National Aeronautics and Space Administration

NASA Earth Science Division Applied Sciences Program

DEVELOP National Program

Measuring Reservoir Heights via Satellite Altimetry Products:

Using Reservoir Heights Data for Global Flood Modeling

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Reservoir Heights

Community Concerns

- Near real-time global flood models do not adjust lake levels and river flow rates to reflect effects of dams
- Incorrect data can leave surrounding communities vulnerable to potential flood disasters
- Adjusted flood models that properly account for downstream releases can help to mitigate the effects of future floods

National Applications

Water Resources

Natural Disasters

Advisors

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Reservoir Heights – Overview

Project Objectives

- Determine reservoir heights of selected dam study site
- Create a water balance over time to determine a change in storage
- Provide useful data to help update the NASA-OU CREST flood model and predictions

Study Area

- Garrison Dam, Lake Sakakawea, North Dakota
- Part of Missouri River basin and system
- Lake covers 368,000 acres and can hold 18,110,000 acre-feet of water

Study Period

- All data collected from 2002 to present
- More specific focus from 2008-2010

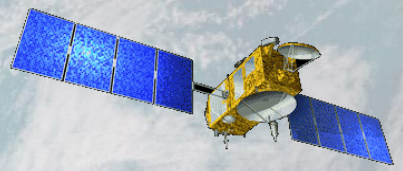
Reservoir Heights – Methodology

Satellites and Sensors

- Jason-1: Poseidon 2 Altimeter
- Jason-2: Poseidon 3 Altimeter
- Envisat: Radar Altimeter-2

Data Acquisition

- ESA Earthnet Online: Data Products
- LEGOS
- NEODC
- NOAA CLASS
- PO.DAAC
- United States Geological Survey
- U.S. Army Corps of Engineers



Jason-1

• NASA altimetry satellite used to measure sea-surface height, with continuous data
• Provides data in 10-day cycles, in near-real time

Jason-2

• Has 3 new instruments which provide enhanced data quality and accuracy to measure sea surface heights
• Provides data in 10-day cycles, in near-real time

ENVISAT

• European Space Agency altimetry satellite
• Monitors environmental entities such as the Earth's surface and atmosphere
• Provides data in 35-day cycles, in near-real time.

