Pasquale Perrini

25 years

Civil & Environmental Engineer

Ph.D. student (37th cycle enrolled in the 2nd year of the course) in “Sustainable Land Management” between the University of Bari Aldo Moro and the Polytechnic University of Bari

UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO

Politecnico di Bari

UNIVERSIDADE DA CORUÑA

Grupo de Ingeniería del Agua y del Medio Ambiente

My supervisors

Andrea Gioia

Umberto Fratino

Vito Iacobellis

Extended research group

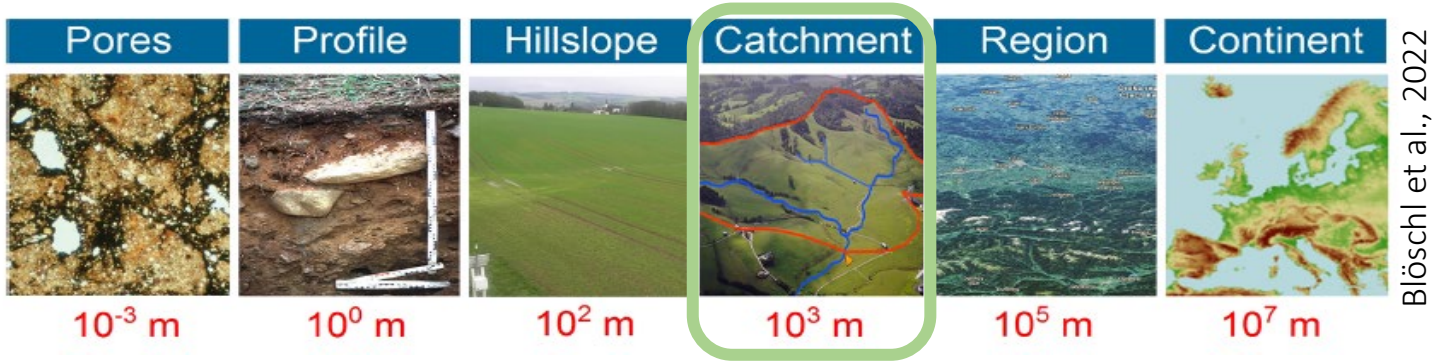
Francesco Chiaravalloti

Mauro Fiorentino

Salvatore Manfreda

Ph.D. topic

"Implementation of enabling technologies in the assessment of hydrological processes at basin scale, aimed to protect and increase the resilience of metropolitan areas at hydraulic risk"

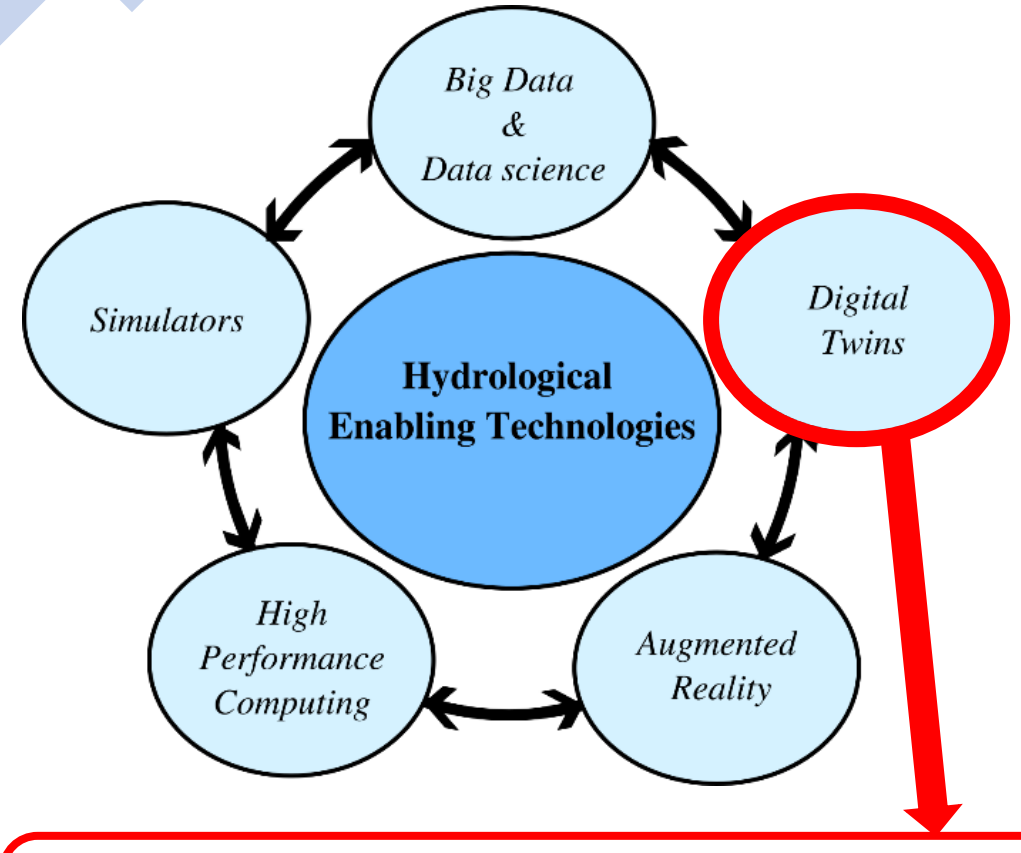


Blöschl et al., 2022

Ph.D. Goal

Step forward Hydrological Digital Twins

Enabling Technologies for hydrology



Original definition of the European Community

Enabling technologies (ETs) are "knowledge-intensive tools associated with high Research & development intensity, rapid innovation cycles, substantial investment expenditure"…

… that could decrease epistemic uncertainties and generate transversally new holistic solutions for hydrological sciences and associated risks."

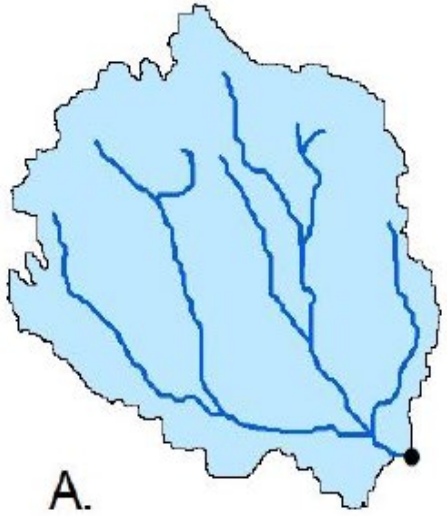
(in the view of natural disaster and environmental modeling)

A digital twin is formally considered a dynamic, multi-resolution, four-dimensional representation of an entity or system, which is constantly updated and enhanced over time; to represent the current structure and behavior of that physical artifact.

