7.4 Geostrophic currents estimated through EOF's

In the EOFs methododology, the thickness eigenmodes and their corresponding amplitudes are used to reproduce the CTD derived thickness profiles (down to the bottom depth) and, in shallow areas, to extrapolate the profiles below the bottom down to the reference level (500 m). These extrapolated profiles are used to obtain the dynamic thickness and the corresponding geostrophic currents.

Unlike for the *T, S* and *St* distributions, checking the EOFs results against DT actual data is only possible where CTD profiles reach the reference level. Because reliable current data simultaneous to the cruises are not available, all that can be done is to compare the distributions resulting from the different options: non-standardized and standardized analyses, both with campaign and historic eigenvectors.

Another comparison will be of the DT and geostrophic current distributions obtained interpolating the thickness amplitudes at all stations with those obtained interpolating only the stations located in areas deeper than 100 m. This latter test is motivated by the highly unrealistic density contours obtained from the standardized analysis with historic data eigenvectors, for which the interpolation of all amplitudes usually resulted in enhanced gradients in the shallower shelf, as it was mentioned in the corresponding section.

In Table 7-1 we present the on-grid errors [%] between the DH data from the deep areas, and all the resulting DT distributions from the above experiments. These errors are only representative of the outer slope and open ocean and do not allow to infer the potential ability of the different models to represent the DT distribution in shallower areas (H_b < 500 m). However, it is reasonable to assume that if the fit is poor in the open ocean, where no extrapolation is required, it will probably behave poorly as an extrapolation procedure.

Results from the different oceanographic campaigns are presented following the same order as in previous sections, that is, FANS III, FANS II, FANS I and MEGO 94. For each campaign, results are presented in four figures. The first one shows the DT results from the thickness amplitudes interpolation, followed by the vertical integration. The second one shows the DT distributions resulting from the vertical integration of the interpolated thickness profiles with bottom depths equal to or larger than 100 m. We will refer to both options as ***amplitude interpolation*** and ***profile interpolation*** respectively. The third and fourth figures show their corresponding geostrophic currents (when speed values are larger than 50 $^{cm}/_{s}$ the vector is not plotted).

Each one of the figures consists of six frames (clearly identifiable through column and row divisions) which, in turn, have two plots: the left one corresponds to the non-standardized analysis, while the right one shows the distribution given by the standardized one. The frames of the left column present the results with the campaign eigenvectors (a, c and e), while the ones on the right correspond to the distributions obtained with the historic ones (frames b, d and f). Finally, the rows, from top to bottom, correspond to results at 10, 50 and 100 m.

Amplitude Interpolation		Profile Interpolation			
Non Standardized	Standardized	Non Standardized	Standardized	Depth [m]	Campaign, Eigenvectors: Campaign (CE) or Historic (HE), and number of modes
17.59	33.84	14.39	16.26	10	F1 - CE - 06 modes
17.79	28.63	4.15	7.43	50	F1 - CE - 06 modes
23.64	57.32	14.92	18.80	100	F1 - CE - 06 modes
21.64	37.22	9.68	17.24	10	F1 - CE - 12 modes
21.91	32.98	2.50	7.89	50	F1 - CE - 12 modes
30.21	62.51	9.85	19.46	100	F1 - CE - 12 modes
93.32	1552.80	57.92	378.80	10	F1 - HE - 06 modes
91.58	1660.43	80.14	413.61	50	F1 - HE - 06 modes
114.94	2345.73	78.43	820.68	100	F1 - HE - 06 modes
127.19	1513.13	25.88	418.28	10	F1 - HE - 12 modes
120.92	1457.55	45.83	486.81	50	F1 - HE - 12 modes
126.08	2162.36	69.06	918.63	100	F1 - HE - 12 modes
5.28	1.26	0.91	0.81	10	F2 - CE - 06 modes
6.67	1.57	1.06	0.94	50	F2 - CE - 06 modes
7.46	2.05	1.39	1.20	100	F2 - CE - 06 modes
5.56	1.32	1.00	0.80	10	F2 - CE - 12 modes
7.03	1.63	1.15	0.93	50	F2 - CE - 12 modes
8.00	2.07	1.57	1.21	100	F2 - CE - 12 modes
39.11	53.66	5.79	1.71	10	F2 - HE - 06 modes
48.79	56.25	6.30	2.71	50	F2 - HE - 06 modes
51.81	68.33	8.65	2.65	100	F2 - HE - 06 modes
34.69	49.79	3.73	1.55	10	F2 - HE - 12 modes
43.42	61.11	4.11	1.99	50	F2 - HE - 12 modes
48.16	69.13	6.02	2.56	100	F2 - HE - 12 modes
6.79	21.79	6.17	6.08	10	F3 - CE - 06 modes
2.35	6.34	1.95	3.08	50	F3 - CE - 06 modes
2.57	3.64	2.73	2.10	100	F3 - CE - 06 modes
4.36	19.05	6.07	5.57	10	F3 - CE - 12 modes
1.64	6.25	1.65	3.18	50	F3 - CE - 12 modes
2.03	3.66	2.73	2.06	100	F3 - CE - 12 modes
29.57	96.38	4.88	124.52	10	F3 - HE - 06 modes
11.47	35.16	2.39	57.03	50	F3 - HE - 06 modes
5.16	27.23	1.87	48.16	100	F3 - HE - 06 modes
25.16	109.26	3.82	114.64	10	F3 - HE - 12 modes
10.14	38.77	2.66	53.25	50	F3 - HE - 12 modes
3.55	26.73	1.46	47.31	100	F3 - HE - 12 modes

