Water Cycle: Lessons using data skills

Royal Geographical Society with IBG

Advancing geography and geographical learning

Lesson 5: Changing water resources: discharge response across the USA

Lesson Objective

- To use the data collected during the passage of a flood wave to quantify when sediment moves during a flood
- To use the same data to begin to think about how changing flood magnitude might affect sediment transport flux

Setting the Scene

Most of the world's big rivers are composed of sand beds (Figure 1). When this sediment is transported by the river it forms 'bedforms' which are effectively underwater sand dunes. The size of these bedforms is controlled by discharge where, generally, larger bedforms are formed under higher discharges. Consequently, during the passage of a flood these bedforms change their size and we know they can raise the water level during the flood, however little is known about exactly how they grow and decay as the flood wave passes. This makes flood prediction and navigation along these big rivers difficult. This lesson is focused on beginning to explore this problem.

The Data

We can quantify how the bedforms change during the passage of a flood wave by measuring the elevation over areas of the river bed at different discharges and creating a digital elevation model, similar to a map. We can either do this in a laboratory under controlled conditions in an indoor river called a flume or directly in the field by measuring the bed topography during the passage of a real flood wave.

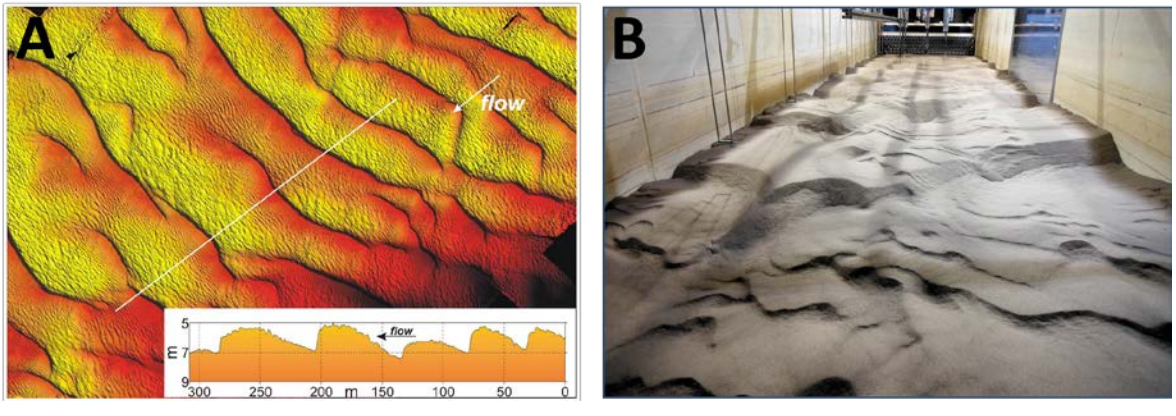

Figure 1: (a) Digital Elevation Model of the sand bed of the Rio Parana (Parsons, 2005) collected from a boat based survey (b) sand bedforms developed in a flume during a 4 hour flood experiment.

This lesson uses data collected from a flume. We filled the flume with sand and ran water down the flume at discharges to represent the discharges experienced during a flood. This data is collected from an experiment that was run using a hydrograph with a 58 minute rising limb and 50 minute falling limb and which was representative of a 1 in 5 year return period winter snowmelt flood on the Mississippi River. The hydrograph was created by changing the discharge 17 times on the rising and 17 times on the falling limb. Digital elevation models were taken at change in the discharge and allow us allows us to see how the flood wave affects the size of the bedforms. The data set contains information on bedform height and bedform wavelength.

