HyMeX : Hydrological Cycle in the Mediterranean Experiment

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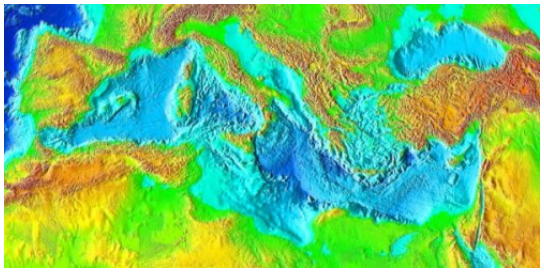
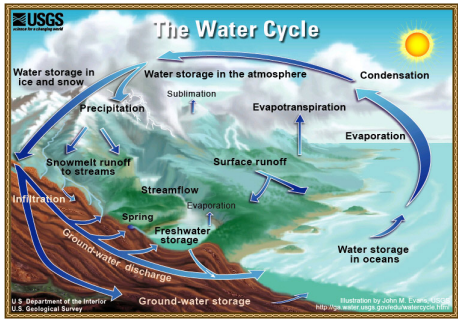
cnrs METEO FRANCE

HyMeX Motivations and Societal Stakes



A nearly enclosed sea surrounded by very urbanized littorals and mountains from which numerous rivers originate



⇨ **A *unique highly-coupled* (Ocean-Atmosphere-Land) *system***

⇨ **A region prone to *high-impact events* related to water cycle**

Heavy precipitation, flash-flooding during fall

Strong winds, large swell during winters

Droughts, heat waves, forest fires during summers

⇨ ***Water resources: a critical issue***

Freshwater is rare and unevenly distributed in a situation of increasing water demands and climate change (180 millions people face water scarcity)

⇨ **The Mediterranean is one of the two main *Hot Spot regions* of the *climate change***

Large decrease in mean precipitation, increase in precipitation variability during dry (warm) season, large increase in temperature (+1.5 to + 6°C in 2100*)*

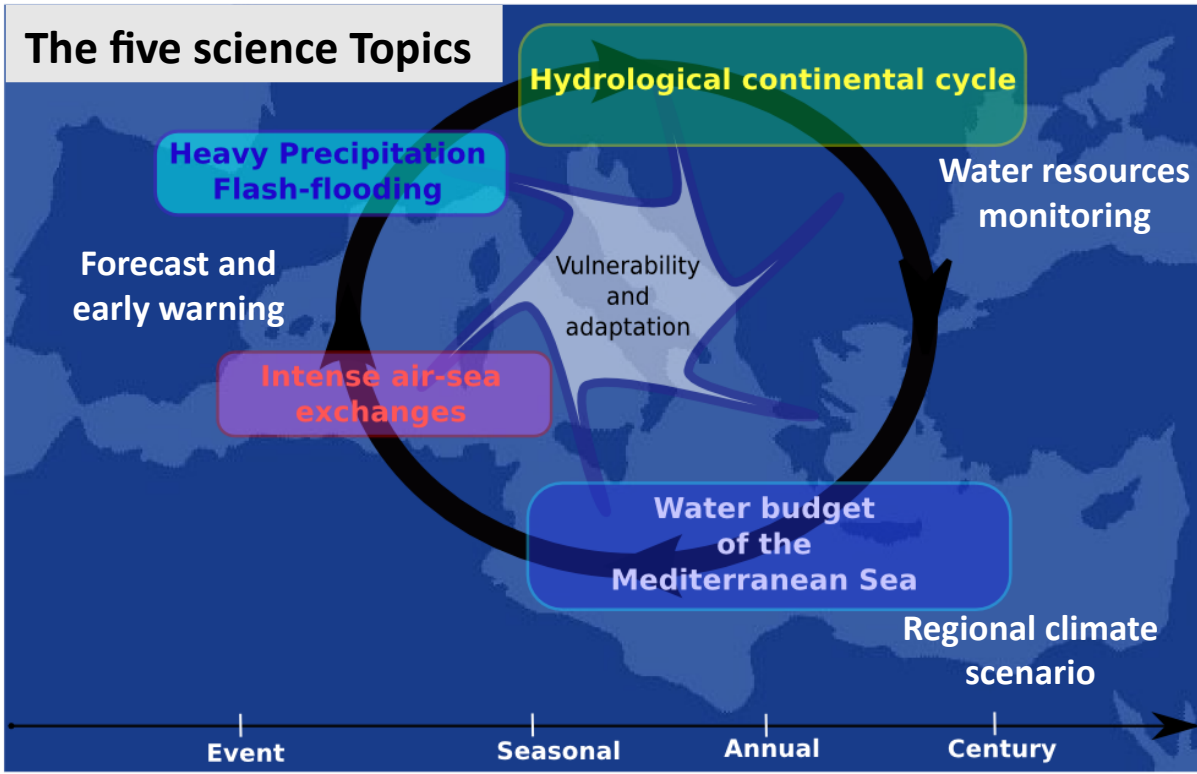
⇒ **Need to advance our knowledge on *processes related to water cycle within all Earth compartments*, to progress in the *predictability of high-impact weather* events and their evolution with *global change*.**

HyMeX Objectives & Science Topics

➲ to improve our understanding of the *water cycle* with emphases on the *predictability* and *evolution* of *intense events*

⇨ by monitoring and modelling the Mediterranean *coupled system* (atmosphere-land-ocean), its *variability* (from the event scale, to the seasonal and interannual scales) and characteristics over *one decade (2010-2020) in the context of global change*

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



Drobinski et al (BAMS, 2014)

HyMeX people & endorsement

- Scientists from ~15 countries contribute to HyMeX objectives (France, Italy, Spain, Germany, Switzerland, Croatia, Greece, Netherlands, Israel, Tunisia, Morocco, USA, Turkey, Bulgaria, Serbia,…)

- Many young scientists: > 55 PhD (incl. on going)

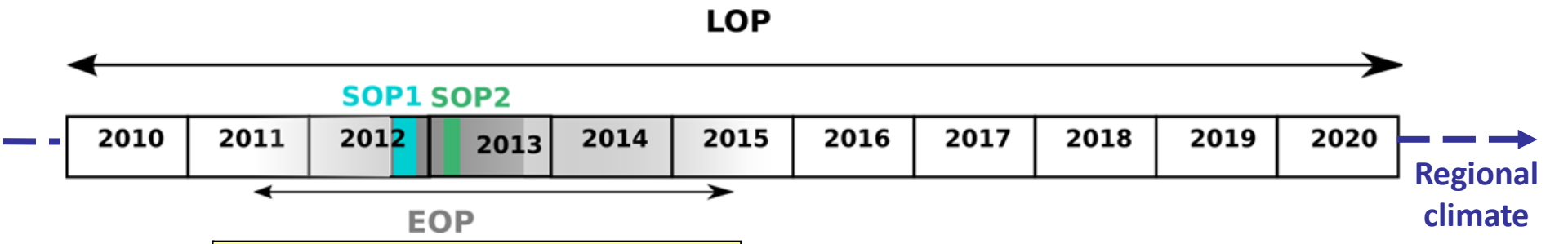
- ~ 500 registered users of the MISTRALS/HyMeX database

- HyMeX is endorsed by WWRP and WCRP (GEWEX, CORDEX) of WMO and is supported by national and european agencies through dedicated projects (MISTRALS/HyMeX, ENVI-MED, ANR IODA-MED/ FLOODSCALE/ ASICS-MED/ REMEMBER/ MOBICLIMEX/ MUSIC, FEDER CORSICA, FP7 EARTH2OBSERVE/ CLIMRUN/ DRIHM, DESERVE…)

HyMeX Observation Strategy

A « Nested » approach to tackle the whole range of processes and interactions and to estimate budgets

SOP: Special observing periods of high-impact events in selected regions of the EOP target areas (aircraft, R/V, balloons,…): *process studies*



EOP: Enhanced existing observatories and operational observing systems in the target areas of high-impact events: *budgets and process studies*

LOP: Current operational observing system and observatories over the whole Mediterranean basin: *budgets*

(data access)

EOP (in 2016) in Central and Eastern Mediterranean is under consideration

Precipitation variability (aerosol-cloud interaction) & water resources

HyMeX Model-Observations Strategy

Seasonal and interannual variability

Process Understanding

Observations

Models

LOP/EOP observations
SOP/EOP field campaigns

Model Validation

Improvement of model parameterizations

Data assimilation in cloud/precipitation

Regional Earth System models

Convection-permitting ensemble hydrometeorological prediction systems

Mesoscale (incl. land surface) data assimilation

- ✓ quantify and reduce uncertainties of the future climate projections,
- ✓ advance the modeling of the continental hydrological cycle and the monitoring of water resources and droughts
- ✓ improve the prediction capabilities of high-impact events by developping convective-scale ensemble hydrometeorological forecasting systems and mesoscale data assimilation

HyMeX

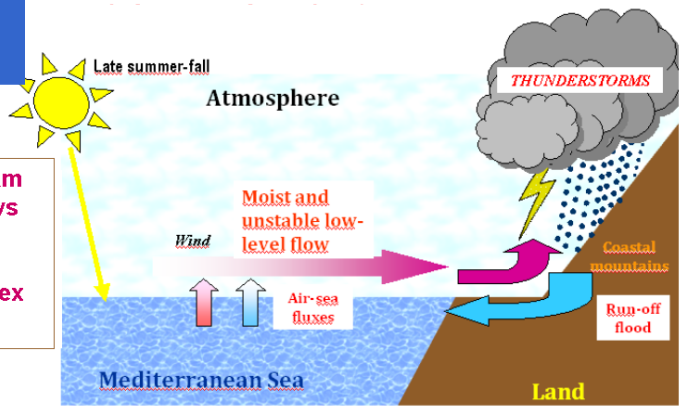
2012-2013: two major field campaigns in NW Med (SOP1 & SOP2).

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

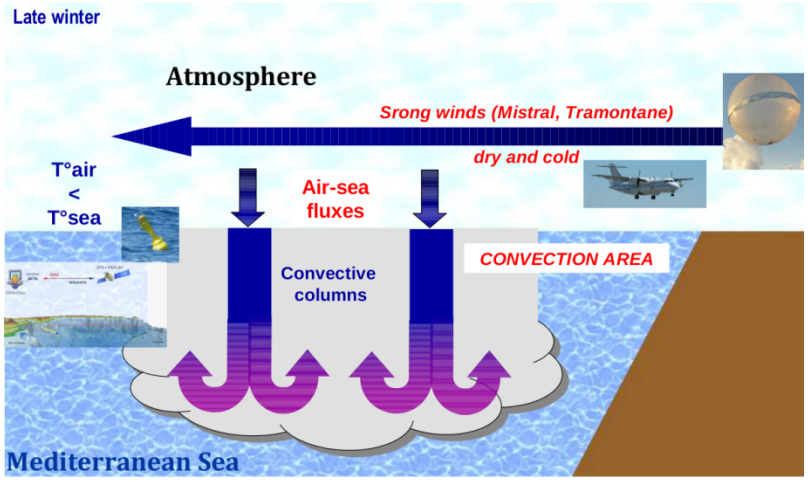


The distributed hydrological response of the Mediterranean watersheds

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

Ducrocq et al (2014)

SOP2 (27 Jan - 15 March 2013)



