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Acoustic measurements applied to geophysical processes during dense water cascading events in the Southern Adriatic basin (Italy)

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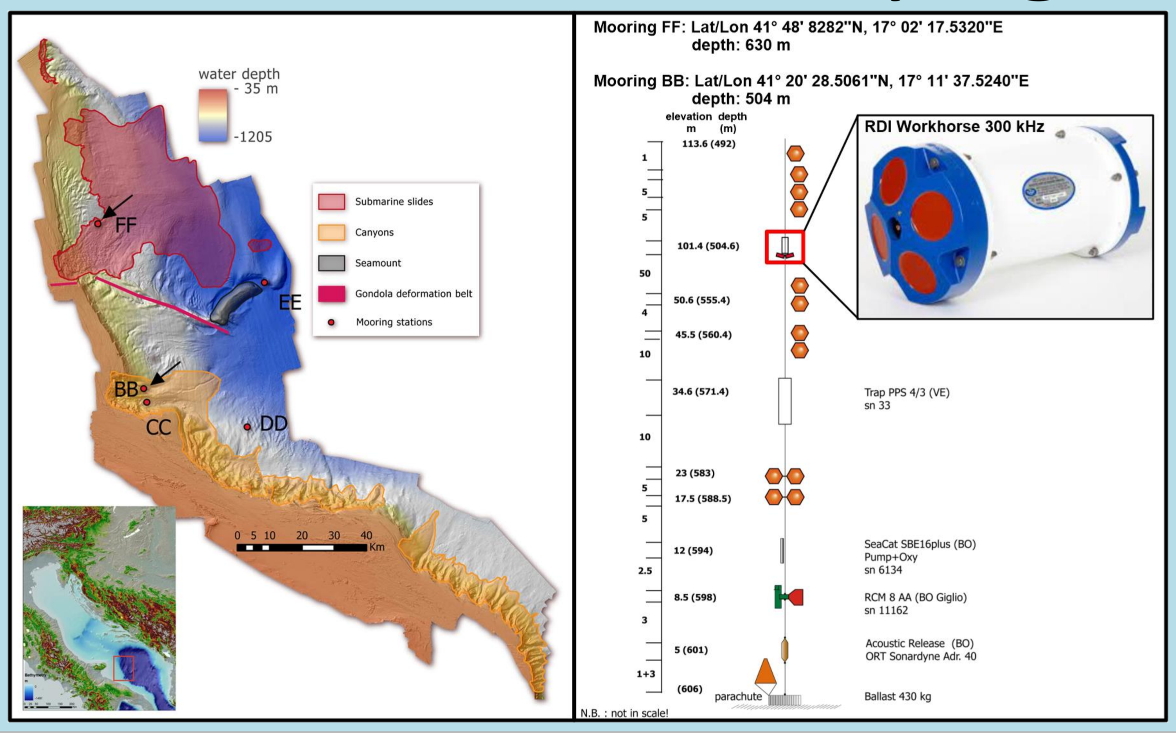
The Adriatic Sea is one of the favorable areas for dense water masses production triggered by multiple factors driving water renewal and oxygen injection in deep-water. Robust literature has described the dynamic of water masses from its generation in the northern sector of Adriatic Sea and subsequent flow to the deep of southern basin. When these water masses arrive to the shelf edge they cascade along the open slope or are channelized trough the Bari canyon playing a first order control of the sediment transfer off the western margin of the Southern Adriatic Sea. Two moorings deployed since 2012 in this area have continuously recorded oceanographic parameters and two downward oriented acoustic doppler current profilers, ADCPs (Workhorse RDI 300kHz) have measured current speeds and echo intensity along 100m of the water column. The use of broadband systems which have low random fluctuations of backscatter data, combined with the recommended TRDI backscatter formulation to improve the estimation also in low backscatter environment, allowed to test the backscatter fluctuations as a proxy of the suspended matter dynamic induced by dense water cascading events.

