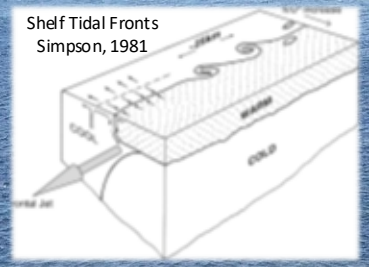
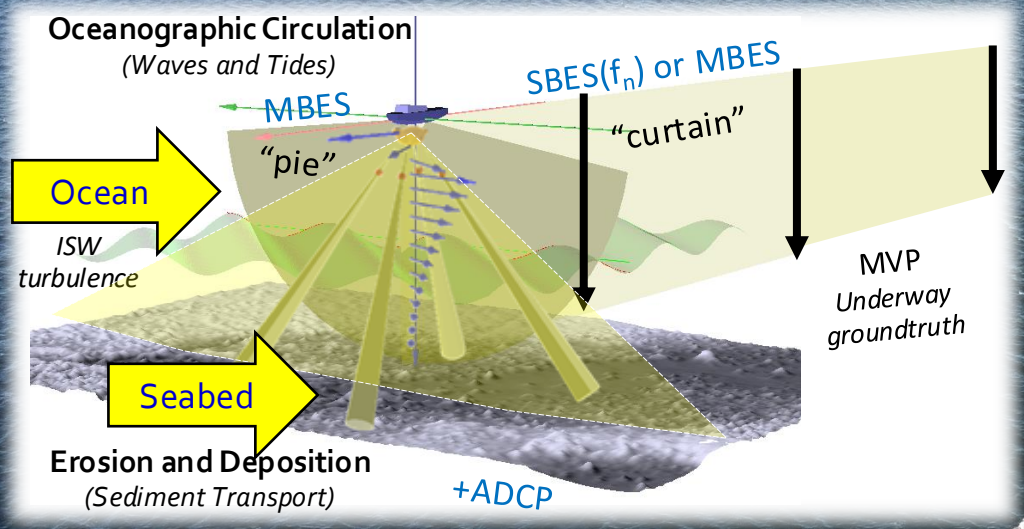
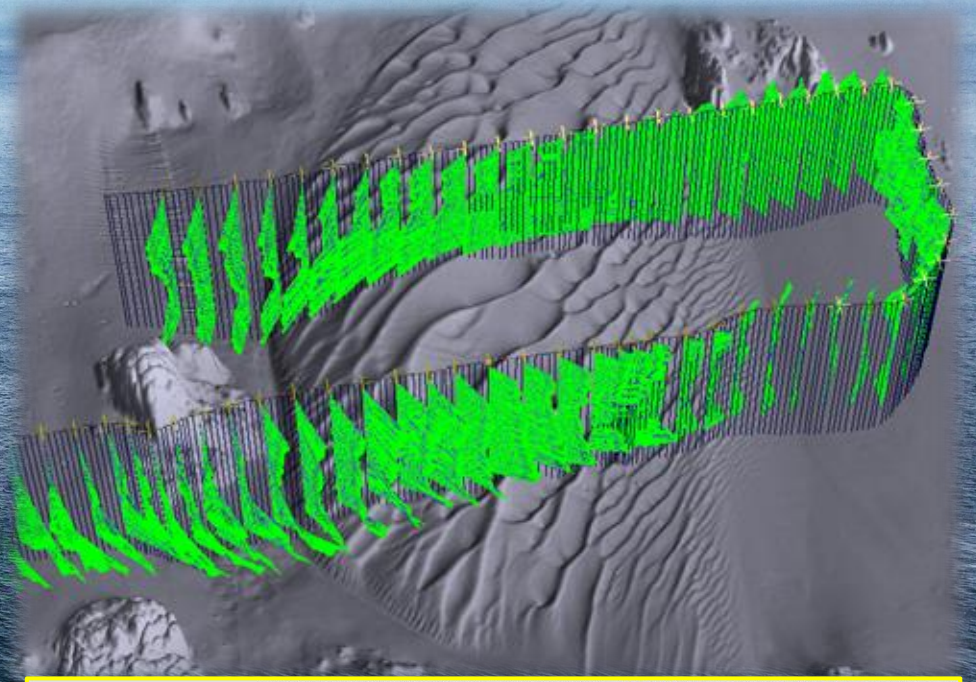
Resolving Tidally-Driven Seabed Sediment Transport: Simultaneous Operation of Multiple Acoustic Sensors

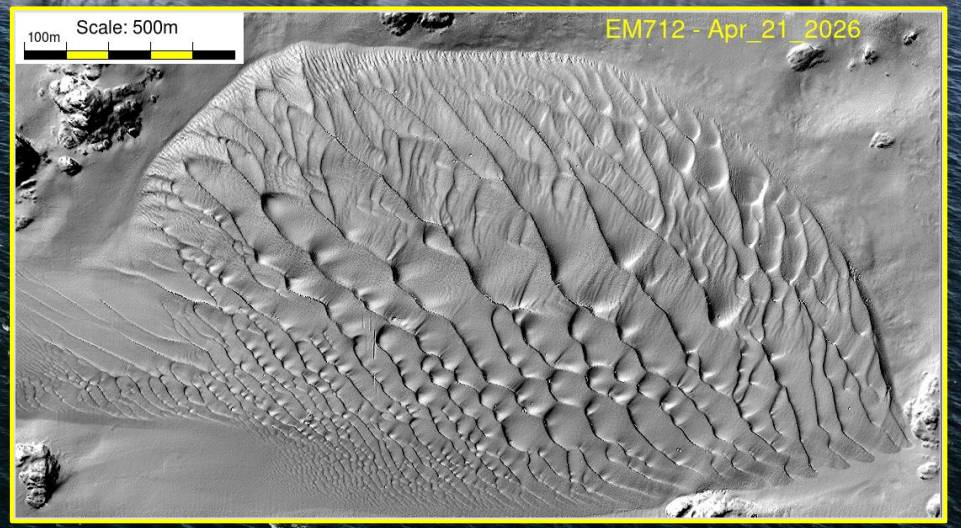




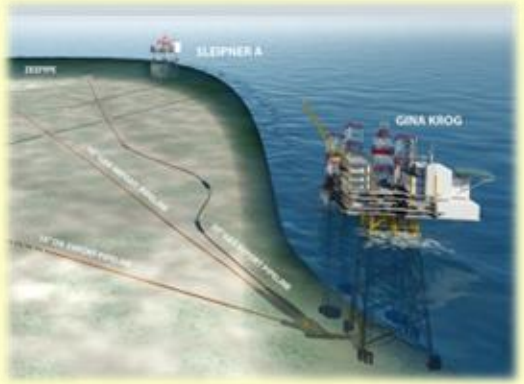
John E. Hughes Clarke
CCOM/UNH

Tor Inge Lønmo
Kongsberg





Infrastructure Hazards due to Erosion and Deposition in Shallow (Storm &) Tidally-Driven Seas.

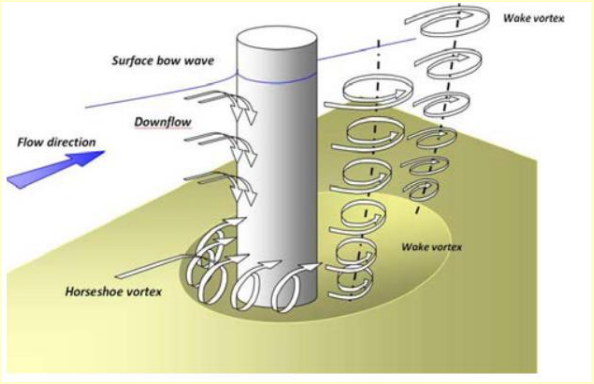












Optimal Configuration of 4 new NOAA National Science Platforms



Class-A
NOAA, 73m



Class-B
NOAA,~70m

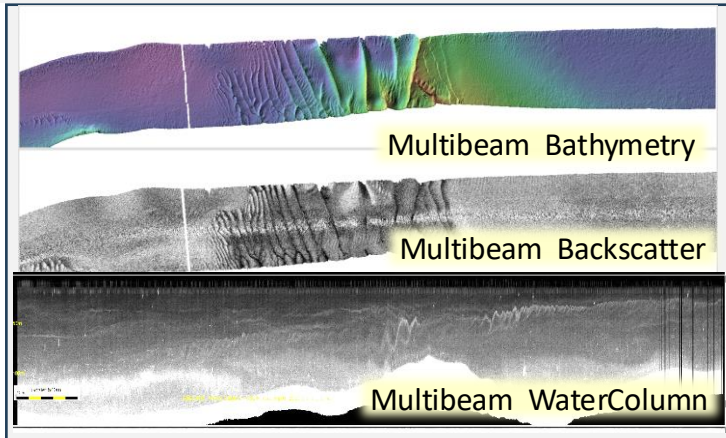
	Class-A	Class-B
MBES	• **EM124** *(1°x2°)* - 11-13 kHz • **EM712** *(0.5°x 1°)* - 40-100 kHz • **EM2040** *(0.5°x 1°)* - 200-400 kHz	• **EM304** *(0.5°x1°)* - 20-34 kHz • **EM2040** *(0.5°x 1°)* - 200-400 kHz
EKs	• **EK80** x 6 + **ME70** 18 38,70,120,200,333 kHz	• **EK80** x 6 18,38,70,120,200,333 kHz
SBP	• **SBP29** 6°x6° ~ 2-9 kHz	• **SBP29** 6°x6° ~ 2-9 kHz
ADCP	**ADCP x4** 38,75,150,300 kHz	**ADCP x4** 38,75,150,300 kHz

Multi-Mission Objectives

K-Sync (V2)

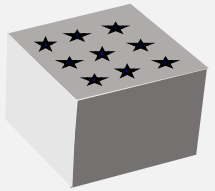


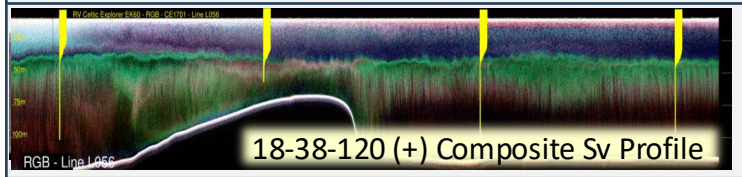
Instrument-Specific Mission Priorities:



Multibeam:

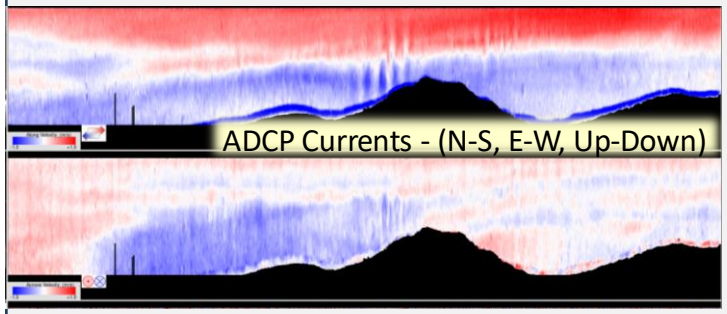
1. "100%" Bathymetry - meeting *Sounding Density Requirements* (3x3)
2. No Bathymetric Mistracking
3. Interference-Free Backscatter
4. Overprint-Free Water Column imaging





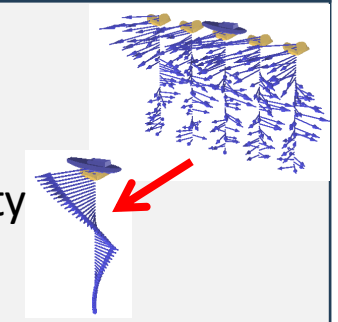
Fisheries Sonars:

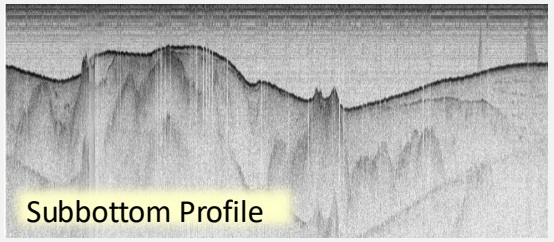
1. Overprint-Free Water Column Imaging
2. Bias-free TS and Sv estimates



ADCP:

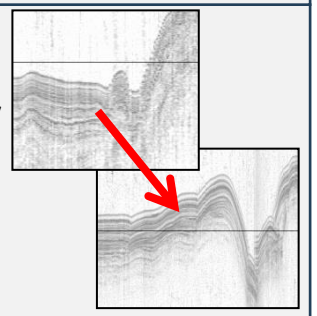
1. Interference free velocity bins
2. Sufficient Along-track ping density to allow Ensemble Averaging



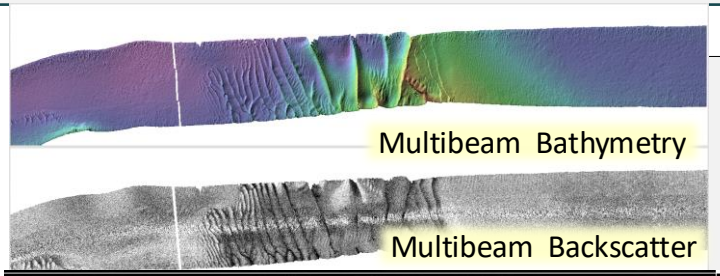


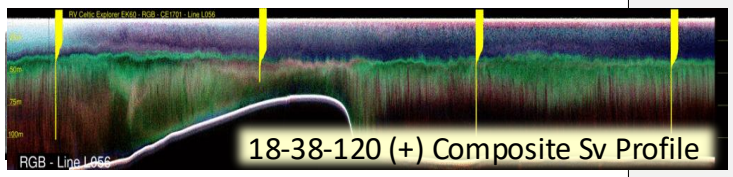
Subbottom:

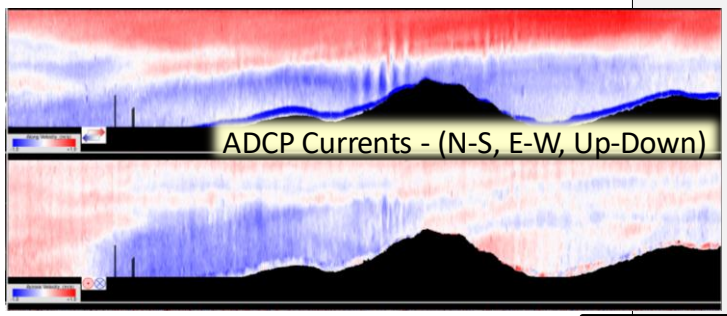
1. Sufficient along-track ping density (stacking to improve SNR)
2. SL to provide Sufficient SNR (without impacting other sonars)

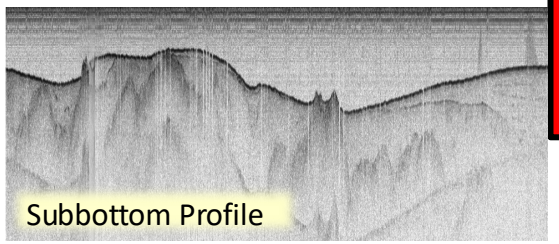


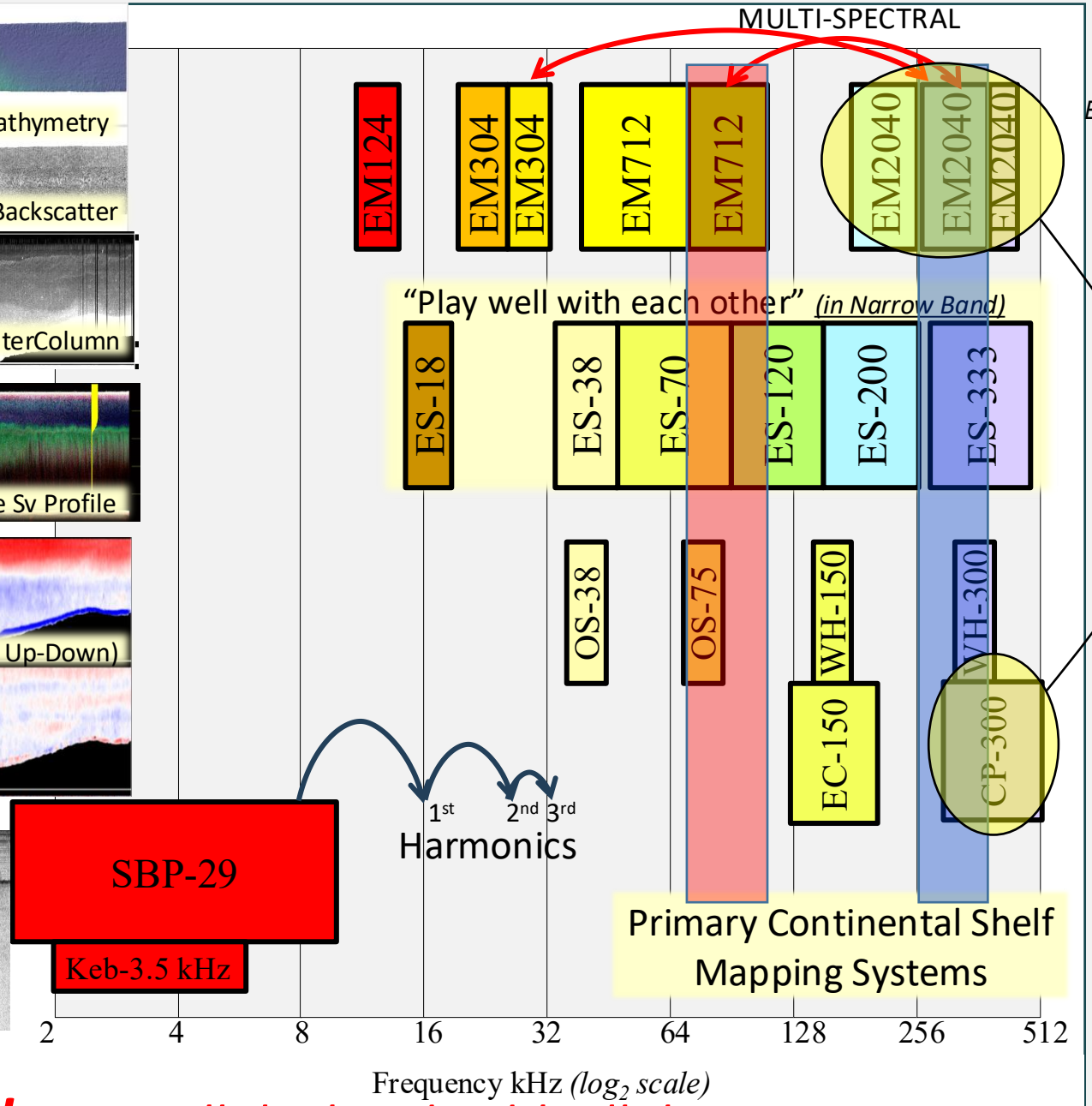
EM-EK-ADCP-SBP Potential Interference?













