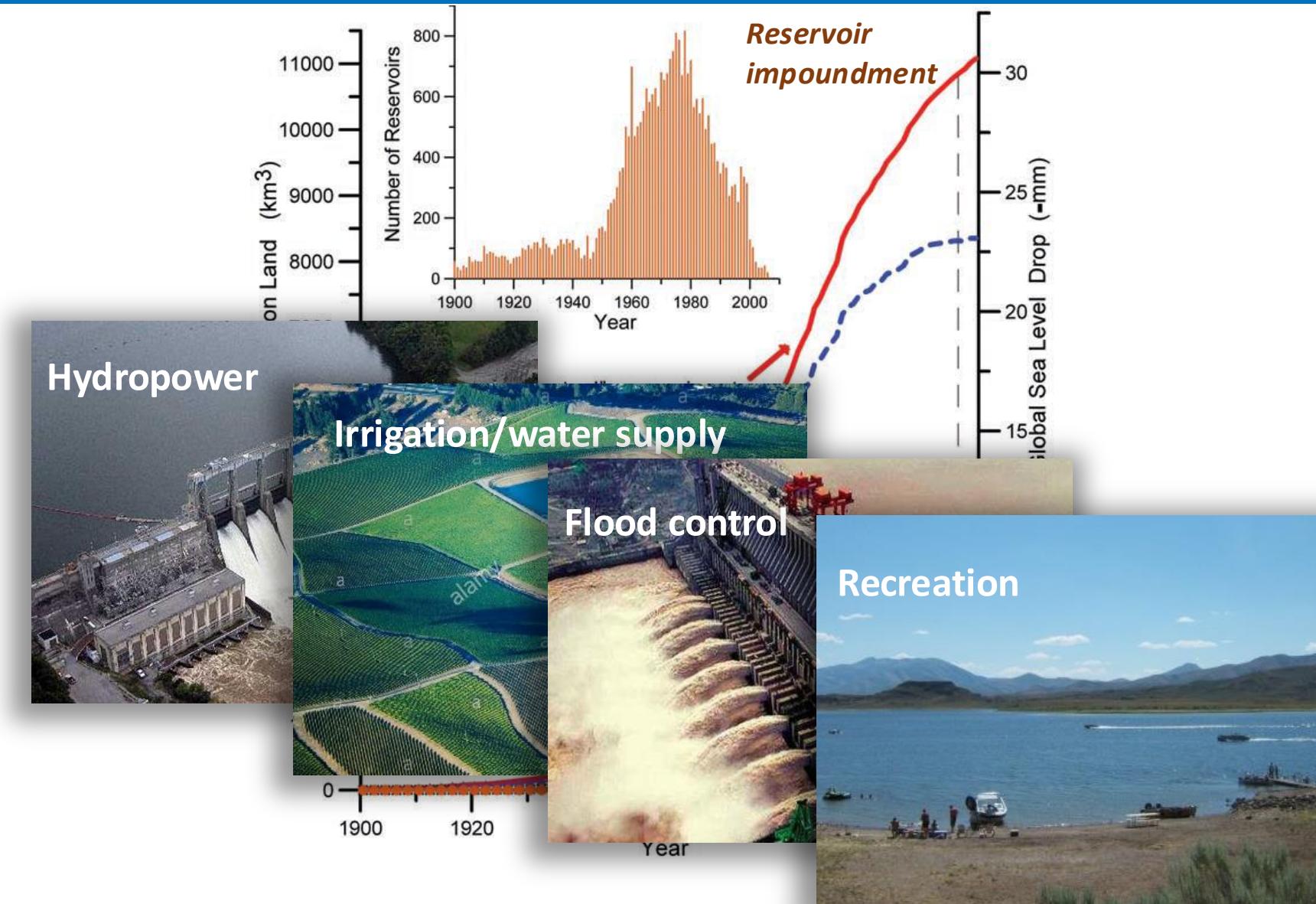


Monitoring reservoirs using multi-satellite observations

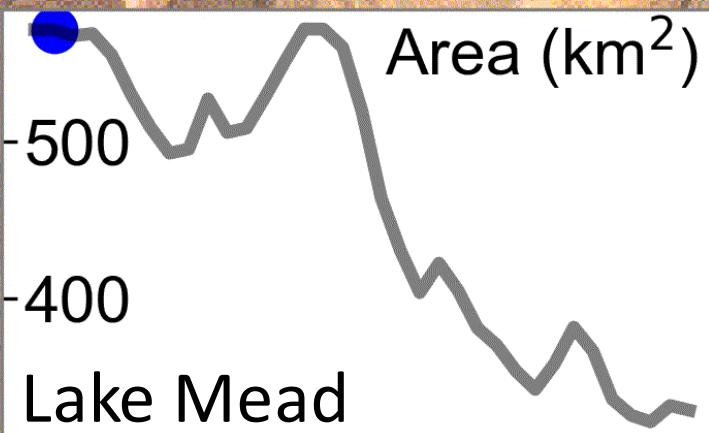
Huilin Gao
Dept. Civil & Environmental Engineering
Texas A&M University
5/18/2025

Reservoir Water Impoundment and Functions



1985

Las Vegas



Lake Mead

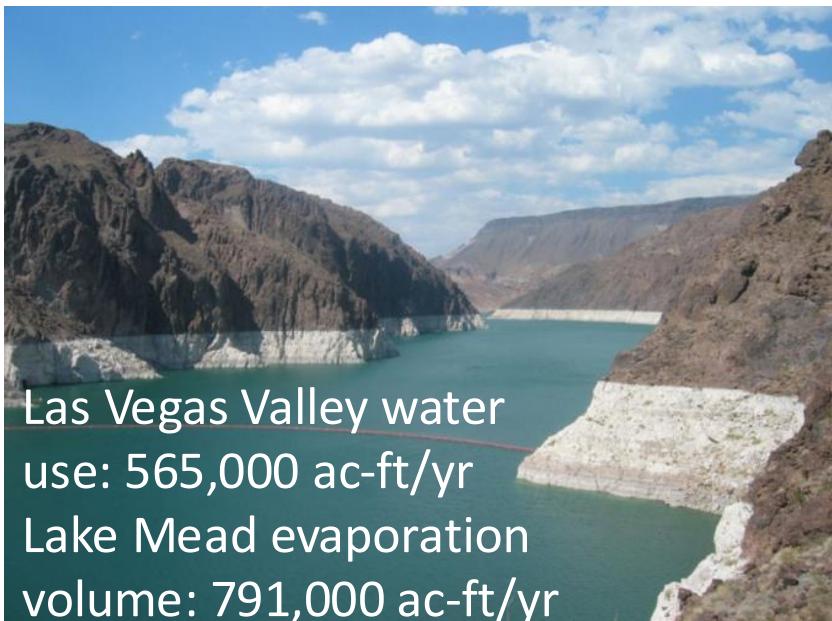
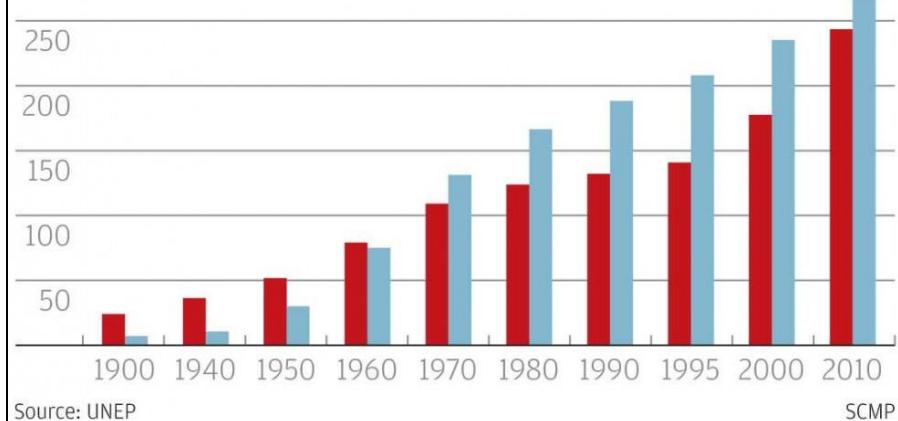
Lake Evaporation

A global phenomenon

Industrial and domestic consumption

Evaporation from reservoirs

300 (km³ per year)



