HyMex organisation

- WG1: The water budget of the Mediterranean Sea
- WG2: The continental hydrological cycle and related water resources
- WG3: Heavy rainfalls, flash-floods and floods
- WG4: Intense sea-atmosphere interactions
- WG5: Societal and economic impacts

Each working group has its scientific objectives. It organises science teams to coordinate and focus the collaborations.

HyMeX

MISTRALS

5-y Science Review

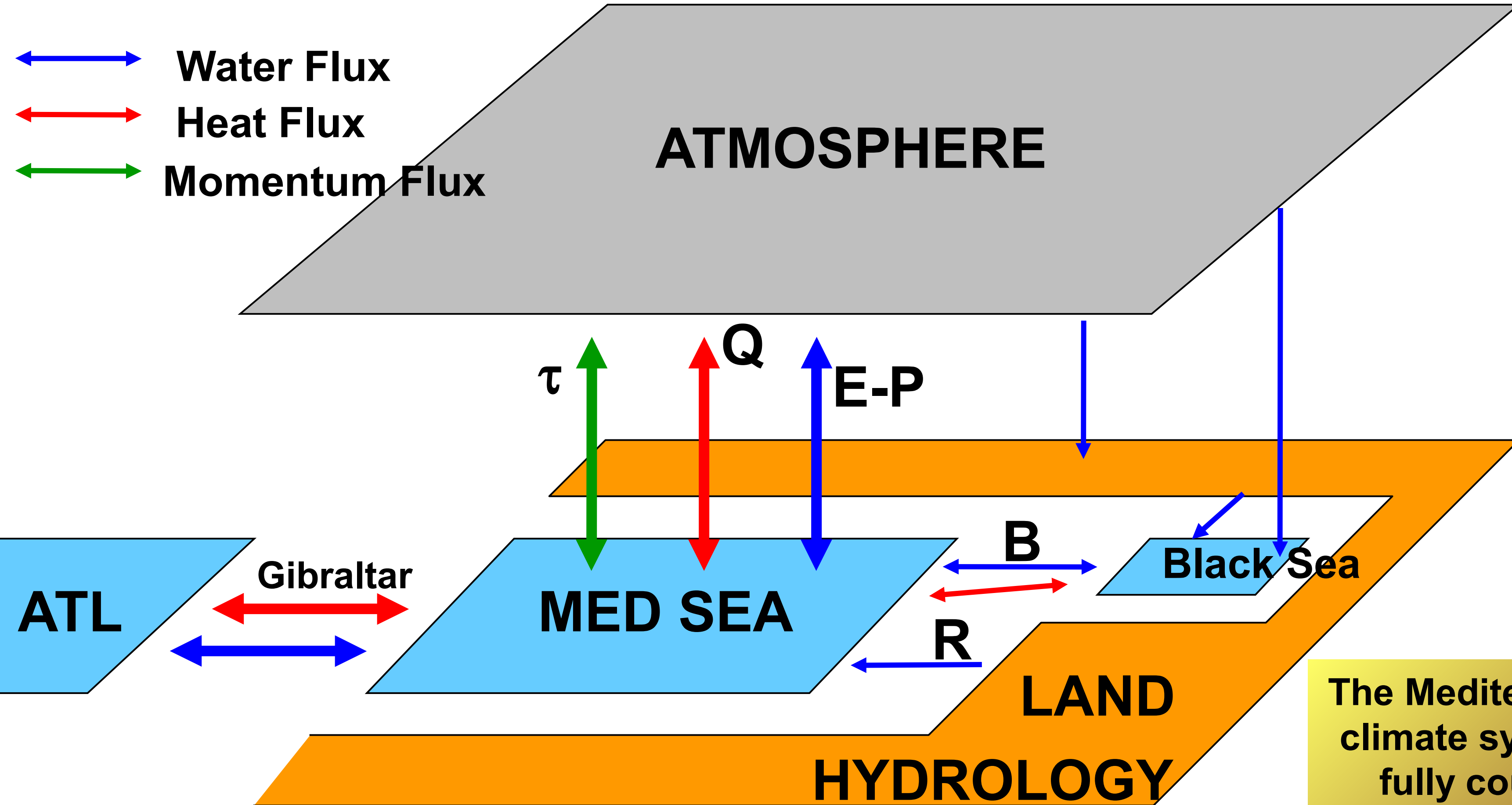
Mediterranean Sea Water Budget (MSWB)

Samuel SOMOT

Météo-France/CNRM-GAME, Toulouse, France

MISTRALS International Conference, 20-22 October 2015, Marseille, France

Concept : Mediterranean Sea Water Budget (MSWB)



The Mediterranean climate system is fully coupled

Somot, HyMeX white paper

The sea level and water masses are integrators of the MSWB

The Mediterranean Sea Water, Heat and Mass Budgets are strongly interrelated : MSWB, MSHB, MSMB

Scientific Objectives

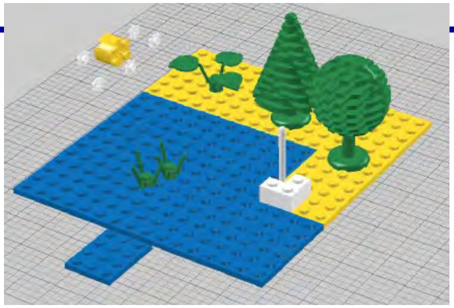
➲ **Question 1 : What are the long-term mean values of the Mediterranean Sea Water Budget (MSWB) terms and associated uncertainties ?**

➲ **Question 2 : What is the variability of the MSWB at seasonal, interannual and decadal time scale ? Understanding the main driving factors ?**

➲ **Question 3 : How do spatially and/or temporally localised intense events affect the MSWB ?**

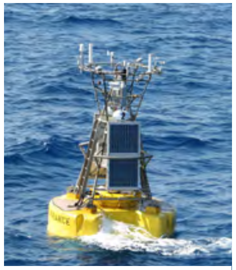
➲ **Question 4 : How will the MSWB evolve under future-climate conditions along the 21st century ?**

Strategy



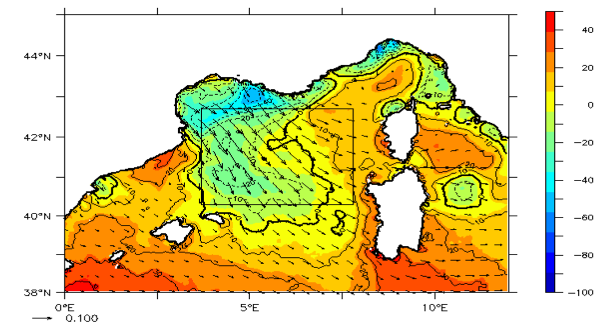
➲ Multi-scale/multi-component approach :

- Atmosphere, Ocean, Land-surface, River (Black Sea)
- From local observations to basin-scale analyses
- Direct and indirect estimates of the MSWB terms



➲ Reference super-sites:

- Establish reference datasets at well-observed localised tiping points
- Very-high resolution process models

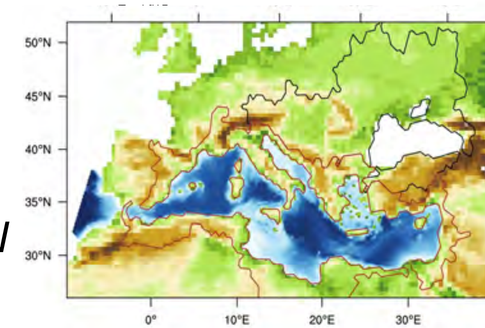


➲ North-Western Mediterranean focus area :

- Using HyMeX-LOP, MOOSE, HyMeX & MerMex SOP
- Ocean-based indirect estimates

➲ Mediterranean Sea basin-scale :

- Recent satellite-based products and in-situ-based reanalyses
- Developpment of dedicated fully-coupled Regional Climate System Models (Med-CORDEX initiative)

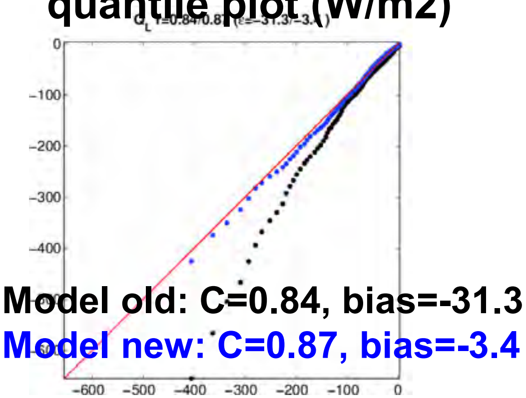


Funding: MISTRALS/HyMeX, ANR-REMEMBER, MOOSE, FP7 CLIM-RUN ENVI-MED MED-MaHb, Grant AXA, Spanish projects, PhD, Masters

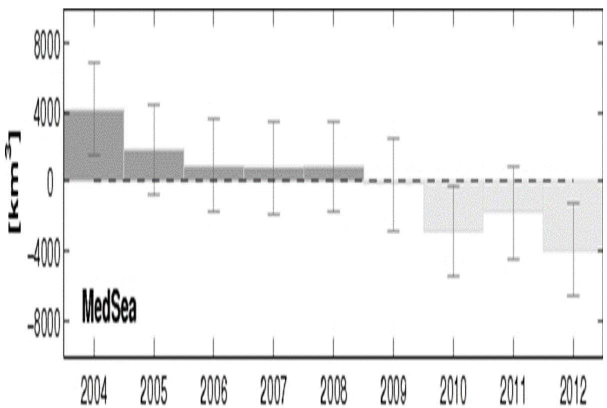
Results-Q1: Long-term mean values and uncertainty of the MSWB ?

- Multi-annual reference time series at the Gibraltar Strait for the outflow waters
- Multi-annual reference time series at the LION and AZUR buoys/moorings
- Multi-annual reference time series for heat and salt contents of the Mediterranean Sea (ENVI-MED MED-MaHb ARGO, gridded reconstructions)
- Reference dataset for the 3D heat, salt and mass contents of the NW Mediterranean Sea for year 2012-2013 (MOOSE, HyMeX and MerMex SOPs)
- Indirect estimate of the NW Mediterranean air-sea fluxes for year 2012-2013
- *Despite tries, no reliable quantification of the precipitation over sea (ESA project)*

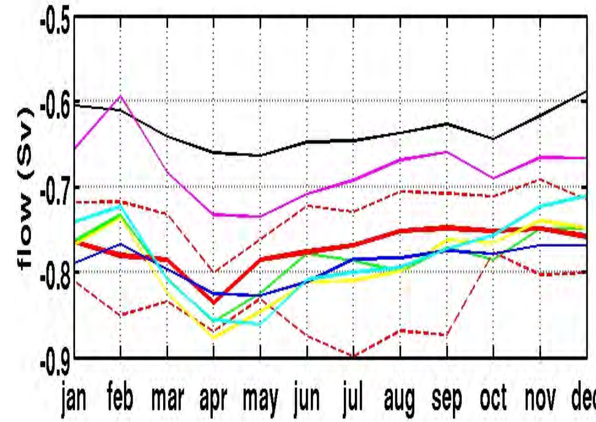
Latent heat loss daily quantile plot (W/m2)



Ocean freshwater content (km³, 0-700m)



Seasonal cycle of the Gibraltar outflow (Sv)

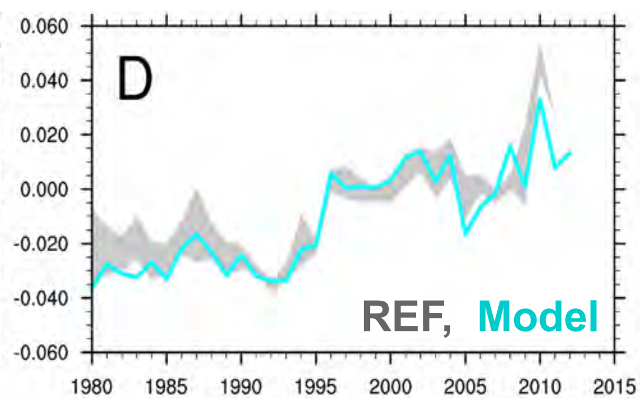


References: Soto-Navarro et al. 2014, Herrmann et al. 2011, Durrieu-de-Madron et al. 2013, Caniaux et al. in prep, Houpert et al. 2014, Von Schuckmann et al. in prep, Llasses et al. in prep., Houpert et al. in prep., Waldman et al. in prep.

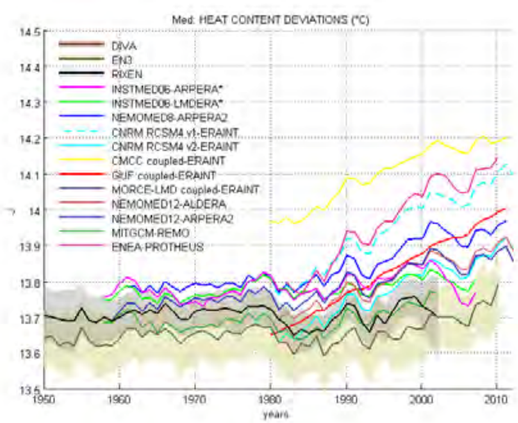
Results-Q2: Climate variability of the MSWB ? Driving factors ?

