Potential variations in low flow hydrological indices associated with climate change.

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HydroPredict conference

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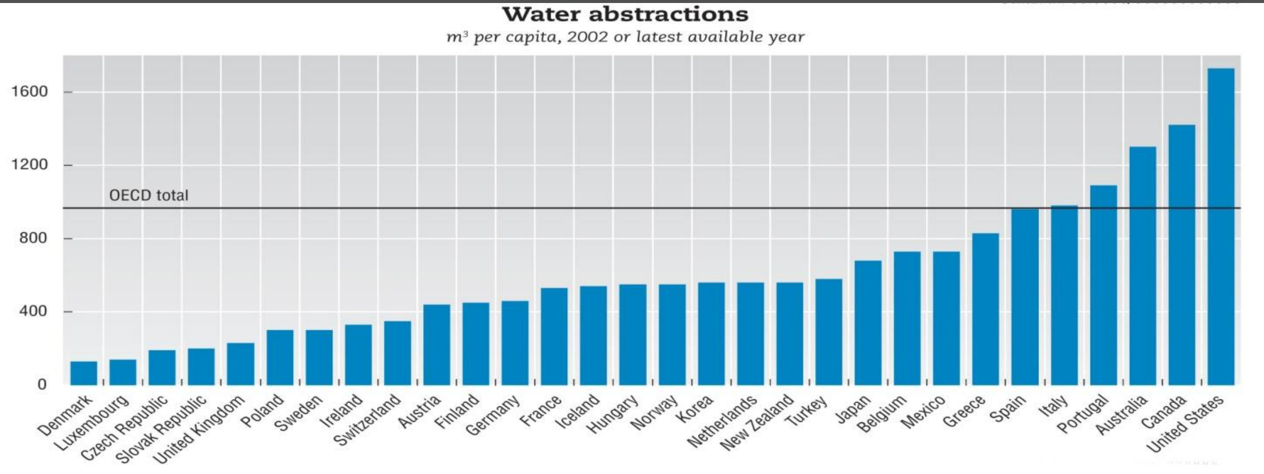
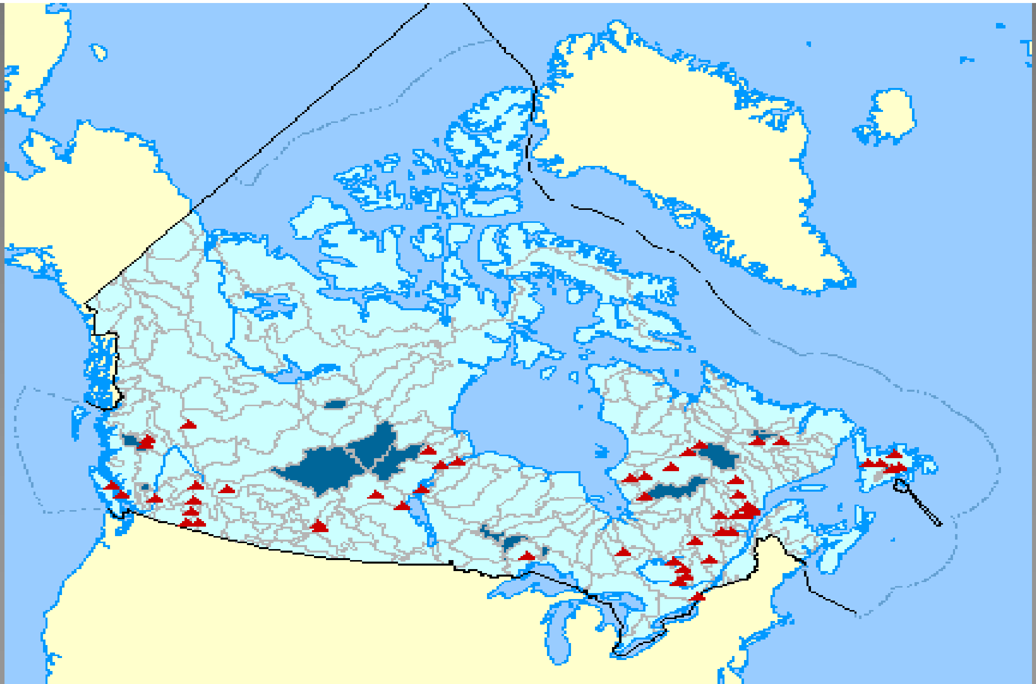
Canada: A water rich country… but not without some challenges



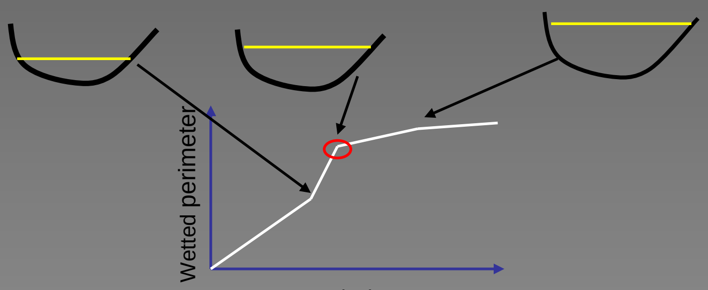


Instream flow needs must be quantified

Introduction to Hydrologic indices

Existing methods for instream flow evalution (Tharme 2003):

- Univariate hydrological approaches : Minimum flow requirements: e.g. Tennant (1976)
- Hydraulic Approaches:
  - Wetted perimeter, Hydraulic Radius(Reiser et al., 1989).



- Habitat Preferences :
  - Establish links between habitat variables (depth, velocity, substrate) and fish or invertebrate preferences (Bovee et al. 1986).

