TURBIDITY VARIABILITY IN LAKE BANYOLES (GIRONA, SPAIN): RELATIONSHIP WITH ANOMALOUS RAINFALL AND ATMOSPHERIC SYNOPTIC FLOW PATTERN

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LAKE BANYOLES AND THE SEDIMENT FLUIDIZATION PHENOMENA

A problem that has been studied over the past 20 years

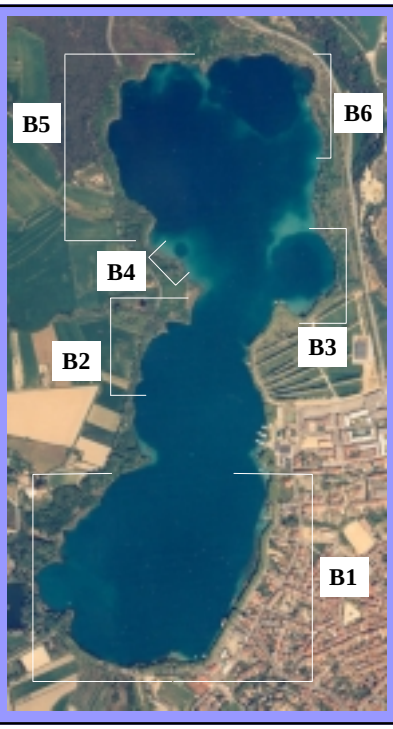
Small multi-basin lake (surface area of 1.12 km^2) in the eastern Catalan pre-Pyrenees at (42°07'N, 2°45'E)

B1 supplies around the 85 % of the total incoming water by subterranean springs (at 75 m depth approx) and the rest is supplied by river flows

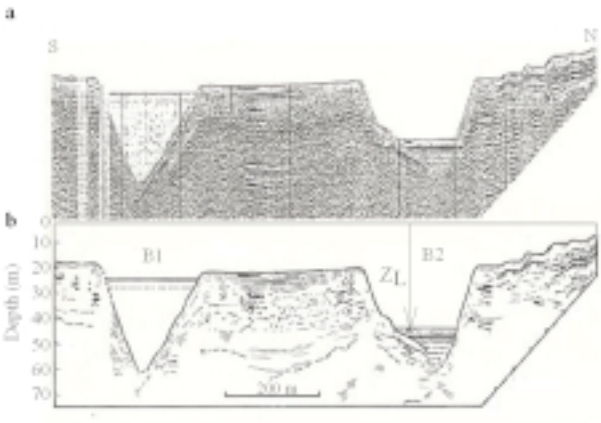
The tectonic constraint of the lake forces the vertical discharge of ground water flow through the bottom of the basins

In B1, the subterranean springs mix the sediments above up to a fairly sharp interface known as the lutocline (**chronic fluidization**)

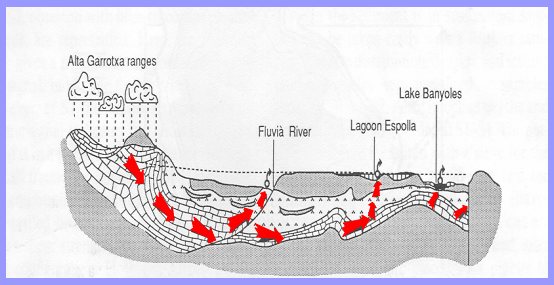
Usually, the sediment **in basin B2** remains consolidated at the bottom, with the lutocline at a depth of 44 m approximately. Following high precipitation periods, the subterranean springs in B2 supply water to the lake at a rate comparable to B1 (about ½ m^3/s), which in turn increase the pressure enough for the incoming water to resuspend the confined and consolidated sediment (**episodic fluidization**)

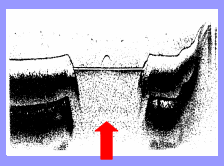


(a) South-North seismic transect, and (b) schematic interpretation of the section from B2 to B1



The **lutocline** is well detected by the seismic profile and is **located at a depth ZL** from the surface

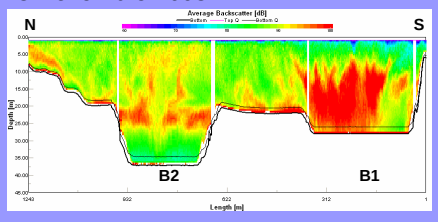


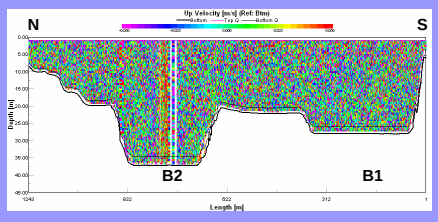


The sediment fluidizations in B2 are of **great limnological interest** because convection occurs above the lutocline interface. This phenomena carry particles in suspension from the lutocline upward into the lake water column which affect both **fish distribution and sedimentary records** (pVC as high as 44 µl/l, 8-29 times larger than usual)

