Testing SWAT under contrasted climate conditions (Province of Québec, Canada)

SWAT 2013
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en prévisions et actions hydrologiques

Département de génie civil et génie des eaux

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Plan of presentation

1 Scientific context and objectives

3 Material and methods

4 Results and discussion

5 Conclusion

Scientific context and objectives

▪Building hydrological models suitable for investigating the impacts of climate change is a major challenge for the scientific community. The associated uncertainties mainly emerge from structural and stochastic issues (**Breuer et al., 2009**).

Yet stochastic uncertainty is also linked to parameter identification since the model parameters are often determined through a calibration procedure exploiting one or more objective functions. This commonly used procedure may face equifinality issues (**Beven and Freer, 2001**).

▪How much the issue of parameter identifiability of hydrological models influences hydrological projections?

→In a climate change context, the transposability in time of hydrological models should be assessed and used as a criterion for the selection of appropriate projection tools.

Scientific context and objectives

1) best-parameter set or equifinality ?

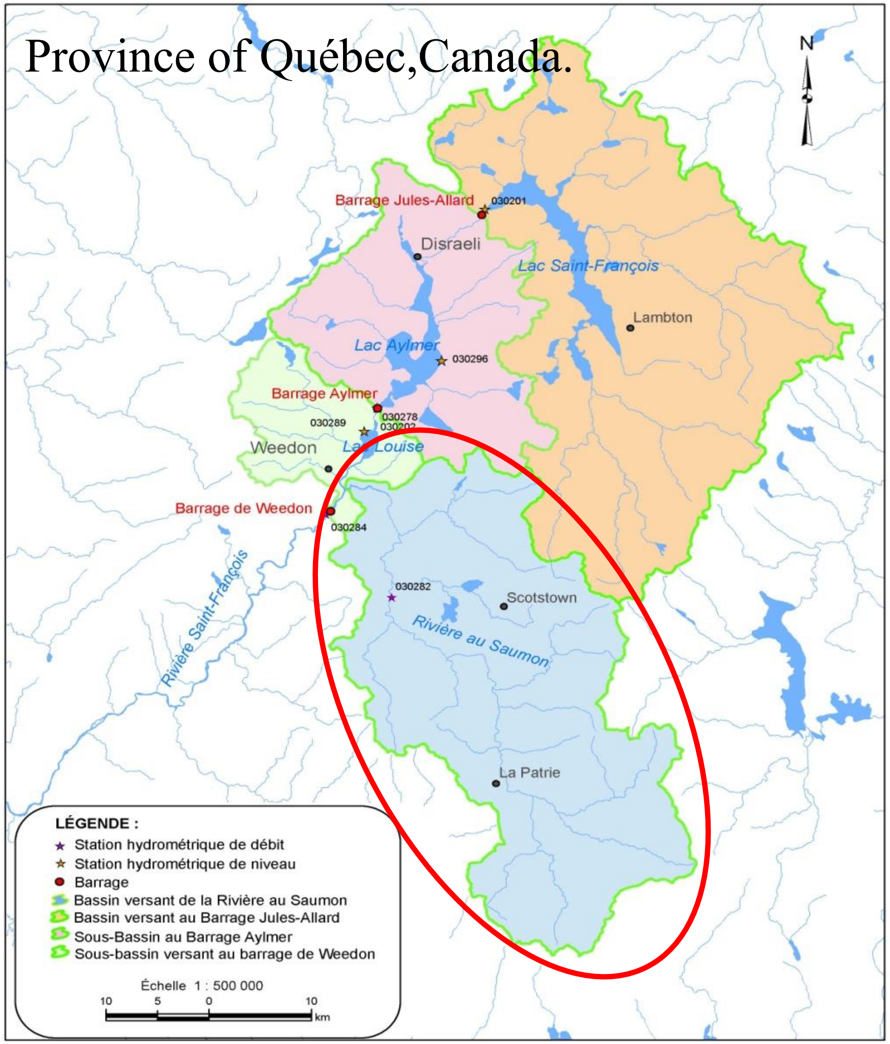
2) Multi-contrasted periods of calibration –validation

