The Role of Spaceborne Radar for mapping of Wetland Ecosystem Extent and Changes

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With significant contributions from:
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T. Tadono, JAXA

Outline

- A few words about satellite radar
- The Global Mangrove Watch
- Forested wetlands
  - A few more words about satellite radar
  - A new wetlands product

The Global Mangrove Watch

A bit of history…

- **1990s:** JERS-1 - the first mangrove change image
- **2011:** Launch of Global Mangrove Watch (GMW) to support Ramsar
- **2013:** STRP17 – GMW and GWOS
- **2016:** Wetlands Int'l
- **2018:** Launch of first GMW map at COP13 (Dubai)

1872 PRIFYSGOL ABERYSTWYTH UNIVERSITY

soloEO

Wetlands INTERNATIONAL

The Nature Conservancy

The Global Mangrove Watch constellation

Partners

Donors

Supported by

Human vision vs. Radar vision

Human vision: a passive observation system

Transmitter: the Sun

Receiver: the human eye

Wavelength and polarisation: Whole spectrum (white light), non-polarised light, is transmitted and received.

Radar: an active observation system

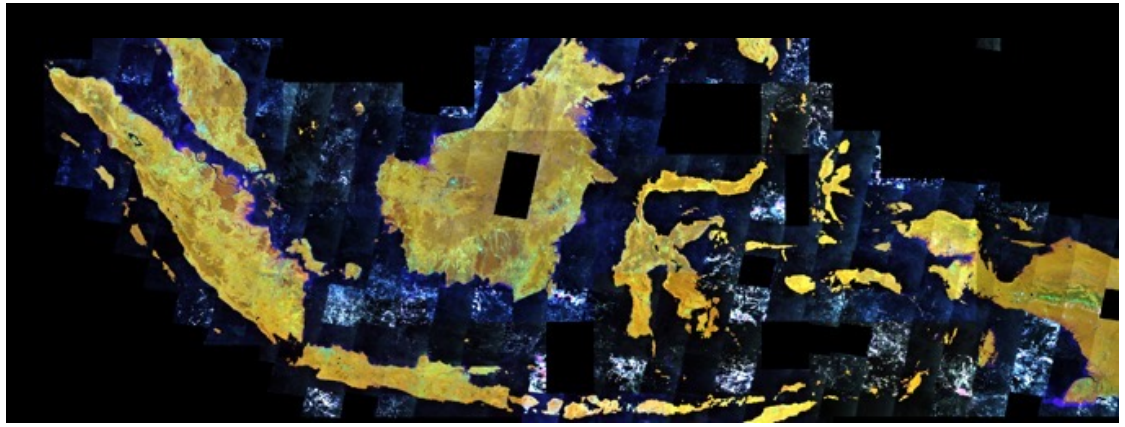
Transmitter: the radar antenna

Receiver: the radar antenna

Wavelength and polarisation: Single wavelength (laser), polarised light.

A radar operates like a flash camera in a dark room. The part of the transmitted light that is reflected back (i.e. backscattered) towards the camera is recorded.

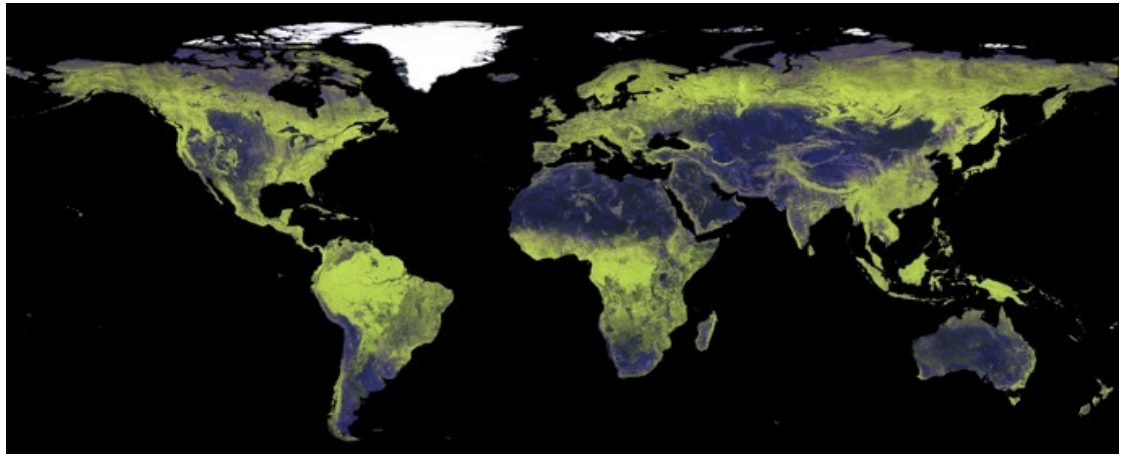
Satellite data used



Optical mosaics

Optical satellite data (Sentinel-2 & Landsat):

- Sensitive to vegetation spectral characteristics.
- Distinction of mangrove/non-mangrove.
- Limited by cloud cover
- Used for 2010 (Landsat) and 2020 (Sentinel-2) baselines



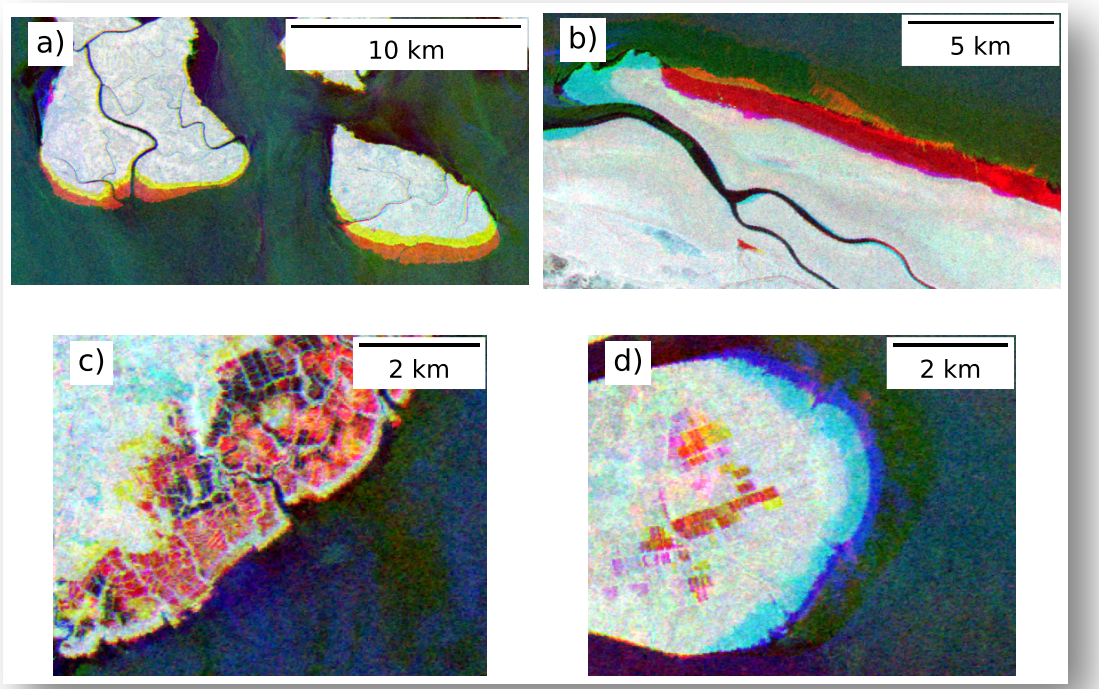
Radar mosaics

Synthetic Aperture Radar (JERS-1, ALOS, ALOS-2):

- Acquisitions regardless of clouds, smoke and haze.
- L-band wavelength (23.5 cm) sensitive to vegetation structure and for detection of changes.
- 20 annual epochs between 1992 and 2023

GMW change classification

- Mangroves have a vertical structure → high radar backscatter.
- Smooth surface of ponds, water and mudflats → low radar backscatter.
- Change classification approach:
  - A mangrove pixel with low backscatter → change to non-mangroves
  - A non-mangrove pixel with high backscatter → change to mangroves.



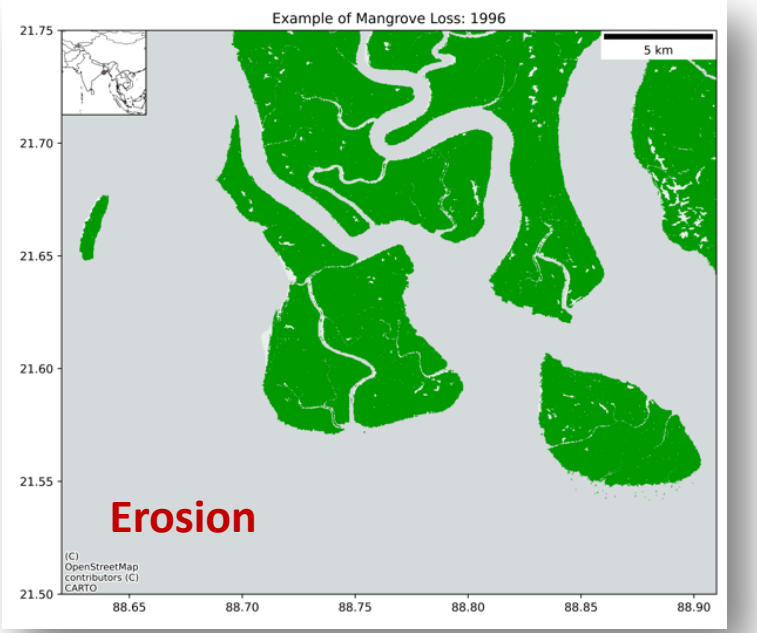
L-HH composites: **Red**: 1996, **Green**: 2010, **Blue** 2020

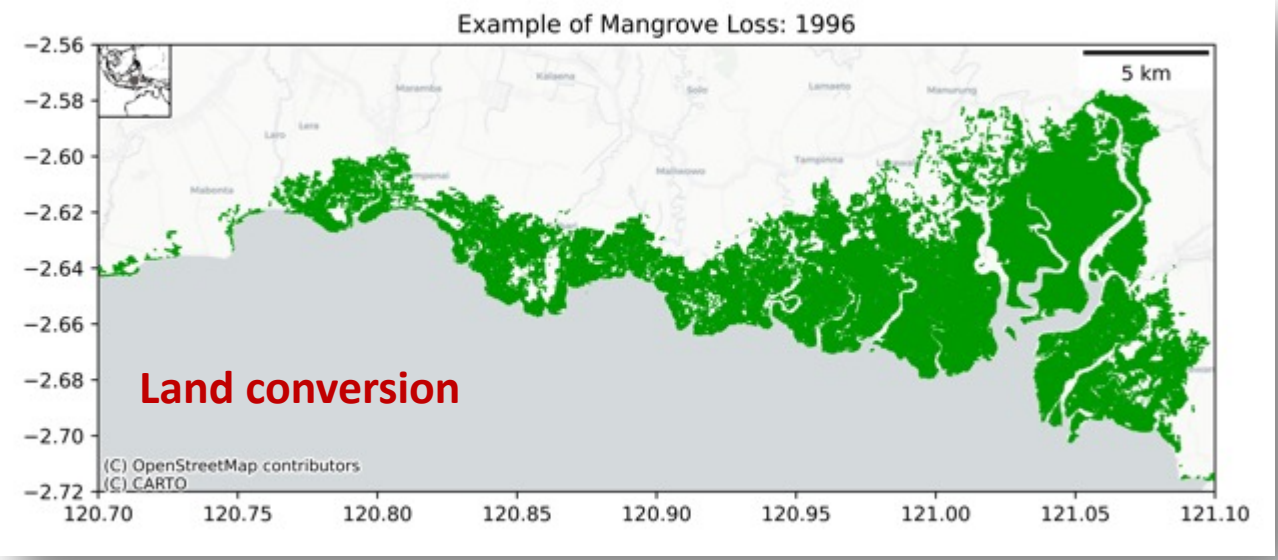
Red: High backscatter in 1996 low in other years (Loss)
Blue: High backscatter in 2020 low in other years (Gain)

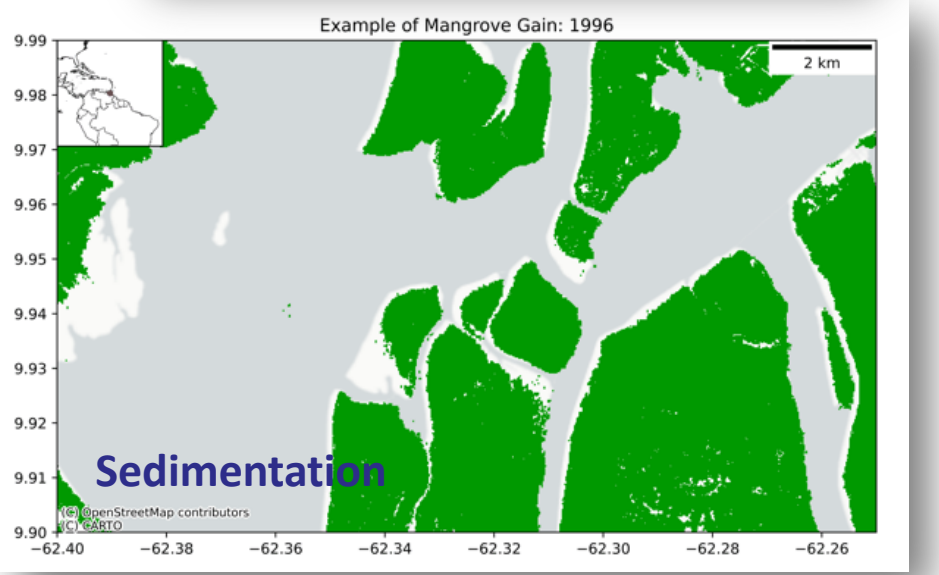
GMW v3.0

GLOBAL MANGROVE WATCH

- Launched 2022
- Time series 1996 – 2020
- 11 annual epochs.







GMW Accuracy assessment

- Accuracy assessment across 38 sites using 17,366 points.
  - Mangroves > Non Mangroves: 702 points
  - Non Mangroves > Mangroves: 413 points
- GMW 2010 mangrove extent: 93.8 % (95th conf int: 91.1 – 94.5 %)
- Mangrove change accuracy about 60% for both gain and loss
  - error was predominately due to residual mis-registration in the radar satellite data.

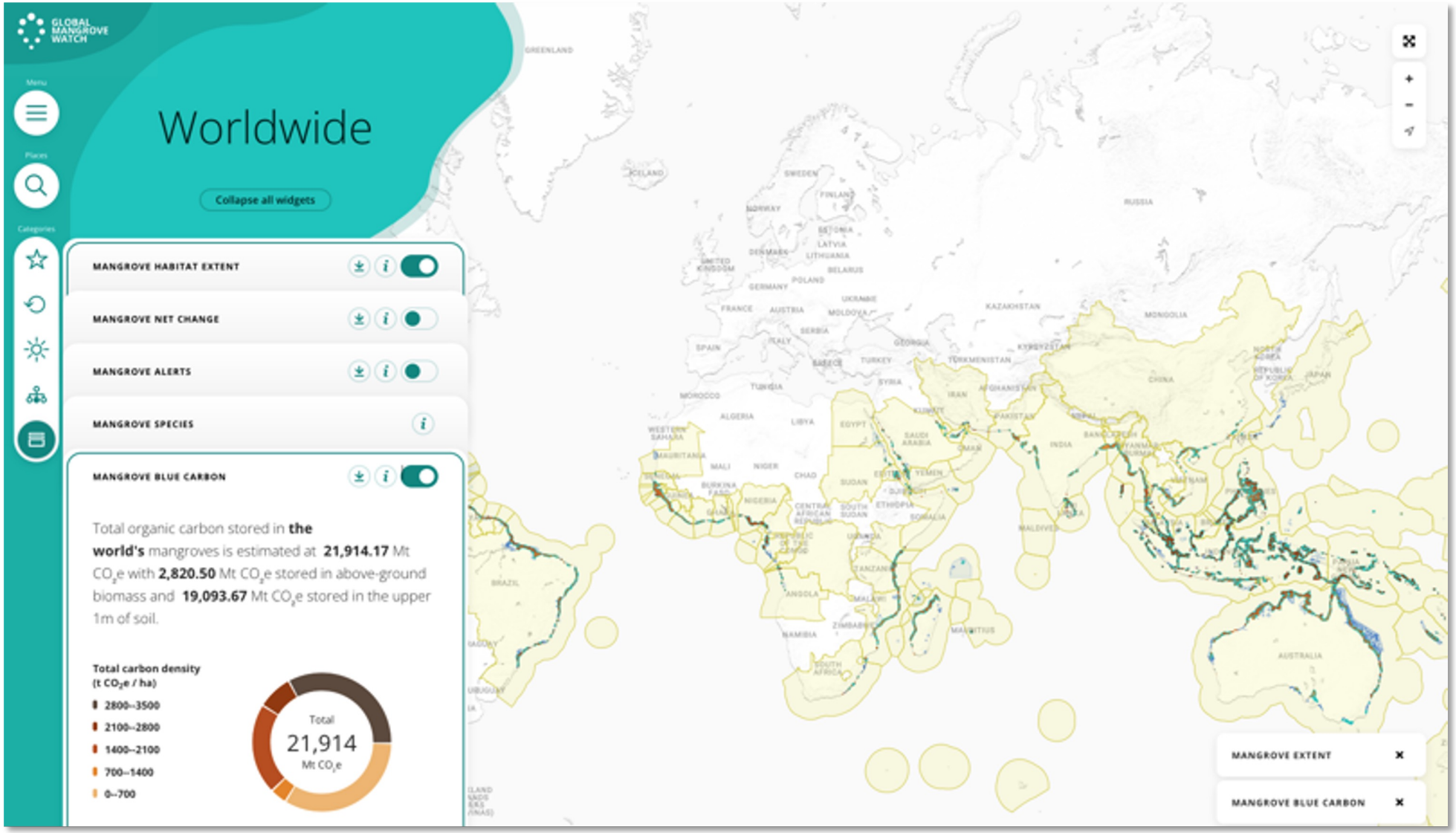
Class	f1-score (95th Conf. Int.)
Mangroves	87.4 % (86.2 – 88.3)
Mangroves > Not Mangroves	60.4 % (56.1 – 64.8)
Not Mangroves	94.6 % (94.2 – 95.1)
Not Mangroves > Mangroves	58.1 % (52.4 – 65.3)

GMW v4.0

- New mangrove baseline for 2020
  - Much improved in completeness and coverage of mangroves mapped using Sentinel-2 10 m
- Improved spatial registration
  - Reduced uncertainty of the change estimates.
  - Reduced false positives for change (gains and losses)
  - Inclusion of several JERS-1 and Landsat coverages from the 1990s will help “stabilise” the first extent estimate
- GMW v4.0 release
  - New 2020 mangrove baseline released in 2024
  - Change 1996 – 2023 – release in 2025/Q1

The GMW Platform – www.globalmangrovewatch.org

National Dashboard
Mangrove Habitat Extent
Mangrove Net Change
Mangrove Habitat Change
Mangrove Alerts
Species Location by Country
Mangrove Species Distribution
Mangrove Species by Red List Status
Mangrove Protection
Mangrove Restoration
Mangrove Biomass
Mangrove Height
Mangrove Blue Carbon
Mangrove Emissions Mitigation
Mangrove International Status
Carbon Market Potential
Drivers of Change
Mangrove Fisheries
Coastal Protection
Protected Areas
Allen Coral Atlas
Salt Marsh
Tidal Flats
Global Tidal Wetland Change

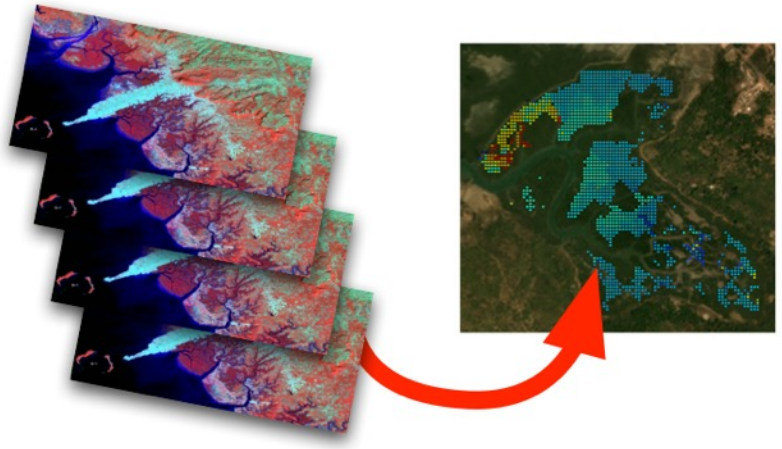


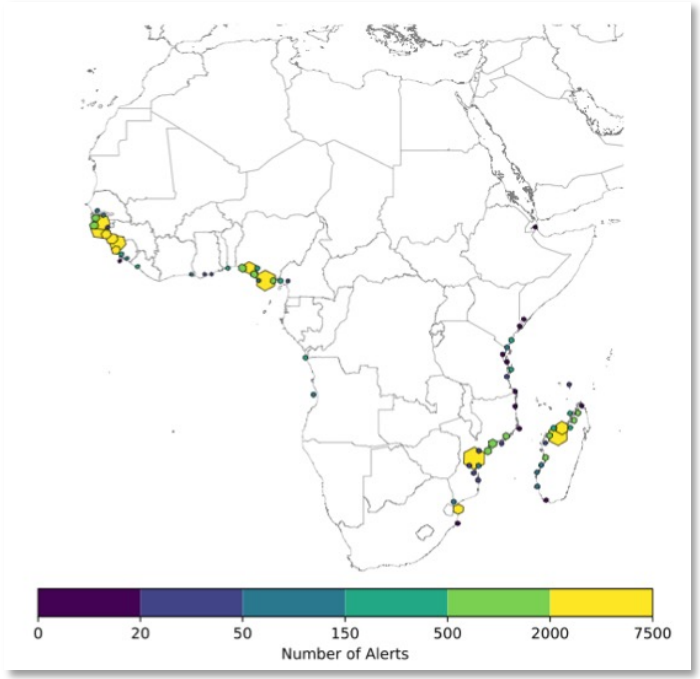
Mangrove Change Alerts

GLOBAL MANGROVE WATCH

GMW Alerts –
Early Warning system for mangroves

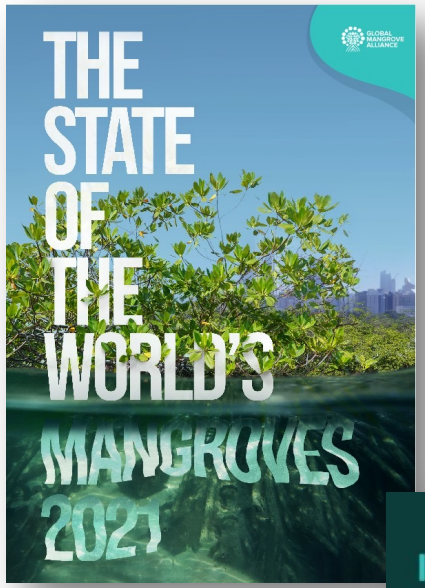
- Operational service on the GMW Platform
- Based on Sentinel-2 optical time-series
- Monthly updates
- Currently covering Africa + selected countries.
- Global coverage foreseen in 2025

