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This PDF version is of lower quality

Statistical analysis for flood mapping estimation

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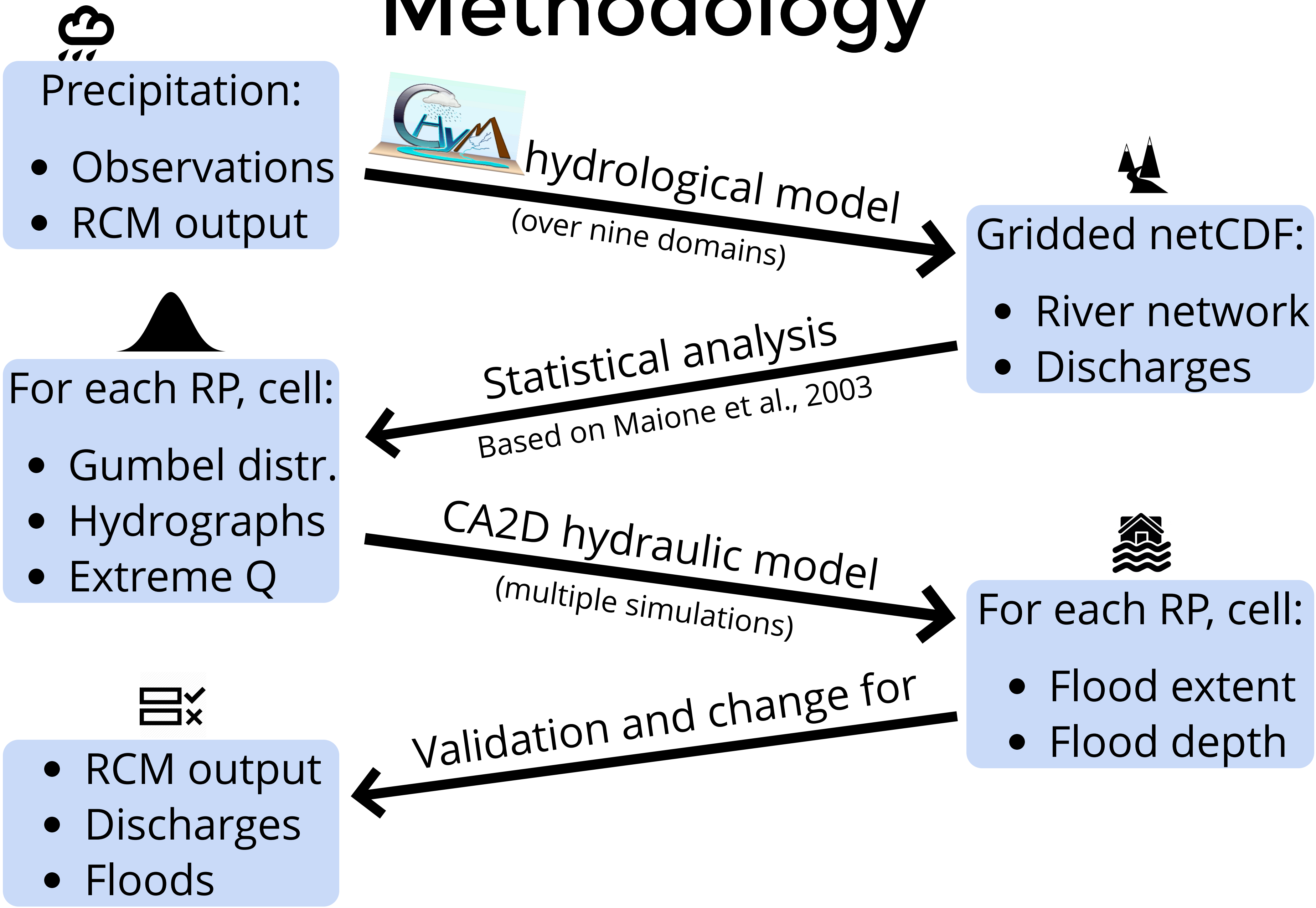
Objective: flood hazard maps

- Different Return Periods (probabilities): 100, 200, 500 years...
- Italian territory
- Future climate projections
- Using data from hydrological model

Methodology



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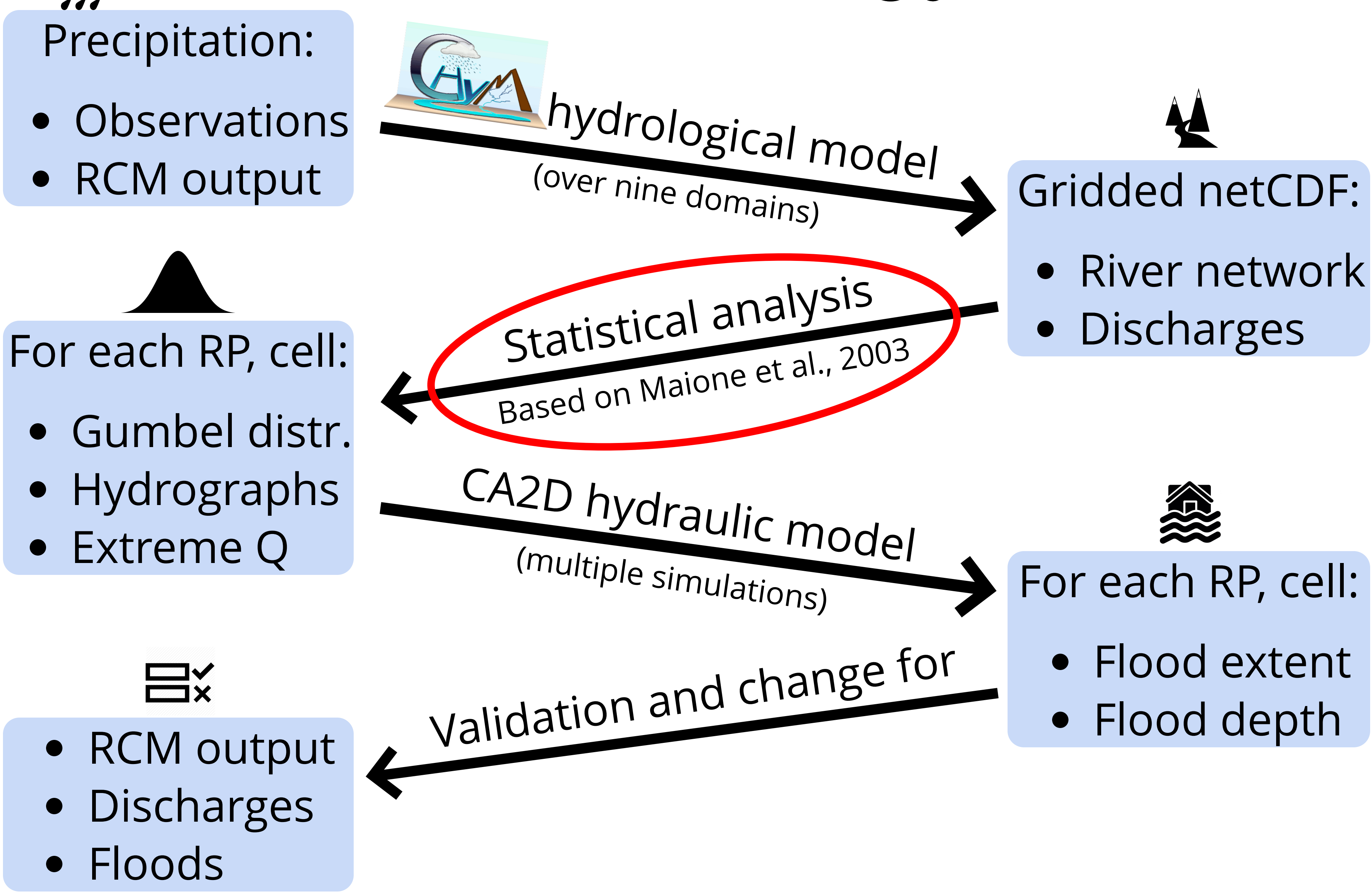
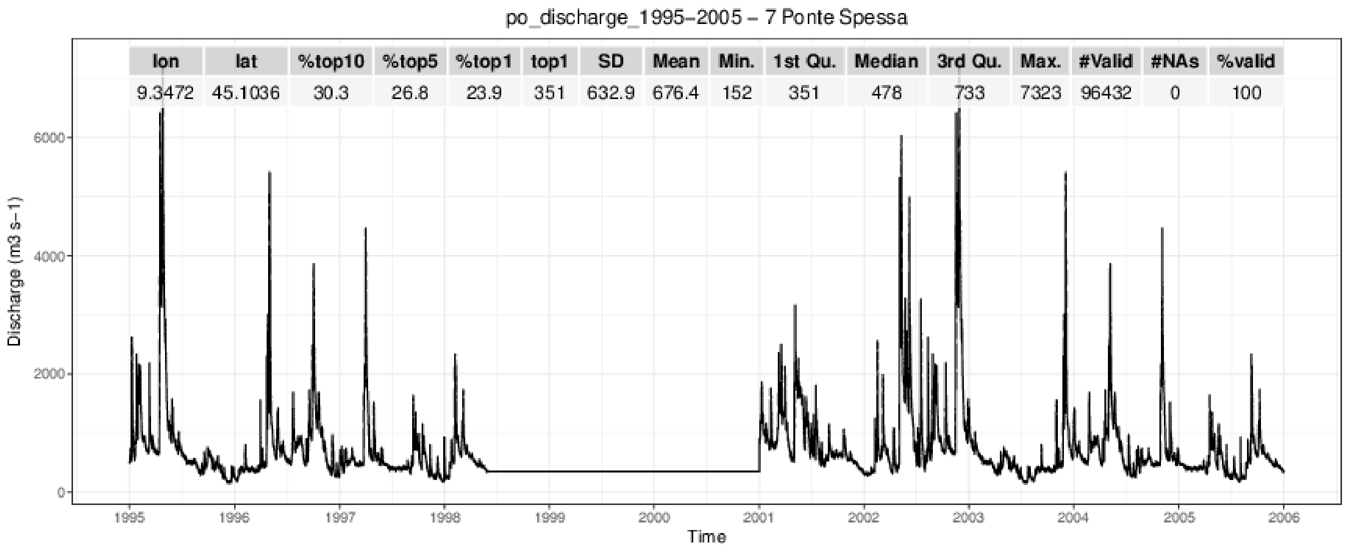