3) Projection Reference vs Future

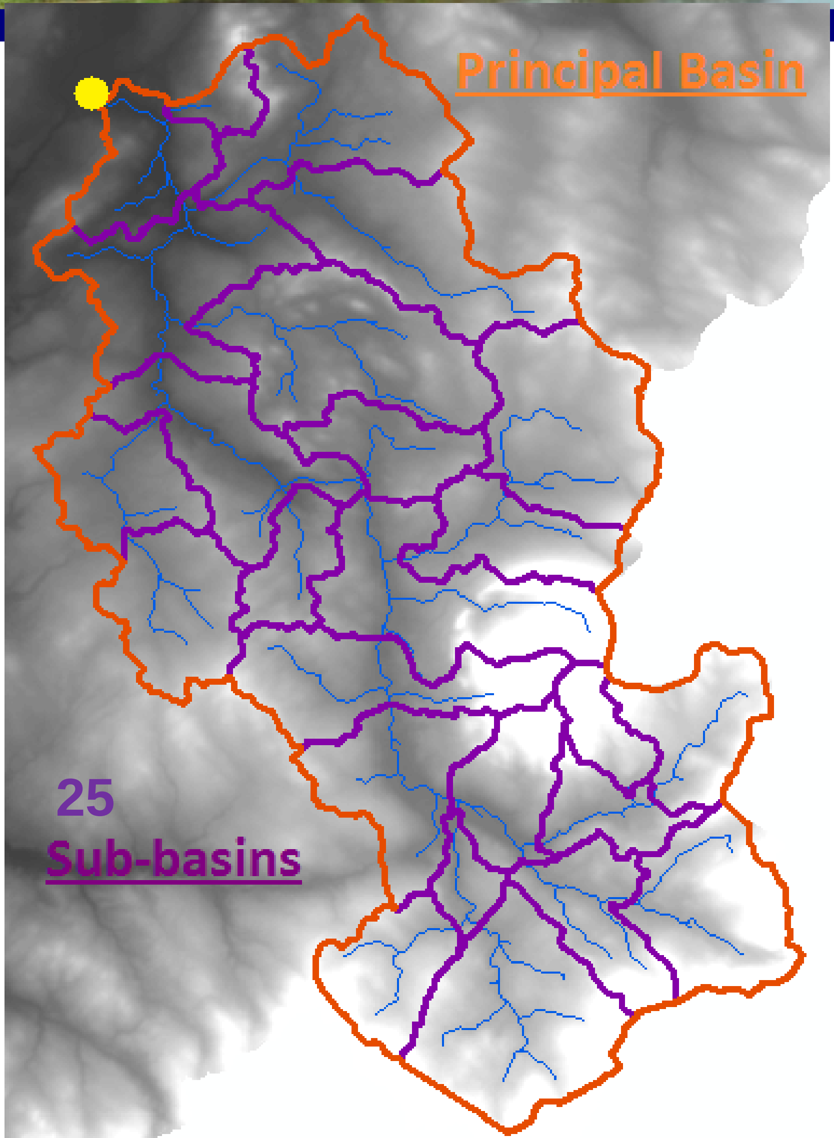
Material and methods
Studied catchment

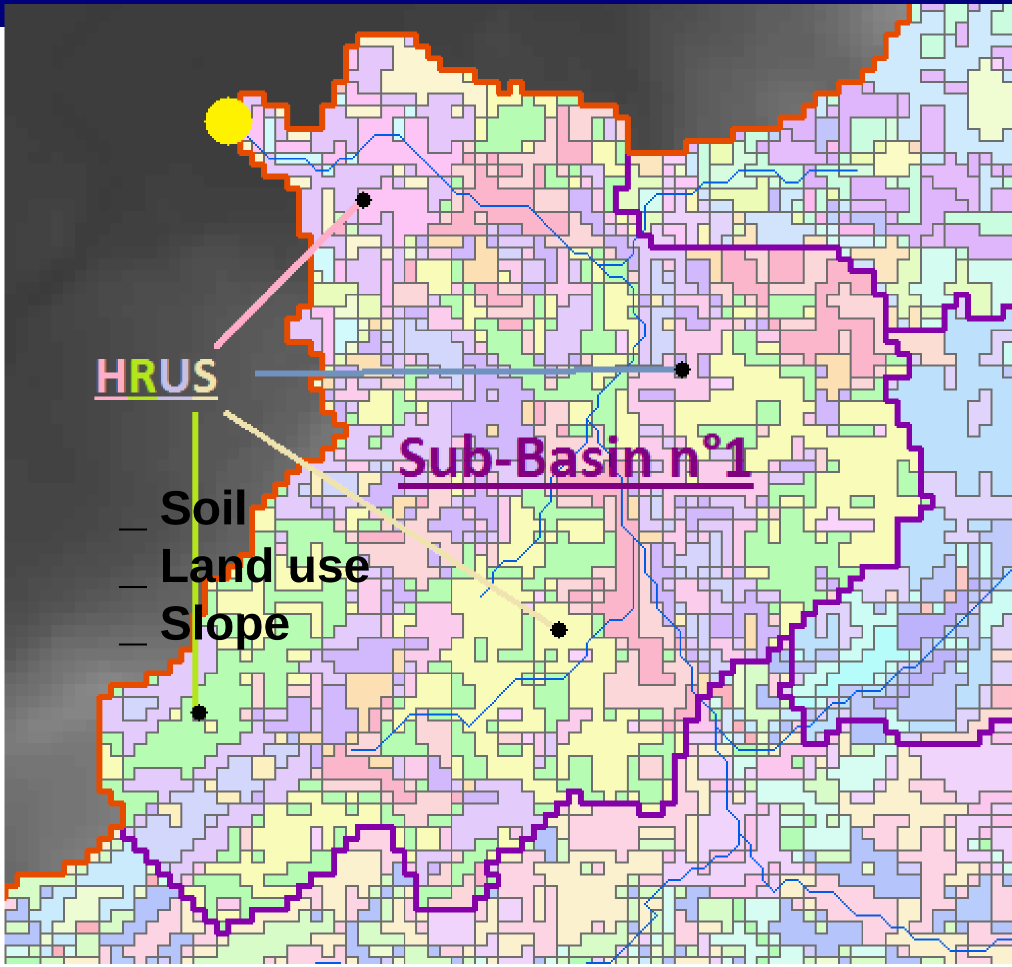
•**Haut Saint François (HSF)** catchment **2940 km2** :
→The site is representative of water management for hydroelectric production, flood protection and recreational activities,

•A single natural sub-catchment is studied in order to avoid additional complexities linked to dam management : the **Au Saumon (SAU)** catchment (738 km2).
→ altitude ranges between 277 and 1092 m.
→ 1284mm (1975–2003), of which 355mm is snow, leading to a mean annual discharge of 771mm.



