Meteorological Information Integration for Trajectory Based Operations

Concept

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1 Introduction

1.1 Purpose and scope of the document

The Meteorological Information Integration for Trajectory Based Operations Concept provides guidance to better understand Meteorological (MET) information integration considerations, assists in identifying the type and level of MET support required to Trajectory Based Operations (TBO) and forms a baseline to develop the required provisions. This baseline should enable the members of the Air Traffic Management (ATM) community to consider the types and quality of MET information services and the level of integration that is proportional to their specific needs.

The following aspects need to be considered but is not necessarily limited to these when considering MET information integration for TBO:

1) A description of the global evolution and context of the ATM system foreseen, detailing the performance focus which identifies a number of key areas where ATM and MET will evolve;

2) Guidance on MET information integration and the associated roles and responsibilities of ATM service and the MET service providers are identified;

3) Guidance on how MET information services could be categorised and linked to Operational Concept Components including the contribution to relevant performance areas, and;

4) Guidance on how MET information integration requirements could translate into defined MET Information requirements from an ATM stakeholder' (e.g. pilot, controller, airline operations staff) perspective.

1.2 Relationship to other documents

The relation between the Meteorological Information Integration for Trajectory Based Operations Concept and other provisions should be considered from two perspectives. The Concept relates directly to existing or to be developed provisions in ICAO Annexes, Procedures for Air navigation Services and Guidance Material relevant to TBO and meteorological service provision, see Figure 1-1.

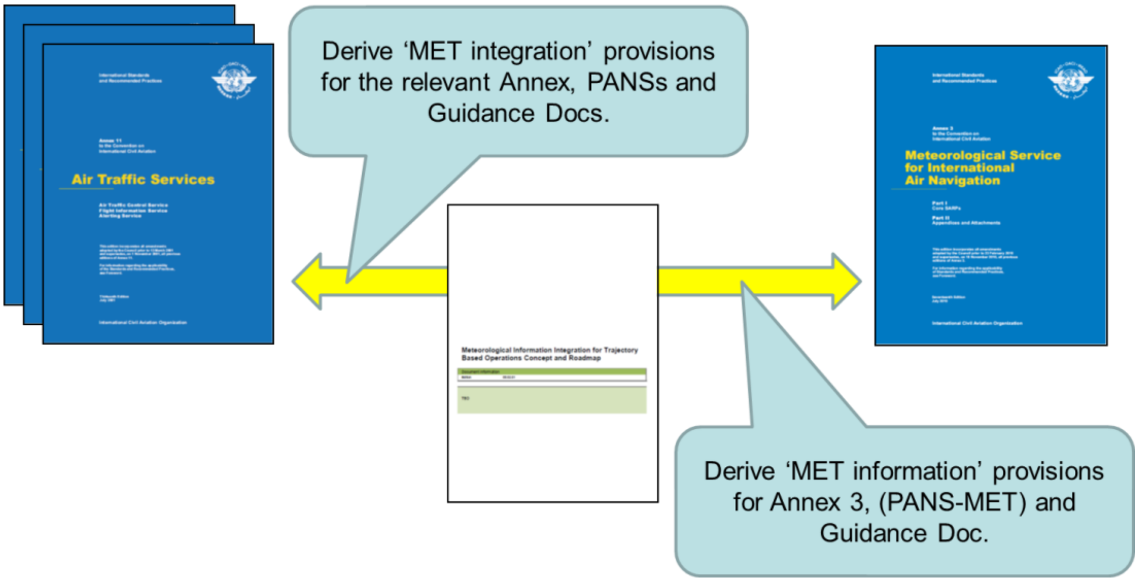


Figure 1-1

1.3 Terms used with a limited meaning

For the purpose of this document, the following terms are used with a limited meaning as indicated below:

a) “weather’ is used solely in the context of the state of the atmosphere that humans and systems experience or are effected by;

b) “meteorological” is used solely in the context of describing the current or future state of the atmosphere;

c) to avoid confusion in respect of the term “service” between a service considered as an administrative entity, the service which is provided and an information/data service as identified in a Service-oriented architecture (SOA) approach, “MET provider” is used for the administrative entity, “MET service” is generically used for the service provided and “MET information service” is used for a service provided by a MET provider related to the exchange of MET information between provider and user and which is adhering to SOA principles (§ 2.4.2); and

d) “capability” is used solely in connection with the provision of services in general or making available information services and for MET specifically referring to the set of controllable functions and processes required by a MET provider to provide a MET service or making available a MET information service.

2 The evolving Global Air Transport System

The evolution of the Global Air Transport System requires an ATM system that delivers the requested services to meet agreed levels of performance. MET information plays a key role in the Air Transport system due to the impacts weather can bring to the operations. As such, the MET information needs to be considered in the framework of gate-to-gate or enroute-to-enroute operations. MET information should support decisions on what assets need to be deployed, to deliver what required services, to obtain what expected performance, while thinking across and within global concept components, across and within time horizons, and end-to-end.

The evolution of the Global Air Transport System and the consequential changes to how MET information shall be provided, exchanged, integrated and used could be described in high level terms from 5 perspectives. These perspectives are:

1. Trajectory Based Operations;
2. Performance Focus;
3. Evolution of User Needs:
4. The Enablers for Change, and;
5. Key Changes Identified.

2.1 Trajectory Based Operations

A move from the present ATM model (where the present location of the aircraft is known) to a trajectory-based management concept (where the future location of the aircraft is also known and shared) is fundamental to increasing the efficiency of flight planning. By using shared dynamic trajectory information between adjacent air navigation service providers (ANSPs) in the same and neighbouring flight information regions (FIRs), the ATM system will be able to analyse and accurately predict future situations based on three-dimensional and ultimately four-dimensional parameters including time. To support TBO the MET information system plays a pivotal role and will require improvements in the availability, accuracy, resolution and other quality of service. The MET information required should be exchanged on a system wide basis and integrated in decision support processes for TBO.

2.2 Performance Focus

The notion of a performance-based air navigation system emanated from good industry practices that have evolved over many years outside of aviation. The benefits that organizations within the ATM community can expect are:

a) improvement in the effectiveness of day-to-day economic management of their business;

b) a channelling of their efforts towards better meeting stakeholder expectations (including safety) as well as improving customer satisfaction; and

c) change-management in a dynamic environment.

This vision is expressed in terms of eleven ICAO key performance areas (KPAs) [Doc 9883] which serve as the global, top-level categorization framework for the performance measurement of ATM.

These Key Performance Areas are:

- KPA 01 – Access and Equity
- 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
- KPA 11 – Security

MET information integration in stakeholder decision making processes will contribute positively to almost every Key Performance Area, directly or indirectly, but mainly to KPA 02, 03, 04, 05 and 09. An improved provision and exchange of the MET information itself will already contribute to KPA 01 and 07.

Note: The Global Air Navigation Plan (GANP), fourth edition, [Doc 9750] defines performance improvements by applying on Block 0 and Block 1 related Modules a benefits metric based on all or only the relevant above listed ICAO KPAs except Security (KPA 11).

In the following chapter on MET information service identification, the direct and indirect contributions to identified KPA will be indicated. It is however important to recognise that by introducing performance-based approach based on the eleven key areas, the intrinsic need to validate the contribution of MET information on the identified areas is introduced.

This validation needs to take place at the level of the overall operational improvement of integrating MET information into a process instead of strictly on the scientific correctness of MET information only. In other words, it is not necessary to strive for a 100% match between what is forecast and what was actually observed. The quality/accuracy of MET information and the contribution to a performance area should be measured in relation to the intended use of the MET information taking into consideration the operational decision making environment. As a consequence, the real cost-benefit of the MET information can be established and the inclusion of the requirement for the MET service and the appropriate governance can be justified.

2.3 Evolution of User Needs

The evolution of the Global Air Transport system towards TBO will require a shift in how users will utilise MET information and the consequential requirements for making this MET information available. Pilots, airline operations staff, air traffic controllers, flow managers, aerodrome operations staff and all other stakeholders will rely more and more on the outcomes of complex decision making processes for which access to the relevant or time critical MET information is crucial. Not only access to information will become increasingly important, also the access to a common set of information in emerging operating environments is needed to support working from a common operating picture and to enable concepts such as Airspace organisation and management (AOM), Demand/capacity balancing (DCB), Aerodrome operations (AO), Traffic synchronisation (TS), Conflict Management (CM) and Airspace user operations (AUO).

It will not suffice anymore that on one hand pilots and airline operations staff have access to a specific set of MET information whilst aerodrome operations staff or ATM staff have access to other MET information resulting in a different understanding between the different stakeholders how the weather will influence -positively and negatively-, the foreseen (‘en-route to en-route’) trajectory.

New ways of exchanging, sharing, visualising and using MET information is crucial in order to assess the impact on the common environment. This improvement will allow all the stakeholders to collaboratively conclude a system response when required to anticipate impacting weather phenomena. Agreement is therefore required on the specific MET information to create a Common Operating Picture (COP) for weather impacts for all stakeholders.

Whilst describing the collective information needs of the system as a whole, the user needs for MET information to support individual decisions in their sphere of influence is another crucial aspect in a TBO environment. Pilots, airline operations staff, air traffic controllers, flow managers, aerodrome operations staff and all other stakeholders involved need to be served with the information to support their individual decisions when performing AOM, DCB, AO, TS, CM and AUO.

In general, the information made available needs to be tailored to the specific concern of these users. One of the key considerations however in addressing these user needs is the required balance between the direct accessibility (text, voice, graphical) of MET information and the principle of only having access to MET information when the decision support information needs to be better understood. Information overload of individual decision makers needs to be avoided. For complex decision making processes the accessibility of MET information should only be required when the understanding on the outcome of decision support processes needs to be improved.

2.4 The Enablers for Change

2.4.1 Network Centric Operations

Local (national) airspaces and aerodromes cannot continue to be regarded as singular and isolated components of ATM. Each should serve as a node interlinked with all others within the system. This transition to a service-centric, *whole-of-network-management* approach within a global business framework is essential to manage air traffic in partnership. Especially in the case of weather, which has no regard for national or FIR boundaries, this dynamic management of airspace, flight demand and flights in execution impacts becomes increasingly important. Elementary to this 'borderless' operation is to manage the risk and costs for all stakeholders by fully supportive and collaborative processes that take due account of weather impacts.

2.4.2 SWIM and Service Oriented Architecture

The ATM system will be reliant on automation and it will deliver a broad portfolio of services to its myriad of clients. This networked approach will be enabled by System Wide Information Management (SWIM) and designed using the principles of Service Oriented Architecture (SOA).

SWIM addresses (a) the need to increasingly complement human-to-human communication with machine-to-machine communication, and (b) the need to emphasize better data distribution and accessibility in terms of quality and timeliness.

SOA is a general concept or paradigm for 'organizing and utilizing distributed capabilities that may be under the control of different owners'. While there is no formally agreed definition of SOA, it is generally considered that partitioning of functionality into non-associated, self-contained and therefore reusable services that can be discovered by potential users is a key feature that discriminates SOA from more traditional architectural paradigms. The SOA paradigm has been used successfully in many industries including manufacturing, banking, health care, and merchandise retailing.

A service orientation is assumed for information exchanges between ATM stakeholders. That is, an information provider publishes and exposes its services for the use of information consumers; this is done via interconnected registries which list the services and the specific details for consuming them.

When empowered by SOA, SWIM will enable the aviation stakeholders to capitalise on opportunities, new services and capabilities by at least becoming more agile in service delivery, simplifying systems and lowering integration costs.

2.5 Key Changes Identified

It is widely recognised and understood that no aircraft is dispatched without MET information that advises the pilot of MET conditions for the departure and destination aerodrome and the expected MET conditions en-route with alternative routing for unexpected events. The future of ATM is to go further in integrating MET into its operations whenever appropriate to meet its performance targets and support the implementation of concepts such as TBO. In consequence, there are a number of key changes that have been identified by all stakeholders that are required to support the management and interchange of MET information relevant for the operation of the future global ATM system.

2.5.1 Proactive versus reactive decision making

A major factor in decision making is the accuracy, timeliness and completeness of the information on which the decisions are based. Currently, a reactive rather than proactive approach to decision making is the norm in dealing with weather as the perceived level of associated risk is considerably lower than in the proactive alternative. An example is where aerodrome stakeholders are reluctant to plan reduced aerodrome capacity hours on forehand, based on a convective weather forecast for the aerodrome. Since the level of confidence for these types of forecast is quite often assumed low and the operational and financial consequences of dealing with convective weather results in a dilemma for decision makers to plan based on the forecast versus the possibility that the event forecasted does not occur.

To change this practice, or at least to establish the tipping point between to-act or not-to-act on a MET forecast, it is clear that significantly greater access to shared MET information and an improved understanding of the level of confidence is required between the provider of information and the user of information to support decision making. The lack of confidence or an understanding how information on confidence level could be turned into operational information is the greatest detriment to improve the integration of MET information in decision making processes. An important consideration in this context is the understanding that based on the appropriate risk assessment, for some types of decisions a low level of confidence could suffice whilst for other types of decisions it is detrimental to have a high confidence.

Another important aspect in this context is the relationship between the scale of the weather phenomena in time and coverage, the means to observe and the related predictability of the phenomena and the consequential need to express predicted weather in terms of uncertainty and confidence. An indication of this relationship is provided by WMO in Doc N°488 and shown in Figure 2-1 below.

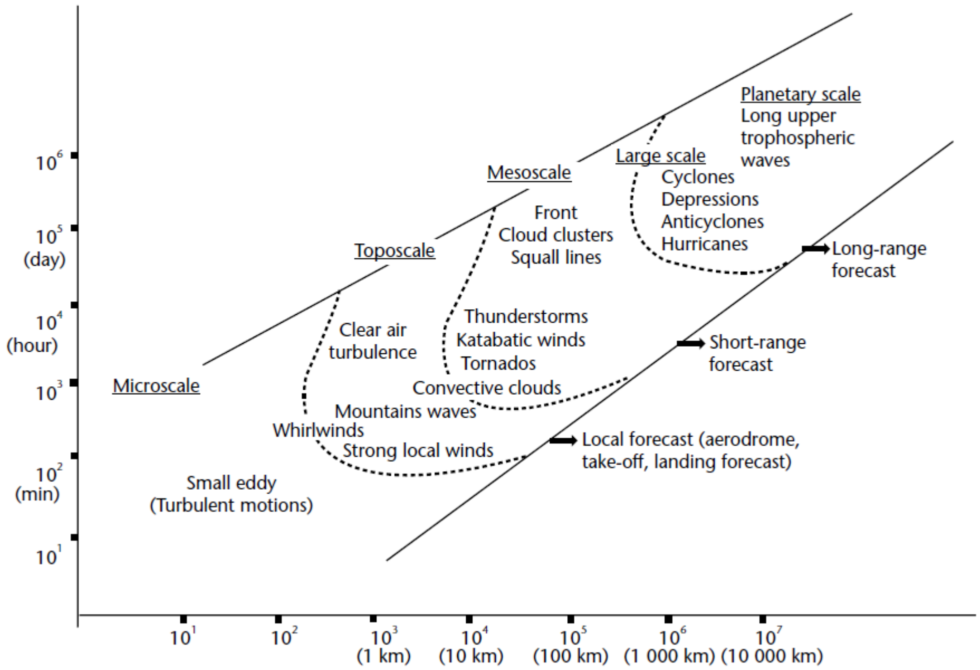


Figure 2-1 - Horizontal scales and timescales of meteorological phenomena

The objective should be the identification of the key MET information attributes that are needed to assure a high degree of confidence in the information and so serve as a platform for decision making. Key to this proactive knowledge based decision making is the proper use of uncertainty (or probabilistic) information that is associated with the MET information conveyed. This form of risk management enables decision-makers to make executive decisions according to their own objectively-determined thresholds for action.

2.5.2 Better utilisation of already available MET information

Though advances in observation systems and forecasting through numerical modelling have improved the quality and accuracy of the MET information, the uptake of these advancements by the air transport community is low due to various reasons. It is important to understand that different than describing the past and current state of the atmosphere, the future state of the atmosphere is difficult to describe in a deterministic manner from a MET perspective. Nevertheless, meteorological forecast information can be statistically or probabilistically characterised for a specific use. This would aid the determination of uncertainty and risk associated with a weather phenomenon and its impact, and as such serve ATM decision making. The level of uncertainty associated with existing MET information 'products' could be used in the identification of risk and the determination of a range of options for action can be addressed with powerful analytical techniques. The further exploitation of these existing products and techniques will be already a significant contribution to meet the defined performance targets.

Examples to consider in this context are forecasts of wind direction and speed for the terminal area (TMA) along the approach path or for the aerodrome perimeter at high spatial and time resolution to support traffic synchronisation and aerodrome ground operations. Whilst low granular gridded wind information for the upper air and point forecasts for aerodrome are currently the norm, dependent of the use case, this type of information could be expressed in a deterministic or probabilistic manner.

