Data acquisition in coastal areas: use of floating robots and numerical models

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The Hydronet Project

The main objective of the HydroNet project is to design, develop and test a network of autonomous sensorised, radio-interconnected marine robots embedded into an Ambient Intelligence controller. They will supply spatial and temporal information on water quality. The core of the system are sensors (bio-, optical- and chemo-sensors) hosted inside fixed buoys and moving robots, able to communicate with a remote land control station (Fig. 4).

The sensorised robot network will sample and quickly analyse several chemical and physical water parameters. The obtained information will be transmitted in real time, continuously providing data on the measured parameters and the chemical status of the water bodies. New miniaturised sensors will detect pollutants (Cr, Cd, Hg, and oil) in water. An integrated modelling tool is also being developed to simulate the transport and processes of pollutants in rivers, lakes, and coastal waters.

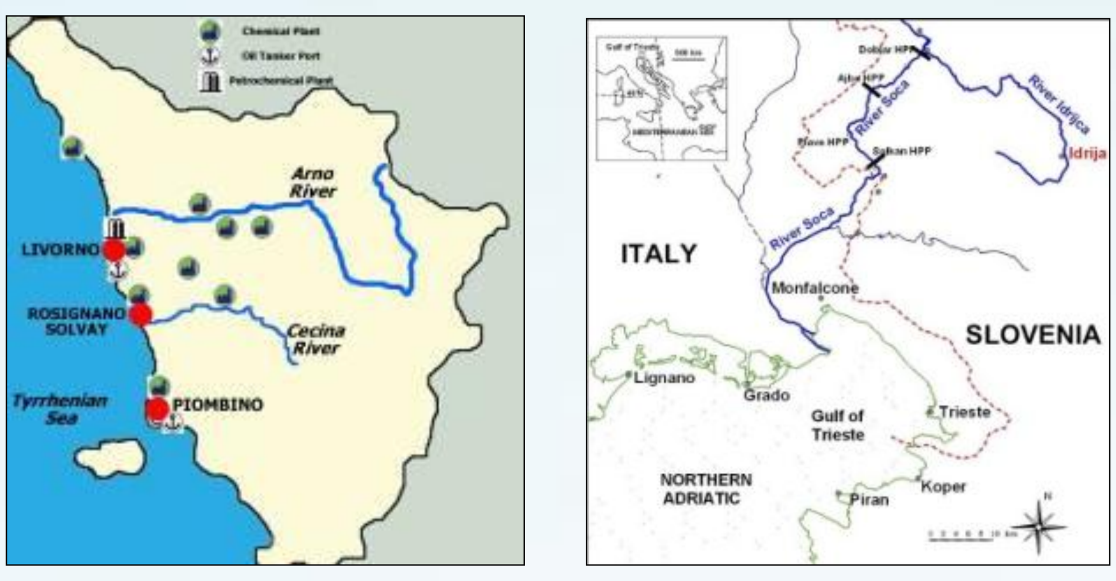

Figure 1. The coastal areas under study

Robots and sensors

In the coastal areas under study: the Gulf of Trieste, the Grado and Marano Lagoons and the Livorno coastal area (Fig. 1), a catamaran vessel (carbon-fibre, 2 m long, weight 80 kg) will be used for sampling. The two hulls will contain all the needed modules. The main components of the vessel (Fig. 2) are:

Main controller	Localisation system (GPS)
Wireless communication module	Locomotion
Batteries (power supply)	Solar Cells
Obstacle avoidance system	Sampler (Fig. 3) and sensors

Figure 2. The catamaran vessel

The sampler can collect water in five different depths (up to 50 m) and bring it to the vessel. While sampling, several water quality parameters will be measured using a commercial probe YSI 6920V2: temperature, turbidity, pH, DO, Eh and conductivity. The sampled water brought to the vessel will then be analysed for Cd, Hg, Cr and hydrocarbon concentrations using several sensors. The following sensors are being developed:

An electrochemical Hg sensor
A bio-sensor for Hg
An electrochemical sensor for Cd
An electrochemical sensor for Cr
A chemical sensor for hydrocarbons

