SimHydro 2010 conference

Assessment of *E. coli* contamination in the Thau lagoon : combined use of physically based modelling and geostatistics

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1 Ifremer

2 Geovariances
Where no one has gone before

Sophia Antipolis, France
2 - 4 juin / 2 – 4 June

STUDY SITE

Thau lagoon: 75 km² (≃ 19 km x 4 km)
Mean depth : 4,5 m
Max depth : 11 m

Connected to the Mediterranean Sea via 2 outlets (Sète channel and Pisses-Saumes channel)

Drainage area of ≃ 230 km²

High population growth: + 42 % / 15 years

THE OMEGA-THAU PROJECT

1st Mediterranean shellfish farming area, 10 % of the national production (13 000 tons of oysters, 2500 tons of mussels)

Since 2004 category B (EU) → Shellfish purification needed

B standard regularly exceeded (~ 1 / year)

Shellfish involved in Foodborne Disease Outbreaks (2003, 2006, 2009)

2006 – 2010

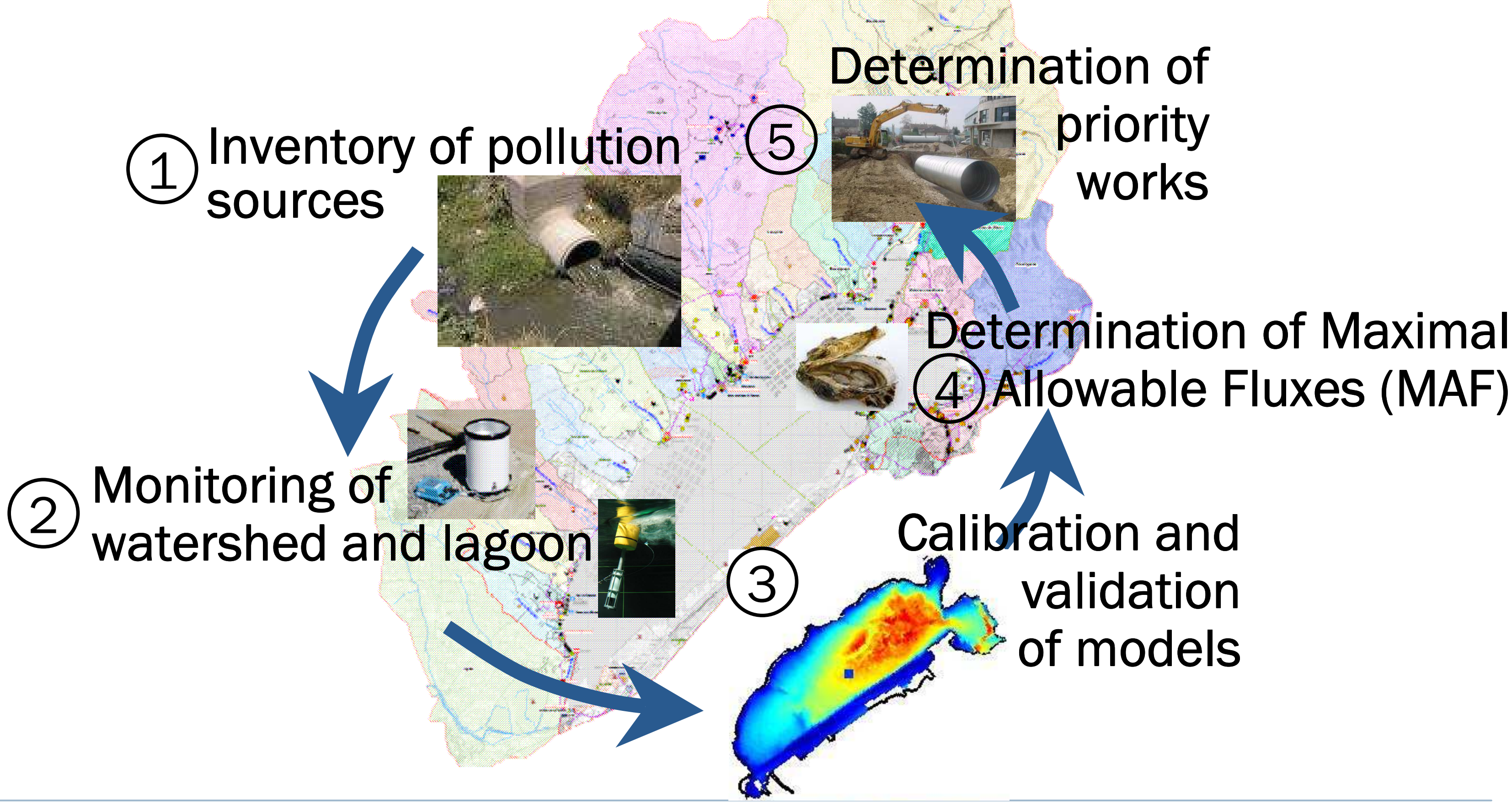
THE OMEGA-THAU PROJECT

A management tool to achieve microbial shellfish and water sanitary standards on Thau lagoon (“Contrat d’étang” framework)

OBJECTIVE
How to optimize management to reduce the faecal pollution in the Thau lagoon?

To determine the works according to the impact of faecal sources on Thau water & shellfish quality

