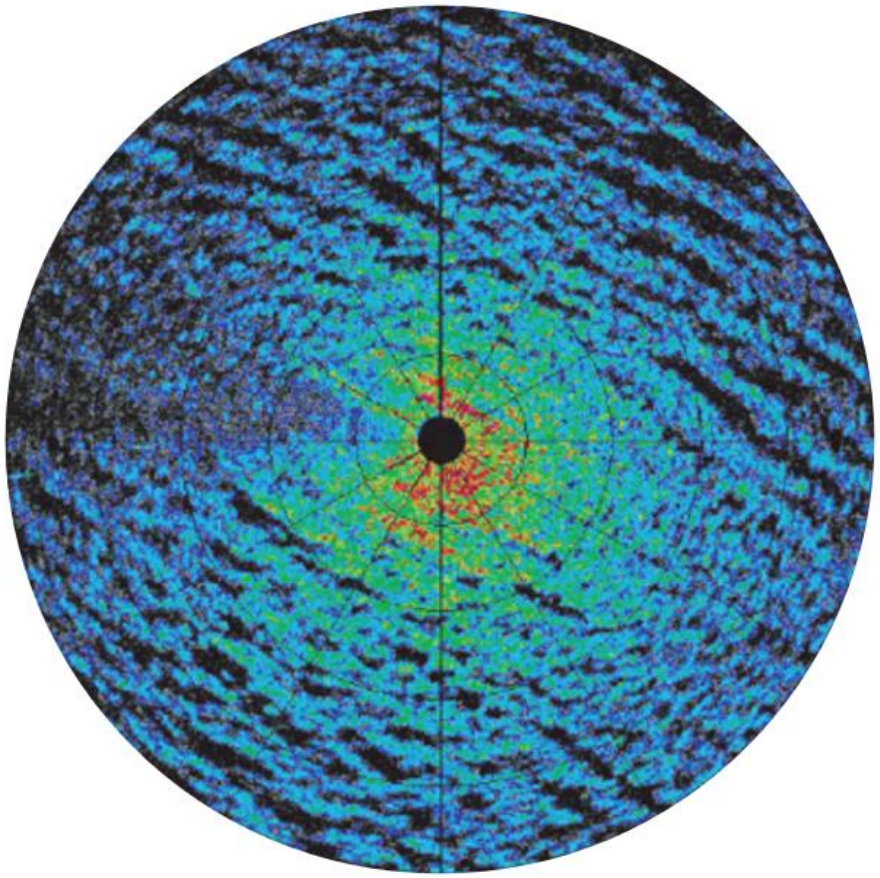
Towards real-time sea surface reconstruction from X-band radar and Lidar measurements

23/09/2025

Rollon BARTHELEMY

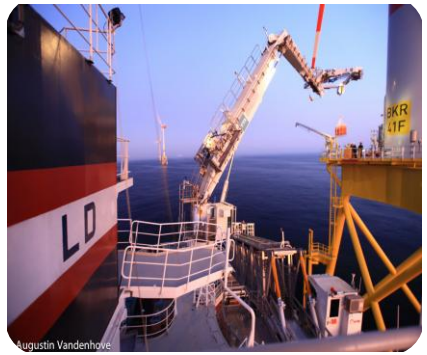
CONTEXT

Sea surface



Radar image

APPLICATION OF REAL-TIME WAVE FORECASTING



Decision support systems

in offshore operations:

- Ship-to-ship operations,
- (short) drilling operations,
- AUV/ROV launch and recovery,
- helicopter landing

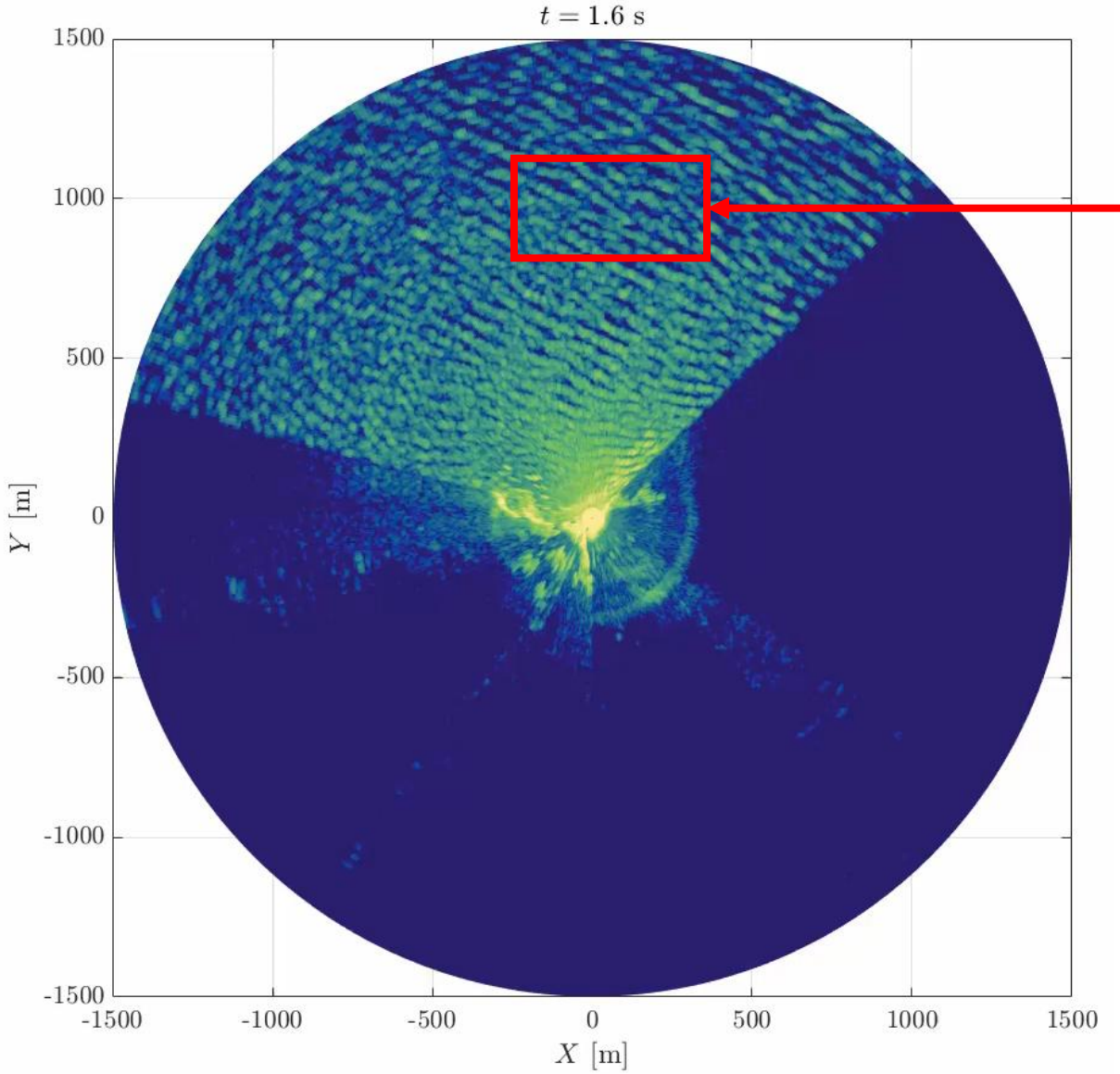
Control applications:

- heave compensation systems,
- dynamic positioning,
- predictive vessel stabilization,
- floating wind turbine control

Scientific research:

- Sea waves and current interaction,
- Wave dynamics,
- Coastal erosion,
- Validation/calibration models or satellites altimeters,
- Sea waves dynamic on high resolution and big distances