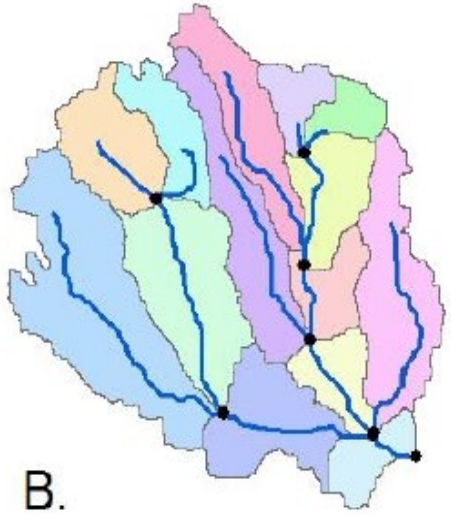
Bauer, 2021 & Rigon, et al., 2022

Hydrological models (event scale)

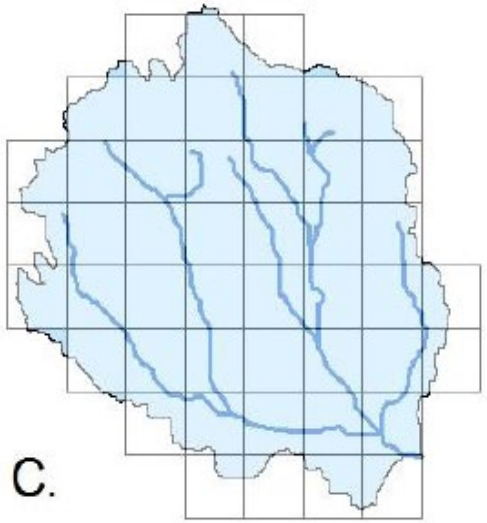
Lumped



Semi Distributed



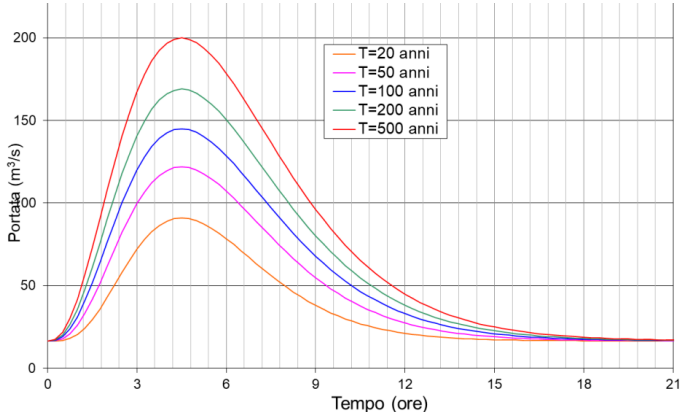
Distributed



from Sitterson et al., 2015

OUTPUT

Flow Hydrographs



Low relative Physical basis

Hydrological

Flow Routing

Hydraulic

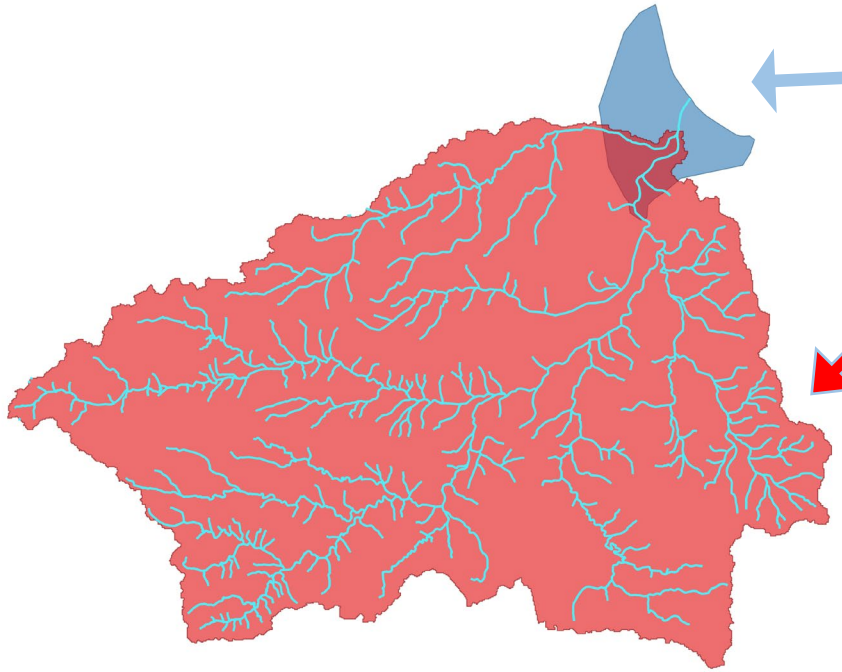
High relative Physical basis

Rational Method	Unit hydrograph	Nonlinear Reservoir Eq.s	Kinematic Wave Eq.s	Diffusive Wave Eq.s	Shallow Water Eq.s	Navier Stokes Eq.s

