INTERNATIONAL CIVIL AVIATION ORGANIZATION

GUIDELINES FOR THE IMPLEMENTATION OF METEOROLOGICAL INFORMATION IN SYSTEM WIDE INFORMATION MANAGEMENT

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TABLE of CONTENTS

TABLES AND FIGURES

TABLES

FIGURES

1 Introduction

1.1 Background

As of November 2024, International Civil Aviation Organization (ICAO) Member States are recommended to implement System-Wide Information Management (SWIM)-compliant information services for the dissemination of aeronautical meteorological (MET) information required by ICAO Annex 3, *Meteorological Service for international Air Navigation*.

SWIM is a means for managing and exchanging information. It replaces the current point-to-point message exchange paradigm with the information exchange via interoperable services based on internet technologies.

At the sixth Meeting of the Meteorology Panel (March 2025, Montreal), it was agreed to endorse the new *Guidelines for MET-SWIM Implementation* document as an informal guidance document but without an ICAO document number at this stage, noting that future iterations of the document may require its elevation to a formal ICAO document.

1.2 Purpose and Scope of the Document

This document, *Guidelines for MET-SWIM Implementation*, provides guidance on best practices to disseminate aeronautical MET information via information services. The document provides approaches and concepts for the exchange of MET information, high-level concepts regarding MET information exchange models, and describes the role of MET information in SWIM.

This document is intended to align with ICAO Doc 10203, *Manual on System-wide Information Management (SWIM) Implementation*. Where ICAO Doc 10203 provides guidance for all information domains, this document intends to apply these generic SWIM principles specifically to the aeronautical MET domain.

This document has been developed for ICAO Member States and other interested parties seeking information on integrating their MET-SWIM information management within a global SWIM construct. The plan does not specifically address any individual MET information service consumer.

This document will be updated as new provisions relating to MET-SWIM and information services are introduced into Annex 3 and ICAO Doc 10157, *Procedures for Air Navigation Services – Meteorology* (PANS-MET).

The intended purpose of this document is to assist States' designated information service providers implement MET services in accordance with the ICAO SWIM concept.

1.3 Relationship to Other Documents

The ICAO Information Management Panel (IMP) defines the SWIM concept, and as such, publishes a number of documents related to SWIM.

> ICAO Doc 10199, *Procedures for Air Navigation Services – Information Management* (PANS-IM), contains requirements supporting the transition towards a global air navigation system network as described in the ICAO Global Air Navigation Plan (GANP). The document also includes requirements for an information security framework to have a common understanding on the level of protection of the information and to provide end-to-end information security in a scalable approach.

> ICAO Doc 10039, *Manual on System-Wide Information Management (SWIM) Concept*, establishes guidelines for providing information services via a Service-Oriented Architecture (SOA) approach that enables Air Traffic Management (ATM) service providers (ASPs) to deliver global interoperability. Its objectives are two-fold: 1) to assist in the creation of a common lexicon to ease communication when States/groups desire to coordinate on related topics; and 2) to provide a background framework for assisting States/Regions which have not yet undertaken the development and implementation of SWIM instantiations.

> ICAO Doc 10203, *Manual on the System-Wide Information Management (SWIM) Implementation*, contains guidance for information service providers and consumers when implementing SWIM. It addresses the exchange of, for example, flight and flow, aeronautical and meteorological information in a SWIM environment. The SWIM technical infrastructure provides capabilities such as messaging and service monitoring. The scope is limited to the exchange of information between information service providers and consumers. It touches on data origination in the quality management system aspects; however, the global aspects of data and information management are out of scope of the document. The document also describes the Global Information Framework (GIF) and architectural frameworks that provide the backbone for interoperability.

The ICAO Meteorology Panel (METP) is responsible for developing SWIM provisions specific for the aeronautical MET domain. As such, the METP manages the following documents related to MET-SWIM.

ICAO Doc 10157, *PANS-MET*, contains the technical specification and means of compliance for the Standards and Recommended Practices (SARPs) in ICAO Annex 3 to be applied by the MET centres and MET offices in supplying various MET services to aeronautical users.

ICAO Doc 10003, *Manual on the ICAO Meteorological Information Exchange Model (IWXXM)*, assists States in implementing IWXXM for the exchange of aeronautical MET information to meet the latest requirements set forth by ICAO Annex 3.

The *Guidelines for the Implementation of OPMET Data Exchange using IWXXM* aims to assist with the implementation of IWXXM for operational meteorological (OPMET) data and its intra- and inter-regional exchange over the Aeronautical Fixed Service (AFS) as defined in ICAO Annex 3. The document is updated as new provisions relating to IWXXM and its exchange are introduced into Annex 3 and as new policies for exchange of IWXXM are agreed.

The *Roadmap for Meteorology in SWIM* (MET-SWIM Roadmap) describes the transition plan for implementing aeronautical MET information in SWIM (MET-SWIM).

Additionally, SWIM is an integral part of ICAO Doc 9750, Global Air Navigation Plan (GANP), which drives the evolution of the global air navigation system to meet the ever-growing expectations of the aviation community. The GANP contains the following Aviation System Block Upgrade (ASBU) elements related to SWIM and MET-SWIM contained in Table 1.

ASBU Element	Element Title	Element Description	ASBU	Timeline
AMET-B1/4	Dissemination of MET Information	Represents the dissemination of meteorological products using a variety of formats	1	2019 – 2024
AMET-B2/4	MET Information Service in SWIM	Establishes standards for global exchange of the MET information within the SWIM environment	2	2025 – 2030
AMET-B3/4			3	2031 – 2036
AMET-B4/4			4	2037 – 2042
SWIM-B2/1	Information Service Provision	Defines the requirements for an information service provider to make aviation-related information available as an information service	2	2025 – 2030
SWIM-B2/2	Information Service Consumption	Defines the requirements for an information service consumer to discover and access aviation-related information provided via information services	2	2025 – 2030
SWIM-B2/3	SWIM Registry	Implements a SWIM registry as a means for the information service producer to publicize and for an information service consumer to discover information services within a SWIM environment	2	2025 – 2030
SWIM-B2/4	Air/Ground SWIM for Non-Safety Critical Information	Enables airspace users, specifically flight crew, to make information available to the air navigation service provider (ANSP), including reroute	2	2025 – 2030

		preferences and air reports / airspace conditions		
SWIM-B2/5	Global SWIM Processes	Establishes global access to aviation-related information by connecting information service providers and consumers within a global interoperability framework	2	2025 – 2030
SWIM-B3/1	Air/Ground SWIM for Safety Critical Information	Extends Air/Ground SWIM to enable the exchange of safety critical information	3	2031 – 2036

Table 1: ASBU elements related to SWIM and MET-SWIM.

2 Components of MET-SWIM

2.1 Information Service Definitions

An information service definition is necessary when a particular service will be implemented by more than one MET provider. A service definition is issued by a community of interest. It places community agreed requirements on service providers that intend to implement the described service with the goal to harmonise service implementations.

An information service definition includes service design information, expressing what the information service should do and how it should work. It covers organisational and business aspects of the information service (e.g., the operational needs and quality of service to be satisfied by the information service), information requirements and technical details (e.g., interfaces, operations, and payload). The metadata within the information service definition can be categorized as supporting one of two objectives: metadata describing the information service definition to aid in discovery and usability of the information service definition, and harmonisation requirements to ensure congruence of developed information services.

