Chapter 4. Hydrometeorological conditions during the 10–12 November 2007 catastrophic storm, chronology of events, administrative actions taken and consequences of the disaster

Ovsienko S., Fashchuk D., Zatsepa S., Ivchenko A., Petrenko O., Kabatchenko I., Filippov Yu., Yurenko Yu., Ilyin Yu., Chernov V.

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4.1. Synoptic situation

Storms of a magnitude similar to the Kerch accident may happen in the North-Eastern part of the Black Sea every 10–20 years (Buhanovskiy A. V. *et al.*, 2009). Typically, those catastrophic Black Sea storms are conditioned by a two-center depression with a secondary-cyclone drifting over the sea. Ikonnikova L. I. (1977, 1980) described the mechanisms behind as follows. A thermal depression builds-up over the Black Sea underlying warm surface during the transient and cold seasons of the year. That weak and motionless local disturbance tied to the warm underlying surface becomes a powerful stimulator of cyclogenesis (cyclone-generation). As soon as a Black Sea depression finds itself within the borders of a Southern periphery depression of central cyclone, it starts contributing to a secondary-cyclone build-up. Under those conditions the warm and humid air filling the Black Sea depression rushes to the secondary-cyclone center and rises up. In the meantime, the secondary-low develops as a «thermal» cyclone typical for the tropics and receives through vertical convection an additional energy by using humid instability, and makes an especially strong impact on water dynamics to produce the worst possible coastline and facilities destruction. The critical conditions required to be present for a destructive secondary-cyclone build-up are as follows: The atmospheric pressure in the center has to be lower than 985 hPa, the pressure decrease in three hours — more than 3 hPa, water temperature — higher than 8–9ºC, difference between the water and air temperatures — more than 2ºC, the secondary-cyclone moving velocity — 40–80 km/h and the wind velocity at the surface has to exceed 25 m/sec.

By all the features, the storm of 10–12 November 2007 has to be recognized as one of the most severe and destructive storms on the Black Sea among those with similar synoptic conditions of build-up under the influence of a secondary-cyclone developing as a thermal low.

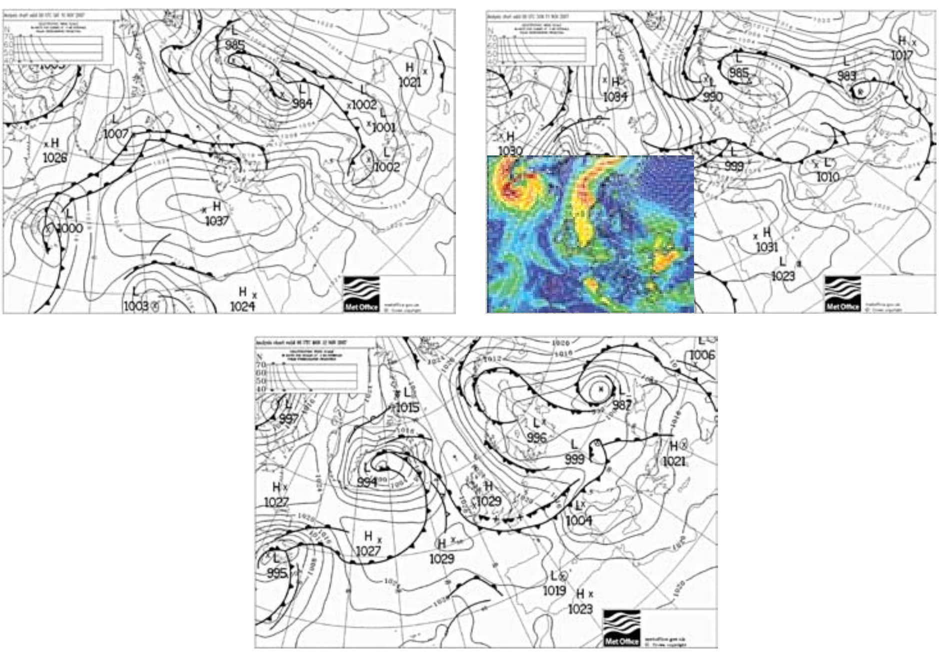

Fig. 4.1a. Evolution of the near-ground baric field and fronts over the Azov-Black Sea basin on 10 November at 00:00, the baric field and the near-ground wind on 11 November at 00:00 and on 12 November 2007. (http://www.wetterzentrale.de, Bracknell).

During the mentioned period, the European part of Russia was under the influence of a broad and deep cyclone with its center slowly drifting along Northern Europe (Fig. 4.1a, b). The cyclone build-up started on 9 November 2007 in the center of a baric depression (972 hPa) spreading from Scandinavia to the South of Western Europe.

On 10 November, a secondary-cyclone emerged over Italy and the Balkans at the South-Western periphery of that area of lower pressure (1001 hPa in the center, Fig. 4.1b).

During the day (from 00:00 GMT on 10 November till 00:00 GMT on 11 November) the secondary-cyclone was drifting from Southern Italy through the Balkan Peninsula and North-Western Turkey in the direction of the Crimean Peninsula advancing by 20 hPa at the velocity of 70 km/h and rushing to the Crimea (Buhanovskiy A.V. *et al.*, 2009; Postnov A.A. ed., 2009). The pressure was down to 983 hPa in the center of the cyclone that had stabilized over the Western part of the Black Sea. The horizontal baric gradients between that cyclone and the anti-cyclone in the South-Eastern part of the sea had gone up to reach 3–4 hPa at the 1º meridian. Over the Western Black Sea area and in the rear of that cyclone, the pressure difference between Varna and the Crimean coast was reaching 27 hPa. The cyclone moving velocity was close to around 80–85 km/h and it was building-up a zone of maximal horizontal baric gradients over the Kerch Strait and the Azov Sea (Fig. 4.1b). The hurricane wind velocity zone (25–32 m/sec, 700 hPa) was encompassing the whole European Continent.

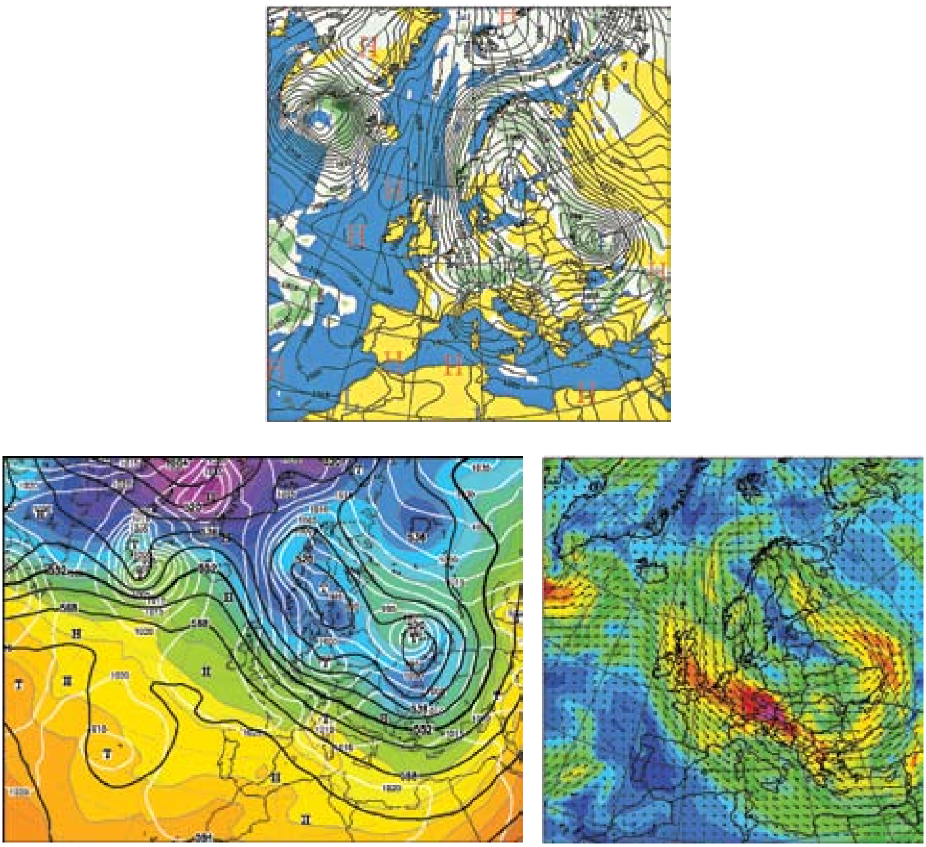

Fig. 4.1b. The storm synoptic conditions over the Black Sea on 11 November 2007: A near the ground baric field, the wind field at the height of 700 hPa and baric topography at the height of 500 hPa. (http://www.westwind.ch).

