
# Tidal processes and their spatial and temporal variability in the mid-field Guadalquivir ROFI

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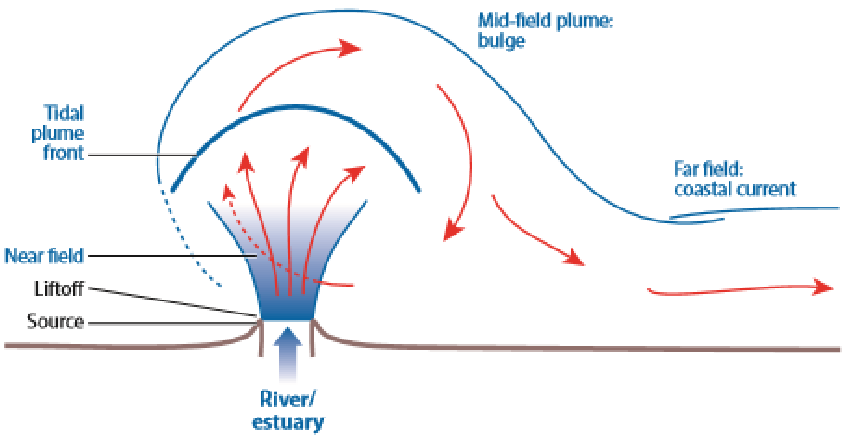
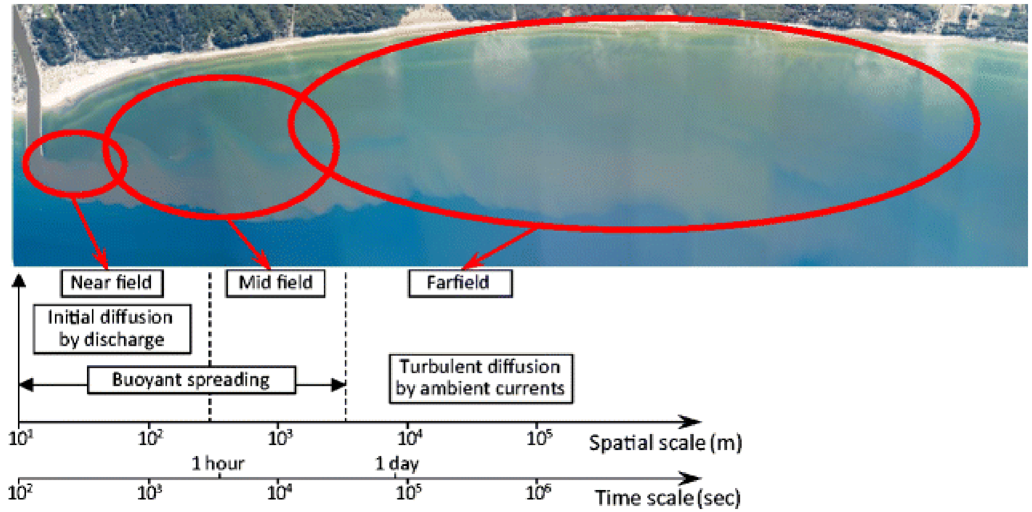



- The river discharges form river plumes: regions of freshwater influence
- Different processes in river plumes ⟹ three distinct regions:

  - near-field region: tidal advection of freshwater lenses released from the Estuary. Tides are dominated by the jet/ inlet
  - far-field region: tidal straining is dominant, earth rotation, wind stress, and bottom stress. Tides those of the continental shelf
  - **mid-field region:** characteristic processes of the far-field and near-field regions interact

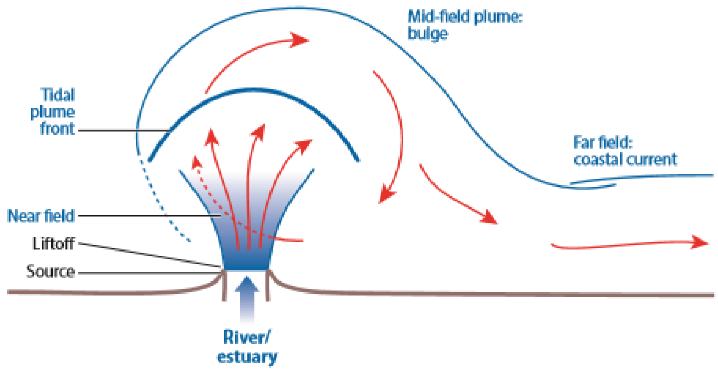
How is the tidal dynamic at the mouth of the Guadalquivir estuary?

