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CHANGE DETECTION USING A REGIONAL MODEL FOR UNGAUGED BASINS

b.blagojevic@eunet.rs
jplavsic@grf.bg.ac.rs

dr Borislava Blagojević, University of Nis, SERBIA
dr Jasna Plavšić, University of Belgrade, SERBIA

Introduction

- Change-variability [1]
  - ***Climate change***

    WRCP usage:

    "Climate change defines the difference between long-term mean values of a climate parameter or statistic, where the mean is taken over a specified interval of time, usually a number of decades".
  - ***Climate variability***

    "The extremes and differences of monthly, seasonal and annual values from the climatically expected value (temporal means). The differences are usually termed anomalies."

[1] WMO (1988) Analyzing Long Time Series of Hydrological Data with respect to climate variability and change, WCAP-3, WMO/TD-No 224, 3 pp.

Introduction

- Change detection phases [2]:
  - **Exploratory data analysis**
  - **Statistical analysis**
- This research is product of change detection for regional hydrologic model parameter estimation.
- Change detection is limited to the exploratory data analysis. It is important to eliminate basins with detected change for reliable parameter estimation at this stage of regional hydrologic model development.

[2] UNESCO&WMO (2000) Detecting trend and other changes in hydrological data, Kundzewich Z.W. and Robson A. (eds.), WCDMP-45, WMO/TD-No. 1013, Geneva

Introduction

- Characteristics of regional hydrologic model for generating monthly flows in ungauged basins [3]:
  - Statistical model – normalized nonlinear multiple regression combined with two parameter exponential model
  - Homogeneous region identification is necessary for selection of multi-donors for model parameter estimation
  - Input data: hydrological data only (observed time series – mean monthly flow yields [l/s/km^2]) and physiographic characteristics of basins

[3] Blagojevic B. (2011) Development of spatial interpolation model for hydrologic time series in ungauged basins, (*Razvoj modela za prostornu interpolaciju hidroloških vremenskih serija na neizučeniim profilima*), Doctoral dissertation, Faculty of Civil Eng. and Arch., University of Nis

Methodology

Regression model for flow at ungauged site x_0 is based on flows x_i at l stations [4]: $\tilde{x}_0 = a_0 + a_{01}x_1 + \ldots + a_{0l}x_l$,

the corresponding normalized regression:

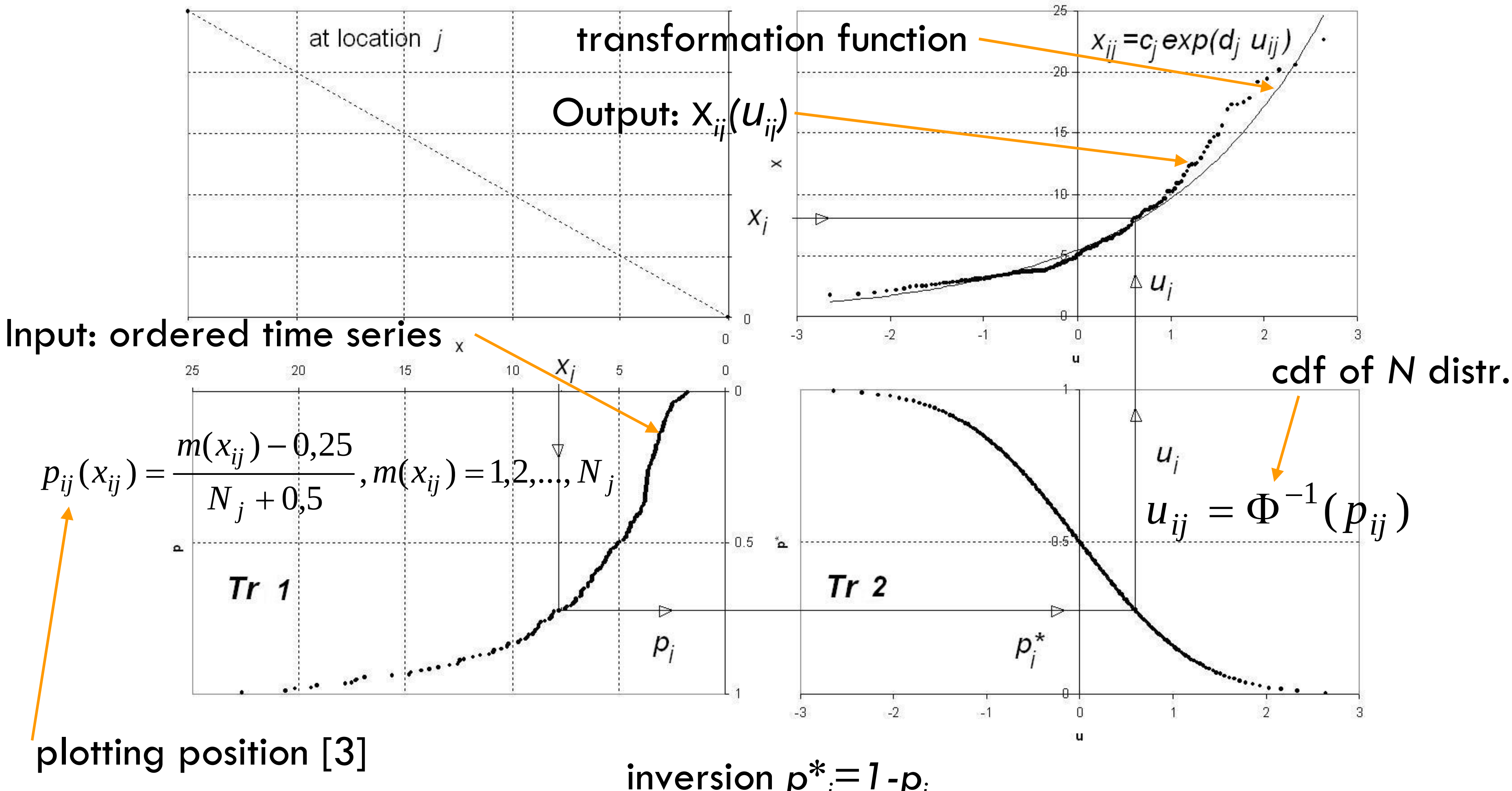
$$\tilde{u}_0 = \alpha_{01}u_1(x_1) + \ldots + \alpha_{0l}u_l(x_l)$$

