Source : CICOS website

Spatial altimetry to assess hydropower potential of the Congo basin

Windhoek, April 2nd

AGENDA

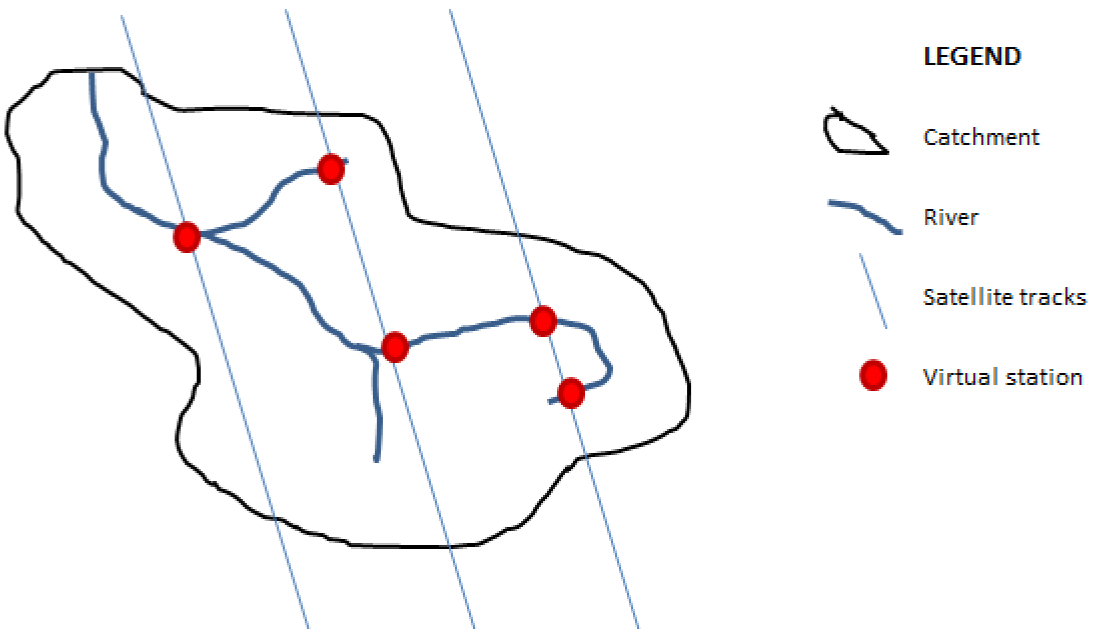
1. CONTEXT AND PROJECT BACKGROUND
2. INTRODUCTION
3. METHODOLOGY
4. DISCUSSIONS
5. CONCLUSION

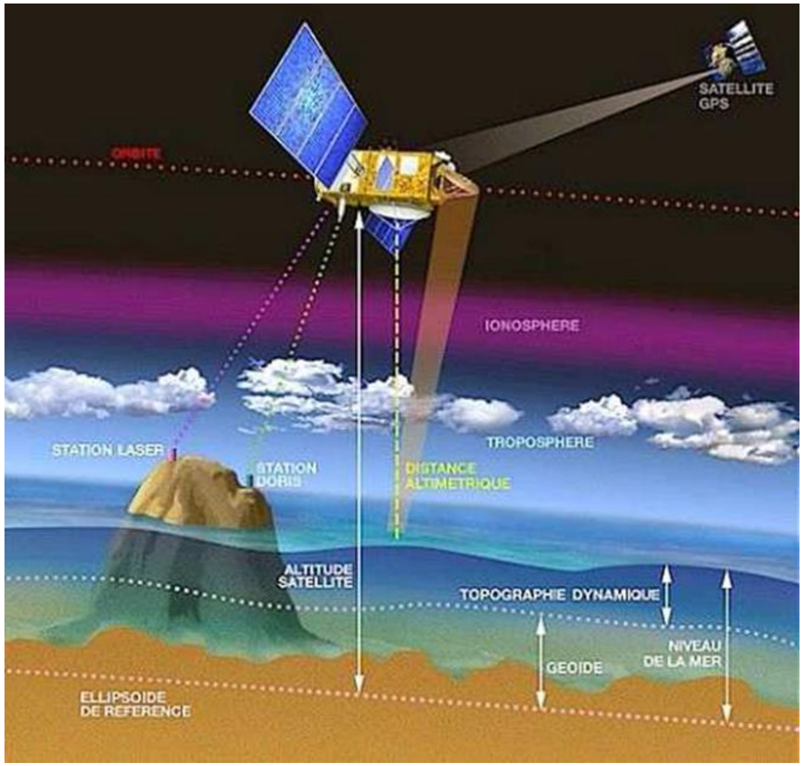
CONTEXT AND PROJECT BACKGROUND

- **SPATIAL HYDROLOGY WORKING GROUP**
  - Objective:
    - develop operational applications using satellite data as input, and especially spatial altimetry, in context with few data
    - prepare French-US SWOT program (Surface Water Ocean Topography), a satellite that will be launched in 2021
  - The Congo Basin is defined as first pilot basin
  - AFD as funding agency
  - CNR as member of the 8 French entities involved in the project

PRINCIPLES OF SPATIAL ALTIMETRY

- Altitude measurement of water bodies by satellites
- Intersections between rivers and satellite tracks are called virtual stations
- Accuracy around 10 cm