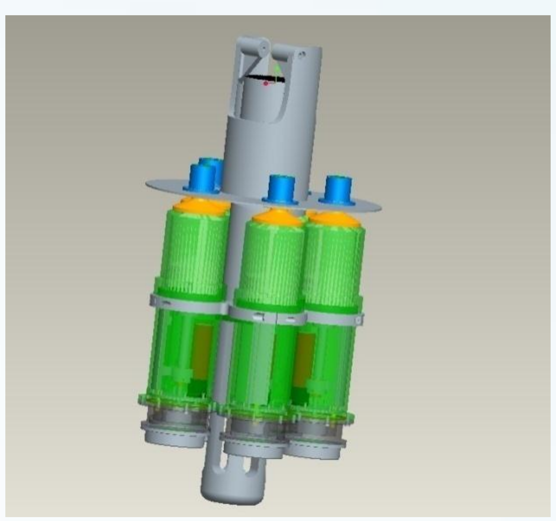

Figure 3. The sampler

The Ambient Intelligence System (AmI)

The Ambient Intelligence System consists of several modules: the remote robot navigation system, wireless transmitter and receiver of data, visualisation tool of the planned and performed robot pathways, storage system for data collected by robots, storage of modelling results, interfaces for communication with the modelling tool and an early-warning system. The last monitors both measured results obtained from regular monitoring, and the results of modelling simulations. In case of elevated concentration in either measurements or simulations, the most probable sources of pollution are determined and the robot vessels are sent to re-measure and collect more data.

All in-situ measured values are transmitted to the central database, where they are stored for further use. They can be statistically analysed or used for calibration and validation of numerical models.

