Offshore Oil Exploration: Probabilistic Simulations of Plume Dispersion and Potential Impacts on Beaches

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Main Topics

- Approaches for simulating the transport and fate of oil spills

- Differences and applications of Trajectory (deterministic), Stochastic (Probabilistic), and hindcast (backtrack) modeling approaches, with examples of two recent CPE studies in South America

- Importance of simulation studies in potential impact evaluation and decision making

- Real-time (operational) monitoring and modeling for contingency planning and risk-mitigation

- Implications /Recommendations to the Florida Coast

Physical Properties of Oil

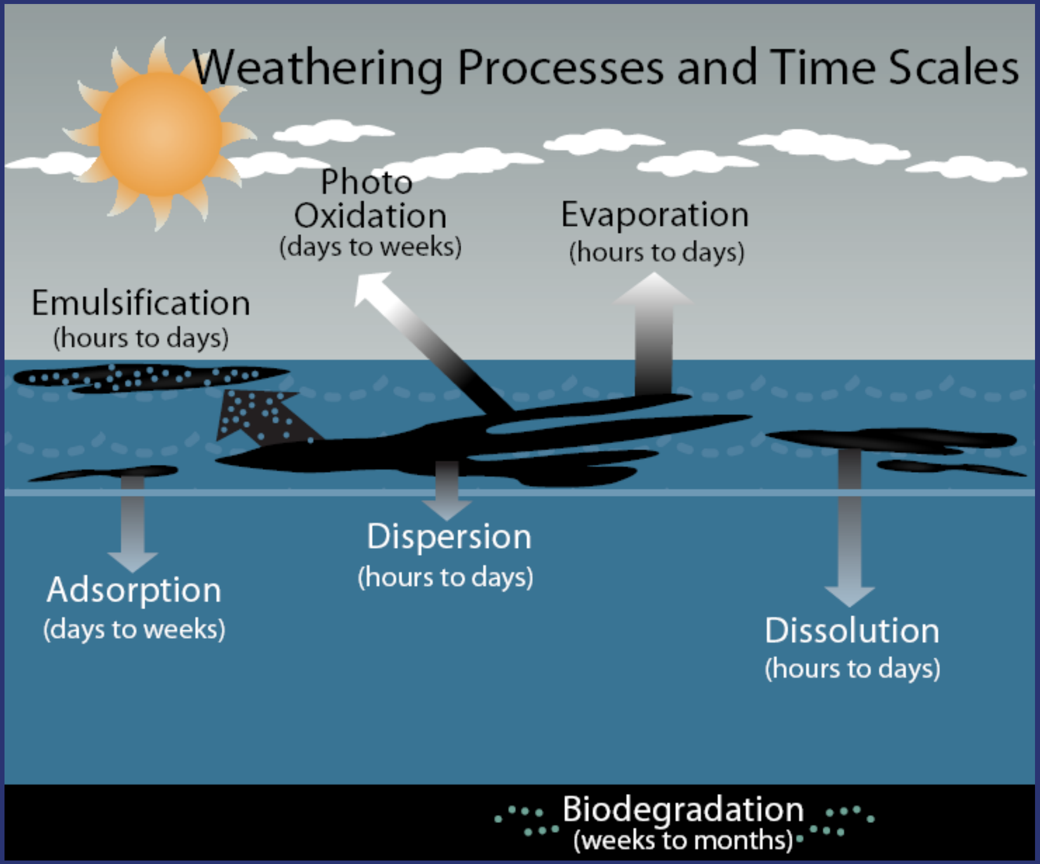
• The term OIL describes a broad range of hydrocarbon-based substances.

• Each type of oil has distinct physical and chemical properties. These properties affect the way oil will spread and break down and the hazard it may pose to aquatic life, human life, as well as to natural and man-made resources.

• The rate at which an oil spill spreads will determine its effect on the environment. Most oils tend to spread horizontally into a smooth and slippery surface, a slick, on top of the water. Factors which affect the ability of an oil spill to spread include *surface tension, specific gravity, and viscosity*.

Weathering Processes and Time Scales

The physical and chemical characteristics of petroleum change almost immediately when spilled in the marine environment due to ***evaporation, dispersion, emulsification, dissolution, oxidation, sedimentation, and biodegradation***. All of these processes interact with each other and are collectively referred to as ***oil weathering.***



WEATHERING PROCESSES AND TIME SCALES

Weathering processes and time scales important for emergency response

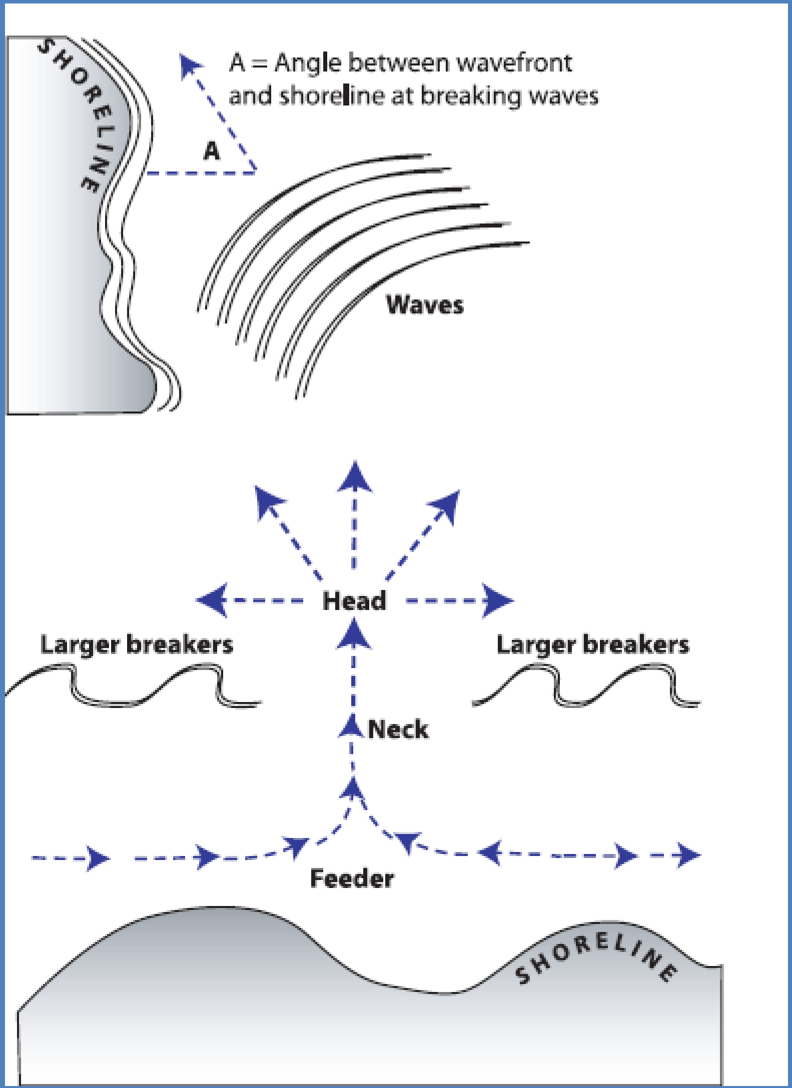
Weathering Process	What is It?	Why is it Important?	Time Scales
Evaporation	Conversion of liquid to a gaseous phase. The lighter fractions in the oil are lost first.	Major process that accounts for the loss of oil, particularly light oils. At 15°C, gasoline evaporates completely over a 2-day period, 80% of diesel fuel evaporates, 40% of light crude, 20% of heavy crude, and only about 5-10% of Bunker C.	< 5 days
Emulsification, or formation of mousse	Very small water droplets are mixed into the liquid oil. Water content often reaches 50-80%. Occurs on water, needs some wave action.	Can increase the amount of pollutant to be recovered by a factor of 2-4. Slows down other mixing processes.	Onset can be delayed for days but the emulsification process happens rapidly.
Natural dispersion	Breakup of an oil slick into small droplets that are mixed into the water by energy.	Removes the oil from the water surface.	< 5 days
Dissolution	Mixing of the water-soluble components of oil into the water.	The most water-soluble components of oil are most toxic.	< 5 days
Biodegradation	Breakdown of oil by microbes into smaller compounds, eventually to water and carbon dioxide.	Rate depends on oil type, temperature, nutrients, oxygen, and amount of oil.	weeks to months
Formation of tarballs	Breakup of slicks of heavy crudes and refined oils into small patches that persist for long distances.	Tarballs are hard to detect, so the slick appears to be going away though it is still a threat.	days to weeks

OIL TRANSPORT

Two major processes transport oil spilled on water: *spreading* and *advection*. For small spills (<100 barrels), the spreading process is complete within the first hour of the release.

Winds and *currents* are advection mechanisms that can transport oil great distances. In general, the oil movement can be estimated as the vector sum of the wind drift, currents and diffusion processes.

OIL TRANSPORT



Alongshore currents, rips, tidal circulation, turbulent mixing, wave induced dispersion *etc.*

Coastal Geology and Sensitivity

Shorelines can vary dramatically in their forms and compositions. From sandy beaches, to beaches formed from cobbles and pebbles, to rocky headlands and steep cliffs. The composition and structure of the coast will determine the potential effects of oil on the shoreline.

In the oil spill model the following coastline types can be diferenciated: sandy, rocky, mangroves, marsh and vertical wall (need mapping input)

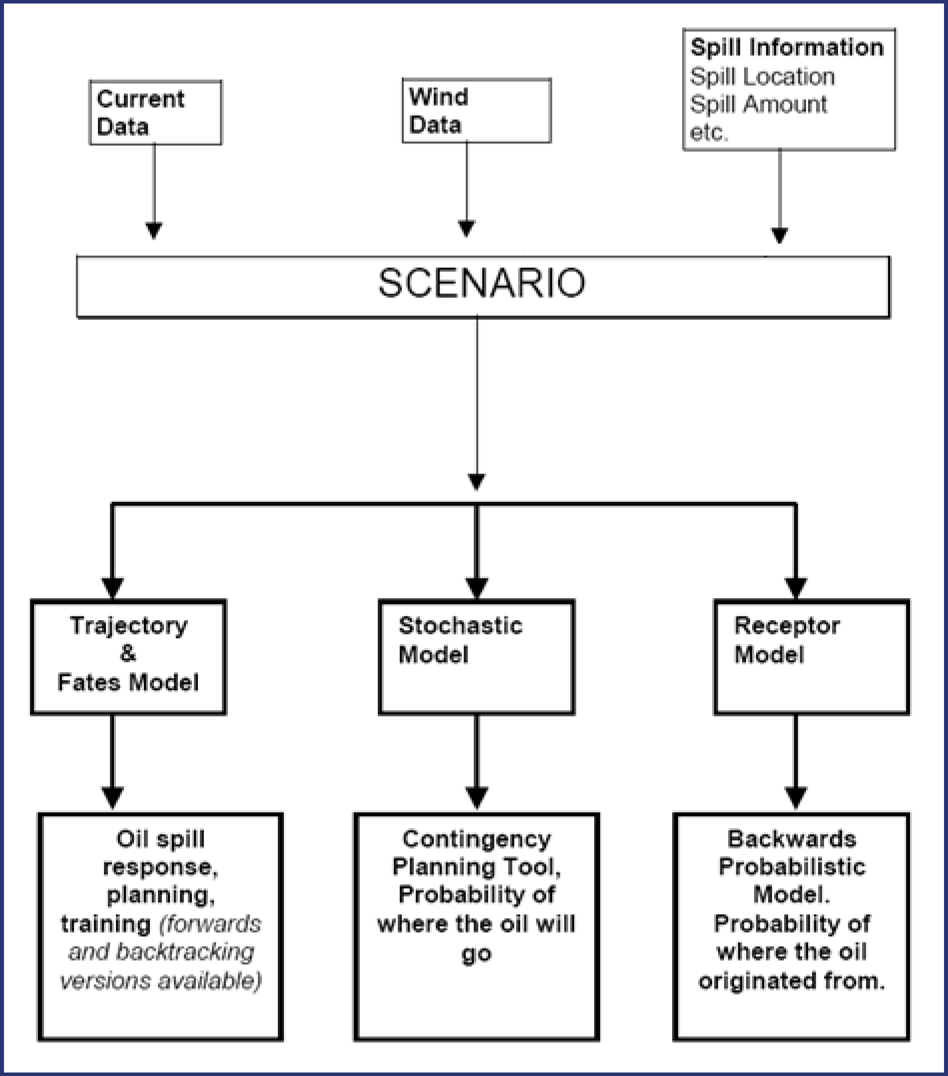
OIL SPILL MODELING

Oil spill model systems are used routinely by industry and government to assist in planning and emergency decision making.

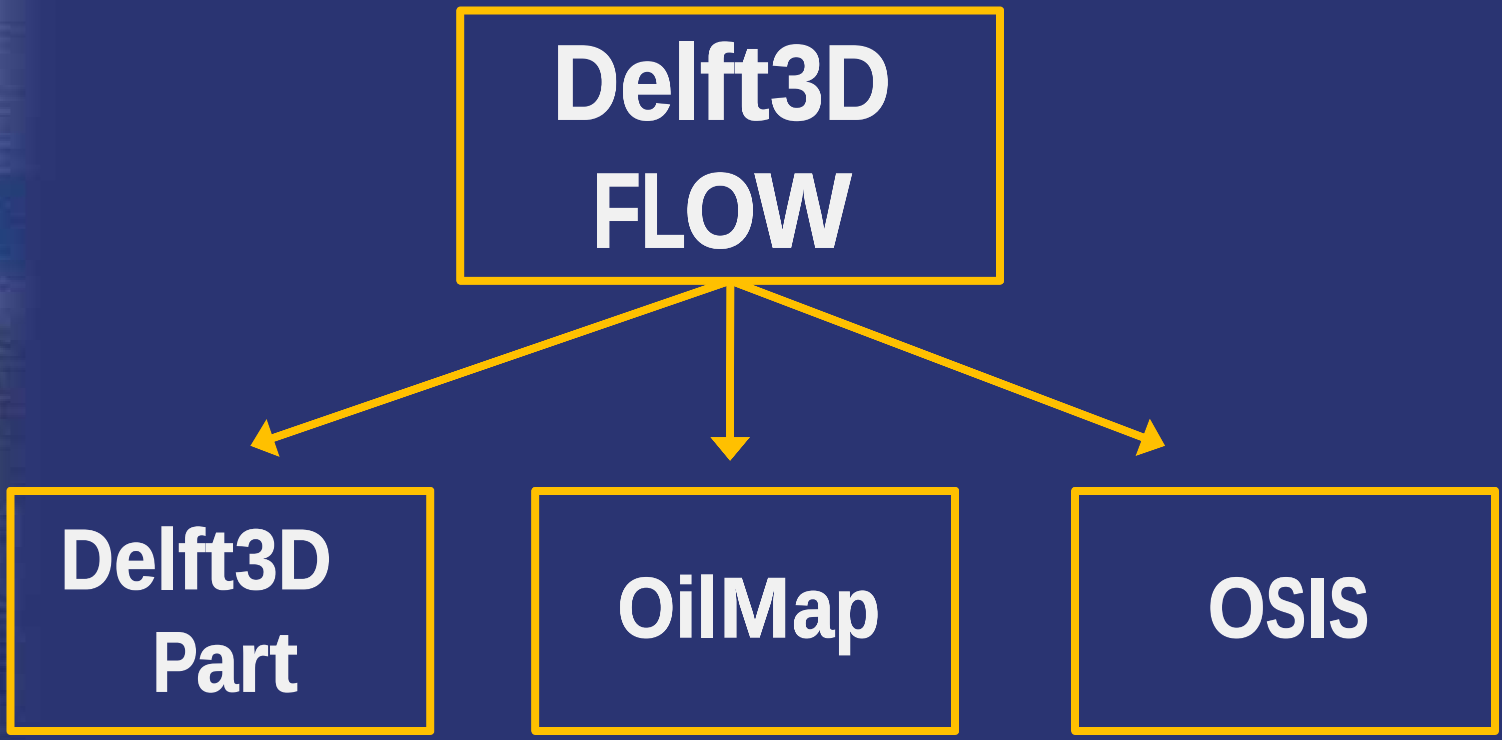
"Where will the oil go?"