To determine *E. coli* threshold fluxes

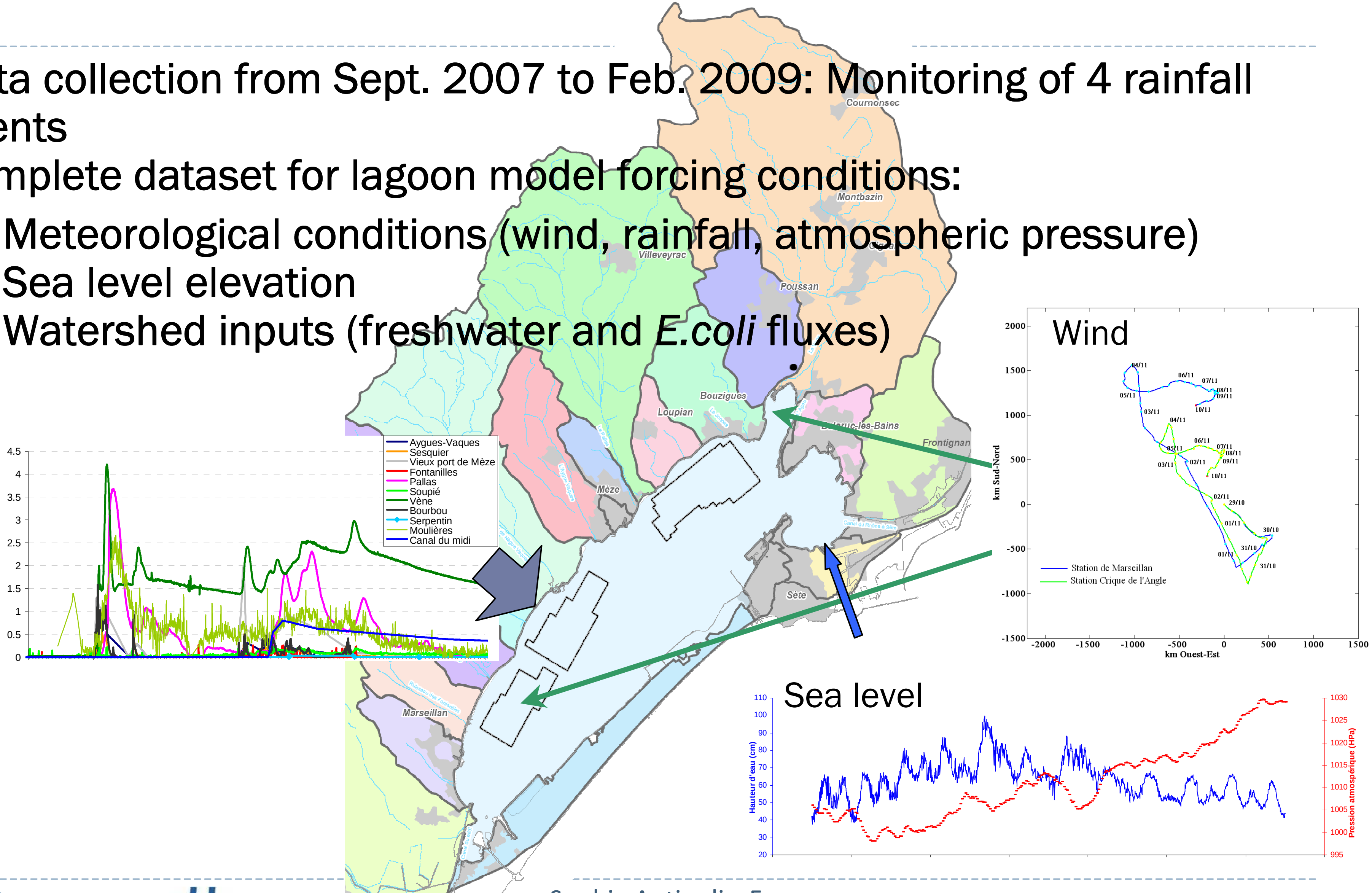


MONITORING OF WATERSHED AND LAGOON
Dataset for lagoon modelling

Data collection from Sept. 2007 to Feb. 2009: Monitoring of 4 rainfall events

Complete dataset for lagoon model forcing conditions:

- Meteorological conditions (wind, rainfall, atmospheric pressure)
- Sea level elevation
- Watershed inputs (freshwater and *E.coli* fluxes)

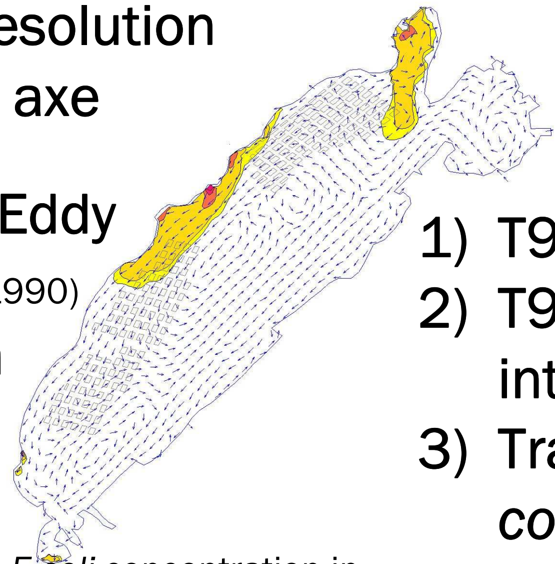


CALIBRATION OF LAGOON HYDRODYNAMICS AND *E.Coli* MODELS

The hydrodynamic model : Model for Application at Regional Scale (MARS-3D) Lazure and Dumas (Advances in Water Resources, 2008)

100 m x 100 m horizontal resolution
10 σ level along the vertical axe

Turbulence closure model : Eddy kinetic energy model (Gaspar, 1990) is tuned with the dissipation parameter (C_{KL})



Simulated *E.coli* concentration in surface water during nov. 2008 rainfall event

Three models of *E. coli* mortality in seawater:

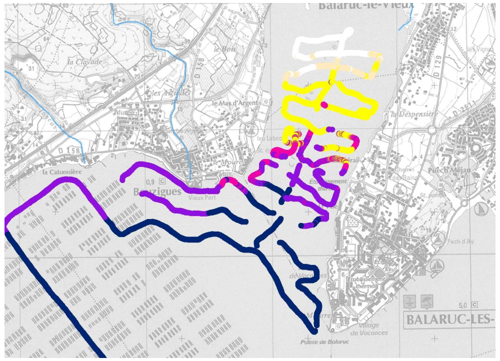
1) T90 constant
2) T90 as a function of light intensity
3) Transformation of viable *E. coli* from a culturable to a non-culturable state