Class-A

EM712-EM2040



Class-B

EM304-EM2040

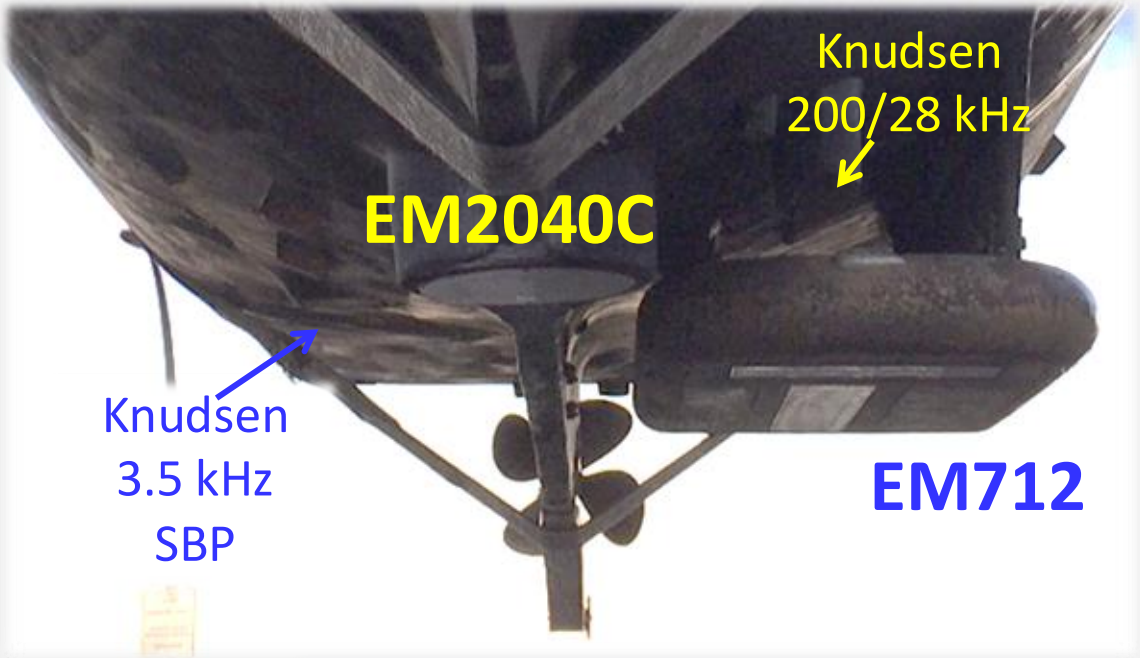
Example Focus here

*** don't **need** to use all the bandwidth all the time....*



CSL Heron

Multi-Sensor Test Platform



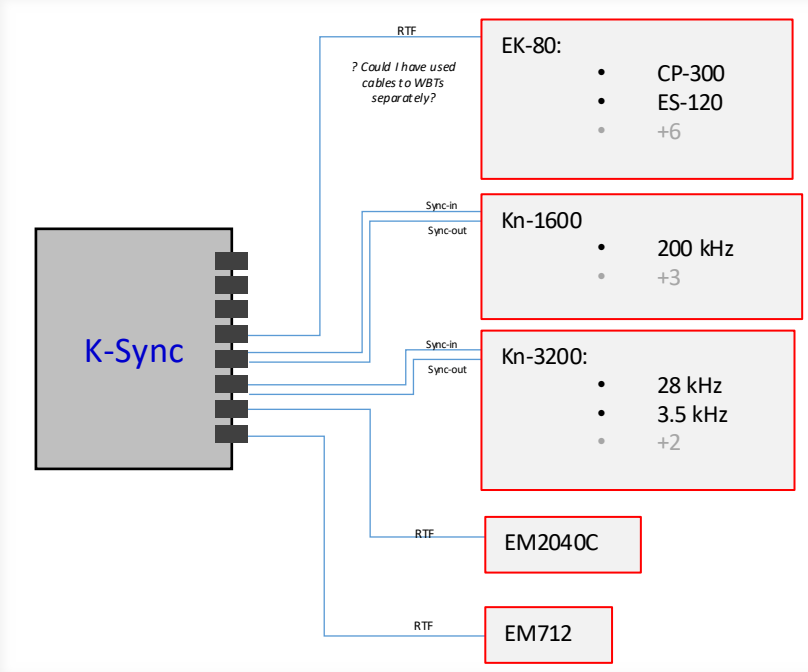
2024



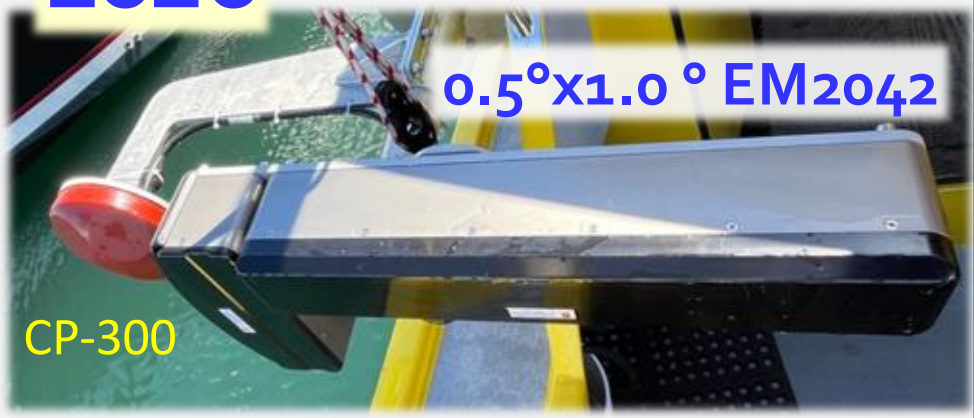
2025

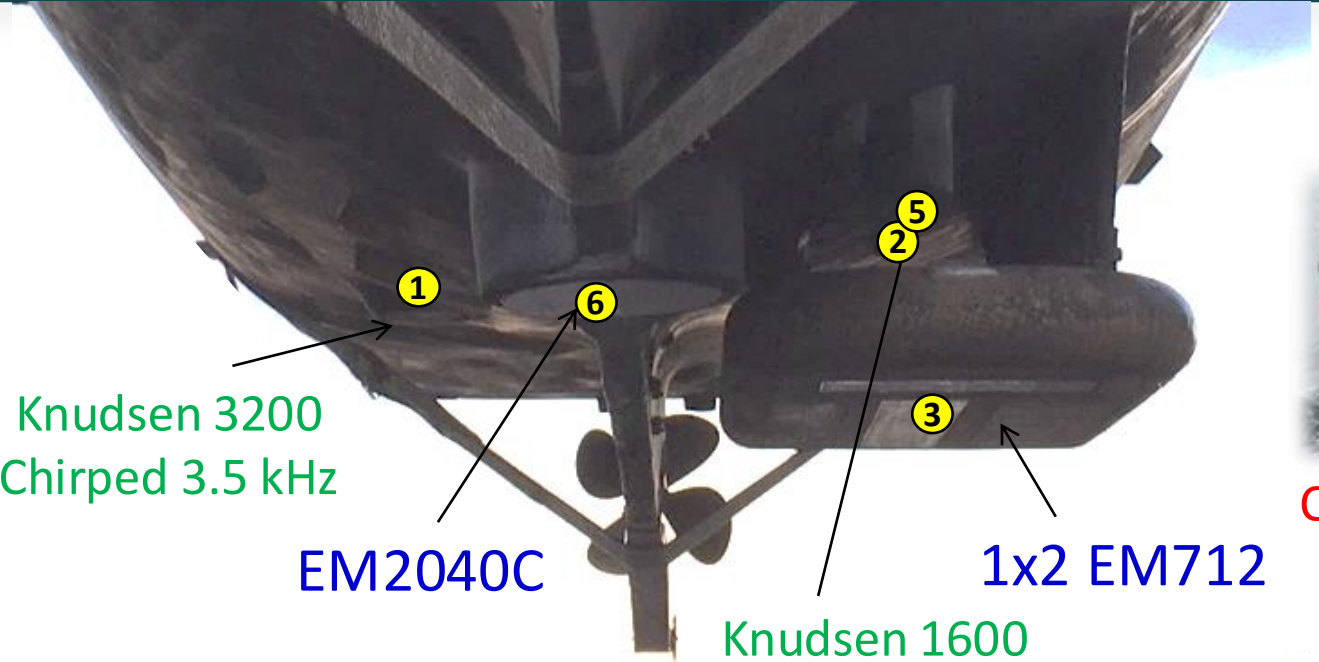




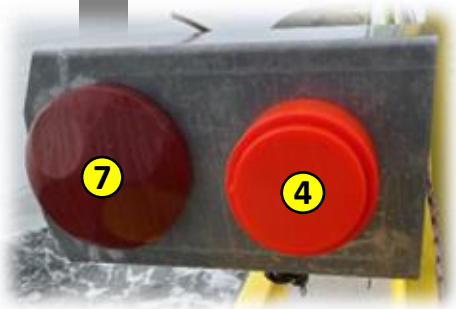


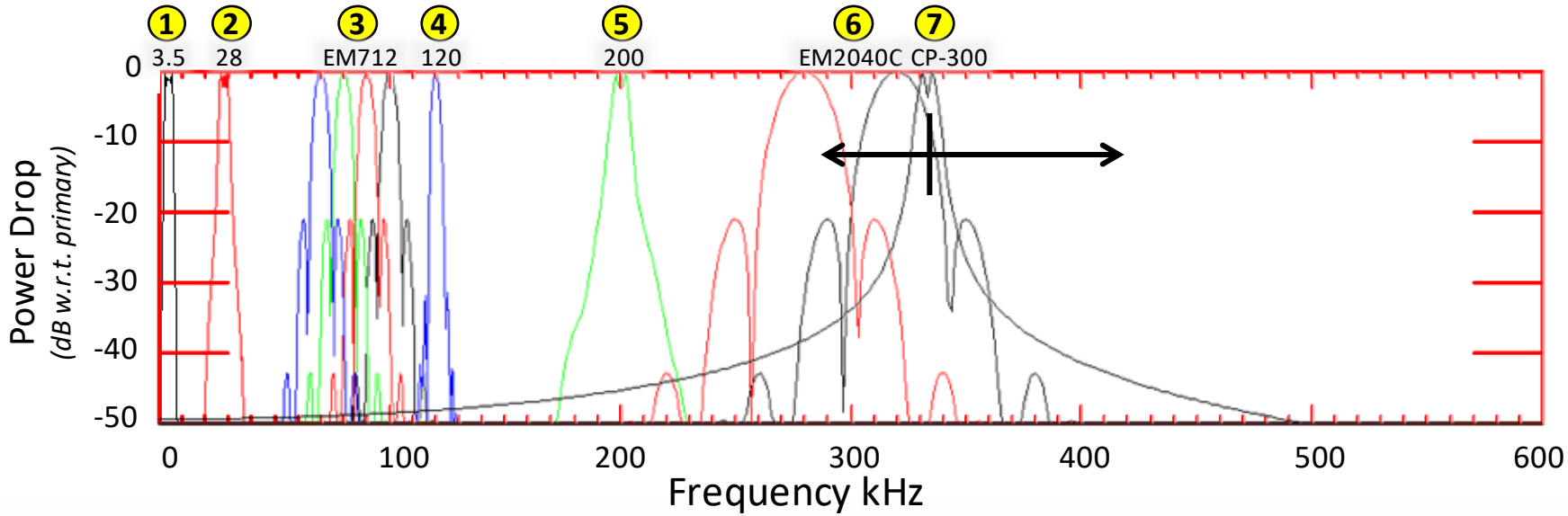
2026



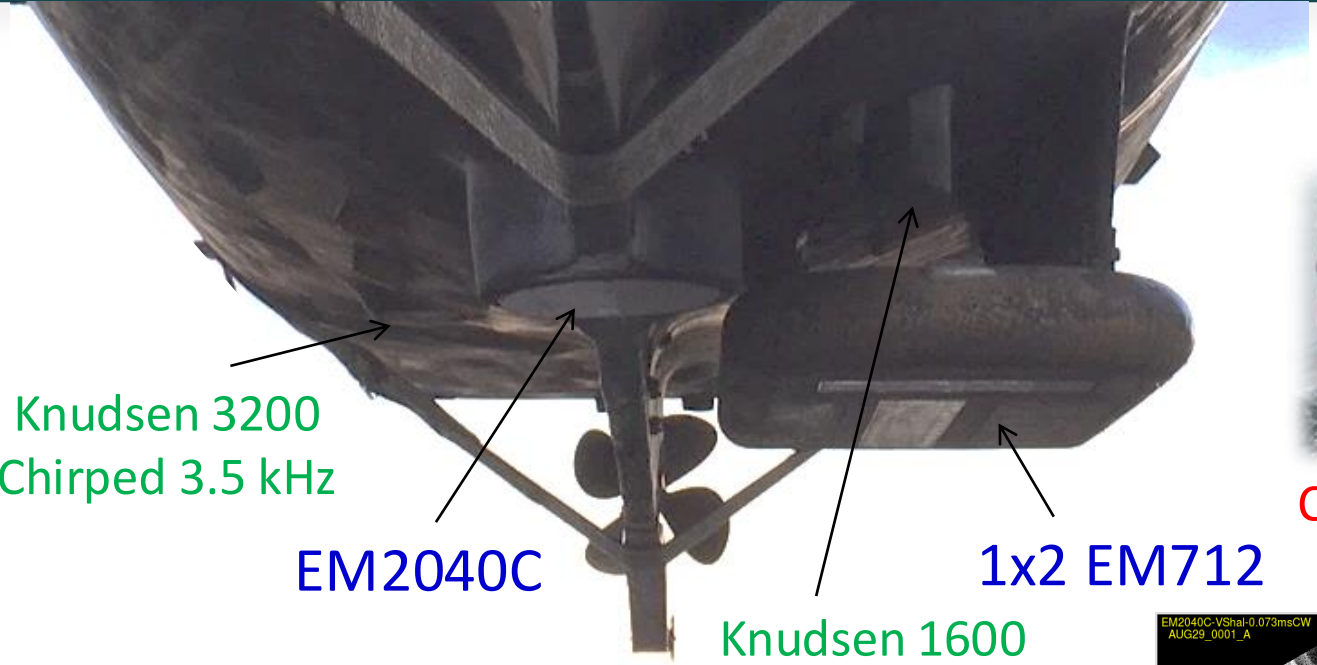


Pole mounted





Primary Overlap



Knudsen 3200
Chirped 3.5 kHz

EM2040C

Knudsen 1600
Chirped 200 & 28 kHz

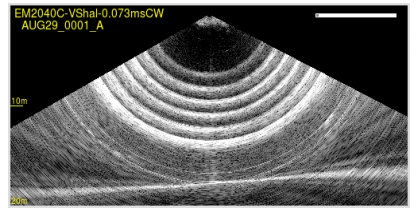
1x2 EM712

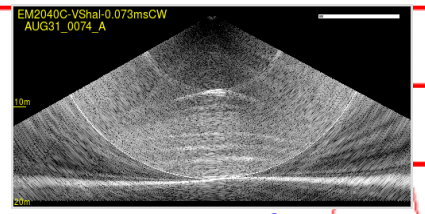
Pole mounted



CP-300

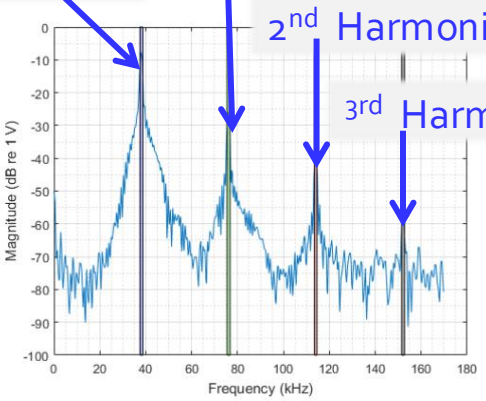
ES120 -7CD





EM712 6 Tx interference
on **EM2040C** WCD

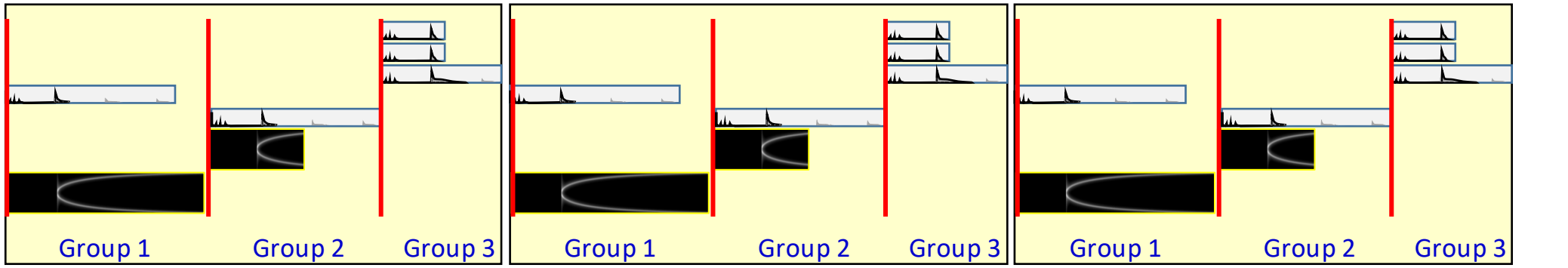
Primary
1st Harmonic
2nd Harmonic
3rd Harmonic



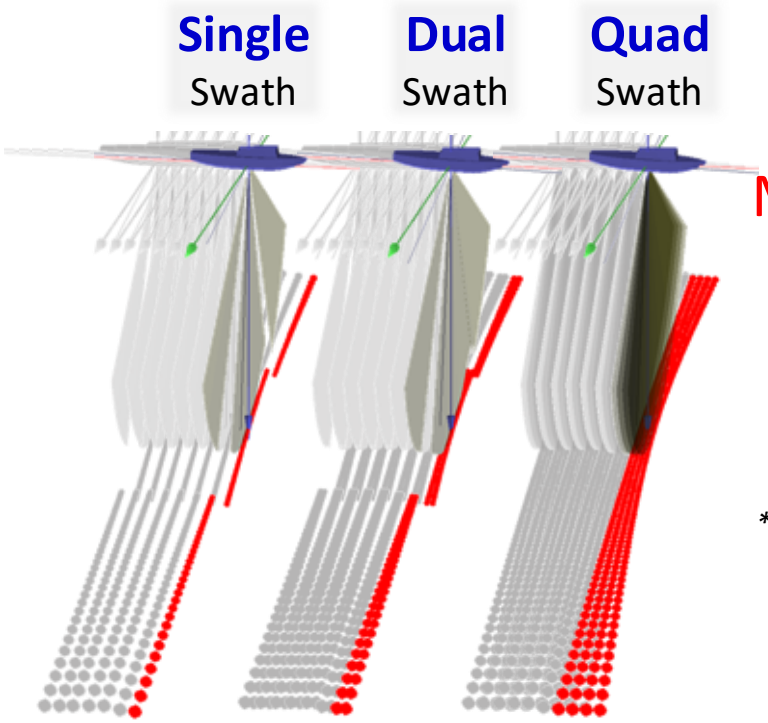
Primary & Harmonics Overlap

Sequenced **Grouped** Firing:

1. K-200
2. K28
3. ES-120
4. CP-300
5. K-SBP
6. EM2040C
7. EM712



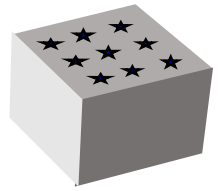




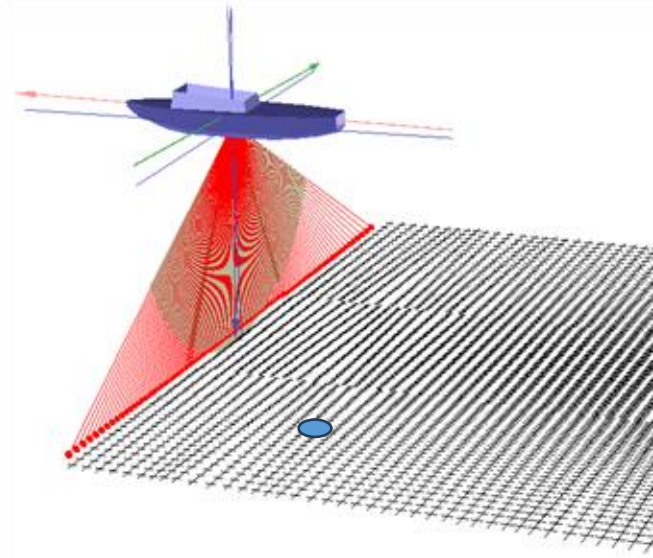
Multi-Swath
a (partial)
Solution

*** hardly a new solution!*
"Quin-Swath"
TSM-5265
Sea-Falcon
(1998)

Strategies to Compensate for Grouped Firing

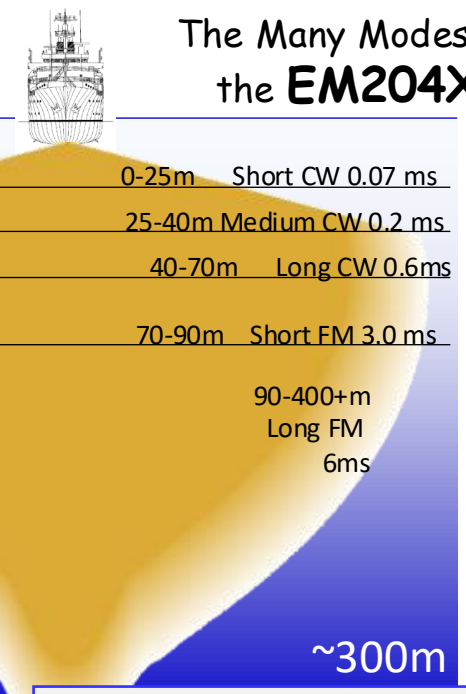


Any grouping risks
not achieving
"three strikes along track"
on a target.

