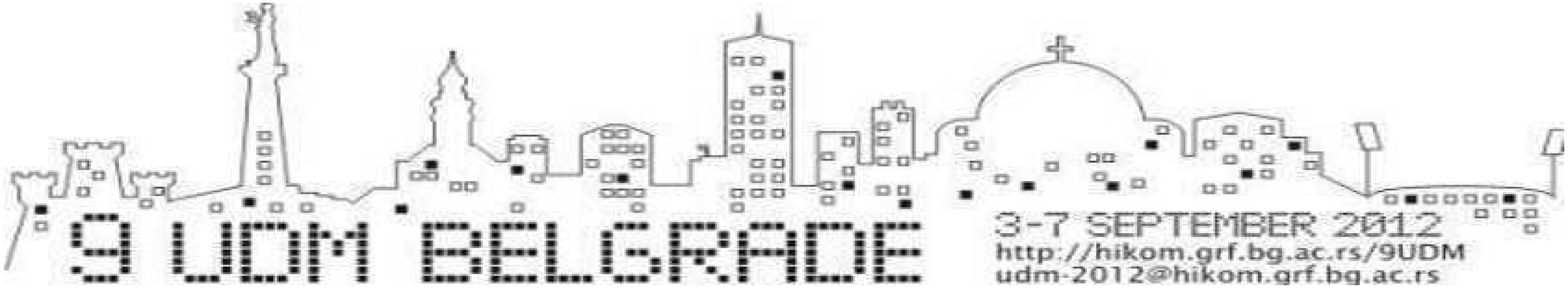

Modelling of E. coli distribution in coastal areas subjected to combined sewer overflows

De Marchis M., ***Freni G.,*** *Napoli E.*

UNIVERSITÀ DEGLI STUDI DI PALERMO

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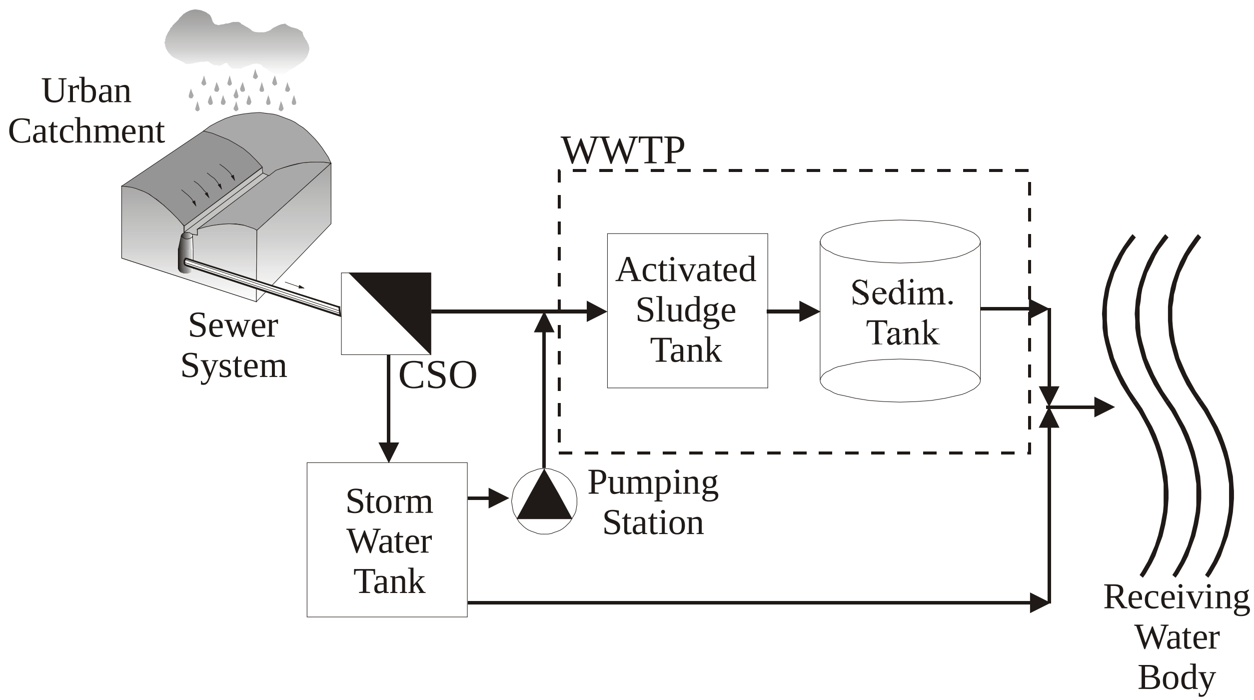
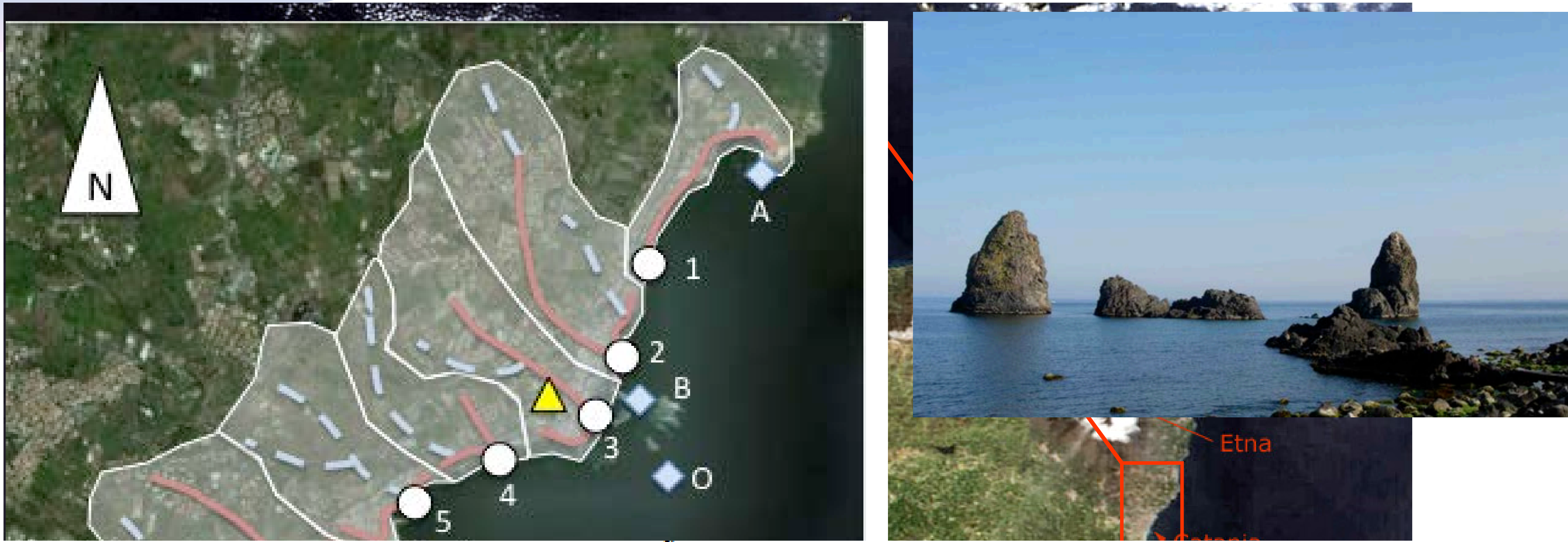
Introduction and aim of the study

Integrated models aim to joint analysis of two or more elements of the integrated urban drainage system



