River morphodynamic metrics derived from satellite images

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Introduction

River morphodynamics are driven and influenced by a wide variety of processes and conditions, such as flow variability, climate, human interference, vegetation development, sediment characteristics and valley geometry. Anticipating the long-term and large-scale dynamics of river planforms is therefore difficult and requires insights into dominating processes and their impacts. There have been many attempts to characterize and classify river planforms, such as definitions of planforms of straight, meandering and braided. Empirical observations are the basis of achieving such understanding, and this can be supported by modelling studies or theoretical considerations. Large dynamic rivers are often characterized by anabranching channel patterns, with relatively stable vegetated islands (Latrubesse, 2008). The understanding of physical processes and drivers that lead to the formation of anabranching river planforms is still limited (Carling et al., 2013). Remote sensing, specifically satellite imagery, might be a key instrument to study planform dynamics of such large multi-channel rivers. By measuring actual morphodynamic observations on large scales, the key drivers of planform dynamics can be quantitively investigated.

Automated detection of river morphodynamics

The analysis of river morphodynamics with satellite imagery is performed using automated classification in Google Earth Engine. For the detection of river changes Landsat imagery is used, which provides images over the last 30 years with a horizontal resolution of 30 meters. Change is studied on a yearly time scale, where images are selected from each dry season due to the low cloud cover.

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A factor that complicates river change analysis with automated classification is the change in water surface area with varying water levels in the river, which is especially important for natural (multi-channel) rivers with gently sloped banks. Even though water level fluctuations may be relatively small during the dry season, we circumvent the effect of water level variability by detecting the vegetation boundary to mask the active channel. For this approach, a combination of a water index (Normalised Difference Water Index or NDWI) to detect the water surface and the Short Wave Infrared (SWIR) band to detect sediment bars is used. A similar approach was used by Monegaglia et al. (2018), who focussed on migration of meandering rivers. Further river studies that use remote detection of the vegetation boundary can be found in Rowland et al. (2016) and Schwenk et al. (2016).

To quantify morphological changes between consecutive years we calculate the eroded surface area, the deposited surface area and the total active river surface (total area between river bank lines). Also, we defined a relative migration rate which represents the amount of migration (erosion + deposition) compared to the total river surface. A local migration rate of 1 means that the river has migrated an entire river-width.

Selected case: Ayeyarwady river

We chose a ~250km long section at the start of the Ayeyarwady river delta in Myanmar as case-study. With a mean annual discharge of approximately 13,000 m^3/s (Jansen et al., 1994), it is one of the larger rivers of Asia. Furthermore, it is one of the last long free flowing rivers in Asia (WWF, 2019), which means the natural variation in discharge and sediment transport dynamics is still present. The river planform is multi-channelled with relatively large vegetated islands. The Ayeyarwady river is characterised by intense morphological changes, including significant channel shifts, bar movements and avulsions on a year-to-year basis. The hydrology in the Ayeyarwady basin shows distinct dry and wet seasons, with relatively steady low water levels during the months December–April (dry season) and high water levels in the months June-October (wet season).

Results

We found significant changes over time in the measured morphodynamics metrics in the period of 1988-2019. Next, we compared the metrics to the magnitudes and duration of the high water levels during the preceding wet season. We defined the average yearly flood stage (averaged water level during the 4-month wet season) and found strong correlations to the various defined morphodynamic metrics (see Figure 1). This result clearly indicates the importance of the overall intensity of the flood season. The positive relation between the morphodynamic metrics, erosion, migration and change in active channel area, and the average flood stage, can be easily understood: higher and longer flood periods bring high flow velocities and thus lead to more erosion. The negative relation with deposition values seems counter intuitive as higher and longer floods deliver more sediment. However, as the deposition is detected by measuring the advance of the vegetation boundary a different dynamic is responsible. Not only sufficient sediment supply is needed, but vegetation needs time and space to develop. For vegetation-covered areas to expand, the average flood season intensity needs to be low (see also Figure 1, relation between change in active channel area and stage). This explains the negative relation between metric of deposition and the stage.

Outlook

This study shows that automated detection of planform dynamics can help in identifying key drivers. With satellite imagery becoming more widely available and of higher resolutions, combined with improved automated processing techniques, and identification of useful metrics as proposed here, the prospects are promising to achieve better understanding of river morphodynamics through global-scale investigations.

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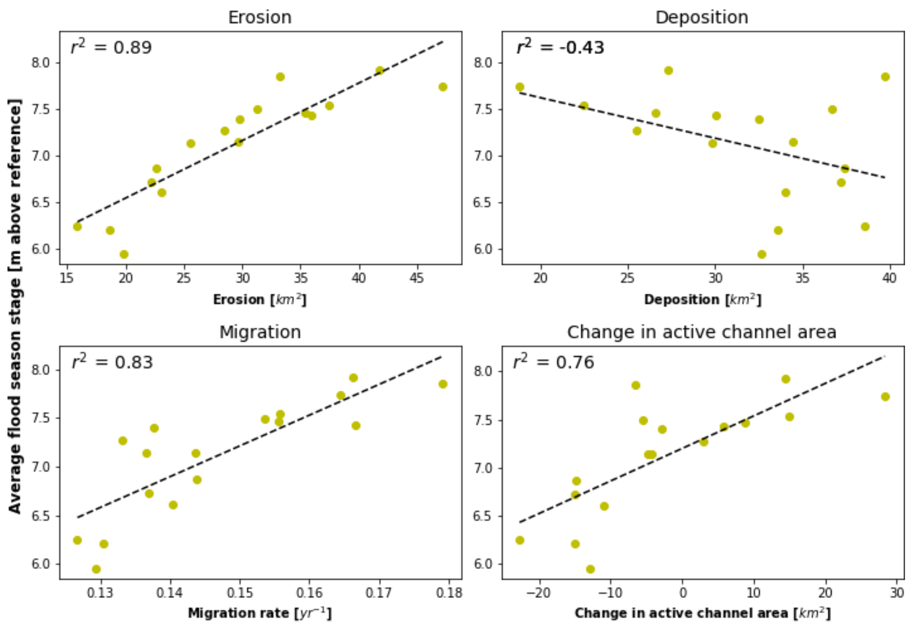

Figure 1. Relation between measured morphodynamics and average flood season stage during the same year