OAK RIDGE National Laboratory

Challenges to modeling the GHG footprint of hydropower reservoirs

Carly Hansen, PhD

Water Resources Engineer

Water Resources Science and Engineering Group – Environmental Sciences Division

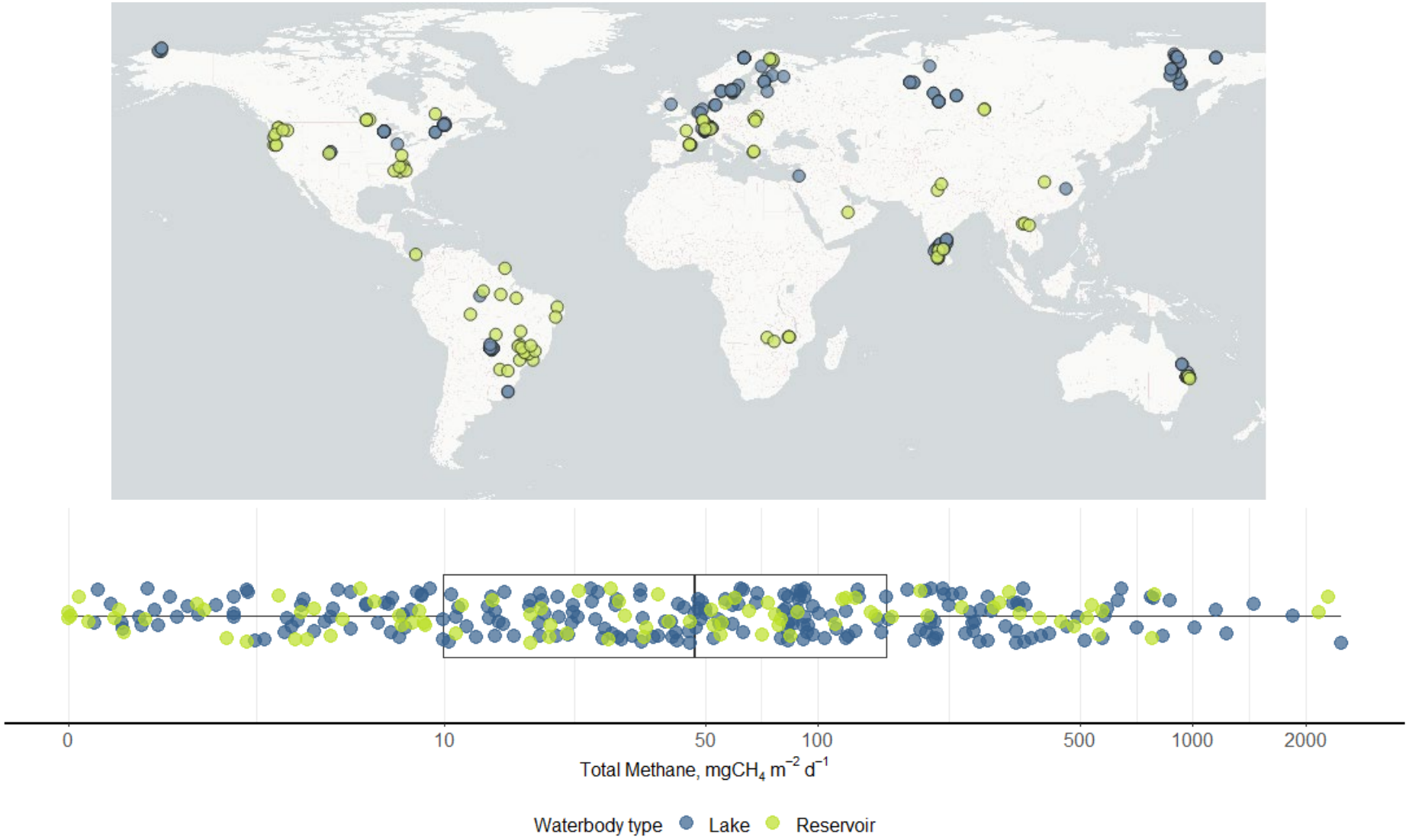
ORNL is managed by UT-Battelle LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

Waterbody GHG footprinting is critical

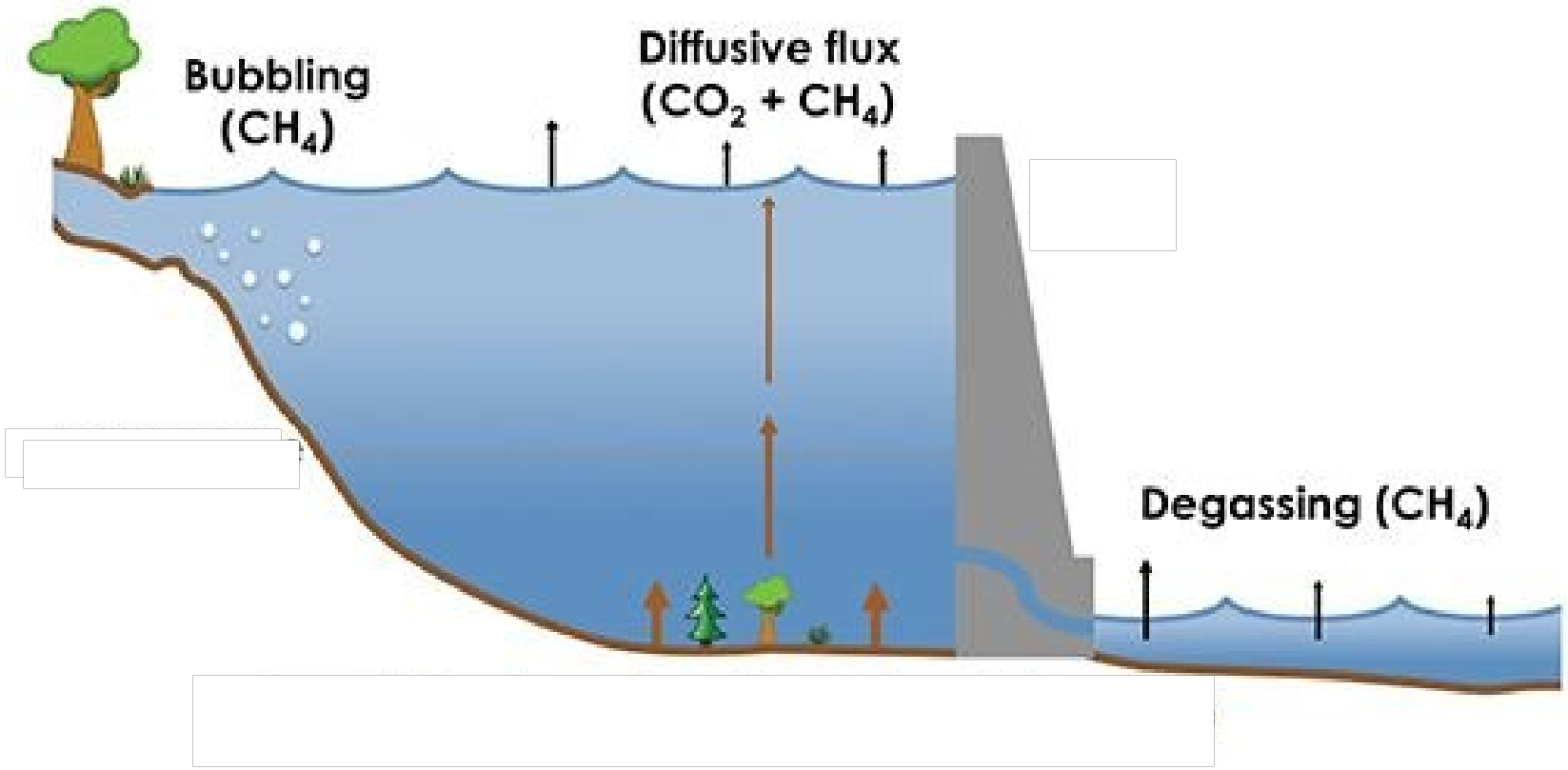
- Accurate emissions accounting is necessary to **ensure emissions reduction targets are met**
- Knowing what influences emissions can help **identify where we have leverage to mitigate**
- "GHG footprint" is key to **talking about emissions** from a systems perspective and comparing alternatives
- Better understanding of challenges and factors that contribute to uncertainties is the first step to improving GHG footprints

