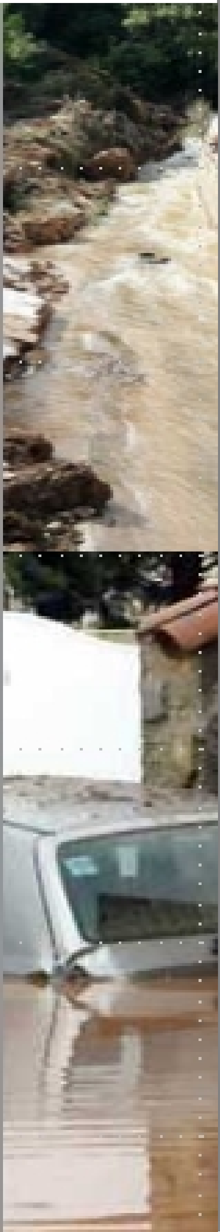

DRIHM and DRIHM2US: e-Infrastructures for hydro-meteo research

Fabio Delogu
CIMA Research Foundation

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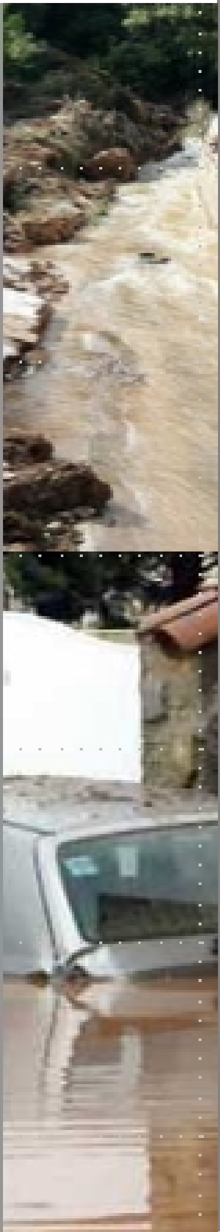
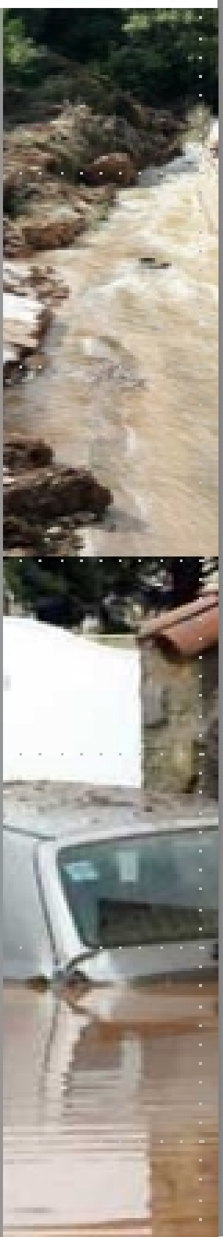
in cooperation with:

A. Provenzale, D. Kranzlmueller, J. von Hardenbergh, E. Palazzi, A. Pieri, A. Clematis, D. D’Agostino, A. Galizia, D. Gochis, M. Schiffers, F. Siccardi, A.Parodi, N. Rebora, L. Molini, E. Fiori, T. Bedrina, F. Viterbo

Outlook

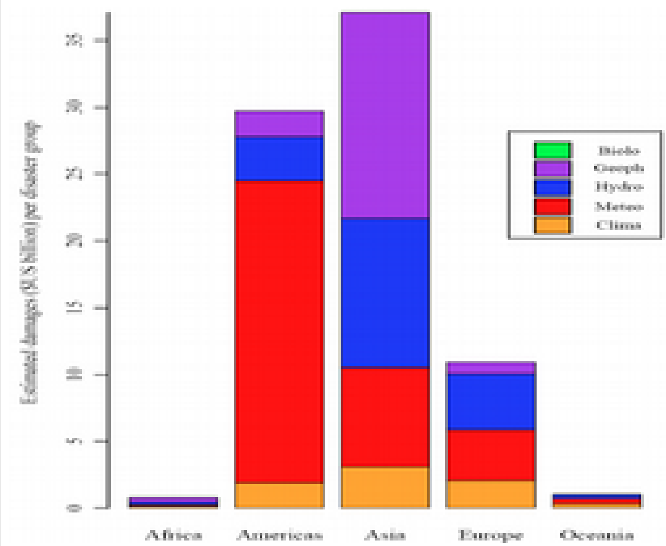


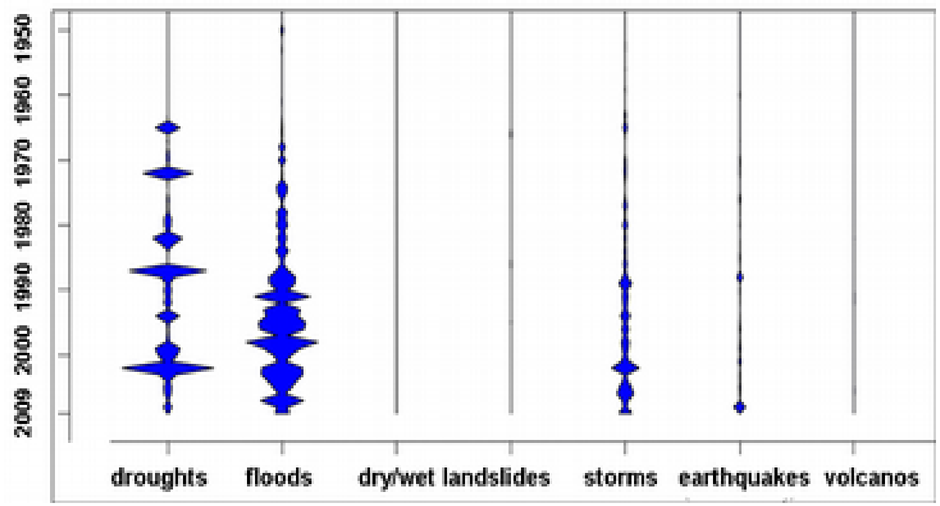
- Motivations
- Severe events classification
- Mediterranean area and a paradigmatic event
- Hydro-meteorology and e-Infrastructure: DRIHM project
- DRIHM2US project
- Conclusions



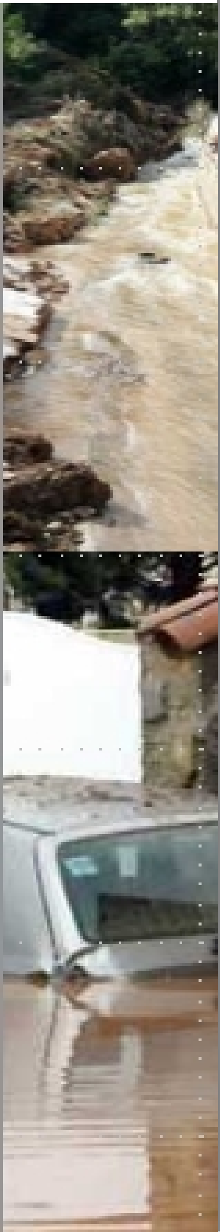
Motivations

- Severe storms, and floods/flash-floods are highly impacting on human society and economical activities

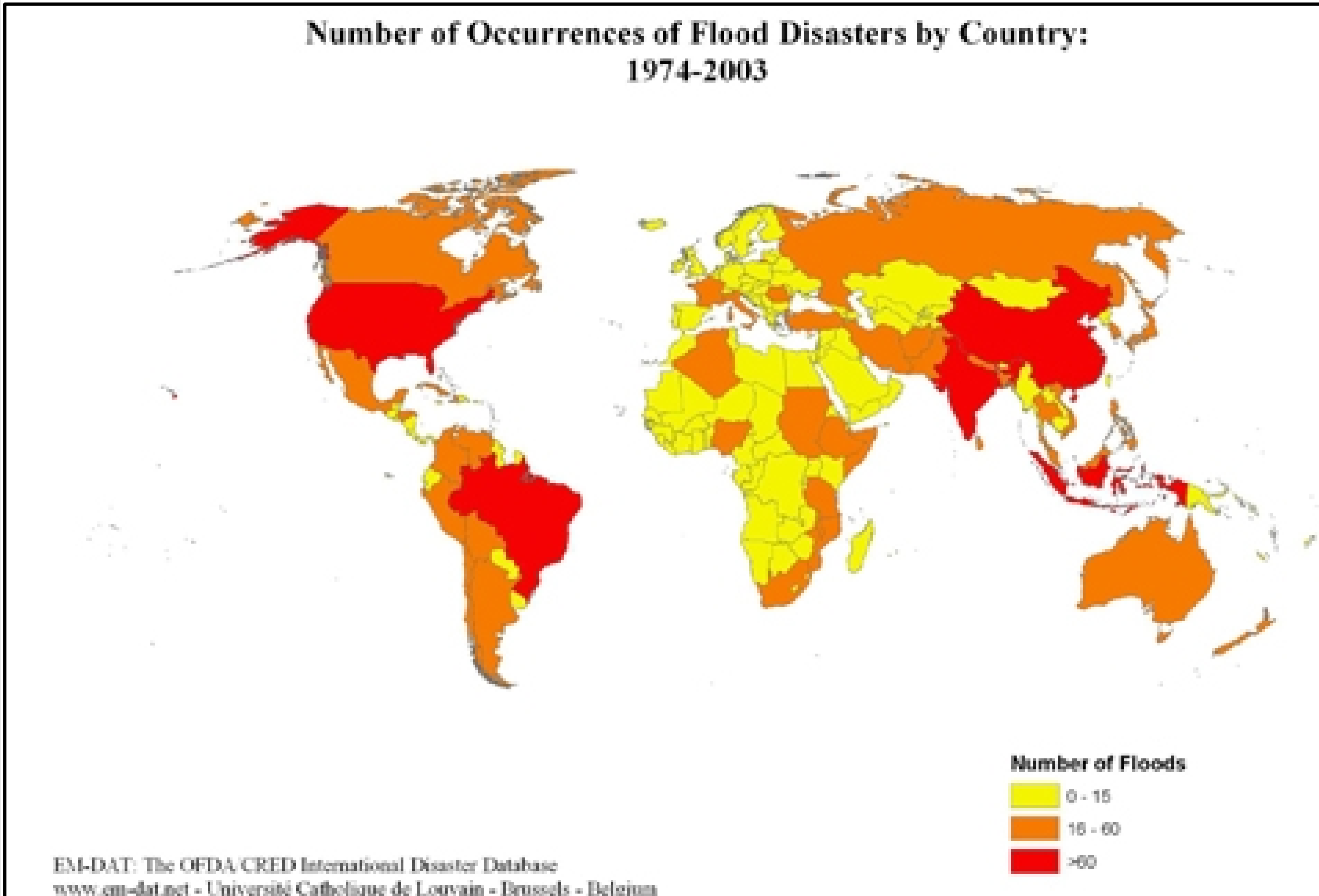




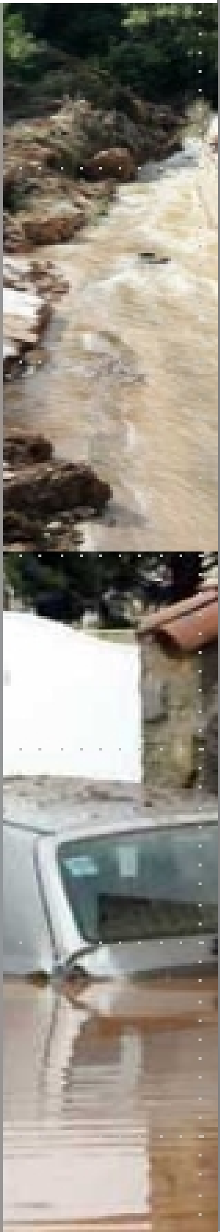
Left panel: annual damages ($USA billion) caused by reported natural disasters (1990 – 2009, source:/www.emdat.be, International Disaster Database). Right panel: number of people affected by natural disasters (1950-2009, source:/www.emdat.be).

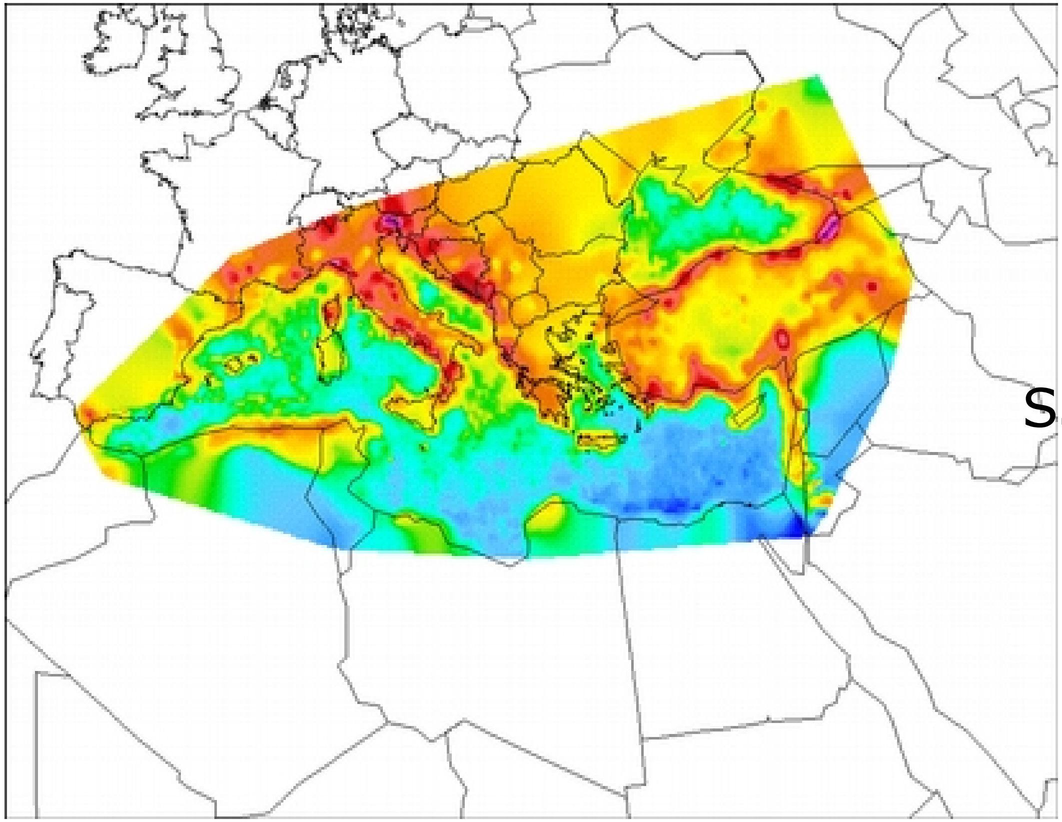


Motivations



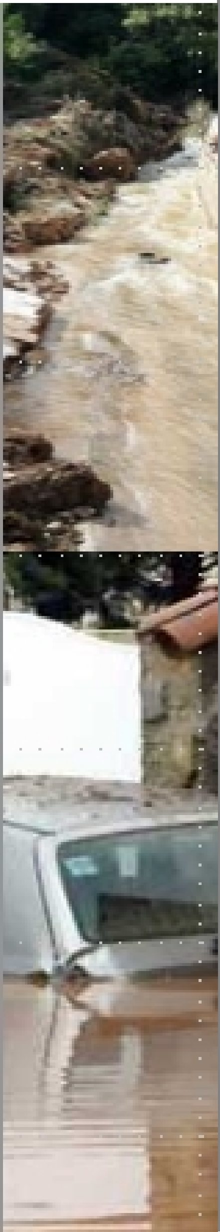
The Mediterranean region



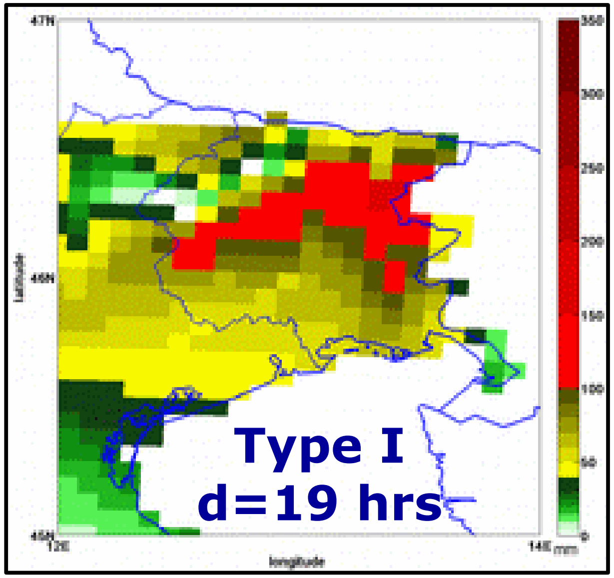


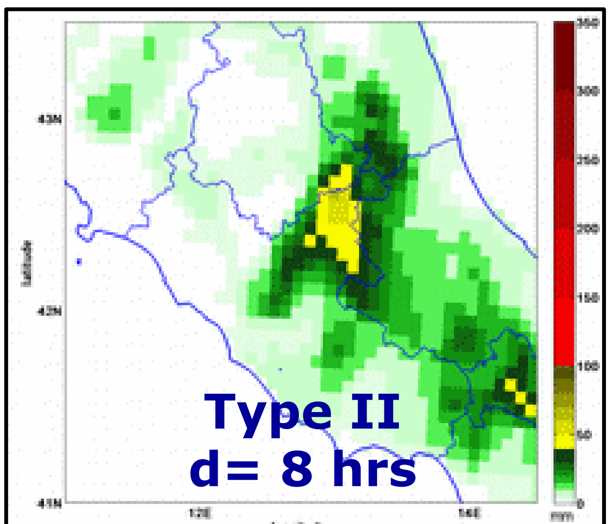
SSMI and raingauge observations 1978-1994

- The FLASH project estimated over 29 billion euros the material damages produced by floods in the Mediterranean region during the 1990-2006 period
- The total number of casualties has been estimated over 4,500, concentrating in the Mediterranean African countries.



Severe events classification

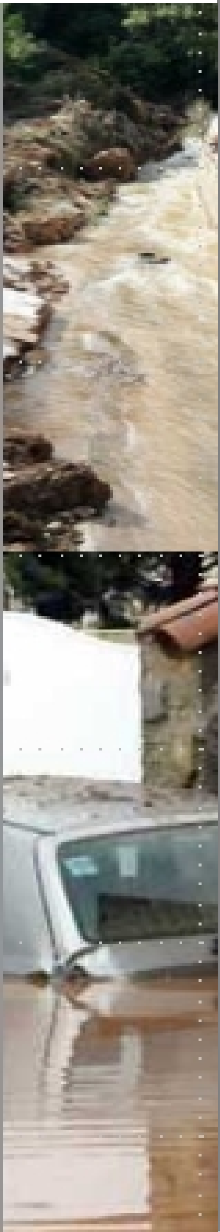


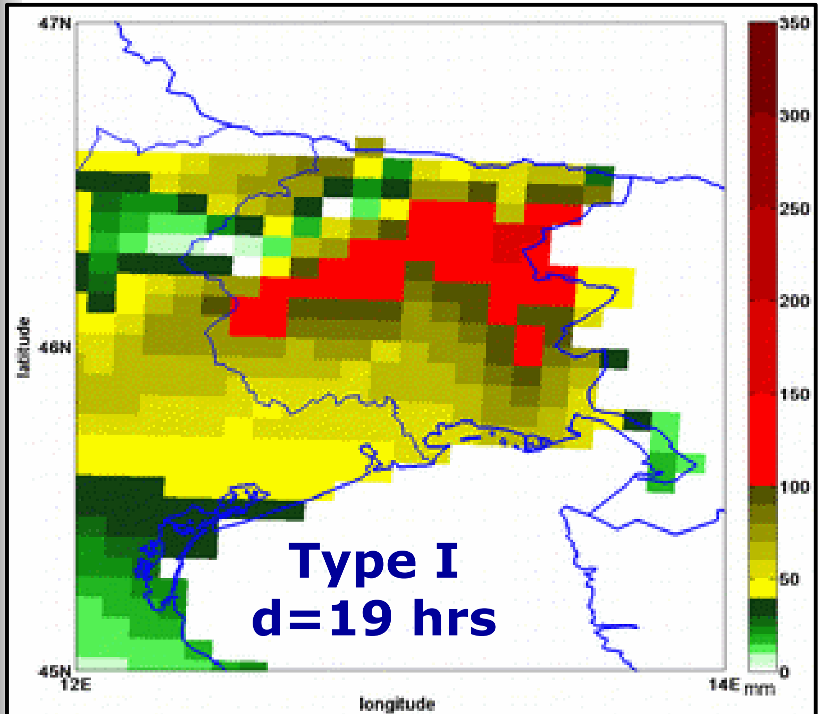


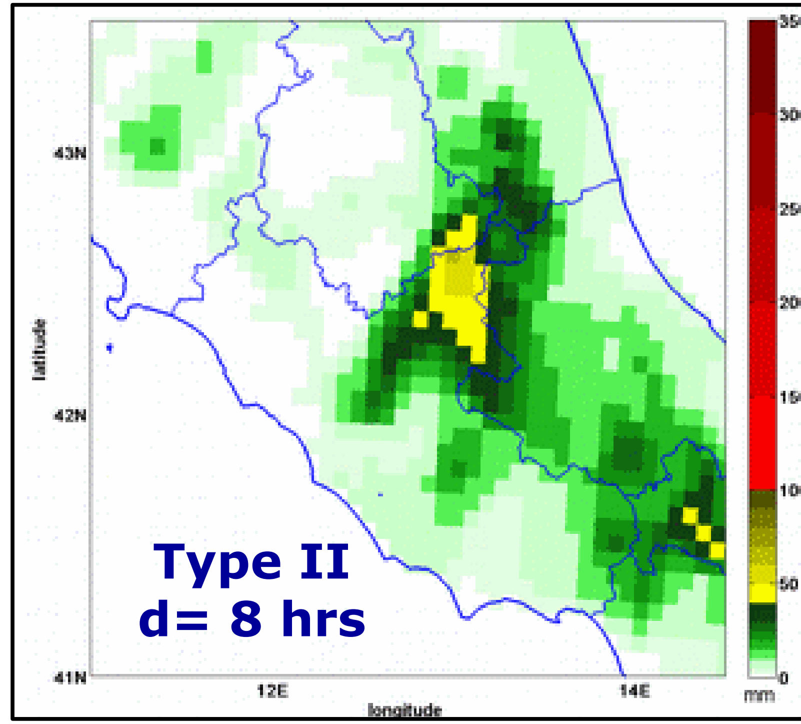
Molini et al. developed a procedure to single out heavy rainfall events and to classify them on the basis of:

1. Duration
2. Spatial extent
3. Large/small-scale triggering

Molini, L., Parodi, A., & Siccardi, F. (2009). Dealing with uncertainty: an analysis of the severe weather events over Italy in 2006. Nat. Hazards Earth Syst. Sci, 9, 1775-1786.







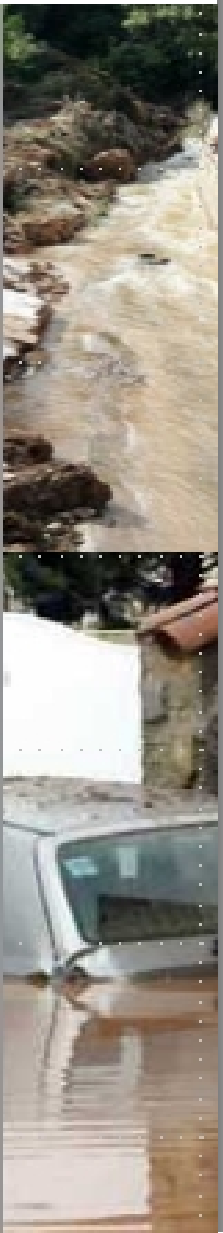
Type I events:

- Long-lived (lasting more than 12 hours)
- Spatially distributed (more than 50x50 km^{2})

Type II events:

- Brief and localized (lasting less than 12 hours)
- Spatially concentrated (less than 50x50 km^{2})

Equilibrium and non-equilibrium



LOW degree of predictability ↔ **Non-Equilibrium conditions**

↓

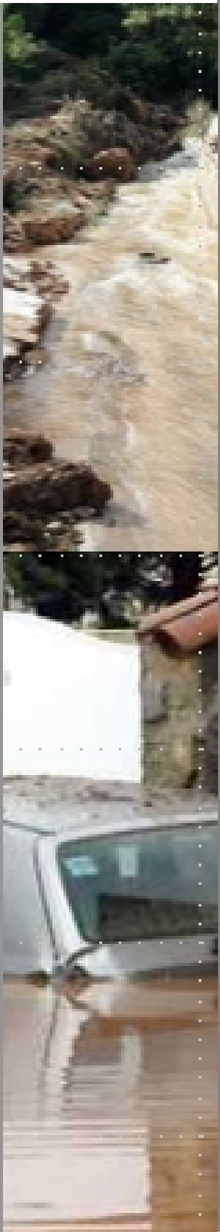
CAPE (convective available potential energy) is build up from large scale processes over long timescales and removed by sudden triggering of deep moist convection

←

Triggering condition determines the spatio-temporal behavior of the corresponding **severe rainfall events**

$$\frac{dCAPE}{dt} = \begin{pmatrix} \text{Rate of creation} \\ \text{by forcing} \end{pmatrix} - \begin{pmatrix} \text{Rate of destruction} \\ \text{by convection} \end{pmatrix}$$

Equilibrium and non-equilibrium



HIGH degree of predictability ↔ **Equilibrium conditions**

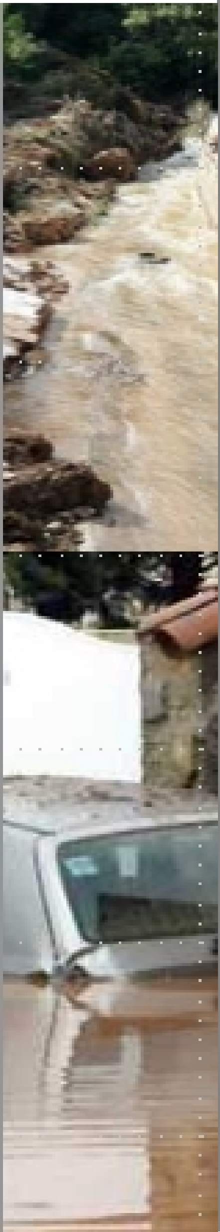
↓

The rate of creation of CAPE by forcing is balanced by its consumption by convection

←

Large scale forcing determines the statistical properties of convection and **the spatio-temporal behavior of the** corresponding **severe rainfall events**

$$\frac{dCAPE}{dt} = \begin{pmatrix} \text{Rate of creation} \\ \text{by forcing} \end{pmatrix} - \begin{pmatrix} \text{Rate of destruction} \\ \text{by convection} \end{pmatrix}$$



A convective time scale for equilibrium e non-equilibrium conditions

A convective adjustment timescale τ_c

is estimated from the rate at which instability (measured by CAPE) is being removed by convective heating

Molini, L., Parodi, A., Rebora, N., & Craig, G. C. (2011). Classifying severe rainfall events over Italy by hydrometeorological and dynamical criteria. Quarterly Journal of the Royal Meteorological Society, 137(654), 148-154.