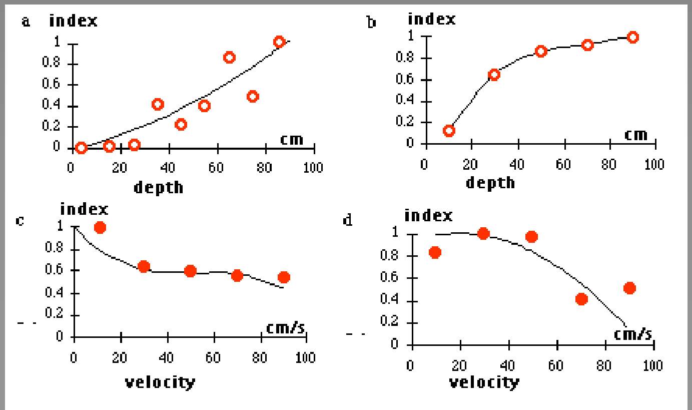


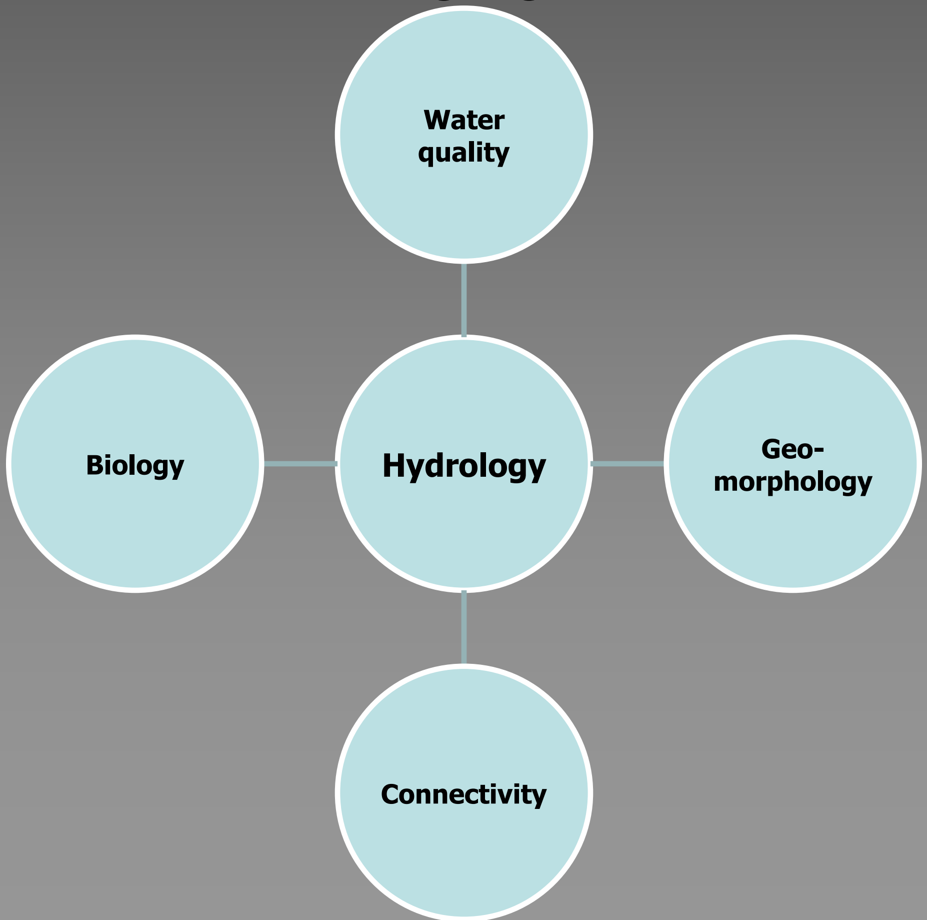
Fig. 1: Adult (a,c) and juveniles (b,d) brown trout suitability curves for depth and velocity in the Adda River

Minimum flow approaches may be insufficient

… And the application of habitat preference models can be costly and difficult

Natural Flow Paradigm:

- Flow is the master variable that modulates available habitat. Characteristics of the natural hydrogram should be conserved when managing flows.



Flow Indices

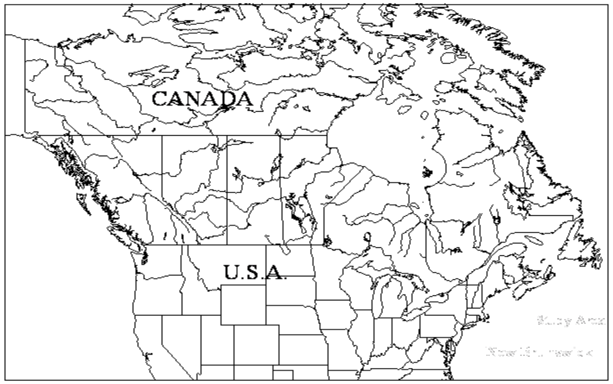
- Flow characteristics are described through the use of Hydrologic Indices (HI).

- High number of existing indices:
  - 32 (Richter 1996)
  - 171 (Olden & Poff 2003)
  - 201 (Monk et al. 2006).

- Are these indices pertinent for Eastern Canada?
- Can they be used to quantify changes to low flow conditions (and eventually, habitat changes)?
- How will they evolve as a function of climate change?

1. Hydrologic Indices related to low flows

Catégories	# HIs	Examples
Amplitude	24	▪ Annual min; ▪ Monthly Min; ▪ *Base flow Index*.
Duration	21	▪ Q7; ▪ Q30 days/Qmed; ▪ Mean event duration under the 25^{th} percentile.
Frequency	2	▪ # events under the 25th percentile; ▪ # events under 5% of MAF.
Occurrence	3	▪ Julian day of min annual flow; ▪ Mean date of the 7 lowest annual flows.
Variabilitty	15	▪ coefficient of variation of monthly min; ▪ coefficient of variation of Q7; ▪ coefficient of variation of dates of the 7 lowest annual flows.

