Hydrology and Climate Change Scenarios in the Po River Basin

C. Cacciamani, P. Mercogliano, S. Pecora, S. Tibaldi, R. Vezzoli

Parma,
27 June 2014

arpa agenzia regionale prevenzione e ambiente dell'emilia-romagna

EU.WATERCENTER
Inspired by water, driven by innovation

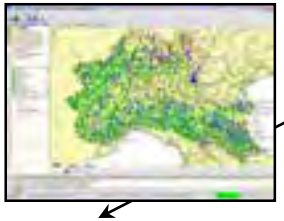
cmcc Centro Euro-Mediterraneo sui Cambiamenti Climatici ISC - Capua

Po river
Monitoring and Forecasts

The Po flood forecasting system

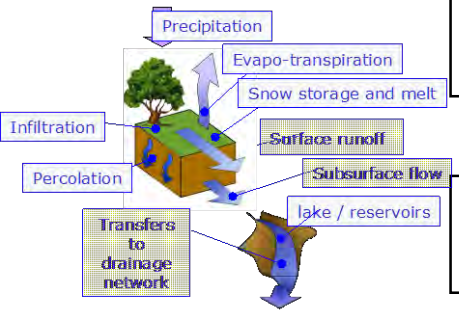
METEOROLOGICAL MODELS } **LM/Ensemble**

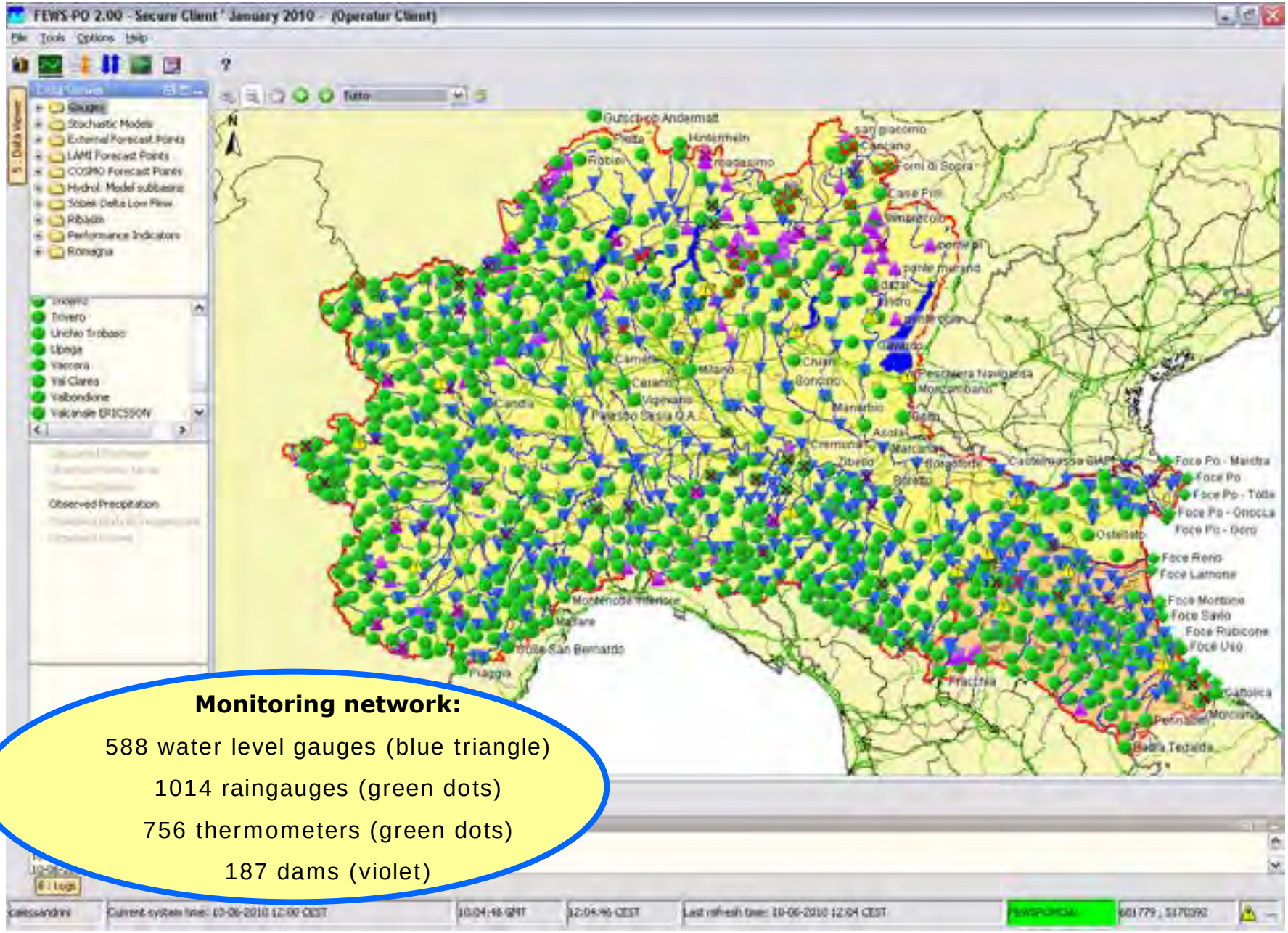
RAINFALL
TEMPERATURE
LEVEL/DISCHARGE } **Observed/Telemetry**



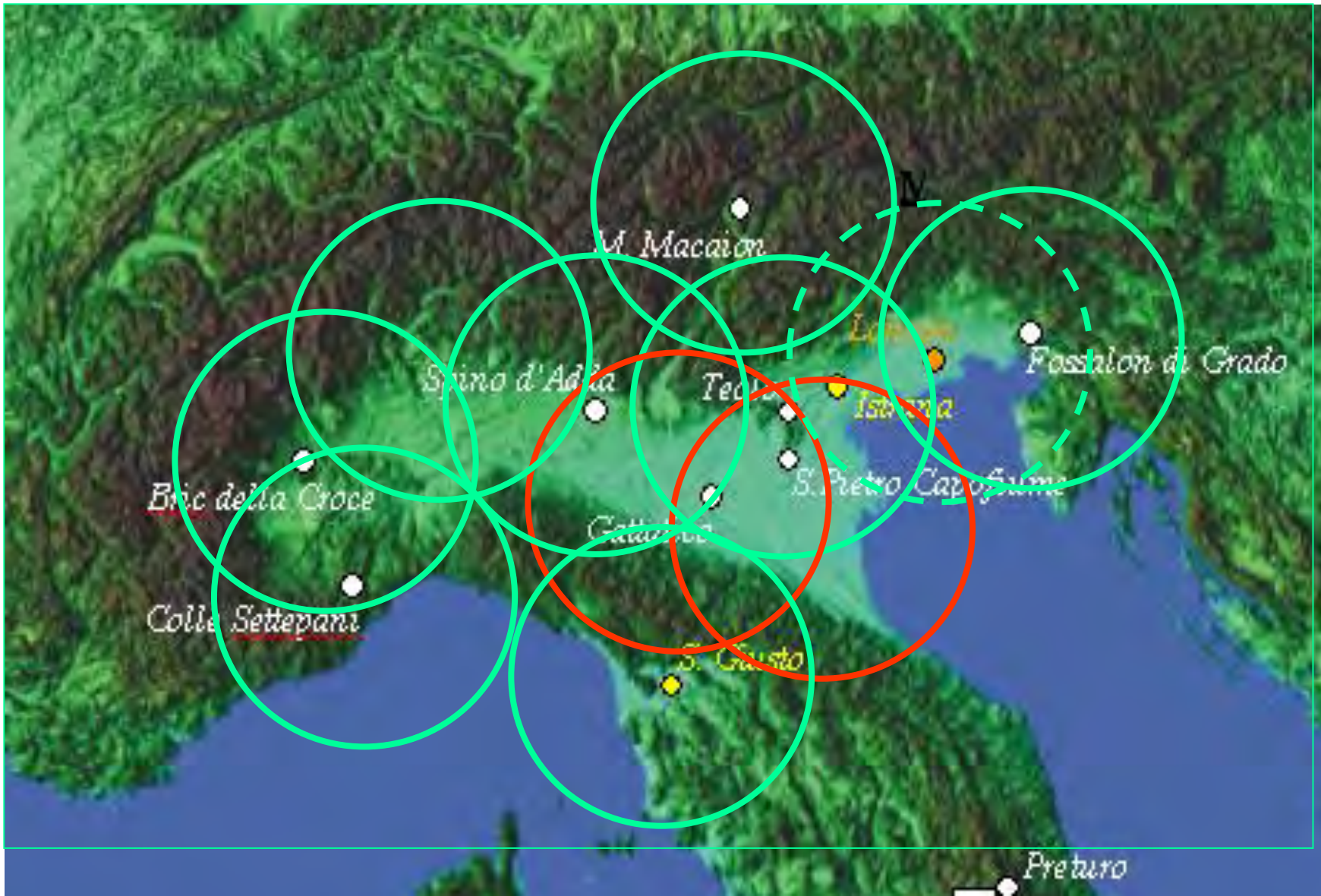
VALIDATION, INTERPOLATION AND TRANSFORMATION DATA

First chain	Second chain	Third chain	User config chain
HEC-HMS	MIKE11-NAM	TOPKAPI	HMS/NAM/TOPKAPI
HEC-RAS	MIKE11-HD	SOBEK/PAB	RAS/MIKE11/SOBEK /PAB

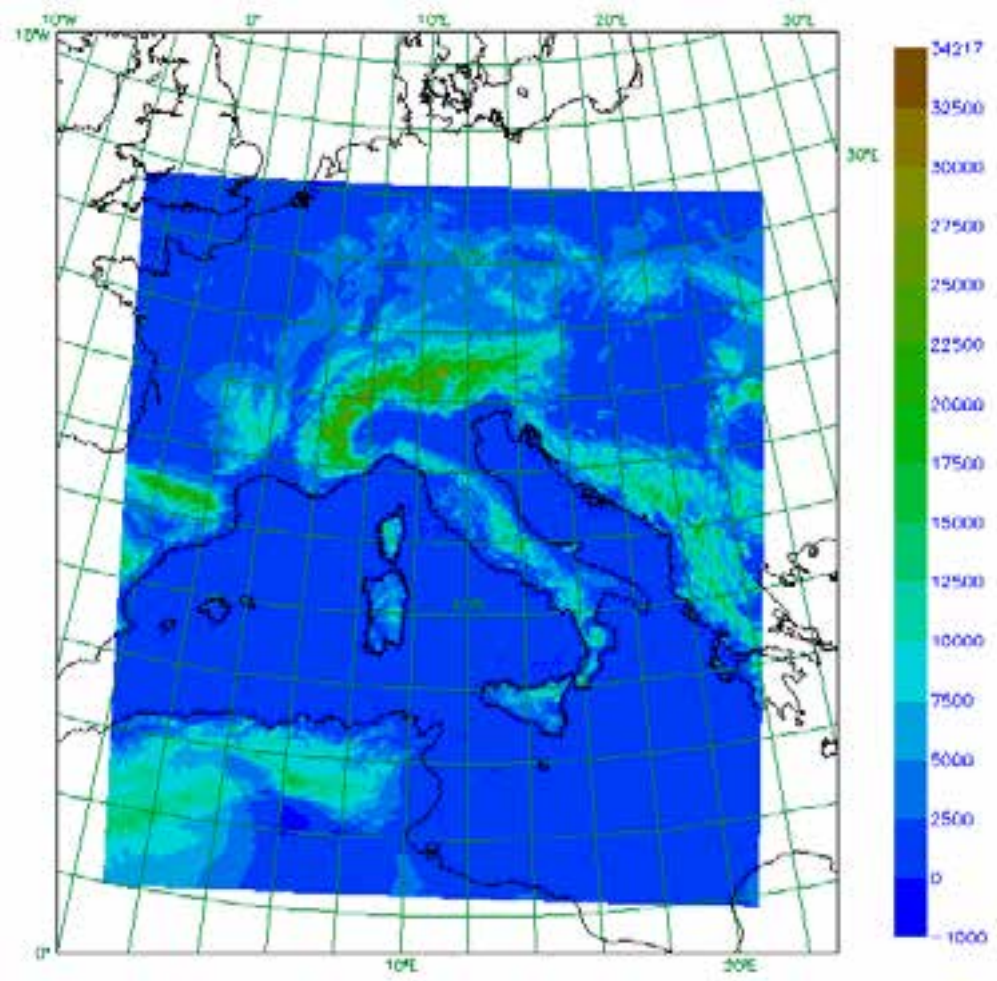



FEWS-PO 2.00 - Secure Client * January 2010 - (Operator Client)
File Tools Options Help
Gauges
Stochastic Models
External Forecast Points
LAMI Forecast Points
COSMO Forecast Points
Hydrol. Model sublasins
Sobek Delta Low Flow
Ribasim
Performance Indicators
Romagna
Observed Precipitation
Monitoring network:
588 water level gauges (blue triangle)
1014 raingauges (green dots)
756 thermometers (green dots)
187 dams (violet)

