ANNEX 9: ADVECTION-DISPERSION ANALYSIS AT THE LNG REGASIFICATION PLANT

ADVECTION-DISPERSION ANALYSIS AT THE LNG REGASIFICATION PLANT IN TARANTO, ITALY

INDICE GENERAL

Figure index

Table index

ADVECTION-DISPERSION ANALYSIS AT THE LNG REGASIFICATION PLANT IN TARANTO, ITALY

1. ADVECTION-DISPERSION ANALYSIS OF THE WATER DISCHARGE

1.1. Introduction

GAS NATURAL is in the processes of the construction of an LNG terminal and regasification plant at the Port of Taranto in Italy. As part of the design studies for the plant, the company ALATEC, S.A. has performed the present study to analyze the water discharge dispersion and advection. The present study has been performed in order to assess the extend of the water discharge and possible negative effects, as well as to investigate the possibilities of a water recirculation into the water intake.

The study area is located in the Taranto province at the Regione Puglia, southeast Italy. The port of Taranto is one of the most important industrial ports in Italy, bringing economic wealth to the region. The layout of the Port of Taranto is shown in figure 1.

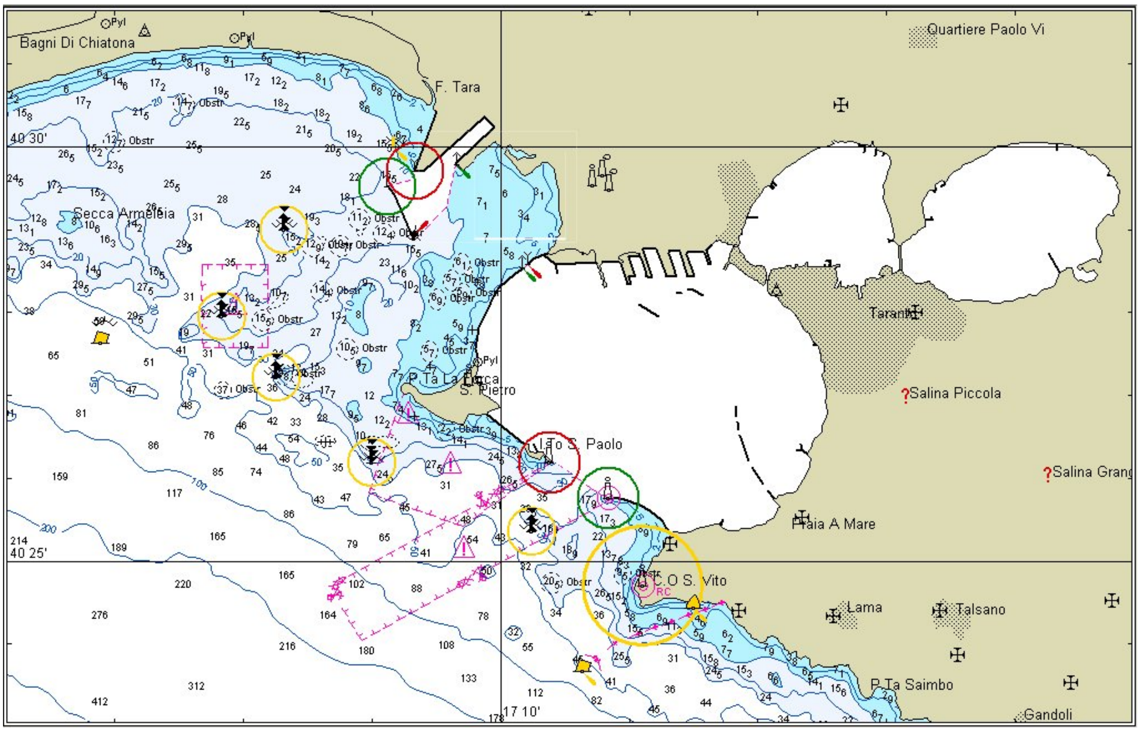


figure 1. Port of Taranto

The location at the Port of Taranto for the regasification plant and the LNG terminal is shown in figure 2.

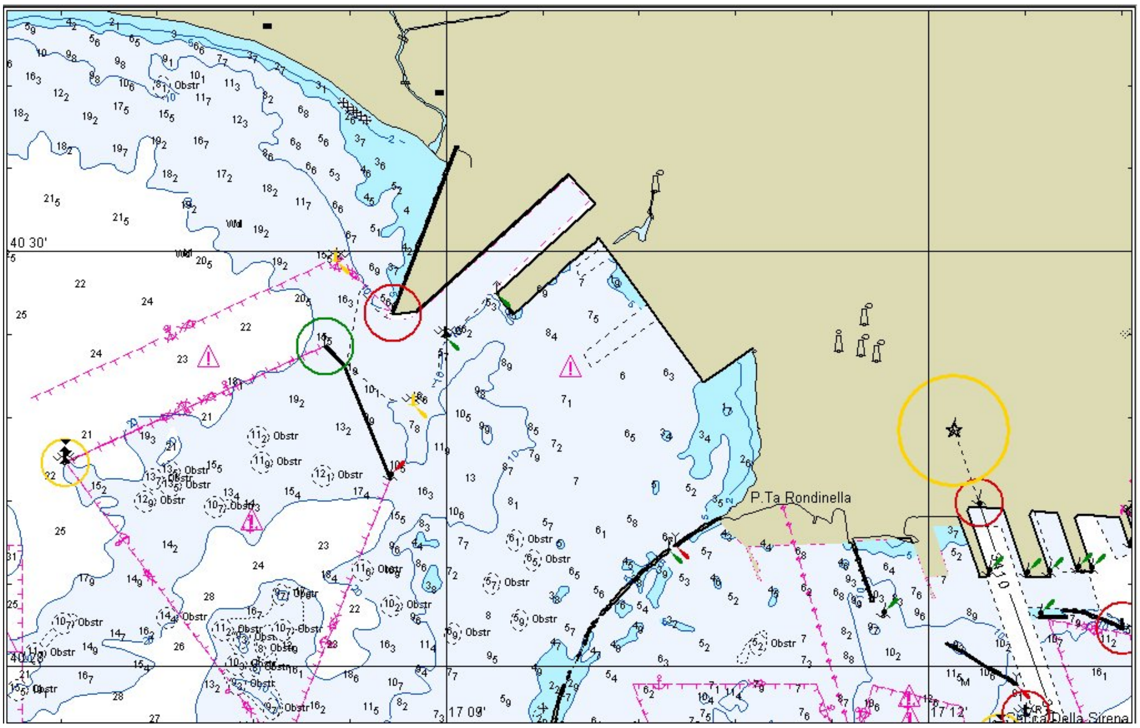


figure 2. Location for the LNG terminal at the Port of Taranto

The layout for the LNG terminal, including the location of the water intake and water discharge locations is shown in figure 3. As it is shown, the water discharge is located approximately at the 5 m depth countour at a depth of 3.5 m and about 300 m from the water intake.

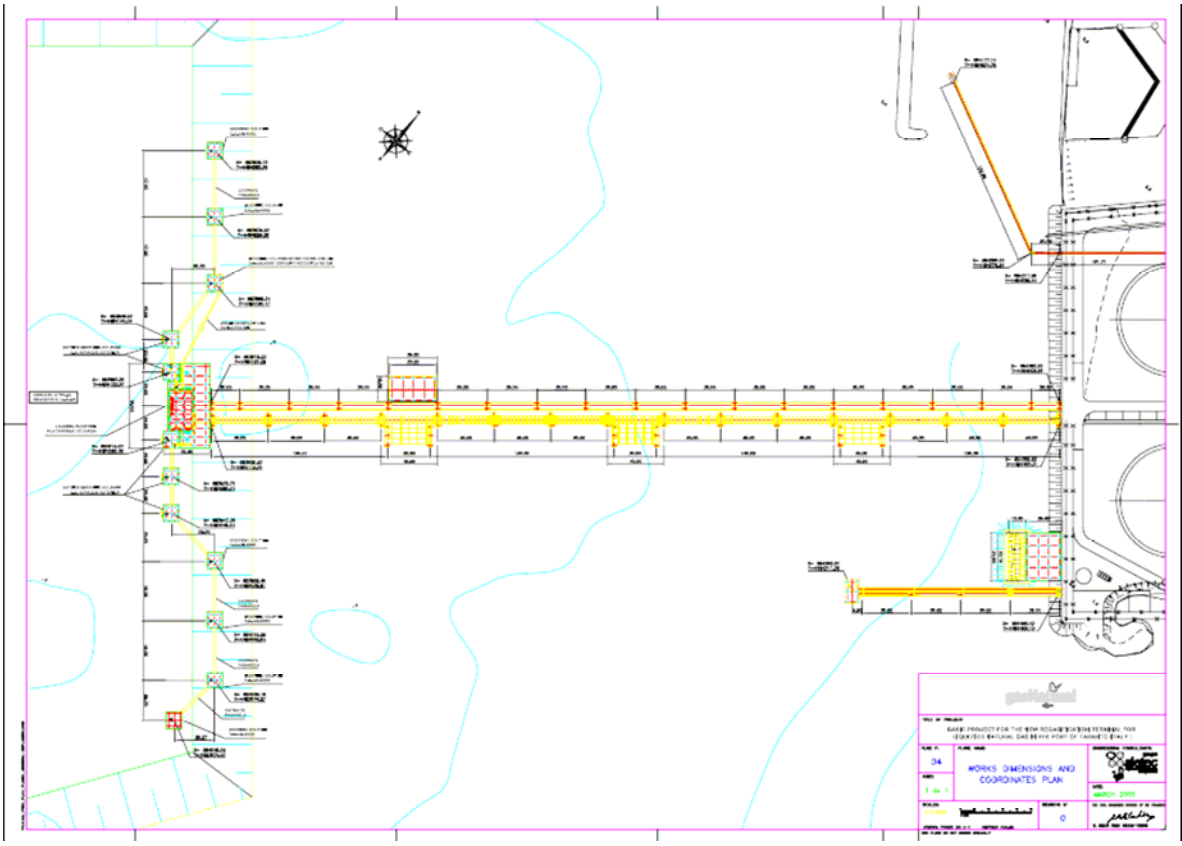


figure 3. Layout for the LNG terminal, water intake and water out-take

The water discharge that will result from the regasification process is expected to have a temperature of -6 ºC with respect to the seawater temperature. In such way, this study analyzes the temperature advection-dispersion of the water discharge at a water depth of 5 m (discharge at 3.5 m depth), in order to assess the extension of the discharge influence and evaluate if any recirculation can be expected.

1.2. Numerical modeling

Numerical modeling was selected to analyze the advection-dispersion of the cold water discharge, since it is a powerful tool to predict the behavior of a discharge with the characteristics under study, allowing to assess its extension and influence over the receptor water. Under this section it is presented the model setup, input data, model description and the modeling results.

1.2.1. Modeling strategy

In order to study the behavior of the cold water discharge it is needed to establish hydrodynamic conditions in the fist place, and secondly, to assess the advection-dispersion. The *MIKE 21* software developed by DHI - Water & Environment, was used, applying the HD module for hydrodynamics modeling and the AD module for water discharge dispersion-advection. The flux diagram shown in figure 4 shows the modeling strategy used for bidimensional modeling, showing the input data as well as boundary conditions used and the model interaction.

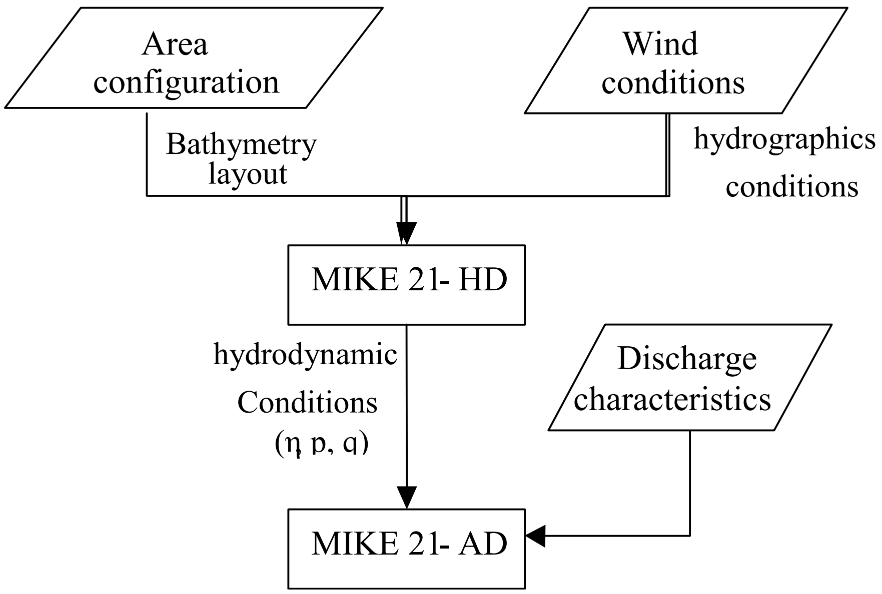


figure 4. Flux diagram for bidimensional modeling

On this manner, the HD module simulates the hydrodynamic conditions based on the forcing agents, such as the wind, and the results obtained will directly affect the discharge dispersion. Such dispersion and advection is then simulated with the AD model, which simulated the cold water discharge and its dispersion under the previously calculated hydrodynamics.

1.2.2. Input data

1.2.2.1. Bathymetry

The bathymetry used in the study was obtained from the nautical charts and updated with the surveys performed by ALATEC in December 2004. The bathymetry used for modeling is shown in figure 5.

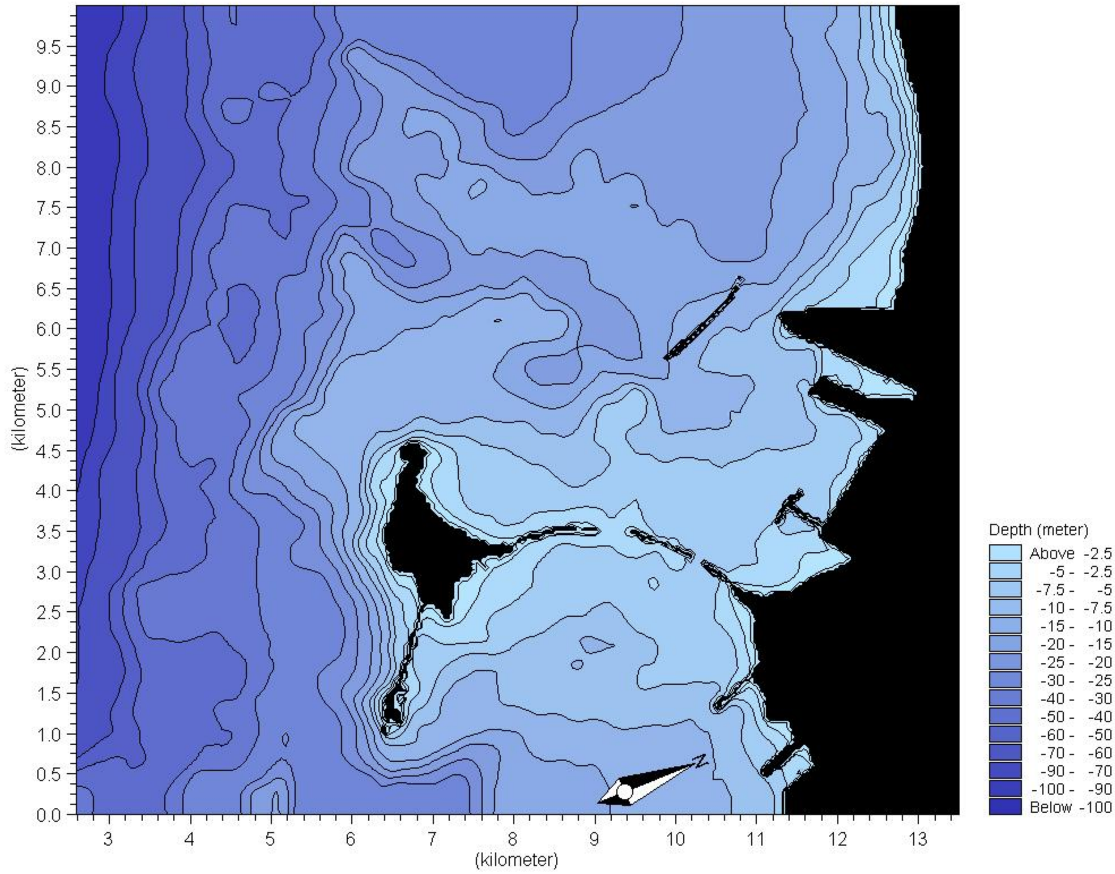


figure 5. Bathymetry of the study area used for numerical modeling

1.2.2.2. Tides

The tides in the area of Taranto are semidiurnal with a tidal range of 24 cm; as such, the tides are considered irrelevant for modeling purposes since it is not expected to have tidal currents.

1.2.2.3. Winds

The winds at the study area are shown in figure 6, showing that the most frequent wind are from the North and South sectors. Since there are no tides in the area, the winds are the main force that will generate currents. This has been confirmed by the Meto-Marine study performed by MEDEA ENGINEERING S.A. for the project “Progetto Preliminare Terminale di Ricezione e Rigassificazione Gas Naturale Liquefatto (GNL), where it is reported that the currents at the study area are wind dominated currents.

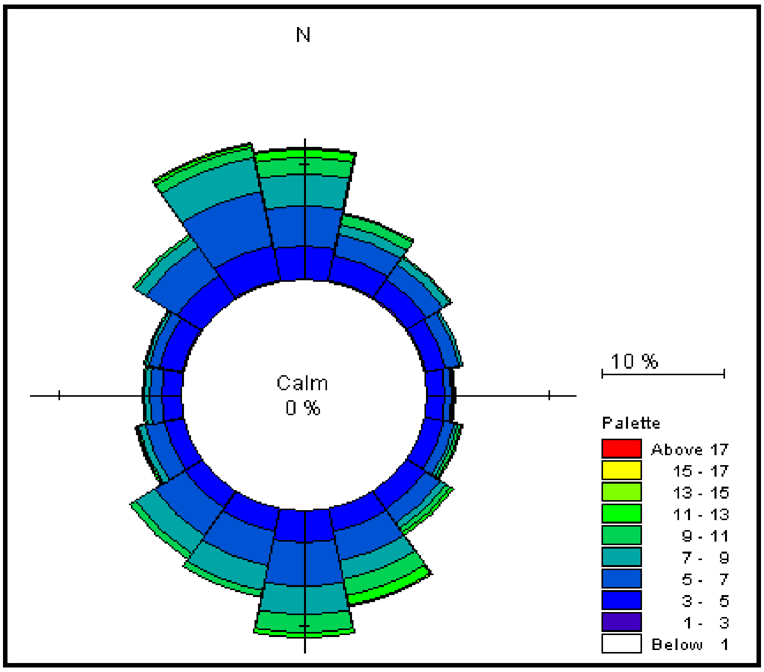


figure 6. Wind rose in the Taranto area

From the wind conditions and the table of occurrences (found in the corresponding appendix of the constructive project), the wind conditions to be modeled were selected, they are shown in the following table. The selected wind directions correspond to the most frequent directions, with the exception of condition 09, which correspond to the most negative situation with regards to water recirculation into the water intake, since the wind is blowing from the water discharge to the water intake.

Condition	Wind direction
00	-
01	315º
02	337.5º
03	0º
04	22.5º
05	157.5º
06	180º
07	202.5º
08	225º
09	247.5º

table 1.- Selected wind directions

Since 65% of the time the wind has a speed between 1 to 5 m/s, it was decided to select 5 m/s for the simulations. The lower velocity scenarios are covered by the calm conditions simulation, while for the upper limit it was decided to performed the simulations with a wind speed of 10 m/s. The following table shows the wind conditions considered for the simulations.

Condition	Wind direction	Wind speed
00	-	-
01	315º	5 m/s
02	337.5º	5 m/s
03	0º	5 m/s
04	22.5º	5 m/s
05	157.5º	5 m/s
06	180º	5 m/s
07	202.5º	5 m/s
08	225º	5 m/s
09	247.5º	5 m/s
11	315º	10 m/s
12	337.5º	10 m/s
13	0º	10 m/s
14	22.5º	10 m/s

15	157.5º	10 m/s
16	180º	10 m/s
17	202.5º	10 m/s
18	225º	10 m/s
19	247.5º	10 m/s

table 2.- Selected wind speeds and directions

1.2.3. Hydrodynamic modeling

The numerical model *MIKE 21-HD* was applied in order to obtain the current field at the study area for the different wind conditions to be modeled. The hydrodynamic module simulates the variation on water level and the flux variations in response to the forcing functions in coastal waters. The sea level and fluxes are solved in a rectangular grid covering the study area, and are calculated including the effects of bottom friction, wind forcing, barometric pressure gradients, Coriolis force, momentum dispersion and wave induced currents.

The system solves the non lineal continuity equations, as well as those for mass conservation, using a finite differences scheme with a second order precision. The effects and facilities included in the model are the following:

- Convective and cross momentum
- Bottom shear stress
- Wind shear stress at the surface
- Barometric pressure gradients
- Coriolis forces
- Momentum dispersion (through eg the Smagorinsky formulation)
- Wave-induced currents
- Sources and sinks (mass and momentum)
- Evaporation
- Flooding and drying

The obtained results consist on sea level and fluxes (velocities) in the computational domain.

The hydrodynamic model was applied to the shown bathymetry, which has a resolution of 33 x 33 meters, which was considered necessary in order to resolve the different morphological and port features in the area.