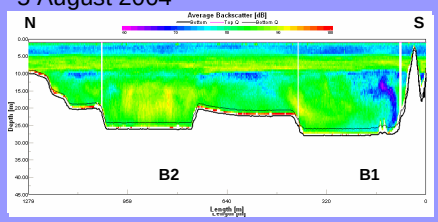
ADCP

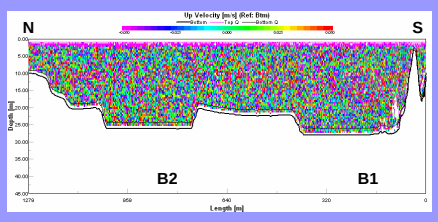
3 November 2003

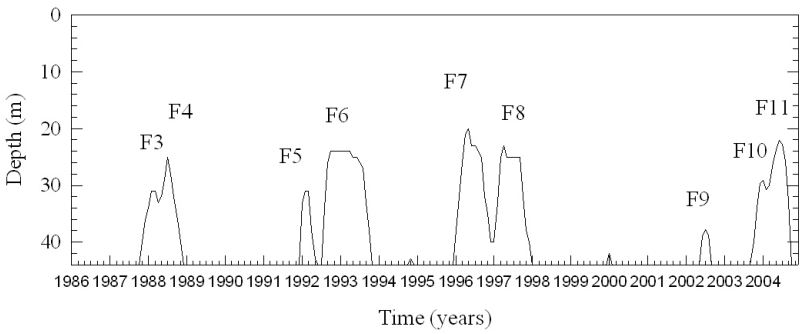




5 August 2004





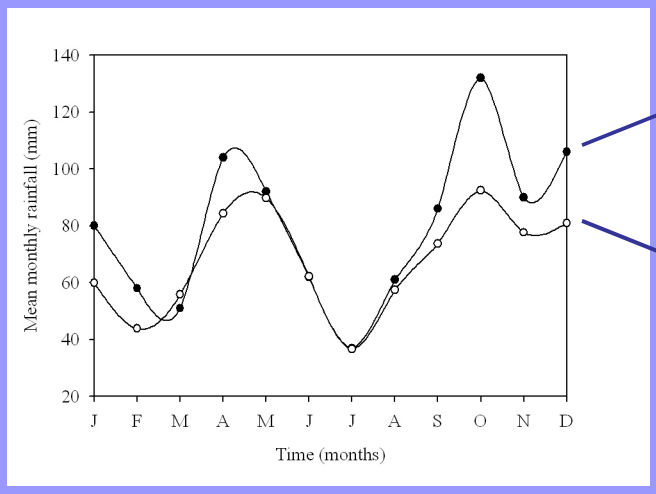


The **fluidization events** (F1, F2, etc) were **detected** by measuring the depth of the lutocline ZL in basin B2. The lutocline level was well detected by either seismic profiles, echosounding profiles, or continuous water temperature measurements

Sediment fluidizations in B2 detected during **39.9% of the whole historical record**

