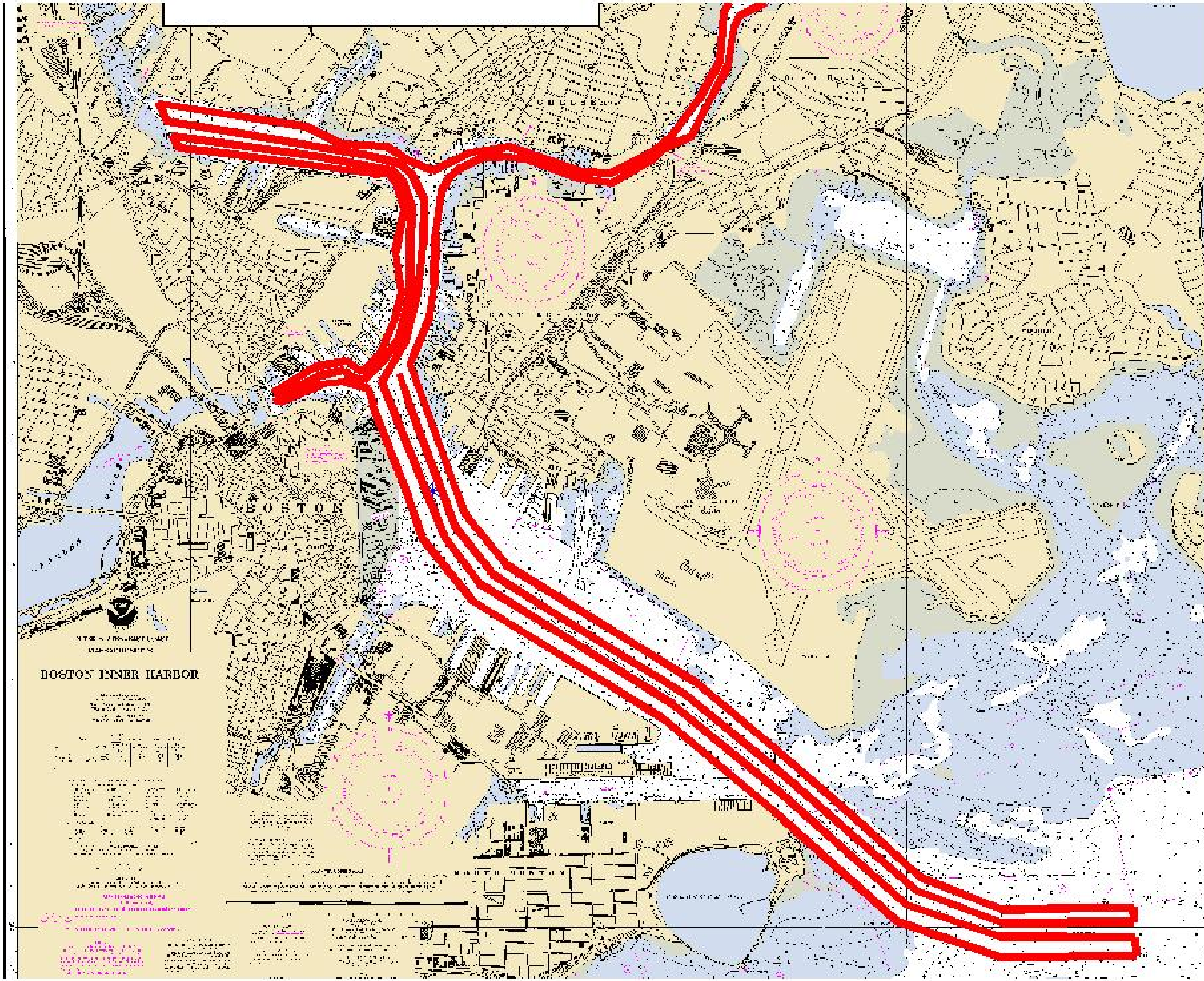


Chart scale	Line Width	Plot Color	Draw Path?	Save jpg file?
xxlarge	3	Red	☐ yes	☑ yes

GPS 42 20.618 N 071 00.605 W SPD: 3.0 HDG:316.9

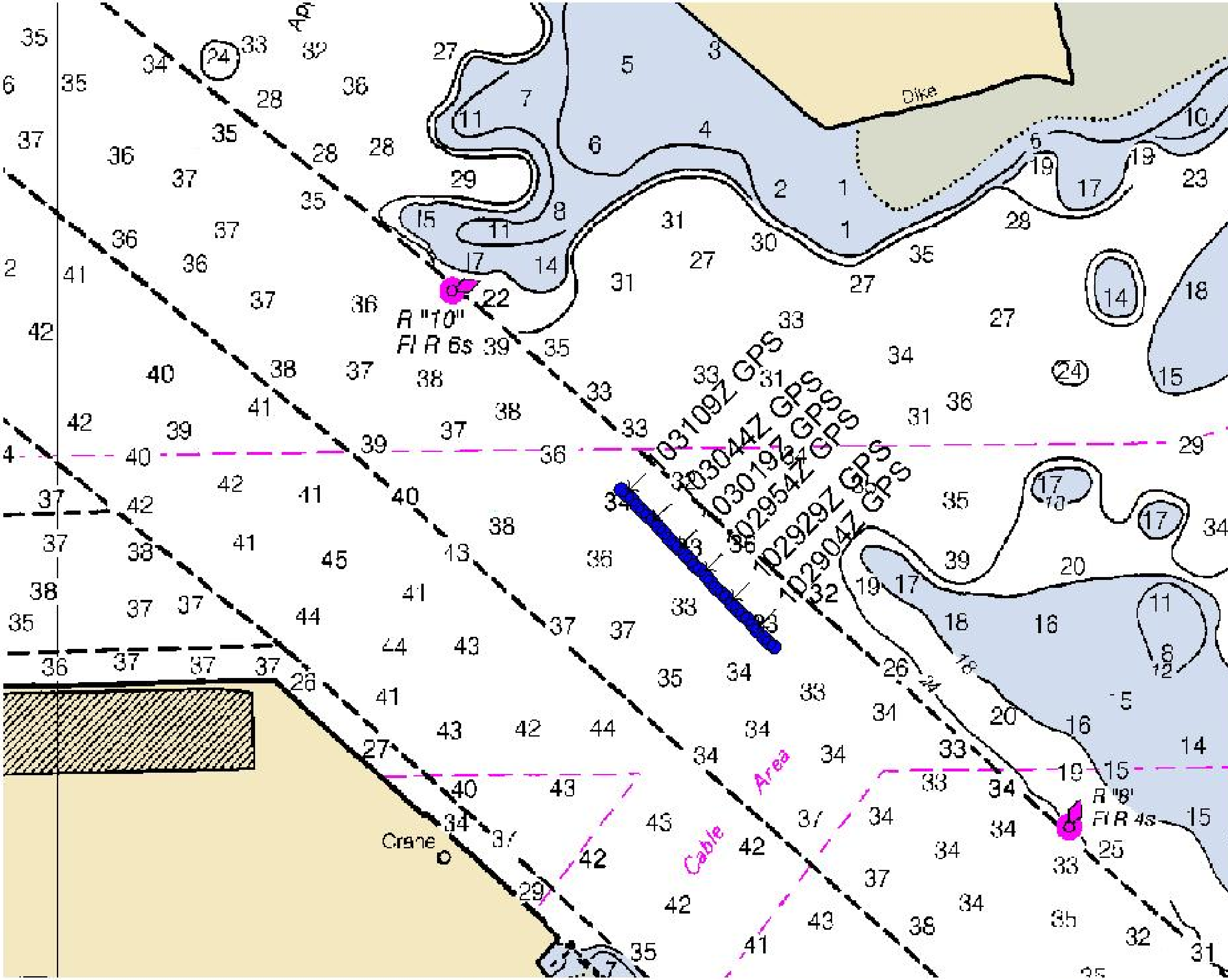


Chart scale	Plot Freq	Plot History	Time	Plot Course
medium	6 sec	30 pt	☑ Stamp	☐ Vector