Material and methods
Model set up





→The water balance is calculated at each HRU.

Material and methods

The temporal transposability of SWAT

•Temporal transposability can be understood as the capacity of the model to perform with the same level of accuracy under conditions different from the calibrations ones.

▪in order to investigate it of SWAT model under contrasted climate conditions . A calibration/validation procedure was applied on the model using :

▪→ **Differential Split Sample Test procedure (DSST)**

Material and methods
Differential Split Sample Test procedure (DSST)

5 years for 4 contrasted periods

Four tests :

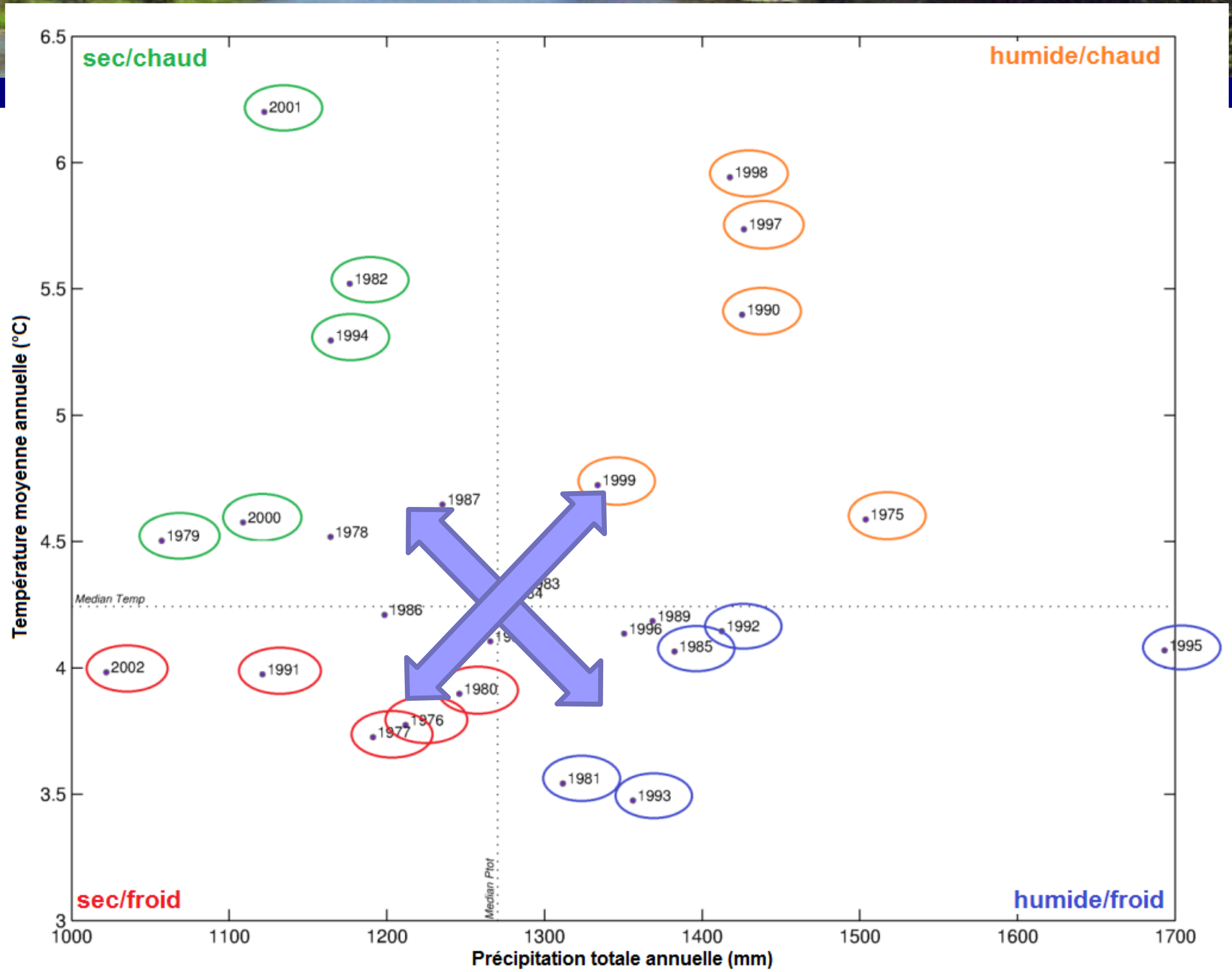
Cal / Val

DW→HC

HC→DW

DC→HW

HW→DC



Adapted from Klemeš, 1986
Seiller and all, 2012

Material and methods

Problem of transposability

- **Identification of the parameter sets (calibration)**

  Associated parameters to hydro-climatic conditions remain valid on simulation periods ?