Furthermore, the ICAO World Area Forecast System (WAFS) at its initiation in 1983 provided the framework for a global MET information service structure with the provision of the gridded wind and temperature forecasts. With amendment 76 to Annex 3, *Meteorological Service for International Air Navigation*, the WAFS provides global turbulence, icing and cumulonimbus (CB) clouds in grid point format to the WAFS global data set. These parameters are provided in 4 dimensions, but in coarse spatial, vertical and temporal resolutions. While the WAFS data may be sufficient for present en-route flight planning needs in uncongested airspace, users have stated that it is not sufficient for the present needs of ATM in congested airspace, for more advanced methods of advanced aircraft operations or could also be seen as a limiting factor in user preferred routing. As such this framework needs to evolve. Similarly, there are issues with the provision of in-flight advisories in that the current practices need to evolve to meet the future ATM system using a phenomena based system rather than restricting information to FIRs.

2.5.3 Future MET capabilities

With the expected advances in sensing technology and numerical prediction MET information can be improved in temporal and spatial resolution and improved for specific applications such as forecasting and reporting of hazardous phenomena (convection, wind shear, low level turbulence, wake vortex, low visibility and winter conditions). The evolution of MET information provision and the associated MET capabilities are however strongly linked with a clear identification of user requirements on MET information integration concepts as further discussed in the following chapters.

In a TBO environment, a key conditioner for establishing the different instances of the trajectory (from planning to execution) is to stay clear from areas with hazardous or unfavourable weather and to take benefit of favourable conditions. For instance the improved prediction of medium to large scale convective areas with potential hazards such as severe turbulence, severe icing, strong up and downdraft, hail, lightning are typical aspects to consider in developing the different instances of the trajectory and for this specific example will as such contribute to enhanced aviation safety.

2.5.4 ATM Information Management

Integral part of the evolution of MET service provision is the development of information exchange standards that ensure global interoperability in the context of SWIM. This is not only required from a MET service provision perspective but needs to be interlinked with other identified data domains that are relevant for ATM. Decision support tools will not only use MET information but will fuse it with other relevant information such as Aeronautical Information (AIS/AIM) and Flight Information to support knowledge based decision making. This fusion of information will enable a common picture to be made available to all partners in the ATM system to improve safety, traffic predictability and operational flexibility and as such builds on the generic principles explained in §2.4.

The highest level of common situational awareness is to have all the relevant information available to every air transport stakeholder, including pilots, air traffic controllers, flow managers, airline operations staff, involved in collaborative decision making. An essential facet of common situational awareness is the understanding of all actors on the limitations of individual stakeholders in accessing, visualising or processing the information. For years to come, it is expected that not all stakeholders will have access to all the shared information and applications to support decision making processes. Pilots will not always have the same information available due to technical constraints as ground-based staff irrespective of who has the best or most relevant information. Therefore, sound information/data management principles, specifications and associated systems to overcome these differences are crucial.

Common information exchange standards, the interlinked metadata specifications and established information management principles will also enable improved traceability of the information and its source (data) including associated cost recovery aspects.

The ICAO Meteorological Information Exchange Model (IWXXM) and the Weather Information Exchange Model (WXXM) are supplementary common information exchange standards that support the required exchange of information in digital format(s) through terrestrial, airborne and satellite data links.

Furthermore, these exchange standards enable the sophisticated filtering of information and therefore eliminating the current practice of exchanging information on the basis of pre-defined geographical areas. Especially for the current practice of exchanging gridded data, a required improvement of the horizontal and vertical spatial resolution would lead to a significant increase in the size of the data to be exchanged when this will be based on pre-defined areas. Sophisticated filtering of the data with the relevant spatial resolution for distinct segments of the trajectory will overcome this potential issue.

3 MET-ATM Information Services identification

In chapter 2, an overview of the foreseen global evolution of the ATM system was provided including the TBO environment and a number of key areas where ATM and MET will evolve in the short and medium to long terms. From this high level understanding, a global framework is developed on how both ATM and MET stakeholders can identify the type of MET information services required for the integration in a specific ATM environment.

The notion ‘information service’ in this context is used independently from how the service is used. Such a service can be deployed in a machine-to-machine information exchange context, in a machine-to-human or in a human-to-human context. Moreover, it should be understood that considering the intrinsic variability of earth’s atmosphere and the current and emerging MET provider capabilities to describe and forecast this atmosphere, human-to-human communication will be required for the foreseeable future.

This so-called MET-ATM Information Service identification framework is developed using three main categories of interdependent service qualifiers. MET-ATM information services are first identified at the level of the ATM Concept Component it supports. Since this qualification is not always sufficient to derive detailed service requirements, per ATM Concept Component a next category of qualifier is identified, the Operational Environment for which the service needs to be utilised. A third level of service identification is introduced by applying an objective measure for the strategic or tactical phase of operations the service needs to support.

3.1 ATM Concept Components Identification

The ATM system is based on the provision of integrated services. However, to better describe how these services are to be delivered, seven concept components are described[1]. In addition to the seven concept components, information services describe the exchange and management of information used by the different processes and services.

Figure 3-1 depicts the interrelationship of the system components and their convergence into a single system.

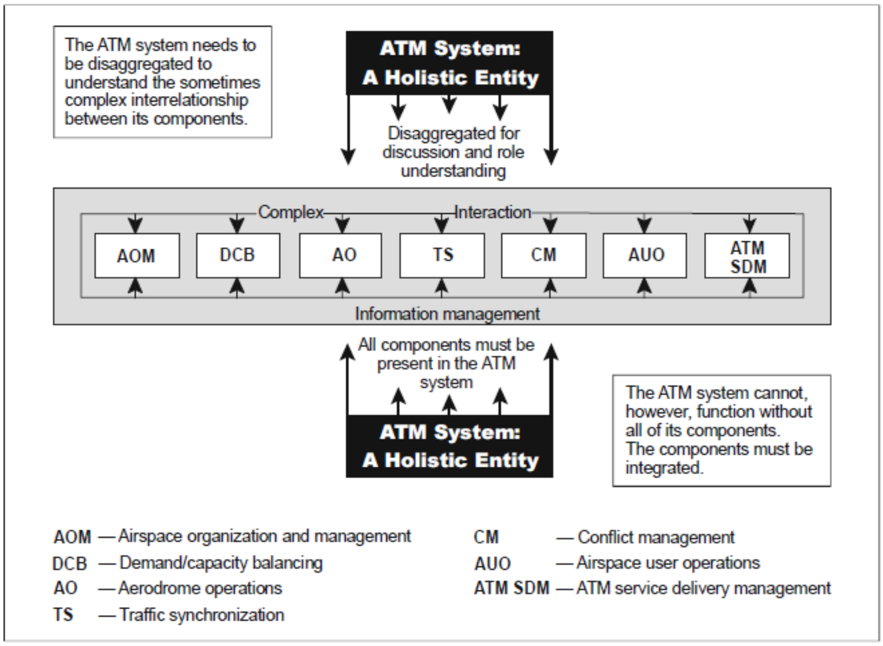


Figure 3-1

[1] The ATM system needs to be disaggregated to understand the sometimes complex interrelationships between its components. The ATM system cannot, however, function without all of its components, which must be integrated. The separate components form one system.

To describe the relationship between MET information and TBO there is a need to identify the key concept components where there is a demonstrated impact on the performance. MET information from a concept component perspective is by default a sub-domain of the information management domain.

The concept components identified in the context of MET Information Integration for TBO are:

- Airspace organisation and management (AOM)
- Demand/capacity balancing (DCB)
- Aerodrome operations (AO)
- Traffic synchronisation (TS)
- Conflict Management (CM)
- Airspace user operations (AUO)

3.2 Operational Environment Identification

The identification of the ATM Concept Components form the baseline of attributing required MET information services. This identification is however too coarse in the context of attributing MET information services. An example is where Traffic Synchronisation (TS) applies from gate to gate and the required MET information services to deliver TS could vary from the operational context TS is performed. TS in the en-route phase requires other MET information services than TS delivered in the TMA already due to the different levels of the atmosphere the actual TS service delivery is taking place.

The distinction between these different operational context (operational environment) could be further detailed based on the various levels of characteristics that could be attributed. The impact of weather and as such the required MET information services to support operational decisions are dependent upon a number of characteristics for which the following are typical examples:

- Aerodrome capacity utilisation and traffic characteristics (density);
- TMA traffic complexity;
- En-route traffic complexity;
- Oceanic and Network air traffic flows and complexity; and
- Weather characteristics (climatological constraints)

For the purpose of this concept document, the main dividing characteristic is described per operational environment but it is recognised that for local reasons other characteristics are used to allocate MET information services.

Furthermore, when considering an operational environment, an additional level of detailing could be provided by identifying the information service needs from an ATM stakeholder (e.g. pilot, air traffic controller and airline operations staff) perspective.

3.2.1 Aerodrome

The ATM Concept Components DCB, AO, TS, CM and AUO defined by Doc 9854 have a service delivery element that is applicable for the aerodrome operational environment. This operational environment is sub-divided in the way their available capacity is utilised. High utilization means that the aerodrome is more vulnerable to disruptions due to adverse weather conditions. In those cases the impact on the air transport network may be large in that there could be ripple effects from one aerodrome to other aerodromes in the network. Aerodromes with lower utilisation will be less impacted due to adverse weather conditions or other type of disturbances. Table 3 indicates the aerodrome classification based on utilisation.

Class	Indicator
Highly utilized aerodromes/runways.	High density aerodrome(A-HD)
Medium/low utilized aerodromes/runways.	Medium/low density aerodrome (A-MLD)

Table 3: Aerodrome utilisation - identification

3.2.2 TMA

The ATM Concept Components AOM, DCB, TS, CM and AUO have a service delivery element that is applicable for the TMA operational environment. This operational environment is sub-divided on the basis of the volumes and mainly complexity of the traffic flows. Table 4 indicates the TMA classification based on utilisation.

Class	Indicator
Highly complex TMA.	High complexity TMA (TMA-HC)
Medium/low complexity of TMA	Medium/low complexity TMA (TMA-MLC)

Table 4: TMA complexity - identification

3.2.3 En-route

The ATM Concept Components AOM, DCB, TS, CM and AUO have a service delivery element that is applicable for the En-route operational environment which will be developed around the notion of user preferred routing. This operational environment is sub-divided on the basis of the volumes and mainly complexity of the traffic flows. Table 5 indicates the en-route airspace classification based on utilisation.

Class	Indicator
Highly complex En-route.	High complexity En-Route (ENR-HC)
Medium/low complexity of En-route	Medium/low complexity En-route (ENR-MLC)

Table 5: En-route complexity - identification

3.2.4 Oceanic

The ATM Concept Components AOM, DCB, TS, CM and AUO have a service delivery element that is applicable for the Oceanic operational environment (OO). This operational environment may be subdivided using the same parameters for the en-route environment in terms of services provision.

3.2.5 Flow Management

The ATM Concept Components AOM, DCB, AO, CM, AUO and TS have a service delivery element that is applicable for the Flow Management operational environment (FM).

Note: There is no indication that the Operational Environment Flow Management currently requires an additional level of sub-division on the basis of the volumes and mainly complexity of the traffic flows to identify MET information service needs.

3.3 Decision Making Horizon Identification

To differentiate between information and systems that are utilised in decision making process to support ‘strategic’ or ‘tactical’ operations usually suffices to express functional and non-functional requirements for a service. For MET information services identification purposes it is required to identify an additional level of granularity to design, develop and deploy the appropriate MET information service.

The distinction between MET information services required for a planning decision, a near real-time decision or a real-time decision is essential to a MET information service provider. It is an important qualifier for establishing the most efficient, in terms of development, industrialisation and deployment, and levels of quality, accuracy and latency of the MET information required.

3.3.1 ATM planning decisions

MET information supports decision making with a `time to decision of the ATM stakeholder' of more than 20 minutes (planning). Various stages of enhanced planning will become possible by integrating MET information and the associated uncertainty. It is recognised that by identifying only one category for planning and to define this category by a 'time to decision of the ATM stakeholder of more than 20 minutes' this could be observed as too coarse for the design and development of an information service. Local considerations could warrant a further segmentation of the planning service however for the purpose of this document it is assumed that this one planning category is sufficient to group similar functional and non-functional requirements which as a group are distinctively different than the two categories that follow.

Examples of MET information that qualify for its utilisation in a planning decision making environment are enhanced MET information services in support of trajectory/flight planning and the en-route re-planning of trajectory/flight. This includes information on forecast meteorological hazards such as icing, CAT, volcanic ash clouds, etc. and basis parameters such as wind, temperature, humidity and air pressure. Furthermore, information on the future state of the atmosphere (including the consequences on low visibility conditions, convective weather, winter conditions) to assess the Network impact from a MET perspective on a day-1 up to day-7 is included.

3.3.2 ATM near real-time decisions

MET information supports decision making with a `time to decision of the ATM stakeholder' between 3 and 20 minutes (near real-time). This requires MET information that is made available and exchanged in an agile manner to support various stages of enhanced near real-time MET information integration in ground and airborne systems. The core focus is on implementing weather mitigation strategies by the various actors including pilots.

Examples of MET information that qualify for its utilisation in a near real-time decision making environment are MET information that enables the avoidance of convective cell en-route and its associated hazards or the avoidance of an area of severe icing. It includes information to support enhanced wake vortex separation in an arrival, departure and en-route environment and it includes the provision of the relevant MET parameters to support ground and aircraft systems to modify their trajectory.

3.3.3 ATM real-time decisions

MET information supports decision making with a `time to decision of the ATM stakeholder' less than 3 minutes (real-time). This requires MET information that is made available and exchanged in an extremely agile but robust manner including the supporting infrastructure. The core focus is on improved MET information supporting both air and ground automated decision support tools for implementing real-time weather mitigation strategies.

Examples of MET information that qualify for its utilisation in an real-time decision making environment are enhanced microburst alerts and low level wind shear and turbulence alerts when the aircraft is on final approach, enhanced severe turbulence information for trailing aircraft (wake turbulence) and enhanced thunderstorm information for ground handling processes or for aircrew and air traffic controllers, especially in the departure and arrival phases of flight.

3.4 Consolidated View

Based on the identified Concept Components indicated Operational Environment and the associated Decision Making Horizon indicated in paragraphs 3.1 to 3.3, a consolidated view of an individually identified operational service context is provided.

Concept Component	Operational Environment	Decision Making Horizon		
AOM	High density aerodrome(A-HD)	Planning	Near-real time	Real-time

Concept Component	Operational Environment	Decision Making Horizon		
	Medium/low density aerodrome (A-MLD)	Planning	Near-real time	Real-time
	High complexity TMA (TMA-HC)	Planning	Near-real time	Real-time
	Medium/low complexity TMA (TMA-MLC)	Planning	Near-real time	Real-time
	High complexity En-Route (ENR-HC)	Planning	Near-real time	Real-time
	Medium/low complexity En-route (ENR-MLC)	Planning	Near-real time	Real-time
	Oceanic	Planning	Near-real time	Real-time
	Flow Management	Planning	Near-real time	Real-time
DCB	High density aerodrome(A-HD)	Planning	Near-real time	Real-time
	Medium/low density aerodrome (A-MLD)	Planning	Near-real time	Real-time
	High complexity TMA (TMA-HC)	Planning	Near-real time	Real-time
	Medium/low complexity TMA (TMA-MLC)	Planning	Near-real time	Real-time
	High complexity En-Route (ENR-HC)	Planning	Near-real time	Real-time
	Medium/low complexity En-route (ENR-MLC)	Planning	Near-real time	Real-time
	Oceanic	Planning	Near-real time	Real-time
	Flow Management	Planning	Near-real time	Real-time
AO	High density aerodrome(A-HD)	Planning	Near-real time	Real-time
	Medium/low density aerodrome (A-MLD)	Planning	Near-real time	Real-time
	High complexity TMA (TMA-HC)	Planning	Near-real time	Real-time
	Medium/low complexity TMA (TMA-MLC)	Planning	Near-real time	Real-time
	High complexity En-Route (ENR-HC)	Planning	Near-real time	Real-time
	Medium/low complexity En-route (ENR-MLC)	Planning	Near-real time	Real-time
	Oceanic	Planning	Near-real time	Real-time
	Flow Management	Planning	Near-real time	Real-time
TS	High density aerodrome(A-HD)	Planning	Near-real time	Real-time
	Medium/low density aerodrome (A-MLD)	Planning	Near-real time	Real-time
	High complexity TMA (TMA-HC)	Planning	Near-real time	Real-time
	Medium/low complexity TMA (TMA-MLC)	Planning	Near-real time	Real-time
	High complexity En-Route (ENR-HC)	Planning	Near-real time	Real-time
	Medium/low complexity En-route (ENR-MLC)	Planning	Near-real time	Real-time

Concept Component	Operational Environment	Decision Making Horizon		
	Oceanic	Planning	Near-real time	Real-time
	Flow Management	Planning	Near-real time	Real-time
CM	High density aerodrome(A-HD)	Planning	Near-real time	Real-time
	Medium/low density aerodrome (A-MLD)	Planning	Near-real time	Real-time
	High complexity TMA (TMA-HC)	Planning	Near-real time	Real-time
	Medium/low complexity TMA (TMA-MLC)	Planning	Near-real time	Real-time
	High complexity En-Route (ENR-HC)	Planning	Near-real time	Real-time
	Medium/low complexity En-route (ENR-MLC)	Planning	Near-real time	Real-time
	Oceanic	Planning	Near-real time	Real-time
	Flow Management	Planning	Near-real time	Real-time
AUO	High density aerodrome(A-HD)	Planning	Near-real time	Real-time
	Medium/low density aerodrome (A-MLD)	Planning	Near-real time	Real-time
	High complexity TMA (TMA-HC)	Planning	Near-real time	Real-time
	Medium/low complexity TMA (TMA-MLC)	Planning	Near-real time	Real-time
	High complexity En-Route (ENR-HC)	Planning	Near-real time	Real-time
	Medium/low complexity En-route (ENR-MLC)	Planning	Near-real time	Real-time
	Oceanic	Planning	Near-real time	Real-time
	Flow Management	Planning	Near-real time	Real-time

Table 6 Consolidated View Operational Service Definition

In Table 6, every green cell in the column "Decision Making Horizon' represents a MET information service identified. In the development and deployment of such a service, it can be decided to group these information services together since the required MET capability is similar or identical. Note: grey cells are included for completeness and should be understood as not applicable.

