1.4.2.501 – Methane Emissions

Natalie Griffiths
Oak Ridge National Laboratory

griffithsna@ornl.gov

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Project Overview

Project Summary

Estimates of greenhouse gas (GHG) emissions from reservoirs are highly uncertain and range from 0.14 to 6.6% of global GHG emissions. Our project is using a coupled modeling-measurement approach to reduce uncertainty in GHG emission estimates, particularly methane, both within individual hydropower reservoirs and across reservoirs in the U.S. Development and validation of novel, in-situ GHG measurement technologies combined with comprehensive, statistically based monitoring designs informed by GHG emission models will be critical components of this project.

Intended Outcomes

The outcome of this project will be a reduction in the uncertainty in GHG emission estimates from U.S. hydropower reservoirs that will arise from the analysis of field measurements, model assessments, and data syntheses efforts as well as the development and use of novel measurement technologies. Accurate quantification of GHG fluxes is paramount for the hydropower industry to assess its role in decarbonization and because GHG emissions may be considered when evaluating hydropower's status as a form of renewable energy.

Project Information

Principal Investigator(s)

- ORNL: Natalie Griffiths, Carly Hansen, Yetta Jager, Paul Matson, Rachel Pilla

Project Partners/Subs

- Collaborating on US EPA's "Survey of Reservoir Greenhouse Gas Emissions project (SuRGE)."

Project Status

- New

Project Duration

- Start: FY21
- End: FY23

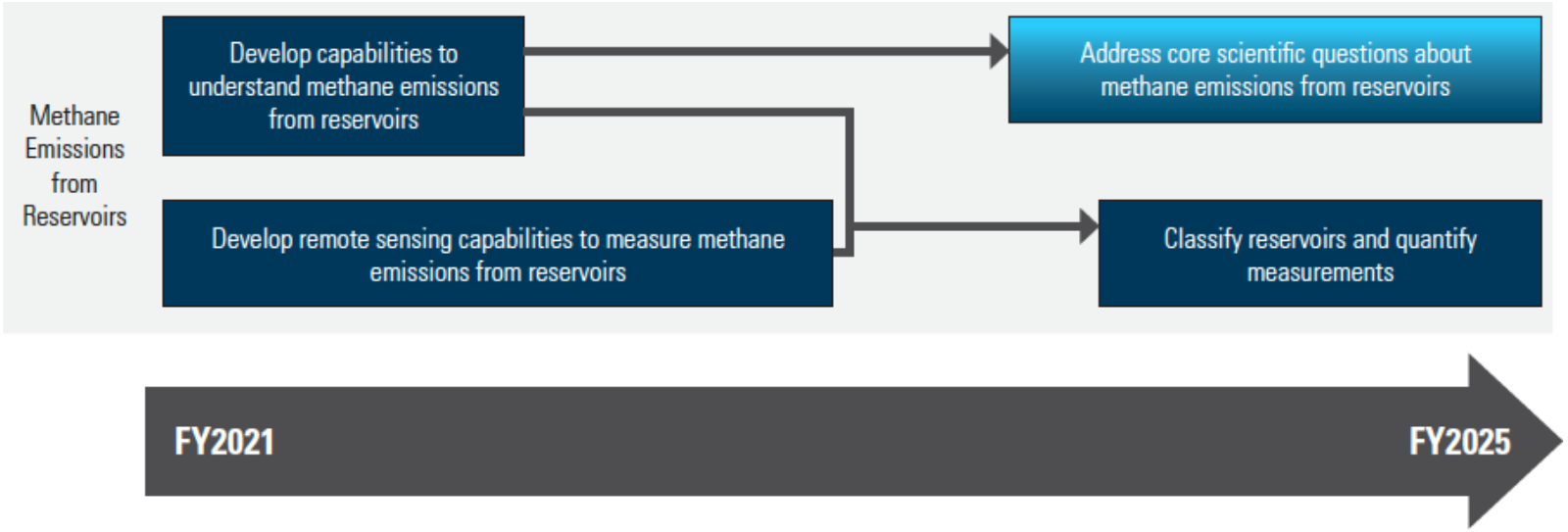
Total Costed (FY19–FY21)

- $402K

Project Objectives: Relevance

Relevance to Program Goals:

- A key challenge identified in WPTO's MYPP is: "uncertainties about long-term climate change and hydrologic variations or extreme events and the associated operational and ecological impacts."
- Our project is addressing this critical challenge by utilizing a coupled modeling-measurement approach to reduce uncertainty in GHG emission estimates from reservoirs and "assess risk of potential methane emissions from water bodies". This work will support WPTO's goal to "validate new technologies to more accurately characterize and model methane emissions from reservoirs and other water bodies".



