



Università di Trieste
Corso di Laurea in Geologia

Anno accademico 2020 - 2021

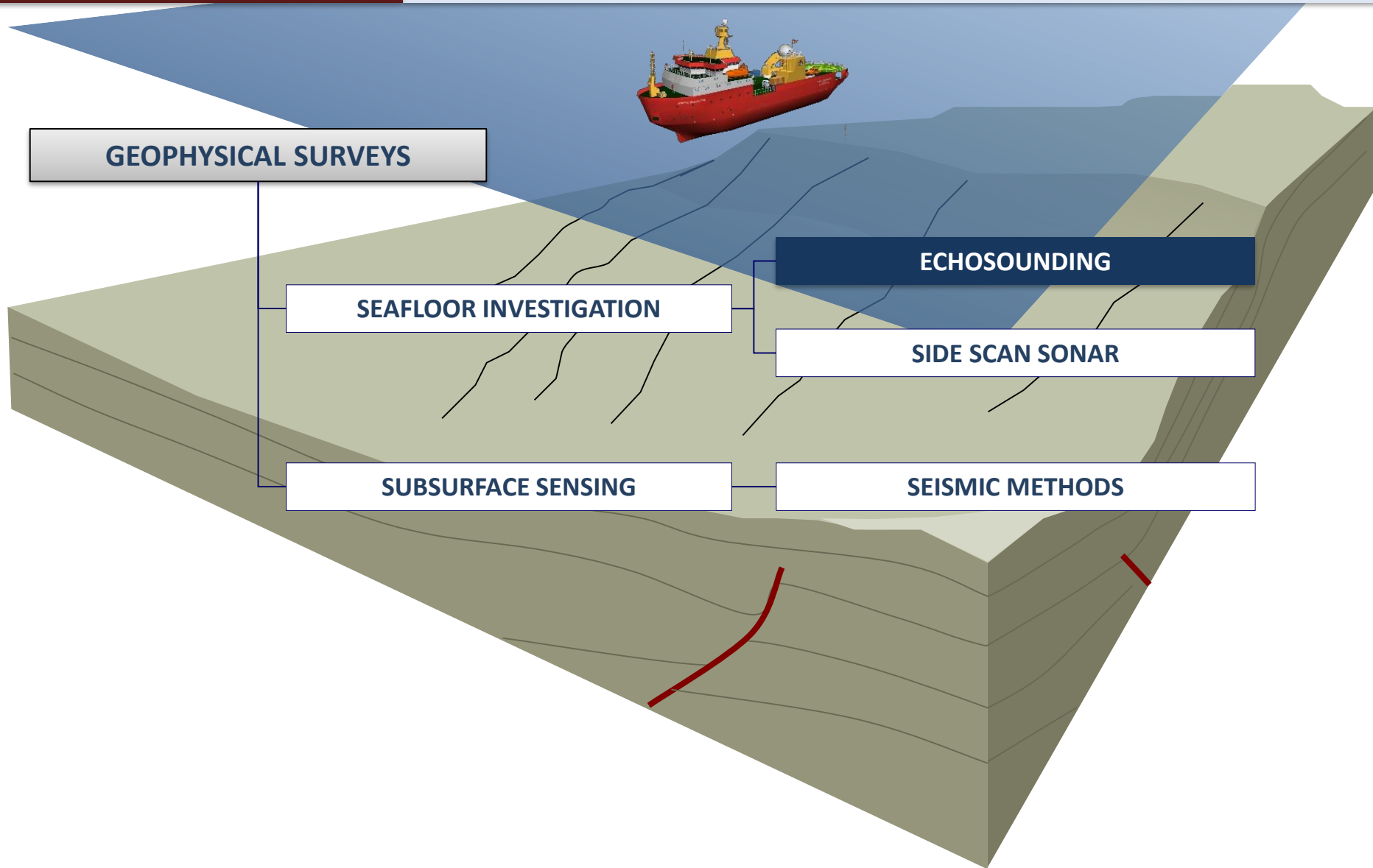
Geologia Marina

Parte I

Modulo 2.1 Multibeam Echosounders

Docente

Fabrizio Zgur

MULTIBEAM ECHOSOUNDER**OVERVIEW**

MULTIBEAM ECHOSOUNDER

OVERVIEW

IT IS USED FOR

Morphobatymetry surveys aim at mapping the seafloor with large areal coverage. The result is a 3D **D**igital **T**errain **M**odel (**DTM**) mad up of a grid of cells whose size depends on the resolution.

HOW IT WORKS

Multibeam echosounders use transducers that produce a fan of pre-formed beams. The fan can vary from 45° to up to 150° depending on the unit. The returns from these beams can be processed with GPS position information and ship motion compensation to give bathymetry as well as the backscatter information that is obtained by conventional sidescans. A single ship's track can map a swath between 2 and 7.4 times water depth, depending on the system. Beam widths fore and aft vary between 1.5° and 4.5° depending on the system.

MULTIBEAM ECHOSOUNDER

USES AND OBJECTIVES

ENVIRONMENT AND SOCIETY

Navigation charts

- Bathymetric surveys
- Pre / Post dredge surveys
- Breakwaters, piers, bridges
- Harbor and rivers surveys
- flood damage assessment
- Underwater inspections

RESEARCH

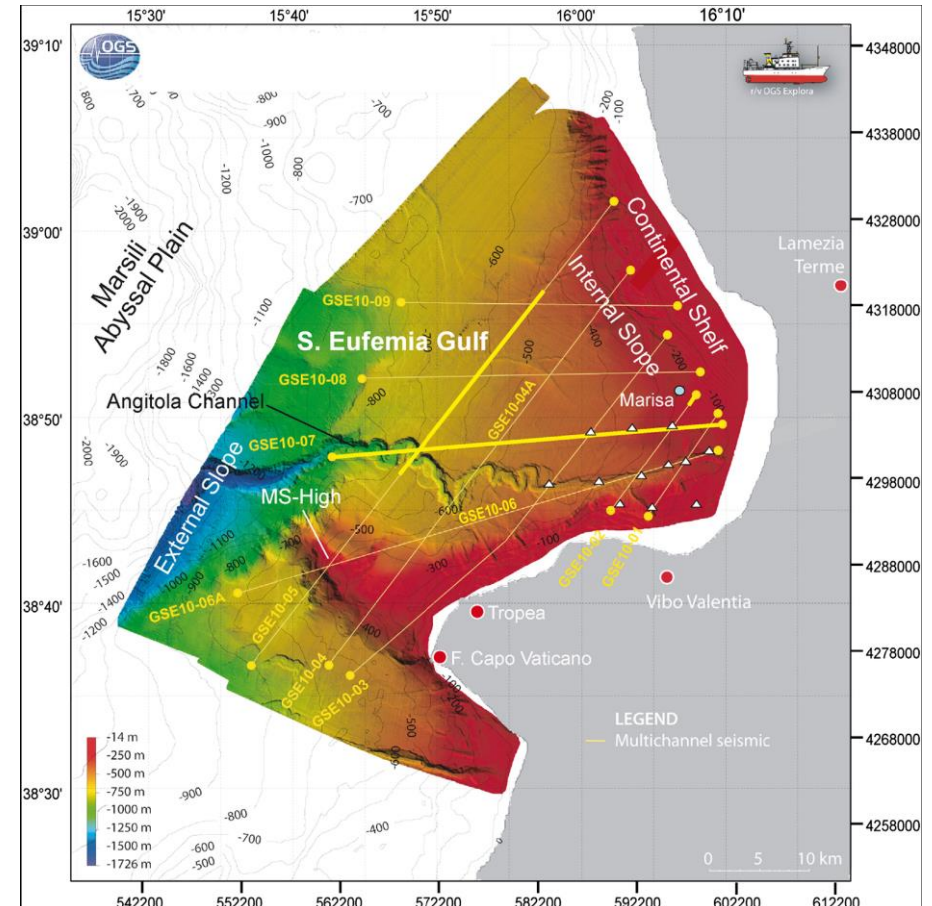
Marine Geology and Biology

- Geomorphology
- Geo hazard (slope stability)
- Fluid escapes (water column)
- Neotectonic related surface expressions
- Study of benthic habitats

INDUSTRY

Foundation studies for offshore infrastructures

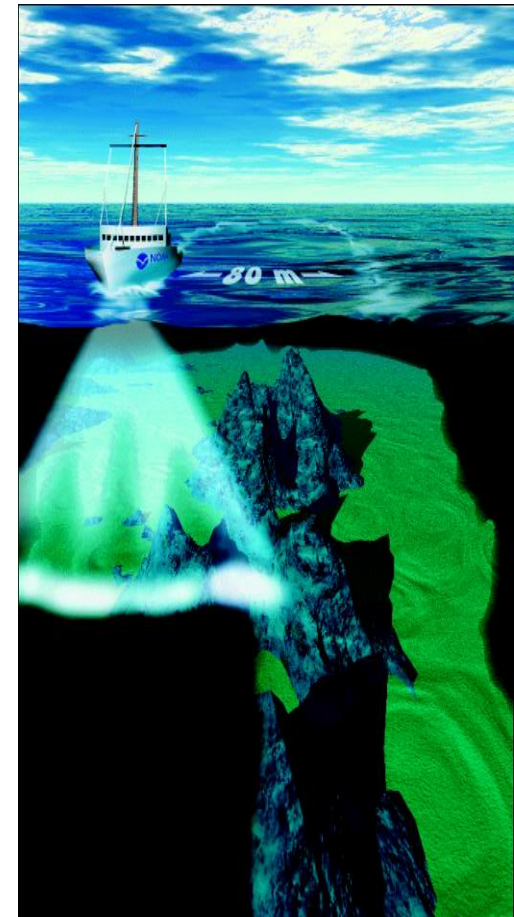
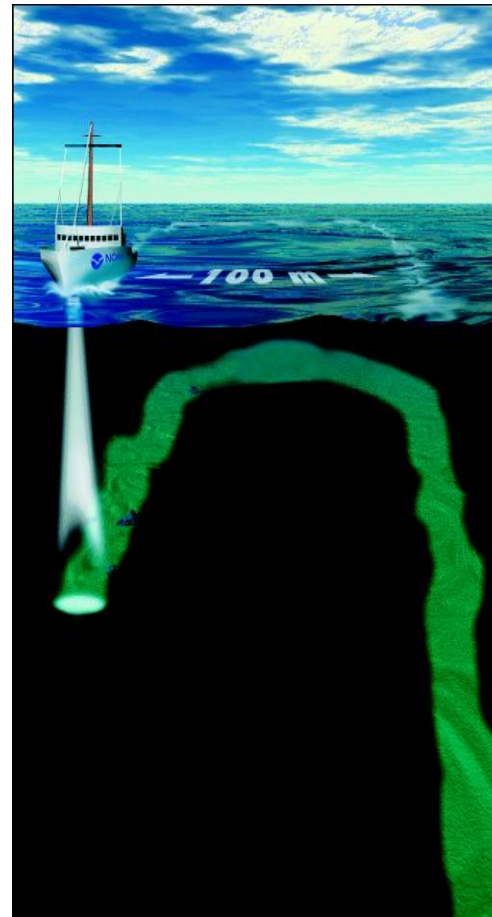
- Cable surveys
- Well site surveys

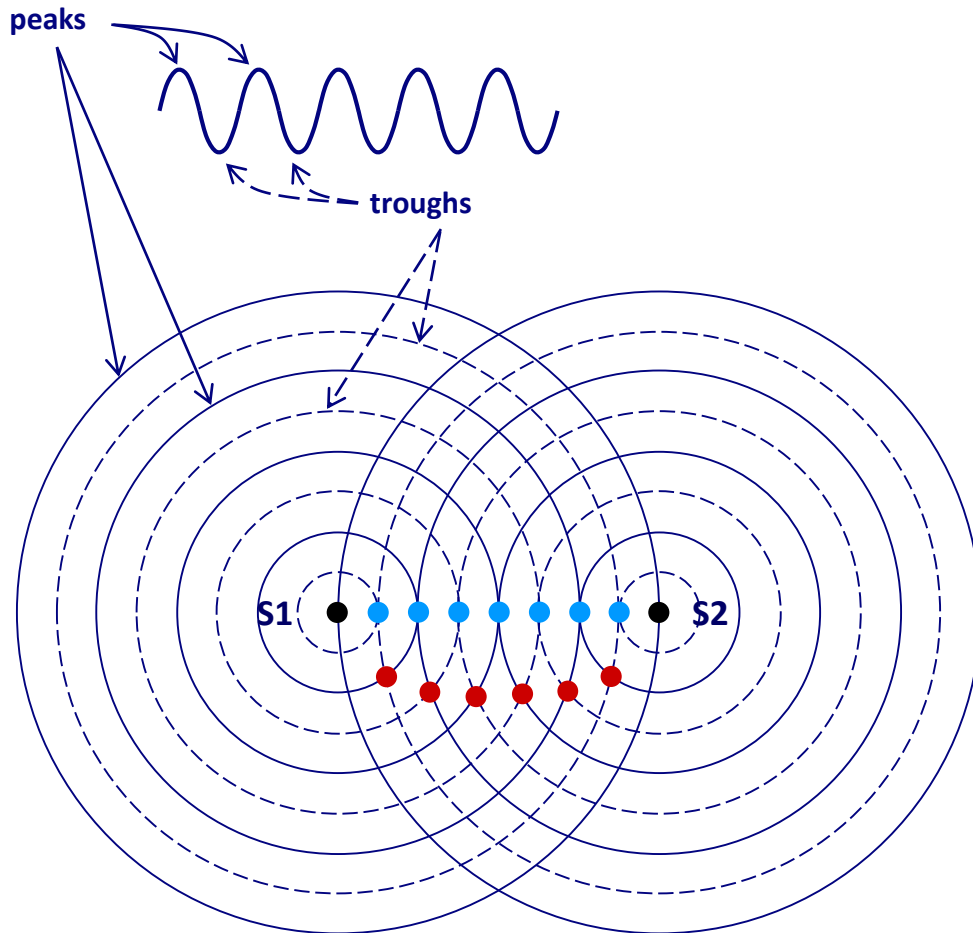
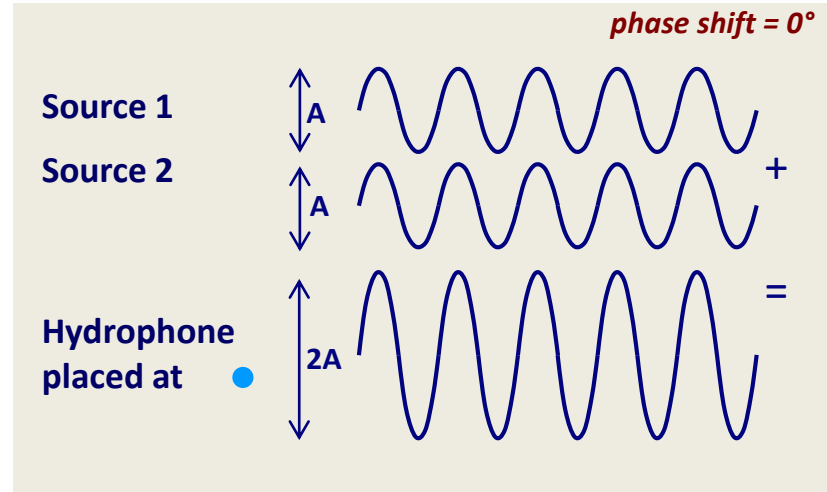
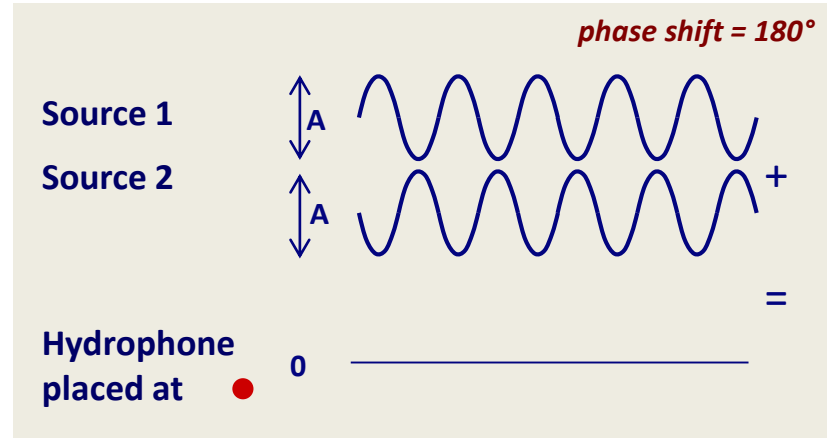


Loreto et al., 2013. Approaching the seismogenic source of the Calabria 8 September 1905 earthquake: New geophysical, geological and biochemical data from the S. Eufemia Gulf (S Italy). *Marine Geology* 343 (2013) 62–75.

