Hydrographical and Hydrodynamical from the Hermes 2 Cruise in the Gulf of Lion (NW Mediterranean)

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HERMES 2 Cruise in the Gulf of Lion

1. Objectives and summary of operations

The primary objective of the cruise was to describe the characteristics of a plume of dense water from its origin on the Gulf of Lion shelf and its evolution by mixing with ambient water during its transit down the continental slope. The strategy of measurements consisted in mapping the core of dense water for different transects located on the continental shelf upstream from the Cape de Creus and across the shelf and slope downstream of the cape. Transects were composed of a set of CTD and Lowered–ADCP stations that encompass the dense water plume. Water sampling were carried out on one station near the centre of the plume with the Niskin bottles mounted on a rosette for small volume samples and with an in-situ pump for large volume samples. Bottle water samples were collected throughout the water column, but were denser in the near-bottom layer. In situ pump water samples were solely collected next to the seabed.

The various measurements collected above and within the plume were physico-chemical parameters (temperature, salinity, density profiles), hydrodynamics (profiles of current speed and direction) and biogeochemical (profiles of suspended particles concentration, fluorescence, particulate and dissolved organic matter, nutrients). Large volume water sample aimed at measuring the isotopic (^{3}H, ^{12}C, ^{13}C, ^{15}N), organic (sugars) and mineral (metals) composition of the dense water.

Three transects were performed in two stages before and after a storm which prevented any observations during 48 hours. During the first phase transects were focused on the continental shelf and shelf edge (Fig. 1). During the second phase, the southernmost transect was partially remade and completed by extending it towards the open slope. Significant hydrological changes were observed at stations sampled before and after the storm.

The first transect (hereafter called NS for Northern Shelf) crosses the continental shelf north of the Cape de Creus Canyon; it is composed of 11 stations ranging between 53 and 133 m deep. The second transect (hereafter called CC for Cape Creus) crossed the narrow passage between the Cape de Creus and the southern flank of the canyon; it is composed of 9 stations ranging between 89 and 575 m deep. The core of dense shelf water was identified as a colder and more turbid bottom layer of few tens of meters high that covered the shelf and overflowed the shelf edge. The third transect was located slightly upstream of the Palàmos Canyon. The portion conducted prior to the storm (hereafter called SS for Southern Shelf) comprised 8 stations ranging between 97 and 511 m deep. The portion conducted on the open slope after the storm (hereafter called OS for Open Slope) comprised 15 stations ranging between 186 and 963 m deep.

During the last day of the cruise, few stations were collected between the northernmost and southernmost transects in order to determine the spatial evolution of the thermo-haline characteristics of the dense water plume and the temporal changes occurring on the transects before and after the storm.

Scientific crew

The following scientists and students participated to the Hermes 2 cruise in the Gulf of Lions:

X. Durrieu de Madron	**CEFREM, University of Perpignan, Chief scientist** **CTD, ADCP**
G. Saragoni	CEFREM, University of Perpignan, Mooring, in situ Pump
P. Kerhervé	CEFREM, University of Perpignan, Mooring, CTD, Water sampling
F. Bourrin	CEFREM, University of Perpignan, ADCP, CTD, Water sampling
J. Avril	CEFREM, University of Perpignan, ADCP, CTD, Water sampling
P.M. Théveny	DT-INSU, La Seyne-sur-mer Electronic and Computer