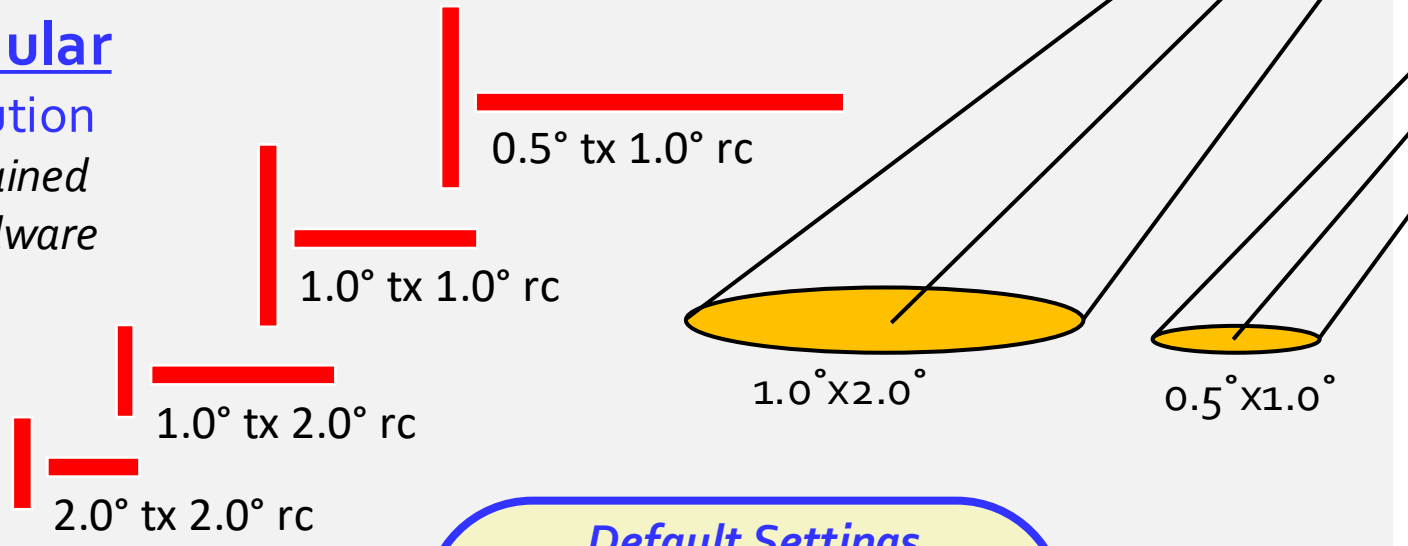


Strategies to Improve Resolution

The Many Modes of the **EM204X**



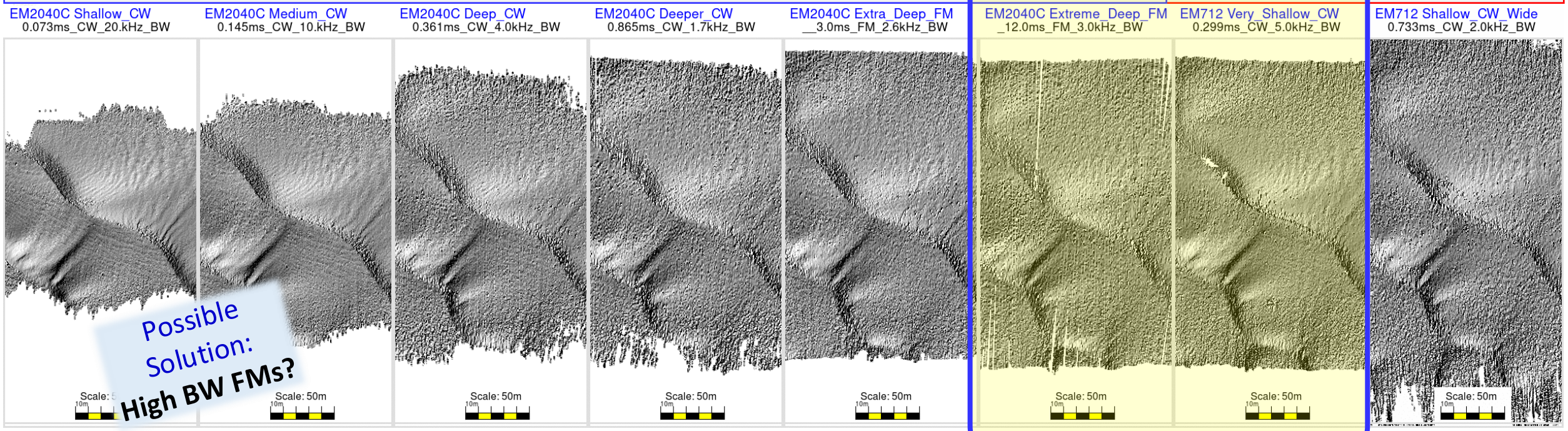
A: **Angular** Resolution
Constrained by hardware



B: **Time/Range** Resolution
Operator selection *tradeoff with Range Performance*

Default Settings

EM2040C | 70-100m depth | EM712



Possible Solution: **High BW FMs?**

The Many Modes of the **EM204X**

SHAL

0-25m Short CW 0.07 ms

25-40m Medium CW 0.2 ms

40-70m Long CW 0.6ms

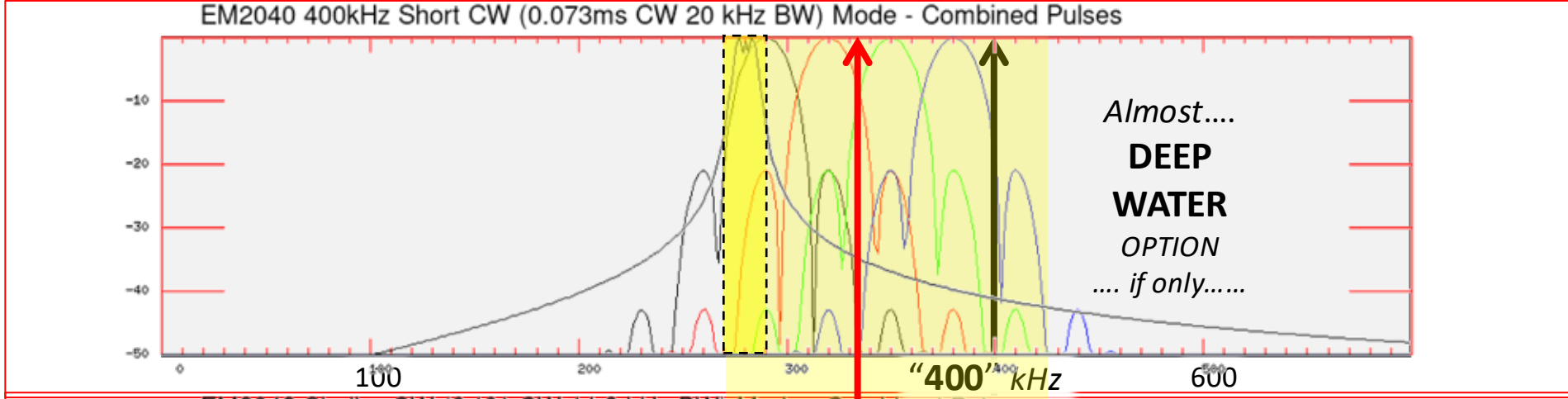
70-90m Short FM 3.0 ms

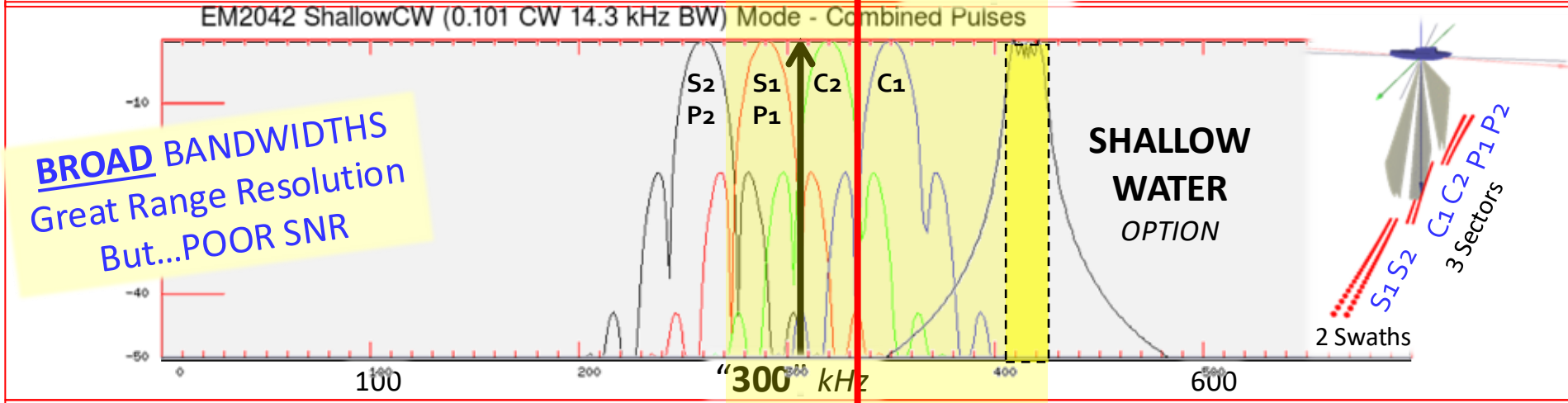
90-400+m
Long FM
6ms

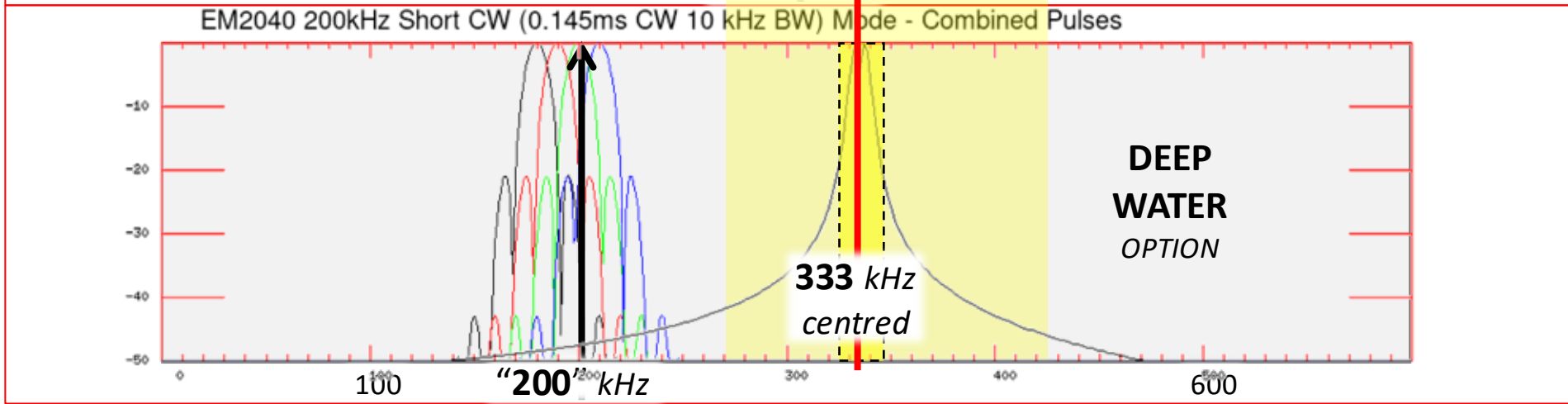
~300m

Trying to avoid
CP-300 -EM204X
Cross-talk

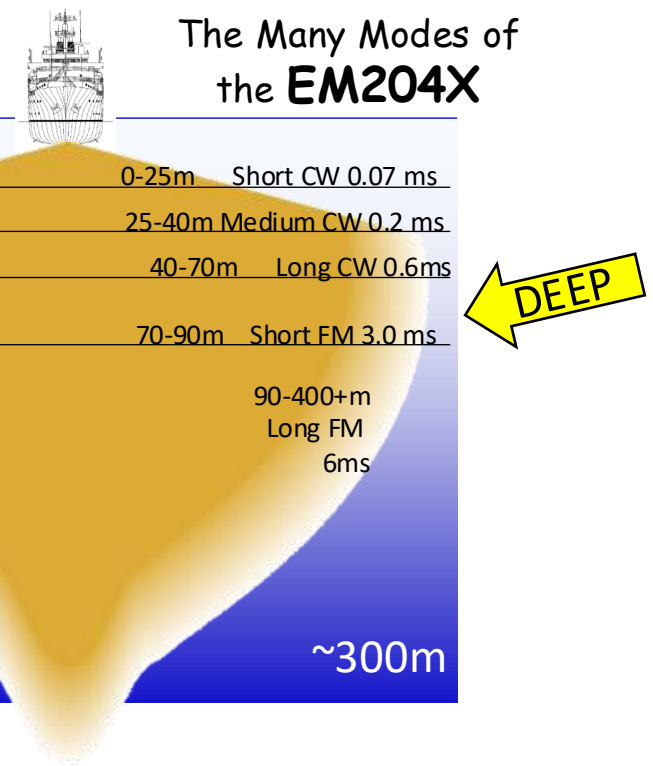








The Many Modes of the **EM204X**

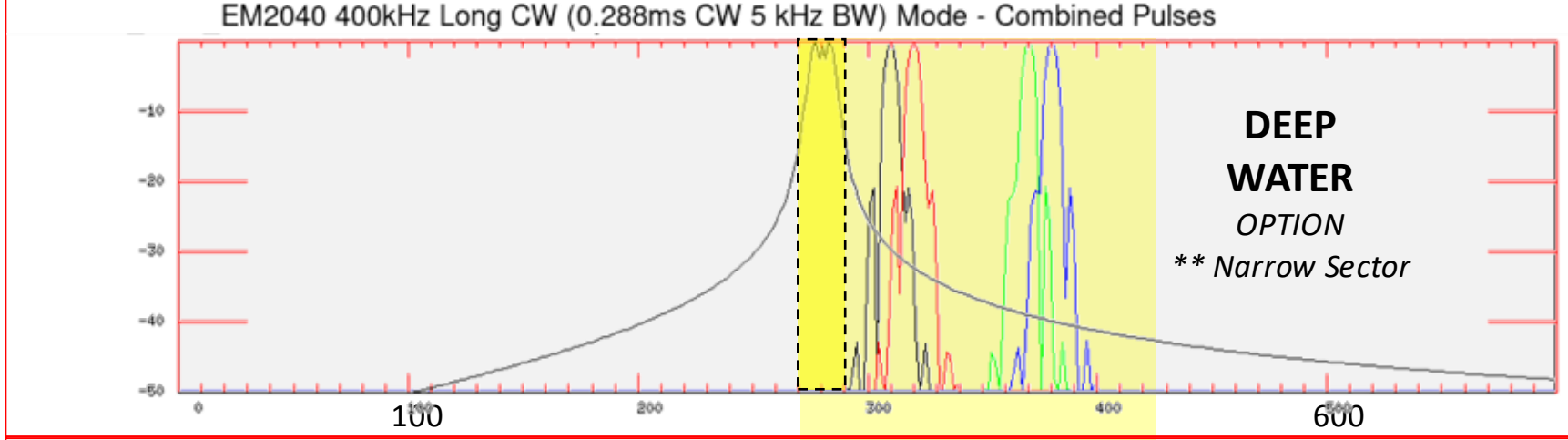


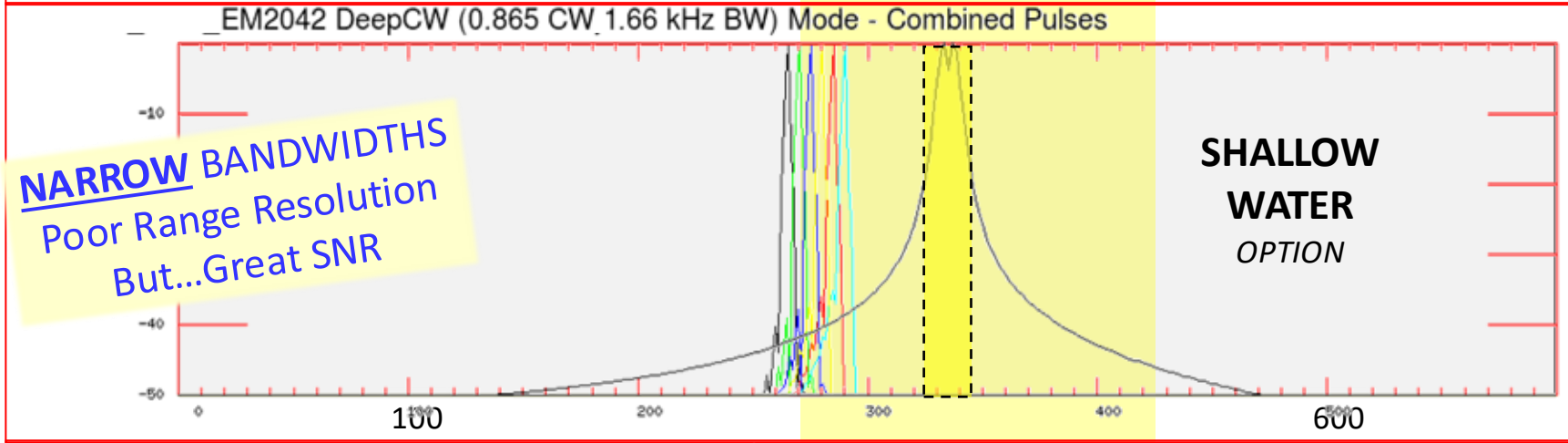
Trying to avoid

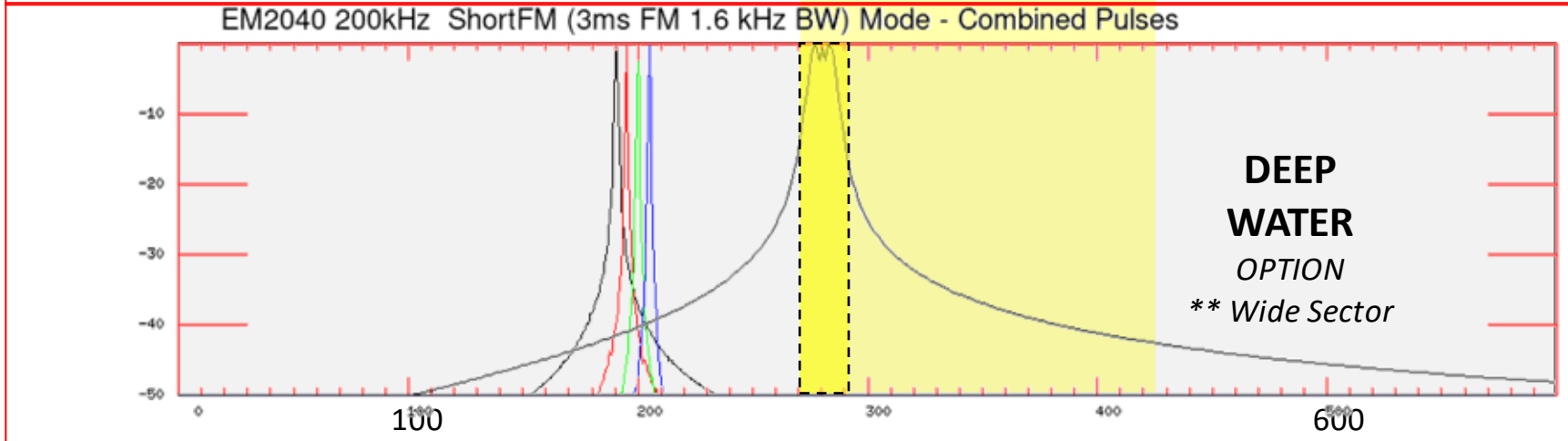
CP-300 -EM204X

Cross-talk





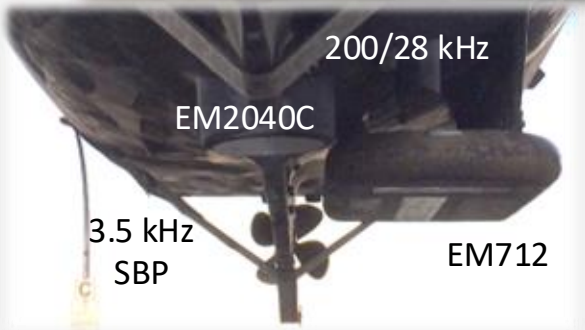


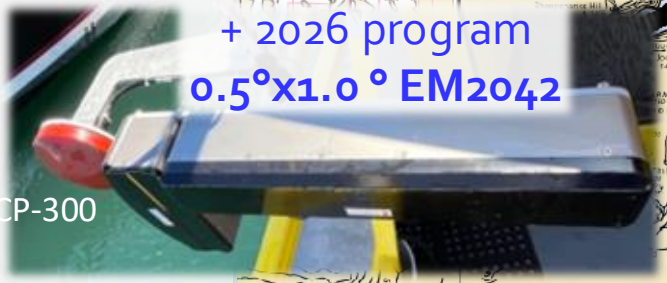


Multi-Sensor Test Platform

CSL Heron (34 ft)







+ 2026 program

0.5°x1.0 ° EM2042

Simultaneous Operation of:

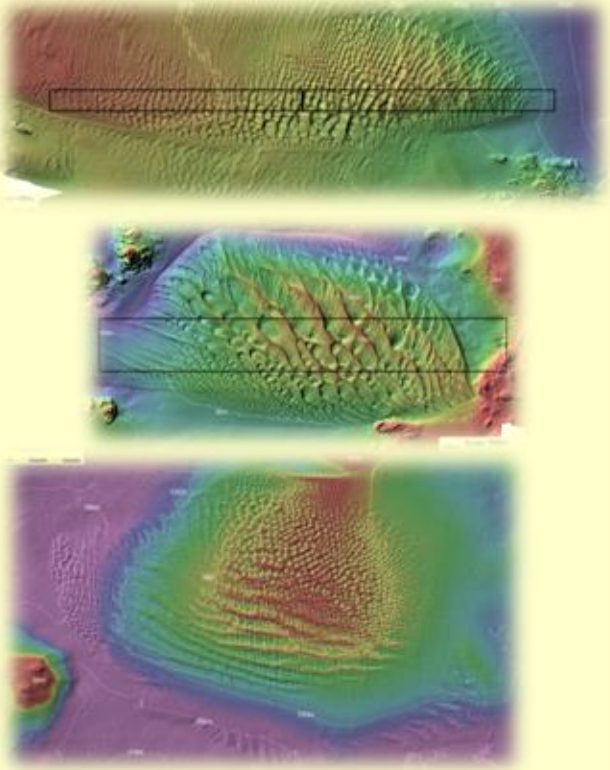
K-Sync (V2)



1. EM2040C
2. EM712
3. CP-300 ADCP
4. ES-120-7 split beam
5. 3.5 kHz subbottom
6. 28 kHz imaging
7. 200 kHz imaging

Testing synchronization strategies

Monitoring Sediment Transport while Testing Achievable Bathymetric Resolution



While ***Simultaneously*** Monitoring Tidally Modulated Estuarine Oceanography *(that drives the sediment transport)*

Resolving/Monitoring Tidal Current Field and Bedform Migration

Coastal to Continental Shelf Depths

14-20 m
depth range

EM2040
Usual Operational Depths

70-100 m
depth range

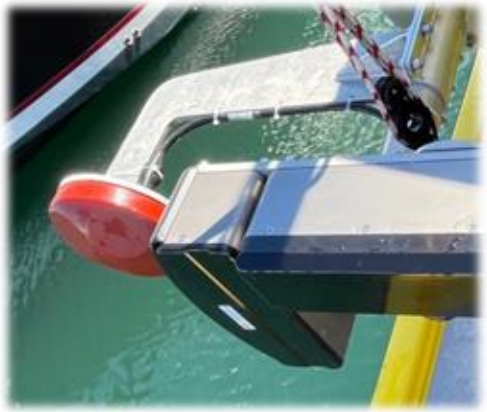
The challenge
Can you do this
5 x Deeper?