Hydrodynamic models

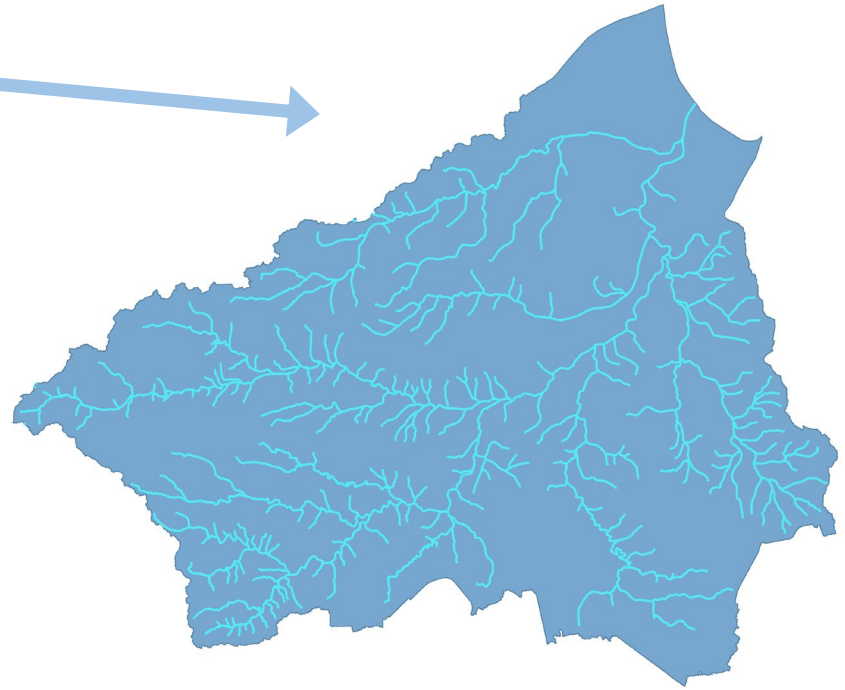
Upstream boundary condition approach

Rain on grid approach



Hydraulic Component

Hydrological Component



Low relative Physical basis

Hydrological

Flow Routing

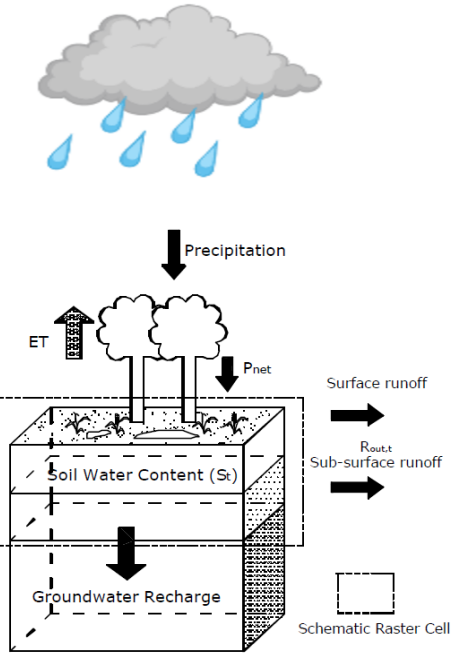
Hydraulic

High relative Physical basis

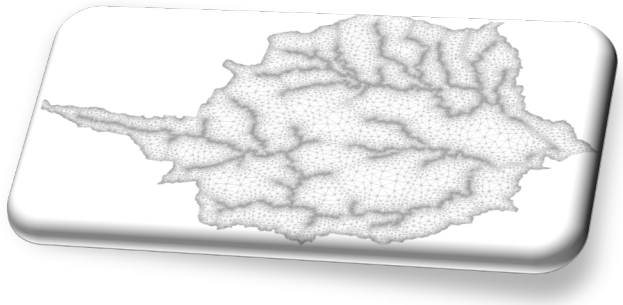
Rational Method	Unit hydrograph	Nonlinear Reservoir Eq.s	Kinematic Wave Eq.s	Diffusive Wave Eq.s	Shallow Water Eq.s	Navier Stokes Eq.s

Could we improve the «output» of a distributed hydrological model?

The Runoff-on-Grid approach



(Manfreda S., et al., 2005)



(Cea L., et al. 2022)

$$S_{t+\Delta t} = \min(S_t + I_t - ET_{soil} - RG_t \pm RS_t\ , S_{max})$$ *Water Budget equation*

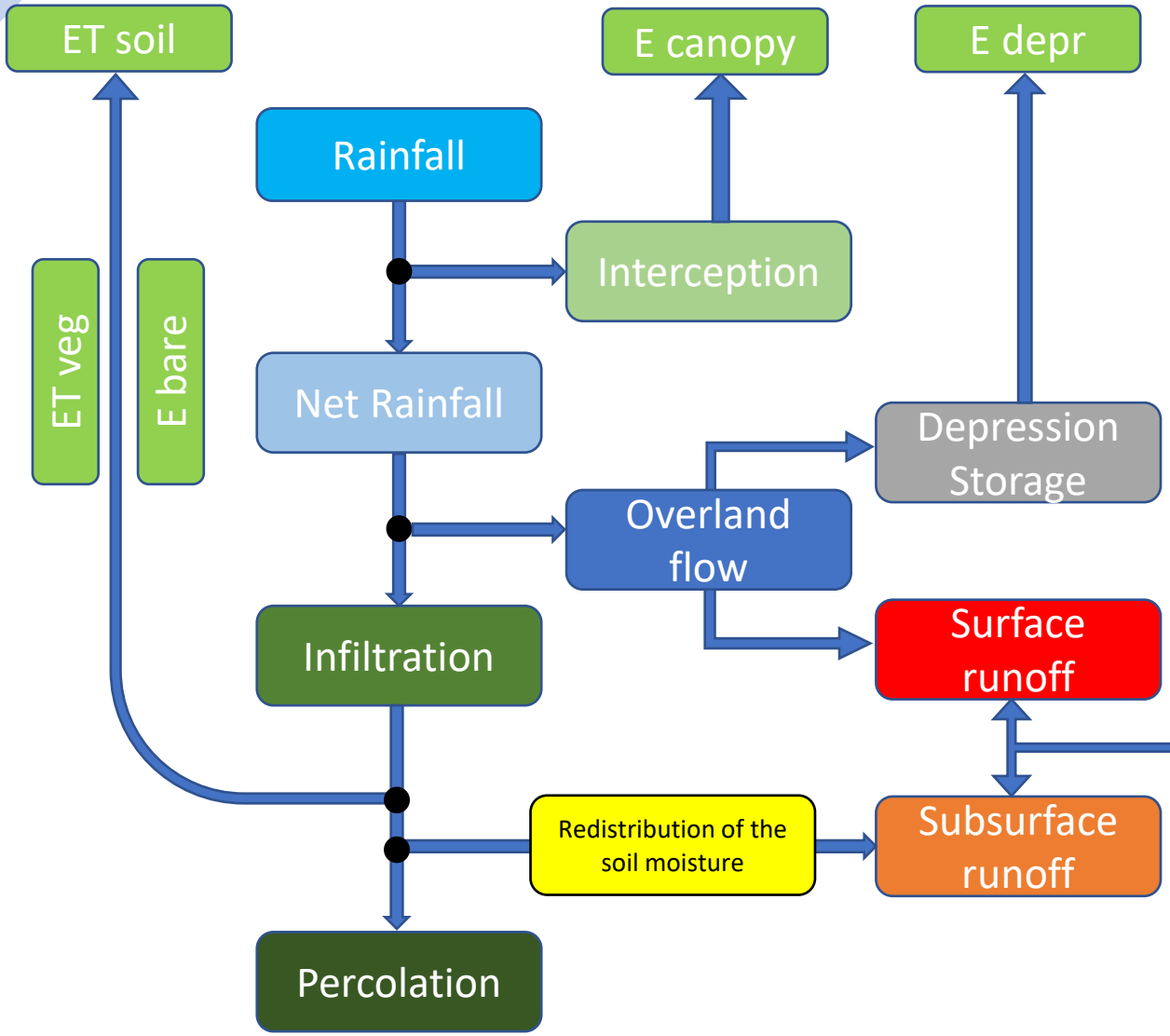
$$R_{tot,t} = \max(R_t + SS_t\ , 0)$$ *Distributed Total Runoff*

