HyMeX — Flash Flood research in HYMEX

Isabelle Braud, IRSTEA, France
Marco Borga, Univ Padova, Italy
+
many others from
the WG on FlashFloods

HyMeX — Introduction- WG3

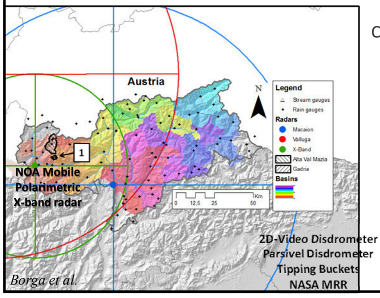
- Questions addressed in the ST-Flashfloods
  - WG3-SQ1: characteristics of extreme hydrometeorological events in the Mediterranean
  - WG3-SQ3: Improvement of hydrological processes knowledge and prediction
  - WG3-SQ4: Evolution of extremes in a global change context
- Some illustrations of the 2010-2015 progresses
  - Observation and documentation of flash floods and rainfall from the small to the meso scale
  - Progress in knowledge derived from observations/modelling
  - Flash flood regional modelling
  - Flash flood forecasting
  - Trends in extremes and impact of climate change

HyMeX — Observation – WG3

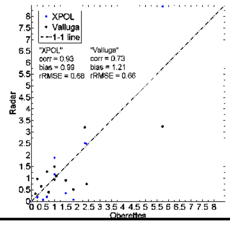
- Some characteristics of flash floods
  - Generally occur in ungauged catchments
  - Affect large scale areas
  - High spatial and temporal variability
  - Difficult to gauge (dangerous for operators and sensors)
- Observation strategy during HyMeX EOP
  - Focused on hydrometeorological observatories (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
  - Develop new gauging methods
  - Post flood events survey (hydro and socio-hydro)

HyMeX — Rainfall estimation – WG3

- Improvement of rainfall estimation at small scale: comparison of Xpol, Cband, disdrometer estimations in NE-Italy HO
- Xpol radar in better agreement with in situ data. Sometimes sees rainfall not detected by the C-band radar

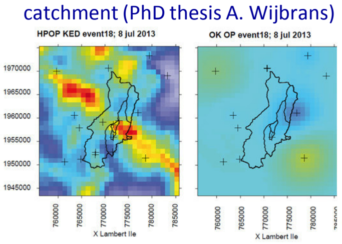


Comparison Xpol, Cband radar with in situ data

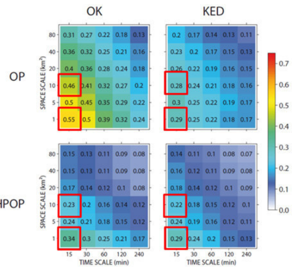


HyMeX — Rainfall estimation – WG3

- Production of radar/raingauges reanalyses in the Cévennes-Vivarais HO 2007-2013 (Delrieu et al., 2014) and at finer scales on a 100 km2 catchment (PhD thesis A. Wijbrans)



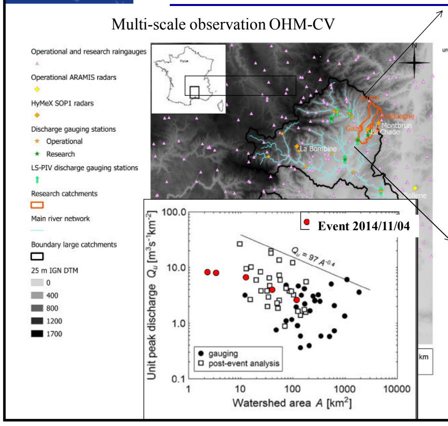
Rainfall estimation using KED : radar/rain gauges (left) and kriging (rain gauges Hpiconet). Auzon catchment 100 km2

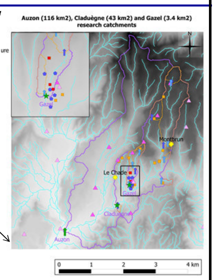


Rainfall error as function of space and time scales: KED improve estimation at small spatial and time scales