All standard MET information services, included in Annex 3, are required to have an information service definition.

Service definitions have been developed for intended MET information services and are included in Appendix 10 to the PANS-MET. Changes to these definitions will be published through updates to the PANS-MET.

2.2 Information Service Overviews

An information service overview describes a running service. It is a list of the information service metadata intended to promote service discovery and an initial evaluation of an information service. It is the responsibility of the information service providers (e.g., MET service providers (MSPs), ANSPs, etc.) to ensure that Service Overview information is available to describe the SWIM information services.

All MET information services are required to have a service overview.

The ICAO IMP has developed a service overview template to be tailored for each information domain. This template is presented in Table 5-1 of the PANS-IM, and contains field names, detailed requirements, field schema, and general examples.

A MET-specific service overview example is presented in Table 2.

Field Name	**MET Example**	
Information service name	*Aerodrome Meteorological Observation Information Service for [State]*	
Information service version	*1.0.0*	
Information service life cycle status	*OPERATIONAL*	
Information service life cycle date	*2018-07-31*	
Information service functions	Name	*Request observed aerodrome meteorological information*
	Description	*The service consumer is able to request observed meteorological information for an aerodrome filtered by aerodrome, phenomenon and according to spatial, temporal and logical (e.g. severity threshold) operators.*
	Real-world effect	*The meteorological information is received and can be used by the service consumer.*

	Name	*Subscribe to observed aerodrome meteorological information*
	Description	*The service consumer is able to subscribe/unsubscribe in order to receive information based on given criteria such as the severity/threshold of the weather phenomenon.*
	Real-world effect	*The service consumer is subscribed to the observed aerodrome meteorological information or has managed the subscription as requested.*
	Name	*Distribute observed aerodrome meteorological information*
	Description	*When new observed meteorological information is available, it is distributed to the subscribers.*
	Real-world effect	*The service consumer is sent a message containing the relevant meteorological information.*
Information category	*Meteorological Information*	
Brief description of the information service	*The Aerodrome Meteorological Observation Information Service provides the service consumer with observed meteorological information at all aerodromes within [state name].* *The service consumer can subscribe to the service, specifying what sort of information is of interest, and receive information as it becomes available.* *It is also possible to send a direct request, using a request-reply mechanism, to the service to get the relevant meteorological information.* *The meteorological information is issued by each designated Aeronautical Meteorological Station (AMS).* *The service implements the ICAO Aerodrome Meteorological Observation Subscription and Request Service.*	
Additional information on the information service	*Additional information on the information service can be found at [insert link].*	
Quality of the service	*The service has achieved a quality that is sufficient to ensure the service is fit for purpose. The achieved results were:* *CAPACITY: 2000 service requests per hour* *RESPONSE TIME: maximum of 2s delay* *AVAILABILITY: 99.5%*	
Information service validation type	*USER-VALIDATION*	
Information service validation description	*The service was validated by the service consumers earmarked as early-adopters.*	

	The meteorological information offered was validated against the applicable sections, including quality requirements, of ICAO Annex 3 and PANS-MET (Doc 10157). *The meteorological information offered by the service was validated against the WMO No. 8 (2018) Guide to Meteorological Instruments and Methods of Observation.*
Filtering available	*The service consumer is able to request observed meteorological information for an aerodrome filtered by aerodrome, phenomenon and according to spatial, temporal and logical (e.g. severity threshold) operators, in compliance with chapter XX of PANS-MET (Doc 10157).*
Access restrictions	*The meteorological information is only intended to be used by service consumers within the aviation domain.* *Service consumers cannot pass the information obtained from the service to non-aviation users without prior authorisation from the service provider.* *[include any other access restrictions or preferred terms here]*
Message exchange patterns	*PUBLISH_SUBSCRIBE* *REQUEST_REPLY*
Information exchange models	*The service uses IWXXM version [xxx].*
Geographical extent of information	*The aerodromes and their vicinities within [State].*
Source of information	*The State-designated Aeronautical Meteorological Station (AMS) – [insert organisation name].*
Information security category	*Intermediate*
Provider organization	*[Insert organisation name]*
Support availability	*Support for the information service is provided by contacting [insert contact].* *Technical support for the information service is available under the following terms [insert reference].*
Provider point of contact	*To request access to the service, contact [insert contact].*

Table 2: MET-specific service overview template.

2.3 Making Information Services Discoverable

2.3.1 Registries

ICAO Doc 10039 describes the need for a registry for use in SWIM. The fundamental purpose of the SWIM registry is to provide a repository of information about what information services are available, what information they provide, who provides the information service, and a range of metadata detailing the information service.

Per the PANS-IM, SWIM registries should be used by a) information service providers as a means to publicise available information services; and b) information service consumers as a means to discover information services. The implementation of a SWIM registry could be done by any stakeholder; information service providers could use a SWIM registry already implemented rather than implement their own SWIM registry.

Per the PANS-IM, when a SWIM registry is used, it shall:

- Make information service overviews available;
- Provide access control for the registration of information service overviews;
- Provide search functionalities on information service overviews and its fields;
- Provide notification functionalities on changes to information service overviews and its fields; and
- Be made publicly available.

All MET information service overviews are required to be published in a SWIM registry.

A MET-specific registry is not expected to be developed. Registries will advertise all information services to minimise the total number of registries.

2.3.2 AIPs and Notifications

MET-SWIM providers shall make necessary arrangement with State authorities responsible for the publication of the Aeronautical Information Publication (AIP) to refer to the location of the SWIM registry, containing the MET-SWIM information services, the State AIP. The reference will only include the web address to be minimal and non-repetitive.

MET-SWIM information service providers shall implement mechanisms (ex: administrative messages) to notify users of their service of any change (ex: new airports, changes to versions of the software or data format, etc.).

Per the PANS-IM, Information service providers shall inform information service consumers where they can access the information service overviews and the metadata on information services therein. The uniform resource locator (URL) where information service overviews are publicized shall be included in the AIP. In case a SWIM registry is used, the URL shall be the one of the registry.

2.4 Data Access Policy

Aeronautical Meteorological Information controlled under the Chicago Convention is required to be provided to a range of users as specified in Chapter 2, Paragraph 2.1.2, Note 1 of ICAO Annex 3.

Paragraph 2.1.2 of Chapter 2 of ICAO Annex 3 specifies such users as: *operators, flight crew members, air traffic services units, search and rescue services units, airport managements and others concerned with the conduct or development of international air navigation, with the meteorological information necessary for the performance of their respective functions.*

It is the prerogative of each ICAO Contracting State to determine the access of aeronautical meteorological information, including the policy for the use and re-use of such information and how the service provision shall be funded.

Information Service Providers have the right to impose Terms and Conditions on Information Consumers based on the national policies of its governing State.

3 Roles and Responsibilities

Some organizations may have multiple roles and responsibilities in relation to SWIM information provisions. For example, VAACs, AMOs, MWOs, and MET Service Providers may be Data Originators and information service providers.

