# HyMeX : Hydrological Cycle in the Mediterranean Experiment

*Update on recent achievements*

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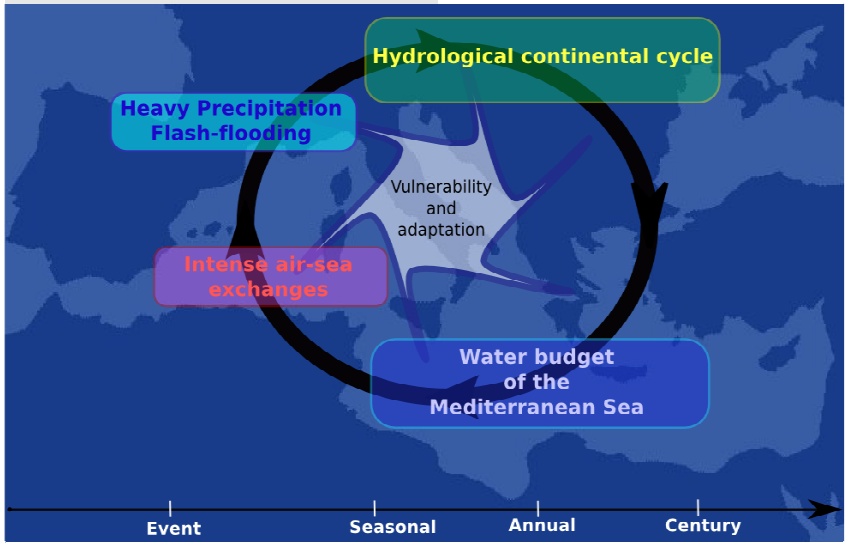
www.hymex.org

# Objectives & Science Topics

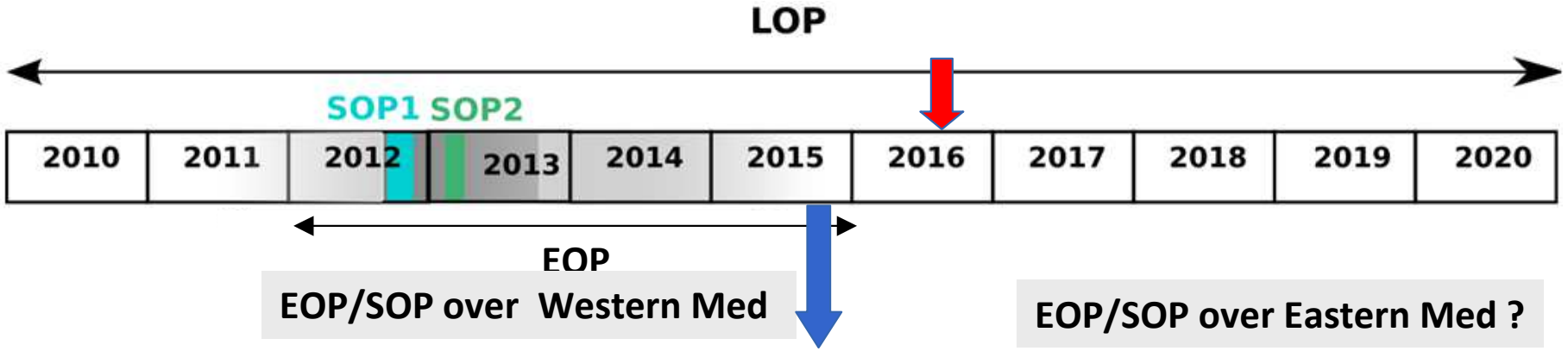
➲ to improve our understanding of the *water cycle* with emphases on the *predictability* and *evolution* of *high-impact weather events*

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

The five science Topics




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




Drobinski, P., Ducrocq, V., Alpert, P., Anagnostou, E., Béranger, K., Borga, M., Braud, I., Chanzy, A., Davolio, S., Delrieu, G., Estournel, C., Filali Boubrahmi, N., Font, J., Grubisic, V., Gualdi, S., Homar, V., Ivančan-Picek, B., Kottmeier, C., Kotroni, V., Lagouvardos, K., Lionello, P., Llasat, M. C., Ludwig, W., Lutoff, C., Mariotti, A., Richard, E., Romero, R., Rotunno, R., Roussot, O., Ruin, I., Somot, S., Taupier-Letage, I., Tintoré, J., Uijlenhoet, R. and Wernli, H., 2014: HyMeX, a 10-year multidisciplinary program on the Mediterranean water cycle, *Bulletin of the American Meteorological Society,* 95, 1063-1082.

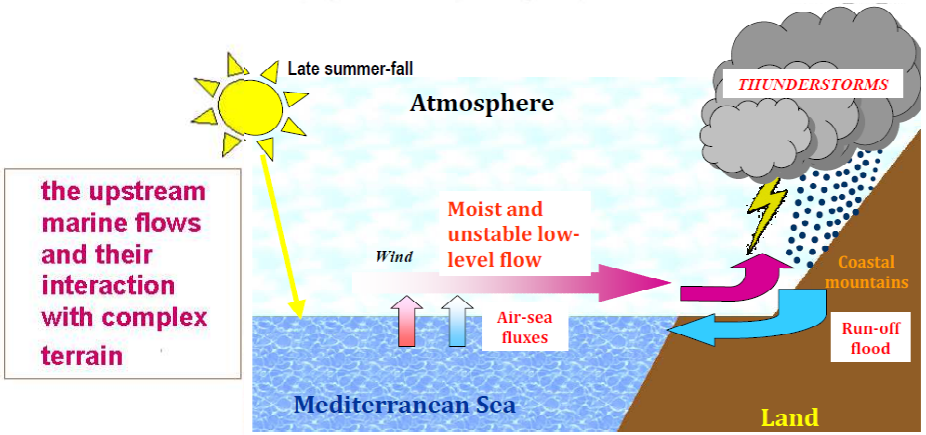
# 2012-2013: two major field campaigns in NW Med (SOP1 & SOP2)