Talk A. Wijbrans, TH1.2

HyMeX — Multi-scale hydrological observation – WG3



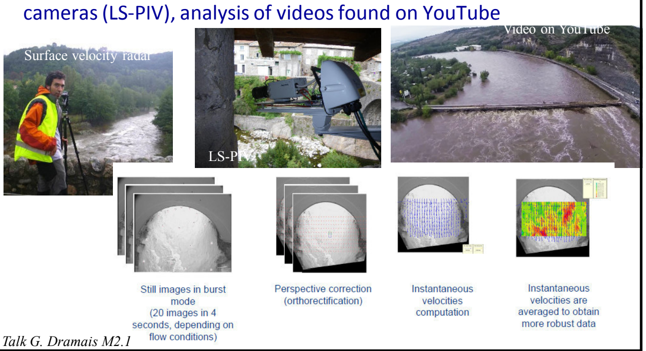


Documentation of scales not much documented until now

Braud et al., HESS, 2014
Nord, 2015

HyMeX Gauging flash floods and uncertainty – WG3

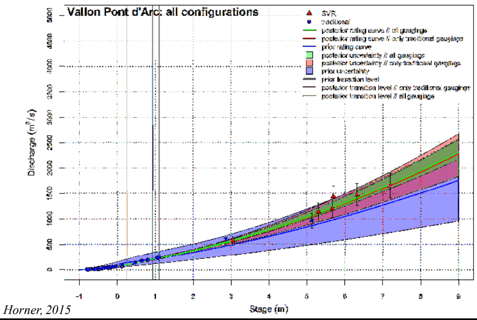
- Development and validation of non contact techniques (opportunistic campaigns using portable radar velocimeters, in situ cameras (LS-PIV), analysis of videos found on YouTube



Talk G. Dramais M2.1

HyMeX Gauging flash floods and uncertainty – WG3

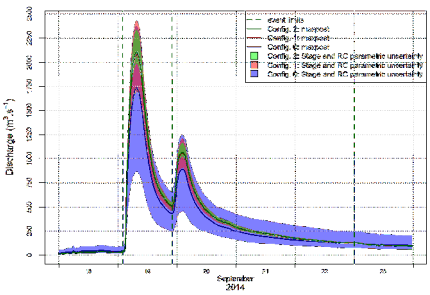
- Characterization of rating curve uncertainty using the BaRatin Bayesian method (Le Coz et al., JoH, 2014) and propagation to hydrographs



F. Branger and I. Horner, 2015

HyMeX Gauging flash floods and uncertainty – WG3

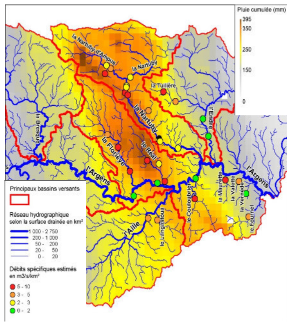
- Characterization of discharge uncertainty using the BaRatin Bayesian method (Le Coz et al., JoH, 2014) and propagation to hydrograms



Still to be investigated: Non-stationarity in stage-discharge relationship (change in river bed after major events)

F. Branger and I. Horner, 2015

HyMeX Post flood events survey– WG3

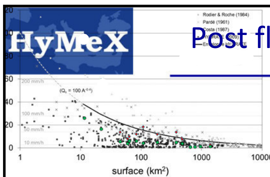


Var 2010 event

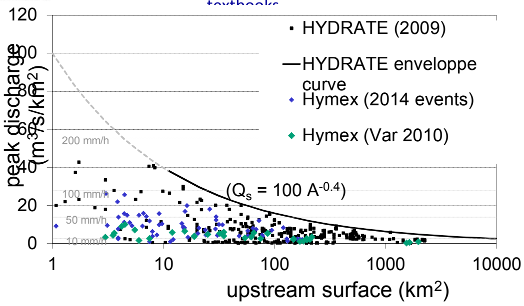
- Documentation of peak discharge in ungauged catchments
- Methodology for common socio-hydro surveys (Ruin et al., 2014)
- Initiative to gather a Mediterranean data base (MEDEFF) of primary data about flash floods in order to increase the number of documented (M. Borga et al., in progress: so you can still provide your data!)