Boston Survey

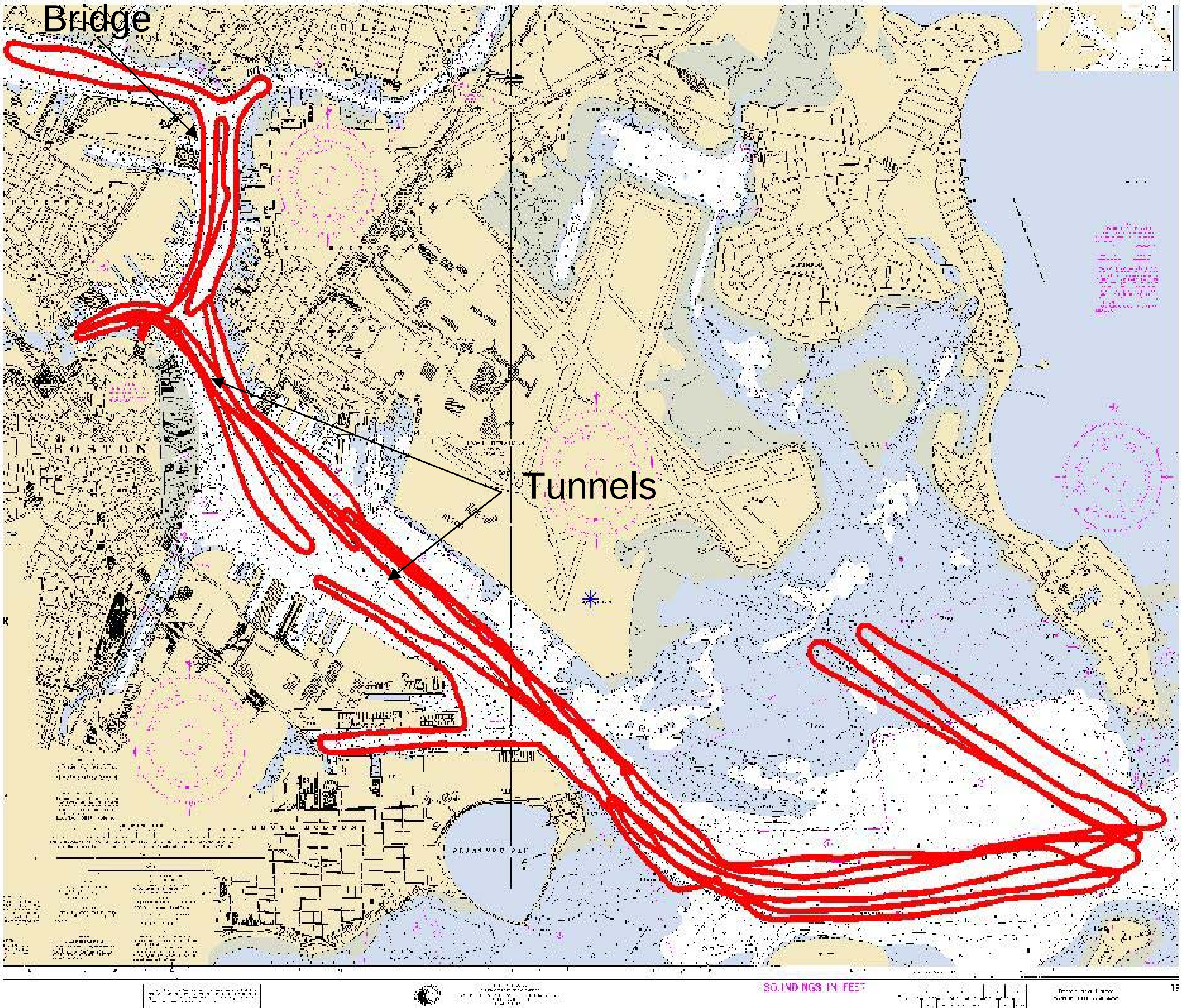
- Completed preliminary survey on July 17th (before planning & executing software done)
  - Data for both WAAS (WGS-84) & DGPS (NAD-83) collected
- Need to collect more data
  - Study seasonal variations
- Establish ASF format and grid size
- Data follows

Software tools for analyzing surveys

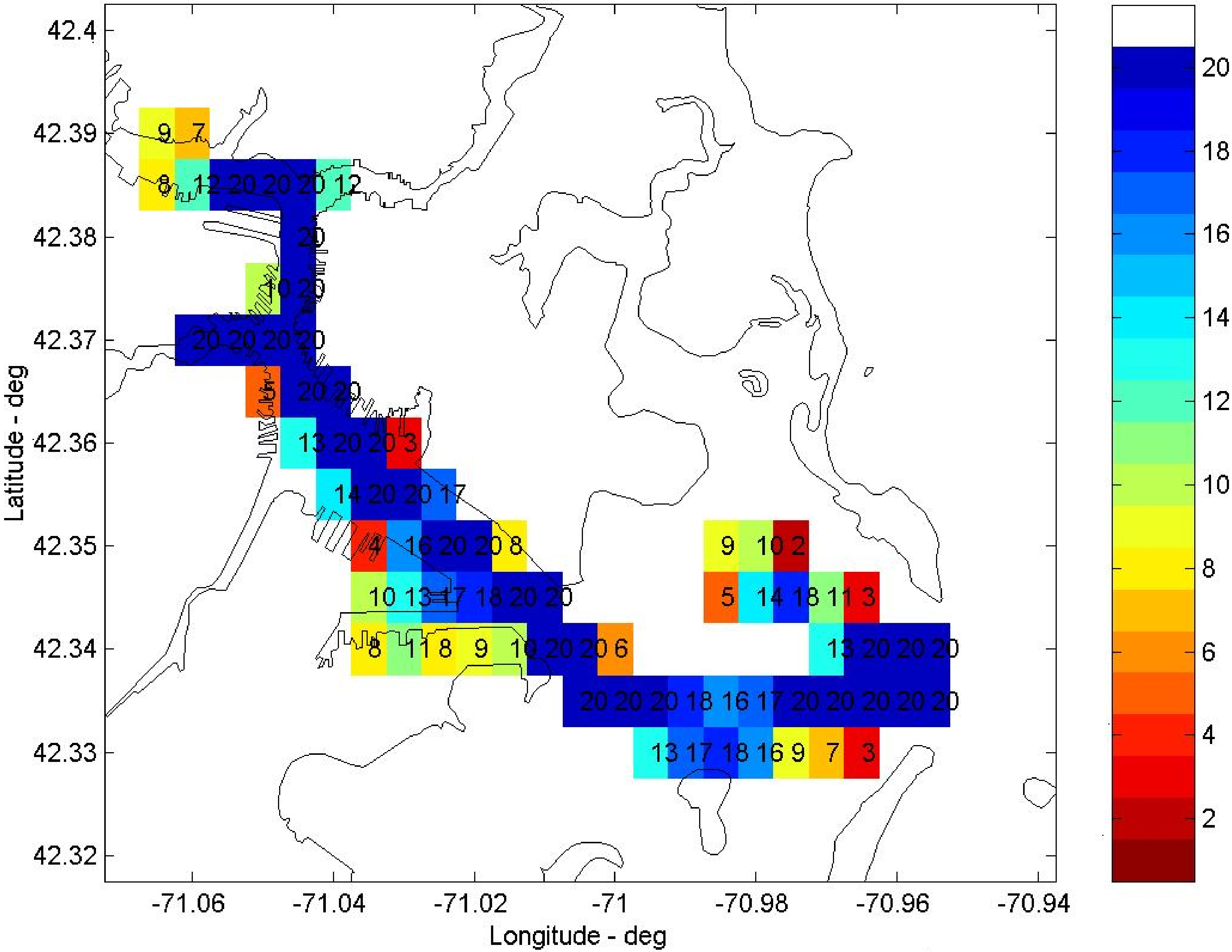
- ASFs are calculated and organized by cells
  - Cell size is variable TBD, it may vary from port to port or even within a port
- Calculates & plots for each cell
  - Number of samples
  - Mean
  - Standard deviation
  - Max difference to any adjacent cell
- Idea is to validate
  - Enough data was collected
  - The data is valid
  - Cell density is sufficient such that Variations within a cell or between adjacent cells are adequately bounded

