Linking climate change, hydrology and water resource systems in impact assessment studies

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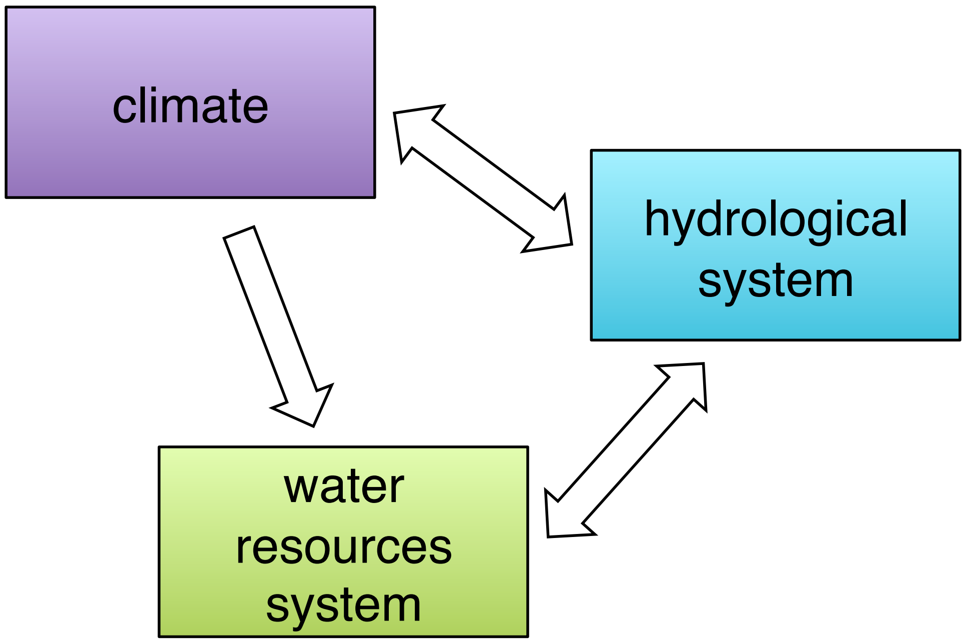
Introduction

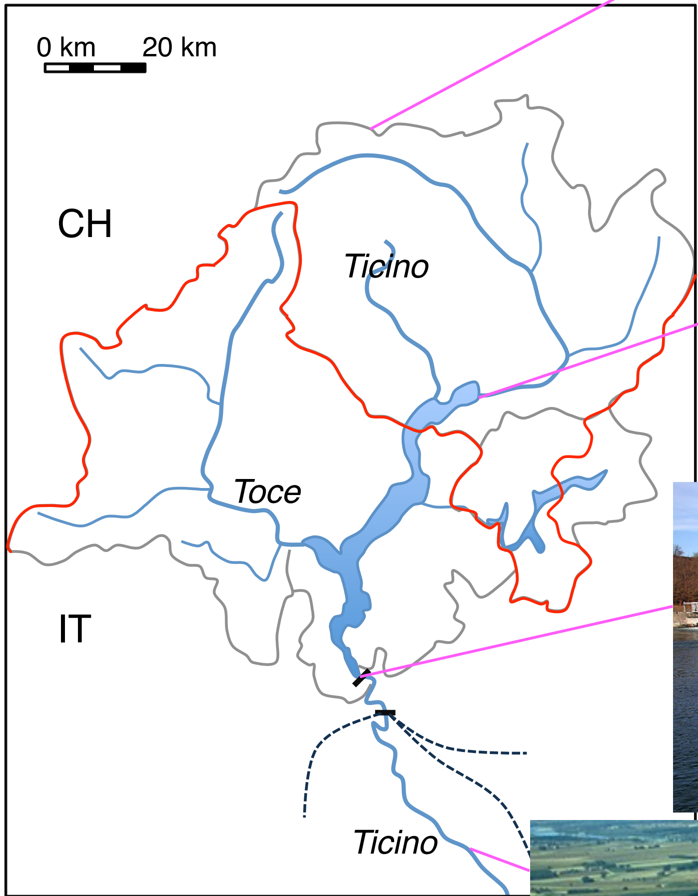
Water availability has been changing in the last years and this is expected to continue in the future. One issue in water management is to quantify this change in order to effectively adapt to it [1].

Aim of the talk: identify climate change trend on hydrological variables and water-related impacts in case of strong inter-annual variability



[1] D. Anghileri, F. Pianosi, and R. Soncini-Sessa. A framework for the quantitative assessment of climate change impacts on the water-related activities at the basin scale. Hydrology and Earth System Sciences, 15(6):2025–2038, 2011 http://www.hydrol-earth-syst-sci.net/15/2025/2011/hess-15-2025-2011.html

Case study



Lake Maggiore

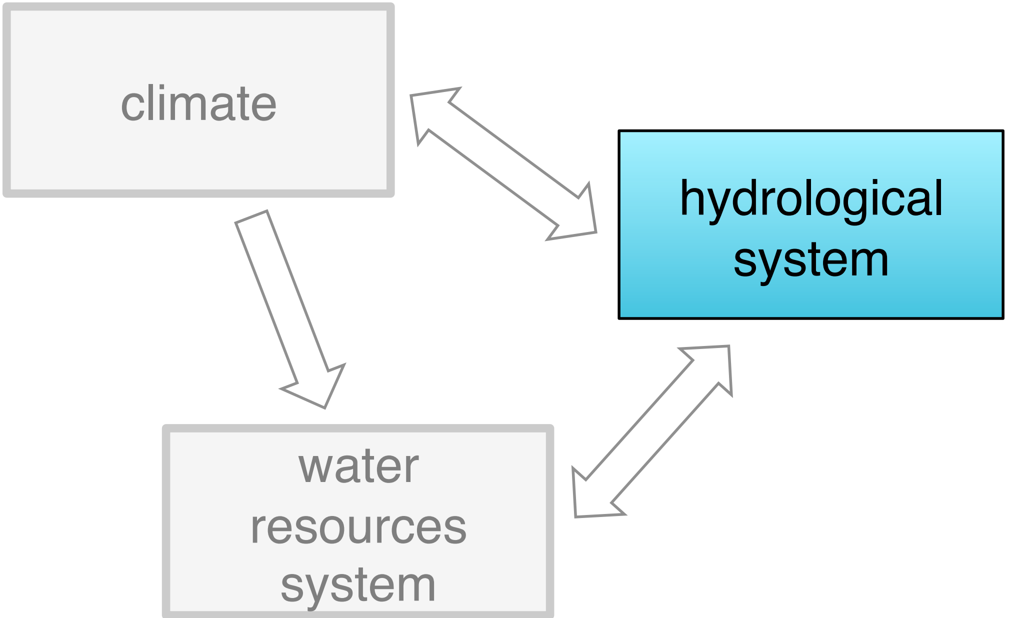
- Alpine lake
- Active storage: 420 Mm^3
- Catchment: 6600 km^2.

EU-INTERREG Project (STRADA, Action 2.1)

- data availability
- water resources model

Hydrological system

Historical time series of inflow to the lake from 1974 to 2010 (37 years)



State of the art

The standard method to detect trend in climate and hydrological time series is to perform a Mann-Kendall test (see among the others [1], [2]).

Mann-Kendall test is a well known statistical test to find monotonic trend in time series. The null hypotesis is the absence of the trend.

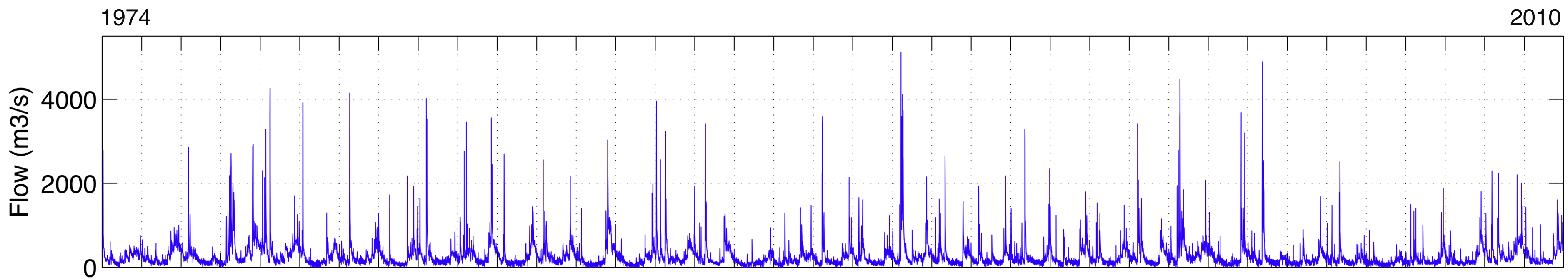
Computation of Sen’s slope is commonly used to quantify the trend intensity.

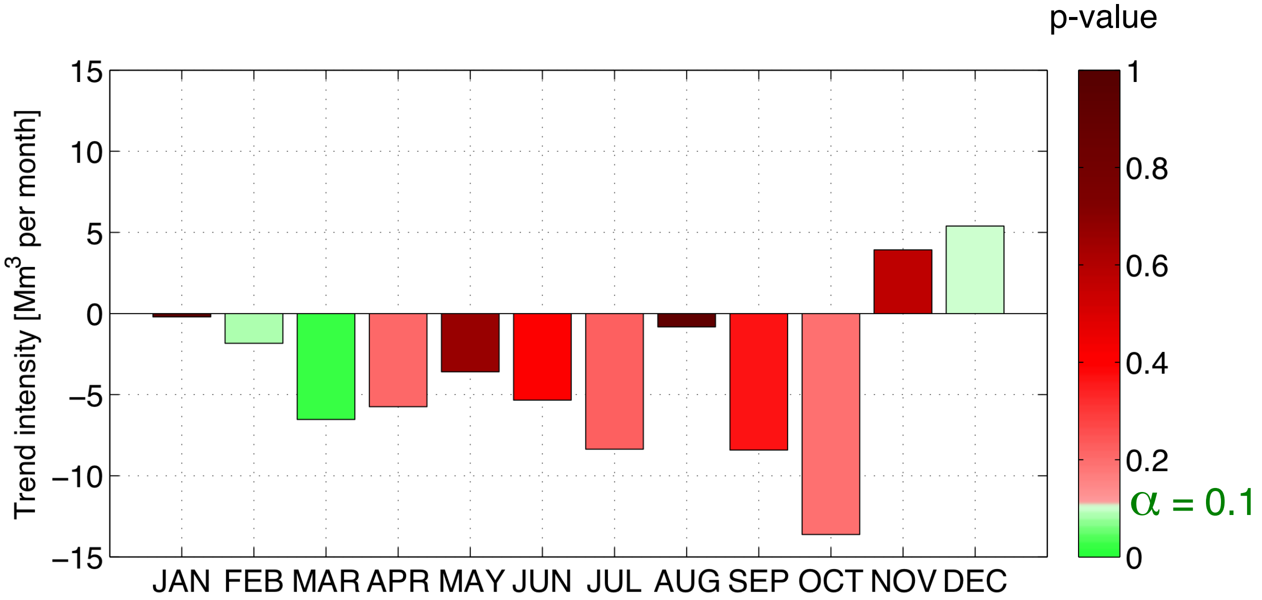
[1] S. J. Déry, T. J. Mlynowski, M. A. Hernández-Henríquez, F. Straneo. Interannual variability and interdecadal trends in Hudson Bay streamflow, *Journal of Marine Systems*, 88,3, 341–351, 2011.