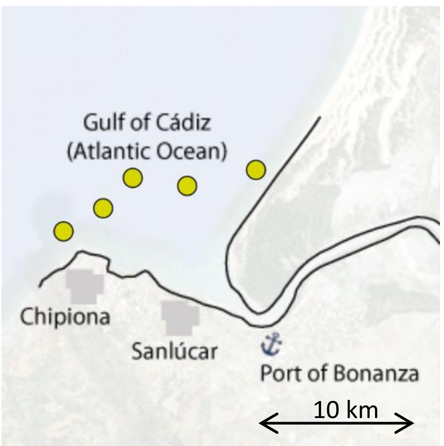
**Objective: To study the spatial and temporal variability of tidal elevations and currents in the mid-field Guadalquivir ROFI**

This study is addressed in the Guadalquivir estuary ROFI

# METHODOLOGY: FIELD SURVEY







- Instruments were placed along an arc, and closing the estuary mouth.
- Variations of:
  - free water surface
  - dynamic pressure
  - current profile
- Every 20 min (10 min AWAC)
- In the entire water column, between 10 m and 18 m depth

Thus, these instruments located at the mouth of the estuary allowed to study the spatial-temporal tidal variability in the mid-field of the GRE-ROFI.

Guadalquivir estuary:

- Fresh water discharge regimes:
  - Low river flows ($Q < 40\ m^3/s$). Tidally-dominated
  - High river flows ($Q > 400\ m^3/s$)
- Plume extension:
  - Maximum during late fall and winter (~395 $km^2$)
  - Small scale or inexistent in late spring and summer

## ❑ Elevation

- ❑ M2 and M4 amplitude and phase
- ❑ The oscillatory motion of the tide →

$$\epsilon = \frac{\pi}{2} - \left(\varphi_{\eta M2} - \varphi_{currentsM2}\right)$$

- ❑ Tidal asymmetry →

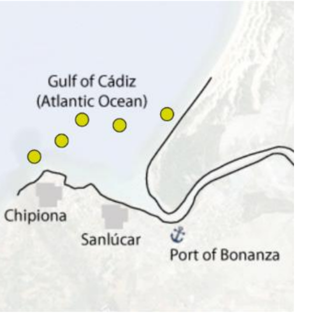
$$DD = \frac{\eta_{M4}}{\eta_{M2}}$$

$$DF = \left|2\varphi_{\eta M2} - \varphi_{\eta M4}\right|$$

## ❑ Currents

- ❑ Tidal ellipses
  - ❑ Inclination
  - ❑ Semimajor and seminor axes
- ❑ Eccentricity →

$$\varepsilon = \frac{a_{M2}}{A_{M2}}$$




1. Short-time harmonic analysis → water elevations / currents → non-stationary tidal dynamics

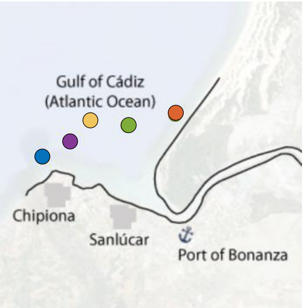
- time series of both tidal elevation amplitudes and phases of the resolved constituents were obtained.

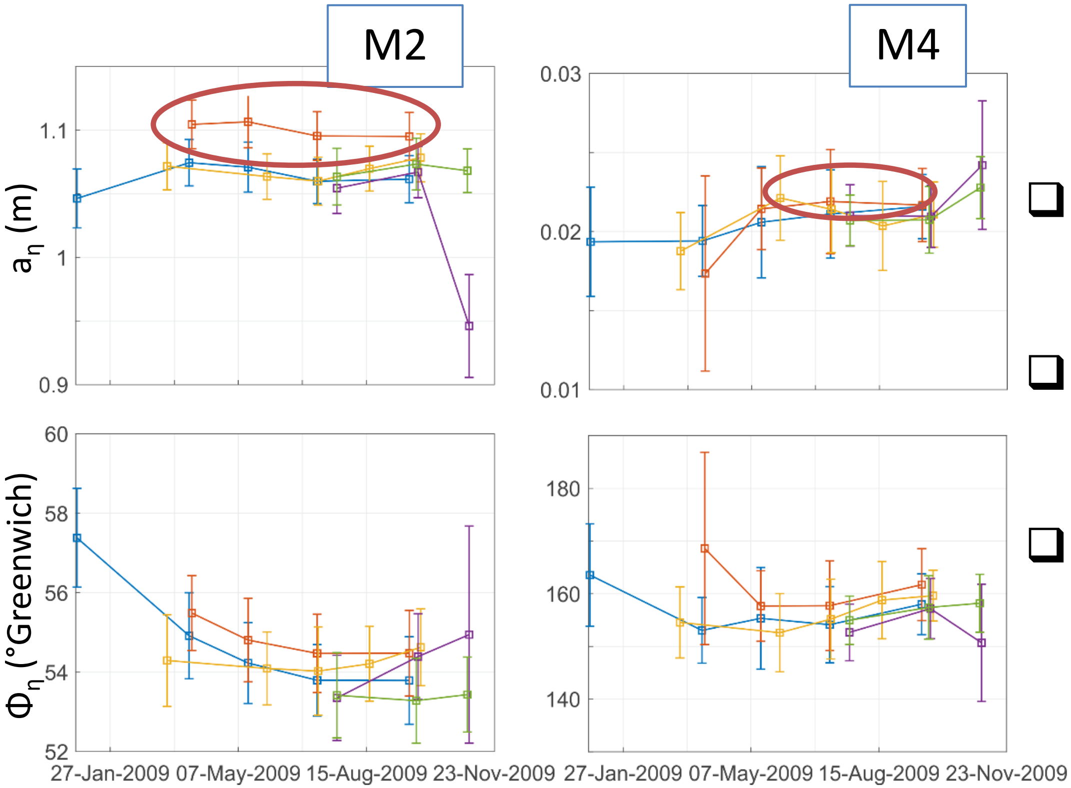
  temporal evolution with depth of the four tidal ellipse parameters from current data was also obtained.