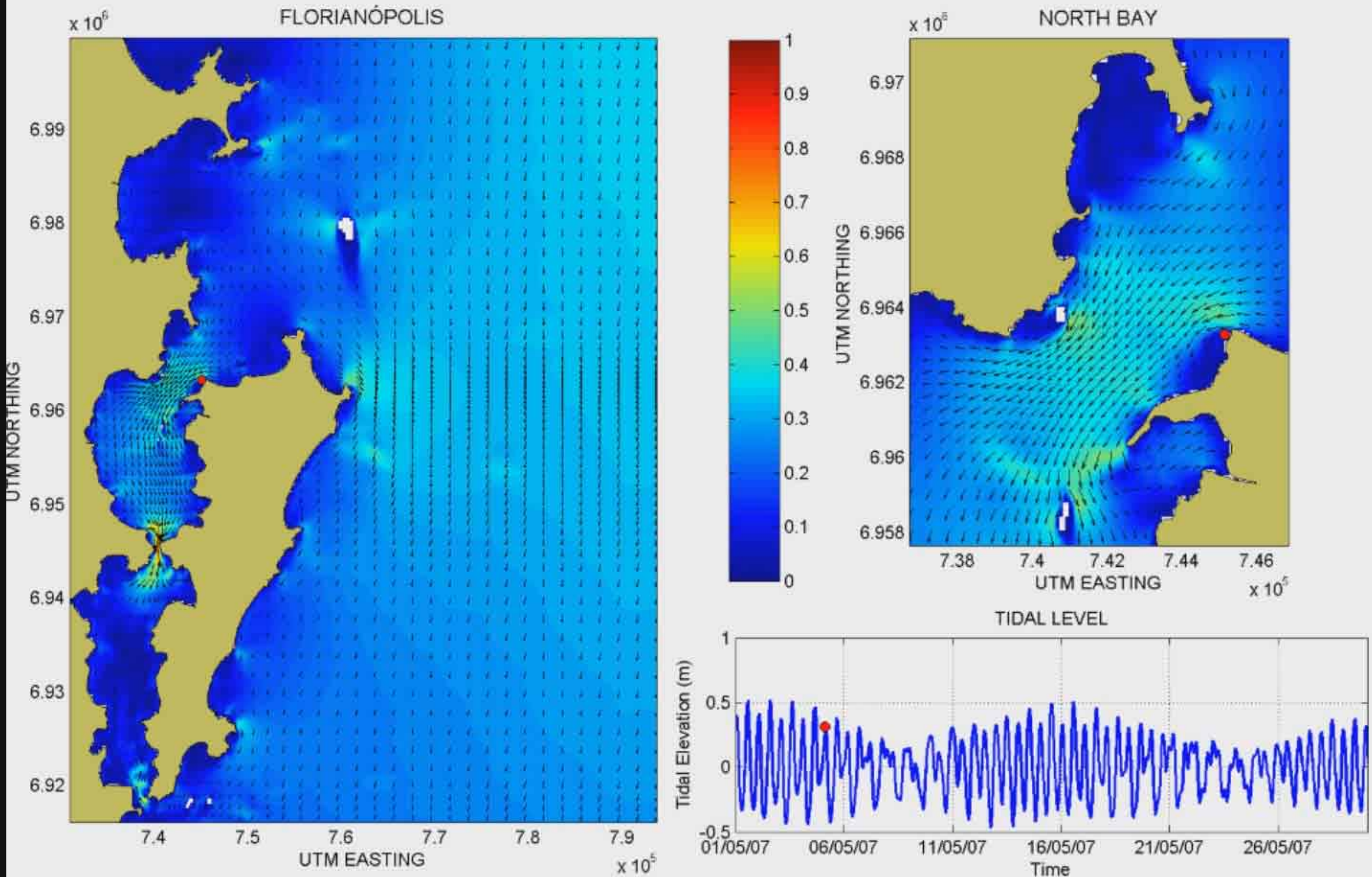
This is a critical question asked by the emergency responder during an oil spill. Knowing the trajectory of the spill gives decision-makers critical guidance in deciding how best to protect resources and direct cleanup.

OIL MODEL MAIN COMPONENTS



Need for Good Hydrodynamic Models





FLORIANÓPOLIS
x 10^6
6.99
6.98
6.97
6.96
6.95
6.94
6.93
6.92
UTM NORTHING
7.4
7.5
7.6
7.7
7.8
7.9
UTM EASTING
x 10^5
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
NORTH BAY
x 10^6
6.97
6.968
6.966
6.964
6.962
6.96
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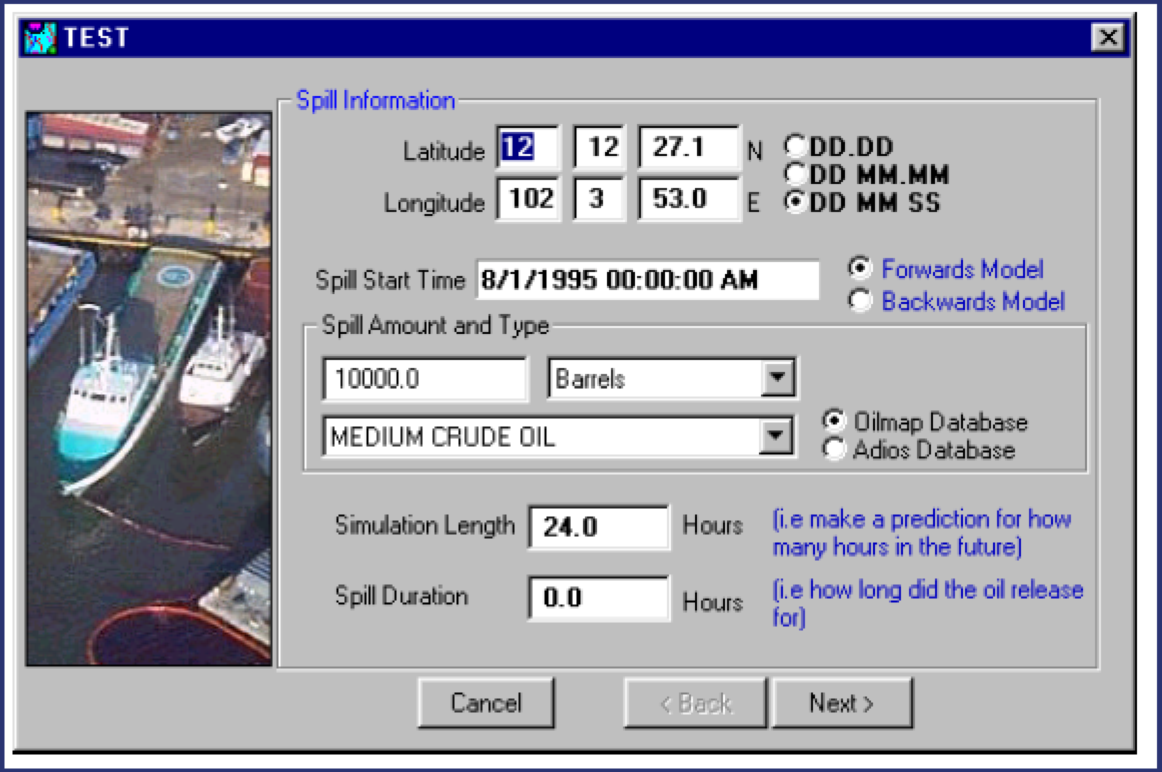
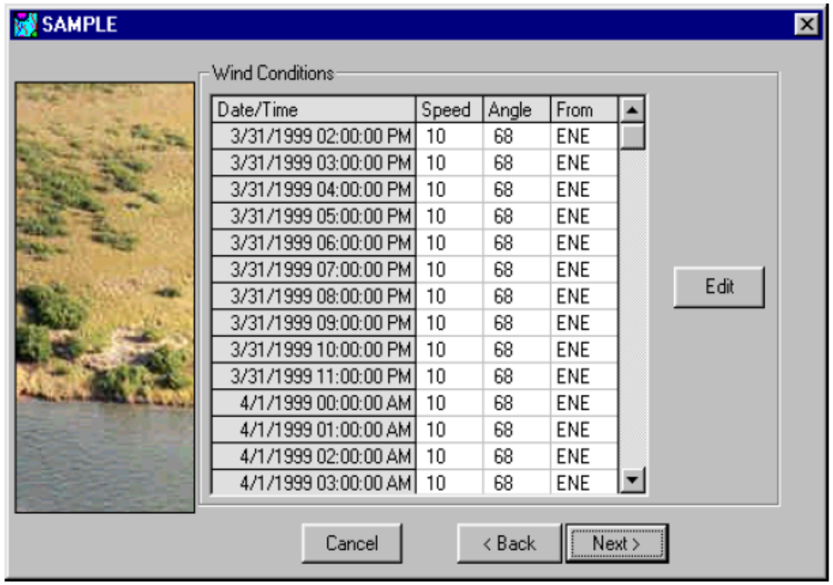
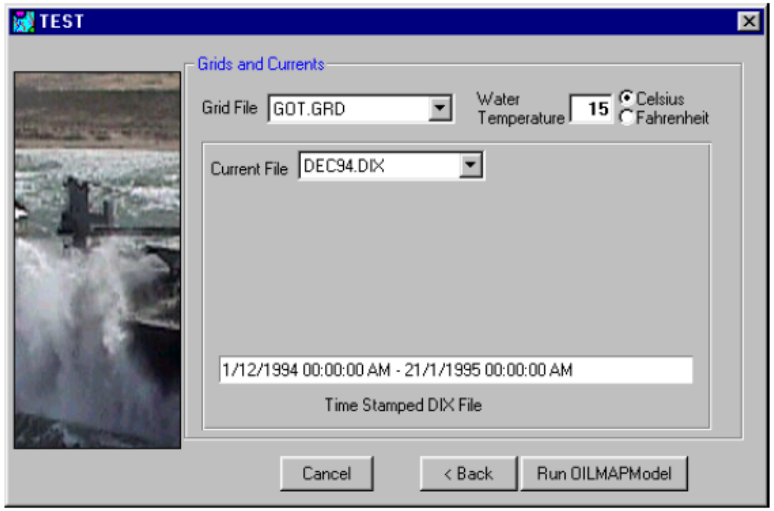
UTM NORTHING
7.38
7.4
7.42
7.44
7.46
UTM EASTING
x 10^5
TIDAL LEVEL
Tidal Elevation (m)
1
0.5
0
-0.5
01/05/07
06/05/07
11/05/07
16/05/07
21/05/07
26/05/07
Time

