Applications of ELCIRC at LNEC

stratification in the Guadiana estuary

tidal propagation in the Óbidos lagoon

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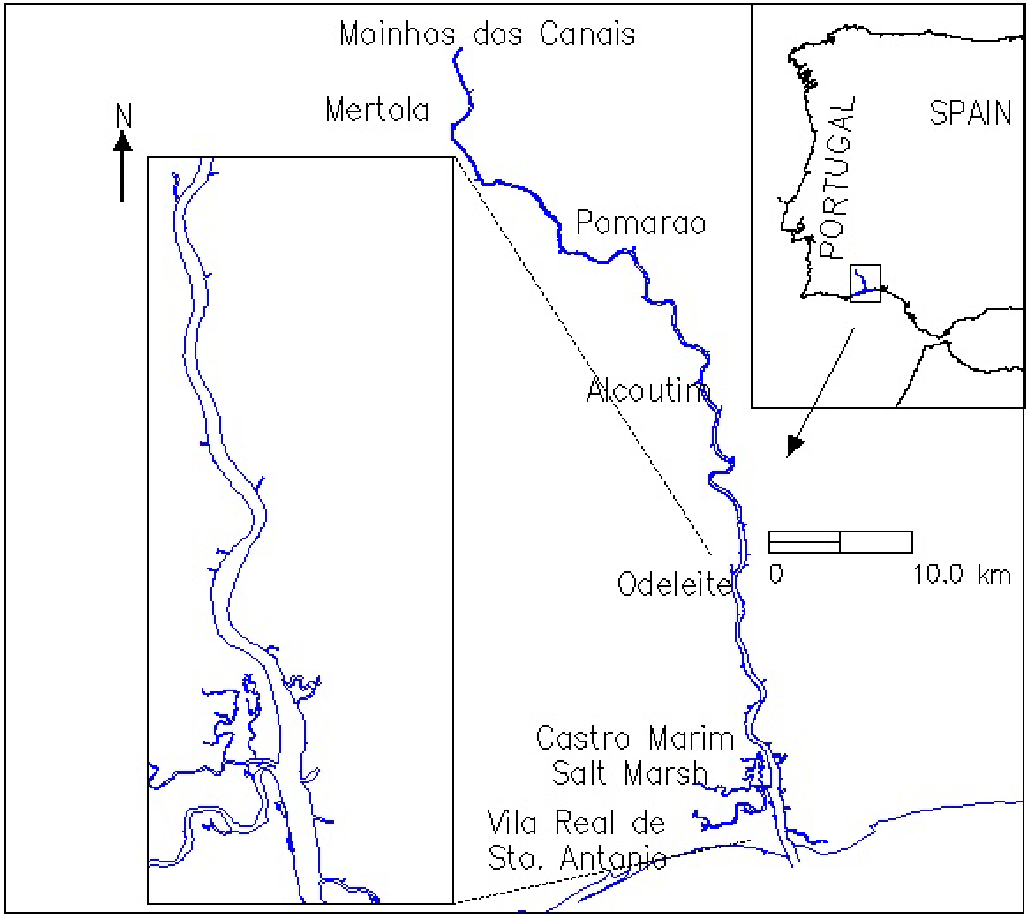
Outline

- Stratification in the Guadiana estuary
  - The Guadiana estuary
  - Objectives
  - Field data review
  - Model set-up and validation
  - Stratification analysis
  - Summary and conclusions
- Tidal propagation in the Óbidos lagoon

The Guadiana estuary

- **River flow:**

Year	Monthly-averaged river flow (m^3/s)	
	min	máx
Dry	2.5	14.2
Wet	13	277
Very wet	15	1480



- **Semi-diurnal tides: 0.6 - 3.5 m**

- **Old stratification analysis (empirical criteria)**
  - **well-mixed:** **$Q < 10\ m^3/s$**
  - **stratified:** **$Q > 100\ m^3/s$**

Objectives

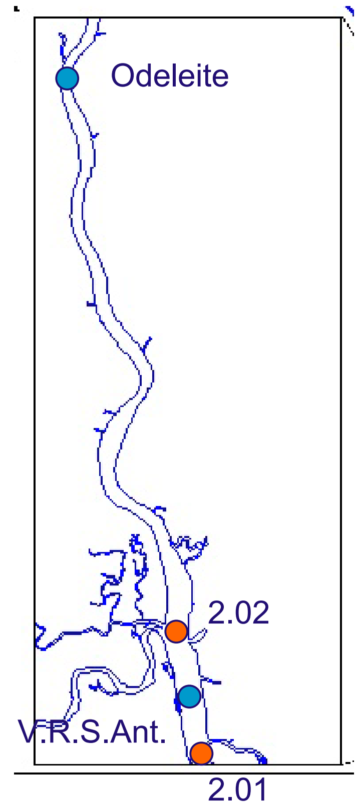
- **Analyze the conditions for stratification in the Guadiana estuary**
- **Characterize the salinity field under stratified conditions**

Combination of field data analysis and numerical modeling

Field data review

2001 Data campaigns

Date	Stations	River flow (m^3/s)	Tides
Feb. 2		384	neap tide
Feb. 10	V.R.S.António	2005	spring tide
Sept. 11	Odeleite	4	neap tide
Sept 18		4	spring tide
May 23		70	spring tide
May 29	2.01	35	neap tide
Oct. 18	2.02	20	spring tide
Oct. 24		249	neap tide



- **14 h vertical profiles, 1 m spacing in the vertical**
- **ADCP at station 2.01 for February and September campaigns**

Model set-up

Version 4.01 (triangular elements)

Domain discretization

- **Horizontal: 12000 nodes, spacing 9-3600 m**
- **Vertical: 32 levels, spacing 0.75-200 m**
- **Extent defined through satellite images**