INTRODUCTION – COMPANIES' PROFILES

- CICOS

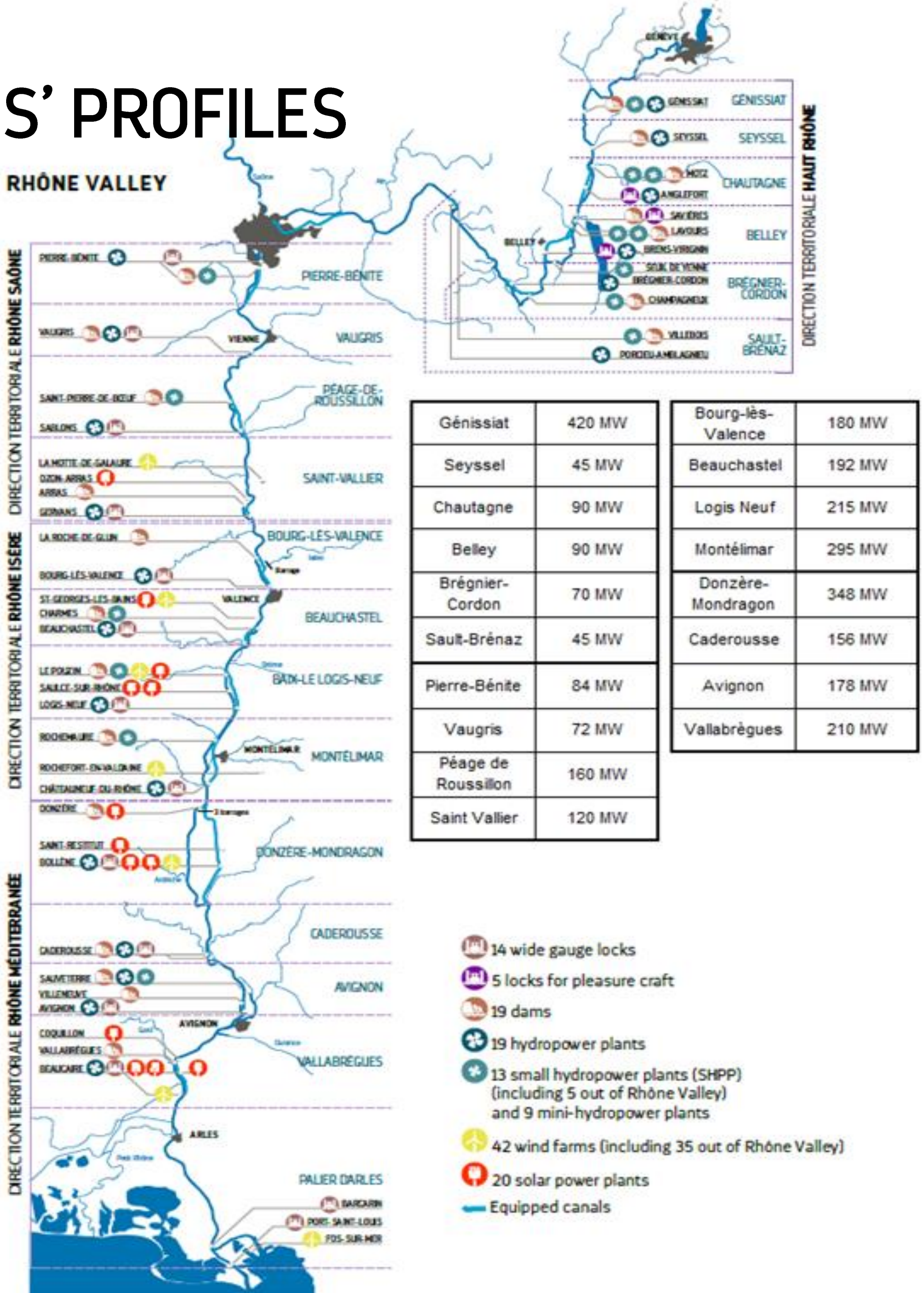
CICOS (International Commission for Congo-Oubangui-Sangha basin)	
Creation date	1999
Member States	Rep. of Cameroon (1999) Central African Rep. (1999) Rep. of Congo (1999) Dem. Rep. of Congo (1999) Rep. of Angola (2007 as observer, 2015 as member) Rep. of Gabon (2010)
Missions :	1999 : inland navigation promotion 2007 : integrated water resources management

INTRODUCTION – COMPANIES' PROFILES

- CNR, holder of the Rhone River concession in South-East of France with three historical missions:

Hydropower (3000MW) | Inland navigation | Irrigation

- CNR offers technical support in the fields of hydropower, navigation and river engineering
- CNR, member of French SWOT working group on space altimetry



Génissiat	420 MW
Seyssel	45 MW
Chautagne	90 MW
Belley	90 MW
Brégnier-Cordon	70 MW
Sault-Brénaz	45 MW
Pierre-Bénite	84 MW
Vaugris	72 MW
Péage de Roussillon	160 MW
Saint Vallier	120 MW

Bourg-lès-Valence	180 MW
Beauchastel	192 MW
Logis Neuf	215 MW
Montélimar	295 MW
Donzère-Mondragon	348 MW
Caderousse	156 MW
Avignon	178 MW
Vallabrègues	210 MW

INTRODUCTION – CONTEXT AND OBJECTIVE

- **CICOS AND HYDROPOWER**
  - SDAGE: CICOS has adopted a master plan for water development and management ("SDAGE")
  - Program of measures 2016-2020:
    - Identification of projects within the framework of the "SDAGE"
    - Three strategic objectives: economic development of the region, social equity and preservation of environment
  - Design and implementation of micro and pico-hydropower plants associated to drinking water supply is part of the main projects identified

INTRODUCTION – CONTEXT AND OBJECTIVE

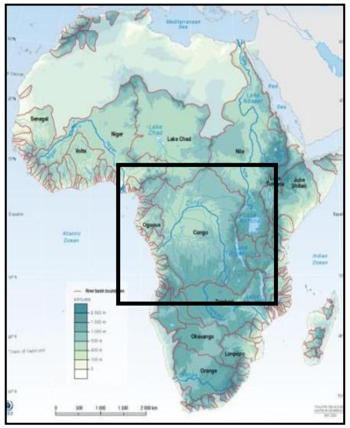
- OBJECTIVES
  - Assess hydropower potential of river sections on the Congo and Ogooué basins
  - Use spatial altimetry data and study its added-value
  - Subsequently identify sites to be equipped, in cooperation with states Rural Electrification Agencies