Las Vegas Valley water

use: 565,000 ac-ft/yr

Lake Mead evaporation

volume: 791,000 ac-ft/yr

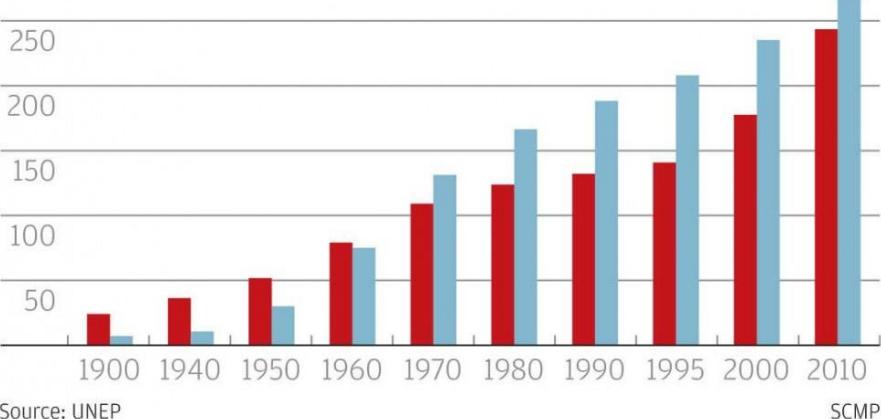
Lake Evaporation

A global phenomenon

Industrial and domestic consumption

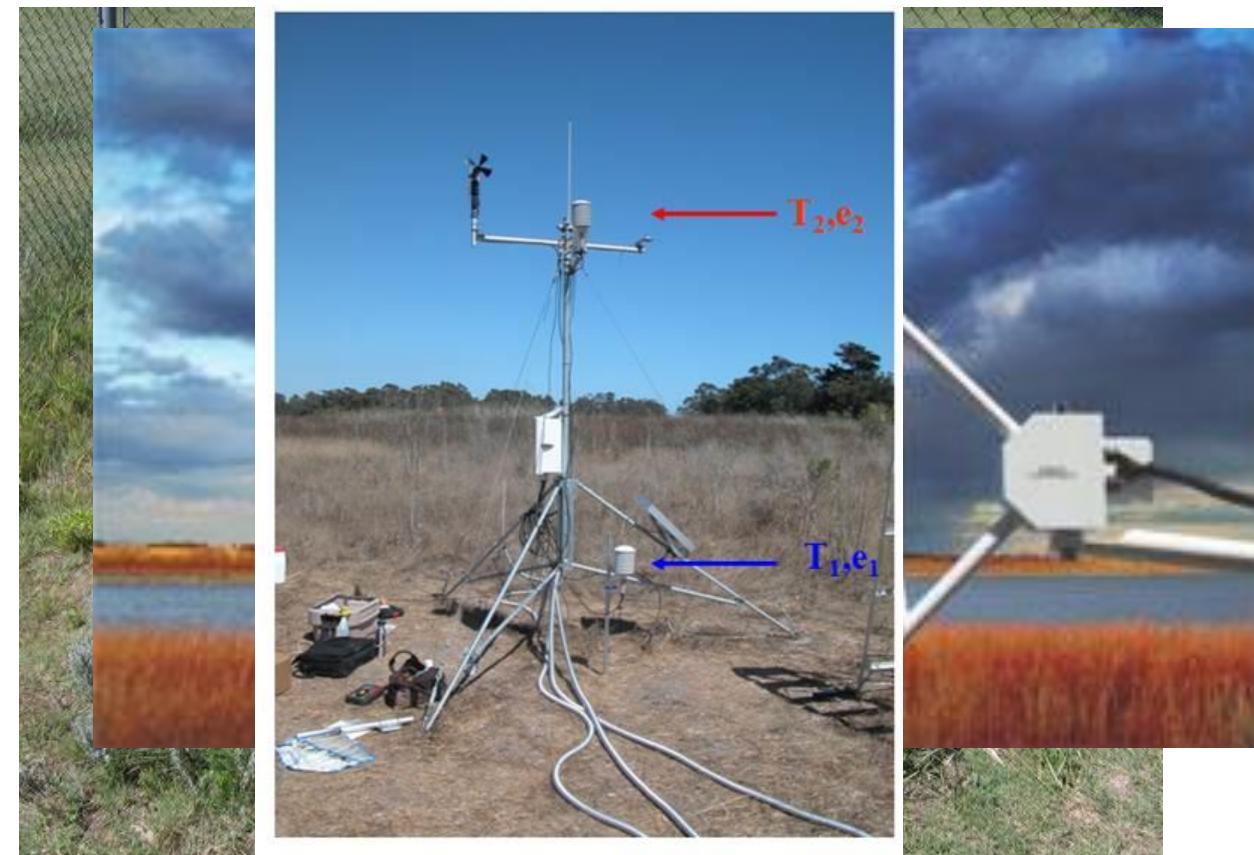
Evaporation from reservoirs

300 (km³ per year)



Limited in-situ observations

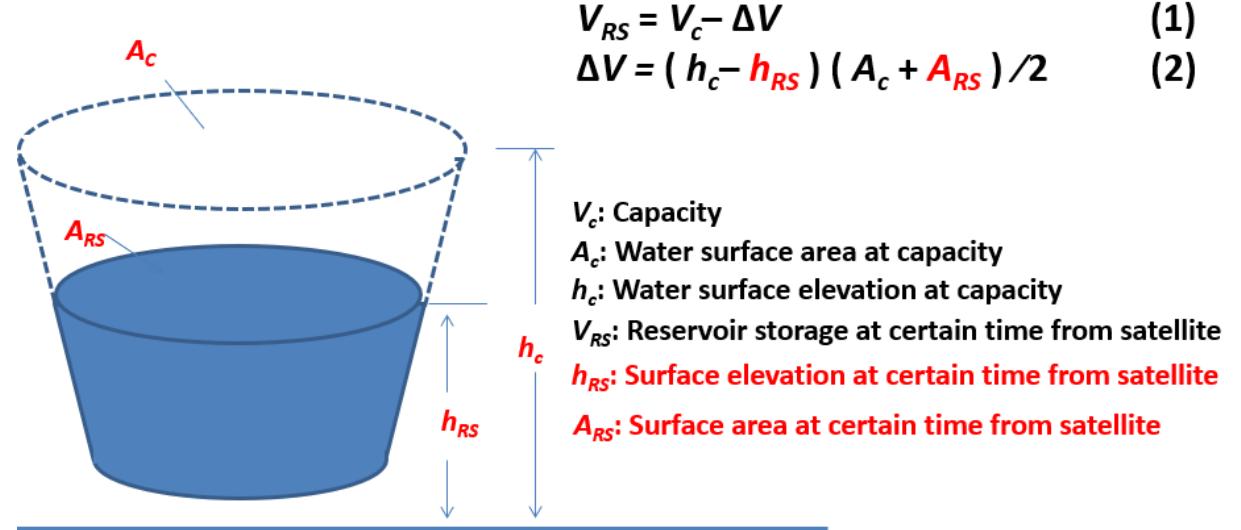
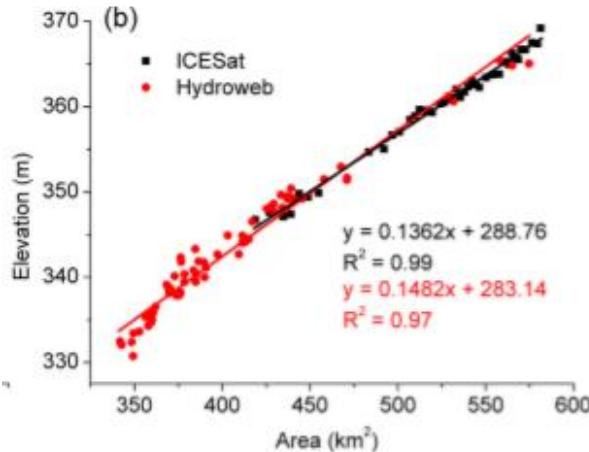
- Class-A pan evaporation
 - Large uncertainty
- Eddy covariance
 - Expensive and data is difficult to process
- Bowen ratio energy balance
 - $LE = R_n - H + \Delta U + F_{in} - F_{out} - G$



Remote Sensing of Reservoir Elevation, Area, and Storage

Sensors for elevations

- Radar altimeters (e.g., T/P, Jason 3)
- Lidar altimeters (e.g., ICESat-2)
-



Sensors for area estimations

- Landsat
- MODIS/VIIRS
- AVHRR
- Sentinel-2
- Sentinel-1 SAR
-

With the Area-Elevation (A-E) relationship and parameters at capacity, the storage can be estimated from either A or E values

Remote Sensing of Reservoir Evaporation and Evaporation Volume

Penman Equation

$$E = \frac{s(R_n - \Delta U) + \gamma f(u_2)(e_s - e_a)}{\lambda_v(s + \gamma)}$$

Heat storage effect

Wind function

Zhao and Gao, 2019

s : slope of the saturation vapor pressure curve ($\text{kPa} \cdot ^\circ\text{C}^{-1}$)

R_n : net radiation ($\text{MJ} \cdot \text{m}^{-2} \cdot \text{d}^{-1}$)

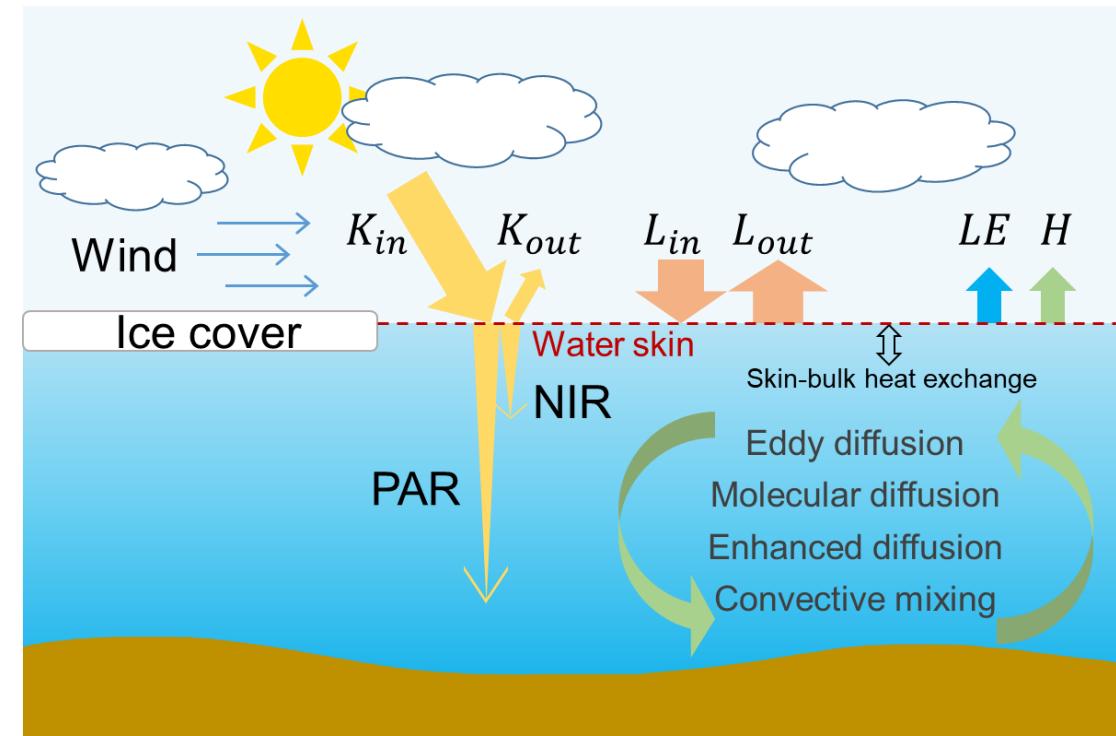
γ : psychrometric constant ($\text{kPa} \cdot ^\circ\text{C}^{-1}$)

$f(u_2)$: wind function ($\text{s} \cdot \text{m}^{-1}$)

δ_e : vapor pressure deficit (kPa)

λ_v : latent heat of vaporization ($\text{MJ} \cdot \text{kg}^{-1}$)

