



HAL
open science

Hydrology of the Black River (Rio Negro) in the La Niña Period (2020/2021) and the Climate of the Amazon

Newton Silva de Lima, Alan dos Santos Ferreira, Daniel Valentim Mansur #,
Robson Calazães, Aldemir Malveira de Oliveira

► To cite this version:

Newton Silva de Lima, Alan dos Santos Ferreira, Daniel Valentim Mansur #, Robson Calazães, Aldemir Malveira de Oliveira. Hydrology of the Black River (Rio Negro) in the La Niña Period (2020/2021) and the Climate of the Amazon. Engineering school. environmental engineering, Manaus - Brazil, Brazil. 2021, pp.1-12. hal-03274077

HAL Id: hal-03274077

<https://hal.science/hal-03274077v1>

Submitted on 29 Jun 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Hydrology of the Black River in the La Niña Period (2020/2021) and the Climate of the Amazon

**Newton Silva de Lima
Alan dos Santos Ferreira
Daniel Valentim Barros Mansur da Silva
Robson Matos Calazães
Aldemir Malveira de Oliveira**



Hydrology of the Black River in the La Niña Period (2020/2021) and the Climate of the Amazon

Lutheran University Center of Manaus - CEULM | ULBRA

Ave. Carlos Drummond de Andrade, 1460 - Conjunto Atílio Andreazza – Japiim
CEP 69077-730 - Manaus/AM – Brazil - Telephone: +55 (92) 3616-9800

- e-mail: acsmao@ulbra.br
- e-mail: newton.lima@ulbra.br
- e-mail: alan.ferreira@ulbra.br
- e-mail: danielvmansur@gmail.com (Juiz de Fora Federal University – Minas Gerais | Brazil)
- e-mail: matoscalazaes@gmail.com
- e-mail: amoliveira@gmail.com (Amazonas Federal University | Brazil)

Presentation

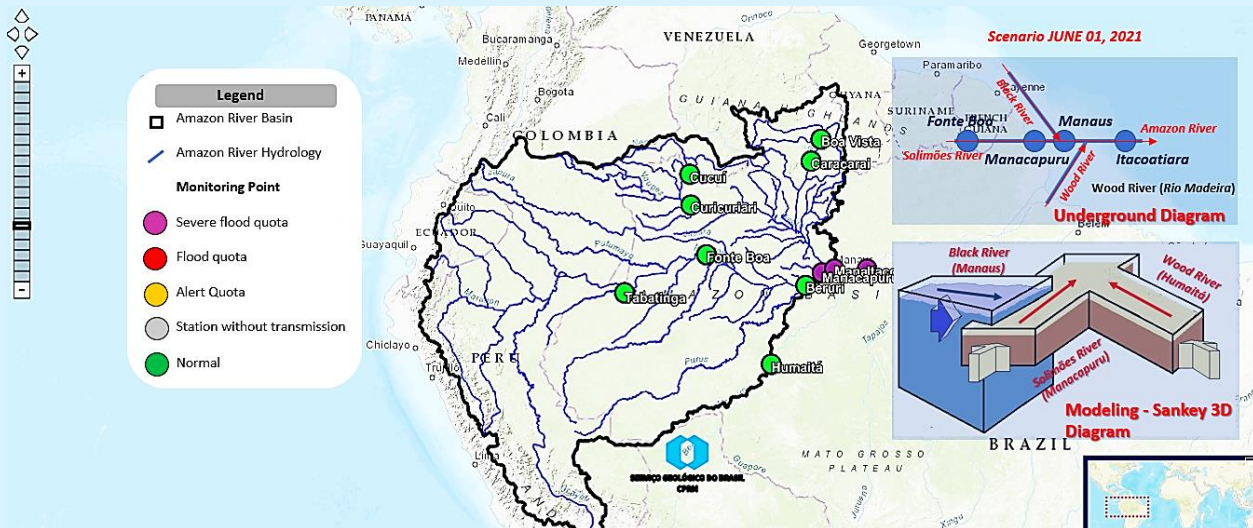
The Black River (Rio Negro) is a river that rises in the Guyanese shield in North South America in Colombian territory (Guainia River) and comes towards the great Amazon River (Brazil), where it has its mouth, where its black waters meet the waters of the Solimões river in front of the city of Manaus (Latitude: - 3.10719 Longitude: - 60.0261). Its volume is strongly influenced by the seasonal climatological phenomena of El Niño, when it reaches 13.63 m and in the La Niña period, it reaches up to 30.00 m, as the normal elevation oscillates between 17.54 m and 21.77 m, in relation to sea level, which is distant from its mouth, another 1,054 km to the Atlantic Ocean. It is the largest tributary on the left bank of the Amazon River, being the seventh largest river in the world by volume of water, responsible for 7% of the water it discharges into the Atlantic, the Black drains an area corresponding to 10% of the 7 million kilometers squares of the Amazon Basin. In, Zeidemann, 2001, more water flows through its bed than flows in all the rivers in Europe combined.

In this observation period (June 05, 2021) indicates the increase in the level in the Black basin, which reached a record level of 30.00 m in Manaus (Brazil), the year of La Niña. At the meteorological stations in sequence to Manaus coming from São Gabriel da Cachoeira, the height ruler is 12.23 m, (average 9 m), in Santa Isabel do Rio Negro it is 7.78 m (average 6.70 m) and in Barcelos it is at 9.39 m (average 6 m), being the next in Manaus. (Brazilian Geological Survey - BGS, 2021).

From November 2020 to June 2021, the La Niña phenomenon, and the warming of the South Atlantic in the tropical region, plus the formation of the Intertropical Convergence Zone - ITCZ parking over the region in this period, favored greater rainfall intensities over the Amazon and the entire sector North of South America.

From then onwards (second half of June), the Black River (Rio Negro) tends to start its ebb process until it reaches its minimum level. The end of the ebb, in turn, does not have a preferential period, and may occur between October and January of the next year.