Convective timescale

$$\tau_c = \frac{CAPE}{dCAPE/dt} \sim \frac{CAPE}{Precip.\ rate}$$

Equilibrium expected when τ_c small compared to forcing timescale

$$\frac{dCAPE}{dt} = \frac{1}{3600}\frac{i_R L_v g}{T_0 \rho_0 c_p} \approx 0.025 \cdot i_R$$

where

i_R is the rainfall intensity [mm/h]

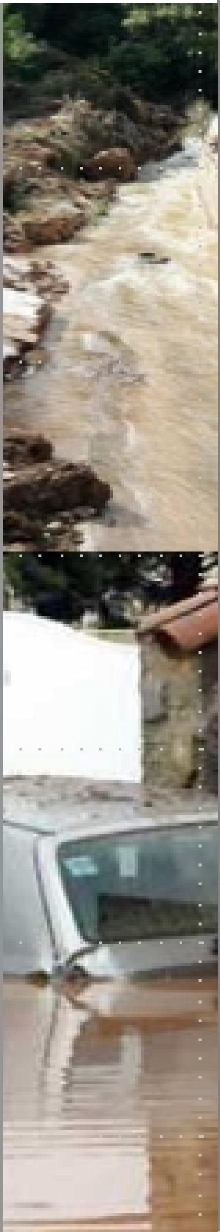
L_v is the latent heat of vaporization

g is the gravity acceleration

c_p is the specific heat at constant pressure

T_0 is the air temperature

ρ_0 is the air density



A convective time scale for equilibrium e non-equilibrium conditions

$$\tau_C = \frac{CAPE}{\frac{dCAPE}{dt}} = \frac{CAPE}{0.045 \cdot i_R}$$

0.022

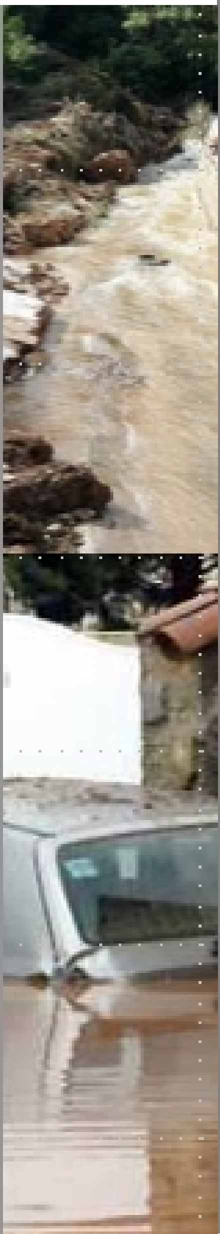
Equilibrium conditions

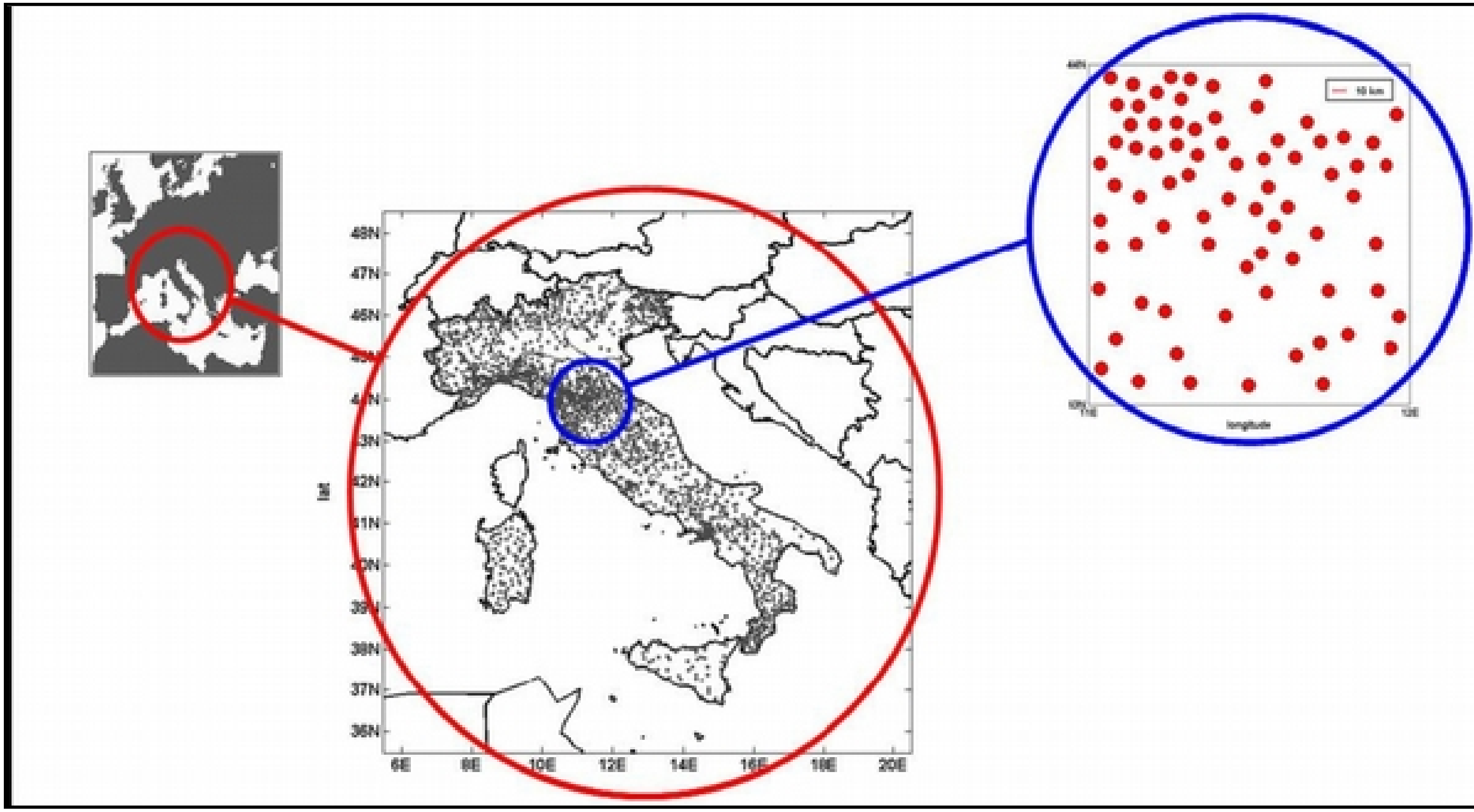
Non-Equilibrium conditions

Convective timescale

τ_{CS} ~ 6 hours

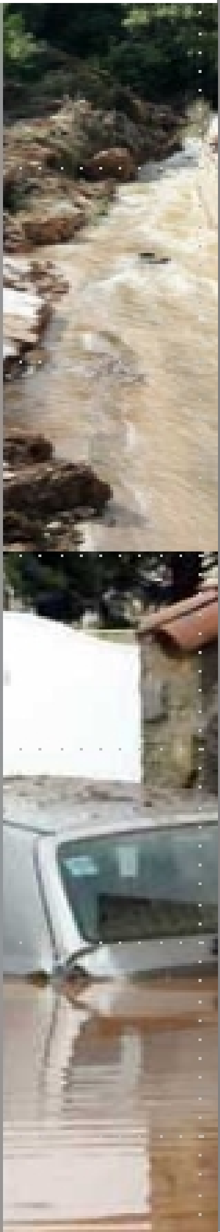
Italian raingauges network

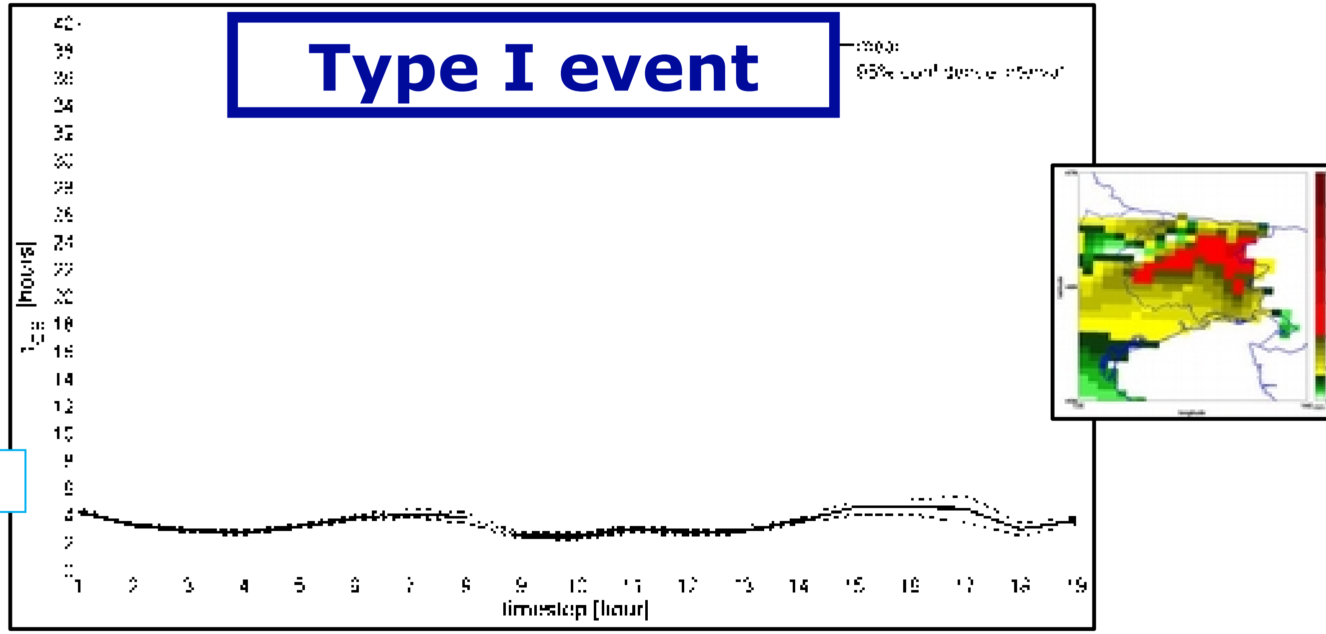




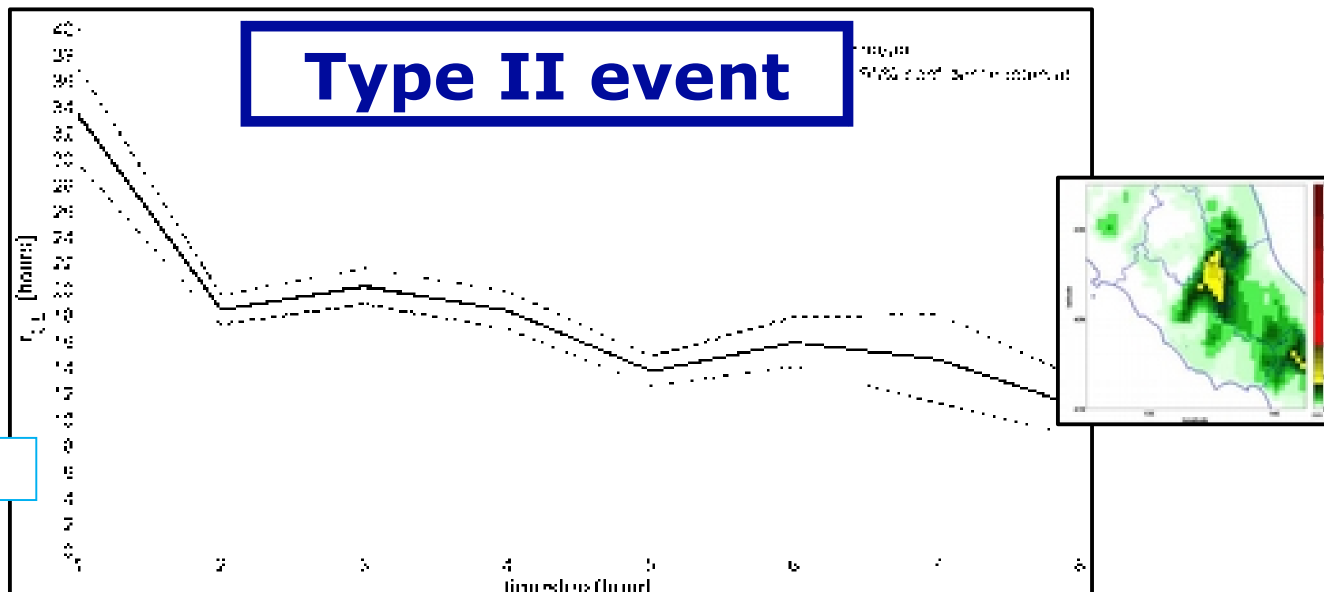
81 severe events (2006-2009):

- **<u>51</u>** events **<u>Type I</u>** events lasting more than 12 hours and striking an area bigger than 50x50 km^2;
- **<u>30</u>** events **<u>Type II</u>** events lasting less than 12 hours and striking an area smaller than 50x50 km^2.

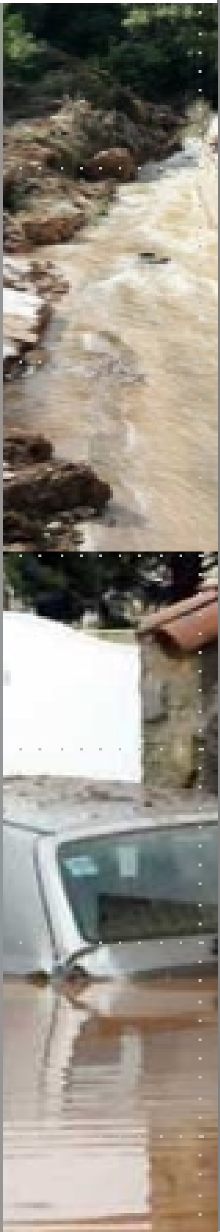


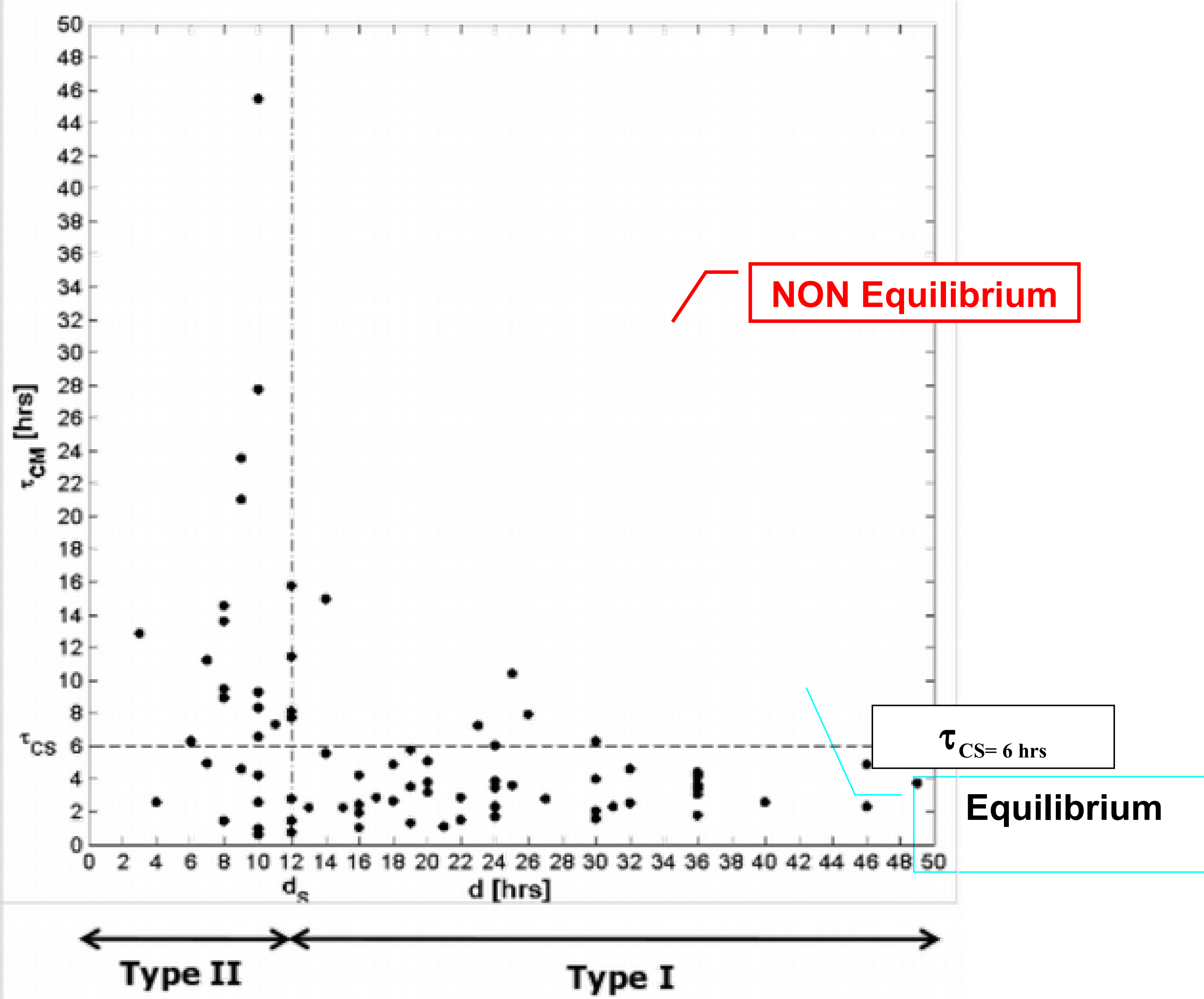


τ_{CS}= 6 hrs



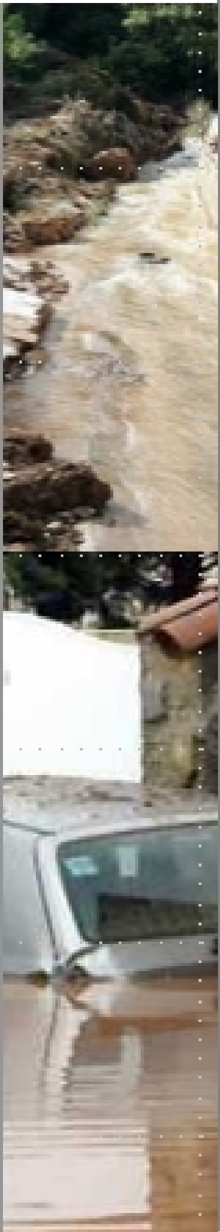
τ_{CS}= 6 hrs





NON Equilibrium
$\tau_{CS= 6\ hrs}$
Equilibrium
τ_{CM} [hrs]
τ_{CS}
d_S
d [hrs]
Type II
Type I

When do these events occur?

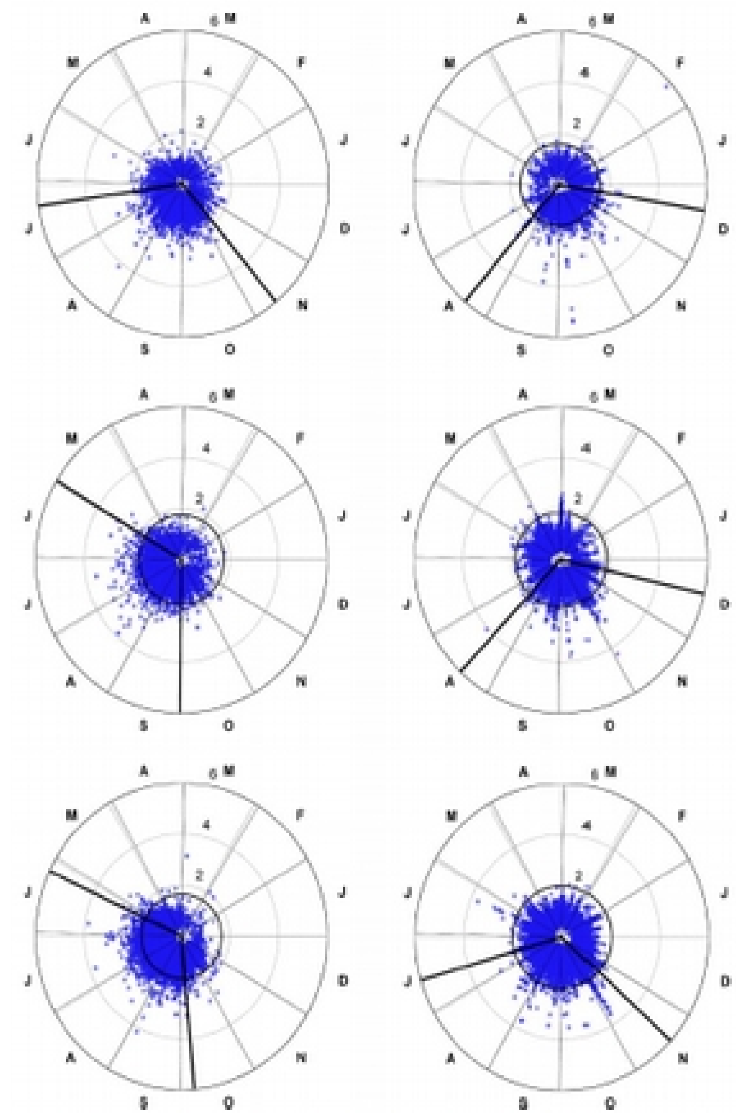


1h annual rainfall maxima *24h annual rainfall maxima*

Liguria

Piedmont

Triveneto



Boni, G., Parodi, A., & Rudari, R. (2006). Extreme rainfall events: Learning from raingauge time series. Journal of Hydrology, 327(3), 304-314.

Boni, G., Parodi, A., & Siccardi, F. (2008). A new parsimonious methodology of mapping the spatial variability of annual maximum rainfall in mountainous environments. Journal of Hydrometeorology, 9(3), 492-506.

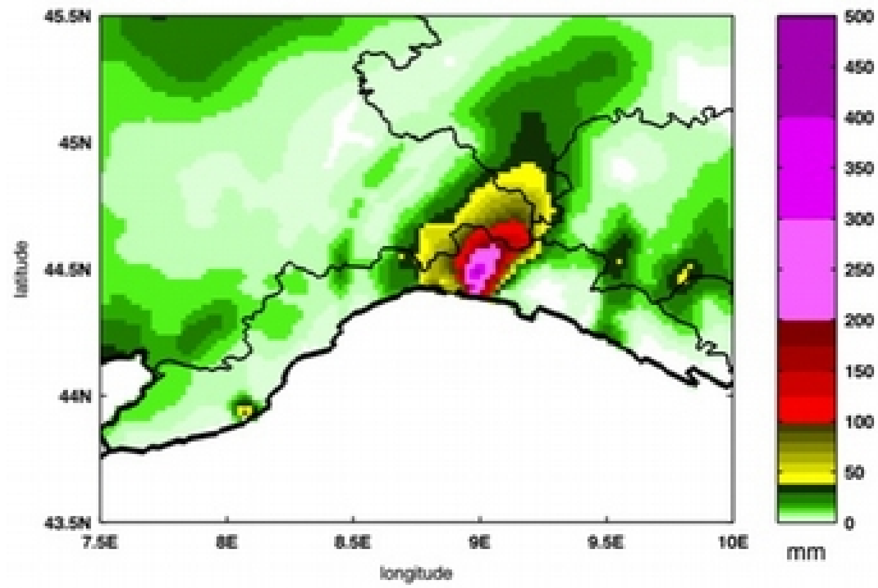
A Mediterranean paradigmatic event: Genoa 2011 flash-flood

On November 4th, the city of Genoa, Liguria region capital, was gutted by a torrential rainfall event with about 500 millimeters of rain – a third of the average annual rainfall - fell in 5 hours (between 10 and 15 UTC). Six people were killed. Television footage showed cars floating freely and people wading knee-deep through flooded streets.

