An XML format for cyclone analyses and forecasts

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1 Summary

The Sixth WMO International Workshop on Tropical Cyclones recommended that all tropical cyclone-related Numerical Weather Prediction (NWP) products, including full set of ensemble forecasts, be made available to all operational and research users in real-time. Meanwhile, the THORPEX Interactive Grand Global Ensemble (TIGGE) project is developing plans for the Global Interactive Forecast System (GIFS) for the real time dissemination of ensemble data and products in support of high impact weather prediction. No generally used encoding, however, exists for the exchange of tropical cyclone related data, as the various producing centers use a variety of formats.

To facilitate easy exchange of information, a standard format to represent analyzed and forecast data for tropical and extra-tropical cyclones is proposed. The new format, called Cyclone XML (CXML) is descriptive and human-legible, making it easy for all human users and most automated applications to read. CXML is defined so it can carry data from observations and analyses, manual and NWP forecasts, multiple cyclones and multiple forecasts (ensembles). In its current version, it can include all information conveyed in other existing formats, while its flexibility and extensibility makes it simple to add new kinds of data as needed. CXML is not envisioned as a replacement for the WMO standard BUFR and CREX formats used in operational centers, but as a simple alternative.

The adoption of CXML as a standard format will not only benefit the tropical cyclone community in general, but also the THORPEX community in their effort in establishing GIFS for the improved prediction of high-impact weather worldwide. Moreover, the use of CXML will further the immediate goals of the THORPEX Pacific-Asian Regional Campaign (Sept. 2008-March 2009, T-PARC), designed to study the lifecycle of tropical and extratropical cyclones over the northern Pacific.

A copy of this proposal, the CXML schema, and sample data files can be found online at http://www.bom.gov.au/bmrc/projects/THORPEX/CXML/index.html. Scripts for CXML reading and writing will be added to this site as they become available.

2 Motivation

Observationally based analysis and subjective and numerical forecast information on tropical cyclones is routinely produced by National Hydro-Meteorological Centers (NHMCs), a number of Regional Specialized Meteorological Centers (RSMCs), Tropical Cyclone Warning Centers (TCWCs), and other Numerical Weather Prediction (NWP) centers and forecast agencies. Currently the different producing centers use a variety of formats to convey tropical cyclone related information.

At the recent WMO International Workshop on Tropical Cyclones (IWTC-VI; HKO 2006), the tropical cyclone research and operational communities recommended the improved sharing of information within these communities:

> The WMO should take all necessary action to:
> – improve the communication between operational centres and facilitate the dissemination of all tropical cyclone-related NWP products, such as the deterministic and ensemble forecasts (including the full set of ensemble runs),
> – make them available to all RSMCs, TCWCs and researchers in real-time.
>
> WMO should investigate the most appropriate ways to achieve this goal:
> – coordinate with the NWP and major operational centres (RSMCs and TCWCs) in order to define a set of resolvable tropical cyclone characteristics to be provided and timely disseminated by the NWP centres through the GTS (e.g. centre location, minimum sea level pressure, max wind, wind radii by quadrants, etc…) and define the appropriate standardised format,
> – and/or find a WMO-sponsored dedicated reference centre (similarly to what has been done with the Severe Weather Information Centre for the dissemination of the analysis and forecast products issued by the main operational centres) able to host and maintain a single global data base of the tropical cyclone forecasts originating from the different NWP centres.

Meanwhile, the THORPEX community is preparing plans for the development of the Global Interactive Forecast System (GIFS 2007), which is a multi-center ensemble based NWP system for improvements in the prediction of high impact weather events. GIFS will be based on real time access to and processing of forecast data produced at different NWP and Regional Specialized Meteorological Centers (RSMCs). The upcoming THORPEX Pacific-Asian Regional Campaign (T-PARC) during 2008-2009 (THORPEX 2007), with its focus on tropical cyclogenesis, landfall, recurvature, extra-tropical transitioning, and extra-tropical storm development and propagation, present an opportunity for quick advances in the next year or two. The confluence and importance of these activities was recognized by the TC community in the following high-priority recommendation:

> IWTC-VI considers that the tropical cyclone community should engage and cooperate with the THORPEX activities of relevance to the tropics, especially the THORPEX Pacific Asian Regional Campaign (T-PARC) and the THORPEX Interactive Grand Global Ensemble/Global Interactive Forecast System (TIGGE/GIFS), which aims in particular to develop generic probabilistic forecast products from a global archive of ensemble forecasts originating from a number of NWP centres.

If both the tropical cyclone and the THORPEX communities decide to capture this unique opportunity to work together, tropical cyclone forecasting may become the proving ground for testing new GIFS procedures and techniques designed to eventually improve all high impact weather forecasts. The current document constitutes a first step in such a collaboration by recognizing the need, and making a recommendation for the adoption of a unified format for the exchange of tropical (and extra-tropical transition and fully extra-tropical) storm related data. The efficient exchange of ensemble and other tropical cyclone forecast information among all

interested and participating parties (such as NHMSs, RSMCs, NWP centers, etc) is essential for the improved services the tropical cyclone and GIFS communities envision.

After reviewing currently used formats for tropical cyclone related information, we make the case that eXtensible Markup Language (XML) is ideally suited for cyclone related data exchange. XML is an internet standard and is used to convey other types of meteorological information.

We present a new format (CXML), designed specifically to convey tropical (and other) storm related analysis and forecast information. An overview of related technical tools is given, while Appendix 1 outlines a proposed schedule that will allow at least some of the goals to be achieved by T-PARC, contributing to the goals of and benefiting both the tropical cyclone and THORPEX communities.

3 Formats for exchanging tropical cyclone data

Within WMO the standard formats for exchange of tropical cyclone data are BUFR and CREX, both table-based formats that require decoding software to interpret the data. In 2003 the BUFR template was extended to include forecasts from ensemble prediction systems (ECMWF 2007). It provides information on storm position, central pressure, 10m wind speed, and location of maximum wind. Currently ECMWF and JMA use the extended BUFR format to encode TC forecasts from their NWP EPS systems, and it has been nominated for use by the Asian Regional Committee of THORPEX.

In the early 1990s the WMO recommended a 1-line text format for sharing critical observed TC information. NCEP refers to this format at "TC vital statistics". An example for Katrina from 29 August 2005 is:

```
NHC 12L KATRINA 20050829 0000 272N 0891W 335 046 0904 1006 0649 72 037 0371
0334 0278 0334 D 0204 0185 0139 0185 72 410N 815W 0167 0167 0093 0167
```

It includes the forecast office, ATCF ID (12L), storm name, date, position, minimum MSLP, max winds (m/s), direction of storm movement, speed of storm movement, value of last closed isobar, radius of last closed isobar, and information on the radii of 34-kt winds in each storm quadrant. This text format is used by NCEP's Central Operations and Tropical Prediction Center (TPC), the Joint Typhoon Warning Center (JTWC), the Central Pacific Hurricane Center, and the Met Office.

For forecast data the TPC and JTWC use an Automated Tropical Cyclone Format (ATCF) text format that includes all of the information in the TC vital statistics, plus additional data on radii at which certain wind speeds are exceeded in quadrants, sea state, eye diameter, and radius of maximum wind (ATCF 2006, 2007). A sample GFDL model forecast for Hurricane Katrina is:

```
AL, 12, 2005082900, 03, GFDT, 0, 270N, 889W, 135, 910, XX, 34, NEQ, 276, 342, 172, 252,
AL, 12, 2005082900, 03, GFDT, 0, 270N, 889W, 135, 910, XX, 50, NEQ, 113, 112,  82,  90,
AL, 12, 2005082900, 03, GFDT, 0, 270N, 889W, 135, 910, XX, 64, NEQ,  78,  68,  63,  69,
```

There are pros and cons associated with each of the above formats. The BUFR format is the officially endorsed format of WMO, and can handle ensemble forecasts. However, the

requirement for a decoder to read the data makes it difficult for users outside of large meteorological centers. The text formats are more easily read but are still somewhat cryptic, and neither of them is currently able to represent ensemble forecasts.