- a moving window of sizes dt=2 days and dt=20 days

2. Principal Component Analysis (PCA) → to identify the main directions of current components

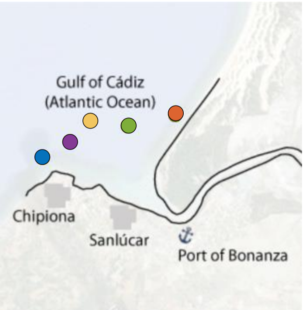
# RESULTS: ELEVATION




- ❑ Tidal amplitudes and phases of elevations
  - M2 → Most energetic constituent
  - M4 → Overtide, generated non-linearly
- ❑ M2 amplitude → spatial variability
  - <0.1 m → 🟠
- ❑ M4 amplitude → spatial variability
  - <0.01 m → 🟠
- ❑ Tidal phases → northward M2 phase propagation, with M2 phase growing from 🔵 to 🟣

**❑ It can indicate that the tide behaves like a Kelvin wave travelling to the North.**

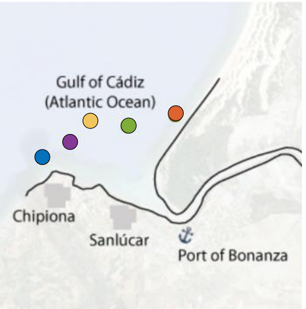



## Oscillatory motion

$$\epsilon = \frac{\pi}{2} - \left(\varphi_{\eta M2} - \varphi_{currentsM2}\right)$$


- **Tides in the Guadalquivir ROFI behave like a standing wave, against that is observed when tides enter the estuary, where tidal motion is progressive co-oscillating (Díez-Minguito, M. et al. 2012)**

  This is induced by the reflection at the continental margin of the northward-propagating tidal Kelvin wave.



