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oceanografía litoral

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Doppler Profilers for Gliders: Capabilities and Limitations

EGO-2011 Workshop and Glider School

Thanks and Intro

Ocean gliders have just started their history as platforms for
- multisensor transport,
- Q on-line communication and
- Dreams for future applications

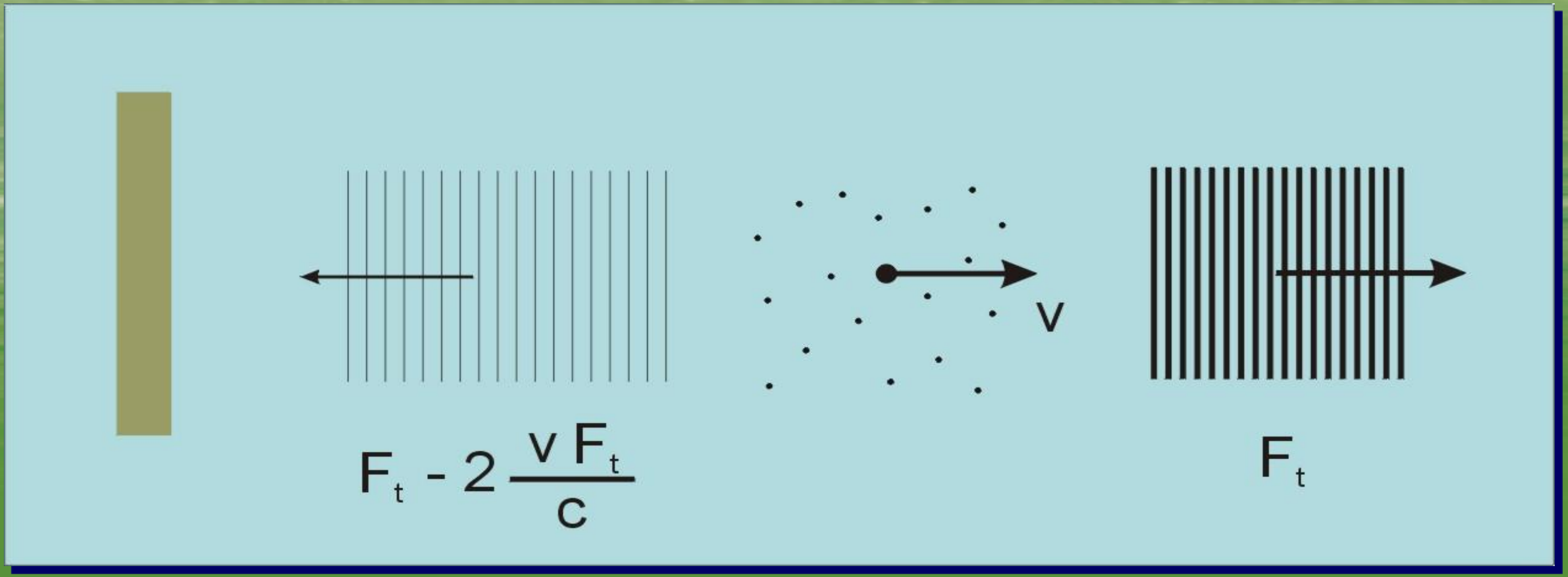
One of the most exciting/tricky applications are current meas.

Doppler profilers are able to gather water column **velocities**

The movement of the system should be accurately known (!)

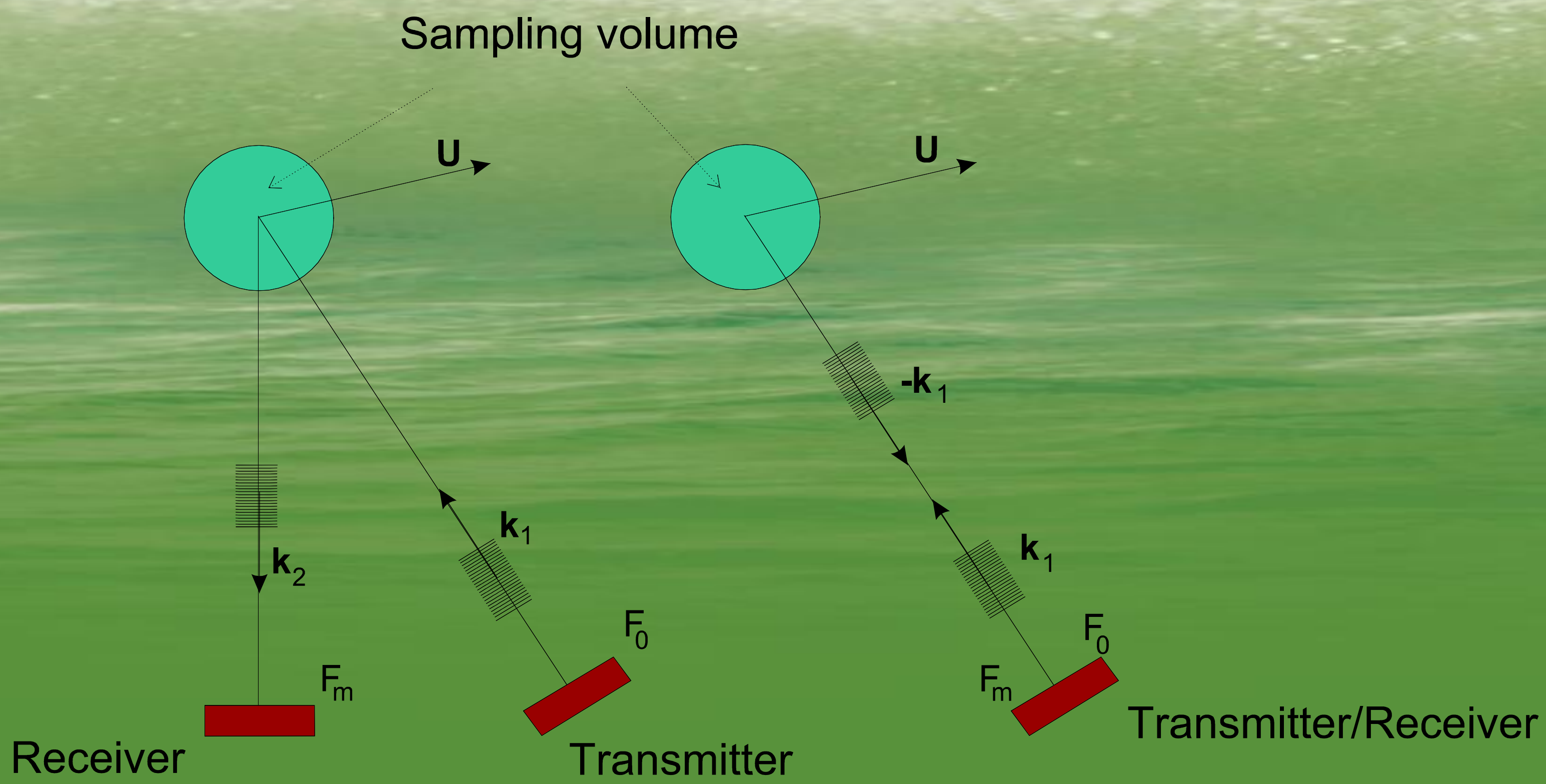
The behavior of a Doppler system too (!!)

