# Novel methods for understanding surface water dynamics in North Carolina and around the world

Tamlin Pavelsky, UNC Department of Geological Sciences
Grant Parkins, UNC IE
Sarah Yelton, UNC IE

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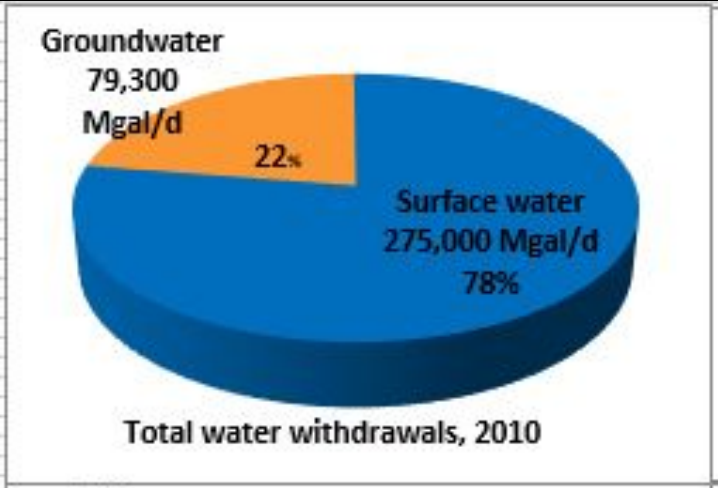
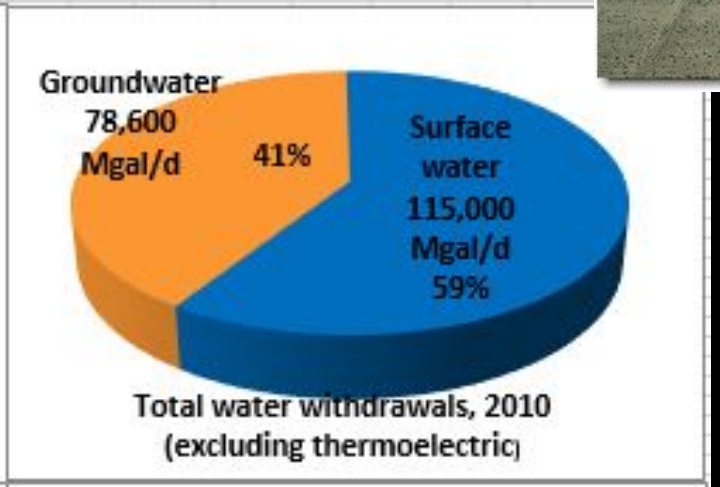
THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

# The Importance of Surface Water Resources

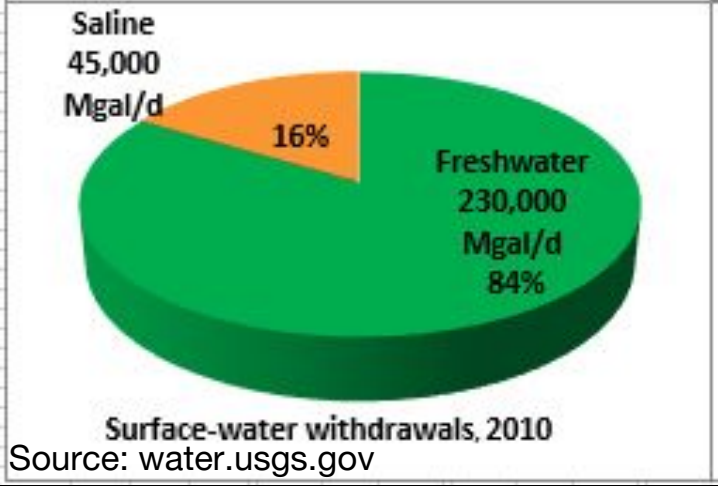
Globally, ~60-80% of water used by humans comes from streams, rivers, and lakes, with large variations among regions.



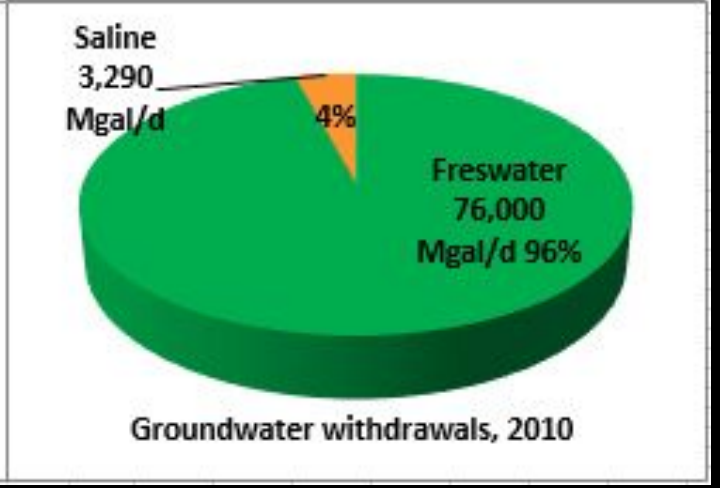
Total water withdrawals, 2010



Total water withdrawals, 2010
(excluding thermoelectric)