The forcing conditions for the model consisted in the wind conditions presented above, which were selected in order to cover the whole range of hydrodynamic conditions in the area. On one hand, the calm conditions were modeled considering no wind, in order to represent the most unfavorable conditions with respect to dispersion and advection, since there is only heat diffusion and no diffusion due to currents. On the other hand the rest of the simulations included wind in order to generate currents, which in turn will affect the water discharge by increasing the diffusion, but also spreading the discharge in the area, this may create adverse situations spreading the discharge into the water intake.

The results for the hydrodynamic simulation under calm conditions are shown in figure 7, while figure 8 and figure 9 show the results for the simulation under a wind speed of 10 m/s from 315º and from 180º. The results for all simulations are shown in Appendix I.

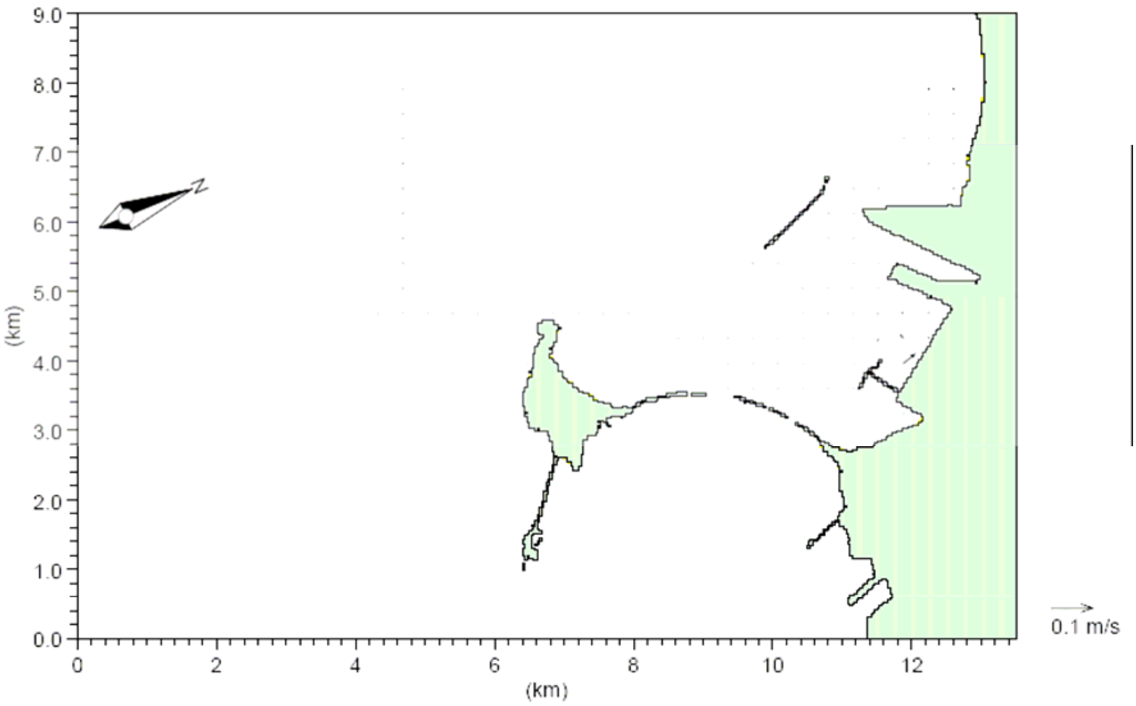


figure 7. Hydrodynamic simulation results under calm conditions

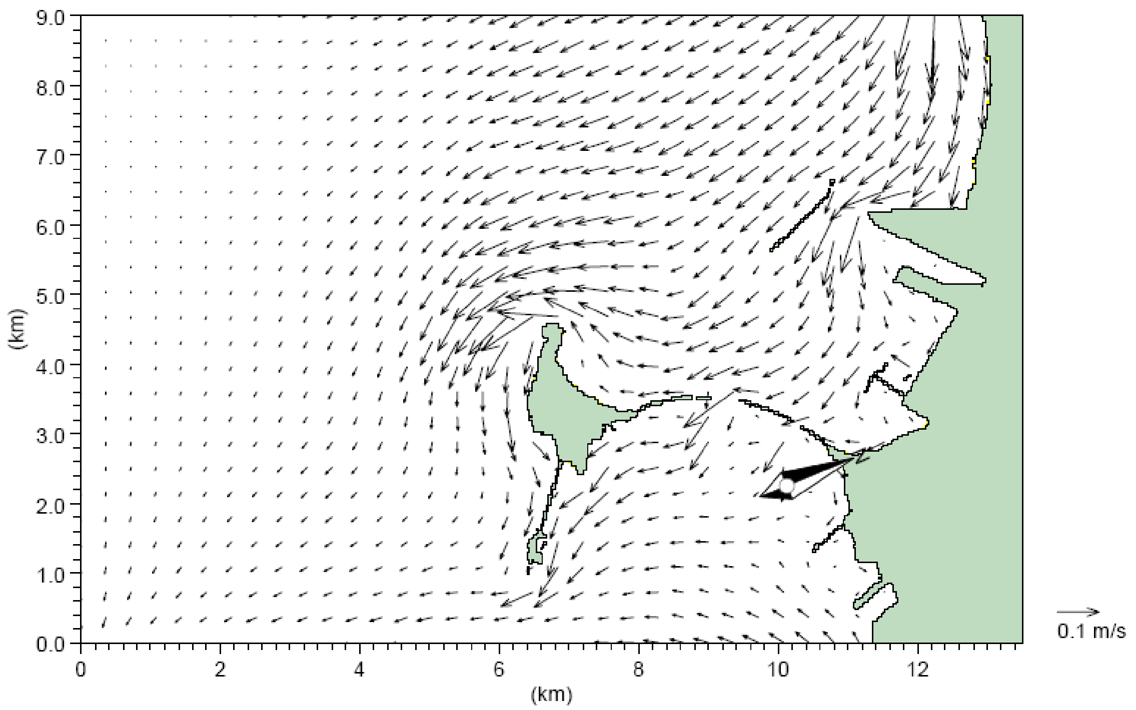


figure 8. Hydrodynamic simulation results considering wind conditions of 10 m/s with direction of 315º

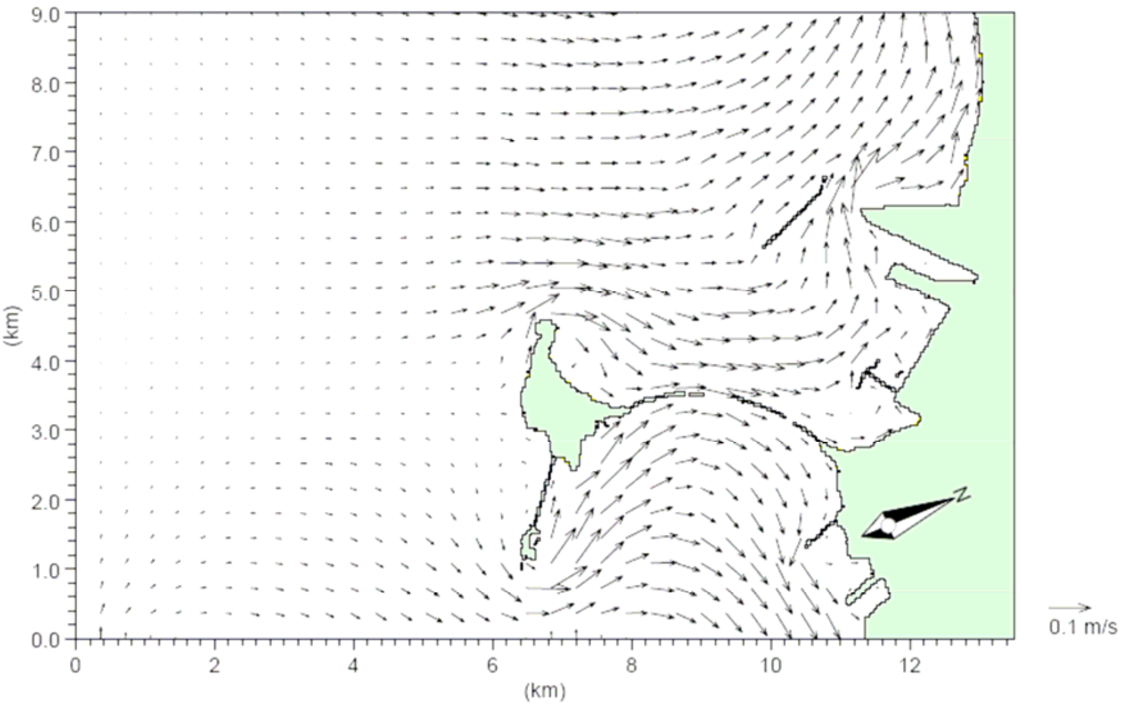


figure 9. Hydrodynamic simulation results considering wind conditions of 10 m/s with direction of 180º

As it is observed, the calm conditions produce no currents, while under winds of 10 m/s the currents hardly arrive at velocities of 0.1 m/s, so that it can be stated that the currents in the area are very low.

1.2.4. Advection-dispersion modeling

The *MIKE 21-AD* model was used in order to evaluate the advection-dispersion of the water discharge and to assess its behavior. The aim of applying this model is to use the current fields obtained from the application of the HD model and to simulate the diffusion and the advection of discharges to the sea, in this case a cold water discharge. The AD model simulates the propagation of a dissolved or suspended substance in the water, under the influence of fluid transport and the natural processes associated to the dispersion phenomena. The AD model can manage different type of substances, either if the act in a conservative manner, by linear decay, or by heat diffusion. The case under study deals with a heat diffusion problem in which the model calculates the heat “concentration” or temperature, on each of the grid points that cover the area of interest, where the results of the HD model provide the needed information on currents, so that the dispersion and the advection can be calculated.

In order to establish the heat diffusion and advection, the conditions considered for the hydrodynamic simulations where taken in account, given a total of 19 simulations, which encompass the whole range of possible situations in the area.

The simulations were performed using relative temperature, that is, the sea water temperature was considered as zero, while the water discharge temperature was taken as 6ºC, with the aim of performing simulations that will show in a more comprehensive and schematic way the changes in temperature. Nonetheless this do not affect the simulations, but only the interpretation of the results, where the model results show the relative difference of the sea water and the discharge temperatures (as well as the temperatures related to heat diffusion).

The results for all the simulations performed, both for hydrodynamics and for heat advection-dispersion, are shown in Appendix I. The most unfavorable results for temperature dispersion are those for calm conditions, and for those with wind direction from 247.5º and 157.5º, so that these results are shown in the text.

The heat diffusion results for the calm conditions are shown in figure 10, where the relative difference in temperature can be seen at the surroundings of the discharge point. The area of influence of the discharge is clearly seen, obtaining that the heat is greatly diffused, mainly towards NW, reaching a distance of 500m, where only a difference of 1ºC can be appreciated. Since the regasification plant is located in an industrial area, it is not expected to have sensitive ecosystems, since there is already many industries in the area, in fact there is a water treatment plant sewage that discharges close to the area. Due to the high diffusion of the temperature and the poor ecological conditions in the area it is considered that the cold water discharge has no negative effects in the area, and its effect is minimal and very localized. Also, no recirculation is foreseen.

At figure 11 the results with a wind speed of 10 m/s and a wind direction of 247.7º are presented, showing very similar effects as during calm conditions, but with a temperature difference up to 1.5 ºC at the coast. Although it would be the worst scenario towards possible recirculation of the discharged water, there is no recirculation and the dispersion is directed towards NW. The figure 12 shows a very similar dispersion pattern than those of calm conditions, but in this case with wind conditions of a speed of 10 m/s and a wind direction of 157.5º, this scenario results in more spreading of the colder temperature towards the NW, but still, the temperature difference is of a maximum of 1ºC, so that it is not considered to have negative effects towards the environment, and neither to the functioning of the regasification plant due to possible recirculation, which is not expected.

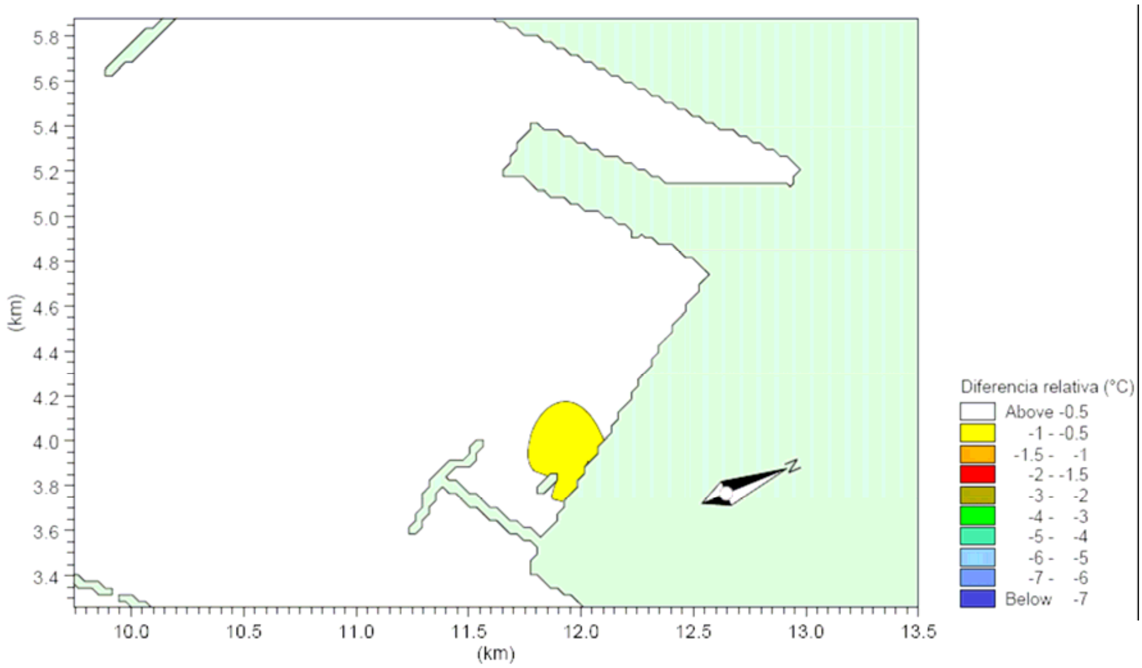


figure 10- Advection-dispersion results for cold water discharge under calm conditions at the Port of Taranto.

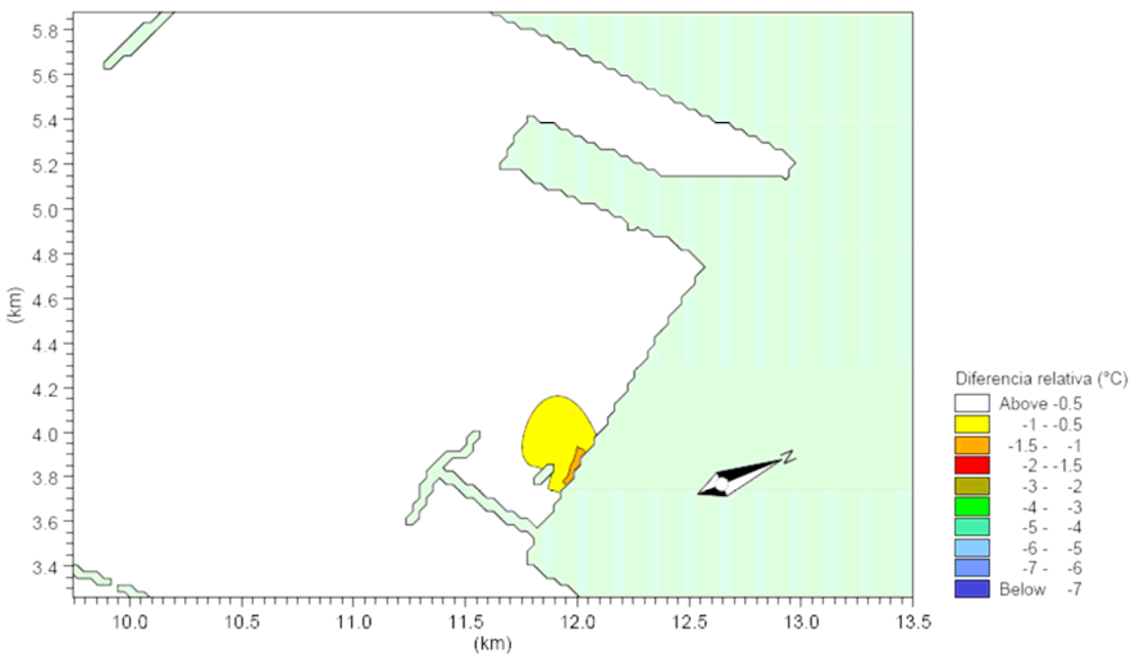


figure 11.- Advection-dispersion results for cold water discharge with a wind speed of 10 m/s and wind direction of 247.5º, at the Port of Taranto.

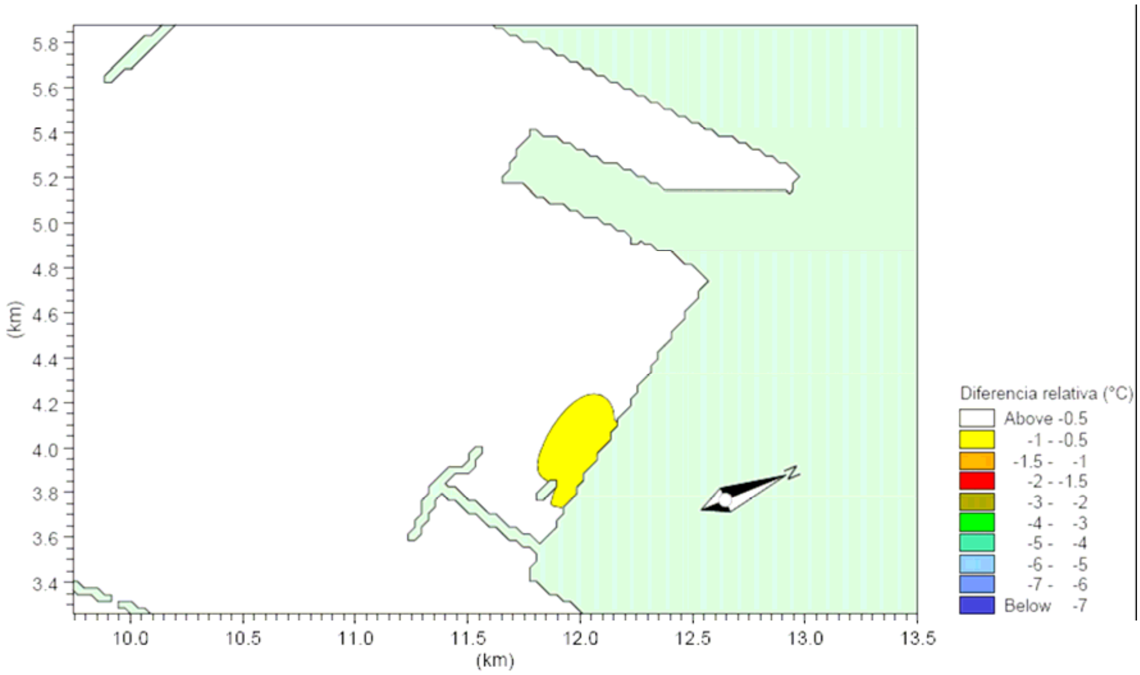


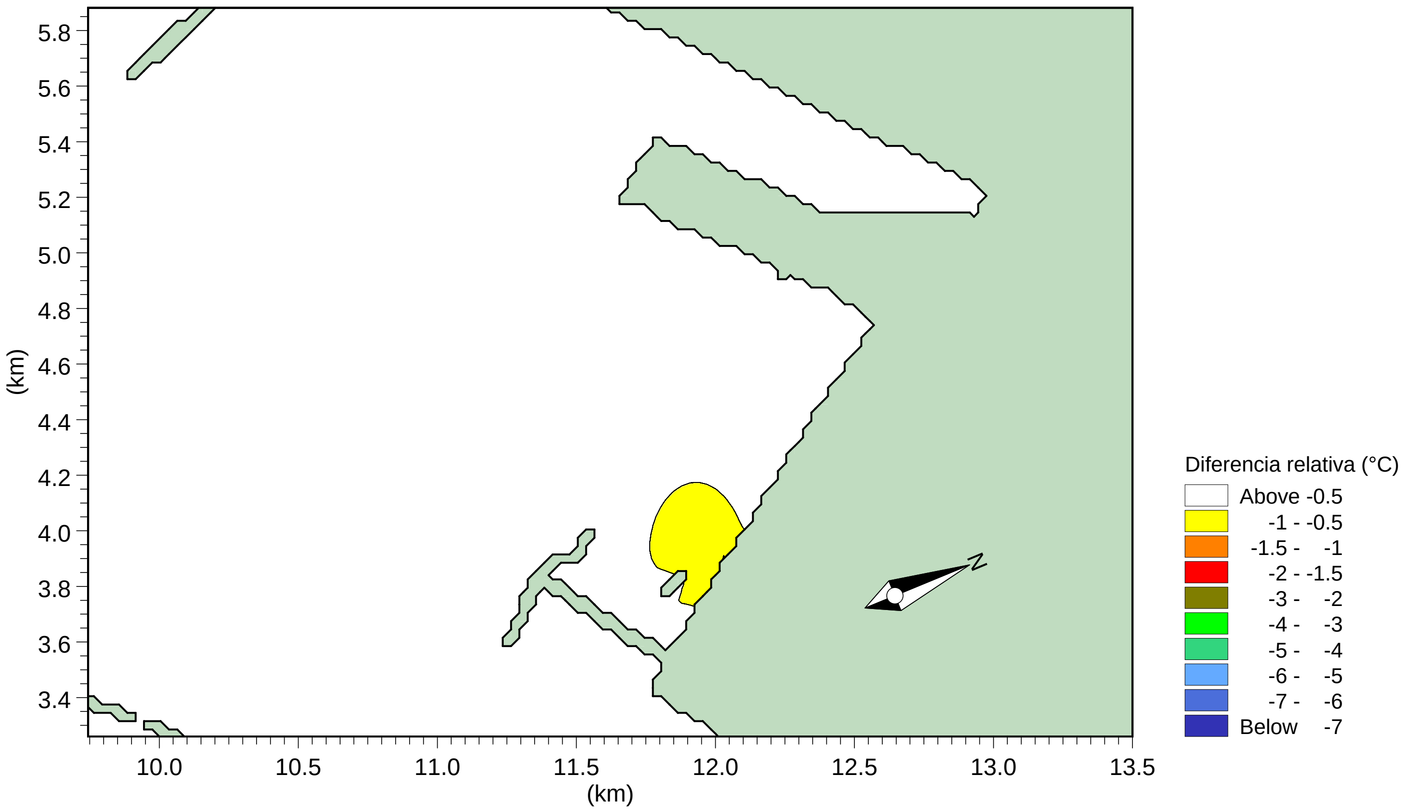
figure 12.- Advection-dispersion results for cold water discharge with a wind speed of 10 m/s and wind direction of 157.5º, at the Port of Taranto.