Time step specification

- **sensitivity analysis: 5, 3, 2, 1.5 min**

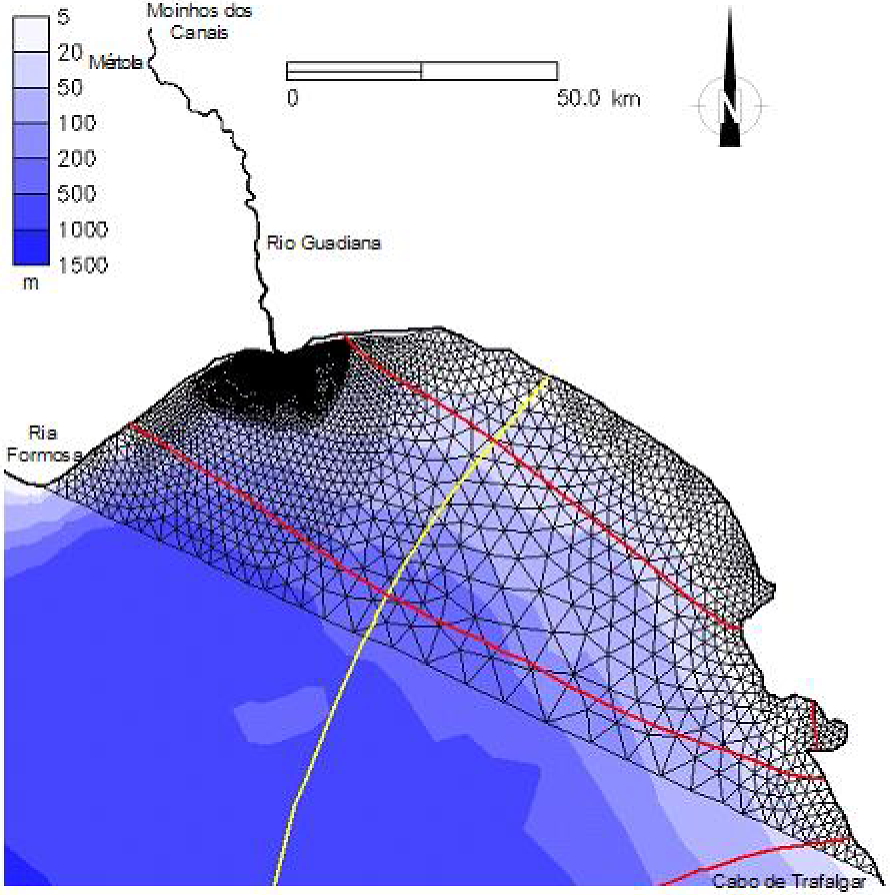
Horizontal diffusion : Set to zero

Level 2.5 Mellor-Yamada

- **Estuary minimum mixing length: 0.15 m**
- **Sea minimum mixing length: 1 m**

Boundary conditions

- **Ocean: regional tidal model**
- **Upstream: daily averaged river flow & elevation**
  - **No elevation data**
    - **Run ADCIRC**
    - **Z0 function of river flow (linear function)**

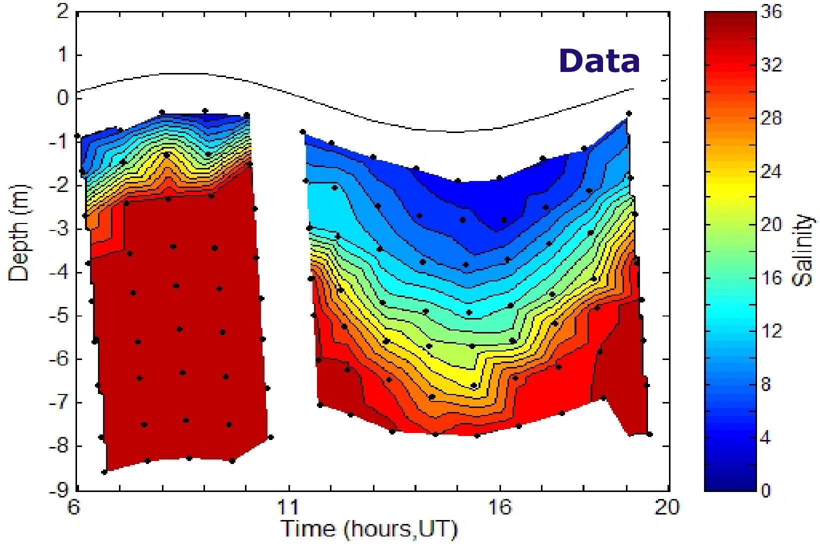


Model validation: Downstream station

Large river flow

Comparison for homogeneous conditions (Q ~ 4 m³/s):

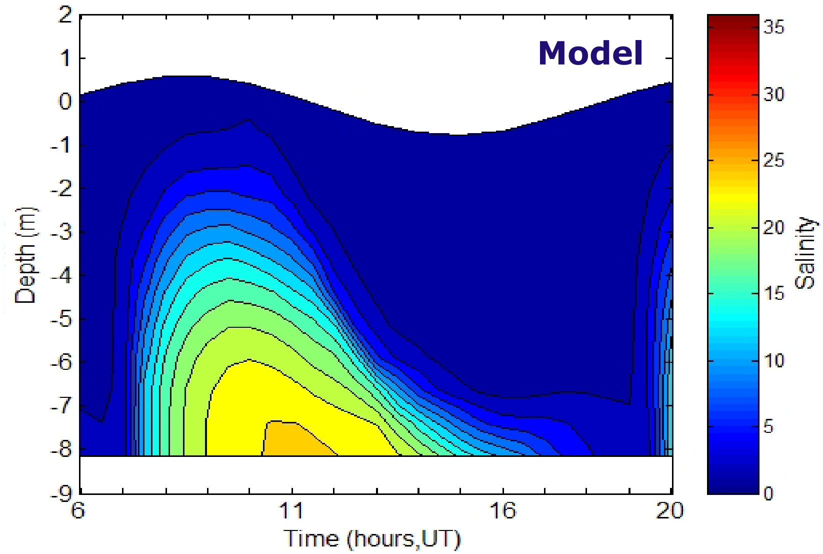
- good representation of the magnitude and vertical structure of salinities
- errors below 2-6 ppt



Comparison for stratified conditions (Q ~ 400 m³/s):

- worse representation of the magnitude of salinities (errors ~ 10 ppt)
- decresing the estuary minimum mixing length to 5 cm did not improve

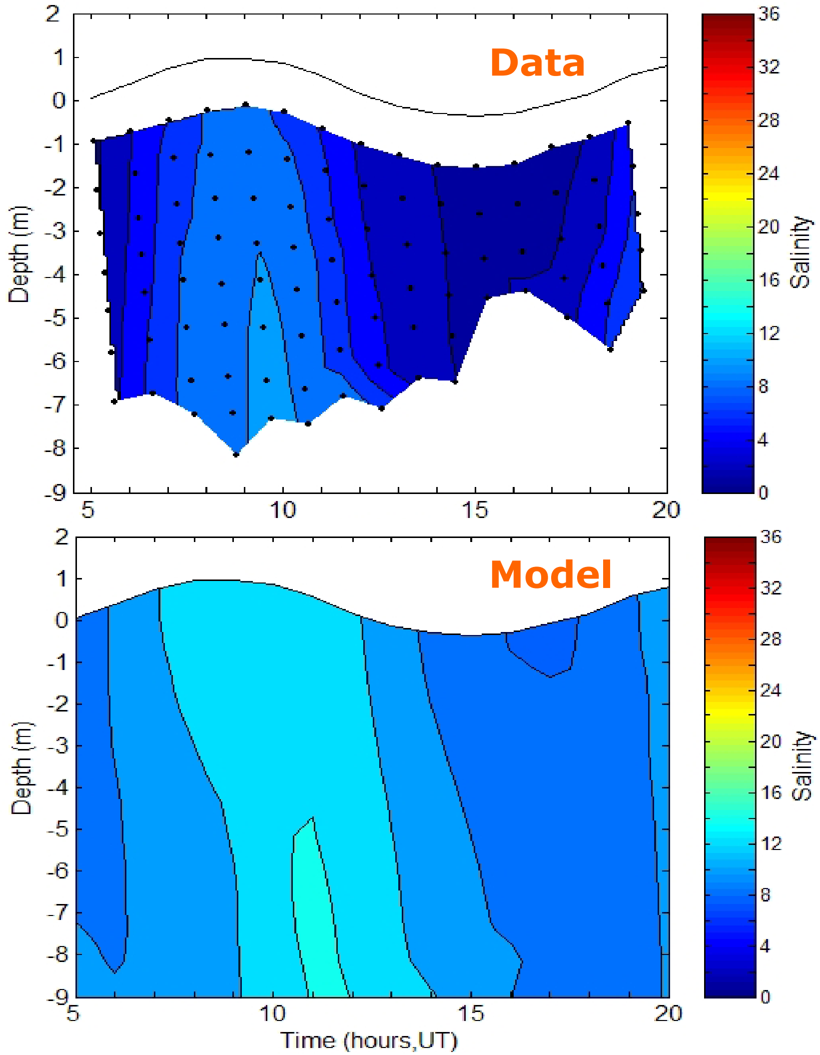
→ Incorrect plume behavior in the continental shelf ?