2092.28	96.74	20.17	17.51	10	ME - CE - 06 modes
2172.00	99.61	18.68	15.41	50	ME - CE - 06 modes
2079.14	102.48	19.83	17.91	100	ME - CE - 06 modes
2093.76	97.41	19.79	17.29	10	ME - CE - 12 modes
2176.06	99.51	18.12	15.40	50	ME - CE - 12 modes
2077.67	103.49	20.73	17.79	100	ME - CE - 12 modes
76.09	48.08	136.65	87.49	10	ME - HE - 06 modes
81.69	74.06	140.51	58.48	50	ME - HE - 06 modes
87.32	43.06	159.81	76.90	100	ME - HE - 06 modes
75.29	58.52	121.86	69.21	10	ME - HE - 12 modes
80.11	56.51	125.96	71.21	50	ME - HE - 12 modes
85.31	42.45	138.58	77.92	100	ME - HE - 12 modes

Table 7-1 On grid error [%] between the DH data and all the experiments in the outer slope and open ocean deep regions (bottom depth 500 m or more).

7.4.1 FANS III

Amplitude interpolation (Figure 7-7): the largest similarities between the non standardized and standardized analysis are obtained with the campaign eigenvectors, particularly at 10 m (frame a). At 50 m (frame c) the structure is more complex, while the outer-shelf and open sea distribution remains very similar at 100 m (frame e). At 50 m there is a clear eddy on the shelf, to the south of the Ebro Delta, which has significant DT gradients on its offshore side.

With historic eigenvectors the DT distributions are significantly different, particularly on the shelf. The non-standardized analysis at 10 m (frame b) results in sharp gradients nearby the Ebro Delta and close to the northern boundary of the domain. The latter are still present at 50 m (frame d), but there is no sign of the eddy. At 100 m the DT contours are very similar in all the three mentioned cases. Instead, the standardized analysis with historic eigenvectors results in a noisy distribution with very sharp, unrealistic gradients, particularly near the coast.

Profile Interpolation: except for the upper shelf (H_b<100m - Figure 7-8), there are not significant differences for the results of the non-standardized analysis obtained with the campaign eigenvectors. The standardized analysis results in a smoother distribution. The latter also applies to the non-standardized results with the historic eigenvectors. On the other hand, even though the shelf DT contours are also smoother in the standardized analysis with historic eigenvectors, the gradients on the outer-shelf, slope and open sea are high, particularly on the southern domain. The largest similarities are found between the standardized analysis with campaign eigenvectors and the non-standardized analysis with historic eigenvectors.

In all the DT contour distributions (and therefore in their associated geostrophic circulation, Figure 7-9 and Figure 7-10), there are common patterns (with the obvious exception of the standardized analyses with historic eigenvectors). In particular, the intrusion across the open sea boundary of a flow that somehow seems to break the southwestward current. This flow continues as a northwestward current, part of which leaves the domain through the northern boundary and another part approaches the coast to the north of the domain.

Comparing the different DT distributions with the DH data at the three depth levels (Table 7-1), the fits are better when the upper shelf data is not considered except for the standardized analysis with historic eigenvectors. In general, the results with campaign eigenvectors are definitely better (with the only exception of the non-standardized analysis at 10 and 100 m, though the differences are not very significant).

In the particular case of FANS III, the profile-interpolation does not seem to result in a significantly better geostrophic circulation estimates on the outer shelf, slope and open sea areas. If we consider the on-grid errors as an indicator, then the only real exception could be the standardized analysis with the campaign eigenvectors at 10 m, where errors are 6.1% (profile int.) vs 22% (amplitude int.). All the possible models (except, of course, the standardized analyses with historic data eigenvectors) result in a very similar pattern: a northwestward current at all levels in the northern half and a southwestward flow to the south.

The upper shelf circulation that results from the non-standardized and standardized analyses with the campaign eigenvectors seems reasonable. With no data to confirm it, it is difficult to quantify the accuracy of the approach. Nonetheless, the data suggests the presence of a north-eastward current adjacent to the coast, which is in agreement with the intrusion of warmer waters from the Gulf of Valencia (observed in the T distributions), and a southward flow north of the Ebro Delta, which would be responsible for the displacement of the Ebro river plume to the south. At 10 m, the peak speeds are around 15 (for the non standardized analysis) and 20 $^{cm}/_{s}$ (for the standardized one), increasing to 20 and 30 $^{cm}/_{s}$ at 50 m and decreasing to around 20 and 14 $^{cm}/_{s}$ at 100 m, respectively.