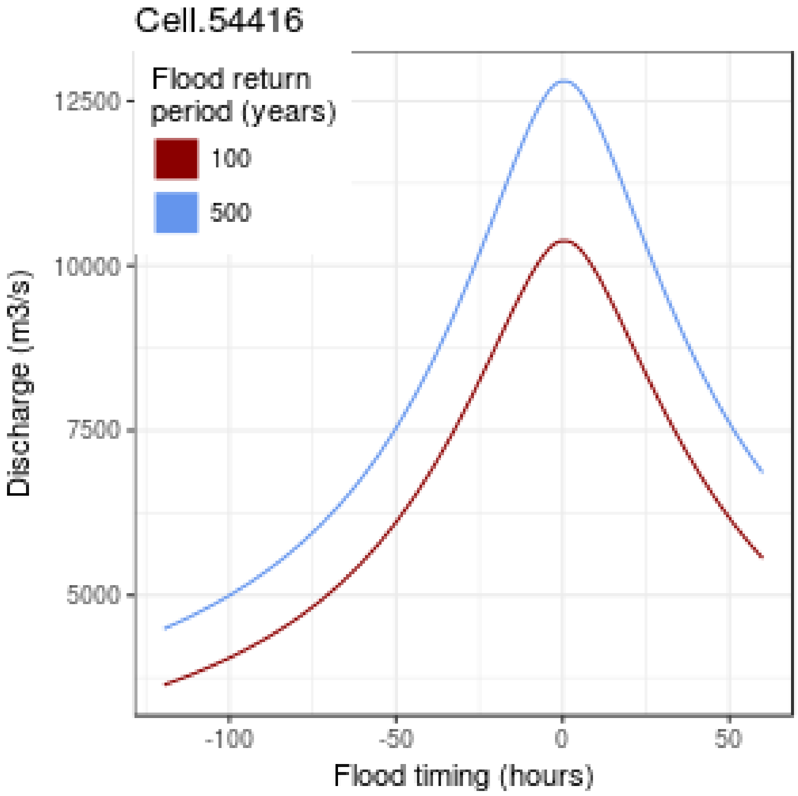
Discharge timeseries from hydrological simulation

HOW?

Synthetic Design Hydrographs: "typical" flood event, input to hydraulic model


po_discharge_1995-2005 – 7 Ponte Spessa
lon lat %top10 %top5 %top1 top1 SD Mean Min. 1st Qu. Median 3rd Qu. Max. #Valid #NAs %valid
9.3472 45.1036 30.3 26.8 23.9 351 632.9 676.4 152 351 478 733 7323 96432 0 100
Discharge (m3 s-1)
0
2000
4000
6000
1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006
Time

HOW?


Cell.54416
Flood return period (years)
100
500
Discharge (m3/s)
5000
7500
10000
12500
-100 -50 0 50
Flood timing (hours)

Basic concept (1): Return Period

The RP is a common measure of probability used for extreme events: it represents the probability of the event happening any given year. For example:

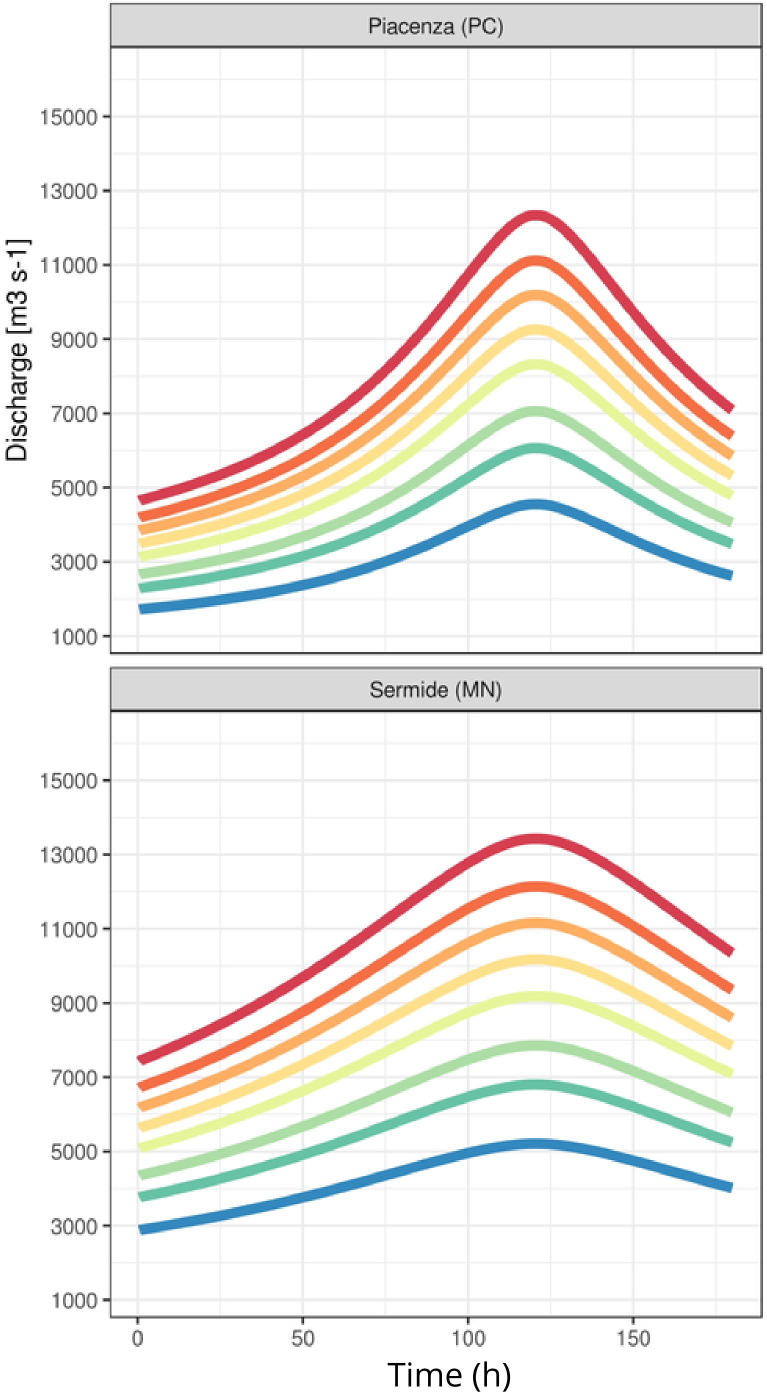
- If an event has RP=100 yr, its probability to happen any given year is 1%
- RP=200 yr => p=0.5%
- Only a **statistical** measure!

Basic concept (2): Synthetic Design Hydrographs

The SDH is the curve giving the "typical" flood event discharge (*Q*) as a function of time (*t*), for any given Return Period (*RP*):

$$SDH = Q_{RP}(t)$$

There are two components to the SDH (at a given RP):



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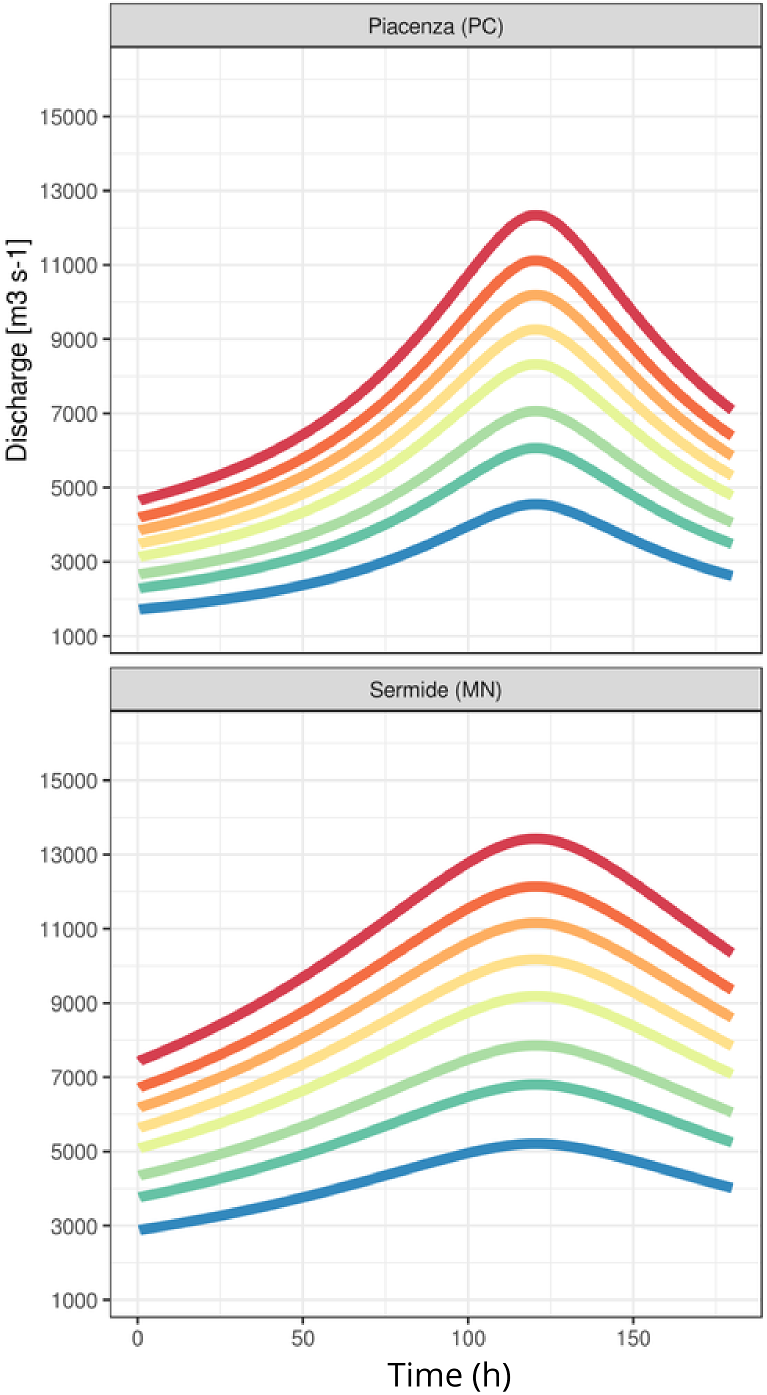

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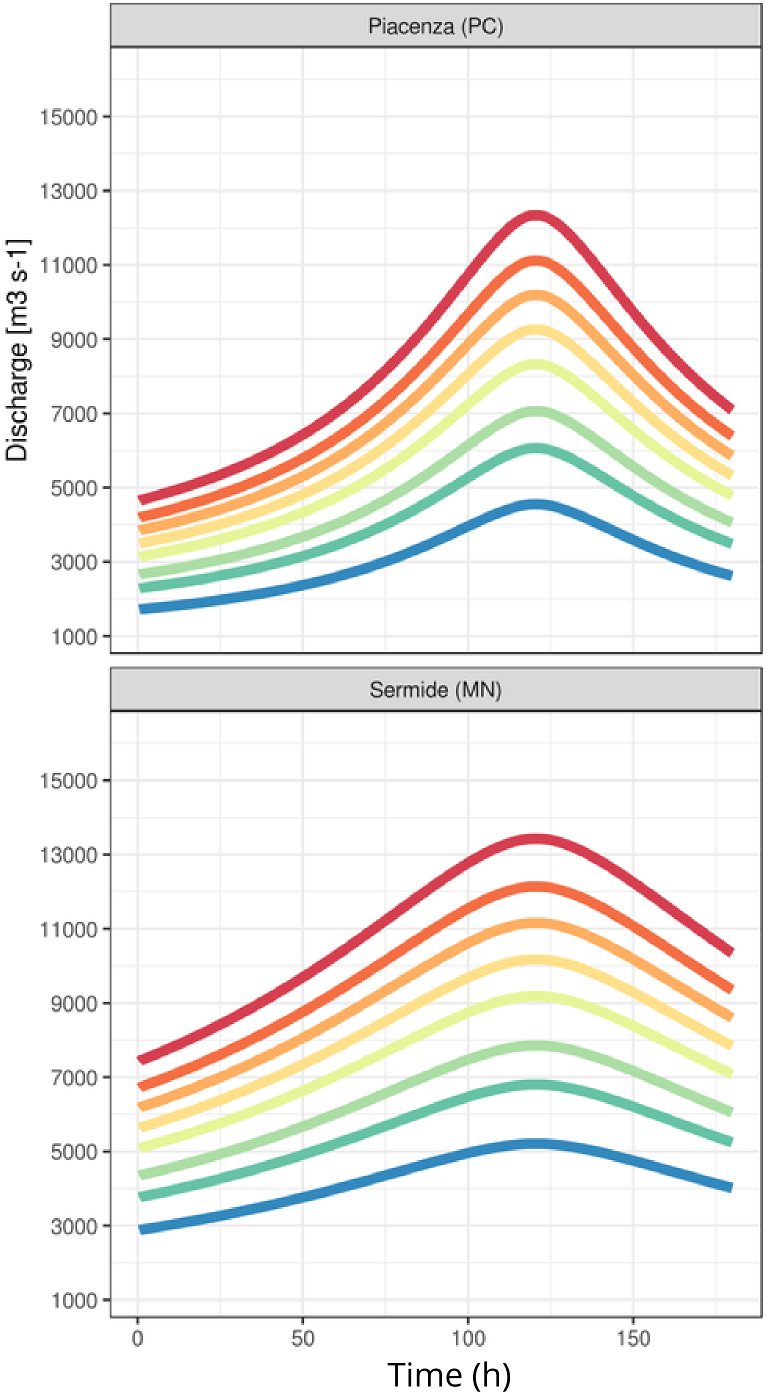
There are two components to the SDH (at a given RP):

