

東北季風期間離岸與近岸風場風向差異分析

Comparative Analysis of Offshore and Coastal Wind Direction Discrepancy During Northeast Monsoon Periods

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摘要

本研究針對台灣西部沿岸在強烈東北季風事件期間，不同測站之風向差異進行探討。選取兩個時間區段內共 20 組具代表性的東北季風事件，分別為 2016 年 10 月至 2017 年 3 月，以及 2022 年 10 月至 2023 年 3 月。風場觀測資料來自三座氣象測風塔：台電 (TP) 離岸測風塔 (距岸約 6 公里，高度 95 公尺)、永傳能源公司 (TGC) 離岸測風塔 (距岸約 8 公里，高度 86 公尺) 以及設於台中清水的標檢局 (BSMI) 近岸測風塔 (高度約 100 公尺)。分別篩選出 11 組 (2016 - 2017) 與 9 組 (2022 - 2023) 強盛季風事件進行比較。所有資料皆經由美國國家海洋暨大氣總署 (NOAA, 2003) 所制定之

《Manual for Real-Time Quality Control of Coastal and Oceanic Wind Observations》中所列之 Test 6、7 與 8 品質管制程序進行檢驗，以確保資料邏輯一致性與可靠性。整體資料的失效率低於 1%，唯 Test 7 約 5% 的數據被標記為異常，經人工檢視後並未發現不合理數據。雖然 NOAA 手冊是針對美國沿岸與大氣觀測所設計，但在台灣尚無風場品管準則的情況下，仍為具參考價值的依據。

研究結果顯示，離岸與近岸測風塔之間的風向具有顯著差異。於 2016 - 2017 年期間，TP 測風塔記錄之平均風向為 316.02° (北北西)，而 BSMI 測風塔則為 29.58° (東北偏北)，兩者相差逾 70°。於 2022 - 2023 年間，TGC 測風塔記錄為 345.71°，而 BSMI 為 28.69°，差異亦超過 40°。地面天氣圖顯示在上述事件中存在穩定的東北風場，而台中地區地面觀測亦顯示為典型東北風。然而，離岸測風塔所觀測到的風向偏向西北，顯示風向會隨測站位置產生顯著轉變。

導致此差異的機制可能包括埃克曼螺旋效應 (Ekman spiral)、海陸表面粗糙度差異，以及地形導引或偏折等現象。雖然埃克曼理論指出北半球風向會隨高度順時針轉向，但一般認為在地表下方 100 公尺內，其轉向角度相對有限 (Tse et al., 2016)。此外，地形效應與地表摩擦力在不同天氣條件下亦會對邊界層中的風向造成顯著影響 (Pena et al., 2014)。本研究顯示，在台灣西部沿岸，不同位置的邊界層風場於約 100 公尺高度處可能呈現顯著風向轉變，此現象可能與地表摩擦力與地形差異有關。研究結果強調，在進行離岸風能資源評估時，應審慎考慮風場的空間變異性與邊界層過程的影響。

特此致謝經濟部標準檢驗局 (BSMI)、台灣電力公司 (Taipower) 與永傳能源公司 (Taiwan Generations Corp.) 提供本研究所需之氣象觀測風場資料。

關鍵字：東北季風、風向差異、埃克曼螺旋、地轉風、表面粗糙度、台灣海峽

Abstract

This study investigates wind direction discrepancies at different locations along the west coast of Taiwan during strong northeast monsoon events. A total of 20 representative monsoon cases were selected during two periods of time:

October 2016 to March 2017, and October 2022 to March 2023. Wind measurements were obtained from three meteorological masts: the Taipower (TP) offshore mast (approximately 6 km offshore, 95 m height), the Taiwan Generations Corp. (TGC) offshore mast (approximately 8 km offshore, 86 m height), and the BSMI onshore mast in Qingshui, Taichung (approximately 100 m height). A total of 11 (2016–2017) and 9 (2022–2023) strong monsoon events were collected for comparison. All data underwent quality control based on Tests 6, 7, and 8 as defined in the Manual for Real-Time Quality Control of Coastal and Oceanic Wind Observations published by NOAA (2003), ensuring logical consistency and data reliability. The overall data rejection rate was below 1%, with the exception of Test 7, which flagged approximately 5% of the records which revealed no significant issues by visual inspection. While the NOAA manual is designed for U.S. coastal and atmospheric environments, it remains a commonly referenced guideline in the absence of a Taiwan-specific quality control standard for wind data.

The results revealed significant discrepancies in wind direction between the locations of the offshore and onshore masts. During 2016–2017, the TP offshore mast recorded a mean wind direction of 316.02° (NNW), while BSMI recorded 29.58° (NNE), with a difference of over 70° . In 2022–2023, TGC offshore mast recorded 345.71° , and BSMI recorded 28.69° , with a difference exceeding 40° . Surface weather charts showed a stable northeasterly flow during these events, and ground-level observations in Taichung also indicated typical northeast wind direction. However, the offshore masts showed a northwesterly direction, suggesting that the wind direction shifted with the locations of the wind masts.

Multiple mechanisms may contribute to this discrepancy, including the Ekman spiral effect, differences in surface roughness between ocean and land, and terrain-induced channeling or deflection. While Ekman theory suggests clockwise turning of wind with height in the Northern Hemisphere, it is generally accepted that within the first 100 meters above ground, the turning angle is rather limited (Tse et al., 2016). Additional factors such as local terrain effects and surface friction may significantly influence the wind direction in atmospheric boundary layer subjected to different weather conditions (Pena et al. 2014).

This study demonstrates that along the west coast of Taiwan, the atmospheric boundary layers at different locations show substantial wind direction shifts at the elevation height of 100 m, which could be due to the effects of surface friction and terrain topology. These findings highlight the importance of accounting for spatial wind variability and boundary layer processes in offshore wind resource assessments.

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Key words : northeasterly monsoon, wind direction discrepancy, Ekman spiral, geostrophic wind, surface roughness, Taiwan Strait

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