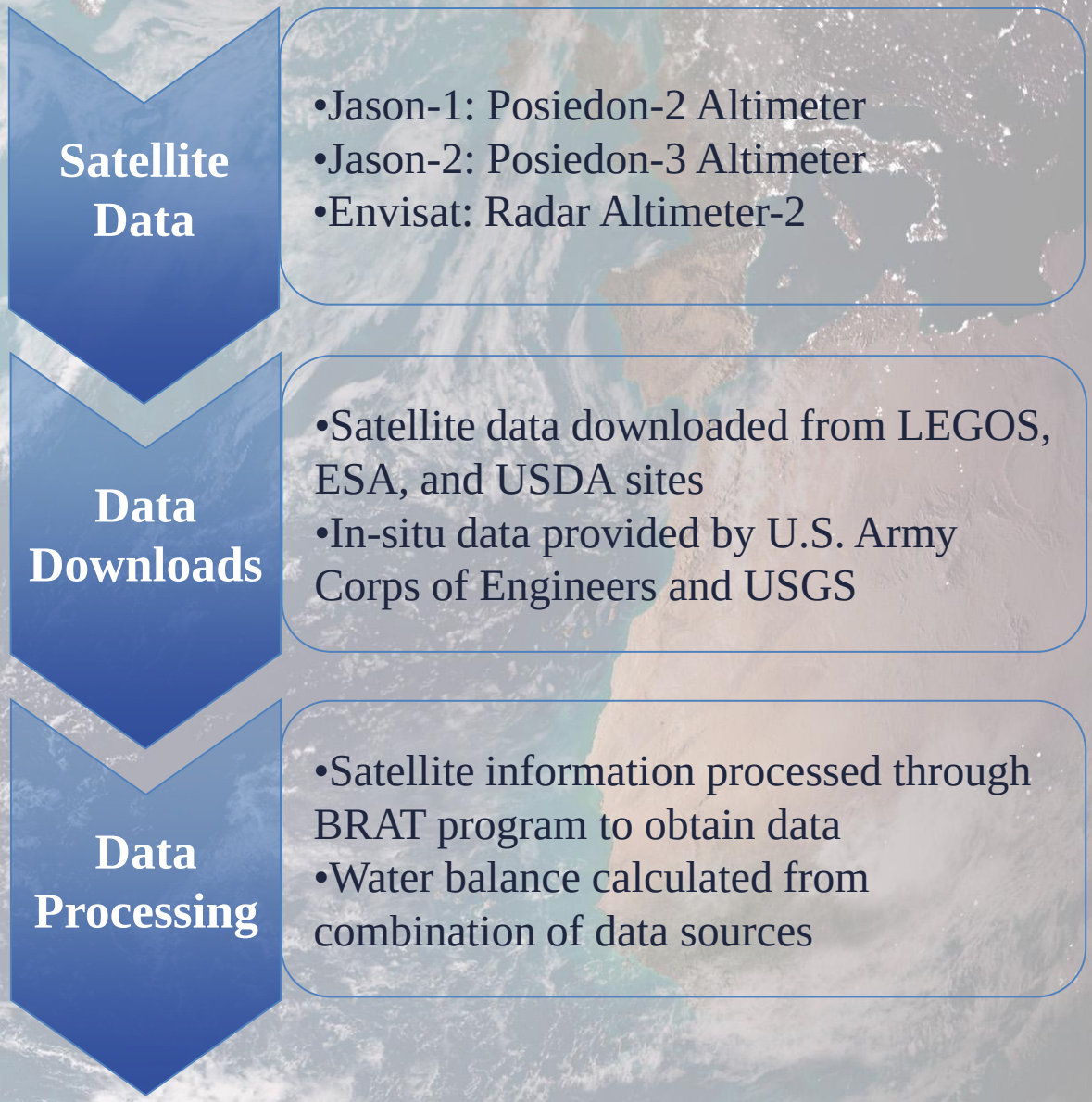
Reservoir Heights – Methodology

Decision Making Process

- The water body created and contained by a man-made dam
- The reservoir must be of a considerable size (> 100km)
- satellite data must be available from NASA Jason-1, Jason-2 satellites or the ESA Envisat satellite
- All data must be available from 2002-present

Decision Support Tools

- List of Global Reservoirs and Lake Monitoring from USDA by Dr. Charon Birkett



Reservoir Heights – Methodology

Satellite Data Processing

- Jason-2 altimetry data was downloaded from the Aviso website for each relevant pass for the needed cycles that covered the study area
- Files were viewed and manipulated using the Basic Radar Altimetry Toolbox (BRAT) program in order to obtain the desired data results (surface height)
- To get the surface height in meters of a point on the ground above sea level, the BRAT manual instructs the user to use the following formula:

H(m) = Altitude – Range – Corrections

  - Where corrections include:
    - ionosphere
    - dry troposphere
    - wet troposphere

- Acquired altimetry data graphed against in-situ data compares accuracy and validity of the satellite data and determines a constant bias needed for the data set