a_{0j}, α_{0j} - regression coefficients.

Normalization of input data (x_i=x_{ij}) is performed through two transformations – *Tr1* and *Tr2* shown on the following slide.

[4] Aleksejev G.A. (1971) Objective methods of smoothing and normalization of correlation with examples from hydrometeorology, (*Обьективные методы выравнивания и нормализации корреляционных связей*), Hydrometeorological publishing, Leningrad

Methodology



Methodology

- Change detection through verification of transfer model at Hydrologic stations (HS)

$$x_{ij} = c_j \cdot e^{d_j u_{ij}}$$

x is mean monthly flow yield [l/s/km^2], *i* is month index $i=1,\ldots,Nj$, *j* is HS index

  - Calculation of uij according to plotting position and cfd
  - Model Parameter (c_j, d_j) identification- LS method
  - Goodness of fit indicators [5]

    1. *E*- Nash-Sutcliffe's coefficient of efficiency

    Qualitative model performance ratings

    unsatisfactory = $E < 0.50$

    satisfactory = $0.50 < E < 0.65$

    good = $0.65 < E < 0.75$

    very good = $E > 0.75$

    2. *d* – Willmott's index of agreement

[5] Harmel R.D., Smith P.K., Migliaccio K.W. (2010) Moddifying goodness of fit indicators to incorporate both measurement and model uncertainty in model calibration and validation, Transactions of the ASABE Vol. 53(1): 55-63

Methodology

Study area: Republic of Serbia without provinces
- 126 HS total

Time series at HS requirements:
- Non-zero flows
- Continuous flow records (no data gaps)
- Studied period 1961-2005 divided in 3 non-overlapping periods (3x180 mths.)

It was not possible to use Kruskal-Wallis test, since the exact probability distribution for H statistic for total sample sizes up to 105 for three groups is computed so far (http://faculty.virginia.edu/kruskal-wallis/).