As indicated in paragraph 3.2, whilst every green cell in the table represents a MET information service, an additional level of detail could be required to specify the specific ATM stakeholder (e.g. pilot, air traffic controller and airline operations staff) needs.

Such a service allocation example with an additional level of detail included is the MET information service required by an arrival sequence management tool that supports an air traffic controller. For this example, the MET information service sits in the green cell of 'TS / High complexity TMA / Near-real time'.

4 Information Integration Functions

The identification of the operational context as described in chapter 3 is an essential component of planning, developing and implementing enhanced capabilities on the MET provider and MET information service consumer side in support of an identified ATM operational need.

When further considering the integration of MET information into ATM decision making a generic framework is applied; this generic framework applies to any type of information that impacts aviation.

Four distinct components within this framework are identified, the:

1) Information on an event
2) Translation of the information into a specific threshold or constraint for air transport
3) Assessment of the translated information into an impact on an air transport stakeholder process
4) Informed decision of the air transport stakeholder based on the impact assessment

Figure 4-1 provides a graphical representation of the four components identified in applying a generic framework to identify distinct functions when integrating information into an air transport stakeholder decision making process.

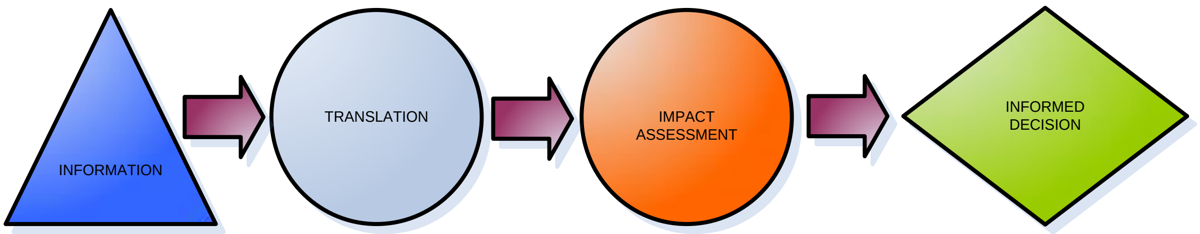


Figure 4-1

By applying this framework, thus separating between clearly identifiable functions, functions could be clearly allocated to a stakeholder, could be generalised or re-assembled to meet a specific operational or business need.

For illustration, Figure 4-2 provides on the left of the graphical representation four different types of information, four separated associated translations functions and four different impact assessment functions resulting in four decisions being made. From a decision makers perspective, thus the information consumer, there could be benefit of applying a generic impact assessment function resulting in a harmonised impact assessment and decision-making support process for the four different type of information (events) and translations which is depicted on the right side of Figure 4-2.

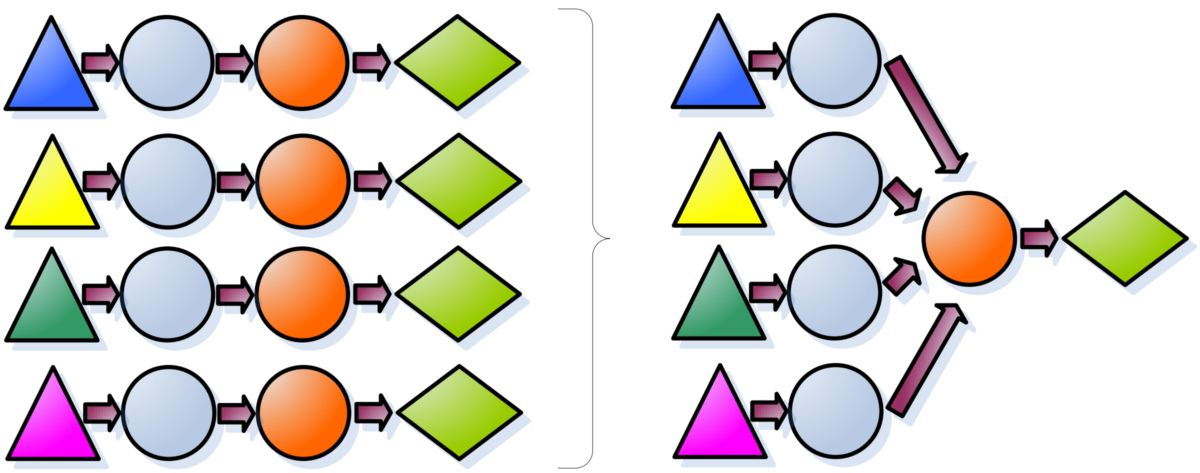


Figure 4-2

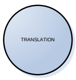
The methodology to define distinct functions and to group them together for a specific need builds on the SOA principle described in paragraph 2.4.2. For each function identified a dedicated service could be envisaged or a combination of services specific to a user need.

4.1.1 MET Information Integration Functions

When applying the generic framework of §4 to MET information and ATM decision making processes, a more specific meaning to the components 'information', 'translation', 'impact assessment' and 'decision' could be given.

MET Information

MET information as an identified function/service is categorised as the provision of information on the past, current and future state of the atmosphere expressed in generic terms and produced and used without considering the user context. This includes data, human readable or graphical representations of observed or forecast weather parameters and phenomena. Examples of MET information are generic weather radar imagery, generic textual area forecasts or gridded data field for temperatures made available without consideration given to a specific user context.



MET Translation

MET translation as an identified function/service could be categorised as the process of deriving information on weather related constraints for an ATM actor based on the provided MET information and the provision thereof. In this process, the MET information is combined with known operational information such as safety regulation, aircraft restrictions, operating thresholds, historical demand information or historical pilot behaviour information to derive an ATM actor specific constraint or threshold value. Examples of MET Translation information are a cloud base or visibility threshold value that sets or onsets low visibility procedures on an aerodrome, low level wind shear thresholds that sets or onsets go-around procedures, wind and humidity information that is translated into the likelihood for in-flight icing for a specific aircraft or a depicted segment of airspace wherefore is likely that it cannot be used combining information on severe convective weather and historical demand and pilot behaviour information.

ATM Impact Assessment for MET

ATM Impact Assessment for MET as an identified function/service could be categorised as the process of deriving ATM impact information for a specific ATM actor environment based on the provided MET Translation information and the provision thereof. In this process, the MET Translation information is combined with actual and planned operational information from the perspective of the ATM actor. In the case of Air Traffic Flow Management this could include the actual and planned air traffic demand and ATC constraints to be applied. Examples of ATM Impact Assessment for MET information include observed or projected operational capacity/demand imbalance for a specific sector due to weather or could be more generally expressed as a predicted operational performance of an ATM resource such as airspace sector, arrival rate or de-icing capacity due to weather.

Informed Decision

An ATM Informed Decision as an identified function/service could be categorised as the process of deriving a strategic or tactical solution in respect of the assessed impact of weather on an ATM actor process/environment. In this process, which could still be manually but will gradually evolve to an automated decision support tool environment due to the quantity and complexity of the information involved, information on ATM impacts due to weather will be processed. ATM impacts assessment information will be enhanced by combining and filtering the information with for instance desired risk levels and latest priorities to derive optimised mitigation solutions and alternatives ('what-if' information). It is also expected that these automated decision support tool environments initially will be introduced for ATM planning decisions and gradually evolve into tools to support ATM near real-time decisions and ATM real-time decisions.

Figure 4-3 provides a graphical representation of the applied framework on MET information in an ATM decision-making environment.

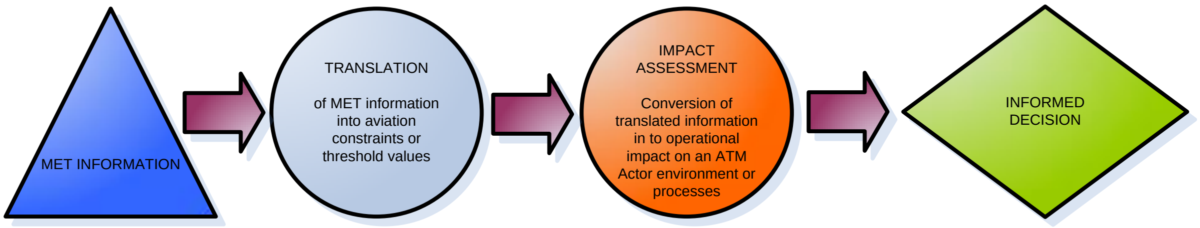


Figure 4-3

4.1.2 Roles, Responsibilities and Supporting Provisions

The four functions/services identified in § 4.1.1 have different roles and potentially responsibilities associated to them which should be allocated to service providers when applied in an operational context.

Traditionally, there is an existing separation between providers of aeronautical MET information services and providers of air navigation services. The functions that belong to the domain of air navigation services are the 'ATM Impact Assessment for MET' and the 'ATM Decision'. The functions that belong to the aeronautical MET information services domain are 'MET Information' and 'MET translation' see Figure 4-4.

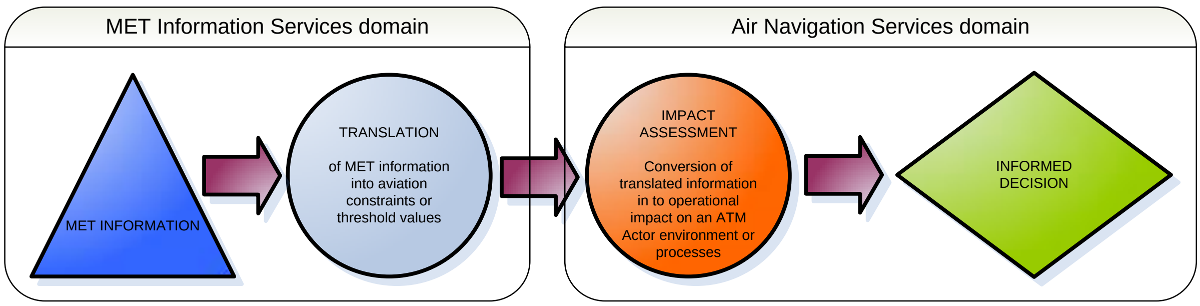


Figure 4-4

The allocation to these two domains is beneficial for capturing the associated roles and responsibilities in the appropriate provisions, mainly Annex 3, *Meteorological Service for International Air Navigation* and Annex 11, *Air Traffic Services* and supporting Procedures, Manuals and Guidance.

Additionally, the allocation principle depicted provides a structure of how the service provision could be allocated in a national, regional or global implementation context. It is however not prescriptive in allocating the functions in a domain to one provider only. The allocation of functions to providers is dependant of local implementation considerations including the available or foreseen capability of the providers.

Furthermore, the separation of responsibilities should not preclude that providers of aeronautical MET information services should not know about the operations that they need to support. Both views need to be considered at the specification and implementation level to provide MET information services that support the required ATM capability.

Various implementations options are possible and two of the most common implementations are visualised in Figure4-5 to Figure 4-6.

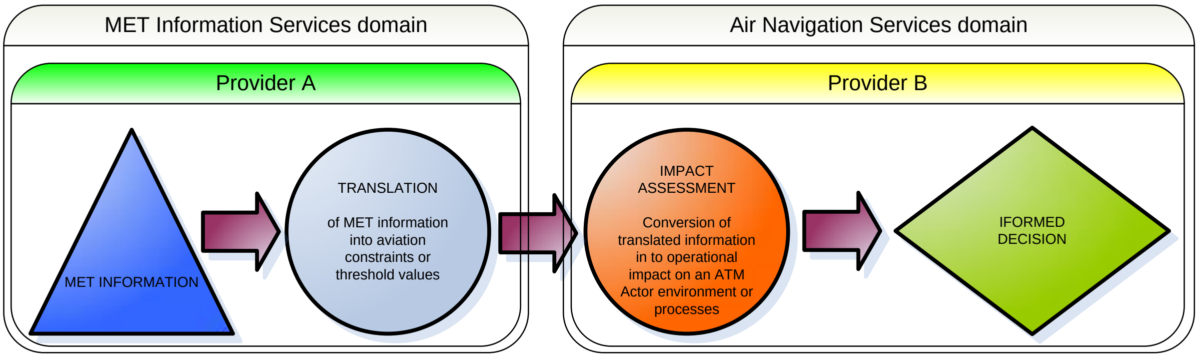


Figure 4-5

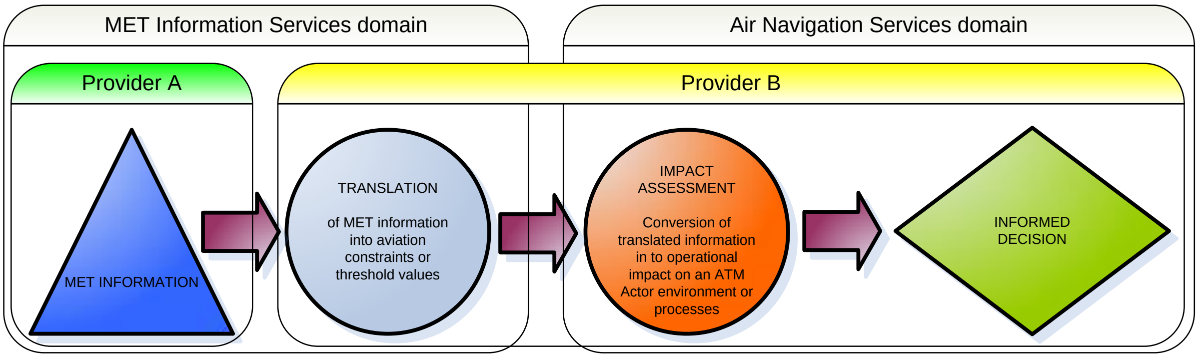


Figure 4-6

4.1.3 MET Information Integration Levels

The framework described for planning, developing and implementing enhanced capabilities on the MET information provider side and ATM consumer side could be considered implemented in progressive steps. The different implementation steps identified are categorised along the notion of 'MET information integration levels' and based on the type of integration functions implemented.