3.1 MET Information Service Providers

The MET information service provider is an entity (e.g., person or organization) that offers the use of capabilities by means of a service.. Per Annex 3, States can determine who, within their State, provides information services. MET information services may be provided by the MET ANSP, VAAC, MWO and/or other entities.

A State may be a MET information service provider or arrange provision of the data/information to another information service provider, as preferred, to fulfil the requirement.

The service provider shall ensure that the meteorological data offered by the service(s) is received from the appropriate authorised data originator. This includes, for example, the regulated MET information service provider acting as the designated Aerodrome Meteorological Office (AMO), in the case of aerodrome forecasts.

3.2 MET Information Producers (Data Originators)

Each State is required to produce meteorological information, including in IWXXM form, as defined in Annex 3. For example, the designated AMO, MWO, VAAC etc have responsibility for fulfilling their defined roles and responsibilities.

It is possible, but not necessary, that the MET Information Producer is a different entity than the MET Information Service Provider.

3.3 MET Information Service Consumers

Intended service consumers of MET information services include ANSPs, airlines, other MET Service Providers, airport operators, civil airspace users, network managers, and other relevant entities.

Some Information Service Consumers may wish to combine or aggregate information from multiple information services and republish this information in a new service (where the originating information service providers allows such reuse). Whilst the original source data must not be altered, the new combined information service must reference the original data sources and any modifications in the information service overview.

MET Information Service consumers are likely to integrate the information contained in these services with other information services to assist pilots, dispatchers, air-traffic controllers and flight optimisation systems make timely decisions. This may be via decision support tools, displays and/or fully automated processes.

4 Information and Data Formats

4.1 Gridded Data

Gridded data is one of the two main formats of MET information. Also known as visual raster data, gridded data represents one-, two- or three-dimensional spatial (1-D, 2-D or 3-D) as well as temporal variation of a specific parameter. Examples include satellite data, radar data and output from numerical weather prediction (NWP) models.

MET-SWIM information service consumers will need access to gridded data. Gridded data is often, but not always, a regularly spaced set of values, such as a set of temperature values over a large geographic area. Data formats designed specifically for such kind of gridded data (e.g. NetCDF) would be very efficient in terms of storage size. However, other formats (e.g. XML) may still be useful if the data grids concern differ significant from the anticipated structure (e.g. gridded data within a corridor). Apart from the structure of the grid, gridded data should also be geo-located on a Coordinate Reference System (CRS), such as the World Geodetic System (WGS-84) geographic CRS (latitude/longitude) or EPSG:4326.

A graphic showing gridded data with nearby map location information (e.g., highways) is shown in Figure 1. The individual grid cells are visible, as is the regular spacing of each data value.

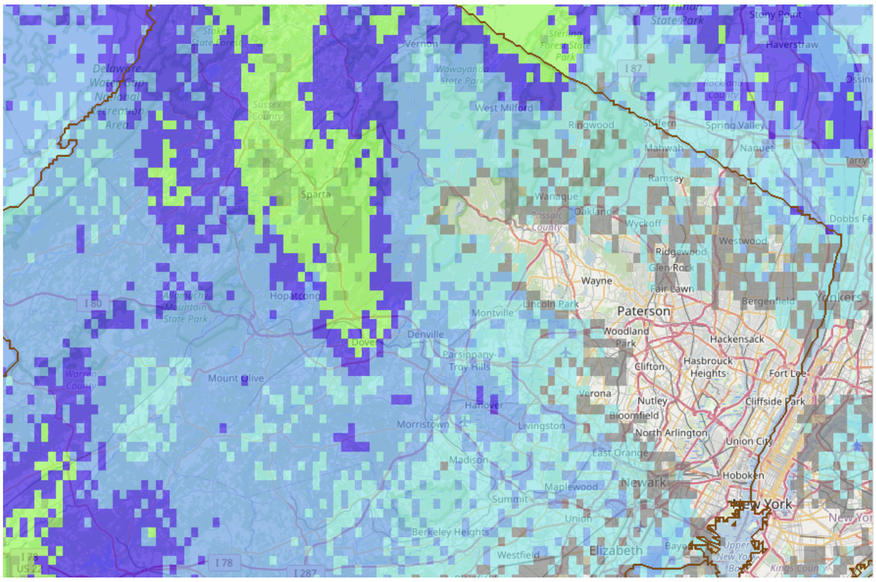

Figure 1: Rendered geographic map with gridded data cells overlaying non-gridded road and political boundaries.

Gridded data is an efficient representation of data values describing physical phenomena referring to in satellite, radar and NWP models, including fields such as wind speed and air temperature.

In aeronautical meteorology, gridded data is often exchanged in either Gridded Binary (GRIB) or Network Common Data Form (NetCDF) file formats. While other formats are used, few of these are as broadly utilized. Gridded data in the meteorological domain is usually updated over time and is comprised of either two or three spatial dimensions (2-D or 3-D) depending upon whether there is a vertical component. Furthermore, when multiple time steps are considered, this information is considered four-dimensional (4-D).

It is important to note that some derived products disseminated via MET-SWIM information services may be in the form of rendered, geo-located images. Examples of image data formats include Joint Photographic Expert Group (JPEG), Portable Network Graphics (PNG), Scalable Vector Graphic (SVG) and Geographic Tag Image File Format (geoTIFF) files, such as those seen embedded in web mapping tools and other web sites. Image data may be useful in cases where data consumers need an authoritative and/or globally consistent visualization of raw data, or they wish to display data in simple user interface, such as a webpage.

While image data is usually created with geo-referencing in mind, most of the commonly used image data formats do not have the necessary metadata to describe the geo-references. Some popular Geographical Information Systems (GIS) are using auxiliary files in simple or XML format to carry geo-referencing information for the image data files in which a minimum or even a standardized set for MET-SWIM may be required.

Image data (or imagery) can be used to visualize both gridded data and objects. An example of both types of data can be seen in Figure 1, which shows non-gridded road and political boundaries overlaid with gridded radar data. Due to the simple representation of images, it can easily be combined with other images (layered) with little effort or much knowledge of the details of the data being represented.

4.2 Data Objects

Objects are the second of two main types of MET information. Known also as vector data, data objects focus on describing individual instance of one or a set of phenomena and its spatial, temporal and affined characteristics. A typical data object may include geometries (e.g., points, lines/arcs, polygons, surfaces and volumes), time (e.g. instances and periods) phenomena properties (e.g. wind, temperature, etc.) and other attributes. Examples include non-gridded information in IWXXM format.

Historically, meteorological information exchanges have mainly relied on simple textual data formats, fusing representation, transmission and presentation requirements into a highly compact but effective form. Advances in data communication, processing and rendering capabilities allow data and metadata rich, self-explanatory data instances to be created, exchanged and consumed. This enables consumers to have better understanding of the data instances and hence enhanced utilisation of the data involved.

IWXXM is the information exchange model designed for meteorological information exchange in the aeronautical domain. The currently defined IWXXM reports (e.g. METAR, TAF, SIGMET, etc.), even though keeping the information model of their respective Traditional Alphanumeric Code (TAC) form, have already taking the benefits of XML and GML to be a better container of meteorological information. To fully explore the potential offered by MET-SWIM, new IWXXM reports are created with the object approach which should facilitate the implementation of MET-SWIM exchange patterns especially request-reply retrieval with queries. In longer terms more data instances would be developed with the object approach, like meteorological observations and forecasts. When they are mature enough, the “legacy” TAC products will be rendered obsolete and removed as an Annex 3 standard at an appropriate time.