Strong winds Atm fluxes

Air-sea interface

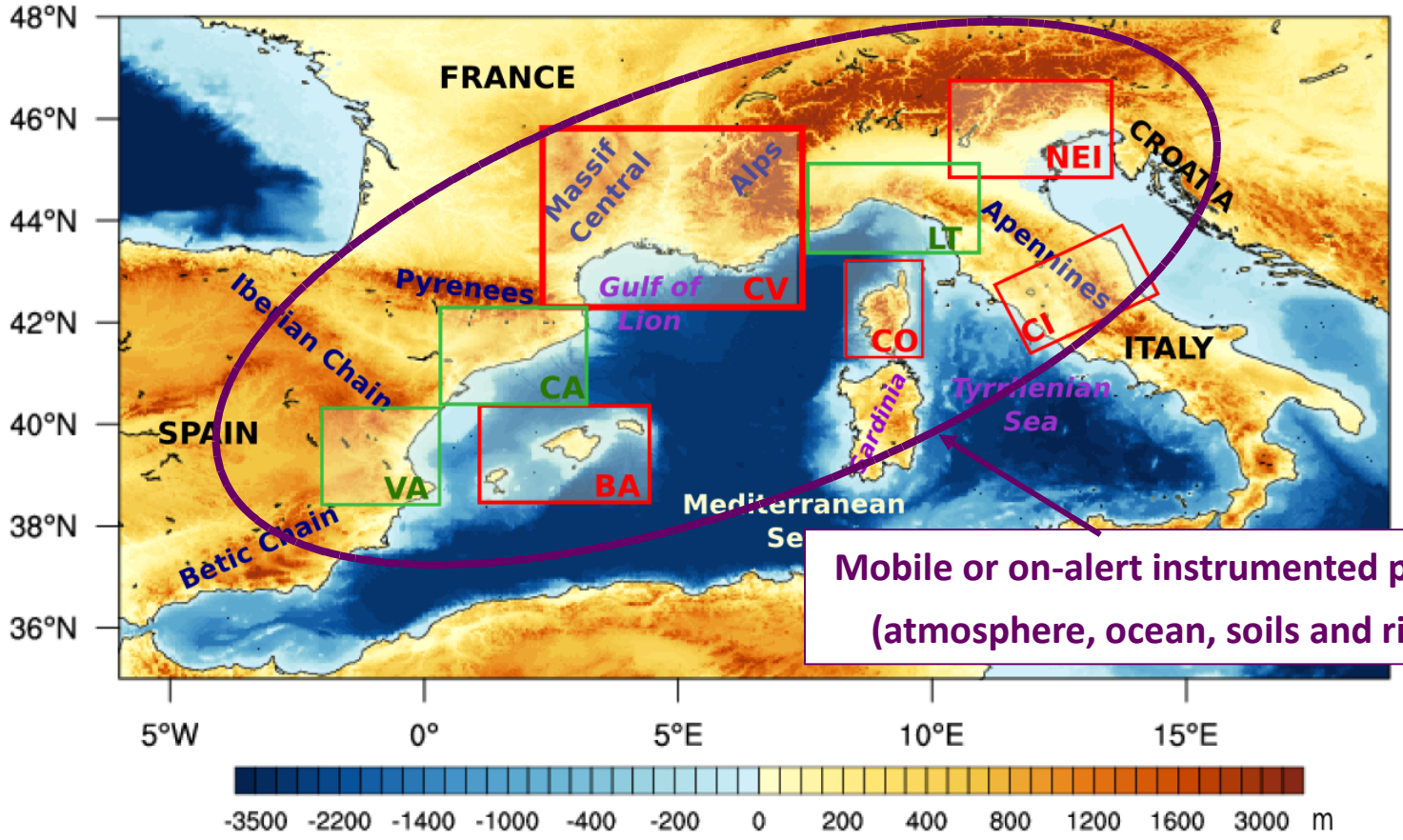
Marine response

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

Estournel et al (2014)

HyMeX SOP1 domain and sites

A large field campaign over the whole Northwestern Mediterranean

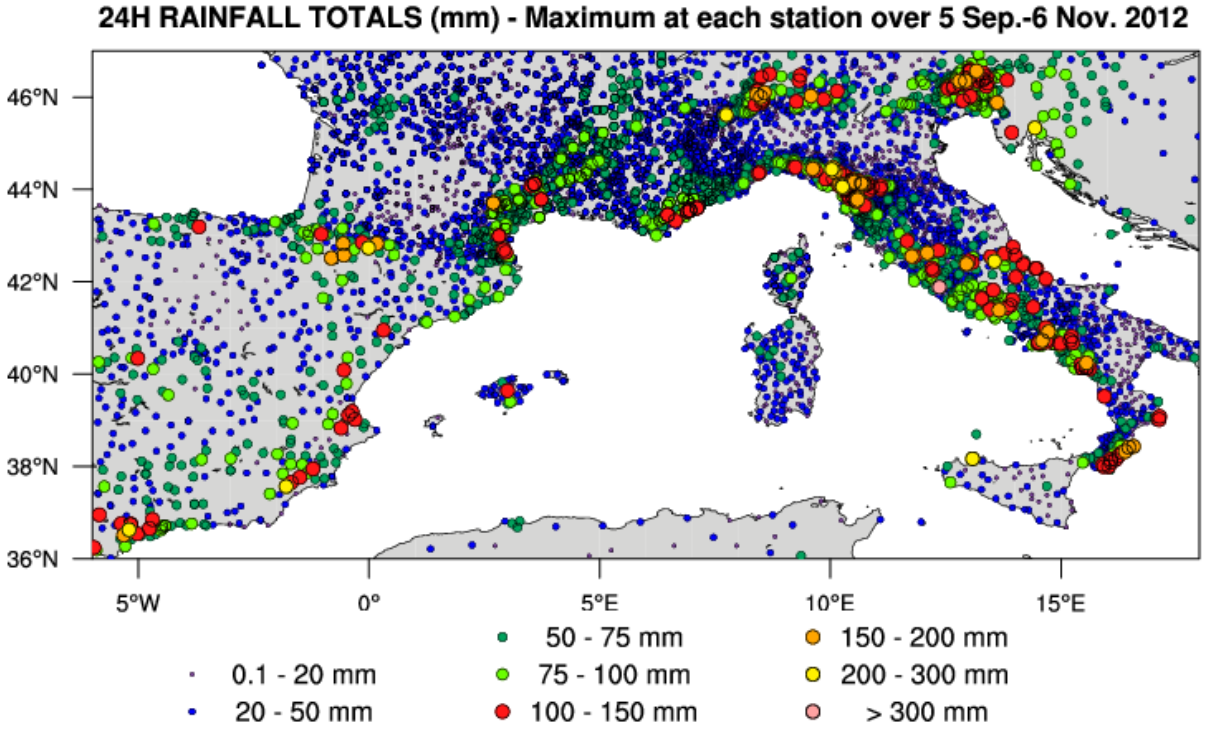


~200 instruments deployed for the field campaign, ~300 scientists involved in the field campaign

Ducrocq et al, 2014 (BAMS)

HyMeX Heavy precipitation events

Maximum of daily precipitation at each raingauge during SOP1 (5 sep.-6 nov. 2012)



20 days with at least one raingauge with more than 100mm/24h
16 IOPs dedicated to Heavy precipitation

Ducrocq et al, 2014 (BAMS)

HyMeX The Aircraft Missions

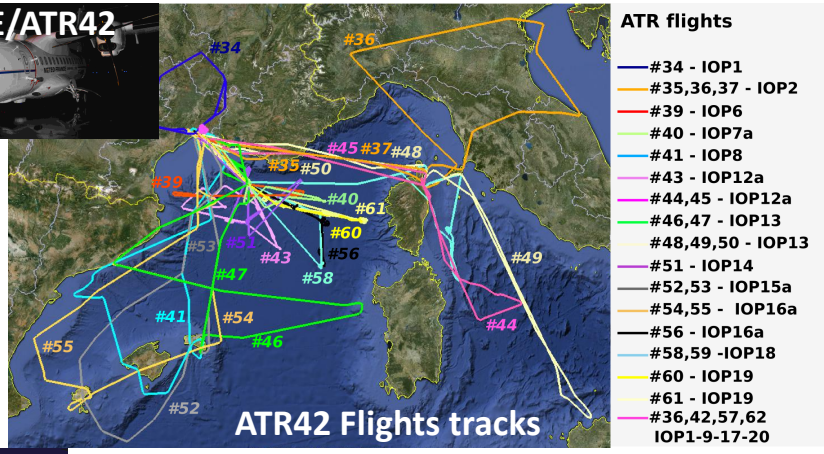
251 Flight hours:

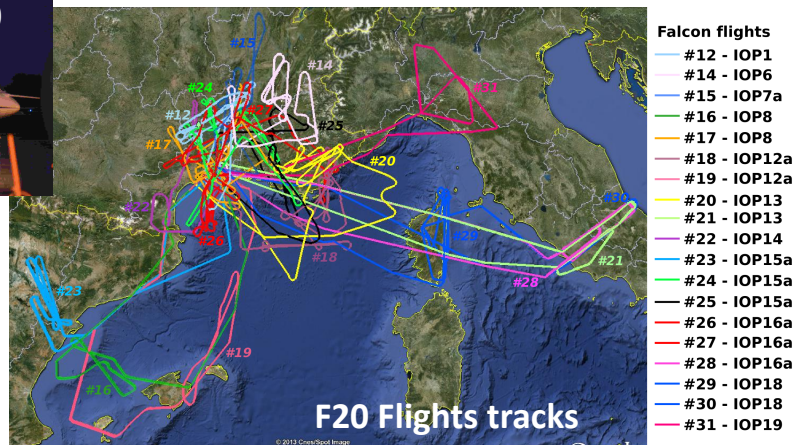
- **SAFIRE/ATR42: 87 h**
  Survey of the upstream flow
  Payload: WV Leandre II Lidar, aerosols, turbulent air-sea fluxes

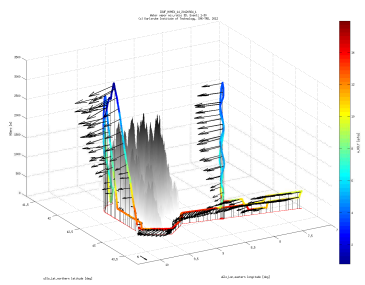
- **SAFIRE/F20: 69 h**
  Dynamics and microphysics within precipitating systems
  Payload: cloud radar, cold microphysics probes, dropsondes launched over the Sea

- **KIT/DO128: 95 h**
  over and offshore Corsica
  Payload: air-sea fluxes, stable water vapour isotopes

+ T-NAWDEX flights (1-20 Oct. 2013)







HyMeX Assimilation of airborne observations

AROME-WMED (Western Med.) developped for the real-time analyses and forecasts during the SOPs of HyMeX (Sept. 2012 – March 2013), archived in the MISTRALS/HyMeX database.

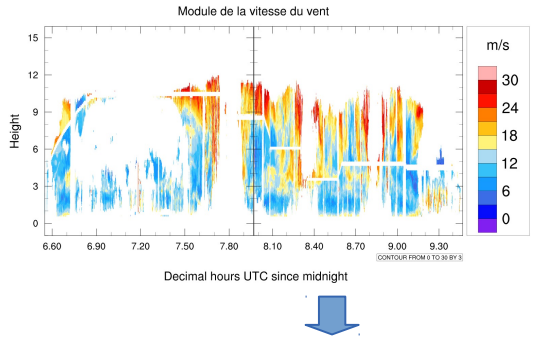
Based on the operational Météo-France AROME-France model, hor. resol=2.5 km,