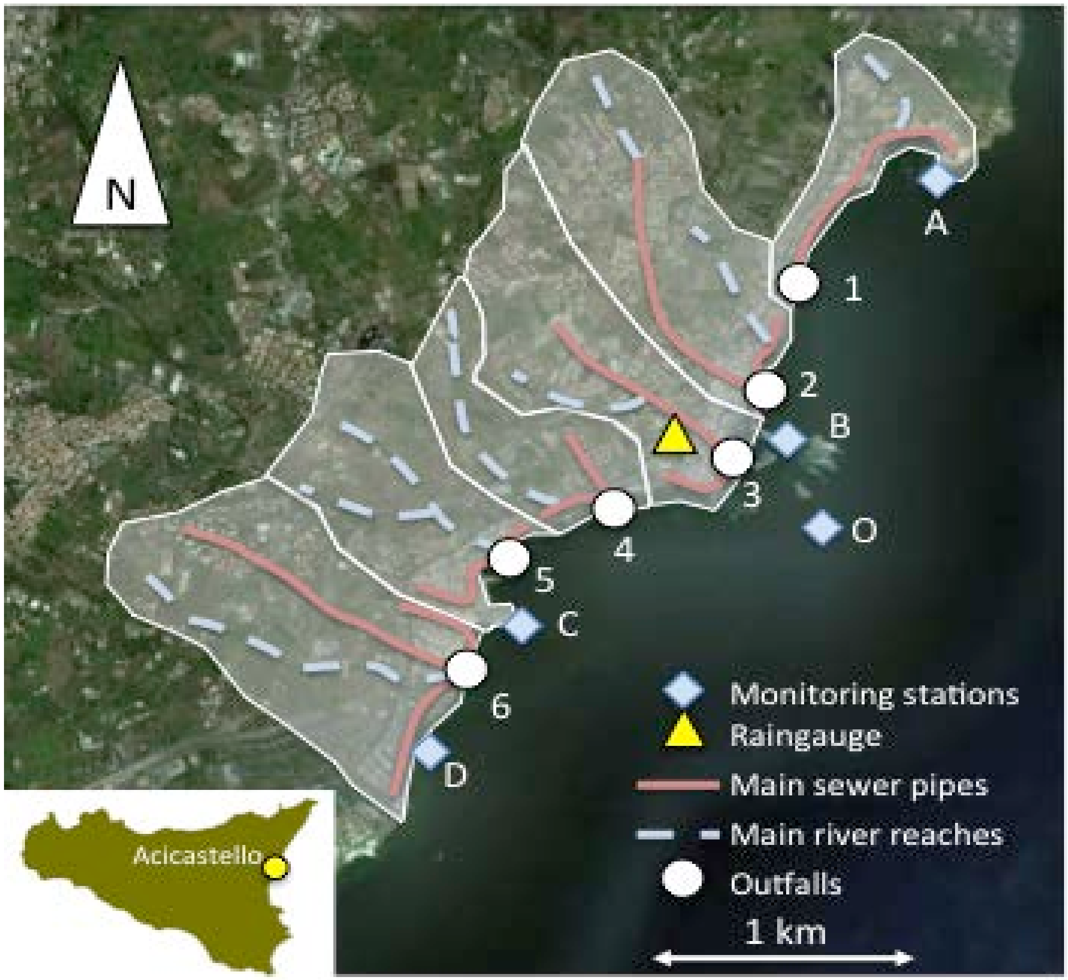
Integrated models are often complex and this complexity increase if the Receiving Water Body is 2D or 3D (lakes, costal areas, etc.)

The study area: the Cyclops coast (Italy)



Catchment	Total area [ha]	Pervious area [ha]	Imperious area [ha]	Population [inhab] – year 2004	Nat. catch. average slope [%]	Urban area average slope [%]
1	58.9	24.5	34.4	6134	34.2%	12.2%
2	125.1	95.2	29.9	5867	38.1%	23.6%
3	108.6	81.9	26.7	4322	24.4%	7.2%
4	65.3	23.1	42.2	6543	19.6%	3.6%
5	97.4	60.1	37.3	5545	45.6%	21.3%
6	180.3	136.2	44.1	7143	65%	35%

The monitoring campaign



- 6 electromagnetic level gauge/velocity gauges (Δt: 1 min)
- Six 24bottles automatic sampler (Δt: 15 min during rainfall events; 1 hour in dry times)
- One tipping bucket raingauge (Δt: 1 min)
- 5 off-shore sampling station (Δt: 1 hour)
- 5 current profiler in O

Catchment, sewer system and river model (SWMM)

Rainfall – runoff transformation: Non linear reservoir (hydrologic losses: surface retention and infiltration)

Sewer and channel propagation: 1D DSV equations

Pollutants build-up and wash-off: Alley-Smith formulation

Pollutants propagation in sewers: Advection – dispersion eq. (<u>no sedimentation is simulated in the sewer network and in rivers</u>)

RWB Governing equations

Reynolds Averaged Navier-Stokes equations for free-surface, constant density flows

$$\frac{\partial \overline{u}_i}{\partial t} + \frac{\partial \overline{u}_i \overline{u}_j}{\partial x_j} - \nu \frac{\partial^2 \overline{u}_i}{\partial x_j \partial x_j} + \frac{1}{\rho}\frac{\partial \overline{q}}{\partial x_i} - \epsilon_{ij3} f \overline{u_j} + g\frac{\partial \overline{\eta}}{\partial x_i} + \frac{\partial \overline{u_i' u_j'}}{\partial x_j} = 0$$

where q is the "dynamic" pressure, f the Coriolis parameter and η the water surface level

Continuity equation for incompressible flows $\frac{\partial u_j}{\partial x_j} = 0$

Kinematic condition for the water surface

$$\frac{\partial \eta}{\partial t} + u_1 \frac{\partial (z_B + \eta)}{\partial x_1} + u_2 \frac{\partial (z_B + \eta)}{\partial x_2} - u_3 = 0$$

where z_B is the bottom level

RWB Pollutant dispersion

The numerical model solves, jointly with the system of conservation equations for momentum, the conservation equations for any pollutant present in the water body:

$$\frac{\partial C}{\partial t} + \frac{\partial\, Cu_i}{\partial x_i} - \alpha \frac{\partial^2 C}{\partial x_i \partial x_i} + \frac{\partial\, \Lambda_j}{\partial x_j} - F_c = Q$$