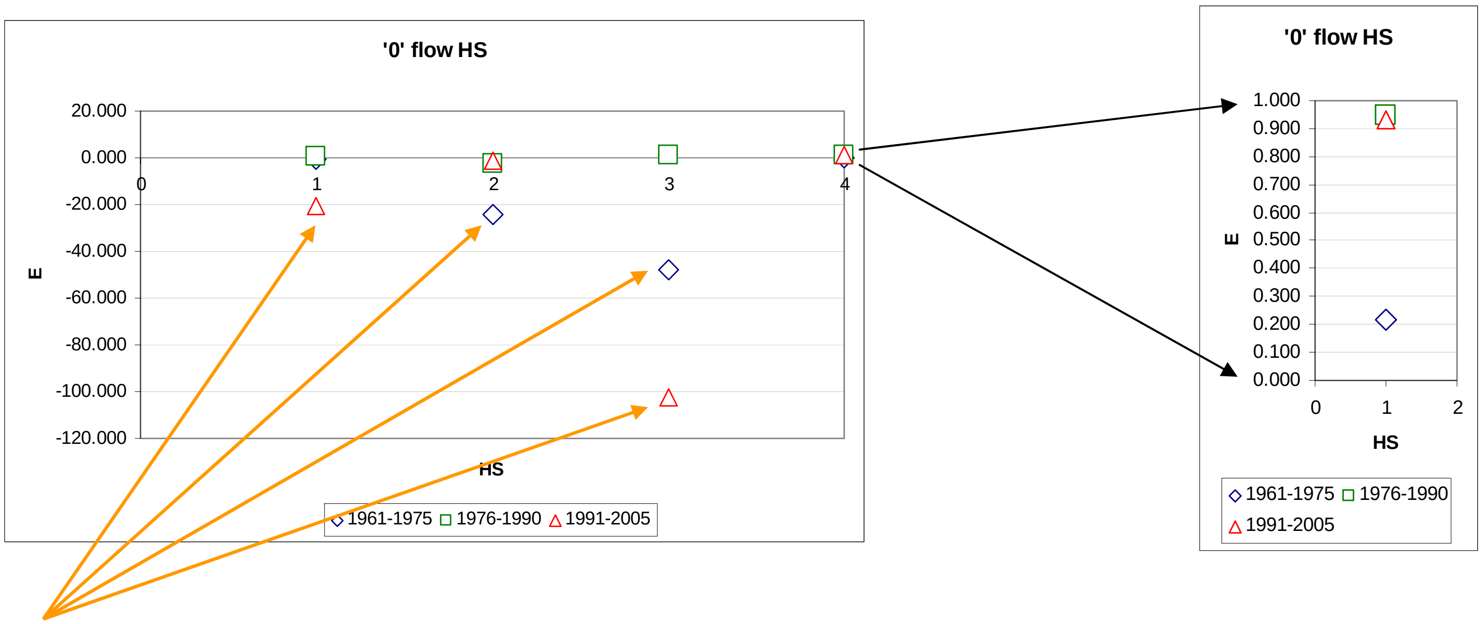
Results and discussion

Transfer model verification at HS in Serbia:

- 63 HS available that fulfill requirements (4 HS with zero flow intentionally included)
- Analysis = Comparison of *E*, *d* and model parameters