MULTIBEAM ECHOSOUNDER**OVERVIEW****ADVANTAGES OF MBES COMPARED TO SBES**

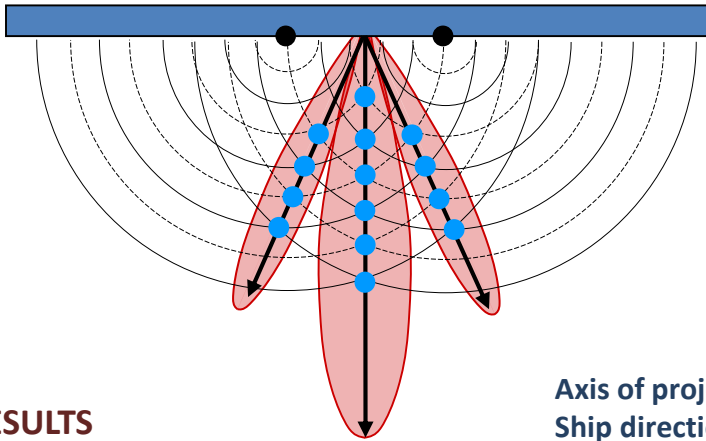
- ➔ Wide profile of depths in a line perpendicular to the ship's direction of travel.
- ➔ Single transmission
- ➔ Multiple receive beams
- ➔ Total ensonification of the bottom possible
- ➔ Wider coverage in deeper water
- ➔ Backscatter imagery for bottom analyses
- ➔ Water column recorded



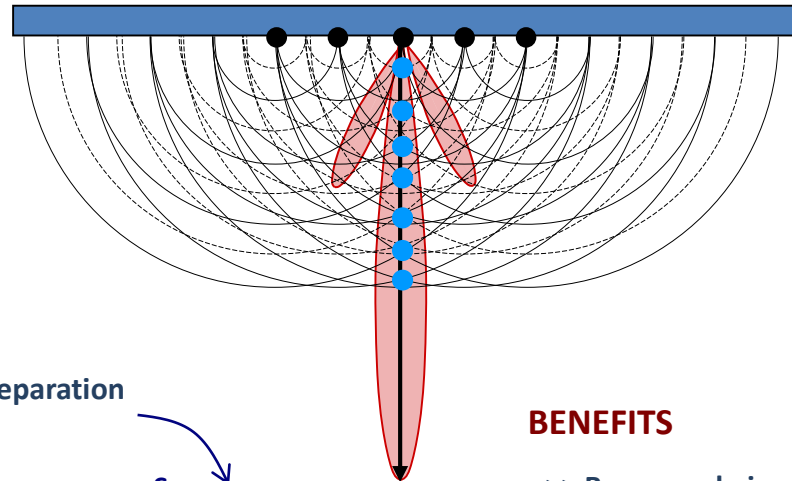
MULTIBEAM ECHOSOUNDER**BEAMFORMING****● CONSTRUCTIVE INTERFERENCE****● DESTRUCTIVE INTERFERENCE**

MULTIBEAM ECHOSOUNDER**BEAMFORMING: PROJECTORS AND RECEIVERS ARRAYS****FLAT ARRAYS**

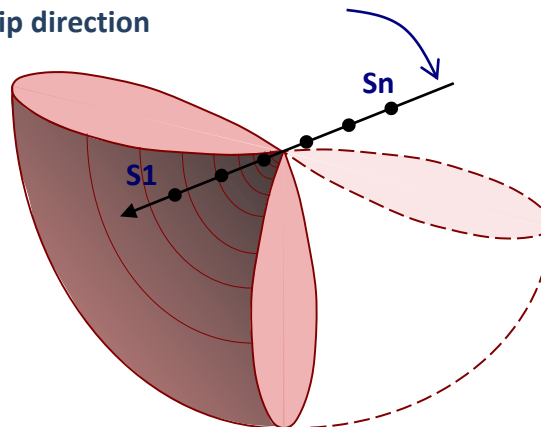
Two sources activated simultaneously



Adding more staves

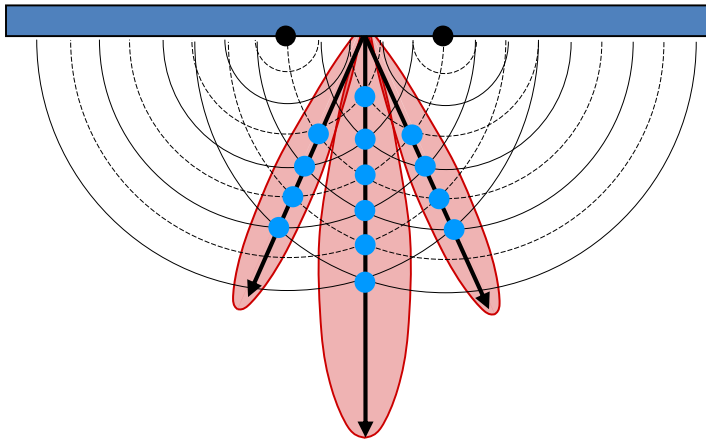
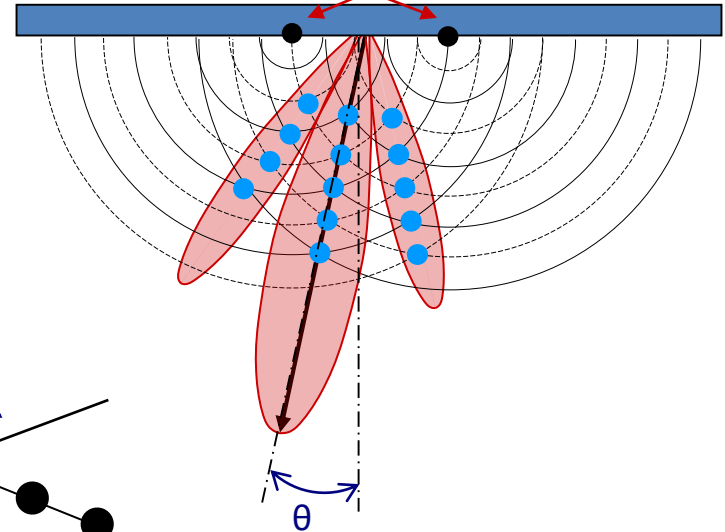
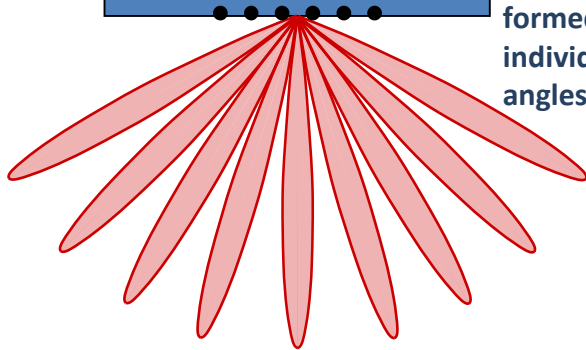
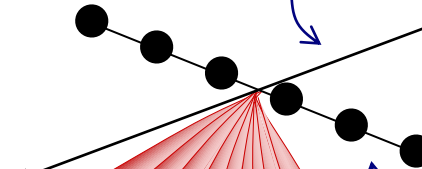
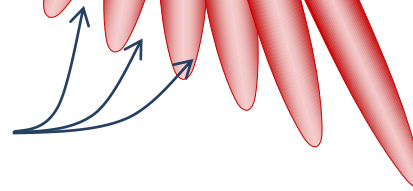
**RESULTS**

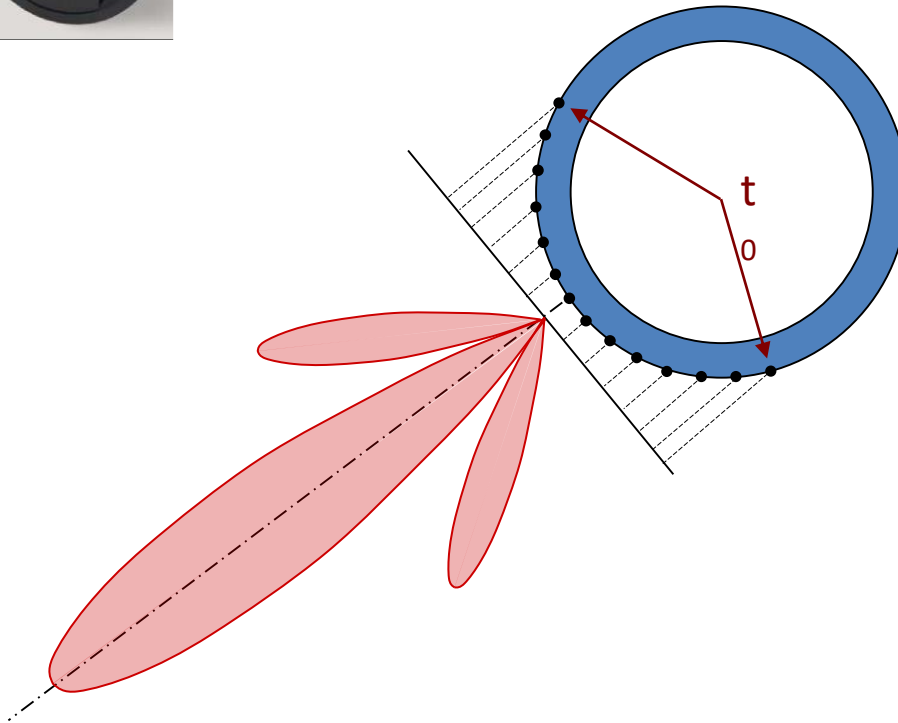
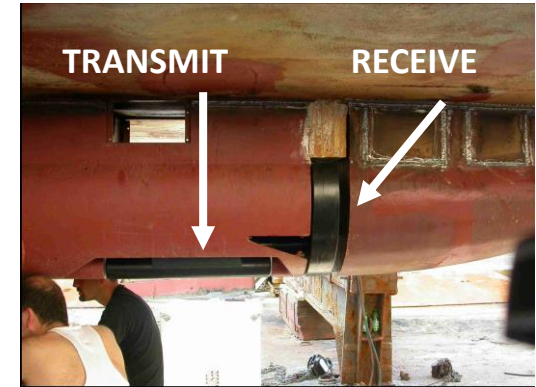
- >> Directivity (90°)
- >> Sidelobes (undesirable side effect)

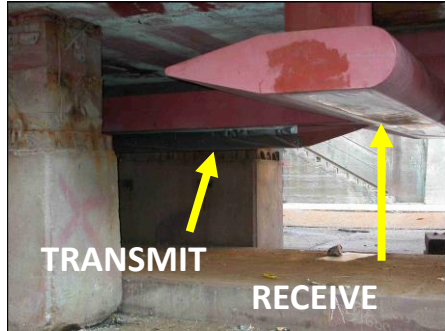
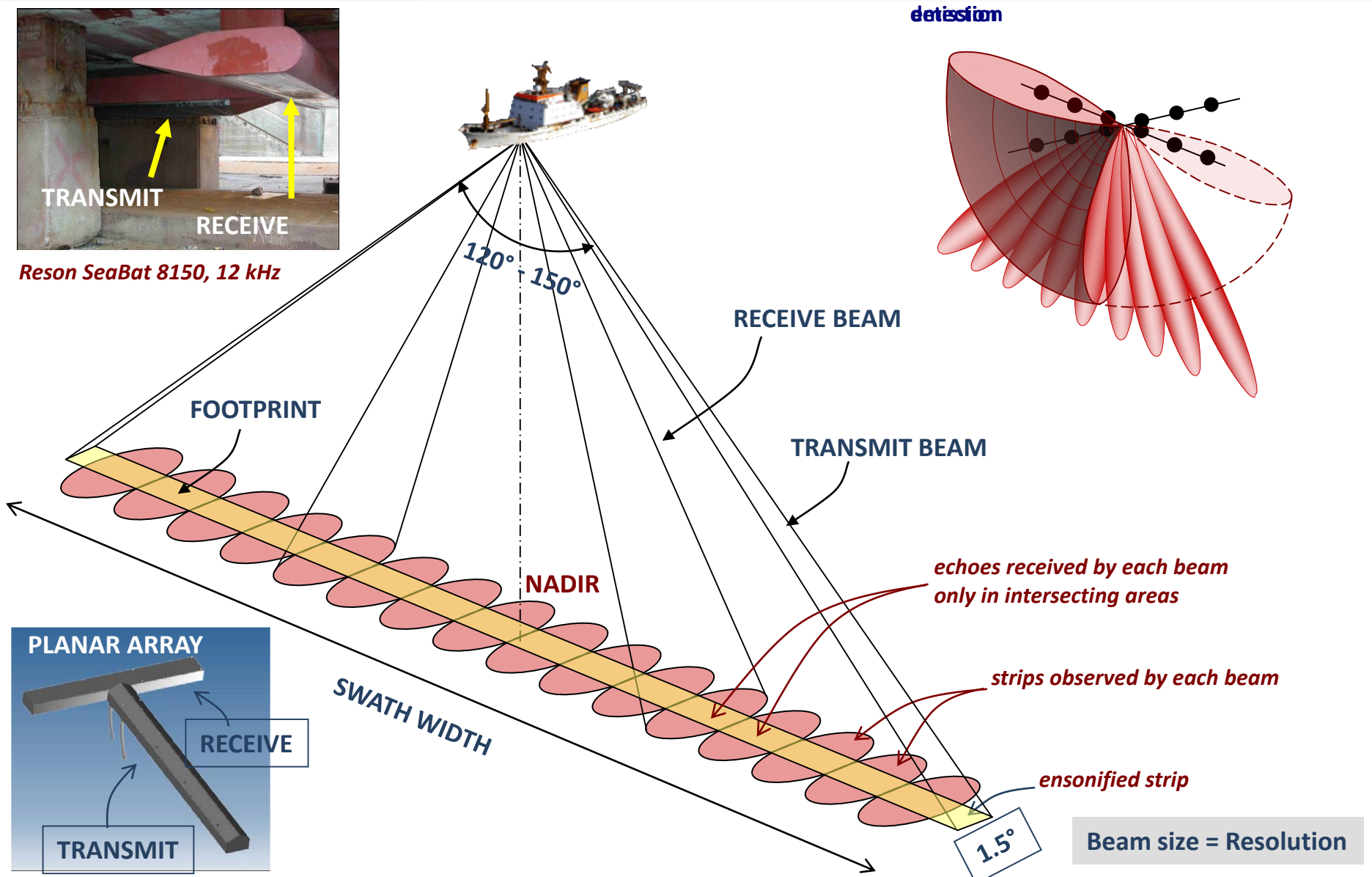
Axis of projector separation
Ship direction**BENEFITS**

