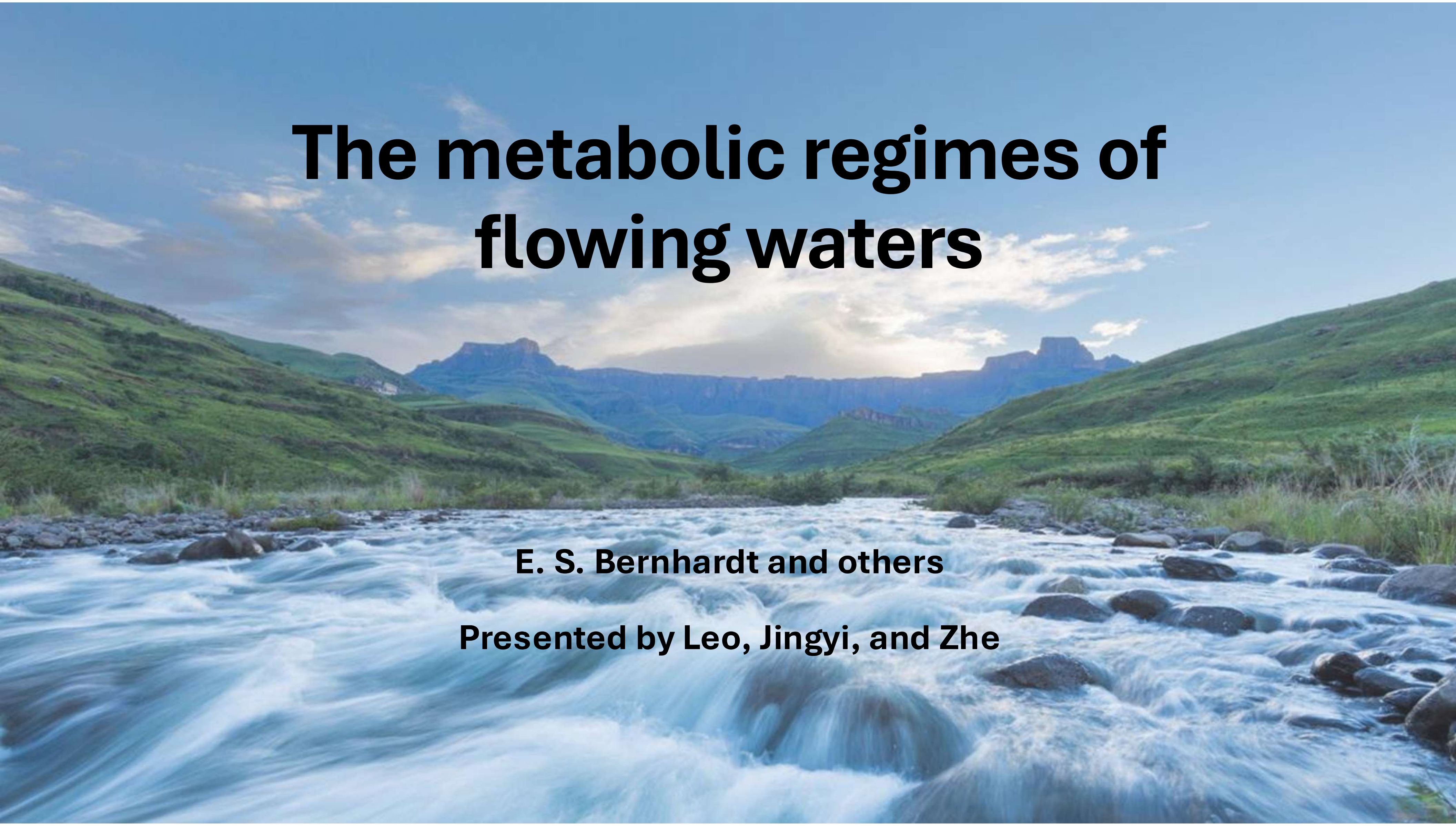
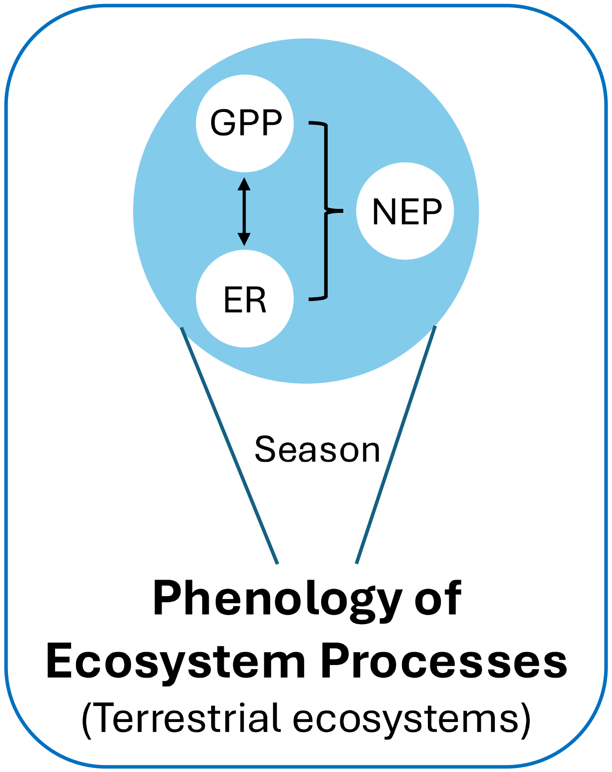


