NoR Projects Sponsorship Final Report

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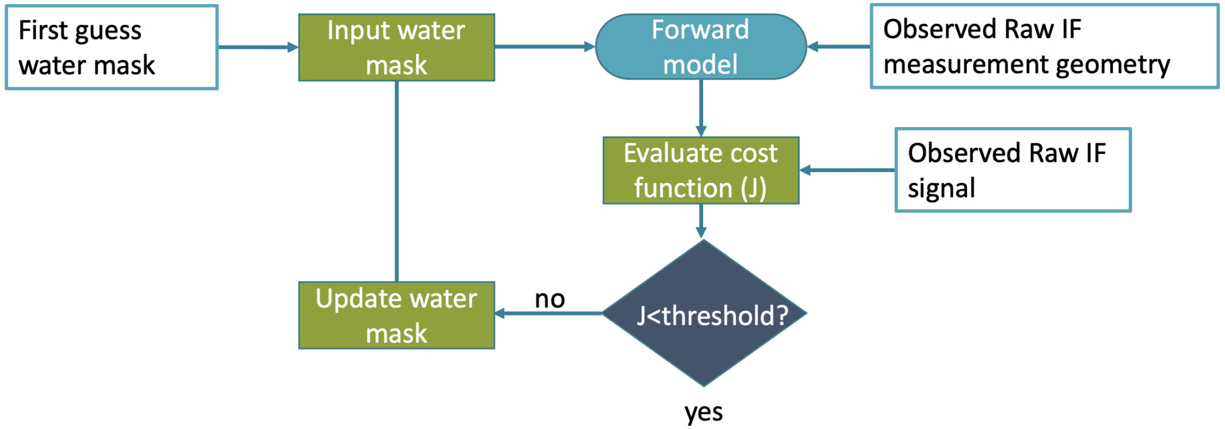
Objective of the project: Remote Sensing of River Flow Rate with CYGNSS Data

- The goal of this project is to utilize CYGNSS data for riverine monitoring
- We seek to develop methods to:
  - Measure river width and streamflow from CYGNSS raw IF data
  - Assess the applicability of these methods to a number of river subreaches and types
  - Validate the measurements with satellite data and streamflow gauge data



Algorithm flow chart for optimizing the input water mask using the forward model and raw IF observations.

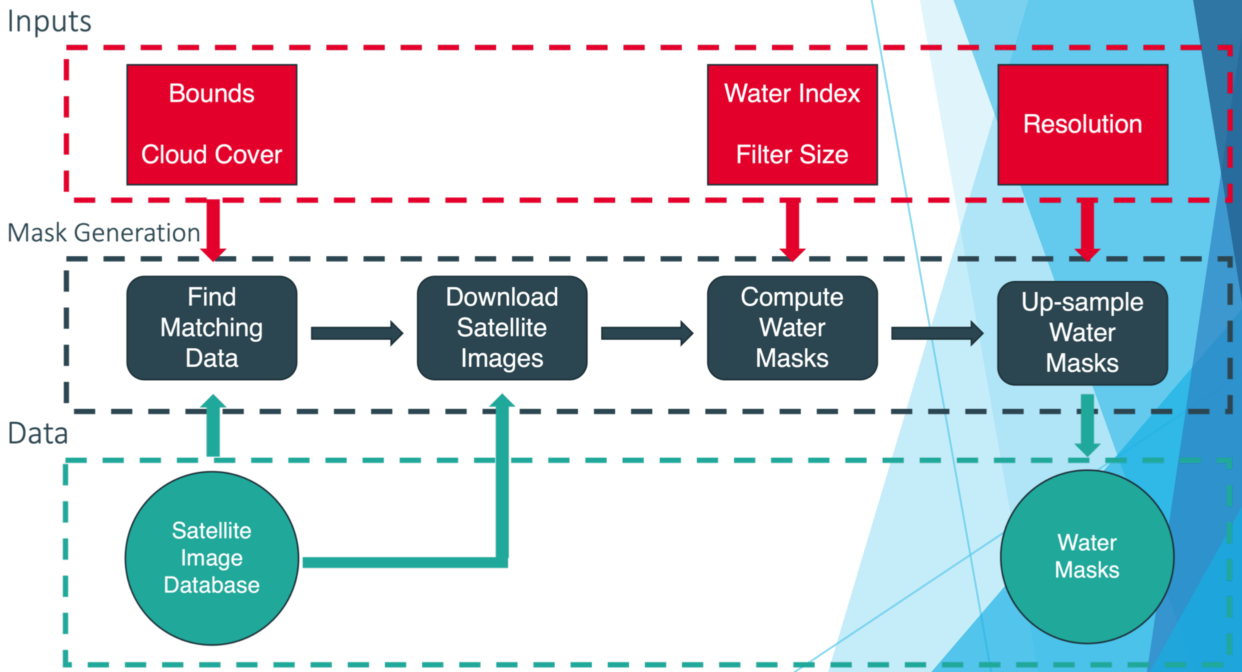
How using tools and data within cloud environments helped to achieve our project goals