Measurements and ground-truth data are limited



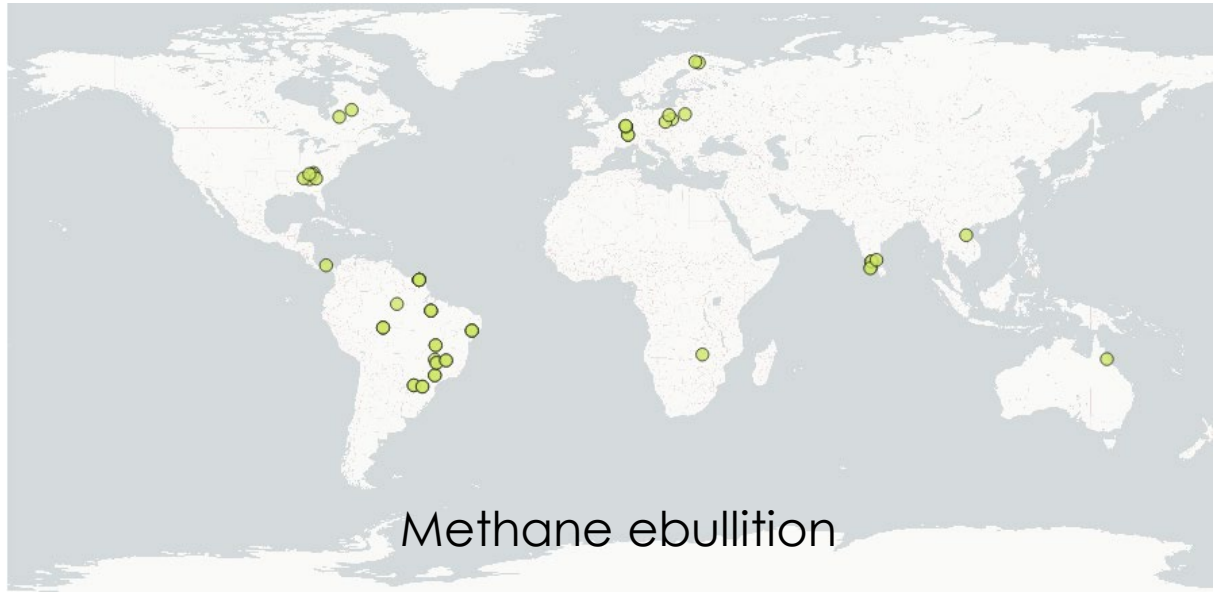
Global lake and reservoir measurements from Rosentreter et al., 2021 "Half of global methane emissions come from highly variable aquatic ecosystem sources"

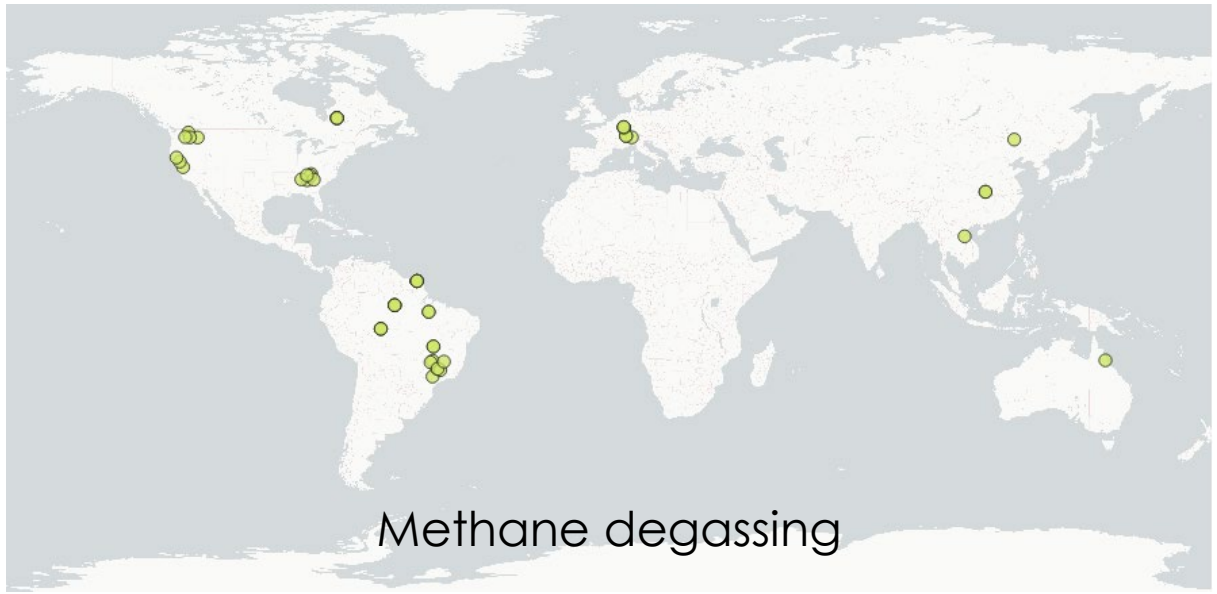
Measurements and ground-truth data are limited