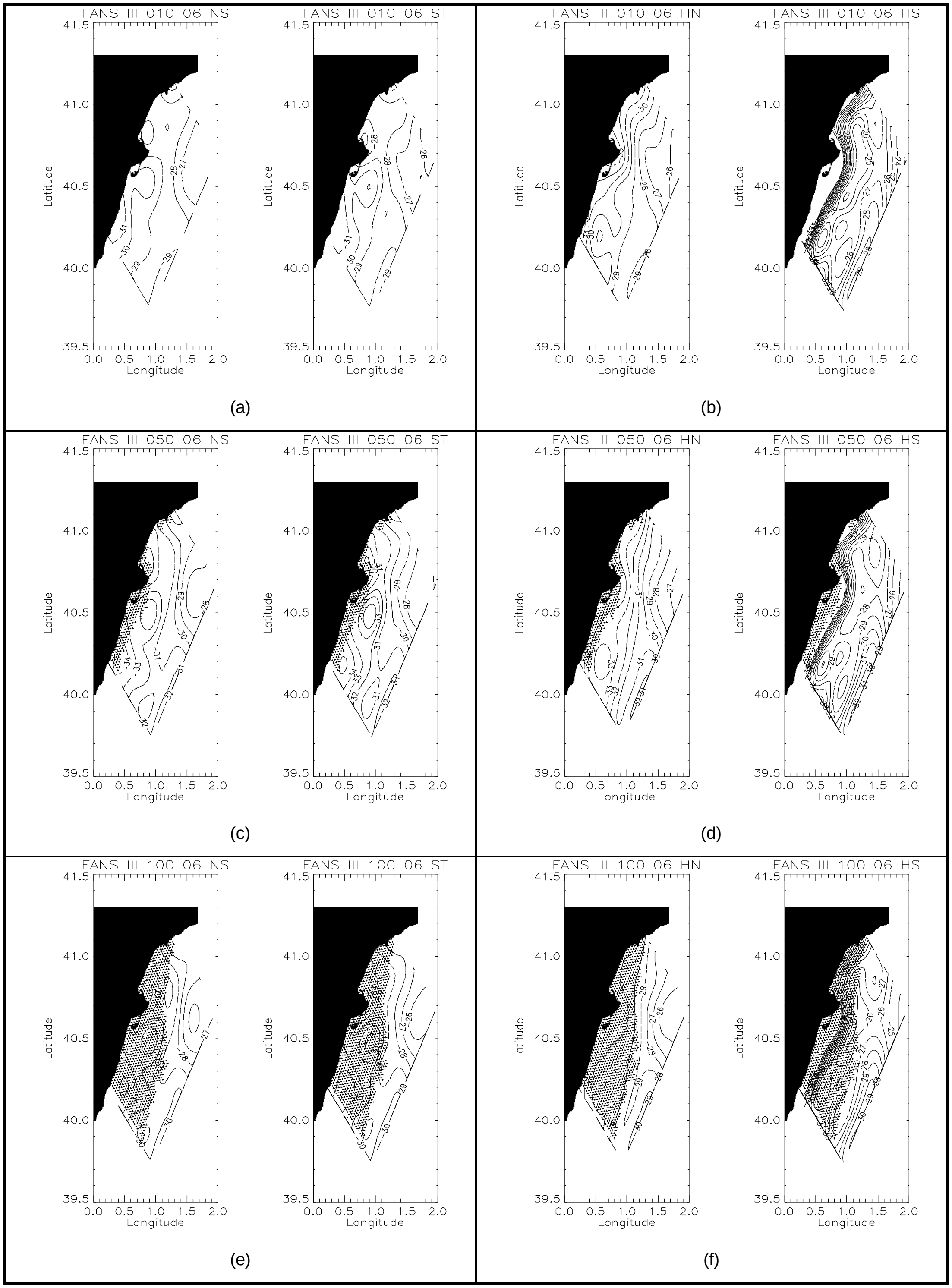

Figure 7-7 FANS III Amplitude Interpolation - Dynamic Thickness (in dyn cm) distribution at 10 (a, b), 50 (c, d) and 100m (e, f) obtained with the campaign (a, c, e) and historic (b, d, f) eigenvectors. The left (right) plot in each frame corresponds to the non-standardized (standardized) analysis. All similar figures have the same arrangement.