HyMeX

## SOP1 (5 Sept. - 6 Nov. 2012)

*WG3 - Heavy Precipitation and flash-flooding*

the microphysics and dynamics of precipitating systems leading to HPE




the upstream marine flows and their interaction with complex terrain

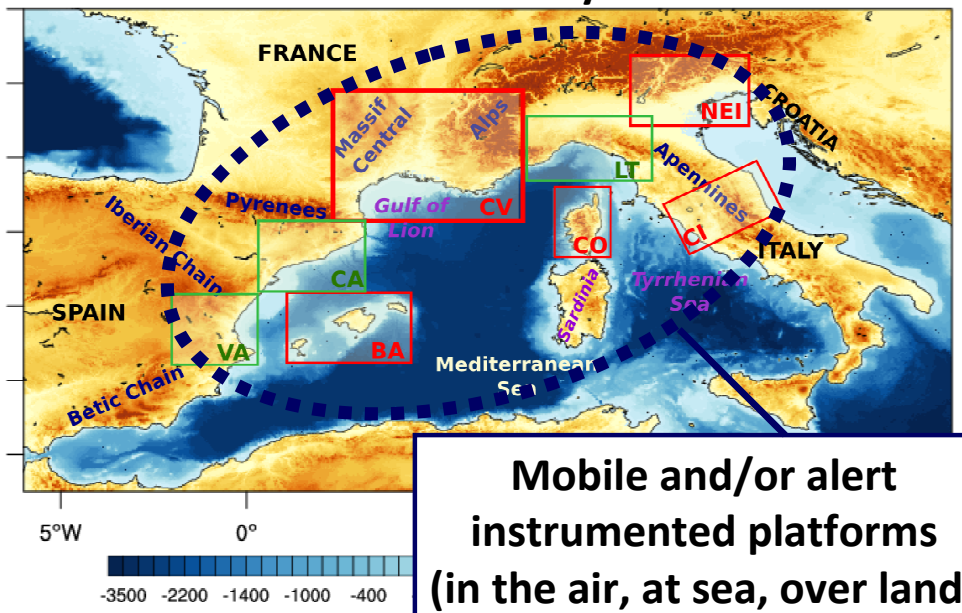
The distributed hydrological response of the Mediterranean watersheds

the air-sea exchanges and ocean mixed layer prior and during HPE

*~200 instruments deployed*
*250 flight hours (SAFIRE/ATR42 & F20, KIT/DO128)*
*~300 scientists on the field*
*16 IOPs dedicated to heavy precipitation*

**SOP1** brings observations over the sea and of precipitating systems forming over the sea and affecting the coastal areas

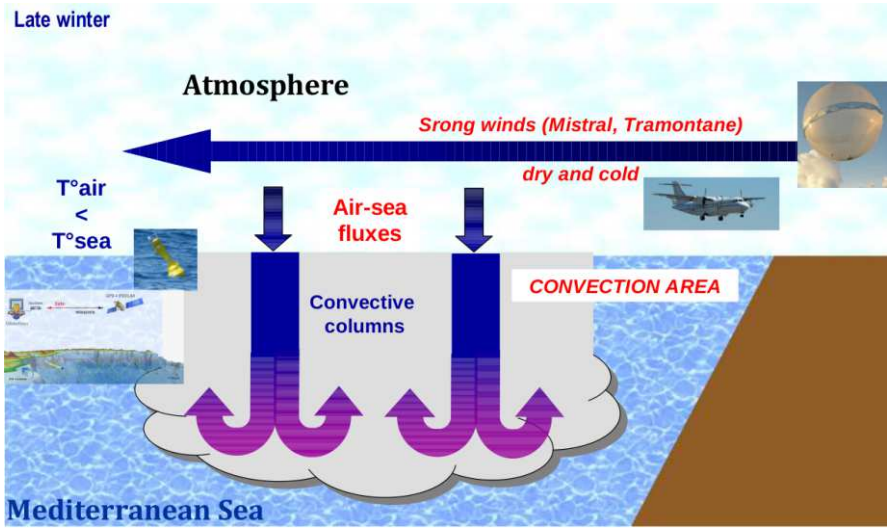
Site with HyMeX instruments




**Mobile and/or alert instrumented platforms (in the air, at sea, over land)**


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)