EM712
Usual Operational Depths

140-200 m
depth range

Can you do this
10 x Deeper?

AND
While **simultaneously operating** other sonars
(WCD imaging, ADCP)



Average depth 187m

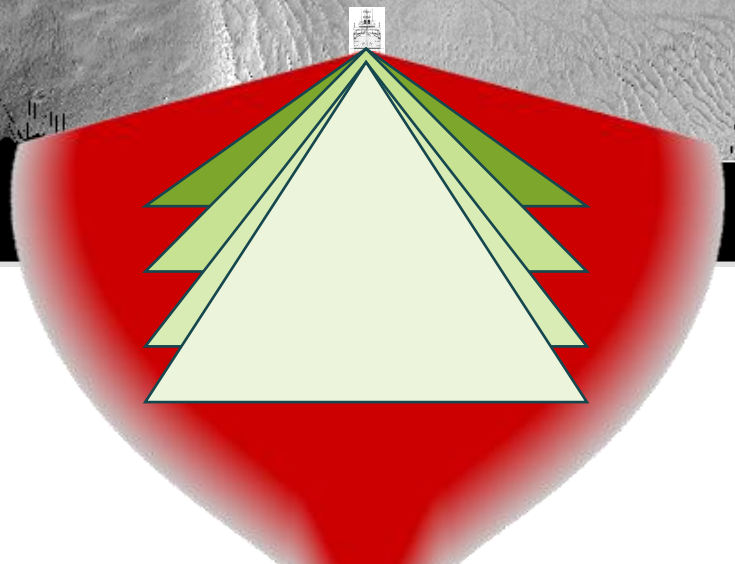
EM712 - Apr_XX_2026

Scale: 500m

100m

Can you resolve the
0.2x5.0 m dunes
in 210m!

We can see the large (50+m) bedforms
*But what is the **limit of resolution**?*



160-210m

140-160m

110-140m

70-110m

200m

150m

250m

300m

100m

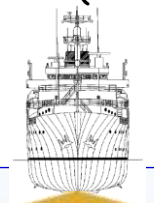
50m

50m

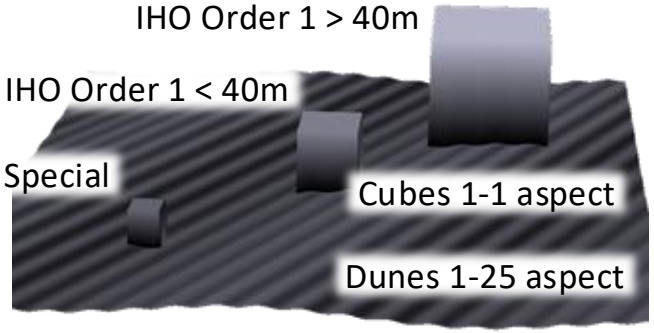
100m

How much Resolution
can we maintain
EM712 & EM204X 70-200m

The Many Modes of the EM204X
(at "300" kHz)

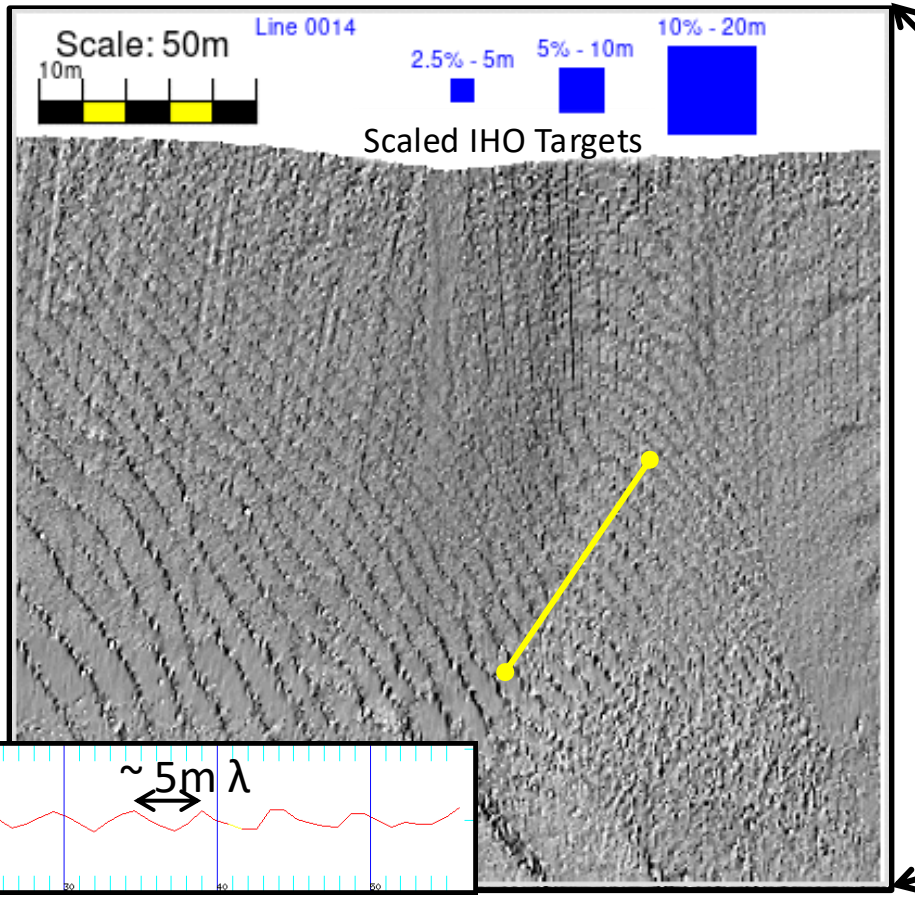


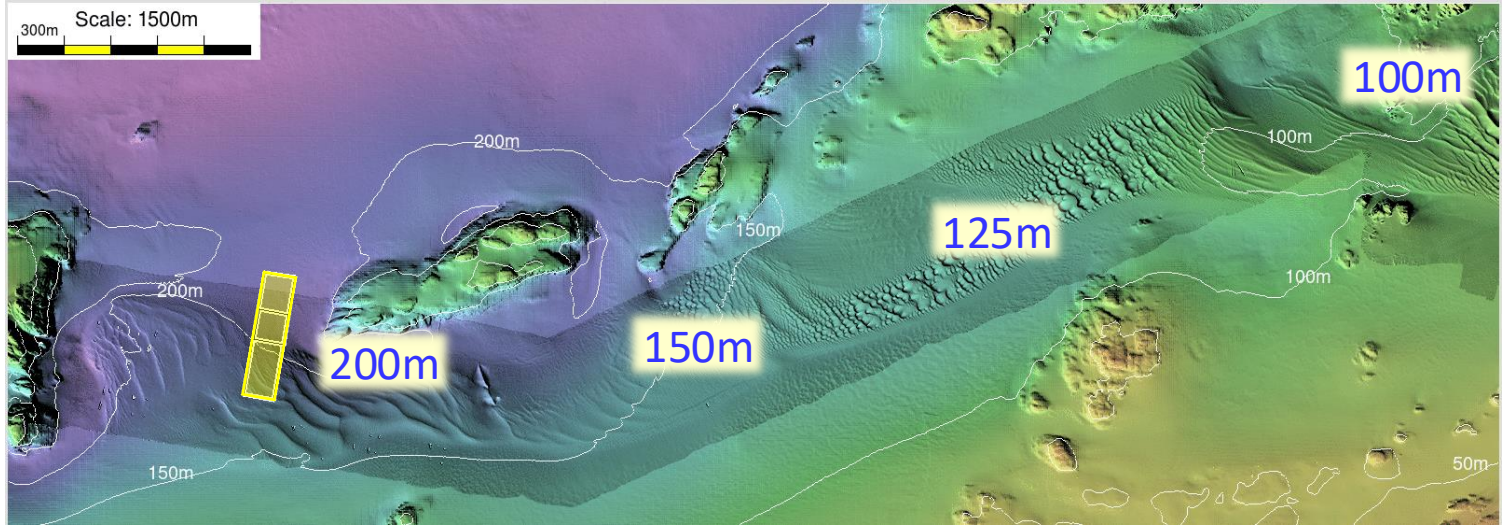


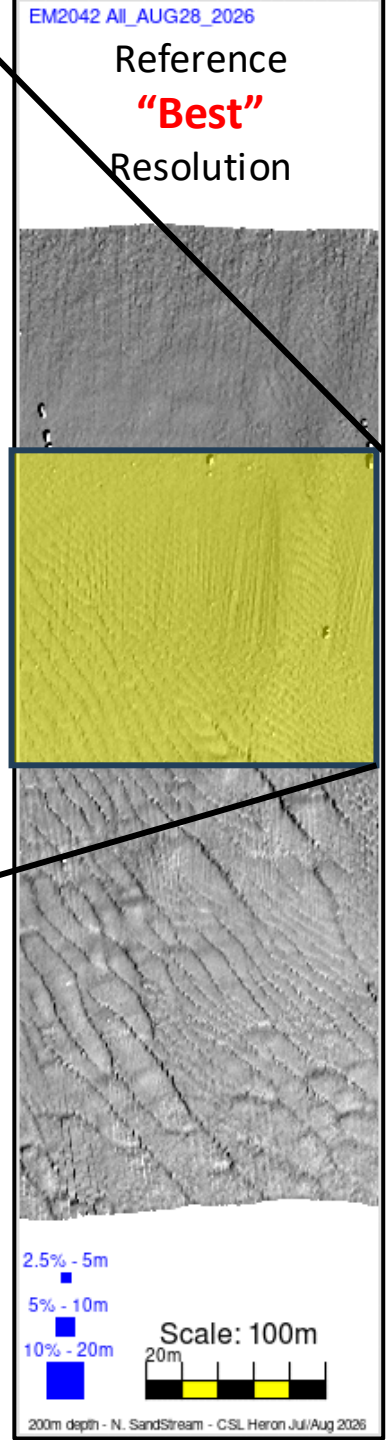


210m Depth
Dune Targets

- **0.1%** Z Amplitude
- **2.5%** Z Wavelength







“200” kHz Modes

EM2042 200kHz_Shallow_CW

“Shallow”
Short CW
0.145 ms CW
10 kHz BW

EM2042 200kHz_Medium_CW

“Medium”
Medium CW
0.288 ms CW
5 kHz BW

EM2042 200kHz_Deep_CW

“Deep”
Long CW
0.865 ms CW
1.7 kHz BW

EM2042 200kHz_VeryDeep_FM

“Very Deep/ Extra Deep”
Short/Long FM
3 or 12 ms FM
1.7 kHz BW

EM2042 All_AUG28_2026

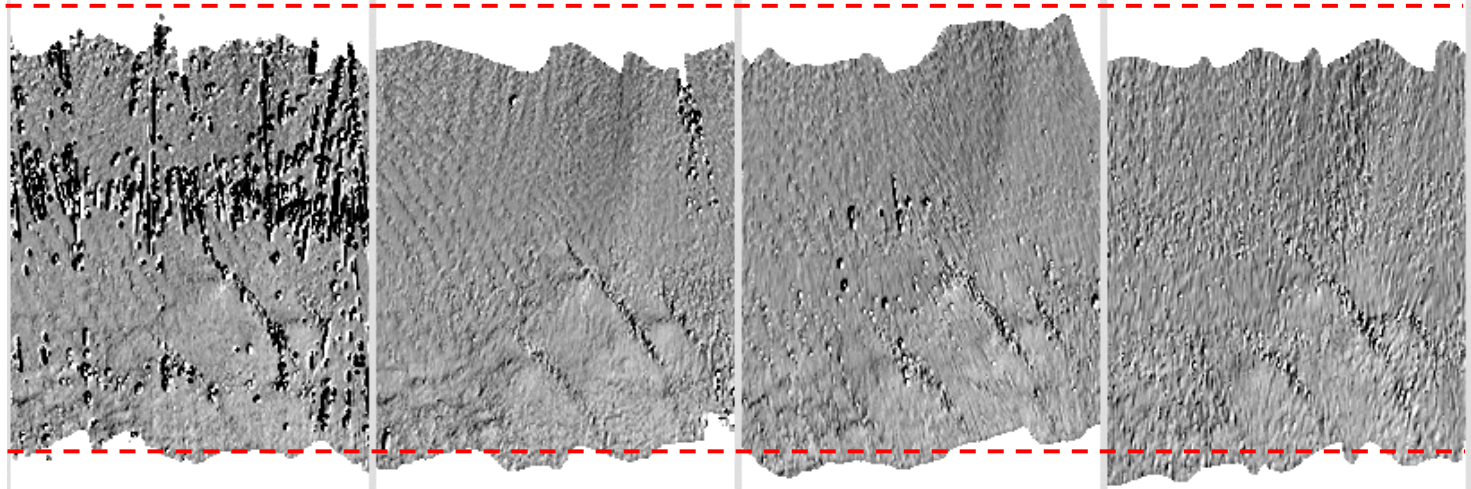
Reference
“Best”
Resolution

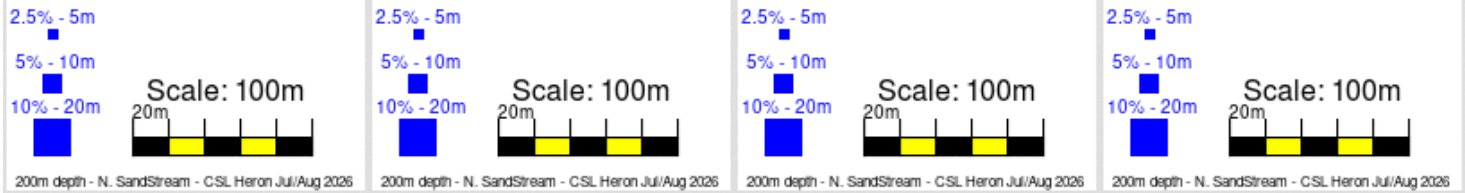
Constrained
+/- 120m

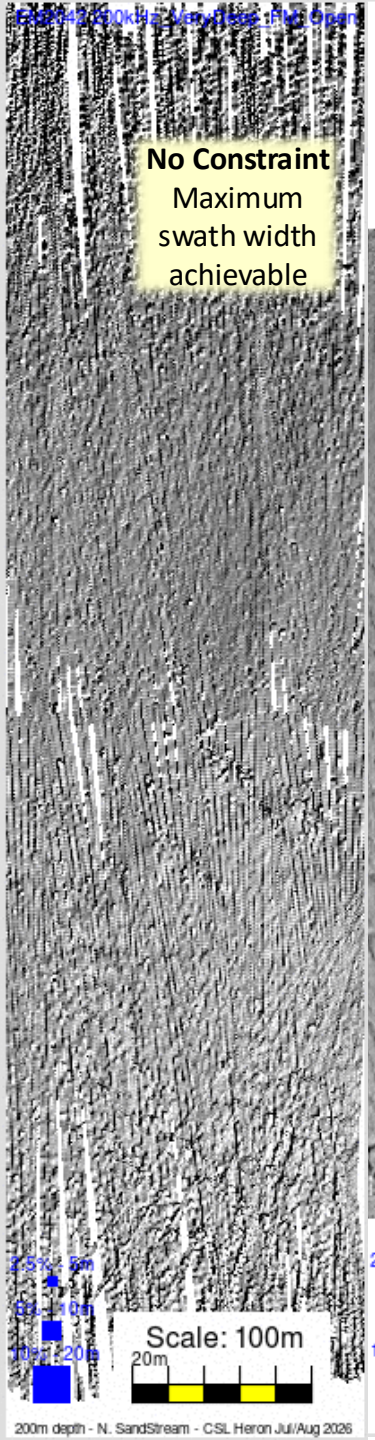
No Constraint
Maximum swath width achievable

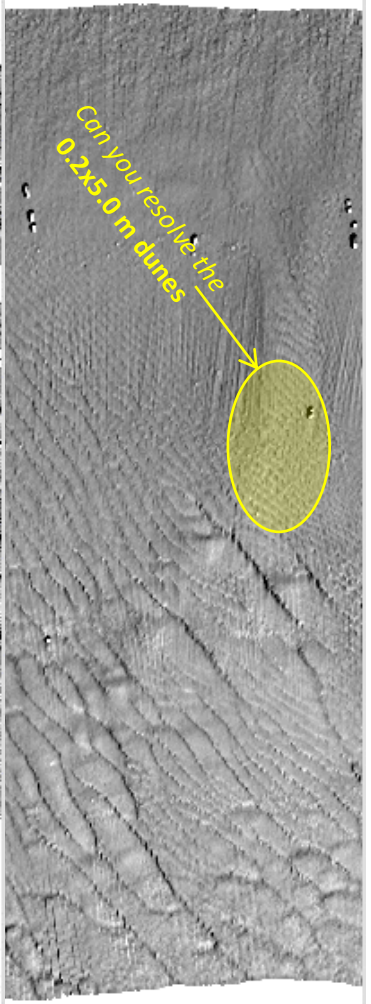
Can you resolve the 0.2x5.0 m dunes

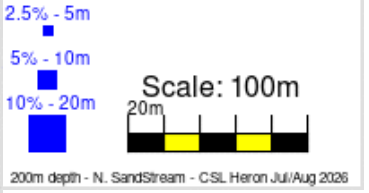
Default Mode









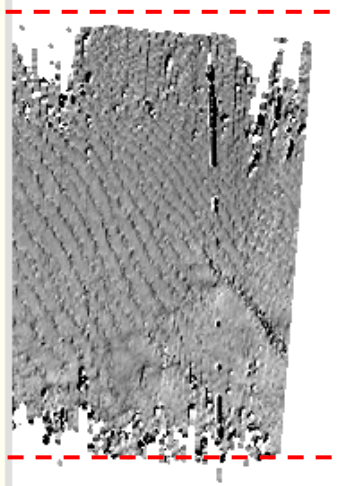


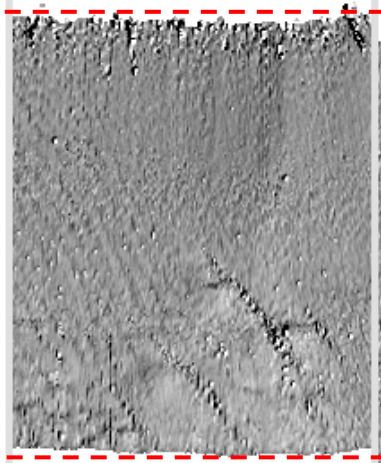
“300” kHz Modes

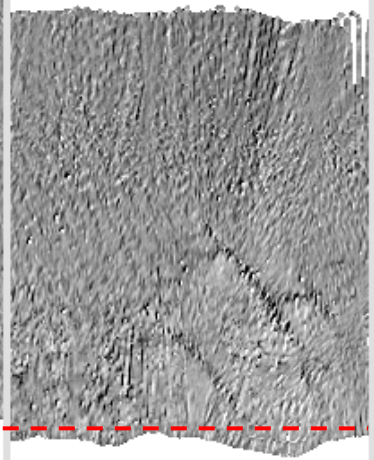
“Shallow”	“Medium”	“Deep”	“Very Deep/ Extra Deep”	“Very Deep/ Extra Deep”	Reference “Best” Resolution
Short CW 0.101 ms CW 14 kHz BW	Medium CW 0.288 ms CW 5 kHz BW	Long CW 0.865 ms CW 1.7 kHz BW	Short/Long FM 2 or 6 ms FM 1.7 kHz BW	**No Constraint** Maximum swath width achievable	Resolution