Acoustics for studying marine geophysics



The dense water masses formation occurs in the northern sector of the Adriatic Sea and once for med they flow southward following the bathymetr ic features. When water masses arrive to the sh elf edge cascade along the open slope or are ch annelized trough the canyons. Previous studies demonstrated the first order control of cascading events on the particulate flux transport of sedime nt from the shelf to the deep basin (Turchetto et al., 2007; Langone et al., 2016). The moorings BB and FF deployed since 2012 are located in the southern Adriatic Sea (Italy) and placed respecti vely at 600 m depth in the northern channel of B ari canyon and at 700 m in a furrow area on the open slope off the Gargano Promontory. Moorin gs equipped with several oceanographic probes measure currents by broadband ADCP RDI Wor khorse 300 kHz downward oriented. The sampli ng of ADCP is structured with a cell size resoluti on of 4 m and temporal sampling of 30 minutes.

The recorded Echo Amplitude is processed to ob tain backscatter signal (BS) using the formulatio n proposed by Dean (1999) for broadband syste ms and optimized by Mullison (2017) also for ver y low backscatter environments. Variation of bac kscatter is analyzed and observed during dense water cascading events highlighting some spatia l and temporal characteristic of the solid transpor t in the mooring sites.
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$$BS = C + 10\log((T_x + 273.16)R^2) - L_{dbm} - P_{dbw} + 2\alpha R + 10\log(10^{\frac{kc(E-Er)}{10}} - 1)$$

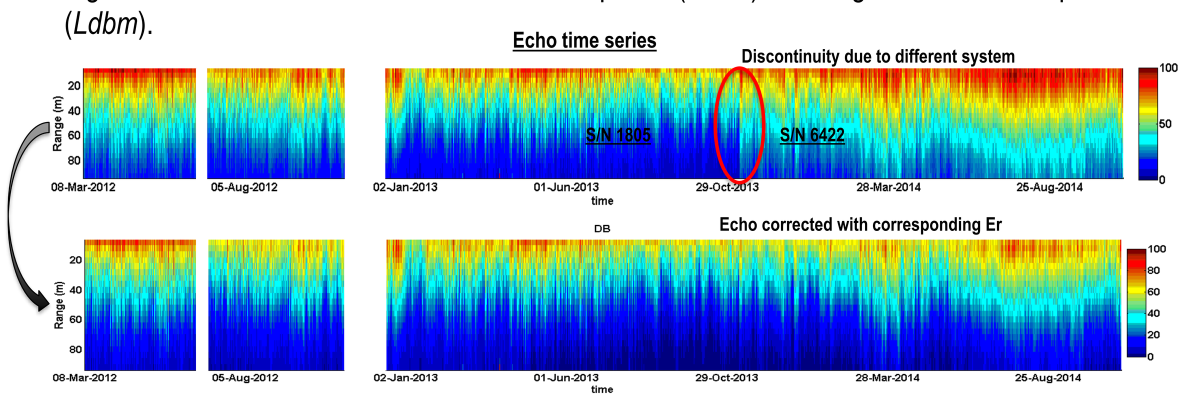
METODOLOGY AND RESULTS

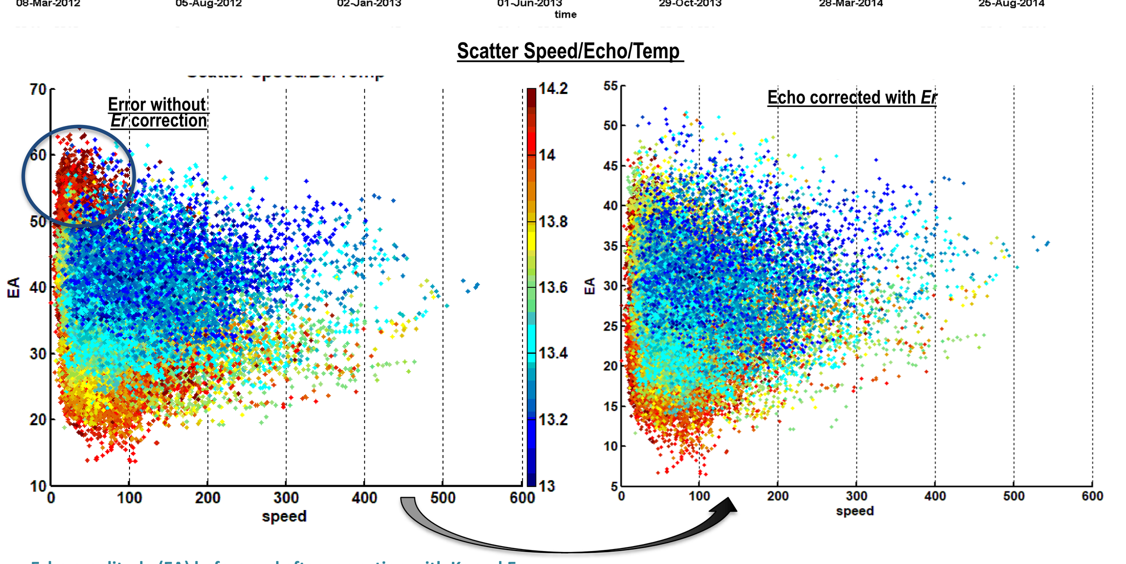
Backscatter processing and data analysis