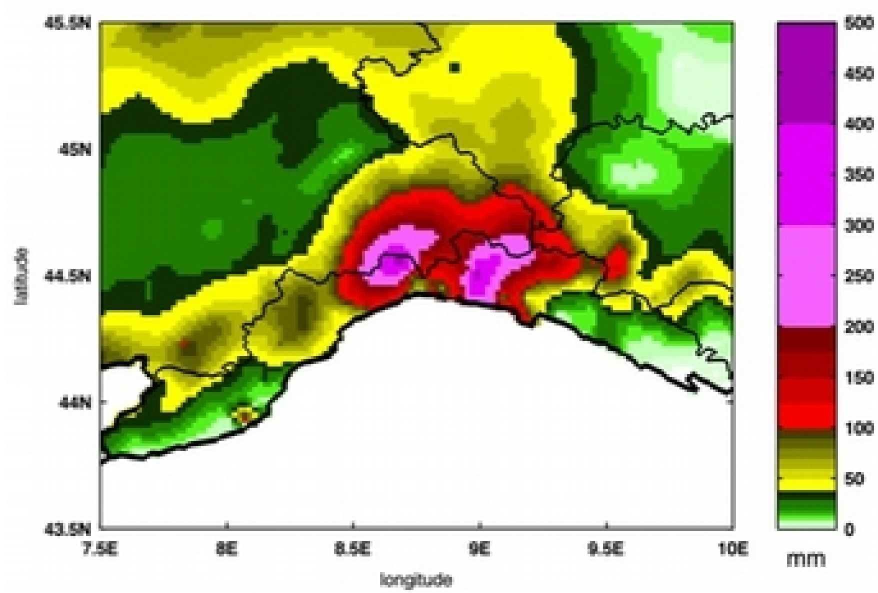
Flash flood of the Genoa town center. Top rigth corner: the similar event of 1970

Rebora, N., and Coauthors, 2013: Extreme Rainfall in the Mediterranean: What Can We Learn from Observations?. J. Hydrometeor, 14, 906–922.
doi: http://dx.doi.org/10.1175/JHM-D-12-083.1

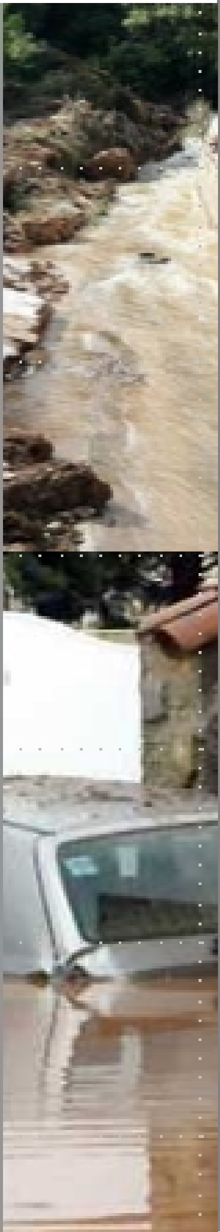
Observed rainfall depth 9-15 UTC

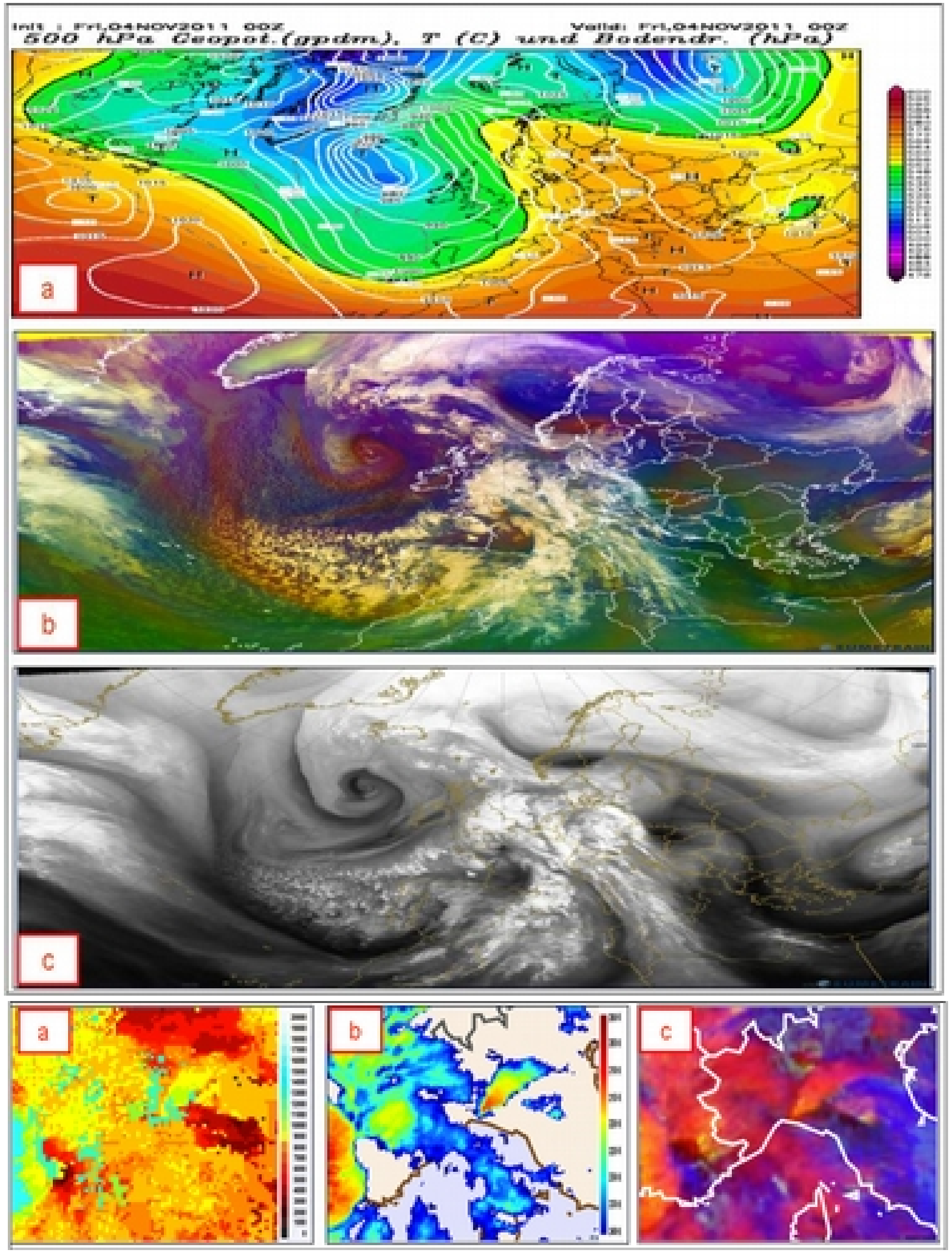


Observed rainfall depth 0-24 UTC

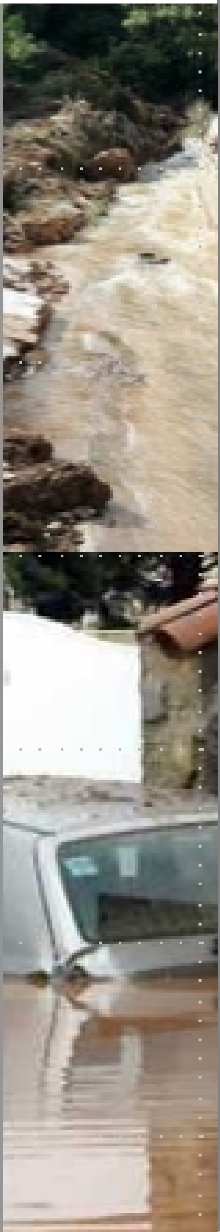


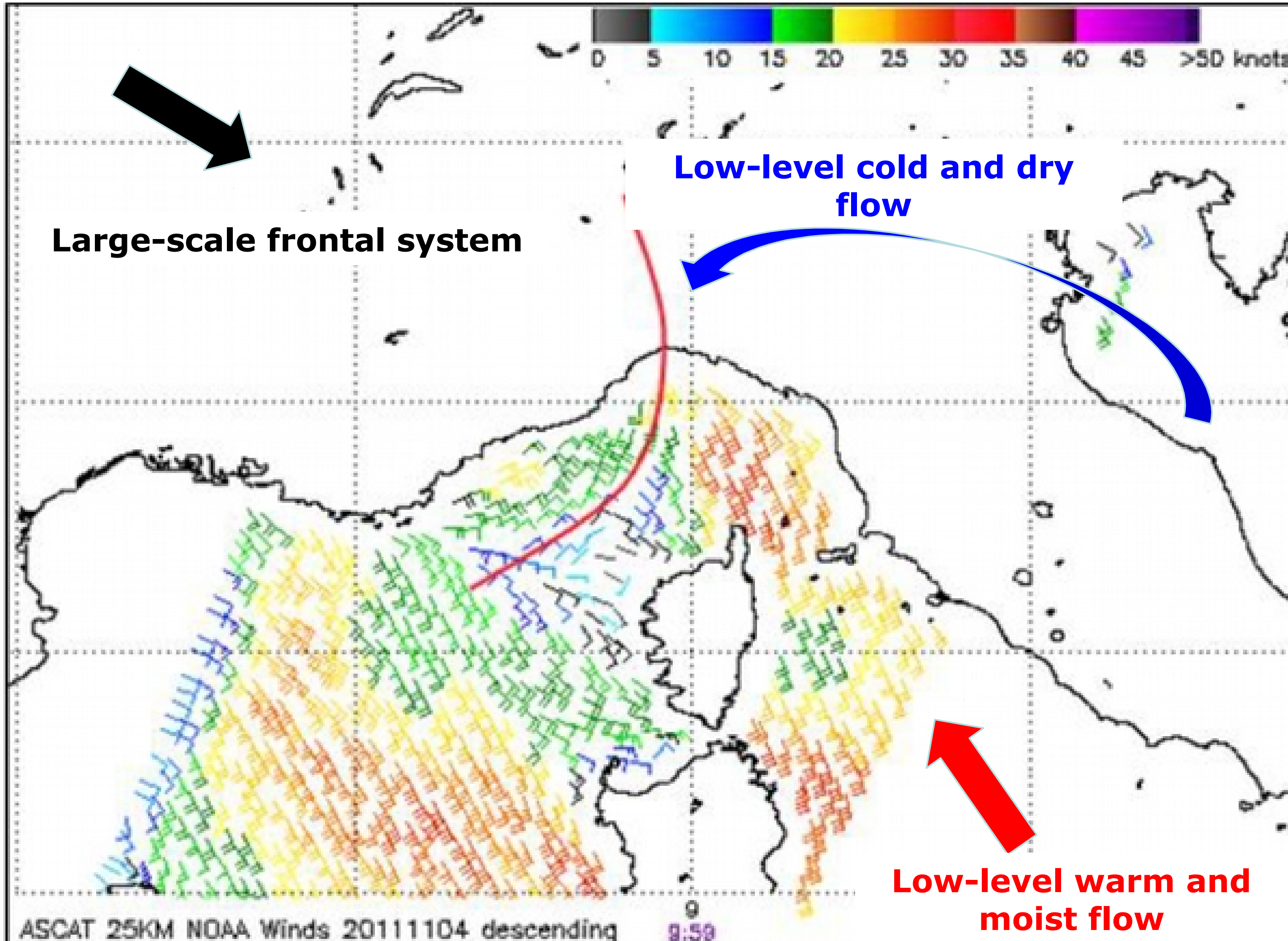
A multiscale severe event: synoptic





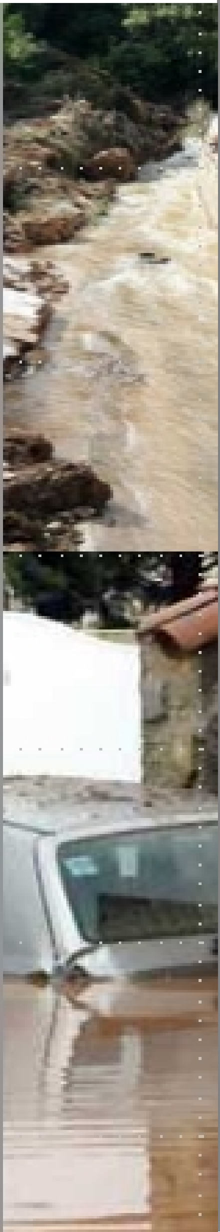
A multiscale severe event: mesoscale

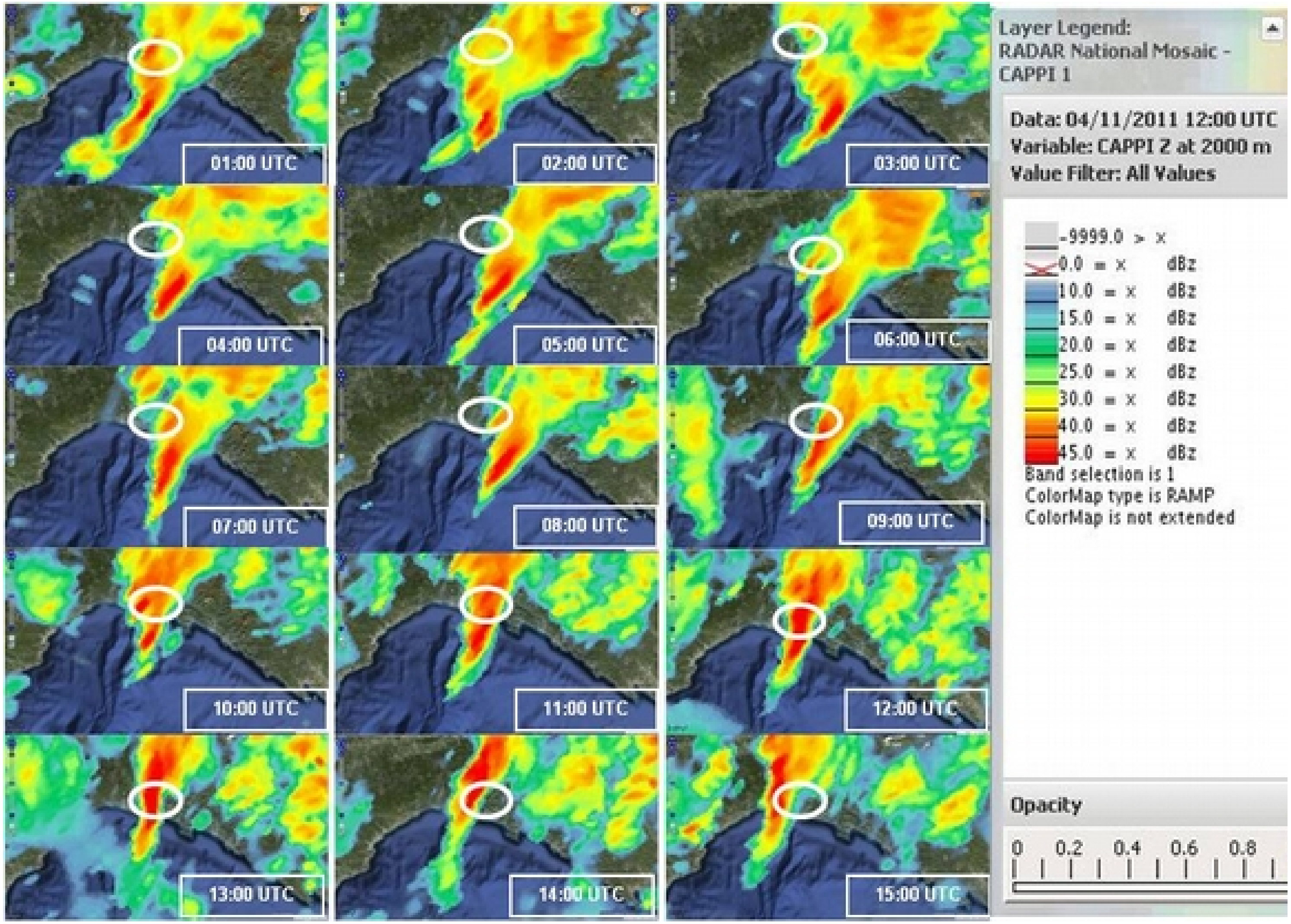




Advanced Scatterometer (ASCAT) ocean surface wind vectors data of 25km resolution, on november 4th 2011, descending pass (10 UTC).

A multiscale severe event: mesoscale



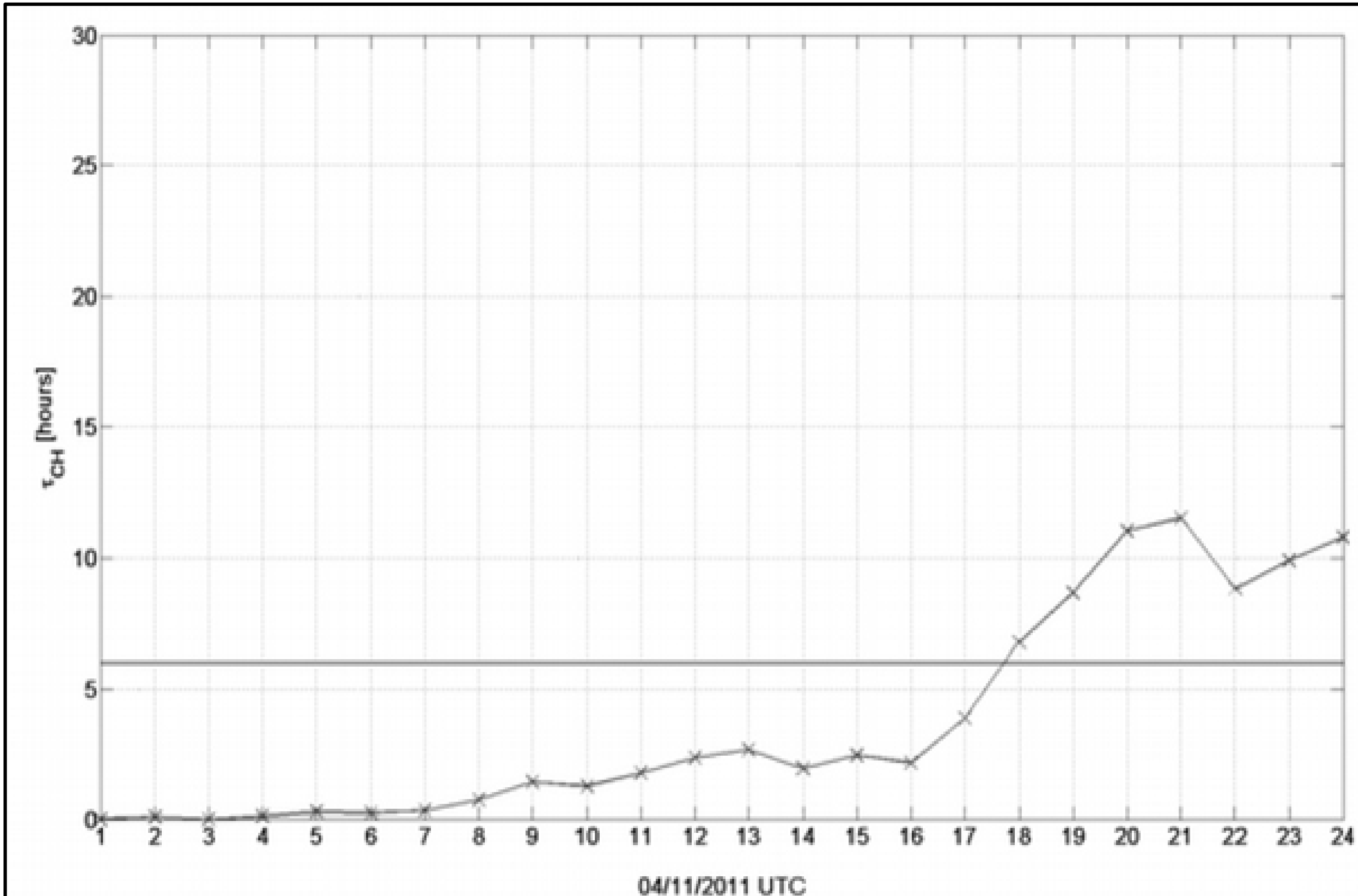


Radar maps from the Italian radar network showing the intense thunderstorm wandering along the Liguria coastline (1-15UTC): White ellipsoid identifies the mostly affected area

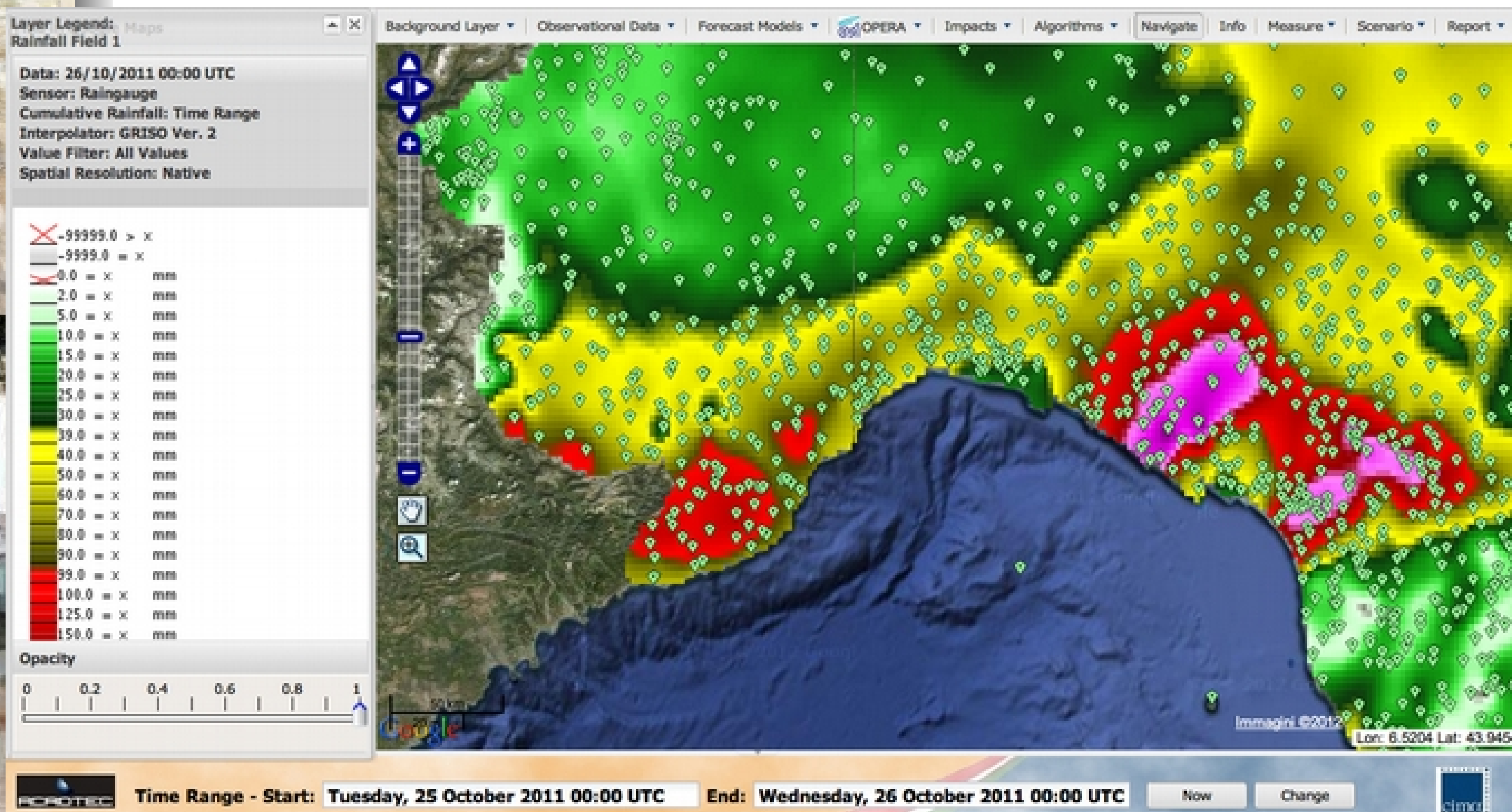
A multiscale severe event: microscale

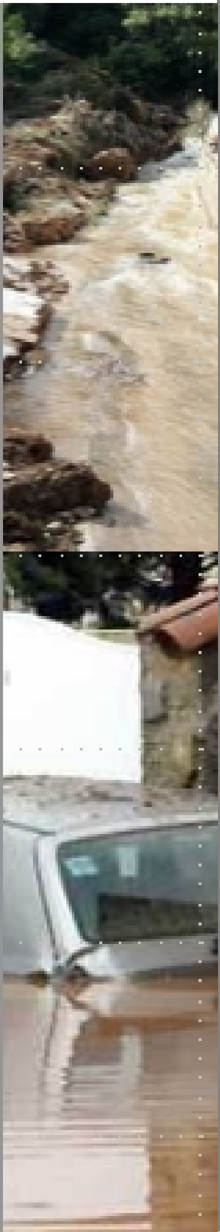
Rain wrapped Tornado/Waterspout taken from Sant'Ilario -GE- looking SW on Nov. 4th at 12.30 PM and 12.35 PM

