Generating Underwater Synthetic EMI Data Using Physically Complete EMI Models

Fridon Shubitidze [1,2], Benjamin Barrowes[3], Gregory Schultz[2], Jon Miller[2], Irma Shamatava[2]
[1] Thayer School of Engineering, Dartmouth College, Hanover, NH
[2] White River Technologies, Inc
[3] USA Army ERDC, Cold Regions Research an Engineering Laboratory
Fridon.shubitidze@dartmouth.edu

SEEDs for AGC

- Seeding is one of most critical components of the DAGCAP
- A set of ISO are emplaced at a recorded location, orientation, and depth
- The emplaced ISO are divided into QC and QA seeds
- The seeding is time consuming and expensive process on land
- Using the same AGC process for UW will result in dramatic cost increase

Approximate seeding cost in UW

There is approximately 10 million acres UW areas contaminated with UXO-s in the USA

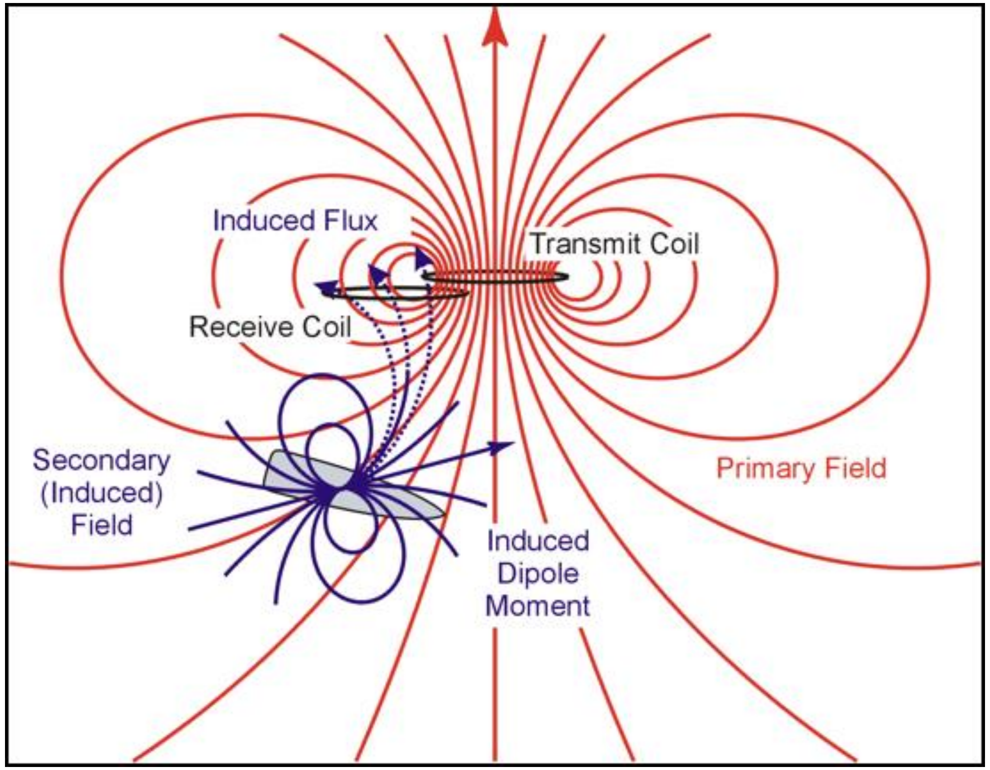
It will cost about 100 Billion dollars to seed 10 ISO per/aces

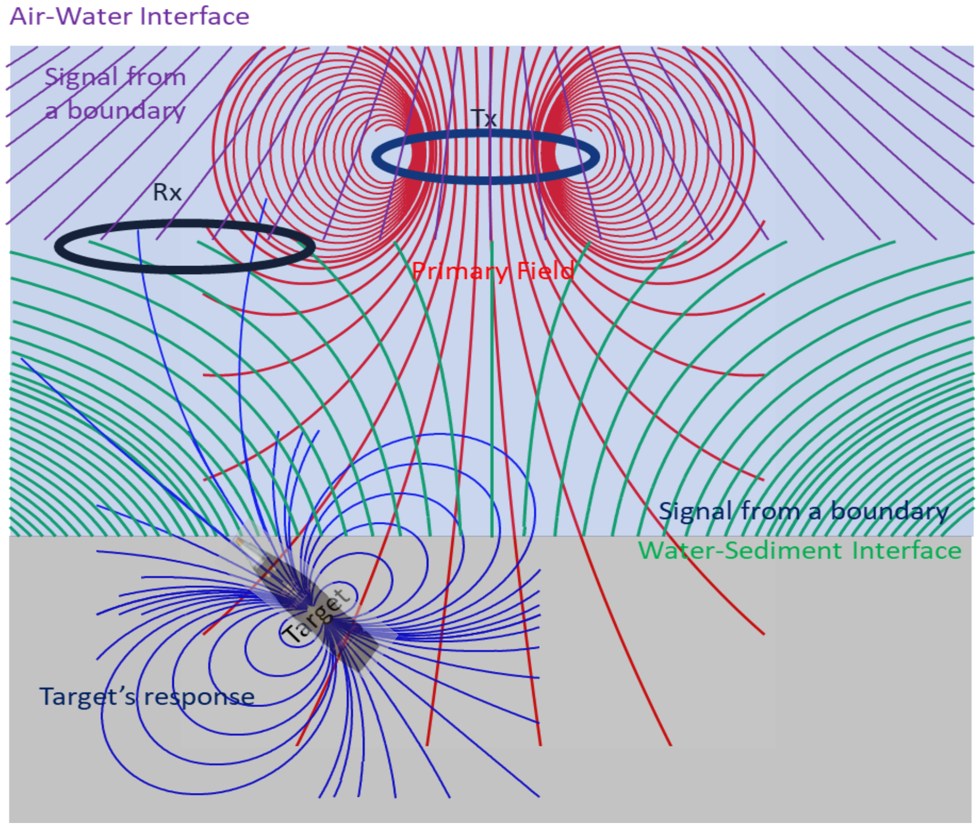
(This calculations are based on: \$1000 dollars per seeded ISO in UW i.e. $\$10^3 x 10 x 10^7 = \$100$ billion).

