CRHyME

(Climatic Rainfall Hydrogeological Modelling Experiment)

a versatile geo-hydrological model for climatic scenario and extreme event simulation at basin scale

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The new model concept called **CRHyME** (**Climatic Rainfall Hydrogeological Modelling Experiment**) represents an extended version of the classical spatially distributed rainfall-runoff models. The main novelties are related to:

- the possibility to have a direct **integration with climatic scenario outputs**, such as rainfall and temperature field data from NETCDF file format,
- the physical description of some **geo-hydrological hazards** strongly related to rainfalls such as shallow landslide, debris flow, watershed erosion and solid transport,
- the possibility to interact with other hydraulic/landslide models applied through the **BMI (Basic Model Interface)** approach at finer scale.

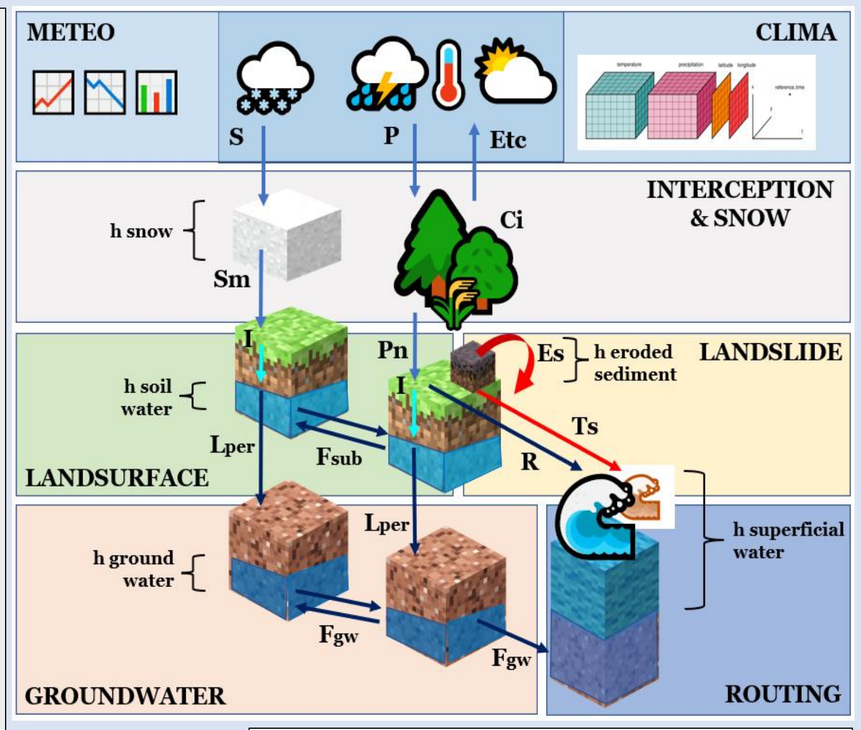
CLIMATIC RAINFALL HYDROGEOLOGICAL MODEL EXPERIMENT

CRHyME

CLIMATIC RAINFALL HYDROGEOLOGICAL MODELLING EXPERIMENT

The model has a modular structure:

- **METEO** & **CLIMA**: where climatological and meteorological data (precipitation **P** and temperature **T**) are elaborated;
- **INTERCEPTION** & **SNOW**: where snow dynamics and canopy interception are quantified;
- **LANDSURFACE**: where infiltration processes, runoff generation and percolation are computed for the superficial soil layer;
- **GROUNDWATER**: where hydrogeology is computed;
- **ROUTING**: where the kinematic or dynamic runoffs are evaluated;
- **LANDSLIDE**: where geo-hydrological processes such as shallow landslide and debris flow triggered, or erosion and solid transport are studied.



The CRHyME model has been completely rewritten to work at a higher spatial resolution. The nominal **resolution of 90 m** is taken from **HydroSHED** digital elevation model that is a worldwide reference for hydrological modelling. From DEM was possible to retrieve other morphological data such as Slope and Aspect.

To acquire the most representative assessment of geo-hydrological hazards, other available data about **soil structure, composition, characteristics and use** have been acquired from the following databases:

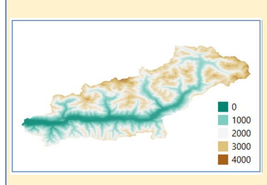
- **Copernicus**: land coverages;
- **SoilGrids**: soil composition;
- **JRC**: 3D hydrogeological properties.

