**NASA DEVELOP National Program**



Wise County Clerk of Court's Office

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Peru Disasters II

Identifying and Mapping Flood Prone Regions in the La Libertad Region of Peru Using NASA's Earth Observations

 **Technical Report**

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# I. Abstract

To be added.

**Keywords**

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

# II. Introduction

**Background Information**

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.

Hydrologic 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 have been improved, thus facilitating the diversity of modeling strategies and multiplicity of hydrologic models. At the 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 exerts 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.

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).

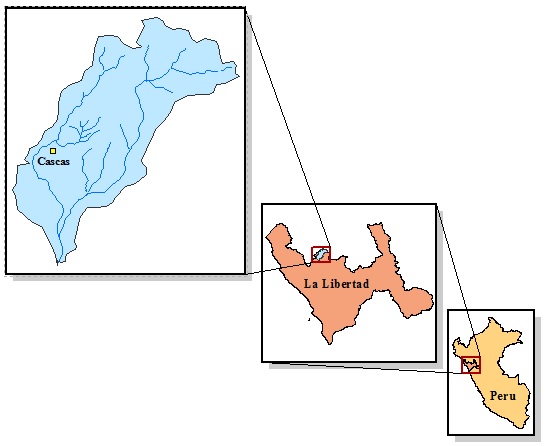
**Project Objectives**

The Wise County DEVELOP team reviewed the performance of flood forecast information from the hydrological NASA/OU CREST 2.0 model through calibration on the Ochape sub-basin. The analysis has been conducted using remotely sensed input data from NASA Earth observations (EO). Our study period spanned 2007 to 2014 with 3 major floods identified during 2008, 2013 and 2014: January to March 2008; February 23 to March 19, 2013; and February 24 to March 10, 2014. The objectives of the Wise DEVELOP team were to produce historic and predictive flood maps utilizing NASA Earth observations and mathematical models for the La Libertad Region of Peru, and to obtain a successful calibration of the CREST 2.0 model.

The national application areas covered were Disasters, Water Resources, and Ecological Forecasting. The project addressed the disaster application area through addressing the mitigation of flood forecasting by hydrologic model. This naturally ties into the water resources application area because the model used in this project has contributed to an enhanced understanding of the factors controlling surface water inundation. And lastly, the results of this project will help hydrologists forecast hydrological events such as flooding.

**Study Area**

Our study area was 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 as represented by *Figure 1*.



**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.

**Project Partners**

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. Our end-products from this term will help Water for People mitigate the risks associated with flooding within their region of operation. This term’s deliverables, along with those of the previous terms, will help Water for People provide complete water security to people within Peru.

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**

A DEM was required to have a precise representation of surface terrain. Digital Elevation Models for the study area were downloaded via the USGS HydroSHEDS site 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 required alterations of the DEM by manipulation of the data to represent flow direction and flow accumulation. The flow direction (FDR) and flow accumulation (FAC) maps are discussed more below.

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

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

**Data Processing**

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 (FDR) and the Flow Accumulation Map (FAC) were produced 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 an 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.

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

# IV. Results & Discussion

To be added.

# V. Conclusions

To be added.

# VI. Acknowledgments

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# VII. References

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

River Diasasters II (NASA DEVELOP). Technical Paper- Appendix A, p26- 30.

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

Water for People “Making a Difference: Peru” Accessed: 24 June. 2015. Available at: <http://www.waterforpeople.org/making-a-difference/peru>

Vieux & Associates, Inc., (2003). Physics-based Distributed Hydrologic Modeling for Flood Forecasting. Available at: <http://www.nws.noaa.gov/iao/InternationalHydrologyCourseCD1/1105/Vieux/presentation(vieux).pdf>

# VIII. Content Innovation

To be added.

# IV. Appendices

To be added.