The Doppler shift



An acoustic echo reflected from moving particles is shifted in frequency (Doppler shifted) in proportion to the particle velocity

The Doppler shift



Bistatic Doppler

($F_m = F_0 - \mathbf{k}_1\mathbf{U} + \mathbf{k}_2\mathbf{U}$)

Monostatic Doppler

($F_m = F_0 - 2\,\mathbf{k}_1\mathbf{U}$)

Velocity of what?

Acoustic return signal:

$$I(t) = I e^{i(\omega_t - \omega_D)t + i\phi(t)}, \quad \text{with } I = \sum_{i=1}^{N} I_i$$

ω_t = Acoustic transmit frequency

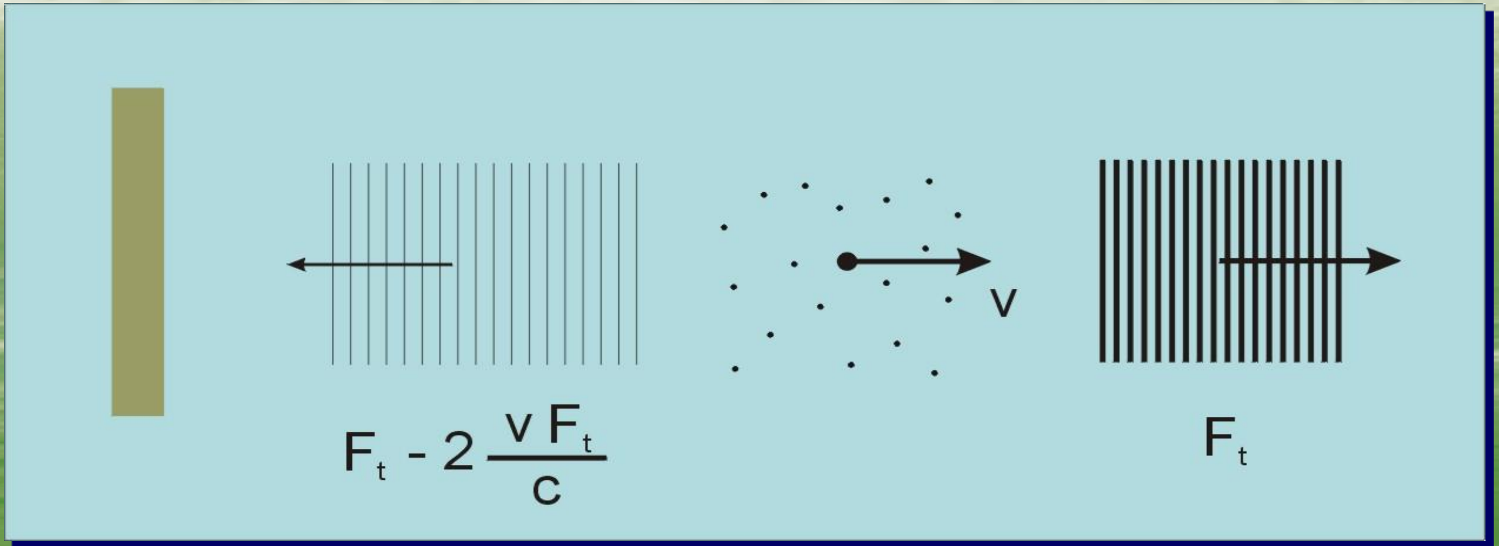
ω_D = Doppler shift

$\phi(t)$ = Random phase

I_i = Intensity of individual scatterers in sampling volume

Velocity of acoustic scatterers, not water !!