It is anticipated that the improvements facilitated by enhanced information services of observations and forecasts, allow for multiple uses based on the specific needs of end users, infrastructure and facility capability and performance, including different visualizations, ingestion into meteorological forecast models and potentially higher-level decision support web services.

4.3 Use Cases for Various Data Formats

4.3.1 Quantitative Volcanic Ash (QVA) Concentration Information Service

The QVA Concentration Information (QVACI) service will provide QVA information in both gridded data (probabilistic and deterministic datasets in NetCDF format) and objects (in IWXXM format) to notify users of significant ash clouds[1]. The service will achieve this by utilizing both request-reply and publish-subscribe mechanisms (detailed in the next section). This is an example of one MET information service that will provide information in multiple data formats.

[1] For more information on QVA, see the QVA Information Flyer on the METP Public website.

5 Information Services and the Exchange of MET Information

There are two main mechanisms by which information is exchanged between producers and consumers: information which may be requested through information services as needed, and on-going real-time feeds of messages (notifications or actual data). The former describes the request-reply message exchange pattern, and the latter describes the publish-subscribe message exchange pattern. Both mechanisms will be utilized by MET-SWIM information service providers.

In addition to receiving the full message, the consumer may specify filtering parameters to pinpoint desired messages, or to even get a fragment of the information within the message, to meet their specific needs. The actual filtering capabilities available to consumers depends on implementation of the information services and is therefore a choice for information services providers to implement. Nevertheless, a service definition may mandate a minimum filtering capability for each service type.

Moreover, the representation of a phenomenon (with grids indicating spatio-temporal variation or with polygons/surfaces showing spatio-temporal boundaries) is largely dependent on how the information is being consumed. Specific technologies will be required to handle the containers (e.g. NetCDF and Extensible Markup Language (XML) files) as well as their payloads of grids and objects. Information service providers may be able to provide information services that can change the representation of the payload from grid to object or vice versa. Some of them may even be able to further process the information with predefined algorithms.

The following sections describe the latest technologies available and being adopted by early information service implementations.

5.1 Request-reply

When first presented, MET-SWIM information services made references to the Open Geospatial Consortium (OGC) Web Services (OWS) Standards including the Web Feature Service (WFS), Web Map Service (WMS), Web Coverage Service (WCS), etc. which implement a Remote-Procedure-Call-over-HTTP architectural style using XML for payloads. However, technology has evolved. New Resource-Oriented application programming interfaces (APIs) provide an alternative to the Service-Oriented Approach, and new OGC Web API Standards are under development to provide API alternatives to the OWS Standards.

Recently developed MET-SWIM information services have started to utilize the OGC API – Environmental Data Retrieval (EDR) Standard which provides a family of lightweight query interfaces to access spatio-temporal data resources by requesting data at a position, within an area, along a trajectory or through a corridor. Other advancements including OGC API – Features to replace the use of WFS for objects; OGC API – Coverages to replace the use of WCS for gridded data; OGC API – Maps to replace the use of WMS for both gridded data and objects are making noticeable progress.

5.1.1 General Services

For all information exchange web services (gridded and objects) the following core capabilities should be supported:

- requesting the set of data offered by the web service;
- requesting the high-level capabilities of the web service;
- requesting the detailed structure and content of the offered data, such as geographic region of the data and the structure of offered data (such as the XML schema that describes offered non-gridded data);
- requesting metadata regarding the data provider, such as contact information and organization name; and,
- requesting metadata regarding the operational status of the web service and/or data, such as metadata indicating experimental products.

For information exchange using OGC API – Features, the following capabilities could be supported in addition to the core capabilities identified above:

- requesting data filtered by a geographic bounding box;
- requesting data within a time range or at a time instant;
- requesting data within a fixed distance from a route of flight (e.g., returning a vertical cross section, 4-D corridor, or horizontal slice); and,
- requesting data that matches free-form queries, such as all aircraft observations where altitude is greater than flight level (FL) 400 and where the aircraft type is ‘Boeing 747’.

For information exchange using OGC API – Coverages, the following capabilities could be supported in addition to the core capabilities identified above:

- requesting data filtered by a geographic bounding box;
- requesting data within a time range or at a time instant;
- requesting data which was generated from a specific model run;
- requesting data within a fixed distance from a route of flight (e.g., returning a vertical cross section, 4-D corridor, or horizontal slice); and,
- requesting data that is re-sampled to a new grid spacing.

For information exchange using OCG API – Maps, the following capabilities could be supported in addition to the core capabilities identified above:

- requesting data filtered by a geographic bounding box;
- requesting data within a time range or at a time instant (or latest available);
- requesting data which was generated at a specific forecast model run;
- requesting imagery that is at a different image resolution than the original data;
- requesting data with custom rendering options such as colour ranges, transparency and symbology; and,
- requesting data in different image formats, such as SVG, JPEG, and PNG.

Because these web services are built on the top of the data made available from the information exchange services, information exchange web services may be considered general services and a necessary building block for follow-on specialized web services.

5.1.2 Specialized Services

While the information services as described above address the basic needs and potential capabilities for the data exchange requirements of MET-SWIM, other more specialized web services are also possible in a MET-SWIM environment. These web services can be built to utilize data from the information exchange web services to address more specialized requirements.

Specialized web services can be used to address global needs for complex decision-making, authoritative and consistent decisions and/or a synthesis of multiple sources of SWIM data including data from outside the MET domain, such as the AIM domain. Due to their dependence upon general information exchange services for basic data access, implementation of specialized web services in the MET-SWIM system will follow the deployment of general web services. Given the unique and aviation-specific nature of these web services, they may not fit well into existing standardized web service protocols such as WCS, WFS, and WMS, but will be implemented using web services and fit into the general SWIM architecture.

Documentation of specialized services that are proprietary is essential for developers and consumers to understand available features, quality of service and intended use. Tools like OpenAPI[2] may be a useful API description standard.

5.1.3 Tools for Implementation of Request-Reply Patterns

The below sections present potential tools for implementing request-reply patterns.

5.1.3.1 RESTful API Services

For all information services that conform to the Representational State Transfer (REST) architecture style, called RESTful Web services, make information available to users in the form of resources through protocols like HTTP. A RESTful service typically accepts requests from a client, carries out necessary processing on the server, and returns the result back to the client in a transaction. Examples include the extraction of en-route aerodrome observations and forecasts, or gridded wind and temperature data, by providing a flight path in the request.

[2] https://www.openapis.org/

5.1.3.2 OGC EDR API

The use of the OGC EDR standard in information services are recommended wherever possible. The OGC EDR API architecture is another possibility for SWIM-enabled exchange of aeronautical MET information.

