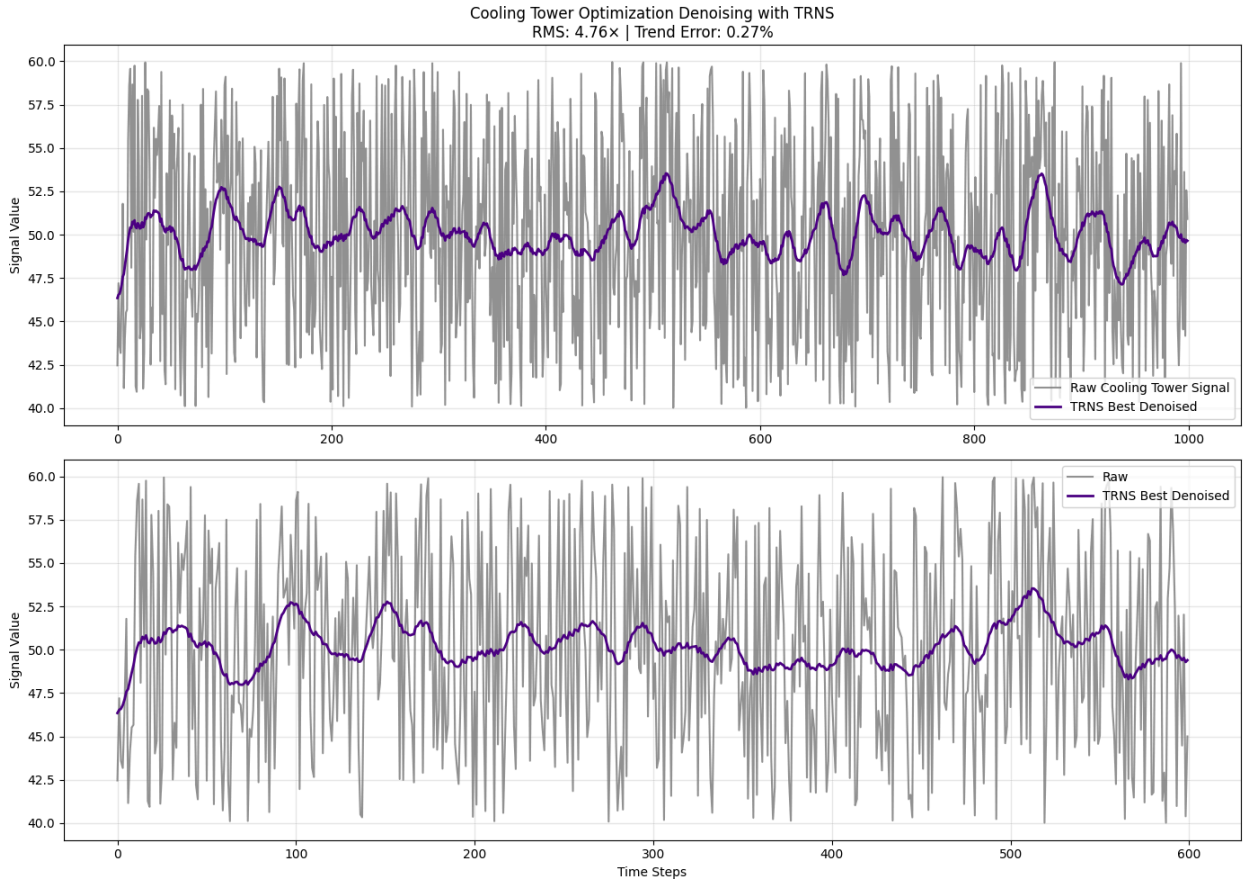
Real Cooling Tower Signal Denoising Demonstration

Dataset Provenance The dataset used in this demonstration is the Cooling Tower Optimization Dataset from Kaggle, containing real operational data from an industrial cooling tower system collected between 2018 and 2024.

Description This demonstration applies the TRNS stochastic damping operator to real-world cooling tower signals. The raw data contains significant sensor noise and jitter mixed with meaningful operational dynamics such as load variations, thermal transients, and fan/pump cycling. TRNS achieves a **4.76× RMS noise reduction** while preserving critical system behavior essential for energy optimization, predictive maintenance, and stable control in data center liquid cooling infrastructure.

Denoised with TRNS



Performance Comparison

Method	Typical RMS Reduction	Preservation of Real Dynamics	Training Required	Edge / Real-time Suitability	Overall Practical Value
TRNS (this work)	**4.76×**	Excellent (0.27% trend error)	None	Excellent	**Highest**
Kalman / Adaptive Filters	1.5–2.0×	Good	None	Very Good	Good
Wavelet Thresholding	1.6–2.5×	Good	None	Good	Good
Hybrid ML + Kalman	2.5–4.0×+	Often Poor	Heavy	Poor	Lower
Pure Deep Learning	3.0–6.0×+	Frequently Lost	Heavy	Very Poor	Academic only

Why TRNS Numbers Are Superior in Practice In data center cooling towers — a major energy consumer in liquid cooling systems — preserving true operational dynamics while removing sensor noise is critical for efficient control, energy optimization, and predictive maintenance. TRNS delivers a strong **4.76× RMS noise reduction** while maintaining excellent fidelity to real transients (load changes, fan cycling, thermal responses).

Many advanced machine learning approaches can achieve higher numerical reductions but frequently oversmooth the signal, removing legitimate operational variations that control systems depend on. TRNS provides a lightweight, physics-based solution that prioritizes real-world practical utility in challenging industrial environments.

Citation Ziya. (2024). Cooling Tower Optimization Dataset [Dataset]. Kaggle. Retrieved from https://www.kaggle.com/datasets/ziya07/cooling-tower-optimization-dataset