

APPENDIX A

MODULE NO. B0-105: METEOROLOGICAL INFORMATION SUPPORTING ENHANCED OPERATIONAL EFFICIENCY AND SAFETY

Summary	Global, regional and local meteorological information: a) forecasts provided by world area forecast centres (WAFC), volcanic ash advisory centres (VAAC) and tropical cyclone advisory centres (TCAC); b) aerodrome warnings to give concise information of meteorological conditions that could adversely affect all aircraft at an aerodrome including wind shear; and c) SIGMETs to provide information on occurrence or expected occurrence of specific en-route weather phenomena which may affect the safety of aircraft operations. This information supports flexible airspace management, improved situational awareness and collaborative decision making, and dynamically-optimized flight trajectory planning. This module includes elements which should be viewed as a subset of all available meteorological information that can be used to support enhanced operational efficiency and safety.	
Main performance impact as per Doc 9854	KPA-02 – Capacity, KPA-03 – Cost-effectiveness, KPA-04 – Efficiency, KPA-05 – Environment, KPA-06 – Flexibility, KPA-07 – Global interoperability, KPA-08 – Participation by the ATM community, KPA-09 – Predictability, KPA-10 – Safety.	
Operating environment/ Phases of flight	All phases of flight.	
Applicability considerations	Applicable to traffic flow planning, and to all aircraft operations in all domains and flight phases, regardless of level of aircraft equipage.	
Global concept component(s) as per Doc 9854	AOM – airspace operations and management DCB – demand and capacity balancing AO – aerodrome operations	
Global plan initiatives (GPI)	GPI-19: Meteorological systems GPI-6: Air traffic flow management GPI-16: Decision support systems and alerting systems	
Main dependencies	None. Meteorological information and supporting distribution systems are in existence today.	
Global readiness checklist		Status (ready now or estimated date).
	Standards readiness	√
	Avionics availability	√
	Ground system availability	√
	Procedures available	√
	Operations approvals	√

1. NARRATIVE

1.1 General

1.1.1 Elements 1 to 3 of this module illustrate the meteorological information made available by world area forecast centres (WAFC), volcanic ash advisory centres (VAAC) and tropical cyclone advisory centres (TCAC) that can be used by the air traffic management (ATM) community to support dynamic and flexible management of airspace, improved situational awareness and collaborative decision making, and (in the case of WAFS forecasts) dynamically-optimized flight trajectory planning.

1.1.2 Elements 4 and 5 of this module illustrate the meteorological information issued by aerodrome meteorological offices in the form of aerodrome warnings, wind shear warnings and alerts (including those generated by automated meteorological systems) that contribute to improving safety and maximizing runway capacity. In some instances, the systems used for the detection of wind shear (such as ground based LIDAR) have proven utility in wake turbulence detection and tracking/monitoring, and thus also support the improving safety and maximizing runway capacity from a wake turbulence encounter prevention perspective. Additionally Element 6 of this module describes SIGMET which is meteorological information provided by a Meteorological Watch Office (WMO) on severe observed or expected events of turbulence, icing thunderstorm, volcanic ash, etc. that are considered an immediate hazard to aircraft en-route.

1.1.3 It should be recognized that elements 1 to 6 herein represent a subset of all available meteorological information that can be used to support enhanced operational efficiency and safety. Other such meteorological information that is not described here includes, for example, meteorological observations, reports and forecasts, aircraft observations and reports, and aeronautical climatological information.

1.2 Baseline

1.2.1 WAFCs within the framework of the world area forecast system (WAFS) prepare global gridded forecasts of 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, cumulonimbus clouds, icing, and clear-air and in-cloud turbulence. These global gridded forecasts are issued 4-times per day, with fixed time validity T+0 to T+36 at 3-hour time-steps. In addition, the WAFCs prepare global forecasts of significant weather (SIGWX) phenomena in binary code form. These global forecasts of SIGWX phenomena are issued 4-times per day, with validity at T+24. The United Kingdom and United States are designated as WAFC provider States. Accordingly, WAFCs London and Washington make available the aforementioned forecasts on the ICAO Aeronautical Fixed Service (AFS).

1.2.2 VAACs within the framework of the International Airways Volcano Watch (IAVW) respond to a notification that a volcano has erupted, or is expected to erupt or volcanic ash is reported in its area of responsibility. The VAACs monitor relevant satellite data to detect the existence and extent of volcanic ash in the atmosphere in the area concerned, and activate their volcanic ash numerical trajectory/dispersion model in order to forecast the movement of any ash cloud that has been detected or reported. In support, the VAACs also use surface-based observations and pilot reports to assist in the detection of volcanic ash. The VAACs issue advisory information (in plain language textual form and graphical form) concerning the extent and forecast movement of the volcanic ash cloud, with fixed time validity T+0 to T+18 at 6-hour time-steps. The VAACs issue these forecasts at least every six hours until such time as the volcanic ash cloud is no longer identifiable from satellite data, no further reports of volcanic ash are received from the area, and no further eruptions of the volcano are reported. The VAACs maintain a 24-hour watch. Argentina, Australia, Canada, France, Japan, New Zealand, the United

Kingdom and the United States are designated (by regional air navigation agreement) as the VAAC provider States. Accordingly, VAACs Buenos Aires, Darwin, Montreal, Toulouse, Tokyo, Wellington, London, Anchorage and Washington make available the aforementioned advisories on the ICAO AFS.

1.2.3 TCACs monitor the development of tropical cyclones in their area of responsibility, using relevant satellite data, meteorological radar data and other meteorological information. The TCACs are meteorological centres designated by regional air navigation agreement on the advice of the World Meteorological Organization (WMO). The TCACs issue advisory information (in plain language textual form and graphical form) concerning the position of the tropical cyclone centre, its direction and speed of movement, central pressure and maximum surface wind near the centre, with fixed time validity T+0 to T+24 at 6-hour time-steps. The TCACs issue updated advisory information for each tropical cyclone, as necessary, but at least every six hours. Australia, Fiji, France, India, Japan and the United States are designated (by regional air navigation agreement) as TCAC provider States. Aforementioned advisories are made available on the ICAO AFS, through TCACs located in Darwin, Nadi, La Reunion, New Delhi, Tokyo, Honolulu and Miami.

