Detecting and quantifying morphological change in tropical rivers using Google Earth Engine and image analysis techniques

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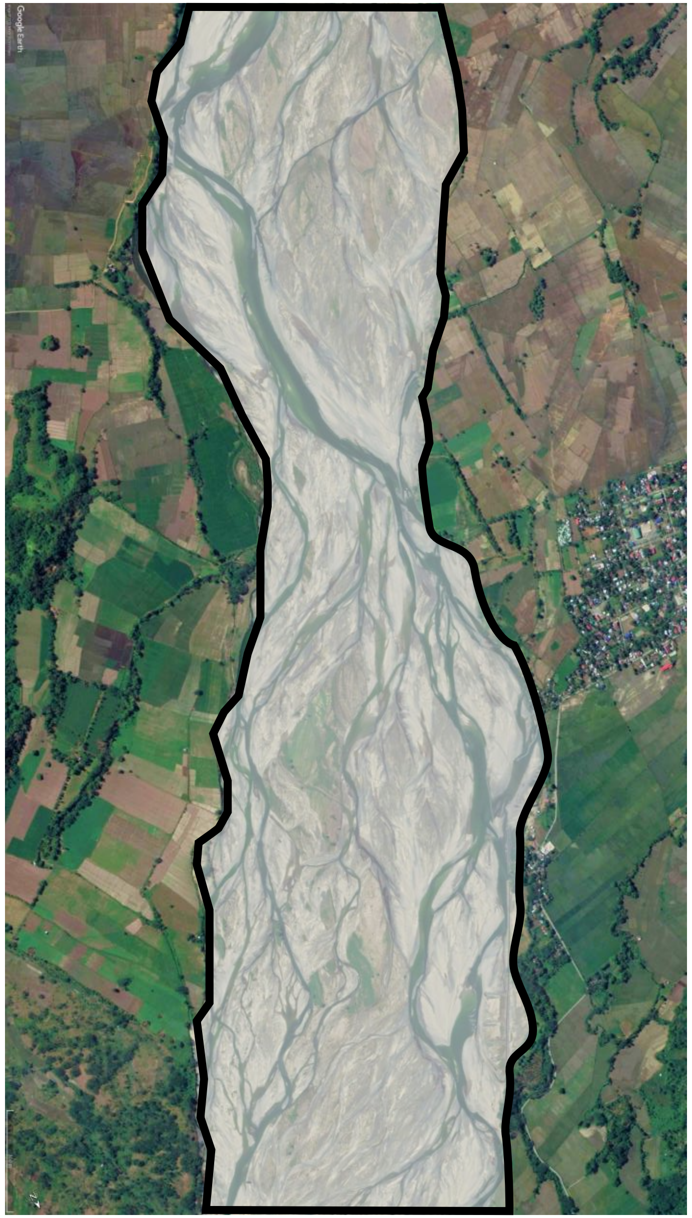
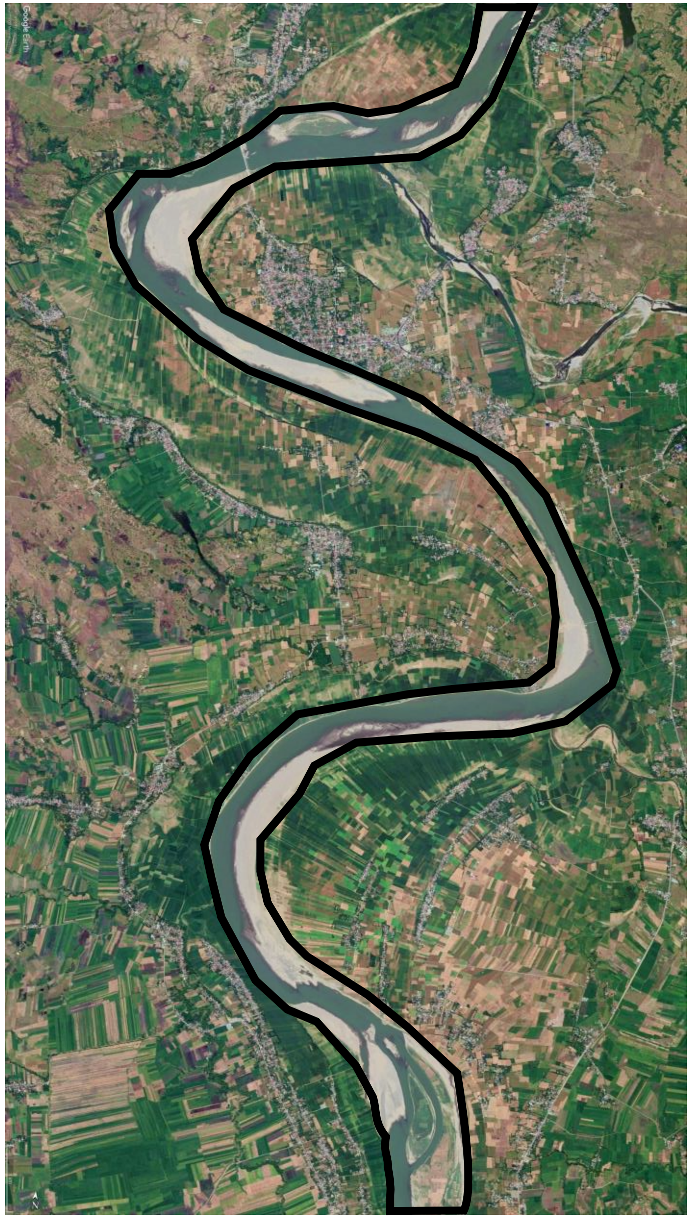
Lumintao River, Mindoro