[2] N. W. Arnell. Relative effects of multi-decadal climatic variability and changes in the mean and variability of climate due to global warming: future streamflows in Britain. *Journal of Hydrology*, 270(3-4):195-213, 2003.

Mann-Kendall test

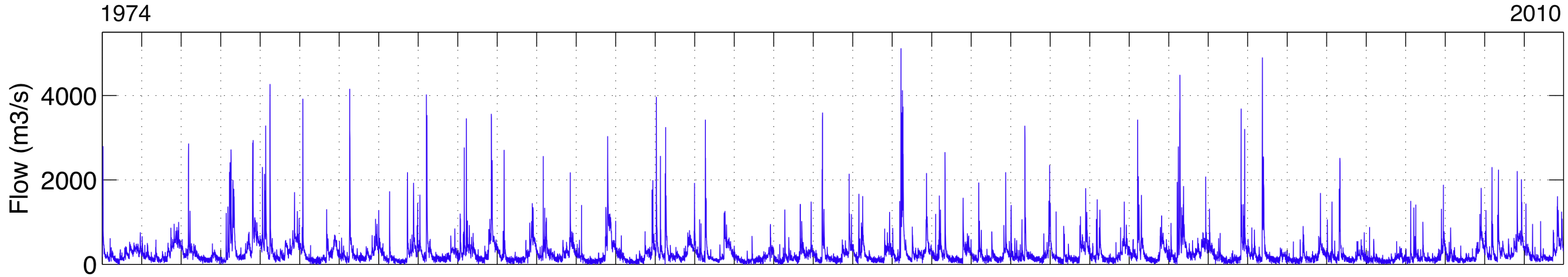
Monthly total volume

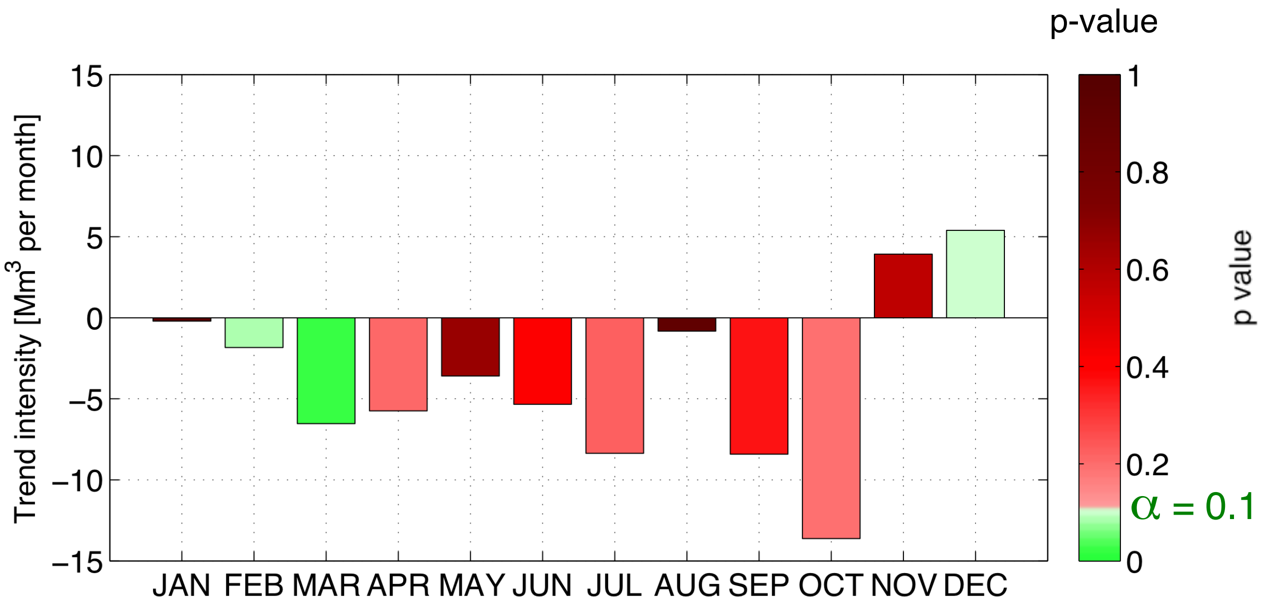