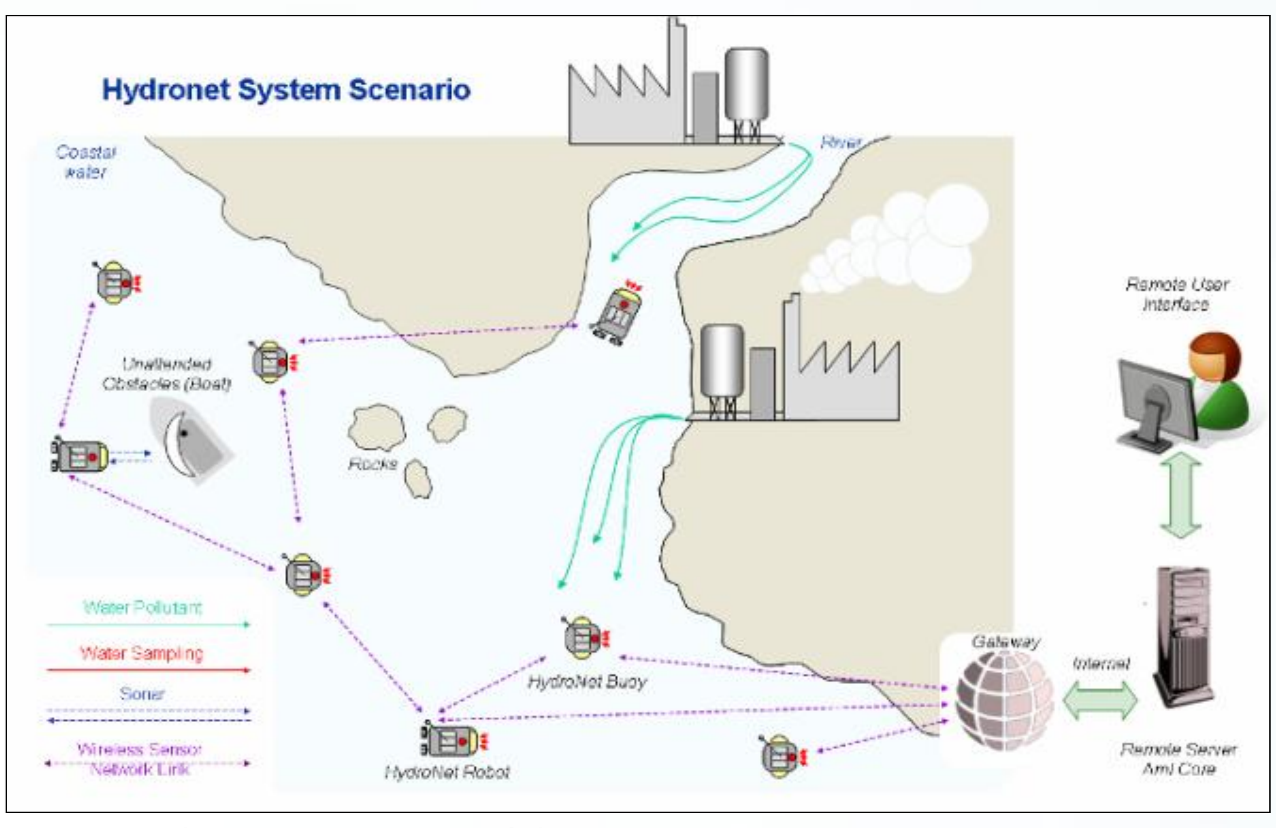

Figure 4. The monitoring part of the AmI system

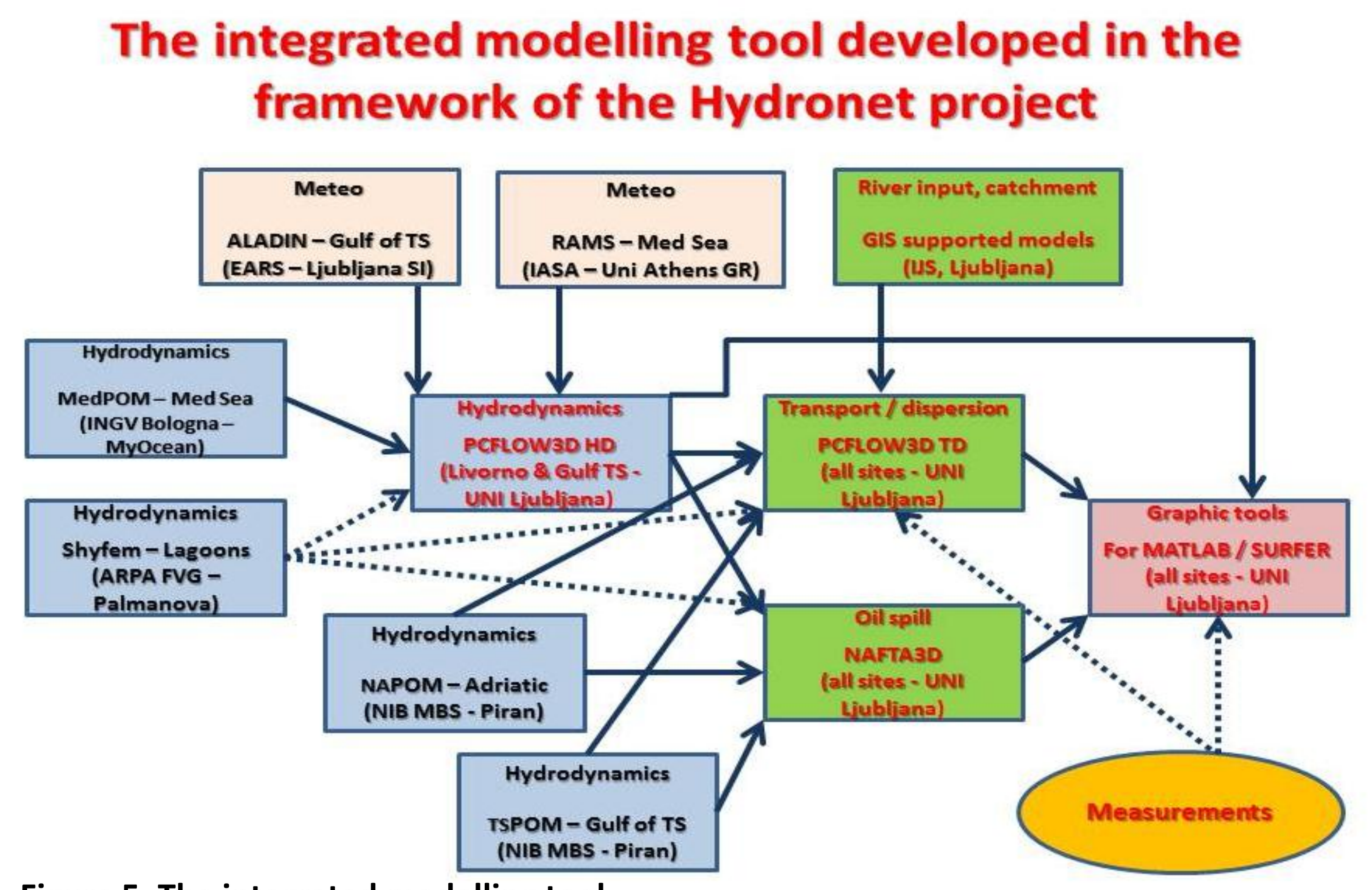

Figure 5. The integrated modelling tool

The Integrated Modelling Tool

In the framework of the Hydronet project several numerical models and their results were coupled through numerous interfaces (Fig. 5). Meteorological, hydrological, oceanographic and pollutant data are obtained from various measurements, models and databases. They are used in:

1. Real-time modelling of circulation. These results help in the decision-making process of navigation of the robots and serve as the first approximation in finding possible pollution sources
2. Further simulations of dissolved and particulate pollutant dispersion based on circulation

Measured data are used for calibration, verification and validation of the individual models and the integrated modelling tool.