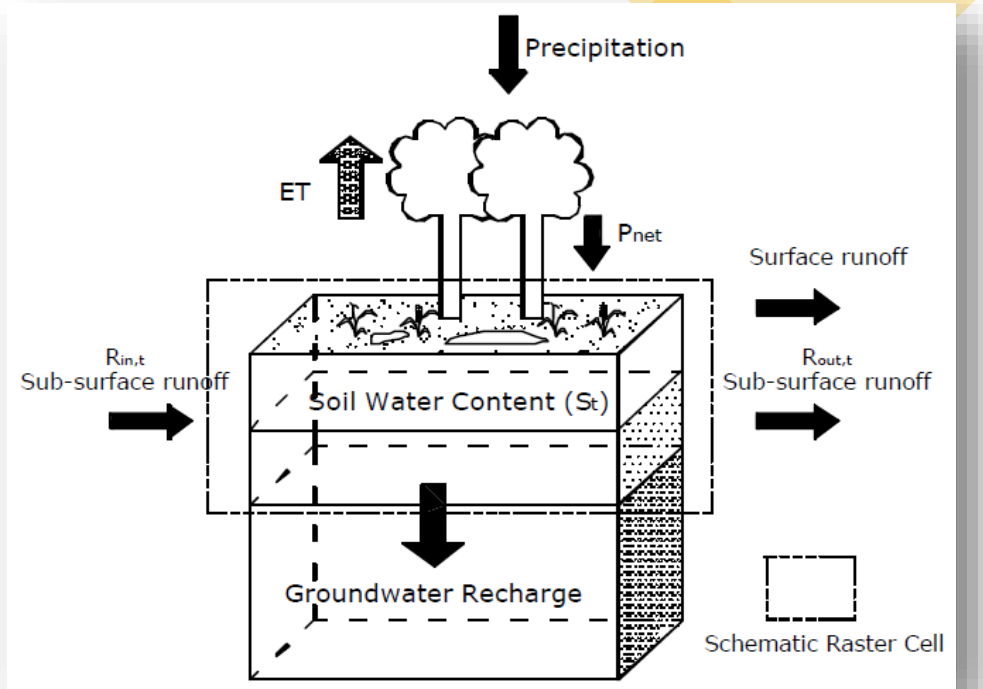
Rainfall-Runoff transformation is already done…

$$\frac{\partial h}{\partial t} + \frac{\partial q_x}{\partial x} + \frac{\partial q_y}{\partial y} = R_{tot,t}$$ *H^2 Continuity Equation*

Note that the Runoff computed by DREAM can be **locally** *higher than the Gross Precipitation, in highly saturated soil moisture conditions.*

Our DREAM Model





(Manfreda S., et al., 2005)

Total runoff

To be routed with

iber

Study Case of Esaro river

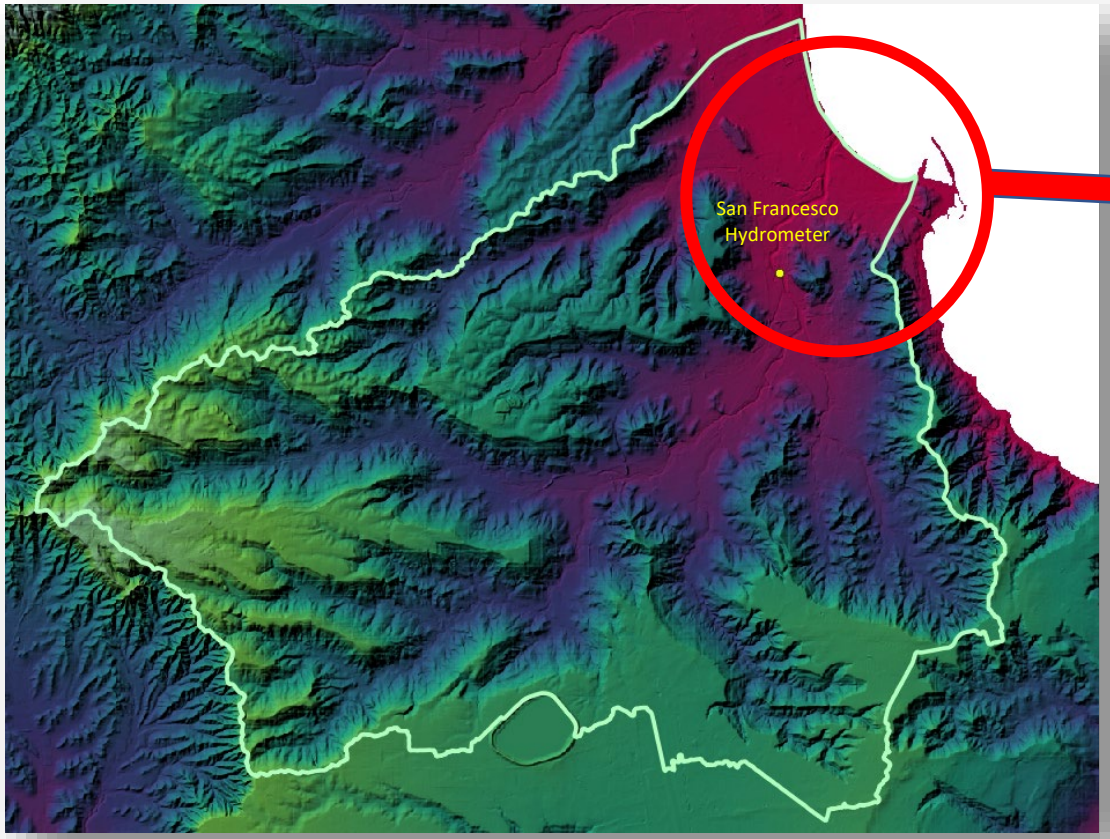
Crotone (Calabria Region, Italy)