MET Information Integration Level 0 – Non-integrated MET information provision

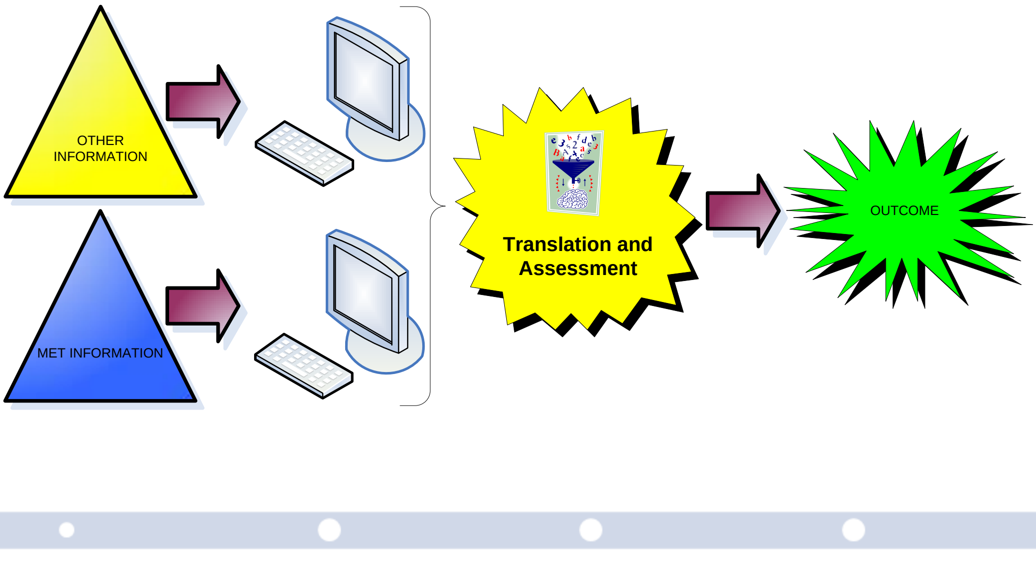


Figure 4-5 **Integration Level 0**

At MET Information Integration Level 0, the ATM decision is based on MET information available for the ATM decision maker. The MET information is displayed similar to other information required to make a decision. How the MET information will be translated into a constraint and how such a constraint will impact the ATM system is solely dependent on the expertise of the decision maker(s) to build a mental map of the situation. In a non-complex ATM environment, level 0 could be sufficient to meet the performance requirements for that specific ATM environment since the processes and information flows are still manageable by decision makers. Since all information is presented by different system and no support for translation and impact assessment of MET information is available, additional attention should be paid to preventing the subjectivism of the outcomes. Moreover, there is a high risk that due to the labour intensive and the complex process of understanding the constraints and impacts for weather, decisions will be made without fully understanding thus considering the impact of weather.

In terms of MET information integration, many existing ATM MET systems fall into this category.

MET Information Integration Level 1 – Consolidated MET information provision

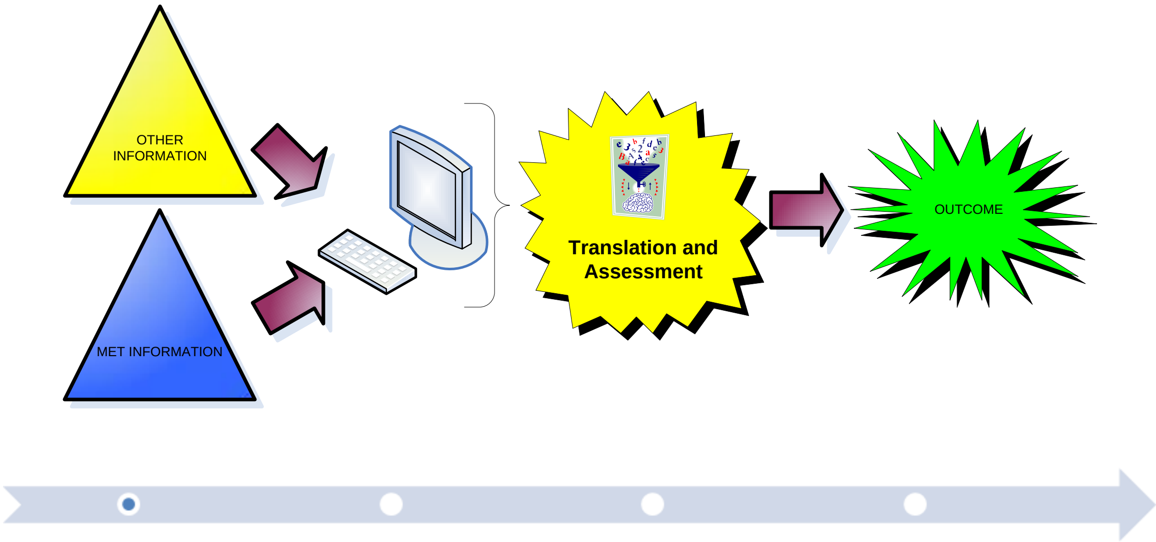


Figure 4-6 **Integration Level 1**

At MET Information Integration Level 1, the ATM decision is still based on having MET information available for the ATM decision maker. The MET information however is consolidated with other information required to make a decision. The translation into a constraint and how such a constraint will impact the ATM system is still fully dependent on the expertise of the decision maker(s) to build a mental map of the situation but are helped by an improved situational awareness. In a less-complex ATM environment, level 1 could be sufficient to meet the performance requirements for that specific ATM environment since the processes and information flows are still manageable by decision makers due to an improved situational awareness compared to level 0. Since no support for translation and impact assessment of MET information is available, additional attention should be paid to preventing the subjectivism of the outcomes. At level 1, the improved situational awareness supports a better overall integration of MET information but compared to level 0 remains labour intensive and complex.

In terms of MET information integration, systems currently deployed that provide an overlay of weather radar information on traffic information for an air traffic controller working position fall into this category.

MET Information Integration Level 2 – Translated MET information provision

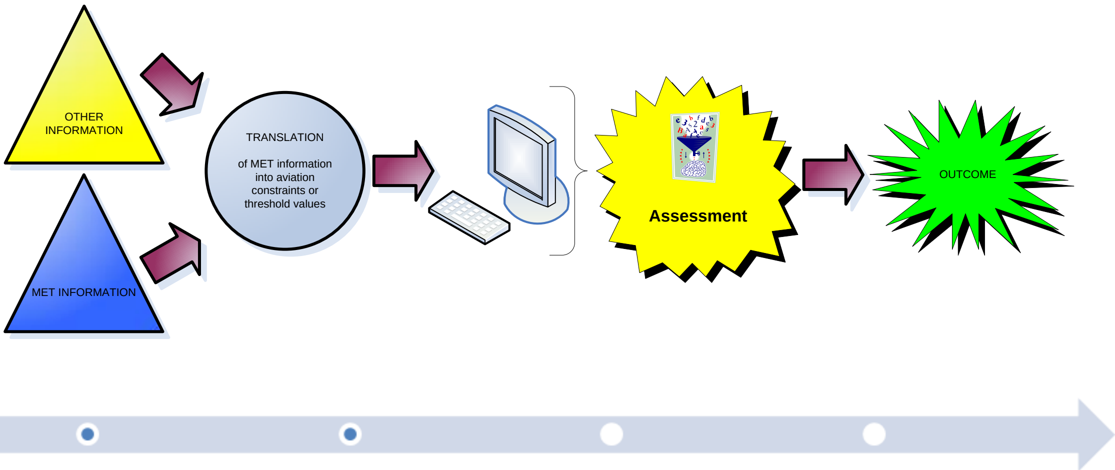


Figure 4-7 **Integration Level 2**

At MET Information Integration Level 2, MET information is translated into constraints or threshold values by using other relevant information. ATM decision makers are notified in an objective manner of a weather event that could impact the foreseen or actual traffic. The handling of the notification of a constraint or threshold value is still fully dependent on the expertise of the decision maker(s) to assess the situation. Compared to level 1 the decision maker is not only supported by an improved situational awareness but the actual translation is done objectively and can be shared easily. In a less-complex ATM environment, level 2 could be preferred above level 1 since the translation is made objective whilst the ATM processes are still manageable by decision makers without further support.

In terms of MET information integration, systems currently deployed that provide information on en-route availability or runway availability based on predicted weather fall into this category.

MET Information Integration Level 3 – Assessed MET information use

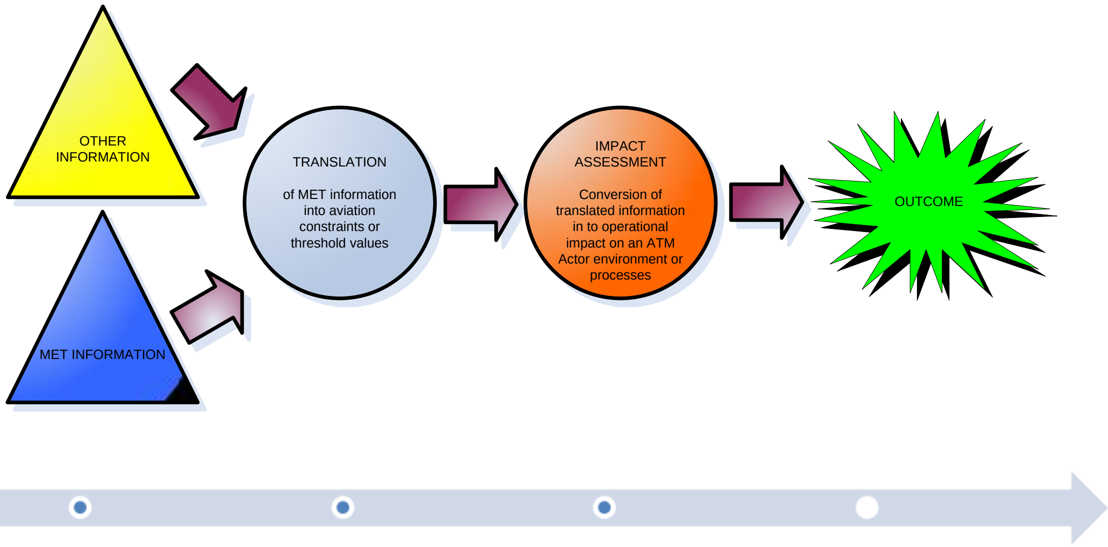


Figure 4-8 **Integration Level 3**

At MET Information Integration Level 3, MET information is translated into constraints or threshold values by using other relevant information and further processed to assess the impact on the actual and foreseen traffic. ATM decision makers in an implemented level 3 environment are fully supported by a full chain of services from the core MET information to the actual impact it could have on the traffic or associated ATM process. At level 3, ATM decision makers are informed about the impact on their specific environment but have no further decision support available to them for the mitigation or the overall outcome of the decision making process.

In terms of MET information integration, systems currently deployed or under development that provide departure or arrival sequencing and where the actual and forecast weather impact is taken into account on a flight-by-flight basis fall into this category.

MET Information Integration Level 4 – Informed Decision Making

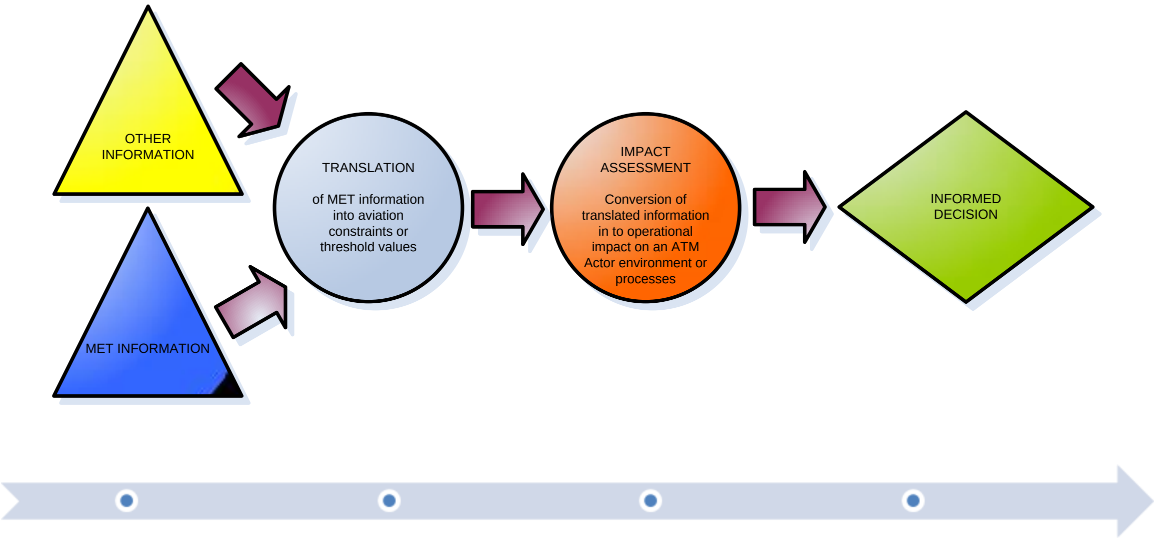


Figure 4-9 **Integration Level 4**

At MET Information Integration Level 4, MET information is translated into constraints or threshold values by using other relevant information and further processed to assess the impact on the actual and foreseen traffic. ATM decision makers in an implemented level 3 environment are fully supported by a full chain of services from the core MET information to the actual impact it could have on the traffic or associated ATM process. At level 4, ATM decision makers are further supported by decision support tools that provide strategic and tactical solutions. In a complex ATM environment, decision support information for weather events is the preferred implementation level of MET information integration to have informed or knowledge based decisions that are objective and have the highest potential to meet the overall performance targets.

In terms of MET information integration, systems currently under development that provide departure or arrival sequencing and where the actual and forecast weather impact is taken into account on a flight-by-flight basis plus optimised solutions against system objectives are provided fall into this category. This type of solution indicates the main difference between level 3 and level 4. Level 3 will deliver a managed chain and associated process of developing an objective impact assessment based on a weather event. Level 4 provides on top of this impact assessment a layer of decision support to put the impact assessment in full context and to provide options for an operational decision maker.

5 MET-ATM Service Descriptions

The separation of functions described in chapter 4 provides a clear description of the four types of MET-ATM services introduced:

1. MET-ATM Information Provision Service (MET Information function)
2. MET-ATM Translation Service (MET Translation function)
3. Impact Assessment Service (ATM Impact Assessment for MET function)
4. Decision Support Service (Informed Decision function)

Per operational context as described in 3.4, these four services need to be described dependent on the level of integration required. It is important to note that in cases were the level of integration is limited to level 0, 1 or 2, there is still an ATM requirement underpinning the need to deploy a level 0, 1 or 2 integration solution. This ATM requirement is in these cases not expressed in the form of an impact assessment service requiring MET information from a translation service but in an ATM need to make available MET-ATM information only.

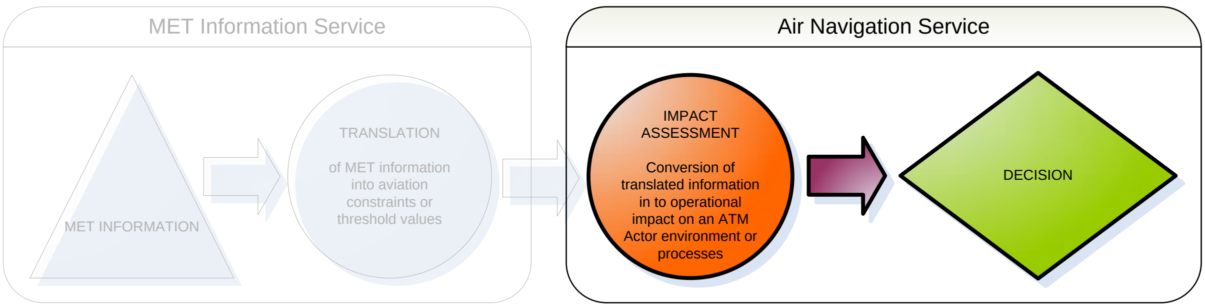
To describe the required services in the four identified types is furthermore essential to support the attribution of roles and responsibilities as discussed in § 4.1.2 and, as earlier discussed, will support the capturing of the associated roles and responsibilities in the appropriate global, regional and local provisions.

To further support this separation of concern introduced and the consequential identified differences between the MET Information Services domain and Air Navigation Services domain, the following paragraphs are structured in the following two categories:

1) Air Navigation Services domain, including:
   a) Impact Assessment Service (ATM Impact Assessment for MET function)
   b) Decision Support Service (Informed Decision function)

2) MET Information Services Domain, including:
   a) MET-ATM Information Provision Service (MET Information function)
   b) MET-ATM Translation Service (MET Translation function)

5.1 Air Navigation Services Domain



5.1.1 Implementation based on GANP

The air navigation services that require MET information services could be identified on the basis of the service identification framework described in chapter 3 and 4. It is however understood to develop regional implementation plans on the basis of the Aviation System Block Upgrades (ASBU) methodology introduced by the Global Air Navigation Plan (GANP), fourth edition Doc 9750. Every ICAO Region, Sub-region and individual States will establish their own air navigation priorities and therefore the required ASBU Modules and priorities. A uniform identification of ASBU modules that are enabled by MET and a consolidated development of provisions and consequently globally interoperable MET information services is required.

Note 1: Only those ASBU Modules are identified that represent a direct operational performance improvement. Therefore no references to Modules are listed that describe improvements to globally interoperable systems and data including the Modules related to improving MET capabilities (##-AMET). It should be understood that the MET information services identified to enable the identified Modules are intrinsically part of the AMET Modules and will be based on SWIM principles.

Note 2: The analysis and identification is based on the current understanding of the operational improvement as described in the fourth edition of the GANP.