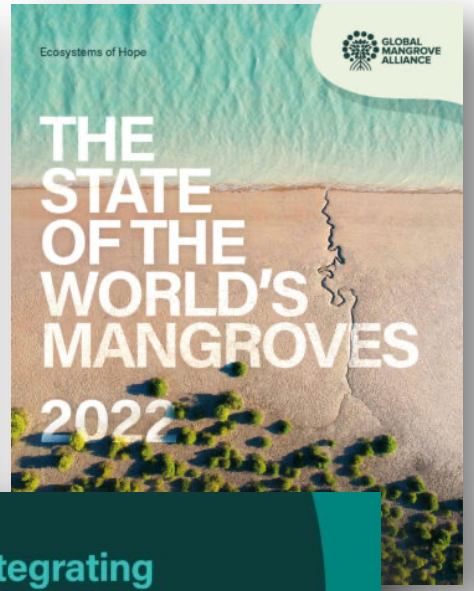


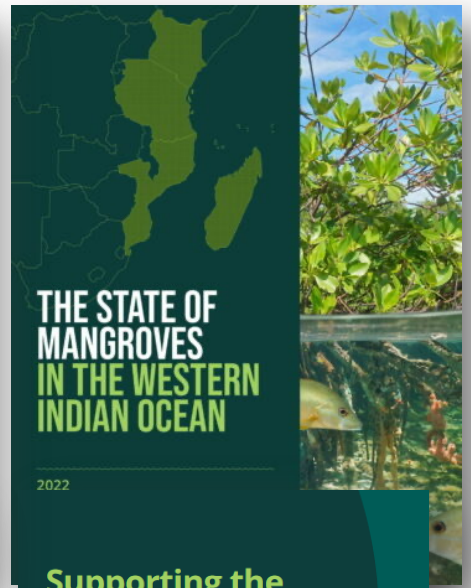


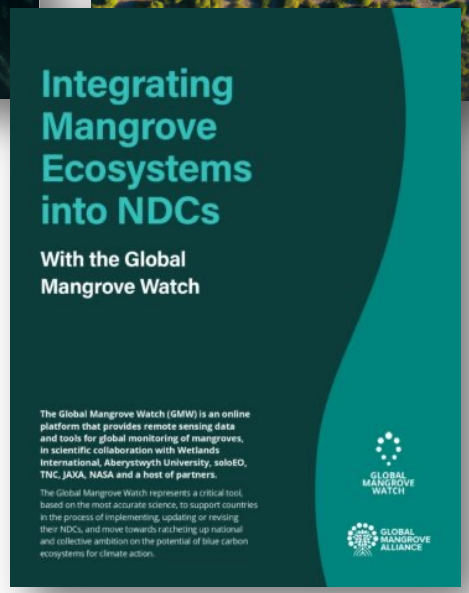
Monthly Alerts of Mangrove Loss 2019–2022

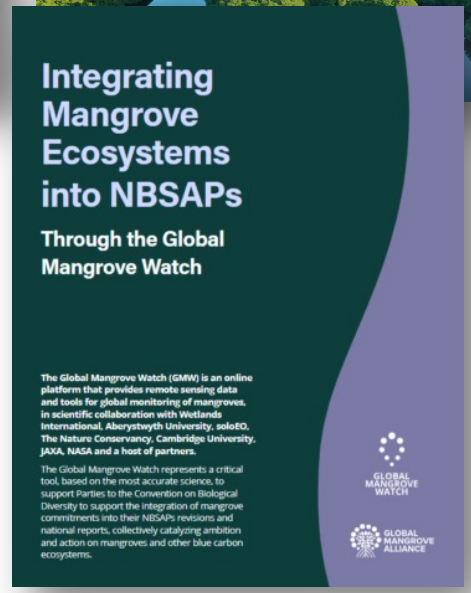
Outreach

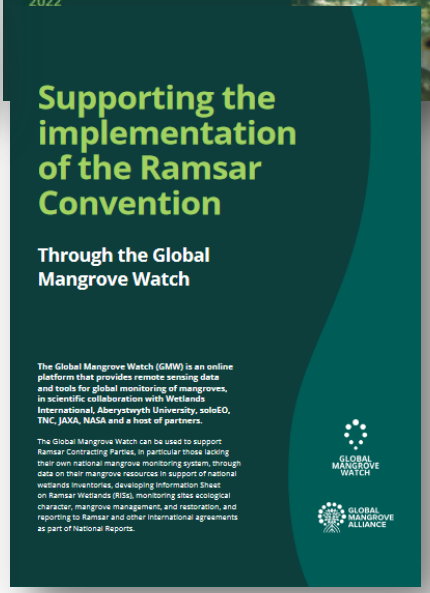






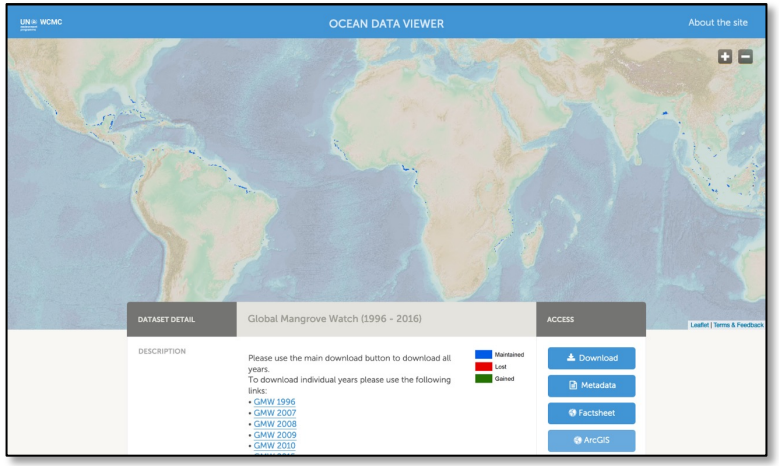




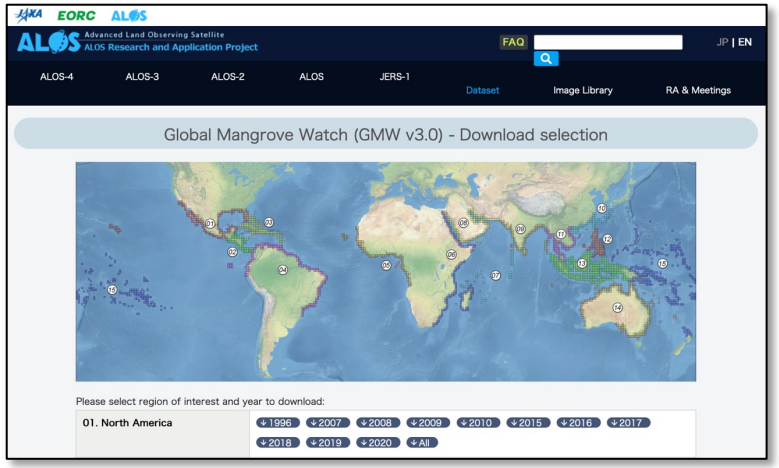


GLOBAL MANGROVE WATCH

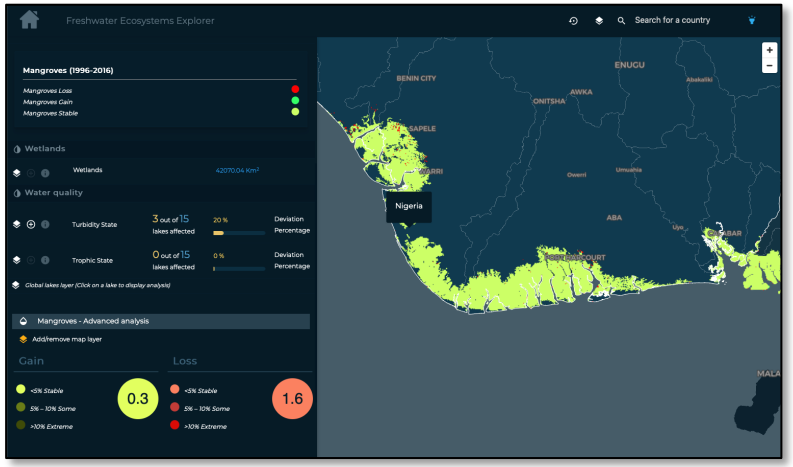
Outreach



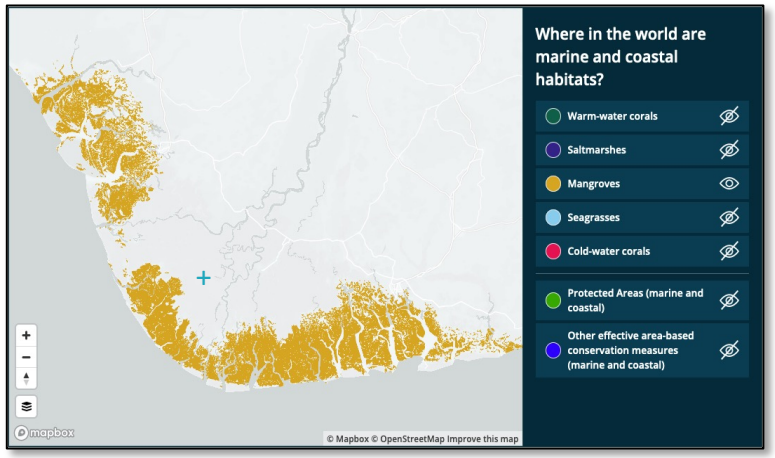
Ocean Data Viewer (UNEP-WCMC)
data.unep-wcmc.org/datasets/45



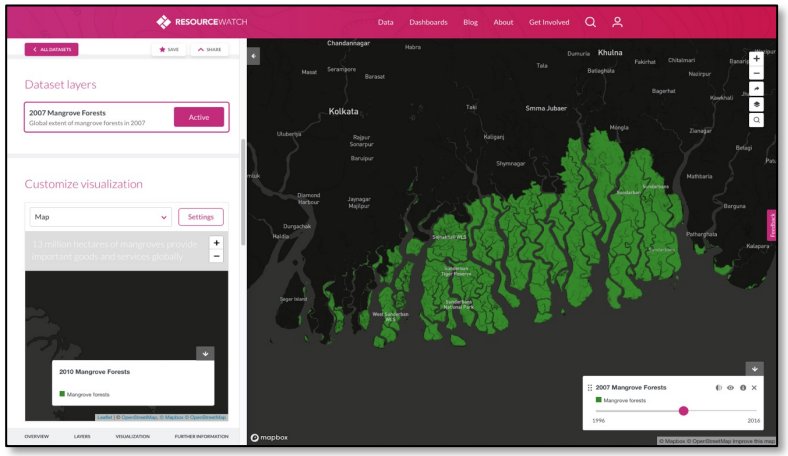
JAXA Earth Observation Research Center
www.eorc.jaxa.jp



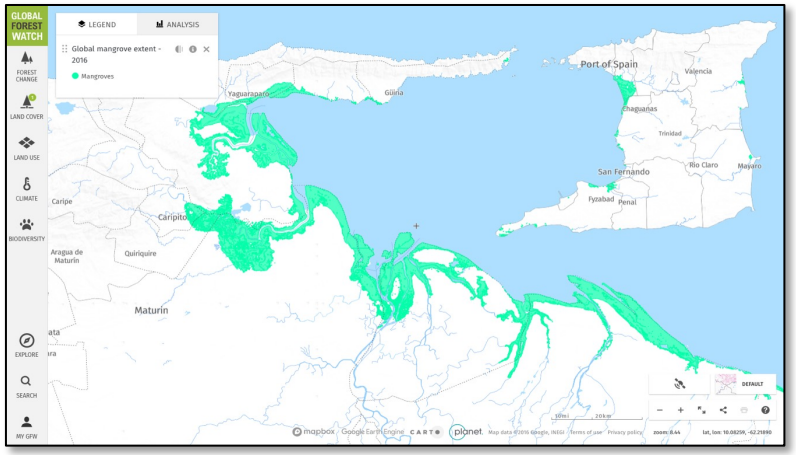
Freshwater Explorer (UNEP)
sdg661.app



Ocean Habitats (UNEP-WCMC)
maps.oceanwealth.org



Resource Watch (WRI)
resourcewatch.org



Global Forest Watch (WRI)
www.globalforestwatch.org

Mapping of Forested Wetlands

EO Consultation Note - extract

a) ***Tools and data: Availability vs. utilization***

i. *Existing tools and data*: A wealth of EO tools, datasets, and content is already available, yet there is a significant lack of awareness and capacity among Contracting Parties to utilise them effectively.

ii. *Country-level data challenges*: While national-level data often exists, it is rarely harmonised or shared.

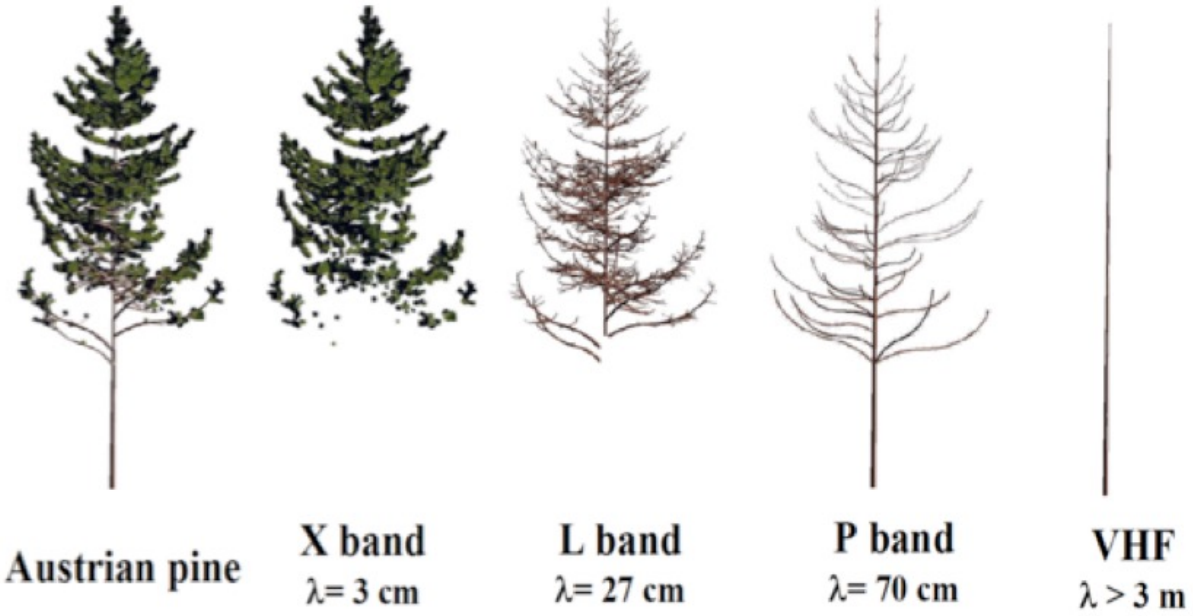
iii. *Spatial indicators and Wetland Extent*: The absence of comprehensive wetland extent data is a recurring issue. Challenges in EO data collection, such as ground-truthing and calibration, compound the problem.

b) ***Phased and flexible approaches****:* Successful NWIs often adopt phased approaches, starting with basic data collection (e.g., wetland boundaries) and progressively refining scope (e.g., ecological character or smaller wetland inclusion). This allows for gradual scaling while meeting initial policy priorities.

c) ***Integration of EO Technologies****:* EO tools, including satellite imagery and LIDAR technologies, are instrumental in mapping large wetland areas and generating essential data. However, limitations persist for small or forest-covered wetlands, highlighting the need for ground-truthing as well as complementary methods.

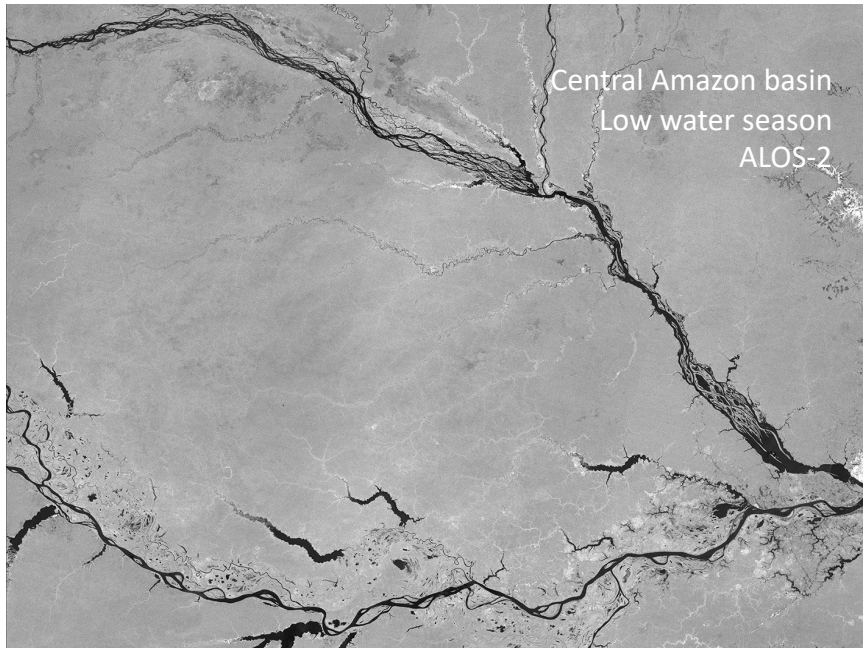
A few more words about satellite radar…

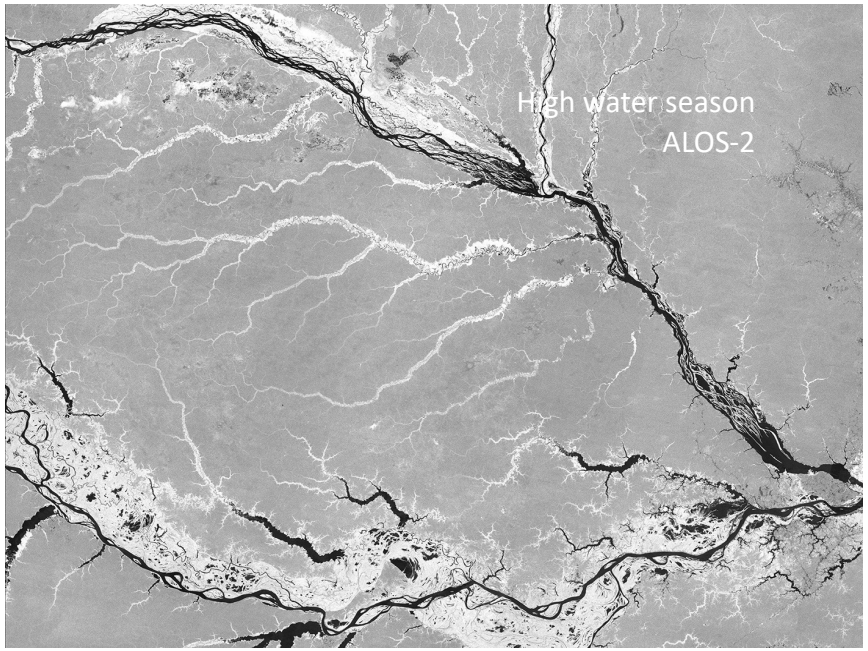
Radar wavelength (λ)

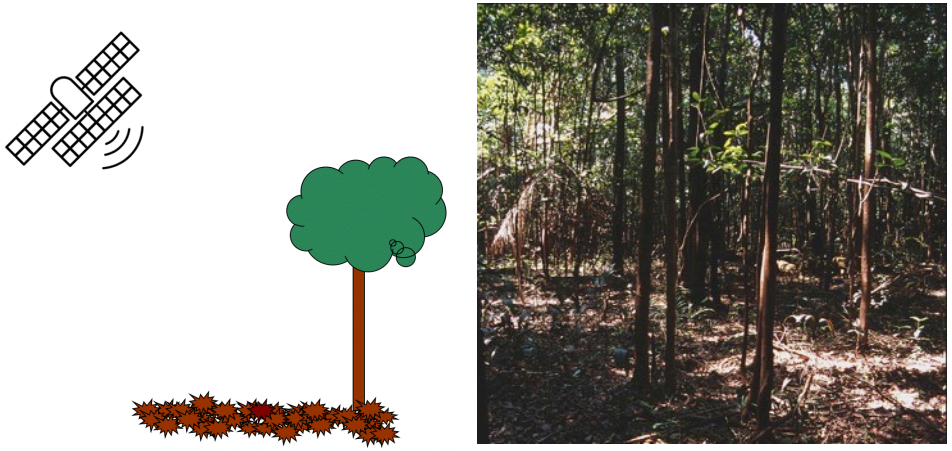


- The radar is sensitive to objects that are of about the same spatial magnitude (size) as λ, and larger
- Objects significantly smaller than λ are transparent (invisible) to the radar (but cause attenuation of the signal).

A few more words about satellite radar…





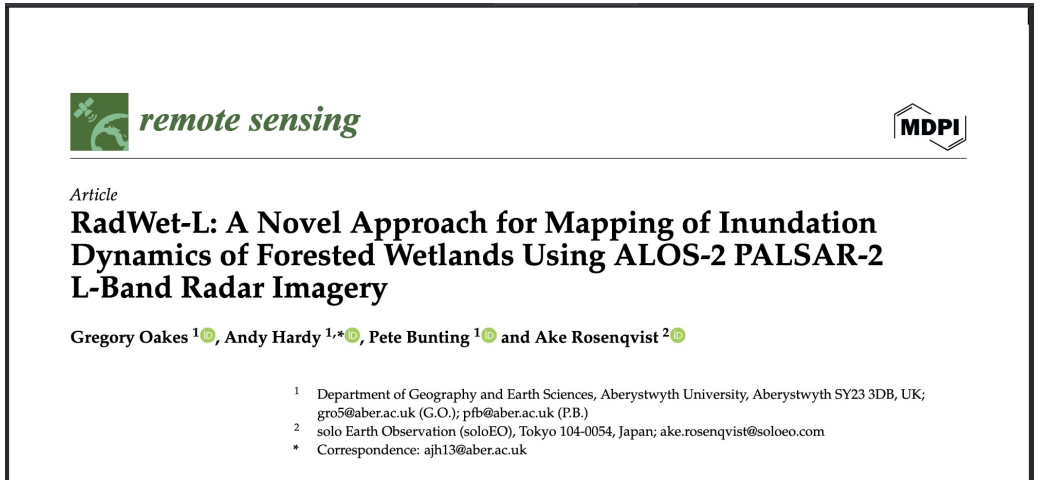


Dry forest

Flooded forest

Forested Wetlands - Classification methodology

- The image classification method to detect inundation in ALOS-2 radar data developed by Aberystwyth University.
- Method uses the ALOS-2 time-series data together with ancillary datasets, such as hydrological terrain (HAND) metrics, DEMs and Land Cover maps, to automatically generate training data for open water and inundated vegetation.
- Data is then used to train an XGBoost machine learning classifier, and applied to time-series of PALSAR-2 tiles across the area of interest.
- The software is light-weight and transferable, and was run on a 4-core laptop computer.



remote sensing

MDPI

Article

RadWet-L: A Novel Approach for Mapping of Inundation Dynamics of Forested Wetlands Using ALOS-2 PALSAR-2 L-Band Radar Imagery

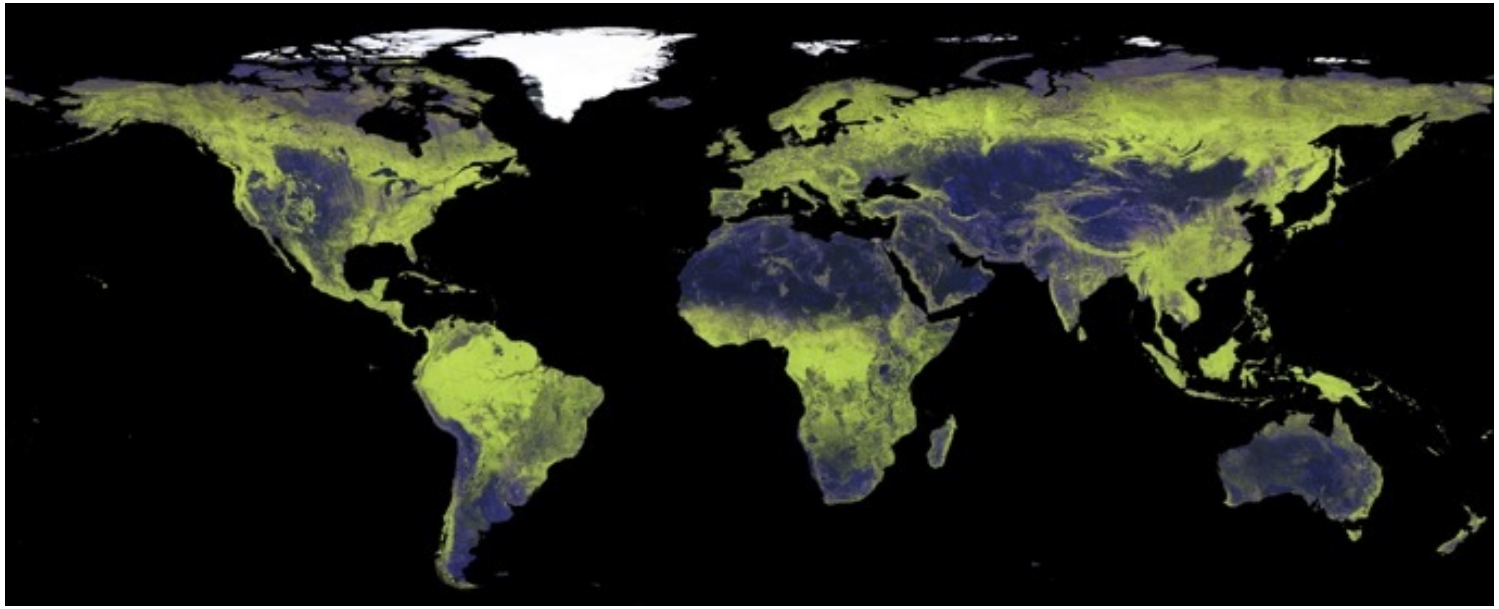
Gregory Oakes [1], Andy Hardy [1,*], Pete Bunting [1] and Ake Rosenqvist [2]