- The forward model need input water masks
- Creating these masks by hand is not feasible – it is too time consuming
- Sentinel-2, combined with the use of spectral water indices, provides a method for generating large-scale water masks in an automated fashion
- In order to generate automated Sentinel-2 water masks, we need to:
  - Have access to a historical database of Sentinel-2 data
  - Be able to clip and manipulate the data with ease; using minimal computer resources
- The NoR sponsorship enabled us to meet these goals by giving us access to the ESA data in a cloud-based environment

Overview of the algorithm for automatically generating water masks from Sentinal-2 imagery

- Four steps to generating water masks:
  1. Find matching data
  2. Download the satellite images
  3. Compute the water masks
  4. Sampling water masks at the specified resolution.

Using tools and data within cloud environments has enabled these steps!



Processing flow for automated water mask generation from multispectral satellite Sentinel-2 imagery

Sentinel-2 data properties and spectral water indices

Band description, central wavelength, and resolution for Sentinel-2 imagery

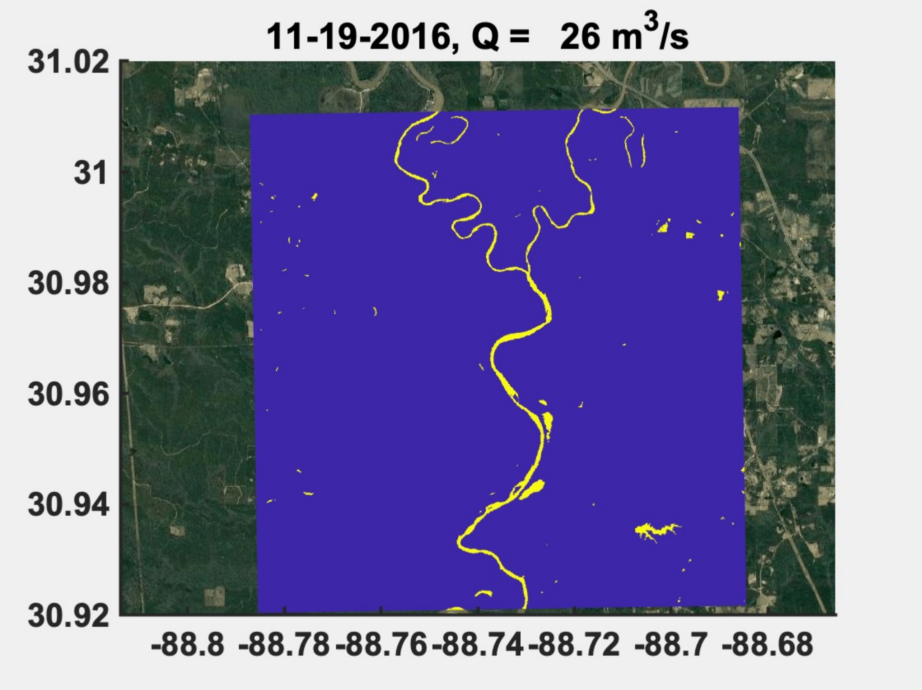
Bands	Central wavelength (micrometers)	Resolution (meters)
Band 1 - Coastal aerosol	0.443	60
Band 2 - Blue	0.490	10
Band 3 - Green	0.560	10
Band 4 - Red	0.665	10
Band 5 – Vegetation red edge	0.705	20
Band 6 – Vegetation red edge	0.740	20
Band 7 – Vegetation red edge	0.783	20
Band 8 – NIR	0.842	10
Band 8A – Narrow NIR	0.865	20
Band 9 – Water vapour	0.945	60
Band 10 – SWIR - Cirrus	1.375	60
Band 11 - SWIR	1.610	20
Band 12 - SWIR	2.190	20