Constrained +/- 120m

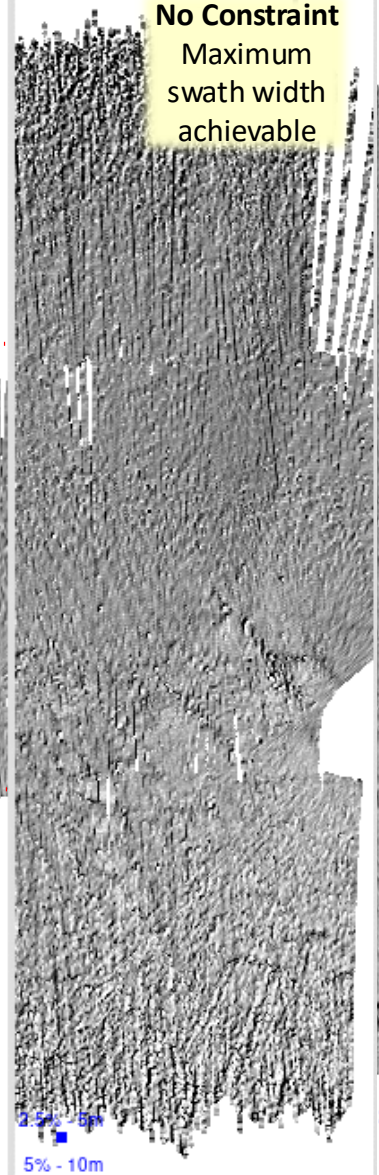
Insufficient SNR

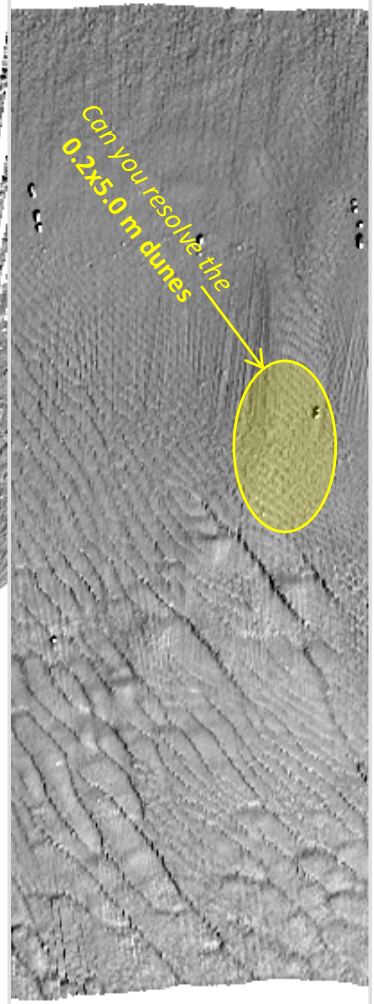


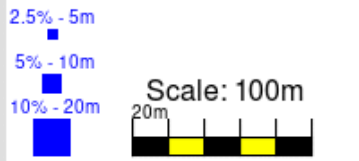


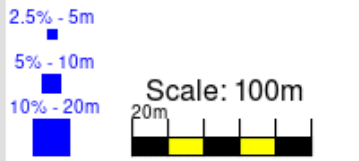


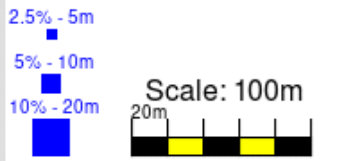
Default Mode

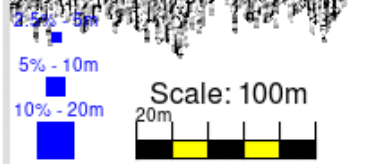


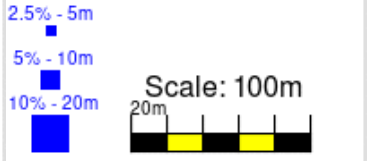












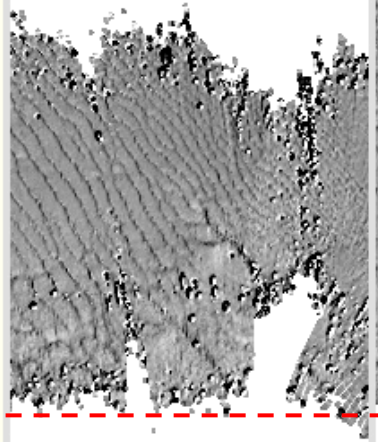
“400” kHz Modes

Current

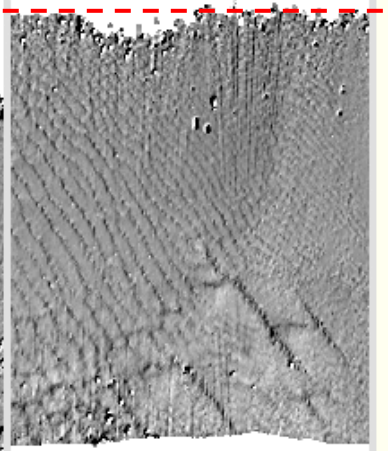
Constrained +/- 120m

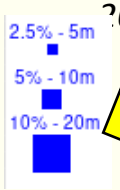
“Shallow”	“Medium”	“Deep”	“Very Deep/ Extra Deep”
Short CW	Medium CW	Long CW	Short/Long FM
0.073 ms CW	0.145 ms CW	0.288 ms CW	1? or 10? ms FM
20 kHz BW	10 kHz BW	5 kHz BW	2? kHz BW
Insufficient SNR			*Never Originally Offered due to high Attenuation* & *200/300 kHz easily meet and exceed IHO target detection (10%Z)*

EM2042 TI20_400kHz_Medium_CW

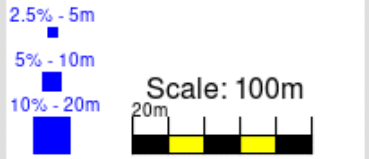


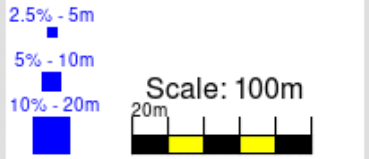
EM2042 TI21_400kHz_Deep_CW





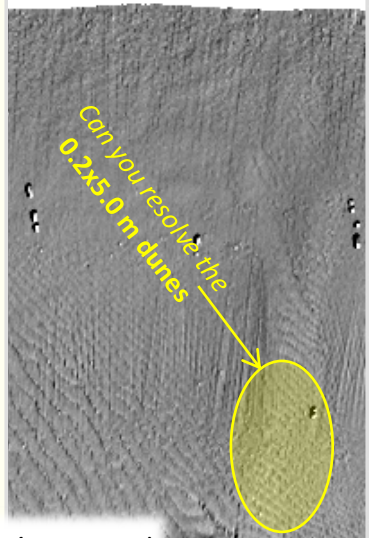
Default *(only viable)* Mode





EM2042 All_AUG28_2026

Reference **“Best”** Resolution



Pulse Mixologist *(Tor Inge)*



https://stockcake.com/i/mixologist-in-motion_2095051_1358334

“400” kHz Modes

Testing

EM2042 TI18_XXXkHz_1sDS_FM35k_5

“Super Shallow”

Short FM

0.5 ms FM

35 kHz BW

EM2042 TI20_400kHz_Medium_CW

“Medium”

Medium CW

0.145 ms CW

10 kHz BW

EM2042 TI21_400kHz_Deep_CW

“Deep”

Long CW

0.288 ms CW

5 kHz BW

EM2042 TI14_400kHz_3sDS_FM11k_5

“Super Deep”

Long FM

2.0 ms FM

11 kHz BW

EM2042 TI15_400kHz_3sDS_FM11k_5

No Constraint

Maximum swath width achievable

EM2042 All_AUG28_2026

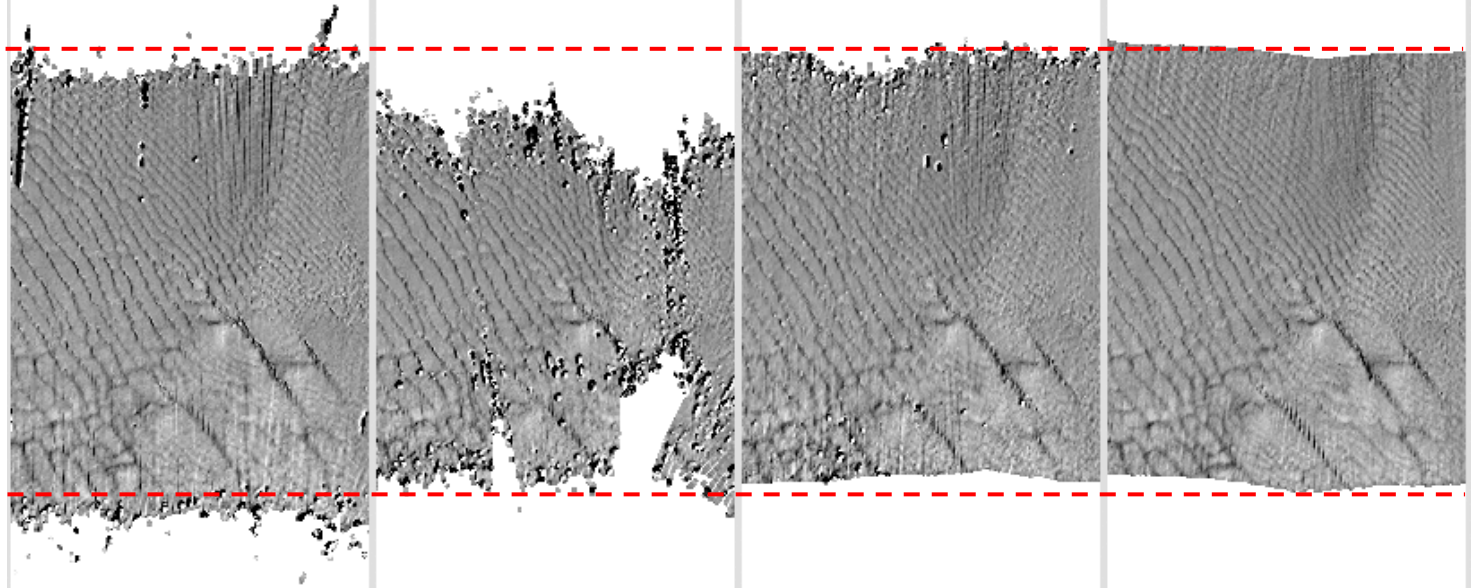
Reference

“Best”

Resolution

Can you resolve the 0.2x5.0 m dunes

Constrained +/- 120m



**

have to drop to

<u>Single Sector</u>

**

can maintain

<u>Three Sectors</u>

2.5% - 5m

5% - 10m

10% - 20m

Scale: 100m

20m

200m depth - N. SandStream - CSL Heron Jul/Aug 2026

The Many Modes of the **EM204X**

0-25m Short CW 0.07 ms

25-40m Medium CW 0.2 ms

40-70m Long CW 0.6ms

70-90m Short FM 3.0 ms

90-400+m
Long FM
6ms

~300m

SUPER MODES!

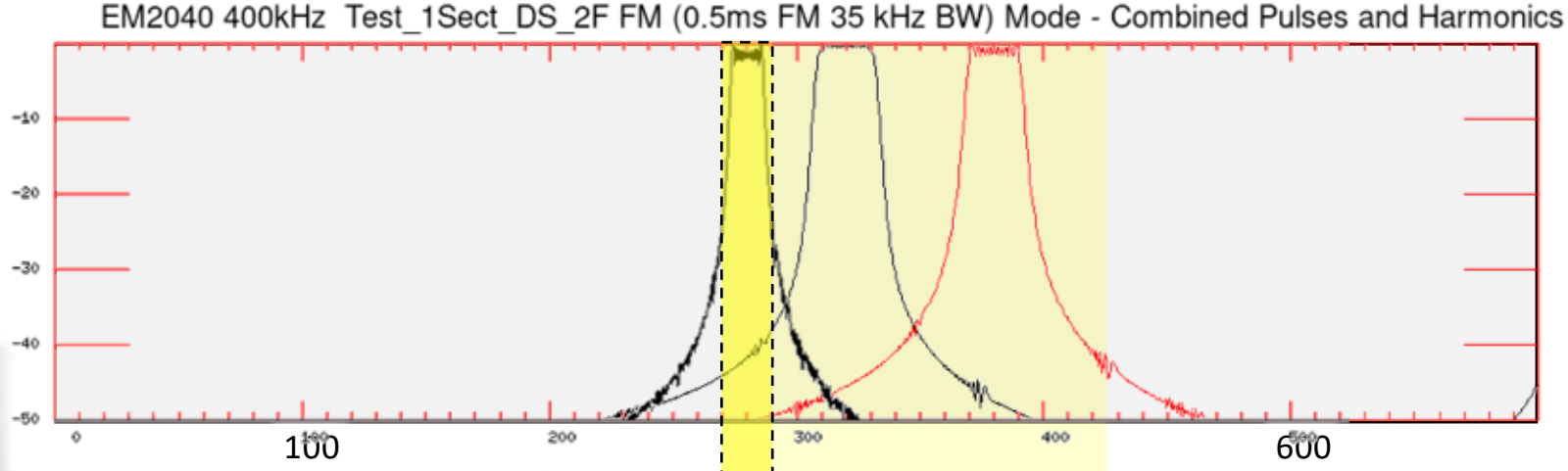


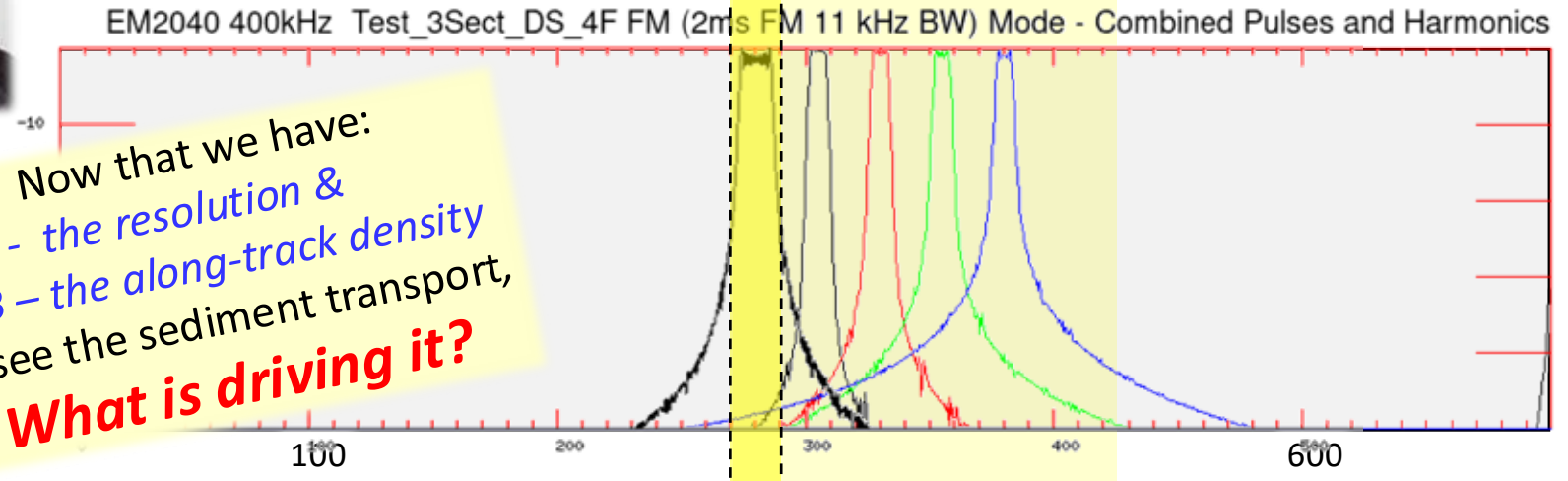
Now that we have:

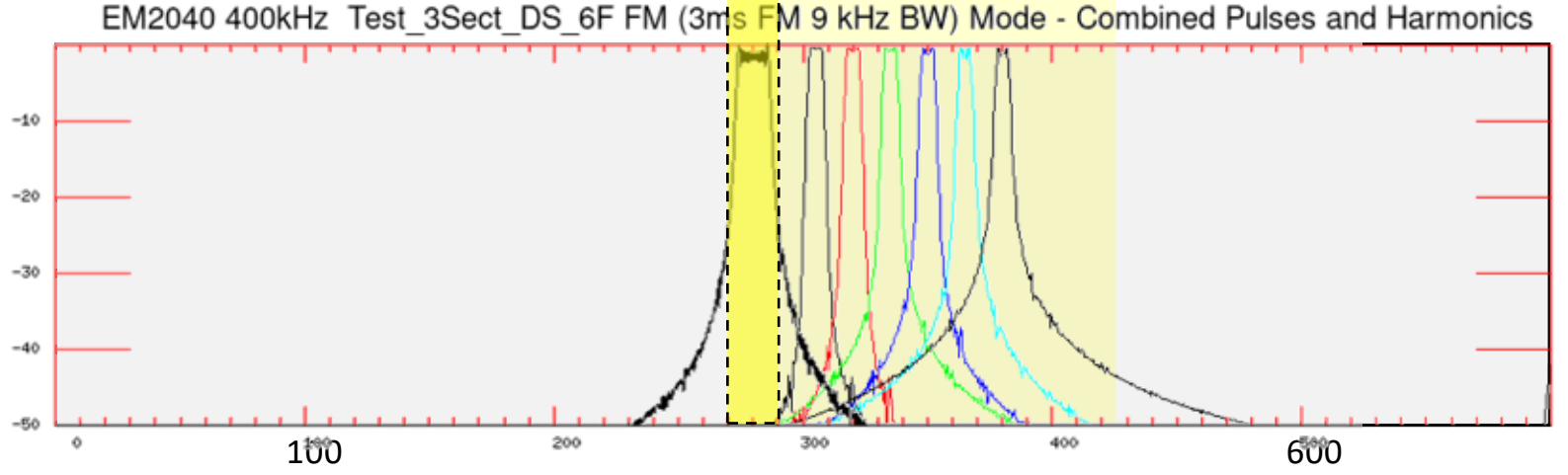
- A - the resolution &
- B – the along-track density

to see the sediment transport,

What is driving it?







