Analysis of in-situ observations in the Strait of Gibraltar

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Ship-board Observations

The Strait of Gibraltar is the choke point for the water mass exchange between the Atlantic Ocean and the Mediterreanean Sea. The Algeciras-Ceuta section was intensively observed, here the interface fluctuations are much smaller than at the Camarinal Sill, where measurements traditionally were made. Data collected on two cruises with 181 XBT, 134 CTD/ADCP casts and several vmADCP sections covering the complete M2 tidal cycle were combined with long time series (over four years) from moorings to analyse the structure of the flow.

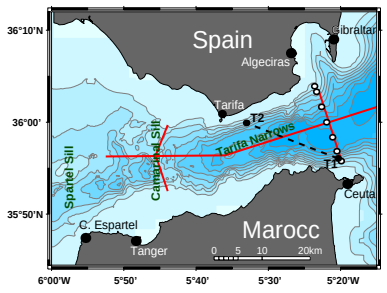

Figure 1. Bathymetry of the Strait of Gibraltar, showing the position of the acoustical instruments T1, T2 and the raypath between them (dashed line). ADCP sections are shown as red lines and CTD stations at the eastern entrance as dots.

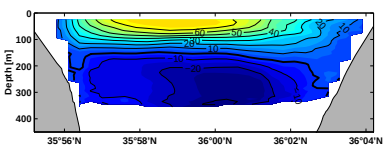

Figure 2. Approximate tidal-mean along-strait current [cms^{-1}] through the eastern entrance of the Strait of Gibraltar from two vmADCP sections, each over one tidal cycle.

- **quasi-synoptic vmADCP sections were used to describe the mean flow in the upper 300 meters at the sill and at the eastern section**
- **rapid CTD-yoyo casts and a vmADCP allowed us to observe the physical properities and evolution of the internal bore**
- **simultaneous ADCP and CTD time series over one tidal cycle give estimates of the composite Froude number for spring and fall**
- **along-strait vmADCP sections contribute to the understanding of the transmission zone between the Atlantic Ocean and Mediterranean Sea**

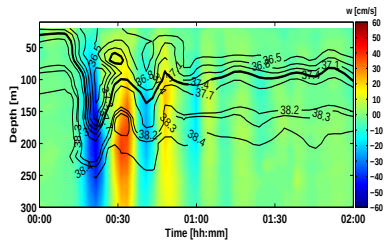

Figure 3. Observation of an internal bore (April 1996) near Camarinal Sill. *Background*: Vertical currrent [cms^{-1}] (vmADCP). *Contour lines*: Isohalines (CTD). Bold line is the 37.4-isohaline.

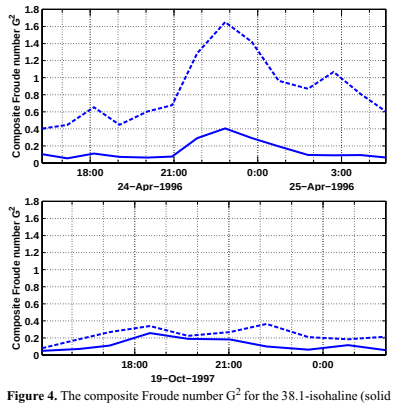

Figure 4. The composite Froude number G^2 for the 38.1-isohaline (solid line) and for the 37.4-isohaline (dashed line) for a time-station with CTD-yoyo and vmADCP at the eastern section during neap tide. *Top*: spring 1996. *Bottom*: fall 1997.

Inverse Model

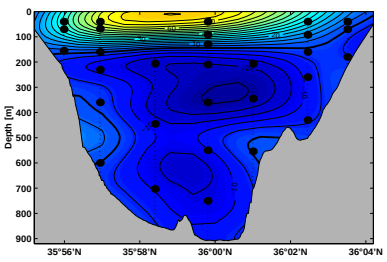

Figure 5. Measured mean along-strait current [cms^{-1}] at the eastern section. Tides were removed by the inverse model. The dots represent moored rotor-current-meters.

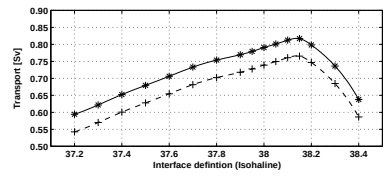

Figure 6. Relation between interface definition (isohaline) and calculated volume transport of the upper layer (solid) and lower layer (dashed).

Inverse modeling provides a tool to combine long timeseries from moorings with ship-board observations providing high spatial resolution, which allows it to extract the temporal as well as the spatial information from the measurements. This means that also the locations with an insufficient temporal sampling can be taken into account and complemented with information from adjacent locations.