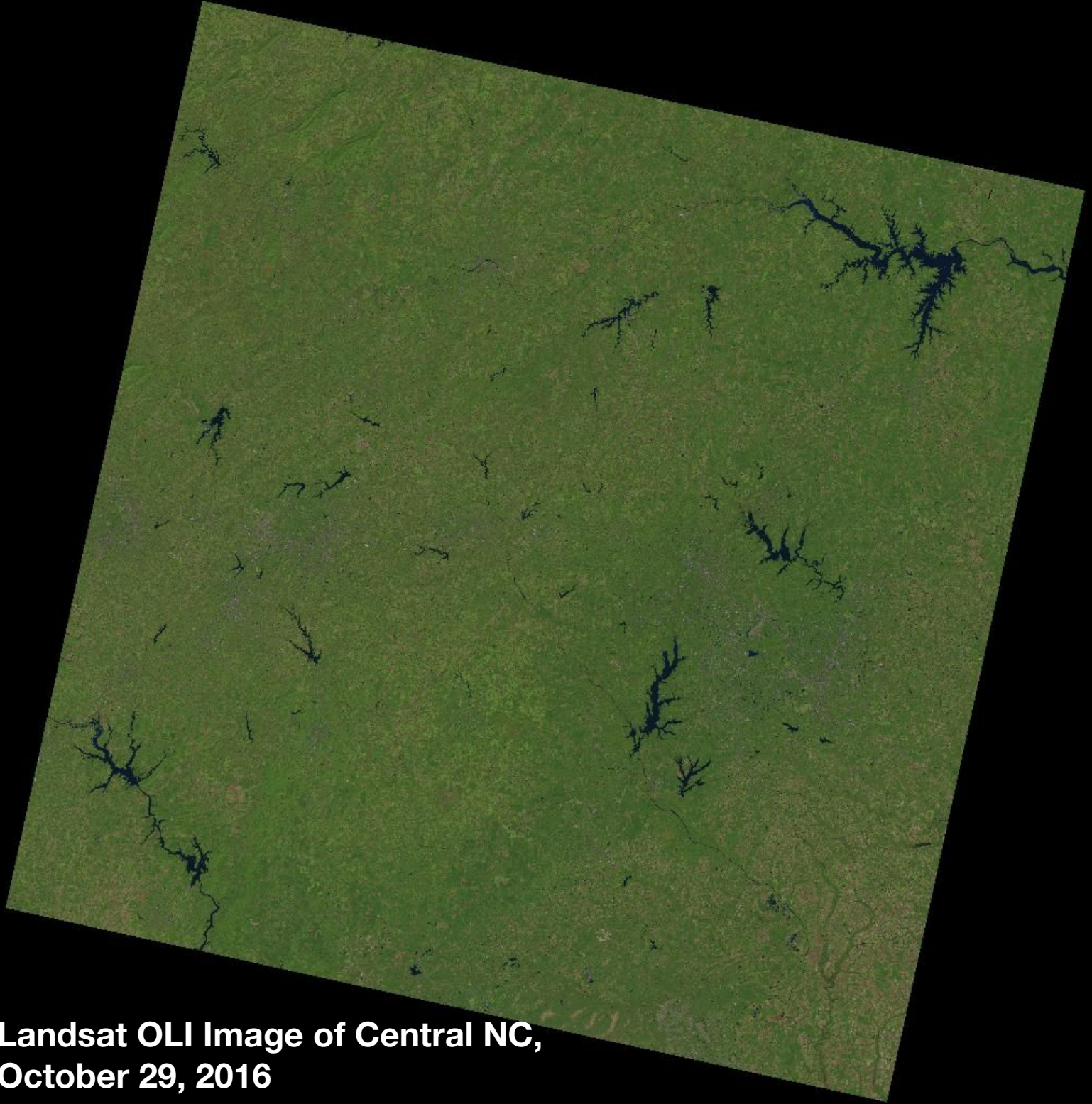
Surface-water withdrawals, 2010



Groundwater withdrawals, 2010

Source: water.usgs.gov

Lakes and rivers are important resources for scientists, too, because they integrate upstream processes.



Landsat OLI Image of Central NC,
October 29, 2016

North Carolina relies on surface water resources for a substantial fraction of its water resources needs.

October 12, 2005

September 19, 2005

# Global Flood Hazard

- Floods are the most deadly natural disasters worldwide.
- Over the period 1990-2009, ~500-600k people died in floods.
- Over the same period, approximately 2.8 billion people were affected by floods (including in NC).

*Landsat Imagery from 2005 of large-scale seasonal flooding in India and Bangladesh (courtesy NASA).*