SPILL INFORMATION

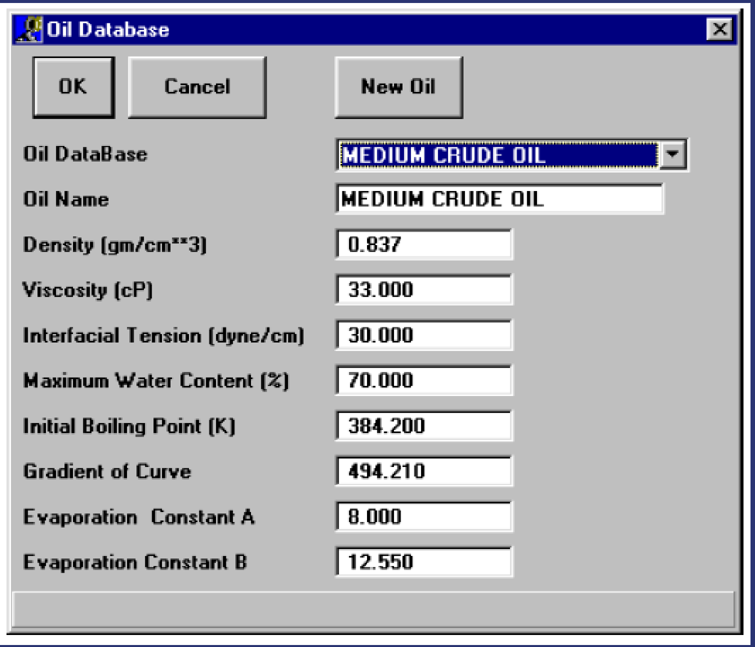


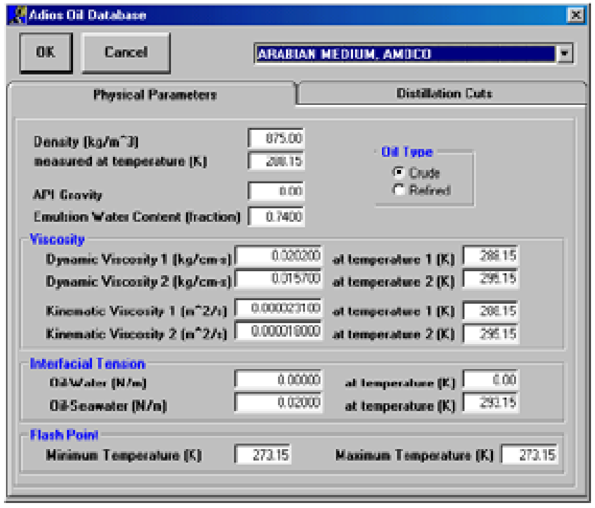
LOADING WIND AND CURRENT DATA

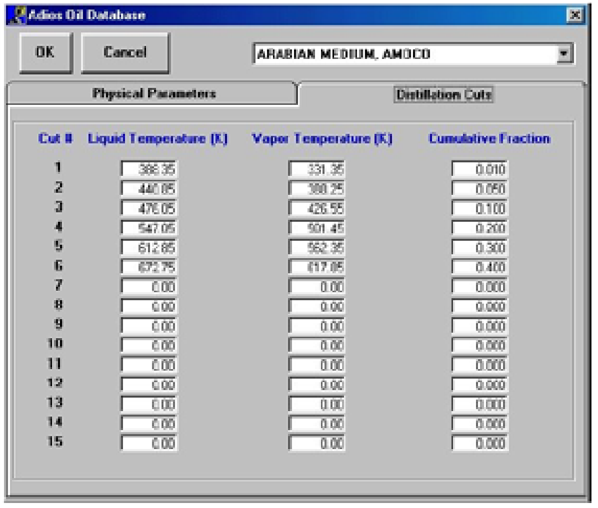




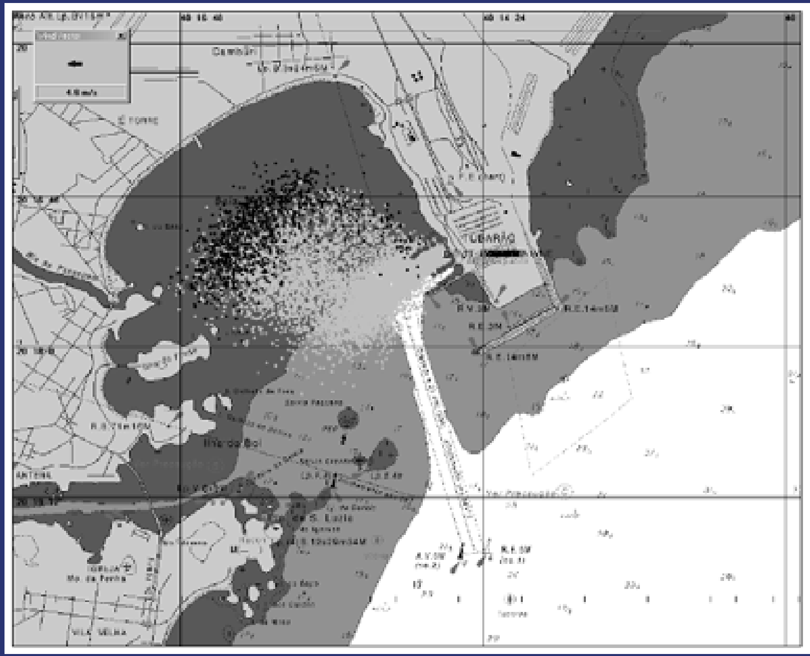
OIL DATABASE

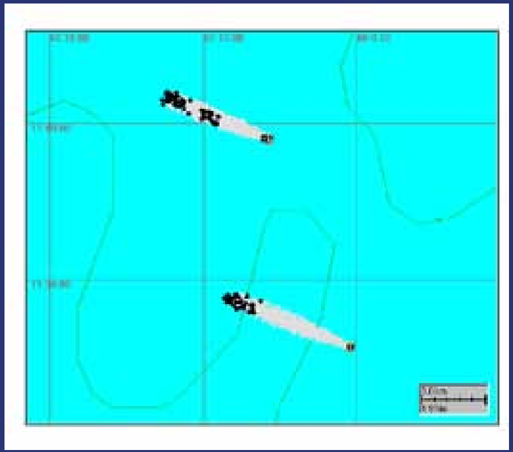




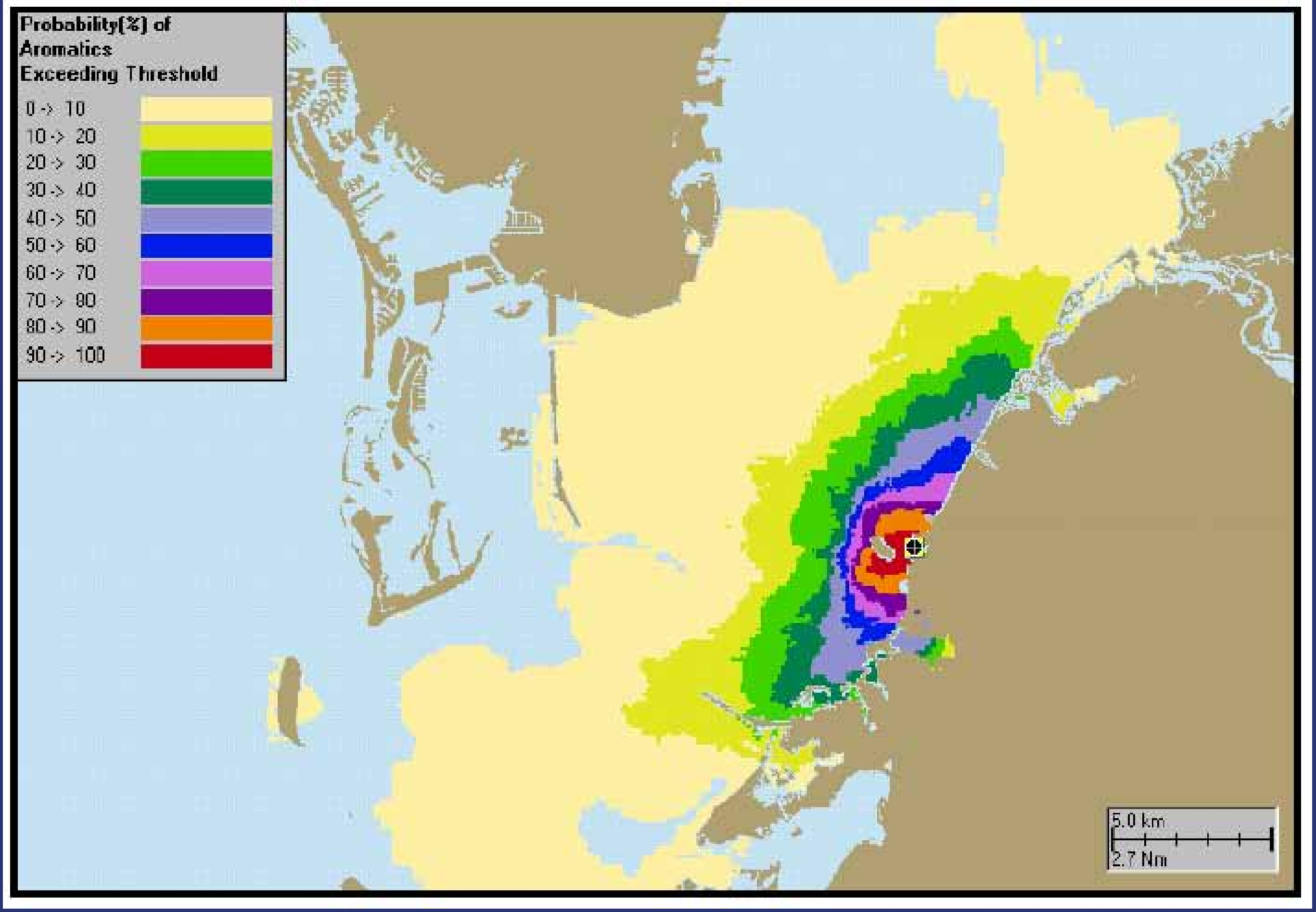


DETERMINISTIC SCENARIO





STOCHASTIC SCENARIO
500 SIMULATIONS STARTING RANDOMLY ALONG THE WIND RECORD



STUDY AREA – FLORIANÓPOLIS SOUTH BRAZIL

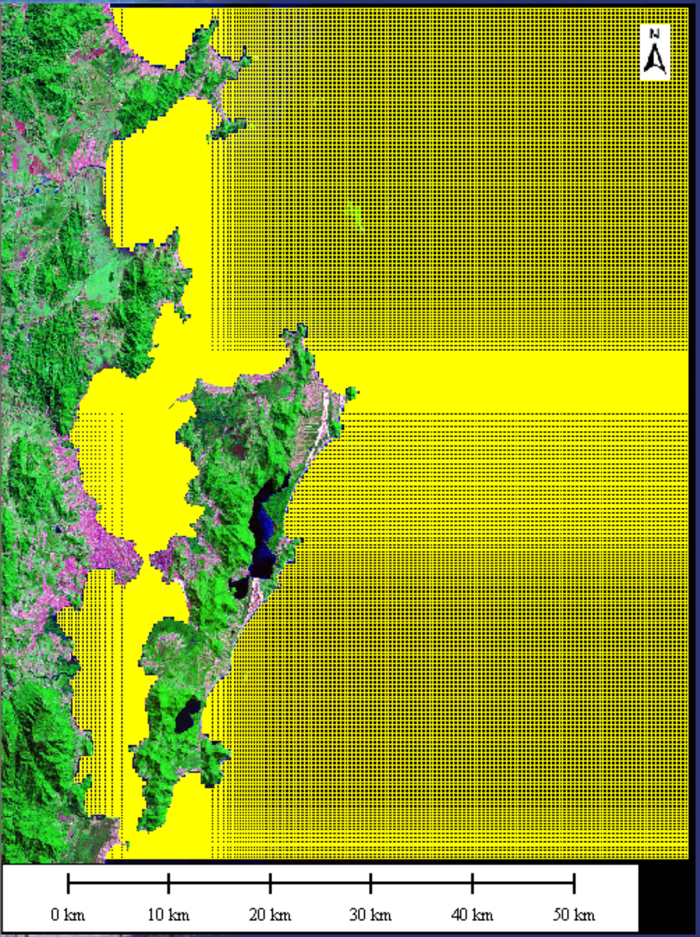
Study Area – Florianópolis

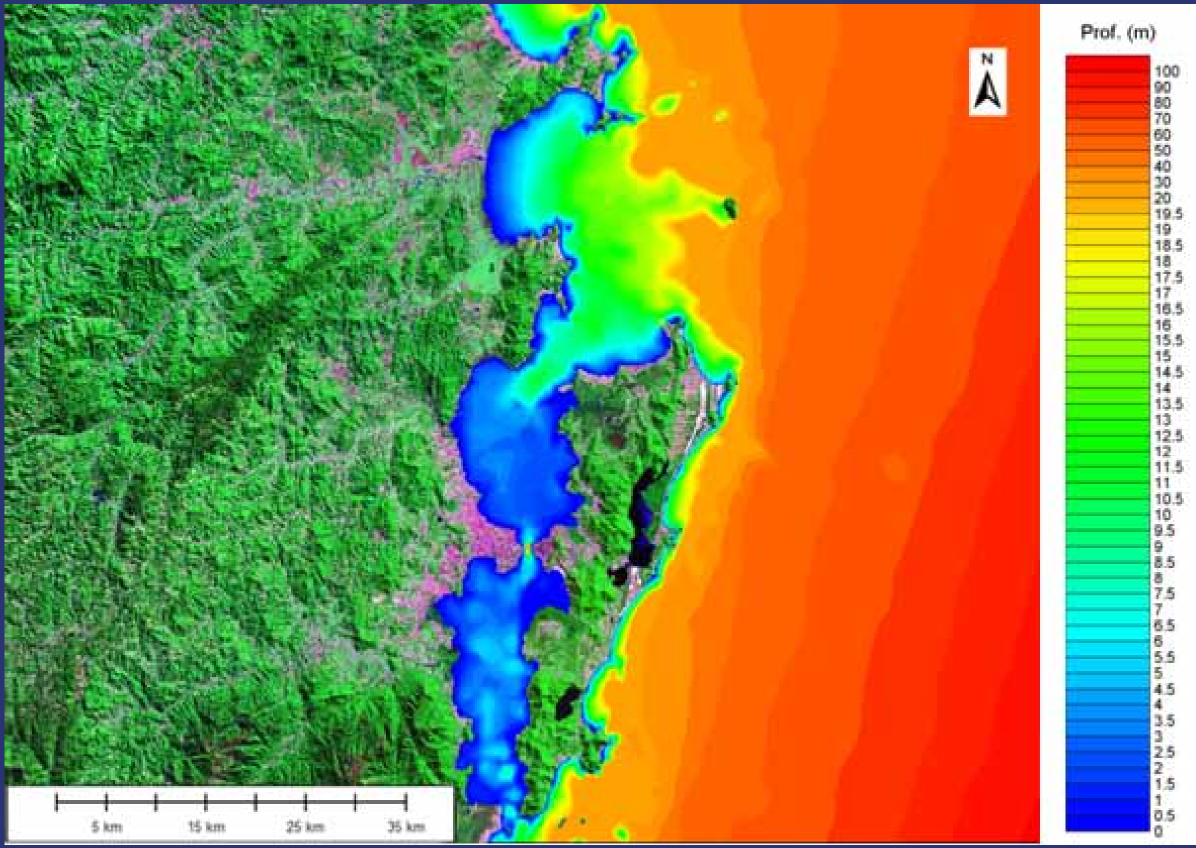
Large investment, development, thousands of new jobs

&

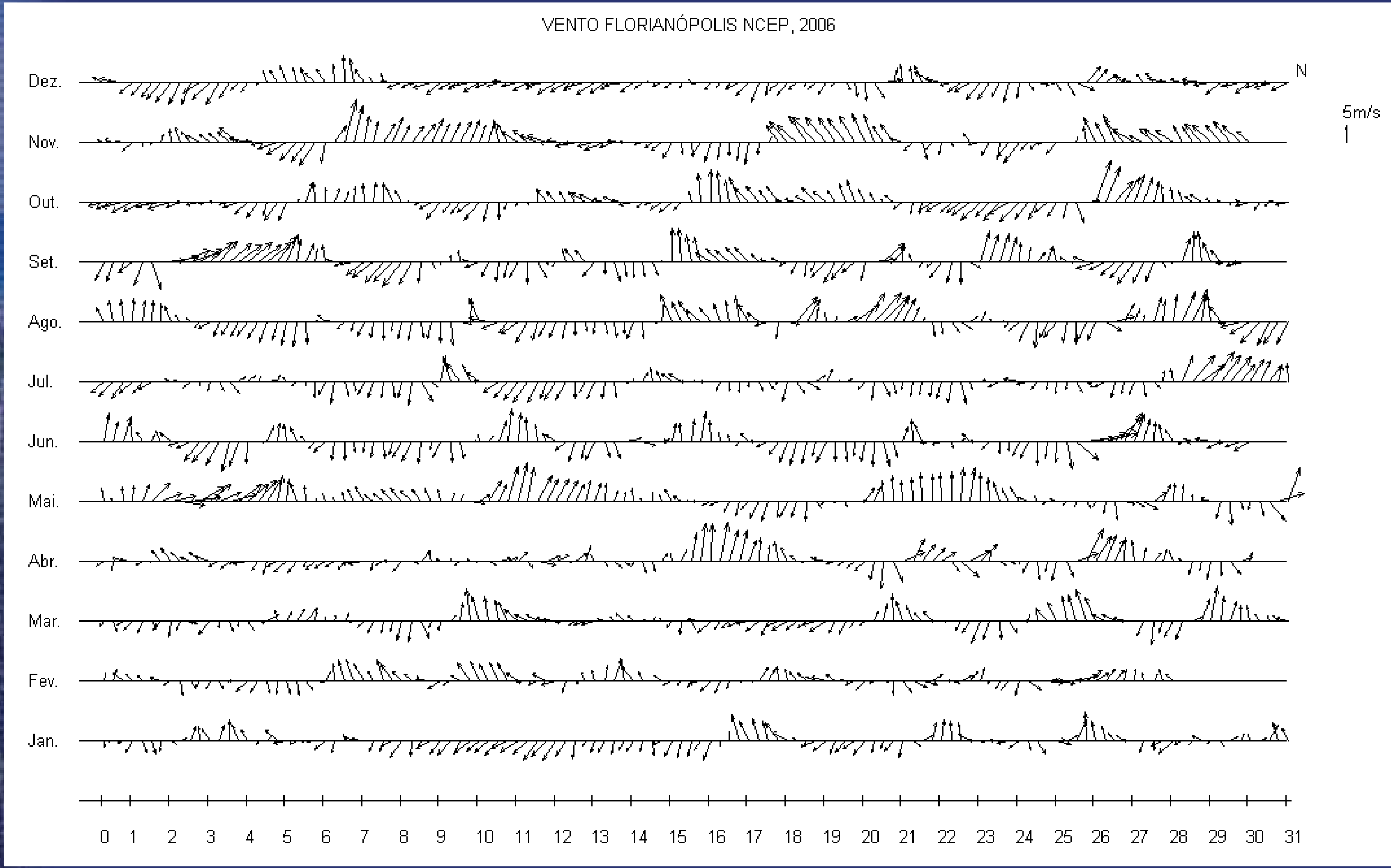
Environmental Sensitive Areas & Hyper-Active Tourism Industry