SEDIMENT FLUIDIZATION EVENTS RELATED TO LOCAL RAINFALL

Quantification of a well-known relationship



Darnius, in the area of the aquifer recharge

Banyoles, in the area of study

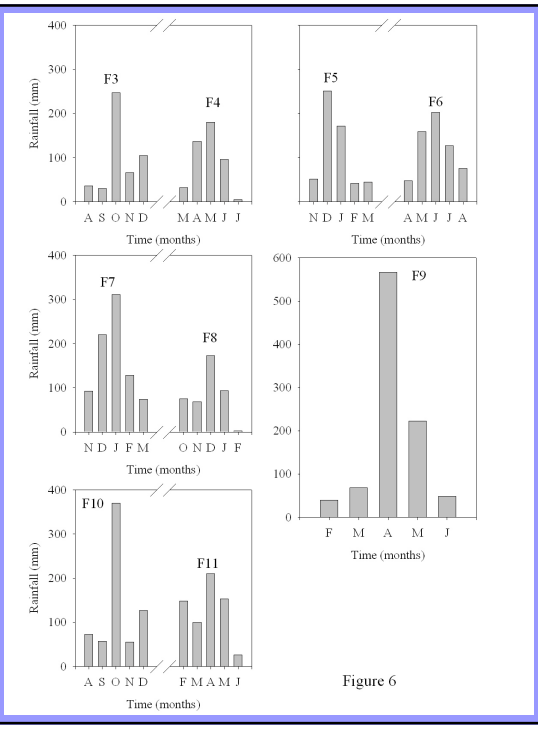
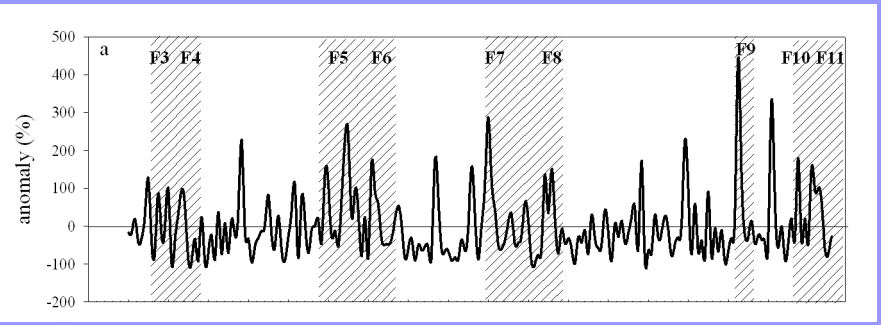


Figure 6

Local monthly rainfall during the fluidization events in the area of aquifer recharge

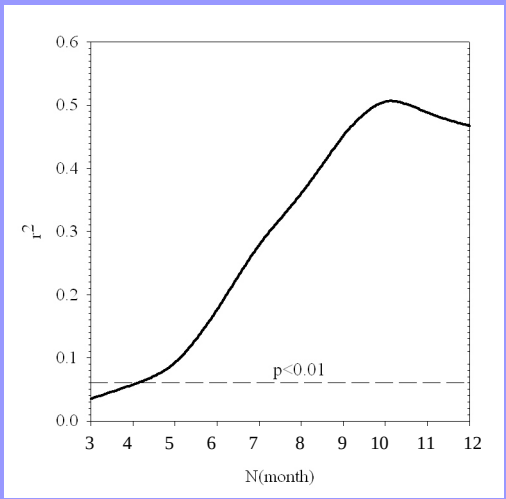
The central value corresponds to the month of initiation of each fluidization event

Monthly rainfall anomaly in the area of aquifer recharge



The mean anomaly for the months of initiation
of the **fluidization events** is 167 %.
Then, the local monthly rainfall is **2.67 times the mean monthly rainfall**

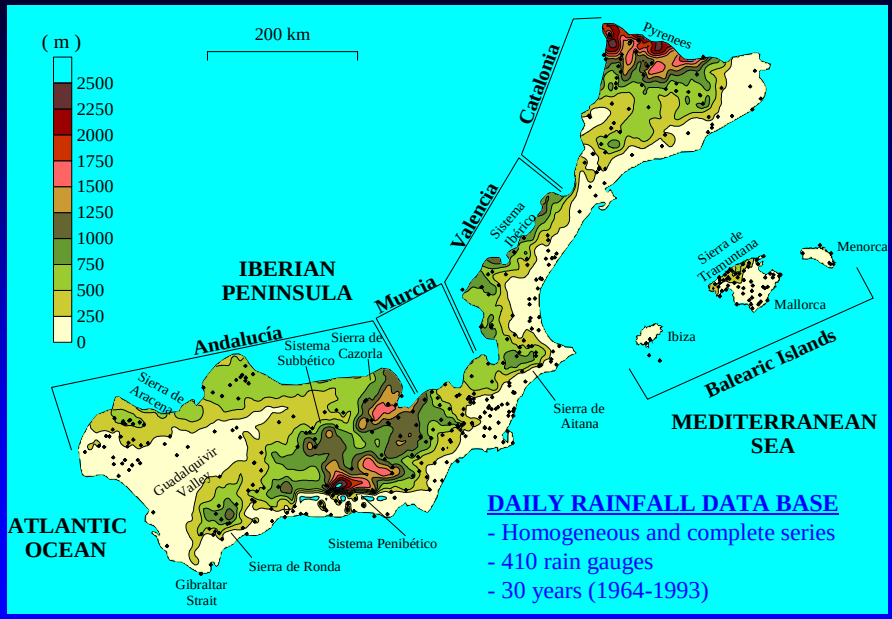
Coefficient of determination (r^2) between the vertical depth of the lutocline and the accumulated rainfall in the preceding N months



