High-Precision Positioning Unit 2.2 Summative Assignment: Change Detection with Kinematic GNSS

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This is a generalized guide on how GNSS surveys can be applied to solve a geologic, geomorphic, or geodetic question. It is intended to assist with site selection, survey design, and analysis. One example workflow is provided for assessing geomorphic change from a point-to-point survey.

Introduction

Change detection is a valuable tool for quantifying many processes that take advantage of the temporal resolution afforded by high-resolution GNSS surveys. You will design, prepare, and then conduct a Kinematic GPS/GNSS survey that measures some degree of change within your study area. You will then process the data and analyze your results.

Project Description

Site Selection and Reconnaissance

Select a site that has relatively rapid movement such as an eroding river bar, mass hillslope movement, fault scarp, or sand dune. Site location will typically be decided by the instructor or given to you. View satellite images of the site and previous data if available. Tools such as Google Maps can help you visualize what processes might be active and how to best organize your survey. Consider and anticipate potential obstacles and complications such as sky view, line of sight, and overhead obstructions. Additionally, think about where you might place your base station in a safe, stable, accessible location with good survey control (likely a benchmark or monument) and line of site to your survey target.

Survey Design

Consider how you will approach the study area and select points to be measured. This can be accomplished in the field or at home. Kinematic GNSS equipment can measure points several times per minute, but think about a realistic expectation for the extent of the survey and how often you need to sample to capture the anticipated change. Increased sampling does not always increase study quality. Think carefully and then write up a **design proposal** 5–7 sentences long that includes:

1. A ~three-sentence articulation of the question you intend to address for the study
2. A 3+ sentence summary of techniques used and why they are the best for this study
3. A hand-drawn map of the study area, with landmarks, rough topography, base station locations, and anticipated measurement sites.

Execute the Survey

Pack all appropriate equipment, travel to the study area, and begin the survey. Remember to use the Kinematic GNSS Methods manual for any questions on equipment setup and methods. Make certain to **collect good notes in the field**. *Include*: date, time, location, team, conditions; equipment used (antenna height, make, model, occupation length, etc.), base station characteristics (location, benchmark, antenna height, hardware, etc.), sites measured with the rover (time, point ID, conditions of the marks, etc.). Once the survey is complete, ensure your digital and written data are secure, pack all of the equipment, and return to the office.

Process the Data

Change detection can be processed using many methods, as simple as Excel, or as advanced as change detection algorithms in ArcPro or CloudCompare, depending on your training. Export data files and process them using the appropriate tools and methods manual so that you have a workable data set of points. Analyze the data in your program of choice for change detection. The simpler the software used, the better. Differencing is typically done by subtracting final minus initial states. Look for outliers and ask whether they are credible. If you have to remove some data, you MUST justify your choice.

If working with distributed data, here is an ArcPro workflow for differencing interpolated surfaces:

1. Open ArcPro and create a new geodatabase and map document for the project.
2. *Add Data* to your map file, including GNSS points and a basemap of your choice. Be careful of which data you add first, as this will define the working projection for your map document unless otherwise specified. You can view or change this by right clicking an individual layer and going to *Properties > Source > Data Source.*
3. If you are adding raw GNSS data, you will often use the *Map > Add Data > Add XY Data* feature. Assign the appropriate *X*, *Y*, *Z* or Lat, Long, Height fields depending on the coordinate system you used for surveying.
4. Rename your data layers so it is clear what the data sets are and when they were taken.
5. Use your preferred interpolation tool to create a surface from your GNSS point data. Example: *Toolbox > Spatial Analysis Tools > Interpolation > Kriging.* Input your GNSS points, Height values for the *Z* field, and use default settings.
6. Repeat this for both of your data sets to create an initial and final raster map of elevations.
7. Difference your two elevation maps using the *Raster Math* toolset. *Toolbox > Spatial Analysis Tools > Map Algebra > Raster Calculator*. Subtract your initial from your final raster map to get a difference map.
8. Take some time to look at the dataset and tweak how change is symbolized. A general guideline is to use a stretched gradient map for changes in elevation.
9. Finalize your map by adding a title, legend, north arrow, scale bar, and grid. In particular pay attention to your symbols for changes in height.
10. Export the map as an image file or pdf.