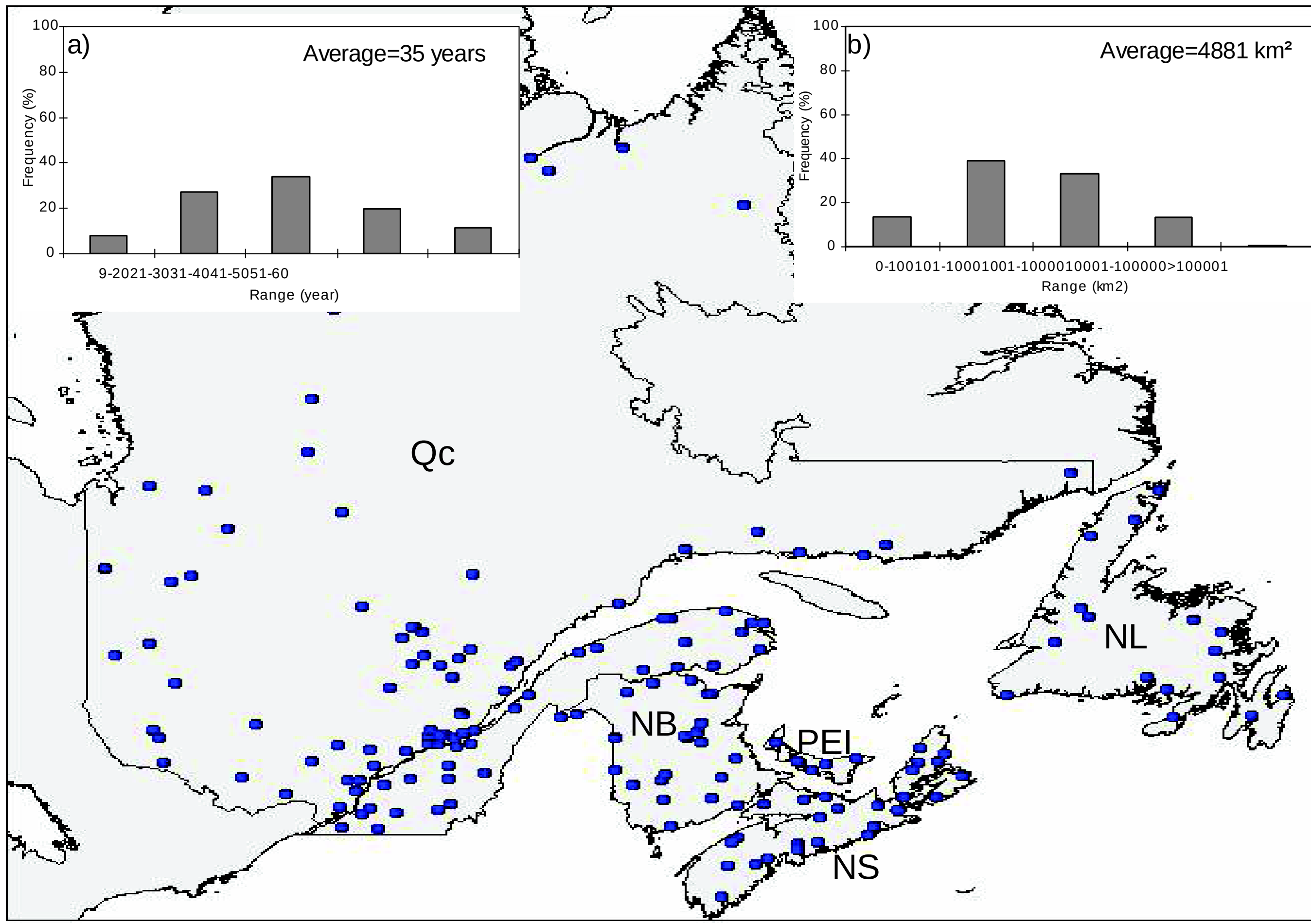


2. Data Base

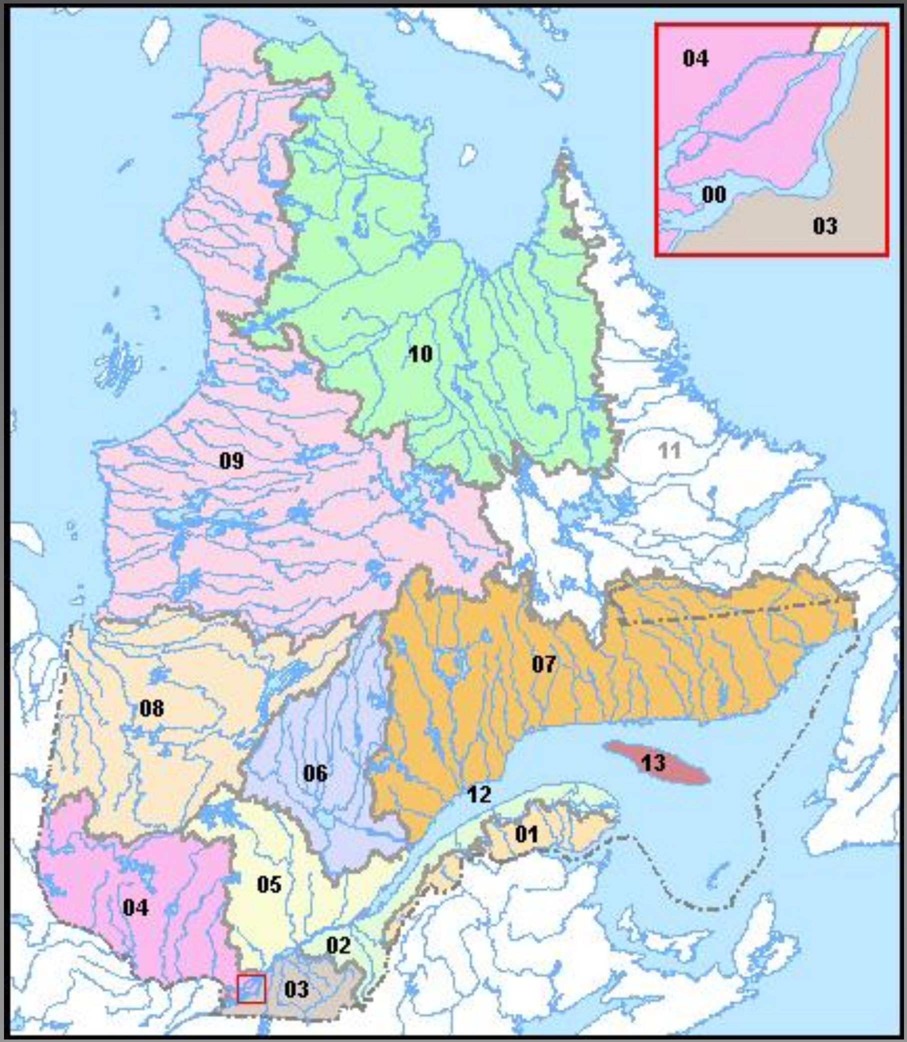
Number of stations:

Qc :104
N.-B: 23
N.S.: 26
PEI: 6
N.&L: 16

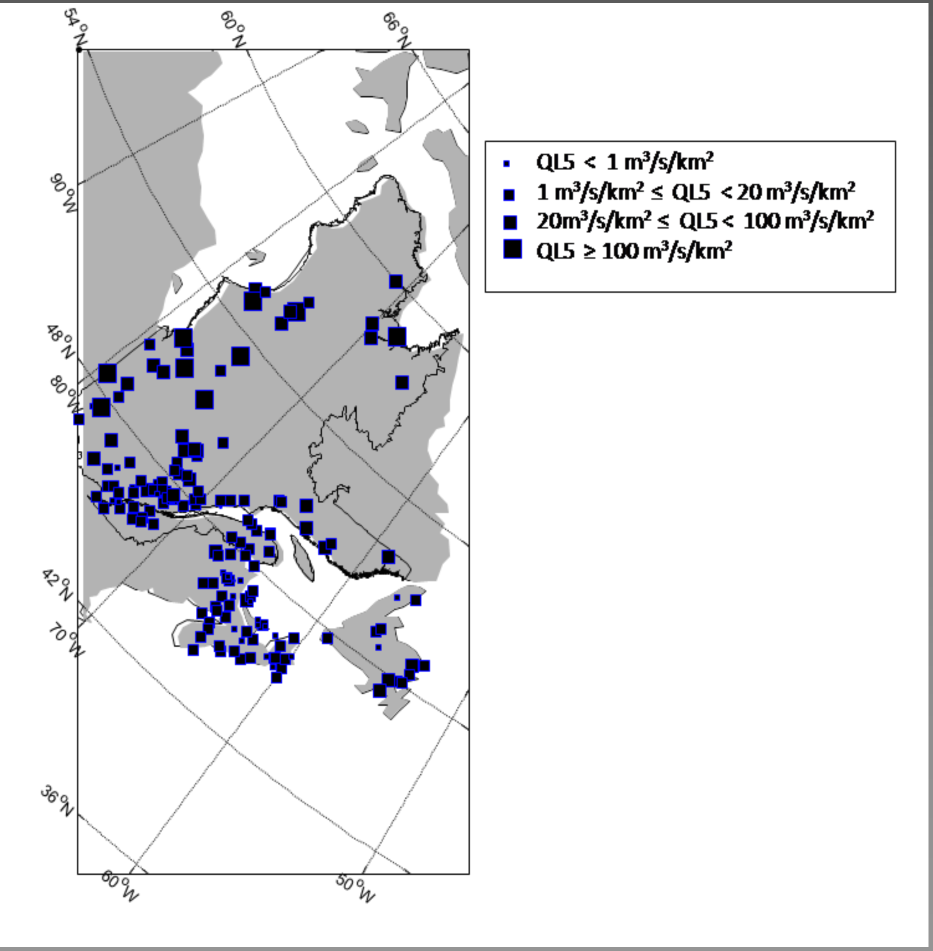
Total: 165

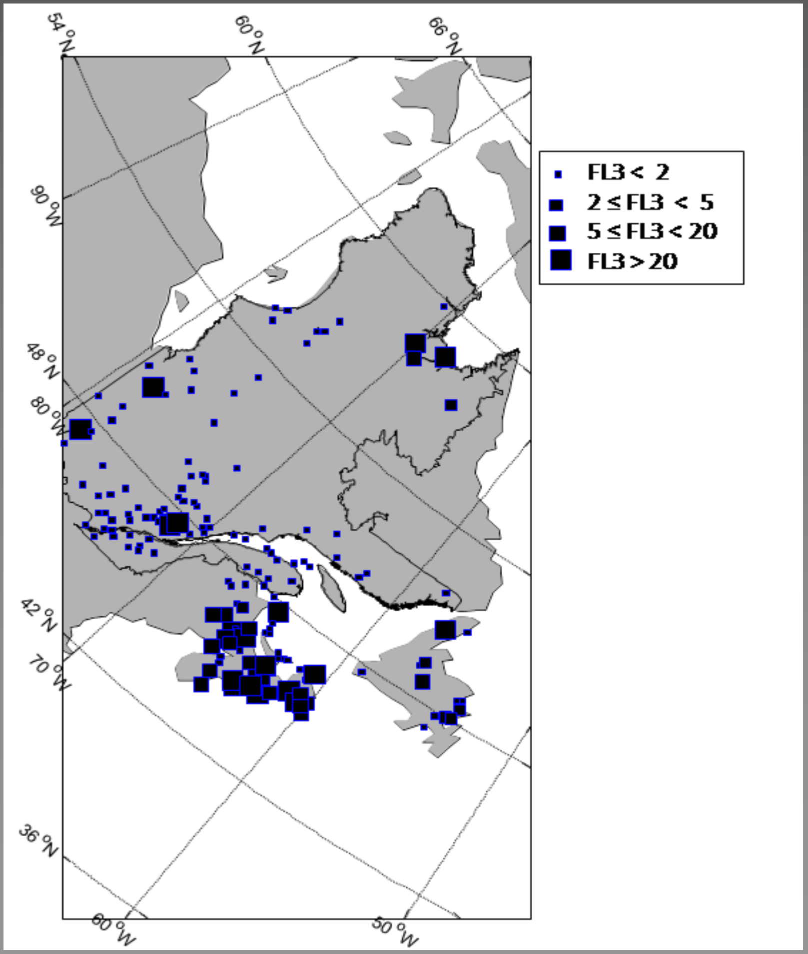


Quebec hydrological regions



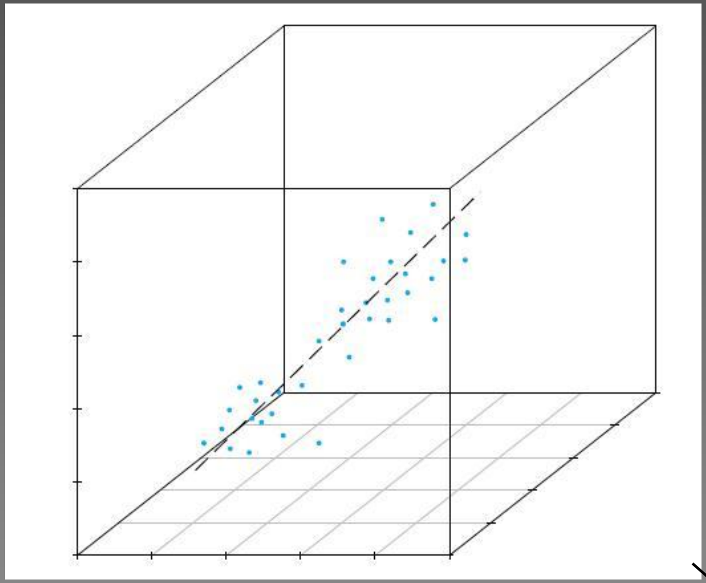
Example of the spatial distribution of some HI



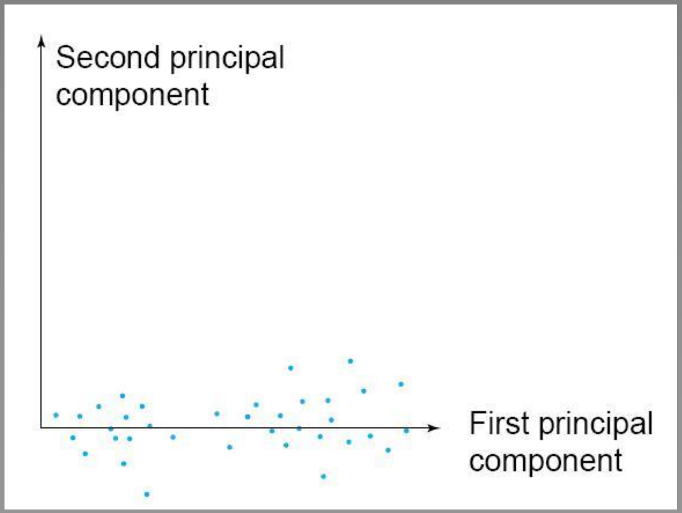


3. Multivariate analysis

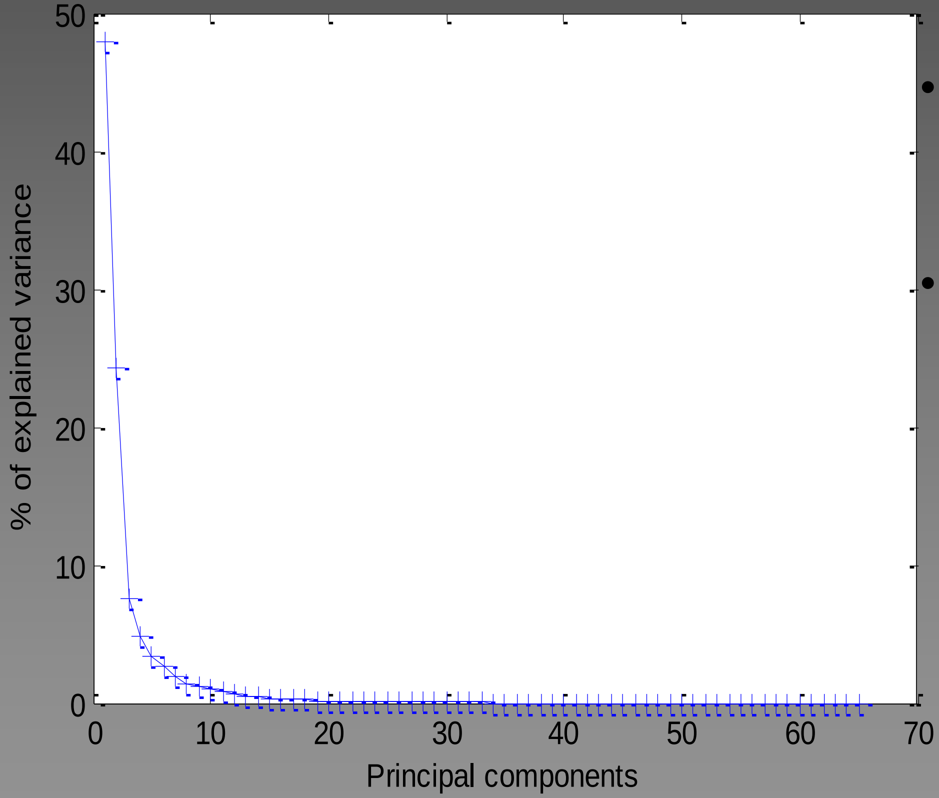
- 65 *HIs:* Space with 65 dimensions.