Model validation: Upstream station

Upstream station Odeleite, Q = 4 m³/s:

- **reasonable representation of the magnitude of salinities (errors below 6-10 ppt)**
- **reasonable representation of the maximum salinity propagation**

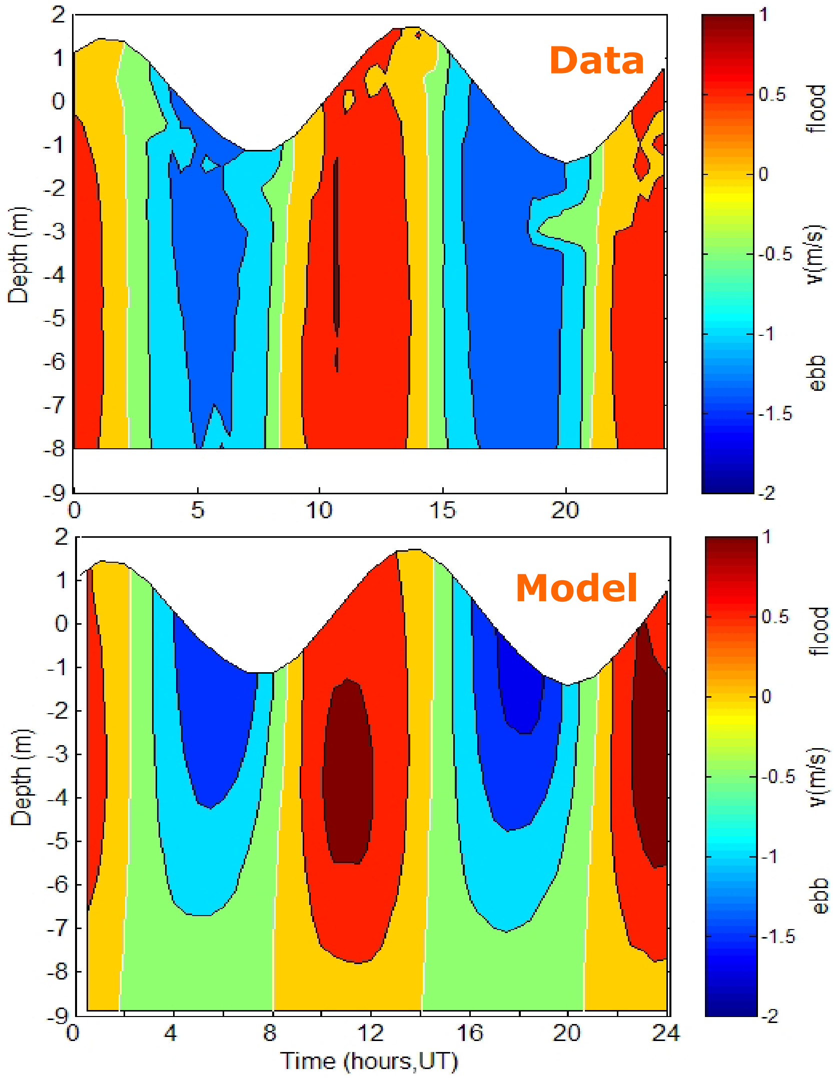


Model validation: ADCP data

Velocity: Comparison with ADCP data

- Reasonable representation of magnitude, vertical structure
- Good representation of flow inversion
- Near-bottom velocity is under-predicted

➔ Insufficient vertical resolution ?

