

Investigation of bathymetric artifacts in deep-sea AUV Ulyx

How overcoming lost attitude data in post-processing led
to a new analytical approach to sounding position
computation

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Ulyx^x in brief

Designed and built
in cooperation between
Ifremer and **Exail**

dimensions : 4.5 x 1.0 x 0.8 m

mass : 2.7 t

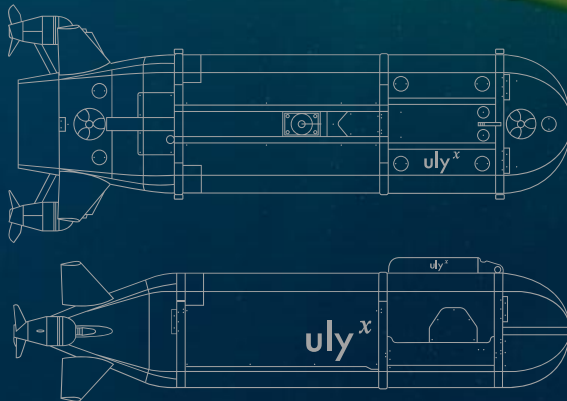
energy : 28 kWh (LI)

speed : 0 – 3 kts

autonomy : 24h / 80km

depth max : 6000m

operated since : 2020



Ulyx in brief

High speed, large coverage, surveying
Seabed tracking and following
High precision hovering

2 longitudinal
steerable
thrusters

2 vertical
thrusters

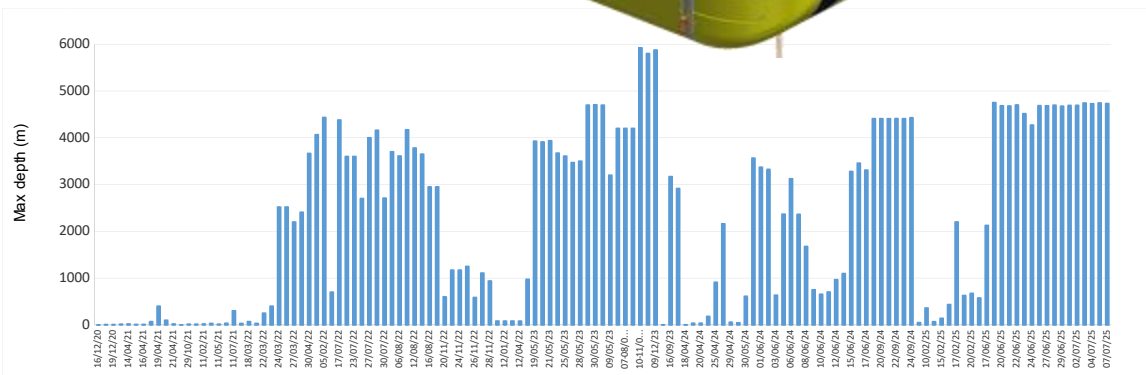
ROS-based controller

2 battery pods

reversible
water ballast

modular scientific sensor bay

4 rudders



138 dives (as of 07/2025)
61 dives > 3000 m
37 dives > 4000 m

Uly^x in brief

multi-scale + multi-sensor → permanent payloads

Physico chemical

CTD
pH
redox
O₂
turbidimeter
fluorimeter
magnetometer (x3)