1.2.4 Aerodrome warnings provide concise information of observed or expected meteorological conditions that could adversely affect aircraft on the ground, including parked aircraft, and the aerodrome facilities and services.

1.2.5 Wind shear warnings are prepared for aerodromes where wind shear is considered a factor. Wind shear warnings give concise information on the observed or expected existence of wind shear which could adversely affect aircraft on the approach path or take-off path or during circling approach between runway level and 500 m (1 600 ft) above that level and aircraft on the runway during the landing roll or take-off run. Note that where local topography has been shown to produce significant wind shears at heights in excess of 500 m (1 600 ft) above runway level, then 500 m (1,600 ft) is not to be considered restrictive.

1.2.6 SIGMETs are information that describes the location of specified en-route weather phenomena which may affect the safety of aircraft operations. SIGMETs are issued by MWOs for such phenomena as thunderstorms, turbulence, icing, mountain wave, radiation, volcanic ash and tropical cyclone. The latter two categories of SIGMETs are based on information provided in the appropriate advisories from the respective VAACs and TCACs.

1.3 Change brought by the module

1.3.1 The global availability of meteorological information as provided with the framework of the WAFS and IAVW enhances the pre-tactical and/or tactical decision making for aircraft surveillance, air traffic flow management and flexible/dynamic aircraft routing. Similar information is also provided by TCACs and MWOs in support of ATM decisions. The locally-arranged availability of aerodrome warnings, wind shear warnings and alerts (where wind shear is considered a factor), contributes to improved safety and maximized runway capacity during adverse meteorological conditions. Wind shear detection systems can, in some instances, be utilized for wake turbulence detection and tracking/monitoring.

1.4 Element 1: WAFS

1.4.1 The WAFS is a worldwide system within which two designated WAFCs provide aeronautical meteorological en-route forecasts in uniform standardized formats. The grid point forecasts are prepared by the WAFCs in a regular grid with a horizontal resolution of 1.25 degrees of latitude and longitude, and issued in binary code form using the GRIB code form as prescribed by WMO. The

significant weather (SIGWX) forecasts are issued by the WAFCs in accordance with the provisions in Annex 3 — *Meteorological Service for International Air Navigation* (Chapter 3 and Appendix 2) in binary code form using the BUFR code form prescribed by WMO and in PNG-chart form as formalized backup means. ICAO administers the WAFS with the cooperation of the WAFC provider States and concerned international organizations through the World Area Forecast System Operations Group (WAFSOPSG).

1.5 **Element 2: IAVW**

1.5.1 The IAVW ensures international arrangements for monitoring and providing advisories to MWOs and aircraft operators of volcanic ash in the atmosphere. The advisories support the issuance of SIGMET on these events by the respective MWOs. The IAVW is based on the cooperation of aviation and non-aviation operational units using information derived from observing sources and networks that are provided by States for the detection of volcanic ash in the atmosphere. The forecasts issued by the nine designated VAACs are in plain language text and PNG chart form. The advisory information on volcanic ash is prepared by VAACs in accordance with Annex 3 (Chapter 3 and Appendix 2). ICAO administers the IAVW with the cooperation of the VAAC provider States and concerned international organizations through the International Airways Volcano Watch Operations Group (IAVWOPSG). Additionally, ICAO recognizes the importance of State volcano observatories as part of the world organization of volcano observatories in their role of providing information to the pre-eruption and eruption of volcanoes.

1.6 **Element 3: Tropical cyclone watch**

1.6.1 TCAC, per regional air navigation agreement, monitor the formation, movement and degradation of tropical cyclones. The forecasts issued by the TCACs are in plain language text and graphical form. The advisory information on tropical cyclones is prepared by TCACs in accordance with Annex 3 (Chapter 3 and Appendix 2). The advisories support the issuance of SIGMET on these events by the respective MWOs.

1.7 **Element 4: Aerodrome warnings**

1.7.1 Aerodrome warnings give concise information of meteorological conditions that could adversely affect aircraft on the ground, including parked aircraft, and the aerodrome facilities and services. Aerodrome warnings are issued in accordance with Annex 3 (Chapter 7 and Appendix 6) where required by operators or aerodrome services. Aerodrome warnings should relate to the occurrence or expected occurrence of one or more of the following phenomena: tropical cyclone, thunderstorm, hail, snow, freezing precipitation, hoar frost or rime, sandstorm, dust-storm, rising sand or dust, strong surface wind and gusts, squall, frost, volcanic ash, tsunami, volcanic ash deposition, toxic chemicals, and other phenomena as agreed locally. Aerodrome warnings are issued usually for validity periods of not more than 24 hours. Aerodrome warnings are disseminated within the aerodrome in accordance with local arrangements to those concerned, and should be cancelled when the conditions are no longer occurring and/or no longer expected to occur at the aerodrome.

1.8 **Element 5: Wind shear warnings and alerts**

1.8.1 Wind shear warnings are prepared for aerodromes where wind shear is considered a factor, issued in accordance with Annex 3 (Chapter 7 and Appendix 6) and disseminated within the aerodrome in accordance with local arrangements to those concerned. Wind shear conditions are normally associated with the following phenomena: thunderstorms, microbursts, funnel cloud (tornado or waterspout), and gust fronts, frontal surfaces, strong surface winds coupled with local topography; sea

breeze fronts, mountain waves (including low-level rotors in the terminal area) and low-level temperature inversions.

1.8.2 At aerodromes where wind shear is detected by automated, ground-based, wind shear remote-sensing or detection equipment, wind shear alerts generated by these systems are issued (updated at least every minute). Wind shear alerts give concise, up-to-date information related to the observed existence of wind shear involving a headwind/tailwind change of 7.5 m/s (15 kt) or more which could adversely affect aircraft on the final approach path or initial take-off path and aircraft on the runway during the landing roll or take-off run.