Land vs UW EMI problems

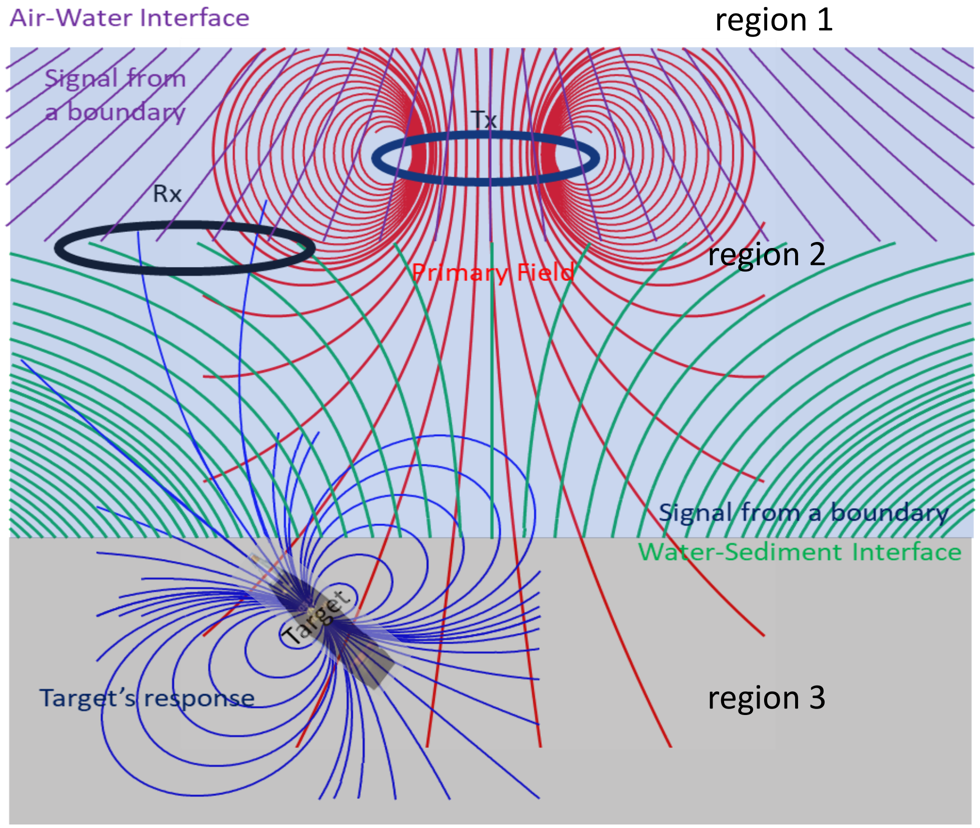
Land

UW





UW EMI sensing



- The primary electromagnetic fields induce currents in conducting media
- The total field in region 2 is sum of fields produced by a Tx coil (response from water), reflected fields from Boundaries and fields from a target
- The fields in region 1 are transmitted fields
- The total field in region 3 is sum of transmitted fields and response from a target

Received Voltage

The magnetic field in marine environment

$$\mathbf{H}(\mathbf{r},\mathbf{r}',t) \approx \sum \bar{\bar{\mathbf{G}}}(\mathbf{r},\mathbf{r}',t)\cdot\ \mathbf{m}(\mathrm{t})$$

The magnetic field in terrestrial environment

$$\mathbf{H}(\mathbf{r},\mathbf{r}',t) = \sum \bar{\bar{\mathbf{G}}}(\mathbf{r},\mathbf{r}',t=0)\cdot\ \mathbf{m}(\mathrm{t})$$

and the induced *emf* (voltage) in the receiver coil is the time derivative of the magnetic field

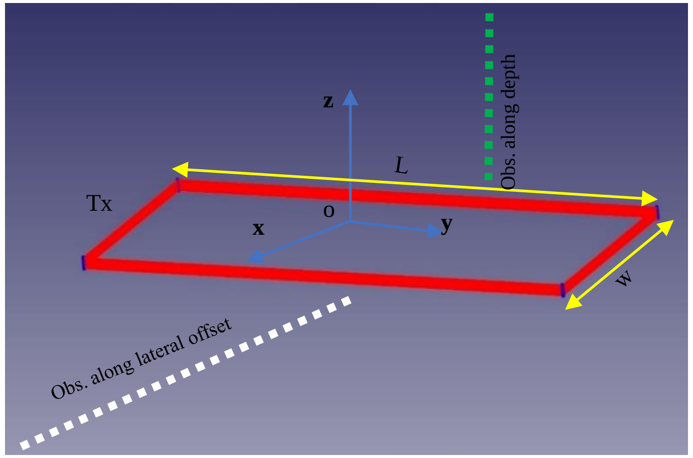
$$V(t) = \frac{\partial \mathbf{H}(\mathbf{r},\mathbf{r}',t)}{\partial t} \approx \sum \bar{\bar{\mathbf{G}}}(\mathbf{r},\mathbf{r}',t=0)\cdot \frac{\partial \mathbf{m}(\mathrm{t})}{\partial t} + \frac{\partial \bar{\bar{\mathbf{G}}}(\mathbf{r},\mathbf{r}',t)}{\partial t}\cdot\ \mathbf{m}(\mathrm{t{=}0})$$

Old model:
Voltage due to the time derivative of magnetic dipole

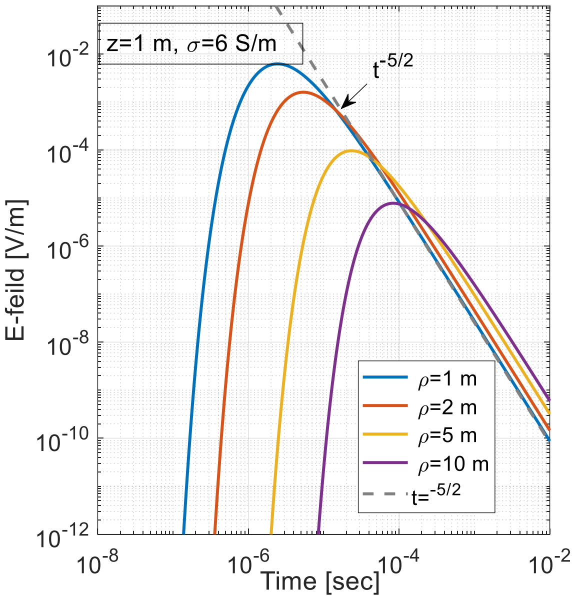
Complete model:
Voltage due to both the magnetic dipole and its time derivative