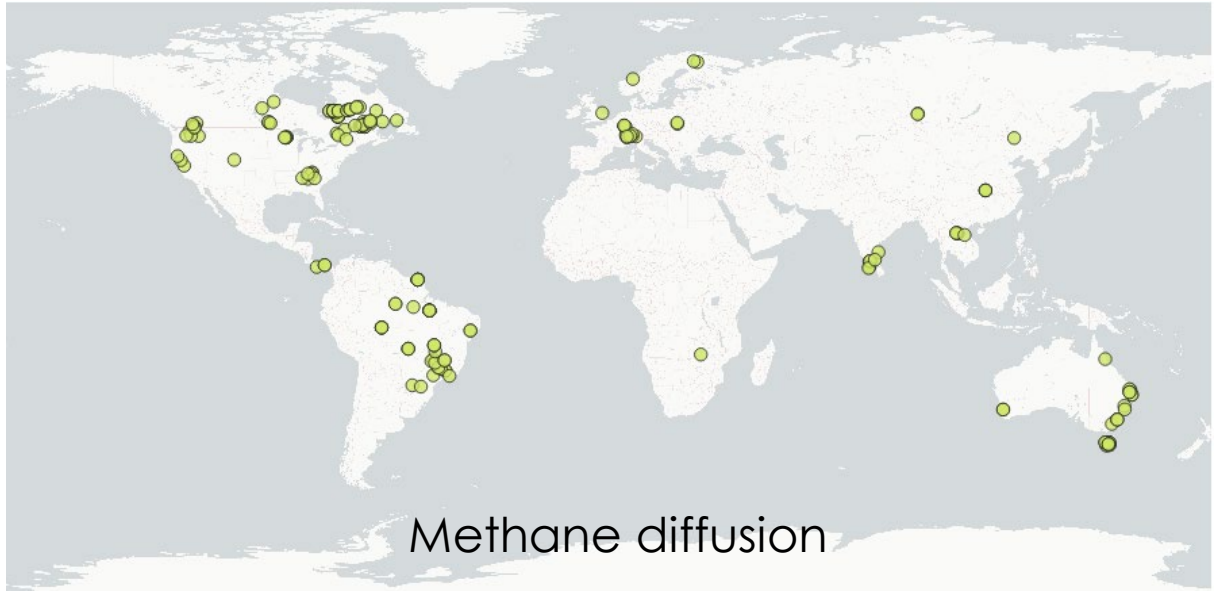


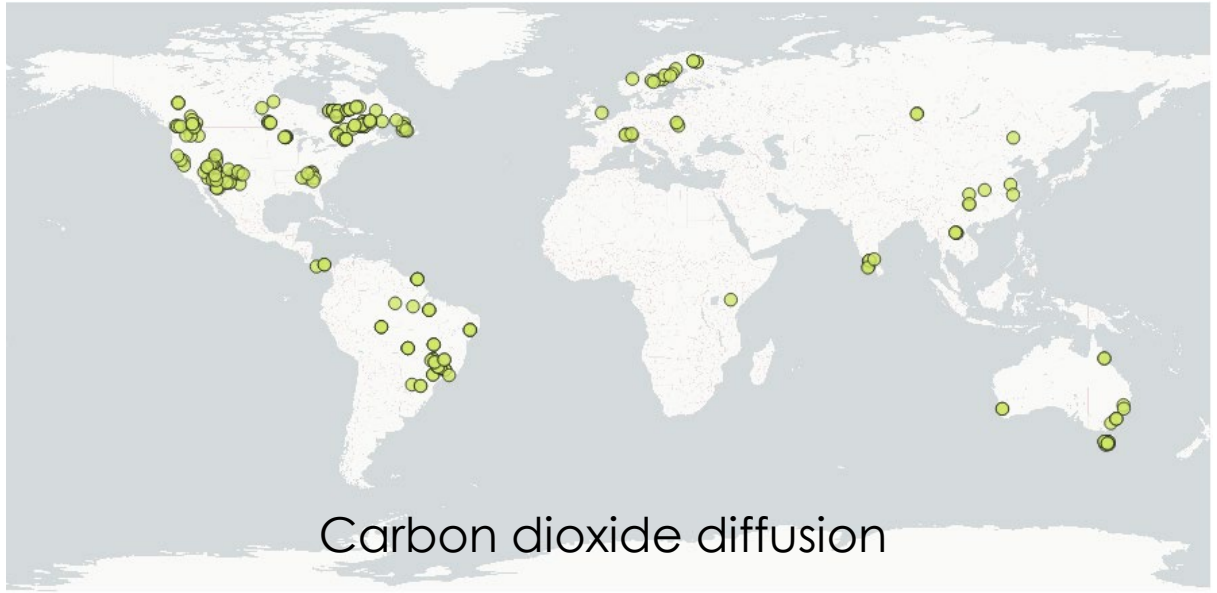
Adapted from International Hydropower Association's
hydropower.org explainer on the G-res modeling tool