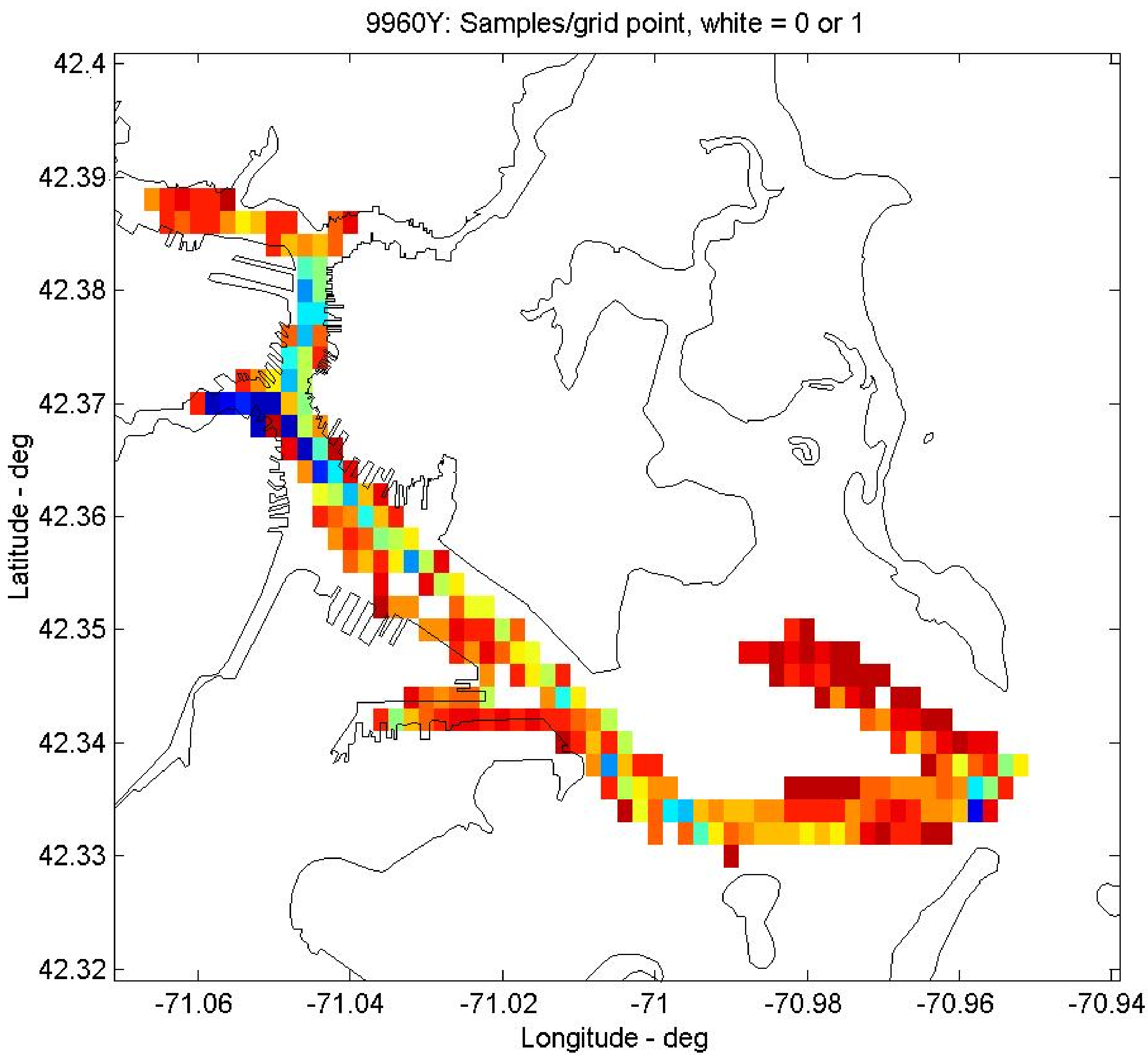
Path of survey in Boston Harbor

42 21.112 N 071 00.528 W Total path 46.1 NM



9960X: Samples/grid point, white = 0 or 1





9960Y: Samples/grid point, white = 0 or 1
Latitude - deg
Longitude - deg
42.4
42.39
42.38
42.37
42.36
42.35
42.34
42.33
42.32
-71.06
-71.04
-71.02
-71
-70.98
-70.96
-70.94
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18
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10
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6
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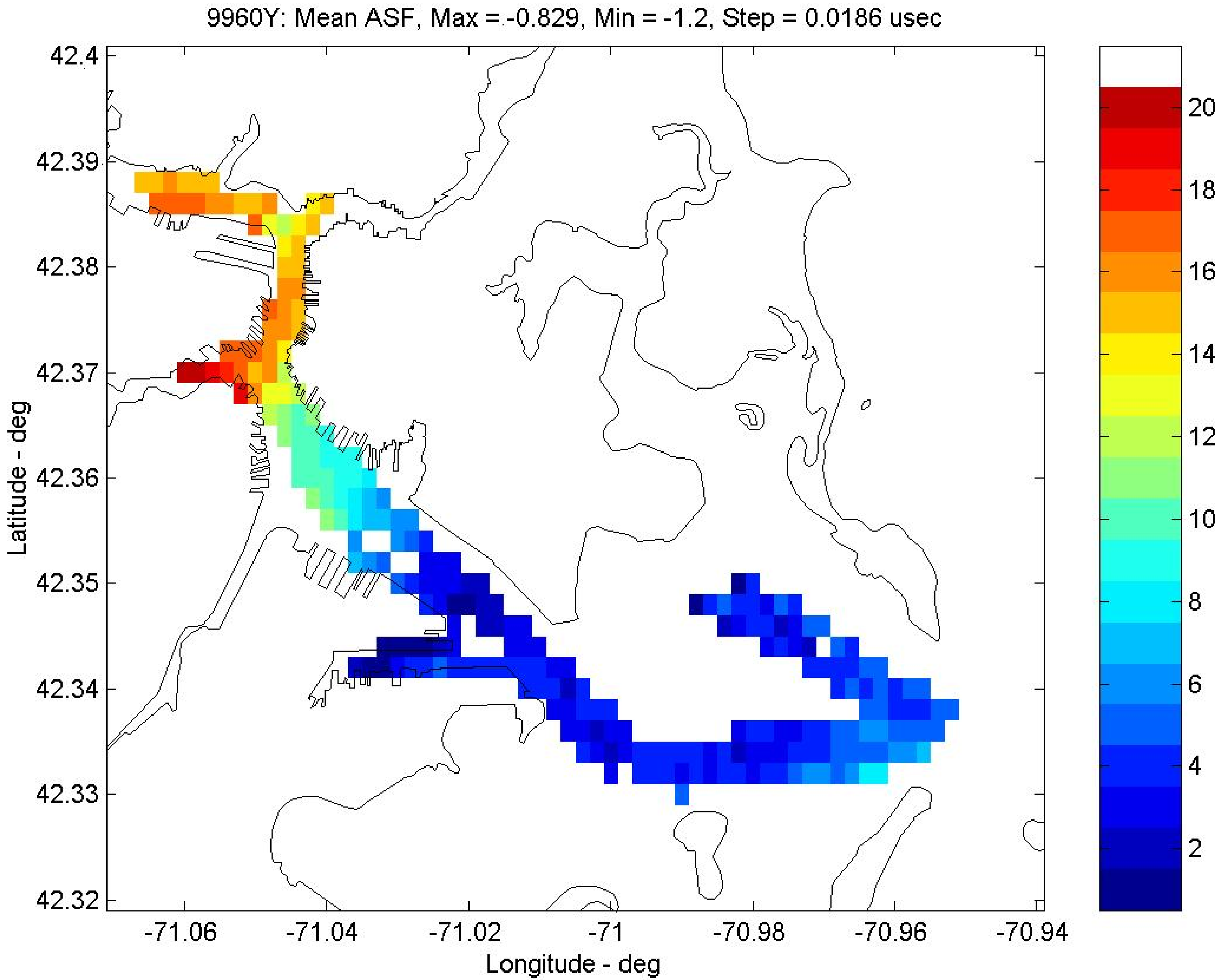
2