The present work shows the climatic phenomenology of the Manaus region (Brazil) at the meeting of the waters of the Black River with the Solimões River (Rio Solimões). The Black flows near Manaus over soil from the Mesozoic Geological Era in the Cretaceous Period (144 – 66 million years) after the Jurassic period, while the Solimões River runs over the ground of the Quaternary of the Cenozoic Era (1.8 – 0.15 million years old), in this convergence of two geological formations, the beds are of different depths and ages. At this meeting of the waters, the Black has a depth during the flood period of approximately 90 m and the Solimões 42 m. (3D simulation with Sankey Diagram and didactic view of the Underground Diagram - Subway), to better understand the positions and locations of the cities around the rivers, in addition to the bathymetry at the meeting of the waters shown here in the history of 1978, 1988, 1998 and 2013, illustrating the changes and dynamics of the profiles and turbulence at the site of observations.

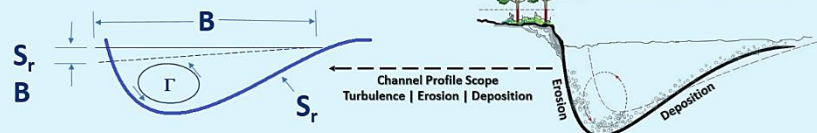
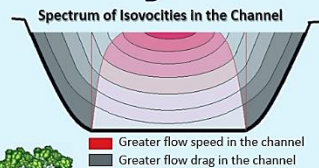
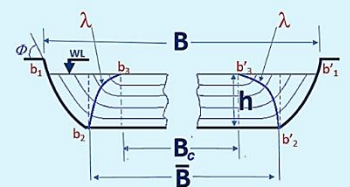


Legend

WL – water level
 $B/h < 40$ (formation of meanders is overstressed)
 $B \gg h$ (open-channel)
 B – width ($B = b_2 b_2'$)
 B_c – width (of the central region)
 m – varies depending on the cross-section geometry and boundary roughness.
 h – depth
 $\lambda - \lambda'$ – lines formed by the points where the curvature of the isovels practically vanishes.
 S_r – transverse free surface slope.
 N – number row (horizontal burts)
 Γ – cross-sectional circulation
 ϕ – angle of repose
 $b_2 b_2'$ – bed horizontal
 $b_1 b_1'$ – banks
 $b_2 b_2'$ – curvilinear
 C – Chézy coefficient (dimensionless)
 $C = \sqrt{8g/c}$; $v = C \sqrt{SR}$; $v^* = \sqrt{gSR}$
 $c = v/v^*$
 c = Friction Fator = (average flow velocity by shear velocity)
 ω – dimensionless variable determining N
 S = slope
 $R = h = \text{flow depth}$
 $g = 9,816 \text{ m.s}^{-2}$

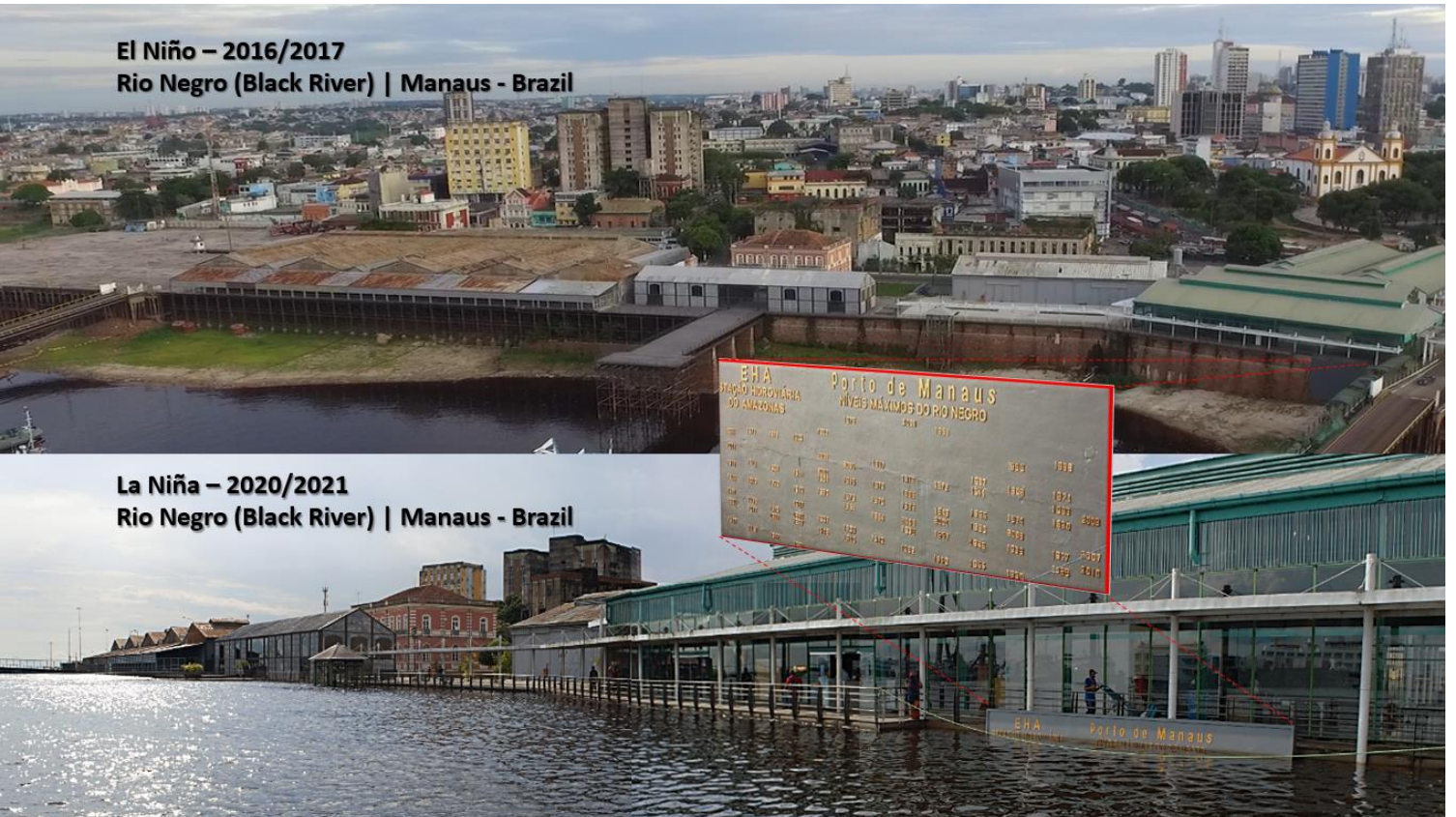
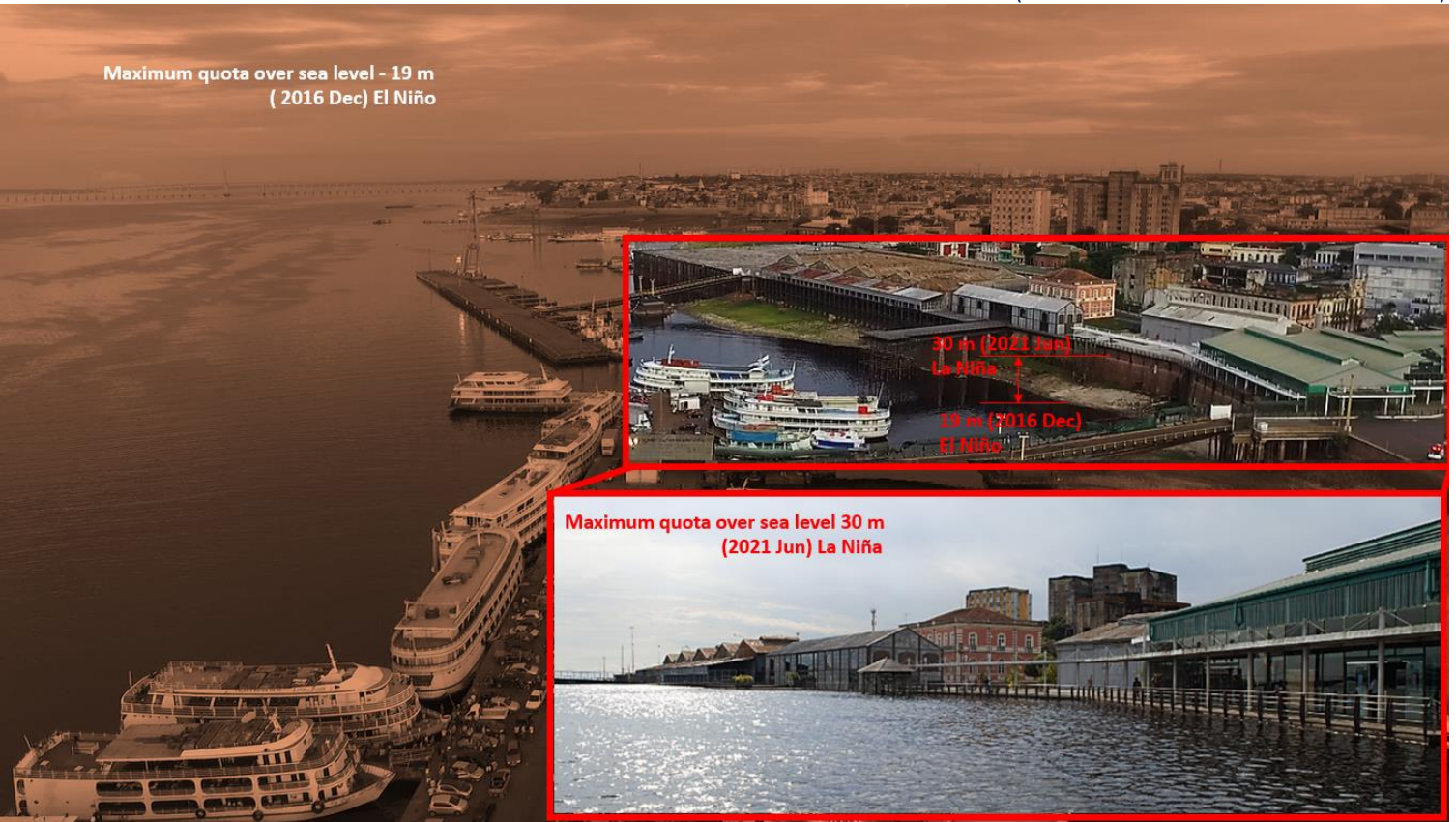
Width (B) and Depth (h) Ratio