C is the tracer concentration

α the molecular diffusivity

Λ_j the turbulent diffusive flux modelled as

$$\Lambda_j = -\Gamma \frac{\partial C}{\partial x_j}$$

Γ the turbulent diffusivity

$$\frac{C}{C_0} = e^{-t/t_f}$$

t_f e-folding time

The numerical model

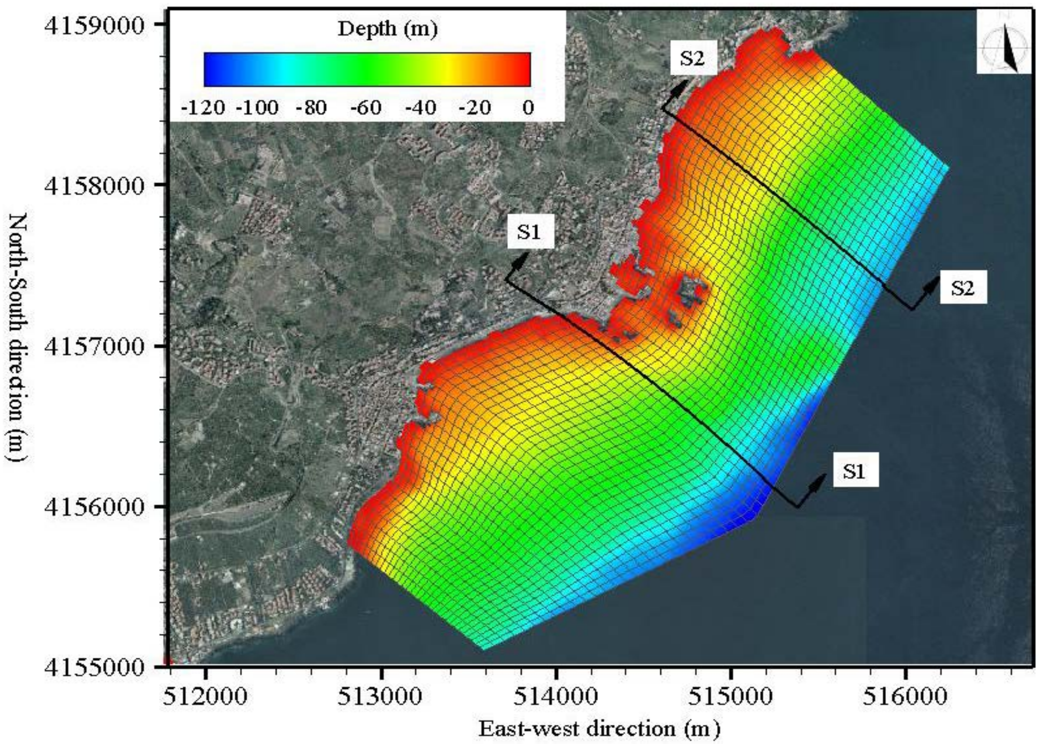
The equations are solved using a 3D finite-volume numerical model solver (PANORMUS, Parallel Numerical Open-souRce Model for Unsteady Flows) http://www.panormus3d.org

A second-order accurate semi-implicit method is used for the time advancement of the solution (Crank-Nicolson implicit method for the vertical diffusive and turbulent terms, Adams-Bashfort explicit scheme for the remaining terms)

The pressure-velocity decoupling problem typical of incompressible fluids is overcome using a fractional-step method: at each time step RANS equations are solved assuming a hydrostatic pressure distribution without imposing mass conservation (predictor-step); a Poisson-like equation then is solved to obtain a conservative velocity field, to be added to the predictor-step field to obtain the divergence-free velocity field (corrector-step).

Parallelization is achieved using the Message Passing Interface (MPI) libraries.

Computational domain

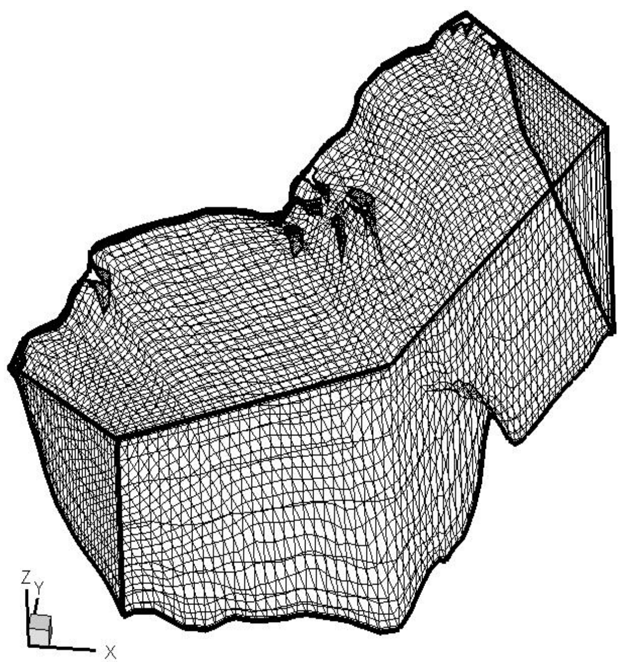


The domain was discretized into 64 cells in the E-W directions

128 cells in the N-S direction

16 cells in the vertical direction

Average cell dimension: 25 m



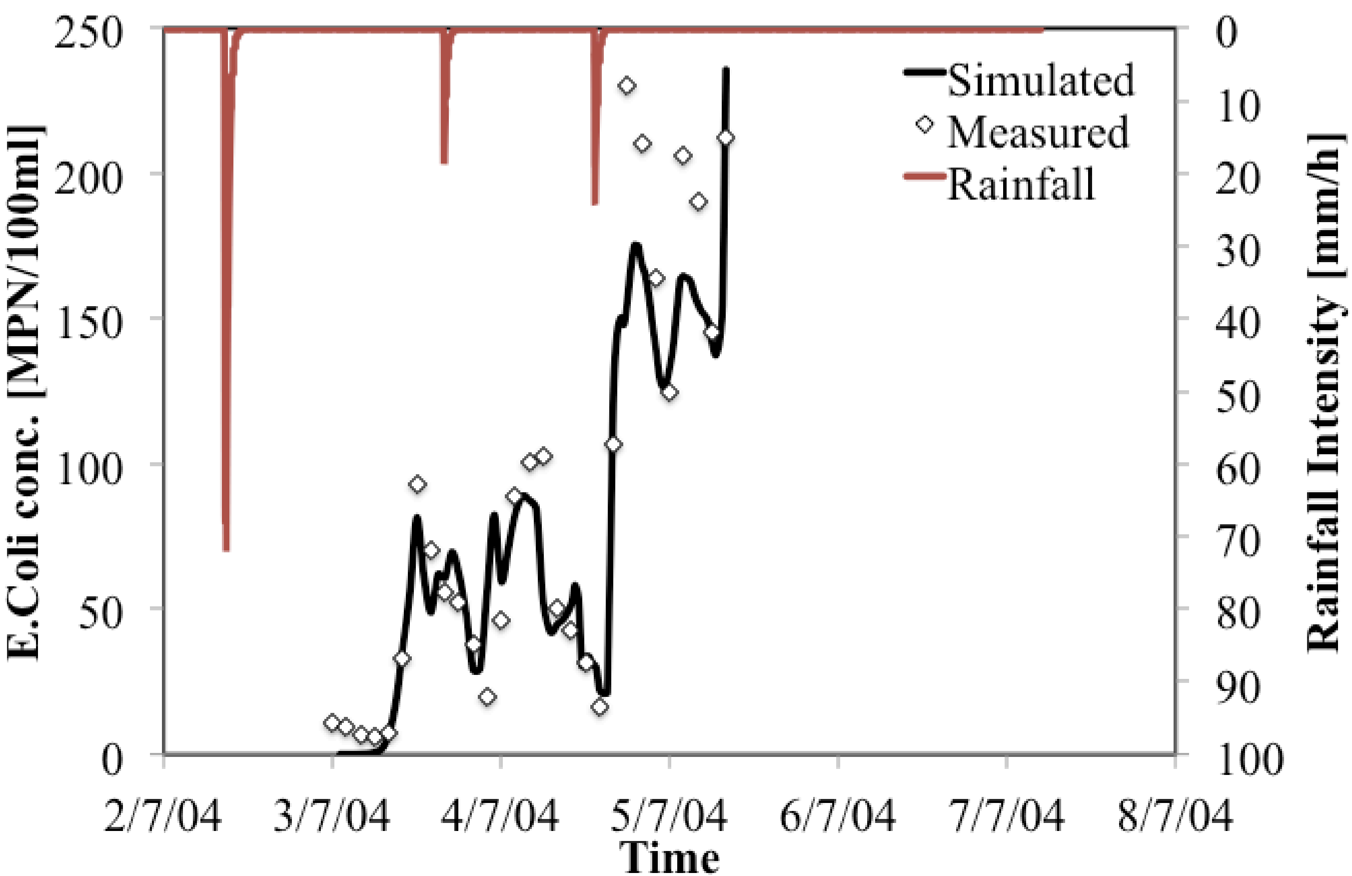
Available database and model calibration