- Multi-annual reconstruction of the variability of the sea level of the Mediterranean Sea
- Multi-annual estimates of the variability of the various terms of MSHB
- Multi-annual estimates of the variability of E-P over land, E over sea, Rivers
- Regional Climate System Models evaluation and improvements
- Understanding of the role of the SST, air-sea coupling, near-Atlantic conditions, rivers, aerosols and model atmospheric physics to explain the MSWB climate variability

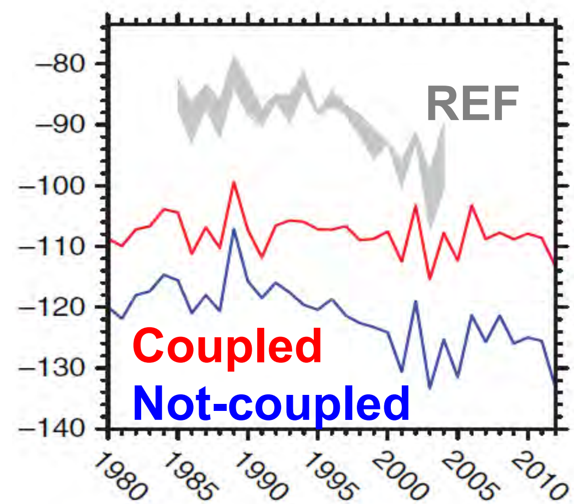
Sea level anomaly (m, hindcast, 1980-2012)



Ocean heat content (°C,1960-2013)



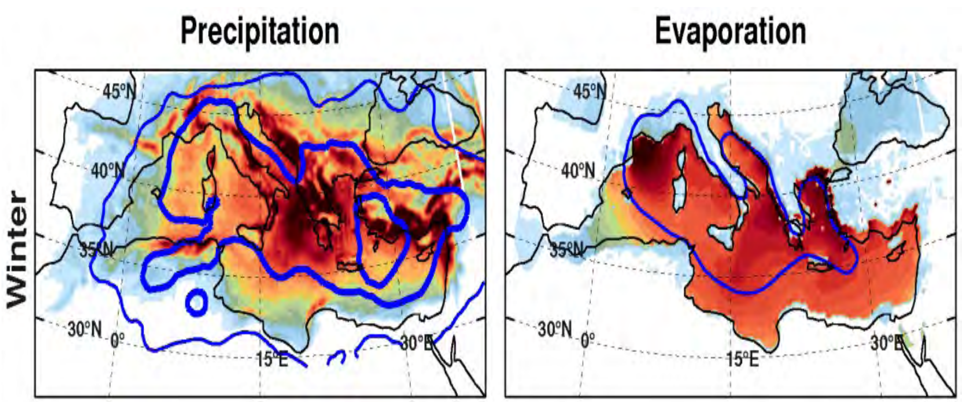
Latent heat flux (W/m², 1980-2012)



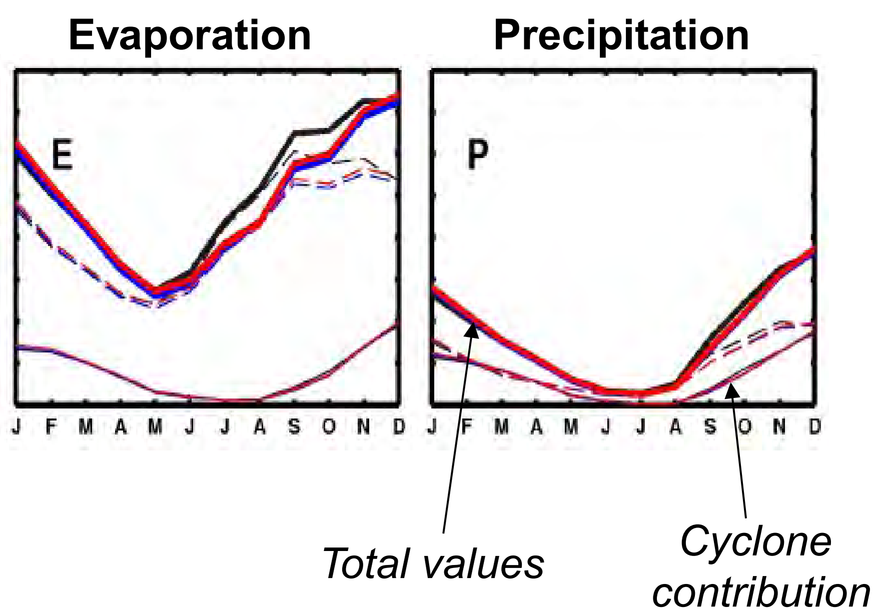
References: Calafat and Jordà 2011, Meyssignac et al. 2011, Adloff et al. in prep., Szczypta et al. 2012, Sanchez-Gomez et al 2011, Ludwig et al. 2009 revisited, Llasses et al. in prep, Harzallah et al. in prep., Sevault et al. 2014, Nabat et al. 2014, 2015, Lebeaupin-Brossier et al. 2015

Results-Q3 : How do spatially and/or temporally localised intense events affect the MSWB ?

- Seasonal and daily weather regimes strongly influence the MSWB and MSHB terms
- Mediterranean cyclones influence the evaporation and precipitation over the sea
- Rare and intense events (5% of the days) represent 15-17 % of the annual Evaporation budget and 22-30% of the annual Precipitation budget over the sea
- Deep water formation drives the deep sea heat and salt variability
- *Question not fully tackled yet in HyMeX but tools are ready*



% of cyclone contribution (>25% thin blue, >50% thick blue)



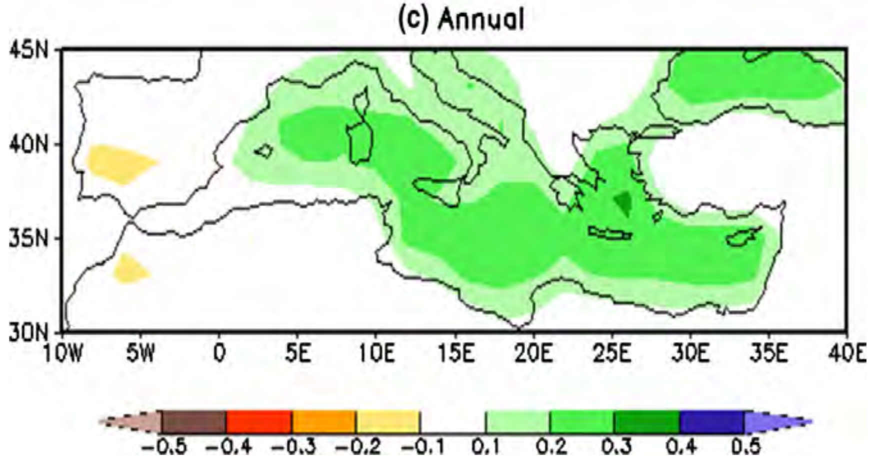
References: Josey et al. 2011, Papadopoulos et al 2012, Durrieu de Madron et al. 2013, Somot et al., in prep, Flaounas et al. 2015, Lebeaupin-Brossier et al. 2015, Llasses et al. in prep. , Caniaux et al. in prep

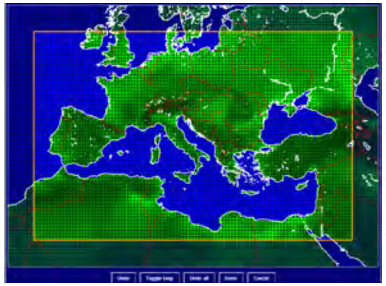
Results-Q4 : Future evolution of the MSWB along the 21st century ?

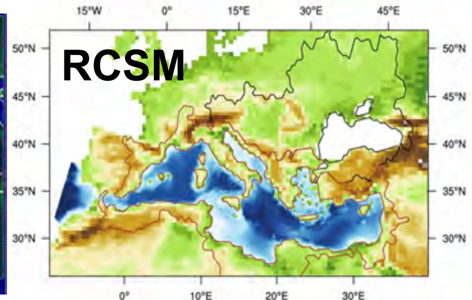
- Using pre-HyMeX simulations (ENSEMBLES, CIRCE, CMIP5), the long-term future drying is confirmed : increase in potential evapotranspiration over land and in evaporation over sea, decrease in precipitation and in river runoff discharges.
- Time of Emergence of the signal should be around 2040s, large uncertainties remain
- A large international coordinated initiative of fully-coupled Regional Climate System Model intercomparison (HyMeX/Med-CORDEX). 12 differents RCSMs, 9 hindcast runs and 6 RCP scenario runs. *Scenario simulation analysis is on-going.*

Projections of evaporation change

(mm/d, RCP4.5, CMIP5, 2071-2098 vs 1980-2005)







MedCORDEX – TIER1 simulations RCSM (same atm as corresponding ARCM)				ERAI	HIST	RCP8.5	RCP4.5	RCP2.6
	institute	model	comp.	1979-now	1950-2005	2006-2100	2006-2100	2006-2100
RUN	ENEA	PROTHEUS	ALRO	1982-2010	1971-2005		2006-2100	
	MPI	REMO/MPI-OM	ALRO					
	CNRM	RCSM4 v1	ALRO	1980-2013	1950-2005	2006-2100	2006-2100	2006-2100
	LMD	LMDZ4NEMOMED8	ALO	1979-2009	1950-2005	2006-2100	2006-2100	
	Univ. Belg.	EBU/POM	ALO	1989-2008				
	IPSL	WRF311NEMO-20km	ALO	1989-2013				
	UCLM/UPM	PROMES/NEMOMED12	ALO					
	INSTM	LMDZ/ROMS-MED	ALO	1979-2009				
	UAH-AWI-ROM	REMO/MITgcm	ALROB					
	GUF	CCLM-NEMO	ALO	1980-2012				
	CMCC / U. of Salento	CCLM4-21-NEMOMFS	ALO	1980-2011	1950-2005	2006-2100	2006-2100	
	ITU	RegCM4/ROMS	ALO					

unknown planned done archived

Source: Mariotti et al. 2008, Sanchez-Gomez et al. 2009, Dubois et al. 2012, Planton et al. 2012, Mariotti et al. 2015, Ruti et al. 2015

HyMeX Achievements and needs for 2016-2020

MISTRALS

➲ 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 developement 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*

5-y Science Review

Continental Water Cycle, Water Resources and Drought

P. Quintana-Seguí

Observatori de l'Ebre (URL-CSIC), Roquetes, Spain.

Objectives

HyMeX Science Questions related to the continental water cycle:

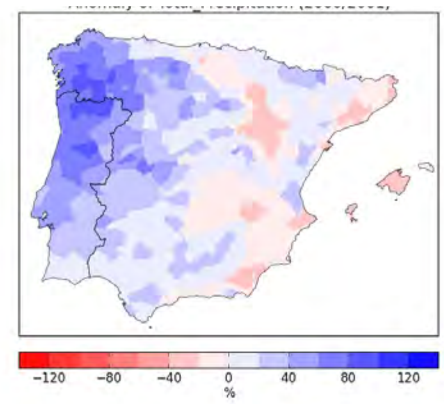
- ➲ 1: How to **quantify the water cycle components over the Mediterranean basin** through an improved hydro-meteorological framework.
- ➲ 2: Can we better understand and simulate the specificities **of the hydrological processes in the Mediterranean**?
- ➲ 3: **How will the continental hydrological cycle evolve in relation to global change?**

Results

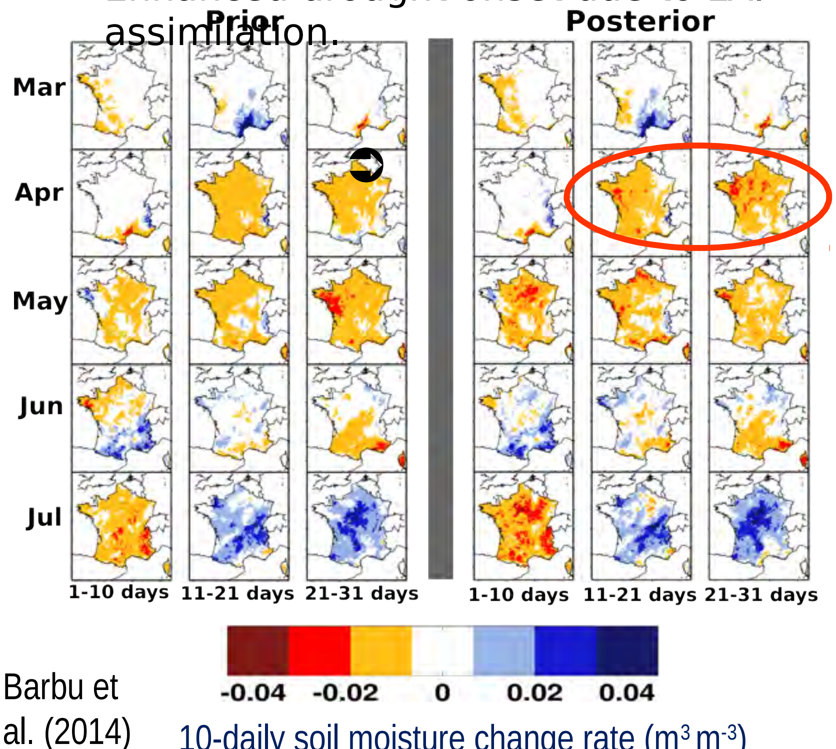
- Improved simulation of the continental water cycle at basin, country and Mediterranean scales.

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

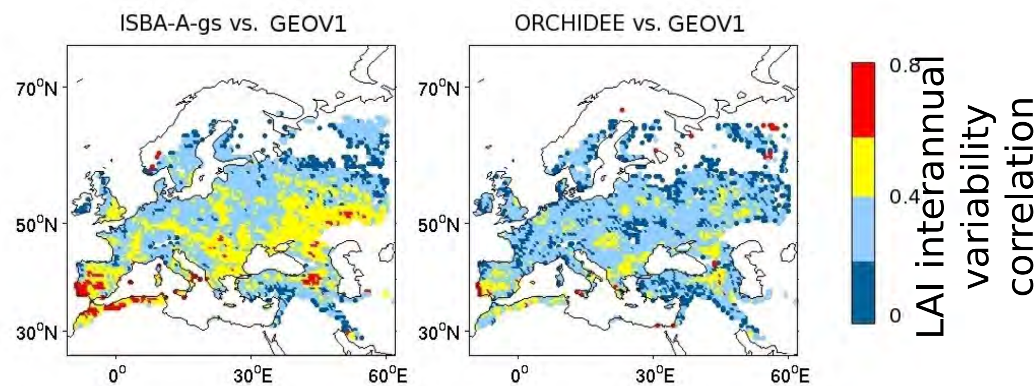
Yearly anomalies of precipitation



Enhanced drought onset due to LAI assimilation.