Trying to avoid

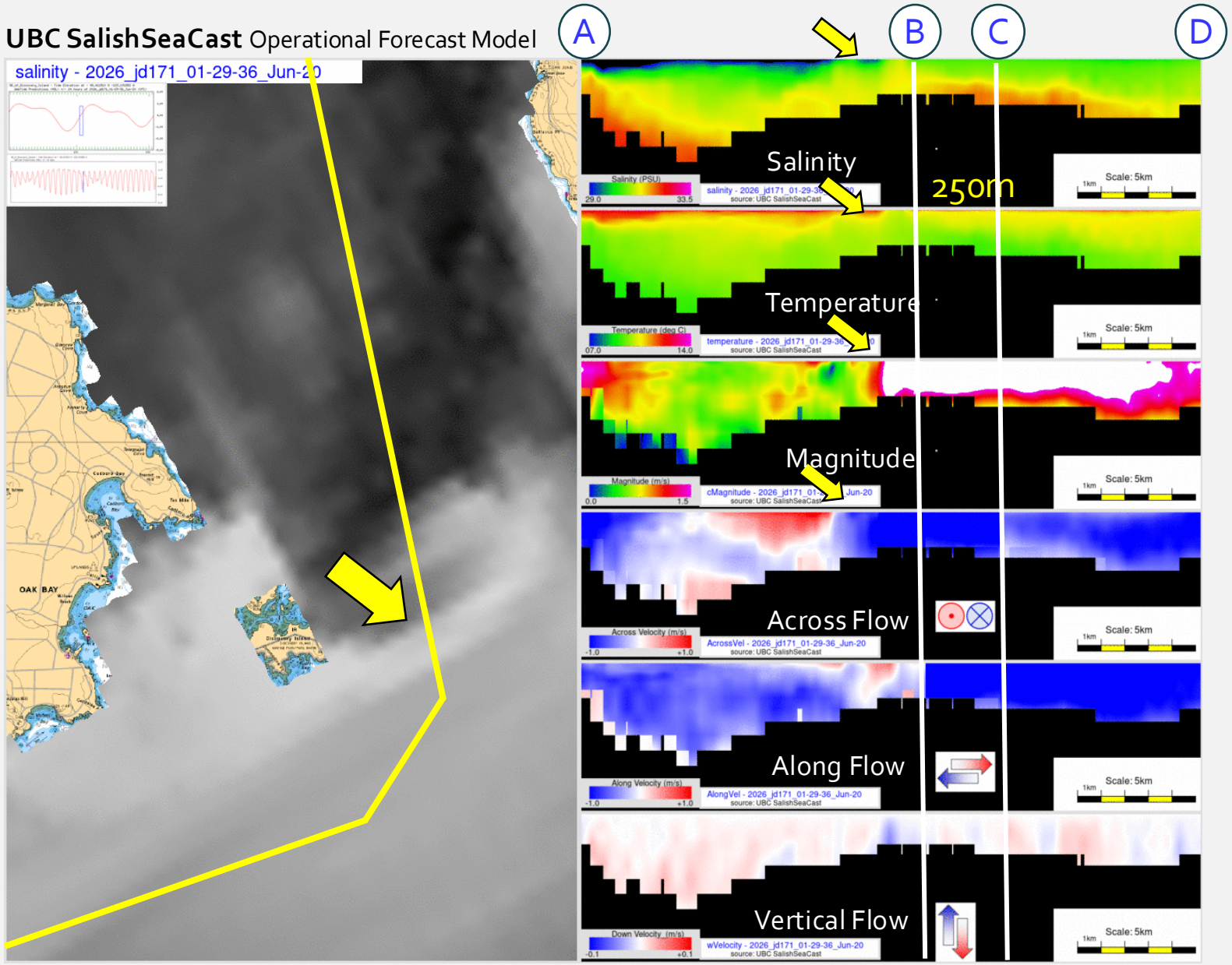
CP-300 -EM204X

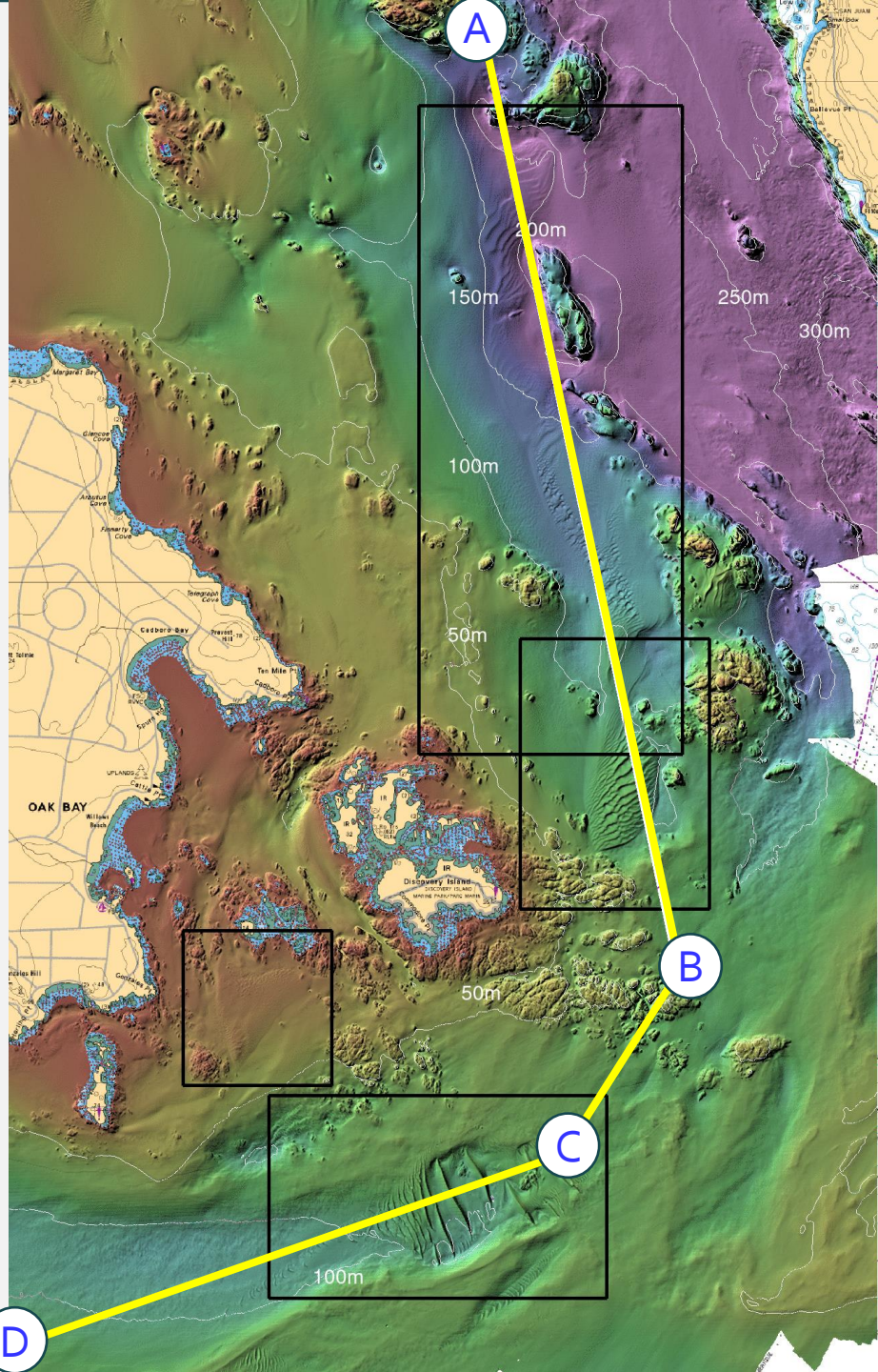
Cross-talk



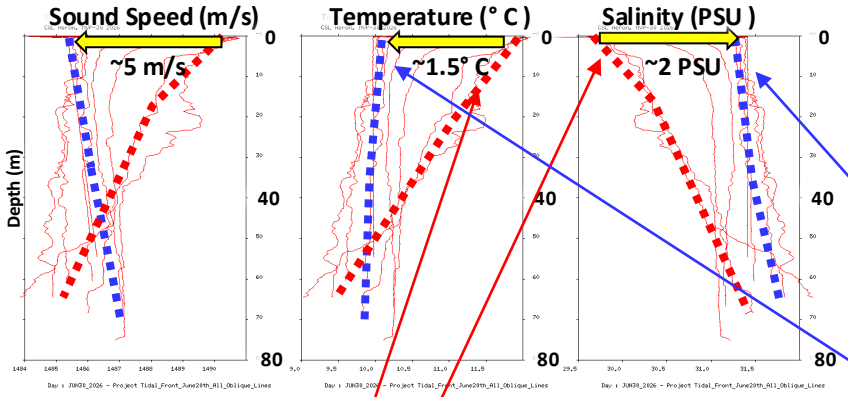
Model Definition of 3D Baroclinic Tidal Circulation

UBC SalishSeaCast Operational Forecast Model





Delineating a Pronounced Tidal Front



VIEW 2

upwelled
Juan de Fuca
(cold-saltier)

3+ knots

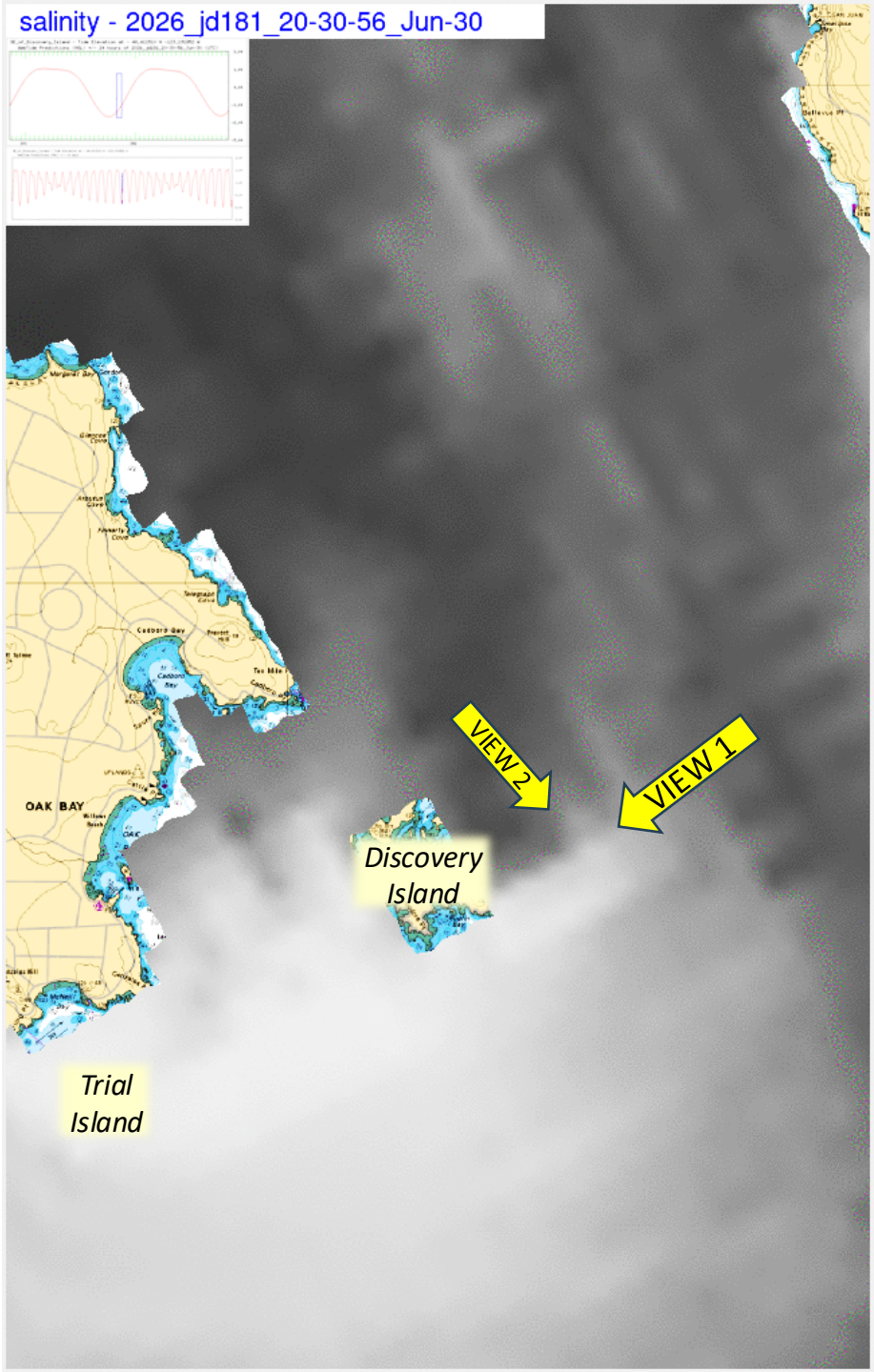
distal
Fraser River
(hot-brackish)

~0.5 knots

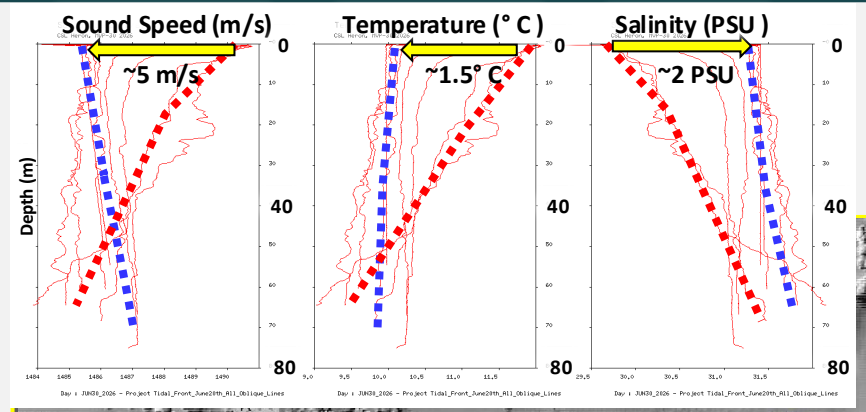
CSL Heron
10m long

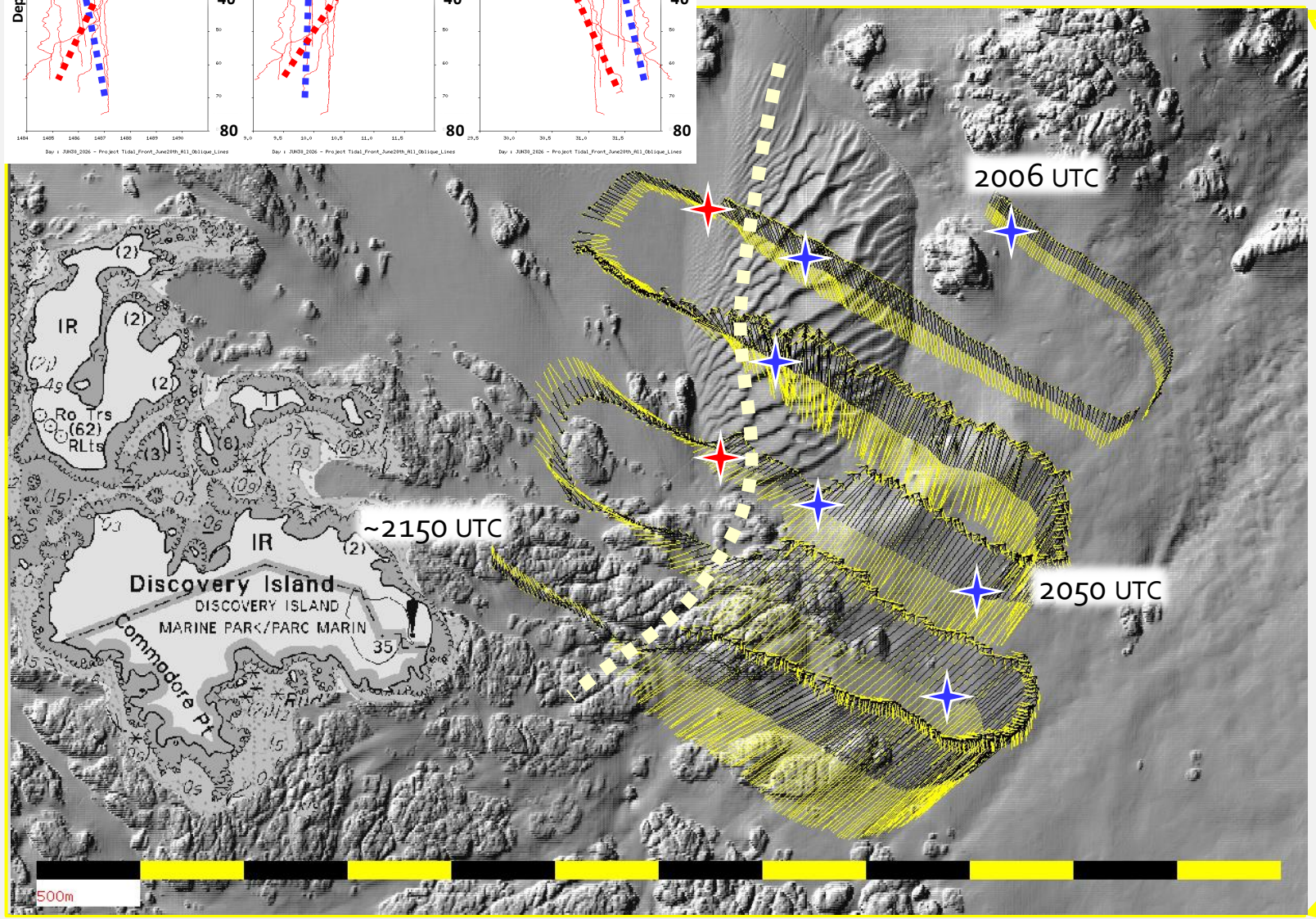
Three simultaneous agendas:

1. *High along-track ADCP resolution*
2. *High resolution Bedform Migration*
3. *High SNR to Image Sediment Transport*

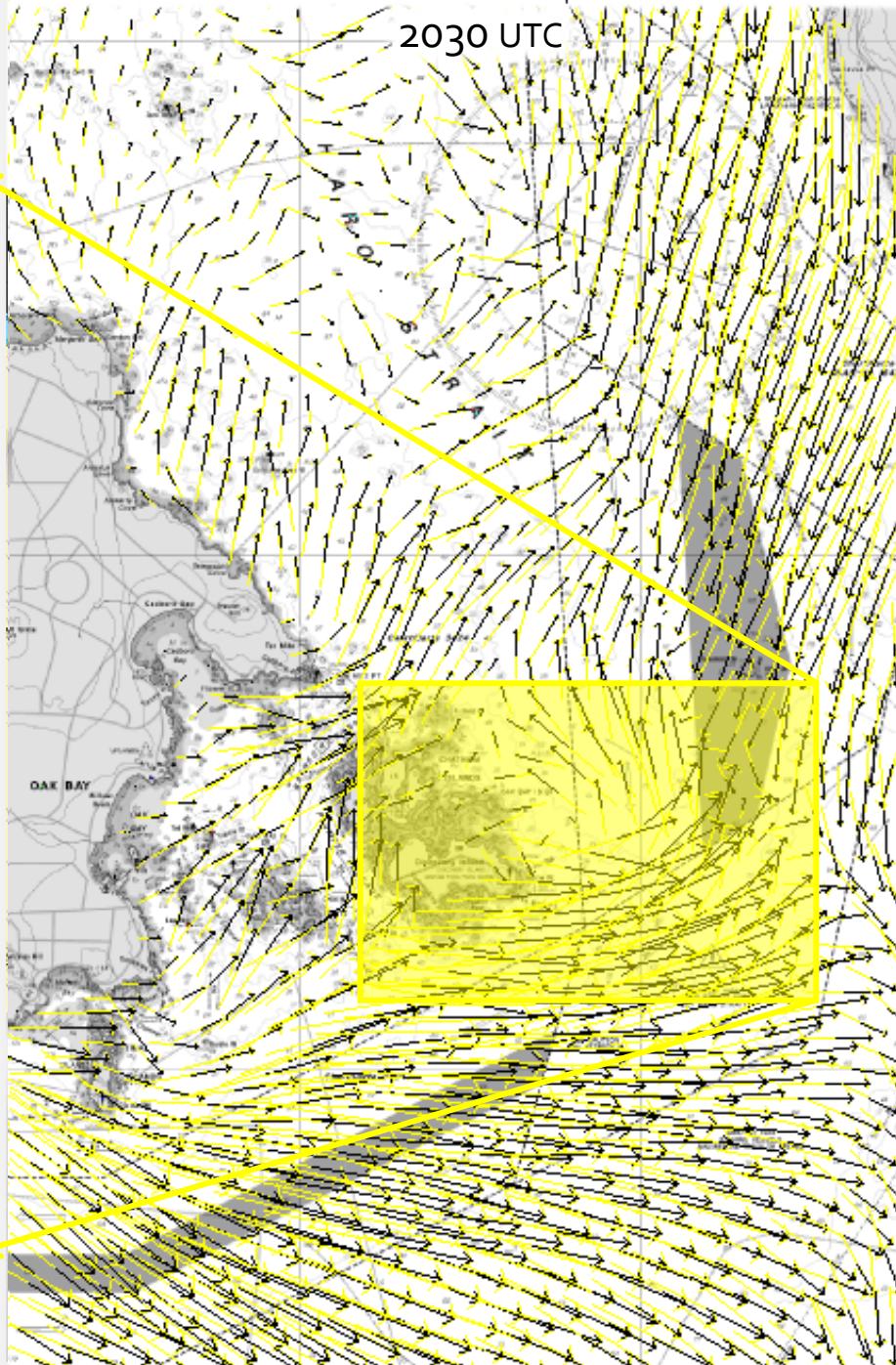


Delineating a Pronounced Tidal Front



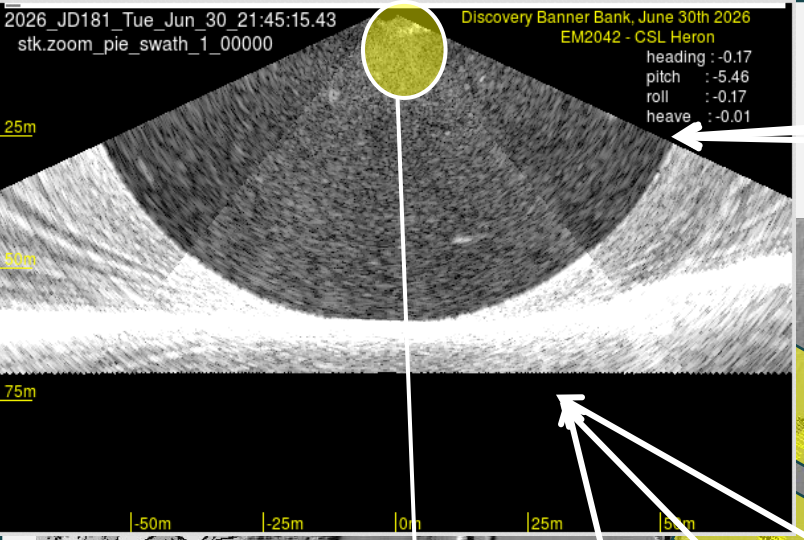


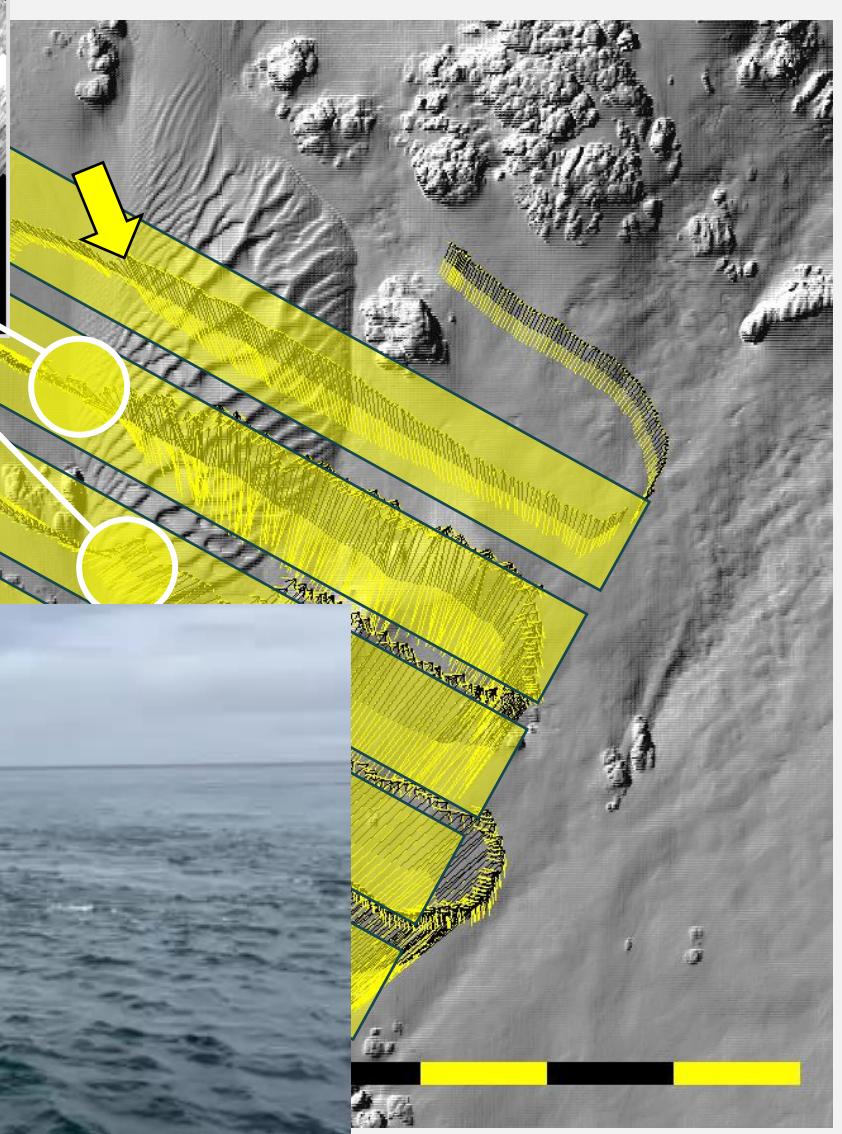
Surface Currents: UBC SalishSeaCast Operational Forecast Model