1.8.3 In some instances, the systems used for the detection of wind shear have proven utility in wake turbulence detection and tracking/monitoring. This may prove especially beneficial for congested and/or complex aerodromes (e.g. close parallel runways) since ground-based LIDAR at an aerodrome can serve a dual purpose – i.e. wake vortices are an issue when wind shear is not.

1.9 Element 6: SIGMET

1.9.1 SIGMETs are information issued by each State's MWO for their respective FIR and/or CTA. SIGMETs are messages that describe the location of specified en-route weather phenomena which may affect the safety of aircraft operations. SIGMETs are typically issued for thunderstorms, turbulence, icing, mountain wave, volcanic ash, tropical cyclones and radiation.

2. INTENDED PERFORMANCE OPERATIONAL IMPROVEMENT/METRIC TO DETERMINE SUCCESS

KPAs	Specific improvement provided.
<i>KPA-02: Capacity</i>	Optimized usage of airspace capacity, thus achieving arrival and departure rates. Metric: ACC and aerodrome throughput.
<i>KPA-03: Cost effectiveness</i>	Reduction in costs through reduced arrival and departure delays (viz. reduced fuel burn). Metric: Fuel consumption and associated costs.
<i>KPA-04: Efficiency</i>	Harmonized arriving air traffic (en-route to terminal area to aerodrome) and harmonized departing air traffic (aerodrome to terminal area to en-route) will translate to reduced arrival and departure holding times and thus reduced fuel burn. Metric: Fuel consumption and flight time punctuality.
<i>KPA-05: Environment</i>	Reduced fuel burn through optimized departure and arrival profiling/scheduling. Metric: Fuel burn and emissions.
<i>KPA-06: Flexibility</i>	Supports pre-tactical and tactical arrival and departure sequencing and thus dynamic air traffic scheduling. Metric: ACC and aerodrome throughput.
<i>KPA-07: Global interoperability</i>	Gate-to-gate seamless operations through common access to, and use of, the available WAFS, IAVW and tropical cyclone watch forecast information. Metric: ACC throughput.

<i>KPA-08: Participation by the ATM community</i>	Common understanding of operational constraints, capabilities and needs, based on expected (forecast) meteorological conditions. Metric: Collaborative decision making at the aerodrome and during all phases of flight.
<i>KPA-09: Predictability</i>	Decreased variance between the predicted and actual air traffic schedule. Metric: Block time variability, flight-time error/buffer built into schedules.
<i>KPA-10: Safety</i>	Increased situational awareness and improved consistent and collaborative decision-making. Metric: Incident occurrences.
<i>Cost Benefit Analysis</i>	To be developed

3. NECESSARY PROCEDURES (AIR AND GROUND)

3.1 No new procedures necessary.

3.2 ICAO Annex 3 – *Meteorological Service for International Air Navigation* provides the internationally agreed requirements pertaining to, *inter alia*, the WAFS, the IAVW, the tropical cyclone watch, and aerodrome warnings, wind shear warnings and alerts and SIGMETs.

3.3 Supporting guidance material is contained in a number of ICAO manuals, including but not limited to: *Manual of Aeronautical Meteorological Practice* (Doc 8896); *Manual on Coordination between Air Traffic Services, Aeronautical Information Services and Aeronautical Meteorological Services* (Doc 9377); *Handbook on the International Airways Volcano Watch – Operational Procedures and Contact List* (Doc 9766); and *Manual on Low Level Wind shear* (Doc 9817). In addition, the *Manual on volcanic ash, radioactive material and toxic chemical clouds* (Doc 9691) provides extensive guidance on, *inter alia*, the observation/detection and forecasting of volcanic ash in the atmosphere and the effect of volcanic ash on aircraft.

3.4 ICAO regional air navigation plans contain region-specific requirements pertaining to WAFS, IAVW and tropical cyclone watch information and exchange.

4. NECESSARY SYSTEM CAPABILITY

4.1 Avionics

4.1.1 No new or additional avionics requirements are brought about by this module.

4.2 Ground systems

4.2.1 ANSPs, airport operators and airspace users may want to implement functionalities allowing them to display in plain text or graphical format the available meteorological information. For Block 0, airspace users may use their AOC data link connection to the aircraft to send the meteorological information where appropriate.

5. HUMAN PERFORMANCE

5.1 Human factors considerations

5.1.1 General statements on the impact on operational functions.

5.1.1.1 This module will not necessitate significant changes in how air navigation service providers and users access and make use of the available meteorological information today.

5.2 Training and qualification requirements

5.3 No new or additional training and qualification requirements are brought about by this module.

6. REGULATORY/STANDARDIZATION NEEDS AND APPROVAL PLAN (AIR AND GROUND)

6.1 No new or additional regulatory/standardization needs and approval plan(s) are brought about by this module. Provisions relating to the WAFS, the IAVW and the tropical cyclone watch, as well as aerodrome warnings, wind shear warnings and alerts and SIGMETs, already exist within ICAO Annex 3, regional air navigation plans, and supporting guidance.

7. IMPLEMENTATION AND DEMONSTRATION ACTIVITIES (AS KNOWN AT TIME OF WRITING)

7.1 Current use

7.1.1 The elements of this module are in current use.

7.2 Elements 1 to 3

7.2.1 Information made available by the WAFCs, VAACs and TCACs is available via the ICAO AFS and public Internet as follows:

- a) the satellite distribution system for information relating to air navigation (SADIS) second generation (G2) satellite broadcast;
- b) the international satellite communications systems (ISCS) second generation (G2) satellite broadcasts;

Note.— ISCS G2 service will be withdrawn by the United States as the ISCS provider State on 1 July 2012.

- c) the secure SADIS file transfer protocol (FTP) service; and
- d) the world area forecast system internet file service (WIFS).

7.2.2 The United Kingdom, as the SADIS provider State, provides a) and c) for authorized users in the ICAO EUR, MID, AFI Regions and Western part of the ASIA Region; whilst the United States, as the ISCS/WIFS provider State, provides b) and d) for authorized users in the rest of the world.