Recent years have seen an increase in the use of web services and service-oriented architectures to deliver information using clear and unambiguous description languages. The eXtensible Markup Language (XML) is a widely used human-legible text format that encloses data within self-describing tags. XML has become an internet standard in recent years. We believe XML is ideally suited for representing cyclone data because of its descriptive nature. Sample TC data written in XML might look something like:

```
<cyclone>
     <name>Katrina</name>
     <basin>North Atlantic</basin>
     <fix type="forecast" time="2005-08-29T00:06:00Z>
          <latitude units="deg N">27.0</latitude>
          <longitude units="deg E">-88.9</longitude>
          <maxWindSpeed units="kt">135.</maxWindSpeed>
          <minimumPressure units="hPa">910.</minimumPressure>
     </fix>
     <fix type="forecast" time="2005-08-29T00:12:00Z>
          <latitude units="deg N">27.1</latitude>
          <longitude units="deg E">-87.8</longitude>
          <maxWindSpeed units="kt">130.</maxWindSpeed>
          <minimumPressure units="hPa">915.</minimumPressure>
     </fix>
</cyclone>
```

Although XML is more verbose than the previously discussed text formats, the meaning of each datum is quite clear. Its general structure is defined by a separate online schema, which is used to validate (check) each data file for structural and obvious data errors. Data encoded in XML is easily interpreted by many internet applications, making it ideal to support interoperability between meteorological and other agencies.

4 XML in meteorology

XML is increasingly being used in a variety of meteorological applications, most commonly to represent metadata and warnings. At an official level, WMO has created a Core Metadata Profile that has been tested for use with TAFs and METARs (WMO CBS IPET-MI 2007). The WMO Core Metadata Profile has also been successfully used as an interface to a relational database within the ACSYS and CliC programs (Miville 2003).

An application of XML for warnings is the Common Alerting Protocol (CAP), developed by the OASIS Emergency Management Technical Committee, as "a simple but general format for exchanging all-hazard emergency alerts and public warnings over all kinds of networks" (OASIS EMTC, 2005). CAP acts as a wrapper for more detailed information which may itself be in XML, such as warnings issued in Emergency Data Exchange Language (EDXL) (OASIS EMTC, 2006), or written as plain language, or sometimes given as a reference to a web location (URI). XML applications have been developed to hold warnings for severe weather including tropical cyclones (Iannella 2006; Sun *et al.* 2006). In fact, simple TC advisories and warnings are now

issued in XML format by both the NWS National Hurricane Center and the Hong Kong Observatory (NHC 2007, Wing 2006).

The development of appropriate schemas for meteorological data (as opposed to metadata and warnings) in XML has been recommended at WMO meetings in recent years (Sanders 2002, Kellett 2005, Thomas 2006). This issue will be taken up by a newly formed WMO Expert Team on Assessment of Data Representation Systems (ET-ADRS), which is tasked to assess advantages and disadvantages, including implications, of different data representation systems (e.g. BUFR, CREX, XML, NetCDF, HDF) for use in real time operational international exchanges between NHMCs and in transmission of information to users outside the NHMCs (Pierre Kerherve, personal communication). It is anticipated that the ET-ADRS will consider the questions of a standard approach for data representation, for example based on the ISO 191** series of geographic standards set by the Open Geospatial Consortium, which includes the XML-based Geography Markup Language (GML).

The National Weather Service developed a Digital Weather Markup Language (DWML) to support the exchange of National Digital Forecast Database (NDFD) data, and with enough flexibility to accommodate other environmental science applications. For example, DWML has been extended to Weather Markup Language (WxML) by the Australian Bureau of Meteorology to accommodate the exchange of nowcast data (Thomas 2006, Ebert *et al.* 2007).

5 CXML – a cyclone format based on XML

After agreeing that it would be a good idea to investigate the representation of cyclone data using an XML format, we did an exhaustive web and e-mail search. We found nothing online that was suitable for cyclone data, and none of the many experts we consulted was aware of any such format (although many expressed interest in using an XML format for TCs). We also consulted the project manager of the WMO Information System, David Thomas, to ask whether WMO had guidelines for the use of XML in meteorological data representation. At this stage we were informed of the mandate of the soon-to-be-formed ET-ADRS (see Section 3), and encouraged to go ahead with our own development.

The name of the proposed XML format for cyclones is Cyclone XML (CXML). In the interest of simplicity we opted for a relatively simple XML format. Future development of CXML in a GML framework is considered in Appendix 5. The CXML data model (Fig. 1) incorporates a variety of information describing the position and intensity of one or more detected and/or forecast cyclones. A key feature of CXML is that most data elements are optional, allowing the representation of data to be as simple or as comprehensive as required.

The header consists of metadata describing the source of the cyclone data. It also gives the current (valid) time of the data, to which the analysis (history) and/or forecast (future state) are referenced. It will link to more complete metadata for the data producer, which may be written in accordance with the WMO Core Metadata Profile.

The data section contains information about one or more cyclones (disturbances), over one or more time periods (fixes). Its content is based on that of the ATCF and BUFR formats for TC data exchange (see Section 2), as well as suggestions from members of the tropical cyclone

community. For example, cyclone phase information has been included (Hart 2003). Note that the extensibility of XML makes it easy to include additional features in the future.

Sample files in Appendix 2 show what TC analyses and forecasts encoded in CXML might look like. The schema describing the structure and relationships of the data is given in Appendix 3, and Appendix 4 gives a table of recommended data units. Appendix 5 considers possible future modifications to CXML to make it compliant with GML.

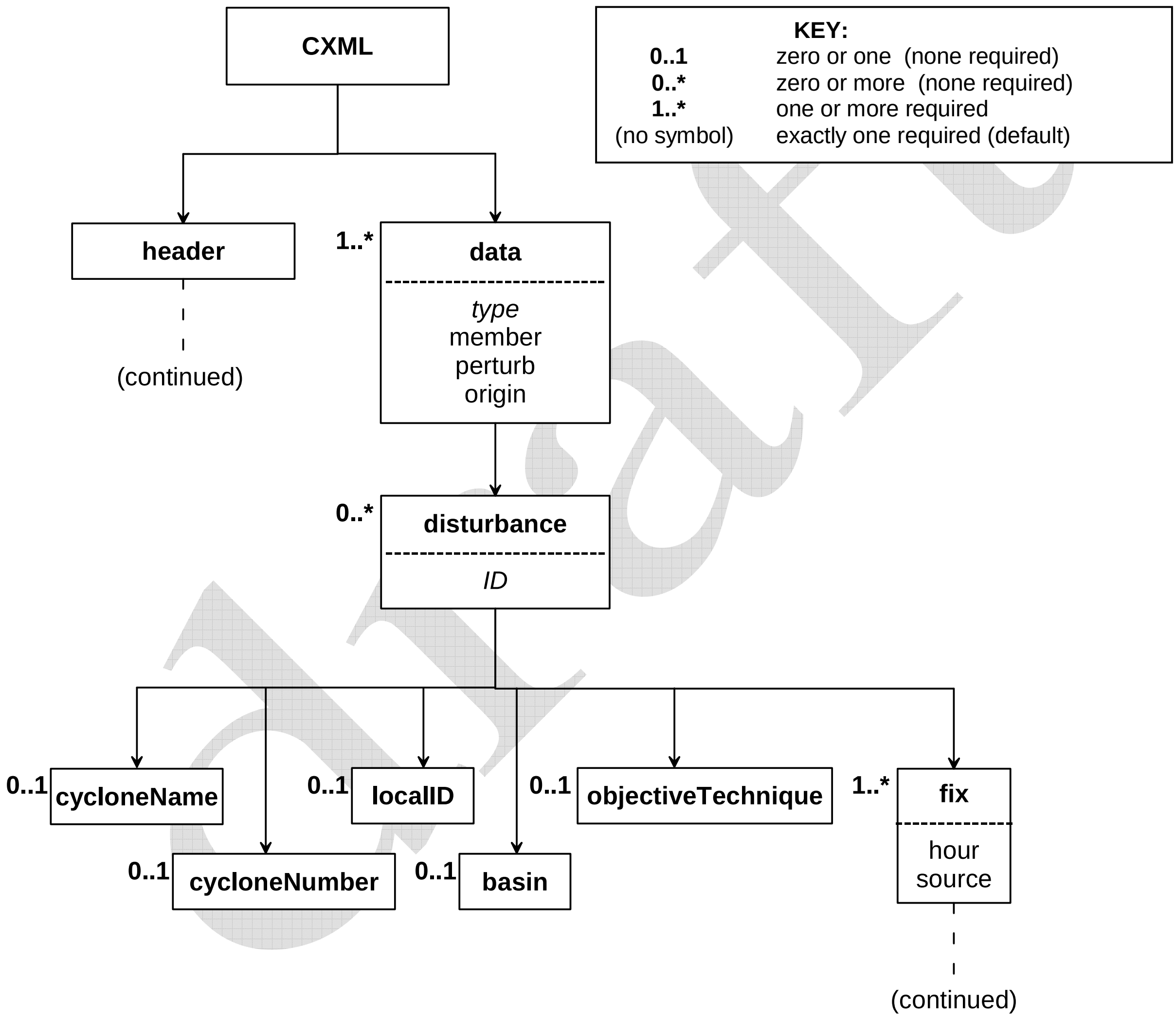

Figure 1. Data model for CXML. The data elements are shown in bold font, where italicized data elements have attributes of units (required) and precision (optional). The plain text in the lower portion of the boxes list additional attributes with those printed in italics being required. The symbols to the upper left of each box indicate the requirements for each element. Details for the header and fix segments are given on the following pages.