The extraction and the elaboration of those data has been automatized using a chain of Python scripts.

clone.map
dem_clip.map
ldd_clip.map
mask01.map
Slope_Filled.map
Slope_Filled_2.map
cellsizeArea.map
CLC_9Cat.map
Sand_SUP90C.map
Sand_BTM90C.map
Silt_SUP90C.map
Silt_BTM90C.map
Clay_SUP90C.map
Clay_BTM90C.map
CoarsFrg_SUP90C.map
CoarsFrg_BTM90C.map
BulkDens_SUP90C.map
BulkDens_BTM90C.map
TSH1_clip.map
TSH5_clip.map
BDRICM_M.map

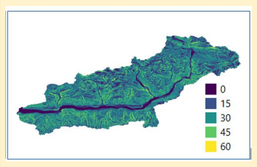
HydroSHEDS

DEM, Slope, Aspect, River Flow Accumulation



Copernicus Europe's eyes on Earth

Land use and Corine Land Cover



ISRIC World Soil Information

Soil Layer granulometry and physical data

JOINT RESEARCH CENTRE
EUROPEAN SOIL DATA CENTRE (ESDAC)

3D Hydraulic properties of terrain and soils

$$\frac{\Delta h_{snow}(t)}{\Delta t} = S(t) - S_m(t)$$

$$\frac{\Delta h_{soilwater}(t)}{\Delta t} = I(t) - ETc(t) - Ex(t) - L_{per}(t) \pm F_{sub}(t)$$

$$\frac{\Delta h_{groundwater}(t)}{\Delta t} = L_{per}(t) - Ex_{gw}(t) \pm F_{gw}(t)$$

$$\frac{\Delta h_{solid}(t)}{\Delta t} = D_s(t) - E_s(t) \pm T_s(t)$$

CRHyME model has been written in **Python** language, using the PCRaster libraries. Its modular structure has been inspired by the **PCR-GLOWB2** model that was implemented at a global scale to study climate change effects on water resource availability.

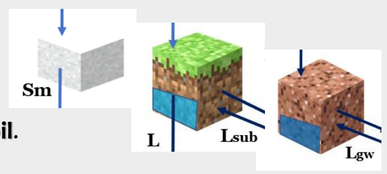
PCR-GLOBWB

python

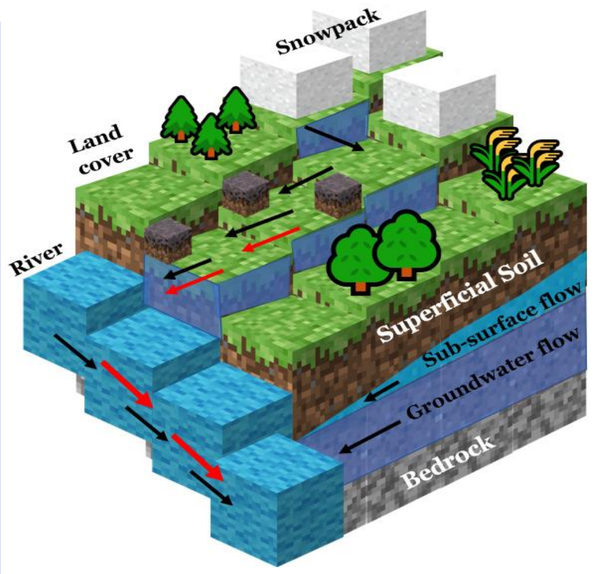
PCRaster 4.3

The equations listed show the water and solid balances computed inside the CRHyME Model. Three reservoir are included:

- **Snowpack**;
- **Superficial Soil**;
- **Groundwater Soil**.

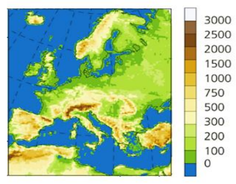


The **superficial water** flowing in the river is also computed as runoff coming from the infiltration processes. A **solid balance** is also computed for considering erosion processes. CRHyME works on discrete matrix and all those balances are computed at each time-step for each cell of the discretized domain.



