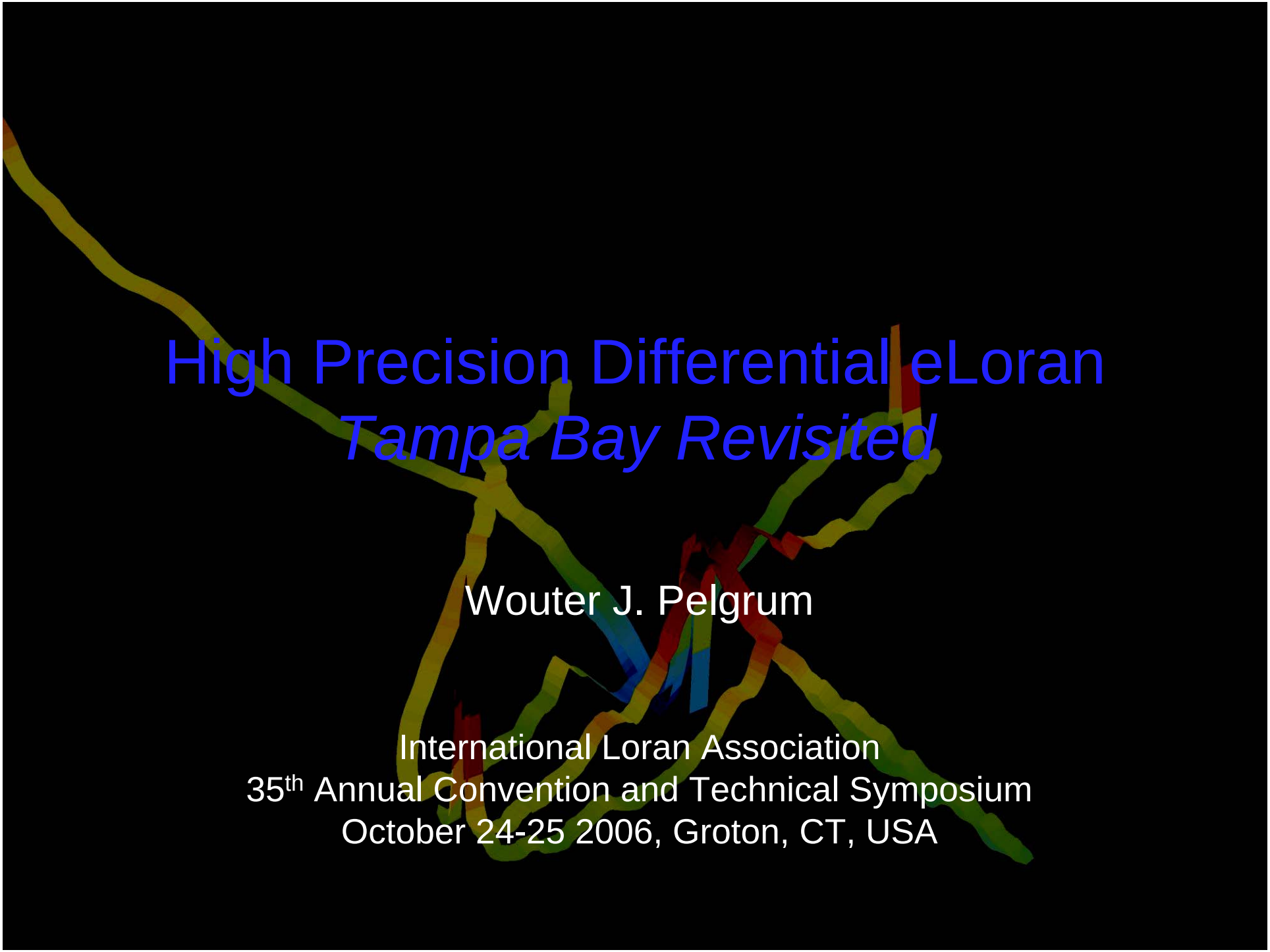
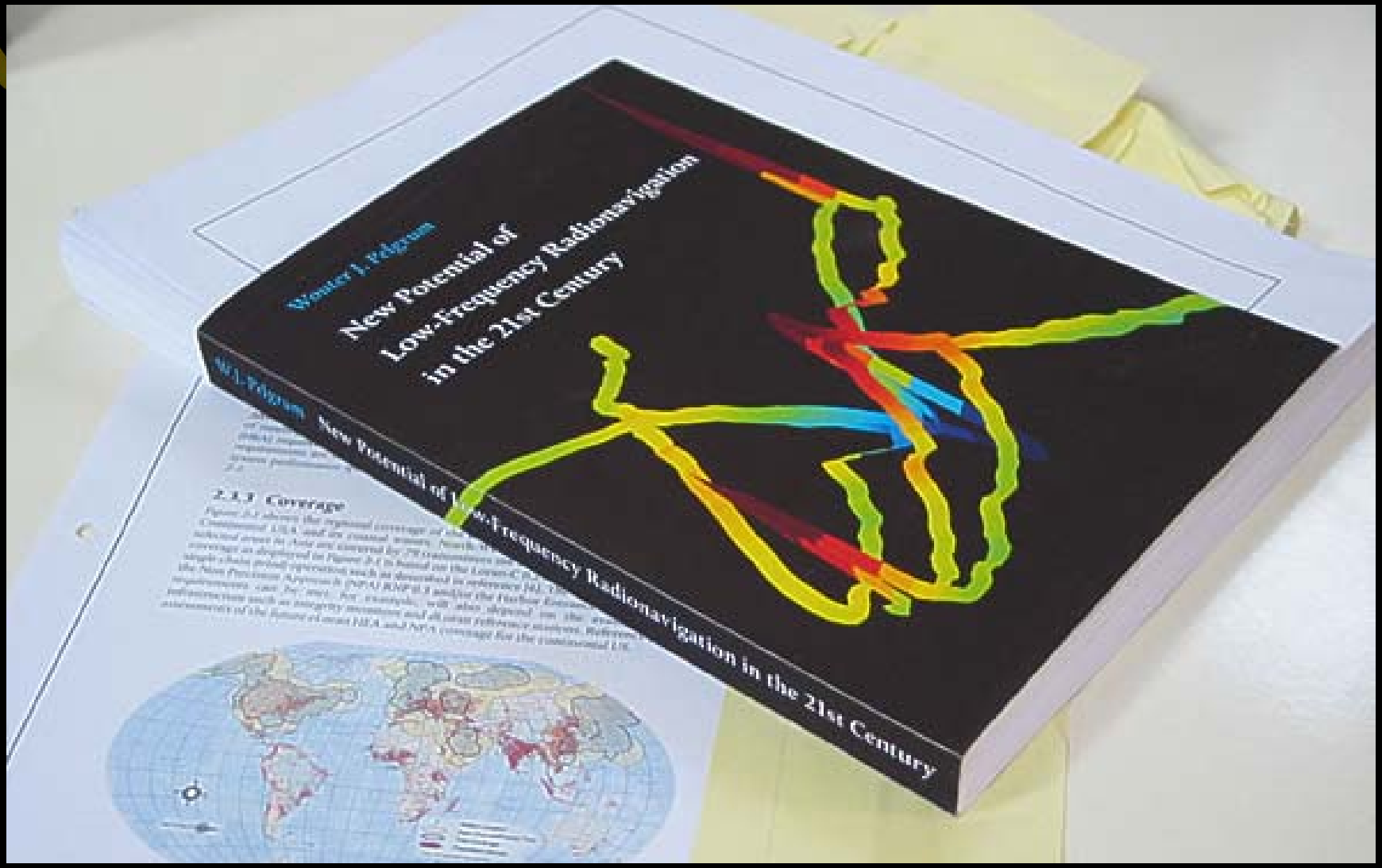


High Precision Differential eLoran
Tampa Bay Revisited

Wouter J. Pelgrum

International Loran Association
35th Annual Convention and Technical Symposium
October 24-25 2006, Groton, CT, USA

New Potential of Low-Frequency Radionavigation in the 21st Century



Overview presentation

- Tampa Bay campaign April 2004
- dLoran error model
- Spatial decorrelation of the temporal correction
- Creation of an ASF correction map
- E-field versus H-field
- Local disturbances
- HEA showcase
- recommendations

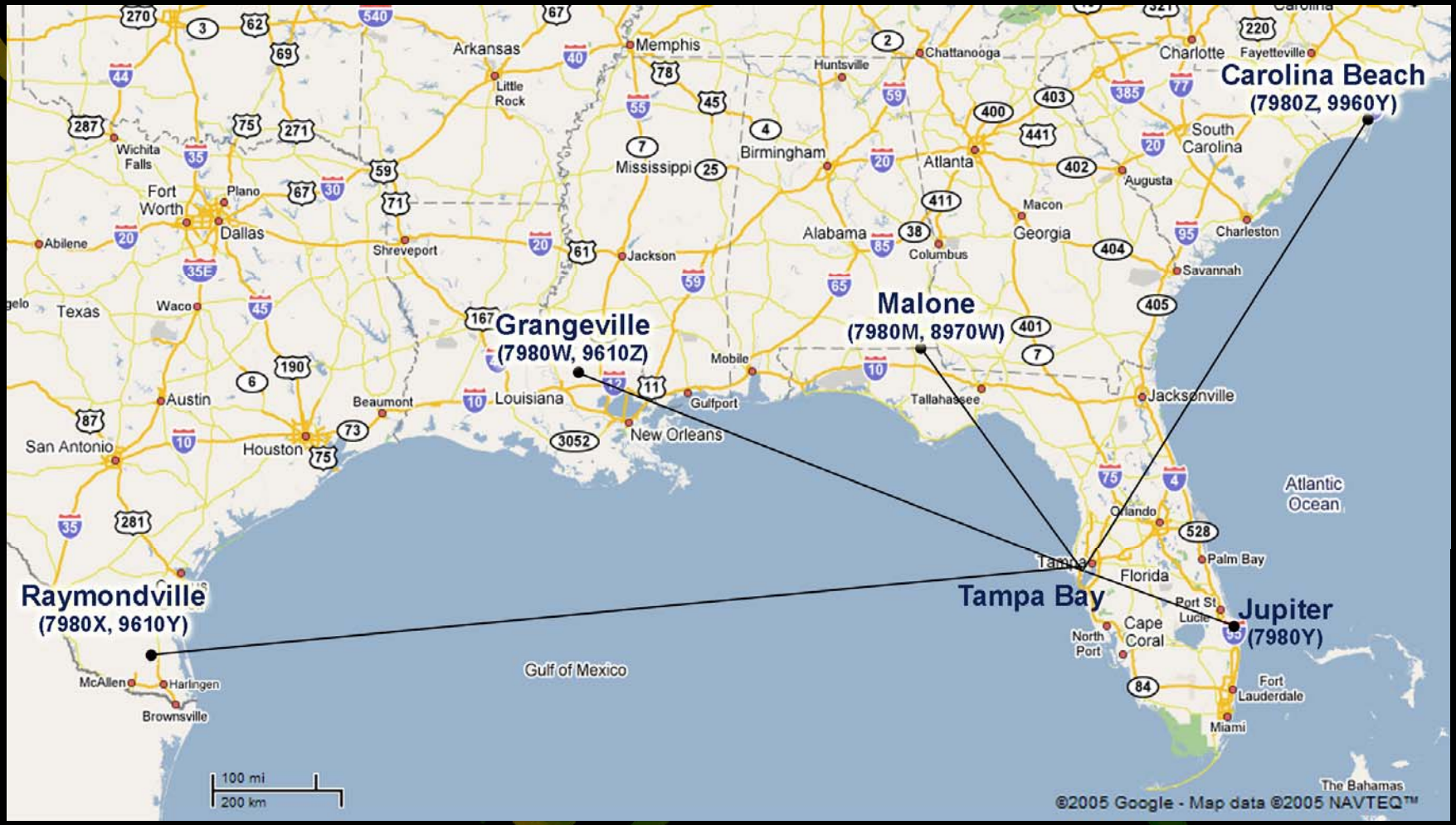
Tampa Bay measurement campaign
April 2004