Results and discussion

4 HS with zero flow – *E* values at HS



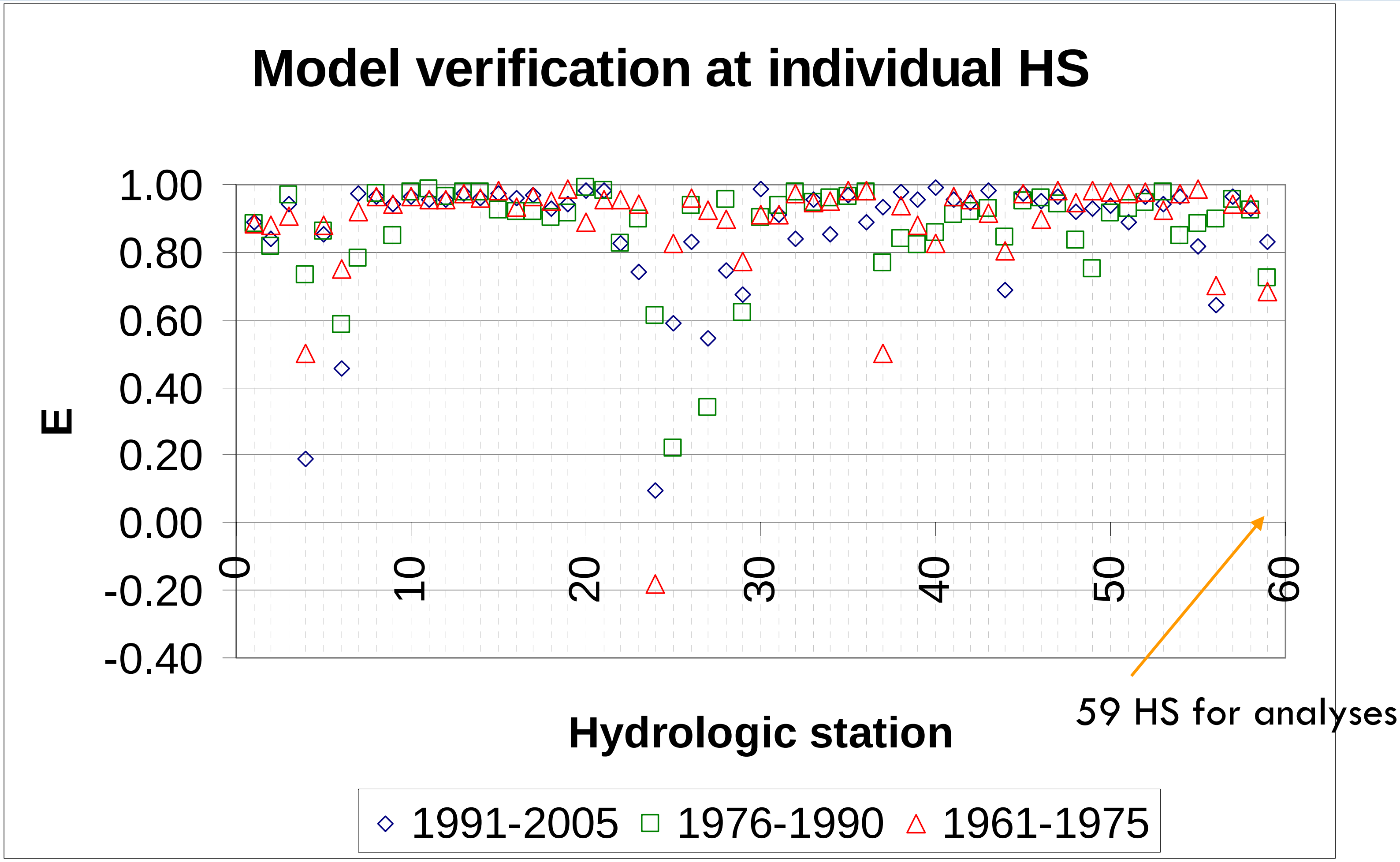
E scale changed to show 'mild' unsatisfactory model performance in the period with only one '0' flow at HS 4.

Extremely unsatisfactory model performance in the periods with '0' flow(s).

At the same periods, Willmot's *d* is not **that** sensitive to '0':

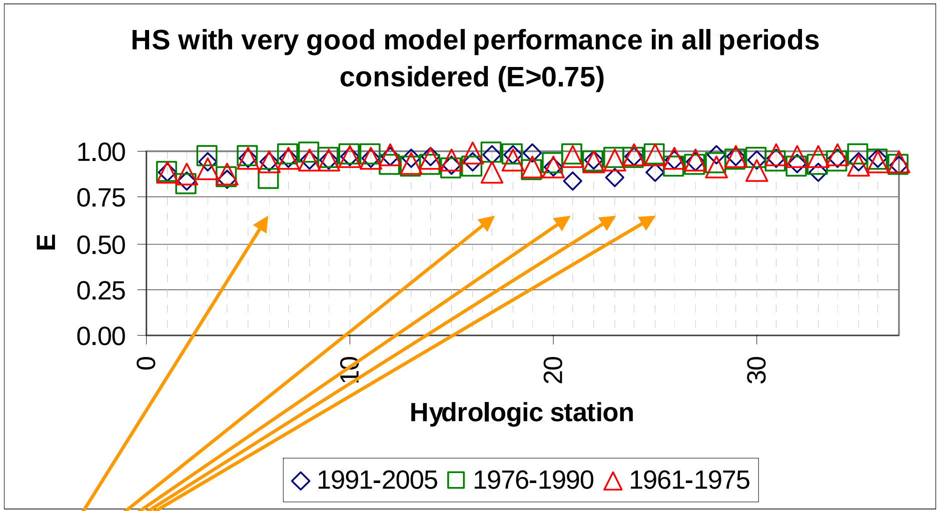
HS	1	2	3	4
1991-2005	0.445	0.770	0.263	0.979
1976-1990	0.920	0.697	0.989	0.984
1961-1975	0.843	0.384	0.338	0.888