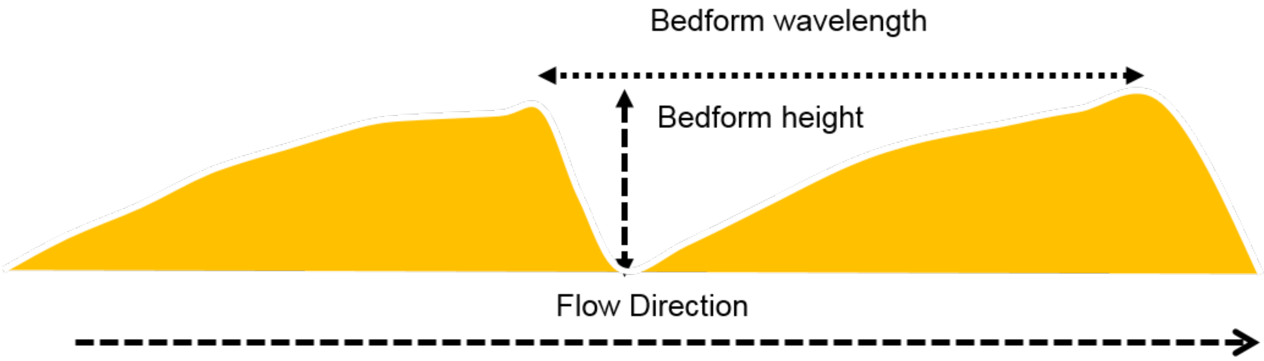

Figure 2: Schematic diagram of a sand bedform and relevant metrics of bedform height and wavelength

Tasks

1) **How do sand bedforms change during the rising and falling limb of a hydrograph?**

Open the Microsoft Excel Bedform Data file. The file has four columns of data: 1) the hydrograph step number, 2) the Discharge (m^3/s), 3) The bedform wavelength (cm) and 4) the bedform height (cm).

Using the data plot x,y scatter graphs of the following:

- Graph 1: Rising Limb Discharge on the x axis and rising limb wavelength on the y axis.
- Graph 2: Falling Limb Discharge on the x axis and falling limb wavelength on the y axis.
- Graph 3: Rising Limb Discharge on the x axis and rising limb bedform height on the y axis.
- Graph 4: Falling Limb Discharge on the x axis and falling limb bedform height on the y axis.

Looking at both relationships compare and discuss the findings. You might want to think about:

- Is there a relationship with discharge?
- Is this relationship the same for both bedform height and wavelength?
- How could you quantify that relationship?

Your graphs should look like the examples below in Figure 3.