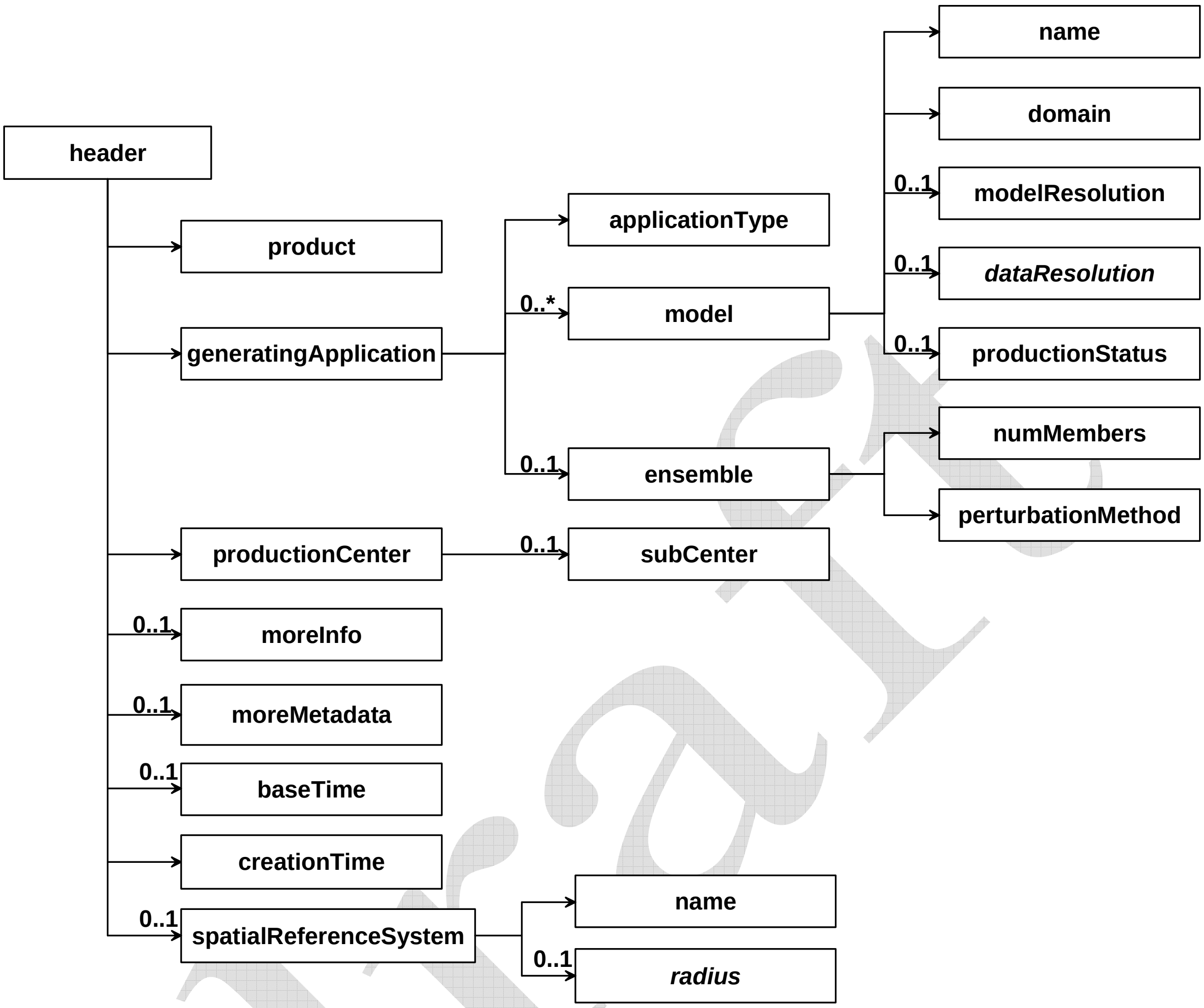

Fig. 1 (continued) Data model for header segment.

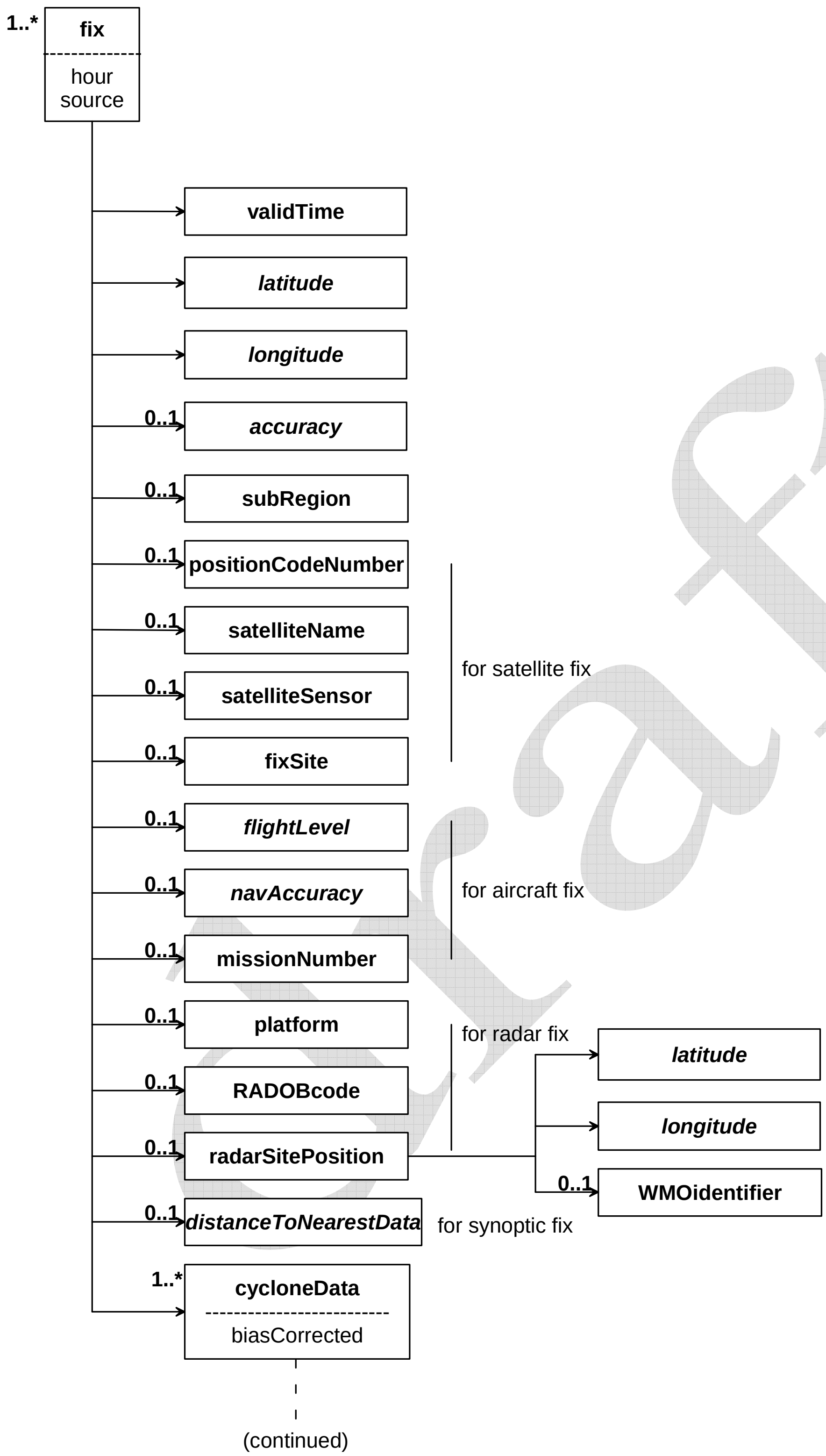

Fig. 1 (continued) Data model for fix.