  > implicit hypothesis of stationarity of the rainfall-runoff transformation

- **Changing climate context :** nonstationarity

- **Temporal transposability in contrasted conditions**

- Must be analyzed

- **What is the capacity of SWAT hydrological model to be used in contrasting climatic conditions? (transposed in time)**

- **Is there an interest to use parameter sets with equivalent performance as an ensemble or sub-slelection ? (multi-parameter sets model approach)**

Material and methods

Methodology

CO2 emission scenario A2 - Global Climate Model

CRCM by Canadian Global Climate Model (CGCM version 3) – **45 km**

biais correction on T° et P with LOCI:
***LOCal** Intensity scaling*

Downscaling
SCALMET – 1 km
SCAling METeorological variables

Observed data(center of water expertise of *Quebec***)**
Q_{obs}**(mm/day), T°max, T°min**

Centre d'expertise hydrique Québec

Automatic Calibration SCEM-UA Jasper and al. 2004

SWAT

Q_{sim}

Q_{ref} **(1970-2000)**

Q_{fut} **(2041-2070)**

OURANOS

LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN LMU

The CRCM data has been generated and supplied by Ouranos (Consortium on Regional Climatology and Adaptation to Climate Change)

Fixed parameters set

Paramètres fixés	Définition	Valeurs
.BSN	**bassin Au saumon**	
SFTMP (°C)	température de chute de neige	-2.5
SMTMP (°C)	température de fonte des neiges	1.75
SMFMX (mm/°C -day)	taux maximum de fonte des neiges par jour (durant la période du solstice d'été)	3
SMFMN (mm/°C -day)	taux minimum de fonte des neiges par jour (durant la période du solstice d'hiver)	2.3
SNOCOVMX (mm)	teneur minimum d'eau dans la neige	1
ETP (mm/hteur d'eau)	évapotranspiration	voir fichier evap.txt (ou pet.pet)
ESCO (0 à 1)	coefficient de compensation de l'évaporation	0.5
EPCO (0 à 1)	facteur de compensation de l'absorption des plantes	0.25
SURLAG	coefficient de surface des eaux de ruissellement	4
.SOL	**caractéristiques du sol**	**exemple: sol "Fredon"**
NLAYERS	nombre de couches du sol	1
SOL_ZMX (mm)	profondeur maximale de racines dans le sol	1524
ANION_EXCL (fraction)	porosité du sol	0.486
SOL_Z (mm)	profondeur du sol	700
SOL_AWC (mm/mm)	capacité en eau disponible	0.156
SOL_K (mm/h)	conductivité hydraulique du sol à saturation	0.068
CLAY (% wt.)	fraction d'argile dans le sol	21
SILT (% wt.)	fraction de limon dans le sol	60
SAND (% wt.)	fraction de sable dans le sol	18
.SUB	**sous-bassins**	
HRUTOT	nombre total d'HRU	5 à 16
SUB_KM (km^2)	surface du sous-bassin	8.93 à 69.97
SUB_LAT (degrees)	latitude du sous-bassin	45.30347 à 45.660231
SUB_ELEV (m)	altitude moyenne du sous-bassin	477 à 556
PLAPS (mm/km)	gradient de précipitation en fonction de l'altitude	3.5 (valeur identique à tout les sbv)
TLAPS (°C/km)	gradient de température en fonction de l'altitude	6 (valeur identique à tout les sbv)

Fixed parameters set

	Parameter name	rangeMin	rangeMax
1	Alpha_Bf	0.001	1
2	Biomix	0	1
3	Blai	-50	50
4	Canmx	0.001	10
5	Ch_K2	-0.01	150
6	Ch_N2	0.01	0.5
7	Cn2	-50	50
8	Epco	-50	50
9	Esco	0.001	1
10	Gw_Delay	0.001	100
11	Gw_Revap	0.02	0.2
12	Gwqmn	0.001	1000
13	Rchrg_Dp	0.001	1
14	Revapmn	0.001	500
15	sub_sftmp	-3	3
16	Slope	-50	50
17	Slsubbsn	-50	50
18	sub_smfmn	0.001	10
19	sub_smfmx	0.001	10
20	sub_smtmp	-5	5
21	Sol_Alb	0.1	1
22	Sol_Awc	-50	50
23	Sol_K	-50	50
24	Surlag	0.001	10
25	sub_timp	0.01	1
26	Tlaps	-50	50
27	Sol_Z	-50	50

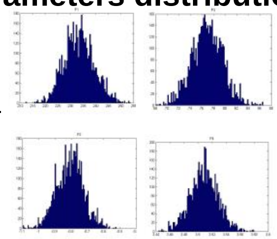
Material and methods
Identification of parameter sets

SWAT

Calibration
SCEM-UA

Q sim

Parameters distributions



1)Test of performance

$90\% * NSE_{opt}(\sqrt{Q})$

yes

Parameters sets with equivalent performance

$$\begin{pmatrix} \overrightarrow{X_{1,j}} \\ \vdots \\ \overrightarrow{X_{N,j}} \end{pmatrix} = \begin{pmatrix} X_{1,1} & \cdots & X_{1,m} \\ \vdots & X_{i,j} & \vdots \\ X_{N,1} & \cdots & X_{N,m} \end{pmatrix}$$

2)Test of Disparities

Euclidean distance

$$D = \sum_{i=1}^{N} \sum_{j=1}^{m} \sqrt{\left(X_{i,j} - X_{(i+1),j}\right)^2}$$