reelektronika

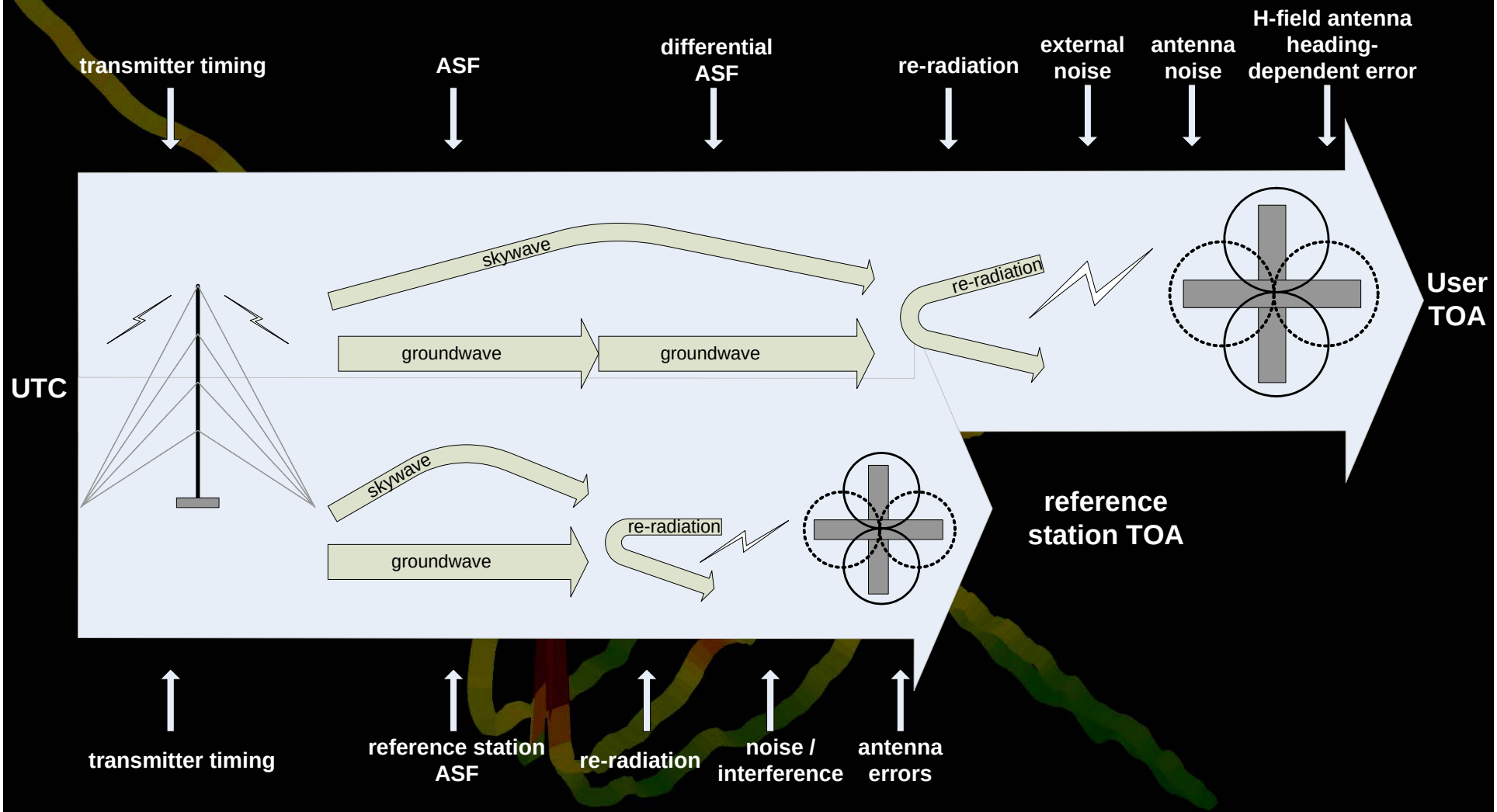
Megapulse

TU Delft

Tampa Bay measurement campaign
April 2004

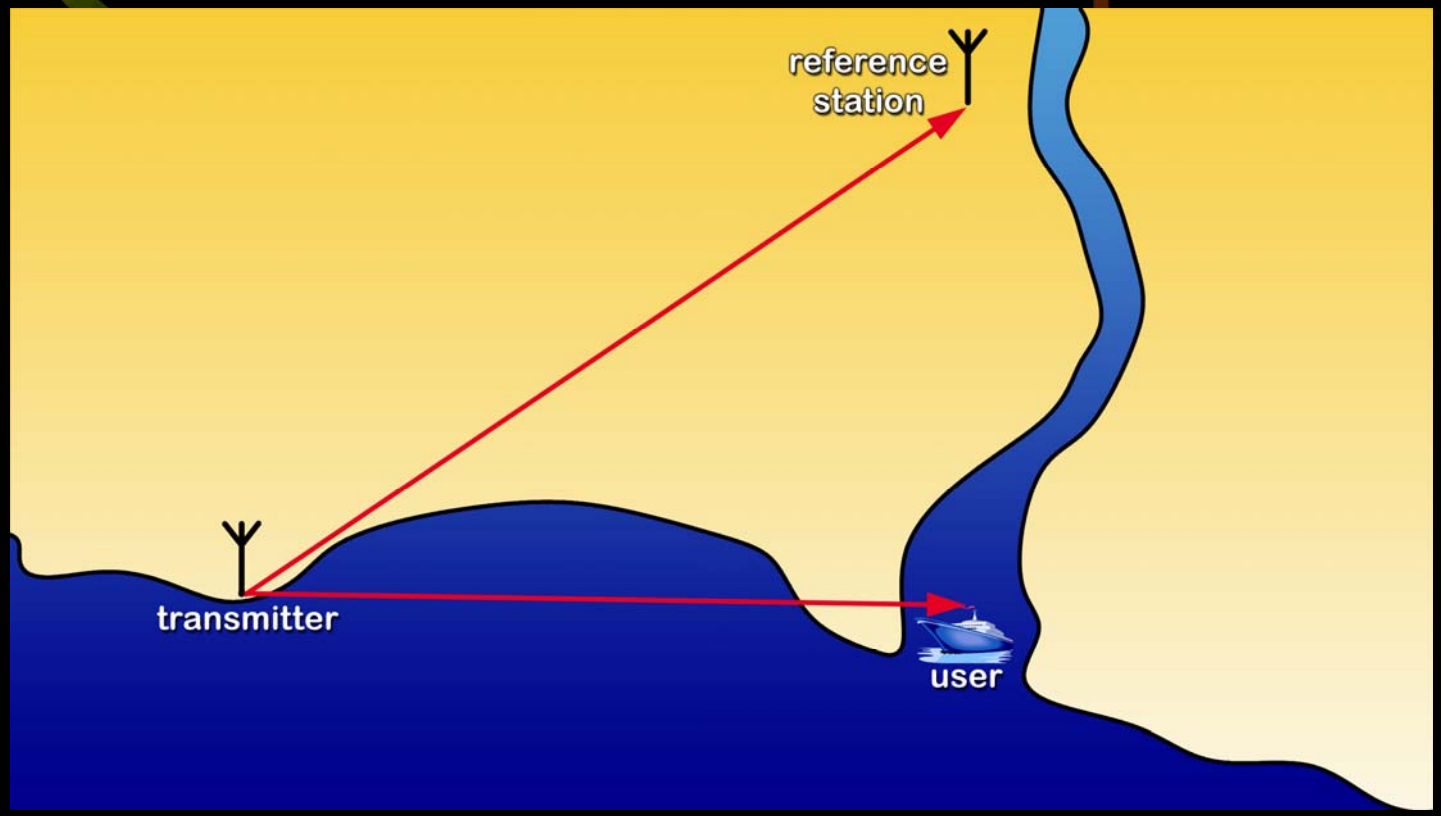


Error model

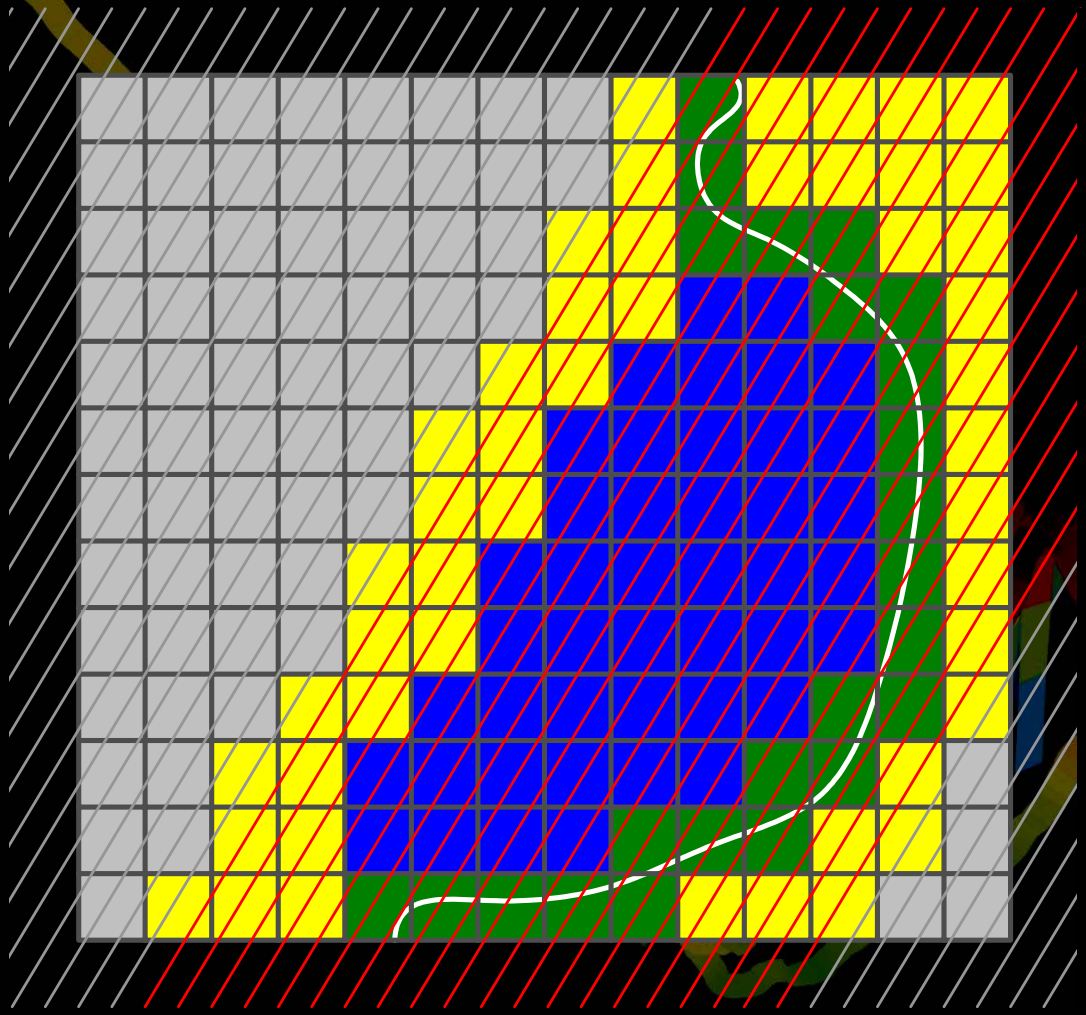

transmitter timing
ASF
differential ASF
re-radiation
external noise
antenna noise
H-field antenna heading-dependent error
UTC
skywave
groundwave
groundwave
re-radiation
User TOA
skywave
groundwave
re-radiation
reference station TOA
transmitter timing
reference station ASF
re-radiation
noise / interference
antenna errors

Spatial decorrelation of the temporal correction

$$ASF_{tot}^{TXi}\left(x_{user}, x_0, t\right) = ASF_{average}^{TXi}\left(x_0\right) + ASF_{spatial}^{TXi}\left(x_{user}, x_0\right) + ASF_{temporal}^{TXi}\left(x_0, t\right) + ASF_{dtemporal}^{TXi}\left(x_{user}, x_0, t\right)$$



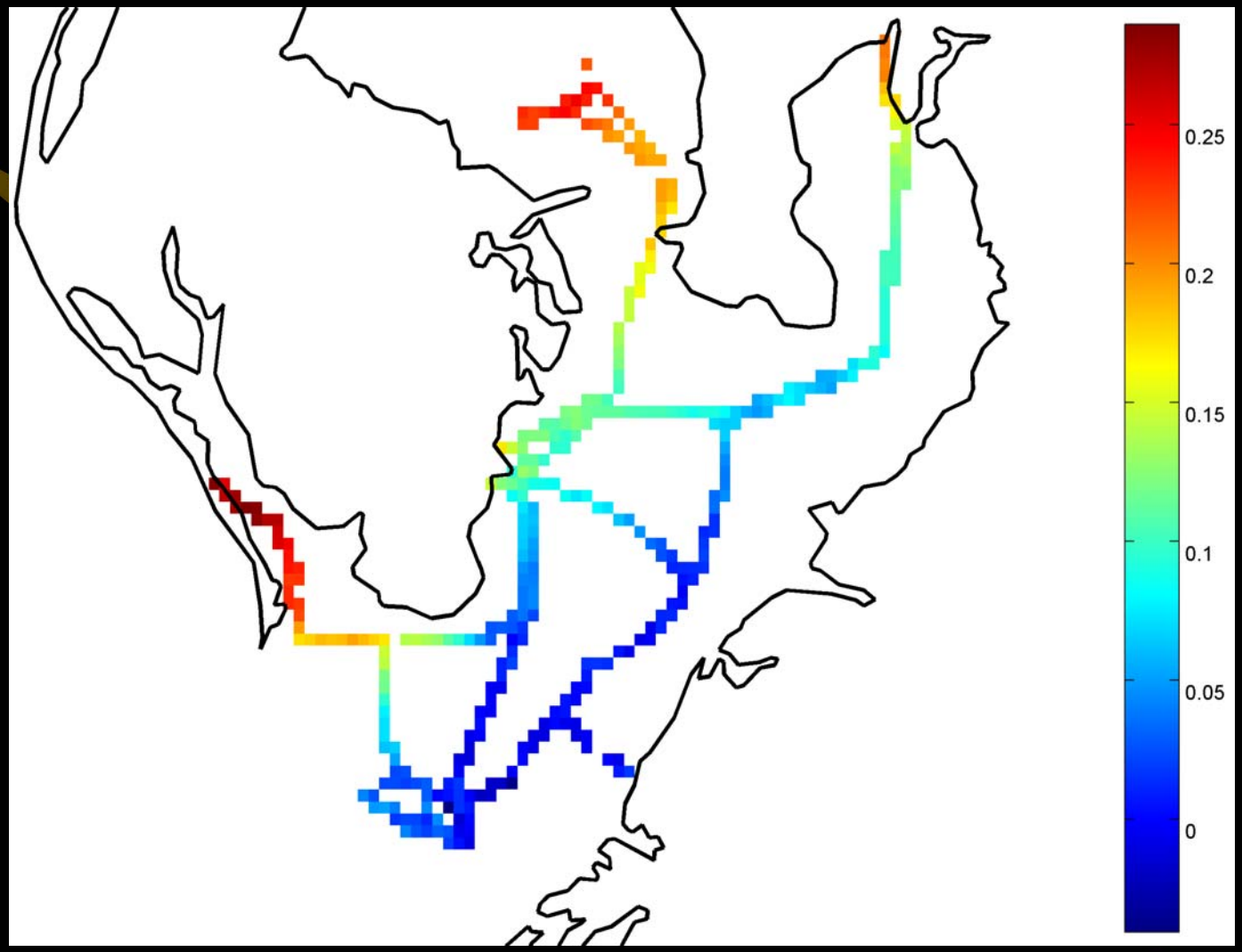
Creation of an ASF-Map: expanding the coverage by interpolation



