Project Details

Name of project: Developing an Open-Source Workflow and Toolset for Quantifying Lacustrine Sedimentation using Publicly Available Data

Project lead and contact details: James (Jake) Gearon, jake.gearon@gmail.com, 240-620-5681

Project partners and contact details: Daniel Fuka (drfuka@vt.edu), Cornel Olariu (cornelo@jsg.utexas.edu), Ron Steel (rsteel@jsg.utexas.edu)

Proposed start and end date: March 2020-Nov 2020

Budget Requested: $8000 USD

Budget Summary:

- $1500 Travel to ESIP Winter Meeting 2021

- $5000 Package building / dev / testing

- $1500 AWS instance for multi-platform/release testing

Project Outline

Project description: We propose to 1) build a robust, generalized workflow for lacustrine analysis including water-level timeseries generation and shoreline extraction hosted as both an open-source python package and a plug-in for common GIS software to be used by the larger scientific community, and 2) demonstrate a use case for the defined toolkit by analyzing lacustrine sedimentation for a suite of lakes within a period of publicly available satellite coverage (effectively 1999-present).

1) There are many publicly available lake-level data sets in varying states of accessibility, upkeep, and accuracy, including the USGS, HydroWeb, Copernicus Global Land Service, NASA, NOAA, and various publications. The collating of data from disparate sources, or data-wrangling, is often the barrier to entry for many scientific projects. Lake water level data particularly suffers from lack of ease of access as it is distributed haphazardly across federal, state, and academic databases. Up-to-date, high-resolution water level values are integral to studies of lacustrine environments due to their high-frequency nature and impact on local communities. Combining lake water level with shoreline extraction in a user-friendly tool will allow for furthered research and hazard prevention. Many previous workers have identified shoreline-recognition methodologies (Liu & Jezek, 2004; Xu, 2006; Geleynse, et al. 2012; Jiang et al. 2014) and others have gone as far as to track shoreline movement through time (Vos et al., 2019). We believe that up-to-date shoreline identification and extraction tools are not publicly available (in the form of web-apps, open source packages, plug-ins, etc.). Recent workers have had success using morphological mathematics to delineate shorelines that have open distributary mouths (Geleynse, et al., 2012) but to date there is no publicly available code for this analysis. We aim to develop a python package which will serve as a plug in for common geospatial software (ArcGIS, QGIS) and as a stand-alone tool to be built on by the remote sensing community. This package will extract shorelines as shapefiles (.shp) from user-identified lake boundary polygons or LANDSAT images over an inputted time step. If lake water-level data is available for the lake of interest, the data will be indexed from the relevant database (USGS,

HydroWeb, CGLS, etc.) and output step-wise for each shoreline and for the entire timestep, respectively (Fig 1).

2) Here we present a use case for the proposed toolkit. Lacustrine environments are excellent candidates for remote study due to their relatively small spatial extents, quantifiable inflow (discharge, precipitation, etc.), and the nature of the shoreline as system boundary, relating external and internal processes that control lacustrine equilibrium (Gilbert, 1978). In other words, lake shorelines respond to external forcing by either moving basin-ward (indicating local deposition) or moving land-ward (indicating erosion). Additionally, we feel more work is needed to quantify patterns in total system sedimentation within the many types of lacustrine environments found around the world. Our project will use existing lake-level data (as it is available for user-defined areas of study) and user-generated bounding polygons (.kml, .shp, geoJSON, etc.) as well as the large catalogue of publicly available satellite imagery data (namely LANDSAT) to achieve this. The methodology is conceptually simple: 1) Lake levels fluctuate seasonally due to changes in precipitation and evaporation, finding the mode value of lake level height assigns the most common lake level state for a water body over a defined time-series window. Extracting lake shorelines for times where lake level is equivalent to the modal value controls for the possibility of vertical water column movement laterally changing shoreline position irrespective of sedimentation or erosion. 2) As a shoreline is a closed shape, changes in shorelines can be computed as areas. Areas created by a land-ward shoreline excursions are designated as erosional areas and assigned a negative value. Basin-ward movements are designated as depositional areas and assigned a positive value. The sum of these measurements gives a positive or negative area measurement, denoting a net depositional or erosional setting respectively. A time-series can be generated of periods of net deposition and erosion, giving insight to the periodicity and magnitude of lacustrine sedimentary regimes. Coupled with a hydrograph, precipitation graphs, and other common lacustrine data, governing forces can be determined more accurately, aiding in a number of scientific, conservatory, and municipal pursuits.