Multidimensional Scaling

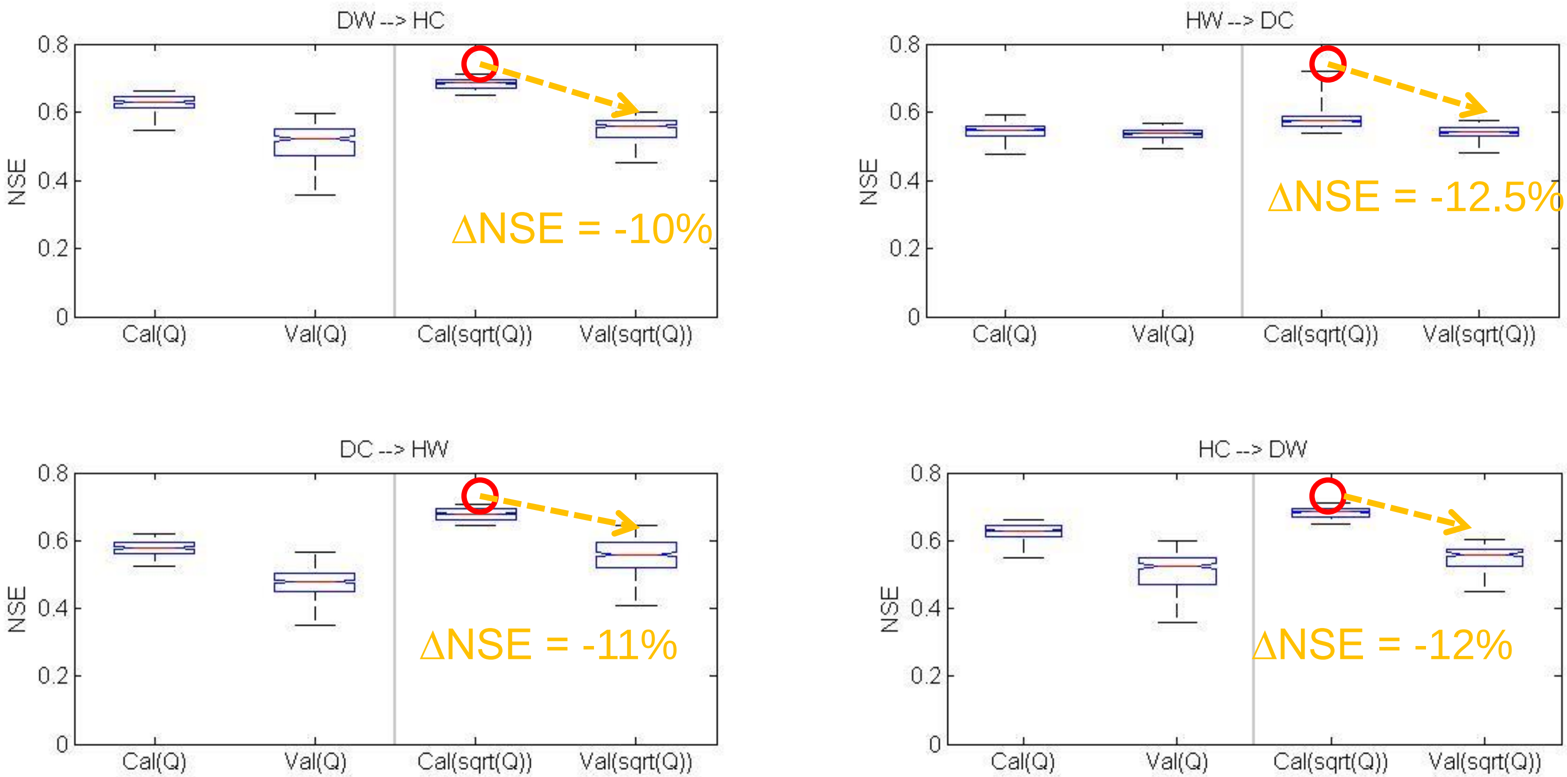
yes

Equifinality & disparities

ensemble approach

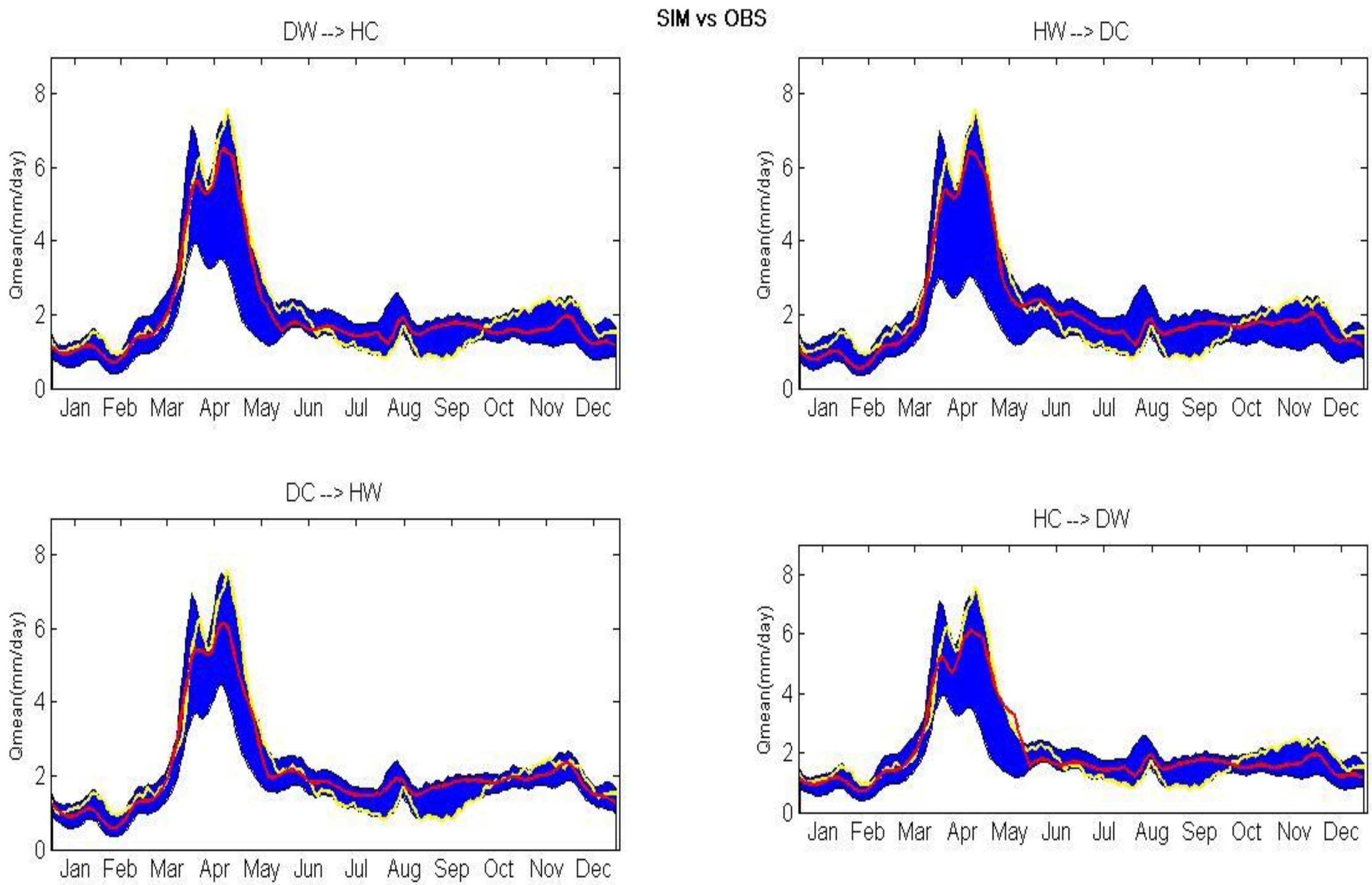
"the right answers for the right reasons"
(Kirchner 2006)