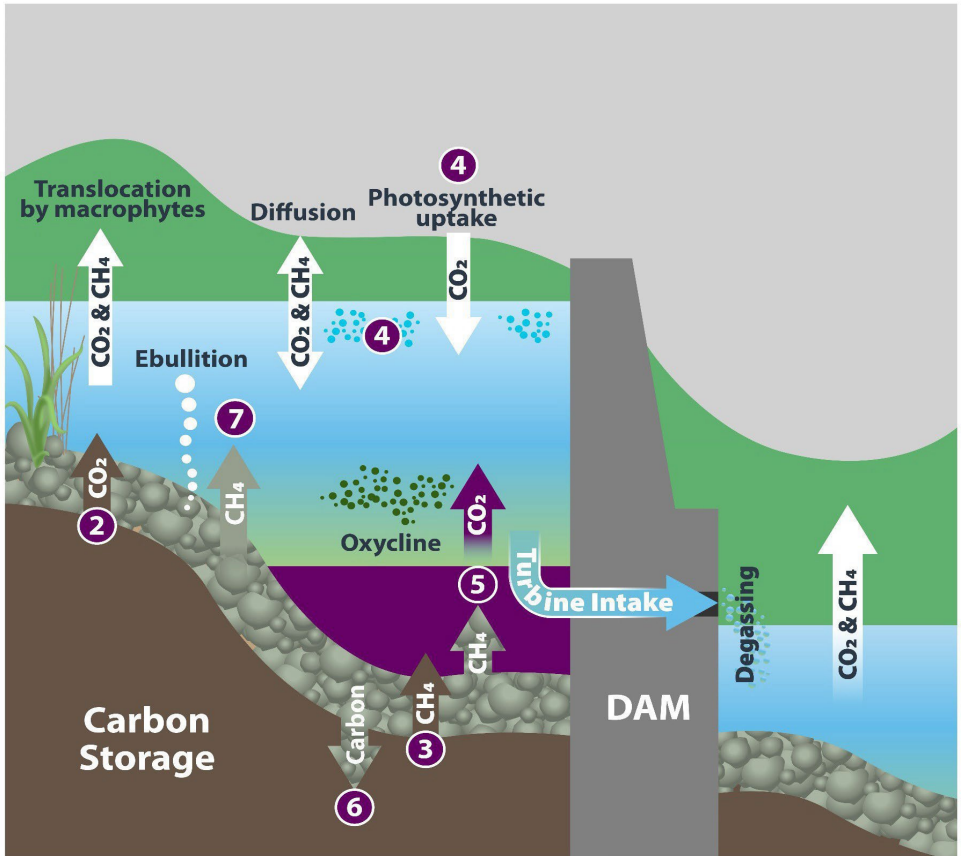
WPTO MYPP, March 2022

Project Objectives: Approach

Approach:

- Reduce uncertainty in GHG emission estimates (particularly methane) both within and across U.S. hydropower reservoirs using a coupled modeling-measurement approach.
- Develop and validate novel, in-situ GHG measurement technologies combined with comprehensive, statistically-based monitoring designs informed by GHG emission models.
- Three interrelated tasks:
  - Synthesis and optimization
  - Modeling
  - Field measurements

Reservoir upstream of dam to tailwater
(river) (side view)



Jager et al. 2022

Project Objectives: Expected Outputs and Intended Outcomes

Outputs:

- Publications, reports, and presentations that describe data syntheses, modeling, and fieldwork efforts focused on improving understanding of GHG emissions and drivers from U.S. hydropower reservoirs.
  - One manuscript published, one in review.
  - 7 presentations to multiple audiences.
- Development, testing, and validation of novel GHG measurement technologies that improve spatial resolution of GHG measurements.