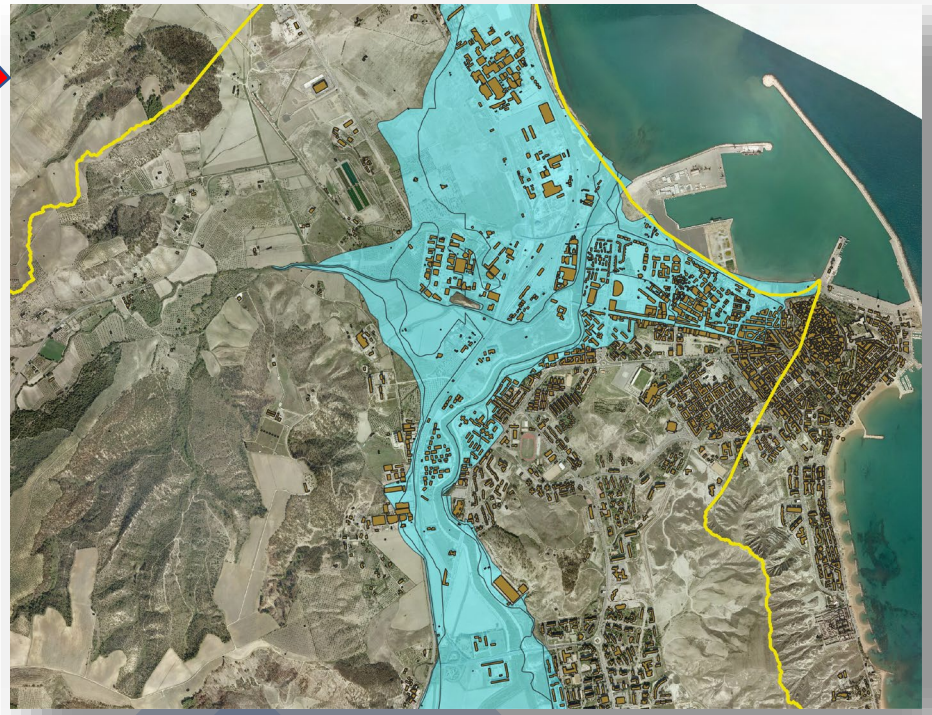
Fluvial Flood in Urban Area – 21-23 November 2020

www.tg24.sky.it Crotone, 21 novembre 2020 _ Donna messa in salvo dalla GDF

to sommerse dall'acqua

Hydrological and Hydrodynamic Computational domain





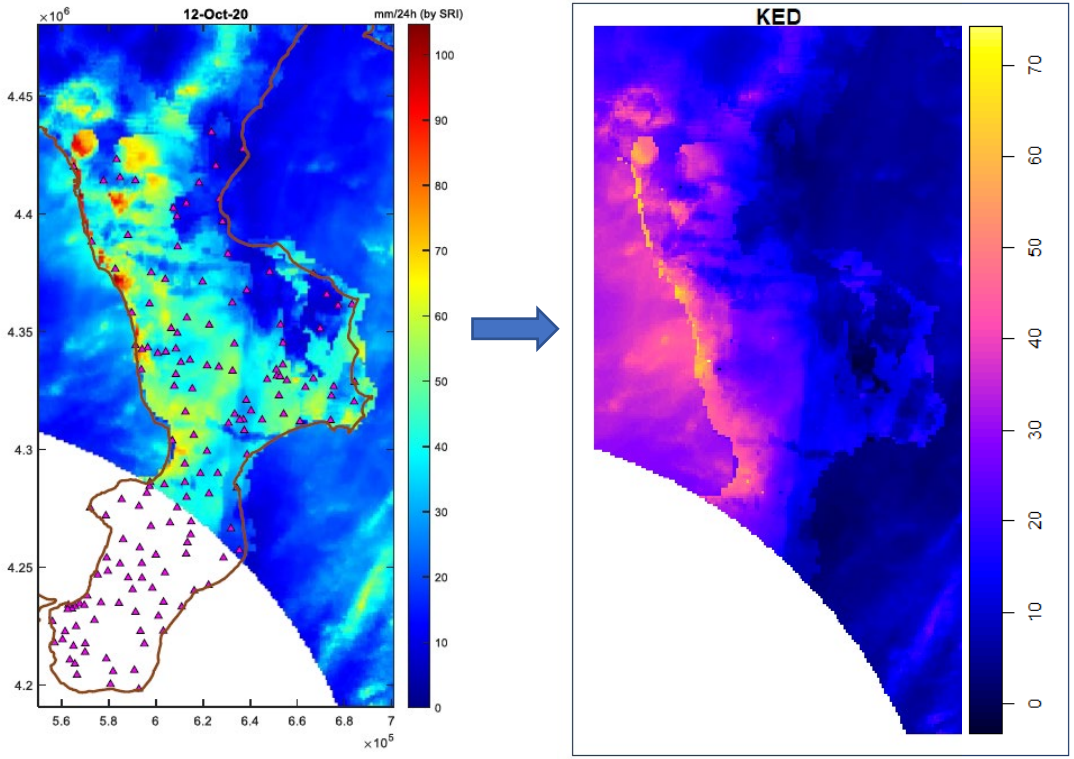
Flood Risk Map – PAI Italy

How to properly reconstruct a flood event?

Driving variables of the modeling system

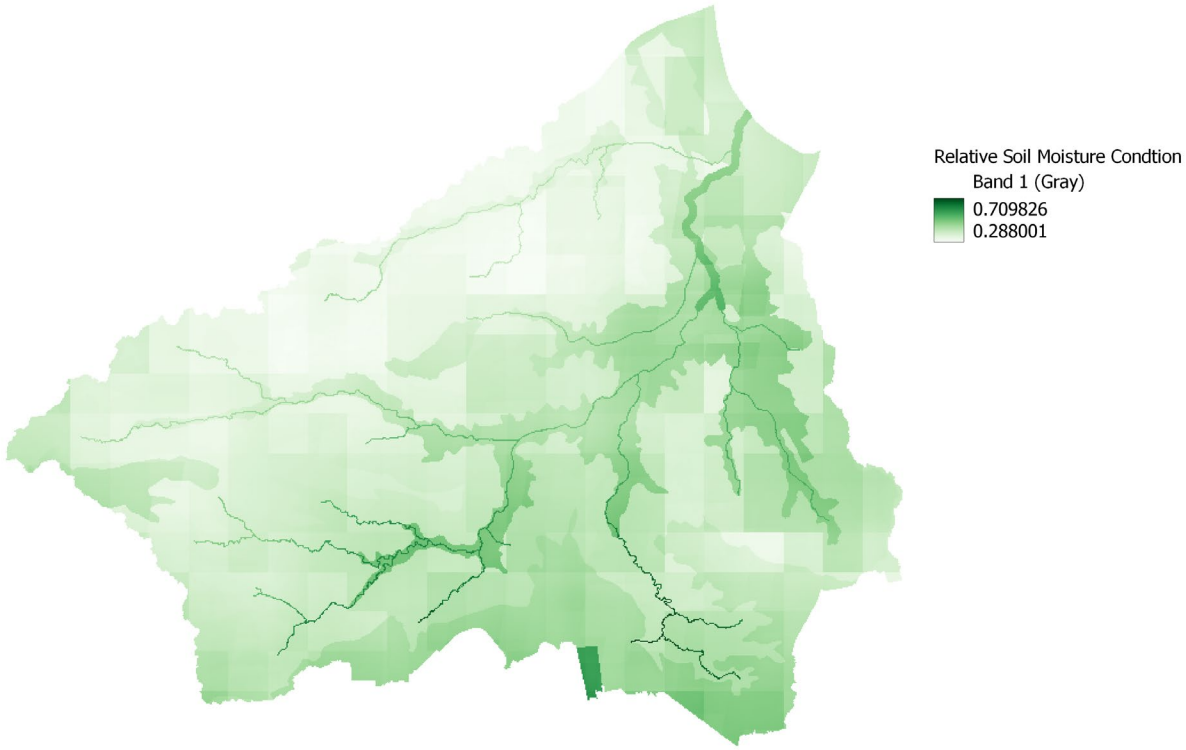
Spatiotemporal distribution of the Rainfall (boundary condition)