- >> Beam angle improvement
- >> Reduced sidelobes
- >> Improved directivity
- >> Narrower beams > HR

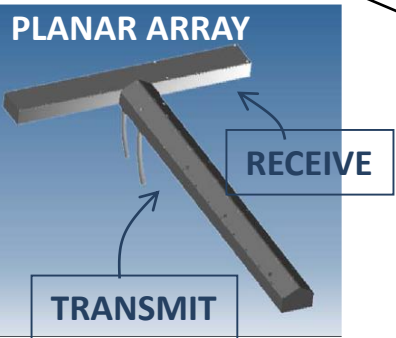
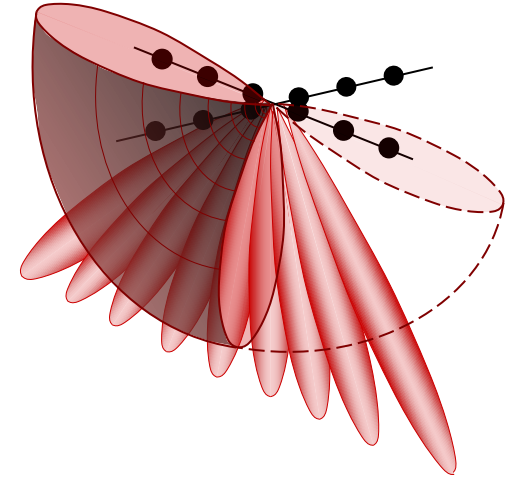
BEAMFORMING APPLIES TO BOTH PROJECTOR AND RECEIVERS ARRAYS

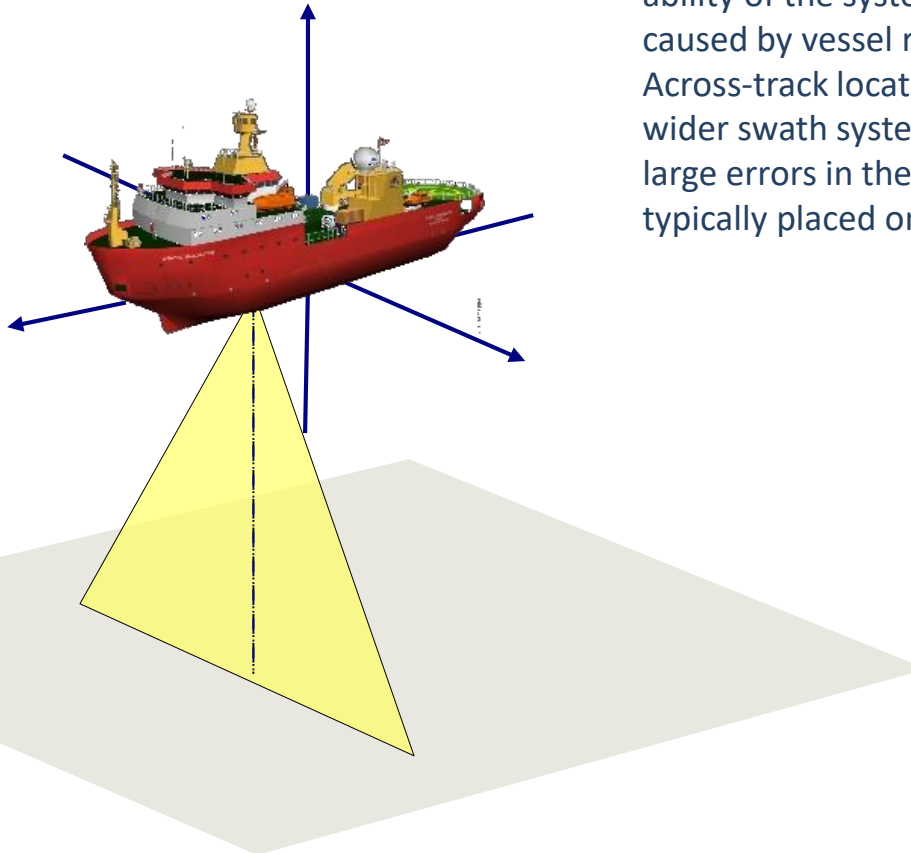
MULTIBEAM ECHOSOUNDER**BEAM STEERING: RECEIVERS ARRAYS****FLAT ARRAYS****Two sources activated simultaneously****Phase shift (time delay) between staves****R1** **Rn****Multiple simultaneously formed beams at individual steering angles****Ship direction****Receiver array Axis****Receive beams**

MULTIBEAM ECHOSOUNDER**BEAM STEERING: RECEIVERS ARRAYS****CURVED ARRAYS****HULL MOUNTED***Reson SeaBat 8111, 100 kHz***PORTABLE**

MULTIBEAM ECHOSOUNDER**THE T CONFIGURATION***Reson SeaBat 8150, 12 kHz*

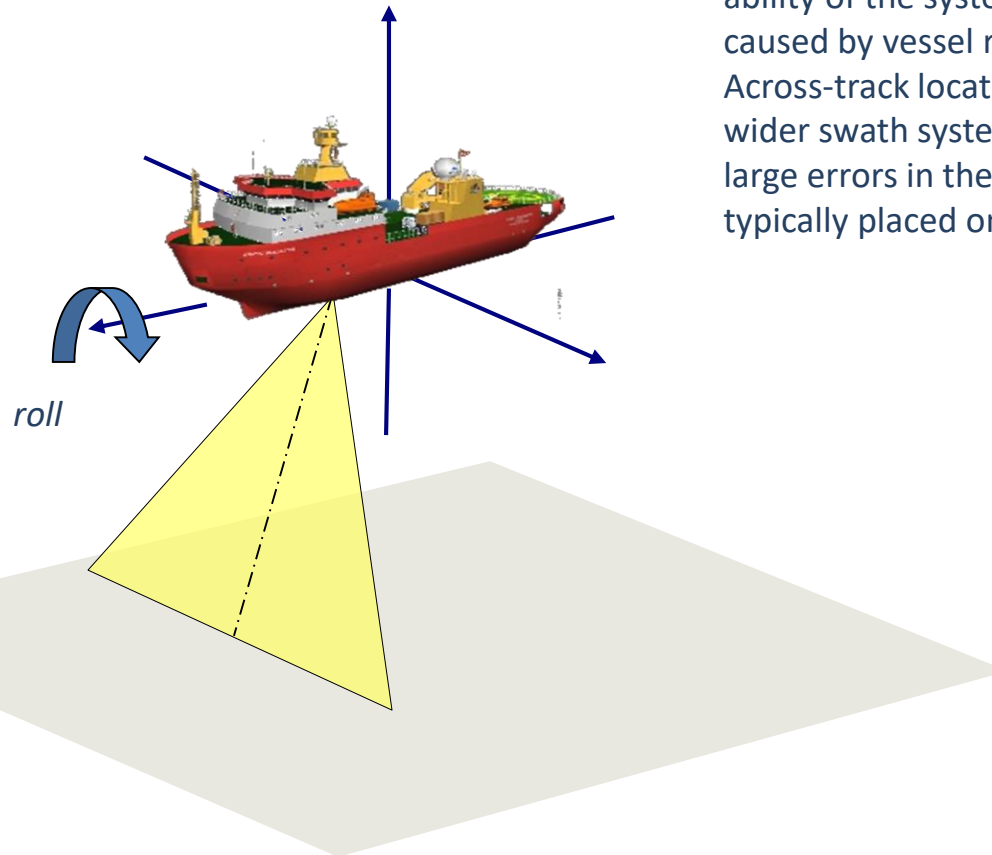
detection



MULTIBEAM ECHOSOUNDER**MOTION COMPENSATION****DYNAMIC CORRECTIONS**

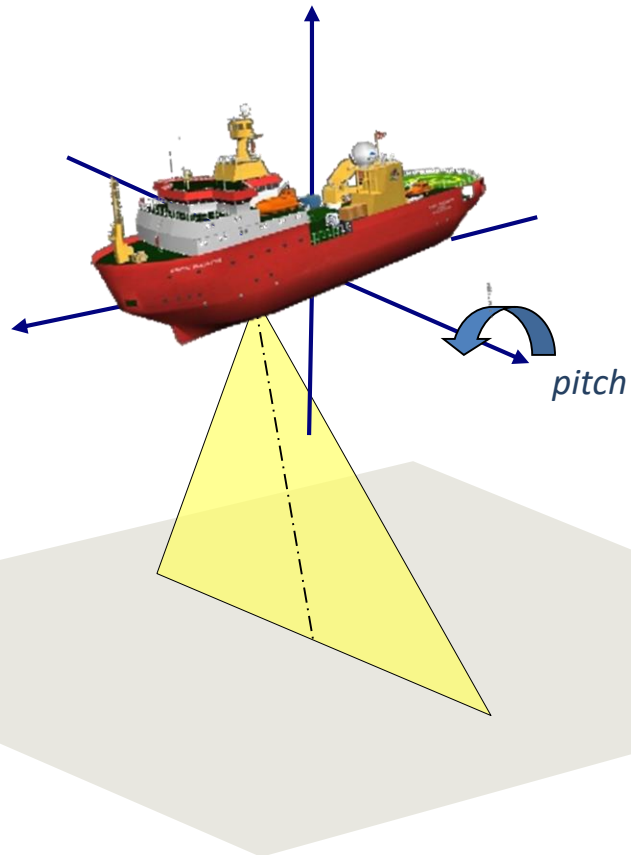
Horizontal positioning accuracy is dependent upon the ability of the system to compensate for pointing errors caused by vessel roll, pitch, and yaw. Across-track location of each bottom point is critical. In wider swath systems, even a small degree of roll can cause large errors in the outer beams; thus restrictions are typically placed on use of outer beam data.

Roll**Pitch****Yaw****Heave****Positioning****Transducer mount**

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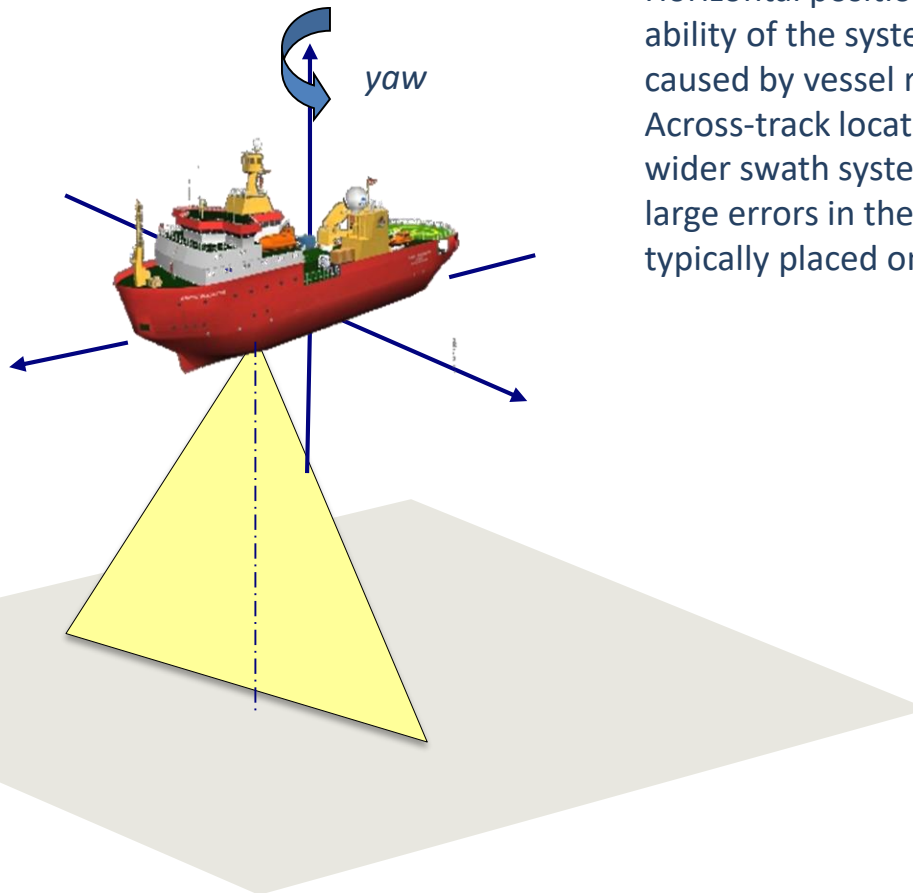
Roll**Pitch****Yaw****Heave****Positioning****Transducer mount**