- I. (B/h)
- II. $B - B_c - \bar{B}$
- III. $Bc = B (1 - 2m[h/B]) \rightarrow m = (B/h) \cdot (1/N)$
- IV. $N = \phi_N(\omega)$
- V. $\omega \sim (B/h)/c^2 \rightarrow c = v/v^*$



2016-2017 Scenarios of El Niño and La Niña 2020-2021 Rio Negro (Black River) Manaus Harbour | Brazil

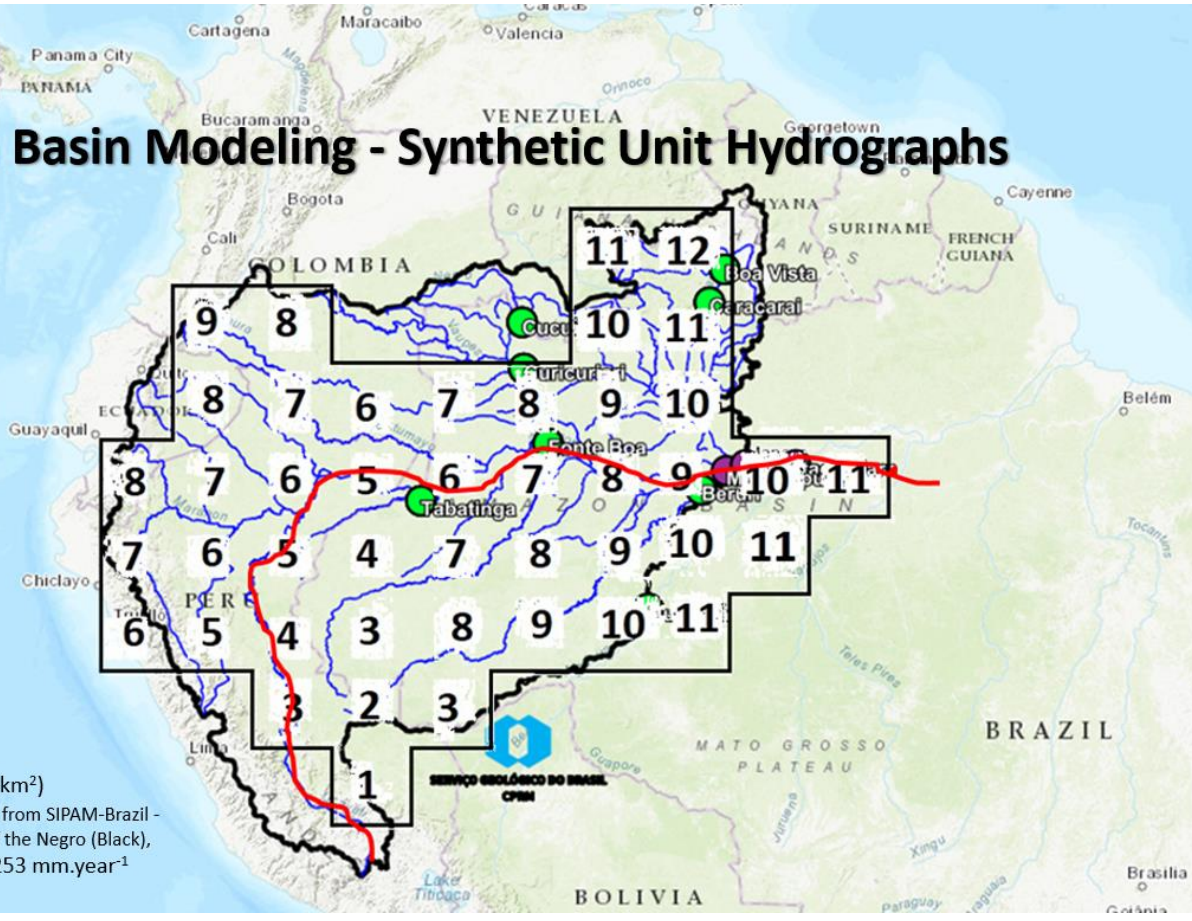
(Photos: Robson Calazães and Niels Lima)