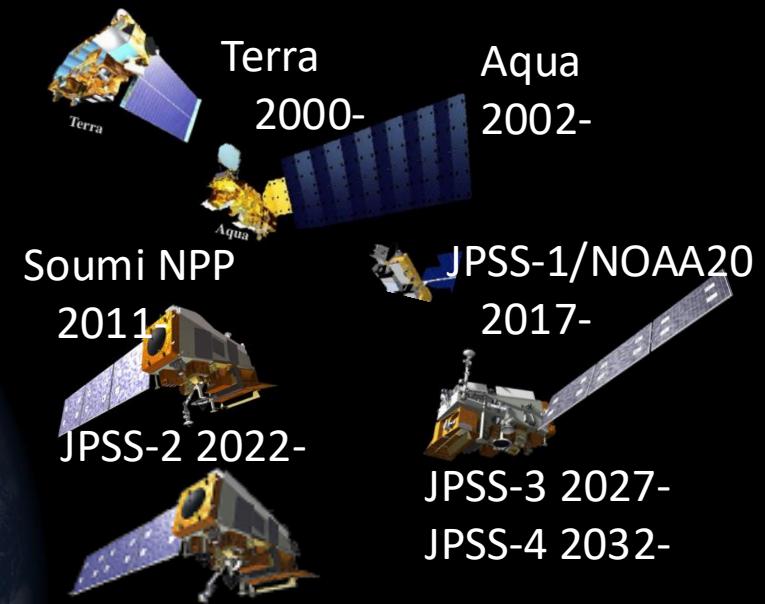
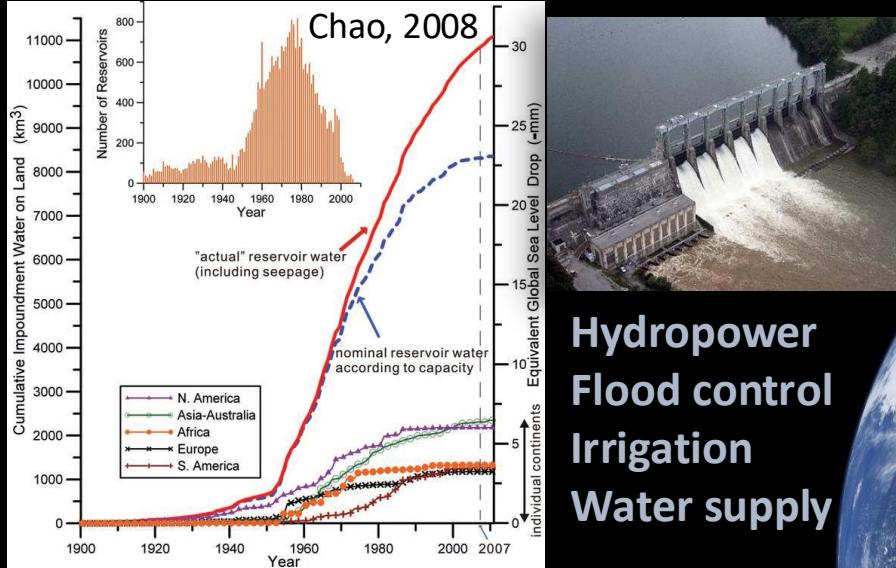
*Evaporation volume = evaporation rate * A*



Zhao et al., 2020

MODIS/VIIRS Global Water Reservoir (GWR) Product

- Everything Everywhere All at Once



MODIS images of Urmia Lake

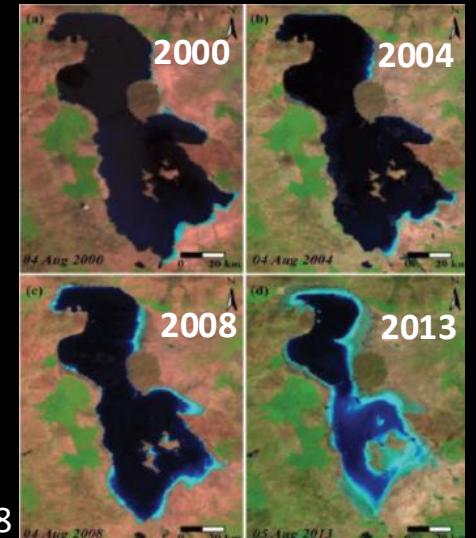
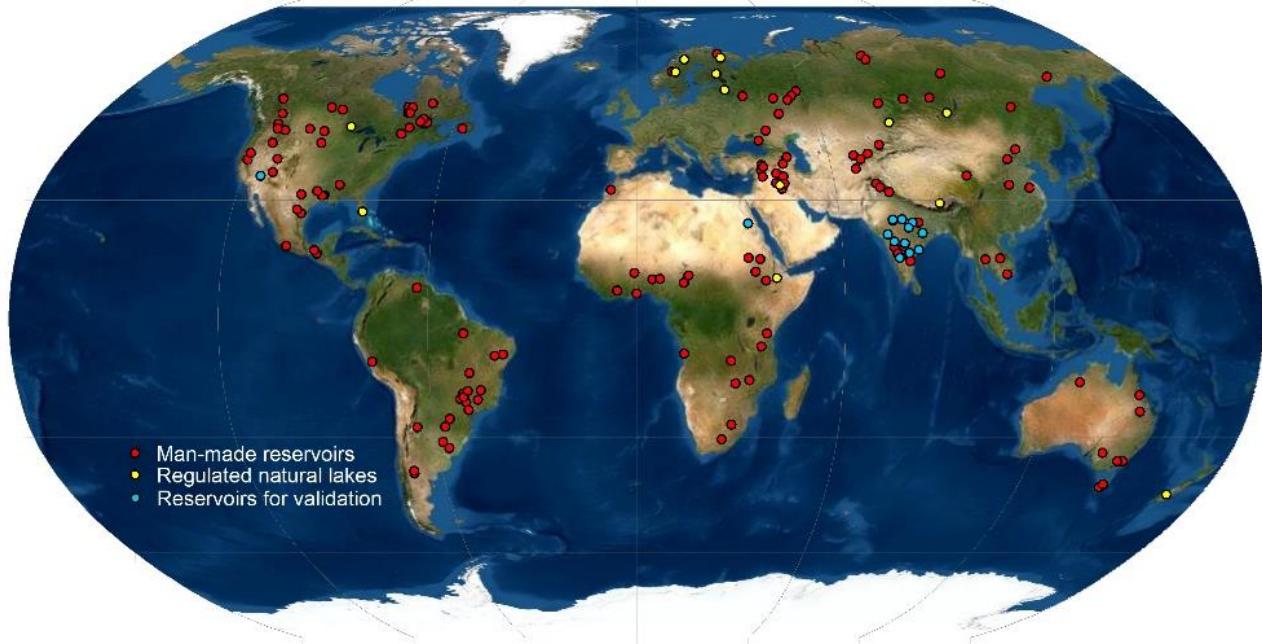


Figure from
Mohebzadeh, 2018

MODIS/VIIRS Global Reservoir Products



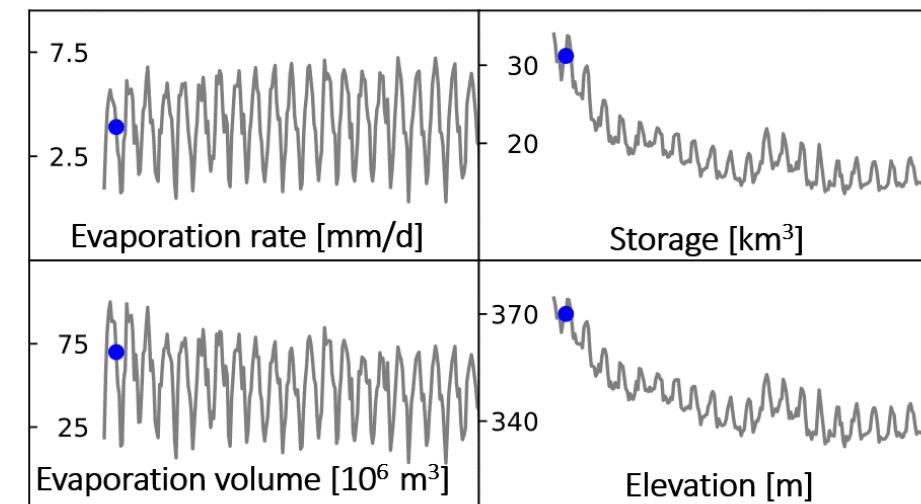
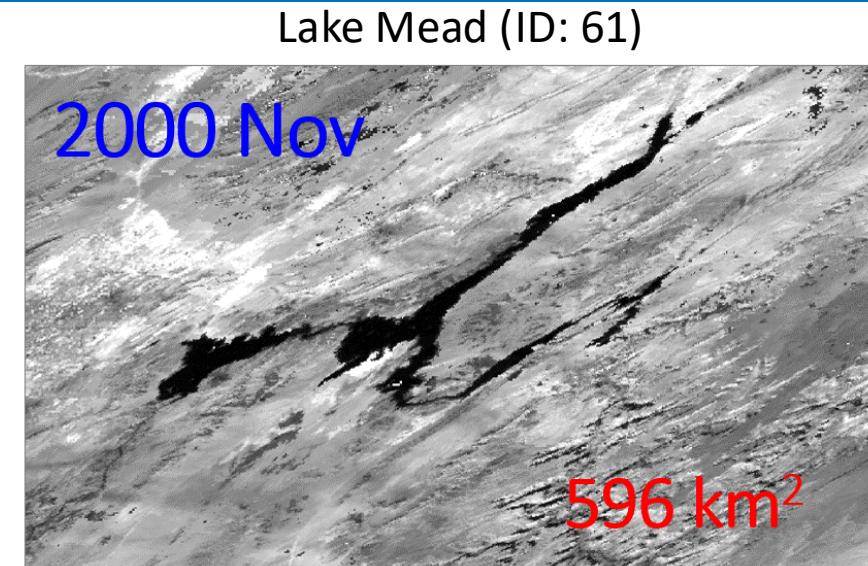
Locations of the 164 reservoirs (46% global capacity)

Key inputs:

8-day reflectance, Monthly LST

Temporal Resolution	Variables
8-day	Area, elevation, storage
Monthly	Area, elevation, storage, evaporation rate and volume