SEA CLUTTER

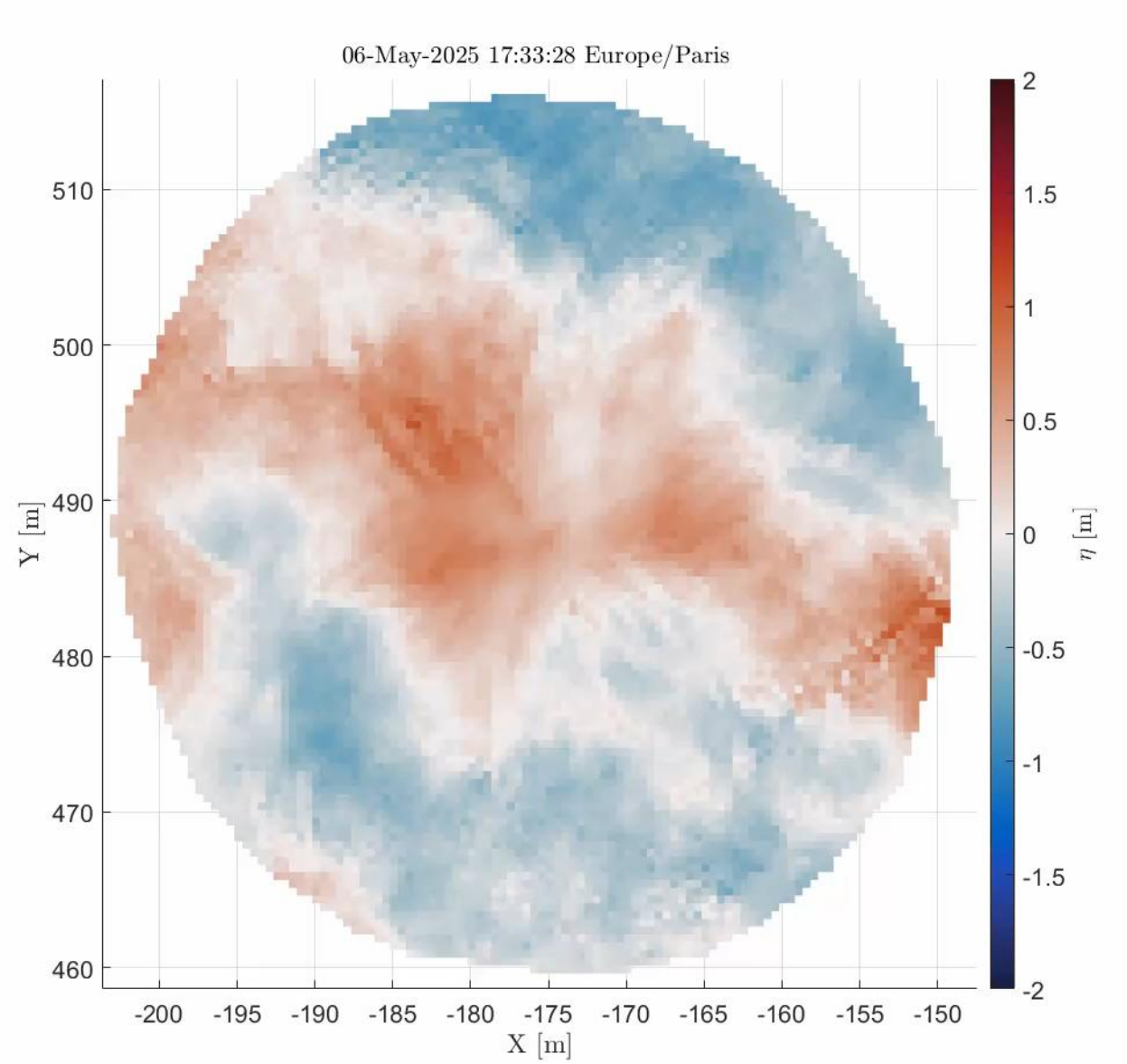


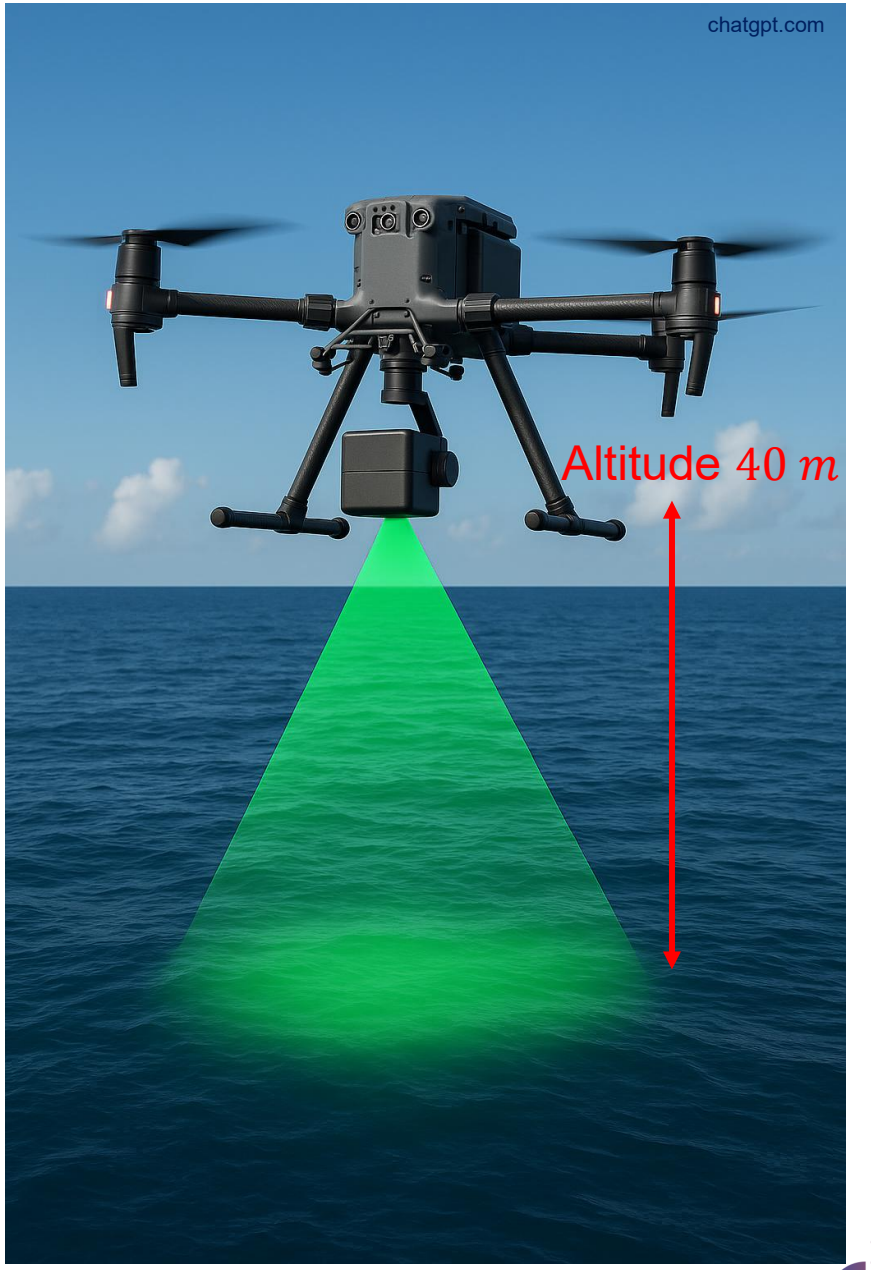
Sea clutter : radar echoes returned from the rough sea surface.
The signal strength increases with the sea state and particularly to the sea waves height.

With a Lidar on a drone, stationary flight over a point to recover sea elevation over a surface area.

At the same time, we save the radar signal to extract the same zone later during processing.