1.3. Conclusions

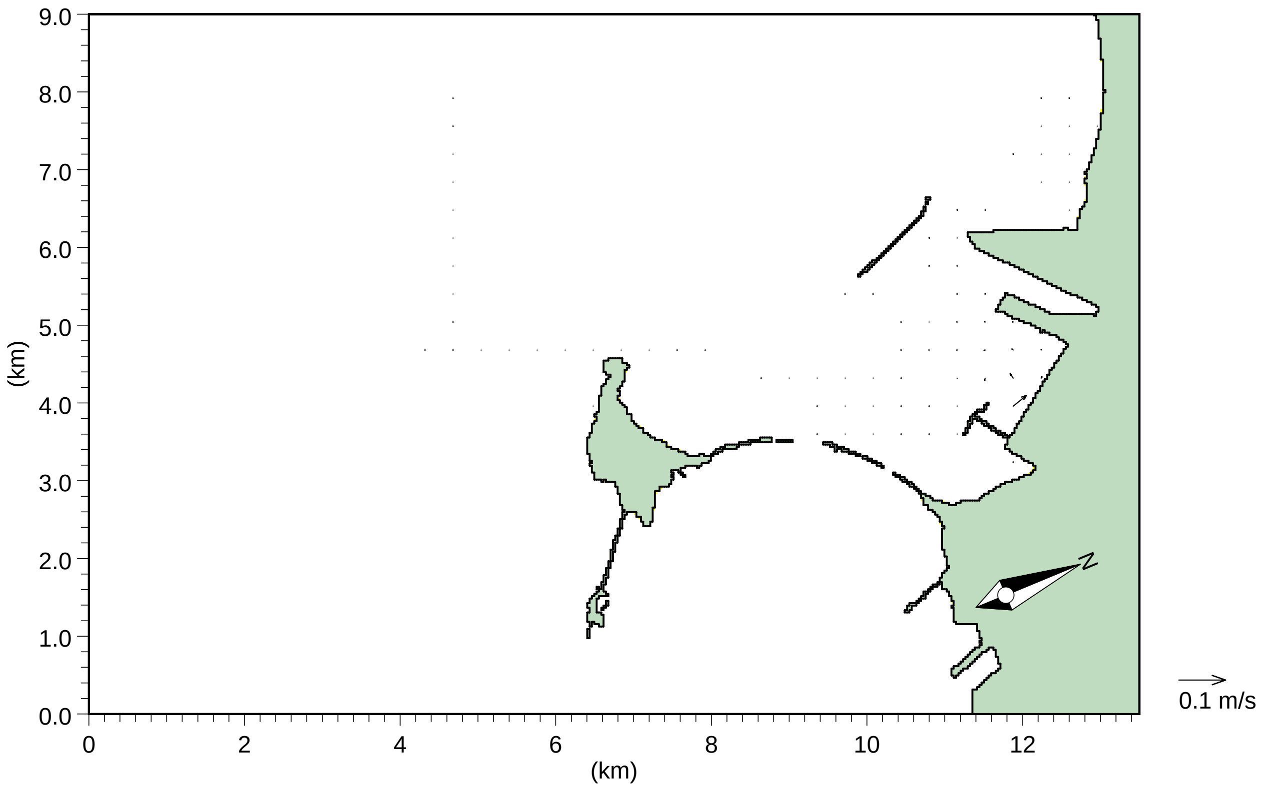
The cold water discharge, result of the regasification plan of GAS NATURAL at the Port of Taranto, has been evaluated with regards to its dispersion and advection. Several scenarios creating different current patterns have been evaluated as a result of different wind conditions in the area, in order to assess the behavior of the water discharge.

The different scenarios showed that the dispersion of the cold water presents very limited spreading in the area, with only a maximum difference of 1ºC at 500 m from the discharge point towards the NW. As such, the effects over the environment can only be very limited and easily assimilated, also considering that the area is an industrial port, the effects over the existing environmental conditions of the area will be minimal. As for the recirculation of the cold water into the water intake, due to the dispersion obtained it is not expected to have any recirculation into the plant. During some scenarios there is a temperature difference of 1.5 ºC at the coast, but as stated above, this has no effects over the environment and on the other hand is compensated with a warm water discharge in that area, performed by other industries.

APPENDIX I – Numerical simulation results

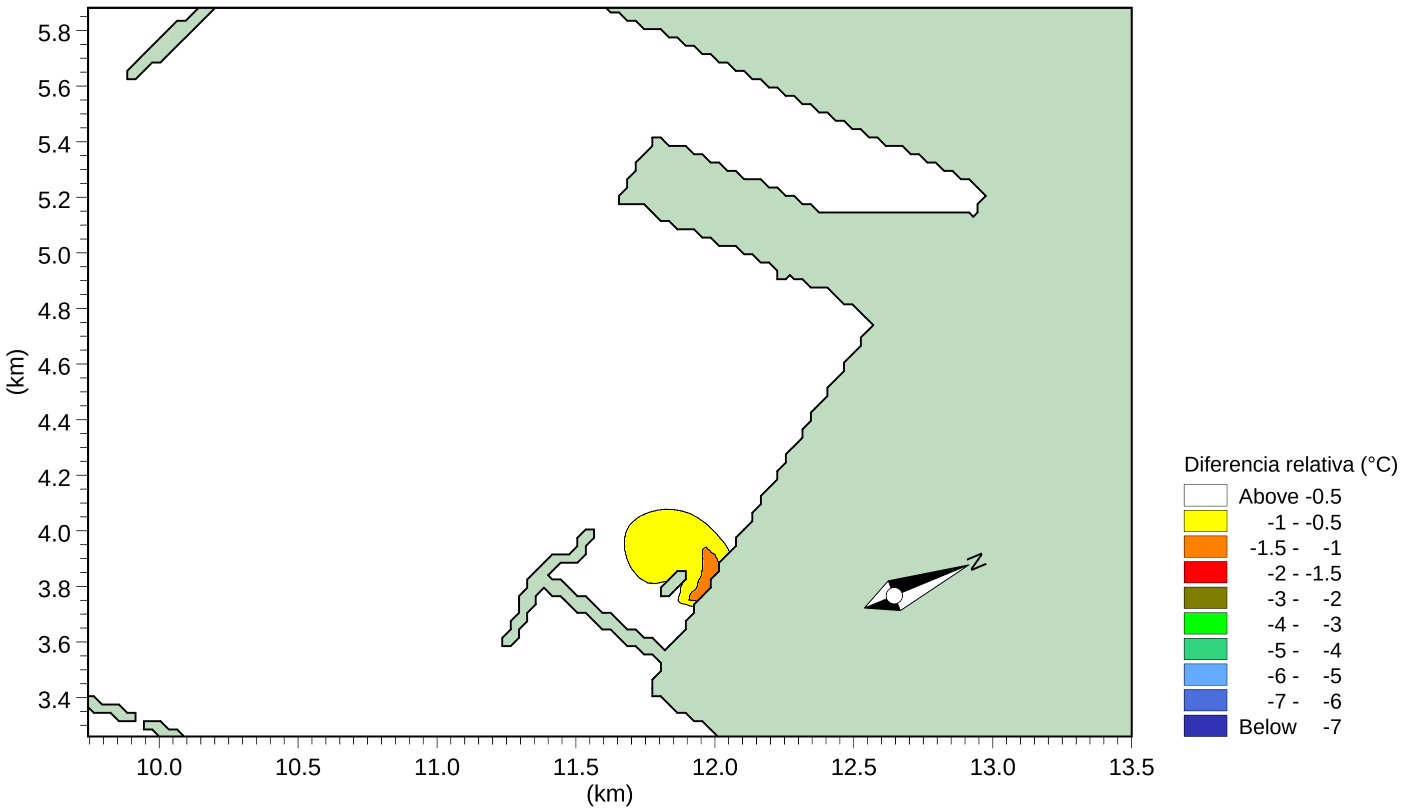


01/01/90 18:00:00

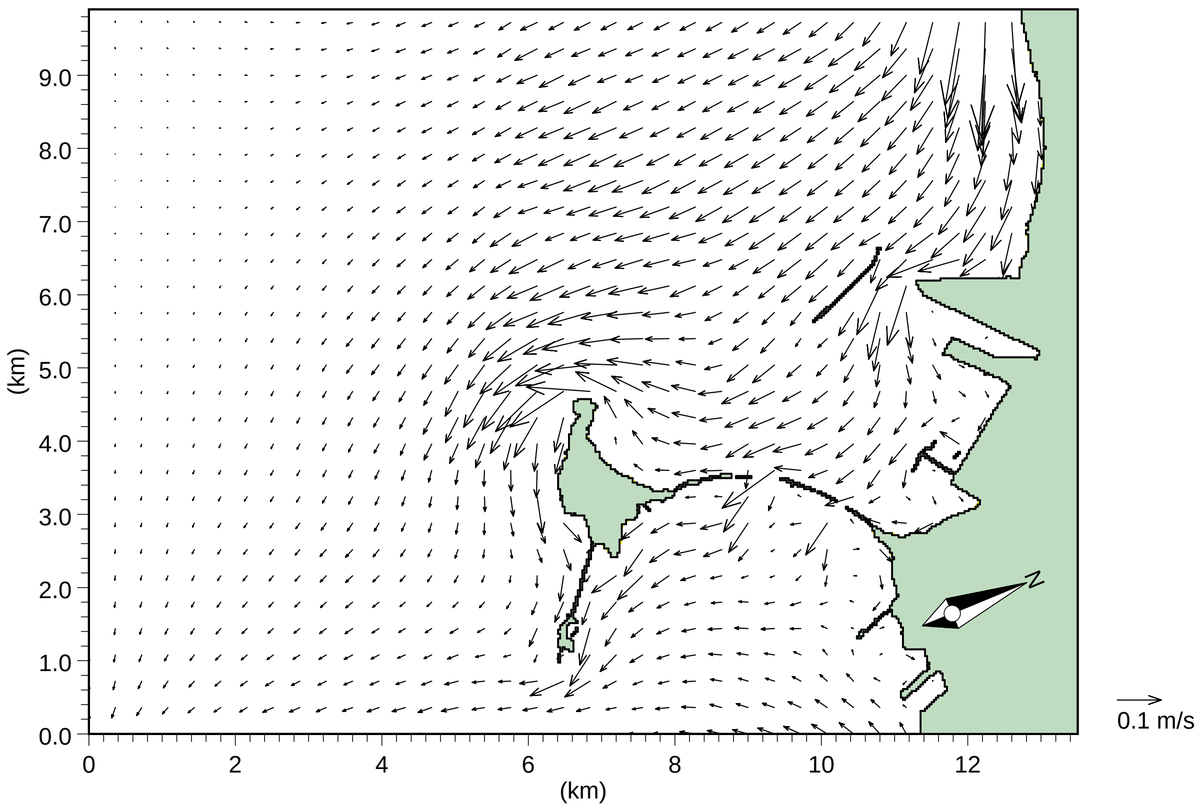


01/01/90 18:00:00

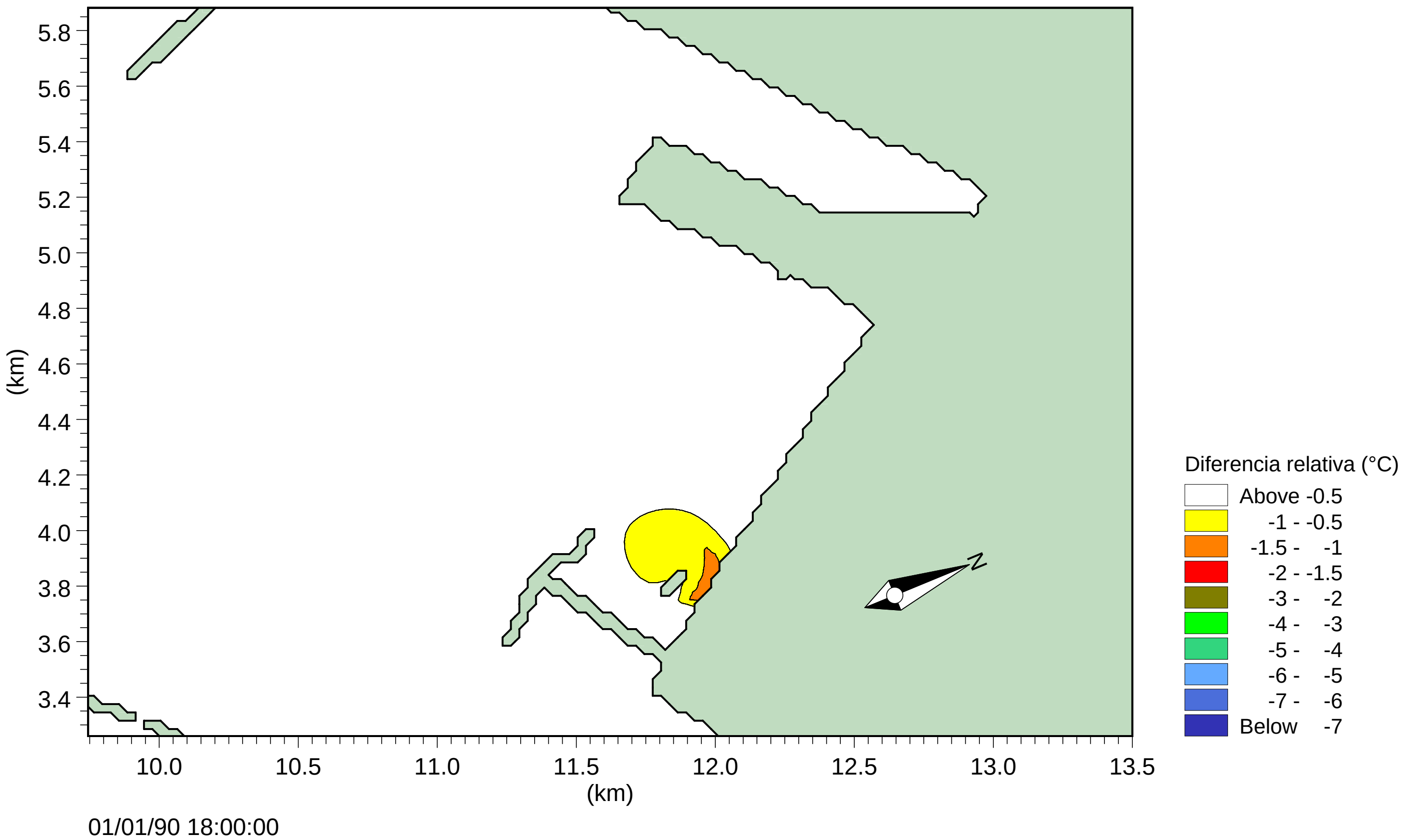
alatec ingenieros consultores y arquitectos	Client: GAS NATURAL	MIKEZero
	Project: P04156D	
Model: Mike 21 - AD	Date: 04/02/05	Spill Advection/dispersion in Taranto Calm conditions (no wind)	Drawing no. DRW 00
	Init: cma		

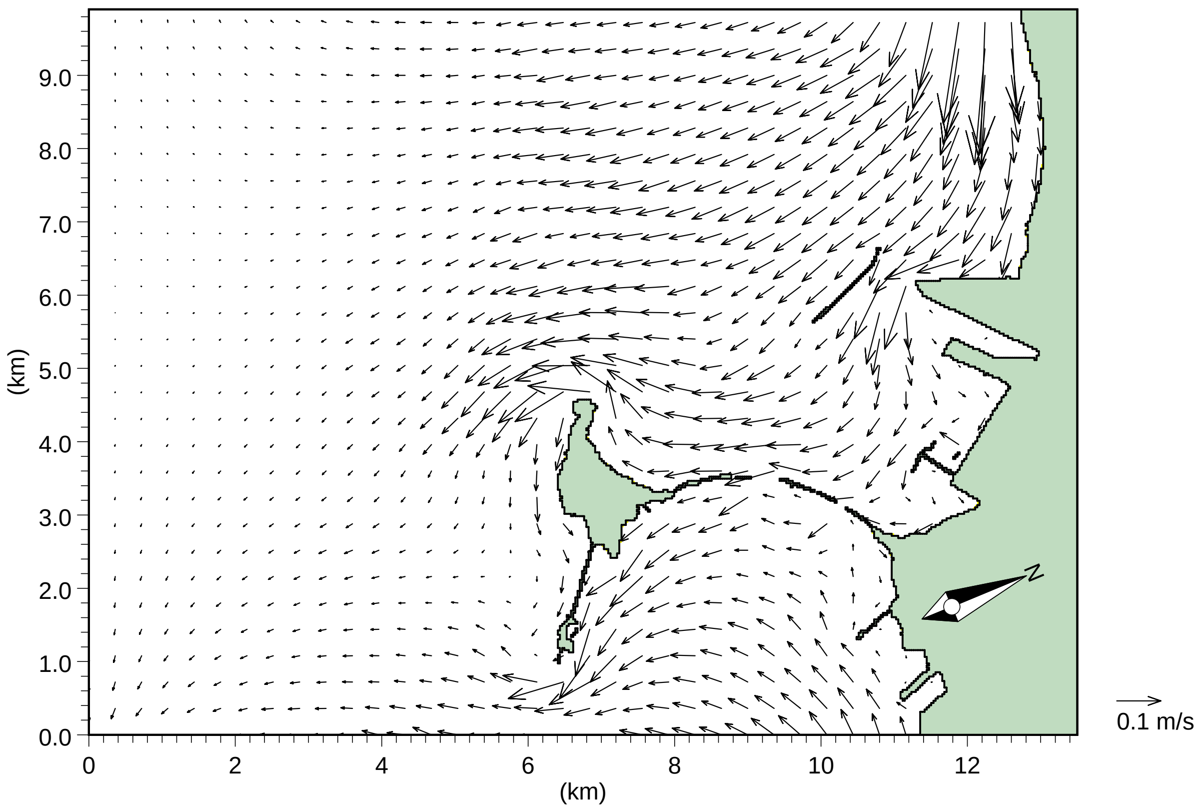


01/01/90 18:00:00



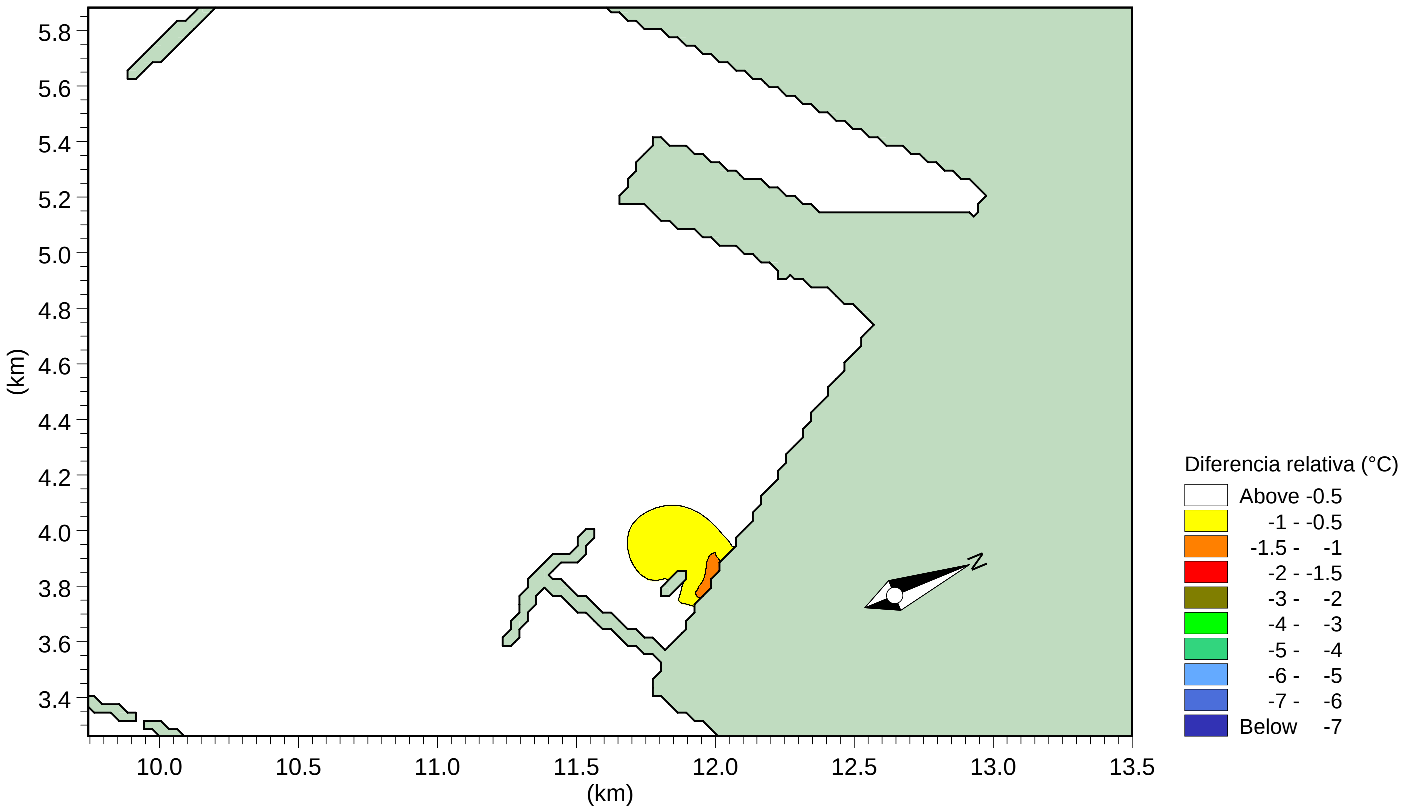
alatec ingenieros consultores y arquitectos	Client: GAS NATURAL Project: P04156D		MIKE Zero
Model: Mike 21 - AD	Date: 04/02/05	Spill Advection/dispersion in Taranto Wind: vel= 5 m/s, dir = 315º	Drawing no. DRW 01
	Init: cma		