E. coli concentration in oysters: use of enrichment factor (Fe = 5)

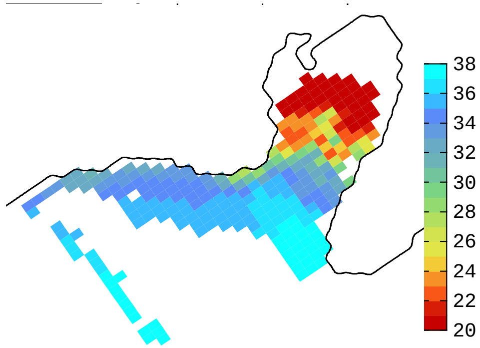
CALIBRATION OF LAGOON HYDRODYNAMICS AND *E.Coli* MODELS
Dataset for lagoon calibration

Spatial & temporal high resolution surface layer hydrological parameters sampling with a towed multi parameters measurement device (EasyFish sensor) in Crique de l'Angle

6 datasets collected between Nov. 3rd - 8



Kriging of measured salinity on the same grid as the MARS-3D one



CALIBRATION OF LAGOON HYDRODYNAMICS AND *E.Coli* MODELS
Geostatistics analysis

The kriged salinity field is compared with simulated field derived from MARS after extraction of simulation depths and times consistent with the observations

Statistical indicators are defined

Bias between model and measures = characterize the ability of the model to reproduce in average the appropriate salinity level

Determination coefficient R^2 = characterize the correlation between measured and observed salinity values

MSE = characterize the consistency between measured and observed salinity values

7 simulations have been done with different values of C_{KL} (0,01 – 0,5)

Statistical indicators are computed for each day and ranked for each simulation

CALIBRATION OF LAGOON HYDRODYNAMICS AND *E.Coli* MODELS
Geostatistics analysis

Statistical indicators

	CKL						
	0,01	*0,05*	*0,1*	*0,16*	*0,3*	*0,4*	*0,5*
03/11/2008							
Nb mesures : 276							
Biais (MARS-Easy)	6,13	**5,11**	**5,11**	5,28	5,67	5,78	5,82
R²	0,73	**0,92**	**0,81**	0,81	0,80	0,79	0,80
EQM	8,26	**6,84**	**6,80**	7,01	7,44	7,58	7,60
05/11/2008							
Nb mesures : 416							
Biais (MARS-Easy)	3,89	4,04	3,98	3,84	3,55	**3,39**	**3,28**
R²	0,66	0,68	0,66	0,68	0,72	**0,76**	**0,79**
EQM	6,36	6,49	6,46	6,33	6,01	**5,83**	**5,70**
06/11/08 am							
Nb mesures : 238							
Biais (MARS-Easy)	5,16	4,75	4,45	4,27	**4,21**	4,22	**4,21**
R²	**0,70**	**0,55**	0,49	0,48	0,51	0,52	0,55
EQM	6,73	6,39	6,30	6,20	**6,16**	6,17	**6,14**
06/11/08 pm							
Nb mesures : 260							
Biais (MARS-Easy)	8,39	7,83	7,84	**7,75**	**7,74**	7,87	7,88
R²	**0,70**	0,59	0,54	0,55	0,59	0,63	**0,64**
EQM	11,02	**10,39**	10,50	10,42	**10,41**	10,50	10,55
07/11/2008							
Nb mesures : 284							
Biais (MARS-Easy)	14,73	14,54	**14,35**	**14,39**	14,46	14,58	14,77
R²	**0,43**	**0,40**	0,39	0,38	0,37	0,36	0,35
EQM	15,98	15,79	**15,60**	**15,66**	15,73	15,86	16,06
08/11/2008							
Nb mesures : 351							
Biais (MARS-Easy)	5,14	5,01	4,87	4,72	4,56	**4,46**	**4,49**
R²	0,12	0,11	0,12	**0,13**	0,12	0,13	**0,14**
EQM	5,82	5,84	5,73	5,60	5,50	**5,42**	**5,38**

Simulated salinity plume shows a good correlation with the observations with much of the observed variability reproduced by the model (R^2 = 0,7)