The radar network

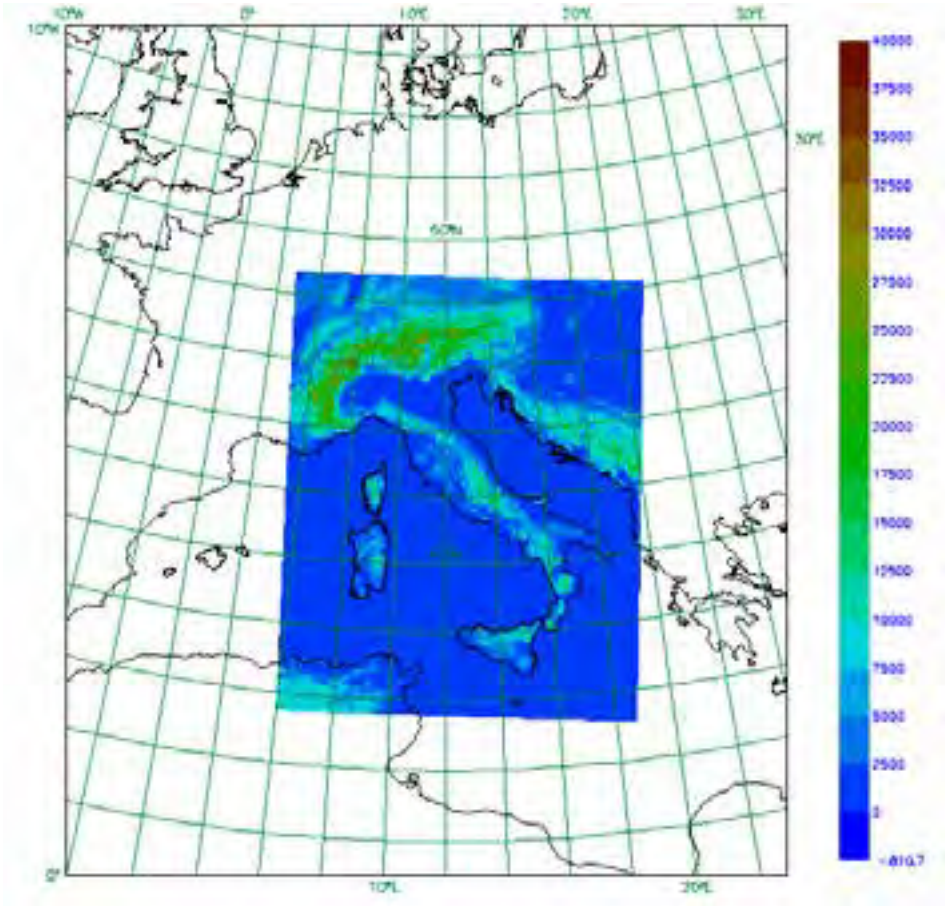


The CosmoI7 Model
USAM – ARPA SIMC - ARPA Piemonte



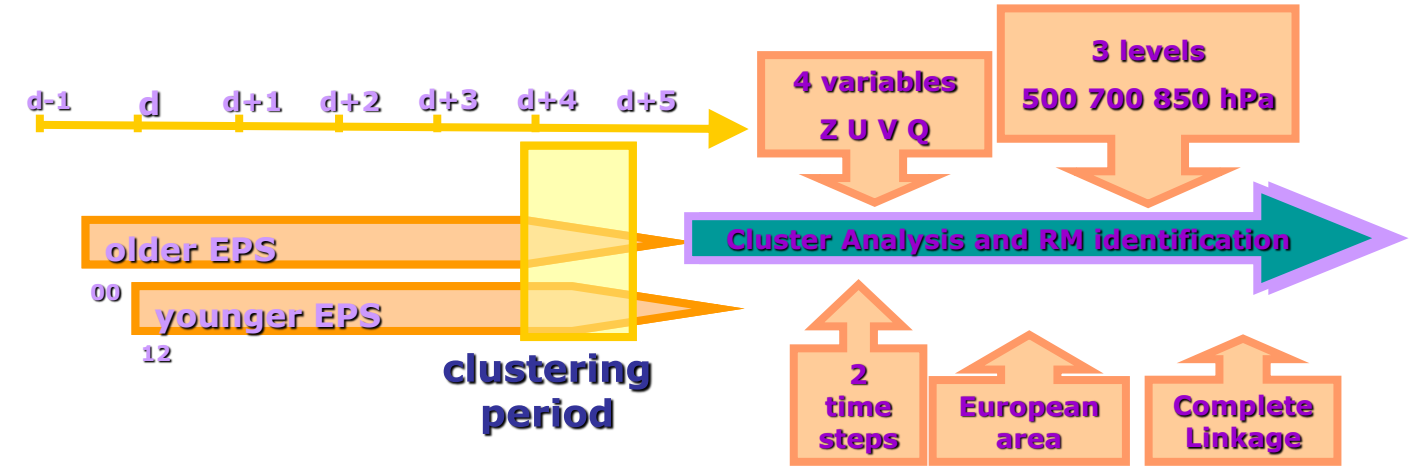
- The HydroMeteoClimate Service of Emilia-Romagna, ARPA-SIMC, has been using COSMO-I7 as the operational forecast model since 2001;
- COSMO-I7 is run twice a day (at 00UTC and 12UTC) for 72 hours with a spatial horizontal resolution of 7 km and 40 layers in the vertical.
- The boundary conditions for COSMO-I7 are supplied by the global model of ECMWF (one-way nesting) every 3 hours. The initial conditions are provided by a mesoscale data assimilation based on the nudging technique

The CosmoI2 Model
USAM – ARPA SIMC - ARPA Piemonte



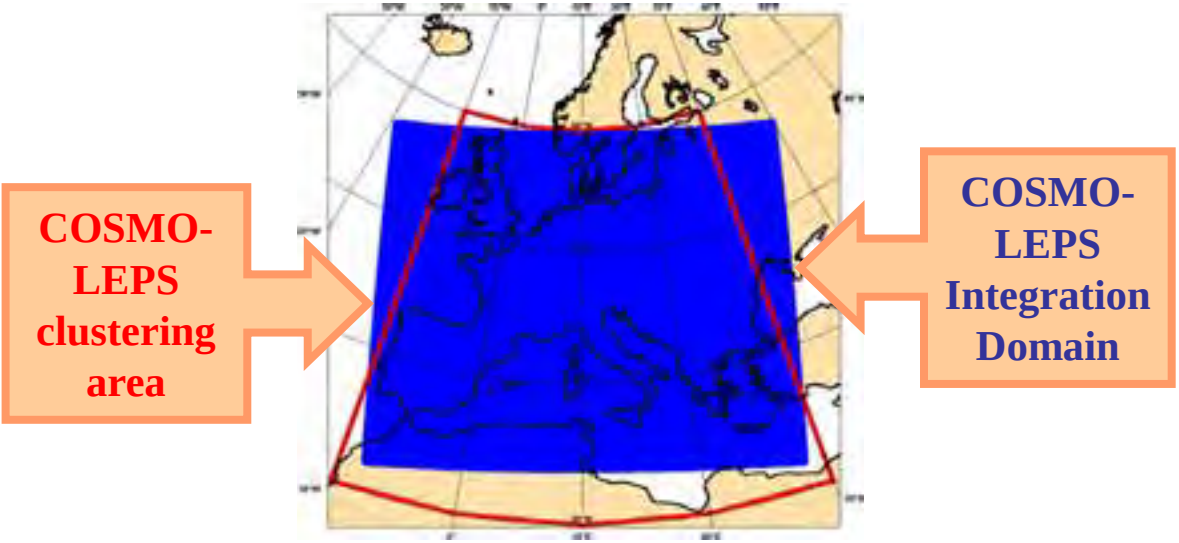
- The HydroMeteoClimate Service of Emilia-Romagna, ARPA-SIMC, has been using COSMO-I2 since 2007;
- COSMO-I2 is run twice a day (at 00UTC and 12UTC) for 48 hours with a spatial horizontal resolution of 2.8 7 km and 45layers in the vertical.
- The boundary conditions for COSMO-I2 are supplied by COSMO-I7 (one-way nesting) every hour. The initial conditions are provided by a mesoscale data assimilation based on the nudging technique

COSMO-LEPS (run at ECMWF)
COSMO Consortium



16 Representative Members driving the 16 COSMO-model integrations (weighted according to the cluster populations)

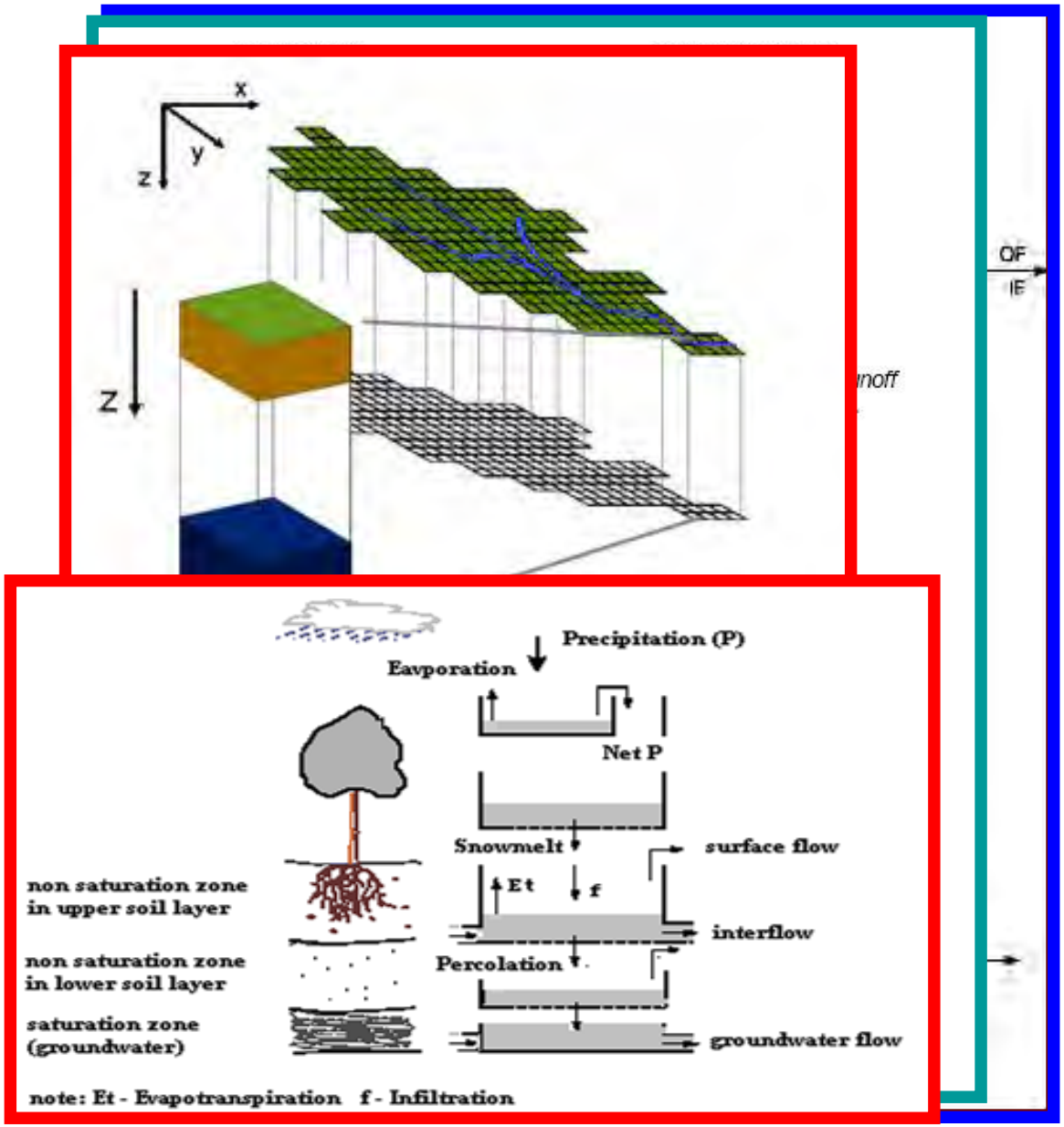
Using either Tiedtke or Kain-Fristch convection scheme (members 1-8 T, members 9-16 KF)
+
Perturbations in turbulence scheme and in physical parameterisations



- suite runs twice a day (00 and 12UTC) as a "time-critical application" managed by ARPA-SIMC on behalf of COSMO consortium;
- Δx ~ 7 km; 40 ML; fc+132h;
- COSM0 v4.26 since January 2013;
- computer time (30 million BUs for 2013) provided by the ECMWF member states in COSMO.