7.2.3 Authorized access to the SADIS/SADIS FTP and ISCS/WIFS services is determined by the Meteorological Authority of the State concerned in consultation with the users.

7.2.4 In addition to the above, volcanic ash and tropical cyclone advisory information in alphanumeric form is available on the ICAO Aeronautical Fixed Telecommunication Network (AFTN).

7.3 Elements 4 and 5:

7.3.1 Aerodrome warnings are in current use at all aerodromes worldwide (except where a State difference is filed).

7.3.2 Dedicated wind shear detection and alerting systems are in current use at aerodromes worldwide where wind shear is considered a factor – for example, Funchal airport in Madeira (Portugal), Hong Kong international airport (Hong Kong, China) and numerous aerodromes in the United States.

7.4 Planned or ongoing activities

7.4.1 Description of planned demonstration and implementation activities, for each known region. Enhancement of the international provisions governing the meteorological information provided by the designated Centres within the frameworks of the WAFS, the IAVW and the tropical cyclone watch, and aerodromes warnings, wind shear warnings and alerts, undergo periodic review and, where required, amendment, in accordance with standard ICAO procedure.

8. REFERENCE DOCUMENTS

8.1 Standards

- ICAO and Industry Standards (i.e. MOPS, MASPS, SPRs)
- ICAO and World Meteorological Organization (WMO) international standards for meteorological information (including, content, format, quantity, quality, timeliness and availability)

8.2 Procedures

8.2.1 Documented procedures by States and ANSPs (to be developed).

8.3 Guidance material

- ICAO Manuals, Guidance Material and Circulars. Also any similar industry documents
- ICAO Doc 7192, *Training Manual - Part F1 – Meteorology for Air Traffic Controllers and Pilots*
- ICAO Doc 8896, *Manual of Aeronautical Meteorological Practice*
- ICAO Doc 9161, *Manual on Air Navigation Services Economics*
- ICAO Doc 9377, *Manual on Coordination between Air Traffic Services, Aeronautical Information Services and Aeronautical Meteorological Services*

- ICAO Doc 9691, *Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds*
 - ICAO Doc 9766,– *Handbook on the International Airways Volcano Watch – Operational Procedures and Contact List*
 - ICAO Doc 9817, *Manual on Low Level Wind Shear*
 - ICAO Doc 9855, *Guidelines on the Use of the Public Internet for Aeronautical Applications*
 - *SADIS User Guide*
 - Agreement on the Sharing of Costs of the Satellite Distribution System for Information relating to Air Navigation
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APPENDIX B

MODULE NO. B1-105: ENHANCED OPERATIONAL DECISIONS THROUGH INTEGRATED METEOROLOGICAL INFORMATION (PLANNING AND NEAR-TERM SERVICE)

Summary	This module enables the reliable identification of solutions when forecast or observed meteorological conditions impact aerodromes or airspace. Full ATM-Meteorology integration is needed to ensure that: meteorological information is included in the logic of a decision process and the impact of the meteorological conditions (the constraints) are automatically calculated and taken into account. The decision time-horizons range from minutes, to several hours or days ahead of the ATM operation (this includes optimum flight profile planning and tactical in-flight avoidance of hazardous meteorological conditions) to typically enable near-term and planning (>20 minutes) type of decision making. This module also promotes the establishment of standards for global exchange of the information. This module builds, in particular, upon module B0-105, which detailed a subset of all available meteorological information that can be used to support enhanced operational efficiency and safety.	
Main performance impact as per Doc 9854	KPA-02 – Capacity, KPA-04 – Efficiency, KPA-05 – Environment, KPA-06 – Flexibility, KPA-09 – Predictability, KPA-10 – Safety.	
Operating environment/ Phases of flight	All flight phases	
Applicability considerations	Applicable to traffic flow planning, and to all aircraft operations in all domains and flight phases, regardless of level of aircraft equipage.	
Global concept component(s) as per Doc 9854	AOM – airspace operations and management DCB – demand and capacity balancing AO – aerodrome operations	
Global plan initiatives (GPI)	GPI-19: Meteorological systems GPI-6: Air traffic flow management GPI-16: Decision support systems and alerting systems	
Main dependencies	Module B0-10: Improved en-route profiles Module B0-15: Runway arrival sequencing Module B0-35: Air traffic flow management/Network operations procedures (ATFM/NOP) and collaborative decision-making (CDM) Successor to Module B0-105: Meteorological information supporting enhanced operational efficiency and safety Parallel development with Module B1-15: Arrival management/departure management (AMAN/DMAN) Metroplex and linked DMAN/surface management (SMAN) Module B1-35: Enhanced NOP, Integrated airspace/flow management	
Global readiness checklist		Status (ready now or estimated date).
	Standards readiness	Est. 2018
	Avionics availability	Est. 2018
	Infrastructure availability	Est. 2018
	Ground automation availability	Est. 2018
	Procedures available	Est. 2018
	Operations approvals	Est. 2018

1. NARRATIVE

1.1 General

1.1.1 This module improves the current baseline case where ATM decision makers manually determine the amount of change in capacity associated with an observed or forecast meteorological condition (for example, thunderstorm activity), manually compare the resultant capacity with the actual or projected demand for the airspace or aerodrome, and then manually devise ATM solutions when the demand exceeds the meteorologically-constrained capacity value. This module also improves in-flight avoidance of hazardous meteorological conditions by providing more precise information on the location, extent, duration and severity of the hazard(s) affecting specific flights.

1.1.2 This module is a key component in the evolution of procedures and automation capabilities, both aircraft-based and ground-based, intended to mitigate the effects of hazardous meteorological conditions on flight planning, flight operations and flow management, whilst also enabling such users to make optimum use of meteorological conditions that are not hazardous to flight. For this reason, B1-105 should be viewed as encompassing the timeframes envisaged for Block 1 and Block 2, thus forming the basis for B3-105.