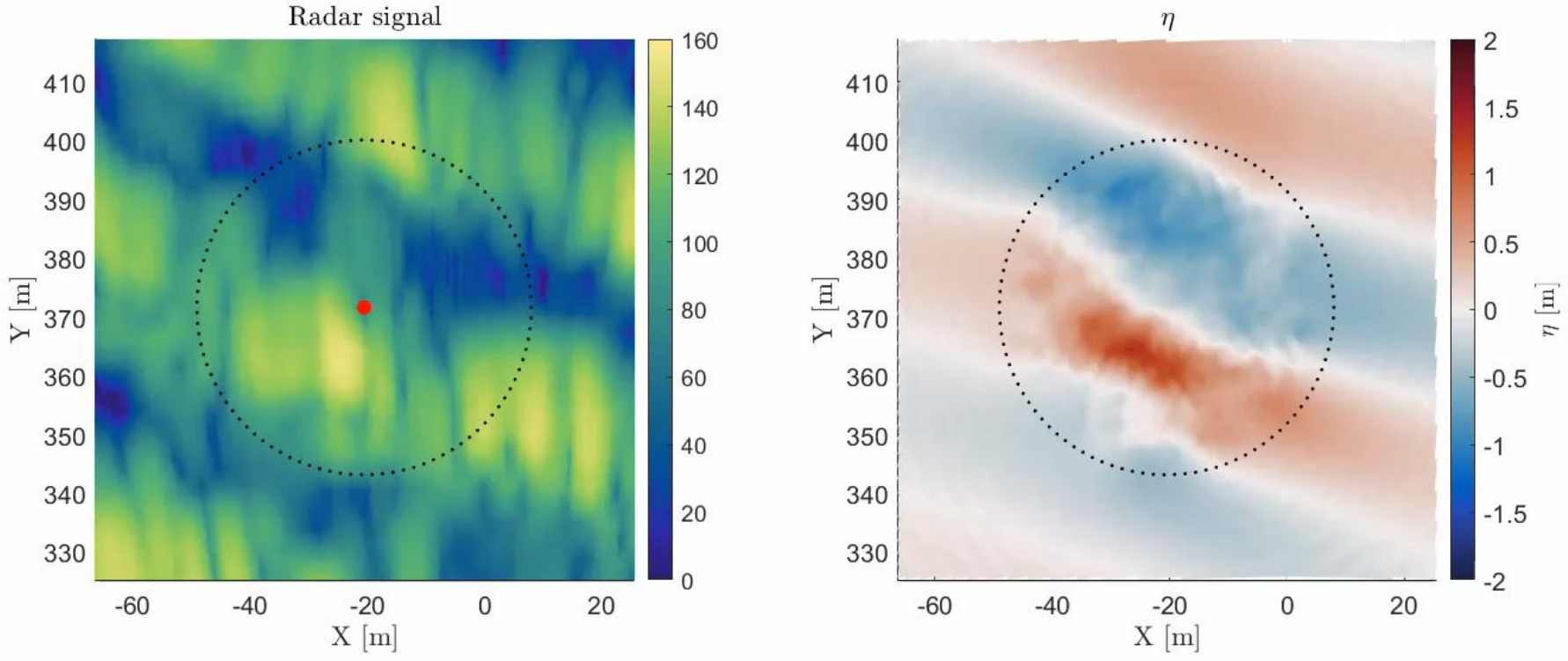
LIDAR DATA





OUTLINE

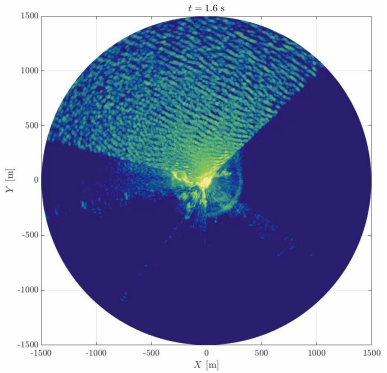
Improving radar model

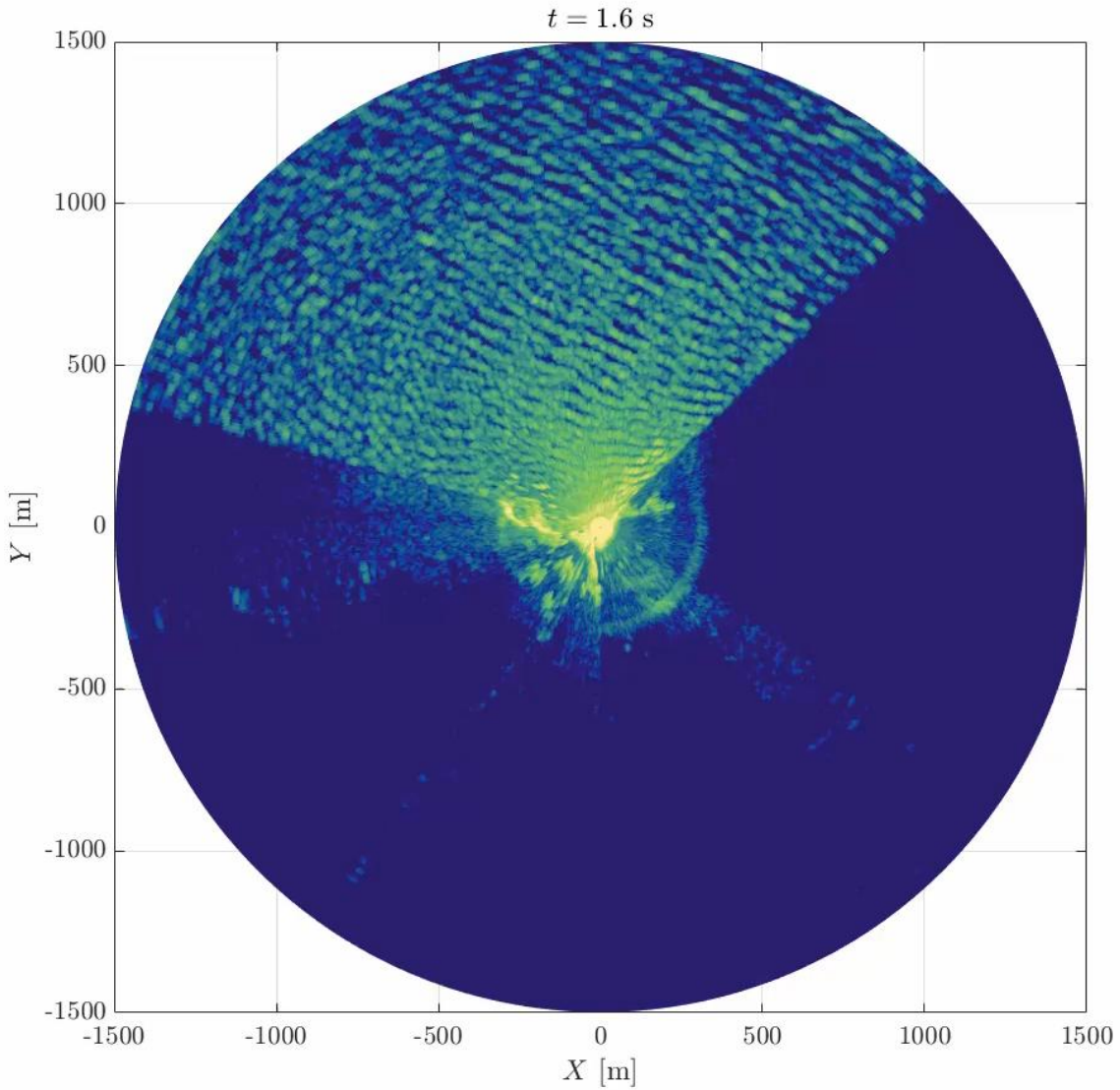


AI inversion

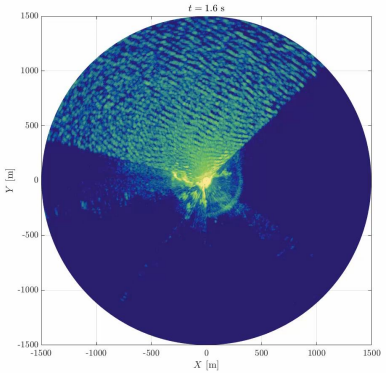
IMPROVING RADAR MODEL

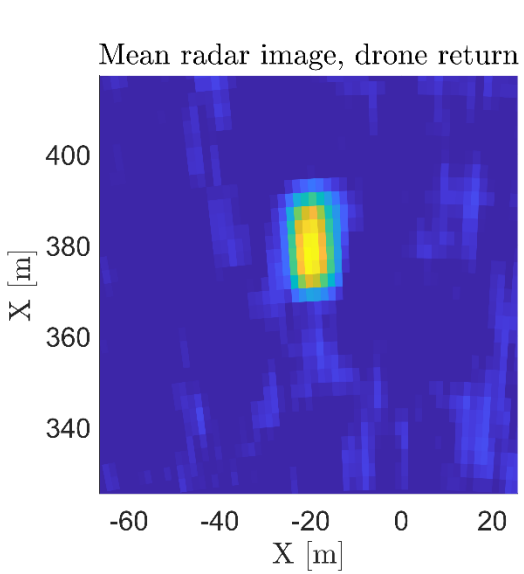
PATHWAY

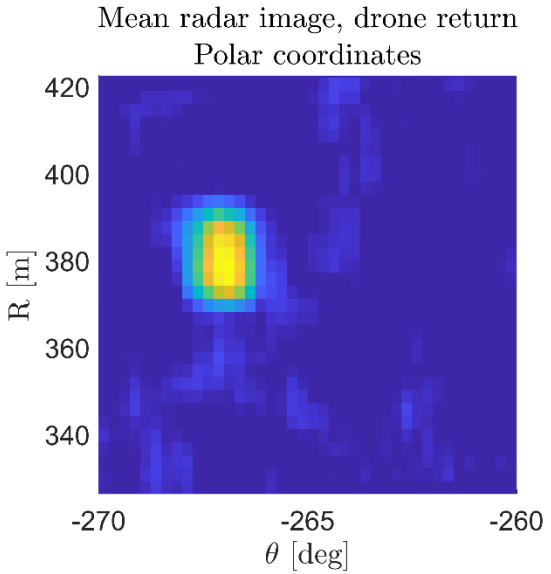


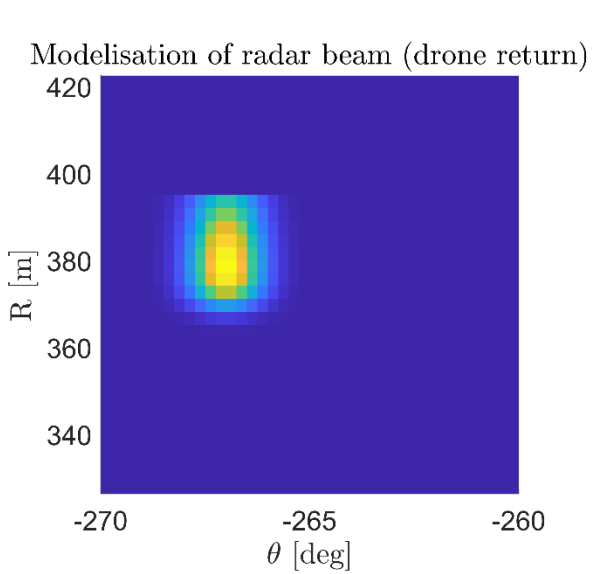


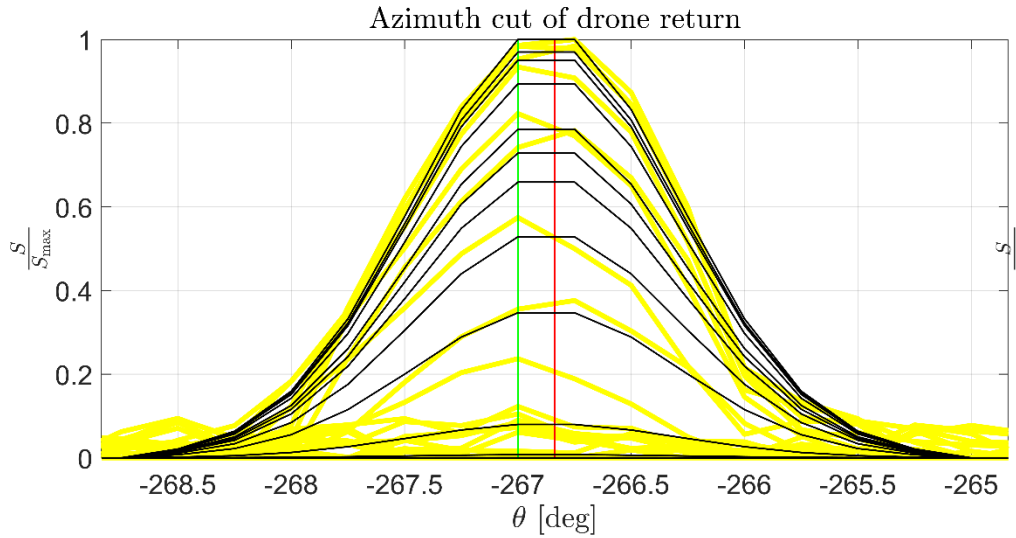