Hydrological models

- MIKE11-NAM
(conceptual lumped)
- HEC-HMS
(Conceptual/empirical lumped/distributed)
- TOPKAPI
(Physically based, distributed)



Po river
Droughts Monitoring System

DEWS – Drought Early Warning System

PRECIPITATION
TEMPERATURE
LEVEL/DISCHARGES

Observed/Telemeasure

METEOROLOGICAL
MODELS

LM + 15 days/Seasonal Forecasts + 3 months

VALIDATION,
INTERPOLATION
AND DATA
TRANSFORMATION
(DEWS)

TOPKAPI

Rainfall-runoff model

RIBASIM

For simulation of river basin management

Hydrological model: TOPKAPI

Distributed and physically based

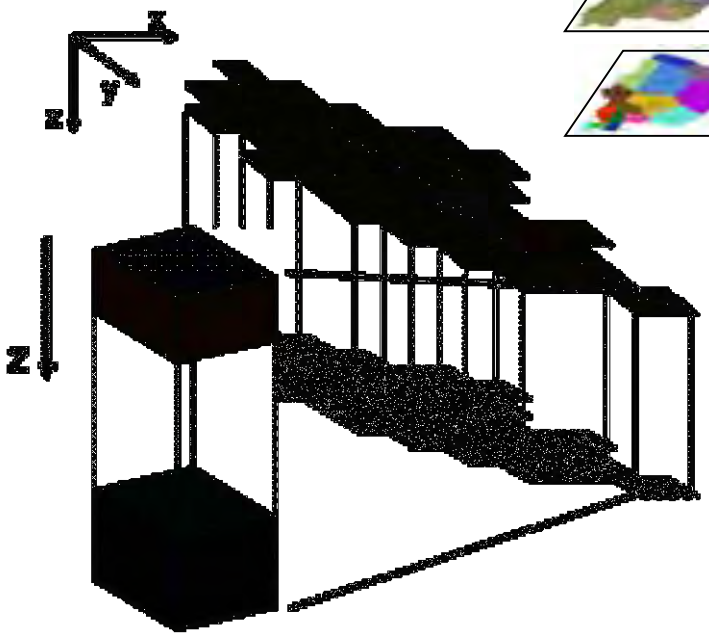
Hydrographs are obtained from:

-climate (weather) inputs

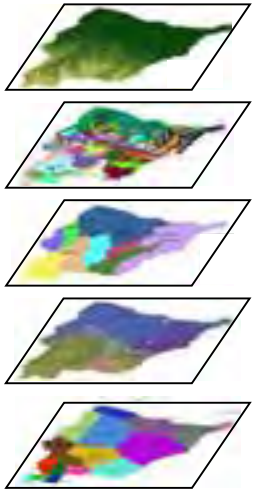
-basin features (morphology)

-land use

-etc



Thematic Maps:



DEM

Soil type

Drainage coefficients

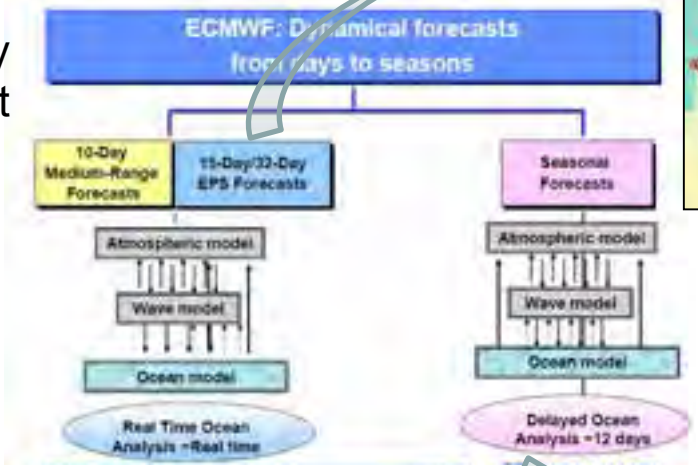
Land use and vegetation type

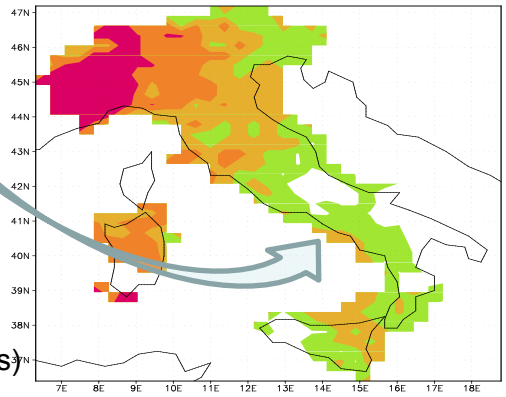
Climate

Seasonal and long term meteorological products

Meteorological centre of ARPA EMR gives an elaboration of ECMWF forecasts feeding the hydrological chain:

1. Are composed of precipitation and temperature fields, given by seasonal and long term forecast products
2. The spatial domain is northern Italy with a grid step from 16 (deterministic) to 35 (seasonal) km, daily precipitation and 6 hours for temperature.
3. The daily detail of seasonal forecasts is given by a statistical post processing, that is a weather generator.





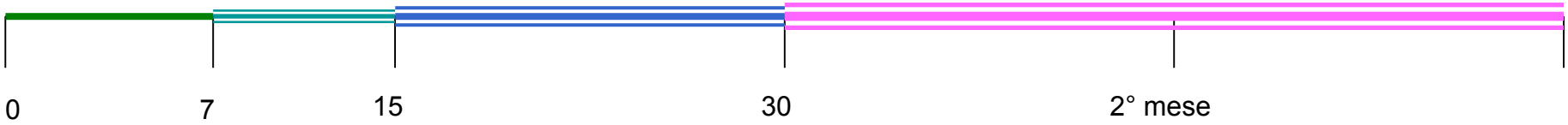
The process contains an harmonization of computational grids, data assimilation and a downscaling of the seasonal forecast.

deterministic forecast ECMWF (0-6 days) – daily updated

ensemble forecast ECMWF EPS (7-14 days) – daily updated (median or scenarios)

monthly ens forecast (15-30 days) – weekly updated (median or scenarios)

seasonal ens forecast (1-3 months) – monthly updated (median or scenarios)

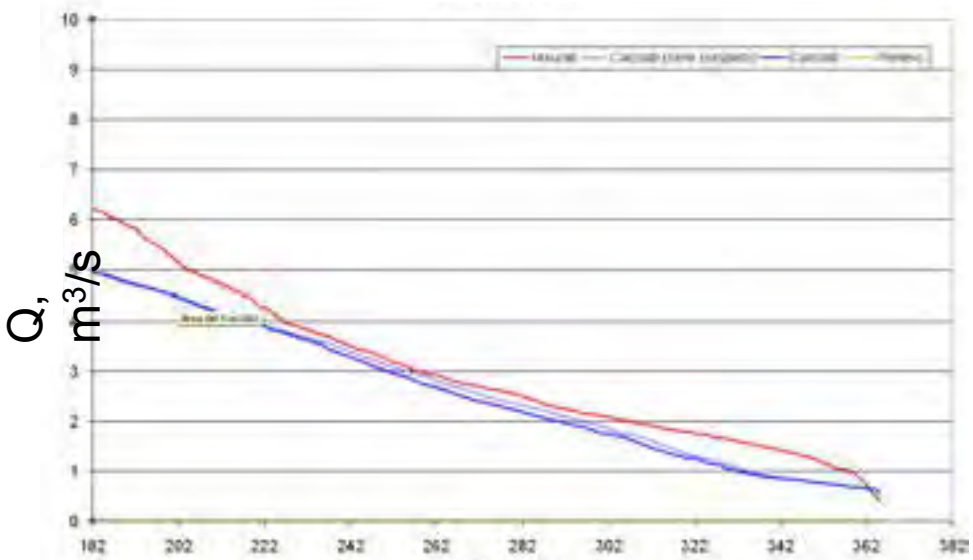


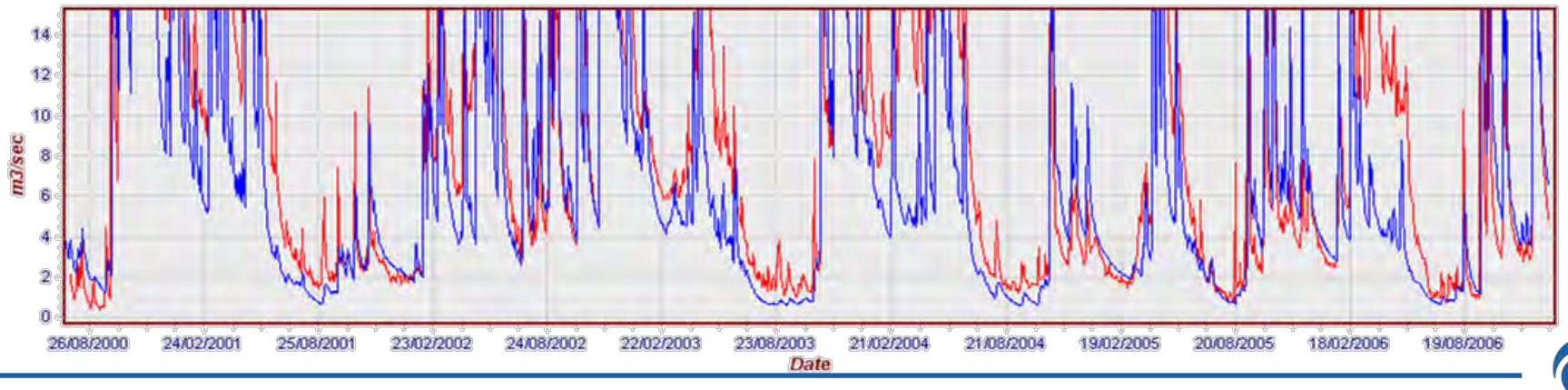
Hydrological model: TOPKAPI

TOPKAPI calibration: Tanaro river at Pian Torre
Calibration period 2000 -2010

Pian Torre – Tanaro river	
Area (km^2)	500
Mean altitudine (m)	103
Annual withdrawal (m^3/s)	0
Summer withdrawal (m^3/s)	0
Winter withdrawal (m^3/s)	0

Flow – Duration Curve



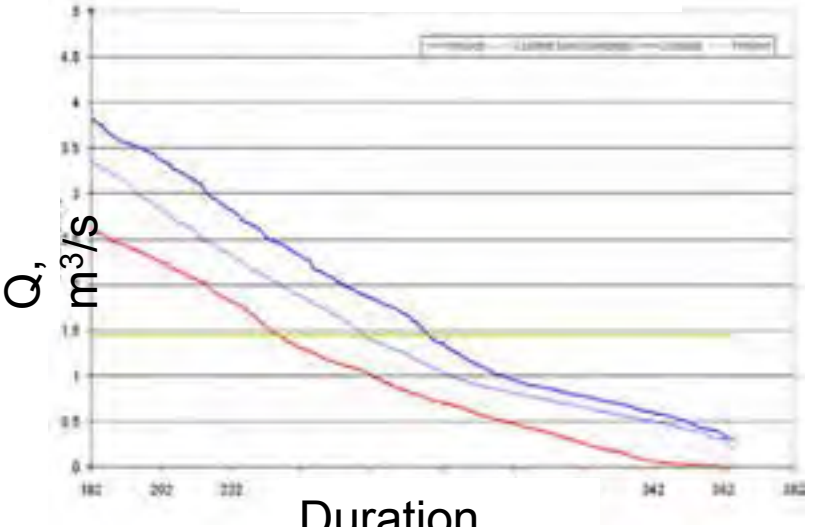


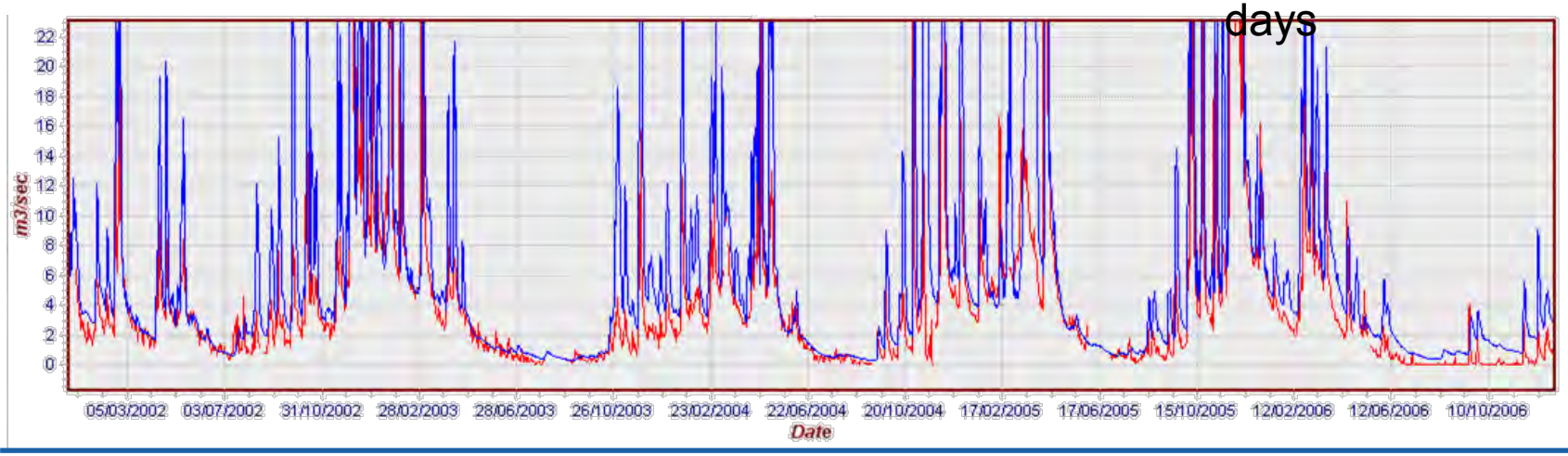
Hydrological model: TOPKAPI

TOPKAPI calibration: Savio river at San Carlo
Calibration period 2000 - 2010

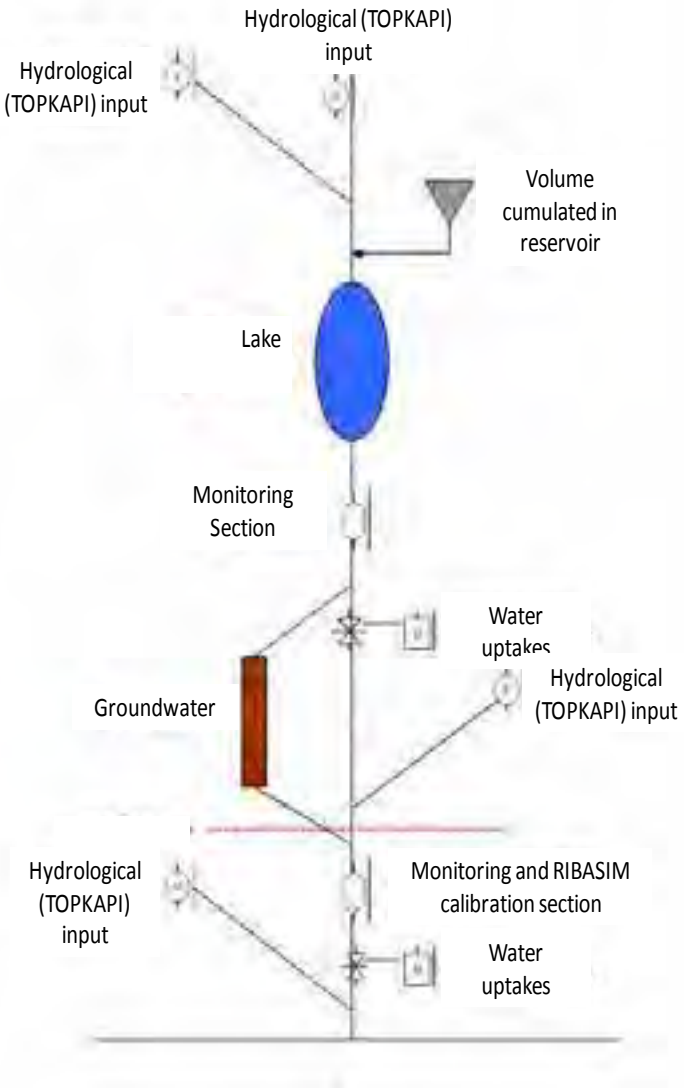
San Carlo – Savio river	
Area (km^2)	588
Mean altitudine (m)	513
Annual withdrawal (m^3/s)	1.47

Flow Duration Curve





River basin balance: RIBASIM



RIBASIM (RIver Basin SIMulation) is a water balance model developed by DELTARES on the basis of MITSIM model from MIT

The hydrological network is defined by links and nodes and water is distributed through links according to schematization and water demand at the nodes.