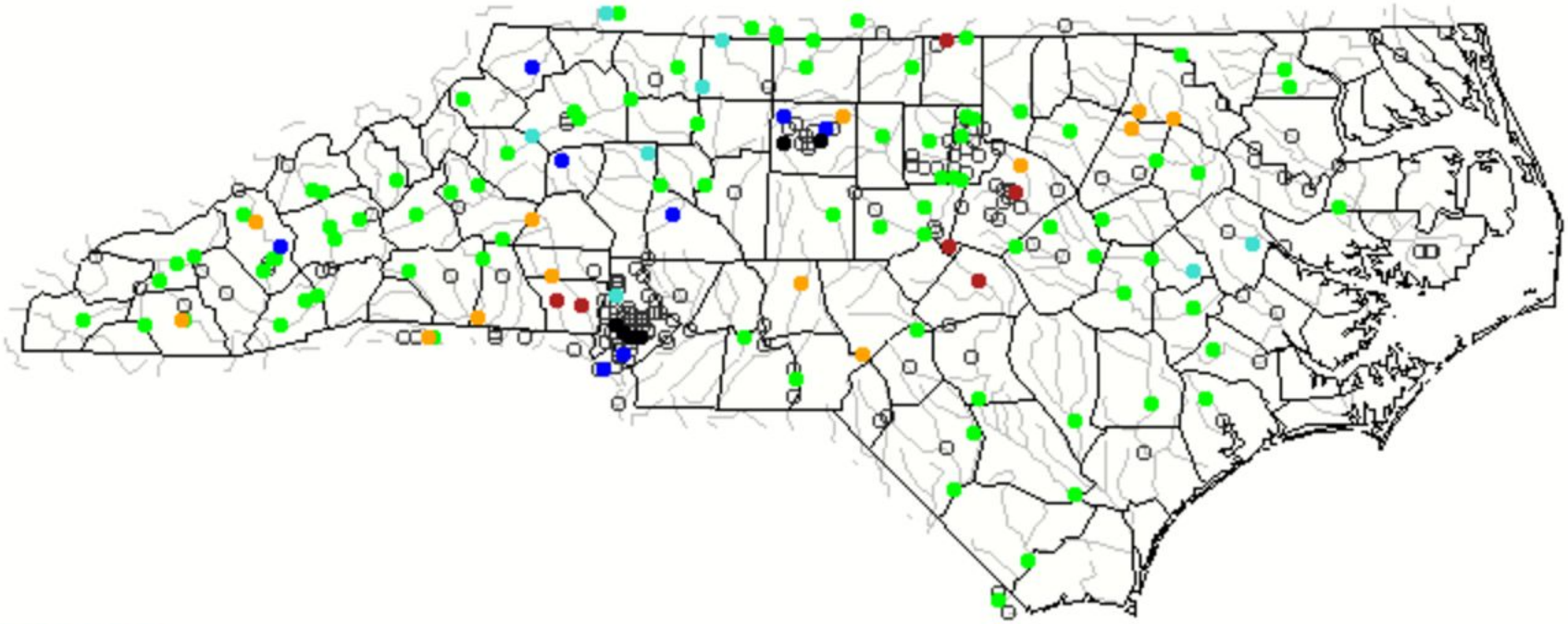
Doocy et al, *PLOS*, 2013

# Flood Hazard in North Carolina


Lumberton, NC after Hurricane Matthew

Source: Wall street Journal

**North Carolina is at considerable risk of flooding from hurricanes like Matthew, which caused ~$1.5B in property damage in the state.**