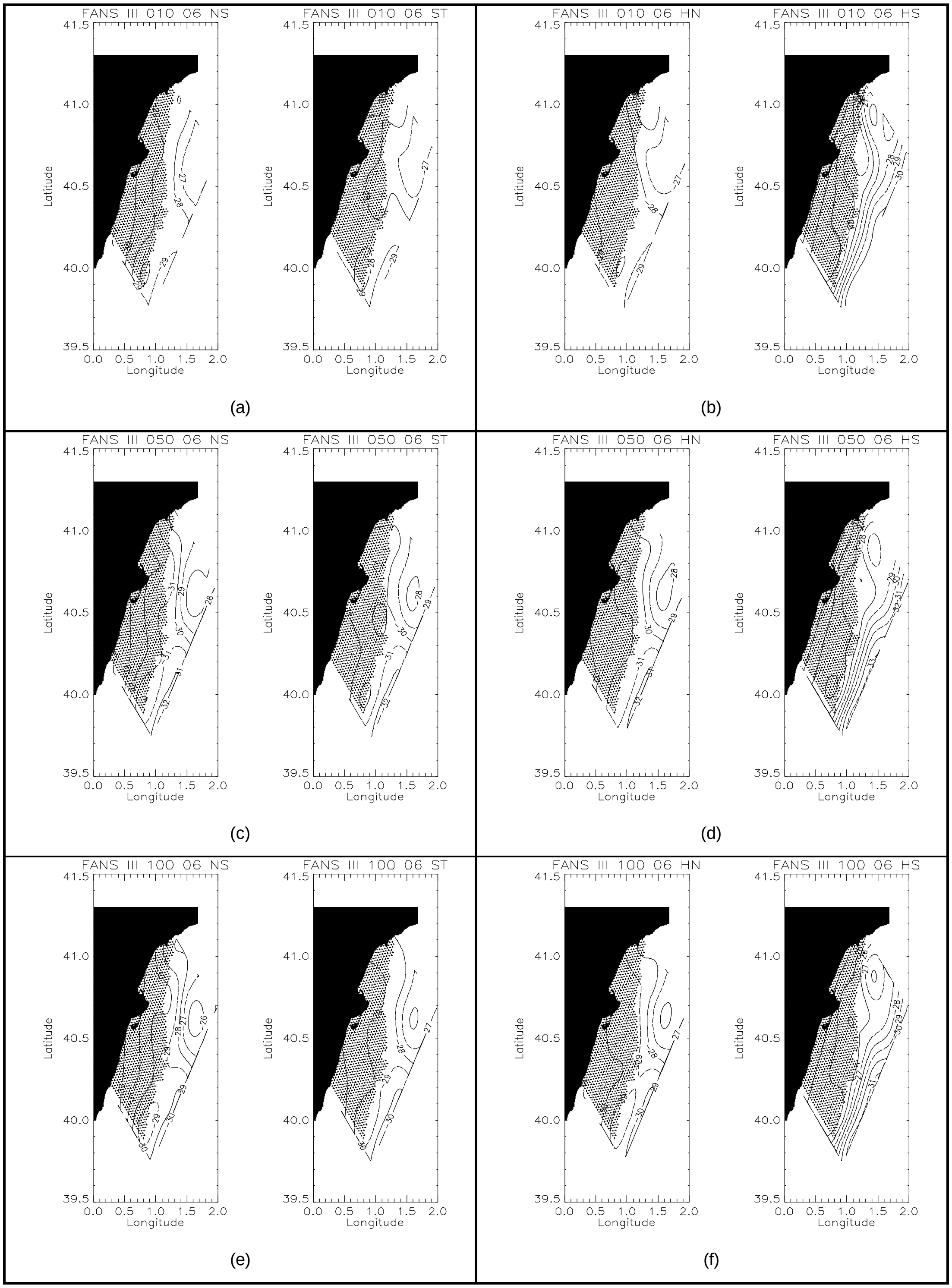

Figure 7-8 FANS III <u>Profile Interpolation</u> – Dynamic Thickness Distribution.

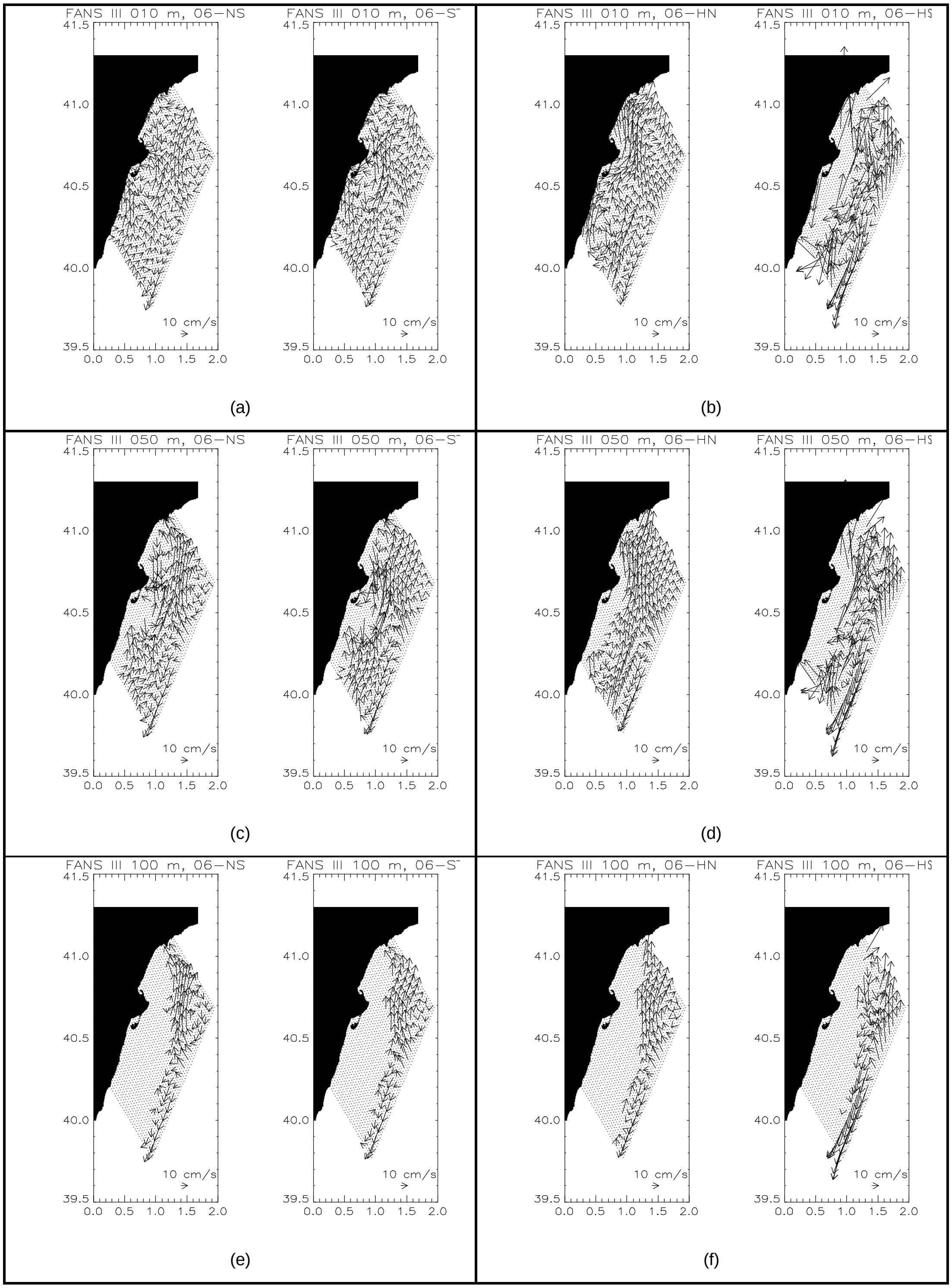

Figure 7-9 FANS III <u>Amplitude Interpolation</u> – Geostrophic Currents at 10 (a, b), 50 (c, d) and 100m (e, f) obtained with the campaign (a, c, e) and historic (b, d, f) eigenvectors. The left (right) plot in each frame corresponds to the non-standardized (standardized) analysis. All similar figures have the same arrangement.