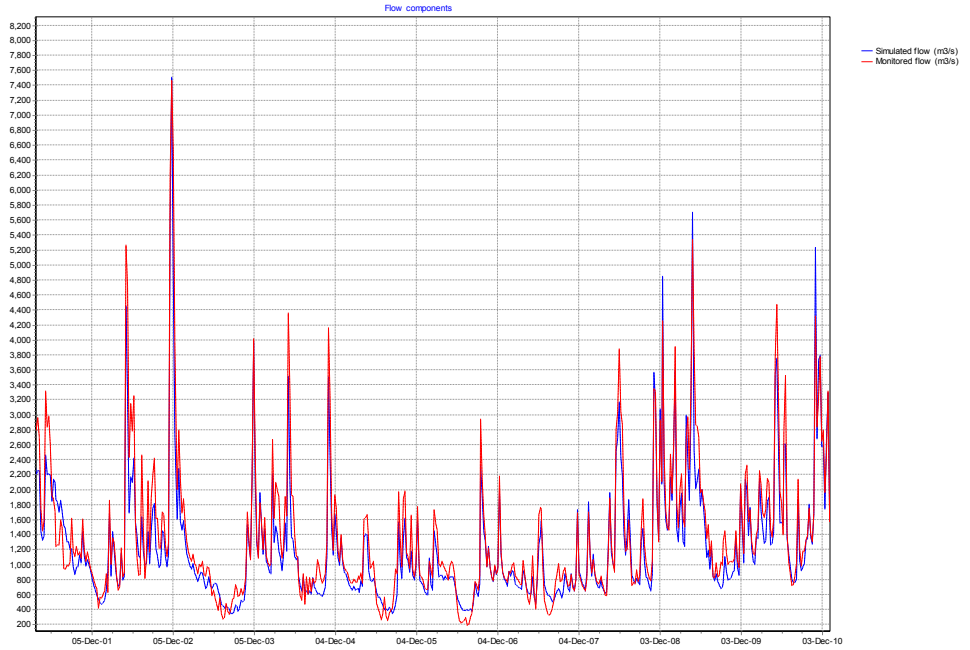
Nodes represent flow input sites (coupling between TOPKAPI and RIBASIM), groundwater and surface water reservoirs, irrigation areas, pubblic water supply points, control/ calibration section where verify the model performances

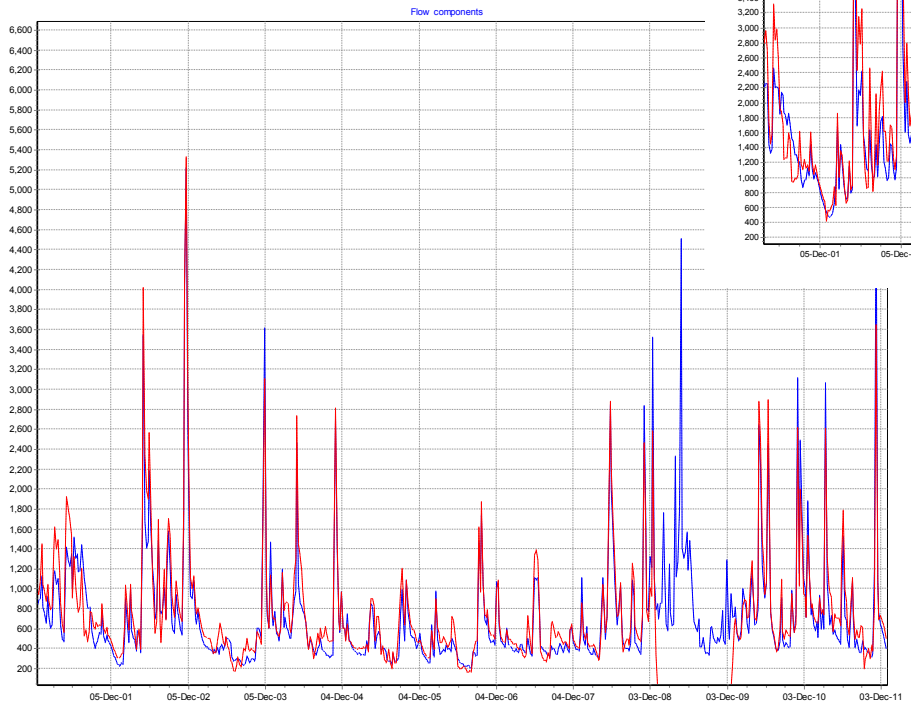
Links represent spatially homogenous river or channels, recharge, abstraction and outflow of groundwater diverted flow, backwater flow of the surface reservoir to end users

River basin balance: RIBASIM

Calibration period 2000 – 2011

Po at Pontelagoscuro





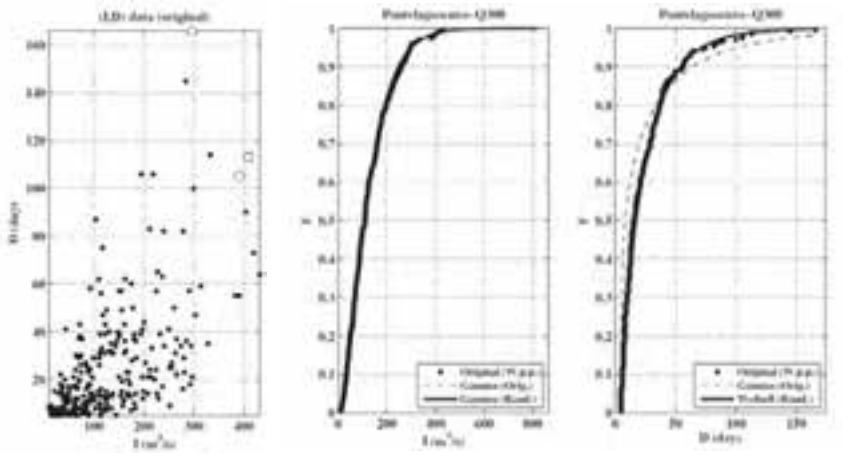
Po at Spessa

Drougths Monitoring

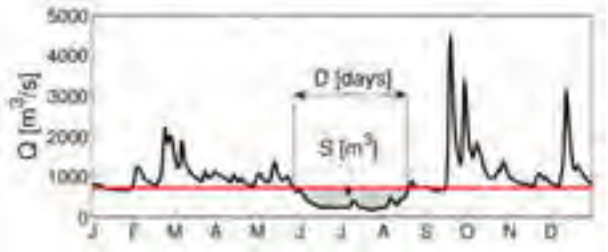
Drougths Monitoring

Analisi del rischio di magra

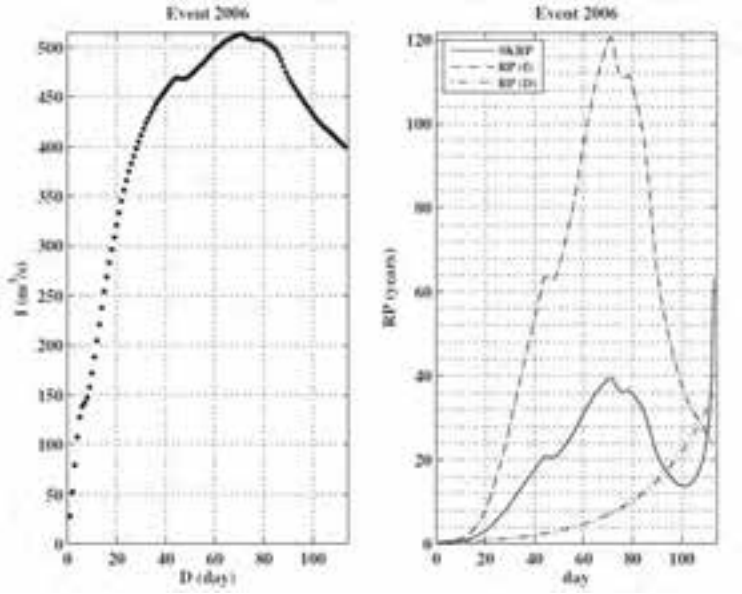
Analisi bivariata delle magre: Po a Pontelagoscuro dati osservati



Definizione della soglia a partire da indicazioni quali DMV / navigabilità / etc



Identificazione degli eventi di magra in termini
di Intensità (Severità/Durata) e Durata