Reservoir Heights – Methodology

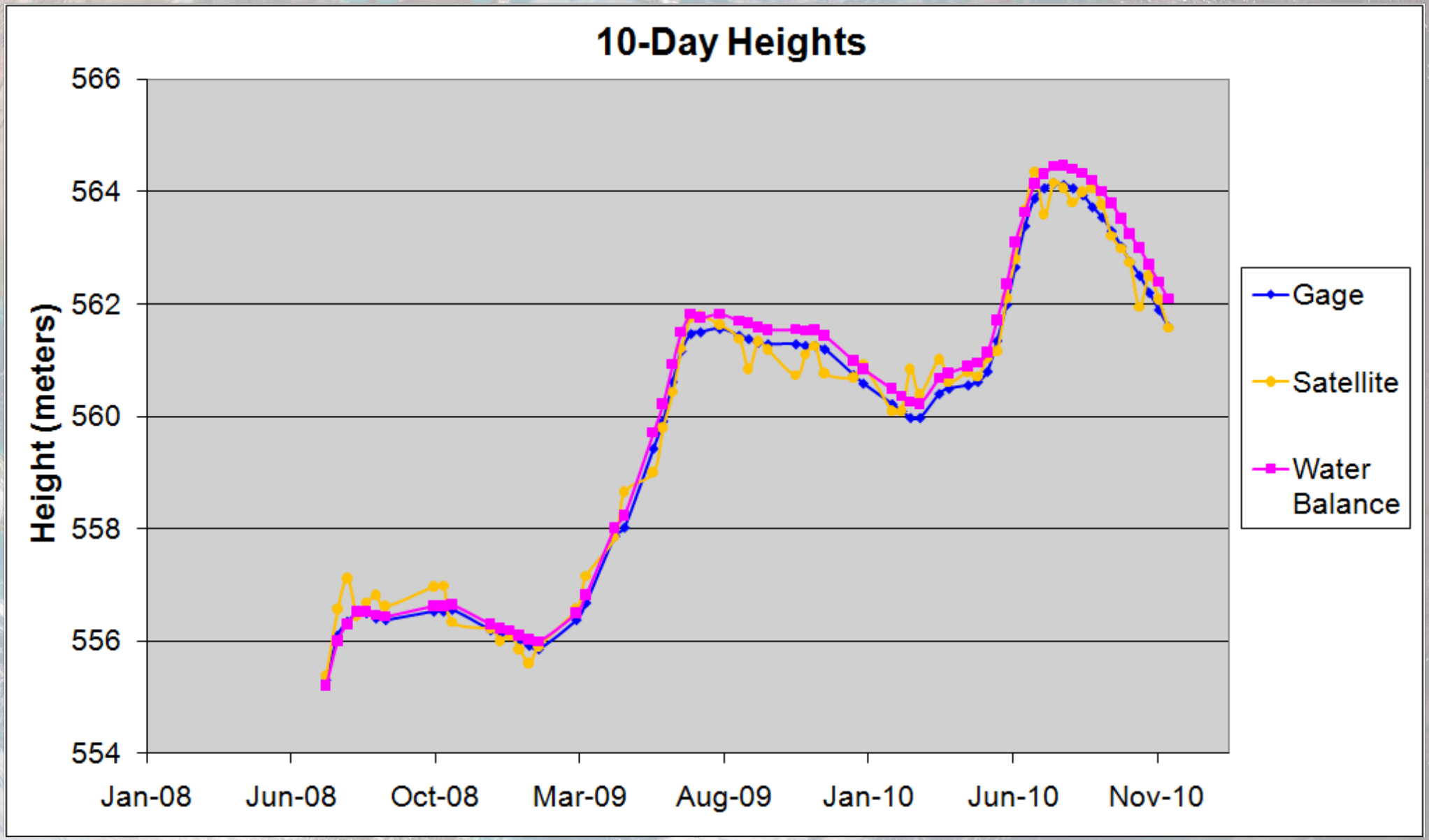
Water Balance Calculations

- Measures the change in storage volume of the permanent pool of the reservoir resulting from the total inflow minus the total outflow
- Inflows consist of precipitation (P) and total inflow (Q-in) into reservoir
- Outflows consist of evaporation (E) and total release (Q-out) from reservoir