[1] Department of Geography and Earth Sciences, Aberystwyth University, Aberystwyth SY23 3DB, UK; gro5@aber.ac.uk (G.O.); pfb@aber.ac.uk (P.B.)
[2] solo Earth Observation (soloEO), Tokyo 104-0054, Japan; ake.rosenqvist@soloeo.com
* Correspondence: ajh13@aber.ac.uk

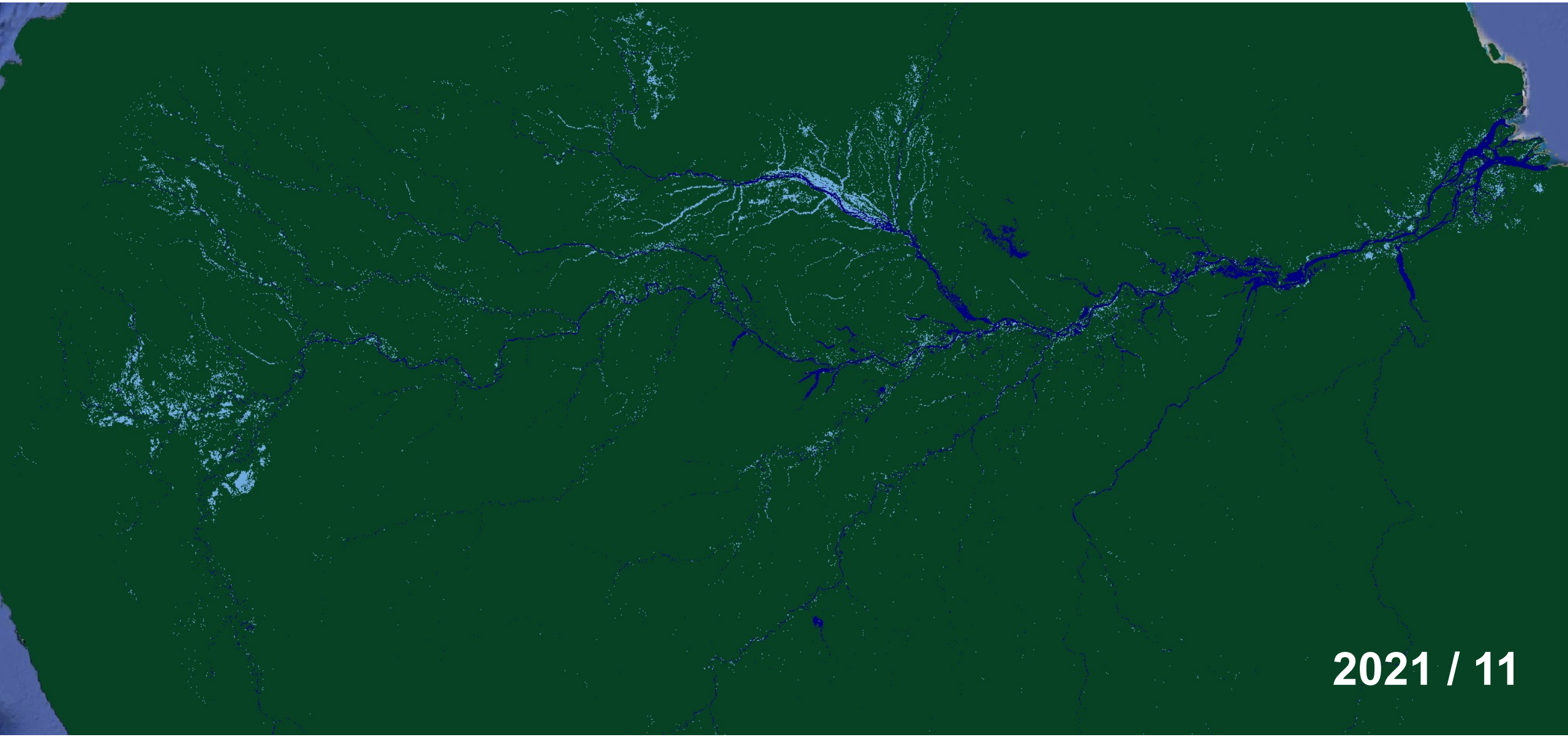
- Method developed by Greg Oakes, Aberystwyth Univ
- Up for his PhD defense TODAY
- Good luck, Greg!!!

Systematic observations of satellite data

- JAXA the first space agency to implement systematic global acquisition strategy
- ALOS-1 and ALOS-2 data acquired globally multiple times per year
  - JERS-1 (1992 – 1998)
  - ALOS-1 (2006 – 2011)
  - ALOS-2 (2014 – present)
  - ALOS-4 (2024 – present0
- ALOS-1 & ALOS-2: 9 times/year over the pantropical zone.



Forested wetlands – Inundation Extent



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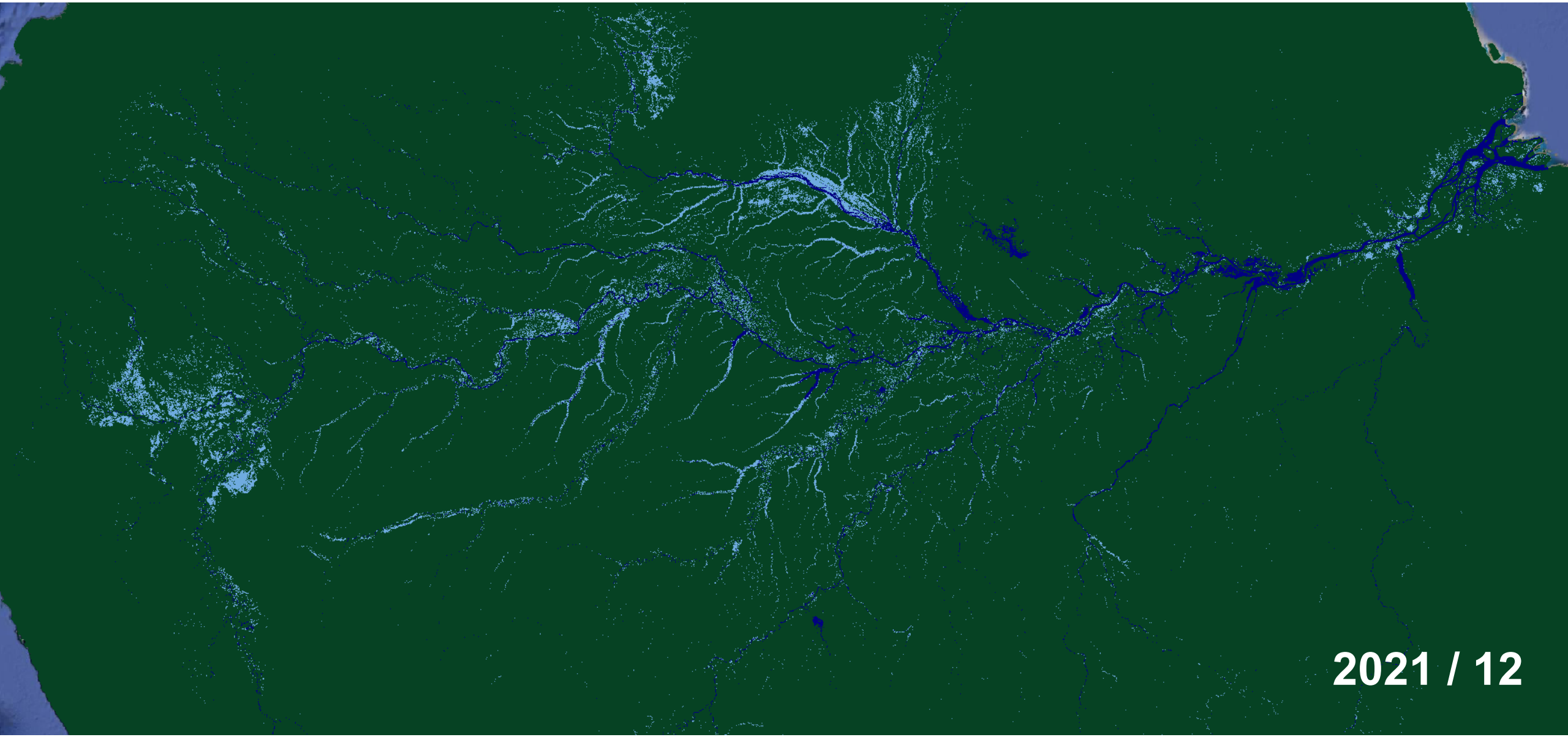

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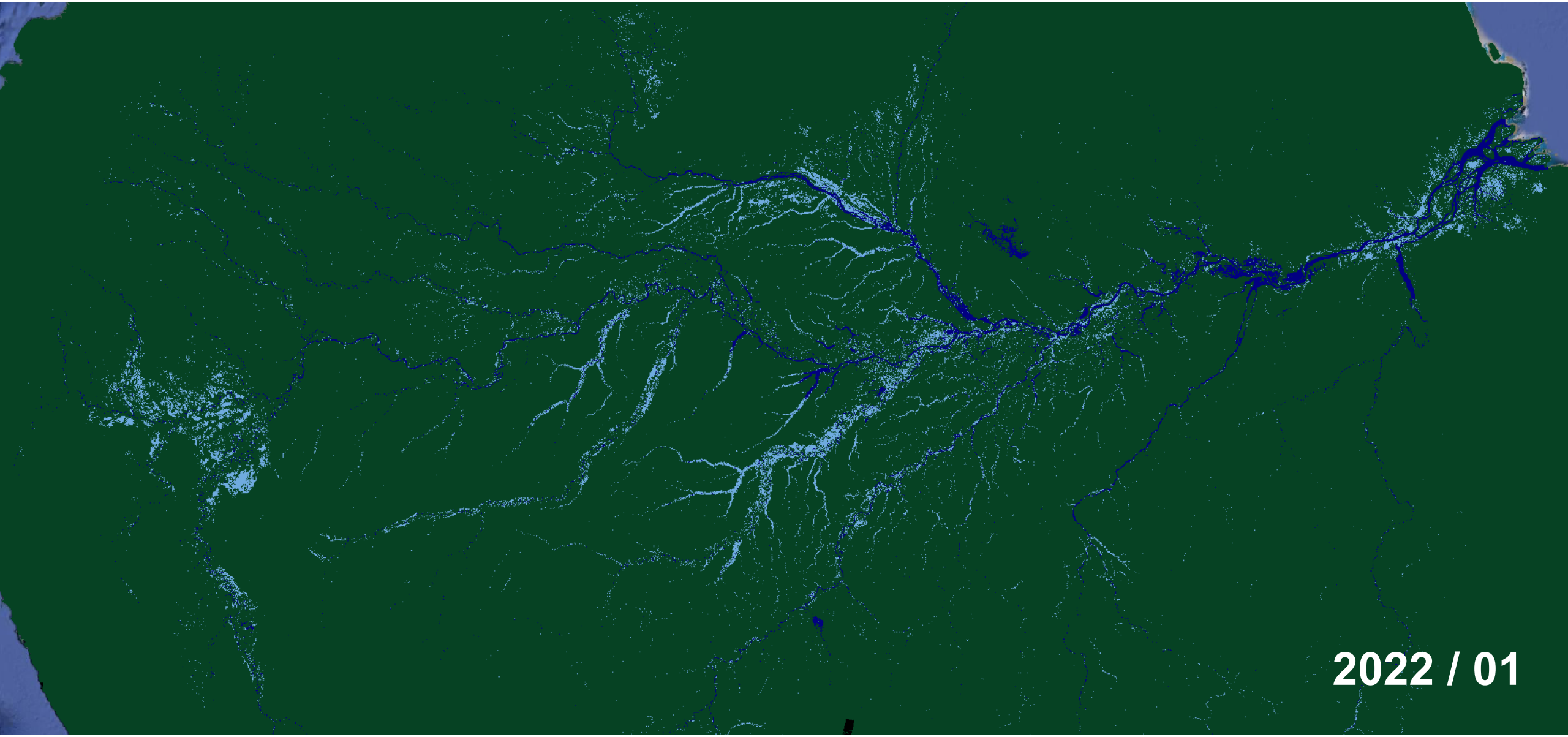

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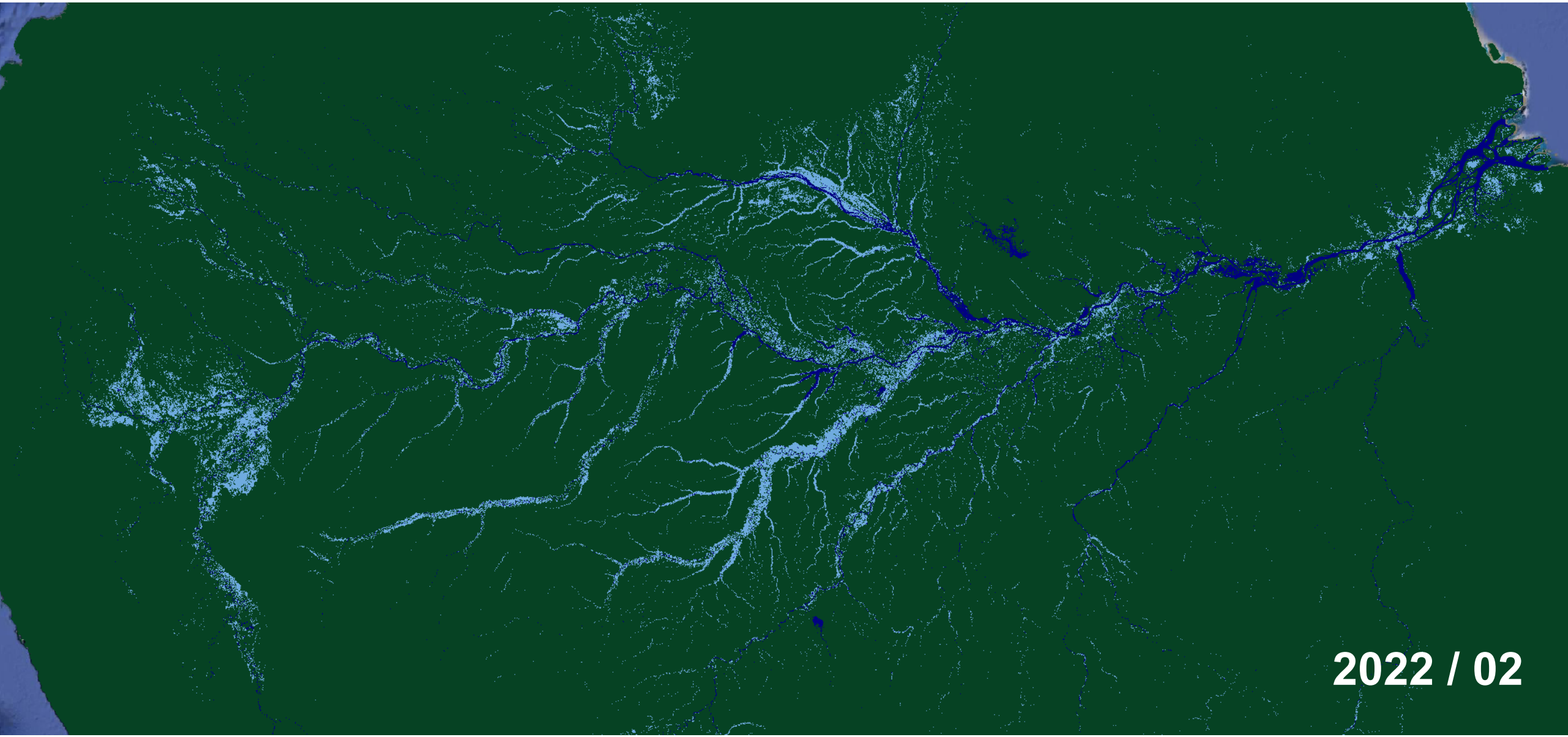

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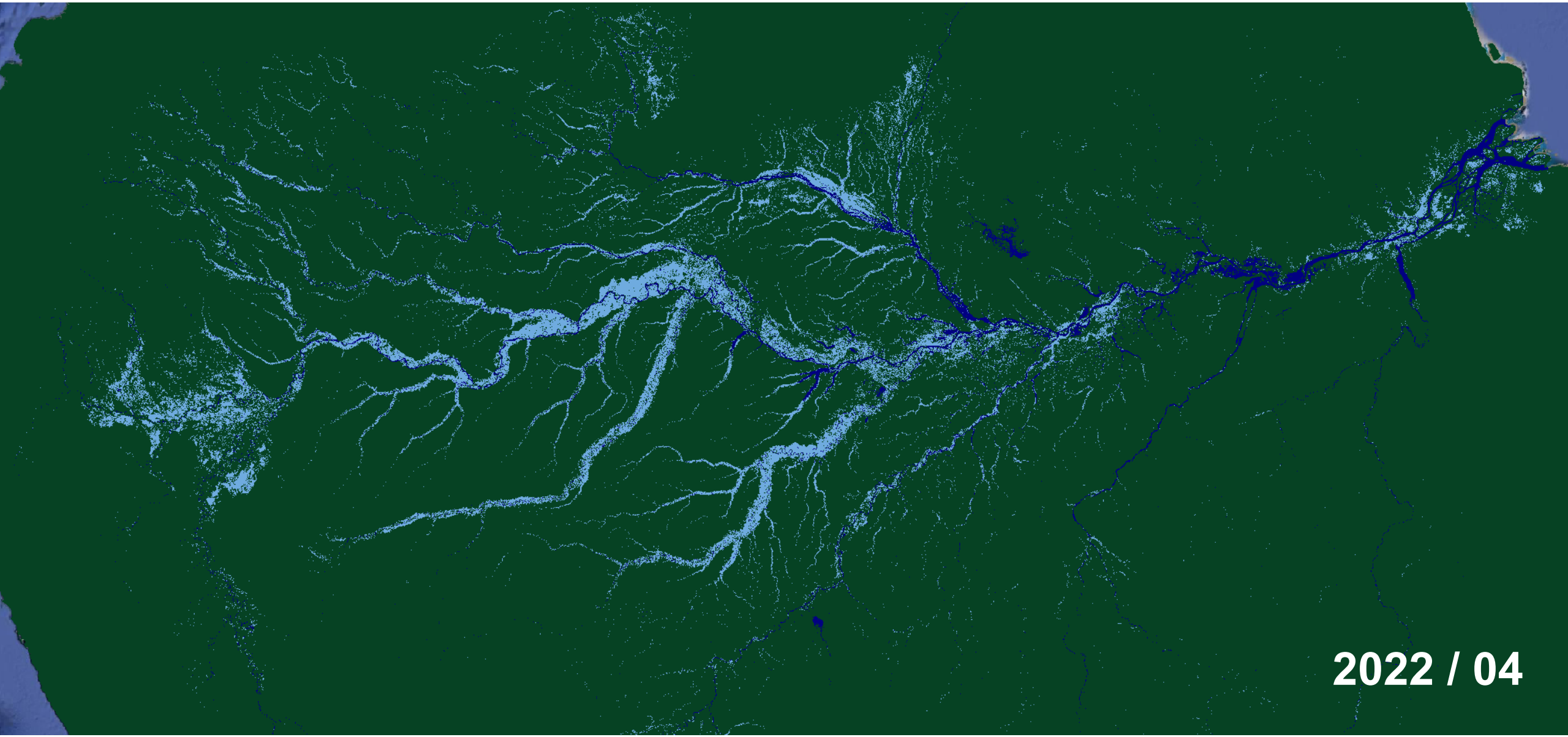

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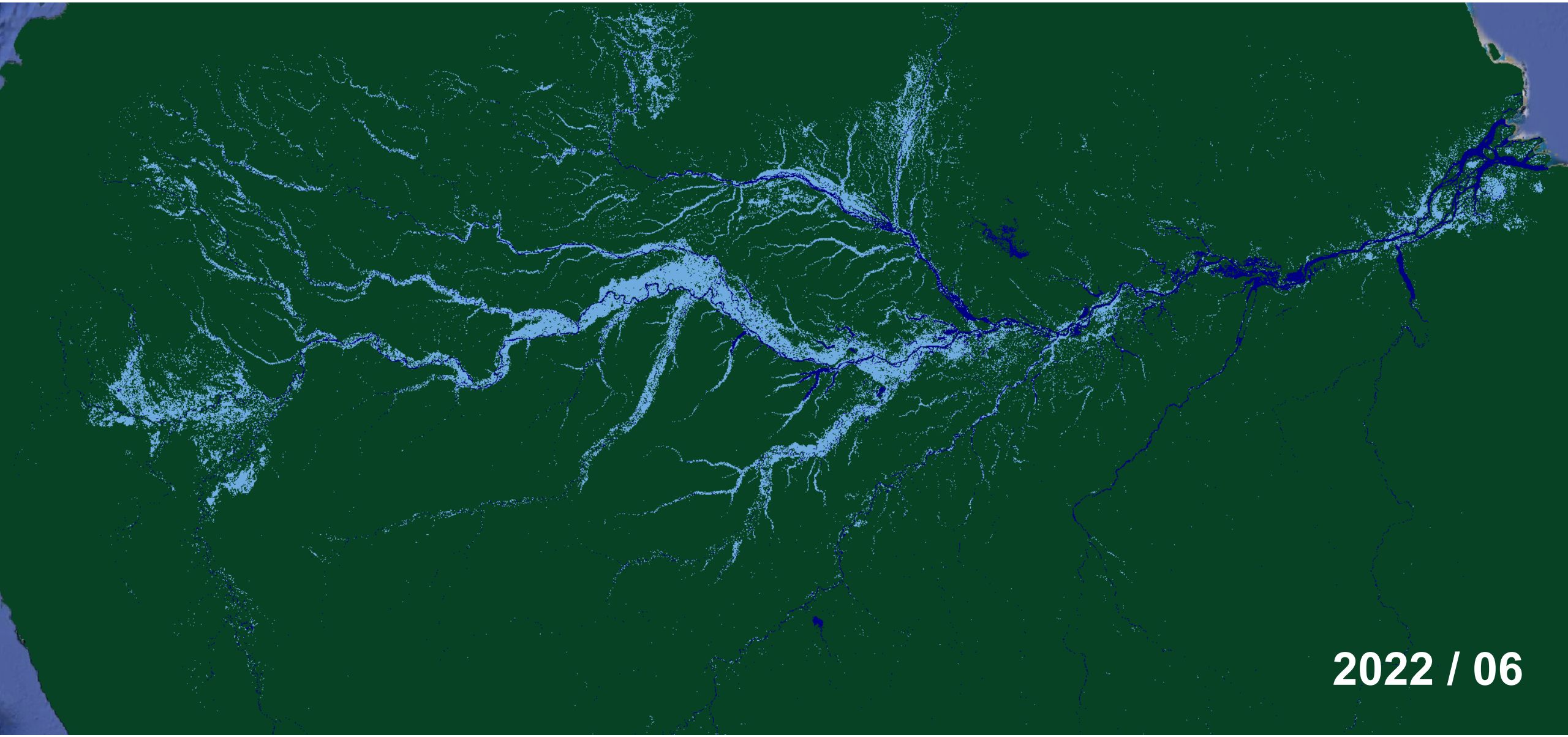

