South Dakota NASA EPSCoR FY2024 Major Research Grant
(Approved for a three-year project)

South Dakota investigator(s) and affiliation	Project title	Funding summary	NASA and Other Collaborators
• Admin. PI at SDSM&T: **Edward F. Duke**, Director SD NASA EPSCoR • Co-I at SDSMT: **Randy Hoover** • Co-I, Science PI at SDSU: **Hankui Zhang** • Co-I's at SDSU: **Maitiniyazi Maimaitijiang**, • Co-I's at OLC: **Dana Gehring**, **Charles Tinnant**	SMD: High Spatial-Temporal Resolution Soil Moisture Retrieval using Deep Learning Fusion of Multimodal Satellite Datastreams	**$750,000** (NASA) **$375,000** (Match)	• NASA Jet Propulsion Laboratory: **Cathleen Jones**, **Simon Yueh** • NASA Goddard Space Flight Center: **Junchang Ju** • Nave Analytics, Inc.: **Val Kovalsky** • Advanced Remote Sensing, Inc.: **David Groeneveld** • USGS EROS: **Gabriel Senay**

Project Summary

SMD: High Spatial-Temporal Resolution Soil Moisture Retrieval using Deep Learning Fusion of Multimodal Satellite Datastreams

Soil moisture measurement is essential for understanding Earth's water cycle, enhancing weather forecasting, undertaking agricultural management, and contributing to our understanding of climate change, ecosystems, and biodiversity. Existing soil moisture data products (e.g., NASA Soil Moisture Active Passive (SMAP) and downscaled SMAP-Sentinel-1 products) typically have low spatial resolution (≥1 km) and relatively high temporal resolution (~3-day revisit). These data cannot meet the 200-m resolution soil moisture requirement identified recently by the NASA Satellite Needs Working Group for a range of applications such as datadriven agriculture management, regional hydrological models, and drought, wildfire, and flood monitoring. This project will leverage new synthetic aperture radar (SAR) data from the soon-to-be-launched (Q1 2024) NASA-Indian Space Research Organization (ISRO) SAR Mission (NISAR) and the European Space Agency (ESA) Sentinel-1A (launched 4/2014), Sentinel-1B (04/2016), and Sentinel-1C (to be launched 2024) to derive high-resolution soil moisture that satisfies the NASA mission requirements. Optical data from Landsat 8 (launched 2/2013) and Landsat 9 (9/2021) and Sentinel-2A/B (6/2015 and 3/2017) will be used to complement SAR data.

This project will develop quasi-operational algorithms to fuse SAR data from NISAR and Sentinel-1 and harmonized optical data from Landsat and Sentinel-2 (HLS) to generate accurate, high spatial resolution (~200 m), and high temporal resolution (<2 day) soil moisture measurements. Our methods can retrieve soil moisture at any satellite data acquisition date, which advances beyond previous efforts that retrieve soil moisture only when the microwave data are contemporaneous with optical data. This innovation is achieved through a novel time series deep learning methodology developed by the South Dakota team to model the vegetation seasonal dynamics to better quantify vegetation coverage and soil moisture. We will use the International Soil Moisture Network (ISMN) in-situ soil moisture measurements as training data, augmented using the land surface reanalysis soil moisture data from the North American Land Data Assimilation System (NLDAS) and the European Centre for Medium-Range Weather Forecasts (ECMWF). Our preliminary experiment using six years of Sentinel-1 data over 178 ISMN sites showed a marked improvement over the NASA 3-km and 1-km SMAP-Sentinel-1 products.

Five tasks will be undertaken with data acquired over the Conterminous United States (CONUS) from 2017 to 2025: (1) Derive training samples by matching satellite data from Sentinel-1, NISAR, and HLS with ground-truth soil moisture data from ISMN; (2) Develop algorithms to derive soil moisture at SAR acquisition dates; (3) Develop algorithms to derive soil moisture for any satellite data acquisition dates; (4) Pre-train the time series retrieval model using land surface reanalysis soil moisture data; and (5) Validate the derived soil moisture through field measurements in partnership with Oglala Lakota College, a Tribal College serving the 9,000 square kilometer Pine Ridge Reservation.

Our project is aligned with NASA fundamental science objectives by developing advanced information techniques for accurate surface soil moisture qualification, and with NASA applied science objectives by inspiring and educating underserved communities in using NASA data. This project builds new and enhances existing collaborations among South Dakota universities, the USGS Earth Resources Observation and Science (EROS) Center, Oglala Lakota College, and NASA collaborators at JPL and GSFC. The project involves local industrial partners who will use the derived soil moisture data to augment their irrigation support systems. This will impact economic growth of the agricultural industry in South Dakota, a $32.1 billion sector responsible for 30% of South Dakota GDP.

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