The metabolic regimes of flowing waters

E. S. Bernhardt and others

Presented by Leo, Jingyi, and Zhe



However, the correlation between climate drivers and GPP and ER is weak in river ecosystems.

Three main reasons:

Light is not correlated with temperature;

frequent high-flow events;

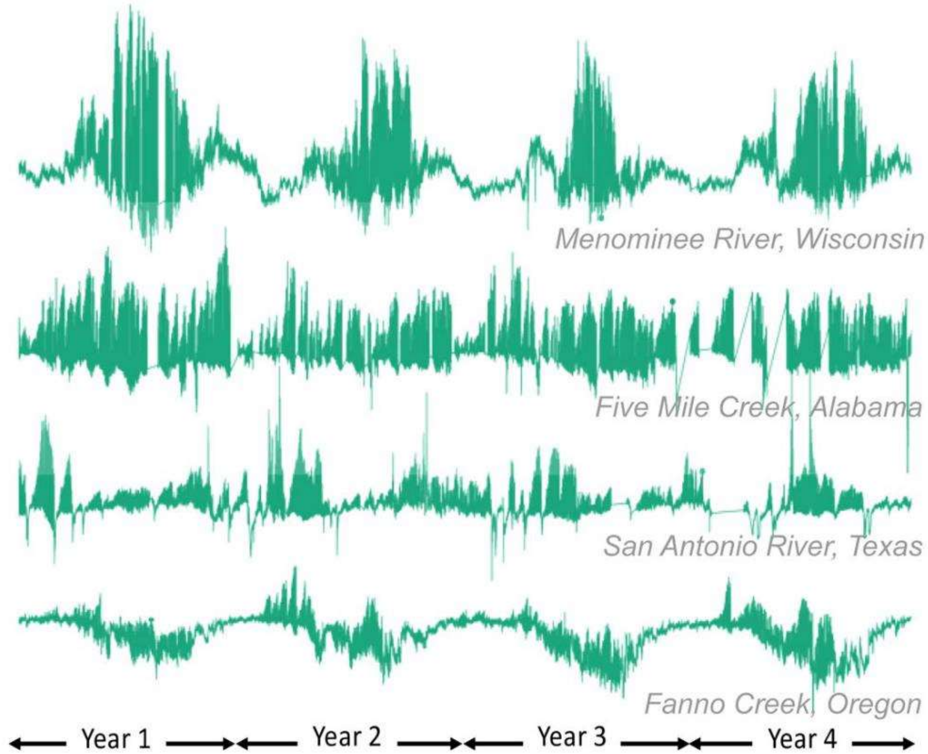
external materials input

So, it is not easy to predict river's metabolic pattern directly from climate factors

Other factors?

- 1 river size
- 2 external organic matter
- 3 Hydrological dynamics
- 4 etc..

