

# Climate Data Management Systems (CDMS)

## Status and Strategy

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*Bruce Bannerman*

*Co-chairs of the Expert Team on Climate Data Management Systems (ET-CDMS)*

WEATHER CLIMATE WATER  
TEMPS CLIMAT EAU



**WMO OMM**

**World Meteorological Organization**

**Organisation météorologique mondiale**

# To discuss

- State of global climate data management
  - In 2012
  - What is the status today ?
- Vision and strategy
  - Thinking Globally
  - Acting nationally

A CDMS, Climate Data Management System, is an **integrated computer-based system** that facilitates the effective **archival, management, analysis, delivery and utilisation** of a wide range of integrated climate data

# 2012 : CDMS Status in NMHS

CCI survey with 72% of response rate :



Have operational issues



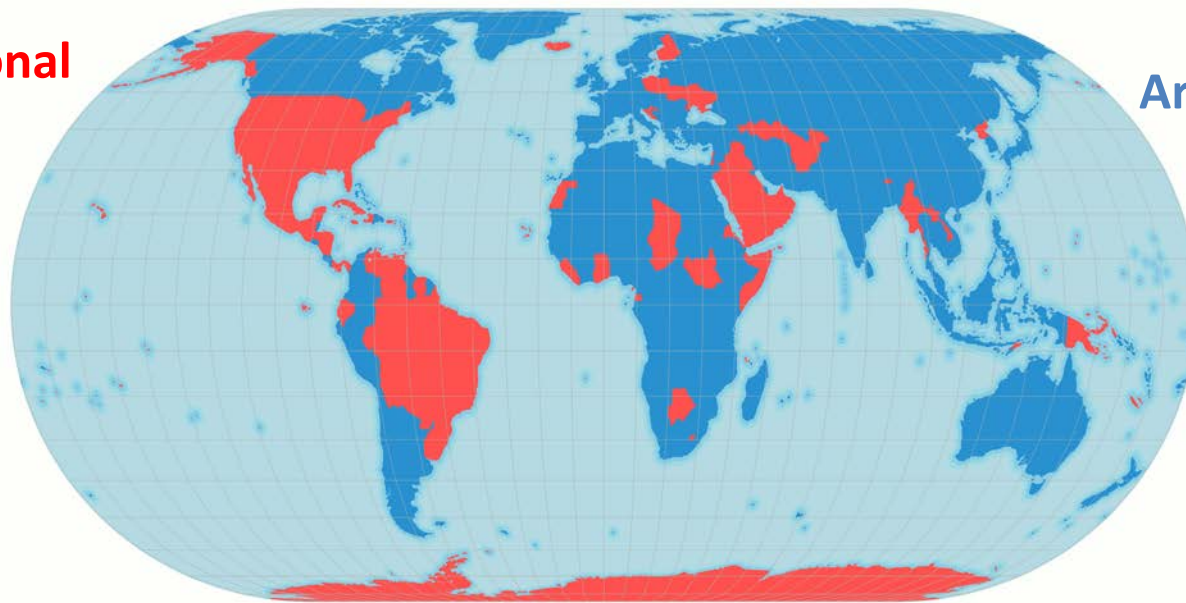
Do not use a database



Have developed their own CDMS

Responded to CDMS Survey

2012 CDMS Survey



Are not operational



Use a spreadsheet



Would like to change their CDMS

Estimated in 2017 : 89 CDMS developed for national purposes

Analysis of 2012 CDMS Survey results:  
Denis Stuber, MétéoFrance

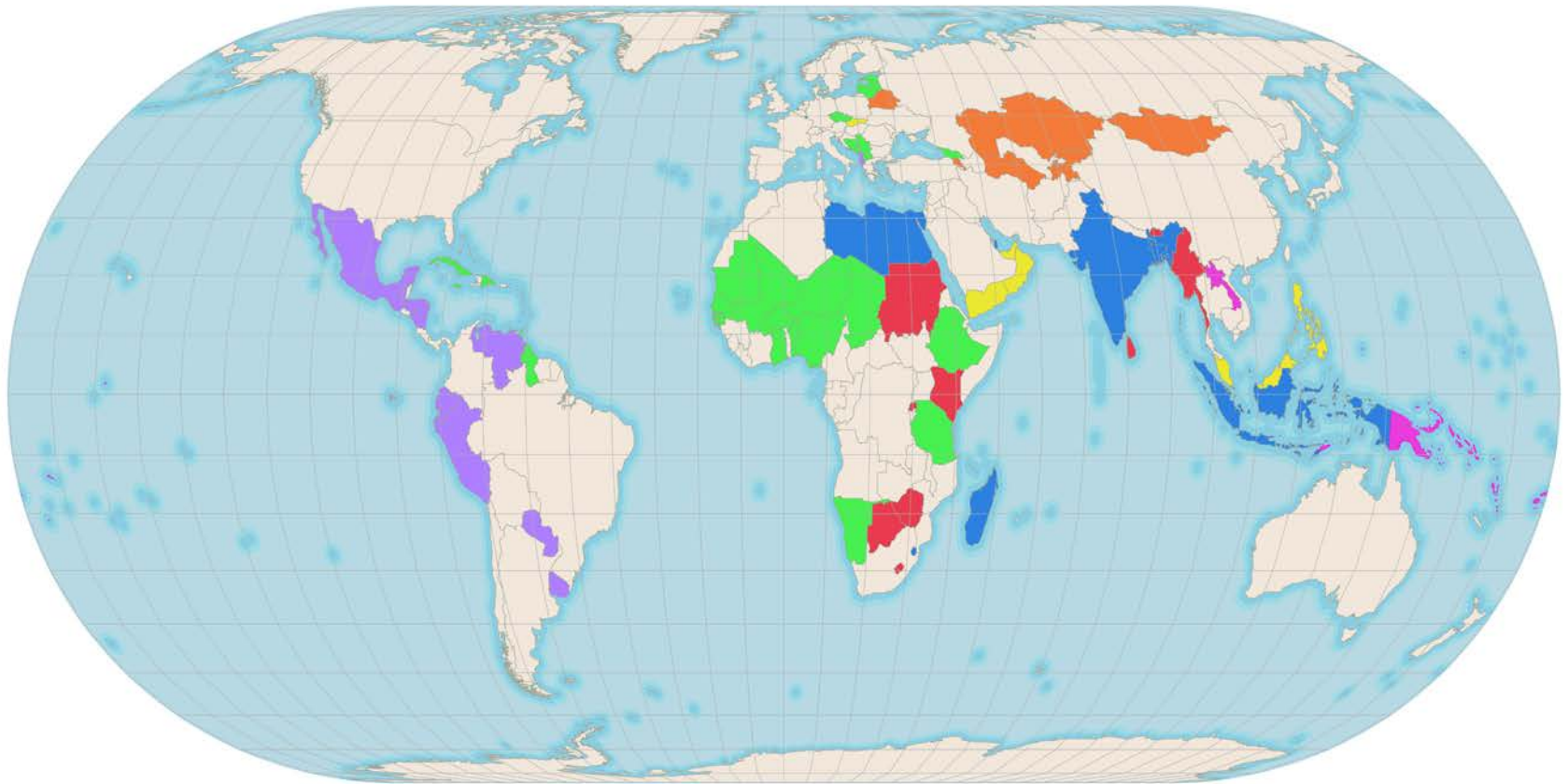
Cartography:  
Bruce Bannerman, Geoinnovations Pty Ltd