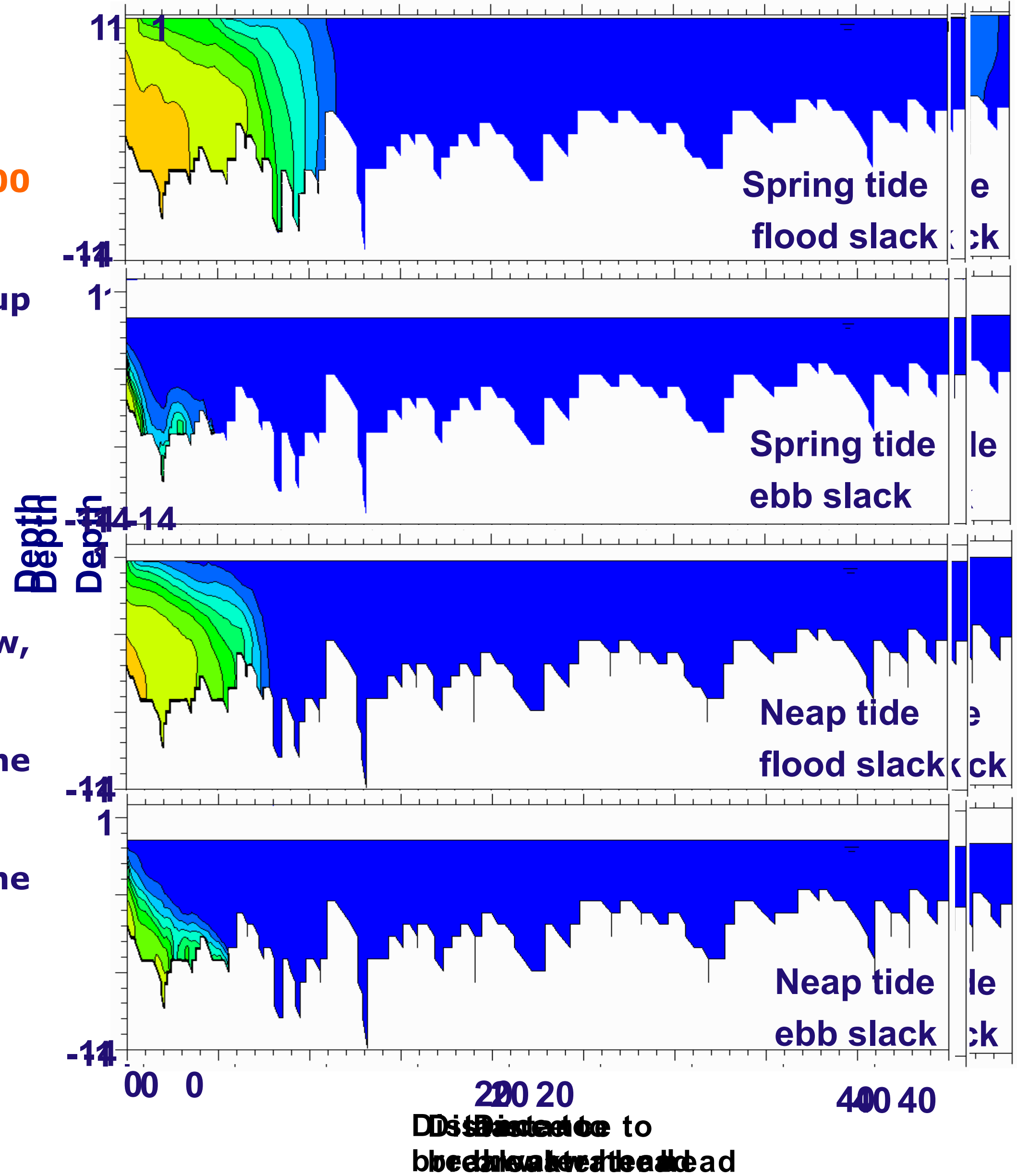


Analysis of stratification

$Q = 200\ m^3/s$

Using model ELCIRC

- **Simulations set-up**
  - **Constant river flow: 2, 10, 50, 100, 200 m³/s**
  - **30 day run, with 15 days warm-up ⇒ spring and neap tides**
  - **45 km transect through the main channel**



- **Main findings**
  - **Stratification increases: larger river flow, smaller tidal amplitudes and during ebb**
  - **Saline front is less stratified than the downstream regions at flood slack**
  - **Ebb slack: retention of saltier water in the deep points**

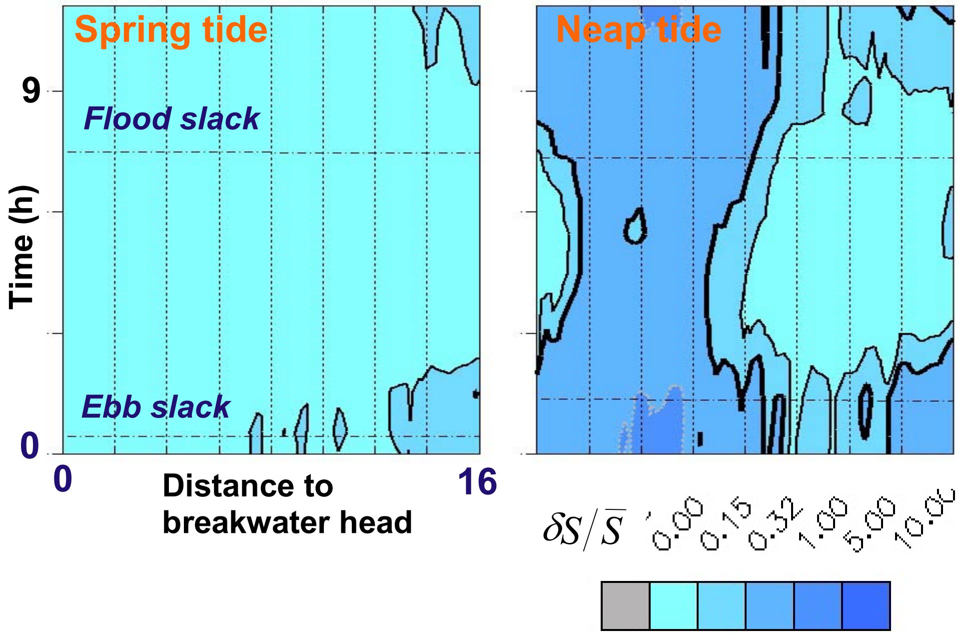
Analysis of stratification

Stratification criterion (adapted from Prandle, 1985)

- Quantify stratification: $\delta S/\bar{S}$ criterion
  - $\delta S/\bar{S} < 0.15$ well mixed
  - $\delta S/\bar{S} > 0.32$ stratified

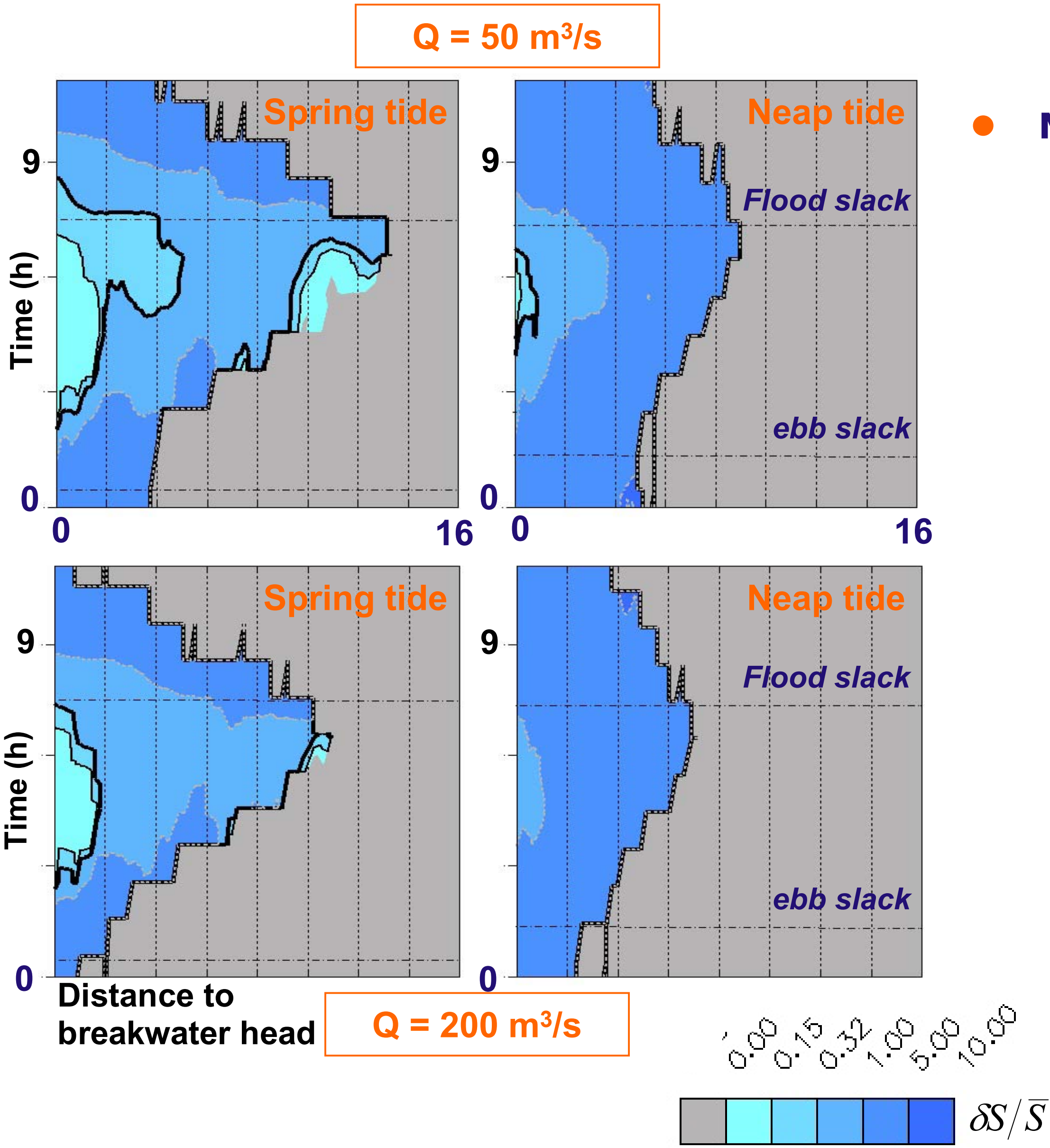
Using the stratification criterion with model results: variability in space and time