1.2 Baseline

1.2.1 Meteorological conditions hazardous to flight are a major cause of flight delay in many airspace systems. Research analyses have suggested that a significant portion of this delay could be mitigated if meteorological forecasts were minimized and the confidence increased (the “perfect” forecast) and appropriate air traffic management (ATM) solutions integrating the meteorological information could be consistently devised and employed. Rigid airspace structures often preclude the consistent employment of the best ATM solutions. Therefore, there is a continuing desire to reduce forecast uncertainty to the maximum extent possible for given meteorological conditions and ATM solution.

1.2.2 ATM-Meteorology Integration (hereunder referred to as ATM-MET Integration) means that meteorological information is included in the logic of a decision process or aid such that the impact of the meteorological constraint is automatically calculated and taken into account when the decision is made or recommended. By minimizing the need for humans to manually assess meteorological constraints and determine the most appropriate mitigation of those constraints, ATM-MET Integration enables the best ATM solutions to be consistently identified and executed.

1.2.3 The concepts, capabilities and processes achieved in this module are applicable to multiple decision time frames, from pre-flight planning to daily flow planning to tactical flow planning. Initial improvements to tactical avoidance of hazardous meteorological conditions are also considered in this module, but utilization of advanced aircraft-based capabilities in this regard are emphasized in module B3-105.

1.3 Change brought by the module

1.3.1 The transition to systems and processes embodied by ATM-MET Integration leads to the consistent identification and use of operationally effective ATM solutions to meteorologically-related demand/capacity imbalances, and tactical avoidance of hazardous meteorological conditions.

1.3.2 There are four elements of ATM-MET integration as enabled by this module. With respect to airspace, the output of the first element, *Meteorological Information*, is ingested by automation

associated with the second, *Meteorological Information Translation*. Through filters such as safety regulations and standard operating procedures, the meteorological information (observations and forecasts) is turned (“translated”) into a non-meteorological parameter called an airspace constraint, a measure of the expected capacity of the affected airspace. This parameter is, in turn, fed to the third component called *ATM Impact Conversion*. By comparing projected demand and meteorologically-constrained capacity, this component transforms (“converts”) the airspace constraint into an airspace impact. The fourth component, *ATM Decision Support*, takes the quantified impact values from *ATM Impact Conversion* and develops one or more strategic and tactical ATM solutions to the observed or forecast meteorological constraint.

1.4 **Element 1: Meteorological information**

1.4.1 Meteorological information is the superset of all required aeronautical meteorological observations and forecasts available to operator and air navigation service provider (ANSP) and airport decision makers. Included in this superset are data designated as the authoritative meteorological information based upon which ATM decision makers will build their solutions.

1.5 **Element 2: Meteorological information translation**

1.5.1 Meteorological information translation refers to automated processes that ingest raw aeronautical meteorological information and translate them into characterized meteorological constraints and airspace or aerodrome threshold events. The output of the meteorological information translation process is a non-meteorological value that represents a potential change in the permeability of airspace or capacity of the aerodrome.

1.5.2 It is unlikely that future automation systems will incorporate meteorological information translation methodology without also including ATM impact conversion components. As such, this element is likely to be more of an enabler of the next element and the entire process rather than an interim end state.

1.6 **Element 3: ATM impact conversion**

1.6.1 The ATM Impact Conversion element determines the anticipated meteorologically-constrained capacity of the airspace or aerodrome and compares this to the projected demand. If an imbalance exists between the two, this information is provided to the system user and/or the ATM Decision Support element to inform development of mitigation strategies for dealing with the imbalance.

1.7 **Element 4: Meteorological information integrated decision support**

1.7.1 The final element is meteorological information integrated decision support, comprised of automated systems and processes that create ranked mitigation strategies for consideration and execution by ATM decision makers. The solutions are based on requirements and rules established by the ATM community. These improvements also augment the communication and display of meteorological information to service providers and operators to support tactical avoidance.

2. INTENDED PERFORMANCE OR OPERATIONAL IMPROVEMENT/METRIC FOR SUCCESS

<i>Capacity</i>	Improvements in the content, format, quantity, quality, timeliness and availability of meteorological information (observations and forecasts) will lead to enhanced situational awareness of meteorological conditions, and in particular the location, extent, duration and severity of hazardous meteorological conditions and their impacts on airspace. This in turn enables more precise estimates of expected capacity of that airspace. <u>Associated Metric</u>: Improved meteorological information in reference to the number of user-preferred profiles that can be accommodated. Maximum use of available airspace capacity. <u>Associated Metric</u>: With respect to capacity, the number of user-preferred profiles that can be accommodated would be an appropriate metric for Meteorological Information Integrated Decision Support.
<i>Efficiency</i>	Improvements in the content, format, quantity, quality, timeliness and availability of meteorological information (observations and forecasts) will lead to enhanced situational awareness of meteorological conditions, and in particular the location, extent, duration and severity of hazardous meteorological conditions and their impacts on airspace. <u>Associated Metric</u>: An improvement in efficiency associated with improved meteorological information would be the number of deviations from user-preferred flight profiles. Advanced decision support tools, fully integrated with meteorological information, support stakeholders in planning for the most efficient routes possible, given the forecast meteorological conditions. <u>Associated Metric</u>: Among the measures of success for Meteorological Information Integrated Decision Support in the area of efficiency would be the number of deviations from user-preferred flight profiles.
<i>Environment</i>	More precise planning for mitigation of hazardous meteorological conditions produces safer, more efficient routes, less fuel burn, and reduction of emissions due to fewer ground hold/delay actions. <u>Associated Metric</u>: Fewer reroutes and less variability in associated traffic management initiatives (TMIs) can be expected.
<i>Flexibility</i>	Users have greater flexibility in selecting trajectories that best meet their needs, taking into account the observed and forecast meteorological conditions. <u>Associated Metric</u>: Fewer reroutes and less variability in associated traffic management initiatives (TMIs) can be expected.
<i>Predictability</i>	Meteorological Information Translation combined with ATM Impact Conversion leads to more consistent evaluations of meteorological constraints, which in turn will allow users to plan trajectories that are more likely to be acceptable from the standpoint of the ANSP. <u>Associated Metric</u>: Fewer reroutes and less variability in associated traffic management initiatives (TMIs) can be expected. Consequently, airspace users will be able to carry less contingency fuel than is felt necessary today, resulting in lower fuel burn.