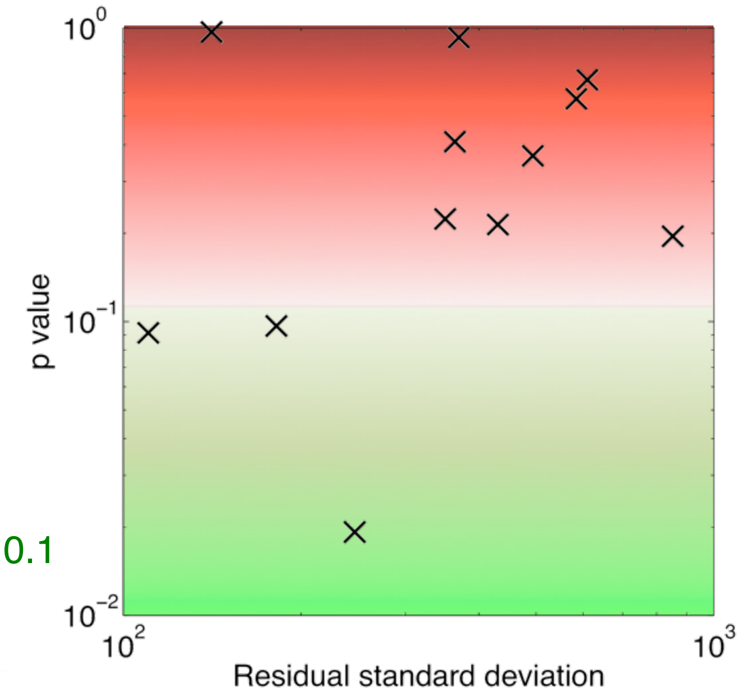


Mann-Kendall test

Monthly total volume

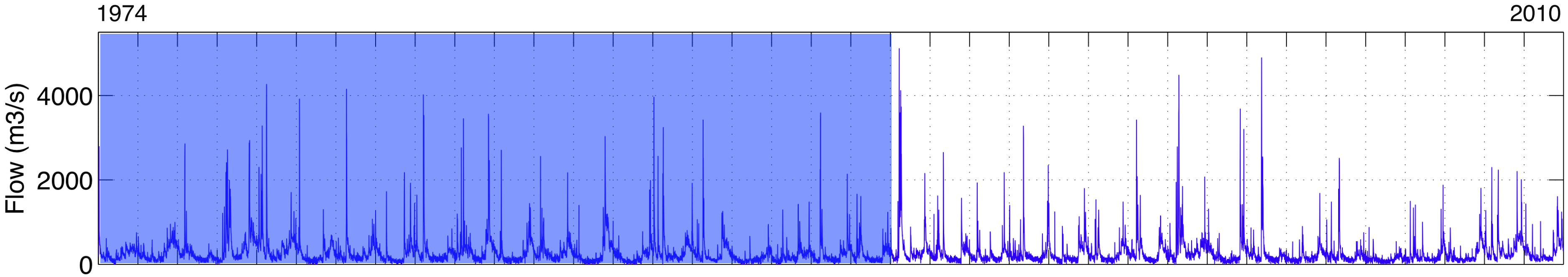


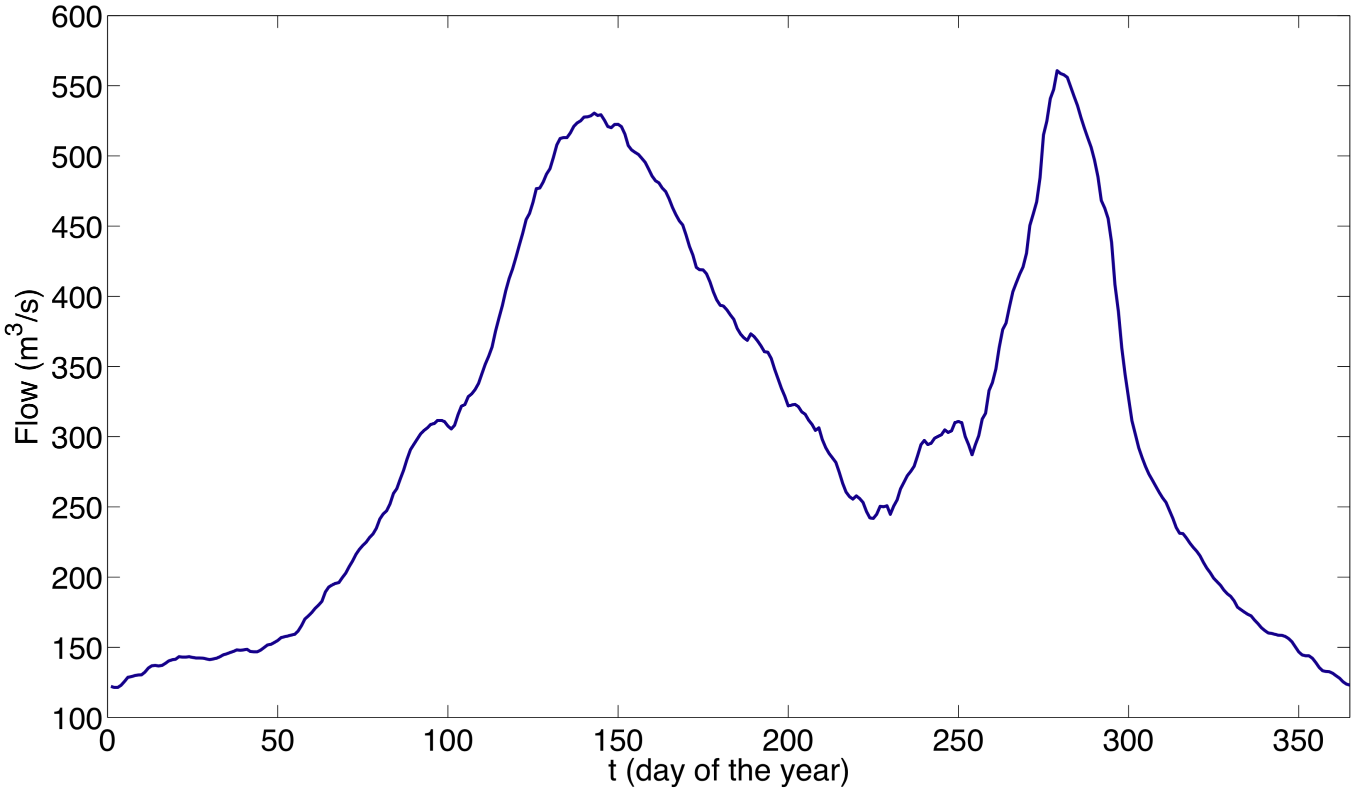




Filtering inter-annual variability

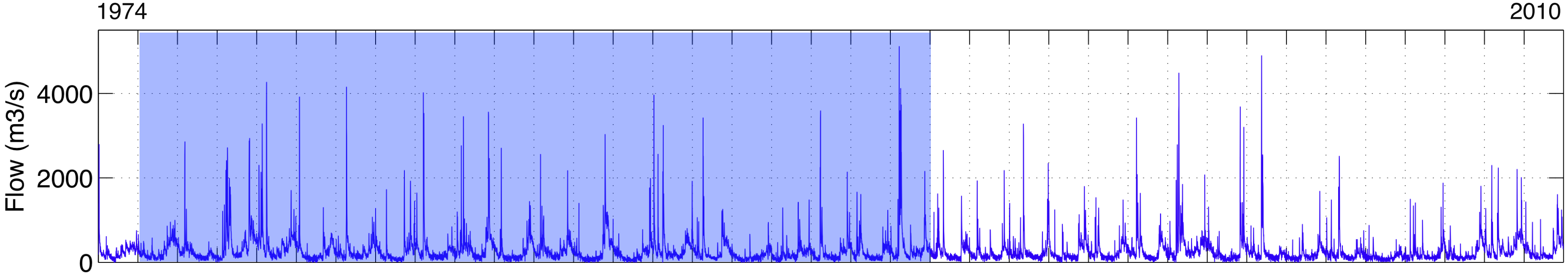
20-year moving average

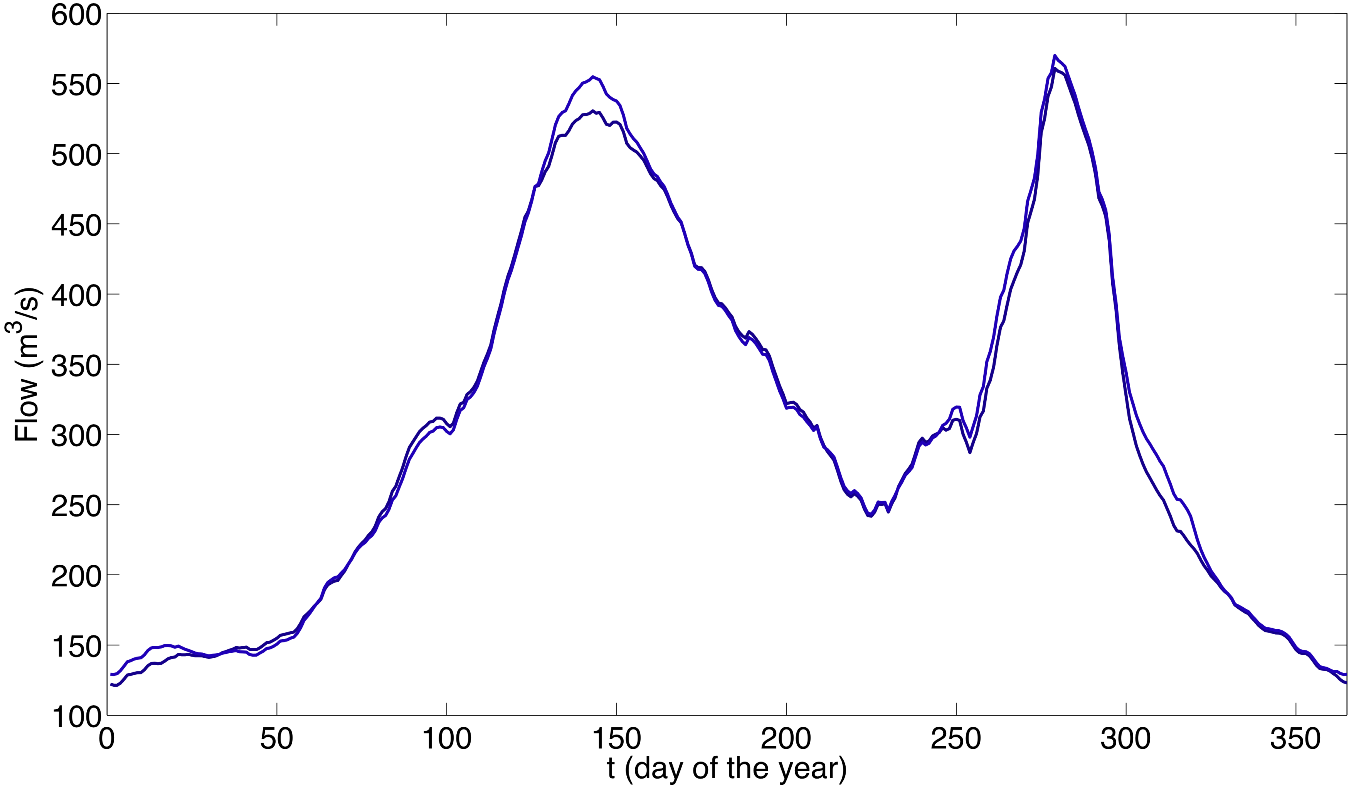




Filtering inter-annual variability

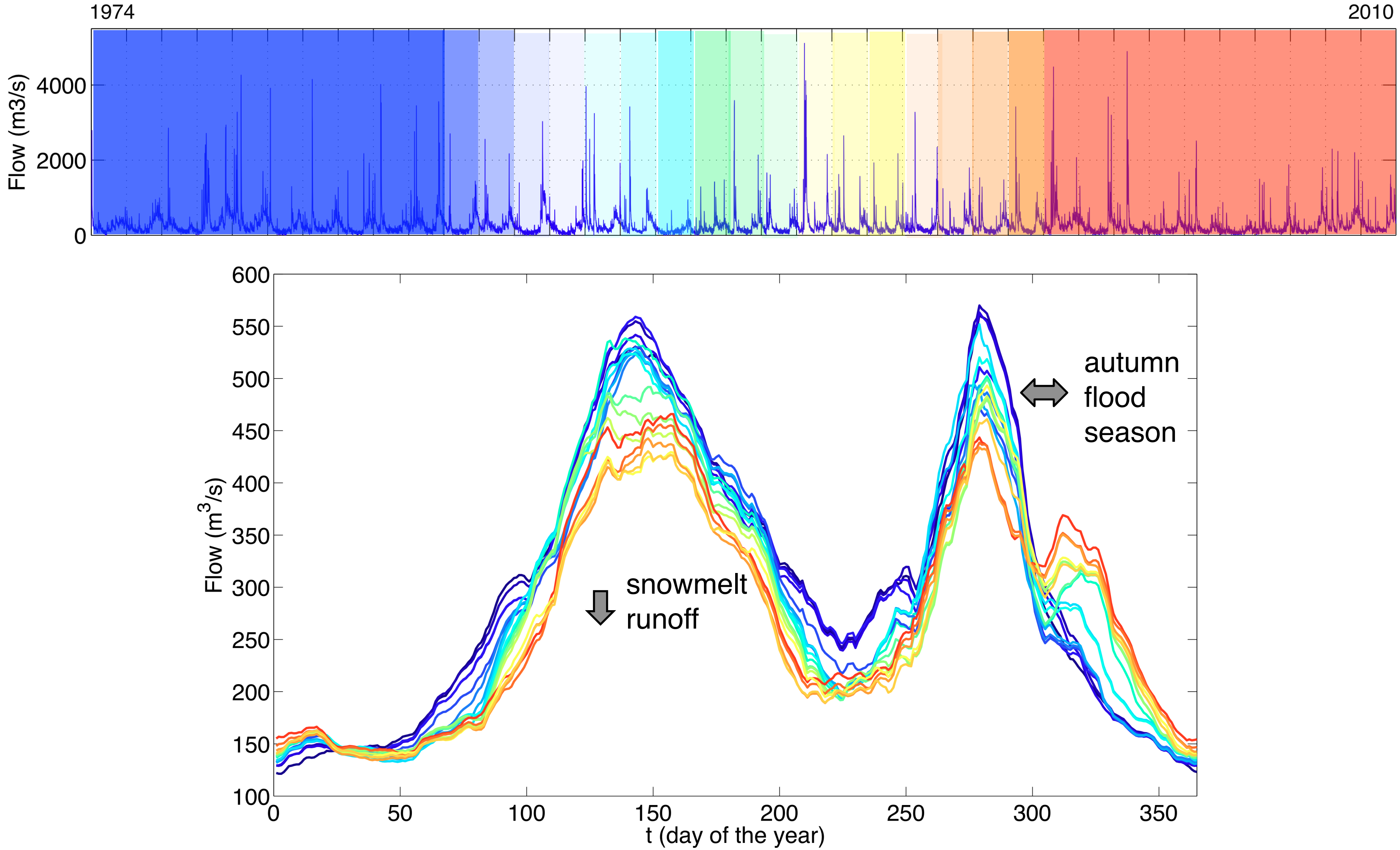
