Introduction to IWXXM

Workshop on Implementing IWXXM
31 May 2016
Aaron Braeckel
Air Navigation Conference
2012

• Global Air Navigation Plan (GANP)
• Aviation System Block Upgrades (ASBUs)
  – IWXXM, AIXM, FIXM part of ASBUs
• System-Wide Information Management (SWIM)
IWXXM MET Meetings

- MARIE-PT (Meteorological Aeronautical Requirements in Information Exchange Project Team) in 2012-2013
- MET Divisional Meeting in 2014
- MET Panel in 2015
- METP WG Meteorological Information Exchange (MIE) – 2015, 2016
There are numerous areas where several WG and WS teams collaborate.

Note – The lead JC and WS responsibilities are shown. There are numerous areas where several WG and WS teams collaborate.
APPENDIX 3. TECHNICAL SPECIFICATIONS RELATED TO METEOROLOGICAL OBSERVATIONS AND REPORTS
(See Chapter 4 of this Annex.)

2. GENERAL CRITERIA RELATED TO METEOROLOGICAL REPORTS

2.1 Format of meteorological reports

2.1.3 Recommendation.— METAR and SPECI should be disseminated, under bilateral agreements between States in a position to do so, in the WMO BUFR coded digital form, in addition to the dissemination of the METAR and SPECI in accordance with 2.1.2.

Note.— The BUFR code form is contained in WMO Publication No. 306, Manual on Codes, Volume I.2 Part B—Binary Codes.

2.1.4 METAR and SPECI if disseminated in digital form shall be formatted in accordance with a globally interoperable information exchange model and shall use extensible markup language (XML) geography markup language (GML).

2.1.5 METAR and SPECI if disseminated in digital form shall be accompanied by the appropriate metadata.

IWXXM Regulation

**ICAO Responsibility:**
Aviation regulation and requirements

**WMO Responsibility:**
Weather regulation and technical implementation
WMO Standards

WMO-No 49 – Technical Regulations

WMO-No 1060 – Manual on WIS
WMO-No 1061 – Guide to WIS

WMO-No 386 – Manual on GTS

WMO-No 306 – Manual on Codes
Data Representations

TAC
- Traditional Alphanumeric Codes
  - Original codes – for Morse/Teleprinter
  - Inflexible
  - METAR/TAF/SIGMET

TDCF
- Table Driven Code Forms
  - Flexible
  - Compact for large data
  - GRIB/BUFR/CREX

MDCF
- Model Driven Code Forms
  - Based on ISO/OGC standards
  - Map to different representations – XML/GML
  - IWXXM/METCE/SAF/OPM/COLLECT
Traditional

FM 15–XV METAR
Aerodrome routine meteorological report (with or without trend forecast)

FM 16–XV SPECI
Aerodrome special meteorological report (with or without trend forecast)

CODE FORM:

METAR
or SPECI

{ VVVV
or CAVOK

{ V_{N}V_{N}V_{N}V_{N}D_{v} } \quad R_{D_{v}}D_{R}/V_{R}V_{R}V_{R}V_{R}i

{ w^{'w'} } \quad \{ \begin{align*}
\text{WS} & \quad R_{D_{R}}D_{R} \\
\text{ALL RWY} & \quad \left( W_{T_{S}}T_{S}/S^{-} \right) \\
\text{or} & \quad \left( W_{T_{S}}T_{S}/H_{5}H_{5}H_{5} \right) \\
\text{or} & \quad \left( R_{D_{R}}D_{R}/E_{R}C_{R}e_{R}e_{R}B_{R}B_{R} \right)
\end{align*} \}

\{ K_{T} \}

\{ VVVV \}

\{ w^{'w'} \}

\{ \begin{align*}
\text{N}_{5}N_{5}N_{5}h_{5}h_{5}h_{5}h_{5} \\
\text{or} & \quad \text{VV}{h}_{5}h_{5}h_{5} \\
\text{or} & \quad \text{NSC} \\
\text{or} & \quad \text{NCD}
\end{align*} \}

\{ (TTTTT
or NOSIG)