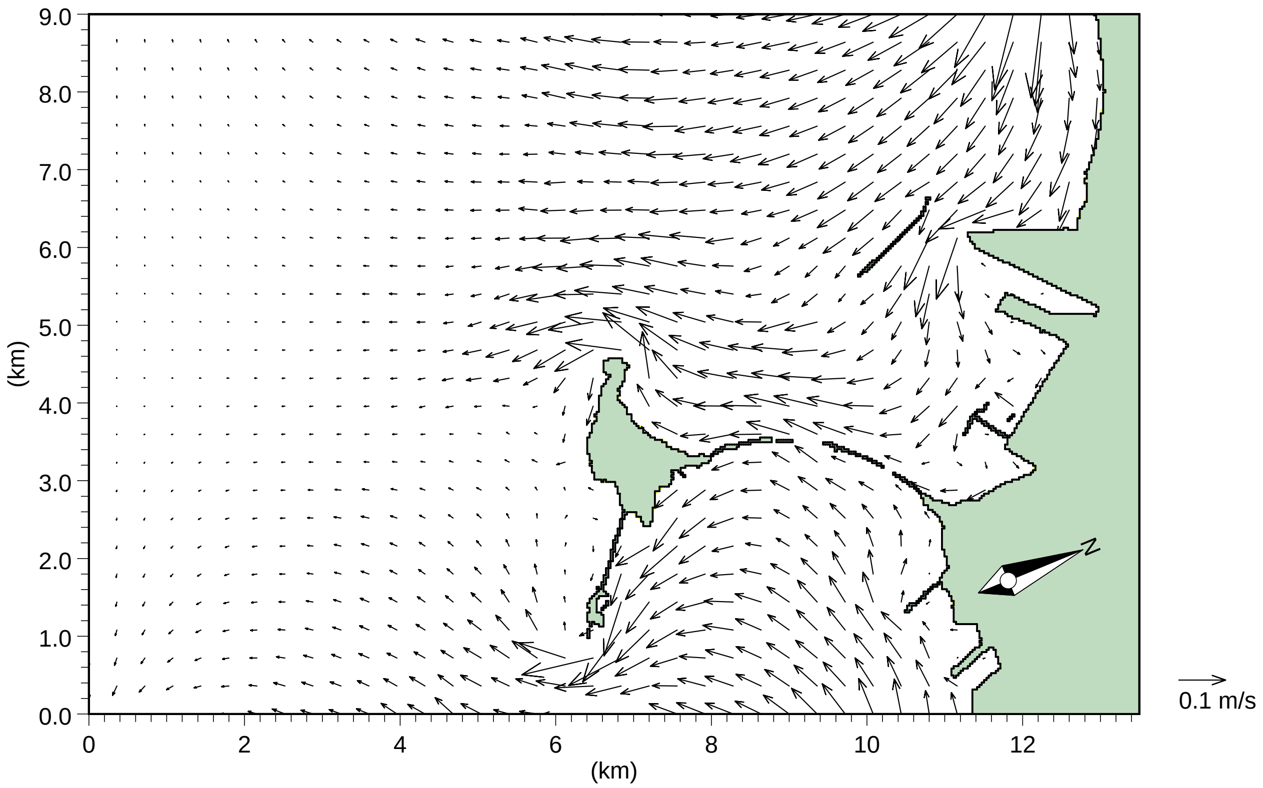


alatec ingenieros consultores y arquitectos		Client: GAS NATURAL	
		Project: P04156D	
Model: Mike 21 - AD	Date: 04/02/05	Spill Advection/dispersion in Taranto Wind: vel= 5 m/s, dir = 337.5º	Drawing no. DRW 02
	Init: cma		

MIKE Zero



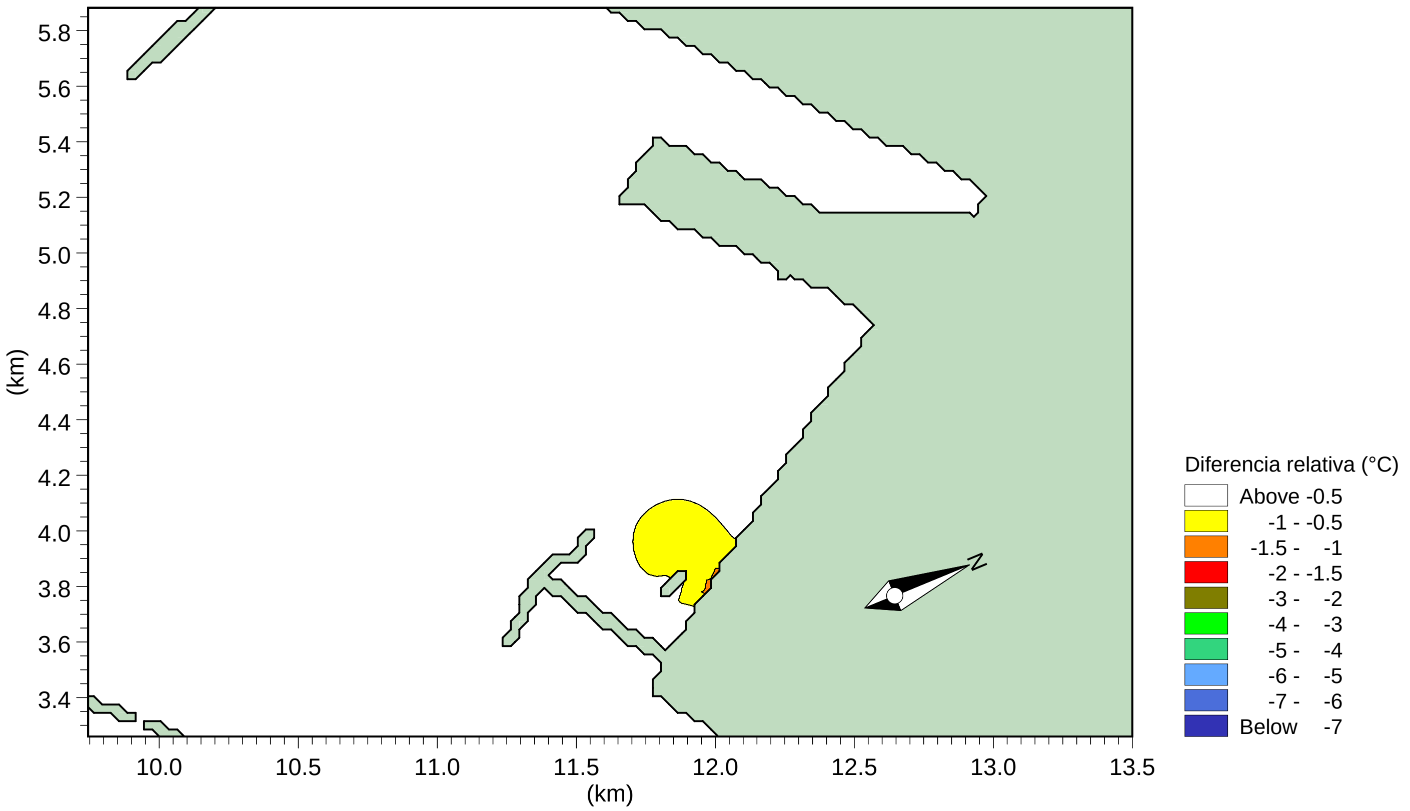
01/01/90 18:00:00



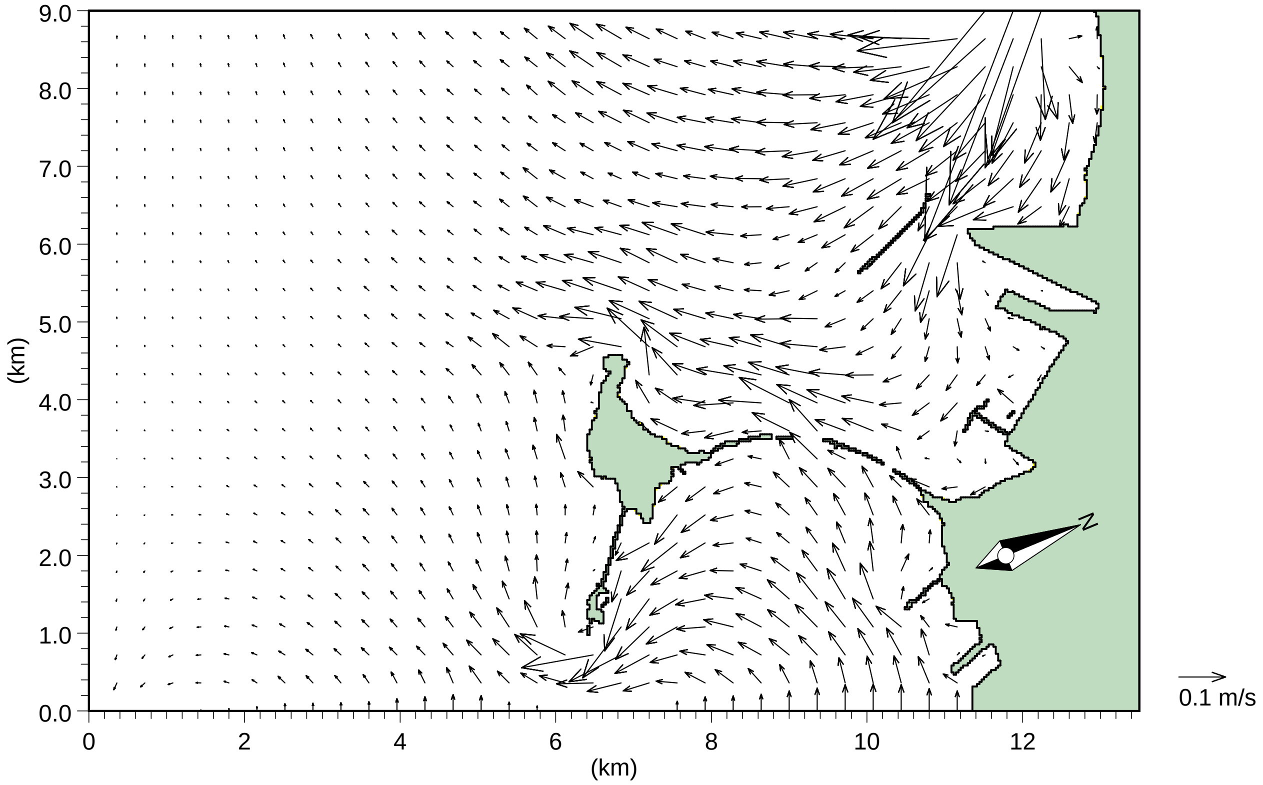
01/01/90 18:00:00

alatec ingenieros consultores y arquitectos

Client: GAS NATURAL		MIKE Zero
Project: P04156D		
Model: Mike 21 - AD	Date: 04/02/05	Spill Advection/dispersion in Taranto Wind: vel= 5 m/s, dir = 0º
	Init: cma	Drawing no. DRW 03

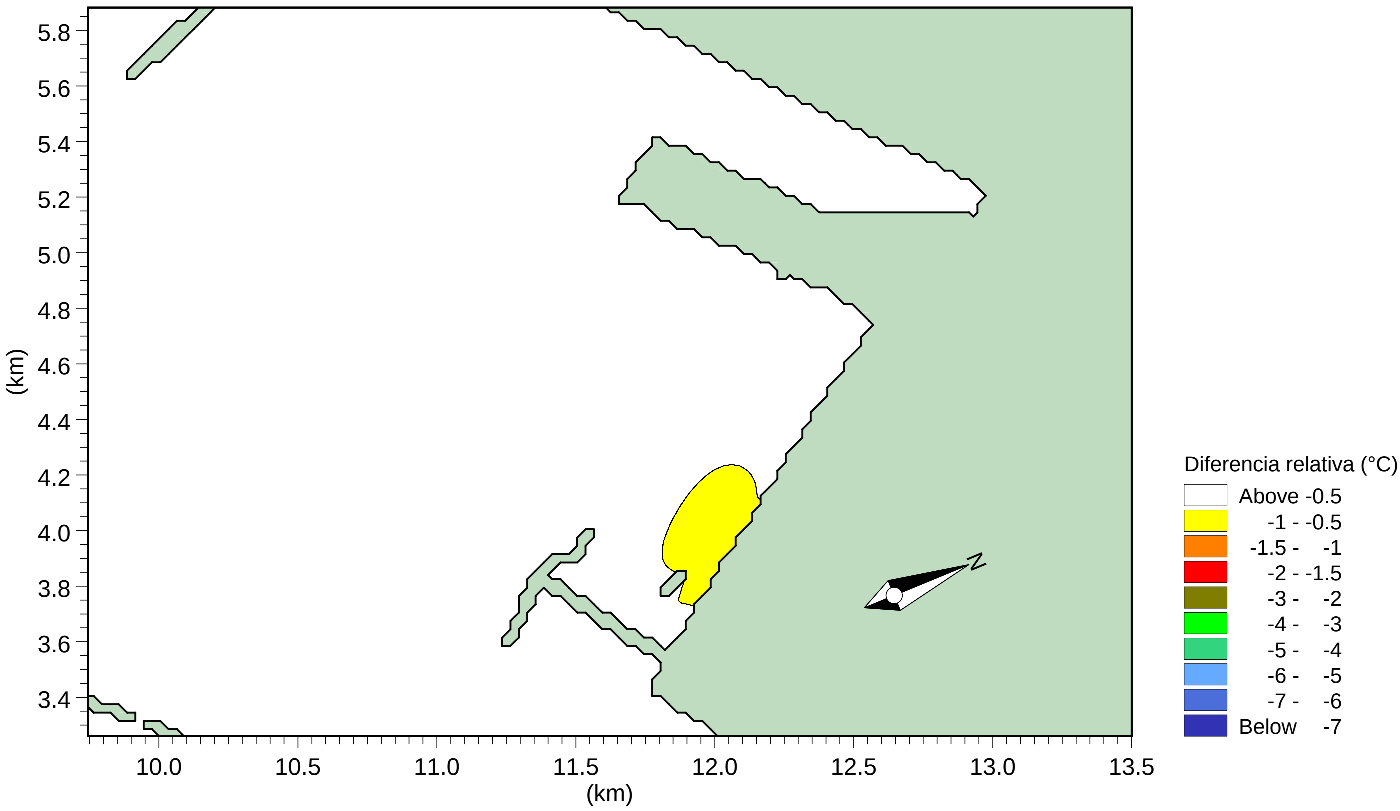


01/01/90 18:00:00

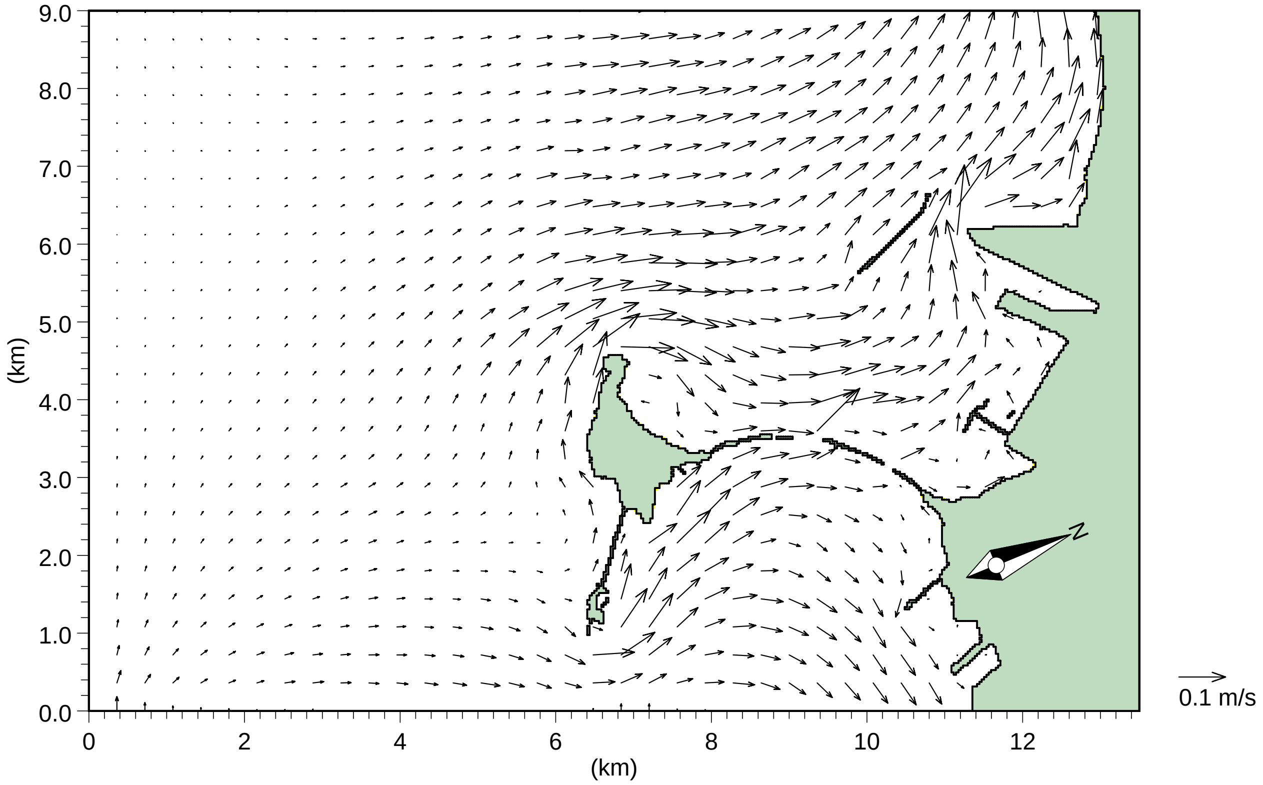


01/01/90 18:00:00

alatec ingenieros consultores y arquitectos	Client: GAS NATURAL	
	Project: P04156D	MIKE Zero
Model: Mike 21 - AD	Date: 04/02/05	Spill Advection/dispersion in Taranto Wind: vel= 5 m/s, dir = 22.5º	Drawing no. DRW 04
	Init: cma		