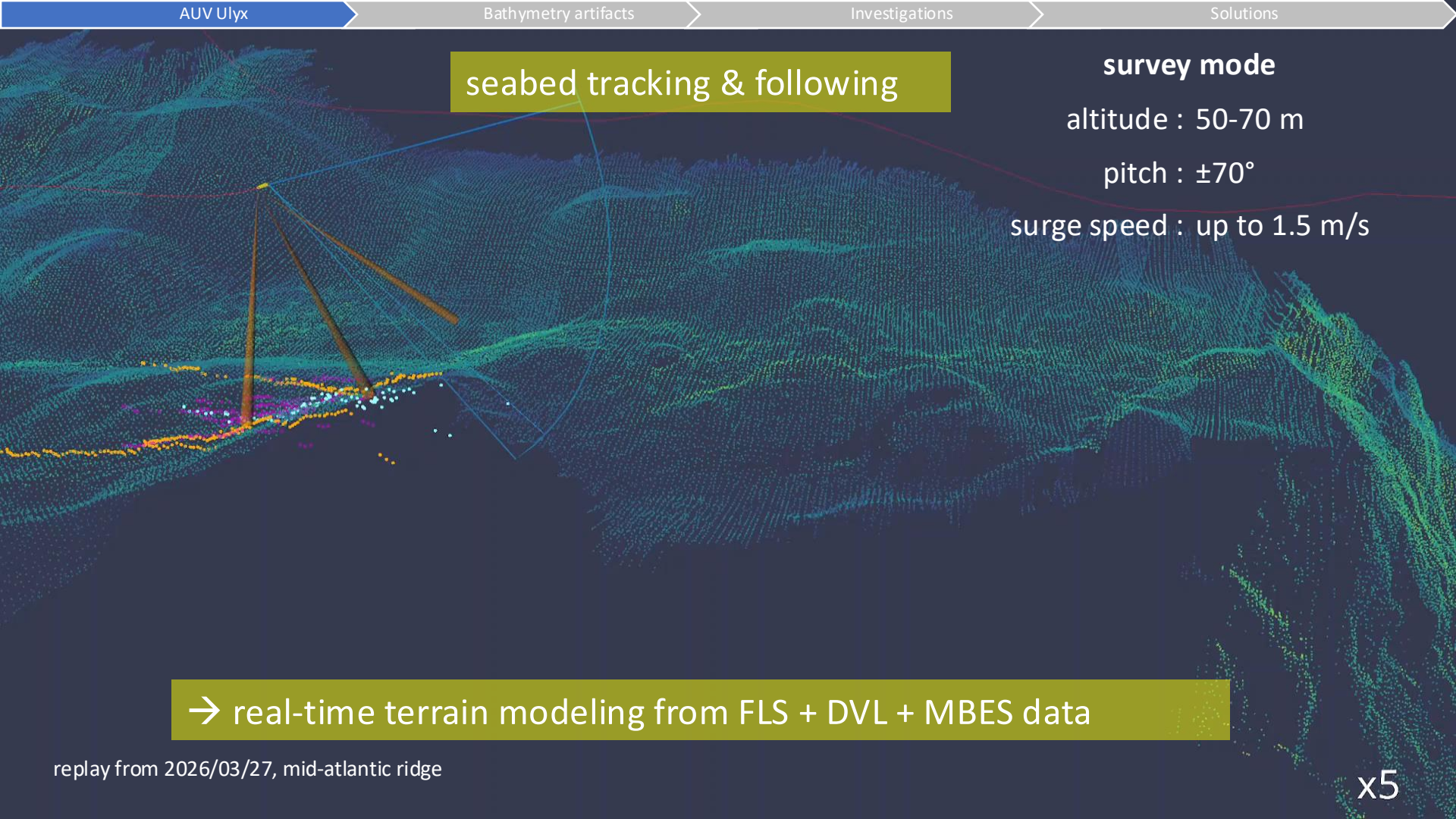
Optic

digital camera
strobe lightning

Acoustic

SAS : SAMS-150 Exail
MBES : EM2040 Kongsberg





seabed tracking & following

survey mode

altitude : 50-70 m

pitch : $\pm 70^\circ$

surge speed : up to 1.5 m/s

→ real-time terrain modeling from FLS + DVL + MBES data

replay from 2026/03/27, mid-atlantic ridge

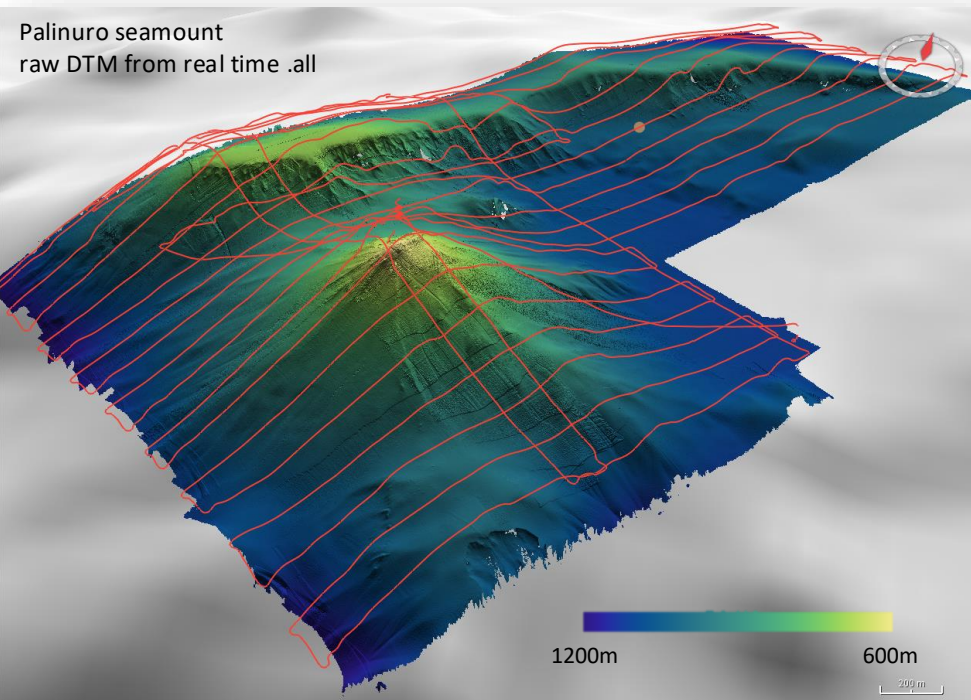
x5

Typical bathymetry survey

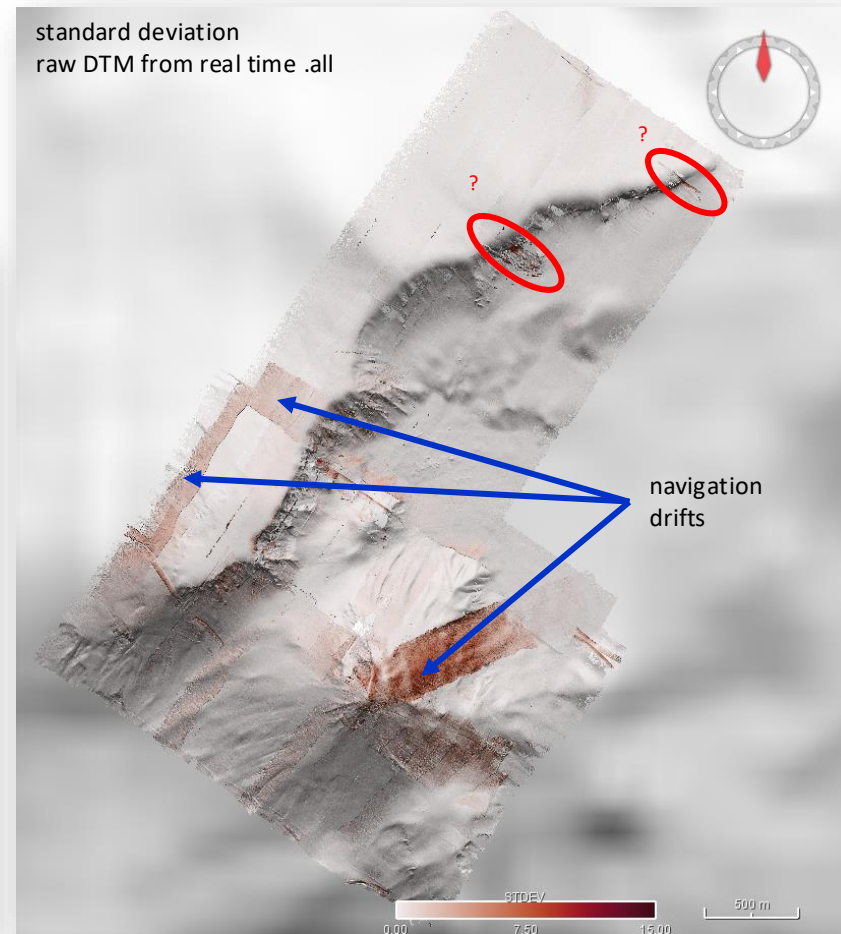
dive time: 17 h

dive track : 80 km

Palinuro seamount