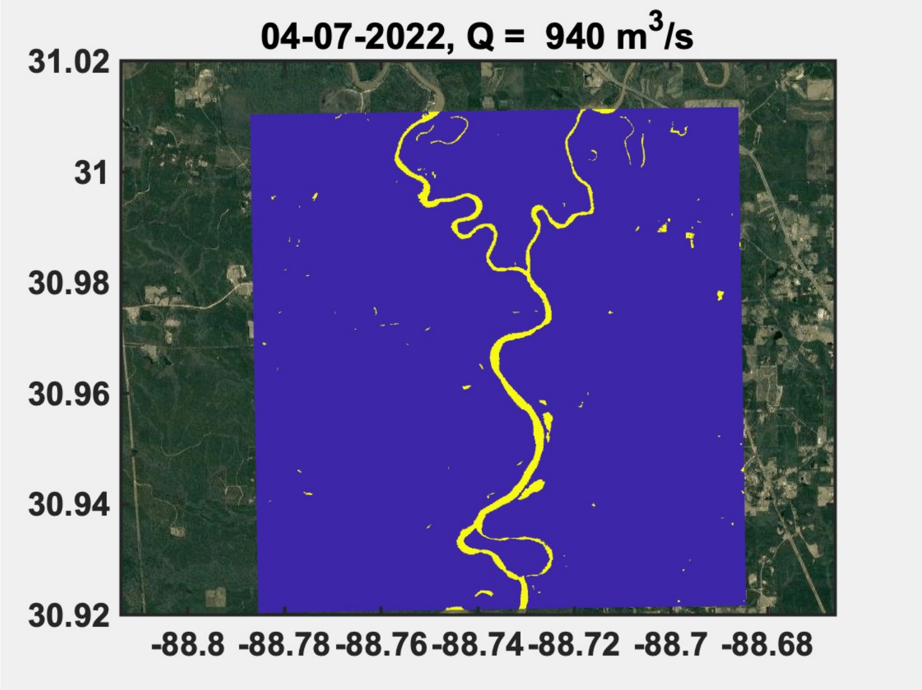
Spectral index equations for the Normalized Difference Water Index (NDWI) and Modified NDWI (MNDWI). ρ represents the spectral reflectance of a band. "Nir" refers to the near-infrared band and "swir1" refers to the short-wave infrared band at wavelength range of 1.55 – 1.75 μm.

Indices	Spectral index equations
Normalized Difference Water Index (NDWI)	$\frac{\rho_{green}-\rho_{nir}}{\rho_{green}+\rho_{nir}}$
Modified NDWI (MNDWI)	$\frac{\rho_{green}-\rho_{swir1}}{\rho_{green}+\rho_{swir1}}$

Example of results

Water masks created with Sentinel-2 data, corresponding to low and high flows on the Pascagoula River