20-year moving average





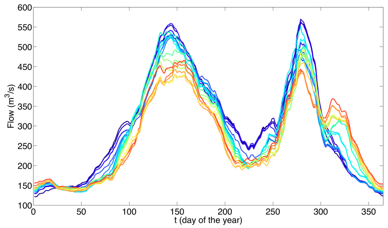
Filtering inter-annual variability

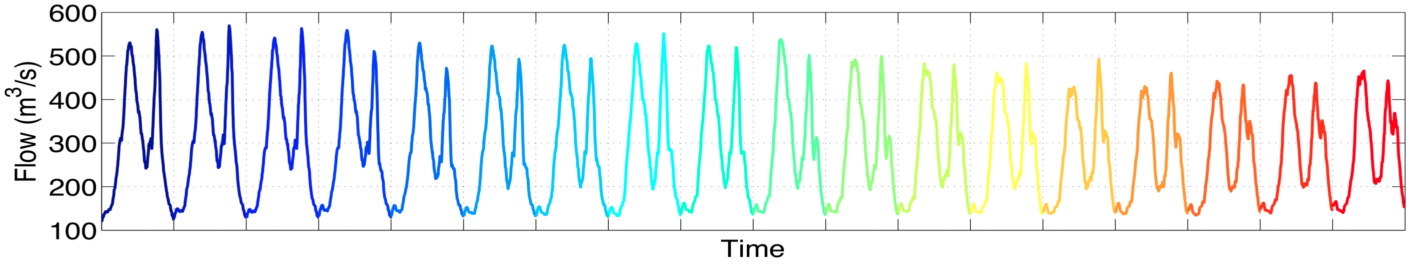
20-year moving average

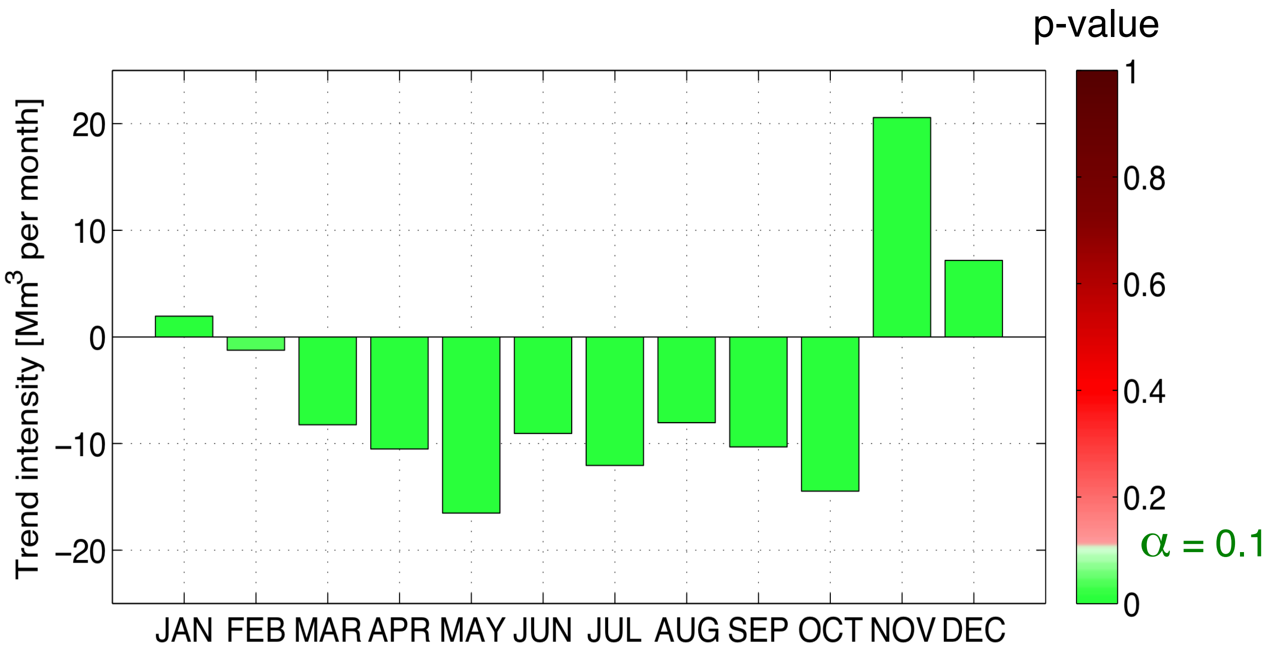


Filtering inter-annual variability

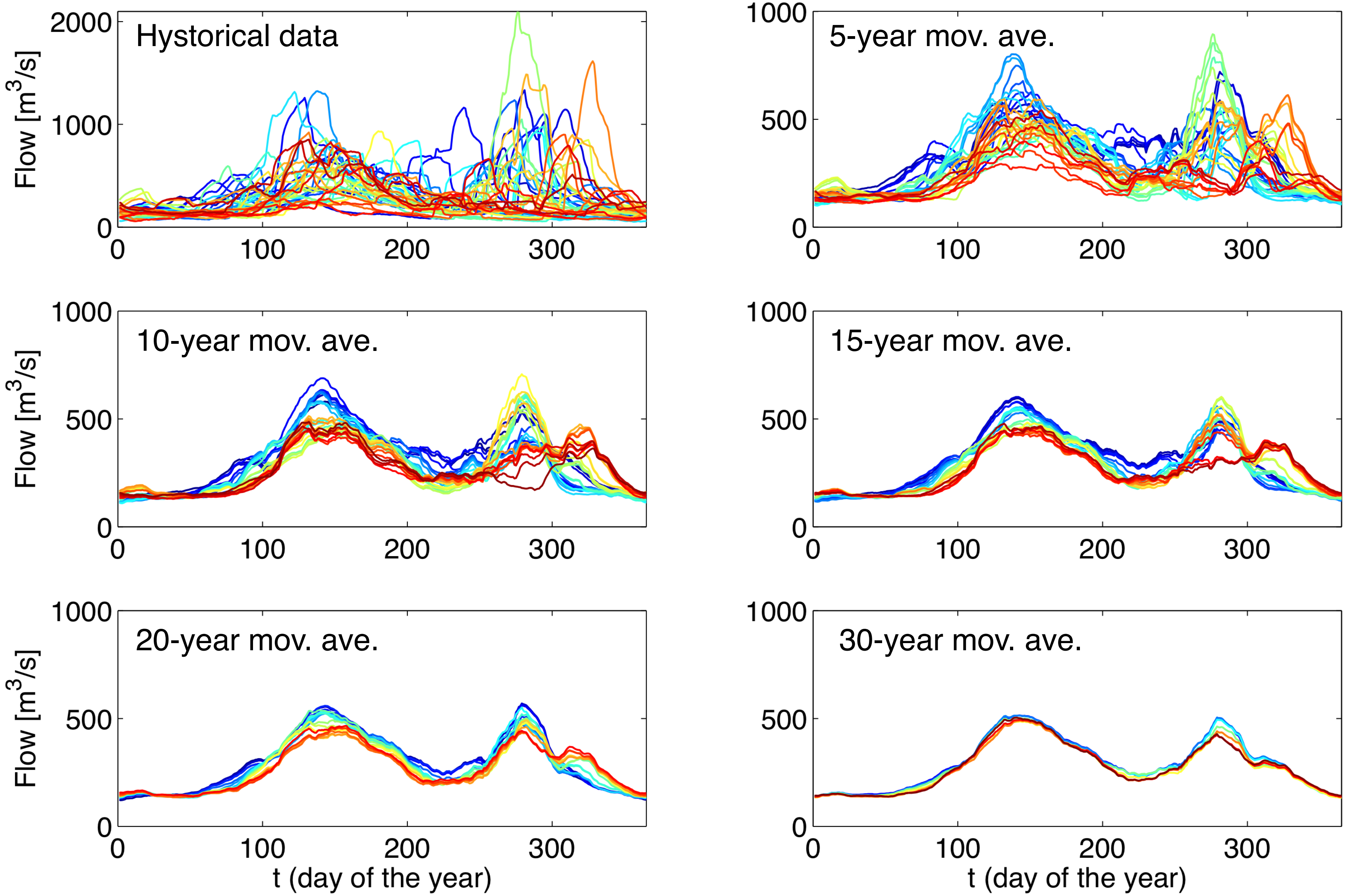
Monthly total volume



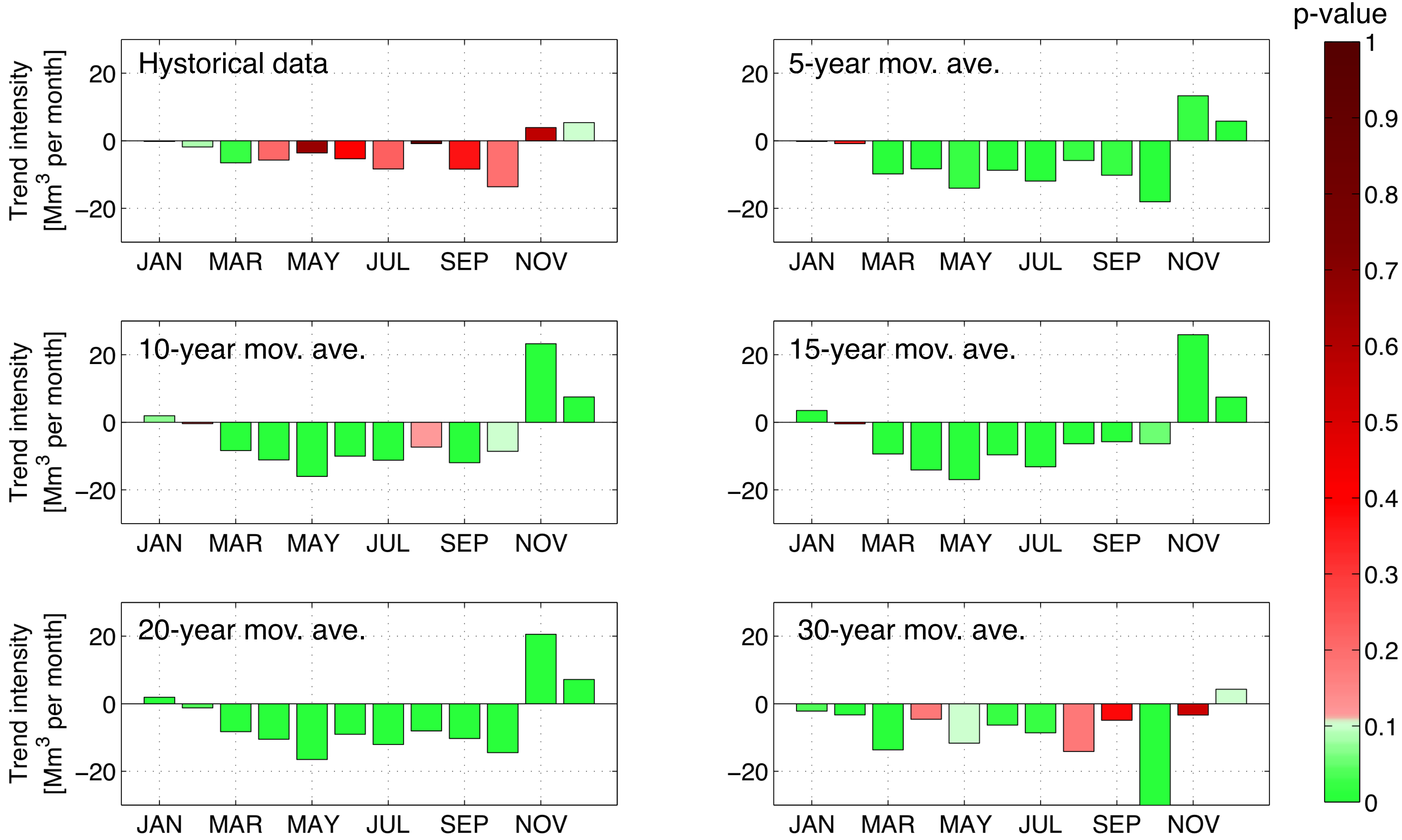




