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CAR/SAM Regional Planning and Implementation Group (GREPECAS)
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Agenda Item 7: Regional MET Requirements for ATM

FOUR DIMENSIONAL (4-D) WEATHER DATABASE IN SUPPORT OF ATM

(Presented by United States of America)

SUMMARY

This paper discusses the use of World Area Forecast System products in support of the development of a four dimensional (4-D) database to support the operational requirements for Air Traffic Management.

1. Introduction

1.1 Historically, there have been three aviation weather parameters operationally produced by global numerical weather prediction (NWP) models for flight planning. They are wind, temperature and humidity. The World Area Forecast System (WAFS) have been the source of these forecasts for global flight planning since the 1990s. Other weather information needed for flight planning, such as turbulence and thunderstorms have been traditionally provided in chart form as WAFS Significant Weather Forecasts, but only for a limited fixed valid time (e.g., 24 hours), and not time sequenced to the available forecasts of wind, temperature, and humidity forecasts which are valid at many time intervals (e.g., 6, 12, 18, 24, 30, and 36 hours). Still other information, such as volcanic ash forecasts is primarily a text based product, and information on space weather is limited and in its infancy.

1.2 WAFS Provider States (United Kingdom and United States) have been producing global forecasts of icing, turbulence and cumulonimbus (CB) clouds in a grid point format on a trial basis since 2007. These new forecasts are produced by the same NWP models as the WAFS wind, temperature and humidity forecasts, and have valid times that match the forecasts of wind, temperature and humidity forecasts. With the addition of grid point forecasts of turbulence, icing, and CB clouds to the WAFS, the WAFS global forecasts become a first generation of a four dimensional (4-D) weather database.

1.3 The concept of a 4-D weather database is one of the key components to the Next Generation Air Transportation System (NextGen) in the United States, as well as SESAR (Single European Sky Air Traffic Management (ATM) Research) in Europe.

2. Discussion

2.1 Aeronautical Meteorological Information (MET) and Air Traffic Management (ATM)

2.1.1 Traditionally aviation weather services utilize weather information to address safety issues. Aviation weather services in the future, such as those being planned for NextGen and SESAR, will be incorporated into decision support tools used by ATM to address capacity and efficiency issues, in addition to safety.

2.1.2 At final resolution and detail, MET will become an important key element for the short and medium term trajectory prediction. MET will be used either in planning the trajectory or in changing the trajectory in the short term due to several factors including the avoidance of weather hazards.

As noted in the *Strategic Guidance in Support of the Execution of the European ATM Master Plan*:

MET will be required in the decision making processes throughout all phases of flight. It will require improvements to the existing meteorological services, the development of new products and services and the introduction of concepts such as the ‘level of uncertainty’ and the ‘level of confidence’ associated to MET, to be used in decision-making processes. This foreseen evolution requires an approach to Information Management which will ensure the timely, accurate, and complete availability of the aeronautical meteorological information within the concept of system-wide information management for all phases of flight.

As noted in the *Concept of Use (ConUse) for Weather in the Next Generation Air Transportation System (NextGen)*:

Traditional weather products do not facilitate the use of forecast uncertainty. They state what will happen and where in a deterministic manner, and rarely quantify less likely weather possibilities. The means of delivery is insufficient. Because current weather dissemination systems were not architected to provide information to all users, not all NAS decision makers receive needed weather products.

Many of the efficiencies and capacity improvements in NextGen concepts such as Trajectory Based Operations (TBO) and Collaborative Air Traffic Management (CATM) will not be fully realized without reducing the impact of weather uncertainties. Probabilistic Forecasts will quantify the uncertainty of operationally significant weather. Air Navigation Service Providers (ANSPs) will use probabilistic forecasts to minimize airspace capacity limitations by reducing the likelihood of overly conservative actions. TBO planning and in-flight navigation tools will use probabilistic forecasts to assess the risk of Four Dimensional Trajectory (4DT) interruption and determine the most efficient 4DT airspace which meets individual flight tolerances for adverse or non-preferred weather conditions. TBO and C-ATM will rely on an integrated, de-conflicted common weather picture available to Air Traffic Management (ATM) decision makers. This common weather picture is known as the Four Dimensional Weather Single Authoritative Source (4-D Wx SAS).

The 4-D Wx SAS will contain four-dimensional (x, y, z, and time) probabilities to aid the Decision Support Tools (DST) in providing risk assessments of weather relevant to aviation: convection, wind shear, turbulence, in-flight icing, ceiling and visibility, volcanic ash, space weather, winds, and precipitation type and intensity. These probabilities will be provided for all

time periods ranging from the near-immediate (analyzed from the latest observations) to the long-term (determined from climatological data and seasonal forecasts) to support decision maker risk assessments.

