**Università di Trieste**
**Corso di Laurea in Geologia**

**Anno accademico 2018 - 2019**

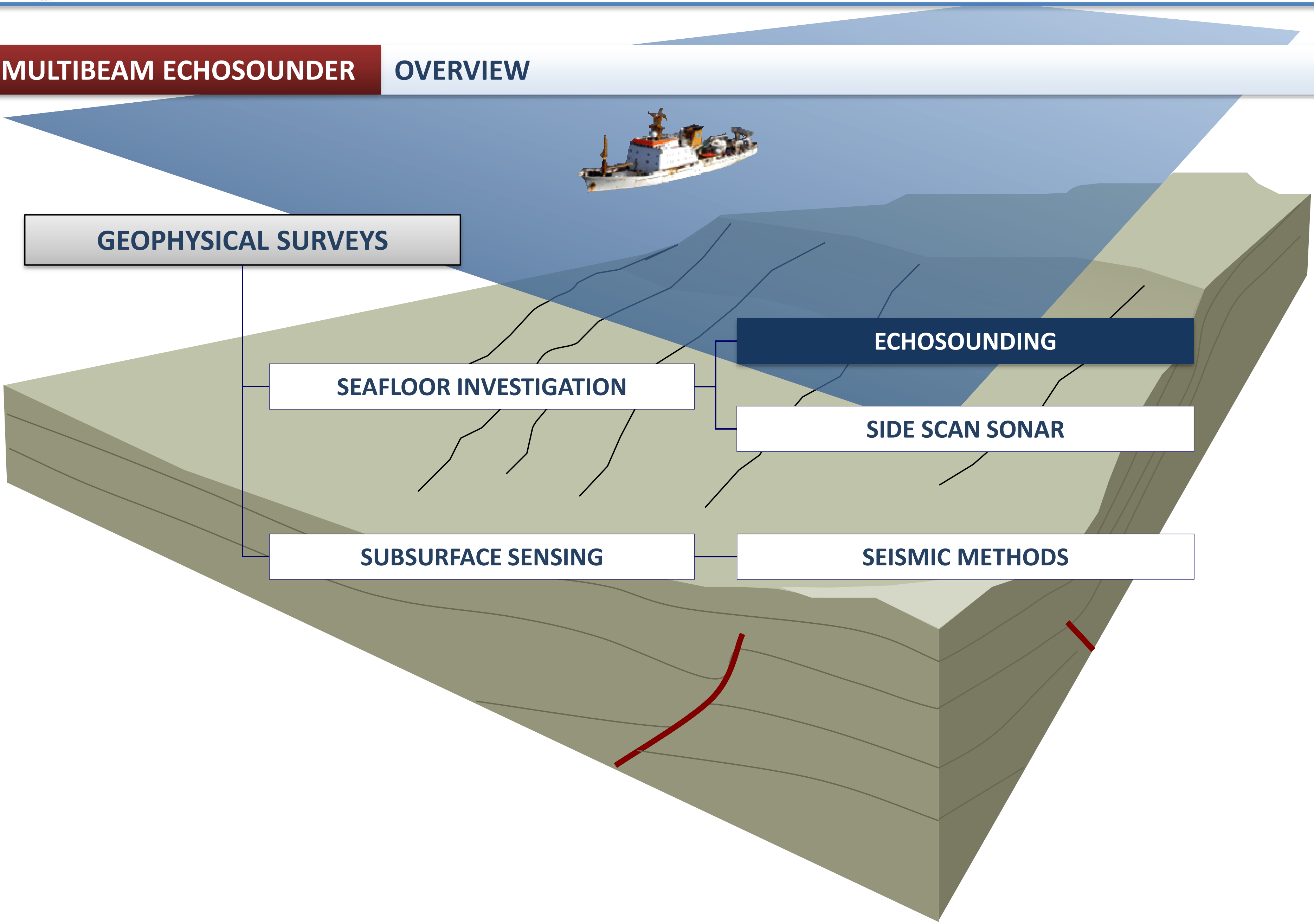
# Geologia Marina

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

## ACADEMIC

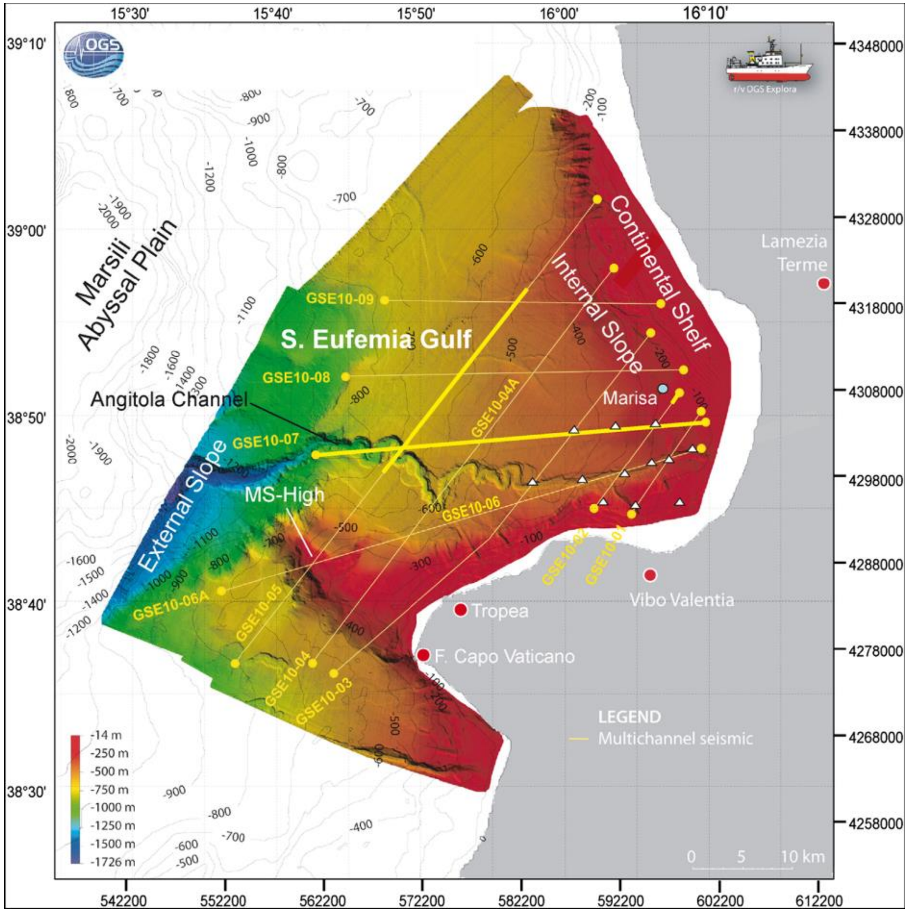
*Marine Geology and Biology*

- 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

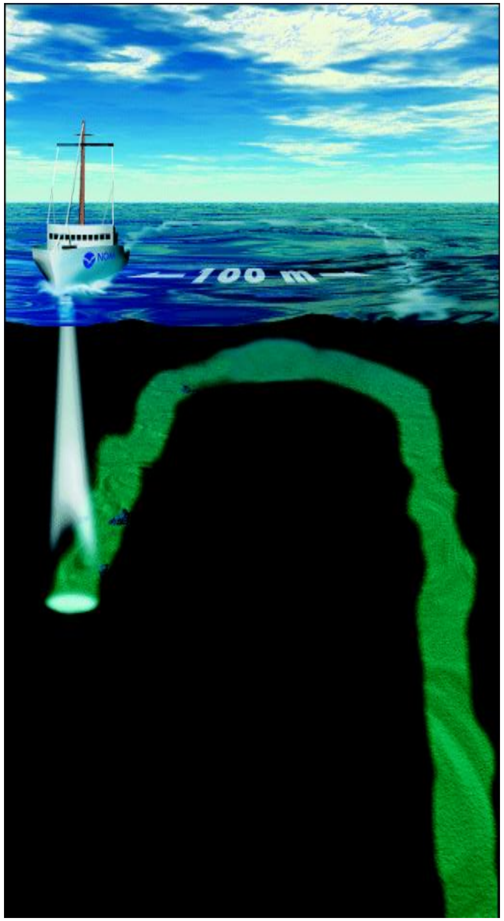


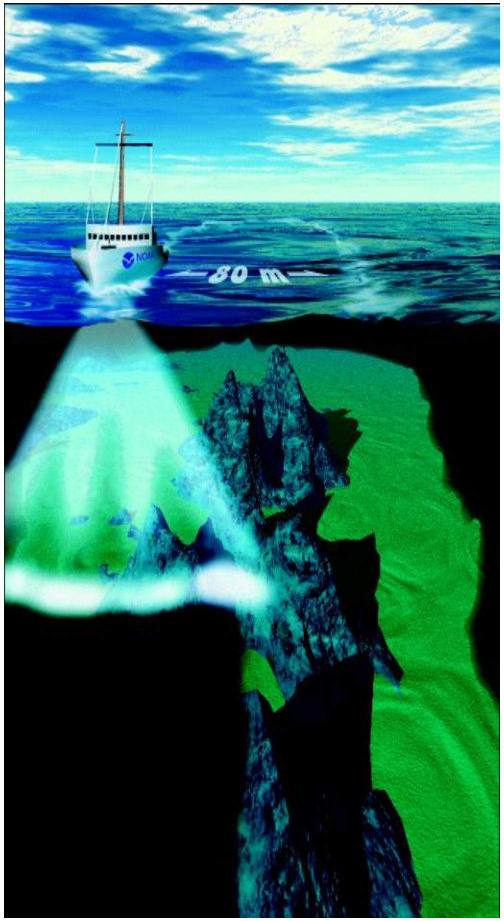

Loreto et al., 2013.Approaching the seismogenic source of the Calabria 8 September 1905 earthquake: New geophysical, geological and biochemical data from the S. Eufemia Gulf (S Italy). Marine Geology 343 (2013) 62–75.