Q = 10 m³/s



- **Main conclusions:**
  - Q = 2 m³/s: Well-mixed
  - Q = 10 m³/s - transition: Well-mixed for spring tides, except ebb slack; Stratified/partially mixed for ebb; stratified in part of domain, well mixed upstream for flood

Analysis of stratification



- **Main conclusions:**
  - **Q >= 50 m³/s: stratified even for spring tides**
    - **X empirical criteria; ✓ data**
  - **tidal amplitude is dominant relative to river flow:**
    - **Q = 50 → 200 m³/s, stratification ↗**
    - **Spring → Neap, stratification ↗ ↗ ↗**

Conclusions

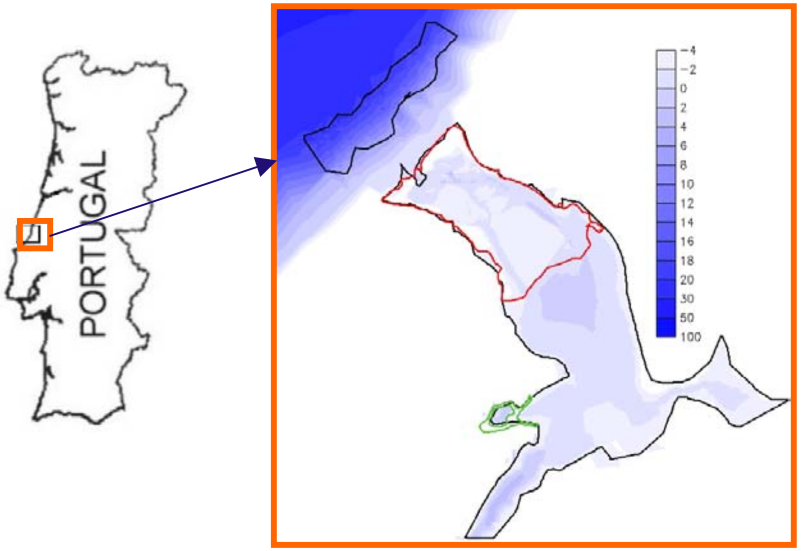
- **Analysis of stratification**
  - **Stronger stratification for high river flows and small tidal amplitude.**
  - **Stratification occurs for river flows of 10 m^3/s (empirical criteria overestimates limits)**
  - **Tidal amplitude is dominant relative to river flow in the strength of stratification**
    - **Contrast with frequently used empirical criteria, agrees with field data**
  - **Saline front is less stratified than the downstream regions**

- **Application of model ELCIRC**
  - **Excellent results of stability, efficiency**
  - **Adequate comparison with field data**
  - **Problems:**
    - **Need to specify both flux and elevation at inflow boundaries**
    - **Simulations with horizontal diffusion are unstable**

Tidal propagation in the Óbidos lagoon

- **The Óbidos lagoon**
- **Model set-up**
- **Field data review**
- **Model calibration: ADCIRC**
- **Model calibration and validation: ELCIRC**
- **Impact of dredging on tidal propagation**
- **Summary**