The analysis of backscatter signal consists on several steps resumed as follow:

Step 1: Echo Amplitude E (counts) is the measured Returned Signal Strength Indicator (RSSI) amplitude reported by the ADCP for each bin along each beam; and Er is the reference RSSI amplitude in the absence of any signal (the noise). Er is constant for each beam of a given ADCP. The records of E are corrected with Er for every beam and then decibel (*dB*) Conversion Factor *Kc* is applied.

Step 2: Sampling parameters are extracted and used to compute the Slant Range R together with ADCP characteristics of transmit power (*Pdbw*) and length of transmitted pulse (*Ldbm*).





Echo amplitude (EA) before and after correction with Kc and Er

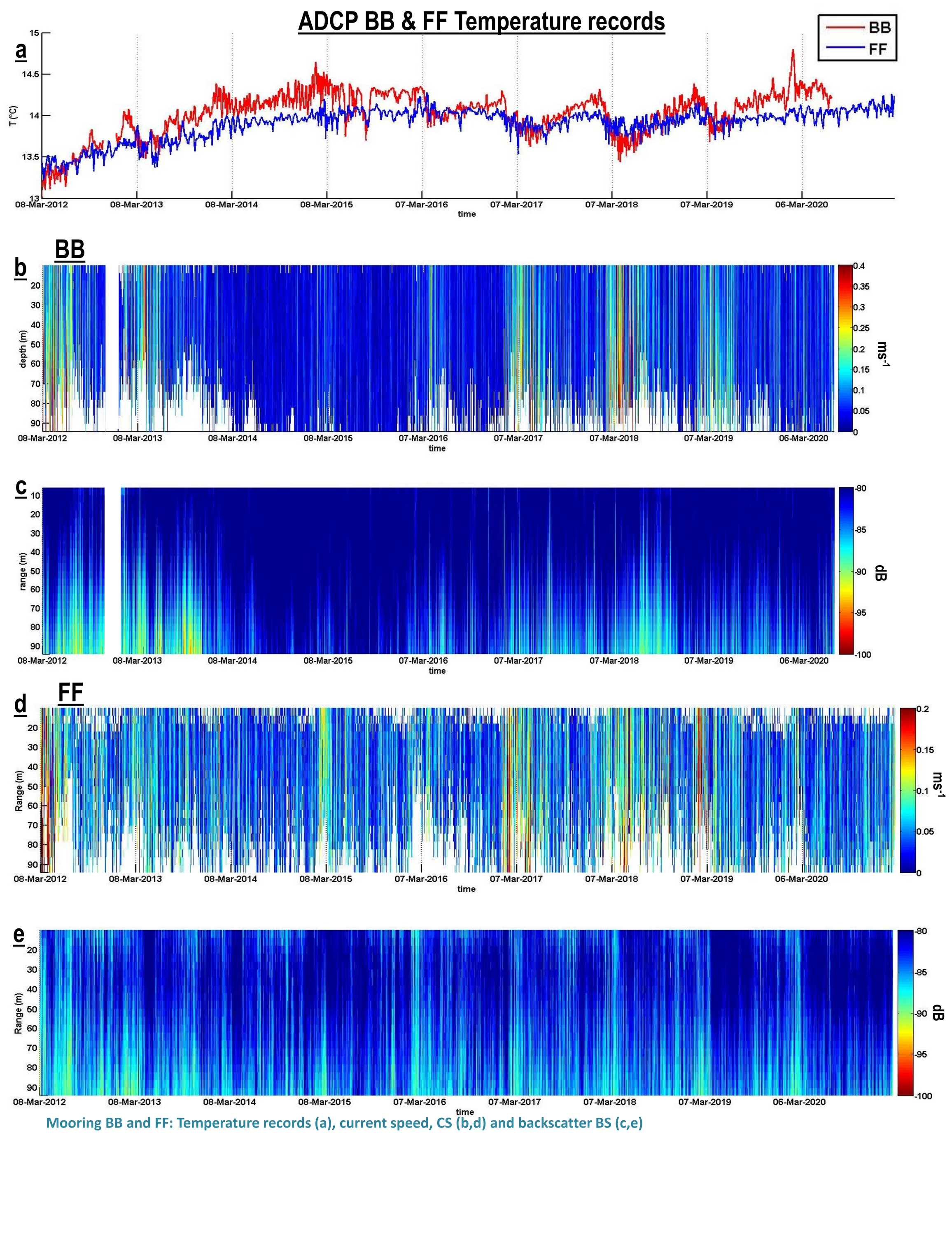
Step 3: Compute the Sound Absorption Coefficient α (dB/m) for every cell along the time series using Temperature (T) and Salinity (S) data records.