WCRP CORDEX Coordinated Regional Climate Downscaling Experiment

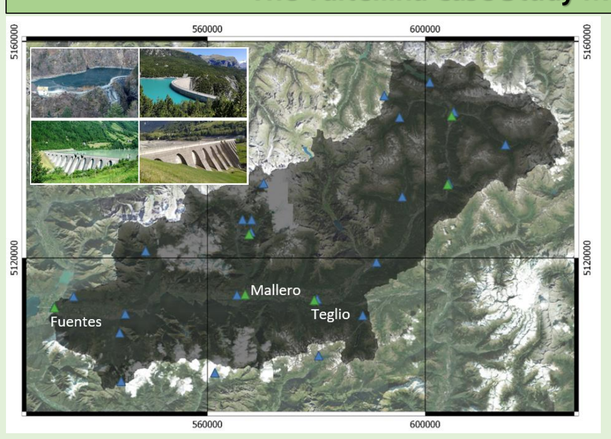
Regional Climate Model (EURO-CORDEX)



ipcc INTERGOVERNMENTAL PANEL ON climate change

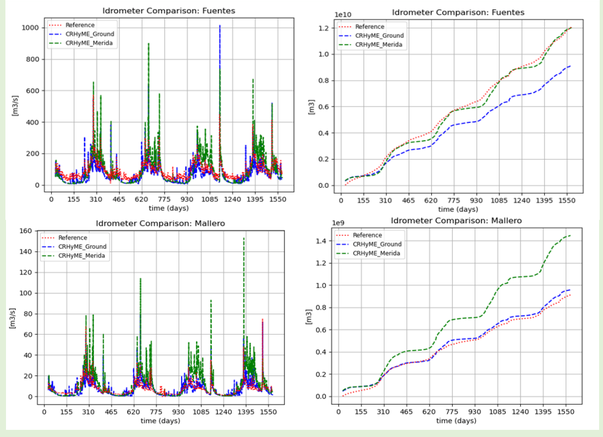
CRHyME model is initialized starting from meteorological and climatological data. Meteorological data comes from historical data-series taken in correspondence of weather stations and rain gauges. Climatological data are generally a product of the Regional Climate Model (**RCM**) such as the data coming from **EURO-CORDEX project**. In this project, for European area are computed an ensemble of climatical models considering different radiative forces following the prescription of the **IPCC** (Intergovernmental Panel on Climate Change).

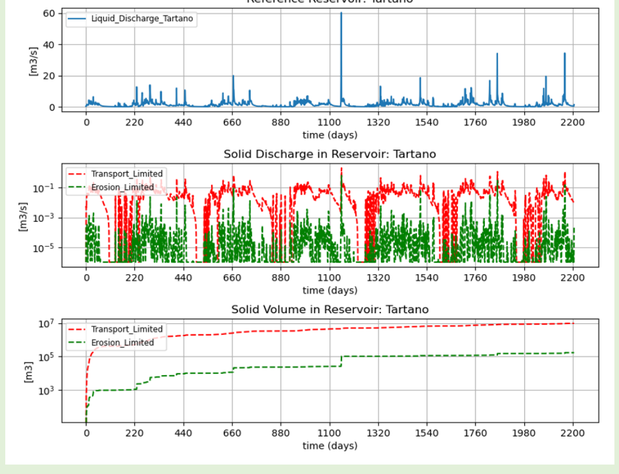
Application of CRHyME model to Past Meteorological Scenario and a Future Climatic Scenario: **The Valtellina Case Study METEOROLOGICAL ANALYSIS**

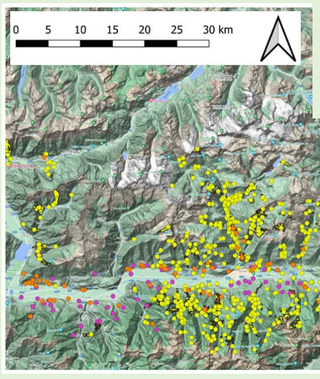


Using the CRHyME, the **water discharge** (**Q**) in correspondence of a hydrometric station can be computed. If a past simulation is carried out, a comparison with the recorded series can assessed considering also some efficiency indexes such as **Nash–Sutcliffe Efficiency** (**NSE**). For the Valtellina case study, Fuentes and Mallero hydrometric stations were selected.