On the morning of 11 November, the Western wind velocity went up to 25–32 m/sec in the South-Western Crimea zone (Sevastopol), while the height of the waves spreading from the South-West was reaching 3–5 meters at the Cape of Chersonesos (the Chersonesos beacon). Starting from that moment, the zone of hurricane wind velocity adjacent to the cyclone center from the South-East started shifting to the Kerch Strait through the Black Sea along the cyclone trajectory. By mid-day of 11 November, the velocity of the South-South-Western wind had reached 25 m/sec (Feodosia) in the North-Eastern part of the sea, while the high waves in the Southern part of the Kerch Strait were standing at 4–5 meters.

Photo: High waves sea, 11th of November 2007, Novorossiysk, Black Sea, photo by *Alexander Kuznetsov*.

According to the information provided by the Kerch AMS, in the period of 10–16 November wind directions varied from the South-South-East to the North-West-North and the wind velocity — from still to 20 m/sec (Fig. 4.1c).

The North-Caucasian Inter-Regional Territorial Division on Hydrometeorology and Environment Monitoring reported the following on the Azov Sea: During the night of 10–11 November, 2007, the South-Eastern wind increased up to 15–20 m/sec in the period from 1:35 AM to 2:30 AM; then the wind turned to the South-West and its velocity reached 20 m/sec with the gusts of 26 m/sec at 11:20 AM; at the port of Temruk, the South-Eastern wind blew with a speed of 15–20 m/s at 2:30 AM; in the town of Eiysk, the Eastern wind turned its direction to the South and its speed became 15–22 m/sec at 1:35 AM; in the Doljanskaya tiny village (stanitsa), the Eastern wind turned to the South-West blowing at a 16–22 m/sec velocity at 5:40 AM; and the South-Western wind of a 13 m/sec velocity with gusts of 26 m/sec blew at 2:51 PM.

In Anapa (on the Black Sea coast), the Southern wind of a 20–25 m/sec velocity was observed at 2:38 AM; later — of 25 m/sec velocity at 7:40 AM with the gusts of 35 m/sec. In Novorossiysk, the South-Eastern wind turning to the South-West blew with a velocity of 17–22 m/sec at 2:45 AM through 6:00 PM. In Gelendzhik, the South-Eastern wind turning to the South-West blew with a velocity of 12–15 m/sec with the gusts of 17–23 m/sec at 2:40 AM till 5:00 PM; at 4:00 AM its velocity was 25 m/sec. In Djubga, the South-Eastern wind turning to the South-Western direction blew with a velocity of 7–12 m/sec with the gusts of 18–21 m/sec at 6:20 AM.

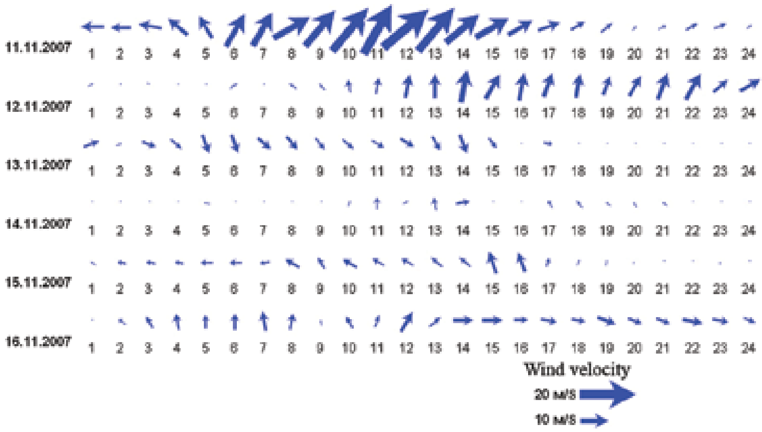

Fig. 4.1c. Velocity and direction of wind on 11–16 November, 2007 according to hourly observations of the Kerch AMS.

No wind observations were taken at the Kerch Strait itself. However, the wind field was re-constructed with a certain precision based on the field of pressure data with a 6-hour time step (Fig. 4.1d) and through using the Russian National Wind-Wave Model (Zakharov V. E. *et al.*, 1999, Kabatchenko I. M. *et al.*, 2001, Kabatchenko I. M., 2007, Kabatchenko I. M., Matushevsky G. V., 1998, Ovsienko S. N. *et al.*, 2009).

Based on series of precise calculations, it has been established that on 11 November an average wind velocity had a potential to reach up to 25 m/sec (the gusts were not taken into account) on the Kerch Strait (close to the Tuzla Island) at the noon time. Taking into consideration that the re-construction data gives lower wind velocity in comparison with the observed data (Buhanovskiy A. V. *et al.*, 2009), it is most possible that the real wind velocity was reaching up to 30–35 m/sec on the strait. Similar calculations were received through using the Meso-Scale Atmospheric Model (Peskov B. E., Dmitrieva T. G., 2009). After the storm, the still that happened lasted for the whole night of 12–13 November.

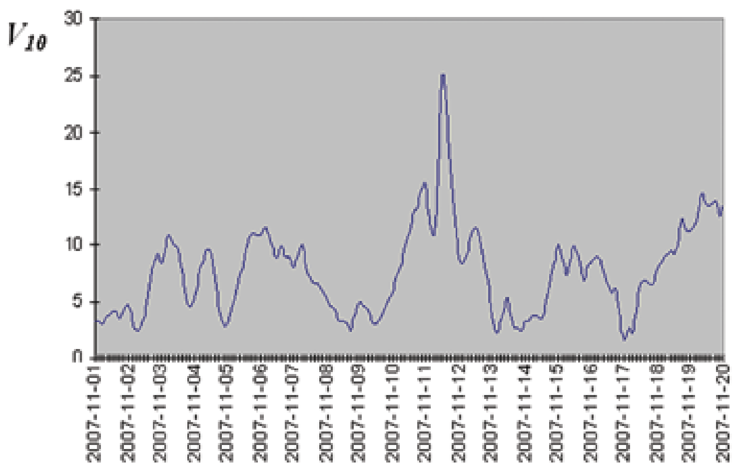

Fig. 4.1d. Wind velocity (m/sec) on the Kerch Strait close to the Tuzla Island through 1–20 November, 2007 according to the calculations based on the field of pressure.

4.2. Wave conditions

During the described above synoptic situation, the most dangerous disturbance (rough sea, high-waves) occurred by the North-Eastern Black Sea coast, since strong winds blew over the sea along the maximum-high wave fetches. Based on the data presented by the coastal hydro-meteorological stations (HMS), located in the Russian section of the Black Sea, waves of more than 3 points (Beaufort number) was observed in the Southern part of the water space (in the vicinity of Sochi) and up to 4 points — in its Northern part (the Anapa-Kerch Strait region) on Saturday, 10 November resulting from the impact of largely Southern and South-Eastern winds of 5–10 m/sec (Fig. 4.2a, b).

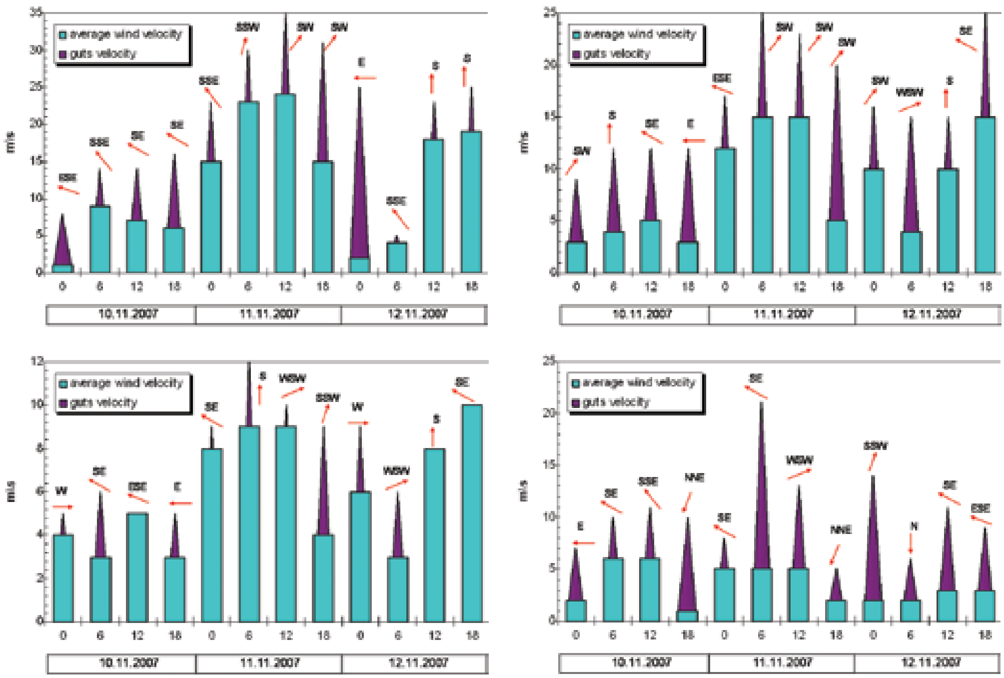

Fig. 4.2a. Wind characteristics based on the observations made (within the standard time) by the coastal HMS on 10–12 November, 2007: average wind velocity (blue) and guts velocity (brick) in Anapa, Gelendzhik, Tuapse and Sochi.