It's hard to predict the dynamic patterns

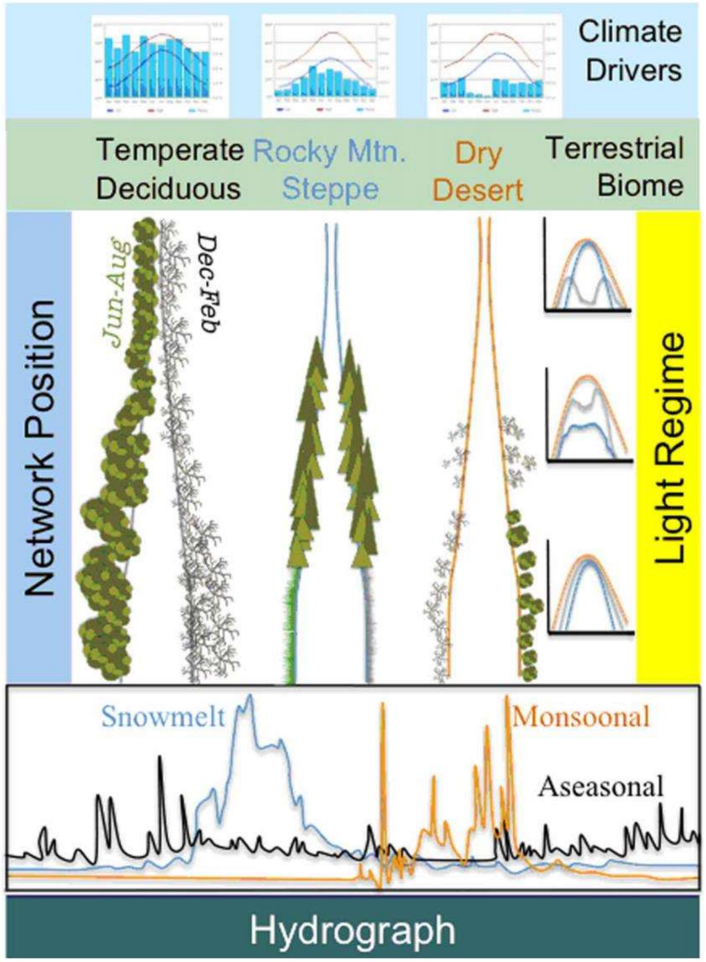


The term **'metabolic regimes'** is more appropriate than phenology to describe these patterns in river ecosystems

Metabolism

- H.T. Odum first developed the general concept of river ecosystem metabolism in 1956.
- Rivers have extremely dynamic nature of metabolism compare with other ecosystems
- Difficulty in predicting metabolic rate on daily and annual scales
- MODEL: River Continuum Concept, RCC