Eddy currents in a conducting environment

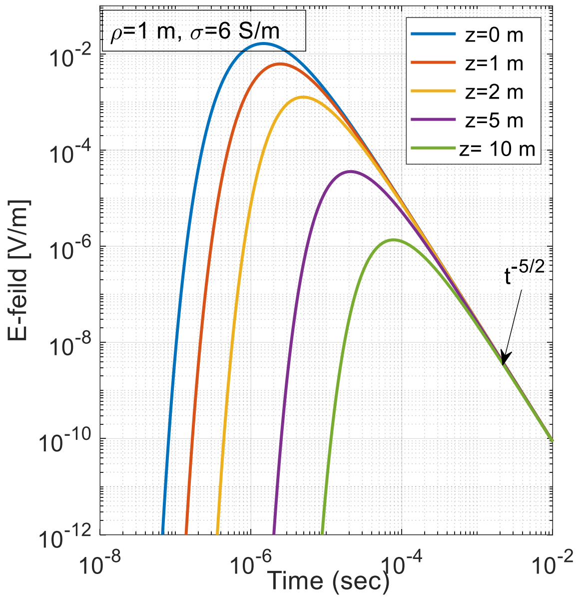
Eddy current: $\mathbf{J} = \sigma \mathbf{E}$



A horizontal 2m x1 m Tx coil is placed in a medium with conductivity of 6 S/m



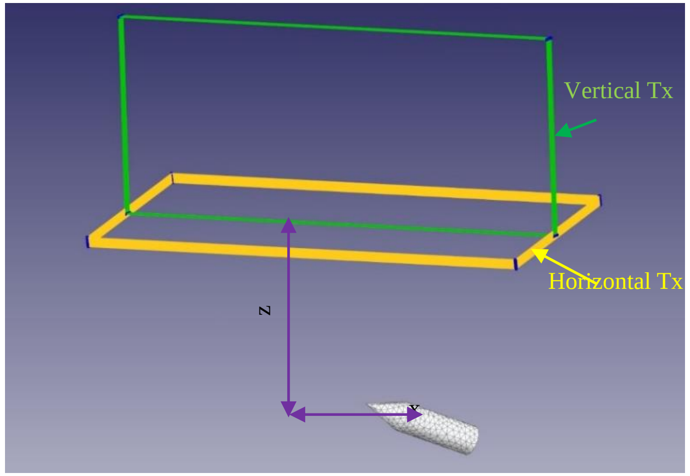
electric field at four different locations along lateral offset, for fixed z=1 m

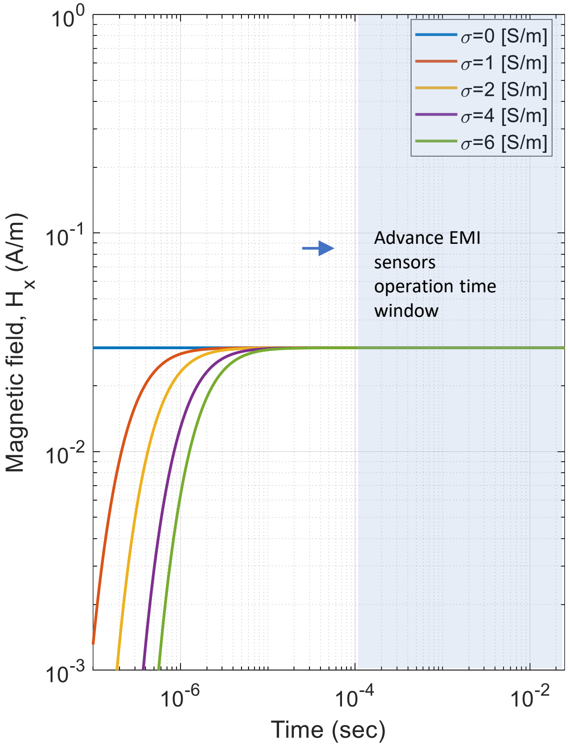


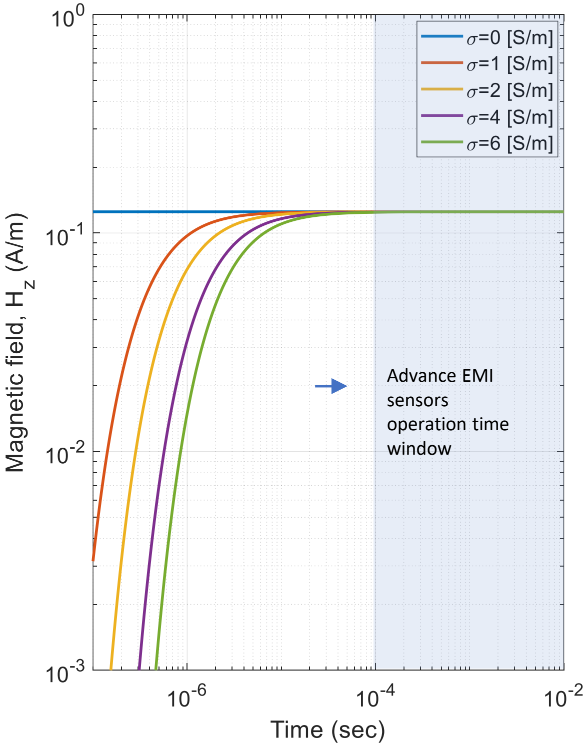
electric field at five locations along depth for fix ρ=x=1m

Dashed line corresponds to $t^{-5/2}$ decay for comparison;