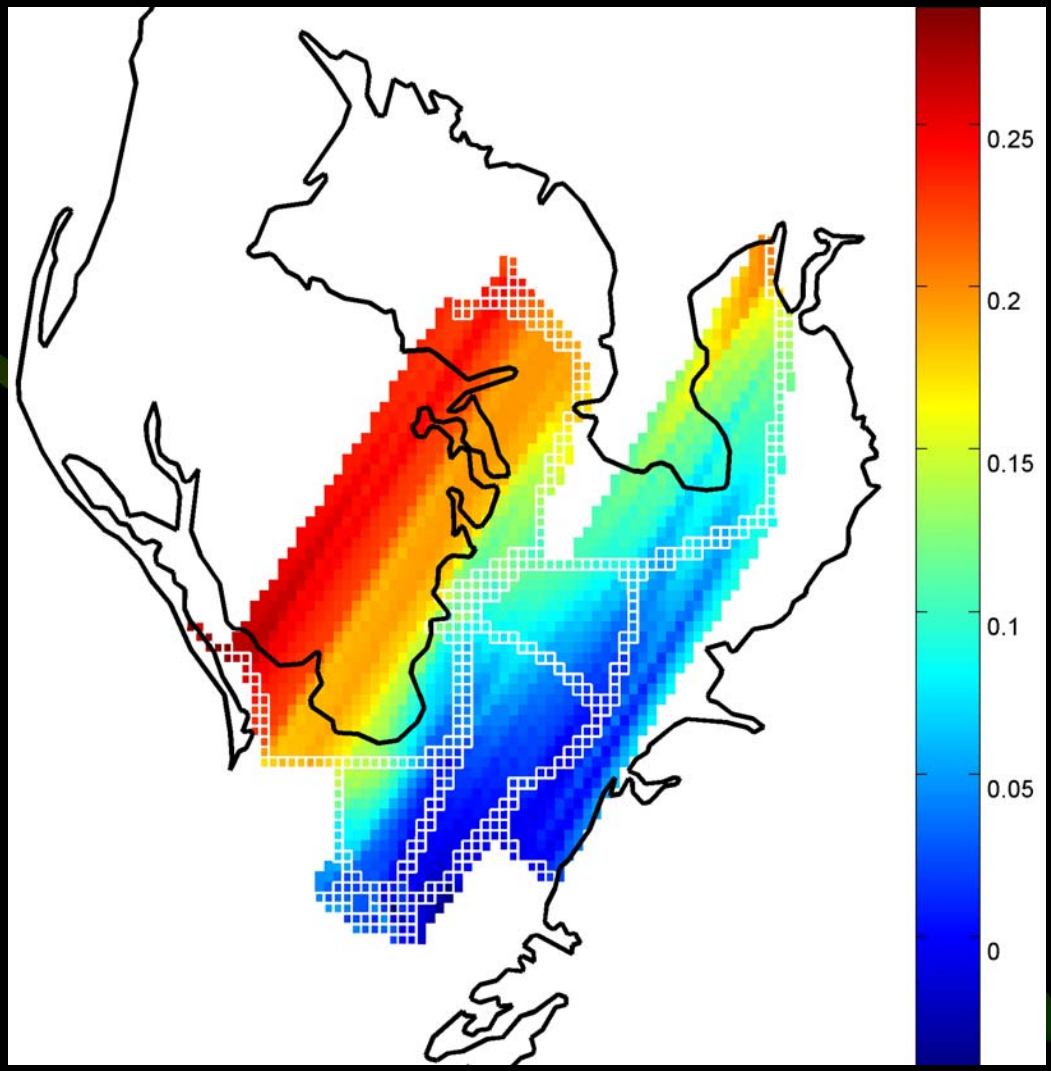
Track
Transmitter radial
Transmitter radial through measured cell
Measured
Radial interpolation
Radial extrapolation
Closest neighbor

Wouter J. Pelgrum

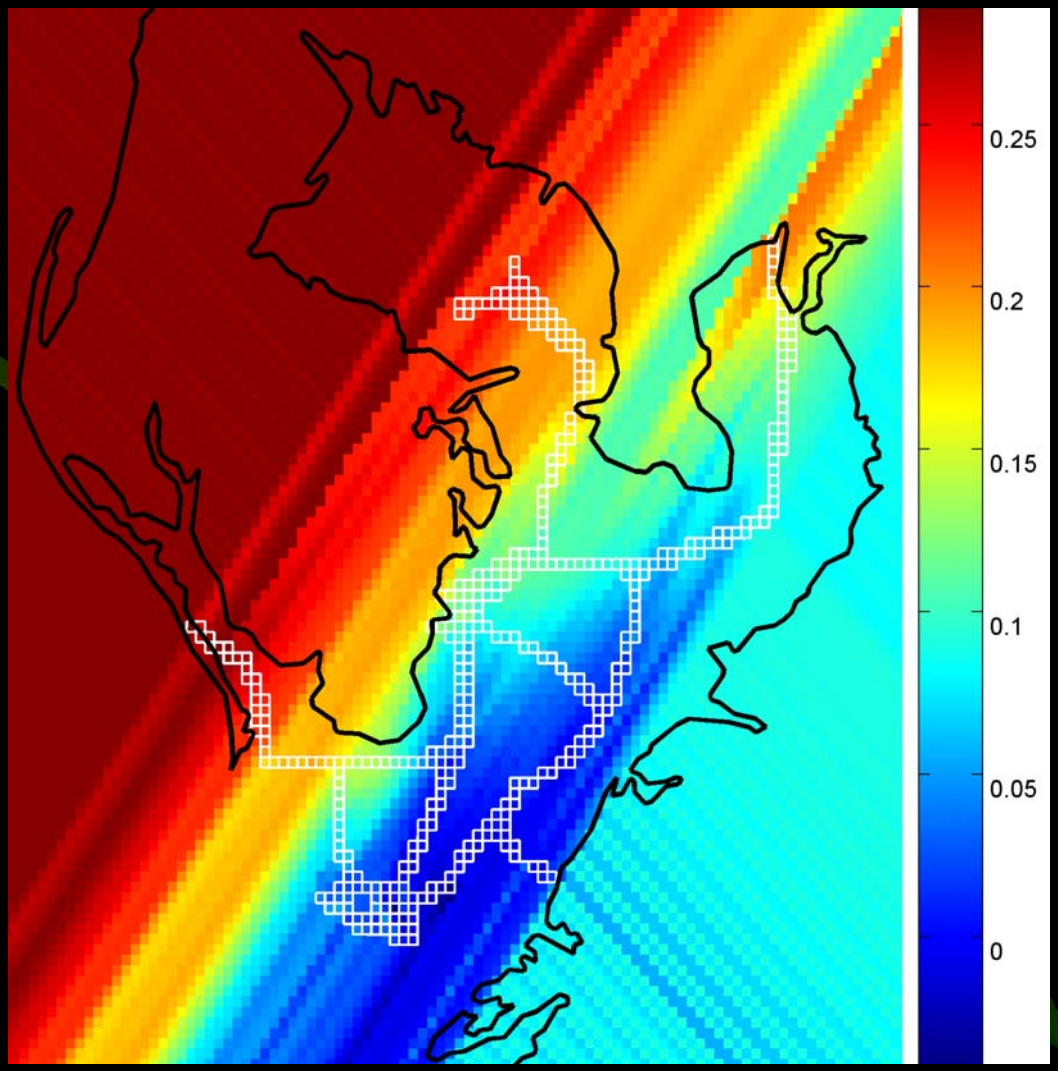
Creation of an ASF-Map: gridding of the data



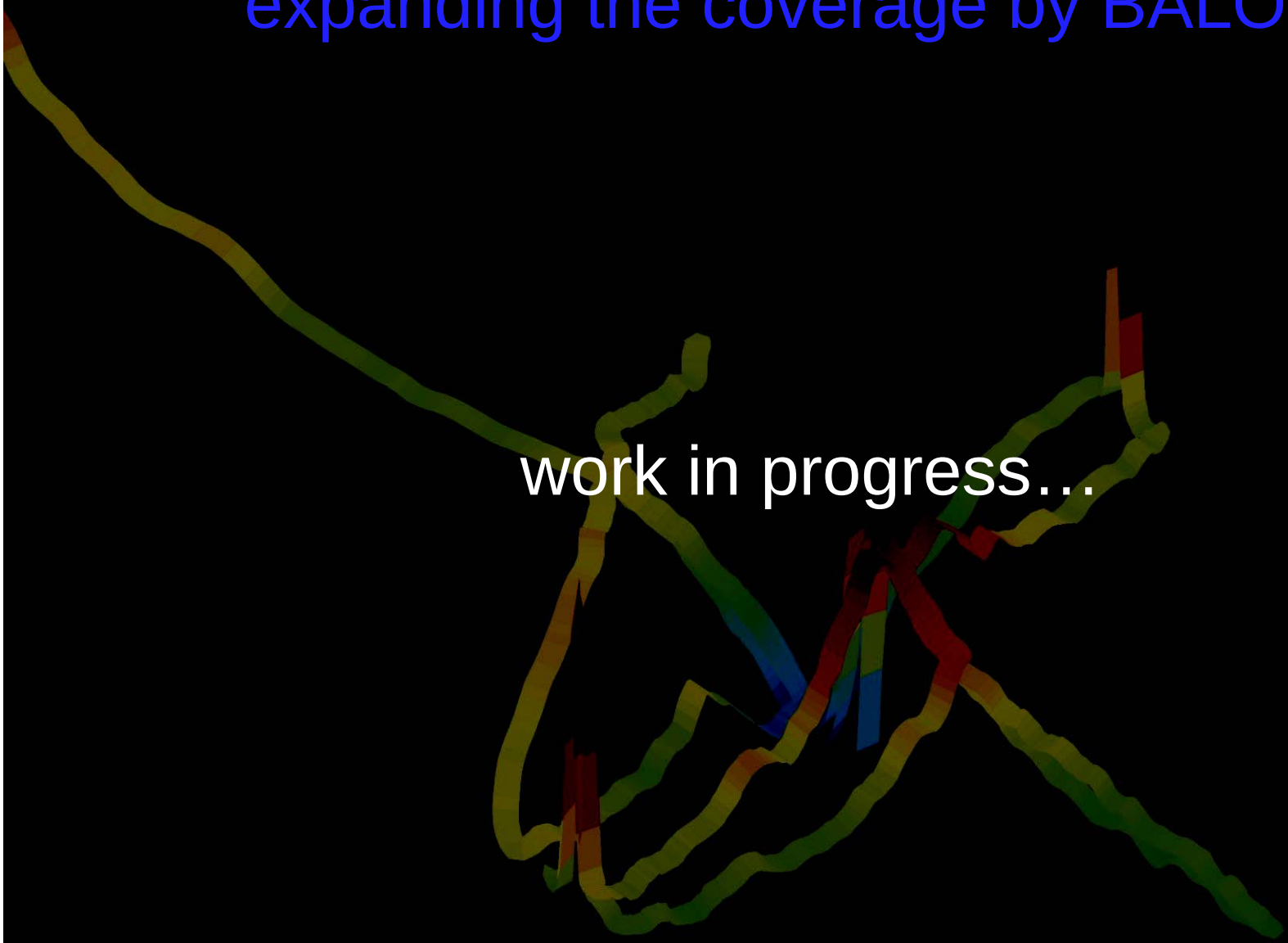
Creation of an ASF-Map: expanding the coverage by interpolation



