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Water and ecological quality in the Aljezur coastal stream (Portugal)

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Outline

> The Aljezur Coastal Stream

> Model Description

- Hydrodynamic Model – SELFE
- Fecal Contamination Model
- Ecological Model
  - Oxygen Cycle

> Application to the Aljezur Coastal Stream

> Final considerations and future work

The Aljezur Coastal Stream

> Southwest coast of Portugal

> Natural Park of the Sudoeste Alentejano and Costa Vicentina; classified in the Natura 2000 Network and IBA (Important Bird Area)

> Recreational activities (Amoreira beach)

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DE ENGENHARIA CIVIL

Objectives

> **Study the effects of the inlet bathymetric changes in the water and ecological quality of the Aljezur coastal stream**

> **Extend and validate a water quality and ecological model**

Oxygen Cycle
(Water Framework Directive)

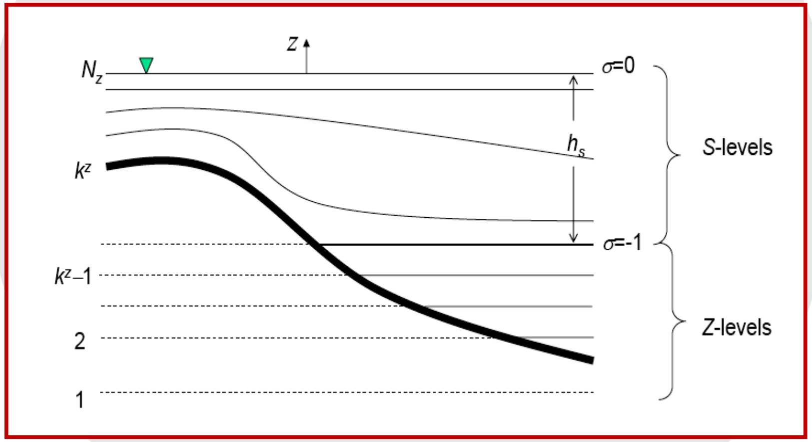
Fecal Contamination Variables
(Bathing Waters Directive)

Model Description

Hydrodynamic Model - SELFE

> **SELFE (Zhang and Baptista, 2008):**

- Computes the free-surface elevation and the 3D velocity, salinity and temperature fields
- Unstructured grids (horizontal)
- Hybrid S-Z coordinates (vertical)

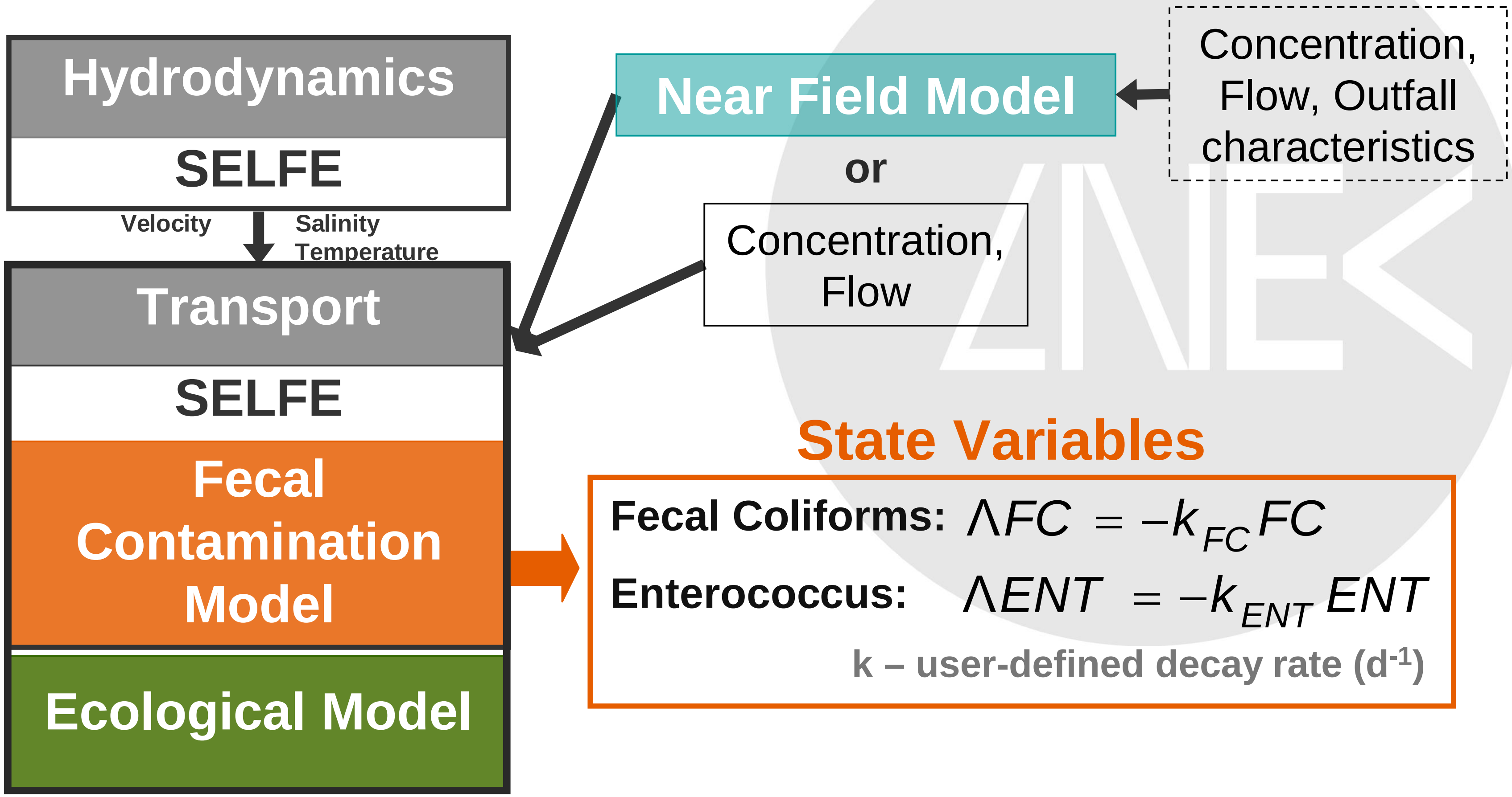


- User-defined tracer transport module:

$$\frac{\partial C}{\partial t} + u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} + w\frac{\partial C}{\partial z} = \frac{\partial}{\partial z}\left(\kappa\frac{\partial C}{\partial z}\right) + F_c + \Lambda C$$