9960Y: Mean ASF, Max = -0.829, Min = -1.2, Step = 0.0186 usec
42.4
42.39
42.38
42.37
42.36
42.35
42.34
42.33
42.32
Latitude - deg
-71.06
-71.04
-71.02
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Longitude - deg
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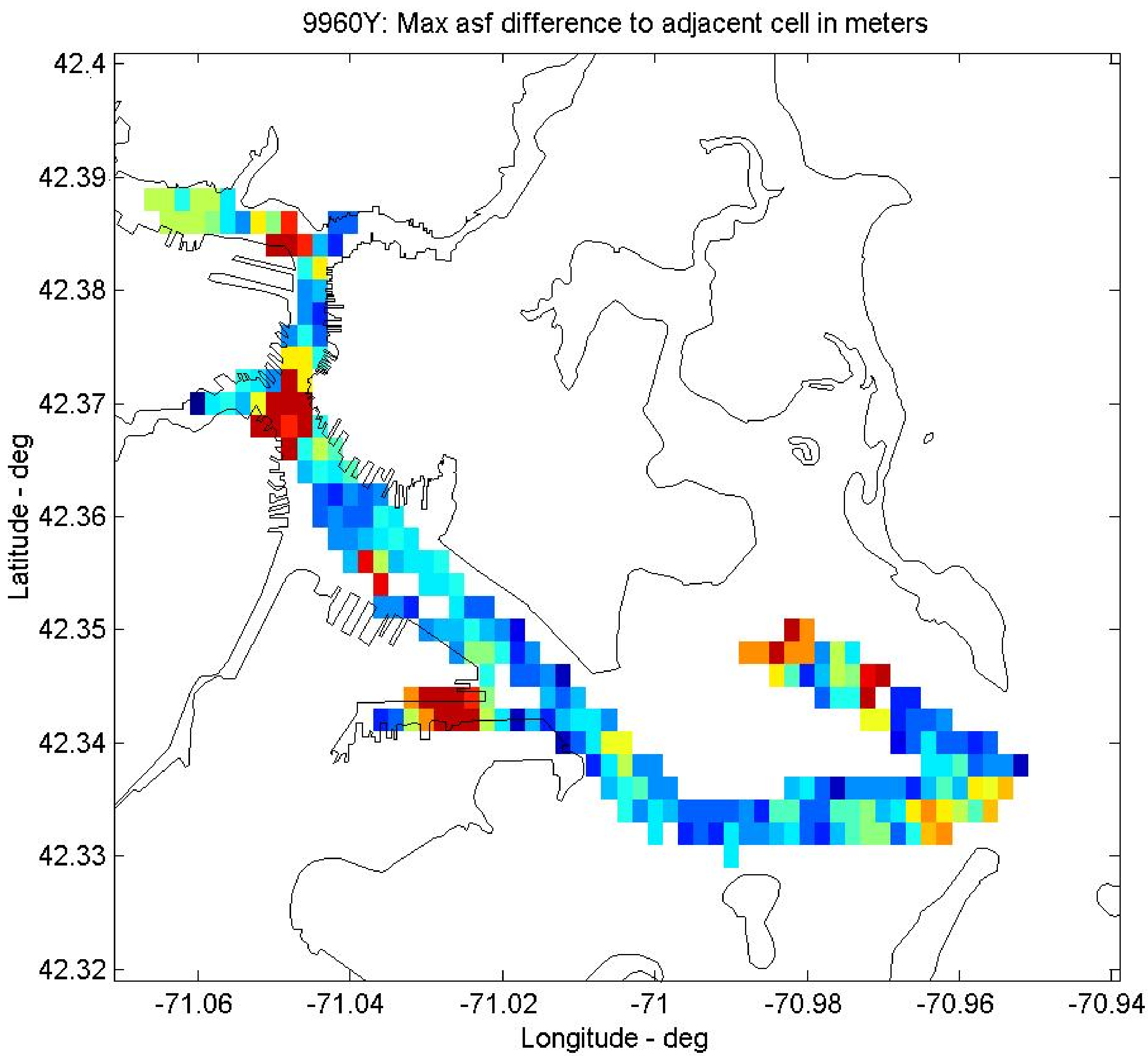
9960Y: Max asf difference to adjacent cell in meters
Latitude - deg
42.4
42.39
42.38
42.37
42.36
42.35
42.34
42.33
42.32
Longitude - deg
-71.06
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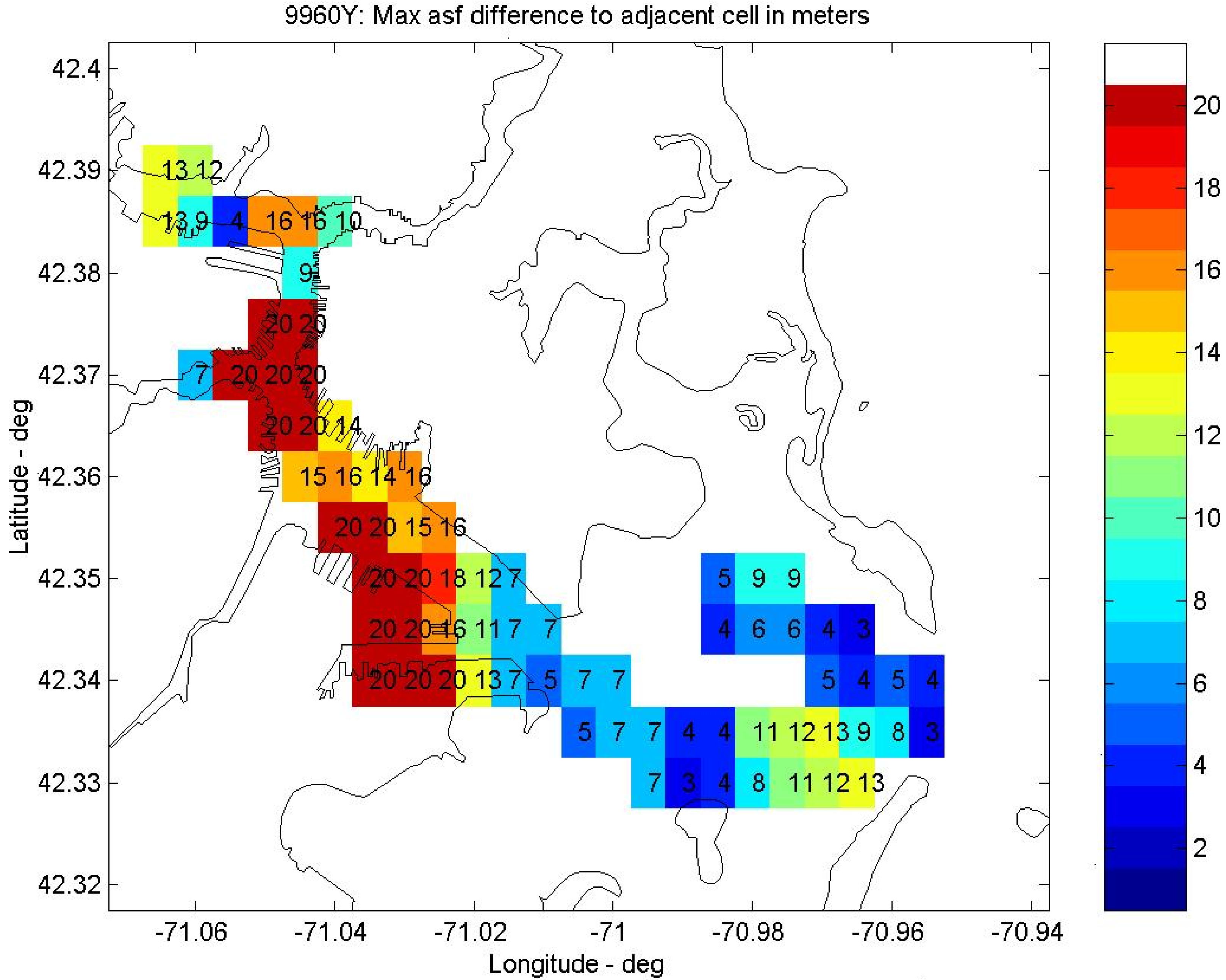
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20 20 18 12 7
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20 20 20 13 7 5 7 7
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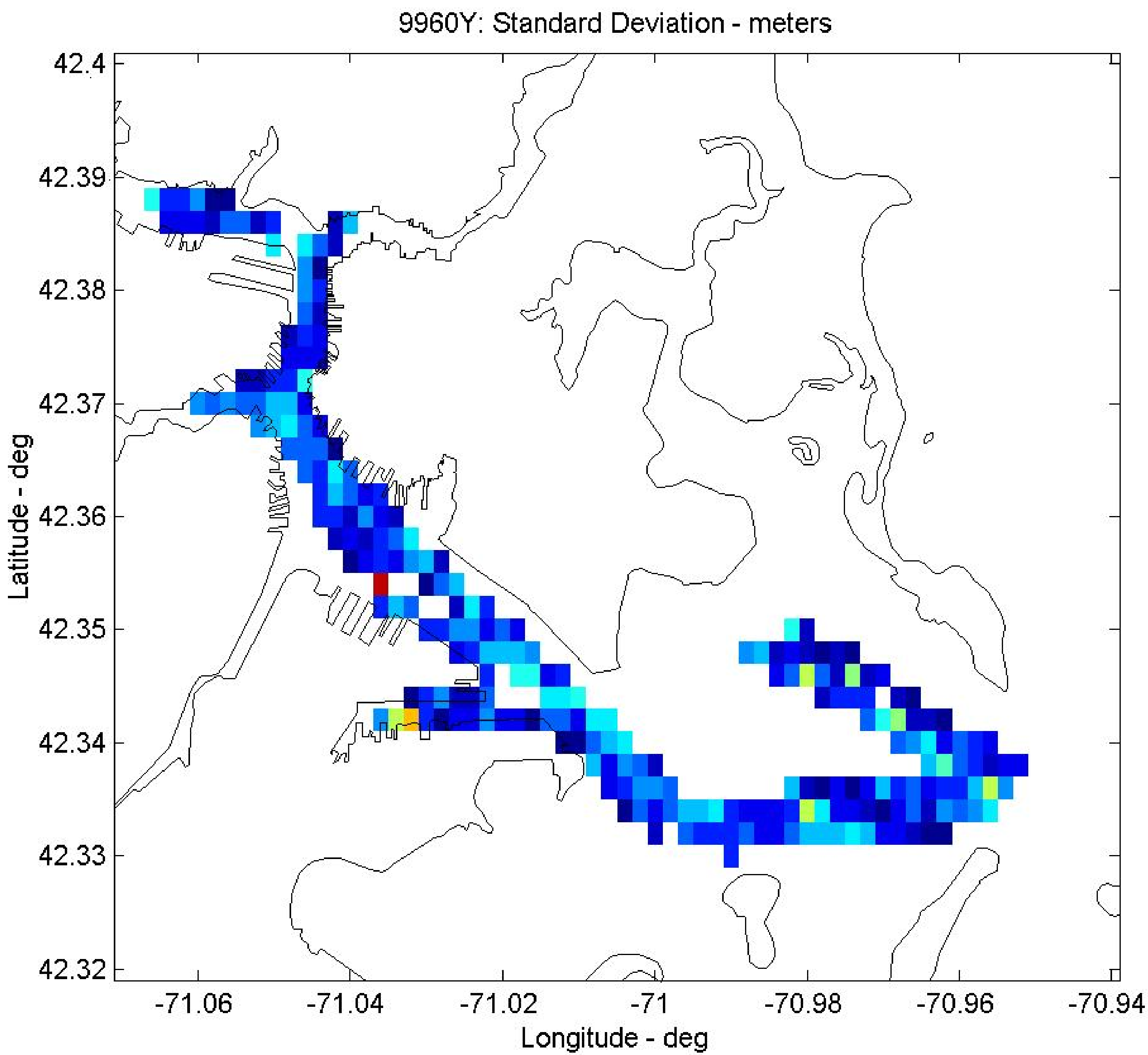
5 4 5 4