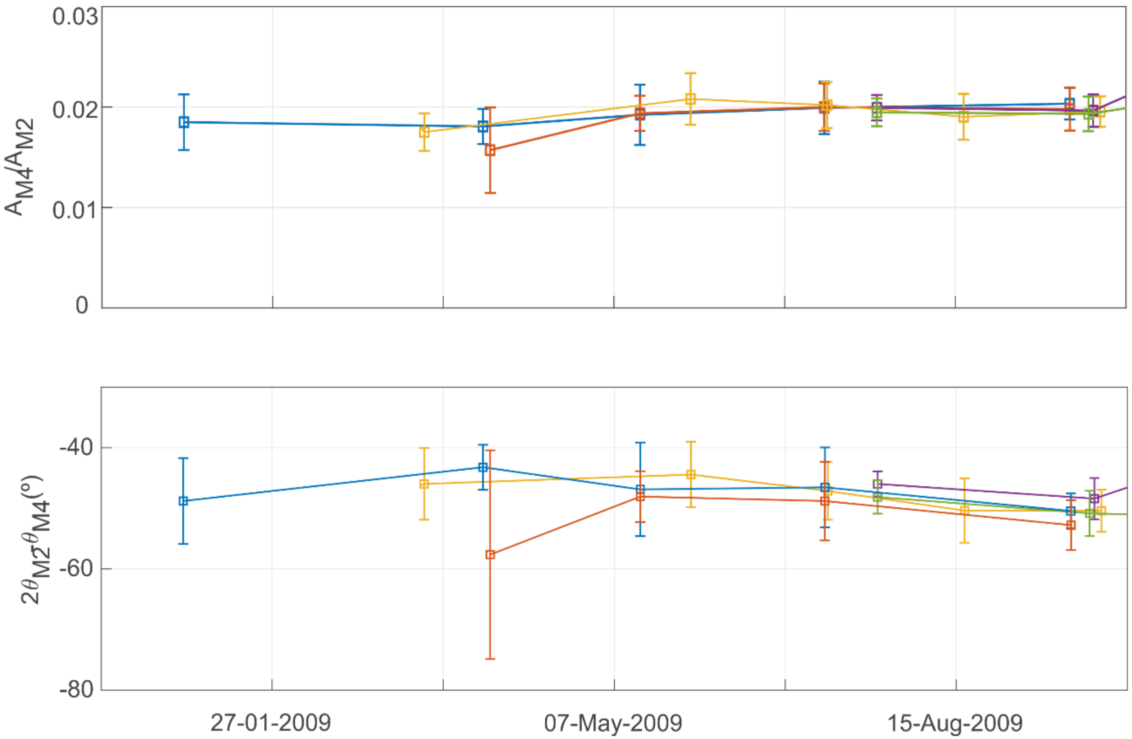

Tidal asymmetry

$$DD = \frac{\eta_{M4}}{\eta_{M2}}$$

$$DF = |2\varphi_{\eta M2} - \varphi_{\eta M4}|$$

*DD* >0.01: significant distortion tidal wave

*DF*: 0-180: flood dominant
180-360: ebb dominant




- ❑ Tidal distortion degree ⟶ 0.02 Tide is almost undistorted and Symmetrical. When tide enters the estuary, this ratio increase from 0.02 to 0.10 (Díez-Minguito, M., et al 2012)

- ❑ Tidal dominance factor ⟶ 0º-180º. Ebb dominance. When tide enters the estuary, phase difference is between 0-180º (Díez-Minguito, M., et al 2012)

- ❑ **Although the inner estuary is flood-dominant, in the mid-field ROFI zone ebb currents are slightly stronger than flood currents.**

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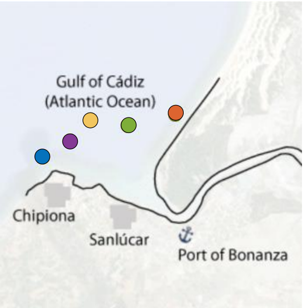
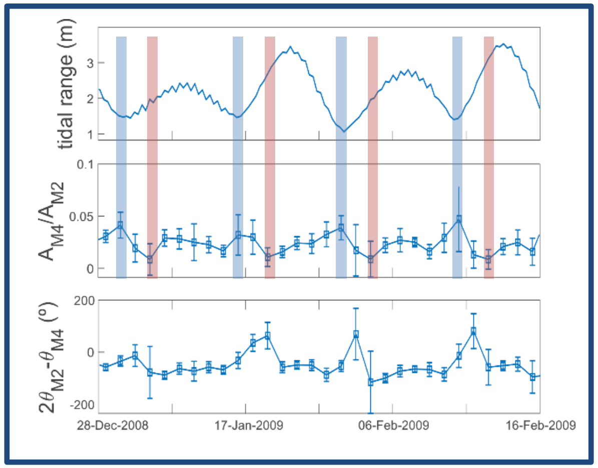
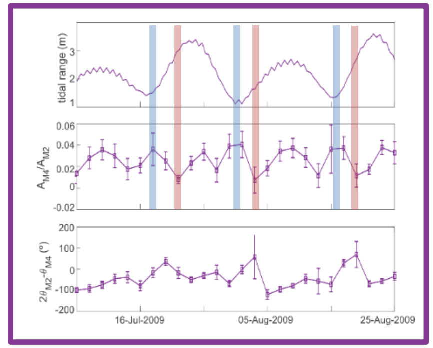
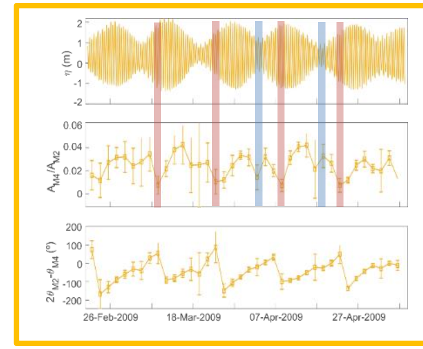
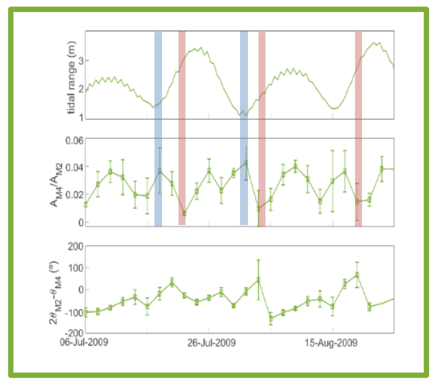