R^2 decreases with time for all simulations

Simulated surface salinity values were systematically overestimated

Rangs moyens

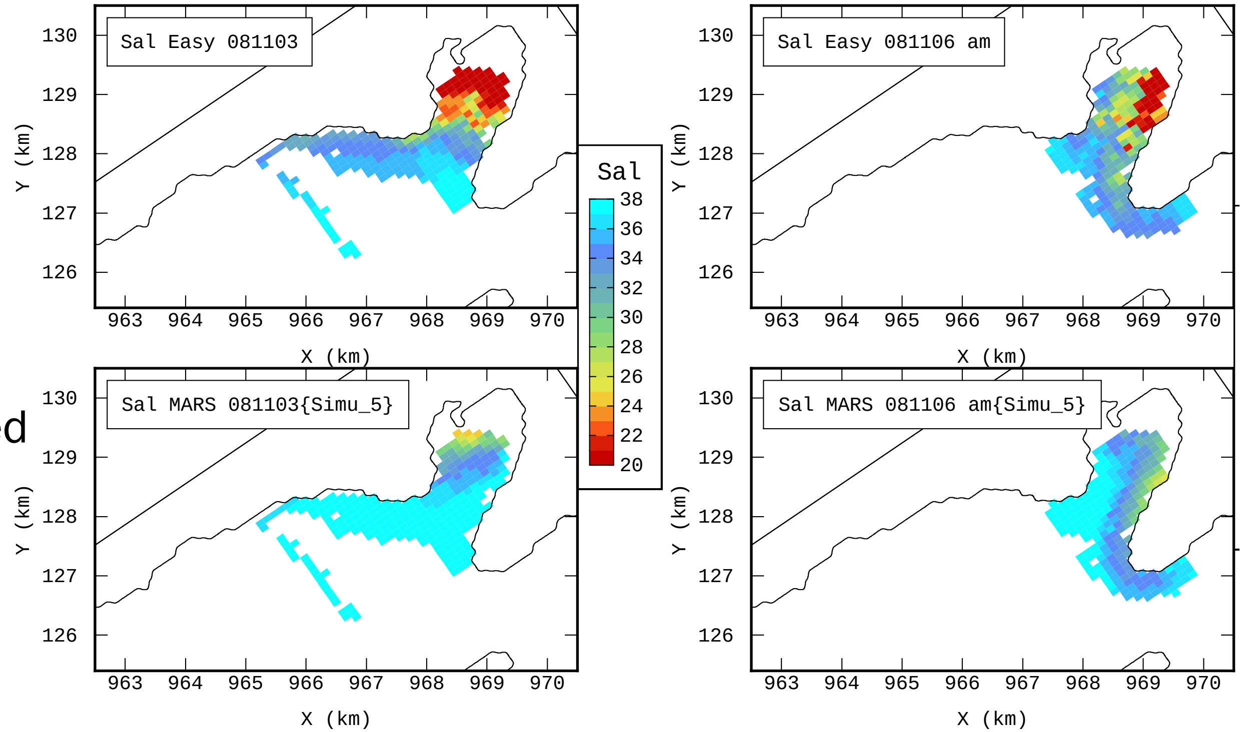
	CKL						
	0,01	*0,05*	*0,1*	*0,16*	*0,3*	*0,4*	*0,5*
Biais	6,5	4,5	3,8	**3,2**	**2,5**	3,5	4,0
R²	3,5	**3,3**	5,0	4,5	4,5	4,0	**3,2**
EQM	6,3	4,5	3,8	**3,3**	**2,8**	3,5	3,7
Moyenne des rangs	5,4	4,1	4,2	3,7	**3,3**	3,7	**3,6**