Mixing Radar Technology with Geostatistic



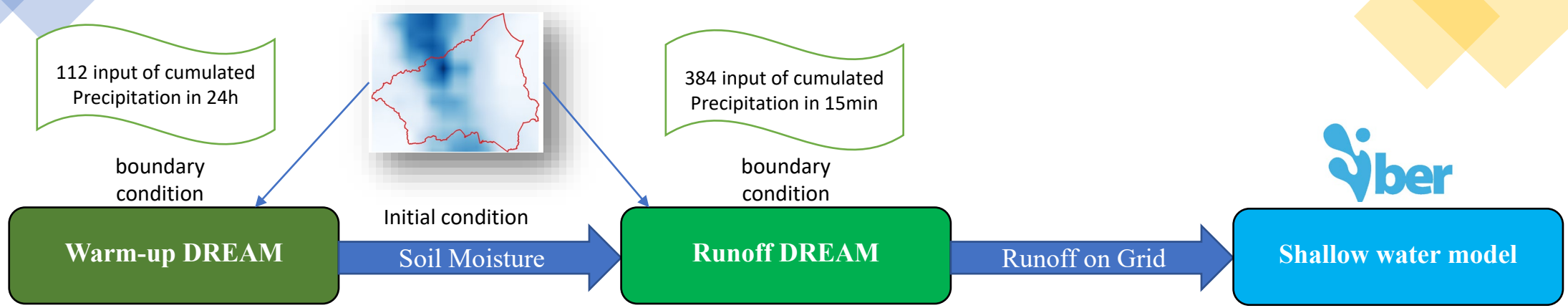
Antecedent Soil moisture condition of the catchment (initial condition)

WarmUP model



WorkFlow adopted

For my study case



Daily time step

from 31/07/2020 to 19/11/2020

112 days of simulation time

Interception

Infiltration

Surface depression Storage

Actual Evapotranspiration

Percolation

Sub-surface runoff

Surface runoff

→ ...near zero

Sub-hour time step

from 20/11/2020 to 23/11/2020

4 days of simulation time

Interception

Infiltration

Surface depression Storage

Percolation

Sub-surface runoff

Surface runoff

from 20/11/2020 to 23/11/2020

4 days of simulation time

Depths

Velocities

Discharges

Fluvial Flood Hazard

No data … No Party !!!

Elevation (DTM)

Slope

Land Use

Topographic Wetness Index (TWI)

Soil Type [USDA],

% sand, % loam, %clay, %organic component

Soil rooting depth

Mandatory for the application of the DREAM

Soil Water Index (Copernicus)

{Max/Min/Mean} Daily Temperature (Italy – Protezione Civile)

Daily Wind Speed (ERA5 reanalysis)

Potential Evapotranspiration (FAO 56, Allen 1998)

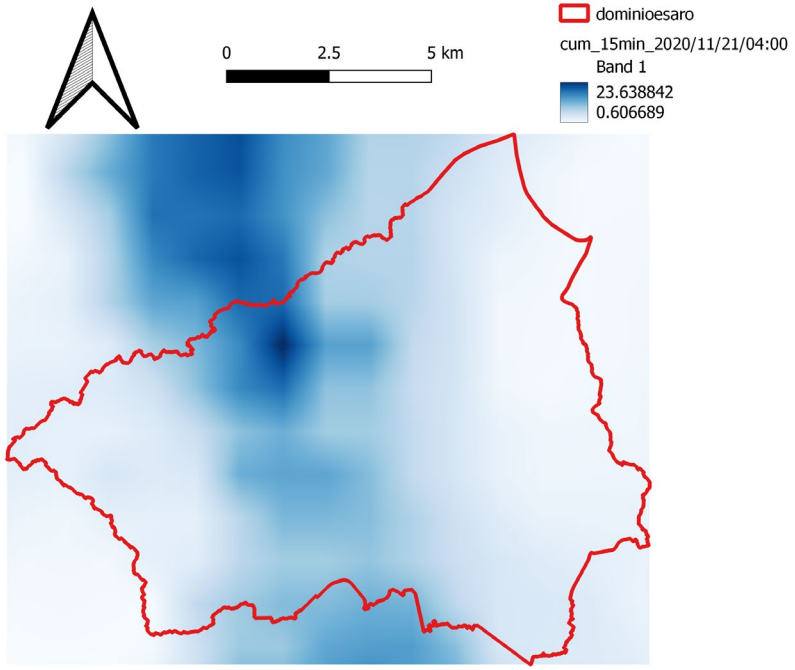
Leaf Area Index (MODIS 4 days temporal res. 500m spatial res.)

Radar Rainfall Products (Italy – Protezione Civile)

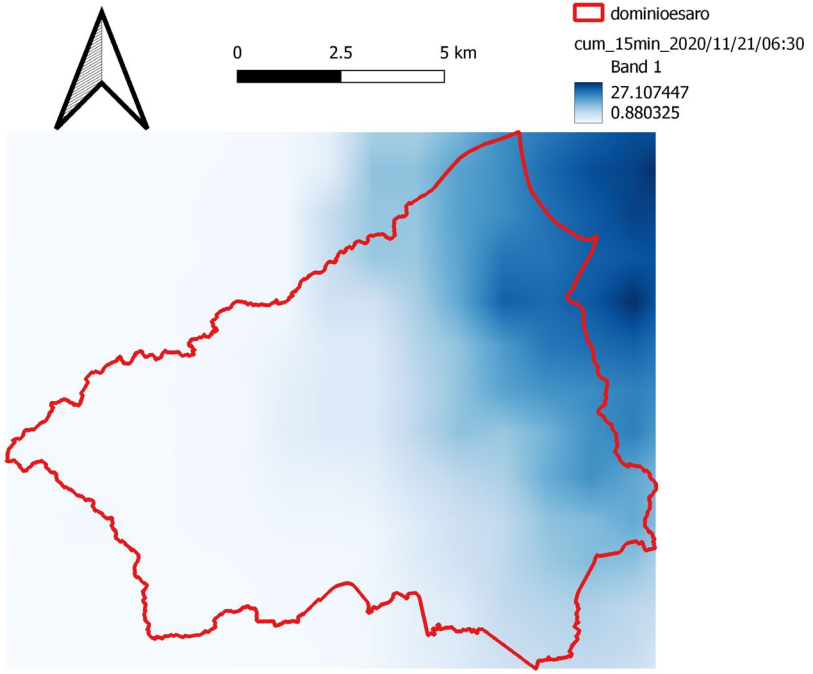
Pluviometers Measurement (Italy – ARPACAL)