Principal Component Analysis reduces the number of variables by combining indices

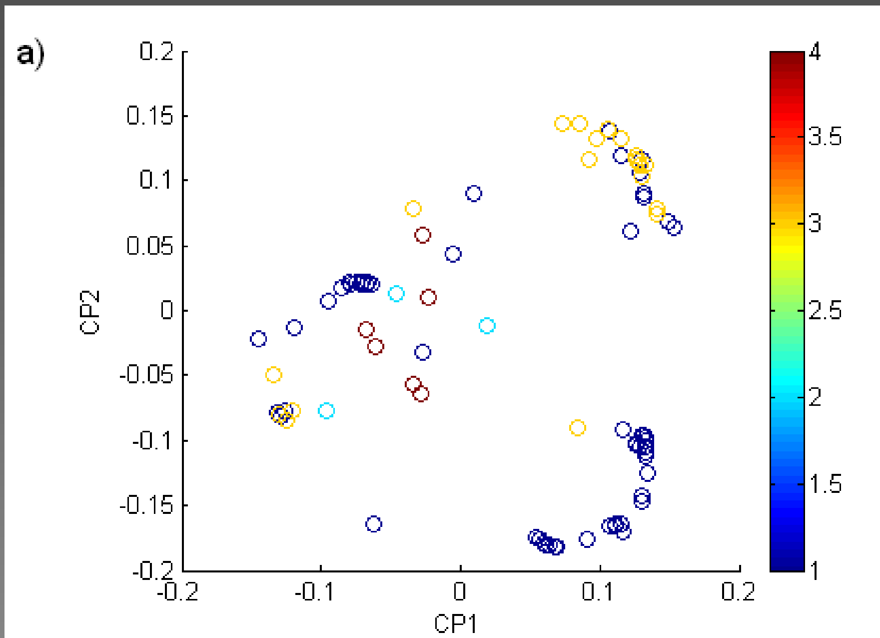


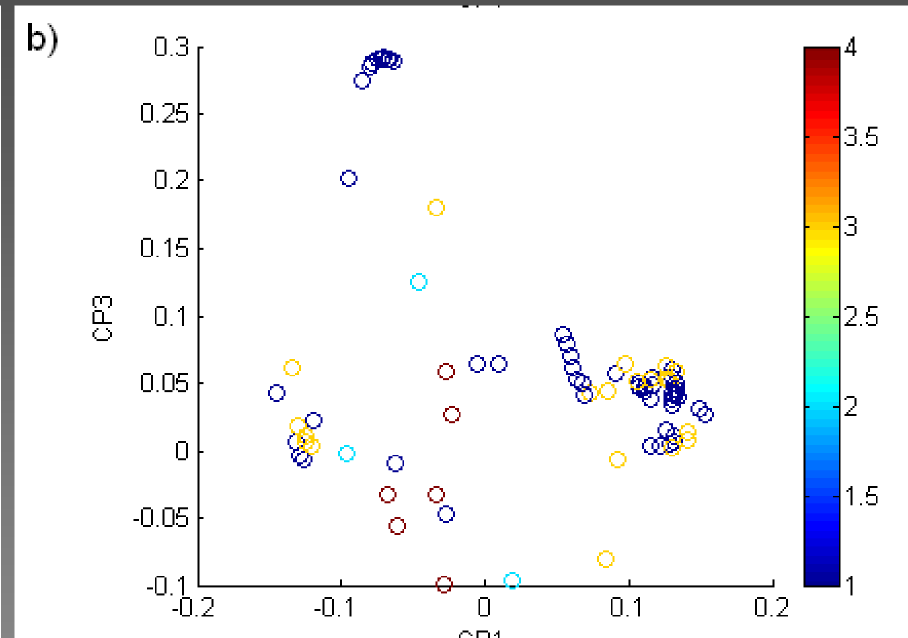
Multivariate Analysis: Scree plot



- First three principal components:80% of variance
- PC1 explains nearly 50% of variance.

3. PC loadings of the 65 indices





1 (blue) = amplitude
2 (light blue) = frequency/timing
3 (yellow) = duration
4 (red) =variation

5. Climate Change scenarios

Three Quebec rivers were selected: Romaine, Manic 5, Aux Outardes

(1) Climate scenarios (10 for Romaine, 7 for Manic 5 and Outardes 4) were used to provide input to hydrological models

(2) SSARR (Streamflow Synthesis and Reservoir Regulation) was used on all three systems.

(3) HSAMI (Hydro-Quebec forecasting model, Fortin et al., 2000) was also used on the Romaine River.

5. Romaine River

- 13 000 km^2
- 53 years of hydrological data (1956-2008)

- Planned Hydroelectric complex
- 1550 MW, 4 dams

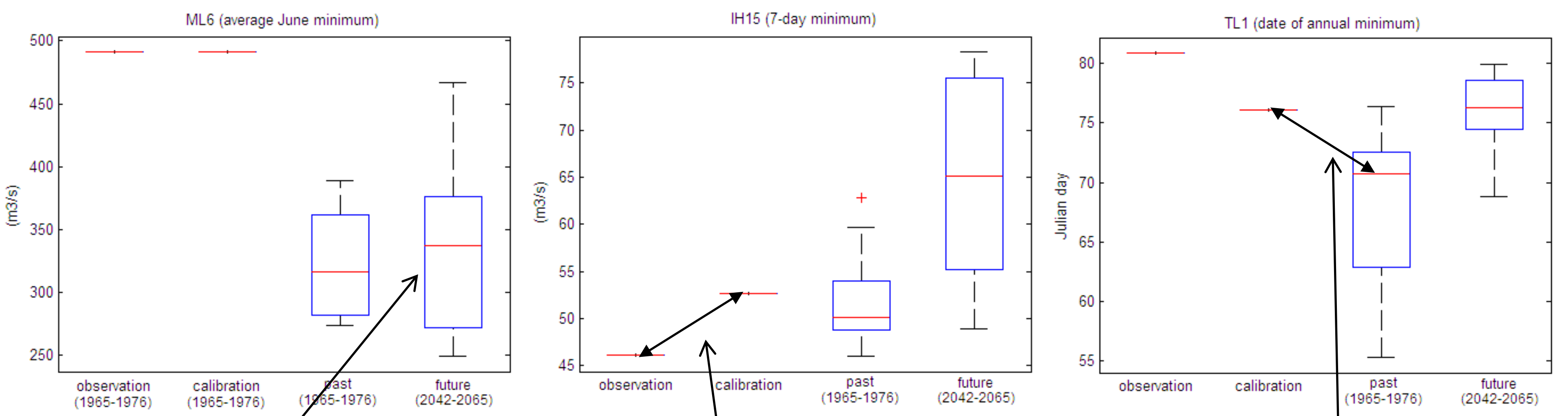
5. Climate change scenarios used

:

Description	#	delta Tmin	delta Tmax	**delta Tmoy**	delta Prec (ratio)	**delta Prec (%)**
MRCC afa (direct and de-biased)	**7**	**3.4**	**2.7**	**3.1**	**1.2**	**17.9%**
Echam5 EH5_OM_A2_2	**11**	**3.0**	**2.4**	**2.7**	**1.1**	**9.8%**
cgcm3_1_t47 sresa2_3 (direct and de-biased)	**22**	**3.4**	**2.9**	**3.2**	**1.2**	**17.1%**
cnrm_cm3 sresb1 run1	**35**	**1.3**	**1.1**	**1.2**	**1.0**	**1.7%**
ipsl_cm4 sresa2 run1	**51**	**4.5**	**4.0**	**4.2**	**1.1**	**10.5%**
miroc3_2_hires sresa1b run1	**53**	**5.0**	**4.4**	**4.7**	**1.2**	**15.9%**
miub_echo_g sresa1b run1	**61**	**3.8**	**3.3**	**3.6**	**1.1**	**6.4%**
mri_cgcm2_3_2a sresb1 run2	**81**	**1.6**	**1.4**	**1.5**	**1.1**	**9.8%**