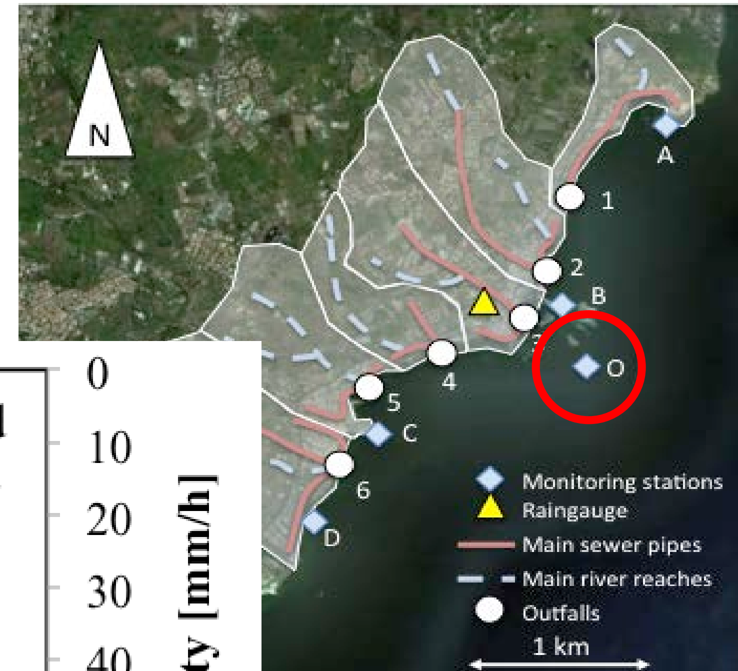
	Event 1 25/04/04	Event 2 12/05/04	Event 3 12/07/04	Event 4 17/07/04	Dry Weather (3 days)
Rainfall duration [min]	140	158	850	112	-
Rainfall volume [mm]	15.4	21.8	16.2	52.8	-
Rainfall max. intensity [mm/h]	18.1	20.4	11.4	102.6	-
Rainfall av. intensity [mm/h]	6.6	8.1	1.1	28.3	-
ADWP [h]	47	180	553	88	-
Outfall 1 N° of water quality data points	24	24	15	24	72
Outfall 2 N° of water quality data points	20	23	14	24	72
Outfall 3 N° of water quality data points	19	24	16	23	72
Outfall 4 N° of water quality data points	24	24	17	21	72
Outfall 5 N° of water quality data points	24	24	20	18	72
Outfall 6 N° of water quality data points	20	24	19	22	72
RWB (offshore) No of water quality data points	6	8	4	3	24(*)

