**NASA DEVELOP National Program**



Wise County Clerk of Court's Office

*Summer 2015*

Peru Disasters II

Identifying and mapping flood prone regions in the La Libertad Region of Peru using NASA's Earth Observations

 **Technical Report**

Rough Draft – June 25, 2015

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# I. Abstract

**Keywords**

Flood Mitigation, Earth Observation System (EOS), Landsat 8, TRMM, CREST, Digital Elevation Model (DEM), Flow Direction (FDR), Flow Accumulation (FAC), Inundation Model

# II. Introduction

***Background Information***

**Peruvian flooding & Water for People**

Although seasonal flooding is inevitable in the Peruvian highlands, extreme flooding events in 2008, 2013, and 2014 inflicted widespread devastation across areas of western Peru. The Chicama River, like dozens of other rivers, flows through a mountainous coastal region, entering the Cascas district through the Ochape sub-basin before flowing down to the coast. Sixty-eight percent of the district’s population lives in rural areas and the remainder inhabits the town of Cascas, the capital of Gran Chimu province (Water for People, 2015). Agriculture of the area’s river valleys includes rice, alfalfa, tomatoes, fruits, and well-renowned viticulture around the town. This basin was selected as the study area due to its active involvement in projects done by Water for People, a non-profit that has been working in the district since 2011.

**Hydrological modeling overview**

Hydrological models theoretically portray the hydrologic cycle using specific inputs and forced parameters. With the rise of Geographic Information Systems (GIS), the methodologies used to organize input parameters and other geospatial data within hydrologic models has been improved, thus facilitating the diversity of modeling strategies and multiplicity of hydrologic models. At a most basic level, these models can be assessed as either deterministic or stochastic (Vieux, 2003). Here we are interested in deterministic modeling, which puts forward representations of real-world processes that often include surface runoff, channel flow, and inundation to name a few.

Distribution within the concept of a distributed hydrologic model refers to the real world spatial variability of the land surface and atmosphere, which exert control over local hydrological patterning. The bounty of data from earth observations has made this distributed concept possible.

As described by Vieux & Associates, distributed hydrologic modeling is best characterized by:

* Division of the watershed into grid cells
* Connection of the cells to form a drainage network
* Use of physics to predict runoff rates and volume
* Use of GIS data to describe terrestrial features
* Inputs from radar, satellite, and rain gauges etc.

**Coupled Routing and Excess Storage (CREST) Distributed Hydrological Model**

The CREST distributed hydrological model is a strategy that was jointly conceived by the University of Oklahoma and NASA SERVIR Project Team. Using inputs of rainfall, digital elevation models (DEM), flow direction and accumulation maps, and potential evapotranspiration (PET) data, the model generates a water extent map and calculates flow through cell to cell routing of surface water. The runoff generation component and routing scheme are coupled, providing realistic interactions between atmospheric, land surface, and subsurface water (Wang, et al., 2011).

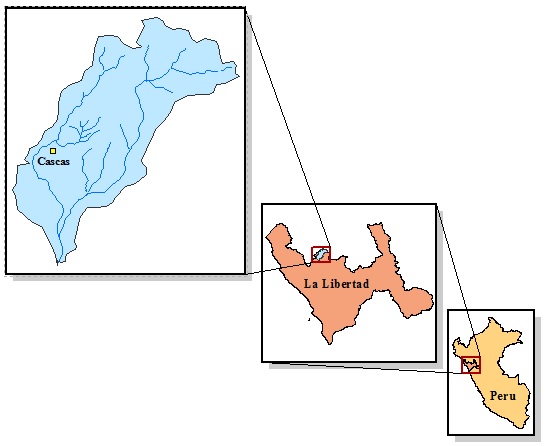
***Project Objectives***

The Wise County DEVELOP team will review the performance of flood forecast information from the hydrological NASA/OU CREST 2.0 model through calibration on the Ochape sub-basin. The analysis will be conducted using remotely sensed input data from NASA’s Earth Observation Systems (EOS). Objectives of the Wise team include:

* Producing historic and predictive flood maps utilizing NASA Earth Observations and mathematical models for the La Libertad Region of Peru
* Obtaining a successful calibration of the CREST 2.0 model

***Study Area***

Our study area is the Ochape Sub-Basin, located in the District of Cascas, Gran [Chimú](https://en.wikipedia.org/wiki/Gran_Chim%C3%BA_Province) Province. This lies within the region of La Libertad, Peru.



**Figure 1.** This image relates our specific study area to the region and country it is located in. The Ochape Sub-Basin (top left) is found in the northern area of La Libertad.

***Study Period***

2007 – 2014, including 3 major floods identified during 2008, 2013 and 2014:

* January- March, 2008
* February 23- March 19, 2013
* February 24- March 10, 2014

***National Applications***

**Disasters**

The mitigation of natural dangers such as flooding can potentially be forecasted by the hydrological model.