Strong winds
Atm fluxes

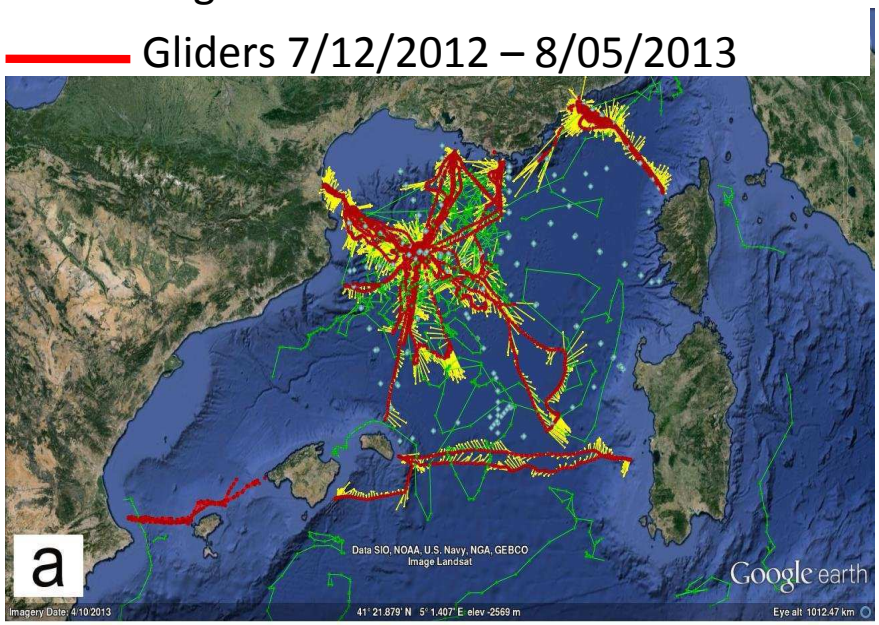
Air-sea interface

Marine response

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

Argo floats  CTDs

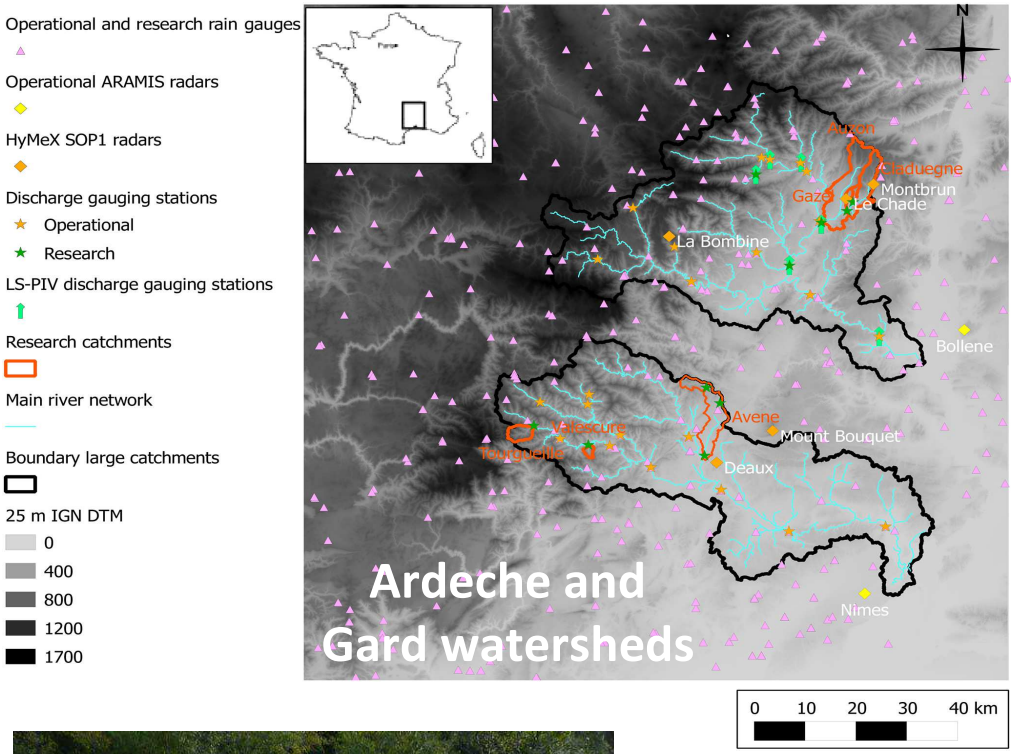
Gliders 7/12/2012 – 8/05/2013




**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)

Estournel, C., et al, 2014: HyMeX-SOP2, the field campaign dedicated to dense water formation in the north-western Mediterranean, *Oceanography*. (in revision)

# EOP: Hydrological measurements over French Mediterranean catchments




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**

Braud, I.et al., 2014: Multi-scale hydrometeorological observation and modelling for flash-flood understanding *Hydrology and Earth System Sciences*, 18, 3733–3761.

# LOP

## ➲ 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

Centre d'Observation Régional pour la Surveillance du Climat et de l'environnement Atmosphérique et océanographique en Méditerranée occidentale
CORSiCA

## ➲ Make available some research operational observations from meteorological and hydrological services

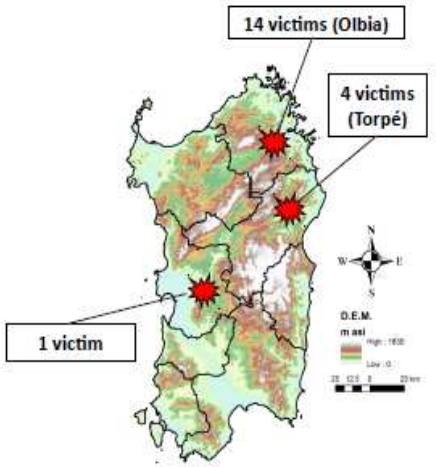
Meteorological and hydrological obs from France and Spain

## ➲ Post-event surveys

Hydrology, social impacts

# LOP: Intensive Post-event Campaigns (IPEC)

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




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




➲ 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

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,…)

# Model-Observations Strategy


LOP/EOP observations
SOP/EOP field campaigns

Regional Earth System models

Convection-permitting ensemble hydrometeorological prediction systems

Process models

Mesoscale (incl. land surface) data assimilation

Coupled O-A-wave km-scale models

Motorist mobility and exposure model

**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, Quaterly 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

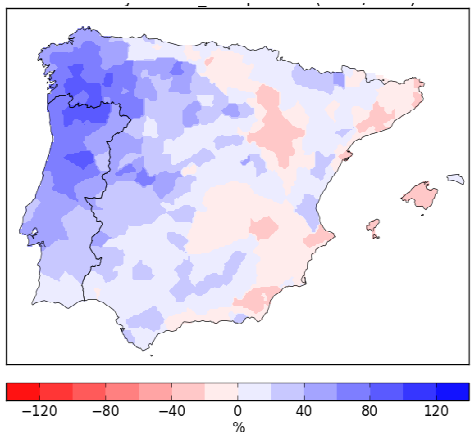
*mid-term review*

# Results

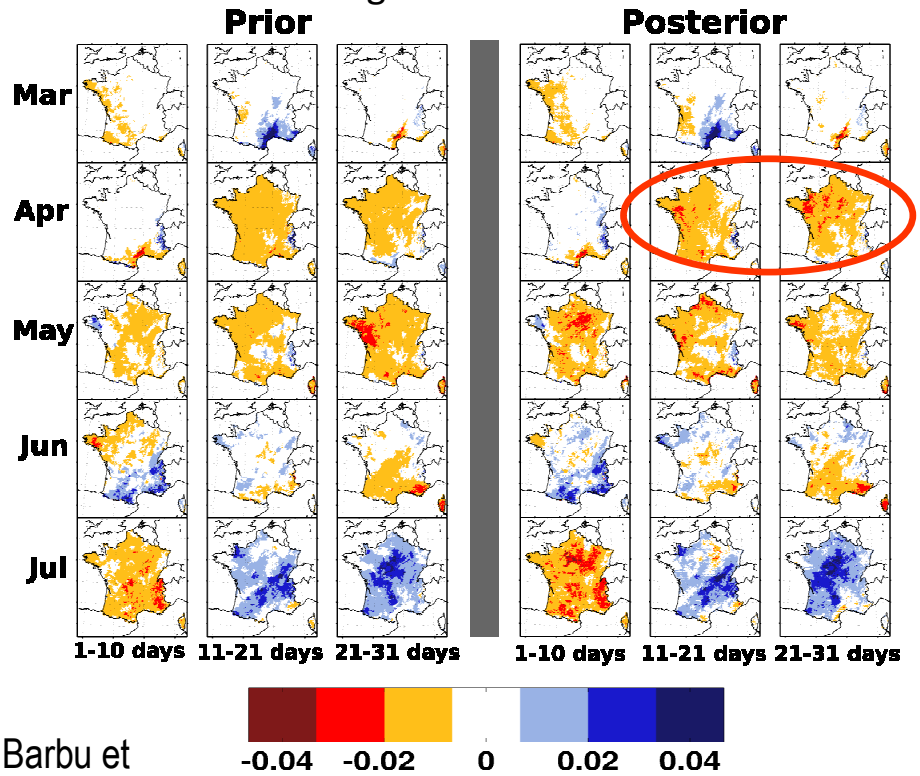
➲Improved simulation of the continental water cycle at basin, country and Mediterranean scales.

New meteorological gridded datasets, used to force LSM simulations, allow a better quantification of the continental water cycle.
Quintana-Seguí et al. 2015.