Barbu et al. (2014)



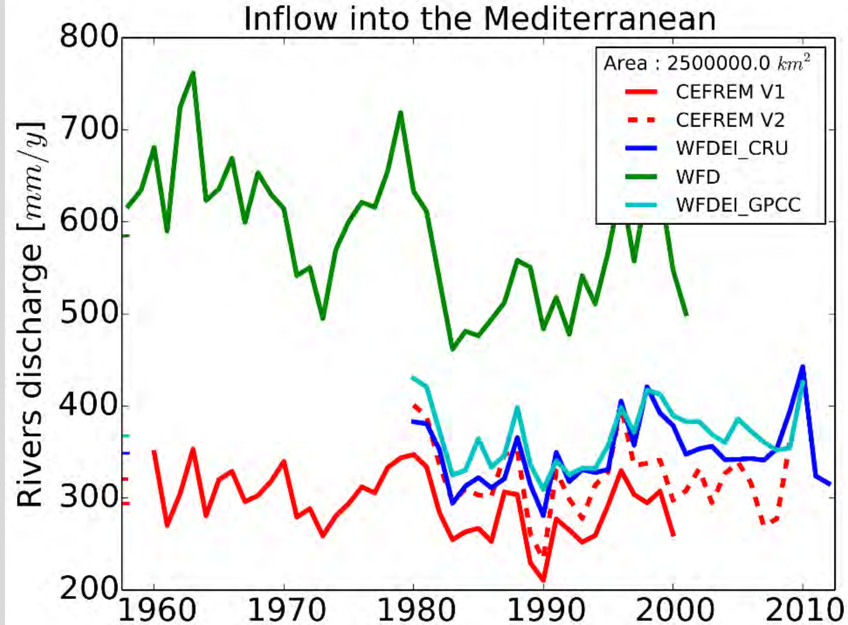
The use of LSMs with active vegetation and remote sensing data is improving our knowledge on the role of Mediterranean vegetation on the water cycle.

Szczypta et al. (2014)

Results

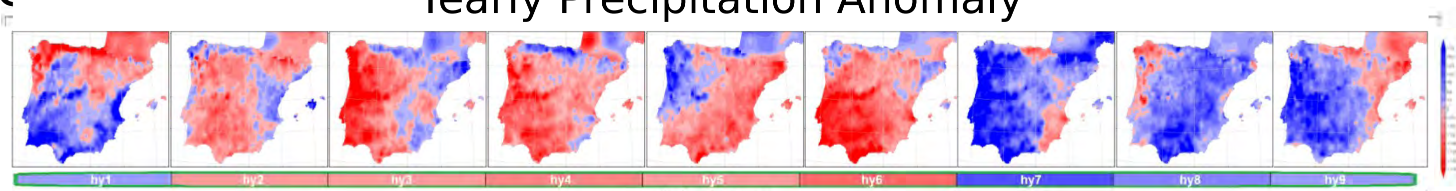
- Quantification of freshwater inputs to the Mediterranean.
- Better understanding of underground water processe

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.

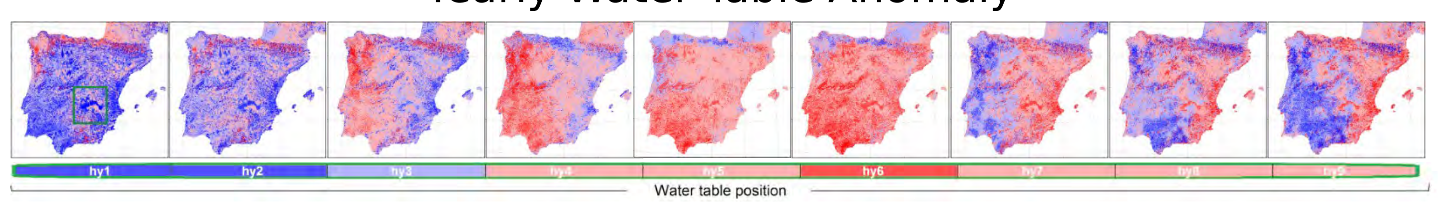


Underground water is coupled with the land surface and it introduces memory into the system. Míguez-Macho et al. 2014.

Yearly Precipitation Anomaly



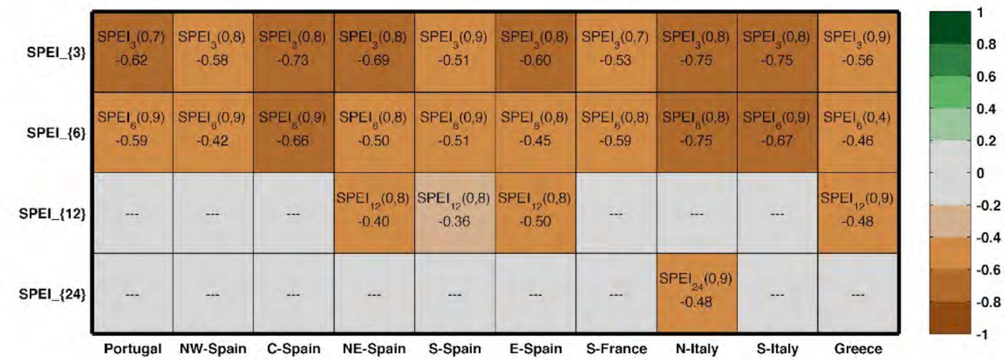
Yearly Water Table Anomaly



Results

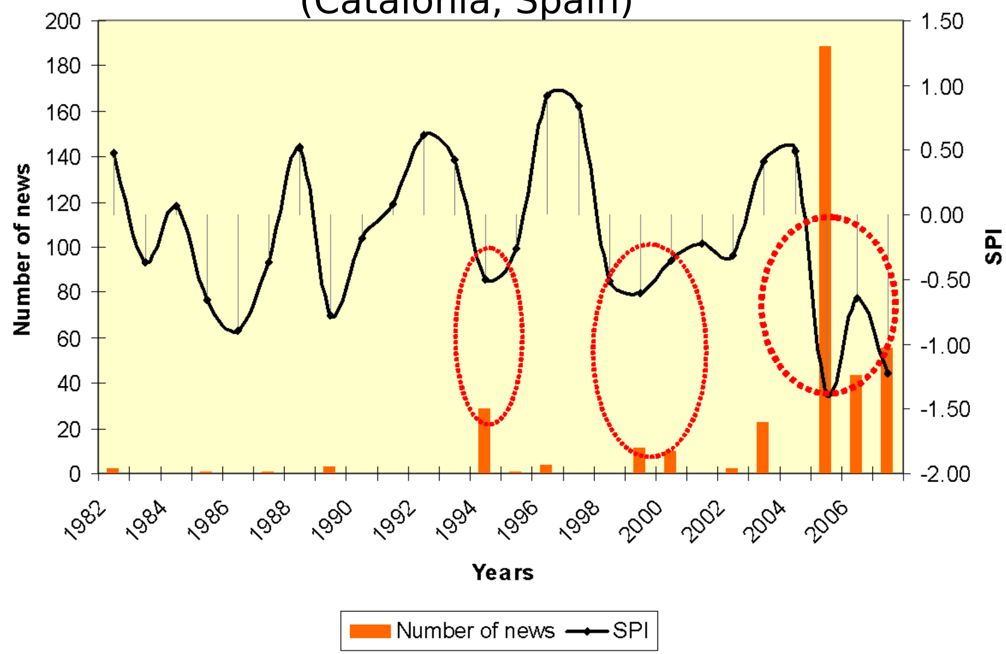
- Links of the continental water cycle with forest fires.
- ➲ Societal impacts of continental water cycle extremes.

Forest fires are correlated with drought in the Med.
Turco et al 2015.



Turco et a. 2015

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



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

Achievements

Quantification of the water cycle.

- ➲Land Surface Models allowed us the 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 extremes.

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.

5-y Science Review

Heavy Precipitation

S. Davolio
CNR-ISAC, Bologna, Italy

HEAVY PRECIPITATION

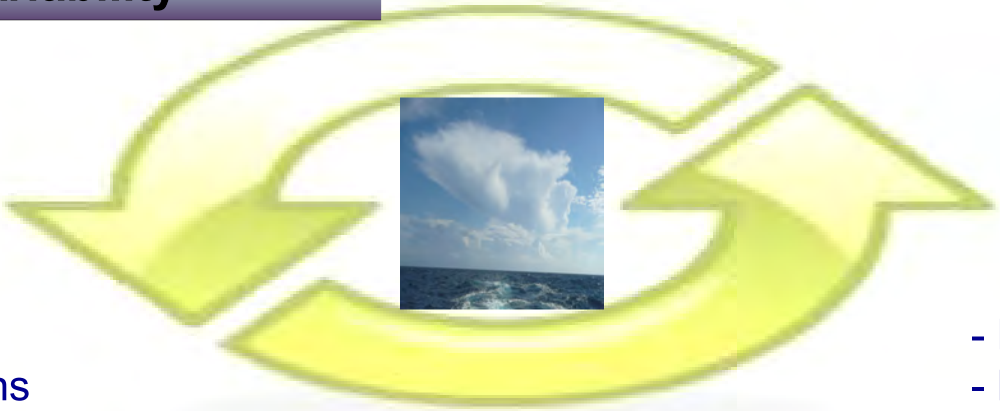
Different approaches and tools, different time scales, synergies to be exploited

Seasonal and Interannual Variability

Process Understanding

OBSERVATIONS

- SOP field campaigns
- LOP/EOP observations



MODELS

- High-res NWP models
- RCM

Models validation and verification

Data assimilation in cloud/precipitation

Improvement of model parameterizations

SEAMLESS

from the scale of the single event (meteorology) to regional climate

Objectives

HYMEX WG3: Heavy Precipitation Events, floods and flash floods

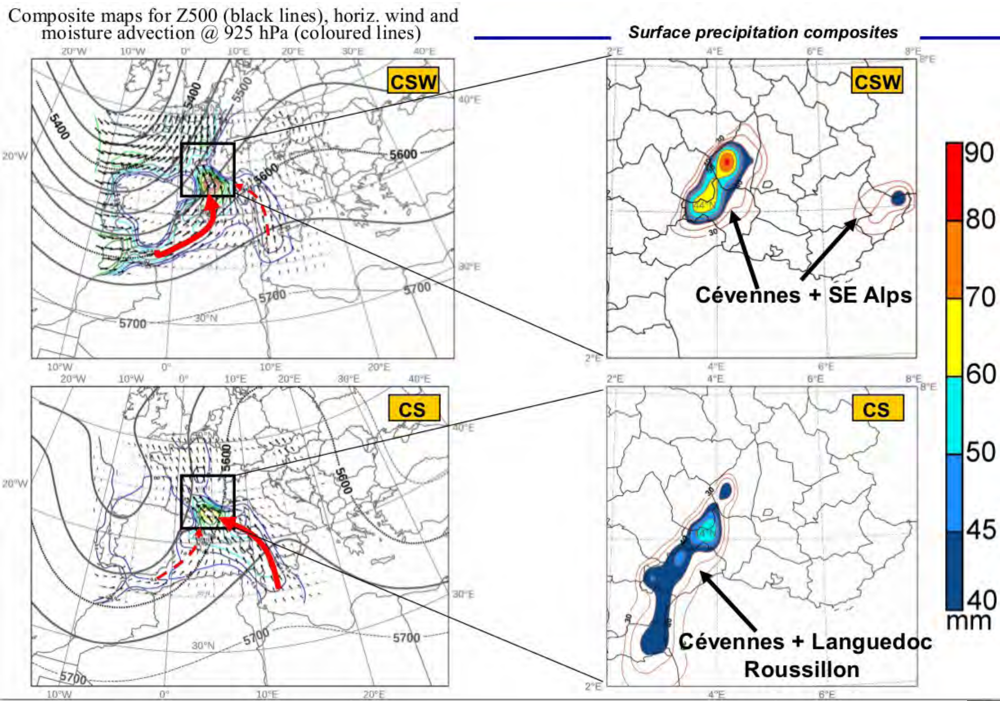
➲ **WG3 - SQ1:**
What are the characteristics of extreme hydro-meteorological events in the Mediterranean?

➲ **WG3 – SQ2:**
How can we improve heavy rainfall process knowledge and prediction?

➲ **WG3 – SQ4:**
How will extreme hydrometeorological events evolve with climate change?

Results

Large-scale/mesoscale mechanisms leading to HPE

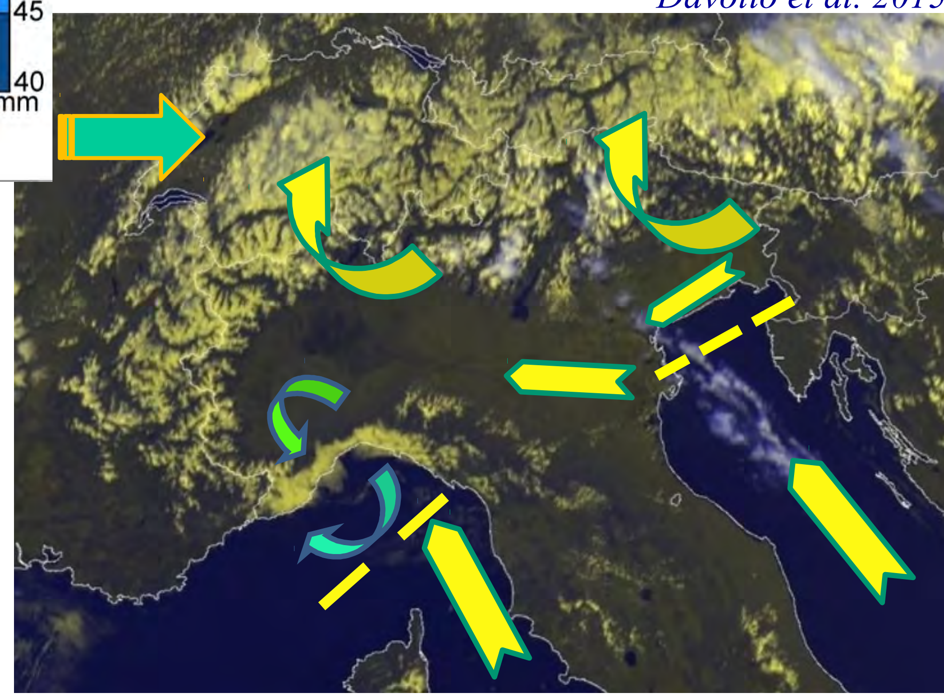


Nuissier et al. 2011

REQUIRED "INGREDIENTS"

- **Upper level trough NW of the area**
- **Low-level jet**
- **Low-level moisture convergence**

Davolio et al. 2015



Role of the **interaction of Tropical Cyclones** with mid-latitude flow over the W-Atlantic: **it does not lead to a systematic intensification of precipitation over the Mediterranean.** Different with results obtained so far for the Pacific.