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Roll

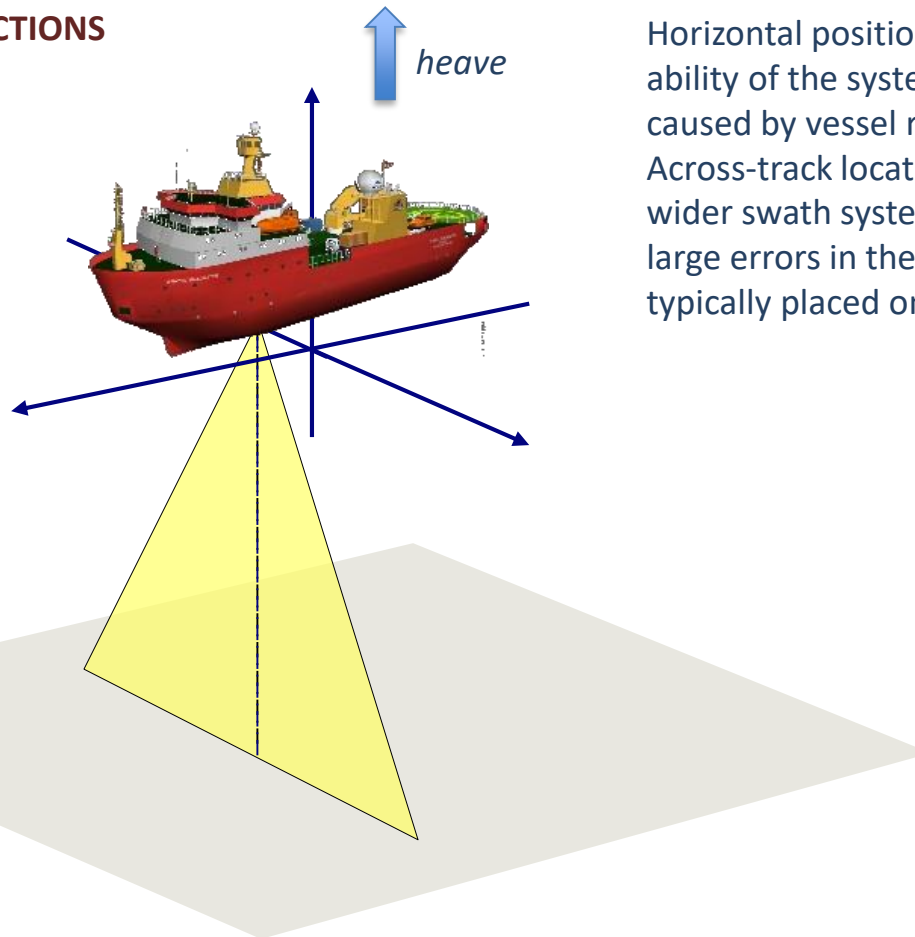
Pitch

Yaw

Heave

Positioning

Transducer mount

MULTIBEAM ECHOSOUNDER**MOTION COMPENSATION****DYNAMIC CORRECTIONS**

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Roll

Pitch

Yaw

Heave

Positioning

Transducer mount

MULTIBEAM ECHOSOUNDER**SOUND VELOCITY**

Sound velocity can vary considerably from point to point in the ocean

Vs is dependent on three main factors:

SALINITY

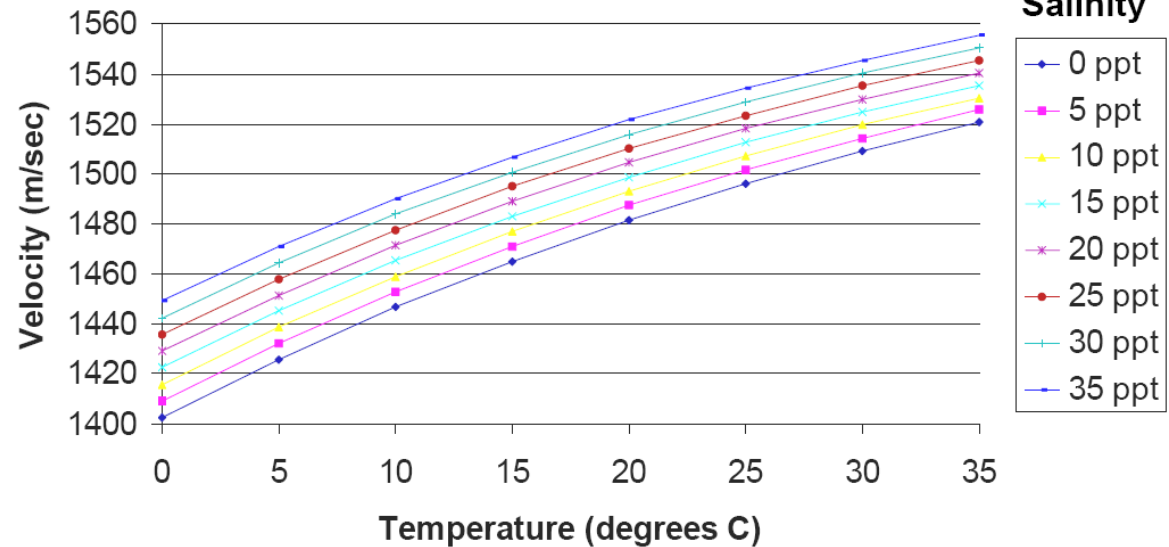
- Ranges from 32 - 38ppt (parts per thousand)
- A change in salinity causes a density variation which changes the sound propagation velocity
- Varies geographically (Baltic 7ppt, Dead Sea 300 ppt)
- Change of 1ppt = approx 1.3m/s velocity change



Oceanic fronts, river mouths, ice

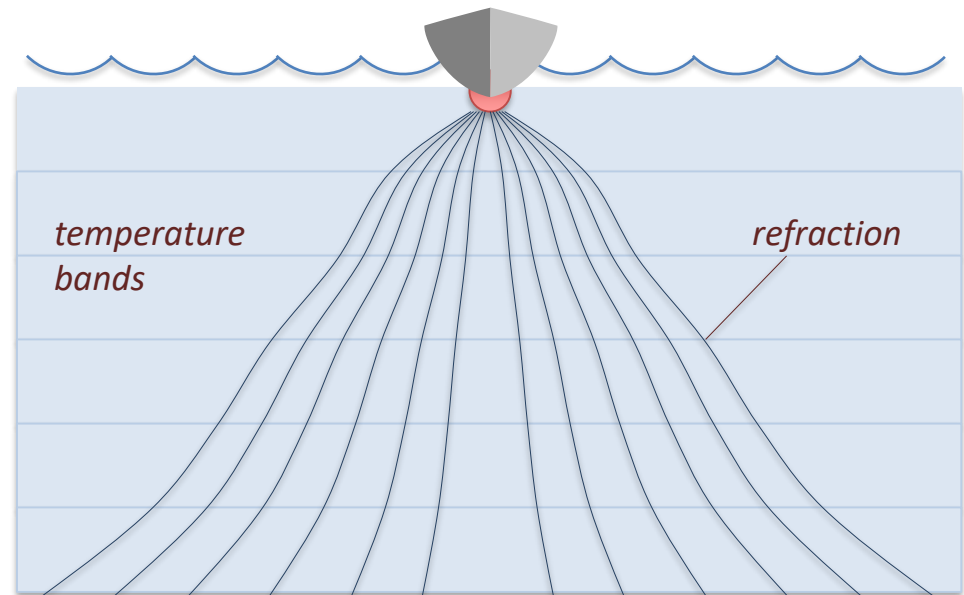
TEMPERATURE

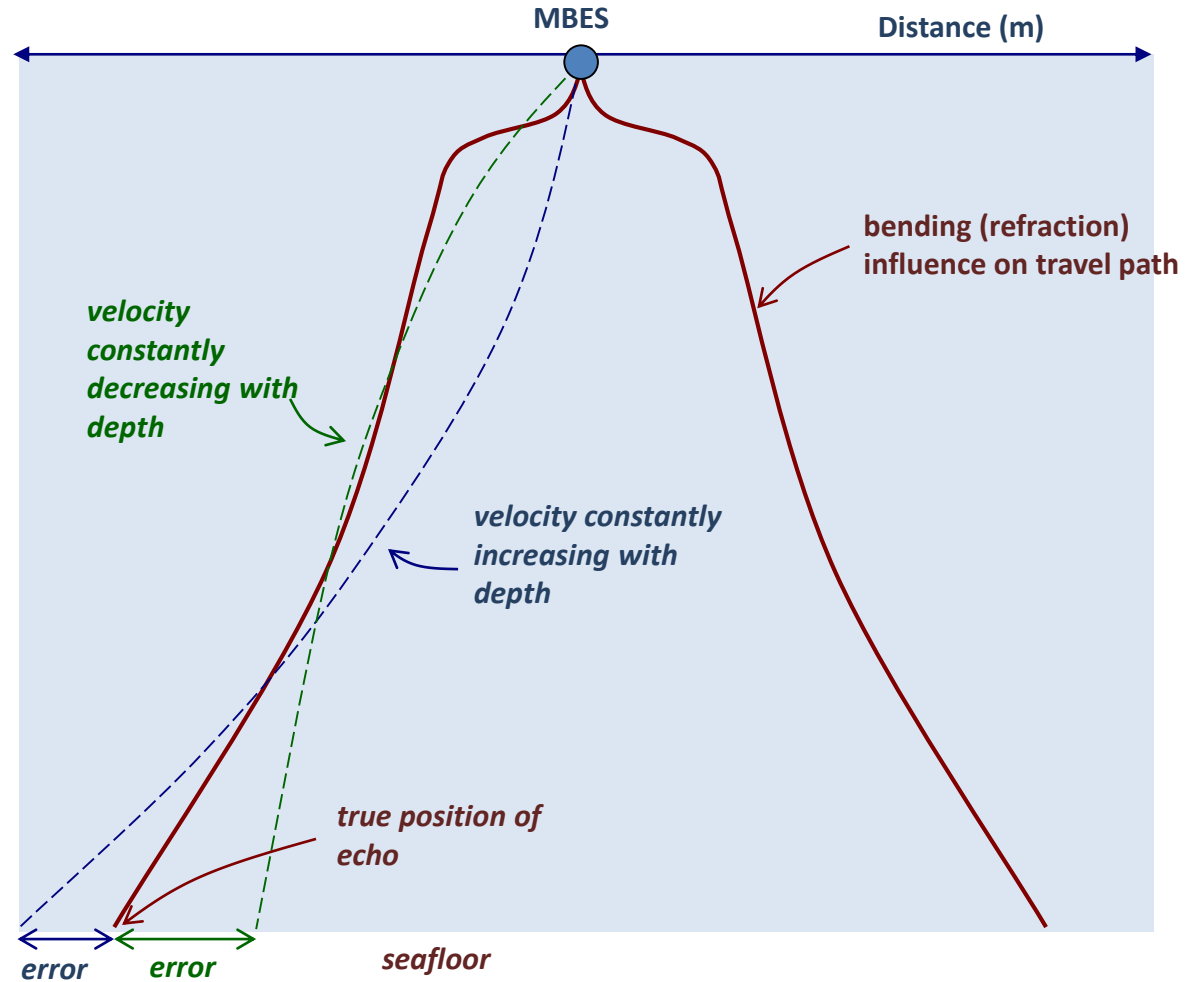
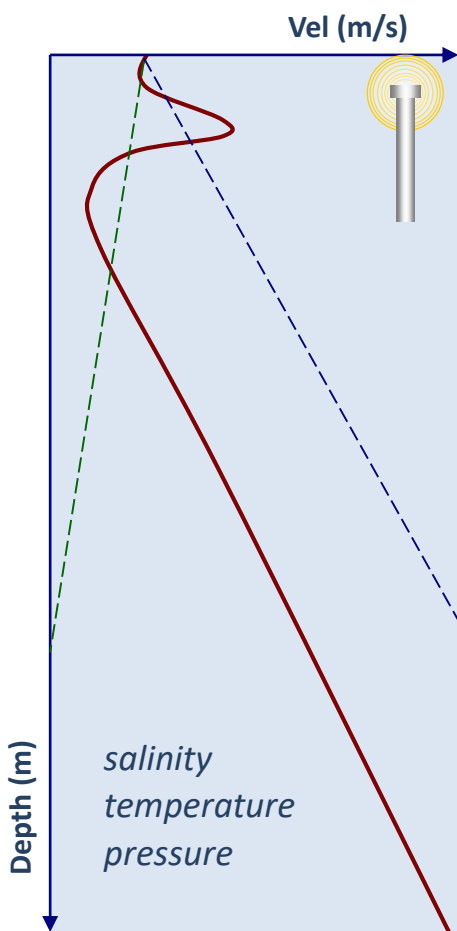
- Temperature usually decreases with depth
- A change of 1°C will change Vs by 3m/s
- Above 1000m water depth, temperature is the predominant influence on underwater sound velocity

Sound velocity (at surface)

MULTIBEAM ECHOSOUNDER**SOUND VELOCITY****RAY BENDING**

- MBES are dependent upon the two-way travel time of sound (i.e. sound velocity) in water
- The value for sound velocity in oceanic water is subject to changes associated with differences in density (primarily a function of temperature)
- Depending on the angle of beam travel, bending (refraction) can cause deviations in the travel path as a result of changes in density
- Generally, the greater the beam direction angle, the more likely the chances are for refraction

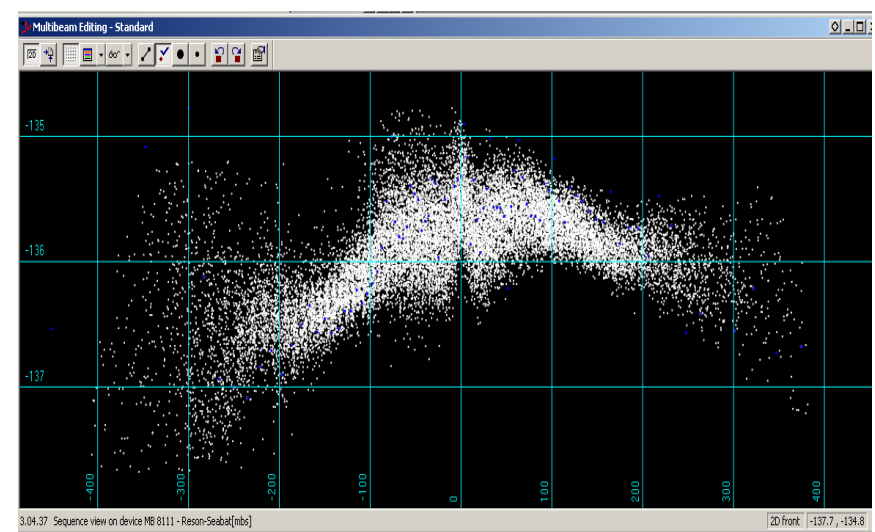
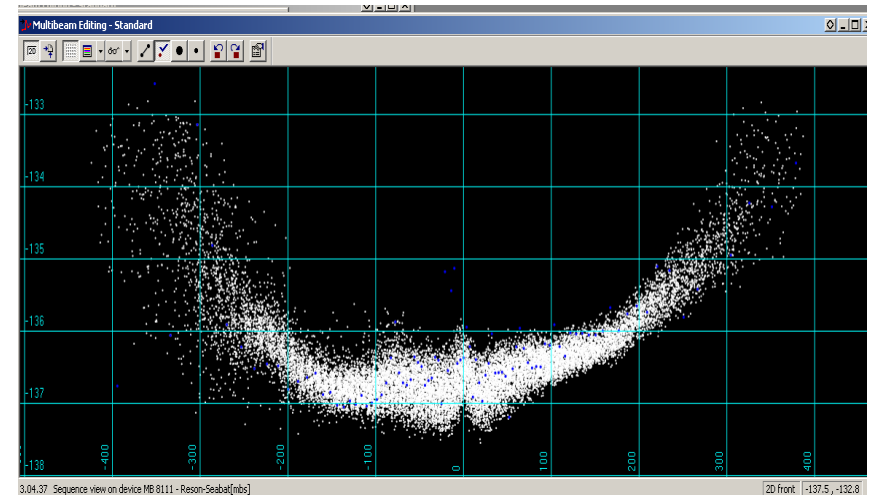
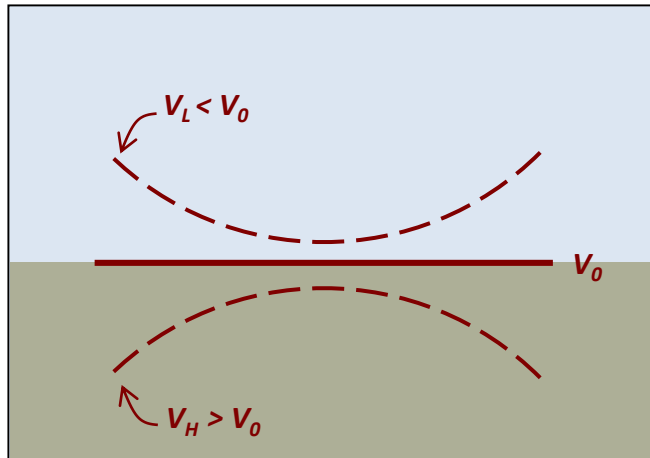