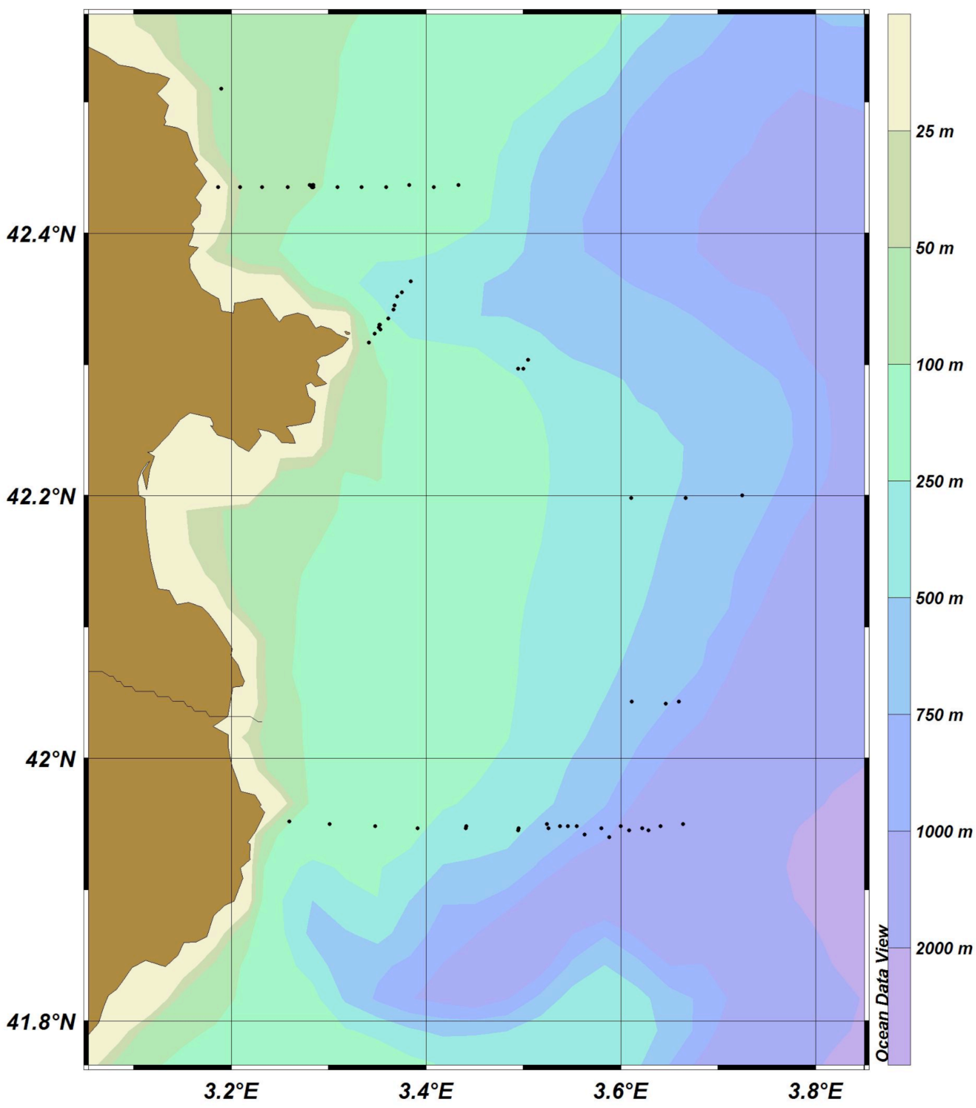

Figure 1. Locations of hydrological casts

2. Hydrographic, L-ADCP and water samples data Processing

3.1. Hydrographic Data Acquisition and Processing

63 CTD casts were completed using the Seabird 911Plus CTD probe (Table 4). Seven data channels (pressure, temperature, conductivity, elapsed time, light transmission, fluorescence and altimetry) were measured at a data rate of 24 Hz during the data acquisition. Light transmission was measured with a 25-cm optical path length C-Star transmissometer. Fluorescence was measured with a Chelsea Aquatracka-3 fluorometer.

The raw binary data were then converted into engineering units using the laboratory calibration coefficients, generating time and pressure series data sets.

The temperature and conductivity sensors were replaced at mid-cruise, after the completion of the first (northernmost) transect, because they were defective. The conductivity measurements were very noisy and skewed due probably to a broken cell. The temperature sensor's response appeared correct but was offset by -0.014 deg. C when compared with thermosalinograph near-surface measurements. Consequently, conductivity measurements for the northernmost transect was discarded and derived parameters (salinity, density) were not computed.