- peak discharge
- shape



Basic concept (3): Flow Duration Frequency curve

The FDF is the curve maximising the flood event discharge (*Q*) averaged over a duration (*D*) around the peak, so that for a given event:

$$\mathrm{FDF} = Q_D = \frac{1}{D} max \int_t^{t+D} Q\left(\tau\right) d\tau$$

Notice that, by definition, for an idealised event with Return Period RP, the peak flood discharge is:

$$Q_{D=0}(RP) = Q_{RP}(t=0)$$

Basic concept (3.1): confused?

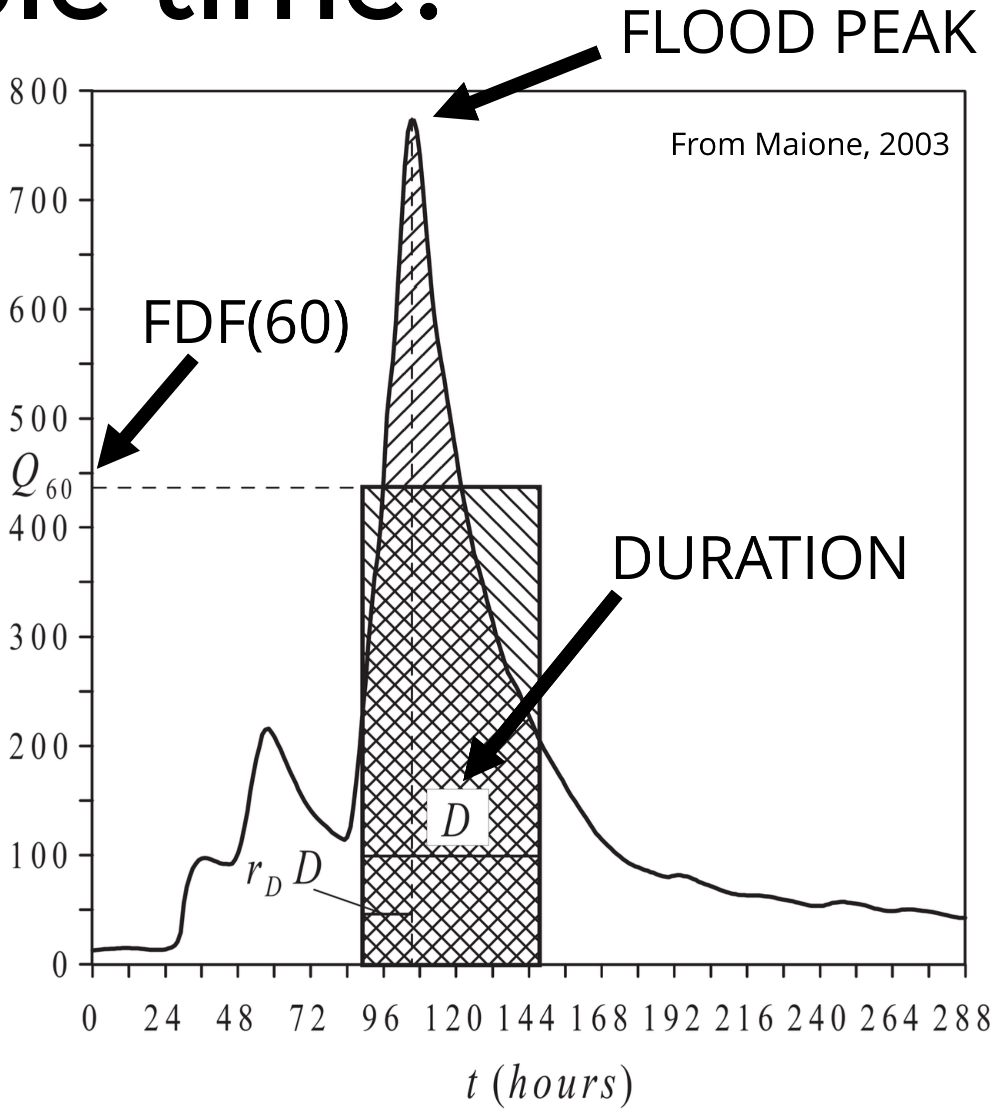
Example time!

The shape of the SDH is dictated by the peak-duration ratio r_D, which is the ratio of the time before the peak and the total duration (*D*) of the averaging window.

The smaller the r_D, the more skewed the hydrograph will be towards steeper (flatter) rising (falling) limbs of the hydrograph.

Also notice that:

$$Volume = Q_D \times D$$



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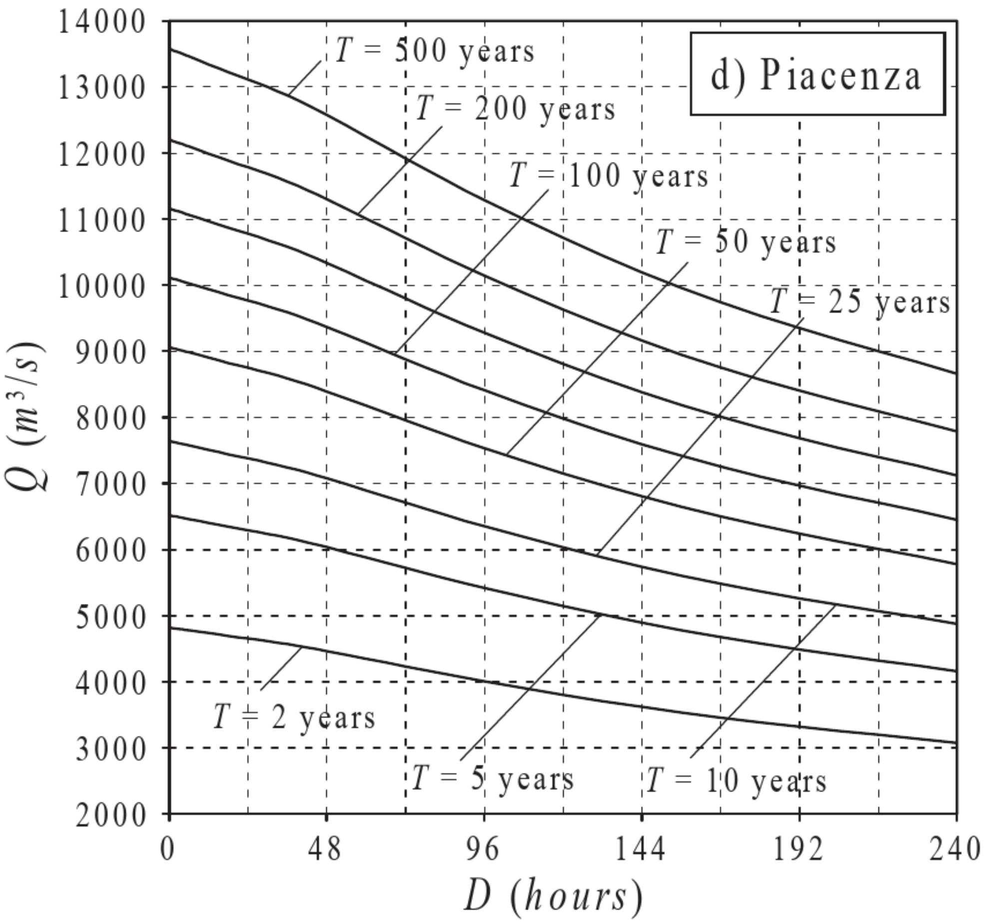
From Maione, 2003



Two assumptions

Following Maione et al. (2003), we assume that the reduction ratio (ε_D), which is the ratio of the FDF and the peak flood discharge $Q_0\,(RP)$ is **constant** for any Return Period (*RP*), so that:

$$\varepsilon_D = \varepsilon_D\,(RP) = \frac{Q_D(RP)}{Q_0(RP)}$$

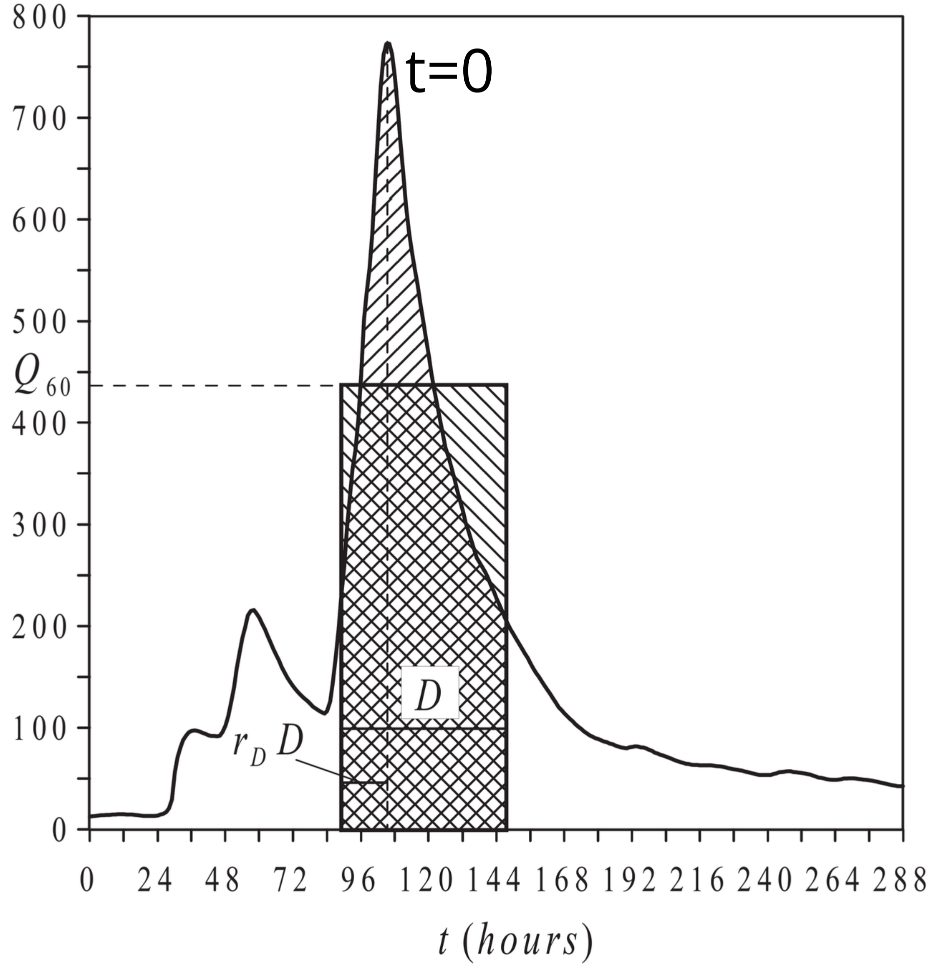
Which is a reasonable assumption also according to NERC (1975): the shape of the hydrograph, given by this ratio, does **NOT** depend on the RP!

Moreover, following Alfieri et al. (2014), we assume that the hydrograph is **symmetric**, that is to say that:

$$r_D = \frac{1}{2}$$

Step 1: split the hydrograph

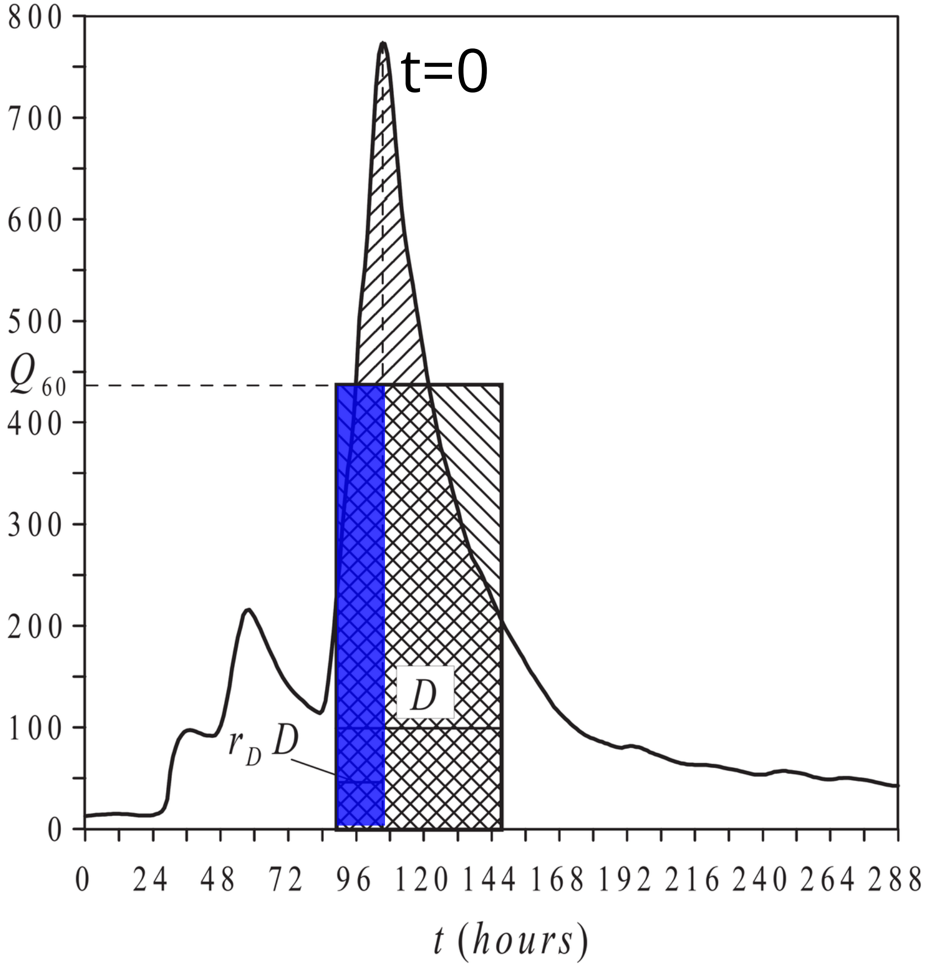
Set the flood peak as t=0, and split the left and right limb of the SDH as follows:



Step 1: split the hydrograph

Set the flood peak as t=0, and split the left and right limb of the SDH as follows:

$$\int_{-r_D D}^{t=0} Q(\tau) = r_D D Q_D(RP)$$



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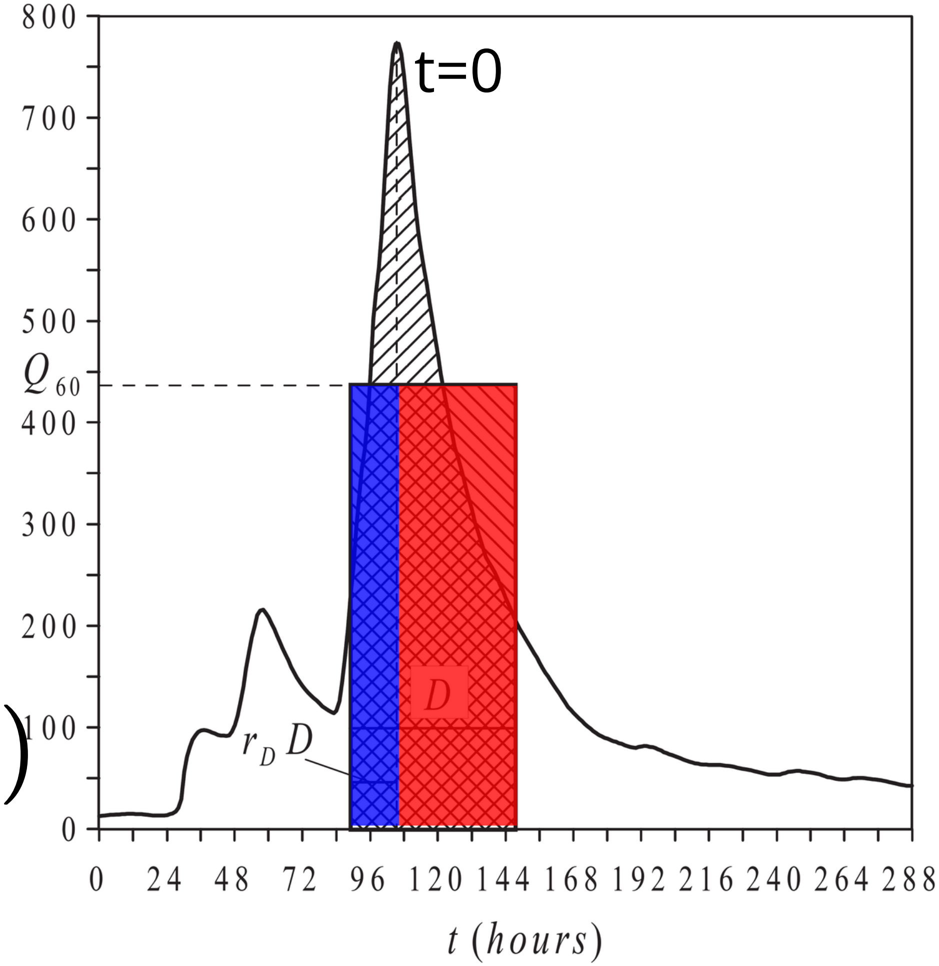
Set the flood peak as t=0, and split the left and right limb of the SDH as follows:

$$\int_{-r_D D}^{t=0} Q(\tau) = r_D D Q_D(RP)$$

$$\int_{t=0}^{(1-r_D)D} Q(\tau) = (1 - r_D) D Q_D(RP)$$



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FDF

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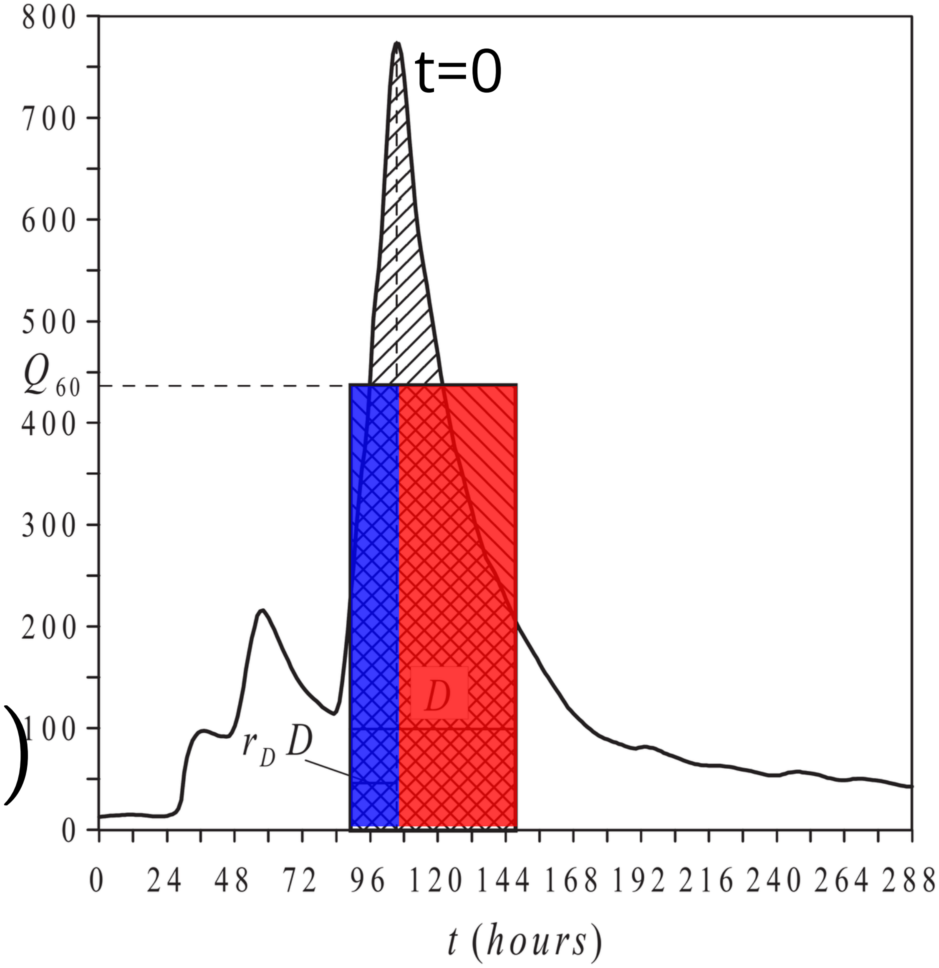


Step 2: differentiate for D

Only for the falling limb, differentiate the previous equation with respect to *D*:

$$\mathrm{SDH} = Q_{RP}\,(t) = \frac{d/dD[(1{-}r_D)DQ_D(RP)]|_{D=D(t)}}{d/dD[(1{-}r_D)D]|_{D=D(t)}}$$

Where:

$$t = (1 - r_D)\,D$$

Once we know the reduction ratio and the FDF, we can then calculate the SDH!

