Multi-Scale, Sensor-Based Net Daily Metabolism Estimates in Streams, Lakes, and Coastal Waters: Master Variable of Aquatic Ecosystem Changes?

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Introduction: Is the Timing Right for a Unifying Effort on Aquatic Metabolism Rate Estimates?

Methods for using dissolved oxygen (DO) and temperature time series data to estimate the gross primary production (GPP) and community respiration (CR) in aquatic systems evolved over the past 50 years in the fields of stream ecology, limnology and ocean science. These estimates can be ambiguous and difficult to compare for different locations. However, if adequately standardized, they may very well be useful for assessing the status of and changes in stream ecosystems in the context of a watershed management and coastal water quality management. It may then be worthwhile to consider developing tools for comparing GPP/CR rate estimates for water quality monitoring stations in streams/river, lakes, and oceans around the world. This brief statement discusses the motivation for such a monitoring network, and some of the collaborative tool development which might expedite such comparisons. As we grow adept at collecting, analyzing and interpreting local time series data, we need to identify relevant remote sensing platforms and schemes for integrating in-situ and remote sensing data to arrive at metabolism estimates accurate over larger spatial scales relevant to watershed and coastal stakeholders and policy-makers.

Local Metabolism Estimates: Can We Automate Cross-Site Comparisons?

Methods for estimating rates of aquatic photosynthesis (GPP) and CR locally are readily implemented using the time series data generated by dissolved oxygen and temperature sensors deployed at river gauging stations or buoys in lakes or oceans. However, the pathway from streaming data to valid metabolism estimates is a long one, bogged down by myriad manual and routine data analysis processes. Scientists spend significant time collecting data in the field and preparing it to be useful for running computational models encapsulating their concepts of flow, chemistry and biology. When the raw data is transmitted or brought back to the lab, it needs to be checked for consistency and anomalies. For example, data filtering is generally needed to remove noise and spurious data points or sometimes sensor calibration drift necessitates systematic adjustment of the data. Without these quality control steps, the data would bias any data analysis, such as that using simulation models.

Even when the data are ready for analysis, there remain multiple modeling approaches to choose from, particularly with respect to physical reaeration (air-water oxygen transfer) and community respiration components of the metabolism calculations. In effect, the scientific process here-- hypothesize, observe, analyze, interpret—can take so long that the best we can achieve are *post priori* interpretations of metabolism. Furthermore, in uncontrolled (real) systems, we often learned only late in the analysis part of the cycle that our experiment has failed due to unexpected changes in river flow or water chemistry.

Lastly, as if managing the data transfers across individual tools and models were not challenging and time consuming enough, metadata is often poorly managed and laborious to integrate into the analysis. Key metadata is often archived locally by key investigators but not moved along with the data throughout the scientific process. Metadata for analytic results is not ever created. What are needed are integrated environments for managing end-to-end analysis that offer a comprehensive treatment of metadata throughout the processes.

The time-lag between sensor observations and their interpretation make it difficult for researchers to discover the cause and effect links between different drivers (e.g., climate and land use change) and the aquatic ecosystem function on a timescale less than years, or even decades. By automating and compressing the life cycle of data collection, integration, and analysis, and incorporating a comprehensive metatdata treatment scheme throughout the life cycle, we achieve the goal of rapid cross-site comparison of local PP and CR estimates.

Scaling Up Metabolism Estimates: Can We Integrate In-Situ and Remote Sensing Data?

Local sensor data may also include optical sensing data, such as chlorophyll-a (fluorometry), turbidity (light scattering), or (less commonly) in-situ imaging spectrometer sensors which can be used to as ground-truth data for aerial or satellite remote sensing data, including the AVIRIS sensor. Depending on the aircraft, the AVIRIS data can be acquired at spatial resolutions of 4 to 20 m. Although admittedly challenging, this suggests that linkages may be identifiable between local and larger scale maps keyed primary production may be possible.

One obviously major challenge to inferring a dynamic process like a metabolic rate from remote sensing data products is the lack of temporal coverage in the remote sensing data product. It may be possible to bridge this temporal gap through the planned excursions of autonomous underwater vehicles (AUVs) which could recirculate through the remote sensing footprint to provide some time series data for multiple locations. It is not clear, however, that this would be sufficient coverage. Investigating links between local primary production rate estimates and other imaging spectrometry techniques may be more fruitful.