An equilibrium event



Another example in the Mediterranean: 25 october 2011





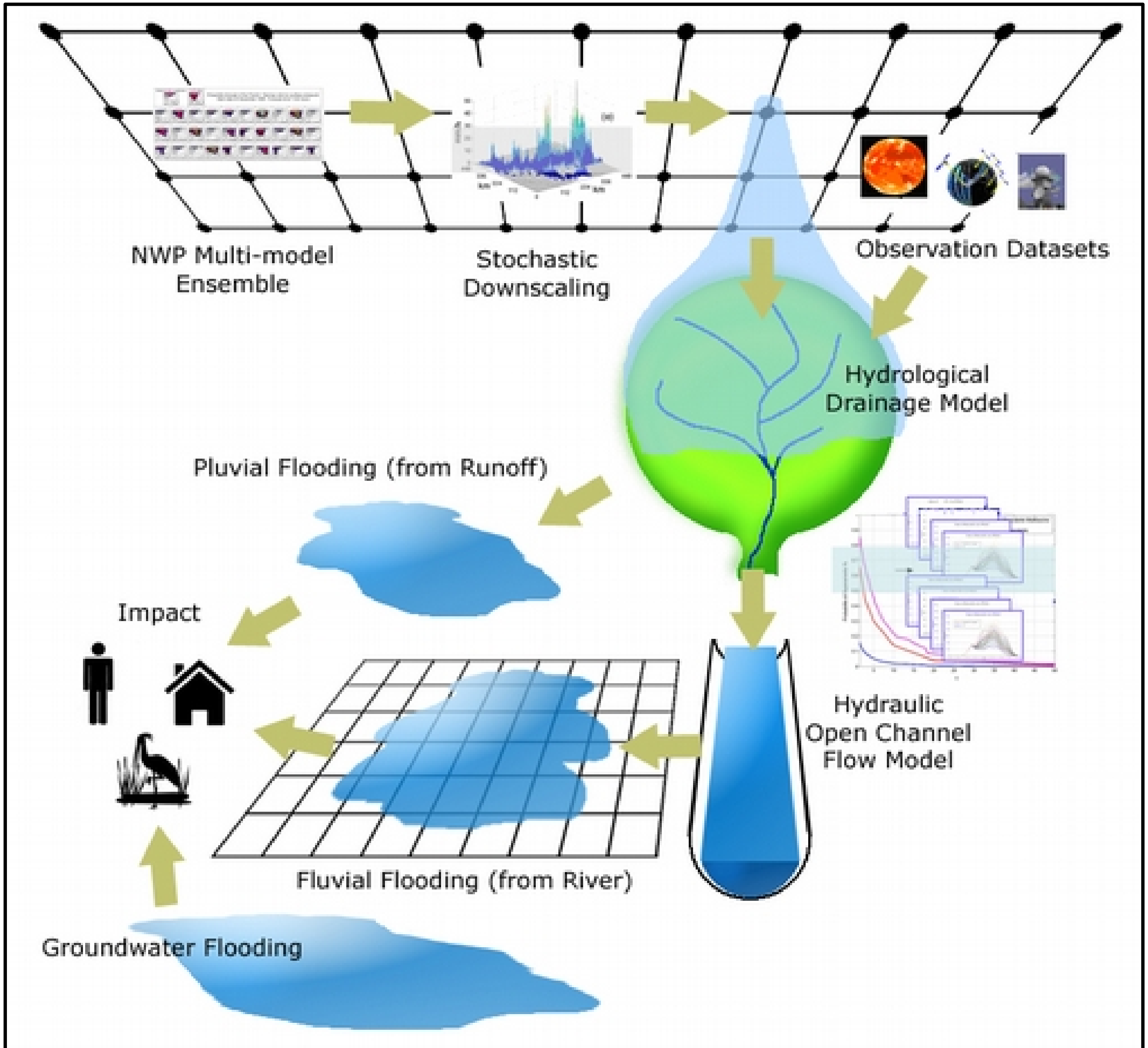
All together, these events challenge our current scientific understanding and call for focused and joint hydro-meteorological and ICT research to:

a)understand, explain and predict the physical processes producing such extreme storms;

b)understand the possible intensification of such events in the Mediterranean region and their physical origin;

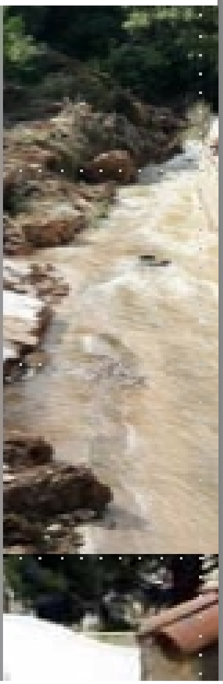
c)explore the potential of the increasing computational power and Information Communication Technology (ICT), such as grid computing and petascale computing systems, to provide deeper understanding of those events.

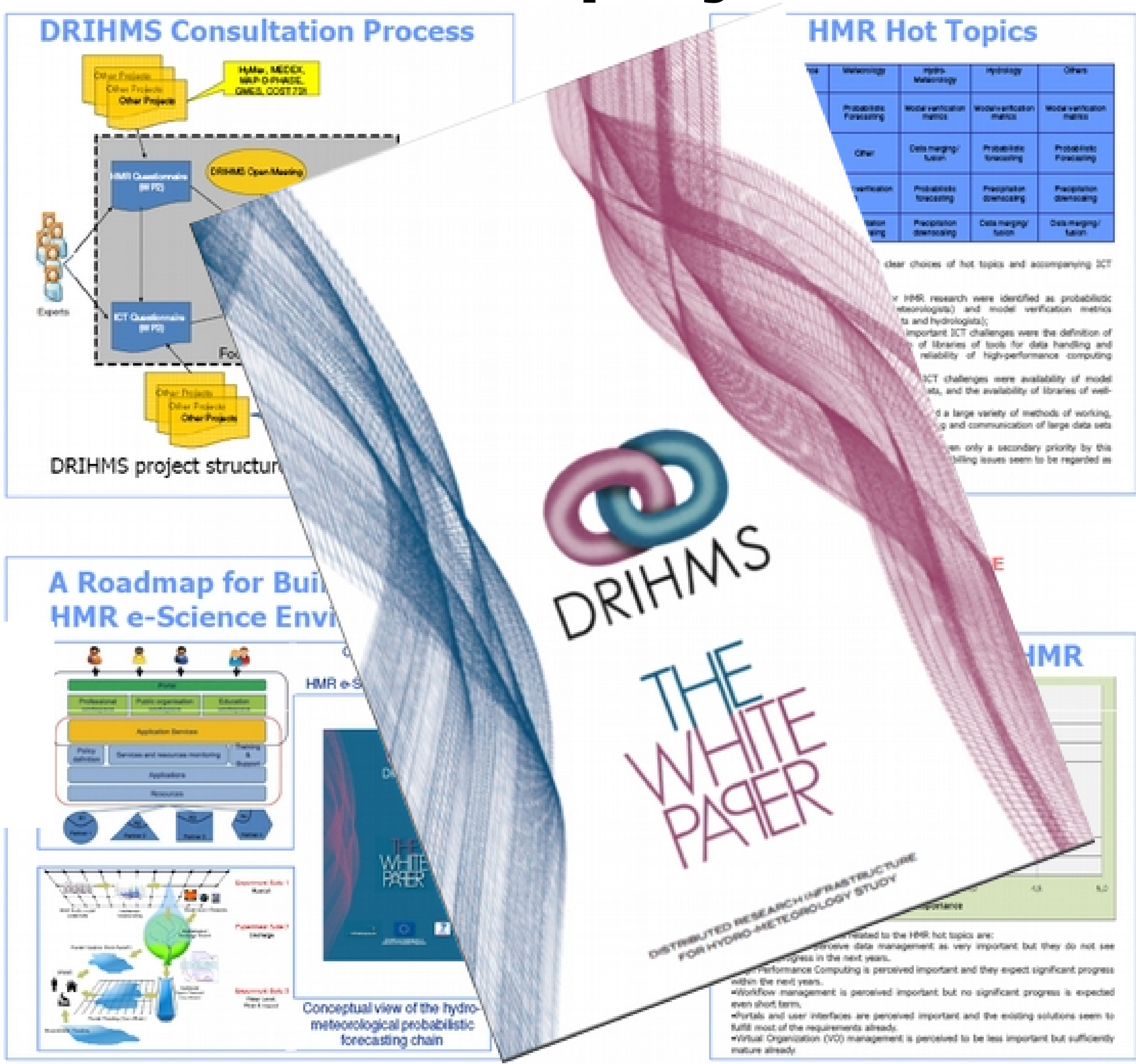
Conceptual showcase



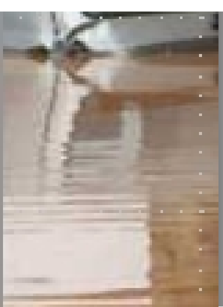
That’s the reason why…

FP7 DRIHMS project

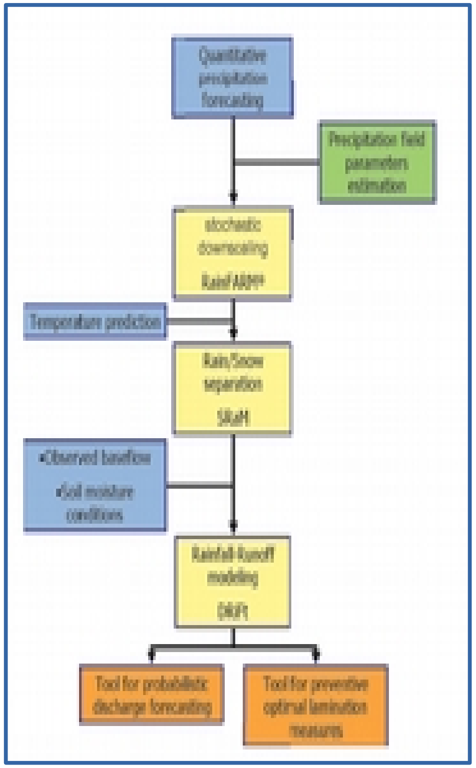




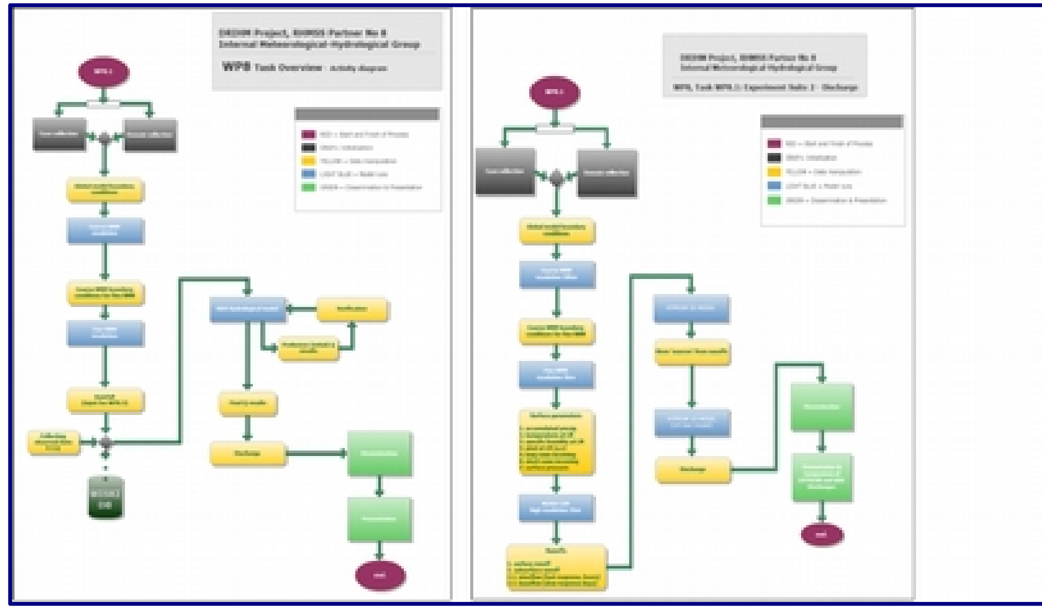
DRIHMS: 2009-2011
Budget: 0.25 Meuro
Project Director:
A. Parodi (CIMA)



The ICT-HMR challenge…



CIMA Baseline Chain

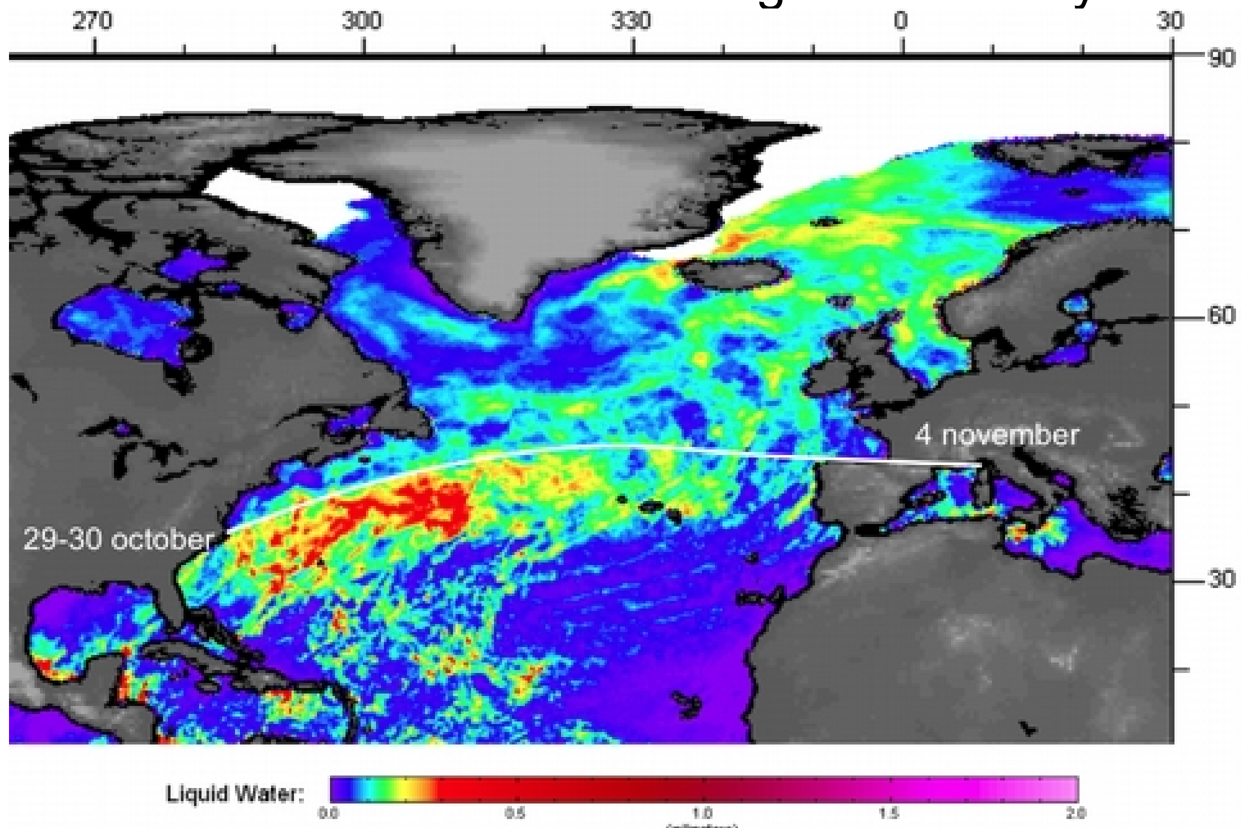


RHMSS Baseline Chain

Requirements collection & Limitations today

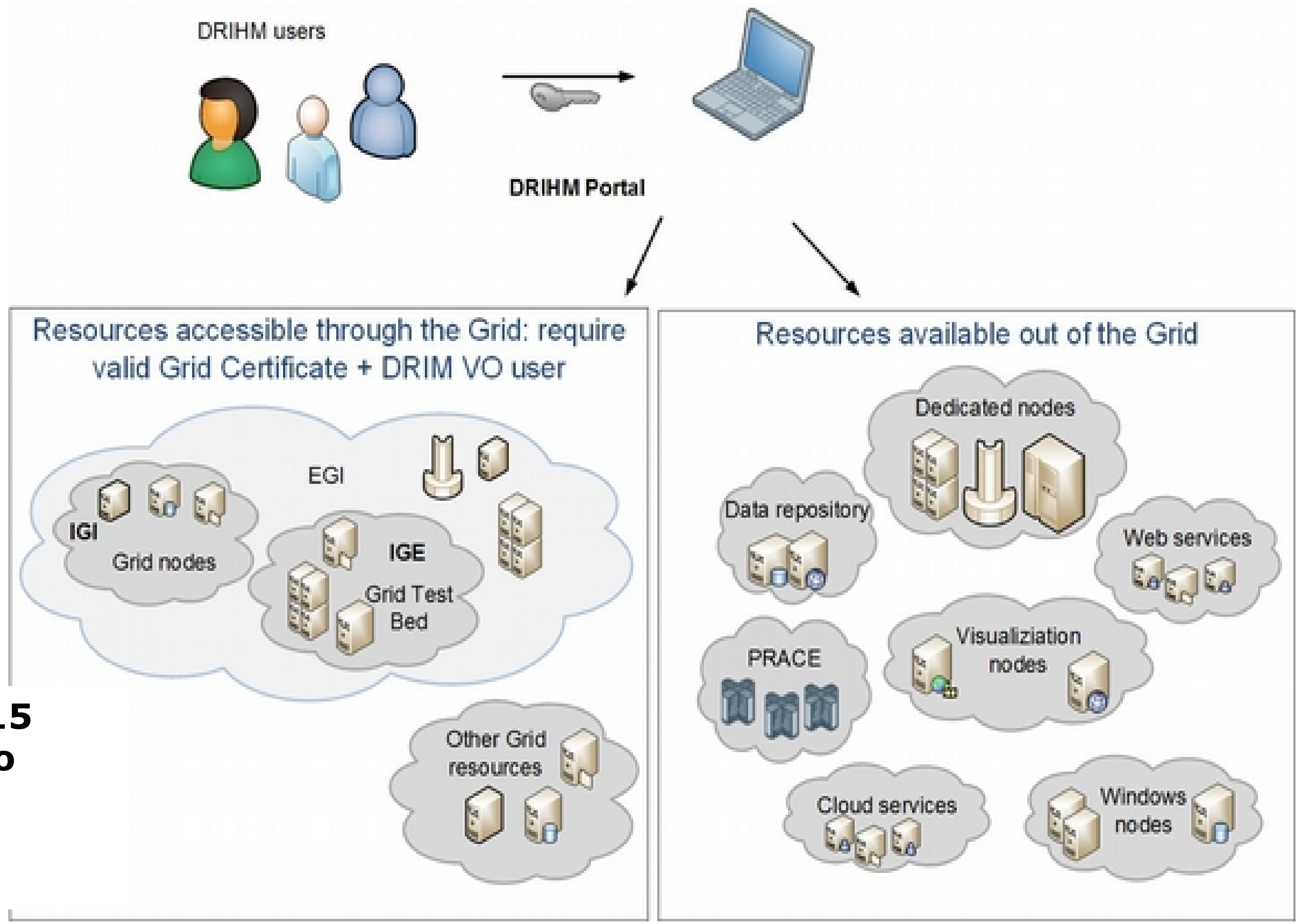
Why DRIHM?

- Forecasting severe storms and floods is a key topic in HMR/early warning
- Storms do not respect country boundaries – a pan-European approach to data access and modeling is necessary

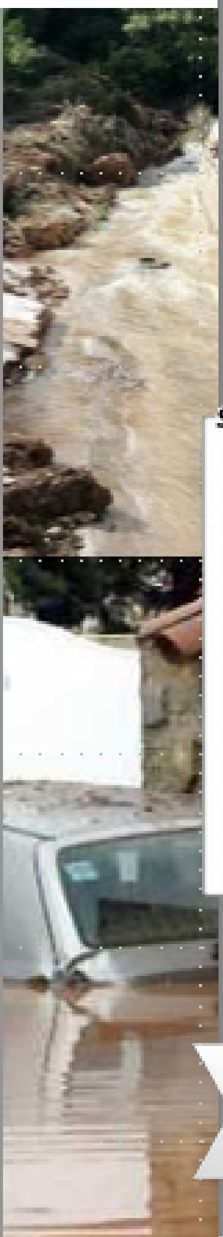


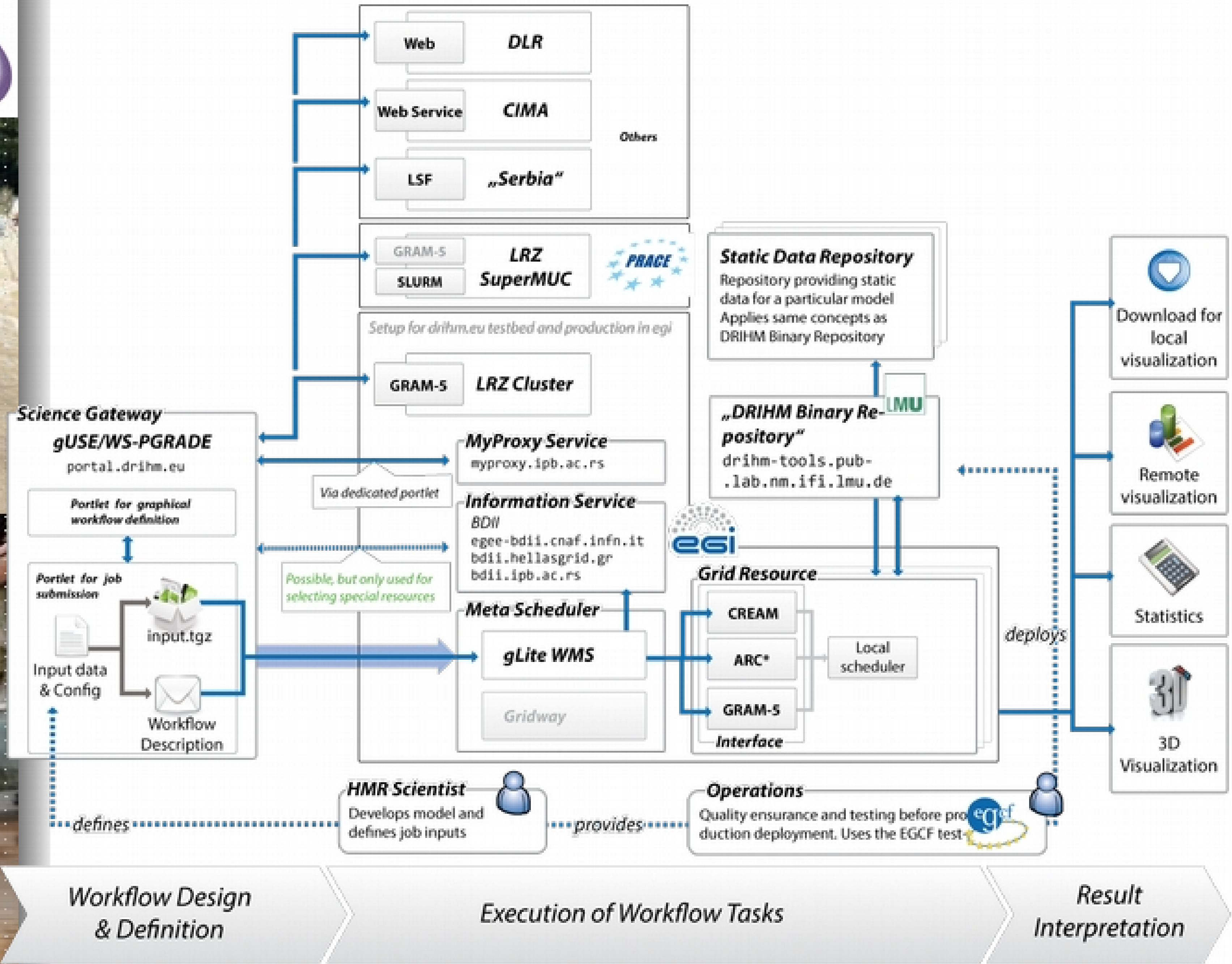
Satellite cloud liquid water composite (week ending 5/11/2011) clearly shows the cyclone track from USA east coast to Mediterranean.