Measurements and ground-truth data are limited



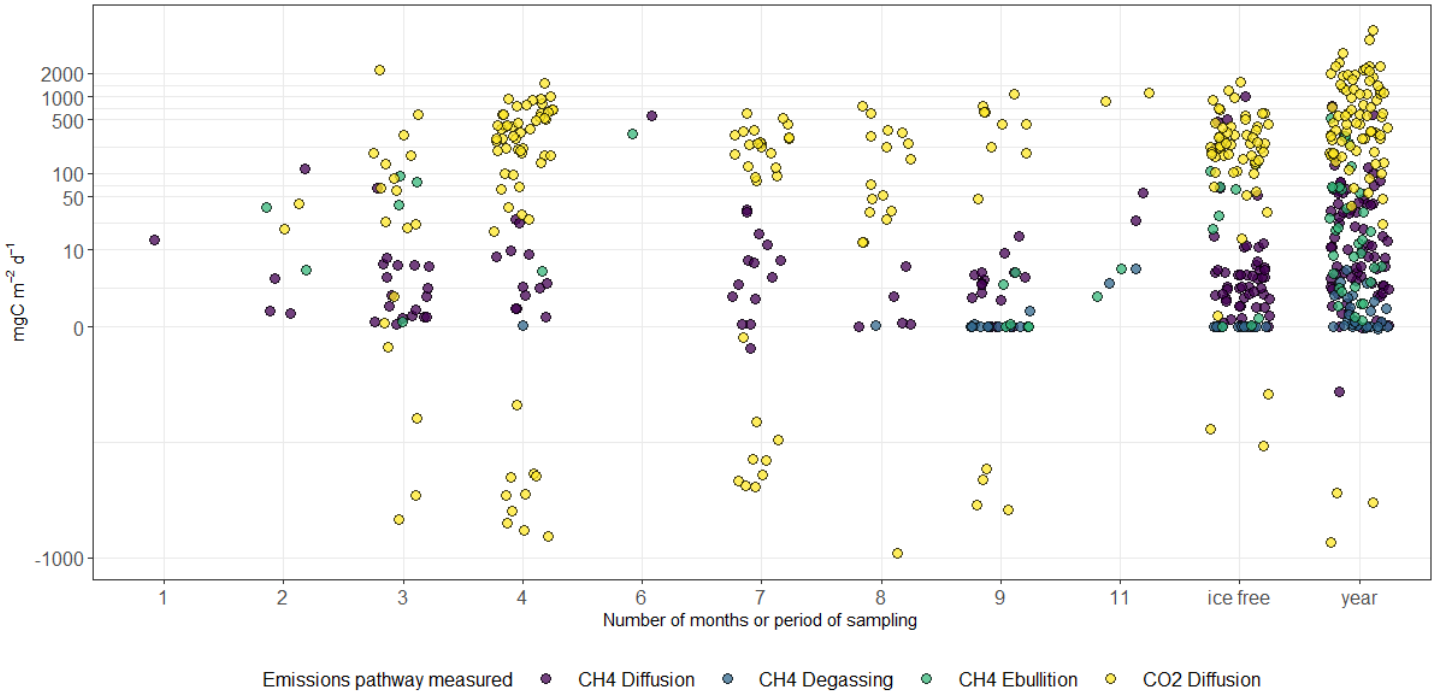




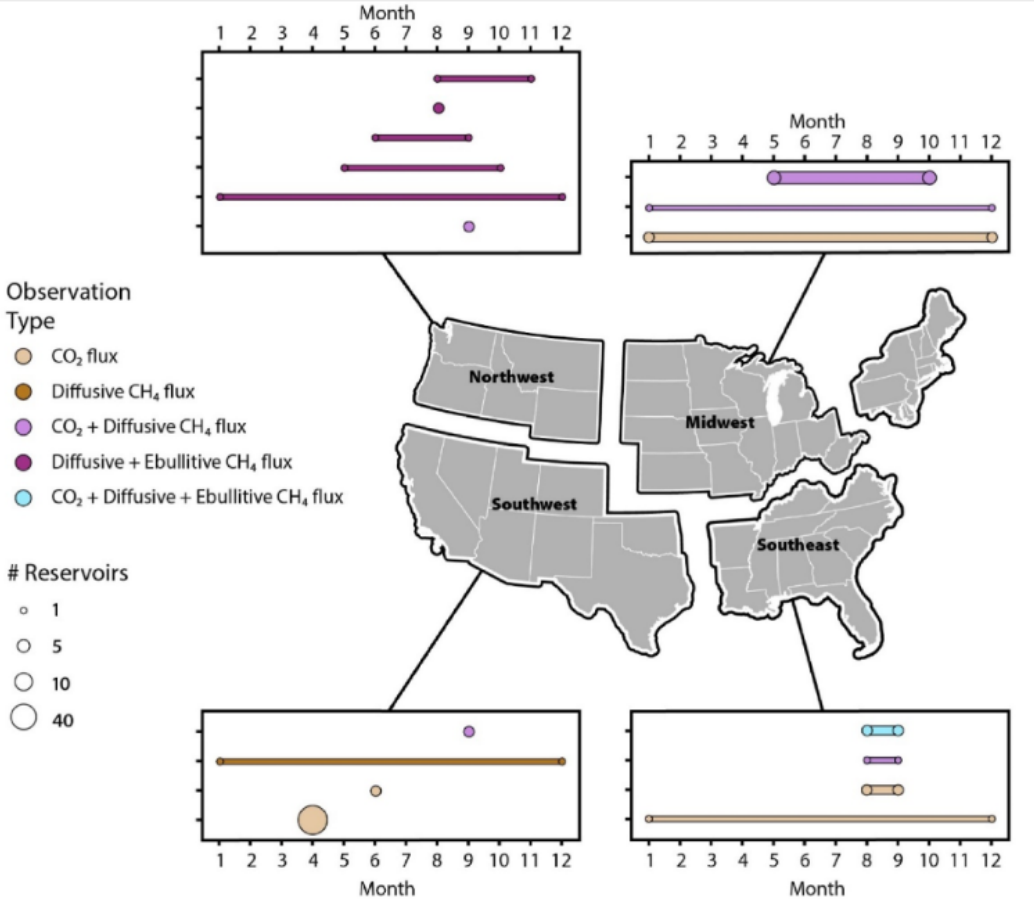


Reservoir measurements from Prairie et al., 2021 "G-res tool modelling database"

Measurements and ground-truth data are limited



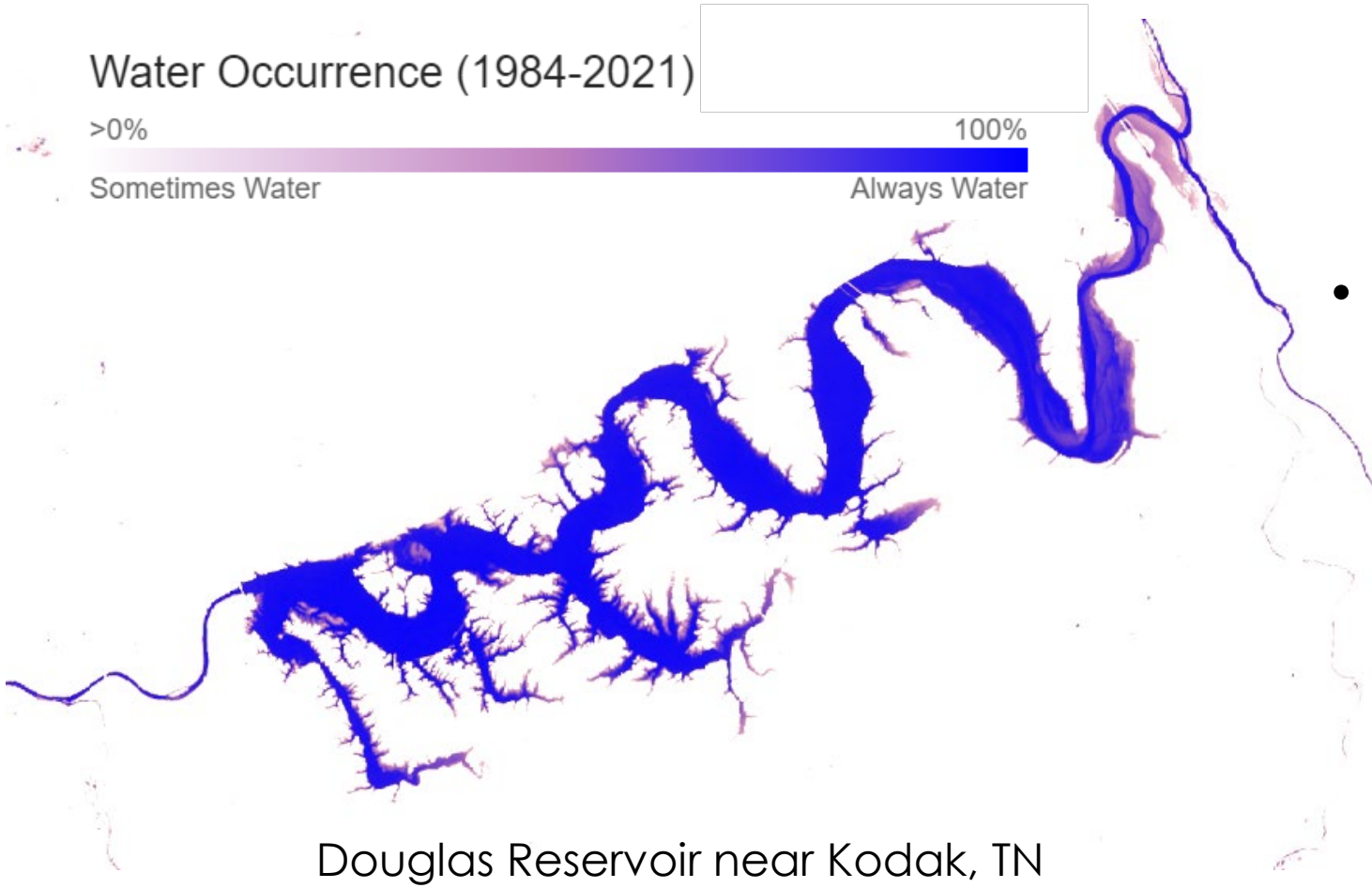
Measurement info from Prairie et al., 2021 "G-res tool modelling database"



From Jager et al., 2022 "Getting lost tracking the carbon footprint of hydropower"