# MULTIBEAM ECHOSOUNDER OVERVIEW

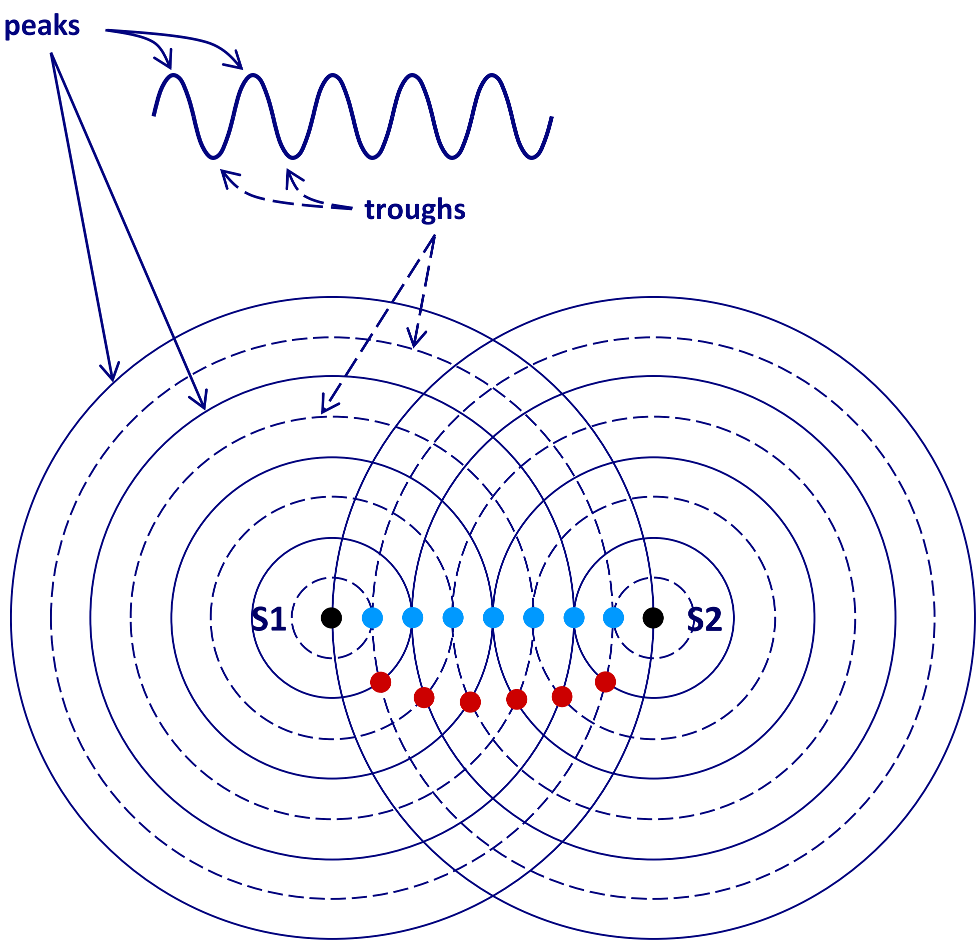
## ADVANTAGES OF MBES COMPARED TO SBES

- 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

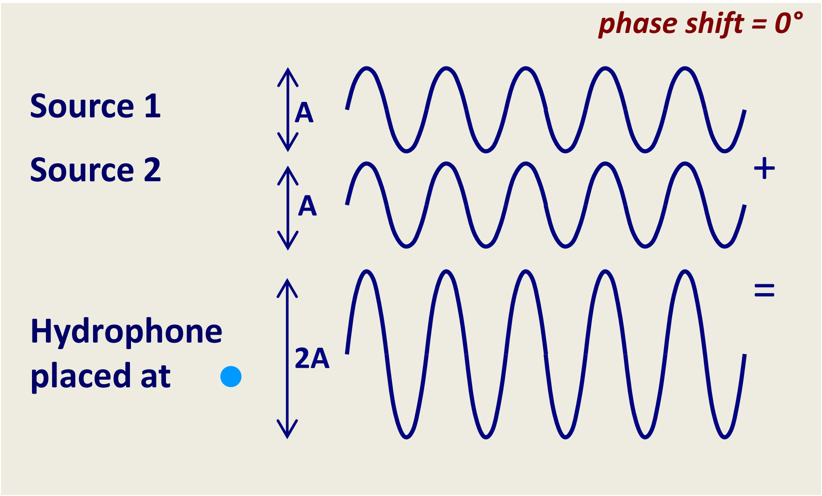


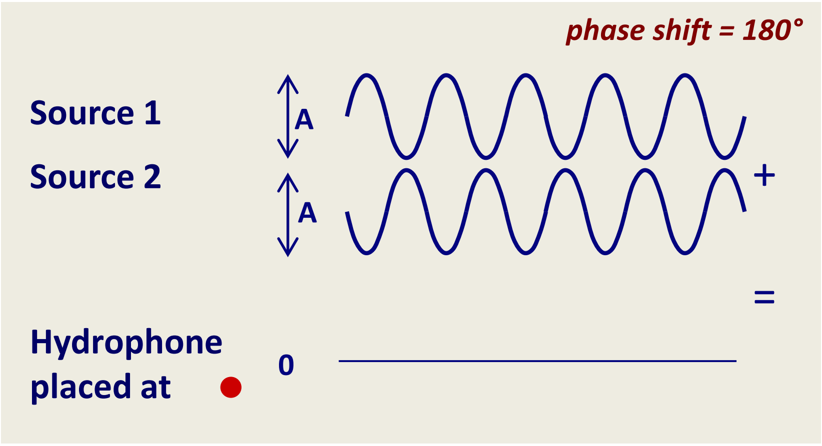
# MULTIBEAM ECHOSOUNDER
## BEAMFORMING




● **CONSTRUCTIVE INTERFERENCE**

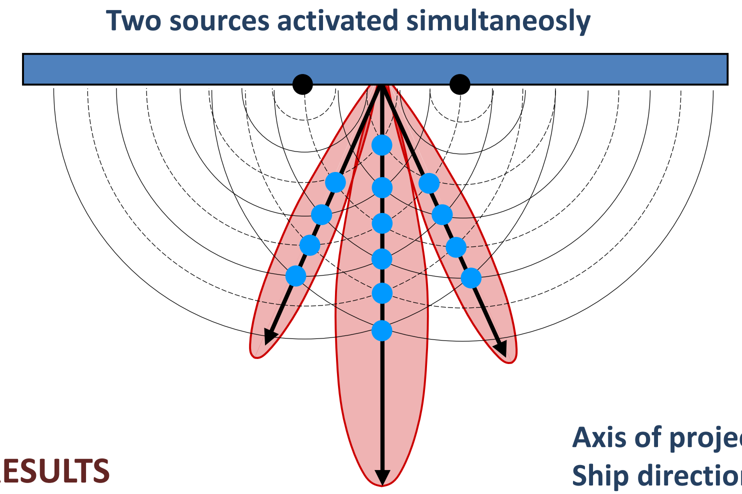


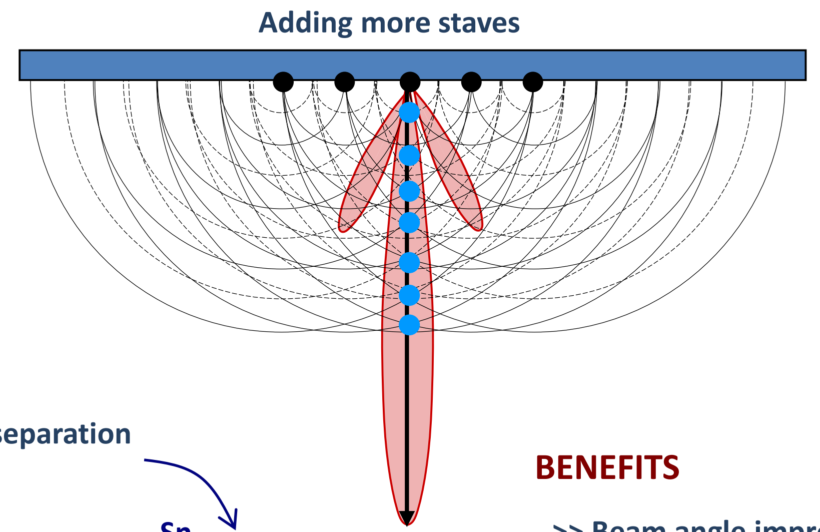

● **DESTRUCTIVE INTERFERENCE**



# MULTIBEAM ECHOSOUNDER | BEAMFORMING: PROJECTORS AND RECEIVERS ARRAYS

## FLAT ARRAYS

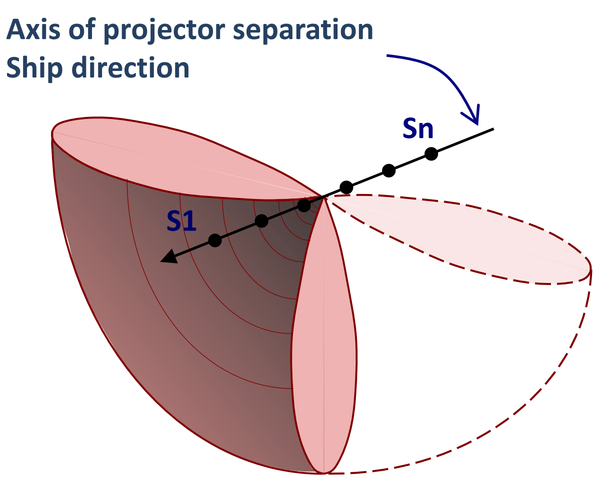



## RESULTS

>> Directivity (90°)

>> Sidelobes
(undesirable side effect)