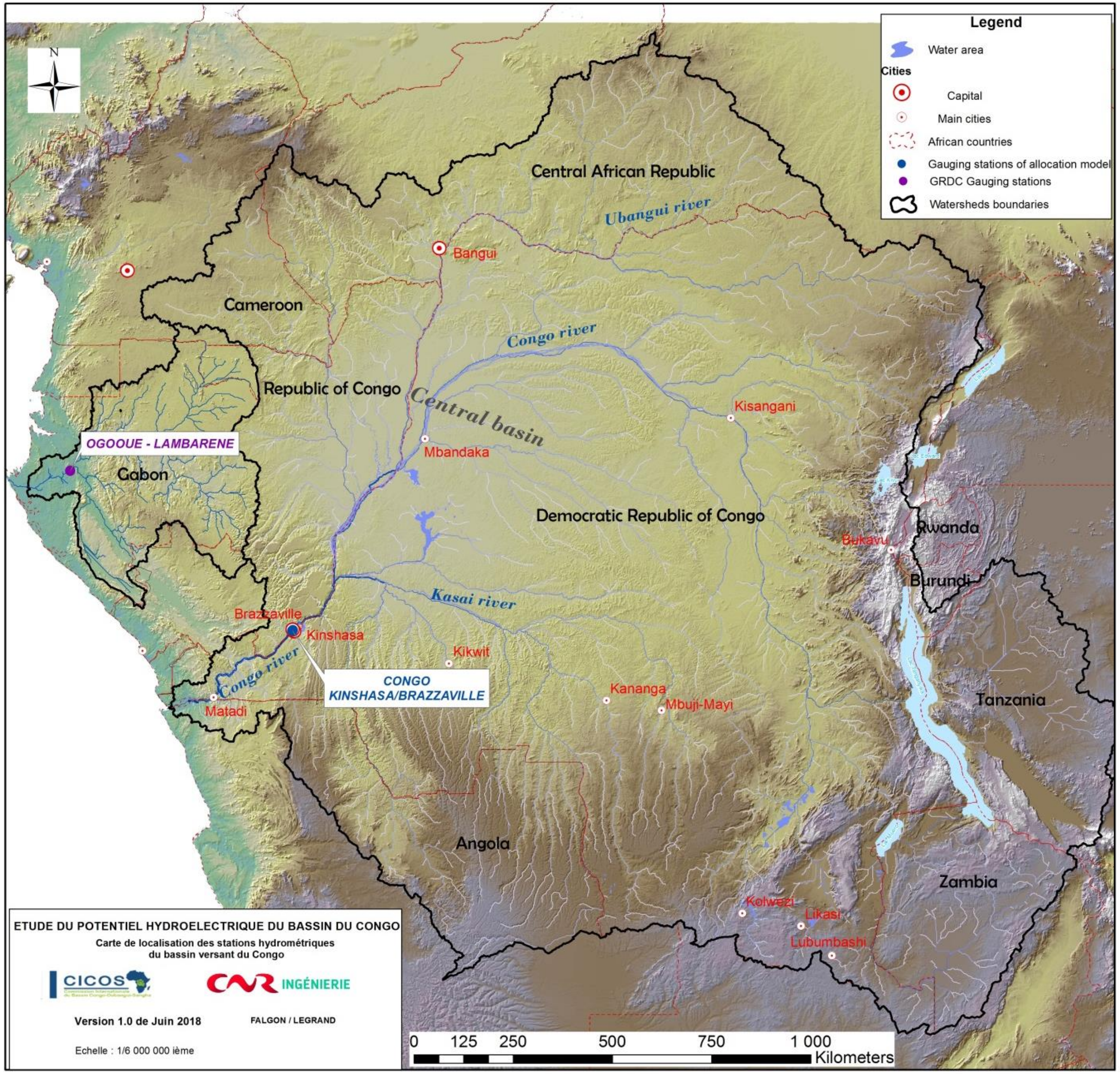
METHODOLOGY – CASE STUDIES

• CATCHMENTS' MAIN CHARACTERISTICS

River	Congo	Ogooue
Catchm. Size	3.8 M km^2	224,000 km^2
Mean annual flow	41,000 m^3/s at Kinshasa / Brazzaville[1]	4,700 m^3/s at Lambarene[2]

