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Overcoming Big Data Challenges in Satellite Observation: A Variable Resolution Scheme for Modeling Land Surface Phenology

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As the volume of satellite observation data experiences exponential growth, our ability to process this data and extract meaningful insights is struggling to keep pace. This challenge is particularly pronounced when dealing with dynamic and variable phenomena across diverse spatiotemporal scales. Achieving accurate representation of these nuances necessitates data generation at high spatial and temporal resolutions, resulting in significant redundancy in computation and storage.

This issue is notably evident in the case of products that monitor plant phenology over time, which are crucial for assessing the impacts of climate change and monitoring agriculture. Computational complexities often limit these products to coarse resolutions (500m-1km) or short time frames, distorting our understanding of phenology across scales. In contrast, various approaches in hydrology and land surface modeling have utilized tiled grids and meshes to capture spatial heterogeneity and reduce dimensionality for complex modeling. This is accomplished through decomposing or aggregating modeling surfaces into response units representative of system drivers and have been shown to enable improved computational capabilities while still maintaining accurate approximations. We believe that similar modeling techniques can be leveraged to enable phenological modeling at higher resolutions.

Building on these advancements, we develop a variable resolution scheme to represent land surface heterogeneity for modeling Land Surface Phenology (LSP) and decompose Landsat and Sentinel-2 Enhanced Vegetation Index (EVI) into adaptive areal units. Through this method we operationalize the Bayesian Land Surface Phenology (BLSP) model, a hierarchical Bayesian algorithm capable of constructing LSP data for the complete Landsat archive. While BLSP produces highly valuable results, it faces computational challenges for large-scale applications as its current time series approach necessitates each pixel to be computed individually. Our innovative approach reduces the dimensionality of modeling LSP by an order of magnitude to improve computational efficiency and enable the production of a 30 m BLSP product. These improvements are key to provide a region wide long-term phenometrics product at 30m resolution necessary to support studies into the long-term changes at a fine scale.