MULTIBEAM ECHOSOUNDER**RAY BENDING**

MULTIBEAM ECHOSOUNDER**VELOCITY ERRORS****SMILES & FROWNS**

Indicates errors in the sound velocity setting

$$\text{Range} = \frac{1}{2} * V * \Delta t$$

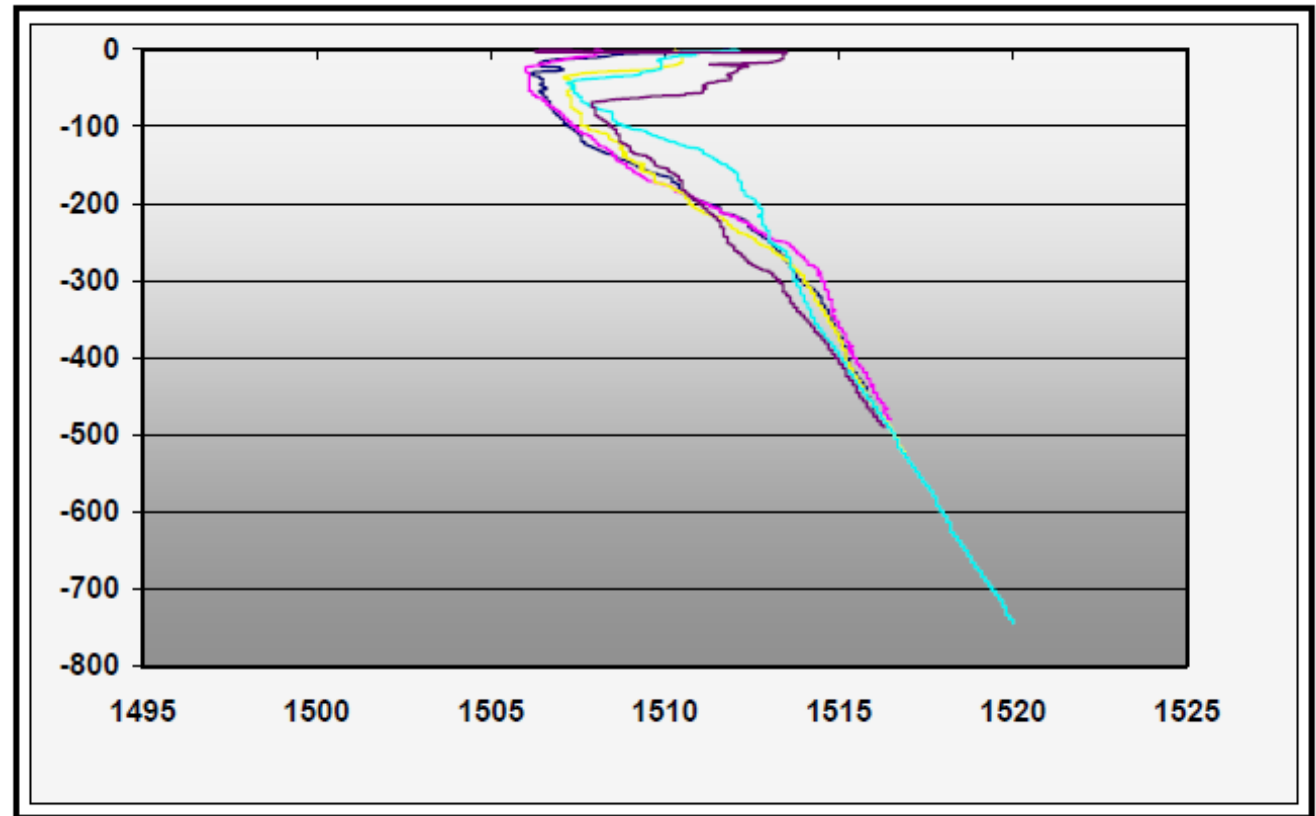


MULTIBEAM ECHOSOUNDER

SOUND VELOCITY PROFILES

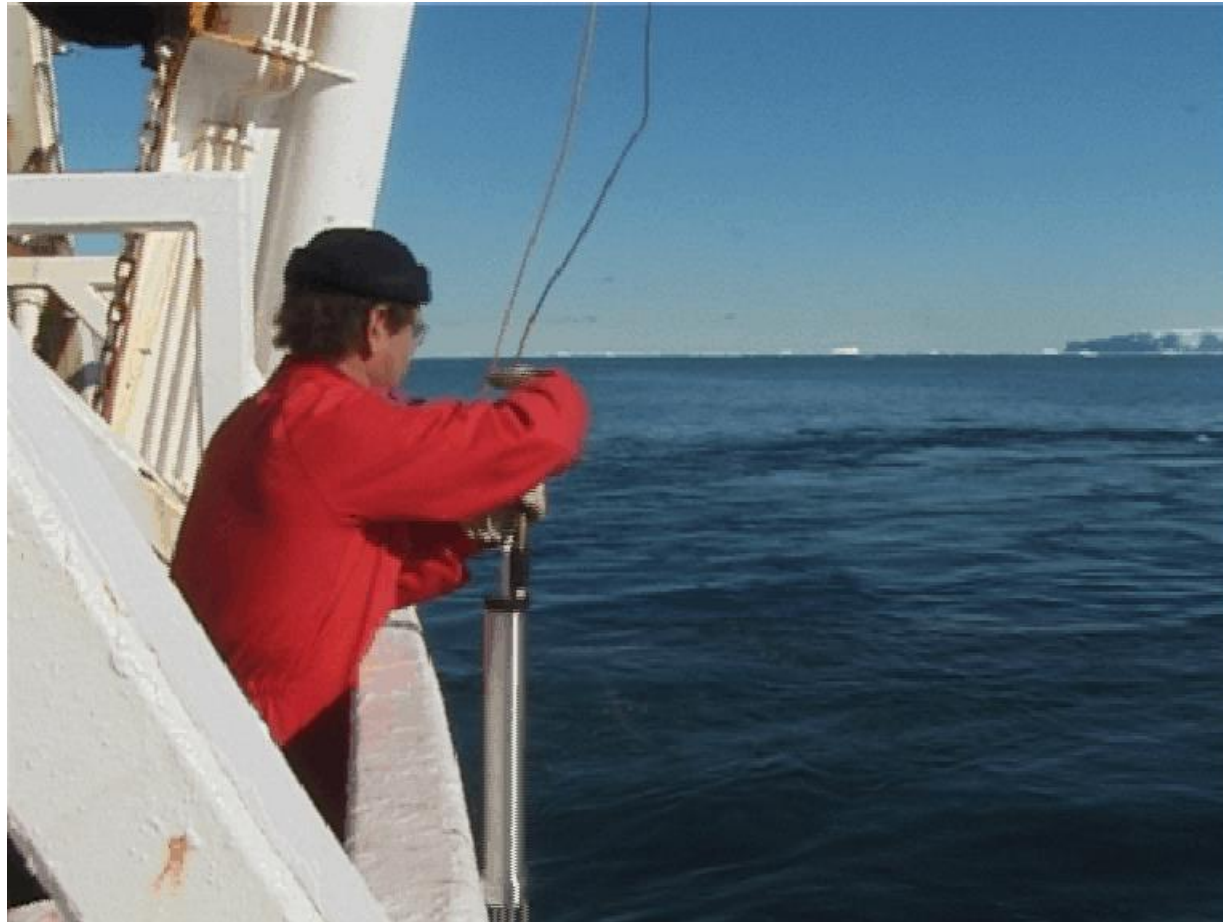
SOUND VELOCITY PROBE

- Collects a profile of sound velocities at predetermined depth intervals
- Operates autonomously (no electrical cable)
- Data downloaded into computer and uploaded in the acquisition software



MULTIBEAM ECHOSOUNDER

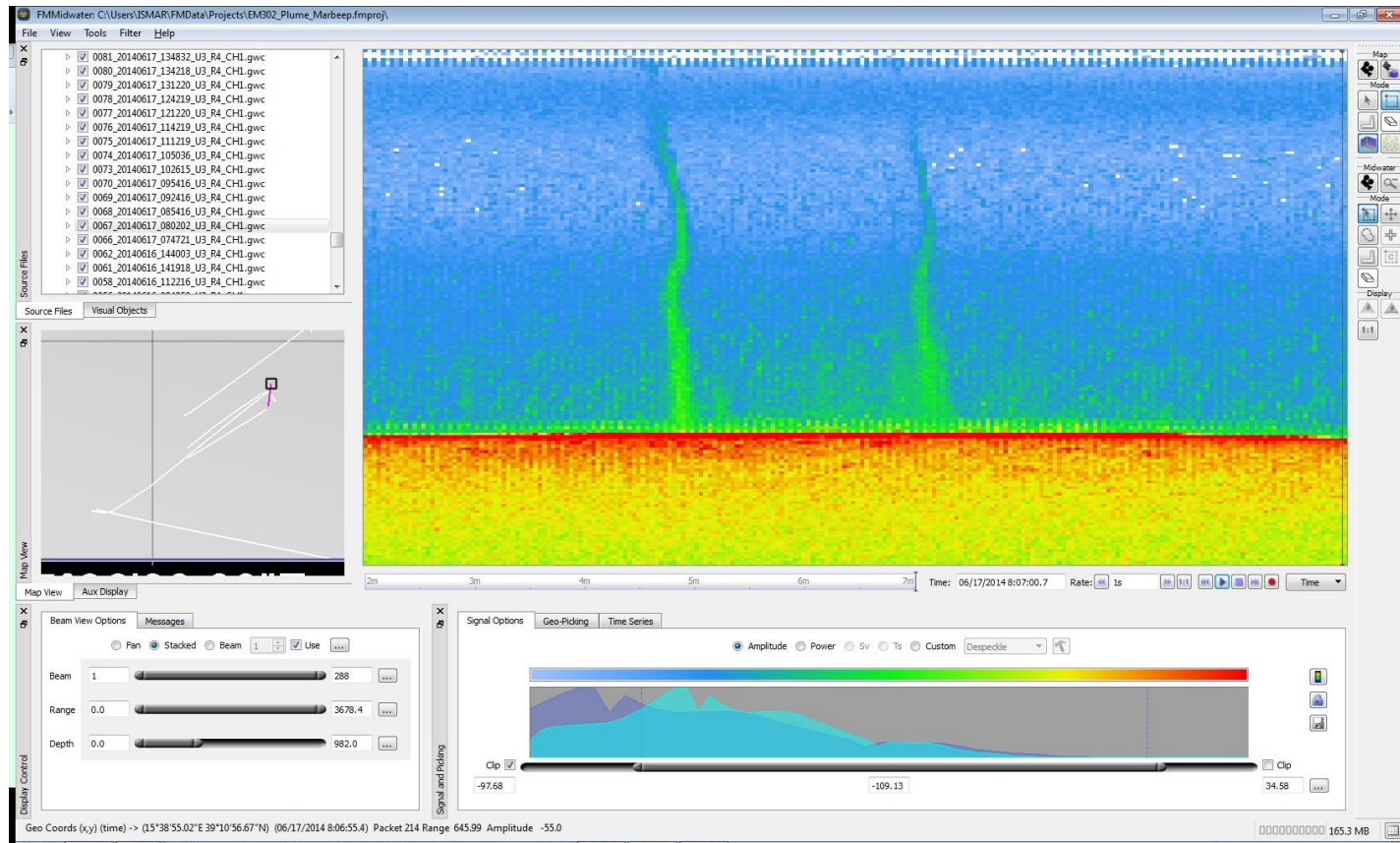
SOUND VELOCITY PROFILING



MULTIBEAM ECHOSOUNDER

WATER COLUMN

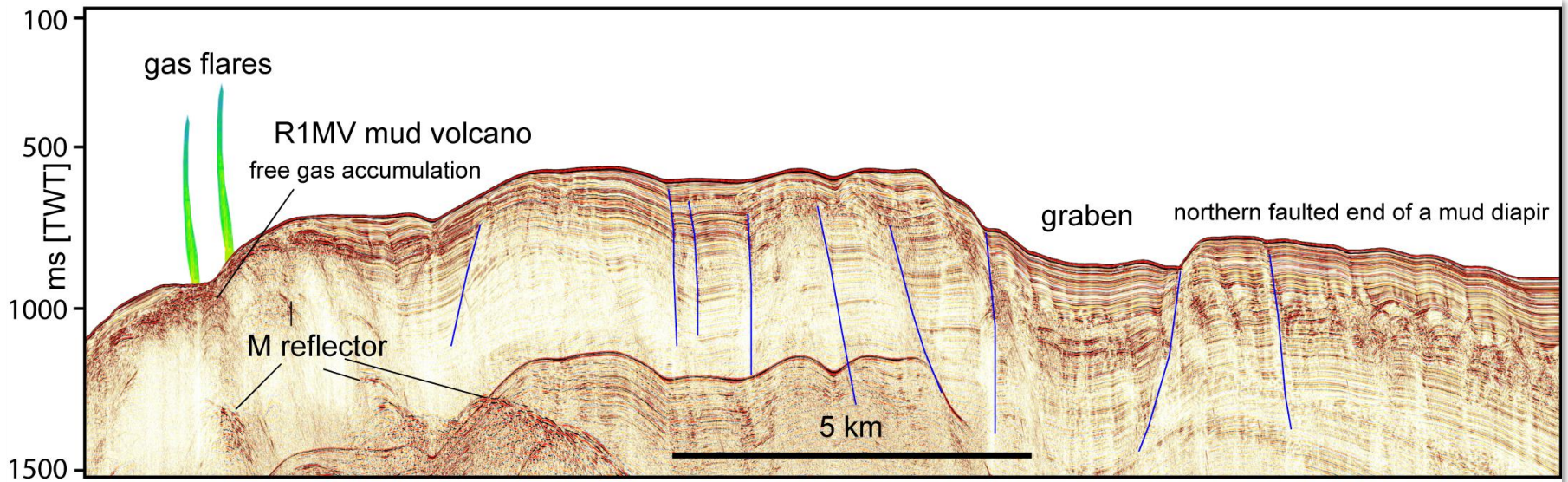
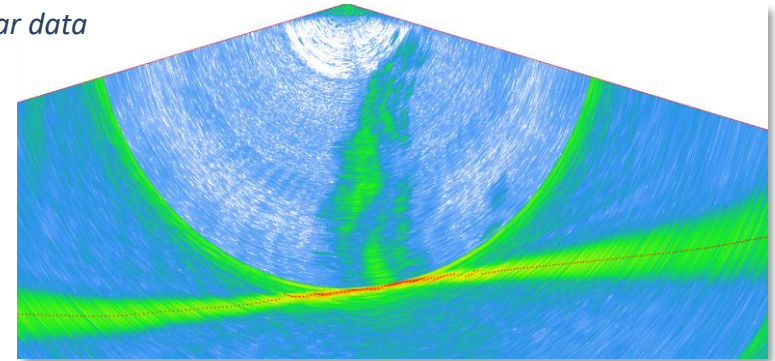
GAS PLUMES