CALIBRATION OF LAGOON HYDRODYNAMICS AND *E.Coli* MODELS
Geostatistics analysis

Good correlation between observations and simulations

Kriged salinity fields

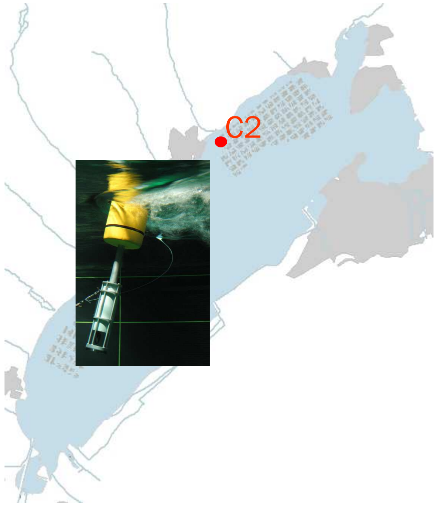
Simulated fields derived from MARS-3D



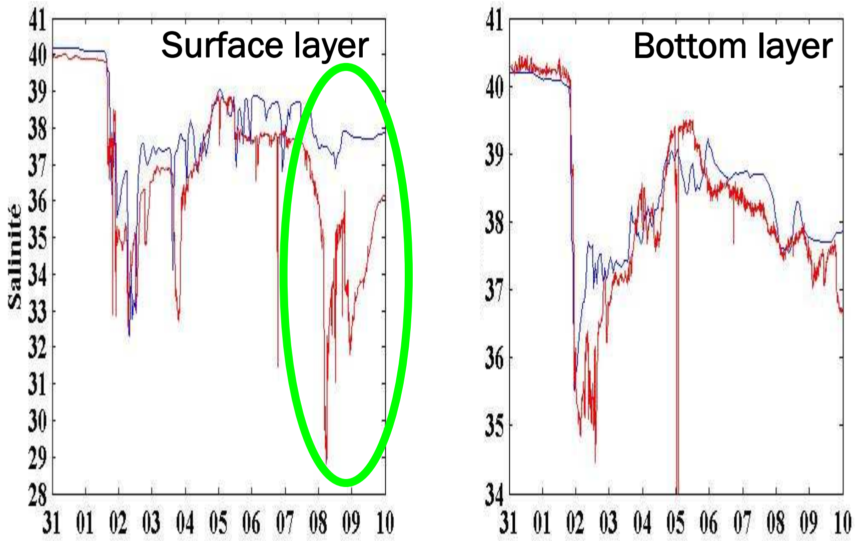
Strong spatio-temporal variability of the salinity plume (related to wind conditions) is well simulated

CALIBRATION OF LAGOON HYDRODYNAMICS AND *E.Coli* MODELS
Geostatistics analysis

R^2 decreases with time for all simulations



Observed and simulated temporal variations of salinity at C2 sampling station in surface layer and bottom layer

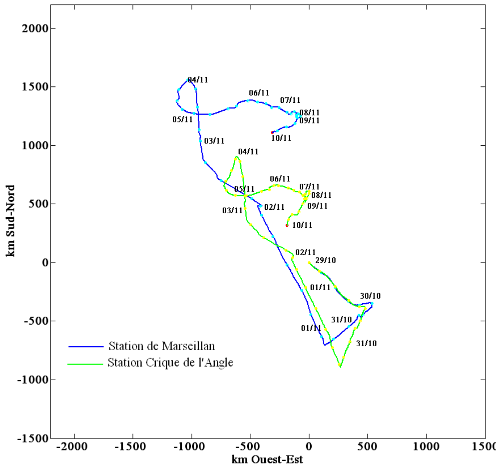


Monitoring of freshwater inputs were not exhaustive at the end of the rainfall event (?)

CALIBRATION OF LAGOON HYDRODYNAMICS AND *E.Coli* MODELS
Geostatistics analysis

Simulated surface salinity values were systematically overestimated
- Did we have a good estimation of freshwater inputs (?)
- Is the vertical spread of the plume well reproduced by the model ?

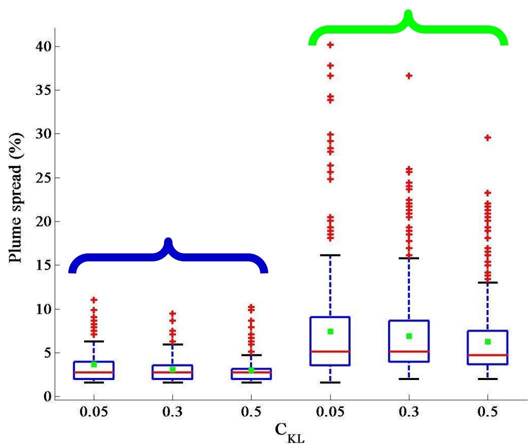
What we know (!)