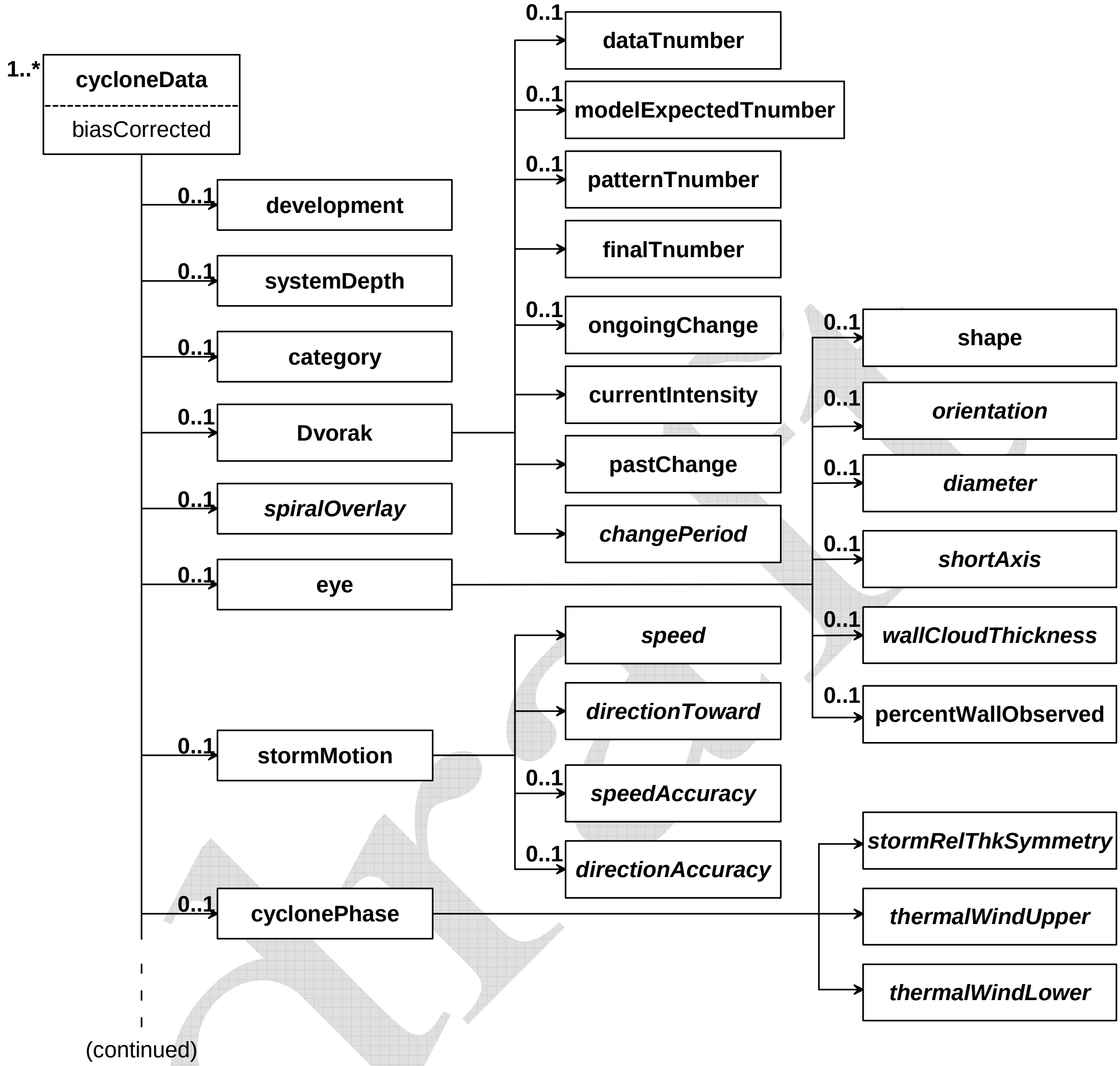

Fig. 1 (continued) Data model for the cyclone data segment: cyclone characteristics.

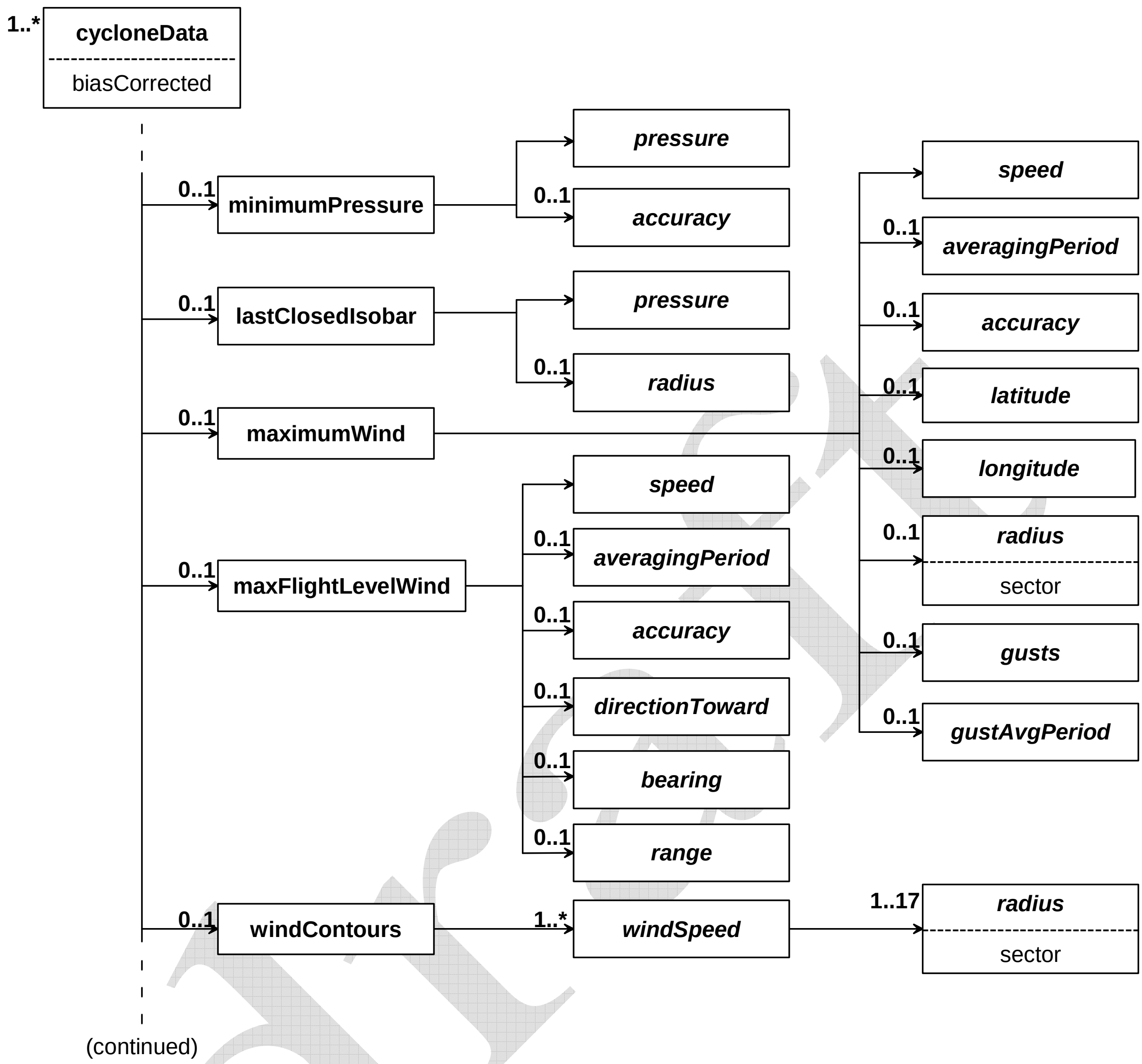

Fig. 1 (continued) Data model for the cyclone data segment: pressure and winds.