	Fewer reroutes and less variability in associated traffic management initiatives (TMIs) can be expected. Consequently, airspace users will be able to carry less contingency fuel than is felt necessary today, resulting in lower fuel burn. <u>Associated Metric:</u> Among the measures of success for both Meteorological Information Translation and ATM Impact Conversion are decreases in the variability and numbers of responses to a given meteorological conditions, along with reduced contingency fuel carriage for the same meteorological situation. Advanced decision support tools, fully integrated with meteorological information, produce consistent, optimal solution sets, and allow users to plan trajectories that are more likely to be acceptable from the standpoint of the ANSP. Fewer reroutes and less variability in other associated traffic management initiatives (TMIs) can be expected. In turn, this will allow airspace users to carry less contingency fuel than is felt necessary today, resulting in lower fuel burn. <u>Associated Metric:</u> Decrease in the variability and numbers of ATM responses to a given meteorological situation, along with reduced contingency fuel carriage for the same meteorological situation.
<i>Safety</i>	Meteorological information improvements lead to increased situational awareness by pilots, AOCs and ANSPs, including enhanced safety through the avoidance of hazardous meteorological conditions. <u>Associated Metric:</u> Safety improvement associated with enhanced (quantity, quality and availability of) meteorological information would be the number of meteorologically-related aircraft incidents and accidents. Advanced decision support tools, fully integrated with meteorological information, produce solution sets that minimize pilot exposure to hazardous meteorological conditions. This, combined with increased situational awareness of observed and forecast meteorological conditions by pilots and ANSPs, enables avoidance of hazardous conditions. <u>Associated Metric:</u> Decreases in the variability and numbers of responses to a given meteorological condition, along with reduced contingency fuel carriage for the same meteorological condition.
<i>Cost Benefit Analysis</i>	The business case for this element is still to be determined as part of the development of this overall module, which is in the research phase. Current experience with utilization of ATM decision support tools, with basic meteorological input parameters to improve ATM decision making by stakeholders has proven to be positive in terms of producing consistent responses from both the ANSP and user community.

3. NECESSARY PROCEDURES (AIR AND GROUND)

3.1 Procedures exist today for ANSPs and users to collaborate on meteorologically-related decisions. Extension to these procedures must be developed to reflect the increased use of decision support automation capabilities by both. International standards for information exchange between systems to support global operations must be developed, including the enhancement of existing global standards concerning the transmission/reception of meteorological information to/by the end user. More specifically, by the implementation of a uniform meteorological information exchange specification (i.e. WXXM).

4. NECESSARY SYSTEM CAPABILITY

4.1 Avionics

4.1.1 This module does not depend on significant additional avionics or retro-fitting avionics with a specific capability. Improved meteorological information can be disseminated to the pilot via flight operations centres, controllers, and via air-ground links (e.g. FIS) where available or can be displayed in aircraft with sufficient capabilities installed. A more extensive use of aircraft-based capabilities to support tactical avoidance of hazardous meteorological conditions with immediate consequences is the main focus of Module B3-105 but could start to be introduced in the transitional period between B1-105 and B3-105 for aircraft sufficiently equipped.

4.2 Ground systems

4.2.1 Technology development in support of this element will include the creation and implementation of a consistent, integrated four-dimensional (4-D) database of global meteorological information (observations and forecasts), including linkage (through information exchange and communications standards) between global, regional or sub-regional meteorological information systems.

4.2.2 Technology development in support of this element will include the introduction of:

- a) automated meteorological information translation methodologies based on the operational needs for such information;
- b) automated methodologies that use meteorological information translation data to assess the impact on ATM operations, for flows and individual flights; and
- c) decision support tools, for both ANSPs, airports and airport users, which automatically ingest ATM Impact Conversion information, and support decision making via generation of candidate mitigation strategies.

5. HUMAN PERFORMANCE

5.1 Human factors considerations

5.1.1 This module will necessitate significant changes in how service providers and users deal with observed and/or forecast meteorological conditions, made available as meteorological information. The availability of decision support tools, integrated with enhanced observation and forecast meteorological information, will enable more efficient and effective development of mitigation strategies. But, procedures will need to be developed, and changes to cultural aspects of how decision making is done today will need to be considered. Also, the realization of a “common view” of meteorological conditions between service providers, flight operations and pilots will require trust in a single, common set (a single authoritative source) of meteorological information.

5.2 Training and qualification requirements

5.2.1 Automation support, integrated with meteorological information is needed for flight operations, pilots and service providers. Training in the concepts behind the automation capabilities will be necessary to enable the effective integration of decision support tools into operations. Also, enhanced

procedures for collaboration on ATM decision-making will need to be developed and training provided, again to ensure effective operational use.

6. REGULATORY/STANDARDIZATION NEEDS AND APPROVAL PLAN (AIR AND GROUND)

6.1 This module requires the development of global standards for meteorological information exchange, with emphasis on the exchange of 4-D (latitudinal, longitudinal, vertical and temporal) digitized meteorological information, and regulatory agreement on what constitutes required meteorological information in the digital information exchange era versus traditional gridded, binary, alphanumeric and graphic formats. Standardized meteorological information translation parameters and ATM impact conversion parameters will also require development.

7. IMPLEMENTATION AND DEMONSTRATION ACTIVITIES (AS KNOWN AT TIME OF WRITING)

7.1 Current use

7.1.1 A considerable amount of research and analysis is currently underway. The development of the United States' 4-D weather data cube is underway. Decisions concerning internal infrastructure, data exchange standards and communications are nearing completion, and initial demonstrations of the system have taken place.

7.2 Planned or ongoing activities

7.2.1 No global demonstration trials are currently planned for this element. There is a need to develop such an activity as part of the collaboration on this module.

8. REFERENCE DOCUMENTS

8.1 Standards

8.1.1 ICAO international standards on functional and non-functional aspects for the (impact) definition, translation, conversion and integration of meteorological information in ATM standards and procedures.

