

閃電偵測網的誤差分析與估計

Analysis and Estimation for Lightning-Detection Networks

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摘要

雷暴內閃電的分布與強度，是診斷雷暴從萌發期發展至成熟對流期的有力指標。本研究採用美國閃電偵測網的方法學，評估區域性閃電偵測網路的閃電偵測效能、定位精度及誤差傳播。本研究採用最小平方方法對閃電位置進行時空反演，並透過蒙地卡羅模擬，結合參數化的接收器閾值與實際的源功率分佈，以量化在各種站點幾何配置下的偵測效率與偏差。我們對於閃電偵測站的分析，透過稀疏與密集網路配置對，評估重建閃電空間精度的影響。結果顯示，在典型網路 100 公里範圍內，多數站點的綜合偵測效率最佳的狀況；然而，隨著偵測距離增加，效率與位置精度均顯著下降，這凸顯了最佳站點佈置的重要性。這些發現為提升台灣閃電偵測系統的設計提供了量化依據，並為未來旨在改善雷暴預警能力的陣列部署提供了可行的指導方針。

關鍵字：閃電、誤差分析

Abstract

The distribution and intensity of intra-storm lightning provide a powerful diagnostic for storm development from the development to mature convective phases. This study uses the Lightning Detection Network (LDN) methodology to evaluate flash detection performance, location accuracy, and error propagation in a regional area. Flash locations were inverted using a minimum least square algorithm, while Monte Carlo simulations incorporated variable receiver thresholds and realistic source-power distributions to quantify detection efficiency and bias across a range of station geometries. The simulation framework also assessed the impact of sparse versus dense network configurations on the spatial precision of reconstructed flash centroids. Our preliminary analyses indicate that within 100 km of a typical network the combined detection efficiency achieves its best performance for most stations, yet both efficiency and positional accuracy decline markedly with increasing range, underscoring the importance of optimal station placement. These findings provide a quantitative basis for enhancing lightning-detection system design in Taiwan, offering actionable guidance for future array deployments aimed at improving thunderstorm warning capability.

Keywords : Lightning, Error Analysis