The identified ASBU modules enabled by MET information services are:

Block-0		
	Module reference	*Module scope*
Performance Improvement Area 1: Airport Operations	B0-APTA	Optimization of Approach Procedures including Vertical Guidance
	B0-ACDM	Improved Airport Operations through Airport-CDM
	B0-RSEQ	Improved Traffic Flow through Runway Sequencing (AMAN/DMAN)
Performance Improvement Area 3: Optimum Capacity and Flexible Flights	B0-NOPS	Improved Flow Performance through Planning based on a Network-Wide view
Performance Improvement Area 4: Efficient Flight Path – Through Trajectory-based Operations	B0-CDO	Improved Flexibility and Efficiency in Descent Profiles (CDO)
	B0-CCO	Improved Flexibility and Efficiency in Departure Profiles — Continuous Climb Operations (CCO)

Block-1		
	Module reference	*Module scope*
Performance Improvement Area 1: Airport Operations	B1-APTA	Optimised Airport Accessibility
	B1-WAKE	Increased Runway Throughput through Dynamic Wake Turbulence Separation
	B1-ACDM	Optimized Airport Operations through Airport-CDM Total Airport Management
	B1-RSEQ	Improved Airport Operations through Departure, Surface and Arrival Management
Performance Improvement Area 3: Optimum Capacity and Flexible Flights	B1-FRTO	Improved Operations through Optimized ATS Routing
	B1-NOPS	Enhanced Flow Performance through Network Operational Planning

Performance Improvement Area 4: Efficient Flight Path – Through Trajectory-based Operations	B1-CDO	Improved Flexibility and Efficiency in Descent Profiles (CDOs) using VNAV
	B1-TBO	Improved Traffic Synchronization and Initial Trajectory-Based Operation

Block-2		
	Module reference	*Module scope*
Performance Improvement Area 1: Airport Operations	B2-WAKE	Advanced Wake Turbulence Separation (Timebased)
Performance Improvement Area 3: Optimum Capacity and Flexible Flights	B2-NOPS	Increased user involvement in the dynamic utilization of the network
Performance Improvement Area 4: Efficient Flight Path – Through Trajectory-based Operations	B2-CDO	Improved Flexibility and Efficiency in Descent Profiles (CDOs) using VNAV, required speed and time at arrival

Block-3		
	Module reference	*Module scope*
Performance Improvement Area 3: Optimum Capacity and Flexible Flights	B3-NOPS	Traffic Complexity Management
Performance Improvement Area 4: Efficient Flight Path – Through Trajectory-based Operations	B3-TBO	Full 4D Trajectory-based Operations

5.1.2 Block 0

5.1.2.1 B0-APTA

Concept Component	Operational Environment	Decision Making Horizon
AO, AUO	A-HD / A-MLD / TMA-HC / TMA-MLC	Planning
Level of integration		
1 to 3		

The use of Performance-based Navigation and ground-based augmentation system (GBAS) landing system (GLS) procedures will allow for lower approach minima with demonstrable benefits. While approaches become less sensitive for low visibility (and clouds) conditions, there remains to be a category of weather conditions in which no approaches are possible based on the established procedures.

These weather conditions mainly expressed in terms of extreme low visibility and low cloud conditions are typically considered to be rare events. As such these events are more difficult to forecast. To ensure that the predictability and reliability objectives for approaches to runways with lower approach minima meets the expectations, specific MET capabilities and associated MET information services are required.

5.1.2.2 B0-ACDM

Concept Component	Operational Environment	Decision Making Horizon
AO	A-HD / A-MLD	Planning, near-real time and real time
Level of integration		
1 to 3		

A large number of aerodrome operational processes and more specifically surface operations are conditioned by weather. The implementation of collaborative applications to work from a ‘common operational picture’ requires a wider availability of MET information.

For B0 related improvements, the focus is mainly on making existing MET information developed for one specific user group available to a broader aerodrome user community and preferably by integrating the MET information into the SWIM environment. This also requires the capability of collaborative application used for Airport-CDM to ingest, to process or to visualise MET information.

5.1.2.3 B0-RSEQ

Concept Component	Operational Environment	Decision Making Horizon
TS	A-HD / A-MLD	Planning, near-real time and real time
Level of integration		
2 to 3		

The management of arrivals and departures to and from a multi-runway aerodrome or locations with multiple dependent runways at closely proximate aerodromes requires a good understanding on the prevailing weather that conditions these arrivals and departures. The availability of wind information and to some extent pressure information enables operational decision makers and their support systems to efficiently utilize the inherent runway capacity.

For B0 related improvements, the focus is mainly on making existing information on wind and pressure available so it can be utilised by the above mentioned operational decision makers. This also requires the capability of and the relevant support systems to ingest, to process or to visualise the available MET information.

5.1.2.4 B0-NOPS

Concept Component	Operational Environment	Decision Making Horizon
AOM, DCB	FM	Planning and near-real time
Level of integration		
1 to 3		

The envisaged flow performance improvements for the B0 timeframe are from a MET perspective strictly related to a better exchange and use of existing MET information by the stakeholders involved. This improved exchange and use will directly contribute to a greater common understanding on the various operational constraints, capabilities and needs.

5.1.2.5 B0-CDO

Concept Component	Operational Environment	Decision Making Horizon
TS	TMA-HC / TMA-MLC	Planning, near-real time and real time
Level of integration		
1 to 3		

There is a direct relationship between the optimum descent profile for an aircraft, the predictability and therefore the stability of this profile and the atmosphere predicted and encountered for the ‘descent-volume’ in time and space. Depending on the complexity and therefore the level of PBN components to implement, the requirement on the MET information (both in observation and forecast terms) may vary as well.

For B0 related improvements, it should also be understood that there are intrinsic limitations to on-board systems such as FMS that could not always lever the potentially available MET information at higher granularity and higher refresh intervals that could be made available already without improving MET capabilities.

Consequently, the improvement on MET information shall primarily be focused on tailoring existing MET capabilities on the existing FMS capabilities and whenever possible inflight updates. And as such to move away from using wind information obtained during the flight briefing process which was not optimised for CDO.

5.1.2.6 B0-CCO

Concept Component	Operational Environment	Decision Making Horizon
TS	TMA-HC / TMA-MLC	Planning, near-real time and real time
Level of integration		
1 to 3		

There is a direct relationship between the optimum climb profile for an aircraft, the predictability and therefore the stability of this profile and the atmosphere predicted and encountered for the ‘ascent-volume’ in time and space. Depending on the complexity and therefore the level of PBN components to implement, the requirement on the MET information (both in observation and forecast terms) may vary as well.

For B0 related improvements, besides the similar constraint as indicated for FMS in a B0-CDO context, it should also be understood that the sensitivity of CCO for MET information in the B0-timeframe is less clear as for CDO.

The improvement on MET information shall exclusively be focused on tailoring existing MET capabilities on the existing FMC capabilities with respect to continuous climb operations. And similar to B0-CDO, to move away from using wind information obtained during the flight briefing process which was not optimised for CCO.

5.1.3 Block 1

5.1.3.1 B1-APTA

Concept Component	Operational Environment	Decision Making Horizon
AOU, AO	A-HD / A-MLD / TMA-HC / TMA-MLC	Planning and near-real time
Level of integration		
3 and 4		

The further progress on the implementation of Performance-based Navigation and ground-based augmentation system (GBAS) landing system (GLS) procedures that allow for lower approach minima will not directly evoke new MET information service requirements compared to the B0-timeframe.

When operational minima will decrease further, the category of weather events in which no approaches are possible based on the established procedures will become even rarer; with the consequential increased difficulty to forecast these events. To maintain the desired predictability and reliability for approaches to runways with lower approach minima specific MET capabilities and associated MET information services are required.

5.1.3.2 B1-WAKE

Concept Component	Operational Environment	Decision Making Horizon
TS, CM	A-HD / TMA-HC	*Near-real time and real time*
Level of integration		
3 and 4		

The operational improvement to increase the throughput on departure and arrival runways through the dynamic management of wake turbulence separation minima based on the real-time identification of hazardous wake turbulence requires the actual and near-future meteorological conditions, in particular wind conditions.

It is recognized that the application of wake turbulence separation is directly related to the accuracy and timeliness of the required MET information describing especially the wind climate at and around the aerodrome of concern.

New MET information services including the required MET capabilities need to be implemented to provide wind information of sufficient quality to assist the local stakeholders to enact reduced turbulence mitigation measures timely.

5.1.3.3 B1-ACDM

<table>
<tr><th>Concept Component</th><th>Operational Environment</th><th>Decision Making Horizon</th></tr>
<tr><td>AO</td><td>A-HD / A-MLD</td><td>Planning, near-real time and real time</td></tr>
<tr><th colspan="3">Level of integration</th></tr>
<tr><td colspan="3">3 and 4</td></tr>
</table>

The further enhancement of the planning and execution of aerodrome operational processes will require an improved integration of MET information into the decision making processes. Depending on the complexity of the aerodrome operations and the required planning and execution related processes in place, the level of sophistication of required MET information services will vary as well.

Where for BO-ADCM the emphasis is on making existing information available in a SWIM-like manner, the B1-ACDM implementation will require MET information services that support the specific operational aerodrome processes identified. Fully dependent of the complexity to address, dedicated MET information service to support winter operations from planning to execution or to support runway selection in high wind conditions go well beyond the scope of the typical 'warning-type' of information that is in the B0-timeframe the norm.

5.1.3.4 B1-RSEQ

<table>
<tr><th>Concept Component</th><th>Operational Environment</th><th>Decision Making Horizon</th></tr>
<tr><td>TS</td><td>A-HD</td><td>Planning, near-real time and real time</td></tr>
<tr><th colspan="3">Level of integration</th></tr>
<tr><td colspan="3">3 and 4</td></tr>
</table>

The management of arrivals, surface operations and departures for major hubs in metropolitan areas require an improved understanding on the prevailing weather that conditions these arrivals, surface operations and departures.

Besides the information that is made available as MET information services to support B0-RSEQ, a new category of MET information services will enable important aspects such as a greater compliance to the controlled time of arrival (CTA) of individual aircraft but also to the increased predictability of the aerodrome performance in general.

MET information services shall be implemented to assist operational decision makers to efficiently manage the whole consolidated chain from arrival, surface operations to departure. This will be guided by decision support systems that ingest, process or visualise the available MET information. This MET information should be of a sufficient quality to make operational decisions with an agreed level of confidence. However, systems shall be able to manage the intrinsic level of uncertainty associated with MET information especially in support of planning and near-real time decisions.

5.1.3.5 B1-FRTO

<table>
<tr><th>Concept Component</th><th>Operational Environment</th><th>Decision Making Horizon</th></tr>
<tr><td>TS</td><td>TMA-HC / TMA-MLC / ENR-HC / ENR-MLC / OO / FM</td><td>Planning and near-real time</td></tr>
<tr><th colspan="3">Level of integration</th></tr>
<tr><td colspan="3">2 to 4</td></tr>
</table>

To minimise the difference between the planned and executed trajectory flown based on optimised ATS routings, including free routing, reduced route spacing and dynamic sectorisation, a shared understanding of the route availability or on less preferable routes from a user perspective are key elements to consider when implementing B1-FRTO. The availability of routes, user-preferred profiles and consequently dynamic routing are heavily conditioned by weather.

The benefits B1-FRTO will operationally deliver are therefore closely linked with the knowledge available on the expected weather along the route. MET information services shall be implemented to assist operational decision makers to support optimised ATS routing and to understand from a general ATM perspective the user intent with respect to user-preferred profiles.

Decision support systems to support optimised ATS routings will need to ingest, process or visualise the available MET information. This MET information should be of a sufficient quality to make operational decisions with an agreed level of confidence. However, systems shall be able to manage the intrinsic level of uncertainty associated with MET information especially in support of planning and near-real time decisions with a sufficient level of confidence.

5.1.3.6 B1-NOPS

Concept Component	Operational Environment	Decision Making Horizon
AOM, DCB	FM	Planning and near-real time
Level of integration		
2 to 4		

Similar to the B0 timeframe, from a MET perspective the introduction of enhanced processes to improve the flow performance further from a MET perspective, is mainly related to the improved sharing of MET information by the stakeholders involved. When this module is planned to be fully implemented, which is applicable for areas with the highest traffic density, consideration should be given to the development of specific MET information services to support the common understanding on the various operational constraints, capabilities and needs.

5.1.3.7 B1-CDO

Concept Component	Operational Environment	Decision Making Horizon
TS	TMA-HC / TMA-MLC	Planning, near-real time, real time
Level of integration		
2 to 4		

When using VNAV, the direct relationship between the optimum descent profile for an aircraft, the predictability and therefore the stability of this profile and the atmosphere predicted and encountered for the 'descent-volume' in time and space remains to be an important aspect to consider.

Also the enhanced FMS capabilities in general could start to demonstrate benefits when levering the MET information at higher granularity and higher refresh intervals that were not used before.

MET information services in support of B1-CDO are an enhancement of the services implemented for B0-CDO and improving the resolution of the (mainly wind) information vertically and horizontally, and more frequent updates in line with the available FMC capabilities.

5.1.3.8 B1-TBO

Concept Component	Operational Environment	Decision Making Horizon
TS	TMA-HC / TMA-MLC / ENR-HC / ENR-MLC / OO / FM	Planning, near-real time and real time
Level of integration		
3 and 4		

An improved traffic synchronisation including the optimisation of approach sequences is heavily reliant on a shared awareness of the expected traffic, its evolution and the overall predictability thereof. Weather is a significant conditioner for these aspects.

MET information services to support B1-TBO implementation will primarily focus on consolidating and harmonising the required MET information services that are required for the relevant B0 and B1 modules and as such form the intrinsic elements of initial trajectory based operations.

5.1.4 Block 2 & 3

Since the full detail of Block 2 and moreover Block 3 operational improvements is not known at this stage of concept development, the level of detail provided for enablers such as MET information will remain to be at a high level. Notional improvements to be achieved by integrating MET information in the identified operational improvement areas are indicated but will need to be refined when further detail on these Block 2 and 3 improvements will become available.

5.1.4.1 B2-WAKE

Concept Component	Operational Environment	Decision Making Horizon
TS, CM	A-HD / TMA-HC	Near-real time and real time
Level of integration		
4		

The operational improvement to introduce the application of time-based aircraft-to-aircraft wake separation minima and changes to the procedures the ANSP uses to apply wake separation minima requires the actual and near-future meteorological conditions, in particular wind conditions.

Compared to the dynamic management of wake turbulence separation minima based on the real-time identification of wake turbulence hazards an enhanced dependency will be introduced between the operational process and the availability of accurate and timely MET information, mainly wind information.

This will require a further enhancement of the MET information services including the required MET capabilities to provide wind information of sufficient quality to assist the local stakeholders to enact of time-based aircraft-to-aircraft wake separation.

Moreover, this wind information needs to be fully integrated in the decision support tools available to the stakeholders since the manual assessment of MET information separate from the other information required to support time-based separation is expected to be sub-optimal from a decision support information point of view.

5.1.4.2 B2-NOPS

Concept Component	Operational Environment	Decision Making Horizon
AOM, DCB	FM	Planning and near-real time
Level of integration		
3 and 4		

By the introduction of increased user involvement in the dynamic utilization of the Network the reliance of the users on a common operating picture will further increase compared to what is already implemented in the B0- and B1-timeframe.

From a MET perspective, the introduction of CDM applications supported by SWIM that permit airspace users to manage competition and prioritization of complex ATFM solutions when the network or its nodes (aerodromes, sector) no longer provide enough capacity to meet user demands will further drive the development of specific MET information services to support the common understanding on the various operational constraints, capabilities and needs.

In addition, this information will be fully integrated into the CDM applications to provide this common operating picture with respect to weather and will together with other relevant information deliver ATM the ability to offer/delegate to the users the optimization of solutions to flow problems related to weather. Benefits include an improvement in the use of available capacity and optimized airline operations in degraded situations.

5.1.4.3 B2-CDO

Concept Component	Operational Environment	Decision Making Horizon

TS	TMA-HC / TMA-MLC	Planning, near-real time and real time
Level of integration		
4		

Building on the B0-CDO and B1-CDO implementations, an improved flexibility and efficiency in Continuous Descent Profiles (CDOs) will require that the relationship between this optimum descent profile for an aircraft, the predictability and therefore the stability of this profile and the atmosphere predicted and encountered for the 'descent-volume' in time and space becomes increasingly important. As such these optimised arrivals are a component of trajectory-based operations (TBO) initiatives.

MET information services in support of B2-CDO are a further enhancement of the services implemented for B1-CDO, B1-FRTO and B!-NOPS. Improvements when required to the resolution of the (mainly wind) information vertically and horizontally, and improving the update frequency of the information in line with the available FMS capabilities are foreseen but it is expected that the focus of MET information improvements will be on the accuracy and therefore the predictability of the descent profiles from a MET perspective including Top Of Descent (TOD).