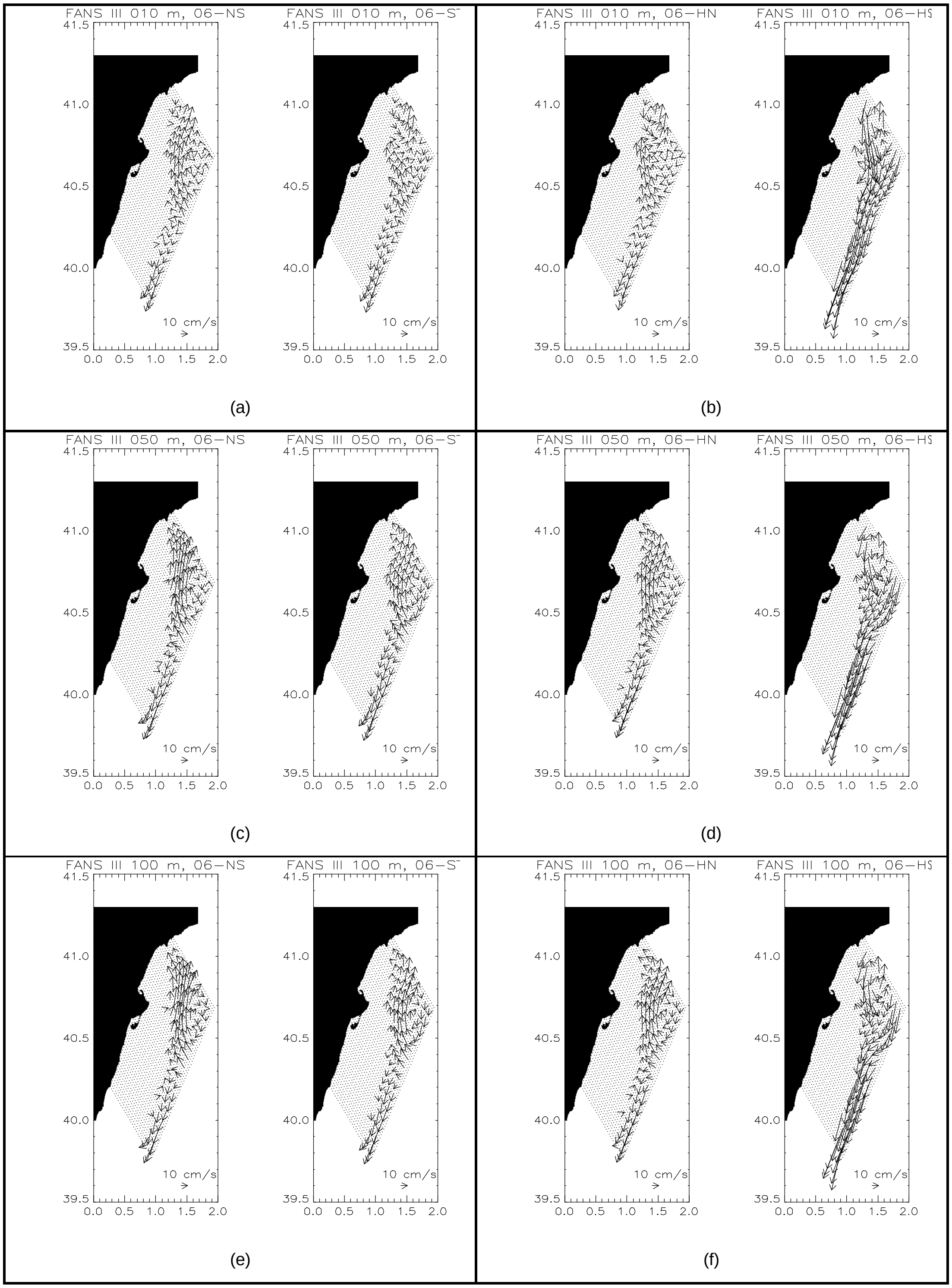

Figure 7-10 FANS III <u>Profile Interpolation</u> – Geostrophic Currents.

7.4.2 FANS II

Amplitude Interpolation: The distributions with the campaign eigenvectors (Figure 7-11) are similar, but with the standardized analysis showing weaker gradients to the south, near the coast. In all the frames (a, c, e) the orientation is predominantly from the northeast to the southwest, with little variation. There are areas in which the gradients are unrealistically sharp, as to the northwest, adjacent to the coast, and just in front of the Ebro Delta. All figures also show a lower gradient region nearby the northern boundary.

The distributions obtained with the historic eigenvectors (frames b, d and f) are also similar among them, but remarkably different from the previous ones. They show very little structure in the southern third of the domain, while to the north there is a partial eddy–like distribution which extends further to the south in the standardized analysis.

Profile Interpolation: the overall DT distributions on the outer shelf, the slope and the open ocean change just slightly with the campaign eigenvectors (Figure 7-12). The large gradients adjacent to the coast disappear, but that area is not resolved by this approach. The distributions from the non-standardized analysis with the historic data eigenvectors changes slightly, but for the standardized analysis they are similar to those obtained from the campaign eigenvectors.

Comparing these distributions with the dynamic height data contours from the amplitude interpolation, it is evident that eliminating the influence of the upper shelf does significantly improve the fit. In fact, the DT errors for depths larger than 500 m (Table 7-1) are consistently lower with the campaign eigenvectors (the largest error being 1.21%, versus an 8% with the amplitude interpolation). This improvement is more marked for the historic ones (from less than 10% to values higher than 50%).