March 2018



# 2017 : Distribution of named CDMS

as at June 2017



7 CDMS for 86 implementations - 3 Open source CDMS for 42 developing countries

## CDMS

Custom developed CLIDATA CLIDE CLIMSOFT CLISYS CLIWARE IMS MCH

*Data source: CDMS suppliers*

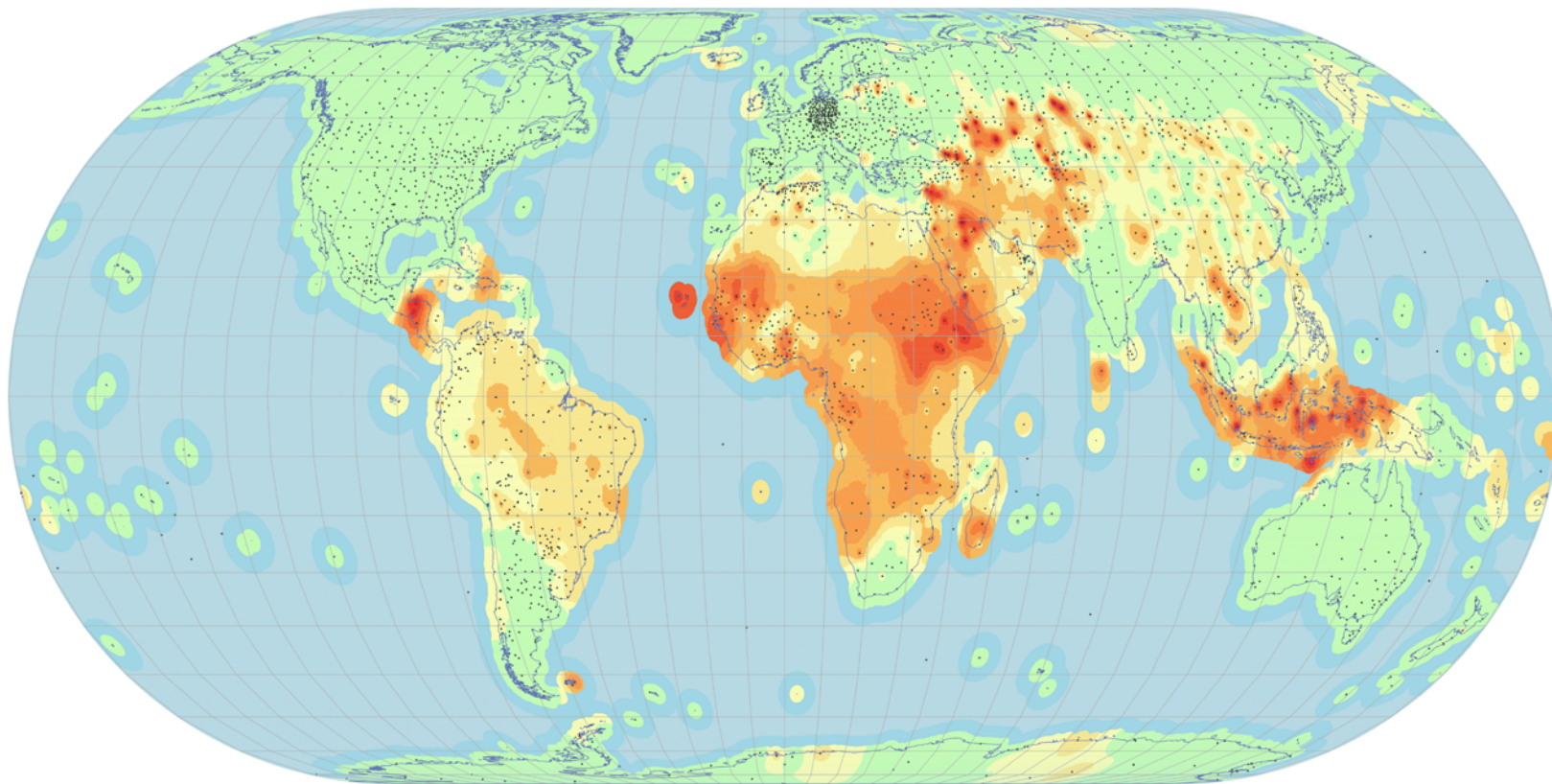


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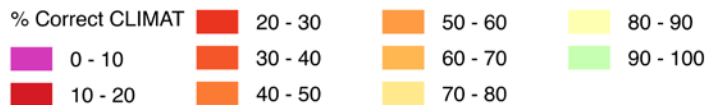
# How effective are we at climate data management globally?

% correct global CLIMAT messages received

10 year average 2007 - 2016



## Legend



Estimate of the trend of historical CLIMAT messaging using spatial autocorrelation.

Analysis of historical CLIMAT messages:  
Christiana Lefebvre, Deutscher Wetterdienst (DWD)

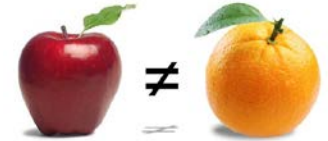
Spatial Analysis and Cartography:  
Bruce Bannerman, Geoinnovations Pty Ltd



September 2017

# Summary of key CDMS issues

- For **190 countries** there are approximately **96 different CDMS**;
- Current CDMS have been developed in the **absence of formal specifications**. Therefore they have different and inconsistent capabilities;
- In 2012, **48% of the survey respondents had operational issues** with their CDMS. Difficulties are also reflected by the 10 year statistics on CLIMAT messages ;
- **42 Developing Countries** rely on an open source CDMS that is **at risk of failure** because (1) severely **limited funds for maintenance and development** and (2) **Key person dependencies** with typically only one developer per system.



Significant CDMS improvements are required globally, It will be very expensive and wasteful of resources to develop the same functionality for each current CDMS



# We can fix this!

## But we need to work together, collaboratively.

### CDMS Strategy Vision

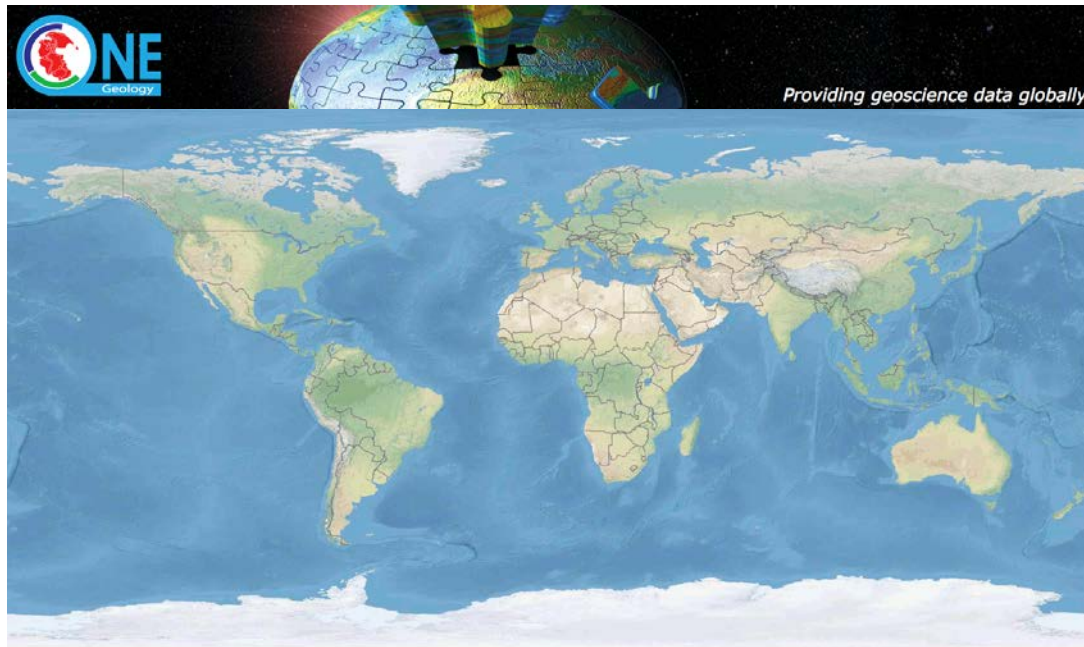
Achieve a step-change in the management of climate data by:

**Thinking globally** of what climate data management capability is required to answer many questions of societal need; and

**Acting nationally** to implement and evolve consistent and sustainable CDMS that will address national requirements for climate data, and in addition help to address regional and global needs.

# 10+ year Vision

## Federated Climate Data Services



### An example of the Federated Data Service Concept

Derived from the OneGeology geoscience community

***Consistent with WIS-2 future direction***



A climate researcher wishes to undertake an annual climate forecast analysis.

The climate researcher initiates an automated process that downloads observations data and associated observations metadata for all available countries in the world.

All data conforms to the WMO climate observations logical data model and application schema, with a known structure and semantics.

The data is automatically loaded into the researcher's CDMS.

The researcher undertakes the required analysis without having to waste considerable time worrying about the semantics and formatting of the source data.

# To give to NMHS foundations for Climate Services

Guide to Climatological Practices  
WMO-No. 100

CDMS Specifications  
WMO-No. 1131

future Manual on High Quality  
Global Data Management  
Framework

Framework that defines the requirements of a modern CDMS, that will ensure high quality climate data : consistent, authoritative, valued, trusted and easily accessible for global, regional and **national use**.