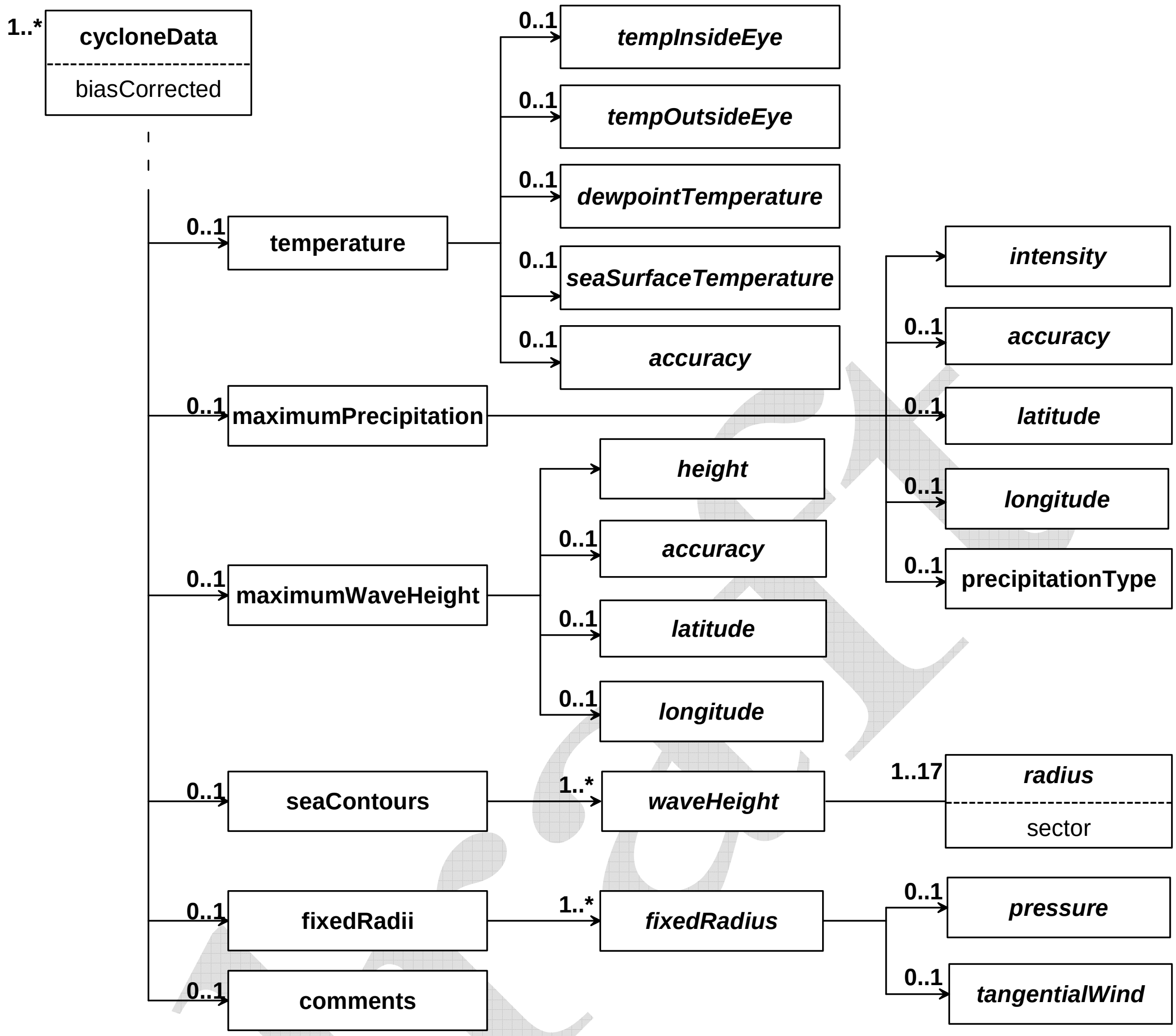

Fig. 1 (continued) Data model for the cyclone data segment: temperature, precipitation, and seas.

6 Tools for working with XML

Working with data in XML format is facilitated by numerous freely available libraries written in various languages. Table 1 lists web sites from which routines for parsing (reading) and writing XML files can be downloaded, as well as proprietary software that includes XML capability.

Reading from XML files is done using a "parser", which extracts the data. Writing a parser is quite difficult, so it is much simpler to use one from Table 1 that has been developed and tested by experts. Since XML is just text, writing data in XML format can be done fairly easily using most languages. Some of the libraries in Table 1 also offer XML-writing routines.

Table 1. Libraries for working with XML

Language	Library	URL
Fortran	XML-Fortran Project	http://xml-fortran.sourceforge.net/
C++	Xerxes	http://xerces.apache.org/xerces-c/
C (interfaces to C++, Perl, Python, Tcl, .NET, Java, C#)	Expat	http://expat.sourceforge.net/
	Libxml2	http://xmlsoft.org/
Python	Dave's Page	http://www.rexx.com/~dkuhlman/#pyxmlfaq
Perl	Xerxes	http://xerces.apache.org/xerces-p/
Java	(several)	http://java-source.net/open-source/xml-user-interface-toolkits
	Xerces	http://xerces.apache.org/xerces-j/
	Unidata	http://www.unidata.ucar.edu/software/idv/docs/javadoc/ucar/unidata/xml/package-summary.html
IDL	Provided with application	
Matlab	Provided with application	

7 Acknowledgements

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8 References and links

ATCF, 2006: ATCF Best Track/Objective Aid/Wind Radii Format – [Online http://www.nrlmry.navy.mil/atcf_web/docs/database/new/abrdeck.html, 25 October 2007].

ACTF, 2007: ATCF Tropical Cyclone Database. [Online http://www.nrlmry.navy.mil/atcf_web/docs/database/new/database.html, 25 October 2007].

Ebert, E., S. Dance, D. Scurrah, R. Potts, and E. Dozortseva, 2007: An XML format for nowcast data. *33rd Conf. Radar Meteorology, Amer. Met. Soc., Cairns, Australia, 6-10 August 2007.* [Online http://ams.confex.com/ams/pdfpapers/122401.pdf, 25 October 2007].

ECMWF, 2007: Tropical cyclone trajectory forecast products. [Online at http://www.ecmwf.int/services/dissemination/3.1/TROPICAL_CYCLONE_trajectory_forecast_products.html#pgfId-385523, 25 October 2007].

GIFS (Global Interactive Forecast System), 2007: High Impact Weather Forecasting for GEOSS: The Global Interactive Forecast System. Draft Planning Document by Sub-group of THORPEX Working Group on TIGGE/GIFS, accessible at: http://wwwt.emc.ncep.noaa.gov/gmb/ens/THORPEX.html

Iannella, R., 2006: Modeling and Integration of Severe Weather Advisories for Situational Awareness [Online http://nicta.com.au/__data/assets/pdf_file/0019/7255/Modeling_and_Integration_of_Severe_Weather_Advisories.pdf, 25 October 2007].

Hart, R.E., 2003: A cyclone phase space derived from thermal wind and thermal asymmetry. *Mon. Wea. Rev.*, **131**, 585-616.

Hong Kong Observatory, 2006: The Sixth WMO International Workshop on Tropical Cyclones (IWTC-VI), San José, Costa Rica, 21-30 November 2006. [Online http://severe.worldweather.org/iwtc/, 25 October 2007].

Kellett, S., 2005: Create XML standards for exchanging meteorological data. *WMO CBS Meeting of Expert Team on Data Representation and Codes, Muscat, Oman, 5-8 December 2005.* [Online www.wmo.ch/pages/prog/www/ISS/Meetings/ET-DRC_Oman2005/Doc6(1).doc, 25 October 2007].

Kuhlman, D., 2007: Dave's Page [Online http://www.rexx.com/~dkuhlman/#pyxmlfaq, 25 October 2007].

Markus, A., 2007: XML-Fortran page. [Online http://xml-fortran.sourceforge.net/, 25 October 2007].

Met Office, 2006b: OGC Web Services and GML Modelling for Operational Meteorology, 6th – 10th February 2006. Communiqué – workshop findings and outcomes. [Online http://home.badc.rl.ac.uk/lawrence/papers/ExeterCommunique06.pdf, 25 October 2007].

Met Office, 2006a: Geospatial Interoperability for Operational Meteorology. [Online http://www.metoffice.gov.uk/informatics/, 25 October 2007].