Sources and sinks term

Fecal Contamination Model



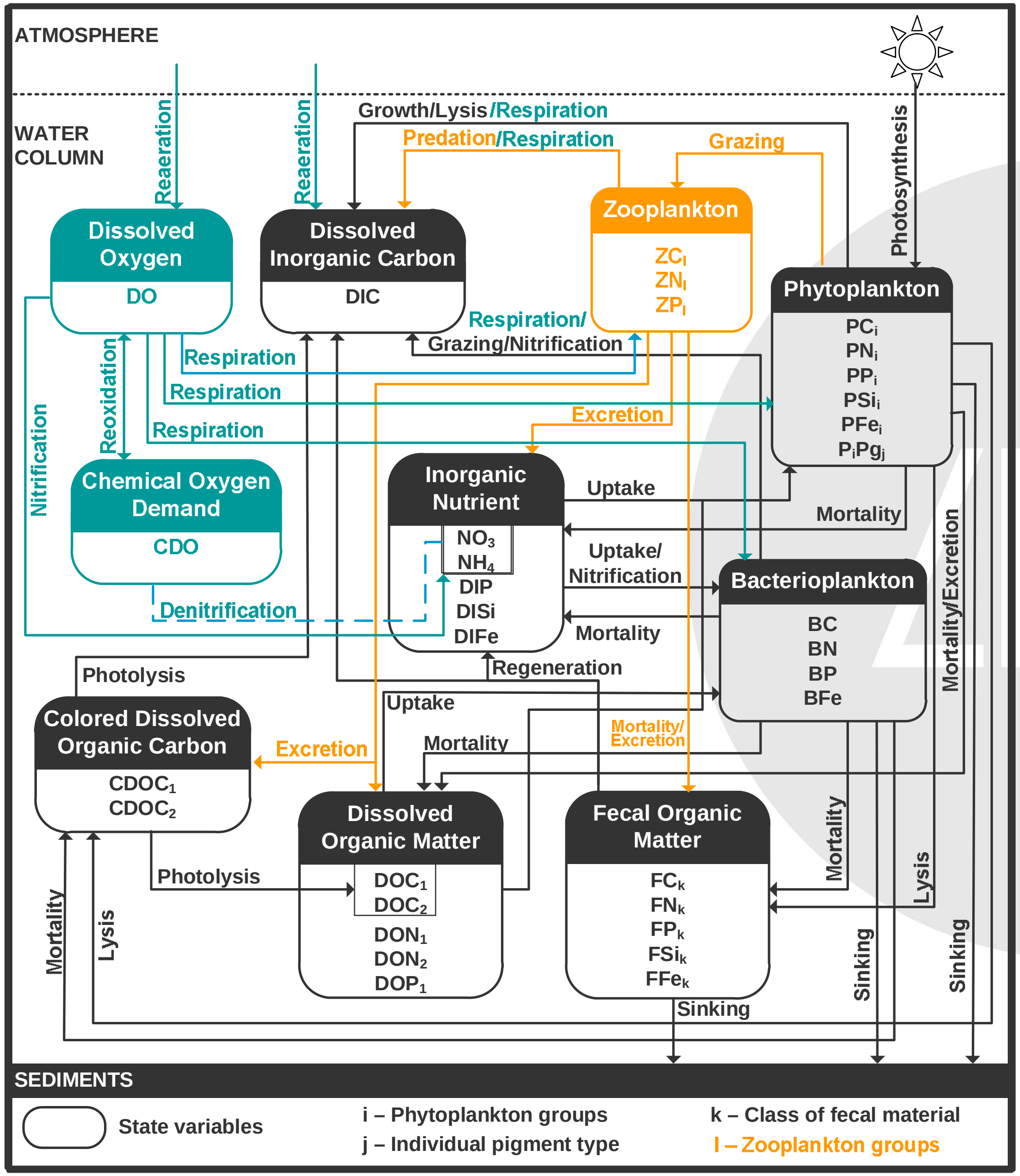
Ecological Model

> **Model extended from EcoSim 2.0 (Bisset et al., 2004):**

- EcoSim 2.0 includes the C, N, P, Si and Fe cycles
- Zooplankton simulation (formulation developed from Vichi et al. 2007 and based on Leandro et al. 2006 studies in the Ria de Aveiro)
- Oxygen cycle (formulation developed from Vichi et al. 2007)

State Variables

Zooplankton
Phytoplankton
Bacterioplankton
Dissolved Organic Matter
Particulate Organic Matter
Inorganic Nutrients
Dissolved Inorganic Carbon
Dissolved Oxygen
Chemical Oxygen Demand



EcoSim 2.0 (Bisset et al., 2004)

+

Zooplakton

+

Dissolved Oxygen

Chemical Oxygen Demand

Oxygen Cycle

Dissolved Oxygen

Sources

Gross primary production

Reaeration

Sinks

Zooplankton, phytoplankton and bacterioplankton respiration

Nitrification

Pelagic chemical reactions

$$\Lambda DO = \Omega_C^O \sum_i \left(\mu_{r\_i} PC_i - respP_i\right) - \Omega_C^O \sum_l respZ_l - \Omega_C^O f_B respB + reaer - \Omega_N^O AtoN - \frac{1}{\Omega_O^S} COD$$

- Gross primary production: $\mu_{r\_i} PC_i$
- Phytoplankton respiration: $respP_i$
- Zooplankton respiration: $\Omega_C^O \sum_l respZ_l$
- Bacterioplankton respiration: $\Omega_C^O f_B respB$
- Reaeration at the surface boundary: $reaer$
- Nitrification: $\Omega_N^O AtoN$
- COD: $\frac{1}{\Omega_O^S} COD$

Dissolved Oxygen

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- **Phytoplankton Growth:**

$$\mu_{r\_i} = \left[\min\left(\mu_{LI\_i}, \mu_{NI\_i}, \mu_{PI\_i}, \mu_{SI\_i}, \mu_{FI\_i}\right)\right] PC_i$$

- **Phytoplankton Respiration:**

$$respP_i = b_{Pi} Q_{Pi}^{\frac{T-10}{10}} PC_i + \gamma_{Pi}\left(\mu_{r\_i} PC_i - e_i PC_i\right)$$

- **Zooplankton Respiration:**

$$respZ_l = b_{Zl} Q_{Zl}^{\frac{T-10}{10}} ZC_l + (1-\beta_{Zl})(1-\eta_{Zl})\mu_{z\_l} ZC_l$$

- **Bacterioplankton Respiration:**

$$respB = b_B Q_B BC + \left[1 - GGE_C + GGE_C^O (1 - f_B)\right]\rho_B$$

- **Nitrification**

$$AtoN = Nit\, Q_N^{\frac{T-10}{10}} \left(\frac{DO}{DO + K_{s\_Nit}}\right) NH_4$$

- **Reaeration**

$$reaer = K_{reaer}\left(DO_{sat} + DO_w - DO\right)$$

μ – growth rate (d^{-1})

b - basal specific respiration rate (d^{-1})

Q - temperature coefficient (nd)

T - water temperature (ºC)

γ - fraction of assimilated production (nd)

e - excretion rate (d^{-1})

β - excreted fraction of uptake (nd)

η - assimilation efficiency (nd)

GGE_C - growth efficiency (nd)

GGE_{CO} - decrease in growth efficiency under anoxic conditions (nd)

f_B - oxygen regulating factor (nd)

ρ_B - bacterioplankton uptake

Nit - specific nitrification rate (d^{-1})

K_{s_Nit} – half-saturation for the nitrification (mmol $O_2.m^{-3}$)

K_{reaer} - reaeration coefficient ($m.d^{-1}$)

Oxygen Cycle

Chemical Oxygen Demand

Sources	**Sinks**
Bacterioplankton respiration	**Denitrification** **Reoxidation**

$$\Lambda COD = \underbrace{\Omega_{C}^{S}\,\Omega_{C}^{O}\,(1 - f_{B})\,respB}_{\text{Bacterioplankton respiration}} - \underbrace{\Omega_{C}^{S}\,\Omega_{C}^{O}\,AtoDenit}_{\text{Denitrification}} - \underbrace{reox}_{\text{Reoxidation}}$$

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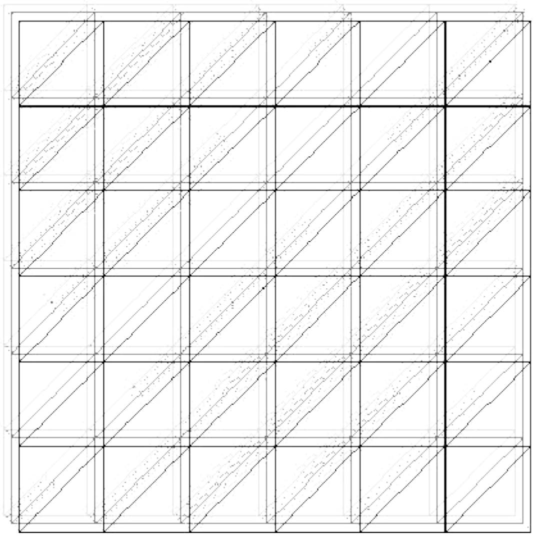
BioToy Test Case

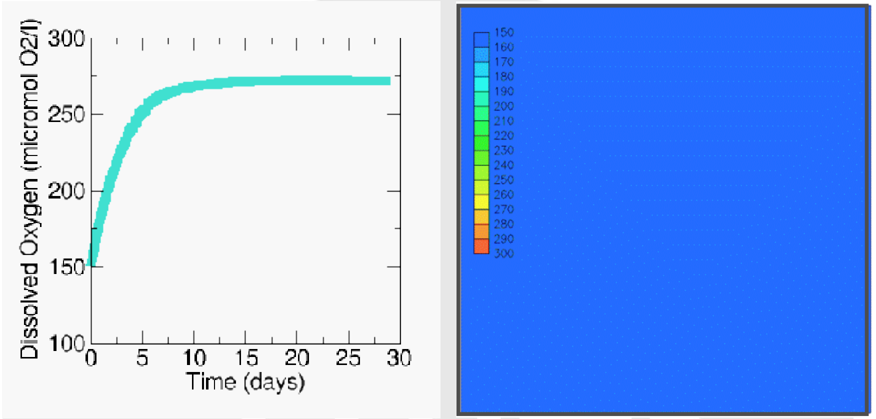
> **Horizontal grid:**
> **49 nodes and 72 elements**