PATHWAY

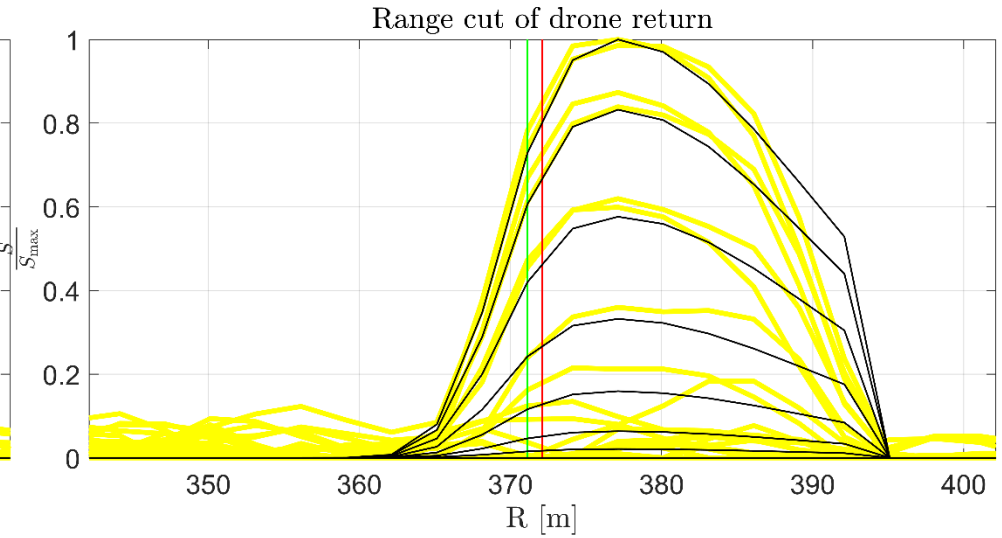




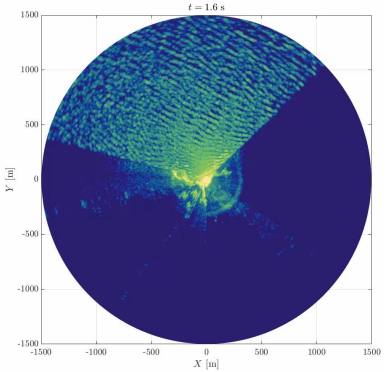


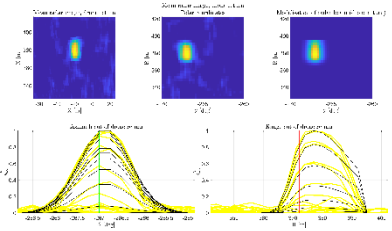


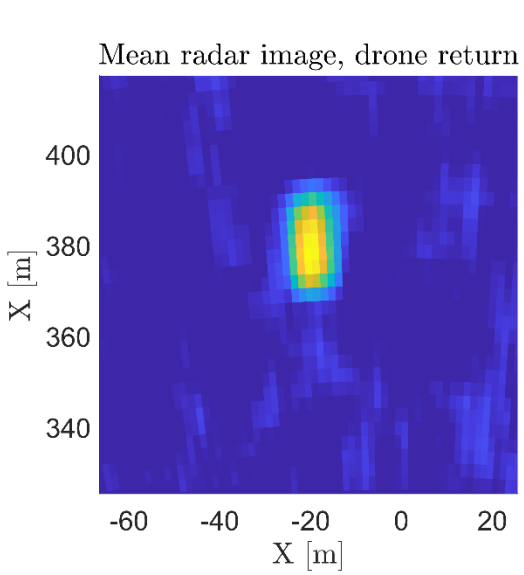


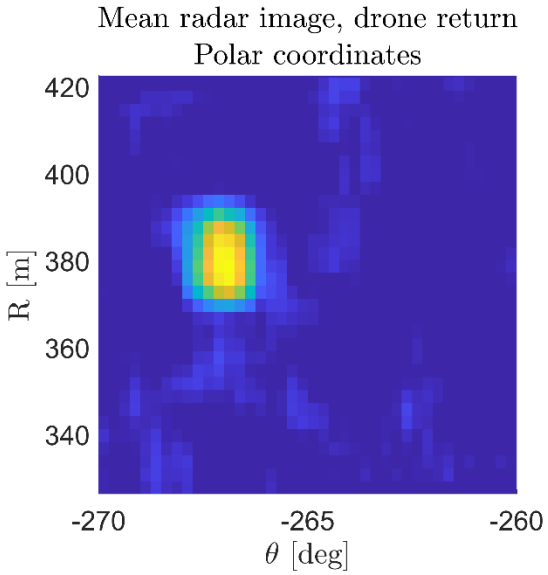


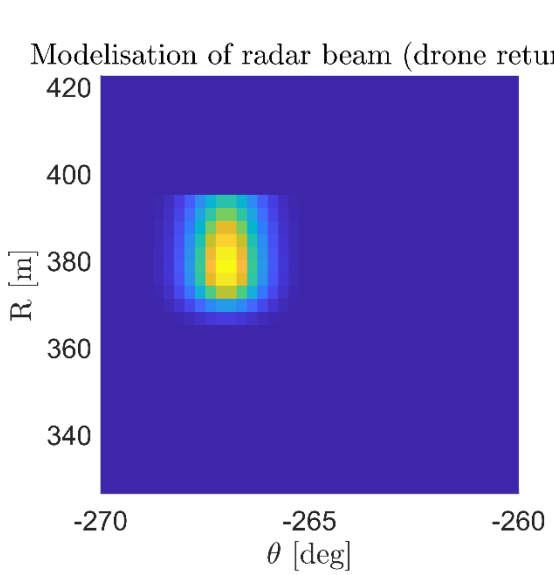
PATHWAY

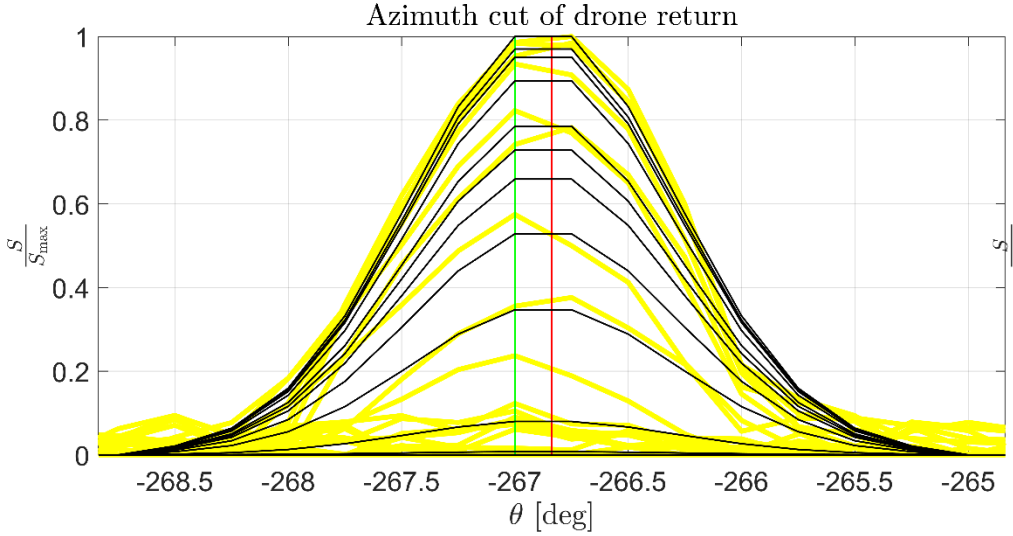


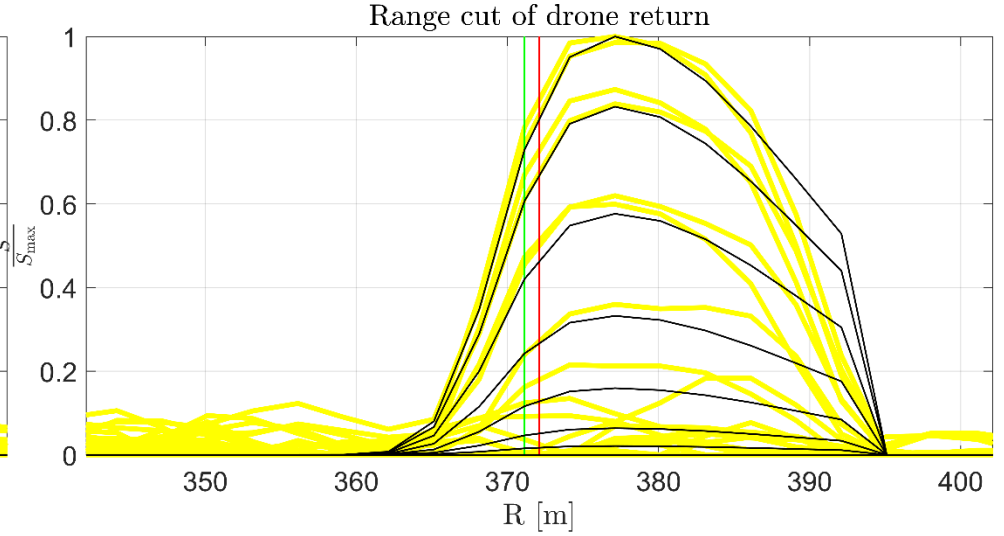




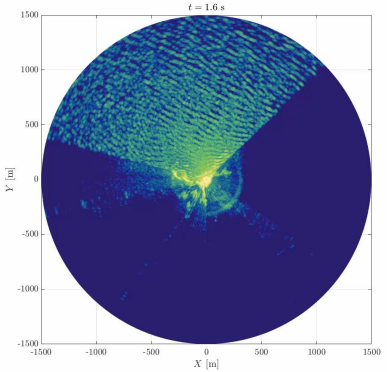