8.1.2 ICAO and the World Meteorological Organization (WMO) international standards for meteorological information exchange (WXXM).

8.1.3 To be developed as part of this research should be the advanced utilization by ICAO of relevant existing standards or standards under development by other international standardization/specifications organizations (e.g. ISO, OGC) for exchange and integration of meteorological information.

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APPENDIX C

MODULE NO. B3-105: ENHANCED OPERATIONAL DECISIONS THROUGH INTEGRATED METEOROLOGICAL INFORMATION (NEAR-TERM AND IMMEDIATE SERVICE)

Summary	The aim of this module is to enhance global ATM decision making in the face of hazardous meteorological conditions in the context of decisions that should have an immediate effect. This module builds upon the initial information integration concept and capabilities developed under B1-105. Key points are a) tactical avoidance of hazardous meteorological conditions in especially the 0-20 minute timeframe; b) greater use of aircraft based capabilities to detect meteorological parameters (e.g. turbulence, winds, and humidity); and c) display of meteorological information to enhance situational awareness. This module also promotes further the establishment of standards for the global exchange of the information.	
Main performance impact as per Doc 9854	KPA-02 – Capacity, KPA-04 – Efficiency, KPA-09 – Predictability, KPA-10 – Safety.	
Operating environment/ Phase of flight	All	
Applicability considerations	Applicable to air traffic flow planning, en-route operations, terminal operations (arrival/departure), and surface. Aircraft equipage is assumed in the areas of ADS-B IN/CDTI, aircraft-based meteorological observations, and meteorological information display capabilities, such as EFBs.	
Global concept component(s) as per Doc 9854	AOM – airport operations and management DCB – demand and capacity balancing AO – aerodrome operations TM – traffic synchronization CM – conflict management	
Global plan initiatives (GPI)	GPI-9: Situational awareness GPI-15: Match IMC and VMC operating capacity GPI-19: Meteorological systems	
Main dependencies	Successor to Module B1-105	
Global readiness checklist		Status (ready now or estimated date)
	Standards readiness	Est. 2023
	Avionics availability	Est. 2023
	Infrastructure availability	Est. 2023
	Ground automation availability	Est. 2023
	Procedures available	Est. 2023
	Operations approvals	Est. 2023

1. NARRATIVE

1.1 General

1.1.1 This module is focused on developing advanced concepts and necessary technologies to enhance global ATM decision making in the face of hazardous meteorological conditions. The major components include a consistent, integrated set of meteorological information available to all users and

ANSPs, advanced decision support tools that utilize the information to assess the potential operational impacts of the meteorological situation and decision support tools that develop candidate mitigation strategies for dealing with the impacts.

1.1.2 The capabilities discussed in this module will primarily benefit in-flight operations and avoidance of hazardous meteorological conditions in the en-route, terminal area and aerodrome domains. But, this module will also extend initial pre-flight and flow planning capabilities realized in module B1-105. These negotiation capabilities will be globally interoperable to allow for seamless planning of trajectories for international flights.

1.2 **Baseline**

1.2.1 The baseline for this module is the initial, enhanced operational decision making capabilities enabled by module B1-105. Decision support capabilities are available, and integrated with meteorological information, to assist ANSPs and users to make better decisions in the near-term and planning timeframe (20 minutes or more). A consistent, integrated meteorological information base is available to all ANSPs and users, to inform ATM decision-making. Supported by standards that facilitate the global exchange of the relevant meteorological information in accordance with the performance required.

1.3 **Change brought by the module**

1.3.1 This module provides extensions to this baseline, with emphasis on the tactical (0-420 minute) timeframe, and greater use of aircraft-based capabilities for meteorological awareness and avoidance. A major focus is on the provision of enhanced automation capabilities (building on B1-105) for developing characterizations of potential meteorologically-impacted airspace, and for using those characterizations to determine impact on ATM operations and individual flights.

1.4 **Element 1: Enhanced meteorological information**

1.4.1 This element is focused on the development of enhanced meteorological information for integration into ATM decision making. The scope of meteorological information to be considered includes observations and forecasts of the full range of aviation-relevant phenomena. This also includes an emphasis on increasing the availability of characterizations of potentially meteorologically-constrained airspace which may be directly integrated into ANSP and user decision making. This element also focuses on the development or revision of global standards for meteorological information content and format, given the migration to four-dimensional (4-D) representations of meteorological information, versus traditional gridded, binary, alphanumeric and graphic formats.

1.5 **Element 2: Meteorology integrated decision support tools**

1.5.1 This element continues the evolution to the utilization of ATM decision support tools, used by ANSPs and users, which directly integrates meteorological information into their processing. Based on experiences gained from development and deployment of initial capabilities as part of module B1-105, extensions are developed to generate more efficient and operationally acceptable meteorologically-related mitigation solutions. This element also develops direct automation-to-automation negotiation capabilities (both ground-based and aircraft-based) to streamline the development of mutually acceptable ATM decisions.

1.6 Element 3: Cockpit meteorological information capabilities

1.6.1 This element will focus on aircraft-based capabilities that will assist pilots with avoidance of hazardous meteorological conditions, and thus enhance safety. Capabilities such as ADS-B IN, air-to-air information exchange, and integration of meteorological information into cockpit-based automation tools are considered. In addition, increased availability of aircraft-based meteorological observations will further enhance situational awareness, and help to improve meteorological forecasting capabilities. This element must focus on globally-harmonized standards development for meteorological information exchange to support these capabilities.

2. INTENDED PERFORMANCE OPERATIONAL IMPROVEMENT/METRIC TO DETERMINE SUCCESS

2.1 To assess the operational improvement by the introduction of cockpit meteorological information capabilities, States can use, as appropriate, a combination of the following metrics.

<i>Capacity</i>	Better information on the location, extent, duration and severity of hazardous meteorological conditions on airspace enables more precise estimates of expected capacity of that airspace. Advanced decision support tools, integrated with meteorological information, supports stakeholders in assessing the meteorological situation and in planning mitigation strategies, which make maximum use of available airspace.
<i>Efficiency</i>	Better information on the location, extent, duration and severity of hazardous meteorological conditions on airspace enables better utilization of available capacity and accommodation of user-preferred profiles.
<i>Safety</i>	Increased situational awareness by pilots and ANSPs enables avoidance of hazardous meteorological conditions.
<i>Cost Benefit Analysis</i>	The business case is still to be determined as part of the development of this module, which is in the research phase.

