WORLD AREA FORECAST SYSTEM OPERATIONS GROUP (WAFSOPSG)

EIGHTH MEETING

Bangkok, 2 to 5 September 2013

Agenda Item 6: Development of the WAFS

6.1: Improved WAFS gridded global forecasts for cumulonimbus clouds, icing and turbulence

USING ENSEMBLE MODELLING TECHNIQUES TO CREATE WAFS HAZARD FORECASTS

(Presented by WAFC Provider States)

SUMMARY

This paper introduces concepts of ensemble modeling and how ensemble techniques may be applied to the WAFS.

1. INTRODUCTION

1.1 The world area forecast centres (WAFCs) are generating gridded world area forecast system (WAFS) forecasts of cumulonimbus clouds (CB), icing and turbulence from a blend of numerical model output between the US Global Forecast System (GFS) and the UKMO's Global model. The final forecast for icing and turbulence is provided in two sets, a mean grid output and a maximum grid output, that give the user the average between and the maximum of the GFS and UKMET grids. However, this output is a simple average between two deterministic models and represents only two possible solutions. Because the atmosphere is a non-linear and dynamical system, even minuscule differences in deterministic models grow upscale resulting in considerable forecast uncertainty.

1.2 The ensemble modeling approach takes into account the inherent nonlinearity of atmospheric processes, errors in observations, and limitations of numerical models by utilizing a wide range of initial and boundary conditions and differences in model physics to generate a number of possible future states of the atmosphere. For long-term planning purposes, ensemble output provides air traffic managers potential best- and worst-case scenarios along with quantification of uncertainty in the occurrence of a hazard forecast.
2. **CONCEPTS OF ENSEMBLE MODELING**

2.1 **Mean and Median.** The average of all individual ensemble members filters the inconsistencies amongst the members and provides a consensus forecast. While this is useful in removing outlying member solutions, it can wash out the magnitude of a forecast, introduce displacement errors and reduce meaningful gradients in the forecast.

2.2 **Maximum and Minimum.** For a particular hazard, the highest and lowest member forecast identify possible extremes in a forecast, which highlight potential best- and worst-case scenarios.

2.3 **Standard Deviation and Spread.** The standard deviation of the ensemble members with respect to the ensemble mean reflects the overall degree of variability amongst the ensemble members, thus providing information on uncertainties and/or confidence. In general, small spread indicates smaller variation in the range of forecast values and large spread greater variation in forecast values.

2.4 **Probability.** This is simply the percentage of predictions out of all members that satisfy a specified criterion. Probability products quantify the degree of uncertainty or likelihood of a predicted outcome occurring, which contributes a level of confidence in the forecast.

2.5 **Joint probability.** This is the occurrence of two or more events and conditional probability, which is the probability of one event given another event has occurred.

2.6 **Probability Matched Mean.** Simply using the arithmetic mean to assess hazard intensity over a particular spatial domain can be misleading because the magnitude of the hazard can be “smeared” out and lost over a broad area. This technique uses probability (histogram) matching to preserve the higher intensity forecasts from individual members that may have been lost during averaging, while removing some of the excess lower intensities.

3. **ENSEMBLE TECHNIQUES APPLIED TO WAFS**

3.1 **Mean and Median.** The ensemble mean provides a consensus solution to the most probable location of WAFS hazards, which can be useful in determining which flight routes are most likely to be impacted by the hazard. For example, an ensemble mean of icing potential from multiple members would provide an agreeable solution to the most likely spatial corridor of icing potential and whether or not a particular flight path will be impacted. However, the intensity of the icing hazard will be smoothed out.

3.2 **Maximum and Minimum.** When viewing only the ensemble means, the best and worst case scenarios are often missed in longer-range forecasts. For example, because of the erratic and unstable nature of CB and clear air turbulence (CAT) phenomena, ensemble member consensus and deterministic forecasts may be unreliable. Maximum and minimum ensemble solutions enable air traffic planners to consider and prepare for worst case outcomes of CB extent and severe CAT.

3.3 **Standard Deviation and Spread.** While the ensemble mean of WAFS gridded forecast may provide a qualitative confidence in the spatial pattern of a particular hazard, quantifying that confidence is accomplished by calculating the standard deviation about the mean. For example, an air traffic planner may decrease confidence on a particular location highlighted for icing potential by the ensemble mean if the spread is very high.
3.4 **Probability.** The probability of exceeding the pre-defined WAFS hazard thresholds is the best way for WAFS users to consider the uncertainty of weather forecasts and potential impacts. Probabilistic information can be used to estimate airspace capacity due to the hazard and provide guidance for planning air traffic flows. For example, a higher probability of a severe CAT threshold could be interpreted as a lower air flow capacity in that region.

3.5 **Joint and Conditional Probability.** WAFS users could consider only ensemble probabilities for which other pre-defined conditions are met. For example, a gridded probability of CB tops greater than FL370 could be created, where probabilities are only generated from ensemble members with a particular CB extent threshold met. This technique is very useful for customizing probability outputs to a very specific user need.

3.6 **Probability Matched Mean.** This concept is most useful for CB extent output that uses model-derived convective precipitation rate. The magnitude and intensity of convection from individual members is often lost in the ensemble mean. Using a probability matched mean conserves the location distribution of the individual members, while maintaining the higher intensities.

4. **ACTION BY THE WAFSOPSG**

4.1 The WAFSOPSG is invited to note the information contained in this paper.

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