Sensitivity analysis

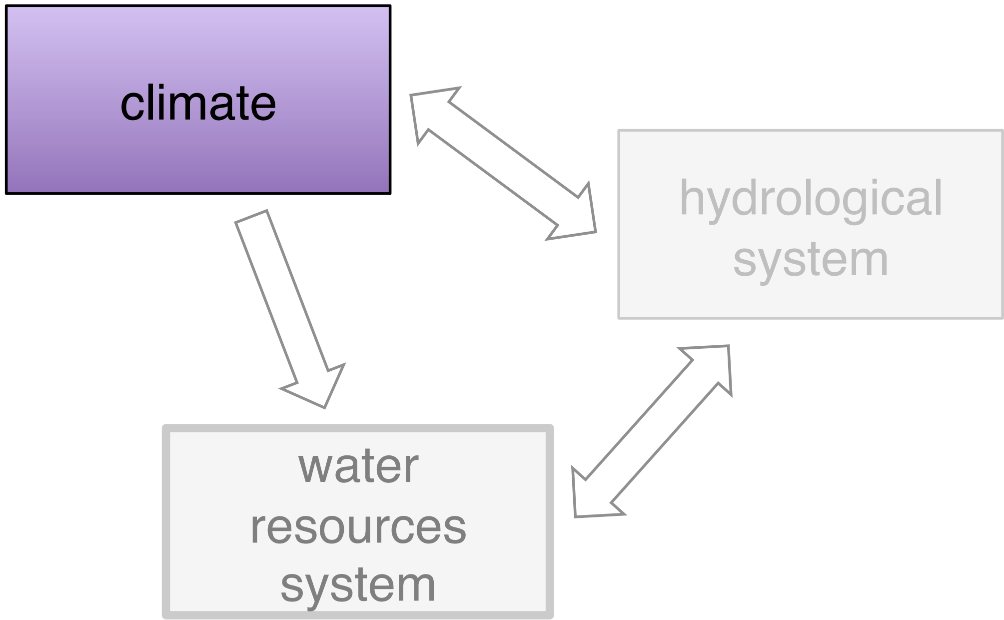


Sensitivity analysis

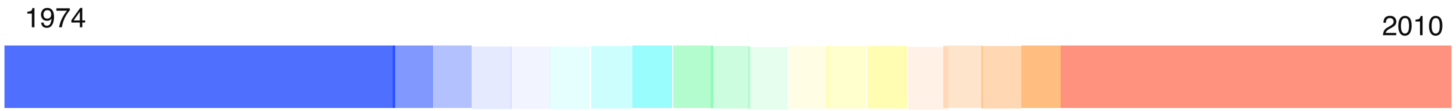


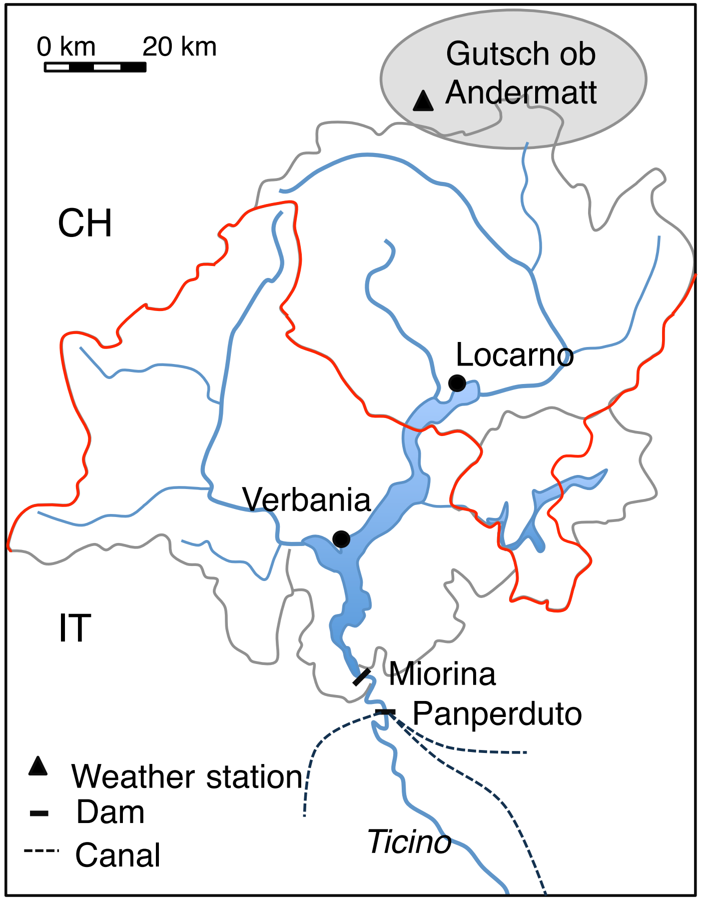
Climate

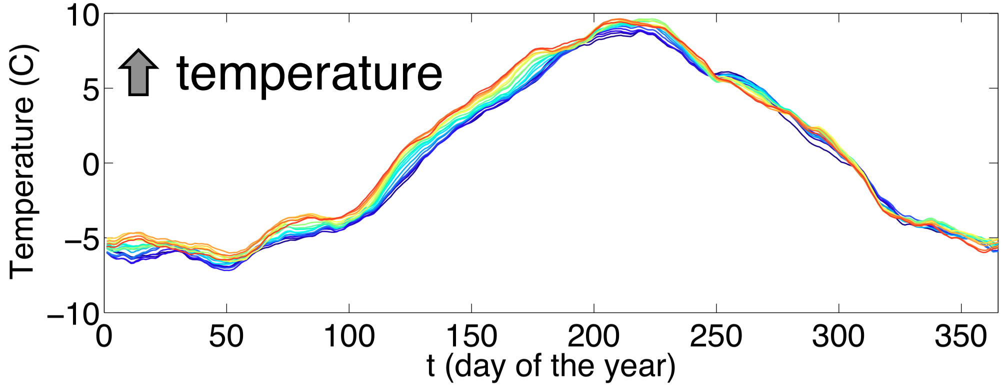
Historical time series of precipitation and temperature in two representative measurement stations from 1974 to 2010 (37 years)