The range limitation

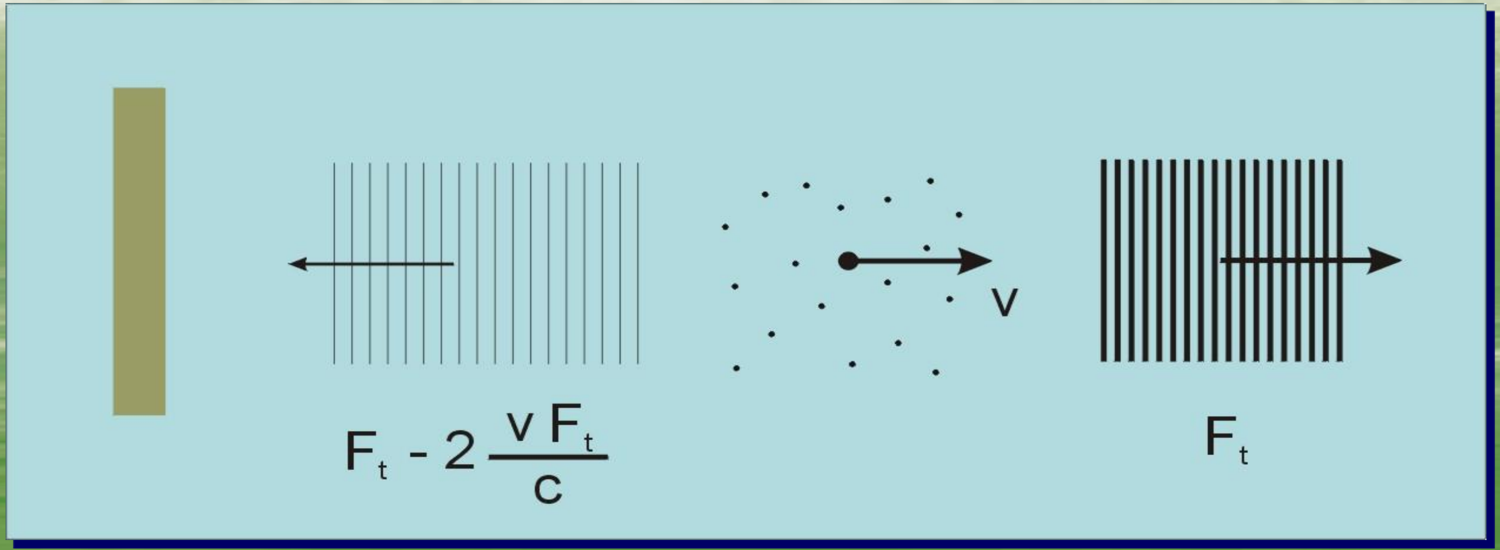


Dopplers use reflections from particles in the water to determine the velocity.

- Open ocean clear water means less particles: weaker return
- Absorption and geometric spreading limit the range
- The longer the range (lower freq), the longer the sensor
- Increasing range means weaker signal
- Border interaction renders in noise
- While diving no absolute velocities

2.-Doppler velocity

Counter-benefits of limitations



Anywhere at sea there are particles enough get a return.

- Advance signal processing provide nice info from ocean waters
- Signal-to-noise info lets evaluate data quality
- Advance ceramics permit lower freqs with lesser transducers
- Repeated measurement along a portion of water
- A glider is 99% of its dives far from the borders
- When in surface it can be '*GPSed*' for true vector velocities

Doppler sensor velocity calculation

V = D·c ·T

D - ***Measured Doppler shift***

Linear response

No zero bias observed at flows down to 0.04 cm/s

c - ***Speed of sound (user input)***

Function of temperature and salinity

5°C change ⇒ 1% change in speed of sound

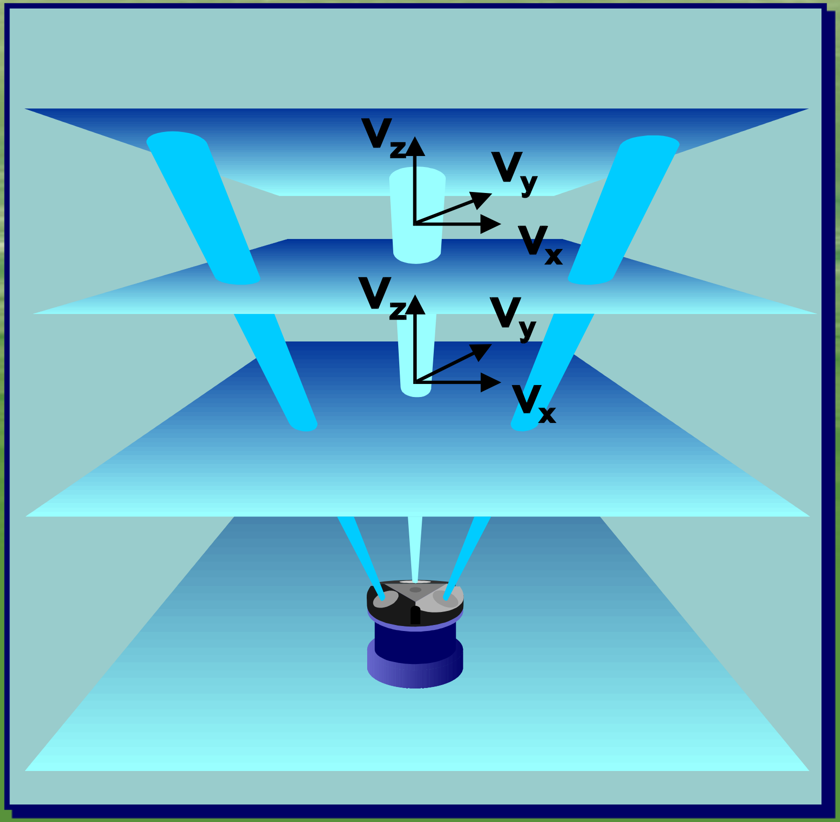
12 ppt change ⇒ 1% change in speed of sound