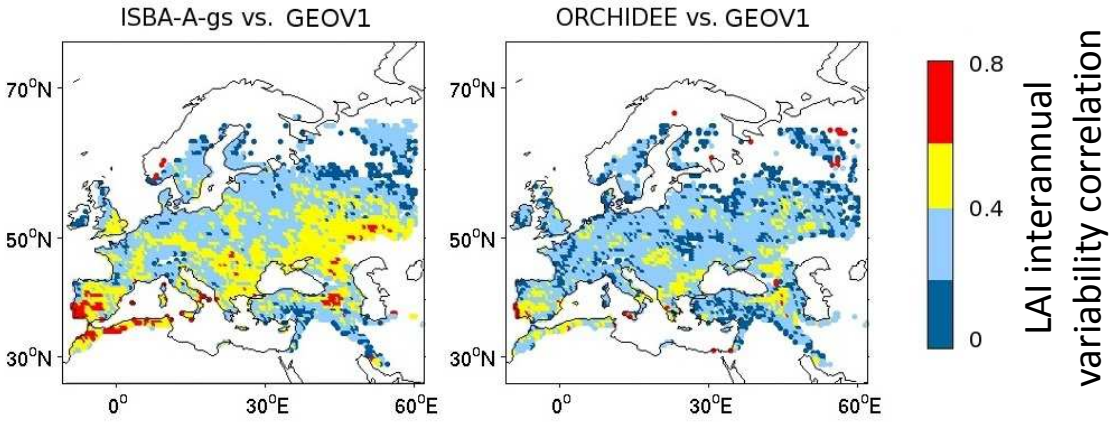
Yearly anomalies of precipitation




Enhanced drought onset due to LAI assimilation.




Barbu et al. (2014)




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.

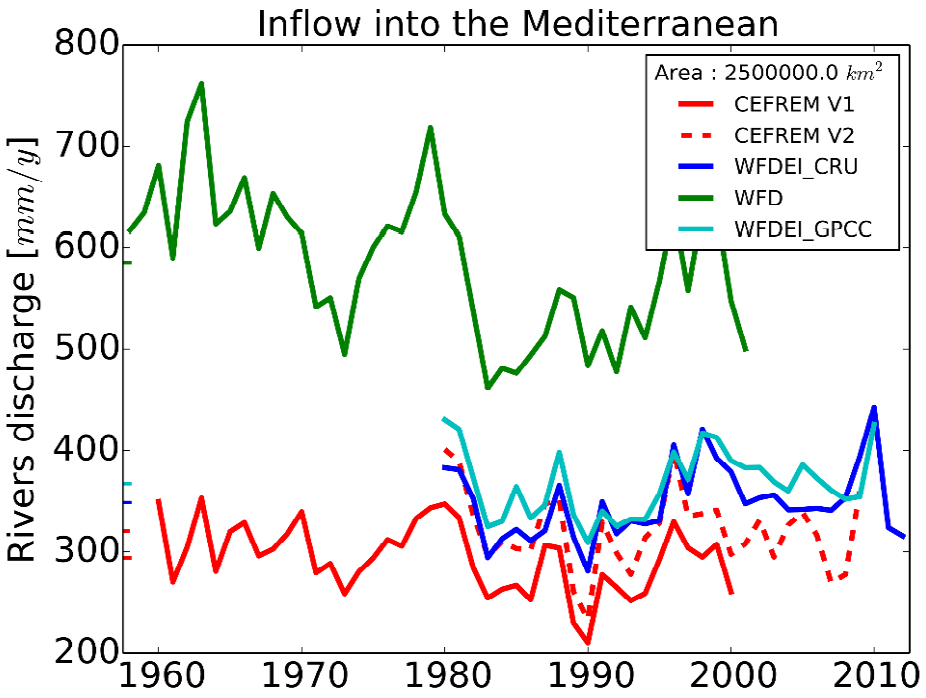
Szczypta et al. (2014)

# Results

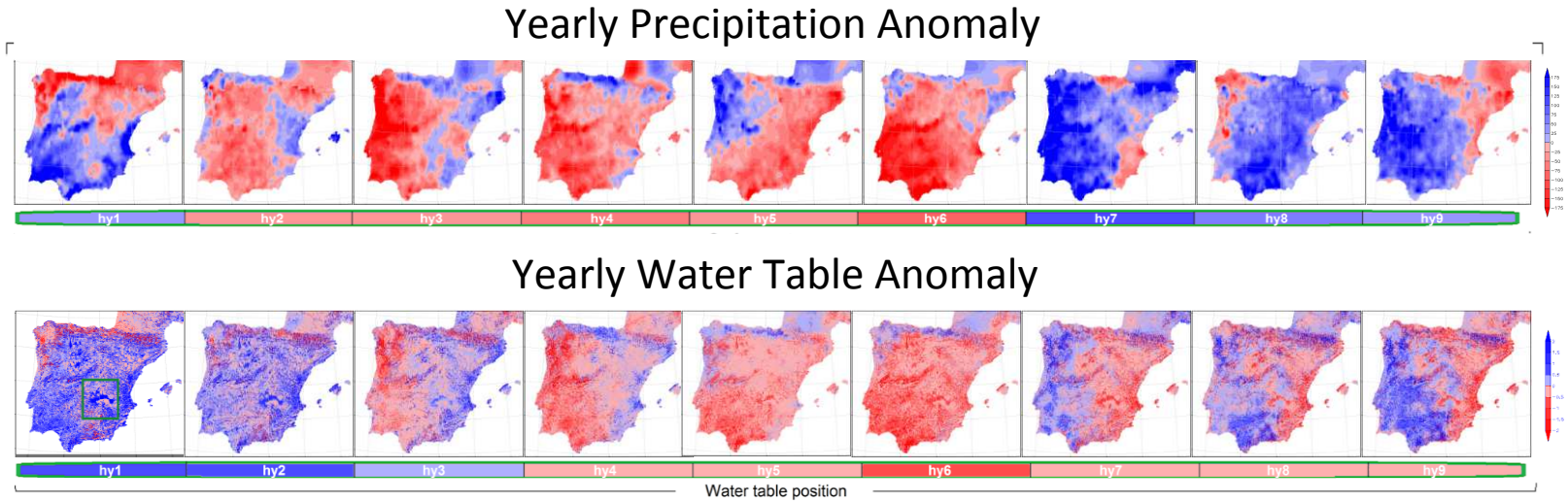
➲ Quantification of freshwater inputs to the Mediterranean.

➲Better understanding of underground water processes.

The quantification of the freshwater inputs to the Mediterranean with a LSM (ORCHIDEE) is allowing us to investigate sources of error in forcing datasets and model processes and physiography at large scale. J. Polcher et al. 2015.