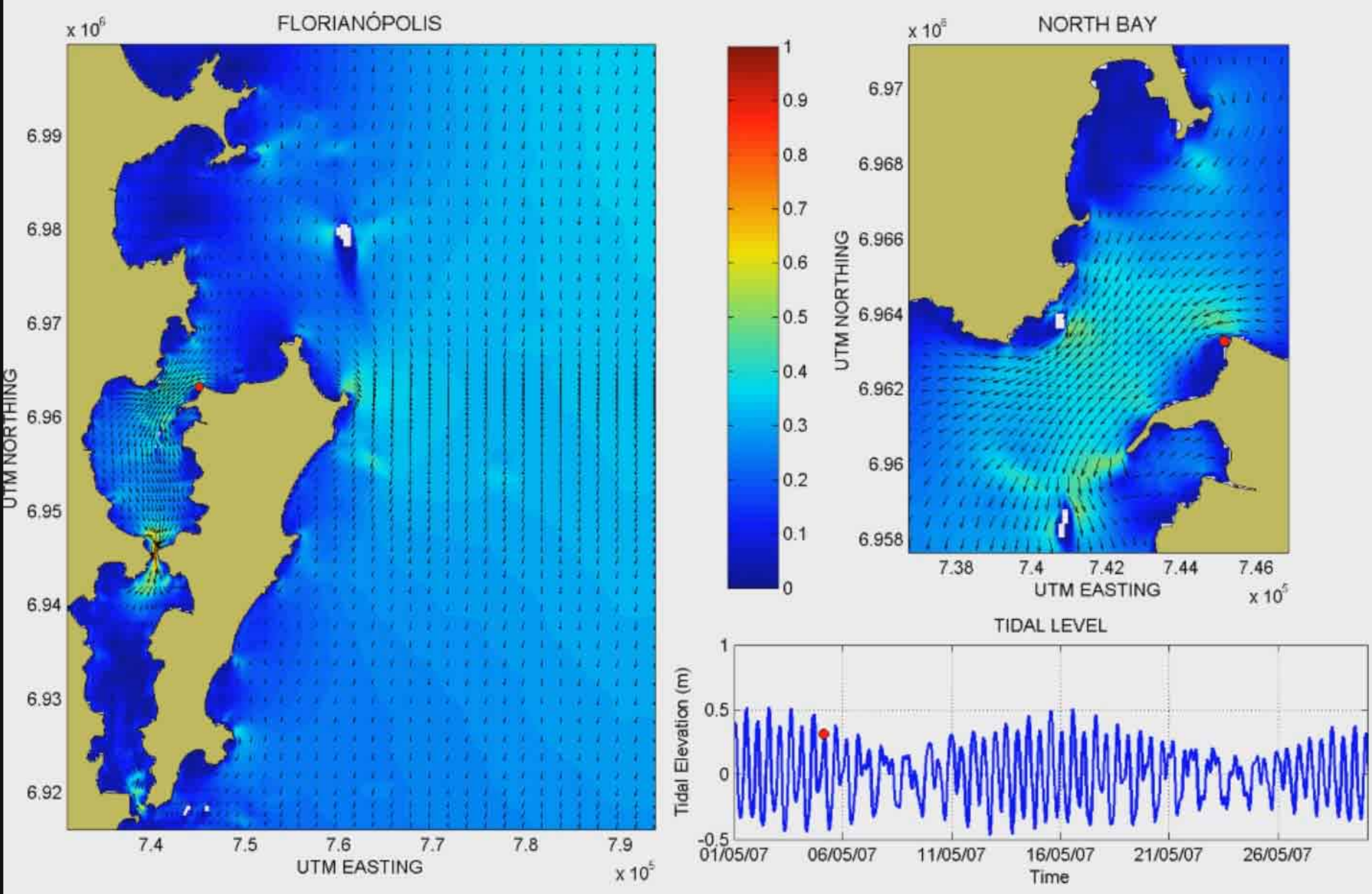
HYDRODINAMIC GRID AND LOCAL BATHYMETRY





WIND DATA ANALYSIS





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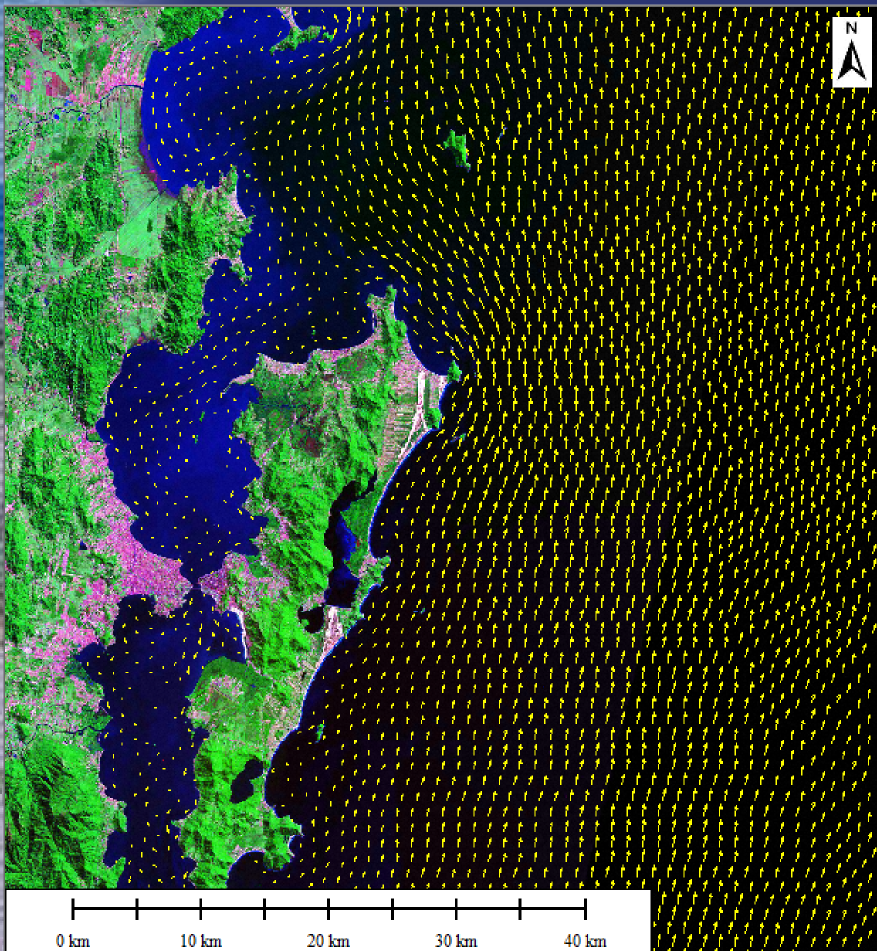
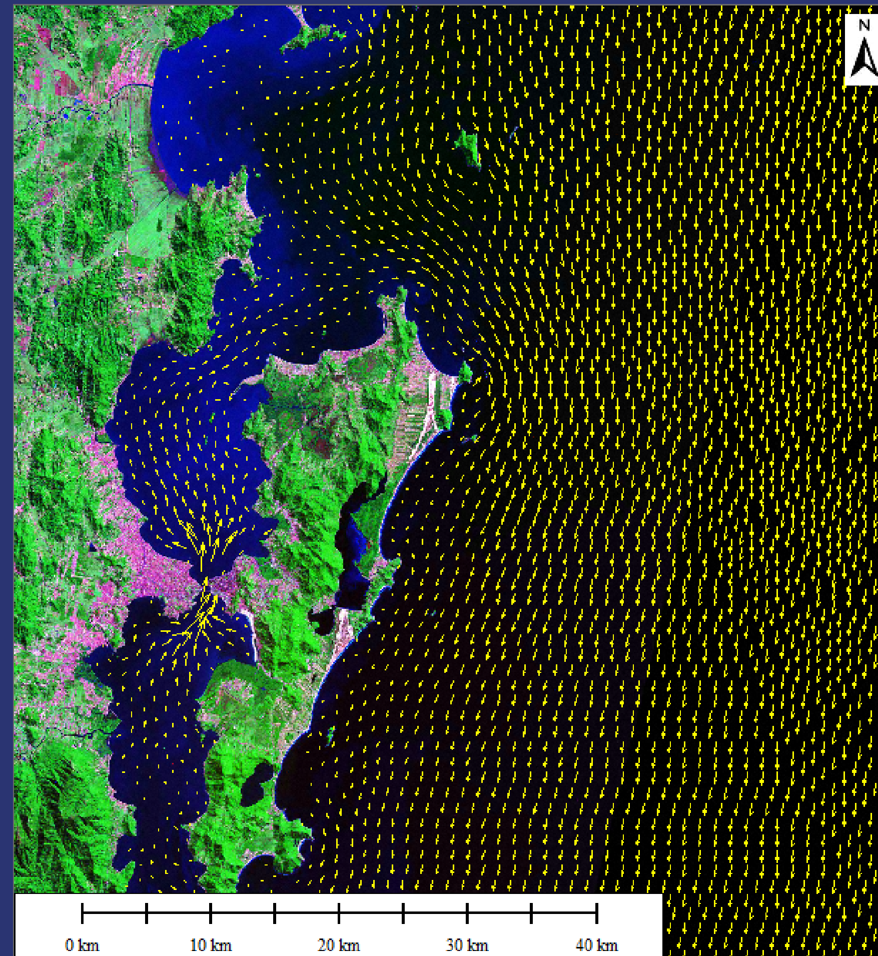
26/05/07
Time

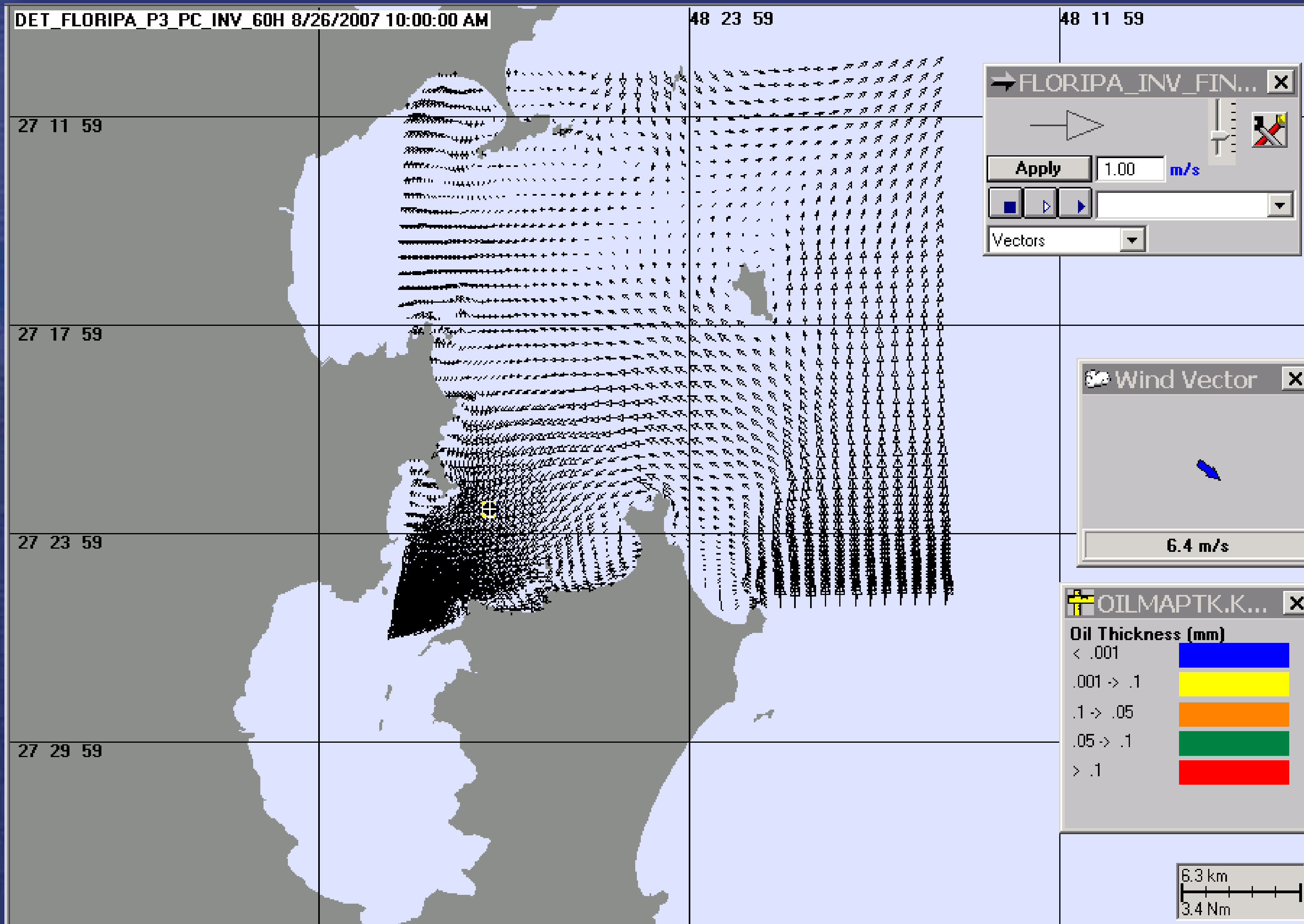
- 3 MONTH SEASONAL CURRENT FIELD WINTER AND SUMMER PATTERN
- 450 Runs for Each Probilistic Output