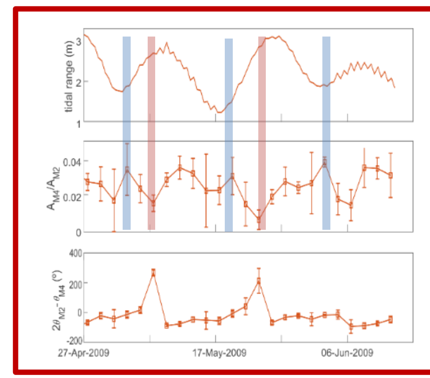

Tidal asymmetry



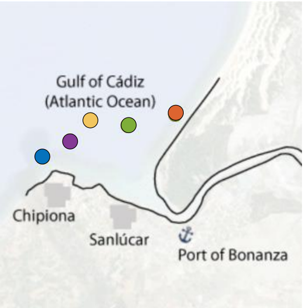



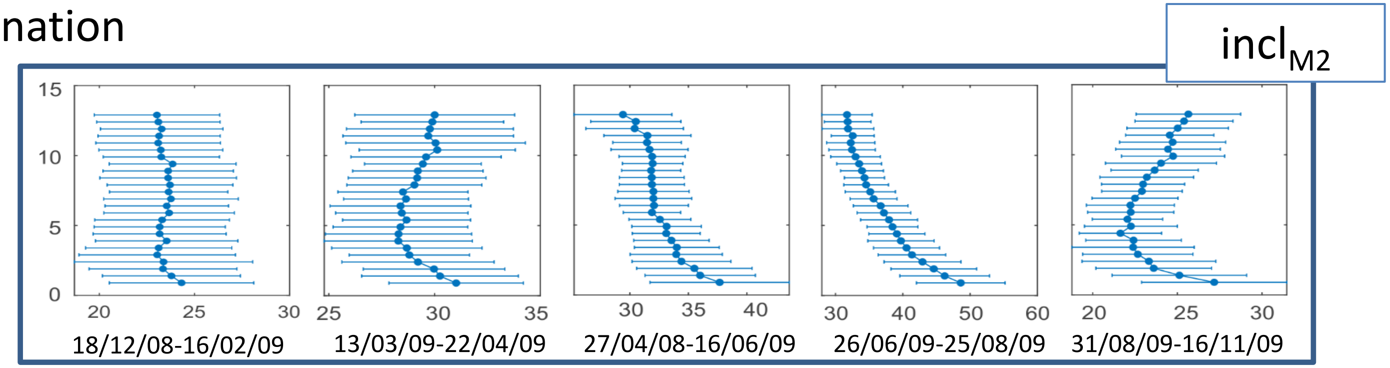



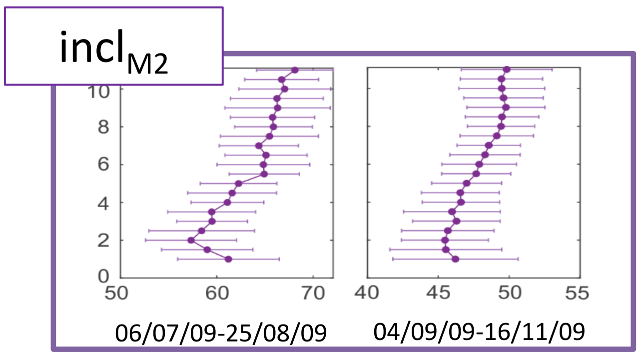

- Fortnightly variations are observed in the ratio of the M4 and M2 tidal amplitudes. Remarkably, the minimum values occur during the transition periods from neap to spring tides, whereas the maximum values are observed during neap tides. These results might suggest that there is still some influence of the tidal jet in this region. The results could also be due to a particular phasing relationship between mixing and stratification.