During the night of 10–11 November, the South-Eastern wind increased to 15–25 m/sec, the sea waves — to 4–5 points and the situation continued developing through the whole day of 11 November. Wave height (the wave parameters observed by the coastal HMS are usually taken as secured by the system parameters by 3–5 per cent) at the Sochi coast was reaching 1.5–2.2 meters during the day time, while in the vicinity of Tuapse it was 4.0–4.5 meters from the South and the South-West with a strong gusty Southern wind blowing with a gust velocity of up to 25–30 m/sec. In the region of Anapa and Gelendzhik, the wave height was reaching 3.5–3.7 meters with a strong Western and South-Western wind blowing at the gust velocity of 25–35 m/sec.

In the evening of 11 November the wind went down in Sochi (2–5 m/sec from the Northern bearings); while a high velocity of the South-Western wind continued in the Northern part of the water space reaching 5–15 m/sec at the Tuapse-Gelend-

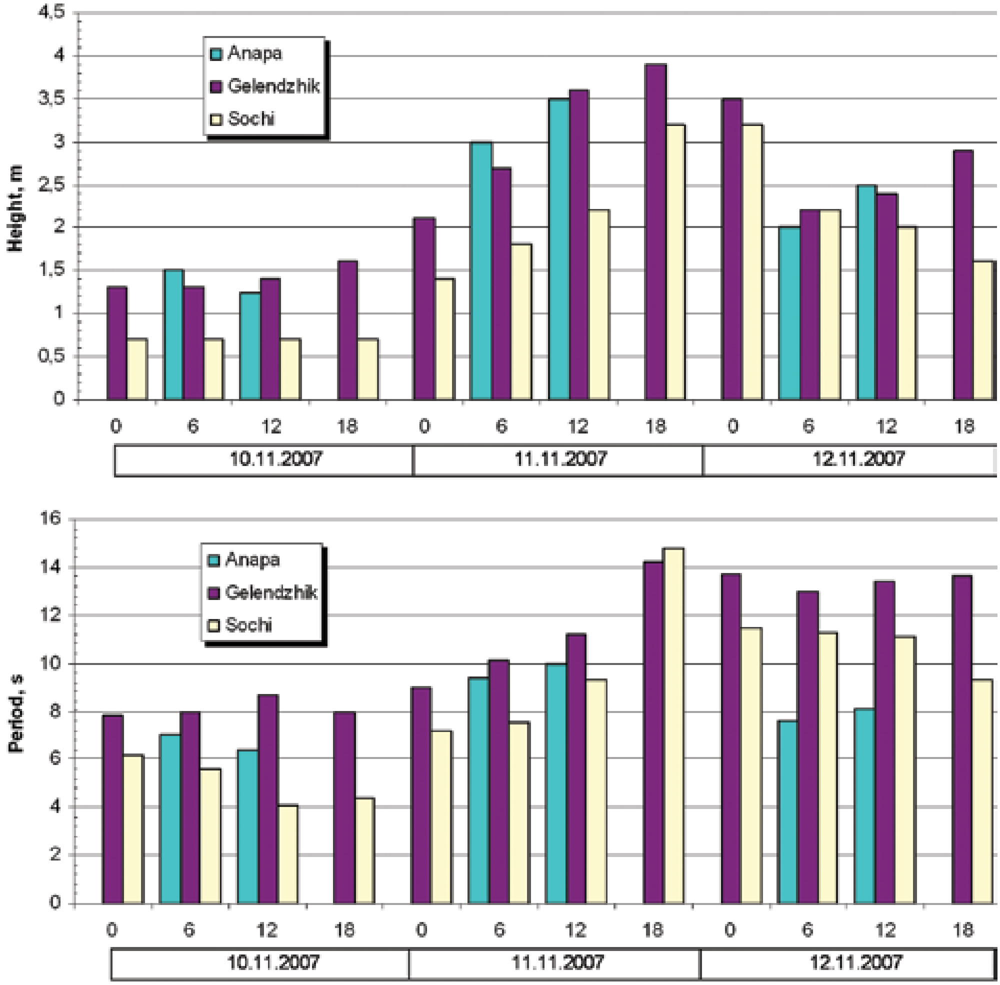

Fig. 4.2b. Wave parameters according to the observations made by the coastal HMS: period and height of waves in Anapa, Gelendzhik and Sochi.

zhik section and 15–25 m/sec around Anapa. In the meantime, the sea storm was increasing and during the night of 11–12 November the height of the South-Western and Western waves reached 3.0–3.2 meters at the Sochi coast, and 5.0 and 4.0 meters accordingly at the Tuapse and Gelendzhik coasts. At 18:00 GMT on 11 November 2007, for the first time in the history of observations carried out in the Sochi section, a wave period of 14.8 sec. was recorded, while the wave length at the coast was registered as standing at 106 meters (at the depth of 5.0–5.5 meters)

The storm maximum development phase was characterized by activation of the long-wave dynamics in the sea coastal zone. Thus, based on the registrations made by a depth-gauge installed at the open sea in Sochi, the amplitude growth of the infra-gravitation (long-period) waves started in the day time of 11 November from 10–15 cm to reach by the evening (18:00–20:00 GMT) the height of 35–45 cm. At the same time, the infra-gravitation wave period went down from 10–12 to 3 minutes. According to the depth-gauge observations taken in Tuapse, the amplitude growth of the infra-gravitation waves

Photo: High waves sea, 11 November 2007, Novorossiysk, Black Sea, photo by *Alexander Kuznetsov.*

in the sea-port water space was observed as well during the day time of 11 November to reach its maximum level (40–50 cm) at 14:00–17:00 GMT.

The maximum development of the storm was characterized by the activization of the long-waves dynamics in the coastal waters of the sea. According to records of the tide-gauge installed at the open sea shore in Sochi, amplitude growth of long period waves has begun in the afternoon of 11 November starting from 10–15 cm and reaching 35–45 cm by 18–20 GMT. The period of the long period waves decreased from 10–12 minutes to 3 minutes. According to the tide-gauge observations in Tuapse, amplitude growth was observed during 11 November with maximum of 50 cm at 14–17 GMT.

The storm induced high waves during the night of 11–12 November were accompanied by the sea middle-level rise by 20–30 cm (Fig. 4.2c). The water level peak rises at the long-wave crests were reaching the mark over the sea level at 510 cm in Anapa and 495 cm in Tuapse.

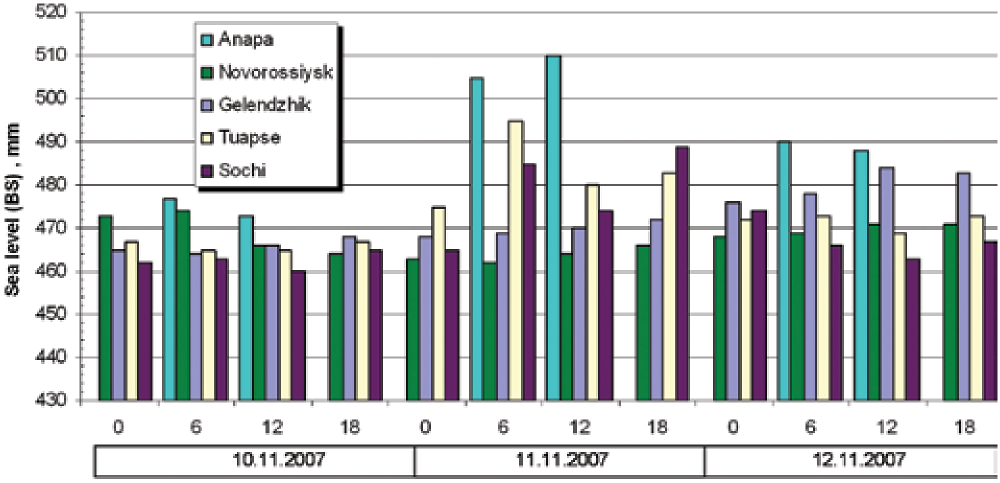

Fig. 4.2c. The sea level characteristics according to the observations made by the coastal HMS.