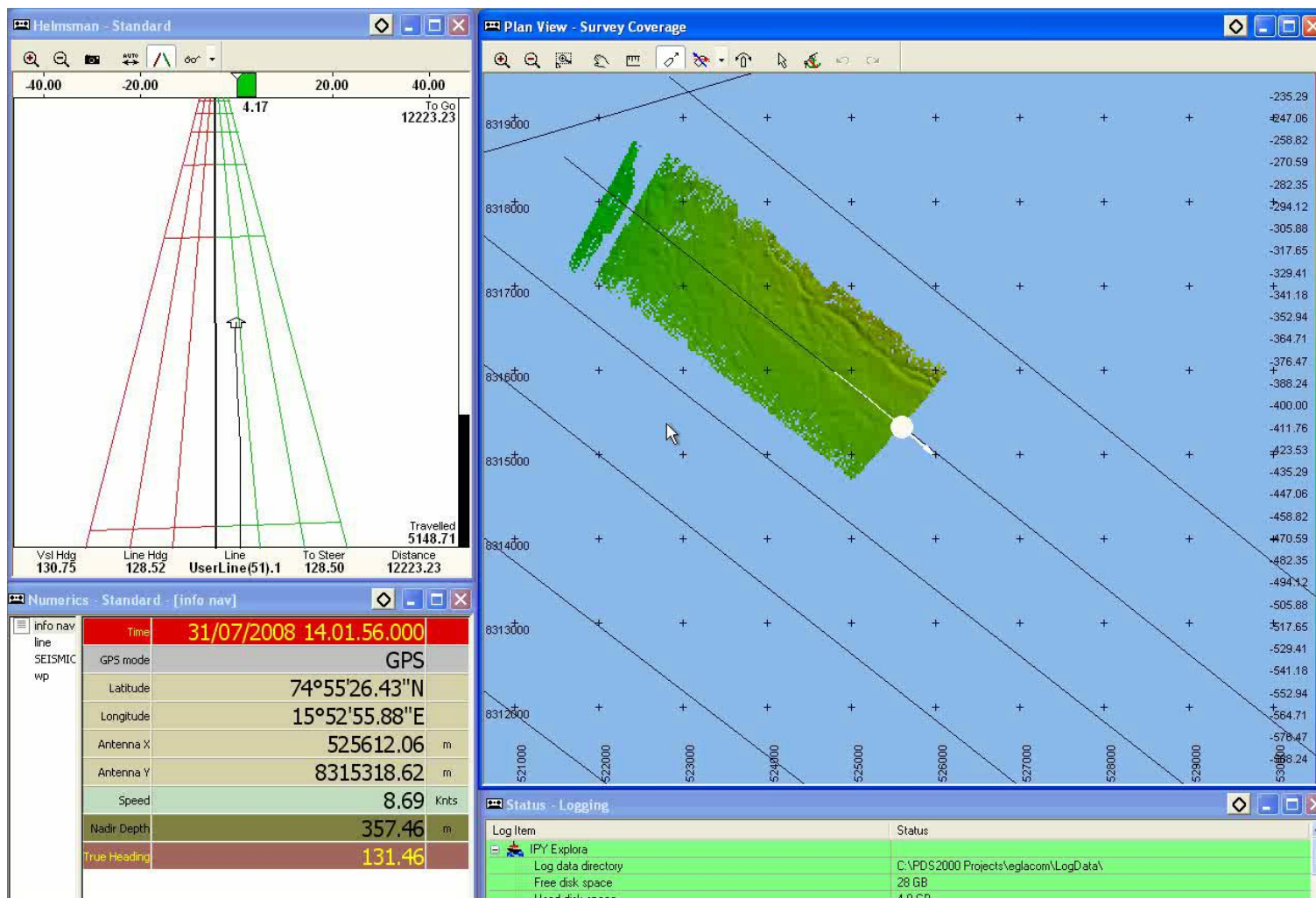


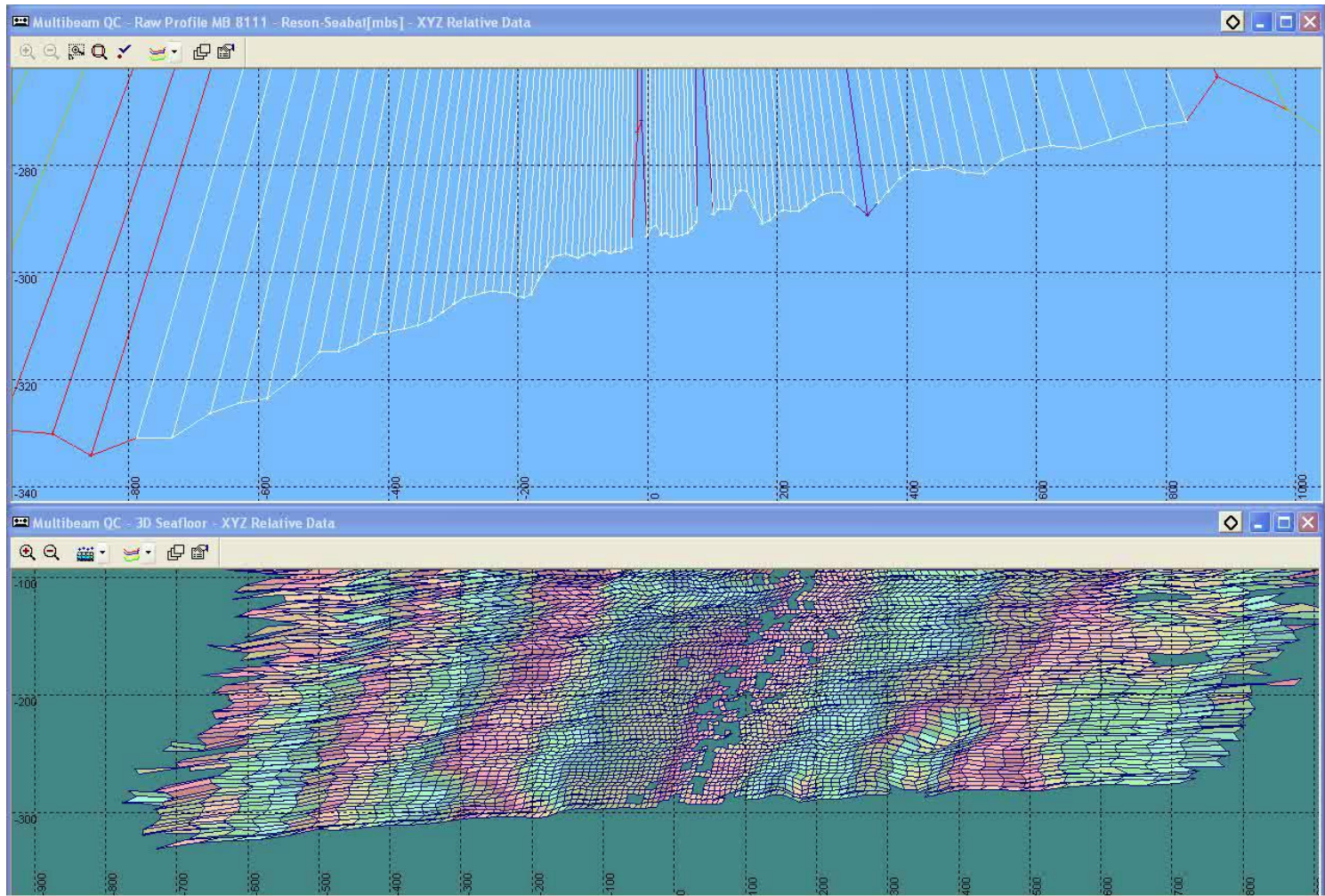
Stacked gas plumes detected in the water column by the EM302 multibeam system along a transect over a mud volcano. Rovere et al., 2014. Normal faults control fluid flow structures at the rear of the Calabrian Arc (Paola Ridge, southeastern Tyrrhenian Sea). GNGTS 2014.

MULTIBEAM ECHOSOUNDER**WATER COLUMN****GAS PLUMES**

Integration with seismic data

Raw sonar data

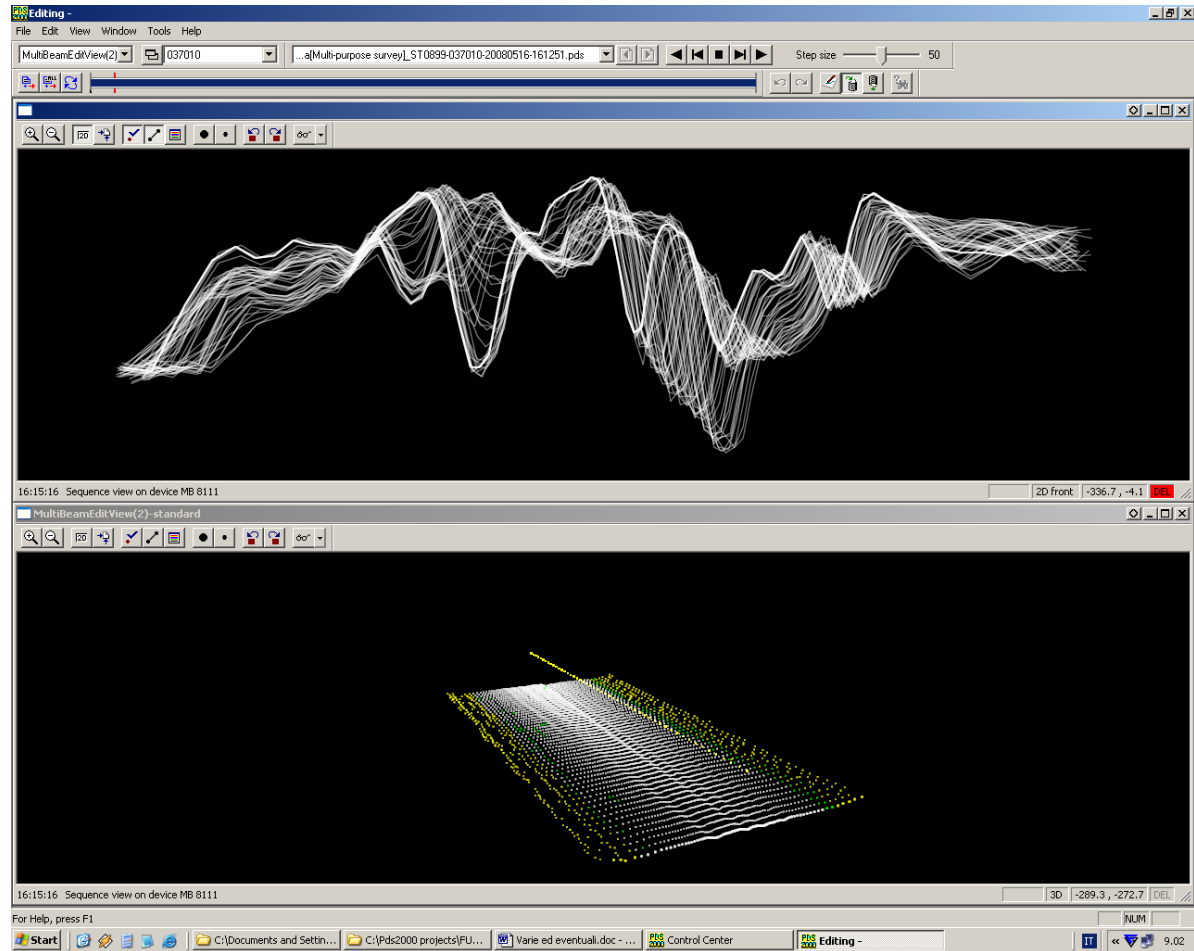
MULTIBEAM ECHOSOUNDER**DATA ACQUISITION**