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



# Results

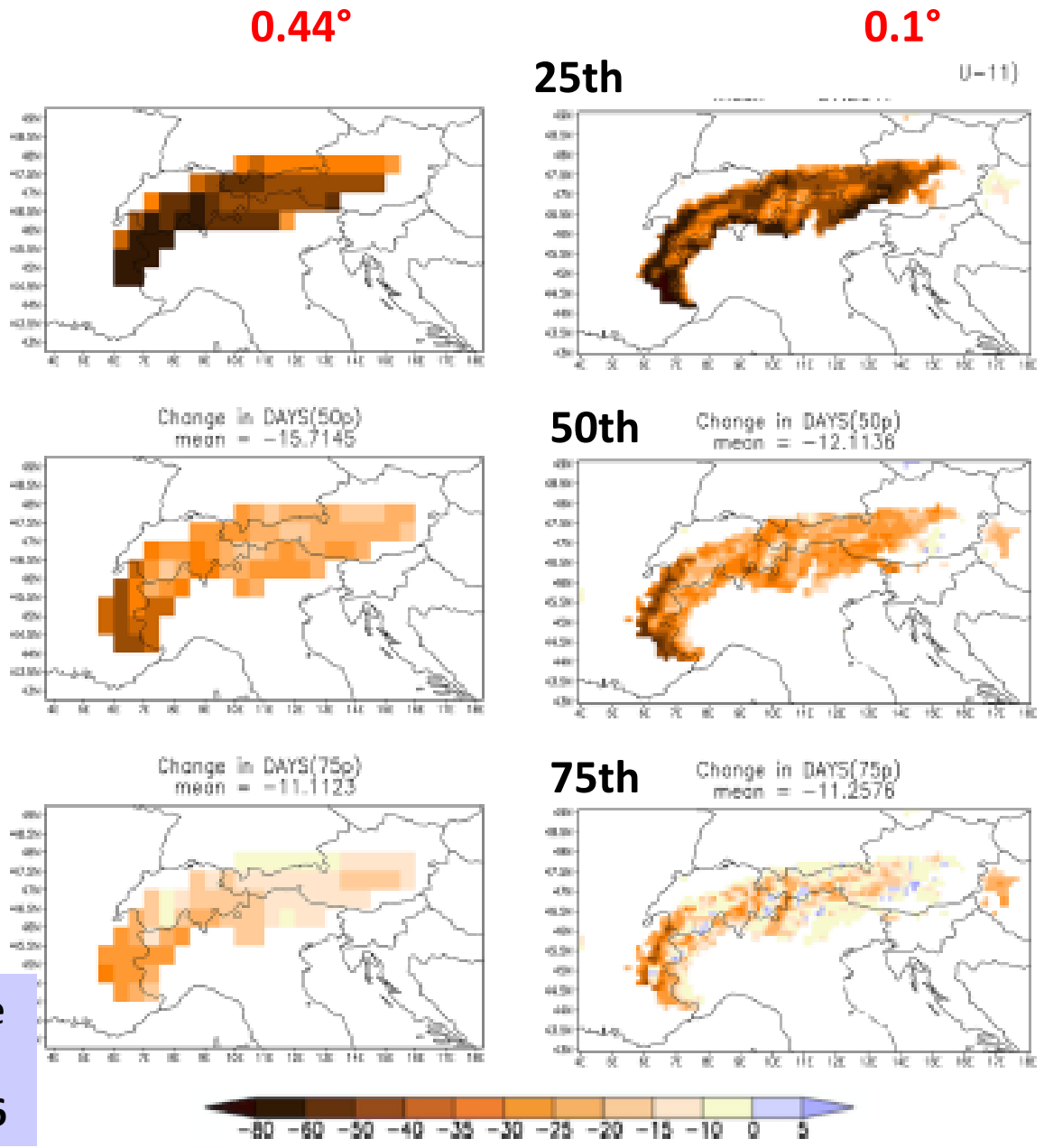
➲ Impacts of climate change.

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 sping snow melt**

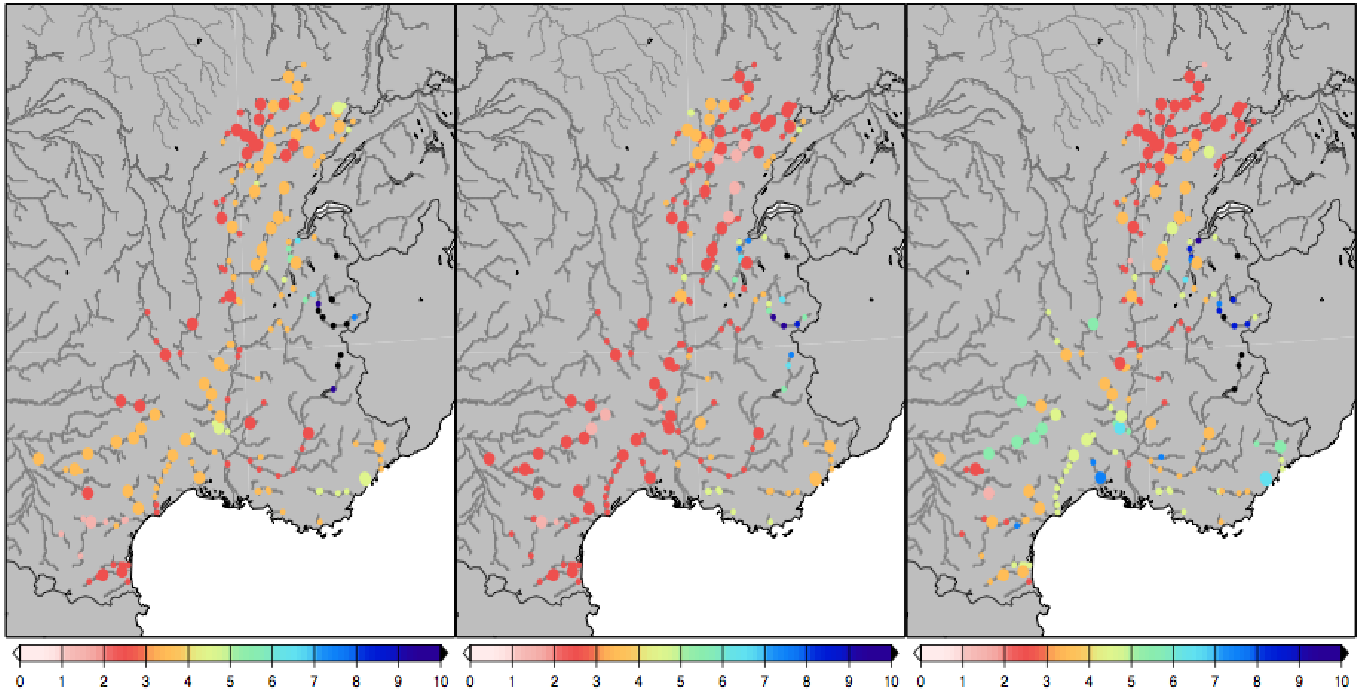
Strong impact of the resolution on the simulation of snow melt driven runoff
**Coppola et al, Climate Dynamics, 2016**



# Results

➲ 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 specifities 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.