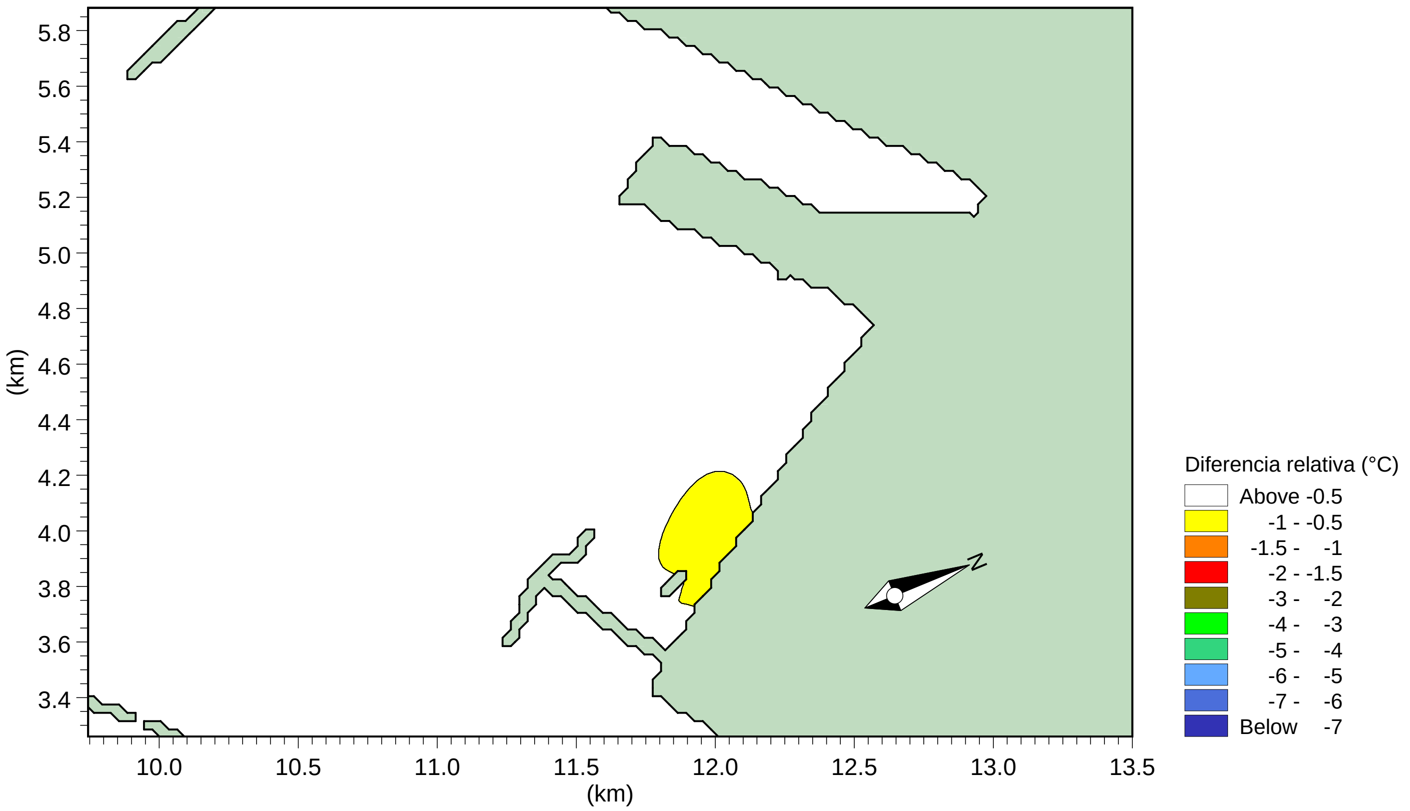


01/01/90 18:00:00

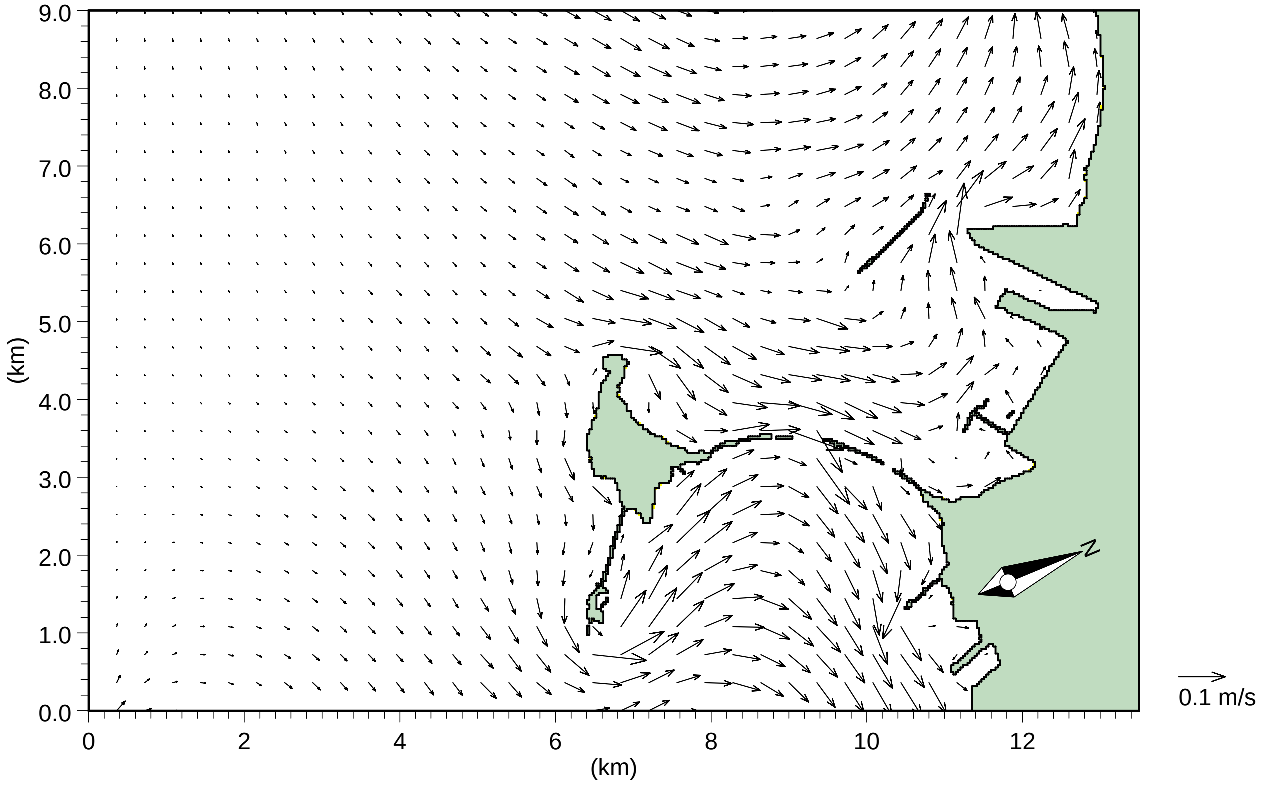


01/01/90 18:00:00

alatec ingenieros consultores y arquitectos	Client: GAS NATURAL	
	Project: P04156D	MIKE Zero
Model: Mike 21 - AD	Date: 04/02/05	Spill Advection/dispersion in Taranto Wind: vel= 5 m/s, dir = 157.5º	Drawing no. DRW 05
	Init: cma		



01/01/90 18:00:00

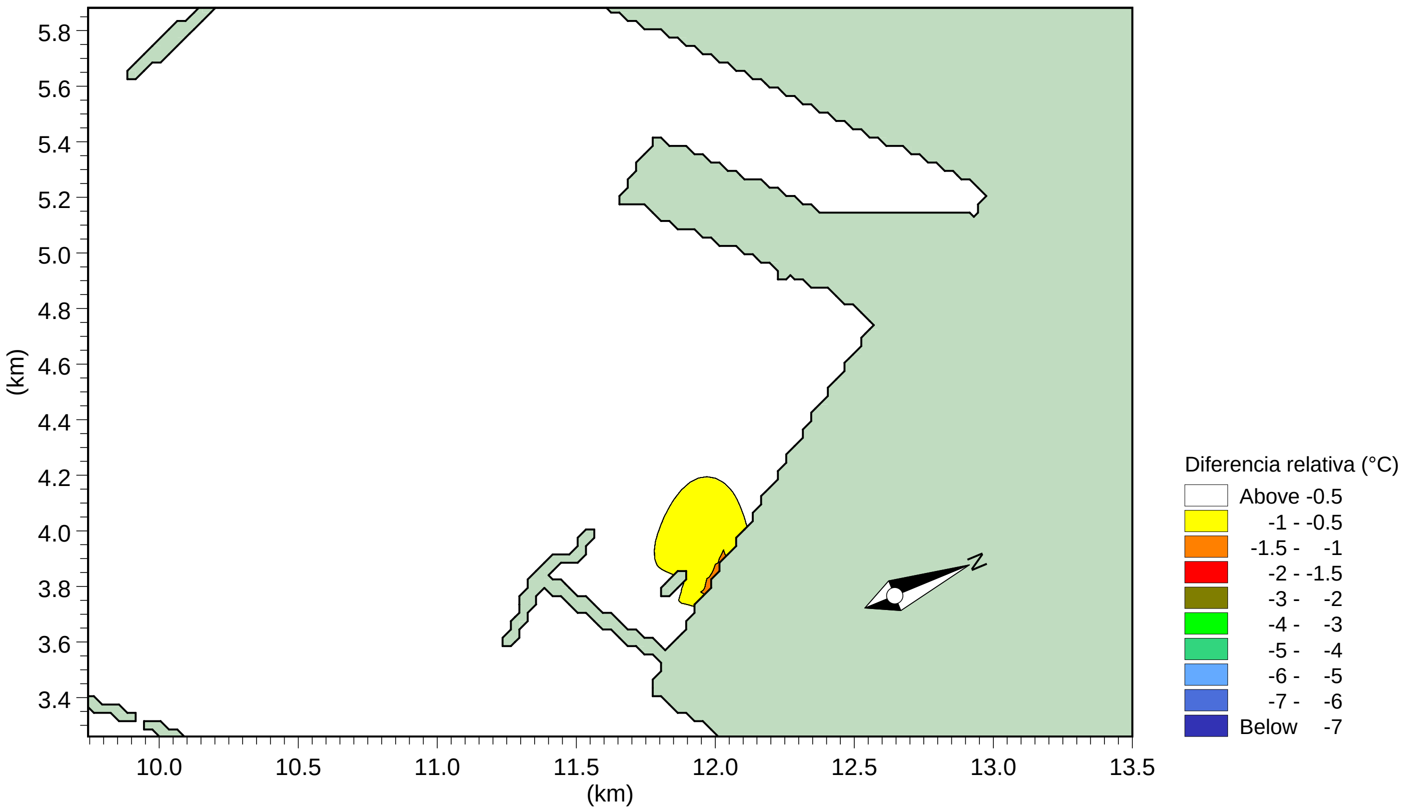


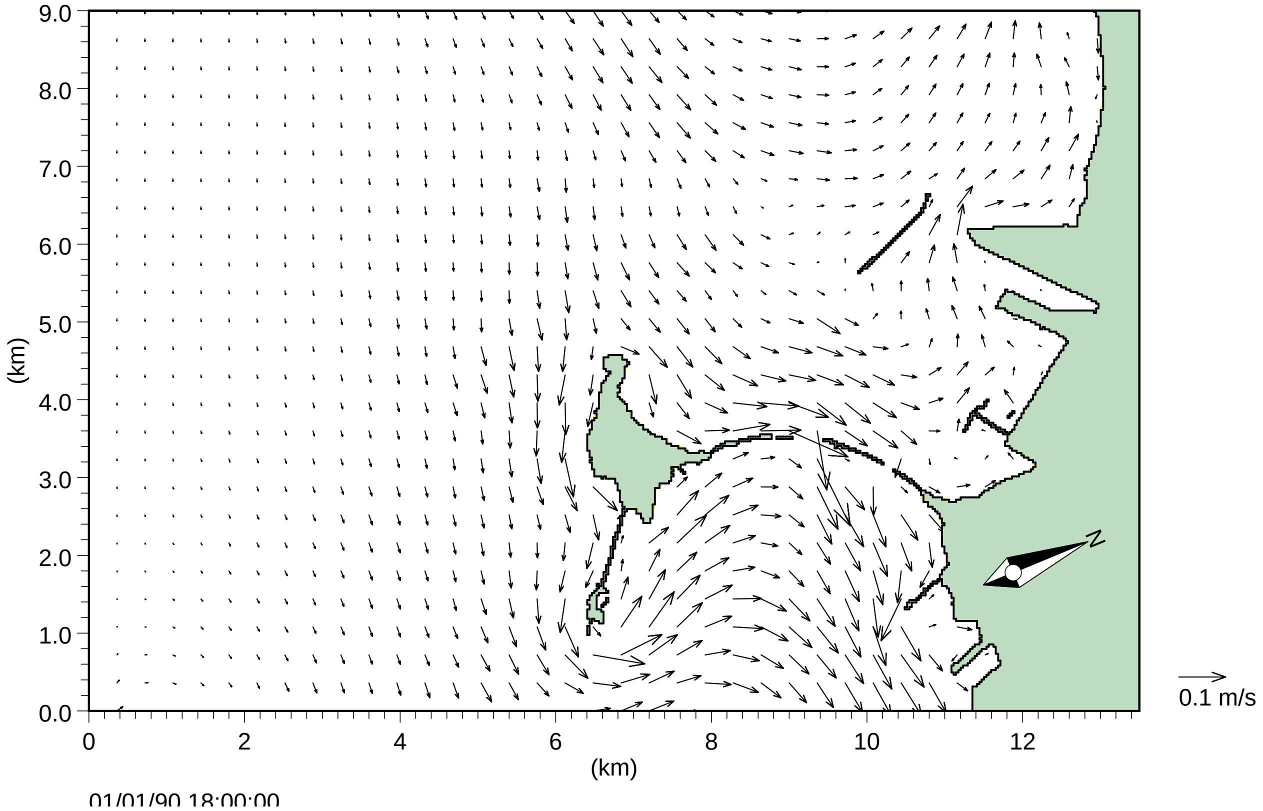
01/01/90 18:00:00

alatec ingenieros consultores y arquitectos

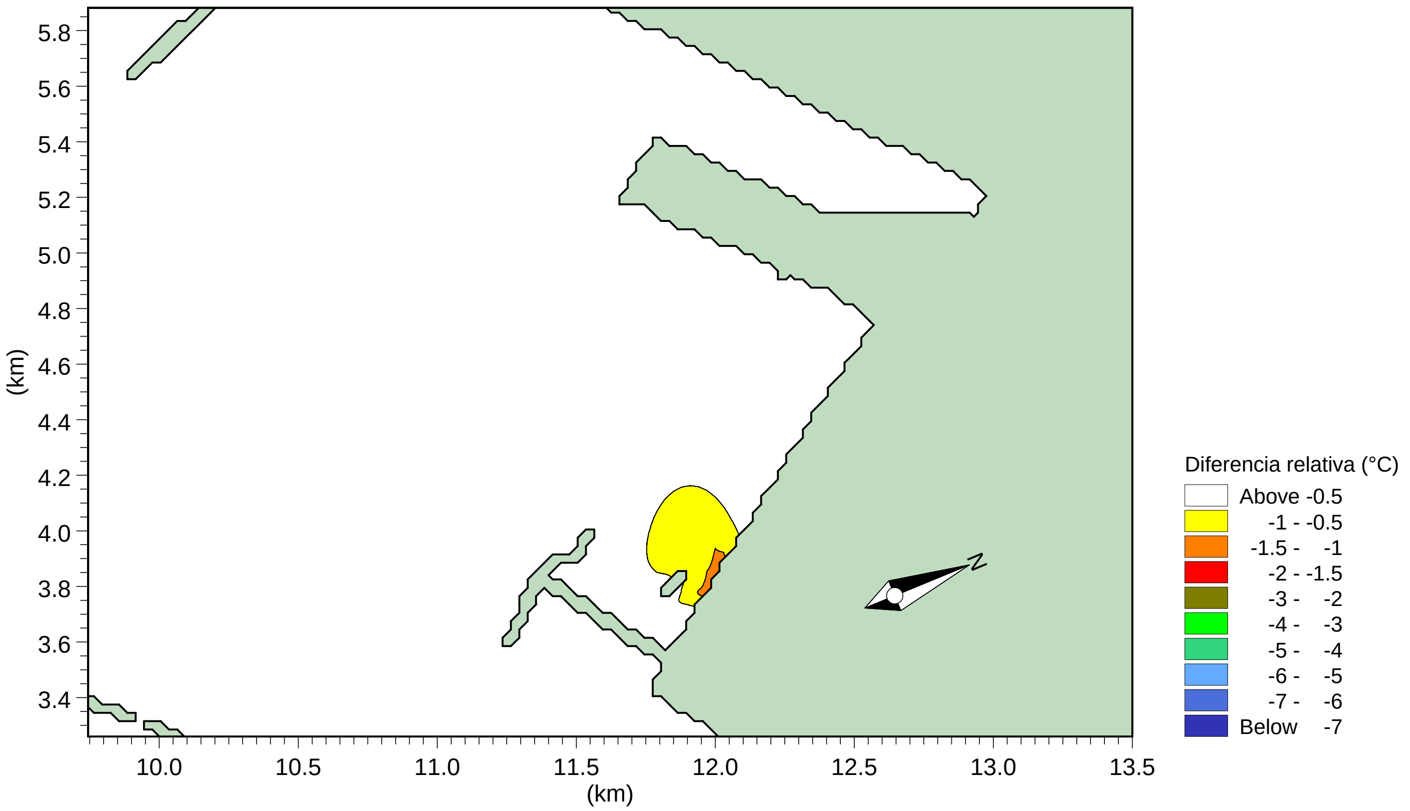
Client: GAS NATURAL	
Project: P04156D	MIKE Zero

Model: Mike 21 - AD	Date: 04/02/05	Spill Advection/dispersion in Taranto Wind: vel= 5 m/s, dir = 202.5º	Drawing no. DRW 07
	Init: cma		

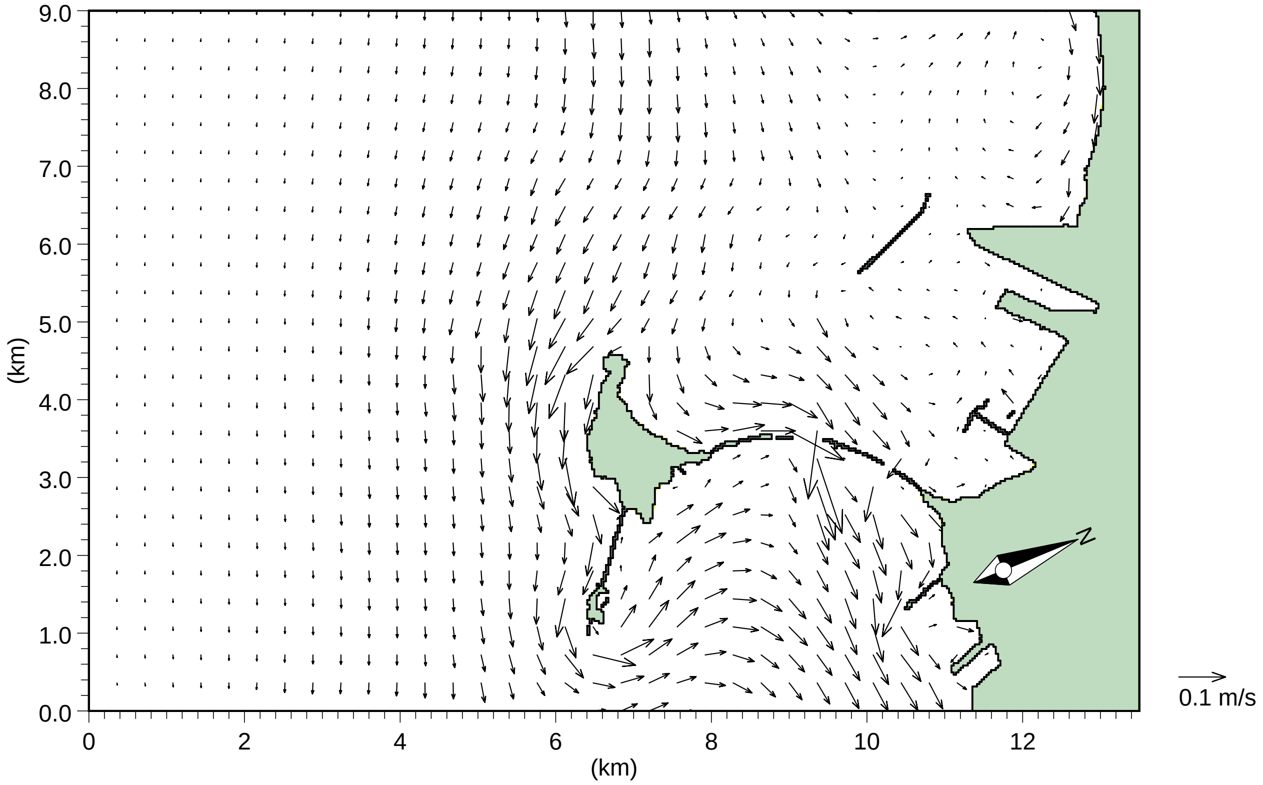




alatec ingenieros consultores y arquitectos	Client: GAS NATURAL		MIKEZero
	Project: P04156D		
Model: Mike 21 - AD	Date: 04/02/05	Spill Advection/dispersion in Taranto Wind: vel= 5 m/s, dir = 225º	Drawing no. DRW 08
	Init: cma		