1. Source: CICOS
2. Source: GRDC website





METHODOLOGY – DATA

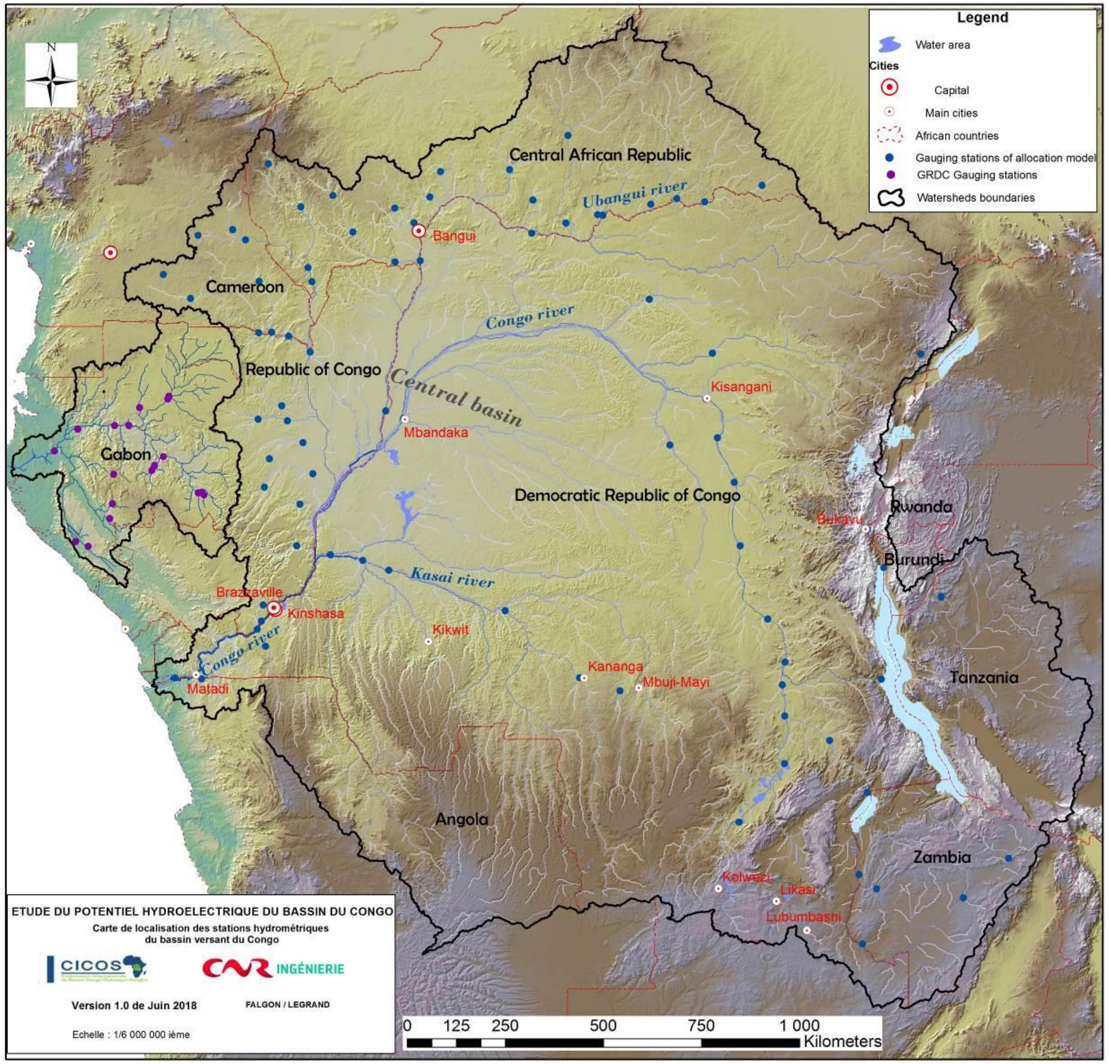
• GAUGING STATIONS

Type	Hydrological data
Source (Congo River)	Runoff data observed and reconstructed[1]
Comments	82 stations Period: 1948-2012 Time step: Daily
Source (Ogooué River)	GRDC database
Comments	18 stations Period: varying Time step: Annual mean

1. Runoff reconstructed in a previous project (source CICOS / BRLi)

HYDROELECTRIC POTENTIAL STUDY ON THE CONGO BASIN

Location map of gauging stations



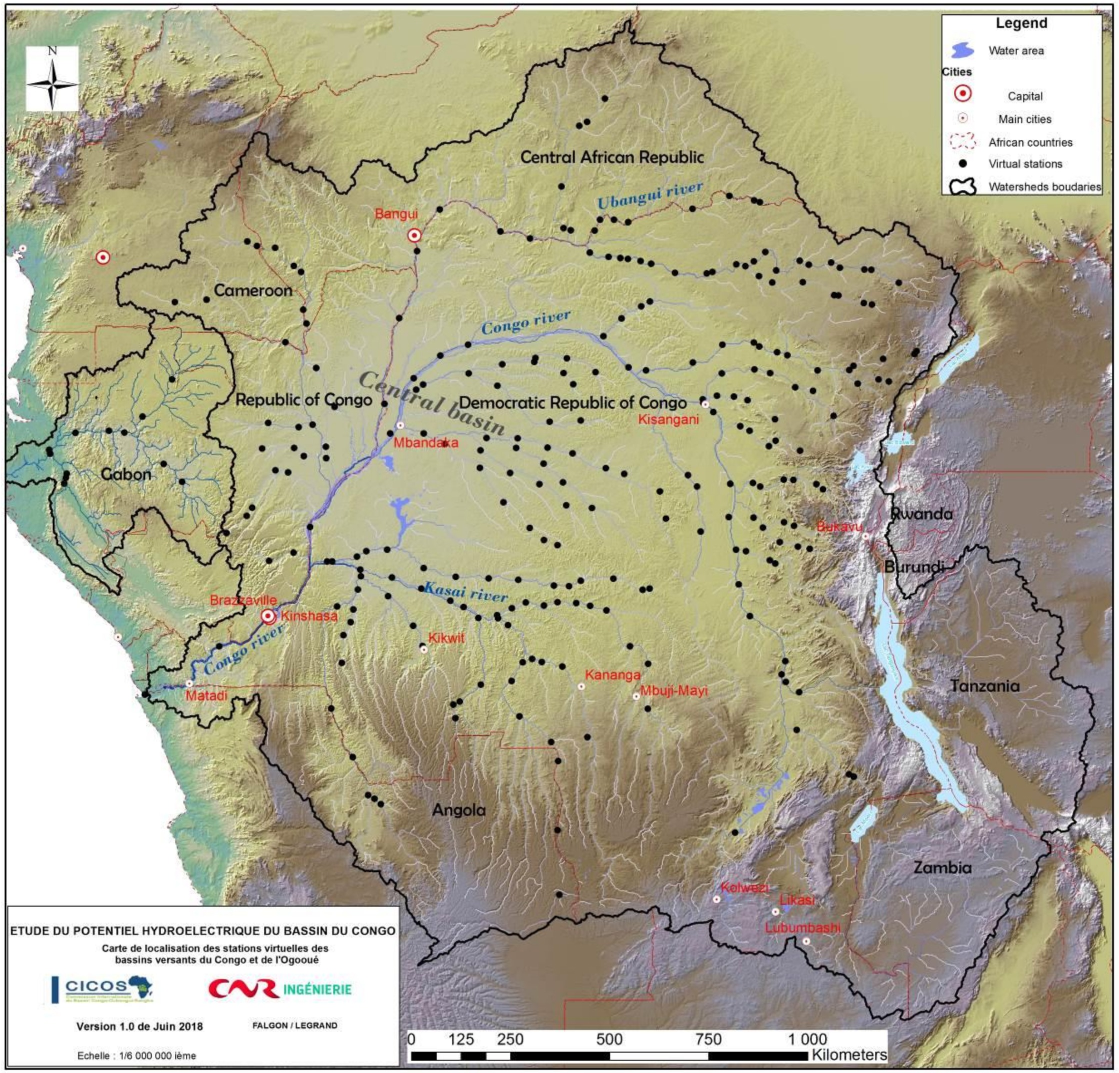
METHODOLOGY – DATA

• VIRTUAL STATIONS

Type	Virtual stations
Source (Congo River)	Data from CICOS / IRD-LEGOS
Comments	745 stations before selection 253 stations after selection
Source (Ogooué River)	Hydroweb Theia
Comments	21 stations before selection 13 stations after selection