The OGC API-EDR API Part 1 (Core) provides a family of lightweight query interfaces to access spatio-temporal data resources (e.g., observations and coverages) by requesting data for an item, location, or for meteorological shapes for a position, area, radius, cube, trajectory or corridor. The OGC API-EDR Part 2 (Publish-Subscribe Workflow Standard) provides recommendations on applying publish-subscribe (pub/sub) architectural patterns to implementations of one or more OGC API Standards in order to support event-driven applications. The goal of the EDR API is to make it easier to access a wide range of data through a uniform, well-defined simple web interface, and to achieve data reduction to just the data needed by the user or client while hiding much of the data storage complexity.

It is important to note that OGC EDR API is not possible for every kind of service because it does not allow dynamic operations on the coverage.

5.2 Publish-Subscribe

While request-reply services provide advanced capabilities for accessing MET data, publish-subscribe services, like the Advanced Message Queuing Protocol (AMQP), offer low latency and are preferred for continuous use of data and event-based notifications (such as warnings). ICAO Doc 10039 describes common messaging capabilities (the pub/sub messaging pattern) to be used throughout SWIM and MET-SWIM information service providers will utilize this capability to reliably distribute data, notifications and status updates. Messaging is particularly useful with data that is issued at an unpredictable or non-routine rate, data that must be delivered as quickly as possible, or data that represents a series of frequent and small updates. Publish-subscribe messaging technology is generally not well suited to distributing large data files or messages directly, and as such will be utilized by MET-SWIM information service providers for:

- notifying information service consumers that data is available for access through a web service such as when a new gridded forecast is available for retrieval;
- pushing relatively small data files directly to information service consumers as they are made available by the information service provider, such as non-gridded data like aerodrome observations; and,
- mission-critical service updates to information service consumers, such as notifications of a web service outage, data outage, service/maintenance windows, notification by surveillance, or degraded provider capabilities.

Publish-subscribe messaging can be utilized to publish information in either a static or dynamic fashion. Static publish-subscribe configurations may be considered a design-time configuration regarding what information is published to predefined topics and/or queues. In the case of static configurations, information service providers publish to a fixed set of topics and/or queues which do not change while the system is running. With a dynamic publish-subscribe configuration, the set of published data and the destination topics and/or queues can be modified as the information service is running. For example, a filtered meteorological observation within a specific geographic area could be delivered to a small group of interested SWIM service consumers as needed. Dynamic configuration requires an additional request-reply web service on each information service provider to allow modifications to published information at runtime such as described in the OGC Publish-subscribe Interface standards. The publish-subscribe system requires either a defined static subscription for generic information or dynamic subscriptions (e.g., for monitoring).

5.2.1 AMQP

The designated protocol for Publish-subscribe data provision and consumption via SWIM is AMQP. Initial experience using AMQP covers the utilization of different client and broker implementations (open source or commercial off-the-shelf) and integration into products or systems of known system providers in the market.

MET-SWIM information service providers could utilize AMQP, for example, to push information directly to service consumers. The service consumers are able to choose the “right” service provider and/or client systems on the market as appropriate for their requirements. Additional guidance on the use of AMQP, including advantages and disadvantages of ‘topics’ versus ‘queues,’ best practices for brokers and client implementation, business rules for caching messages, and filtering is provided in Chapter 6 of this document.

6 Application and Use Cases

6.1 Considerations for Use of AMQP

AMQP allows a number of different ways to distribute data. Information service providers looking to utilize AMQP will need to decide the following:

- Which broker to use (if using one at all);
- Whether to use special distribution concepts (ex: Topic, Fanout, etc.);
- Whether to setup one queue per user or one queue per user and dataset;
- Whether to offer pre-filtering (provider-side) of the data;
- How a user can subscribe to a service and add filters;
- How maintenance messages will be distributed to the user (e.g., through a queue or through a separate communication channel, like email);
- Which information to include in the header of the AMQP message to make it easier for the user to distinguish the kind of data sent through the queue (and simplify consumer-side filtering for the user).

6.1.1 Subscription

Users of AMQP need to subscribe to an AMQP queue or topic. This can be done on request by the data provider, or by the user with the help of a landing page. All subscribers will receive messages published on their specific topic.

6.1.2 Best Practices for AMQP

6.1.2.1 “Topics” and “Queues”

While using AMQP with a broker software, there are two main options (among others) for distributing data to a consumer: topics and queues.

When using an AMQP broker, there are options for a “topic” method of data distribution. Topics follow a “Fire and Forget” logic, where all data fed into a Topic is sent out and received by users currently subscribed and connected to this topic. For the service provider, this is a very effective way to distribute the data. On the consumer side, data is only received when the connection to the Topic is established. Since there is no caching of the data on the provider or broker side, Topics are an efficient solution for disk-space or memory-usage on the broker side. But unintentional loss of connection leads to missing data on the consumer side. Therefore, Topics might be a good solution in case of data updated in a high frequency, but probably do not meet the requirements for exchanging the existing typical MET data. Other data with a high update frequency, such as high-resolution data from Automated Weather Observing System (AWOS) (e.g., 1-minute update rate) or some data retrieved from nowcasting procedures (e.g., 5 minutes update rates), would be suitable for Topics.

The easiest concept is a direct queue between the data provider and the consumer. Queues are individual to each client that has been subscribed to the particular service. Compared to the topic data distribution, the data can be cached for a certain time to be delivered, for example, after a connection loss. Particular MET data, like the Significant Meteorological Information (SIGMET), would be predestined for Queues because of its importance for the data consumer and occasional data-delivery-character.

As an example of creating topics for MET information, consider two airports in Germany: Frankfurt and Hamburg. A single airport topic, Frankfurt, could be described with all relevant data for observations, forecasts, and warnings over the airport available via one queue. Similarly, a separate airport topic, Hamburg, would have its data available via another queue.

6.1.2.2 Brokers, Clients, and Caching

There are many different AMQP Brokers on the market such as RabbitMQ, ActiveMQ, and Qpid. When choosing an AMQP Broker, a user should consider which version of AMQP it can support. For example, in Europe, the EUROCONTROL SWIM Yellow Profile requires brokers to support AMQP version 1.0, as it is the official version standardised by OASIS. Some brokers may support multiple version of AMQP (e.g., 0.9.1 and 1.0) and/or do not implement all features defined in the (1.0) standard. As an example, this is the case for RabbitMQ which is a widely-used broker that natively supports AMQP version 0.9.1 and uses a plug-in for version 1.0. Users should check the websites of specific brokers for a list of supported features.

There are also several client libraries on the market such as java-based Swift-MQ or python-based Qpid-Proton. In Germany, MET service providers are using an integrated solution into their systems developed by IBL, and have developed some basic client AMQP examples for customers with Proton and SwiftMQ[3].

The data provided through a queue can be cached and will reside within the queue in case of clients dropping connection until the connection is established again or a configured time limit is exceeded. Caching the data using Queues for clients that are subscribed but not connected may require a significant number of resources. A time limit should be implemented for caching data, oriented on the update rate or valid period of the data to be distributed through the respective queue. An example would be one hour for routine aerodrome MET reports (METARs), or six hours for aerodrome forecasts (TAFs) or SIGMETs.

6.1.2.3 Filtering

There are two ways of filtering messages: filtering before the data comes into the queue/topic (provider-side) or leaving it to the client logic (consumer-side).

Provider-side filtering can be done in in two different ways, and always depends on the queuing concept chosen for distributing the data. If a queue is chosen per user and dataset, all data in that queue would already be provided. However, more detailed filters require a process before sending data to a queue.