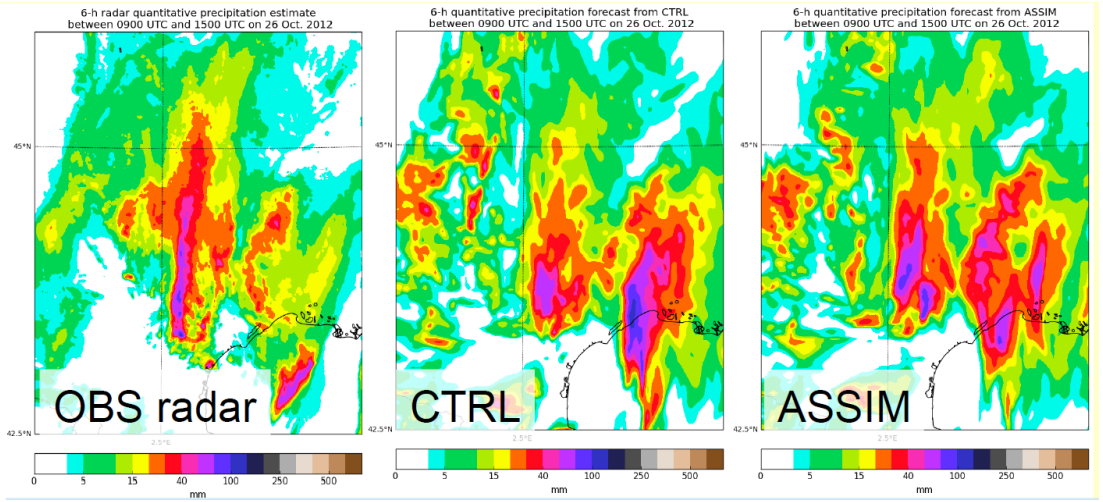
3-h data assimilation cycle

➲ **A tool for data assimilation researches**

Assimilation in AROME-WMED of RASTA Doppler winds

F20 flight 6UTC-9UTC, IOP16a



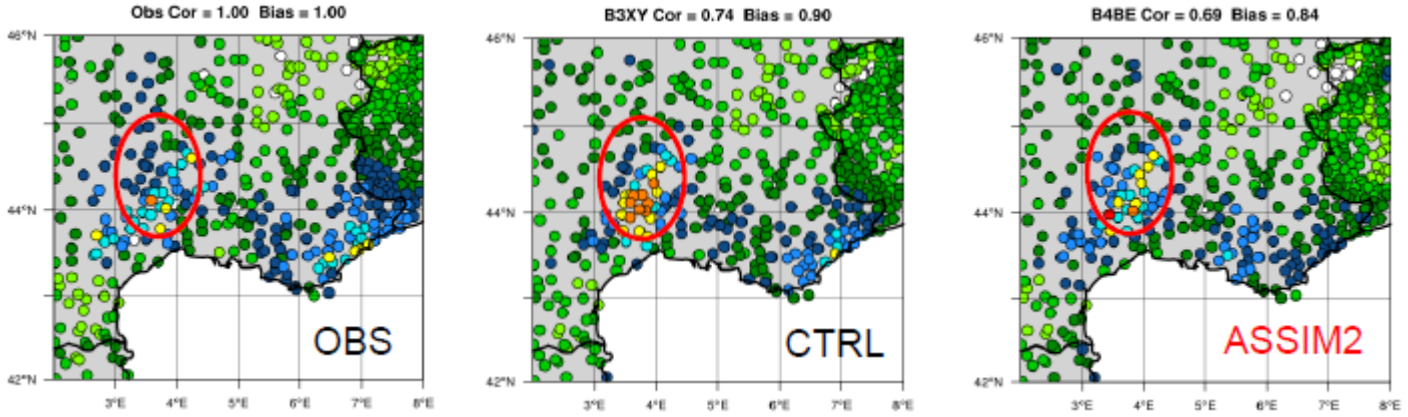


6-h accumulated precipitation 9UTC-15UTC, 25 Oct. 2012

Courtesy : O. Caumont

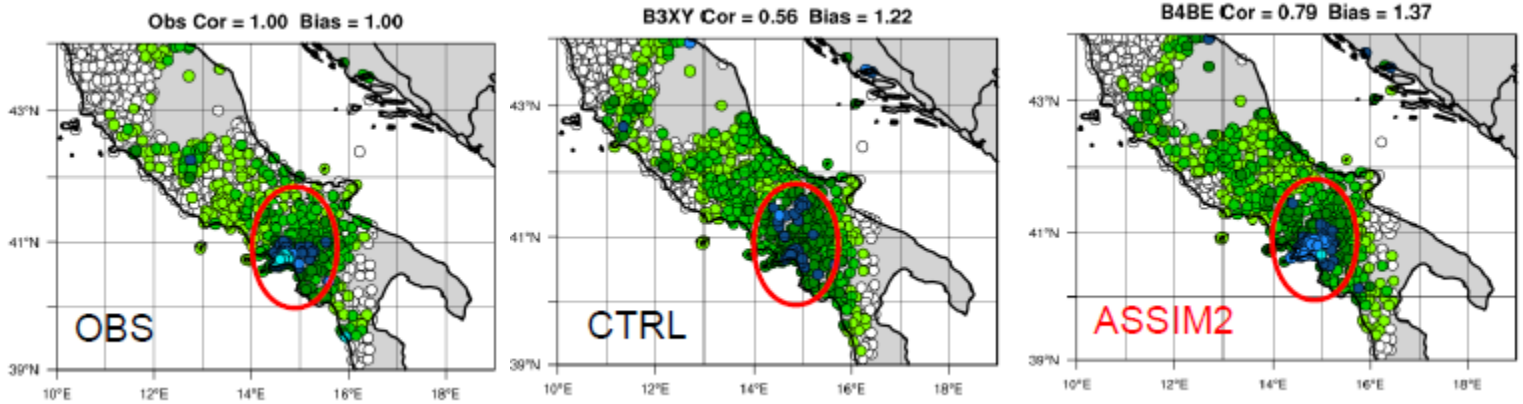
HyMeX Assimilation of airborne observations

Assimilation of airborne LEANDRE Water Vapour Lidar (ATR42) in AROME-WMED



6-h accumulated precipitation
0UTC-24UTC, 26 Oct. 2012

IOP16a
Strong reductition of the overestitimatition of the orographic precipitation



6-h accumulated precipitation
6UTC-12UTC, 13 Sept. 2012

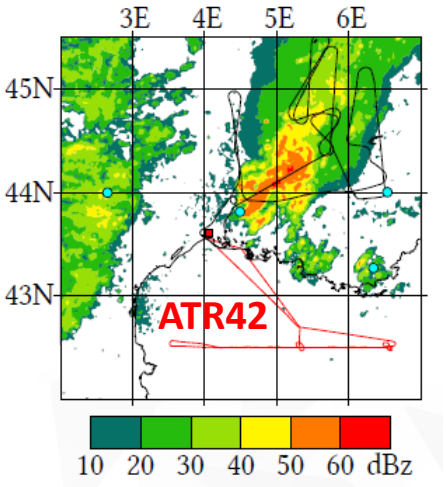
Better representation of the convective system

Richard et al (2014)

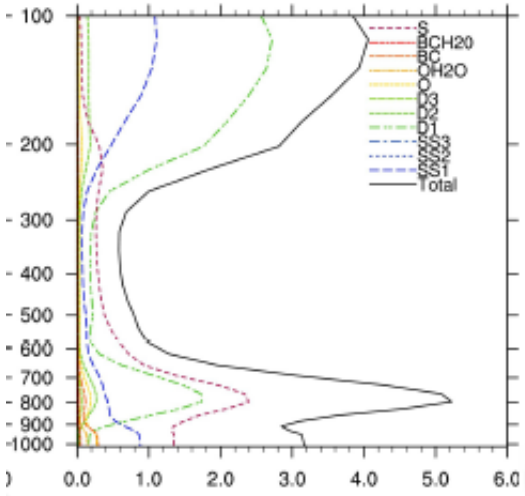
Validation of microphysical parameterization

- **2-moment, mixed-phase microphysical scheme in Meso-NH model (LIMA)**
  - **Explicit interactions between aerosols, clouds and precipitations**
    - ✓ CCN activation extended from Cohard and Pinty 2000 → cloud droplets
    - ✓ IN nucleation following Phillips (2008,2013) → ice crystals
  - **Prognostic evolution of a realistic aerosol population**
    - ✓ Multimodal (lognormal size distributions), 3D externally mixed aerosols
    - ✓ Distinction between several types of CCN / IN / coated IN

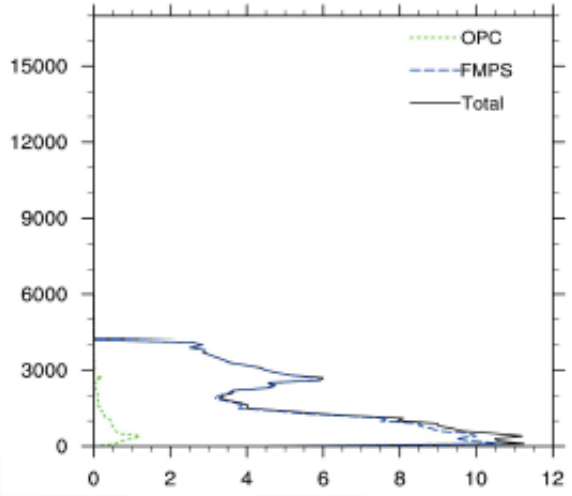
Validation of MACC analyses using ATR42 measurements



Vié and Pinty (2014)



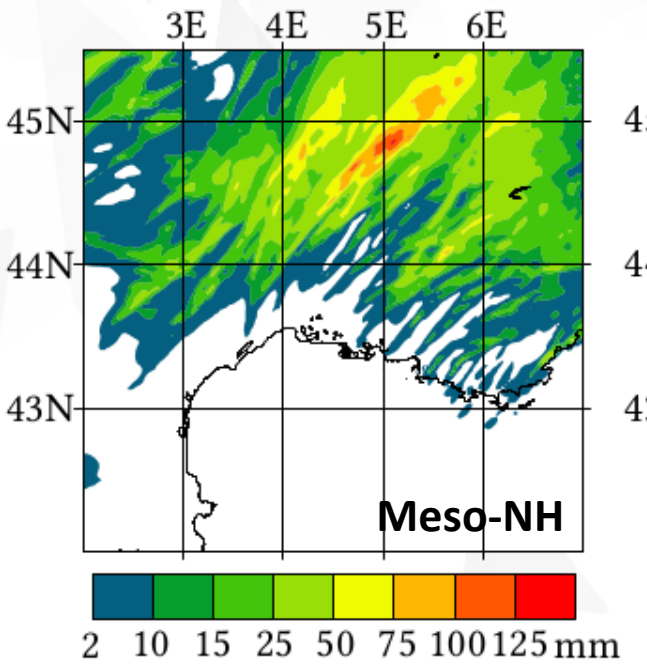
MACC without large and medium sea salt



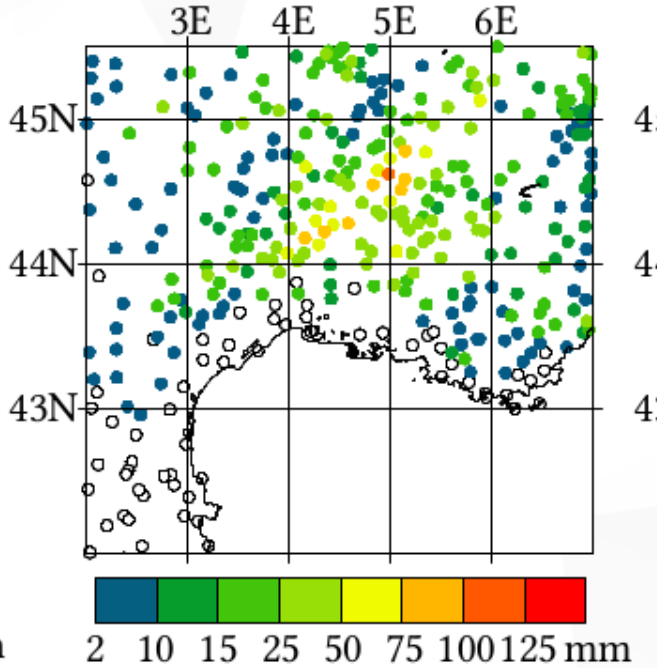
Computed from observations

Validation of microphysical parameterization

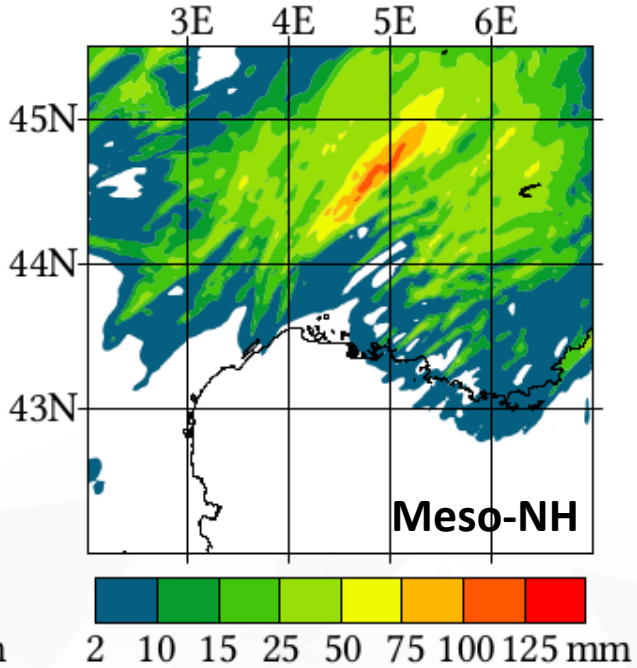
Southeastern France, 12-h accumulated precipitation (mm), 2012/09/24, 12 UTC (IOP6)



