German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig
Puschstraße 4, 04103 Leipzig, Germany

sDiv working group meeting report

"sPectra 1"

Working group meeting report

The sPectra group had its first meeting at iDiv from May 27 to 31, 2024. We focused on describing and interpreting the major dimensions of variation in plant reflectance spectra—the signatures of light's reflectance from vegetation across wavelengths. Increasingly, reflectance spectroscopy is used to rapidly phenotype vegetation function, including at landscape scales via remote sensing. Decades of research have elucidated the most important determinants of plant reflectance spectra, but other aspects of plant function are likely to have a more subtle and diffuse influence. Rather than treat spectra just as a tool for estimating functional traits, we proposed to identify major dimensions of spectral variation—at both leaf and landscape scales—and link them to traits afterward. In this way, we might find, for example, that there are dimensions of spectral variation that may appear to be ecologically important without clearly relating to the most well-studied functional traits. We also wanted to examine the feasibility of using plant reflectance spectra directly to address questions about plant community assembly at global scales.

We spent some time on the first day introducing ourselves and getting to know each other. After introductions, PI Shan Kothari gave a whiteboard talk on the idea described in the proposal and its conceptual basis, and PI Teja Kattenborn gave a presentation on methods of dimensionality reduction, which play a central role in the proposed project. These presentations were each followed by intense discussions, which continued into the afternoon. Group members all had some experience with reflectance spectroscopy—albeit at varying scales and in varying ecosystems—so although our scientific backgrounds differed in other ways, we found it relatively easy to establish a common language to discuss our ideas.

Although our original plan was to conduct analyses at the leaf scale at the first meeting and the canopy scale at the second meeting, we ended up deciding to work at both scales in parallel. At the canopy scale, we took advantage of a synthesis dataset of spectra, measured traits, and metadata whose curation had been led in large part by a couple of our group members. At the leaf scale, no such synthesis dataset was readily available, so we resolved to build one from scratch.

We spent much of the second and third days of the meeting in breakout groups, alternating with a few full-group discussions for groups to update each other. About half of us focused on the leaf data synthesis, setting guidelines to ensure that data would be comparable and trying to cobble together a preliminary (but still broadly representative) synthesis dataset to pass on to the second group. By the third day, we had enough datasets compiled in a standardized form for the second group to carry out preliminary analyses. The complete leaf data synthesis remains ongoing.

The second group focused on reducing the dimensionality of the spectral dataset using linear and non-linear methods—principal components analysis and variational autoencoders, respectively. We tried both because we considered it uncertain at the outset, and possibly

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empirically testable, whether linear methods would be suitable for capturing the structure of covariance within spectral datasets. The group began with the canopy data, since they had already been compiled, and incorporated the leaf data once enough had been compiled to yield plausible results. The group succeeded in creating preliminary embeddings in low-dimensional space using both methods, which could be passed on to the third group. Methods for the variational autoencoders are still being refined.

The third group focused on using multivariate statistics and visualizations to interpret the major dimensions of spectral variation. These early analyses have revealed that spectral data are inherently complex and multidimensional, and their underlying dimensions do not always map neatly onto traits. However, there is clearly strong ecological structure in the spectral data, which we are continuing to explore. This group has continued to make tremendous progress since the meeting, trying out new and creative ways to show the complex links between the spectral, trait, and environmental data.

By the end of the week, we emerged with the outline of a first manuscript with several preliminary figures, which we plan to flesh out within the coming months. At the end of the meeting, we planned out a timeline for the next year and delegated various responsibilities. Most importantly, we agreed to aim to complete a first manuscript draft by November—and ambitious goal meant to induce us to keep up our momentum.

We owe a great debt to sDiv, not just for our travel but for continual support throughout the week, including tech support, food, and childcare. This support afforded us the opportunity to get straight to work thinking about, discussing, and implementing our ideas. We certainly could not have made nearly as much progress without it. We also had two members joining online, and the presence of 360° cameras and other AV equipment streamlined their participation as much as possible. Many thanks are due to Luise Dietel and Marten Winter for their advice and organizational savvy.

The second sPectra meeting is being scheduled now and will occur sometime in 2025. If we manage to achieve our goal of having a manuscript draft complete (and perhaps even submitted) well in advance of the meeting, we could take this second meeting to discuss further analyses that could deepen the insights from the first manuscript. We also hope to start developing an application for researchers to explore the major dimensions of spectral variation for themselves.

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