Amazon Basin Modeling - Synthetic Unit Hydrographs

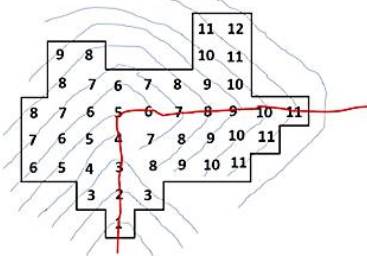
Features

- Basin Area:** 2.1 million (km²)
- 1 Unit Hydrograph:** ~ 48 thousand (km²)
- Average annual precipitation:** (data from SIPAM-Brazil - considering the total area of the basins of the Negro (Black), Solimões and Madeira (Wood) rivers.) 2,253 mm.year⁻¹

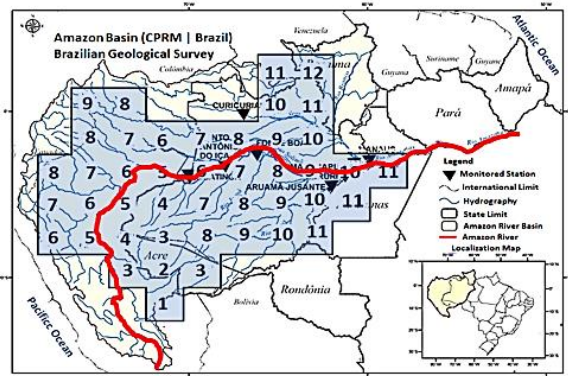


Time-Area Unit Hydrograph Development

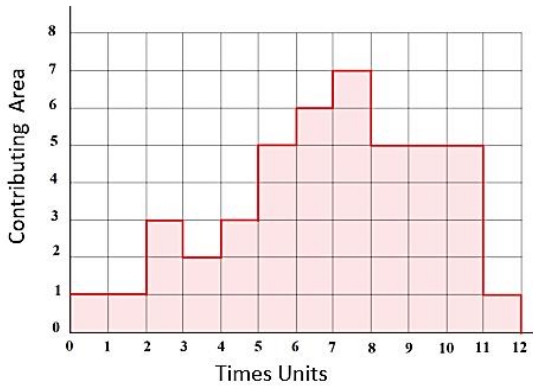
The watershed is divided into 44 subareas of equal area, all subareas contributing to the outlet within 12 time units.



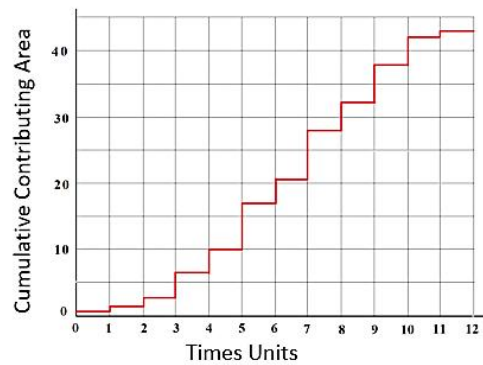
1. Watershed and Travel Times (iso-time lines)