Default aerosol population



Raingauge observations

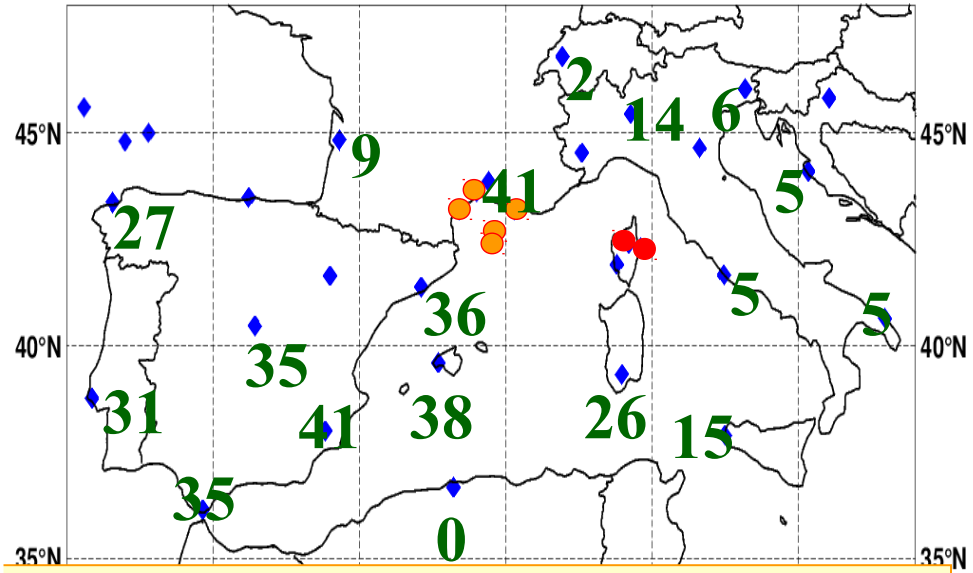


MACC aerosols

Vié and Pinty (2014)

HyMeX Radiosoundings and balloons

About 850 radiosoundings (research and oper. stations), most sent as TEMP BUFR messages to GTS



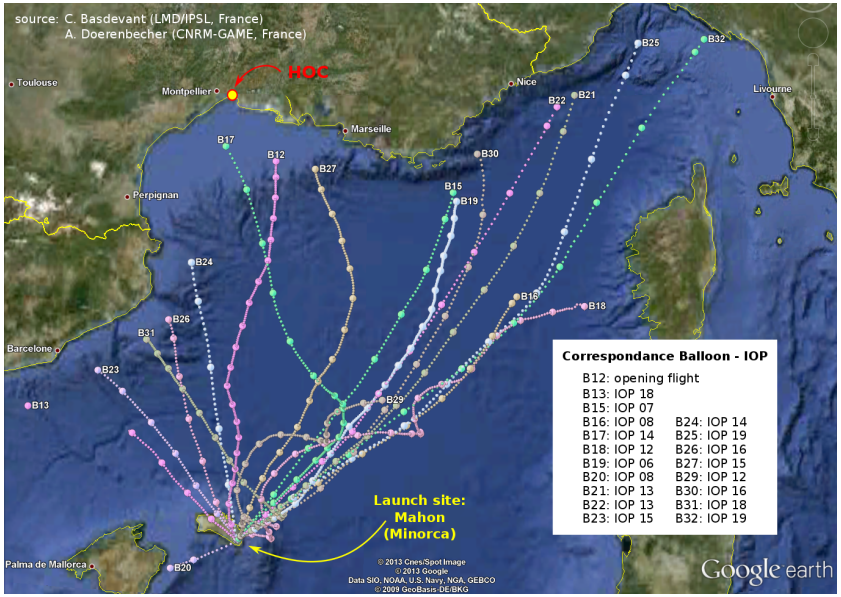
Blue: operational network

Orange: HyMeX research mobile radiosounding (CNRM)

Red: HyMeX research radiosounding (KIT)

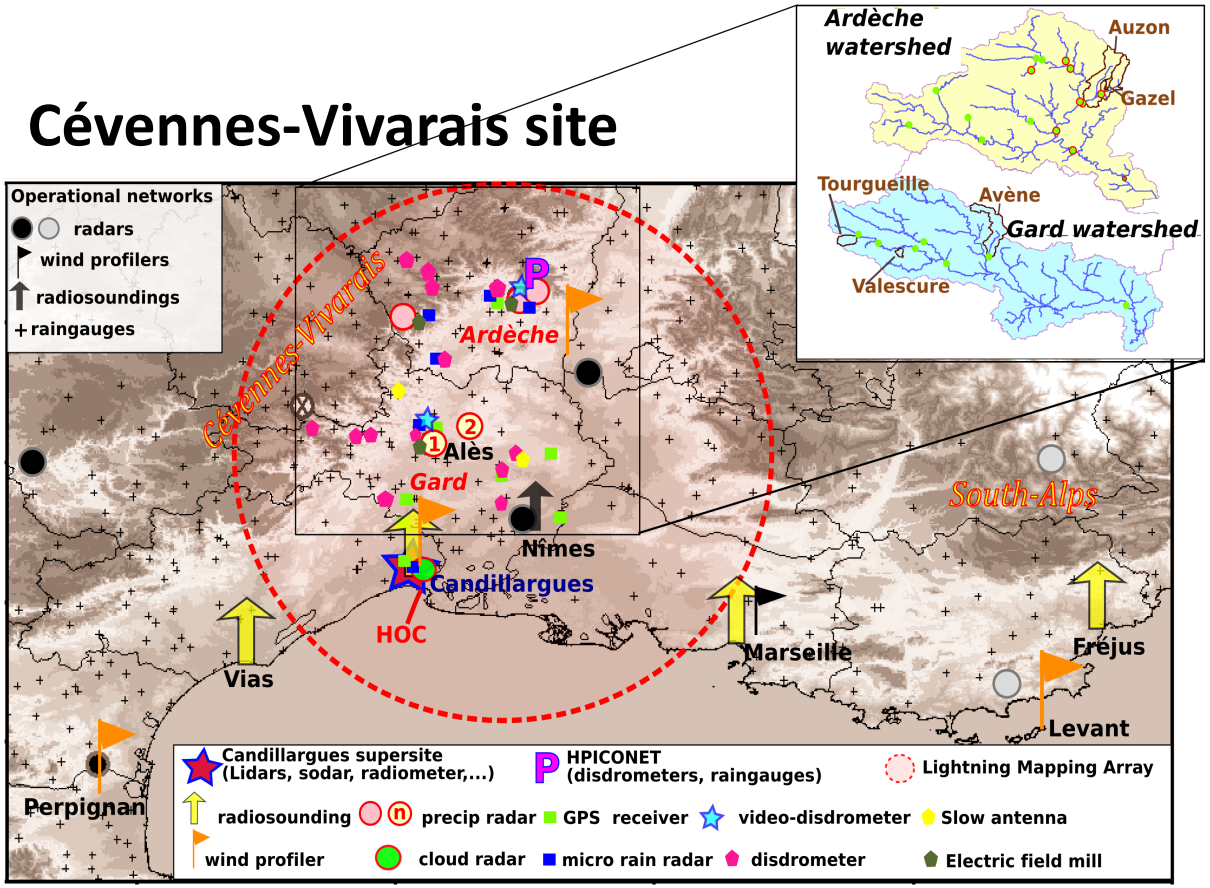
xx: additional DTSope soundings

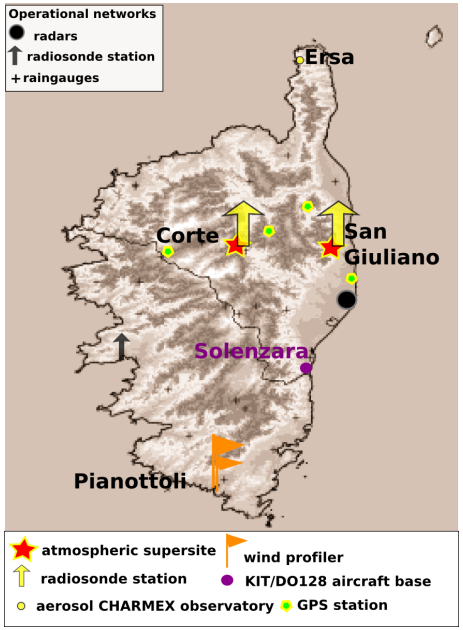
19 Boundary layer balloon launches from Menorca



HyMeX Instrumented Sites

Cévennes-Vivarais site

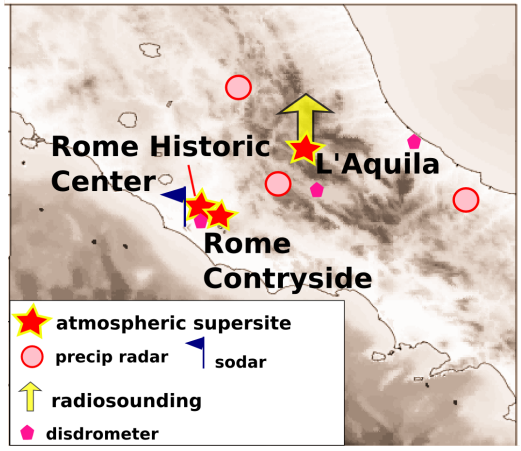




Corsica site

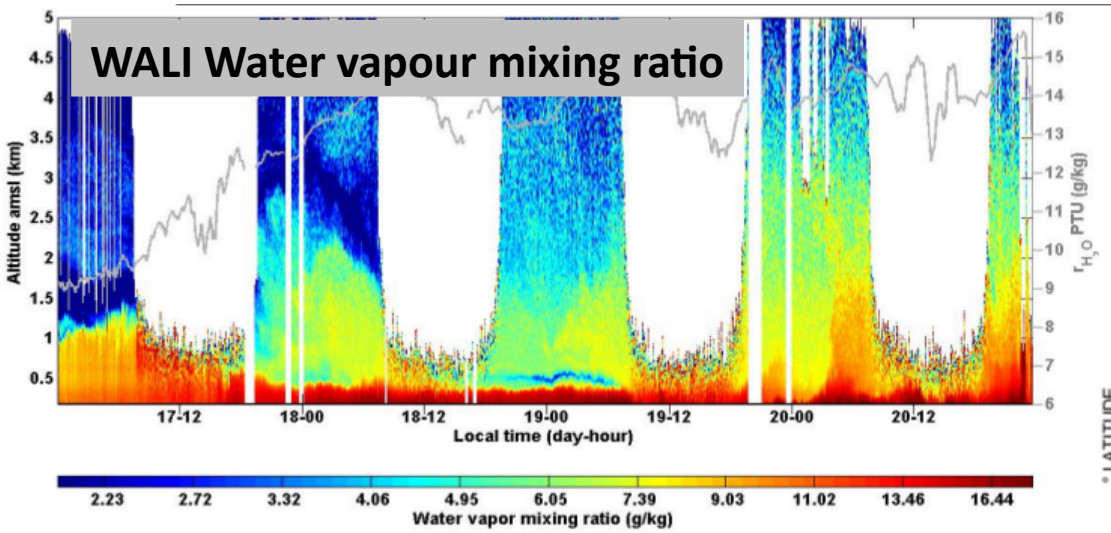
+ Northeastern Italy site and Menorca site