Thus, the storm's special feature became an intense development of long-wave processes («surf-shaken beats» type) in the coastal zone of the sea that contributed to strengthening the storm-wave up-rush to the shore and build-up of a destructive swash. During the day of 12 November, the strong disturbance persisted along all the Black Sea Eastern coastal waters sustained by a 10–25 m/sec storm wind of Southern and South-Western directions. The wave height reached in Sochi 2.0–2.5 m, in Tuapse — 3.0 m, in Gelendzhik — 2.5–3.0 m and in Anapa — 2.0–2.5 m (Fig. 4.2b).

Photo: High waves sea, 11th of November 2007, Novorossiysk, Black Sea, photo by *Alexander Kuznetsov*.

In line with the METU3 WAVE model (Turkey) calculations, during the 10–12 November storm the waves maximum heights in the deep waters of the open sea exceeded 11 m ($h_{1\%}$ ~ 9.0m), (Fig. 4.2d).

Very limited wind waves data was collected during the emergency situation in the Kerch Strait area. According to the reports of the North Caucasus Hydrometeorological De-

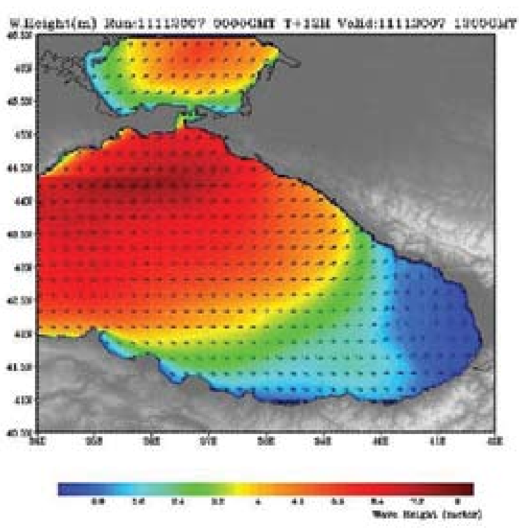

Fig. 4.2d. The wave heights prognostic field for 12:00 GMT on 11 November 2007 calculated through the METU3 WAVE model (Turkey).

partment of Roshydrtomet (NC HMD) and of the South Center of the Russian Federation Ministry of Emergency Situations, on 11 November: At the Temruk port, the waves height was 1.0 m at 9:00 AM; in the Doljanskaya tiny village (stanitsa), the waves height was 0.5 m at 9:00 AM; in Novorossiysk, the maximum waves height was 4.0 m (time was not specified).

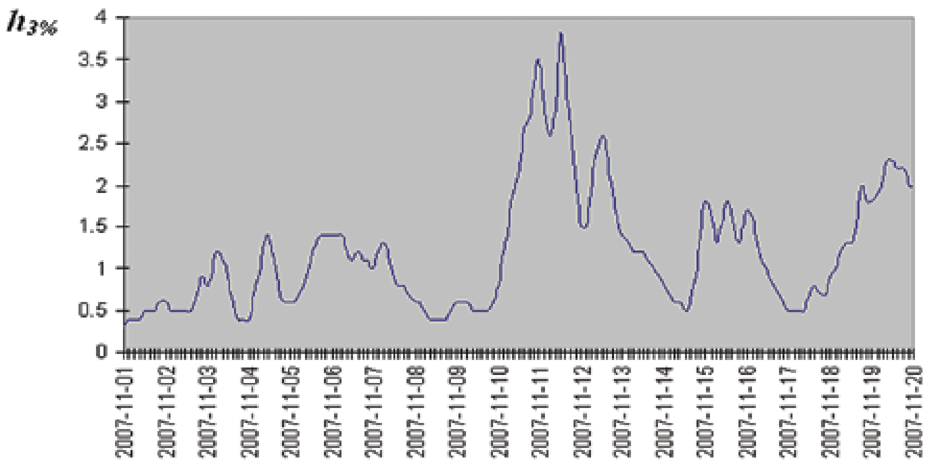

Fig. 4.2e. The waves height dynamics with a 3 per cent probability in the Kerch Strait close to the Tuzla Island in November 2007 (calculations were made through the Russian Wind-Wave Model).

Under those circumstances, the wind waves conditions assessment was based on the mathematical modeling. The Russian National Wind-Waves Model (Zakharov V. E. *et al.*, 1999, Kabatchenko I. M. *et al.*, 2001, Kabatchenko I. M., 2007, Ovsienko S. N. *et al.*, 2009) has produced the following results (Fig. 4.2e): In the Kerch Strait close to the Tuzla Island (from the Black Sea side), the wave height did not exceed 1.5–2.0 m during the period of 1–10 and 13–20 November. In that area the waves reached their maximum height of 4 m on 11 November. At the same time, the wave height reached 7–8 m in the Black Sea at the entrance of the strait, while the wave direction of movement was from the South-West to the North-East (Fig. 4.2f).

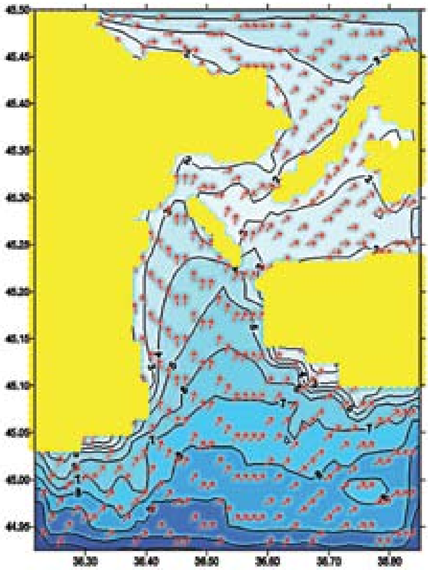

Fig. 4.2f. The field of waves (m) with a 3 per cent probability in the Kerch Strait at 12:00 AM on 11 November 2007. The arrows are the waves movement directions.

4.3. Water dynamics in the Kerch Strait and adjacent waters during the period of 11–19 November 2007

Current fields of the upper layer of the sea presented at the figures were calculated with the hydrodynamic model based on integration of the three dimensional Navier-Stokes equations with explicit-implicit fine definite method (Ivanov K.A., Filippov Yu. G., 1978, Filippov Yu. G., 1997). The water flows in the Kerch Strait during the period of 11–16 November were exclusively directed from the Black to the Azov Sea with branches from the Kerch Strait to the Taman Bay (Fig. 4.3a, b). At the South-Eastern coast of the Azov Sea were observed the South-Eastern and Eastern flows carrying the waters from the North-West to the South-East and further on to the East along the Russian coast. Therefore and due to the water-flow regime existing at the beginning of the Kerch accident and later, no possibilities for the oil spill to enter the Western part of the Azov Sea and to further move to the Ukrainian coast were present.

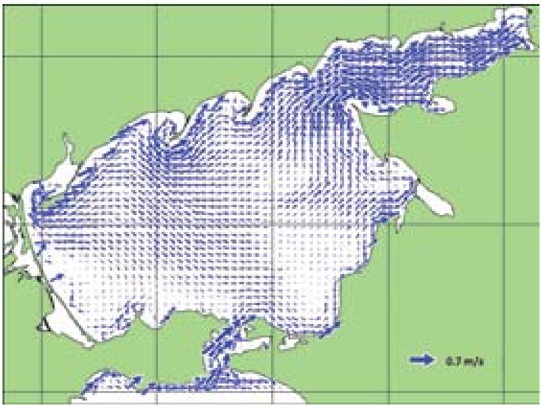

Fig. 4.3a. The field of water flow in the Kerch Strait and adjacent water areas of the Azov and the Black Seas at 12:00 AM (Moscow time) on 11 November 2007. The scale of arrow is 0.70 m/sec (on the bottom right).

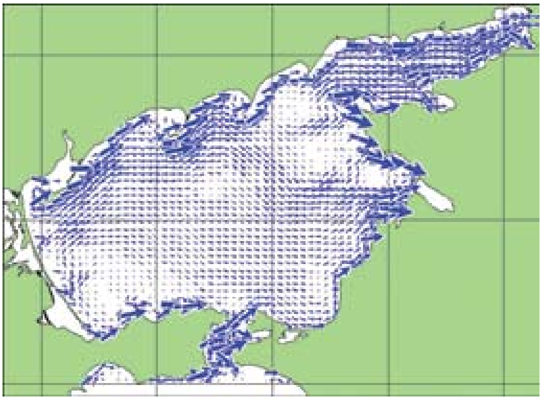

Fig. 4.3b. The field of water flows in the Azov Sea and the Kerch Strait at 12:00 AM (Moscow time) on 16 November 2007.

Starting from 17 November and due to the change in wind direction and velocity, the water flows in the Kerch Strait turned to the opposite direction with prevailing inflow from the Azov to the Black Sea and further on to the South-East along the Russian coast (Fig. 4.3c, d). In the South-Eastern part of the Azov Sea, the water flows heading to the South-East and East turned to the opposite direction as well on 17 November, limiting water inflow from the Kerch Strait to the North. At the same time, the waters that had entered the Azov Sea earlier went back to the Strait and hence to the Black Sea.