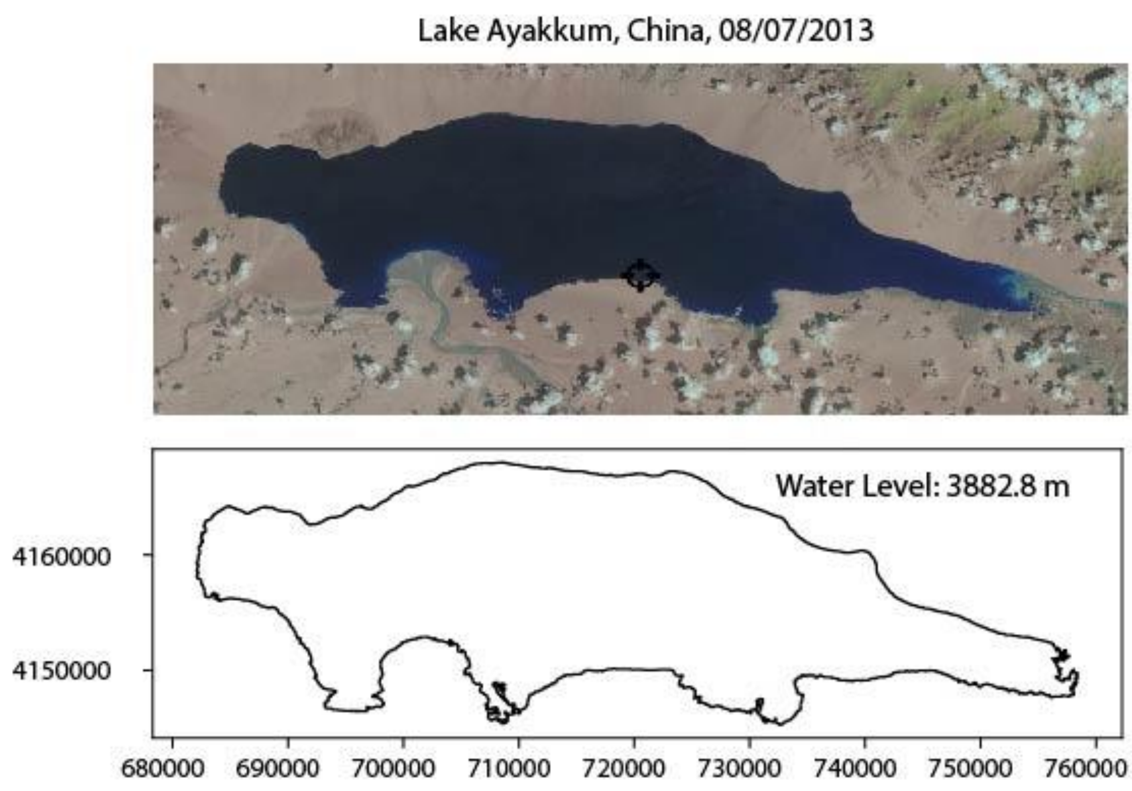

Figure 1: Lake Ayakkum, China and extracted shoreline.

Project objectives, significance, and impact:

Objectives: The main objectives of this project are 1) a user-friendly, well documented python package available for collaboration, download, and augmentation. This package will be hosted on GitHub and have extensive documentation and examples in the form of Jupyter Notebooks (.ipynb). 2) A plug-in for ArcGIS or QGIS for increased ease-of-use with associated documentation. 3) A robust use-case aimed at wide audience of geologists, environmental scientists, remote sensing workers, students, and citizen scientists to exemplify how this tool will allow for tracking of historic and future changes in lacustrine sedimentological regimes in the face of global climate change.