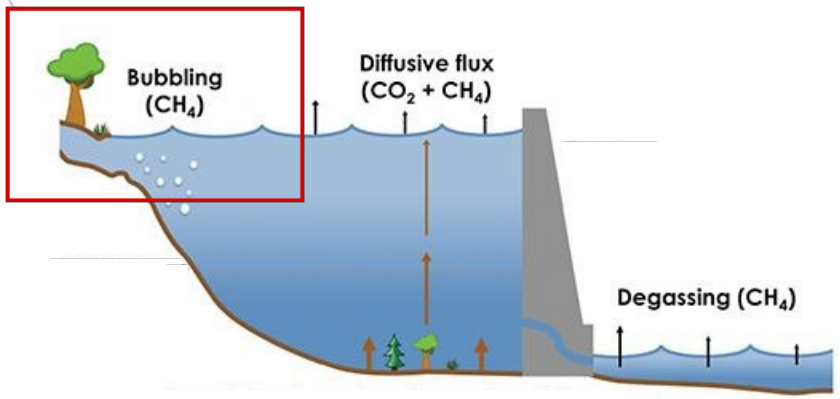
OAK RIDGE National Laboratory

Waterbodies are not constant



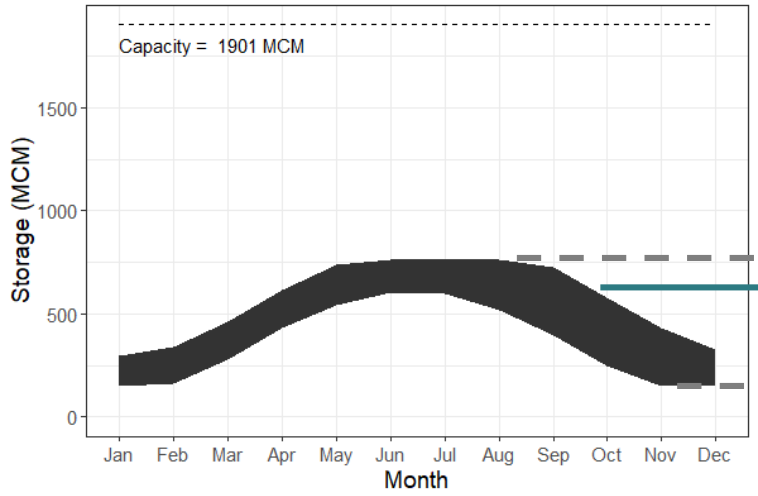
Douglas Reservoir near Kodak, TN

- Physical extent of a reservoir is not constant
  - Creates uncertainty for up-scaling and determining areal flux
- Extent + morphology is important for different types of emissions (especially methane ebullition in the littoral zone)



Waterbodies are not constant

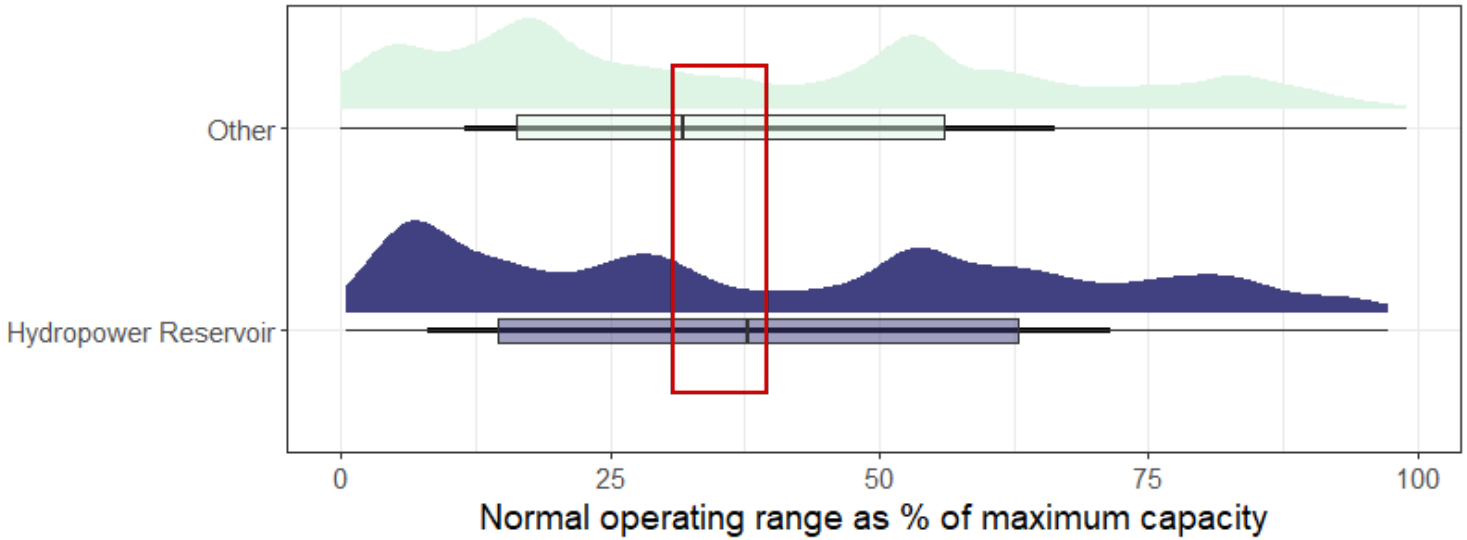
Douglas Reservoir – storage (lake level and area) varies seasonally and year-to-year



600 MCM, 30% of the total capacity

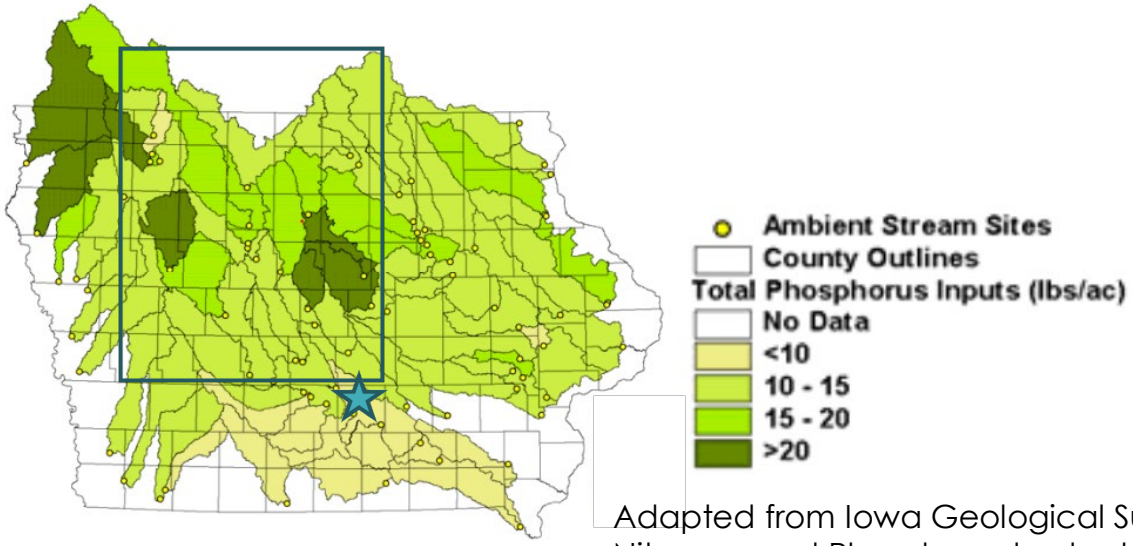
Median for the upper bound of normal operating range: 596 MCM

Among large reservoirs in the US, the median difference between upper and lower bounds of the normal operating range is about 30% of the total reservoir capacity