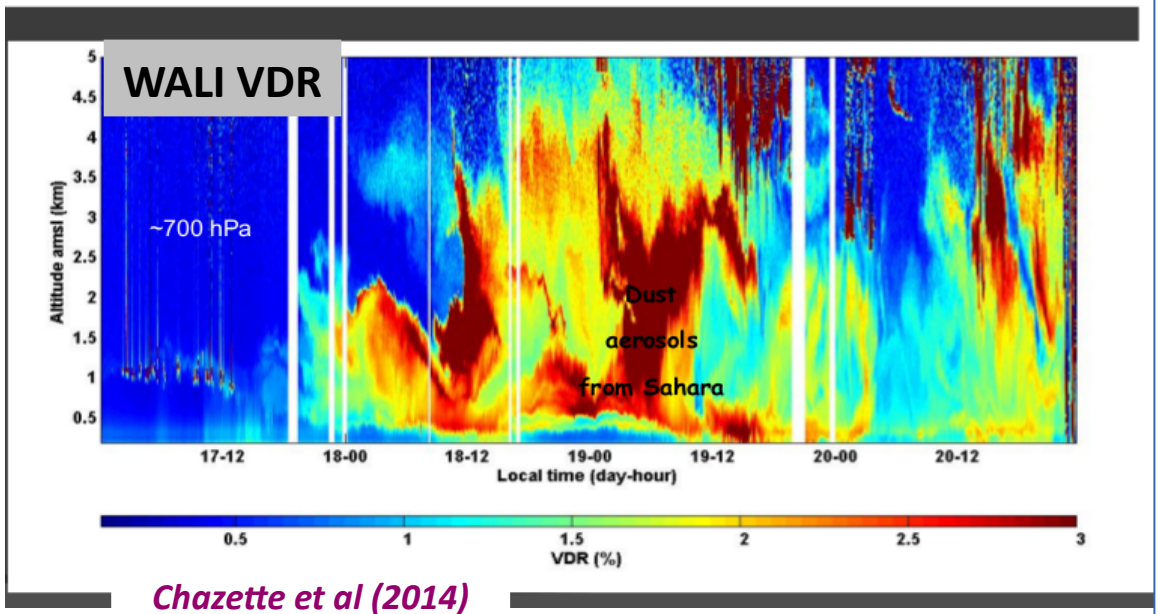
Central Italy site



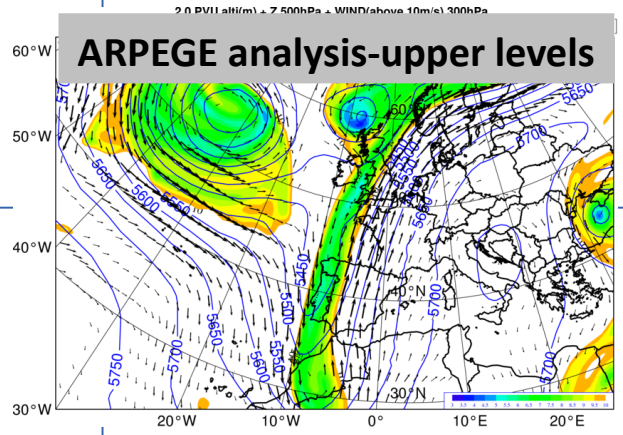
Example of observations from the WALI Lidar in Menorca

HyMeX

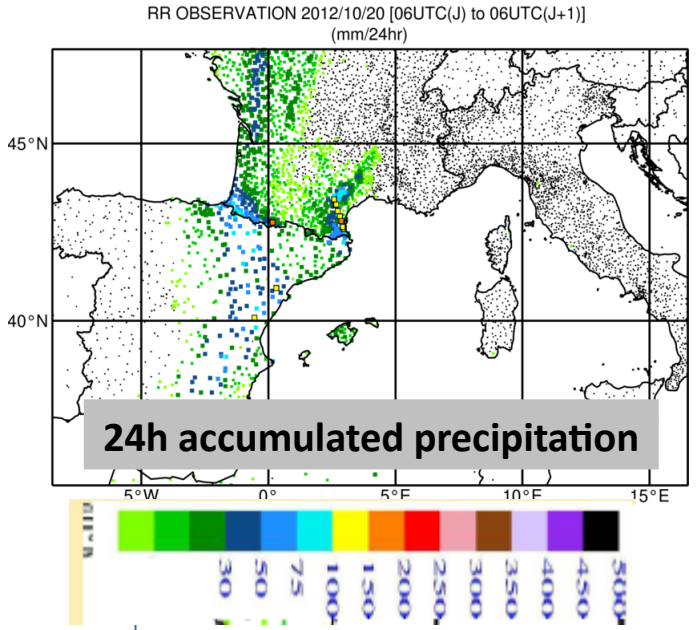




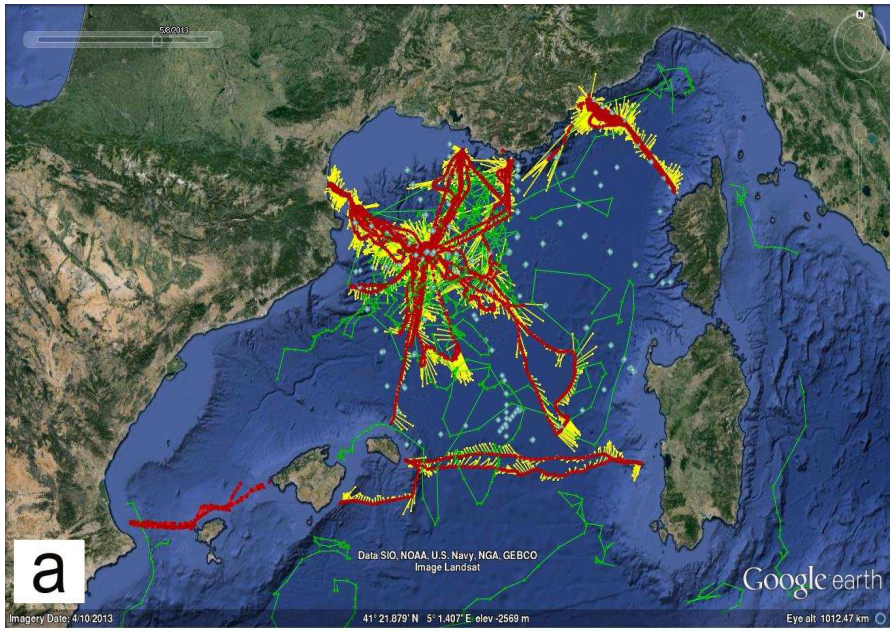
Chazette et al (2014)