raw DTM from real time .all

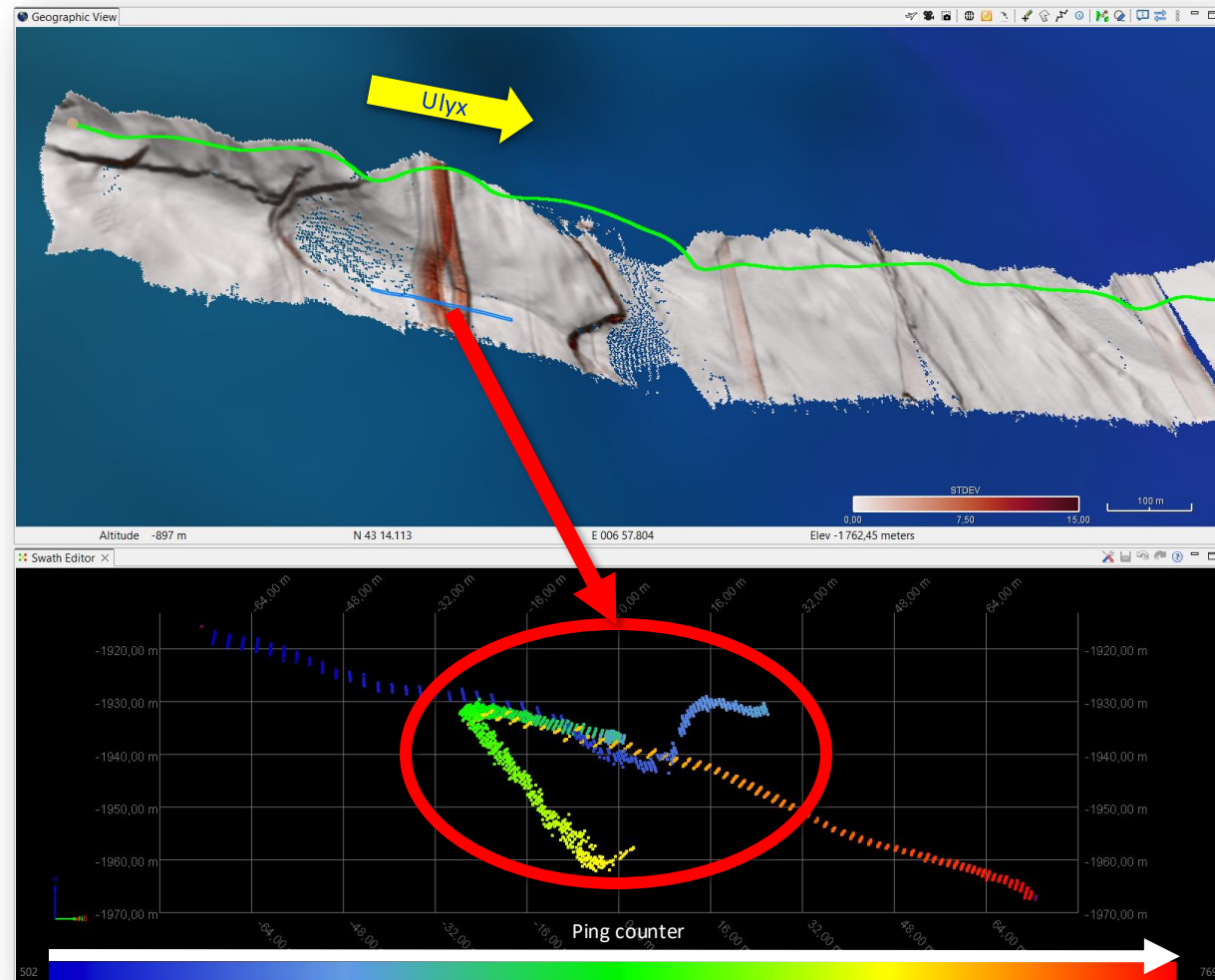


standard deviation
raw DTM from real time .all



Artifacts

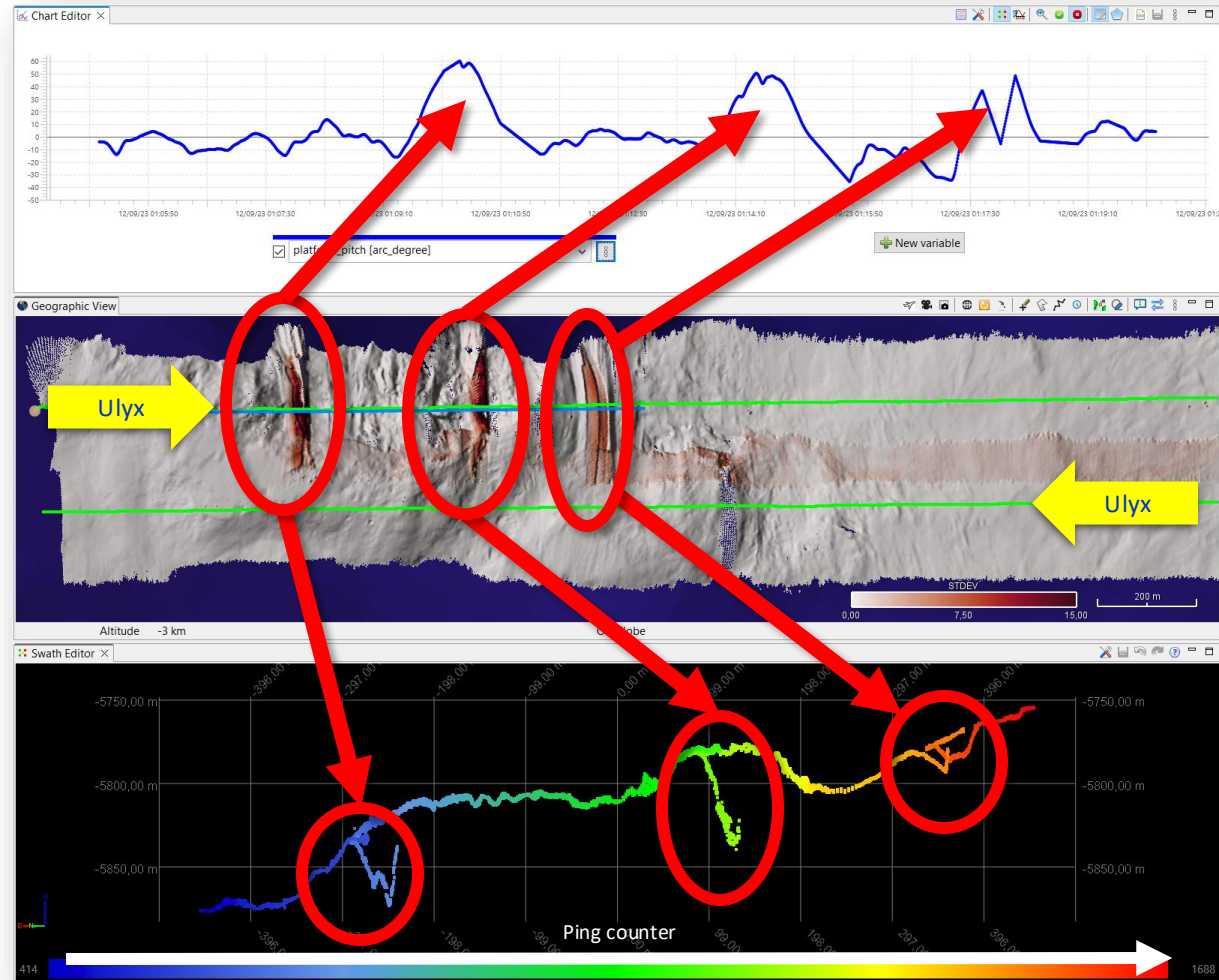
- **perpendicular** to AUV track
- soundings look like
« **folded** » backward
- seems **correlated to pitch**



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→ **mispositioned** soundings **alongtrack** in real time by PU



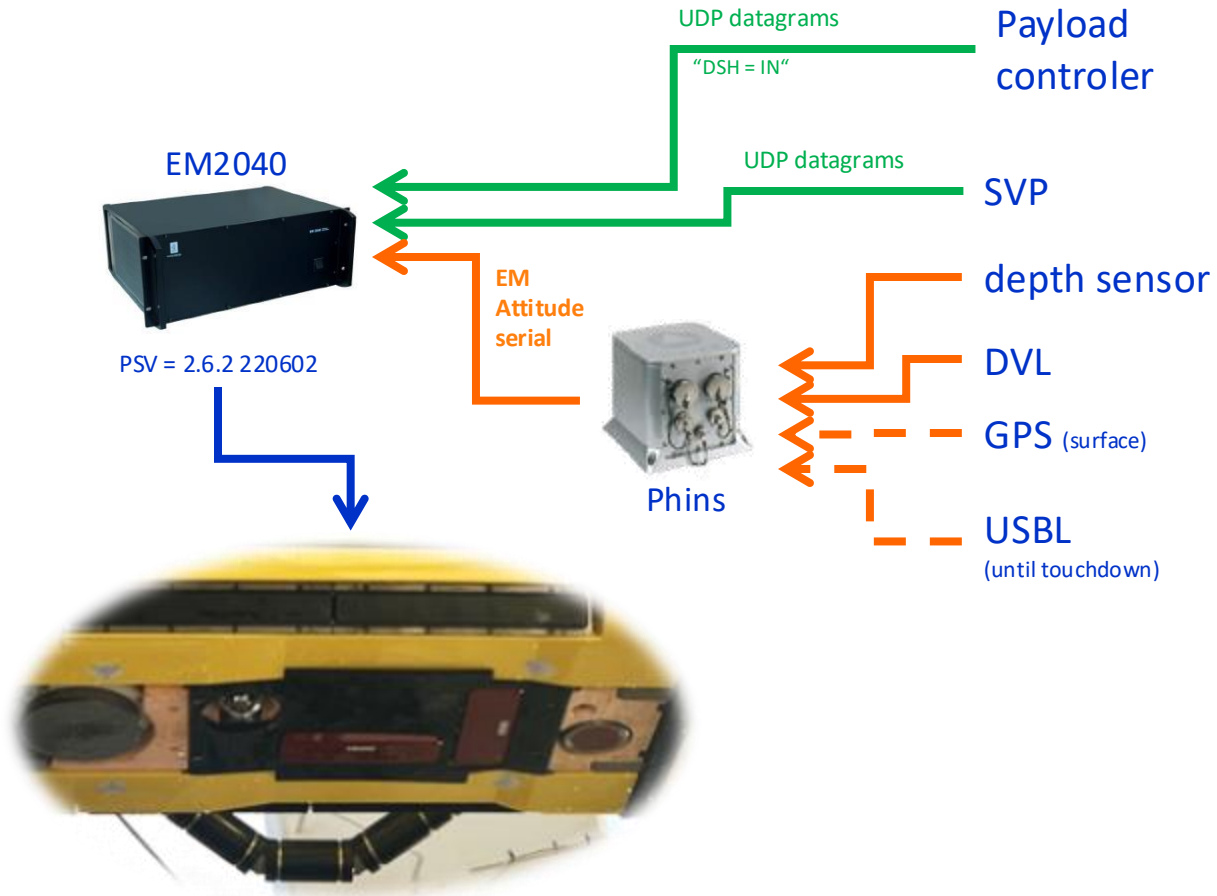
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EM2040 setup