Numerical simulations and results

During the calibration/validation phases, several simulations of hydrodynamic circulation and dispersion of various pollutants were performed. While real-time data for hydrodynamic simulations are available, the data on pollutants mostly stem from previous measurements and from databases. The initial and boundary conditions for hydrodynamic simulations are obtained on a daily basis from other models used in the Mediterranean area in the framework of EU FP6 and FP7 projects MFSTEP and MyOcean.

The numerical grid in the Hydronet simulations is significantly refined compared to the grids in MFSTEP and MyOcean. Within the MyOcean project the Mediterranean Sea is modelled in the resolution of about 5 x 5 km, while the Hydronet simulations for the Livorno coastal area are performed on 0.5 x 0.5 km grid. The grid refinement is even more prominent in both domains in the Northern Adriatic, where a 150 x 150 m numerical grid is used. The layer thickness varies: within the Gulf of Trieste, 1 m thick layers are used, and in the Livorno area, the thickness varies from 1.5 m at the surface to 20 m at the depths above 150 m.

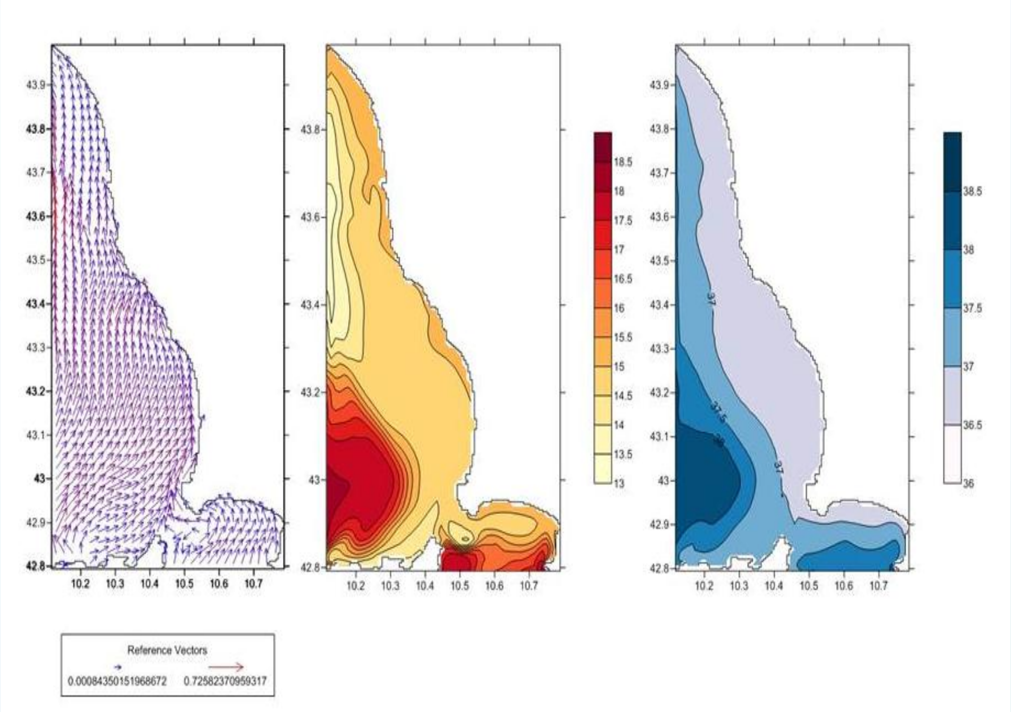

Figure 6. An example of geo-referenced hydrodynamic results: velocities, temperature and salinity in the surface layer (Livorno coastal area)