2.1.3 Decision Support Tool (DST) are generally software applications used to automate the weather impact evaluation and air traffic/customer response. Flight data are input into the DST, typically in the form of a proposed 4-dimensional trajectory through space and time. Along with trajectory information are added the particular weather sensitivities or risk tolerance of the flight under consideration. According to the spatial and temporal attributes of the flight (takeoff time/place, flight level, waypoints, and estimated landing time/place) relevant weather information is retrieved from the 4D Weather Database. The DST then automatically compares the weather parameters to particular sensitivities of the flight under consideration. By applying relevant rules and thresholds (aircraft weather avoidance limits, risk tolerance, Federal Aviation Regulations, etc.) the DST converts weather information into weather impacts. The result of this logical integration is an output decision aid.

2.1.4 For example, a segment of a proposed flight trajectory may enter an area of forecast turbulence. If this forecast turbulence exceeds certain severity or probability limits the DST automatically flags these segments as Red. More sophisticated DSTs may recommend weather-optimized trajectories through an iterative process of query and response. Thus, the trajectory flagged as Red for turbulence initially may be rendered Green by an earlier takeoff, a higher flight level, or a different route.

2.2 WAFS as a Four-Dimensional (4-D) Weather Database

3.1.1 As noted in the information above taken from NextGen and SESAR plans, detailed MET data will be required in four dimensions (space and time) for all phases of flight. WAFS has the potential to initially provide most of the required elements, albeit at a global scale.

3.1.2 Amendment 75 (effective Nov 2010) to Annex 3 makes for the provision of the following weather elements in grid point format:

- Upper wind
- Upper air temperature and humidity
- Geopotential altitude of flight levels
- Flight level and temperature of tropopause
- Direction, speed and flight level of maximum wind
- Turbulence
- Icing
- Cumulonimbus (CB) Cloud

3.1.3 All the above elements will be provided in 4 dimensions (x,y,z,t) and establish the framework for the first global 4-D Weather Database:

- X and Y = Spatial resolution of 1.25 degree of latitude and longitude.
- Z = Vertical resolution in layers from 850 hPa (FL 050) up to 100 hPa (FL 530) (depending on the element).
- T = 3 hourly temporal resolution from 6 hour through 36 hour. All will be produced 4 times a day based on 00Z, 06Z, 12Z, and 18Z data.

3.1.4 Once operational, WAFS 4-D Weather Database will be the ICAO source of MET in support of flight planning. These data will be provided in GRIB2 format to serve automated flight planning systems with the ability to plan for optimum routing decisions for their aircraft operations.

2.3 **Applying WAFS for Regional and Global ATM**

2.3.1 The WAFS 4-D Weather Database is best suited for medium and longer term ATM and flight planning, e.g., from 6 hours to 36 hours. For the WAFS 4-D Weather to serve shorter term ATM (less than 6 hours), as well as NextGen and SESAR, will require higher resolution scales in all four dimensions, as well as more data sets in addition to the basic elements of the WAFS database described above. This detailed MET will primarily be needed at and near airports, as well as high traffic areas.

2.3.2 Examples of improved or additional data sets needed, which have been identified in NextGen and SESAR plans to support ATM:

- Volcanic Ash;
- Space Weather;
- Improved accuracy, timeliness and forecast range of convective weather information, turbulence and icing;
- Improved accuracy reliability and lead time of visibility / ceiling forecasts including a measure of uncertainty;
- Provision of high accuracy, high resolution, short range wind forecasts to support approaches and departures, as well as runway specific tail- and crosswind components in connection with runway conditions.

2.3.3 Two of the items from the above list, space weather and volcanic ash, are very critical for ATM as well as safety of flight. Unlike turbulence and convection, airspace may be closed due to ash and space weather, requiring significant re-routing or grounding of flights. Although forecasts of these phenomena are currently provided, the formats and scales are not suitable for efficient ATM.

2.3.4 The WAFS 4-D Weather Database could evolve into an Initial Operating Capability (IOC) of NextGen and SESAR if opportunities are provided for enhancements to the current WAFS algorithms as well as finer scale production and interaction with decision support systems. There are plans to upgrade existing algorithms used in providing the WAFS products to improve the characteristics of intensity of icing and turbulence, as well more detailed thunderstorm forecasts.

3. **Conclusion**

3.1 Aeronautical meteorological information is a key part of regional and global ATM. New WAFS grid point forecasts will be provided in four dimensions, and an increased time scale from today's products, such that the WAFS 4-D Weather Database has the potential to be viewed as the framework for MET for regional and global ATM.

3.2 The AERMET MET/ATM TF may wish to consult with ICAO ATM Panel to help identify specific operational requirements for MET/ATM in the CAR/SAM Region, including:

- Inclusion of Space Weather and Volcanic Ash
- Provision for sub-WAFS scale forecasts to be used in high traffic areas as well as transition to and from aerodromes.
- Provision for the integration of MET with ATM and decision support tools, using uncertainty or probability, for efficient trajectory based flight operations.

4. **Action required**

- 4.1 The meeting is invited to take note of the information provided in this paper.

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