- EM attitude input (100Hz)
- data (.all) logged on PU



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EM2040 setup

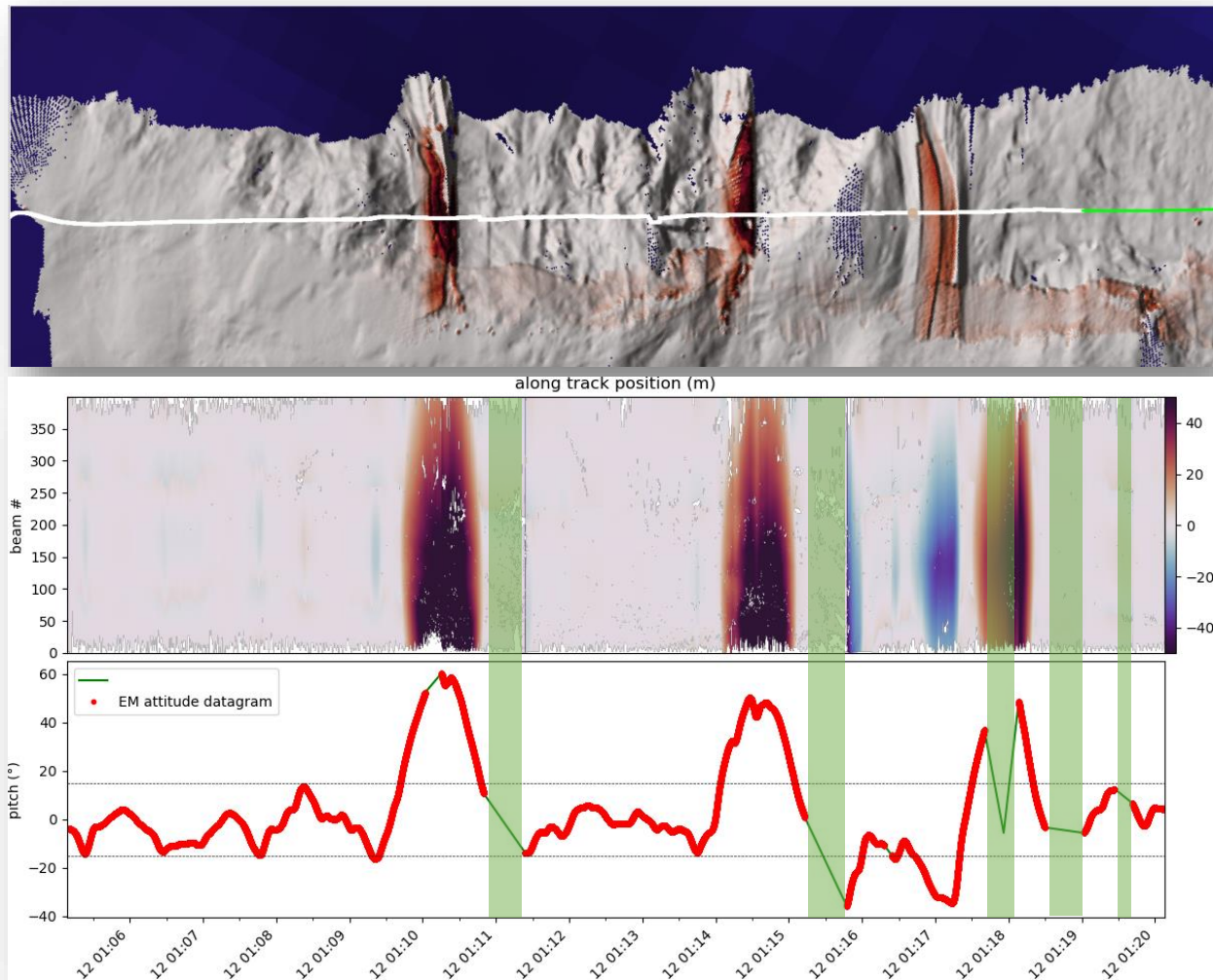
- EM attitude input (100Hz)
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Possible causes

- ~~pitch stabilization~~
- **missing attitude packets**

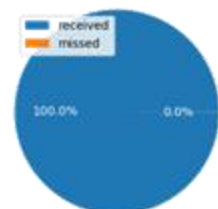
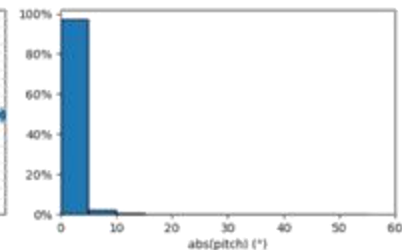
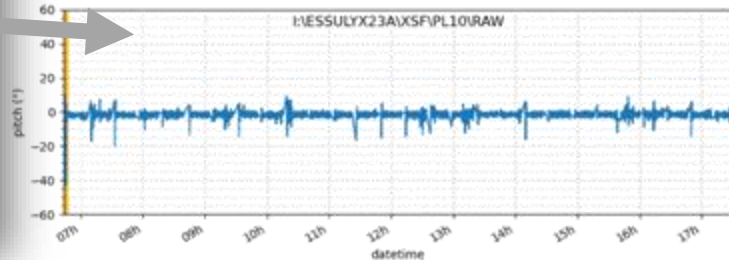
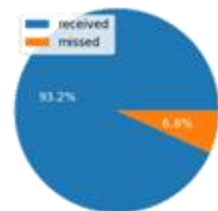
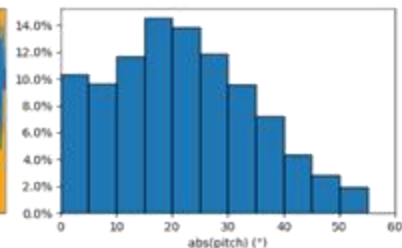
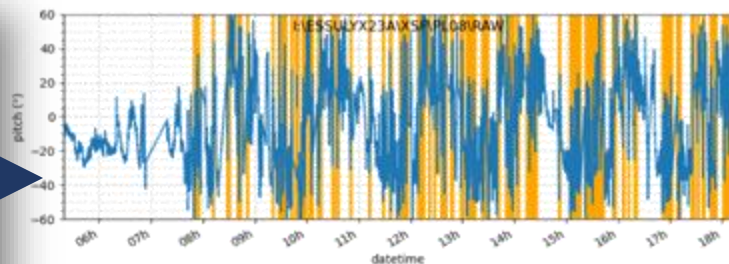
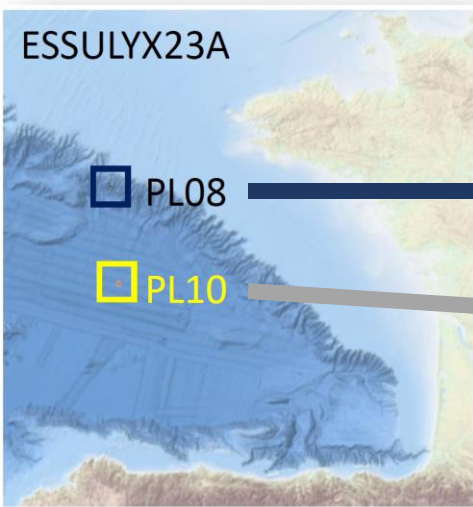
From KD support :

PU get stuck on the last attitude value
received → mispositioning



Cause identified :

missing EM attitude packets, seems to be correlated to attitude (pitch ?...)



Rough relief, high pitching → **missing attitude** packets (7%)

Flat areas, no pitch → **No missing attitude** packets

Cause identified : missing EM attitude packets

seems to be correlated to attitude (pitch ?...)



record EM attitude packets between Phins and PU
specifically designed dives to trigger artifact

EM2040



Phins



EM
Attitude
serial

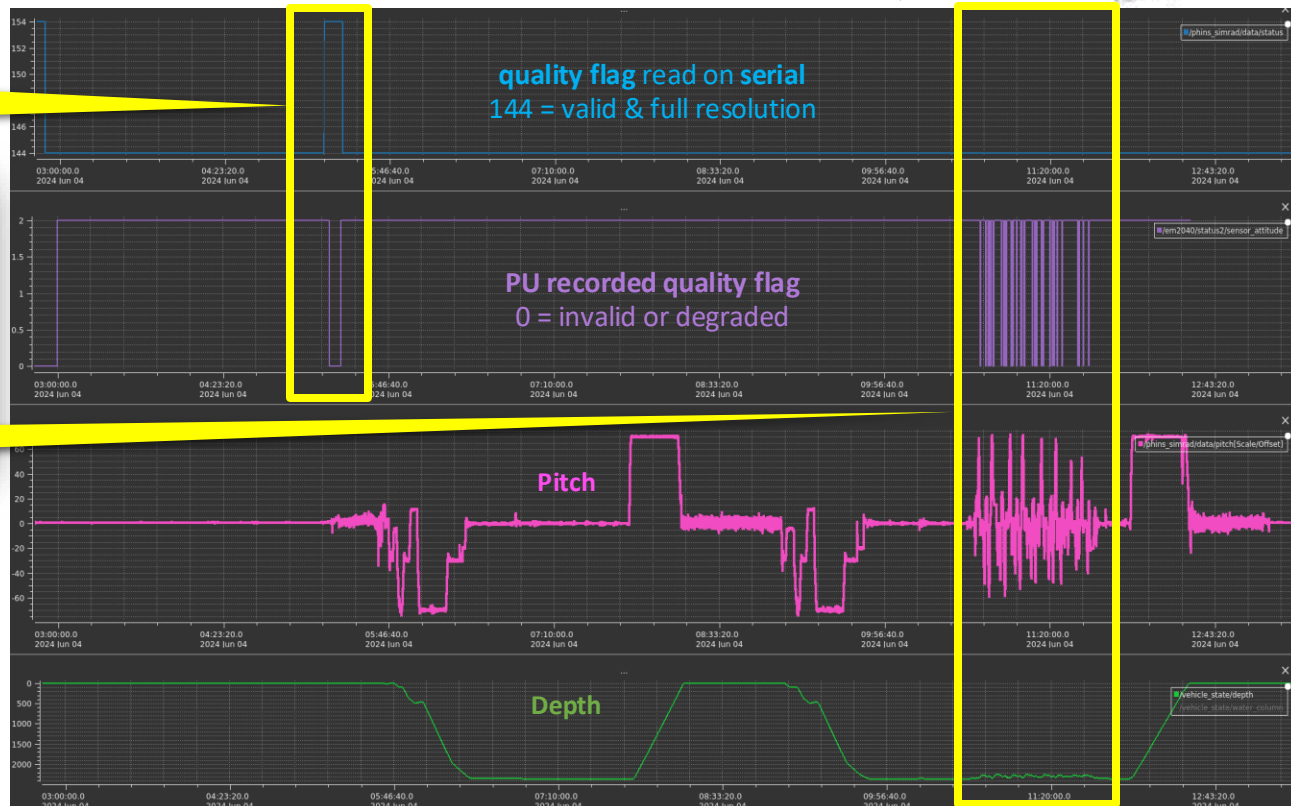
Phins calibration
(dive start)