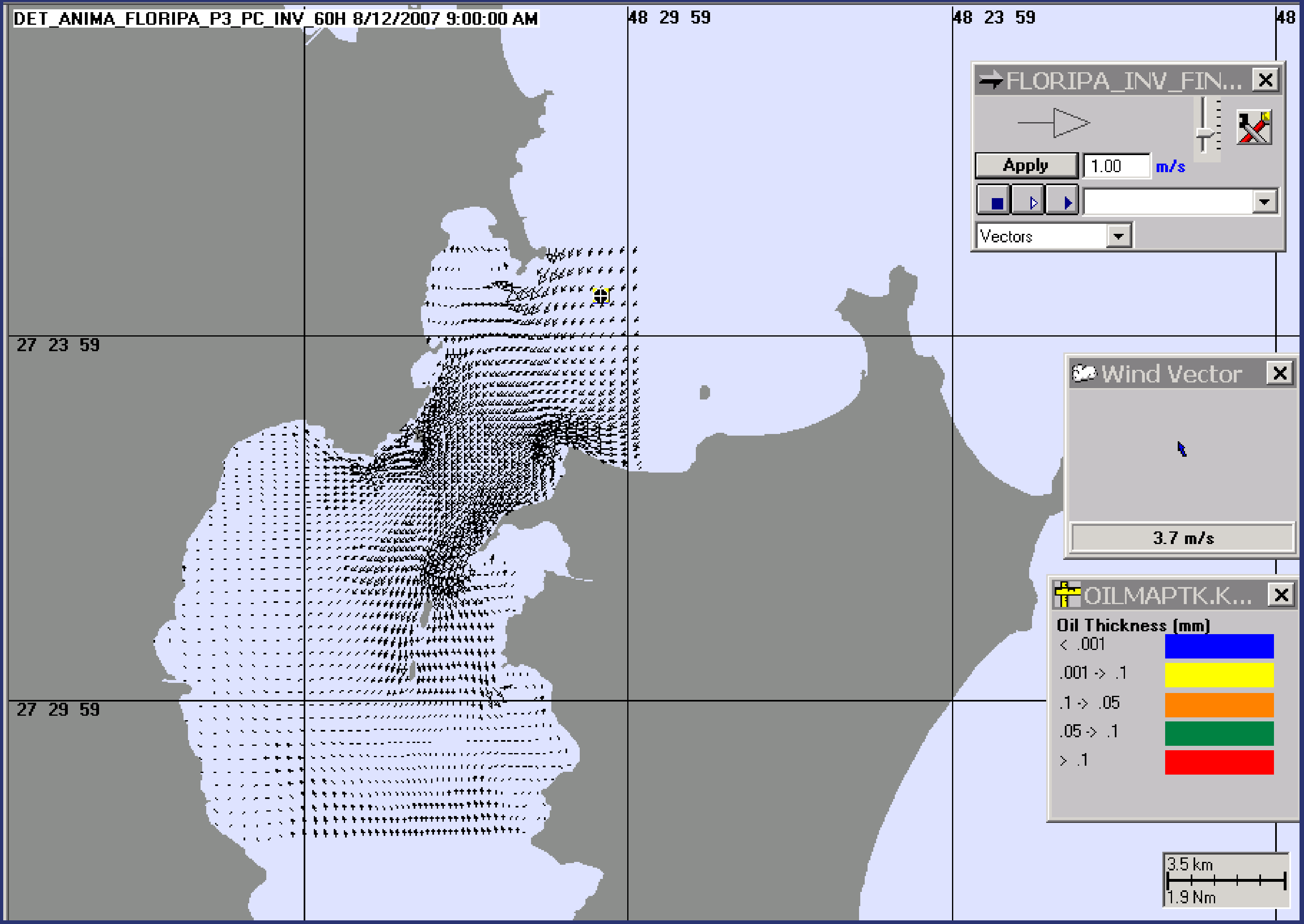


SPILL SITE SELECTED FROM LOCAL OPERATIONS

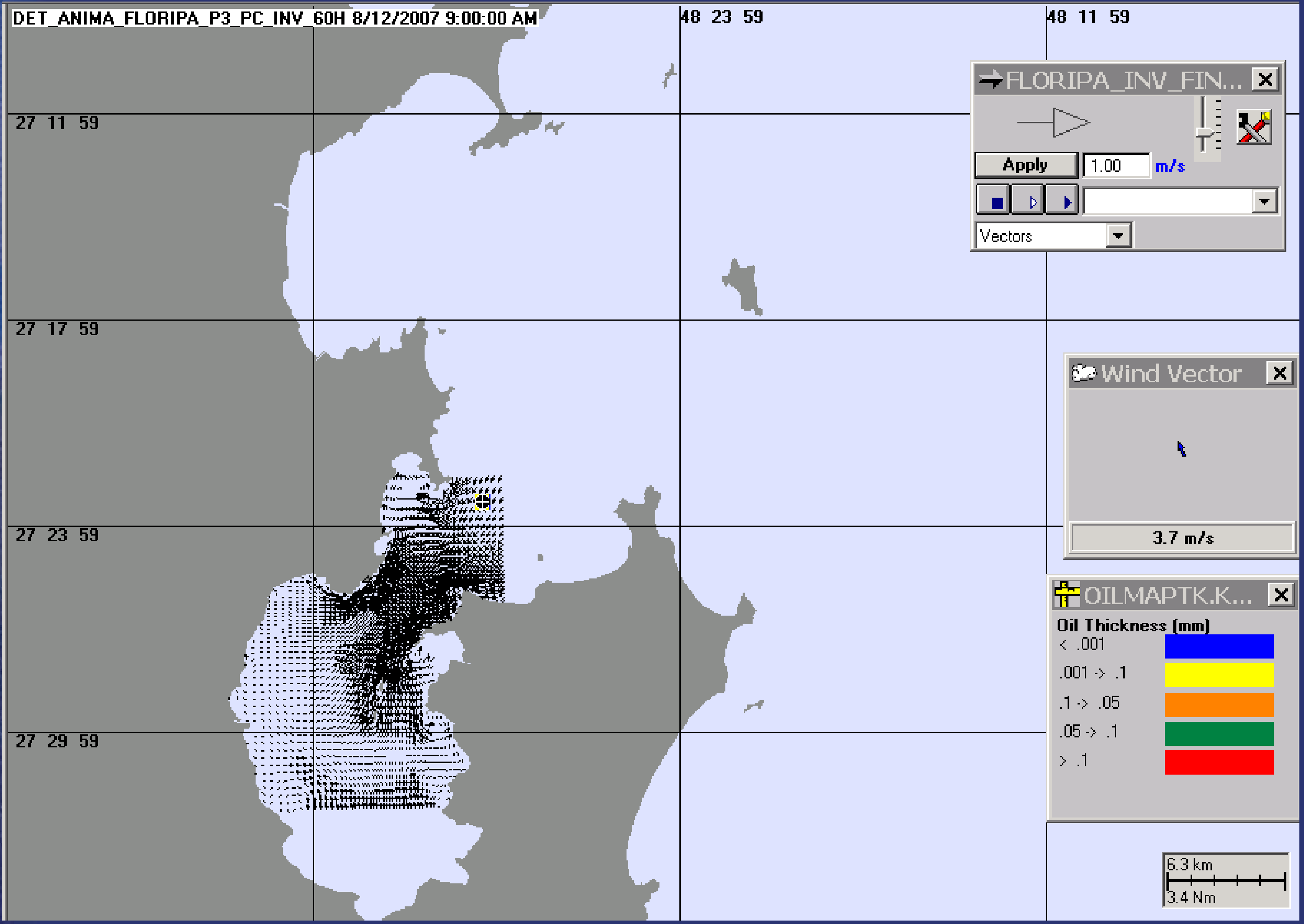
OIL THICKNESS EVOLUTION – SW WIND



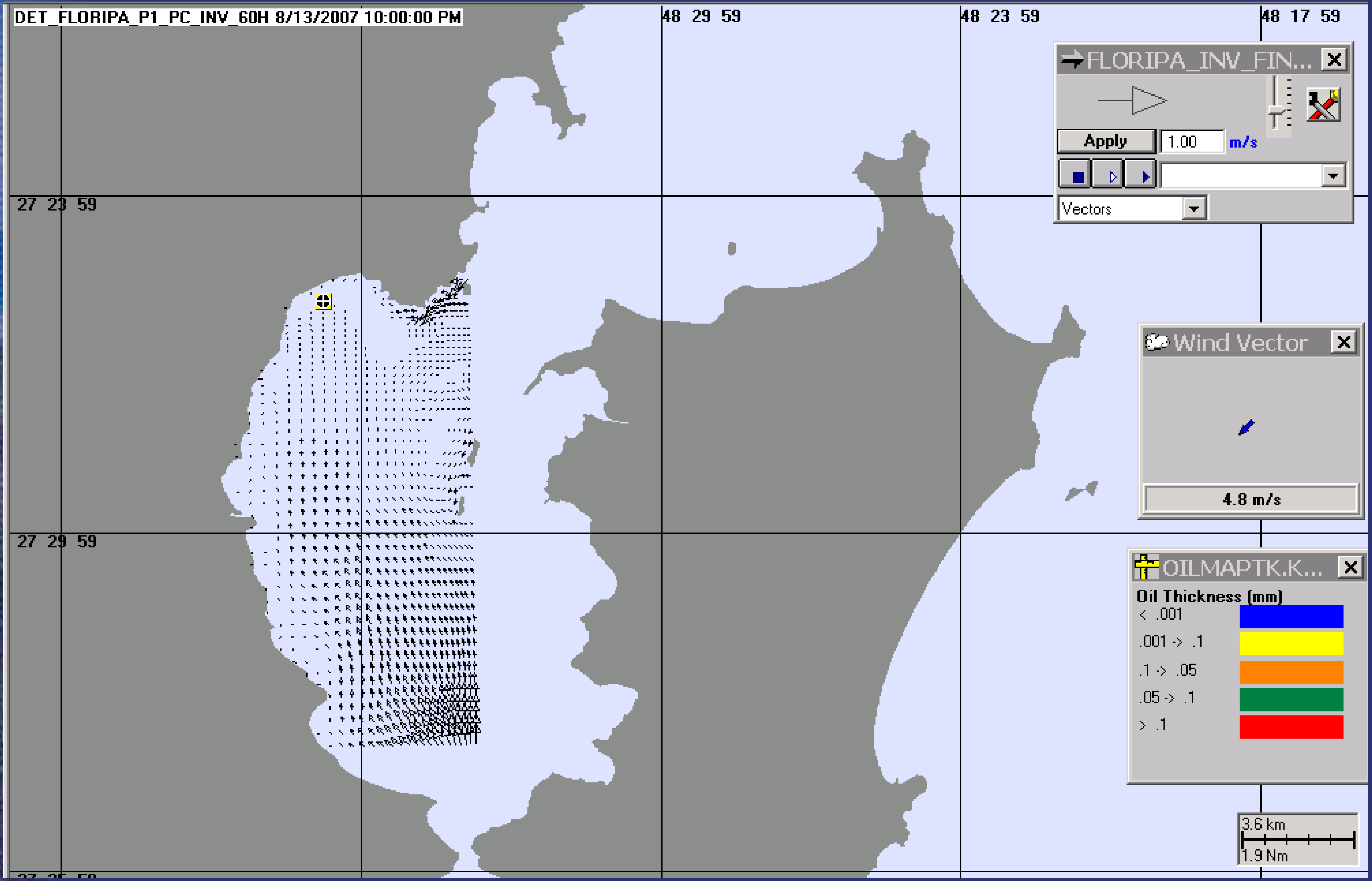
OIL THICKNESS EVOLUTION – P3-INV



OIL THICKNESS EVOLUTION – NE WIND

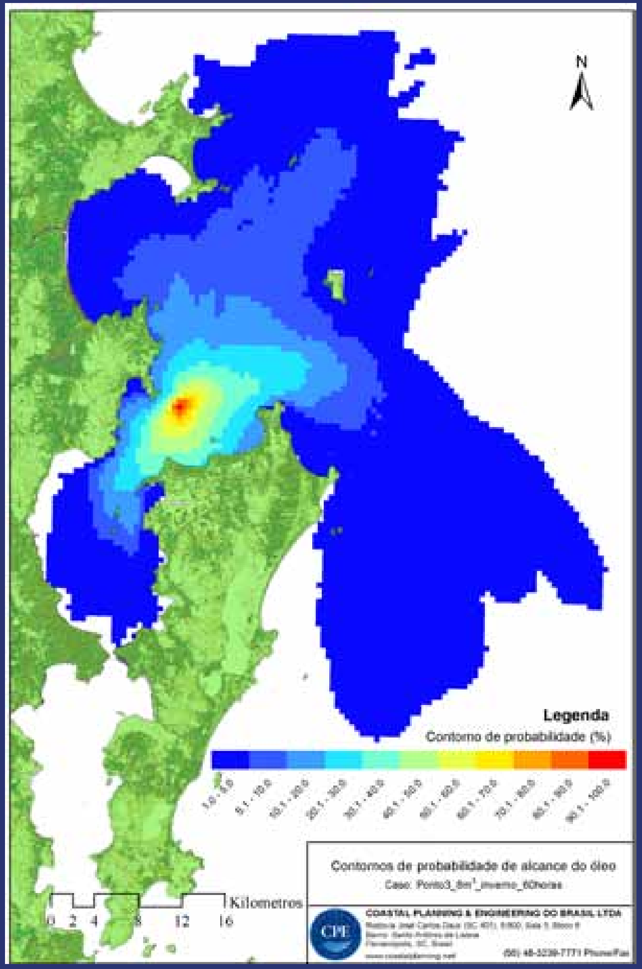


OIL ASHORE- P1

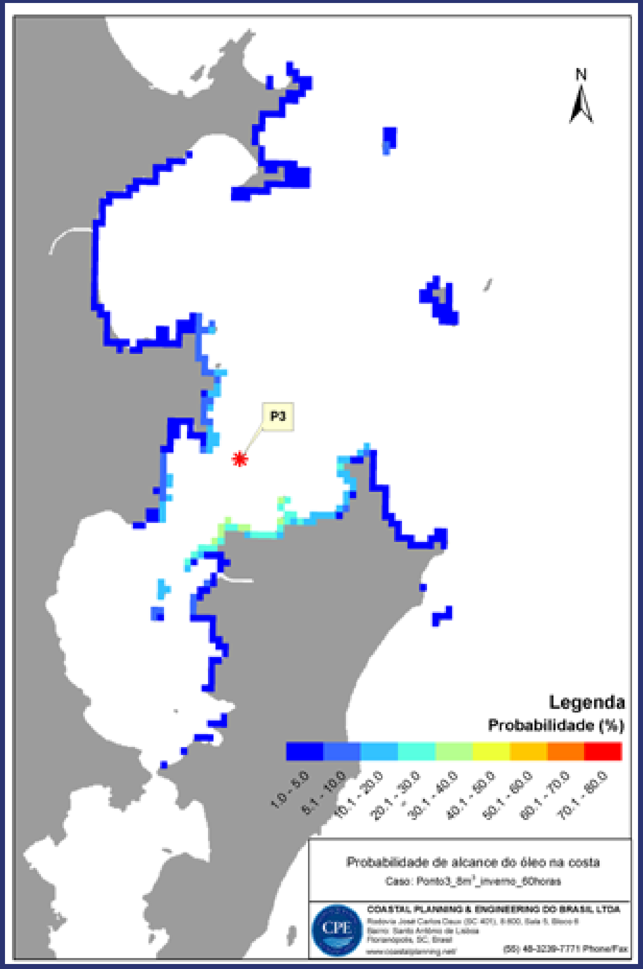


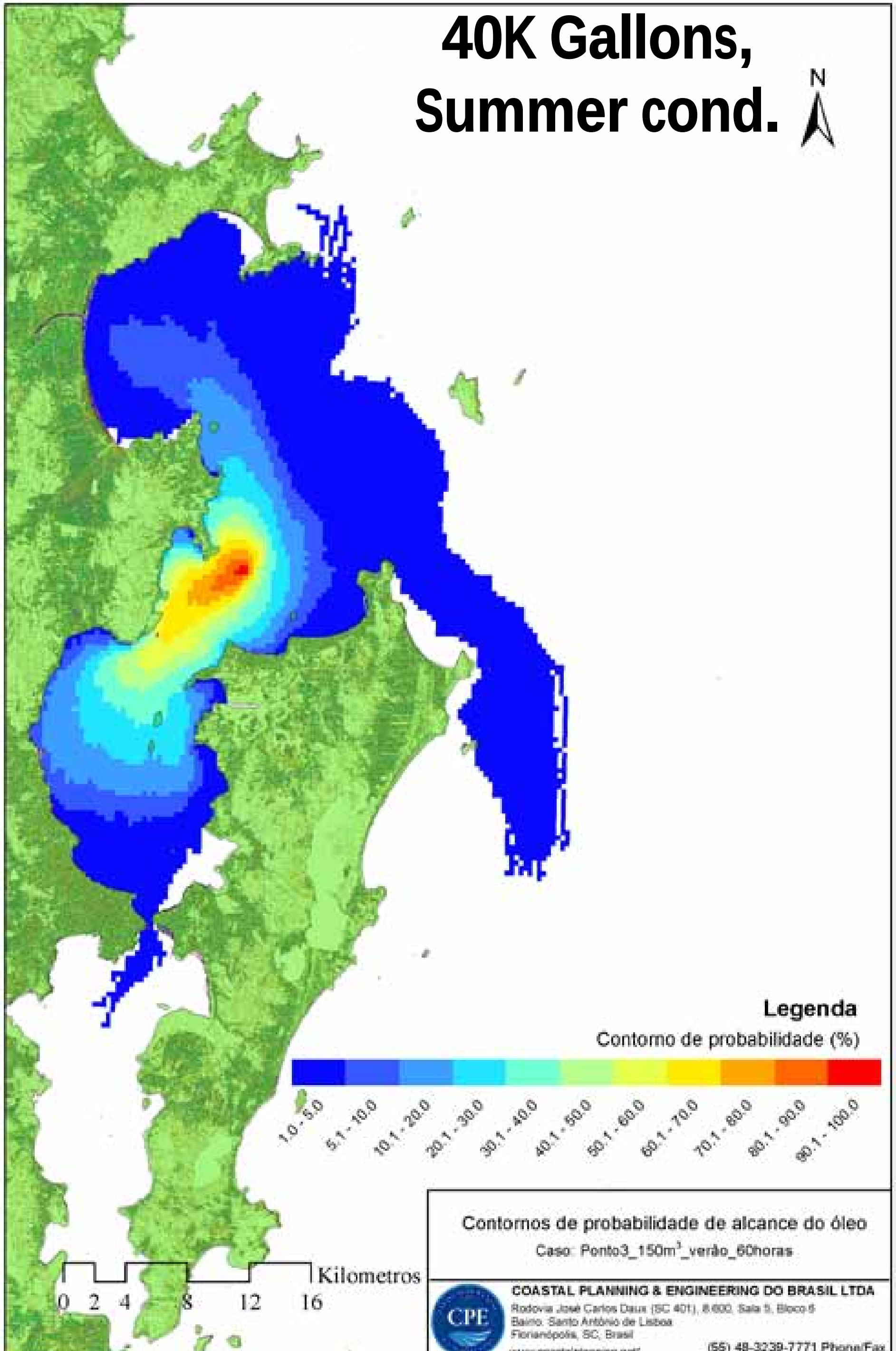
Stochastic Model Outputs

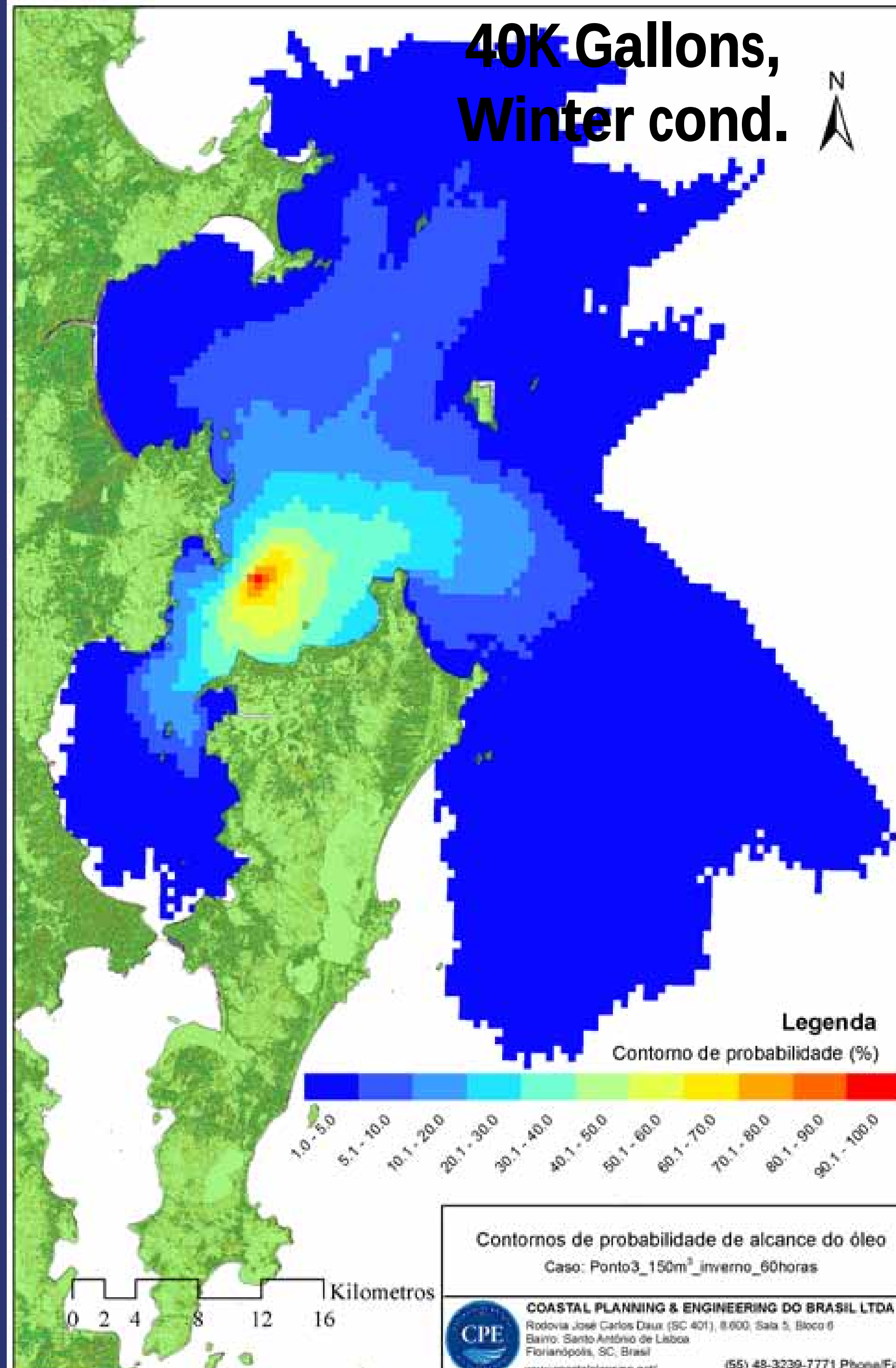
Water Probability



Shore Probability




40K Gallons,
Summer cond.
N
Legenda
Contorno de probabilidade (%)
1.0 - 5.0
5.1 - 10.0
10.1 - 20.0
20.1 - 30.0
30.1 - 40.0
40.1 - 50.0
50.1 - 60.0
60.1 - 70.0
70.1 - 80.0
80.1 - 90.0
90.1 - 100.0
Contornos de probabilidade de alcance do óleo
Caso: Ponto3_150m³_verão_60horas
Kilometros
0 2 4 8 12 16
CPE
COASTAL PLANNING & ENGINEERING DO BRASIL LTDA