O. Payrastre, Ifsttar

HyMeX Post flood events survey– WG3



- New data to complement envelope curves of specific peak discharge versus watershed area
- Bed roughness generally lower than in textbooks



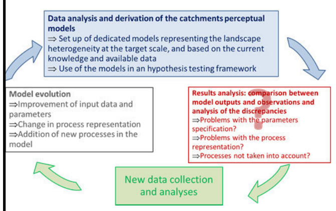
Talk O. Payrastre ...

HyMeX Synthesis on observation– WG3

- 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
- Further investigations needed
  - A large amount of collected data: past years mainly devoted to high quality data acquisition, in depth analysis of the data still to be done
  - Propagation/use of the quantified uncertainty on rainfall and discharge time series in model evaluation and calibration
  - How to involve citizens in data collection about floods (photos, videos), given security constraints?

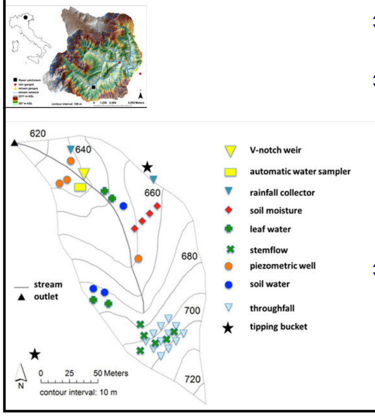
HyMeX — Hydrological processes understanding – WG3

- Major addressed questions
  - Which dominant hydrological process (overland flow, sub-surface flow) during flood events? Is it dependent on rainfall event characteristics and/or catchment characteristics: geology, land use?
  - Which contribution of the sub-soil to runoff? Is the sub-soil impervious?



- 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

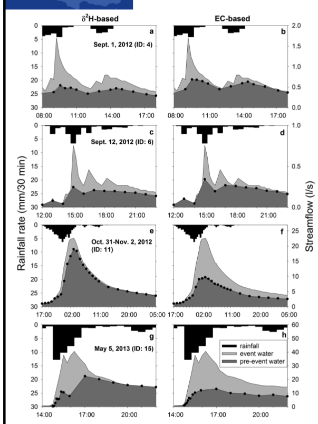
HyMeX — Hydrological processes understanding– WG3



- Ressi catchment (1.96ha), NE-Italy-HO
- Discharge, isotope signature, electric conductivity, soil moisture, piezometric level measurements between August 2012 and August 2013
- To understand dominant runoff processes and the origin of water

Borga et al.

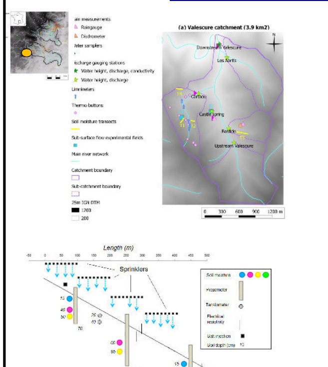
HyMeX — Hydrological processes understanding– WG3



- 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

Borga et al.

HyMeX — Hydrological processes understanding– WG3

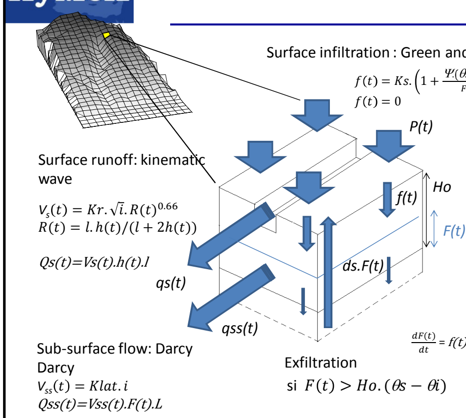


Transect for sub-surface flow characterization

- Valescure cartchment (3.9 km²)
- High surface saturated hydraulic conductivity > 1000 mm/hr => no surface runoff
- Characterization of sub-surface lateral flow: several m/s
- High infiltration in the weathered bedrock
- Rapid exfiltration in ephemeral river streams
- High variability of soil depth and no link with catchment characteristics
- Geochemistry sampling during flood events: partition of event and old water

Bouvier et al., JoH, submitted
Talk C. Bouvier M2.1

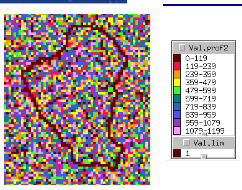
HyMeX — Hydrological processes understanding– WG3