As an example, consider aerodrome observations in Frankfurt. If a user wants access to all METARs from Frankfurt, this would require a process before the METARs are sent. A provider-side filter of “all METARs from Frankfurt below zero degrees Celsius” could be added to the existing queue or accessed separately in a second queue. When using the Topic concept from a broker, there are built-in functionalities that offer filtering to a user that are mainly derived from the filename of the data sent to the broker.

Consumer-side filtering depends on the way the data provider sends the data through AMQP. For example, if the provider “annotates” the message with one or more metadata (e.g. additional properties like a “subject”, a “geographical applicability”, a “criticality”, etc.), the consumer may filter the received message just by processing these metadata without opening the actual message content. Otherwise, if more detailed filtering is required, the entire message content would need to be processed (normally requiring more computational effort).

For example, for a queue of airport observations, the airport ID could be used to filter the message. For a queue of the aerodrome, the data type (e.g., observation or forecast) could be used to filter the message.

6.1.2.4 Header Information

Header information will be used from the broker and the client software to handle and route the data in the right way without looking at the data itself. The message consists of different message sections as shown in Figure 2:

An annotated message consists of the bare message plus sections for annotation at the head and tail of the bare message. There are two classes of annotations: annotations that travel with the message indefinitely, and annotations that are consumed by the next node. The bare message consists of three sections: standard properties, application-properties, and application-data – the payload[4].

Use Case in Germany

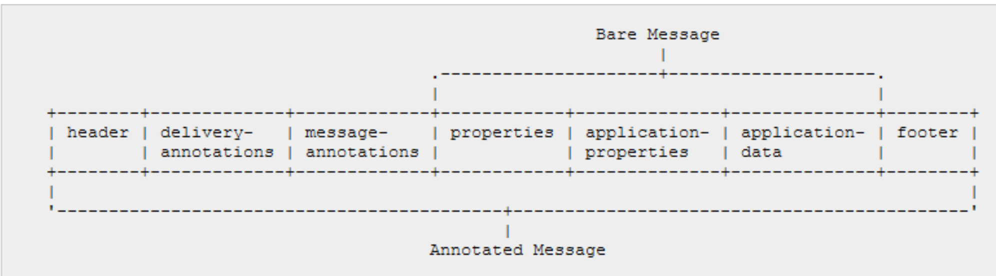

Figure 2: Sections of an AMQP message.

[3] For more information on SwiftMQ and Qpid-Proton, see: https://github.com/iitsoftware/swiftmq-client and https://qpid.apache.org/proton/.

[4] Source: https://docs.oasis-open.org/amqp/core/v1.0/os/amqp-core-messaging-v1.0-os.html#type-header.

By way of an example, the following use case from Germany, explains that the MET service provider has developed a concept for using header fields to route messages to consumers within a single queue.

Three message sections – “header,” “properties,” and “application-properties” – are used to deliver additional information with the payload. Three different types of messages are used: business message (with the payload), technical message (maintenance message), and heartbeat message. These three message types should be sent over the same queue which is used for transmitting the payload, meaning that there must be a mechanism within the header section to distinguish information type and then message type (business, technical, or heartbeat).

In the headers section, the keywords are predefined in the standard as follows:

- durable
- priority
- ttl
- first-acquirer
- delivery-count

The “ttl”-field is important as is used to set the lifetime of a message

In the properties section, the keywords are predefined in the standard as follows:

- message-id
- user-ID
- to
- subject
- reply-to
- correlation-id
- content-type
- content-encoding
- absolute-expiry-time

The “message-id”, “user-id” and “to”-field, “content-type” and “content-encoding” will be filled in. The “absolute-expiry-time”-field depends on message type (business, technical, or heartbeat), and the subject fields could potentially contain a suggested filename to distinguish the message type.

Within the application-properties-section, providers are free to define their own keywords to be sent with the payload. Germany is in discussions with one of their main consumers, an ATC Provider, to define the following keywords:

- Business Message Type: the type of a business message if all are sent over the same queue
- Location Indicator: the ICAO four-letter location indicator of the respective location
- Payload timestamp: Issue time of the report as defined in IWXXM element “issueTime”
- Payload Subject: Deutsche Wetterdienst (DWD)-specific identifier of data delivery for debugging
- Signature: should be a SHA256 value
- API version: DWD label publication API version

6.2 Messaging vs. Web Service

An example of a messaging web service is a warning service which would enable customized warnings to be pushed (over publish-subscribe communications) to consumers. The warning web service would allow consumers to be notified of crucial information for decision-making without needing access to large amounts of raw aeronautical meteorology information. As MET-SWIM information is updated, thresholds and geographic areas would be checked, and warnings pushed to consumers as appropriate. Consumers could submit the following to the warning web service:

- any number of data variable names (such as composite reflectivity or observed wind speed);
- geographic area(s) of interest (bounding box, flight path and distance, or polygon area);

- time period(s) of interest; and,
- rules describing when warnings are issued, such as the relationships between data variables, upper and lower data variable thresholds, geographic areas and time periods.

Additionally, when comparing web services to messaging services, a web service will likely defer error handling to the client; if the server fails, the client must take responsibility to handle the error. When the server is working again, the client is responsible for requesting a resend of the information, and if the server gives a response to the request and the client fails, the operation is lost. There is no contention with web services, meaning that if too many clients request a web service on one server in one second, the server will probably go down.

When using messaging, different and more fault-tolerant results can be expected. If a server fails, the queue persists the message (optionally, even if the machine shutdown). When the server is working again, it receives the pending messages. If the server gives a response to the request and the client fails, if the client didn't acknowledge the response, the message is persisted. If there is contention, the service provider can decide how many requests are handled by the server at once.

Message queues have many more features, but requires the client to setup initial infrastructure, which requires the client knowing how they want to consume the data. If the client wants to receive this data long-term, it might be a better choice to get the data via an AMQP message queue. Otherwise, if the client used a web service, they may not know when new data on the server was published, and thus would always need to request the data and it may not be available right at the time of the request. For data to be delivered after a fix period (e.g., model runs), web services would work, but data that is occasionally delivered (e.g., SIGMETs) may be more difficult via web services. Clients who only need data occasionally with certain timestamps may prefer a web service.

6.3 Number of Service Instances

It may be considered preferable to only implement one service instance within a State (or sub-division of a State into FIR groups, zones or territories), for each service type (or information service definition), as opposed to each individual aerodrome implementing a service instance.

In the former scenario, the information for many aerodromes are all contained in one service and the service overview (published in the registry) should include a list of all aerodromes for which the service provides information. The service metadata will allow a user to filter by aerodrome. Such an approach is especially applicable to states in which there are many aerodromes.

From a user/consumer perspective, utilizing a single service per state means that accessing MET data is a more streamlined process. Because there is a single point of contact for each service per state (e.g., a single point of contact for observations, and a single point of contact for forecasts), fewer data requests will be required, since many requests will be for (or include) several airports within a single state.

The implementation from the service provider perspective is also more efficient and lessens the administrative burden (e.g., managing the user accounts, subscriptions, requests, etc.) because all the services available are far less fragmented.