Rodovia José Carlos Daux (SC 401), 8.600, Sala 5, Bloco 6
Bairro: Santo Antônio de Lisboa
Florianópolis, SC, Brasil
www.coastalplanning.net/
(55) 48-3239-7771 Phone/Fax


40K Gallons,
Winter cond.
N
Legenda
Contorno de probabilidade (%)
1.0 - 5.0
5.1 - 10.0
10.1 - 20.0
20.1 - 30.0
30.1 - 40.0
40.1 - 50.0
50.1 - 60.0
60.1 - 70.0
70.1 - 80.0
80.1 - 90.0
90.1 - 100.0
Contornos de probabilidade de alcance do óleo
Caso: Ponto3_150m³_inverno_60horas
Kilometros
0 2 4 8 12 16
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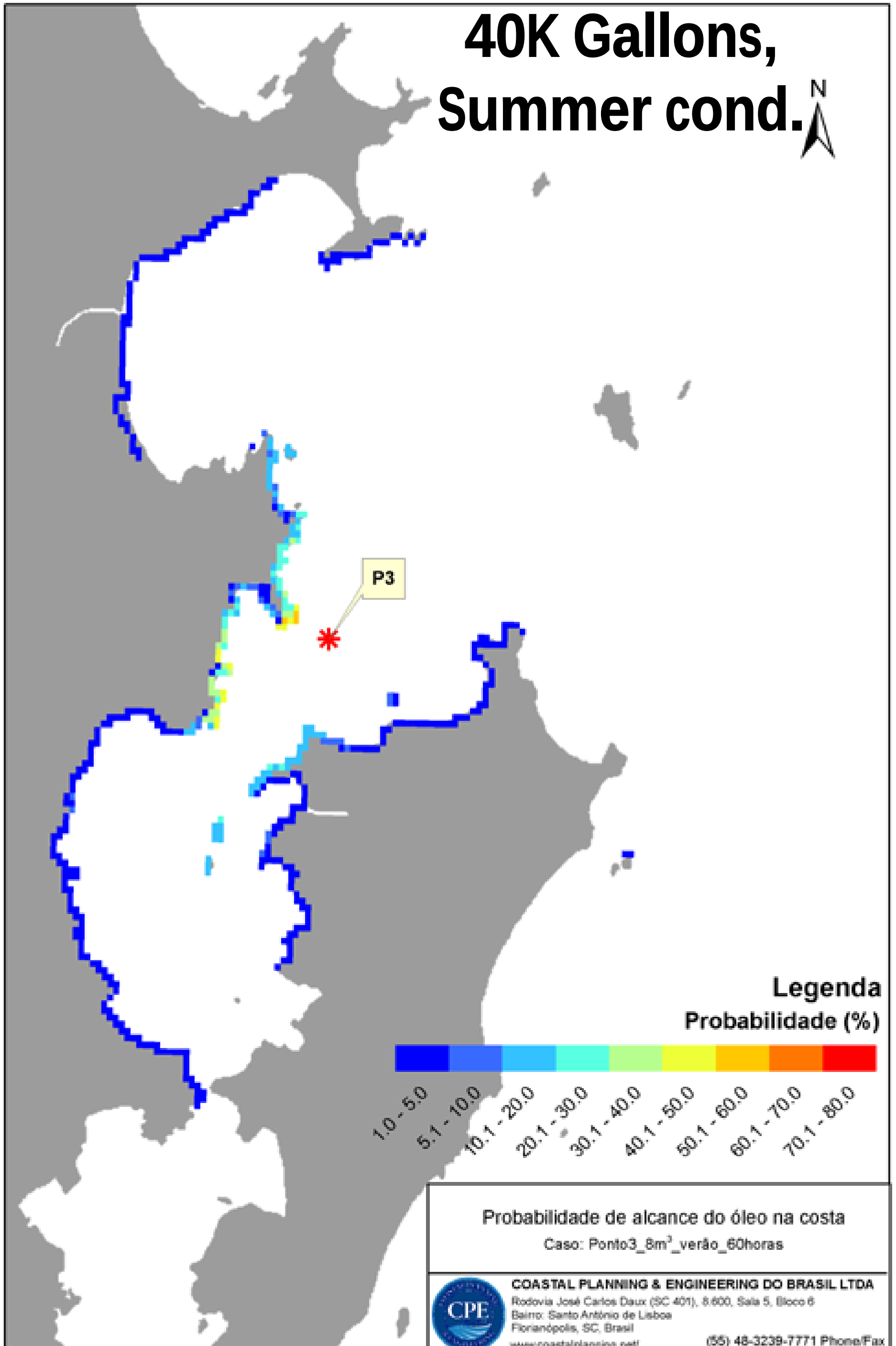

40K Gallons,
Summer cond.
N
P3
Legenda
Probabilidade (%)
1.0 - 5.0
5.1 - 10.0
10.1 - 20.0
20.1 - 30.0
30.1 - 40.0
40.1 - 50.0
50.1 - 60.0
60.1 - 70.0
70.1 - 80.0
Probabilidade de alcance do óleo na costa
Caso: Ponto3_8m³_verão_60horas
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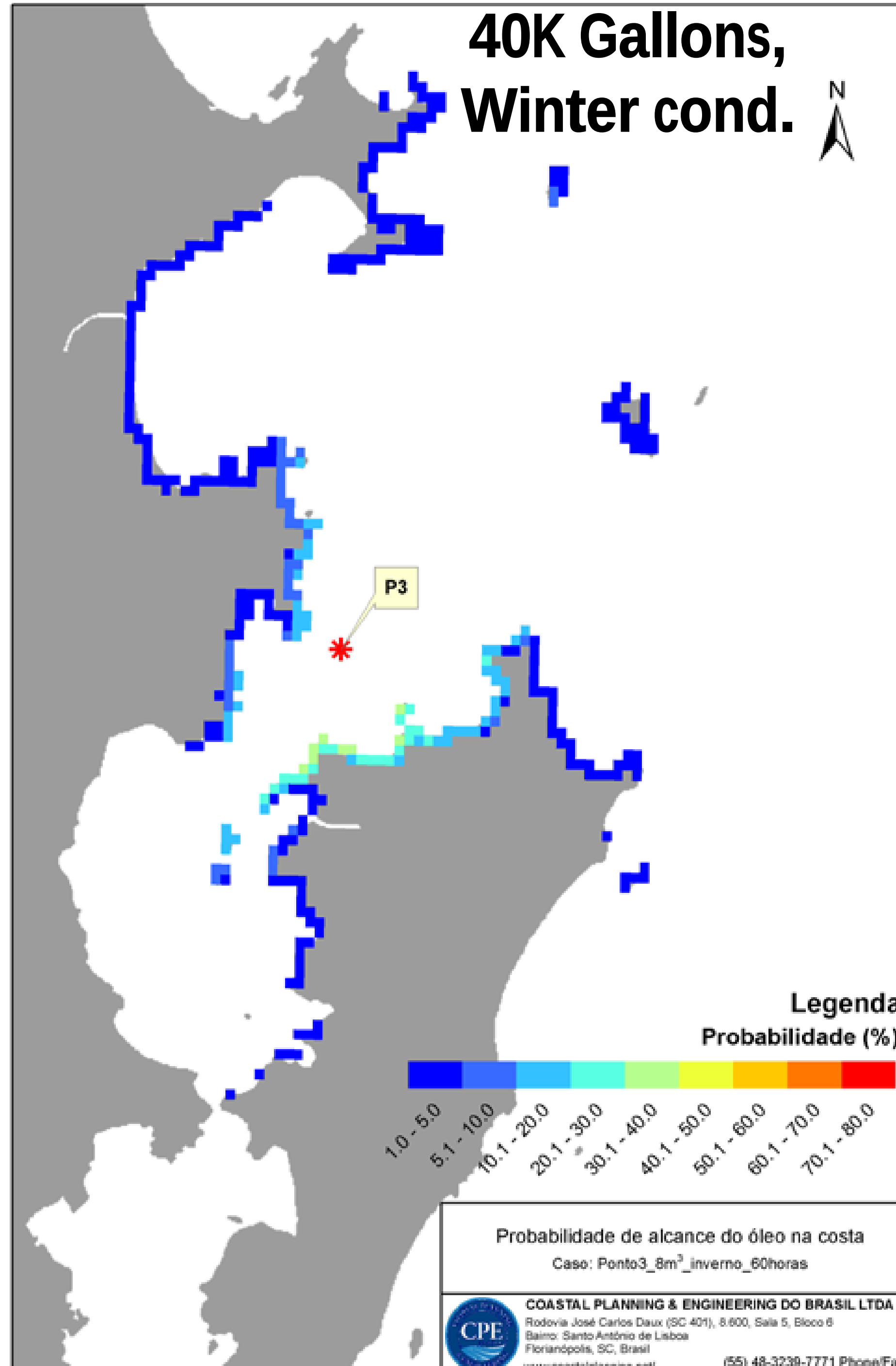