quality flag read on serial
144 = valid & full resolution

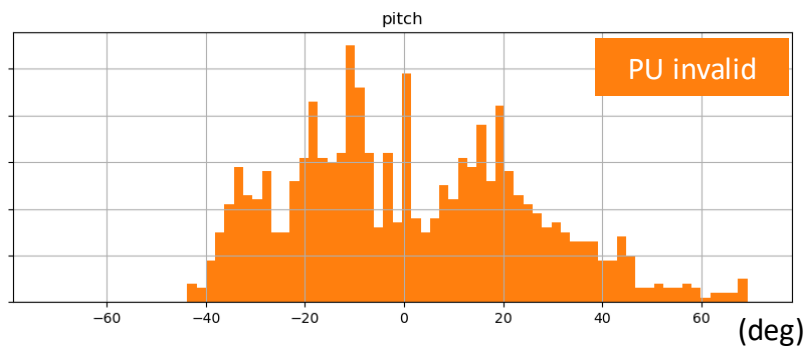
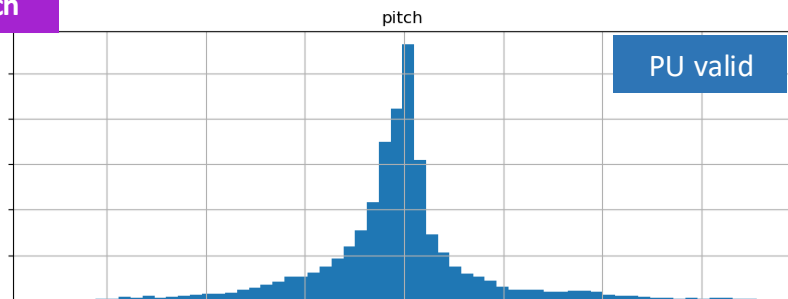
PU recorded quality flag
0 = invalid or degraded

AUV pitching
(stepped dive path)

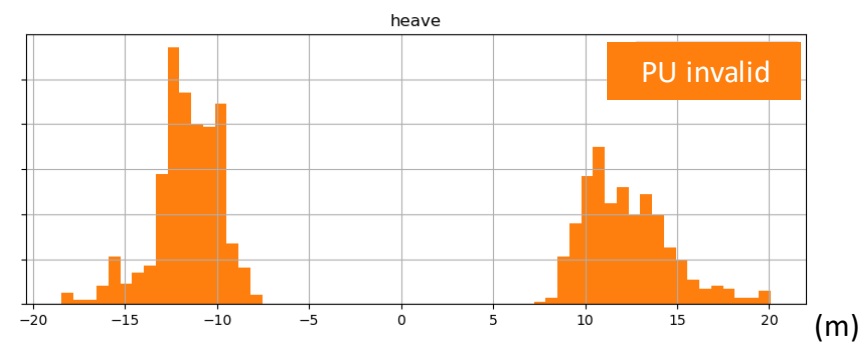
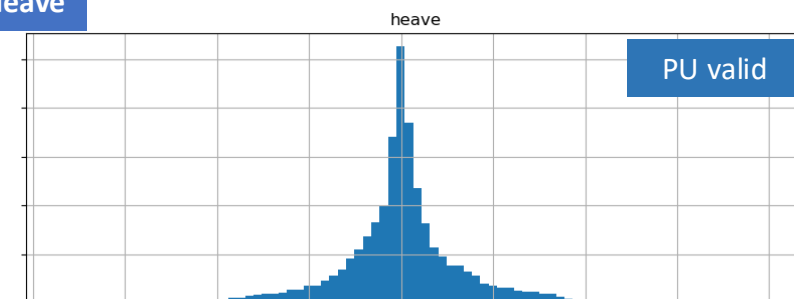
PU flags
valid attitude data
as invalid...



Pitch



Heave



Installation parameters **DSH = IN**

“the heave of an underwater vehicle is presumed to be measured by the vehicle’s depth sensor and the heave sensor input is not used by system”

but ...

Attitude data invalidated by PU corresponds to heave data falling outside the validity ranges: ± 9.99 m (cf. KD doc)

Root cause clearly identified :

attitude data invalidated by PU due to heave data falling outside the validity ranges (± 9.99 m) ... although “DSH=IN”

Input datagrams

EM Attitude input format

The EM attitude format is a 10-byte

- Byte 1: Sync byte 1 = 00h, or
- Byte 2: Sync byte 2 = 90h
- Byte 3: Roll LSB
- Byte 4: Roll MSB
- Byte 5: Pitch LSB
- Byte 6: Pitch MSB
- Byte 7: Heave LSB
- Byte 8: Heave MSB
- Byte 9: Heading LSB
- Byte 10: Heading MSB

where LSB = least significant byte

All data are in 2's complement binary and 1 cm resolution for heave.

- Roll is positive with port side up with $\pm 179.99^\circ$ valid range
- Pitch is positive with bow up with $\pm 179.99^\circ$ valid range
- Heave is positive up with ± 9.99 m valid range
- Heading is positive clockwise with 0 to 359.99° valid range.

Non-valid data are assumed when a value is outside the valid range.



Still valid attitude data

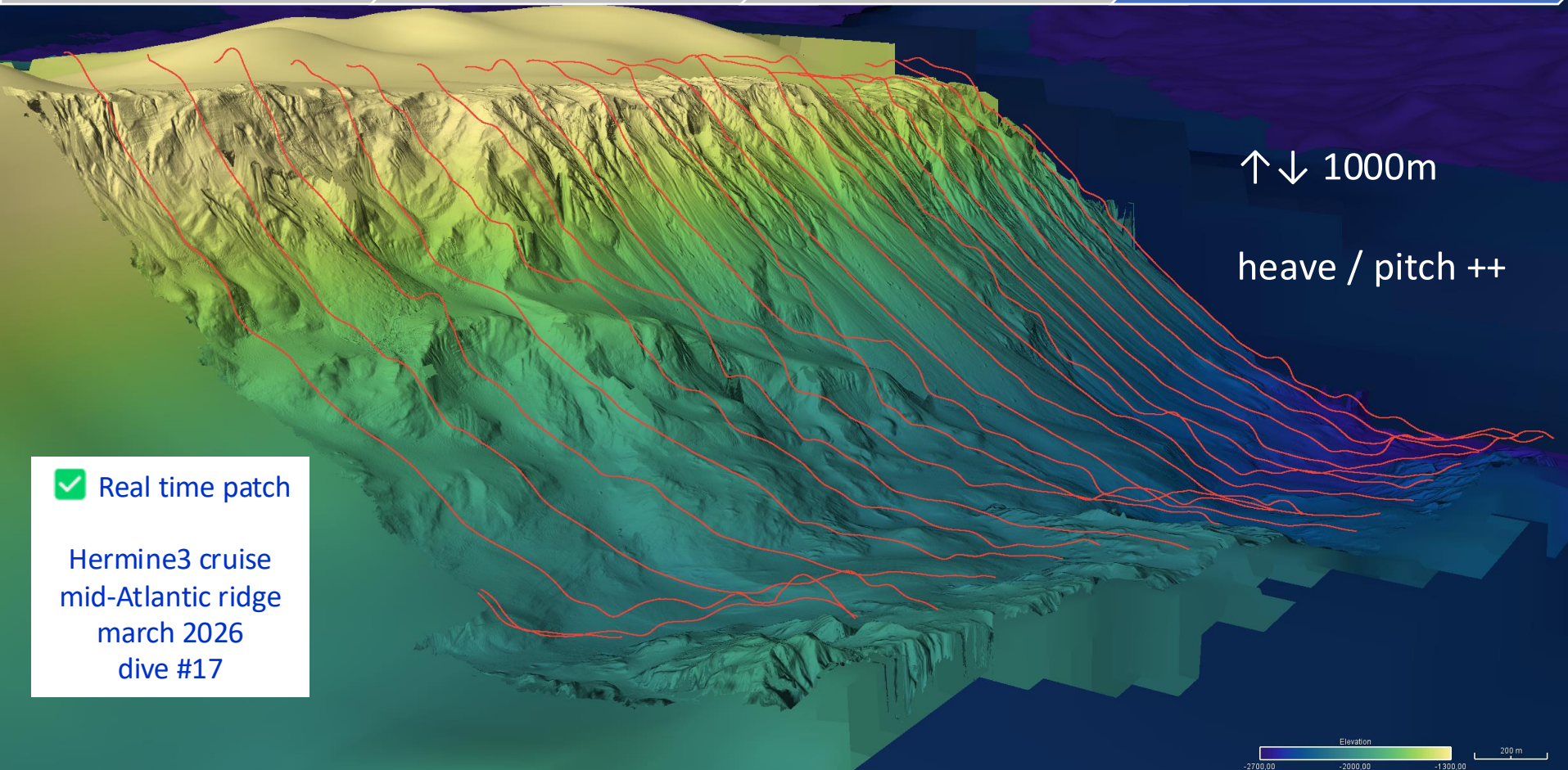
Possible solutions in real time :