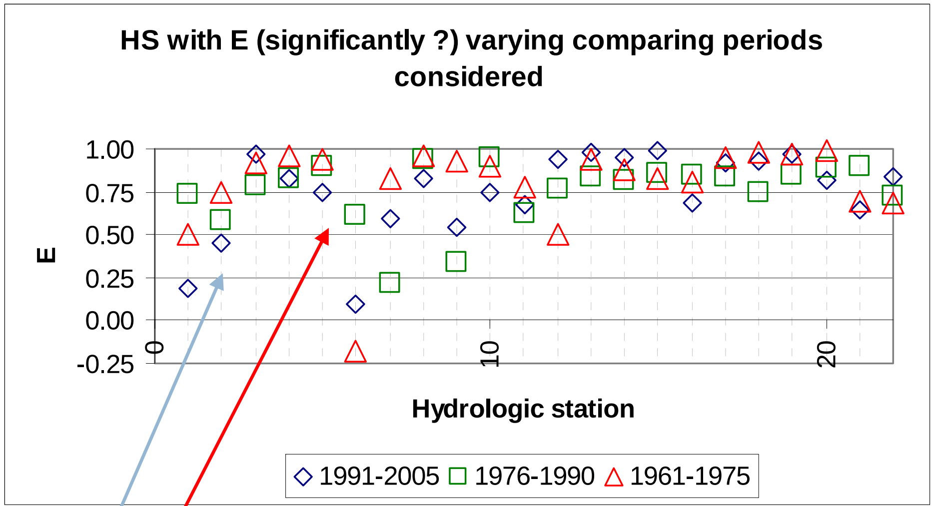
Results and discussion



Results and discussion

The initial grouping of HS according to *E* values in studied time periods





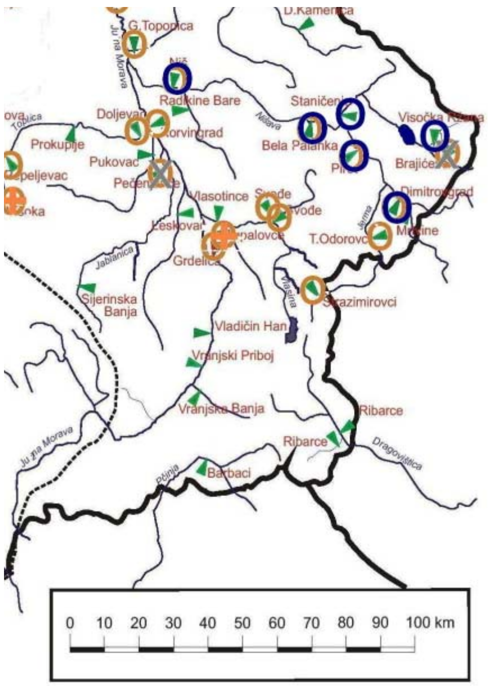
Regardless of very good performance, these HS have *E* in one of the periods that deviates from other two *E* values.

Two types of *E* values change for these HS:

- **Gradual change** (chronologically decreasing or increasing)
- Abrupt change (*E* in one of the periods that deviates from other two *E* values)

Results and discussion

For all of the HS where **abrupt change** was registered, the interventions either in the basin or in the river close to HS were performed (diversions, reservoir construction, exploitation for water supply etc.) in the period when *E* value deviates from *E* in other two periods.