- Model built from observations
- 40 events from 2003-2014
- Parameters specificied from observations, parameter for bedrock infiltration calibrated
- First trials to transfer to larger scales successful

Bouvier et al., JoH, submitted

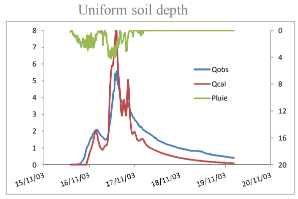
HyMeX — Hydrological processes understanding– WG3

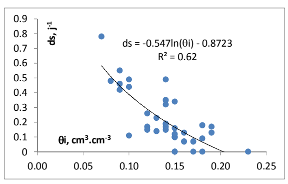


Random variability of soil depth

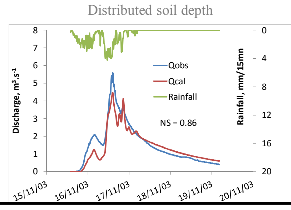
Impact of soil depth variability on simulated hydrographs

Uniform soil depth



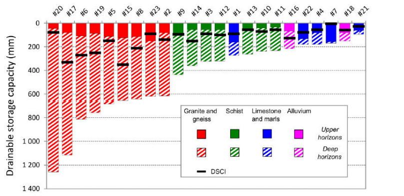


Distributed soil depth

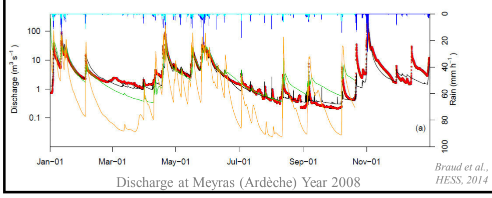


HyMeX — Hydrological processes understanding– WG3

- Soil water storage derived from soil data bases is underestimated as compared to values derived from recession analysis
- Geology is the main explanatory variable



Vannier et al., Hyd. Proc, 2014



Discharge at Meyras (Ardèche) Year 2008

Braud et al., HESS, 2014

Inclusion of weathered bedrock improves discharge simulation

HyMeX — Synthesis on hydrological processes – WG3

- 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?
- Further investigations needed
  - Continue data analysis and modelling
  - Assess how knowledge acquired at small scale can be transferred to larger scales
  - How to transfer these new knowledge into operational models?

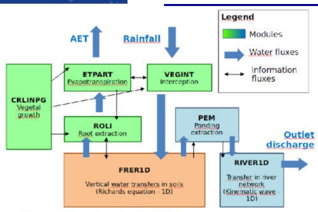
HyMeX — Regional hydrological modelling– WG3

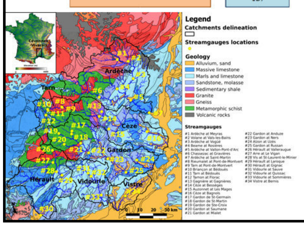
- Main questions
  - Are we able to set up distributed physically-based hydrological models adapted to flash flood simulation at the regional scale?
  - Which process representation? Which spatial and time scale?
  - How do we regionalize parameters?
- Methodology
  - Several types of models have been designed and evaluated
    - for flash flood understanding
    - for flash flood forecasting
  - Models generally set up on a selection of large catchments (not yet for the whole territory)
  - Parameters generally prescribed from available data to avoid calibration, but also some calibrated models for forecasting

HyMeX — Regional hydrological modelling– WG3

- Examples of developped models
  - ISBA-Topmodel (Vincendon et al., 2010) set up over several Mediterranean catchments in France, one catchment in Spain and in a catchement at the border between Bulgaria and Greece
  - HEC-HMS model set up in some catchments in Catalunya
  - MARINE (Roux et al., 2011), CVN (Vannier et al., submitted), over a large set of Mediterranean catchments in France using a bottom-up approach
  - Simpleflood (Adamovic et al., submitted) model designed from data analysis and applied to two meso-scale catchments
  - CINECAR model over the Gard department to predict road cuts