{ TTGg g }

{ dddffG_{f_{m}f_{m}} } \quad \{ \begin{align*}
\text{KS} & \quad V_{VVVV} \\
\text{or} & \quad \text{CAVOK} \\
\text{or} & \quad \text{NSW} \\
\text{or} & \quad \text{NSC}
\end{align*} \}

\{ N_{5}N_{5}N_{5}h_{5}h_{5}h_{5}h_{5} \\
\text{or} & \quad \text{VV}{h}_{5}h_{5}h_{5} \\
\text{or} & \quad \text{NSC}
\}

\{ \text{RMK} \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \}

METAR EGLL 181350Z 26009KT CAVOK 19/09 Q1014 NOSIG=
Table Driven

FM 92-XIV GRIB  General regularly distributed information in binary form

**CODE FORM:**

- **SECTION 0**  Indicator section
- **SECTION 1**  Identification section
- **SECTION 2**  Local use section
- **SECTION 3**  Grid definition section
- **SECTION 4**  Product definition section
- **SECTION 5**  Data representation section
- **SECTION 6**  Bit-map section
- **SECTION 7**  Data section
- **SECTION 8**  End section

**Code table 4.2 – Parameter number by product discipline and parameter category**

Notes:
1. By convention, the flux sign is positive if downwards.
2. When a new parameter is to be added to Code table 4.2 and more than one category applies, the choice of category should be made based on the intended use of the product. The discipline and category are an important part of any product definition, so it is possible to have the same parameter name in more than one category. For example, “water temperature” in discipline 10 (oceanographic products), category 4 (subsurface properties) is used for reporting water temperature in the ocean or open sea, and is not the same as “water temperature” in discipline 1 (hydological products), category 2 (inland water and wetland properties), which is used for reporting water temperature in freshwater lakes and rivers.

<table>
<thead>
<tr>
<th>Product discipline</th>
<th>Parameter</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Temperature</td>
<td>K</td>
</tr>
<tr>
<td>1</td>
<td>Virtual temperature</td>
<td>K</td>
</tr>
<tr>
<td>2</td>
<td>Potential temperature</td>
<td>K</td>
</tr>
<tr>
<td>3</td>
<td>Pseudo-adiabatic potential temperature</td>
<td>K</td>
</tr>
<tr>
<td>4</td>
<td>Maximum temperature*</td>
<td>K</td>
</tr>
<tr>
<td>5</td>
<td>Minimum temperature*</td>
<td>K</td>
</tr>
<tr>
<td>6</td>
<td>Dewpoint temperature</td>
<td>K</td>
</tr>
<tr>
<td>7</td>
<td>Dewpoint depression (deficit)</td>
<td>K</td>
</tr>
<tr>
<td>8</td>
<td>Lapse rate</td>
<td>K m⁻¹</td>
</tr>
<tr>
<td>9</td>
<td>Temperature anomaly</td>
<td>K</td>
</tr>
<tr>
<td>10</td>
<td>Latent heat net flux</td>
<td>W m⁻²</td>
</tr>
<tr>
<td>11</td>
<td>Sensible heat net flux</td>
<td>W m⁻²</td>
</tr>
<tr>
<td>12</td>
<td>Heat index</td>
<td>K</td>
</tr>
<tr>
<td>13</td>
<td>Wind chill factor</td>
<td>K</td>
</tr>
<tr>
<td>14</td>
<td>Minimum dewpoint depression'</td>
<td>K</td>
</tr>
<tr>
<td>15</td>
<td>Virtual potential temperature</td>
<td>K</td>
</tr>
<tr>
<td>16</td>
<td>Snow phase change heat flux</td>
<td>W m⁻²</td>
</tr>
<tr>
<td>17</td>
<td>Skin temperature</td>
<td>K</td>
</tr>
<tr>
<td>18</td>
<td>Snow temperature (top of snow)</td>
<td>K</td>
</tr>
<tr>
<td>19</td>
<td>Turbulent transfer coefficient for heat</td>
<td>Numeric</td>
</tr>
<tr>
<td>20</td>
<td>Turbulent diffusion coefficient for heat</td>
<td>m² s⁻¹</td>
</tr>
<tr>
<td>21</td>
<td>Apparent temperature**</td>
<td>K</td>
</tr>
<tr>
<td>22-191</td>
<td>Reserved</td>
<td></td>
</tr>
<tr>
<td>192-254</td>
<td>Reserved for local use</td>
<td></td>
</tr>
<tr>
<td>255</td>
<td>Missing</td>
<td></td>
</tr>
</tbody>
</table>
Model Driven

1) Define the structure of the information

2) Map onto a particular representation
What is IWXXM?

