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The 1985-1986 Gibraltar Experiment Hydraulic Control

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During 1985-1986 a consortium of scientists from Spain, Morocco, France, the United Kingdom, Canada, and the United States studied the fluid dynamics of the flow through the Strait of Gibraltar. Individual scientific groups had various objectives, including the effect of the strait on the large scale oceanic circulation, the level of dissipation and small scale structure in the strait, and the forcing of the subinertial flows. The central theme for the experiment, however, was the role of hydraulic control in the dynamics of strait flows. We will discuss the new results in the understanding of hydraulic control as it applies to the Strait of Gibraltar.

Nearly 40 years ago Stommel and H. G. Farmer used hydraulic control and mixing conditions to infer estuarine dynamics. These ideas also appeared fruitful for the understanding of semi-enclosed seas and their straits, and they had been applied to the Mediterranean prior to the Gibraltar Experiment. It was clear that hydraulic control at the strait could profoundly alter the interaction of the Mediterranean Sea and the Atlantic Ocean. In this regard, there were three questions addressed by the Gibraltar scientists:

1. Does internal hydraulic control exist in the Strait of Gibraltar?

2. If so, how does it work? Existing theory considered an ideal strait: single sill, two-layer stratification, regular lateral and bottom boundaries, no rotation, no friction, and steady flow. Could simple theory illuminate the flow in the strait, and which of the idealizations are fundamental?

3. Once the strait dynamics are understood, how can this understanding be integrated into knowledge of the Mediterranean system?

Although work on strait dynamics and on Gibraltar Experiment data continues, there are answers to these questions. The existence of internal hydraulic control within the strait is well established. In particular, the time dependence of the flow and the multiple-sill and contraction geometry of the strait are fundamentally important. The hydraulic control has a profound effect on the Mediterranean, being a key factor in establishing its stratification.

We will present a brief overview of these results, drawing on the work of many Gibraltar investigators. Particularly active in the application of hydraulic theory have been Armi, D. M. Farmer, Bormans, Thompson, Garrett, Stommel, Canizo, and Dalziel. We will focus on the lessons of steady two-layer flow in the strait under the constraint of hydraulic control, and its ramifications for the Mediterranean Sea.

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Interannual variability of the air - sea interaction along the eastern Adriatic Coast

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Recent worldwide scientific interest in the air-sea interaction on climatic time scales in different regions has revealed that sea-level and sea-surface temperature variations are good tracers of ocean circulation, water mass and heat balance variabilities.

In order to study air-sea interaction at the climatic time scales, six variables from three locations along the eastern Adriatic coast were analysed in period from 1959 to 1984. Station Pula represents shallow northern Adriatic area with the River Po mouth on the other side of the coast, Split represents middle Adriatic channel area and Dubrovnik represents the southernmost coastal area characterised by the narrow and smooth shelf. The 35-year data set contains monthly means of air-pressure (PRE), air-temperature (ATE), relative humidity (HUM), sea-surface temperature (SST) and sea-level (LEV), as well as monthly totals of rainfall (RAN). Missing data were linearly interpolated after comparing two nearby stations. Instead of PRE data set at Pula, that could not be extrapolated because of the lack of measurements at a nearby position, mean monthly PRE at Trieste (Italy) were used. After applying a symmetrical 24m214 filter smoothed curves are obtained (Figure 1), containing signals of few-year periods with different amplitudes for different variables. Trends are evident in ATE, SST and RAN, not necesserily of the same sign at all the stations.

The EOFs of the filtered data sets at three stations show features of interaction between sea and atmosphere variables.

Dominating variance at Pula (constituting 35% of the total variance) is accounted for by the connection between PRE and LEV, suggesting their out-of-phase variability. Beside the "inverted barometer" effect, PRE variations are in a conjuction with the frequency of atmospheric disturbances passing over the area (cyclones and anticyclones), and their characteristic wind systems, which affect advection and changes in LEV. With the small percentage of their individual variances, ATE and SST correlations are present in the first mode, too. In the second mode (30%) good interrelation between RAN, HUM, PRE and SST variations was obtained, which explains that evaporation and latent heat flux (represented by the SST) may be affected by meteorological forcing (fluctuations in a frequency of atmospheric disturbances). In the third mode (17%) ATE variations are coupled to an out-of-phase RAN variations. The thermal forcing (SST-LEV correlation) at this station is not evident.

The first mode at Split (38%) gives very good correlation among PRE, RAN and LEV, suggesting that the PRE decrease (connected to increased frequency of lows on the long-term time scale) is followed by the RAN increase that can both yield a LEV increase. The second mode explains almost the same percentage of the total variance (37%) as the first one, extracting exclusively thermal effect in LEV variations (in-phase changes of ATE, SST and

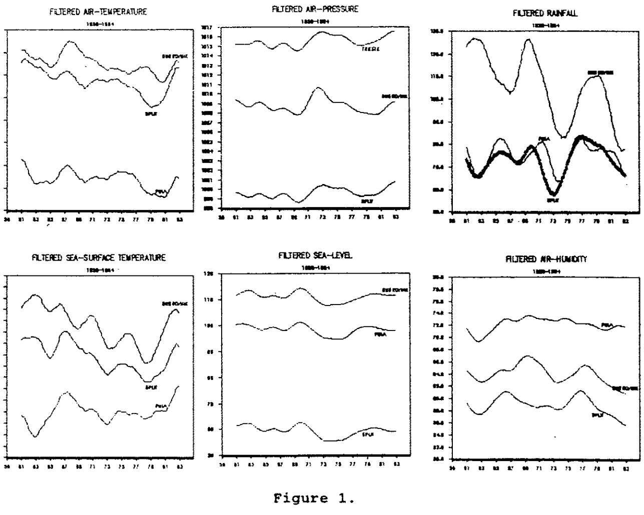

Figure 1.

LEV). The third mode (19%) explains the greatest part of HUM variability, without acceptable physical explanation.

The first mode at Dubrovnik (48%) contains the largest percentage of the LEV variance (70%). It can be related to the combined influence of the thermal forcing, RAN and to a lesser extent, PRE forcing. Correlation between SST and ATE is weaker than in Split and SST appears strongly dependent on PRE in the second mode (21%). This can be explained in terms of the advection of warmer and saltier water from the Ionian sea. The advection from the south should induce stronger SST, as well as LEV variations, in southern than in the northern part of Adriatic, with no obvious relation to ATE. In order to confirm this, salinity data should be taken into account, as they are a good indicator of stronger Levantine water inflow to the Adriatic.

In conclusion it may be pointed out that sea-level changes along the coast of the northern Adriatic are induced by the meteorological forcing due to long-term changes of a frequency of passing cyclones over the area, with the atmospheric pressure being the most effective. In the central Adriatic influence of the thermal forcing due to the air-sea heat exchange is very pronounced in sea-level variations. In the southern Adriatic thermal forcing is less effective than in the central Adriatic, and heat balance is prevalently due to advective processes.