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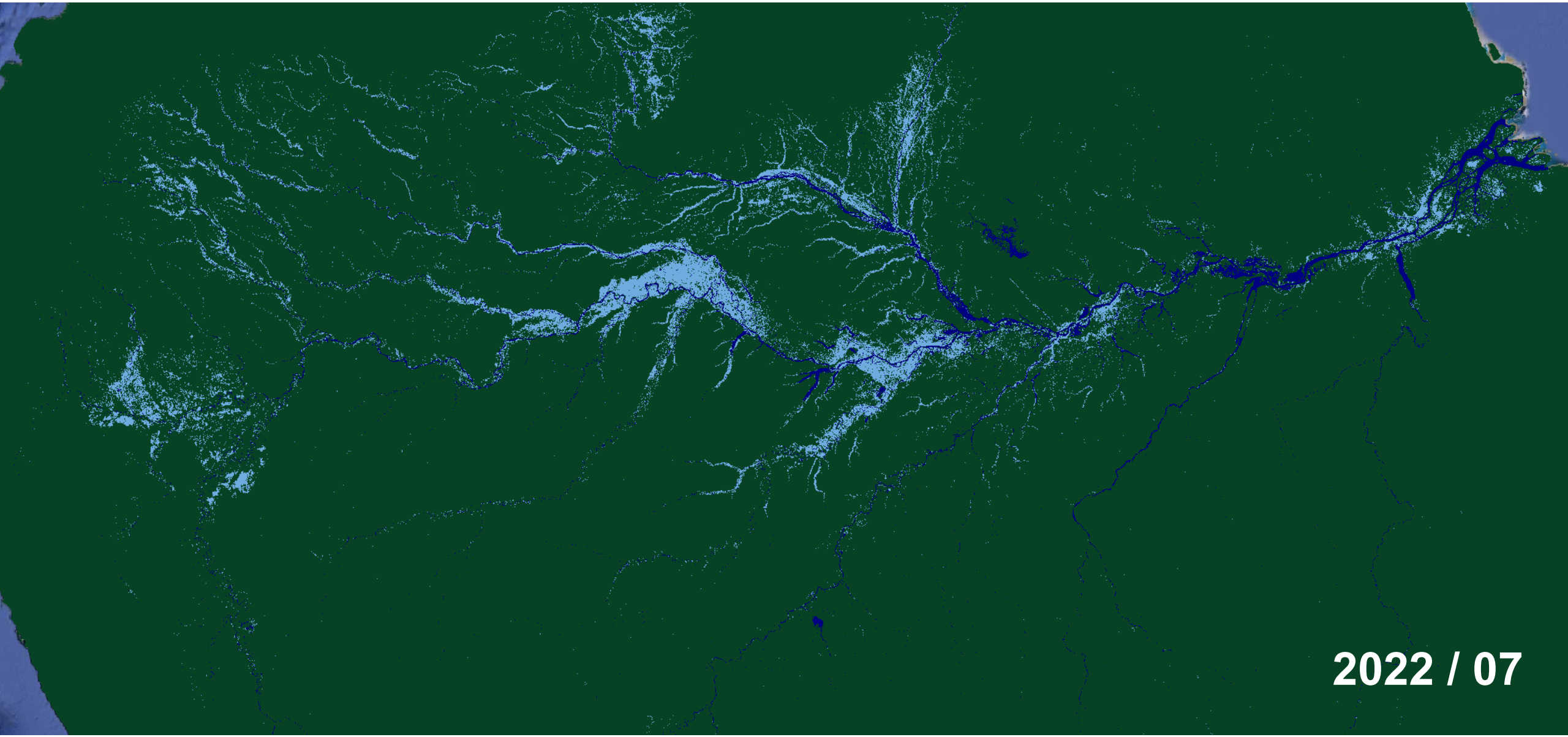

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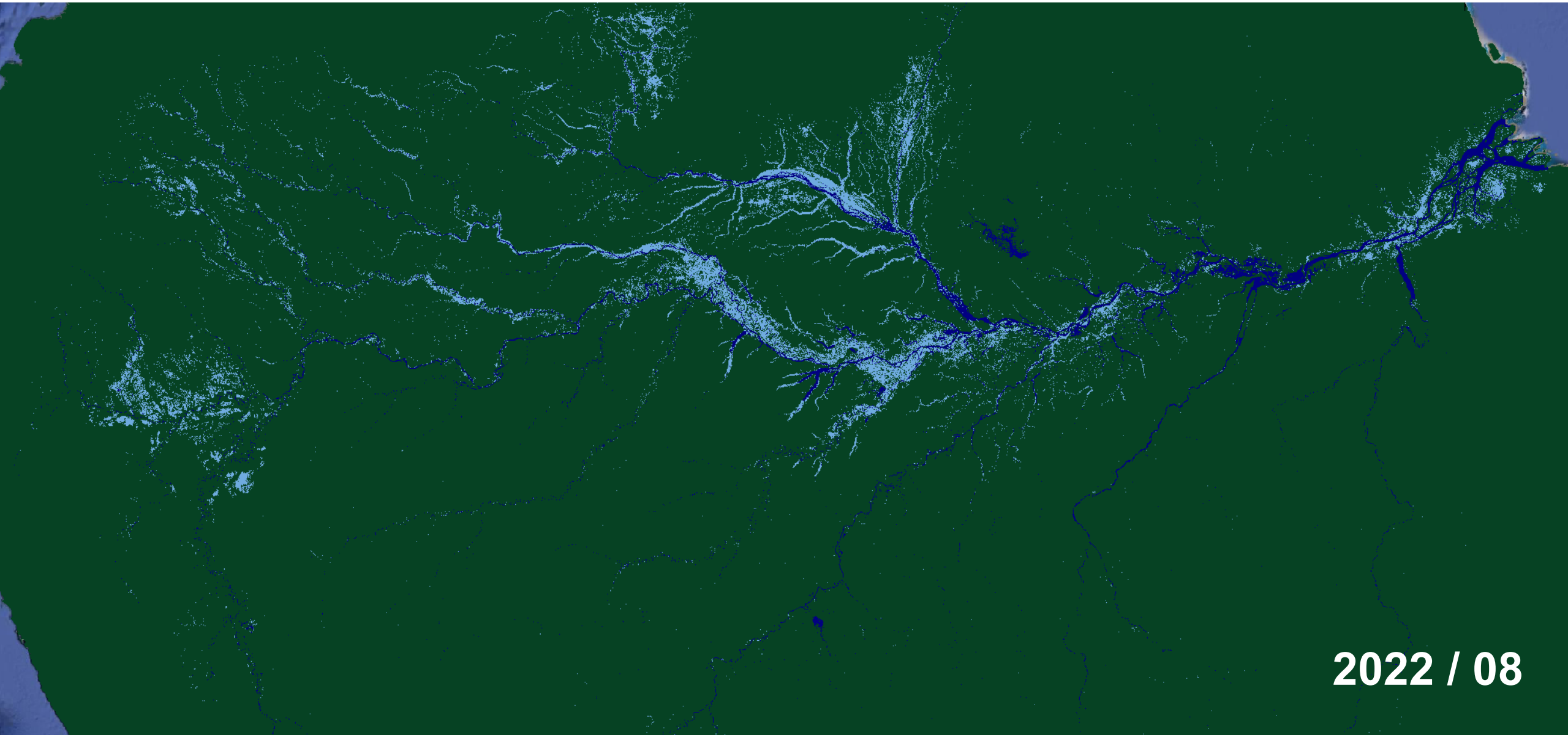

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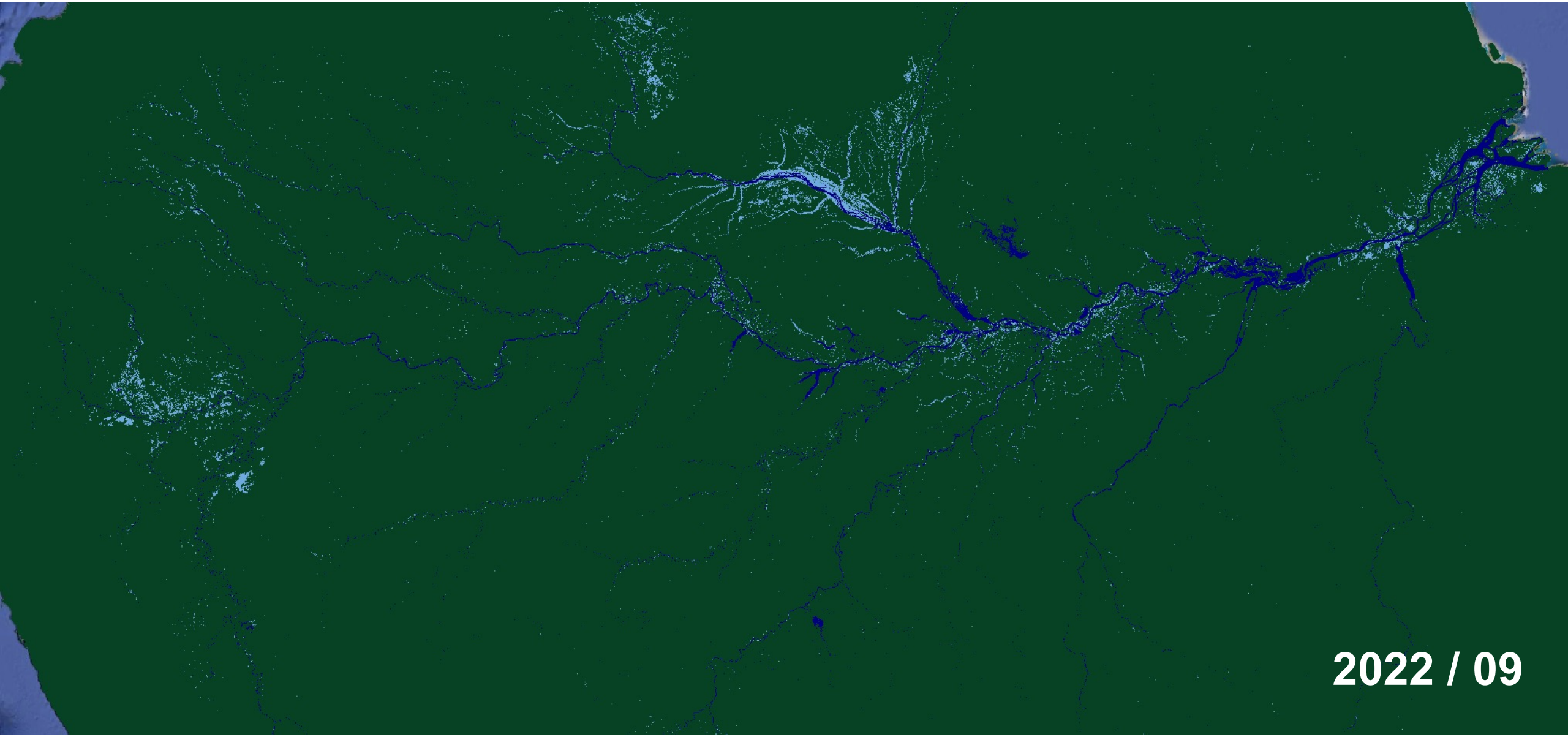

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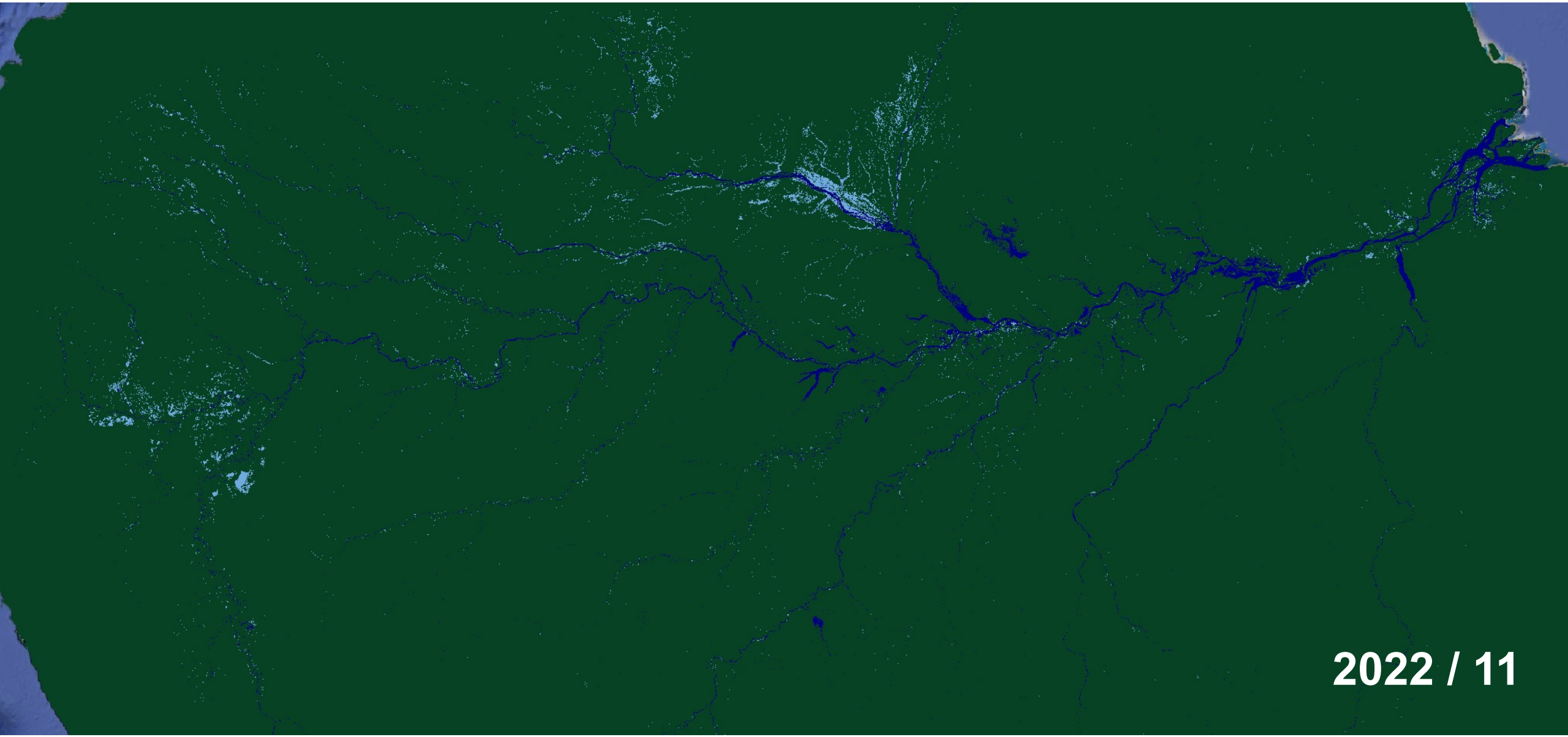

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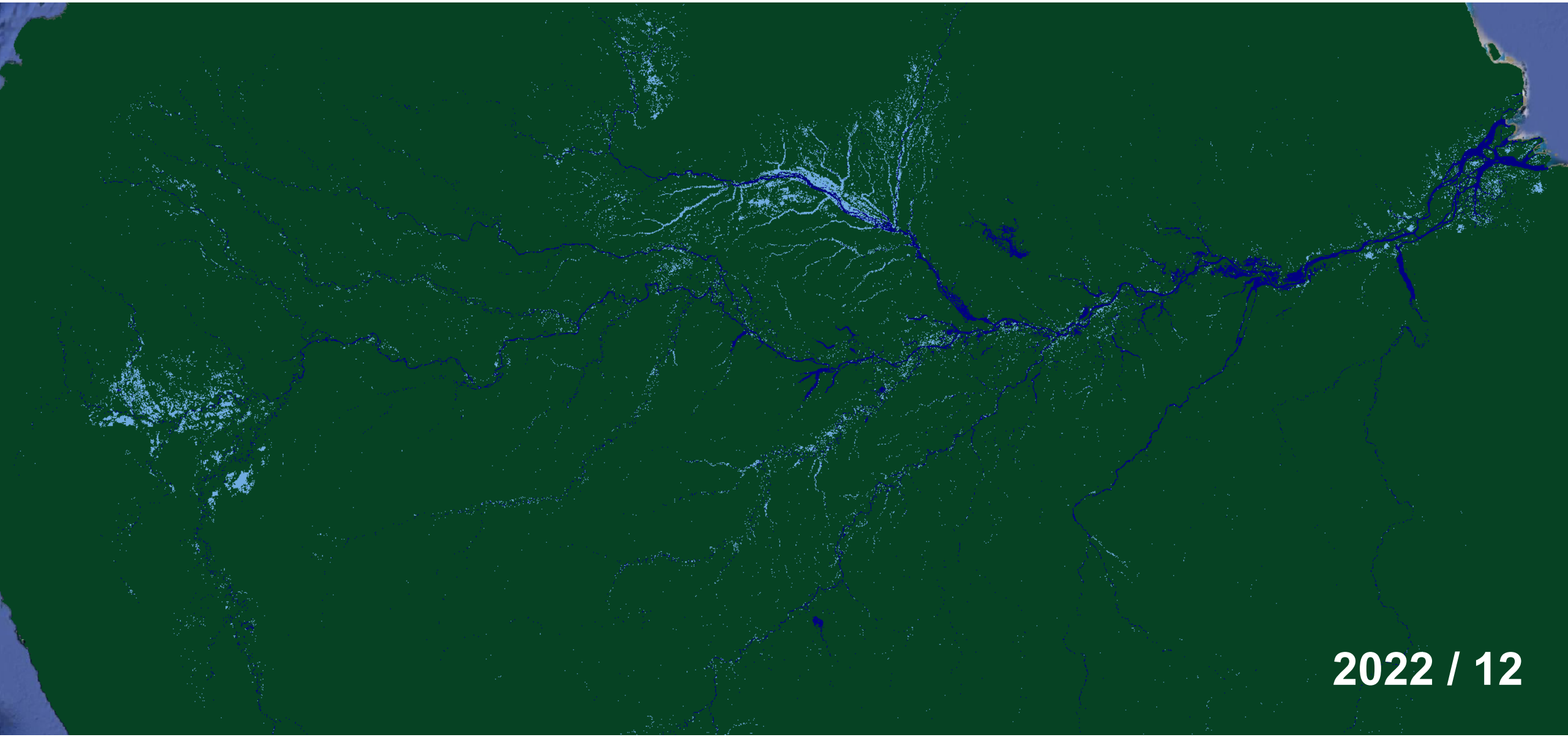

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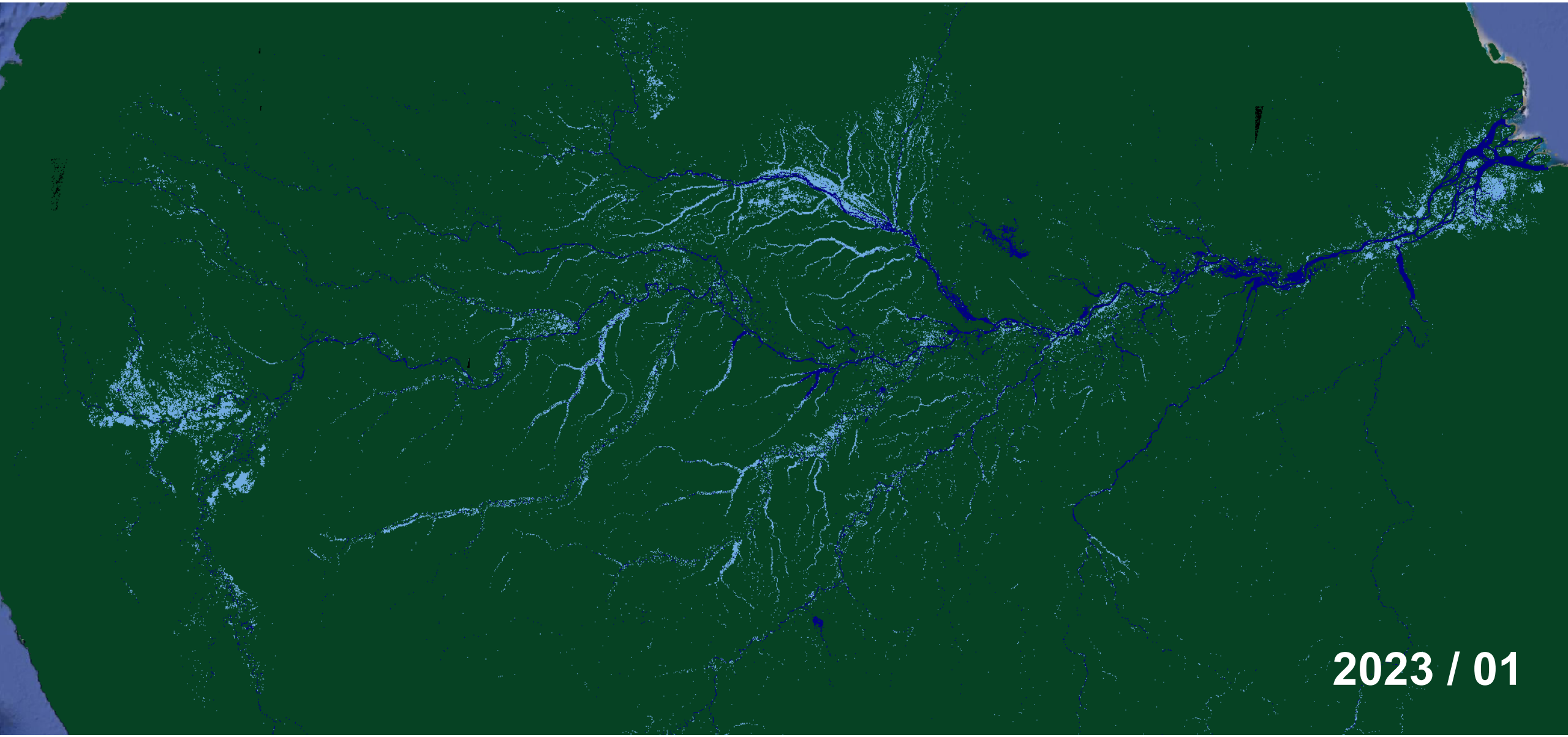

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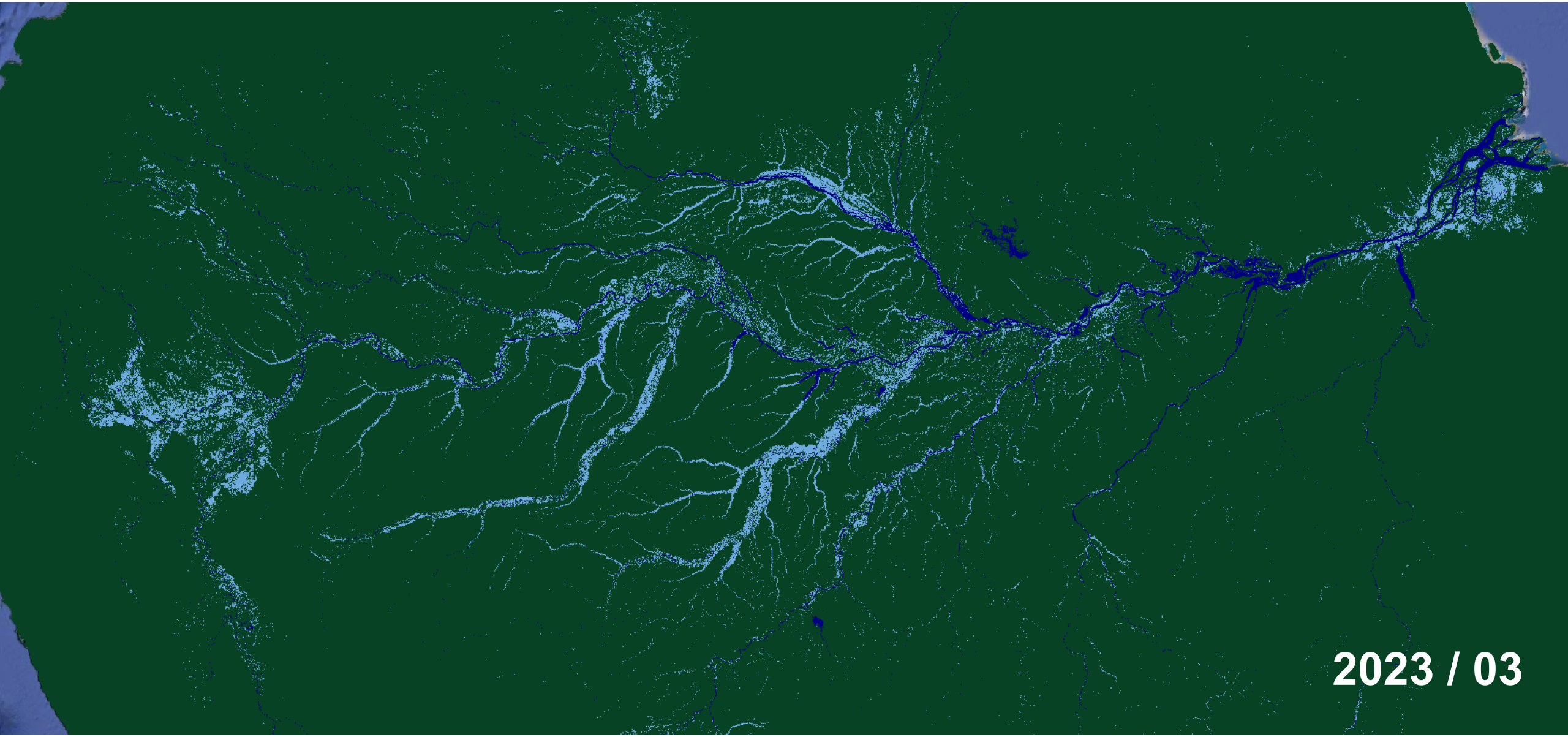