**Water**

Based on the hydrologic cycle, the model used in this project will contribute to an enhanced understanding of the factors controlling surface water inundation.

**Ecological Forecasting**

The results of this project can help hydrologists forecast hydrological events such as flooding.

***Project Partners***

***Water For People***

[www.waterforpeople.org/](http://www.waterforpeople.org/)

Water for People is a non-profit organization currently working with local Peruvian governments to enhance water resource management systems in the Cascas and Asuncion districts. DEVELOP teams from the Fall of 2014 and Spring of 2015 helped develop tools and methodologies for these water resource efforts.

**Instituto Nacional de Defensa Civil**

<http://www.indeci.gob.pe/>

INDECI is directly responsible for disaster management in Peru. Partners from Water for People are currently in contact with INDECI and Consejo de Cuenca. End results can be used to produce flood inundation maps, as well as aid project partners in future decision making and flood prediction.

# III. Methodology

***Data Acquisition***

**DEM from USGS HydroSHEDS**

A DEM is required to have a precise representation of surface terrain. Digital Elevation Models for the study area were downloaded via USGS at a resolution of 90 meters. Due to the large scale of our study area, the DEM was resampled to 30 meters using the Resampling Tool in ArcGIS. CREST requires alterations of the DEM by manipulation of the data to represent flow direction and flow accumulation. The FDR and FAC maps are discussed more below.

**Precipitation data from TRMM**

Precipitation data is another necessary input for calibrating the CREST model. The model utilizes average rainfall data for the study area during flood prone months of the year. Rainfall data was acquired by NASA’s Tropical Rainfall Measuring Mission (TRMM) that ceased data collection in the spring of 2015 and has been replaced by Global Precipitation Measurement (GPM) data.

**Potential Evapotranspiration data**

Potential Evapotranspiration (PET) data is required for the CREST model. This data simulates evaporation rates given a specific amount of water. The interpretation of PET data is important for the CREST model simulation, as it dictates how much water is available for the cell-to-cell routing scheme.

**Shapefiles from DIVA-GIS**

Political boundary shapefiles were obtained from DIVA-GIS, a free online database. The shapefiles were acquired to assist us with the display of our study area. The study area boundary itself was digitized and was not taken from this website.

***Data Processing***

**DEM, FDR and FAC**

The DEM resolution was upgraded to 30-meter resolution in order to better gauge our large-scale study area. This was done using the Resampling tool in ArcMap. The Fill function in ArcMap was then used on this resampled DEM to correct any missing data with a built-in algorithm. Following this, the creation of the Flow Direction Map and the Flow Accumulation Map occurred in sequence as outlined in the 2012 Upper Missouri Rivers Technical Paper Appendix A (Skym, et al., 2012). The FDR is a raster dataset showing the direction of flow from each cell to its steepest counterpart. The FDR is required as input for determining water routing patterns. This sets the stage for the creation of the FAC, which tracks the accumulation of flow to each cell.

**CREST 2.1 Inputs**

The CREST model requires datasets for the study area encompassing precipitation data, DEM, FDR, FAC and potential evapotranspiration (PET) data. All data must be set to World Geodetic System 1984 reference system while the map units must be set to decimal degrees.

**Calibration Settings**

**Data Analysis**

# IV. Results & Discussion

Insert images, graphs, maps, charts, etc. here. Choose the most important results to highlight here. No word cap, but two to six pages is a good range.

Things to discuss:

* Analysis of Results: What can you tell from your graphs, images, etc? What does this mean for your project?
* Errors & Uncertainty: What factors could you not account for, what things didn’t work out like you expected they would, etc.
* Future Work: If this project was to be selected for another term, what would be the focus? What other areas would be of interest?

# V. Conclusions

Final conclusions. Word count: 200-600 (~a page).

# VI. Acknowledgments

Insert here. Keep to a concise paragraph or bullet-list of names of all the people who helped reach a conclusion of this project. End with the following sentence.

This material is based upon work supported by NASA through contract NNL11AA00B and cooperative agreement NNX14AB60A.

# VII. References

Skym, P., Spelman ,D., Rodriguez, L., Policelli, F., Ouzounov, D., (2012). Upper Missouri

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Wang, J., Hong, Y., Li, L., Gourley, J. J., Khan, S. I., Yilmaz, K. K., Adler, R. F., et al. (2011). The coupled routing and excess storage (CREST) distributed hydrological model. *Hydrological Sciences Journal*, *56*(1), 84–98. doi:10.1080/02626667.2010.543087

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\*Glossary Viewer – readers can hover over words for definitions

Inline Supplementary Material (figures, tables, computer code)

Interactive Map Viewer

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Nomenclature Viewer

# IV. Appendices

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