Creation of an ASF-Map: expanding the coverage by extrapolation

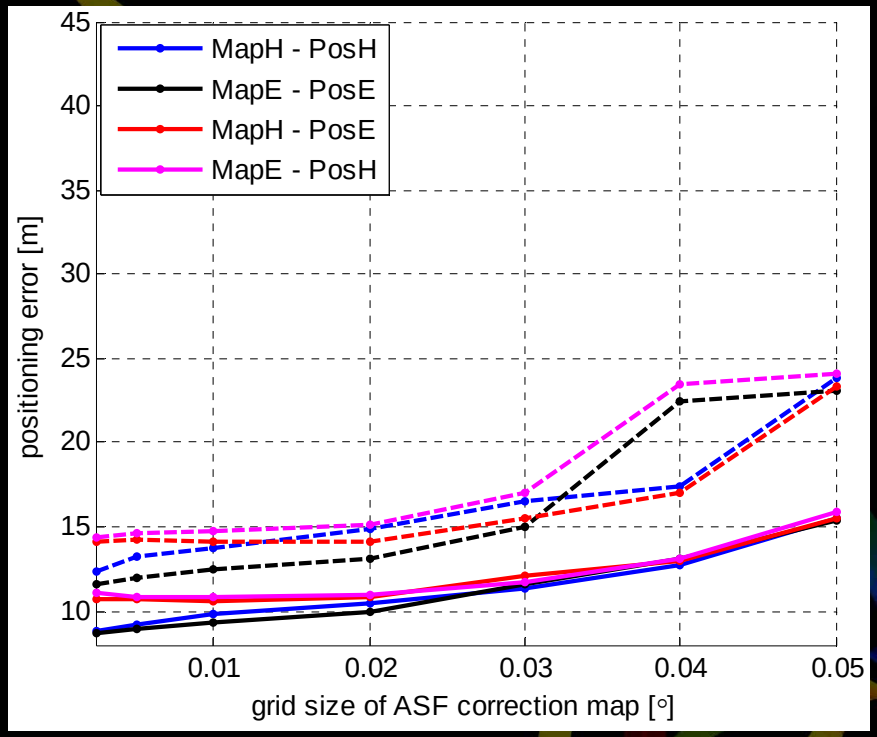


Creation of an ASF-Map: expanding the coverage by BALOR

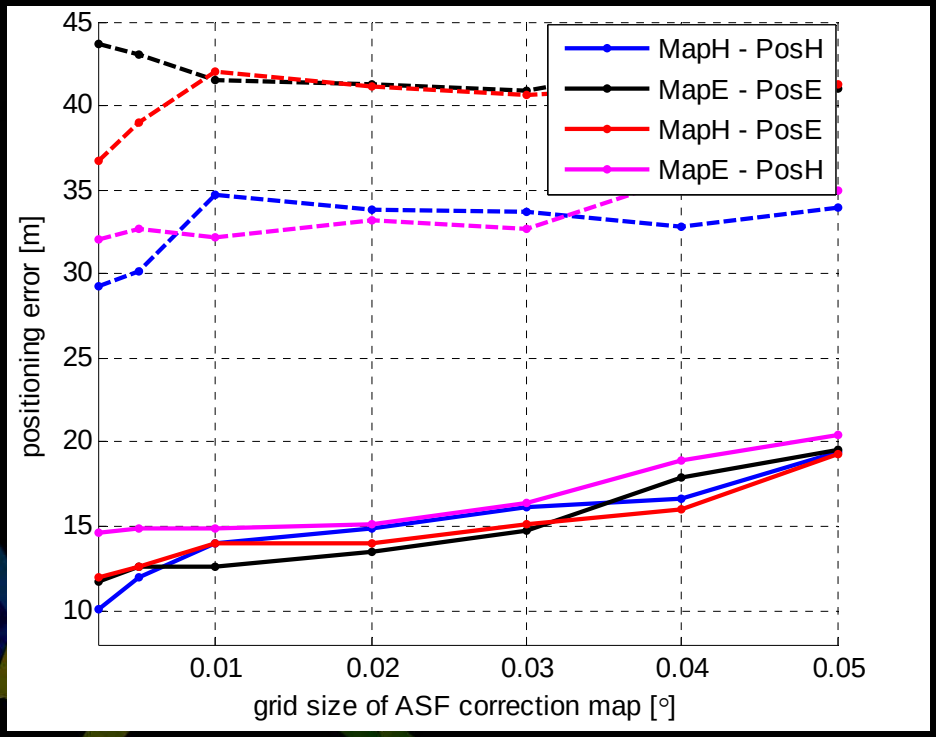


Creation of an ASF-Map: influence of grid size on positioning accuracy

re-radiation excluded

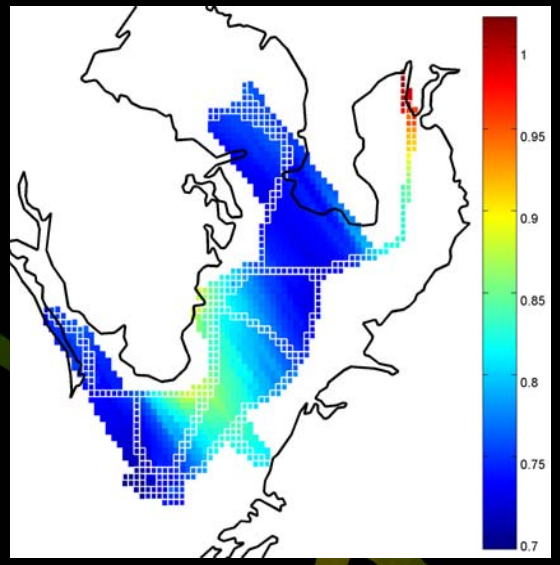


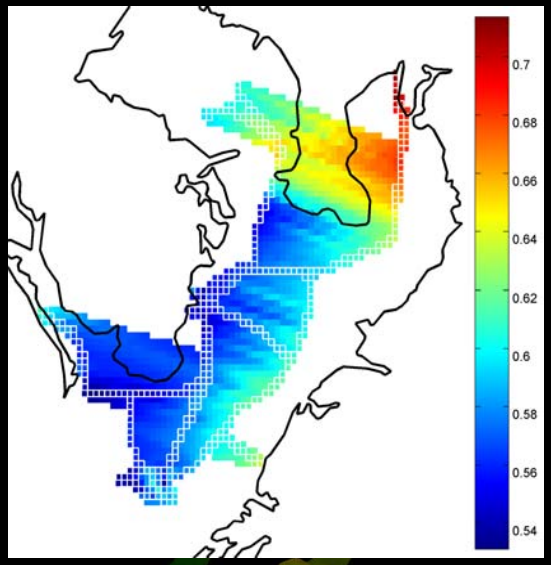
re-radiation included



Tampa Bay ASF maps

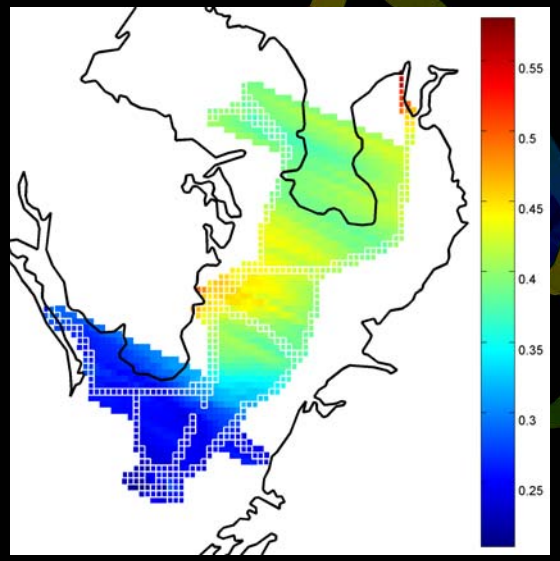
Malone (7980M / 8970W)

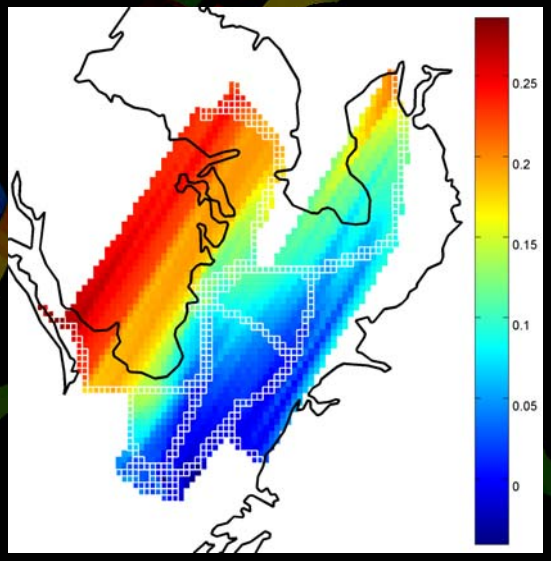




Jupiter (7980Y)

Grangeville (7980W / 9610Z)





Carolina Beach (7980Z / 9960Y)

E-field versus H-field

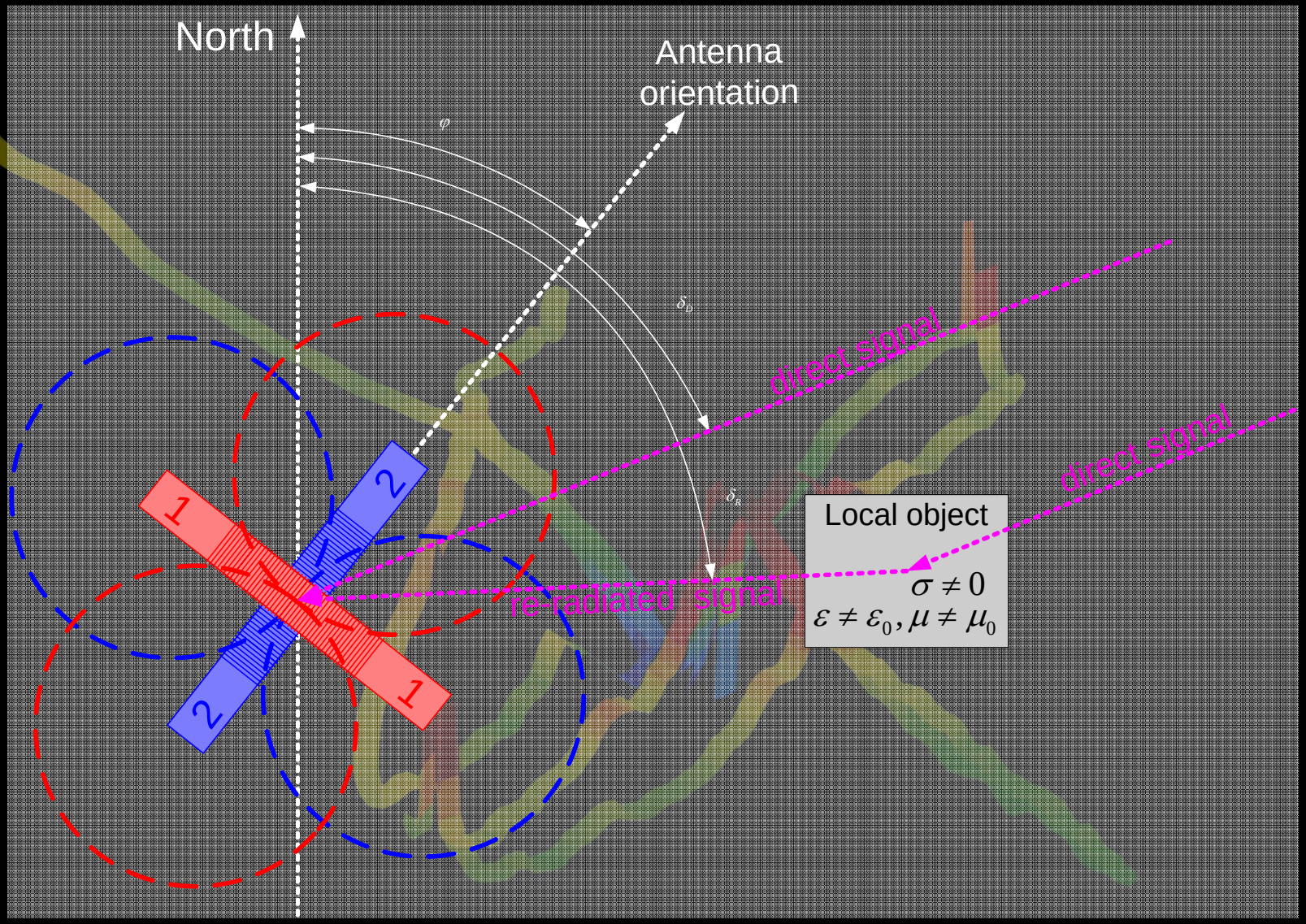
If there is no re-radiation, E-field and H-field should have a fixed relation, resulting in the same ASF:

		Mean ASF (µs)		Std ASF (µs)	
Station	**Id**	**H-field**	**E-field**	**H-field**	**E-field**
Malone	7980M	0.552	0.551	0.067	0.067
Malone	8970W	1.033	1.031	0.069	0.067
Grangeville	7980W	0.231	0.233	0.086	0.086
Grangeville	9610Z	0.480	0.481	0.090	0.088
Jupiter	7980Y	0.594	0.585	0.040	0.040
Carolina Beach	7980Z	0.176	0.173	0.086	0.085
Carolina Beach	9960Y	0.036	0.032	0.088	0.087

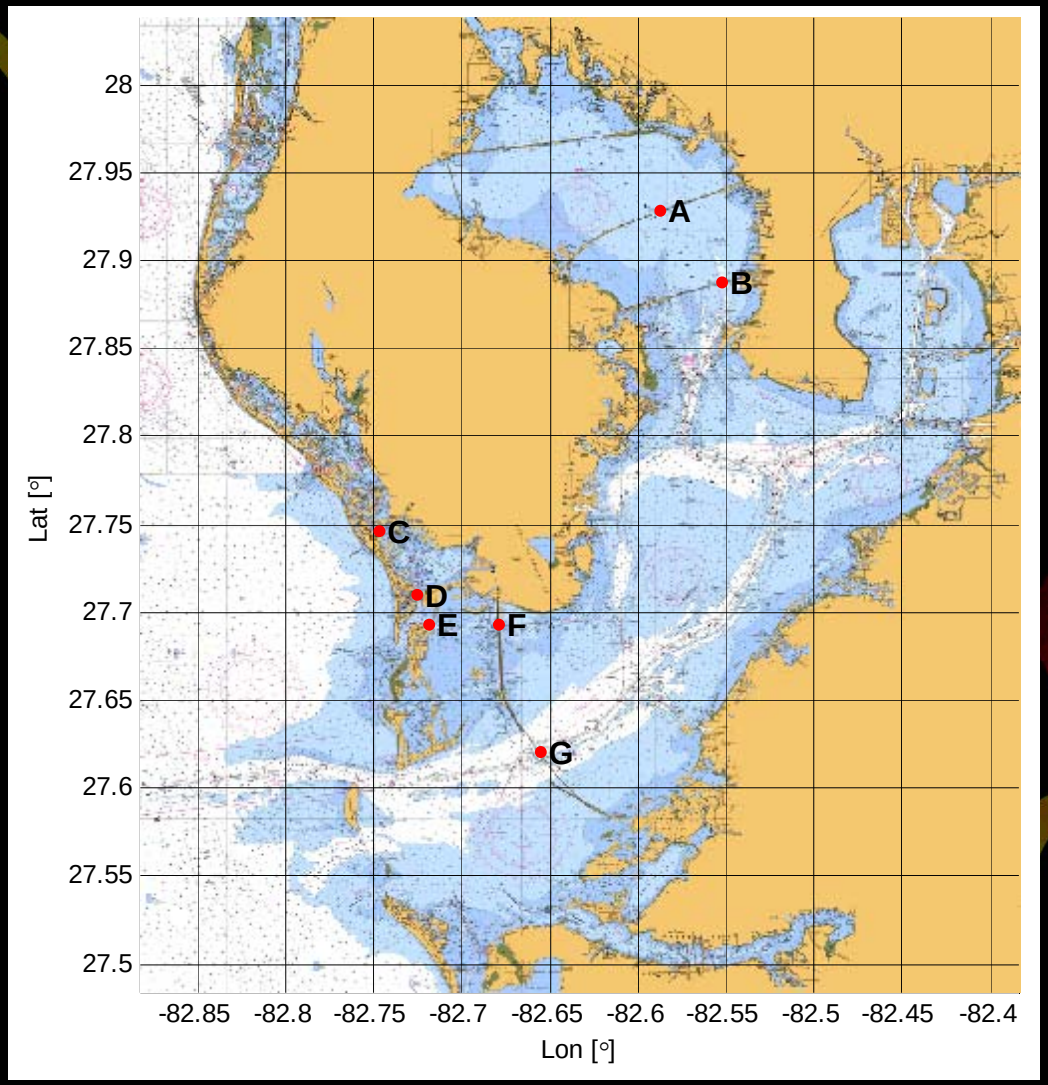
E-field positioning performance after correction with H-field on a per-epoch basis