Horizontal Tx: Primary magnetic field in a conducting environment

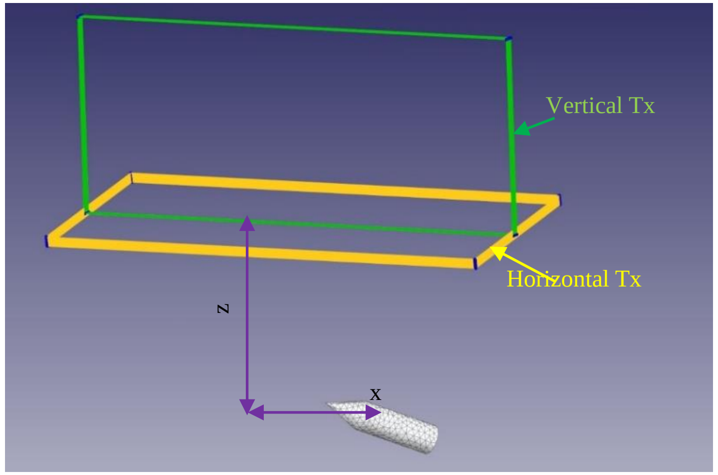


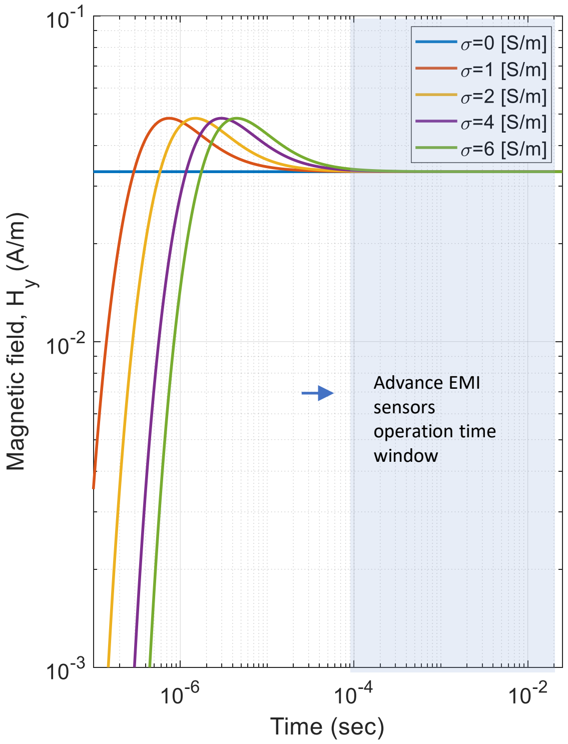


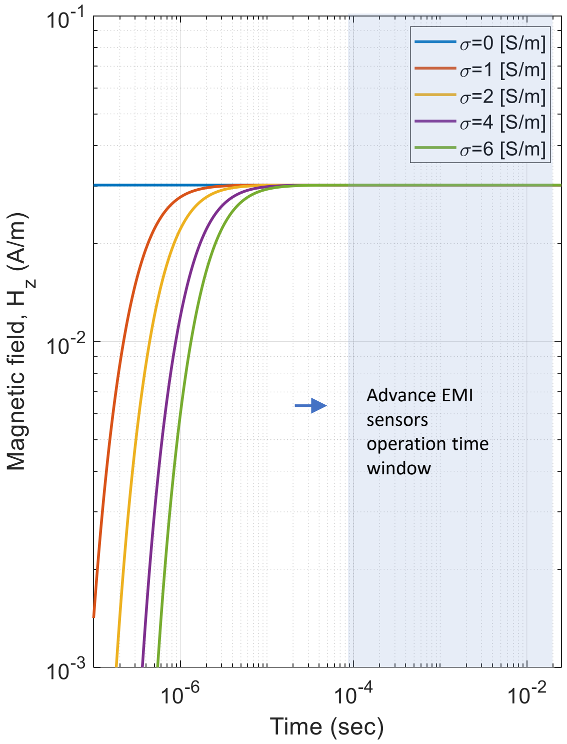


Primary magnetic field vs time for the horizontal 2m x 1m Tx coil placed in free space and in a medium with different conductivities; x=0.4 m, z=1.5 m