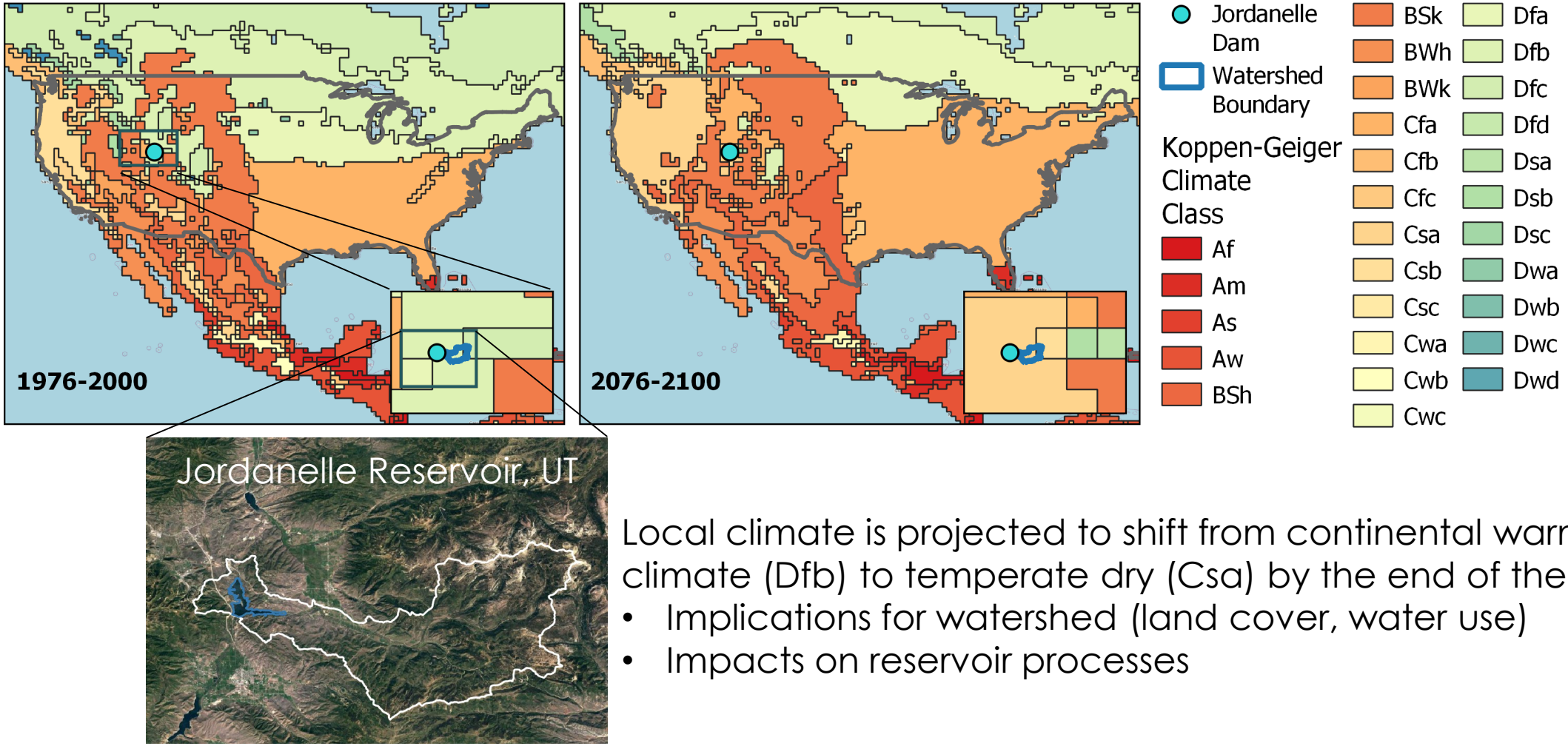
Waterbodies are not constant

- Conditions in the watershed change over time
  - Differences in nutrient loading
  - Wastewater
  - Wildfires



Adapted from Iowa Geological Survey report on Nitrogen and Phosphorus budgets for Iowa Watersheds

Waterbodies are not constant

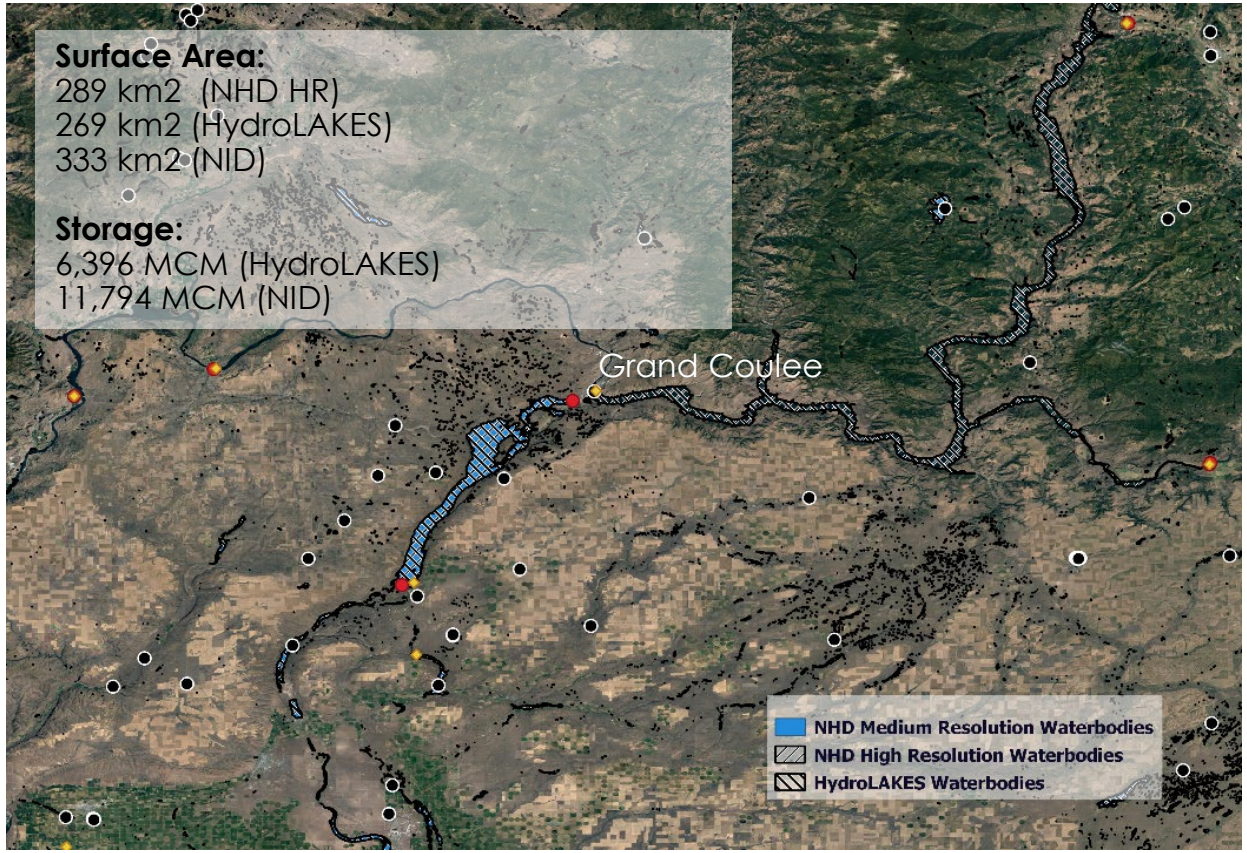


Local climate is projected to shift from continental warm climate (Dfb) to temperate dry (Csa) by the end of the century

- Implications for watershed (land cover, water use)
- Impacts on reservoir processes

When is a reservoir not a reservoir?