Cagayan River, Luzon



Schematic active channel (including water, exposed sediment and vegetation)

Overview

Previous analyses of river planform change in the Philippines found meanders migrating at rates of up to 30 $m.a^{-1}$ (Dingle et al., 2019).

Multi-temporal, catchment-scale applications are needed to further test this result and investigate the fundamental controls on tropical river morphodynamics and their evolutionary trajectories.

We focus on approaches to look beyond mapping wet channel extents and instead map the wider riverscape (i.e. water, sediment, vegetation) and its dynamics.

Traditional approaches (i.e. desktop-computing) have restricted the spatial scales and temporal resolutions of remote sensing analysis. Google Earth Engine (GEE), a cloud-based computing platform for planetary-scale geospatial analyses, offers the opportunity to relieve these spatiotemporal restrictions.

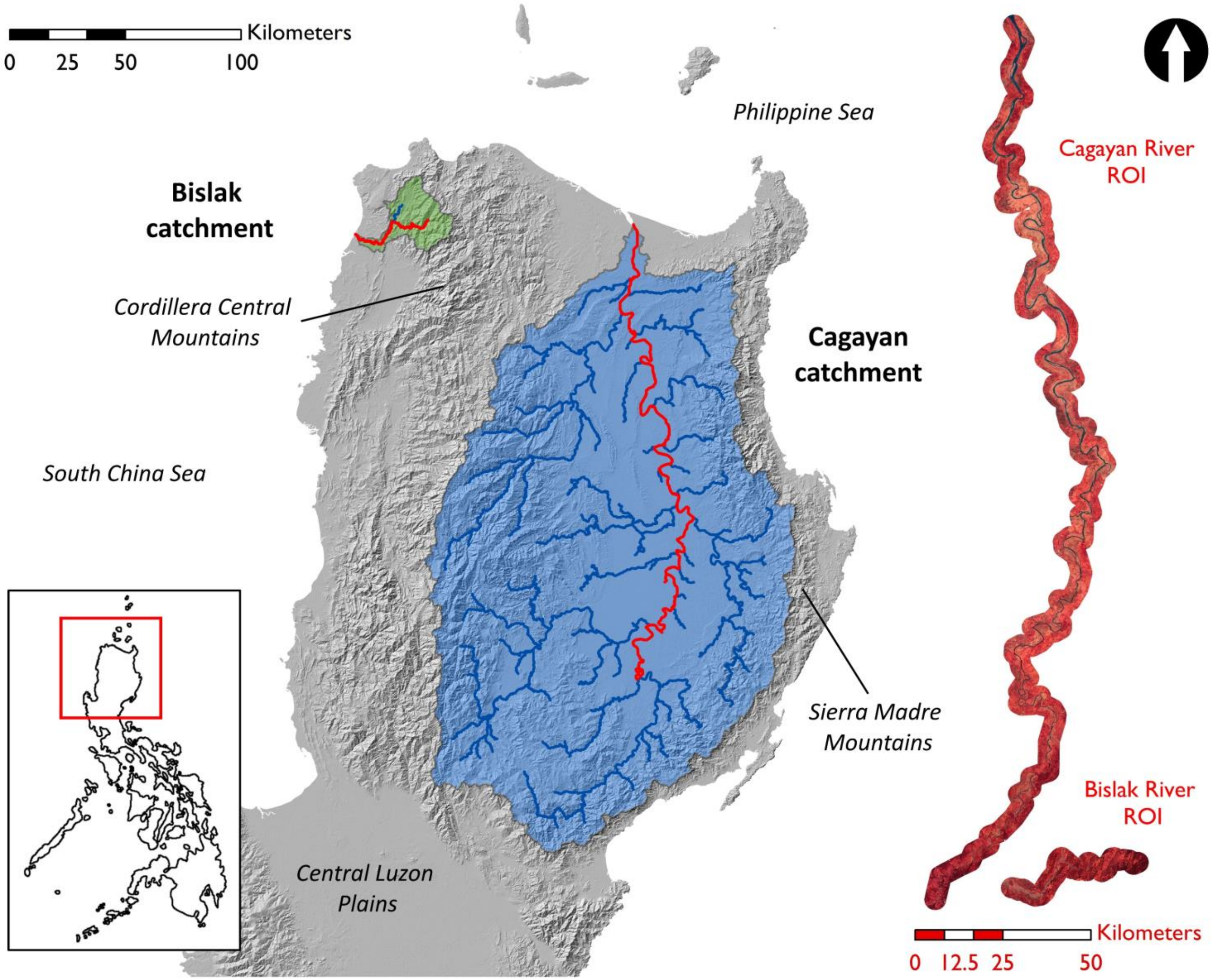
Two tropical river systems on Luzon Island (Philippines) were selected for analysis.