Vertical Tx: Primary magnetic field in a conducting environment

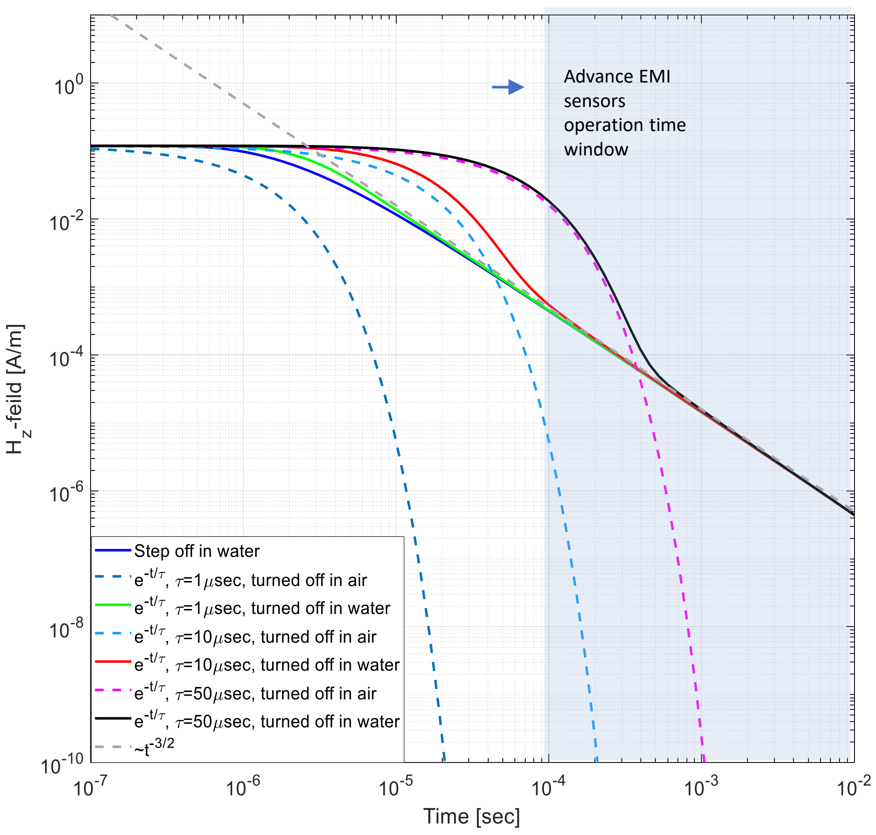


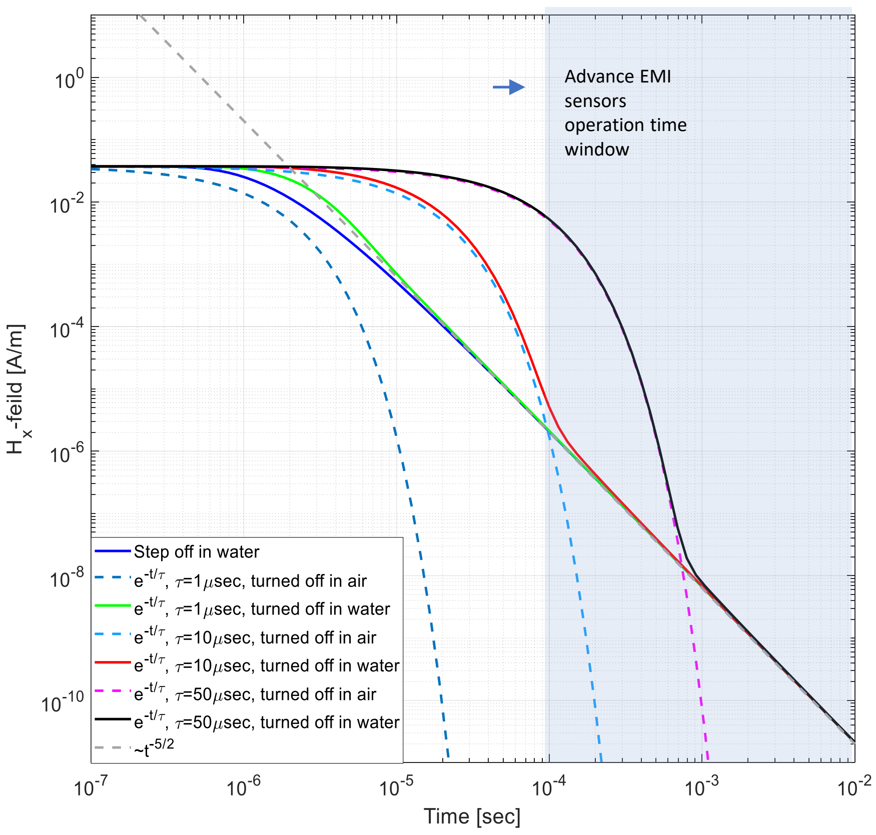




Primary magnetic field vs time for the vertical 2m x 1m Tx coil placed in free space and in a medium with different conductivities; x=0.4 m, z=1.5 m

Tx Turned-off effect: Primary magnetic field in a conducting environment

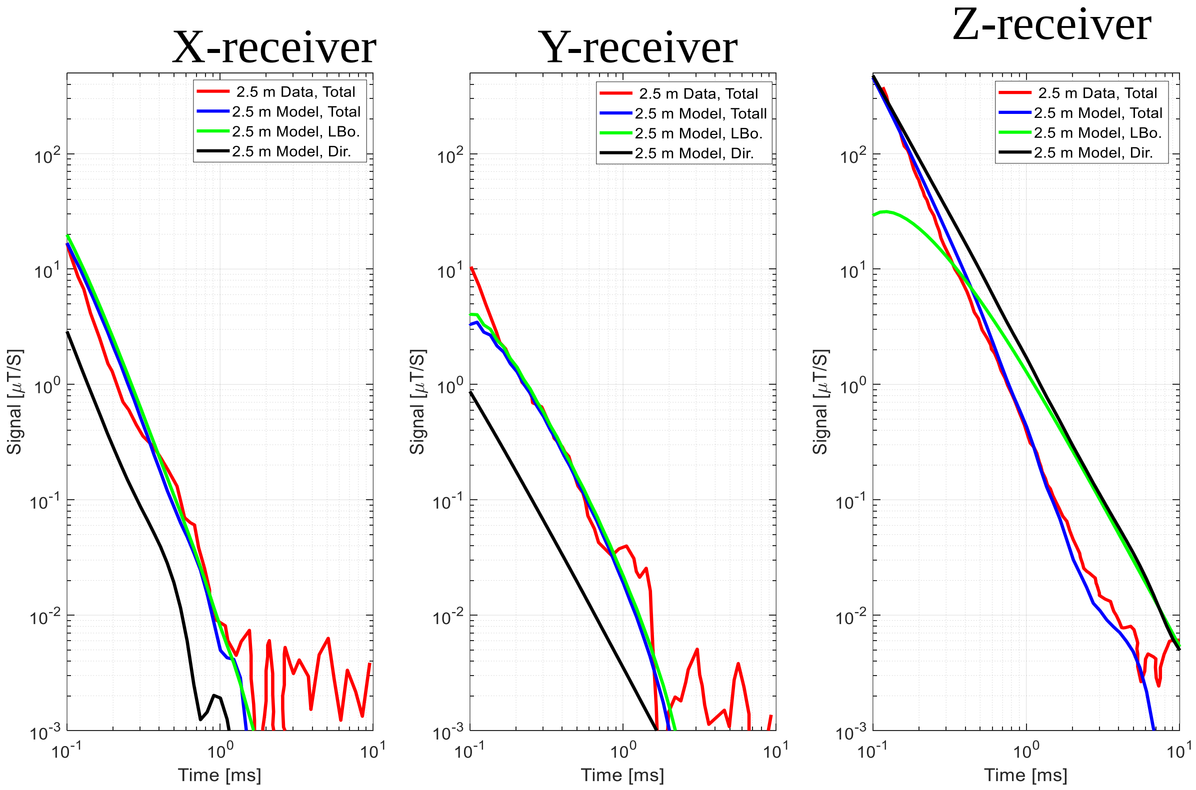




H_z (left) and H_x (right) components of magnetic field in free space and in conducting environment for various values of turned off time.

