對流尺度系集預報系統（CEPS）2026 年作業更新與效能評估

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摘要

對流尺度系集預報系統（Convective-scale Ensemble Prediction System, CEPS）利用系集預報方法結合快速更新資料同化策略，據以提供更準確且即時的機率預報資訊。自 2025 年上線以來，已成為午後對流極短期預報與機率預報的重要參考指引。CEPS 之擾動來源包含初始場擾動與側邊界擾動。初始場擾動來自局地系集轉換卡曼濾波（LETKF）所產製之 16 組成員分析與預報場；側邊界條件利用氣象署雷達資料同化預報系統（RWRF）之 2 公里側邊界資料，結合區域系集預報系統（WEPS）之預報擾動場，產製 擾動側邊界條件。

2026 年上線更新主要包含模式物理過程更新、加入模式物理參數擾動功能，以及擾動計算流程平行化。模式物理過程更新包含使用更適合複雜地形之擴散方案，及 Noah 土壤模式中之都市地區地表參數調整，能改善近地面溫度與水氣場之模擬能力；模式物理擾動則導入蘇等人（2025）發展之 YSU 邊界層參數法之隨機參數擾動方案（YSU-SPP）與 RRTMG 輻射參數法之隨機參數擾動方案（RRTMG-SPP），以提升系集預報離散度表現。此外，透過擾動計算平行化，有效解決極短期預報作業中模式擾動產製時間過長之問題。

測試結果顯示，加入平行化機制後，即使啟用 SPP 功能，整體計算時間僅增加約 5 分鐘，相較原先近倍增之計算成本大幅降低。新版 WRF 在地面溫度與相對濕度預報上均能有效降低誤差，而 YSU-SPP 則有助於提升地面風速預報之離散度表現。降水驗證結果顯示，系統對降水空間分布具有良好掌握能力。在個案分析方面，CEPS 對午後對流事件之預報表現最佳；鋒面與颱風個案則受惠於 LETKF 初始場品質，在預報前期具良好表現，但後期仍可能受到大尺度環境掌握不足及模式範圍限制影響，使降水預報技巧下降。

關鍵字：WRF、對流尺度系集預報、SPP

Operational Updates and Performance Evaluation of the Convective-Scale Ensemble Prediction System (CEPS) in 2026

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Abstract

The Convective-scale Ensemble Prediction System (CEPS) combines ensemble forecasting with rapid-refresh data assimilation to provide timely probabilistic forecasts. Operational since 2025, it is a key guidance tool for afternoon convection nowcasting. CEPS derives its initial condition (IC) perturbations from a 16-member Local Ensemble Transform Kalman Filter (LETKF) analysis, and its lateral boundary condition (LBC) perturbations by merging 2-km Radar-WRF (RWRF) fields with Weather Ensemble Prediction System (WEPS) perturbations.

The 2026 updates introduce model physics upgrades, a stochastically perturbed parameterization (SPP) function, and parallelized perturbation workflows. The updates to the model physics processes involve employing a diffusion scheme better suited for complex terrain and adjusting urban surface parameters within the Noah land surface model, which successfully improve the simulation of near-surface temperature and moisture fields. To enhance ensemble spread, the YSU boundary layer and RRTMG radiation schemes now incorporate SPP schemes (YSU-SPP and RRTMG-SPP) developed by Su et al. (2025). Furthermore, parallelized computation resolves processing bottlenecks in short-range operations; even with SPP enabled, total runtime increases by only ~5 minutes, drastically lowering the previously doubled computational cost.

Validation shows the updated WRF reduces surface temperature and relative humidity errors, while YSU-SPP improves surface wind speed spread. The system accurately captures spatial precipitation patterns. Case studies reveal that CEPS performs best for afternoon convection. Frontal and typhoon cases show high skill in early forecast hours due to quality LETKF ICs, though skill degrades later due to large-scale environmental uncertainties and domain size limitations.

Keywords: WRF, Convective-scale ensemble prediction, SPP