- Waterbody datasets describe systems differently
  - Especially important at large scales (regional or national analysis)

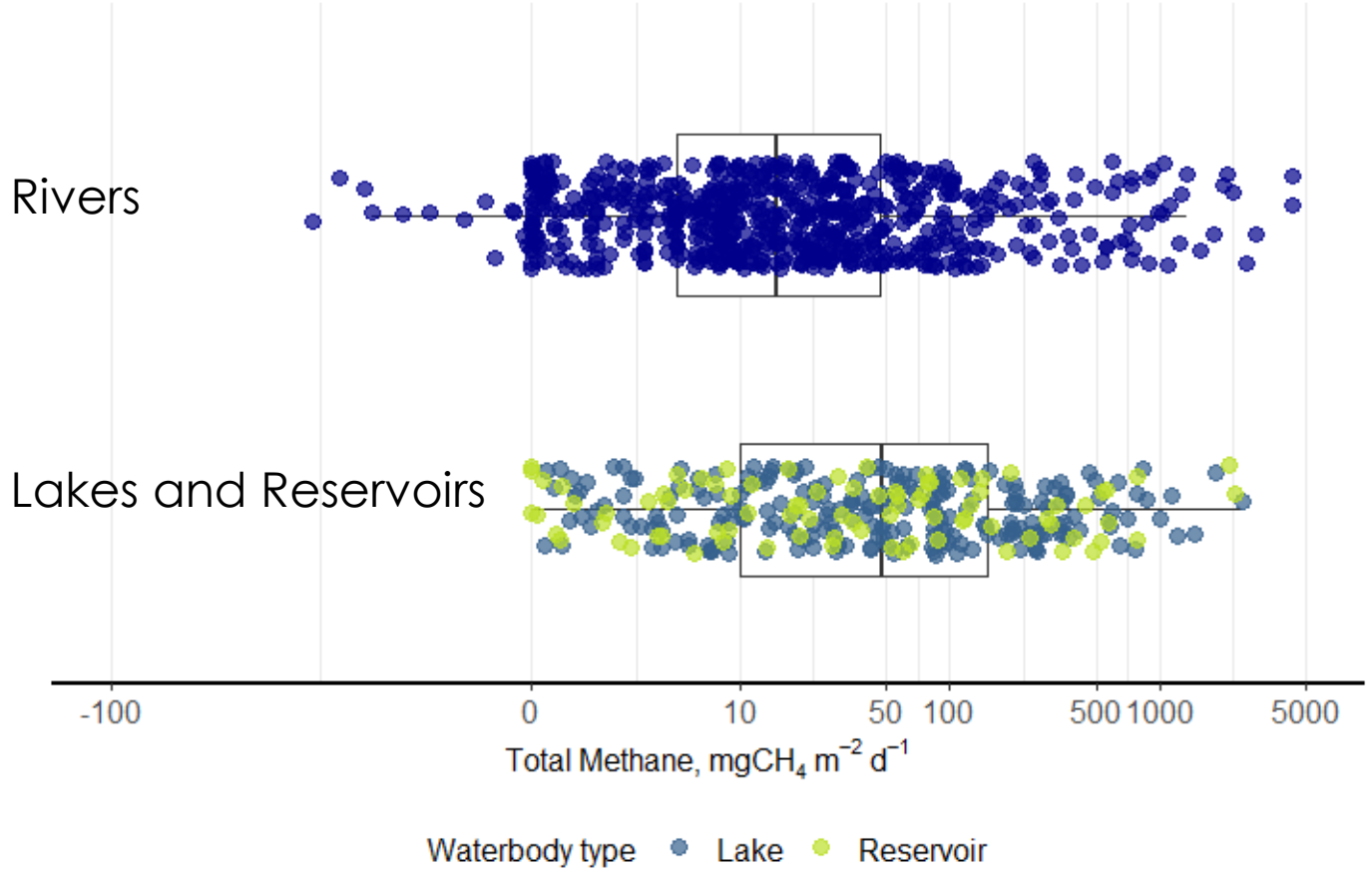


The impounded part of the Columbia River upstream of Grand Coulee = Lake Roosevelt

- NHD Medium Res = not included as a waterbody,
- NHD High Res = lake/pond,
- HydroLAKES = reservoir,
- ESRI USA Detailed Waterbodies = stream/river

When is a reservoir not a reservoir?

- Important to delineate when certain relationships apply to systems on the lentic – lotic spectrum



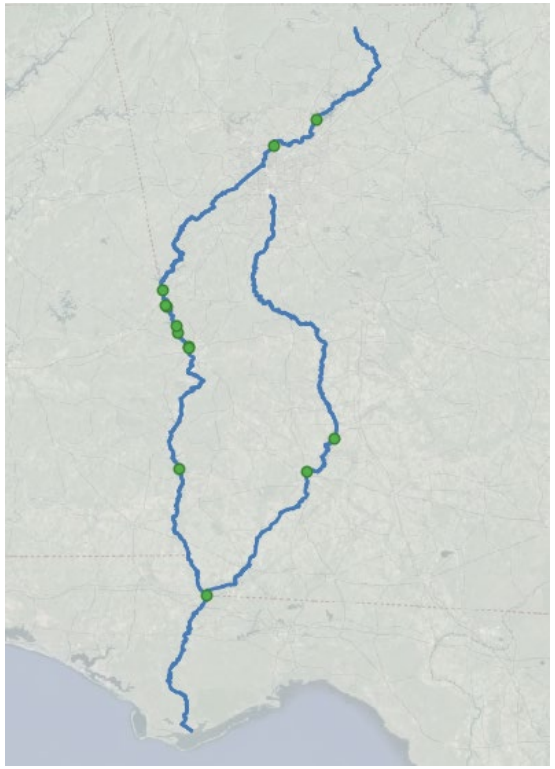
Global river & lake/reservoir measurements from Rosentreter et al., 2021 "Half of global methane emissions come from highly variable aquatic ecosystem sources"

Additional considerations

- Reservoirs are often connected to each other
  - Cascading or coordinated operations
  - How can we best delineate a reservoir's footprint when operations and conditions are linked to other reservoirs?

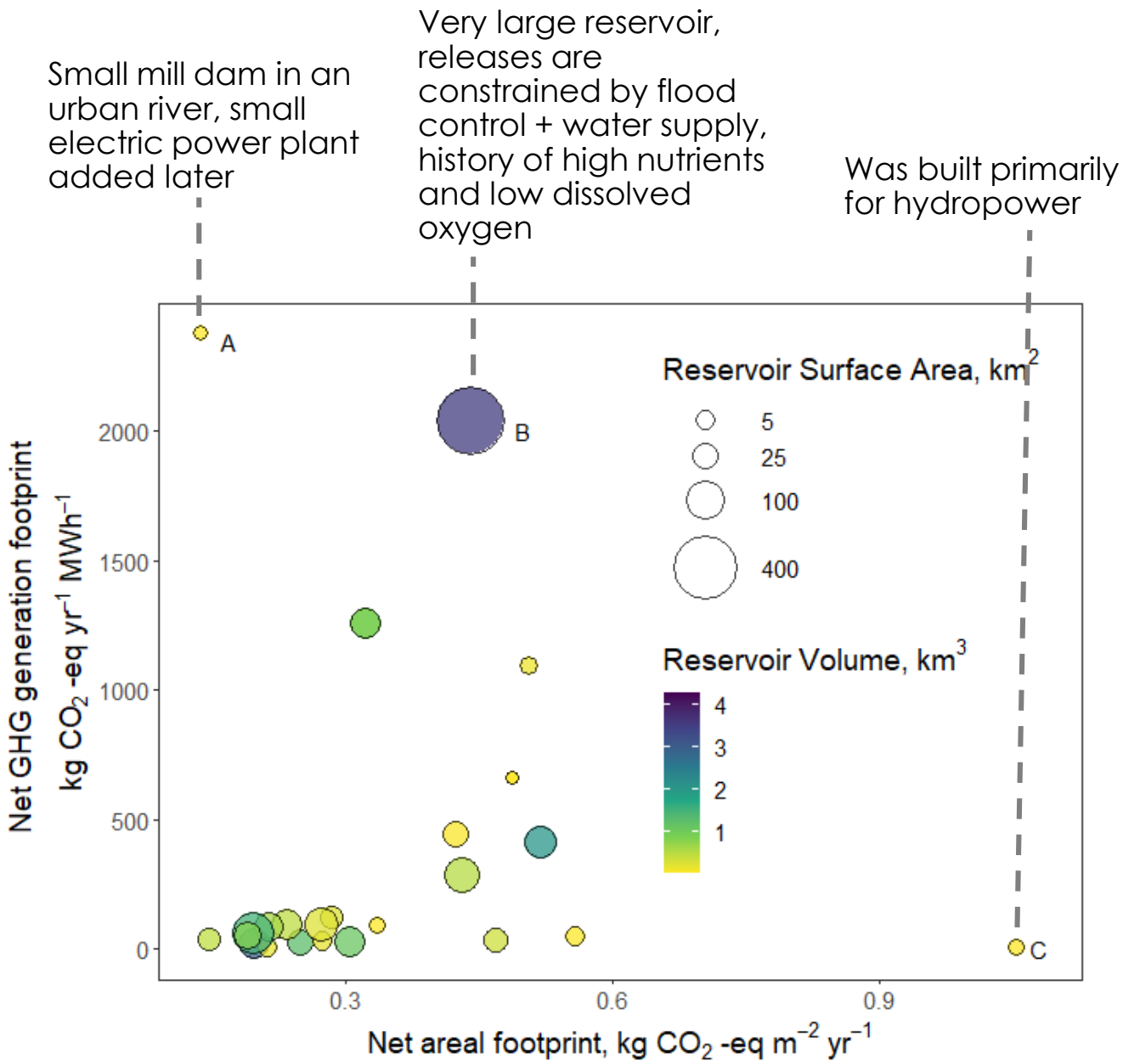
Series of hydropower + non-hydropower reservoirs in the Southeastern US (Apalachicola-Chattahoochee-Flint River Basin)