20 Oct. 2012

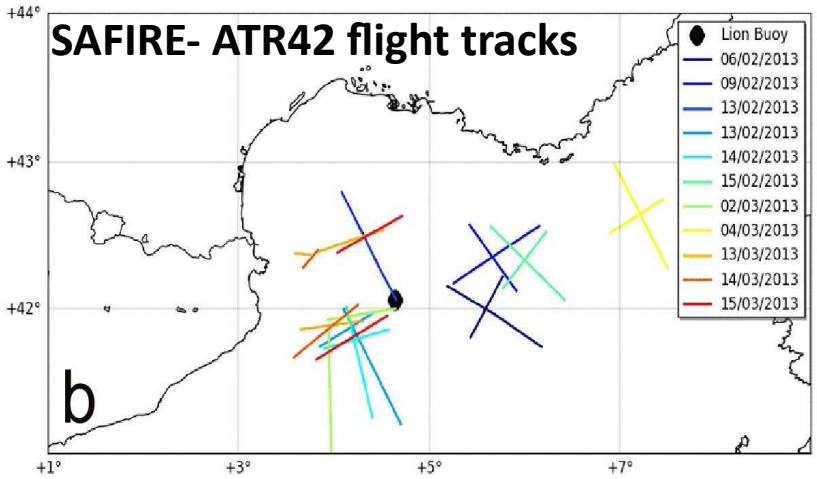


HyMeX SOP2 observations

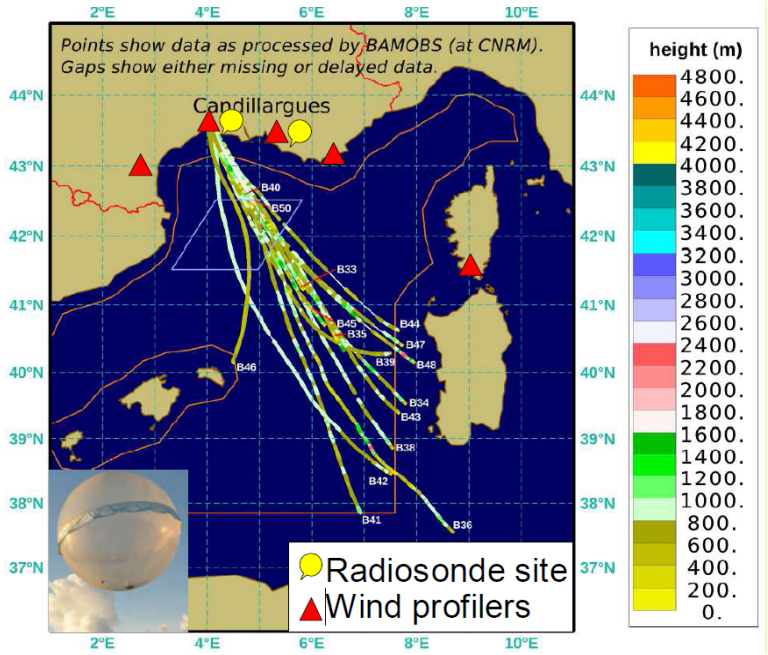


- Argo floats trajectories
- Gliders 7 Dec. 2012 – 8 May 2013
- CTDs

+ Marisondes and SVP buoys, fixed moorings and buoys



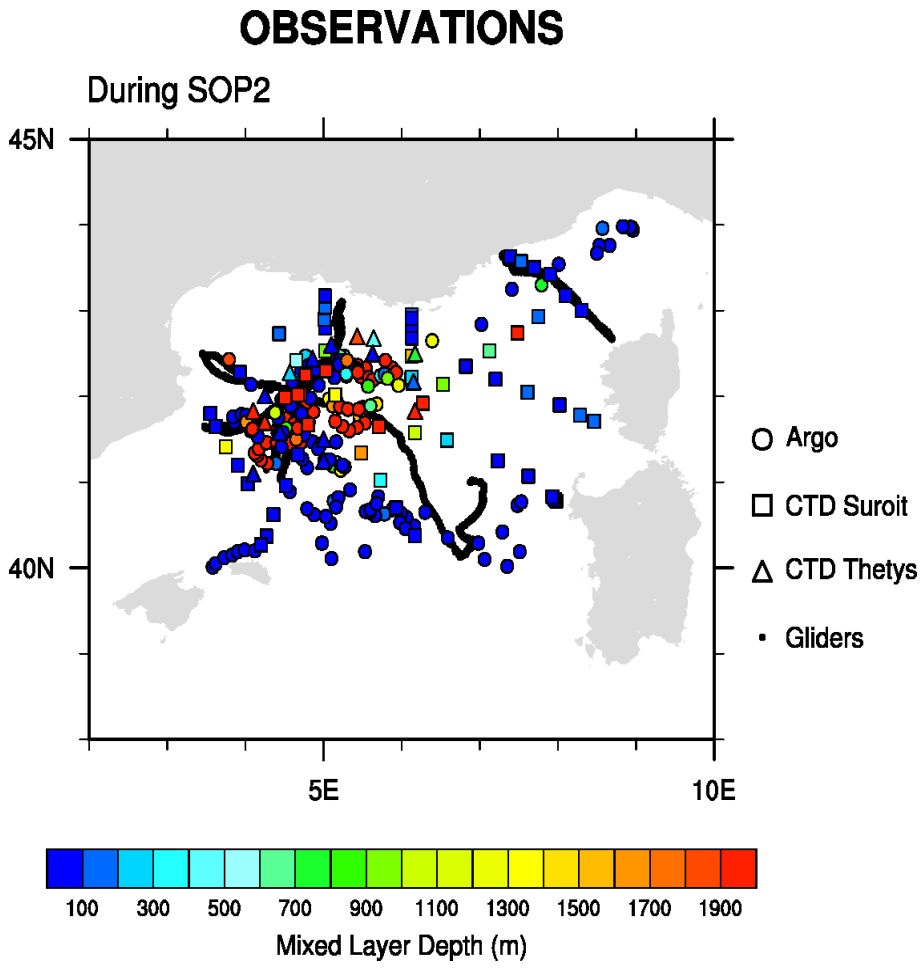
Boundary layer balloon trajectories

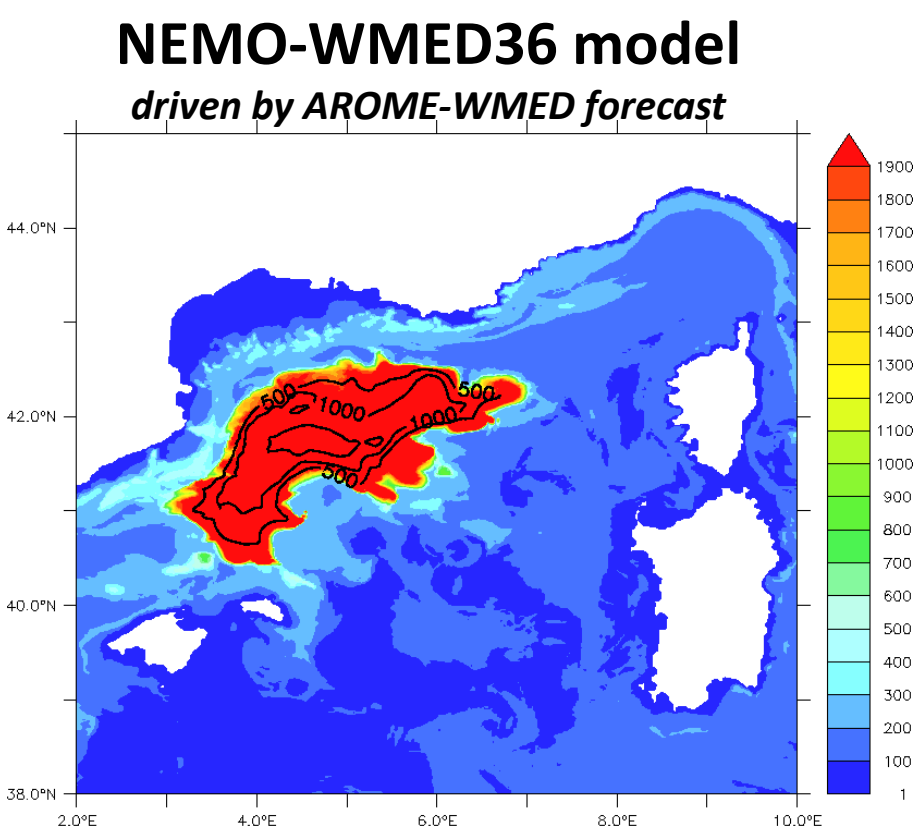


Estournel et al (2014)

Example of model validation using SOP2 observations

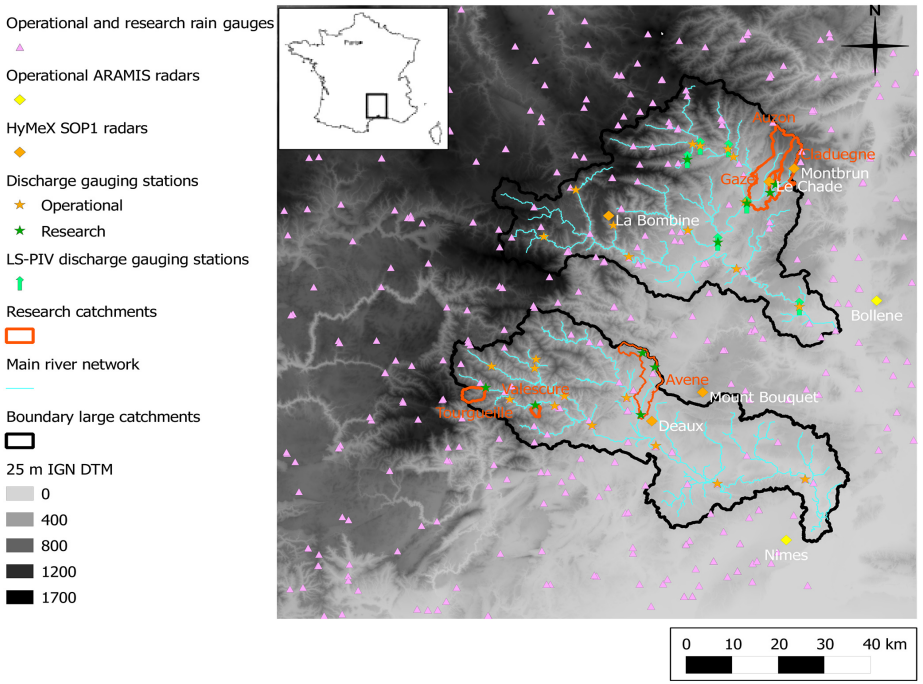
Ocean mixed layer depth

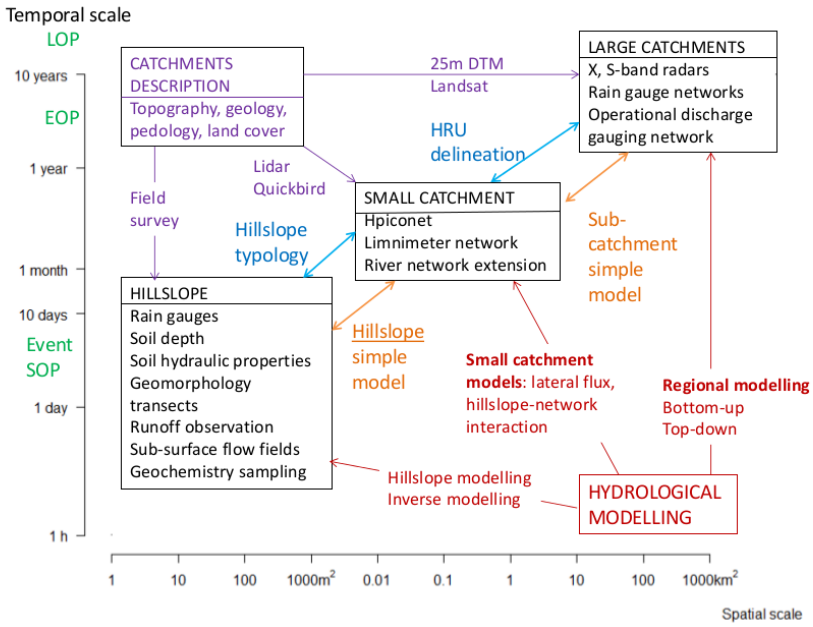




Lebeaupin-Brossier et al (2014)

EOP: Hydrological measurements over Gard and Ardèche catchments





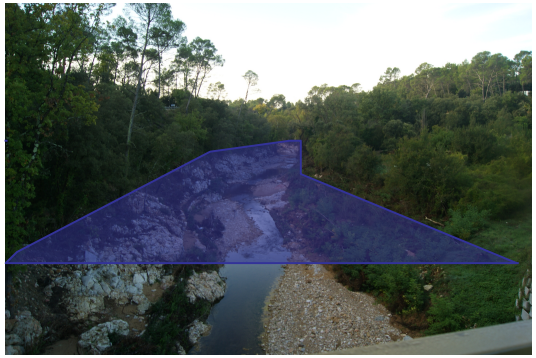
21-23 oct. 2013

Routine and on alert measurements each autumn since 2012

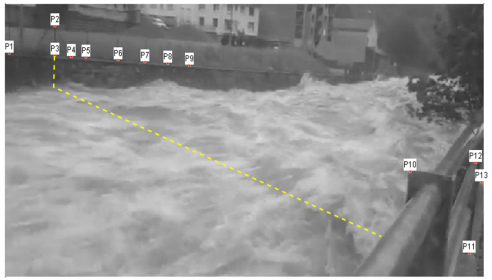
Braud et al, 2014

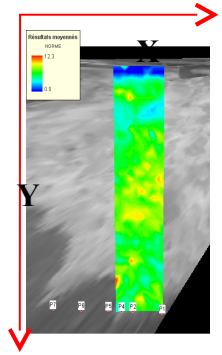
LOP: Intensive Post-event Campaigns (IPEC)

- Collation of rivers cross sections data with flood mark levels
- Interviews of eyewitnesses for information on dynamics of the flood and confirmation of flood levels
- Research and exploitation of videos for estimation of flow velocities



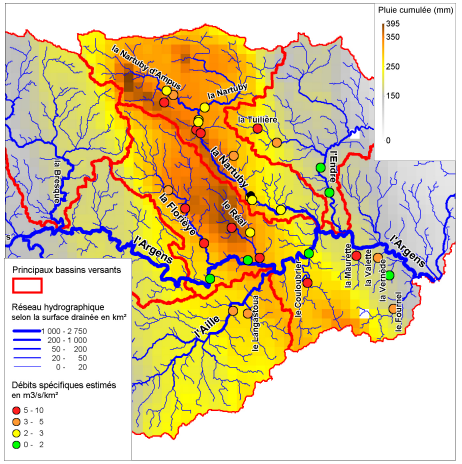
(source: R. Le Boursicaud)





Results :

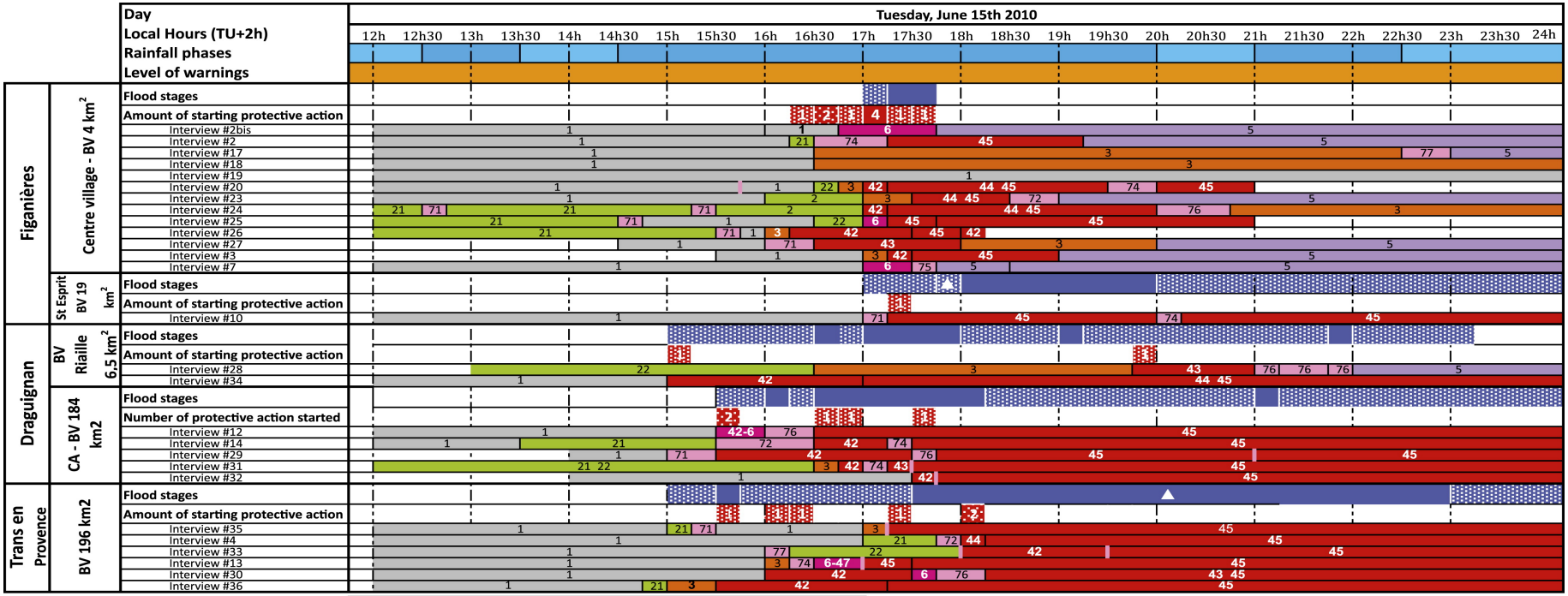
- Estimation of peak discharge on ungauged rivers
- Information on flood peak time