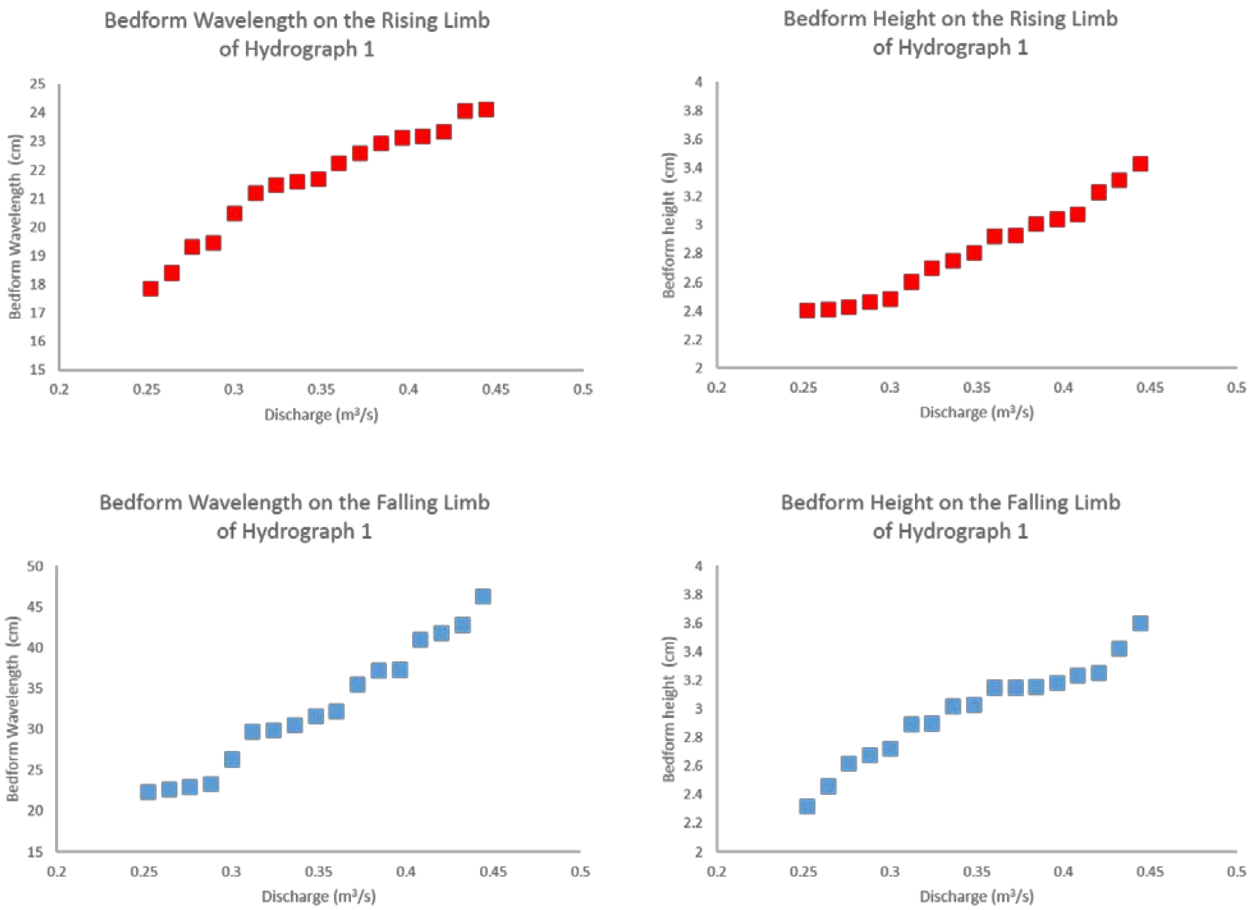

Figure 3: The relationship between bedform wavelength (a and c) and bedform height (b and d) with discharge

2) Comparing the rates of change in bedform growth

Add linear regression lines to all four graphs. You need to include the regression equation and the R^2 values on the graphs as well. The gradient is given in the regression equation and is the average rate of change of either bedform wavelength or bedform height over the hydrograph. For example in Figure 4a the gradient is represented by the number before the x, in this case 30.856. The higher the value, the faster the rate of change. The R^2 value tells us how good our regression equation is at describing the data – the closer the value is to 1, the better the fit. For example if we compare Figure 4a with Figure 4b we can see Figure 4a has a R^2 value of 0.949 as compared to and R^2 value of 0.978 in Figure 4b. This tells us that the equation used in Figure 4b is better at describing the data.

Looking at regression equations and R^2 values compare and discuss the findings. You might want to think about:

- What does the R^2 value tell us about the relationship?
- Are there any outliers to the relationships? What would happen to the trend of these outliers were removed?
- Looking at the bedform height plots are there differences in the gradient of the regression line between the rising and falling limb? Can you describe these differences?
- Looking at the wavelength plots are there differences in the gradient of the regression line between the rising and falling limb? Can you describe these differences?

Your graphs should look like the examples in Figure 4.