Infrastructure  
and  
Transportation  
Management



Disaster  
Resilience



Water  
Resources  
Management



Energy and  
Mineral  
Resource  
Management



Sustainable  
Urban  
Development



Food Security  
and Sustainable  
Agriculture



Public  
Health  
Surveillance



Biodiversity  
and Ecosystem  
Sustainability



WMO OMM

# ET-CDMS Policy Statement (November 2015 Prague)

## ➤ ET-CDMS notes that:

- Currently, significant investment is needed to maintain a multitude of CDMS worldwide to generate data for regional and global analyses.
- These CDMS are not compliant with the new **WMO-No.1131**, Climate Data Management Systems Specifications.
- Significant investment will be required to conform to the requirements of **WMO-No. 1131**.
- It will be very expensive and wasteful of resources to develop the same functionality in many CDMS.
- There are several open source CDMS used by WMO Members.
- There is considerable potential to address this situation by rationalising these open source CDMS.

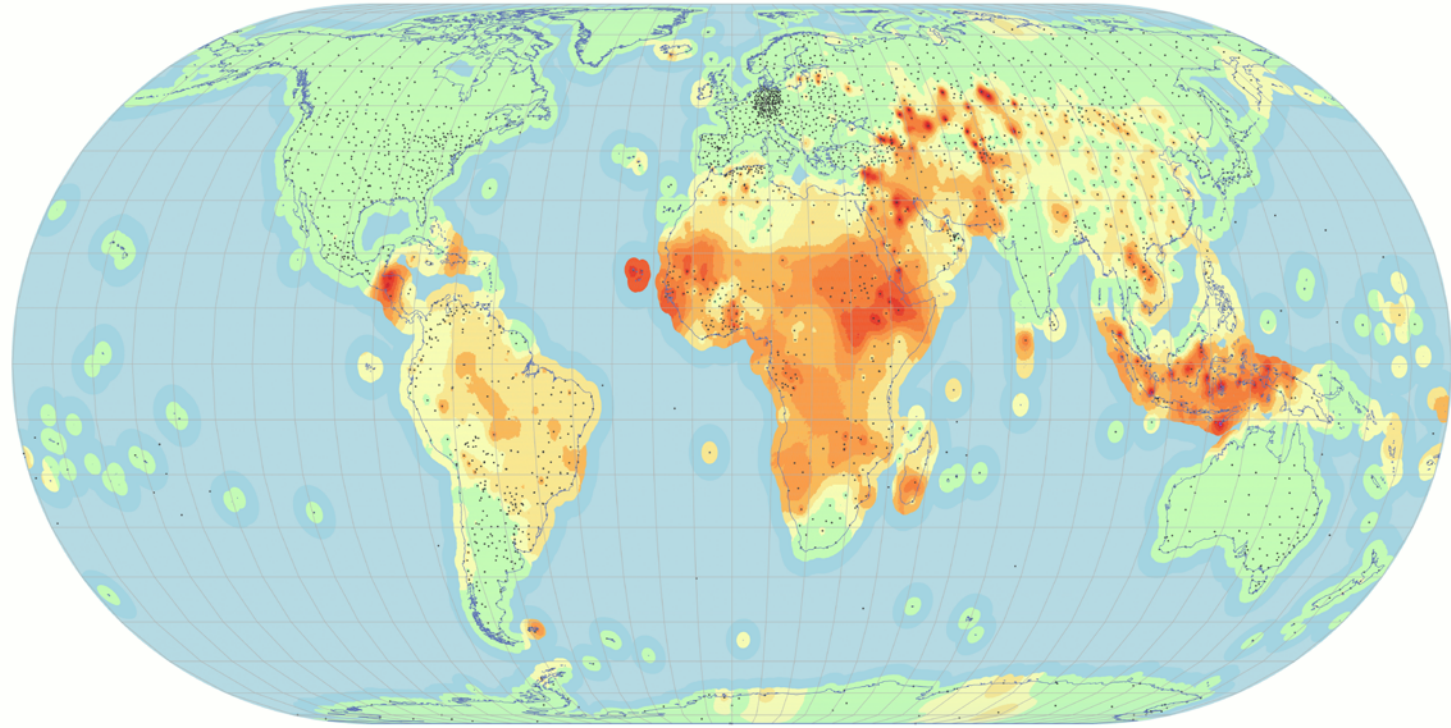
## ➤ Therefore ET-CDMS proposes that:

- Open source CDMS should converge on one Reference Open Source CDMS, namely Open-CDMS.
- Investment is required to make this happen.



# Act, urgently, on an operational, consistent and sustainable system : towards a **Reference Open Source CDMS**

% correct global CLIMAT messages received  
10 year average 2007 - 2016



Legend

% Correct CLIMAT	<span style="color: red;">■</span> 20 - 30	<span style="color: orange;">■</span> 50 - 60	<span style="color: yellow;">■</span> 80 - 90
	<span style="color: magenta;">■</span> 0 - 10	<span style="color: orange;">■</span> 30 - 40	<span style="color: lightgreen;">■</span> 90 - 100
	<span style="color: red;">■</span> 10 - 20	<span style="color: orange;">■</span> 40 - 50	<span style="color: yellow;">■</span> 70 - 80

Estimate of the trend of historical CLIMAT messaging using spatial autocorrelation.

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September 2017

# شكرا, 谢谢, Thank you, Merci, Спасибо, Gracias

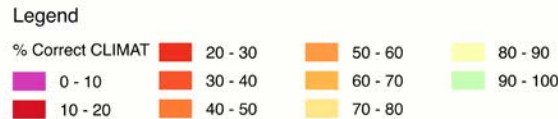
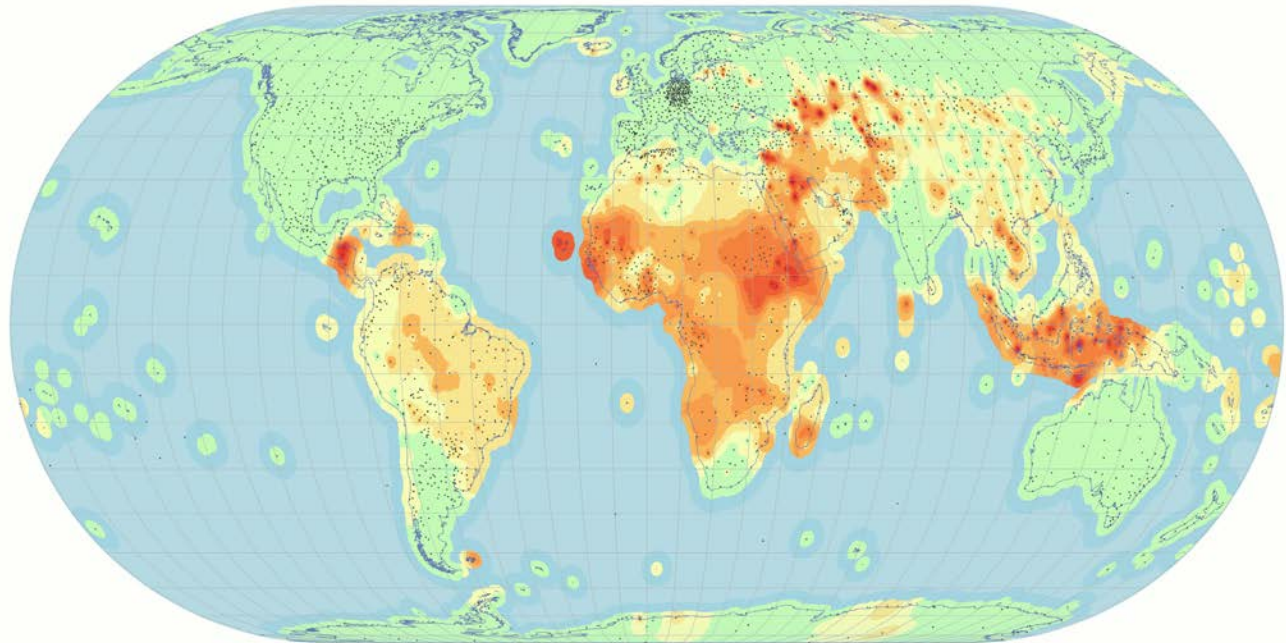
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10 year average 2007 - 2016



CDMS contact :  
[cdms.info@wmo.int](mailto:cdms.info@wmo.int)