1% error in speed of sound ⇒ 2% error in velocity

T - ***Transformation matrix (manufacturer input)***

Depending only on transceiver geometry

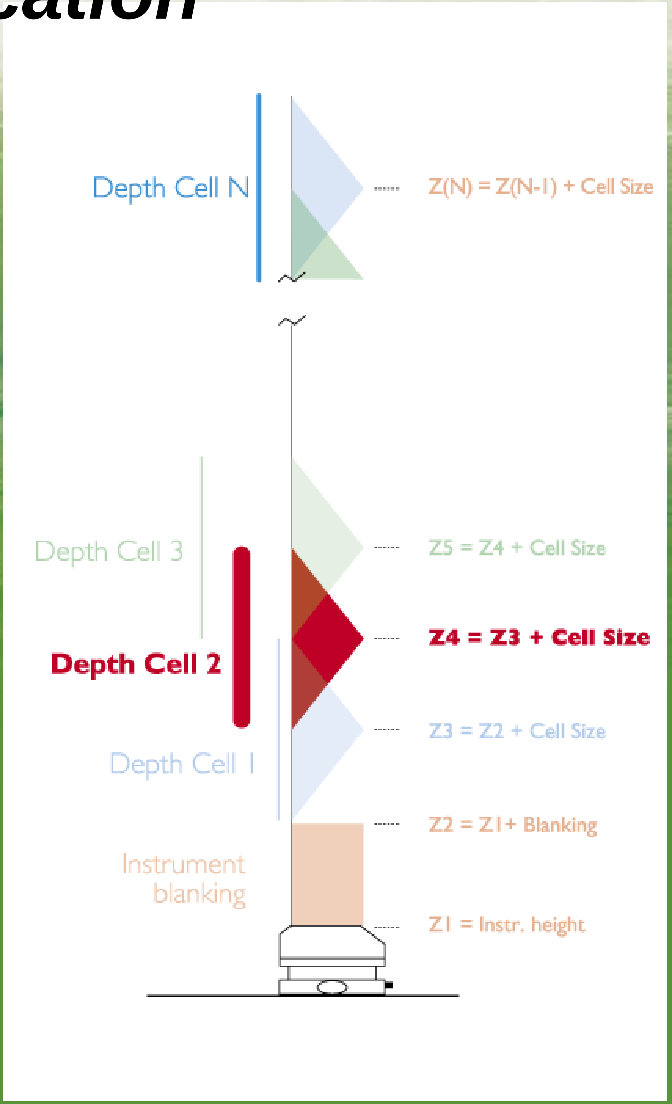
Doppler profiler



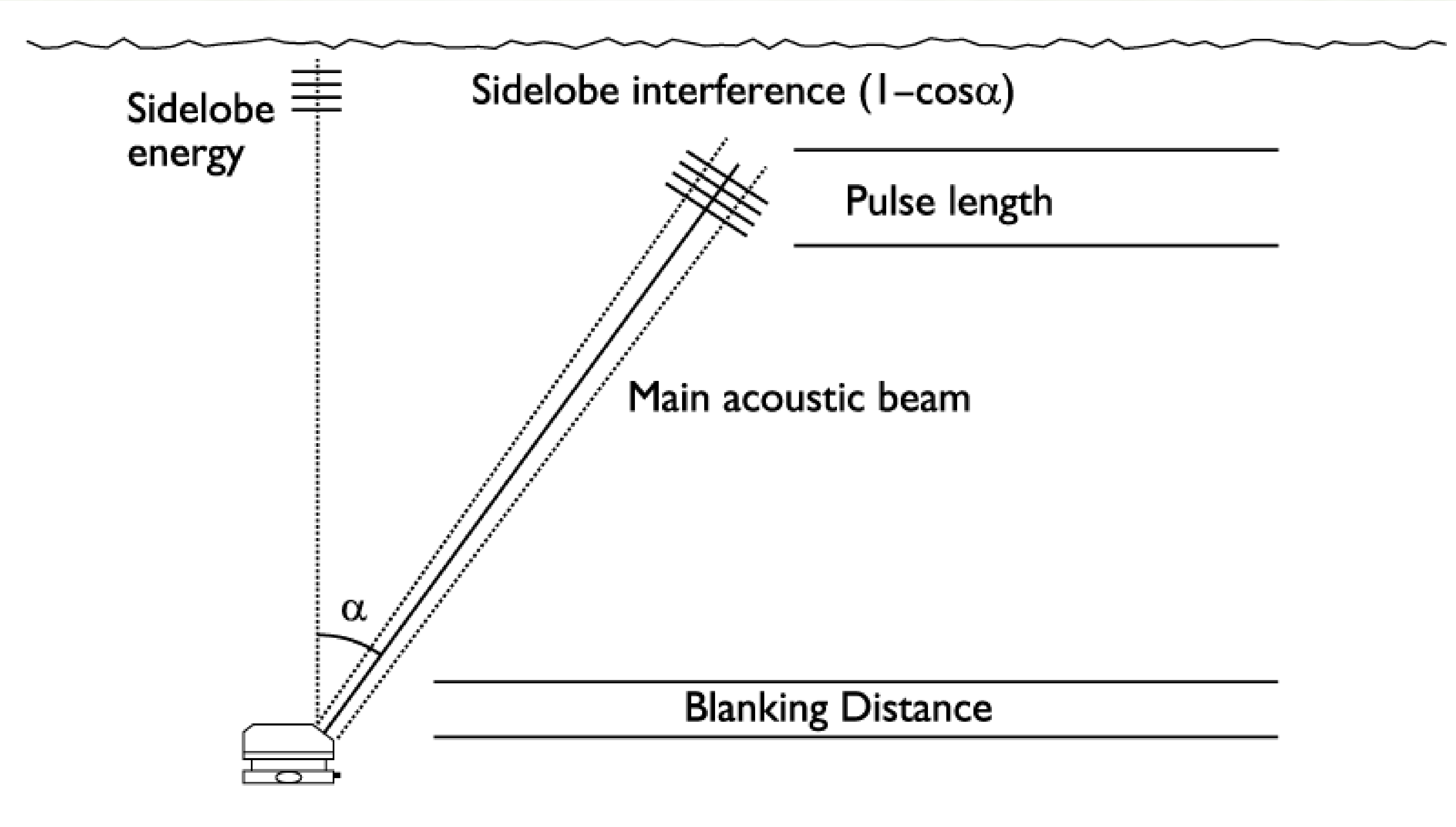
- Velocity measured at three spots (cells) at each level (layer)
- Acoustic signals are sent and received along the same axis
- Profiling range depends on freq. and amount of scattering material
- Broad output rates: from 1 Hz to 1 hour