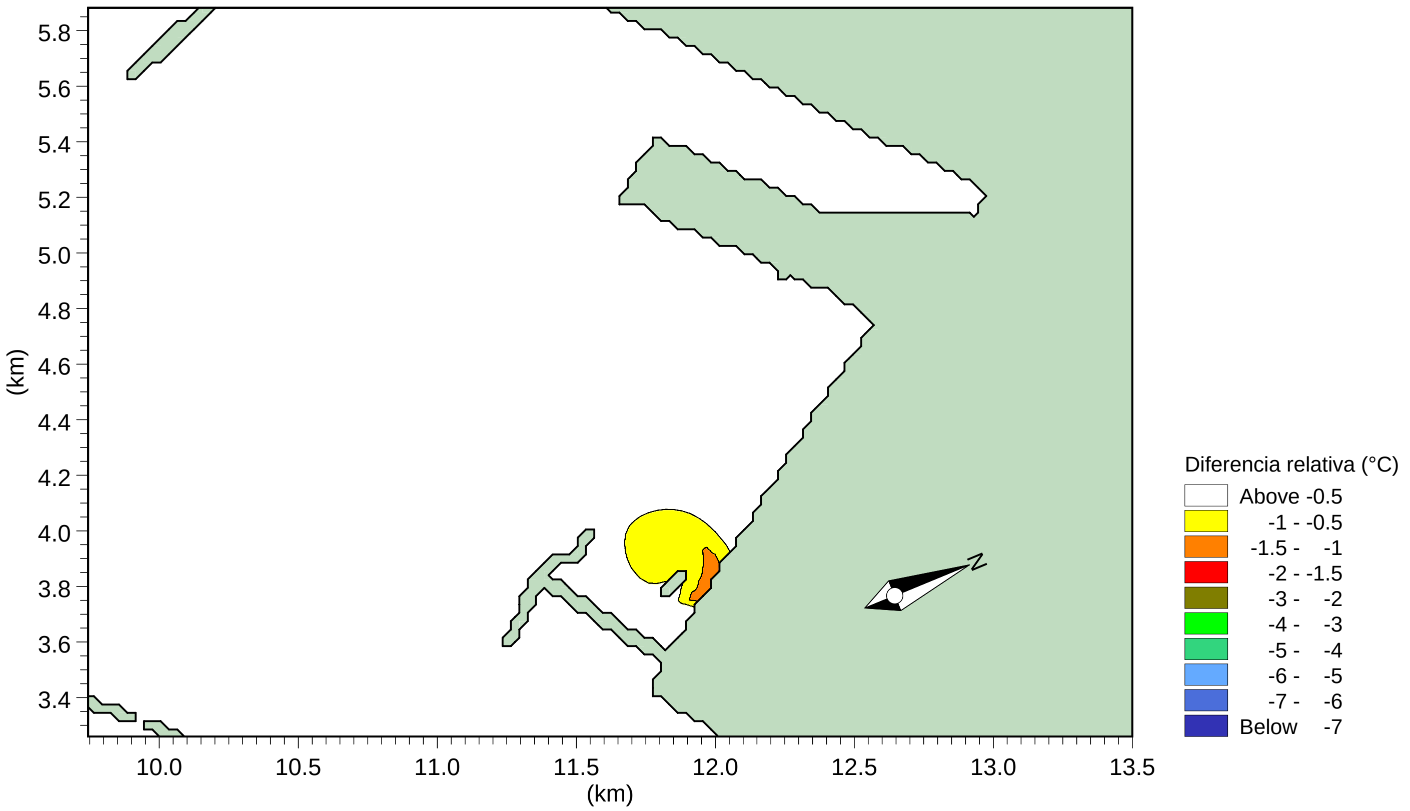


01/01/90 18:00:00

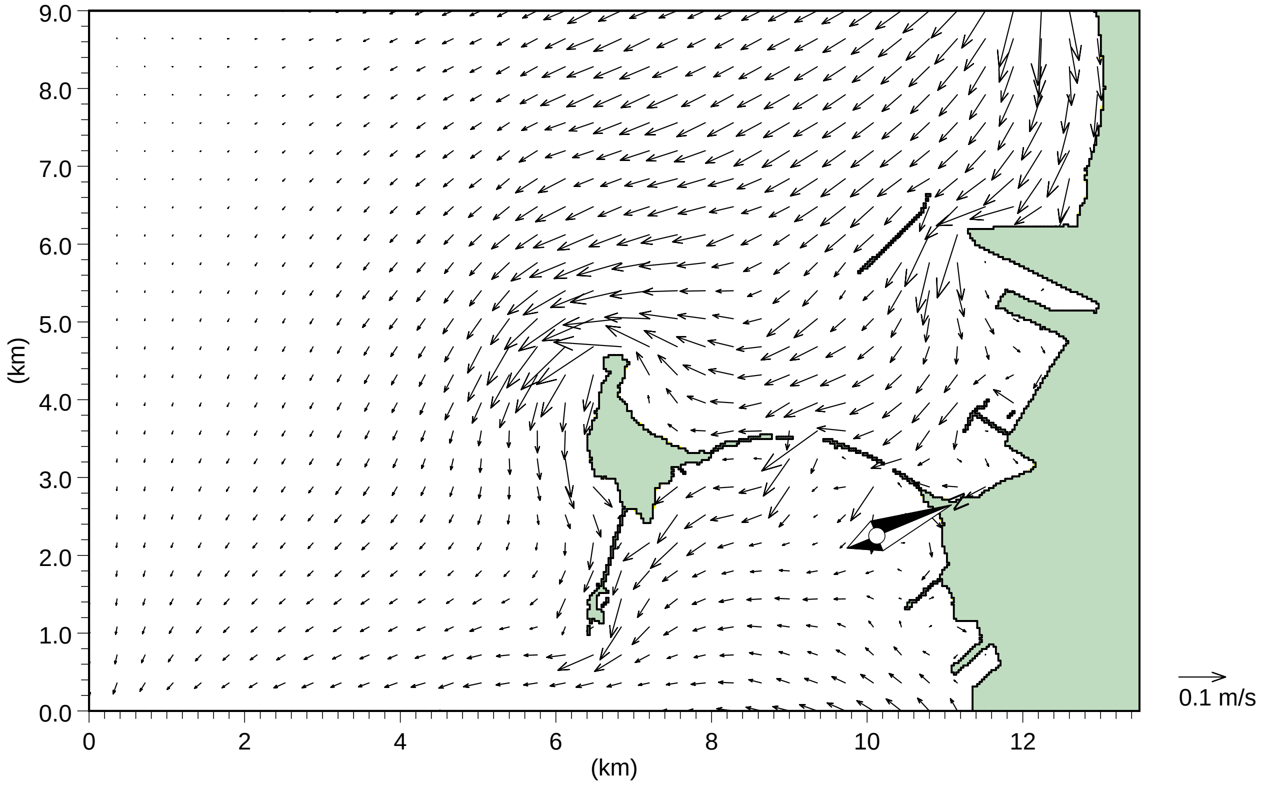


01/01/90 18:00:00

alatec ingenieros consultores y arquitectos		Client: GAS NATURAL Project: P04156D	MIKEZero
Model: Mike 21 - AD	Date: 04/02/05	Spill Advection/dispersion in Taranto Wind: vel= 5 m/s, dir = 247.5º	Drawing no. DRW 09
	Init: cma		

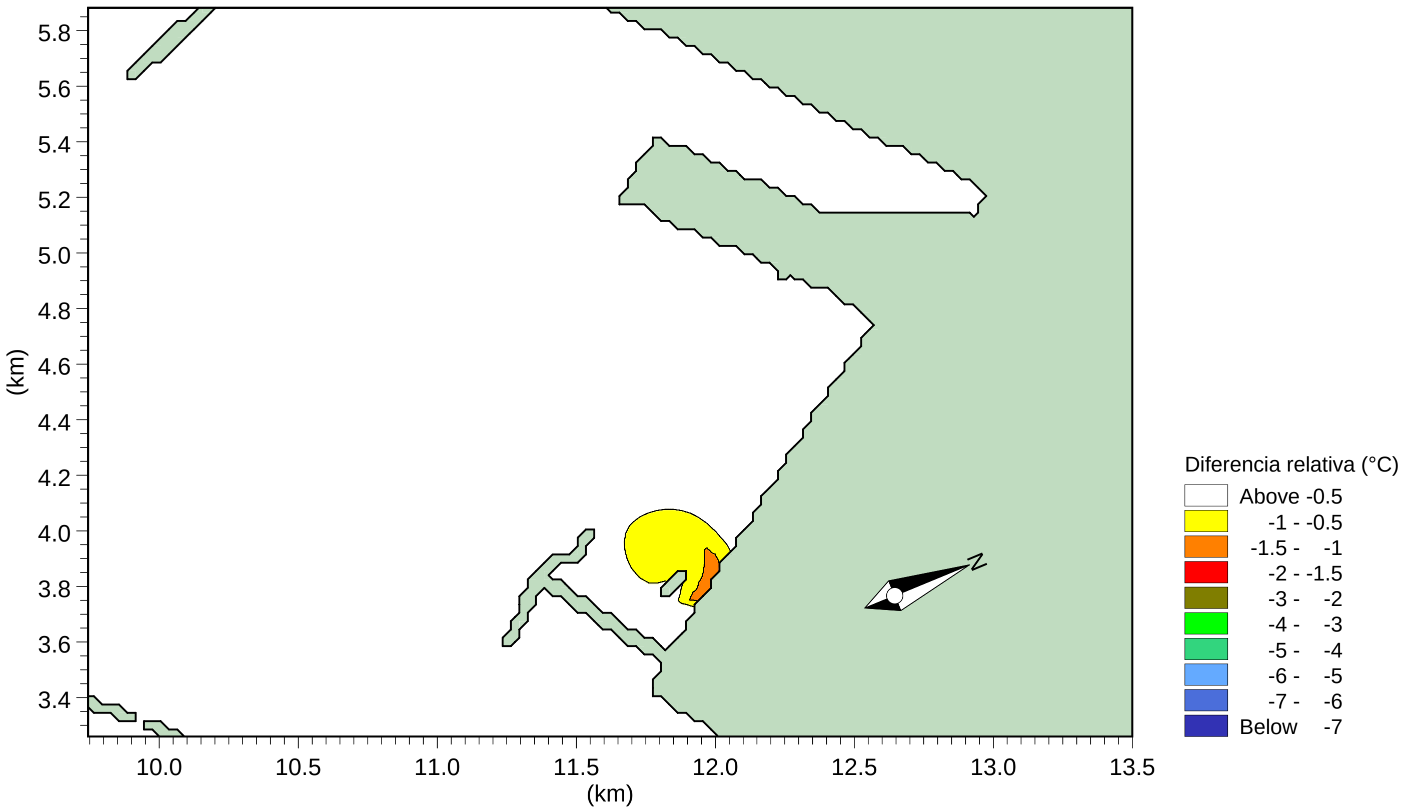


01/01/90 18:00:00

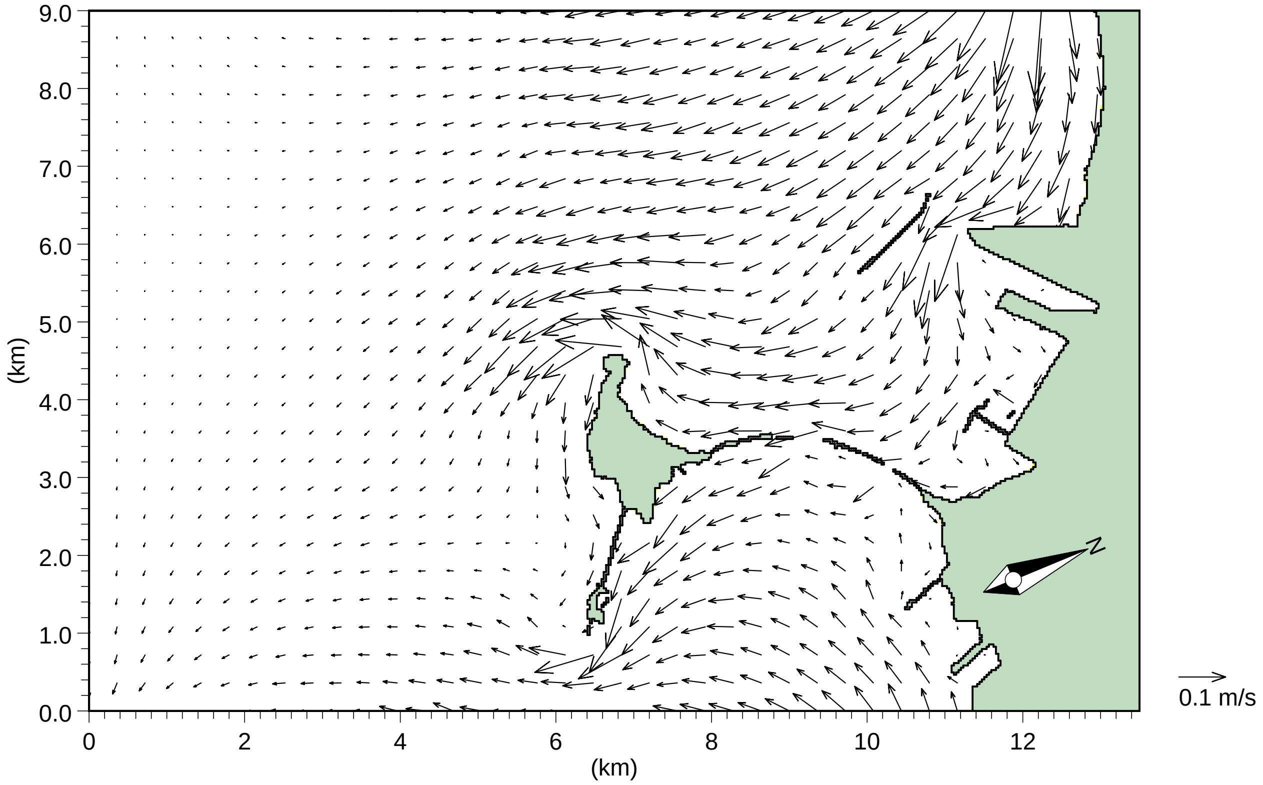


01/01/90 18:00:00

alatec ingenieros consultores y arquitectos		Client: GAS NATURAL Project: P04156D	MIKEZero
Model: Mike 21 - AD	Date: 04/02/05	Spill Advection/dispersion in Taranto Wind: vel= 10 m/s, dir = 315º	Drawing no. DRW 11
	Init: cma		

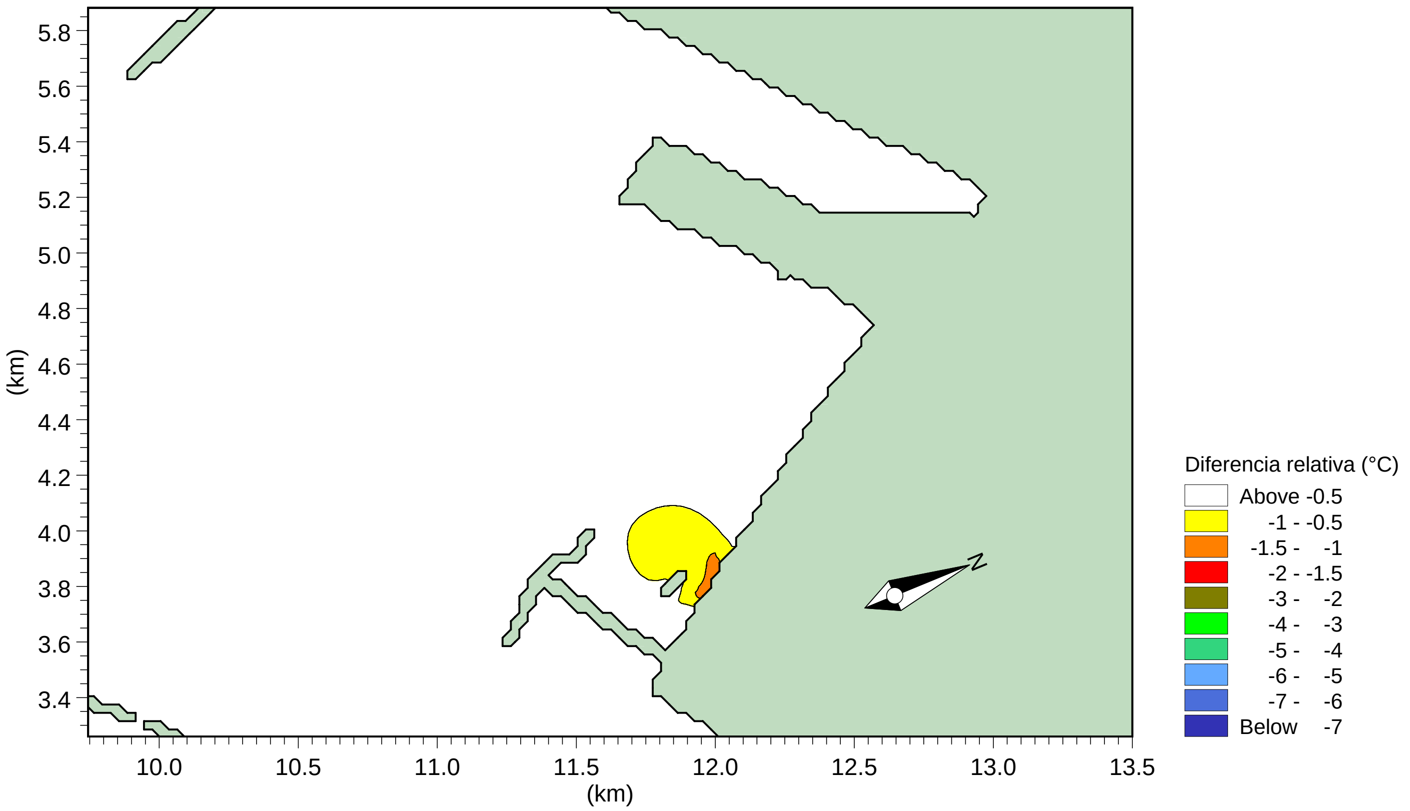


01/01/90 18:00:00

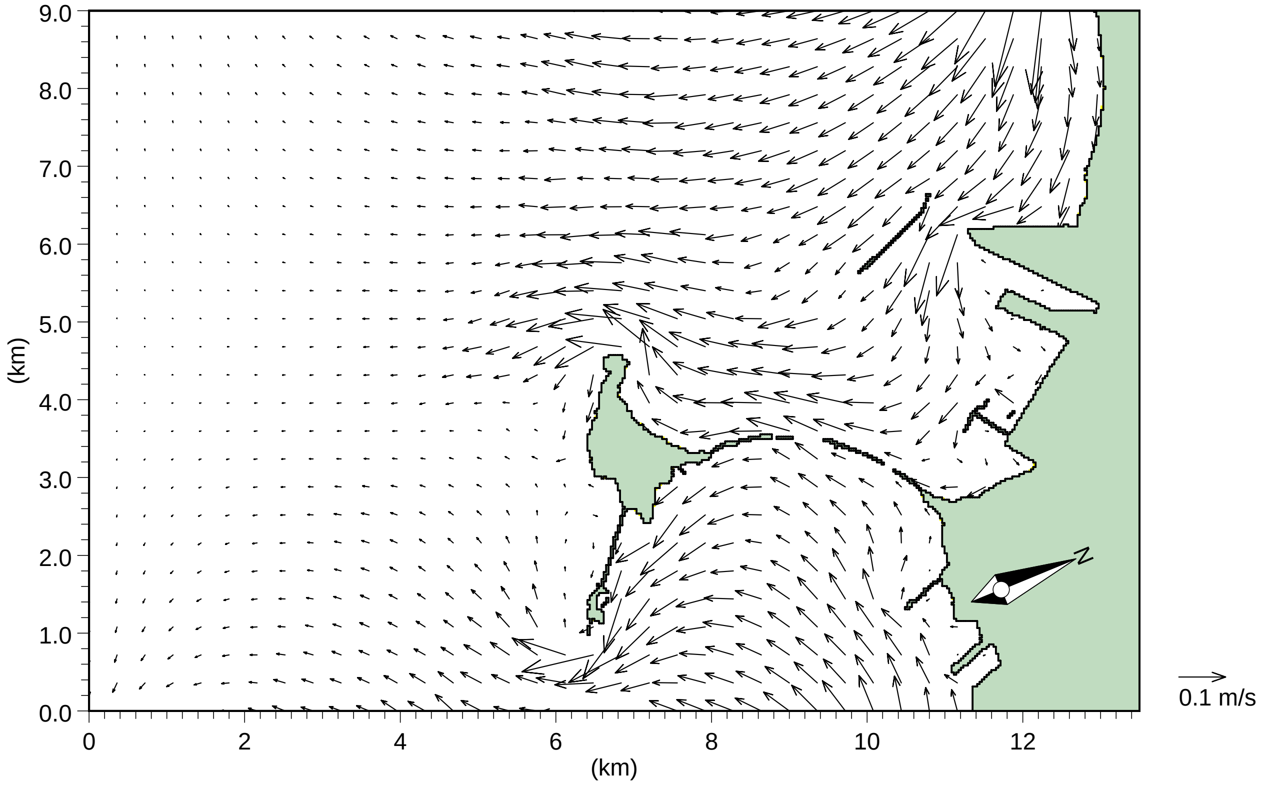


01/01/90 18:00:00

alatec ingenieros consultores y arquitectos	Client: GAS NATURAL Project: P04156D		MIKE Zero
Model: Mike 21 - AD	Date: 04/02/05	Spill Advection/dispersion in Taranto Wind: vel= 10 m/s, dir = 337.5º	Drawing no. DRW 12
	Init: cma		