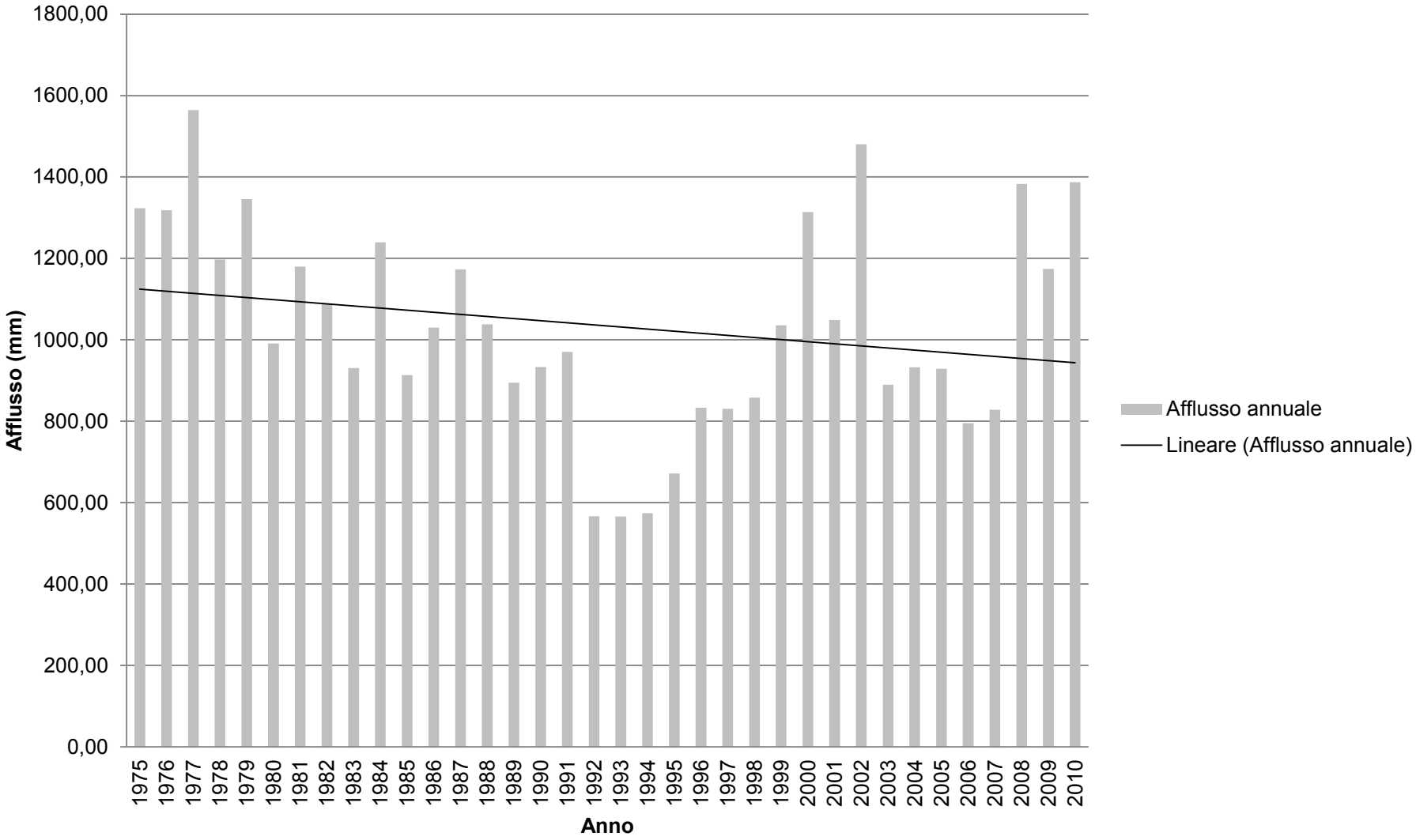


Caratterizzazione statistica delle due variabili e loro distribuzione congiunta

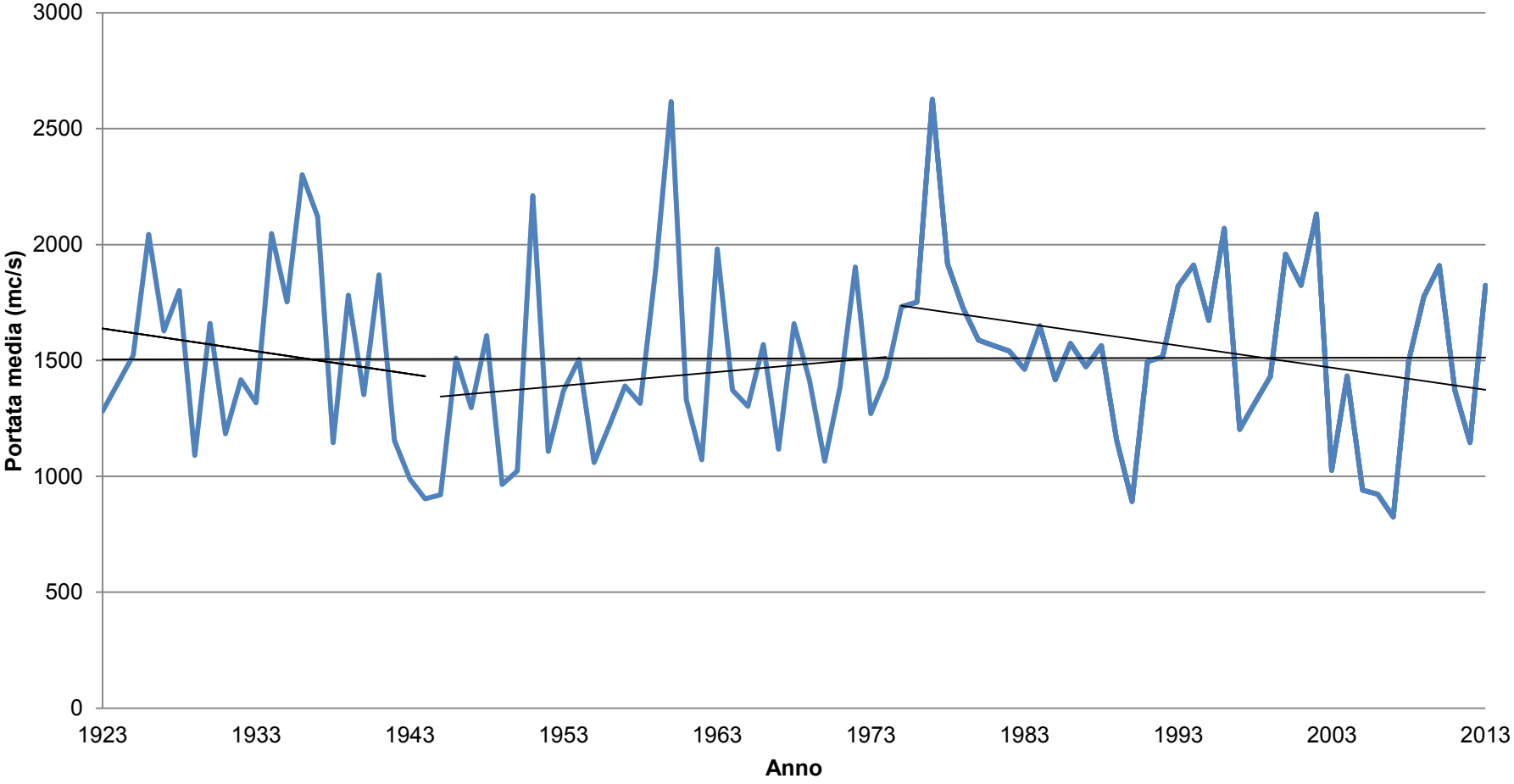
Stima del periodo di ritorno congiunto

Po river Hydrology

PIOGGIA MEDIA ANNUALE SUL BACINO DEL PO DAL 1975 AL 2013: RIDUZIONE DI CIRCA 11%

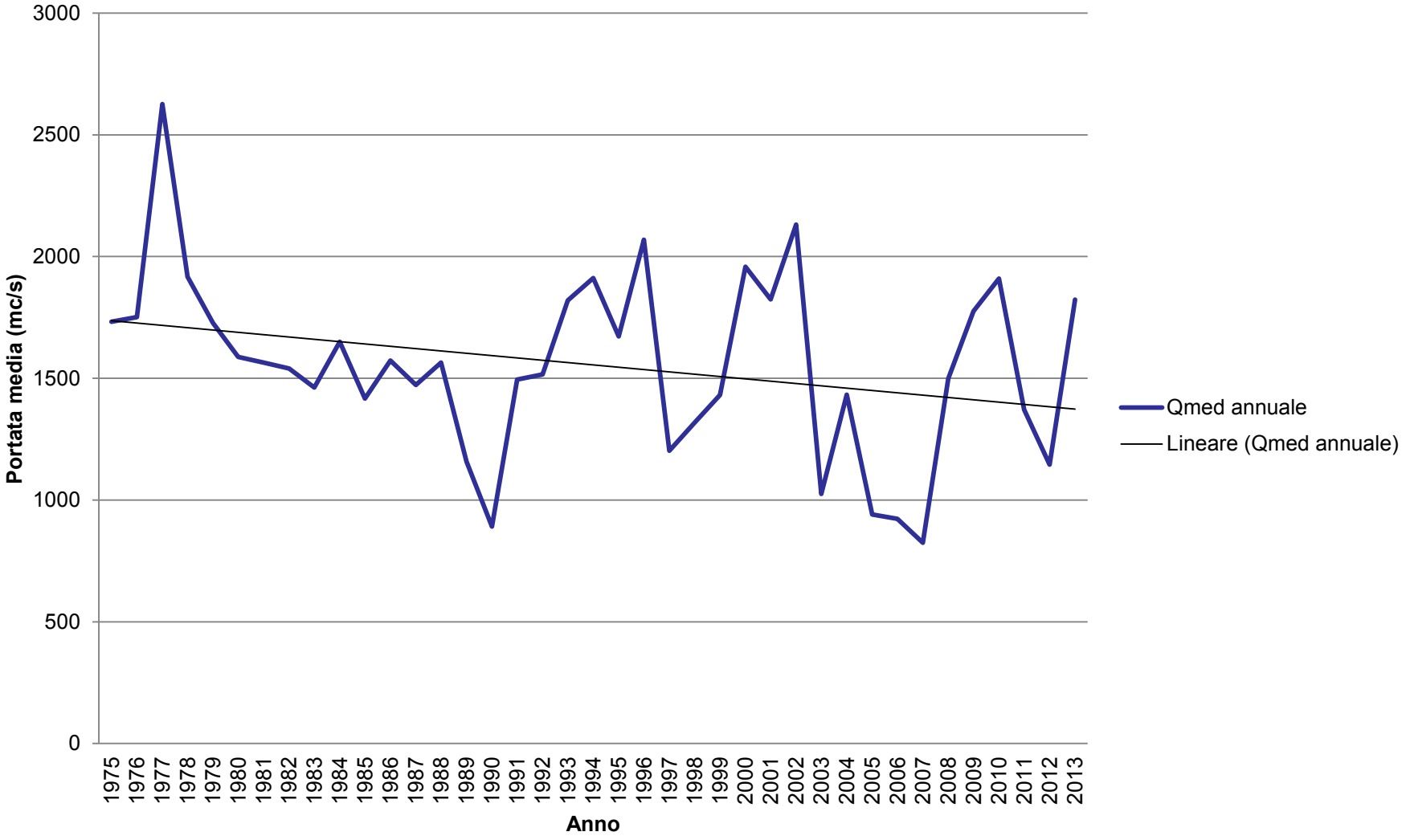


LE PORTATE DEL PO A PONTELAGOSCURO 1923 - 2013



Si osservi la sequenza di anni particolarmente critici :2003, 2004, 2005, 2006 (+2007)

Portate medie annuali, Po a Pontelagoscuro (riduzione 21%) 1975-2013 (m3/s)

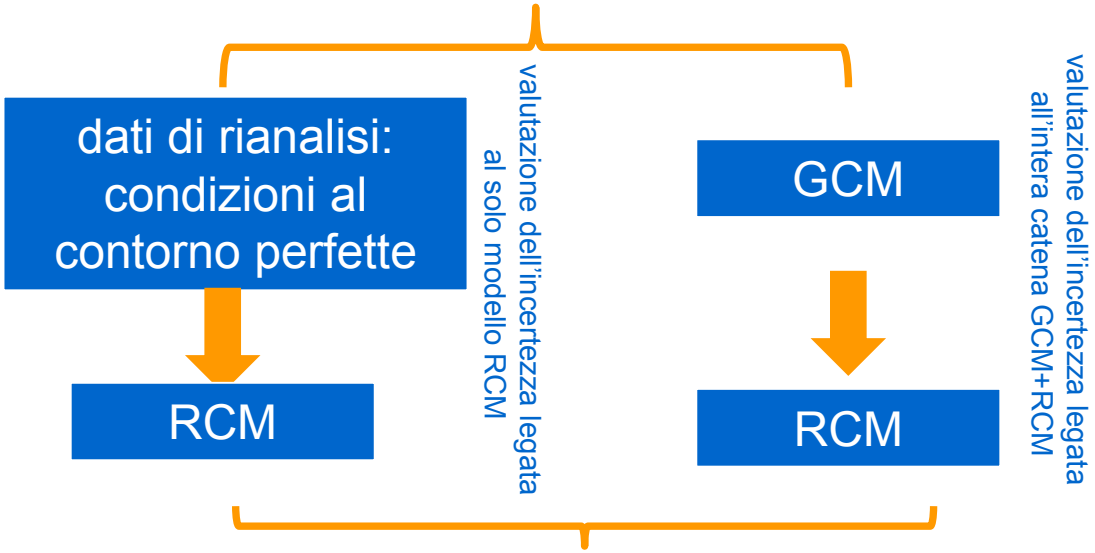


Climate Change Scenarios in the Po River Basin

La catena modellistica per la valutazione del potenziale effetto dei CC sui trend delle variabili atmosferiche di interesse

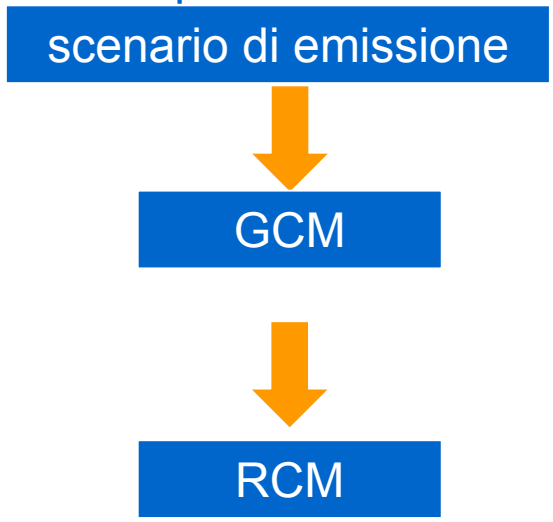
La stima di impatti (come i fenomeni di dissesto idrogeologico) su aree di estensione limitata presuppone l'utilizzo di modelli atmosferici ad elevata risoluzione spaziale e temporale.
Per tale motivo, usualmente è operato un downscaling dei modelli di circolazione globale tramite tecniche di tipo statistico (tecniche MOS, componenti principali) , dinamico (modelli climatici regionali) o weather generators.