• Two parts (jointly referred to as ‘IWXXM’):
  – A UML conceptual model
  – An XML format

• Operationally it can be considered an XML format for representing ICAO Annex 3 TAC products (METAR, SPECI, TAF, SIGMET, AIRMET, TCA, VAA)
Traditional Alphanumeric Codes (TAC) – METAR, TAF, SIGMET, ...

Useful for:
• Human readability (pilots, flight briefers, ...)
• Machine readability (visualization, storage, weather models, ...)

TAC has primarily addressed human-readability. Parsing TAC with software is time-consuming and imperfect due to human-readable text, variations from standard, and other issues.

XML aids machine-readability and can readily be transformed to many other forms.

XML schema can be used to check messages for correctness (i.e., ‘validation’) – especially useful for data producers.
TAC Examples

METAR YUDO 221630Z 24004MPS 0600 R12/1000U DZ FG SCT010 OVC020 17/16 Q1018 BECMG TL1700
0800 FG BECMG AT1800 9999 NSW

TAF YUDO 160000Z 1606/1624 13005MPS 9000 BKN020 BECMG 1606/1608 SCT015CB BKN020 TEMPO
1608/1612 17006G12MPS 1000 TSRA SCT010CB BKN020 FM161230 15004MPS 9999 BKN020

TAF AMD YUDO 161500Z 1606/1624 CNL

YUDD SIGMET 2 VALID 101200/101600 YUSO –
YUDD SHANLON FIR/UR OBSC TS FCST
S OF N54 TOP FL390 MOV E WKN
XML

- Textual
- Structured
- Extensible

Elements

Attributes

```xml
<breakfast_menu>
  <food inStock="true">
    <name>Belgian Waffles</name>
    <price>$5.95</price>
    <description>Two of our famous Belgian Waffles with</description>
    <calories>650</calories>
  </food>
  <food inStock="false">
    <name>French Toast</name>
    <price>$4.50</price>
    <description>Thick slices made from our homemade</description>
    <calories>600</calories>
  </food>
  <food inStock="true">
    <name>Strawberry Belgian Waffles</name>
    <price>$7.95</price>
    <description>Light Belgian waffles covered with</description>
    <calories>900</calories>
  </food>
  <food inStock="true">
    <name>Berry-Berry Belgian Waffles</name>
    <price>$8.95</price>
    <description>Light Belgian waffles covered with</description>
    <calories>900</calories>
  </food>
</breakfast_menu>
```
Side by Side Example

METAR YUDO 221630Z 24004MPS 0600 R12/1000U DZ FG
SCT010 OVC020 17/16 Q1018

<iwxxm:MeteorologicalAerodromeObservationRecord gml:id="or1" cloudAndVisibilityOK="false">
  <iwxxm:airTemperature uom="C"">17.0</iwxxm:airTemperature>
  <iwxxm:dewpointTemperature uom="C">16.0</iwxxm:dewpointTemperature>
  <iwxxm:qnh uom="hPa">1018</iwxxm:qnh>
  <iwxxm:surfaceWind>
    <iwxxm:AerodromeSurfaceWind variableDirection="false">
      <iwxxm:meanWindDirection uom="deg">240</iwxxm:meanWindDirection>
      <iwxxm:meanWindSpeed uom="m/s">4.0</iwxxm:meanWindSpeed>
    </iwxxm:AerodromeSurfaceWind>
  </iwxxm:surfaceWind>
  <iwxxm:visibility>
    <iwxxm:AerodromeHorizontalVisibility>
      <iwxxm:prevailingVisibility uom="m">600</iwxxm:prevailingVisibility>
    </iwxxm:AerodromeHorizontalVisibility>
  </iwxxm:visibility>
</iwxxm:MeteorologicalAerodromeObservationRecord>
Why XML?