5.1.4.4 B3-NOPS

Concept Component	Operational Environment	Decision Making Horizon
AOM, DCB	FM	Planning and near-real time
Level of integration		
4		

The module requires further enhanced MET information which is vital for TBO functioning, as well as for general system predictability and grater levels of performance <To be developed further>

5.1.4.5 B3-TBO

Concept Component	Operational Environment	Decision Making Horizon
TS	TMA-HC / TMA-MLC / ENR-HC / ENR-MLC / OO / FM	Planning, near-real time and real time
Level of integration		
4		

This element focuses on aircraft-based capabilities that assist pilots with weather and other aircraft avoidance, and thus enhance safety. Examples of such capabilities are ADS-B IN, air-to-air information exchange, and integration of MET information into cockpit-based automation tools. <To be developed further>

5.2 MET Information Services Domain

The focus of this paragraph is on providing guidance and examples of functional MET information needs to define MET-ATM Information Provision Services and/or MET-ATM Translation Services.

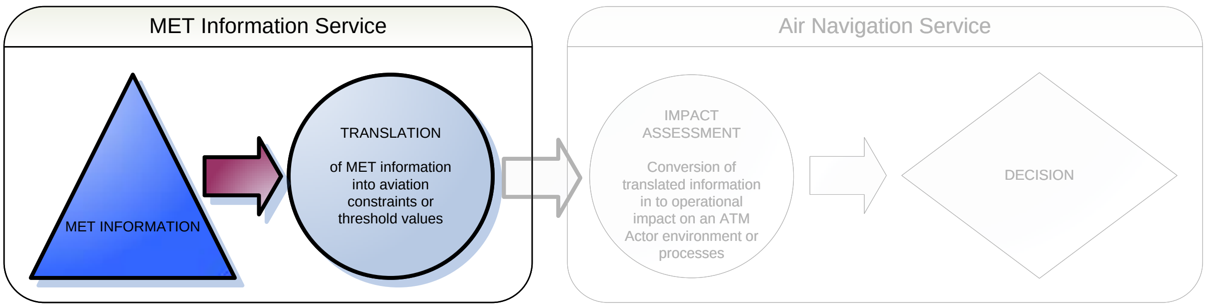


Figure 5-1

It provides examples of functional links established between MET capabilities and the different operational environments described in chapter 3.

Figure 5-2 provides a simplified diagram showing MET information that is typically needed during various phases of flight as discussed in chapter 3.

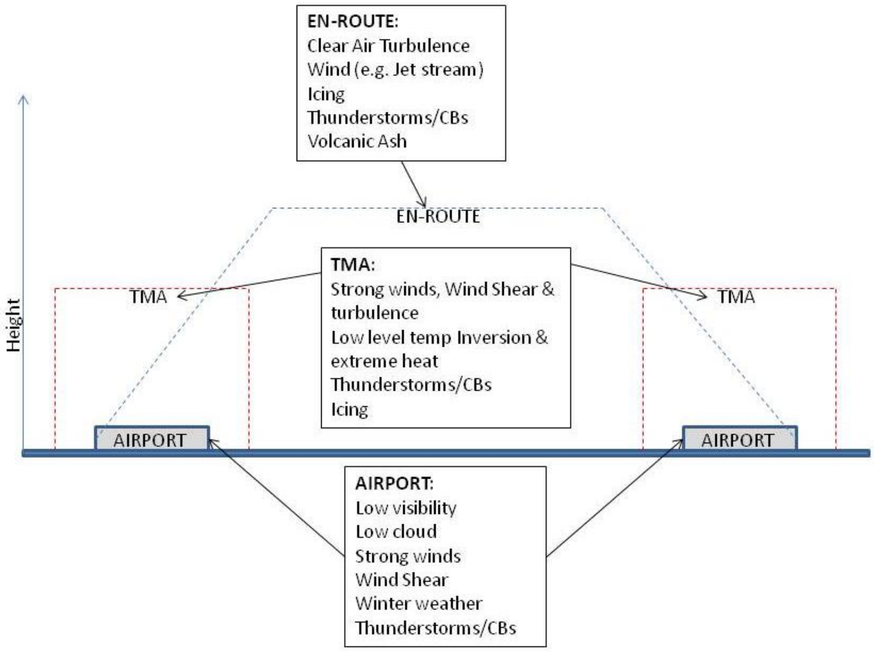


Figure 5-2 Shows MET information typically needed during different phases of flight

Figure 5-3 provides a graphical representation of MET information in relation to operational needs and decision making timeliness. These typical weather events or phenomena will condition the operations; and therefore, the actual and forecast state of such an event needs to be identified as part of the MET information service.

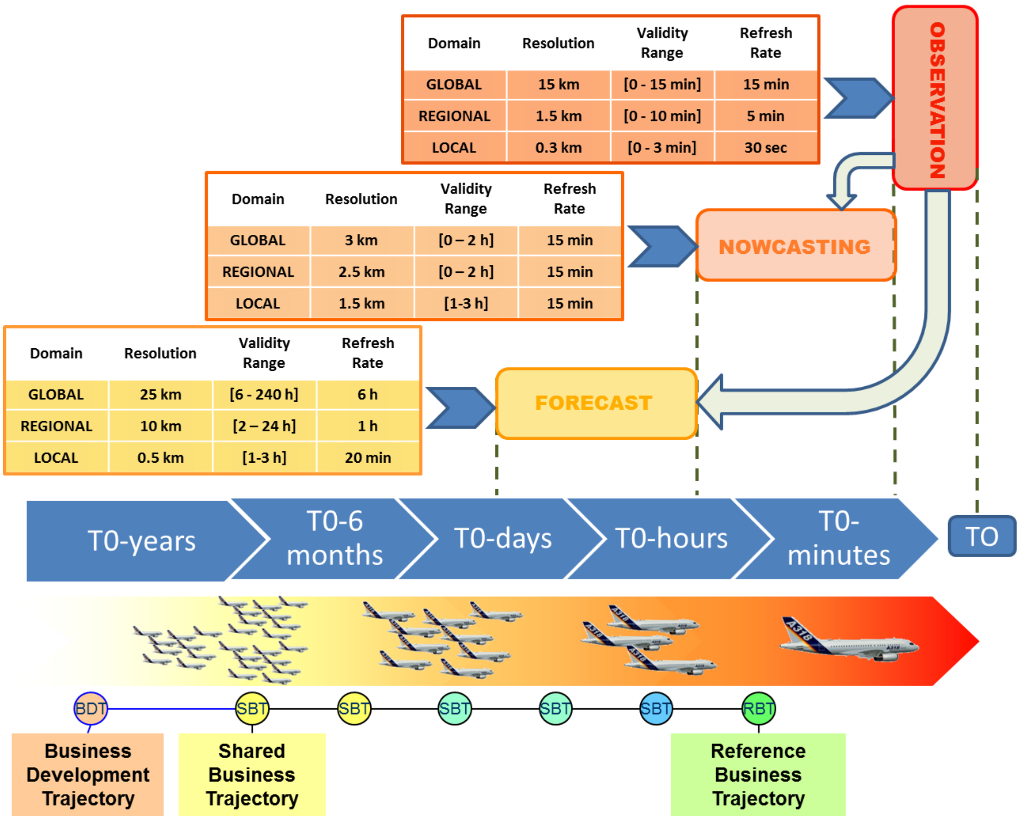


Figure 5-3 Conceptual Framework that depicts Provision of MET Services in relation to time and scale.

Note 1: metrics are intended as illustrative as what maybe operationally desirable

Note 2: Nowcast is a description of current weather and a short-period (0-2hours) forecast

Appendix A provides a conceptual overview of capabilities from a MET provider's perspective in support of the identified ASBU modules in Block 0 leading into Block 1. These suggested capabilities typically represent MET information services at the functional level of MET-ATM translation (Integration level 2) or types of MET information Services that could be used for the translation service (integration level 1). These described information services are correlated with the ATM Concept Components, the operational improvement and the ICAO KPA they potentially could contribute to. These listed capabilities should however not be seen as (performance) requirements committed for implementation but merely as indicative when developing detailed provisions for MET information.

Appendix B provides a similar indicative overview except it only includes envisioned MET capabilities and associated MET information services as they relate to expected operational improvements in the context of ATM Concept Components and applicable for the Block 2 timeframe and onwards.

The table in the following sub-paragraph provides an overview of functional MET information needs linked to an operational environment without considering the decision making horizon or the concept component they could be linked to. A requirement on the decision making horizon the MET information service needs to support will determine an additional level of needs with respect to the quality, accuracy and latency the service needs to adhere to.

Due to the distinct different nature and in general also distinctively different specification for quality and accuracy a separation should be made when defining the information service in further detail between a functional need related to MET observation information and MET nowcast/forecast information.

It should be understood MET observation information provides information on the current state of the atmosphere or other artefacts in the scope of MET-ATM information. From a MET information service provider's perspective this is information that is measured, derived or assessed but still reflects the current state.

MET nowcast/forecast information however provides information on the future state of the atmosphere or other artefacts in the scope of MET-ATM information. The functional MET nowcast/forecast information needs listed are expressed irrespective if they need to be expressed in deterministic or in more probabilistic terms. The need for probabilistic information will increase with the level of integration required and the level of complexity of the decision support that is required. These aspects are directly correlated with the complexity of the operational environment.

5.2.1 MET Information Functional Needs

	Functional Needs[2]	Operational Environment
Wind		
	Surface wind direction, speed, and gusts at aerodrome	A-HD, A-MLD
	Surface wind direction, speed, and gusts for all runways (touchdown zone, midpoint, departure)	A-HD, A-MLD
	Surface gust fronts in relationship to runways	A-HD, A-MLD
	Low-Level Wind Shear	A-HD, TMA-HC
	Upper winds (speed, direction)	TMA-HC, TMA-MLC, ENR-HC, ENR-MLC, OO, FM
	Location and altitude of maximum wind (i.e., jet stream)	TMA-HC, TMA-MLC, ENR-HC, ENR-MLC, OO, FM
	Microbursts	A-HD, TMA-HC
Precipitation		
	Surface precipitation at the aerodrome (rain, drizzle, freezing rain, freezing drizzle, snow, ice crystals, ice pellets, hail, snow pellets), including intensity (light, moderate and heavy), liquid water equivalent (at selected aerodromes), accumulation and characteristics (freezing, blowing, drifting)	A-HD, A-MLD
	Precipitation away from the aerodrome (determine location, type, intensity)	TMA-HC, TMA-MLC ENR-HC, ENR-MLC
Thunderstorm		
	CB clouds and lightning (determine thunderstorm and density when appropriate)	All
	Tornadic Vortices (including funnel clouds)	A-HD, A-MLD
	Meso-cyclones	TMA-HC, ENR-HC, OO, FM
Visibility		
	Aerodrome surface (aeronautical) visibility	A-HD, A-MLD
	Surface (aeronautical) visibility for each runway (touchdown zone, midpoint, and stop-end)	A-HD, A-MLD
	Runway Visual Range (touchdown zone for Cat I, II and III runways, midpoint for Cat I and II runways, and stop-end for Cat III runways)	A-HD, A-MLD
	Visibility aloft in order to determine flight visibility and slant range	TMA-HC

[2] The spatial extent of required observations will depend on the air space characteristic.

Functional Needs[2]		Operational Environment
	visibility for approach corridors	
Obscuration		
	Surface obscuration (fog, mist, freezing fog, smoke, haze, sand, dust)	A-HD, A-MLD TMA-HC
	Obscuration Aloft (haze, smoke, dust, sand)	TMA-HC
	Duststorm and sandstorm	All
	Dust/sand whirls (dust devil)	A-HD, A-MLD TMA-HC
Cloud		
	Clouds (amount, layers, height of bases)	A-HD, A-MLD
	Location of clouds (amount, bases, tops, layers)	TMA-HC, TMA-MLC, ENR-HC, ENR-MLC
Radioactive cloud (location, depth, movement)		All
Temperature and Moisture		
	Surface air temperature and dew-point temperature	A-HD, A-MLD
	Runway temperature	A-HD, A-MLD
	Upper air temperature, upper-air humidity and moisture content	TMA-HC, TMA-MLC, ENR-HC, ENR-MLC, OO, FM
	Height of tropopause	ENR-HC, ENR-MLC
Atmospheric pressure		
	Surface atmospheric pressure	A-HD, A-MLD
	Upper atmospheric pressure	TMA-HC, TMA-MLC, ENR-HC, ENR-MLC, OO, FM
Sea Surface (wave height & temperature) Conditions		A-HD, A-MLD
Volcanic Activity		
	Volcanic Eruption	All
	Volcanic Ash/Gaseous Cloud (location, coverage, top, base, layers, movements)	All
	Volcanic ash accumulation (runways, taxiways and ramp)	A-HD, A-MLD
	Ash concentration (a place holder for whenever values are determined)	TMA-HC, ENR-HC, OO, FM
Tropical Cyclone		
	Tropical cyclone (location of the centre, horizontal extent, intensity, movement)	All
Turbulence		
	Turbulence (clear air, in-cloud, convectively-induced, terrain-induced)	TMA-HC, TMA-MLC, ENR-HC, ENR-MLC, OO, FM
	Mountain Wave activity (variance of vertical speed) and wave characteristics (breaking vs benign)	TMA-HC, TMA-MLC, ENR-HC, ENR-MLC, OO, FM
Wake Turbulence		
	In terminal area	TMA-HC, A-HD
	En-route	ENR-HC, OO
Icing		

Functional Needs[2]		Operational Environment
	In-flight icing	TMA-HC, TMA-MLC, ENR-HC, ENR-MLC, OO, FM
	Super-cooled large droplets aloft	TMA-HC, TMA-MLC, ENR-HC, ENR-MLC, OO, FM
	Ground icing (airframe icing, rime, frost)	A-HD, A-MLD
Space Meteorological Conditions		ENR-HC, ENR-MLC, OO, FM
	To Be Determined	

6 Support to Provision Development

Based on this concept, more detailed functional requirements and ICAO provisions should be developed in support of the TBO Concept and in general terms to support the identified operational improvements included in the GANP.

These functional requirements need to be developed for the required MET information services and its underpinning capabilities, and for the air navigation services that integrate MET information.

Appendix C provides an overview of what is currently included in Annex 3 and gives suggestions how these provisions could evolve to meet the GANP needs.

A structure for the identification and categorisation of required MET information services and the air navigation services that require these MET information services should be linked to the identified ASBU modules and the level of integration identified (see § 5.1).

6.1 MET information services

Based on the suggested structure, the following MET information services can be identified that require further detailing of their functional requirements and development of associated provisions.

6.1.1 Block 0

The overall capability improvement for MET information services for the Block 0 timeframe can be identified by an improved utilisation of existing MET capabilities especially in the planning phase. By this improved utilisation and the tailoring of these capabilities to the specific use-case, a performance enhancement could already be established compared to the current norm. While the MET capability in general terms exists, supporting provisions may be required to gain the maximum benefit of implementing these capabilities and services.

From an utilisation perspective the required MET information services could be categorised to support:

- Optimization of Approach Procedures including Vertical Guidance
- Improved Airport Operations through Airport-CDM
- Improved Traffic Flow through Sequencing (AMAN/DMAN)
- Improved Flow Performance through Planning based on a Network-Wide view
- Improved Flexibility and Efficiency in Descent Profiles (CDO)
- Improved Flexibility and Efficiency in Departure Profiles — Continuous Climb Operations (CCO)

6.1.2 Block 1

The overall capability improvement for MET information services for the Block 1 timeframe focus on improved or new capabilities to support planning and near-real time decision making processes. This will require the development of functional requirements and provisions for MET Information Services to support:

- Optimised Airport Accessibility
- Increased Runway Throughput through Dynamic Wake Turbulence Separation
- Optimized Airport Operations through Airport-CDM
- Improved Airport Operations through Departure, Surface and Arrival Management
- Improved Operations through Optimized ATS Routing
- Enhanced Flow Performance through Network Operational Planning
- Improved Flexibility and Efficiency in Descent Profiles (CDOs) using VNAV

- Improved Traffic Synchronization and Initial Trajectory-Based Operation

6.1.3 Block 2

The overall capability improvement for MET information services for the Block 2 timeframe focus on improved or new capabilities to support near-real time and real-time decision making processes. This will require the development of functional requirements and provisions for MET Information Services to support:

- Advanced Wake Turbulence Separation (Timebased)
- Increased user involvement in the dynamic utilization of the network
- Improved Flexibility and Efficiency in Continuous Descent Profiles (CDOs) using VNAV, required speed and time at arrival

6.1.4 Block 3

The overall capability improvement for MET information services for the Block 3 timeframe focus on improved or new capabilities to further enhance near-real time and real-time decision making processes. This will require the development of functional requirements and provisions for MET Information Services to support:

- Traffic Complexity Management
- Full 4D Trajectory-based Operations

6.2 Air navigation services

It will not be sufficient to only develop provisions that will arrange for the availability of the required MET information; which is the intent of paragraph 6.1. How the MET information should be used and integrated should also be part of relevant provisions to ensure a uniform use and understanding on how MET information should be integrated.