Miville, B., 2003: Operational implementation of the WMO Core Metedata Profile. The ACSYS and CliC programmes experience.*WMO CBS Expert Team on Integrated Data Management, 3rd Meeting, Geneva, 15-18 December 2003.* [Online www.wmo.int/pages/prog/www/WDM/ET-IDM-3/Doc-3-1(5).doc, 25 October 2007].

National Hurricane Center, 2000: NHC RSS feeds. [Online http://www.nhc.noaa.gov/aboutrss.shtml, 25 October 2007].

National Weather Service Meteorological Development Laboratory, 2007: Digital Weather Markup Language Specification (Version 1.0). [Online http://www.weather.gov/mdl/XML/Design/MDL_XML_Design.pdf, 25 October 2007].

OASIS Emergency Management Technical Committee, 2005. Common Alerting Protocol, v. 1.1. *OASIS Standard CAP-V1.1*, October 2005. [Online http://www.oasis-open.org/apps/org/workgroup/emergency/download.php/14205/emergency-CAPv1.1-Committee%20Specification.pdf, 25 October 2007].

OASIS Emergency Management Technical Committee, 2006: Emergency Data Exchange Language [Online http://xml.coverpages.org/edxl.html, 25 October 2007].

Open Geospatial Consortium, 2007: Network. [Online http://www.ogcnetwork.net/gml, 25 October 2007].

Sanders, C., 2002: Meteorological data and XML. *WMO CBS Meeting of Expert Team on Data Representation and Codes, Prague, Czech Republic, 22-26 April 2002.* [Online www.wmo.ch/pages/prog/www/DPS/ET-DR-C-PRAGUE-02/Doc6(1).doc, 25 October 2007].

Sun, S., R. Iannella, and K. Robinson, 2006: Cyclone Warning Markup Language (CWML). Version 1. *NICTA Technical Report*. [Online http://nicta.com.au/__data/assets/pdf_file/0005/8645/CWML-10.pdf, 25 October 2007].

Thomas, D., 2006: Weather Markup Language (WxML) schema. *WMO CBS OPAG on Information Systems and Services – ICT-ISS, Geneva, 18-22 September 2006.* [Online http://www.wmo.int/pages/prog/www/TEM/ICT-ISS2006/Doc6-1(2)wxml.doc, 25 October 2007]

THORPEX, 2007: THORPEX Pacific Asian Regional Campaign (T-PARC). [Online http://www.ucar.edu/na-thorpex/PARC.html, 25 October 2007].

UNESCO, 2007: The MarineXML portal. [Online http://www.iode.org/marinexml/, 25 October 2007].

W3Schools, 2007: XML Tutorial. [Online http://www.w3schools.com/xml/default.asp, 25 October 2007].

Wing, N.G.P., 2006: Weather information in eXtensible Markup Language (XML). [Online http://demo.xml.weather.gov.hk/refdoc/infosheet.doc, 25 October 2007].

WMO CBS ET-WISC-I, 2005: ISO 191xx series of geographic information standards. [Online http://www.wmo.ch/pages/prog/www/TEM/ET-WISC-I/ISO_191xx.doc, 25 October 2007].

WMO CBS IPET-MI, 2007: WMO Core Metadata Profile. [Online http://wis.wmo.int/2006/metadata/WMO%20Core%20Metadata%20Profile%20(October%202006)/documentation.htm, 25 October 2007].

Woolf, A. and D. Lowe, 2007: Climate Science Modelling Language. Version 2. User's manual. [Online http://ndg.nerc.ac.uk/csml/, 25 October 2007].

Appendix 1: Suggested timeline for tropical cyclone products GIFS

1) TIGGE/GIFS WG agrees on what tropical cyclone properties (e.g., geographical position, intensity, etc) will be shared from ensemble forecasts, and in what format (e.g., GML, special form of XML format – Dec 2007). Share plans with tropical cyclone user community, incorporate feedback into final plan on data content and format (Feb 2008).

2) Each global ensemble producing center identifies position and other agreed upon properties of tropical cyclones in their high resolution control and ensemble member forecasts (May 2008)

3) Each providing center posts tropical cyclone data in real time in agreed upon format on their ftp server to allow access by other centers and the general user community during and after T-PARC (July 2008).

4) Set up Beta test version of common web interface for accessing tropical cyclone data from all providing centers (Dec 2008).

5) Each producing center archives or arranges for the archiving of their operational tropical cyclone forecast data (June 2009). Points 1-5 satisfy TIGGE Phase-2 plans and requirements for tropical cyclone data.

6) Develop methods to combine and statistically improve tropical cyclone forecast data originating from various sources (initial toolbox development, Dec 2009).

7) Develop procedures to support enhanced GIFS web interface for tropical cyclone forecasting: (a) request derived tropical cyclone product via common web interface; (b) generate products using tools from the toolbox; (c) provide requested information to users (web display of data, product, or services, Dec 2010). Points 1-2 complete the GIFS-Product stage for tropical cyclone forecasting.

Appendix 2: Sample CXML files

The same cyclone data is encoded here as if derived from analyzed data, a manual forecast, a NWP model, and an ensemble prediction system. For brevity only one disturbance (cyclone), and one fix (data corresponding to a particular time) are shown. Normally data corresponding to several fixes would be given. In the case of a global NWP model or EPS there may be several disturbances.

The headers shown in these examples contain essential metadata along with a reference to more complete metadata resident elsewhere. Many of the elements in header segment and most of the elements in the data segment are optional, allowing the CXML files to be brief or extensive as the application requires.

1. Tropical cyclone analysis

```
<?xml version="1.0" encoding="UTF-8"?>
<cxml xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.bom.gov.au/bmrc/projects/THORPEX/CXML
http://www.bom.gov.au/bmrc/projects/THORPEX/CXML/cxml.0.1.xsd">

   <header>
      <product>Cyclone Analysis</product>
      <generatingApplication>
         <applicationType>Manual hurricane analysis</applicationType>
      </generatingApplication>
      <productionCenter>NWS
         <subCenter>National Hurricane Center</subCenter>
      </productionCenter>
      <moreInfo>http://www.nhc.noaa.gov/</moreInfo>
      <moreMetadata>http://www.nhc.noaa.gov/TCanal/metadata.html</moreMetadata>
      <baseTime>2007-07-25T12:00:00Z</baseTime>
      <creationTime>2007-07-25T15:42:00</creationTime>
   </header>

   <data type="analysis">
      <disturbance ID="2007072518_134N_1102E">
         <cycloneName>George</cycloneName>
         <cycloneNumber>1</cycloneNumber>
         <localID>NHC0001</localID>
         <basin>Southern Hemisphere</basin>
         <fix hour="0">
            <validTime>2007-07-25T12:00:00Z</validTime>
            <latitude units="deg N">13.2</latitude>
            <longitude units="deg E">110.0</longitude>
            <accuracy units="deg">0.3</accuracy>
            <cycloneData biasCorrected="false">
               <development>tropical cyclone</development>
               <category>2</category>
               <Dvorak>
                  <finalTnumber>3.0</finalTnumber>
                  <currentIntensity>3.0</currentIntensity>
                  <pastChange>D1.0</pastChange>
                  <changePeriod units="h">24</changePeriod>
               </Dvorak>
               <eye>
                  <shape>circular</shape>
                  <diameter units="km">35.</diameter>
```

```
            </eye>
            <minimumPressure>
               <pressure units="hPa" precision="1.">989.</pressure>
               <accuracy units="hPa">0.5</accuracy>
            </minimumPressure>
            <maximumWind>
               <speed units="m/s" precision="0.2">49.8</speed>
               <averagingPeriod units="min">10.</averagingPeriod>
               <latitude units="deg N">13.24</latitude>
               <longitude units="deg E">110.13</longitude>
               <radius units="km">25.2</radius>
               <accuracy units="m/s">2.</accuracy>
            </maximumWind>
            <maxSeas units="m">40.</maxSeas>
            <windContours>
               <windSpeed units="kt">34
                  <radius sector="AAA" units="km">235.</radius>
                  <radius sector="NEQ" units="km">200.</radius>
                  <radius sector="SEQ" units="km">243.</radius>
                  <radius sector="SWQ" units="km">301.</radius>
                  <radius sector="NWQ" units="km">228.</radius>
               </windSpeed>
               <windSpeed units="kt">50
                  <radius sector="NEQ" units="km">159.</radius>
                  <radius sector="SEQ" units="km">138.</radius>
                  <radius sector="SWQ" units="km">121.</radius>
                  <radius sector="NWQ" units="km">107.</radius>
               </windSpeed>
               <windSpeed units="kt">63
                  <radius sector="AAA" units="km">64.</radius>
               </windSpeed>
            </windContours>
            <seaContours>
               <waveHeight units="m">10
                  <radius sector="AAA" units="km">200.</radius>
               </waveHeight>
               <waveHeight units="m">20
                  <radius sector="AAA" units="km">120.</radius>
               </waveHeight>
            </seaContours>
         </cycloneData>
      </fix>
   </disturbance>
  </data>
</cxml>
```