Available database and model calibration

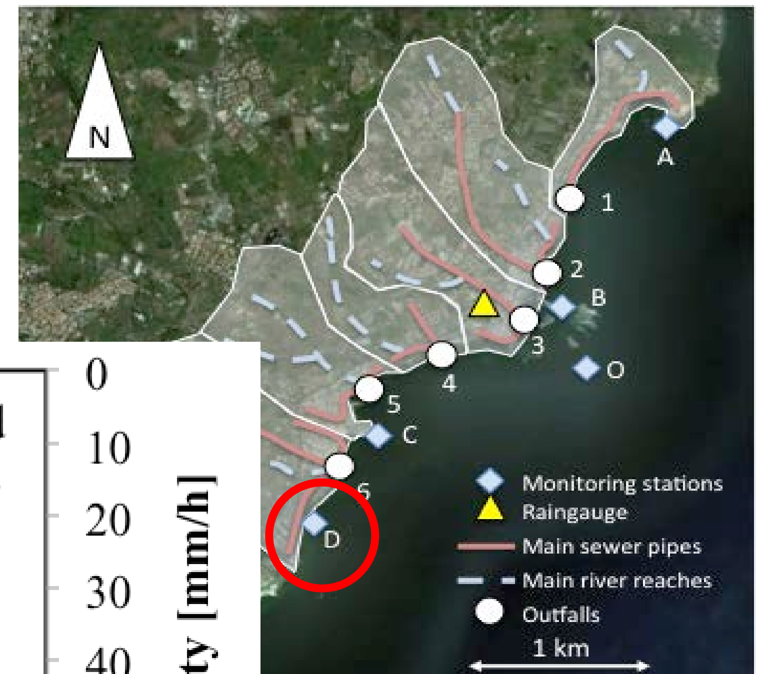
Monitoring station O

Event 3 – 12 July 2004



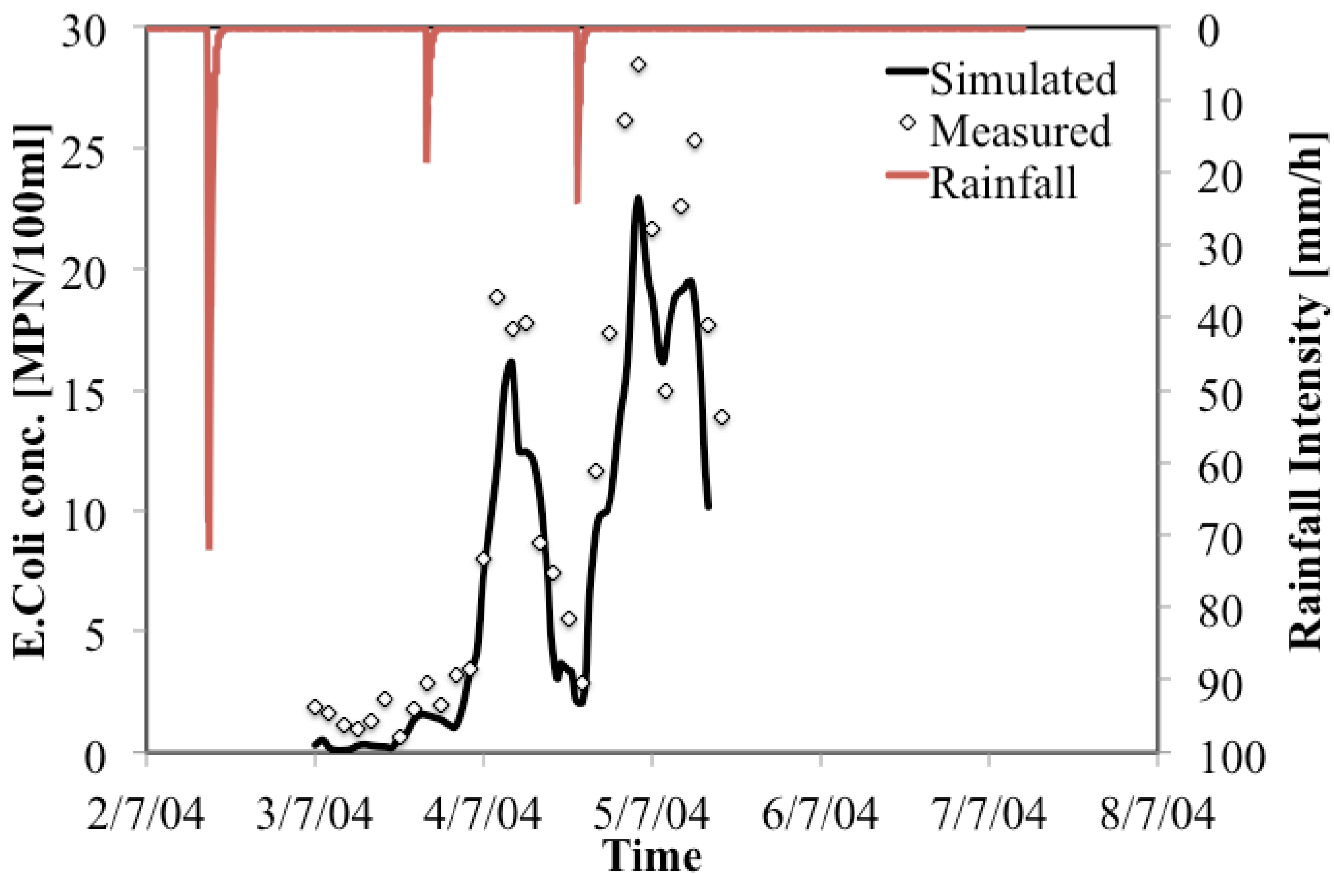


Available database and model calibration

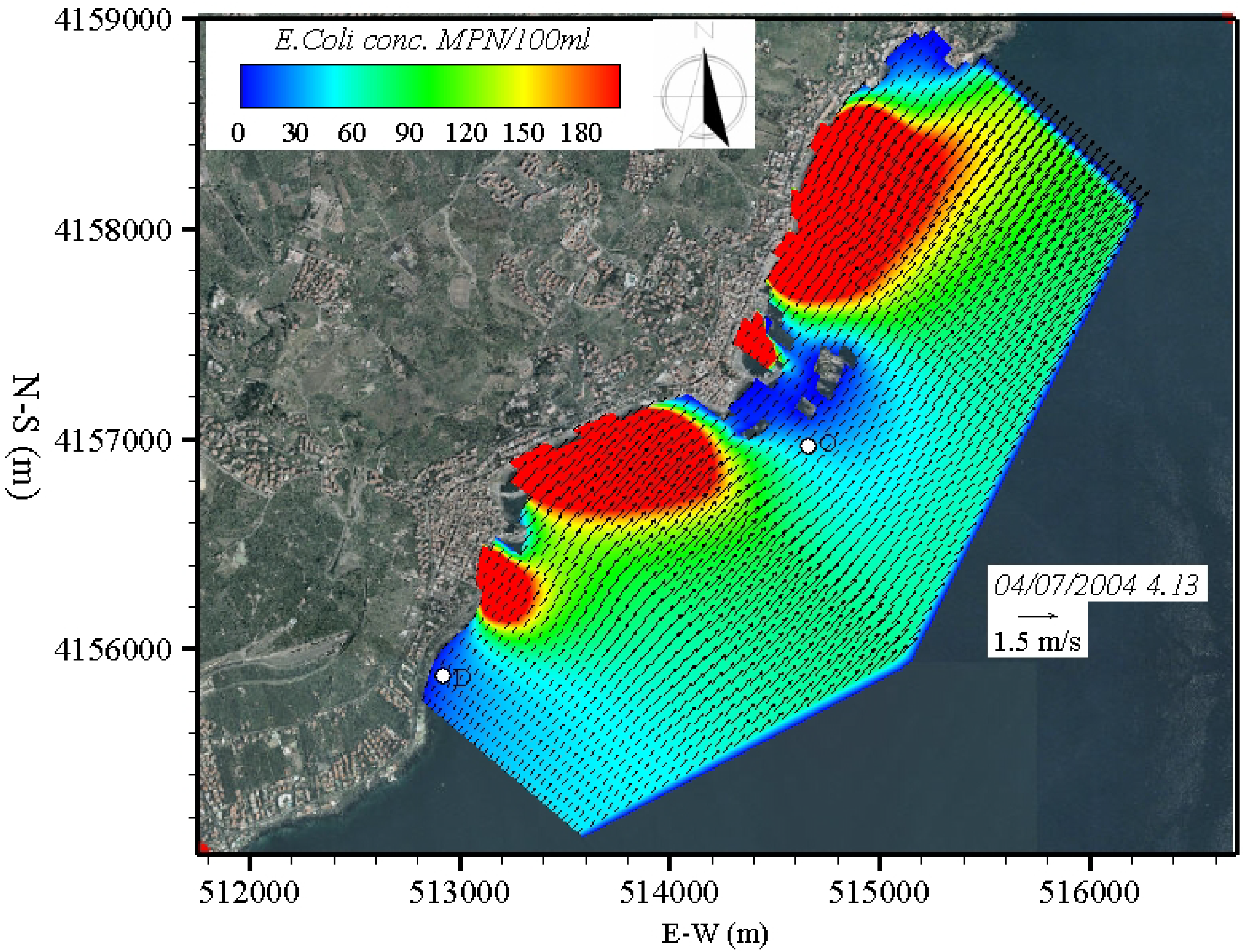


Monitoring station D