	Re-radiation excluded		**Re-radiation included**	
	95%	**99%**	**95%**	**99%**
E-field vs. H-field	10.4m	14.3m	11.5m	39.8m

Local disturbances: spatial domain re-radiation detection

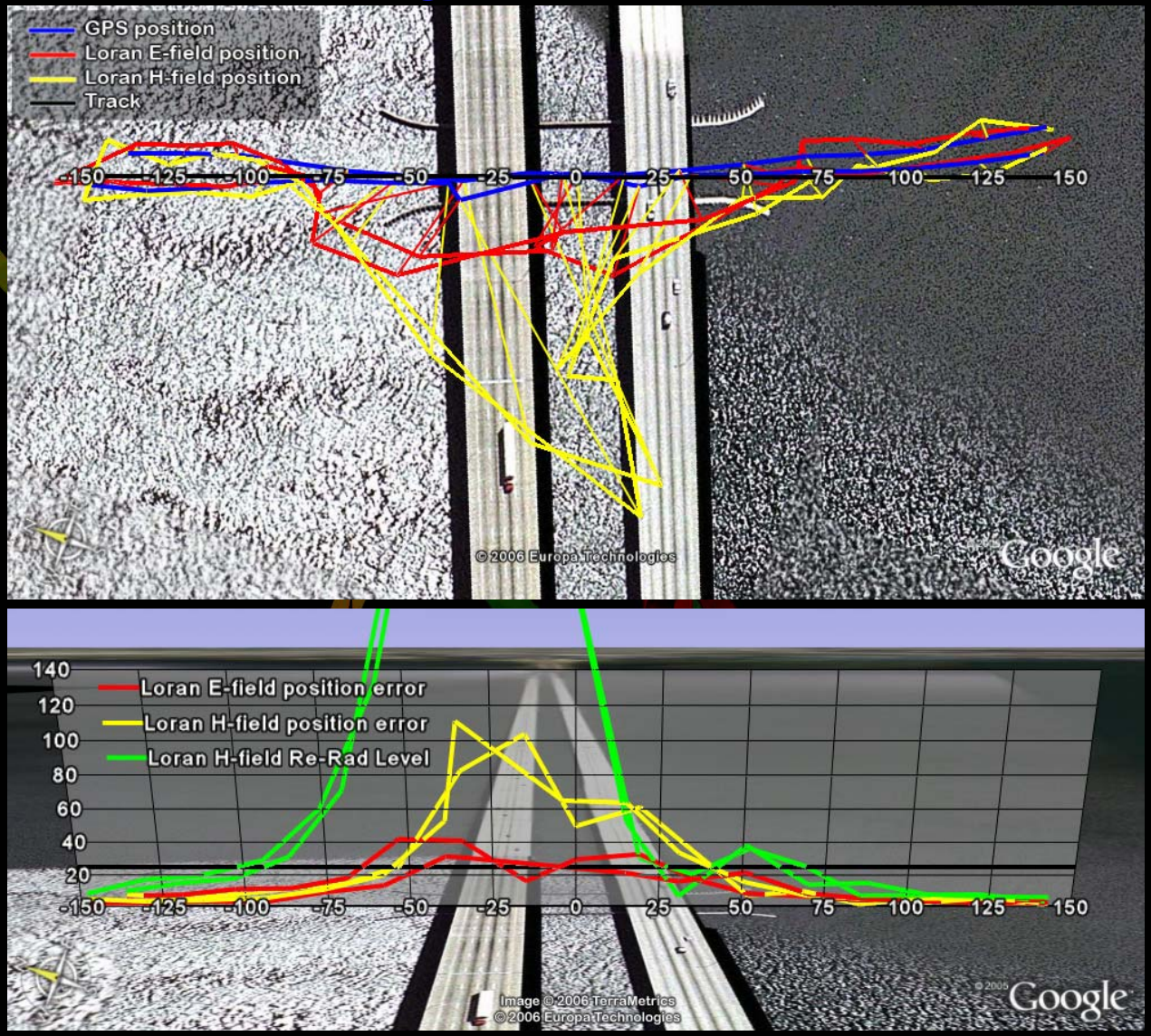


Local disturbances: Tampa Bay bridges

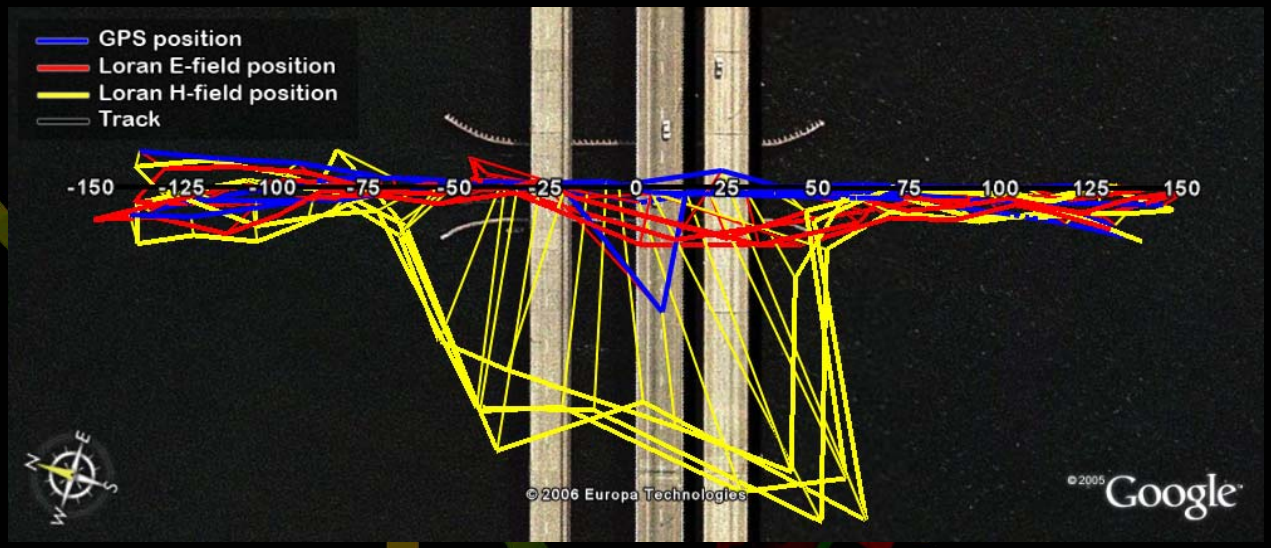


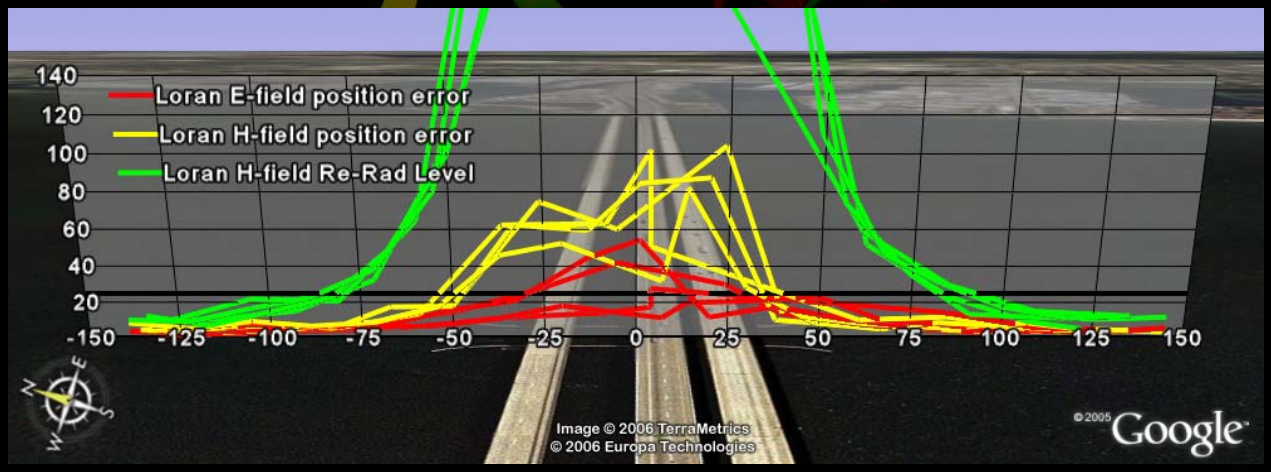
A E. Howard Frankland Bridge
B Friendship Trail Bridge
C Corey Causeway Bridge
D Tierra Verda
E St. Petersburg Bridge
F Sunshine Skyway
G Sunshine Skyway Bridge

Local disturbances: influence of bridge A on E-field and H-field

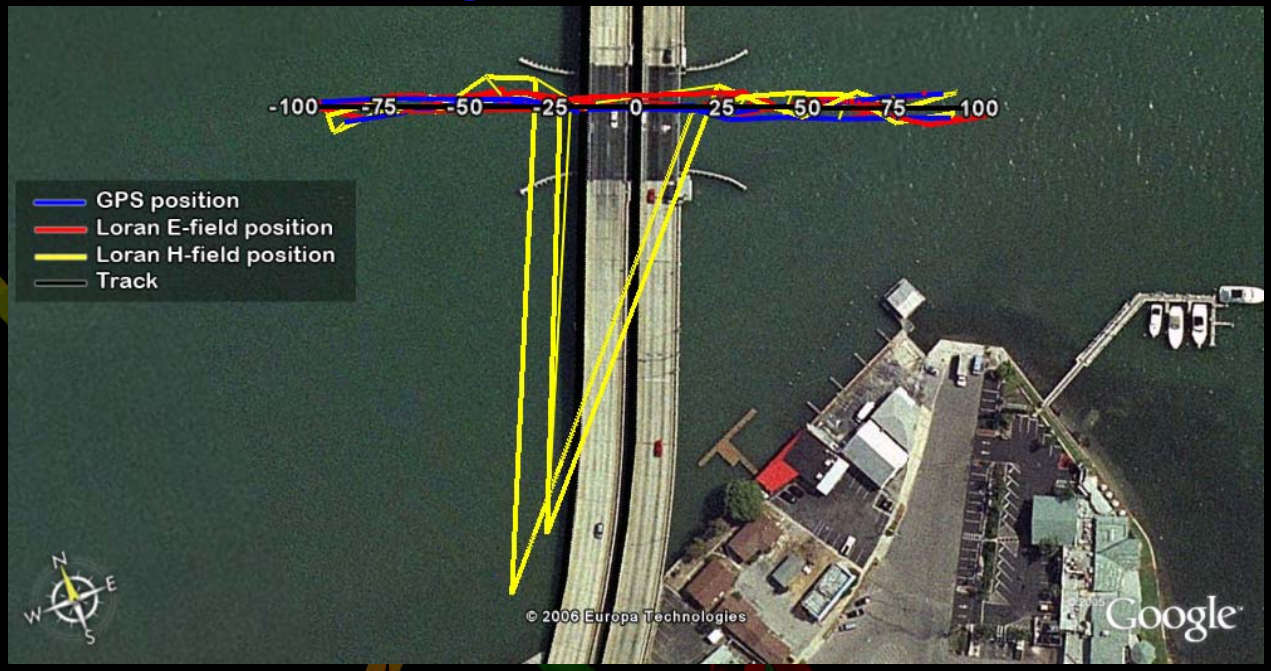


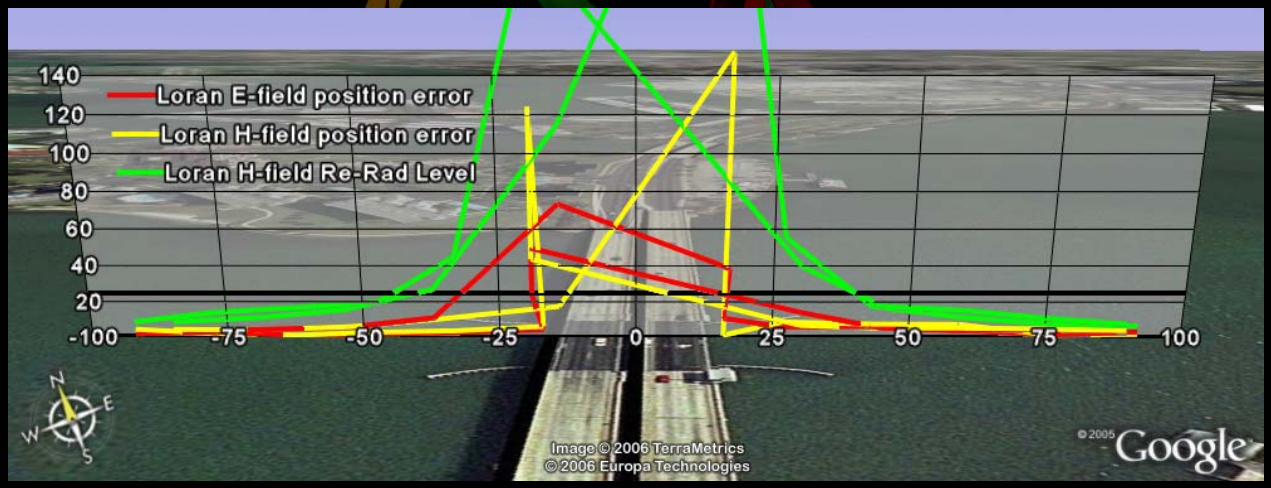
Local disturbances: influence of bridge B on E-field and H-field