# Acknowledgements

- **WMO-N0 1131, and subsequent follow up work undertaken in close collaboration by:**
  - **Bruce Bannerman**, formerly of Australian Bureau of Meteorology
  - **Denis Stuber**, Météo-France
- **Supported by:**
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  - **William Wright**, Australian BoM and CCI Management Group
  - ET-CDMS Teams 2010-1014 and 2014-2018
    - **Radim Tolasz**, Czech Hydrometeorological Institute
    - **Rachid Sebbari**, Direction Météorologie Nationale du Maroc
    - **Stephen Palmer** and **Karen McCourt**, United Kingdom Meteorological Office
    - **Anyuan Xiong** , China Meteorological Administration
    - **Hernán Veiga** , Argentina
    - **Joffrey Boekhoudt**, Curacao
    - And also:
      - **John Flannery**, Australian Bureau of Meteorology
- **In inter-action with Expert Teams:**
  - on Wigos Metadata (**TT-WMD**), on Education and Training (**ET-ETR**), on Climate Services Information System (**ICT-CSIS**), and on Data Rescue (**ET-DARE**), and different teams of the Information Systems and Services (**OPAG ISS**)



# Useful

- Wiki of the CCI Expert-Team on Climate Data Management Systems, <https://wiswiki.wmo.int/tiki-index.php?page=CDMS>
- Climate Data Management Systems Specifications (WMO-No 1131), [https://library.wmo.int/opac/index.php?lvl=notice\\_display&id=16300](https://library.wmo.int/opac/index.php?lvl=notice_display&id=16300)
- Climate Data Management Systems: Status of implementation in developing countries, [https://www.researchgate.net/publication/278063397\\_Climate\\_Data\\_Management\\_Systems\\_Status\\_of\\_implementation\\_in\\_developing\\_countries](https://www.researchgate.net/publication/278063397_Climate_Data_Management_Systems_Status_of_implementation_in_developing_countries)
- Status of worldwide implementation of CDMS in NMHS (2013), <http://www.wmo.int/pages/prog/wcp/wcdmp/documents/SummaryReport.doc>
- Concept of Operation of High Quality Global Data Management Framework for Climate, HQ-GDFMC, (Draft) , <http://www.wmo.int/pages/prog/wcp/ccl/opace/opace1/documents/HQ-GDMFC-CONOPS-VER2.5-31Mars2016-1.pdf>

# Who uses our climate data?

- Not just NMHS and WMO!
- Climate data is used widely across many areas of society to support a wide variety of decision making processes
- Examples using GEO's Societal Benefit classifications

- **Water Resources Management**



- A water manager can analyse climate forecasts for the coming seasons, together with historical rainfall over a catchment to determine if water restrictions should be implemented and enforced

- **Food Security and Sustainable Agriculture**



- A farmer can analyse climate forecasts for a predicted El Nino event that indicates that his property could be affected by drought. He reviews historical conditions over his farm to understand the risks of planting seed and selling stock for the coming season

- **Public Health Surveillance**



- An epidemiologist can analyse the relationship between disease outbreaks and prevailing climatic conditions over a region in order to provide early warning of an increased risk of disease, e.g. malaria

# Who uses our climate data? #2

## – Disaster Resilience



- An Emergency Services analyst can investigate the relationship between vegetation curing, forecast and historical climatic conditions, in order to plan bushfire risk mitigation actions for the coming season

## – Energy and Mineral Resource Management



- A renewable energy analyst can review historical solar radiation data for a region in order to determine what type of solar system is best suited for their client

## – Infrastructure and Transportation Management



- A Civil Engineer can analyse the historical potential for rain and floods over the areas shortlisted for a new road and bridge project to determine the optimal locations

## – Biodiversity and Ecosystem Sustainability



- A land manager can analyse climate change projections, together with historical climatic conditions for specific species so that they can better mitigate against potential climate change impacts

## – Sustainable Urban Development



- A City Planner can analyse the historical potential for rain and floods over the areas shortlisted for a proposed new housing development to determine whether approval should be granted for the development



# Other related work by ET-CDMS

- **Consolidating work on CDMS Specifications**
  - To support CDMS developers
    - User Stories
    - Conceptual Architecture
  - Register of identified changes
- **Undertake further CDMS surveys to provide metrics showing the impact of CDMS work**
- **Establish and maintain a CDMS Register**
  - Showing CDMS compliance with WMO #1131
  - Will use a technical survey, with results publicly available
- **Developed a policy statement on the need for open source CDMS development**



# What is missing

- Establish the WMO Climate Data Framework
  - Recommendation 11.1, WMO #1131
  - This could be within the next evolution of WIS
  - Based on Spatial Data Infrastructure principals (e.g. INSPIRE)
  - Resurrect work on foundation WMO logical data models and data definitions that was previously undertaken by IPET-MDRD
    - [METCE](#)
    - Climate Observations
    - [WMO Codes Registry](#)
  - Establish formal semantic data definitions for GCOS ECV
    - Based on METCE and WMO Codes Registry
  - Community Agreed WMO data policies e.g.
    - Definition of Data Quality Flags
    - Basic concepts
      - Rules on calculating Climatological Standard Normals
      - What is a climatological day
      - Rules to use when data is missing
      - etc



# What is missing #2

- Better Collaboration with other WMO teams
  - There has been very productive collaboration with the following teams:
    - CBS IPET-MDRD
      - Metadata and Data Representation Development
    - WIGOS TT-WMD
      - WIGOS (Observations) Metadata
    - CCI ET-DARE
  - There is an opportunity for other teams to work with us
    - A second version of WMO #1131 will be prepared next Intersessional Period
    - Are your team's requirements captured in WMO #1131
    - If not, what is missing?
- WMO #1131 compliant CDMS
  - We need to ensure adequate funding to develop and maintain compliant CDMS



# ET-CDMS Policy Statement

- ET-CDMS notes that:
  - Currently, significant investment is needed to maintain a multitude of CDMS worldwide to generate data for regional and global analyses.
  - These CDMS are not compliant with the new WMO-No.1131, Climate Data Management Systems Specifications.
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- Therefore ET-CDMS propose that:
  - Open source CDMS should converge on one Reference Open Source CDMS, namely Open-CDMS.
  - Investment is required to make this happen.



# GCOS Essential Climate Variables

## Formal Data Definitions are required!

ECV provide a good starting point for a formal set of data definitions

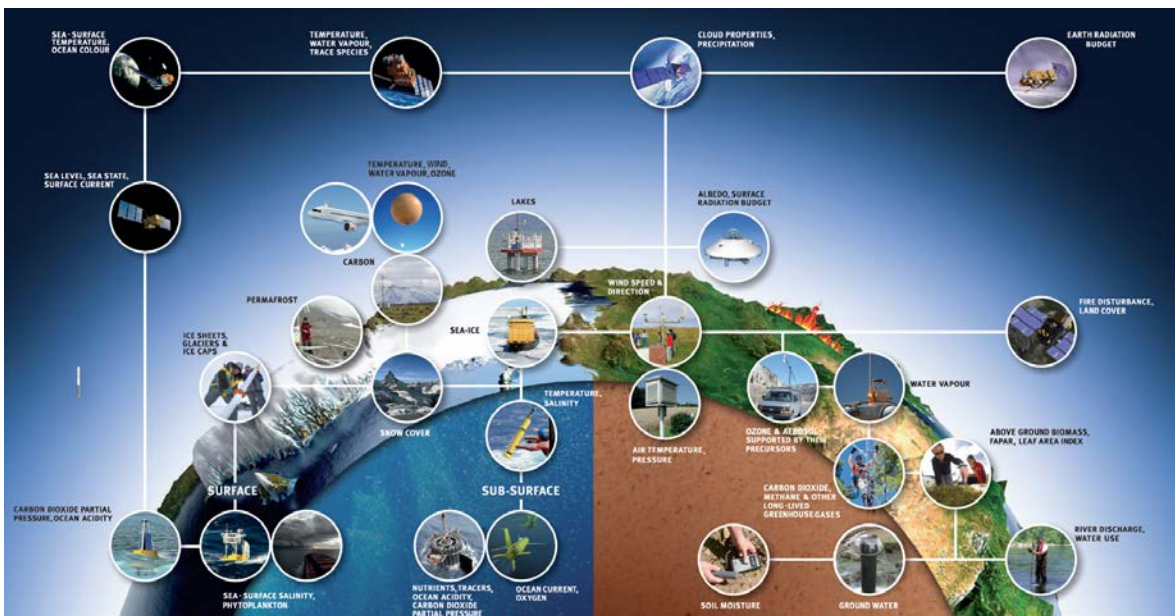
*“An ECV is a physical, chemical or biological variable or a group of linked variables that critically contributes to the characterization of Earth’s climate”*

Note: [GCOS Monitoring Principles](#), compare these with WMO #100 requirements

Observations data:

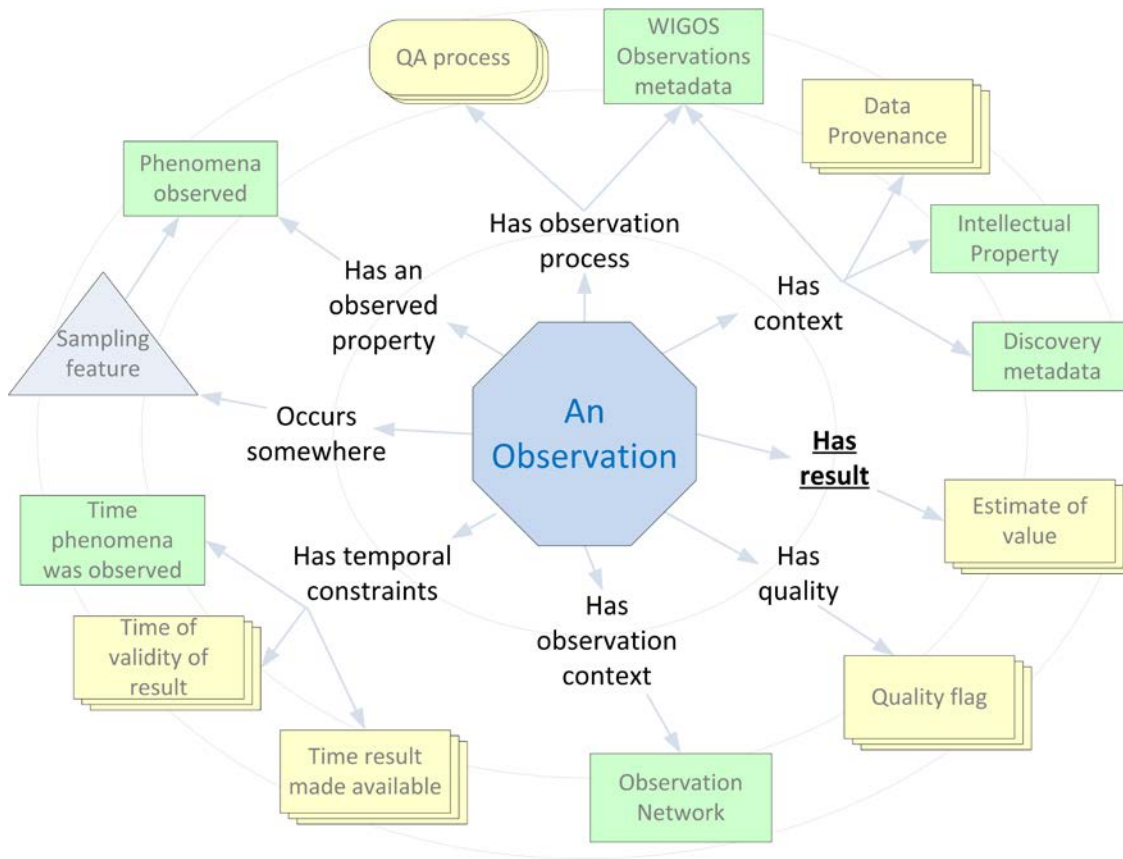
- We have a good start in data definition, e.g. [Temperature](#)
- However we need more
- Look at work by hydrology community within the OGC
  - [WaterML 2](#)

We need formal semantic data definitions to remove any dataset ambiguity and facilitate future federated global data services



# CDMS Conceptual Architecture

## An Observation



CDMS: An Observation  
Revision 0.4  
Bruce Bannerman and Denis Stuber  
30 Nov 2016

From current ET-CDMS work

### Conceptual diagram

- The context of an observation that we are interested in
- Based on concepts in ISO 19156 Geographic Information - Observations and Measurements
- Noting potentially long Quality Assurance life cycle
- The results of an observation may change over its lifecycle
- For future automated and federated data services, we need to ensure that these semantic and contextual nuances are formally defined

This architecture pattern is conformant with SDI requirements

# Supporting CDMS Developers: Example of CDMS Conceptual Architecture work CDMS Data Services

## Relationships between CDMS components

The same data services support many end uses

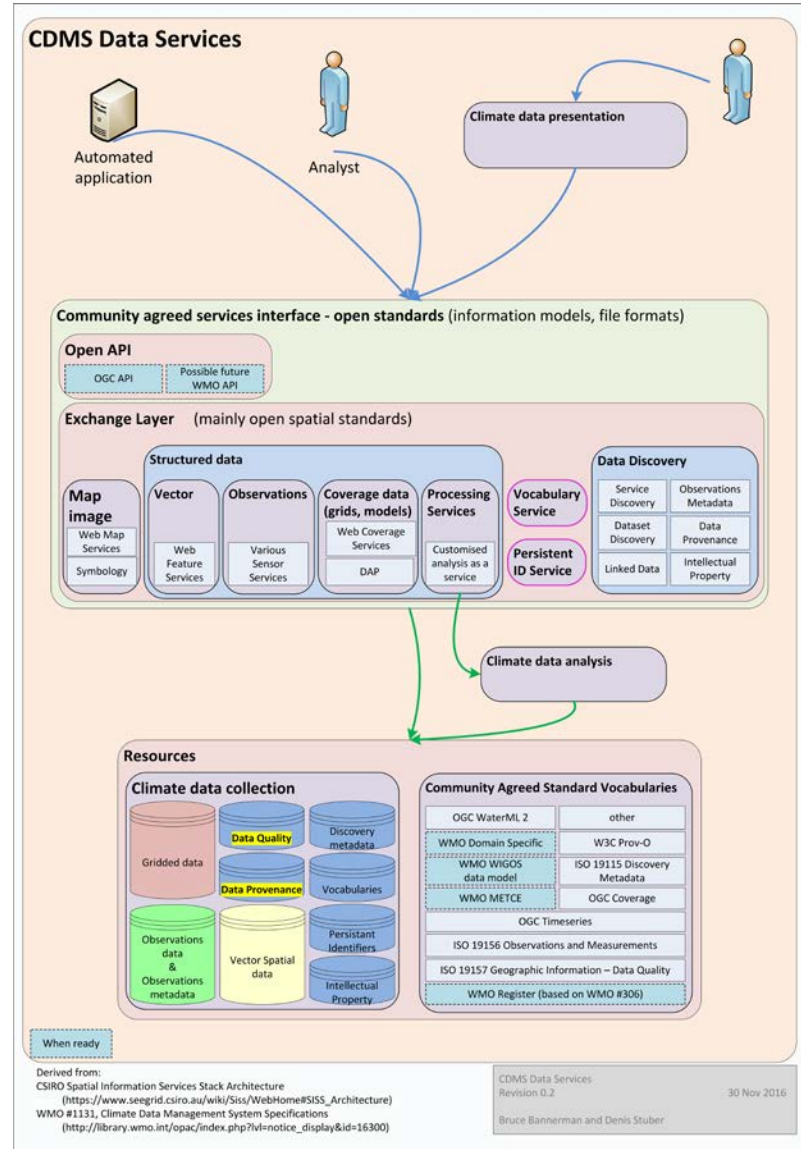
Well defined data service interfaces conform to open standards