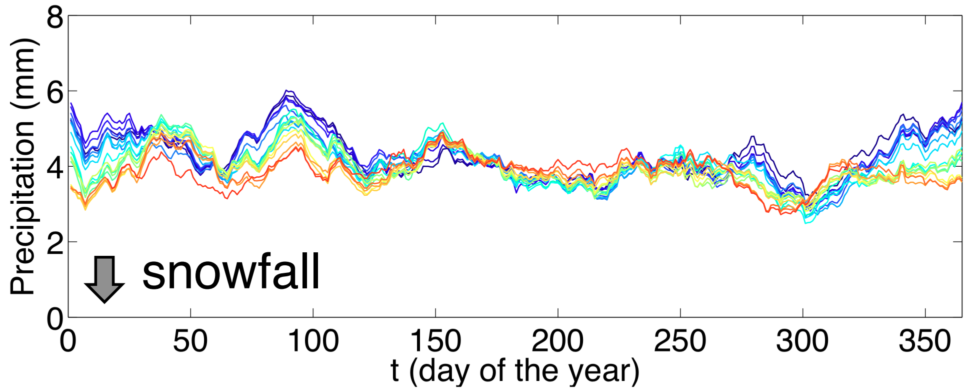


Moving average plot

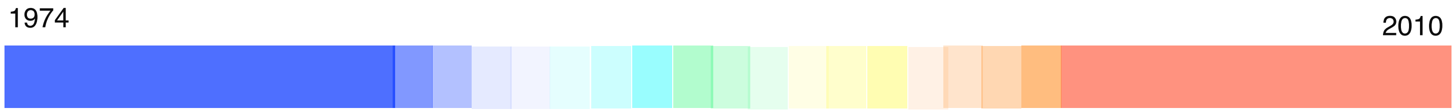


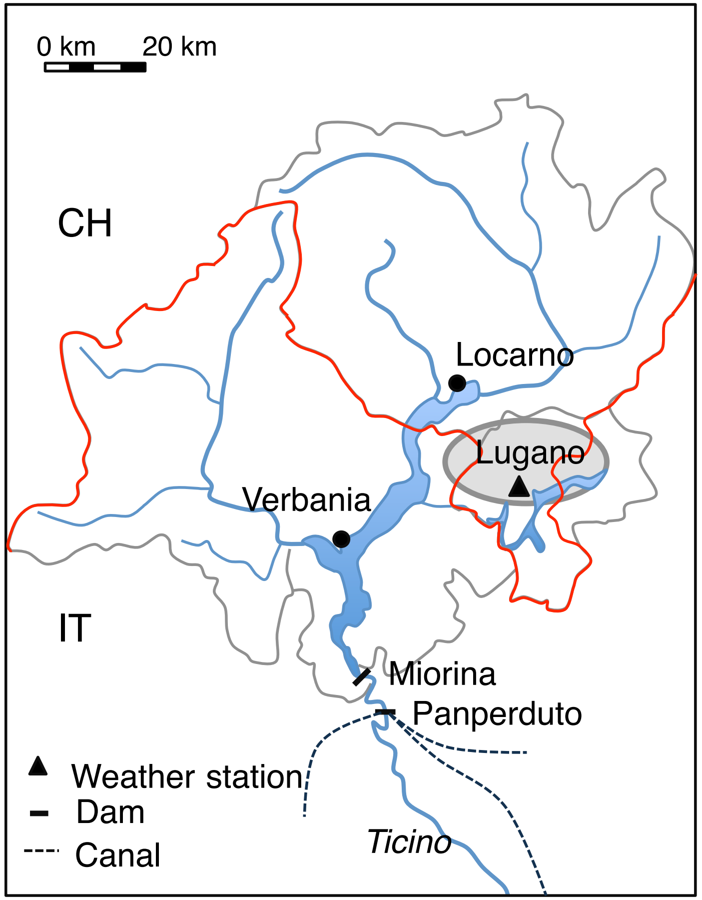


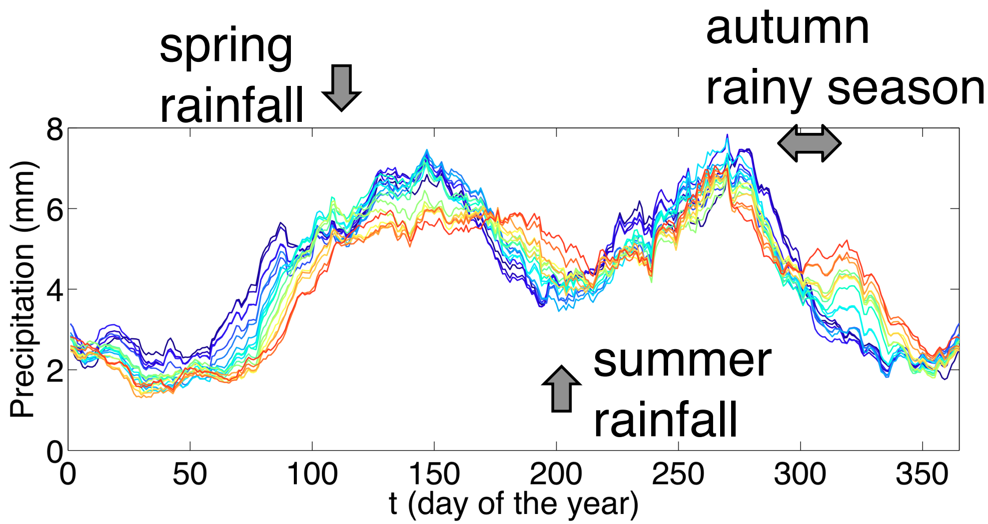




Moving average plot



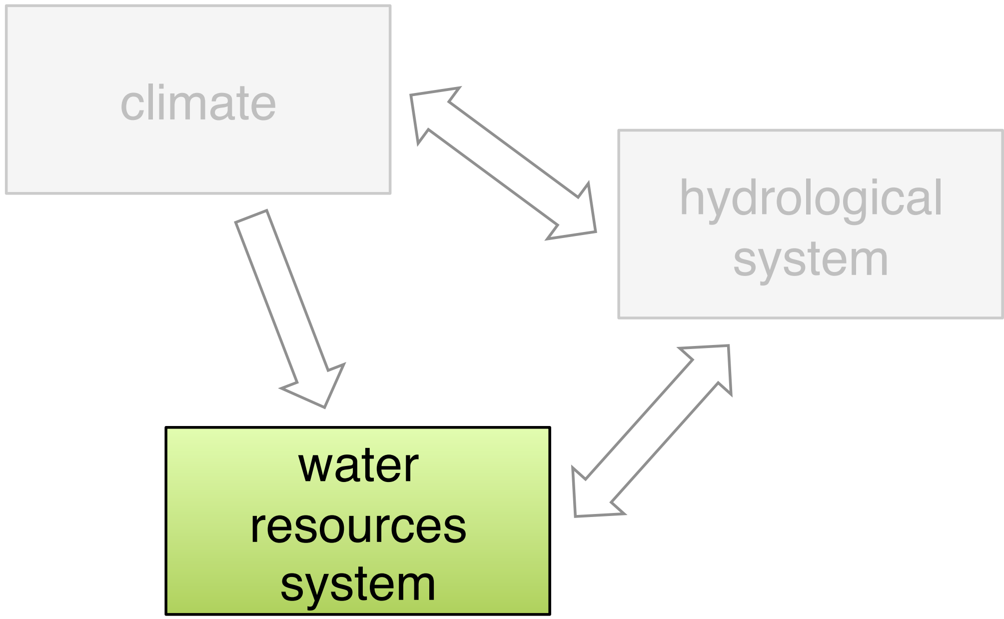




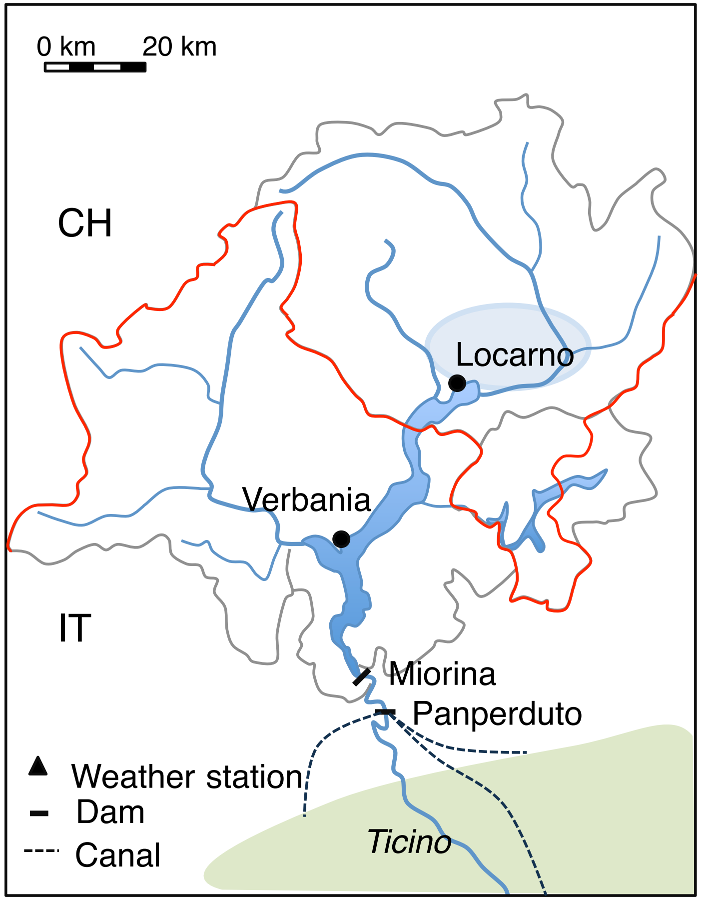
The trend observed in hydrological pattern seems to be a consequence of the trends observed in temperature and precipitation time series

Water-resources system

Impacts are simulated by matematical models (lake water balance model, operation model) using historical time series as input



Impact map



Performance indicators:

Mean annual flooded area in the city of Locarno

Mean annual irrigation deficit with respect to an a-priori demand

Water system model:

Proposed in previous studies [1]

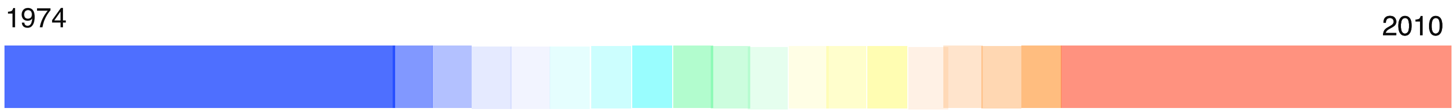
Management model

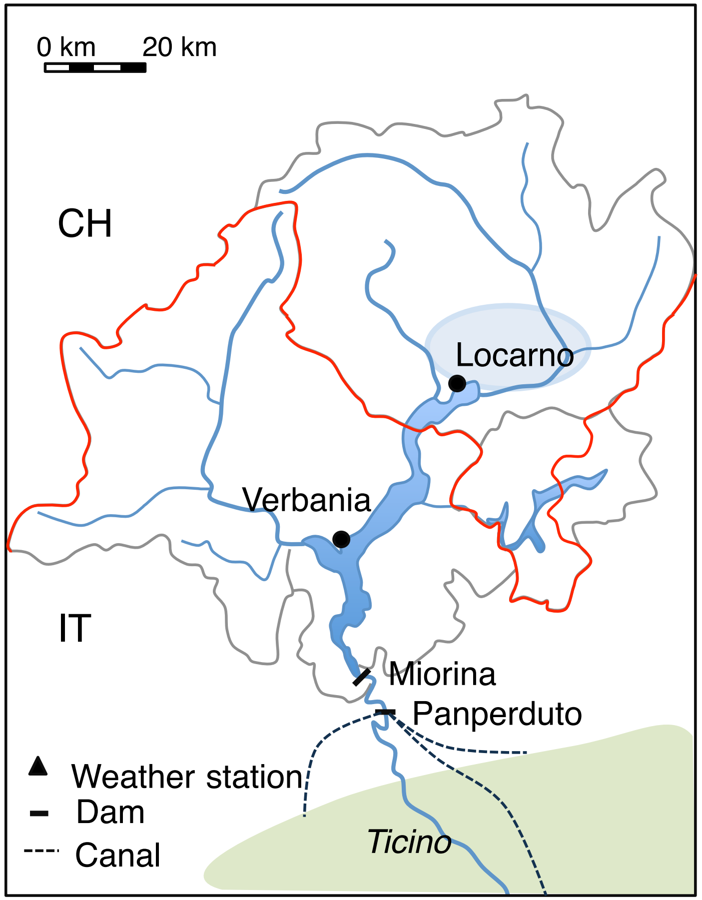
We cannot use hystorical management policy, since the water regulator could have changed his policy over time, possibly hiding the effect of climate change

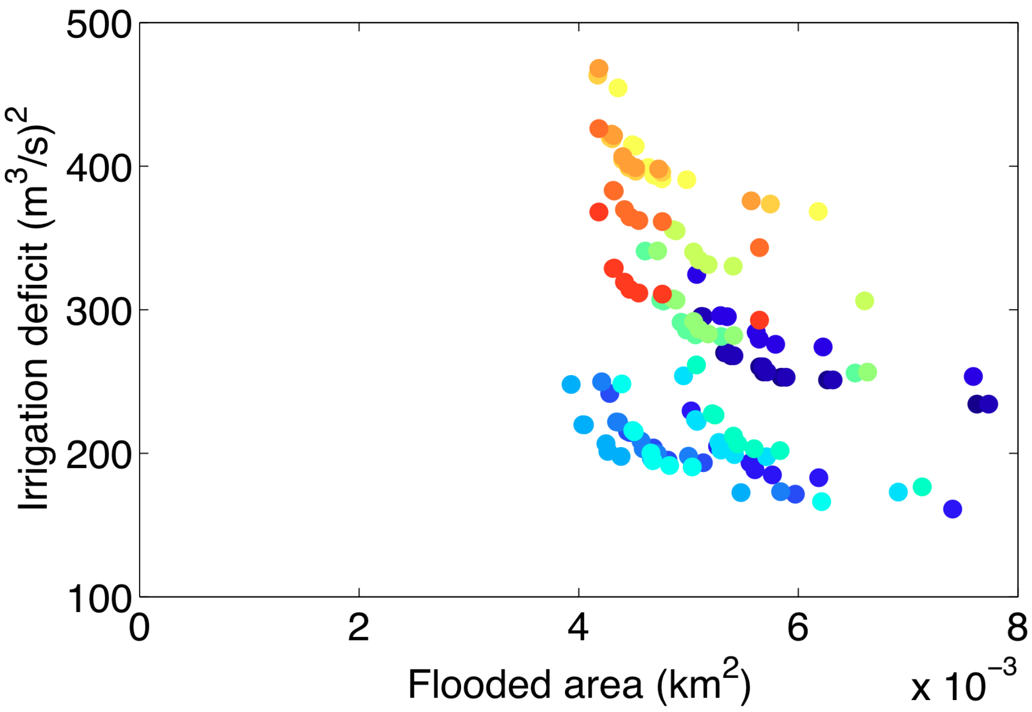
We solve a 2-objective optimal control problem obtaining 8 different Pareto-optimal management policies

[1] F. Pianosi and R. Soncini-Sessa. Real-time management of a multipurpose water reservoir with a heteroscedastic inflow model. *Water Resources Research*, 45:W10430, 2009.