2.-Doppler velocity

Current profiler cell location



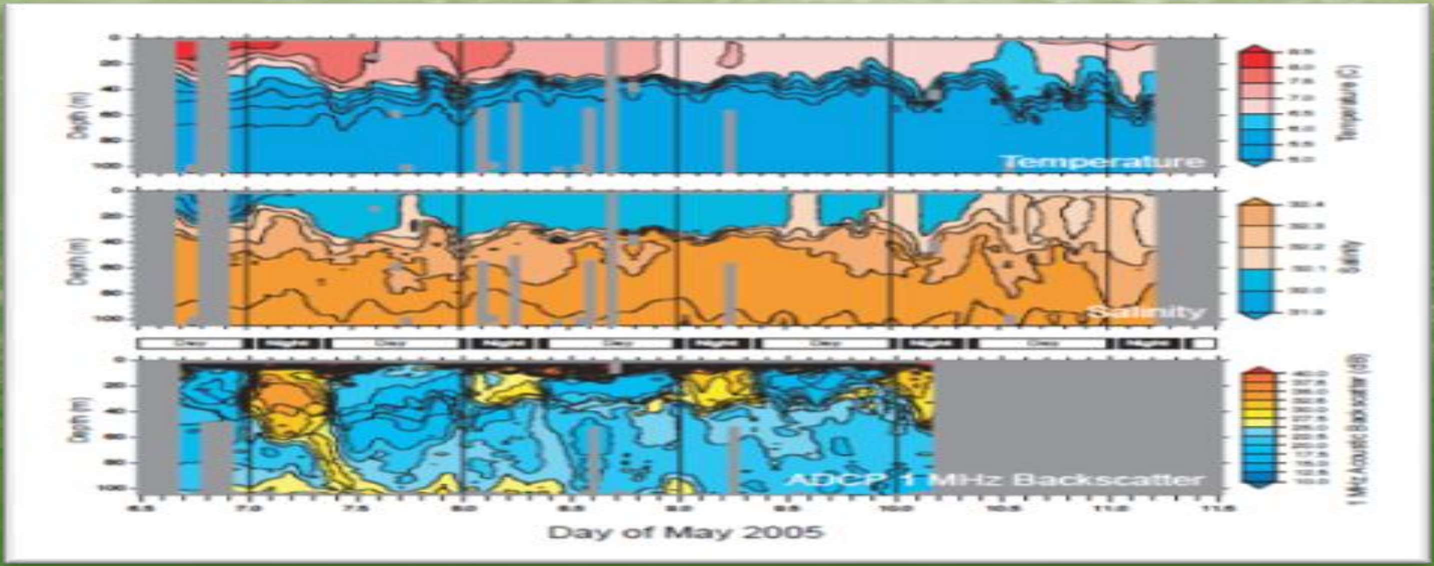
2.-Doppler velocity



3.- Some experiments

Deployment of a **Webb Research Slocum** 200 m glider with self-contained Nortek 1 MHz **Aquadopp Profiler**. A fleet of similarly-equipped vehicles were used by WHOI researchers to explore relationships between physical and biological fine structure in the ocean (Siegel, 2009)

3.- Some experiments



Time series of T, S and backscatter amplitude. Acoustic backscatter at 1 MHz seems to be an effective proxy for the vertically-migrating copepod *Calanus finmarchicus. (After Frantantoni, 2008)*

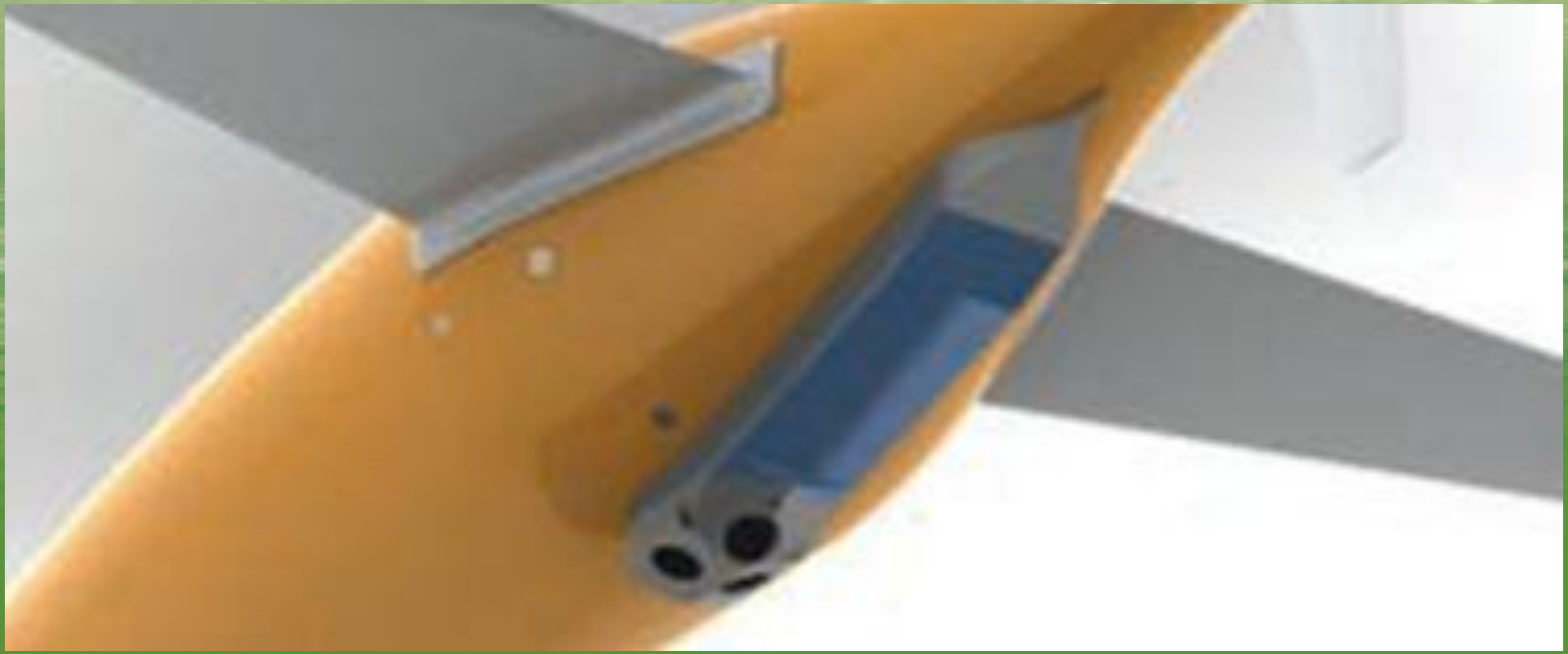
4.-Hardware

A 400 kHz Aquadopp Profiler in black fairing can be seen pointing downward under Glider wings

4.- Hardware

A 400 kHz Nortek Aquadopp Profiler mounted on the underside of a **Webb Research Slocum** glider operated by researchers at Memorial University

4.-Hardware



Detail of a four-transducer 600 kHz Aquadopp Profiler mounted on a **Seaglider**. Transducers are used in sets of three. (Image Siegel, 2009)

5.-More Doppler velocity

Doppler for Waves?