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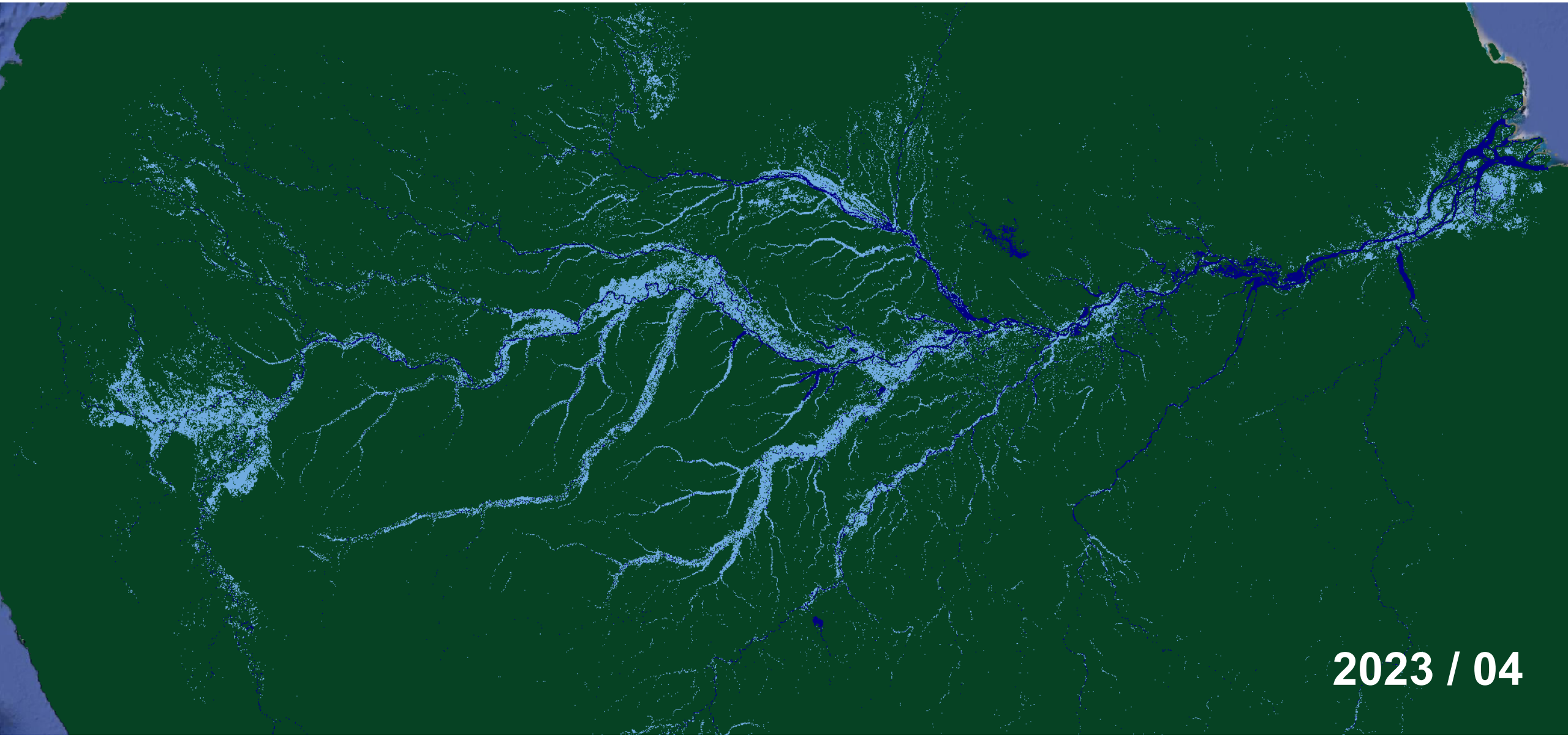

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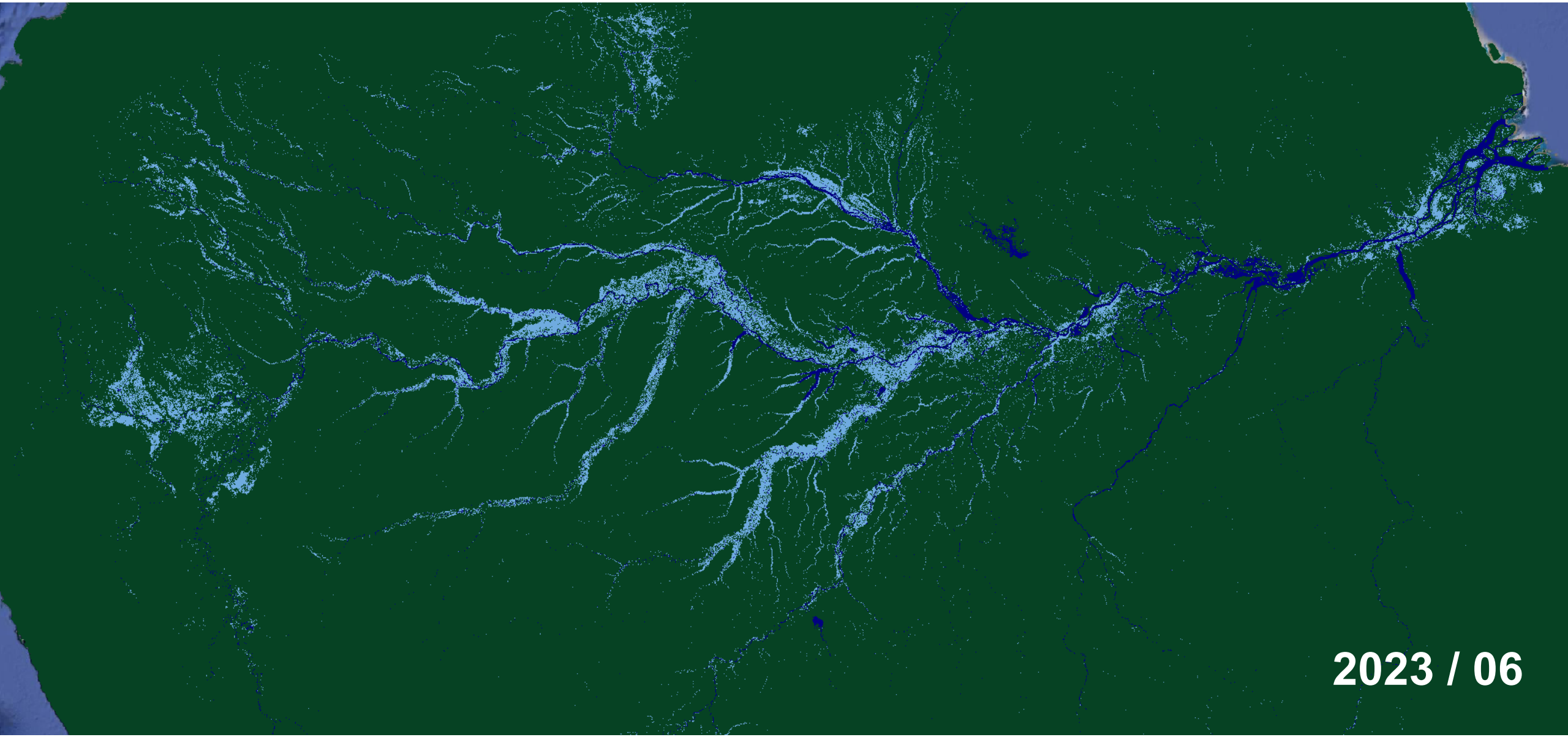
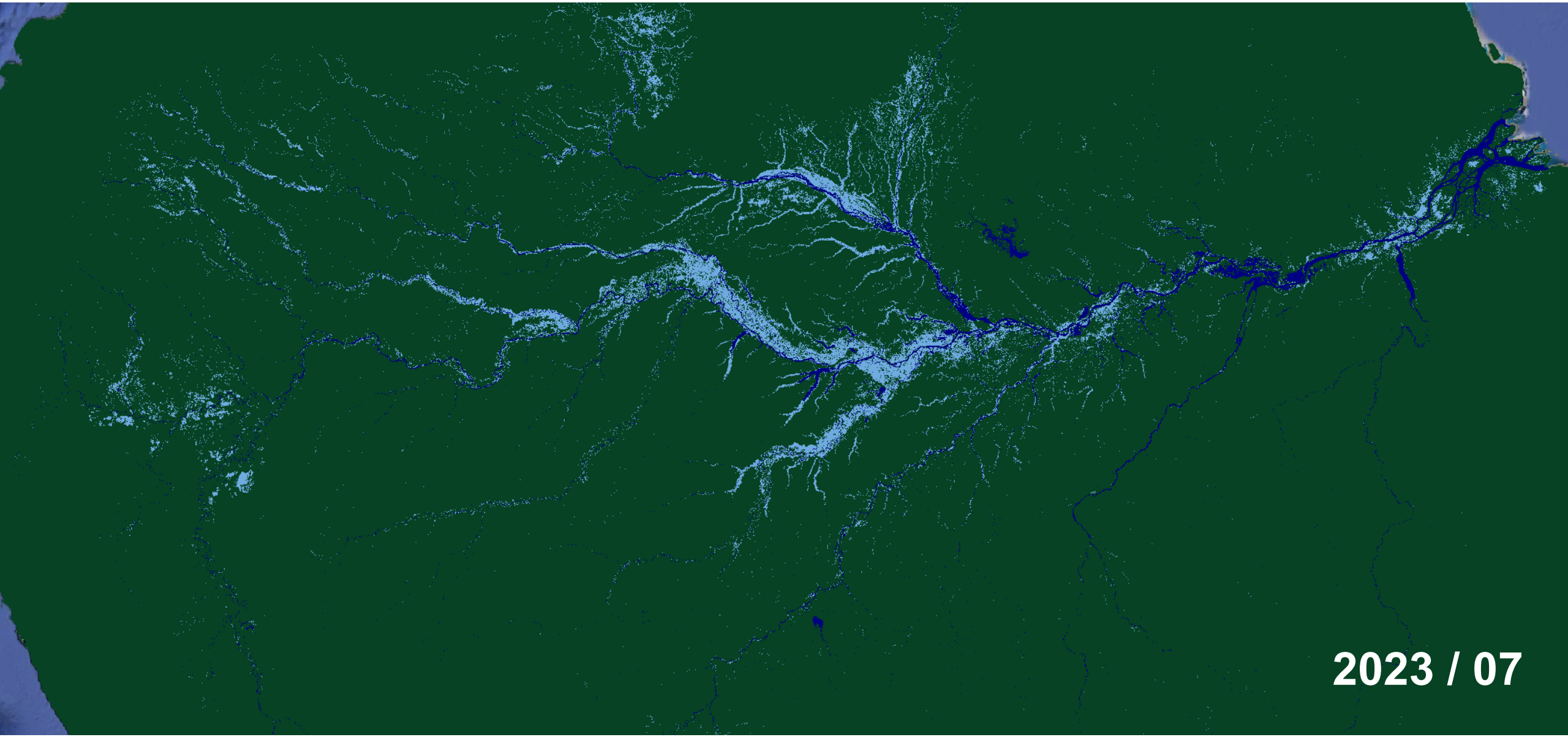
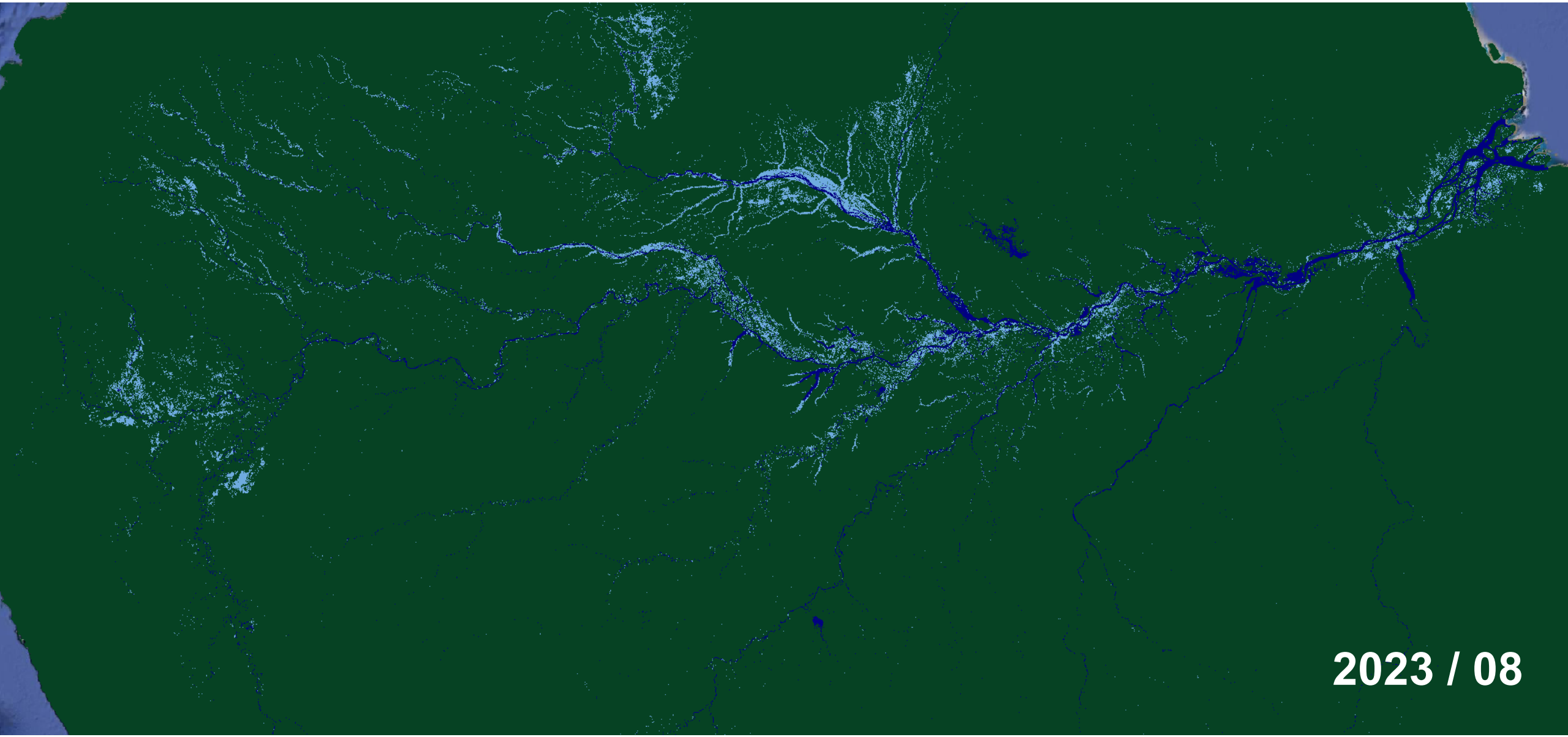