> **Vertical grid:**
> **10 *S* levels**

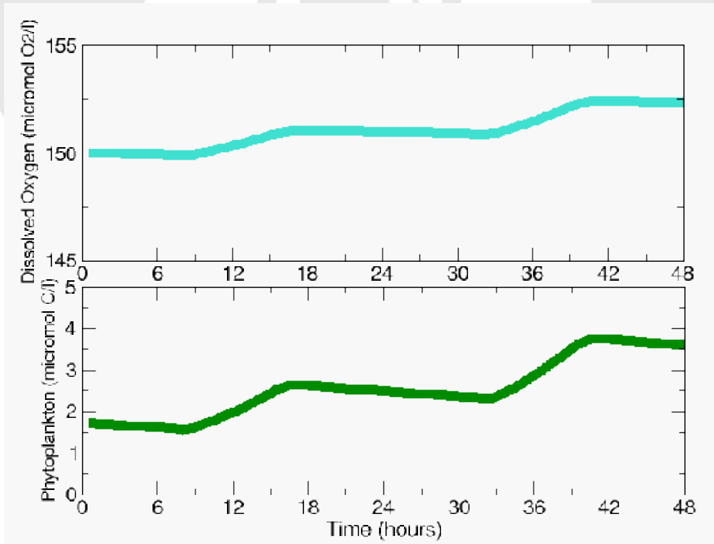
> **All boundaries closed**



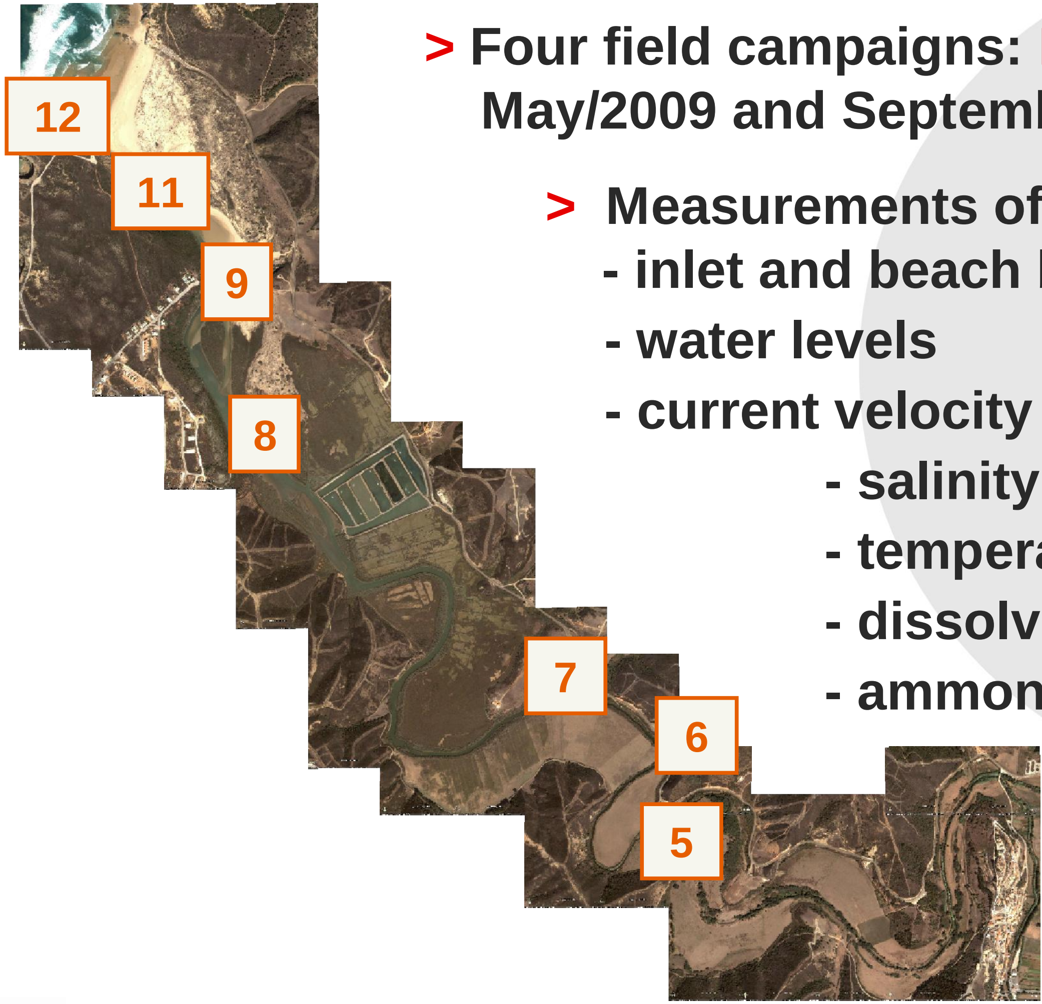
Surface reaeration



Diurnal variation



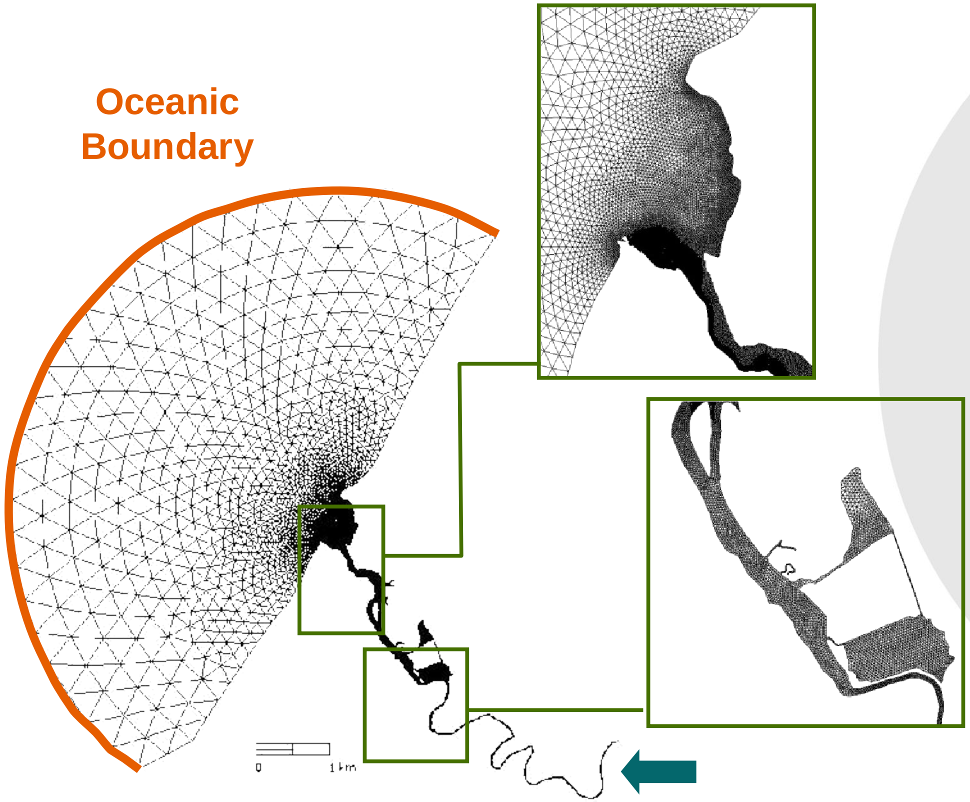
Application to the Aljezur Coastal Stream



> Four field campaigns: May/2008, September/2008, May/2009 and September/2009

> Measurements of:
- inlet and beach bathymetry
- water levels
- current velocity
- salinity
- temperature,
- dissolved oxygen
- ammonium, nitrate, phosphate and silicate
- chlorophyll a
- fecal coliforms and enterococcus