- Recent pass: calibration period of hydrological models (1964-1976)
- Futur climate (2042-2065)

Example of calculated indices:

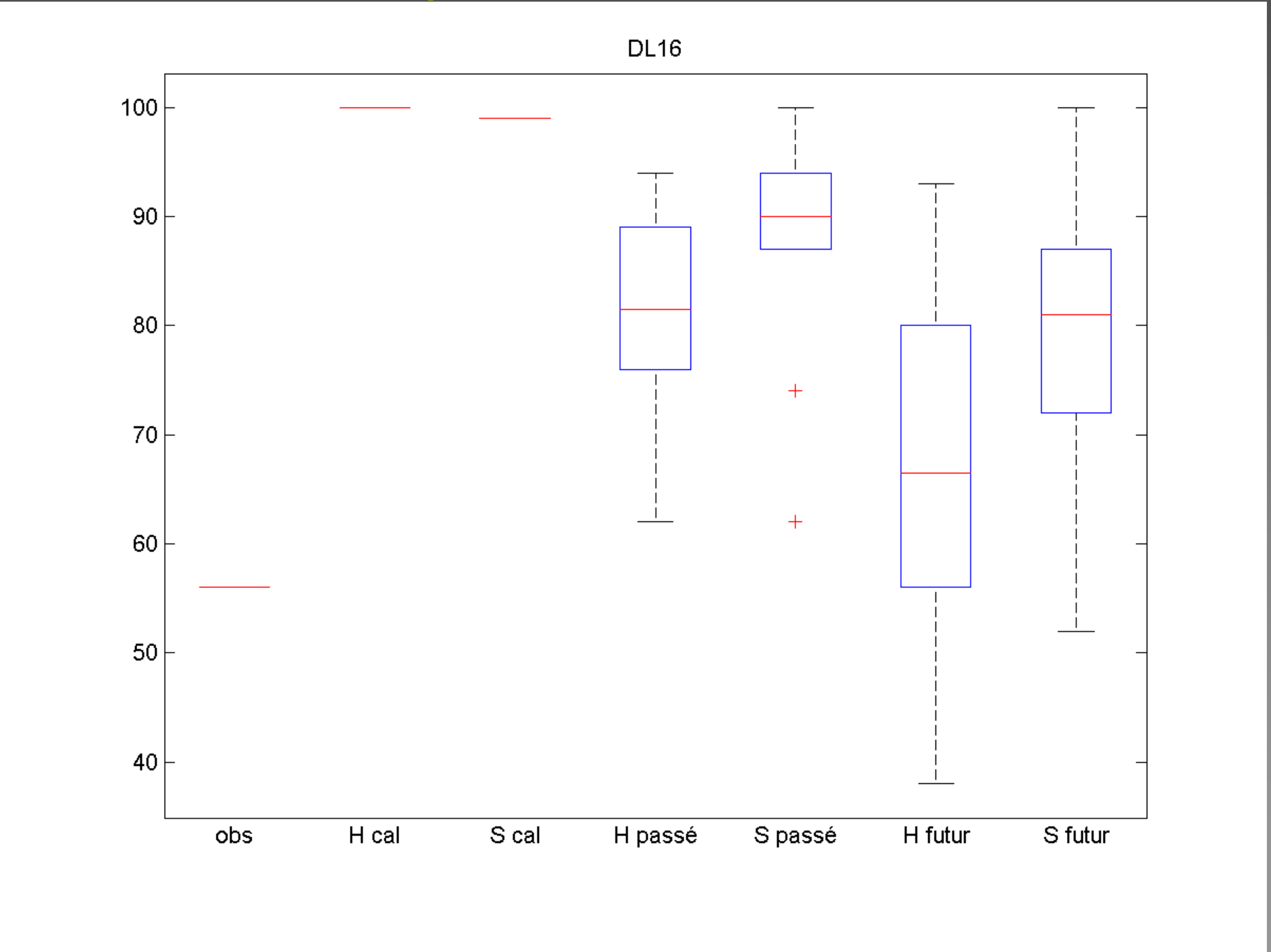


10 models

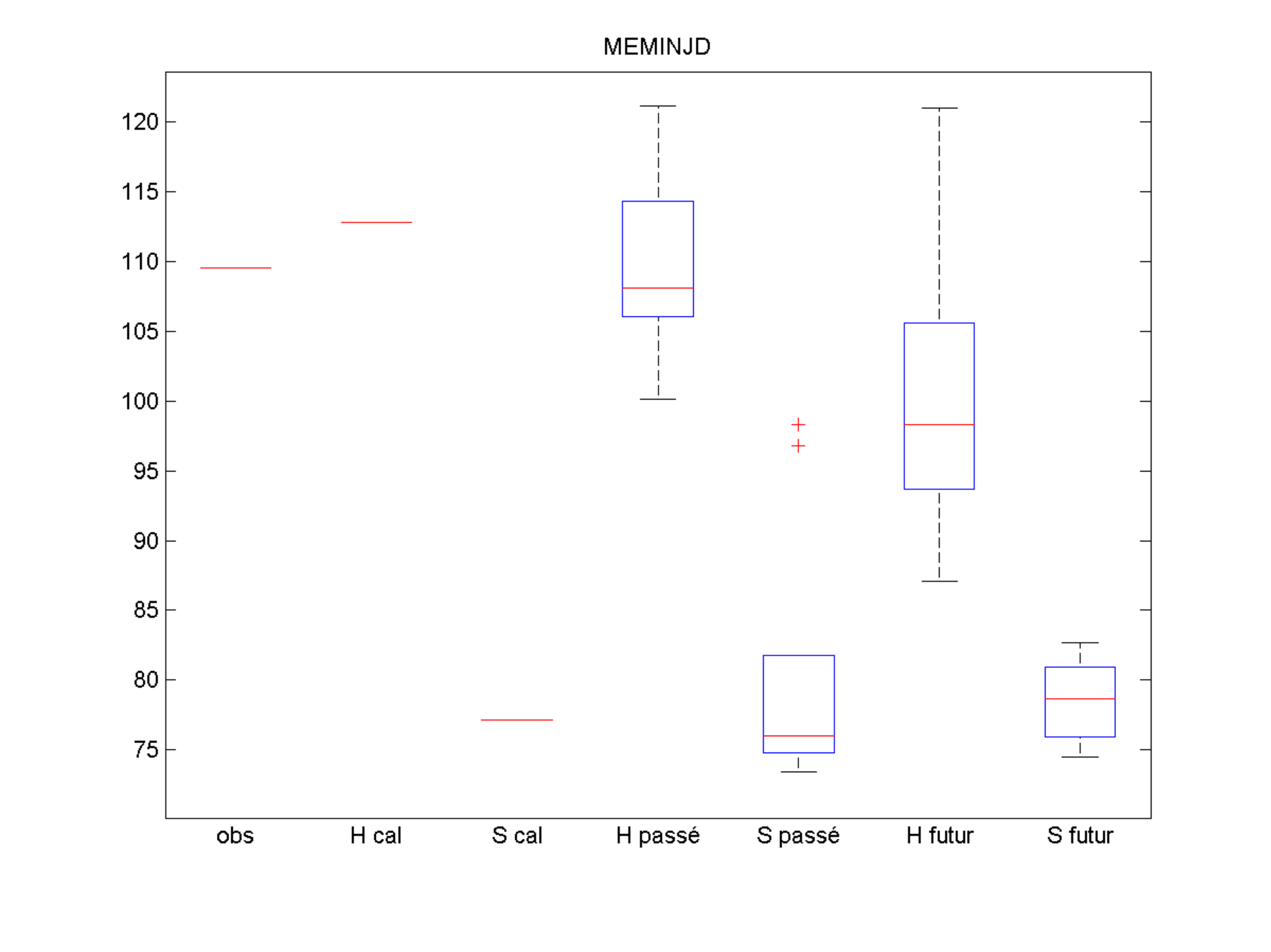
Calibration error

Climate models bias

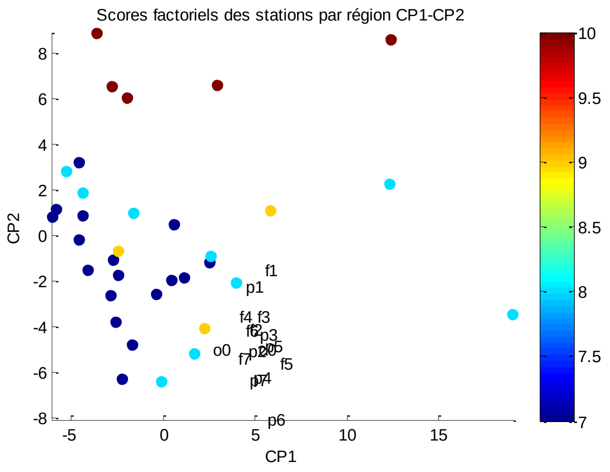
Median duration of events under 25th percentile