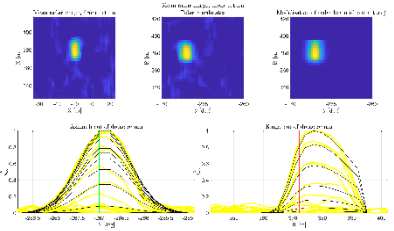


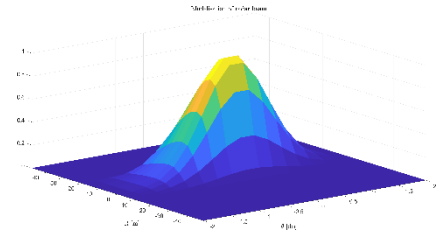




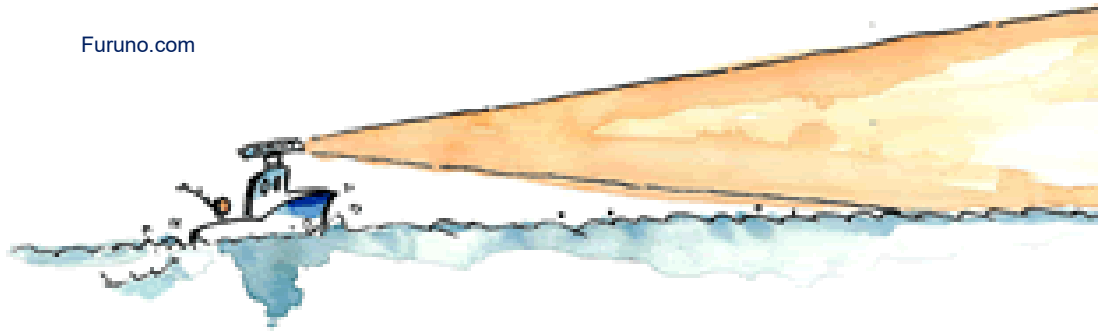
PATHWAY

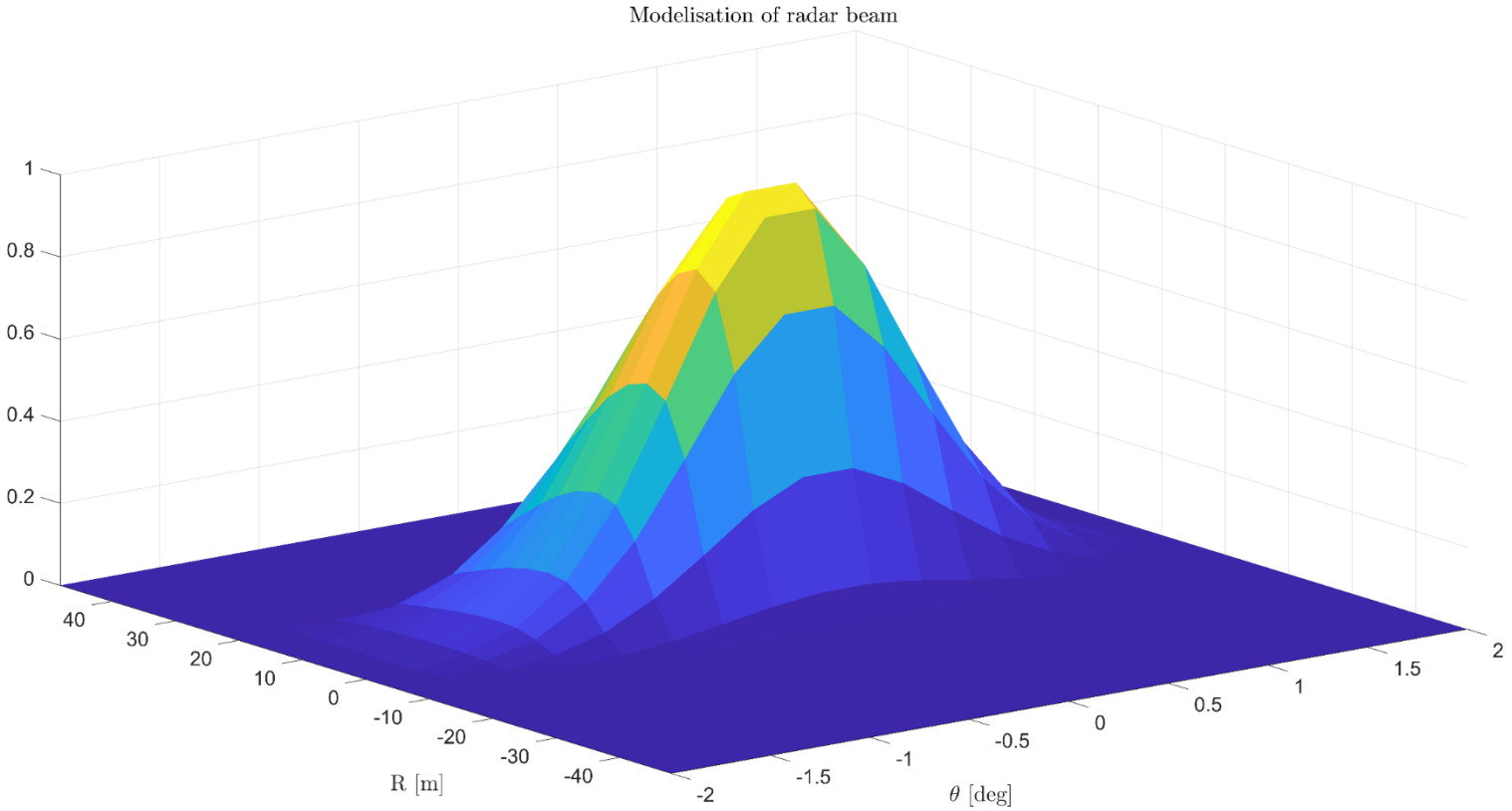




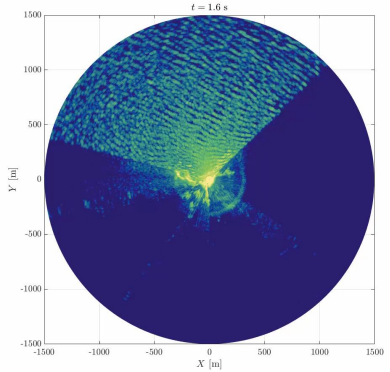


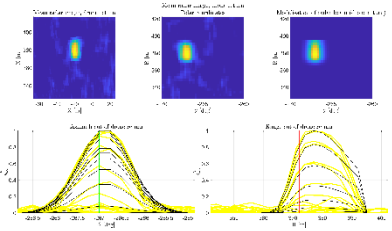
Furuno.com

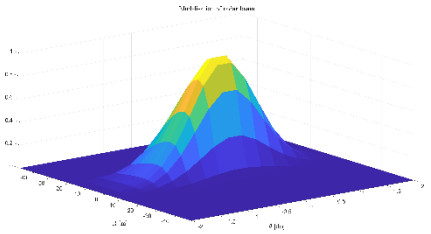


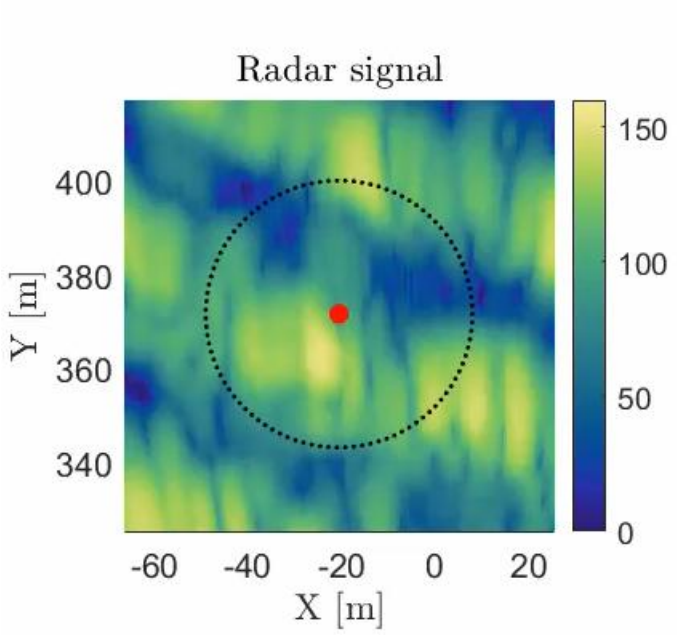


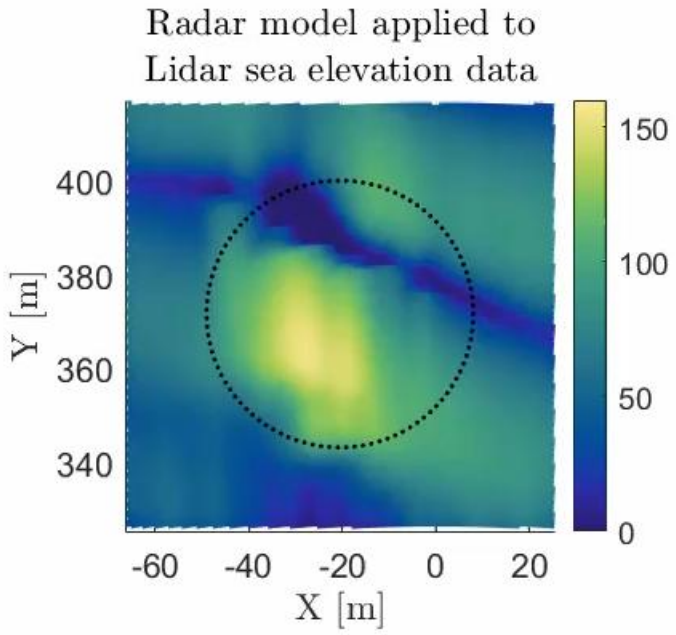