Model Setup



> **Horizontal grid:**
> **41000 nodes and 75000 elements**

> **Vertical grid:**
> **11 *S* levels**

> **Δt = 5 s**

> **2 open boundaries:**
> - **1 oceanic**
> - **1 riverine**

> **Atmospheric forcing:**
> **NCEP, Windguru, Port of Sines and SNIRH**

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Hydrodynamics – Wind and River Flow

May/2008

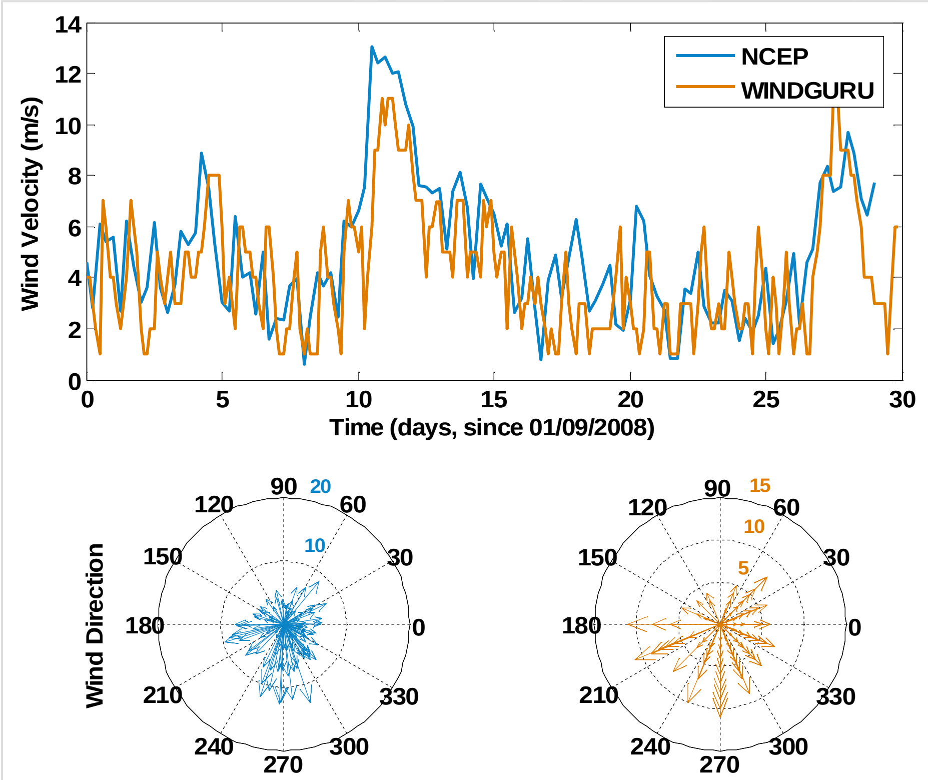
River Flow

Downstream Wind:
WINDGURU

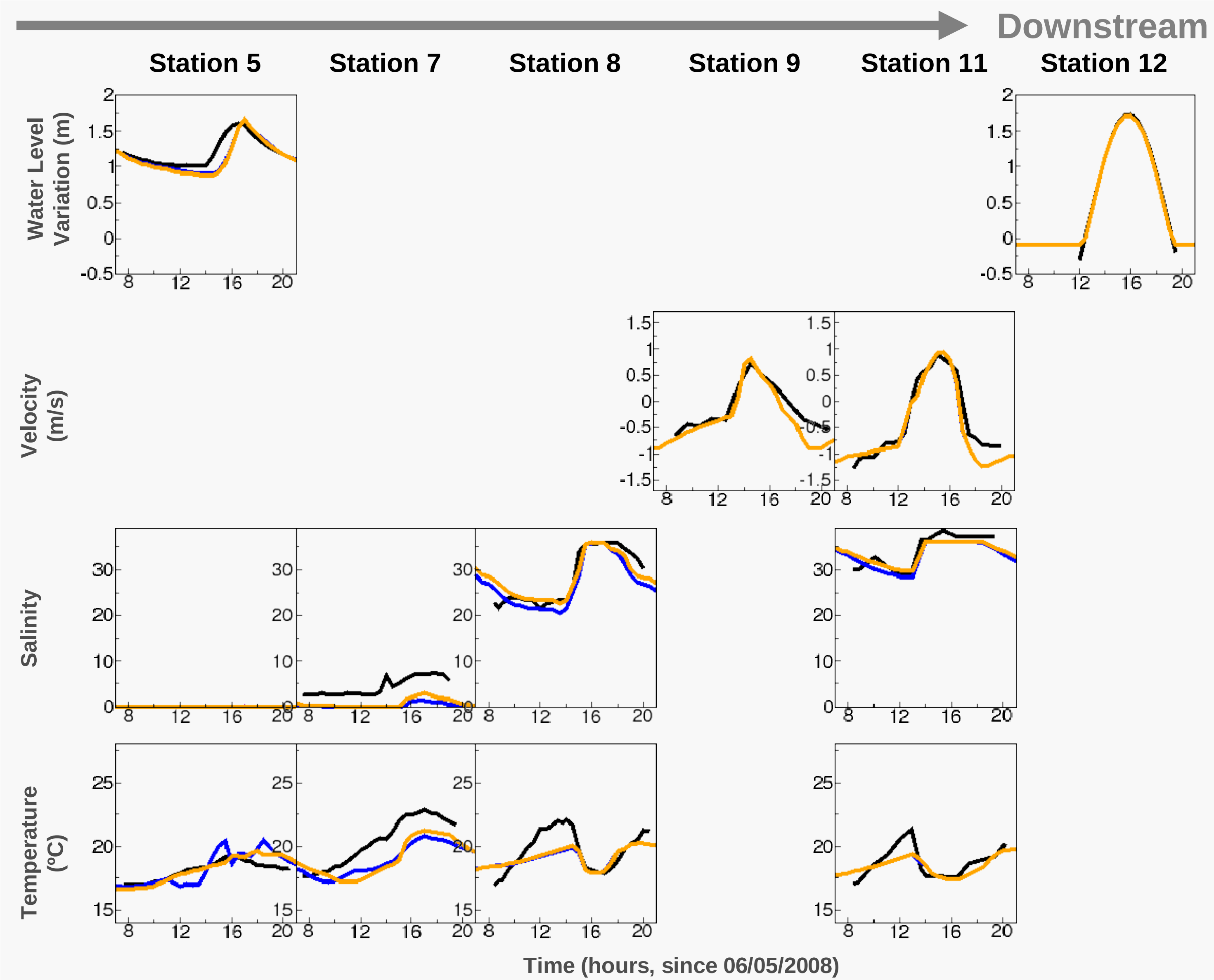
September/2008

River Flow = 0.03 m³/s

Downstream Wind



Hydrodynamics – May/2008

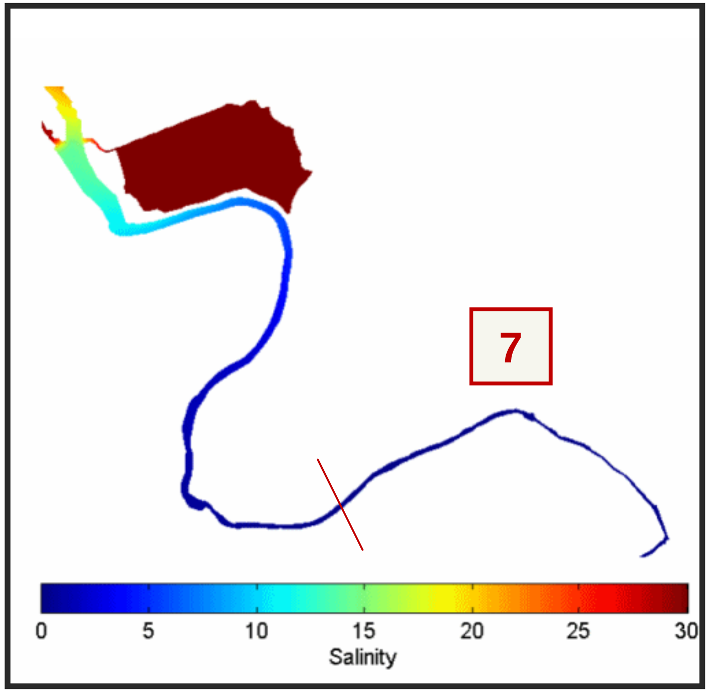


Legend:

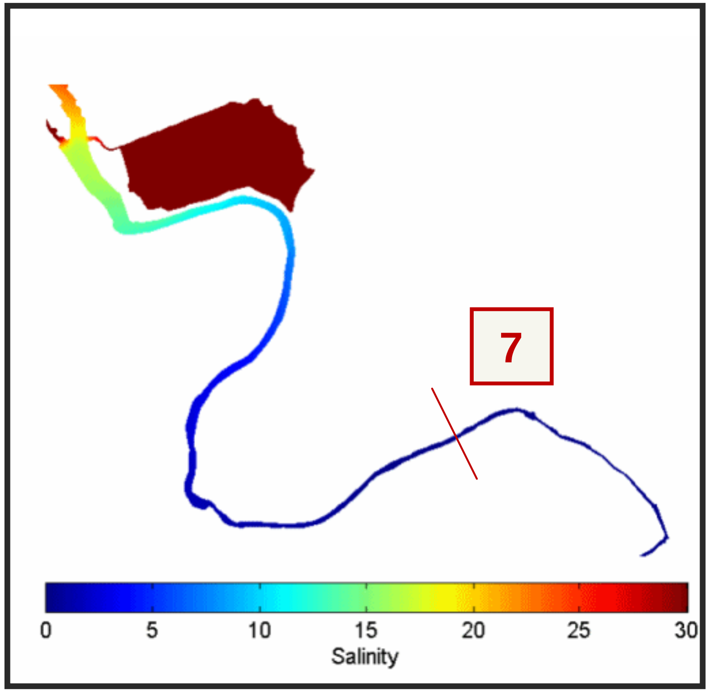
- **Data**
- **0.20 m³/s, WINDGURU**
- **0.15 m³/s, WINDGURU**

Salinity – May/2008

River Flow = 0.2 m³/s

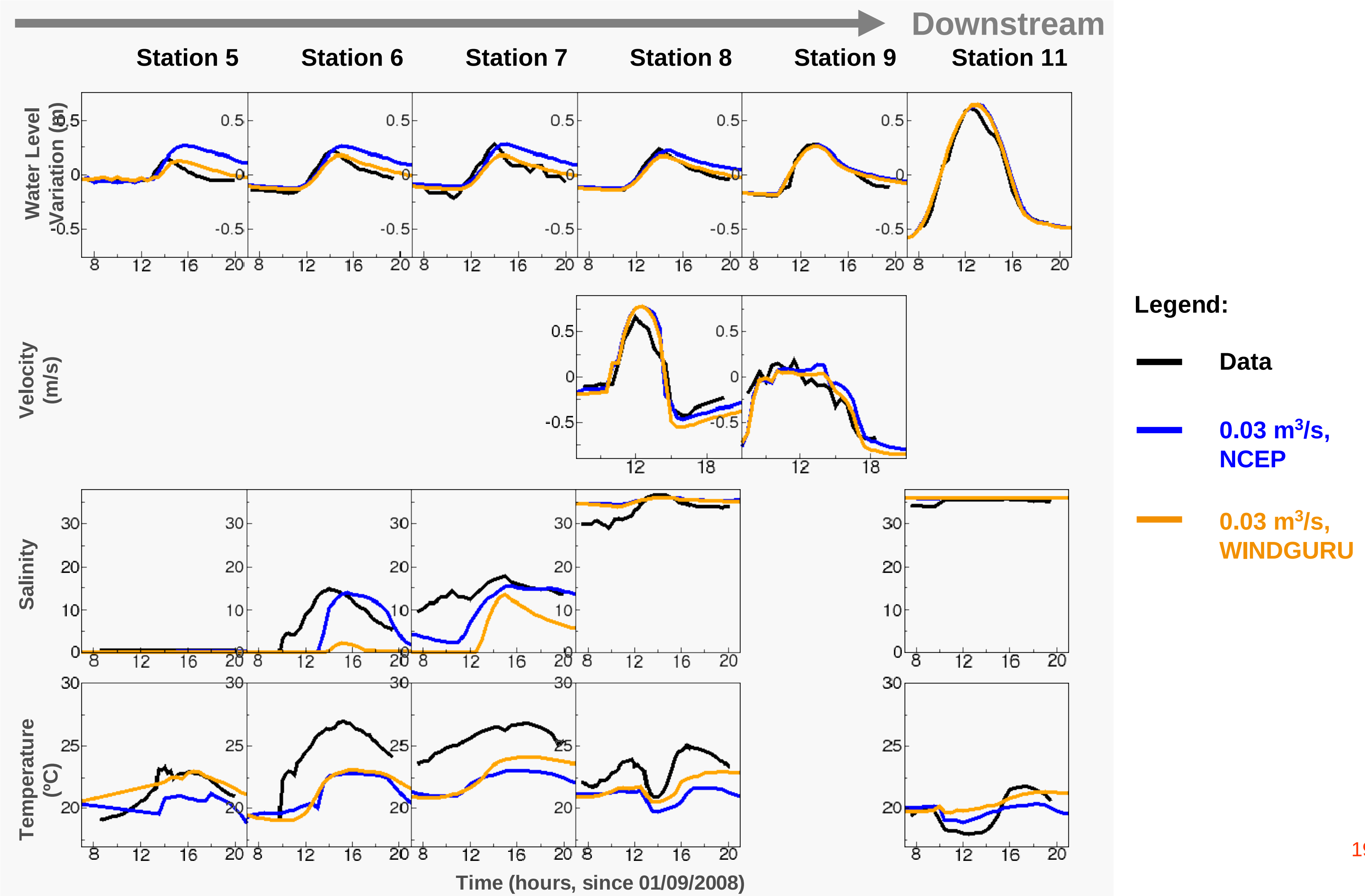


River Flow = 0.15 m³/s



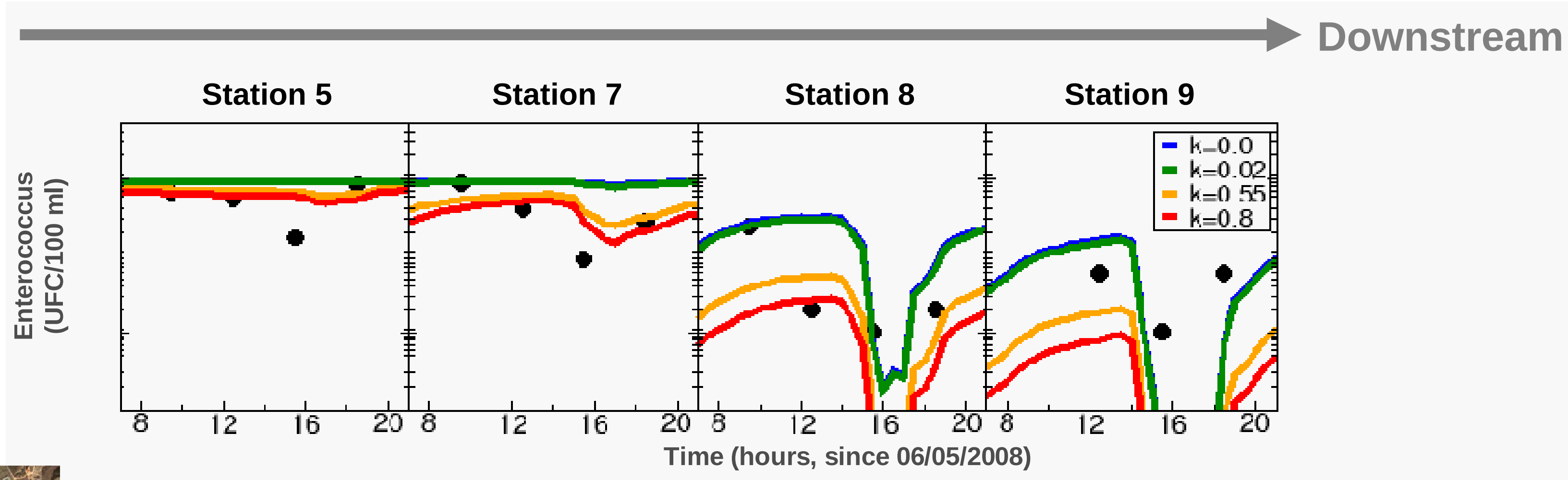
> Salt wedge limit - sensitivity to the river flow