DRIHM e-Science environment

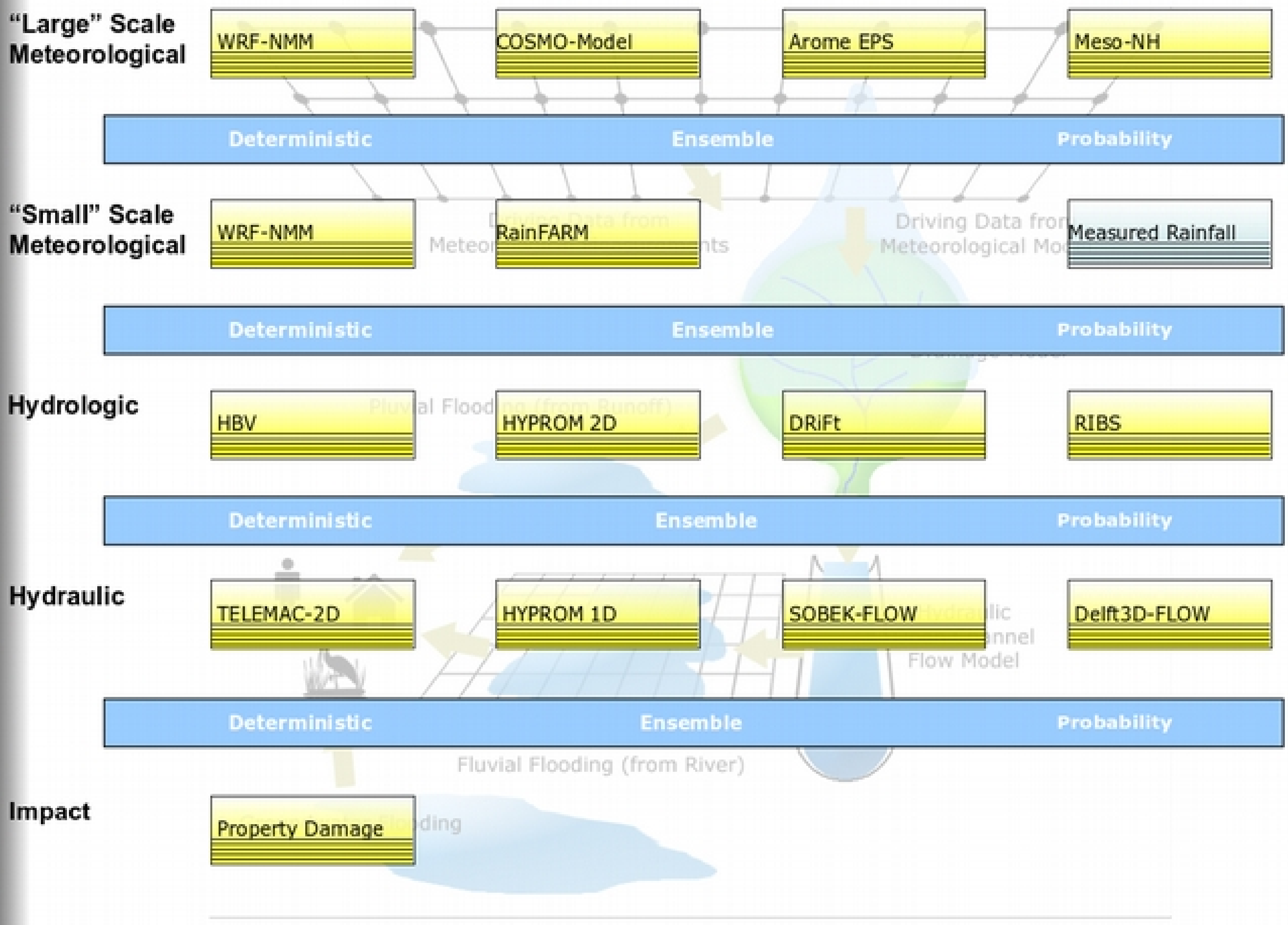


DRIHM: 2011-2015
Budget: 3.5 Meuro
Project Director:
A. Parodi (CIMA)

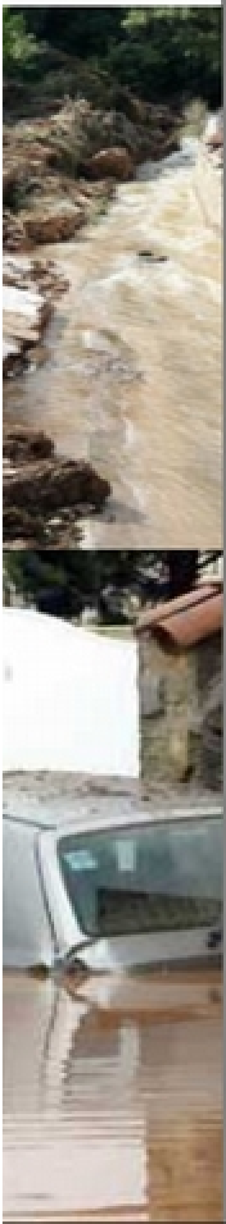


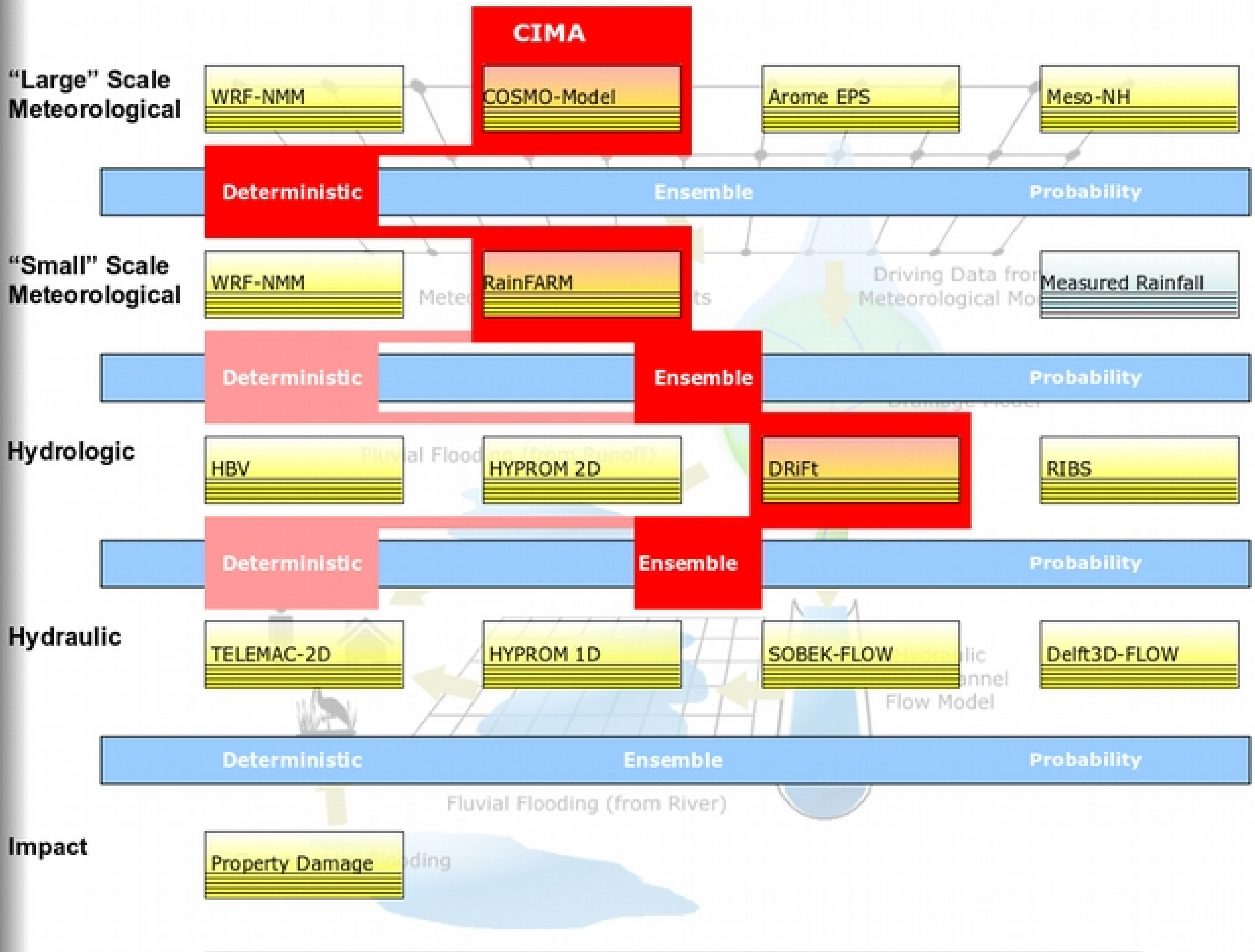

Web
DLR
Web Service
CIMA
LSF
„Serbia"
Others
GRAM-5
SLURM
LRZ SuperMUC
PRACE
Static Data Repository
Repository providing static data for a particular model
Applies same concepts as DRIHM Binary Repository
Setup for drihm.eu testbed and production in egi
GRAM-5
LRZ Cluster
LMU
„DRIHM Binary Repository"
drihm-tools.pub-.lab.nm.ifi.lmu.de
Science Gateway
gUSE/WS-PGRADE
portal.drihm.eu
MyProxy Service
myproxy.ipb.ac.rs
Via dedicated portlet
Portlet for graphical workflow definition
Information Service
BDII
egee-bdii.cnaf.infn.it
bdii.hellasgrid.gr
bdii.ipb.ac.rs
egi
Download for local visualization
Remote visualization
Possible, but only used for selecting special resources
Portlet for job submission
input.tgz
Input data & Config
Workflow Description
Meta Scheduler
gLite WMS
Gridway
Grid Resource
CREAM
ARC*
GRAM-5
Interface
Local scheduler
deploys
Statistics
3D Visualization
HMR Scientist
Develops model and defines job inputs
defines
provides
Operations
Quality ensurance and testing before production deployment. Uses the EGCF test
egcf
Workflow Design & Definition
Execution of Workflow Tasks
Result Interpretation

DRIHM Model Chains

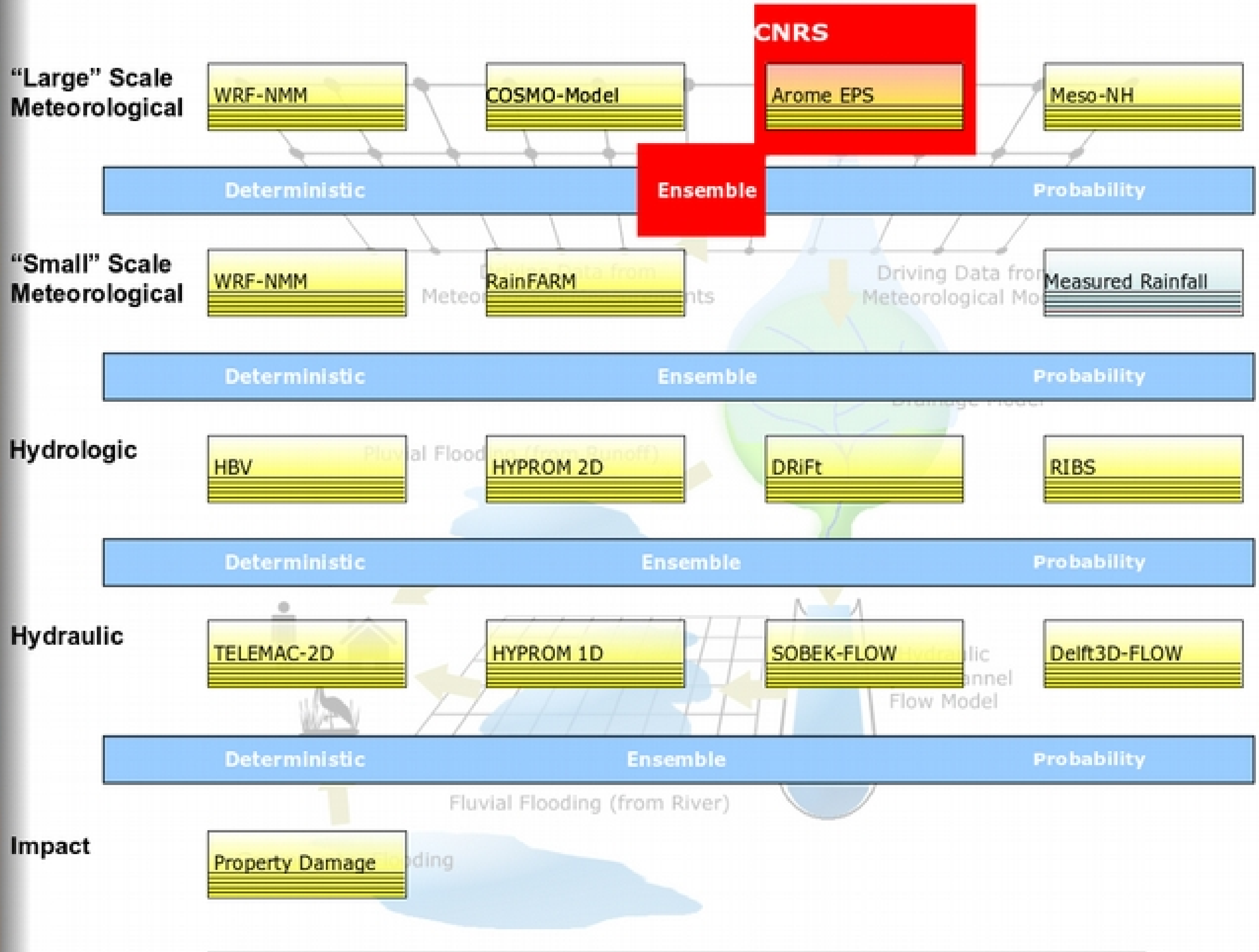


DRIHM Model Chains

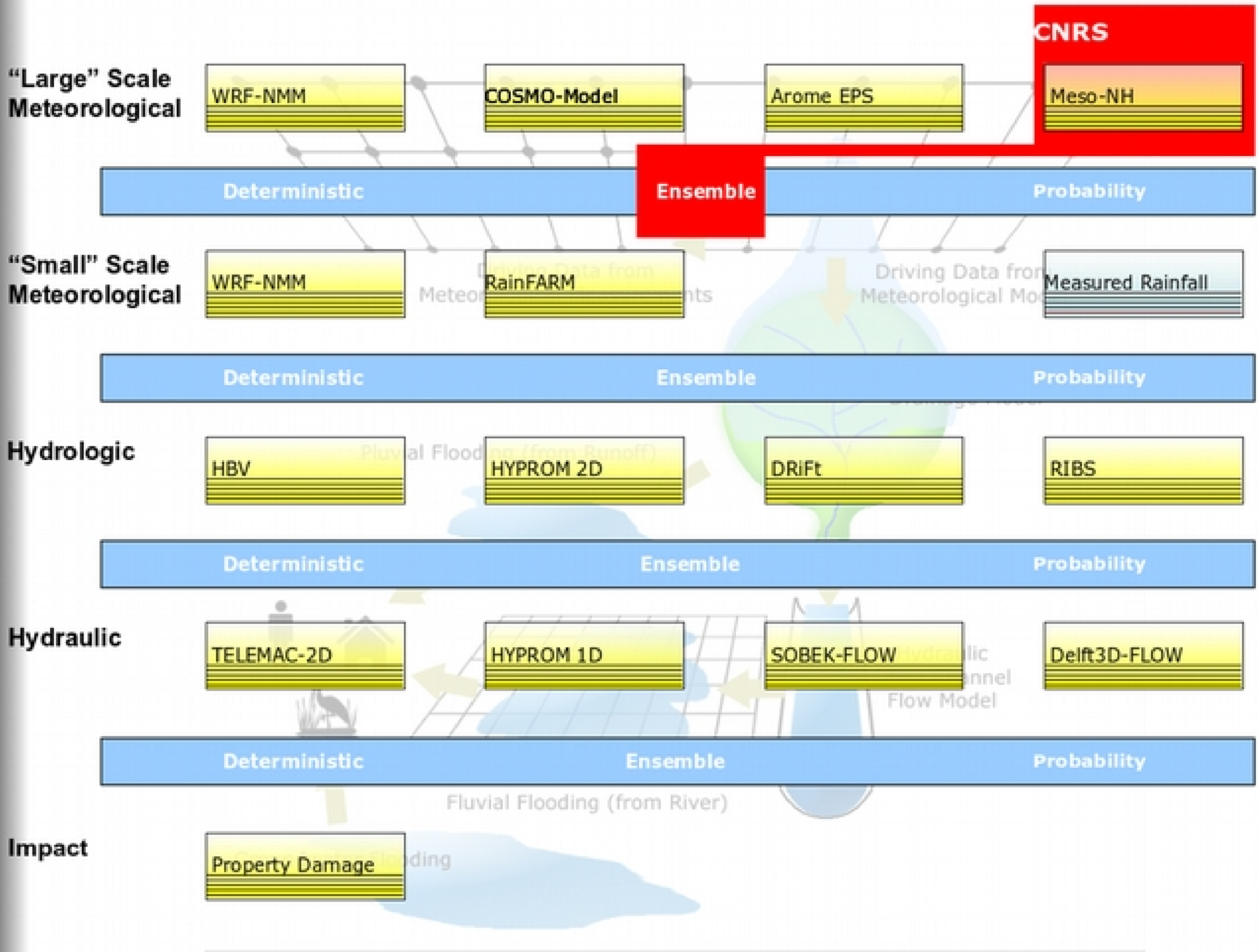




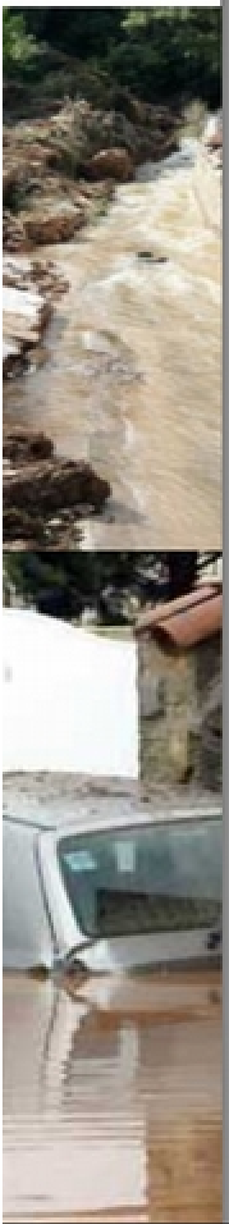
DRIHM Model Chains

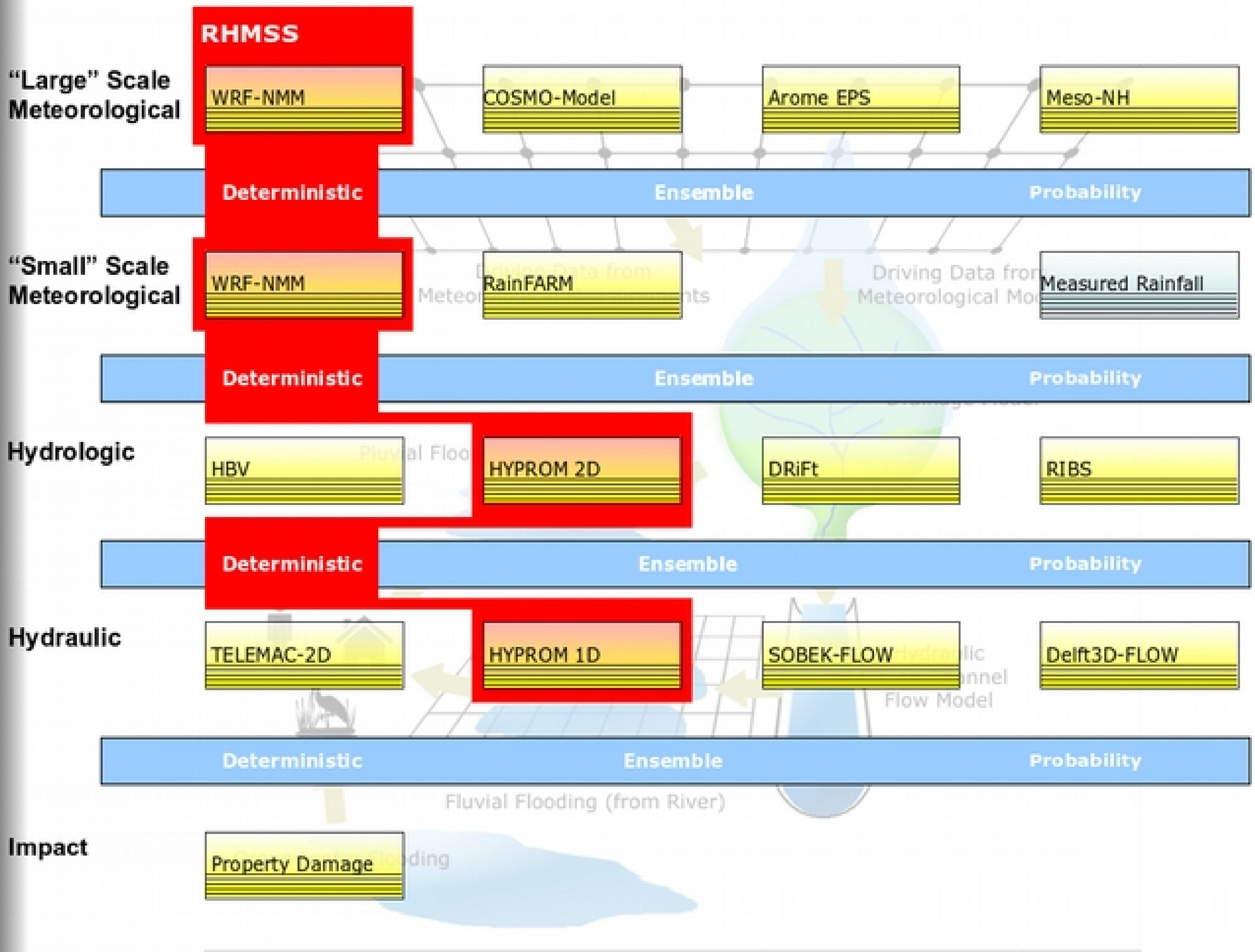


DRIHM Model Chains



DRIHM Model Chains





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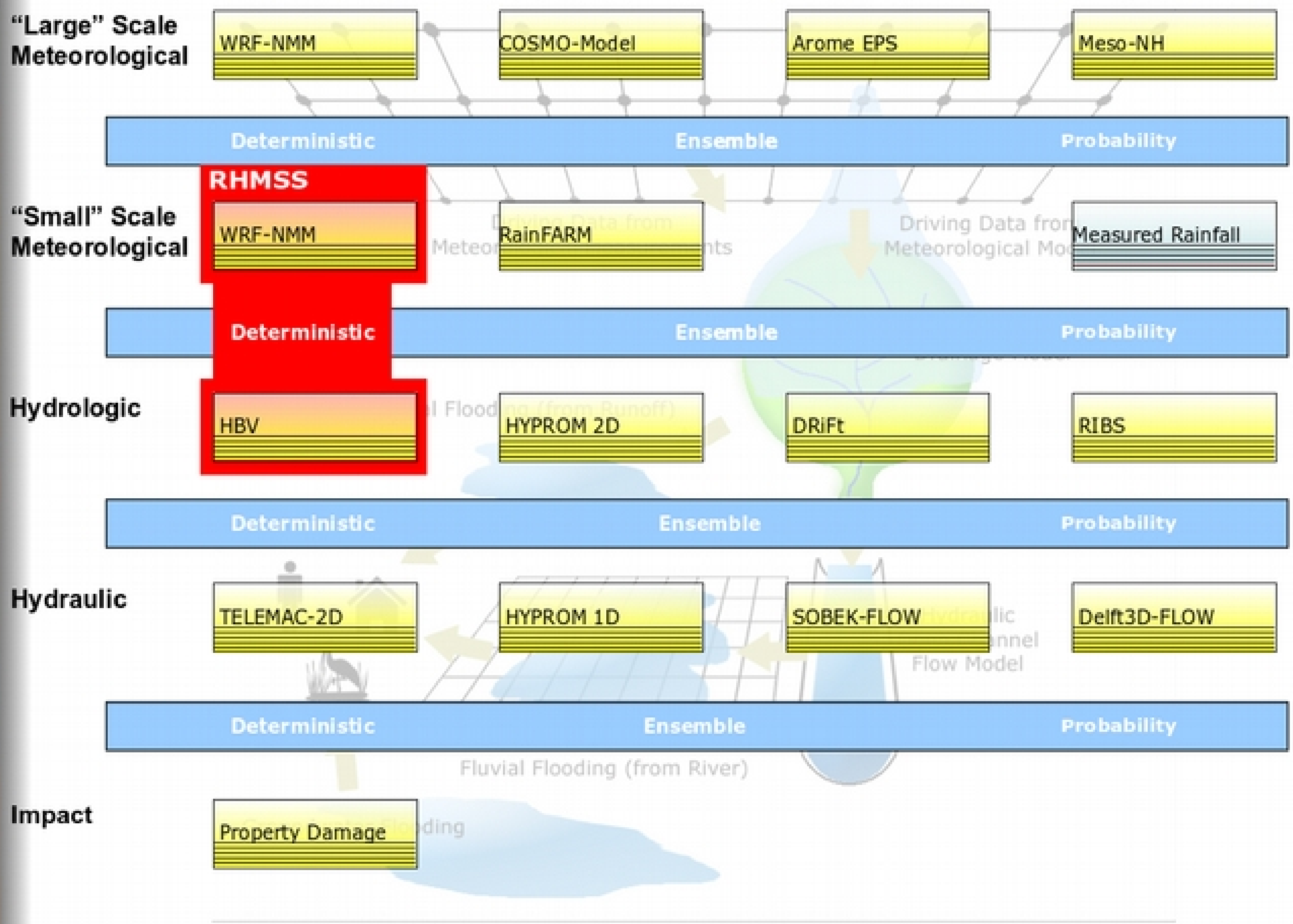