USGS

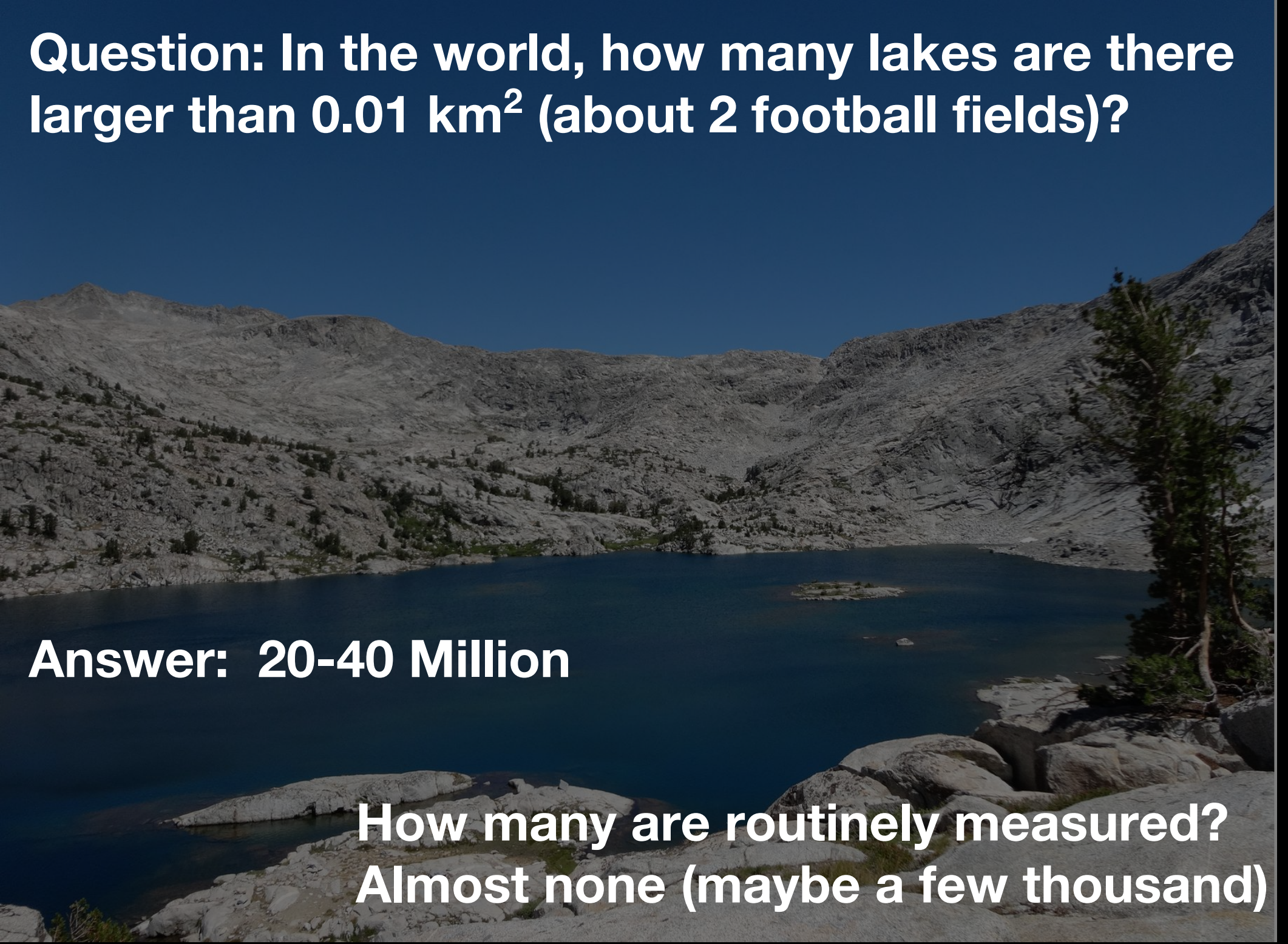
Search USGS streamgage

**Choose a data retrieval option and select a location on the map**

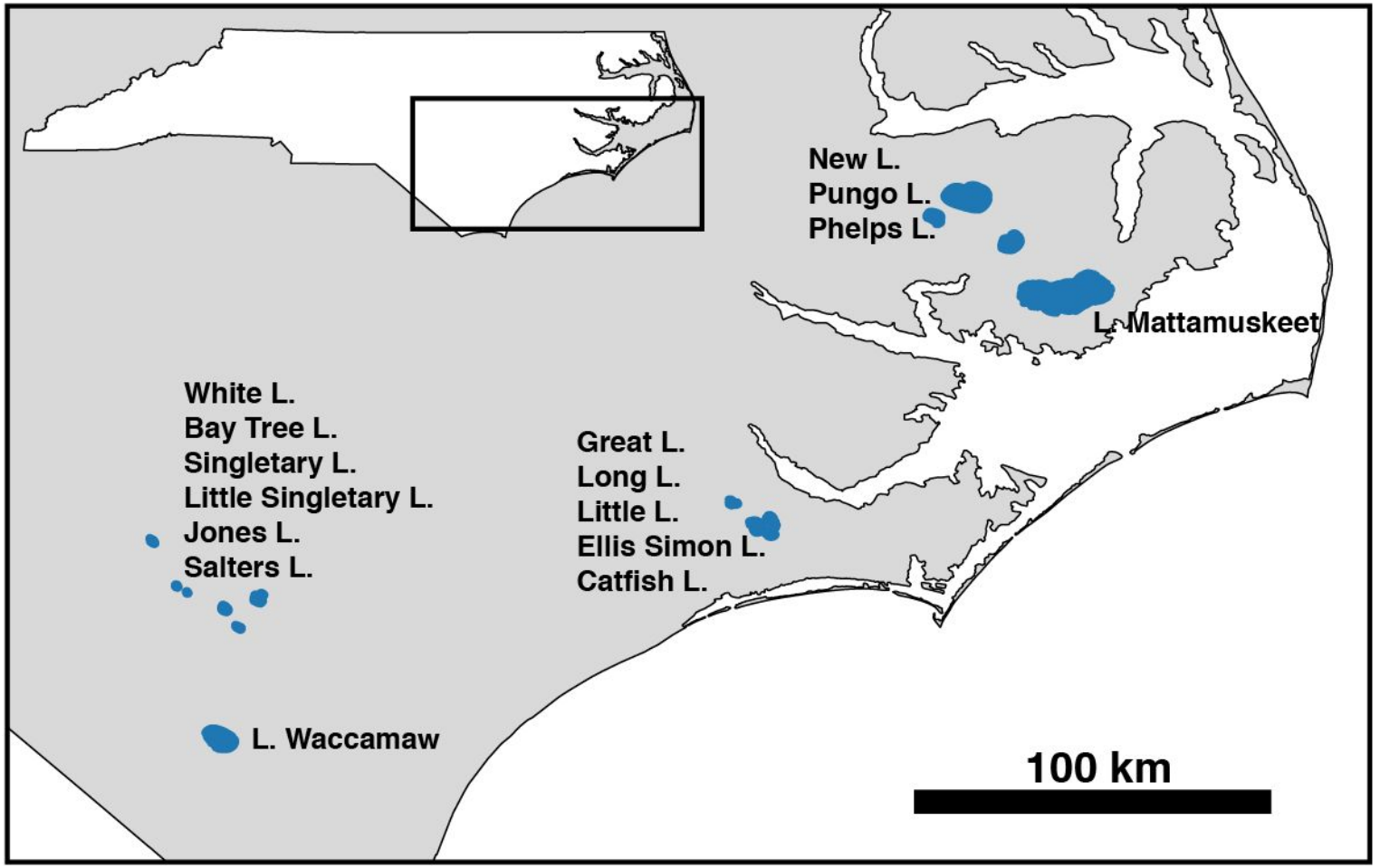
○ List of all stations ◉ Single station ○ Nearest stations ○ Peak flow

| Explanation - Percentile classes | | | | | | | |
|---|---|---|---|---|---|---|---|
| ● | ● | ● | ● | ● | ● | ● | ○ |
| Low | <10 | 10-24 | 25-75 | 76-90 | >90 | High | Not-ranked |
| | Much below normal | Below normal | Normal | Above normal | Much above normal | | |

