Integrating Physical and Remote Sensing Models to Map Inundation at High Spatial and Temporal Resolution

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Biogeochemical processes are strongly influenced by hydrology, particularly in coastal wetlands where drastic changes in inundated and hydrologically connected areas occur over short time scales. Wetlands are vital to carbon sequestration and are known hotspots of methane (CH_4) emissions when inundated. Being able to map these short-term, and possibly small-scale inundation events is therefore a critical component in accurately quantifying global biogeochemical cycles. Current remote sensing products are neither spatially nor temporally sufficient to accurately map such ephemeral inundation extents. Moreover, optical remote sensing alone usually underestimates inundation occurring under closed forest canopies. Our study created high spatiotemporal resolution inundation probabilities (daily, 10-m) in a forested, coastal wetland area by integrating predictions from a multi-source remote sensing model with the physically-based, distributed hydrologic model PIHM-Wetland. A random forest model was used to classify inundation with a suite of spectral signals obtained from Landsats 8-9 and Sentinel-2 imagery, Sentinel-1 SAR VV backscatter, and terrain-derived features as predictors. PIHM-Wetland and remotely sensed estimates of inundation state were integrated using a Kalman filter-based approach that estimates a posterior inundation probability via uncertainty-weighted averaging. An advantage of this method is the ability for PIHM-Wetland estimates to be favored in places or at times that lack remote sensing observations (e.g., under closed vegetation canopies or during times of cloud cover). This method was used to map daily inundation for coastal wetlands within the Albemarle-Pamlico Peninsula, a 5,020 km^2 region in North Carolina, United States, from 2015 to 2021 and validated with in-situ measurements. Preliminary results suggest improvement in inundation accuracy over using a single model alone, especially in densely forested portions of our study area. With the anticipation of sea-level rise and climatic variation, this novel integration scheme provides a method to capture transient inundation events in any coastal wetland, providing a crucial step forward in quantifying components of the water cycle and their interactions with biogeochemical cycles on earth.