This approach will also allow States to better support each other in implementing the new services due to less complexity. With better defined points of contact, coordination is easier and neighboring states can easily access and subscribe to the services provided by their neighbors.

A high-level architectural view of this approach is presented in Figure 3.

A key enabler for the one service instance per state setup will be minimum or mandatory filtering options because in many cases, users/consumers will not require the services or service types from all aerodromes, only a specific selection. There should therefore be an option for consumers to use a filtering option or request to subscribe only to the airports where data is needed from (§5.0 of this document refers).

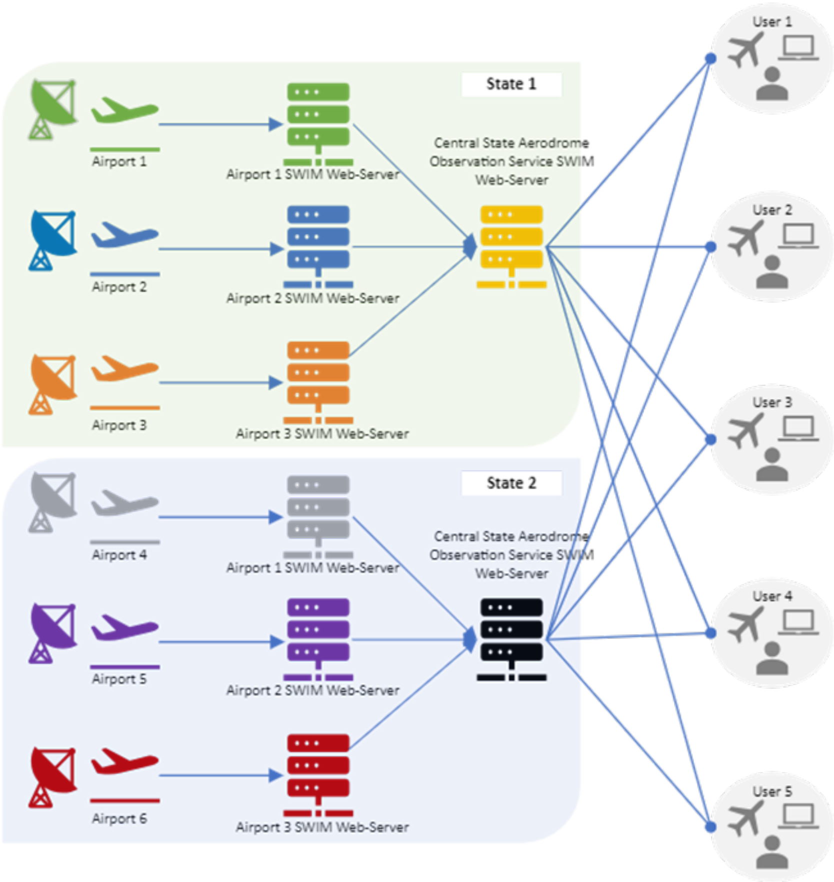

Figure 3: High-level architecture of the one service instance (Aerodrome Meteorological Observation Information Service (AMOIS)) per State approach.

Whilst it is not mandatory to implement this approach, there are significant benefits. The following alternative approaches may also be considered:

- One service instance per airport (for each service-type)
- One service instance per area/region or territory or FIR, within a State.

In all cases, the service overview must clearly describe the geographical coverage of the service content, and the AIP must include information on the services and their geographical coverage that are provided by that State.

6.4 Examples

An example of a publish-subscribe MET information service using an AMQP Proton client implementation is presented below in Figure 4.

Connect.json

```
{
    "scheme": "amqps",
    "host": "test.swim.dwd.de",
    "heartbeat": 500,
    "tls": {
        "ca": "",
        "cert": "",
        "key": "",
        "verify": false
    },
    "sasl_enabled": true,
    "mechanisms": "PLAIN",
    "user": "<user>",
    "password": "<password>"
}
```

Consumer.py

```
from proton.handlers import MessagingHandler
from proton.reactor import Container
from pathlib import Path
from time import time
from os import getenv
from os import linesep
import argparse
import sys
import logging

logging.basicConfig(level=logging.INFO, format='%(asctime)s - %(filename)s
- %(levelname)s - %(message)s')
logger = logging.getLogger(__name__)


class Client(MessagingHandler):
    """A simple client that connects to certain resource (e.g. 'queue')
     and receives messages asynchronously."""
    def __init__(self, resource_address: str, output_dir: Path):
        super(Client, self).__init__()
        self.resource_address = resource_address
        self.output_dir = output_dir

    def on_start(self, event):
        """
        Triggered on client start. Initiate a connection and create a
receiver link from the resource_address.
        """
        durable = None

        self.connection = event.container.connect(virtual_host="/")
        self.receiver = event.container.create_receiver(self.connection,
source=self.resource_address, options=durable)
        logger.info(f"Opened receiver link from queue:
'{self.resource_address}'")

    def on_link_opening(self, event):
        """
        Triggered when a link is opened externally.
        We simply leave a log trace if any links are opened from outside.
        """
```

Figure 4: Example of an AMQP Proton client implemetnation for a pub/sub MET information service.

7 Terminology and Acronyms

The following Table 3Table 1 presents a list of terms used in this document and their associated meanings.

Term	Meaning
Authoritative Source	A State authority organization or an organization formally recognized by State authority that originates or publishes data meeting the data quality requirements.
Availability (of a service)	The degree to which a service is operational and accessible when required for use.
Capability	The ability of a system to provide a service or perform a function that, either on its own or with other services or functions, can deliver a definable level of performance.
Capacity (of a service)	The maximum rate at which a service can process transactions and the maximum message size of responses. *Note.— Measurements can include the number of items that can be stored, the number of concurrent users, the communication bandwidth, throughput of transactions and size of messages.*
Confidentiality (of a service)	The degree to which a service ensures that data are accesible only to those authorized to have access.
Data	A representation of facts, concepts, or instructions in a formalized manner suitable for communication, interpretation or processing.
Data exchange language	Data definition language for describing data and data structures in an information exchange.
Data format	A structure of data elements, records, and files arranged to meet standards, specifications, or data quality.
Exchange schema	Formal description of the data involved in an information exchange, including, in particular, the encodings and other applicable constraints. *Note.— An exchange schema assists information service consumers in understanding the syntax of the data delivered by the information service, and the technologies required for locally processing the data received. An exchange schema is based on a data exchange language which is standardized. For example, XML Schema is a World Wide Web Consortium (W3C) data exchange language used to define XML encoded messages.*
Governance	The set of bodies, standards, policies, and processes that ensure globally interoperable information is provided by reliable and trusted sources.
Information	The result of the assembly, analysis, formatting, and documenting of data, to make the data useful in an ATM context.
Information domain	The scope of the integrated data for a distinct set of business activities that produce a set of unique information products and services.