Step 4: Computation of backscatter (BS) using formulation for every cell considering the number of cells (N) and determination of backscatter profile (BS: m4π)-1

"EOFs analysis" applied to backscatter and currents speed data allowed to identify backscatter profiles patterns and describe dynamic characteristics of the mooring sites during the cascading events

ADCP measurement and backscatter results

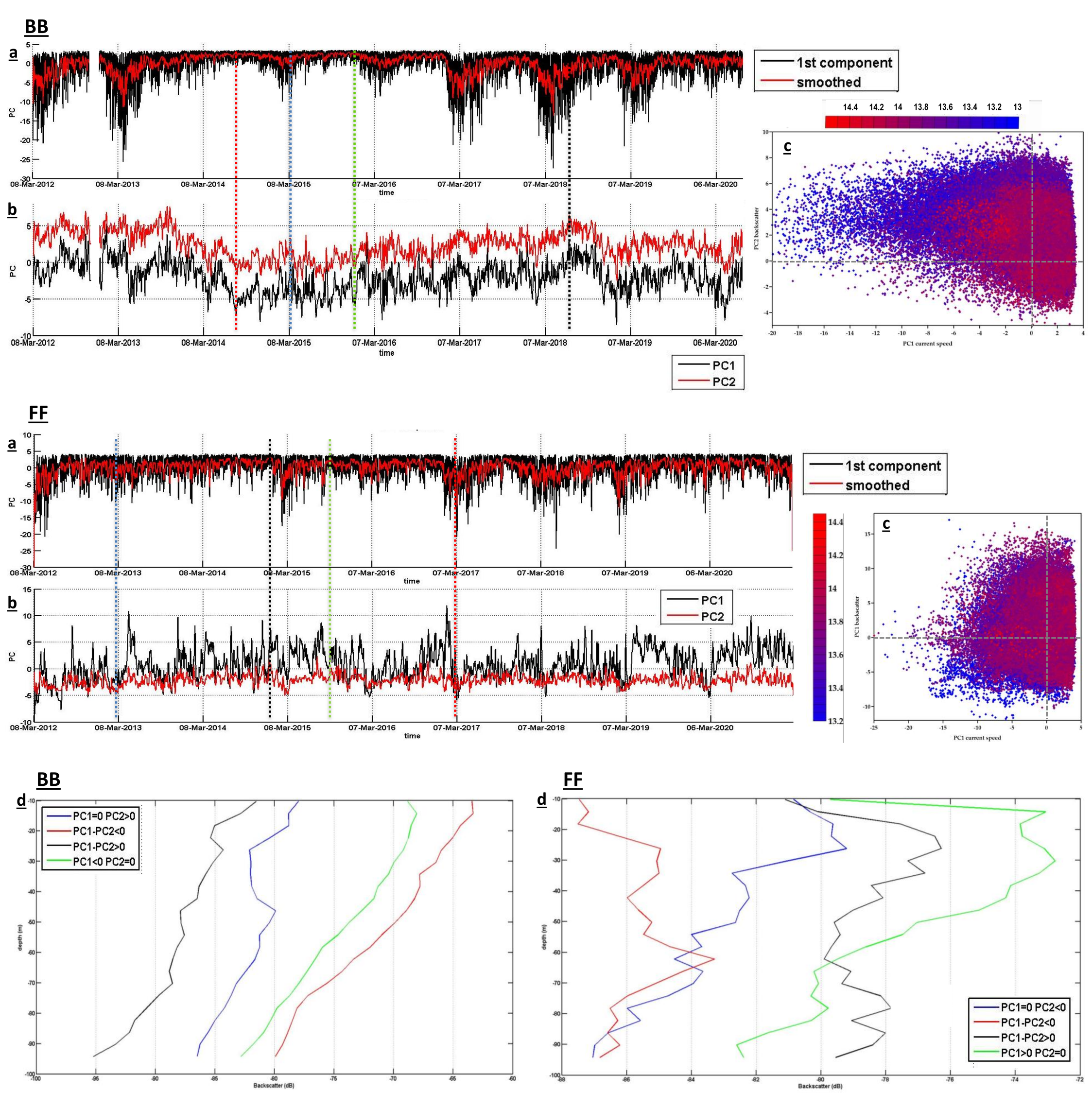
The temperature fluctuations occur in both moorings but more marked in the BB station rather than FF (a). The backscatter signal strength vary in time and space; a clear positive gradient of the signal strength occur in BB station (c) while in FF is more uniform distributed along the water column (e). In both moorings the water cooling peaks are followed by current pulses followed also by backscatter strength enhancement.