River Continuum Concept



Measurement

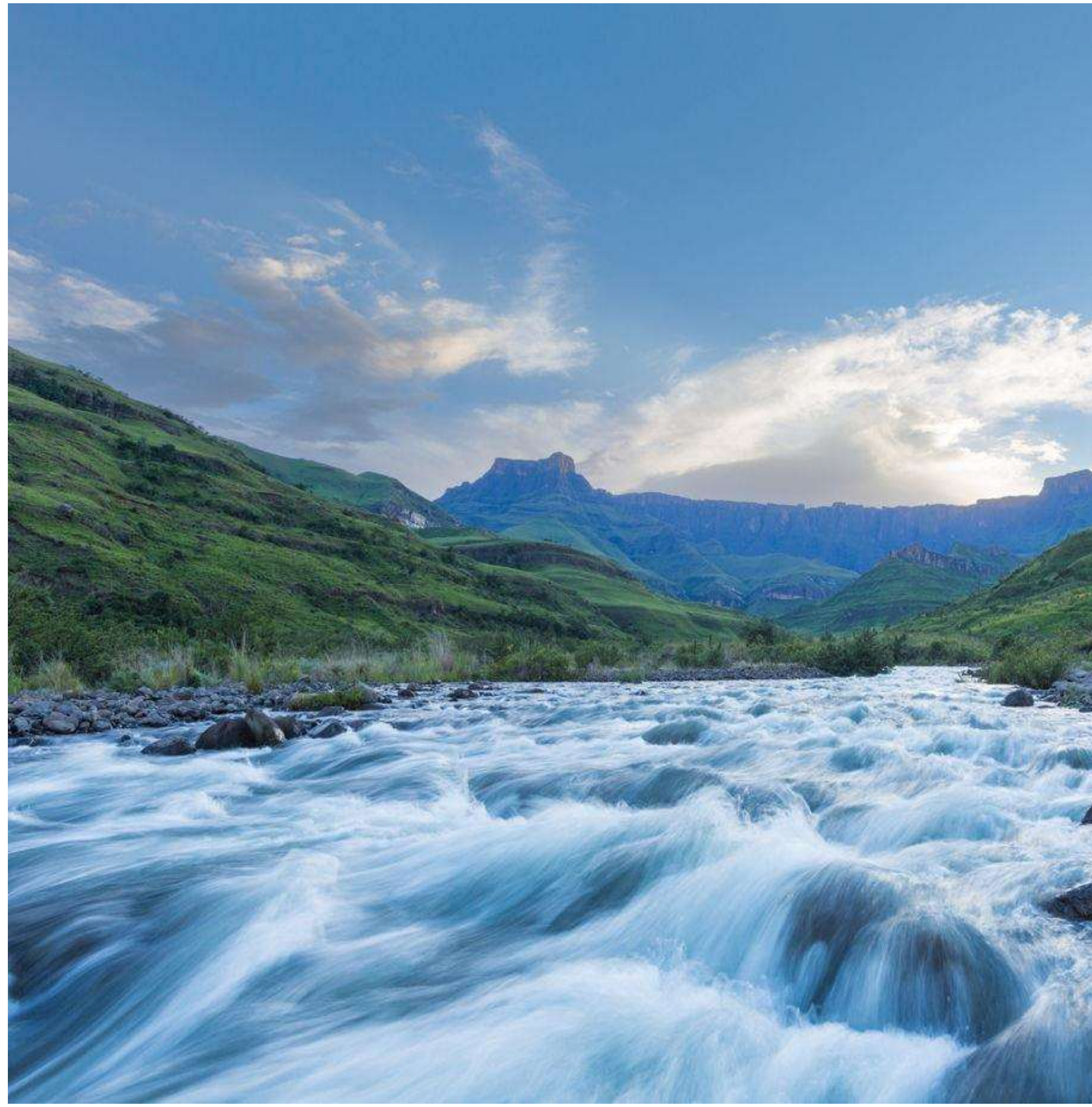
Limited success in uncovering patterns or building predictive models of river ecosystem metabolism can be attributed to the challenging combination of **technological constraints** and **the dynamic physical environment characteristic** of many rivers

- Manual measurement in early studies
- Limitations of first-generation sensors
- Sampling bias and lack of representation

With more reliable environmental sensors available today, we can better understand how river ecosystems function and address key questions:

- What controls the variation in the magnitude and timing of productivity within and among rivers?
- How are these controls changing in response to climate or land use change?
- How will resulting changes in river ecosystem productivity constrain their capacity to support freshwater biodiversity, food production, and the maintenance of water quality?

What do we know so far ?



How we measure and model river metabolism

Oxygen production

Oxygen Consumption

How fast gas exchange happens

Variation in disolved oxygen in time

$$\frac{d\mathrm{DO}}{dt} = \frac{\mathrm{GPP} + \mathrm{ER}}{z} + K(\mathrm{DO}_{\mathrm{sat}} - \mathrm{DO})$$

Mean depth

How we measure and model river metabolism

Post presentation precision : ER is a negative value here, that is removal of DO

Oxygen production

Oxygen Consumption

How fast gas exchange happens

Variation in disolved oxygen in time

$$\frac{d\mathrm{DO}}{dt} = \frac{\mathrm{GPP} + \mathrm{ER}}{z} + K(\mathrm{DO}_{sat} - \mathrm{DO})$$