## BENEFITS

>> Beam angle improvement

>> Reduced sidelobes

>> Improved directivity

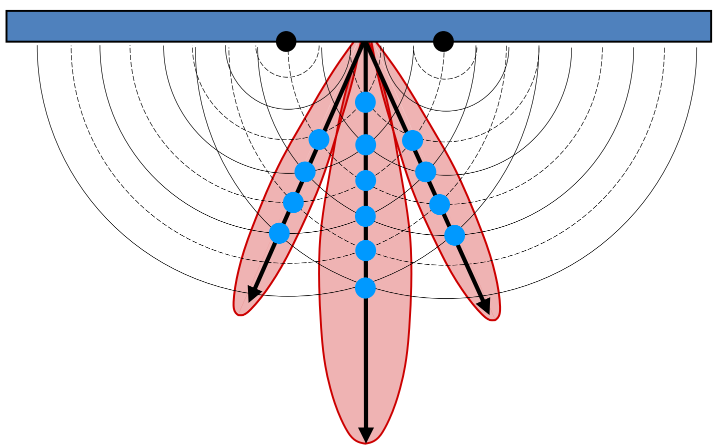
>> Narrower beams > HR

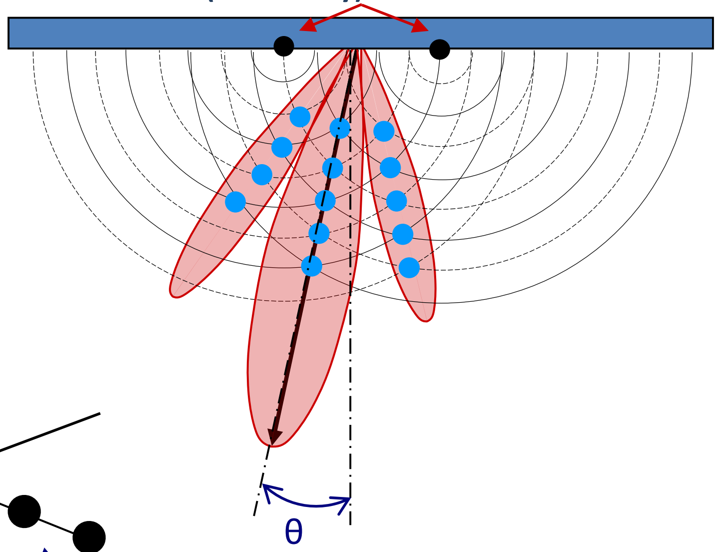
**BEAMFORMING APPLIES TO BOTH PROJECTOR AND RECEIVERS ARRAYS**

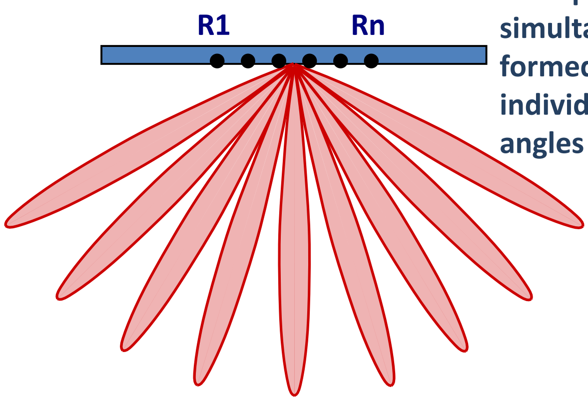
## MULTIBEAM ECHOSOUNDER

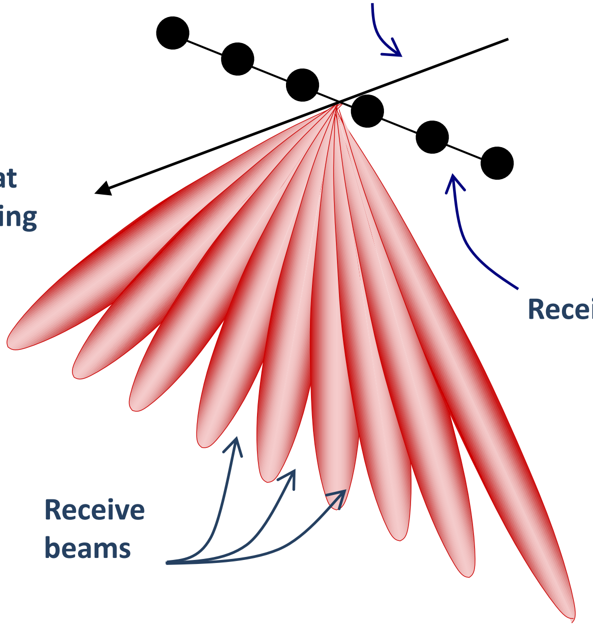
## BEAM STEERING: RECEIVERS ARRAYS

### FLAT ARRAYS



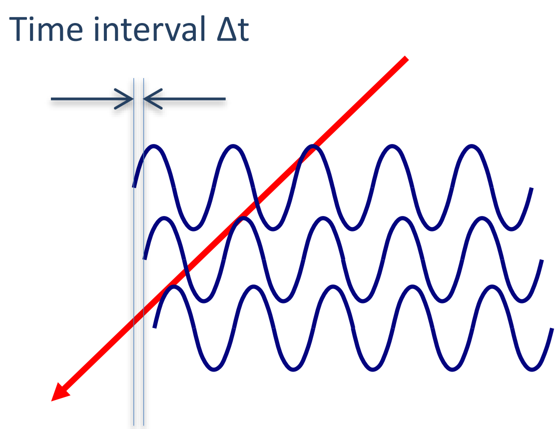



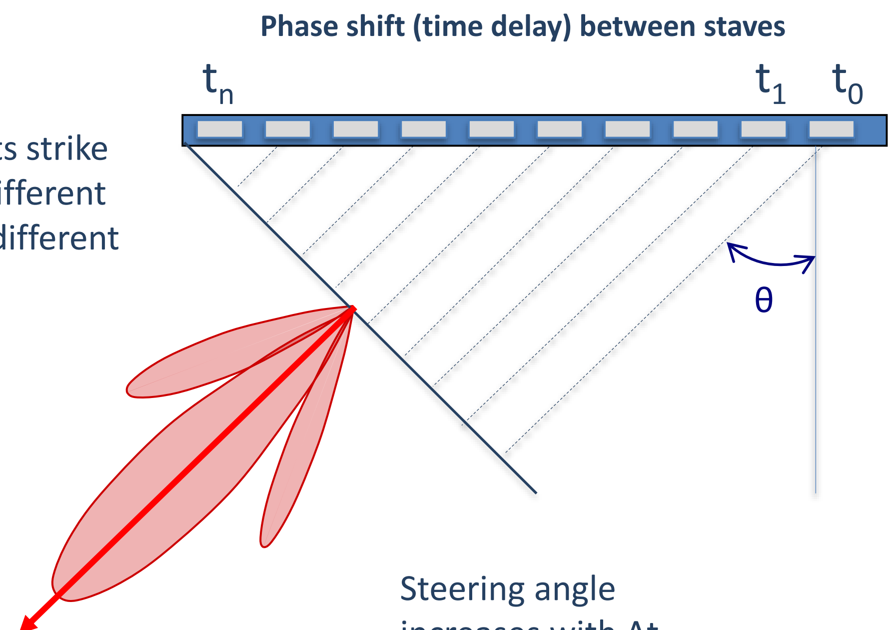



# MULTIBEAM ECHOSOUNDER

## BEAM STEERING: RECEIVERS ARRAYS




Wave fronts strike staves at different time with different phase



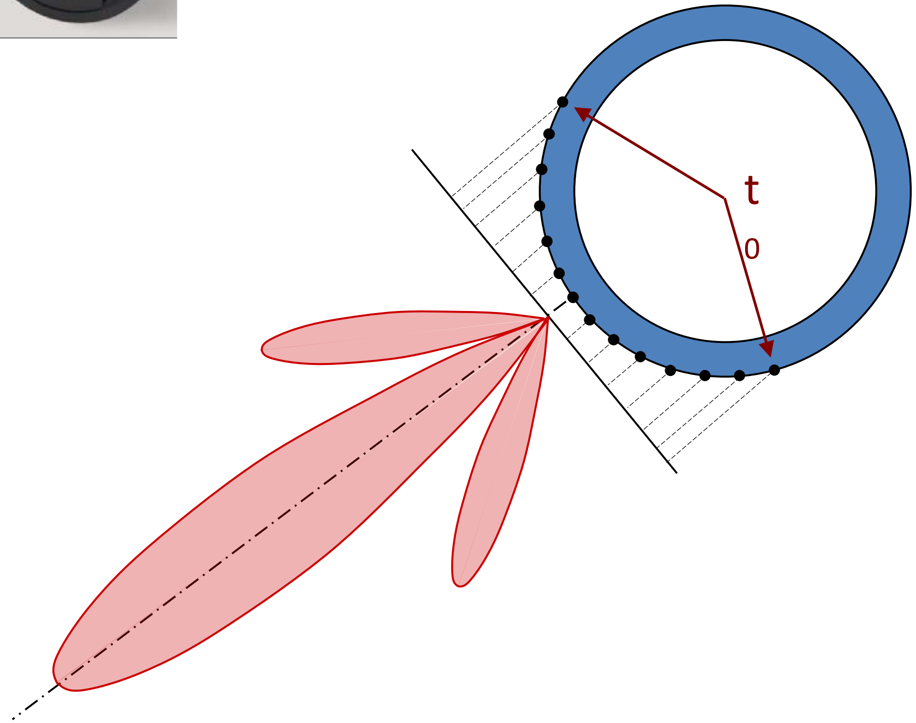

Steering angle increases with Δt

Sound speed at stave surface must be known!

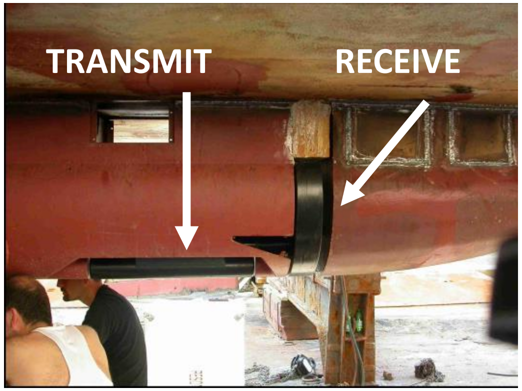
# MULTIBEAM ECHOSOUNDER

## BEAM STEERING: RECEIVERS ARRAYS

### CURVED ARRAYS




### HULL MOUNTED

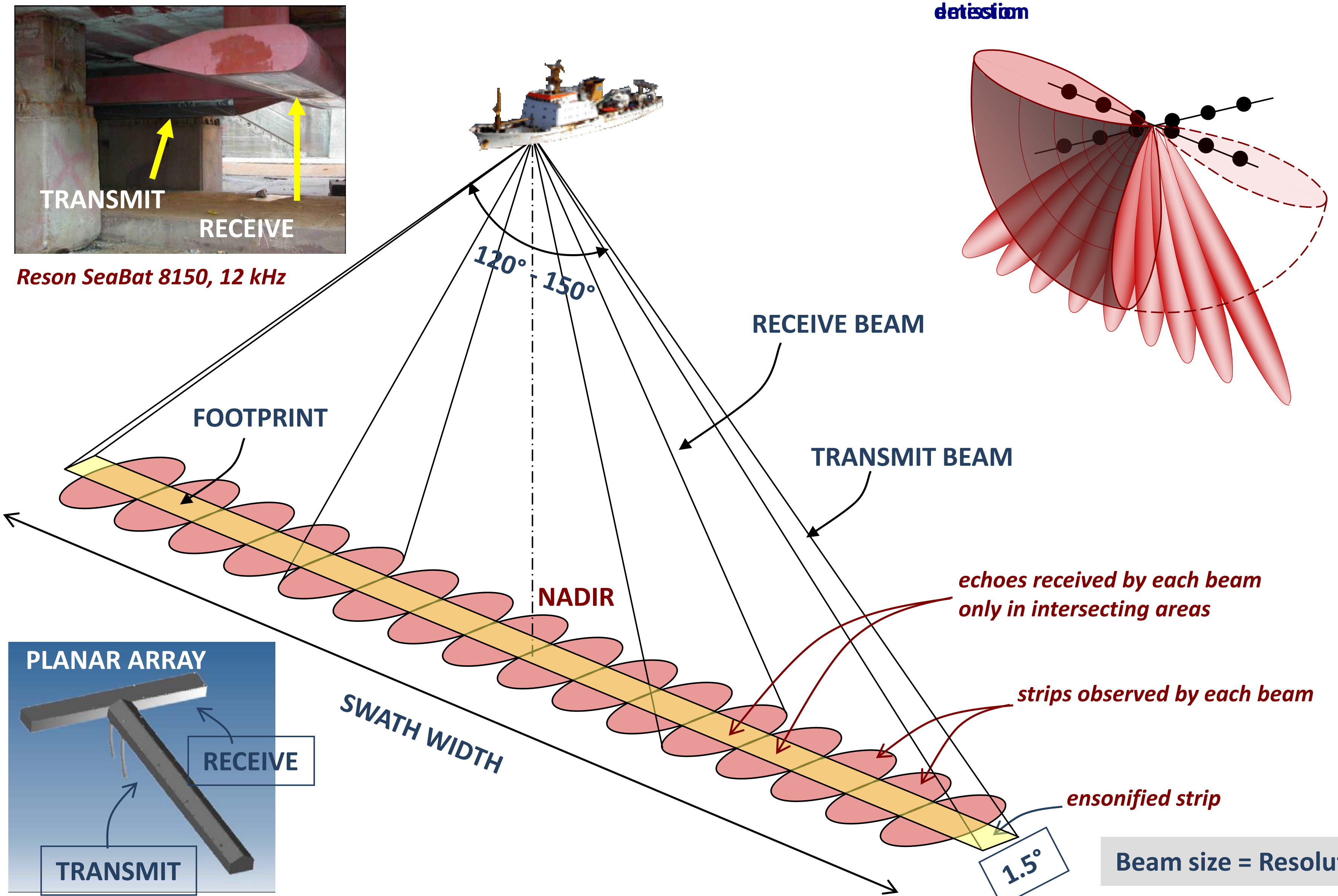



*Reson SeaBat 8111, 100 kHz*

### PORTABLE

# MULTIBEAM ECHOSOUNDER

## THE T CONFIGURATION

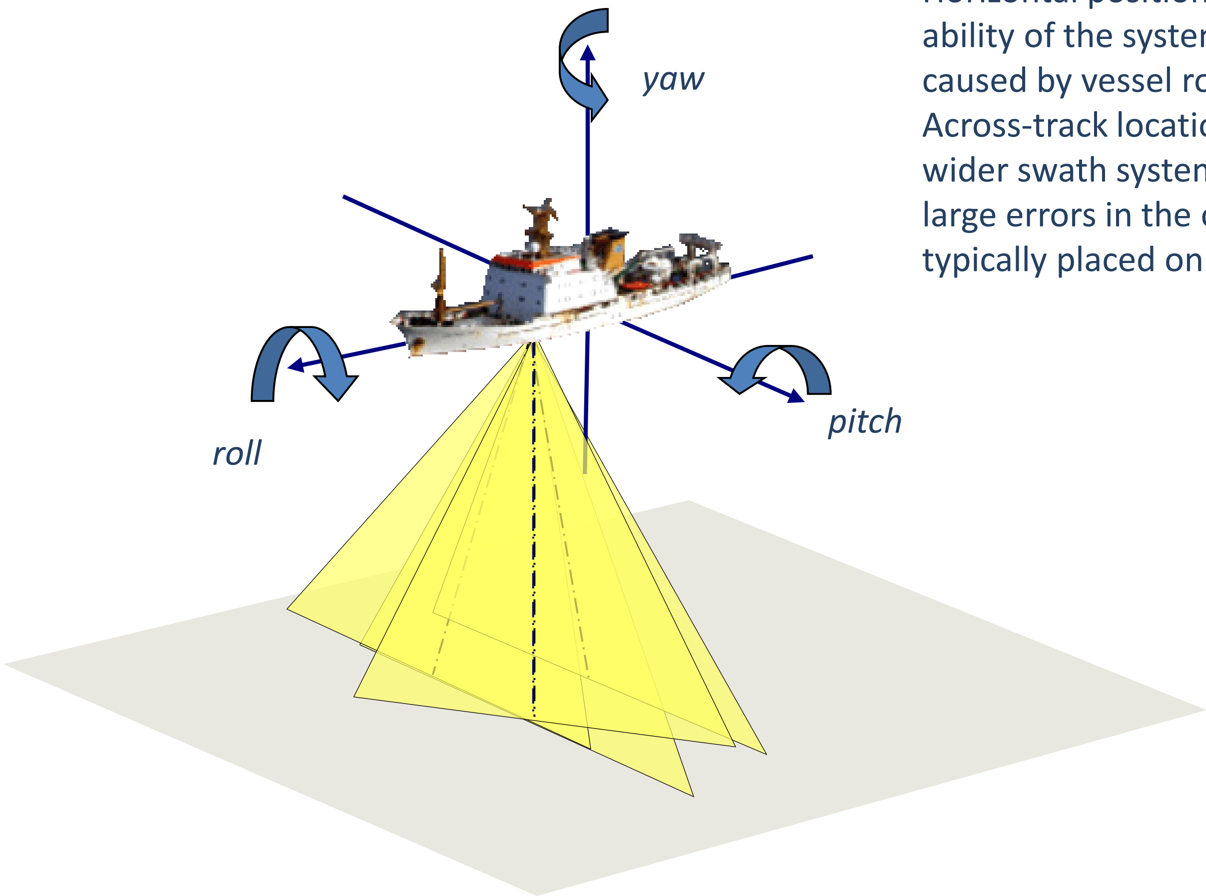



*Reson SeaBat 8150, 12 kHz*

**Beam size = Resolution**

# 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**
- **Heading**
- **Heave**
- **Positioning**
- **Transducer mount**

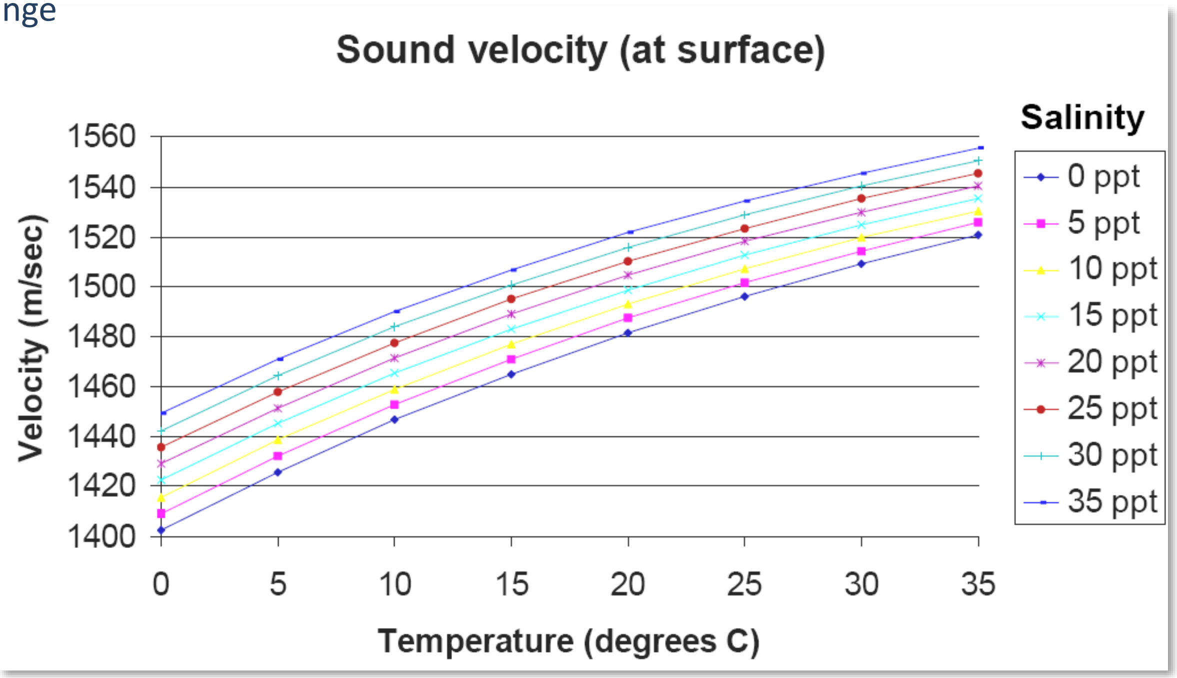
# MULTIBEAM ECHOSOUNDER — SOUND VELOCITY

