HYDROLOGICAL CYCLE IN THE MEDITERRANEAN EXPERIMENT (HyMeX): TOWARDS A MAJOR FIELD EXPERIMENT IN 2010-2012

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1. INTRODUCTION

The Mediterranean basin has quite a unique character that results both from physiographic conditions and historical and societal development. The region features a near closed sea surrounded by very urbanized littorals and mountains from which numerous rivers originate (Fig. 1). This results in a lot of interactions and feedbacks between oceanic-atmospheric-hydrological processes that play a predominant role on climate and its ecosystems. These processes frequently cause extreme events that produce heavy damages and human losses; heavy precipitation and flash-flooding during the fall season, severe cyclogeneses associated with strong winds and large swell or droughts accompanied by forest fires during summer are examples of Mediterranean high-impact weather events. The capability to predict such dramatic events remains weak because of the contribution of very fine-scale processes and their non-linear interactions with the larger scale processes. Progress in the understanding of the Mediterranean climate has thus important environmental, societal and economical implications. There is a clear lack of an experimental project relying on up-to-date innovative instrumentation in order to go one step further in the understanding and predictability of the Mediterranean weather events.

2. THE HYMEX CONTEXT

In France, the research community has recently recognised the necessity to develop a major multi-disciplinary and multi-scale experimental project to address the main issues related to the Mediterranean coupled system within the 2010-2015 period. The hydrological cycle in the Mediterranean region has been identified as a key scientific, environmental and socio-economic issue that has to be addressed within such experimental project. The HyMeX (HYdrological cycle in the Mediterranean EXperiment) project aims at a better quantification and understanding of the hydrological cycle and related processes in the Mediterranean, with emphases put on high-impact weather events and regional impacts of the global change including that on ecosystems and the human activities. The targeted period is [2010-2012]; a phasing of the special observing period with a European THORPEX[1] Regional Campaign (named T-NAWDEX) in 2010 (or 2011), in connection with the Medex Phase 2, is looked for.

A white book for HyMeX is currently written by a panel of scientists (listed here as co-authors) in atmosphere, hydrology and ocean sciences. It aims at highlighting some key open scientific questions related to the study of the water cycle at different time and temporal scales in the Mediterranean. The first version of the white book has been largely debated with the research community during the first HyMeX workshop in January 2007 (see http://www.cnrm.meteo.fr/hymex/) and are currently presented at various international conferences. ICAM 2007 constitutes therefore one of these opportunities to discuss and integrate propositions of the international community.

[1] THORPEX is an international global atmospheric research and development program of the WMO World Weather Research Program (http://www.wmo.ch/thorpex/).

3. HYMEX SCIENTIFIC TOPICS

Besides societal and economic aspects, five main overall scientific issues (also called objects hereafter) have been identified for the water cycle in the Mediterranean (Fig. 2). As the Mediterranean system is highly coupled, these objects involve generally more than one single compartment (ocean, atmosphere, continental surfaces and hydrology) and need in order to be addressed to consider interactions between compartments. Considering the time-scales, the first two objects cover from the seasonal to the century scale in priority, without ignoring the impact of extreme events on the average values. The temporal range of the three others is mainly comprised from the event to the seasonal scale, without isolating them from the climate change evolution:

3.1 Water budget of the Mediterranean sea

The Mediterranean sea is characterized by a negative water budget (excess evaporation over freshwater input) balanced by a two-layer exchange at the Strait of Gibraltar composed of a warm and fresh upper water inflow from the Atlantic superimposed to a cooler and saltier Mediterranean outflow. Light and fresh Atlantic waters are transformed into denser waters through interactions with the atmosphere that renewals the Mediterranean waters at intermediate and deep levels and generates the thermohaline circulation. Although the scheme of this thermohaline circulation is better understood, little is known about its variability at seasonal and inter-annual scales. For example, a better understanding of the formation of Levantine Intermediate Water (LIW) in the eastern Mediterranean is needed because LIW plays a major role in the formation of other kind of dense waters in the whole Mediterranean and its signature is still visible in the Mediterranean outflow water at the Strait of Gibraltar. The budget of the Mediterranean Sea has also to be examined in the context of the global warming, and in particular by highlighting the impact of an increase of Sea Surface Temperature (SST) on high-impact weather frequency and intensity.

3.2 Water resources-hydrological continental cycle

The rainfall climatology of the Mediterranean region is characterized by dry summers frequently associated with very long drought periods, followed by fall and winter precipitation that are mostly very intense. This results in high daily/seasonal variability in aquifer recharge, river discharge, soil water content and vegetation characteristics, for which the interaction with the atmosphere is not well known. This includes for example the impact of the large extension forest fires associated with drought during summer on the evapotranspiration component of the hydrological cycle. The role of the surface states (land use/land cover) and of the soils on the modulation of the rainfall needs also to be better understood. Hydrological and hydrogeological transfer functions are also characteristic of the Mediterranean basin, notably because of the specificities of the peri-mediterranean karstic and sedimentary aquifers. Progress in their understanding is of primary importance for the development of integrated management of the hydrosystems, and its adaptation to the climate change.