Outcomes:

- Reduction in the uncertainty in GHG emission estimates from U.S. hydropower reservoirs that will arise from the analysis of field measurements, model assessments, and data syntheses efforts as well as the development and use of novel measurement technologies.

Project Timeline

FY20:

- Initial synthesis and modeling efforts originated in HydroSource project.

FY21:

- Project initiated with 3 main tasks (synthesis/optimization; modeling; field measurements).
- Synthesis/review paper completed: *"Getting lost tracking the carbon footprint of hydropower."* Jager et al. 2022; Renewable and Sustainable Energy Reviews.
- Modeling analysis completed: *"Extreme variability in modelled reservoir greenhouse gas emissions: How US hydropower compares against global estimates."* (Hansen et al. in review).
- Collaboration established with US EPA on SuRGE project; participated in EPA-led field methods training.
- On-boarded post-doctoral research associate on fieldwork task.
- Acquired and tested field equipment, initiated fieldwork in fall 2021.
- Designed drone system for high-spatial resolution GHG measurements.

Project Budget

FY19	FY20	FY21	Total Actual Costs FY19–FY21
Costed	Costed	Costed	Total Costed
--	--	$402K	$402K

- Spending was lower in FY21 due to supply chain-related delays with fieldwork purchases. Focused on synthesis and modeling work.
- Spending has increased in FY22 (equipment arrived, fieldwork ramped up).

End-User Engagement and Dissemination

Engagement and Dissemination:

- Multiple intended beneficiaries and users:
  - Hydropower operators and those conducting environmental assessments at hydropower facilities.
    - Technology development for GHG measurements and conceptual model on modifying hydropower operations to reduce GHG emissions risk can be incorporated into operation and monitoring programs.
  - International groups (IHA) focused on developing best practices for measuring and estimating GHG emissions from reservoirs.
    - G-res modeling, including potential identification of model deficiencies, can be used to improve future versions of the G-res tool.
  - Multiple agencies (US EPA, Army Corps) and the larger scientific community engaged in GHG research.
    - Field measurements of GHG dynamics can be used to improve estimates of GHG emissions from aquatic ecosystems and quantify carbon fluxes and GHG inventories at national, regional, and global scales.

End-User Engagement and Dissemination

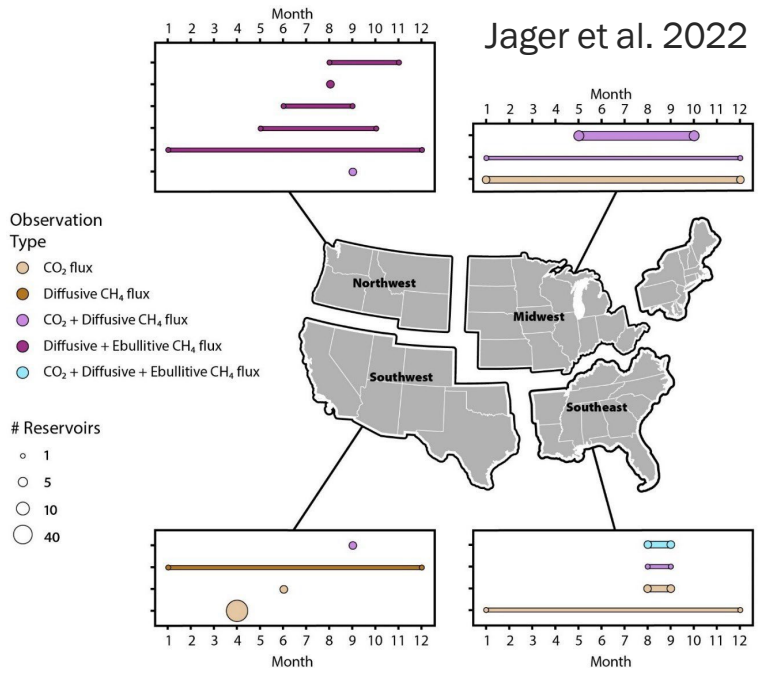
Engagement and Dissemination:

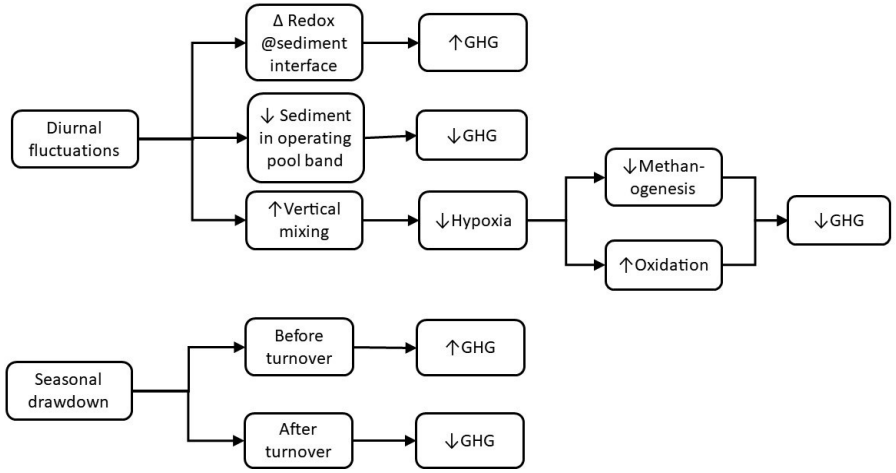
- Results will be shared through publications, reports, and presentations:
  - Presentations to multiple audiences: Joint Aquatic Sciences Meeting, Global Lake Ecological Observatory Network meeting, Environment and Water Resources Institute conference, North American Lake Management Society symposium.
- Engagement with Uncommon Dialogue (presentation in November 2021, anticipate future discussions/input sessions).
- Collaboration with US EPA on SuRGE project.
- Discussions with TVA, Army Corps, G-res modeling team, NASA researchers (remote sensing).

Performance: Accomplishments and Progress

Synthesis/Optimization Task:

- Published review paper that summarized the science on reservoir carbon footprints and suggested improvements (Jager et al. 2022):
  - GHG emission estimates from U.S. reservoirs are sparse.
  - Improved accounting for hydropower effects is complex due to multiple uses of reservoirs.
  - Need to clearly define and quantify counterfactual scenarios.
  - Current approaches treat reservoirs in isolation; suggest characterizing GHG footprint in context of carbon entering from upstream and reservoir position in the watershed.
- Progress on paper assessing how coordinated operation of reservoirs in river networks influence GHG emissions:
  - Conceptual model describing how water-level fluctuations in reservoirs influence GHG at different scales and pathways.