2. Tropical cyclone forecast

The metadata specifies the source of the forecast. The data content is essentially the same as above, but the <data> tag now specifies type="forecast" instead of type="analysis".

```
<?xml version="1.0" encoding="UTF-8"?>
<cxml xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.bom.gov.au/bmrc/projects/THORPEX/CXML
http://www.bom.gov.au/bmrc/projects/THORPEX/CXML/cxml.0.1.xsd">

   <header>
      <product>Cyclone Forecast</product>
      <generatingApplication>
         <applicationType>Subjective hurricane forecast</applicationType>
```

```
    </generatingApplication>
    <productionCenter>NWS
      <subCenter>National Hurricane Center</subCenter>
    </productionCenter>
    <moreInfo>http://www.nhc.noaa.gov/</moreInfo>
    <moreMetadata>http://www.nhc.noaa.gov/TCfcst/metadata.html</moreMetadata>
    <baseTime>2007-07-25T12:00:00Z</baseTime>
    <creationTime>2007-07-25T15:42:00</creationTime>
  </header>

  <data type="forecast">
    <disturbance ID="2007072518_134N_1102E">
      <cycloneName>George</cycloneName>
      <cycloneNumber>1</cycloneNumber>
      <localID>NHC0001</localID>
      <basin>Southern Hemisphere</basin>
      <objectiveTechnique>BLND</objectiveTechnique>
      <fix hour="6">
        <validTime>2007-07-25T18:00:00Z</validTime>
        <latitude units="deg N">13.2</latitude>
        <longitude units="deg E">110.0</longitude>
        <cycloneData biasCorrected="true">

(etc…)

        </cycloneData>
      </fix>
    </disturbance>
  </data>
</cxml>
```

3. Tropical cyclone forecast from NWP

This data is similar to the manual forecast above, but the header now includes information about the model. The forecast data includes an (optional) abbreviated analysis segment (<fix hour="0">) and cyclone phase information derived from upper level fields.

```
<?xml version="1.0" encoding="UTF-8"?>
<cxml xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.bom.gov.au/bmrc/projects/THORPEX/CXML
http://www.bom.gov.au/bmrc/projects/THORPEX/CXML/cxml.0.1.xsd">

  <header>
    <product>Cyclone Forecast</product>
    <generatingApplication>
      <applicationType>Global spectral model</applicationType>
      <model>
        <name>ECMWF</name>
        <domain>global</domain>
        <modelResolution>T799</modelResolution>
        <dataResolution units="degrees">0.25</dataResolution>
      </model>
    </generatingApplication>
    <productionCenter>ECMWF
      <subCenter>Operations Division</subCenter>
    </productionCenter>
    <moreInfo>http://www.ecmwf.int/</moreInfo>
    <moreMetadata>http://www.ecmwf.int/ifs/metadata.html</moreMetadata>
    <baseTime>2007-07-25T12:00:00Z</baseTime>
    <creationTime>2007-07-25T15:42:00</creationTime>
```

```
  </header>

  <data type="forecast">
    <disturbance ID="2007072518_134N_1102E">
      <cycloneName>George</cycloneName>
      <cycloneNumber>1</cycloneNumber>
      <localID>IFS0001</localID>
      <basin>Southern Hemisphere</basin>
      <fix hour="0">
        <validTime>2007-07-25T12:00:00Z</validTime>
        <latitude units="deg N">13.2</latitude>
        <longitude units="deg E">110.0</longitude>
        <cycloneData biasCorrected="false">
          <development>tropical cyclone</development>
          <minimumPressure>
            <pressure units="hPa" precision="1.">989.</pressure>
            <accuracy units="hPa">0.5</accuracy>
          </minimumPressure>
          <maximumWind>
            <speed units="m/s" precision="0.2">49.8</speed>
            <averagingPeriod units="min">10.</averagingPeriod>
            <radius units="km">25.2</radius>
          </maximumWind>
        </cycloneData>
      </fix>
      <fix hour="6">
        <validTime>2007-07-25T18:00:00Z</validTime>
        <latitude units="deg N">13.2</latitude>
        <longitude units="deg E">110.0</longitude>
        <cycloneData biasCorrected="true">

(etc…)

          <cyclonePhase>
            <stormRelThkSymmetry units="hPa">50.</stormRelThkSymmetry>
            <thermalWindLower units="m/s">50.</thermalWindLower>
            <thermalWindUpper units="m/s">-250.</thermalWindUpper>
          </cyclonePhase>
        </cycloneData>
      </fix>
    </disturbance>
  </data>
</cxml>
```

4. Ensemble TC forecast from NWP

The main changes from the NWP forecast above are the inclusion in the header of metadata about the ensemble, and the <data> tag now specifies that this is an ensemble forecast with attributes giving the ensemble member number and perturbation status. Information on storm maximum precipitation has been added to the forecast data.

```
<?xml version="1.0" encoding="UTF-8"?>
<cxml xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.bom.gov.au/bmrc/projects/THORPEX/CXML
http://www.bom.gov.au/bmrc/projects/THORPEX/CXML/cxml.0.1.xsd">

  <header>
    <product>Cyclone Forecast</product>
    <generatingApplication>
      <applicationType>Global ensemble prediction system</applicationType>
```

```
        <model>
          <name>ECMWF</name>
          <domain>global</domain>
          <modelResolution>T399</modelResolution>
          <dataResolution units="degrees">0.5</dataResolution>
        </model>
        <ensemble>
          <numMembers>51</numMembers>
          <perturbationMethod>SVD</perturbationMethod>
        </ensemble>
      </generatingApplication>
      <productionCenter>ECMWF
        <subCenter>Operations Division</subCenter>
      </productionCenter>
      <moreInfo>http://www.ecmwf.int/about/eps.html</moreInfo>
      <moreMetadata>http://www.ecmwf.int/about/eps/metadata.html</moreMetadata>
      <baseTime>2007-07-25T12:00:00Z</baseTime>
      <creationTime>2007-07-25T15:42:00</creationTime>
    </header>

    <data type="ensembleForecast" member="0" perturb="control">
      <disturbance ID="2007072518_134N_1102E">
        <cycloneName>George</cycloneName>
        <cycloneNumber>1</cycloneNumber>
        <localID>EPS0001</localID>
        <basin>Southern Hemisphere</basin>
        <fix hour="0">
          <validTime>2007-07-25T12:00:00Z</validTime>
          <latitude units="deg N">13.2</latitude>
          <longitude units="deg E">110.0</longitude>
          <cycloneData biasCorrected="true">
            <development>tropical cyclone</development>
            <minimumPressure>
              <pressure units="hPa" precision="1.">989.</pressure>
              <accuracy units="hPa">0.5</accuracy>
            </minimumPressure>
            <maximumWind>
              <speed units="m/s" precision="0.2">49.8</speed>
              <averagingPeriod units="min">10.</averagingPeriod>
              <radius units="km">25.2</radius>
            </maximumWind>
          </cycloneData>
        </fix>
        <fix hour="6">
          <validTime>2007-07-25T18:00:00Z</validTime>
          <latitude units="deg N">13.2</latitude>
          <longitude units="deg E">110.0</longitude>
          <cycloneData biasCorrected="false">

(etc.)

            <maxPrecip>
              <intensity units="mm/h">68.</intensity>
              <latitude units="deg N">13.05</latitude>
              <longitude units="deg E">110.25</longitude>
              <precipType>rain</precipType>
            </maxPrecip>
          </cycloneData>
        </fix>
      </disturbance>
    </data>
</cxml>
```

Appendix 3: CXML schema

The schema gives the structure and "rules" for the CXML files, and is still being finalized. In particular it does not yet contain information on the WMO Core Metadata Profile, and further utilization of GML syntax may be desirable.

The schema can be viewed on the CXML web page http://www.bom.gov.au/bmrc/projects/THORPEX/CXML/index.html.

Basic information on XML file structure and XML schemas is available on the W3Schools page http://www.w3schools.com/default.asp.

