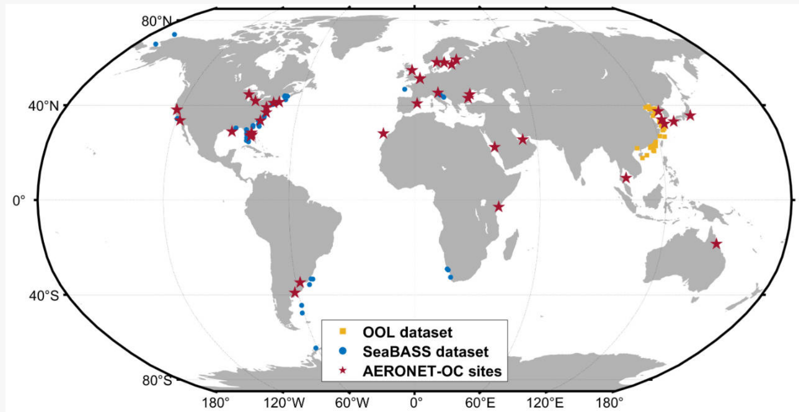
ACA-SIM: A robust way to decode satellite signals over complex waters

GA, UNITED STATES, December 24, 2025 /EINPresswire.com/ -- A new study introduces ACA-SIM (atmospheric correction based on satellite–in situ matchup data), a neural-network-based atmospheric correction algorithm that uses real satellite–Aerosol Robotic Network-Ocean Color (AERONET-OC) matchups to improve the accuracy of atmospheric correction over coastal waters. By learning from real-world satellite radiance and in-situ reflectance data, ACA-SIM significantly reduces errors and striping artifacts in ocean color products, outperforming existing models in turbid water and complex-aerosol conditions such as the Bohai Sea, North Africa dust zones, and Australian bushfire regions.



The spatial distribution of field-measured data used in this study.

Coastal waters are among the most dynamic and complex environments on Earth, where suspended sediments, dissolved organic matter, and aerosols make satellite observation extremely challenging. Traditional atmospheric correction methods often rely on simplified assumptions that fail in turbid or dusty regions, resulting in inaccurate retrievals of ocean color and water quality parameters. The difficulty is further amplified by sensor noise and striping artifacts. Due to these challenges, it is essential to develop a robust atmospheric correction approach that can adapt to real-world conditions in coastal environments, improving the reliability of global ocean color observations.

Researchers from Xiamen University published (DOI: 10.34133/remotesensing.0886) their findings in the Journal of Remote Sensing on October 16, 2025. Their paper presents ACA-SIM (atmospheric correction based on satellite–in situ matchup data)—an atmospheric correction algorithm based on satellite–Aerosol Robotic Network-Ocean Color (AERONET-OC) matchup data—which uses neural networks trained on real satellite and field measurements. The method addresses the persistent problem of retrieving accurate remote-sensing reflectance (Rrs) from coastal waters affected by aerosols, dust, and smoke, offering a promising alternative to existing NASA approaches.

The ACA-SIM algorithm employs a multilayer neural network trained on more than 8,800 satellite–AERONET-OC matchups spanning diverse water and aerosol types worldwide. Unlike previous models that relied on simulated data, ACA-SIM directly incorporates real-world sensor effects—such as striping and stray light—into its learning process. When tested against independent field data, ACA-SIM achieved an average mean absolute percentage difference (MAPD) of ~15% in blue spectral bands, compared with ~32% for OC-SMART and >50% for NASA's standard algorithm. It maintained stable performance even under high solar angles, strong glint, or absorbing aerosol conditions, demonstrating its resilience and general applicability to various coastal environments.

To construct the training dataset, the team combined satellite top-of-atmosphere reflectance (ρt) from MODIS-Aqua with in-situ Rrs from more than 40 AERONET-OC stations worldwide. These matchups captured a wide range of observation geometries, turbidity levels, and aerosol types—from marine and continental aerosols to strongly absorbing dust and smoke. A four-layer multilayer perceptron (512–256–128–64 neurons) was optimized to predict Rrs at 12 MODIS wavelengths between 412 and 869 nm. Validation against AERONET-OC and ship-based datasets confirmed that ACA-SIM consistently outperforms NASA and OC-SMART methods in both accuracy and robustness. When applied to MODIS-Aqua imagery over the Bohai and Yellow Seas, West Africa dust regions, and Australian bushfire zones, ACA-SIM eliminated negative Rrs values, minimized striping artifacts, and preserved realistic water-mass patterns—delivering clean, physically consistent ocean color maps even in challenging atmospheric conditions.

“Our goal was to let the algorithm learn from reality rather than simulation,” said Prof. Zhongping Lee, corresponding author of the study. “By training ACA-SIM on genuine satellite–field matchups, we allowed it to capture subtle sensor behaviors and atmospheric effects that synthetic datasets cannot reproduce. The outcome is a smarter, more reliable correction system that ensures accurate monitoring of coastal ecosystems under even highly complex atmospheric scenarios.”

The team compiled global AERONET-OC data (2002–2024) and matched them with MODIS-Aqua satellite radiance within a ±1-hour window to ensure temporal consistency. A rigorous data-quality screening excluded contaminated pixels while preserving moderately glinted or hazy cases to enhance model generalization. The neural network was trained using 80% of the matchups and validated on the remaining 20%, with early-stopping criteria to prevent overfitting. Statistical metrics—including coefficient of determination (R^2), MAPD, and bias—were used to benchmark ACA-SIM against NASA Standard and OC-SMART algorithms.

The success of ACA-SIM highlights the power of data-driven approaches in Earth observation. The researchers plan to extend this framework to other satellite sensors such as VIIRS and Sentinel-3, aiming for a unified, cross-platform atmospheric correction model. By generating consistent and accurate ocean color products, ACA-SIM could transform long-term coastal monitoring, improve assessments of algal blooms, sediment transport, and carbon fluxes, and ultimately support sustainable management of marine environments in an era of accelerating climate change.

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