# What about lakes?

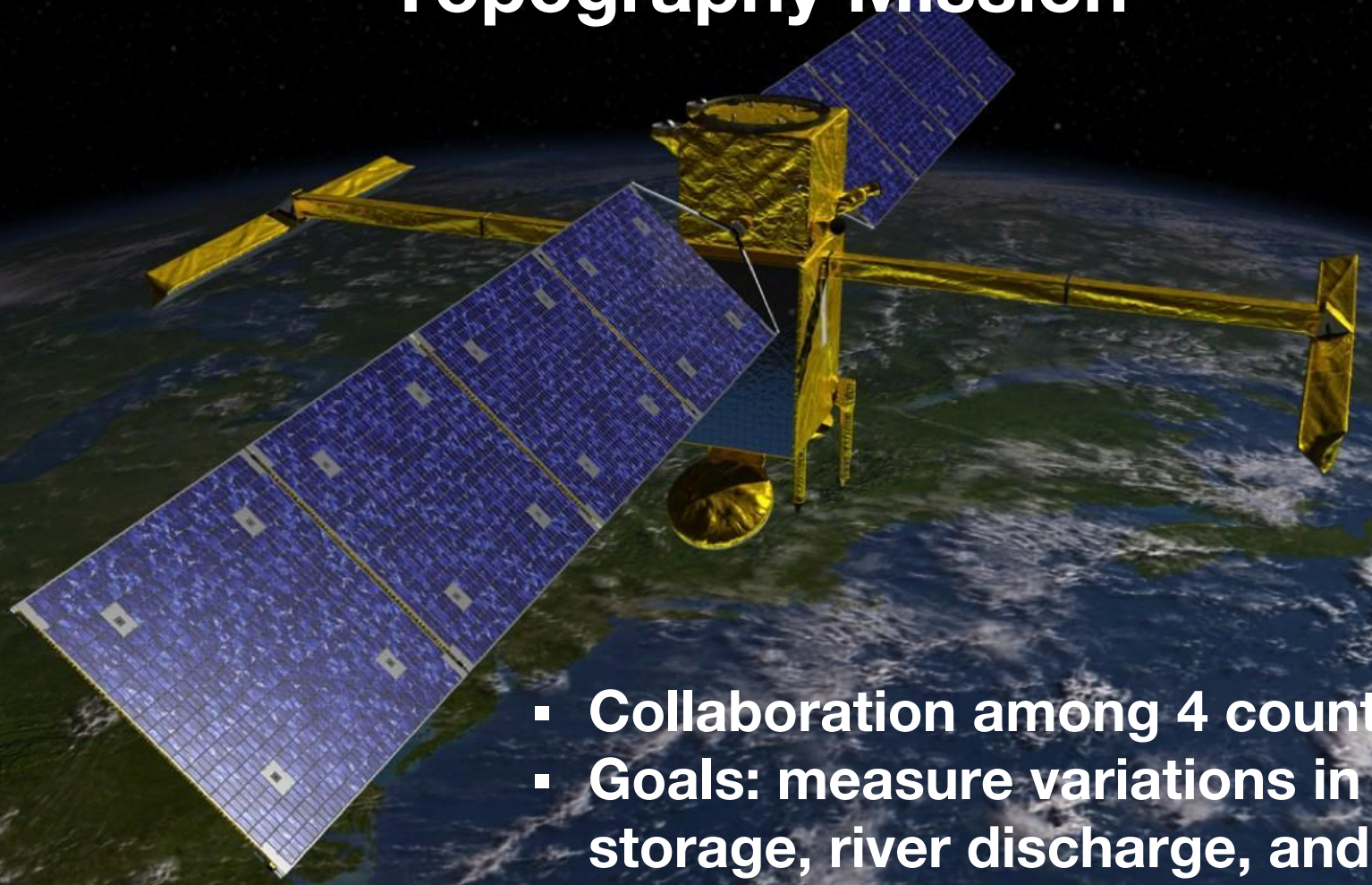

Question: In the world, how many lakes are there larger than 0.01 km$^2$ (about 2 football fields)?
Answer: 20-40 Million
How many are routinely measured?
Almost none (maybe a few thousand)

# Natural Lakes in North Carolina




**Only Lake Mattamuskeet has a long-term, high quality gauge**

# SWOT:
# The Surface Water and Ocean Topography Mission



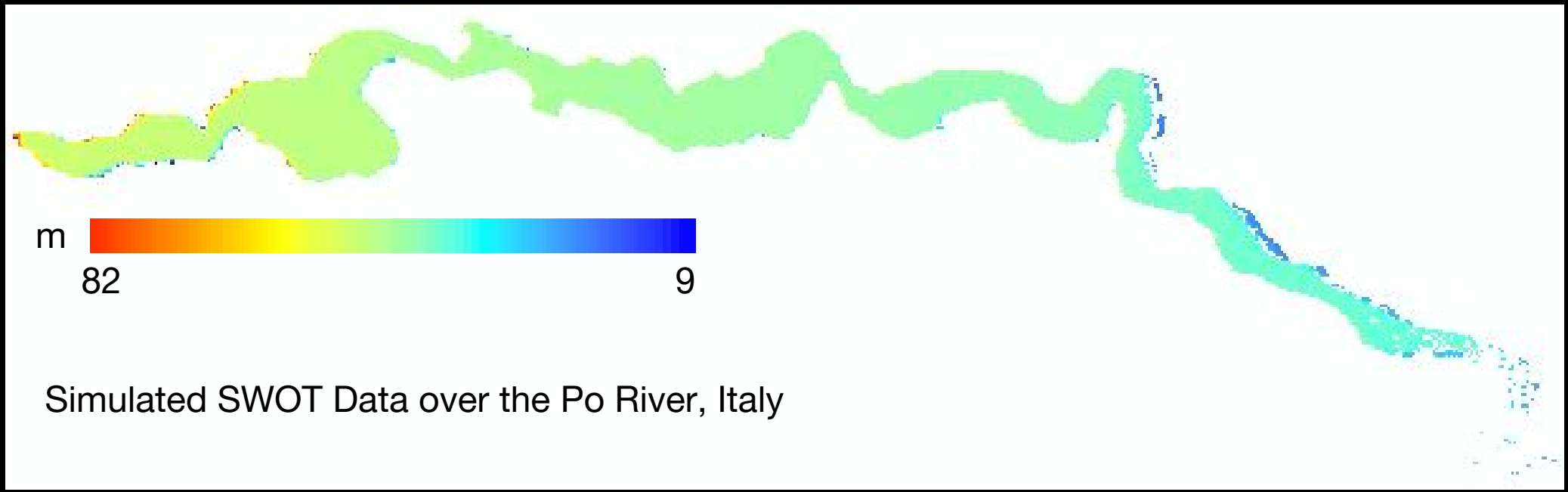
- Collaboration among 4 countries
- Goals: measure variations in lake storage, river discharge, and ocean circulation globally
- Budget: ~$1.1B
- Launch: 2021

# SWOT Mission Objectives

- Measure river water surface height to +/- 10 cm for rivers wider than 100m
- Measure river slope to better than +/-1.7 cm/km for river wider than 100 m
- Measure river inundation extent to +/-15% for rivers wider than 100 m

- Measure lake area to +/-15% (25%) for lakes larger than 1 $km^2$ (250m x 250 m)
- Measure lake height to +/-10 cm (25 cm) for lakes larger than 1 $km^2$ (250m x 250 m)