The Óbidos lagoon



Semi-diurnal tides: 1.5 m

1970

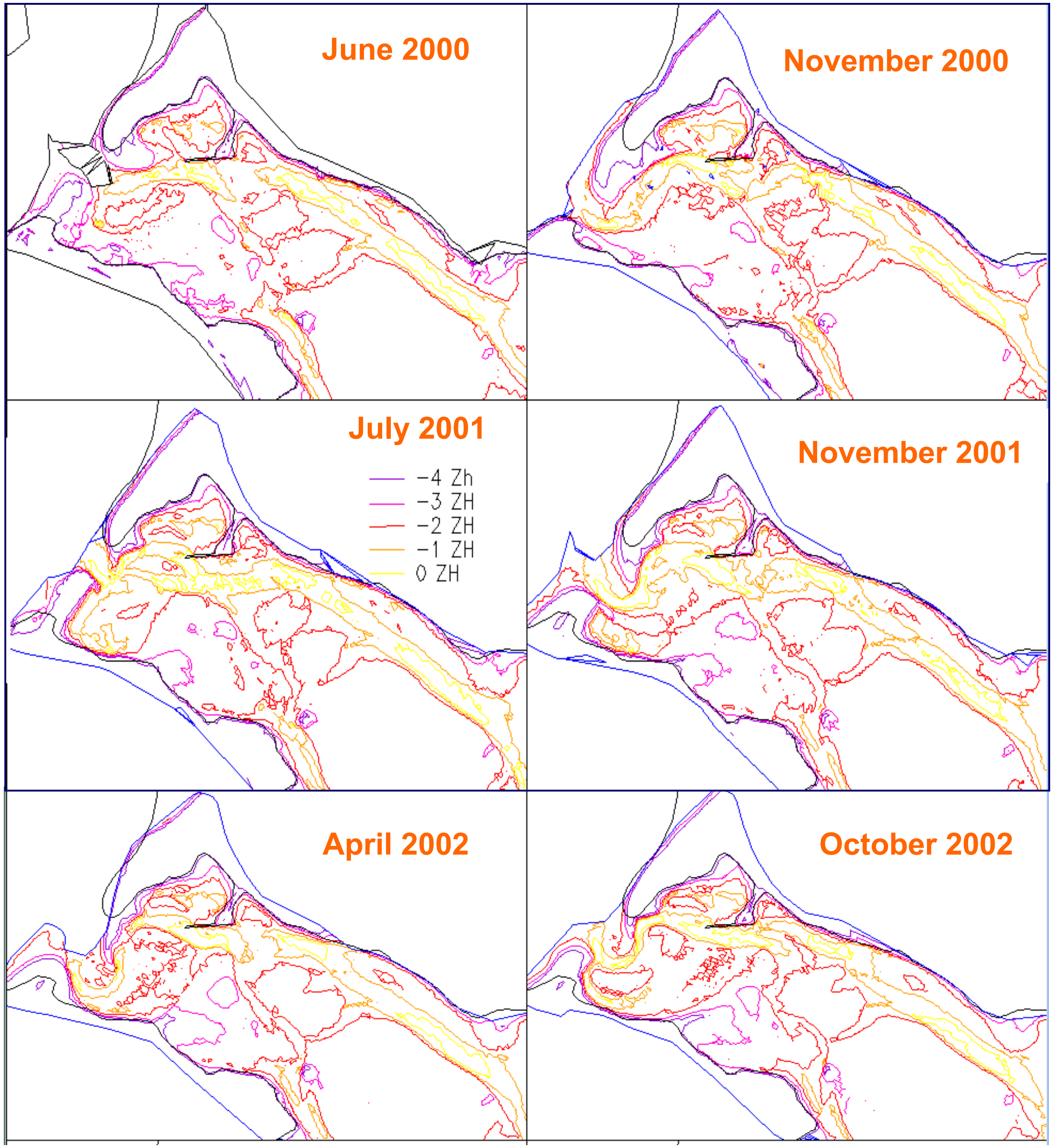
1980

1995

2000

- **Goal:**
    - **Simulate barotropic tides for several bathymetric configurations**
    - **Reproduce well the flood dominance**
    - **Reproduce well the wetting and drying**

The Óbidos lagoon: bathymetry



Model set-up

Domain discretization

- Horizontal: 20000 nodes, spacing 5-1300 m

Boundary conditions

- Ocean: regional tidal model

Bathymetry

- November 2000, July 2001 and October 2002

Model: ADCIRC

Time step: 0.6 s

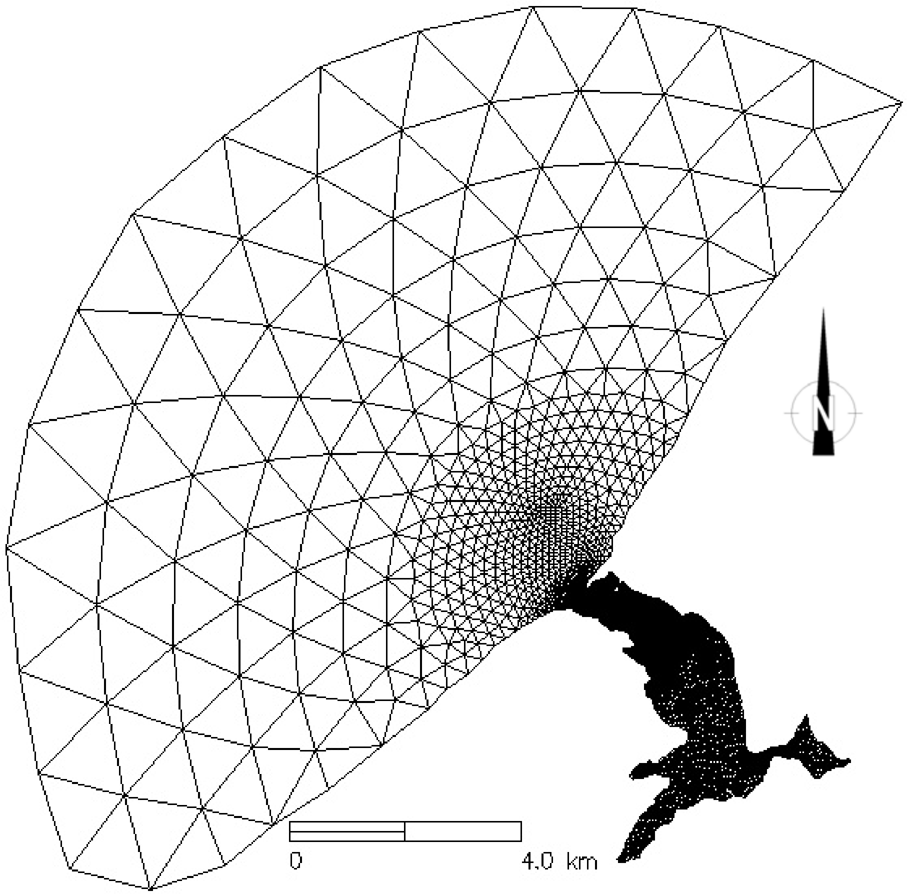
Horizontal diffusion: 1 m^2/s

Model: ELCIRC

Time step: 90 s

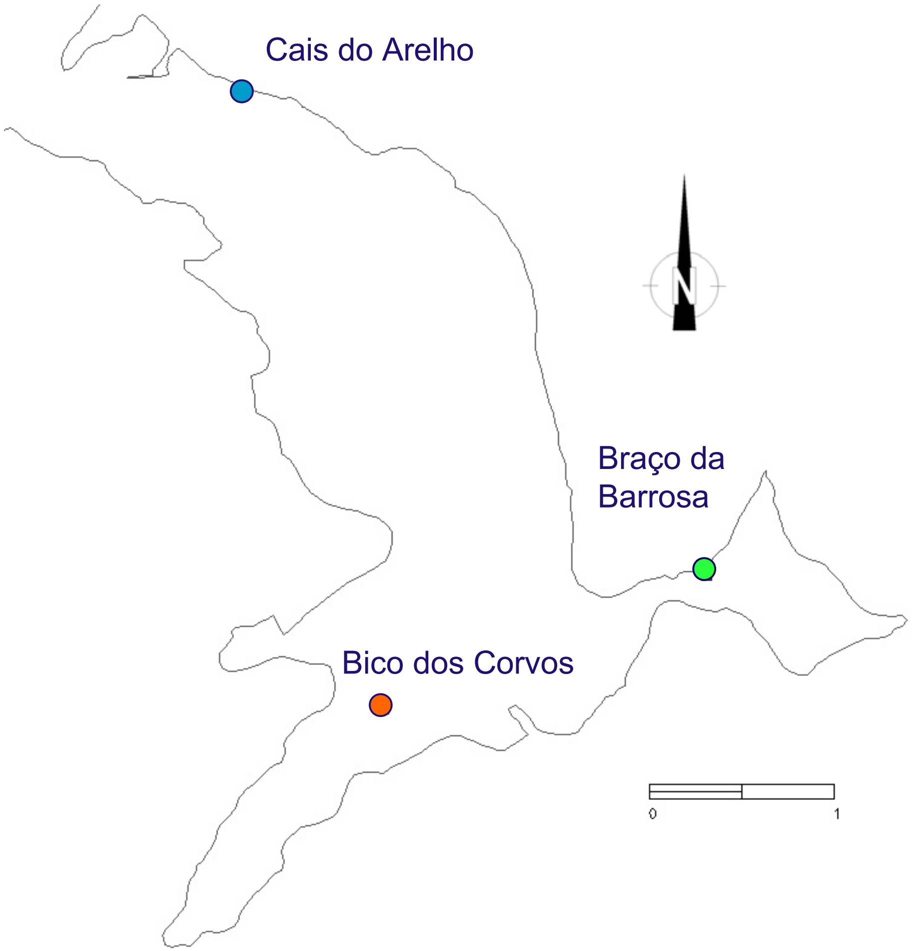
Model adaptations

- harmonic analysis of elevations and depth-integrated velocities
- Friction using Manning formulation