HyMeX — Regional hydrological modelling– WG3

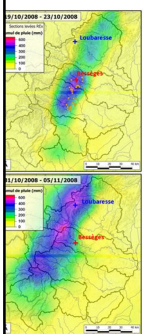




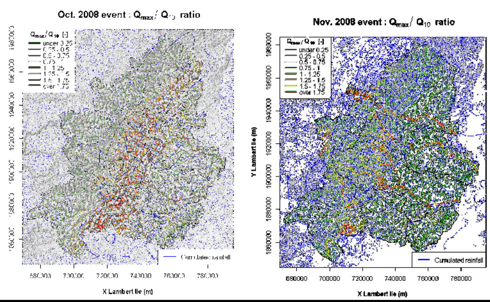
- Example of the CVN model
- SAFRAN hourly forcing and radar data during events
- Inclusion of two soil horizons: surface soil and weathered bedrock according to geology
- Better results on long term and events simulations in granite catchments than in schist catchments

Vannier et al., JoH, submitted

HyMeX — Regional hydrological modelling– WG3



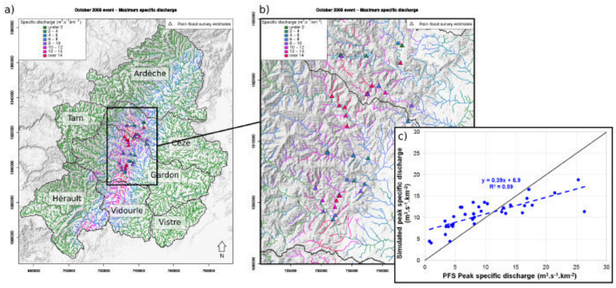
- Two contrasted events
- Simulation of peak discharge: in yellow, orange and red: Qpeak > Q10years



Vannier et al., JoH, submitted

HyMeX — Regional hydrological modelling– WG3

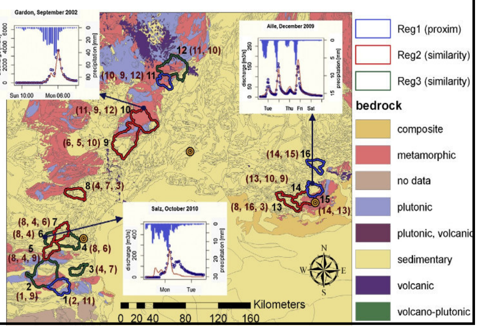
- Specific peak discharge and comparison with post flood survey data



Vannier et al., JoH, submitted

HyMeX — Regional hydrological modelling– WG3

- Evaluation of different parameters regionalization methods based on similarities in catchment descriptors and/or proximity
- Parameter describing soil depth/storage, related to geology descriptors

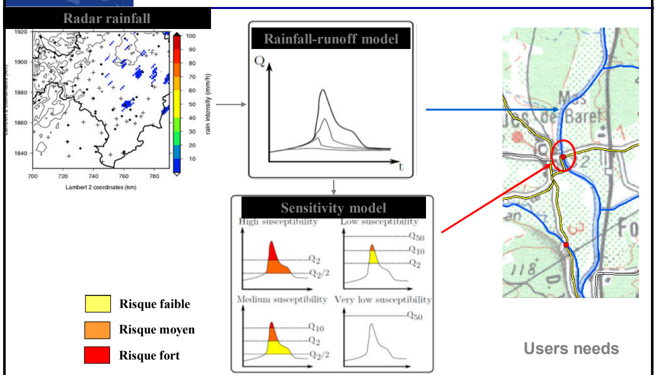


Garamblois et al., JoH, 2015

HyMeX — Flash flood forecasting– WG3

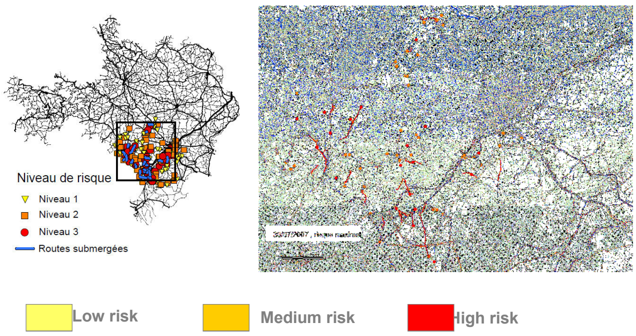
- Main questions
  - Are we able to design usefull models for flash flood forecasting and providing useful information for warning and civil protection?
  - Does ensemble forecasting provide additional information as compared to deterministic forecast?
- Methodology
  - Based on regional scale models, combine hydrological prediction and vulnerability assessment to provide road cut warnings
  - Use of perturbation of a deterministic forecast to provide ensemble
  - Use directly ensemble provided by a Numerical Weather Prediction model

HyMeX — Road cut forecasting chain



Payrastre, Naulin et al.