HYDROELECTRIC POTENTIAL STUDY ON THE CONGO BASIN

Location map of virtual station



METHODOLOGY – DATA

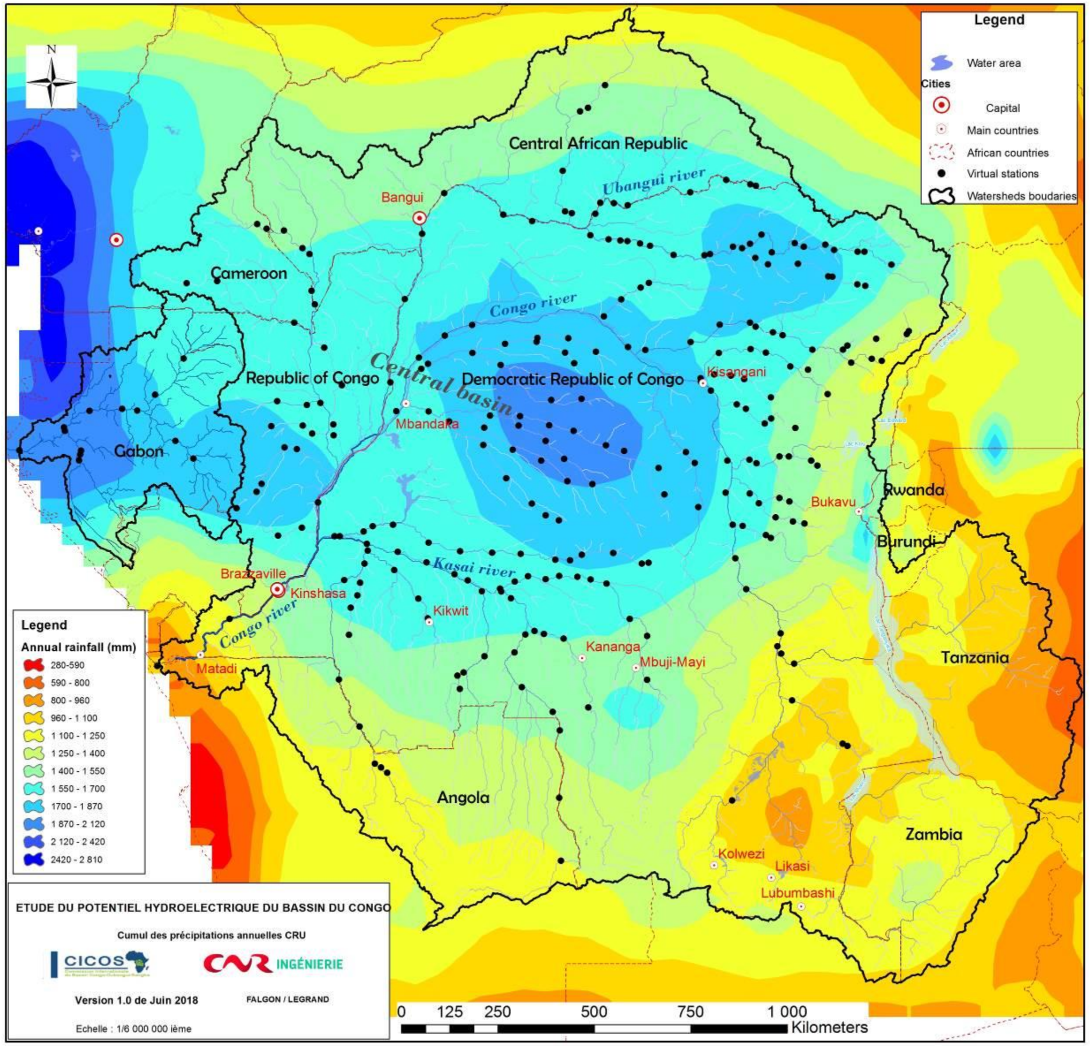
• RAINFALL AND DEM

Type	Rainfall
Source	CRU observed rainfall
Comments	Resolution: 0.5° grid Period: 1901-2016 Time step: Monthly

Type	DEM
Source	HydroSHEDS
Comments	Resolution: 30'' (926m at the Equator)