- Estimate variations in lake water storage
- Estimate variations in river discharge




Simulated SWOT Data over the Po River, Italy

Domenghetti et al., *in review*, WRR

# How Do We Validate SWOT Globally?

Validation of changes in **lake water storage** requires knowledge of:

Lake Water Height:

- Professional measurements in a few lakes
- Citizen scientist measurements in many more

Lake Area:

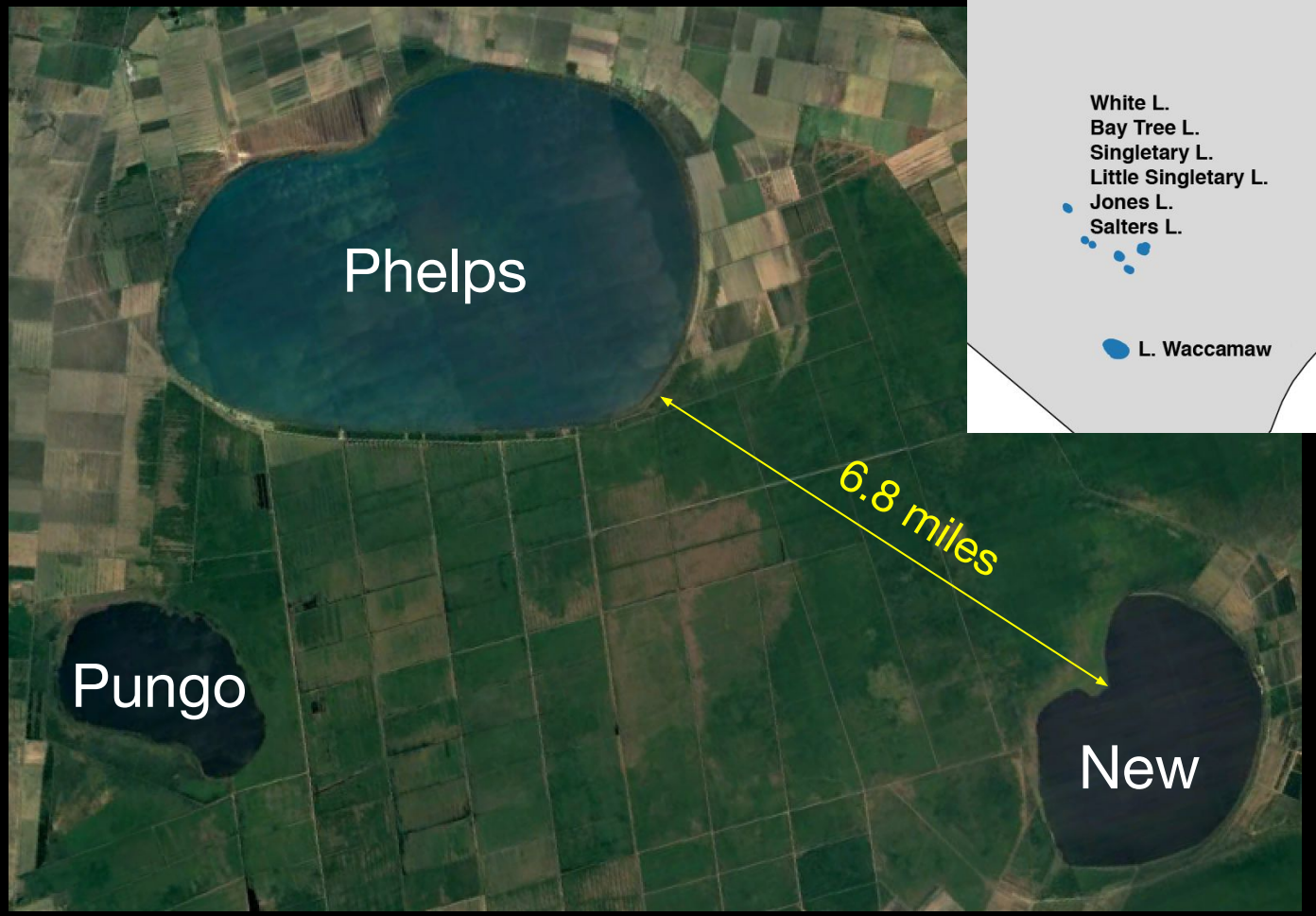
- Walk around the lake with a GPS (not very practical)
- Compare against measurements from other satellites and aerial photographs

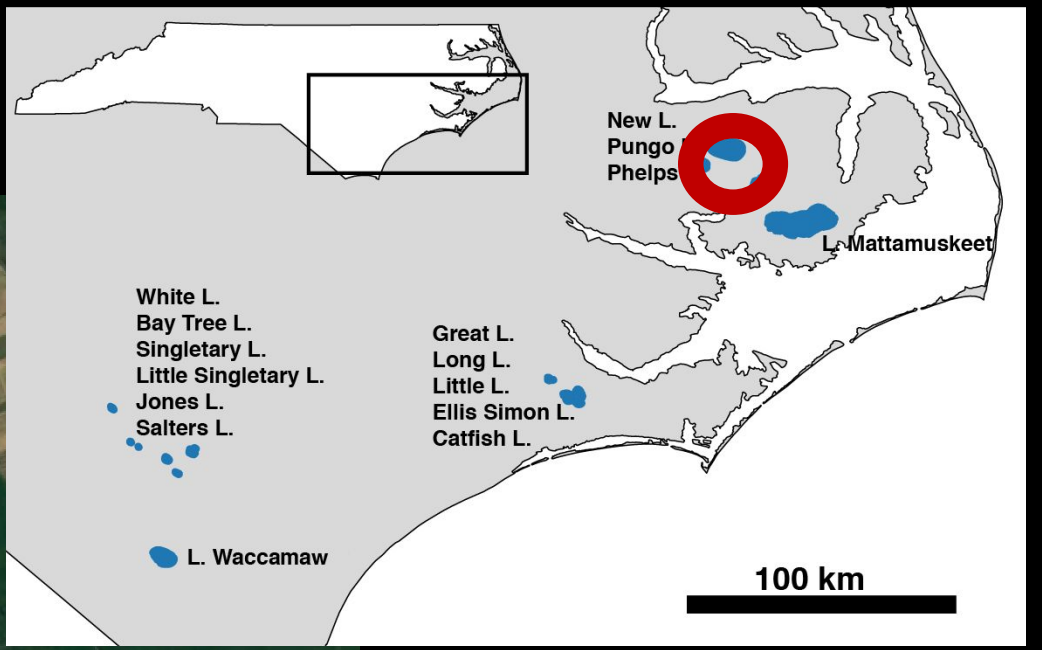
**New NASA grant to UNC:**
*Tracking Water Storage in Lakes: Citizens and Satellites*
Principal Investigator: T. Pavelsky
1-year Prototype Phase focused on Eastern North Carolina

