HyMeX : Hydrological Cycle in the Mediterranean Experiment

Update on recent achievements

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Objective & 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:

2012-2013: two major field campaigns in NW Med (SOP1 & SOP2)

SOP1 (5 Sept. - 6 Nov. 2012)

WG3 - Heavy Precipitation and flash-flooding

Ducrocq, V., et al, 2014: HyMeX-SOP1, the field campaign dedicated to heavy precipitation and flash flooding in the northwestern Mediterranean, Bulletin of the American Meteorological Society, 95, 1083-1100.
2012-2013: two major field campaigns in NW Med (SOP1 & SOP2)

SOP2 (27 Jan - 15 March 2013)

WG4 – Intense air-sea exchanges
Dense water formation and ocean convection

SOP2 was part of a joint observation effort over a year that allowed for the first time to monitor a full annual cycle of dense water formation (pre-conditioning/convection/restratification-spreading)

Routine and on-alert measurements each autumn since 2012 (sampling of flood events for geochemistry analysis, gauging of flooding rivers, soil moisture measurements, field observations of runoff) over some French Med watersheds

A lot of events in autumn 2014
(17-20 sept, 10-13 oct, 3-4 nov, 14-15 nov, 27-29 nov)

EOP reinforcing observatory and operational observations during four years: a very successful proof of concept for flash-floods

Research Observatories steering by HyMeX needs ocean (MOOSE), hydrometeorology (e.g. OHM-CV) + HyMeX-funded instrumented platforms:

- For air-sea interface: Ship of opportunities, additional sensors and 0-200m mooring line on operational buoys,
- Atmospheric observations over Corsica

Make available some research operational observations from meteorological and hydrological services

Meteorological and hydrological obs from France and Spain

Post-event surveys

Hydrology, social impacts
**LOP: Intensive Post-event Campaigns (IPEC)**

- Estimation of peak discharge over ungauged rivers, one IPEC each year

- Collection of rivers cross sections data with flood mark levels
- Interviews of eyewitnesses for info on dynamics of the flood and flood levels
- Use of videos for estimation of flow velocities

**Sardinia, Nov. 2013**
Precipitation: 469 mm/12 hours
Estimated 1 billion € damages

**Cévennes region, autumn 2014**
24 casualties
Estimated 660 millions € damages

4 events documented

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**Hydrological IPEC provides fine-scale spatial and temporal information about river flooding that are also needed for analysing social impact IPEC data about crisis behavioral responses during flood events (face-to-face interviews, on-line surveys, media network,...)**
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.
Facts and figures

More than 300 peer-reviewed articles in scientific journals contributing to HyMeX

Coordination of 4 special issues in international journals:
Advances in understanding and forecasting of heavy precipitation in the Mediterranean through the HyMeX SOP1 field campaign, Quarterly Journal of the Royal Meteorological Society, vol.142, August 2016, 1-471.
« Flash floods, hydro-geomorphic response and risk management » in the Journal of Hydrology,
Regional climate modelling in Climate Dynamics (in review process)
Dense water formations in the North Western Mediterranean: from the physical forcings to the biogeochemical consequences in the Journal of Geophysical Research ocean-atmosphere (on-going)

Training & young scientists:
More than 75 PhD (incl. on-going PhDs) contributing to HyMeX, 110 MSc students
23 Post-docs and research associate fellowships
Contribution to 4 summer schools

~450 datasets in MISTRALS/HyMeX database (http://mistrals/sedoo.fr/hymex)

List of publications at: www.hymex.org/?page=publications
Continental hydrological cycle, Droughts and water resources

mid-term review
Results

Improved simulation of the continental water cycle at basin, country and Mediterranean scales.

New meteorological gridded datasets, used to force LSM simulations, allow a better quantification of the continental water cycle.

Quintana-Seguí et al. 2015.

Enhanced drought onset due to LAI assimilation.

Barbu et al. (2014) 10-daily soil moisture change rate (m$^3$ m$^{-3}$)

The use of LSMs with active vegetation and remote sensing data is improving our knowledge on the role of Mediterranean vegetation on the water cycle.

Szczypta et al. (2014)
Results

- Quantification of freshwater inputs to the Mediterranean is allowing us to investigate sources of error in forcing datasets and model processes and physiography at large scale. J. Polcher et al. 2015.