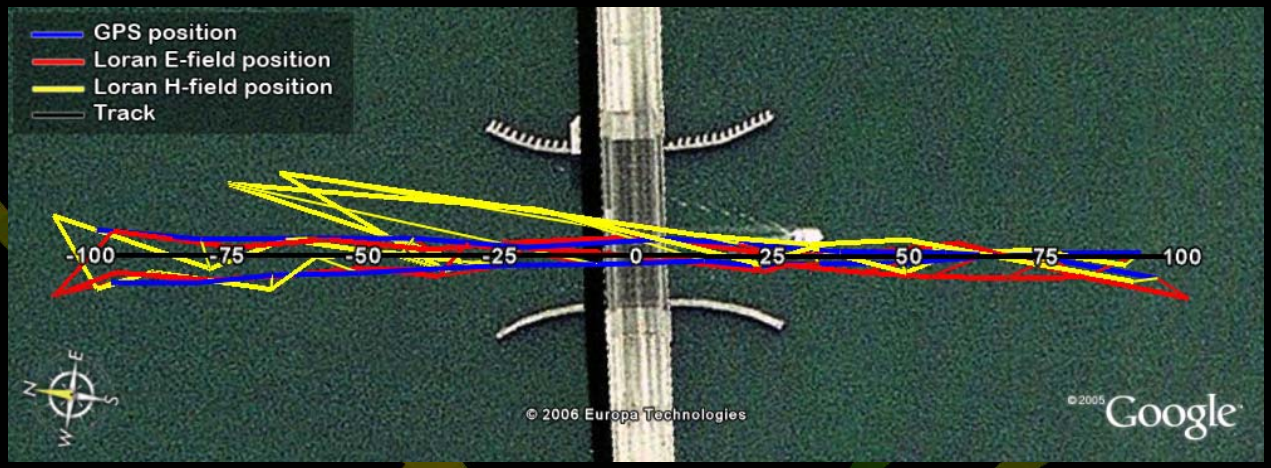


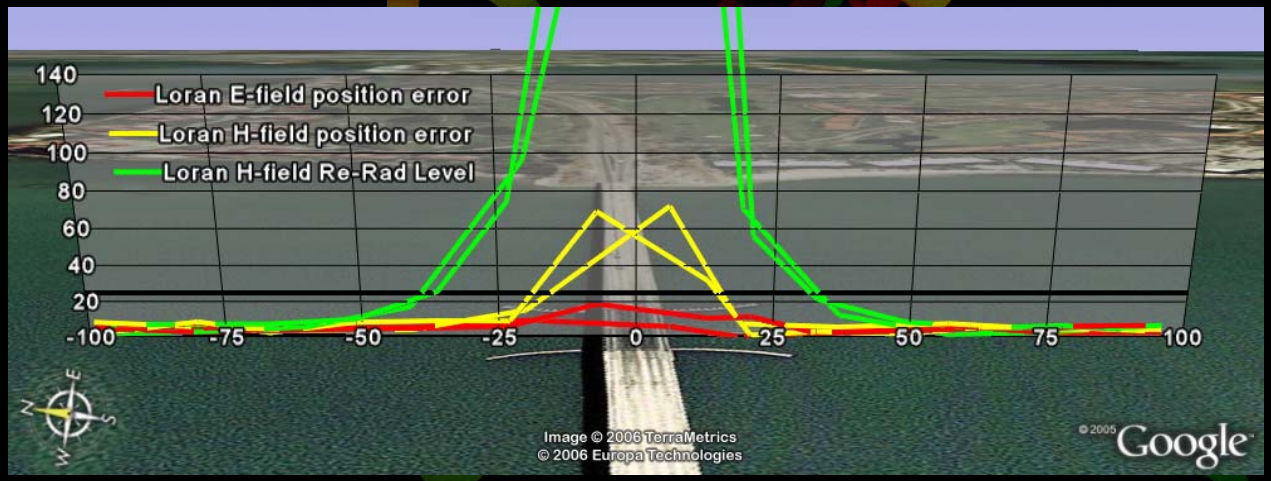
Local disturbances: influence of bridge C on E-field and H-field