PATHWAY

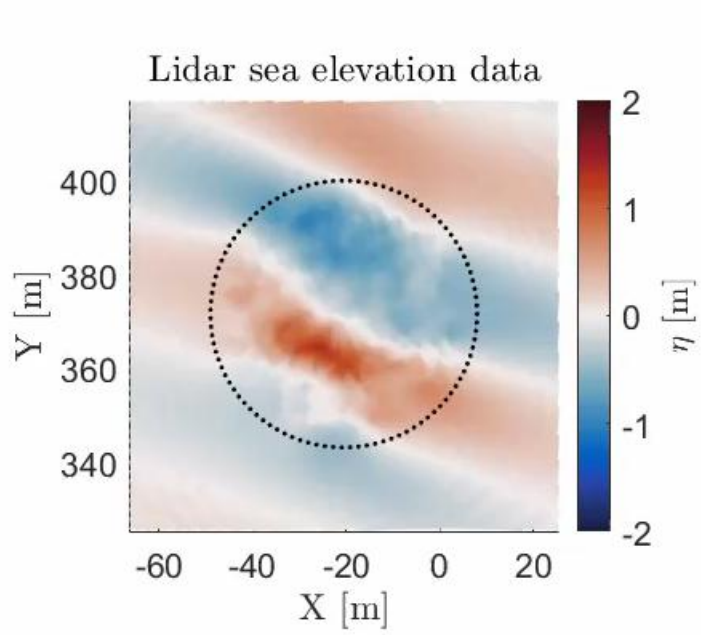








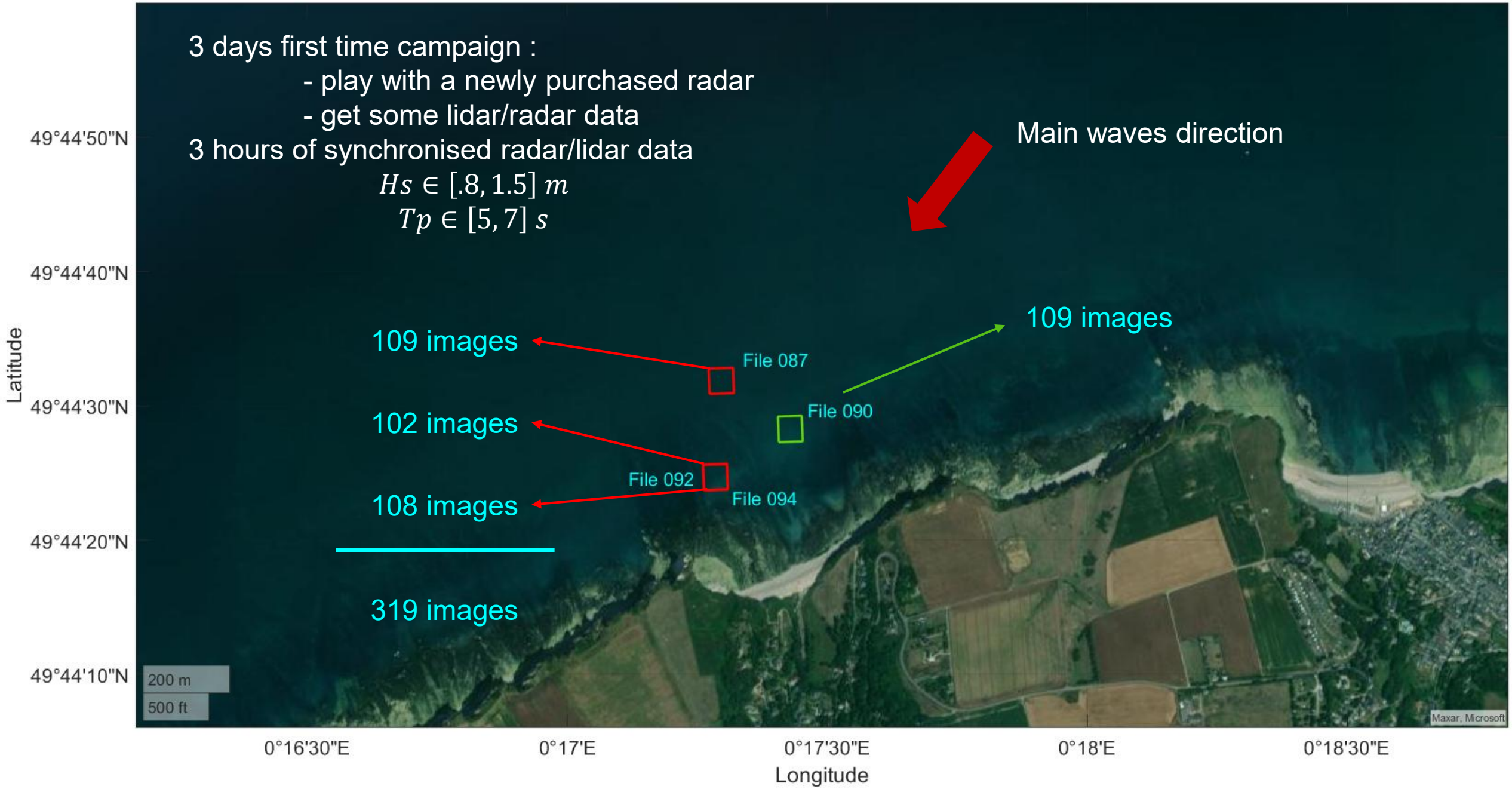




Sea elevation and radar signal synchronisation

AI INVERSION

Lidar measurement location

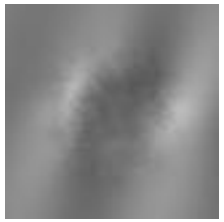


DEEP LEARNING

Sea elevation, Lidar data

- Training on 50 or 280 pairs of images randomly chosen from $319 - N + 1$ images
- Loss function : Structural SIMilarity (SSIM)