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



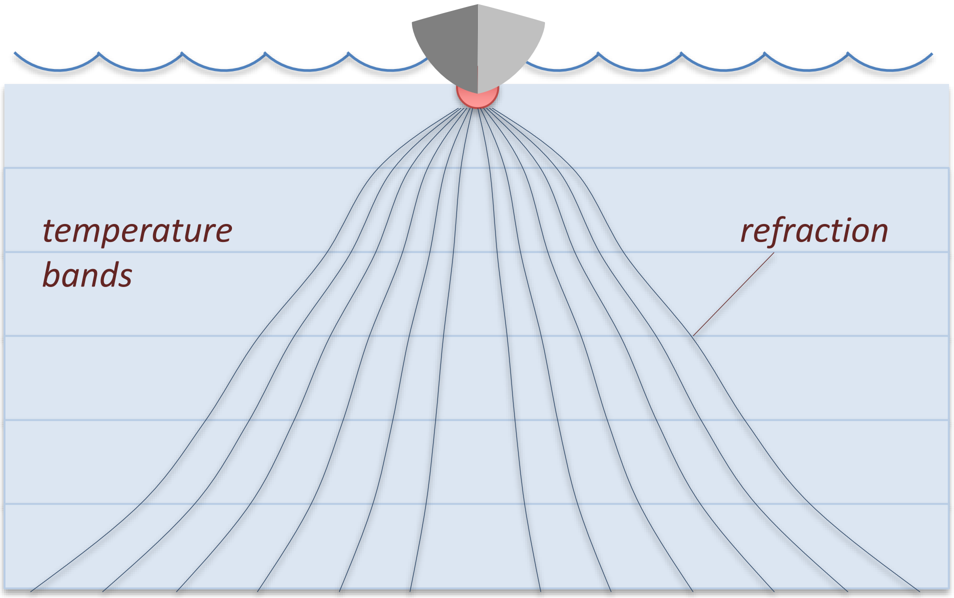

## TEMPERATURE

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

**MULTIBEAM ECHOSOUNDER** SOUND VELOCITY

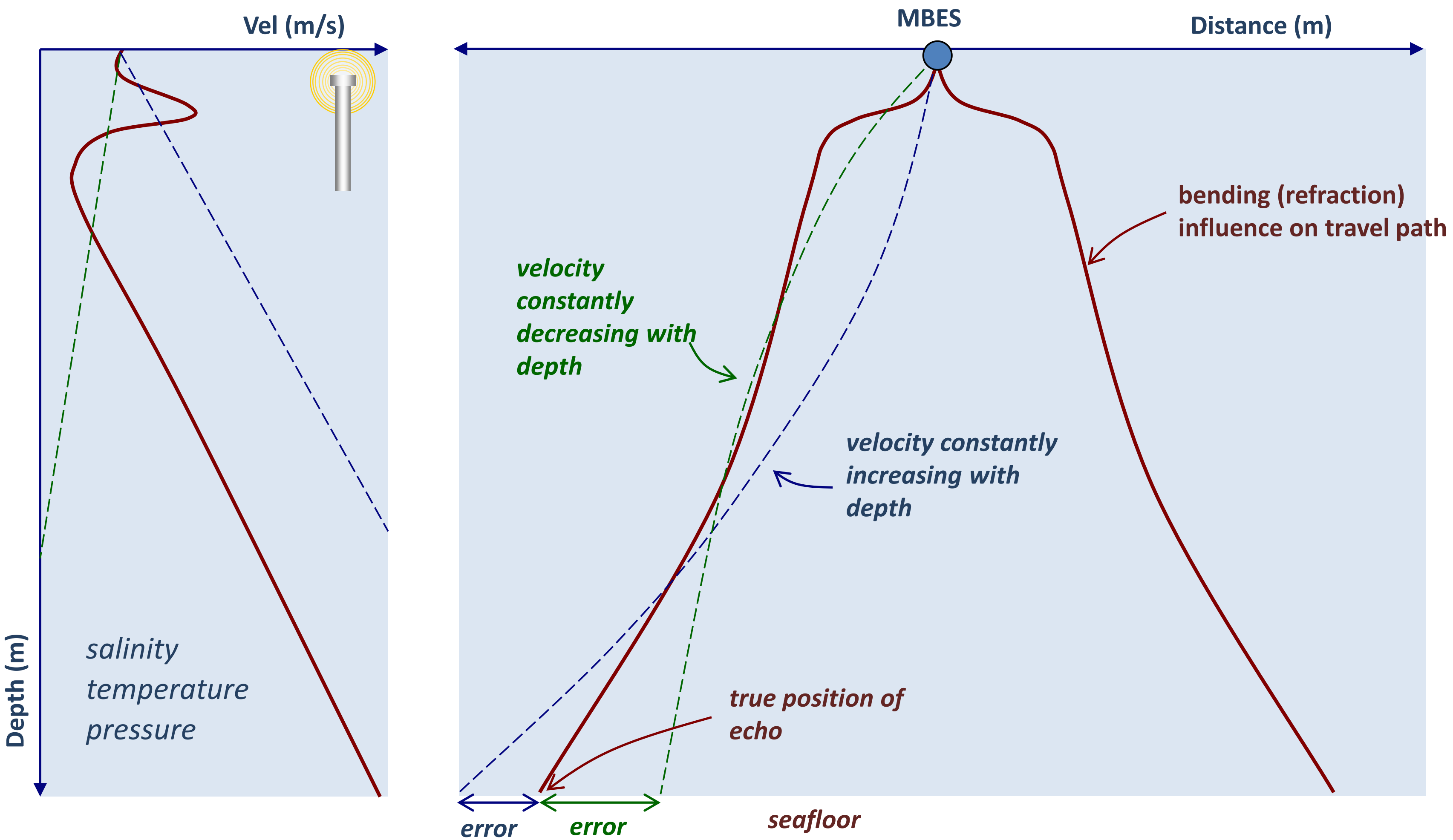
## RAY BENDING

- 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

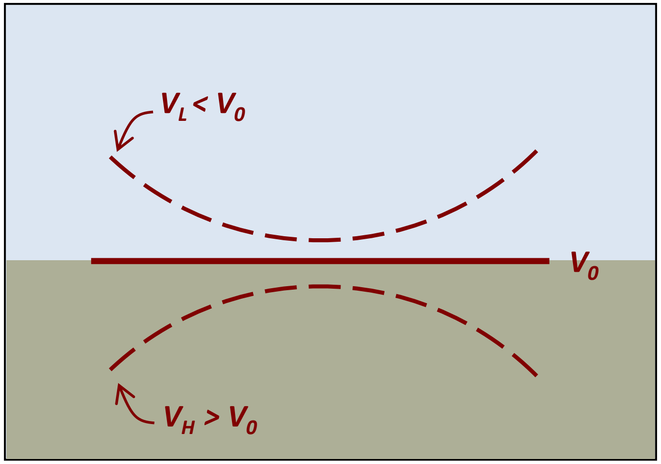


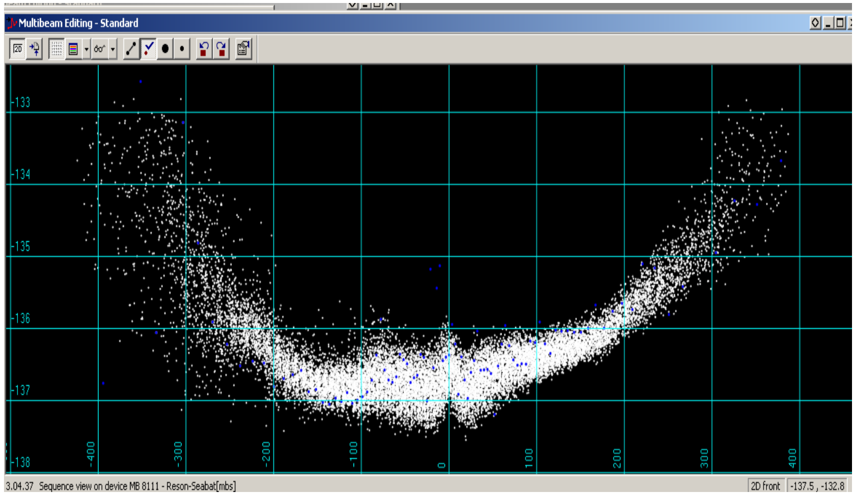
# MULTIBEAM ECHOSOUNDER | VELOCITY ERRORS