Isolating end users from managed data

Reducing risk of vendor lock-in

Each climate data ECV is abstracted as one or more data services

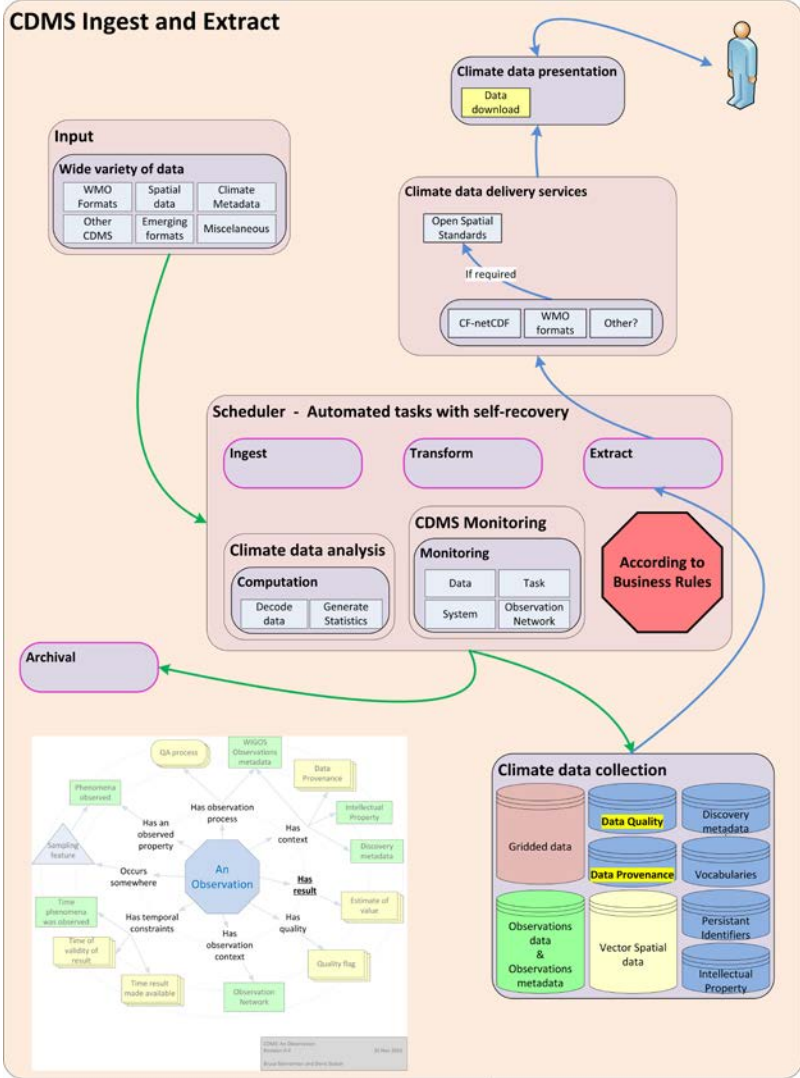
allowing ease of future IT change



# CDMS Conceptual Architecture

## Ingest and Extract

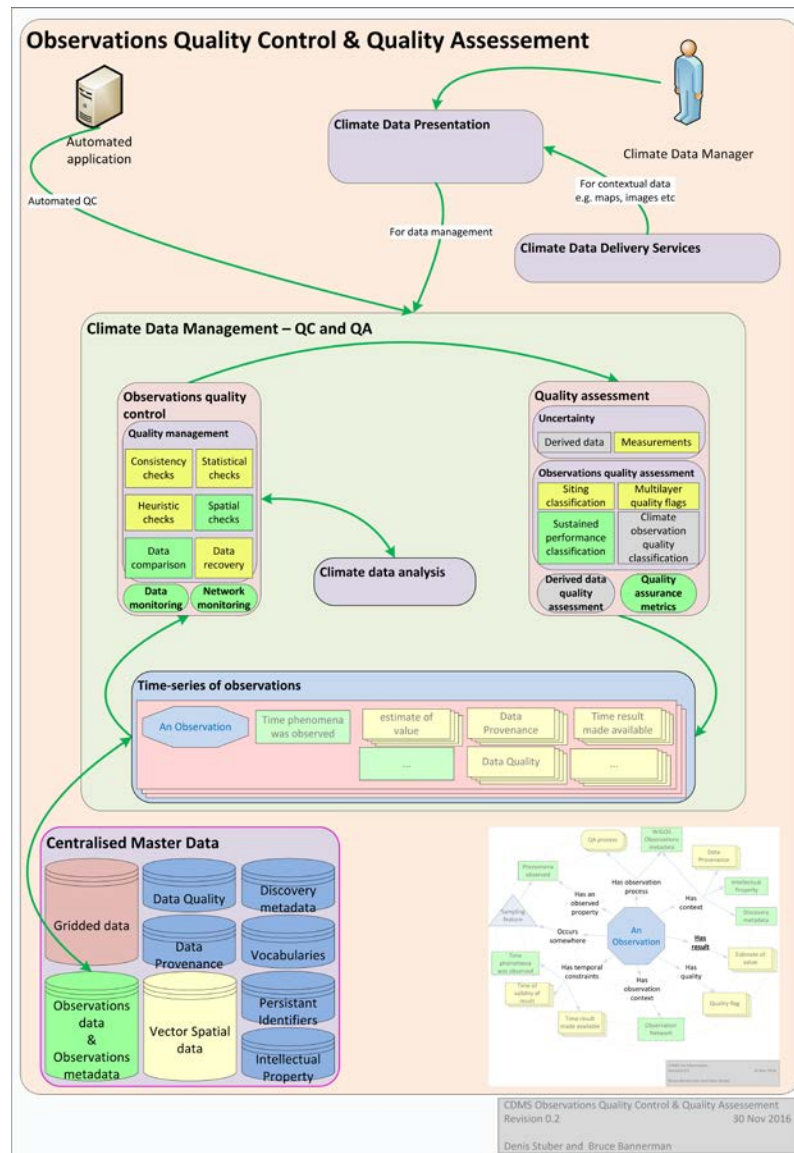
Showing relationships between CDMS Spec components