Comparisons between modeled and actual data for a multi layer environment after Tx is Turned off: 2.5 m Water depth

The data and photo are taken from the SERDP project #MR-2412



Total: Signal from LBo +Signal from Water (Direct coupling)

LBo: Layer Boundaries

Dir: Signal from Tx to Rx, i.e. water response

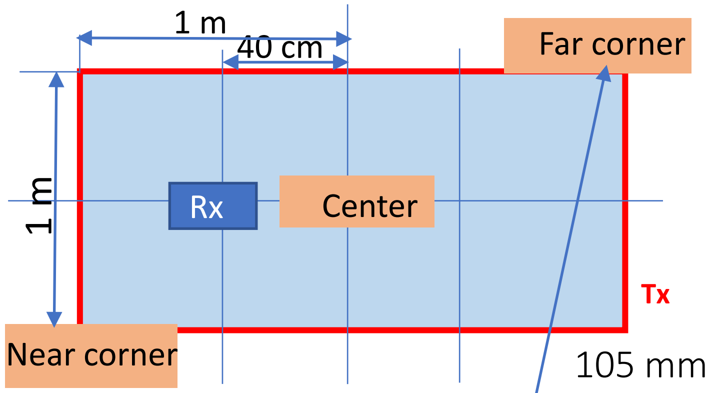
Modeled vs actual data

$$V(t) \approx \sum \bar{\bar{\mathbf{G}}}(\mathbf{r},\mathbf{r}',t)\cdot \frac{\partial \mathbf{m}(t)}{\partial t} + \frac{\partial \bar{\bar{\mathbf{G}}}(\mathbf{r},\mathbf{r}',t)}{\partial t}\cdot \mathbf{m}(t)$$

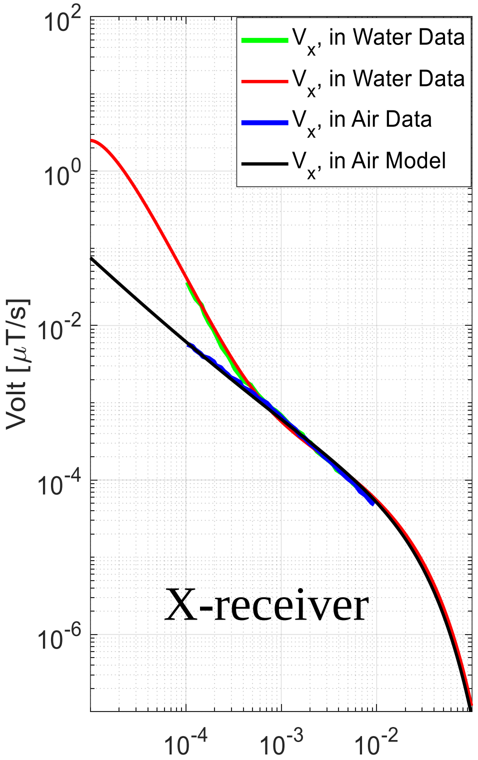
Old model:

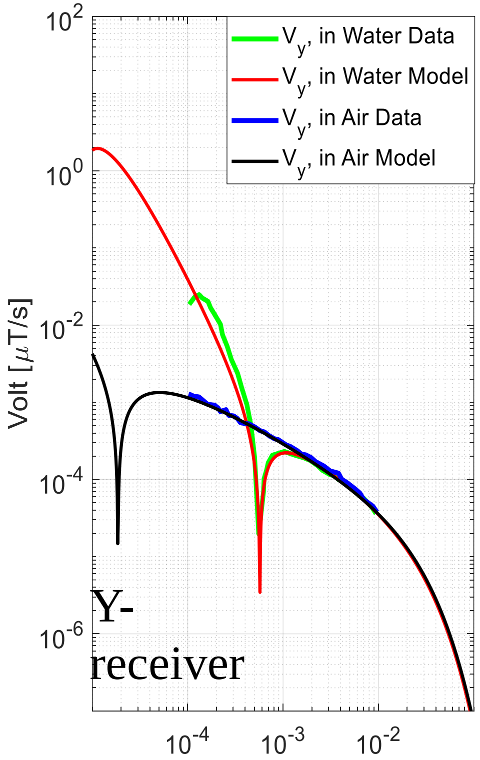
Complete model:

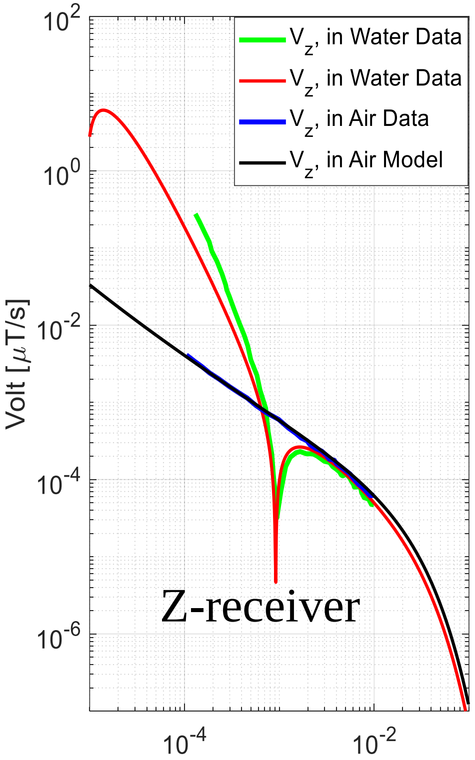
Data are taken from the SERDP project # 2412.