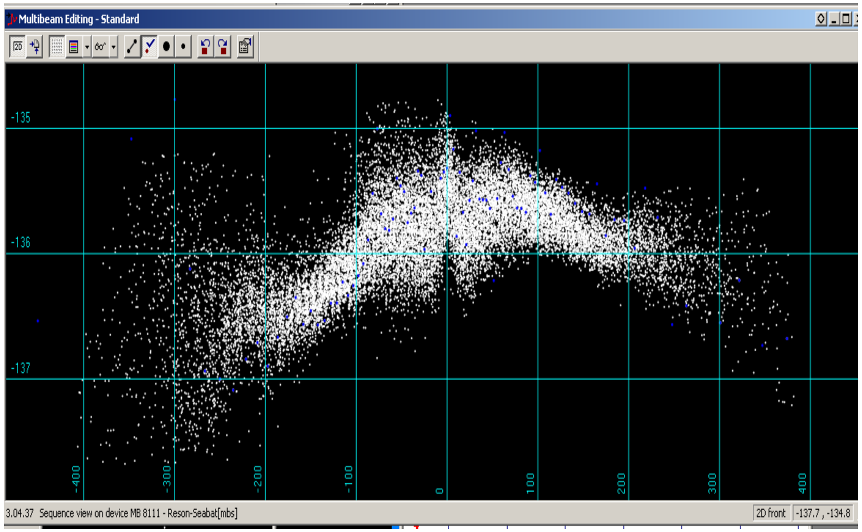
## SMILES & FROWNS

Indicates errors in the sound velocity setting

Range = ½ * V * Δt



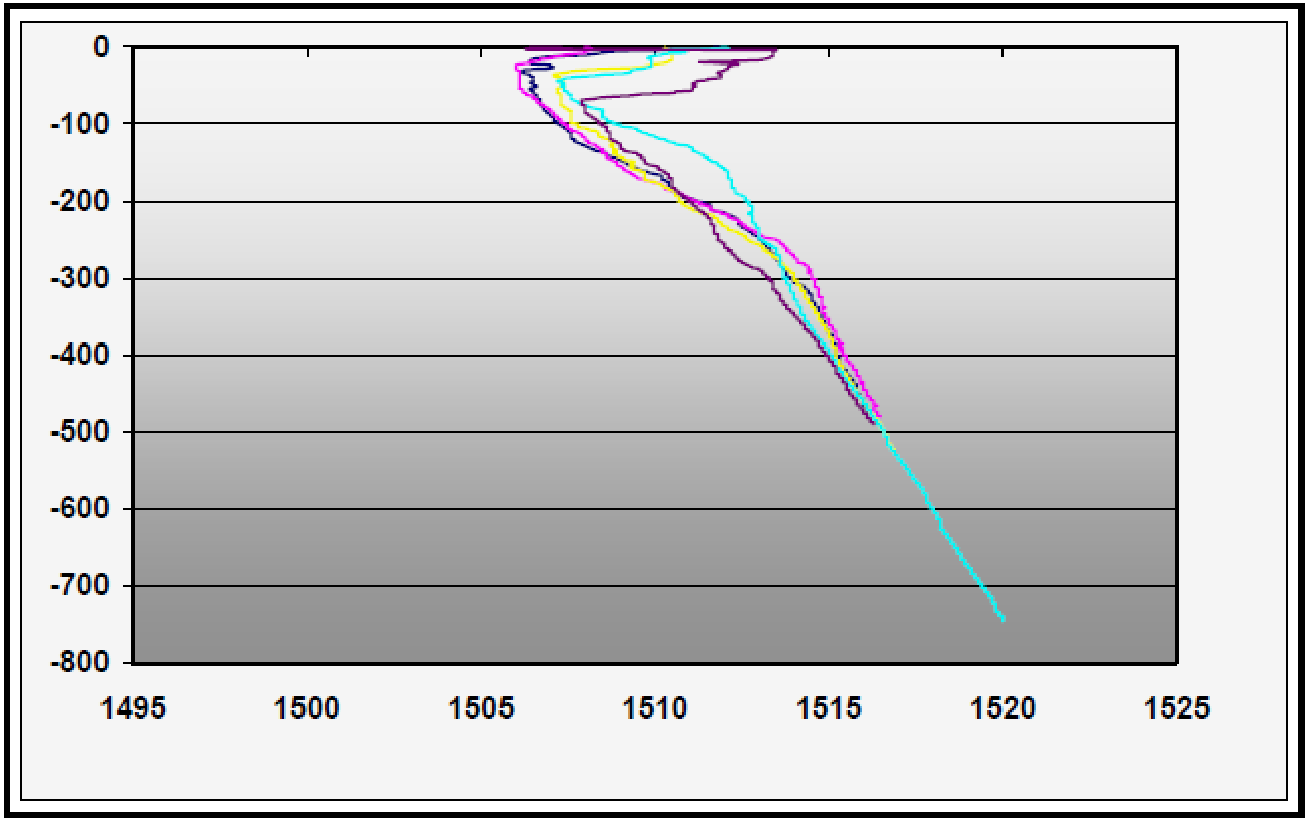



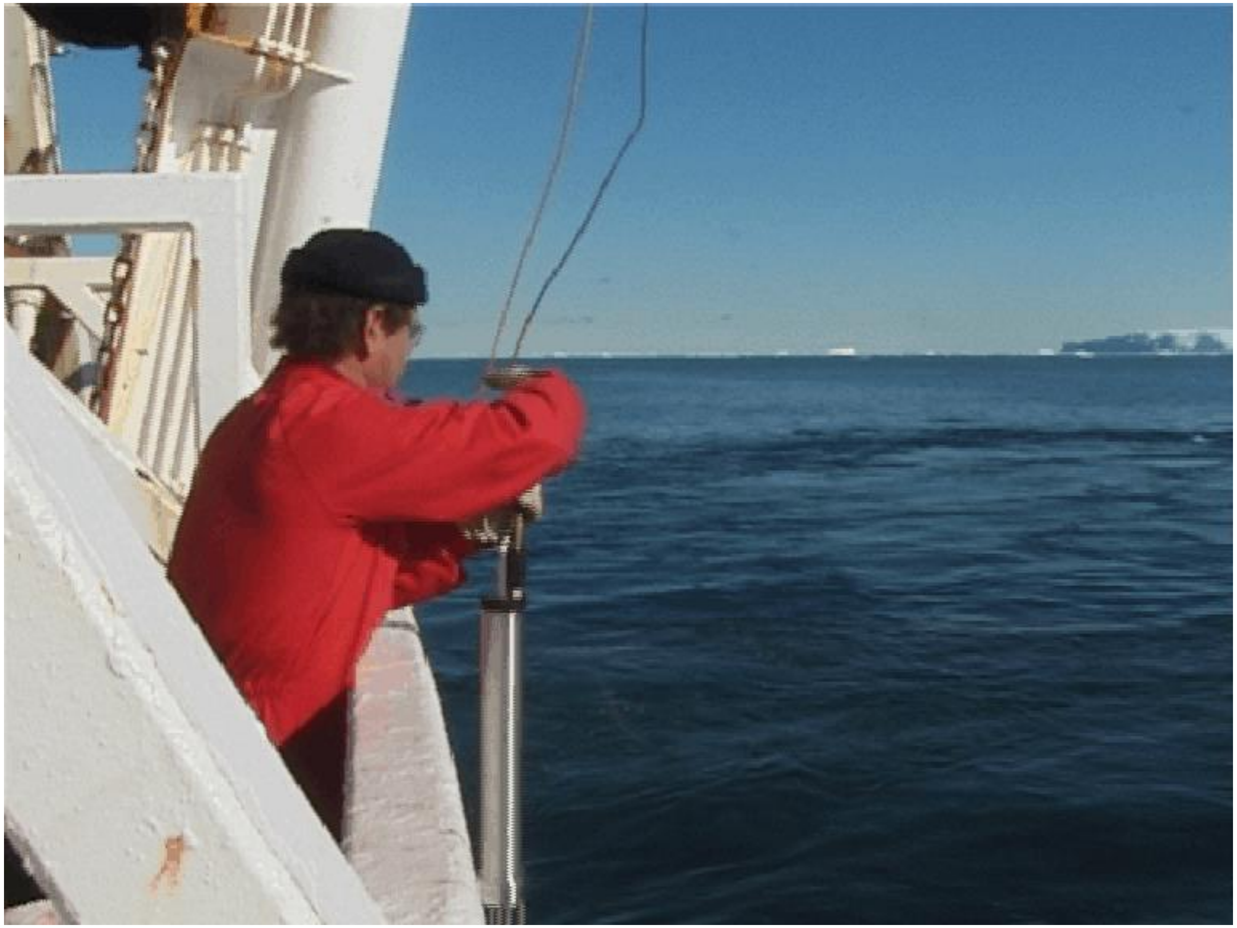
# MULTIBEAM ECHOSOUNDER | SOUND VELOCITY PROFILES

## 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

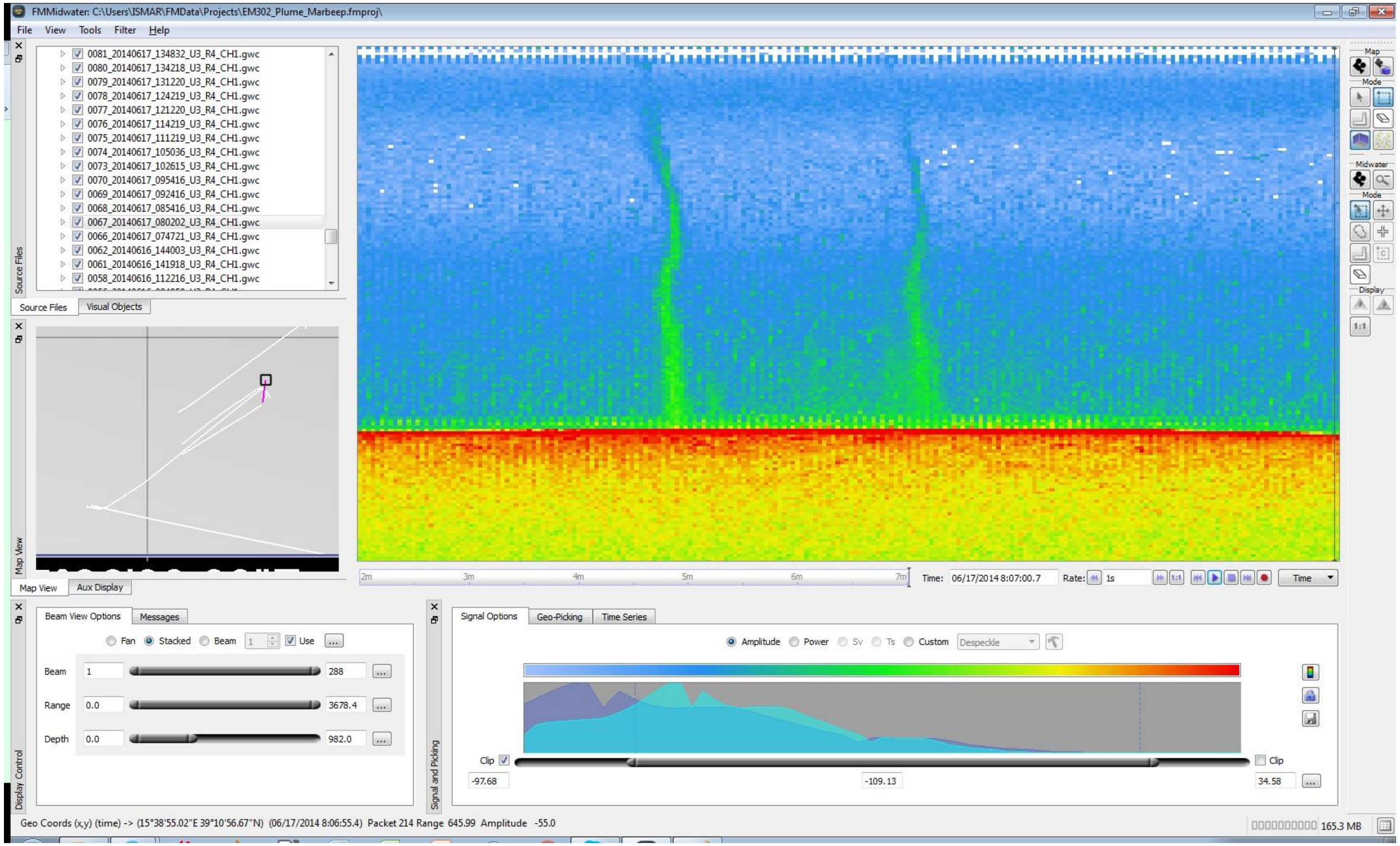


## MULTIBEAM ECHOSOUNDER SOUND VELOCITY PROFILING



# MULTIBEAM ECHOSOUNDER WATER COLUMN

## GAS PLUMES



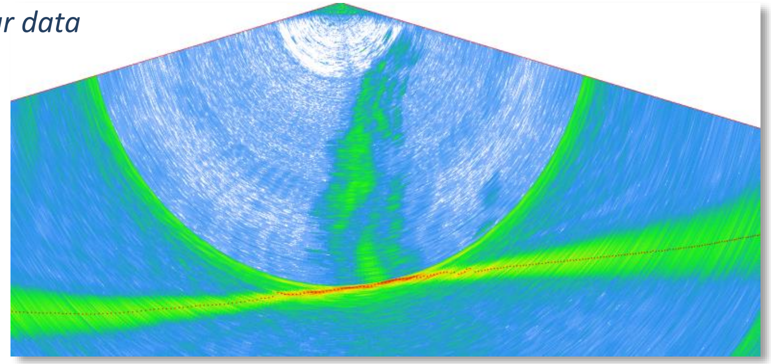
Stacked gas plumes detected in the water column by the EM302 multibeam system along a transect over a mud volcano. Rovere et al., 2014. Normal faults control fluid flow structures at the rear of the Calabrian Arc (Paola Ridge, southeastern Tyrrhenian Sea). GNGTS 2014.