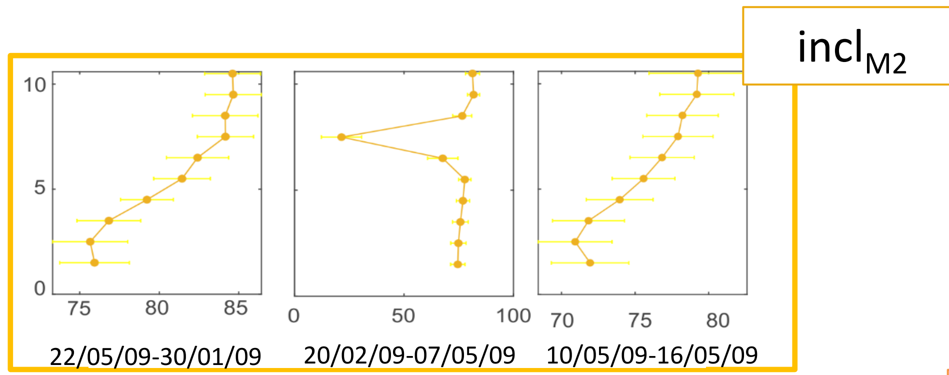
# RESULTS: TIDAL CURRENTS

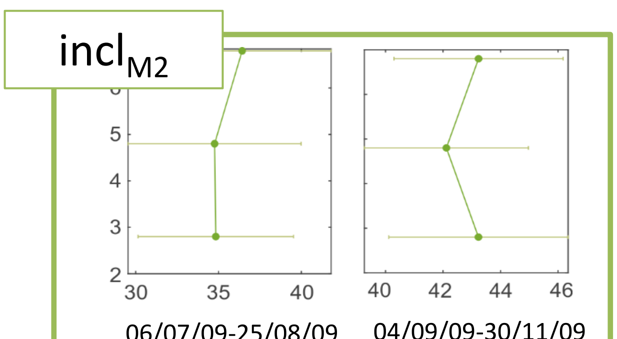


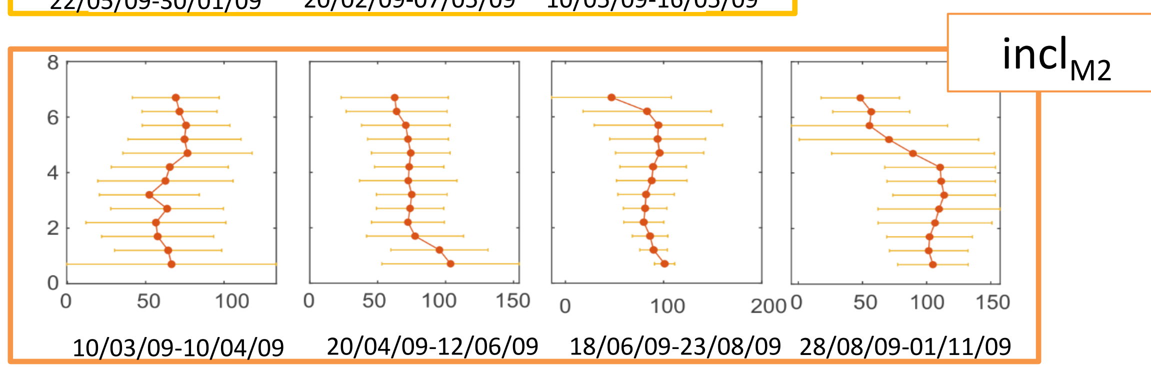

Tidal ellipses:
inclination



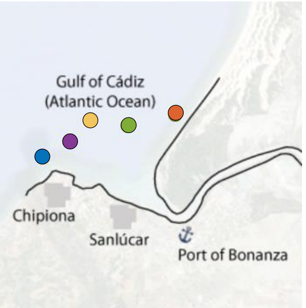



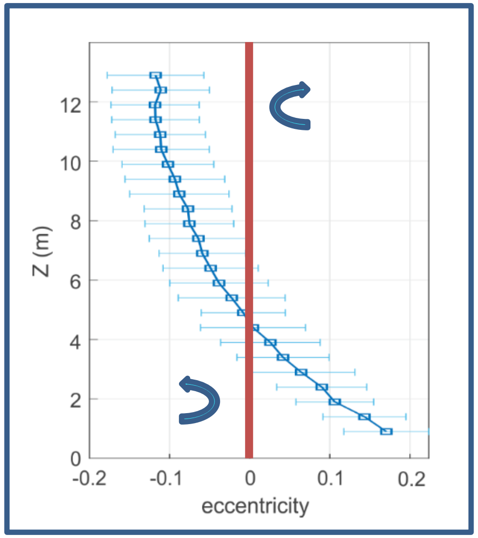



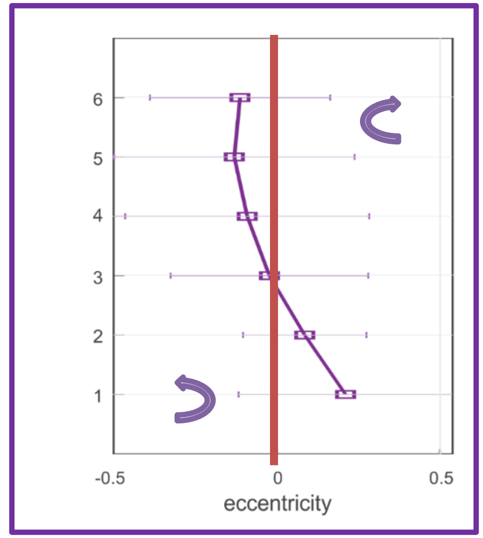




- ❑ M2 inclination varies with depth, being maximum near the bottom in the southern part of the ROFI, and minimum near the bottom at the demain moorings. Tidal currents inclination also varies with time in the southern part of the ROFI.

