The Hydrological cycle in the Mediterranean Experiment (HyMeX):
where do we stand? where do we go?

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Objectives & Science Topics

- to improve our understanding of the *water cycle* with emphases on the *predictability* and *evolution of high-impact weather events*

- to evaluate the *social and economical vulnerability* to extreme events and the *adaptation capacity*.

- A three-level nested observation approach over the 10-y program:

  - **LOP**

  - **EOP**

  - **LIAISE**
  - **PERLE**
  - **LIAISE**

Where do we stand? Where do we go?

**Objectives & Science Topics**

- **Multiscale**: sharing of methodologies, expertises, between regional climate -NWP-process based models

- **Integrated interdisciplinary** approaches (e.g. integrated forecast of heavy precipitation to impacts)
A **strong modelling component** (ocean-atmosphere-hydrology, process-weather prediction-climate models) from the beginning that allows to design the field campaigns for model validation and improvement. **A lot of cross-validation and cross-analysis** have been carried out.
Mediterranean water cycle

- Characterization of MSWB terms and of their variability
  - Well achieved with direct and indirect estimates (MSWB, MSHB, MSMB, sea level)
  - Need for better estimates for atmospheric moisture transport, sea precipitation, strait transport and other sub-regions than the NW Mediterranean
  - HyMeX-LOP (incl. buoy/mooring/MOOSE) is currently too short. To be continued
  - Need for Mediterranean-dedicated satellite products (coastal area, small-scale)

- Modelling/Understanding of MSWB terms and of their variability
  - Well achieved with the development of a coordinated ensemble of high-resolution and fully-coupled Regional Climate System Models (Med-CORDEX)
  - Improvement in the understanding main driving factors of the MSWB variability
  - More work required on model improvement (atmosphere param., air-sea coupling)
  - Human influence on land-use and water-use must be included
  - Natural and anthropogenic aerosol representation must be improved

- Past trends and future evolution of MSWB terms
  - Past trends identified but longer-term « climate-aware » monitoring is required
  - Work on the role of regional climate drivers on past trend attribution to be done
  - Qualitative evolution of the MSWB terms is confirmed using new GCM/RCM runs
  - Need for more Med-CORDEX scenario runs to assess MSWB future evolution
Mediterranean water cycle

Climate variability of the MSWB ? Driving factors ?

Sea level anomaly
(m, hindcast, 1980-2012)

Ocean heat content
(°C, 1960-2013)

Latent heat flux
(W/m², 1980-2012)


References: Pellet et al. 2017, 2018
How do localized intense events affect the MSWB?

Future evolution of the MSWB along the 21st century?

Projections of evaporation change
(RCP4.5, CMIP5, 2071-2098 vs 1980-2005)

References: Josey et al. 2011, Papadopoulos et al 2012, Durrieu de Madron et al. 2013, Somot et al., in prep, Flaounas et al. 2015, Lebeauin-Brossier et al. 2015, Llasses et al. in prep, Caniaux et al. in prep

Quantification of the water cycle and specific Mediterranean processes
- Land Surface Models for quantifying the Med. water cycle at different scales
- Remote Sensing Data and LSMs with active vegetation allowed us to better understand the role of vegetation on drought and heatwaves.
- Progress in the quantification of the effects of underground water.
- Better understanding of the links between droughts and forest fires.
- Progress in seasonal forecasting of heat waves, droughts and dam levels
- Better description of specific Mediterranean vegetation processes.
- Process that trigger and maintain drought.
- Need for a DROUGHT-impact database, analysis of social & institutional responses

Future evolution in relation to global change
- Uncertainty propagation is better understood and quantified.
- RCM models are improving our ability to study the impacts of climate change on hydrological extremes
- More studies on the impacts of climate change.
- Improvement of our understanding of global change (human impacts) → simulation of the real water cycle (inclusion of human water infrastructure)
Global Earth Observation for Integrated Water Resource Assessment

Quantification of the freshwater inputs to the Mediterranean with a LSM (ORCHIDEE) → sources of error in forcing datasets and model processes and physiography at large scale.

Underground water is coupled with the land surface and it introduces memory into the system.

References: Quintana-Seguí et al. 2011; Barbu et al., 2014; Szczypta et al., 2014; Míguez-Macho et al. 2014; Polcher et al. 2015; Raymond et al. 2016, 2017
Water resources and drought

How do continental water cycle and water resources evolve with climate change?

References: Tramblay 2015; Raymond et al. 2018
What are the characteristics of extreme hydro-meteorological events in the Mediterranean?

- Observations: (1) Rainfall reliable estimation at much smaller space and time scales than before and quantification of their uncertainty; (2) Progress in gauging flash floods (non contact techniques, uncertainty quantification, diffusion in operational services); (3) Socio-hydro post event surveys; (4) Documentation of flash flood processes at much smaller scales than before

- Hydrological process understanding: (1) Rainfall spatial and temporal variability remains the first driver; (2) Hydrological processes active during flash floods are variable in space and time; (3) Initial soil moisture, geology and soil properties have a significant control on the response, less clear for land use?