HyMeX — Example of road cut risk simulation



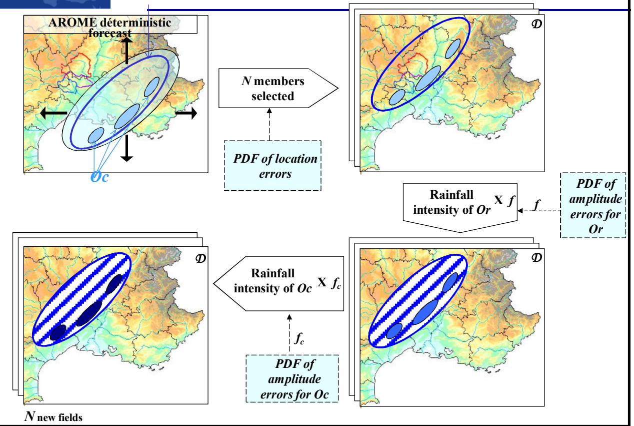
- Application available as a demonstrator

heberge.ifsttar.fr//prediflood/index.php

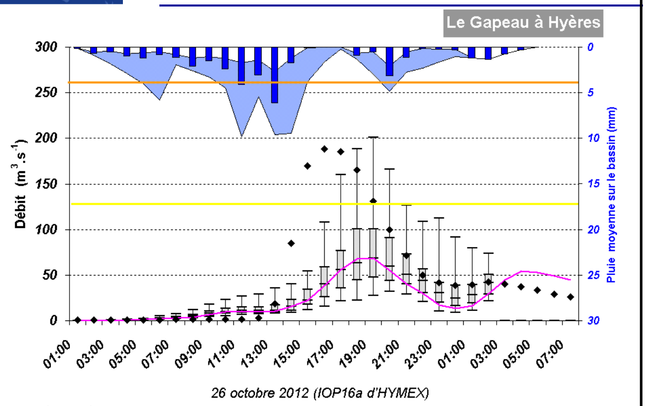
Payrastre et al.

HyMeX — Perturbation generation method

Or *(Vincendon et al., 2011)*

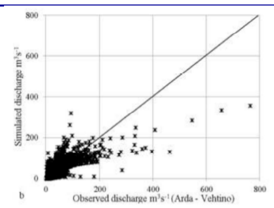


Perturbation generation method



Vincendon et al.

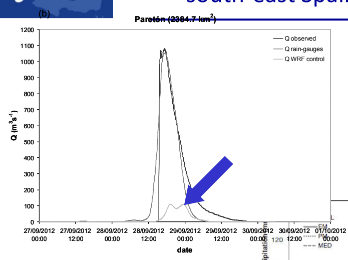
Flood forecasting system in Bulgaria



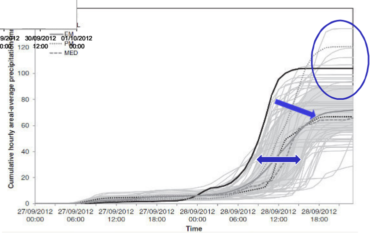
- Based on ISBA-TOP
- Running since 2014
- Application available on a bilingual web site (Bulgaria, Greece), with information on rainfall, water levels, snow, etc..

Artiyian et al., JoH, submitted

Assessment of ensemble forecast: example in south-east Spain, 2012/09/28, Murcia



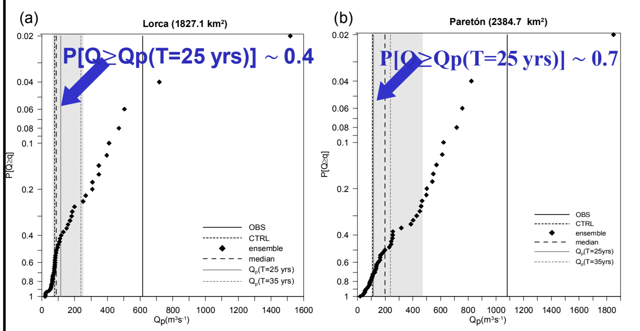
- WRF simulation leads to a very large underestimation of discharge as compared to raingauges



- Ensemble rainfall forecast provides estimates closer to observations

Amengual et al.