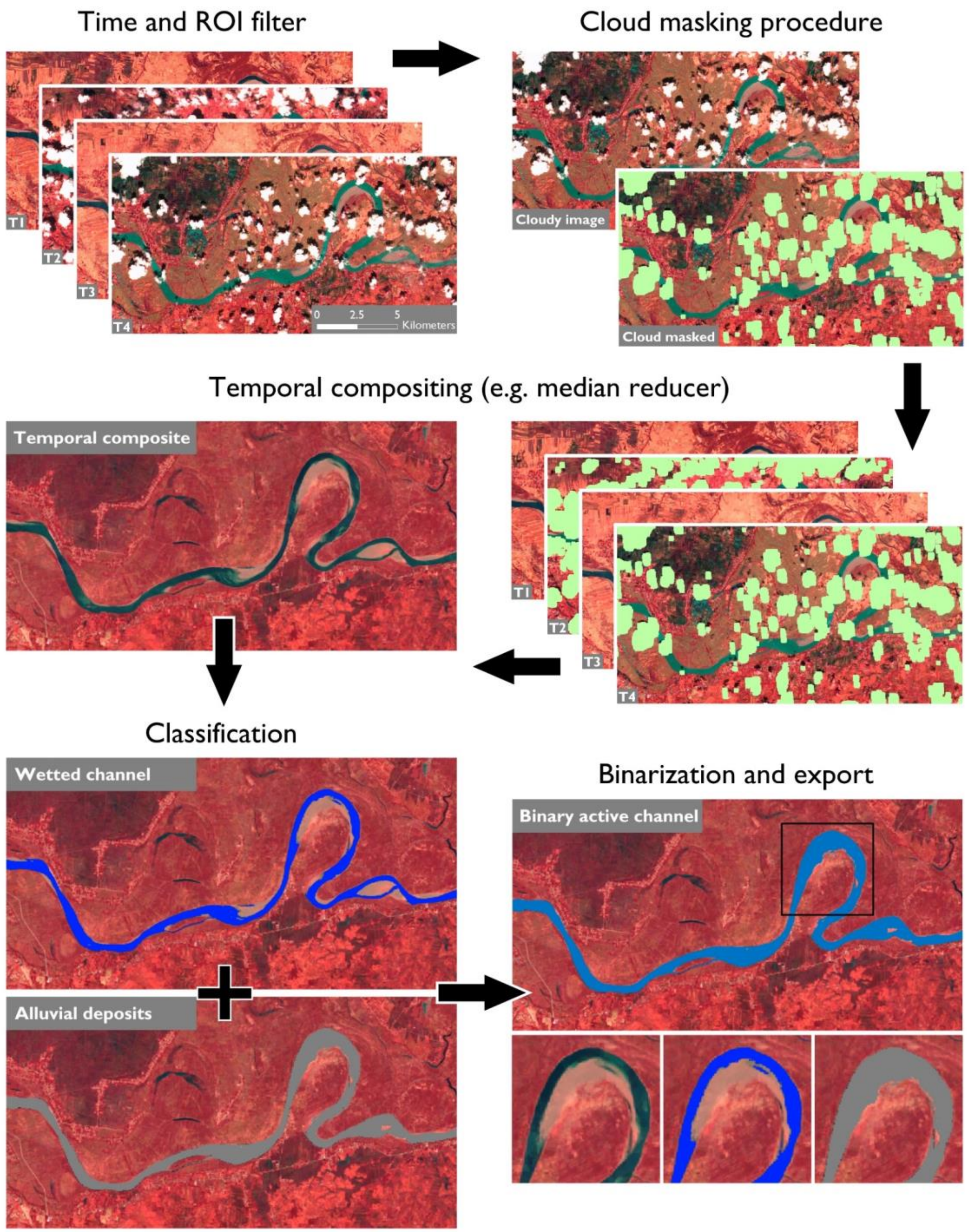
Both are prone to extreme meteorological events (typhoons, tropical cyclones) that can generate geomorphically effective flows from elevated water and sediment discharges.