9960Y: Standard Deviation - meters
Latitude - deg
Longitude - deg
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42.36
42.35
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42.32
-71.06
-71.04
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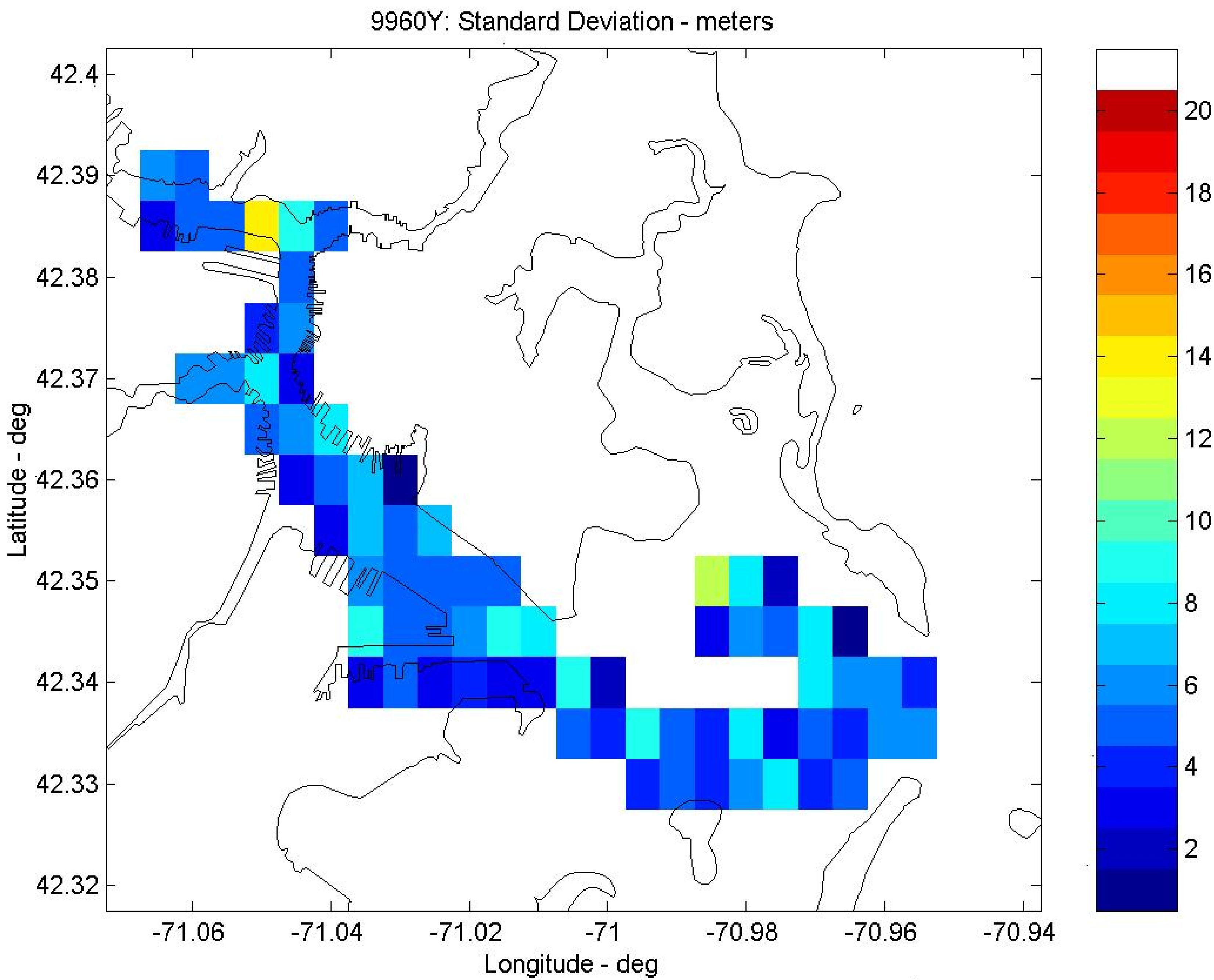
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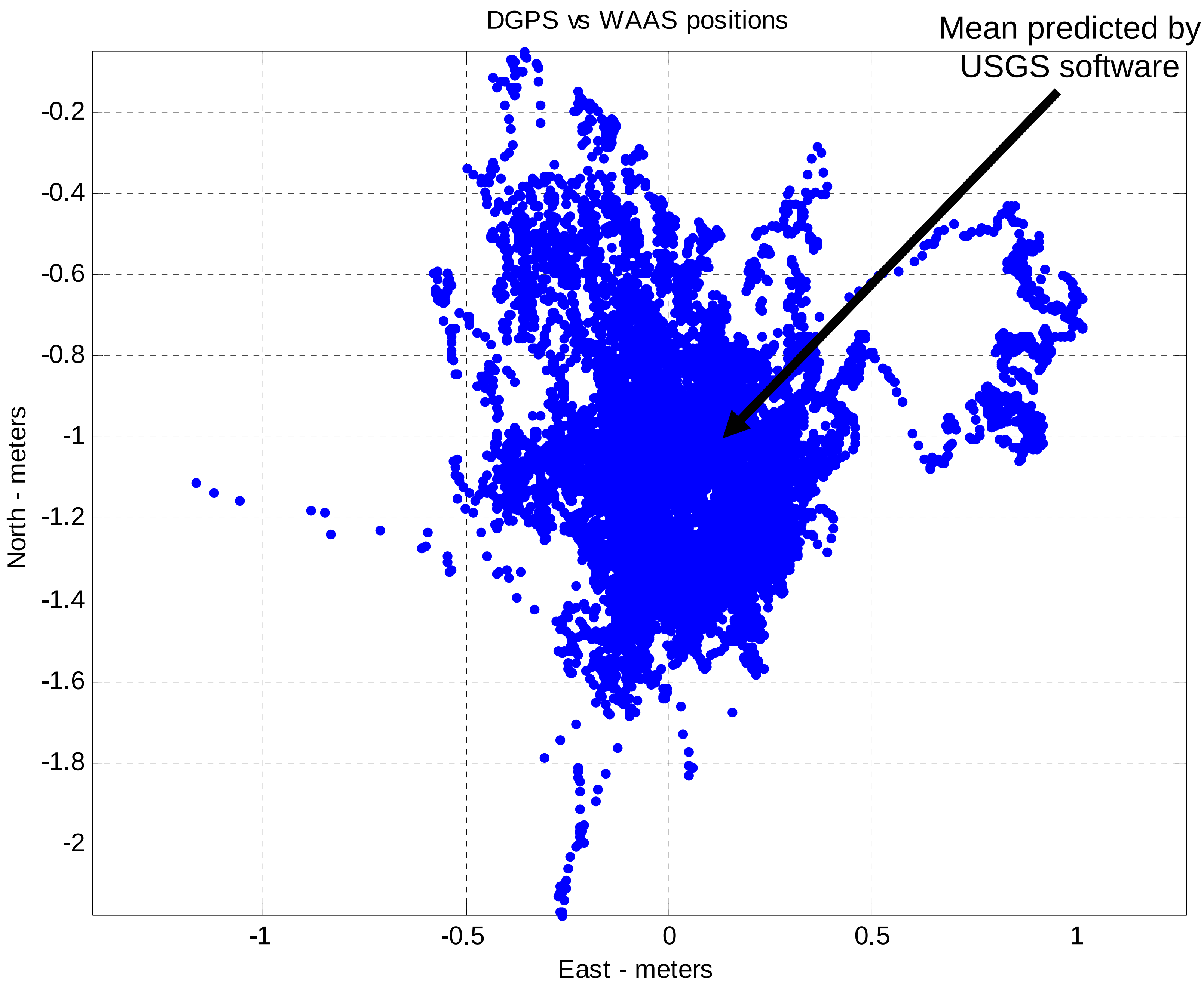


DGPS vs WAAS positions
Mean predicted by
USGS software
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2
North - meters
-1
-0.5
0
0.5
1
East - meters

DGPS (NAD-83) vs WAAS (WGS-84) positions (13901 values)

- East difference
  - Mean = 0.05 m, σ = 0.24 m
- North difference
  - Mean = -1.05 m, σ = 0.26 m
- Predicted by HTDP.exe from NGS Geodetic Tool Kit (www.ngs.noaa.gov)
  - East: 0.18 m
  - North: -1.01 m

9th pulse PPM vs EUROFIX

- Both have comparable data rates & message lengths, EUROFIX could easily transmit the same data we are proposing. Why a new format??
- 2 dB more minimum separation between symbols & entire word in single pulse means far lower word error rate
  - Partially offset by more Reed Solomon parity in EUROFIX