Validazione sul periodo di controllo:



La capacità di riprodurre le statistiche relative alle variabili atmosferiche di interesse è stimata, in maniera quantitativa, tramite il confronto con datasets di osservazioni

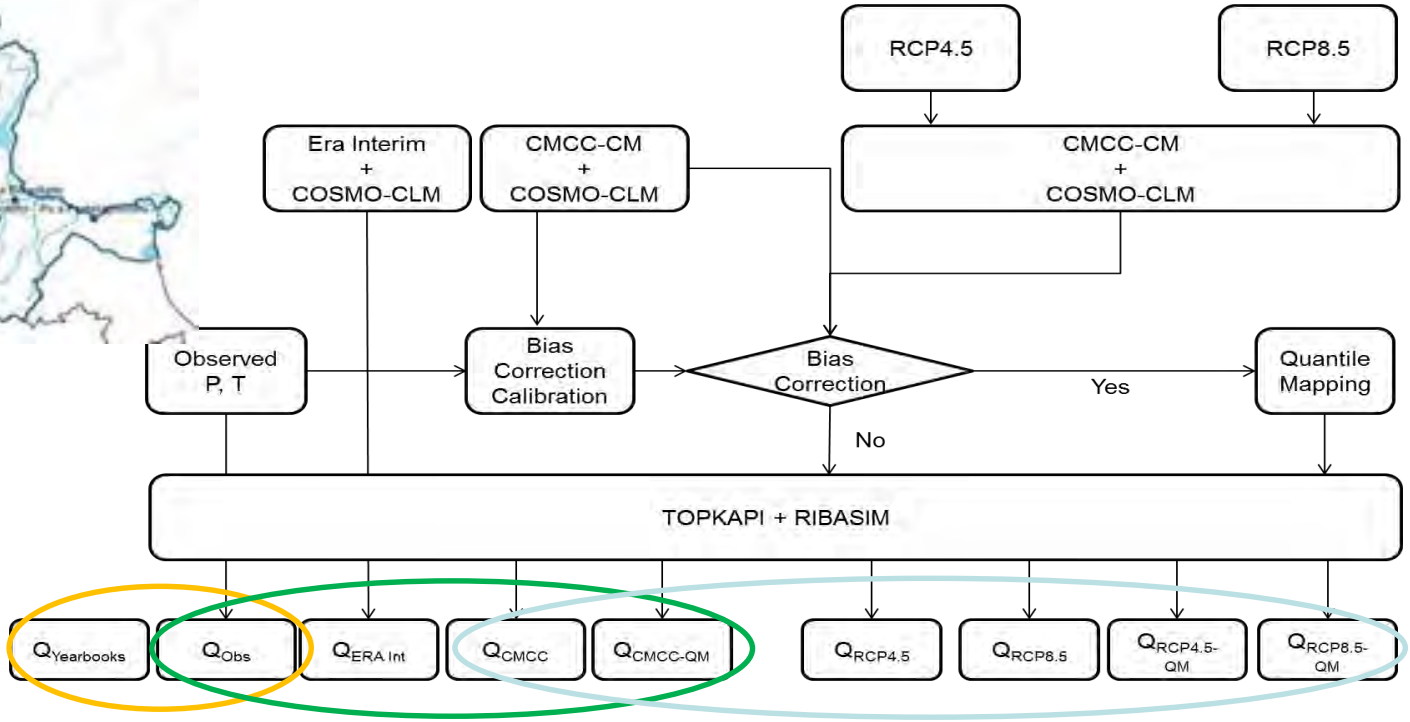
Sul periodo futuro:



Ulteriore fonte di incertezza è legata alle ipotesi sulle quali si basano gli scenari di emissione di gas serra, e solfuri funzioni dello sviluppo sociale ed economico a scala globale e regionale

Hydrological Impacts: the Po River

A climate-hydrological modelling chain has been developed to evaluate the impacts of CC at different sections of Po River up to the end of the XXI century



Step 1
Validation of the outputs of the hydrological/water balance models

Step 2
Validation of the GCM or Re-analysis/RCM with or without BiasCorrection/Hydrological/Water Balance models outputs

Step 3
Po river discharge projections under climate change scenarios

Vezzoli et al. (2014) - Hydrological simulations driven by RCM climate scenarios at basin scale in the Po river, Italy Evolving water resources systems: understanding, predicting and managing water–society interactions - **Proceedings of ICWRS2014**, (IAHS publ. 364, 2014)

More details are reported in the poster: **Hydrological simulations driven by RCM climate scenarios at basin scale in the Po river in Italy**

Modelling Chain: Climate

ECMWF ERA40 Reanalysis

The ECMWF (European Centre for Medium-Range Weather Forecasts) Reanalysis are used to perform simulations with “perfect boundary conditions” as forcing

horizontal resolution of 1.125°(about 128km)
49 vertical levels
3 soil levels

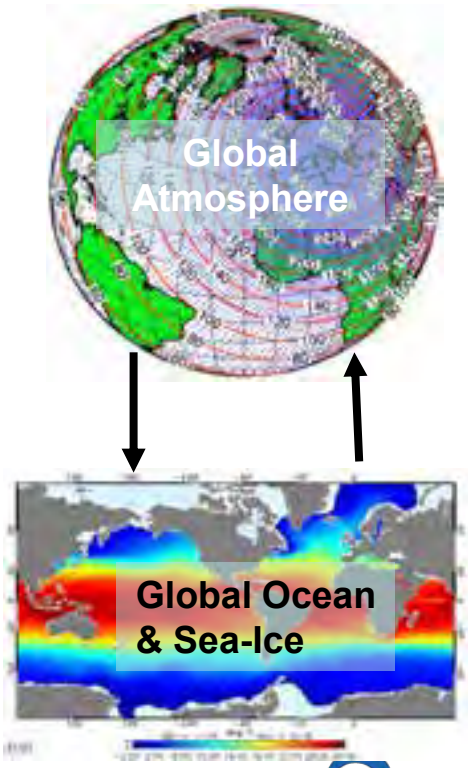
Uppala S.M. et al, 2006. The ERA-40 re-analysis, Quart. J. Roy. Meteor. Soc., 612: 2961-3012

Global climate model: CMCC - CM

Coupled atmosphere-ocean general circulation model developed at CMCC.

- Atmospheric component: ECHAM5, Gaussian grid of about 0.75° x 0.75°.
- Global ocean component: OPA 8.2, horizontal resolution of 2°x 2° with a meridional refinement near the equator, approaching minimum 0.5° grid spacing.
- High resolution model of the Mediterranean sea: regional configuration of the NEMO model, with a 1/16° horizontal resolution and 71 levels along the vertical.
- Coupler used: OASIS3
- Coupling frequency: 160 minutes.

horizontal resolution of 0.75°(about 85km)
31 vertical levels
4 soil levels



Gualdi et. al., 2012. The CIRCE simulations: a new set of regional climate change projections performed with a realistic representation of the Mediterranean Sea. Bull. Amer. Meteor. Soc., 10.1175/BAMS-D-11-00136.1

Modelling Chain: Climate

COSMO-CLM is a non hydrostatic regional climate model developed by the CLM-Community where CMCC is involved in the validation WP

The non hydrostatic formulation

- better represents the convective phenomena (and the severe precipitation events)
- made it eligible for dynamical downscaling at 20 km or less (spatial resolutions between 1 and 50km) and for long simulation time scales up to centuries

The high horizontal resolution allows a better description of the terrain orography with respect to the global climate models.

It allows an improved representation of subgrid scale physical processes (clouds, aerosols, orography, land and vegetation properties).

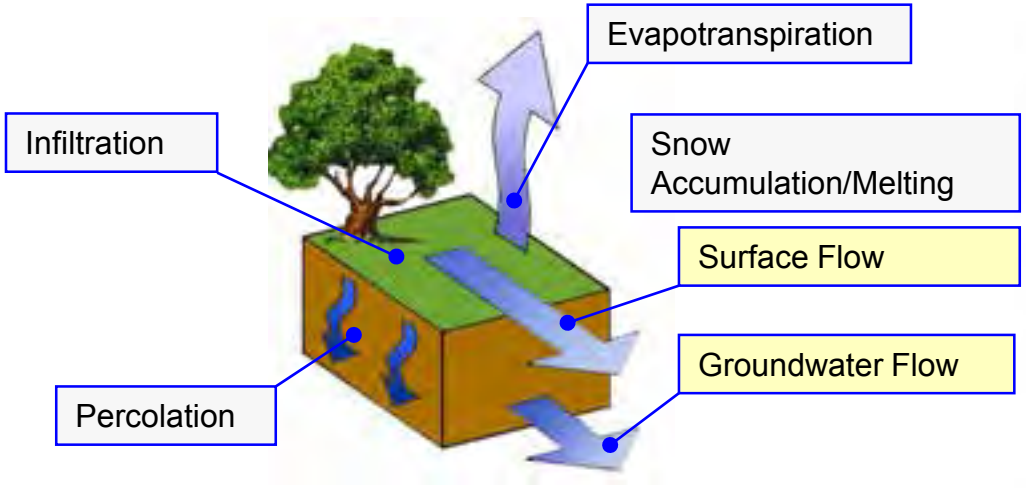
It is continuously updated, thanks to the continuous development of the LM version.

Its range of applicability encompasses

1. operational numerical weather prediction (NWP),
2. regional climate modelling of past, present and future (RCM),
3. idealized studies (ITC).

Modelling Chain: Hydrological and Water Balance Models

Hydrological model (TOPKAPI)

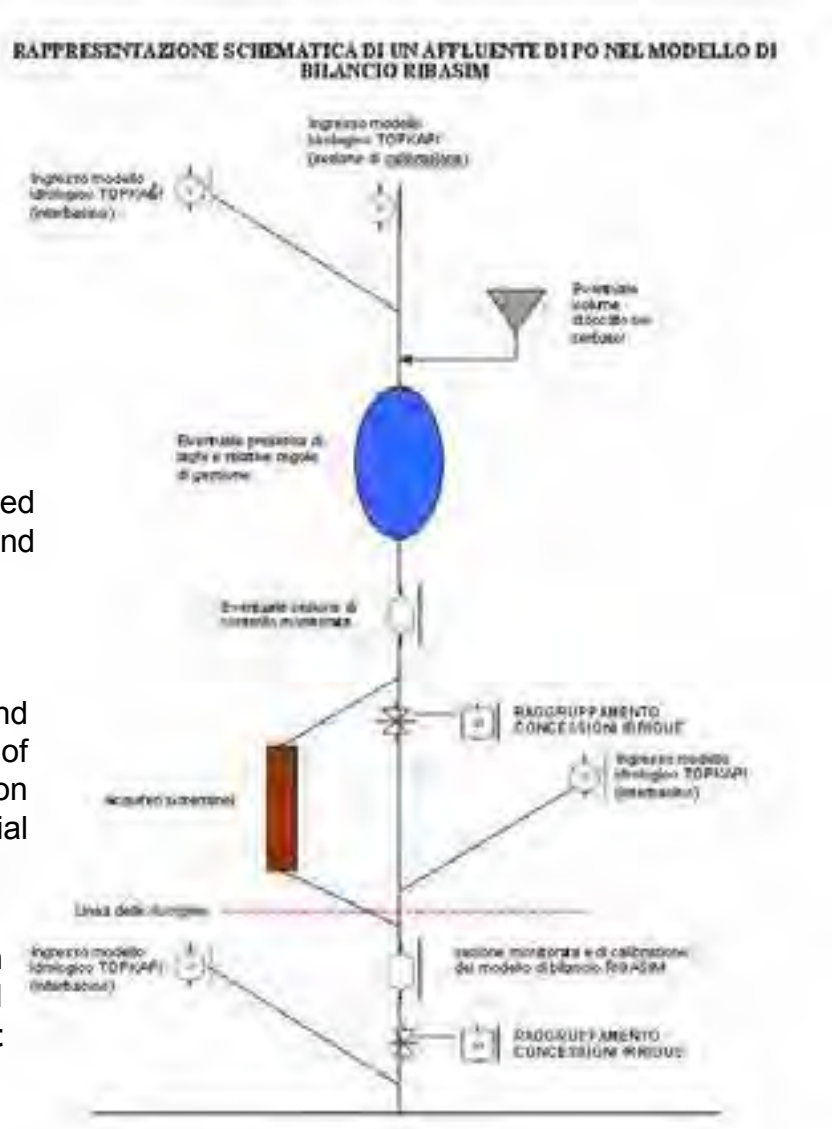


The hydrological model (TOPKAPI) is a distributed and physically based model. The flow hydrographs are shown from the input meteorological and physical and morphological characteristics of the river basin.

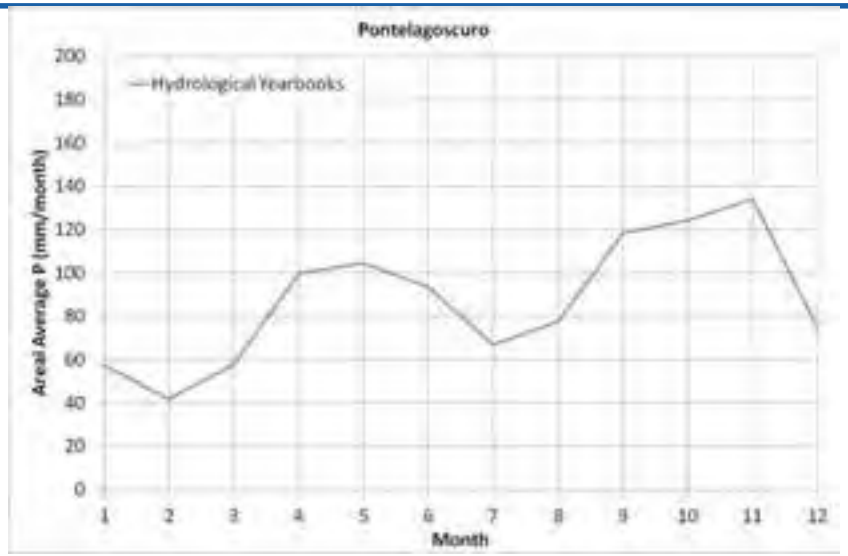
The water balance model (RIBASIM) allows integrated management and optimization of water resources of the basin by computing the distribution of the flow, simulated by the hydrological model TOPKAPI distribution networks consist of rivers, open canals, reservoirs or artificial control/hydropower production and aqueducts.

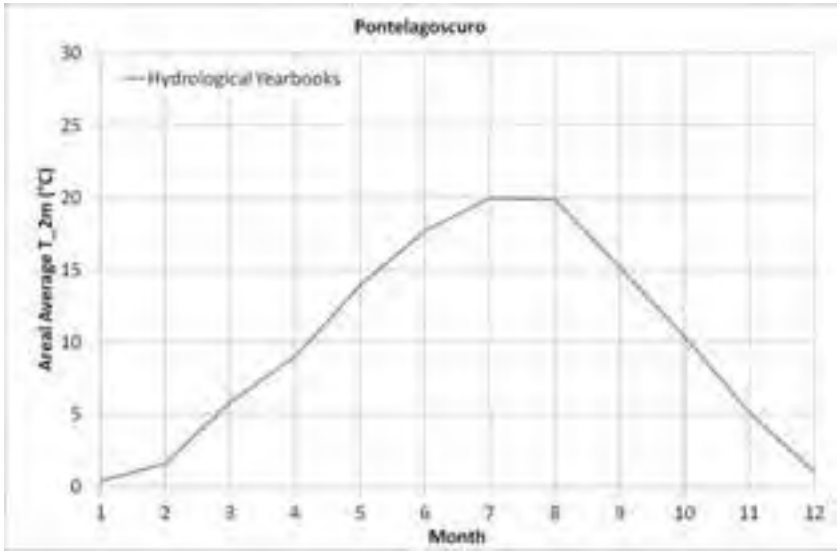
The simulation of the flow rate distribution is therefore an assessment of how the availability of water quantity and effectiveness of the distribution system are, or may be able to meet the demand of individual users.