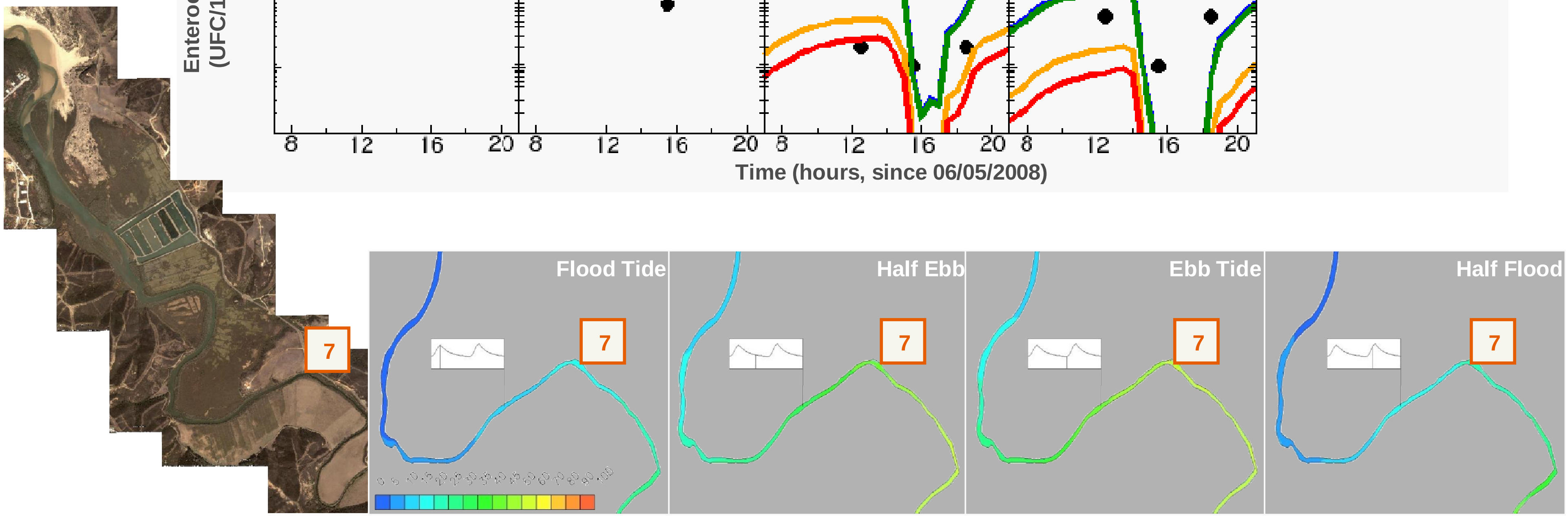
Hydrodynamics – Sept./2008



Fecal Contamination – May/2008

> Sensitivity to the decay rate (0.15 m^3/s river flow, WINDGURU wind)





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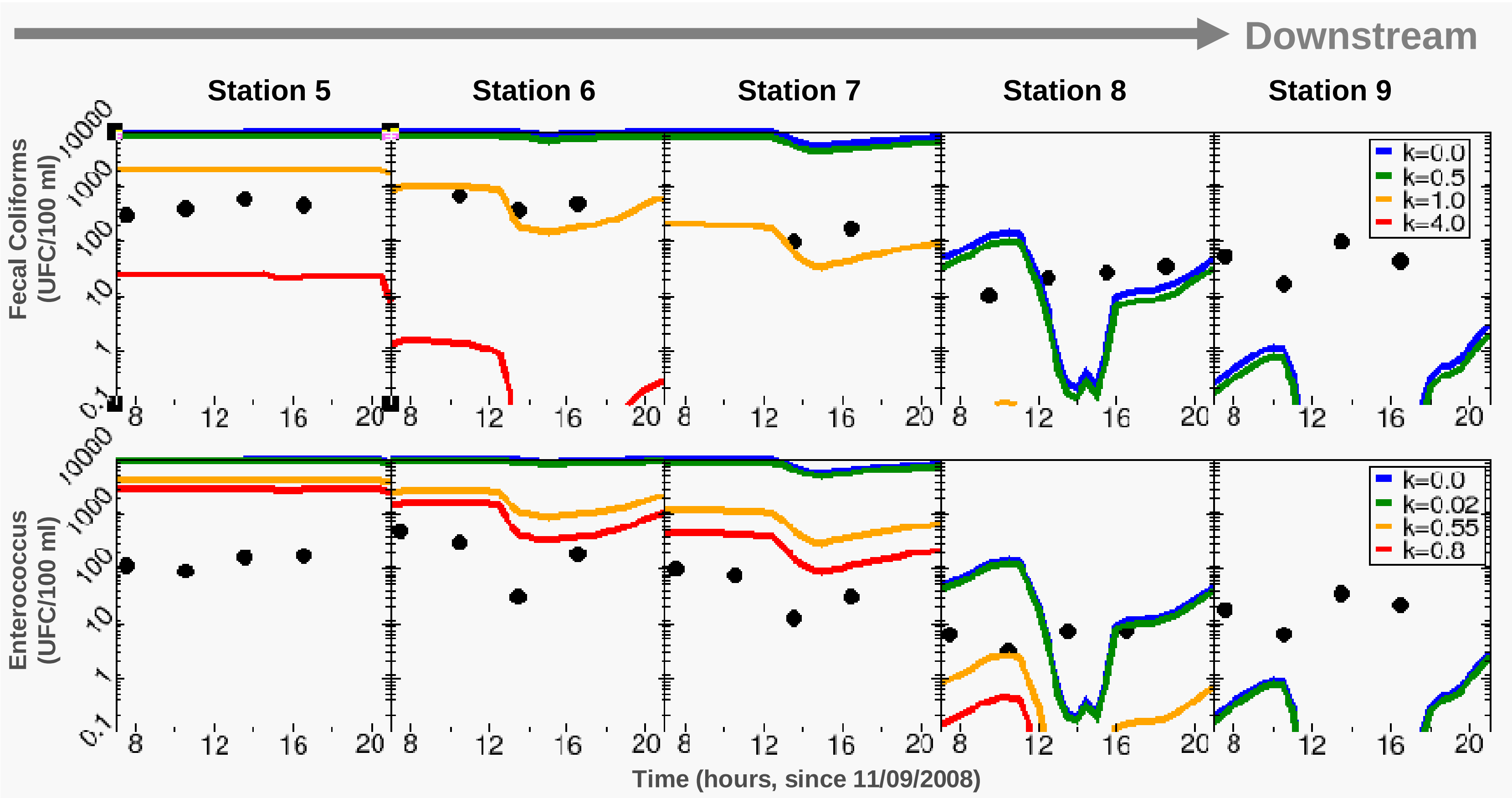
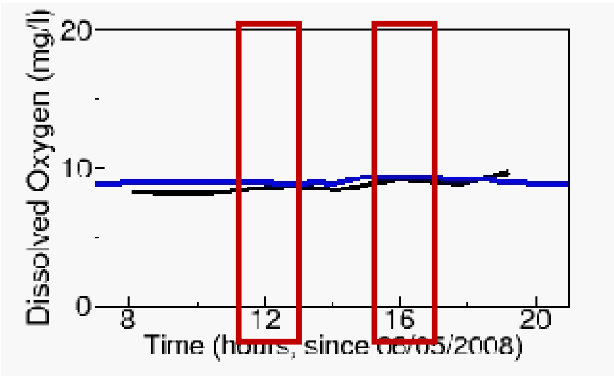
Fecal Contamination – Sept./2008