The geostrophic currents that result from the previous DT distributions are presented in Figure 7-13 and Figure 7-14. With the amplitude interpolation, the non-standardized and standardized analyses with the campaign eigenvectors result in peak speeds larger than 120 cm/s at 10 m. There is no need to say that these values on the upper shelf are highly unrealistic for the region. In the outer shelf and slope (also from the amplitude interpolation), peak speeds are about 115 cm/s.

With the profile interpolation, the highest speed obtained with the campaign eigenvectors is 35 cm/s, significantly smaller than the previous 115 cm/s within the same domain. Such a large difference holds at all levels, so that unlike for FANS III, considering only the profiles located in regions deeper than 100 m only improves the DT and geostrophic currents results. The circulation on the upper shelf is not resolved by the amplitude interpolation, which generates very unrealistic velocities.

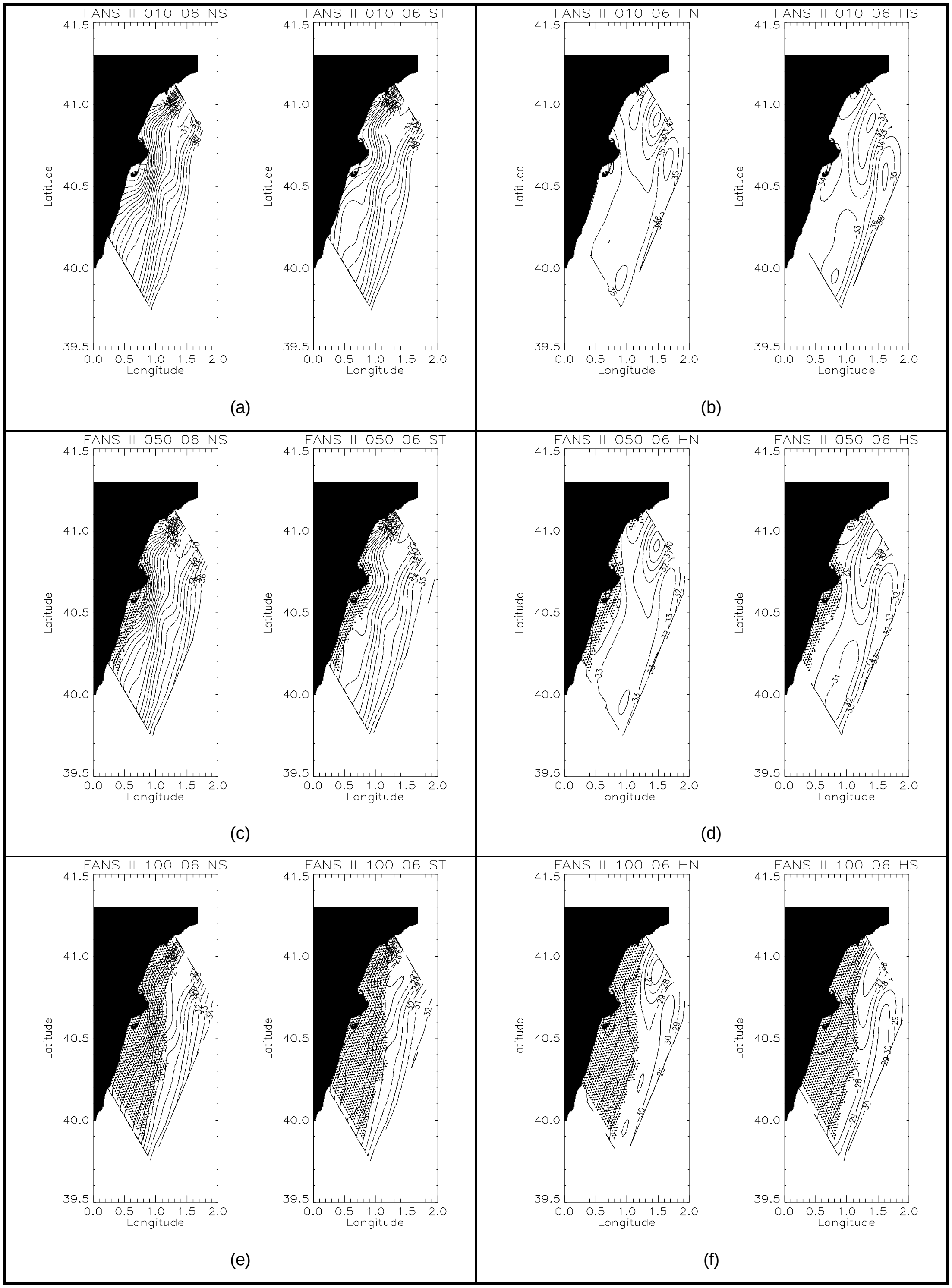

Figure 7-11 FANS II Amplitude Interpolation – Dynamic Thickness Distribution

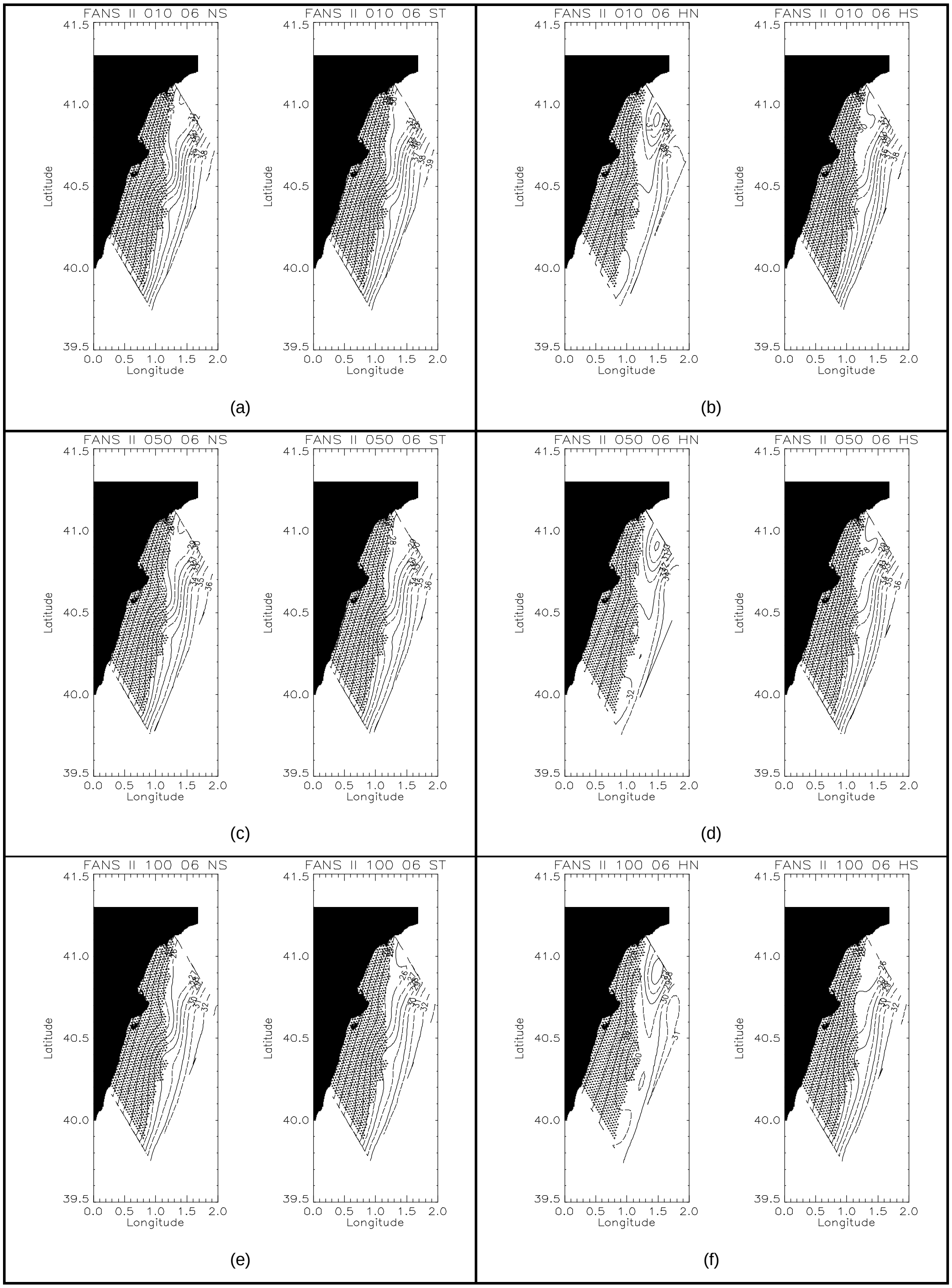

Figure 7-12 FANS II <u>Profile Interpolation</u> – Dynamic Thickness Distribution