- Kongsberg PU patch
- PU update (K-controller)
- Tweak EM attitude input

→ Phins EM datagram format modified to constantly stream 0m heave

✓ Real time patch

src : EM Series Multibeam echo sounders, Datagram formats, rev. W



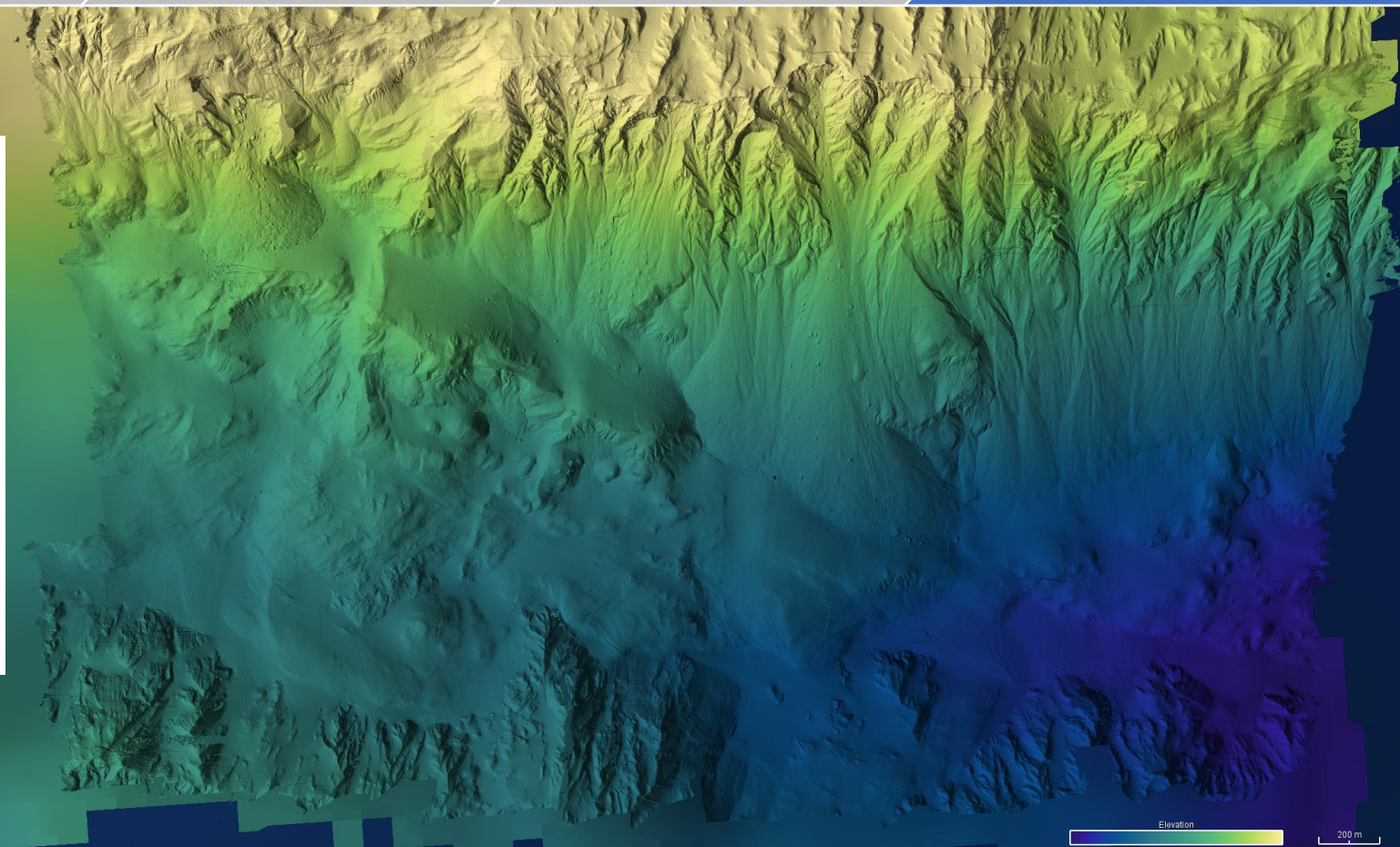
Heave / pitch ++

✓ Real time patch

No more artifacts

Hermine3 cruise
mid-Atlantic ridge
march 2026
dive #17

Top view

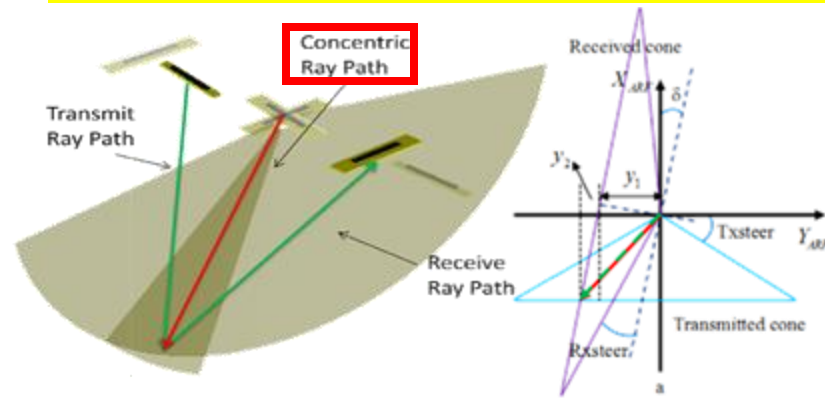


What about legacy data ?...