MULTIBEAM ECHOSOUNDER**DATA ACQUISITION**

MULTIBEAM ECHOSOUNDER

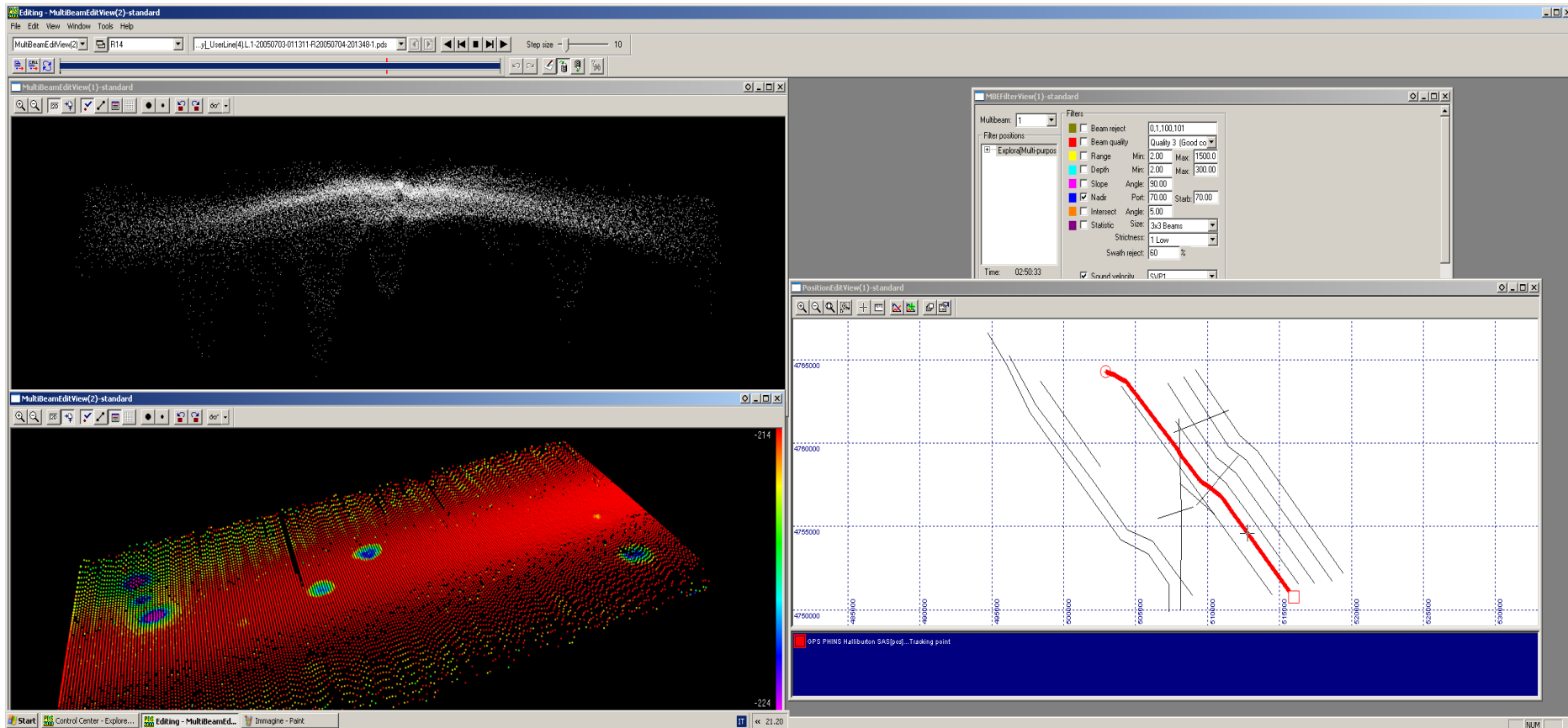
QC AND PROCESSING

SWATH EDITING



MULTIBEAM ECHOSOUNDER

QC AND PROCESSING



MULTIBEAM ECHOSOUNDER**SURVEY PLANNING AND DESIGN****INPUT PARAMETERS***Area general setting*

WATER DEPTH

MORPH. SETTING

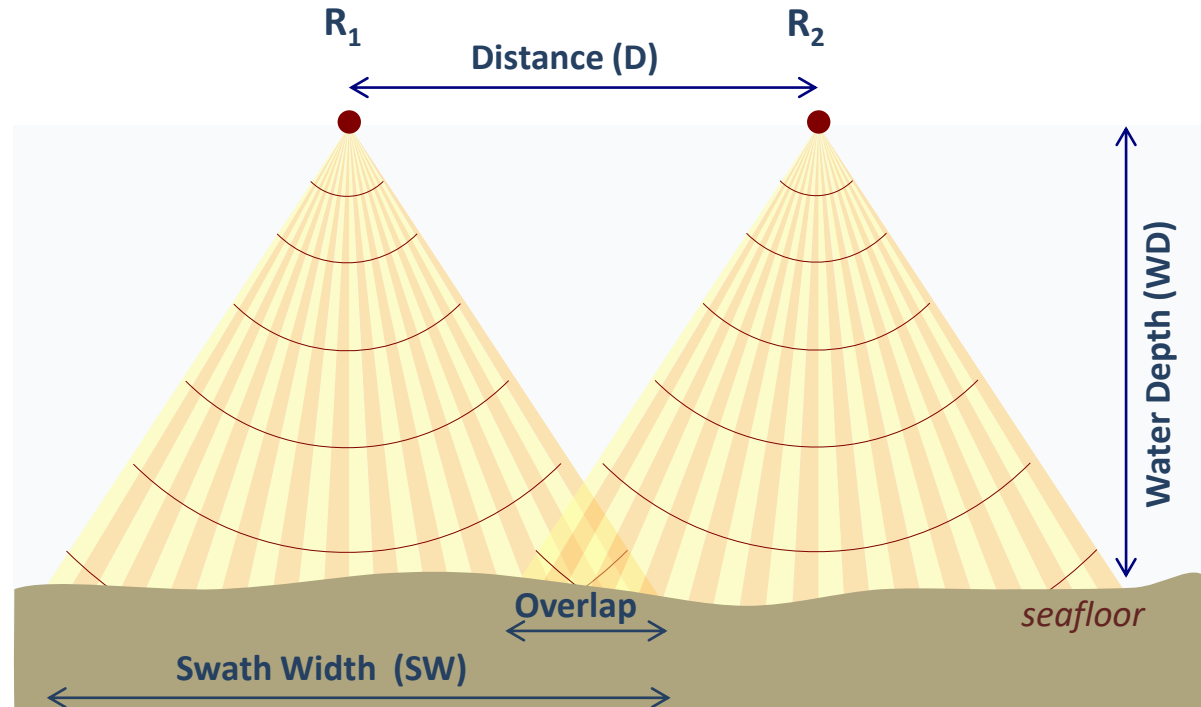
System Performance

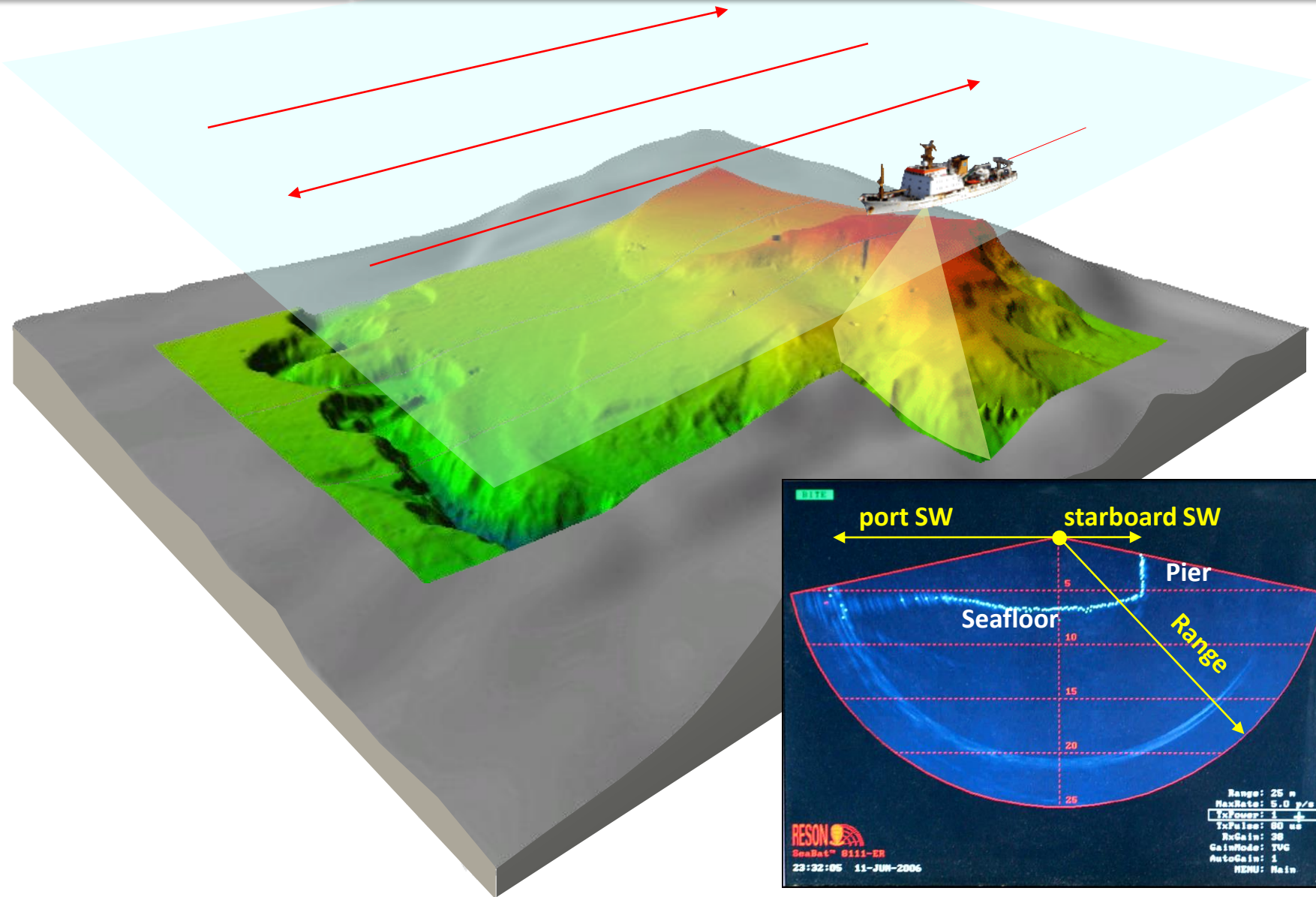
SWATH vs DEPTH

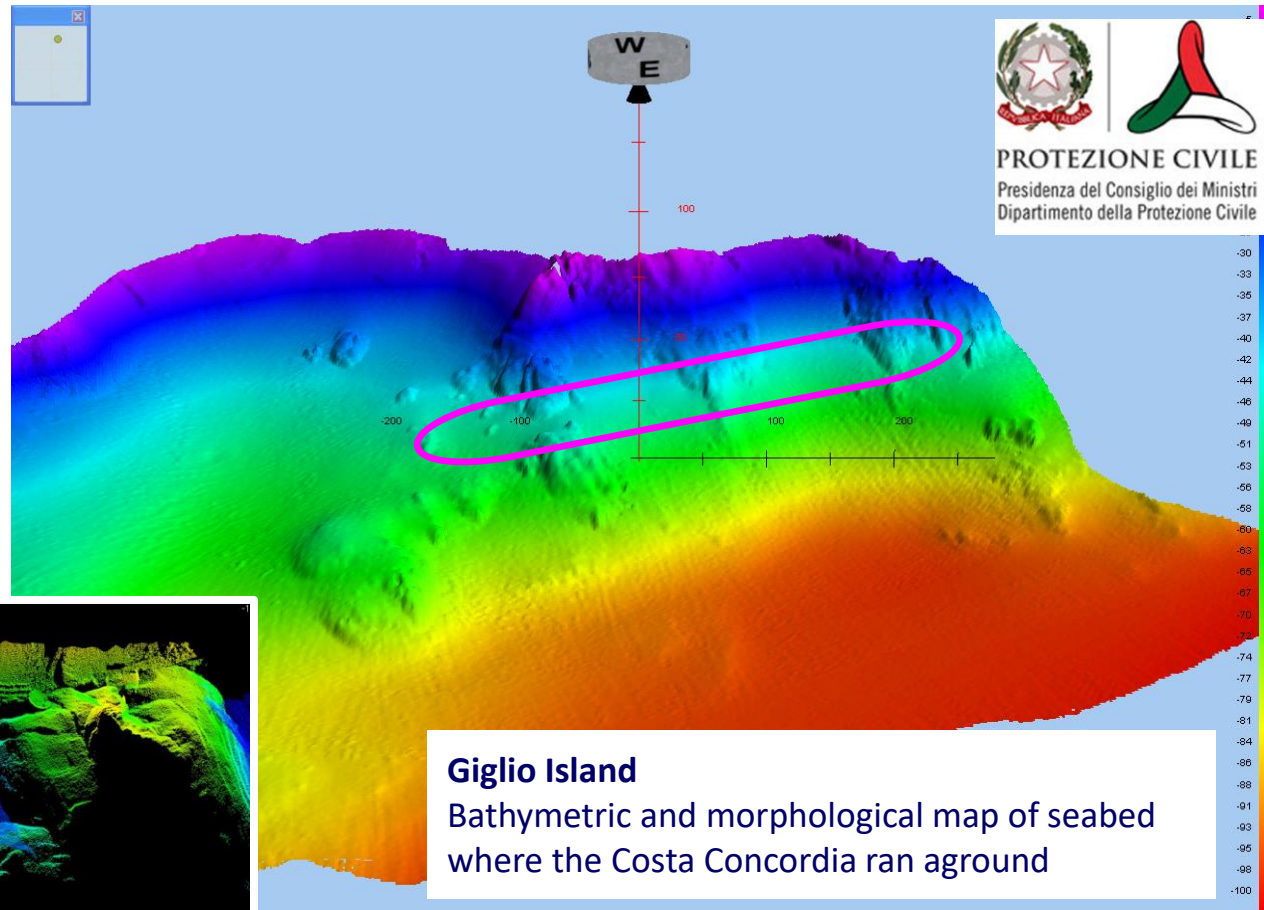
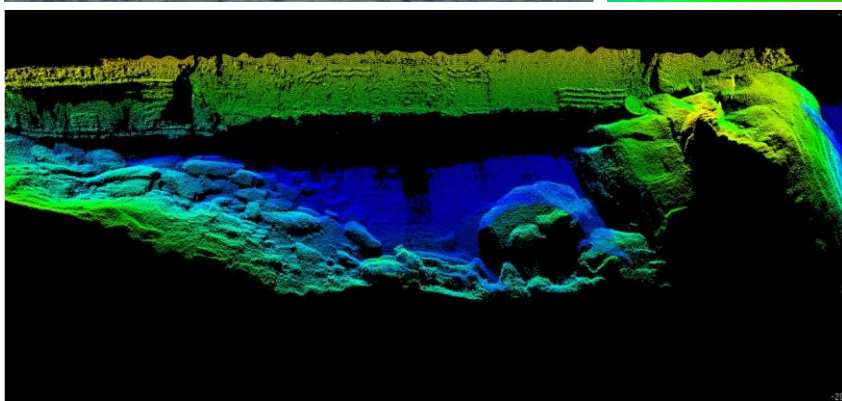
SURVEY GEOMETRY*Route planning*

DIRECTION

DISTANCE

*Routes parallel to isobathes**Overlap between adjacent swaths 20% - 30%* $D = 2 \times SW - 0.3 \times SW$ *EXAMPLE $SW = 4000 \text{ M} > D = 6800 \text{ M}$*