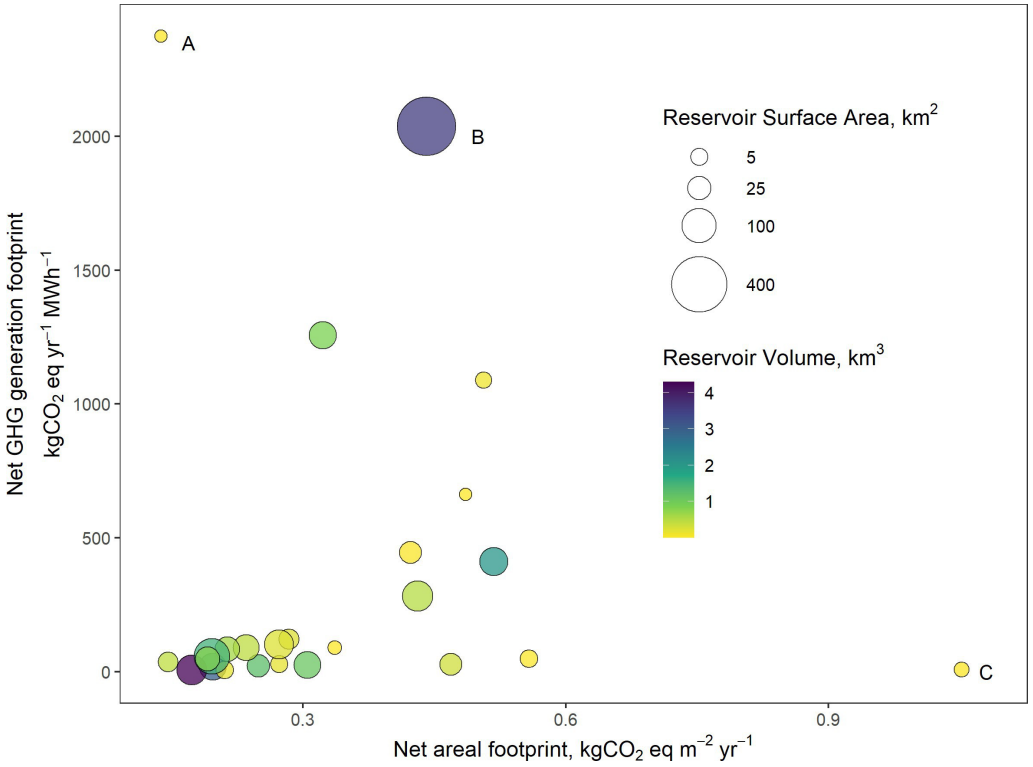


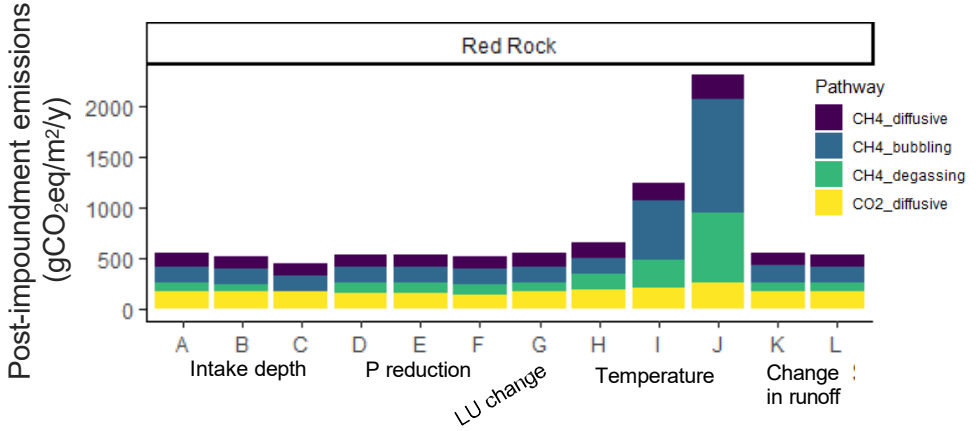


Performance: Accomplishments and Progress

Modeling Accomplishment Task:

- Evaluated the applicability of IHA's G-res modeling tool to estimate emissions from U.S. reservoirs (Hansen et al. in review):
  - Identified issue that multi-purpose nature of reservoirs complicates the narrative that emissions can be predicted by size or energy generation.
  - Demonstrated that differences in GHG emission pathways are highly individual.
- Evaluated how operations/management affect GHG emissions:
  - Emissions varied by <5% for most scenarios.
  - Challenges: drivers in G-res are independent but in reality are connected. Not all operations/reservoir management practices are represented.

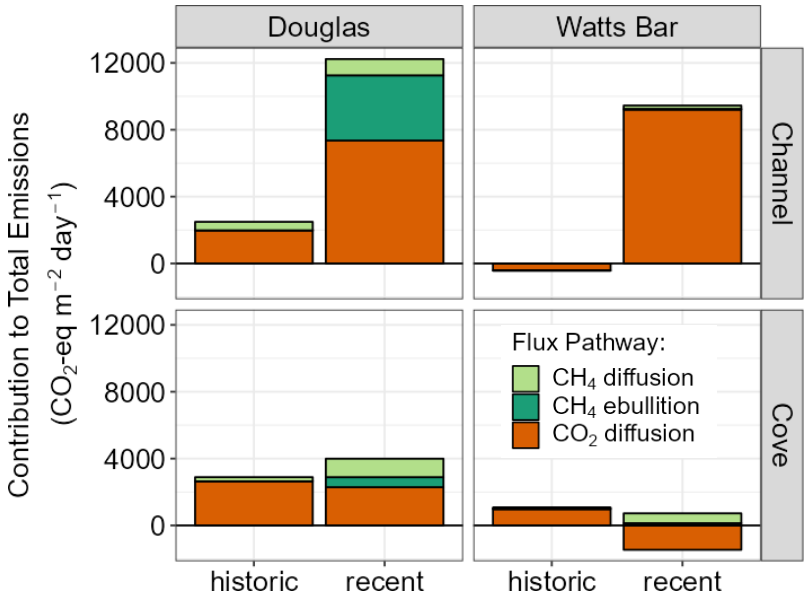




Performance: Accomplishments and Progress

Field Measurements Task:

- Initiated GHG emissions measurements via multiple pathways (diffusion, ebullition, degassing) in two reservoirs with hydropower in the southeastern U.S.
- Designed a surface-water drone platform for high-spatial resolution measurements of GHGs.
- Established collaboration with EPA's SuRGE project: national-scale survey of GHG emissions from reservoirs; sampling southeast reservoirs in 2022.

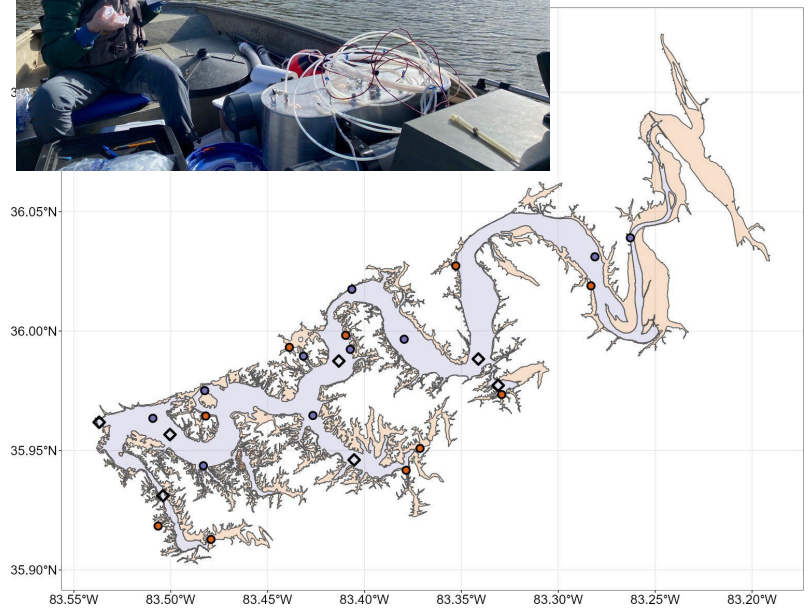


'historic' = Bevelhimer et al. 2016

Images from maritimerobotics.com, fondriest,com, ysi.com, biosonicsinc.com

Future Work

Research Plans for FY22-23:



- Synthesis and optimization:
  - Analyze how coordinated operation of reservoirs in river networks coupled with future changes may affect GHG emissions.
- Modeling:
  - Describe the range of conditions that are important for GHG production/ emission processes via G-res modeling.
  - Examine potential improvements for estimating for reservoir littoral area, a key parameter for ebullitive emissions, using remote sensing.
- Field measurements:
  - Conduct comprehensive measurements of GHG emissions in southeast U.S. reservoirs.
  - Utilize high-spatial-resolution measurements over time using traditional and novel approaches.
  - Collaborate on national-scale EPA survey; contextualize emissions from hydropower reservoirs with non-powered systems, natural lakes, rivers.
- Fieldwork poses the greatest challenges (weather, supply chain issues), requiring active management, evaluation, and adaptation.

Future Work

Next 3-5 years:

- Conduct comprehensive measurements of GHG emissions in southeastern U.S.
  - Include measurements of understudied but potentially important pathways (degassing, ebullition), locations (drawdown areas), and periods of time (water withdrawals).
- Initiate CONUS-scale assessment of GHG emissions from reservoirs to understand temporal patterns (daily, seasonal, interannual) within a regional context.
- Develop and validate novel measurement techniques.
- Move toward watershed-scale assessments of GHG emissions from reservoirs.
- Begin to assess operation-specific effects on GHG emissions.
- Assess ability of current models to upscale and explore and develop process-based models for examining mechanistic drivers of GHG production and emissions.

Reducing uncertainty in GHG emission estimates from reservoirs and understanding the role of hydropower is a large challenge that requires a long-term, coordinated research program.

Q&A