Development of Rating Curves Estimates for River Discharge using RADARSAT imagery

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1. BACKGROUND

Discharge measurement is an important parameter for many scientific and water management applications. This parameter is currently measured at ground-based gauging stations, for many rivers across the world. However, these gaging stations are scarce in high latitudes and in remote regions, are sometimes closed during maintenance operations and have a limited lifetime. The development of alternative methods to estimate discharge without in-situ measurements is thus essential.

Objectives

- To improve discharge estimates and forecasting in ungauged sites, through the development of width-discharge rating curves based on SAR imagery.

- To develop a non site-specific and fully automated method, applicable to rivers with a variety of fluvial morphology.

2. WIDTH-DISCHARGE RATING CURVES METHODOLOGY

Innovative aspect of the method

Unlike previous studies, the method **only requires SAR backscattering values and discharge values**. These few requirements for the modelling process descreases input uncertainty levels.

Overview of the method
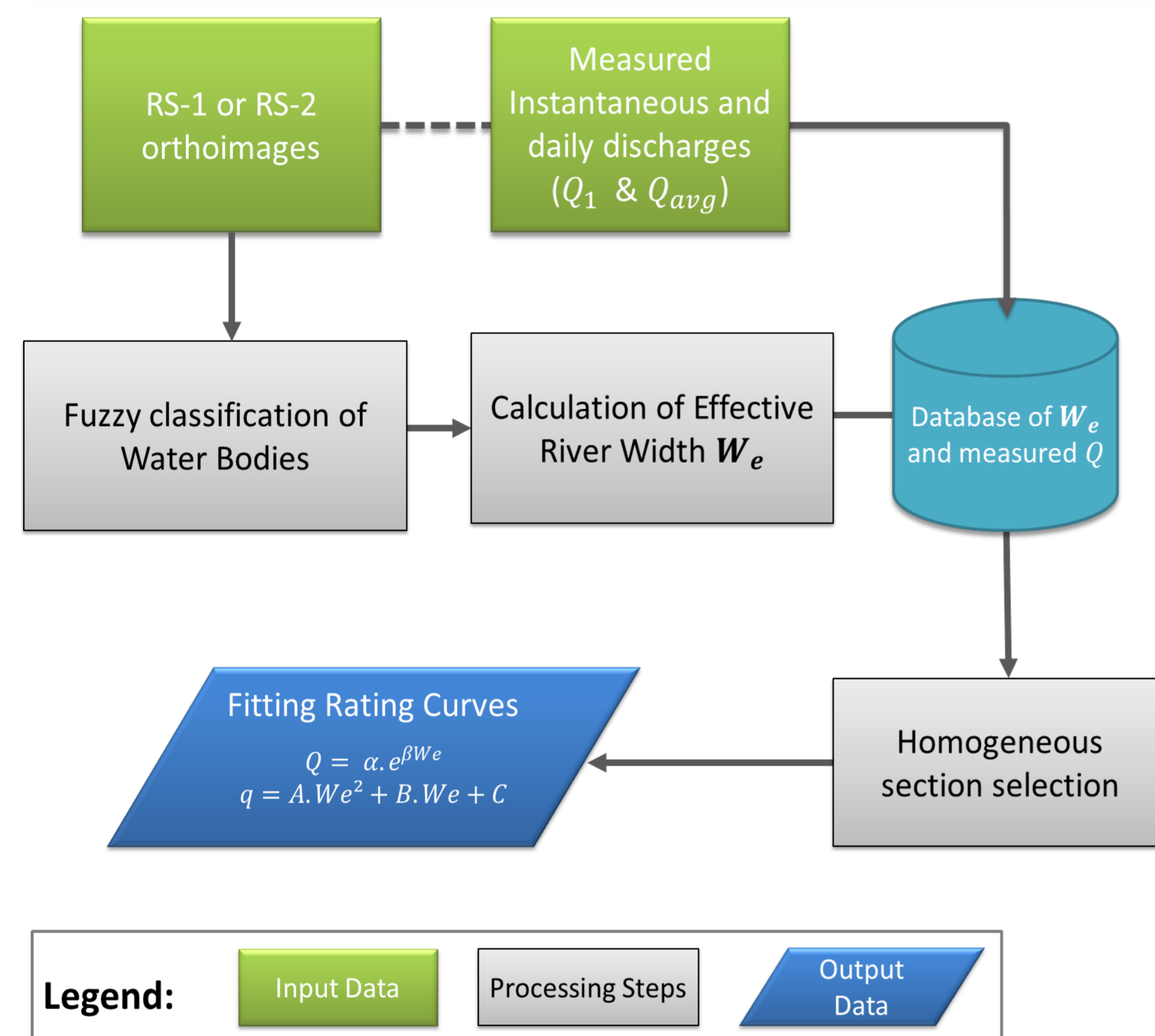
Overview of the width-discharge rating curves methodology