2. Watershed (Amazon River) in North South America

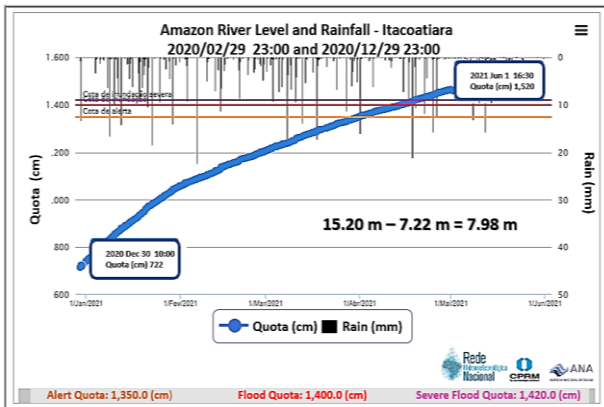
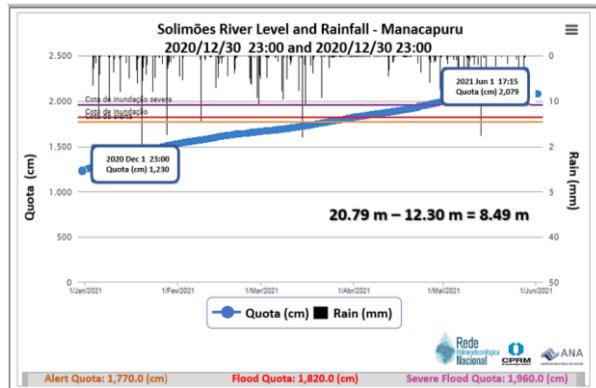
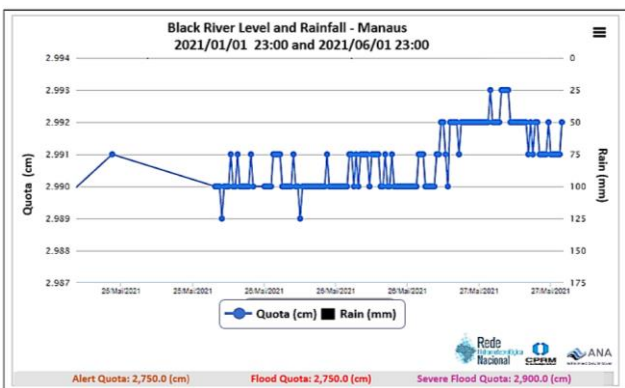
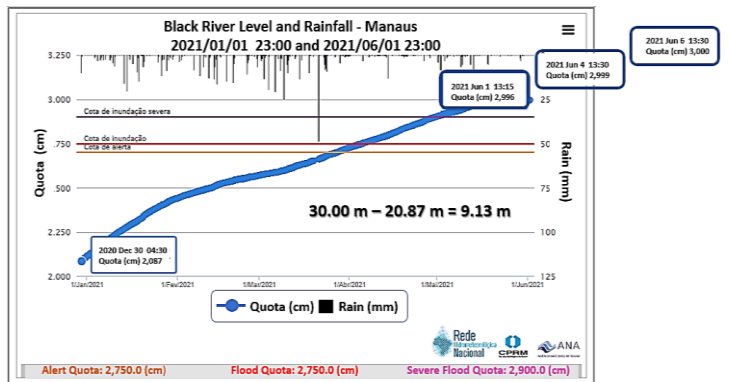
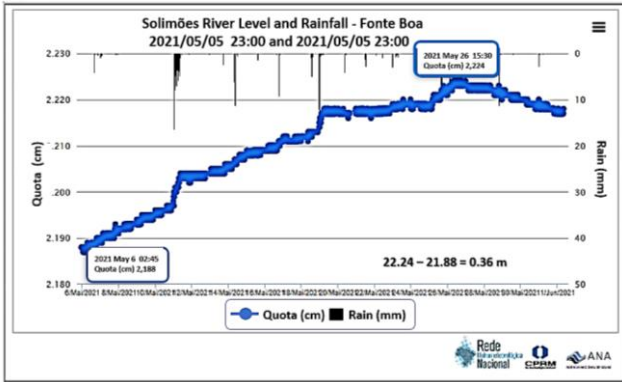