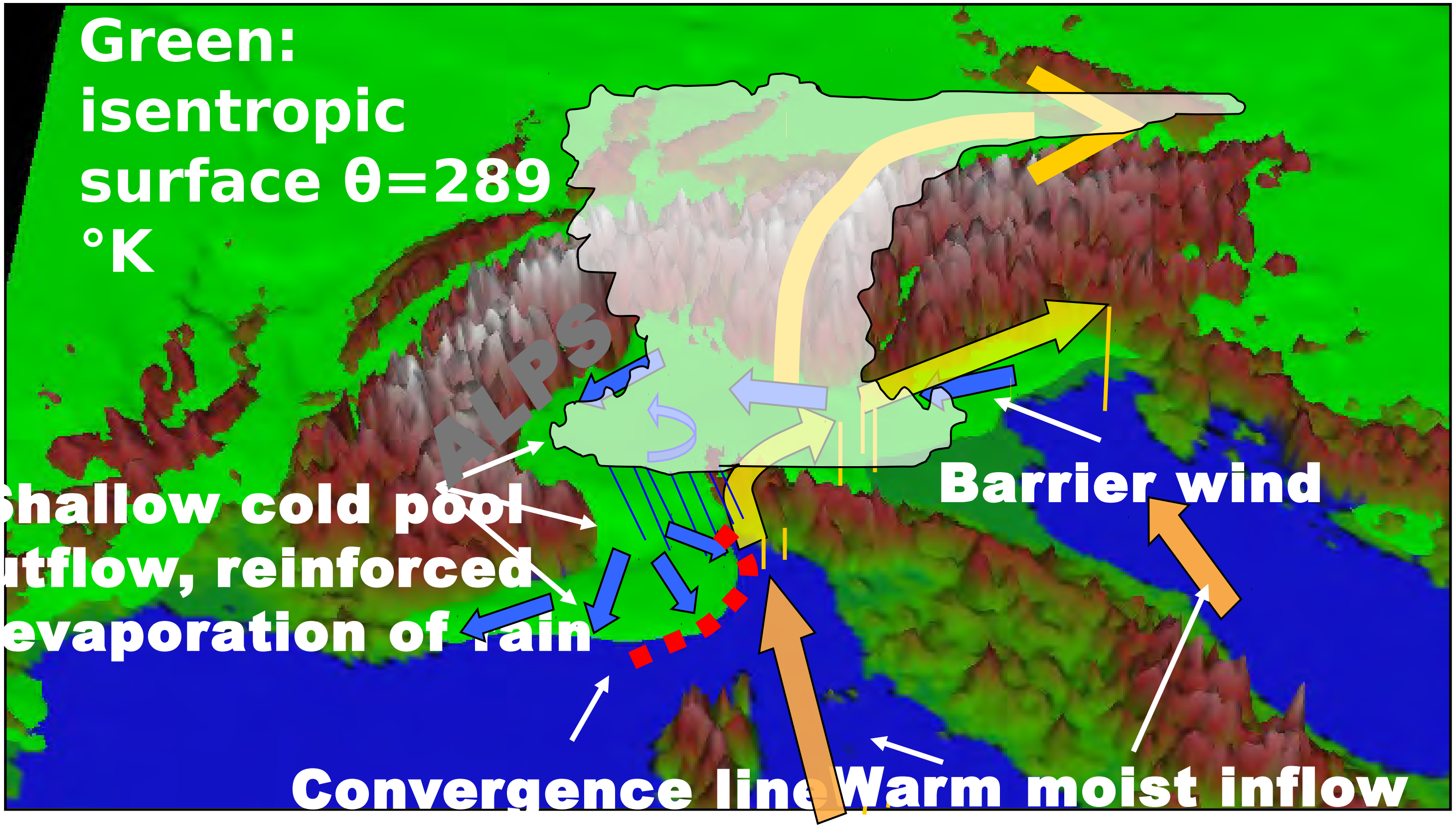
Pantillon et al. 2015

Results

Mechanisms leading to heavy precipitation

SOP1 brings observations of **precipitating systems forming over the sea** wrt other field campaigns on HPE => **significant progress in understanding the formation of convective systems over the sea** (and not "just" enhancement of precipitation by mountains as in MAP) due to the complex Mediterranean terrain-induced low-level circulation over the sea (evaporation, air-sea-wave coupling).

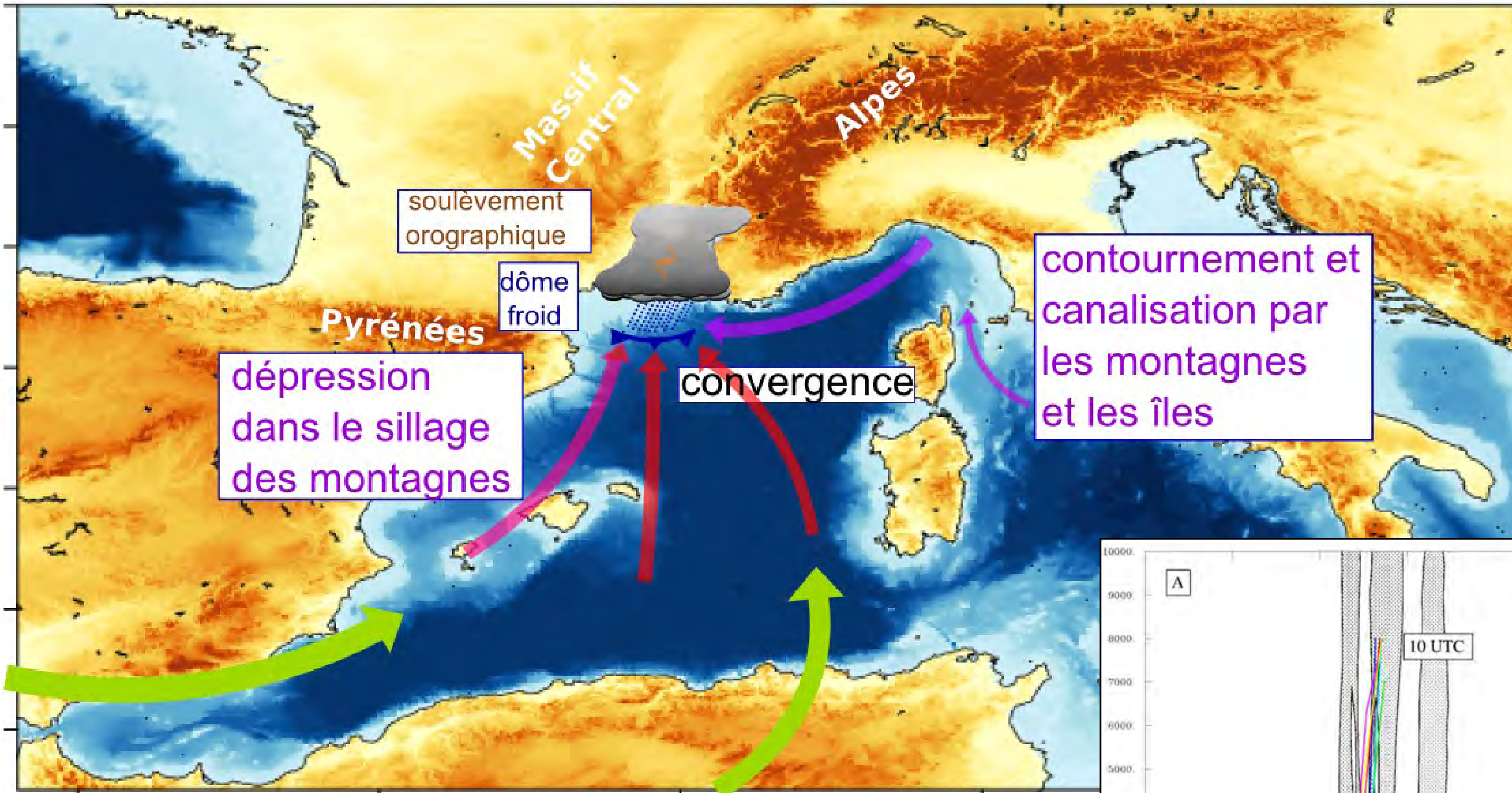
Characterisation of the low-level mesoscale environment.

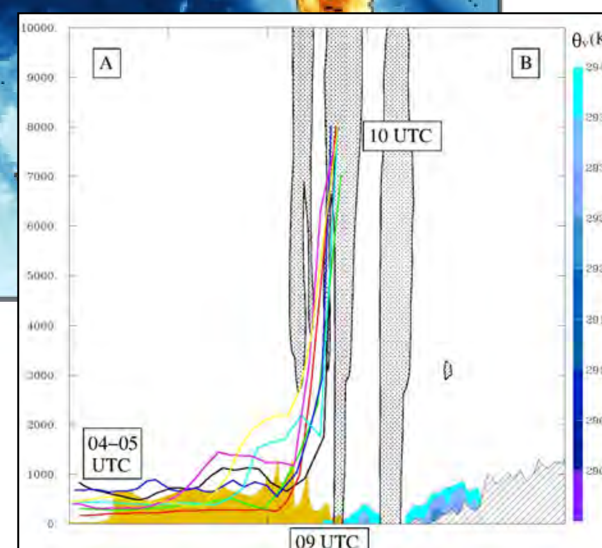


Buzzi et al. 2014; also for IOP16a over Gulf of Lion Duffourg et al. 2015

Results

Mechanisms leading to heavy precipitation





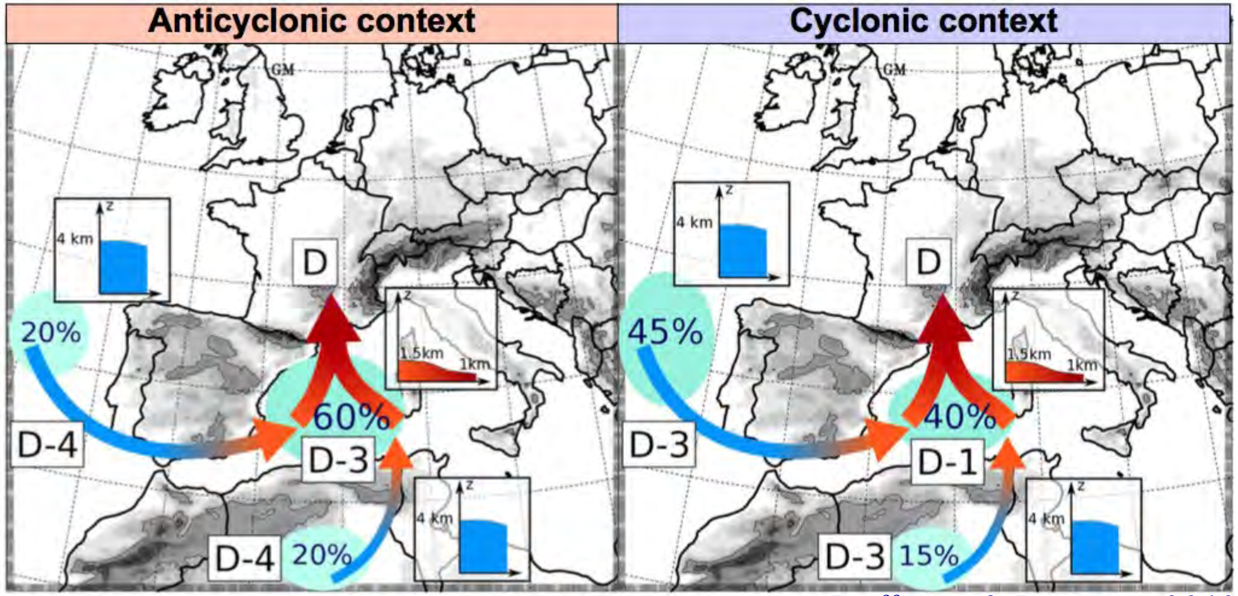
→ Important role of mountain ranges and islands

→ Low-level moisture convergence

Bresson et al. 2012, Scheffknecht et al. 2015, Duffourg et al. 2015, Barthlott and Davolio, 2015, Ivancan-Picek et al. 2014, Trapero et al. 2013