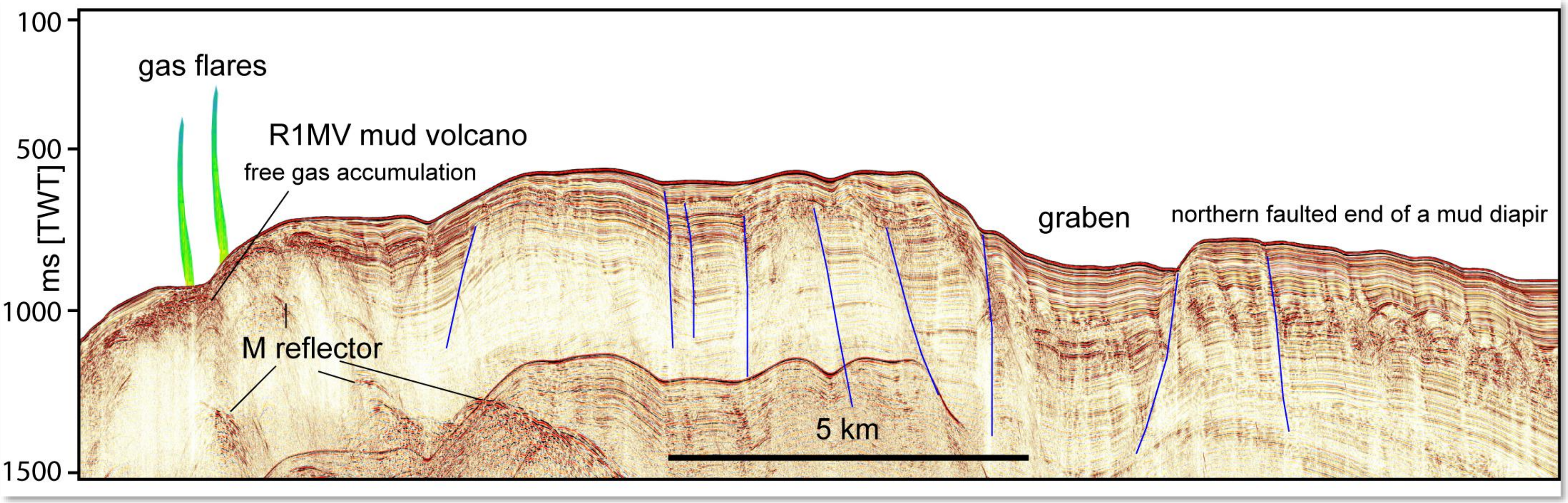
# MULTIBEAM ECHOSOUNDER WATER COLUMN

## GAS PLUMES

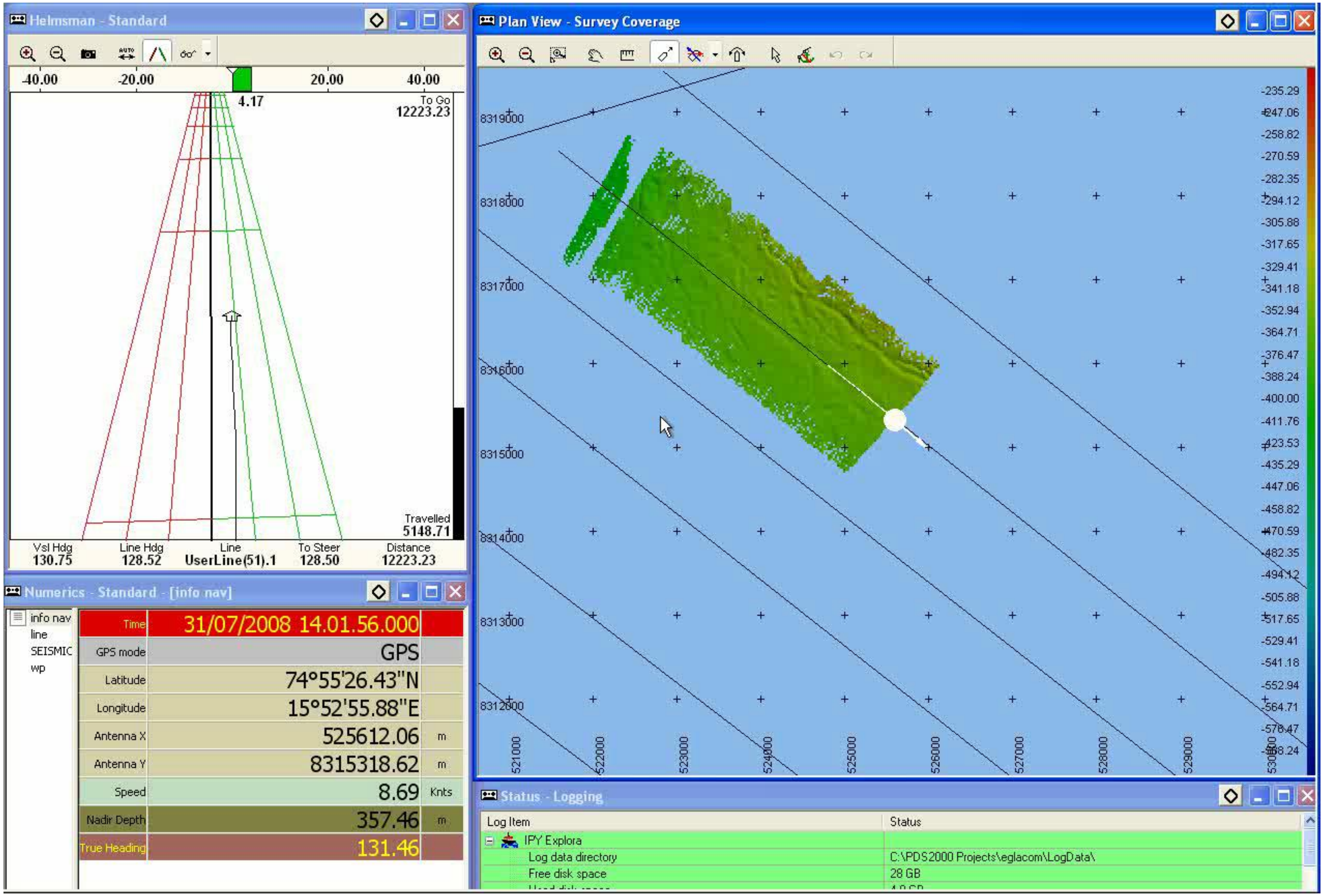
### Integration with seismic data

*Raw sonar data*

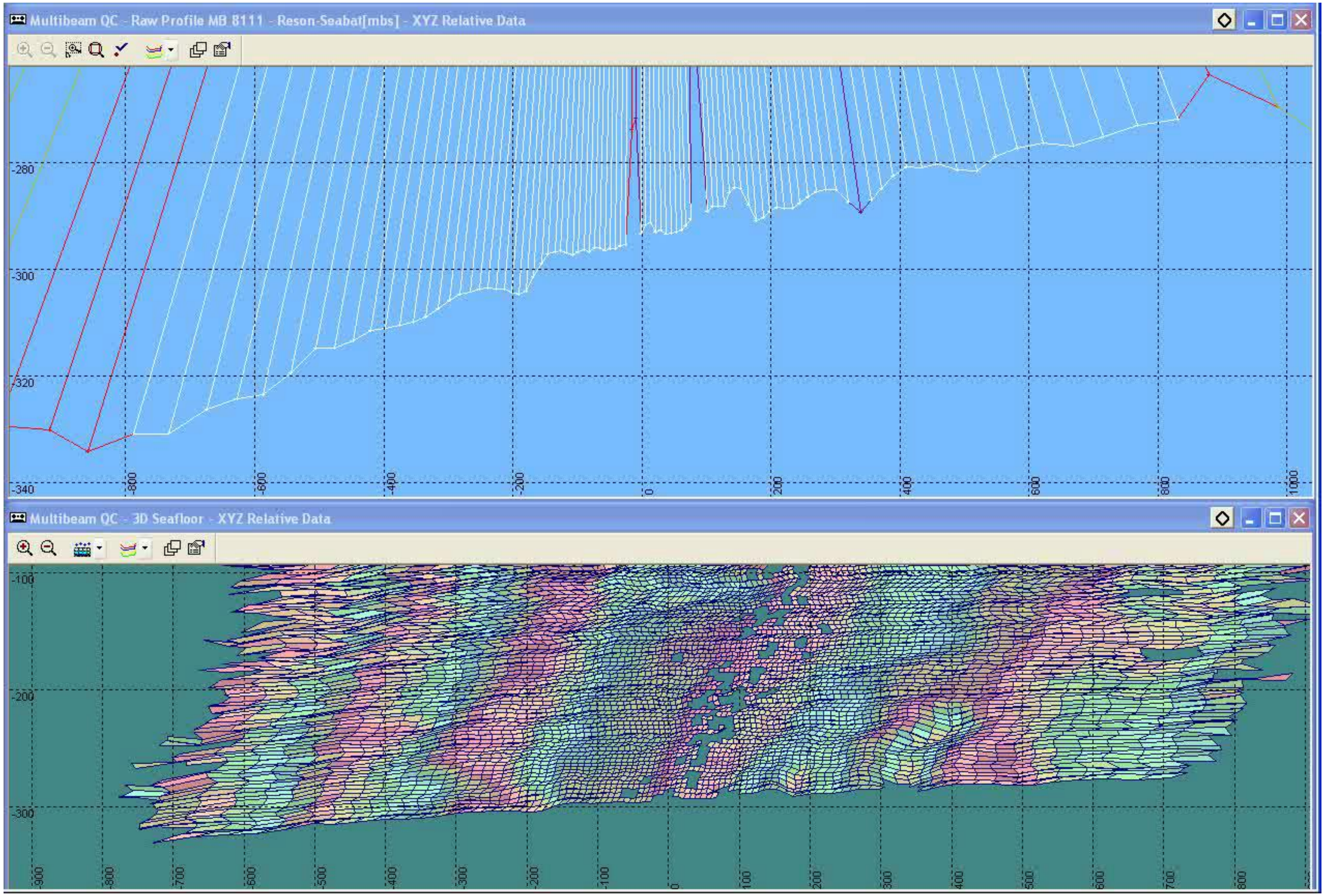




# MULTIBEAM ECHOSOUNDER DATA ACQUISITION

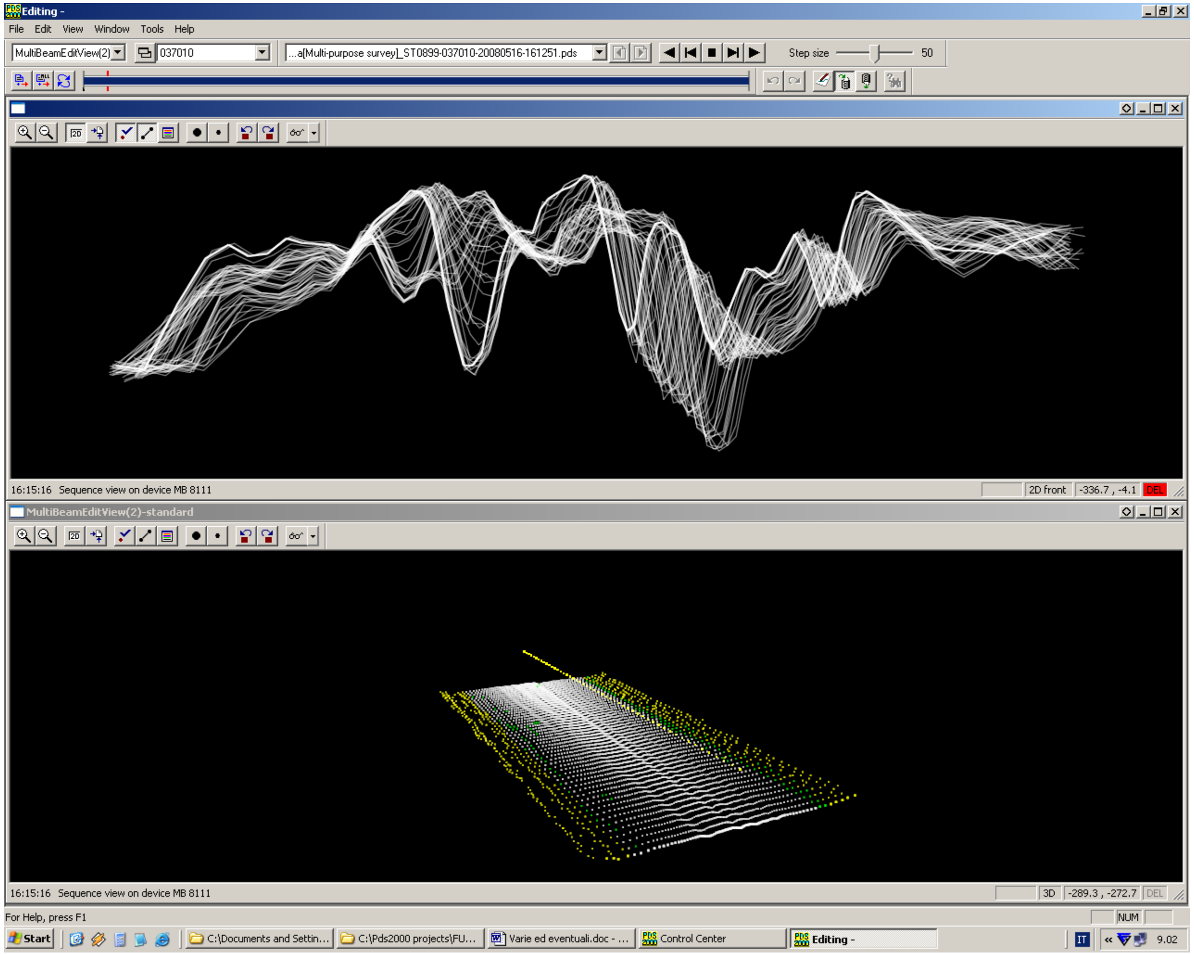


## MULTIBEAM ECHOSOUNDER DATA ACQUISITION

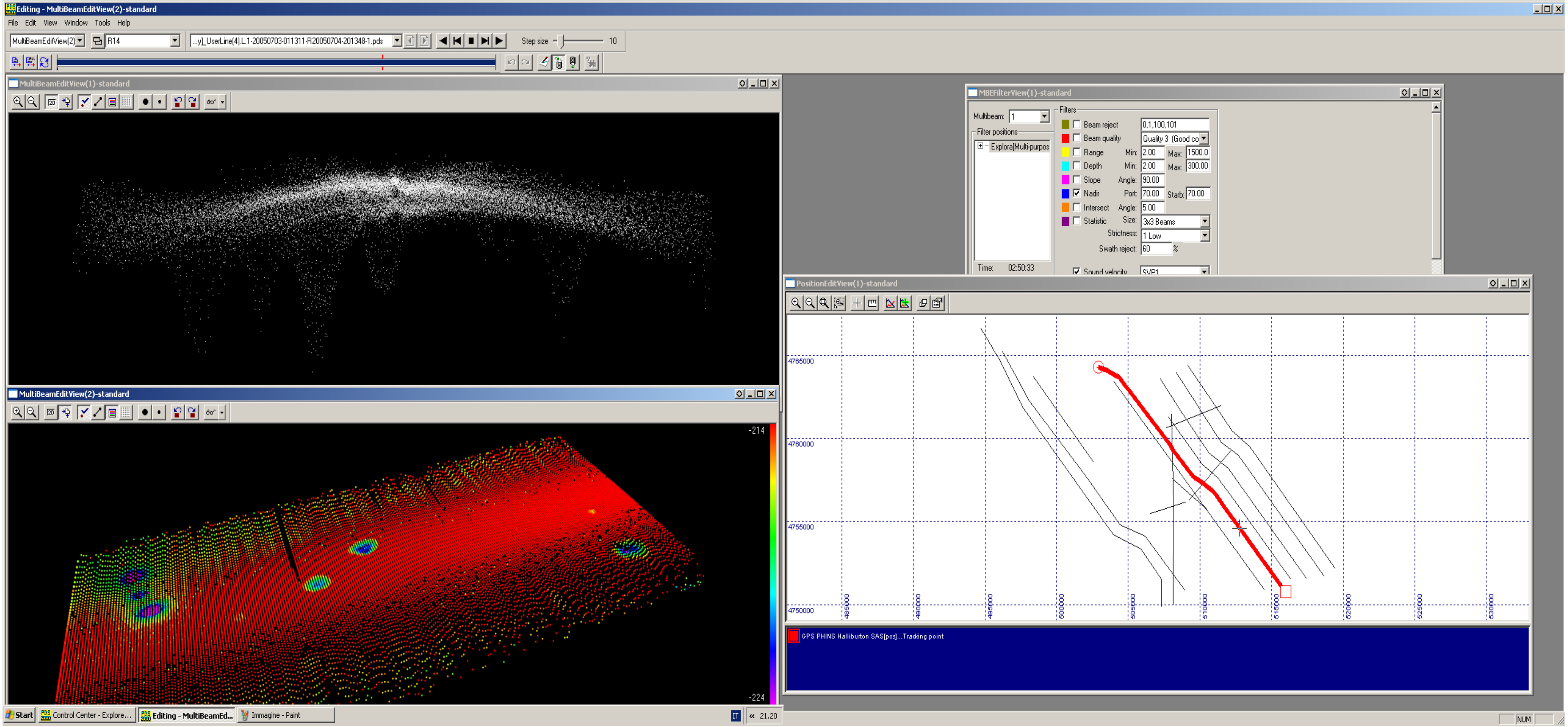


# MULTIBEAM ECHOSOUNDER QC AND PROCESSING

## SWATH EDITING



# MULTIBEAM ECHOSOUNDER QC AND