Mooring BB and FF: Temperature records (a), current speed, CS (b,d) and backscatter BS (c,e)

Data Analysis results

From EOFs analysis the first component of current speed (CS) account more than 95% of the variance while for the BS the significant variance is described by two components. In BB negative peaks of CS eigenvalue that correspond to positive peaks of the both BS components have a match to water temperature decrease (c).



EOF component eigenvalue of CS (a) and BS (b) –– scatter plot of EOF component of CS, BS related to T - backscatter profiles in BB and FF (d) . The coloured dotted lines on a and b correspond to the points where the backscatter profiles are extracted (c).

In the mooring FF the cooling of the sea-water correspond to negative eigenvalues of BS components and negative peaks of CS (c).
The BS profiles patterns was determined selecting different combination of the components eigenvalues (a, b) and taken as representative of the dynamic variability. The site BB (d) shows in all cases increasing trend of BS signal toward the seabed with larger values in phase with the CS increase. In the site FF (d) the variations are less pronounced and BS profiles shows larger variability. The signal can be more uniformly distributed along the depth (red line) or with a positive gradient toward the seabed (blu line).

DISCUSSION AND CONCLUSIONS

In this experiment the backscatter formulation for broadband system optimized by Mullison (2017) was used to determine the BS signal strength in two mooring site placed in the southern Adriatic basin. The results highlight in both sites the correspondence of BS signal intensification with currents pulses and cooling of water but the backscatter appear to be distributed in different way along the water column. In BB site the BS profiles patterns show a well defined ascendent gradient toward the seabed while in FF the BS profiles patterns show a bimodal dynamic behavior. Profiles present both a quite constant trend and increasing trend toward the sea-bed. In the study area, is well demonstrated the role of cascading events in the production of pulse of currents in phase with minimum temperature and maximum water density that promote active sediment transport (Turchetto et al., 2007). The south-flowing dense bottom currents have down-slope component and strongly interacts with bottom topography (Turchetto et al., 2007) and when captured by Bari Canyon System cascading current become confined mimicking a very dilute turbidity current (Trincardi et al., 2007) with a increasing gradient of solid load along the water column. The northernmost mooring site FF, closer to the inception of the cascading process, showed active cascading and several dynamical differences from the canyon (Chiggiato et al. 2016). Cascading events are organized in multiple pulses where the thickness of the energetic dense water flow descending the continental slope can change from 20-30 m to 100 m (Langone et al. 2016) justifying the variability observed in BS profiles. During the current pulses the observation of a profile without gradient within 100m layer could be therefore limited by the observation thickness as the phenomenon could involve a greater thickness of the water column. The observations agree with previous studies performed by numerical simulations and oceanographic surveys and extend the knowledge of solid transport processes during the dense water cascading events.

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