Better understanding of underground water processes.

Underground water is coupled with the land surface and it introduces memory into the system. Míquez-Macho et al. 2014.
**Results**

- **Impacts of climate change.**

  Use of Med-CORDEX (and Euro-CORDEX) simulations to study the impact of climate change on precipitation extremes and runoff.

  Change in Julian day of the 25th, 50th, 75th of the total runoff for the 2070-2099 day with respect to the 1970-2000 period.

  Earlier spring snow melt.

  Strong impact of the resolution on the simulation of snow melt driven runoff.

  Coppola et al, Climate Dynamics, 2016
Analysis of uncertainties in climate change impact studies.

Impact models (hydrological) amplify climatological uncertainties. Quintana-Seguí et al. 2011.

Future return period of the low flow with a 5 yr return period calculated using three different downscaling methods.
Mid-term program achievements

- **Quantification of the water cycle.**
  - Land Surface Models allowed us to quantify the Mediterranean water cycle at different scales.

- **Mediterranean specificities of the hydrological processes.**
  - Remote Sensing Data and LSMs with active vegetation allowed us to better understand the role of vegetation on drought and heatwaves.

- **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 cycle and extremes.
Mid-term program achievements

 Unexpected achievements.

- 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.

 Missing achievements.

- Better description of specific Mediterranean vegetation processes.
- Process that trigger and maintain drought.

 What remains to be done.

- 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 in our LSMs.
Next 5-y program orientations
General orientations

More scale continuum in object oriented studies

More integrated transdisciplinary studies
- **Process knowledge**: Further valorization of observations from HyMeX SOP1 and of the new-developed ocean-atmosphere(-waves) coupled models at kilometric scale for process studies

- **Model improvement**: Development of new and/or improvement of physical model parameterizations (microphysical, turbulence, convection, air-sea fluxes)

- **Climate change**: Evolution of precipitation extremes through use of the Med-CORDEX regional climate runs and the future Med-CORDEX/Euro-CORDEX convection-permitted runs (Flagship Pilot Studies)
Flash-flood and social vulnerability

- Flood understanding and modelling: exploitation of EOP data, transfer knowledge at small scales to larger watershed scale models, urbanized coastal regions
- Cross-analyses of multi-scale characteristics of hazards, vulnerability and exposure to explain high-impact weather events
- Risk communication, warning responses: crowd sourcing data and more classical data to analyze individual behaviour, social and institutional responses
Towards integrated prediction of Heavy precipitation, Flash-flood and Impacts

Numerical Weather Prediction: data assimilation (e.g. WV ground Lidar, satellite Lightning imager)

Flash-flood and flood plain forecasting: regional-scale models, hydrological-hydraulic coupling, modelling risks of run-off and of road submersion

Coupling of hydrological and social vulnerabilities models: development of impact-based prediction models (e.g. driver exposure)

Coupled atmosphere-ocean-hydrology models: continuum way from heavy precipitation, to the watershed and sea, coupled data assimilation

Ensemble Prediction Systems: seamless probabilistic prediction from observations, to nowcasting and short-range forecast

Applied research driven by needs of meteorological and hydrological services, emergency authorities and crisis managers
Water resources, droughts and impacts

- Modelling anthropogenic water regulation (irrigation, dams)
- Drought processes (soil moisture, vegetation, fertilization), forecast and impacts (wildfires, water shortages, ...)
- Water resource evolution in climate change
More information about the **Droughts and water resources HyMeX science team** => Pere Quintana-Segui talk at the GEWEX/GLASS meeting this week

**10th HyMeX workshop** in Barcelona, 4-7 July 2017 (or in May?)

Thanks for your attention!
Impact of climate change on snow melt driven runoff

Models:
ALADIN, RegCM4 (Med-CORDEX)
CCLM, RACMO22E (Euro-CORDEX)

At both 0.11° and 0.44° resolution

Julian Day of the 25th, 50th, 75th percentiles of the total runoff for the model ensemble average, observations superimposed 1970-2000

Coppola et al, Climate Dynamics, 2016
Results

- Links of the continental water cycle with forest fires. 
  Forest fires are correlated with drought in the Med. Turco et al 2015.

- Societal impacts of continental water cycle extremes.

Press databases allow us to better understand the impacts of hydrological extremes on water resources and society. Llasat et al.