40K Gallons,
Winter cond.
N
P3
Legenda
Probabilidade (%)
1.0 - 5.0
5.1 - 10.0
10.1 - 20.0
20.1 - 30.0
30.1 - 40.0
40.1 - 50.0
50.1 - 60.0
60.1 - 70.0
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Probabilidade de alcance do óleo na costa
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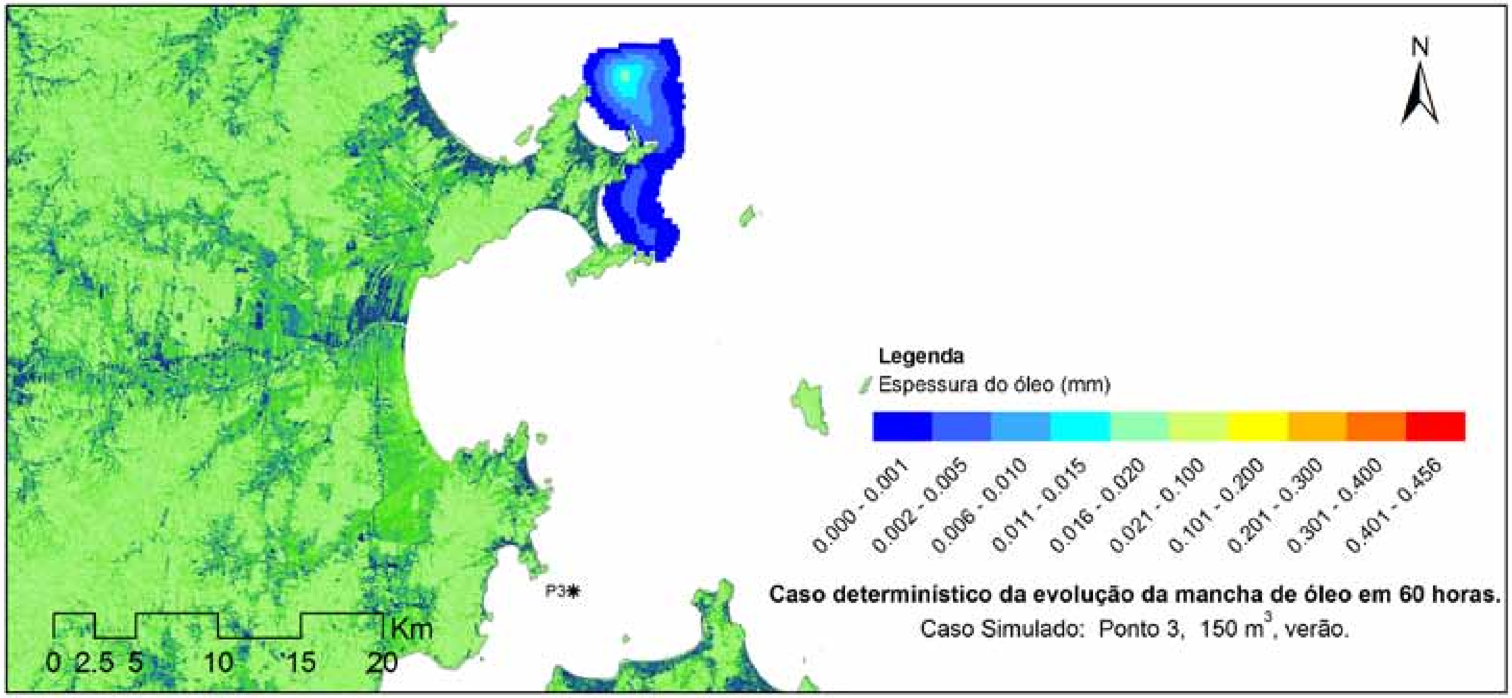
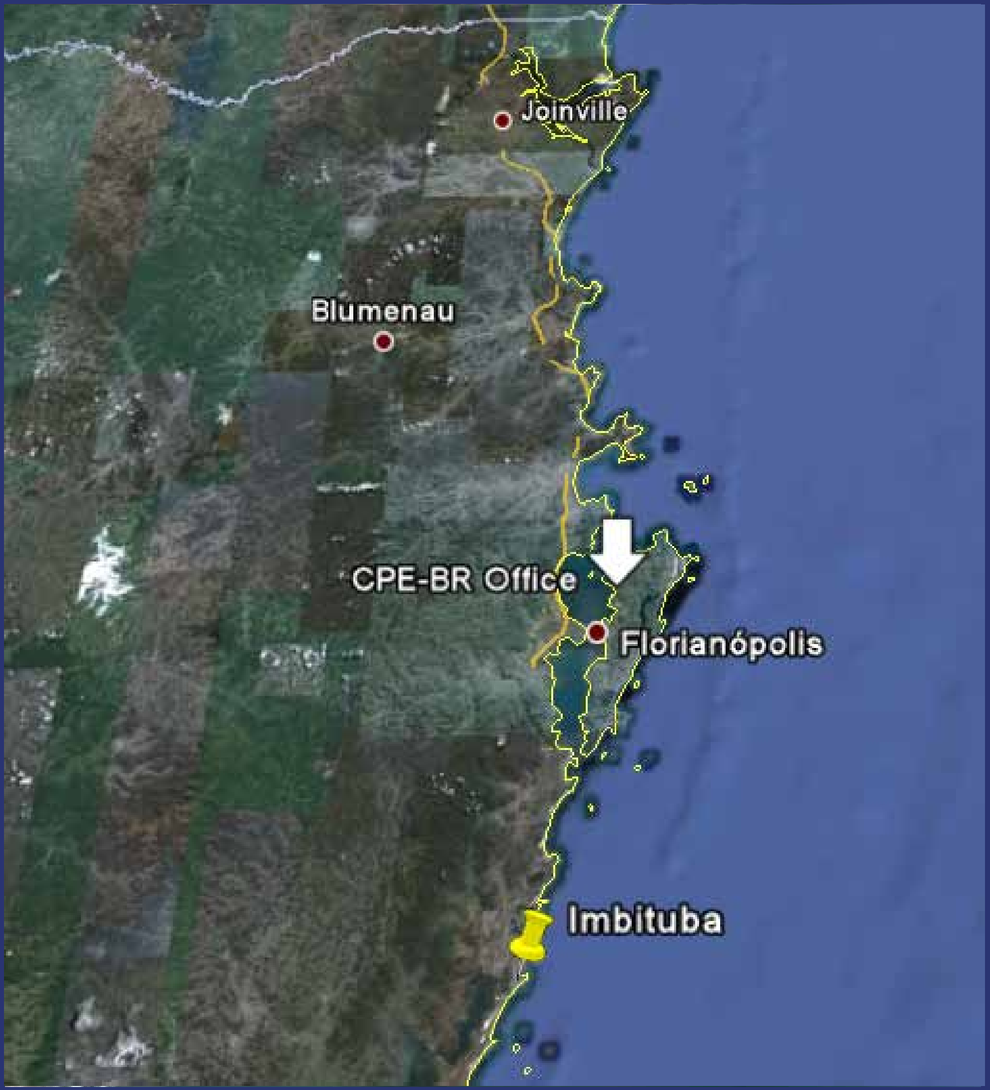
DETERMINISTIC MODULE FOR THE WORST CASE SCENARIO



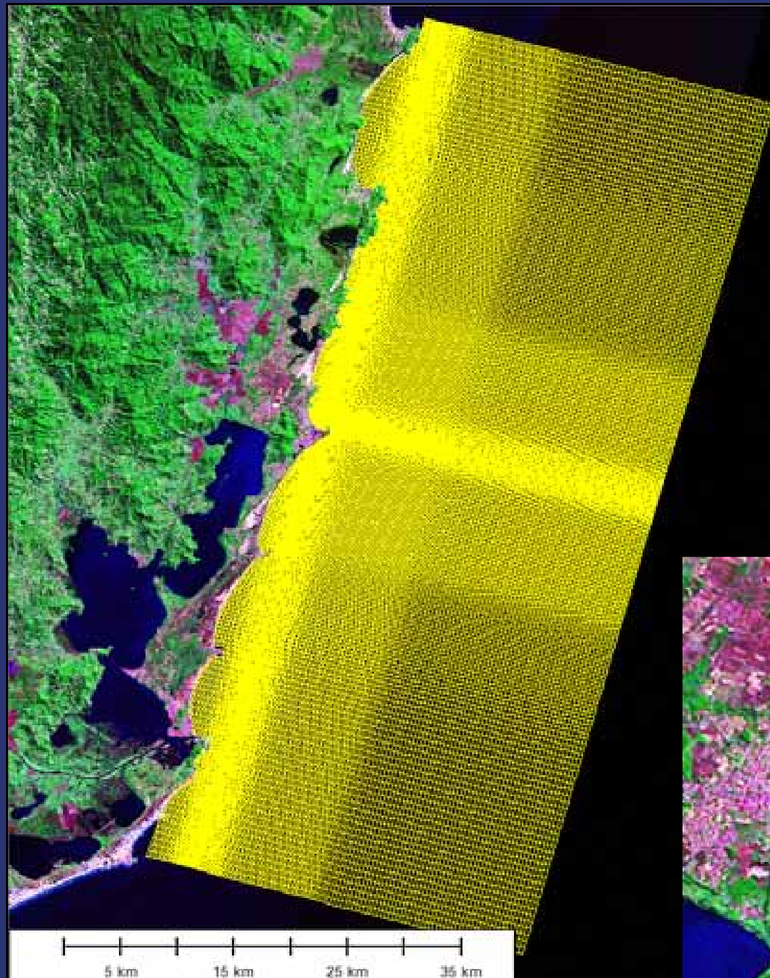
Caso determinístico da evolução da mancha de óleo em 60 horas.
Caso Simulado: Ponto 3, 150 m^3, verão.