Example of Var event 2010:
36 peak discharges estimated

Courtesy : O. Payrastre

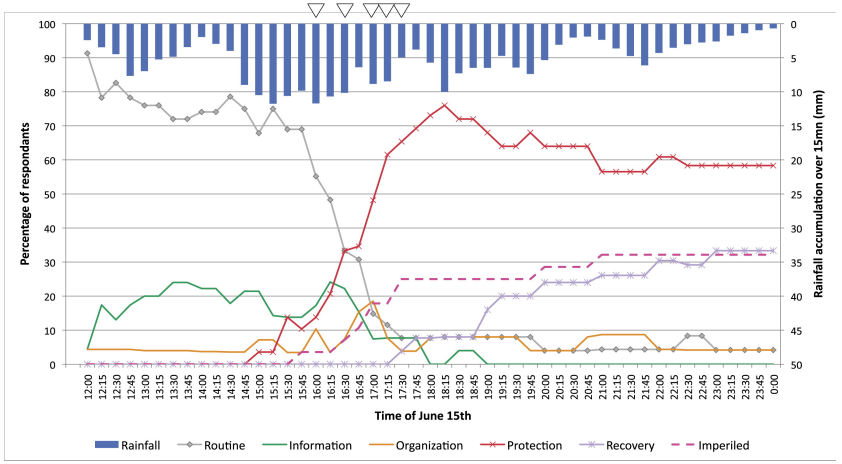
LOP: Intensive Post-event Campaigns (IPEC)



Collection and analysis of data about crisis behavioral responses during flood events

Ruin et al (2014)

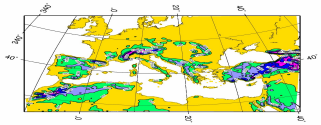
Rainfal phases		Medium intensity
		High intensity
Weather warning stages		Météo France orange vigilance (3rd level over 4)
Flood stages (CETE HWM)		Few observation of flooding stage
		Observation on Peak flow
REX-Hydro (Gaume et al.)	△	Peak discharges simulation
Social phases of activity		**1 Routine**
		2 Information
		21 Incoming info
		22 Outgoing info
		3 Organization
	4	**4 Protection**
		41 Adapt/Cancel activity
		42 Goods protection
		43 Rescue/help someone
		44 Climb upstairs
		45 Shelter
		46 Evacuation
		47 Be rescued
	5	**5 Recovery**
	6	**6 In danger**
	7	**7 Travel**
		71 Travel usual
		72 Travel info
		73 Travel vigilance
		74 Travel protection
		75 Travel recovery
		76 Dangerous travel
		77 Adapted travel



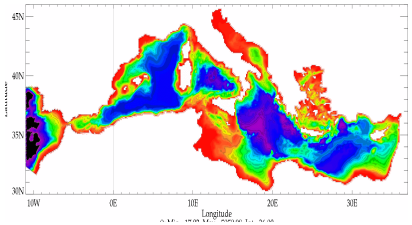
Joint HyMeX & WCRP/MedCORDEX regional climate modelling

HyMeX

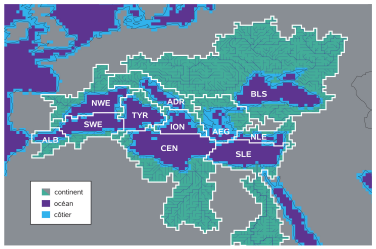
12km - atmosphere



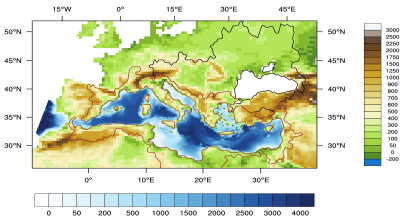
10km - ocean

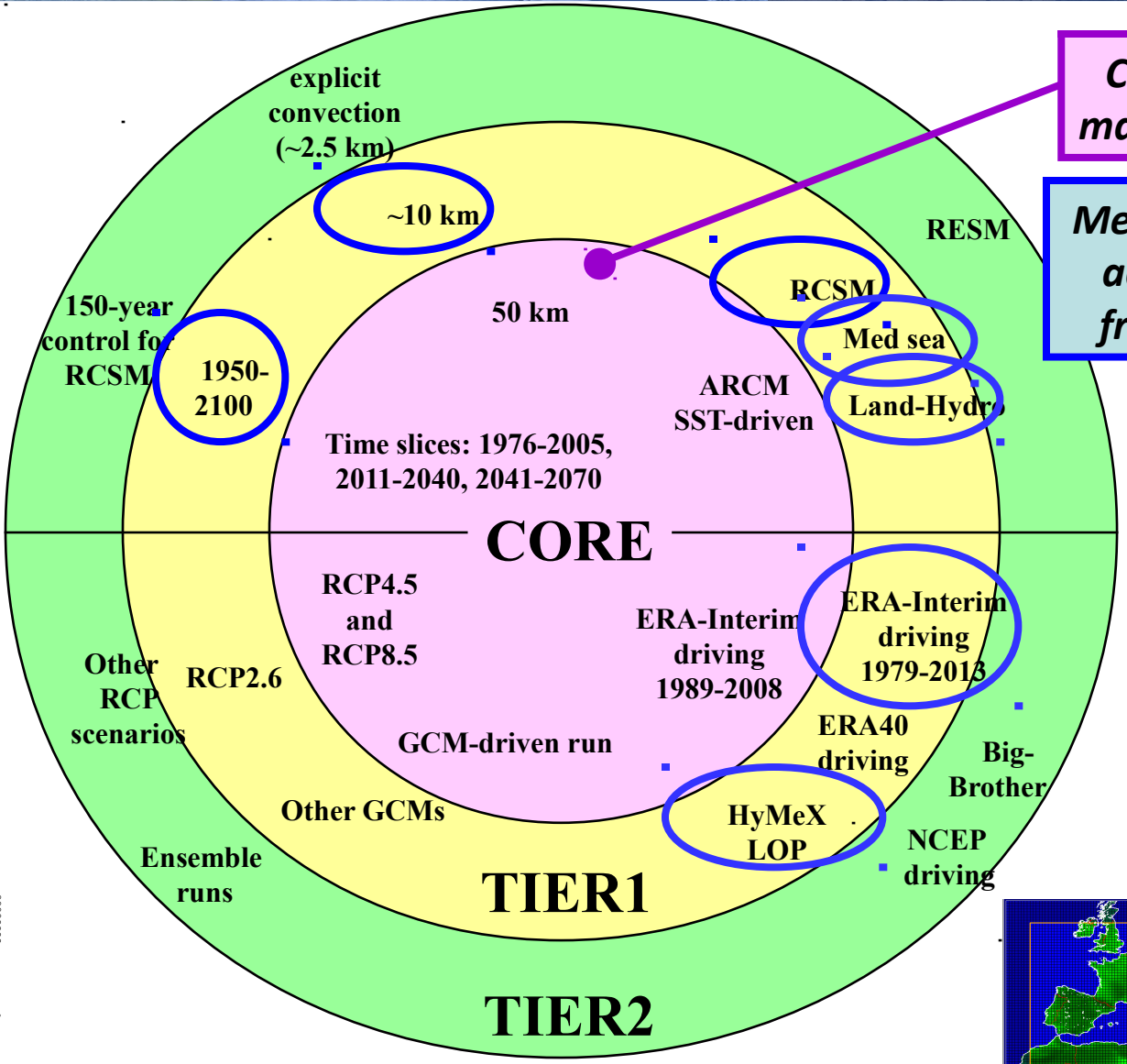


50km – river



RCSM





CORDEX mandatory

Med-CORDEX additional framework

Courtesy: S. Somot

HyMeX

MEDCORDEX Core runs

MedCORDEX - CORE simulations Atmosphere-RCM: MED-44 (50km, 0.5°)				ERAI	ERA40	HIST	RCP8.5	RCP4.5
				1979-now	1958-2001	1950-2005	2006-2100	2006-2100
RUN	institute	model	resol.					
	ITU	RegCM4	50km	1989-2008		1971-2005	2006-2100	
	ENEA	RegCM3.1	30km	1982-2010	1958-2001			
	ICTP	RegCM4.3	50km	1979-2008	1958-2001	1970-2005	2006-2100	2006-2100
	MPI	REMO	50km	1989-2008	1958-2001			
	CNRM	ALADIN5.2	50km	1979-2012	1958-2001	1950-2005	2006-2100	2006-2100
	LMD	LMDZ	30km	1979-2009	1958-2001			
	Univ. Belgrade	EBU	50km	1989-2008				
	IPSL	WRF3.1.1	50km	1989-2008				
	UCLM	PROMES	50km	1989-2008				
	GUF	CCLM4-8-11	50km	1989-2008				
	GUF	CCLM4-8-18	50km	1979-2011		1950-2005	2006-2100	
	CMCC / U. of Salento	CCLM4-8-19	50km	1979-2012		1950-2005	2006-2100	2006-2100
	BSC	NCEP NMMB	50km	1989-2008				

unknown | planned | done | archived

*: 1979-2008, planned

Coordinated analyses

Model evaluation - Variability study - Process study - Scenarios

- Statistics on precipitations and HPEs
- Droughts and heat waves
- Strong wind over land
- Intense sea wind and strong air-sea fluxes
- Dense Water Formation (G.of Lions)
- Eastern Mediterranean Transient (Aegean)
- Mediterranean cyclones, Medicanes
- Water vapor and cloud evaluation
- Med Sea Water/Heat Budgets (incl. straits, aerosols, clouds, heat and salt content)
- Sea level
- Coastal/Island climate (incl. coastal breeze)
- River flow

- Regional ocean/land reanalysis

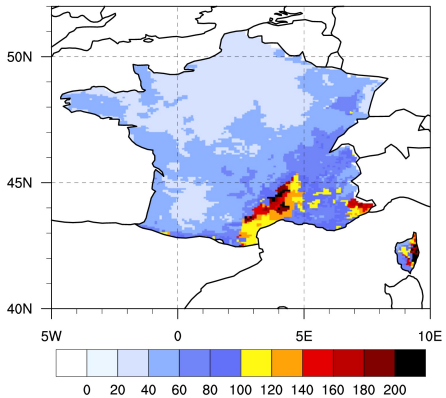
12-km RCM added value for simulation of heavy precipitation

Maps of 99.9 quantiles of daily precipitation over France (30 years, SON, mm/d)

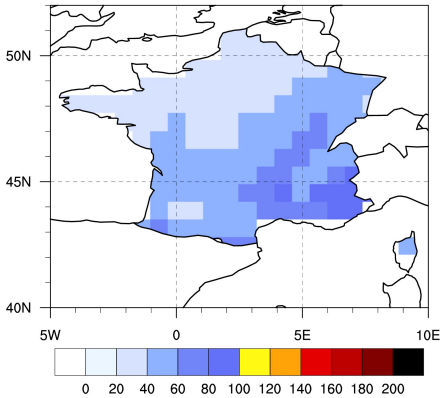
Model: ERA-Int (1980-2009), CNRM-CM5 (1976-2005), ALADIN-Climate