DSST results

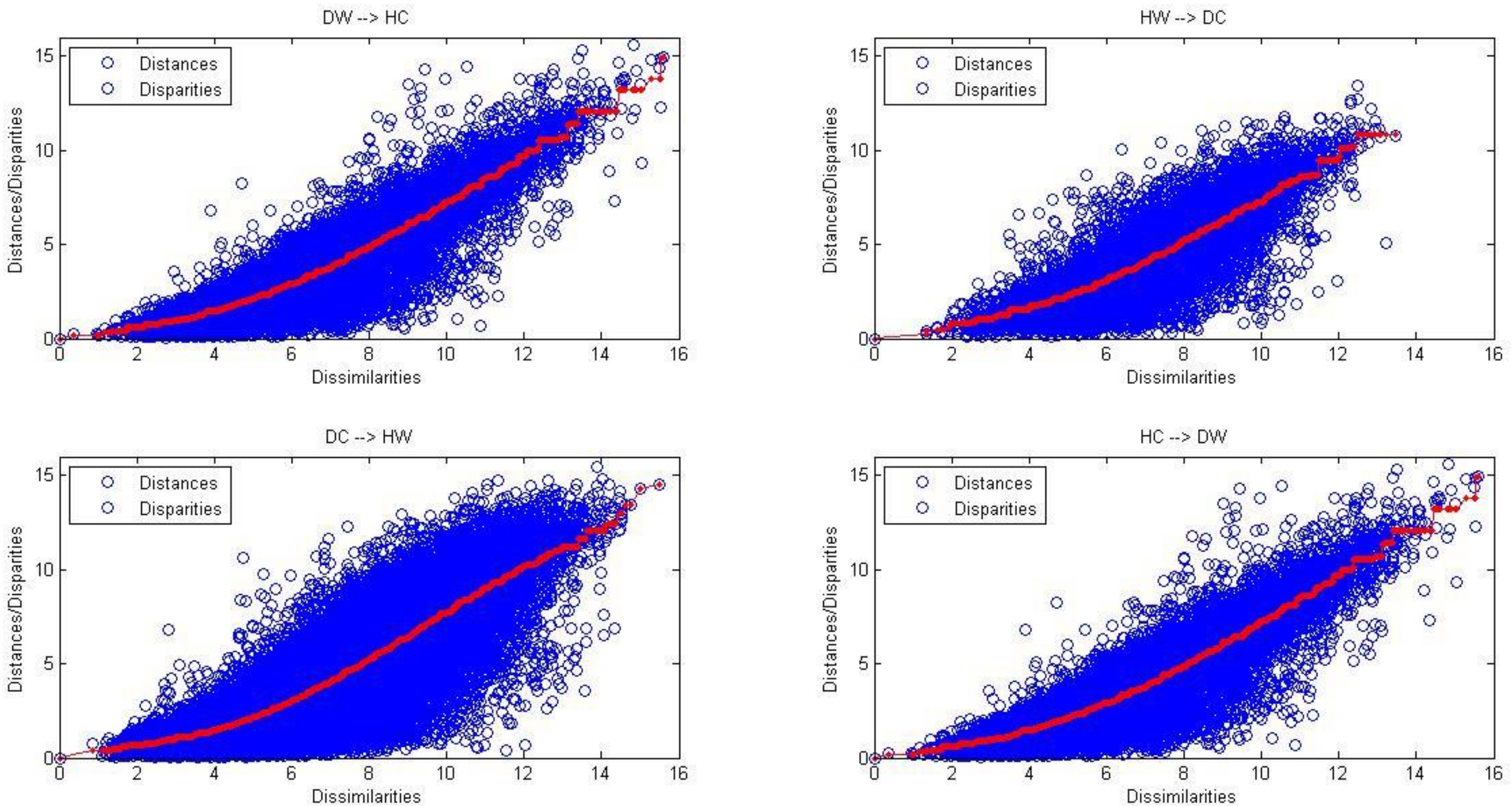


→For a good model, Nash should be at least **0.7** (the maximum being 1)