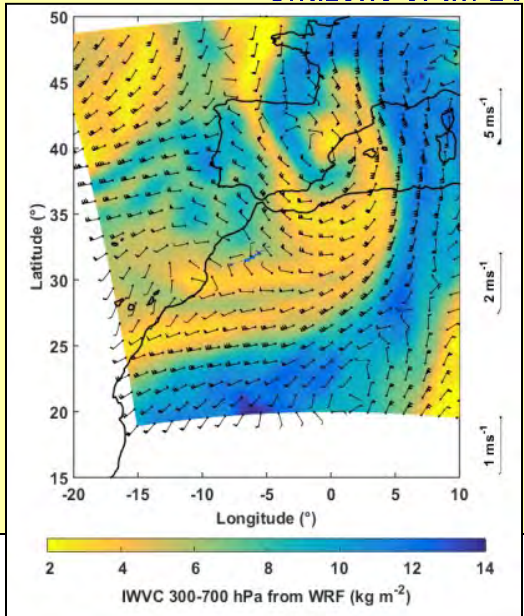
Results
Moisture sources and transport

Where does moisture come from? Identification of WV origin

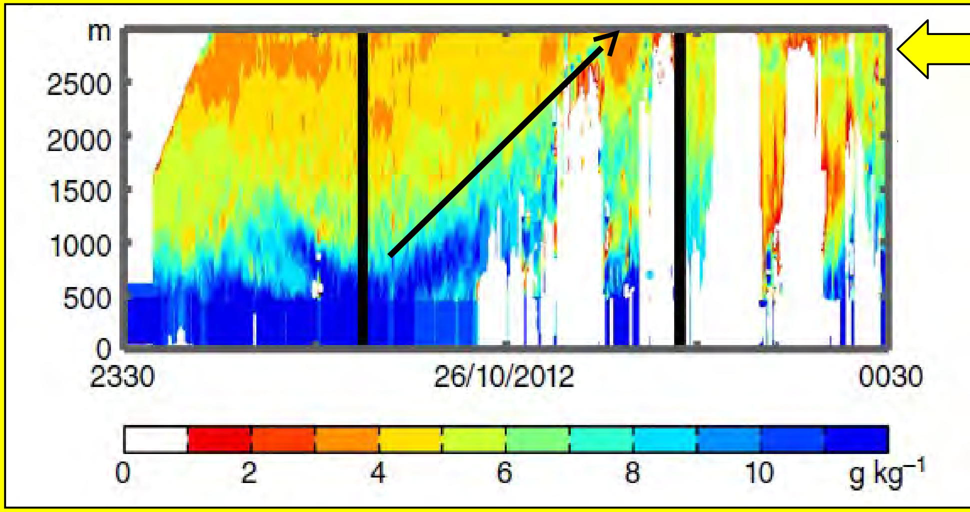


Duffourg & Ducrocq, 2013

modelling studies
Chazette et al. 2015



Tropical plume



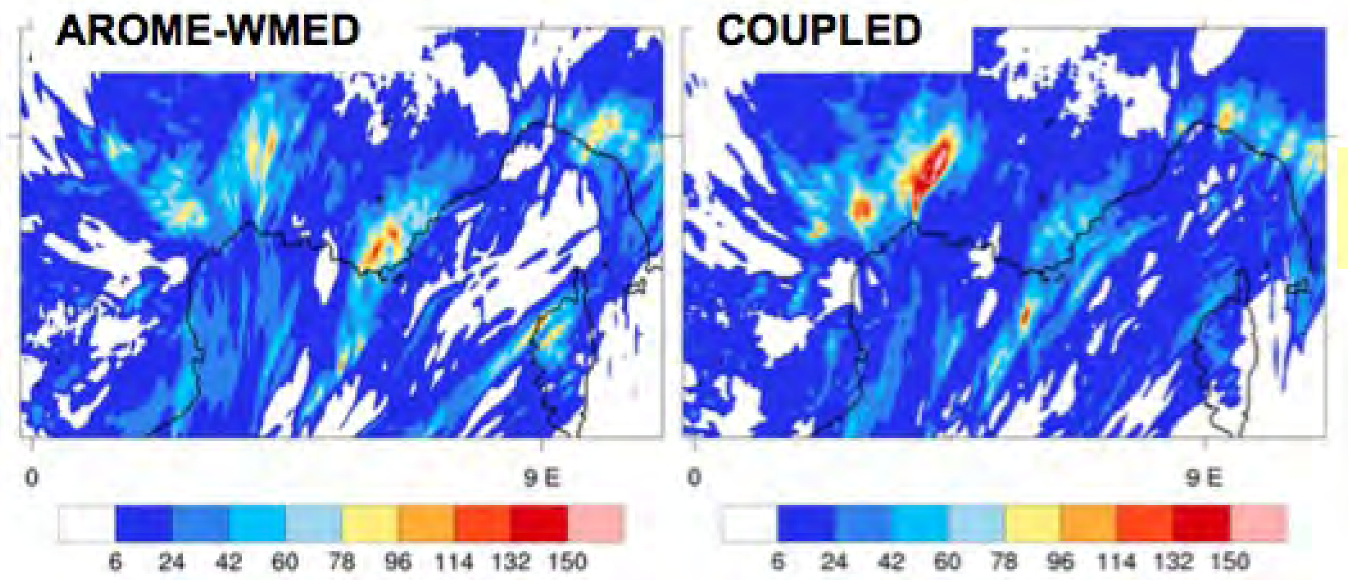
Transport of water vapour along a Warm Conveyor Belt associated to a Mediterranean cyclone, **documented by <u>ATR42 flight (lidar LEANDRE 2)</u>**

Ascending velocity ~ 18 hPa/h

Flaounas et al. 2015

Results
Air-Sea Coupling

Forecasting HPE using COUPLED models (IOP16a)



24h accumulated precipitation from +24h to +48h

AROME-WMED coupled with NEMO: large impact of the coupling for medium range forecasts (24-48h). The more intense are the sfc fluxes before the event, the larger are the OML changes and the impact on the precipitating system.

HPE may occur without significant air-sea fluxes,
BUT large air-sea fluxes are correlated with HPE

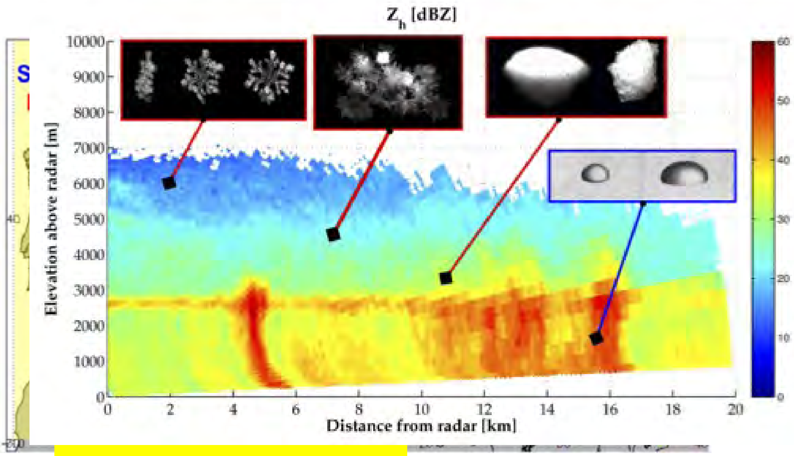
Rainaud et al. 2015, Lebeaupin Brossier et al. 2013, 2014, Berthou et al. 2014, 2015

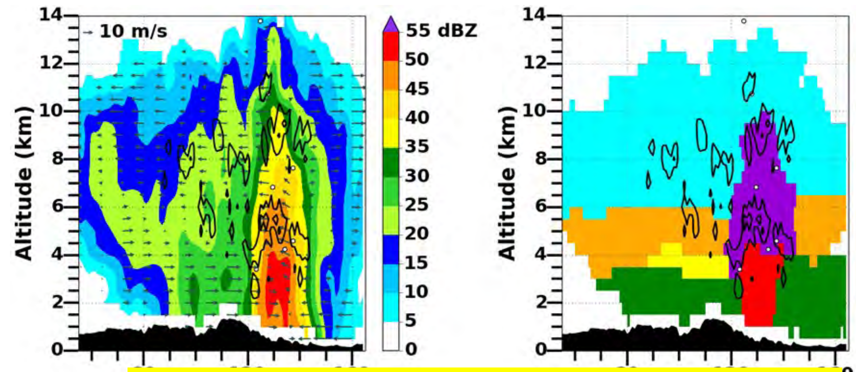
Results

Main advances in documenting HPE

An unprecedented cross-analysis of measurements from various platforms

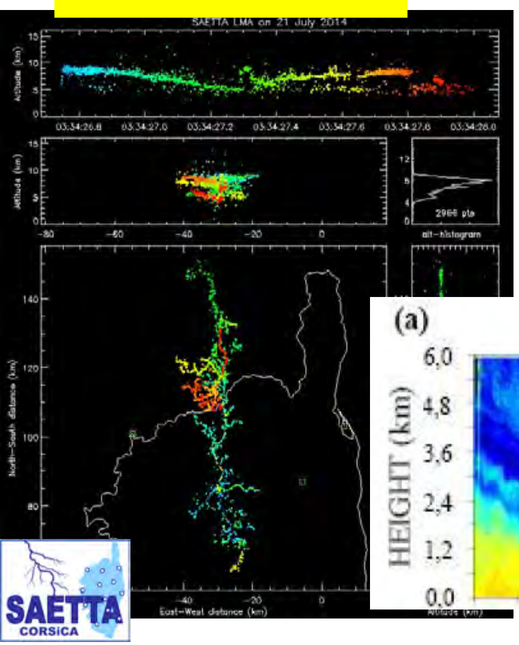
Defer et al., 2015, Bousquet et al. 2015 , Ribaud et al. 2015, Grazioli et al. 2015

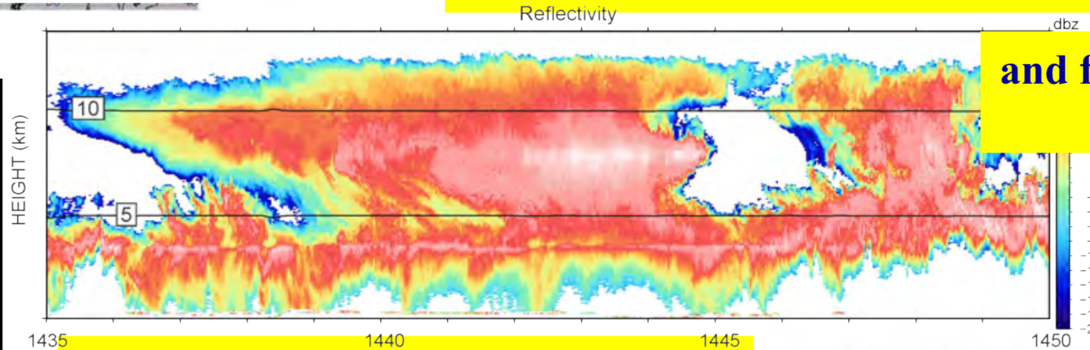




MICROPHYSISCS from RADAR …

LIGHTNING

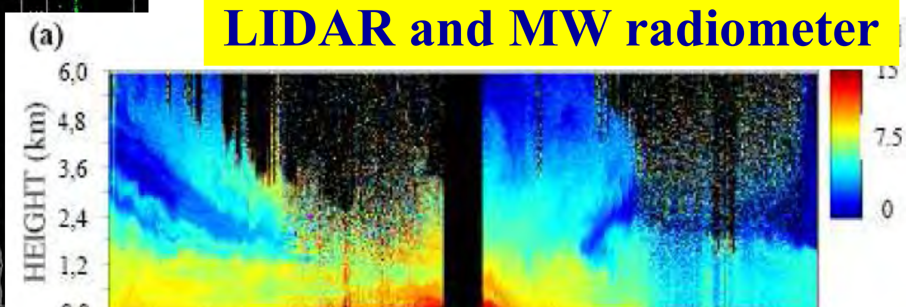




and from AIRCRAFT (Falcon20)

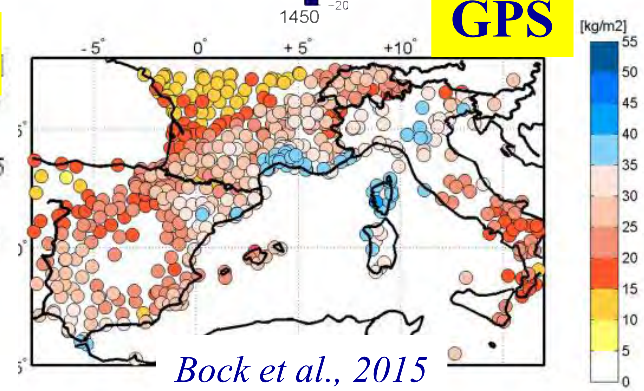
Lee KO et al., 2015

LIDAR and MW radiometer



Di Girolamo et al., 2015

GPS

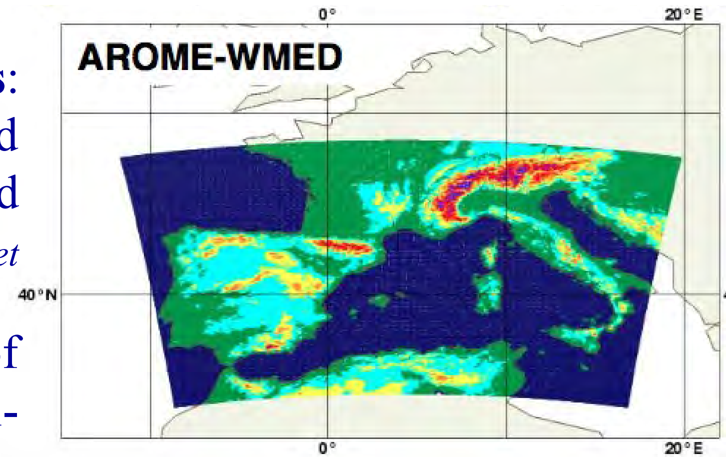


Bock et al., 2015

Results

Main advances in modelling/forecasting

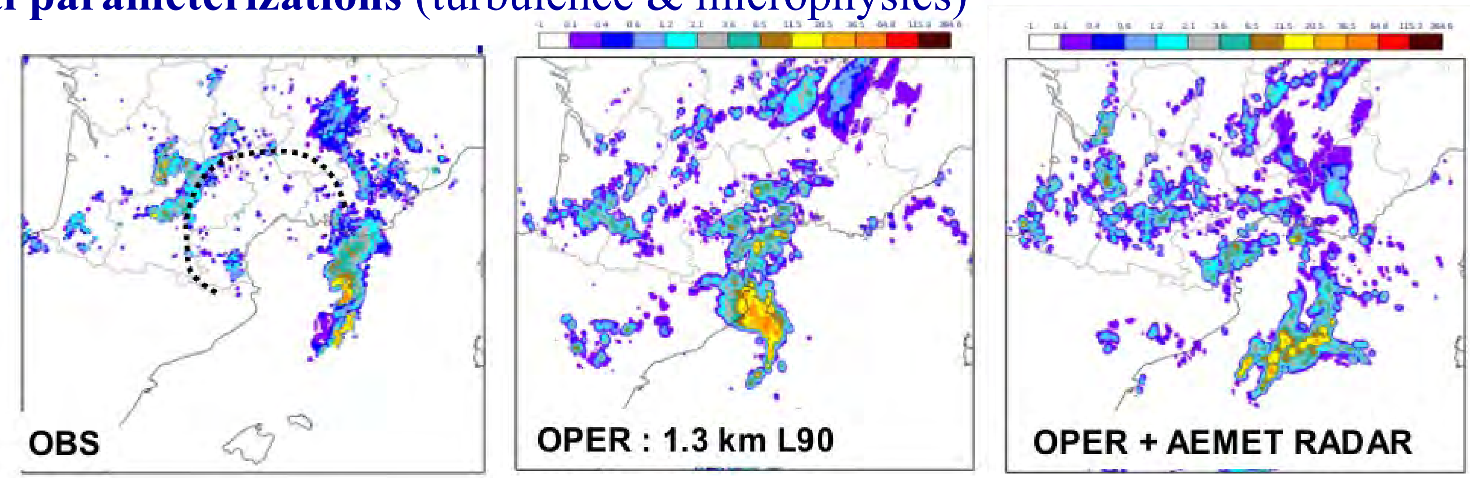
NEW OBSERVATIONS Mesoscale Data Assimilation within cloudy and precipitating systems at convective scale:



- Assimilation of field campaign **research observations**: lightning, MW radiometers, airborne and ground-based WV lidar) **AROME-WMED** SOP real-time and **REANALYSES**, impact studies (*Fourrié et al, 2015; Caumont et al, 2015*)
- Operational Radar data assimilation: assimilation of Spanish radars in AROME (never used before in real-time), radar refractivity, polarimetric weather radar observations (*Augros et al, 2015*)
- Satellite data assimilation: assimilation of cloudy radiance (*Martinet et al, 2013, 2014*)
- Improved **physical parameterizations** (turbulence & microphysics)

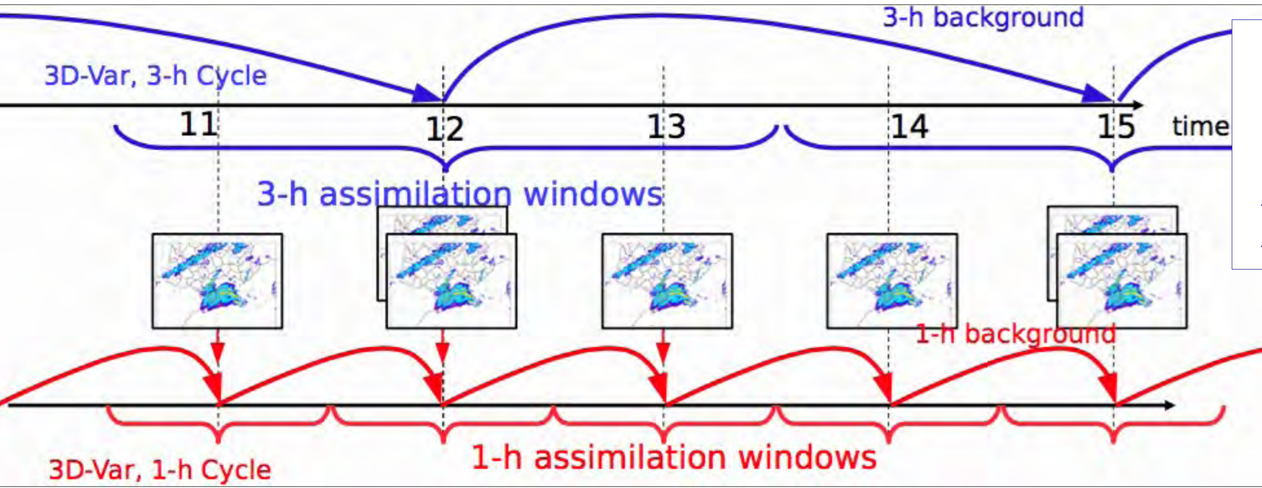
Assimilation of Spanish radar in AROME (oper) 18 h forecast

Montmerle (MF) & Geijo (AEMET)



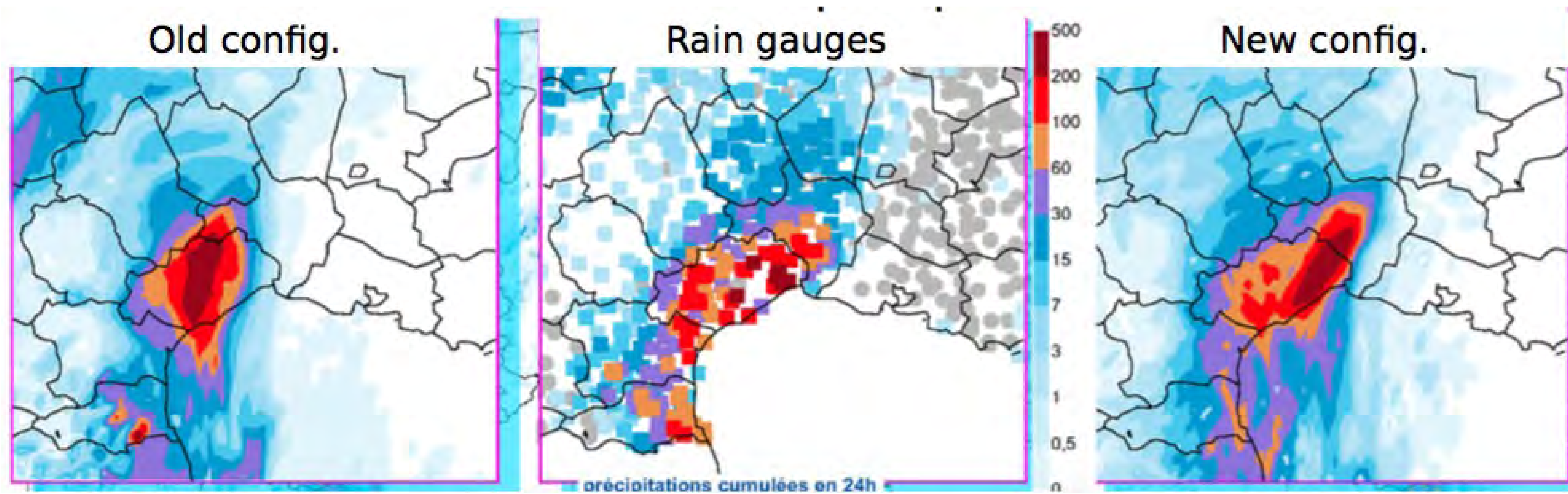
Results

Main advances in modelling/forecasting



New tools/methods for variational DATA ASSIMILATION

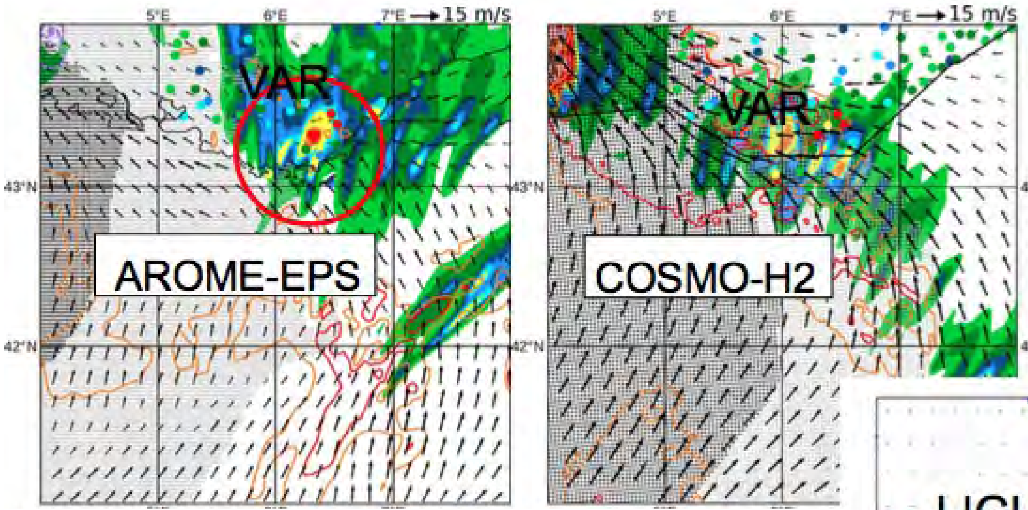
Brousseau et al. 2015



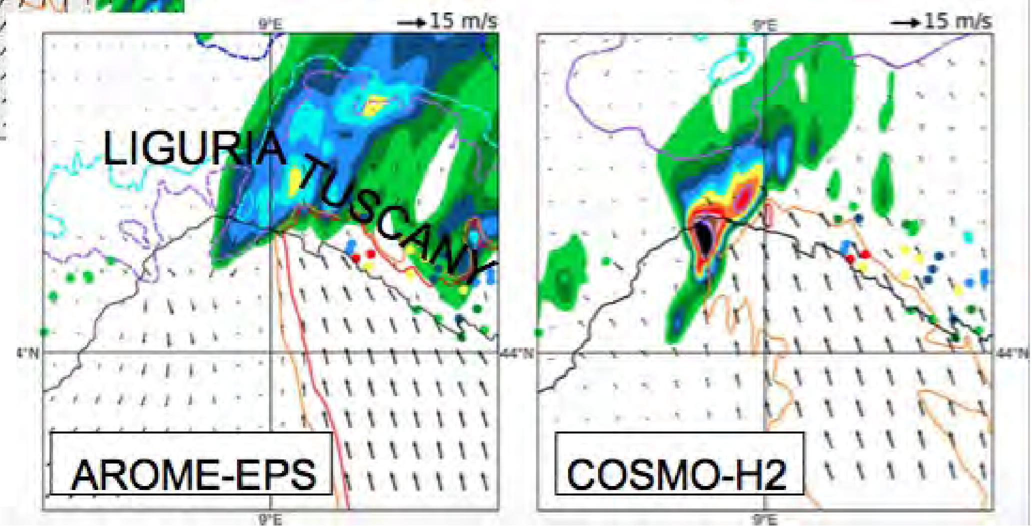
Results
Main advances in modelling/forecasting

ENSEMBLE FORECASTING

- **Convection permitting** ensemble + data assimilation at **mesoscale**
- **Cross evaluation** of ensemble methods
- **AROME EPS** operational at MF in 2016 has been designed and evaluated within HyMeX – *Bouttier et al., 2015*

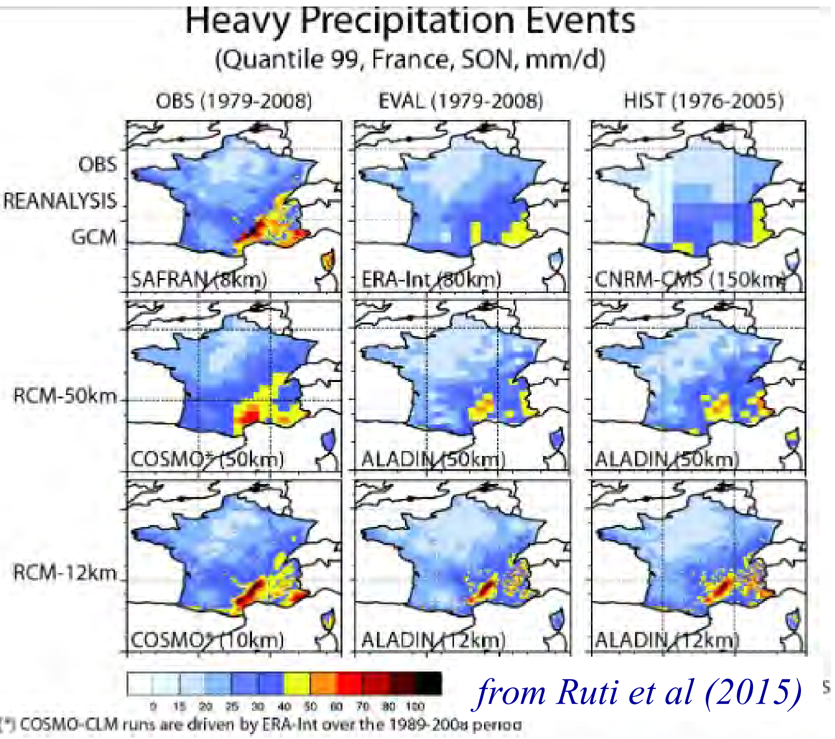


Comparison between
AROME-EPS (Météo France)
COSMO-H2 (ARPA SIMC-Italy)



Results

Regional Climate Models and how HPE will evolve



from Ruti et al (2015)

Added-value of 12-km RCM vs 50km RCM: statistically, **HPEs are better simulated with 12-km RCM** (due to orography, convection, improved physics). This has been verified for different Mediterranean areas and different low-res/high-res - RCM pairs (Med-CORDEX and Euro-CORDEX framework).

Ruti et al, 2015, Harader et al.CDSI , Fosser et al. CDSI, Fantini et al. CDSI, Froidurot et al. CDSI, Cavicchia et al. CDSI

- 12km-RCMs consistently **show an increase in Mediterranean extreme precipitation** in SON at the end of the 21st century but not very strong (few % for a 1°C warming)

Colin, 2011, Beaulant et al., 2011, Planton et al., 2012, Tramblay et al., 2013, Jacob et al., 2013, Harader, 2014, Drobinski et al., CDSI

- **Convection permitting RCM projections** expected in Med-CORDEX2

Achievements

➲ **WE MADE A LOT OF PROGRESSES IN:**

- **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.