But remember that we set the reduction ratio to one half, so that:

$$t = \tfrac{1}{2}D$$

Step 3: obtain the reduction ratio

Remember:

$$\varepsilon_D = \varepsilon_D\left(RP\right) = \frac{Q_D(RP)}{Q_0(RP)}$$

We assume (Maione, 2003):

$$\varepsilon_D \simeq \sqrt{p_2\left[2 + p_1 - \tfrac{3}{2}p_2\left(1 - p_1\right)\right]}$$

Where:

$$p_1 = e^{-4D/\theta} \quad ; \quad p_2 = \frac{\theta}{2D}$$

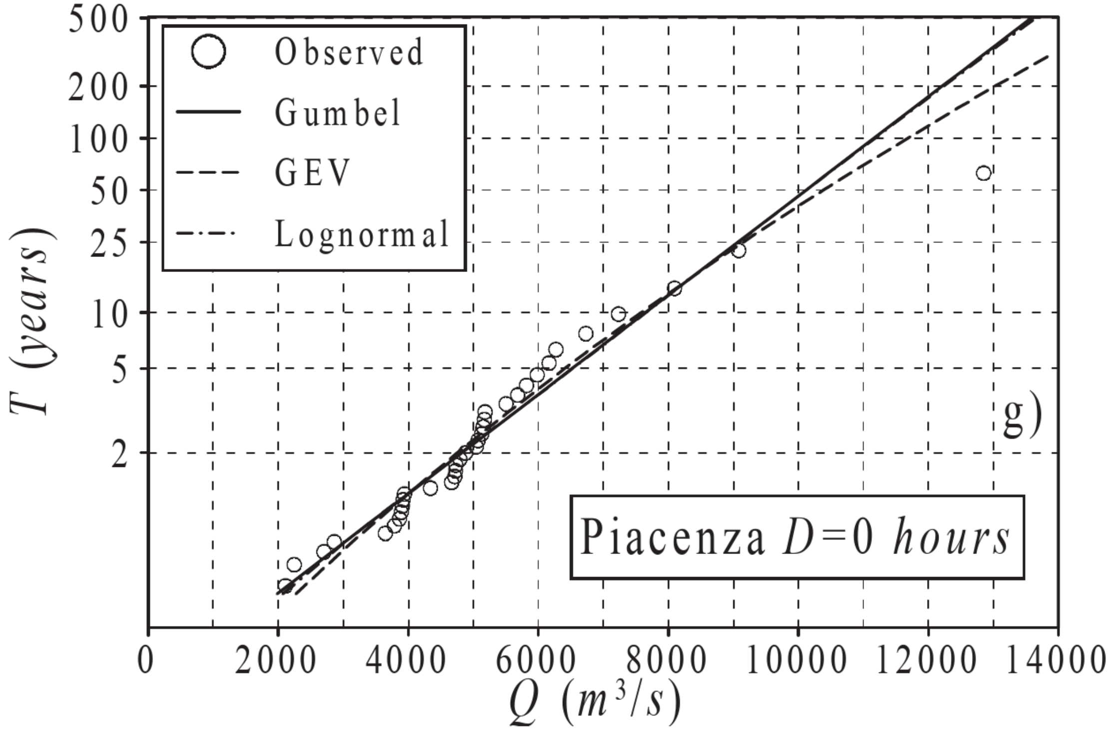
Where θ only depends on the (known!) drained area; a function for it is conveniently obtained by Maione based on observed data. We are only missing $Q_0\left(RP\right)$!

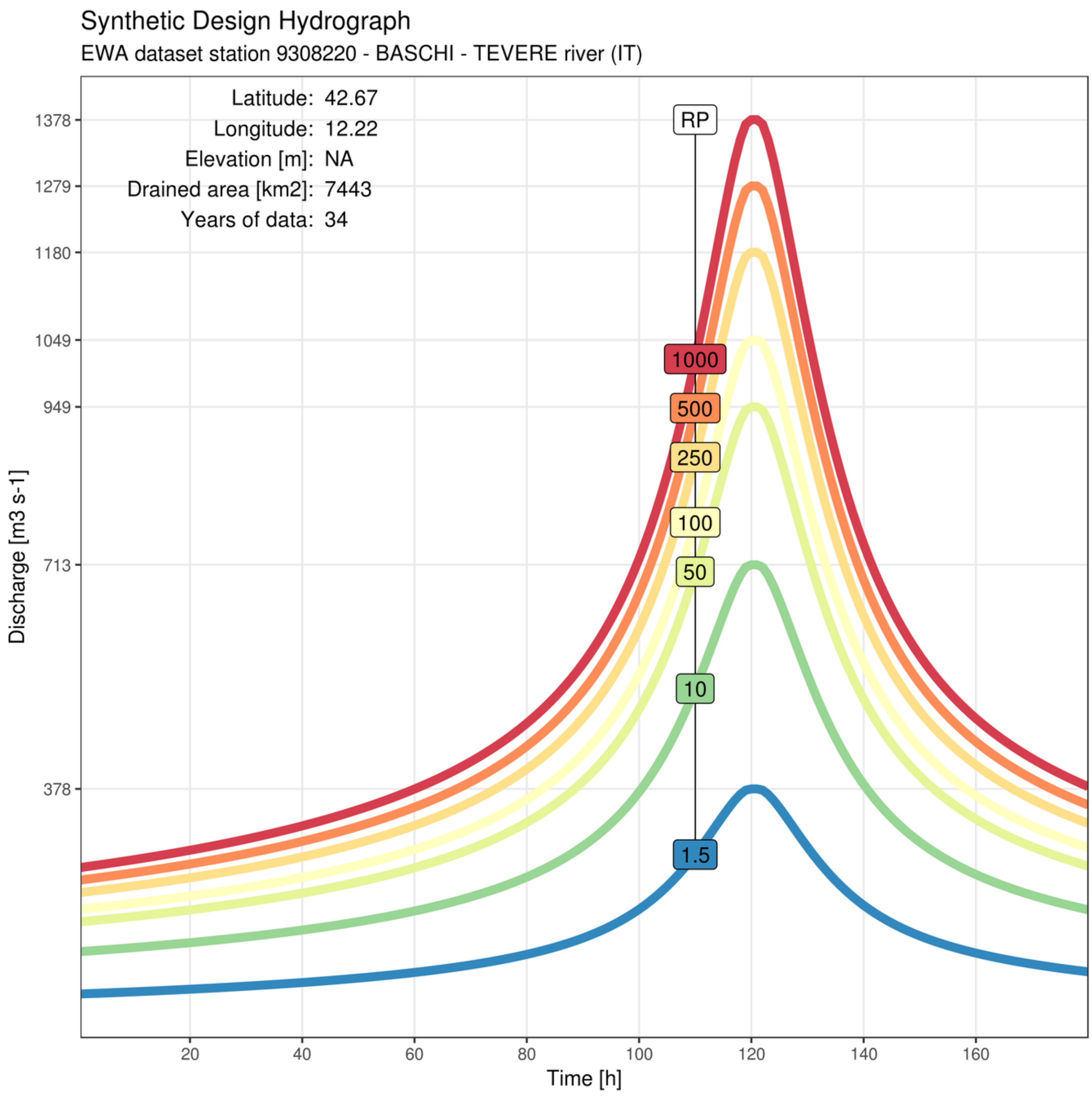
Step 4: obtain the peak discharge

$$Q_{D=0}(RP) = Q_{RP}(t=0)$$

Possible approach: fitting an extreme value distribution, such as a Gumbel distribution (Maione, 2003; Alfieri, 2015) to the distribution of yearly maxima:

we use the available years of data (up to 30) to estimate the peak discharge for any RP, thus extrapolating data for higher Return Periods!