- Coordinated operations for flood control and water supply
- Large range in size and relative location to urban development



Additional considerations

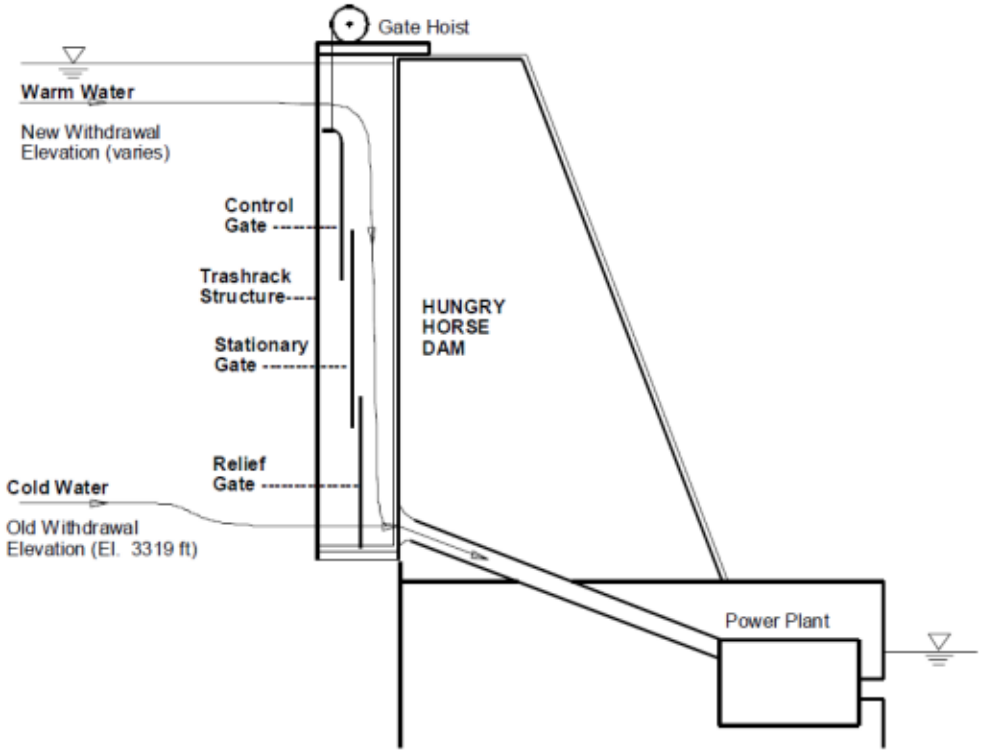
- Attribution and intensity (GHGs per MWh)
  - Even when hydropower is listed as the primary purpose, the reservoir often supports other critical objectives (flood control, irrigation, water supply)
    - 70% of US hydropower reservoirs have multiple purposes in addition to hydropower



from Hansen et al., 2022 (In review)

Additional considerations

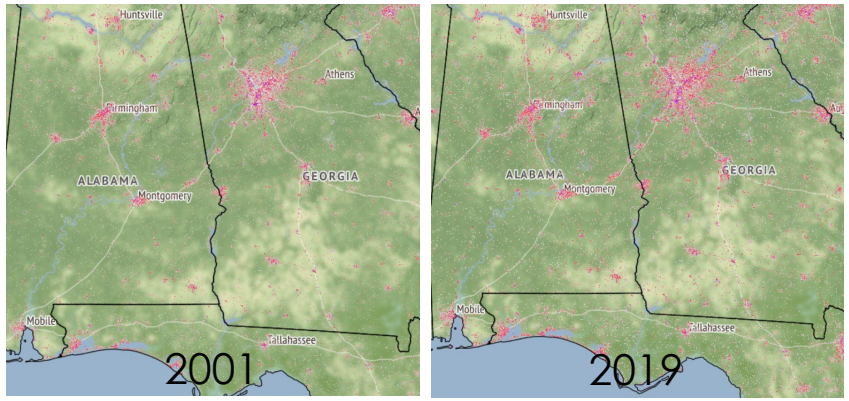
- Attribution
  - Degassing would not likely be an issue without turbines, but degassing emissions are also tied to the depth and water quality of the reservoir and intake depth



From Vermeyen. 2006. "Hungry Horse Selective Withdrawal System Evaluation 2000-2003" Hydraulic Laboratory Report"

Ongoing efforts and emerging techniques to address challenges

- Satellite imagery aids in exploring the recent past:
  - Global surface water occurrence product
  - Landcover change
- Large-scale monitoring to cover diverse waterbodies:
  - Ongoing EPA SuRGE project approaches sampling from large scale
- More comprehensive measuring techniques to support accounting in the future:
  - Remote sensing (satellite such as GHGSat)
  - High frequency monitoring (and monitoring of coincident conditions)
- Linking data about water management infrastructure + hydrology + water quality



National Land Cover Database Impervious Surface (www.mrlc.gov)


A GHGSat sensing instrument (www.ghgsat.com)

Research Team & Acknowledgments







Article on monitoring and modeling project: https://www.ornl.gov/news/researchers-aim-better-quantify-greenhouse-gas-emissions-hydropower-reservoirs

Contact: hansench@ornl.gov or griffithsna@ornl.gov

ORNL research staff, postdocs, technicians, and interns: Natalie Griffiths, Henriette Jager, Paul Matson, Rachel Pilla, Allison Fortner, Jana Phillips, Bilal Iftikhar, Bailey Skinner

IHA G-res Model Development Team, Sara Mercier-Blais

OAK RIDGE National Laboratory