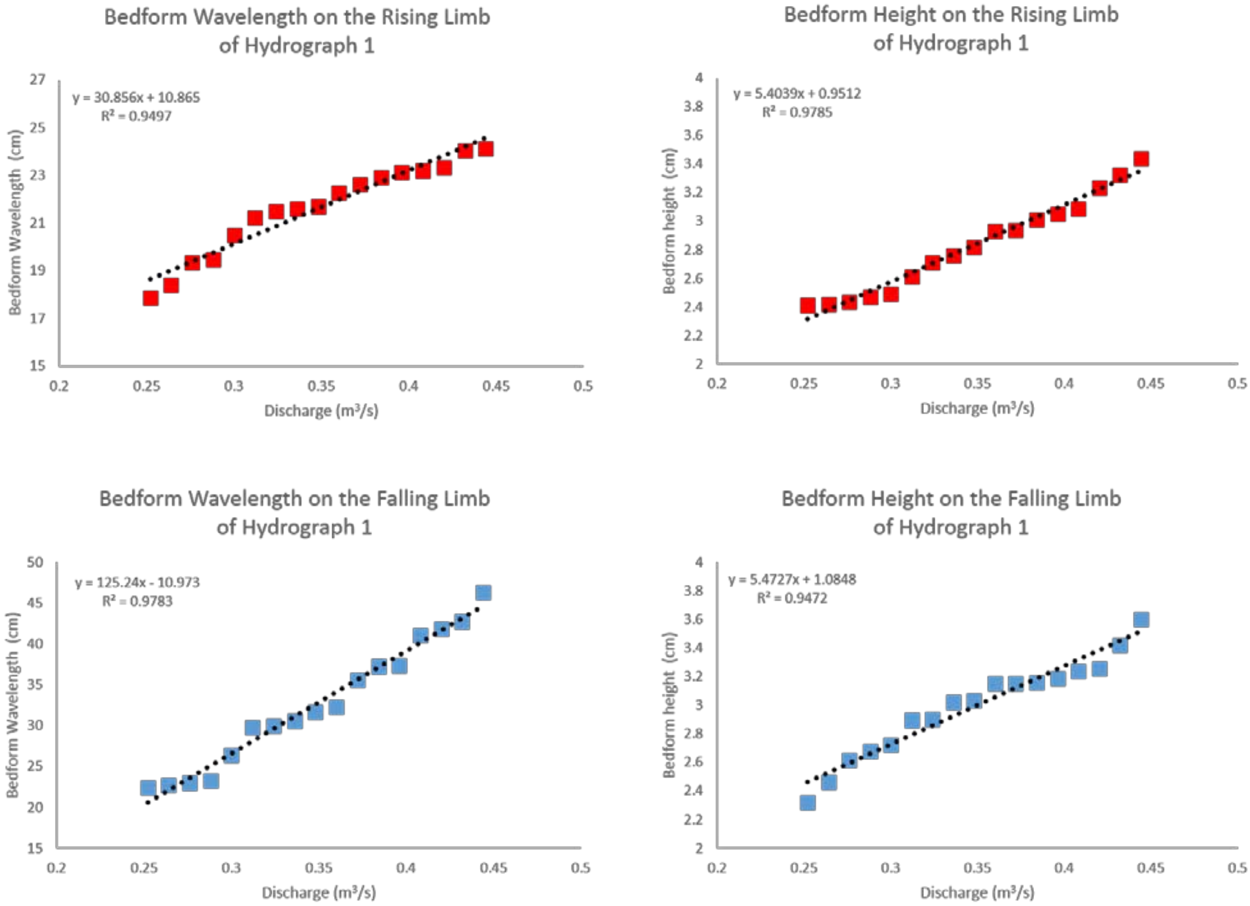

Figure 4: Linear regression applies to the relationship between bedform wavelength (a and c) and bedform height (b and d) with discharge

3) Comparing bedform characteristics over the whole hydrograph

Plot two further graphs:

- Combine the data from Figure 1 with the data for Figure 2
- Combine the data from Figure 3 with the data for Figure4
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Tip: You don't need to draw the graphs from scratch. If you right click on the graph which plots the rising limb data and press copy you can then right click on the graph which contains the data from the falling limb and press copy. This will combine the data.

Looking at both relationship compare and discuss the findings. You might want to think about:

- Are bedforms bigger on the rising or falling limb?
- Is wavelength bigger or smaller on the rising or falling limb?
- How can we begin to explain these trends?

Your graphs should look like the examples below in Figure 5.