- Extensible content
- Independently marked data elements
- Comprehensive validation capabilities
- Broad supported and understood (libraries, documentation, developer experience, etc.)
- Related standards:
  - XSLT for transforming into other forms
  - XPath for selecting portions of XML documents
  - ...
- Usable with Web Services (SOAP, REST, HTTP, ...)
- Loosely human readable*
- Documentation on data elements can be provided in the schema
Validation is used to determine whether an XML message is correctly formed.

The correct form is formally defined by a combination of XML Schema and Schematron. This is checked by general-purpose validation software.

Validation does not necessarily imply that invalid messages are discarded – this is knowledge that can be used in multiple ways (statistics-gathering, discarding, auto-correction, flagging for human analysis, etc.).
Invalid content was found starting with element ‘iwxxm:invalidContent'. One of ‘iwxxm:qnh' is expected."
XML METAR Example

Weather phenomena observed

XML report created by sensor and/or OPMET center

XML report distributed

Report processed and stored

Report transformed for consumption

Graphics

TAC

Forecast Model Integration
Translation

Translation from TAC to XML is possible, but due to the open text nature of TAC it can be challenging.

It is generally easier to generate IWXXM natively when it is practical.
TAC Parsing Challenges

NCAR

External References
Aerodrome (‘KDEN’) locations, waypoint locations, FIR boundaries, etc.

Typographic
“AU” instead of “UA”, “N23 E1175” ambiguity, Capital “O” instead of 0, ...

Human language
SIGMET 1 VALIDO 140019/140600 UTC - FIR SCCI - POR JET STREAM ENTRE LAT 49/54S CON NUCLEO A LOS 35MFT...

“Other” cases
PIREP: /TB MDT WIFE SAYS SVR
AIRMET phenomena in SIGMET reports
Station Locations

WMO: 44.67, -103.2

MIRAKEL: 44.05, -103.07
Typographic

- Extra whitespace
  • "F CST" instead of "FCST"

- Transposed text
  • "AU" instead of "UA"

- Accidental duplicate markers
  • "FCST FCST"

- "N23 E1175"
  • 11.75 or 117.5?

- Among many others...
 Parsing 100% of *standard* content (across all States, Regions, and associated differences) for TAC is a difficult task.

Parsing 100% of the *actual*, real-time content of TAC is quite time-consuming and nearly impossible.

Each of the many thousands of consumers of TAC products today must independently deal with these issues.

The only place all of these errors can be fully and correctly addressed is at the data originator. Later participants can only guess at the intended content.

Producing high-quality messages from the originator saves significant effort for a very large group of consumers.
<table>
<thead>
<tr>
<th>METAR Entry:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ICAO id:</td>
<td><strong>ZGKL</strong></td>
</tr>
<tr>
<td>Obs time:</td>
<td><strong>080600Z</strong></td>
</tr>
<tr>
<td>Wind direction:</td>
<td><strong>190</strong></td>
</tr>
<tr>
<td>Wind speed:</td>
<td><strong>6 MPS</strong></td>
</tr>
<tr>
<td>Variability:</td>
<td><strong>160-230</strong></td>
</tr>
<tr>
<td>Visibility:</td>
<td><strong>9999m</strong></td>
</tr>
<tr>
<td>Air temperature:</td>
<td><strong>30</strong></td>
</tr>
<tr>
<td>Dewpoint:</td>
<td><strong>24</strong></td>
</tr>
<tr>
<td>Clouds:</td>
<td><strong>SCT</strong></td>
</tr>
<tr>
<td>Height:</td>
<td><strong>26FL</strong></td>
</tr>
<tr>
<td>Clouds:</td>
<td><strong>-</strong></td>
</tr>
<tr>
<td>Height:</td>
<td><strong>-</strong></td>
</tr>
</tbody>
</table>