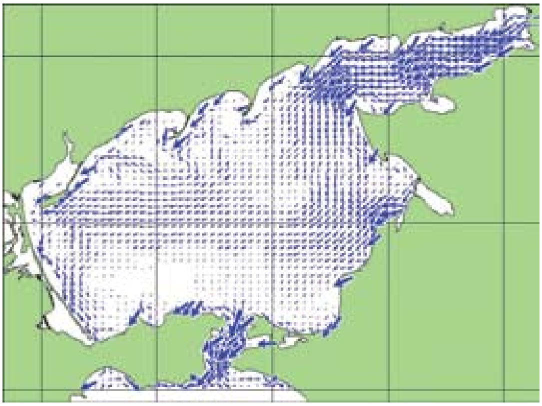

Fig. 4.3c. The field of water flow in the Kerch Strait and adjacent water areas of the Azov and Black Seas at 12:00 AM (Moscow time) on 17 November 2007.

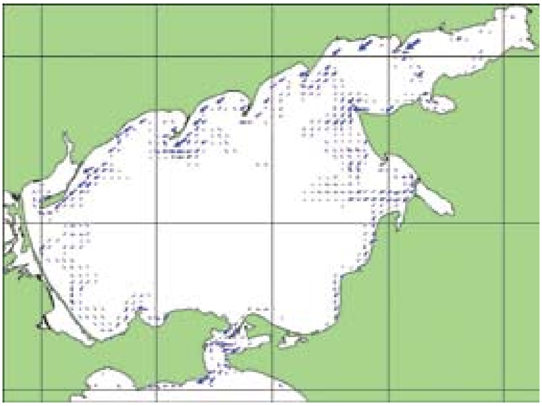

Fig. 4.3d. The field of water flow in the Kerch Strait and adjacent water areas of the Azov and the Black Seas at 12:00 AM (Moscow time) on 18 November 2007.

4.4. Preliminary assessment of heavy fuel oil characteristics

The preliminary assessment of spreading and diffusion of the Kerch oil spill and respective fine-tuning of consequent seabed contamination were based on very limited data, including no information on the chemical composition of heavy fuel oil[1] transported by the *Volgoneft-139* tanker. The assessments and forecasts were needed for rapid organization of response operations.

Estimates were based on the relation between the density of fuel oil and water temperature and salinity within the ranges respectively: 0–25°C and 10–20‰ (Manovjan A. K. 2001). Combining graphs of density for different types of fuel oil (Fig. 4.4a) with density graphs of water in the Kerch Strait in the real for the area ranges of temperature (1–24°C) and salinity (11–18.4‰) allowed making the following conclusions:

[1] Heavy fuel oil (mazut) is a dark brown liquid resulting from fractions or products of oil recycling separating from the oil gasoline, kerosene and gas oil (middle distillate) through boiling at a temperature of 350–360°C. It is a mixture of hydrocarbons (with a molecular weight from 400 to 1000 g/mol), petroleum tar (with a molecular weight of 500–3000 and more g/mol), asphaltenes, carbenes, carboides and organic compounds containing metals (V, Ni, Fe, Mg, Na, Ca). Physico-chemical features of fuel oil depend on the chemical composition of the original oil and the degree of skimming. It is characterized by the following data: the viscosity of 8–80 mm^2/s (at 100°C), the density of 0.89–1.015 g/cm^3 (at 20°C), the pour point of 10–40°C, the sulfur content in range. Heavy fuel oil is divided into three categories density wise: M-100/1015, M-100/1000 and M-100/985 where the numbers in the denominator represent the density of fuel oil kg/m^3 at 20°C. Mazuts are used as fuel for the steam boilers, boiler installations and industrial furnaces, for production of the ship fuel, heavy fuel for the diesel engines and bunker fuel. The outcome of mazut is about 50 % of mass of the crude oil. Mazut is the furth after oil, gas and diesel fuel in the Russian export currency revenue. In 2005 Russia exported 45.8 mln tons of mazut for 10.2 billion dollars; in 2006 in was 47.5 mln tons and 13.7 billion; in 2007 — 55.6 mln tons and 18.2 billion dollars (http://ru. wikipedia. org/wiki).

1) If the *Volgoneft-139* tanker transported the M-100/1015 type fuel oil, then the fuel oil could not raise to the surface because it is denser than water considering the real fluctuations of the water temperature and salinity in the Kerch Strait. It will be denser even if the water temperature rises up to 25°C. Floating of such type of fuel oil is possible only in an unrealistic situation, for instance, if the fuel oil would get warmed up to 22–25°C, and the water temperature at the same time remains within the range of 0 to 7°C.

2) In case the tanker transported the M-100/1000 or M-100/985 type fuel oil, then all petroleum products should have remained on the surface, since at even 20°C temperatures this fuel oil is lighter than water.

3) Fuel oil could rise from the bottom of the Kerch Strait to the surface only, if the *Volgoneft-139* tanker transported a mixture of M-100/1015, M-100/1000, and M-100/985 fuel oil.

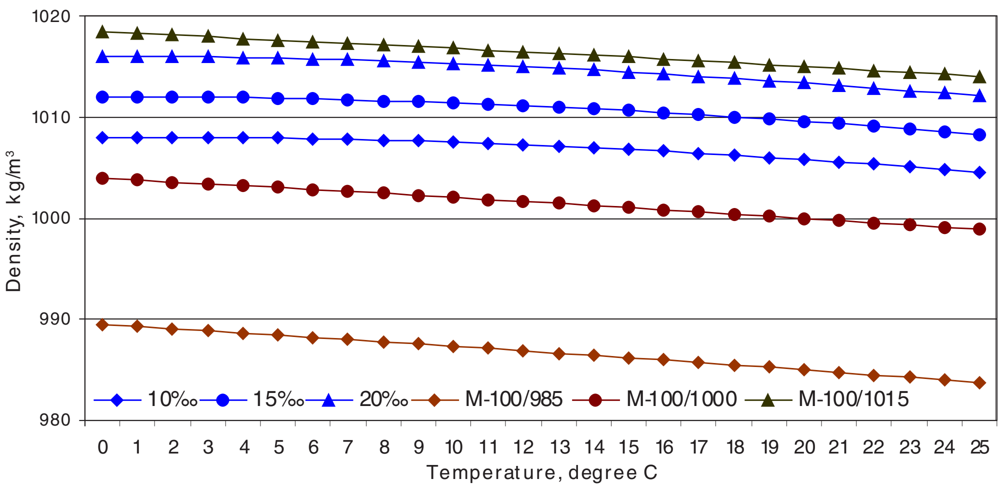

Fig. 4.4a. Density of sea water with levels of salinity 10, 15 and 20‰ and of heavy fuel oil (mazut) under different temperature.

It was estimated that in the case of heavy fuel oil surfacing in the open area between the Chushka Spit, Tuzla Island and the Crimean coast, with a probability of 60% (the proportion of Azov currents in the Strait for a month) the oil spill would be floating to the Black Sea. Therefore, the probability of contamination of the shoreline of the Kerch Strait from Kerch to the exit from the Strait to the Black Sea (the Kyz-Aul Lighthouse) is the highest. The fuel oil patch would be transported into the Sea of Azov with the 35% probability affecting the coast of the Chushka Spit, and the position of the spill would be uncertain in 6% of cases (the proportion of mixed flows for the month).

In case of fuel oil surfacing, to assess the progressing of the Taman Bay contamination during spring and summer was much more difficult. Given the decrease in intensity of water exchange between the Bay and the open water areas of the Strait after the construction of the Tuzla dam, and the consequent change of water circulation mode to an anticyclonic type which intensified the accumulation process in the Bay, the probability of prolonged preservation of fuel oil contamination there was much higher.

4.5. Mathematical modeling of the oil spill accident spread on 11–16 November 2007

The information about the oil spilled and discharged into the sea jointly with its characteristics during the period of the Kerch accident was just partially available for the first mathematical simulations undertaken immediately after the event. Certain assumptions were made that during the storm, not only the oil from the broken-in-two *Volgoneft-139* tanker entered into the sea, but the oil products as well spilled by the washed to the high bed boats were discharged into the water. While trying to take-off from the high bed after the storm, those boats could have discharged their ballast waters containing diesel oil jointly with the fuel from their bunkers. Finally, for the basis for calculations were taken the Ministry of Emergency Situations reports on discharge into the sea of 600 tons of oil from the *Volgoneft-139* tanker bow during the period of 12 hours starting from 4:50 in the morning on 11 November. Three hours later oil started leaking from the stern of the boat that had run aground when approaching the Tuzla Island and the leakage went on for another 12 hours.