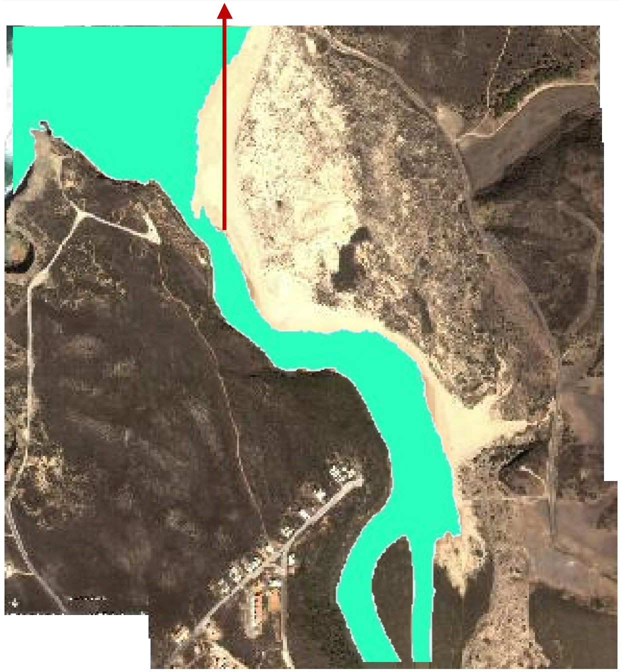
> Sensitivity to the decay rate (0.03 m³/s river flow, WINDGURU wind)



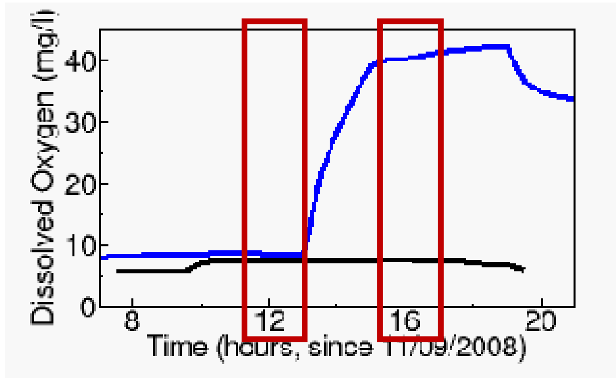
Dissolved Oxygen

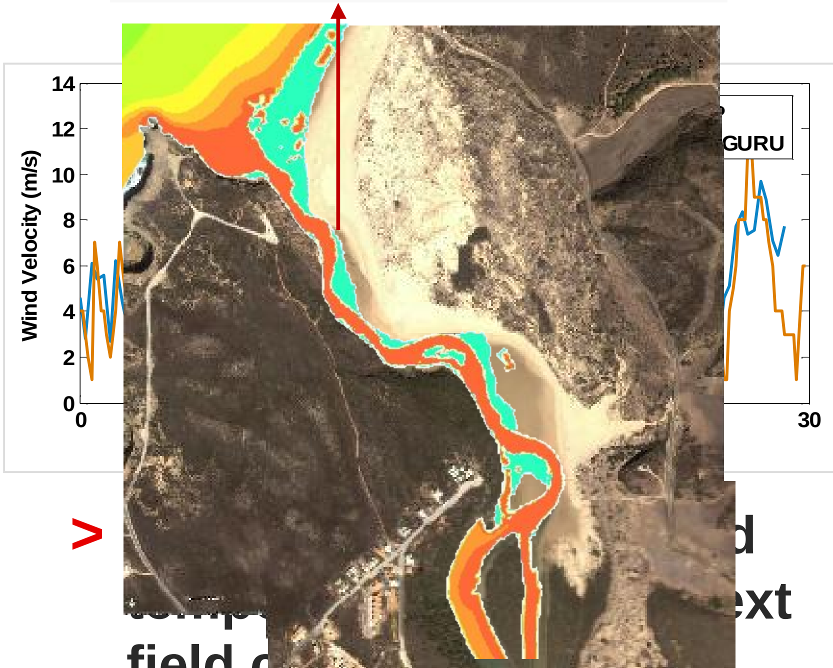
May/2008



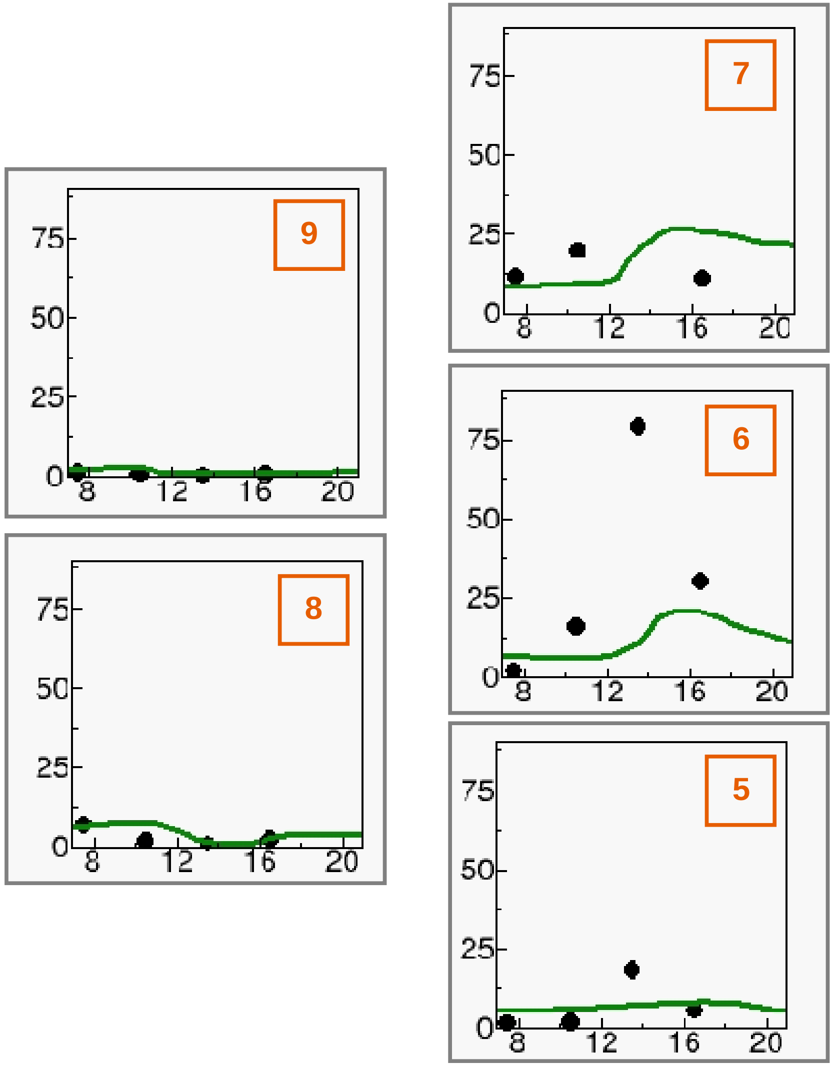


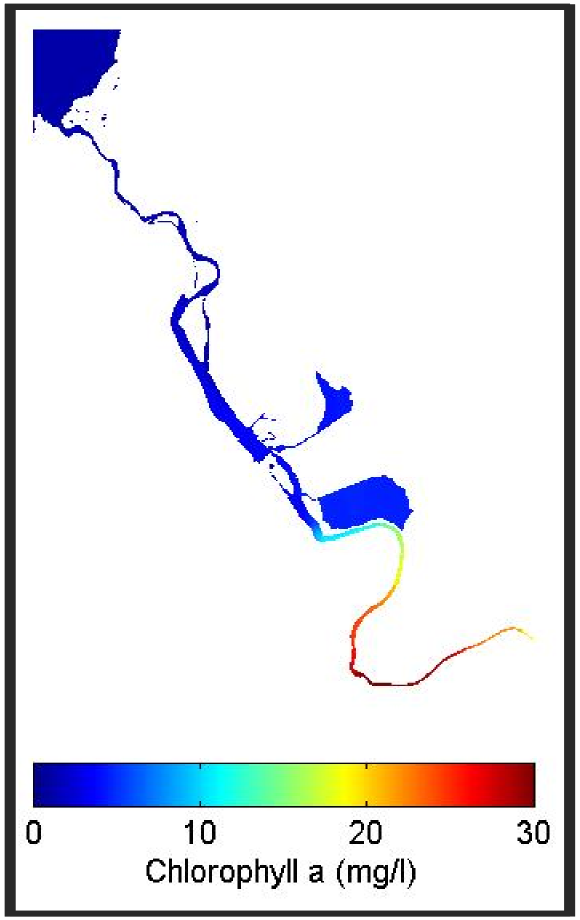
September/2008





Chlorophyll *a* (mg/l)– 11/September/2008





Final considerations and future work (I)