HYDROELECTRIC POTENTIAL STUDY ON THE CONGO BASIN

ANNUAL RAINFALL CRU (Climate Research Unit) - 0.5° GRID



METHODOLOGY – IN A NUTSHELL

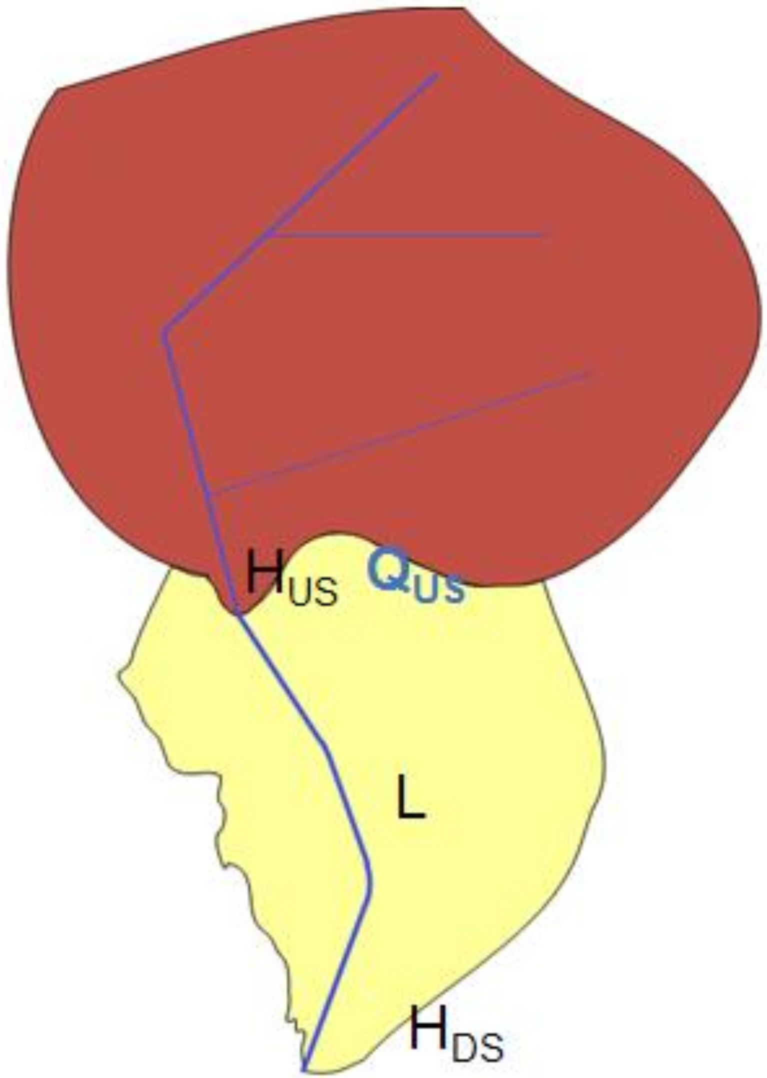
- 3 MAJOR STEPS

1. Calculate water head between two consecutive virtual stations

$$h = H_{US} - H_{DS}$$

2. Extrapolate discharge at virtual stations (Q_{US})

3. Calculate linear power potential for each river section (MW/km)



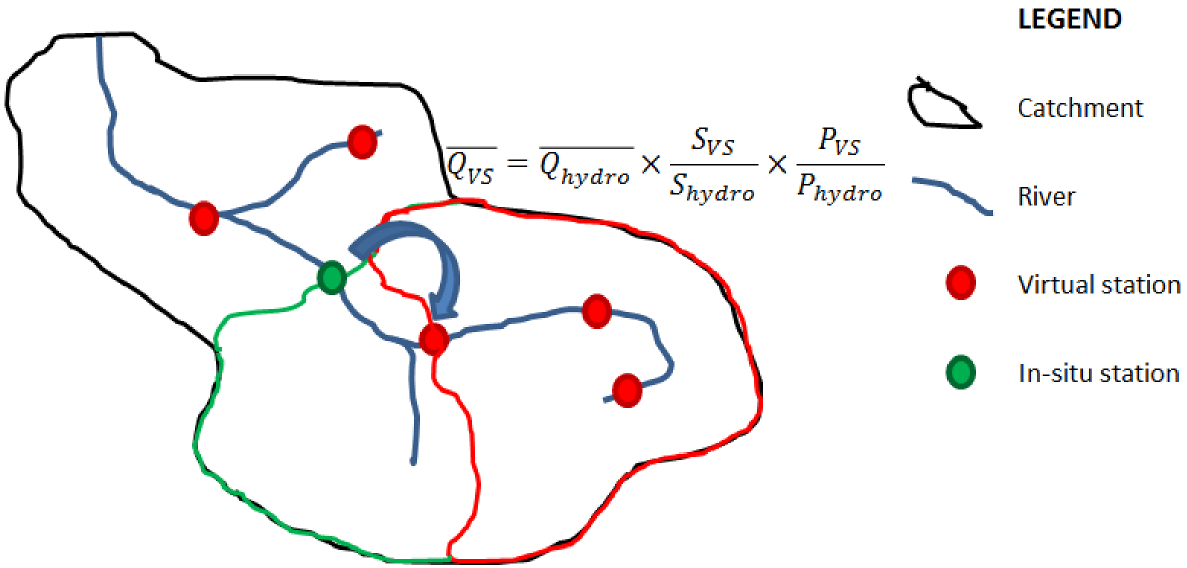
Representation of a catchment with two virtual stations (US: upstream, DS: downstream).

METHODOLOGY – STEP BY STEP

- **STEP 1: CALCULATE WATER HEAD BETWEEN TWO CONSECUTIVE VIRTUAL STATIONS**
  - Preprocessing of virtual stations datasets to:
    - Identify and delete outliers
    - Select relevant subset of stations (number of data, distance to other stations…)
    - Accurately locate virtual stations on the DEM
  - Calculation of average water levels for each virtual station
  - Calculate catchment area at each virtual station

METHODOLOGY – STEP BY STEP

- **STEP 2: EXTRAPOLATE DISCHARGE AT VIRTUAL STATIONS**
  - Calculation of mean annual discharge using observed or reconstructed daily flow for 82 gauging stations
  - Identification of a reference in-situ station for each virtual station
  - Extrapolation of virtual stations mean discharge (Q) using:
    - Rainfall mean annual data (P)
    - Catchment sizes (S)



$$\overline{Q_{VS}} = \overline{Q_{hydro}} \times \frac{S_{VS}}{S_{hydro}} \times \frac{P_{VS}}{P_{hydro}}$$

METHODOLOGY – STEP BY STEP

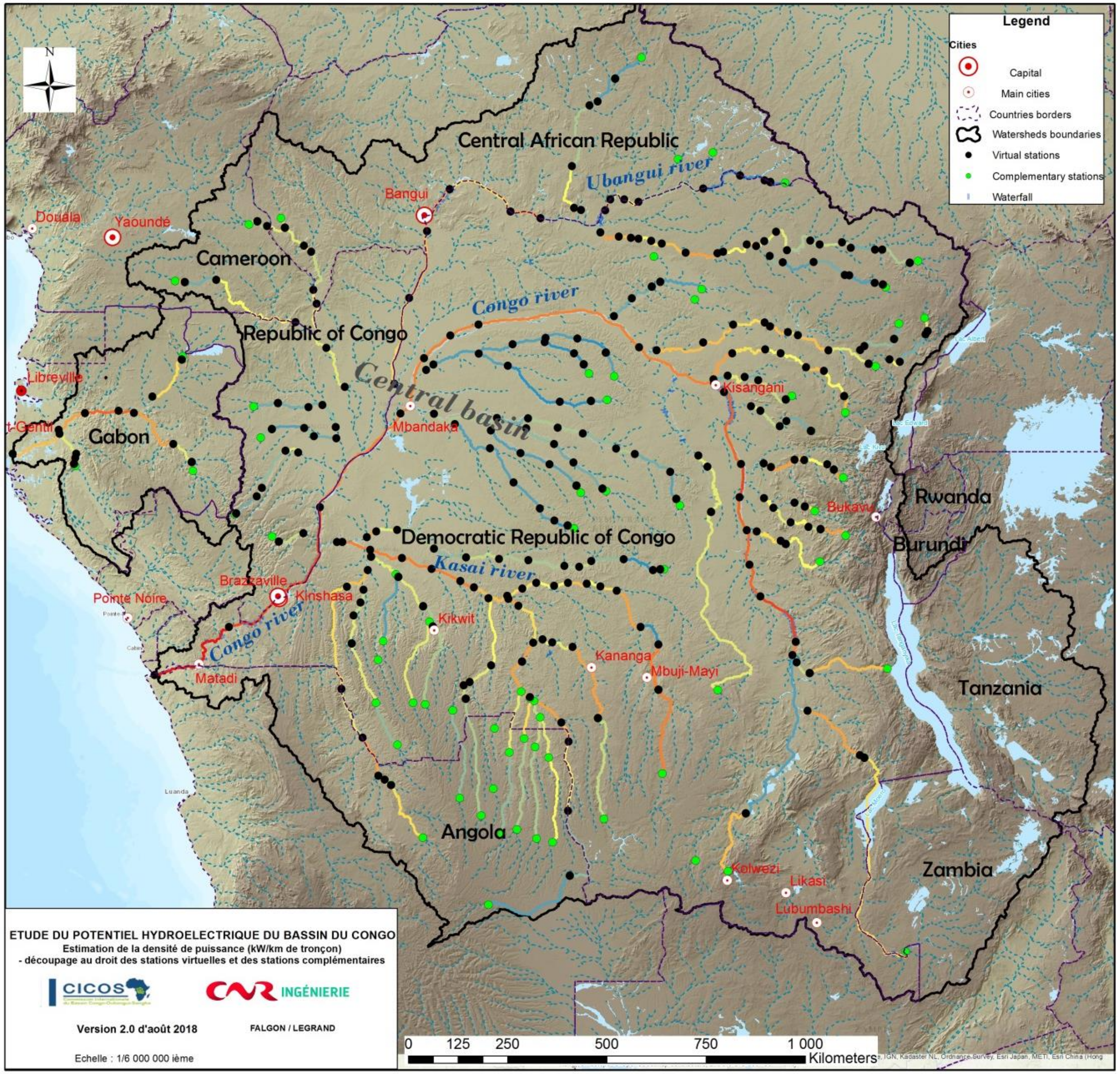
- **STEP 3: CALCULATE LINEAR POWER POTENTIAL FOR EACH RIVER SECTION (MW/KM)**
  - Assessment of power potential: $P \approx 8.\ h.\ Q$
    - h average head between two consecutive virtual stations
    - Q mean annual discharge at the upstream station
  - Transformation into linear power potential (LPP) by dividing P by the length L of the river section between the two corresponding consecutive virtual stations
    - $LPP = P / L$