A reconstruction of the aforementioned *Volgoneft-139* tanker accident looks as follows: Under a stormy South-South-Western wind impact, the oil slick hit the Tuzla Island's Southern coast six hours after the accident had occurred. The oil got partially detained by the Tuzla Island to concentrate by its South-Western coast, while a part of spill started moving around the island from the South-West to proceed spreading through the Pavlov Insularity in the direction of the Chushka Spit and the Azov Sea (Fig. 4.5a).

Fig. 4.5a. Oil spill six hours after the *Volgoneft-139* tanker accident on 11 November 2007, 10:00 Moscow time, the 210° wind — 20 m/sec.

By mid-day on 11 November (12:00 Moscow time) the spreading oil reached the entrance to the Azov Sea and started spreading to the East to the Chushka Spit coast affected by the wind that had taken a South-Western direction (Fig. 4.5b).

The 240° wind prevailing during the day on 11 November had actually saved the Ukrainian Kerch Strait coast from pollution, while contributing to the oil slick arriving to the Western coast of the Chushka Spit and entering the Taman Bay. According to the simulated calculations, it happened 24 hours after the catastrophe had occurred (Fig. 4.5c). The still that happened afterwards to last for the whole night of 12–13 November worsened the ecological catastrophe at the Russian coast of the strait.

In the afternoon on 12 November, the started South-Western wind (190–210°, 10–12 m/sec) tore-off the oil slick from the Chushka Spit coast and had almost brought it into the Azov Sea by 4 o'clock on 13 November (Fig. 4.5d). Still, starting from that

Fig. 4.5b. Oil spill 12 hours after the catastrophe on 11 November 2007, 16:00 Moscow time, the 240° wind — 10 m/sec.

Fig. 4.5c. Oil spill 24 hours after the catastrophe on 12 November 2007, 4:00 Moscow time, a still wind.

Fig. 4.5d. Oil spill 48 hours after the catastrophe on 13 November 2007, 4:00 Moscow time, the 310° wind — 5 m/sec.

moment its direction took a change to the South-West and by 9 o'clock on 13 November the oil slick having changed its direction into the opposite had hit the Taman Northern coast (Fig. 4.5e)

In the afternoon on 13 November, the newly arrived still to practically last till the end of the day on 14 November, contributed to saving from oil pollution the Russian coast of the Azov Sea at the strait entrance. It was the Southern wind started on 15 November only that tore-off the oil slick from the shore to move it to the Azov Sea (Fig. 4.5f).

Fig. 4.5e. Oil spill 54 hours after the catastrophe on 13 November 2007, 9:00 Moscow time, the 320° wind — 5 m/sec.

Fig. 4.5f. Oil spill 96 hours after the catastrophe on 15 November 2007, 3:00 Moscow time, the 100° wind — 3 m/sec.

The integrated picture of the Kerch Strait pollution during 11–15 November established based on the simulated model calculated results has shown the areas of the oil slick spread after the tanker accident (Fig. 4.5g). The oil was originally expected to spread largely by the sea surface. Nevertheless, the oil high density had to be taken into account due to which it could stay on the coast line elements, disperse in thick water and settle down to the strait bottom. All those mentioned had a potential to become a source of a long-term secondary pollution.

When comparing the figures with the helicopter monitoring surveys over the Kerch Strait oil pollution on 14 November 2007, one could recognize consistency present in the modeled calculations received and the actual data which built a trust to the simulated results. This was also confirmed by the Ukrainian ecologists reports who were the workers of the Ecology Department of the Kerch Technological University (a personal statement made by I.A. Kudrik, the Head and PhD in Medical Sciences). According to their provided data, the oil spills after the 11 November 2007 catastrophe was witnessed on the Tuzla Island Southern coast only. The oil spill did not reach the shore within the Kerch Inlet, at the Arshintsev Spit and Ukrainian coast of the strait at the entrance to the Azov Sea.

Fig. 4.5g. The Kerch Strait water space areas affected by the *Volgoneft-139* tanker oil spill on 11–15 November 2007.

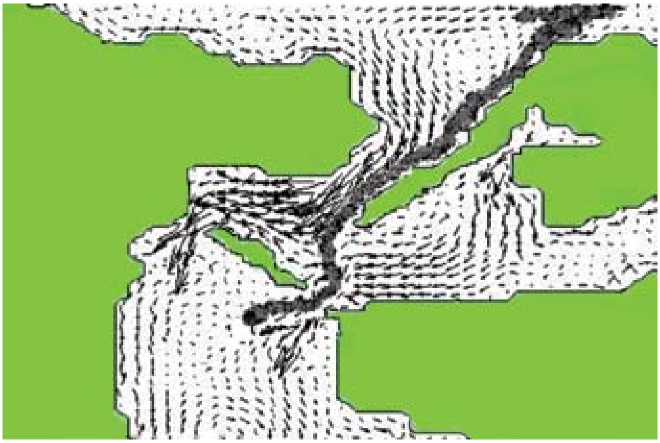

Fig. 4.5h. The calculated pathway of the oil spill from the first part of the tanker *Volgoneft-139* over 48 hours after the catastrophe. Arrows show the currents in the Kerch Strait at 6:00 a. m. Moscow time, 13.11.2007.

Similar results (Fig. 4.5h) were obtained by using a different type of mathematical hydrodynamic model (Ivanov K.A., Filippov Yu. G., 1978, Filippov Yu. G., 1997).

Field studies conducted in spring-summer of 2008 during joint expeditions of various agencies in the area of the *Volgoneft-139* tankershipwreck, allowed to confirm the preliminary assessments results speculating about the fuel oil spreading based on geographical and environmental analysis (Fashchuk D.Ya. 2008, 2008a) and mathematical simulations (Ovsienko S.N. *et al.,* 2008). During the extreme storm under the influence of South-West wind, the Black Sea waters entered the Strait reaching the port of Caucasus and further. Salinity was 17.7‰ there (Matishov G.G. *et al.,* 2008). Fuel oil has neutral buoyancy at this salinity. Part of it had been thrown out by the storm onto the beaches of Tuzla Island and Chushka Spit. The remaining in the water fuel oil was transported by flows into the Azov Sea and begun to settle onto the bottom because it was heavier than the water at its salinity of 12–13‰. After the storm calmed down, the restored Azov compensatory flow brought back the residual fuel oil from the Azov Sea into the Kerch Strait. The fuel oil, under the higher salinity there, emerged to the surface and was casted ashore on the Ukrainian coastline, at the Ak-Burun Cape and Arshintsev Spit, in particular.

Remnants of fuel oil, trapped on the bottom of the Strait in the area of the epicenter of the shipwreck (the Tuzla Spit and Tuzla Island) were moved outside of the area by the prevailing currents during the 2008 spring-summer. Practically, all the bottom of the Strait except for local areas in the far end of the Taman Bay, was void of consequences of the disaster by August, 2008.

The dark spots in the area of the Kerch Strait found on the satellite (SAR, synthetic aperture radar) images, produced at the time of the shipwreck and subsequent days, reflected most probably the films of light fractions of fuel oil (diesel) released from the tanks of the three other ships sunk in the Strait besides the *Volgoneft-139* tanker. On top of this, background «fresh» films remained stable in this area due to the officially banned pumping of oil from small to large ships illegally taking place since 1990 in the Strait (Fashchuk D. Ya., *et al.,* 2007). These «fresh» films break the spectrum of surface waves fixed by space radar images.

4.6. Chronology of the storm events on 10–12 November 2007 and the administrative actions to prevent oil pollution

According to the Russian Ministry of Emergency Situations data, in the morning on 11 November 59 boats, out of which around 20 were the oil-carrier boats of the river-sea navigation type, were present in the vicinity of the Caucasus port. Approximately the same number of boats were anchored at the entrance of the Kerch Strait from the Black Sea with the *Volgoneft-139* river-sea type tanker and the *Volnogorsk, Kovel* and *Nahichevan* dry cargo carriers being among them (Fig. 4.6a).