The maximum explained variance (r^2 = 50.6 %) is obtained for the
monthly rainfall accumulated in the previous 10 months

SEDIMENT FLUIDIZATION EVENTS RELATED TO ATMOSPHERIC PATTERNS

Using a previous AP classification for Mediterranean Spain

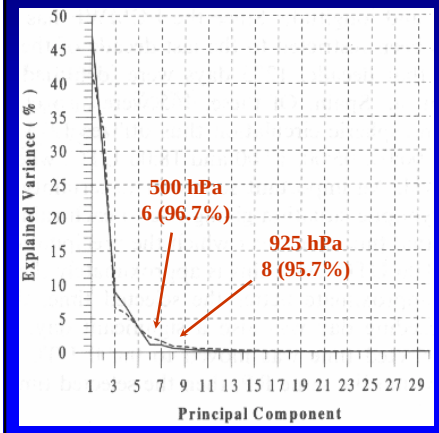


CLASSIFICATION ATMOSPHERIC PATTERNS (APs)

ECMWF analyses on significant days (1984-93) ⟹ *1275 days*

Geographical window 33.75N-45.75N 11.25W-6.00E ⟹ *408 grid points*

Classification based on geopotential height at 500 and 925 hPa



T-mode
(day-by-day)
correlation matrix

↓

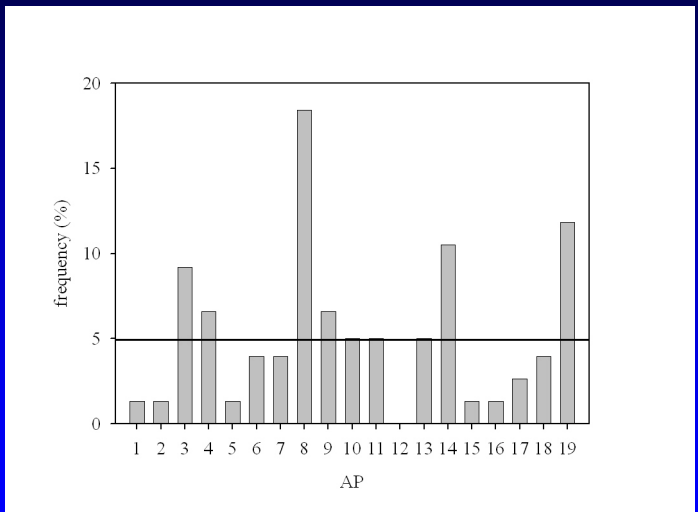
Principal Components Analysis
PCA

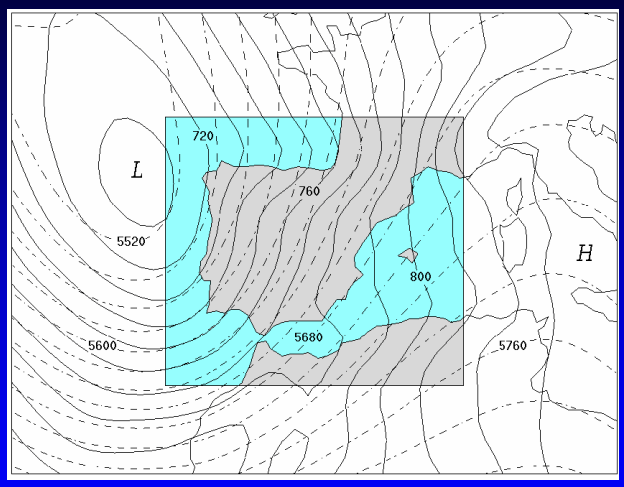
↓

Cluster Analysis (k-means)
CA

19 APs

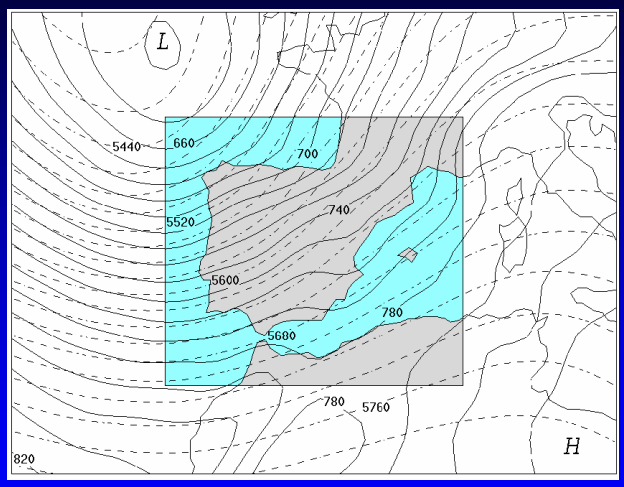
Percentage frequency of each AP
during the period of initiation of the fluidization events