• MLM is a general method for solving directional wave spectra for a spatial array.

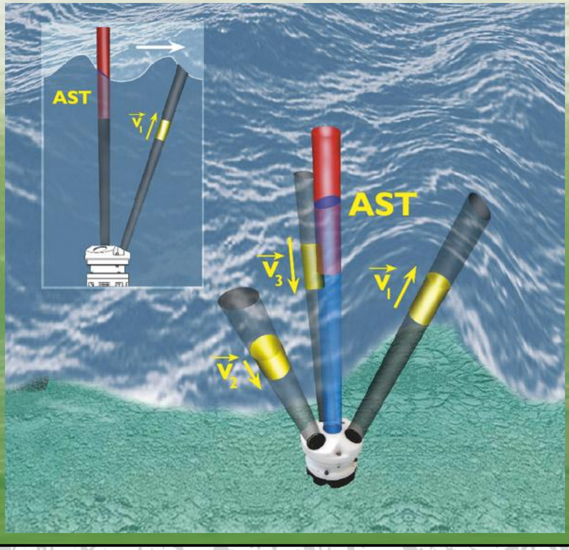
• First introduced by Capon (1969)

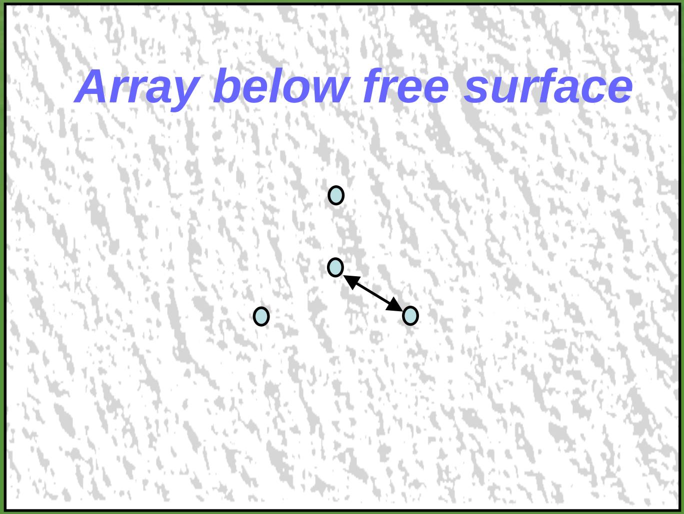
• Math frased by H. Krogstad (TUT), around 2000s

• Transfer function for each cell is directionally dependent

$$D(f,\theta) = \frac{\kappa}{H(f,\theta)^{*t}\Phi(f)^{-1}H(f,\theta)}$$

H =Transfer function
Φ = Cross-power Spectra
k = Normalization constant





5.-More Doppler velocity

Yes, gliders for waves meas.

FROM A VIRTUAL MOORING

Acoustic Wave And Currents (SUV)

- Not belly, but neck installed in an stationay glider

- Slanted transducers measure orbital velocities (MLM)

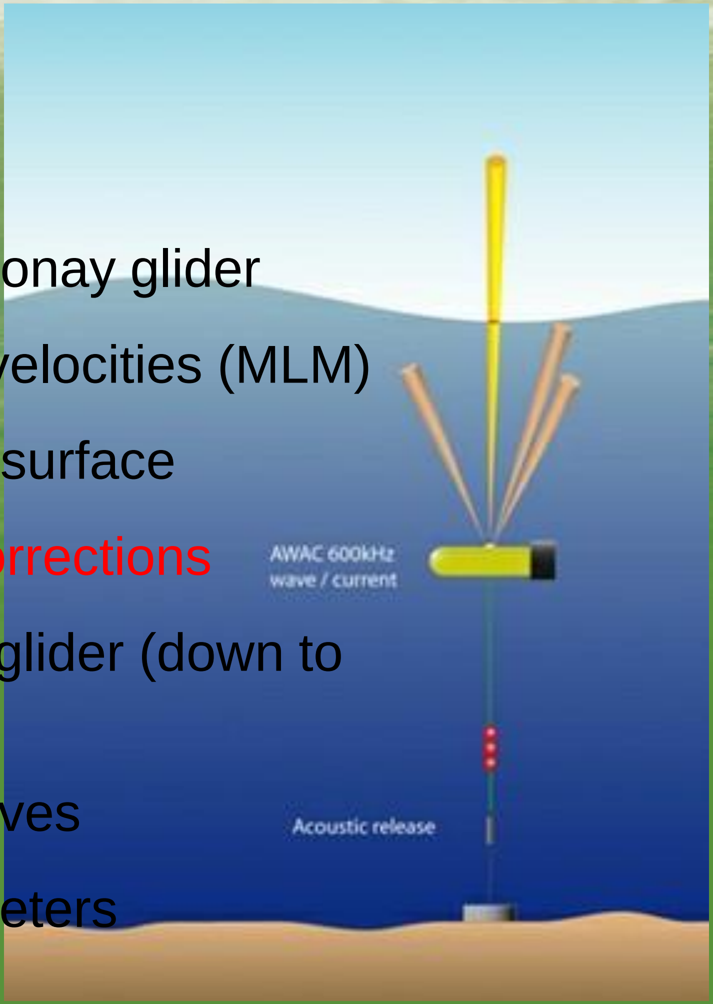
- Vertical transducer meas. distance to surface

- Pressure, accelerometer, surfacing corrections

- The longer the waves the deeper the glider (down to 90 meters)