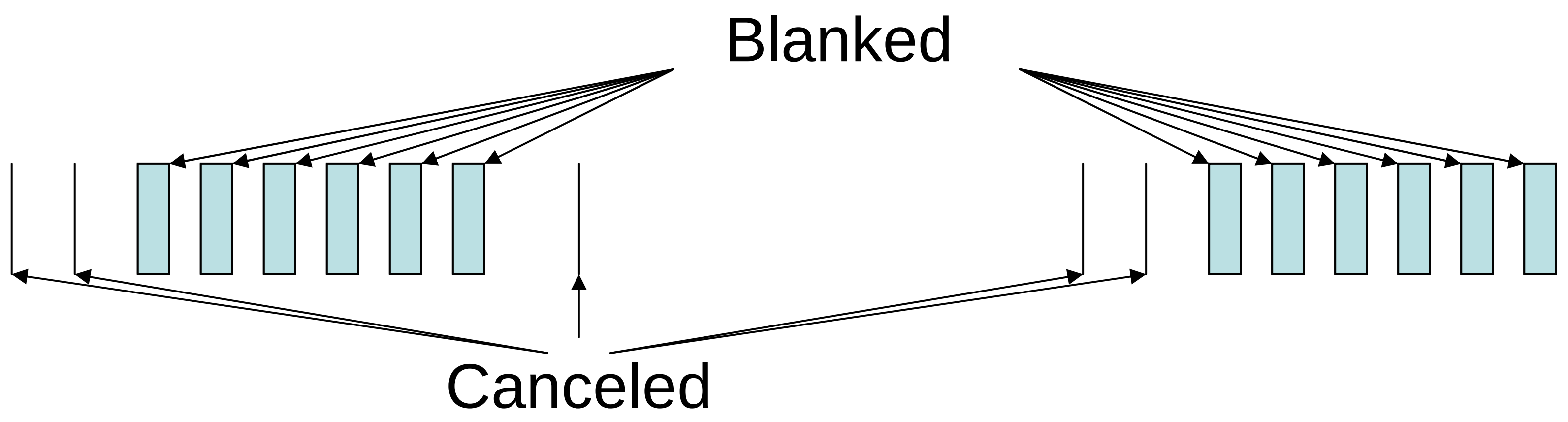
9^{th} pulse PPM vs EUROFIX (cont)

- Main difference is ability to cancel 8/9 of cross rate pulses per GRI vice 2/8
  - It was earlier felt that due to long time constants, maritime & timing receivers can merely blank cross rate: Main issue is aviation where short time constants preclude cross rate blanking
  - However, may be issue for maritime as well due to more stringent accuracy requirements,

9^{th} pulse PPM vs EUROFIX (cont)

- Is it possible to cancel cross rate with Eurofix?
  - After demodulation & data wipeoff – if demodulation errors, canceling not effective, error rate of only those pulses subject to CRI is relevant statistic
    - This can be done sequentially starting by demodulating the strongest signal, wiping off its data & canceling its interference to other rates, then demodulating the next strongest signal, etc.
      - Note: Cross rate as low as -10.2dB can cause demodulation errors without any noise
  - After demodulation and decoding (& data wipeoff) – need delays of up to 3 seconds for completion of message
    - Means running 30-40 EUROFIX receivers in parallel
    - This is what was envisioned in WAAS messaging in 2001, in this case all stations transmitted same data in 1 sec message

Model for CRI blanking in EUROFIX



For each cross rate GRI

$$\text{Fraction of time blanked} = \frac{\text{N signals * 6 pulses/GRI * 0.5 ms/pulse}}{\text{GRI}}$$

Overall fraction not blanked

= product of (1 - Fraction of time blanked for each GRI) for all cross rate GRI’s

Note: Due to cross rate blanking at transmitter, model will not accurately predict multiple cross rate hits, but does accurately predict probability of at least one.