CTD casts were performed from 10 m below the surface down to ~ 5 m above the bottom when combined with L-ADCP measurements, and down to ~ 2 m above the bottom when water samples were collected.

A low-pass filter was used to compensate for the different time response of the sensors and to remove the salinity spikes. A ship-roll and minimum probe velocity filter (20% of 1-minute mean velocity) was applied to each cast to disallow pressure slowdowns and reversals. After filtering, the downcast portion of each cast was pressure-averaged and sequenced into 1 decibar pressure intervals. Recorded surface values were rejected only when it appeared that the drift was caused by sensors adjusting to the in-water transition. Missing near-surface bins were replaced by measures collected during the upcast. Near bottom values of beam attenuation coefficient were rejected when the measurement appear to be contaminated with the impact of the CTD frame with the seabed. Remaining spurious and spiky data were removed manually.

The one decibar pressure, temperature and conductivity data were used to compute the following hydrographic parameters depth, potential temperature (θ), salinity, potential density anomalies (σ_θ, σ_2, σ_4), sound velocity, specific volume anomaly, dynamic height, spiciness, density ratio and buoyancy frequency. Temperature is ITS-68, salinity is PSS-78, density is calculated based on the equation of state of seawater (EOS80; Fofonoff and Millard, 1983), buoyancy frequency is calculated using the adiabatic levelling method (Fofonoff, 1985).

Profiles of size distributions of suspended particles were measured *in situ* with a Sequoia LISST-100 laser particle sizer. This device calculates from light scattering measurements the size distribution on 32 log-spaced size classes between 1.2 and 250 µm with a sampling rate of 1 second. The instrument was also used in laboratory to measure the grain size distribution of sonified samples of sediment and suspended matter collected on filters.

3.2. L-ADCP Data Acquisition and processing

A L(owered)-ADCP system mounted on the CTD frame was used to profile the current throughout the water column. The ADCP was a 300 kHz RDI Workhorse ((20± beam angle) with LADCP mode. Profiles started at 10 m below the surface and ended 5 m above the bottom (m a.b.). The instrument setup is given in Table 1

Bins size	# of bins	Blanking distance	Pinging rate	Ambiguity velocity
1 m	60	1.76 m	1 s	2 m s^{-1}

The inverse method (version 8b) developed by Martin Visbeck (LDEO) (Visbeck, 2002) was used to process LADCP data. This method allows the simultaneous use of GPS navigation data to constraint the ship and CTD horizontal drift, shipboard ADCP data to constraint velocity shear profile in the surface layer (up to 200 m), bottom track data to constraint the velocity profile when the seabed is in range (30 m a.b.), the CTD time and pressure series to constrain the L-ADCP depth and sound speed.

3.3. Processing of water samples

Water samples were collected at 8 levels throughout the water column using a rosette equipped with 12 litres Niskin bottles.. The nominal depths were at the surface, mid-water depth, 50 m a.b., 30 m a.b., 20 m a.b., 10 m a.b., 5 m a.b., 2 m a.b. between 2 and 5 m above the seabed. For each bottles, water sub-samples were collected for dissolved organic carbon and nutrient analyses. Water samples of ~ 2-3 l were filtered on pre-weighted GF/F filter of 0.7 µm mean porosity to measure total particulate carbon and nitrogen, particulate organic carbon and suspended sediment concentration (SSC). Finally, one water sample of ~ 2 l was also filtered on Nuclepore filter of 0.45 µm pore size to measure suspended sediment concentration.

We derived a linear relation between the SSC (expressed in mg l^{-1}) estimated from GF/F and nuclepore filters and the beam attenuation coefficient (expressed in m^{-1}):

$$SSC = 1.691\ c - 0.363 \qquad (r^2 = 0.73, n = 72)$$

Water samples for Dissolved Organic Carbon (DOC) were filtered through 2 pre-combusted (24h, 450°C) glass fiber filters (Whatman GF/F 25 mm) and collected in precombusted glass tubes closed with a screw cap and a teflon liner. Each tube was poisoned with phosphoric acid (H_3PO_4) (5 mg.l^{-1}) and stored at room temperature until analysis. DOC concentrations were determined using a High Temperature Catalytic Oxidation (HTCO) technique (Sugimura and Suzuki, 1988; Cauwet, 1994) with a Shimadzu TOC V analyzer.