# CDMS Conceptual Architecture

## Observations QC & QA

Showing relationships between CDMS Spec components



# Global status of the CDMS that we are using? #2



Have operational  
issues



Are not  
operational



Do not use a  
database



Use a spreadsheet  
to manage data



Have developed  
their own CDMS

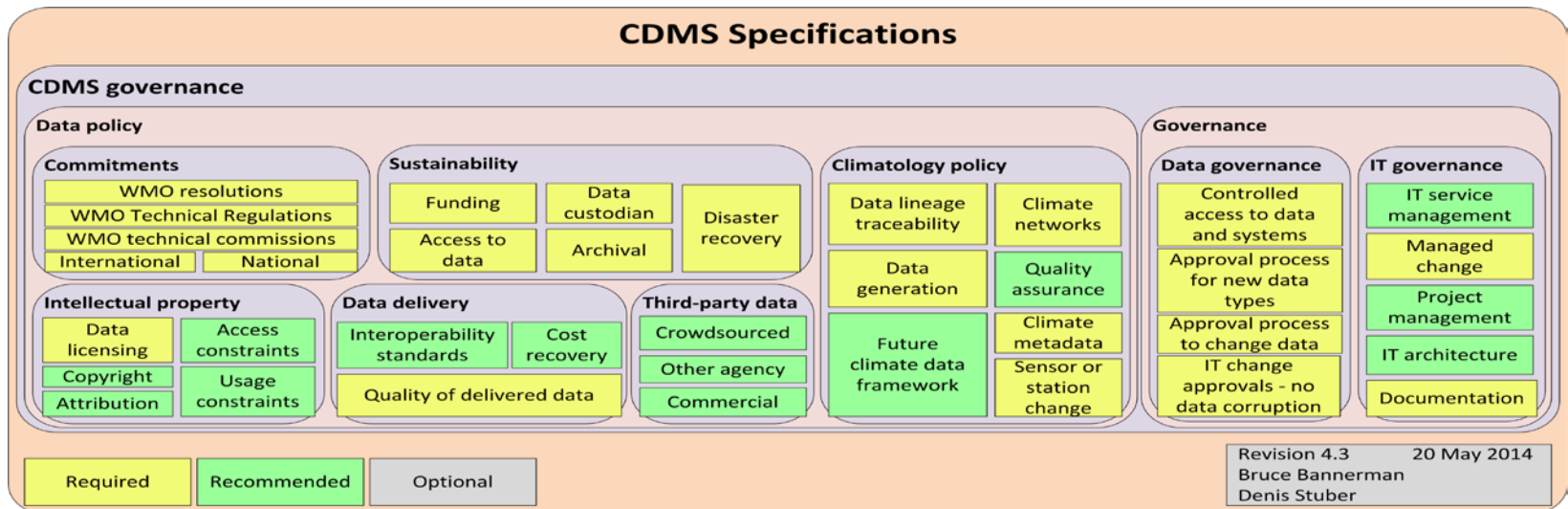


Would like to  
change their CDMS

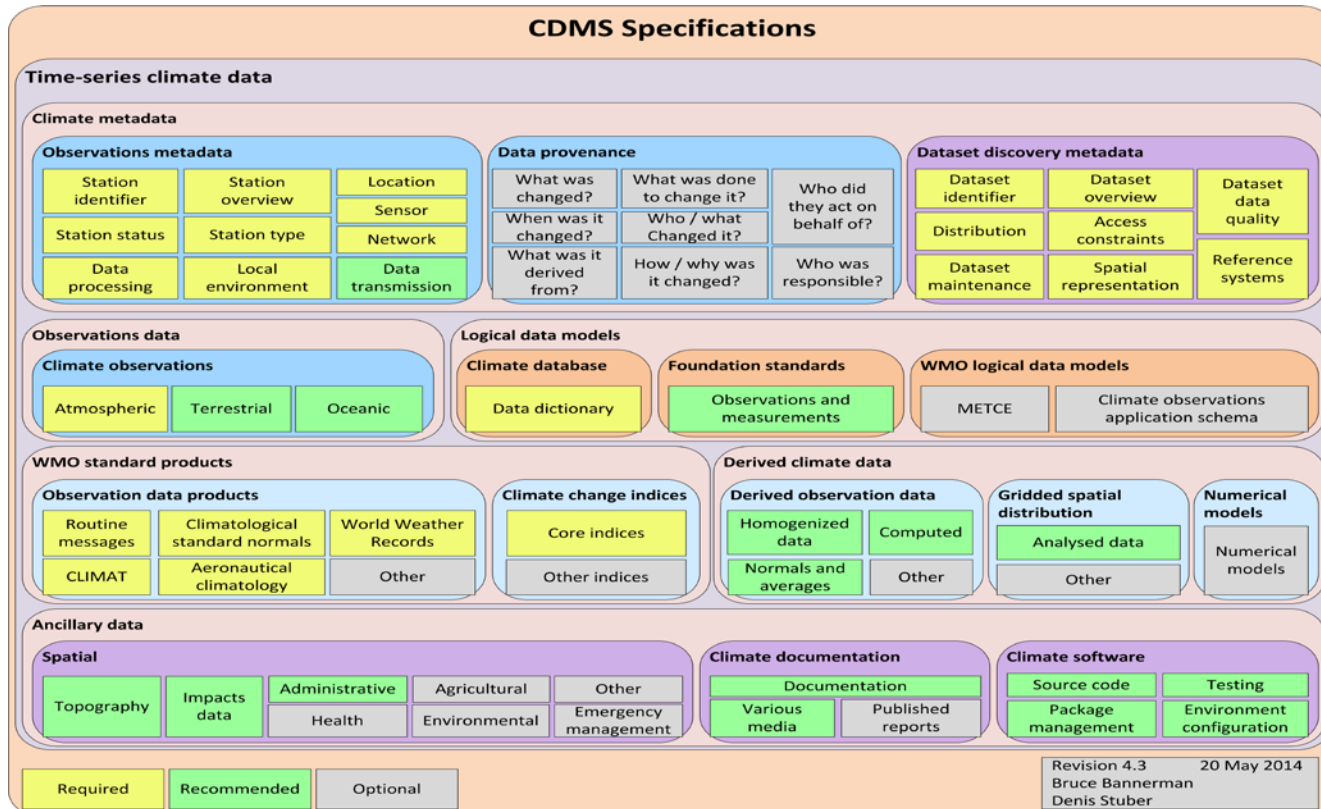
- A CDMS is an integrated computer-based system that facilitates the effective archival, management, analysis, delivery and utilisation of a wide range of integrated climate data
- Current climate data management systems that are labeled 'CDMS' have been developed in the absence of consistent specifications
  - Therefore they have different and inconsistent capabilities
  - We are not comparing apples with apples!
- CDMS in 42 Developing Countries
  - Rely on an open source CDMS that is at risk of failure
    - Severely limited funds for maintenance and development
    - Key person dependencies with typically only one developer
- For 190 countries there are **96 different CDMS**
- Significant CDMS improvements are required globally
  - It will be very expensive and wasteful of resources **to develop the same functionality for each current CDMS**



# CDMS Governance



# Time-series Climate Data



# Climate Data Management

## CDMS Specifications

### Climate data management

#### Ingest and extract

##### Data ingest

WMO messages	Business rules
Vector	Status log
Raster array	Automated with self-recovery
Other formats	Transform