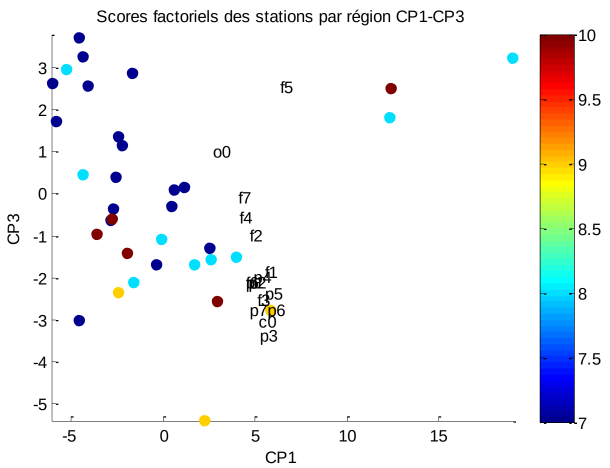


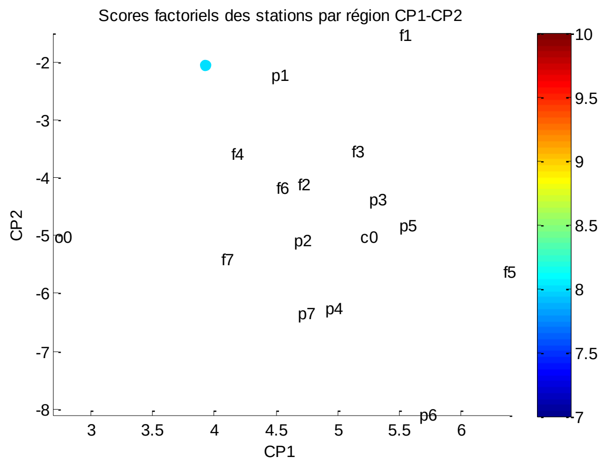
Mean date of annual minimum

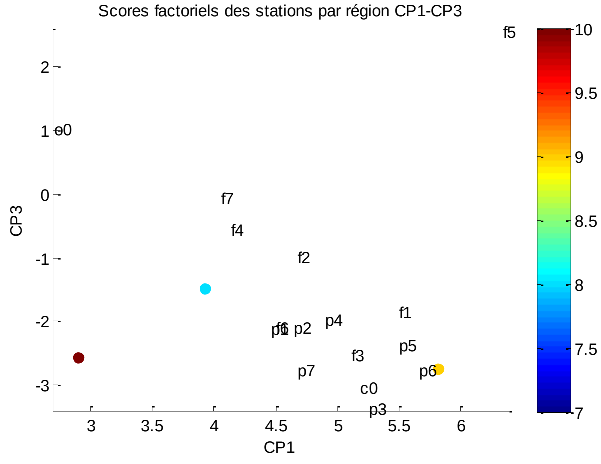


Multivariate assessment of HI: Outardes 4

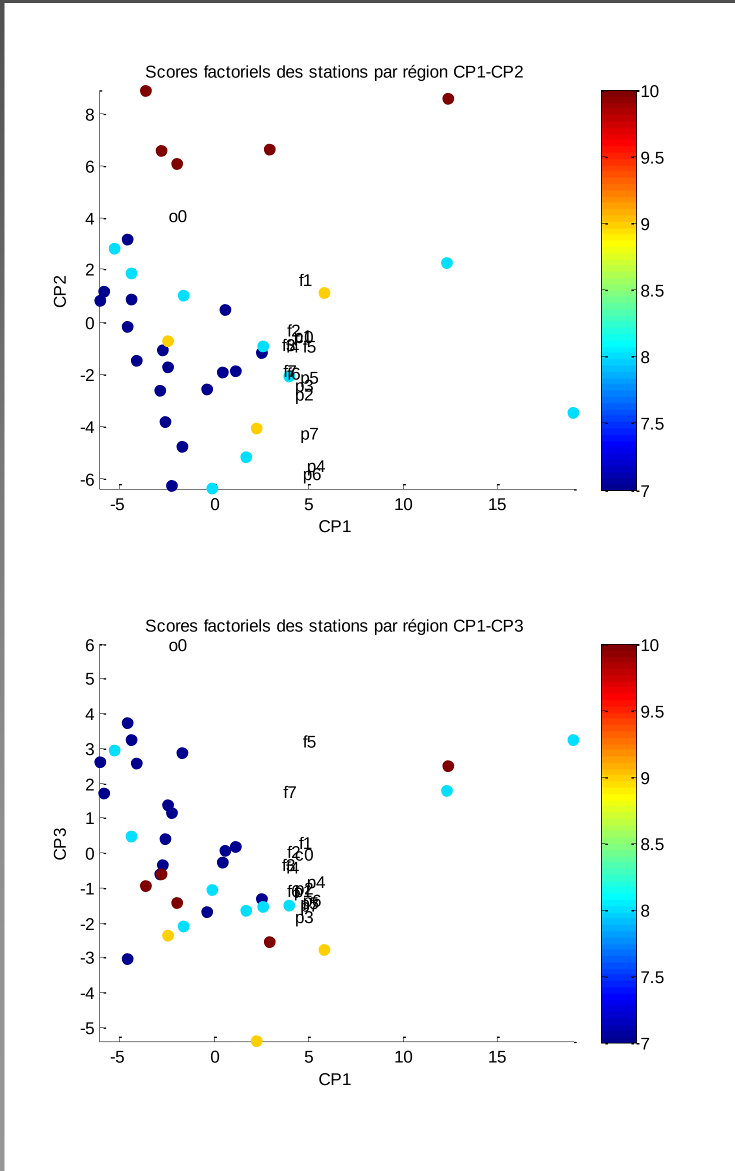


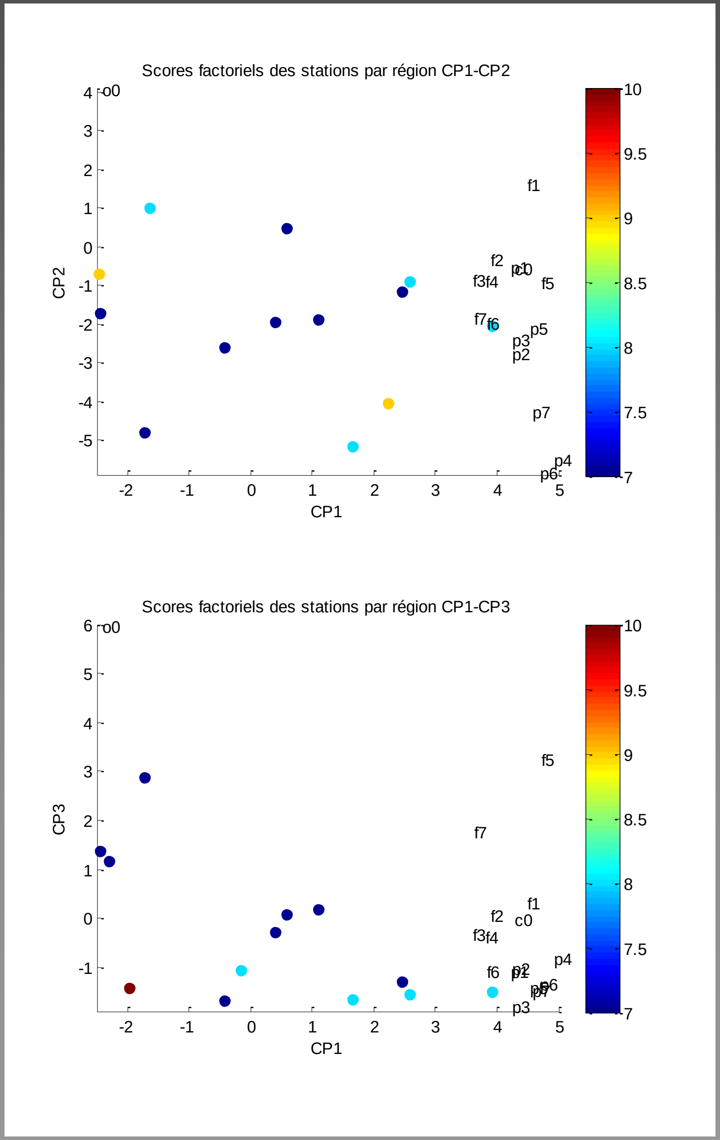






Multivariate assessment of HI: Manic 5





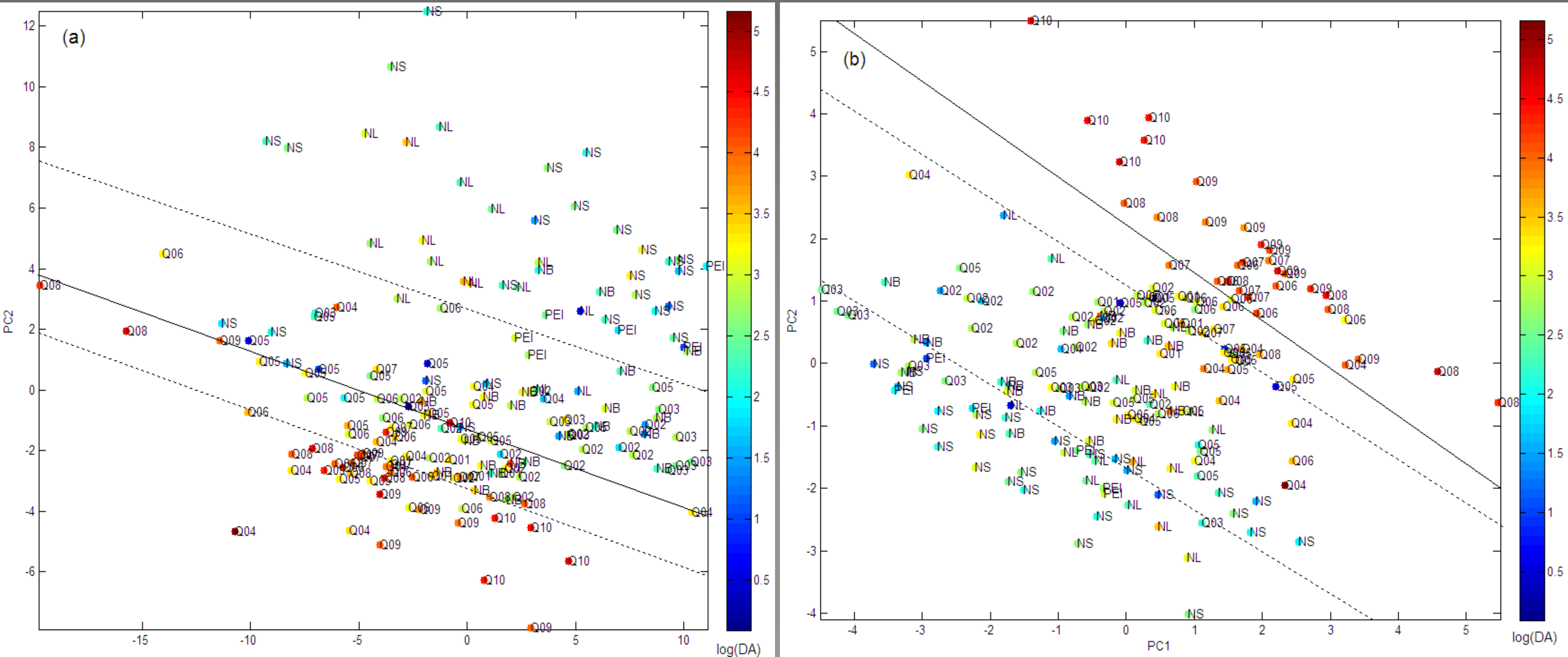
Conclusions

1. The NFP is a promising tool for instream flow studies. It needs to be validated against biological data.
2. Simple multivariate analysis can help to reduce the number of indices.
3. Indices can be calculated from hydrological simulations coupled to climate change scenarios
4. Timing and duration of low flow events will likely differ in the future for the 3 rivers.
5. Hydrological model error can be of the same order of magnitude as climate model errors/ biases.

Thanks!

3. PC scores of stations

- Regional differences are identified



4. HI Selection.

Criteria:

(1) Highest absolute values of loadings on PC1, PC2 et PC3

(2) High separation distance in PC space, orthogonality

(3) Each HI category must be represented in the final selection.

4. Selected List

HI	Définition	classe	Saturation relative		
			PC_1	PC_2	PC_3
QL5	Low flow with return period of 5 years	A	-1.00	-0.13	0.18
ML3	Minimum flow in March	A	-0.01	1.00	-0.19
DL24	Q90/Qmed	D	-0.86	-0.99	-0.14
DL16	Median duration of Q< 25th percentile	D	-0.85	0.45	0.04
FL3	Number of events under 5% of MAF	F	0.86	-0.17	0.20
MEMINJD	Average date of minimum flow	T	0.65	0.30	-0.80
MA3	Cv of MAF	V	0.77	-0.70	-0.01
CVANNMIN Jul-Sept	Cv of summer (Jul-Sept) low flows	V	0.57	-0.98	0.87