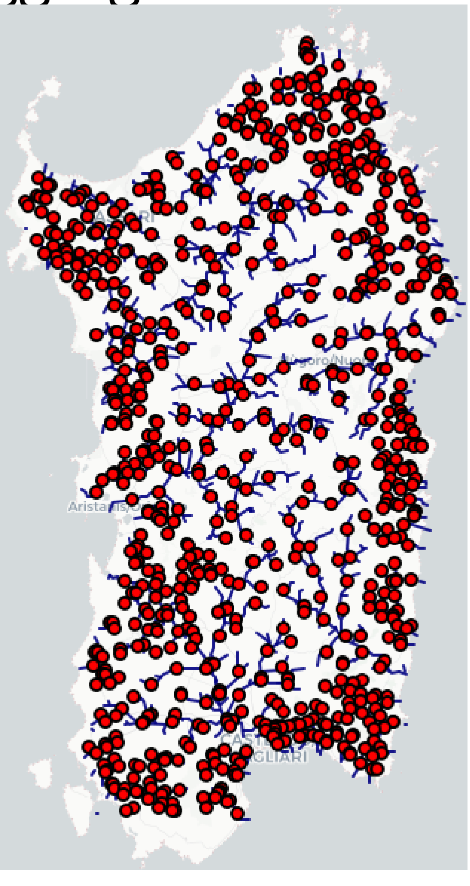




Synthetic Design Hydrograph
EWA dataset station 9308220 - BASCHI - TEVERE river (IT)
Latitude: 42.67
Longitude: 12.22
Elevation [m]: NA
Drained area [km2]: 7443
Years of data: 34
RP
1000
500
250
100
50
10
1.5
1378
1279
1180
1049
949
713
378
Discharge [m3 s-1]
20
40
60
80
100
120
140
160
Time [h]

Now:

- Do this procedure for each 5-10 km along rivers
- Run 5528 hydraulic simulations
- Aggregate data...



Now:

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- Run 5528 hydraulic simulations
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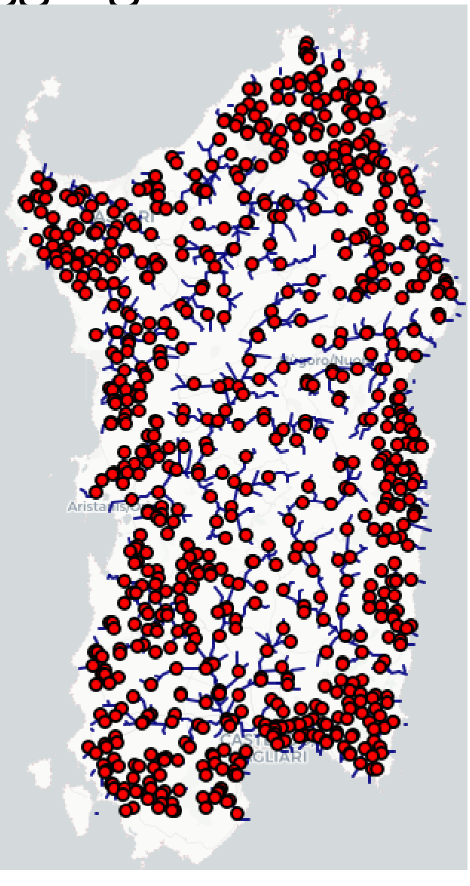

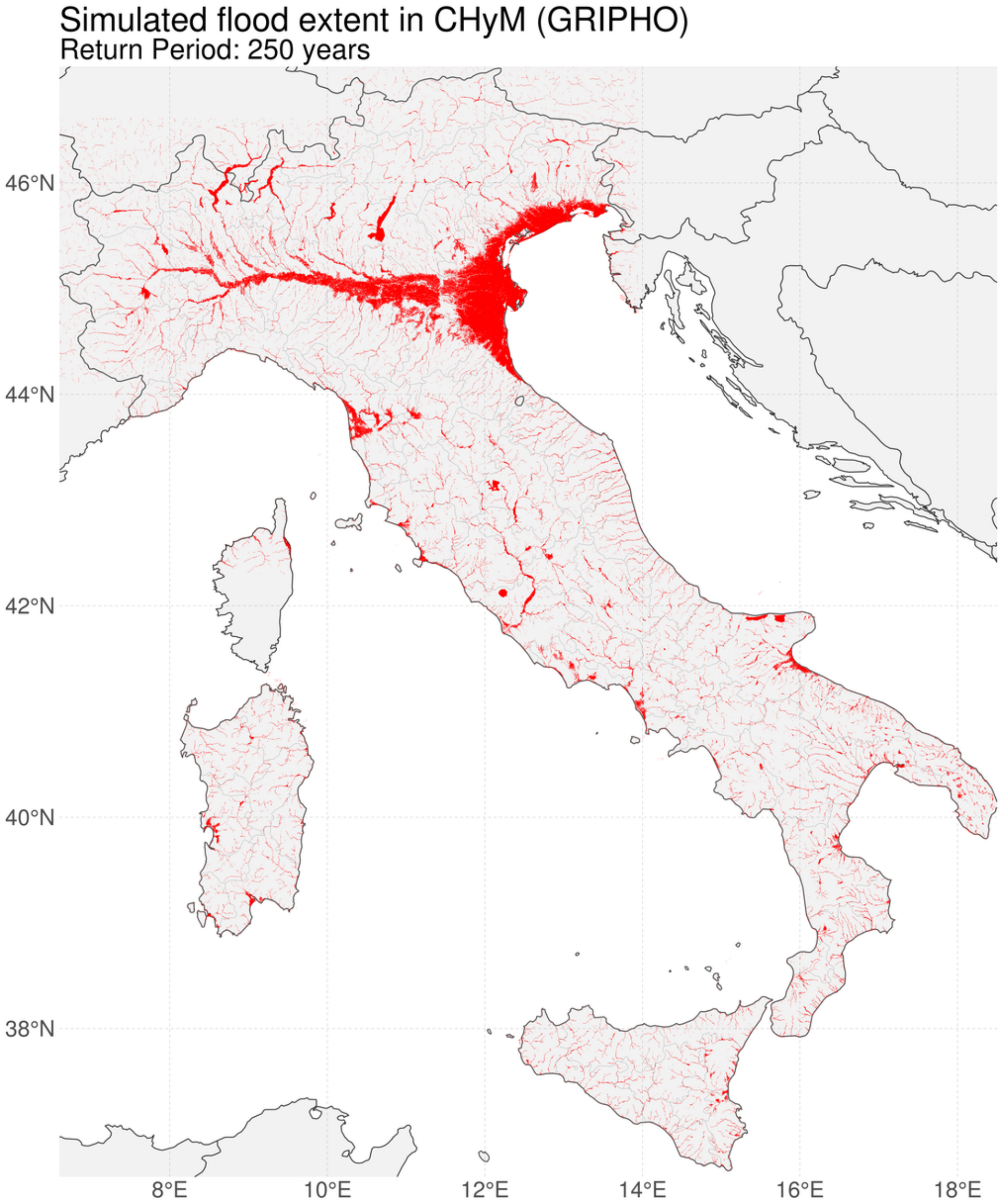

THANK YOU!

- Rita Nogherotto will present the results from the hydraulic model tomorrow!

- Francesca Raffaele will be here next week to answer any question