- ➔ attitude integration from **Phins records**
- ➔ **beam launch vector** computation + raytracing

Virtual Concentric Cone Algorithm (VCCA)

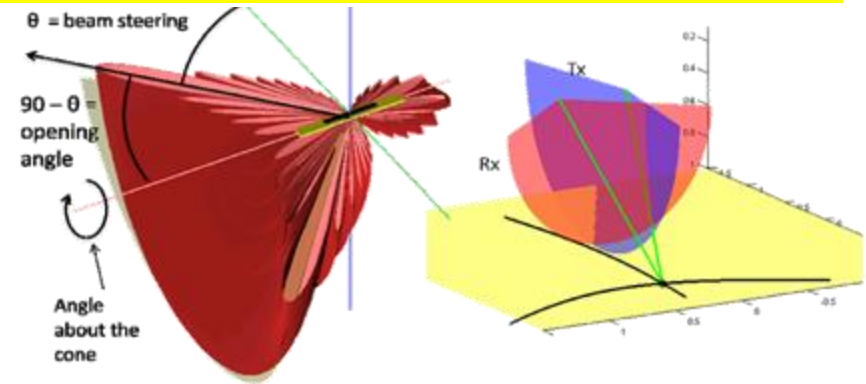
(Beaudoin et al. 2004)



- ✓ **Fast** : geometrically simple, no loop
- ✗ **localization error** : concentric approximation

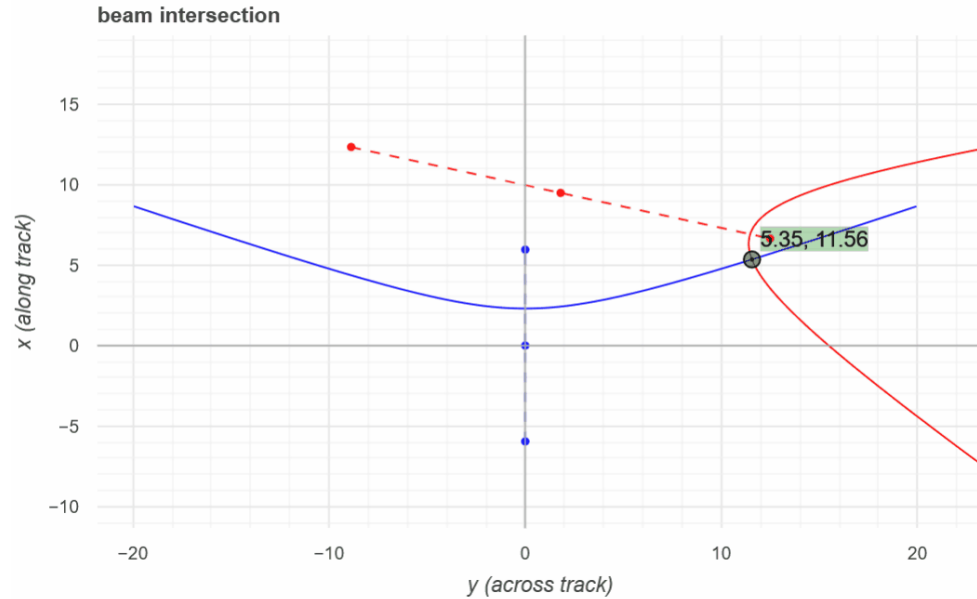
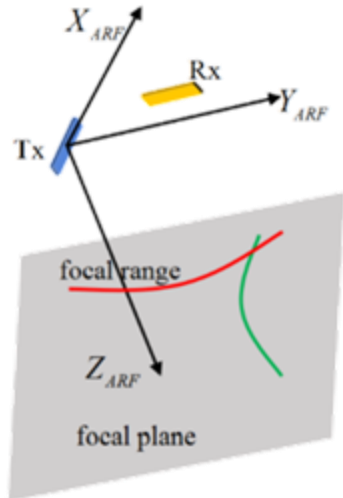
Non Concentric Cone Algorithm (NCCA)

(Hamilton et al. 2014)



- ✓ **Geometrically optimal** :
Accounts for Tx/Rx separation (static and dynamic) + sectors
- ✗ **Slow** :
while loop per detection (3 to 5 iterations)
Hyperbola intersection (iterative Newton optimization method)

NCCA improved : analytical hyperbola intersection algorithm

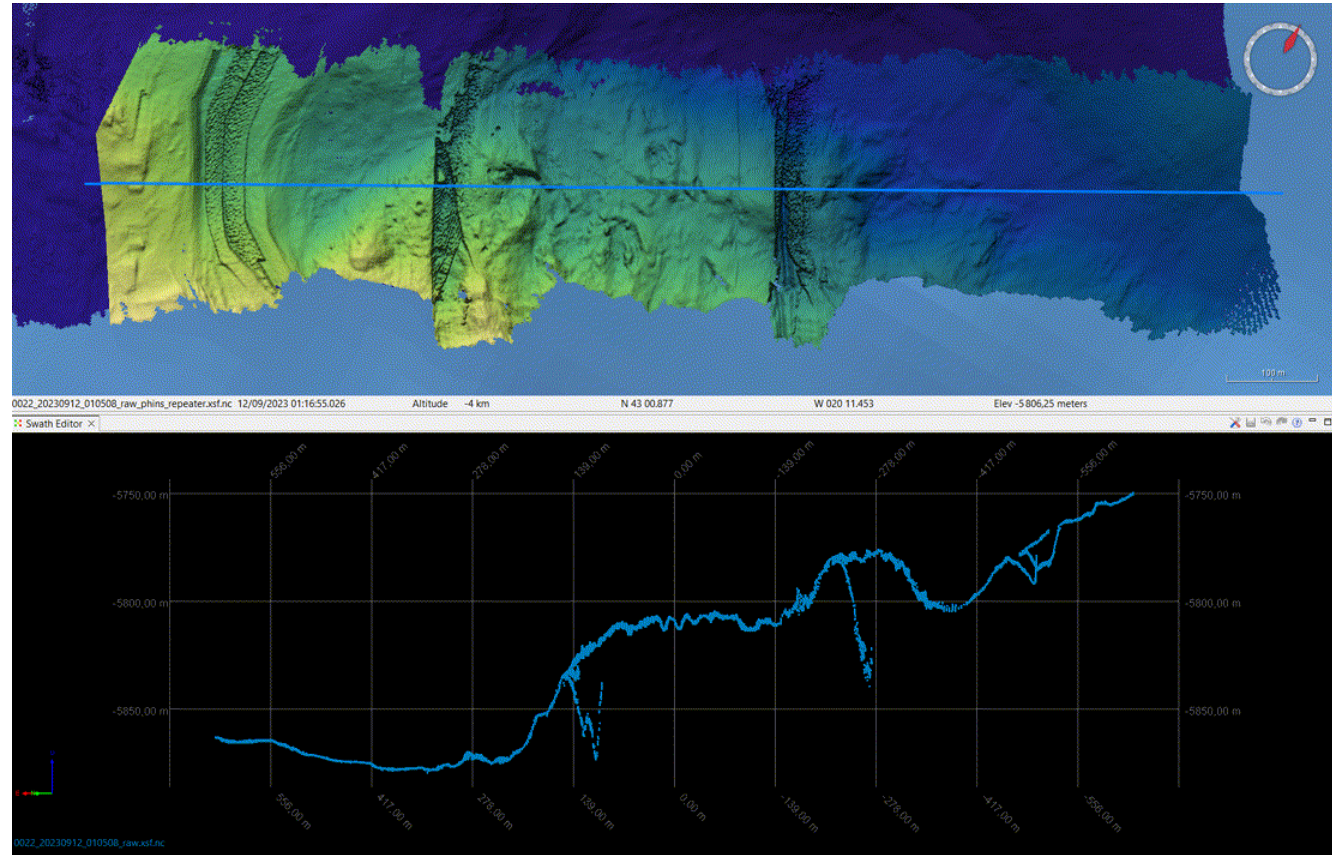


- ✓ **Faster** : no iteration, 6x Newton optimization method, constant time
- ✓ **Optimal** : zero residual errors, no false solution

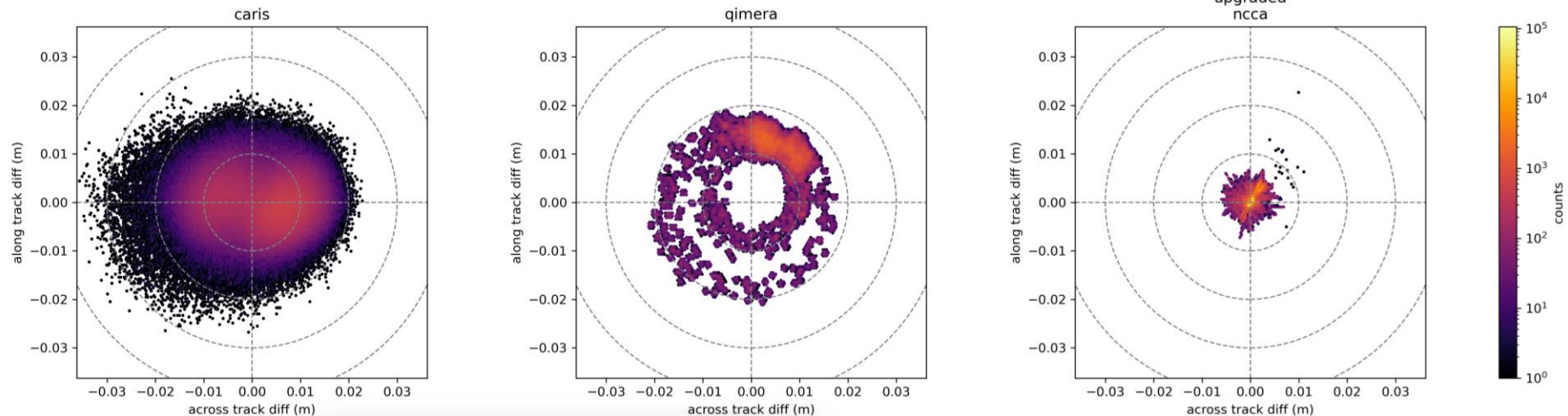
✓ reprocessed
legacy datasets

algorithm validation?

