Despite hundreds of thousands of reference-grade weather stations and multiple satellite observing systems, reliable sub-kilometer observations and forecasts for day-to-day decisions remain scarce. The gaps arise from uneven ground coverage, scale mismatch between models and local processes, limited uncertainty calibration, and the absence of real-time methods to fuse heterogeneous observing systems.

This seminar presents a hybrid observing and modeling framework that synchronizes satellite retrievals with a sparse, high-quality reference grid, then fuses these data with numerical prediction and machine learning to produce analyses, nowcasts, and multi-day forecasts for agricultural decision support. At Washington State University's AgWeatherNet (the Pacific Northwest Mesonet), we developed station-specific hourly forecasts to ten days by combining HRRR, GEFS, and NBM with observations for more than 190 sites. These models improved accuracy by 35 to 81 percent over baseline services for key variables such as temperature and dew point, driving several agricultural decision aid tools for heat stress, frost, spray timing, and pest and disease risk. In collaboration with the Department of Atmospheric Sciences at the University of Washington, we further implemented a bias-corrected 1.33 km virtual weather grid to extend guidance into non-instrumented regions. The pipeline was built on robust sensing: proximal thermal-RGB imaging, UAV-based vertical profiling, and IoT networks for site-specific frost mitigation. Ongoing work extends horizons to 21 days and layers decision models on top of the ten-day station forecasts and mesonet observations.
For example: 1. High resolution gridded evapotranspiration models (OpenET) based irrigation guidance is being regionally calibrated and made more accurate, and
2. EO satellite products integrated for farm specific crop nutrient-management.
Outcomes of above attempts indicated that a minimal but reference-grade network, synchronized with satellites and fused with models, can deliver verifiable, operational local fields and forecasts. The path forward is to establish such reference mesonets with strict quality control, add targeted atmospheric profiling with tethered UAVs and balloons, run edge compute for time alignment and first-stage bias correction, and assimilate satellite, station, and model fields into calibrated probabilistic products, including virtual stations for poorly instrumented areas. The same methods can underpin decision tools beyond agriculture, including air-quality nowcasts, urban heat and fog

guidance, and distributed-energy forecasting for grid operations. Although the primary case studies come from the U.S.
Pacific Northwest, the underlying design principles are directly transferable to monsoon- dominated tropical regions such as India, where sparse but well-calibrated reference networks, coupled with satellites and models, can unlock reliable hyperlocal guidance for agriculture, cities, and energy systems.