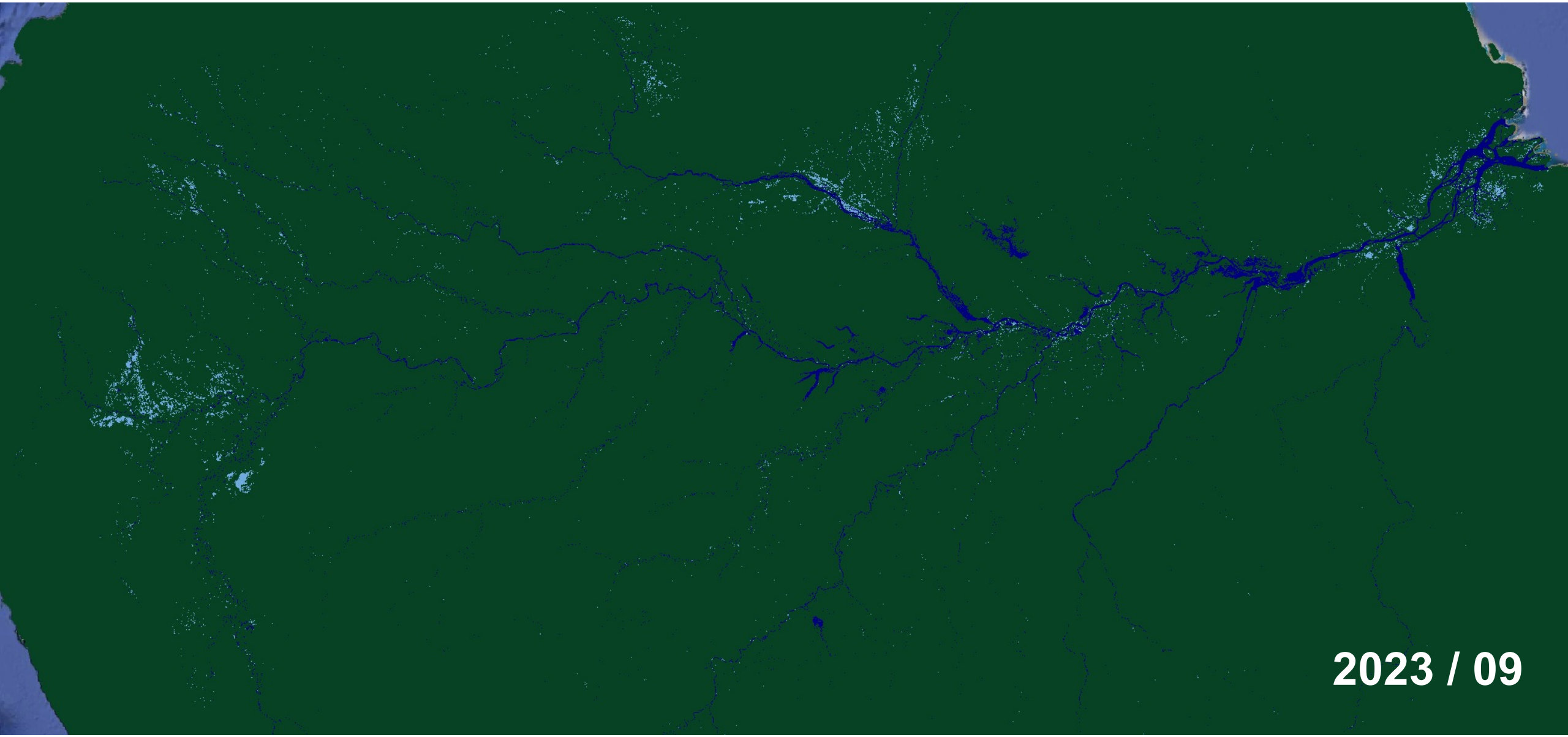
Forested wetlands – Inundation Extent



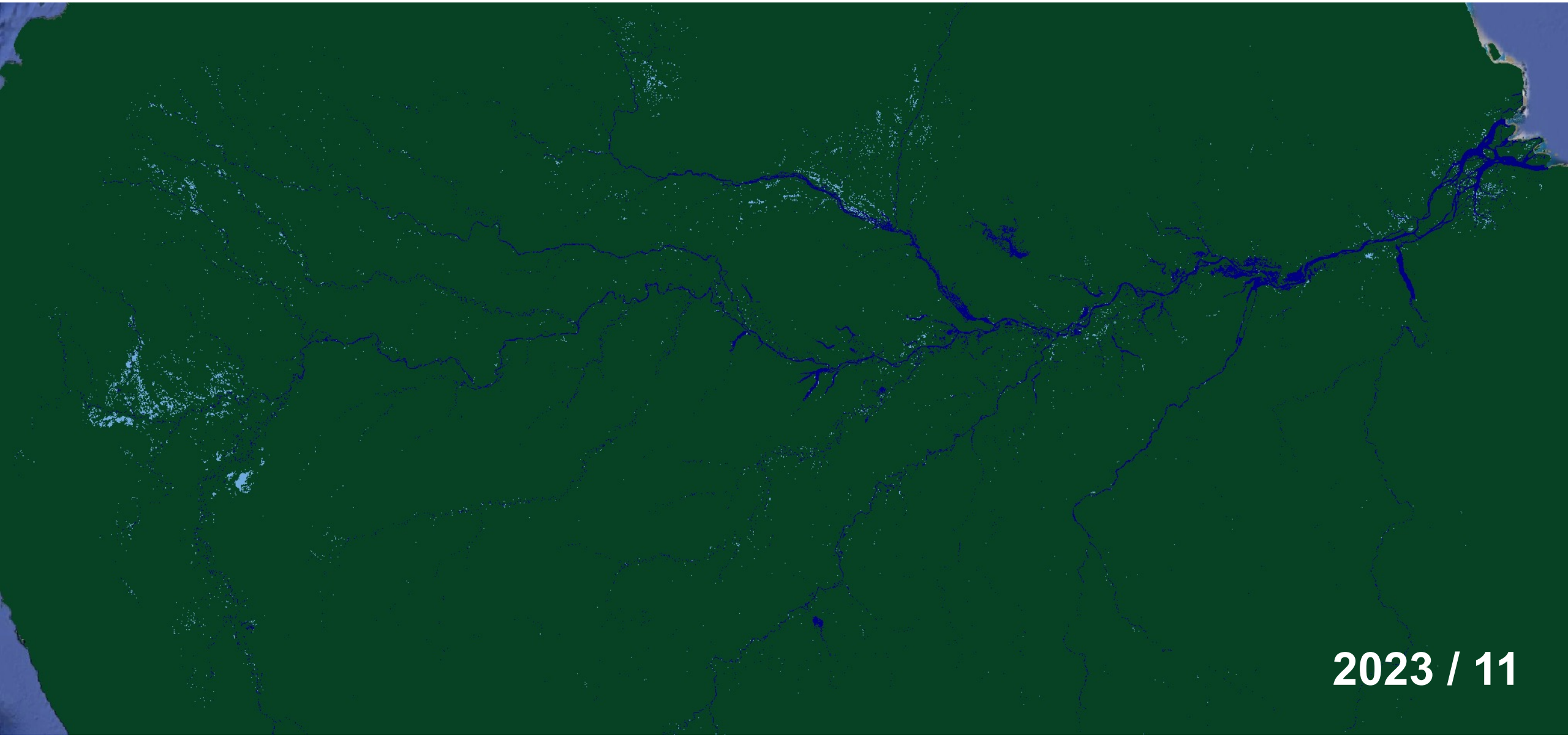
Forested wetlands – Inundation Extent



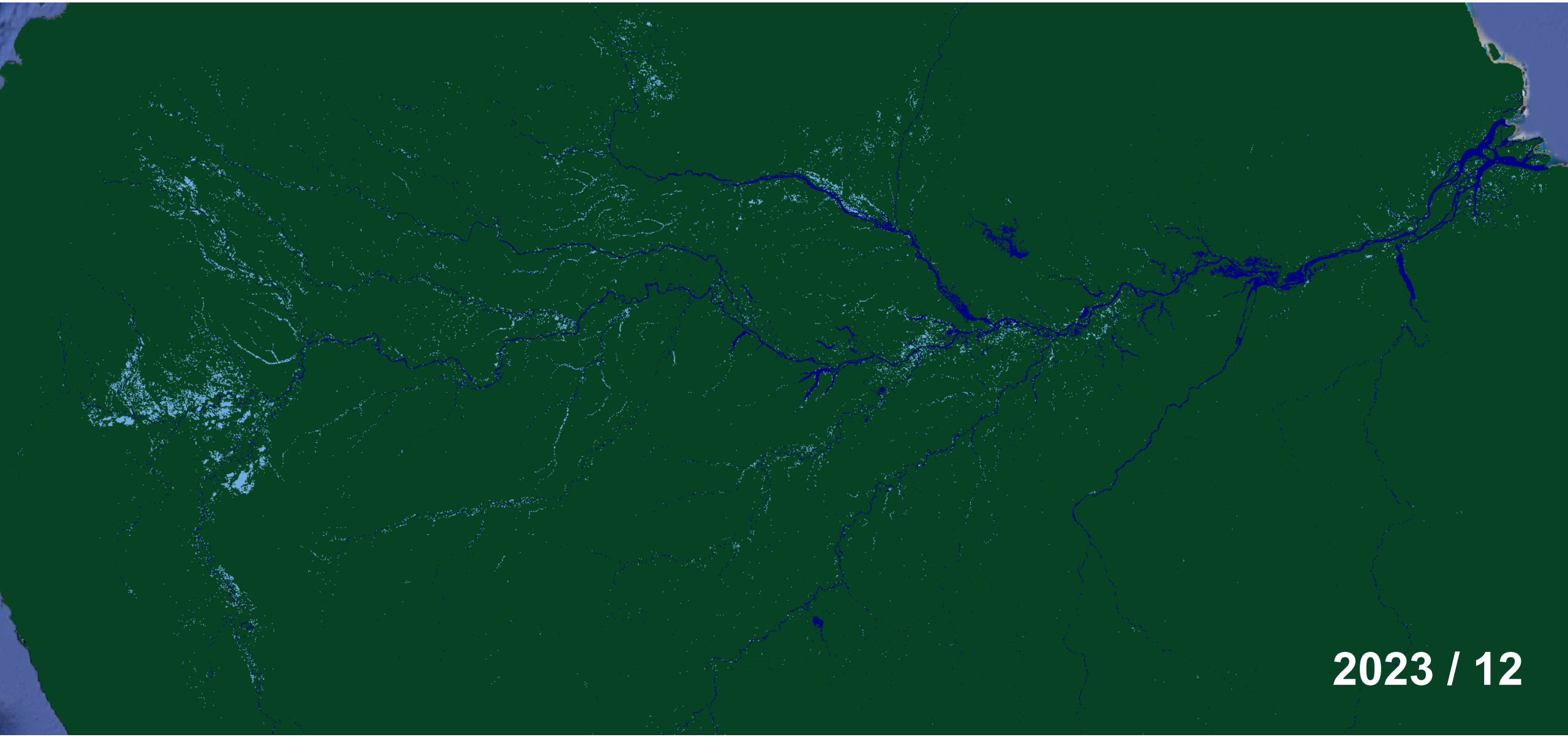
Forested wetlands – Inundation Extent



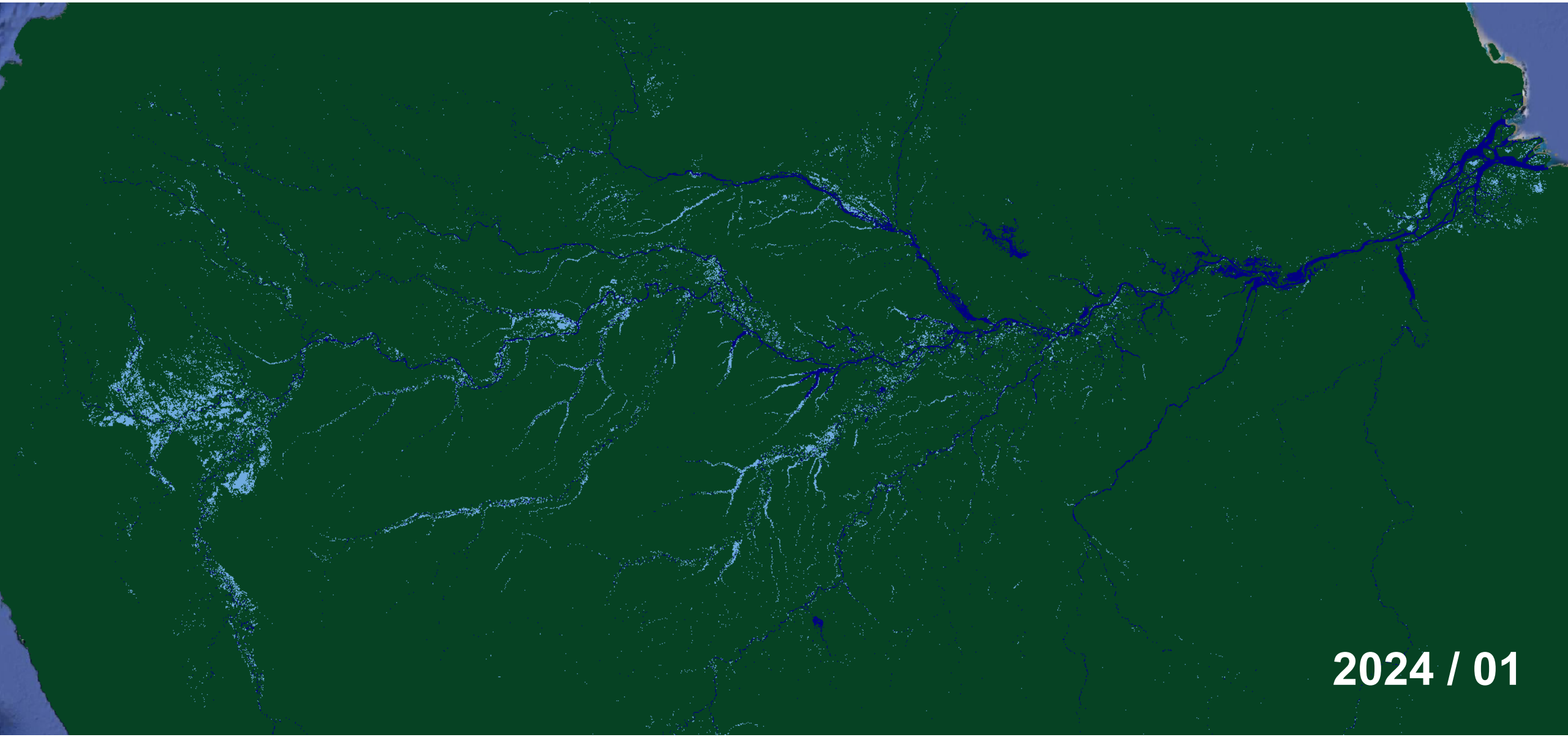
Forested wetlands – Inundation Extent



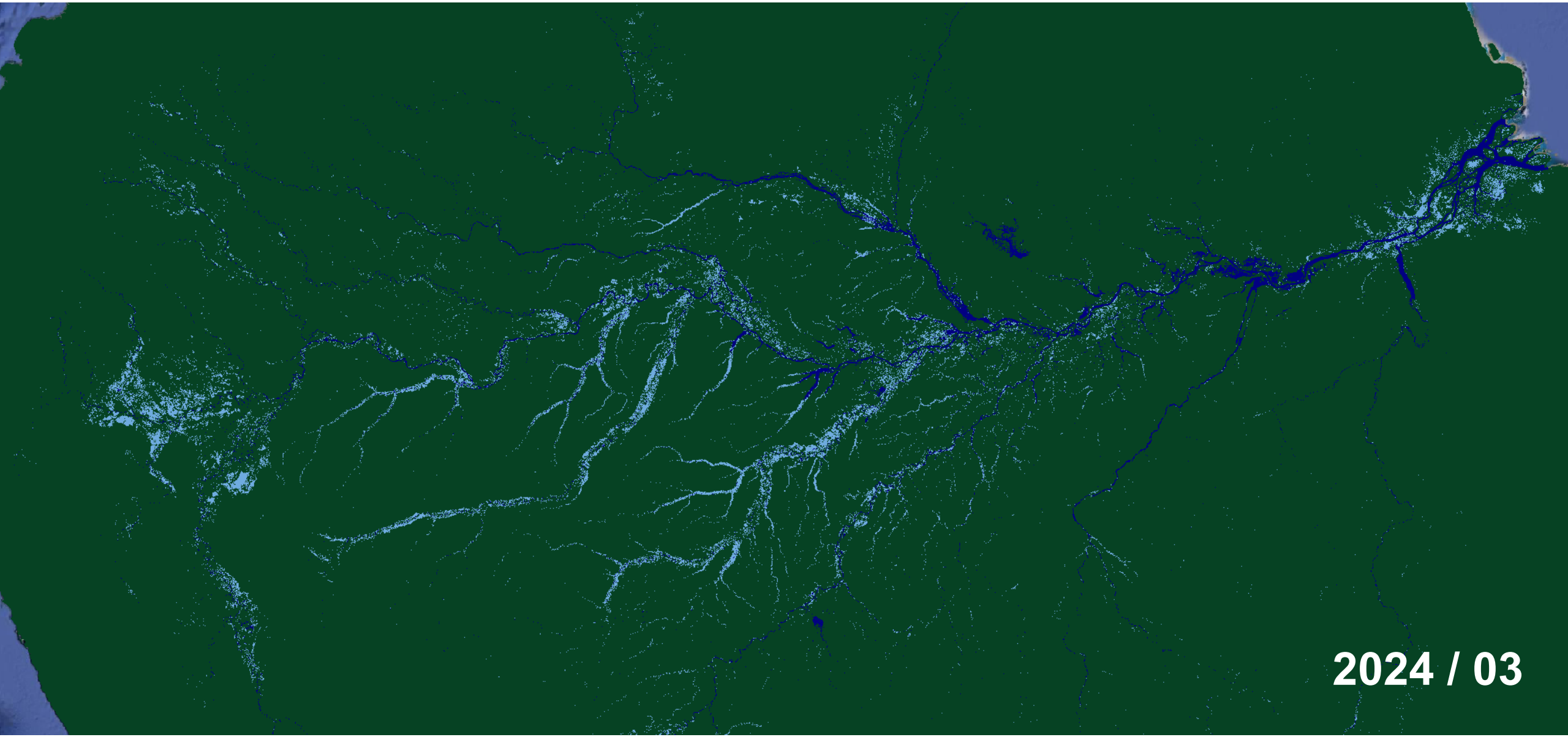
Forested wetlands – Inundation Extent



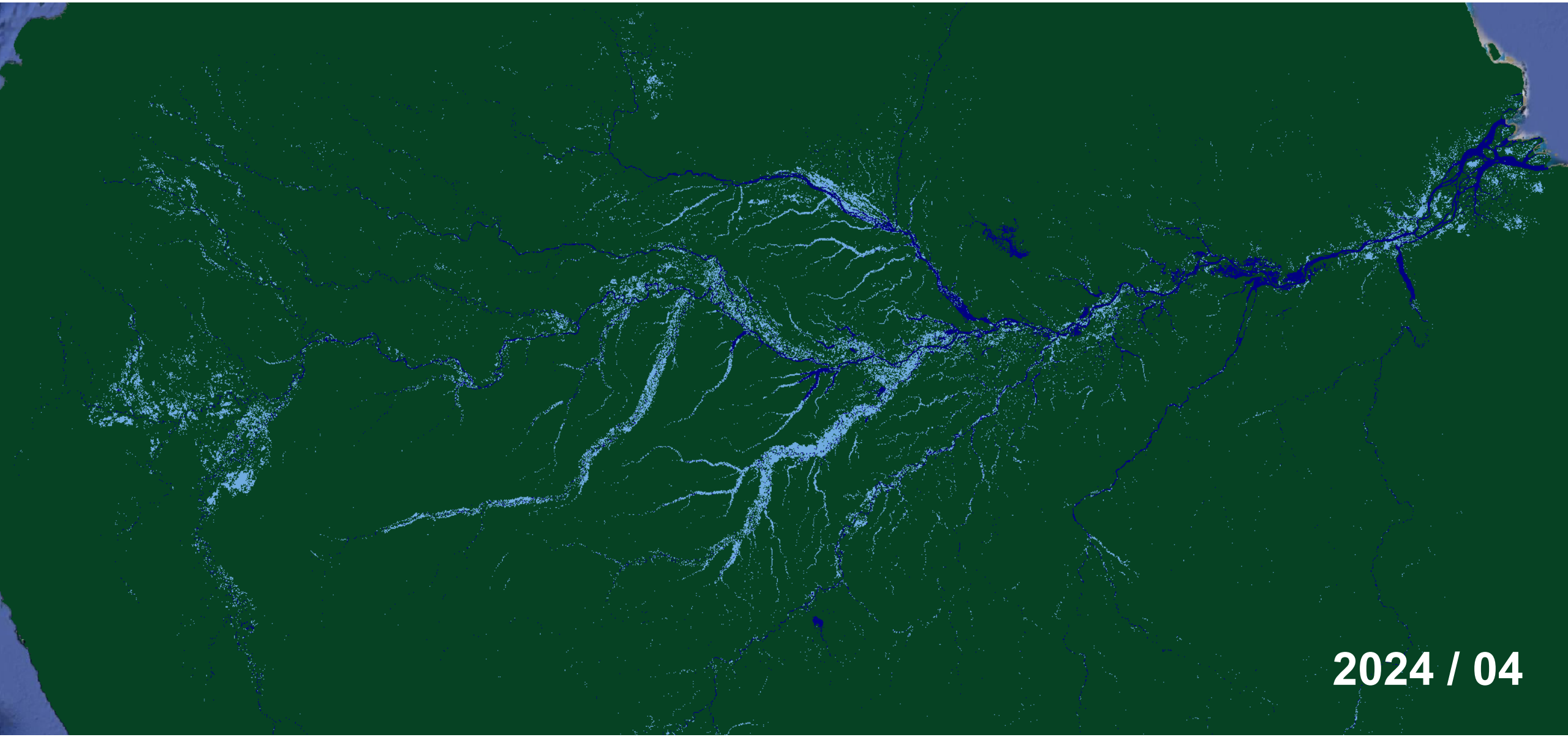
Forested wetlands – Inundation Extent



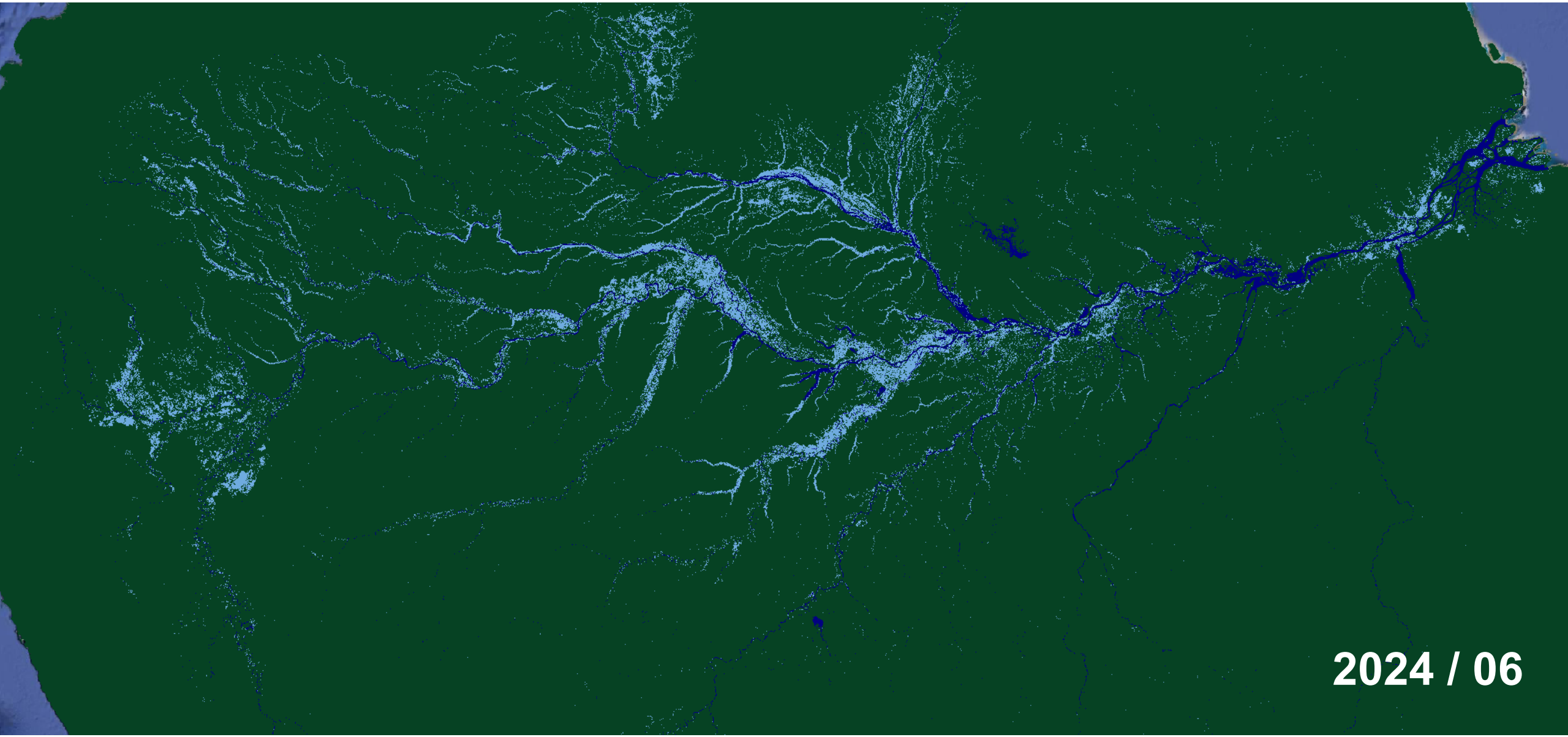
Forested wetlands – Inundation Extent



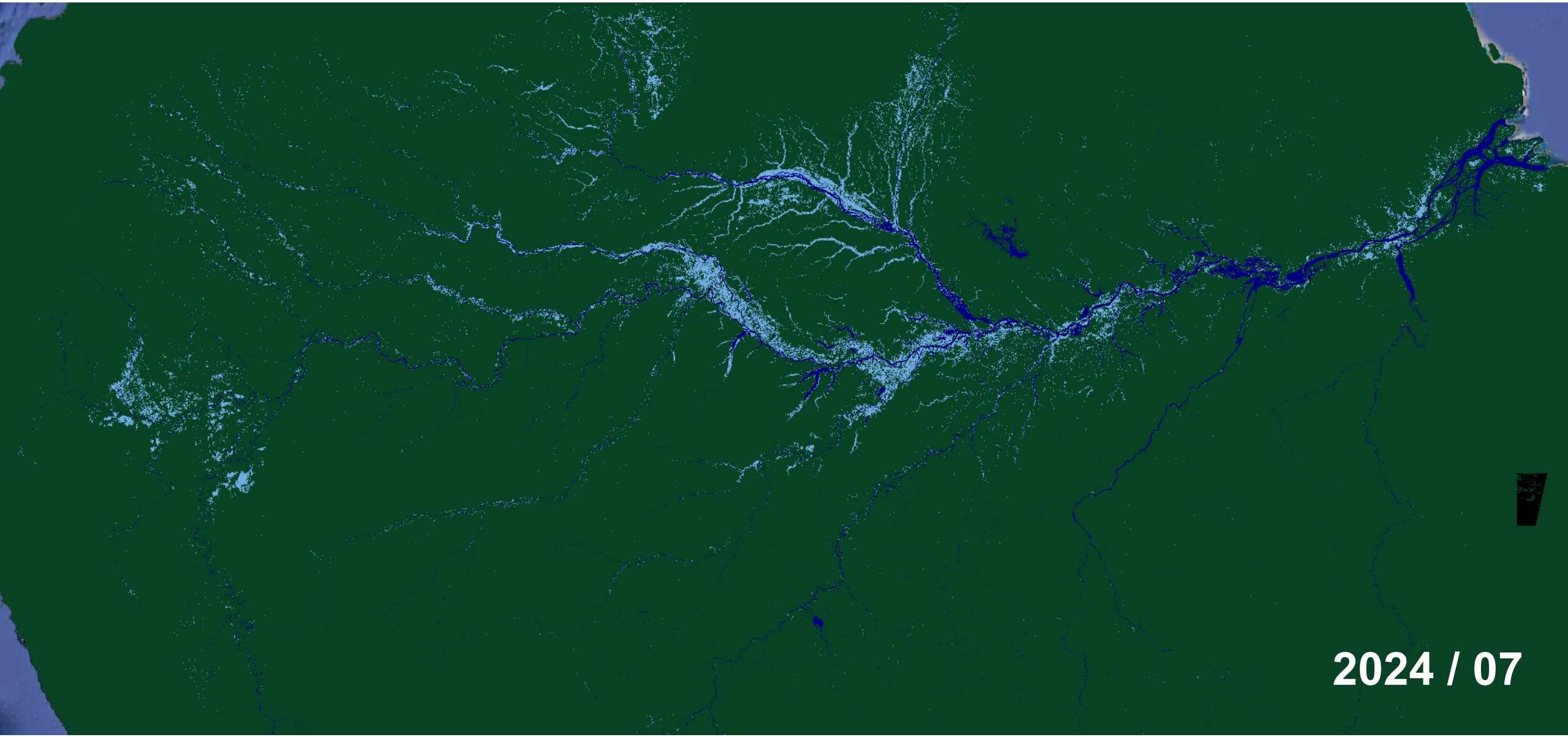
Forested wetlands – Inundation Extent



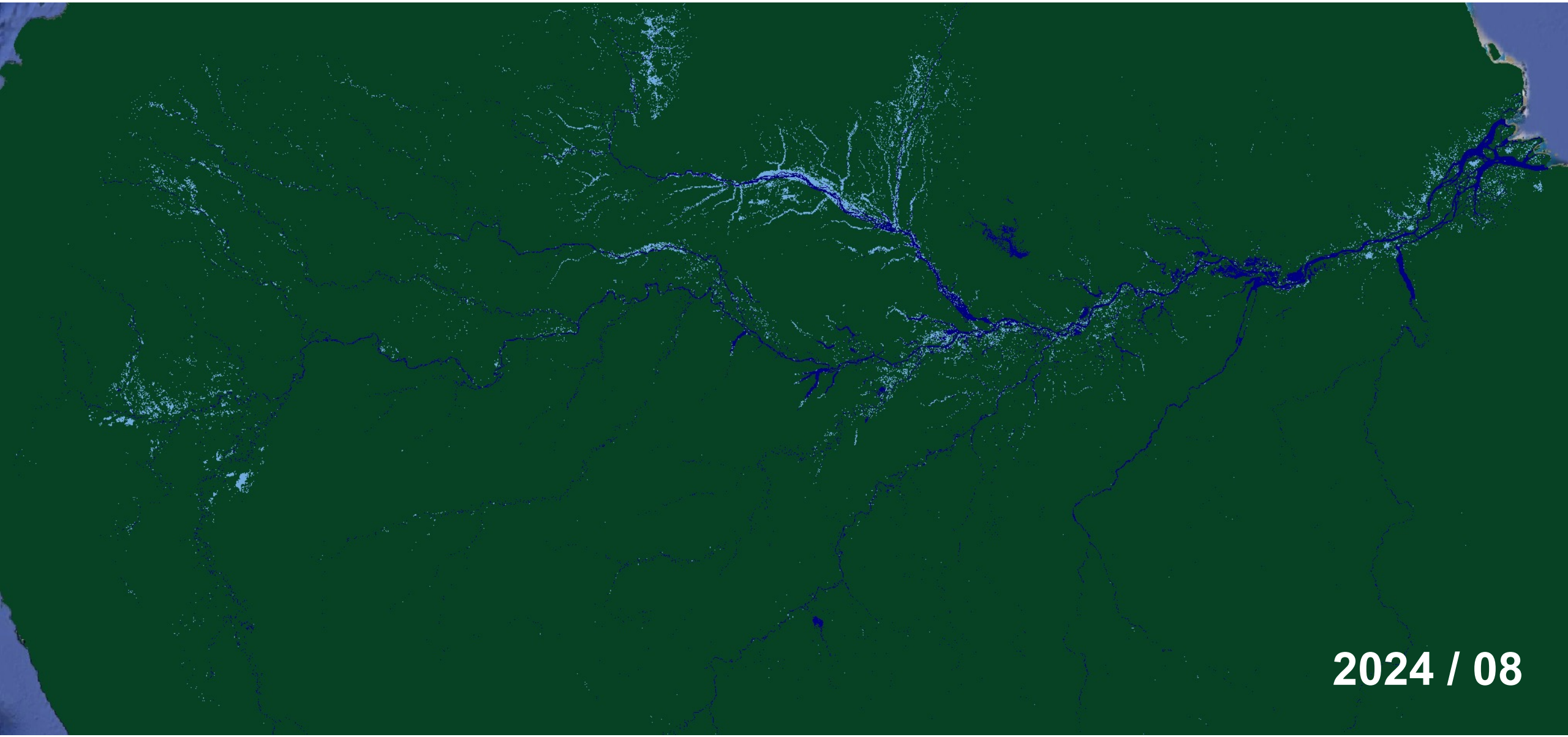
Forested wetlands – Inundation Extent



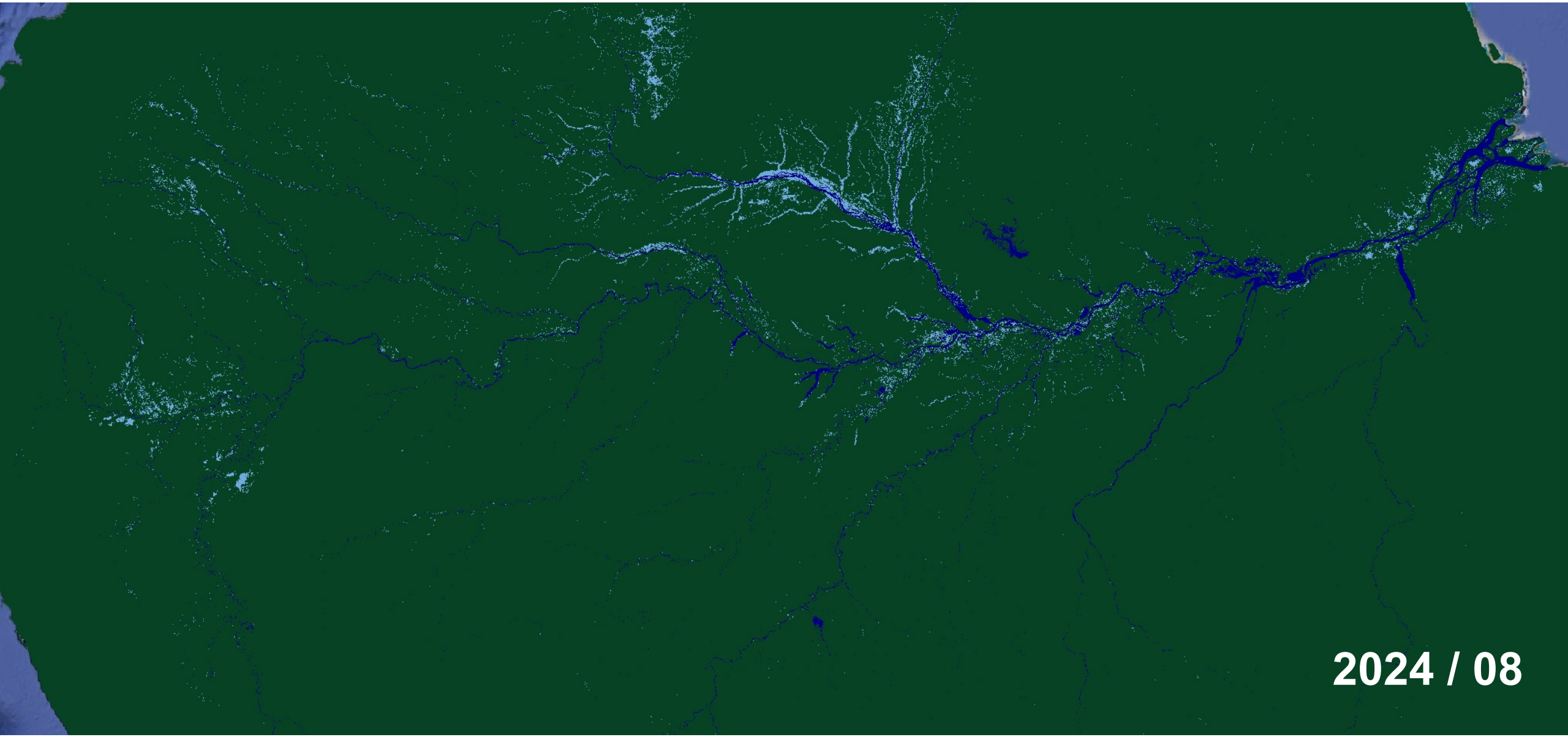
Forested wetlands – Inundation Extent



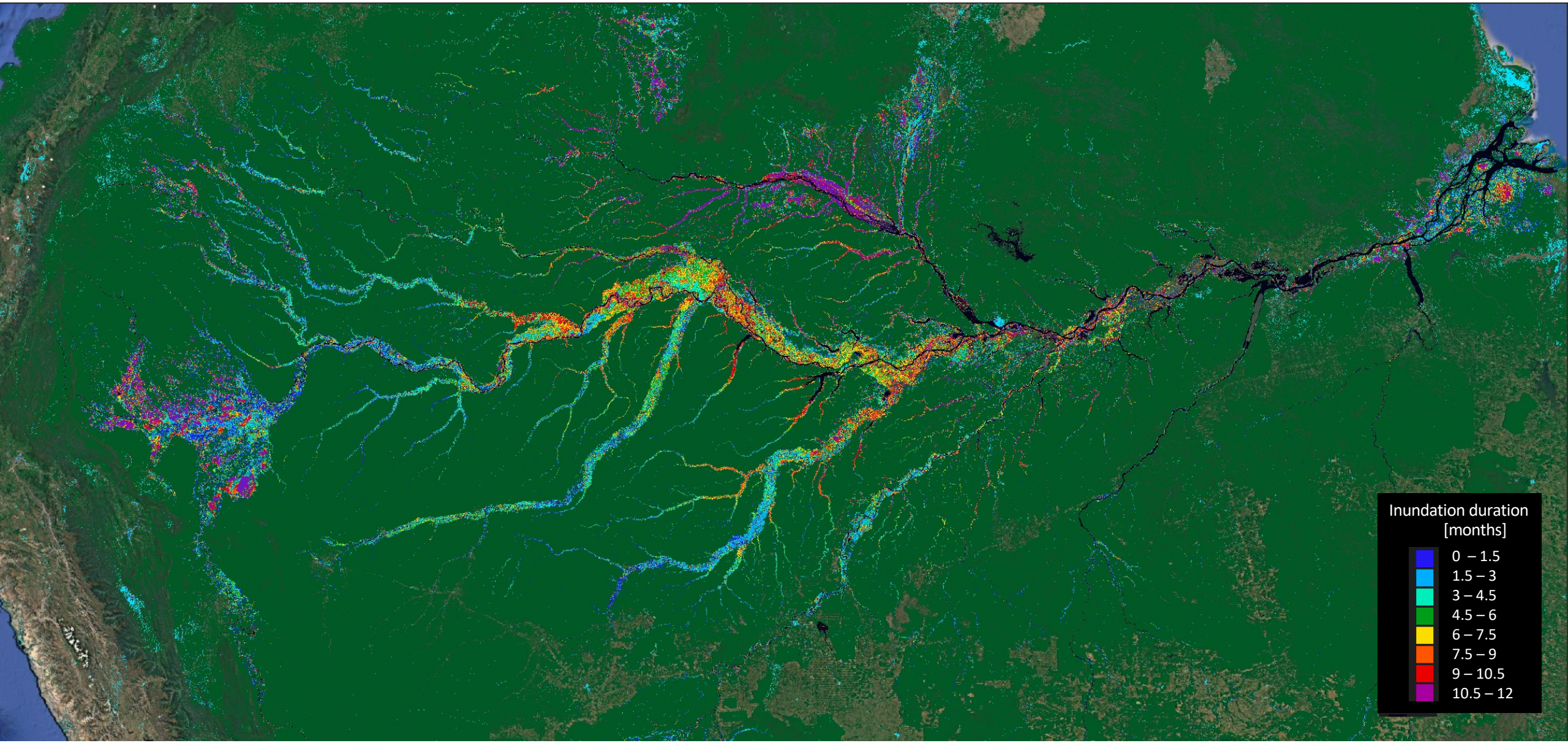
Forested wetlands – Inundation Extent