Assessment of ensemble forecast: example in south-east Spain, 2012/09/28, Murcia



- Ensemble forecast provides information useful for civil protection and issuing warnings

Amengual et al.

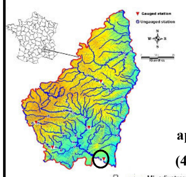
Synthesis on modelling– WG3

- Main results
  - Significant progress in the development and set up of distributed, physically based models at the regional scales (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 demonstrated
  - Results are useful for civil protection and warnings
- Further investigations needed
  - All the initiatives should be shared and discussed to better highlight what is working well
  - Take into account all sources of uncertainties (including hydrological model structure, parameter specification) -> towards multi-hydrological modelling

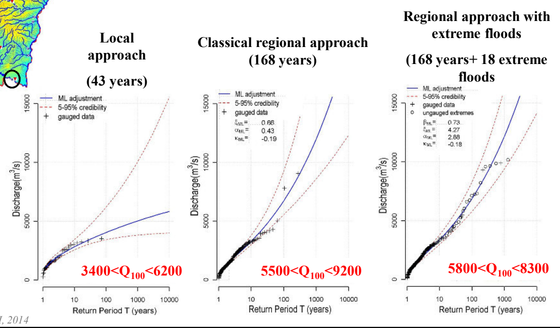
Extremes in rainfall and discharge and impact of climate change– WG3

- Main questions
  - Estimation of robust flood frequency curves (for extreme design flood estimation)
  - Is extreme events occurrence and intensity evolving with time and what could be the 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

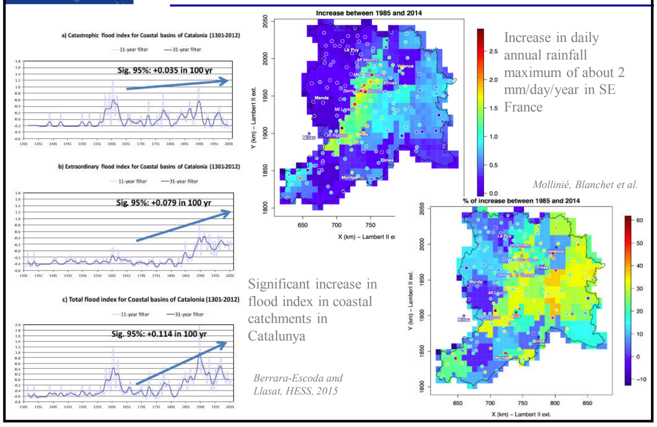
HyMeX — Flood distribution assessment– WG3



- Ardèche department: 168 year-gauges at 5 gauged sites
- 18 extreme floods (16 in ungauged sites), each being the maximum observed flood of the last 50 years



HyMeX — Trends in extreme and impact of climate change– WG3



HyMeX — Conclusions– WG3

- What was planned and not achieved ?
  - For hydrological observations, difficult to coordinate activities amongst countries
  - 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 conex 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

HyMeX — Guidelines

- Science review should be organized along the 5 HyMeX topics (WG1,WG2,WG3,WG4,WG5)
- When possible organize Science review along the HyMex Science Plan questions (WGx-SQn)
- It should be as much of possible a review of **science advances and NOT a review of activities** => highlight new results and findings over the 5 years.
- Outreach activities and beneficial impacts on operational forecasting and tools, practices,… could be mentioned
- It will not be possible to illustrate all the studies, you should make choices!
- Last slide: What are missing with respect to the HyMeX Science Plan ? What have been achieved that were not in the HyMeX Science Plan ?

HyMeX — Land use impact on hydrology and landslides from August 2 2014 event in NE-Italy– WG3

- For this event, no significant signature of land use (forest versus vineyard) on these very high flood event (specific peak discharge 17 m3/s/km2)
- A significant impact of land use on landslide generation

Borga et al.