



## Article

# Quantifying Thermal Discharges from Nuclear Power Plants: A Remote Sensing Analysis of Environmental Function Zones

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**Abstract:** Nuclear energy plays a crucial role in global carbon reduction. However, thermal discharges from nuclear power plants can potentially impact marine ecosystems. This study investigates the long-term thermal impact of the Haiyang Nuclear Power Plant on the adjacent marine environment using a decade-long Landsat thermal infrared dataset. Spatial and temporal patterns of thermal discharge were analyzed, focusing on the temperature difference between intake and outlet water, the warming trend in the thermal mixing zone, and the spatial distribution of the thermal plume. Our results indicate the following: (1) Seasonal Variation in Thermal Discharge: The temperature difference between intake and outlet water exhibited significant seasonal variability, with higher values in winter and lower values in summer. The spatial distribution of the thermal plume was influenced by tidal currents, leading to a cyclical pattern. (2) Long-Term Warming Trend: Prolonged thermal discharge resulted in a notable warming trend in the thermal mixing zone, with an average annual increase of 0.3 °C. This warming effect was most pronounced in winter and least in summer. (3) Spatial Distribution of Thermal Plume: The spatial extent and intensity of the thermal plume varied seasonally. Summer exhibited a larger influence range but with lower temperature rises, while winter showed a smaller influence range but with higher temperature rises. In winter, the 4 °C temperature rise area exceeded the designated environmental functional zone boundary in some instances. These findings provide valuable insights into the thermal impact of nuclear power plants and highlight the importance of considering seasonal variations and long-term monitoring to ensure environmental sustainability.

**Keywords:** thermal discharge; environmental functional zone; nuclear power plant; thermal impact; cooling water

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## 1. Introduction

Nuclear power plants (NPPs) and thermal power plants (TPPs) rely on large volumes of cooling water to maintain operational efficiency. This practice, known as thermal discharge, can significantly impact aquatic ecosystems. With the thermal efficiency of coastal NPPs typically around 33%, and supercritical large-scale TPPs achieving efficiencies of up to 40% [1], a significant portion of the energy input is dissipated as waste heat into cooling water. To facilitate efficient cooling, many power plants are strategically located in coastal areas, leveraging vast bodies of water as heat sinks.

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