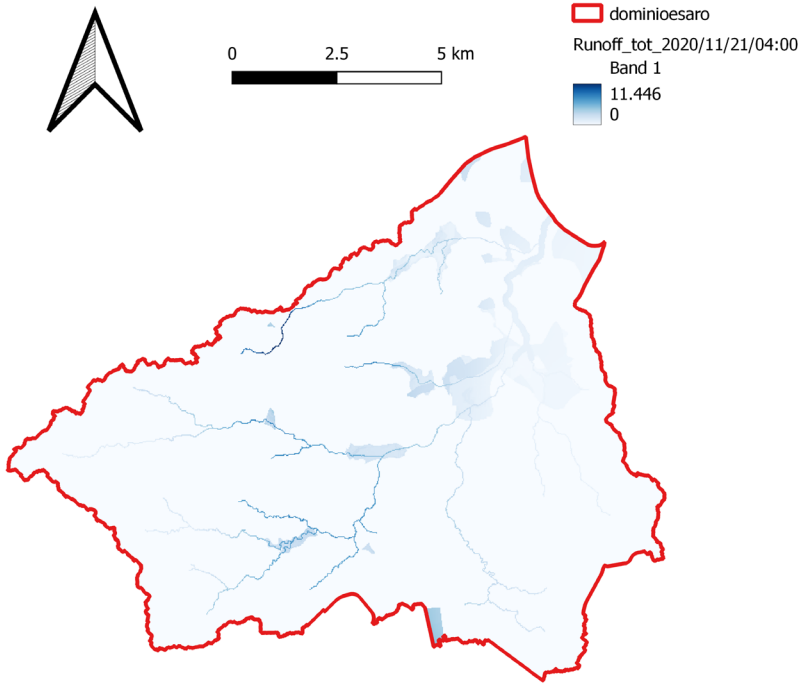
For my study case

Some Preliminary Results…

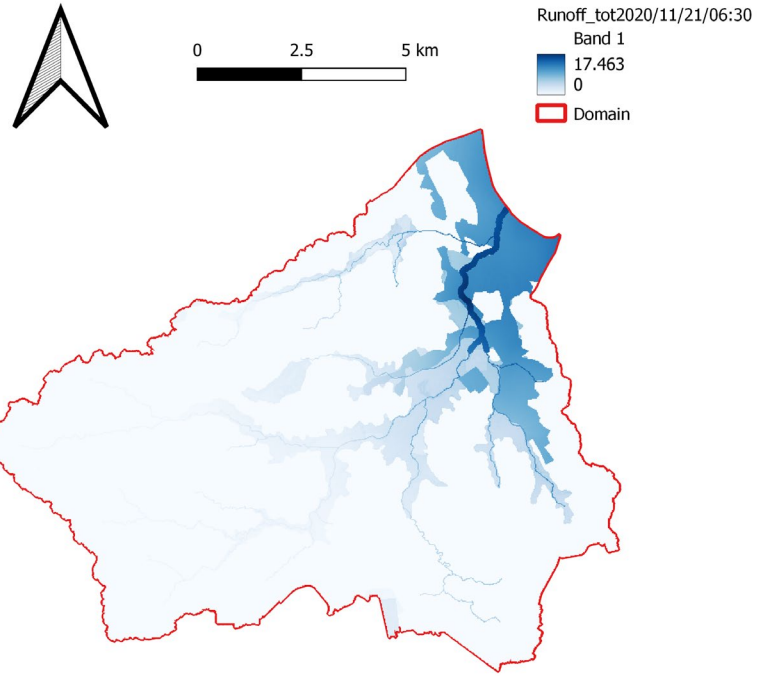


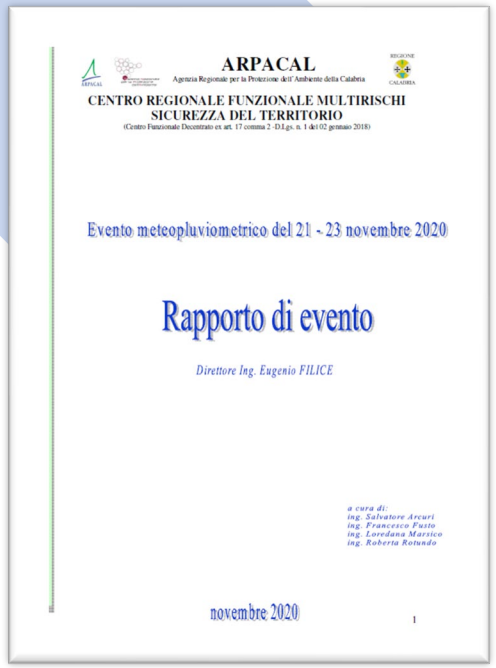
(15 min)
Cumulated Radar Precipitation +KED (mm)





(15 min)
Total Runoff (mm)




ARPACAL
Agenzia Regionale per la Protezione dell'Ambiente della Calabria
CENTRO REGIONALE FUNZIONALE MULTIRISCHI
SICUREZZA DEL TERRITORIO
(Centro Funzionale Decentrato ex art. 17 comma 2 -D.Lgs. n. 1 del 02 gennaio 2018)

Evento meteopluviometrico del 21 - 23 novembre 2020

Rapporto di evento

Direttore Ing. Eugenio FILICE

a cura di:
ing. Salvatore Arcuri
ing. Francesco Fusto
ing. Loredana Marsico
ing. Roberta Rotundo