Results Qmean : Obs vs Sim

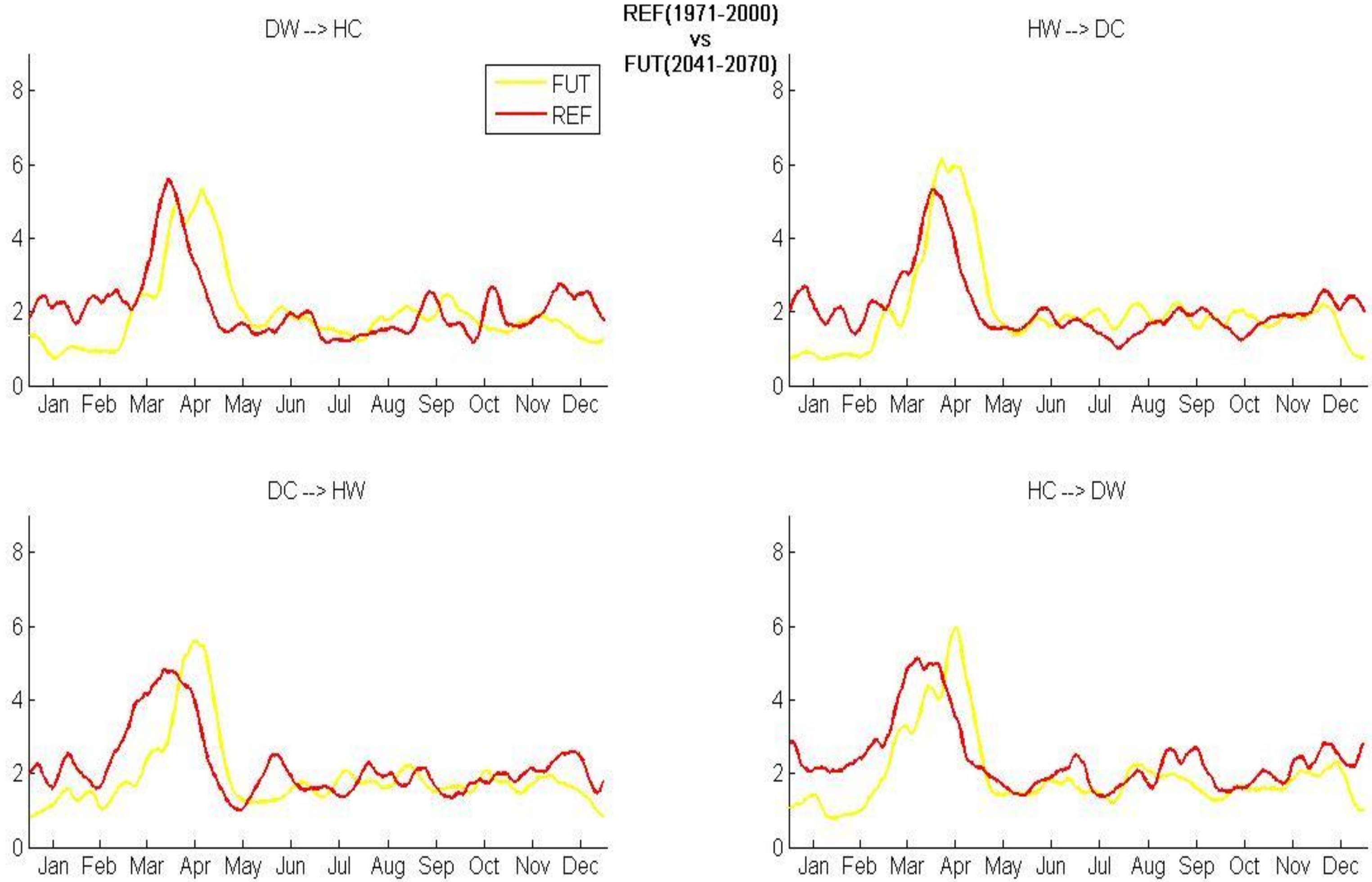


Multidimensional Scaling (Euclidean distance)