Event 3 – 12 July 2004



RWB pollutants propagation

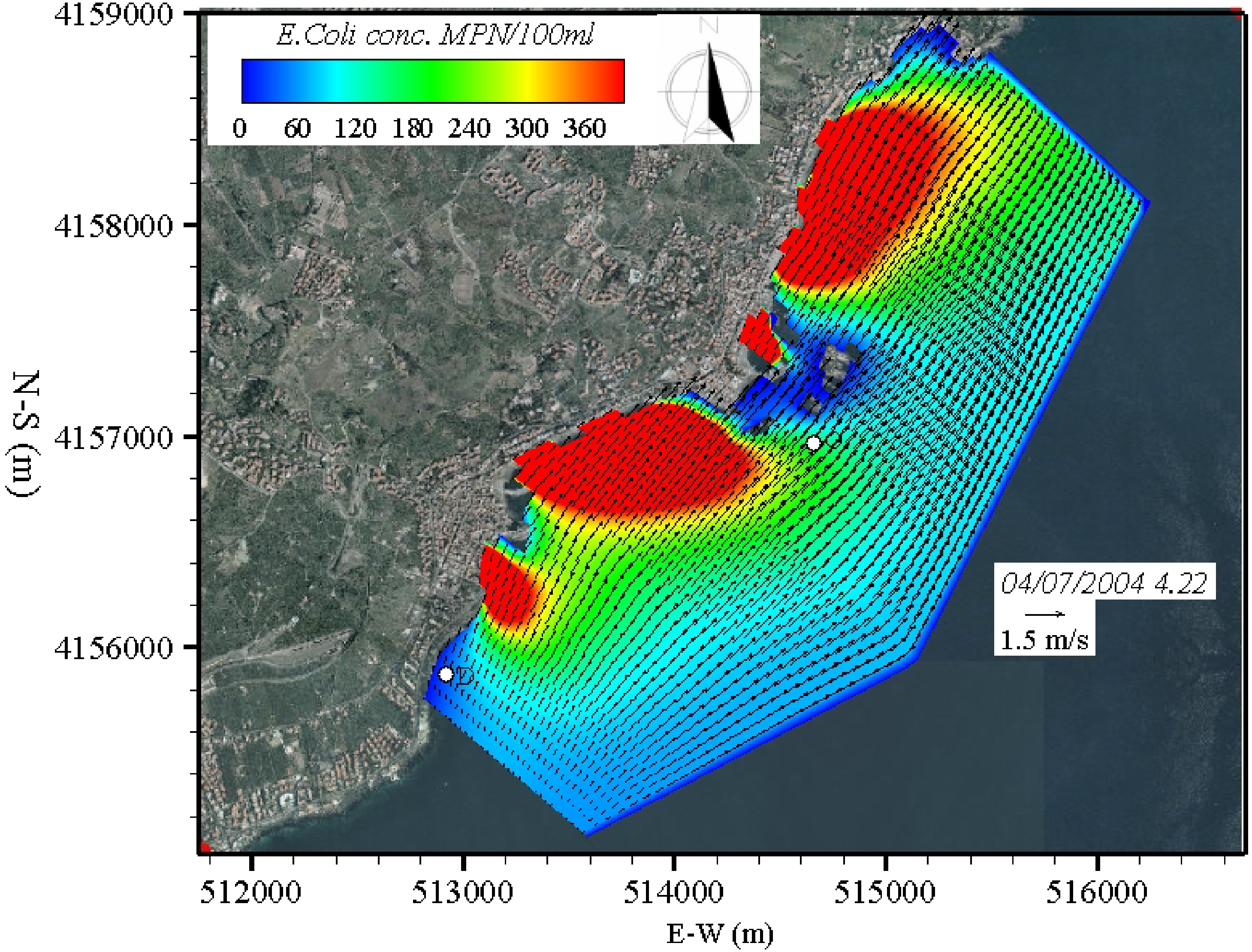


Just after the end of the rainfall event

04 July 2004

1 PM

RWB pollutants propagation

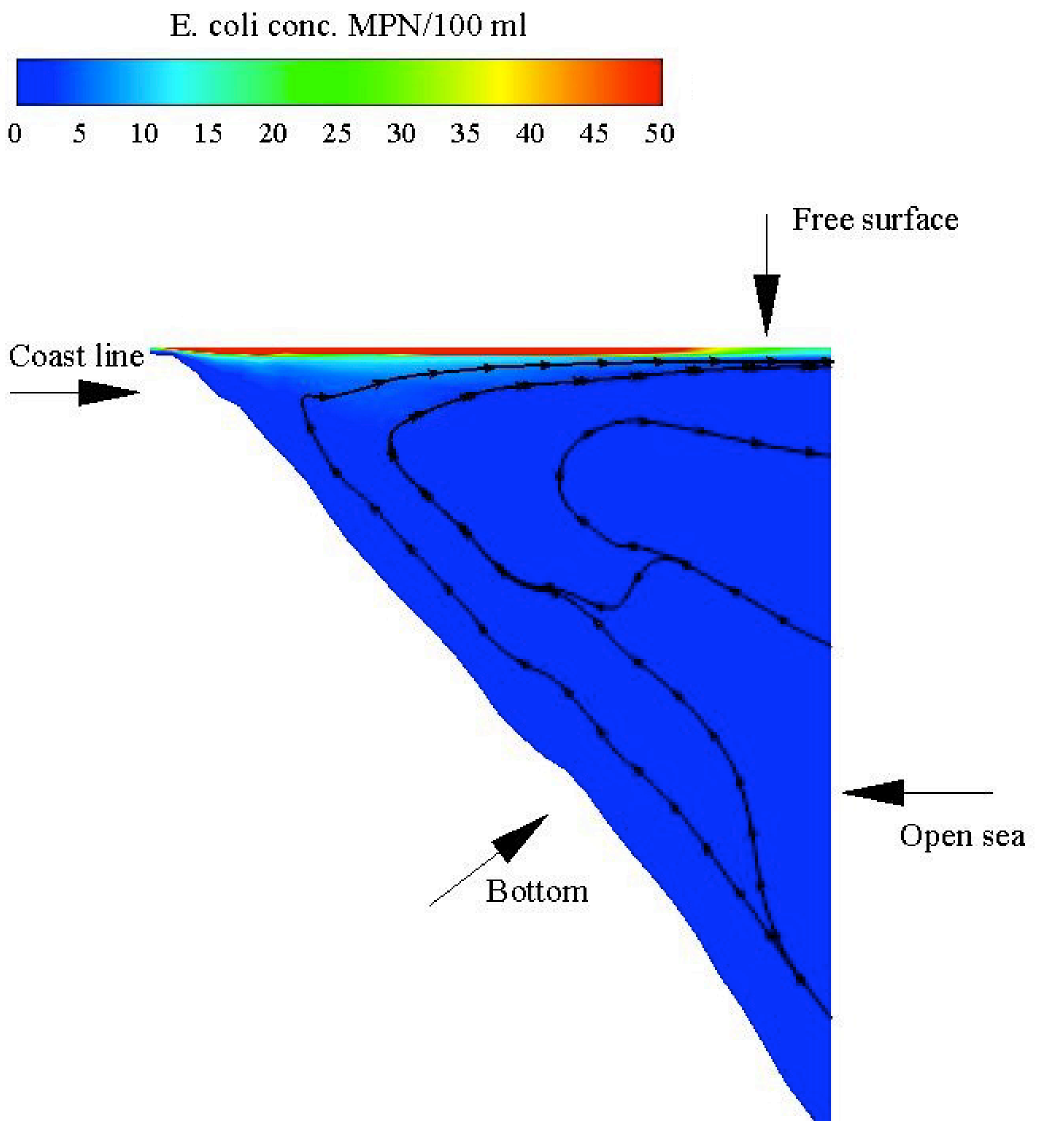


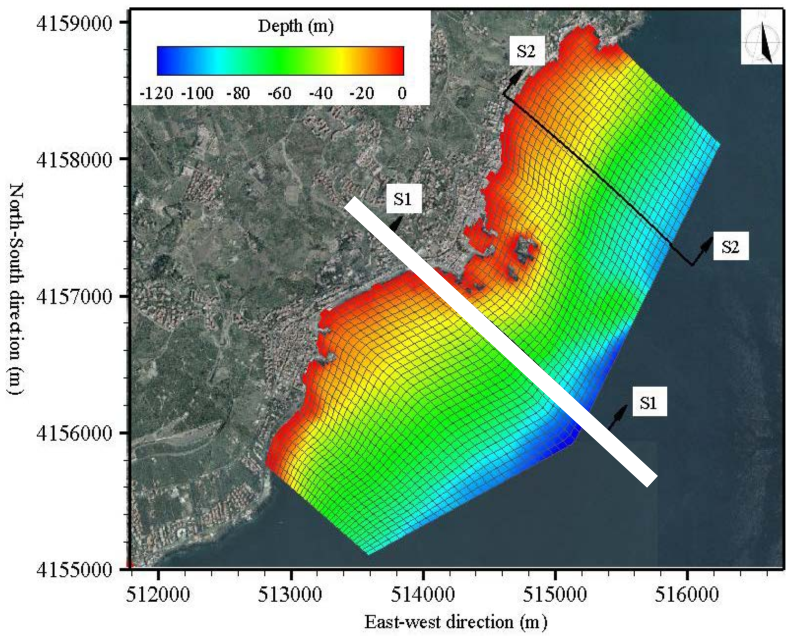