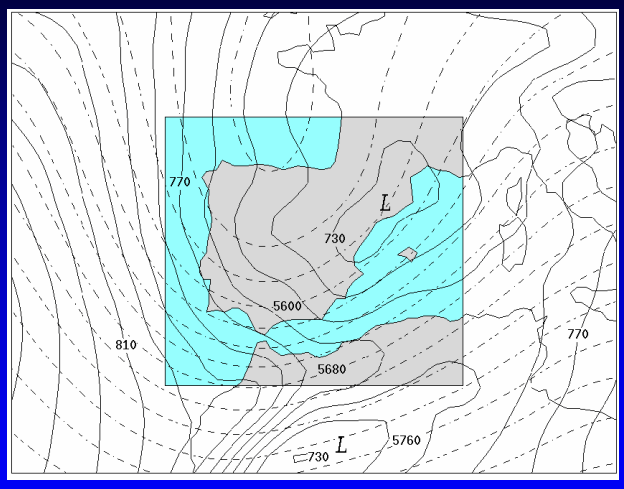
AP3

Aut 54.8%
Heavy 25.0%



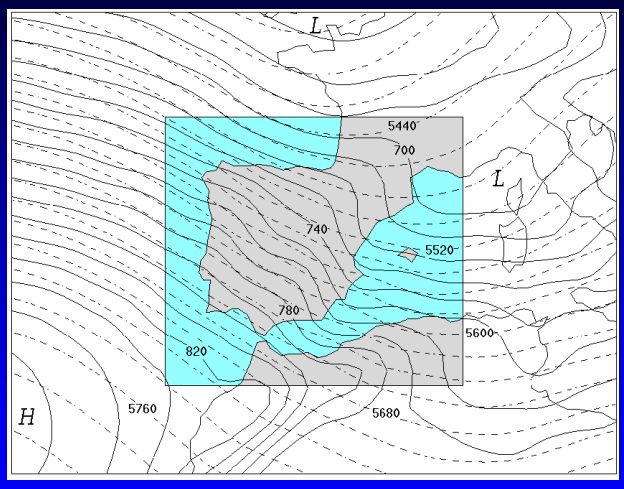
AP4

Aut 41.0%
Heavy 15.2%



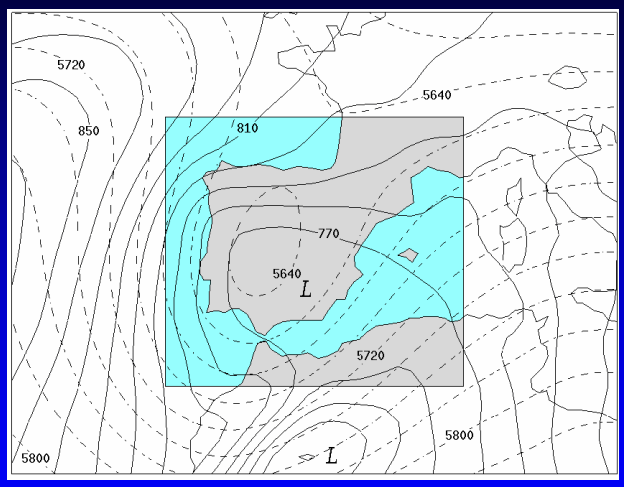
AP8

Spr 42.1%
Heavy 7.9%



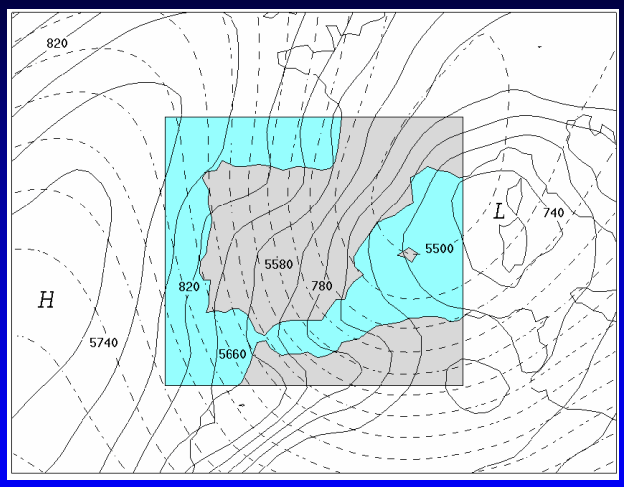
AP9

Win 45.3%
Heavy 3.5%



AP14

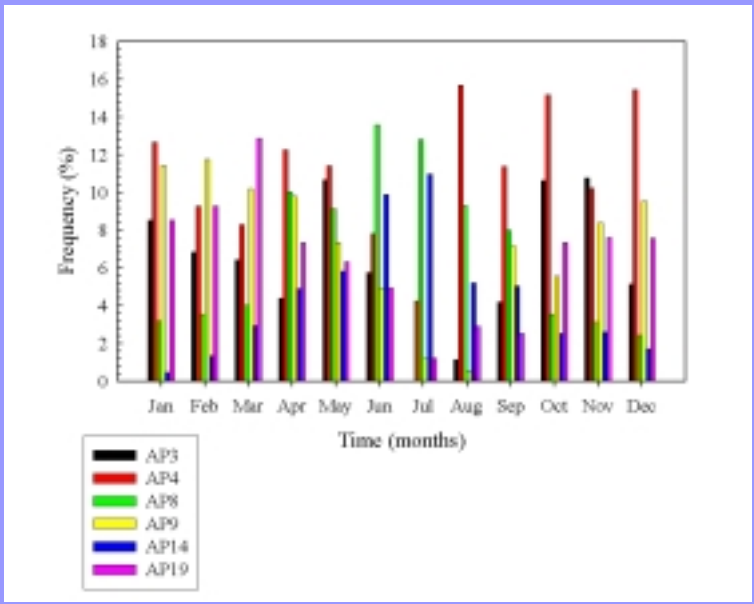
Spr 35.7% - Sum 33.9%
Heavy 19.6%