At 4.50 AM Moscow time on 11 November 2007 in the vicinity of an anchorage by the Southern side of the Tuzla Island the *Volgoneft-139* tanker (Russia flagged ship owned by Bashvolgotanker, JSC, port of registry — Astrakhan, date of construction — 1978, ship crew — 13 persons, cargo on bord — 4077 tons of heavy fuel oil) broke-up in two, coordinates 45°15’0 N and 36°30’0 E, between anchorage areas Nos. 450 and 451) with its bow part remaining after the accident in place, while the stern started shifting in the direction of the Island of Tuzla affected by the wind and current. The other motor vessels being the Russian dry cargo ships of *Volnogorsk* (loaded

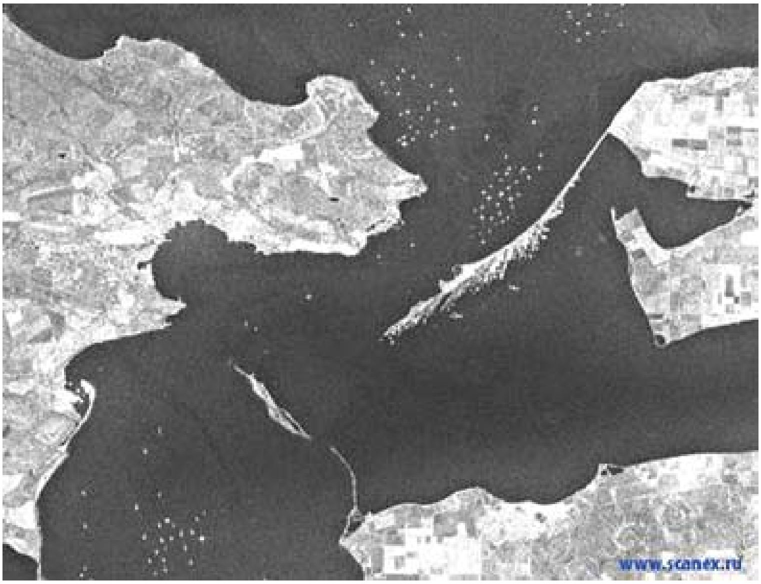

Fig. 4.6a. Position of the boats in the Kerch Strait at the moment of the emergency situation arrival on 11 November 2007.

with 2437 tons of granulated sulphur), *Nahichevan* (2366 tons of sulphur), and *Kovel* (1923 tons of sulphur) started drifting towards the coast of Ukraine (south of Tuzla Island), but sank. It was reported that the sulphur granulates leaked on to the sea floor. Due to the slow reaction in water, it was unlikely that granulates could lead to suspended colloidal sulphur in the short term.

Based on the aforementioned scenario, one could assume that besides the oil discharged into the sea after the *Volgoneft-139* accident, the oil products from other boats washed aground were discharged as well. By general estimation, the oil products volume discharged into the strait water space could reach as much as 1300–1800 tons of heavy fuel oil out of 4777 tons carried by the *Volgoneft-139* tanker as a result of its breaking-up into two (Ovsienko S. N. *et al.,* 2008).

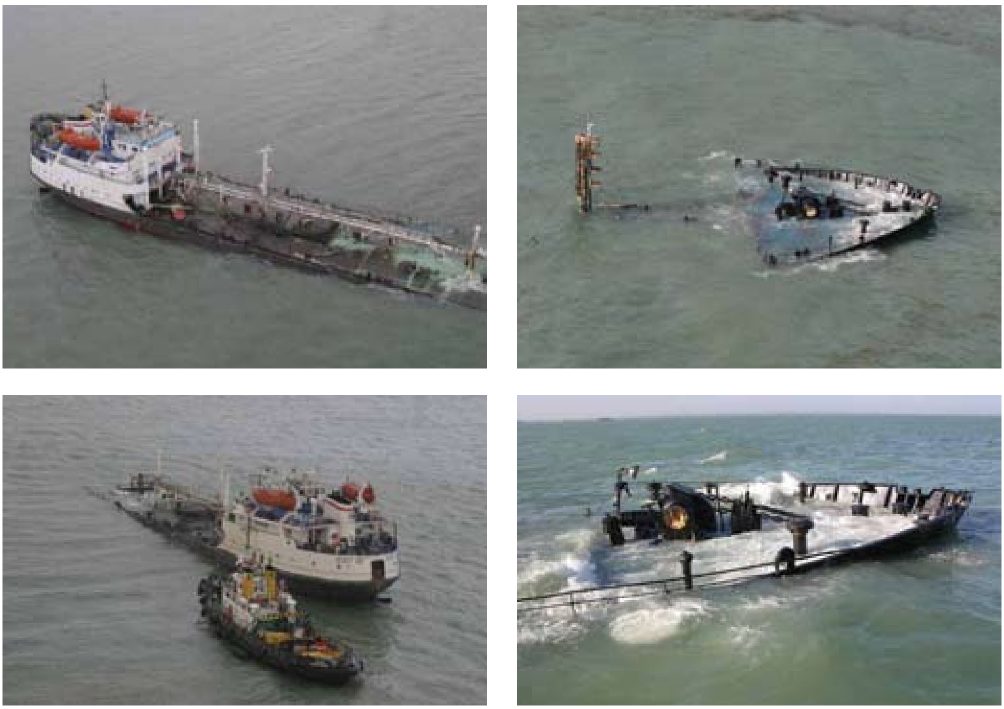

Photo. Parts of the *Volgoneft-139* tanker: the grounded stern, towed to Port Caucasus on 15 November 2007, and the bow removed on 13 August 2008 (www.yuga.ru, Booklet, 2009).

The Kerch Strait storm lasted from the night till evening on 11 November. At 6 AM the Emergency Response Center started its operation in the premises of the Port Vehicle Traffic Monitoring System headed by A. V. Iovlev, the harbor master of the port of Caucasus. Already at 9 AM the Ukrainian Ministry of Emergency Situations diving speed-boat inspected the Tuzla Island coast and by 2 PM it had finished inspecting the Strait water space in the sunken boats vicinity. According to the observation results, no visually floating oil slicks from the *Volgoneft-139* tanker were detected. Separate oil pieces were witnessed at the sea surface covered with the light oil fractions veil (diesel fuel) that were coming into the sea from the bunker tanks of three other boats sunken in the Strait, i. e., the *Volnogorsk, Kovel* and *Nahichevan* dry cargo carriers.

By means of the Russian Ministry of Emergency Situations, at 9.30 AM — 12.30 PM on 14 November 2007 a helicopter survey was carried out over the oil-polluted Strait jointly with mapping the oil slicks in the Strait water space and ashore (Table 4.6a, Fig. 4.6b).

Table 4.6a. Coordinates of the oil spill after the *Volgoneft-139* accident on 11 November 2007 (based on the helicopter survey data).

No	Coordinates	Items
1.	Latitude –45°17’48 N Longitude –36°36’2 E	An oil-fuel slick
2.	Latitude –45°17’48 N Longitude –36°36’2 E	The *Volgoneft-139* aft deck
3.	Latitude –45°15’56 N Longitude –36°30’8 E	An oil-fuel slick
4.	Latitude –45°15’8 N Longitude –36°30’3 E	Two slicks per 50 sq m, four slicks per 10 sq m
5.	Latitude –45°08’22 N Longitude –36°38’8 E	A one-piece oil-fuel slick around 200 sq m
6.	Latitude –45°12’65 N Longitude –36°32’043 E	Light fraction around 200 sq m
7.	Latitude –45°10’200 N Longitude –36°32’732 E	Tail’s start from the *Volgoneft-139* nose part
8.	Latitude –45°11’800 N Longitude –36°32’500 E	Tail’s end Γ shaped
9.	Latitude –45°11’44 N Longitude –36°32’50 E	An oil slick — tail
10.	Latitude –45°12’36 N Longitude –36°32’154 E	Slick’s edge from the *Volgoneft-139* nose part
11.	Latitude –45°12’08 N Longitude –36°32’0 E	Two slicks: 1st — 200 sq m, 2nd — 400 sq m.
12.	Latitude –45°11’5 N Longitude –36°31’64 E	A slick, light fraction, 100 sq m
13.	Latitude –45°17’45 N Longitude –36°36’90 E	An oil-fuel slick of 60 sq m
14.	Latitude –45°22’0 N Longitude –36°43’1 E	Two large slicks at the shore
15.	Latitude –45°26’0 N Longitude –36°46’70 E	The edge point of coastal pollution
16.	Latitude –45°23’67 N Longitude –36°59’65 E	Tail’s start, light fractions
17.	Latitude –45°22’79 N Longitude –36°01’86 E	Tail’s end, 150–200 m wide, light fractions
18.	Latitude –45°26’29 N Longitude –36°53’80 E	Grass mixed with oil-fuel, area: 200 sq m
19.	Latitude –45°22’47 N Longitude –36°43’48 E	Pollution of the coast line

Fig. 4.6b. Results of a helicopter survey carried out by the Russian Ministry of Emergency Situations over the aftermath of the *Volgoneft-139* tanker accident in the Kerch Strait on 14 November 2007 at 10:00–12:00 in the morning. Numbers at the Figure correspond to the items in Table 4.6a.

Apparently, the source of the light oil products fractions tail registered from the entrance of the Kerch Strait (Azov Sea) along the Northern coast of the Kerch Peninsula was the dozens boats hit by the storm. The rest of the oil product slicks found in the sea had resulted from the *Volgoneft-139* tanker accident. Attempts to prevent oil from leaking from the wreck, using booms, appeared to be unsuccessful due to the strong currents in the Strait.