9h after the end of the rainfall event

04 July 2004

22 PM

Three-dimensionality of the current



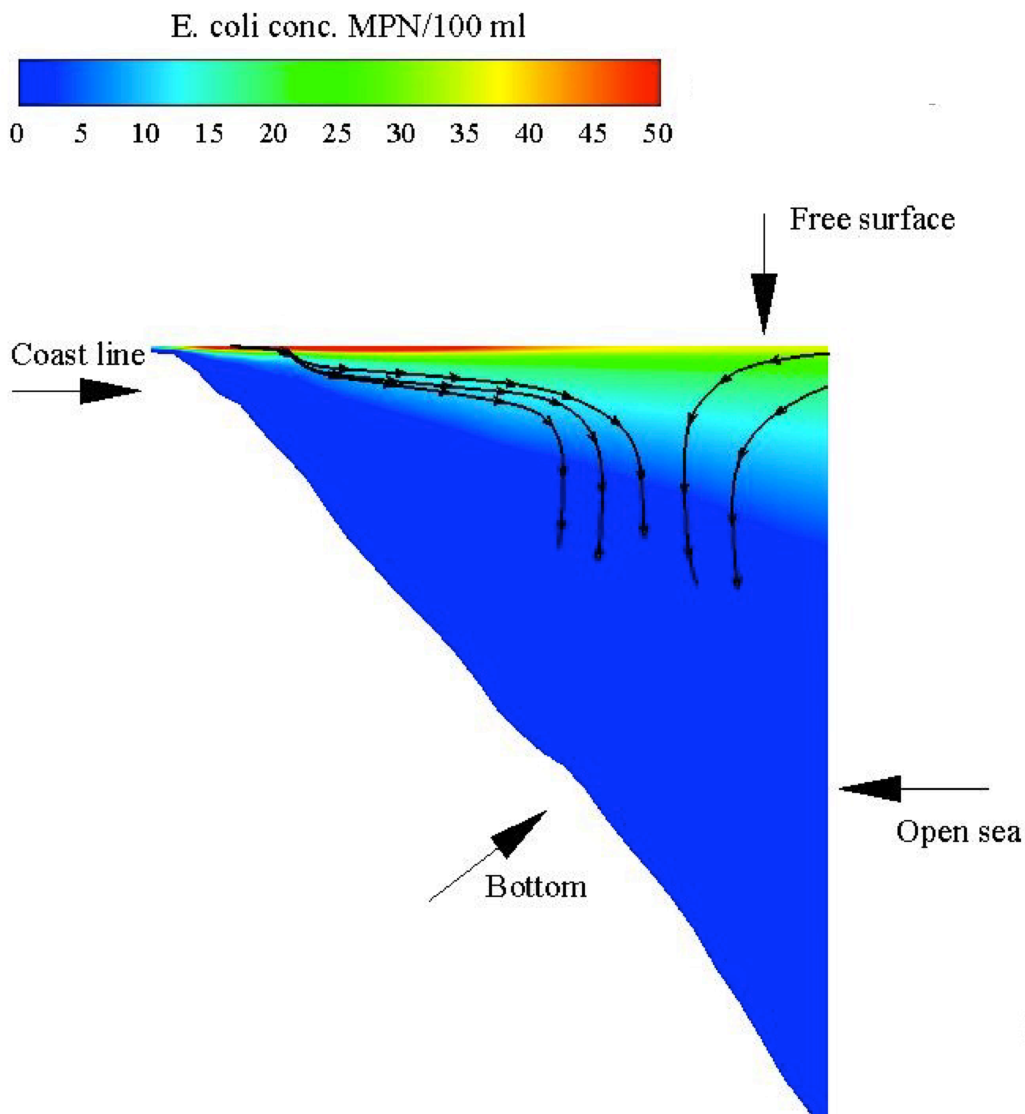


Just after the end of the rainfall event

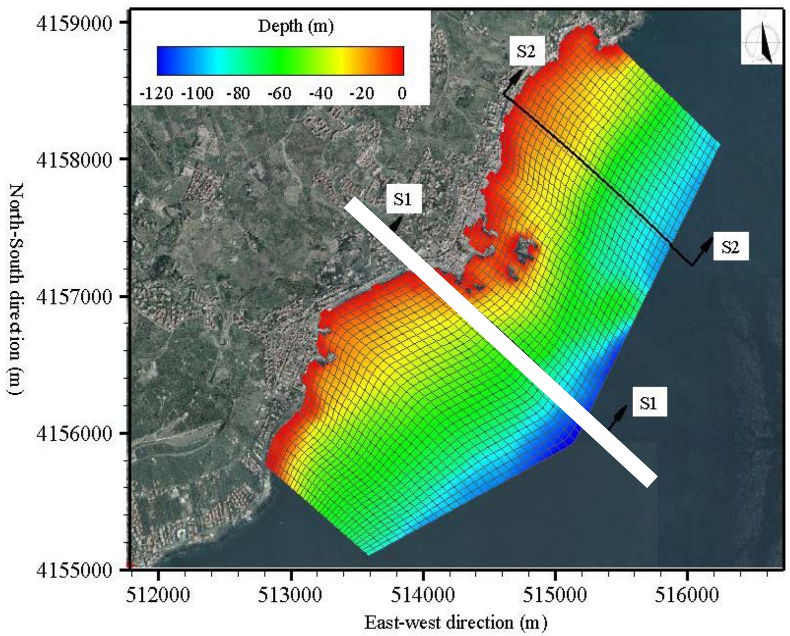
04 July 2004

1 PM

Three-dimensionality of the current



(b)