105 mm
at far corner



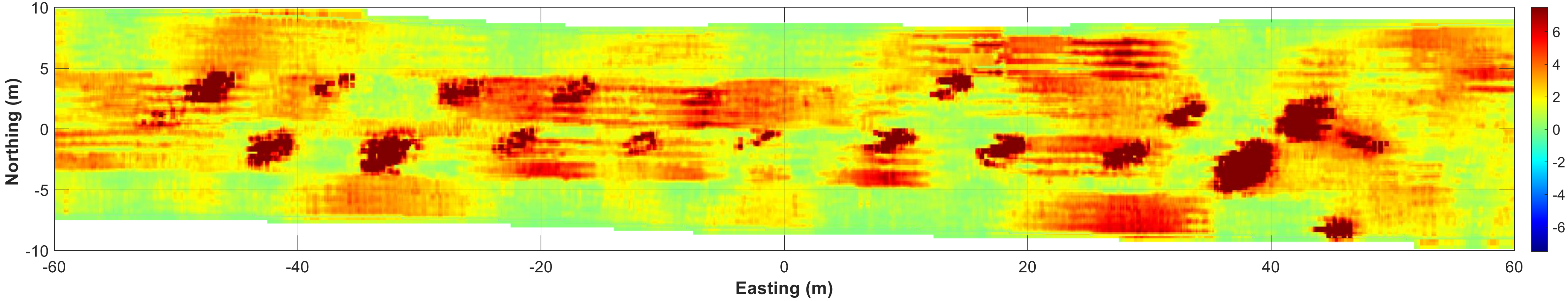




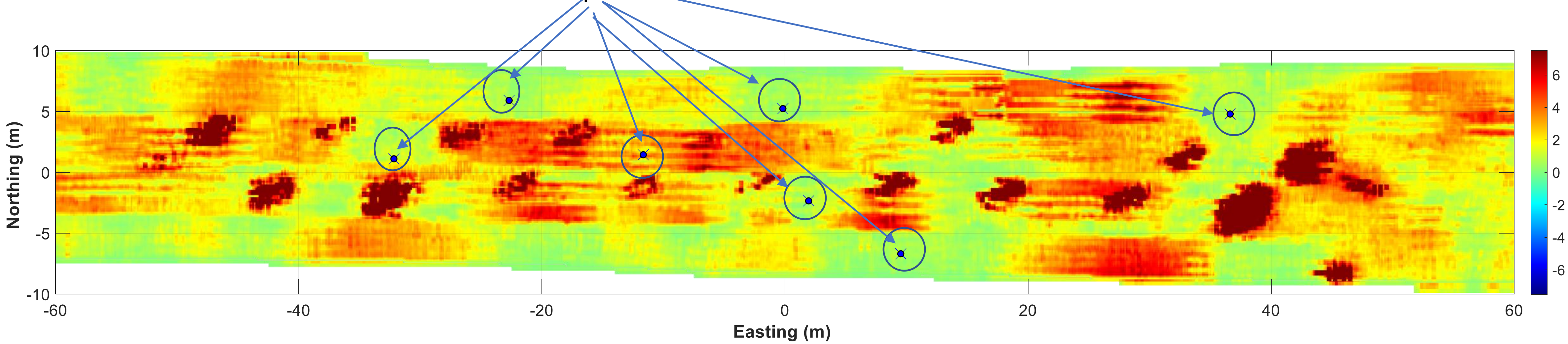
Comparisons between actual and modeled data using the old and enhanced models for a 105 mm projectile placed in marine and terrestrial environments