Information exchange model	An Information Exchange Model is designed to enable the management and distribution of information services data in digital format. Normally this is defined for a specific domain such as aeronautical, flight, or weather information. A formal description of the information that is agreed to be shared between two or more organizations or groups and includes at least one exchange schema for the associated data. *Note.— An information exchange model is normally defined for a specific information domain, such as aeronautical information, meteorological information or flight information. This typically includes the definition of information entities and their relationships.*
Information exchange requirement	A specification of the information that is to be exchanged.
Information quality	The degree or level of confidence for which the data quality and the process used to convert data into information meet user requirements
Information service	A type of service in a service-oriented architecture that provides an ATM-related information-sharing capability.
Information service consumer	A service consumer receiving information from information service providers using information services. *Note.— The information service consumer role and the information consumer role may be allocated to different parties.*
Information Service definition	A document, issued by a community of interest, used to harmonize service implementations.
Information service function	A type of activity describing the functionality of an information service.
Information service interface	The means by which the underlying capabilities of a service are accessed.
Information service overview	A set of information service metadata intended to promote information service discovery and an initial evaluation of the information service characteristics
Information service payload	The assembly of information exchanged using an information service. *Note.— Information service payloads support specified function(s) or purpose, independent of overhead required to enable the information exchange, such as headers, and security requirements.*
Information service provider	A service provider making information available to information service consumers using information services.
Infrastructure service	A type of service that provides SWIM infrastucture capabilities such as interface management, request-reply and publish-subscribe messaging, service security, and enterprise service management.

Interface binding	Specification of the protocols and data formats to be used in transmitting messages defined by the associated interface. *Note — Two systems that implement the same interface binding are considered technically interoperable and can connect to each other and exchange information. There are two types of interface bindings to be distinguished based on the different layers of the internet protocol suite (IPS): service bindings and network bindings. Service bindings specify the service interface protocols in the application layer of the IPS (for example, protocols to interface with the applications, such as hypertext transfer protocol (HTTP) and AMQP). Network bindings specify the transport and network related protocols on the internet and transport layer of the IPS that will be used to exchange data over the network (for example, transmission control protocol (TCP)).*
Interoperability	The ability of information and communication technology (ICT) systems, and of the business processes they support, to exchange data and to enable the sharing of information and knowledge.
Message	A discrete unit of communication intended by the source for consumption by a given recipient or group of recipients. *Note.— The term message refers to a unit of information exchange between systems that communicate via information services. Although there are similarities, no direct comparison should be made with the term message used in other ICAO documents (for example, controller-pilot data link communications (CPDLC) message).*
Message exchange pattern	A template that describes relationships of multiple messages exchanged between interacting components to accomplish a single complete information exchange.
Messaging capability	The technical infrastructure capability enabling the delivery of messages.
MET Service Provider	An information service provider of meteorological data.
Metadata	Information about a resource. *Note.— An information service, an information service overview and a dataset are examples of resources.*
Quality of service	The degree or level of confidence that the performance of a service meets users' requirements.
Recoverability (of a service)	The degree to which, in the event of an interruption or a failure, the desired state of the service can be re-established.
Reference model	An abstract framework for understanding significant relationships among the entities of information domains.
Reliability (of a service)	The degree to which a service performs specified functions under specified conditions for a specified period of time.
Security capability	The technical infrastructure capability enabling secured information exchange.
Service	A mechanism to enable access to one or more capabilities using a prescibed interface.

Service consumer	An entity which seeks to satisfy a particular need with capabilities offered by means of a service.
Service instance	The service deployed into a running ICT system.
Service lifecycle stage	A classification of services in terms of status indicating their current, past, or future availability for provisioning.
Service operation	Specification of a transformation or query that an object may be called to execute.
Service-oriented architecture (SOA)	Architectural style that supports the designing of systems in terms of services and service-based development.
Service parameter	A variable that an operation can interpret when invoked.
Service provider	An entity (person or organization) offering the use of capabilities by means of a service.
SWIM	Standards, infrastructure and governance enabling the management of ATM-related information and its exchange between qualified parties via interoperable information services.
SWIM region	A geographical area in which a group of States and/or ATM stakeholders has agreed upon common regional governance in support of regional system-wide information management implementation. *Note. — A SWIM region can be an ICAO region or any other area in which a community of interest has agreed on common governance. Communities of interest are established in a variety of ways and may be composed of members from one or more functions and organizations as needed for a shared mission.*
SWIM registry	A directory containing entries with the information (metadata) necessary to discover and access information services.
SWIM stakeholder	A stakeholder participating in the SWIM, having distinct roles pertaining to and aligned with the components of SWIM.
Technical infrastructure	The assembly of software and hardware used to enable the provision of information services.
Time behavior (of a service)	A measurement of the processing times of a service. *Note.— This parameter may be expressed as an indication of a maximum time needed for the service provider to complete the request, measured from the time instant the service provider receives the request to the time instant the service provider sends the response or makes it available.*
Validation of information service	An activity whereby an information service is checked for conformance with the information service objectives and requirements.

	Note.— The service objectives and requirements are captured in the information service overview and technical specifications.

Table 3: List of terms and associated meanings.

The following Table 4 presents a list of acronyms used in this document and their associated definitions.

Acronym	Definition
AFS	Aeronautical Fixed Service
AIP	Aeronautical Information Publication
AMO	Aerodrome Meteorological Office
AMOIS	Aerodrome Meteorological Observation Information Service
AMQP	Advanced Message Queuing Protocol
AMS	Aeronautical meteorological station
ANSP	Air navigation service provider
API	Application programming interface
ASBU	Aviation System Block Upgrade
ASP	ATM service provider
ATM	Air traffic management
AWOS	Automated Weather Observing System
CPDLC	Controller-Pilot Data Link Communications
CRS	Coordinate reference system
DWD	Deutsche Wetterdienst
EDR	OGC Environmental Data Retrieval
FL	Flight level
GANP	ICAO Global Air Navigation Plan
GeoTIFF	Geographic Tag Image File Format
GIF	Global Information Framework
GIS	Geographical Information Systems
GRIB	Gridded binary
HTTP	Hypertext Transfer Protocol
ICAO	International Civil Aviation Organisation

ICT	Information and communication technology
IMP	ICAO Information Management Panel
IPS	Internet protocol suite
IWXXM	ICAO Meteorological Information Exchange Model
JPEG	Joint Photographic Expert Group
MET	Aeronautical meteorological
MET-SWIM	Meteorology in SWIM
METAR	Routine aerodrome MET report
METP	ICAO Meteorology Panel
MSP	MET service provider
NetCDF	Network Common Data Form
NWP	Numerical weather prediction
OGC	Open Geospatial Consortium
OWS	OGC Web Services
PANS-IM	*Procedures for Air Navigation Services – Information Management*
PANS-MET	*Procedures for Air Navigation Services – Meteorology*
PNG	Portable Network Graphics
QVA	Quantitative volcanic ash
QVACI	QVA Concentration Information
REST	Representational State Transfer
SARPs	Standards and Recommended Practices
SIGMET	Significant Meteorological Information
SOA	Service-oriented architecture
SVG	Scalable Vector Graphic
SWIM	System-Wide Information Management
TAC	Traditional alphanumeric code
TAF	Aerodrome Forecast
TCP	Transmission Control Protocol
W3C	Worldwide Web Consortium
WCS	OGC Web Coverage Service

WFS	OGC Web Feature Service
WGS	World Geodetic System
WMS	OGC Web Map Service
XML	Extensible Markup Language
2-D	Two-dimensional
3-D	Three-dimensional
4-D	Four-dimensional

Table 4: List of acronyms and associated definitions.