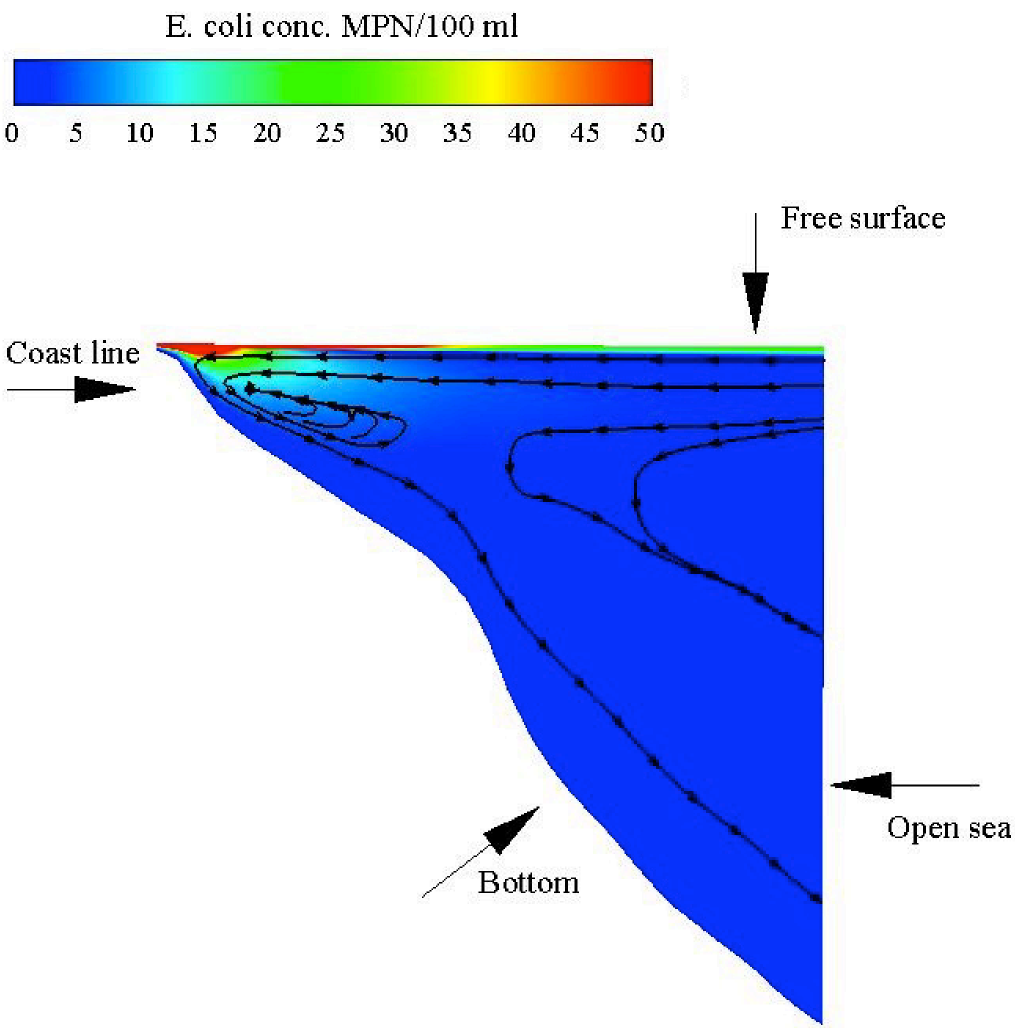


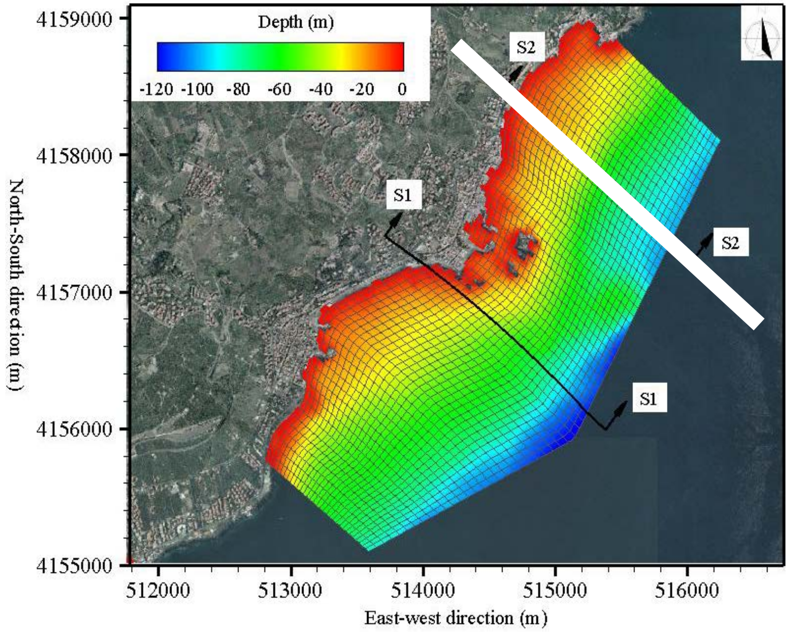
6h after the end of the rainfall event

04 July 2004

7 PM

Three-dimensionality of the current





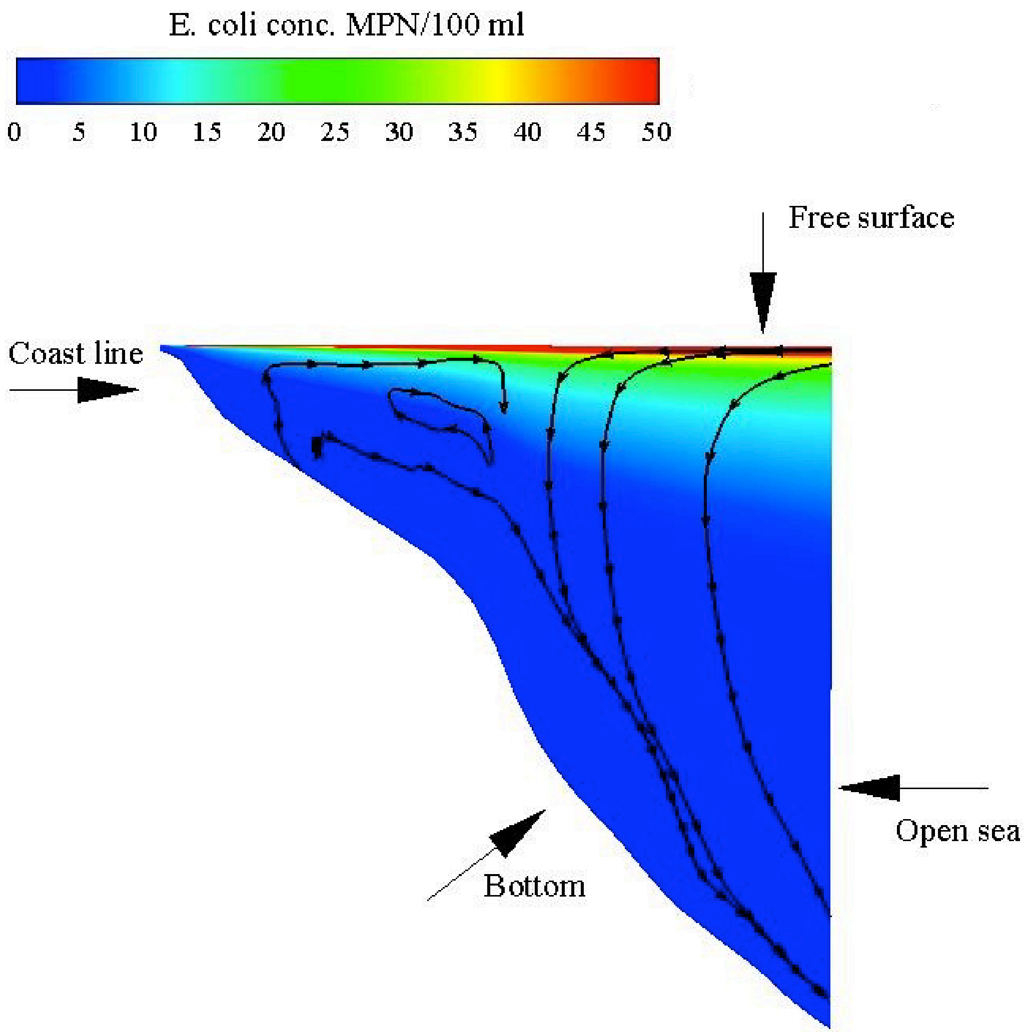
(a)

Just after the end of the rainfall event

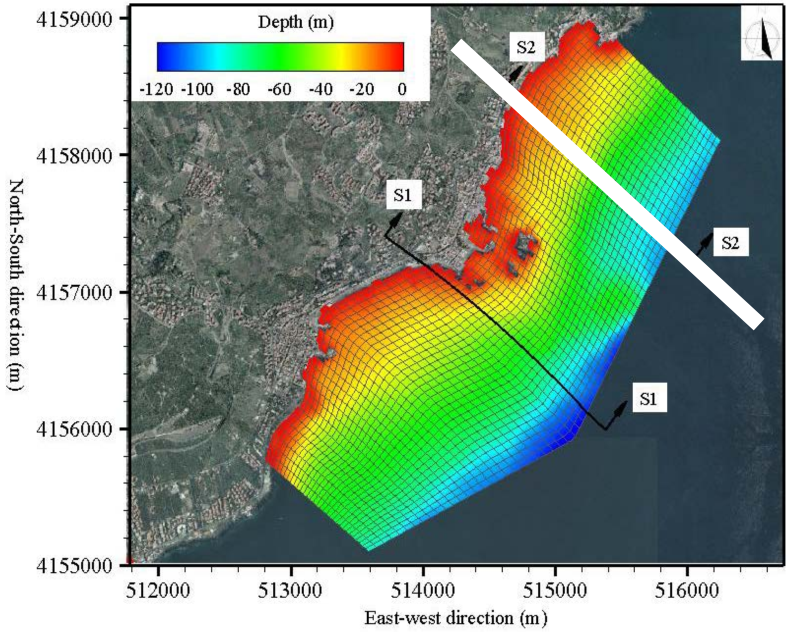
04 July 2004

1 PM

Three-dimensionality of the current



(b)



6h after the end of the rainfall event

04 July 2004

7 PM

Conclusions

- The application of a complex 3D model was necessary for the peculiar characteristics of the RWB being very deep and solicited by complex boundary conditions (mainly currents and wind on the free surface).
- Currents and wind have a relevant impact on the distribution of pollution concentrations in the costal area moving pollutants along the coast or off-shore
- Despite the Coliform mortality rate has been taken into account, the complex hydrodynamic and the boundary conditions played a more important role in the dispersion of the E. coli
- Despite the E. coli concentration is diluted along the coast during the rainfall event, the hydrodynamic circulation causes high concentrations in the open regions due to the floating of polluted river water over the salty seawater.

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Thank you for attention!

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