Model results:

- **description of the flow and interface motion as a function of time and 2D-space.**
- **accurate water mass transport estimates for upper and lower layer ($Q_1 = 0.81 \pm 0.07$Sv, $Q_2 = -0.76 \pm 0.07$Sv)**
- **analysis of amplitude and phase of the most important tidal constituens**

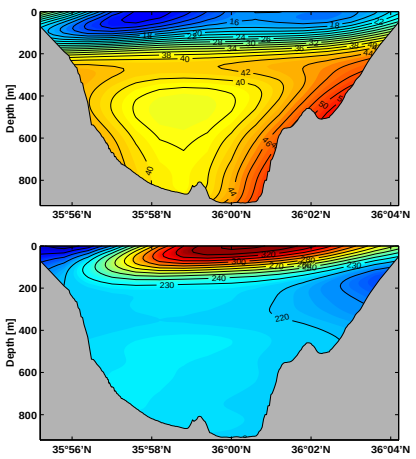

Figure 7. M2-Tide at the eastern section calculated from model *Top:* Amplitude [cm/s]. *Bottom:* Phase [deg]

Acoustic Measurements

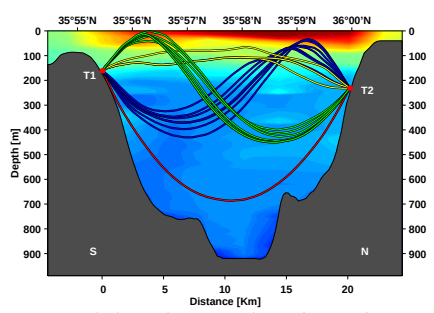

Figure 8. Acoustic eigenrays between T1 and T2. *Red:* -1 ray. *Blue:* -2 rays. *Green:* +2 rays. *Yellow:* other. *Background:* In situ temperature.

Two weeks of acoustical data were collected during spring 1996 to test the suitability of 2kHz trancievers for monitoring the Strait of Gibraltar. Two-way measurements of the sound travel time allow to form the sum and the difference of travel time for resolved sound paths.

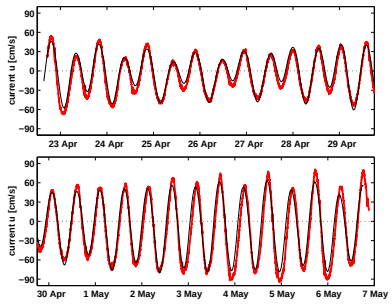

Figure 9. Alongstrait current measured with the T1-T2 transceivers (red line) compared with the sum of the model current and the longterm fluctuations from mooring data (black line).

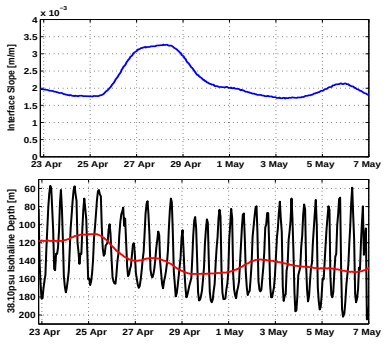

Figure 10. *Upper panel:* Slope of the Interface along the Strait. *Lower panel:* Depth of the interface at the center of the T1-T2 section (black line). The red line shows the 2 day lowpass filtered data.

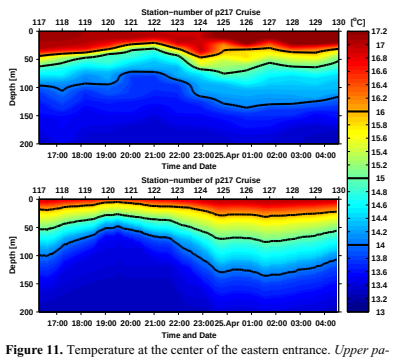

Figure 11. Temperature at the center of the eastern entrance. *Upper panel:* CTD masurement. *Lower panel:* Calculation from the traveltime sum.

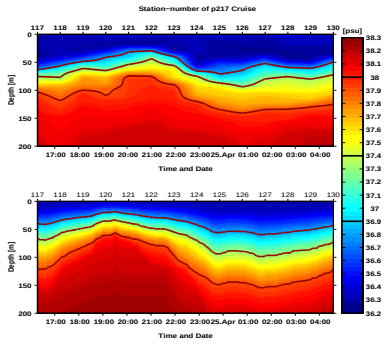

Figure 12. Salinity at the center of the eastern entrance. *Upper panel:* CTD masurement. *Lower panel:* Calculation from traveltime sum.

Applications:

- **measuring mean current of lower layer with high precision**
- **recording temperature and salinity for both layers**
- **monitoring depth of the interface between the Atlantic and Mediterranean Water**
- **register the longperiodic variations of the interface slope along the strait.**

Acknowledgments

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