Analysis and Discussion

Write at least a 500-word report on the analysis of your data, your change detection, and your interpretation of the findings. This should include a discussion of measurement *uncertainty*, and any relevant information on *techniques* or *projections used*, etc. The bulk of the report should focus on a summary of the findings.

Be sure to answer the following questions in your report.

1. Were you able to detect a difference in your measurements?
    a. If yes, what is the spatial distribution of change? How do you explain it?
2. What can you say about the nature of the movement?
    a. Do you record vertical, horizontal, or 3D change?
    b. Can you say if the change was instantaneous, episodic, or continuous?
3. Is there any noise in your change detection signal? Where is the magnitude of change detected greater than the instrumental error?
4. What scientific insights do your change detection provide regarding the landscape you measured? Are these insights new or do they reinforce current thinking?
5. Evaluate how well your selected survey design was able to answer your question of interest. Given unlimited resources, how could you modify this survey design to improve the results?
6. For a given geologic application, justify why it would be worth the extra effort to use kinematic GPS rather than a simpler mapping-grade tool or the more complex static tool. Answer this question by explicitly discussing uncertainties in the methods and the precision needed for your application.
7. What are the societal benefits of this research? Write three sentences in plain English that would communicate this benefit in some public medium like a newspaper.
8. Change detection is often used to assess hazards. If we detect change, how might we communicate this to the public without causing unnecessary concern?

Submit

1. The original **survey design proposal** and sketch and.
2. Your **field book** with good notes or a filled out log sheet.
3. The analysis and discussions **report** described above
4. At least one figure with a clear and insightful caption that **illustrates the change detected**. A final field map is optional.

Rubric

General Considerations	Exemplary work will not just answer all components of the given question but also answer correctly, completely, and thoughtfully. Attention to detail, as well as answers that are logical and make sense, is an important piece of this.	Basic work may answer all components of the given question, but some answers are incorrect, ill-considered, or difficult to interpret given the context of the question.	Nonperformance occurs when students are missing large portions of the assignment, or when the answers simply do not make sense and are incorrect.
Survey Design **(10 points)**	**9–10** points: A well-written survey design accurately assesses change and accounts for potential sources of error. Map is well designed and contains all requested components. It illustrates the written survey design, including points to be collected, station locations, and notations on features to be measured.	**5–8** points: Missing 1–2 of the listed characteristics for an exemplary report and may be poorly written/unclear; AND/OR All characteristics are present but lack detail or are incorrect, showing a lack of comprehension.	**0–4** points: Missing 2–4 of the characteristics, may be poorly written and unclear; AND/OR Most characteristics are present (1–2 missing) but are incorrect, showing a lack of comprehension.
Survey Execution and Notes **(10 points)**	**9–10** points: Students execute the survey and keep a detailed log of events. Students track equipment used, metadata, and other necessary field observations.	**5–8** points: Missing 1–2 of the listed characteristics or poorly written/unclear; AND/OR All characteristics are present but lack detail or are incorrect, showing a lack of comprehension.	**0–4** points: Missing 2–4 of the characteristics, may be poorly written and unclear; AND/OR Most characteristics are present (1–2 missing) but are incorrect, showing a lack of comprehension.
Final Report and Figures **(10 points)**	**9–10** points: A well-written summary that accurately assesses the survey design, potential errors, interpretation of results, and discussion of broader impact of technique. Societal benefit is clearly articulated using nontechnical language.	**5–8** points: Missing 1–2 of the listed characteristics for an exemplary report and may be poorly written/unclear. Societal benefit is listed but not clearly justified. AND/OR	**0–4** points: Missing 2–4 of the characteristics, may be poorly written and unclear; AND/OR Most characteristics are present (1–2 missing) but are incorrect, showing a lack of comprehension.

	Figures and/or map is well designed and contains all requested components. It illustrates the change detected and associated uncertainty. A map should minimally include station locations, base station, and some indicator of the change detected.	All characteristics are present but lack detail or are incorrect, showing a lack of comprehension.	