26th International Congress on Modelling and Simulation, Adelaide, SA, Australia, 30 Nov–4 Dec 2025
mssanz.org.au/modsim2025

Constrained negentropy optimisation (CoNE-opt): leveraging independent component analysis for the fusion of satellite-derived data products

Suraj Shah [1], Yi Liu [1], Seokhyeon Kim [2, 1*], Ashish Sharma [1]

[1] *School of Civil and Environmental Engineering, University of New South Wales, Sydney, Australia*
[2] *Department of Civil Engineering, College of Engineering, Kyung Hee University, Yongin, Republic of Korea*

Abstract: Ensuring high-quality datasets through merging multiple uncertain sources is essential for accurate geophysical analysis and modelling. Typically, random errors in individual datasets are mitigated when merging, resulting in an integrated dataset equal to or exceeding the quality of the best individual input. Conventionally, datasets are merged using weighted averaging, with weights calculated from second-order error statistics derived under assumptions regarding error structures, particularly error cross-correlation (ECC).

Here, we introduce a novel method for merging geophysical data known as Constrained Negentropy Optimisation (CoNE-opt). This innovative approach assumes the genuine data will display the greatest possible departure from Gaussian characteristics—a foundational assumption in Independent Component Analysis (ICA), widely employed for identifying underlying signals. By maximising negentropy as the primary objective function while incorporating linear constraints based on error modelling, CoNE-opt simultaneously estimates both the complete error structure and the optimal weights required for merging datasets.

We validate the effectiveness of CoNE-opt initially through synthetic experiments and subsequently through a practical application merging three globally recognised satellite-derived soil moisture datasets: SMAP, SMOS, and SMOS-IC. Comparison with established reference datasets clearly demonstrates the superior performance of CoNE-opt compared to traditional merging methods based on second-order statistics. Notably, CoNE-opt effectively manages scenarios involving high ECC and significant data outliers, areas in which standard Ordinary Least Squares (OLS)-based merging techniques typically encounter substantial difficulties.

Specifically, soil moisture merging results indicate a marked improvement, with CoNE-opt achieving a normalised Root Mean Square Error (RMSE) of 0.15, significantly outperforming the best comparable OLS-based method (RMSE of 0.34). Consistently surpassing existing techniques and original datasets, these promising results highlight CoNE-opt as a robust and innovative framework for producing enhanced global soil moisture datasets. Such datasets have considerable potential to improve accuracy and reliability in land surface and hydrological modelling, particularly benefiting regions where observational data remain scarce.

Keywords: *Multisource data merging, Error cross-correlation (ECC), Independent Component Analysis (ICA), Negentropy, Constrained optimisation, Surface Soil Moisture (SSM)*