3. Contributing Area versus Times



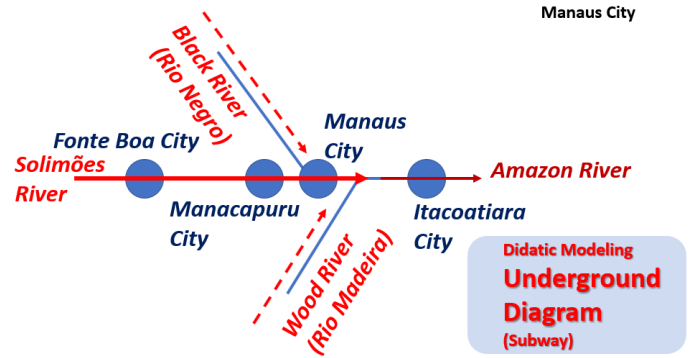
4. S-Hydrograph

River Level and Rainfall

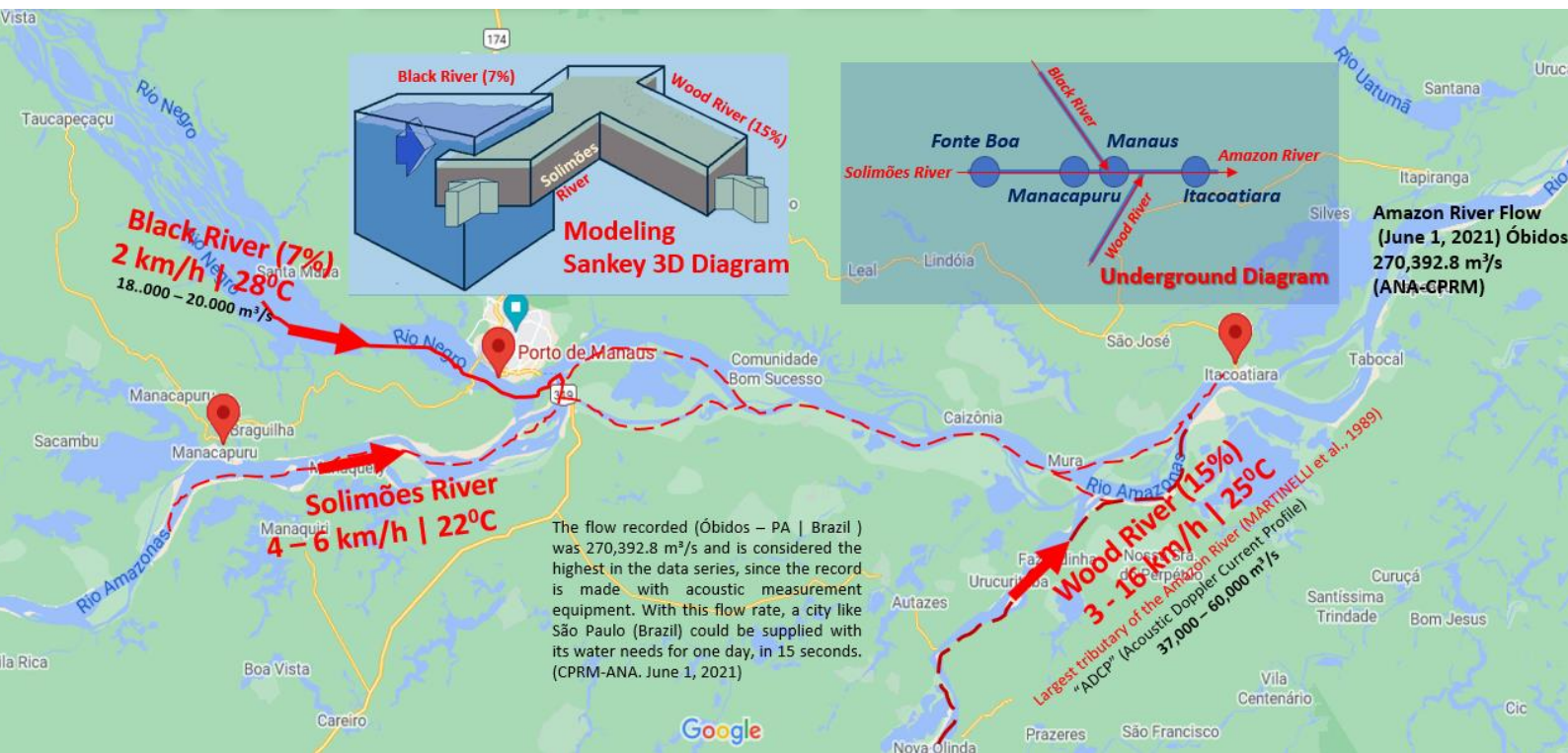


Meeting of the Waters (Black – Solimões)

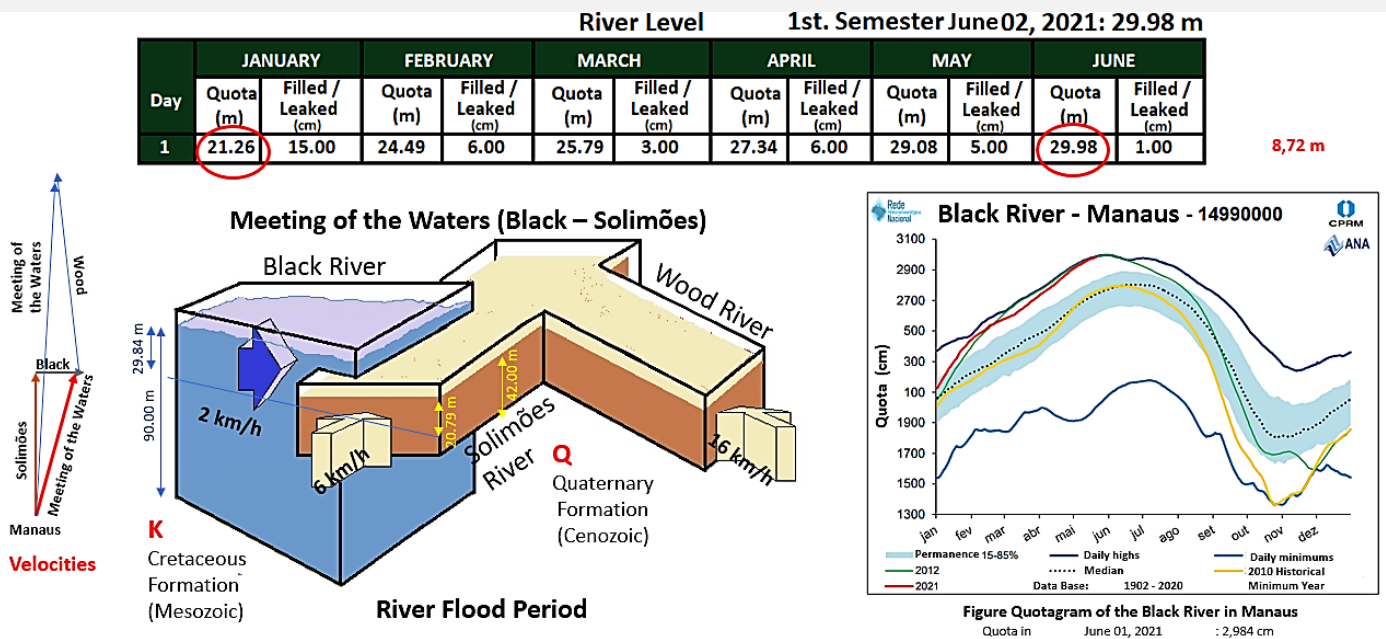
Manaus City



Didactic view of the Underground Diagram - Subway, to better understand the positions and locations of the cities around the rivers. (Black River (Rio Negro) in La Niña period in 2021, June. Photo: Natja Lima)