DATA PROCESSING

- Radar images are geometrically corrected and intercalibrated

- Main river stream is isolated from the hydrographic network

- Water pixels identified using fuzzy classification theory. Pre-defined fuzzy threshold (A: -18 dB and B: -16.5 dB) are used

- Homogeneous sections are then defined according to slope, sinuosity and river width (approach modified from Rosgen, 2004)

- River mean width We is estimated at each section, according to the fuzzy membership of each pixel to the « water class »

- Rating curves are estimated at each section, using We and discharge Q

3. DATASETS AND SELECTED STATIONS

Datasets

RADARSAT-1 AND 2 OBSERVATIONS

Images selection criteria:
- Fine acquisition mode (spatial resolution of 8 m)
- HH Polarization
- No snow or ice cover (visual inspection)

Hydrometric stations selection criteria:
- Minimum of 10 images per station (RS-1 or RS-2, in ascending OR descending mode)
- Availability of instantaneous or daily flow records at the time /day of SAR images acquisitions
- Various hydrological and geomorphological characteristics.

ANCILLARY DATA

- Instantaneous or daily flow rates between 1997 and 2013 (CEHQ and Env. Canada)
- Hydrographic network (National Hydro Network from Natural Resources Canada)
- Elevation database at the 1: 50 000 scale (Natural Resources Canada)
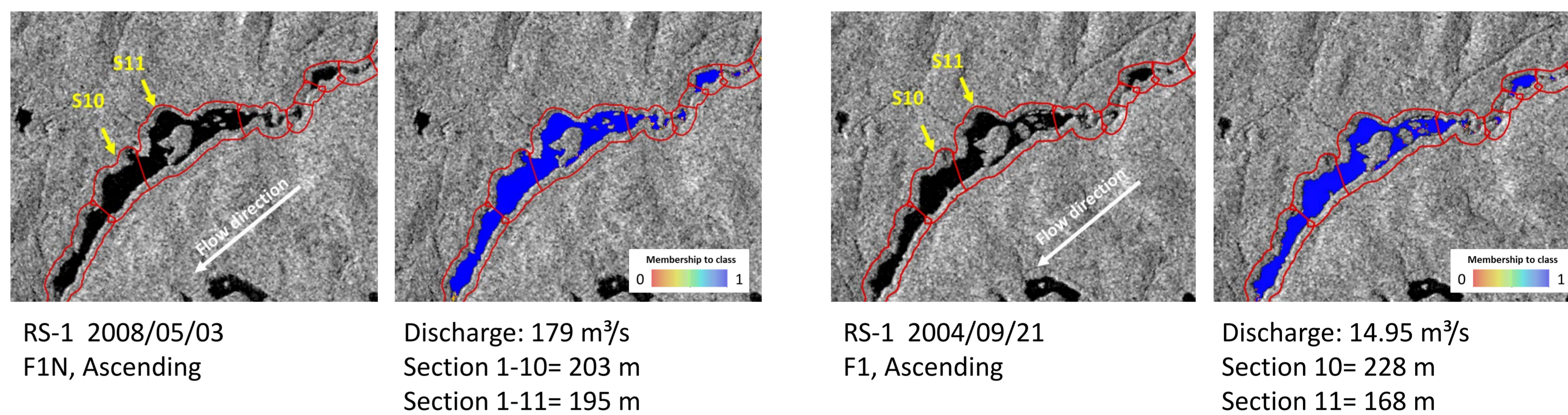
Selected stations

8 stations with different characteristics:
Size of watershed at station location, sinosity, lenght of river upstream of the station, difference between max and min discharge for the RS-1 or RS- 2 images avalaible.