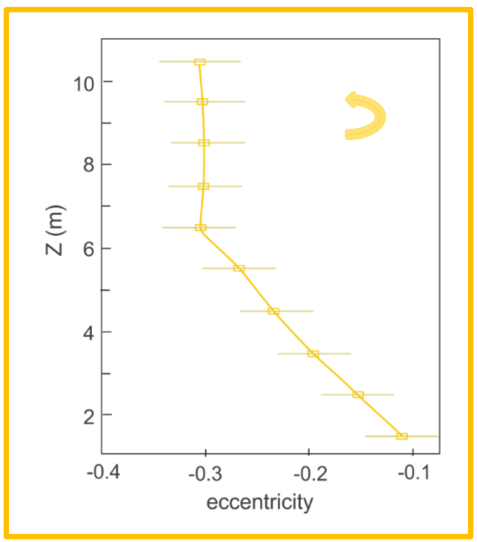


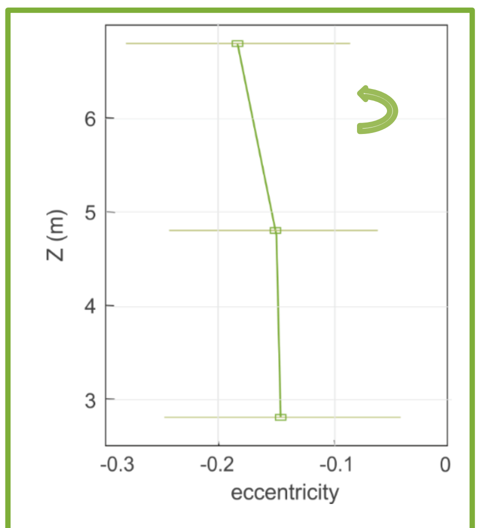

## Eccentricity

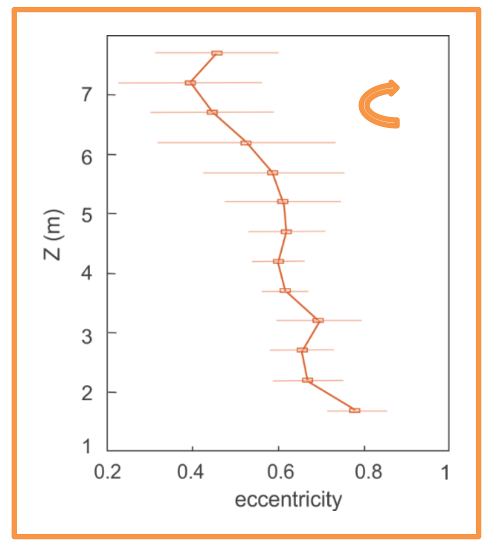


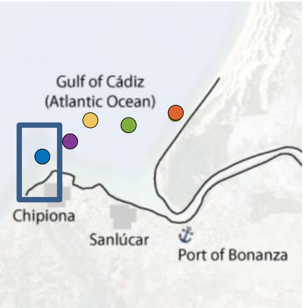

$$\varepsilon = \frac{a_{M2}}{A_{M2}}$$



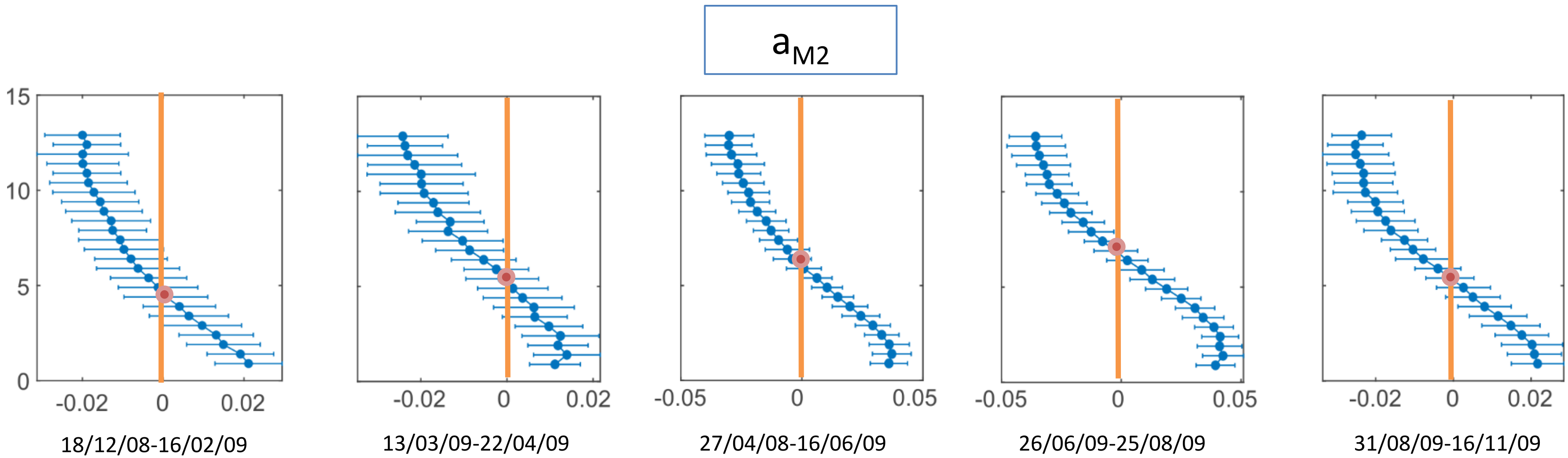




- ❑ **There is an along-coast variability of the vertical structure of the tidal ellipses.**




## Eccentricity with time




❑ **There is a temporal variability of the vertical structure of the tidal ellipses in the southern part of the ROFI.**