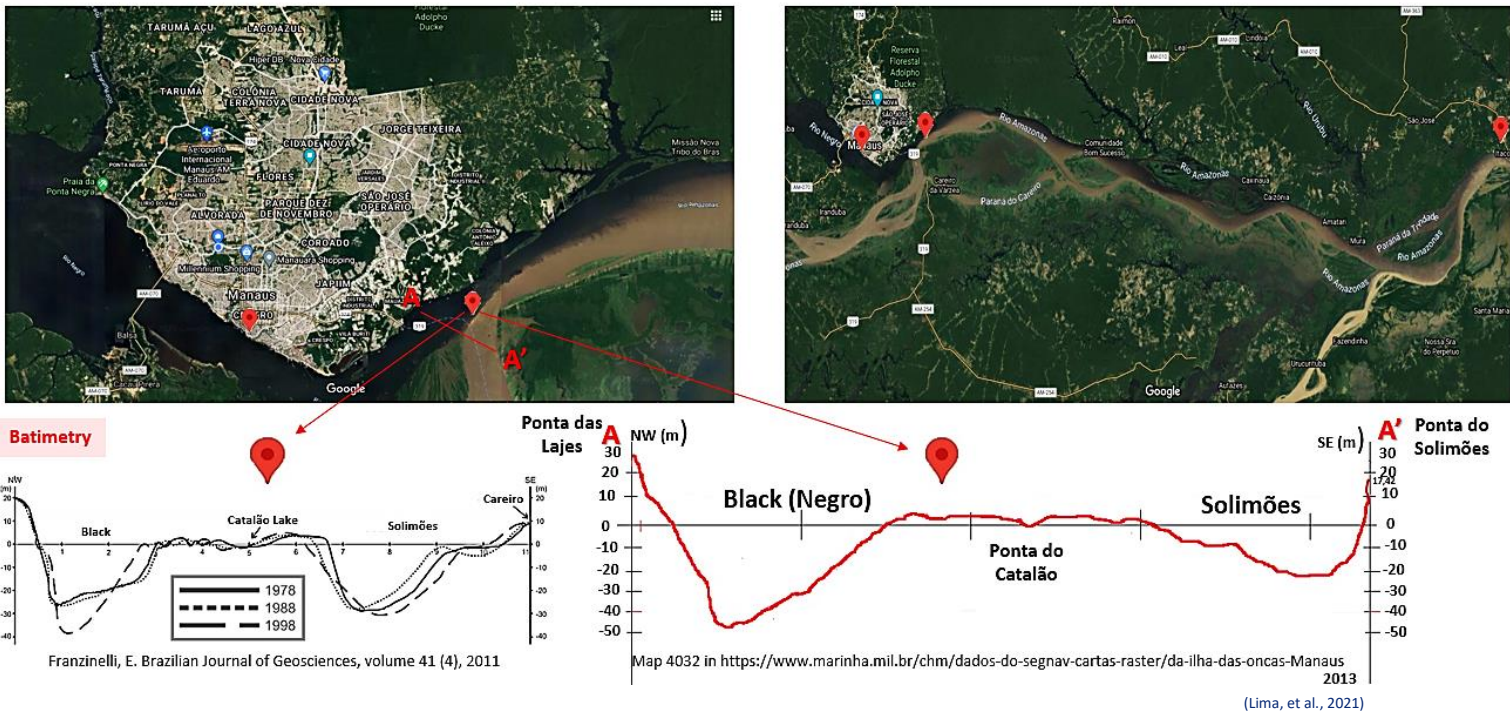


"The flow recorded (Óbidos – PA | Brazil) was 270,392.8 m³/s and is considered the highest in the data series, since the record is made with acoustic measurement equipment. With this flow rate, a city like São Paulo (Brazil) could be supplied with its water needs for one day, in 15 seconds". (CPRM-ANA. June 1, 2021)



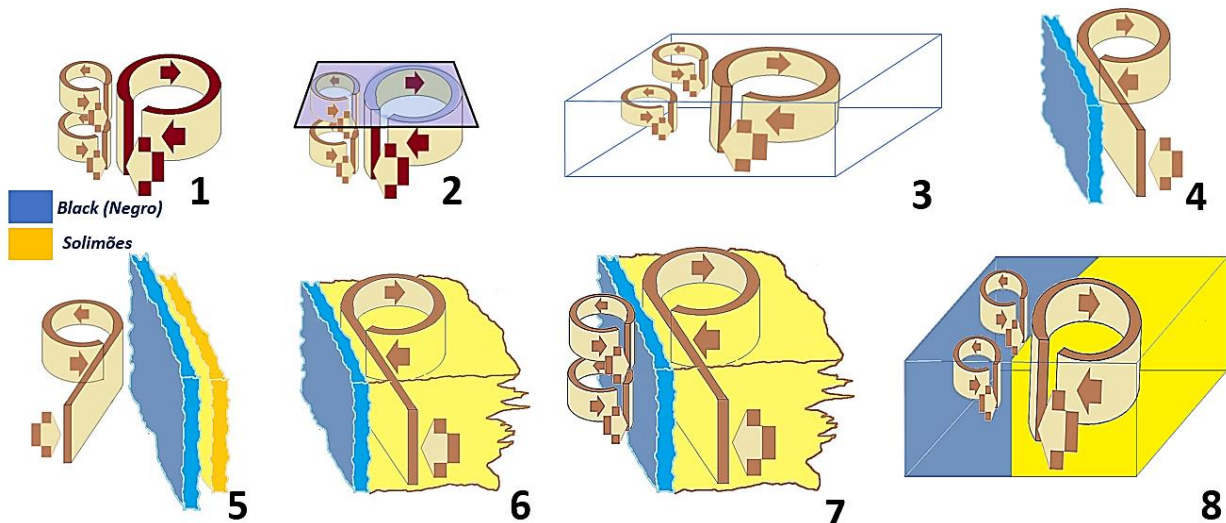
Scenario of the Meeting of the Waters showing a Sankey Flow Diagram in 3D (Map, Drawing and Graphic)

Bathymetry and dynamic analysis of the geological floor at the meeting of waters in over forty years of observations (Black - Solimões)



Turbulence (Meeting of the waters) - Surface View of Horizontal Turbulence

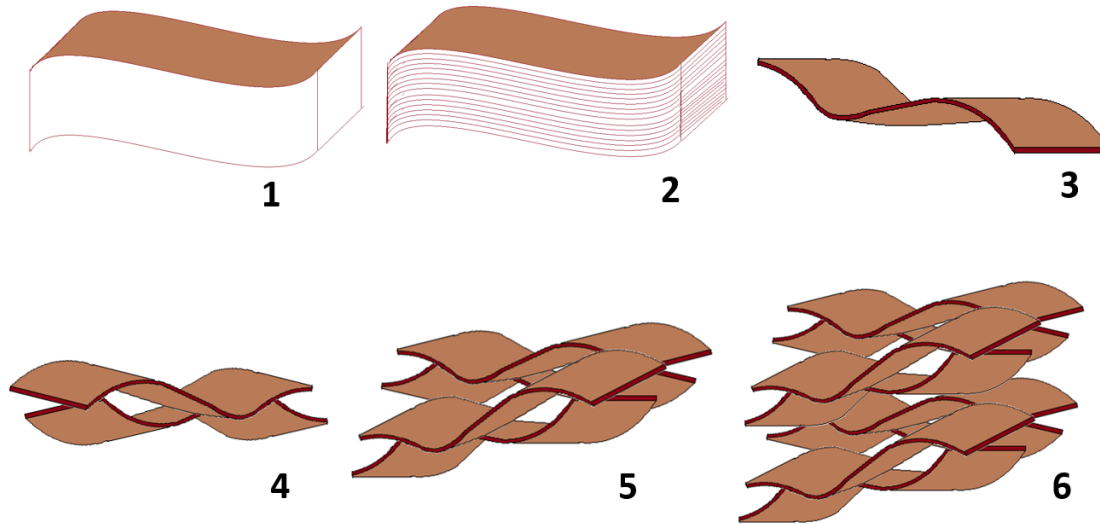
Configuration criteria: horizontal bursts of N-row at the meeting of the waters Black River (Rio Negro) with the Solimões River.



1 - Formation of coherent vortices. **2** - horizontal turbulent formation configuration. **3** - Configuration of the set of swirls that carry out shear when approaching. **4 - 5 - 6 - 7** - Effects of the formation of eddies on liquid walls with different densities, temperature and speeds at the meeting of the waters. **8** - Artistic view of the Turbulence phenomenon.