# Measuring Lake Area from Space

Using well-established techniques and NASA satellite imagery, we can measure variations in lake area over time. We're starting with the lakes of Eastern North Carolina.

New, Phelps, and Pungo Lakes



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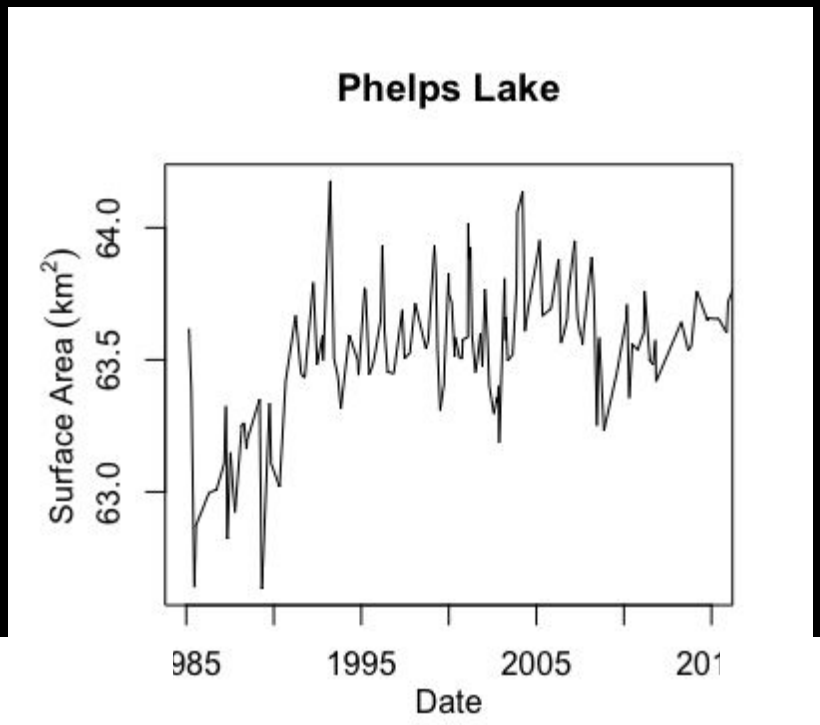
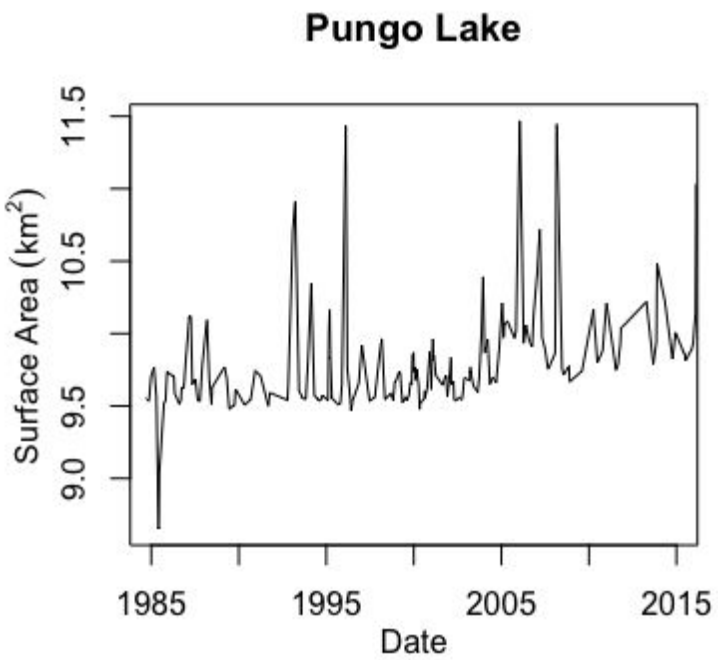
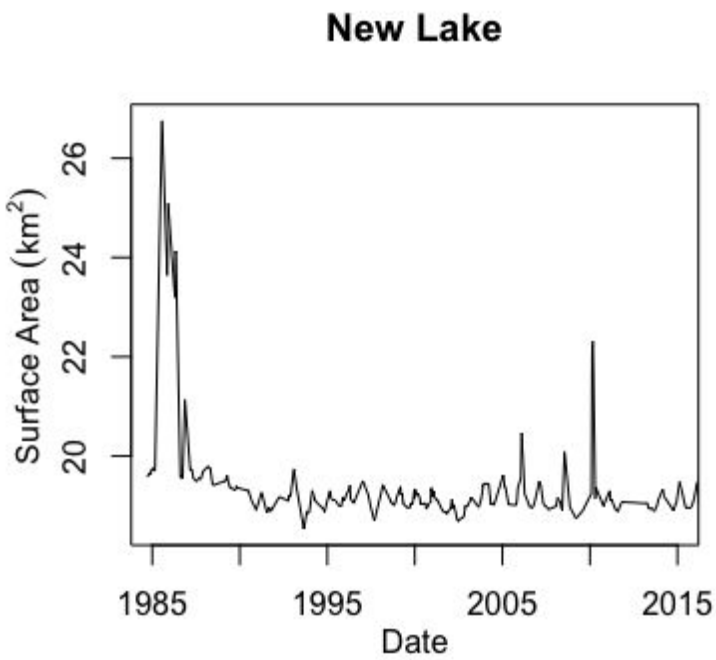
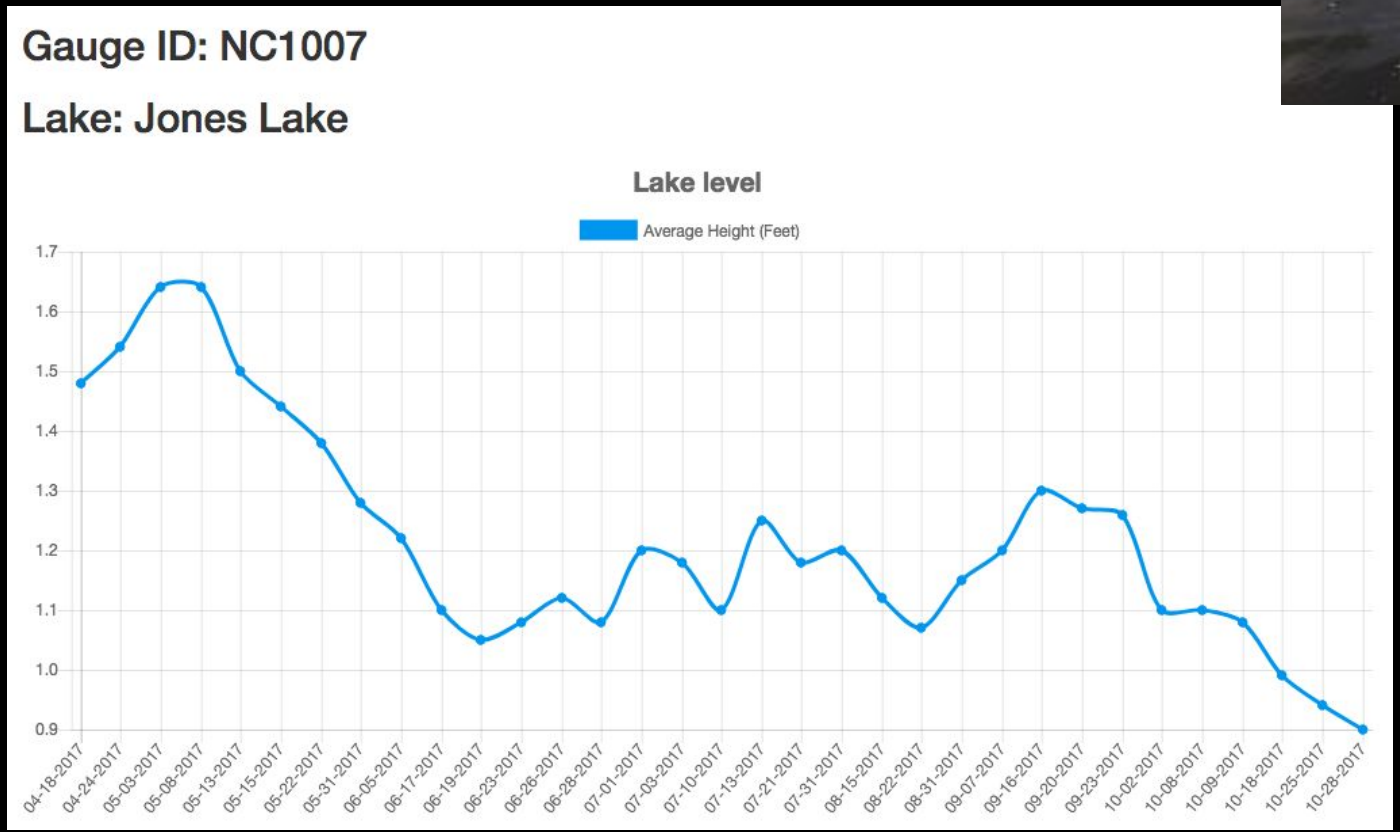