Product name	Period
MxD28 (C6.1)	2000-present
VNP28 (C2)	2012-
VJ128 ² (C2)	2018-2023



MOD28C2 v061



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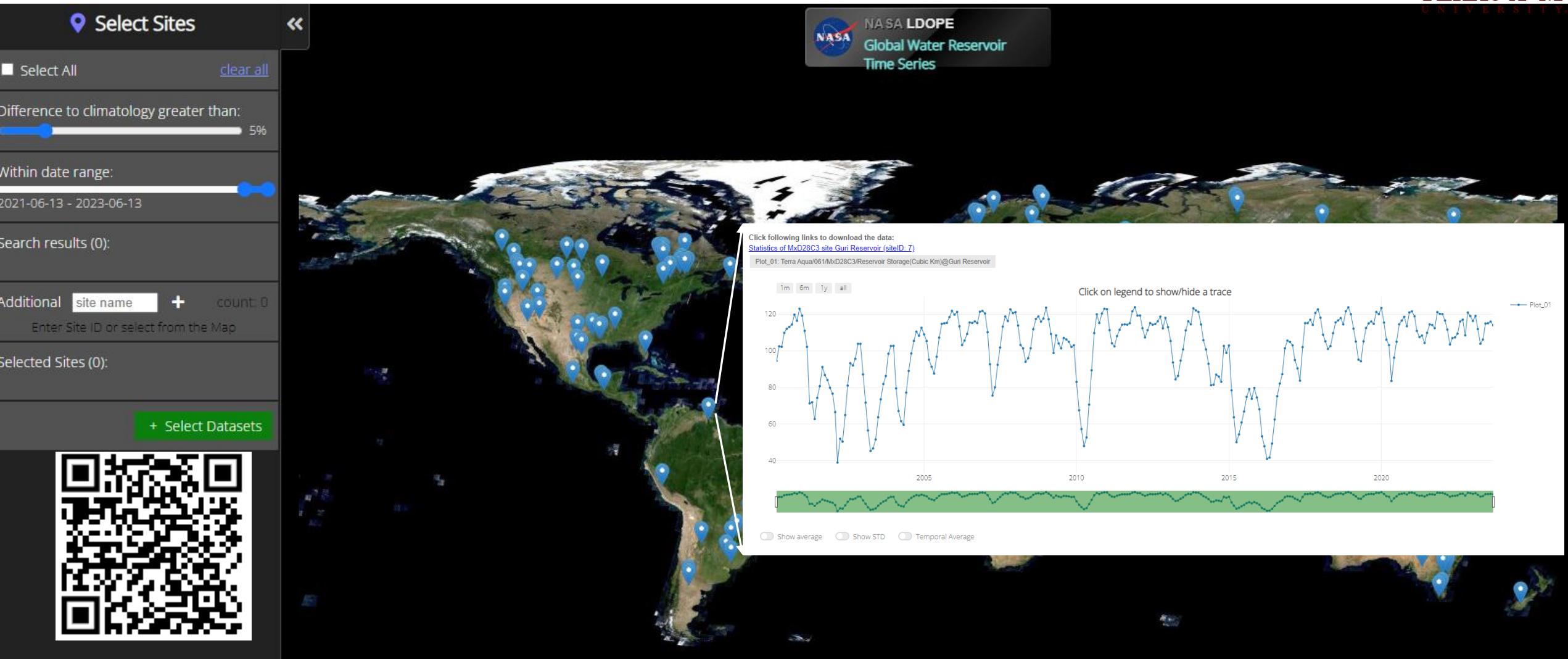


Description

The Terra Moderate Resolution Imaging Spectroradiometer (MODIS) Water Reservoir 8-Day Level 3 (L3) Global (MOD28C2) Version 6.1 product provides current data for 151 man-made reservoirs and 13 regulated natural lakes for a total of 164 reservoirs.

The MOD28C2 Version 6.1 data product provides an 8-day time series of surface area, elevation, and water storage. Datasets are combined with pre-established [Area-Elevation \(A-E\) curves](#) and image classifications of near-infrared (NIR) reflectance from the surface reflectance product acquired by the Terra satellite ([MOD09Q1](#)).

The MOD28C2 data product contains a single layer with information about the reservoir identifier, dam location (longitude and latitude), reservoir area, elevation, and storage capacity.



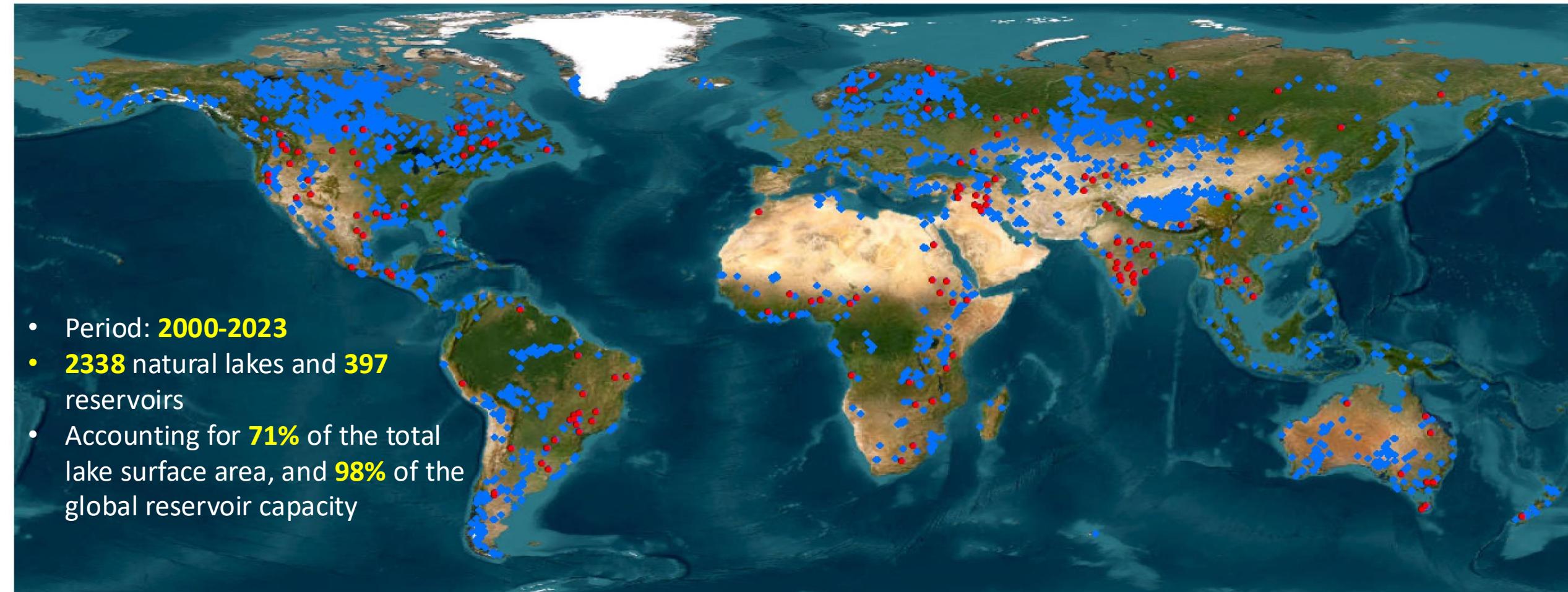


Extended MODIS/VIIRS lake/reservoir dataset

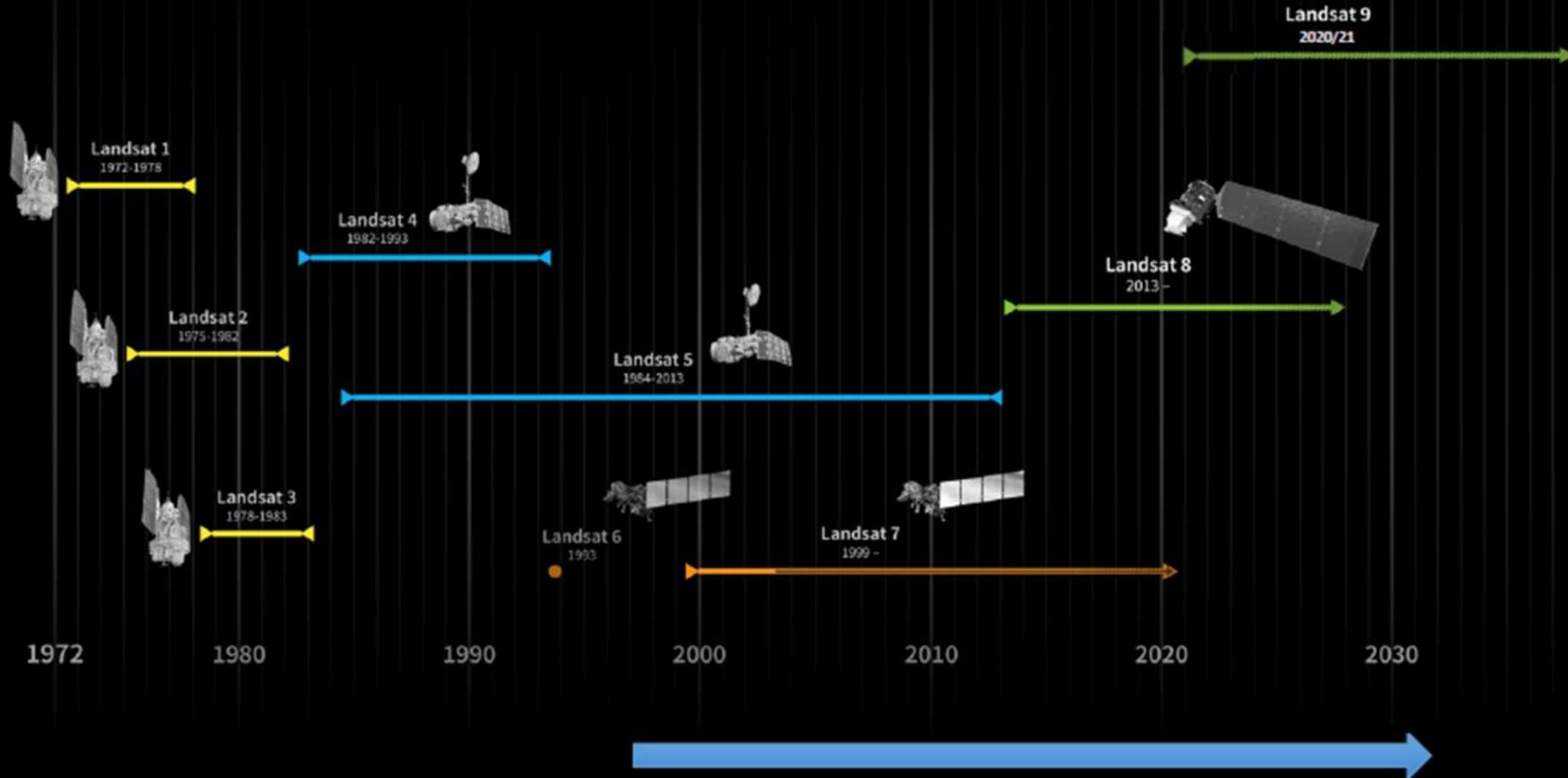
(In development)



TEXAS A&M
UNIVERSITY.