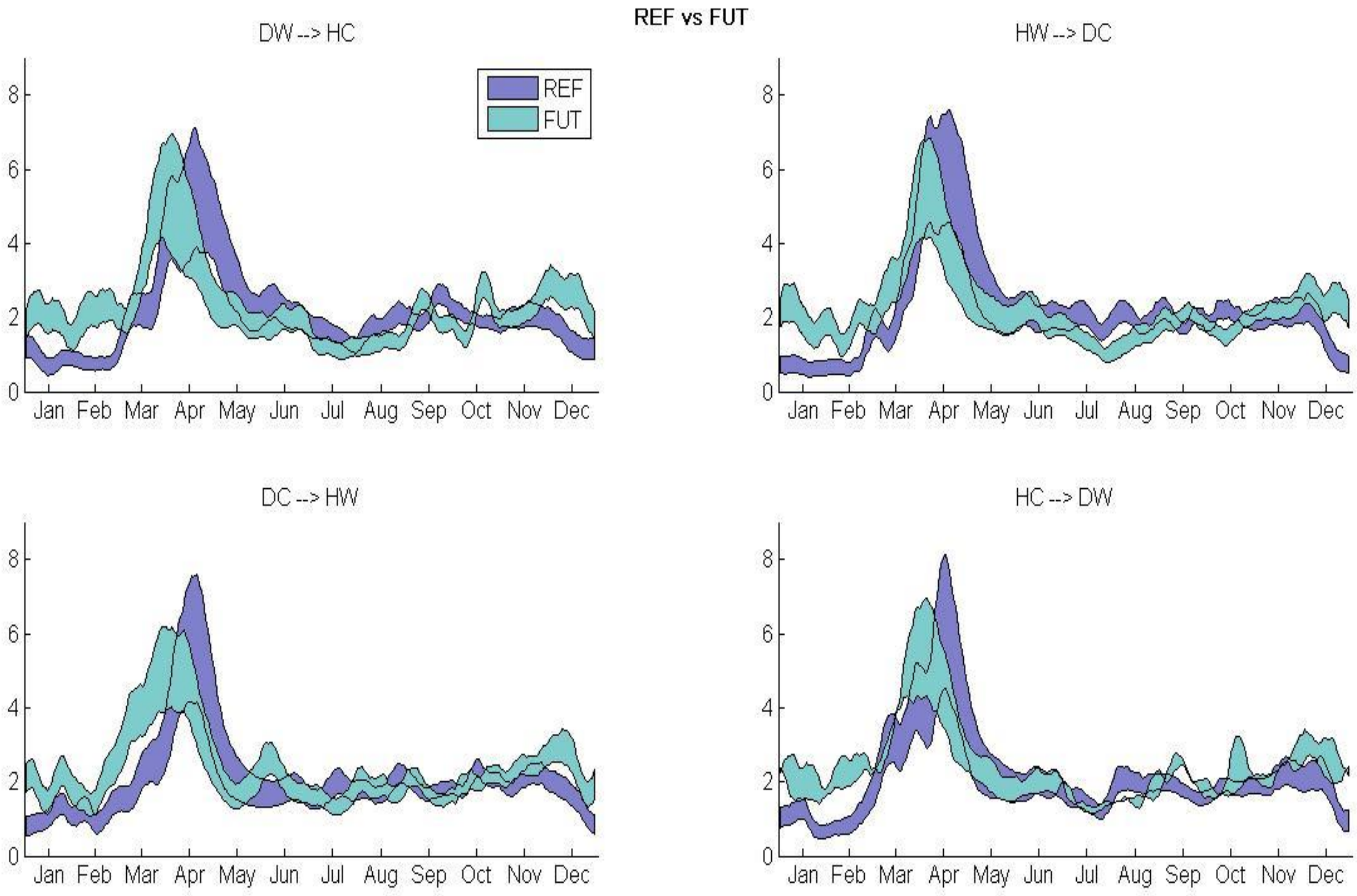


→The typical goal of MDS is to create a configuration of points in two dimensions, whose interpoint distances are "close" to the original dissimilarities. The different forms of MDS use different criteria to define "close". These points represent the set of objects, and so a plot of the points can be used as a visual representation of their dissimilarities.

Results Qmean : Ref vs Fut



Results Qequif_mean : Ref vs Fut



Conclusion

SWAT performs well in contrasted conditions;

SWAT model is transposable in time;

We can make hydrologic projection with swat model;

Needs to improve the uncertainties study on equifinality with swat

Thank you for your attention !

Referencs

•Breuer, L., Huisman, J. A.,Willems, P., Bormann, H., Bronstert, A., Croke, B. F. W., Frede, H.-G., Gr¨aff, T., Hubrechts, L., Jakeman, A. J., Kite, G., Lanini, J., Leavesley, G., Lettenmaier, D. P., Lindstr ¨om, G., Seibert, J., Sivapalan, M., and Viney, N. R.: Assessing the impact of land use change on hydrology by ensemble modeling (LUCHEM), I: Model intercomparison with current land use, Adv. Water Res., 32, 129–146, 2009.

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