The emergency actions after the storm in the water area of the Kerch Strait were undertaken by the personnel and with facilities of the Novorossiysk Department of Search and Rescue, and Diving Operations Management, the Port Authorities of the Port of Taman, the Taman Branch of the «Rosmorport», and Black Sea Fleet.

On 13 November 2007 the fuel oil products transfer from the *Volgoneft-123* to the *Volgoneft-249* boats was completed, and in total 4146 tons of M-40 heavy fuel oil were pumped over. On 15–17 November 2007, the salvage tug *Svetlomor-3* was engaged in collecting oil products in the area of the pollution leakage around the bow part of *Volgoneft-119*. Approximately 43 tons of oil mixture and 1200 kg of heavy fuel oil were gathered (in barrels on board). *Svetlomor-3* together with the *LB-57* speed-boat (Ukraine) collected oil products in the water area of other parts of the Kerch Strait as well under the guidance of the Kerch VTS Centre.

On 14 November, in the vicinity of the Tuzla Spit, works were carried out to put 400-meter (two branches) booms between the spit and the Tuzla Island preventing further distribution of the oil. The oil film around was collected from the sea surface by specialized vessels.

On 15 November, pumping out of heavy fuel oil from the *Volgoneft-119* m/v was completed. Approximately 933 tons were pumped out.

On 16 November, 886 tons of heavy fuel oil was pumped over from the bow section of the *Volgoneft-139* tanker to the *Volgoneft-119* tanker. From water area in position of the stern part of *Volgoneft-139* by facilities and personnel of Novorossiysk Department of Search and Rescue and Diving Operations Management were collected about 50 m^3 of heavy fuel oil and 200 m^3 of oily water (Booklet, 2009). On 15 November 2007, the stern of the *Volgoneft-139* m/v was brought afloat and towed to the port of Caucasus, then surrounded by booms.

On 18 November, the sea-going *Tornado* tug and the *Lamor* technical supply vessel joined the clean-up operations in the water area of the Kerch Strait. The operations were directed by the Novorossiysk Office of Search and Rescue Diving Operations Management. In the period of 20–23 November the cleaning operations around the stern part of the *Volgoneft-139* tanker continued. In total, 1094 tons of heavy fuel oil was collected from the stern part of *Volgoneft-139*.

On 21 December, the *Vodolaz-2* diver cutter and the *Lamor* technical supply vessel made a diving inspection of the bow part of *Volgoneft-139* with a view of its raising. The object conditions were the following: the bow part sat on a sandy bottom, practically on even keel. The depth over the object was 8.5 m. The forecastle deck of the bow part came out of the water. The cargo tanks were evaluated for the level of damage. All parts of equipment and systems on the main deck were found covered with a layer of heavy fuel oil. There were separate spots of heavy fuel oil on the forecastle deck. The scope of the preparatory work for recovery operations was estimated.

On 24 November 2007, organizational matters for recovering of the bow part of the *Volgoneft-139* tanker were resolved with involvement of the Navy Fleet resources. Equipment, rigging, patches, tools and spare materials required for refloating operations were prepared. The project of the ship's bow refloating was developed. On 25 November 2007, under stress of adverse weather and due to the storm warning notice the operations were suspended. On 2–3 December 2007, an attempt of refloating was made, but due to the weather conditions (storm) the work was suspended. On 9 December 2007, the diving investigation and preparation work for refloating and towing of the *Volgoneft-139* bow were resumed. On 9–10 December 2007, mazut pumping from the tanks into the *Mekhanik Razhev* m/v (1020 $meters^3$ of the oily water mixture) were carried out. On 22 May 2008, due to higher air temperature which consequently resulted in heating the heavy fuel oil still remained in the *Voloneft-139* stern part, some heavy fuel oil spots started appearing on the water surface. Additional boom defense arrangements were provided on 20 May 2008, and cleaning operation was conducted. Sorbent agents were used and the spilled oil products were collected on board the *Impulse* emergency response vessel.

Later, on 14 August 2008 the *Volgoneft 139* tanker bow was recovered and towed to berth No 25 of the port of Caucasus. At present, it is being dismantled and re-cycled further.

Photo: Raising operation of bow part and both bow and stern parts of *Volgoneft-139* in the port Caucasus (Booklet, 2009).

Human resources (manpower) exceeding 2.5 thousand persons and more than 300 units of technical equipment were involved in the coastline clean-up operation. The specialized sub-divisions and rescue teams, EMERCOM and military sub-divisions, fire-fighting services were engaged in the process of eliminating the consequences. In addition, representatives of public and environmental protection organizations (see Chapter 6.3), cadets of Maritime Academy, students and other volunteers took an active part in cleaning shoreline operations.

By the end of November 2007, the volunteer workers from the Ministries of Emergency Situations, armed forces of Ukraine and Russia and many other organizations had completed collecting most of the oil at the beaches of the Crimean and Taman coast. In total, 7140 tons of wastes were collected at that time on the Crimean coast (see Chapter 6.3 for more details). At the Russian coast, about 47 000 tons of oily wastes (oil- contaminated substrate and seaweeds) were collected on the beaches. Other source mentioned the slightly less volumes of oil-contaminated substrate collected from the coastline, i. e., about 40 000 tons. Thus, one could assume that nearly all oil products discharged into the sea by an accident arrived ashore and were later collected.

Photo: Oil spilled on the coast of the Tuzla Island, photo of *Igor Golubenkov* (NGO: Saving Taman), http://www.flickr.com/photos/.

The clean-up operations on the coast that continued for months are presented in detail in Chapter 6.3. Search and Rescue, administrative actions after 12 November 2007, post-disaster needs assessments, responsibilities, oil spill preparedness and prevention lessons learnt are presented in Chapter 9 and Annex 5.

4.7. Consequences of the disaster

The consequences of the storm of 10–12 November 2007 were catastrophic. Since the Second World War there was no other case of such a mass and simultaneous wreck of ships. Four sulphur carrying boats (*Volnogorsk, Nahichevan, Kovel*, and *Hach Ismail*) sank in the Kerch Strait and near Sevastopol due to the stormy winds and the 5-meter waves. Six vessels (the *Vera Voloshina, Ziya Koc, Captain Ismael* ships, the *Dika*, *Dimetra* barges and the *Sevastopolets-2* crane barge) were taken away from their anchors and ran aground at different sites at the Black Sea coast. Two tankers (*Volgoneft-139* and *Volgoneft-123*) and the *BT-3754* barge suffered damage. Four people died and four went missing, about 6726 tons of technical sulfur carried by the damaged vessels got discharged into the sea.

The *Volgoneft-139* tanker broke apart at its anchorage No 451 to the South from the Tuzla Island at 4:50 AM Moscow Time on 11 November 2007 causing leakage of heavy oil into the sea. Tanker's bow retained its position while the stern began drifting towards the Tuzla Island. The tanker had carried a total of 4777 tons of heavy oil, about 1300 out of which leaked into the sea. A strong wind and the waves contributed to spreading the oil products over the Strait resulting in the coastline heavy pollution.

Shipwrecks occurred as well in other places of the Russian Black Sea coast since some Georgian and Turkish ships and small boats were washed ashore in Kabardinka and Gelendzhik.

The storm brought about big changes to the coast and bottom of the submerged continental slope. For example, the coastal cliff between the Capes of Iron Horn and Panagya shifted inland by 2–3 m (by 5–7 m in some places) and some deep Earth slips happened.

Separate parts of the bay coastal fulls rose by 0.1–0.3 between Gelendzhik and Tuapse, certain river mouths were partially blocked by the pebble bars and several coast line facilities got damaged. Divers discovered vertical direction modifications of the local sand bottom reaching 0.2–0.3 m near the outskirts of the ridge bench at the depth of 8–11 m. Those bottom modifications were determined by the enhanced sediments shifting within the submerged accumulative ridge and depression terrain limits.

The storm has strongly affected the Imeretin Lowlands coast near the Cape of Konstantinovsky close to the town Adler. There, a cliff shifted 40–50 m inland, a former wave-breaker remnants were washed away and the waves went by 120–170 m inside the lowlands. By means of a scuba-diving survey were discovered the nearly 50–60 m submerged-canyon talweg cut-in into the continental slope and numerous slides on the submerged canyon sides.

A serious damage was inflicted on the coast protecting constructions, recreation beaches and the sea-front embankments, as well as their auxiliary facilities and small sale outlets that were often within the wave-affected zone.

Photo: The storm on 11th of November 2007, Sevastopol, building of IBSS, and it's consequences on the next day. Photo by *Sergey Alyomov.*