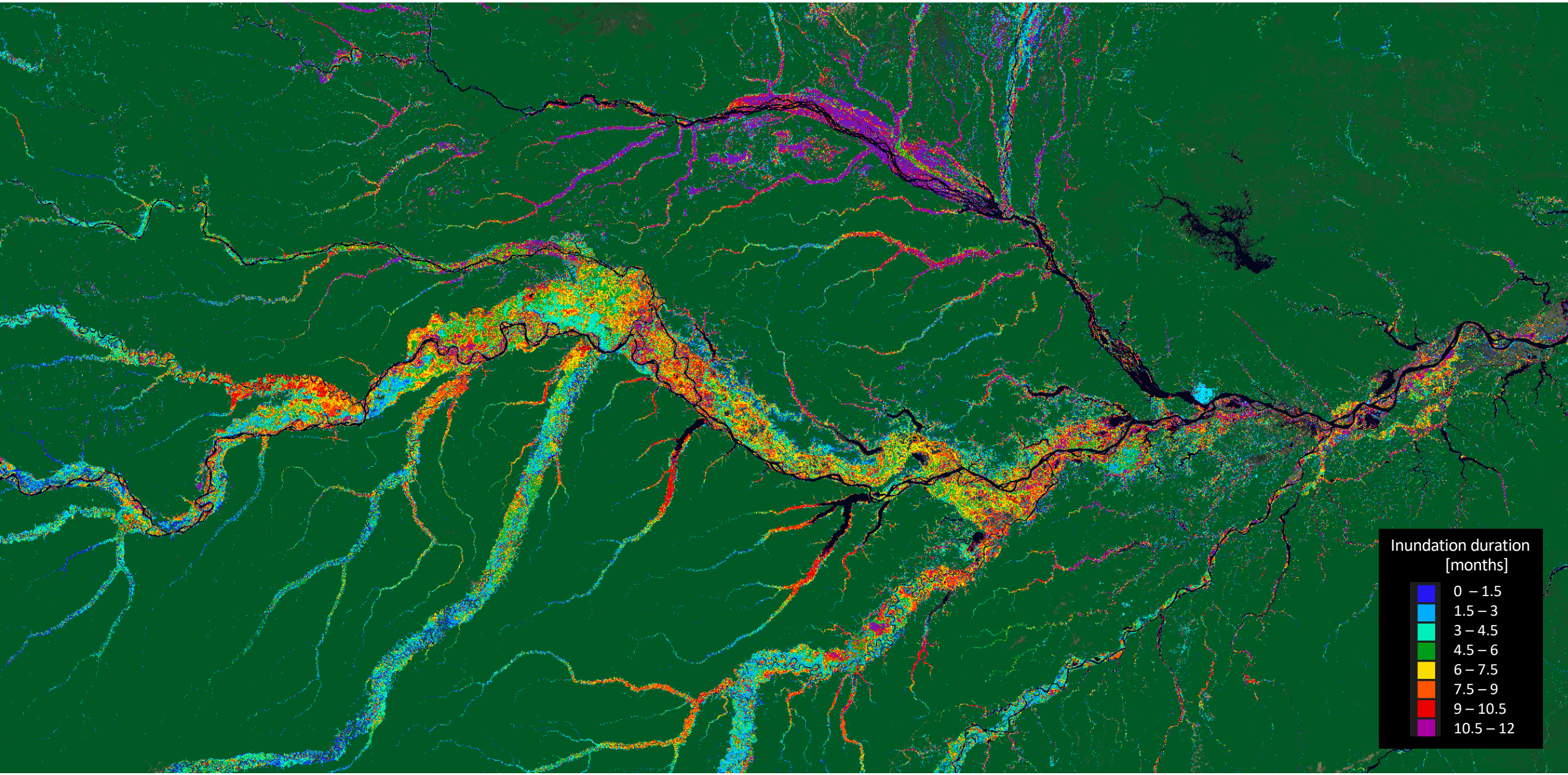
Forested wetlands – Inundation Extent



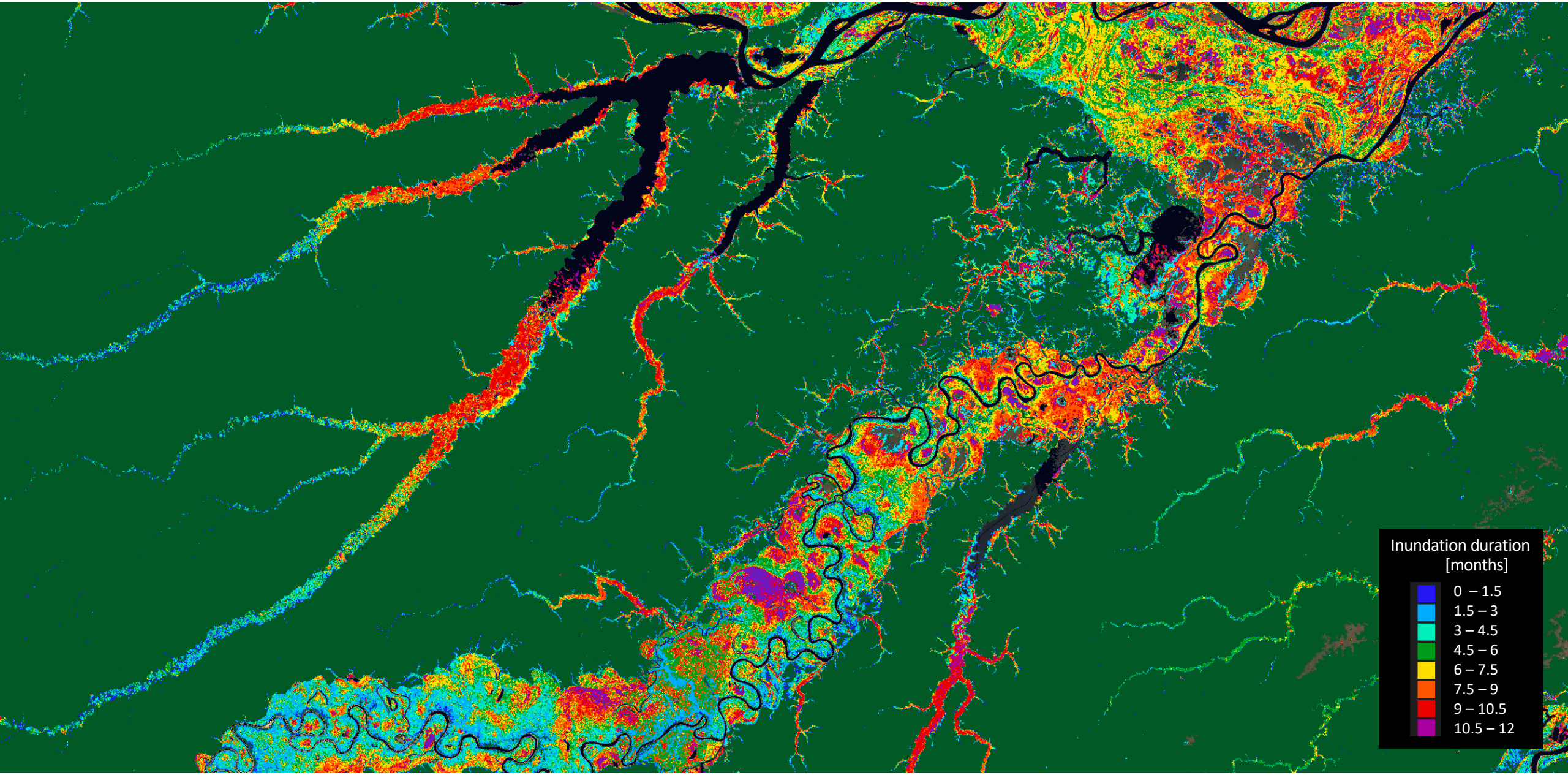
Inundation duration



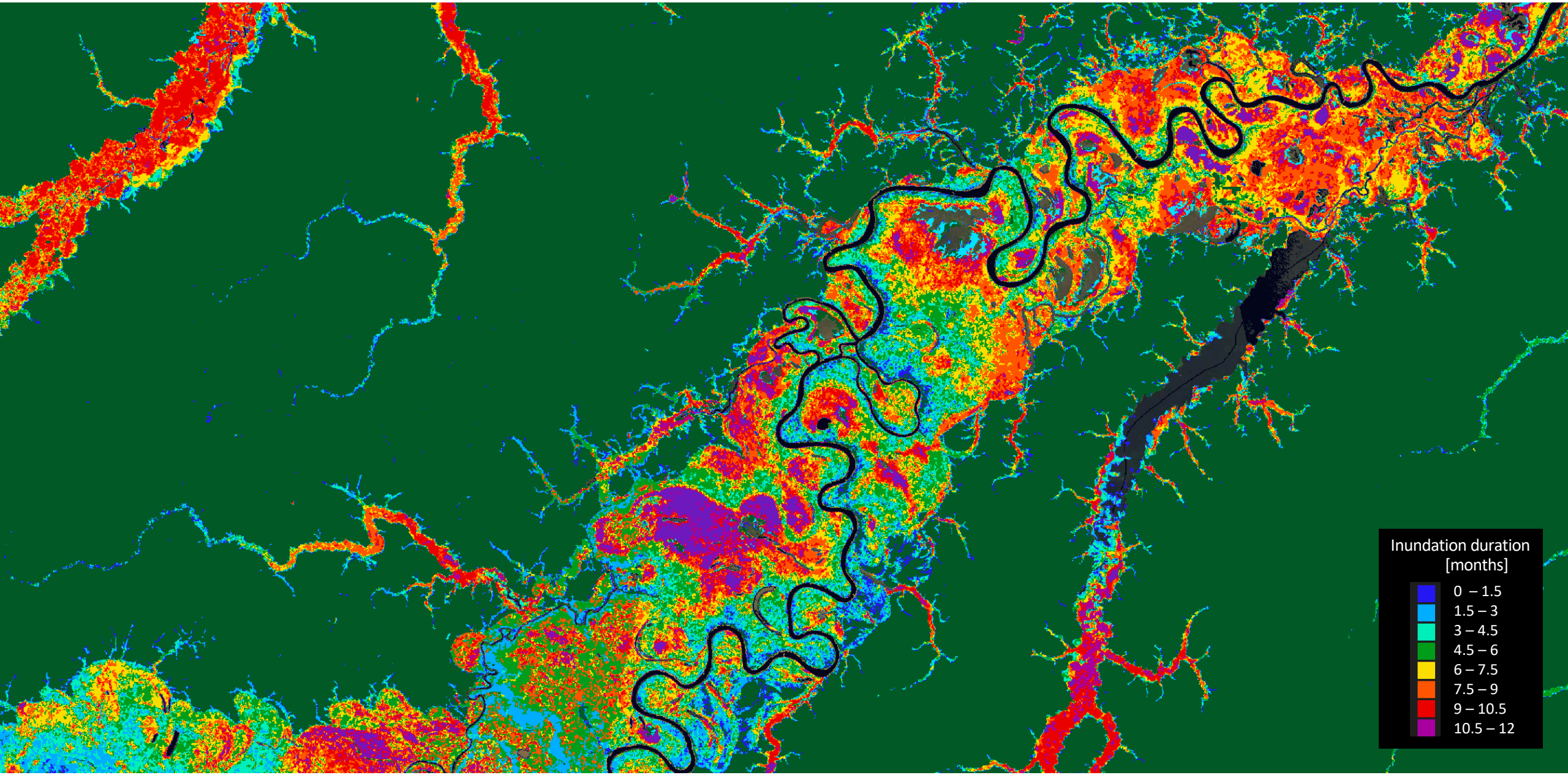
Inundation duration



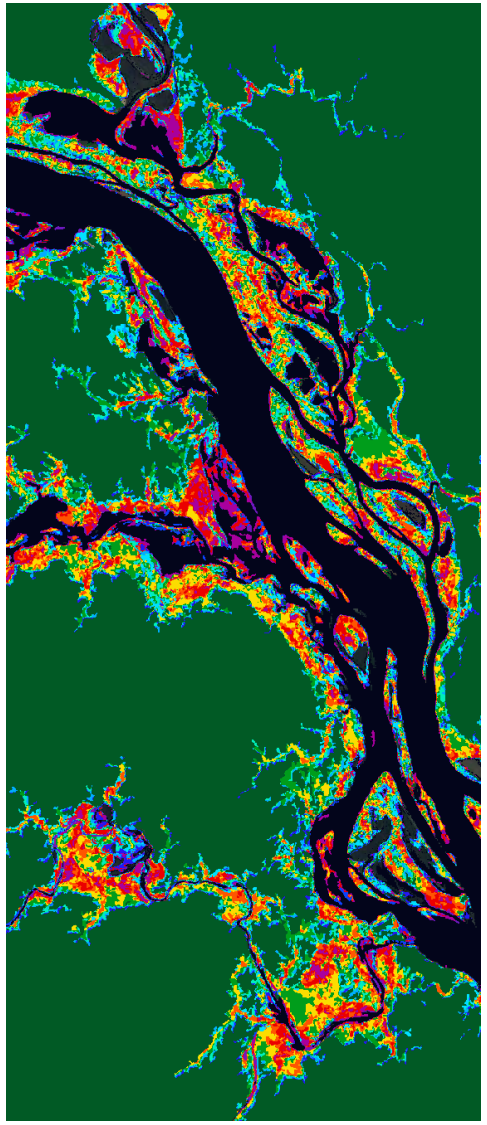
Inundation duration



Inundation duration

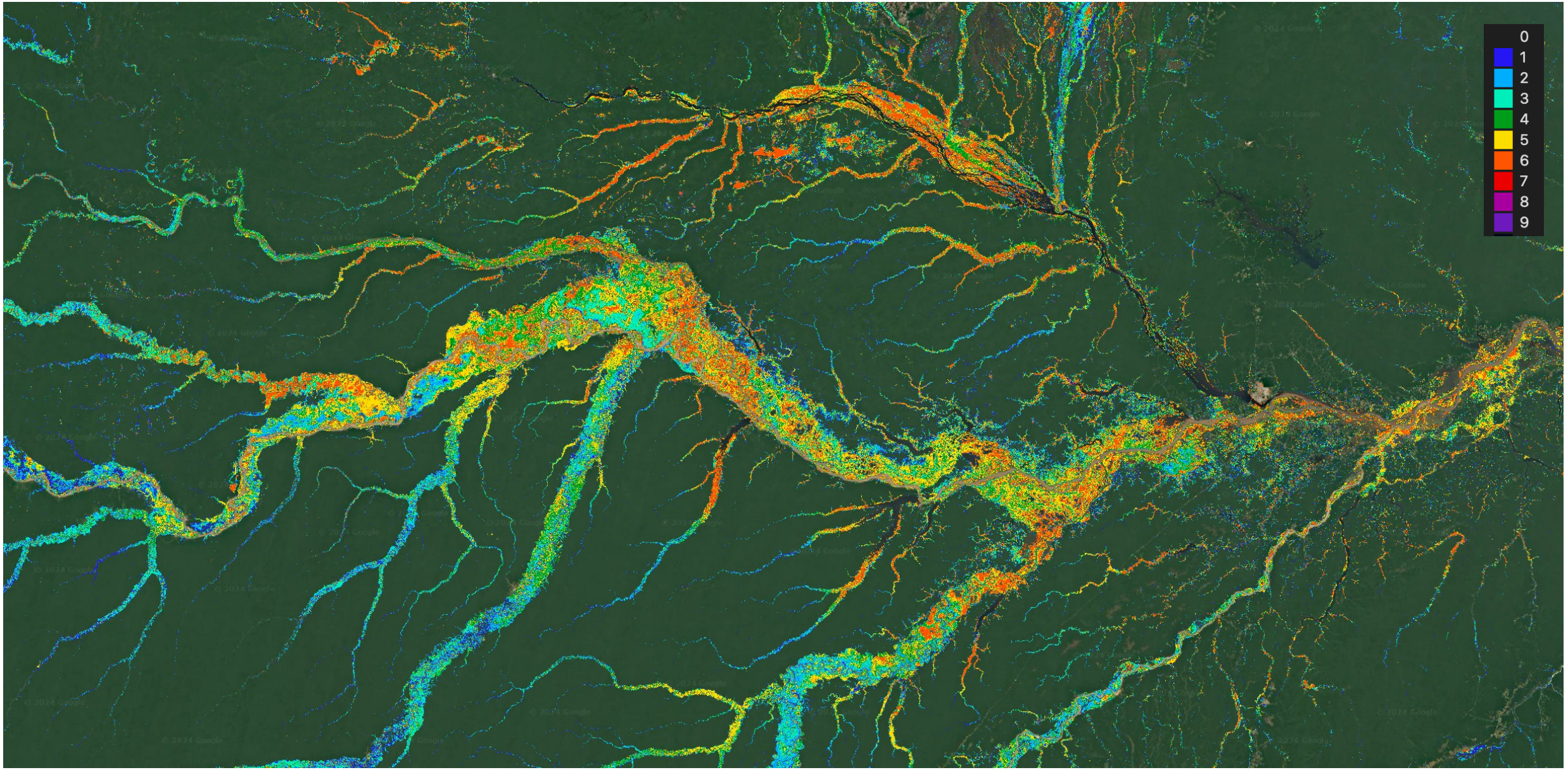


Inundation duration maps – Potential applications

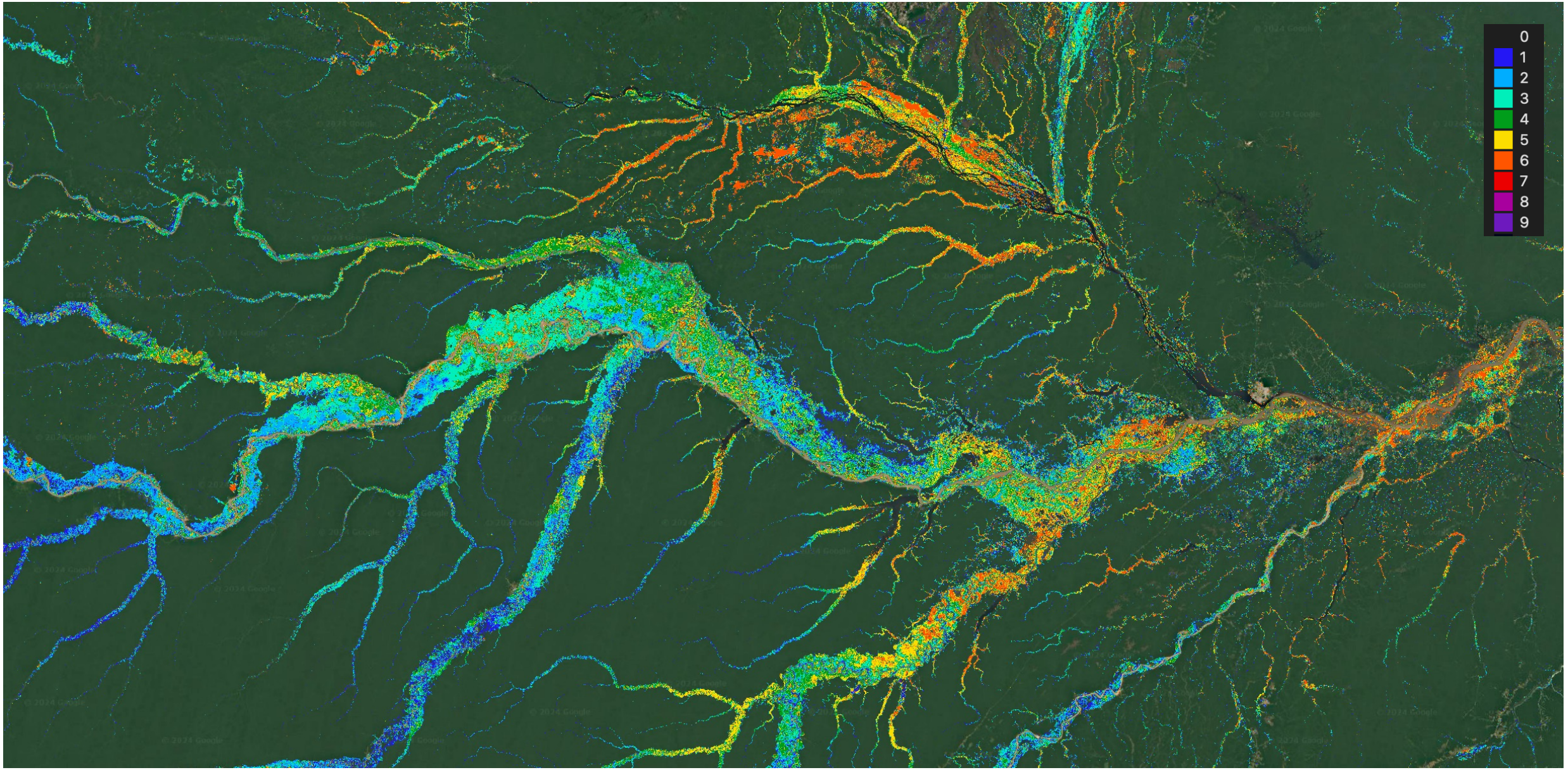


- Support Ramsar CP to include forested wetlands in NWIs
- Inundation maps provide detailed information about wetland MAX / MIN extent and inundation geospatial variations over time
- Ecosystem stratification and habitat mapping
- Input to regional models for CH4 and other trace gas emissions
- Assessment of inundation inter- and intra-annual variations
- Impact of El Niño and La Niña & Climate Change
- Etc…

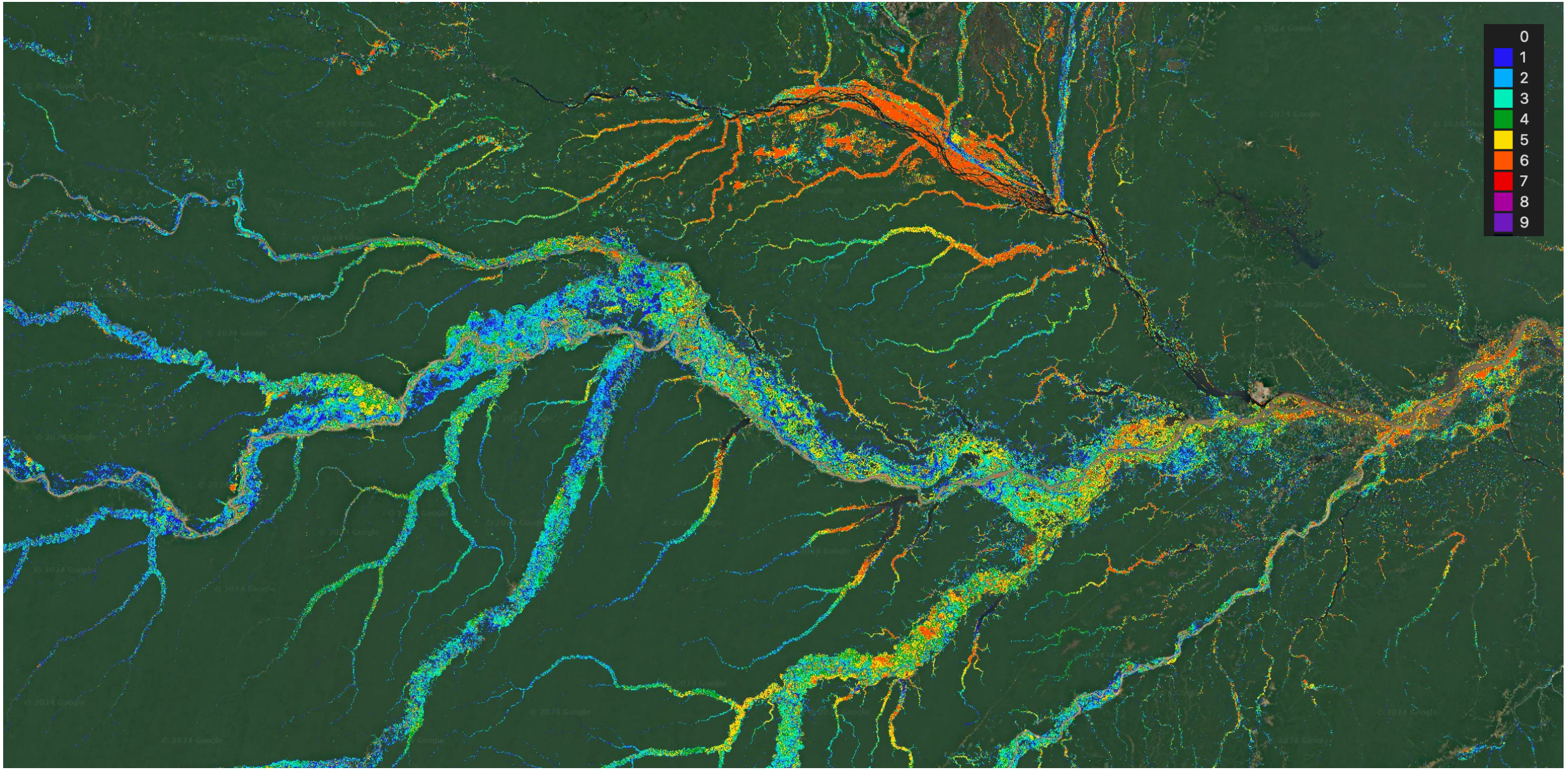
Inundation duration 2021 (Jan – Aug)