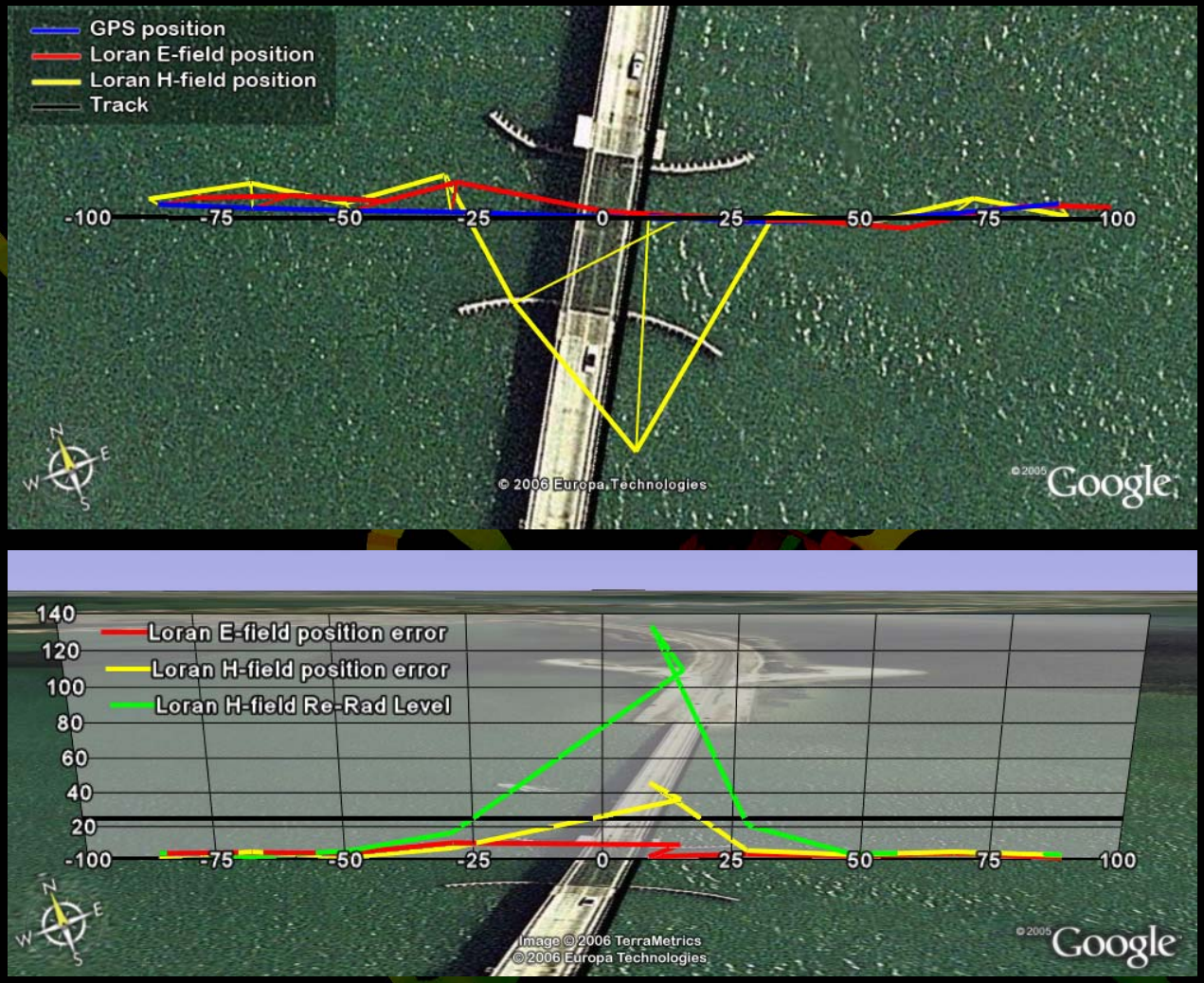


Local disturbances: influence of bridge D on E-field and H-field

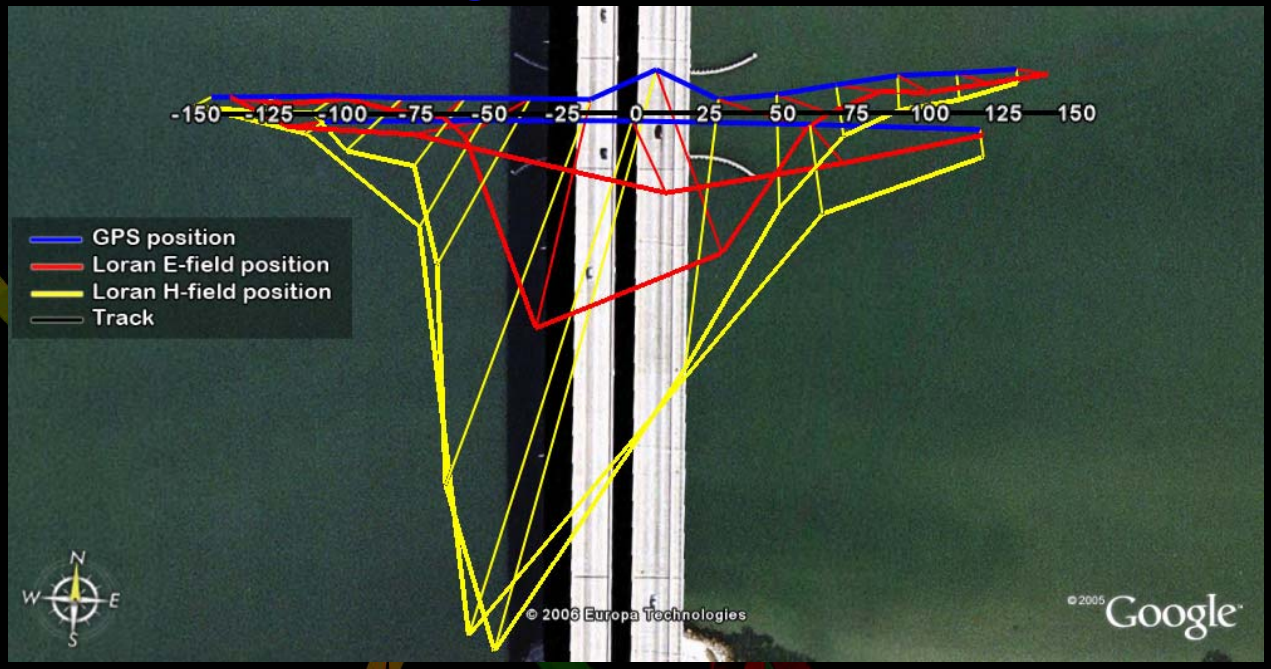


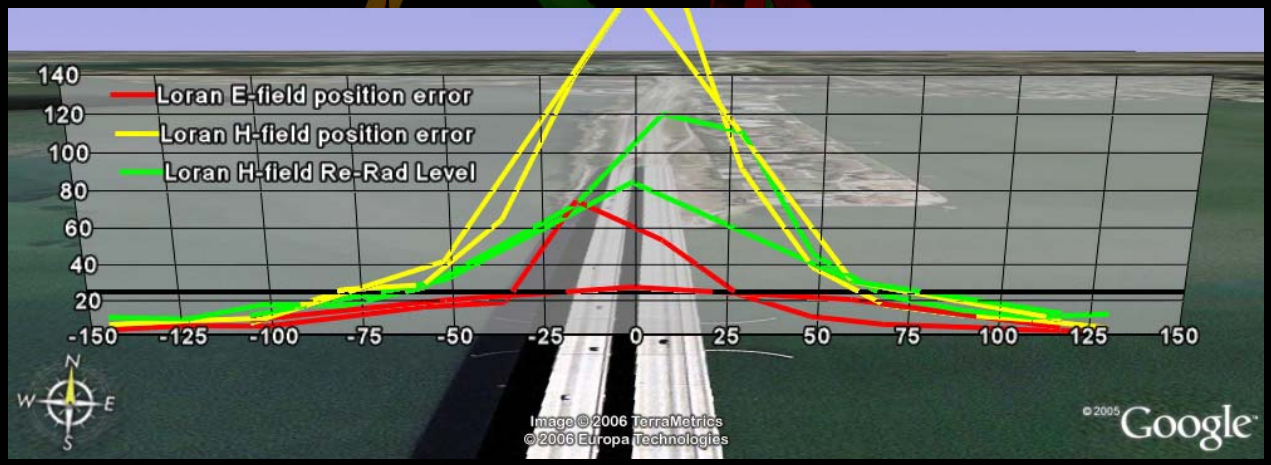


Local disturbances: influence of bridge E on E-field and H-field

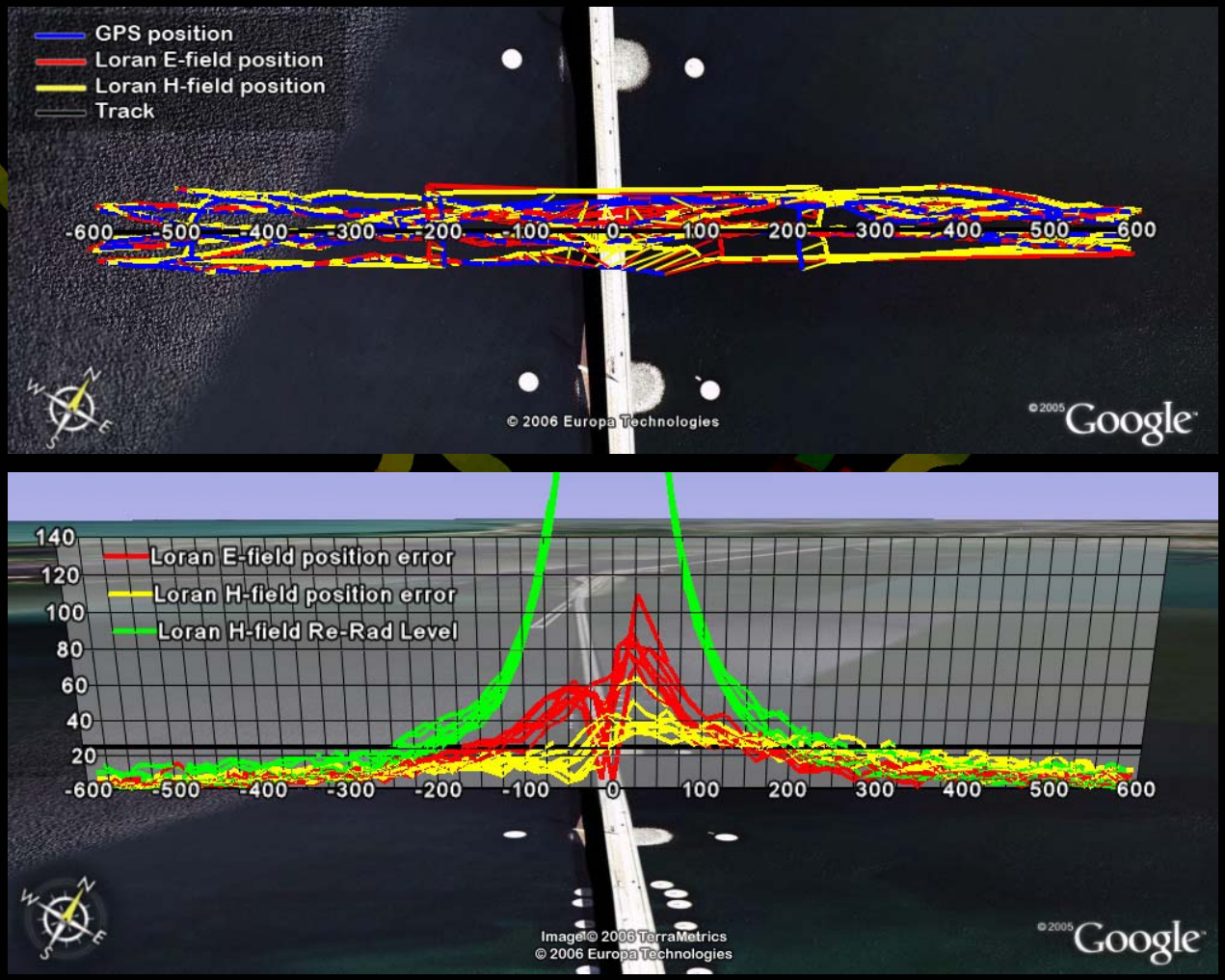


Local disturbances: influence of bridge F on E-field and H-field





Local disturbances: influence of bridge G on E-field and H-field

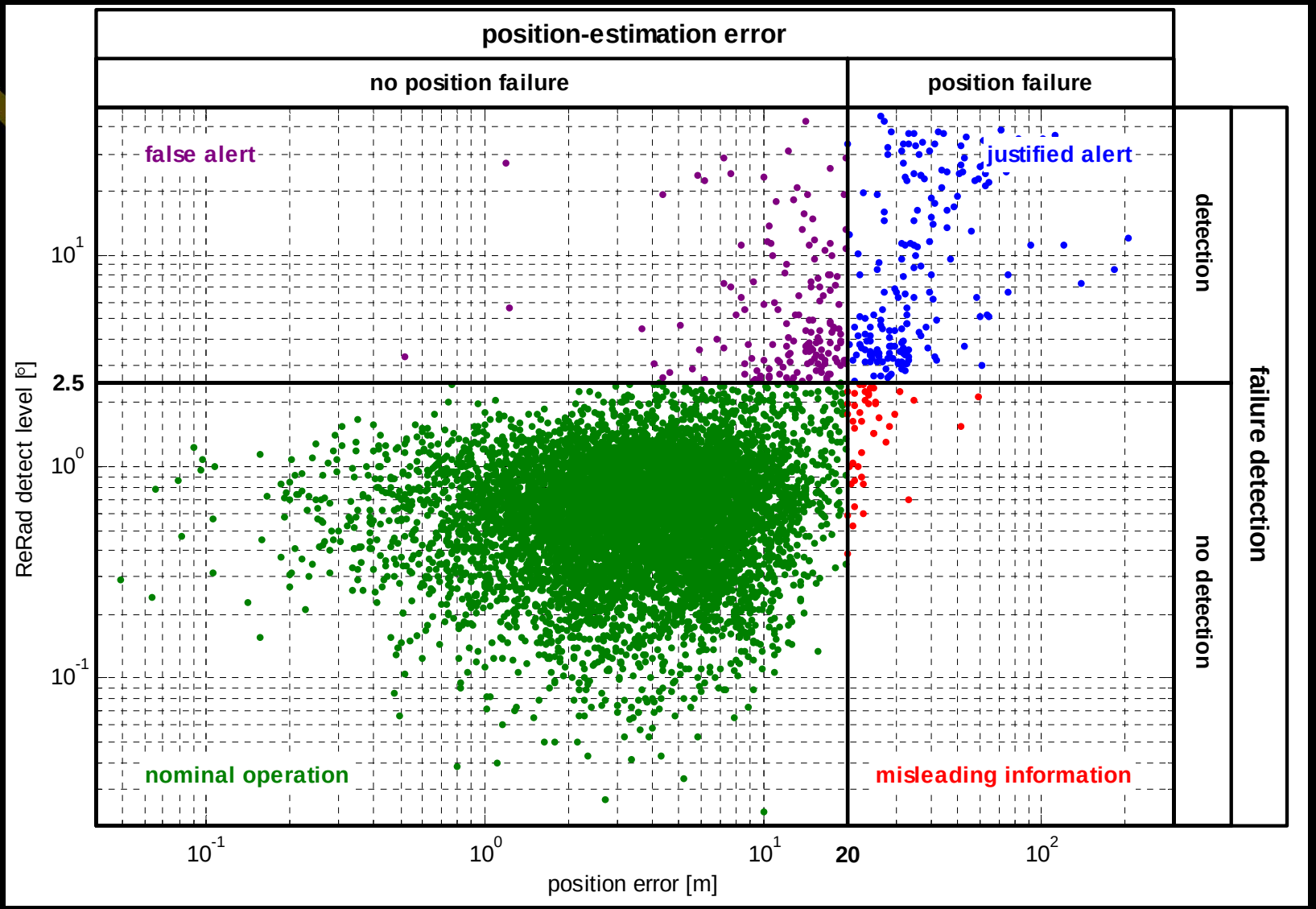


Local disturbances: influence of bridges - statistics

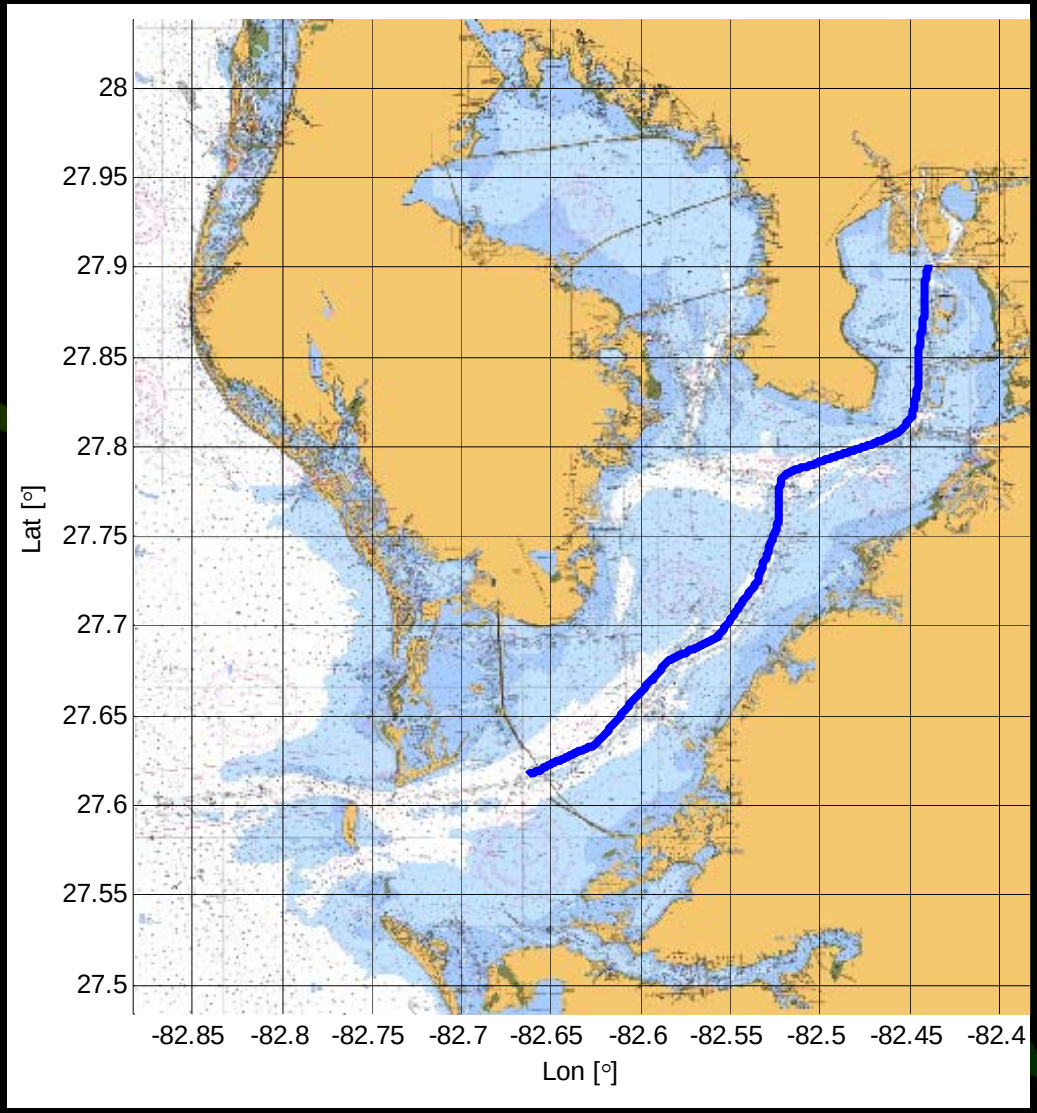
	#	%
Nominal operation	8208	95.8%
Justified alert	162	1.9%
False alert	183	2.1%
Misleading information	12	0.1%
Total	8565	100%