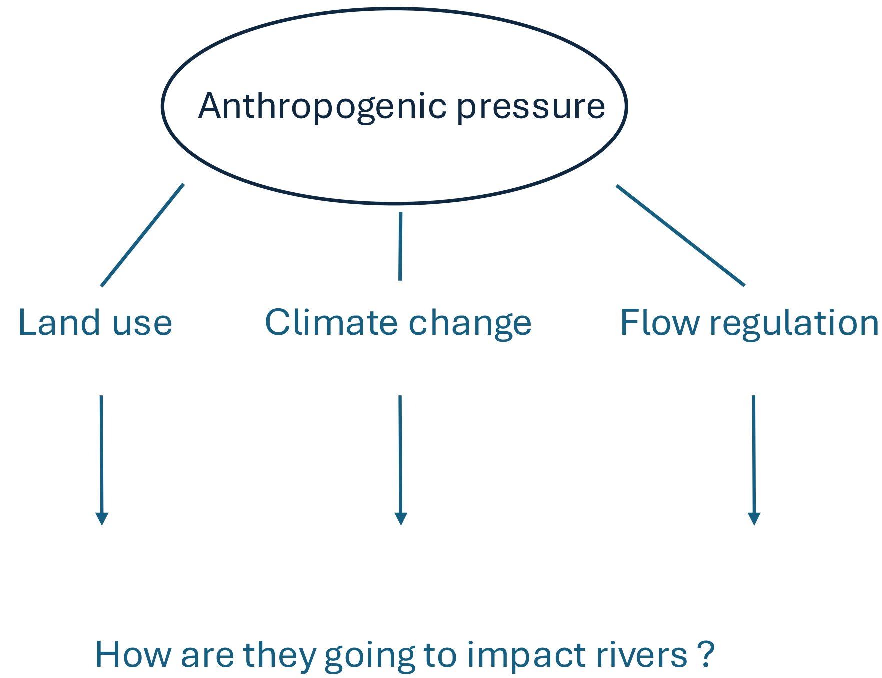
Mean depth

Important drivers :

- Light
- Turbulence
- Temperature
- Organic Matter
- Nutrients
- ...

Why are these drivers important ?

Why are these drivers important ?



The light regime of rivers

- Light recieved by the water might not be linked to terrestrial data

Shading, river orientation..

- Suspended solids, CDOM, shading and depth reduce light availability

- River size is important to determine what drives light availability

smaller streams are more sensitive to shading but larger rivers are more sensitive to light attenuation by depth or turbidity

Disturbance regime

- GPP highest in slow flowing and clear water
- Is the flood event causing bed disturbance ?
- Mobile substrates don't accumulate benthic biomass

smaller streams can have a productive benthic layer (sensitivity to moving bed events), whereas larger ones might not have light reach the deepest layers (sensitivity to turbidity)

The thermal regime of rivers

- Thermal regime not necessarily correlated to terrestrial data but follows seasonal variations
- River size inversely proportional to it's sensitivity
- ER is more sensitive to temperature change than GPP

Global Trajectories

Drivers of Metabolism	GLOBAL WARMING	LAND USE CHANGE	FLOW REGULATION
LIGHT REGIME	• Longer ice free period • Earlier leaf out • Later leaf fall	• Increased Sediment Load • Reduced Riparian Shading	• Reduced Sediment Load • Altered water depth • Altered riparian vegetation
THERMAL REGIME	Higher mean annual temperature	• Reduced Riparian Shading • Channel incision enhances bank shading	• Hypolimnetic release alters natural thermal regime • Retention in shallow basins raises temperatures
FLOW REGIME	• Increasing Drought Severity • Altered timing of Floods • Earlier, reduced snowmelt	• Stormwaters & Tile Drainage Increase Flood Frequency & Magnitude of Peak Flows • Withdrawals reduce baseflow • Leaks enhance baseflow	Hydropeaking increases frequency and magnitude of flood peaks Dams alter timing of seasonal floods and change baseflows

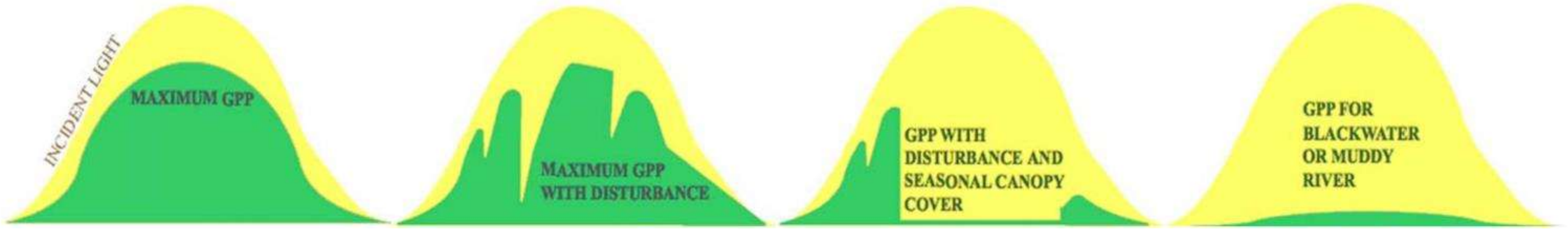
Allochtonous carbon and river metabolism