METHODOLOGY – RESULTS

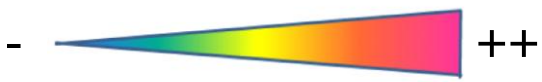
- **IDENTIFICATION OF RIVER SECTIONS WITH HIGH POTENTIAL (LPP)**

– Sections with high potential
  - Sections with high flow (Congo, Ubangui, Kasai)
  - Sections with steep slopes (Congo upstream Kisangani)

– Sections with low potential
  - Central basin
  - Smallest rivers



LPP scale



DISCUSSIONS – ABOUT THE METHOD

- **ADVANTAGES**
  - Method identifying river sections with the most interesting densities of hydropower potential
  - Method based on innovative data
  - Method replicable for other catchments with similar characteristics in terms of river width and catchment size

- **DRAWBACKS**
  - The technically and economically feasible potential has to be derived from the linear power potential
  - The identification of a site requires additional information: proximity of energy consumption points, affordable electricity price, technical information, etc.

DISCUSSIONS – ABOUT SPATIAL ALTIMETRY

• SPATIAL ALTIMETRY: CURRENT LIMITATIONS

– The density of virtual stations varies on the basins:

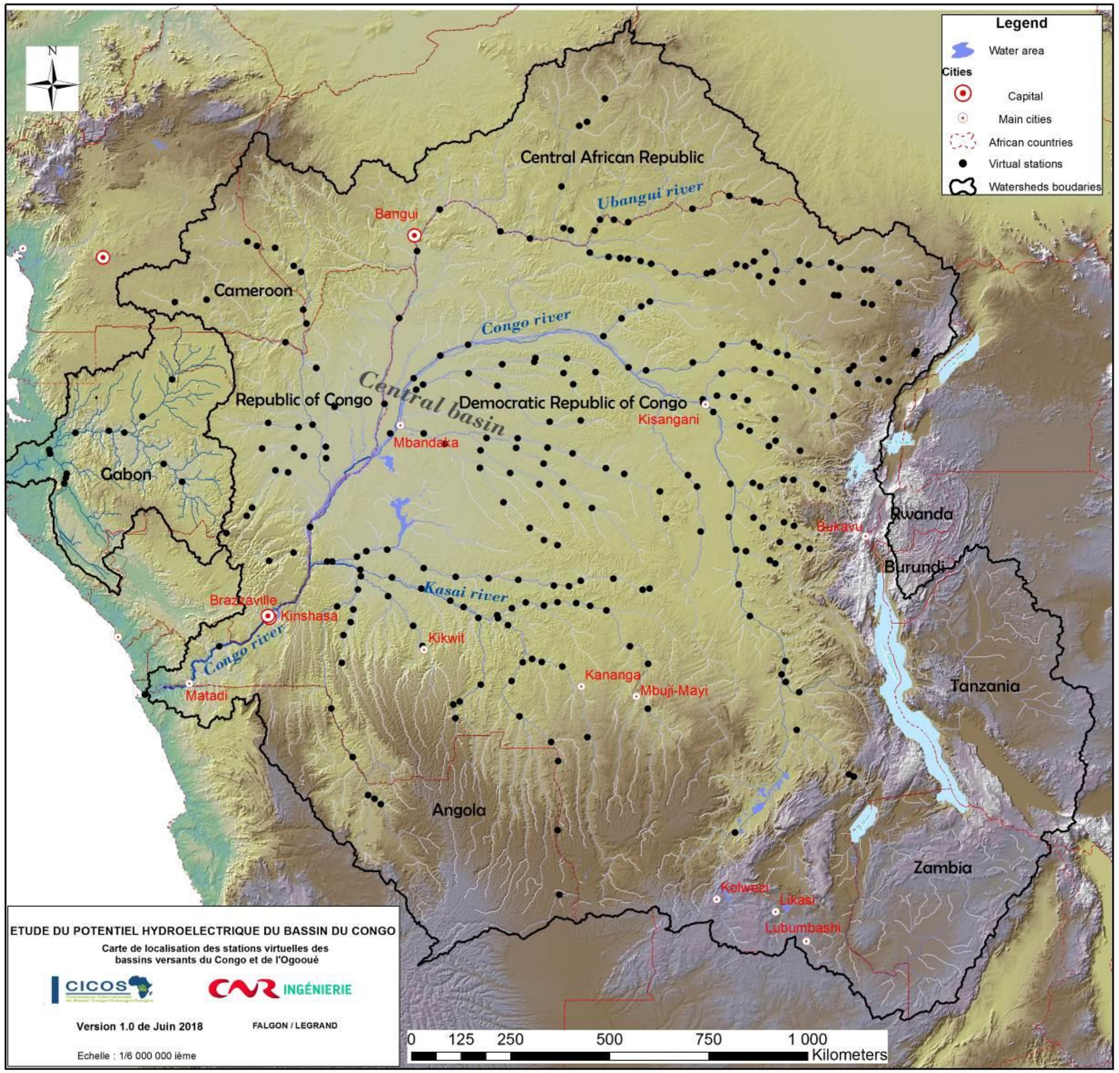
- Over-representation in some areas (largest rivers, Central basin)
- Under-representation in other areas (mountainous areas and northern end of the basin)