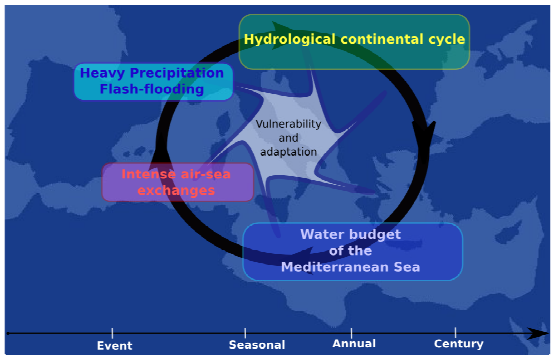
# Mid-term program achievements

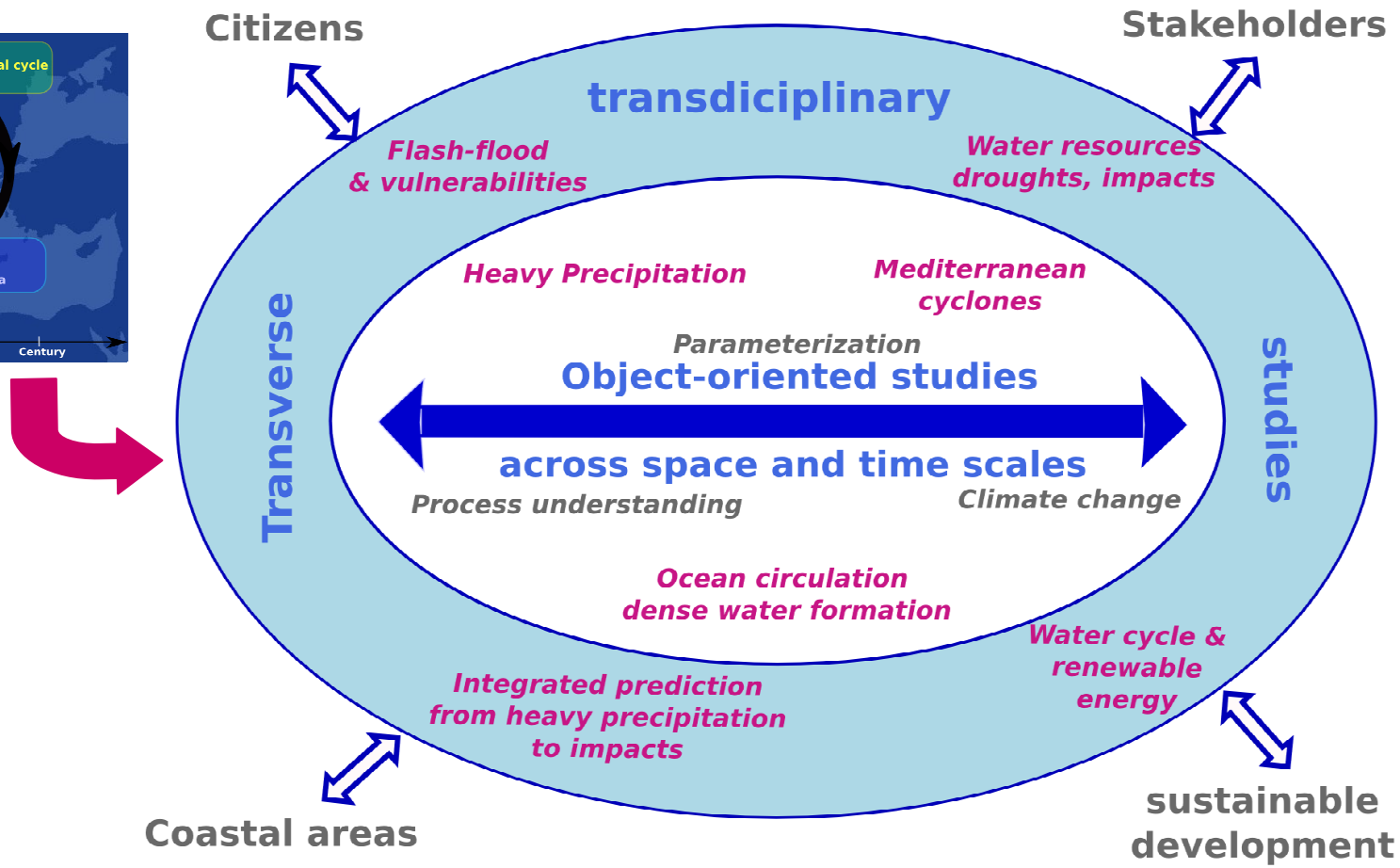
- **Unexpected achievements**.
  - Progress in the quantification of the effects of underground water.
  - Better understanding of the links between droughts and forest fires.
  - Progress in seasonal forecasting of heat waves, droughts and dam levels.
- **Missing achievements.**
  - Better description 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