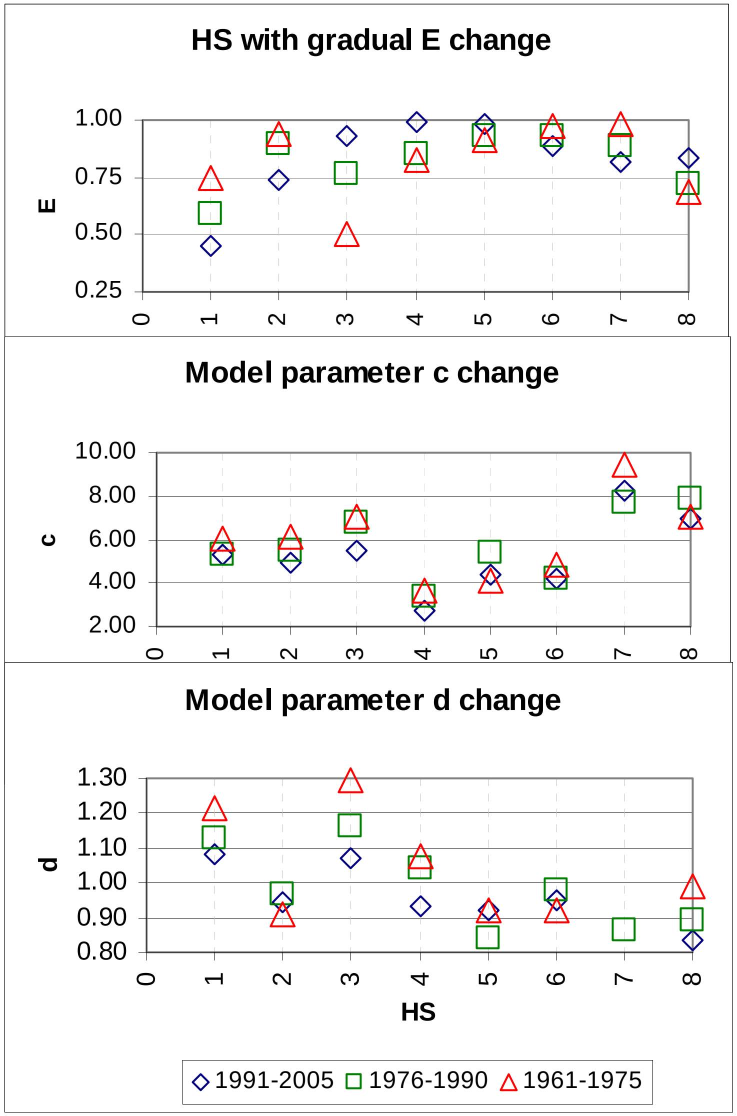


Example [6]:
Testing homogeneity and randomness of time series: annual means, maxima, minima in the period 1961-2002 for 6 HS shown in the pic. left. Known change occurred in 1990 – start of Hydropower plant operations and reservoir fill.

Here, it IS registered as **abrupt change** at one HS under influence as *E* deviation in the period 1991-2005.

[6] Spasic T., Blagojevic B., Prohaska S. (2007) Preliminary analysis of the Zavoj reservoir influence on the Nisava river flow regime in the Sicevo gorge, in 'Jelasnica and Sicevo Gorge Environment status monitoring' Monograph, Fac. Civ. Eng. Arch. & Inst. Nat. Cons. Serb., 107-114

Results and discussion



The second grouping of HS is done for all of the HS where **gradual change** was registered. This kind of change could reveal potential climate change in the basin.

In addition to *E* variation, transfer model parameters c and *d* variation is considered among sub-periods.

For this type of transfer model, parameter estimates for c and *d* are *m* and Cv, respectively.

Results and discussion

The table shows *E*, transfer model parameters *c* and *d* values in three studied periods.

Period	HS	1	2	3	4	5	6	7	8
1991-2005	E	**0.455**	**0.741**	**0.935**	**0.989**	**0.981**	**0.889**	**0.815**	**0.833**
1976-1990	E	**0.586**	**0.897**	**0.767**	**0.856**	**0.930**	**0.927**	**0.884**	**0.725**
1961-1975	E	**0.749**	**0.941**	**0.501**	**0.826**	**0.914**	**0.974**	**0.985**	**0.685**
1991-2005	c	5.350	4.920	5.526	2.723	4.434	4.244	8.218	6.987
1976-1990	c	5.296	5.455	6.740	3.365	5.372	4.163	7.737	7.881
1961-1975	c	6.080	6.181	7.102	3.652	4.080	4.858	9.411	7.079
1991-2005	d	1.081	0.944	1.068	0.931	0.922	0.948	0.769	0.834
1976-1990	d	1.128	0.967	1.164	1.043	0.842	0.978	0.863	0.891
1961-1975	d	1.216	0.906	1.294	1.074	0.924	0.922	0.778	0.991

Since climate change reflects on mean values and variability of monthly values, HS with decreasing model parameter c values are marked.

Conclusion

- Goodness of fit measure *E* for presented model is efficient in exploratory data analysis. Willmot's *d* is not.
- It is possible to differentiate change (gradual vs. abrupt) according to *E* change in sub-periods.
- Using presented model and *E*, modified flow regimes could be identified in preliminary regional analyses in a simple way.
- Further research should include:
  - Combined difference measure of model parameter c and/or *d* with *E* that would detect long-term change without using sophisticated models.
  - Potential of flow prediction based on combined difference measure.

Acknowledgement

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