Millington’s method chart used for Loran signal strength

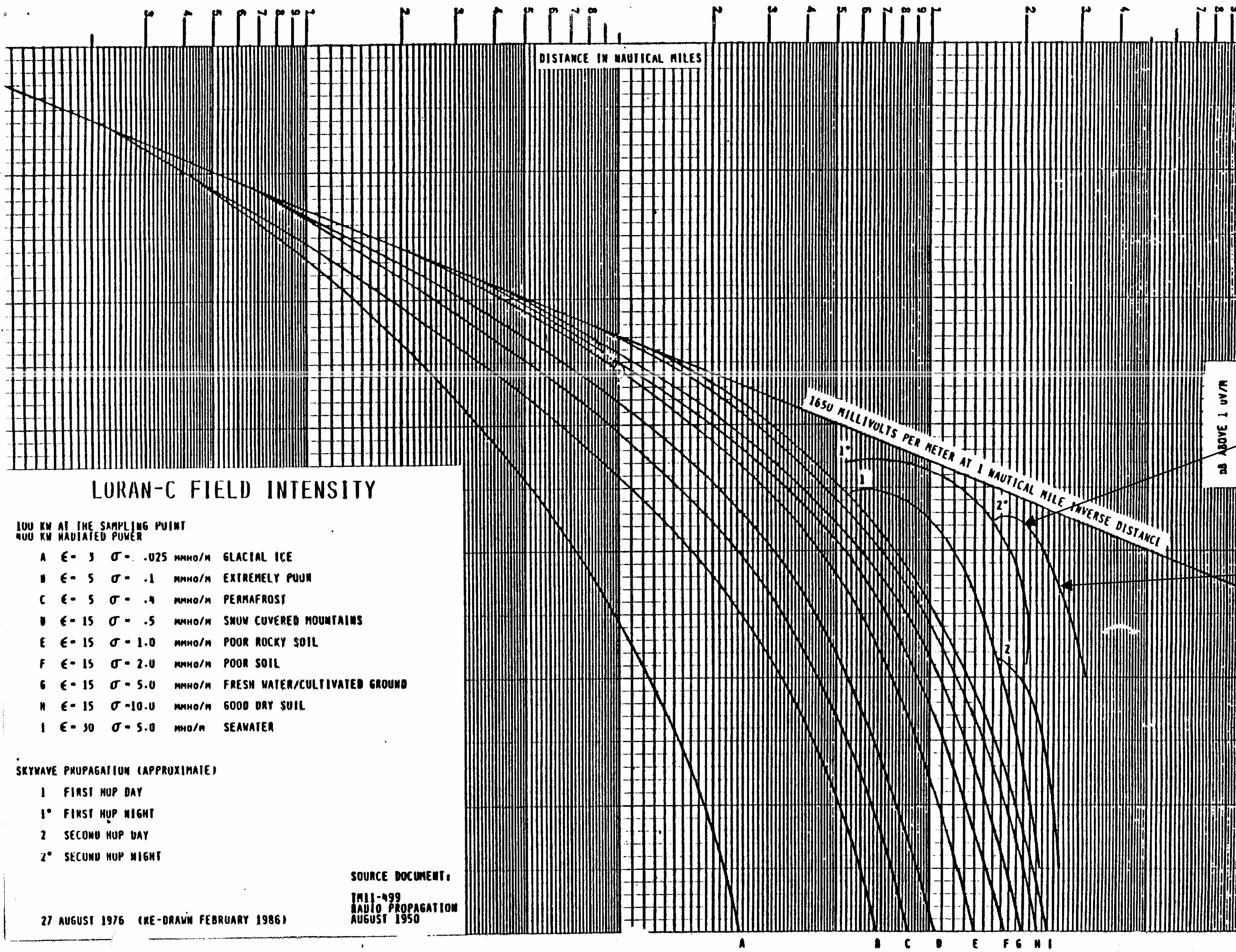


Figure 2 LORAN-C Field Strength vs. Distance

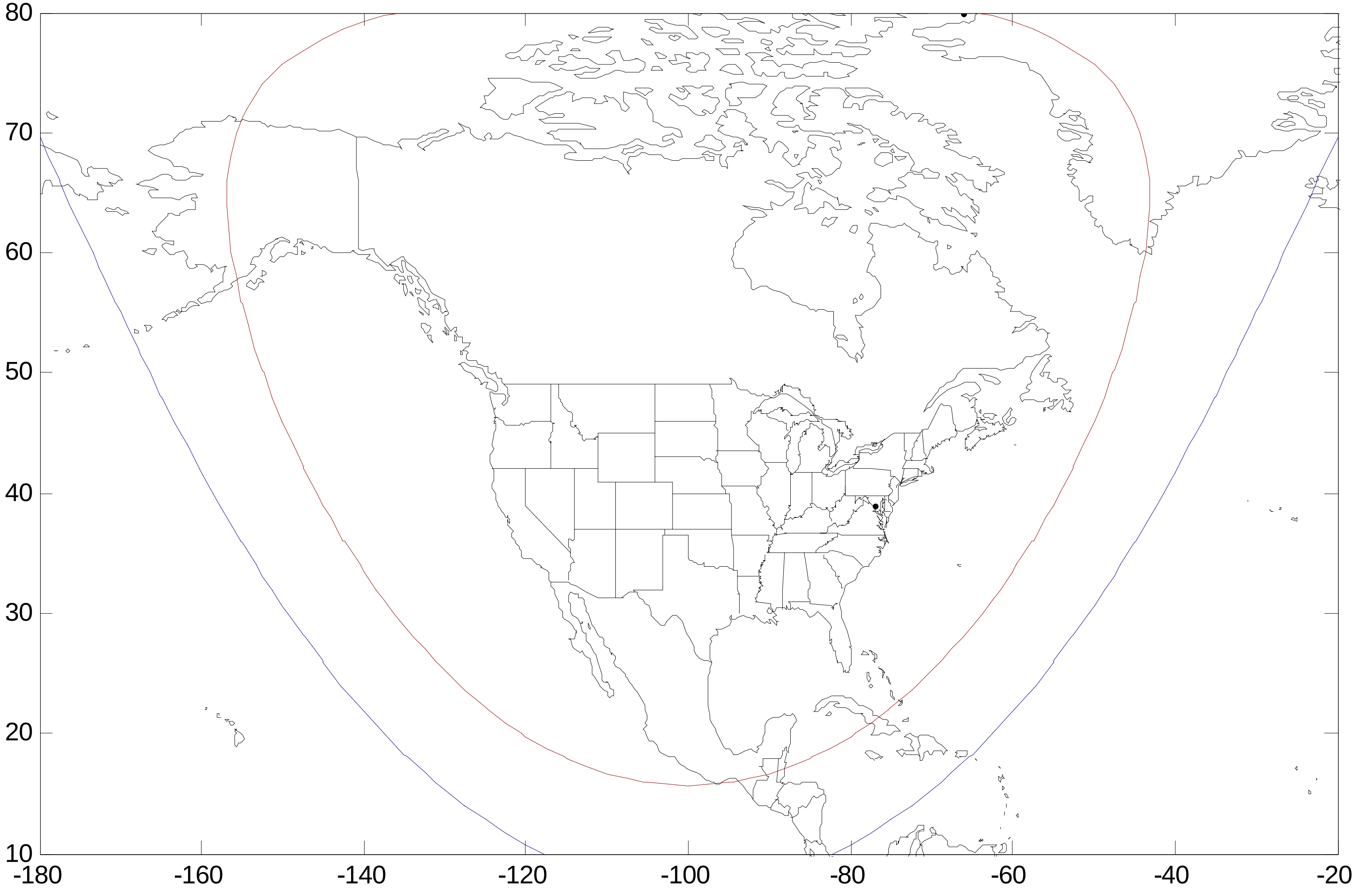
2nd hop night time skywave

54 dB re 1 uv/m at 2000 nm

46 dB re 1 uv/m at 2500 nm

For 400KW

2000 & 2500 NM circles from Upper Midwest

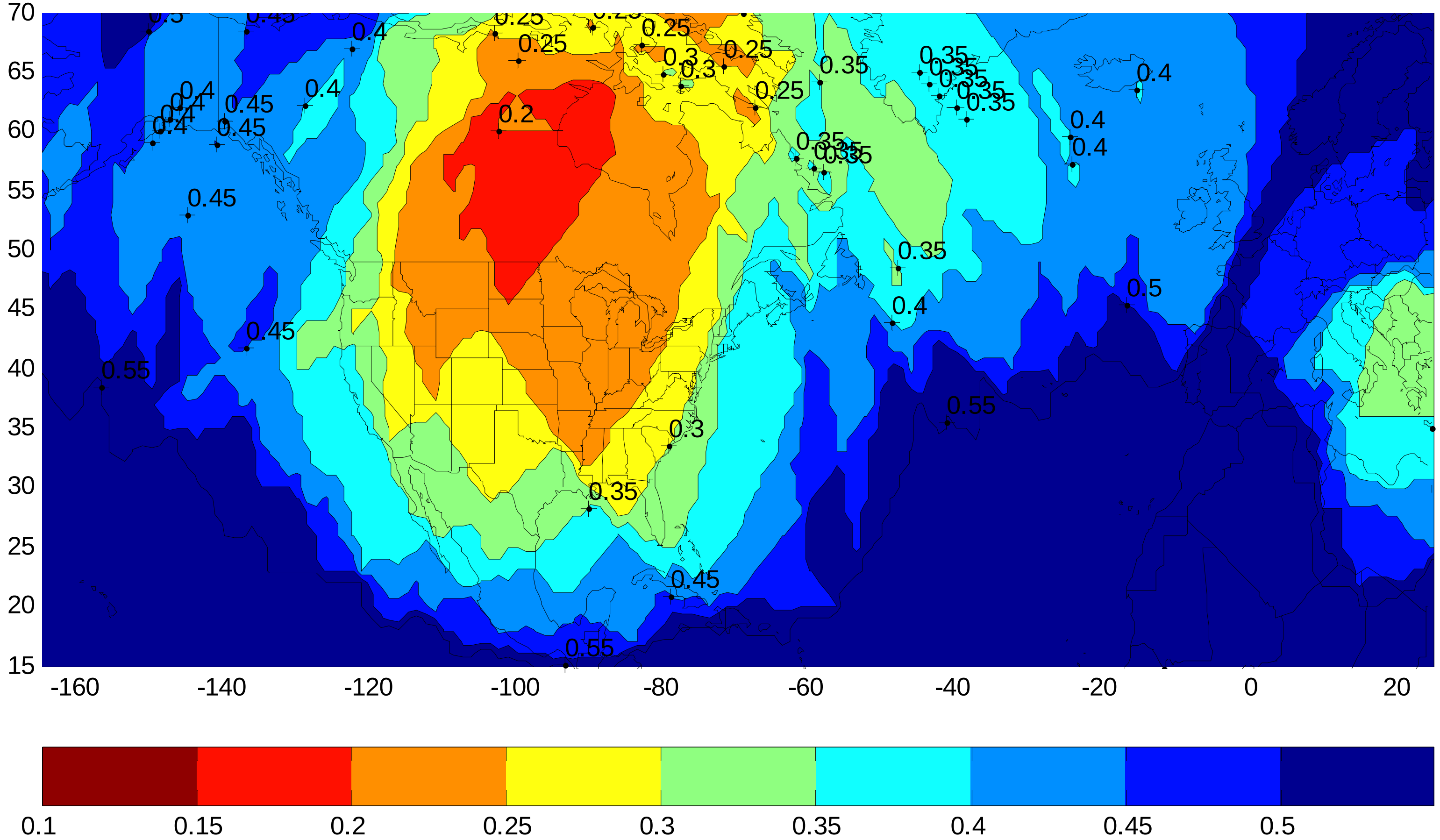


Example Calculation: Upper Midwest, tracking 8290, 2000 NM

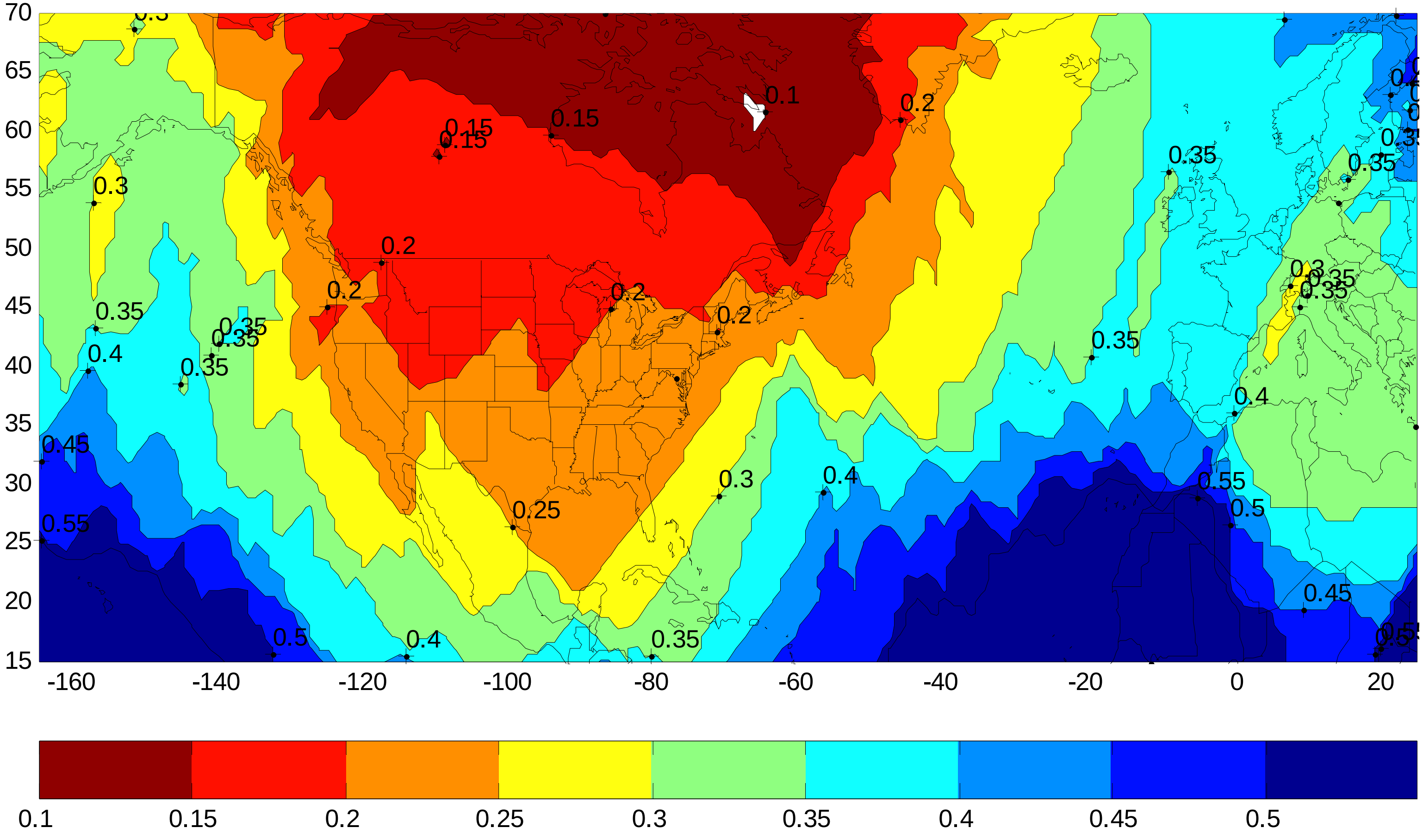
(Overall values are 0.778 and 0.099 for 9th pulse & all pulse blanking respectively.)