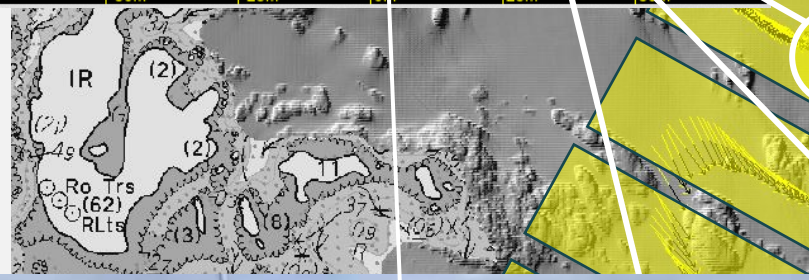


ADCP & WCD Imaging

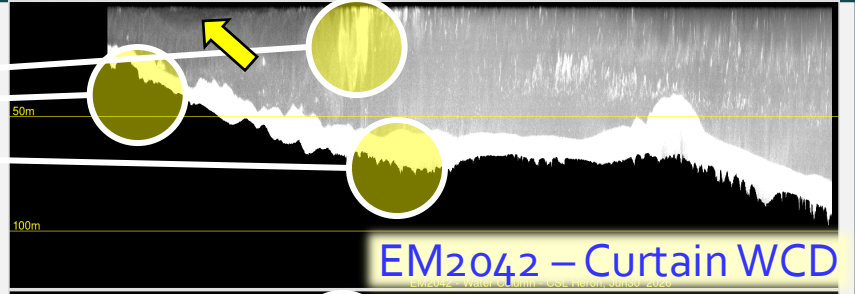
Observations



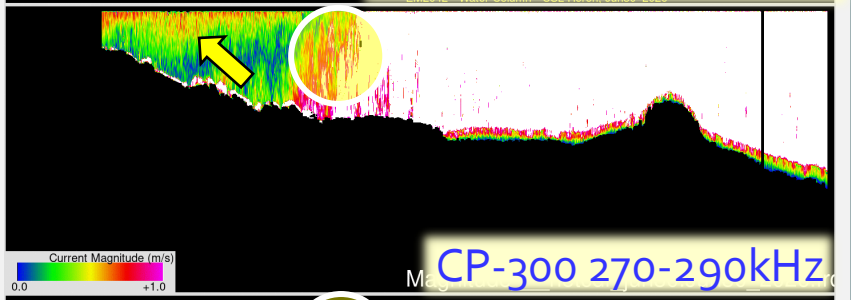




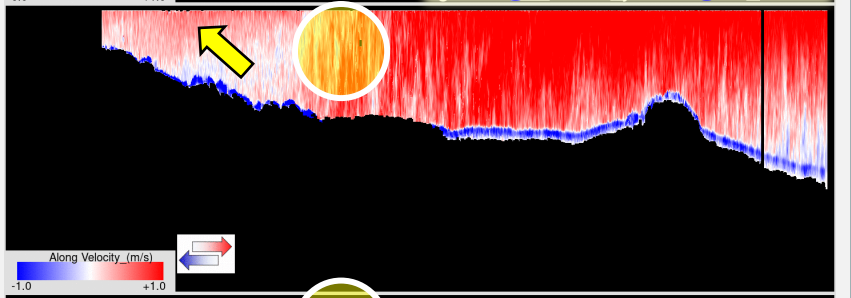


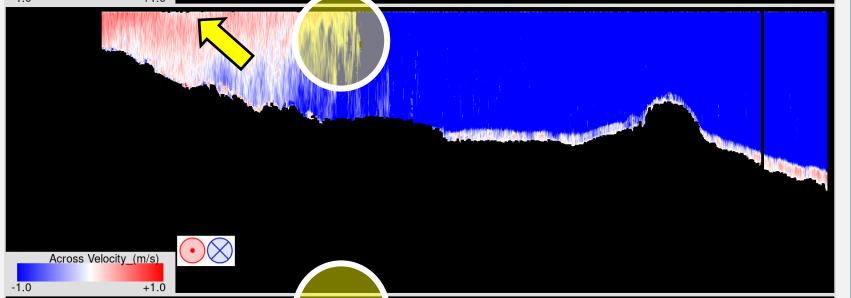


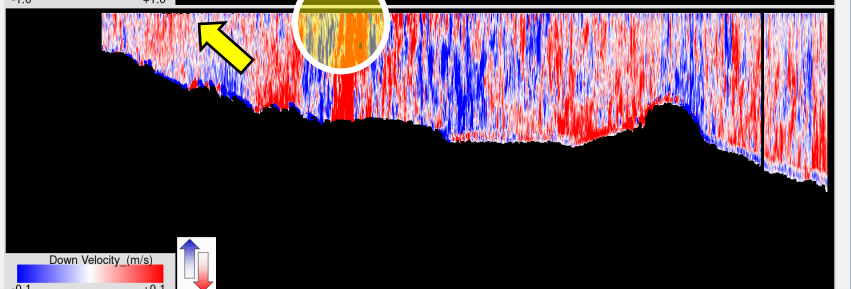
EM2042 – Curtain WCD



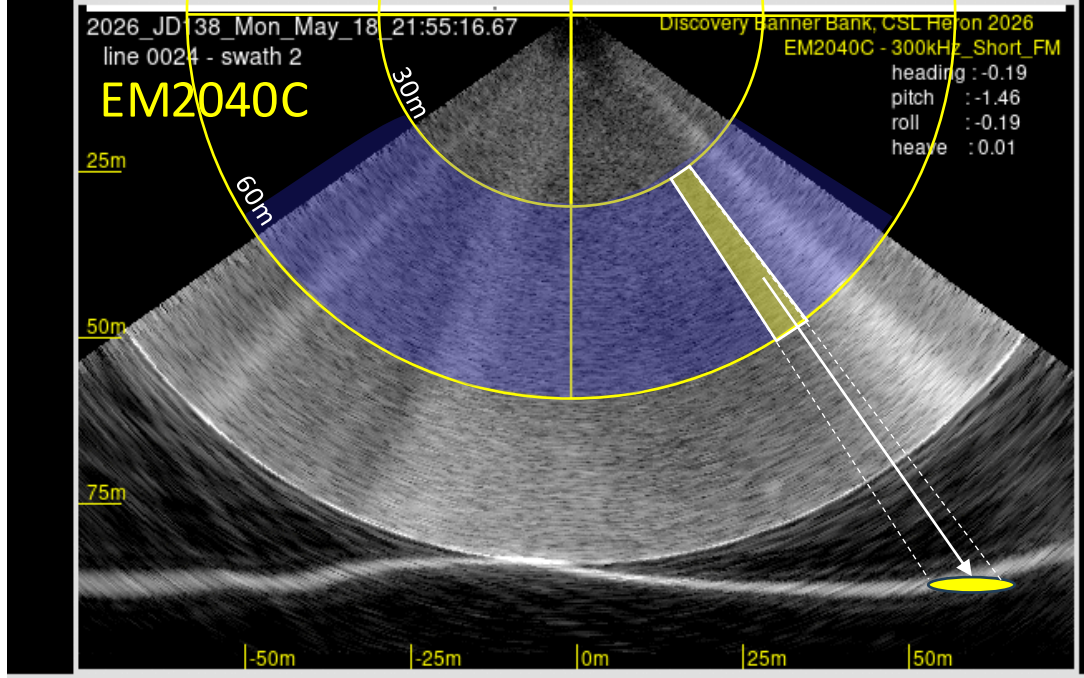
CP-300 270-290kHz

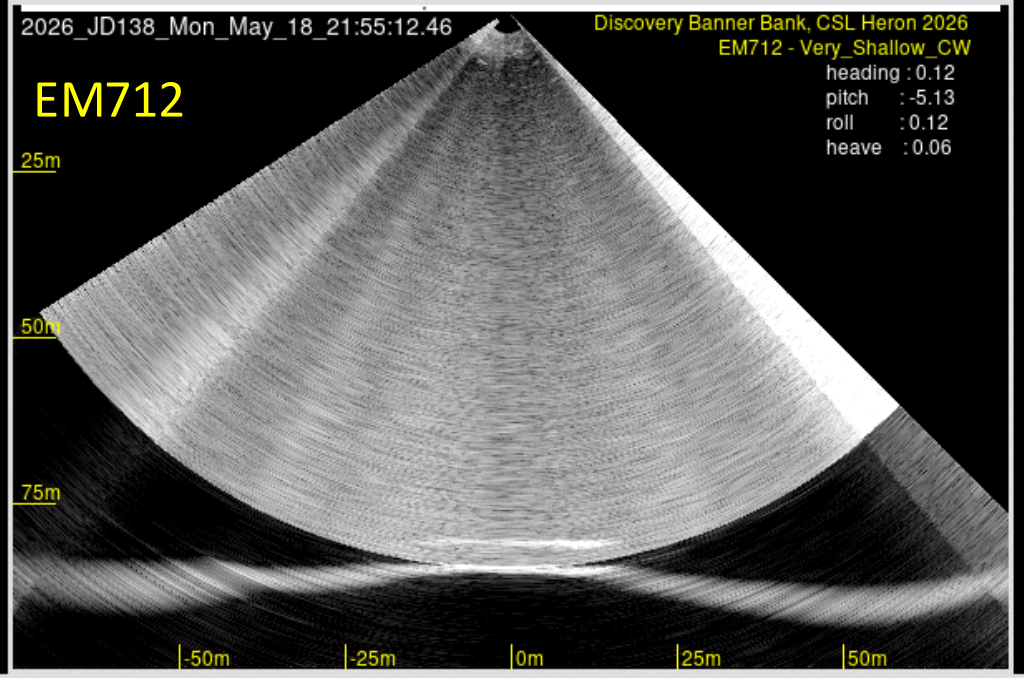


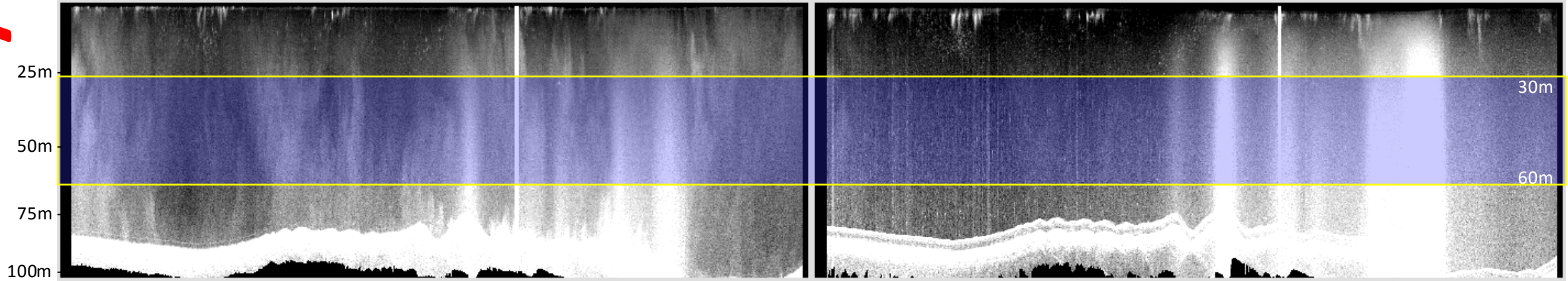


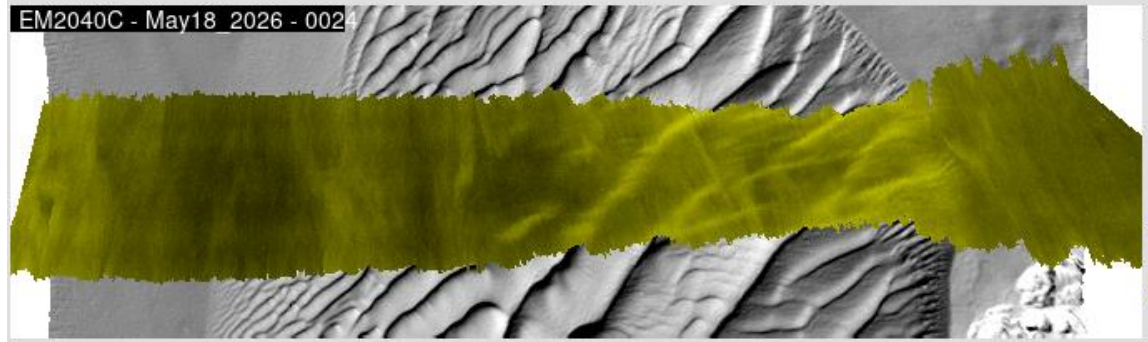


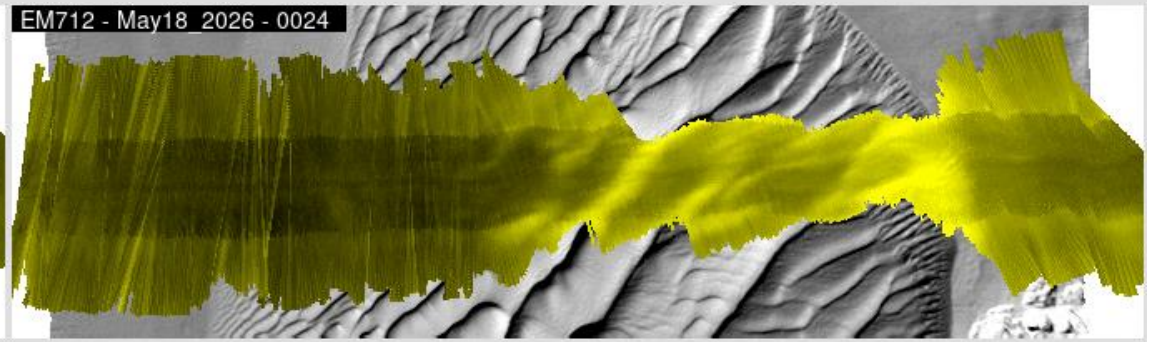
ACTIVE







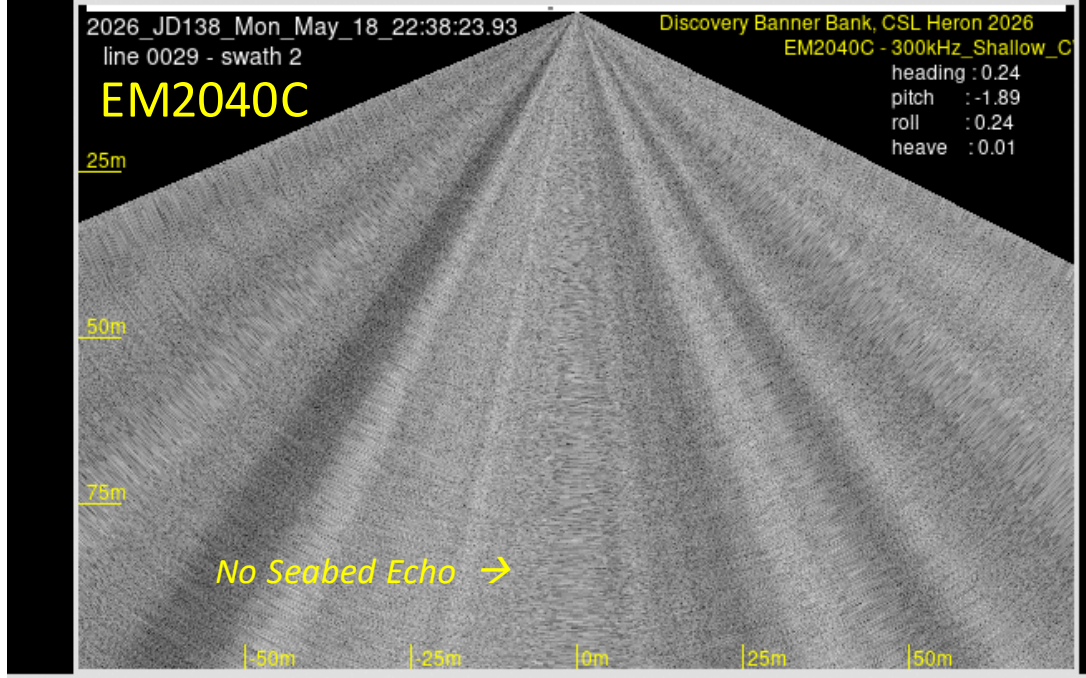


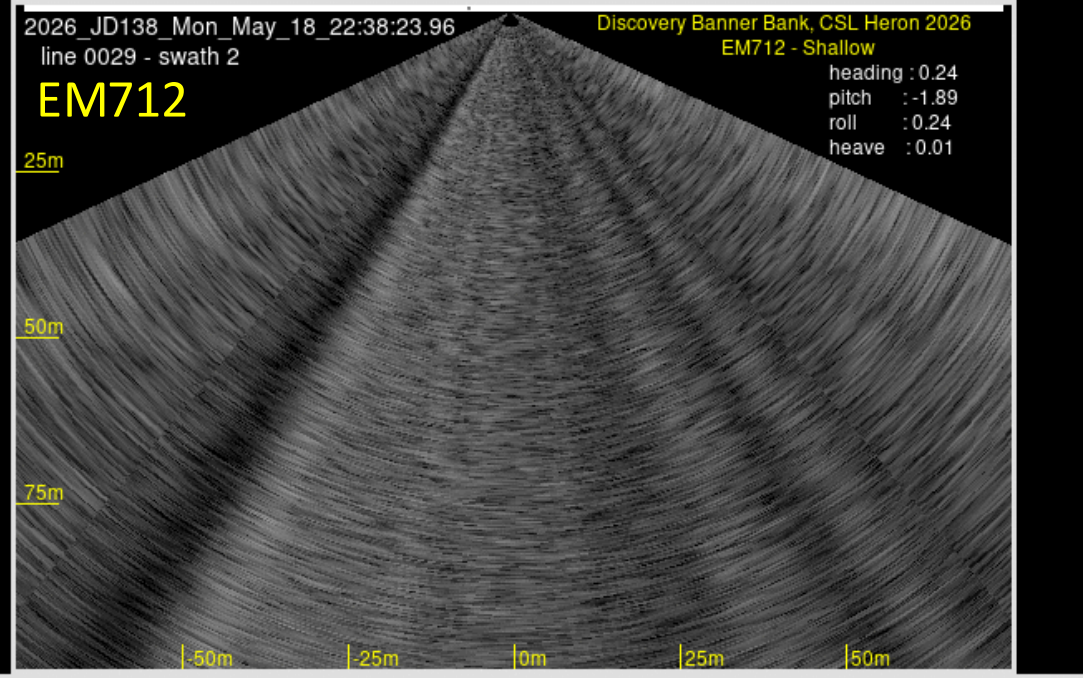


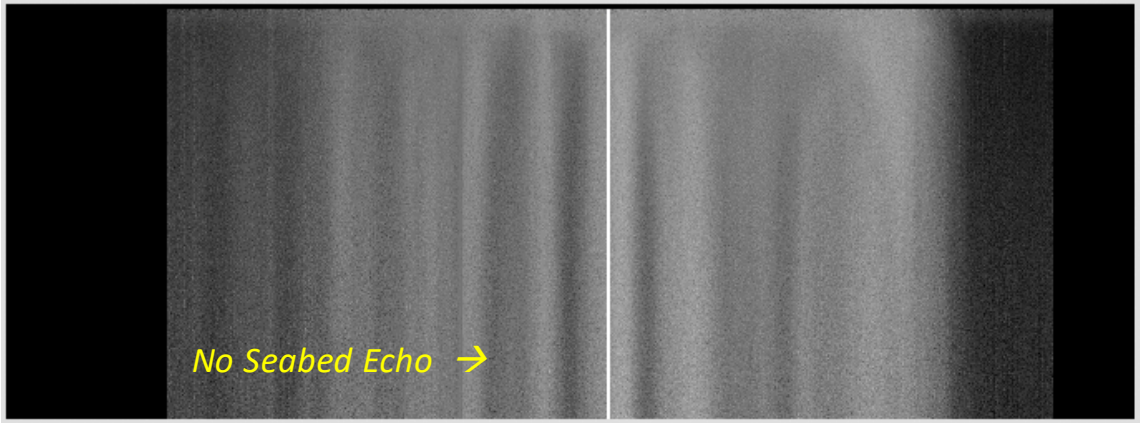
Radial Banded Noise

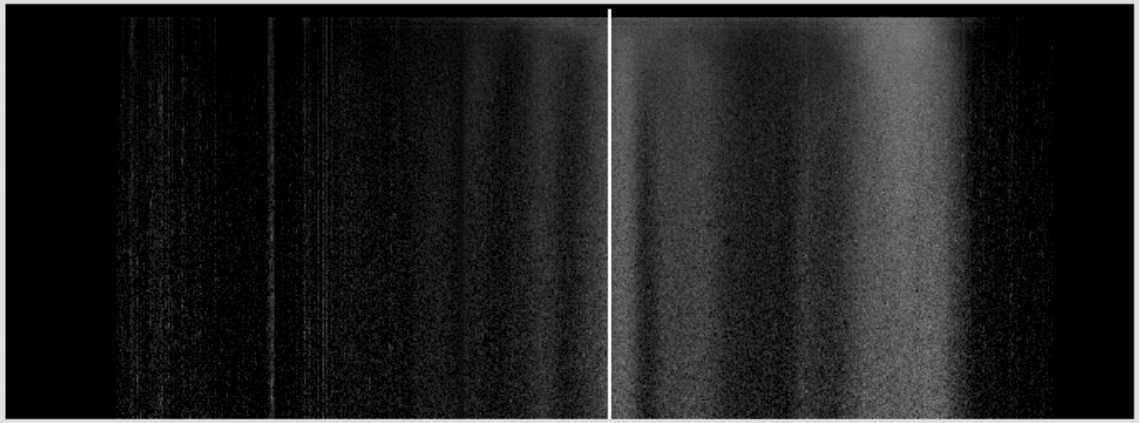
back-projected onto the seabed

PASSIVE

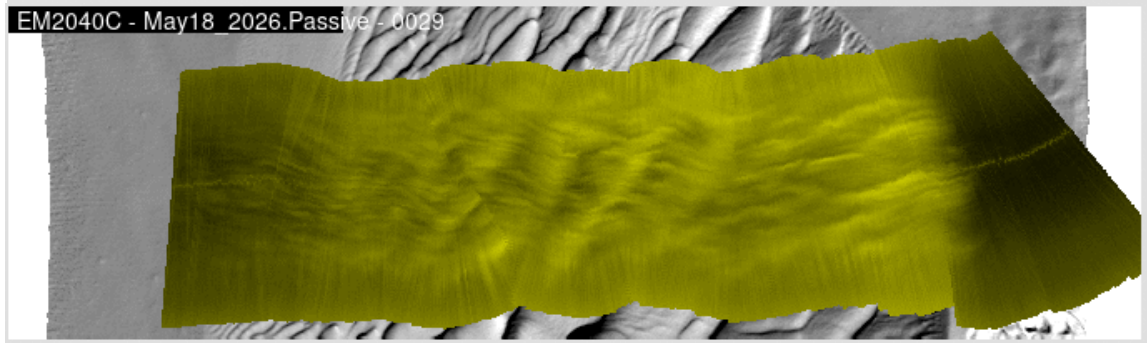


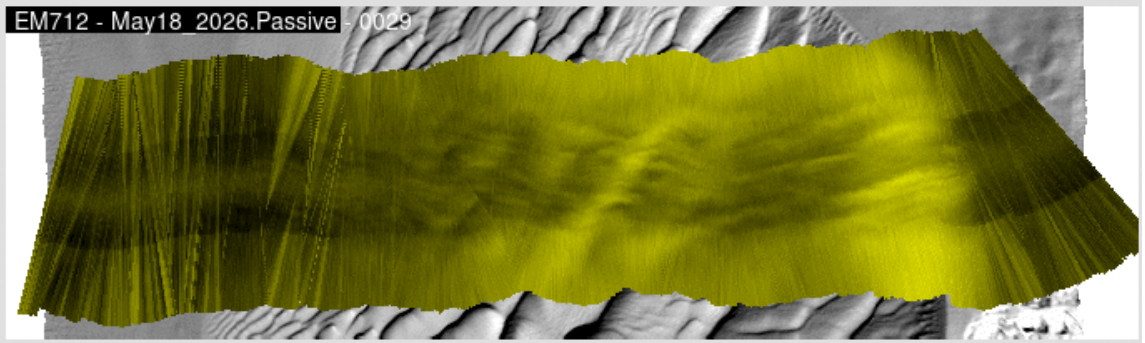




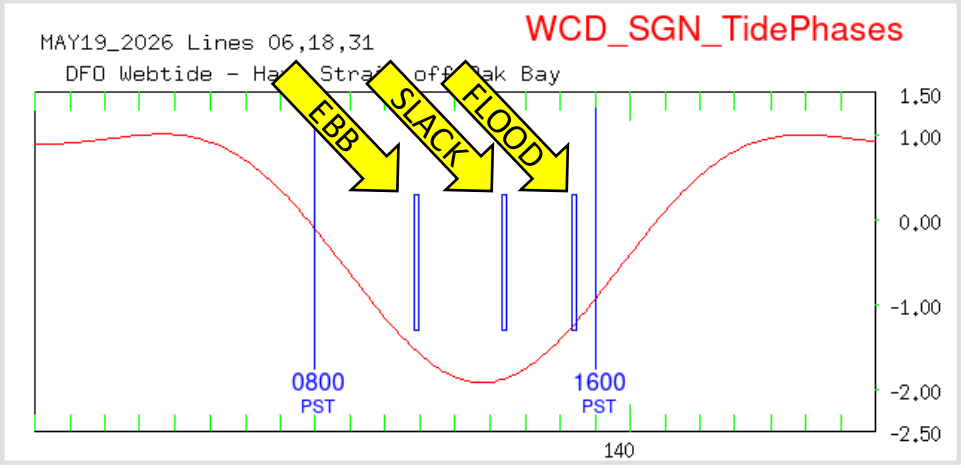


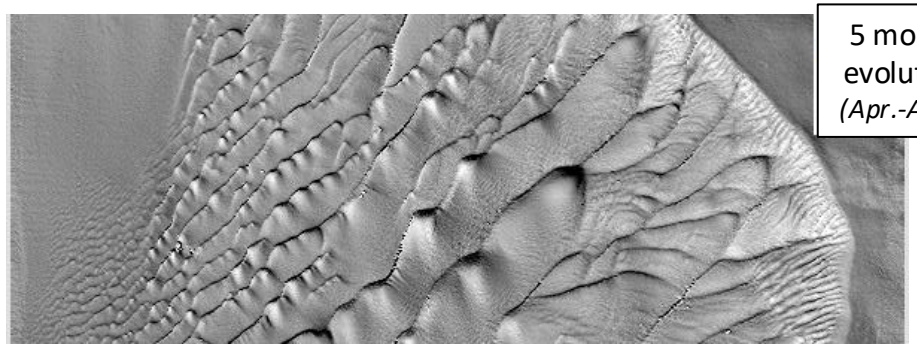
Radial Banded Noise
back-projected onto the seabed





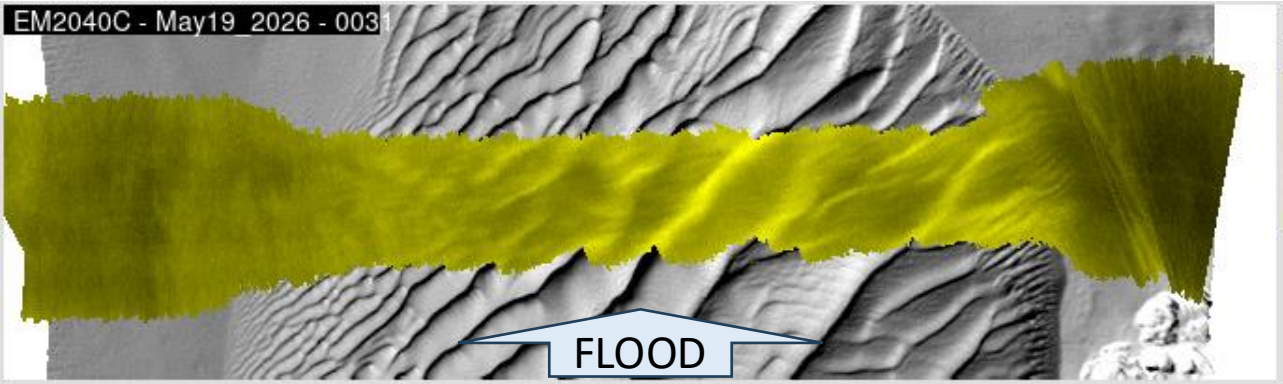
Pattern of Seabed **Sediment Generated Noise** Changes *with phase of Tide*