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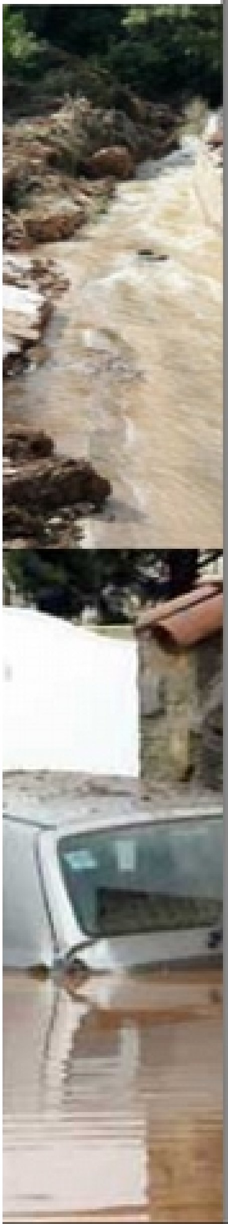
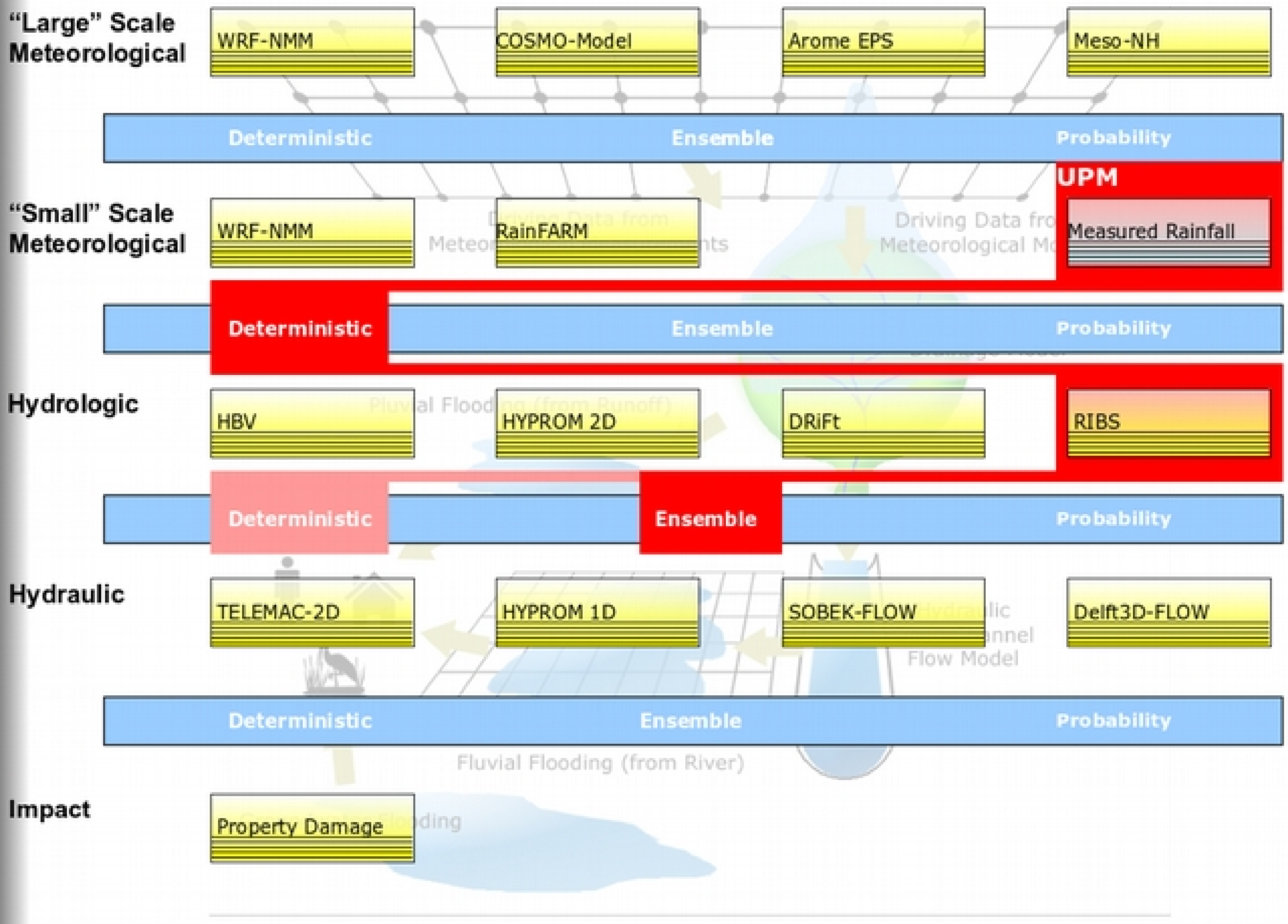
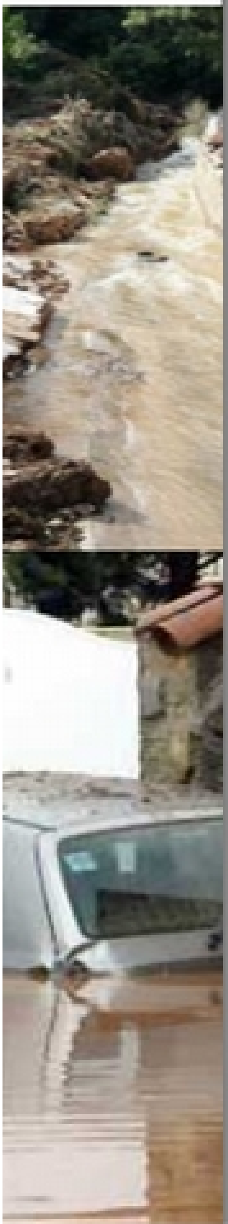
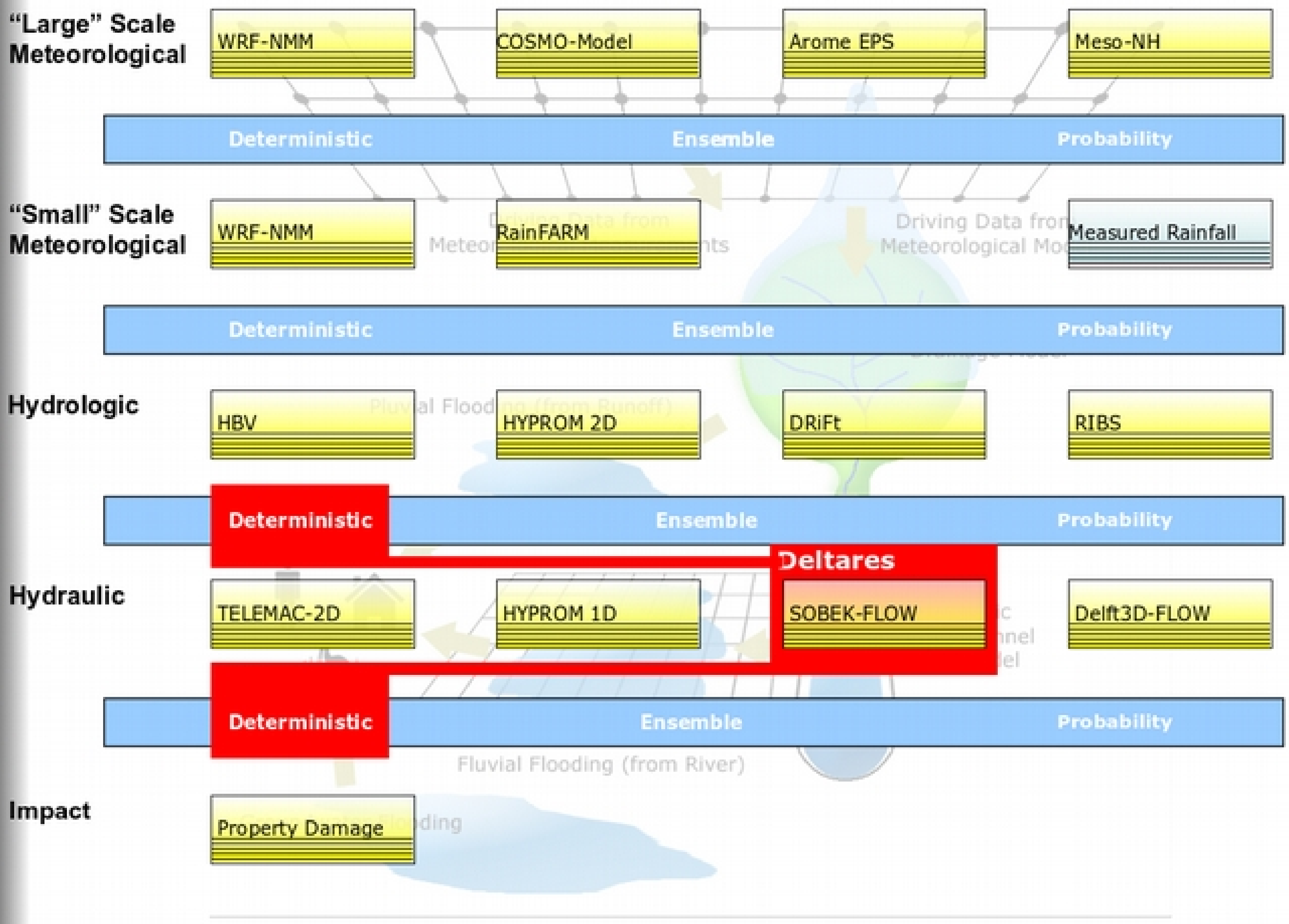




DRIHM Model Chains





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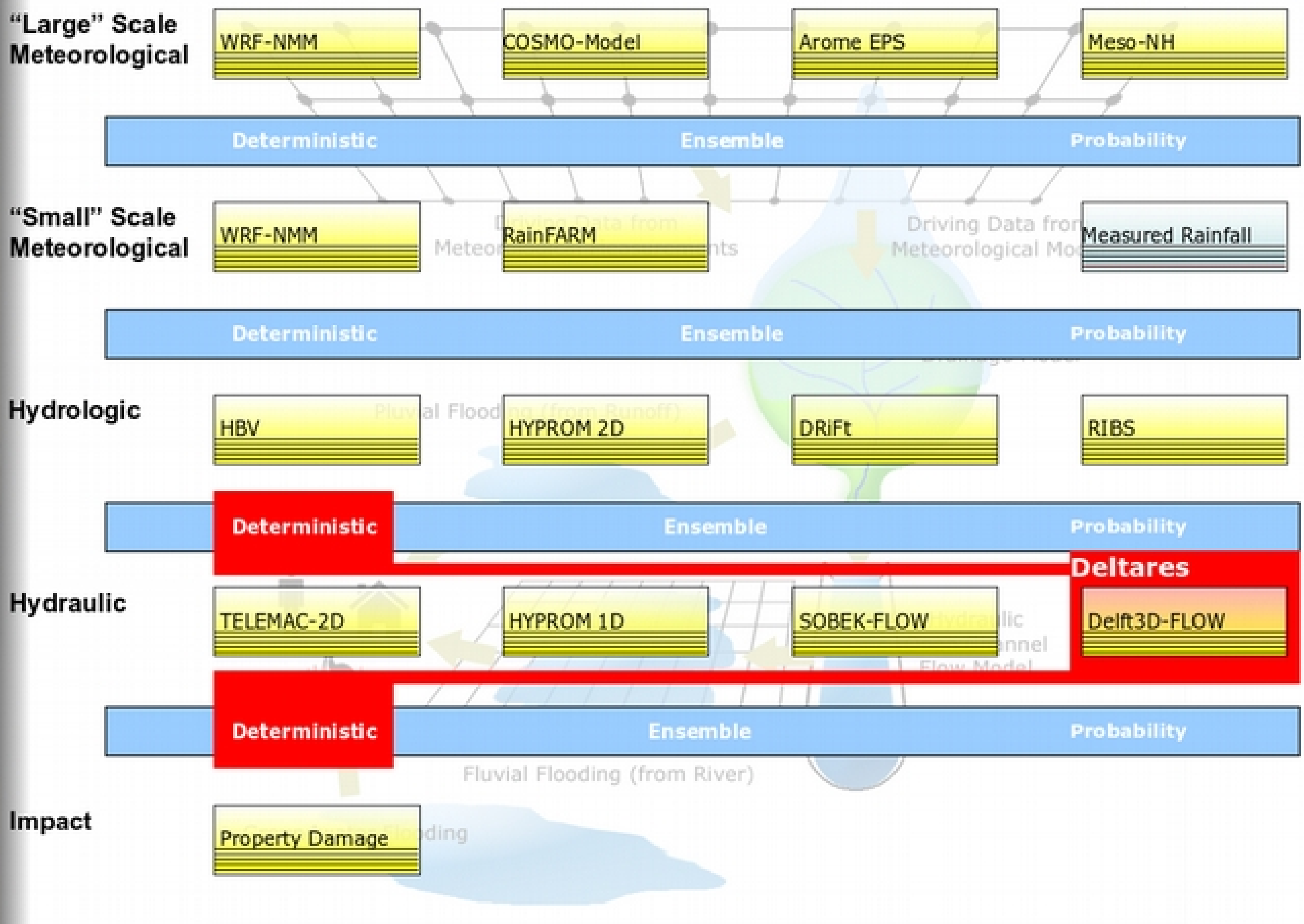
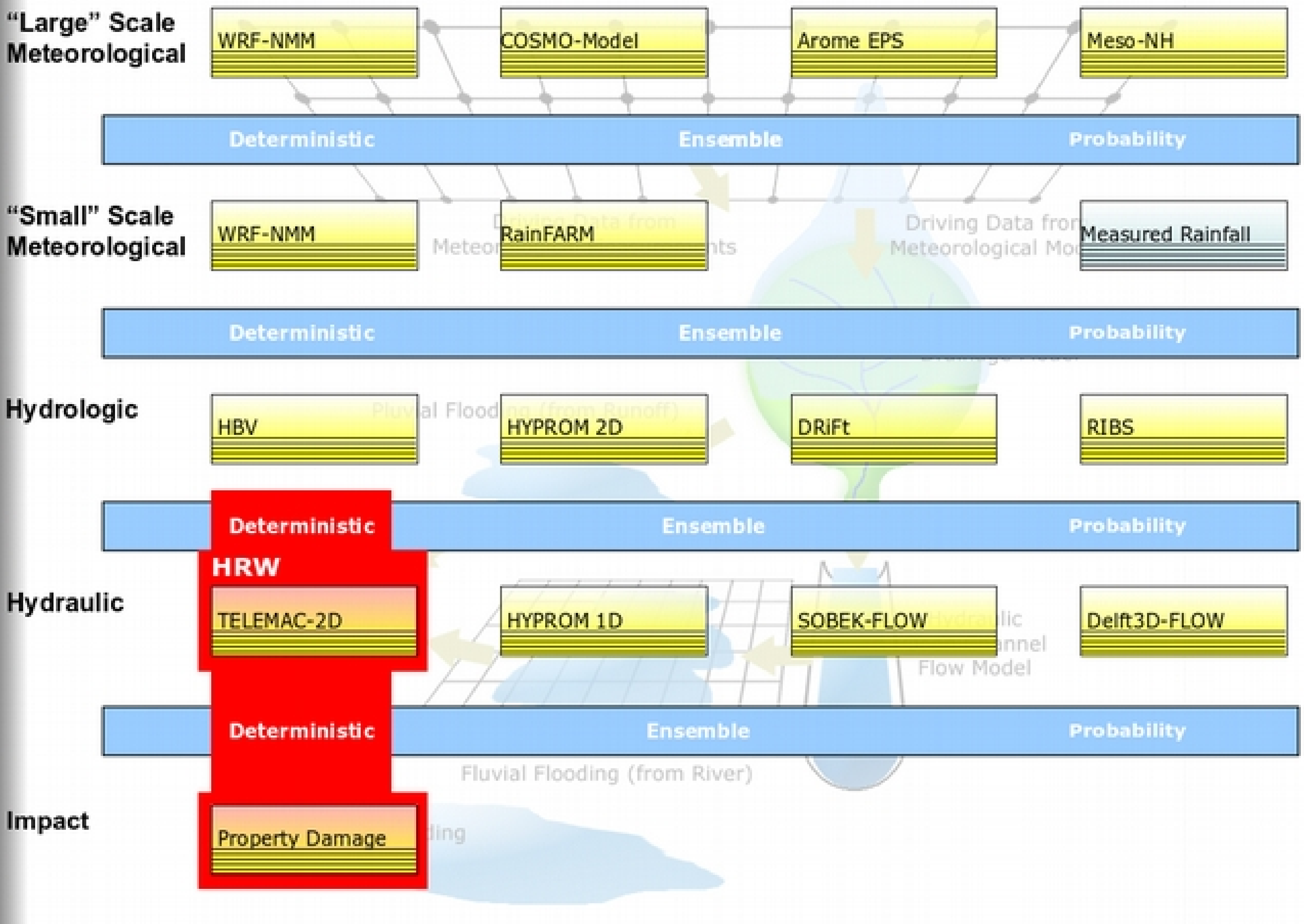
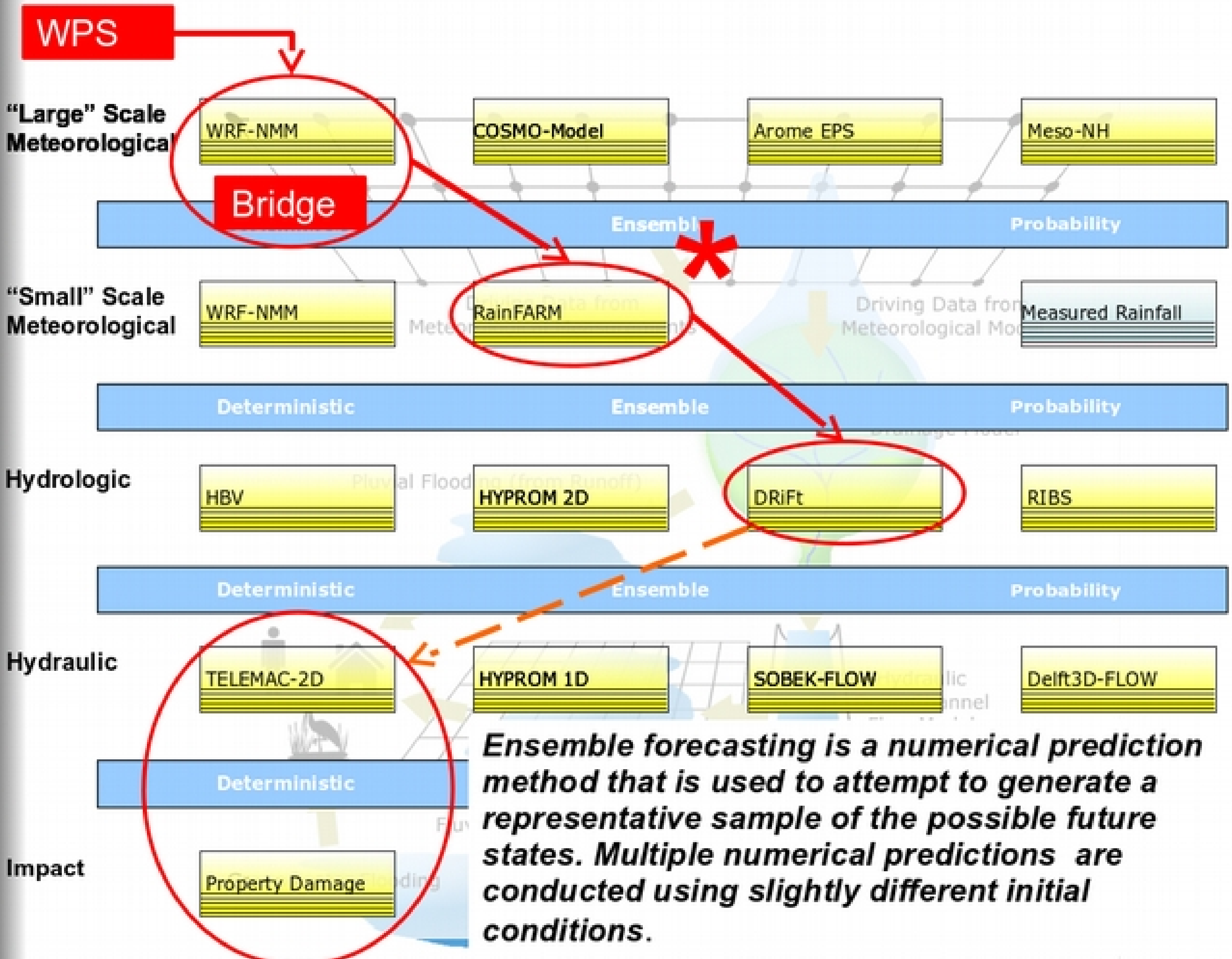