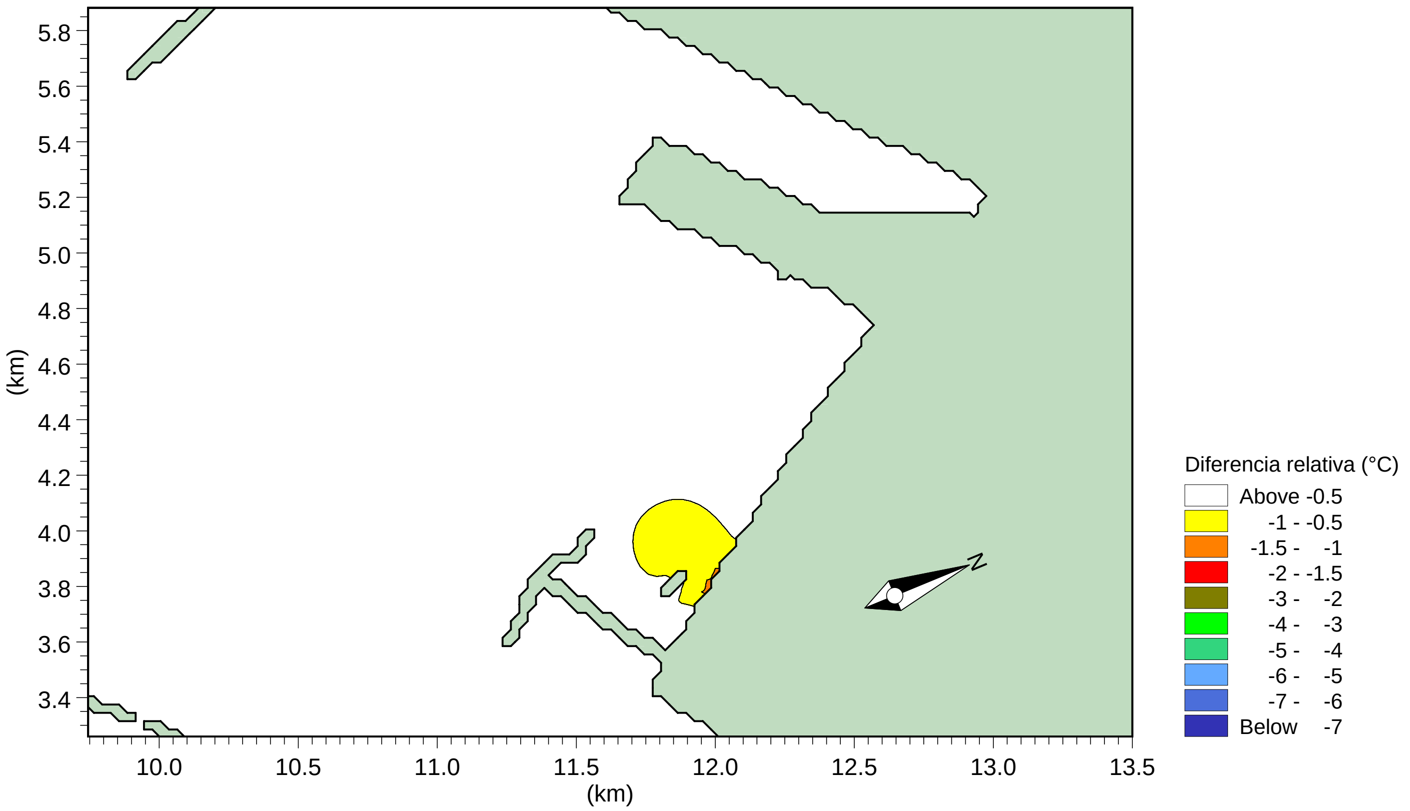


01/01/90 18:00:00

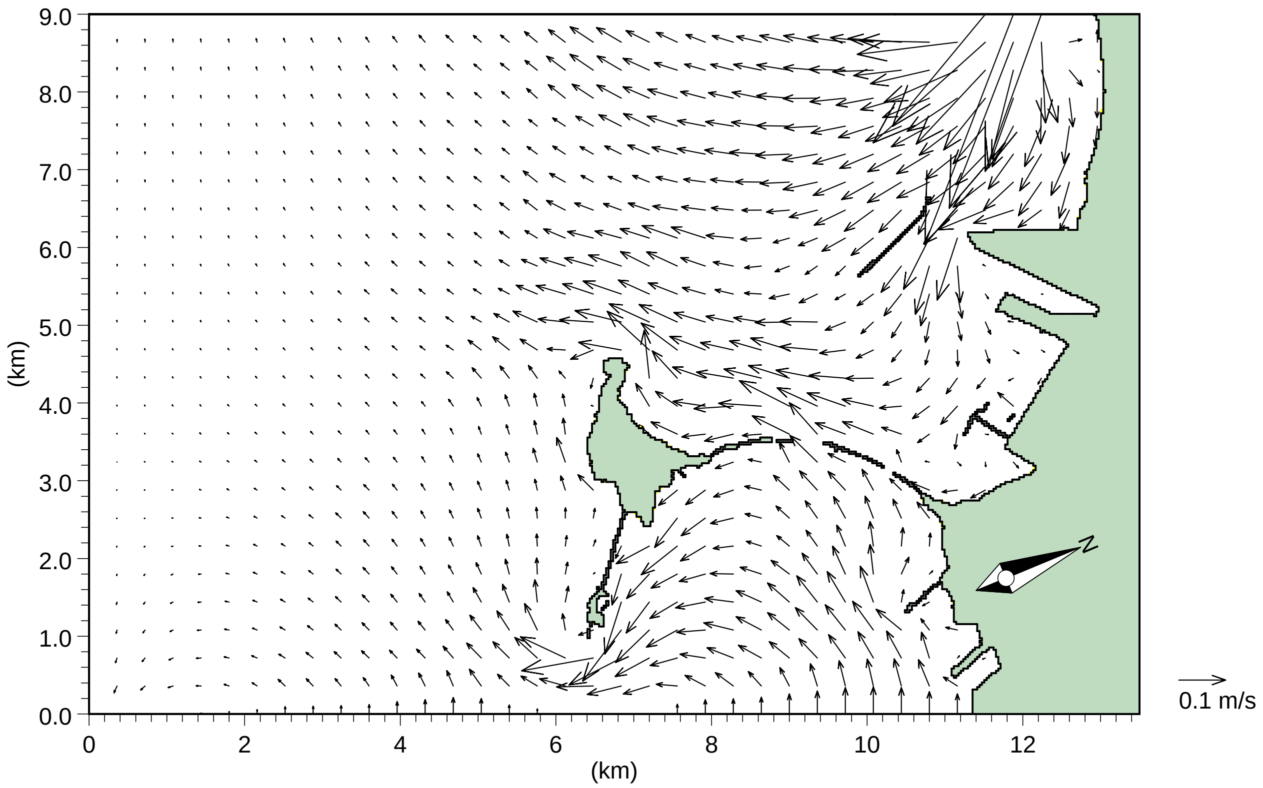


01/01/90 18:00:00

alatec ingenieros consultores y arquitectos		Client: GAS NATURAL Project: P04156D	MIKE Zero
Model: Mike 21 - AD	Date: 04/02/05	Spill Advection/dispersion in Taranto Wind: vel= 10 m/s, dir = 0º	Drawing no. DRW 13
	Init: cma		

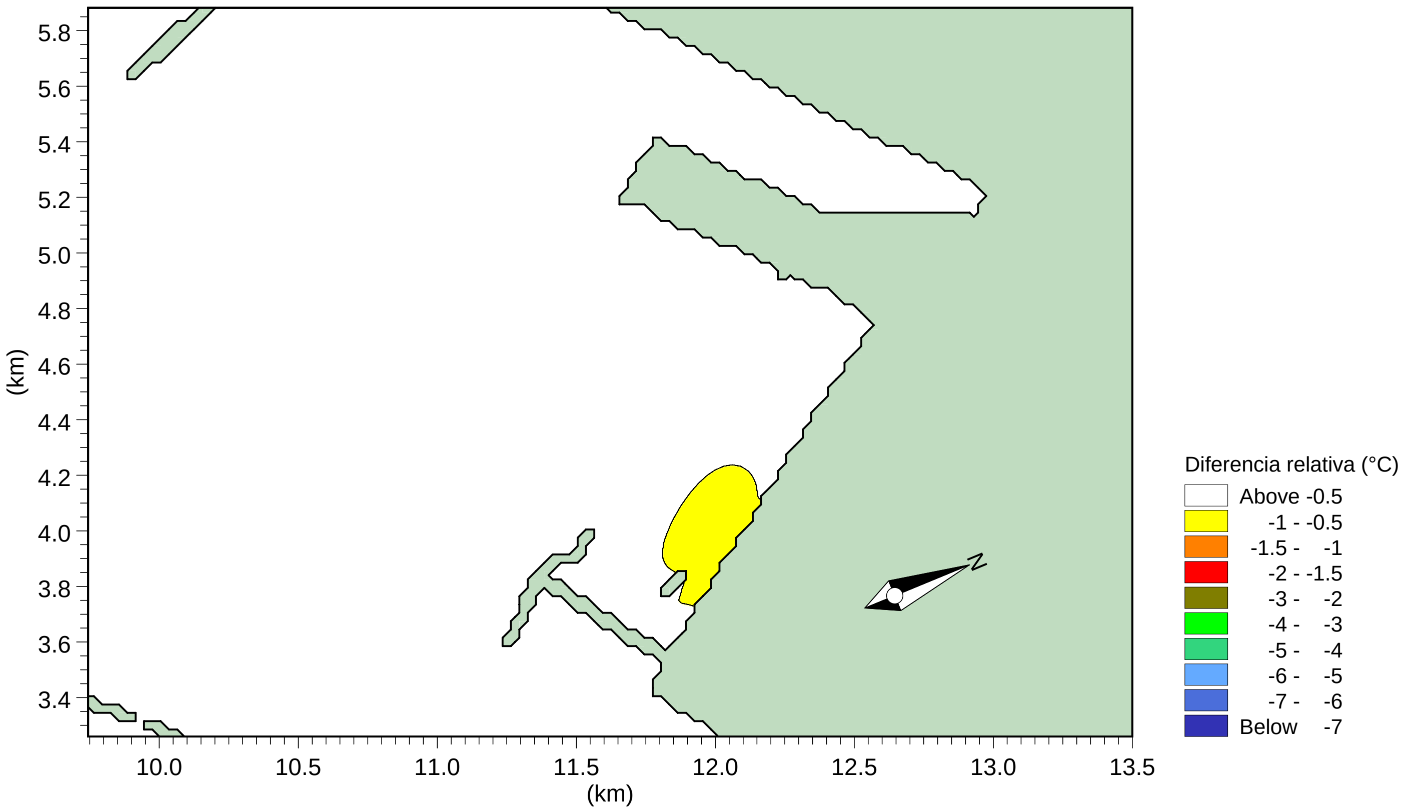


01/01/90 18:00:00

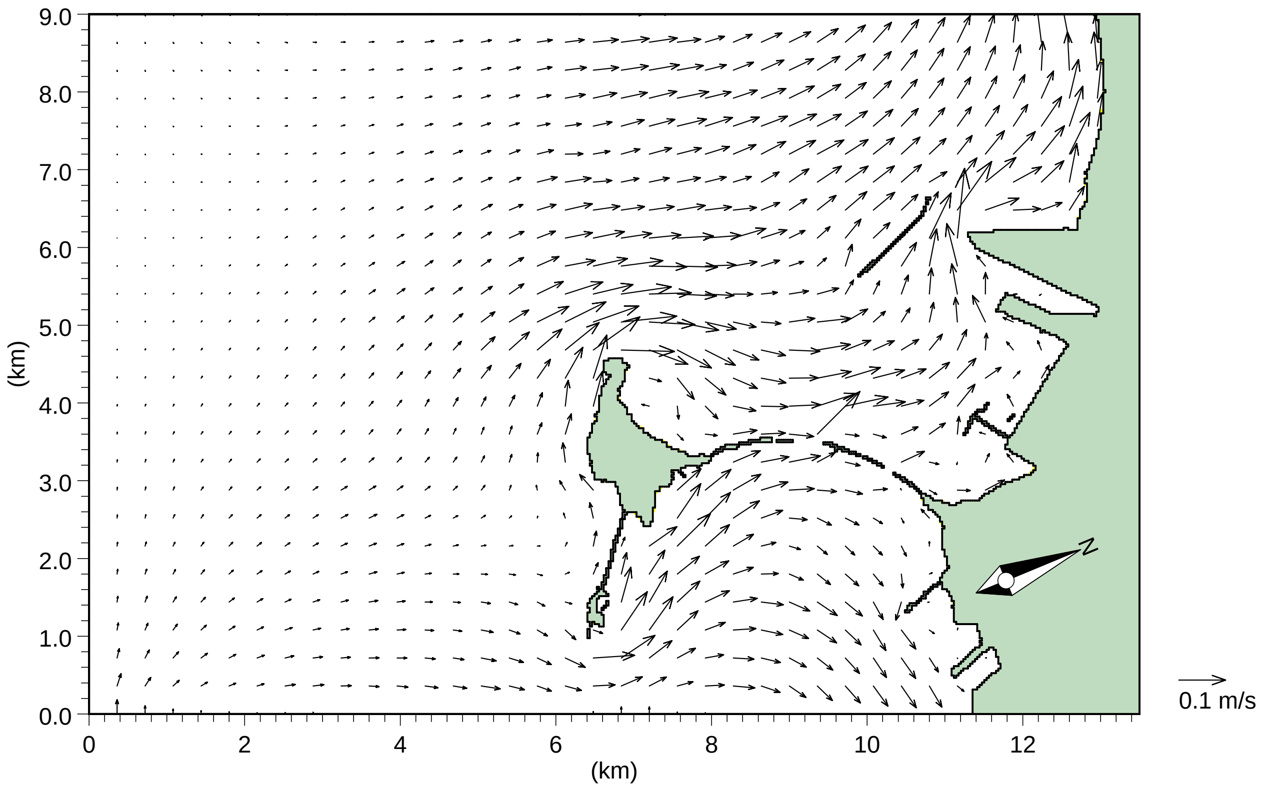


01/01/90 18:00:00

alatec ingenieros consultores y arquitectos		Client: GAS NATURAL	
		Project: P04156D	MIKE Zero
Model: Mike 21 - AD	Date: 04/02/05	Spill Advection/dispersion in Taranto Wind: vel= 10 m/s, dir = 22.5º	Drawing no. DRW 14
	Init: cma		



01/01/90 18:00:00

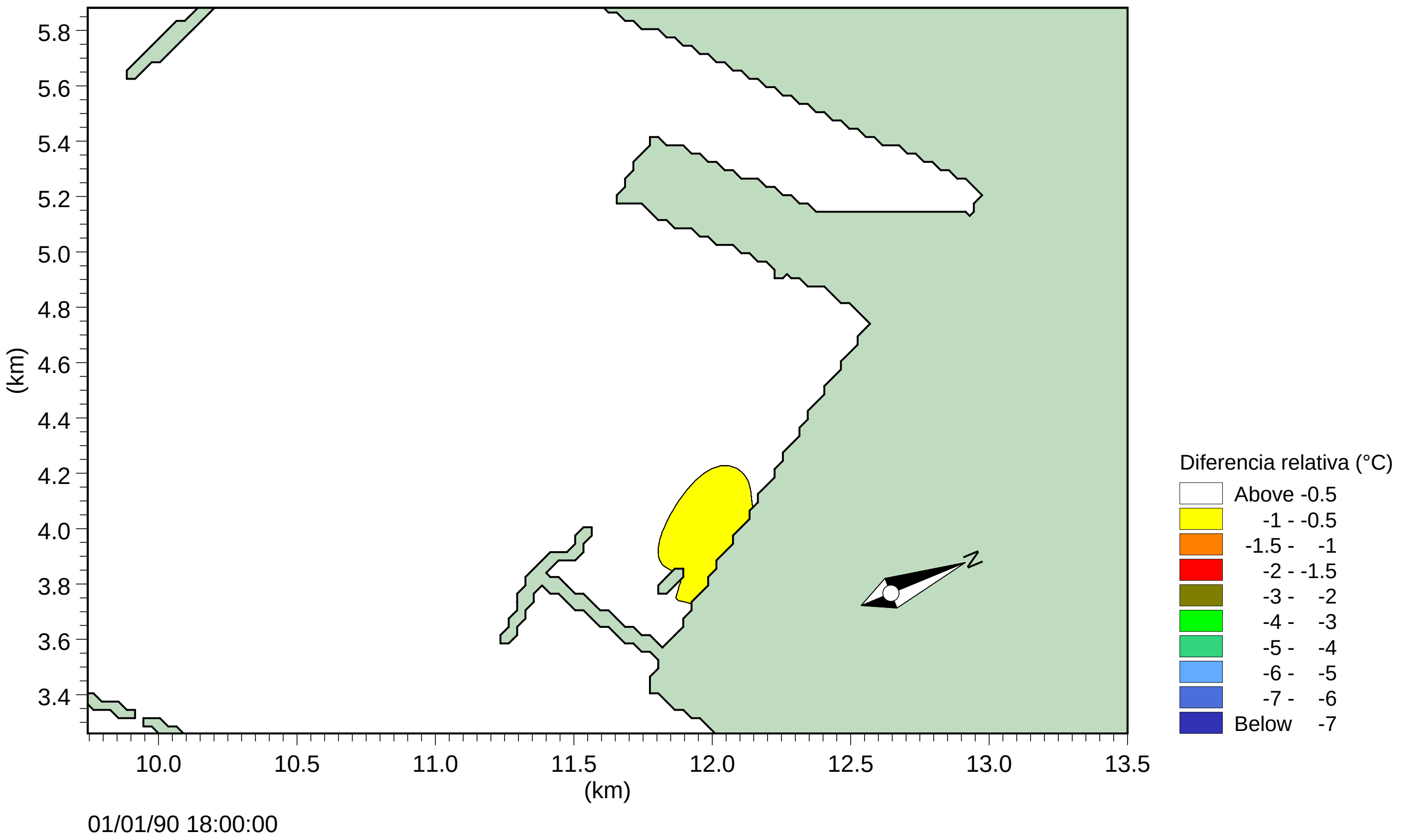


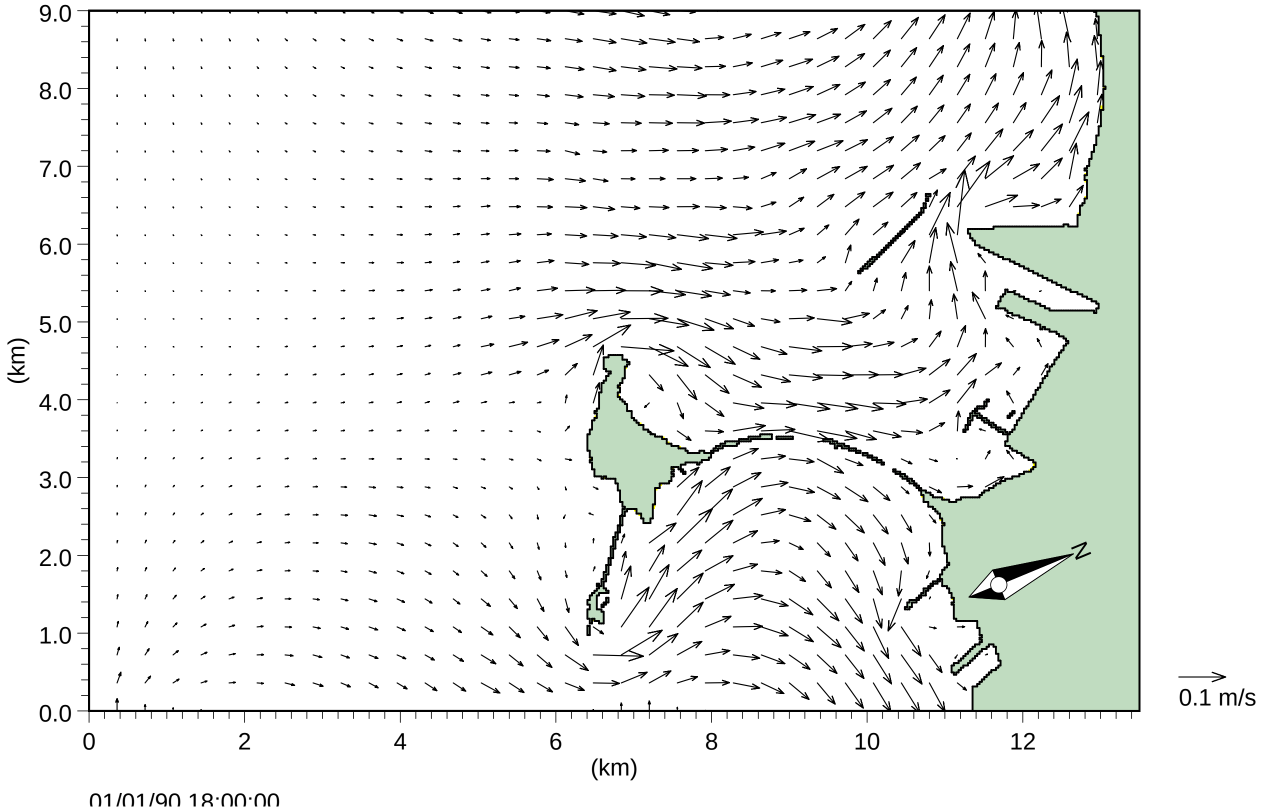
01/01/90 18:00:00

alatec
ingenieros consultores y arquitectos

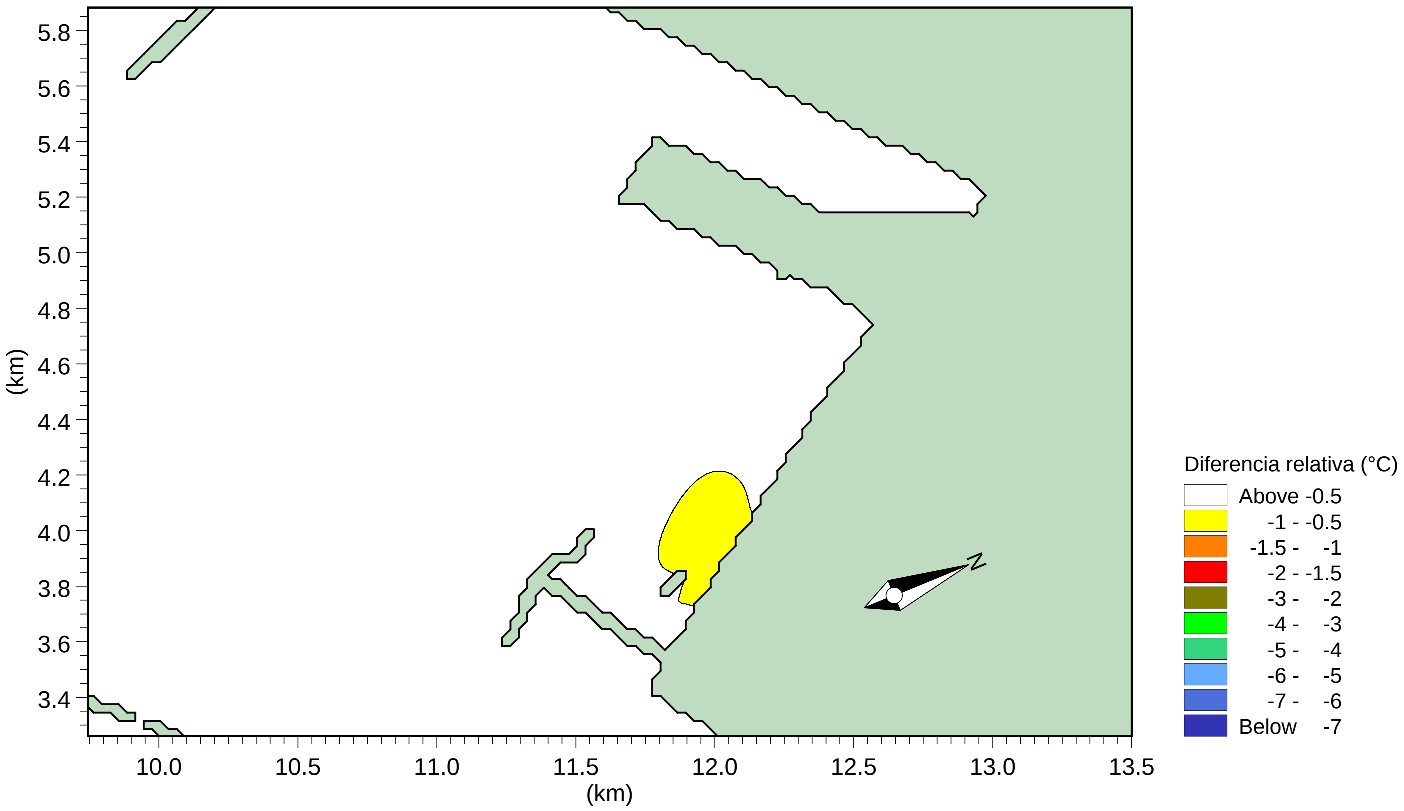
Client: GAS NATURAL			
Project: P04156D			
Model: Mike 21 - AD	Date: 04/02/05	Spill Advection/dispersion in Taranto Wind: vel= 10 m/s, dir = 157.5º	Drawing no. DRW 15
	Init: cma		