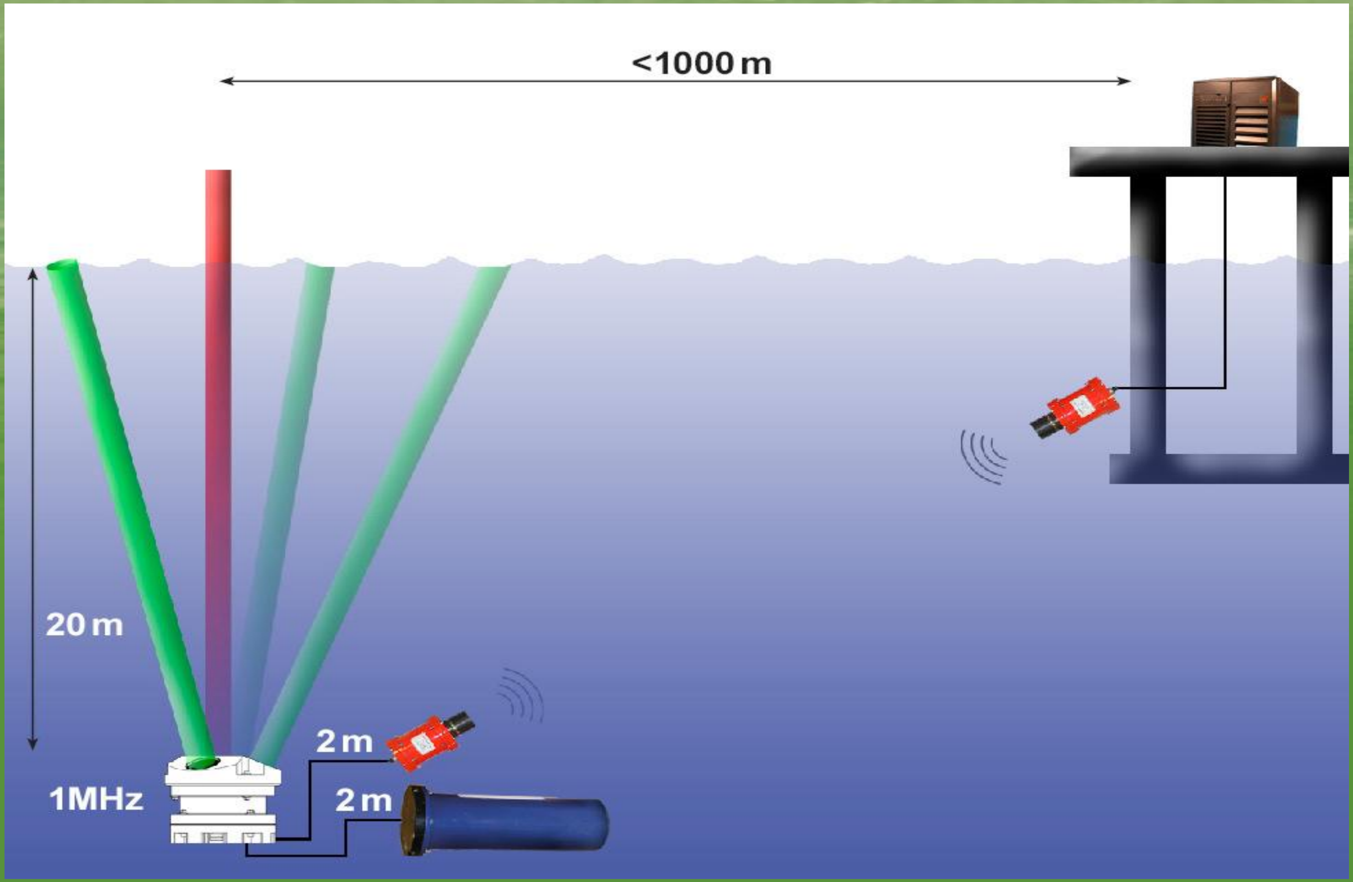
- Glider drifting is slow compared to waves