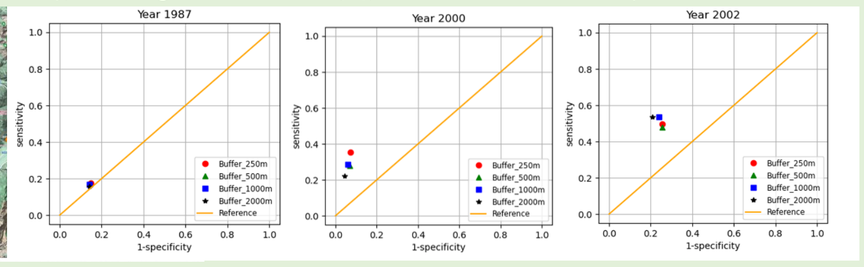
Using CRHyME is also possible to evaluate the sediment yield (**Sed Yield**) and solid discharge in correspondence of hydropower reservoirs. For the Valtellina case study, red triangles represent the reservoirs where those evaluations have been assessed.



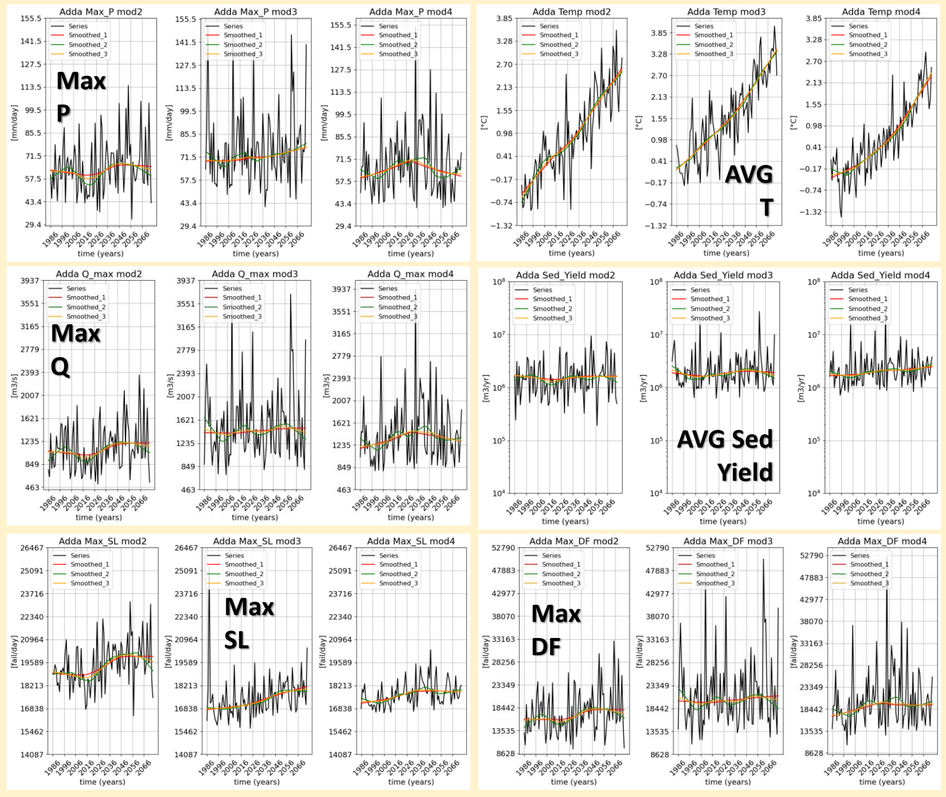




Using CRHyME and applying the ROC methodology, some statistics can be assessed about the **shallow landslide** (**SL**) and **debris flow** (**DF**) triggered in correspondence of strong rainfall events, counting the number of failures that admit a Safety Factor below of 1. In the Valtellina case study, the strong rainfall events of **1987**, **2000** and **2002** have been reproduced.



Application of CRHyME model to Past Meteorological Scenario and a Future Climatic Scenario: **The Valtellina Case Study CLIMATOLOGICAL ANALYSIS**



Using climatological data coming form EURO-CORDEX project, some future simulation have been computed for the Valtellina case study. **Three model** (**mod2, mod3 and mo4**) were chosen from EURO-CORDEX Ensemble. The simulation covered:

- The reference past period from **01-01-1986 to 31-12-2005**;
- The future horizon from **01-01-2006 to 01-01-2075.**

The results show the series compute by CRHyME and the coloured tendency curves are computed using **LOWESS** interpolator technique.

Among others, the **temperature increasing** has a clear signal, while other components (**P max, Q max, Sed Yield, SL and DF**) experience **fluctuations** depending on the future period investigated.

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AISAM Associazione Italiana di Scienze dell'Atmosfera e Meteorologia