The development of air navigation services related provisions is therefore not an activity strictly limited to the core air navigation services aspects when MET information is considered to be an essential enabler for the identified operational improvement. In the process of defining the functional requirements and provisions for the identified operational improvements in paragraph 5.1, due consideration should be given to these MET information use and integration aspects and how they need to be reflected from a provision' perspective when appropriate.

Only then it can be ensured, when MET information is considered to be an essential enabler for an identified operational improvement, that the provision development relevant for the identified operational improvement and the implementation of these provisions will meet the overall defined safety and performance objectives.

Acronyms and Terminology

Term	Definition
ACARS	Aircraft Communications Addressing and Reporting System
ADS-B	Automatic Dependent Surveillance - Broadcast
AMAN	Arrivals Management
AMDAR	Aircraft Meteorological Data Relay
AMOFSG	Aerodrome Meteorological Observations and Forecast Study Group
ANB	Air Navigation Bureau
ANP	Air Navigation Plan
AMHS	Advanced Message Handling System
AOC	Airline Operations Centre
ASMGCS	Advanced Surface Movement Guidance and Control System
ATB	Air Transport Bureau
ATC	Air Traffic Control
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATN	Aeronautical Telecommunications Network
ATS	Air Traffic Services
BUFR	Binary Universal Form for the Representation of Meteorological Data
CAeM	(WMO) Commission for Aeronautical Meteorology
CARATS	Collaborative Action for Renovation of Air Traffic Systems (Japan)
CB	Cumulonimbus
CDM	Collaborative Decision-Making
CDO	Continuous Descent Operations
COTS	Commercial Off-The-Shelf products
DMAN	Departures Management
EUROCAE	European Organisation for Civil Aviation Equipment

FASID	Facilities and Implementation Document (Part II of an ICAO Region's Air Navigation Plan)
FIS-B	Flight Information Services - Broadcast
GANP	Global Air Navigation Plan
GRIB	Gridded Binary Data
ICAO	International Civil Aviation Organisation
IOC	Initial Operating Capability
IP	Internet Protocol
ISO	International Organization for Standardization
MET	Aeronautical Meteorology
METAR	Meteorological Terminal Aviation Routine Weather Report
METEOSAT	System of Observing satellites for Meteorology
MSTA	Meteorological Services in the Terminal Area
NEXTGEN	Next Generation Air Transport System (USA)
NOP	Network Operations Plan
OGC	Open Geospatial Consortium
OPMET	Operational Meteorological Information
PANS	Procedures for Air Navigation
PBN	Performance-Based Navigation
RTA	Required Time of Arrival
RTCA	Radio Technical Commission for Aeronautics
SARPS	Standards and Recommended Practices
SESAR	Single European Sky ATM Research Programme
SOA	Service Oriented Architecture
TAF	Terminal Aerodrome Forecast
USOAP	Universal Safety Oversight Audit Programme
WAFS	World Area Forecast System
WMO	World Meteorological Organization

WXXM	Weather Information Exchange Model
4D	Four dimensional, i.e., x,y,z and t, where “t” is time and “x,y,z” are three dimensional spatial coordinates.

Appendix A

Current and emerging MET capabilities, their expected Operational Benefits and mapped against ATM Concept Components and KPAs

MET element[3]	Concept component	Decision horizon	Existing or emerging MET capability[4]	Expected Operational Benefit	KPA
Convection and Thunderstorm (1)	AOM DCB	Planning Near-real time	Nowcast [0-1hr] of location and severity of convection, including impact on flight path, specific holding area and air traffic control areas. Coverage: air traffic control areas and holding areas, typical within 100-200 km from aerodrome. High spatial resolutions (horizontal : 500m up to few km) Temporal resolution and update frequency : based on resolution of radar/lightning data (order of several minutes)	Tailored forecasts of significant convection and thunderstorms for specific holding area and way points of **TMA-HC** and **A-HD** facilitates ATM to better estimate arrival capacity and adjust flight routes to avoid hazardous weather. Adaptive planning used to optimize use of air space, reduce the weather impact and enhance safety. Sharing of such information will improve airport CDM for all stakeholders which will improve efficiency of AOM, reduce the unnecessary fuel burnt due to holding.	KPA 02 KPA 03 KPA 04 KPA 05 KPA 09 KPA 10

[3] Reference: WMO Doc. N°182

[4] The MET Capability refers to the best possible capability MET services can provide for High Density Airport (A-HD)/High Complexity TMA (TMA-HC). The Medium to Low Density Airport (A-MLC)/Medium to Low Complexity TMA (TMA-MLC) may not require all the Capabilities. The attainable quality, as part of the MET Capability, depends on the weather scenario. For example, for synoptic weather, the valid time can be longer to maintain a certain level of accuracy performance. However, for localized weather, the valid time could only be short to maintain certain level of forecast accuracy.

MET element[3]	Concept component	Decision horizon	Existing or emerging MET capability[4]	Expected Operational Benefit	KPA
	AO	Near-real time Real-time	Nowcast [0-1hr] of location and severity of convection. Impact on flight path, specific holding area and air traffic control areas. . Lightning nowcast for ground operators at the aerodrome Coverage: air traffic control areas and holding areas, typical within 100-200 km from aerodrome. High spatial resolutions (horizontal: 500m up to few km) Temporal resolution and update frequency : based on resolution of radar/lightning data (order of several minutes)	An early anticipation on expected thunderstorms/convective weather conditions will enable airline and aerodrome operations to minimize the impact of weather on the aerodrome (**A-HD**) throughput by optimizing flow to the expected capacity throughout the weather event and consequently will enable a better performance.	KPA 02 KPA 03 KPA 04 KPA 05 KPA 09 KPA 10
Convection and Thunderstorm (2)	AOM DCB	Planning Near-real time	Forecast [1-30hr] of location and severity of convection and impact on flight path, specific holding area and traffic control areas. Both deterministic forecast [1-30hr] of convection and probabilistic forecast of convection and uncertainty information are provided. Coverage: typical of about 300-500 km from aerodrome, air traffic control areas and holding areas. Larger coverage for longer lead time High spatial resolution (horizontal: 2 km or less) for smaller coverage and coarser resolution for larger coverage. Temporal resolution of forecast products: 1 hour for shorter lead time and 3 hours	Tailored forecasts of significant convection and thunderstorms for specific holding area and way points of **TMA-HC** and **A-HD** facilitates ATM to better estimate aerodrome capacity and adjust flight routes (**ENR-HC**) to avoid hazardous weather. Prior arrangement could be made to optimize use of air space, reduce the weather impact and enhance safety. Sharing of such information will improve aerodrome CDM for all stakeholders which will increase efficiency of AOM, reduce the unnecessary fuel burnt due to holding (**TMA-HC**). Uncertainty information helps ATM to	KPA 02 KPA 03 KPA 04 KPA 05 KPA 06 KPA 09 KPA 10

MET element[3]	Concept component	Decision horizon	Existing or emerging MET capability[4]	Expected Operational Benefit	KPA
			for longer lead time. Update frequency : 1 - 3 hours	conduct risk assessment.	
	AO	Planning Near-real time Real-time	Forecast [1-30hr] of location and severity of convection and impact on flight path, specific holding area and traffic control areas. Both deterministic and probabilistic forecast of convection are provided. Coverage: typical of about 300-500 km from aerodrome, air traffic control areas and holding areas. Larger coverage for longer lead time High spatial resolution (horizontal: 2 km or less) for smaller coverage and coarser resolution for larger coverage. Temporal resolution of forecast products: 1 hour for shorter lead time and 3 hours for longer lead time. Update frequency : 1 - 3 hours	An early anticipation on expected thunderstorm/convective weather conditions will enable aerodrome operations (**A-HD**) to minimize the impact of weather on the aerodrome throughput and consequently will enable a better performance. Uncertainty information helps ATM to conduct risk assessment.	KPA 02 KPA 03 KPA 04 KPA 05 KPA 06 KPA 09 KPA 10
Wind shear	AOM AO AUO	Planning Near-real time Real-time	Wind shear alerts, warnings including wind shear magnitudes for different runway corridors. Coverage: departure and final approach paths, ~ 8 km from runway thresholds. Spatial resolution: spatial resolutions of data sources (e.g. LIDAR 100m). Time resolution: time resolutions of data sources (e.g. wind sensors 10s).	Detection (remote-sensing)and nowcasting of wind shear will allow enhanced performance and safety in final approach, landing and departure phases (**A-HD, A-MLD, TMA-HC, TMA-MLC**). Early anticipation of wind shear events will enable airspace operations management to minimize the impact of weather in the approach area and before departure, and consequently will enable a better performance.	KPA 02 KPA 03 KPA 04 KPA 05 KPA 09

MET element[3]	Concept component	Decision horizon	Existing or emerging MET capability[4]	Expected Operational Benefit	KPA
			Update frequency : frequencies and arrival time of data sources (1s at most) Ref. ICAO Manual on Low-level Wind shear, Doc. 9817		
Wind (1)	AOM DCB AO	Planning Near-real time Real-time	Forecast [0-3hr] of headwind/tailwind, and crosswind, including gusts, at the surface and along approach paths, mainly by local/regional numerical weather prediction (NWP) models. Provision of time-series. Provision of probabilistic information. Coverage : typical of areas including final approach airspace and aerodrome, ~50NM from aerodrome Spatial resolution: (a) horizontal : 0.1° or less. (b) vertical: NWP model vertical levels, with 50 to 100hPa resolution. Focus on low levels. Temporal resolution of forecast products: 10 minutes to 1 hour. Update frequency : NWP model update frequency (every 6 hours or less)	Forecasts of head/tailwind, and crosswind, including gusts, at a high resolution along approach paths and runways will allow enhanced performance and safety in final approach and landing/taking-off phases. (**A-HD, A-MLD, TMA-HC, TMA-MLC**) Early anticipation of wind direction changes will facilitate ATM to adjust aerodrome runway configuration and to manage traffic flow consequently. (**A-HD, A-MLD, TMA-HC, TMA-MLC**)	KPA 01 KPA 02 KPA 04 KPA 05 KPA 09 KPA 10
Wind (2)	DCB AO	Planning Near-real time	Surface wind forecast [0-6hr] (intensity and direction) and probability of wind intensity over thresholds.	Forecasts of wind at a very high resolution on the aerodrome (several locations on the aerodrome) will allow to	KPA 01 KPA 02 KPA 03

MET element[3]	Concept component	Decision horizon	Existing or emerging MET capability[4]	Expected Operational Benefit	KPA
		Real-time	Physical and numerical modeling of the aerodrome area and of surface wind flow over this area. Provision of time-series. Provision of probabilistic information. Coverage : typical of areas including track from TMA entry points to aerodrome of arrival, ~150NM from aerodrome Spatial resolution: (a) horizontal : 0.1° or less. (b) vertical: NWP model vertical levels, with 50 to 100hPa resolution. Temporal resolution of forecast products: 1 hour. Update frequency : NWP model update frequency (every 6 hours or less)	better management of ground ops. (**A-HD, A-MLD**) Early anticipation on stormy conditions and strong winds will enable aerodrome operations to minimize the impact of weather on the aerodrome throughput and will enhance safety in ground operations (e.g. embarking/disembarking and tying down on the aircraft in high winds). Consequently it will enable a better balancing of demand and capacity	KPA 04 KPA 05 KPA 09 KPA 10
Wind (3)	AOM DCB TS	Planning Near-real time Real-time	Upper air wind (intensity) gridded forecast [0-12hr] or over areas of interest (e.g. waypoints or TMA entry points). Provision of time-series. Provision of probabilistic information. Coverage : typical of areas including track from TMA entry points to aerodrome of arrival, ~150NM from aerodrome Spatial resolution : (a) horizontal : 0.1° or less. (b) vertical : NWP model vertical levels, with 50 to 100hPa resolution. Temporal resolution of forecast products: 1 hour. Update frequency : NWP model update	Forecasts of wind at a high resolution within TMA (from entry points to aerodrome) will allow better synchronization and management of air traffic in high density TMA. (**TMA-HC**) Early anticipation on strong winds at TMA entry points or in descent phase will allow to adjust flight characteristics (speed, level) to avoid congestion in approach and final phases. (**ENR-HC, TMA-HC**) Forecasts of upper air wind (and temperature) will improve efficiency of CDO through minimizing fuel burning and consequently a better performance. . (**ENR-HC, TMA-HC**)	KPA 02 KPA 03 KPA 04 KPA 05 KPA 06 KPA 07 KPA 09 KPA 10

MET element[3]	Concept component	Decision horizon	Existing or emerging MET capability[4]	Expected Operational Benefit	KPA
			frequency (every 6 hours or less)		
Upper-air turbulence	AOM AUO	Planning Near-real time	Turbulence potential or severity forecast based on NWP models or Object oriented approach for highlighting severity of turbulence (low data volume, could be uplinked) Coverage : typical areas including regional areas Spatial resolution : of underpinning NWP model (e.g. horizontal : ~10km) Time resolution : 1 hour up to typically T+48 Update frequency : NWP model update frequency (every hour)	Forecast of upper-air turbulence will allow enhanced compliance with trajectory while maintaining safety thus optimizing flight trajectory planning (**TMA-HC, TMA-MLC, ENR-HC**)	KPA 02 KPA 03 KPA 04 KPA 09 KPA 10
Ceiling and Visibility (1)	AOM TS	Planning Near-real time Real-time	Ceiling and visibility deterministic or probabilistic forecast. Coverage : typical of areas including track from TMA entry points (AOM,TS) to aerodrome of arrival (AUO/A-HD), ~150 NM from aerodrome. Spatial resolution : depending on model resolution (e.g. horizontal 2.5 km, vertical 100-1000m) Time resolution: typically used resolutions at current: hourly up to T+24. Experimental models in development with 5-minute refresh and hourly forecasts.	High resolution forecasts of ceiling and visibility within a TMA (from entry points to aerodrome) will allow better synchronization and management of air traffic in congested airspace. Improved analysis and forecasts of ceiling and visibility will allow smoother metering of inbound aircraft into high-density terminals. (**A-HD, A-MLD, TMA-HC, TMA-MLC**)	KPA 01 KPA 02 KPA 03 KPA 04 KPA05 KPA 09 KPA 10

MET element[3]	Concept component	Decision horizon	Existing or emerging MET capability[4]	Expected Operational Benefit	KPA
			Update frequency : NWP model update frequency or surface observing measurement frequency		
Ceiling and Visibility (2)	AO AUO	Planning Near-real time Real-time	Ceiling and visibility deterministic or probabilistic forecast. Coverage : typical of areas including track from TMA entry points (AOM,TS) to aerodrome of arrival (AUO/A-HD), ~150 NM from aerodrome. Spatial resolution : depending on model resolution (e.g. horizontal 2,5 km, vertical 100-1000m) Time resolution: typically used resolutions at current: hourly up to T+24. Experimental models in development with 5-minute refresh and hourly forecasts. Update frequency : NWP model update frequency or surface observing measurement frequency	Forecasts of ceiling and visibility will enable aerodrome operations to minimize the impact of weather on aerodrome throughput and will benefit operational users in planning alternate landing sites and efficient fuel loads. (**A-HD, A-MLD**) Also, improved gridded ceiling and visibility forecasts will facilitate low-level operations, such as search and rescue and medical evacuation. (**A-HD, A-MLD**)	KPA 01 KPA 02 KPA 03 KPA 04 KPA05 KPA 09 KPA 10
In-flight icing (1)	AO AUO	Planning Near-real time Real-time	Diagnosis of icing categories and icing intensity based on NWP models enhanced by observational data (including radar and satellite data). Coverage : typical areas including TMA and regional areas Spatial resolution (of underpinning NWP model): (a) horizontal : local 1km ; regional about 10km (b) vertical : NWP model vertical levels	Diagnosis of in-flight icing will allow enhanced performance and safety in final approach and landing/taking-off phases. (**TMA-HC, TMA-MLC**)	KPA 03 KPA 04 KPA 05 KPA 09 KPA 10