The **Bislak River** is the main trunk channel of the Bislak catchment (~ 600 km^2), sourced in the Cordillera Central Mountains. The active channel is narrow (< 200 m) and laterally confined in the upper catchment, but widens (~ 500 m) as the planform becomes braided/wandering towards the downstream outlet.

The **Cagayan River** is the main trunk channel of the Cagayan catchment (~ 27,000 km^2), the largest catchment in the Philippines. The active channel is wider (> 1000 m towards the downstream outlet), exhibiting alternating single and multithreaded reaches.

Study sites





Google Earth Engine (GEE)

A semi-automated GEE workflow was developed to extract active river channels from Landsat imagery.

The workflow uses all available Landsat surface reflectance (SR) imagery (Landsat 5, 7 and 8; nominal resolution 30 m) for the time-period 1987 - 2019. Key steps include:

- **Time and ROI filter** – to construct annual image collections.
- **Cloud masking procedure** – to mask cloud and cloud shadow pixels from image collections.
- **Temporal compositing** – median reducer to aggregate overlapping cloud-masked images to produce annual images (temporal composites).
- **Classification** – water and alluvial deposits classified using established spectral indices (including the MNDWI, NDVI and EVI).
- Binarization – water and active channel masks combined to a single image (i.e. union). The final binary image was exported to Google Drive as a GeoTIFF file.