MIKE Zero

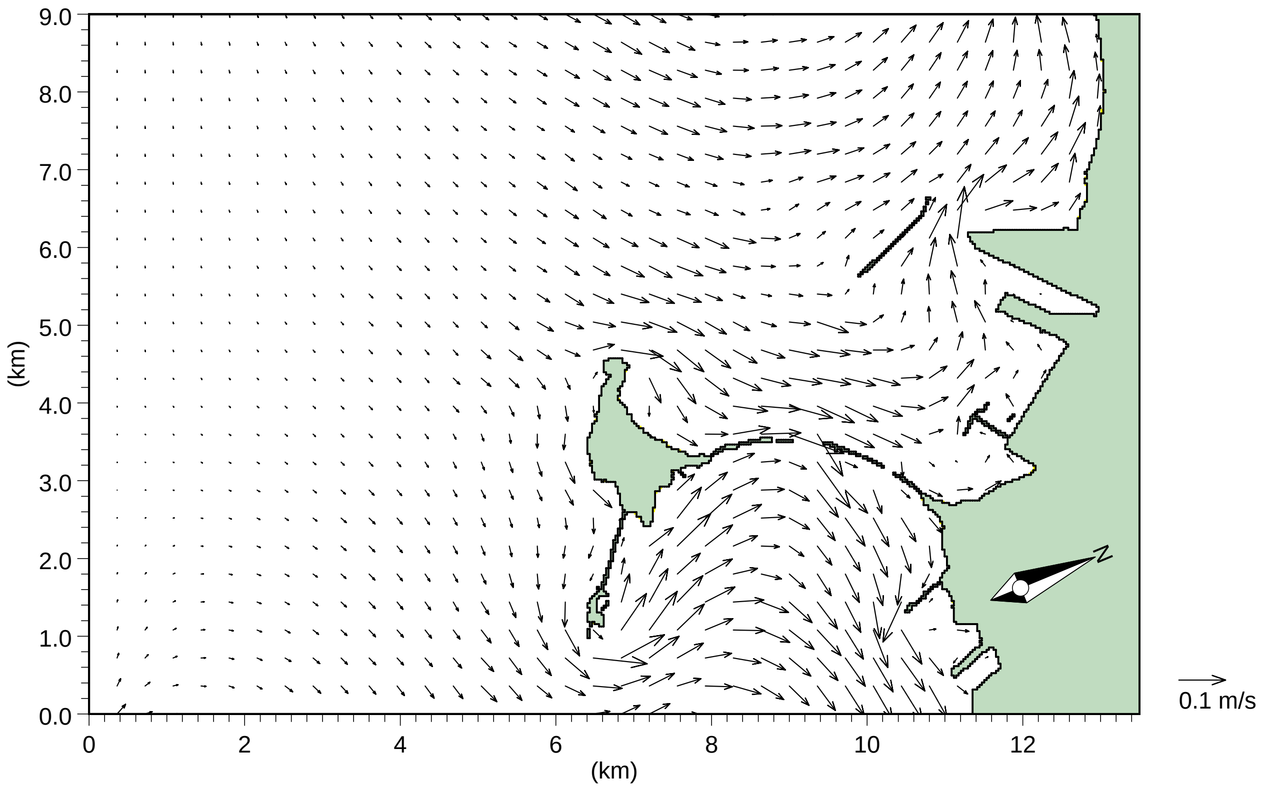




alatec ingenieros consultores y arquitectos		Client: GAS NATURAL Project: P04156D	MIKEZero
Model: Mike 21 - AD	Date: 04/02/05	Spill Advection/dispersion in Taranto Wind: vel= 10 m/s, dir = 180º	Drawing no. DRW 16
	Init: cma		

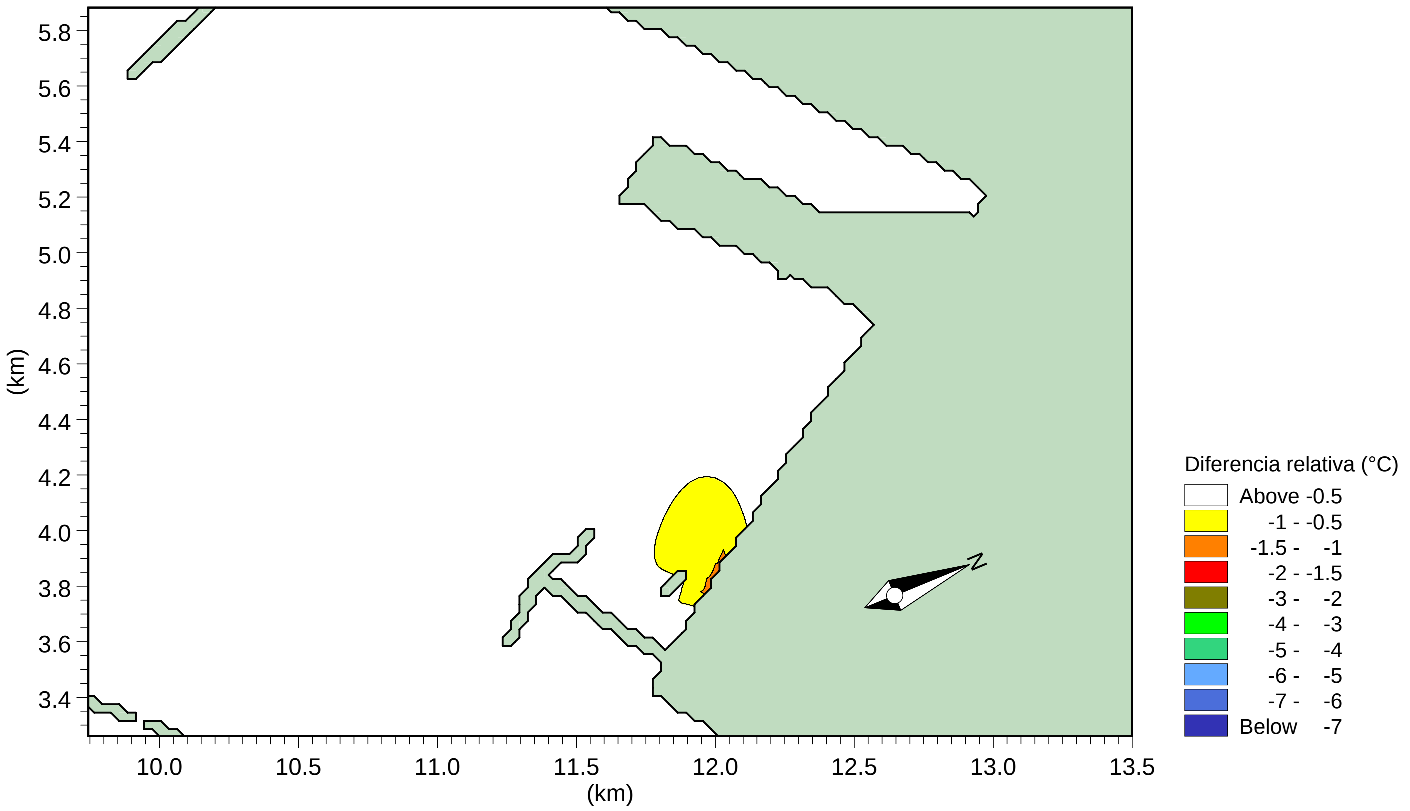


01/01/90 18:00:00

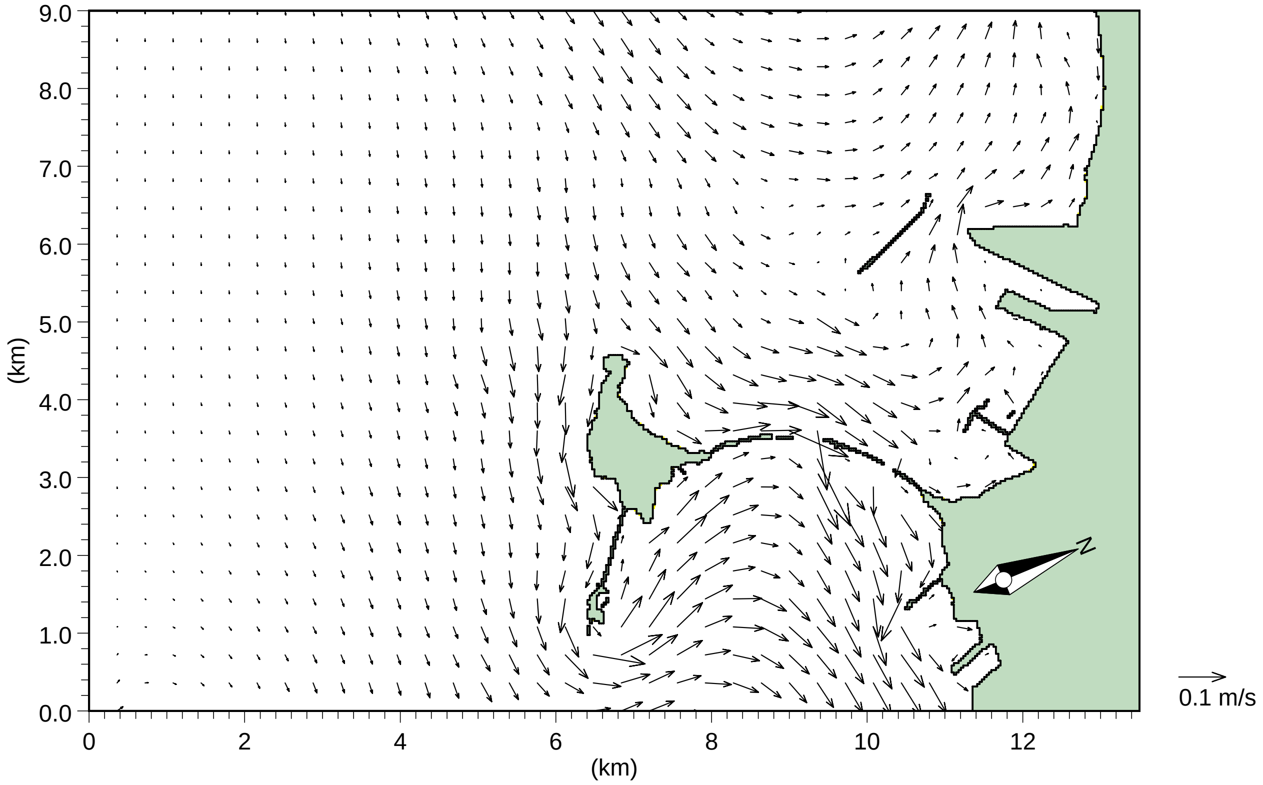


01/01/90 18:00:00

alatec ingenieros consultores y arquitectos	Client: GAS NATURAL Project: P04156D	MIKE Zero
Model: Mike 21 - AD	Date: 04/02/05	Spill Advection/dispersion in Taranto Wind: vel= 10 m/s, dir = 202.5º
	Init: cma	Drawing no. DRW 17

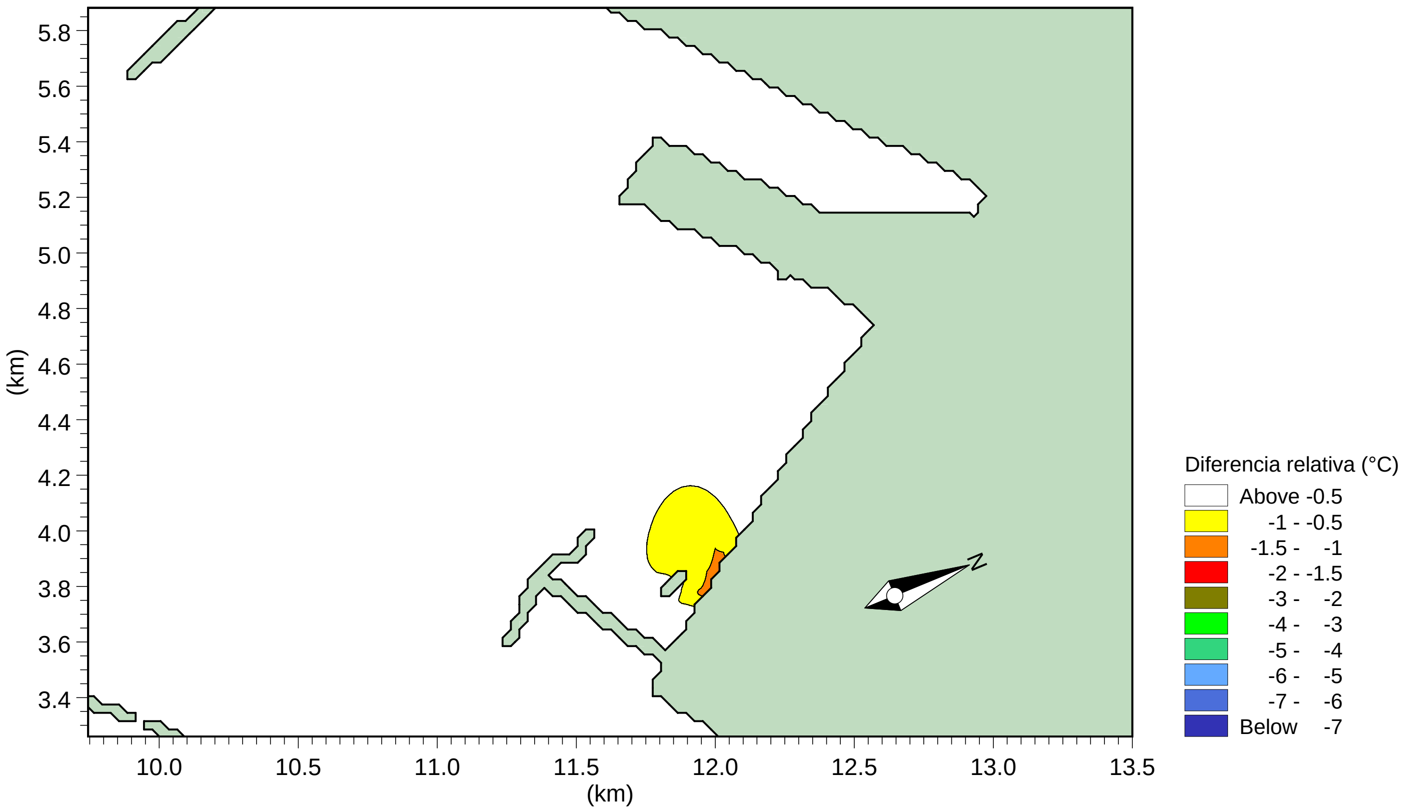


01/01/90 18:00:00

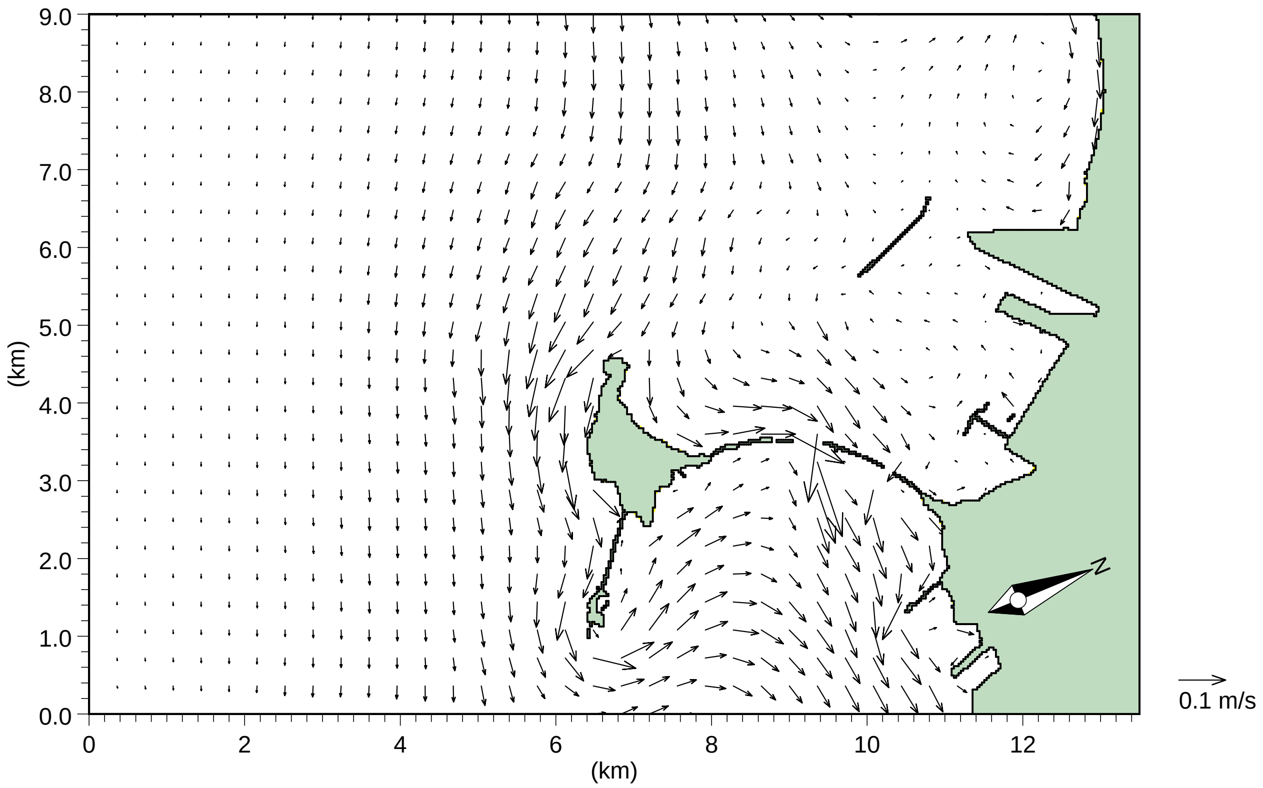


01/01/90 18:00:00

alatec ingenieros consultores y arquitectos		Client: GAS NATURAL		MIKE Zero
		Project: P04156D		
Model: Mike 21 - AD	Date: 04/02/05	Spill Advection/dispersion in Taranto Wind: vel= 10 m/s, dir = 225º	Drawing no. DRW 18	
	Init: cma			



01/01/90 18:00:00



01/01/90 18:00:00

alatec ingenieros consultores y arquitectos		Client: GAS NATURAL Project: P04156D	MIKE Zero
Model: Mike 21 - AD	Date: 04/02/05 Init: cma	Spill Advection/dispersion in Taranto Wind: vel= 10 m/s, dir = 247.5º	Drawing no. DRW 19