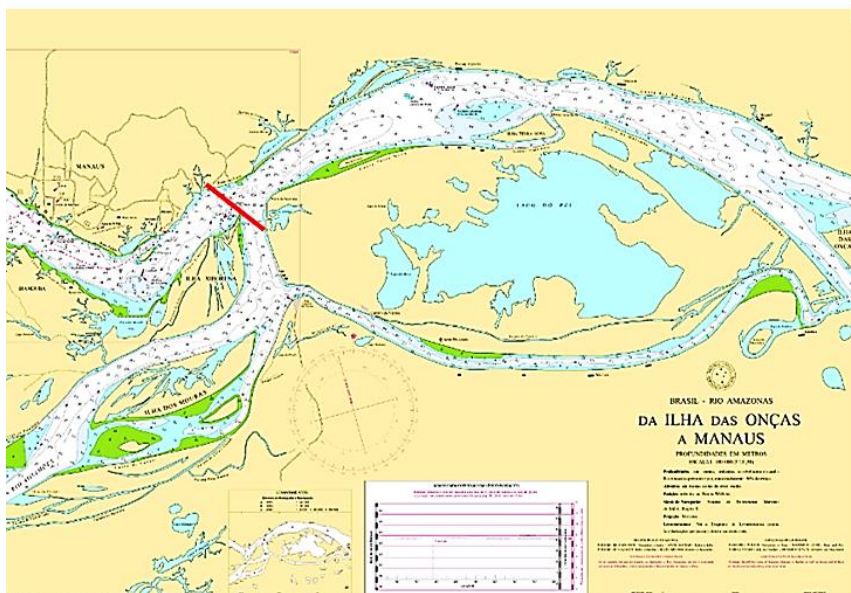
Artistic View of Turbulence within the Channel

(Study based on Turbulence in Fluids - MARCEL LESIEUR, 2008)



1 - Continuum liquid body; 2 - Horizontally quantized body; 3 - $n = 1$; 4 - $n = 2$.
5 - $n = 4$; 6 - n - Flow blades (twist-type turbulence). (*) n = number of blades .

Hydraulic, hydrochemical and sedimentological characteristics of the Solimões and Black rivers at the point where the waters meet.



<https://www.marinha.mil.br/chm/dados-do-segnav-cartas-raster/da-ilha-das-oncas-manau>

Variables	Solimões River	Black River
Basin Areas	2,200,000 km ²	600,000 km ²
Average Amplitude	2 - 5 km	3 - 20 km Maximum on the low Black River
Medium Depth	20 - 35 m	20 - 30 m 90 m maximum where the waters meet
Average Net Discharge	100,000 m ³ /s	30,000 m ³ /s
pH	6.2 - 7.2	3.8 - 4.9
Solid Discharge	700 x 10 ⁸ mt/year	6 x 10 ⁸ mt/year
Dissolved Discharge	205 x 10 ⁶ t/year	5.7 x 10 ⁶ t/year
Bottom Sediments	Coarse, medium and fine sand	Loose cream clay
Current Speed	0.5 - 1 m/s (2 - 2.5 m/s on the ebb)	1 cm/s
Temperature	29°C ± 1°C	30°C ± 1°C

Franzinelli, E. Brazilian Journal of Geosciences, volume 41 (4), 2011

Acknowledgments

The authors are grateful to the Northwest Navigation Survey - Brazilian Navy (NNS - Vila Buriti | Manaus-Brazil) for accessing navigation chart 4032, for bathymetry assistance, they are also grateful to the Brazilian Geological Survey (BGS) for the hydrology and climatology database from CPRM and ANA offices, and Amazon Protection System - SIPAM. Likewise, to the photographer Niels Lima, the Engineer Natja Lima and Engineer Robson Calazães for the images of the Black river and the field geochemical analyses.

References

Brazilian Geological Survey - BGS
(Critical Events Alert System) - CPRM - ANA
<http://www.cprm.gov.br/sace/>

Brazilian Navy. (<https://www.marinha.mil.br/chm/dados-do-segnav/cartas-raster>)

Franzinelli, E. Morphological characteristics of the confluence of the Black and Solimões rivers (Amazon, Brazil). *Brazilian Journal of Geosciences*, volume 41 (4), 2011.

Geo cities project: integrated urban environmental report: GEO report: Manaus/ Supervision: Ana Lúcia Nadalutti La Rovere, Samyra Crespo; Coordination: Rui Velloso. Rio de Janeiro: Consortium Partnership 21, 2002. 188 p.: 21 cm

Horbe, Adriana and Collaborators. Geochemistry of the waters of the middle and lower Wood River and its main tributaries - Amazon – Brazil. *ACTA AMAZONICA*. VOL. 43(4) 2013: 489 – 504.

HAS - Hydrological Alert Service (CPRM - ANA)
BULLETIN ON HYDROLOGICAL MONITORING OF THE WOOD RIVER BASIN BULLETIN No. 14/2021 May 7, 2021 –

Lesieur, Marcel. *Turbulence in Fluids* Fourth Revised and Enlarged Edition. Library of Congress Control Number: 200794115. All Rights Reserved © 2008 Springer.

Martinelli et al., Discharge of total dissolved solids from the Amazon River and its main tributaries. *Geochim. Brazil* 3 (2): 141-148, 1989.

Sternberg, H. O'Reilly. 1975. The Amazon River Of Brazil. *GEOGRAPHISCHE ZEITSCHRIFT*. BEIHEFTE. p.78

Vivian Karina Zeidemann. *Forests of the Black River. The Black Waters River*. Chapter 2 – USP – Company of Letters, Paulista University and The New York Botanical Garden, 2001.
<http://ecologia.ib.usp.br/guiaigapo/florestas.html>

Yalin, M.S. 1992. *River Mechanics*. Pergamon Press. p. 220.

***Black River (Rio Negro) – Manaus Harbour
Black Point Beach (Praia da Ponta Negra)***



Brief view of the Black River (Rio Negro) in front of Manaus (Brazil - November 2016). In Manaus Harbour, the width is 3.0 km at Black Point Beach (Praia da Ponta Negra), 5.0 km in the El Niño dry season (Images: Robson Calazães).