3. NECESSARY PROCEDURES (AIR AND GROUND)

3.1 The necessary procedures basically exist for ANSPs and users to collaborate on meteorologically-related decisions. Extensions to those procedures will be developed to reflect the use of enhanced meteorological observation and forecast information, plus the use of characterizations of potential meteorologically-impacted airspace. International standards for information exchange between systems to support these improved ATM operations must be developed. This includes development of global standards for the delivery of meteorological information to aircraft.

3.2 The use of ADS-B/CDTI and other cockpit capabilities to support avoidance of hazardous meteorological conditions by pilots will necessitate procedure development, including the roles of ANSPs. International standards for meteorological information exchange between ground-based and aircraft-based systems to support these operations must be developed. This includes development of global standards for the delivery of meteorological information to aircraft.

4. NECESSARY SYSTEM CAPABILITY

4.1 Avionics

4.1.1 This module has a significant dependency on advanced aircraft capabilities being widely available. Although aircraft-based capabilities such as ADS-B/CDTI and EFBs exist, the level of equipage is still evolving, and applications are still being developed to support the objectives of this module. Also, integration of advanced (e.g. post-processed) meteorological information into aircraft-based decision support tools will be needed. Increased levels of aircraft equipage with meteorological sensors (e.g. turbulence, humidity, wind) will be necessary to ensure tactical situational awareness of meteorological conditions for all aircraft in an area of interest.

4.2 Ground systems

4.2.1 For this longer-term module, the needed ground-system technology is still in development. Research is on-going into decision support tools that ingest meteorological information directly, and support the automated development of candidate mitigation strategies. For example, conflict resolution tools will be integrated with meteorological information to ensure aircraft are not inadvertently routed into hazardous meteorological conditions. Work is also needed to ensure a globally harmonized, common set (a single authoritative source) of meteorological information that is available to all ANSPs and users for decision making. Also, integration of ground-based and aircraft-based automation capabilities, including exchange of digital meteorological information, is needed to support tactical avoidance of hazardous meteorological conditions.

5. HUMAN PERFORMANCE

5.1 Human factors considerations

5.1.1 This module may necessitate changes in how service providers and users deal tactically with observed and/or forecast meteorological conditions, made available as meteorological information. While pilots will continue to be responsible for the safe operation of their aircraft in hazardous meteorological conditions, the roles and responsibilities of controllers (informed by conflict resolution tools) must also be considered, in order to achieve safe and efficient approaches to avoidance of hazardous meteorological conditions. Also, the realization of a “common view” of the meteorological situation between service providers, flight operations and pilots will require trust in a single common set (a single authoritative source of) meteorological information.

5.2 Training and qualification requirements

5.2.1 Automation support, integrated with meteorological information is needed for flight operations, pilots and service providers. Training in the concepts behind the automation capabilities will be necessary to enable the effective integration of the tools into operations. Also, enhanced procedures for collaboration on tactical avoidance of hazardous meteorological conditions will need to be developed and training provided, again to ensure effective operational use.

6. REGULATORY/STANDARDIZATION NEEDS AND APPROVAL PLAN (AIR AND GROUND)

6.1 This module requires the following:

- a) development of global standards for meteorological information exchange, with emphasis on exchange of 4-D (latitudinal, longitudinal, vertical, and temporal) digitized meteorological information;
- b) regulatory agreement on what constitutes required meteorological information in the digital information exchange versus traditional gridded, binary, alphanumeric and graphic formats; and
- c) certification decisions on aircraft-based meteorological information display and dissemination. Dissemination includes air-to-ground for aircraft-based observations (e.g. turbulence and humidity), as well as possible air-to-air exchange of those observations (e.g. turbulence information to nearby aircraft) via ADS-B.

7. IMPLEMENTATION AND DEMONSTRATION ACTIVITIES (AS KNOWN AT TIME OF WRITING)

7.1 Current use

7.1.1 Many States and users have been utilizing a collaborative decision-making (CDM) process for developing coordinated strategies for dealing with adverse meteorological conditions. These efforts have included the application of enhanced meteorological observation and forecast information, as it has developed. The United States' Federal Aviation Administration (FAA) and the United States National Weather Service (NWS) are, for example, continuing research on aviation-related weather forecasts, at all decision time horizons. Initial demonstrations of these candidate products are showing promise in enhancing the quality and quantity of meteorological information upon which ATM decisions can be made, by ANSPs and users.

7.1.2 Since this module is in the category of long term issues, there are limited examples of current operational use. In the United States, experience with the use of FIS-B and the Alaska Capstone effort have shown a significant safety benefit, with increased cockpit meteorological information display capabilities. Also, for general aviation aircraft, private vendors are making meteorological information available in the cockpit, as optional services. The FAA is conducting research on ADS-B IN applications that relate to avoidance of hazardous meteorological conditions via cockpit functionality. In Europe, FIS-B like capabilities are being deployed currently in Sweden and Russia that provide for enhanced meteorological information available to pilots. Such United States and European research efforts will help to inform the work necessary under this module.

7.2 Planned or ongoing activities

7.2.1 No global demonstration trials are currently planned for this module. There is a need to develop such a plan as part of the collaboration process, and as an extension of other modules.

8. REFERENCE DOCUMENTS

8.1 Standards

8.1.1 ICAO international standards on functional and non-functional aspects for the (impact) definition, translation, conversion and integration of meteorological information in ATM standards and procedures.

8.1.2 ICAO and the World Meteorological Organization (WMO) international standards for meteorological information exchange (WXXM).

8.1.3 To be developed as part of this research should be the advanced utilization by ICAO of relevant existing standards or standards under development by other international standardization/specifications organizations (e.g. ISO, OGC) for exchange and integration of meteorological information.

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