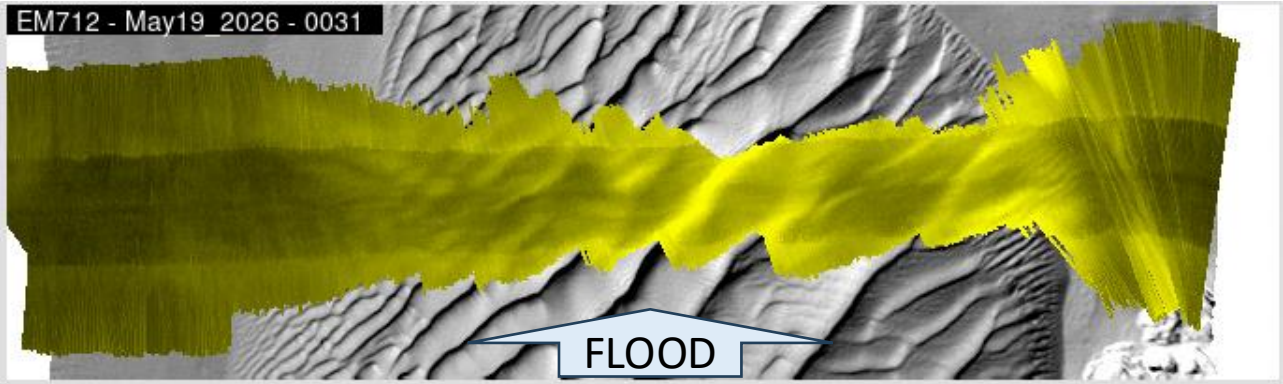


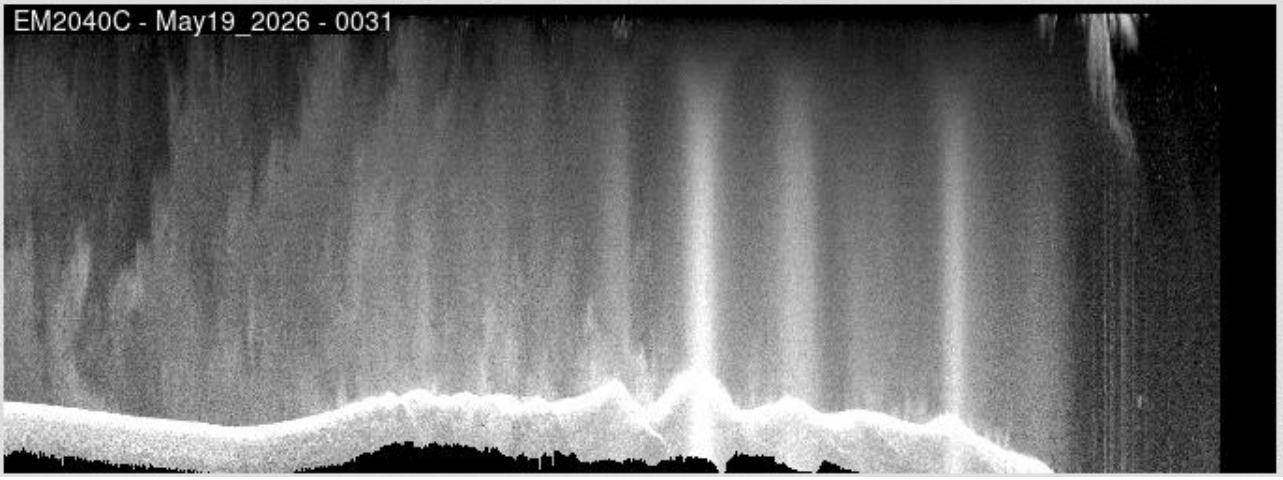


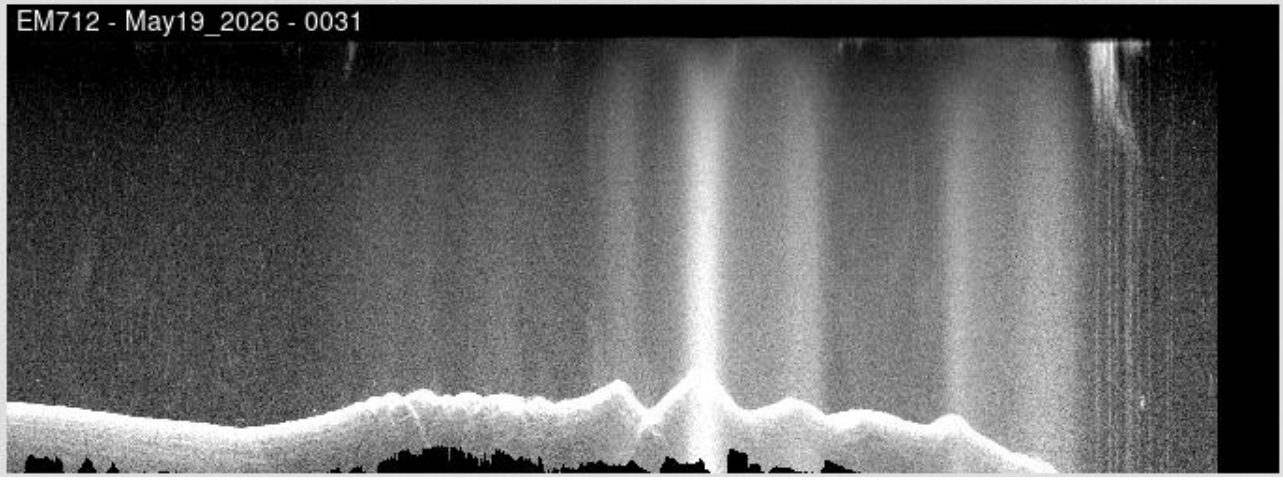
5 month evolution *(Apr.-Aug.)*

EM2040C – 250-350 kHz

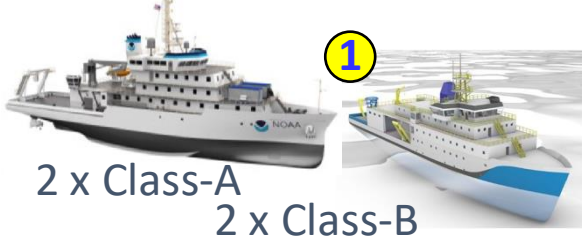


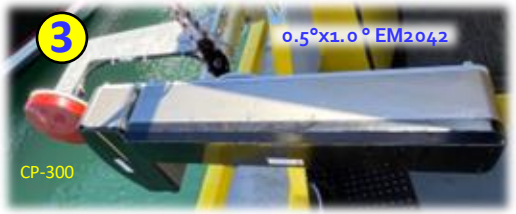


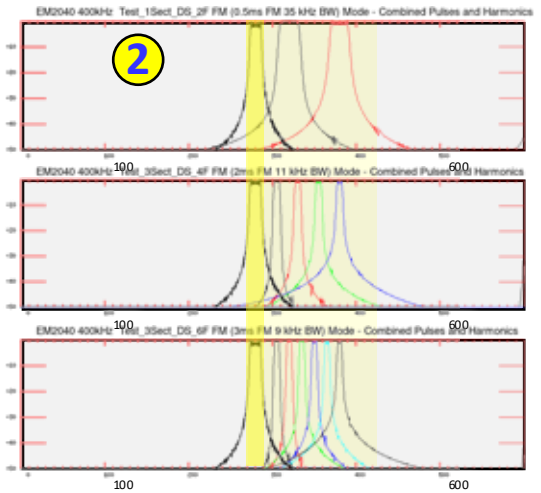


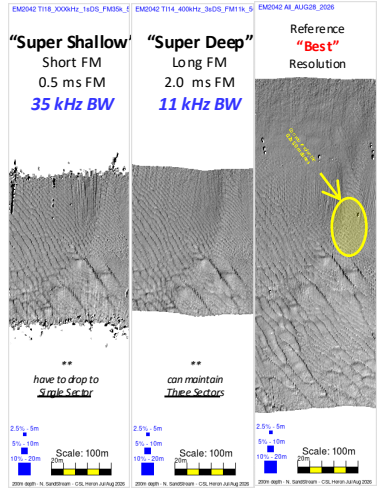


SUMMARY



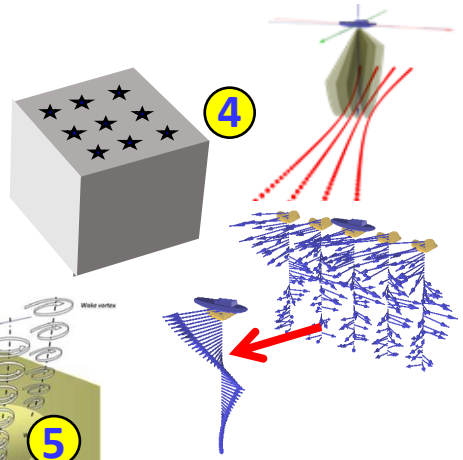






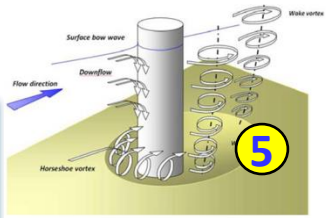
Optimal Multi-Sensor Configurations

1 - National Multi-Mission Vessels
2 - Improved EM Range-Resolution Performance
3 - Managed CP-300 EM2042 interference
4 - to maintain along-track density.



Relevance to Shelf Infrastructure

5 - Wind Farms
6 - Tidal Power

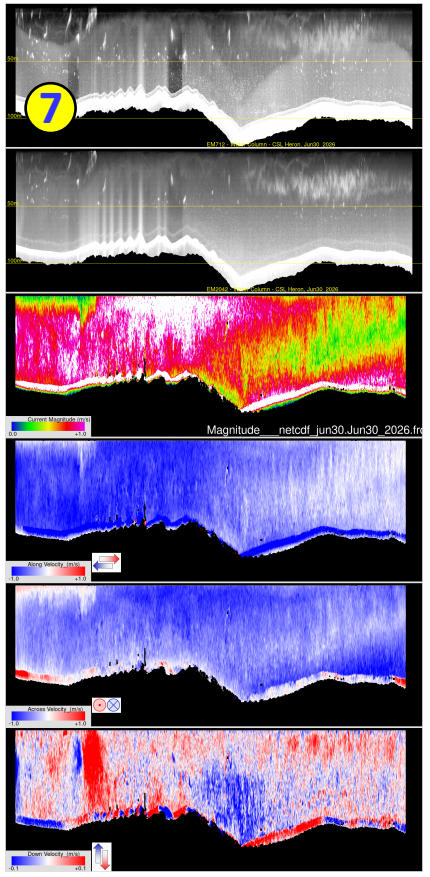


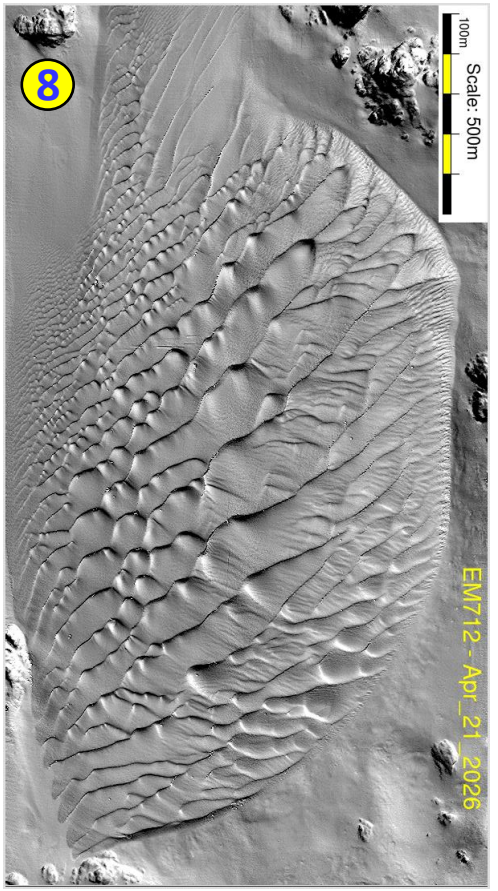


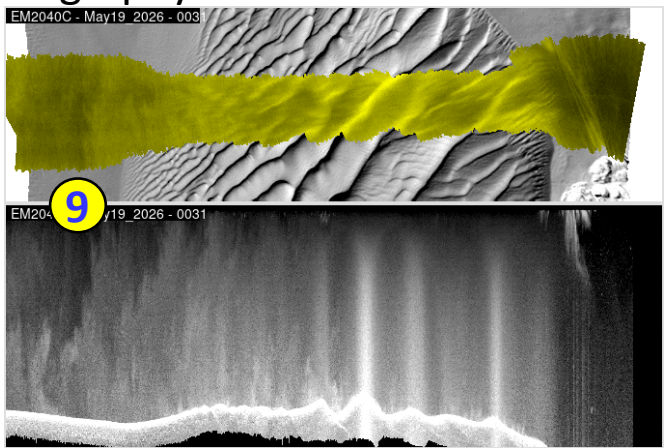
Questions

Scientific Insight into coupled

7 - Tidally-Modulated Estuarine Oceanography
(sound speed variability)
8 - Seabed Sediment Transport
(seabed resurvey requirements)







Serendipitous Insights:

9 - Sediment-Generated Noise
I almost actually believe it….!