– Spatial altimetry is not spatialized

- The use of a DEM is a good alternative for a full coverage of the basin and the choice of relevant river sections

HYDROELECTRIC POTENTIAL STUDY ON THE CONGO BASIN

Location map of virtual station

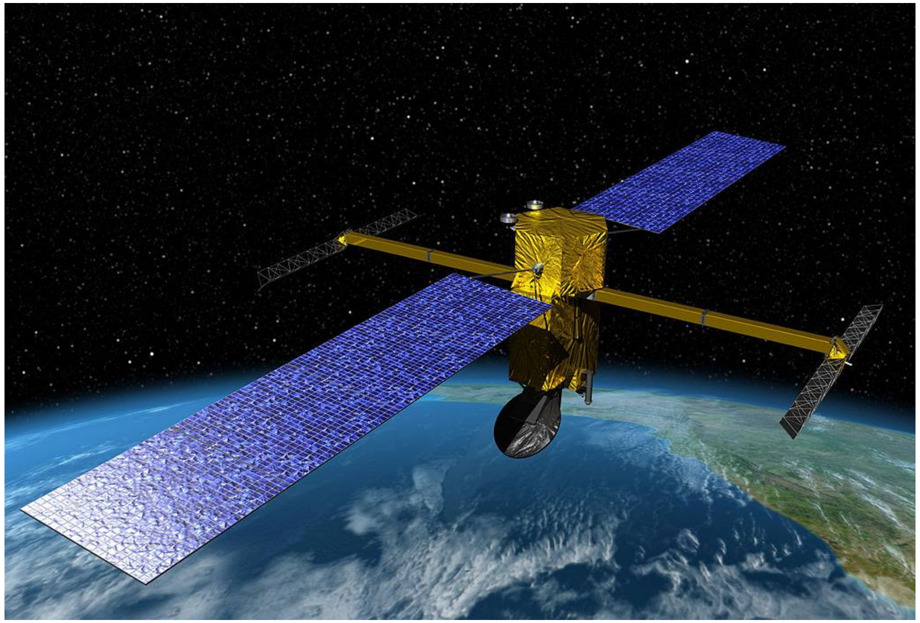


DISCUSSIONS – ABOUT SPATIAL ALTIMETRY

• SPATIAL ALTIMETRY: SWOT PERSPECTIVES

– SWOT will provide continuous information of altitude and slope, with added-value for:

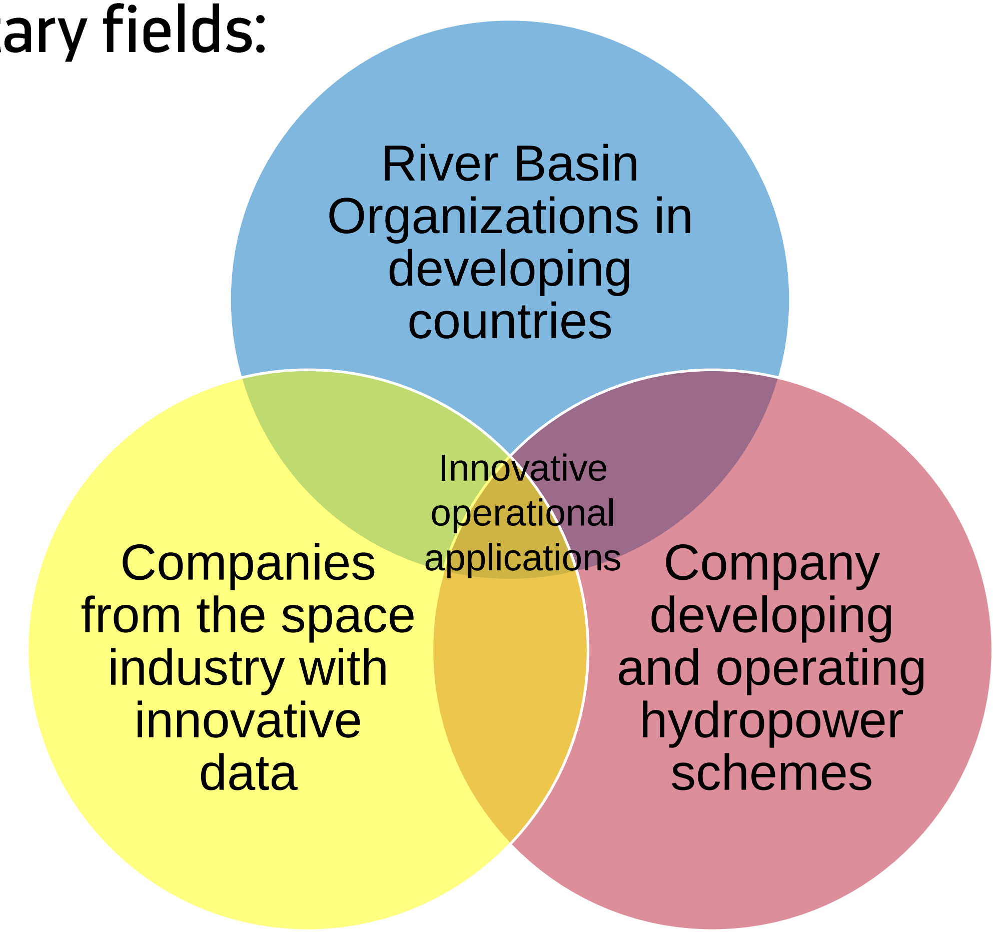
- The global methodology presented
- The local knowledge of the river while studying a specific site



Source: 'Surface Water Ocean Topography Mission' Wikipedia page (consulted March 1st, 2019)

CONCLUSION

- SWOT: a new technology with interesting perspectives available in 2021
- Innovative data benefiting to the knowledge of water resources in scarce data areas
- Partnership between organizations and companies operating in complementary fields:



L'énergie au cœur des territoires

Merci de votre attention!

Thank you for your attention!

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