➲ **NEW QUESTIONS/PERSPECTIVES**

- Object oriented (HPE) approach across time/space scales
- **Coupled system and seamless approach**: complexity which is required
- Role of Mediterranean cyclone in the water cycle and HPE
- <u>Improved process knowledge</u> → Improved models → Improved forecasts

5-y Science Review

Flash floods

I. Braud

Irstea, Lyon, France

Objectives

- General objectives
  - Improve our understanding of processes active during and between flash floods
  - Improve modelling and forecasting of flash floods
  - Assess possible changes in severe floods in a global change context
- Scientific questions
  - WG3-SQ1: Characteristics of extreme hydrometeorological events in the Mediterranean
  - WG3-SQ3: Improvement of hydrological processes knowledge and prediction
  - WG3-SQ4: Evolution of extremes in a global change context

Observation strategy

- Some characteristics of flash floods
  - Generally occur in small ungauged catchments in a short time
  - Affect large scale areas
  - High spatial and temporal variability
  - Difficult to gauge (dangerous for operators and sensors)
- Observation strategy during HyMeX EOP
  - Focused on hydrometeorological observatories (HO), mainly Cévennes-Vivarais, NE-Italy
  - High resolution rainfall estimation: H-Piconet, research radars
  - Set up of multi-scale hydrological observations in HOs for process understanding (continuous and opportunistic measurements during intense events)
  - Develop new gauging methods of flash flood
  - Post flood events survey (hydro and socio-hydro)

Results in terms of observation

- Main results
  - Release of rainfall reliable estimation at much smaller space and time scales than before and quantification of their uncertainty
  - Significant progress in gauging flash floods with development of different complementary non contact techniques, quantification of uncertainties (stage-discharge, hydrographs), diffusion in operational services
  - Proposition of common socio-hydro post event surveys
  - Documentation of flash flood processes at much smaller scales than before

Gauging flash floods and uncertainty

- Development and validation of non contact techniques (opportunistic campaigns using portable radar velocimeters, in situ cameras (LS-PIV), analysis of videos found on YouTube

See also poster and instrument

Still images in burst mode (20 images in 4 seconds, depending on flow conditions)

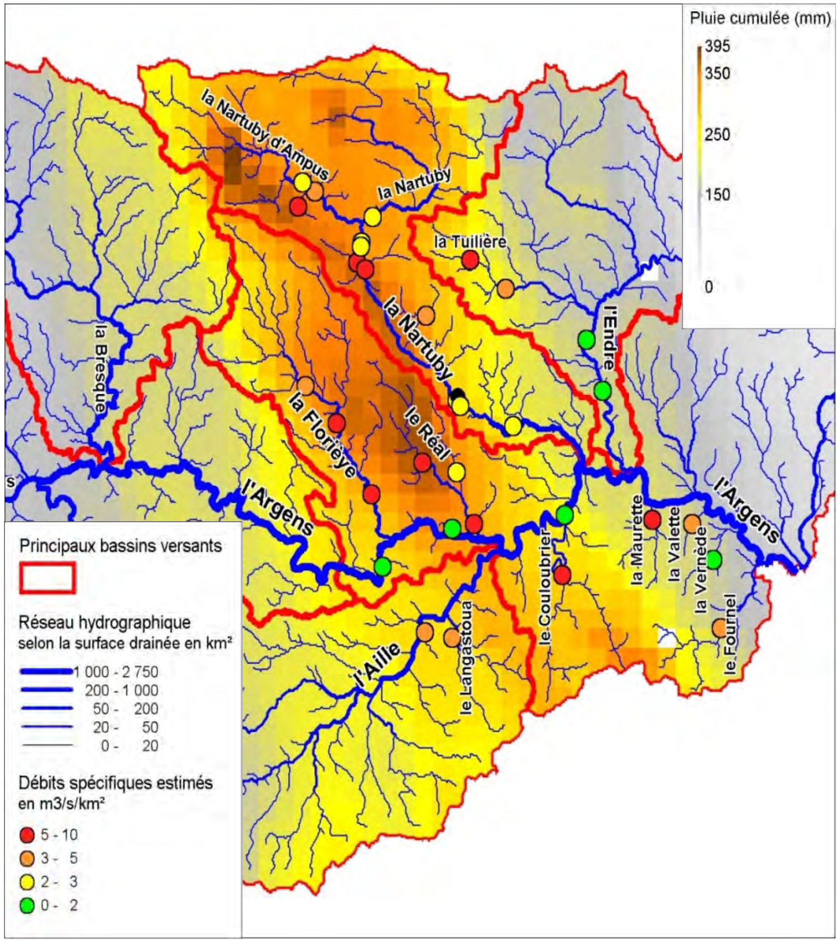
Perspective correction (orthorectification)

Instantaneous velocities computation

Instantaneous velocities are averaged to obtain more robust data

Irstea, Lyon

Post flood events survey

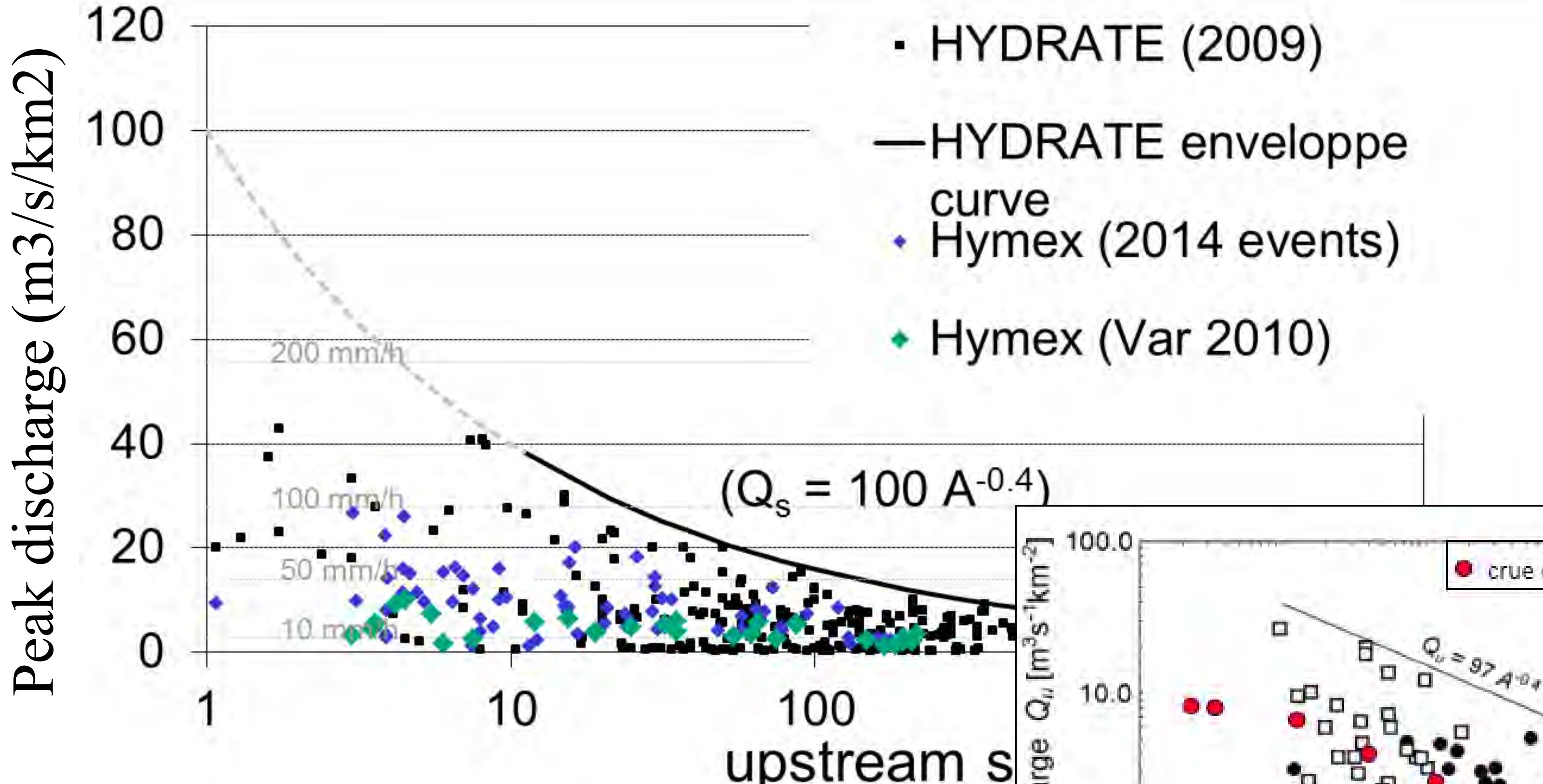


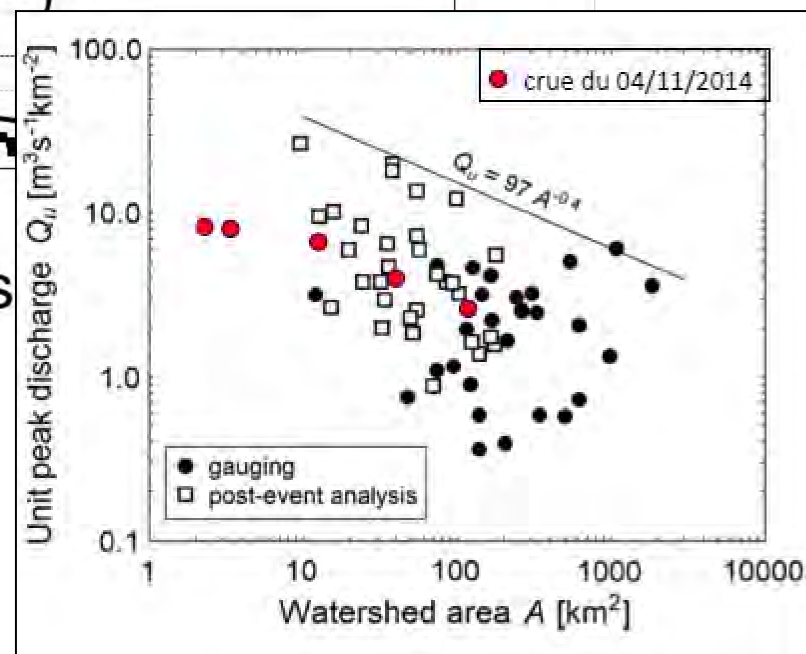
Var 2010 event

- Documentation of peak discharge in ungauged catchments
- Methodology for common socio-hydro surveys (Ruin et al., 2014)
- Initiative to gather a Mediterranean data base (MEDEFF) of primary data about flash floods

From O. Payrastre, Ifsttar

Post flood events survey





Envelope curves from post event surveys and continuous measurements

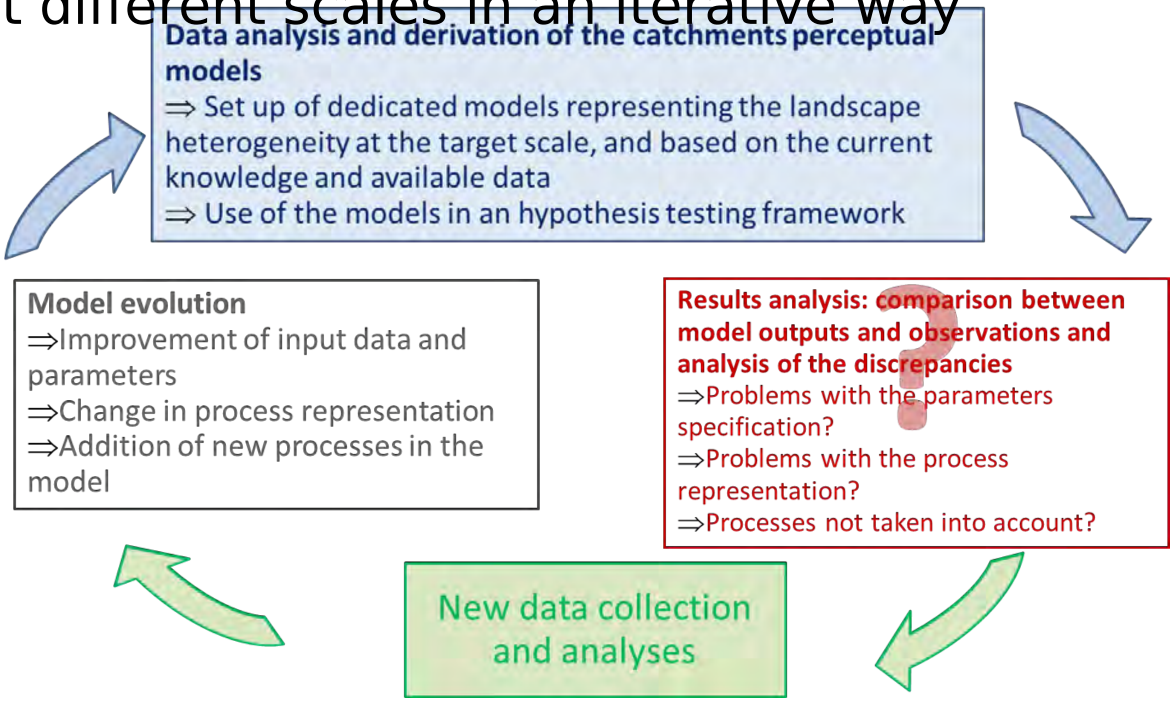
From O. Payrastre, Ifsttar and G. Nord, LTHE