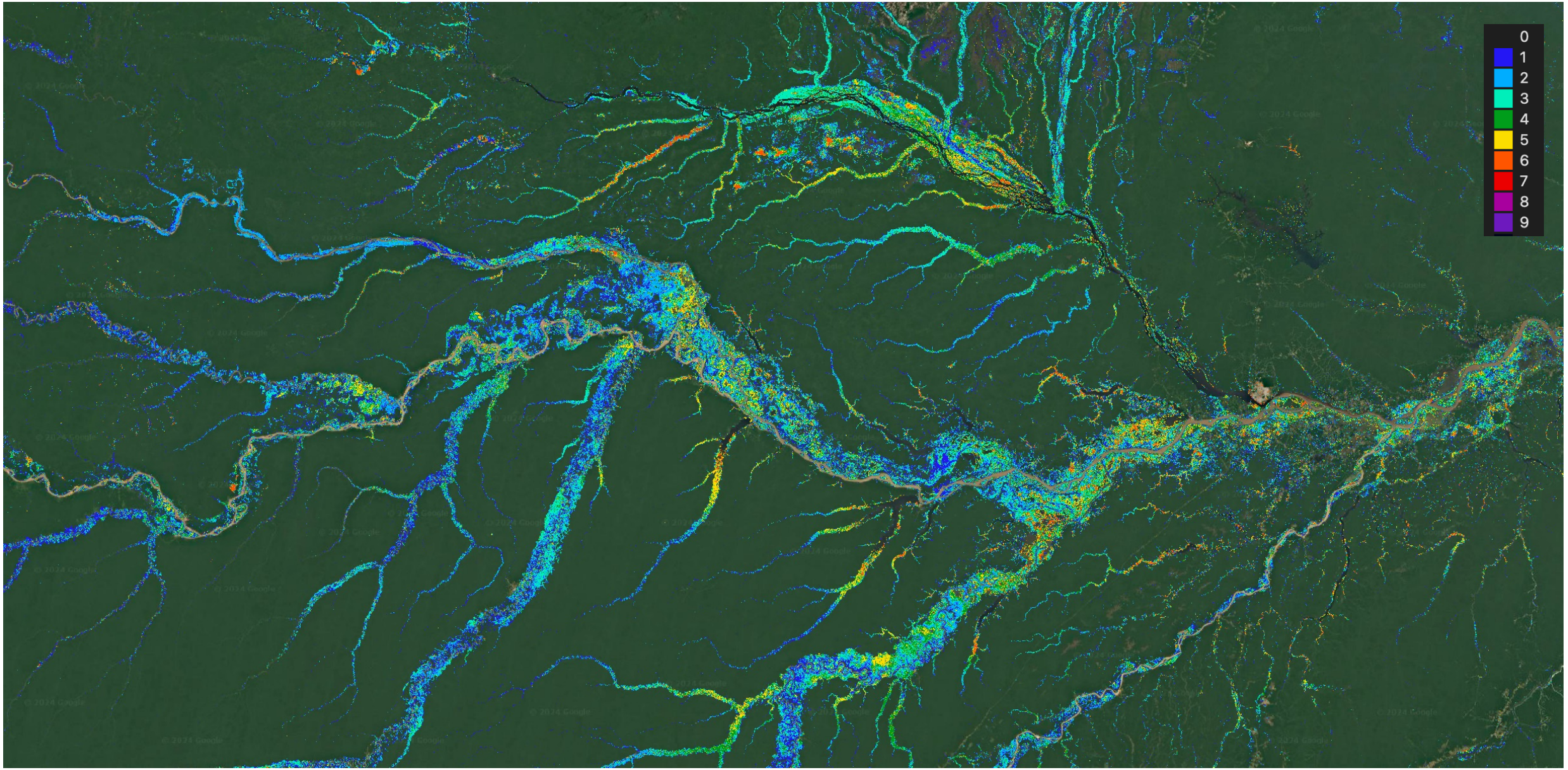
Inundation duration 2022 (Jan – Aug)



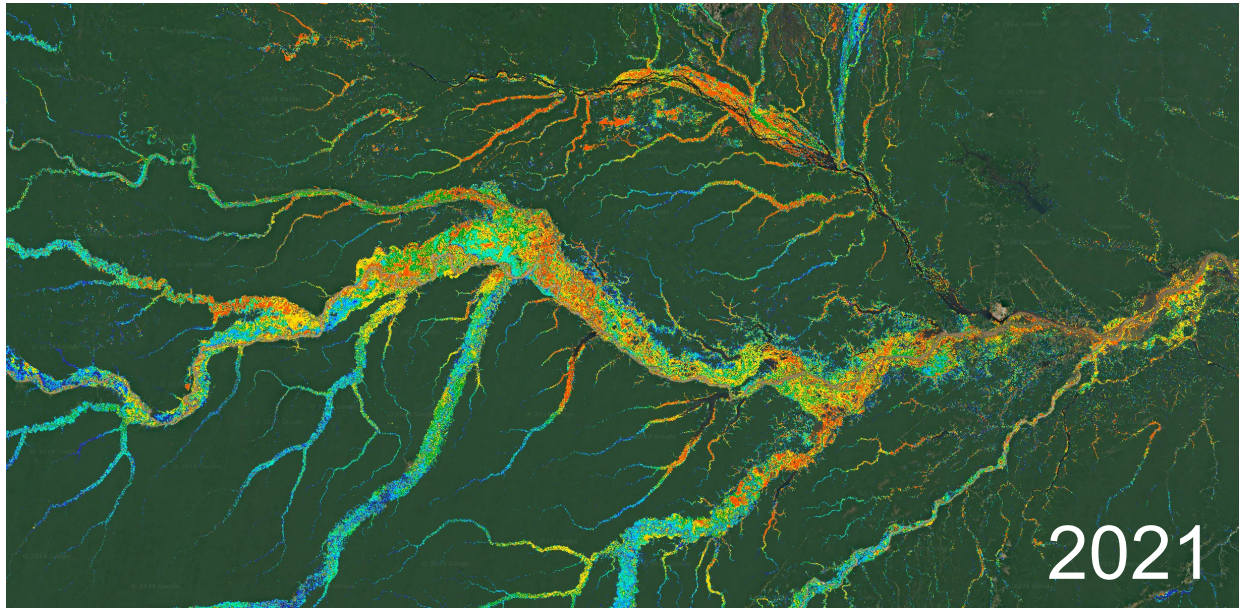
Inundation duration 2023 (Jan – Aug)

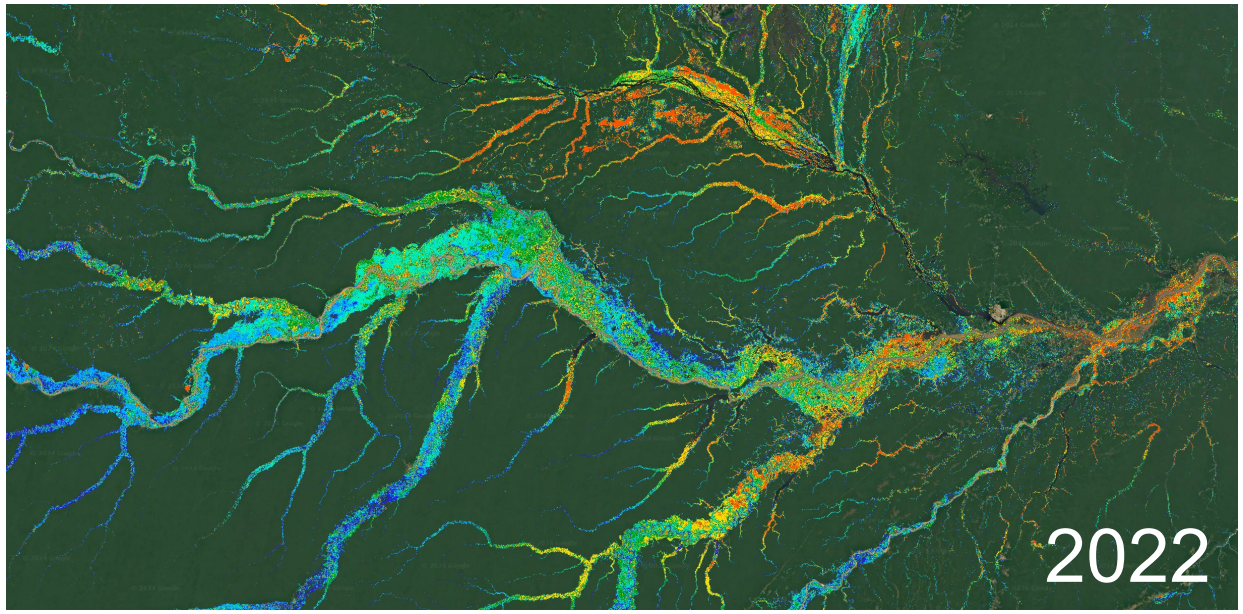


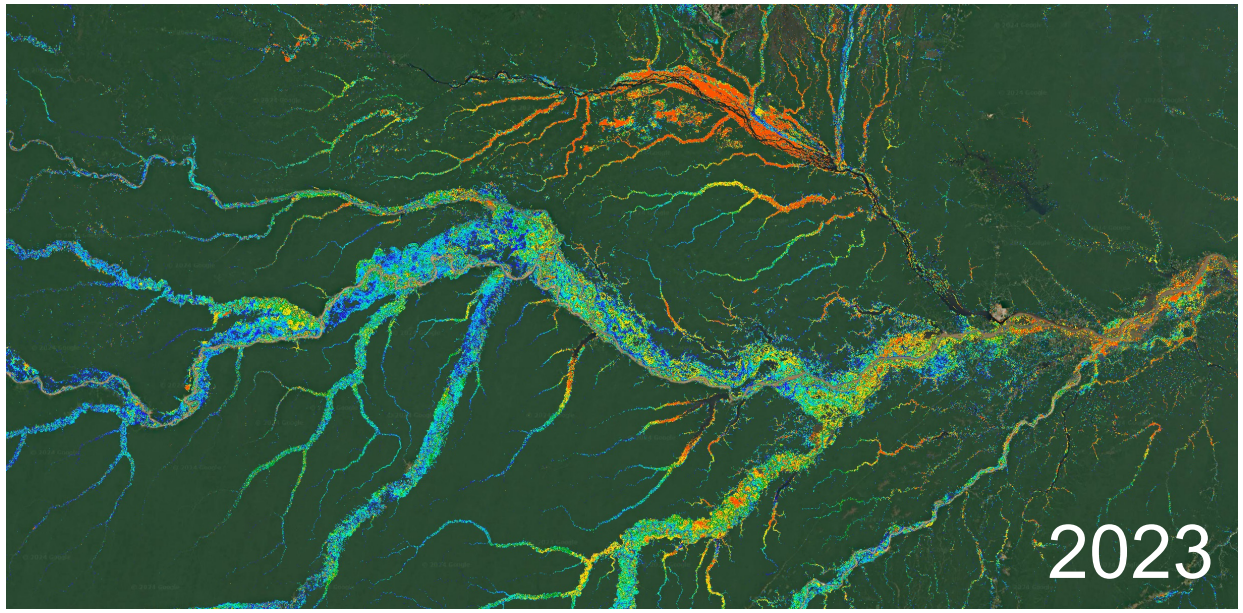
Inundation duration 2024 (Jan – Aug)

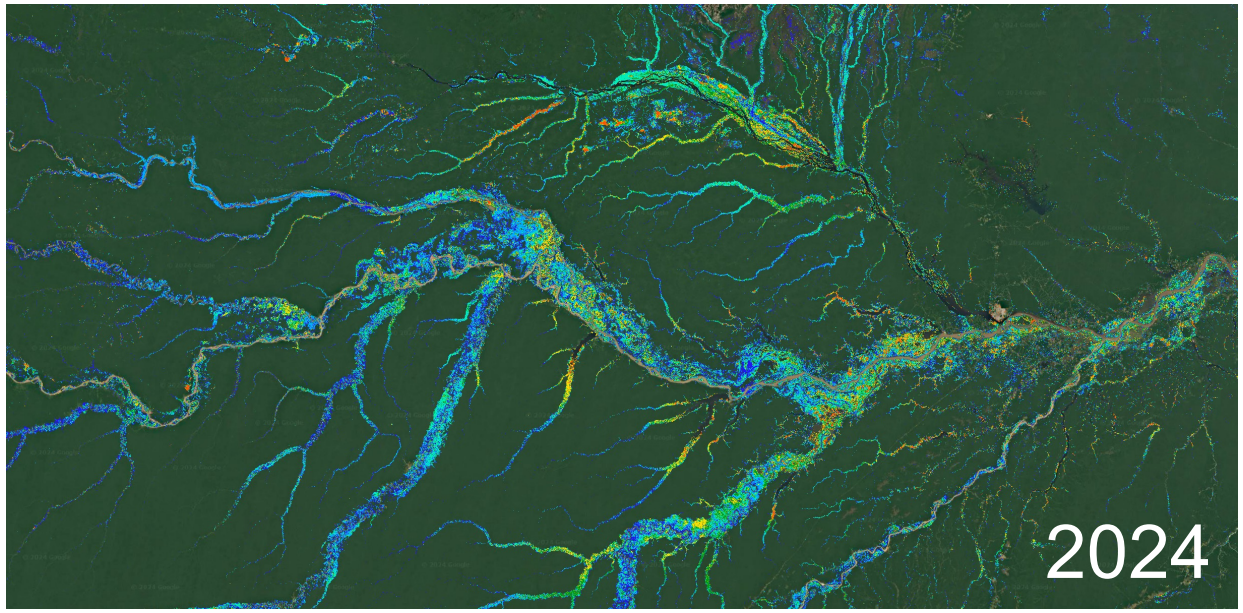


Inundation duration – monitoring trends of change

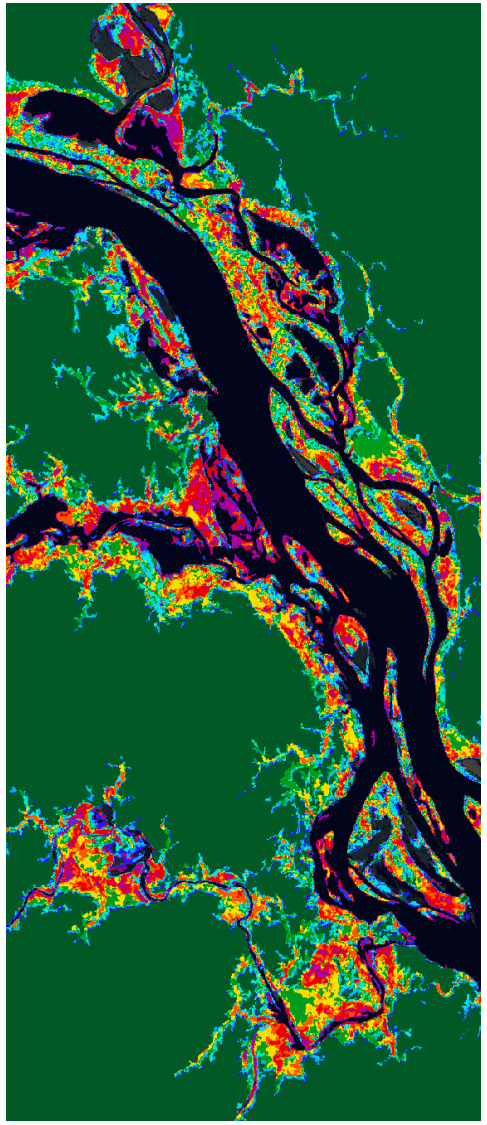








Next steps



- Validation & post-processing

- Process all ALOS-2 data 2015 – present
- Process of ALOS historical data 2007-2010
- Continue with ALOS-4

- Application to other forested wetlands
  - Congo river Basin, Pantanal, Sudd, SE-Asia…

- Following assessment & initial analysis by the science team, all inundation maps will be made publicly available on the JAXA Earth Observation Center www

Thank you for your attention

Peat domes – land conversion & degradation