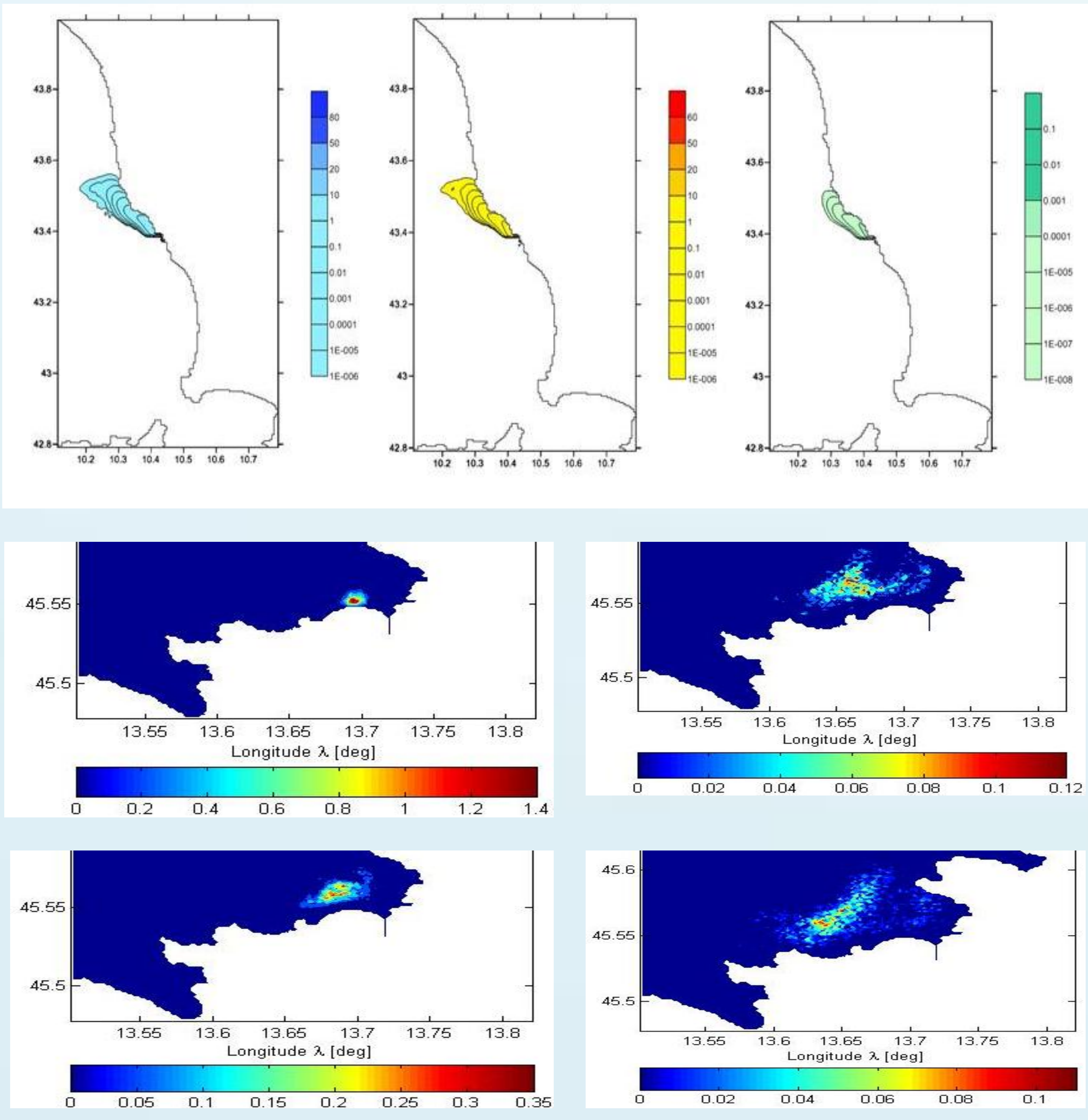

Figure 7. A hypothetical leakage og Hg from Rosignano (ng/m3, after one day, above) and an oil-spill in the Gulf of Trieste (after 10, 30, 50 and 70 h, below)

Examples of simulation results are shown in Figs. 6 and 7. Circulation in the surface layer of the Livorno area (Fig. 6) was used for simulating a hypothetical event: a leakage of about 10 kg of reactive (divalent) mercury (Hg^{2+}) from the Solway chlor-alkali plant in Rosignano. In Fig. 7 the concentrations of the three simulated Hg species, elemental (Hg^0, left), reactive (Hg^{2+}, middle) and monomethyl-mercury (MMHg, right) after 24 hours are presented. The bottom part of Fig. 7 shows the spreading of a hypothetical oil-spill in the Gulf of Trieste after 10, 30, 50 and 70 hours under real meteorological conditions.

Conclusions

Simultaneous use of robot vessels equipped with sensors, and the coupled ensemble of numerical models could significantly lower the costs of regular water quality monitoring in coastal areas. Larger quantity of measured data will also improve the results of the transport/dispersion model predictions. We expect the project and its deliverables to have a significant impact on measurement and modelling techniques and methods in polluted coastal environments.

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