Wind Nowcasting by using Time-Lagged Mesoscale Ensemble Forecast and Flight Data

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Air traffic has increased considerably over the last few decades and current air traffic management (ATM) systems are severely overburdened. To deal with this ever-increasing air traffic, the Next Generation Air Transportation System, Single European Sky ATM Research, and Collaborative Actions for Renovation of Air Traffic Systems have been implemented as ATM modernization programs in the United States, Europe, and Japan, respectively. These programs are designed to increase throughput and capacity, improve safety and efficiency, and reduce environmental impacts over existing ATM systems. One of the main working principles behind these future ATM systems is four-dimensional trajectory-based operations (4D-TBO), which can precisely describe an aircraft path in three-dimensional space and time.

Numerical weather prediction (NWP) is an essential tool for ATM because weather events have a major impact on aviation safety and efficiency. In 4D-TBO, the trajectory of every aircraft is managed and optimized for airline preferences, such as safety and fuel consumption. For example, the accuracy of the estimated time of arrival (ETA) is considerably influenced by prediction uncertainties in NWP for fields such as wind. Thus, considering the effect of uncertainties of NWP is critical to fulfill the required time of arrival.

In general, data assimilation (DA) is performed to reduce the uncertainty of NWP by assimilating observations into the simulation. DA can determine unknown inputs, such as boundary and initial conditions, by assimilating observations. However, the DA update interval of an operational NWP is generally longer than one hour, even for a mesoscale model. Therefore, the results predicted by these NWP models are updated with latencies exceeding one hour after the observational data are obtained. Weather information related to aviation safety and efficiency should be updated as soon as possible to assist aircraft in flight and other operations, as this information has little value after an aircraft has landed.

In this study, to alleviate the effects of weather prediction errors and improve ATM, for example by improving the accuracy of ETA, we propose a nowcasting algorithm for the wind field using ensemble forecasting and aircraft flight data in flight. The main objective of this algorithm is to generate real-time weather information that can be used for route optimization while using on-board flight data in real-time. This algorithm can provide frequent and accurate forecast updates, out to several hours, to support aircraft operations. In this study, the effectiveness of the nowcasting algorithm as a wind nowcasting system is evaluated, with the goal of supporting safe and efficient aircraft operation. We conducted two case studies to evaluate the validity of the algorithm. Each case study used flight data from several commercial aircraft flights over Japan during a two-week period. We evaluated forecast performance with respect to the wind field.

The nowcasting algorithm uses an ensemble-weighted average method. The weight per ensemble member is estimated by using the flight data in flight. Therefore, the computational cost of forecasting is much lower than that of general NWP and DA systems. Thus, the proposed algorithm can predict wind fields in real-time. In the proposed algorithm, the computational cost of forecasting consists of comparing

observed data with ensemble forecast data, estimating weight per ensemble member, and conducting weighted averaging.

For the ensemble forecasts, we used the meso-scale ensemble prediction system (MEPS) of the Japan Meteorological Agency. The MEPS has a 5-km horizontal grid and has 21 members. For the flight-data dataset, we obtained measurement data from downlink aircraft parameters (DAPs), which enable a ground station to obtain real-time aircraft information such as weather information. In the conference, we will report on the forecasting performance of nowcasting in detail.

Keywords: Flight Data, Nowcasting, Ensemble Forecast, Aircraft