- Carbon arrives in pulses from external sources
- These pulses can be predictable (for annual patterns)

  or unpredictable (like during floods or during natural catastrophes)
- Floods mobilize and bury organic matter, which can decouple ER and GPP

Annual patterns of river metabolism

- Rivers can have annual patterns of GPP and ER
- Rythm and structure of these patterns can indicate what are the primary drivers
- Knowing the primary drivers of a river can help understand effects of anthropogenic activities



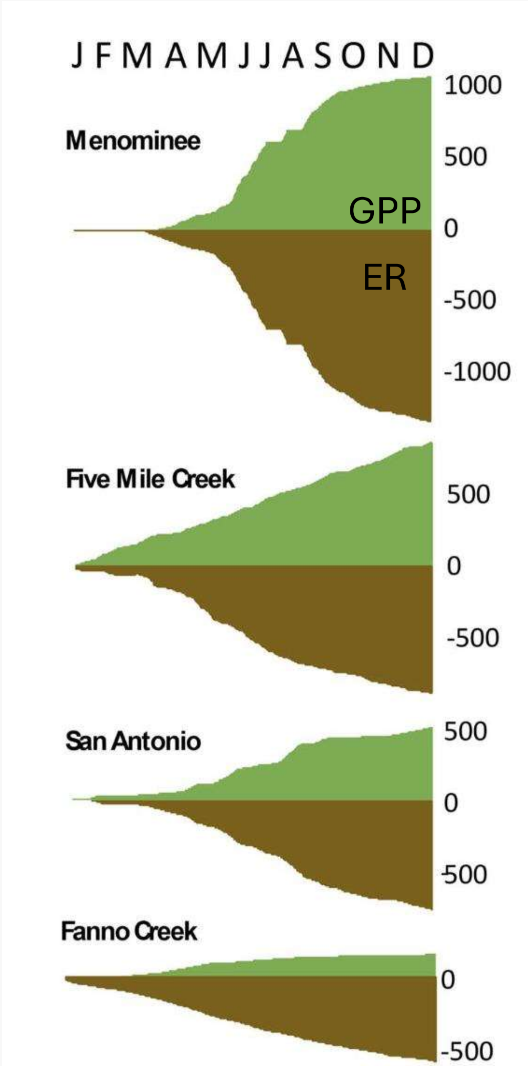
Frontiers

FRONTIER # 1 Linking metabolic regimes and organismal phenology

- **Ecosystem Metabolism**:
  - **GPP** and **ER** peak when resources and producer biomass are abundant.
- **Flow and Foodweb**:
  - **Seasonal or annual shift in resource supply** influence consumer life history, biomass and diversity
  - **Disturbances and flow** have disproportionate effect, both autotrophs and heterotrophs food webs.

Expectations:

1. Widespread measurement → seasonal patterns of energy production and dissipation.
2. Modeling → predict the likely consequences of climate and land use changes.



