# SWOT Discharge Estimation for Multichannel Rivers

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## The Importance of Multichannel Rivers

Are multichannel rivers important for SWOT's global discharge goals? Multichannel rivers, "*anabranching*" [1] (including "*anastomosing*" [2]) and "*braided*" [3], are quite diverse and occur frequently in nature. Figure 1 illustrates the variety of multichannel rive planforms included as principal targets for our work.

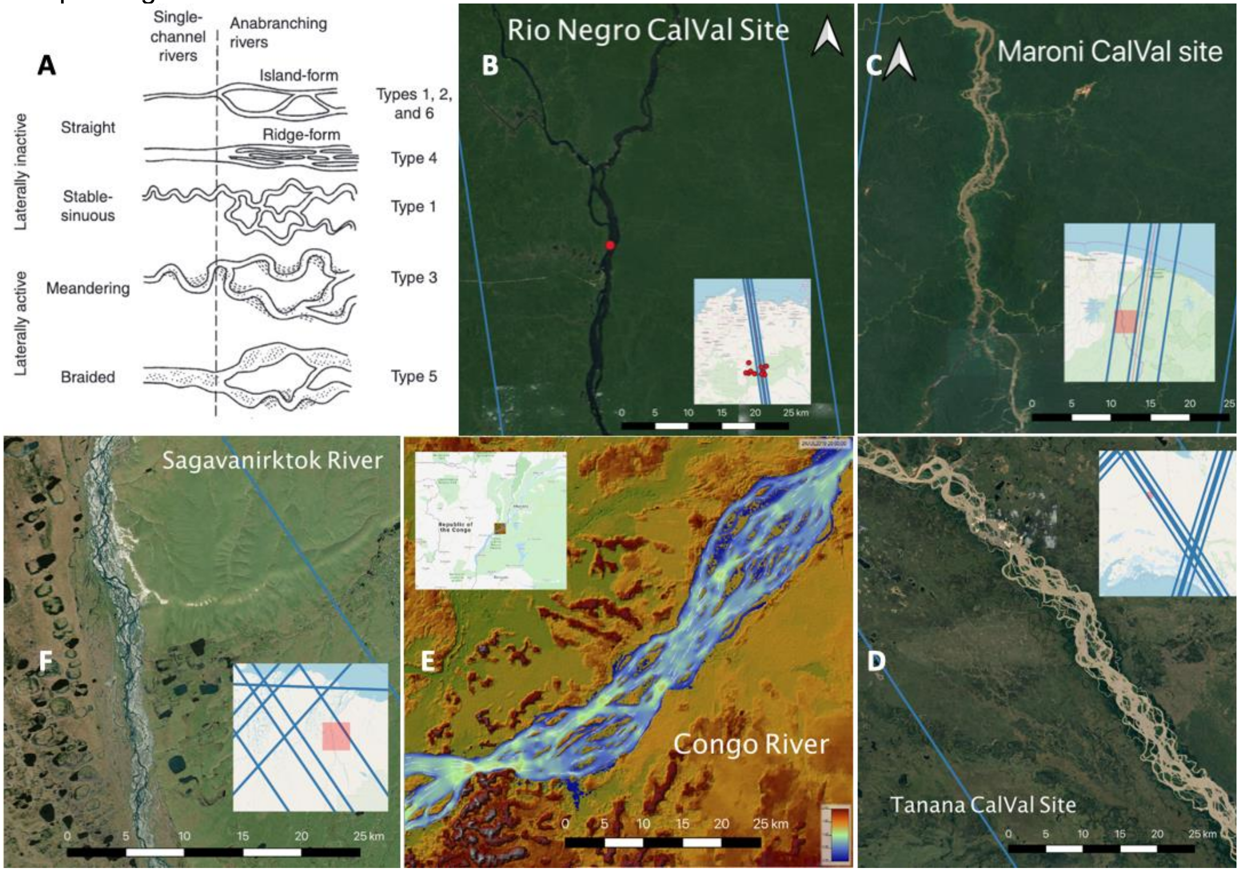

***Figure 1.*** A. Classification of multichannel river types (Gerald C. Nanson and Knighton 1996). (B-E) Some of the anabranching rivers used in this study, with increasing size and complexity going clockwise. (F) Braided river example. The SWOT one-day orbit during the 1-day repeat period is shown in blue when the rivers are imaged in that initial 3-month phase. (Congo topography and flow image courtesy of collaborators Trigg and Tshimanga).

