Re: This letter expresses our intent entering competition for NOAA OAR Weather Program Office Funding Opportunity Number: NOAA-OAR-WPO-2025-28603

(1) Title: Advancing surface-atmosphere exchange using novel land surface data, sub-canopy processes, and dynamic emissions to improve UFS weather and air quality predictions.

(2) Investigators: PI: Dr. Patrick Campbell (GMU), Co-I Irena Ivanova (GMU), Co-I Wei-Ting Hung (GMU). Federal Collaborators: Dr. Paul Makar (ECCC), Dr. Barry Baker (NOAA-ARL), Dr. Rick Saylor (NOAA-ARL), and Dr. Helin Wei (NOAA-EMC).

(3) Competition: 11.459, Weather and Air Quality Research. AQRF-1, AQRF-3, and AQRF-6.

(4) Statement of the problem: NOAA's Unified Forecast System (UFS) weather and atmospheric chemistry and composition (ACC) models are inconsistent in the treatments of the dynamic surface-atmosphere exchange processes that govern coupled weather and air quality predictions. Due to recent efforts NOAA's UFS-Air Quality Model (AQM) is now poised to move beyond prescribing many surface-atmosphere-exchange processes and the widely used assumption of a single layer of combined vegetation and soil (the "big-leaf " approach) in its coupled land, atmosphere, and chemical components. Moving to more realistic satellite-based land/surface data inputs with more unified, dynamic surface-atmosphere exchange processes including vegetative sub-canopy processes that are linked to critical emissions sources will have stark implications for *both* UFS weather and air quality predictions.

(5) Methodologies: We will develop and advance global, high-resolution surface/canopy datasets with Co-I Hung for the UFS using satellite data, in-situ surface observations, and machine learning to derive both observable and non-observable quantities essential for unifying UFS land, weather, and air quality components. These will form novel global, 1-km gridded land surface and canopy data products used across operational and experimental/research UFS weather and air quality applications. We will also advance the development and implementation of explicit, but efficient vegetative sub-canopy processes with Co-I Ivanova that more consistently impact the UFS physics and chemical components. These advanced surface/canopy datasets and unified, dynamic atmosphere-surface exchange with sub-canopy processes will be integrated as products in the UFS-AQM using a multi-faceted approach. This approach will use inline UFS physics/chemistry codes, NOAA-ARL's canopy-app model, and the inline NOAA Emission and Exchange Unified System (NEXUS) that is used in the current operational UFS-AQM. These new canopy data and model products will be tested, constrained, and evaluated in the UFS for implications on regional weather and air quality predictions.

(6) Tasks, products, and outcomes:

Year 1: Development and application of high-resolution land surface datasets. We will advance the satellite-based Global Land Surface Datasets (GLSDs) for the UFS by using in-situ surface observations and machine learning to derive both observable and non-observable quantities. The GLSDs will include observed parameters based on various operational satellite measurements (e.g. MODIS, VIIRS and GEDI), including land surface/vegetation type, vegetation fraction, vegetation canopy height, leaf area index, vegetation clumping index, and vertical plant area volume density profiles. Critical processing steps are needed to more accurately extend these surface parameters for full global coverage, as well as gap-filling within data points that are not available or not specifically designed for use within the UFS. We will further extend this dataset to non-observable parameters such as surface roughness length (z0) and displacement height (d). Use of the global satellite vegetation datasets and ground flux observations will be analyzed using AI approaches to further derive z0 and d. All datasets will share a universal global gridded coordinate with a spatial resolution of 0.01° (~ 1 km).

Year 2: Development and application of dynamic surface-atmosphere exchange. We will advance the development and application of explicit, but efficient sub-canopy processes (e.g., forest shading/photolysis and vertical transport/diffusivity) as unified parameterizations across both chemical and physics components, including the UFS-AQM's future Noah-MP LSM. This includes explicit, vegetative sub-canopy impacts on downward shortwave radiation through forests and the effects on canopy resistances, exchange coefficients, and overall tracer and heat/moisture/momentum fluxes governing near-surface atmospheric temperature, humidity, wind speed, and composition. These efforts will be extended to NOAA-ARL's novel, stand-alone "canopy-app" model and further interface with NEXUS and/or CCPP to impact unified surface-atmosphere exchange processes like novel leaf-scale biogenic emissions, wildfire behavior and emissions, dust emissions, and other related capabilities in the UFS. The products will be developed for the current operational regional air quality model (e.g., UFS-AQM), as well as next-generation global UFS-ACC applications (e.g., UFS CATChem).

Year 3: Evaluation of improved surface-atmosphere exchange and air quality predictions. The advanced satellite-based GLSDs, explicit sub-canopy processes, and dynamic surface-atmosphere exchange processes and products will be systematically tested for regional applications of the UFS-AQM, and will be comprehensively evaluated (for all seasons' vegetation/soil properties) against column-, profile-, and ground-based weather and air quality observations including NOAA's Melodies-MONET system.

(7) Approximate budget table (per year): Total 3 years at $350,000/year = $1,050,000.

	Salaries + Fringe	*Indirect Costs*	*Computing + Supplies*	*Travel*	*Total*
PI: Dr. Patrick Campbell (GMU)	$35K	$30K	$10 K	$5K	$80K
Two Co-Is (GMU)	$190K	$60K	$10K	$10K	$270K

(8) Relevance and technology transfer: The GLSDs and explicit sub-canopy developments with dynamic surface-atmosphere exchange processes are critically needed to improve the UFS-AQM and future UFS-ACC applications. This project addresses AQRF-1, AQRF-3, and AQRF-6 priorities related to 1) development of high resolution modeling capabilities including local phenomena and high resolution surface/vegetation data for the UFS, 2) fine scale sub-canopy and surface-atmosphere exchange processes across the soil/vegetation/urban interfaces that more directly couples the UFS-AQM and LSM, and 3) improving spatiotemporal estimates of dynamic, natural-source emissions, impacts, and improved constraints and evaluation with intensive flux sites and field campaigns. The Readiness Level (RL) is currently at 5-6 (based on preliminary GLSDs, developments of sub-canopy processes in UFS-AQM, and the stand-alone canopy-app model), and the expected RL at project completion is 8-9. We note that a NOAA transition plan has been successfully developed and approved by PI Campbell for an earlier work (FY22 WPO) of including sub-canopy processes and satellite canopy data in the UFS-AQM. The proposed developments will leverage available NOAA and GMU computer resources with all data and codes available at NOAA ARL's GitHub page and NCEI. Primary end-users of these products include NOAA-EMC and the operational UFS-AQM, experimental next-generation UFS-ACC systems and NOAA developers, and the broader weather and air quality modeling research communities.