- Regional modelling and flash-flood forecasting: (1) Development and set up of distributed, physically based models at regional scale (and in ungauged catchments); (2) Assessment of added-value of coupled ensemble atmospheric forecast and hydrological forecast; (3) Useful for civil protection and warnings

- No (few?) measurements of evapotranspiration and still lots of questions about water balance closure (uncertainties should be taken into account)

- Few work on karstic catchments and urbanized areas
How can we improve heavy rainfall process knowledge and prediction?
- Understanding thermodynamic mechanisms leading to HPE (especially those over the plains instead over mountains).
- Relationship between cyclones (Mediterranean cyclones, medicanes, extra-tropical transition of tropical cyclone) and HPE.
- Monitoring of WV, microphysics, to be fully exploited in new development of data assimilation systems and physical parameterization schemes.
- High resolution models and ensemble data assimilation systems
- Object oriented (HPE) approach across time/space scales
- Coupled system and seamless approach: complexity which is required

How will extreme hydrometeorological events evolve with climate change?
- MED-CORDEX simulations used to assess evolution of heavy precipitation (in agreement with already existing trend)
- Need for much more multi-model study at various spatial resolutions in coupled or non-coupled mode
How can we monitor adaptation strategies to heavy precipitation & floods in the Mediterranean basin?
- Collecting data on floods: FLOODHYMEX, the flood impact database
- Need to update FLOODHYMEX and extend to other countries
- Assess the use social media, networks and mobile devices to learn about social responses and emergency behaviours

Which lessons can be learnt from the experience of Mediterranean societies and individuals and how others can use these lessons?
- Analysis of transnational events
- Surveys on people behaviour
- Dissemination of results on individual responses and recommendations
- Summer school “Water and society”

How human vulnerability could change due to global change?
- Comparative analysis of flood trend and land-use trend
What are the characteristics of extreme hydro-meteorological events in the Mediterranean?

References: Braud et al. 2014; Payrastre et al.; Borga et al.
How can we improve heavy rainfall process knowledge and prediction?

Heavy precipitation, floods & impacts

An unprecedented cross-analysis of measurements from various platforms

Defer et al., 2015, Bousquet et al. 2015, Ribaud et al. 2015, Grazioli et al. 2015

LIGHTNING

MICROPHYSICS from RADAR ...

and from AIRCRAFT (Falcon20)

Defer et al., 2015, Bousquet et al. 2015, Ribaud et al. 2015, Grazioli et al. 2015

LIDAR and MW radiometer

Di Girolamo et al., 2015

GPS

Bock et al., 2015
Heavy precipitation, floods & impacts

New tools/methods for variationnal data assimilation

References: Martinet et al, 2013, 2014; Brousseau et al. 2015

New observations → Mesoscale Data Assimilation within cloudy and precipitating systems at convective scale

Assimilation of Spanish radar in AROME (oper) - 18 h forecast
How will extreme hydrometeorological events evolve with climate change?

References: Drobinski et al. 2018, 2019 submitted; Tramblay an Somot 2018

4% / decade
How will extreme hydrometeorological events evolve with climate change?

**Methodology:** Newspapers

**Area:** Calabria

**Study event:** 2000-2014

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**Nartuby-Draguignan**

**Rialle**

**Tuillère**

**Nartuby-Trans**

Cumulated rainfall

**Methodology:**

Face-to-face interviews

**Area:** Var region

**Study event:** June 2010

**Victims:** 25

**People interviewed:** 30
LIAISE campaign

- Water balance over semi-arid (irrigated) areas

EOP/SOP: SOP1 (Spring 2020, UKMO), SOP2 (July 2020, HyMeX) included within a vegetation cycle (EOP, HyMeX)

SS2: Monegros area (one of the most arid regions in Spain, with some irrigated spots)

SS1: Urgell area (at the limit between the irrigated and the non-irrigated area with a very strong contrast in July)

For both sites, local scientists and instruments/data

Additional research instruments for SOP2: SAFIRE/ATR42-15 days Radiosoundings, Thethered balloon, Fluxes stations

Next steps (2018-2020)
→ Quantify the human contribution to the water cycle in the Mediterranean, where direct human pressure on water resources (irrigation, energy, food, drinking water) can be very high. This point could be directly associated with HyMeX / GEWEX LIAISE action

→ Through EO observations, link to very fine, extreme scales of the water cycle and impacts (flooded area, erosion, damage, ...)

→ Concerning the WACMOS-MED database: validation of models (especially MED-CORDEX simulations), or even future satellite missions using the WACMOS-MED database; preparation of field campaigns (e.g. LIAISE); process studies
Thanks!

Scientists on the field