# Working with Citizens to Measure Lake Stage

We are currently working with >50 citizen scientists to monitor water levels in 11 lakes in Eastern North Carolina. Overall, they have collected >400 total measurements since April 2017.




From lakelevel.org, our project website

Measurements are submitted to a central database via text, website, or a scanned and e-mailed data sheet. We hope to expand beyond NC next year (funding permitting).

# Bringing it all together: citizens plus satellites

As an example, we combined citizen measurements of lake water level and Landsat 8 measurements of inundation extent on two dates in summer 2017:

| Jones Lake | | | |
|---|---|---|---|
| | **July 21, 2017** | **August 22, 2017** | **Change** |
| **Lake Height** | 1.18 Feet | 1.07 Feet | **– 0.11 Feet** |
| **Surface Area** | 209.6 Acres | 206.5 Acres | **– 3.1 Acres** |

Our results suggest that Jones Lake contained ~7.5M gallons less water on August 22$^{nd}$ than it did on July 21$^{st}$.

# Summary

- Rivers and, even more, lakes and wetlands in North Carolina and around the world are not adequately monitored by existing gauge networks.
- The SWOT satellite mission will provide unprecedented measurements of lake, wetland, and ocean height variations and river discharge.
- Combining citizen science with satellite remote sensing is a fruitful path towards inexpensive monitoring of surface water in North Carolina and across the globe.

**For more information, please visit:**
**http://lakelevel.org**
**http://www.unc.edu/~pavelsky**