> Validation of the model

- main difficulties associated with the computational times (use of the parallel model)

> Hydrodynamic model:

- able to represent the main circulation patterns in the Aljezur coastal stream
- improvement of the atmospheric forcing

> Fecal contamination model:

- able to represent the main variations upstream
- downstream, results suggest the existence of an additional source of microorganisms, namely the salt marshes
- tests to the formulations for the fecal microrganisms decay - derived from the laboratory work

Final considerations and future work (II)

> **Ecological model:**

- able to represent the dissolved oxygen changes in May/2008

- improvement of the atmospheric forcing

> **Implementation of the near field model**

> **Tests with scenarios – effects of the inlet bathymetric changes on the water and ecological quality of the stream**

Water and ecological quality in the Aljezur coastal stream (Portugal)

Thank you for your attention!

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Participants in the field campaigns:

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LUSO-AMERICAN FOUNDATION

- Project *BGEM - Towards operational forecasting of ecosystem dynamics: benchmarking and grid-enabling of an ecological model*

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- **Denitrification**

$$AtoDenit = Denit\left[\frac{1}{M}\Omega_C^O(1-f_B)respB\right]NO_3$$

- **Reoxidation**

$$reox = reox\_COD\ Q_{COD}^{\frac{T-10}{10}}\frac{DO}{DO+K_{S\_COD}}COD$$

Denit - specific denitrification rate (d^{-1})

M - reference anoxic mineralization rate (mmol $O_2.m^{-3}.d^{-1}$)

Ω – stoichiometric coefficient (mmol O_2.mmol C^{-1})

b - basal specific respiration rate (d^{-1})

f_B - oxygen regulating factor (nd)

Q - temperature coefficient (nd)

T - water temperature (ºC)

$reox\_COD_{reaer}$ – reoxidation rate (d^{-1})

K_{s_COD} – half-saturation for the reoxidation (mmol $O_2.m^{-3}$)

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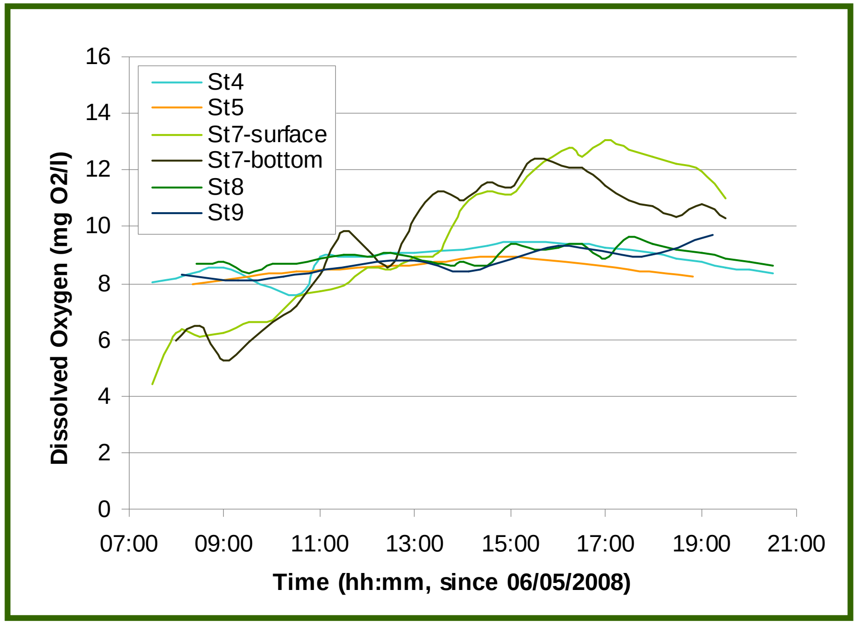
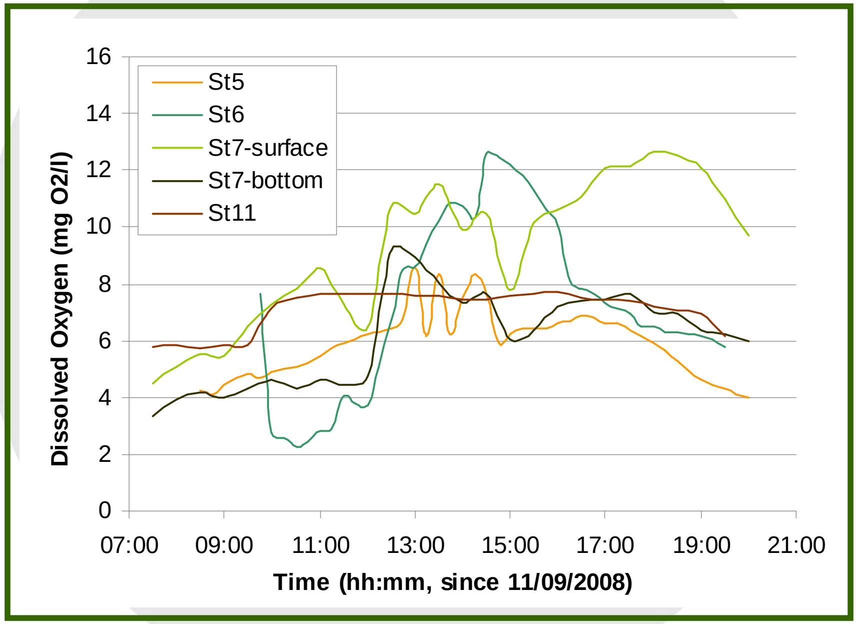
Dissolved Oxygen Data



May/2008

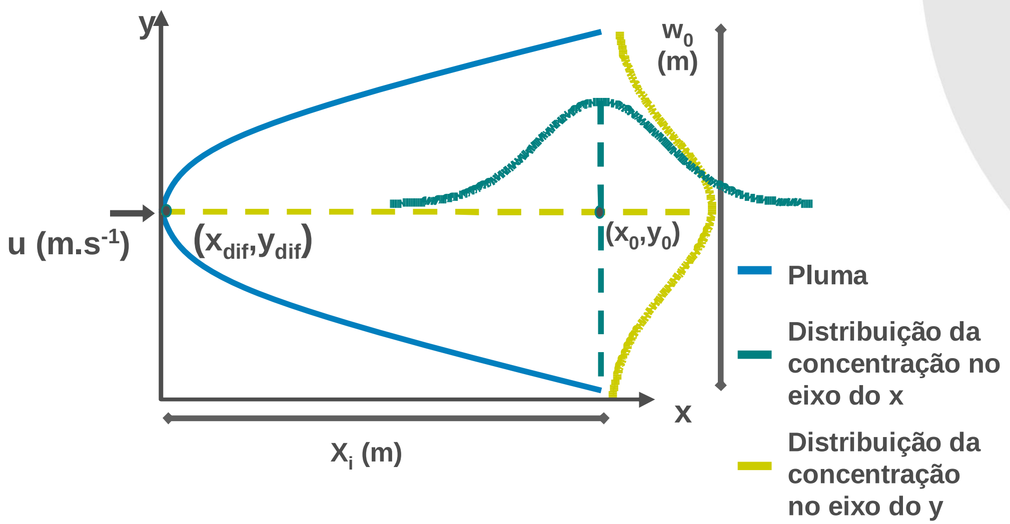


September/2008

Near Field Model

> Baseado no modelo RSB:

- calcula o comprimento do campo próximo, a largura, a espessura e a elevação da pluma e a diluição mínima no campo próximo
- assume-se uma distribuição Gaussiana no campo próximo



Representação esquemática 2D da pluma

X_i – comprimento do campo próximo

w_0 – largura da pluma no campo próximo

h_e – espessura da pluma no campo próximo

z_m – elevação da pluma no campo próximo

S_m diluição mínima