Seawater samples collected for nutrient analysis were immediately poisoned with mercuric chloride and store until analysis were made at laboratory.

Table 1. CTD stations location during the HERMES 2 cruise in the Gulf of Lions

Cast	Station	Date	Local Time (UT+1)	Latitude	Longitude	Bottom Depth (m)	Distance above Bottom (m)	ADCP
HERM2_01	Banyuls	14 Feb 2006	07:10	42°N 30.680	003°E 11.380	71	2	X
Northern Shelf Transect								
HERM2_02	NS1	14 Feb 2006	11:07	42°N 26.190	003°E 11.170	53	2	X
HERM2_03	NS2	14 Feb 2006	11:38	42°N 26.100	003°E 12.530	85	2	X
HERM2_04	NS3	14 Feb 2006	12:14	42°N 26.100	003°E 13.910	90	2	X
HERM2_05	NS4	14 Feb 2006	12:56	42°N 26.110	003°E 15.490	98	2	X
HERM2_06	NS5	14 Feb 2006	13:40	42°N 26.140	003°E 16.990	107	5	X
HERM2_07	NS6	14 Feb 2006	14:25	42°N 26.160	003°E 18.540	115	5	X
HERM2_08	NS7	14 Feb 2006	15:05	42°N 26.170	003°E 20.030	118	5	X
HERM2_09	NS8	14 Feb 2006	15:44	42°N 26.180	003°E 21.540	120	5	X
HERM2_10	NS9	14 Feb 2006	16:24	42°N 26.200	003°E 22.950	122	5	X
HERM2_11	NS10	14 Feb 2006	17:03	42°N 26.150	003°E 24.470	125	5	X
HERM2_12	NS11	14 Feb 2006	17:48	42°N 26.200	003°E 25.980	134	5	X
HERM2_13	NS5	15 Feb 2006	07:35	42°N 26.220	003°E 17.040	106	5	X
HERM2_14	NS5	15 Feb 2006	08:11	42°N 26.260	003°E 17.010	106	5	X
HERM2_15	NS5	15 Feb 2006	09:17	42°N 26.170	003°E 16.950	106	5	X
HERM2_16	NS5	15 Feb 2006	09:49	42°N 26.260	003°E 16.830	106	5	X
HERM2_17	NS5	15 Feb 2006	12:42	42°N 26.240	003°E 17.050	106	1	X
HERM2_18	NS5	17 Feb 2006	08:20	42°N 26.100	003°E 17.060	106	1	
Cap de Creus Transect								
HERM2_19	CC1	17 Feb 2006	09:26	42°N 19.080	003°E 20.490	89	5	X
HERM2_20	CC2	17 Feb 2006	10:03	42°N 19.450	003°E 20.840	98	5	X
HERM2_21	CC3	17 Feb 2006	10:28	42°N 19.690	003°E 21.180	116	5	X
HERM2_22	CC4	17 Feb 2006	10:55	42°N 20.160	003°E 21.670	155	6	X
HERM2_23	CC5	17 Feb 2006	11:29	42°N 20.540	003°E 22.000	256	5	X
HERM2_24	CC6	17 Feb 2006	12:09	42°N 20.760	003°E 22.050	350	5	X
HERM2_25	CC7	17 Feb 2006	13:10	42°N 21.120	003°E 22.210	450	5	X
HERM2_26	CC8	17 Feb 2006	14:11	42°N 21.360	003°E 22.510	495	5	X
HERM2_27	CC9	17 Feb 2006	15:00	42°N 21.810	003°E 23.050	575	5	X
HERM2_28	CC3	17 Feb 2006	16:03	42°N 19.880	003°E 21.150	120	2	X
HERM2_29	CC3	17 Feb 2006	17:51	42°N 19.890	003°E 21.130	119	2	X