PROCESSING



# MULTIBEAM ECHOSOUNDER — SURVEY PLANNING AND DESIGN

## INPUT PARAMETERS

*Area general setting*

- WATER DEPTH
- MORPH. SETTING

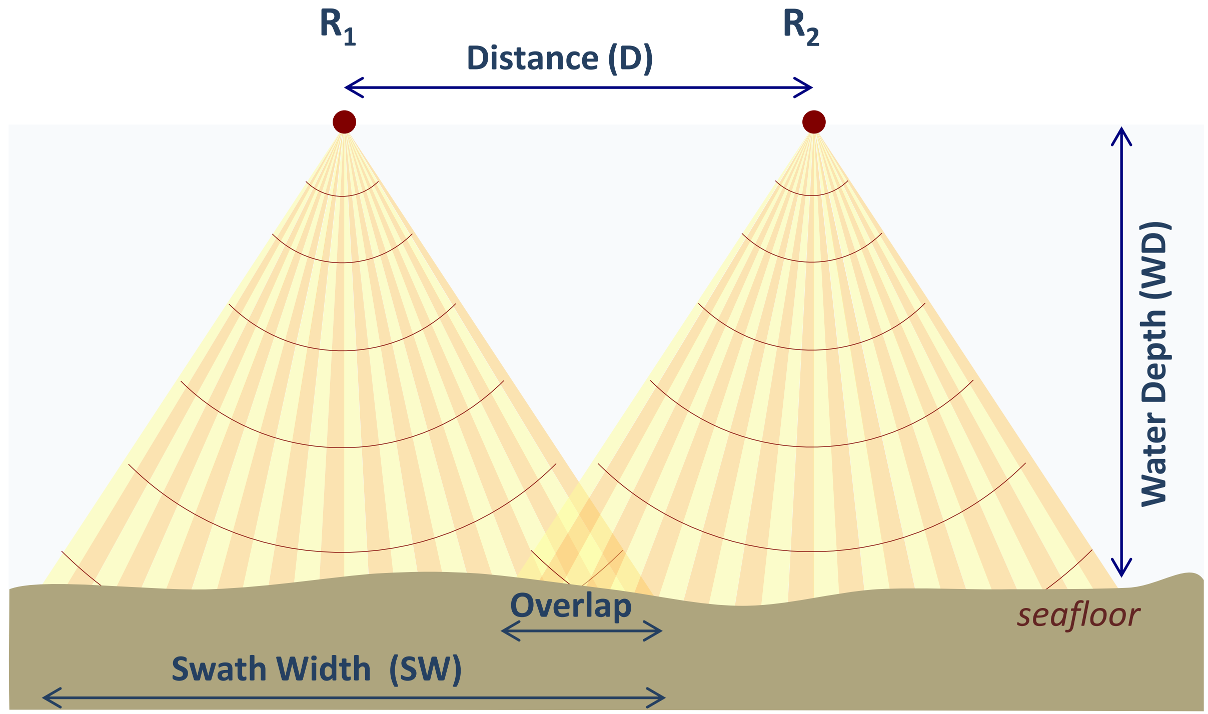
*System Performance*

- SWATH vs DEPTH

## SURVEY GEOMETRY

*Route planning*

- DIRECTION
- DISTANCE

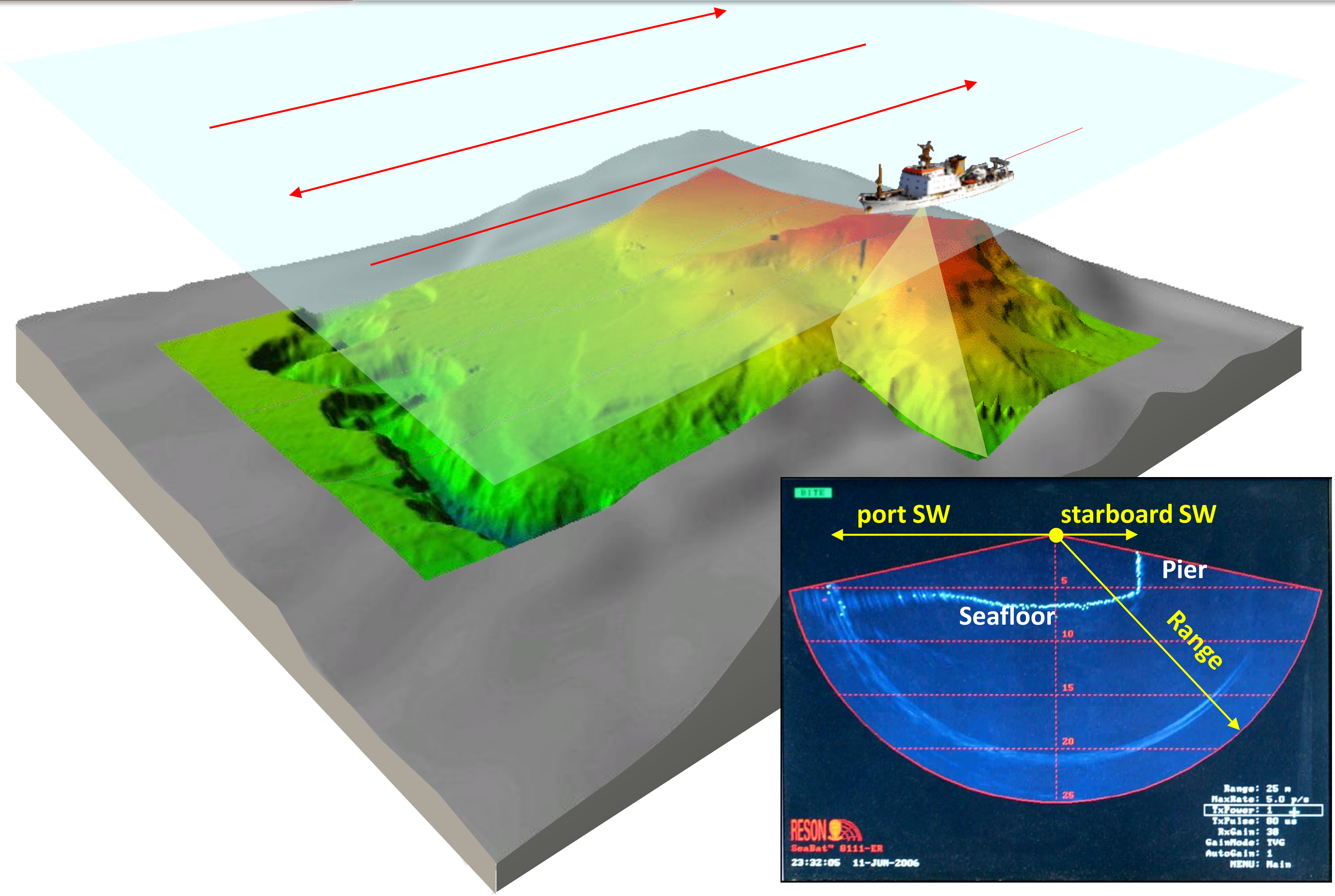



*Routes parallel to isobathes*

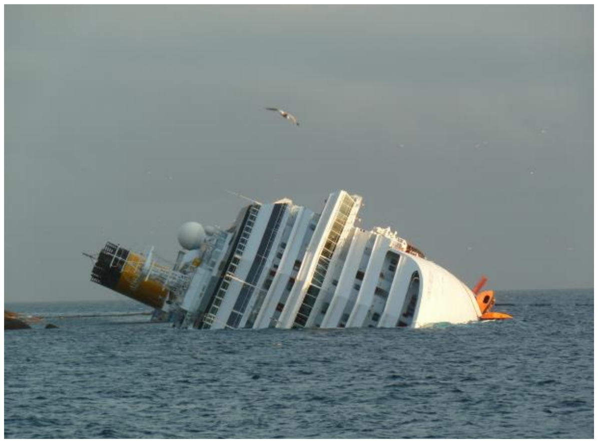
*Overlap between adjacent swaths 20% - 30%*
*D = 2 X Sw – 0.3 Sw*
*EXAMPLE SW = 4000 M > D = 6800 M*