novembre 2020

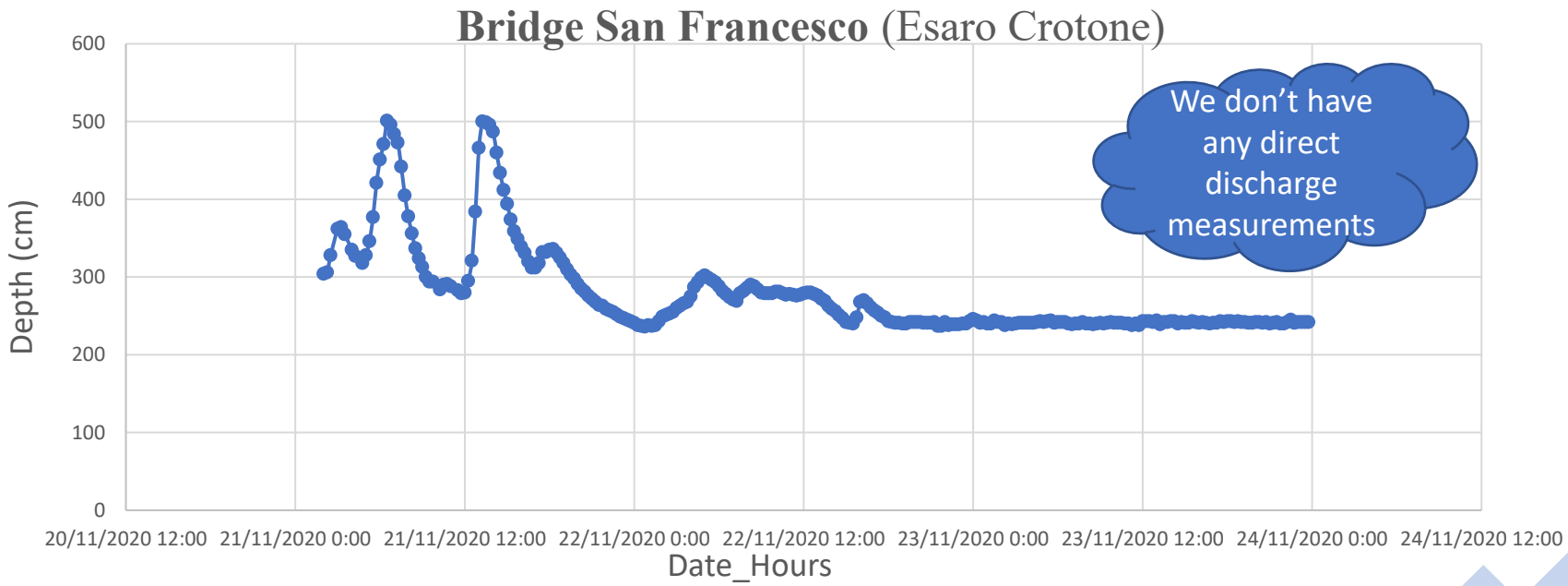
… what about the calibration of the model?

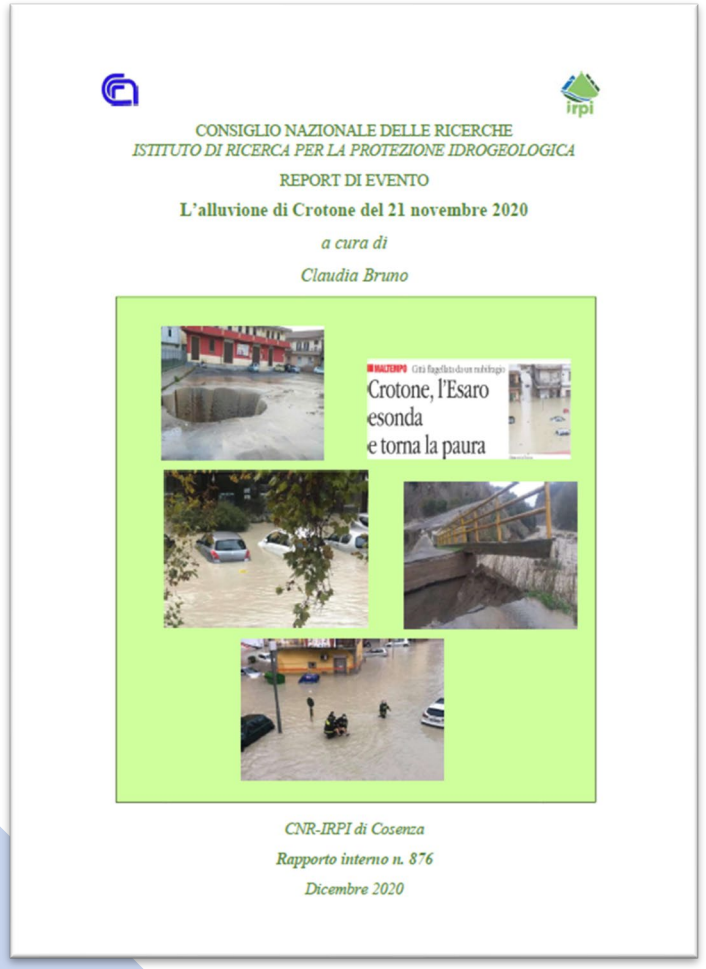
Volumetric calibration → Hydrological model → Root depth, redistribution coefficient…

Shape/Peak calibration → Hydrodynamic model → Manning coefficient

… what about the validation?

Unconventional validation using photographs showing localized water levels during the flood




CONSIGLIO NAZIONALE DELLE RICERCHE
ISTITUTO DI RICERCA PER LA PROTEZIONE IDROGEOLOGICA
REPORT DI EVENTO
L'alluvione di Crotone del 21 novembre 2020
a cura di
Claudia Bruno

Crotone, l'Esaro esonda e torna la paura

CNR-IRPI di Cosenza
Rapporto interno n. 876
Dicembre 2020

CN HPC project

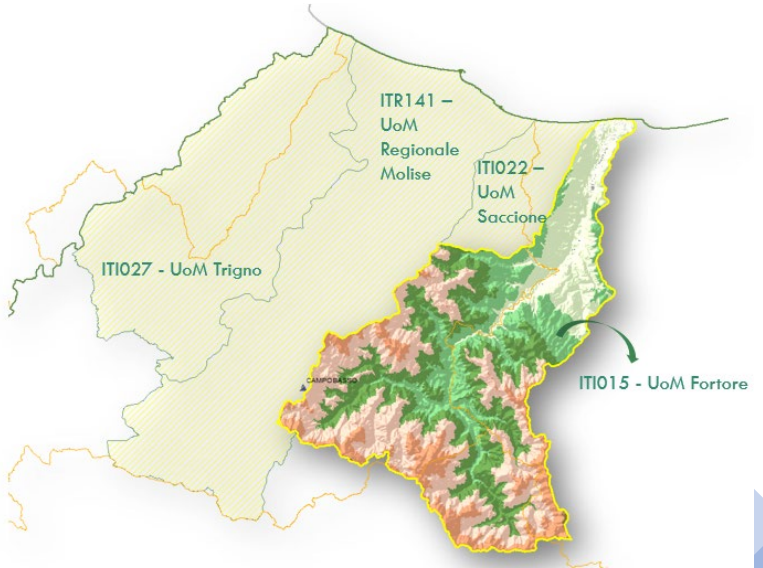
Spoke 5 - Modelling of disaster-inducing processes (Flood)

HPC Infrastructure
RECAS supercomputer

HPC Software
IBERplus

(e.g. 18 Nvidia A100 e 20 Nvidia V100)

High-resolution rainfall-runoff modeling at the basin scale



I am ending my career with much more uncertainty than when I started as a young Ph.D. student in 1971.

Cit. ***Keith Beven,*** *2019*
(the most cited hydrologist in literature)