(Image quality assessment: from error visibility to structural similarity, Wang and al., 2004)

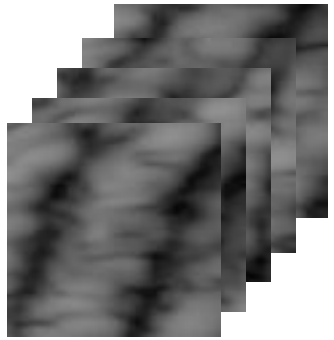


3 different acquisitions

$H_s \approx 1.5\ m$

$T_p \approx 6\ s$

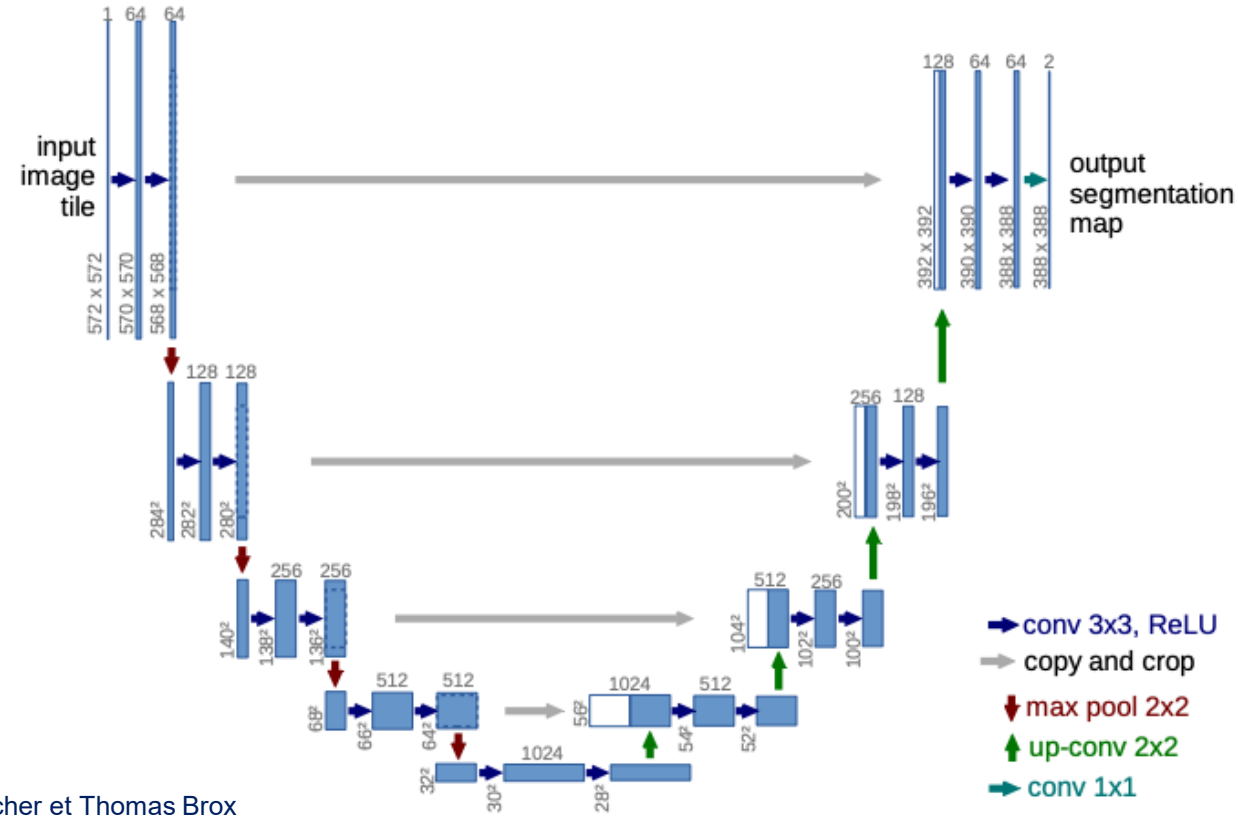
Sea clutter, radar data



N consecutive images

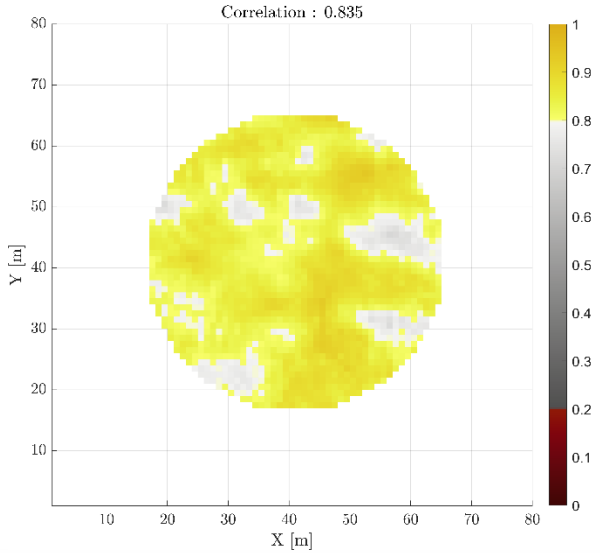
$(80\text{px} \times 80\text{px}) = 80m \times 80m$