Seeding process

Site specific data

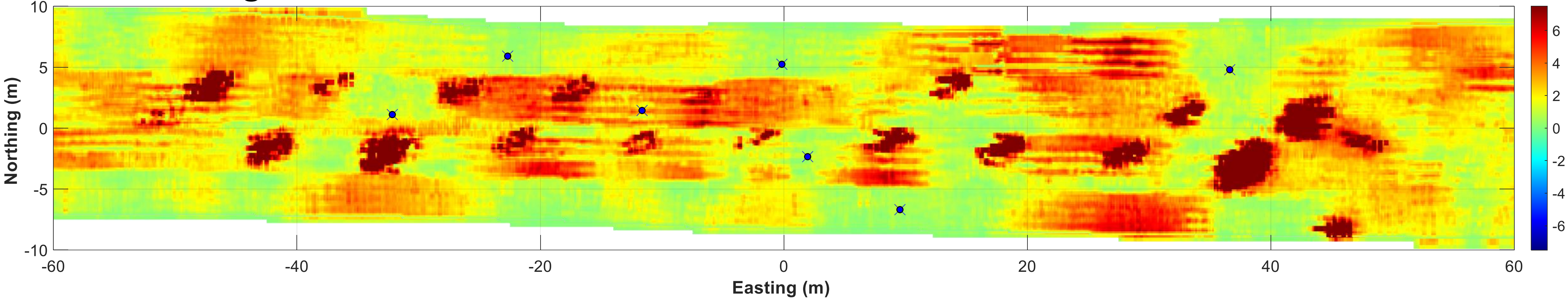


Choose points

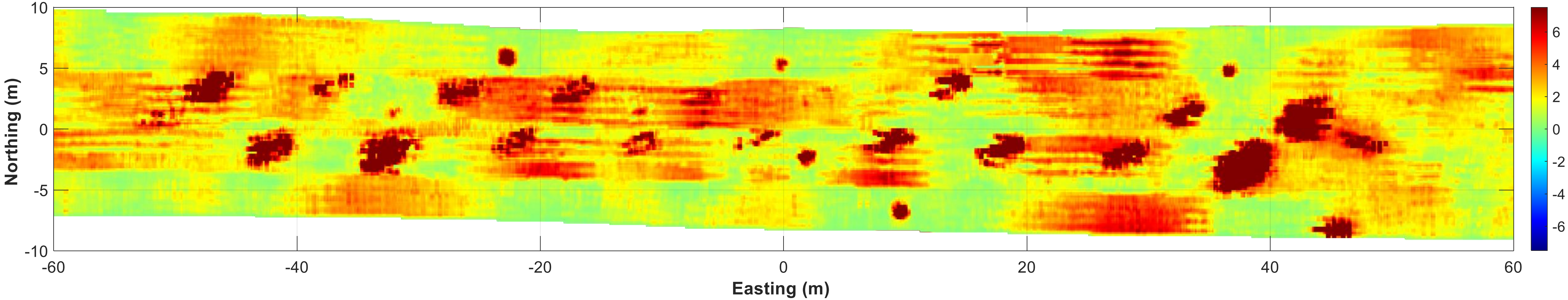


Seeding process

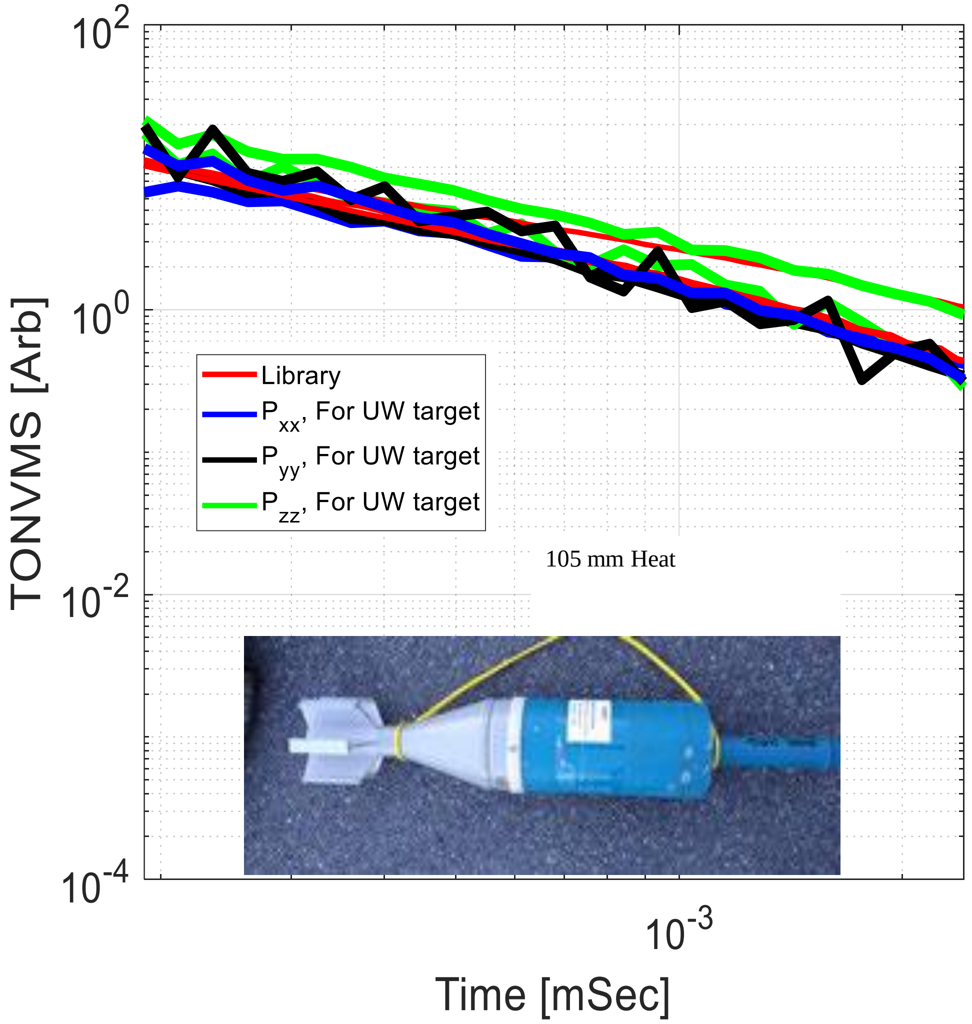
Calculate signals

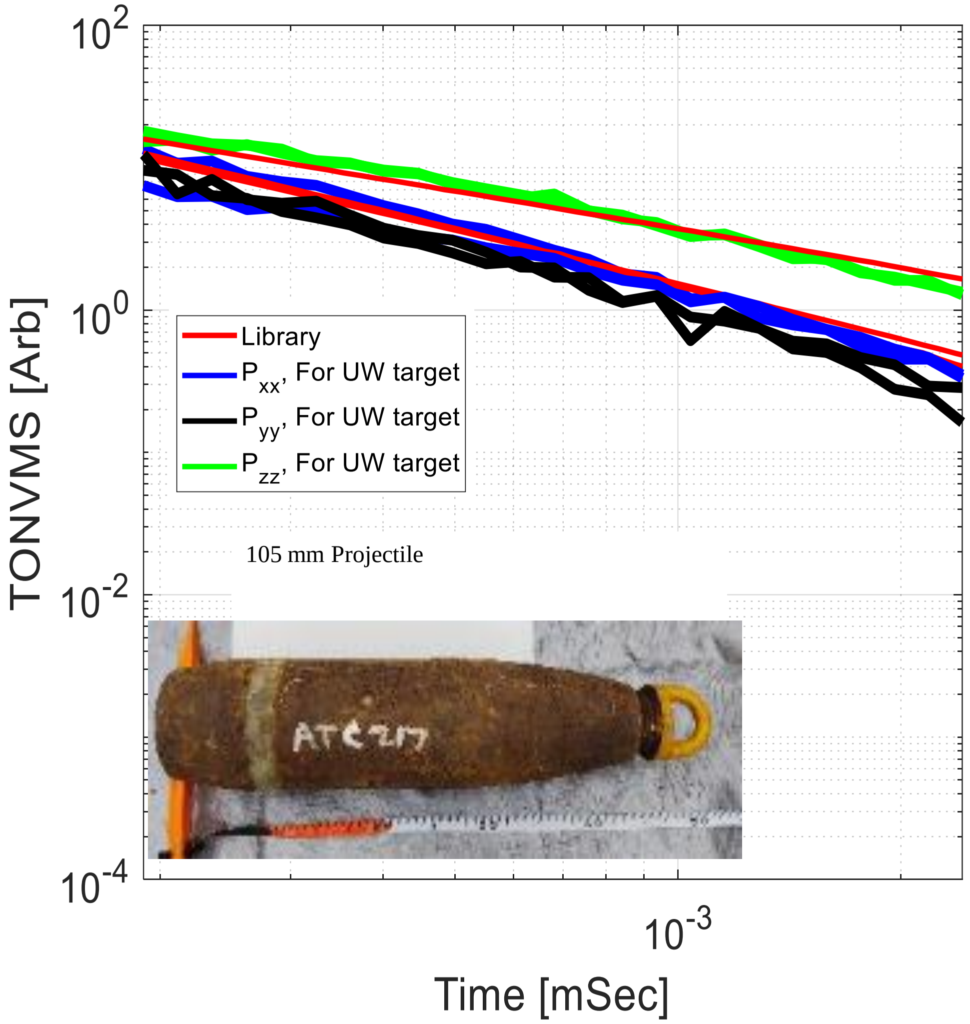


Generate detection map



Extracted effective polarizabilities





Conclusions

- UW synthetic seeding algorithms are developed and demonstrated
- The algorithms model accurately transient responses from: TX, UW targets, layer boundaries and transmitters/receivers surrounding medium
- The models can be used to design and optimize UW sensors, and to generate realistic synthetic data sets for UW DAGCAP validations
- The generated synthetic data can be used for post UW AGC risk assessment

Acknowledgments:

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