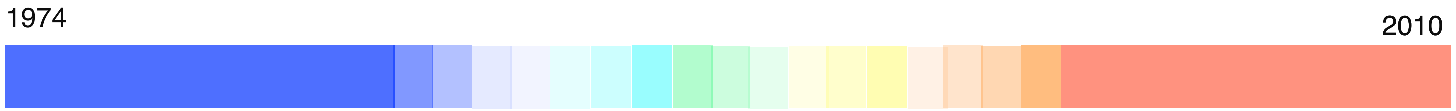
Impact map


1974
2010

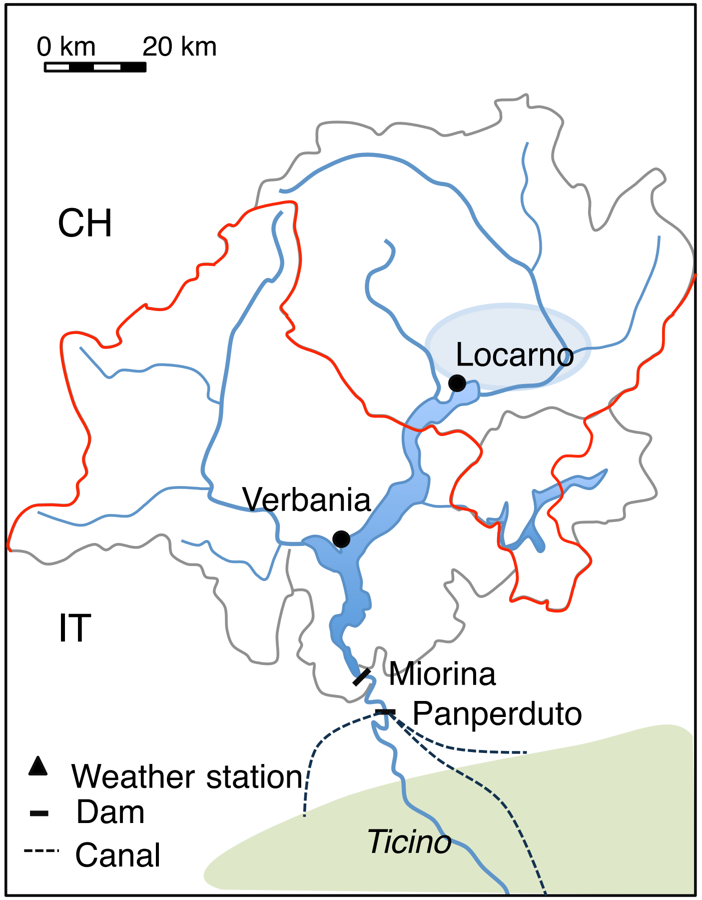

0 km
20 km
CH
IT
Locarno
Verbania
Miorina
Panperduto
Ticino
Weather station
Dam
Canal


Irrigation deficit (m^3/s)^2
500
400
300
200
100
0
2
4
6
8
Flooded area (km^2)
x 10^-3

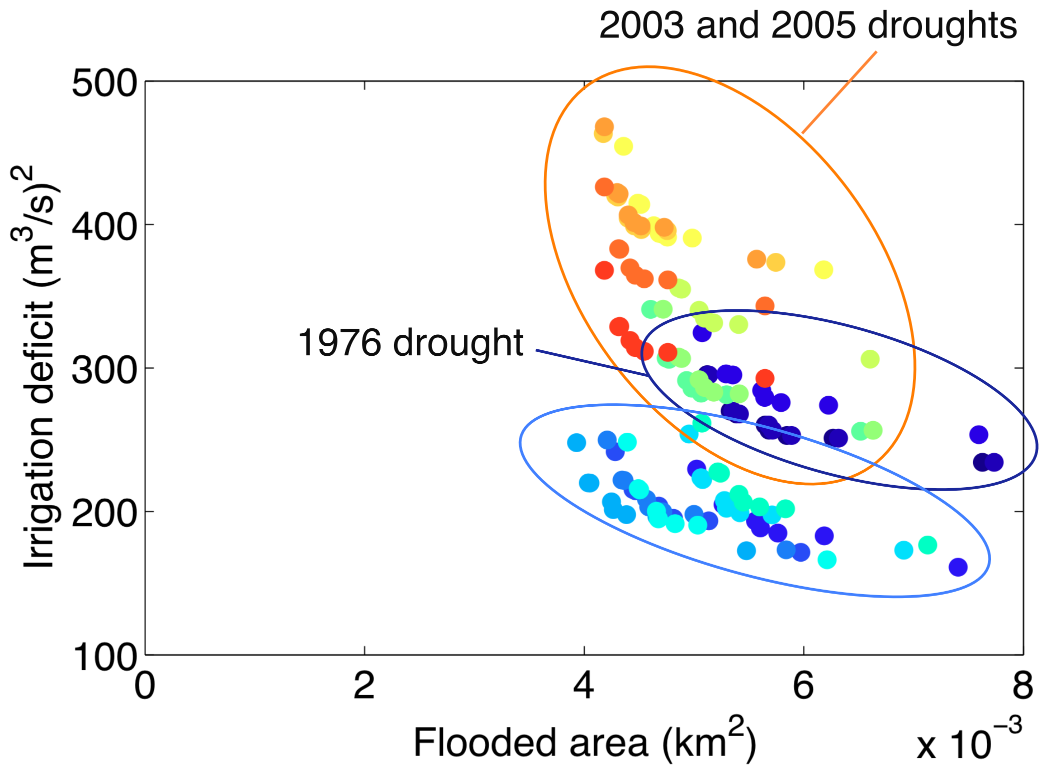
Impact map



1974
2010



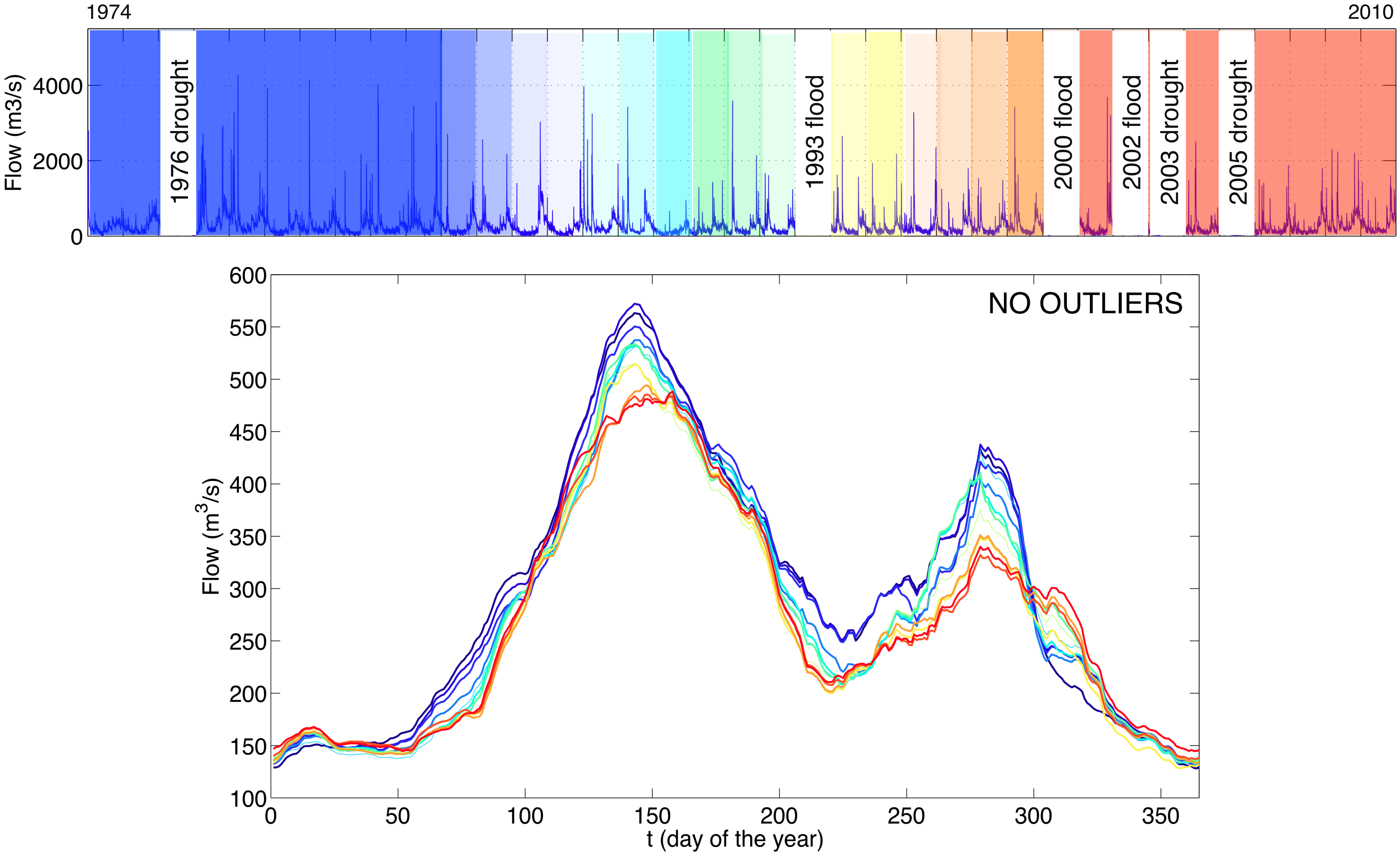
0 km
20 km
CH
IT
Locarno
Verbania
Miorina
Panperduto
Ticino
Weather station
Dam
Canal