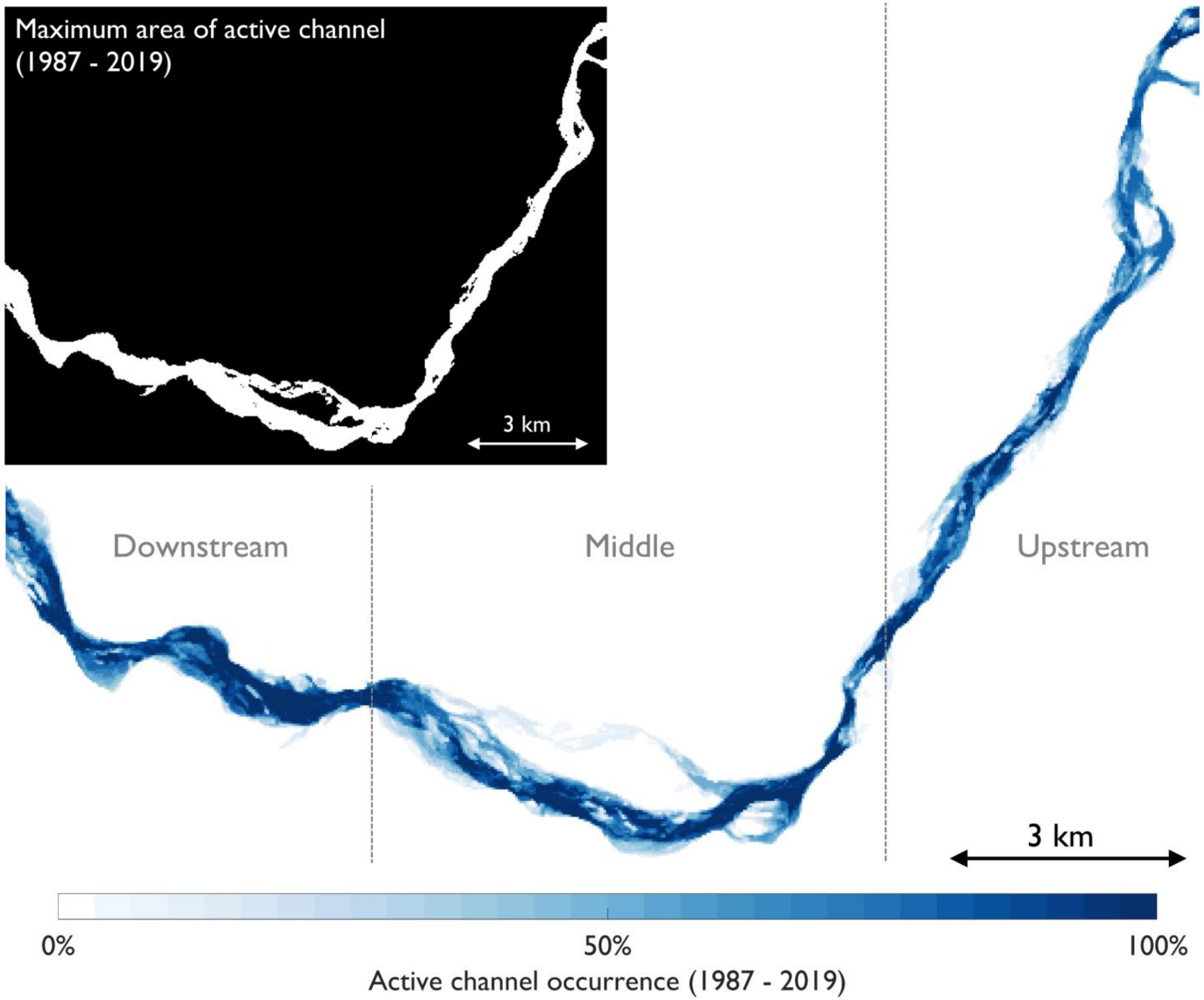
Active channel occurrence frequency

We focus on a 15 km reach of the Bislak River to detect large-scale planimetric change.

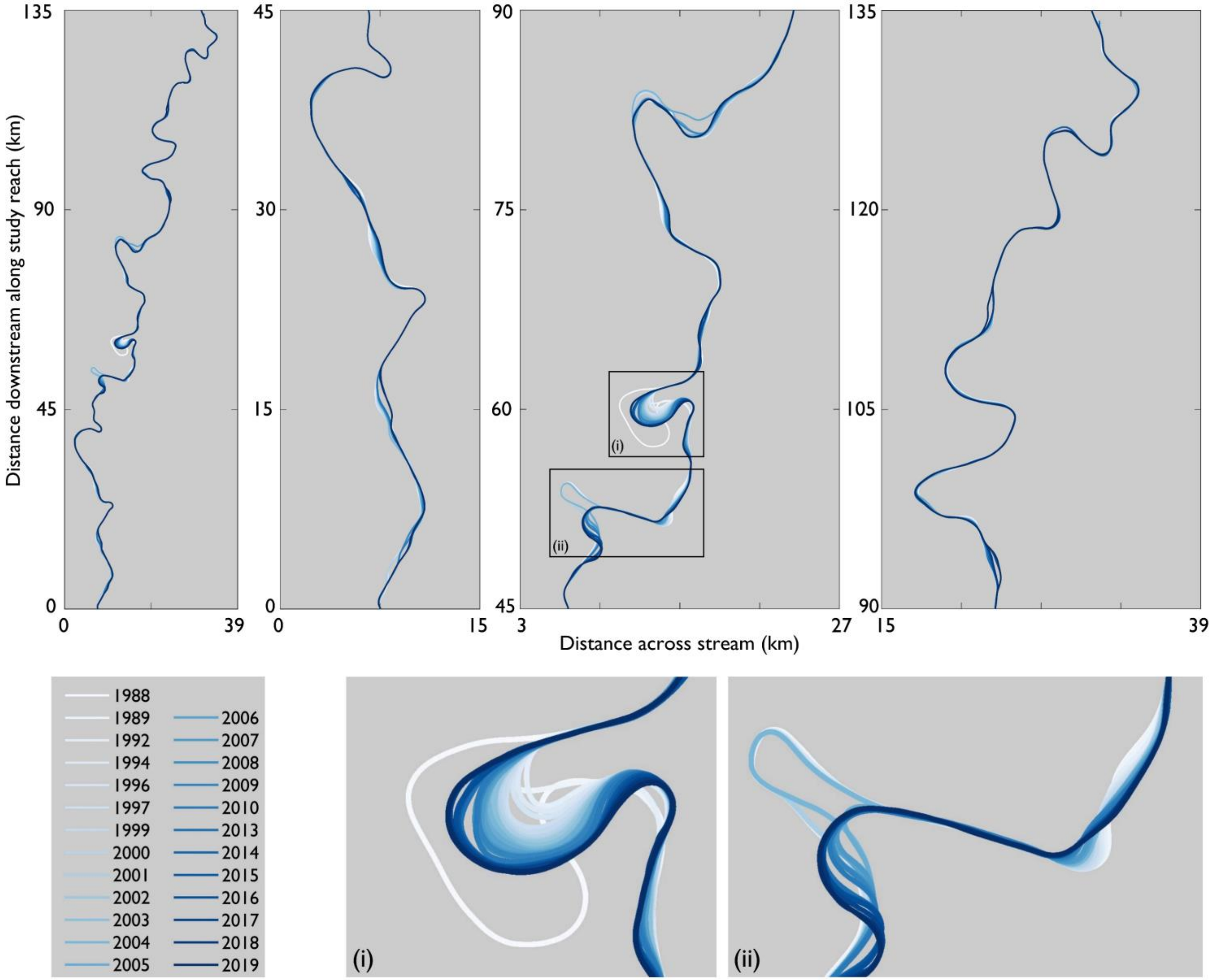
Active river channel occurrence, the frequency with which a pixel is classified as active channel between 1987 and 2019, is mapped to visualize channel dynamics. Darker blues represent more frequent active channel occurrence. Lighter blues represent areas of change.