Note: the many passes under bridges at very low speed blurs statistics

Local disturbances: influence of bridges - statistics

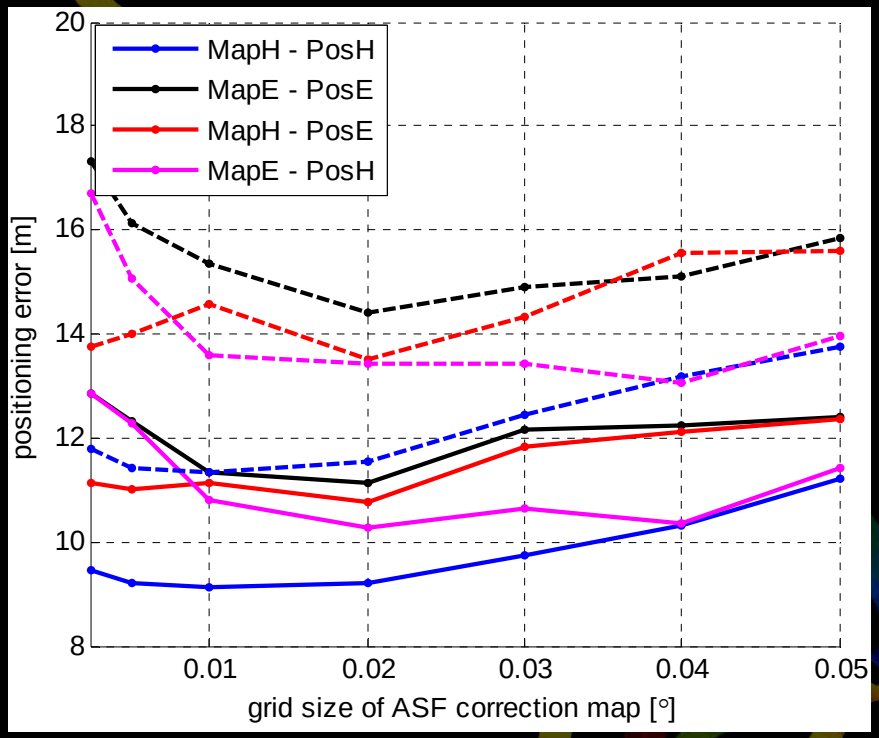


HEA dLoran showcase: track

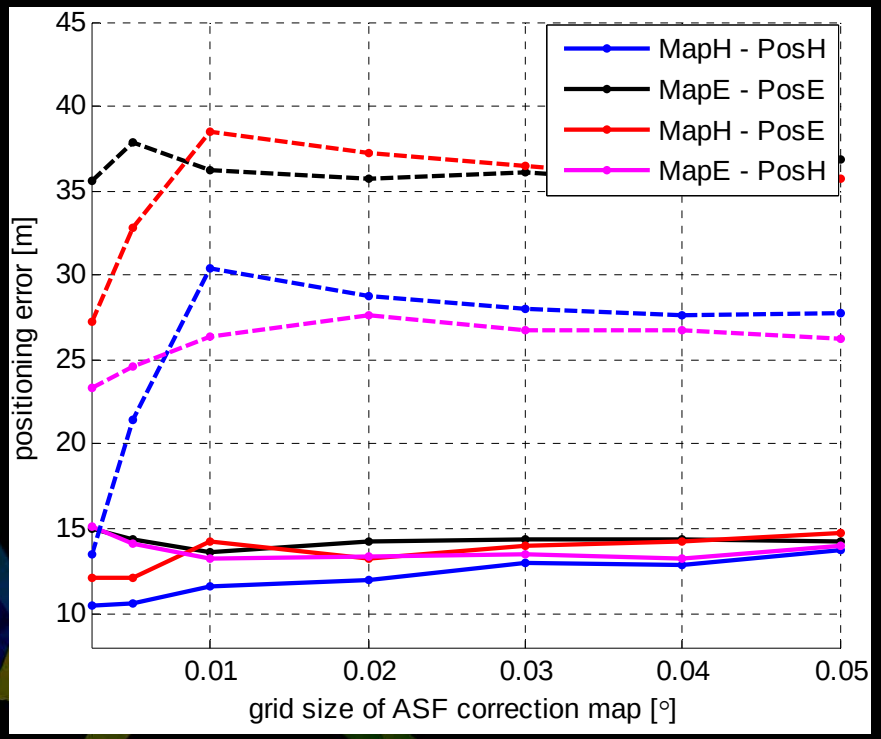


HEA dLoran showcase: influence grid size of ASF map

re-radiation excluded

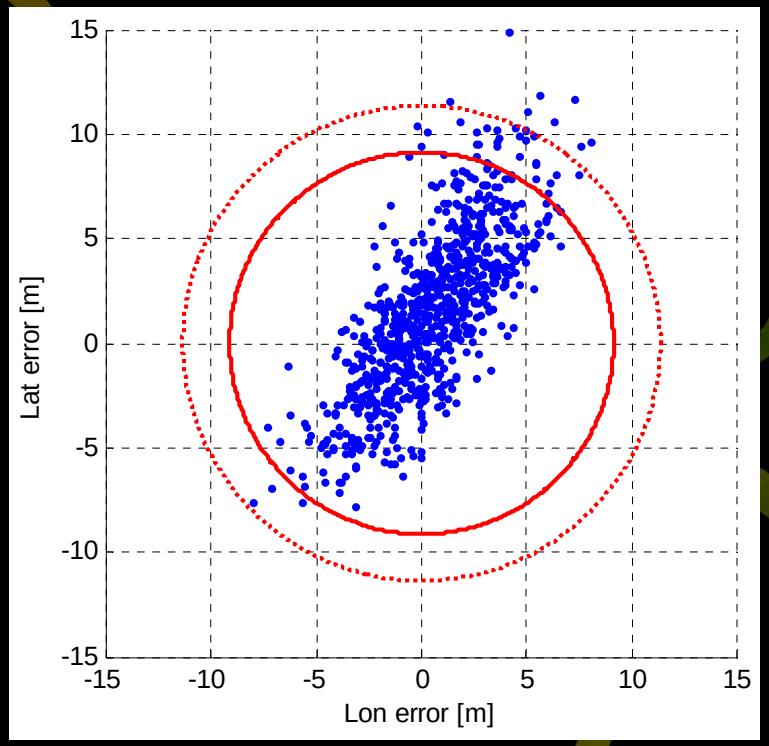


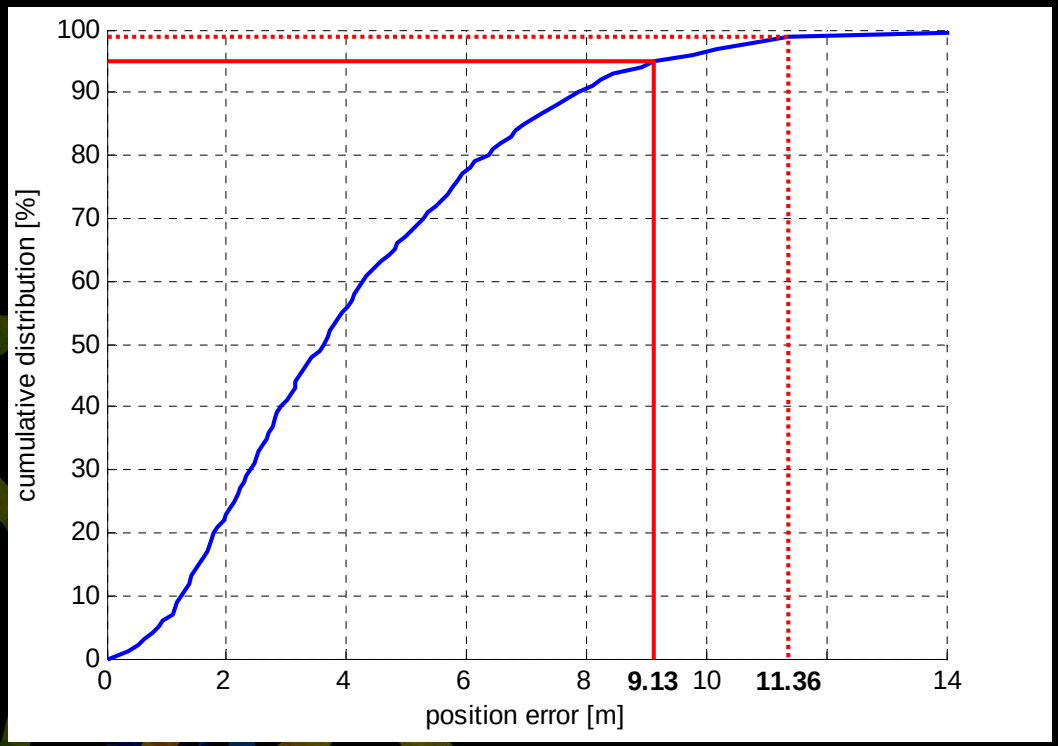
re-radiation included



Grid size of 0.01° chosen

HEA dLoran showcase: re-radiation excluded

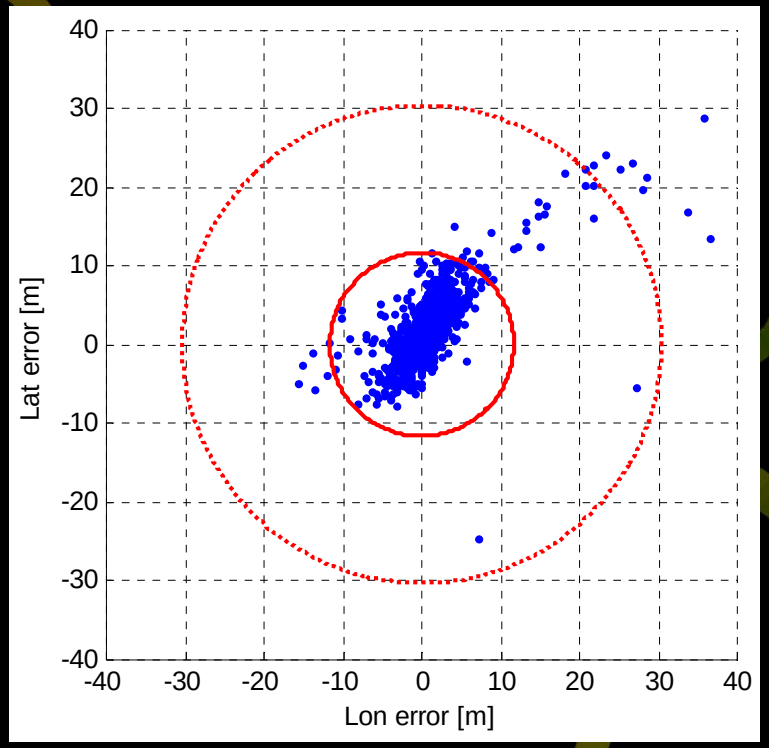


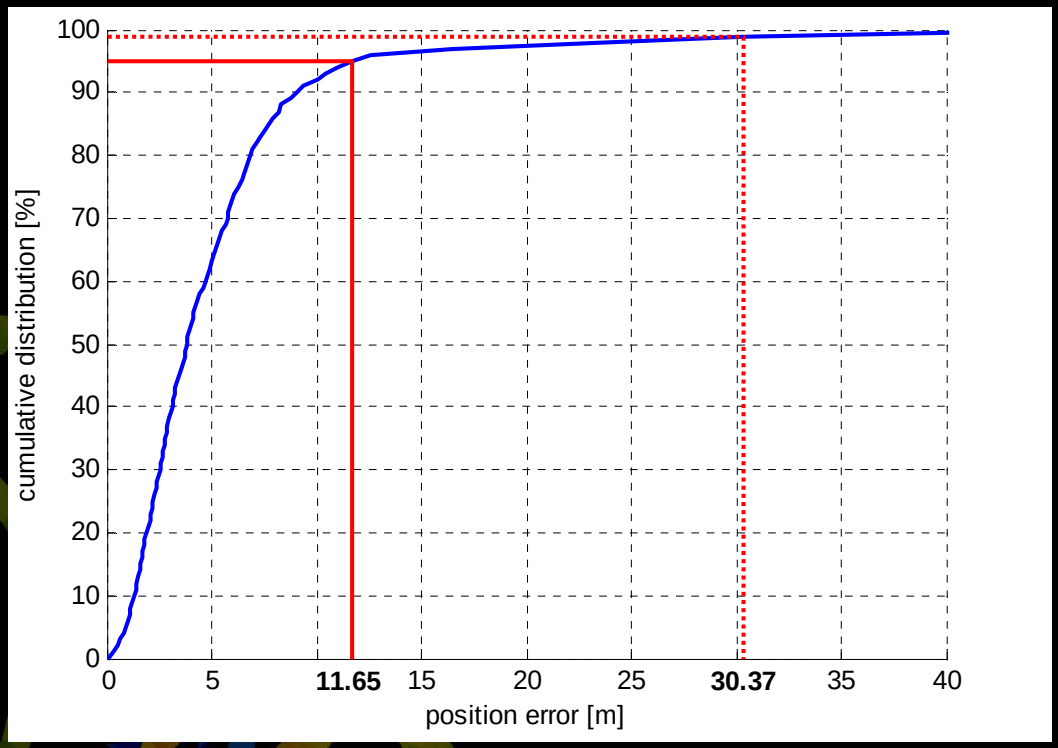


H-field: 9.1m 95% 11.4m 99%

E-field: 11.1m 95% 14.6m 99%

HEA dLoran showcase: re-radiation included



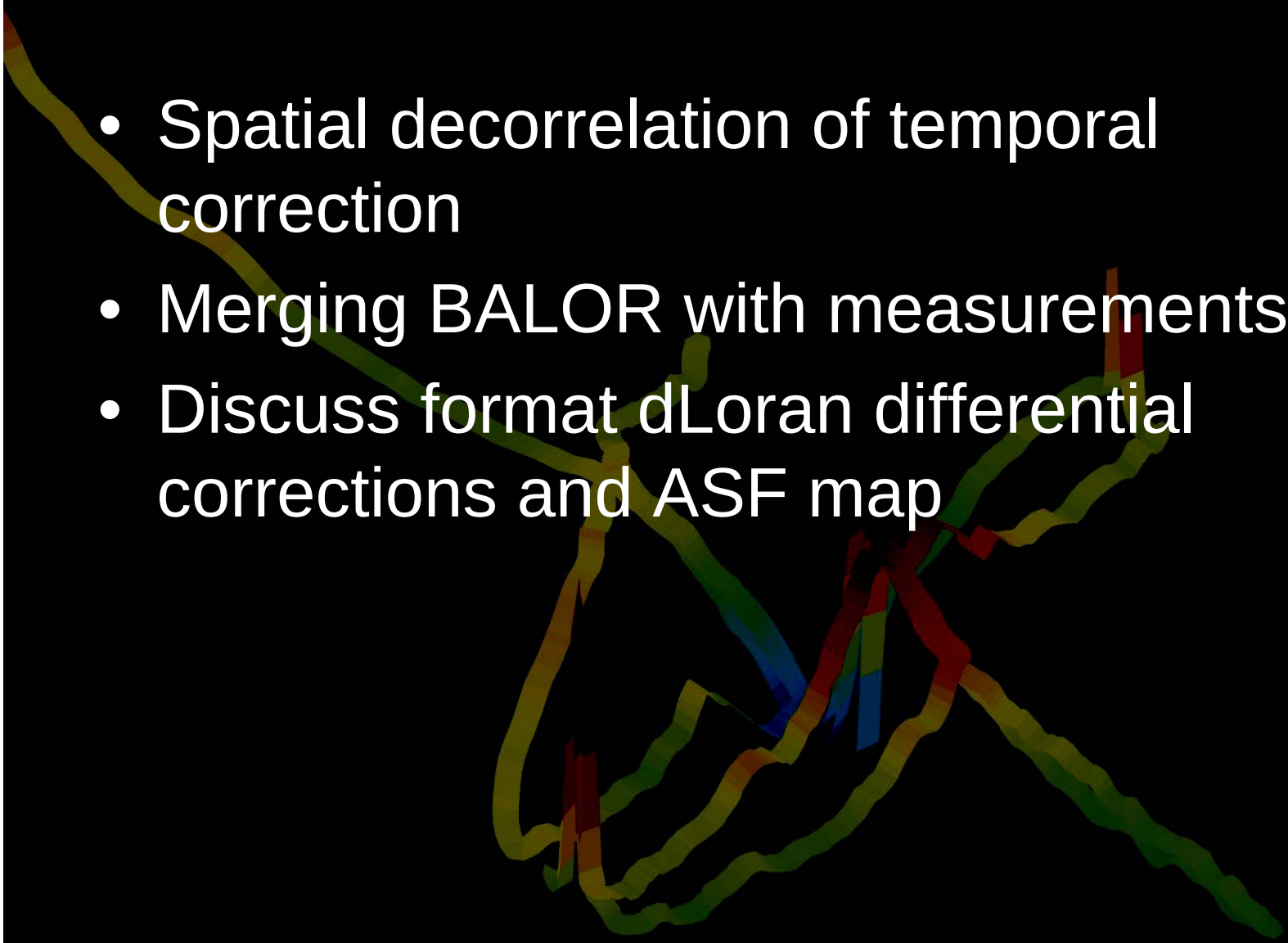


H-field: 11.7m 95% 30.4m 99%

E-field: 14.2m 95% 38.5m 99%

Some recommendations

- Spatial decorrelation of temporal correction
- Merging BALOR with measurements
- Discuss format dLoran differential corrections and ASF map



Wouter J. Pelgrum

New Potential of
Low-Frequency Radionavigation
in the 21st Century

Invitation

Public defense of the Ph.D. dissertation titled "New Potential of Low-Frequency Radionavigation in the 21st Century"

Date

Tuesday, November 28th, 2006

Introduction by the author

9:30 – 10:00 AM

Formal defense

10:00 AM

Venue

Aula of the Delft University of Technology, Mekelweg 5, Delft

Reception

Immediately following the defense

Wouter J. Pelgrum
wouter@pelgrum.org