GRI	N stations	Probability not blanked	
9960	5	0.849	1 - (5*6*0.5/99.6)
8970	5	0.833	
7980	5	0.812	
9610	6	0.813	
5930	4	0.798	
9940	4	0.879	
5990	4	0.800	
7960	3	0.887	Not Port Clarence
7270	3	0.876	
9990	1	0.970	Only Kodiak
Overall		0.197	7.05 dB loss

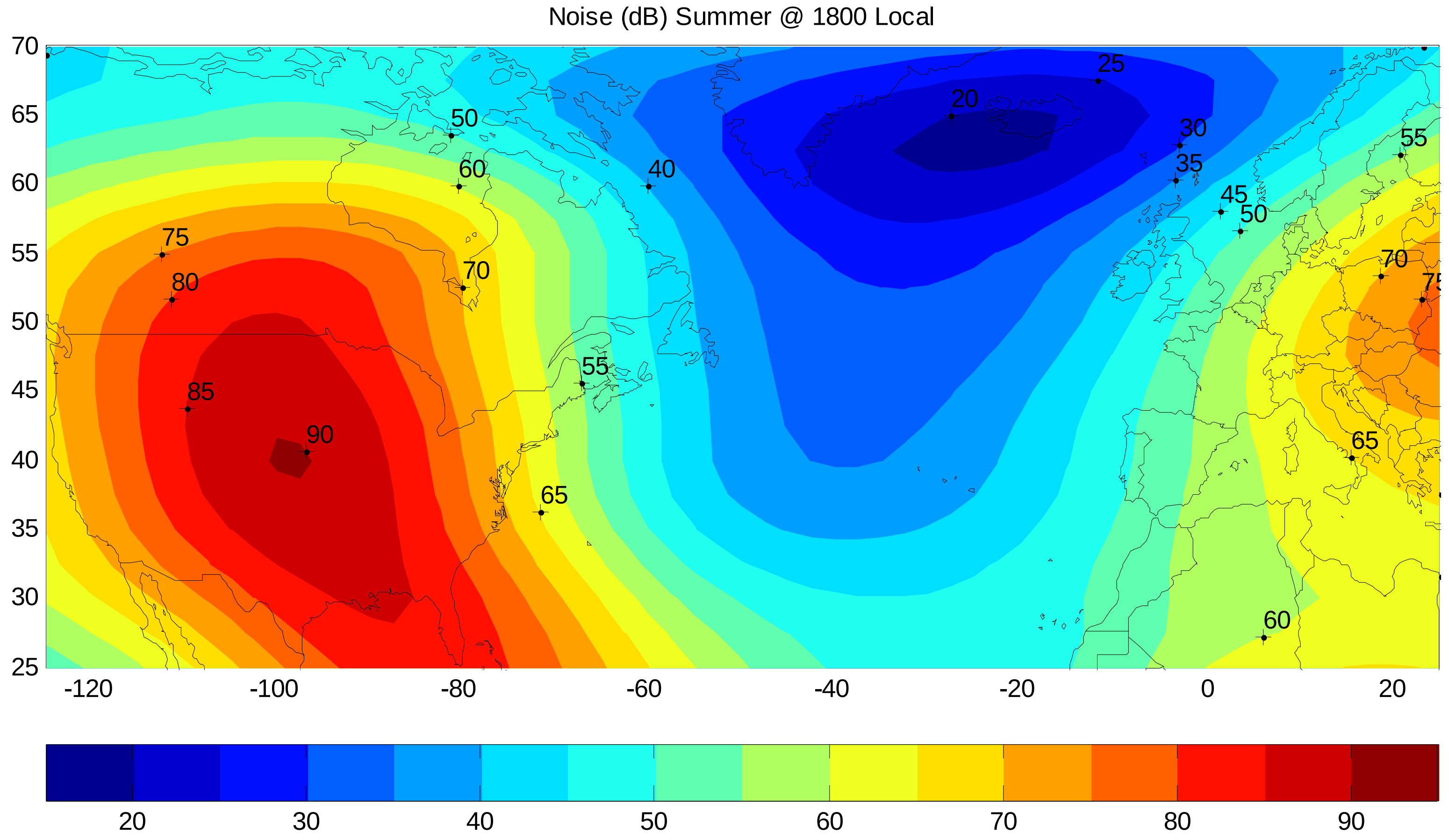
Fraction of pulses not blanked due to CRI: 2000 NM range



Fraction of pulses not blanked due to CRI: 2500 NM range

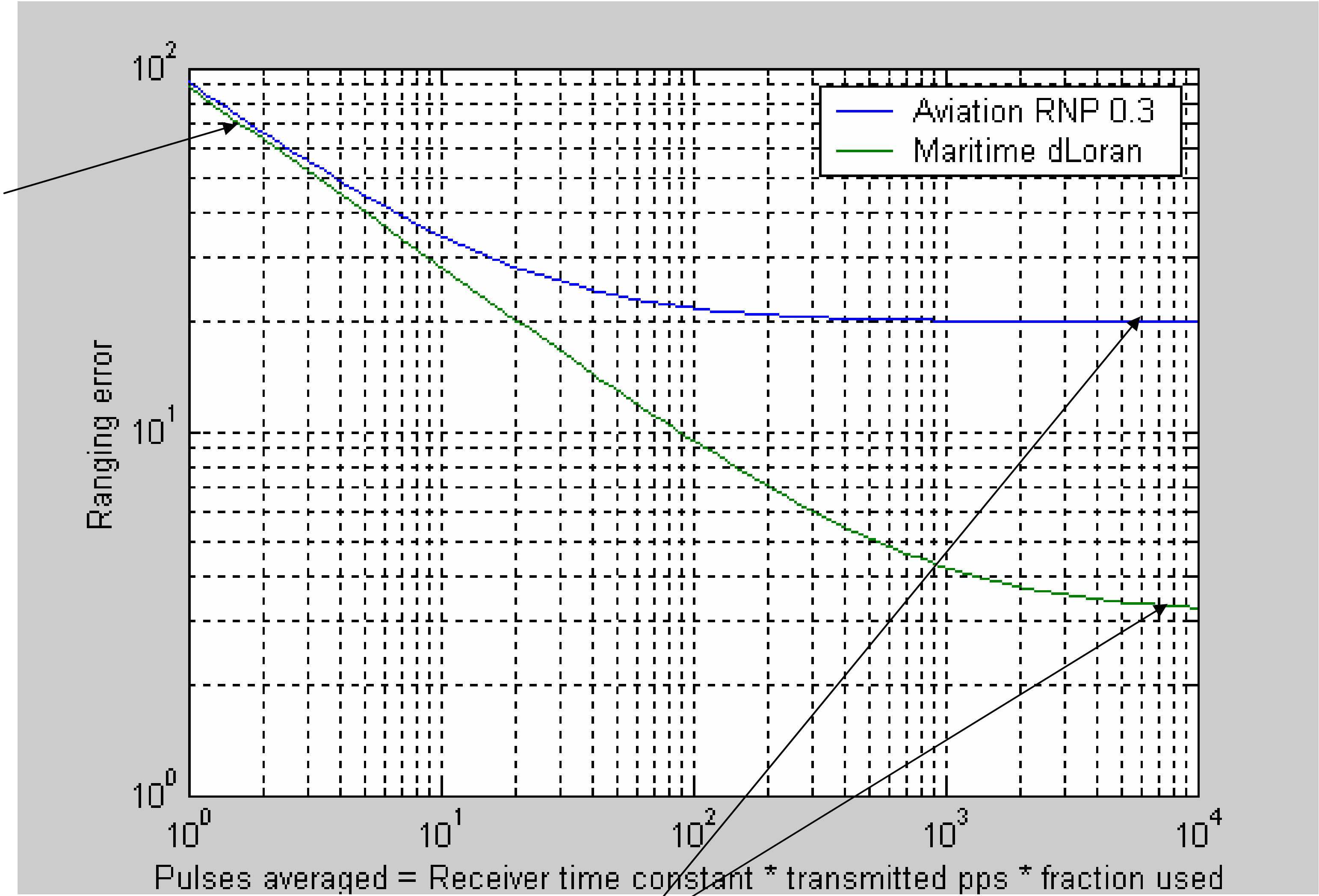


Comparison of ITU Noise predictions for North America and Western Europe



Is aviation the only issue?

SNR & transmitter jitter



Bias error (transmitter bias, ASF survey error, spatial decorrelation of ASF, temporal changes in phase)

Conclusions

- Due to significant differences between North America and Europe, what may be appropriate for Europe (now) is not appropriate for North America
  - Presently, there is far more cross rate interference in North America than in Europe
  - The ITU predicted noise levels in North America are much higher than in Europe requiring either
    - More averaging (Gaussian noise)
    - More data rejected (impulse noise)
  - There appears to be little or no interest in Loran for aviation in Europe, therefore all receivers can blank those pulses interfered with by modulated EUROFIX pulses & still have enough left to navigate due to longer averaging times.
- The amount of cross rate combined with the aviation requirement precludes use of EUROFIX in North America.
- Formats are completely compatible, same transmitter can transmit both, same receiver can receive both.

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