Obs: SAFRAN, gridded analysis, 8km

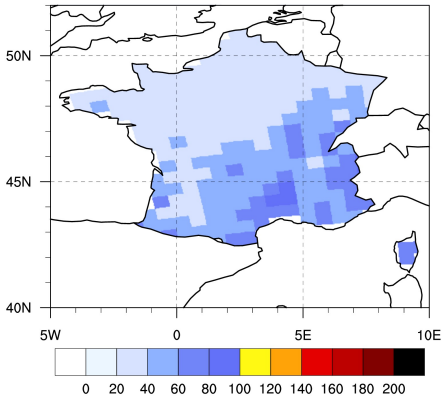
OBS - 8km



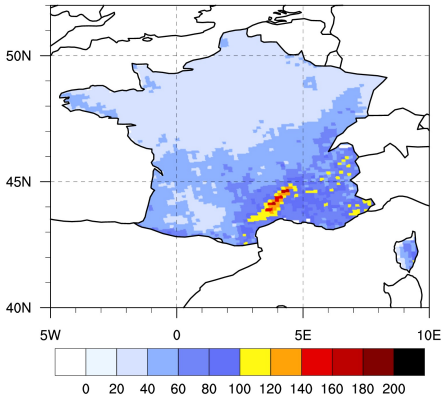
ERAInt - 80km



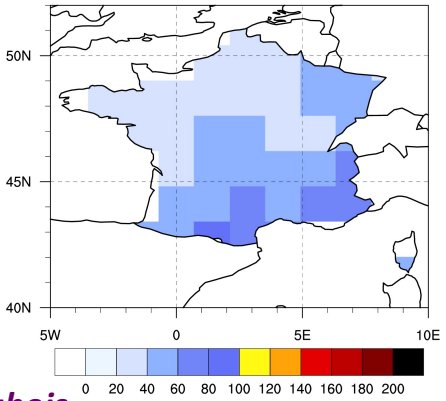
RCM50km - ERAInt



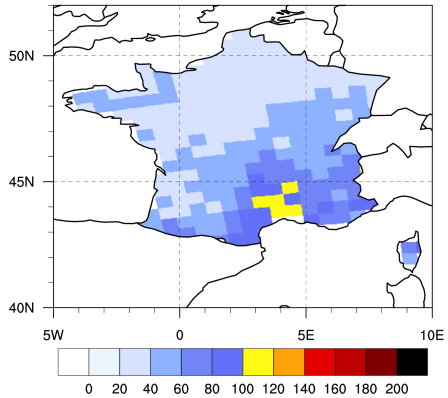
RCM12km - ERAInt



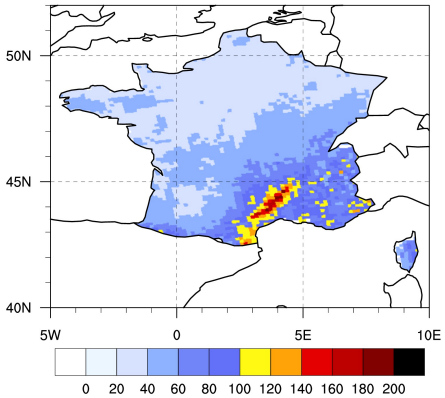
CNRM-CM5 - HIST-150km



RCM50km - HIST



RCM12km - HIST

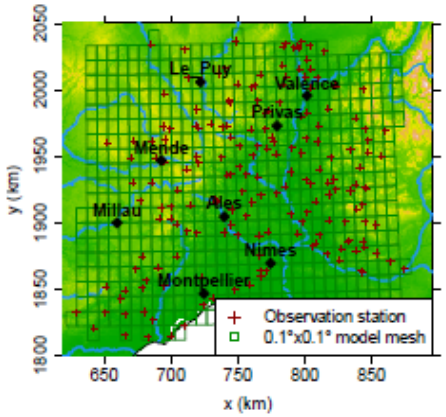


Courtesy: FP7-CLIM-RUN, C. Dubois

Evaluation over Southeastern France - heavy precipitation

HyMeX

Hourly stations

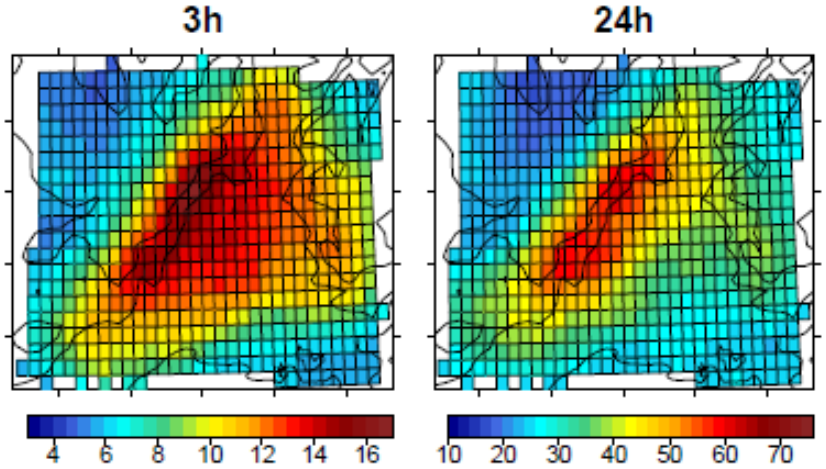


SON 1993-2013

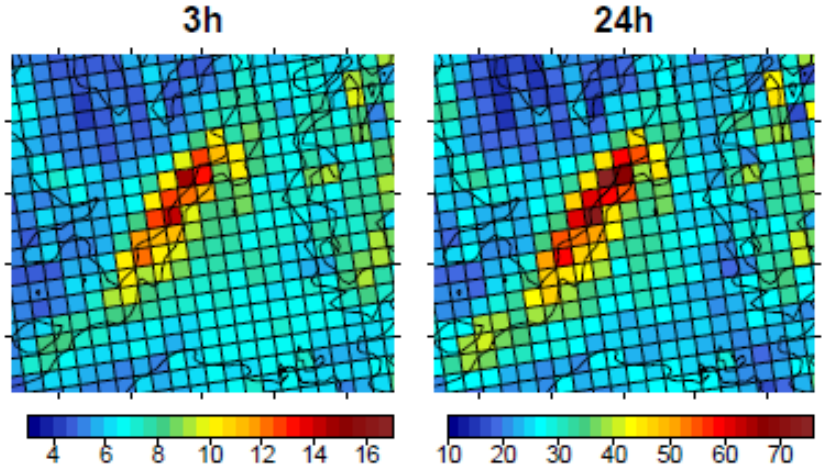
Gridded values

95th percentile

Observations



RCM12km - ERAint



Courtesy: S. Froidurot, G. Molinié, A. Diedhiou, S. Somot, A. Carrière, L. Turcu

MISTRALS/HyMeX database

➲ ~400 datasets in MISTRALS/HyMeX database (http://mistrals/sedoo.fr/hymex)

- ⇨ Observations from operational networks
- ⇨ Field campaign observations
- ⇨ Satellite images and products
- ⇨ Model analyses and forecasts (atmosphere, ocean)
- ⇨ Post-event survey data (hydrological and Social data)
- ⇨ Regional climate simulations (MEDCORDEX)

including archived runs at ENEA database (through interporability between ENEA and MISTRALS databases)

HyMeX Workshops

1st Mediterranean-HyMeX Workshop, 9-11 January 2007, Toulouse, France
2nd HyMeX Workshop, 2-4 June 2008, Palaiseau, France
3rd HyMeX Workshop, 1-4 June 2009, Heraklion, Greece
⇨ Preparation of HyMeX White Book and Science Plan

4th HyMeX Workshop

8-10 June 2010, Bologna, Italy

5th HyMeX Workshop

17-19 May 2011, Minorca, Spain

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7th HyMeX Workshop
7-10 Oct. 2013, Cassis, France

8th HyMeX Workshop
15-18 Sept. 2014, Valletta, Malta

⇨ Collaborative studies to advance HyMeX Science issues

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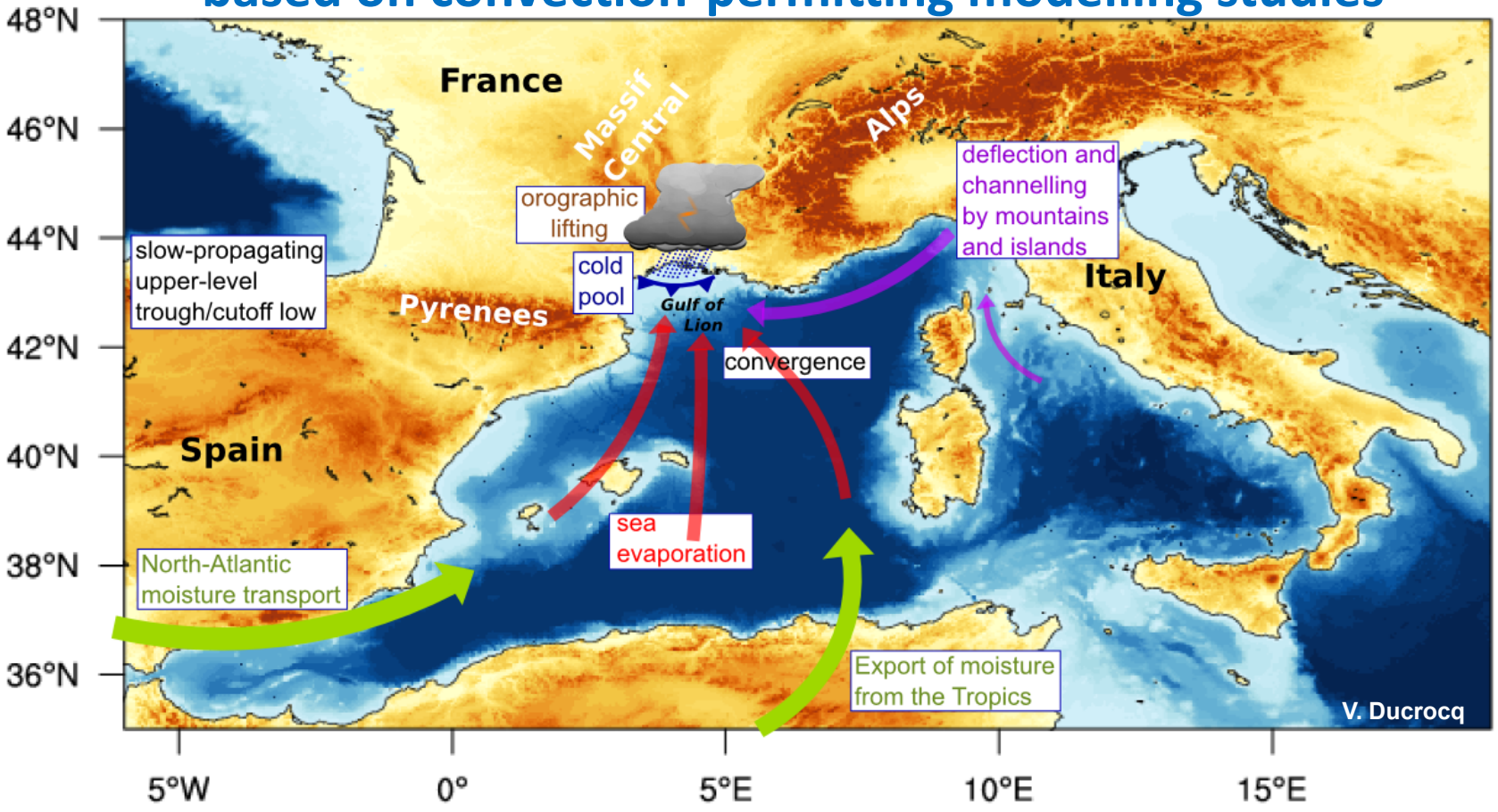
Thank for your attention

Heavy precipitation: A multiscale phenomenom

Conceptual model for HPE

based on convection-permitting modelling studies



On large scale and mesoscale environment:

Nuissier, O., Joly, B., Joly, A., Ducrocq, V. and Arbogast, Ph., 2011 (QJRMS); Ricard, D., V. Ducrocq, L. Auger, 2012 (JAMC)

On triggering mechanisms:

Ducrocq, V., O. Nuissier, D. Ricard, C. Lebeaupin, T. Thouvenin, 2008 (QJRMS); Bresson, E., V. Ducrocq, O. Nuissier, D. Ricard, C. de Saint-Aubin, 2012 (QJRMS)

On water vapour origin and transport:

Duffourg, F. and Ducrocq, V., 2011 (NHESS); Duffourg, F., and V. Ducrocq, 2013 (ASL)