Representativeness-Based Sampling Network Design and Scaling Strategies for Measurements in Arctic and Tropical Ecosystems

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Resource and logistical constraints limit the frequency and extent of environmental observations, particularly in the Arctic, necessitating the development of a systematic sampling strategy to maximize coverage and objectively represent environmental variability at desired scales. Required is a quantitative methodology for stratifying sampling domains, informing site selection, and determining the representativeness of measurement sites and networks. Multivariate spatiotemporal clustering was applied to down-scaled general circulation model results and data for the State of Alaska at 2 km x 2 km resolution to define multiple sets of bioclimatic ecoregions across two decadal time periods. Maps of ecoregions for the present (2000-2009) and future (2090-2099) were produced, showing how combinations of 37 bioclimatic characteristics are distributed and how they may shift in the future. Representative sampling locations are identified on present and future ecoregion maps. A representativeness metric was developed, and representativeness maps for eight candidate sampling locations were produced. This metric was used to characterize the environmental similarity of each site. This analysis provides model-inspired insights into optimal sampling strategies, offers a framework for up-scaling measurements, and provides a down-scaling approach for integration of models and measurements. These techniques can be applied at different spatial and temporal scales to meet the needs of individual measurement campaigns.

For example, we recently applied this methodology to remotely sensed LiDAR measurements and multi-spectral imagery from the WorldView-2 satellite at a resolution of 2.3 square meters within the Barrow Environmental Observatory (BEO). At this resolution, polygonal ground features--such as centers, edges, rims, and troughs--can be distinguished. Using vegetation distribution data collected at these polygonal ground features, we scaled these measurements to a section of the BEO, where the Next Generation Ecosystem Experiment-Arctic (NGEE Arctic) is making other intensive measurements and performing multi-scale modeling experiments. The resulting map provides distributions of plant functional types (PFTs) that can be used in intermediate- and climate-scale models, as well as providing a basis for up-scaling other measurements. In addition, we are using a similar technique to quantify the representativeness of soil cores and other samples collected within the same area of the BEO to inform future sampling campaigns. Finally, we are applying the representativeness methodology at a coarser spatial resolution to identify poorly sampled regions of global tropical forests. Such areas could be the subject of future intensive observational campaigns because of their importance to the global carbon cycle and their poor representation within current Earth system models.