**International Science Plan (2010-2020)**



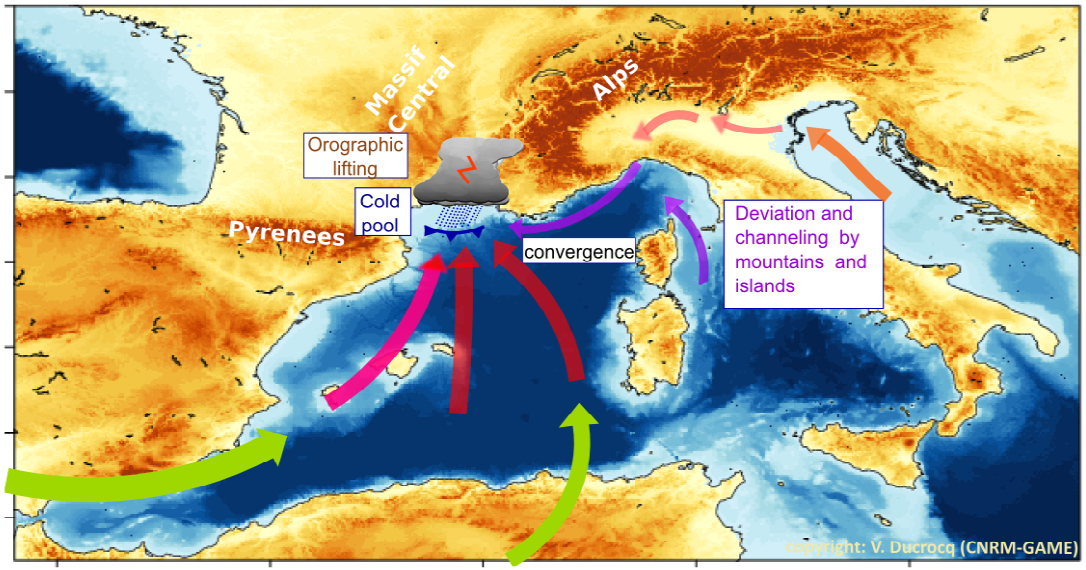




More scale continuum in object oriented studies

More integrated transdisciplinary studies

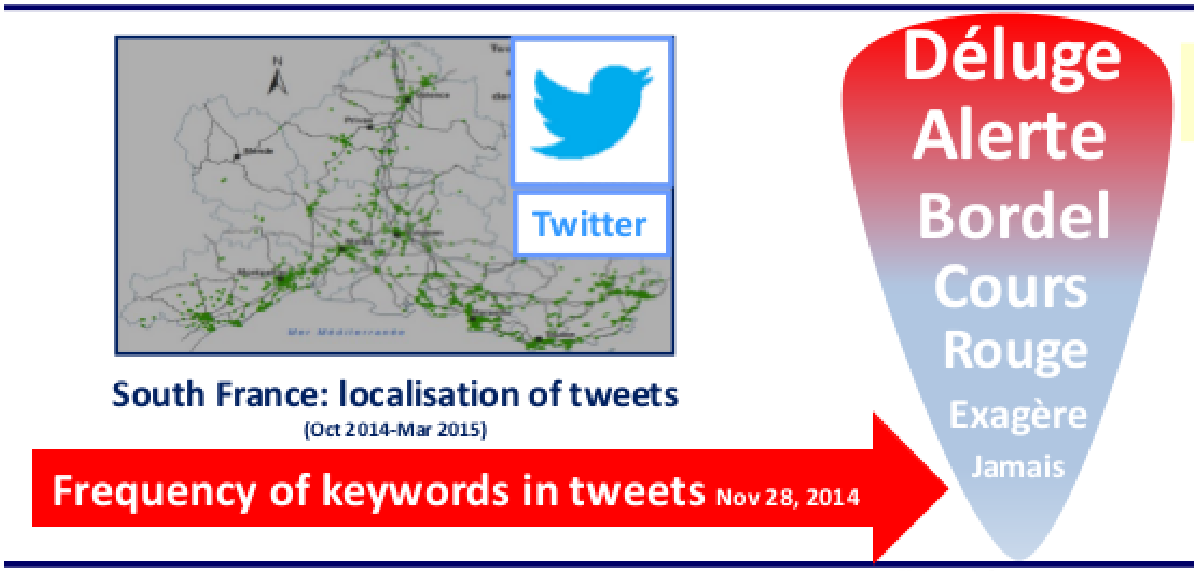
# Heavy Precipitation

- 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*

HyMeX

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)

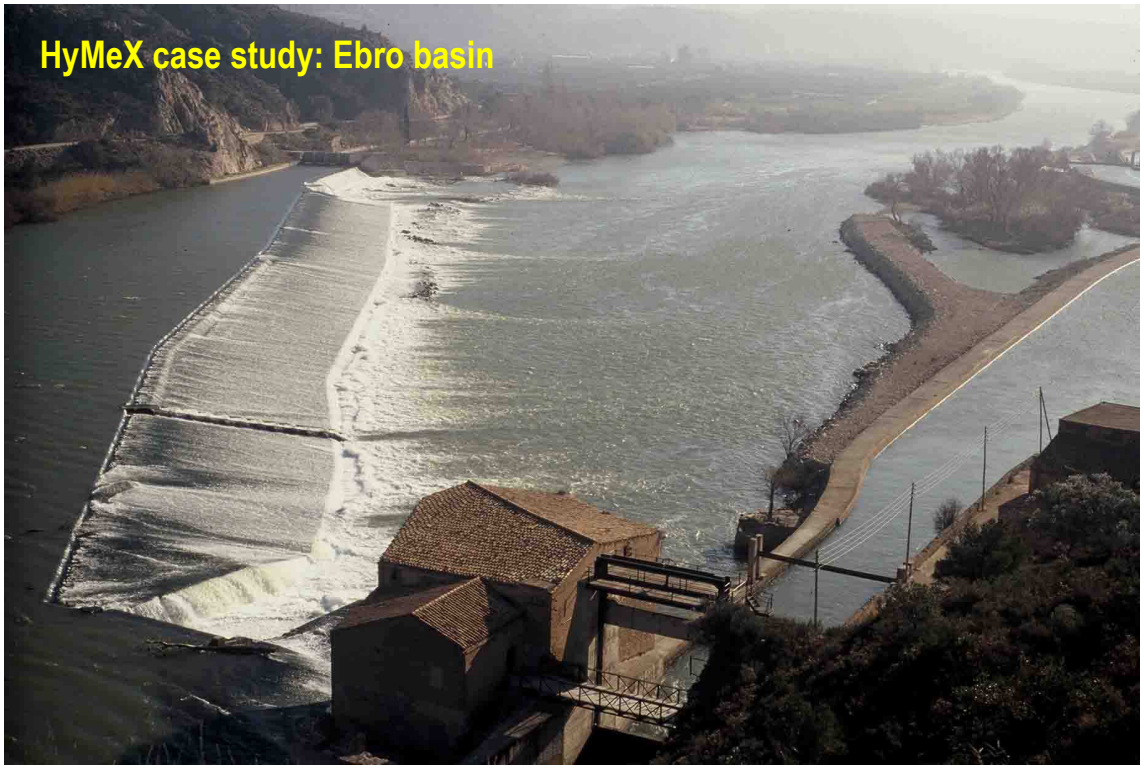
Coupled atmosphere-ocean-hydrology models: continuum way from heavy precipitation, to the watershed and sea, coupled data assimilation

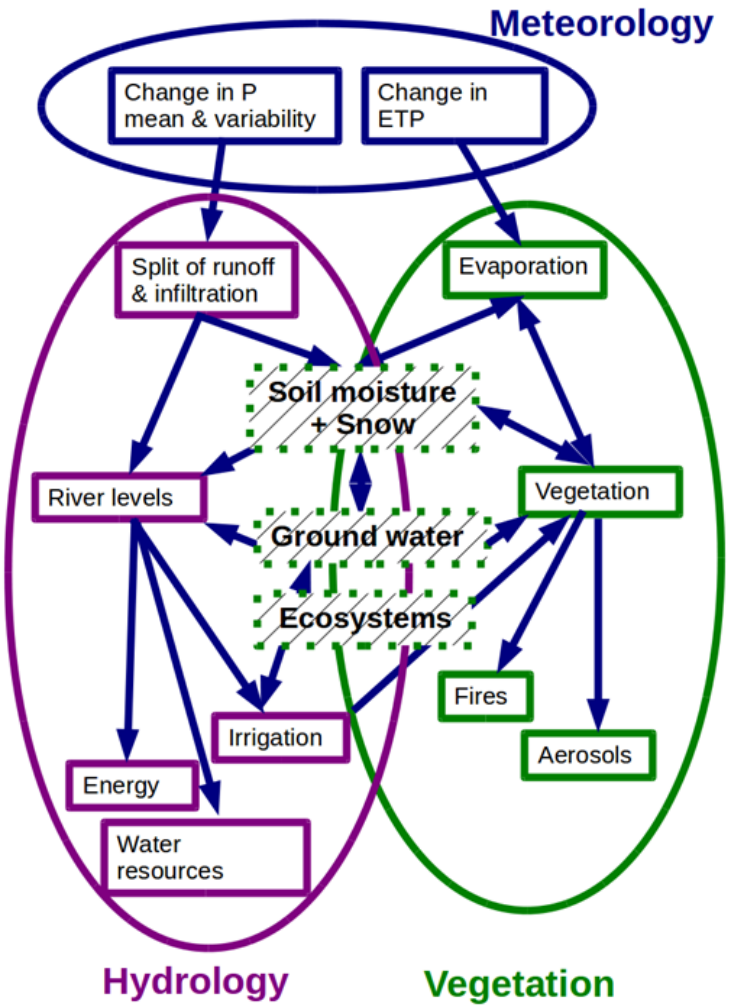
Ensemble Prediction Systems: seamless probabilistic prediction from observations, to nowcasting and short-range forecast