⇒ intercomparaison
to
post processing
industry standards
with
Kongsberg as
“ground truth”



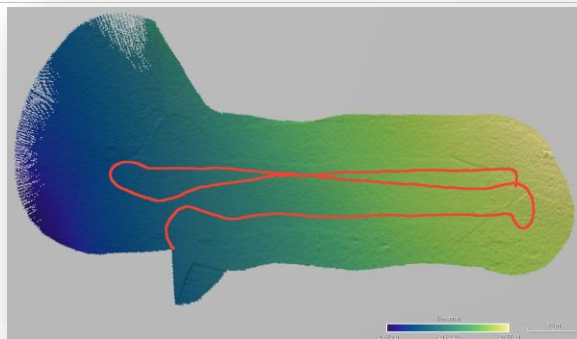
Sounding position dispersion relative to Kongsberg real-time data reprocessed with same SVP, attitude, navigation, as in RT



Flat seafloor

depth : 2100 m

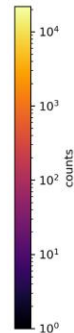
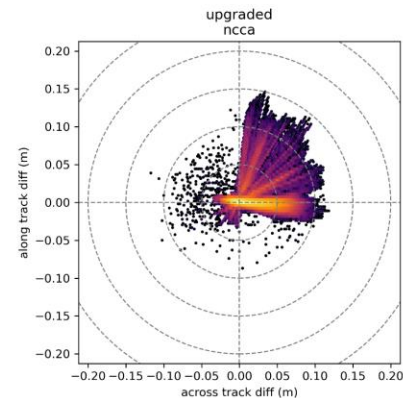
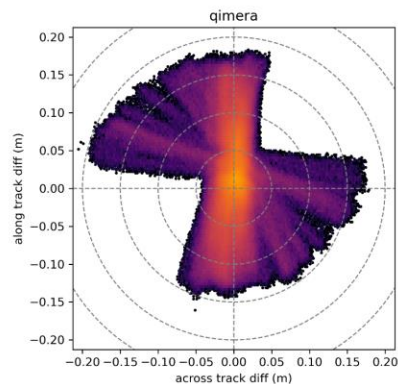
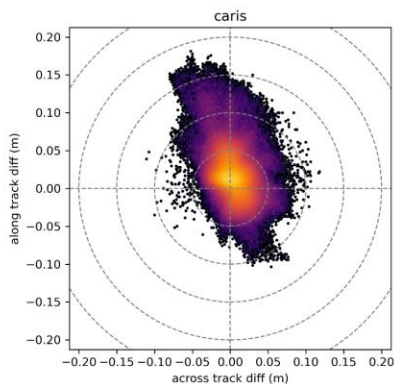
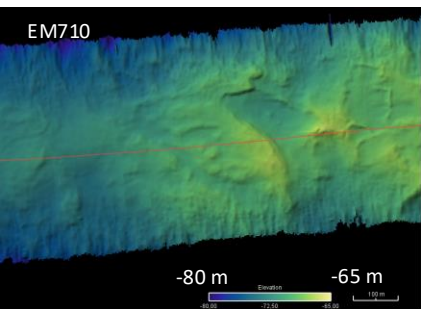
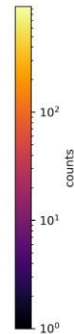
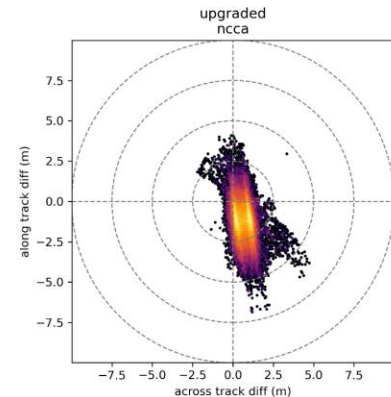
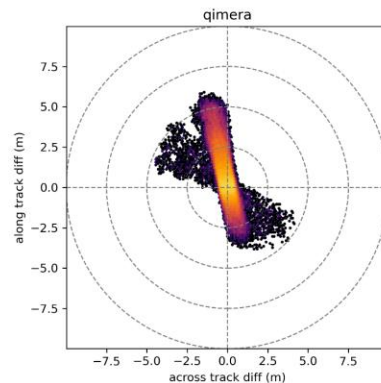
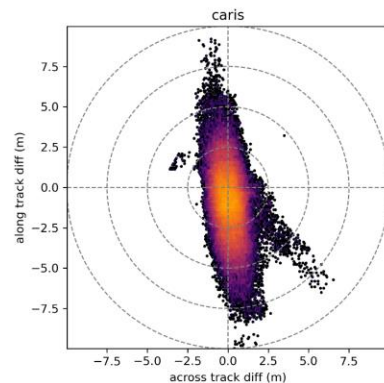
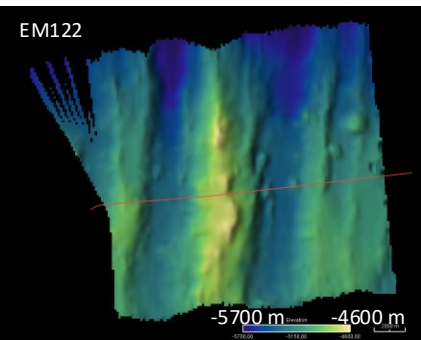
altitude : 6 m



- ✓ positions consistent with KD real time spreading (< 3 cm for all)
- ✓ ours slightly closer to KD real time

Sounding position dispersion relative to Kongsberg real-time data

reprocessed with same SVP, attitude, navigation, as in RT



Conclusion

Core issue identified: PU hard-coded logic causes a **complete attitude data rejection** whenever **heave thresholds are exceeded**, although PU is manually set to ignore heave (DSH=IN)

Workaround solution: **Reconfigured the Phins INS** to output a **static 0m heave** value, successfully bypassing the PU's automated rejection filter

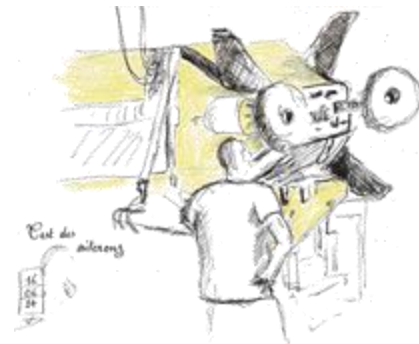
Legacy data recovery: Developed a **new efficient beam launch vector computation** algorithm, matching both PU & hydrographic software sounding accuracy

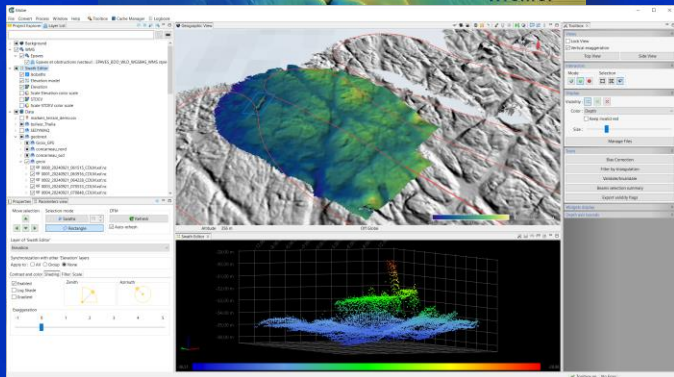
Takeaway: Subsea vehicle integration requires **absolute decoupling of vertical motion sensors in PU**

Perspectives

Core issue: update to K-Controller + KM Binary attitude datagram

Beam launch vector algorithm: paper in preparation + Globe integration





Thanks to

- Marc Roche
- Koen Degrendele
- Olivier Duval



for providing reference data
processed with Qimera, Beamworx and Caris

Thank you for your attention

Data processed with Globe

<https://www.seanoe.org/data/00592/70460/>

globe-assistance@ifremer.fr



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