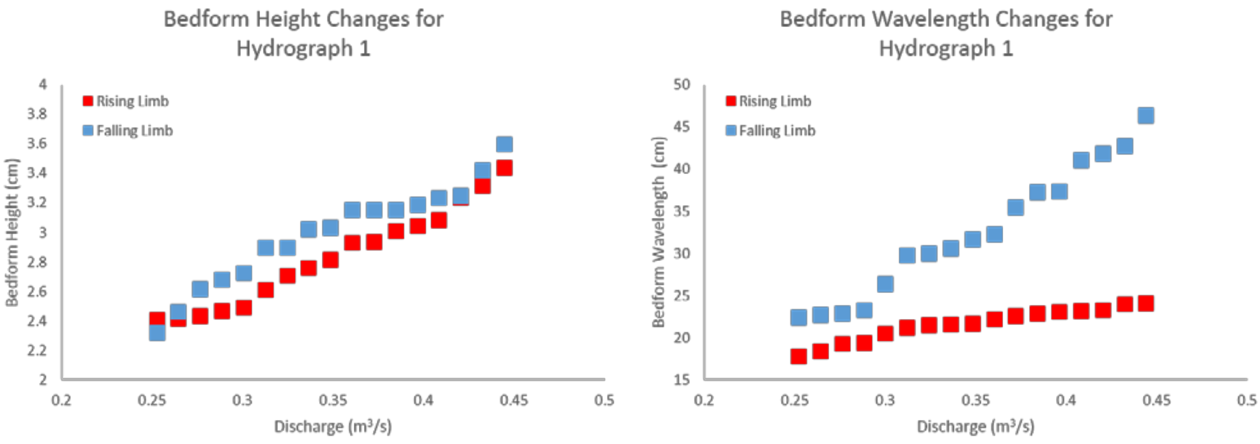

Figure 5: The relationship between bedform wavelength (a) and bedform height (b) over the duration of the hydrograph

Take it Further

The data shows that there is a difference between the size of the bedforms on the rising and falling limbs. You could quantify the difference by calculating the percentage difference between the rising and falling limb for each variable. In a new x,y scatter plot you could then plot discharge on the x axis and the percentage difference you calculated on the y axis.

Your graphs should look like the examples below.

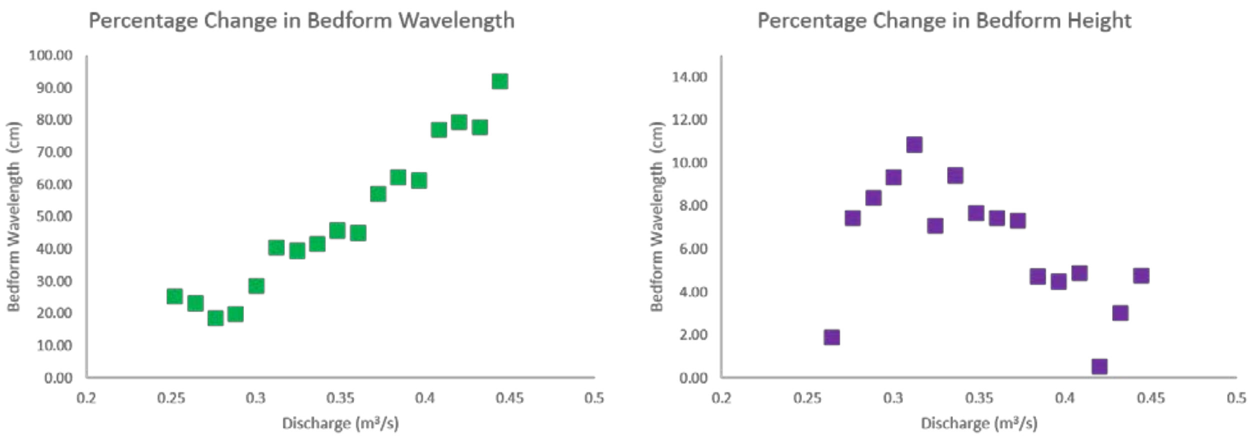

Figure 6: Percentage change in bedform wavelength (a) and bedform height (b) between the rising and falling limb

- Do both bedform height and wavelength respond similarly to a flood wave?
- Are there any trends?
- How can we begin to explain these trends?

Plenary

Return to the main lesson question. Ask the students to discuss:

- How sediment transport changes during the passage of a flood wave.
- Why might the bedforms be bigger on the falling limb?
- Ask the students to think about how changing flood magnitude might affect the development of bedforms? What would happen if the shape of the hydrograph changed?