DRIHM Model Chains

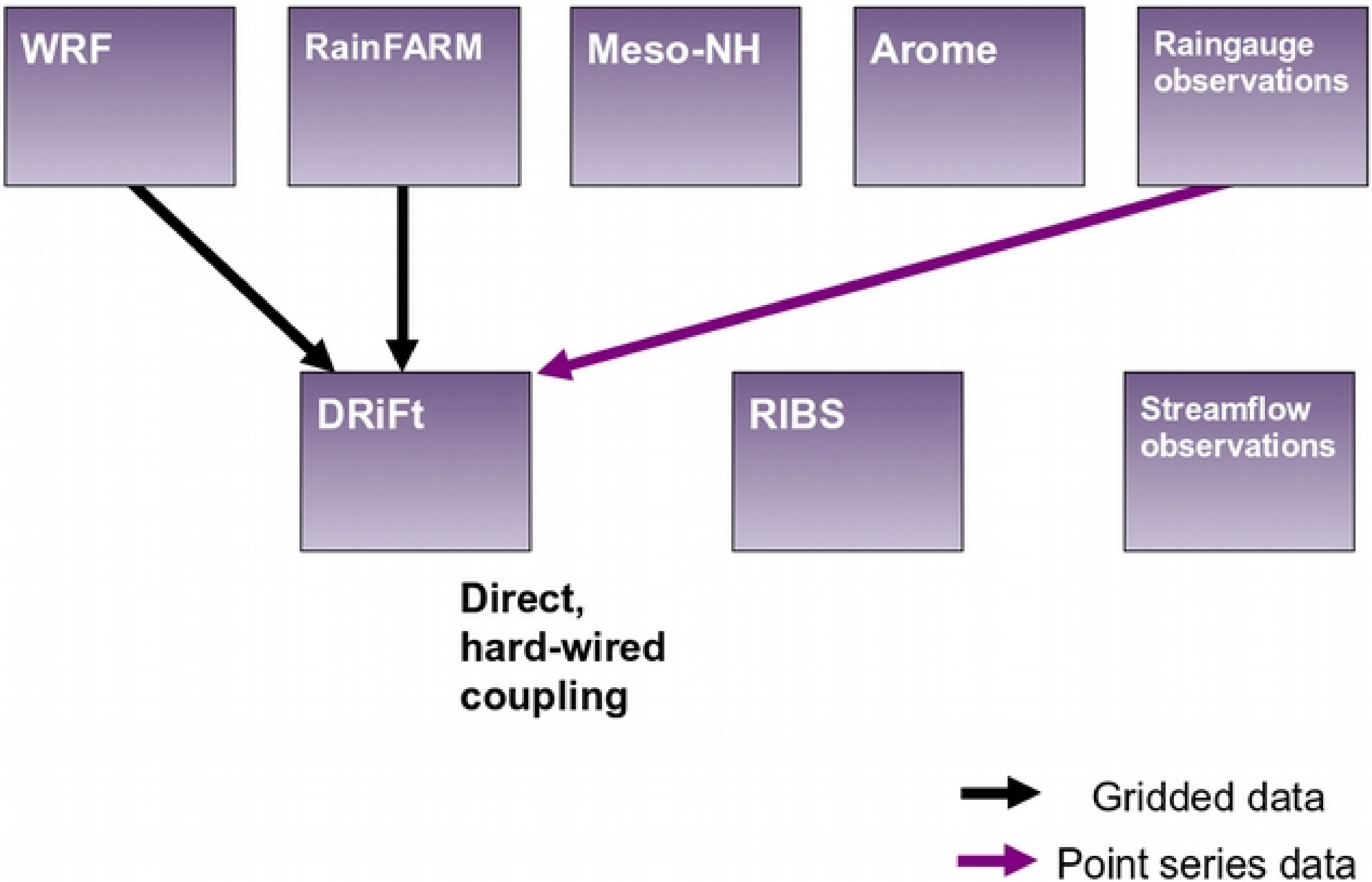


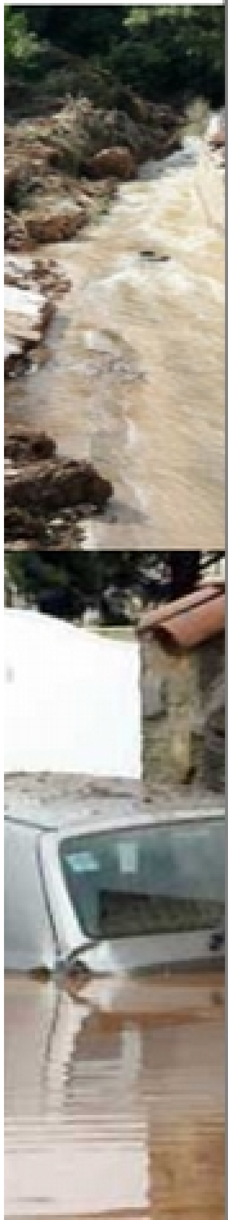
DRIHM Model Chains



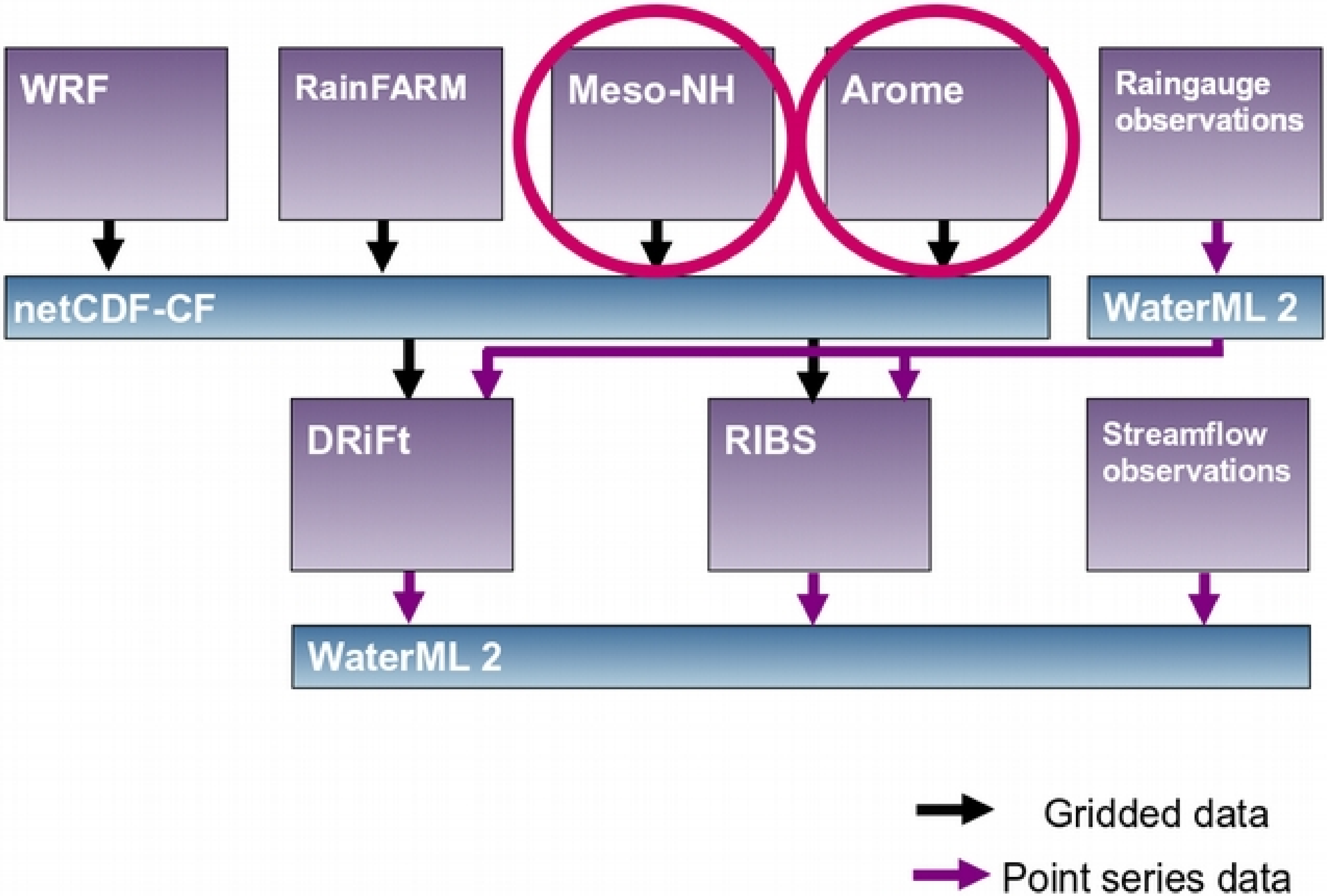
Ensemble forecasting is a numerical prediction method that is used to attempt to generate a representative sample of the possible future states. Multiple numerical predictions are conducted using slightly different initial conditions.

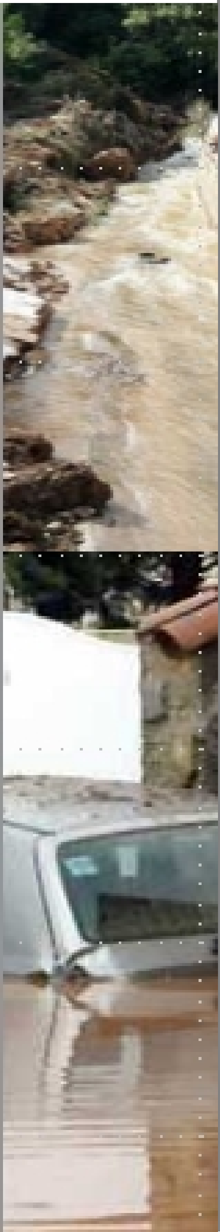
Baseline version of experiment suites 1 & 2





Advanced version of experiment suites 1 & 2



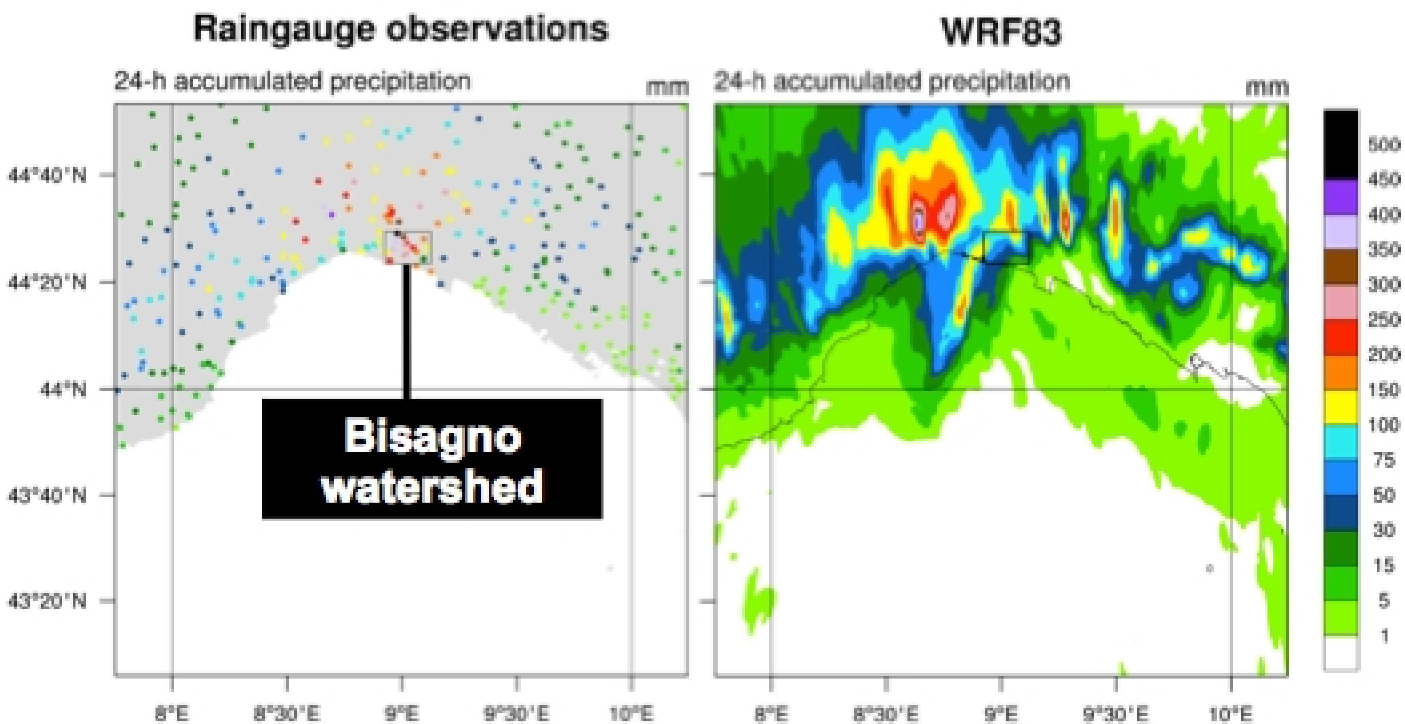


Summary of model setups

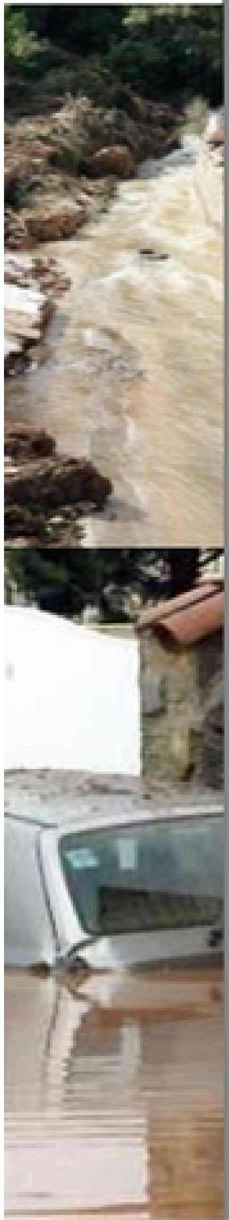
Rain source	Description	Ensemble members	Resolution (km)	# DRiFt runs	# RIBS runs
Observations	Raingauge measurements	1		1	30
WRF	IC & BC: IFS	1	1.0	1	30
Arome	IC AEARO; BC: PEARP	8	2.5	8	240
Meso-NH	IC & BC: Arpege	10	0.5	10	300
Meso-NH	IC & BC: IFS	10	0.5	10	300
RainFARM	Init. dyn. model	20	0.7	7	210
Total		50		37	**1110**

Meteorological scenarios

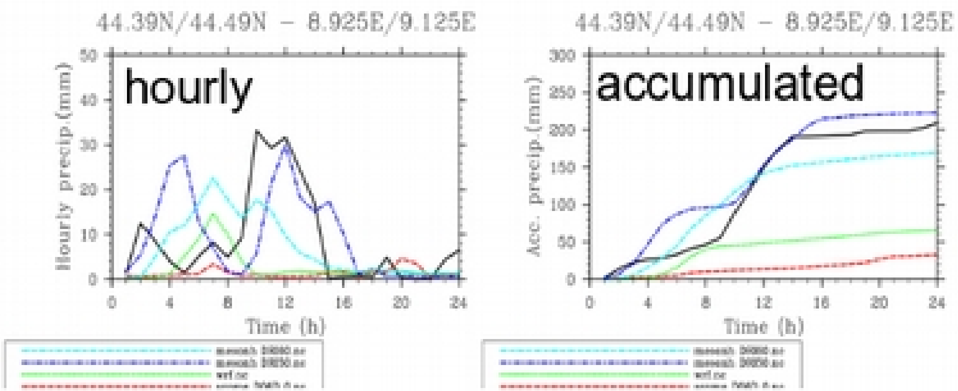
- More than **30 high-resolution**, multi-model scenarios.
- **3 different ensembles** from 2 different ensemble prediction systems.
- In the same format (**netCDF-CF**).
- Allowing processing by many free, off-the-shelf **post-processing** and **visualization softwares** (here the NCAR Command Language – NCL, NC-View, CDO, Panoply).
- Directly **comparable with WaterML 2.0** observations.



Comparison of rainfall time series

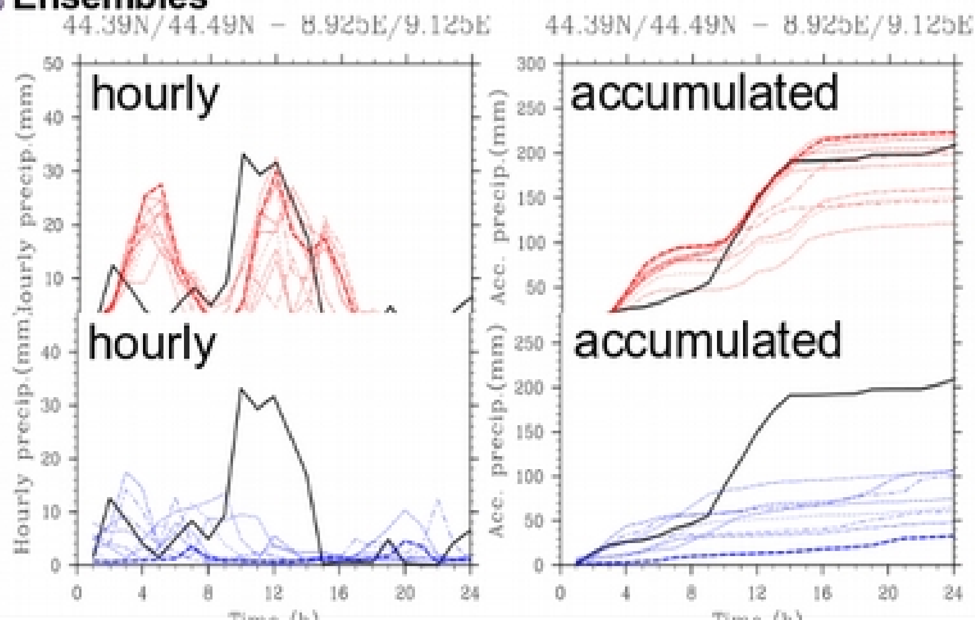


- **Rainfall time series averaged** over the Bisagno catchment



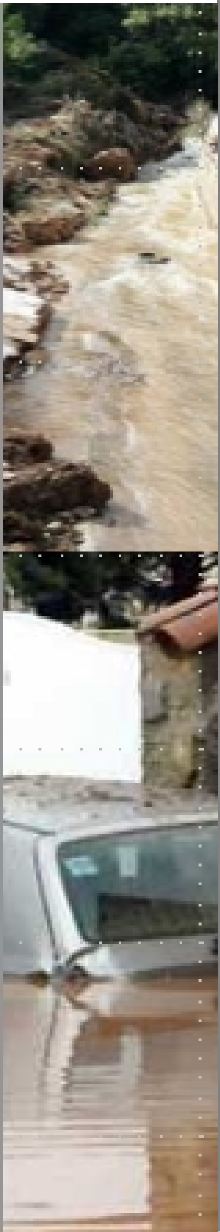
Rainfall time series for raingauge observations and different simulations

- **Ensembles**

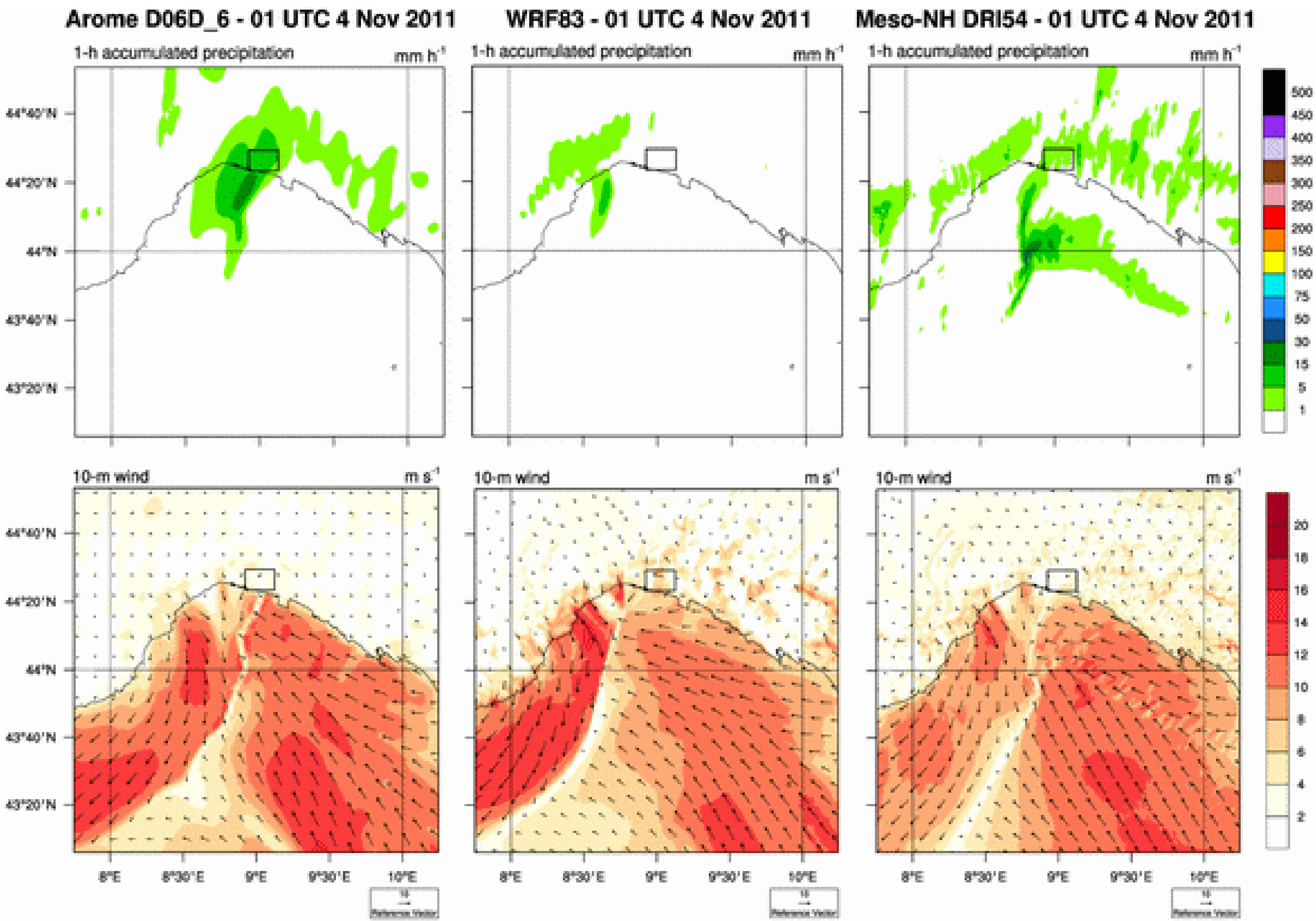


Rainfall time series for **raingauge observations** and **Meso-NH ensemble (DRI5X)**

Rainfall time series for **raingauge observations** and **Arome ensemble**

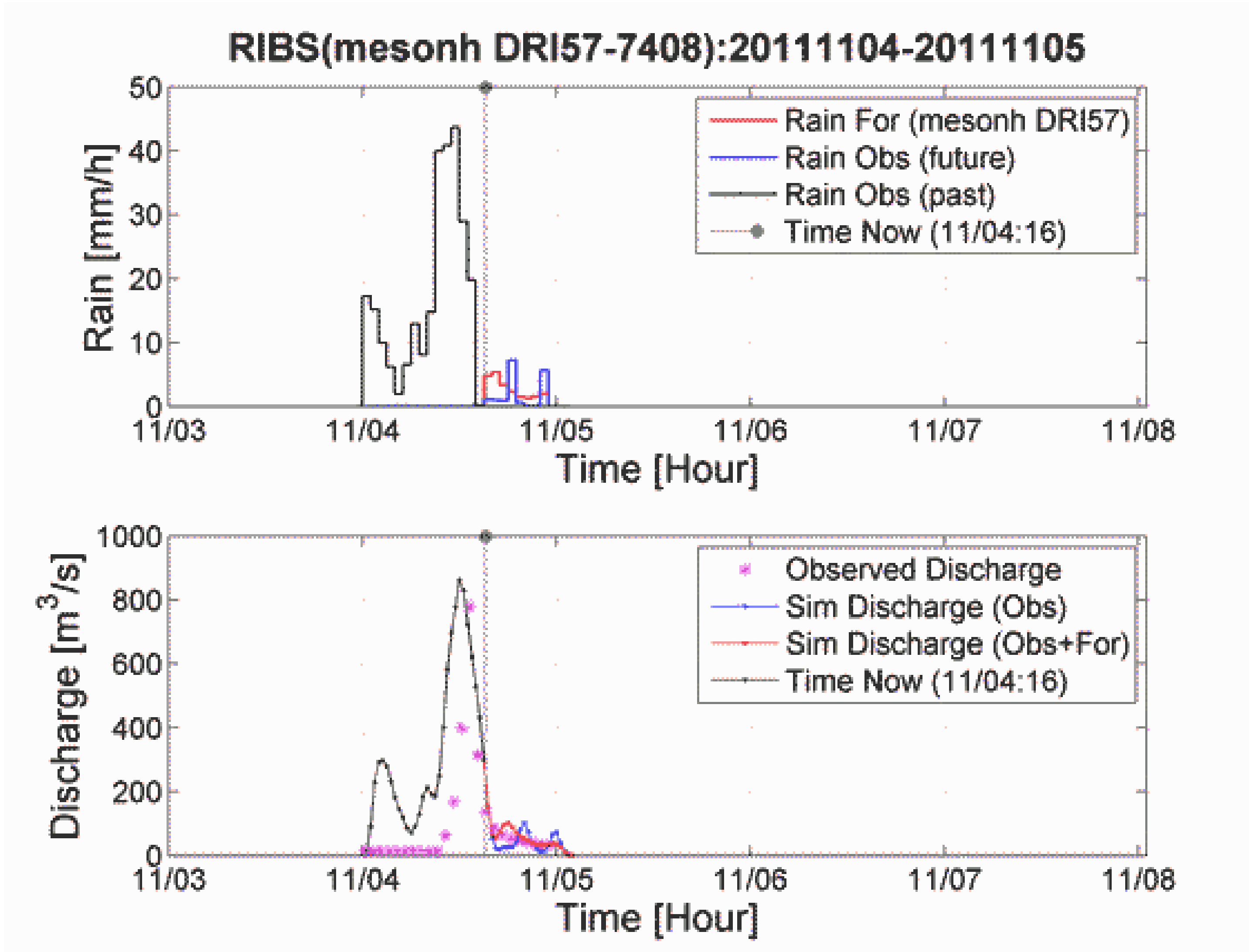


Comparison of model fields

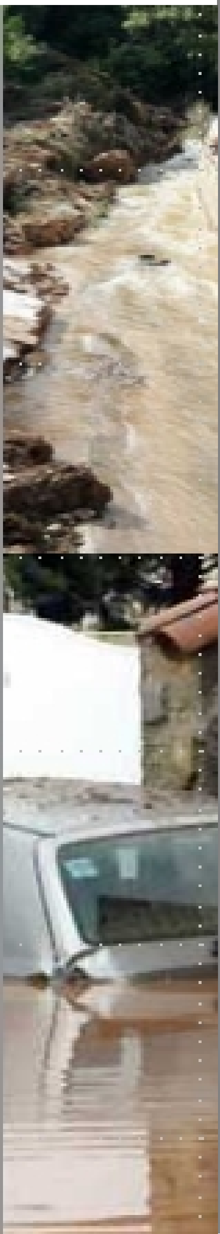


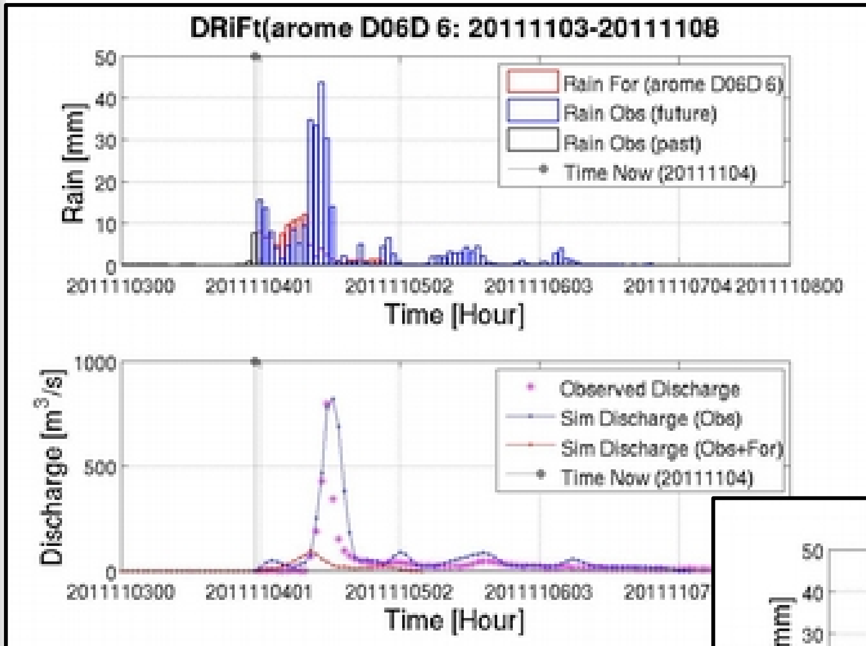
Full hydrometeorological chains

- Summarizing all the information produced by a chain in one plot

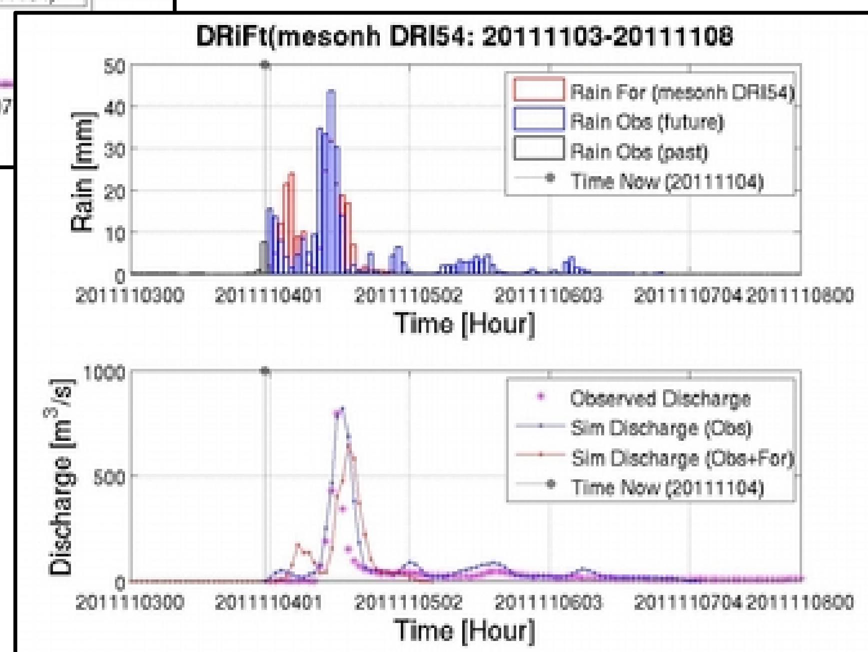


Comparison of different rainfalls



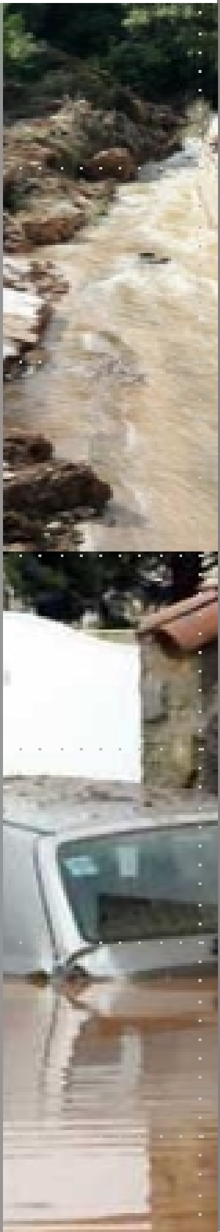


DRiFt driven by
Arome
ensemble
member #6



DRiFt driven by
Meso-NH
ensemble
member DRI54

The happy end...