MULTIBEAM ECHOSOUNDER**SURVEY PLANNING AND DESIGN**

MULTIBEAM ECHOSOUNDER**ENVIRONMENT AND SOCIETY**

Courtesy of D. Cotterle, E. Gordini, and M. Deponete, OGS, 2012

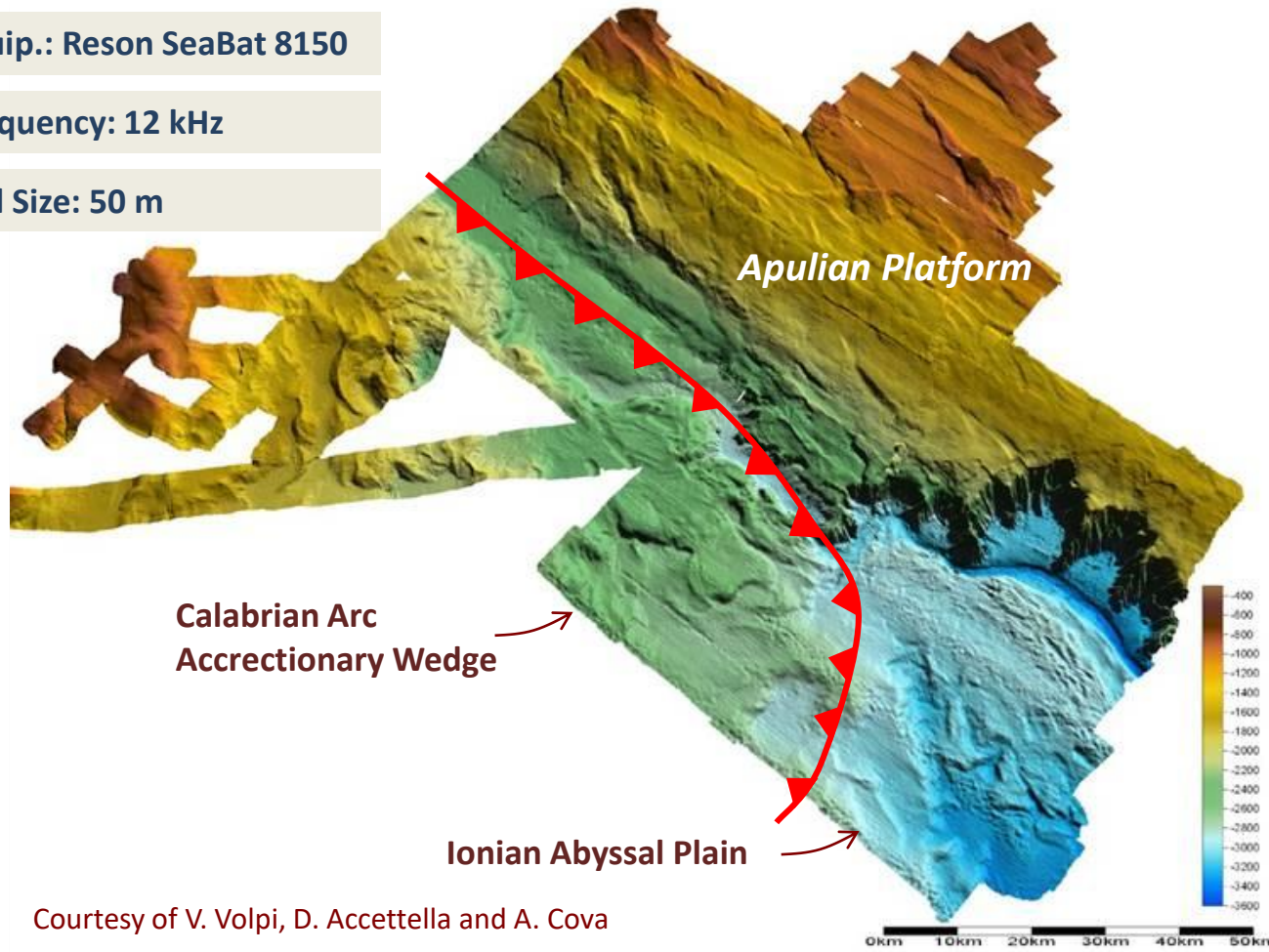
MULTIBEAM ECHOSOUNDER**ACADEMIC**

M/V OGS Explora, 2003

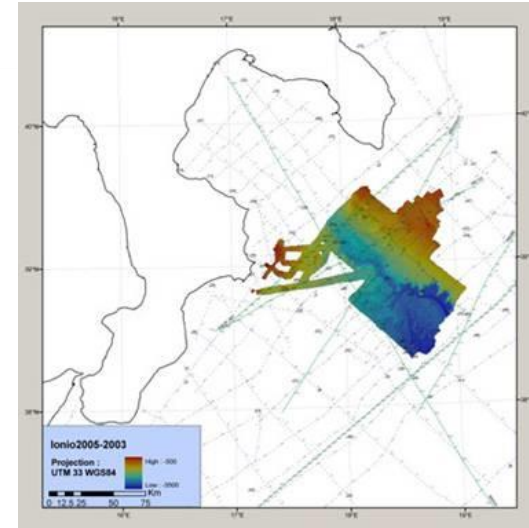
Equip.: Reson SeaBat 8150

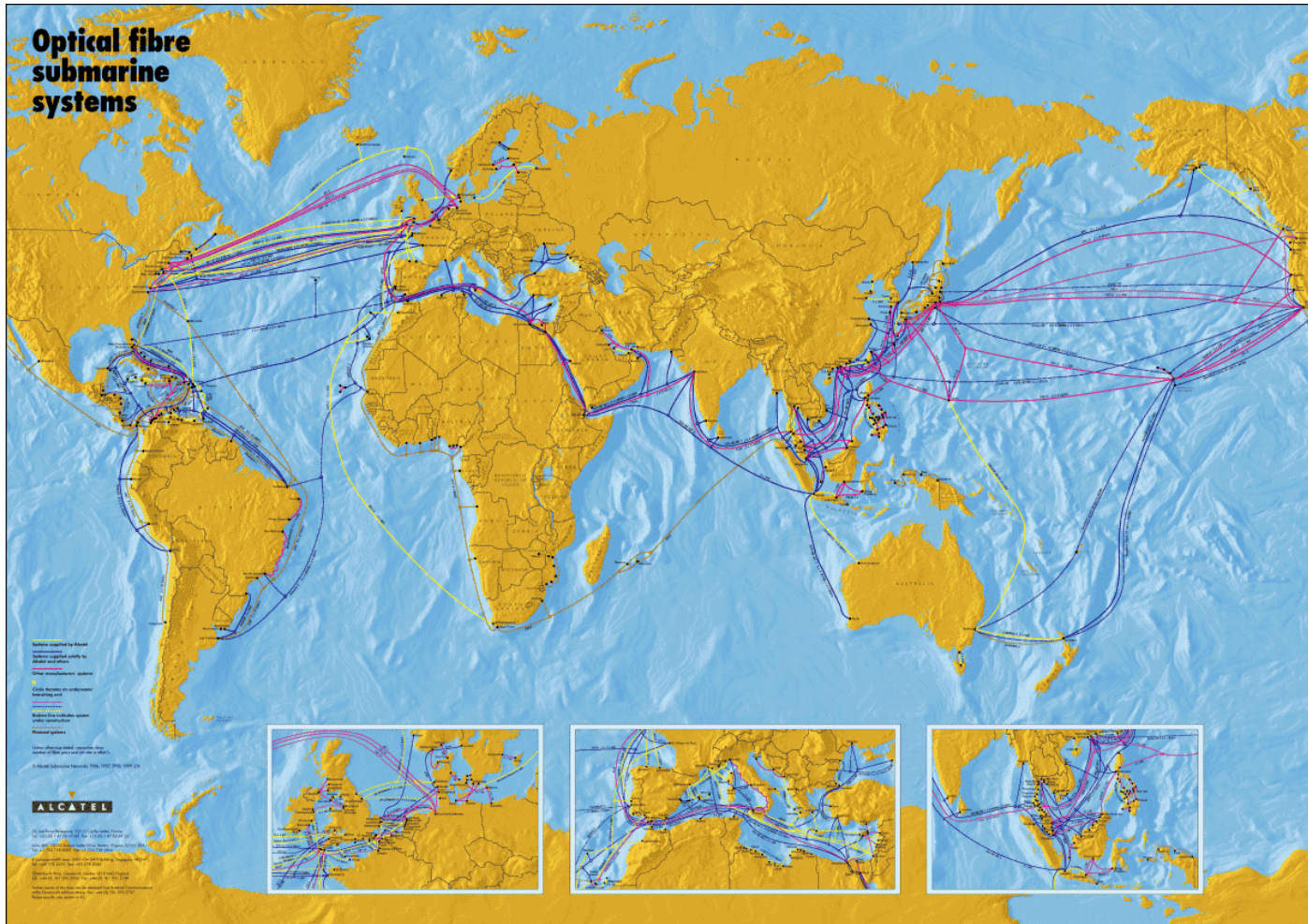
Frequency: 12 kHz

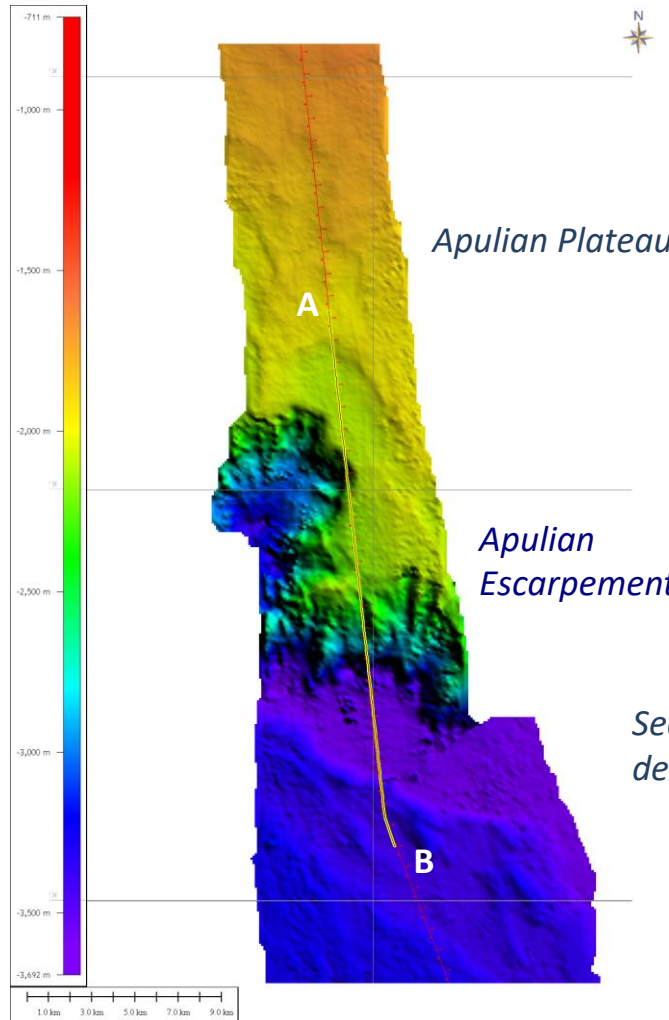
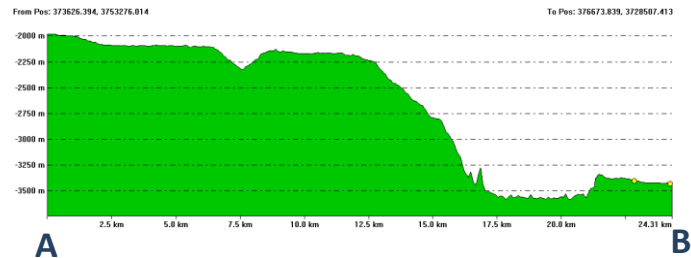
Cell Size: 50 m



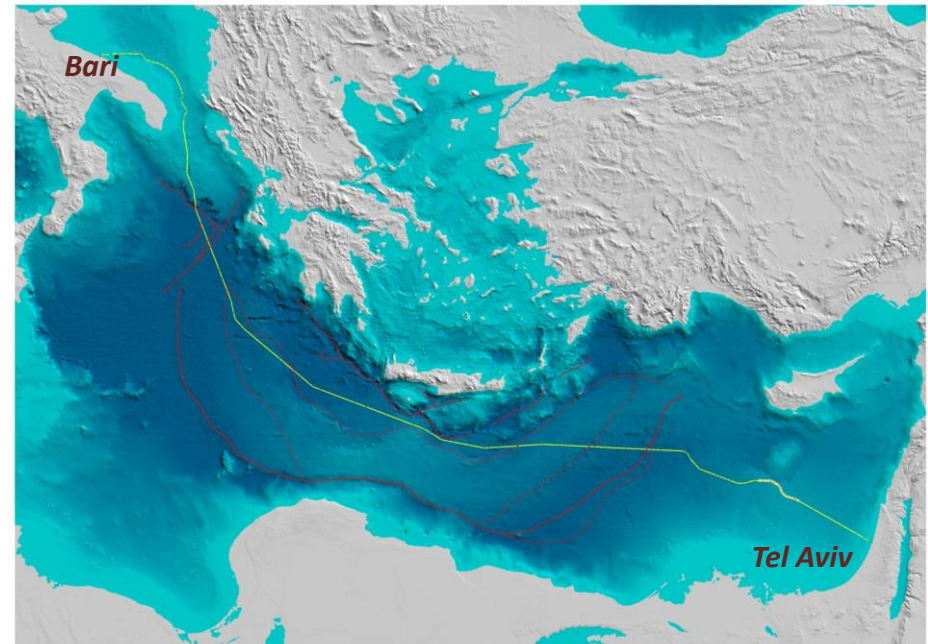
Courtesy of V. Volpi, D. Accettella and A. Cova





MULTIBEAM ECHOSOUNDER**CABLE SURVEY****Bathymetric profile**

Avg. gradient = 25°
Max gradient >40°



CABLE SURVEYS

OBJECTIVES

The \$300m cable that will save traders milliseconds

In the high-speed world of automated financial trading, milliseconds matter. So much so, in fact, that a saving of just six milliseconds in transmission time is all that is required to justify the laying of the first transatlantic communications cable for 10 years at a cost of more than \$300m.

By Christopher Williams, Technology Correspondent, 8:00AM BST 11 Sep 2011



Seabed survey work for the Hibernian Express, as the **6,021km (3,741 mile)** fibre-optic link will be known, is already under way off the east coast of America. The last cables laid under the Atlantic were funded by the dotcom boom in the 1990s when telecoms infrastructure firms rushed to criss-cross the ocean.

The laying of the new transatlantic communications cable is a viable proposition because Hibernia Atlantic, the company behind it, is planning to sell a special superfast bandwidth that will have hyper-competitive trading firms and banks in the City of London and New York queuing to use it. In fact it is predicted they will pay about 50 times as much to link up via the Hibernian Express than they do via existing transatlantic cables. **The current leader, Global Crossing's AC-1 cable, offers transatlantic connection in 65 milliseconds. The Hibernian Express will shave six milliseconds off that time.** Of course, verifiable figures are elusive and estimates vary wildly, but **it is claimed that a one millisecond advantage could be worth up to \$100m (£63m) a year to the bottom line of a large hedge fund.**

Some City experts have criticised the growth in vast volumes of electronic trading, where computers automatically buy and sell stocks with no human input. The British firm laying the cable, Global Marine Systems, is plotting a new route that is shorter than any previously taken by a transatlantic cable. As closely as possible, it will follow "the great circle" flight path followed by London-to-New York flights.

"We spent 18 months planning the route," says Mike Saunders, Hibernia Atlantic's vice-president of business development. "If it ever gets beaten for speed we end up giving our customers their money back, basically, so my boss would kill me if we got it wrong."

And, he says, customers from hedge funds, currency dealers and exotic proprietary trading firms are queuing up for the switch-on in 2013.

"That's the way these guys think," Mr Saunders says. "If one of them is on a faster route, they all have to get on it."