STUDY AREA – PORT OF IMBITUBA SOUTH BRAZIL

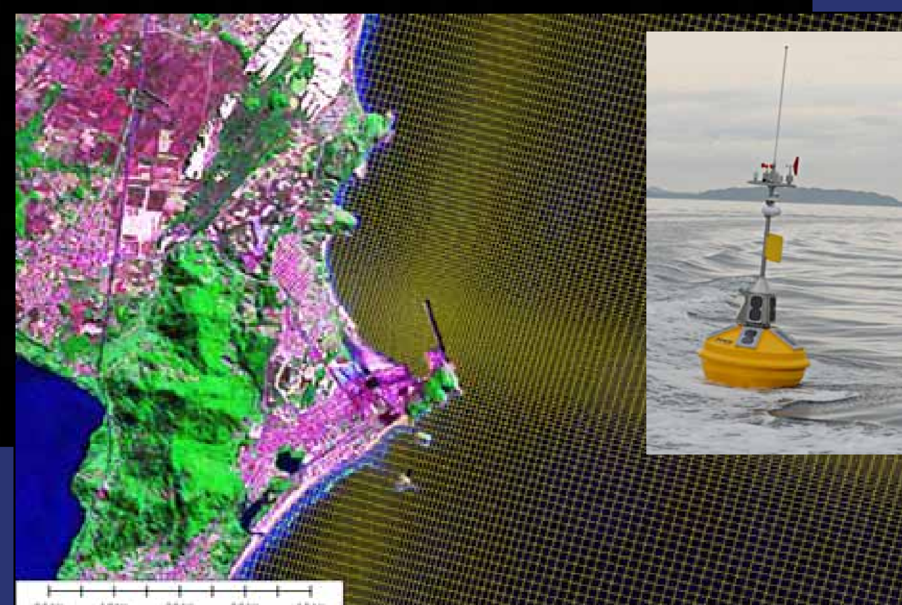


STUDY AREA – PORT OF IMBITUBA SOUTH BRAZIL

HYDRODINAMIC GRID

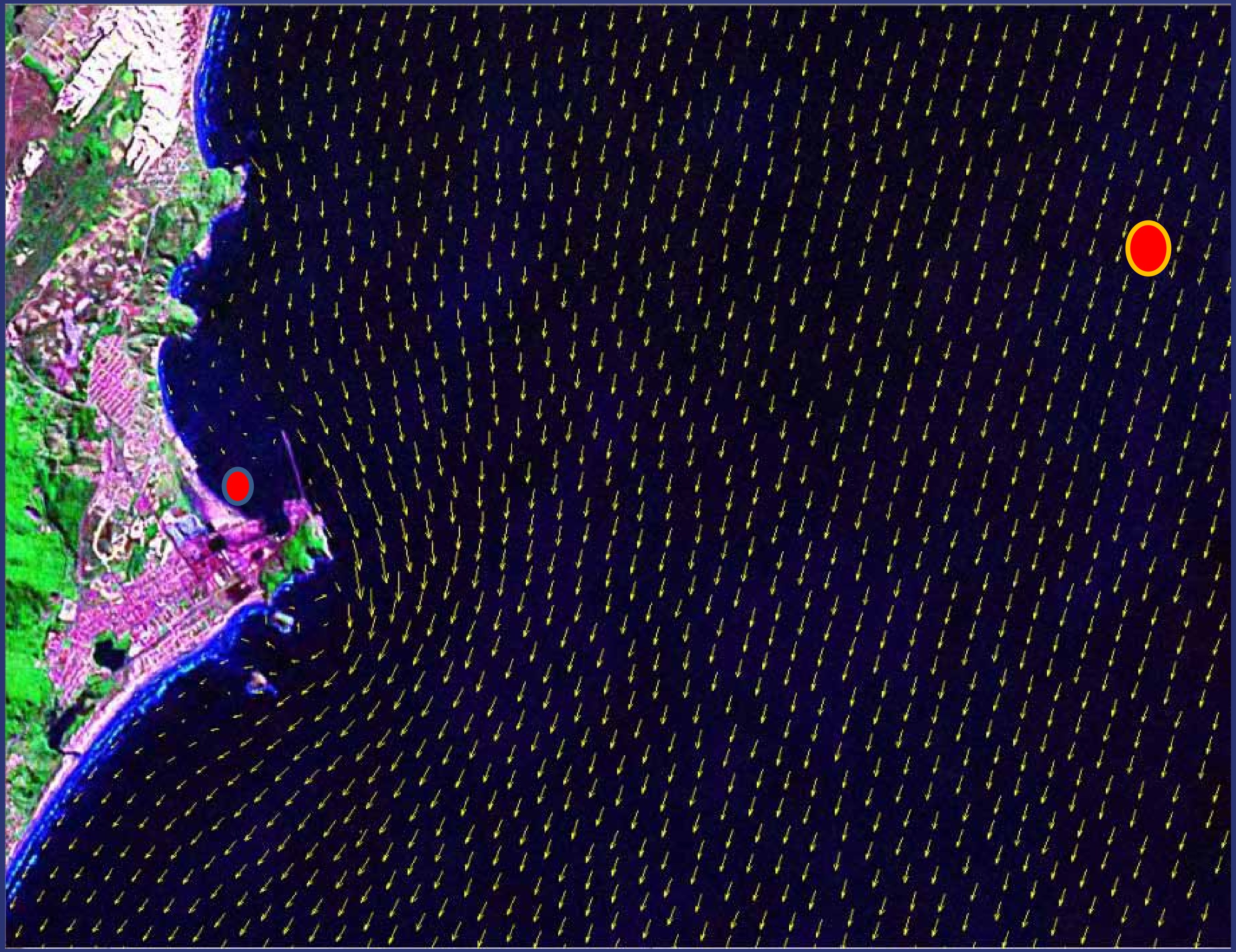


-Wind database
- Tide database
- Wave Database
- 3 month simulations to feed into oil model

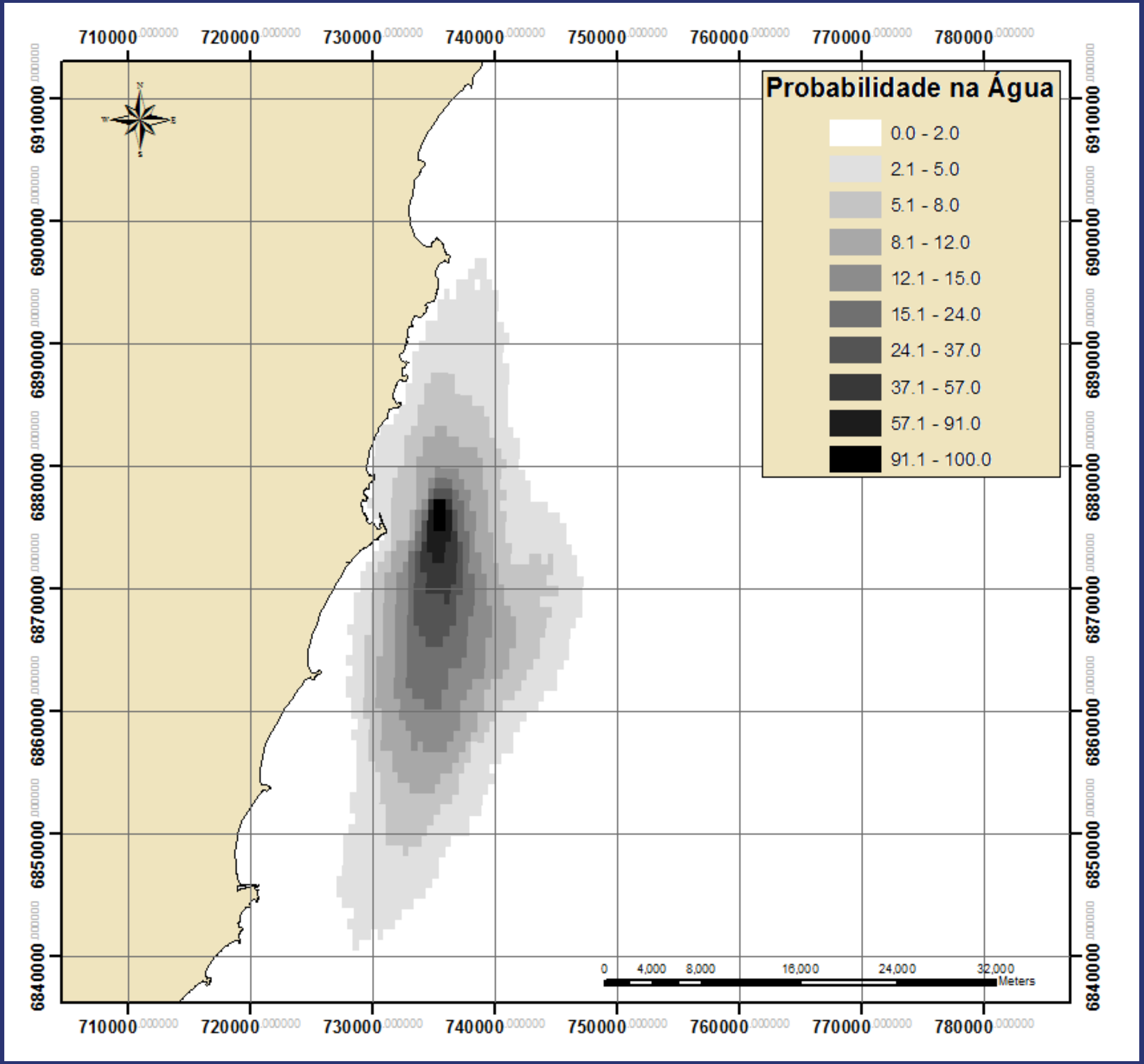


- Month seasonal current field winter and summer patterns

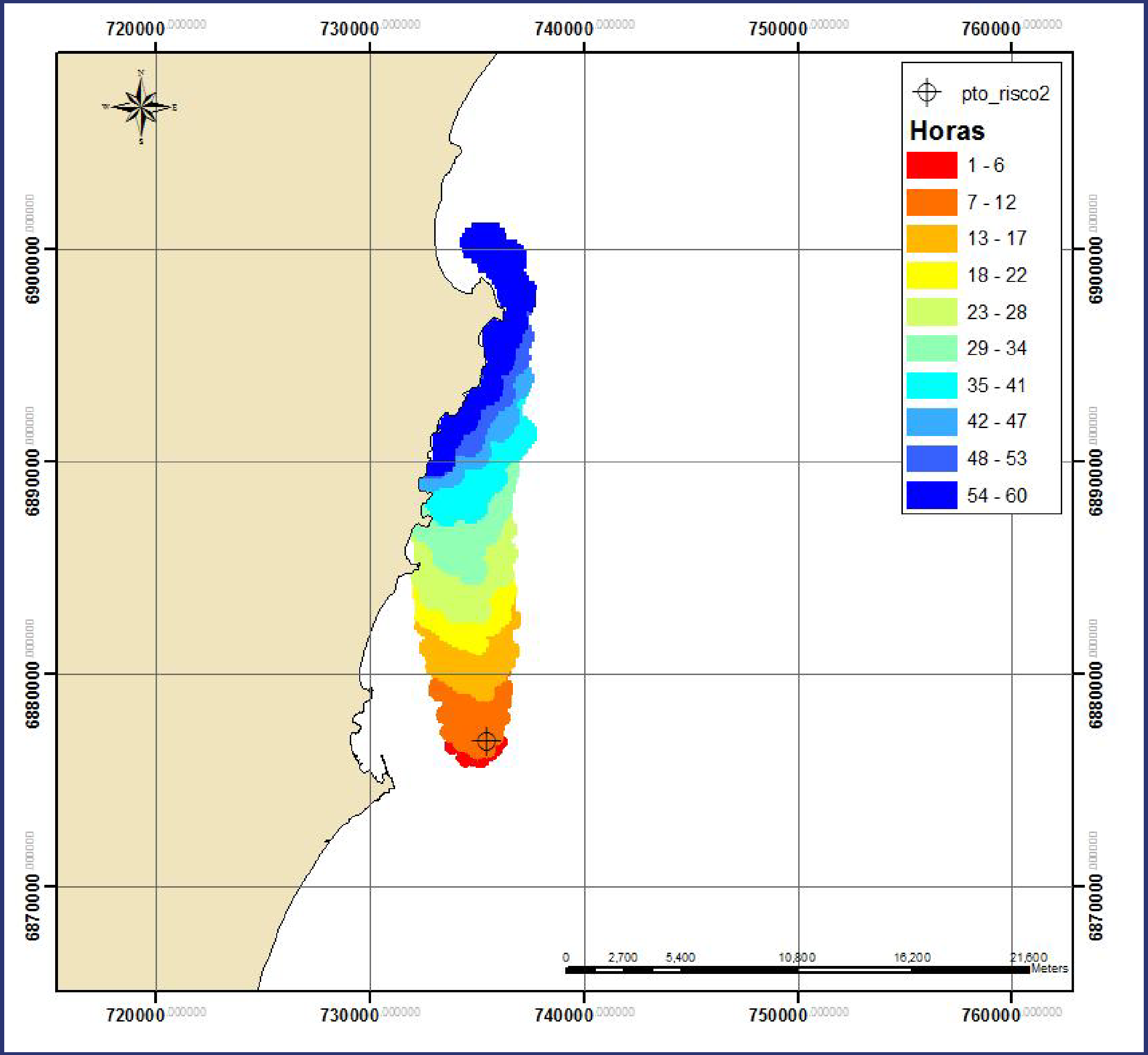
- Spill sites selected based on local operations



PROBABILISTIC SCENARIO



WORST CASE DETERMINISTIC SCENARIO



Final Considerations

- Once the probable locations of impact are defined agencies can make informed decision about permiting and stakeholders can enforce their rights

- Oil spill model results are exported as shapefiles and incorporated into desktop or web-base GIS in minutes. In teh GIS environment the model outputs can be correlated with environmental sensitivty maps for impact quatification

- Oil companies can use the same information to draft up contingency plans and risk-reduction strategies

- Real-time monitoring and deterministic modeling (3-day forecasts issued daily) are of most importance for proper oil spill response

Real –Time Operational Oceanography System

Provides everyday answers for questions such as:

•Where will the oil go?

• What amount is expected at specific sensitive zone? What is the oil state?

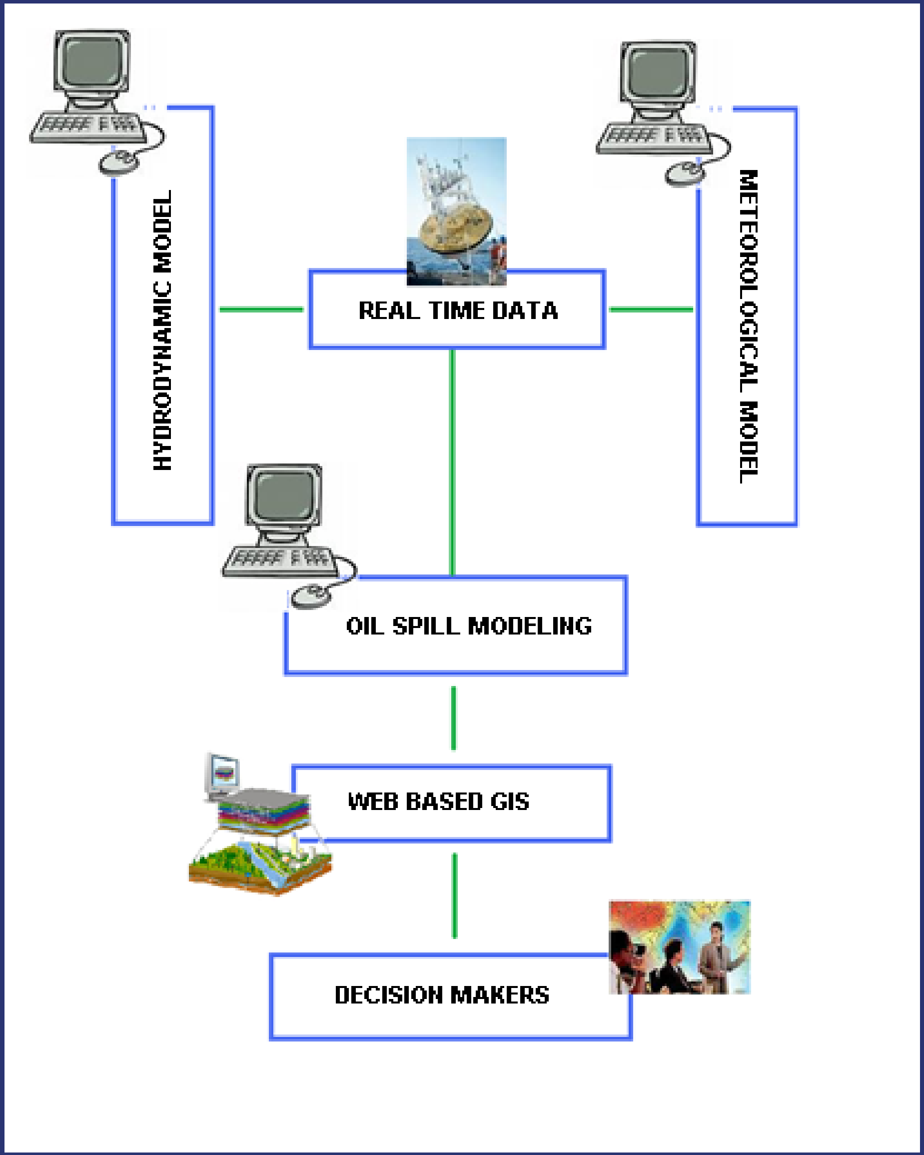
• Can I send my marine and aerial combat systems to contain the spill? What is the sea-state?

•What are the currents like? How will it evolute on the next days? Will be “Skimmers” efficients?

• Can I bring the vessel to the port? Has the rivermouth sufficient depth/draft? What will be the *water level* evolution? Do the wind and current allow the maneuver?

Agencies and stakeholders must enforce implementations of such systems if not enforced by law.

Real –Time Monitoring and Modeling (Operational Oceanography)



Recommendations for the Florida Coast

- Probabilistic simulations are reccomended to answer questions in the air, that is to evaluate the trajectory and fate of spills from possible exploration areas and transport routes to identify which specific areas can be impacted the most

- Decisions should be based on such studies together with other environmental and infraestructure considerations

- Real-time monitoring and modeling at regional and local scales, can provide crucial information for risk-mitigation and effective accident response

THANK YOU