Latrubesse [4] argues that anabranching rivers are the ultimate end member adjustment of mega rivers (see Table 1), and 9 out of the world's 10 largest rivers are dominantly anabranching. Furthermore, anabranching or braiding patterns are prevalent in many of the world's rivers, independent of size, when the slope is small, and are dominant river types in many places, such as the tropics and Boreal/Arctic regions. Larger anabranching systems are also typically integrators of upstream discharge from simpler rivers, so monitoring their discharge is an important gauge of the hydrology of a basin. Due to their typically large sediment transport and heterogeneous habitats, they play a significant role in determining downstream geomorphology [5,6] and are hypothesized to contain ecological diversity hotspots [7]. Due to their large surface area, they contribute significantly to the production of greenhouse gases [8,9]. Finally, given the large discharge of many anastomosing rivers [4], improving discharge estimates even by a few percent will be a significant aid in closing continental water budgets.

Table 1. World's largest rivers by dominant channel pattern, after Latrubesse [4]

| River | Country to the mouth | Mean annual Discharge ($m^3/s$) | Drainage area ($10^3$ $km^2$) | Annual $Q_s$ (Mt/year) | Sediment yield ($t/km^2year$) | Dominant channel pattern |
|---|---|---|---|---|---|---|
| Amazon | Brazil | 209,000 | 6100 | ~1000 | 167 | Anabranching |
| Congo | DR Congo | 40,900 | 3700 | 32.8 | 9 | Anabranching |
| Orinoco | Venezuela | 35,000 | 950 | 150 | 157.8 | Anabranching |
| Yangtze | China | 32,000 | 1943 | 970 | 499 | Anabranching |
| Madeira | Brazil | 32,000 | 1360 | 450 | 330 | Anabranching |
| Negro | Brazil | 28,400 | 696 | 8 | 11.5 | Anabranching |
| Brahmaputra | Bangladesh | 20,000 | 610 | 520 | 852.4 | Anabranching |
| Japura | Brazil | 18,600 | 248 | 33b | 133 | Anabranching |
| Parana | Argentina | 18,000 | 2600 | 112 | 43 | Anabranching |
| Mississippi | USA | 17,000 | 3200 | 330 | 102 | Meandering |

Due to their distributed nature and their frequent inaccessibility, *in situ* estimation of the discharge of multichannel rivers is difficult, and it played a significant role in the science justification for the SWOT mission [10]. Appropriate gauging of a multichannel system would require significant resources, may not be appropriate in many braided systems, and does not exist for many of the world's major multichannel systems. The virtual gauges provided by nadir altimeter measurements [11] can often overcome the access limitations, but are often insufficient for capturing the complexity of a multichannel system, since they only sample a few of the channels, in addition to lacking the measurement density to resolve slope variability [12], a necessary condition to allow discharge inversion. These characteristics argue that multichannel rivers will play a significant role in achieving SWOT's goal of global discharge estimation.