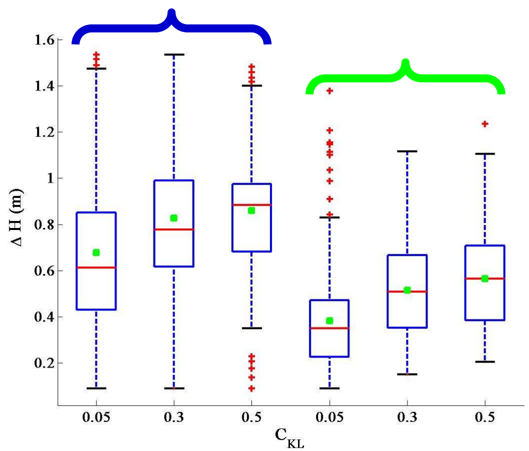


Central wind station

Crique de l'Angle
wind station

There is a strong relationship (via the vertical mixing angle parameter) between wind intensity and spread of the plume





CALIBRATION OF LAGOON HYDRODYNAMICS AND *E.Coli* MODELS
Calibration of *E.coli* survival model

Dataset for lagoon models calibration /validation:

- Water sampling for *E. coli* analyses (300 data/event)

Observations / Simulations

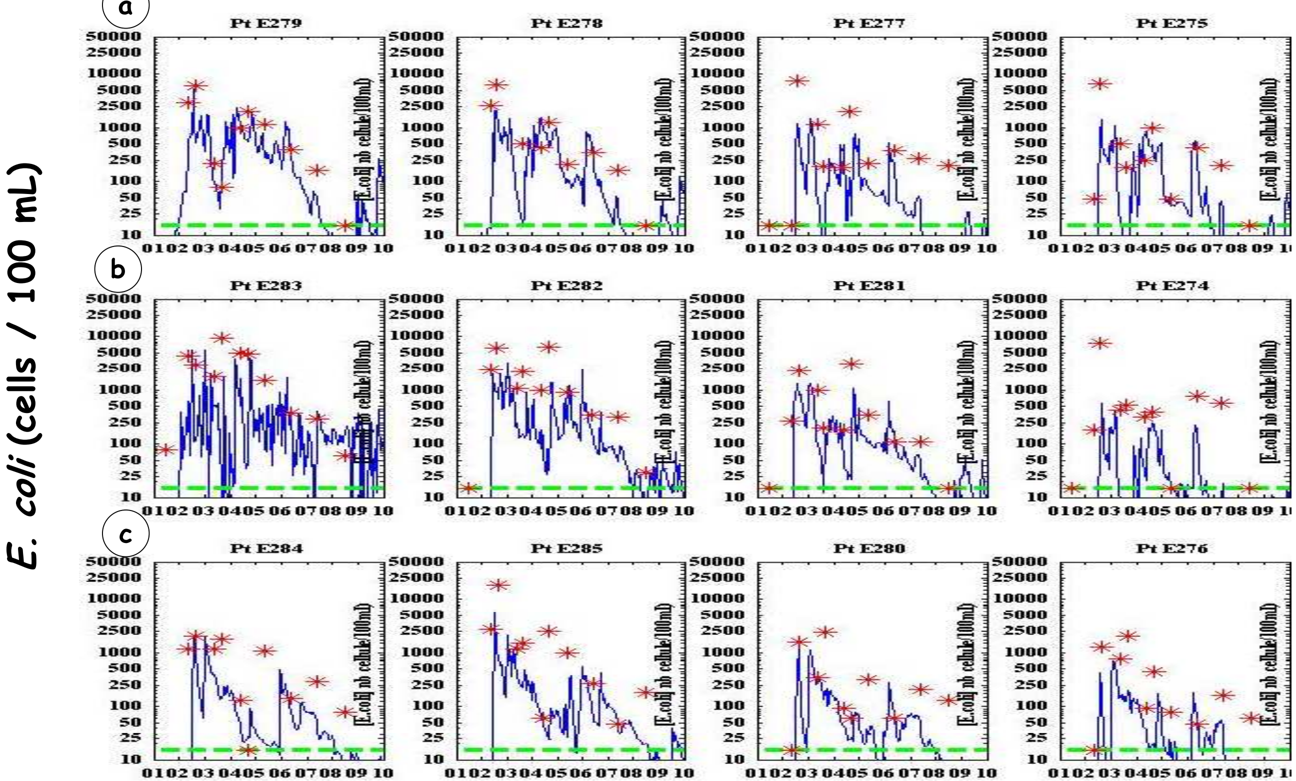
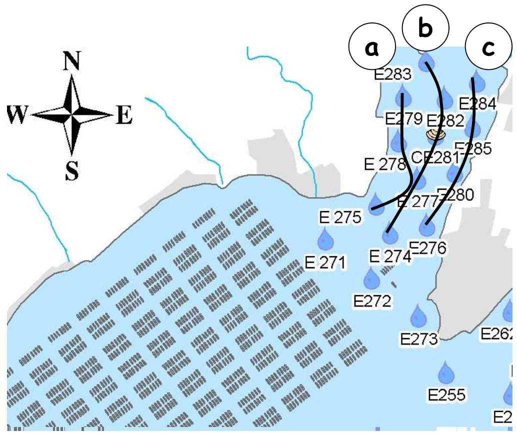