Southern Shelf Transect

HERM2_30	SS1	18 Feb 2006	06:45	41°N 57.190	003°E 15.560	97	5	X
HERM2_31	SS2	18 Feb 2006	07:23	41°N 57.050	003°E 18.070	149	5	X
HERM2_32	SS3	18 Feb 2006	08:06	41°N 56.930	003°E 20.860	161	5	X
HERM2_33	SS4	18 Feb 2006	08:43	41°N 56.860	003°E 23.470	186	5	X
HERM2_34	SS5	18 Feb 2006	09:39	41°N 56.910	003°E 26.480	244	5	X
HERM2_35	SS6	18 Feb 2006	10:30	41°N 56.860	003°E 29.700	340	5	X
HERM2_36	SS7	18 Feb 2006	11:37	41°N 56.870	003°E 31.530	430	6	X
HERM2_37	SS8	18 Feb 2006	12:37	41°N 56.970	003°E 32.250	511	6	X

Open Slope Transect

HERM2_38	OS4	20 Feb 2006	10:21	41°N 57.000	003°E 31.440	421	5	X
HERM2_39	OS5	20 Feb 2006	16:22	41°N 56.950	003°E 32.750	594	5	X
HERM2_40	OS6	20 Feb 2006	17:29	41°N 56.980	003°E 33.270	678	8	X
HERM2_41	OS8	20 Feb 2006	18:35	41°N 56.880	003°E 34.780	705	5	X
HERM2_42	OS10	20 Feb 2006	19:48	41°N 56.990	003°E 36.000	796	6	X
HERM2_43	OS12	20 Feb 2006	21:29	41°N 56.880	003°E 37.320	799	5	X
HERM2_44	OS14	20 Feb 2006	22:44	41°N 56.910	003°E 38.450	841	4	X
HERM2_45	OS15	21 Feb 2006	00:11	41°N 57.000	003°E 39.830	963	5	X
HERM2_46	OS11	21 Feb 2006	01:31	41°N 56.760	003°E 36.500	783	5	X
HERM2_47	OS13	21 Feb 2006	05:17	41°N 56.720	003°E 37.690	800	5	X
HERM2_48	OS9	21 Feb 2006	06:31	41°N 56.400	003°E 35.280	675	5	X
HERM2_49	OS7	21 Feb 2006	07:38	41°N 56.570	003°E 33.770	720	5	X
HERM2_50	OS3	21 Feb 2006	08:39	41°N 56.740	003°E 29.680	340	5	X
HERM2_51	OS2	21 Feb 2006	09:21	41°N 56.890	003°E 26.450	242	5	X
HERM2_52	OS1	21 Feb 2006	09:58	41°N 56.860	003°E 23.480	186	5	X

Intermediate Stations

HERM2_53	IS1	21 Feb 2006	11:52	42°N 02.660	003°E 36.660	565	3
HERM2_54	IS2	21 Feb 2006	12:27	42°N 02.580	003°E 38.750	660	3
HERM2_55	IS3	21 Feb 2006	13:07	42°N 02.650	003°E 39.570	720	3
HERM2_56	IS4	21 Feb 2006	14:44	42°N 11.930	003°E 39.990	548	3
HERM2_57	IS5	21 Feb 2006	15:27	42°N 12.020	003°E 43.480	707	4
HERM2_58	IS6	21 Feb 2006	16:26	42°N 11.900	003°E 36.650	440	4
HERM2_59	IS7	21 Feb 2006	17:30	42°N 17.820	003°E 30.000	261	3
HERM2_60	IS8	21 Feb 2006	17:49	42°N 18.230	003°E 30.290	500	3
HERM2_61	IS9	21 Feb 2006	18:18	42°N 17.800	003°E 29.680	180	4
HERM2_62	CC3	21 Feb 2006	19:11	42°N 19.730	003°E 21.100	115	2
HERM2_63	NS5	21 Feb 2006	20:00	42°N 26.220	003°E 17.020	106	2

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