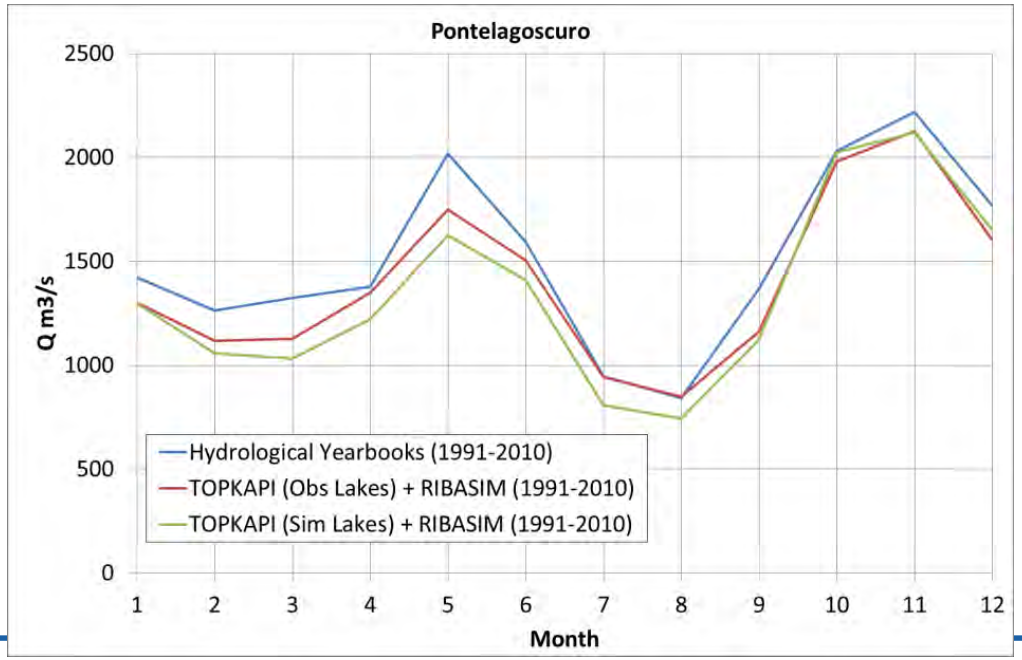
Water balance model (RIBASIM)



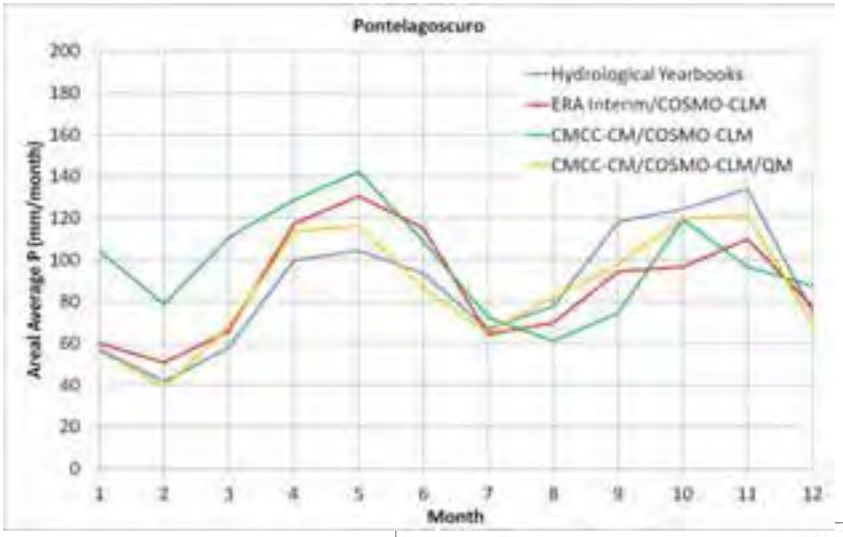
Hydrological Impacts: TOPKAPI/RIBASIM Validation (1991-2010)

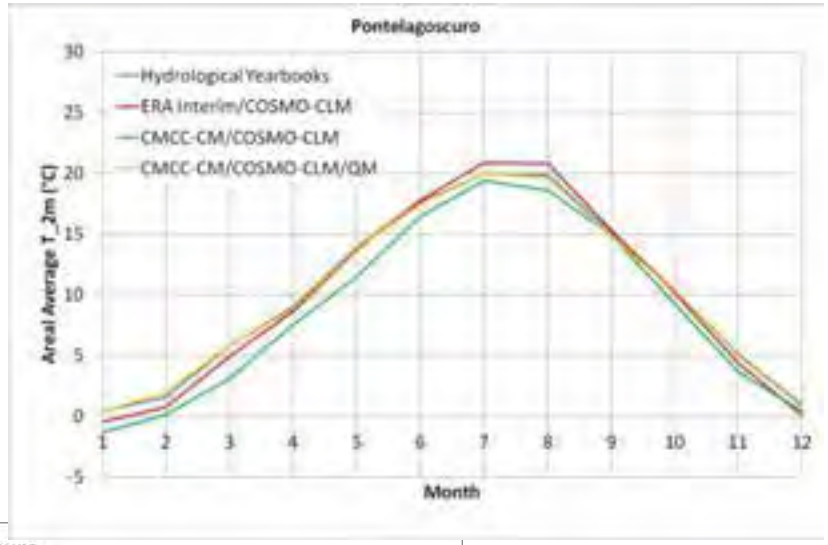


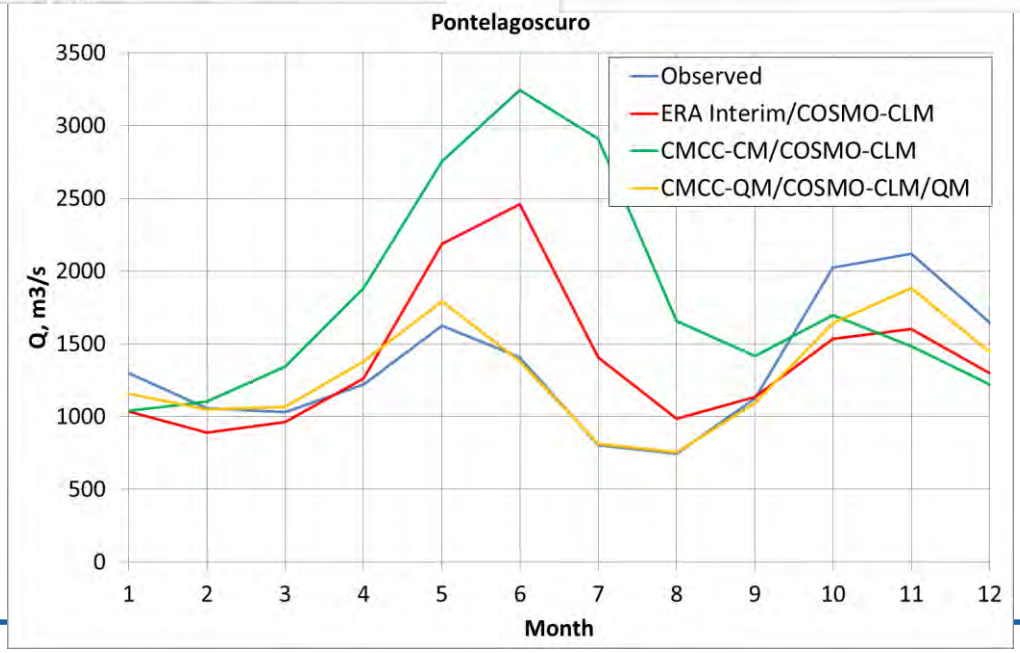




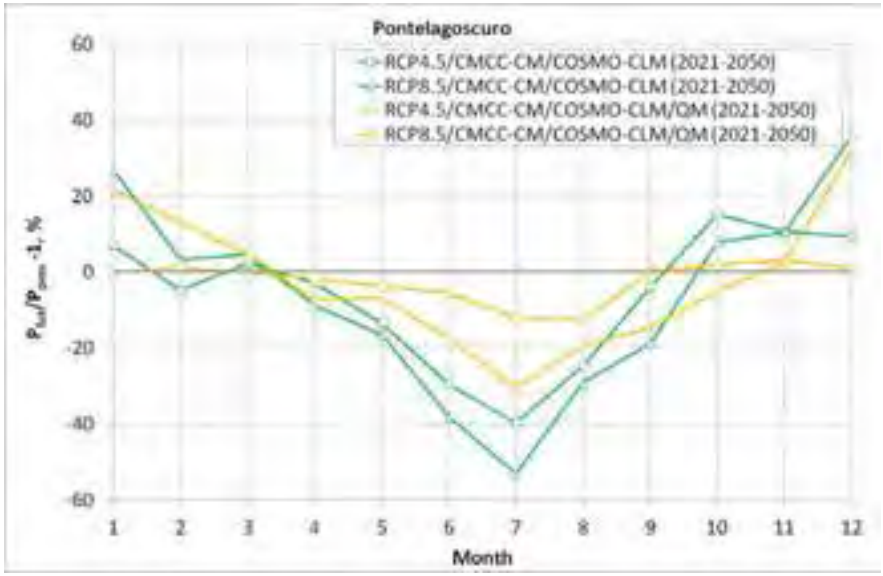
Hydrological Impacts: GCM/RCM/TOPKAPI/RIBASIM Validation (1991-2010)

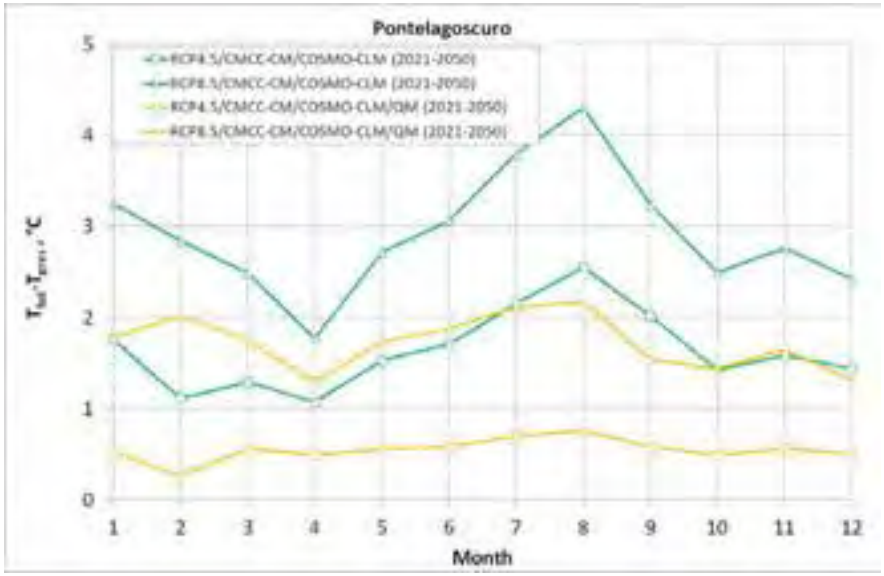


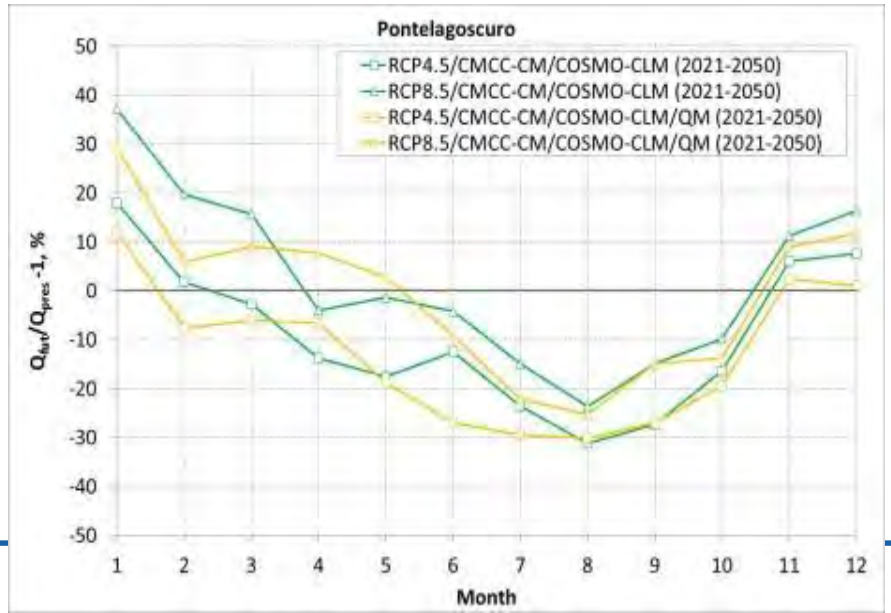




Hydrological Impacts: CC scenarios



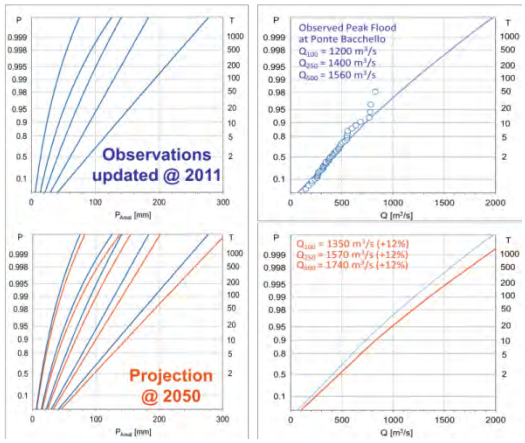




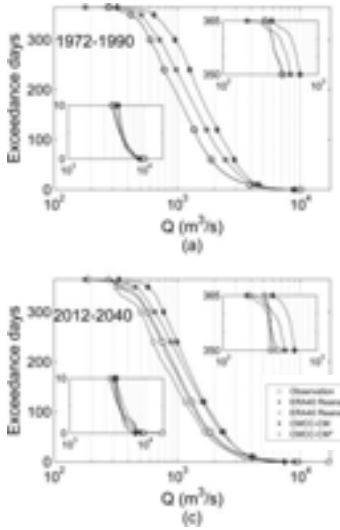
Cambiamento climatico: impatti sulle portate