Hydrological processes understanding

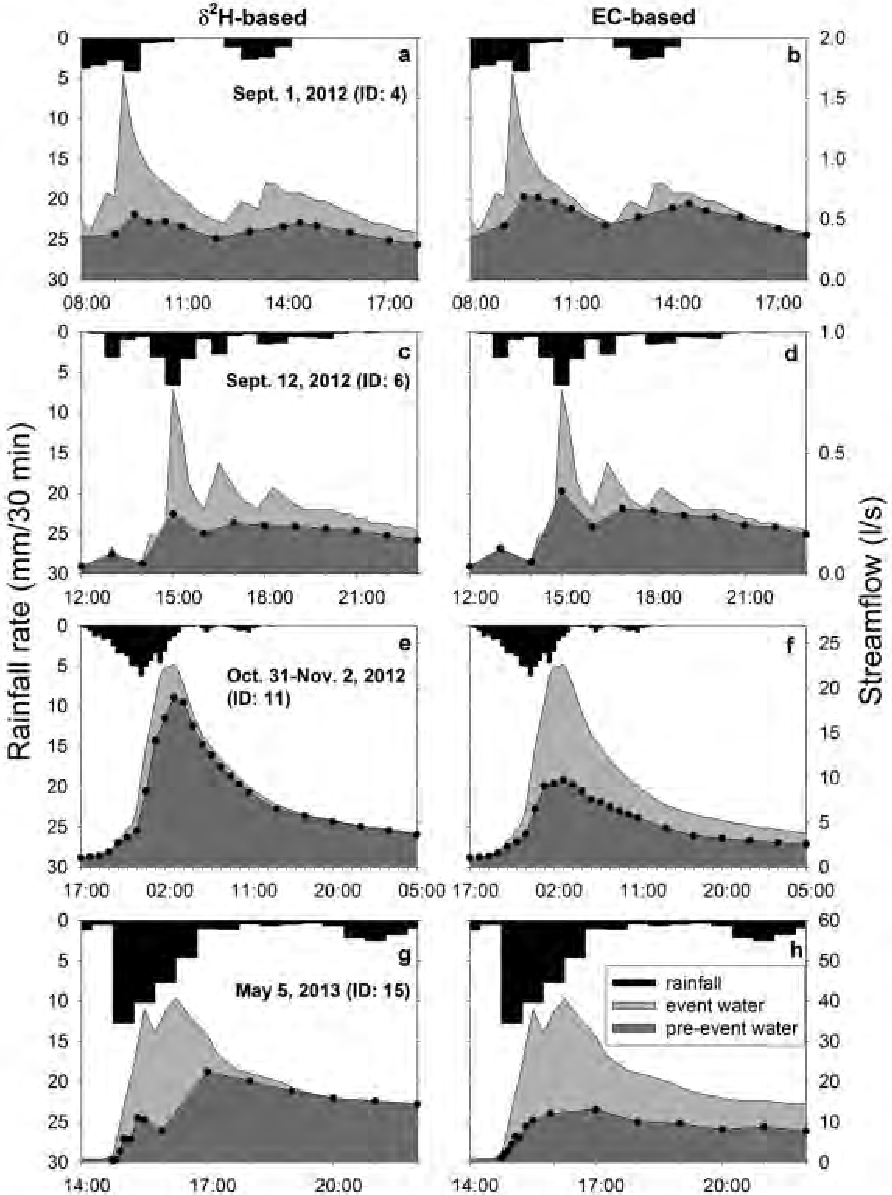
- Main results
  - Rainfall spatial and temporal variability remains the first driver
  - Hydrological processes active during flash floods are variable in space and time
  - Initial soil moisture, geology and soil poperties have a significant control on the response, less clear for land use?

Hydrological processes understanding

- Methodology
  - In situ observations in densely instrumented small catchments (distributed rainfall, discharge, soil moisture, piezometric levels, use of geochemistry sampling, electrical conductivity/temperature measurements to track the origin of water)
  - Use/develpment of models for functionning hypotheses testing et different scales in an iterative way



Hydrological processes understanding



- ➲ High seasonality of runoff response
- ➲ Fraction of event water increases with rainfall event amount and intensity
- ➲ Higher contribution of event water to streamflow in dry conditions with a large contribution of runoff from the riparian zone

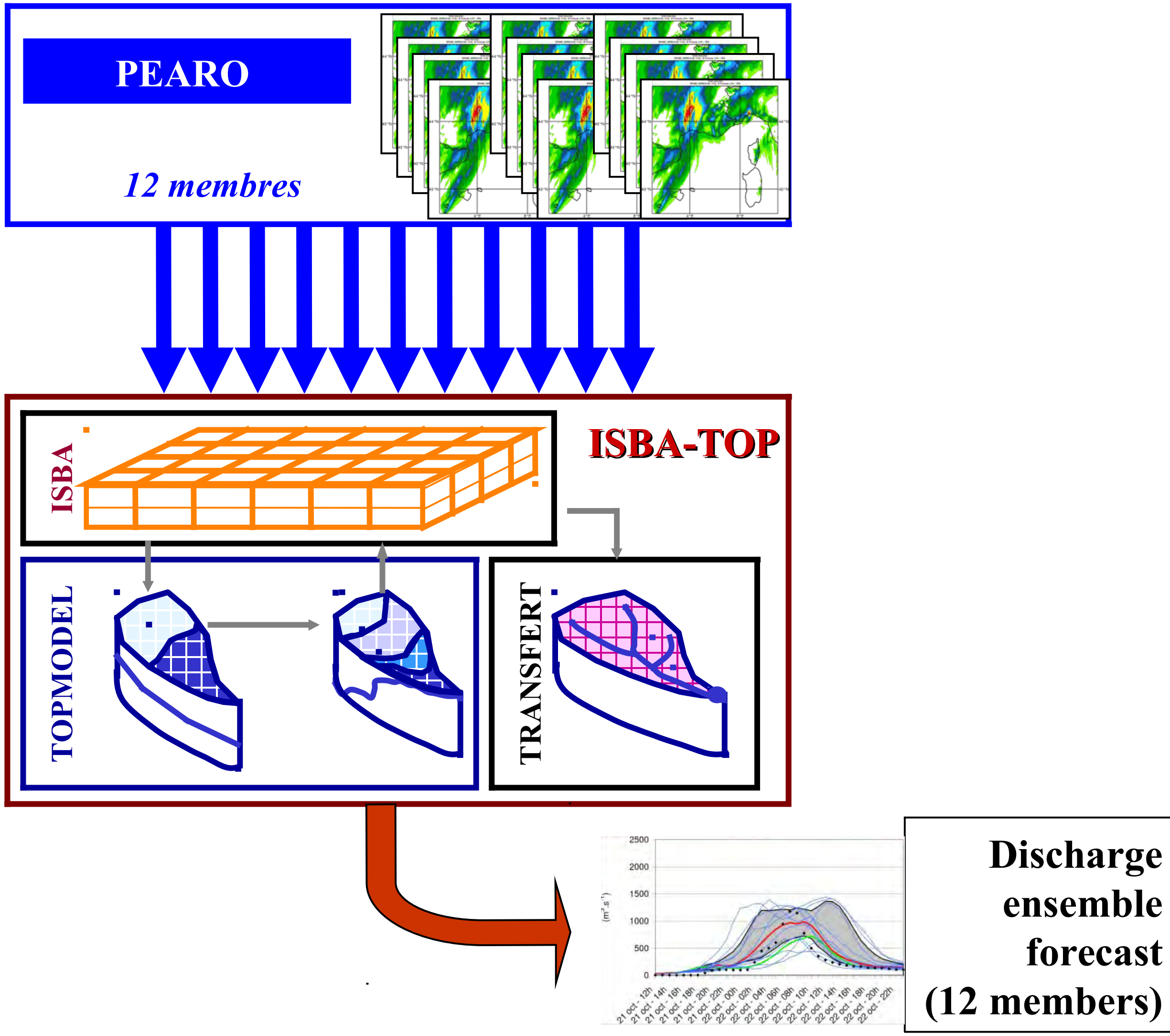
M. Borga et al., Univ. Padova

Regional modelling and flash flood forecasting

- Main results
  - Significant progress in the development and set up of distributed, physically based models at the regional scale (and in ungauged catchments)
  - Uncalibrated models are useful for process understanding and hypotheses testing
  - Several models set up on various catchments
  - Value of coupled ensemble atmospheric forecast and hydrological forecast was demonstrated
  - Results are useful for civil protection and warnings

Ensemble flash forecasting in France

- Use of the ISBA-TOP distributed model
- Two types of ensemble forecasts:
  - Perturbation of the Arôme deterministic forecast (location, intensity of high rainfall cells)
  - Use of the Arôme ensemble forecast



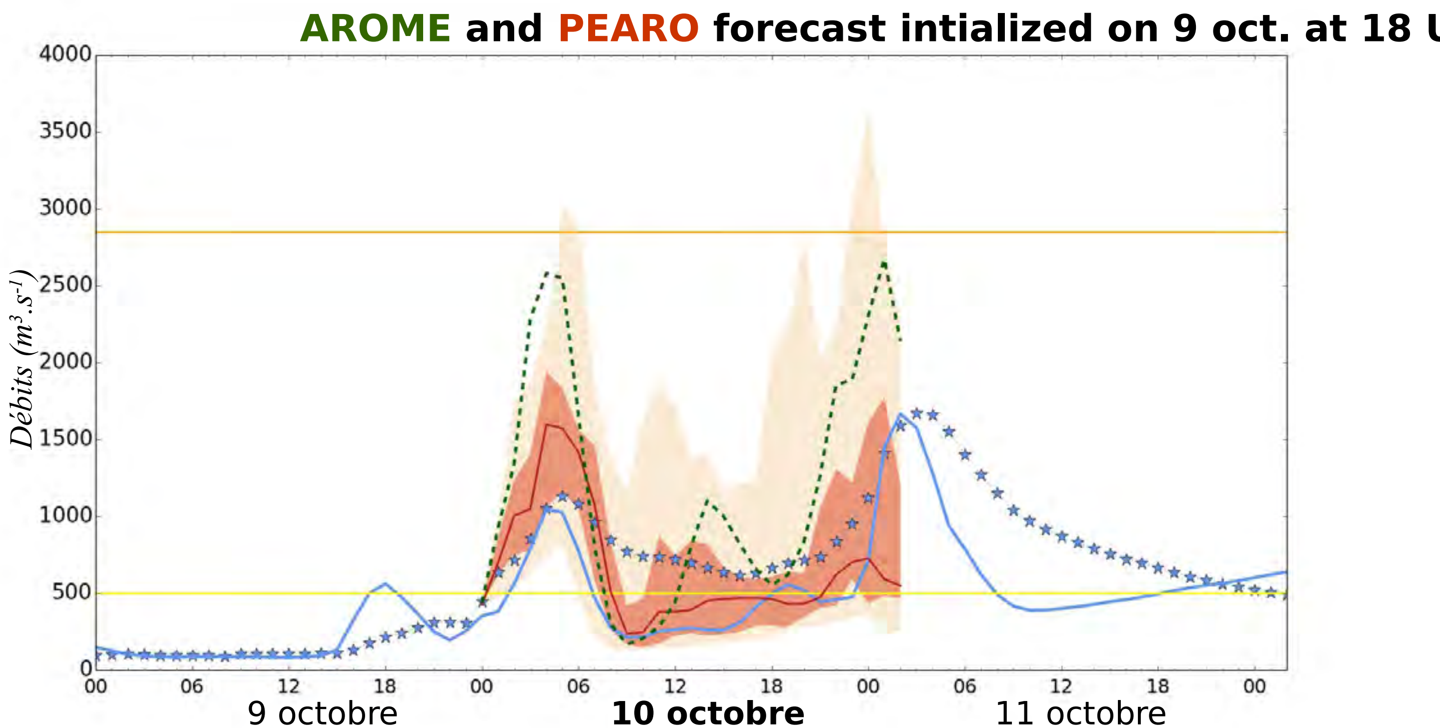
Vincendon et al.,, CNRM

Ensemble flash forecasting in France

Discharge Ardèche at Vallon Pont d'Arc

Second warning level

First warning level



☆ Observed discharge

Simulated discharge– ISBA-TOP forced using observed rain gauges

Deterministic forecast ISBA-TOP forced with operational AROME forecast

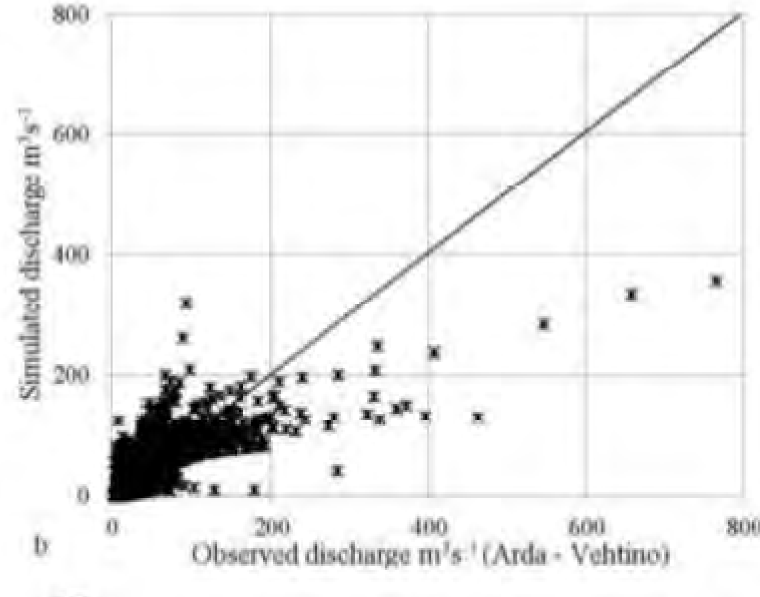
Median of the ensemble forecast ISBA-TOP forced by AROME ensemble forecast

Quantiles 25%-75% of the ensemble forecast ISBA-TOP forced by the AROME ensemble forecast

Min-Max of the ensemble forecast ISBA-TOP forced by the AROME ensemble forecast

Vincendon et al.,, CNRM

Flood forecasting system in Bulgaria



- Based on ISBA-TOP
- Running since 2014
- Application available on a bilingual web site (Bulgaria, Greece), with information on rainfall, water levels, snow, etc..

Artiyian et al., JoH, submitted

Extremes in rainfall and discharge and impact of climate change

- Methodology
  - Use of historical data or data at ungauged site to improve the robusteness of flood frequency estimation
  - Up to now, gathering and analysis of past long term records, using statistical trend tests
- Main results
  - Demonstration of the value of historical data in ungauged catchments to increase the robustness of flood frequency estimation (infrastructrure design)
  - Evidence of significant increase of flood index in several areas of Catalunya (Berrara-Escoda and Llasat, HESS, 2015)
  - Significant increase in annual daily maximum rainfall in south-east France (J. Blanchet and G. Molinié, LTHE, France)

Conclusions

What remains to be done ?

- Continue the scientific exploitation of all the collected data and develop experience and modeling sharing between all teams
- 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

What was achieved and not planned?

- Extend investigation to connex problems: sediment transport, landslides and debris flow
- Building a strong scientific community around the flash flood topic
- Stronger links between hydrology and human science
- Some progresses already transferred to the operational domain

Thank you for your attention