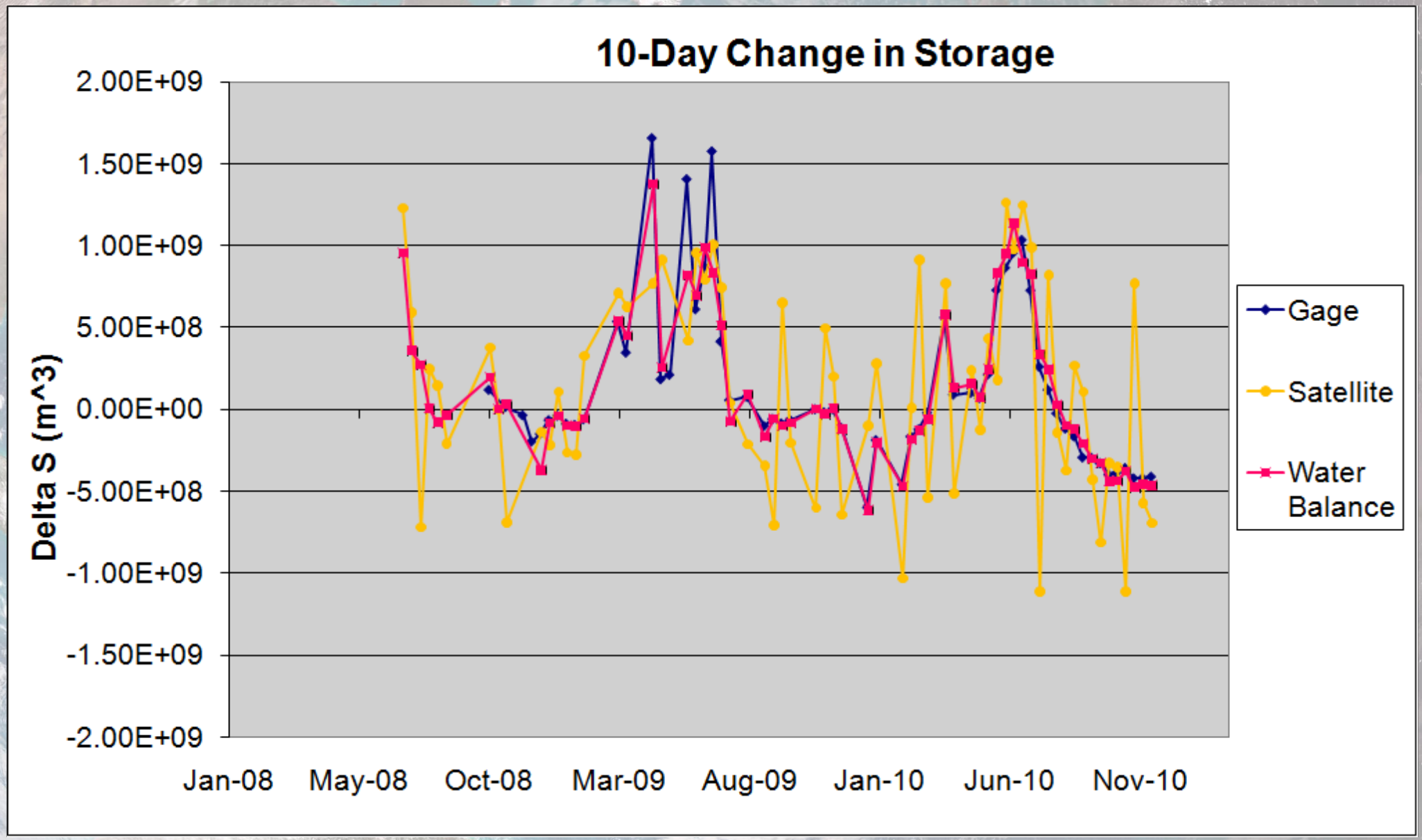
$\Delta V = \Sigma$ Inflow – Σ Outflow

- ΔS = change in storage volume of the reservoir (cubic meters)
- Σ Inflow = sum of all inflows over a period of time
  - stream flow
  - Precipitation
- Σ Outflow = sum of all outflow over a period time
  - discharge
  - evaporation
  - infiltration

Reservoir Heights – Results



Reservoir Heights – Results



Reservoir Heights – Conclusions

Final Analysis

- Using both the satellite and in-situ data, changes in reservoir volumes were calculated for the selected study site
- The calculated changes in storage can be successfully completed with sufficient in-situ data, but altimetry data can be used to compensate for unavailable in-situ data
- Comparison of changes in heights (Δh) from both satellite and in-situ data sets show a close relationship between the two data sources
- Changes in storages (Δs) from all three data approaches show the effectiveness the data.
- Satellite altimetry data can be used to effectively measure reservoir heights and provide information on water storage changes

Reservoir Heights – Project Partners

Partner Need and Project Benefits

Pacific Disaster Center

The PDC provides research and analysis support towards the development of disaster-resilient communities. The PDC will be the end-user of the model, in order to more effectively account for possible flood situations in areas affected by dams

University of Maryland – ESSIC

The Earth System Science Interdisciplinary Center (ESSIC) aims to enhance the understanding of the interaction among the Earth's multiple spheres and the influence of human activity. This project directly relates to the program's focused research on the global water cycle and results generated from using ESSIC data will be shared.