3.3 Heavy precipitation and flash-flooding

During the fall season, western Mediterranean is prone to heavy precipitation and devastating flash-flooding and floods. Daily precipitation above 200 mm are not rare during this season, reaching in some cases exceptional values as huge as 700 mm recorded in September 2002 during the Gard (France) catastrophe. Large amounts of precipitation can accumulate over several day-long periods when frontal disturbances are slowed down and strengthened by the relief (e.g. Massif Central and the Alps), but also, huge rainfall totals can be recorded in less than a day when a mesoscale convective system (MCS) stays over the same area for several hours. Whereas large scale environment propitious to heavy precipitation is relatively well known, progress has to be made on the understanding of the mechanisms that govern the precise location of the anchoring region of the system as well as of those that produce in some cases uncommon amount of precipitation. The consequences of the intense precipitation events are amplified by the specific topography of the region with numerous small and steep river basins, and also by the predominance of karstic aquifers, resulting in flash-flooding.

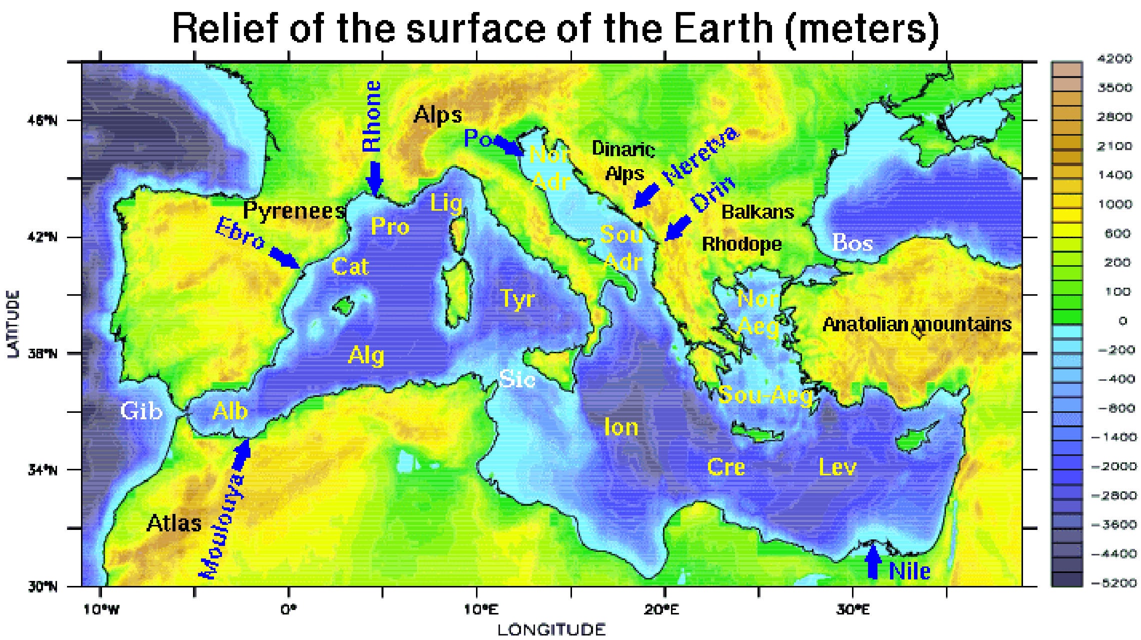

Figure 1: Geographical locations for the Mediterranean region. The Strait of Sicily (Sic) splits the Mediterranean Sea in the Western and Eastern basins, composed of the Alboran (Alb), Algerian (Alg), Tyrrhenian (Tyr), North and South Adriatic (Adr), Ionian, North and South Aegean (Aeg), Cretan (Cre), Levantine (Lev), Catalan (Cat), Provencal (Pro), Ligurian (Lig) sub-basins. The Mediterranean Sea is connected to the Atlantic Ocean by the Strait of Gibraltar (Gib), and to the Black Sea by the Bosphorus strait (Bos).