Dalla variazione climatica attesa è possibile derivare la variazione attesa della linea segnalatrice di probabilità pluviometrica e mediante un approccio statistico la conseguente varizione della portata al colmo di piena

- Scenario climatico
- GCM
- RCM
- Correzione in probabilità dato climatico (opzionale)
- Simulazione idrologica idraulica (TOPKAPI/RIBASIM)
- Correzione in probabilità output idrologico (opzionale)
- Analisi dell'output idrologico: Curva di durata, distribuzione dei minimi, rischio magre, etc

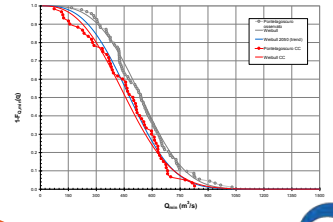


Curva di durata

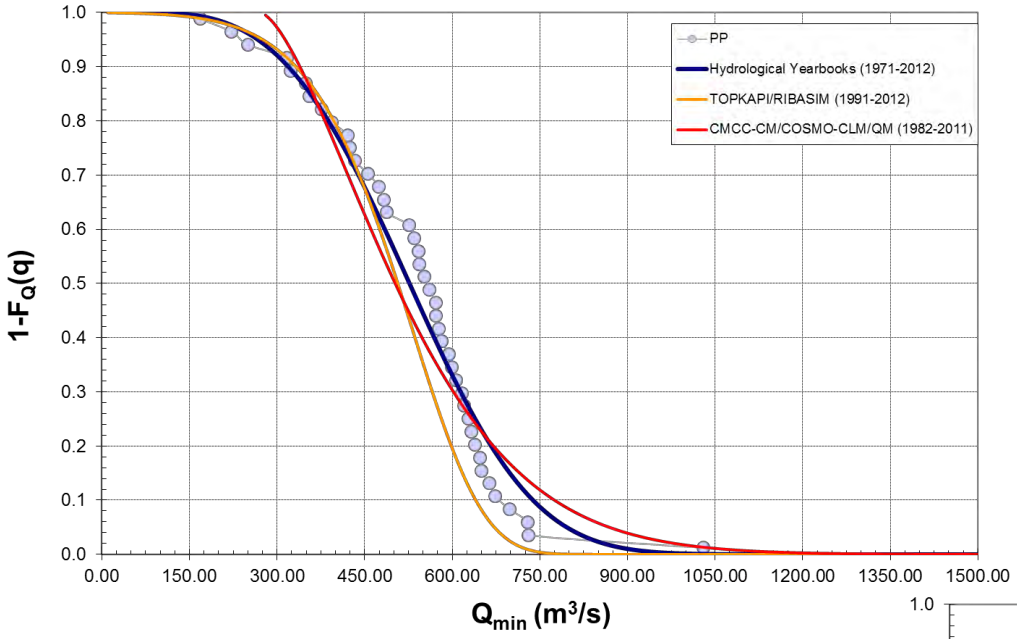


Analisi di trend per derivare la variazione dei parametri della distribuzione sotto CC (replicabile per le portate massime)

Distribuzione dei minimi

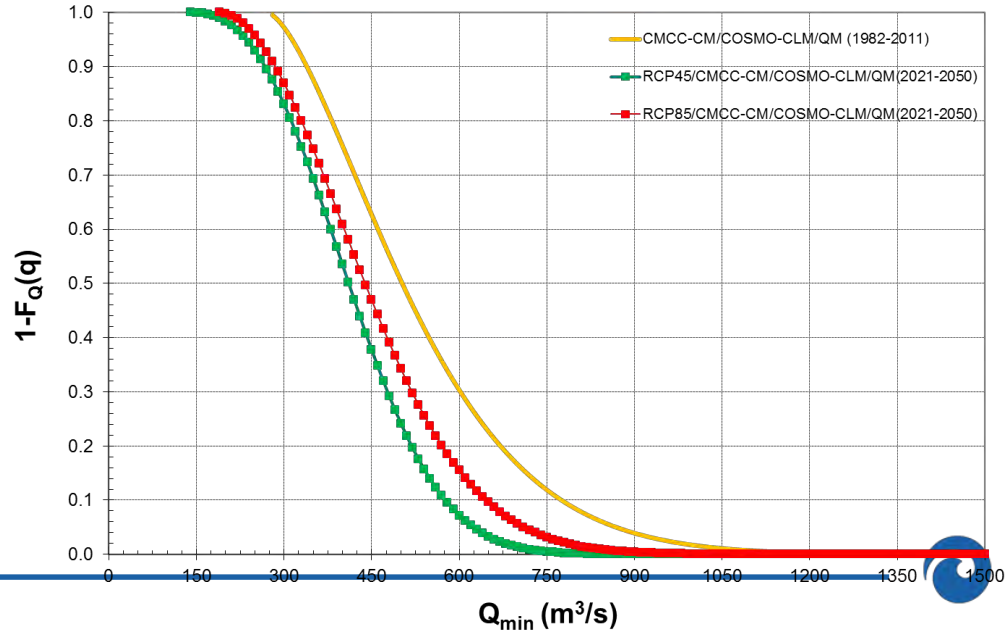


Minimum discharge under CC

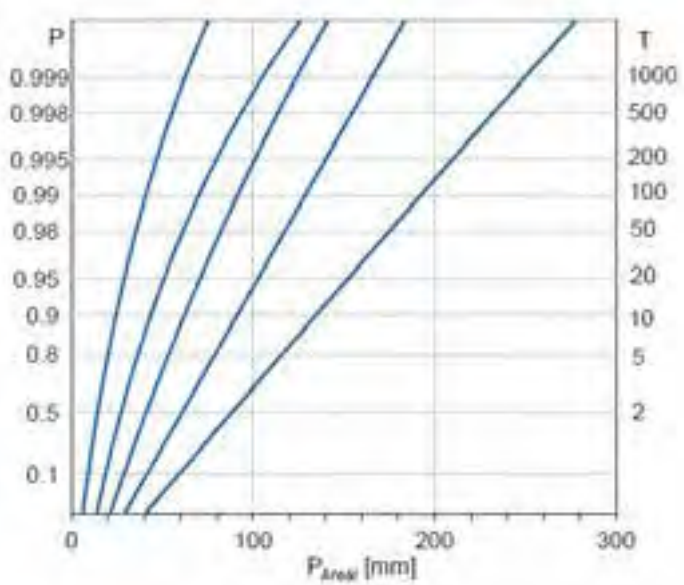


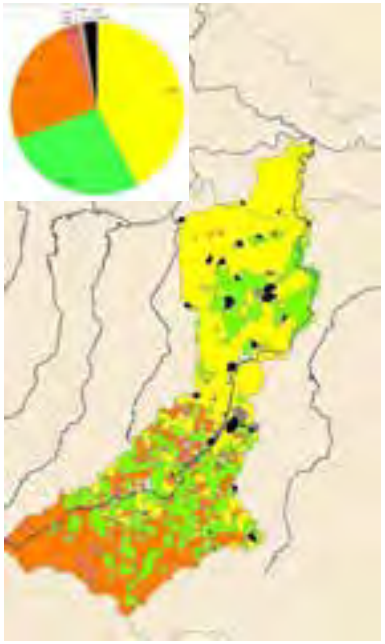
Validation of minimum discharges

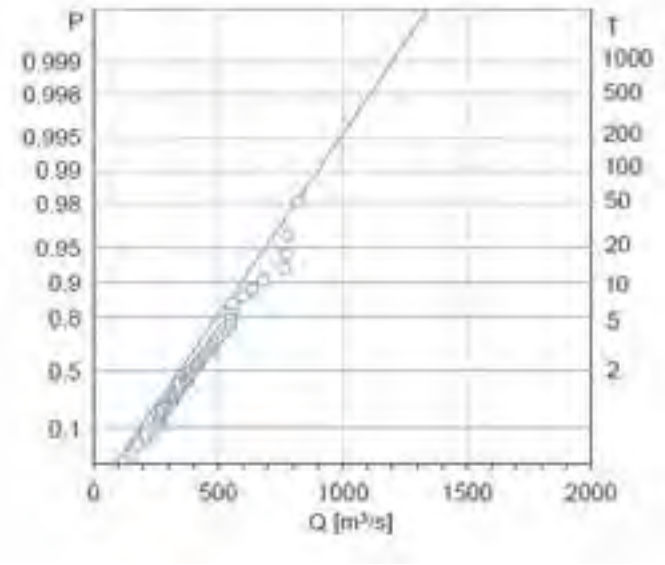
Projected minimum discharges



Secchia River

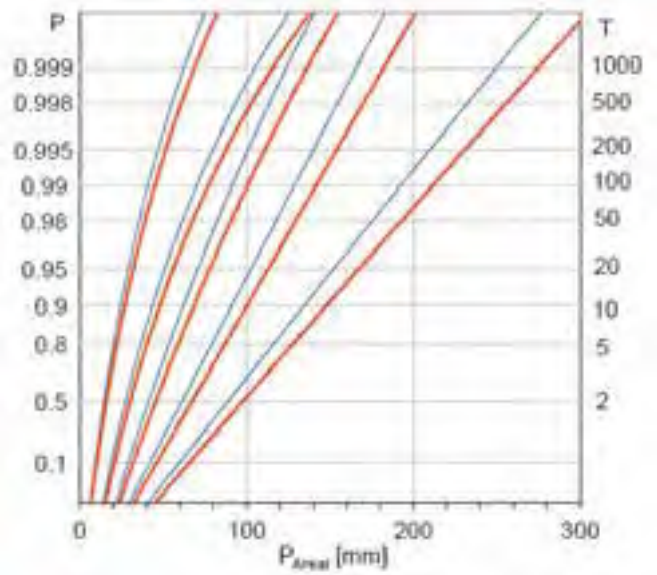


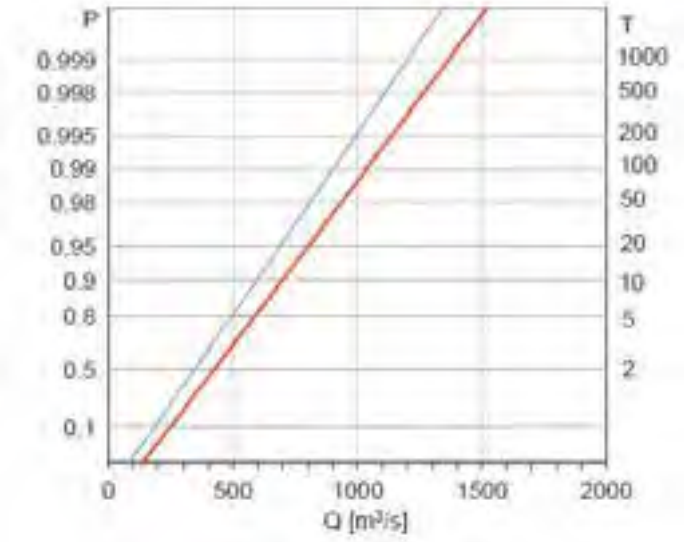


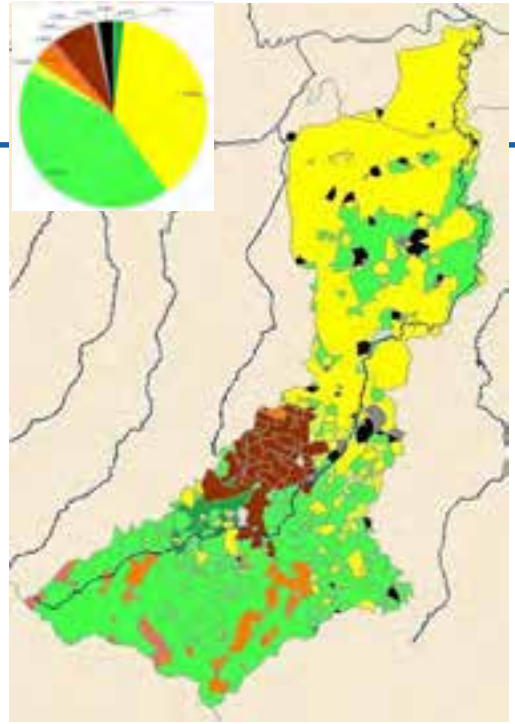


- Water bodies
- Permanent crops
- Arable land
- Heterogeneous agricultural areas
- Mixed agricultural areas
- Forest
- Scrub and/or herbaceous vegetation associations
- Forest and/or herbaceous vegetation associations
- Open spaces with little or no vegetation
- Mine, dump and construction sites
- Industrial, commercial and transport units
- Urban fabric

Secchia River: Land Use & CC







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Thank you
for the attention

arpa agenzia regionale prevenzione e ambiente dell'emilia-romagna
Servizio Idro Meteo Clima

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