Appendix 4: Recommended data units in CXML

Although not enforced by the CXML schema, it is recommended that the units of measurement in CXML files adhere to the following standards to allow ease of recognition and conversion. Following ISO 31 SI units should be used where practical, and preferred abbreviations are indicated.

Table 5.1. Units of length

Full name of units	Text abbreviation(s)
meter	m
kilometer	km
mile (non-SI)	mi
nautical mile (non-SI)	nm

Table 5.2. Units of time

Full name of units	Text abbreviation(s)
second	s
minute	min
hour	h
day	d

Table 5.3. Units of speed

Full name of units	Text abbreviation(s)
meters per second	m/s (preferred), m s-1
kilometers per hour	km/h (preferred), km h-1
miles per hour (non-SI)	mi/h (preferred), mi h-1
nautical miles per hour (knots) (non-SI but accepted for use in SI)	kt (preferred), kn

Table 5.4. Units of geographical position (latitude and longitude)

Full name of units	Text abbreviation(s)
degrees	deg (longitudes between -180 to 180, positive east of the Greenwich meridian; latitudes between -90 and 90, positive north of the Equator)
degrees north	deg N
degrees south	deg S
degrees east	deg E
degrees west	deg W

Table 5.5. Units of pressure

Full name of units	Text abbreviation(s)
Pascal	Pa
hectopascal (millibar)	hPa (preferred), mb

Table 5.6. Units of direction and angle

Full name of units	Text abbreviation(s)
degrees clockwise from true north	deg true
gradians (100th of 90 degree angle)	grad
radians	rad

Table 5.7. Units of precipitation rate

Full name of units	Text abbreviation(s)
millimeters per hour	mm/h (preferred), mm h-1
millimeters per day	mm/d (preferred), mm d-1
meters per hour	m/h (preferred), m h-1
meters per day	m/d (preferred), m d-1
inches per hour (non-SI)	in/h (preferred), in h-1
inches per day (non-SI)	in/d (preferred), in d-1

Appendix 5: Future compliance with Geography Markup Language (GML)

GML has evolved extensively in the last decade to become a widely used XML format whenever geographic information is required (OGC 2007). To ease the exchange of cyclone data with some non-meteorological clients, and anticipating possible recommendations of the WMO Expert Team on the Assessment of Data Representation Systems, it may be desirable in the future to develop a version of CXML that makes greater use of GML syntax and constructs.

A meteorological example of a GML application is the Climate Science Markup Language (CSML) described by Woolf and Lowe (2007). Another is MarineXML, which applies CSML, and by extension GML, to the description of marine data (UNESCO 2007). The Met Office has recently begun to investigate GML as a technology for geospatial data interoperability, both for its own use and for communication with external clients (Met Office 2006a, 2006b).

We are aware of ongoing development of a schema for moving features (ISO 19141) that can be represented in GML (WMO 2005). This may be an appropriate way to represent data associated with cyclones.

It is possible using XSLT (EXtensible Stylesheet Language Transformations) to transform data files from CXML into GML. Users wishing to make use of GML constructs could employ such a conversion as a preprocessing step. Alternatively, a separate version of CXML may be developed as a GML application, meaning that it makes use of GML syntax where appropriate, and XML otherwise. The example below, modified from the second example in Appendix 2, shows what a GML version of cyclone data might look like.

```
<?xml version="1.0" encoding="UTF-8"?>
<cxml xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:gml="http://www.opengis.net/gml
xsi:schemaLocation="http://www.bom.gov.au/bmrc/projects/THORPEX/CXML
http://www.bom.gov.au/bmrc/projects/THORPEX/CXML/cxml.0.1.xsd">

   <header>
      <product>Cyclone Forecast</product>
      <generatingApplication>
         <applicationType>Manual hurricane forecast</applicationType>
      </generatingApplication>
      <productionCenter>NWS
         <subCenter>National Hurricane Center</subCenter>
      </productionCenter>
      <moreInfo>http://www.nhc.noaa.gov/</moreInfo>
      <moreMetadata>http://www.nhc.noaa.gov/TCfcst/metadata.html</moreMetadata>
      <baseTime>
         <gml:validTime>
            <gml:TimeInstant>
               <gml:timePosition>2007-07-25T12:00:00Z</gml:timePosition>
            </gml:TimeInstant>
         </gml:validTime>
      </baseTime>
      <creationTime>
         <gml:validTime>
            <gml:TimeInstant>
               <gml:timePosition>2007-07-25T12:00:00Z</gml:timePosition>
```

```
         </gml:TimeInstant>
      </gml:validTime>
   </creationTime>
</header>

<data type="forecast">
   <disturbance ID="2007072518_134N_1102E">
      <cycloneName>George</cycloneName>
      <cycloneNumber>1</cycloneNumber>
      <localID>NHC0001</localID>
      <basin>Indian Ocean</basin>
      <objectiveTechnique>BLND</objectiveTechnique>
      <fix hour="6">
         <validTime>
            <gml:TimeInstant gml:id="t">
               <gml:timePosition>2007-07-25T18:00:00Z</gml:timePosition>
            </gml:TimeInstant>
         </validTime>
         <position>
            <gml:point gml:id="p" srsName="urn:ogc:def:crs:EPSG:6.6:4283">
               <gml:pos>-110.2,13.4</gml:pos>
            </gml:point>
         <position>
         <cycloneData biasCorrected="TRUE">
            <development>tropical cyclone</development>
            <minimumPressure>
               <pressure uom ="hPa" precision="1.">989.</pressure>
               <accuracy uom ="hPa">0.5</accuracy>
            </minimumPressure>
            <maxWind>
               <gml:speed uom="m/s">49.8</gml:speed>
               <gml:point gml:id="p" srsName="urn:ogc:def:crs:EPSG:6.6:4283">
                  <gml:pos>-110.13,13.24</gml:pos>
               </gml:point>
               <radius uom="km">25.2</radius>
            </maxWind>
            <lastClosedIsobar>
               <pressure uom="hPa">1002.3</pressure>
               <radius uom="km">600.</radius>
            </lastClosedIsobar>
            <stormMotion>
               <gml:angle uom ="degrees">210.</gml:angle>
               <gml:speed uom="m/s">50.</gml:speed>
            </stormMotion>
            <maxSeas uom="m">40.</maxSeas>
            <windContours>
               <windSpeed>
                  <gml:speed uom="kt">34</gml:speed>
                  <geometry srsName="urn:ogc:def:crs:EPSG:6.6:4283">
                     <gml:polygonMember>
                        <gml:Polygon>
                           <gml:outerBoundaryIs>
                              <gml:LinearRing>
                                 <gml:coordinates>
                                    -110.2, 15.4
                                    -111.3, 14.7
                                    -112.7, 13.4
                                    -111.7, 11.6
                                    -110.2, 10.4
                                    -109.7, 12.2
                                    -109.0, 13.4
                                    -109.8, 14.3
                                 </gml:coordinates>
                              </gml:LinearRing>
```

```
                        </gml:outerBoundaryIs>
                     </gml:Polygon>
                  </gml:polygonMember>
               </geometry>
            </windSpeed>
            <windSpeed>
               <gml:speed uom="kt">50</gml:speed>
               <geometry srsName="urn:ogc:def:crs:EPSG:6.6:4283">
                  <gml:polygonMember>
                     <gml:Polygon>
                        <gml:outerBoundaryIs>
                           <gml:LinearRing>
                              <gml:coordinates>
                                 -110.2, 14.4
                                 -111.0, 13.8
                                 -111.7, 13.4
                                 -111.2, 12.3
                                 -110.2, 11.6
                                 -109.9, 12.2
                                 -109.5, 13.4
                                 -109.8, 13.8
                              </gml:coordinates>
                           </gml:LinearRing>
                        </gml:outerBoundaryIs>
                     </gml:Polygon>
                  </gml:polygonMember>
               </geometry>
            </windSpeed>
            <windSpeed>
               <gml:speed uom="kt">63</gml:speed>
               <radius uom="km">64.</radius>
            </windSpeed>
         </windContours>
         <seaContours>
            <waveHeight uom="m">10
               <radius uom="km">200.</radius>
            </waveHeight>
            <waveHeight uom="m">20
               <radius uom="km">120.</radius>
            </waveHeight>
         </seaContours>
      </cycloneData>
    </fix>
  </disturbance>
 </data>
</cxml>
```