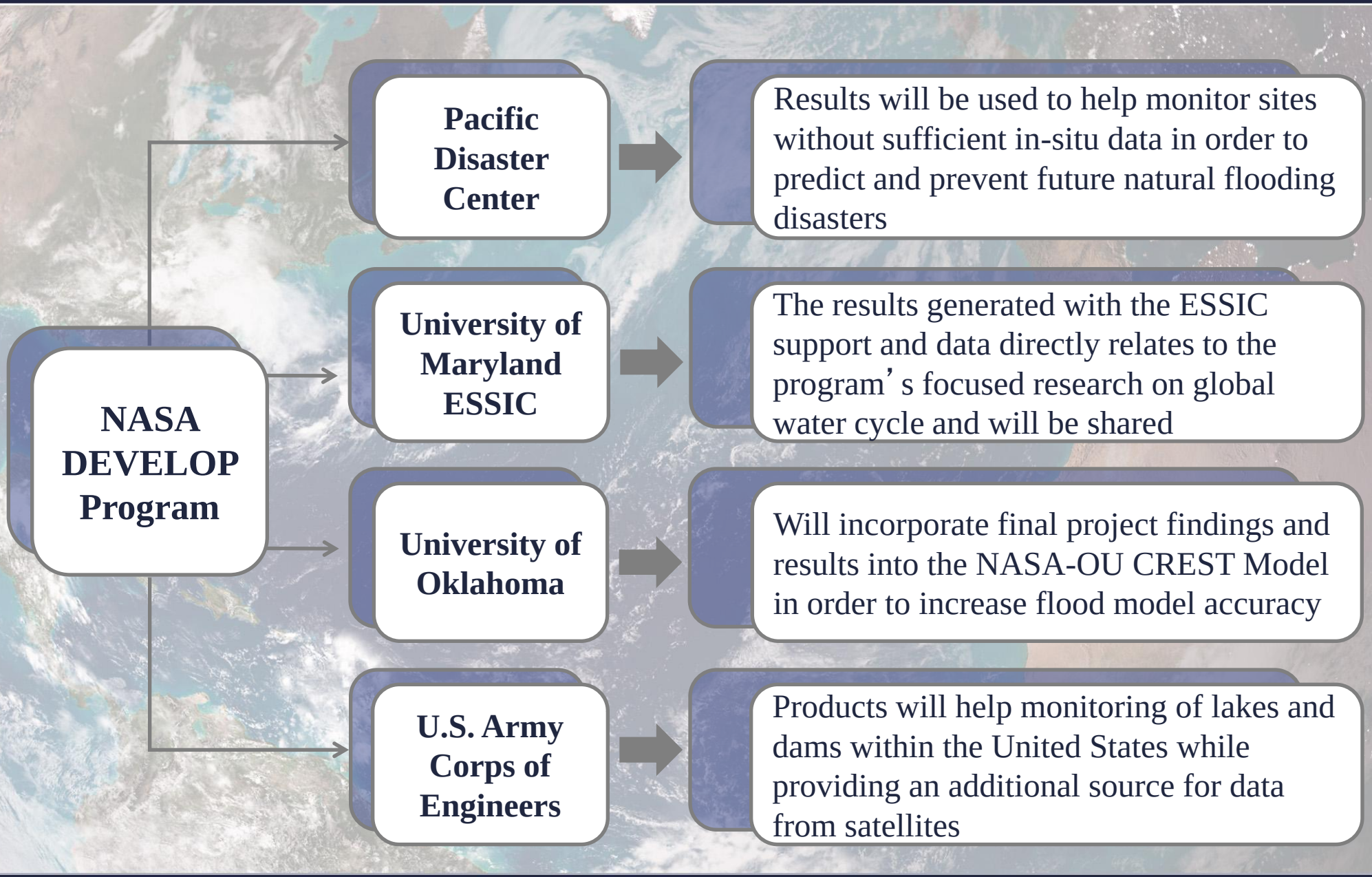
University of Oklahoma

NASA has partnered with University of Oklahoma to help develop the NASA-OU CREST Flood Model in order to simulate water fluxes over time and space. The data products collected and created during this project will help to update and provide more accuracy to the CREST Flood Model

U.S. Army Corps of Engineers

The mission of the US Army Corps of Engineers is to provide vital public engineering services to reduce the risk of disasters. This project will help them achieve that by providing more accurate flood modeling for areas affected by dams, allowing them to more efficiently plan and predict possible floods.

Reservoir Heights – Transition



Reservoir Heights – Future Work

Project Transition

The end result of this Reservoir Heights Project, which proves the utility of data from both ground (in-situ) and space (satellite) sources, should be incorporated and used by those who monitor reservoirs in order to determine the needs and functional challenges of each water balance models per individual dam site

Project Application

- These results once turned over to project partners can be maintained and updated with new data generated daily from both gage and satellite sources
- The results from this one study site can be expanded to study other reservoirs and river basins using this project as a model
- This water balance calculated can be applied to other reservoirs and further incorporated into flood models, such as the CREST Model
- Based on research by our advisor Dr. Birkett, Reservoir heights of dam locations without sufficient in-situ data can now be observed via satellite altimetry data products