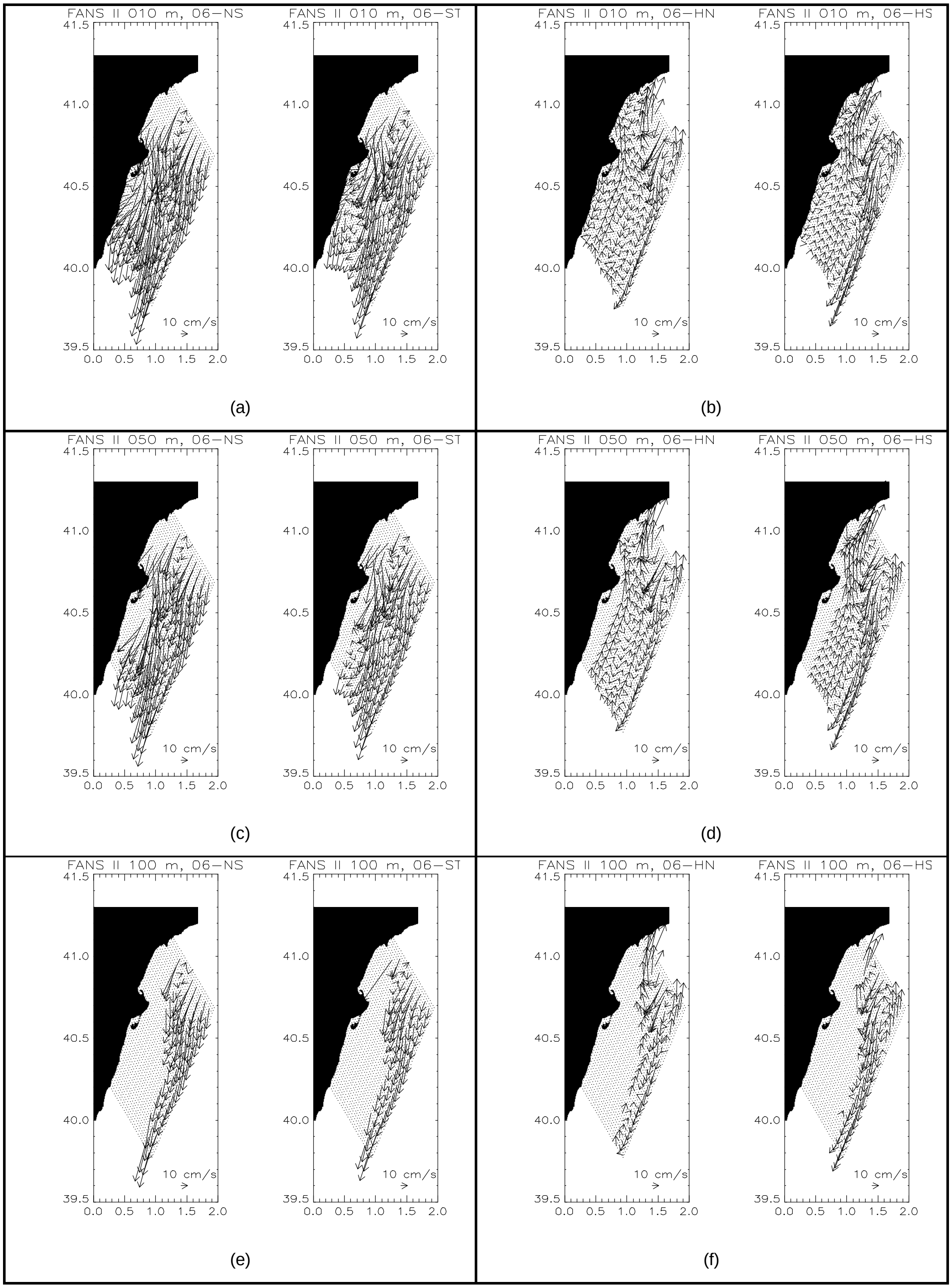

Figure 7-13 FANS II <u>Amplitude Interpolation</u> – Geostrophic Currents.

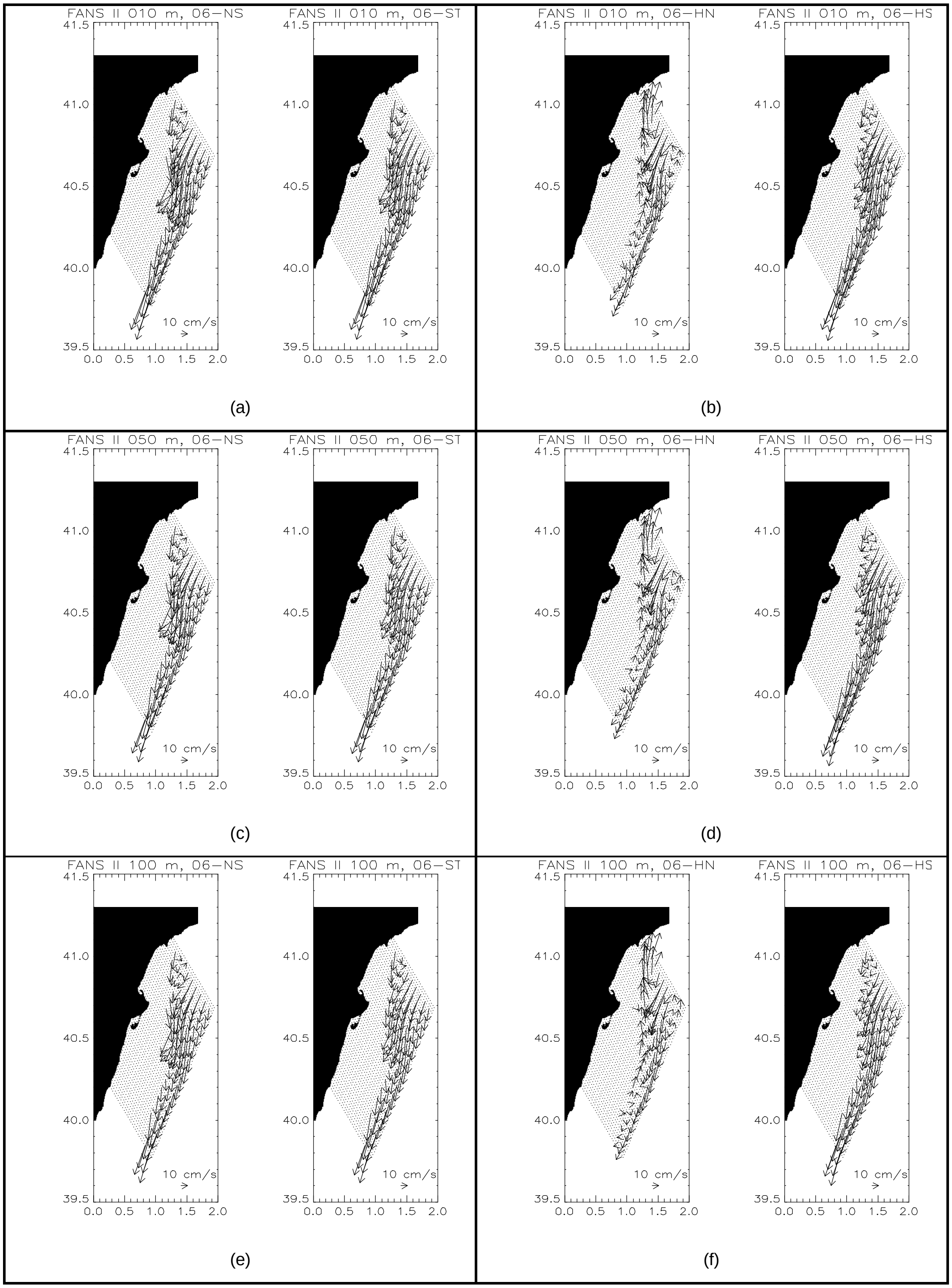

Figure 7-14 FANS II <u>Profile Interpolation</u> – Geostrophic Currents