Data extraction

#### Data rescue

##### Imaging

Document imaging

Optical character recognition

Chart digitization

##### Data entry

Forms

Key entry

Computation

##### Monitoring

Data rescue metrics

#### Observations quality control

##### Quality management

Consistency checks

Statistical checks

Heuristic checks

Spatial checks

Data comparison

Data recovery

Data monitoring

Network monitoring

#### Quality assessment

##### Uncertainty

Derived data

Measurements

##### Observations quality assessment

Siting classification

Multilayer quality flags

Sustained performance classification

Climate observation quality classification

Derived data quality assessment

Quality assurance metrics

#### Climate metadata

##### Manage climate metadata

Create

Maintain

Quality control

Metrics

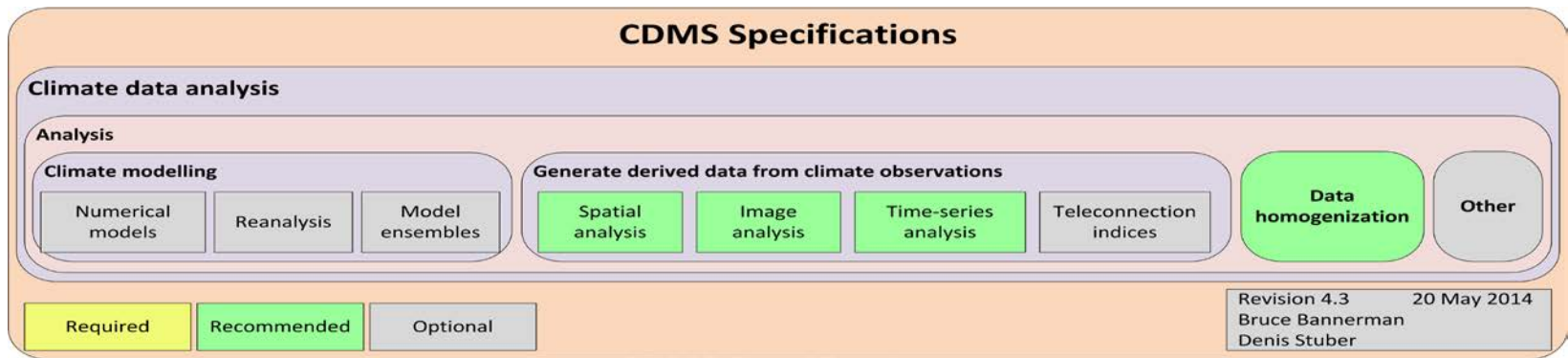
Required

Recommended

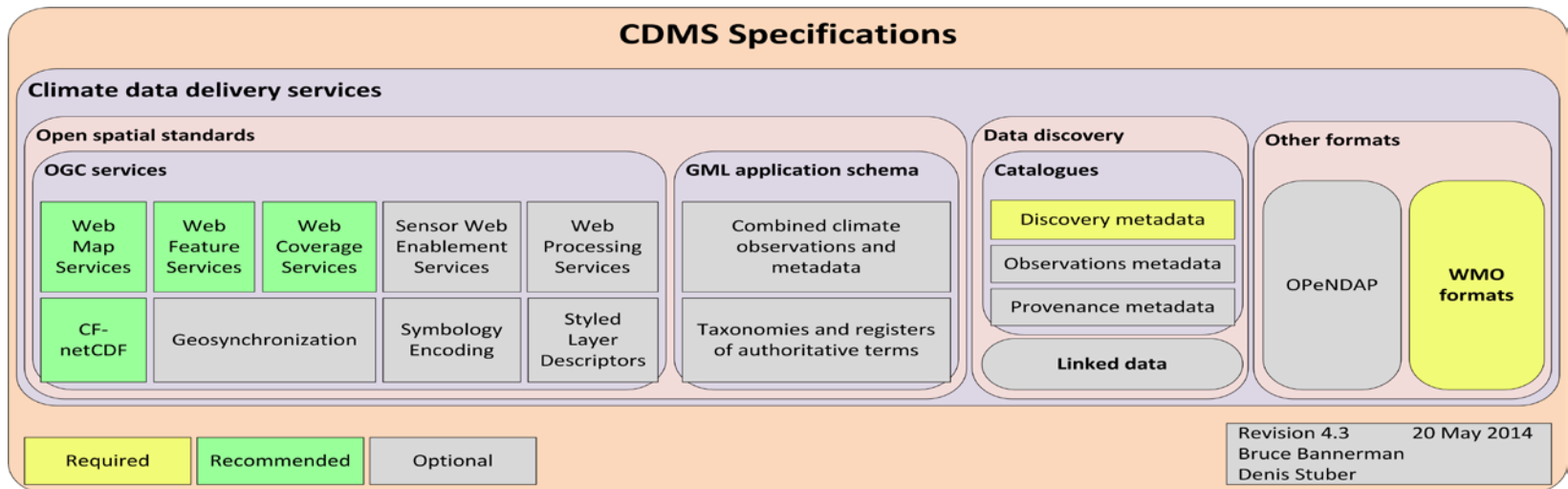
Optional

Revision 4.3 20 May 2014  
Bruce Bannerman  
Denis Stuber

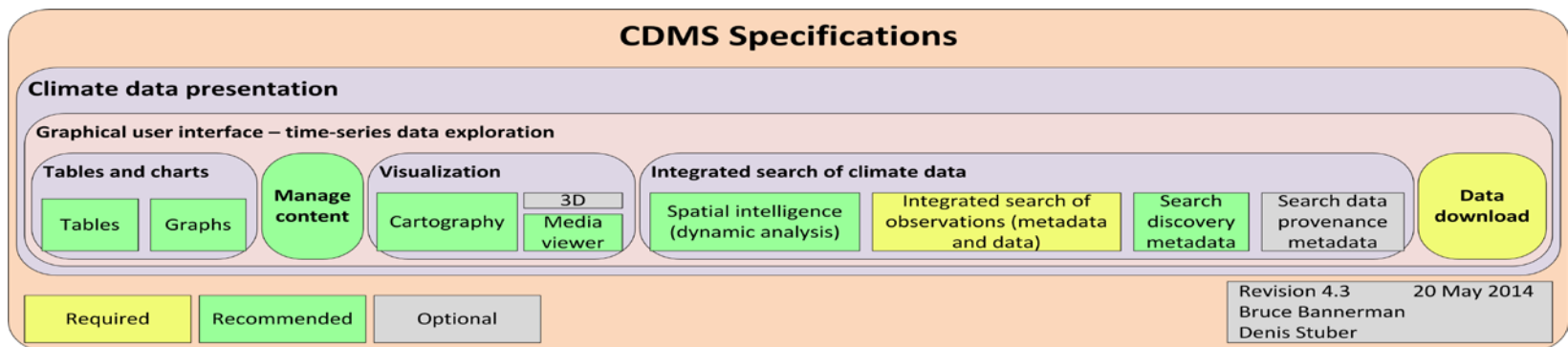
# Climate Data Analysis



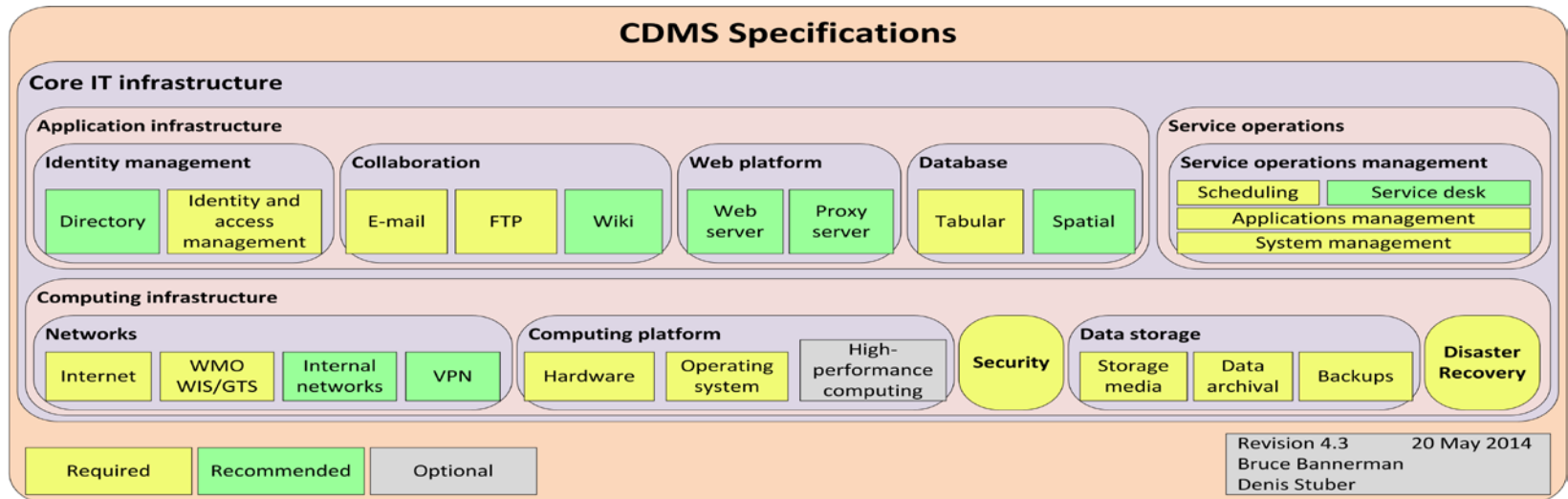
# Climate Data Delivery



# Climate Data Presentation



# Underlying IT Infrastructure





## How can society benefit from high quality climate data?



**A water manager** can decide to enforce water restrictions based on the climate forecast for the coming season and information on historical rainfall over a catchment.



**A farmer** can weigh the risks of planting certain seeds and crops for the coming season using the El Niño climate forecast and historical information about his property.



**An epidemiologist** can provide early warning on the increased risk of malaria by analyzing the relationship between disease outbreaks and prevailing climatic conditions over a region.



**An emergency services analyst** can plan bushfire risk mitigation actions for the coming season by investigating the relationship between vegetation curing, and forecast and historical climatic conditions.



**A renewable energy analyst** can select the best type of solar system for a client by reviewing historical solar radiation data for a region.



**A civil engineer** can determine the optimal location for a road and bridge project by analyzing the historical potential for rain and floods in particular areas.



**A land manager** can create a plan to mitigate climate change impacts on biodiversity and ecosystems by analyzing climate change projections and historical climatic conditions for certain species.



**A city planner** can consider whether a housing development proposal should be approved using information on the historical potential for rain and floods in the area.

## What do we need to generate and manage high quality climate data?

A **Climate Data Management System (CDMS)** is essential. A CDMS is a computer-based system, which facilitates the effective archiving, management, analysis, delivery and use of a wide range of integrated climate data.

## What is the current state of Global CDMS?

The WMO Expert Team on Climate Data Management Systems sent a survey to all 191 WMO Members, of which 72% responded. Survey results showed that:



Do not use a database



Use a spreadsheet to manage climate data



Have developed their own CDMS



Have operational issues



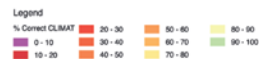
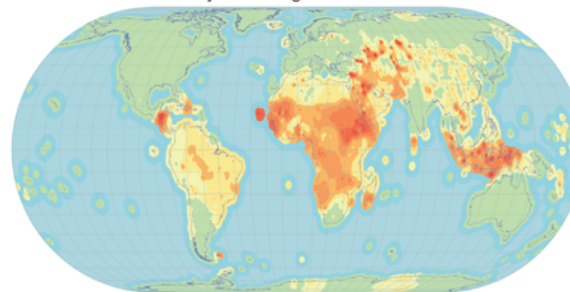
CDMS is not operational



Would like to change their CDMS

The difficulties in global climate data management conveyed in these statistics are also reflected in the map below, which shows the supply of climatological data reported by land-based observation sites to data centres from 2007-2016.

% correct global CLIMAT messages received  
10 year average 2007 - 2016



Estimate of the trend of historical CLIMAT messaging using spatial autocorrelation.  
Analysis of historical CLIMAT messages: Christiana Letzová, Deutscher Wetterdienst (DWD); Spatial Analysis and Cartography: Bruce Biermeier, GeoInformation Pty Ltd  
September 2017

## What can we do to improve global climate data management?

Most current systems that are referred to as CDMSs were developed in the absence of a formal definition of the functionality expected from a CDMS. Consequently, each system has different and inconsistent capabilities.

The WMO Climate Data Management System Specifications (WMO #1131) were developed to provide a clear definition of the functionality expected within a CDMS. WMO #1131 is approved as a WMO Standard.



“ WMO #1131 gave me an authoritative and convincing source for proposing improvements to our CDMS ... and ensuring that we are managing data in the best possible way for our customers and stakeholders. ”

- Charlotte McBride, South African Weather Service

Using a CDMS that complies with WMO #1131 and following the **WMO Guide to Climatological Practices (WMO #100)** will ensure high quality climate data that are consistent, authoritative, valued, trusted and easily accessible for global, regional and national use.

These actions will lead to **consistent, federated global climate data sets**. Climate scientists will then be able to minimize the time spent on integrating data from different CDMSs and **maximize time spent on data analysis**.

Ensure that your CDMS complies with WMO Standards.

## Are you ready?

For more information, email [cdms.info@wmo.int](mailto:cdms.info@wmo.int)  
Download WMO #1131 and WMO #100 at [library.wmo.int](http://library.wmo.int)