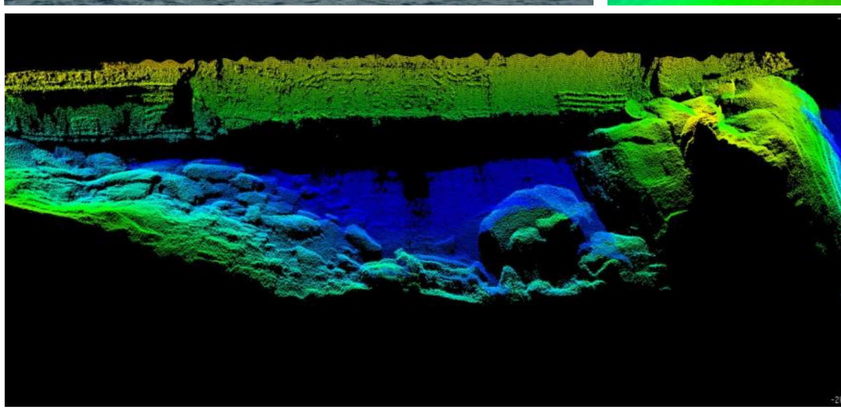
# MULTIBEAM ECHOSOUNDER

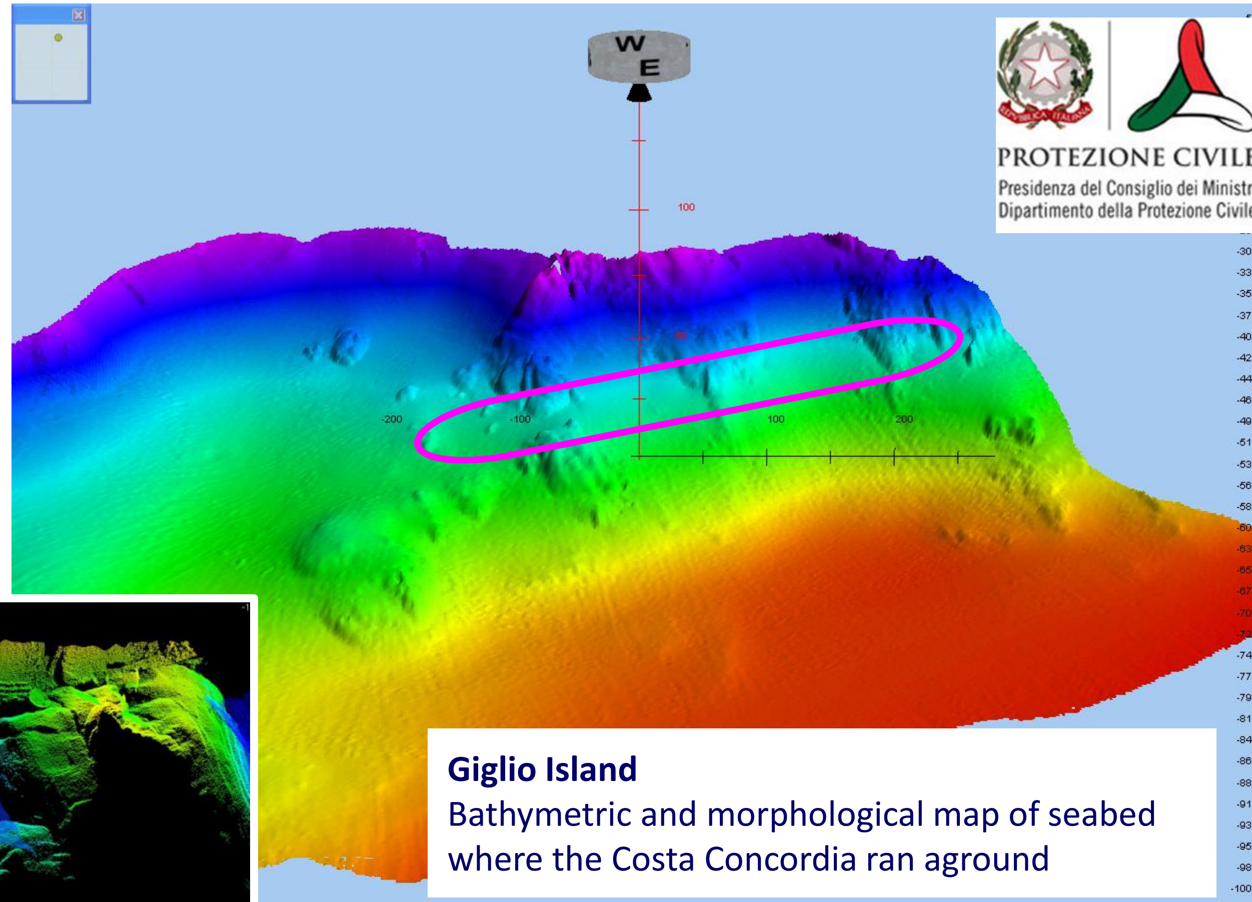
## SURVEY PLANNING AND DESIGN



## MULTIBEAM ECHOSOUNDER | ENVIRONMENT AND SOCIETY








**Giglio Island**
Bathymetric and morphological map of seabed where the Costa Concordia ran aground

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

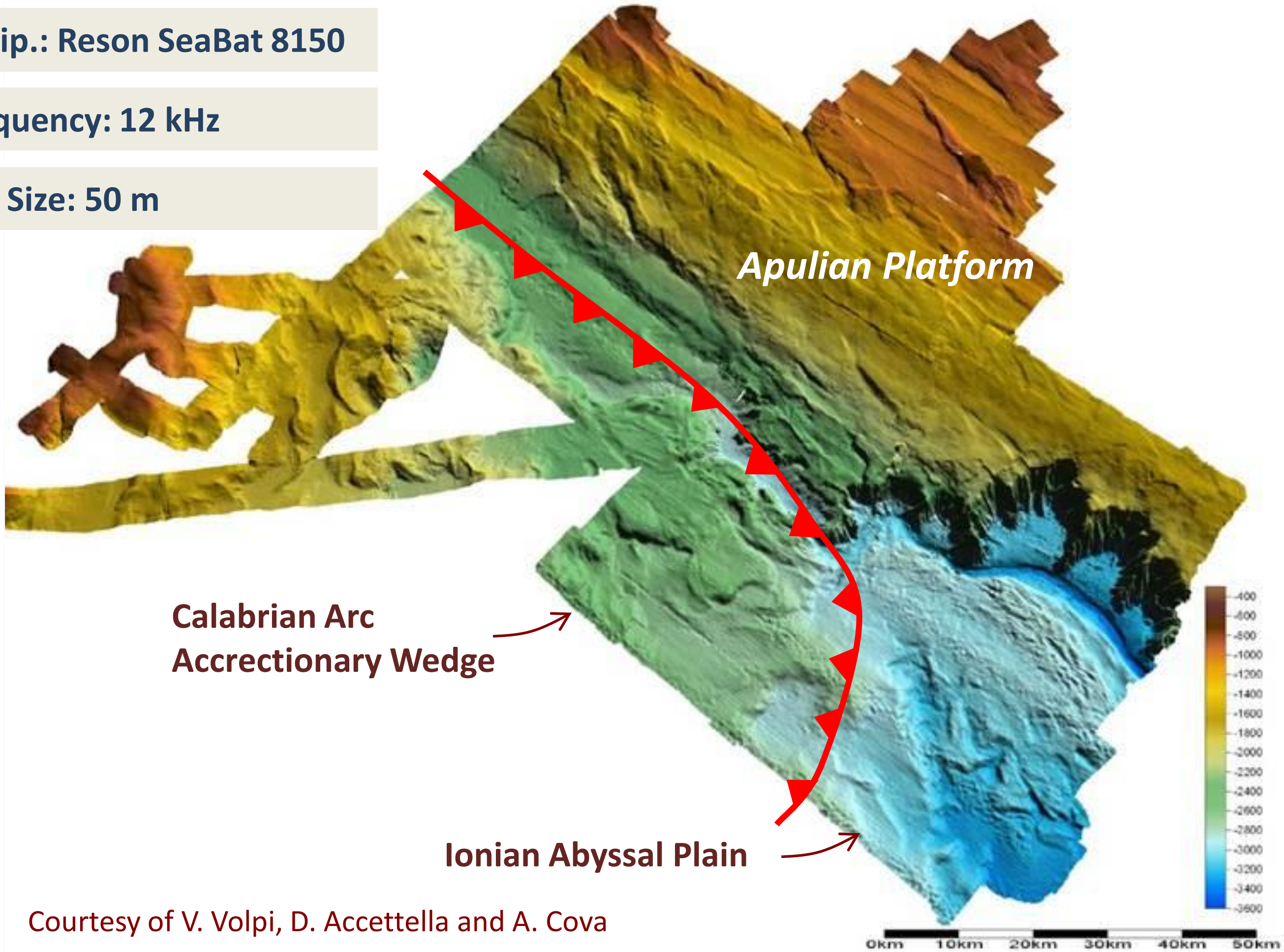
## MULTIBEAM ECHOSOUNDER ACADEMIC

M/V OGS Explora, 2003

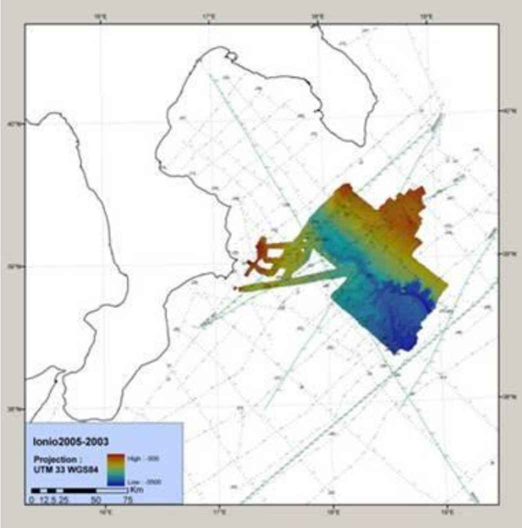
Equip.: Reson SeaBat 8150

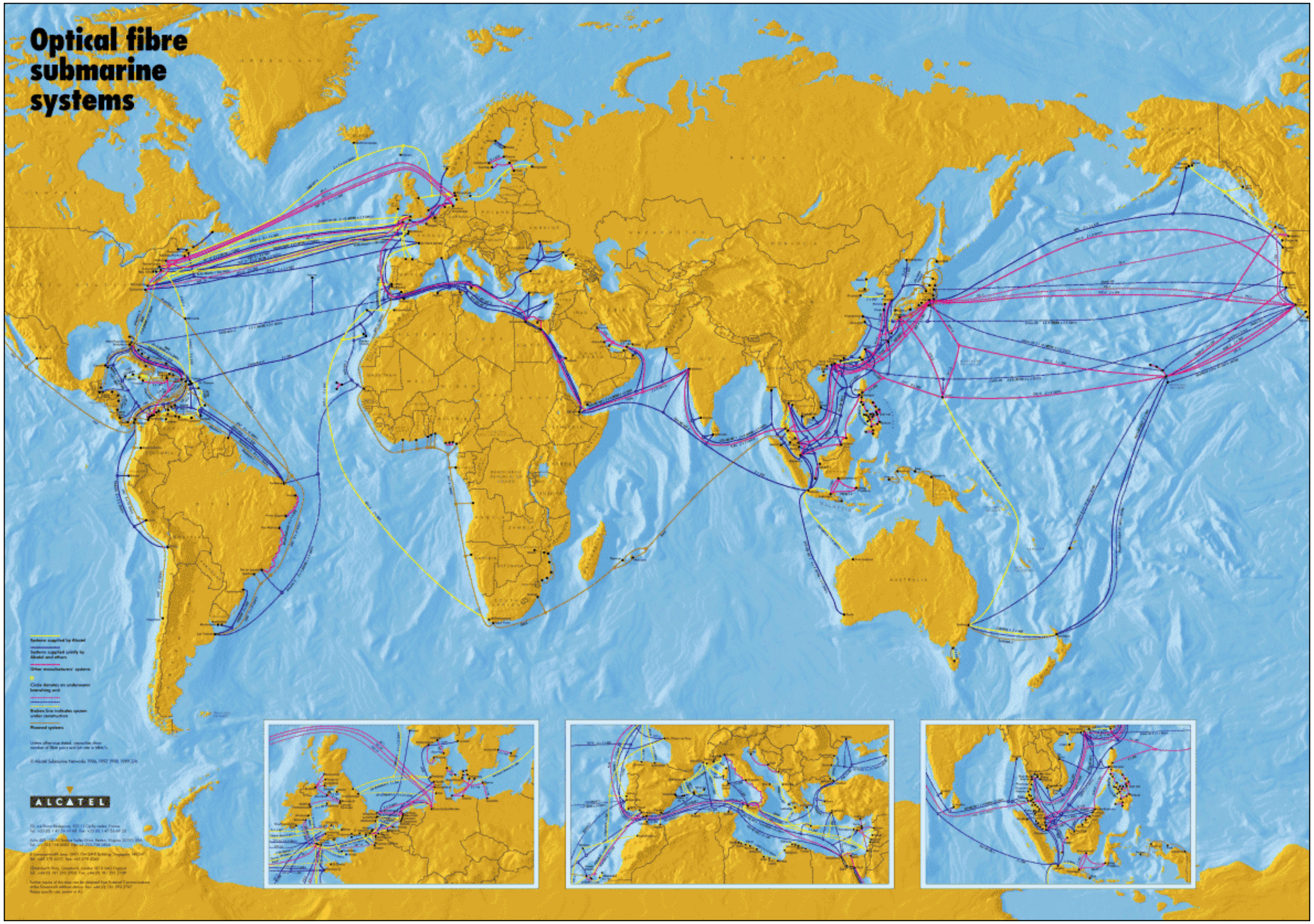
Frequency: 12 kHz

Cell Size: 50 m

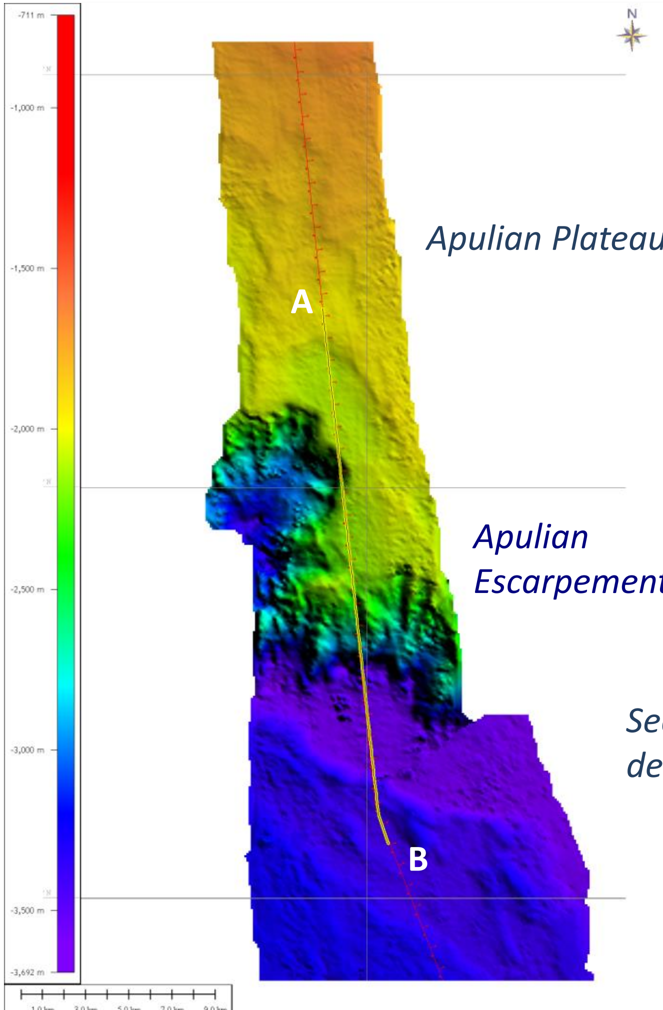



Courtesy of V. Volpi, D. Accettella and A. Cova




Optical fibre submarine systems
ALCATEL

# MULTIBEAM ECHOSOUNDER | CABLE SURVEY



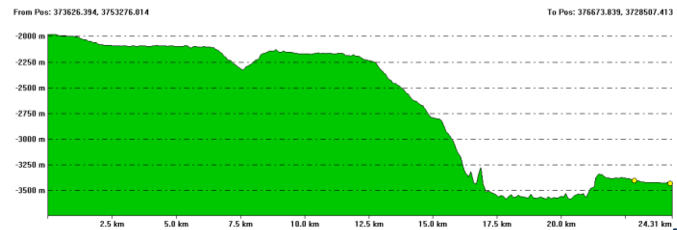

*Apulian Plateau*

*Apulian Escarpment*

*Seabed deep channel*

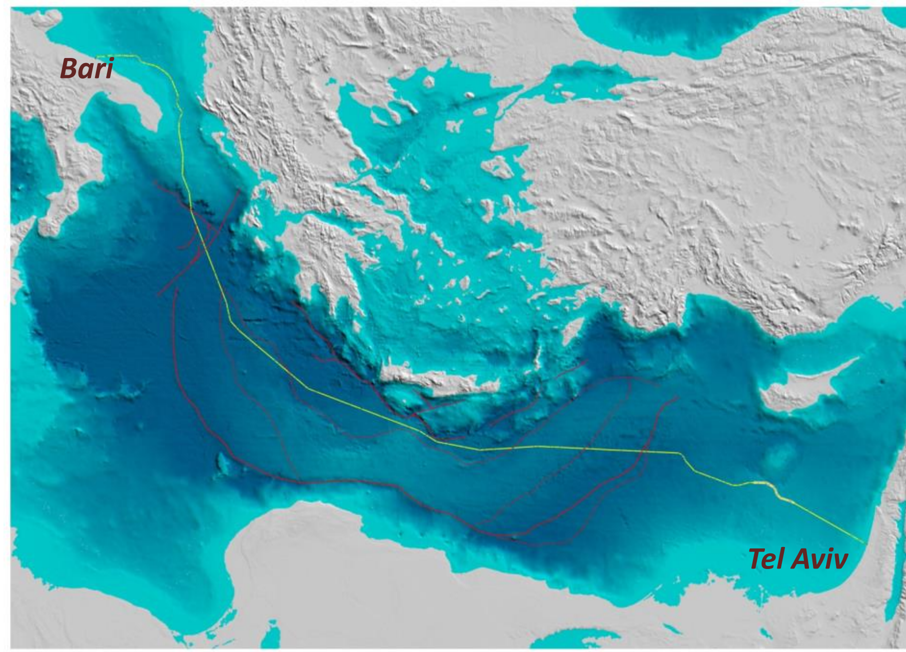
*Outer Calabrian Arc*

## Bathymetric profile




**A** **B**

***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."

http://www.telegraph.co.uk/technology/news/8753784/The-300m-cable-that-will-save-traders-milliseconds.html