# RESULTS: TIDAL CURRENTS

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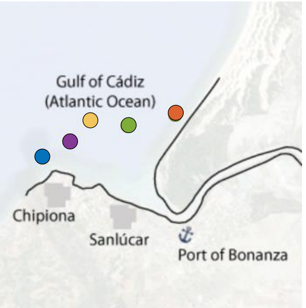
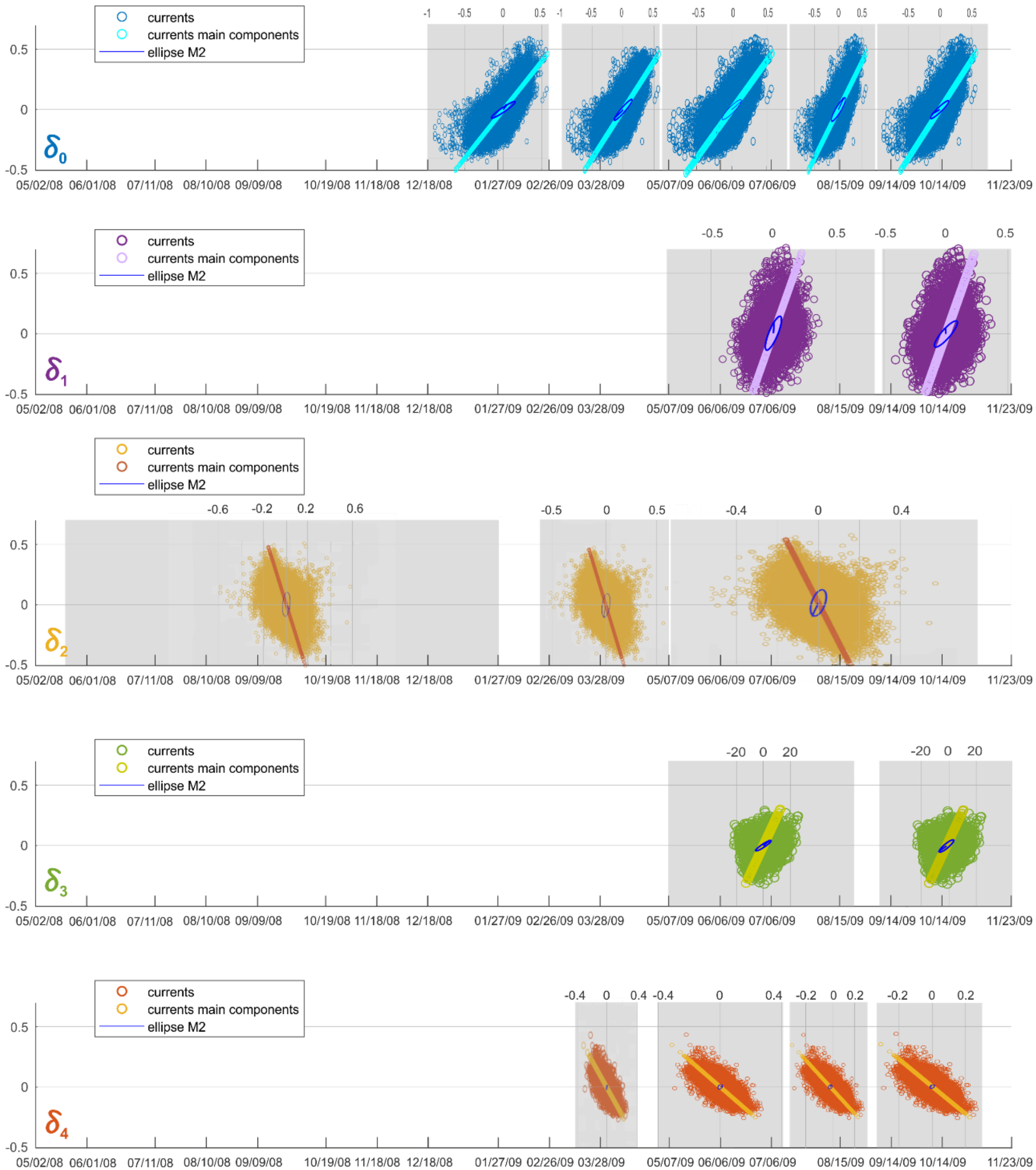



## PCA and main tidal directions



- The tide behaves like a Kelvin wave travelling to the North.
- Tides in the Guadalquivir ROFI behave like a close-to standing wave.
- Although the inner estuary is flood-dominant, in the mid-field ROFI zone ebb currents are slightly stronger than flood currents.
- Fortnightly variations are observed in the ratio of the M4 and M2 tidal amplitudes. Remarkably, the minimum values occur during the transition periods from neap to spring tides, whereas the maximum values are observed during neap tides
- There is an along-coast and temporal variability of the vertical structure of the tidal ellipses.
- The results suggest that the bouyant outflow circulates preferencially southwards, most likely driven by the prevailing winds.


# Thank you for your attention

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