⇨Applied research driven by needs of meteorologiacal 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?)

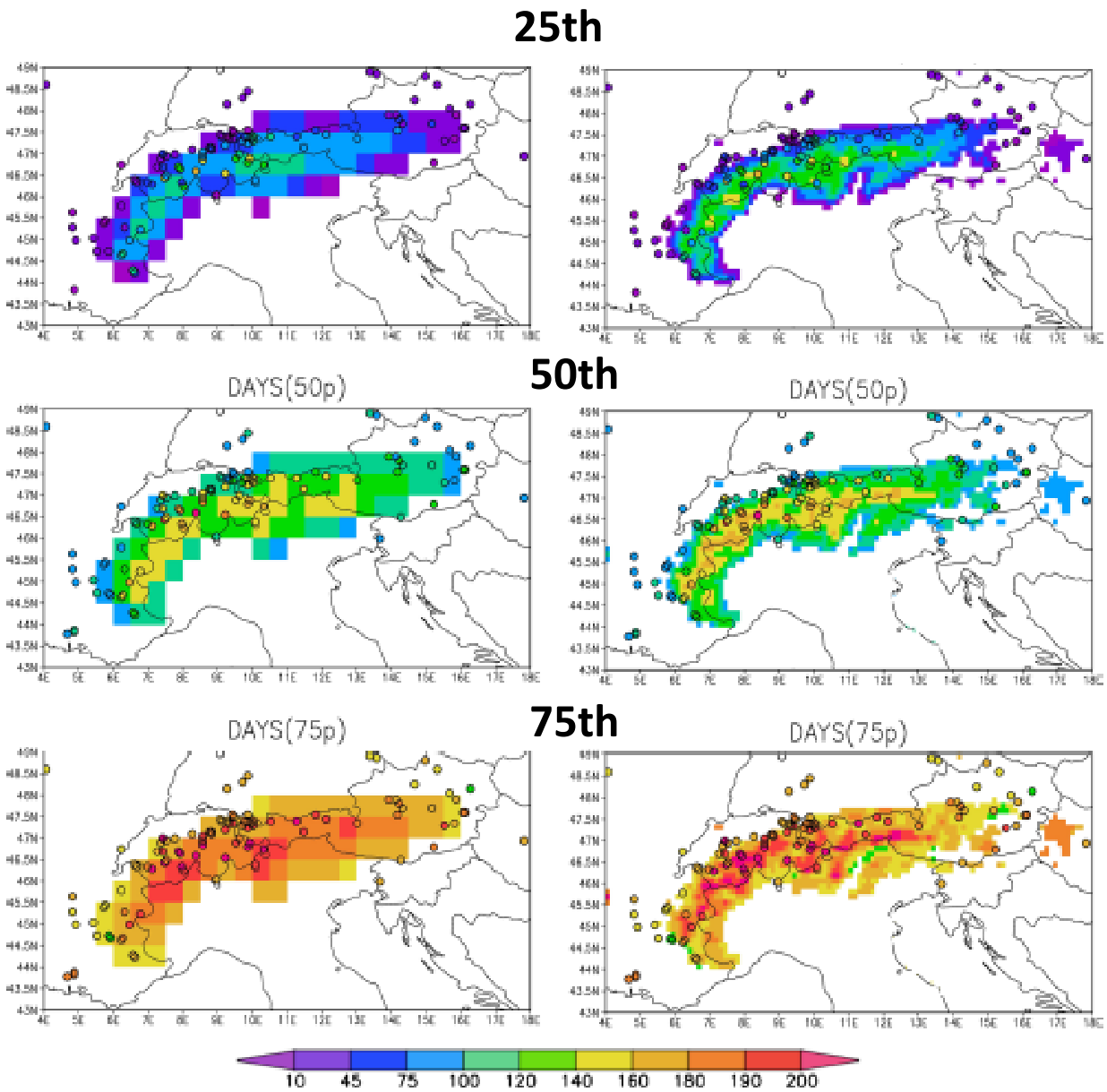
# Thanks for your attention!

# Results

## 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**



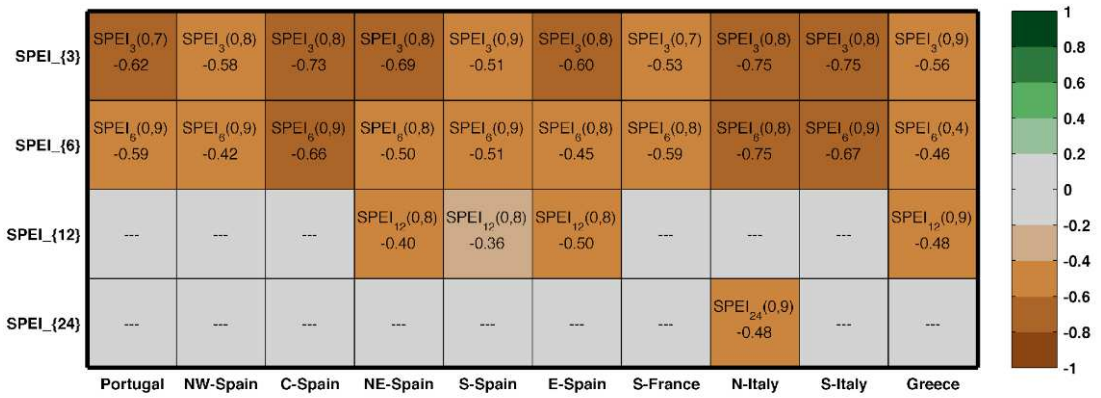

**Julian Day of the 25th, 50th, 75th percentiles of the total runoff for the model ensemble average, observations superimposed 1970-2000**

**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.




Turco et a. 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.

SPI drought index compared to the press database (Catalonia, Spain)