**ZGKL 080600Z 19006MPS 160V230 9999 SCT026 30/24 Q1004 NOSIG**
WMO Code Registry

WMO Codes Registry (http://codes.wmo.int) developed to provide formal, publicly-accessible, semantic access to managed content
WMO Codes

http://codes.wmo.int/306/4678/FG

Authority/ Document (WMO 306)
Code Table (4678)
Code (Fog)

<iwxxm:trendForecast>
<om: Observation gml:id="trend-fcast-1">
<om: type xlink:href="http://codes.wmo.int/49-2/observation-type/IWXXM/1.0/MeteorologicalAerodromeTrendForecast"/>
<!-- time at which the forecast conditions actually occur -->
<om: phenomenonTime> [5 lines] </om: phenomenonTime>
<!-- time at which the results of the observation were made available -->
<om: resultTime xlink:href="$ti-2012082116402"/>
<om: procedure xlink:href="fp-49-2-metar"/>
<om: observedProperty xlink:href="http://codes.wmo.int/49-2/observable-property/MeteorologicalAerodromeTrendForecast"/>
<om: featureOfInterest xlink:href="#sampling-point-03839"/>
<om: result>
  <iwxxm: MeteorologicalAerodromeTrendForecastRecord gml:id="trend-fcast-record-03839-2012082216302-2012082217002" changeIndicator="BECOMING"
    iwxxm: prevailingVisibility uom="m">800</iwxxm: prevailingVisibility>
</iwxxm: MeteorologicalAerodromeTrendForecastRecord>
</om: result>
</om: Observation>
</iwxxm:trendForecast>
IWXXM Content Beyond
Annex 3

• Explicit geo-locations (points, polygons, etc.) for weather phenomena
• Permissible usage: operational, non-operational - test or exercise

Possible:
• Aerodrome ARP
• Full FIR boundary

Future changes are likely to be made to add elements to IWXXM that are not possible to carry in TAC
• Added Volcanic Ash Advisory, Tropical Cyclone Advisory, and AIRMET products
• SAF was replaced by AIXM 5.1 in IWXXM schemas. SAF will no longer be released as part of the TT-AvXML schema package
• Rules added to restrict units of measure on individual fields (such as air temperature) to those allowed by ICAO Annex 3 / WMO No. 49
• A GML 3.2.1 profile was created for use with IWXXM, this is distributed in the release package
• Examples updated to remove unnecessary AIM data portions which are unlikely to be of operational use
• UML model changes performed to support Enterprise Architect as the primary mechanism for generating XML schema
• METAR/SPECI depth of deposit is now nillable to allow for representation of both '//' and '99' from ICAO Annex 3 / WMO No. 49
• Forecast position analysis is now only available on TC and VA SIGMETs
• METAR/SPECI autoHeightUnobservableByAutoSystem has been removed - this can be represented with a nilReason of http://codes.wmo.int/common/nil/notDetectedByAutoSystem
• SIGMET speedOfMotion and intensityChange are now optional. This matches what is specified in ICAO Annex 3 / WMO No. 49
IWXXM 2.0 (Notional)

• Bug fixes
• AIXM 5.1.1
• Add extension capability
• Add permissible usage information
• Add translation centre metadata
• Add original TAC field for translation failures
• Validation web page and library
Changes After IWXXM 2.0 (Notional)

- Reduced Complexity
- Bug fixes
- Additional validation capabilities
IWXXM and WXXM

IWXXM
- Authoritative and official XML representations of ICAO Annex 3 products
- Managed by ICAO and WMO
- Strong support for validating whether messages are formatted correctly
- Updated on roughly the same time scale as ICAO Annex 3 (currently 2 years)

WXXM
- Next-generation aviation and weather data representations
- Managed by Eurocontrol, FAA, and other partners
- Many products and data types beyond ICAO Annex 3
- General purpose, reusable data types (aerial report, profile, trajectory, area forecast, point forecast, etc.)
- Open/extensible content policy

For ICAO data exchange, only IWXXM should be used
Support

Questions and implementation issues should be sent to cbs-tt-avxml@wmo.int

Former discussions are available at https://groups.google.com/a/wmo.int/forum/#!categories/cbs-tt-avxml