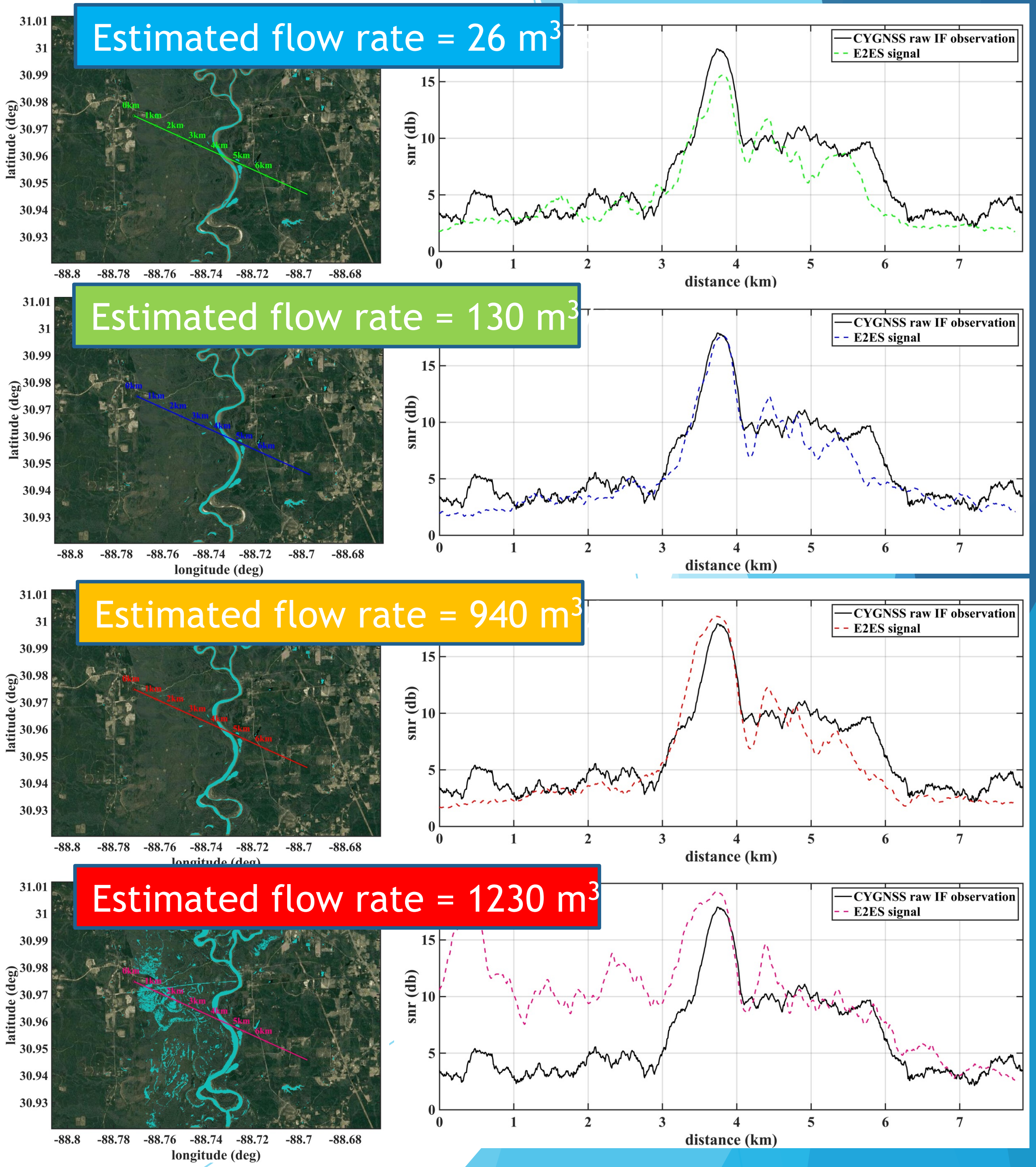




How the results have been used in this project

Example: Brute force minimization

- Raw IF overpass collected 7/11/2022 2200Z.
- Observed flow rate (via USGS streamgage) was **130 m³/s.**
- Forward model is applied over a range of water masks that correspond to increasing flow rates.
- Best agreement between model and obs is achieved using the mask that corresponds to the observed flow rate.



Benefits to society

- Flooding is the most prevalent natural disaster world-wide[1]
- With increase in population and climate change, flooding is an increasing threat
- Improved methods of flood monitoring and detection are of critical importance to mitigating the human impact of flooding
- Our research is directly aligned with the goal of mitigating this risk by providing a novel data source and methodology for monitoring river width and flowrate on a large-scale, up-to-date basis

[1]Yari, A., Ostadtaghizadeh, A., Ardalan, A. *et al.* Risk factors of death from flood: Findings of a systematic review. *J Environ Health Sci Engineer* **18**, 1643–1653 (2020). https://doi-org.sri.idm.oclc.org/10.1007/s40201-020-00511-x