Hydrological impacts of climate change on catchment response in the Mediterranean region

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CONTEXT

This work is being developed within the CIRCE-IP (6th FP) that focuses on the assessment of climate change impacts in the Mediterranean region. In particular, the **Research Line 5** aims at producing an assessment of the expected variations of the water cycle likely to occur on the atmospheric, oceanic and terrestrial components due to global climate changes.

OBJECTIVE

Investigation of major control factors of terrestrial water balance under climate changes and the consequent hydrological response.

FOCUS ON

- The analysis is focused on the water cycle components at the catchment scale which is the typical scale of water resources planning. Therefore a fundamental requisite for the evaluation of climate change impacts on water resources is to bridge the **space-time gap** (Fig.1) between the climate scenarios and the usual scale of the inputs for the water balance prediction models.
- For the hydrological response reasonable mathematical models for basin scale water balance simulations will be adopted, in which the meteorological input data are synthetic time series retrieved from global climate change scenarios issued by GCMs.

Fig.1 Time-space scales in the impact analysis

WORK PLANNING

1. **Data collection**
   - GCMs scenarios: datasets coming out from a Regional Climate Model with spatial resolution around 20 km and daily timestep
   - Observed data: daily climate datasets for the reference period 1961-1990
2. **Downscaling** the available climate scenarios into synthetic daily records from stochastic simulations
   - PRP parameters forced according to GCMs outputs post-processed with the q-q correction method; generation of synthetic time series describing local scenarios.
3. **Impact study** on different water balance components using the model DREAM (soil moisture alteration, hydrologic regimes, drought duration, flood frequency).

DOWNSCALING AND OUTPUT CORRECTION FOR IMPACT STUDY

Impact=*Out* (S) – *Out* (R) (Déqué, 2007)

- **S** output of a model *Out* under climate conditions from a GHG emission scenario: provided by RCM
- **R** output under reference (i.e. current climate) conditions : provided by observations (produced by the same RCM under present day conditions)

Due to the imperfections of the RCM, data from S and R need to be postprocessed (Tab.1), so that S* and R* are used in impact equation.

POSTPROCESSING CORRECTION METHODS		
Confident method	R*(d)= R(d) S*(d)=S(d)	if the model *Out* is reasonably linear without threshold values
Delta method	R*(d)=O(d) S*(d)=O(d)+<S-R>	if the observed daily data are available It assumes that the climate variability is unchanged in the scenario projection
Unbiasing method	R*(d)=R(d)+<O-R S*(d)=S(d)+<O-R>	It assumes a good variability of the RCM
Variable correction method	R*(d)=f(R(d)|O) S*(d)=f(S(d)|O)	*f* is a function build with the observation dataset O
Regime method	R*(d)=O(*d1*) S*(d)=O(*d2*)	*d1* and *d2* are dates properly chosen in the observation dataset
Let O(d) be an equivalent series of observed data, and <.> a multiannual average operator (Déqué, 2007)		

Tab.1 Post-processing correction method (Dèquè, 2007)

VARIABLE CORRECTION METHOD

- As we are interested in extreme events impacts and then in the tail of the precipitation pdfs, the most suitable method is the **Variable correction method** (Fig.2; Déquè, 2007):

R*(d)=*f (R(d)|O)* , ***S*(d)***=*f(S(d)|O)*

f we use for *f(x)* the **quantile-quantile** (*q-q)* function, then the *cdf*, and thus the pdf of the postprocessed reference R*(d) is exactly the same as the *cdf* or *pdf* of the observation

Fig.2 Q-Q plot in the Paris area (Dèqué, 2007) for model (x-axis) versus observation (y-axis) precipitation (mm/day), winter (solid line) and summer (dash line) (Déqué, 2007).

Fig.3 Schematic representation of Poisson Rectangular Pulse (PRP) from Handbook of Hydrology, D. Maidment 1993

POISSSONIAN RECTANGULAR PULSE METHOD

- The ***Variable correction method*** **does not correct the temporal property of the series**.
- One possible way for the correction of the persistence features is to post-process some suitable **STARDEX extreme indices** (http://www.cru.uea.ac.uk/projects/stardex).
- In the case of precipitation, assuming a stochastic description of the arrival-duration-intensity processes (e.g. the Poissonian scheme, Fig.3), the q-q correction of such derived variables may be useful for the synthetic simulation of statistically homogeneous rainfall timeseries that mimic the persistency of daily observations (Fig.4).
- The statistical parameters characterizing **storm occurrence, storm intensity** and **duration** are in fact considered among STARDEX collection of extreme indices.

- The **occurrences** of rainfall events are given as a Poisson process with parameter λt so that the inter-arrival periods (dry durations) T between rainfall events are exponentially distributed and $E[T] = \lambda^{-1}$ is the mean period between storms (***m_{dry}***).
- The **duration** of storm also is a random exp-distributed variable D and $E[D]= h^{-1}$ is the mean duration of storms (***m_{wet}***).
- The **intensity** of storm also is a random exp-distributed variable I and $E[I]= x^{-1}$ is the mean intensity of storms (***m_I***).

Fig.4 Synthetic simulation of statistically homogeneous rainfall timeseries

HYDROLOGICAL MODEL

- The area selected to perform the analysis of impact of a potential climate change on the water cycle components is the Apulia basin. The region is representative of a Mediterranean climate and therefore located in one of region that are expected to suffer significantly from a global change.
- **DREAM** (**Distributed model for Runoff Et Antecedent soil Moisture simulation**), introduced by Manfreda *et alii* in 2005, will adopted to analyse the water cycle components at the catchment scale. DREAM is a semi-distributed hydrological model (Fig.5; Fig.6), suitable for continuous simulations. Within the model, the main hydrological processes are computed on a grid-based representation of the river basin that takes into account the spatial heterogeneity of hydrological variables using digital elevation models, soil and vegetation grid-maps.
- In particular the soil water content, which is the limiting factor of evapotranspiration from vegetation, is redistributed within river sub-basins according to the morphological structure of the basin exploiting the wetness index proposed by Kirkby (1975). While groundwater recharge is obtained as percolation through the vadose zone and is routed as a global linear reservoir.

Fig.5 In-coming and out-going fluxes in a single grid cell. The cell represents the control volume. (Manfreda *et alii*, 2005)

Fig.6 Hydrological model.

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