利用系集敏感度分析與觀測系統模擬實驗評估佈建先進觀測儀器對數值天氣預報之效益

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摘　要

本研究分為兩部分，首先利用系集敏感度分析(Ensemble Sensitivity Analysis, ESA)評估風場、溫度、水氣等模式變數對於鋒面降雨、晴空環流、以及午後對流預報的敏感度。其次，根據系集敏感度高低之排序，選擇可優先佈建先進觀測儀器的站點，儀器則包括可取得氣象變數垂直剖線的遙測設備以及風光達。

決定先進觀測儀器的佈建位置後，本研究進一步使用WRFDA中的三維變分資料同化系統，執行觀測系統模擬實驗(Observation System Simulation Experiment, OSSE)，評估額外同化垂直剖線觀測以及風光達之效益。

系集敏感度分析的結果顯示，高系集敏感度的站點在前述三組個案中皆不相同，具有相當顯著的個案相依性。如果先將有人站依照地區分群，再進行系集敏感度的分區排名，能夠使站點分佈較為均勻。OSSE的結果顯示，在鋒面降雨以及晴空環流個案中將先進儀器佈建站點較均勻的分佈在全臺各地，能夠更有效的提高同化時誤差下修的幅度。但是在午後對流個案中，較均勻的佈建方式對於同化時的誤差下修則較無顯著的效益。

最後對於數值天氣預報的影響顯示，增加先進觀測儀器佈建站點數量能夠提升預報的準確度。當佈建的垂直剖線遙測以及風光達增加時，鋒面降雨與午後對流個案的降雨以及晴空環流中的風速與溫度能更精確地被掌握。

關鍵字：系集敏感度分析、三維變分資料同化、最佳化站點選擇

Evaluate the Impact of Deploying Advanced Instrument on Numerical Weather Prediction via Ensemble Sensitivity Analysis and Observation System Simulation Experiment

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Abstract

This study is divided into two parts. First, the Ensemble Sensitivity Analysis (ESA) is used to evaluate the sensitivity of model variables, such as wind fields, temperature, and moisture, to forecasts of frontal precipitation, clear air circulation, and afternoon thunderstorm. Subsequently, based on the ranking of ensemble sensitivity, sites are selected for the prioritized deployment of advanced observational instruments, including remote sensing equipment capable of obtaining vertical profiles of meteorological variables and wind lidars.

After determining the deployment locations of advanced observational instruments, the study further employs the three-dimensional variational data assimilation system in WRFDA to conduct an Observation System Simulation Experiment (OSSE). These experiments evaluate the benefits of additionally assimilating vertical profile observations and wind lidar data.

The results of ESA show that the high-sensitivity sites vary significantly among the three cases, indicating considerable case dependency. Grouping the stations by region before conducting the regional ranking of ensemble sensitivity can result in a more uniform station distribution. The OSSE results indicate that in the cases of frontal rainfall and clear air circulation, a more uniform distribution of advanced instrument sites across Taiwan can more effectively improve the reduction of analysis errors. However, in the afternoon thunderstorm case, a more uniform distribution does not significantly benefit the error reduction during the assimilation period.

Regarding the impact on the numerical weather prediction, increasing the number of advanced observation instruments enhances the accuracy of forecasts. When more profilers and lidars are deployed, the rainfall in frontal precipitation and afternoon thunderstorm cases, as well as the wind speed and temperature in clear air circulation, can be precisely captured.

Keywords: Ensemble Sensitivity Analysis, 3DVar Data Assimilation, Optimal Site Selection