BUILDING ON THE LANDSAT LEGACY



NASA-USGS Interagency Partnership

- NASA: Space Segment and Launch
- USGS: Operations & Data Processing/Distribution

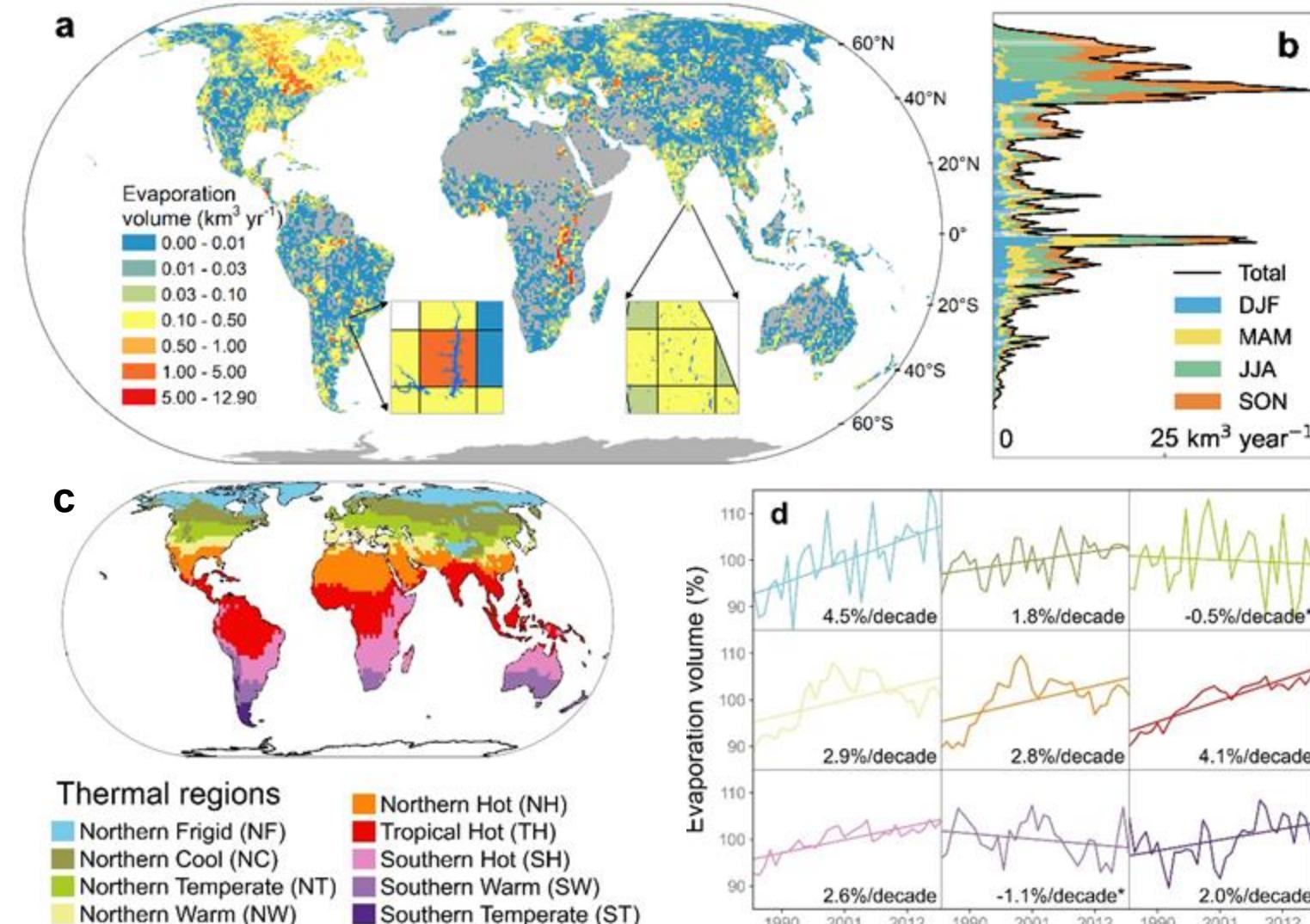
Global Lake Evaporation Dataset

Evaporative water loss
of 1.42 million global
lakes (monthly, 1985-
2018)

Dataset includes:

- evaporation rate
- surface area
- evaporation volume

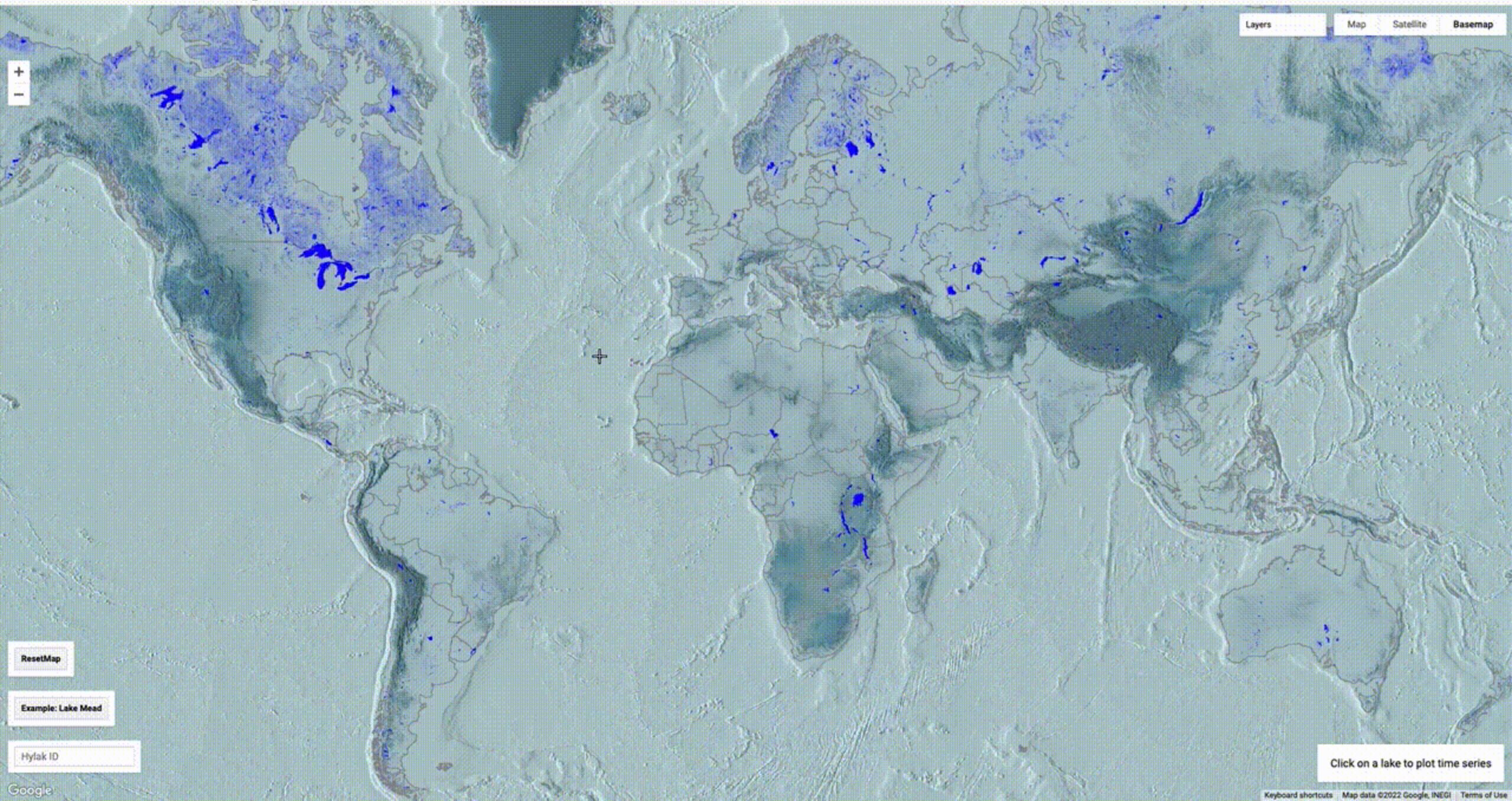
*Reservoir
evaporative losses
increase faster than
natural lakes!*