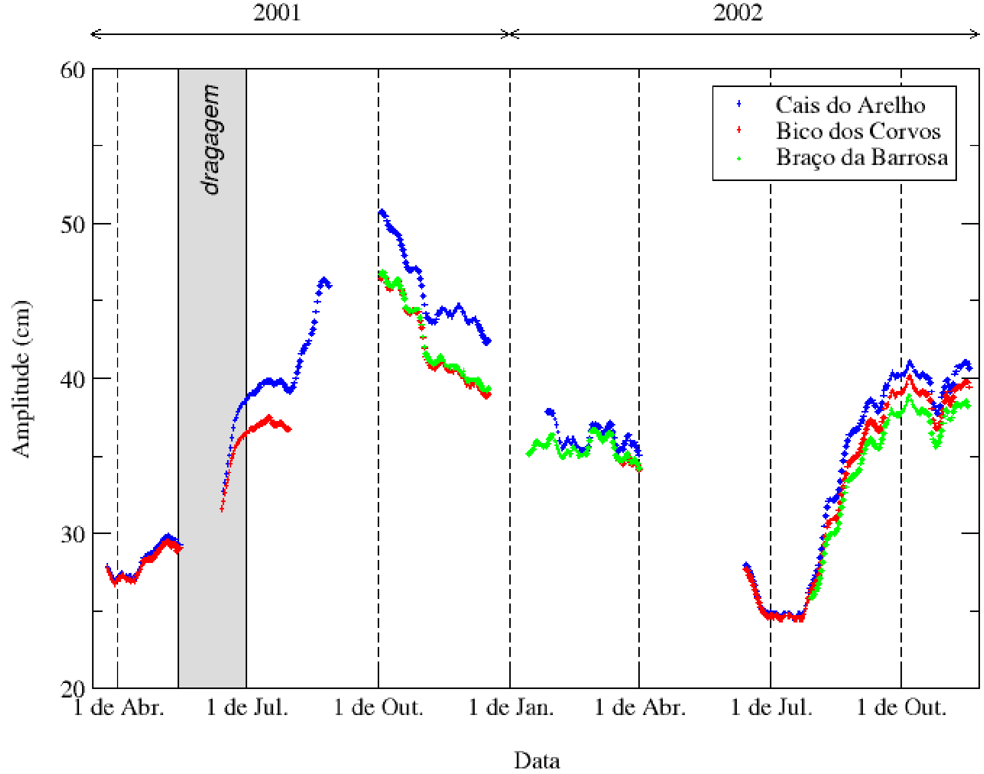


Field data review

2000-2002 water level measurements

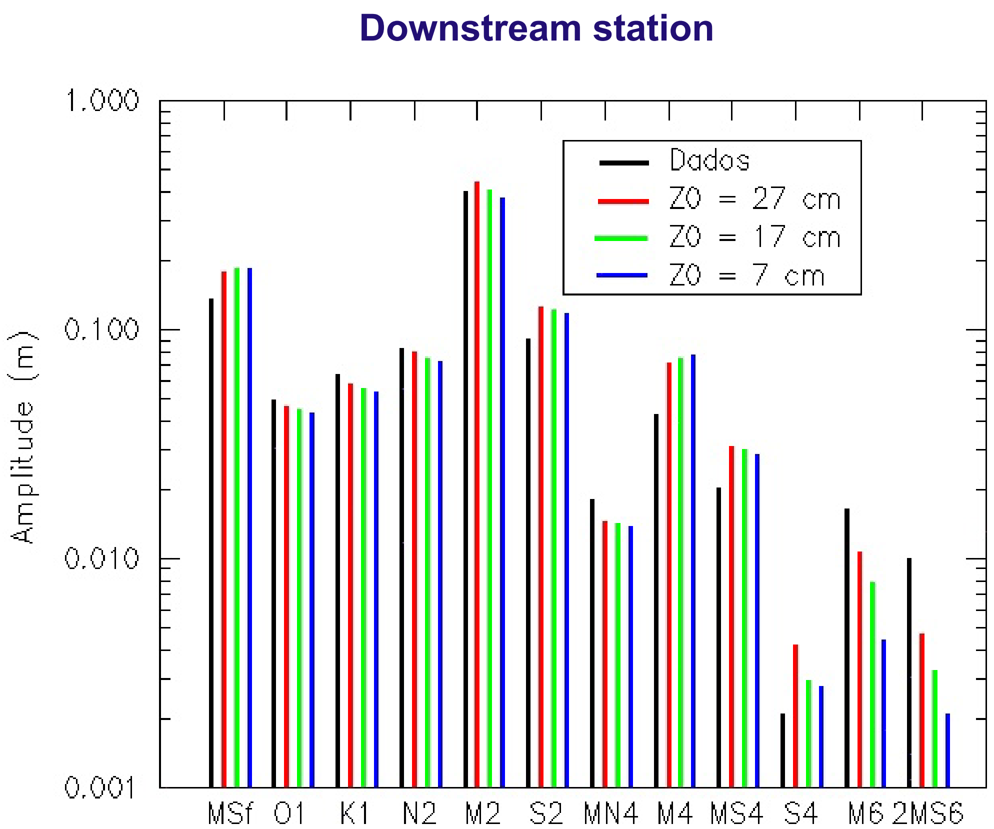


Evolution of M2 amplitudes



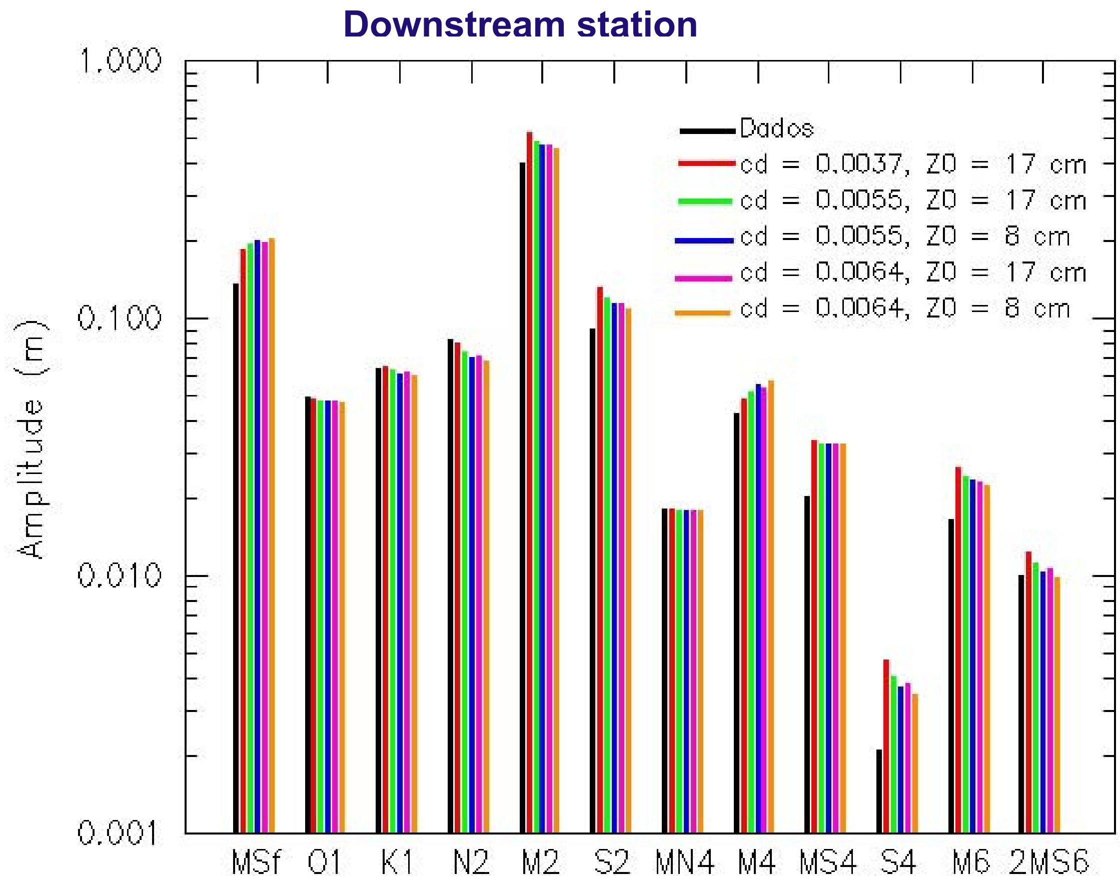
- **Strong variation of tidal characteristics with bathymetry changes**

Model calibration: ADCIRC



- **Mass errors: Up to 50 % differences between ebb and flood tidal prisms**
- **ADCIRC simulations lead to ebb-dominated instead of flood-dominated system**

Model calibration and validation: ELCIRC



Calibration: July 2001

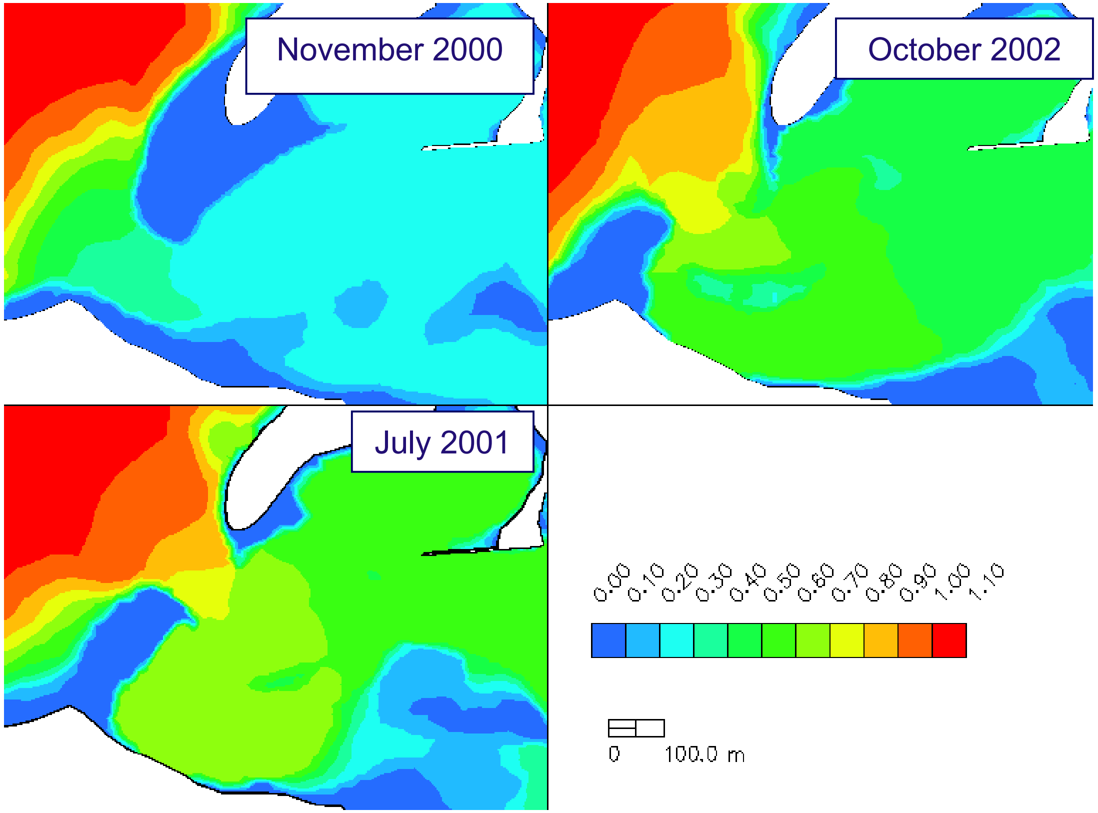
- **Mass errors:**
  4% differences between ebb and flood tidal prisms
- **RMSE: 12 cm**
- **errors in the flood and ebb durations: 1 %**
- **CPU time is 1/7 of ADCIRC CPU time**

Validation: October 2002

- **RMSE: 18 cm**
- **errors in the flood and ebb durations: 13 %**

Impact of dredging on tidal propagation

M2 amplitudes



Tidal prism (% of November 2000 value)

Simulation	
July 2001	**October 2002**
150 (Neap)	**135** (Neap)
198 (Spring)	**145** (Spring)

- **Dredging increases tidal amplitude and tidal prism in the lagoon**
- **Dredging effects are still important 15 months later (October 2002)**

Summary

- **Calibration/validation of a system with a fast bathymetric evolution is difficult**
- **ADCIRC: mass conservation problems**
- **ELCIRC simulations:**
  - **stable**
  - **efficient**
  - **compared well with field data**
  - **Outputs in the frequency domain reduced storage requirements and can be used in morphodynamic simulations**

Summary

- **Problem:**
  - **Very large velocity gradients in drying areas can lead to problems in morphodynamic and residence time calculations**