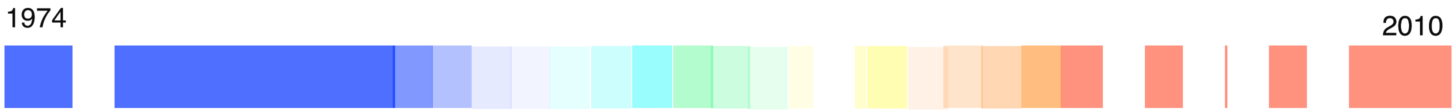
2003 and 2005 droughts
1976 drought
Irrigation deficit (m^3/s)^2
500
400
300
200
100
0
2
4
6
8
Flooded area (km^2)
x 10^{-3}

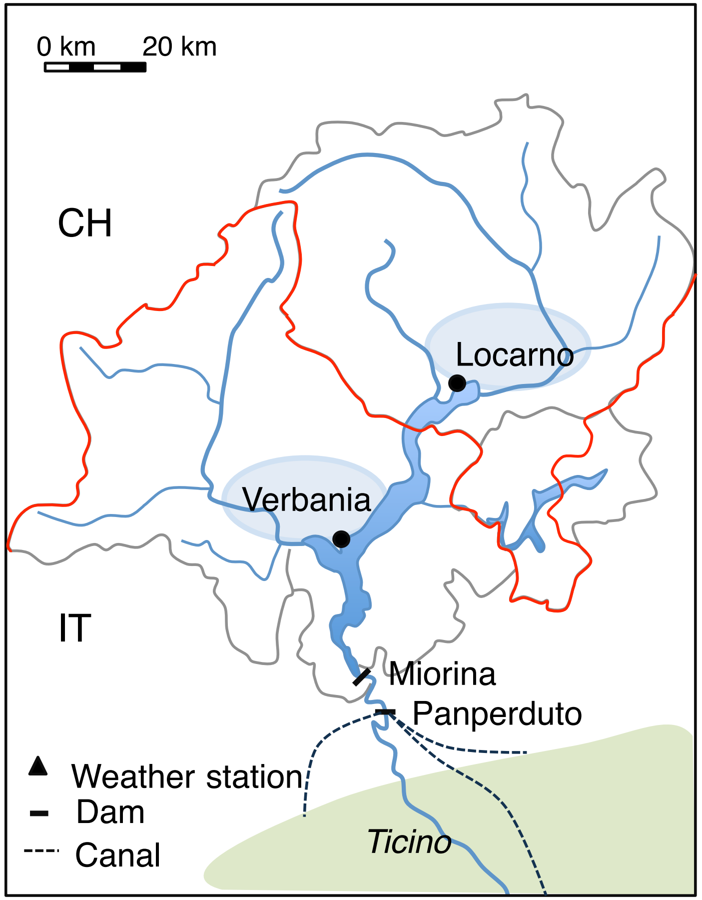
Removing outliers

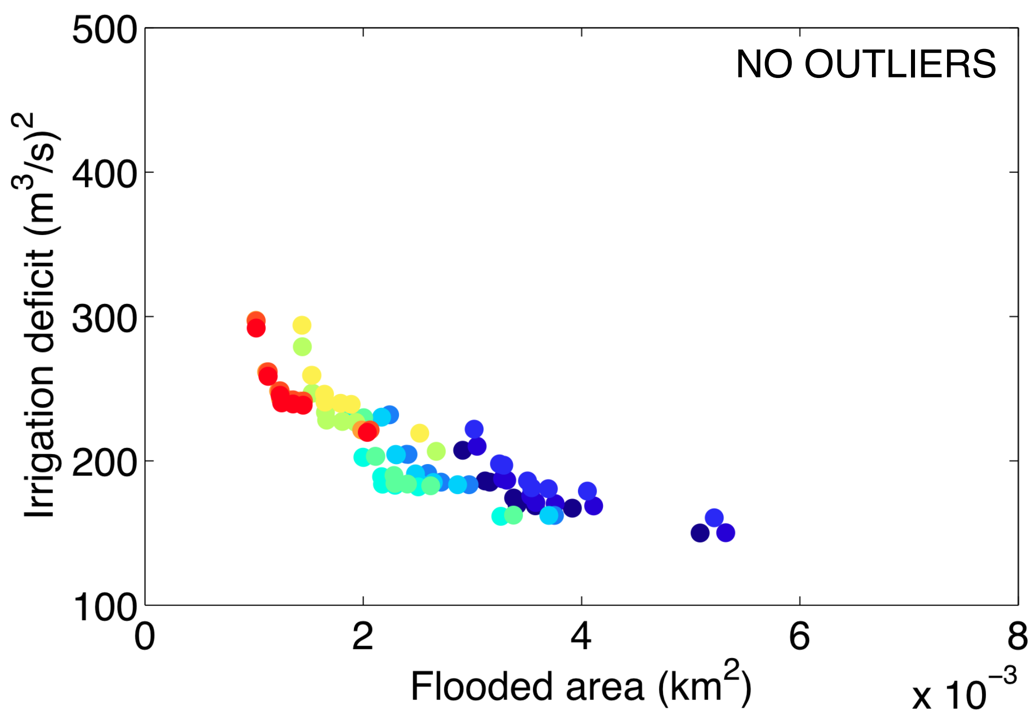
20-year moving average



Removing outliers







⇩ mean annual flooded area

⇧ mean annual irrigation deficit

⇩ conflict

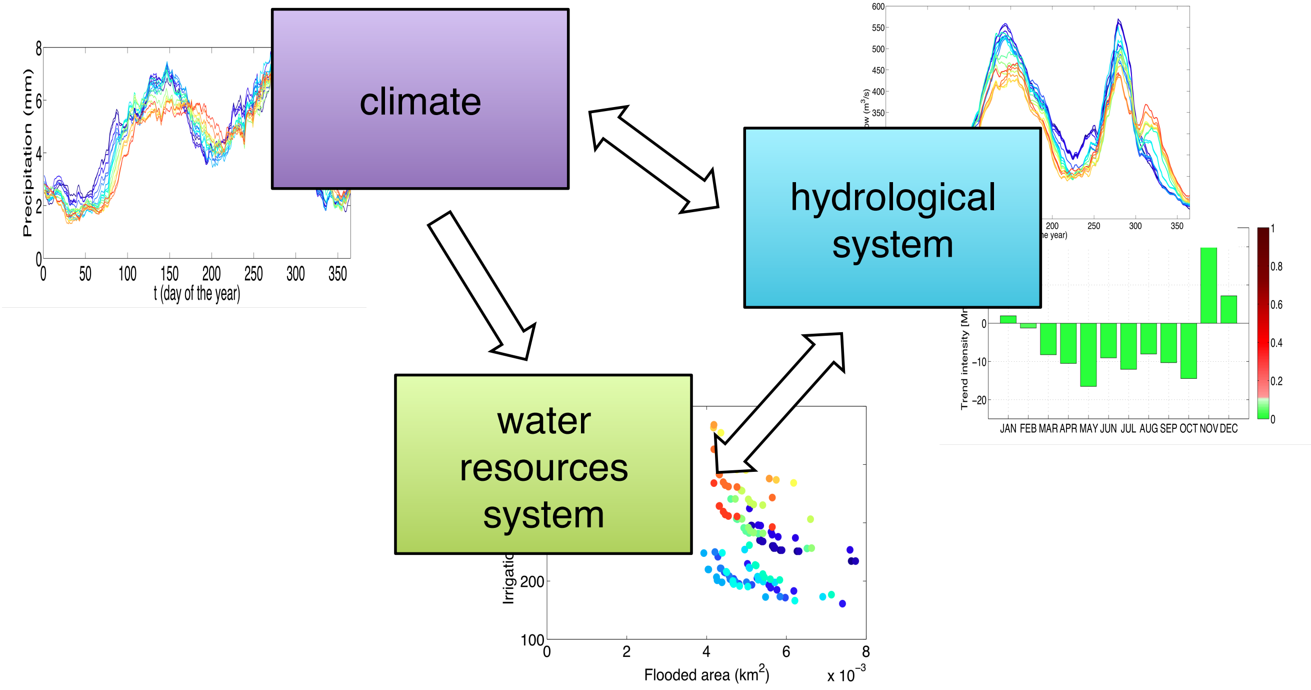
Summary and conclusions

We proposed a set of mathematical and graphical tools for trend detection

→ **moving average plot** for climate and hydrological time series

→ **impact map** for water-related impacts

Combined with the classical statistical tools, they can be useful, expecially in cases of strong *inter-annual variability*.

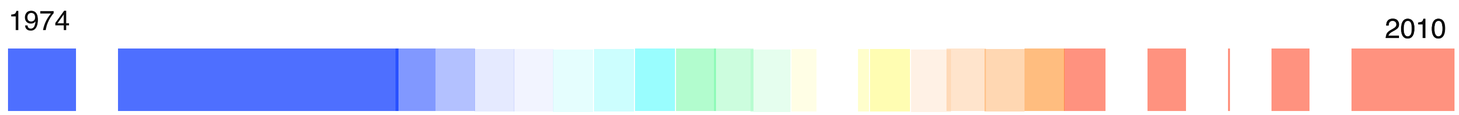


Further researches

Improve the analysis to better account for **extreme** hydrological events

→ Water resources vulnerability to extreme events makes it more difficult to detect trends on water-related impacts

→ The frequency of extreme events is expected to increase



Repeat the analysis on **future** climate model scenarios

→ Preliminary results show that trends in future scenarios are much less clear than in the hystorical data
Climate model uncertainty is still too large to draw conclusions

OVERALL GOAL: Exploit the climate change signal to define **adaptive** water system management policies, possibly mitigating negative impacts

For more details:

D. Anghileri, F. Pianosi, R. Soncini-Sessa, and E. Weber. Modelling climate change uncertainties in water resources management of alpine reservoir systems.
In 10th International Conference on Hydroinformatics HIC 2012, Hamburg, GERMANY, 2012