High accumulation only in summer

Uniform GPP

Alternating high and very low productivity

Low GPP year-round

Cumulative annual metabolism of four rivers

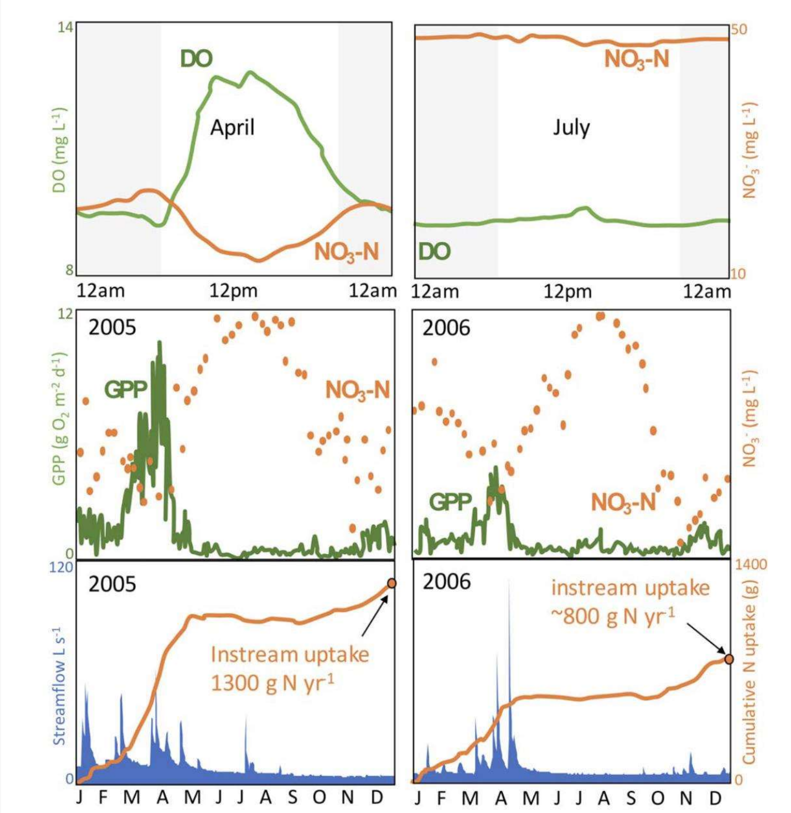
FRONTIER # 2 Coupling energetics and element cycling

Fine-scale and temporal variation in river biogeochemistry:

1. Diel oscillations in a wide range of solutes
2. Physical dynamics of transport
3. Sampling locations (local control by in-stream processes)

Expectations:
1. Experiments + Sensors → estimate whole system and specific biogeochemical processes.

2. Integrative, ecosystem-level models that link metabolic, biogeochemical, and hydrologic processes within rivers.



e.g., upper: diel GPP variation drive in NO_3- oscillations and annual variation; middle and lower: seasonal variation and events (e.g., larger spring algal blooms) accounts for N uptake. From Walker Branch watershed. *Method: high-frequency continuous monitoring*

FRONTIER # 3 River metabolism for diagnosis and management

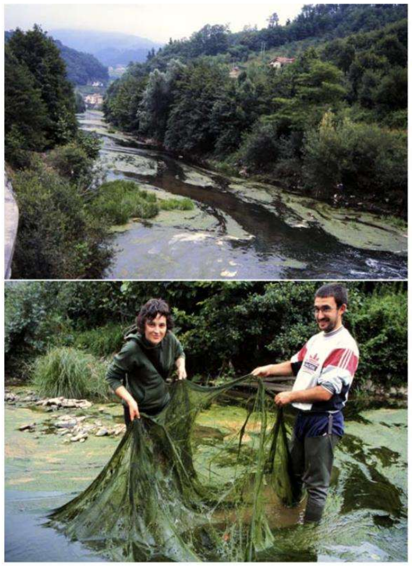
Basal metabolism constrains can be repurposed to provide real time, continuous measures of ecosystem function.

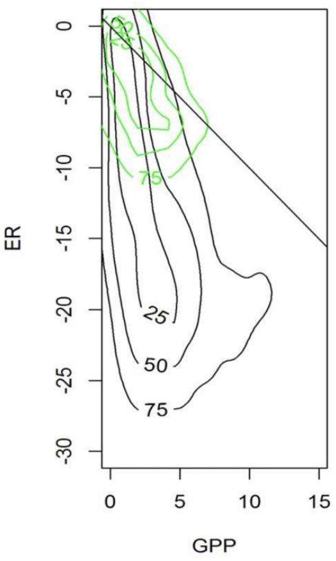
A new diagnostic tool:
The metabolic fingerprint

Will helping:

1. discover recognizable clusters of river metabolic regimes,
2. determine the alteration by pollution, flow regulation or climate change,
3. evaluate the effectiveness of intervention.

How the metabolic "fingerprint" can serve as both a sensitive detector and a clear outreach tool :





Before treatment:

High organic matter, high ammonium, high ER, hyperoxic during day, but hypoxia at night

After Treatment:

Declined pollutants, lower ammonium, reduced GPP and ER, normal and consistent O_2

e.g., The Oria River and its metabolic fingerprint before (black) and after (green) wastewater treatment.

Conclusion

- Current Challenges in River Metabolism Research
- The Need for Annual-Scale Studies
- Impacts of Climate and Land Use Changes
- Prioritizing River Metabolism in Management
- Advances in Technology and Theory
- Transition to Annualized and Scalable Models and Prediction


Thanks for your attention!