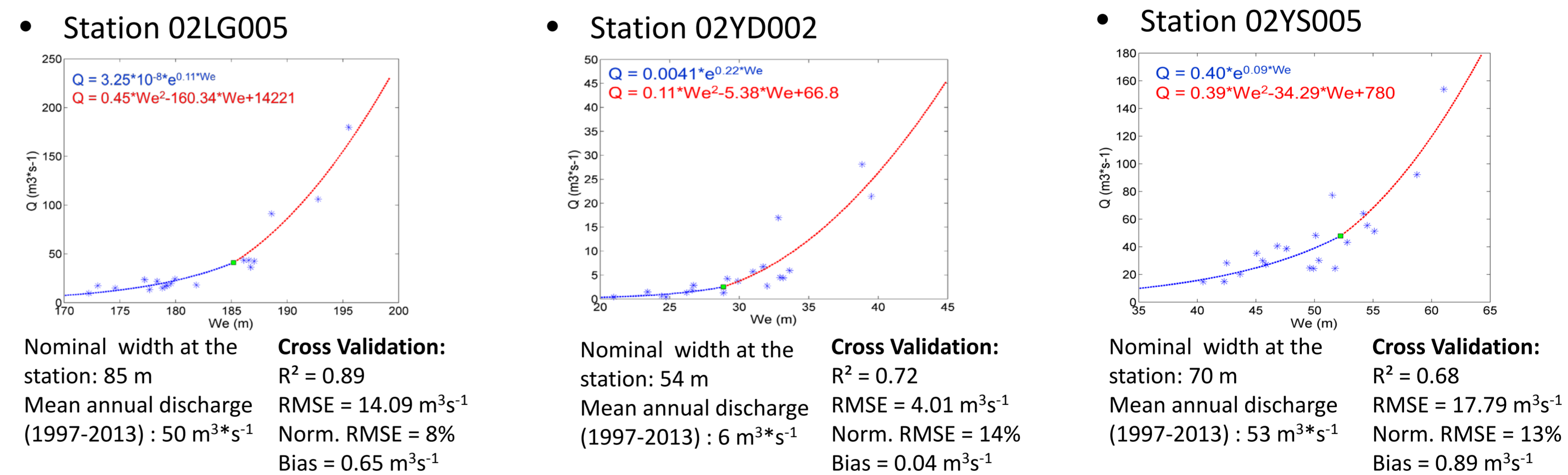| Station	Province	Number of RS images	Orbit	Size of watershed*
01BV006	NB	13 RS-2	Asc.	130 km²
02OJ026	NB	12 RS-2	Desc.	345 km²
02YS005	TN	16 RS-2	Desc.	2000 km²
01AQ002	NB	20 RS-1	Desc.	239 km²
02LE025	QC	41 RS-1	Desc.	879 km²
02LG005	QC	25 RS-1	Asc.	6768 km²
02OB017	QC	30 RS-1	Asc.	1263 km²
02YD002	NL	22 RS-1	Desc.	152 km²

* Estimated at station location

4. RESULTS

Examples of Water presence probability and We estimation: Station 02LG005 (Gatineau River, QC)

RS-1 2008/05/03
F1N, Ascending

Discharge: 179 m³/s
Section 1-10= 203 m
Section 1-11= 195 m

RS-1 2004/09/21
F1, Ascending

Discharge: 14.95 m³/s
Section 10= 228 m
Section 11= 168 m

Example of SAR rating curves for somes of the selected stations

Station 02LG005
$Q = 3.25*10^{-8}*e^{0.11*We}$
$Q = 0.45*We^2-160.34*We+14221$

Nominal width at the station: 85 m
Mean annual discharge (1997-2013) : 50 m³*s⁻¹

Cross Validation:
R² = 0.89
RMSE = 14.09 m³s⁻¹
Norm. RMSE = 8%
Bias = 0.65 m³s⁻¹

Station 02YD002
$Q = 0.0041*e^{0.22*We}$
$Q = 0.11*We^2-5.38*We+66.8$

Nominal width at the station: 54 m
Mean annual discharge (1997-2013) : 6 m³*s⁻¹

Cross Validation:
R² = 0.72
RMSE = 4.01 m³s⁻¹
Norm. RMSE = 14%
Bias = 0.04 m³s⁻¹

Station 02YS005
$Q = 0.40*e^{0.09*We}$
$Q = 0.39*We^2-34.29*We+780$

Nominal width at the station: 70 m
Mean annual discharge (1997-2013) : 53 m³*s⁻¹

Cross Validation:
R² = 0.68
RMSE = 17.79 m³s⁻¹
Norm. RMSE = 13%
Bias = 0.89 m³s⁻¹

5. CONCLUSIONS AND PERSPECTIVES

- The fuzzy logic approach allows precise detection of water and the calculation of We from RADARSAT-1 or 2 imagery

- River discharge can be estimated from RADARSAT imagery for different river widths

- For building a « virtual hydrometric station », we reccomand to :
  - Choose the best river section in terms of We dynamic related to river discharge
  - Use a set of images acquired from the same orbit (Asc. or Desc.), with close or similar incidence angles
  - Calibrate the SAR rating curve over a complete season (ice-free period)

6. ACKNOWLEDGEMENT