The maximum classified area of the active channel is 13.5 km^2, with 55.3% of the area having an occurrence frequency > 50%, and 21.3% of the area having an occurrence frequency > 90%.

Results indicate that the active channel **wanders in the downstream section** with **infrequent activation/disconnection of a secondary chute channel around the middle section.**



Active channel centreline change



We analyse changes in the active channel centreline position using the RivMAP toolbox (Schwenk et al., 2017) in MATLAB.

Annually resolved active channel centrelines show the **complex and active morphodynamics of the Cagayan River**.

Over the 135 km of active channel investigated, the reach averaged migration rate ranged from 7.7 $m.a^{-1}$ in 1988 to 37.0 $m.a^{-1}$ in 2005 (average = 17.7 $m.a^{-1}$).

Locally, the migration rate varies. The middle section of the study reach (45 – 85 km downstream) appears most active, with > 1 km lateral shifts in centreline position between 1988 and 2019.

Spatially heterogenous shifts in the active channel centreline are shown, with meander expansion (erosion and accretion) and cutoff processes recorded.

Ongoing work

- National-scale assessment of active channel change in the Philippines.
- Application of RivWidthCloud (Yang et al., 2019) to quantify multitemporal width change.
- Investigating planform change at sites of critical infrastructure (geomorphic hazard focus).

References

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Schwenk, J., Khandelwal, A., Fratkin, M., Kumar, V. & Foufoula-Georgiou, E. 2017. High spatiotemporal resolution of river planform dynamics from Landsat: The RivMAP toolbox and results from the Ucayali River. *JGR: Earth and Space Science*, 4, 46-75. https://doi.org/10.1002/2016EA000196

Yang, X., Pavelsky, T.M., Allen, G.H. & Donchyts, G. 2019. RivWidthCloud: An Automated Google Earth Engine Algorithm for River Width Extraction From Remotely Sensed Imagery. *IEEE Geoscience and Remote Sensing Letters*, 1-5. https://doi.org/10.1109/LGRS.2019.2920225

Conclusions

Findings begin to quantify patterns of dynamism in tropical river systems and demonstrate the utility of GEE in fluvial geomorphology applications.

We demonstrate large-scale planimetric change in the wandering/braided section of the Bislak River and quantify temporally variable reach averaged migration rates along the Cagayan River.

Tools such as GEE can provide multi-temporal data over large river reaches that will enable theories of geomorphic change to be tested, and the re-assessment of some classic concepts in fluvial geomorphology such as river channel pattern classification.

Multi-temporal analyses can be completed at temporal resolutions relevant to the functional timescales of geomorphic processes of interest. This should allow for the monitoring of gradual and abrupt changes in river systems.

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