Figure 5. Comparison of observed *E. coli* concentrations in the surface layer (red points) and simulated concentrations (blue line) for the period of rainfall in January 2009, along three transects (a, b, c).



Location of the 3 transects
(4 sampling stations/transect).

E.Coli survival time
T90 = 48 h
(in autumn and winter)

CONCLUSIONS

What do we learn from observed and simulated data on hydrobiological characteristics of the ecosystem ?

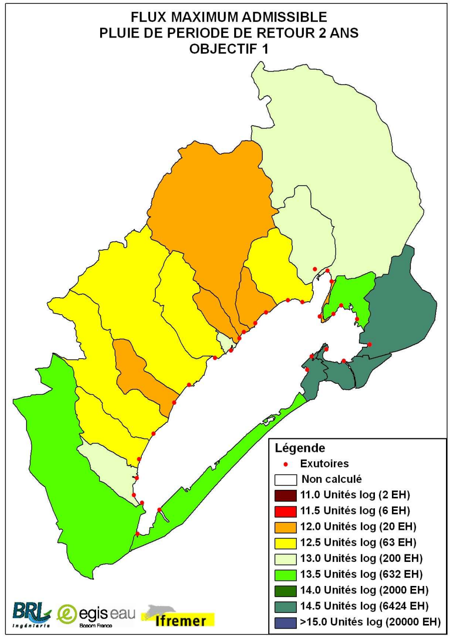
The temporal variations in forcing (wind and river flows) and the low inertia of the system induce a high level of variability of freshwater plume in both time and space.

During periods of rainfall, when the wind is strong, the water column is well mixed. In these conditions, the areas affected in shellfish growing areas are rather limited.
However, during periods without wind, the discharge of freshwater induces stratification of the water column, increasing the horizontal transport of *E. coli.* In these conditions, *E. coli* levels in the plume are higher and the shellfish growing area is at greater risk of being affected.

CONCLUSIONS

This study allowed us to calibrate mixing parameters of the hydrodynamic MARS 3D Thau model. The survival time of *E. coli* in the lagoon has been estimated (for autumn and winter conditions T90 = 48 hours)

Periods of rainfall with no wind have been identified as the conditions that are most likely to promote dispersion of high *E. coli* levels toward shellfish growing areas.



This calibration and validation study enabled us to use these coupled models to determine the maximum *E. coli* inputs that can be reached before observing an effect on water and shellfish quality

Thanks for your attention!

Avec le concours de / In partnership with

OMEGA Thau project - Technical and financial partners