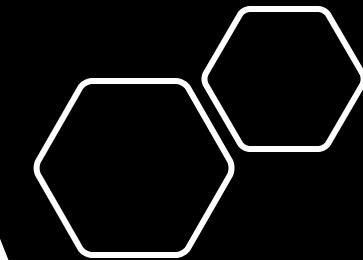
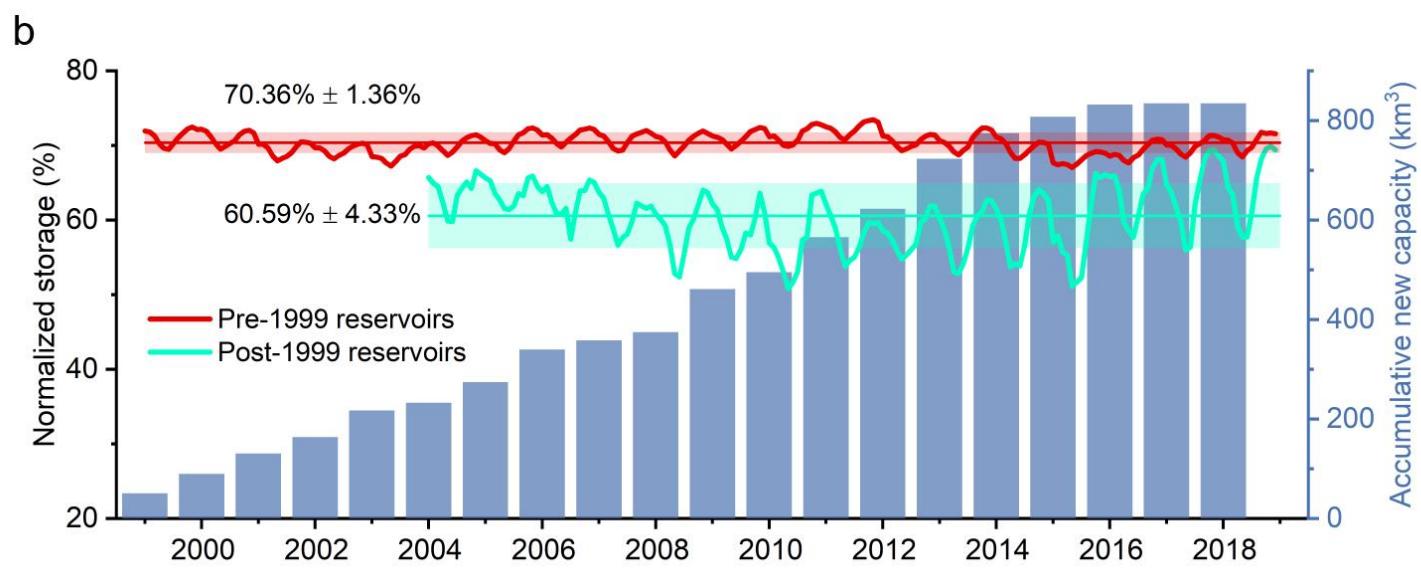
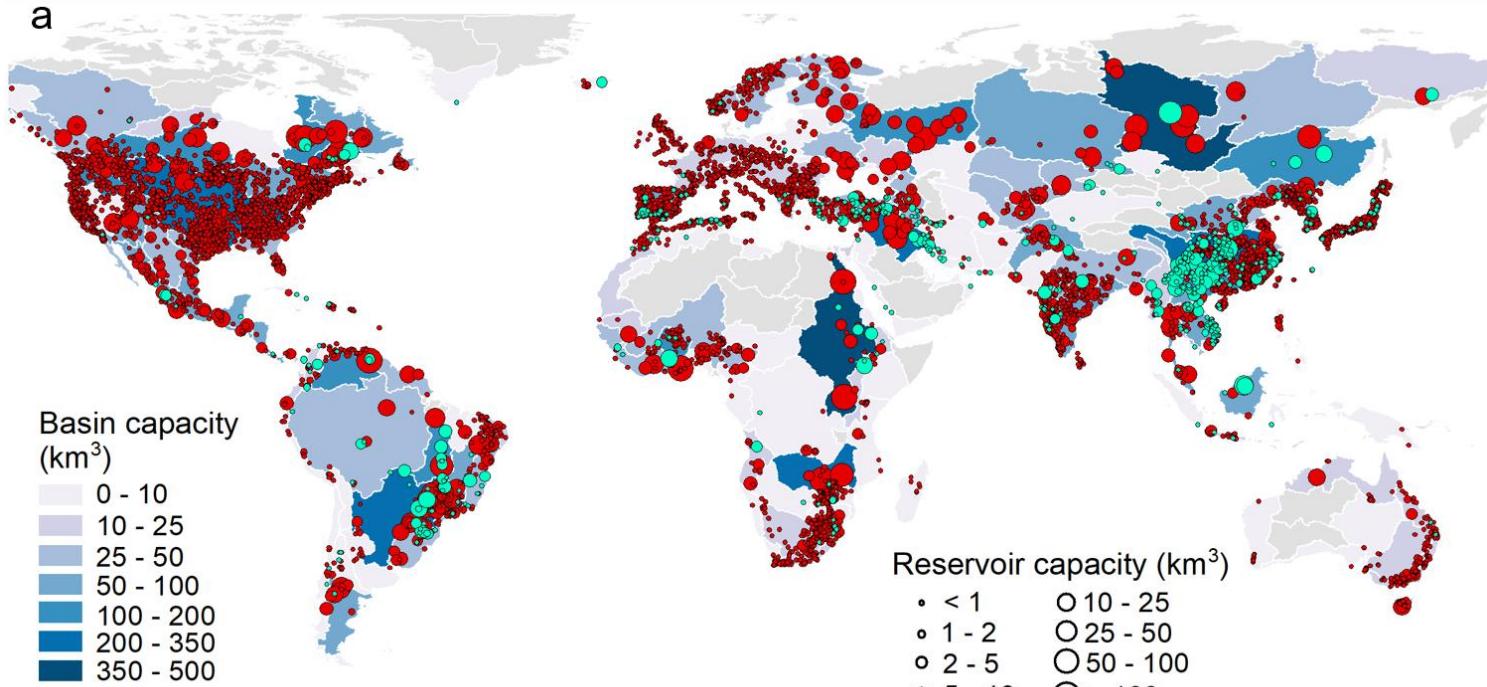


Elephant Butte Lake

<https://zertainty.users.earthengine.app/view/glev>

Earth Engine Apps

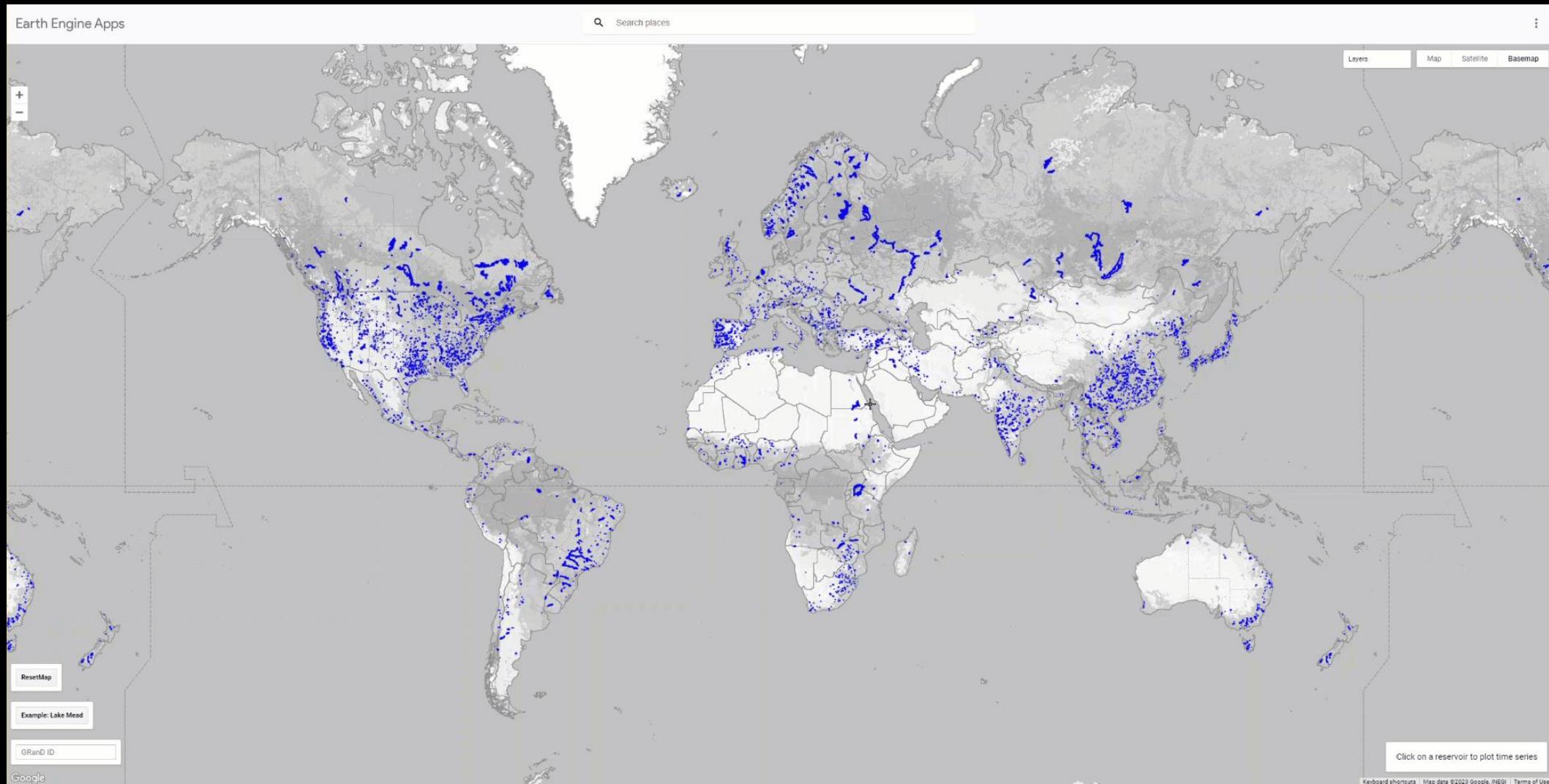




**Diminishing
storage returns of
reservoir
construction
(Li et al., 2023)**

Sobradinho Reservoir, Brazil

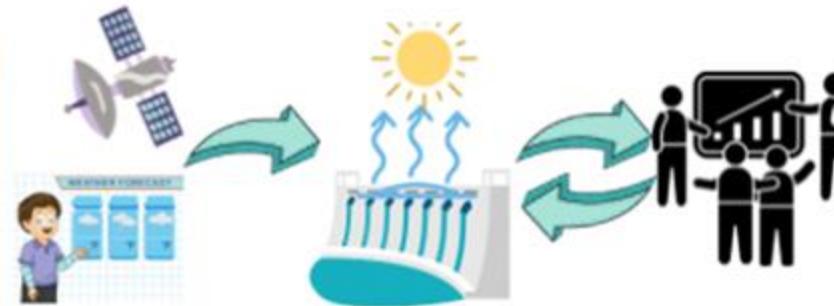
<https://yao.users.earthengine.app/view/grs>



ReVap: Reservoir Evaporation Monitoring and Forecasting System

Inputs:

- Weather products
- Subseasonal forecasts
- Reservoir area&depth
(from in situ and/or satellite)



Data Portal:

An application programming interface (API) and a web map user interface (UI)

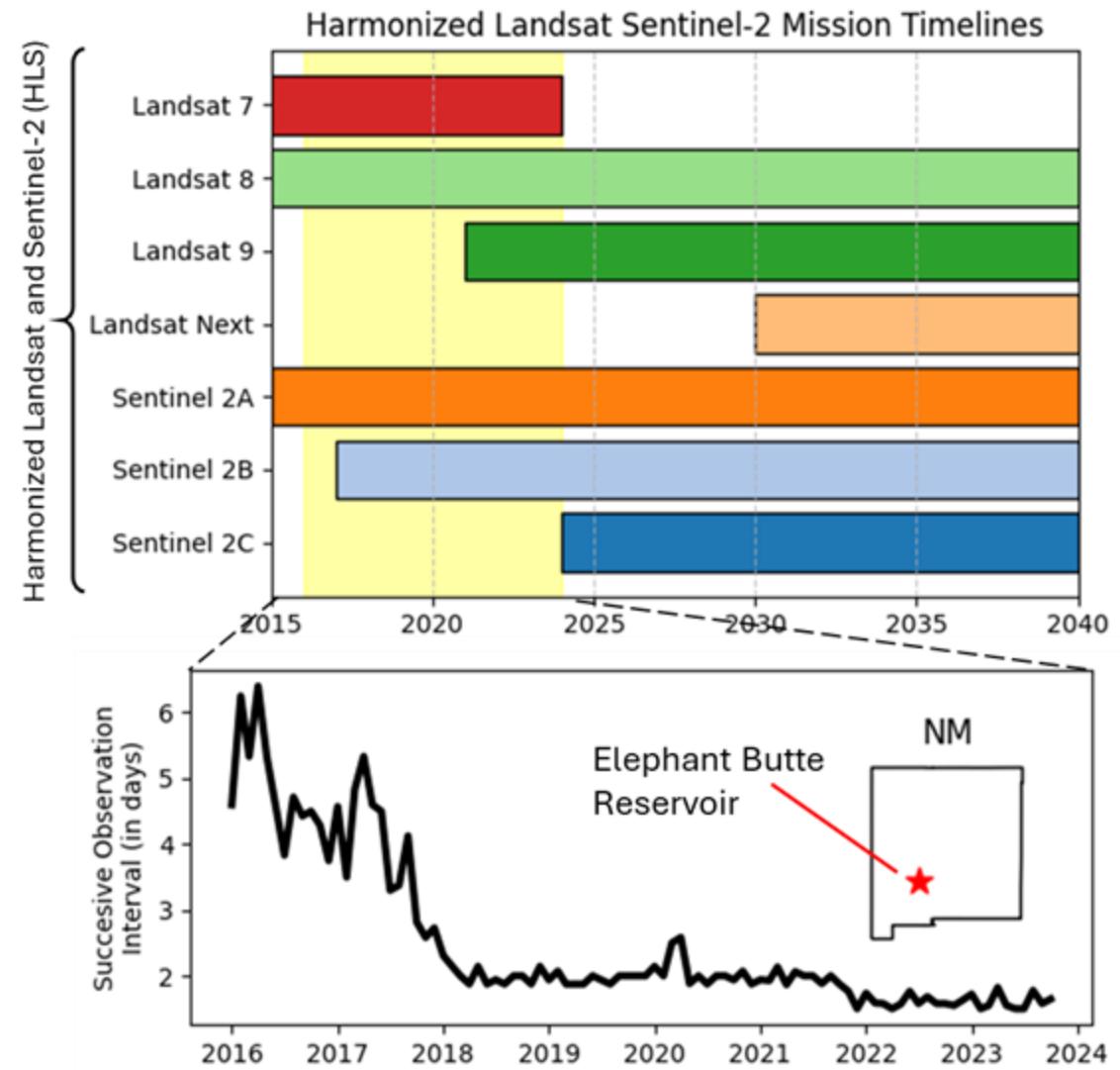
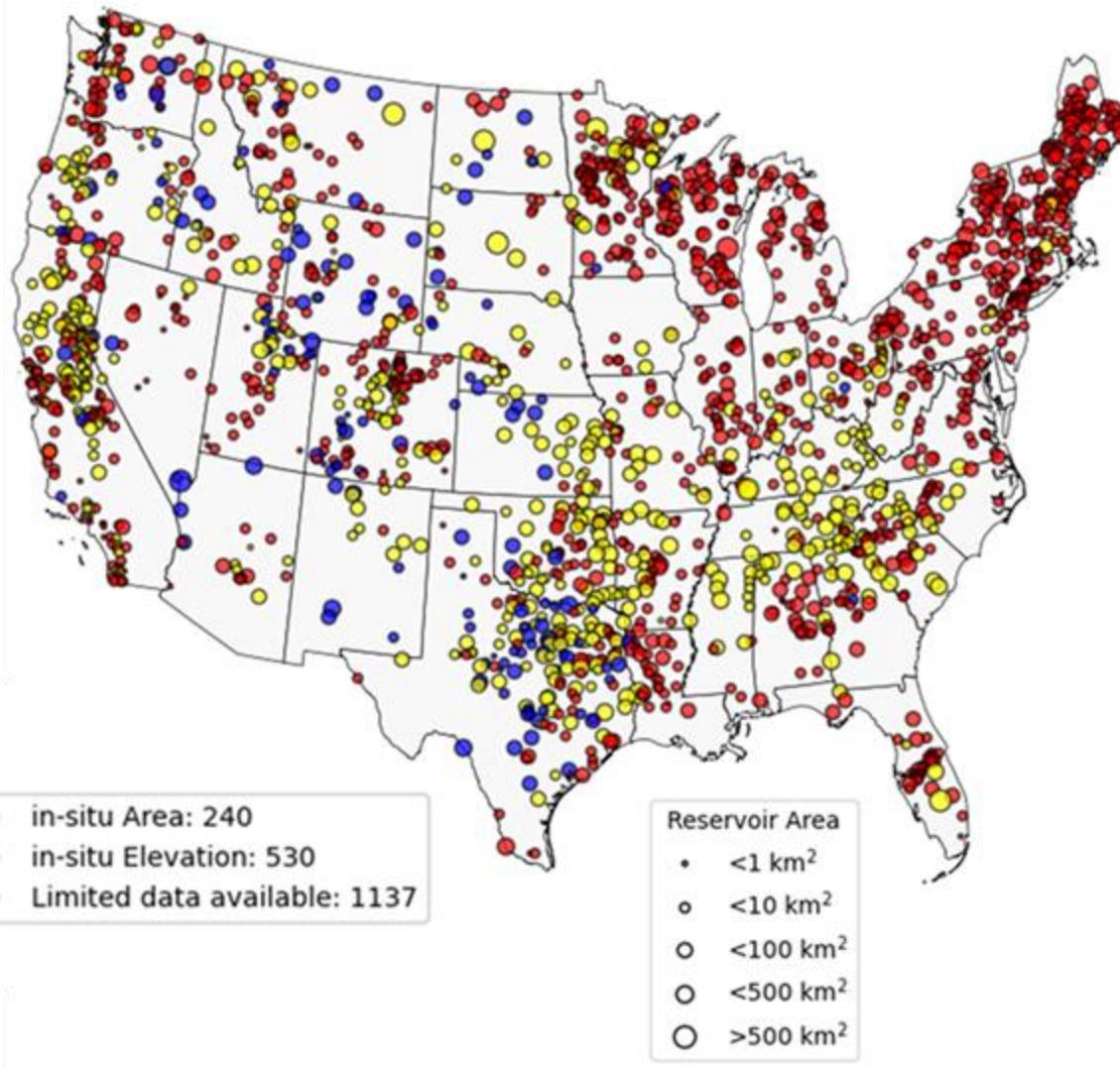
Model:

A validated Daily Lake Evaporation Model (DLEM) for simulating daily reservoir evaporation

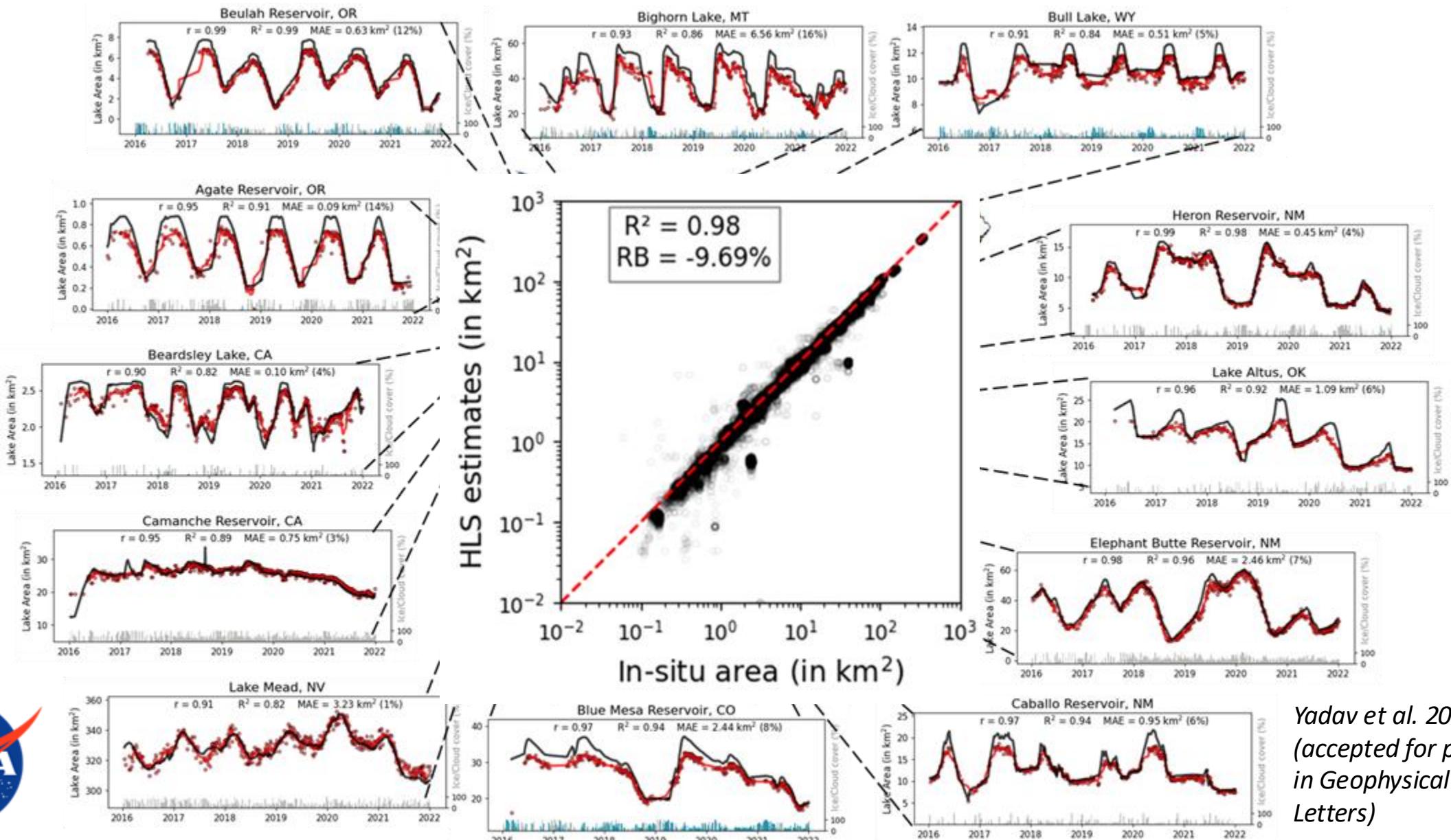
Outputs:

- Daily evaporation estimates (rate&volume)
- 1980 - near real-time
- 28 day evaporation rate forecasts



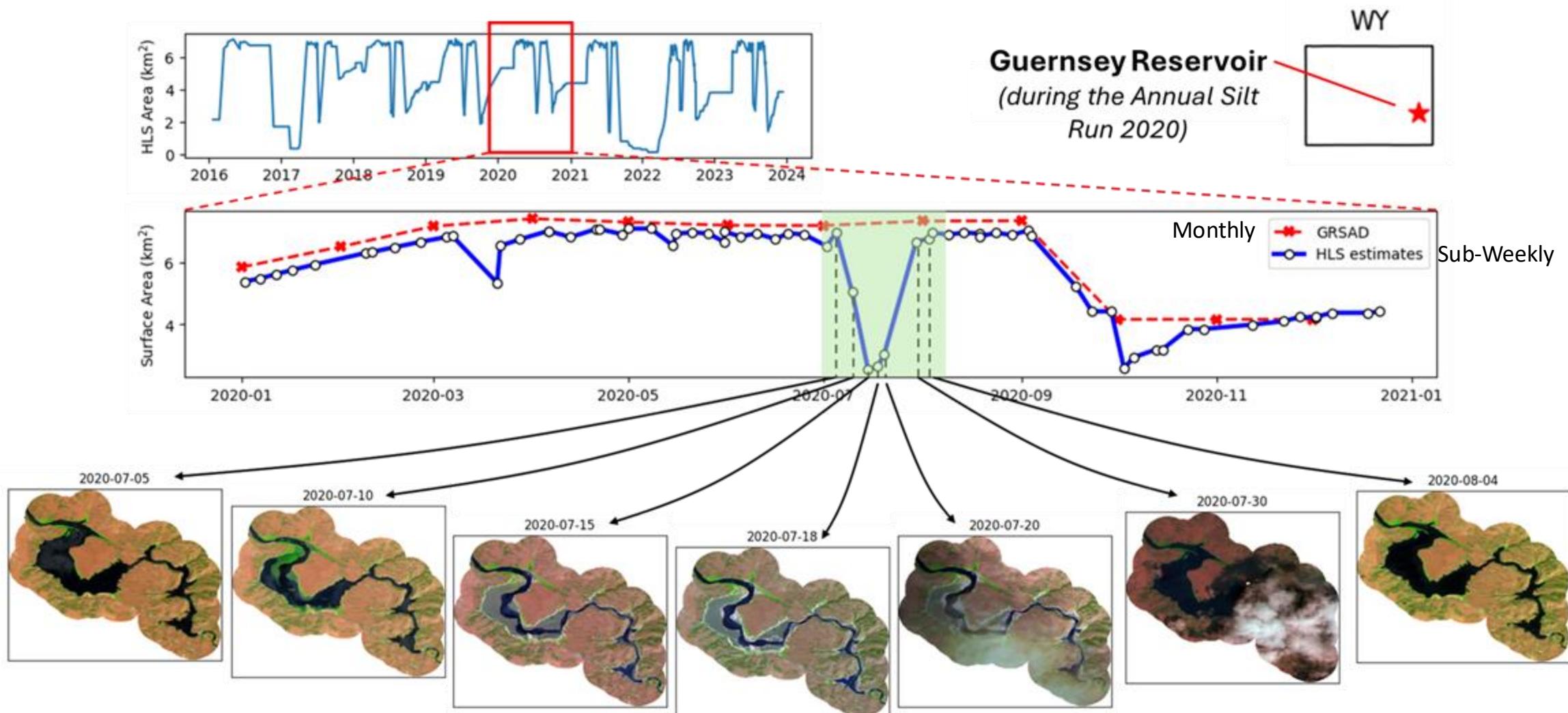


Surface Area Validation



*Yadav et al. 2025,
(accepted for publication
in Geophysical Research
Letters)*

Application: Monitoring sub-monthly transient events



Web App

 BUREAU OF RECLAMATION  DRI   

Search places

Earth Engine Apps

BOR Reservoir Evaporation

Time Step Select Reservoir

Start Year End Year

Historical Evaporation Rate (in/year)



50 65 80

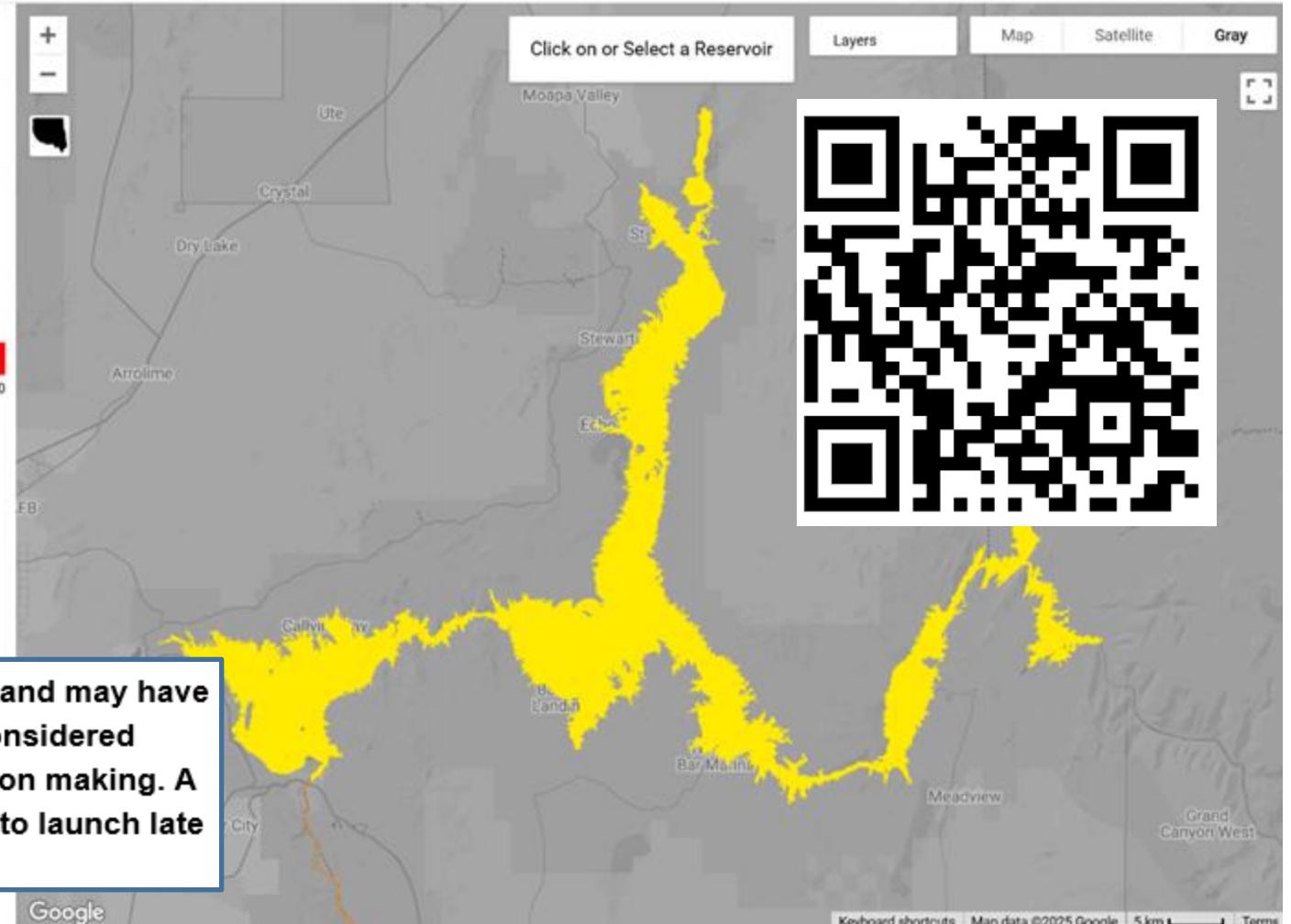
Show Gross Evap Show Net Evap Show Evap Vol Show Area Show Precip

Download Data

Time Step Download Data

Start Year End Year

Beta Status: This website is currently under development and may have some limitations or issues. Evaporation data should be considered provisional and not used for operational support or decision making. A production version of this API and database is scheduled to launch late summer 2025.



Click on or Select a Reservoir

Layers Map Satellite Gray

Google

Keyboard shortcuts Map data ©2025 Google 5 km Terms

22

Hands-on exercises

Thanks!
Questions?

Contact:
hgao@civil.tamu.edu



MODIS/VIIRS
Global Water Reservoir (GWR)



Daily reservoir evaporation
ReVap (Provisional)



Global Reservoir Storage
(GRS)



Global Lake Evaporation Volume
(GLEV)



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