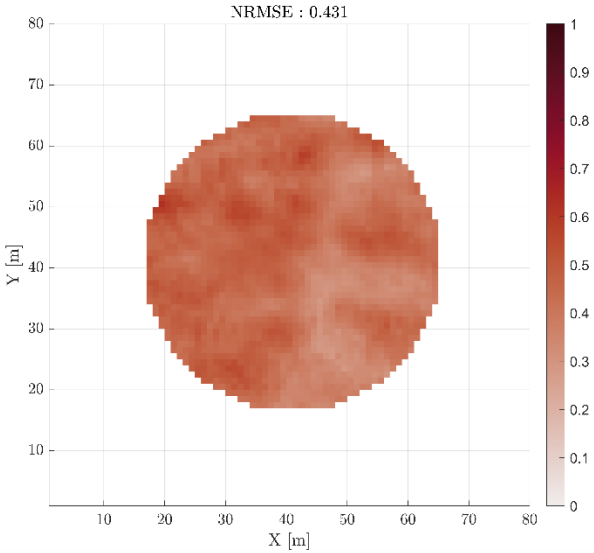
U-Net Convolutional Network

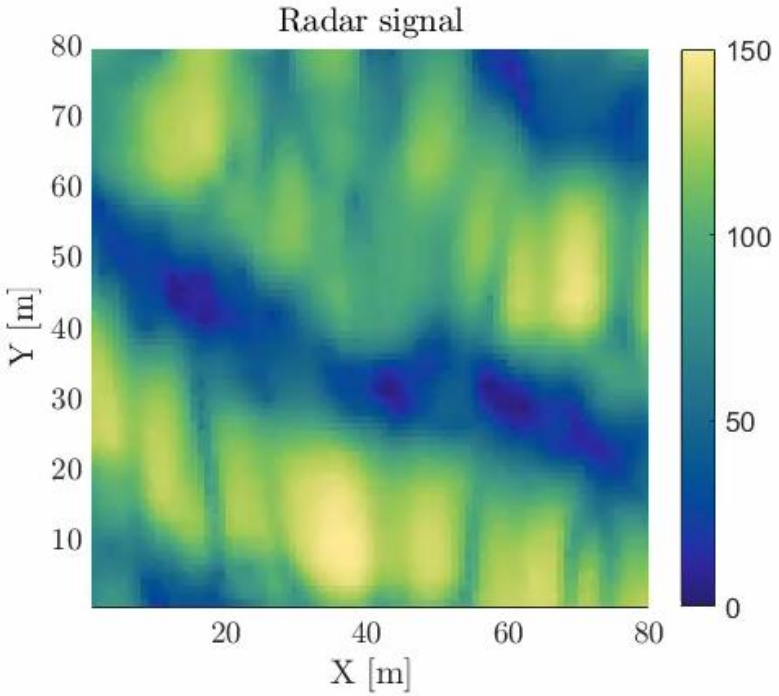


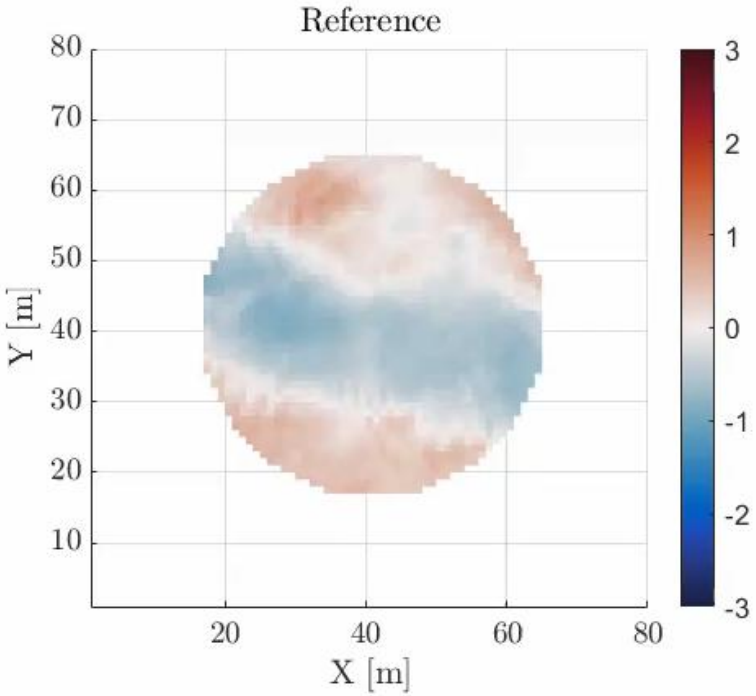
Olaf Ronneberger, Philipp Fischer et Thomas Brox
U-Net : Convolutional Networks for Biomedical Image Segmentation, 2015

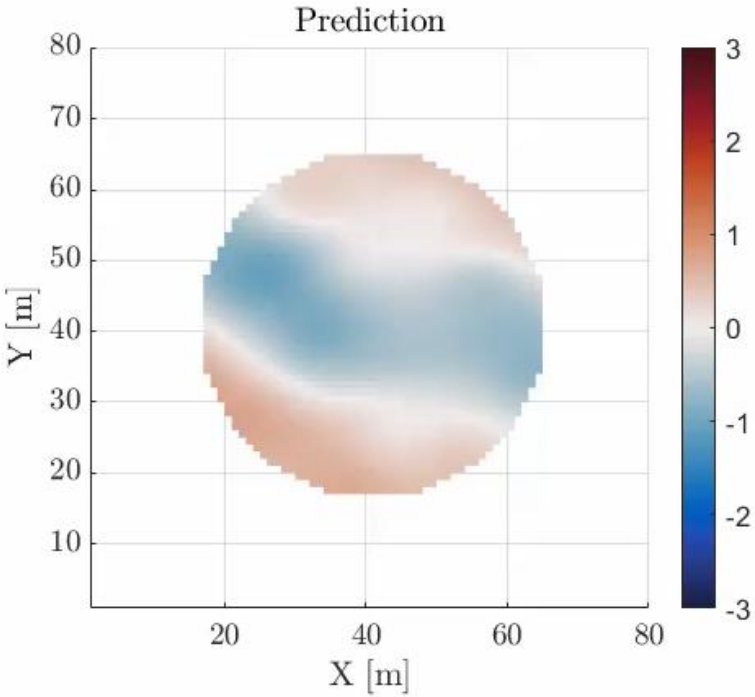
RESULTS



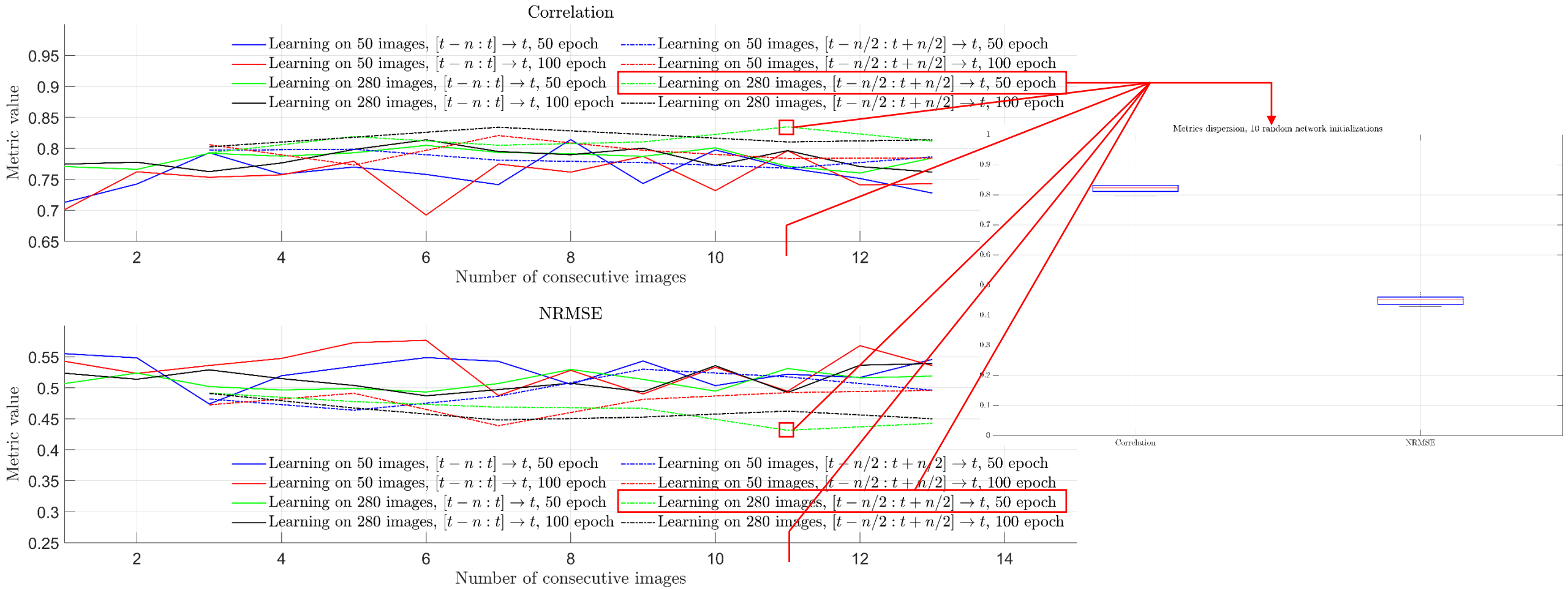








REPEATABILITY OF THE INVERSION



THANK YOU !!!