# Investigation Overview and Objectives

Global estimation of river discharge is one of the primary goals of the SWOT mission. In our work, we will extend SWOT global discharge algorithms developed by the SWOT Discharge Algorithm Working Group (DAWG) to include algorithms especially tailored for multichannel rivers: anabranching, including anastomosing, and braided rivers. We will extend existing algorithms, which work with reach-averaged hydraulic variables, to include geomorphic information, such as sinuosity or other braiding indexes, that are defined at reach-level. A product from our work will be a global braiding index database, to be produced prior to launch using existing data, and updated post-launch using SWOT data. The database will enhance the Global River Width from Landsat (GRWL) dataset used by the SWOT science team, and will be of use to the general hydrology community. We will update the Manning discharge relation to include braiding parameters, extending our work in the previous SWOT science team, which generalized the Manning equation to include subreach variability, resulting in an equation that could be used for reach-level discharge estimation. This generalized discharge relation will then be used, in conjunction with prior braiding parameters, as a basis for a Mass conserved Flow Law Inversion (McFLI) algorithm, extending previous work on the MetroMan and other algorithms to include the updated discharge relation and the use of prior information in the braiding index database. The updated discharge relations and discharge estimation algorithms will be tested prior to launch using calibrated hydraulic models of multichannel rivers. After launch, the algorithm will be demonstrated on the US/Canadian SWOT Cal/Val sites, including the Tanana and Willamette rivers. In collaboration with foreign partners, it will also be tested in the Maroni (French Guyana), Rio Negro (Brazil), Congo (DR Congo), Niger (Mali), Ganges (India/Bangladesh), and Meta (Colombia) rivers. After post-launch algorithm refinement, we will work with the SWOT DAWG to incorporate the algorithm in the operational river discharge data stream to improve the accuracy of SWOT discharge data over multichannel rivers. We expect that the work proposed here will impact the assessment of global discharge, one of the primary SWOT goals, improve regional discharge estimates that will enhance other science studies, and be useful for river managers as a near real-time estimate of discharge.

To achieve the overarching program described above, our specific objectives are:

- We will develop algorithms to estimate multiple channels, braiding intensity parameters, and other relevant parameters, at reach-level. Braiding parameters will be estimated prior to launch using existing remote sensing data, and updated after launch based on SWOT and other remote sensing data. The global channel and braiding parameter database (BraidDB) will be made publicly available and be used for discharge estimation.
- We will develop an effective discharge relation using SWOT observables and appropriate braiding parameters that will replace the single-channel Manning equation assumed in the nominal SWOT processing for multi-channel rivers.
- We will implement a retrieval algorithm to infer unobserved variables, such as channel depth and roughness coefficient, from SWOT data. The estimated parameters will then be utilized in the effective discharge relation to provide an efficient discharge estimator for SWOT global discharge over multichannel rivers.
- We will collaborate with the SWOT CalVal team, and a team of global collaborators, to demonstrate and iterate our discharge algorithms on a variety of multichannel rivers. After algorithm tuning, we will work with the SWOT Discharge Algorithm Working Group (DAWG) to implement the algorithms in an operational context.

To achieve these goals, we have gathered a large group of collaborators with modeling and in situ expertise in a globally distributed set of multi-channel rivers that will be used in our work for algorithm development and post flight validation. These sites with associated river discharge, team member leads, in situ data and models are given in Table 2.

| River name | Ave. Discharge (m$^3$/s) | Type of data | Investigator |
|---|---|---|---|
| Congo (DR Congo) | 40,900 | | A. Carr and M. Trigg |
| Negro (Brazil) | 28,400 | | P-A Garambois |
| Ganges-Brahmaputra-Meghna (India/Bangladesh) | ~20,000 | Hydraulic | P. Uhe |

| | | | |
|---|---|---|---|
| Meta (Colombia) | 6,490 | Model | J.G. León, P-A Garambois |
| Maroni (French Guiana) | 1,700 | | P-A Garambois |
| Niger Inner Delta (Mali) | ~1,500 (variable) | | J. Neal |
| Tanana (Alaska) | 1,180 | | E. Altenau and T. Pavelsky |
| Platte (Nebraska) | 200 | | B. Sanders |
| Tanana (Alaska) | 1,180 | ArcticDEM | I. Howat and M. Durand |
| Sagavanirktok (Alaska) | 133 | | |
| Congo River (DR Congo) | 40,900 | In situ data | R. Tshimanga and M. Trigg |
| Rio Negro (Brazil) | 28,400 | | D. Moreira |
| Meta (Colombia) | 6,490 | | J.G. León, S. Calmant, P-A Garambois |
| Maroni (French Guiana) | 1,700 | | S. Calmant, P-A Garambois |
| Tanana (Alaska) | 1,180 | US SWOT CalVal Sites | C. Gleason, T. Minear, and T. Pavelsky (SWOT CalVal leads) |
| Willamette (Oregon) | 933 | | |

**Table 2.** List of datasets used for testing and validation and their origin.

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