MET element[3]	Concept component	Decision horizon	Existing or emerging MET capability[4]	Expected Operational Benefit	KPA
			Update frequency : NWP model update frequency (every hour or less)		
In-flight icing (2)	AOM AUO	Planning Near-real time	Forecast of icing categories and icing intensity based on NWP models. Could include probabilistic information. Coverage : typical areas including regional areas or global Spatial resolution (of underpinning NWP model): (a) horizontal : about 10km or 40km (b) vertical : NWP model vertical levels (focus on aviation related levels) Time resolution : 1h up to typically T+48 or 3h up to typically T+84 Update frequency : NWP model update frequency (every hour or every 3, 6 hour)	Forecast of in-flight icing will allow enhanced performance and safety as well as optimal flight trajectory planning. (**TMA-HC, TMA-MLC, ENR-HC, ENR-MLC**)	KPA 02 KPA 03 KPA 04 KPA 05 KPA 09 KPA 10
Surface icing & Airframe icing forecast	AO AUO	Planning Near-real time Real-time	Forecast of surface & airframe icing : provision of MET parameters linked to winter weather (temperature, precipitation) => NWP model output Provision of surface parameters (pavement temperature and runway condition) => dedicated nowcast model output. Provision of probability values Coverage : aerodrome Spatial resolution : horizontal : selected	Forecast of surface & airframe icing will allow preventive treatment of runways and de-icing of airframes. Early icing forecast should represent a safety increase, pollution decrease and financial savings. (**A-HD, A-MLD**)	KPA 02 KPA 03 KPA 05 KPA 10

MET element[3]	Concept component	Decision horizon	Existing or emerging MET capability[4]	Expected Operational Benefit	KPA
			locations at aerodrome Time resolution : typically used resolutions at current: hourly up to T+24, 6-hourly up to T+5days Update frequency : NWP model update frequency or surface observing measurement frequency Ref. ICAO Manual on Aircraft De-icing Doc. 9640		
Winter weather	AO AOM DCB TS	Planning Near-real time Real-time	Nowcast and forecast products for snowfall or snow storm incl. probabilistic information. Coverage : typical areas including TMA Spatial resolution (of underpinning NWP model): (a) horizontal : local 1km ; regional about 10km (b) vertical : NWP model vertical levels Update frequency : NWP model update frequency (every hour or less)	An early anticipation of winter weather (snowfall, snow storm, low temperatures...) will enable aerodrome operations to minimize its impact on the aerodrome and consequently will enable a better performance. Anticipated snow removal operations will improve efficiency of AO, and consequently reduce delays in departure and landing, and all ground operations. (**A-HD, A-MLD, TMA-HC**) The improved efficiency of AO and the sharing of winter weather forecast information for all CDM stakeholders will allow to better estimate aerodrome capacity and consequently to improve efficiency of AOM, TS and DCB.	KPA 02 KPA 03 KPA 04 KPA 05 KPA 09 KPA 10
Tropical Cyclone	AOM DCB AO TS AUO	Planning Near-real time	Actual observations and NWP forecast [1-30h]of the location, intensity and wind as well as rain distribution of the tropical cyclone. Probability forecast.	Observed and forecast location, intensity, high wind distribution (e.g. strong radius, gale radius, storm radius and hurricane radius) and movement of tropical cyclones have significant impact to	KPA 01 KPA 02 KPA 03 KPA 04 KPA 05

MET element[3]	Concept component	Decision horizon	Existing or emerging MET capability[4]	Expected Operational Benefit	KPA
			coverage: 500km or larger Spatial resolution: spatial resolution of data sources: radar 0.5km or less, 4km for satellite, 2km or less for NWP Temporal resolution: 1 minute for ground observations; 6 minutes for radar, 15-30 minutes for satellite (10 minutes with next generation satellites); 1 hr for NWP	airspace operation and aerodrome operation. (**A-HD, A-MLD, TMA-HC, TMA-MLC, ENR-HC**) Observed and forecast heavy precipitation associated with tropical cyclones along with observed calculated sea surface level as well as wave/storm surge information as a result of the tropical cyclone have significant impact to aerodrome operation. (**A-HD, A-MLD**) The uncertainty information could help ATM to assess the quality of the model outputs and make risk assessment.	KPA 09 KPA 10
Wake Vortex monitoring	AOM DCB AO AUO	Real-time	Actual observation of wake vortex using LIDAR and anemometers coverage: 3NM from TDZ Spatial resolution: spatial resolution of data sources Temporal resolution: 1 minute or shorter	Real-time observation of wake vortex could be used to optimize the aircraft separation while maintaining the safety of aircraft operation in departing and approaching phases (**A-HD, A-MLD, TMA-HC**)	KPA 01 KPA 02 KPA 03 KPA 04 KPA 05 KPA 09 KPA 10
Volcanic Ash	AOM DCB AO TS AUO	Planning Near-real time Real-time	Refer to Doc 9691 Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds	Volcanic ash may cause damage to the aircraft engines. SO2 gas could also be hazardous to health. Ash deposition on the ground may also reduce friction for the landing aircraft. In addition, ash deposition is needed to facilitate airframe cleaning, since the ash is sharp and corrosive. **(A-HD, A-MLD, TMA-HC, TMA-MLC, ENR-HC)** Ash forecast would then help improve flight safety, better	KPA 01 KPA 02 KPA 03 KPA 04 KPA 05 KPA 09 KPA 10

MET element[3]	Concept component	Decision horizon	Existing or emerging MET capability[4]	Expected Operational Benefit	KPA
				protection of engines and human health	
Radioactive Cloud	AOM DCB AO TS AUO	Planning Near-real time Real-time	Refer to Doc 9691 Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds	Radioactive materials, depending on the type and concentration, could be hazardous to the crew, passengers and ground operators. **(A-HD, A-MLD, TMA-HC, TMA-MLC, ENR-HC, ENR-MLC**). Radioactive material forecast would help enhance flight safety	KPA 01 KPA 02 KPA 03 KPA 04 KPA 05 KPA 09 KPA 10
Space Weather	TBD			(**ENR-HC, ENR-MLC**)	
Tsunami	TBD	Planning Near-real time Real-time	Actual observation and forecast of Tsunami.	Tsunami can reduce aerodrome capacity when the aerodrome facilities are hit by those disasters. With this information, ATM officers can consider contingency plan so that many aircraft in flight can safely go to alternative aerodrome. **(A-HD, A-MLD, TMA-HC, TMA-MLC, ENR-HC)**	KPA 01 KPA 02 KPA 03 KPA 04 KPA 05 KPA 09 KPA 10

Appendix B

Foreseen MET capabilities and foreseen Operational Benefits

Improved or Future Met capability	Support to ATM Concept Components	Operational Environment	Decision Making Horizon	Expected Performance or Operational Improvement	MET parameters and Quality of Service indicators
Improved nowcasting	AOM, DCB, AO, TS	A-HD, A-MLD, TMA-HC, TMA-MLC, ENR-HC, ENR-MLC, Oceanic	Near-real time, Real-time	Operational improvement in negotiated trajectories. A key conditioner for such a negotiation process is to stay clear from areas with hazardous or unfavourable weather and to have knowledge on these phenomena upfront in the negotiation process. Improved prediction of medium to large scale convective areas with potential hazards such as severe turbulence, severe icing, strong up and downdraft, hail, lightning is a typical phenomenon will facilitate the trajectory negotiation process which enhance aviation safety. Short range terminal weather forecasts in support of terminal area operation and capacity forecasts and enhance safety.	Use of high resolution observational data such as weather radar and satellite data for ingestion into high resolution model, and blending with mesoscale NWP model outputs to improve short term forecasts, including: (a) movement and intensity changes of thunderstorms and significant convection (b) convective induced phenomena like wind gusts and tornado (c) convective activity types (d) lightning risk NWP component in blending with nowcast Horizontal resolution : 1-2km to 500m-1km or less Vertical levels: 60 or more Update frequency: 1-3 hour or less

Improved or Future Met capability	Support to ATM Concept Components	Operational Environment	Decision Making Horizon	Expected Performance or Operational Improvement	MET parameters and Quality of Service indicators
					Time period: T+0 -T+ 9 hours to T+15 hours Time interval of forecast products: ~30 min or below Rapid update, short period forecasts for tactical planning
Improved windshear alerting	AUO, AOM	A-HD, A-MLD, TMA-HC, TMA-MLC	Near-real time, Real-time	Improvement in windshear alerting. Better monitoring on small-scale windshear features such as building-induced windshear.	Use of meteorological equipment, such as use of short-range LIDAR and microwave radiometers, to improve windshear monitoring and alerting Increase in horizontal resolution to ~100 m
Increase resolution of NWP models, microphysics processes and data assimilation techniques	AUO, DCB, AO, TS	A-HD, A-MLD, TMA-HC, TMA-MLC, ENR-HC, ENR-MLC, Oceanic, Flow Management	Planning, Near-real time	Improvements in weather information lead to better data concerning the extent, time period and severity of weather impacts on airspace, which will maximize the use of available airspace, fewer re-routes, less variability in associated traffic management.	To improve forecast of weather hazards incl. significant convection and thunderstorms, for terminal and aerodrome areas To improve forecast of mesoscale and convective phenomena using higher resolution model. Increased update frequency and time interval of model forecasts for enhancements of NWP component in blending with nowcast products.

Appendix C

ICAO Annex 3 Provisions versus current and emerging MET capabilities

MET element[5]	Current Annex 3 Provision	Existing or emerging MET capability
Convection and Thunderstorm (1)	SIGMET of CB/thunderstorms observation or nowcast Coverage : FIRs	Nowcast [0-1hr] of location and severity of convection, including impact on flight path, specific holding area and air traffic control areas. Coverage: air traffic control areas and holding areas, typical within 100-200 km from aerodrome. High spatial resolutions (horizontal : 500m up to few km) Temporal resolution and update frequency : based on resolution of radar/lightning data (order of several minutes)
Convection and Thunderstorm (2)	WAFS gridded data of Cb areas forecast [6-36hr] Coverage : global Resolution : 1,25°	Forecast [1-30hr] of location and severity of convection and impact on flight path, specific holding area and traffic control areas. Both deterministic forecast [1-30hr] of convection and probabilistic forecast of convection and uncertainty information are provided. Coverage: typical of about 300-500 km from aerodrome, air traffic control areas and holding areas. Larger coverage for longer lead time High spatial resolution (horizontal: 2 km or less) for smaller coverage and coarser resolution for larger coverage. Temporal resolution of forecast products: 1 hour for shorter lead time and 3 hours for longer lead time. Update frequency : 1 - 3 hours

[5] Reference: WMO Doc. N°182

MET element[5]	Current Annex 3 Provision	Existing or emerging MET capability
Wind shear	Wind shear warnings/alerts	Wind shear alerts, warnings including wind shear magnitudes for different runway corridors. Coverage: departure and final approach paths, ~ 8 km from runway thresholds. Spatial resolution: spatial resolutions of data sources (e.g. LIDAR 100m). Time resolution: time resolutions of data sources (e.g. wind sensors 10s). Update frequency : frequencies and arrival time of data sources (1s at most) Ref. ICAO Manual on Low-level Wind shear, Doc. 9817
Wind (1)	Wind (+ gust) forecast at aerodrome reference point included in TAF Strong wind observation or nowcast included in Aerodrome Warning	Forecast [0-3hr] of headwind/tailwind, and crosswind, including gusts, at the surface and along approach paths, mainly by local/regional numerical weather prediction (NWP) models. Provision of time-series. Provision of probabilistic information. Coverage : typical of areas including final approach airspace and aerodrome, ~50NM from aerodrome Spatial resolution: (a) horizontal : 0.1° or less. (b) vertical: NWP model vertical levels, with 50 to 100hPa resolution. Focus on low levels. Temporal resolution of forecast products: 10 minutes to 1 hour. Update frequency : NWP model update frequency (every 6 hours or less)
Wind (2)	Wind (+ gust) forecast at aerodrome reference point included in TAF Strong wind observation or nowcast included in Aerodrome Warning	Surface wind forecast [0-6hr] (intensity and direction) and probability of wind intensity over thresholds. Physical and numerical modeling of the aerodrome area and of surface wind flow over this area. Provision of time-series. Provision of probabilistic information. Coverage : typical of areas including track from TMA entry points to aerodrome of arrival, ~150NM from aerodrome

MET element[5]	Current Annex 3 Provision	Existing or emerging MET capability
		Spatial resolution: (a) horizontal : 0.1° or less. (b) vertical: NWP model vertical levels, with 50 to 100hPa resolution. Temporal resolution of forecast products: 1 hour. Update frequency : NWP model update frequency (every 6 hours or less)
Wind (3)	WAFS upper wind gridded data [6-36hr] Coverage : global Resolution : 1,25°	Upper air wind (intensity) gridded forecast [0-12hr] or over areas of interest (e.g. waypoints or TMA entry points). Provision of time-series. Provision of probabilistic information. Coverage : typical of areas including track from TMA entry points to aerodrome of arrival, ~150NM from aerodrome Spatial resolution : (a) horizontal : 0.1° or less. (b) vertical : NWP model vertical levels, with 50 to 100hPa resolution. Temporal resolution of forecast products: 1 hour. Update frequency : NWP model update frequency (every 6 hours or less)
Upper-air turbulence	WAFS gridded data [6-36hr] for turbulence potential Coverage : global Resolution : 1,25°	Turbulence potential or severity forecast based on NWP models or Object oriented approach for highlighting severity of turbulence (low data volume, could be uplinked) Coverage : typical areas including r egional areas Spatial resolution : of underpinning NWP model (e.g. horizontal : ~10km) Time resolution : 1 hour up to typically T+48 Update frequency : NWP model update frequency (every hour)
Ceiling and Visibility	Visibility and cloud base forecast at aerodrome reference point, included in TAF	Ceiling and visibility deterministic or probabilistic forecast. Coverage : typical of areas including track from TMA entry points (AOM,TS) to aerodrome of arrival (AUO/A-HD), ~150 NM from aerodrome. Spatial resolution : depending on model resolution (e.g. horizontal 2.5 km,

MET element[5]	Current Annex 3 Provision	Existing or emerging MET capability
		vertical 100-1000m) Time resolution: typically used resolutions at current: hourly up to T+24. Experimental models in development with 5-minute refresh and hourly forecasts. Update frequency : NWP model update frequency or surface observing measurement frequency
In-flight icing (1)	SIGMET for in-flight icing observation Coverage : FIRs	Diagnosis of icing categories and icing intensity based on NWP models enhanced by observational data (including radar and satellite data). Coverage : typical areas including TMA and regional areas Spatial resolution (of underpinning NWP model): (a) horizontal : local 1km ; regional about 10km (b) vertical : NWP model vertical levels Update frequency : NWP model update frequency (every hour or less)
In-flight icing (2)	SIGMET for in-flight icing nowcast Coverage : FIRs	Forecast of icing categories and icing intensity based on NWP models. Could include probabilistic information. Coverage : typical areas including regional areas or global Spatial resolution (of underpinning NWP model): (a) horizontal : about 10km or 40km (b) vertical : NWP model vertical levels (focus on aviation related levels) Time resolution : 1h up to typically T+48 or 3h up to typically T+84 Update frequency : NWP model update frequency (every hour or every 3, 6 hour)
Surface icing & Airframe icing forecast	Rime or frost forecast in Aerodrome warning	Forecast of surface & airframe icing : provision of MET parameters linked to winter weather (temperature, precipitation) => NWP model output Provision of surface parameters (pavement temperature and runway

MET element[5]	Current Annex 3 Provision	Existing or emerging MET capability
		condition) => dedicated nowcast model output. Provision of probability values Coverage : aerodrome Spatial resolution : horizontal : selected locations at aerodrome Time resolution : typically used resolutions at current: hourly up to T+24, 6-hourly up to T+5days Update frequency : NWP model update frequency or surface observing measurement frequency Ref. ICAO Manual on Aircraft De-icing Doc. 9640
Winter weather	Snow forecast at the aerodrome reference point included in TAF and in Aerodrome warning	Nowcast and forecast products for snowfall or snow storm incl. probabilistic information. Coverage : typical areas including TMA Spatial resolution (of underpinning NWP model): (a) horizontal : local 1km ; regional about 10km (b) vertical : NWP model vertical levels Update frequency : NWP model update frequency (every hour or less)
Tropical Cyclone	TCA, TCG, SIGMET	Actual observations and NWP forecast [1-30h]of the location, intensity and wind as well as rain distribution of the tropical cyclone. Probabilitic forecast. coverage: 500km or larger Spatial resolution: spatial resolution of data sources: radar 0.5km or less, 4km for satellite, 2km or less for NWP Temporal resolution: 1 minute for ground observations; 6 minutes for radar, 15-30 minutes for satellite (10 minutes with next generation satellites); 1 hr for NWP

MET element[5]	Current Annex 3 Provision	Existing or emerging MET capability
Wake Vortex monitoring	N/A	Actual observation of wake vortex using LIDAR and anemometers coverage: 3NM from TDZ Spatial resolution: spatial resolution of data sources Temporal resolution: 1 minute or shorter
Volcanic Ash	VAA, VAG, SIGMET	Refer to Doc 9691 Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds
Radioactive Cloud	SIGMET	Refer to Doc 9691 Manual on Volcanic Ash, Radioactive Material and Toxic Chemical Clouds
Space Weather	N/A	Under development
Tsunami	Tsunami forecast in Aerodrome warning	Actual observation and forecast of Tsunami.

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