- Non-directional and directional parameters

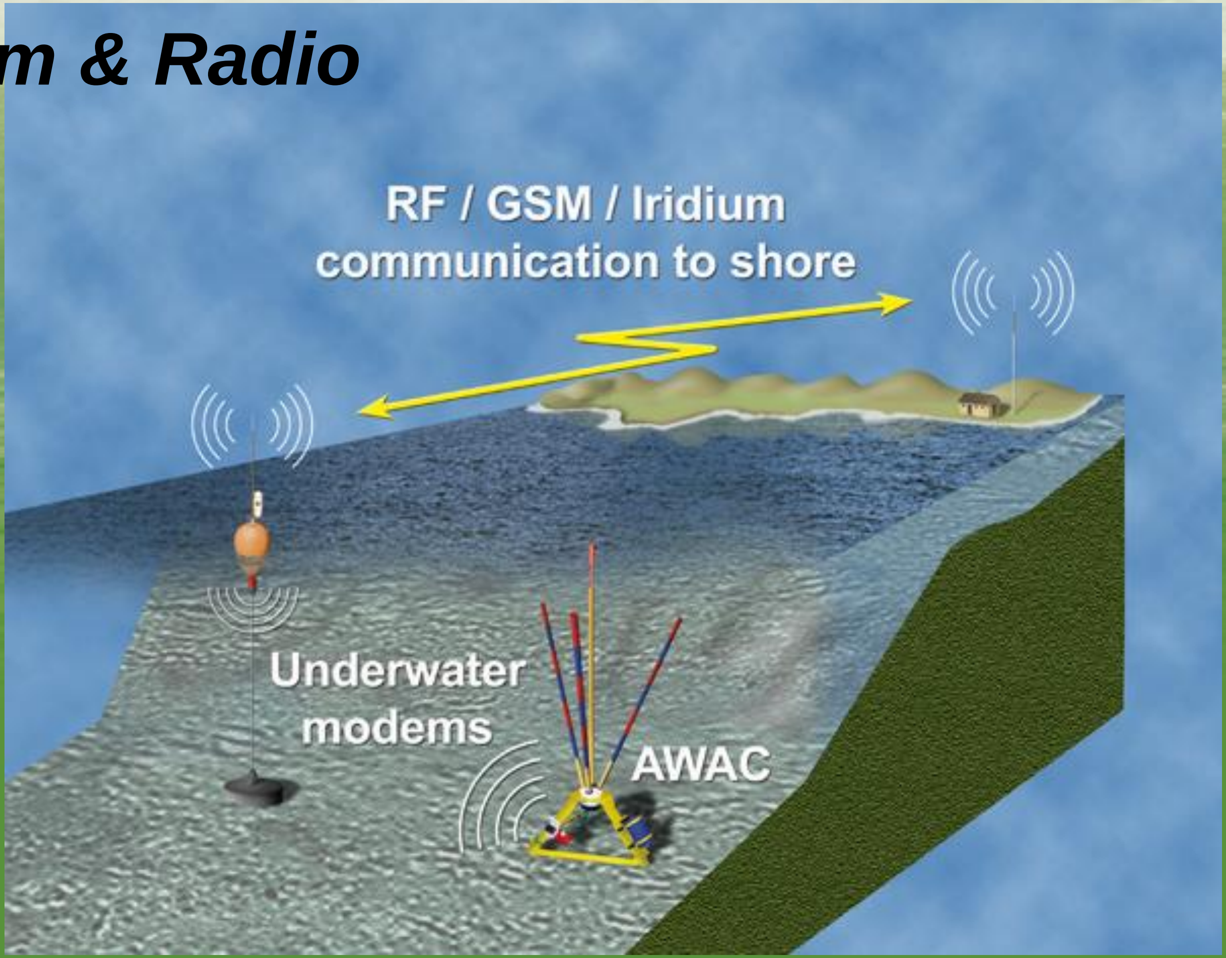


Processing and Communication

6.-Complementary non doppler sensors



Communications: Acoustic Modem & Radio



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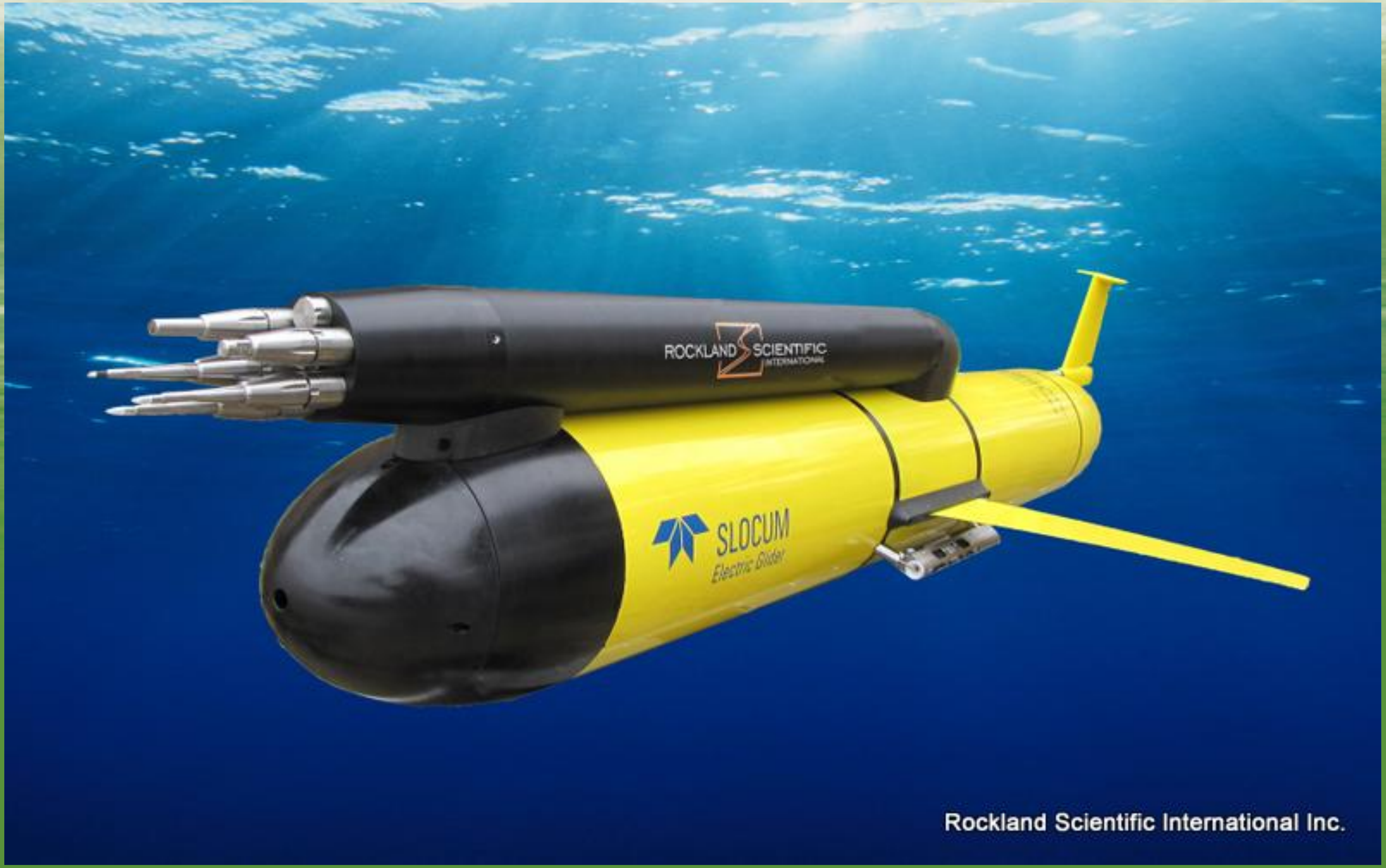
6.-Complementary non doppler sensors

Instrumentation for marine turbulence with HR sensors and eddy flux measurements. The eddy flux system integrate seamlessly with Doppler profilers while determine micro movements of gliders

6.-Complementary non doppler sensors



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Doppler profilers for gliders: capabilities and limitations

Epilogue.- We were there

IMEDEA's Maya mission Mallorca-Tarragona April 2010

Thanks FYA and to PLOCAN staff for organizing this

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