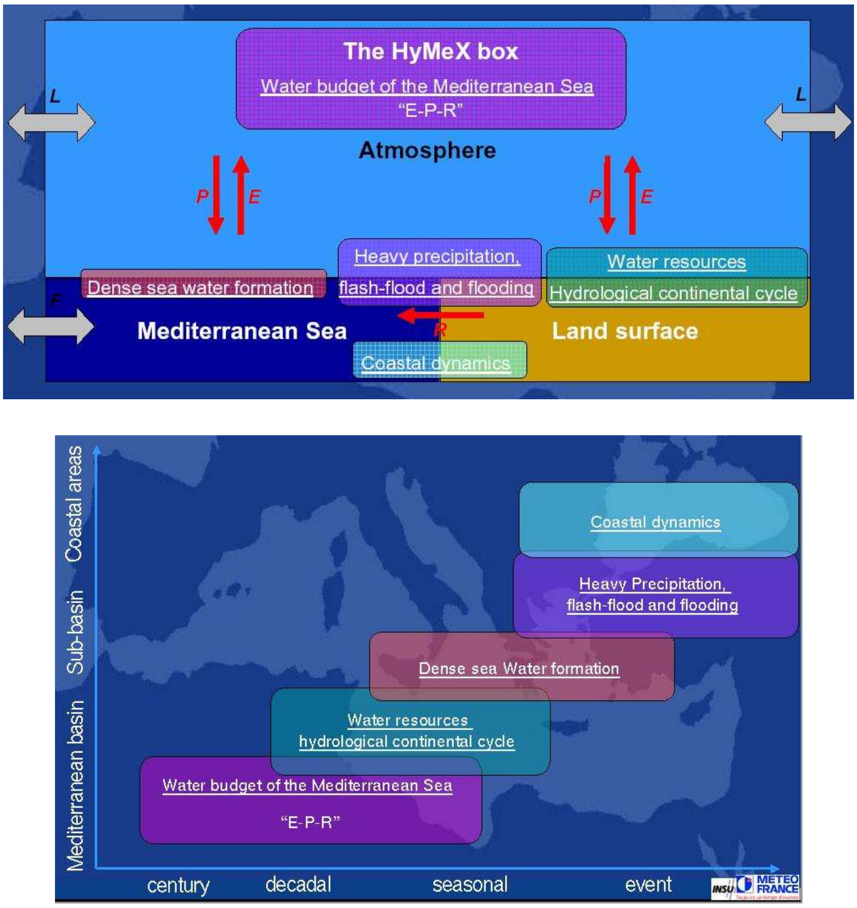

Figure 2: HyMeX topics

3.4 Mediterranean cyclogeneses and Dense water formation

The transformation of incoming Atlantic Water into denser waters occurs mainly during the winter when high evaporation and cooling cause oceanic convection. Deep offshore winter convection happens mainly in four major sites (the Gulf of Lion in the western Mediterranean, and, in the eastern Mediterranean, the Adriatic sea, the Aegean sea and the Levantine basin). Intense Mediterranean cyclogeneses and regional high winds (e.g. Genoa cyclone and Mistral for western Mediterranean) contribute to intense air-sea heat exchanges and sea surface cooling resulting in strong vertical mixing within convective chimneys of diameters of several kilometres. Hydrological and dynamical characteristics and inter-annual variability of the convection, in particular in terms of spatial extent, occurrence and time duration associated to the chimneys, need to be better documented in order to stress the respective role of the atmospheric forcing and oceanic processes (such as mesoscale eddies and submesoscale vorticies) and to progress in the modelling of these processes. Ecosystems functioning are strongly related to this complex dynamic and its impact needs to be addressed.

3.5 Coastal dynamics

A good knowledge of the water circulation and mixing in the coastal zone are keys to understand the transport and transformation of continental rivers and aquifers inputs (biogeochemical and sediment transport), the cycle of major constituents in the coastal zone as well as the formation and cascading of dense waters toward the open sea. Momentum transfer from atmospheric winds largely governs the residence time of the water and nutriments within the continental shelves. The functioning of the coastal zone is therefore very sensitive to the fine scale spatial and temporal variability of the low-level wind field in this region, which result from not well-known interactions with the complex topography of the Mediterranean region.

4. HYMEX EXPERIMENTAL STRATEGY

The experimental strategy will be refined in the future based on the outcome of the white book and its discussion with the national and international communities and projects. For the time being a two-level nested experimental strategy for the field campaign is envisaged:

- *A long observation period (LOP) lasting about 10 years starting around 2010,* which consists in enhancing the current operational observing systems and existing observatories in hydrology, oceanography and meteorology. The main objective of the EOP is to gather and provide additional observations of the whole coupled system that support analysis of the seasonal-to-interannual variability of the water cycle.
- *a special observation period (SOP) envisaged around 2011,* which will aim at providing detailed and specific observations to study key processes of the water cycle in specific Mediterranean regions, with emphases put on heavy precipitation systems. This SOP should be in phase with a THORPEX European Regional Campaign in 2010 (or 2011) in connection with the Medex Phase 2.

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