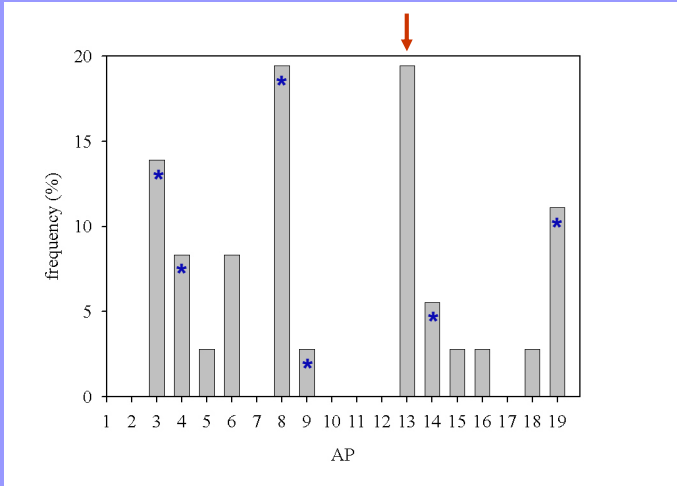
AP19

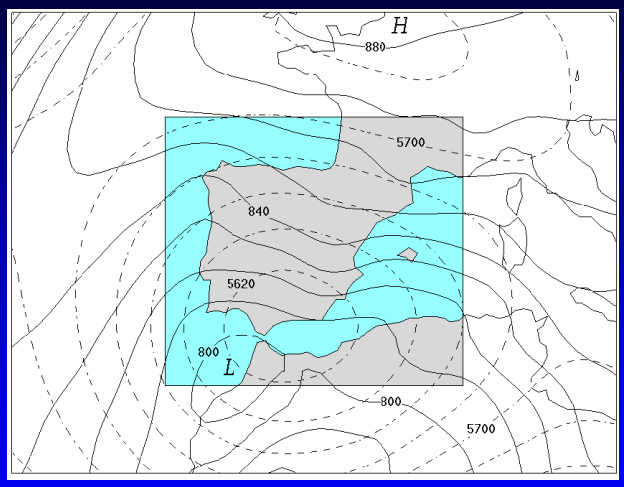
Spr 40.2% - Win 34.5%
Heavy 11.5%

Month-frequencies for the 6 most frequent APs during fluidization events



Percentage frequency of torrential days during the time of initiation of the fluidization events as function of atmospheric pattern





AP13

Win 53.0%
Heavy 37.9%