Significance: Many previous workers have designated remote sensing methodologies and best practices to determine lacustrine environmental parameters: extent, sediment concentration, water volumes, hypsometry, water levels, shoreline movement, etc. We believe the current work falls short of quantifying systemic sedimentation through time. Limnologists have previously described lacustrine clastic sedimentation as an important paleo-climatological proxy (Lamoureux, 1999), meaning that constraining modern sedimentary trends may serve as an important predictive model for local, regional, and global climate change.

Description of key project steps and timeline: Feb-August 2020: Improve, functionalize, and scale existing code. Develop portion of code aimed at gap-filling LANDSAT 7 images, which has proved too computationally intensive without enhanced computing solutions and is integral to data coverage. Create framework for package to be hosted as an open-source plug-in. **August-November 2020:** Small bug fixes, documentation creation, full scale deployment of code to a generated dataset, gather and interpret results. **Winter 2020-2021:** Present results at ESIP 2021

Description of additional funding currently supporting this work: No additional funding to report.

Outreach

What groups/audiences will be engaged in the project? The study of lacustrine environments cuts across many academic fields including geology, biology, environmental science, conservation, and hydrology. We believe researchers from these fields will have a vested interest in an open-source, user-friendly lacustrine analysis package.

How will you judge the project's impact? We will track collaboration via forks on GitHub, track citations from an eventual publication, and receive feedback and scientific conferences.

How will you share the knowledge generated by the project? The results and workflow from this project will be presented (likely at AGU 2020) and sent to publication in TBD relevant journal. Additionally, the examples of lake bounding polygons and associated water-level data and sources will be made available on the project GitHub repository.

Description of *who* (agencies/individuals) should be aware of this project, i.e. potential outreach targets: Generally, the remote sensing, hydrology, and sedimentology communities should be aware of this project. Additionally, depending on the results of the project, local conservancy groups may use this technology to assess changes in reservoir sedimentation (a common problem).

Project Partners (as applicable)

Description of project partners (agencies/individuals) and their involvement: Daniel Fuka (Virginia Tech) will provide validation that the project deliverables meet FAIR Data (and Source Code) Principles (findable, accessible, interoperable and reusable) from inception, and will mentor PI Gearon on publication throughout the project. Cornel Olariu and Ron Steel are PI Gearon's graduate advisors and will assist with sedimentological analysis for use case.

How will this project engage members of the ESIP community: We believe removing or minimizing manual or "mouse-driven" workflows via usable, open-source projects like this one will lower the barrier of entry to water-body analysis for users not familiar with remote sensing, coding, or image analysis. Streamlining processes that involve data wrangling from multiple sources and complex analysis is in line with ESIP's mission and the RFP guidelines

Citations:

1) Liu, H., & Jezek, K. C. (2004). Automated extraction of coastline from satellite imagery by integrating Canny edge detection and locally adaptive thresholding methods. *International journal of remote sensing*, *25*(5), 937-958.

2) Geleynse, N., Voller, V. R., Paola, C., & Ganti, V. (2012). Characterization of river delta shorelines. *Geophysical Research Letters*, *39*(17).

3) Gilbert R. (1978) Lacustrine sedimentation. In: Middleton G.V., Church M.J., Coniglio M., Hardie L.A., Longstaffe F.J. (eds) Encyclopedia of Sediments and Sedimentary Rocks. Encyclopedia of Earth Sciences Series. Springer, Dordrecht

4) Lamoureaux, S. (1999). Spatial and interannual variations in sedimentation patterns recorded in nonglacial varved sediments from the Canadian High Arctic. *Journal of Paleolimnology*, *21*(1), 73-84.

5) Li, X., Jiang, N., Wang, H., & Liu, X. (2005). Dynamic changes of lake shorelines morphology in the Taihu basin during the past 30 years. *Journal of Lake Sciences*, *17*(4), 294-298.

6) Vos, K., Splinter, K. D., Harley, M. D., Simmons, J. A., & Turner, I. L. (2019). CoastSat: A Google Earth Engine-enabled Python toolkit to extract shorelines from publicly available satellite imagery. *Environmental Modelling & Software*, *122*, 104528.