FOCUS ON: How DRIHM can help Mark?

Mark is an Hydro-Meteo Researcher.
He has just designed a modification to his meteo model, but he would like to validate the new model.
There are two tasks required to validate a model:

- compare the prediction computed by the model with measured data
- cross-check the prediction computed by the model, with those computed by other models.

Let's focus on the second task: compare at least two meteo models on the same events, and cross-check the results. Mark already has its new model, but has to fetch, install and use some alternatives.

Required steps are summarized in the following list:

1. Install, compile and optimize the HMR simulation models, possibly developing data converters, connector to further models and visualization tools (hours to days)
2. Find and retrieve input data from other repositories, via ssh, ftp and other command line tools/scripts, learning the process and all the flags (hours)
3. Select and retrieve large data (like static data)
4. Execute convert and pre-process operations on the data (hours)
5. Set execution parameters
6. Select the executable resources
7. Move all the data and ancillary files
8. Launch the execution
9. Monitoring of possible execution faults and re-submit in case of failure
10. Results retrieval
11. Visualization or further processing

For the first execution of a model, Mark need to perform all the eleven steps. Subsequent model runs requires steps from 2 to 11. This means days for testing against a single alternative meteo model. Moreover the IT resources required (SW tools, HW resources, IT expertise) are to be taken into account. DRIHM infrastructure can help Mark in speed-up the whole process, providing him ready to run hydro-meteo models, tools for managing data and high performances computing resources.

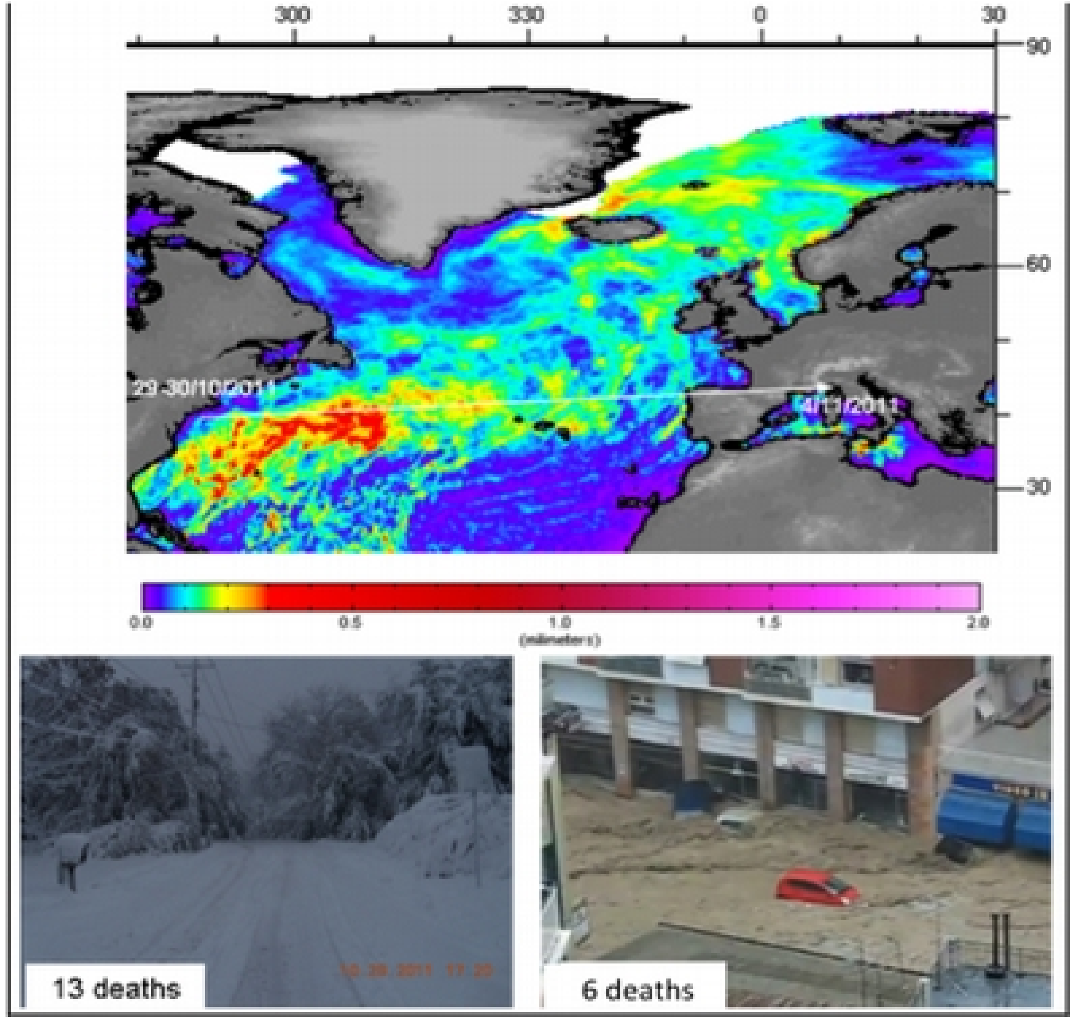
In a DRIHM scenario, the eleven steps become:

1. Select one of the provided models
2. Find input data from other repositories via graphical user interface
3. Select large data
4. Select the conversion and pre-processing operations
5. Set execution parameters
6. --
7. --
8. Launch the execution (the system will take care of selecting the resources, moving converting and pre-processing the data, re-submit in case of failure)
9. --
10. --
11. Visualization or further processing (the system will take care of results retrieval)

Now Mark can squeeze (from days to minutes) the time required to run a simulation on an alternative model, and can focus on improving the new Hydro-Meteo model and accurately validate it.

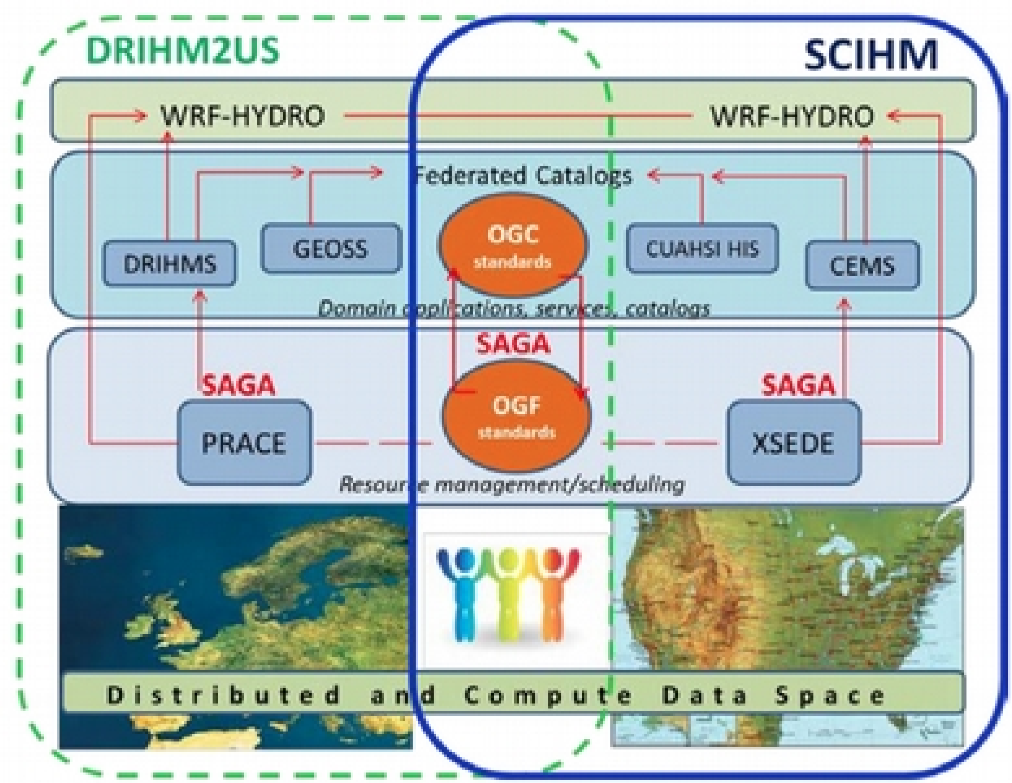
Thinking globally … DRIHM2US

DRIHM2US: 2012-2014
Budget: 0.5 Meuro
Project Director:
A. Parodi (CIMA)



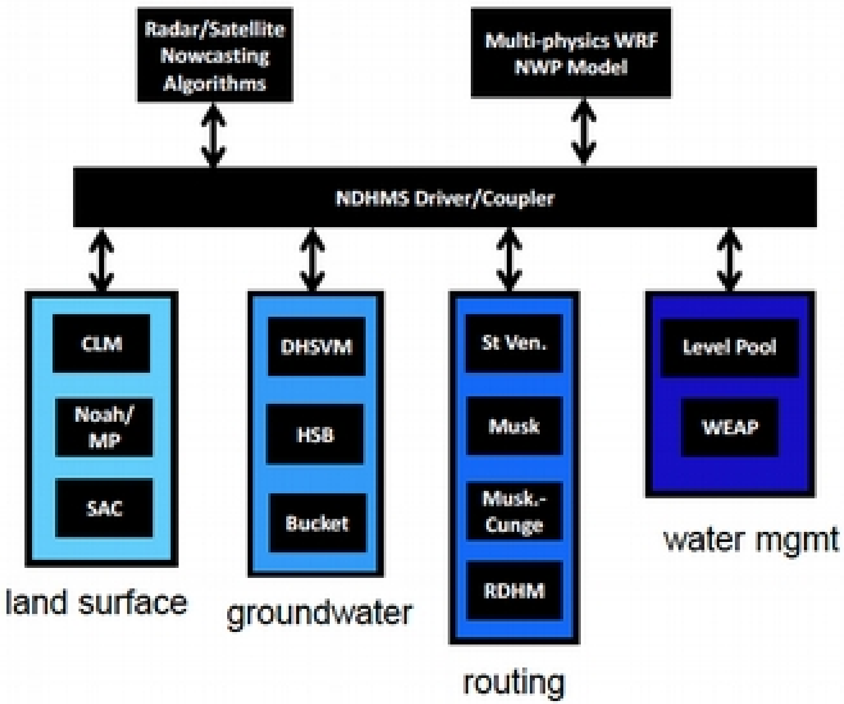
Upper panel: satellite cloud liquid water composite (week ending 5/11/2011) clearly shows the cyclone track from USA east coast to Mediterranean. Lower left panel: snowstorm impacts example on USA east coast. Lower right panel: Genoa city (Italy) under massive flash-flood event.

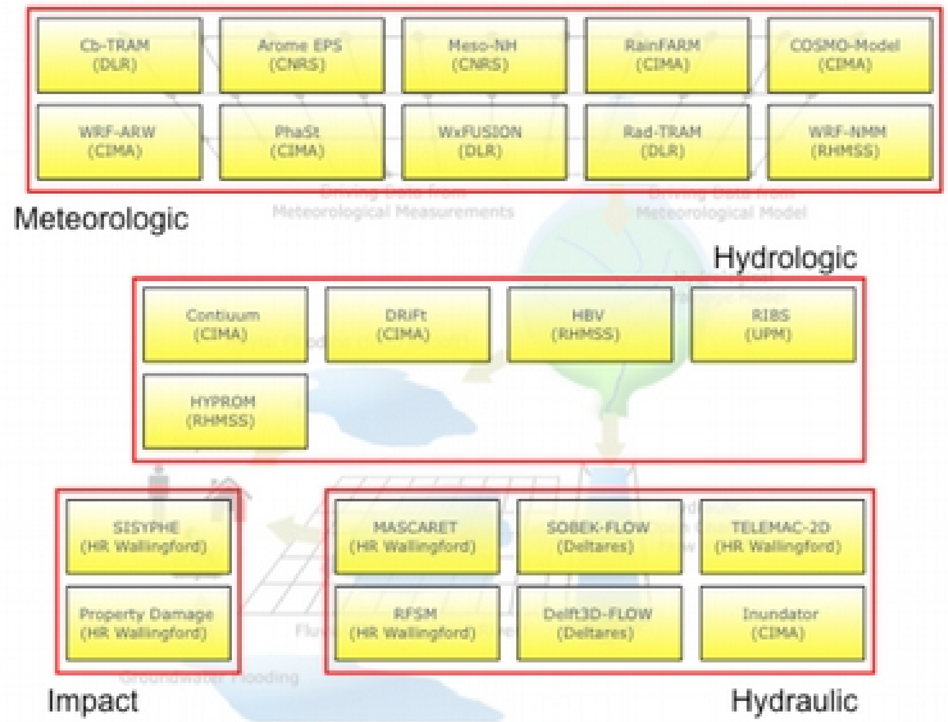
DRIHM2US interoperability testbeds



Main components of our multi-layer design and the interactions between collaborating projects in the US and Europe, in particular as organized under DRIHM2US and its US counterpart, SCIHM (Standards-based CyberInfrastructure for HydroMeteorology). The two projects overlap in their reliance on open community standards developed for high performance resource management and for domain services and catalogs, and on joint use of the data and services infrastructure, as well as parallel institutional development and community engagement.

DRIHM2US interoperability testbeds

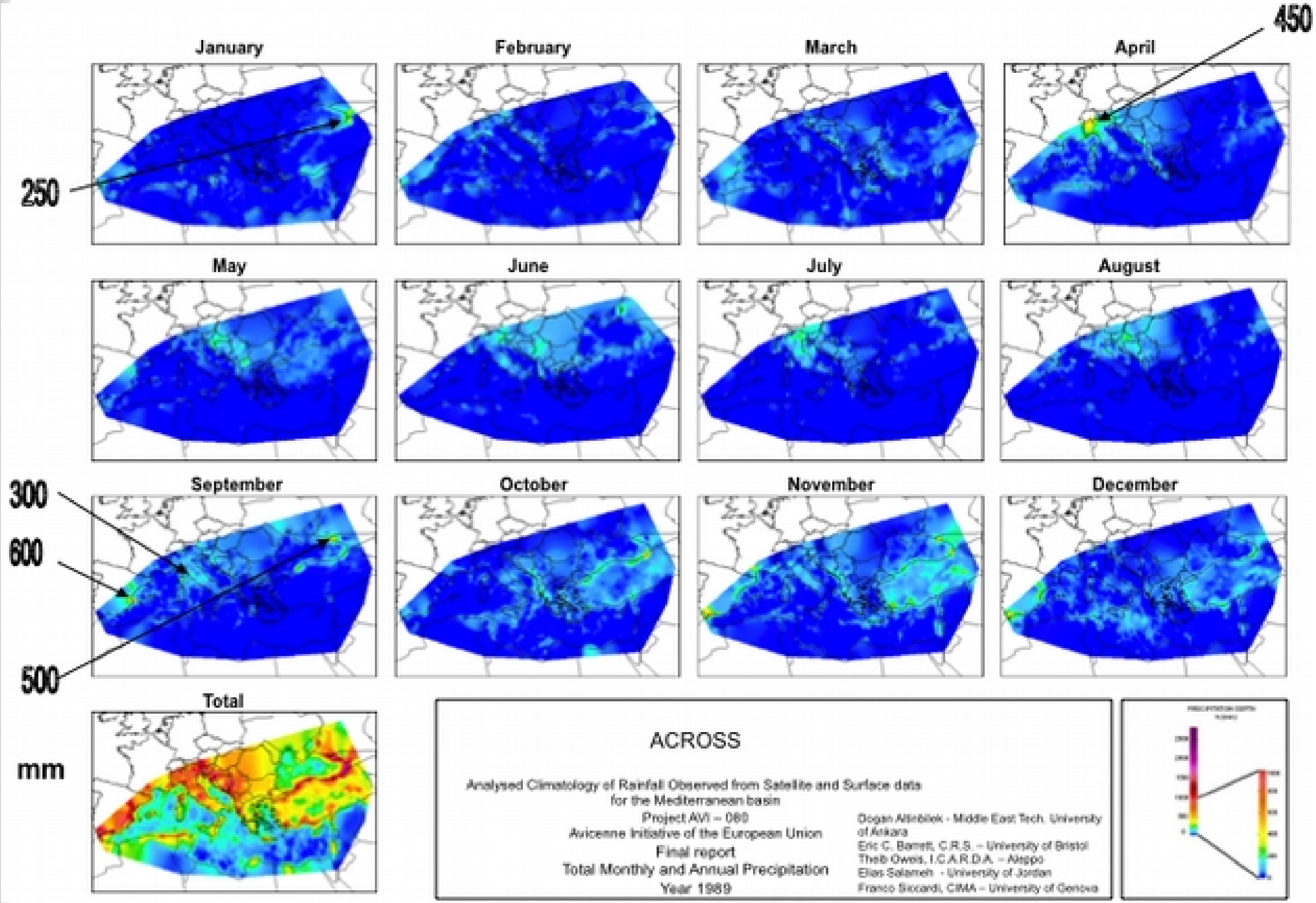




Schematic showing the suite of multi-physics options available for experimentation in the SCIHM use cases from WRF-Hydro (left) or from DRIHM (right).

And the climate change…

SSMI and raingauge observations 1978-1994



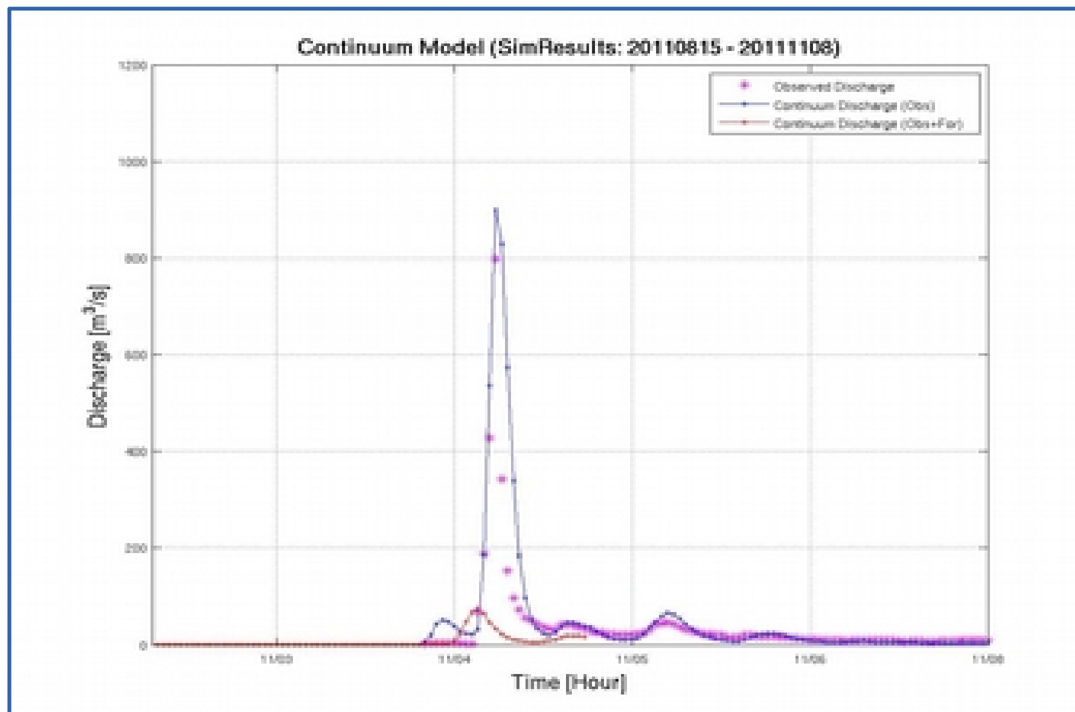
DRIHM2US … WRF-Continuum

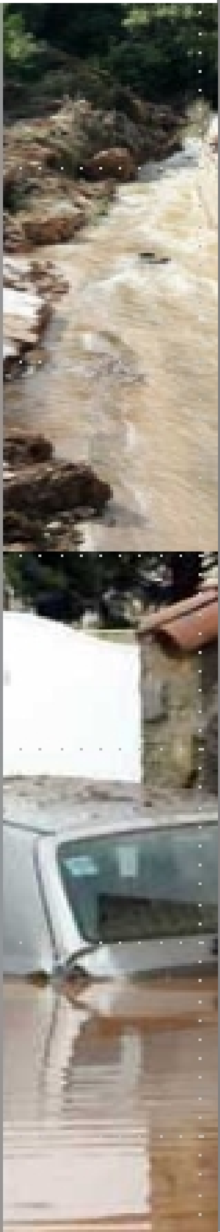
→ **Following the WRF-Hydro scheme and structure**

Problems:

- Continuum is based on a sequential structure;
- Continuum I/O are not in a standard format;
- Continuum code is not parallelized;
- …

F. Silvestro, S. Gabellani, F. Delogu, R. Rudari, and G. Boni
Exploiting remote sensing land surface temperature in distributed hydrological modelling: the example of the Continuum model.
Hydrol. Earth Syst. Sci., 17, 39-62, 2013





DRIHM2US … WRF-Continuum

Work planning:

1) Model benchmark

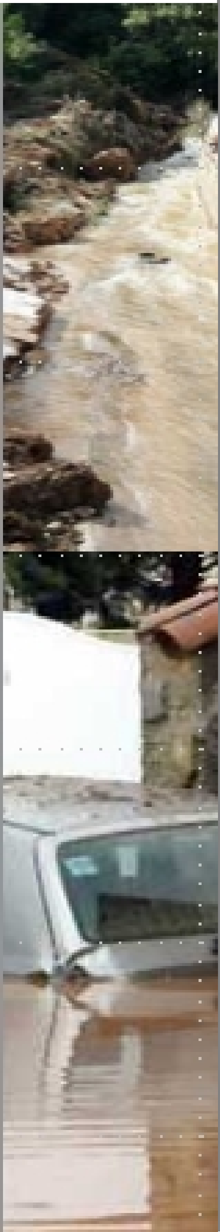
2) Write pre-processing data tools

3) Rewrite Continuum code (drives by Energy Balance) using coupler-driver functions
- Initialization
- Routing
- Finalization ←

4) Couple Continuum with NOAH-LSM

5) Couple Continuum with WRF

6) Parallelize WRF-Continuum



Thank you for your attention!

Questions ?