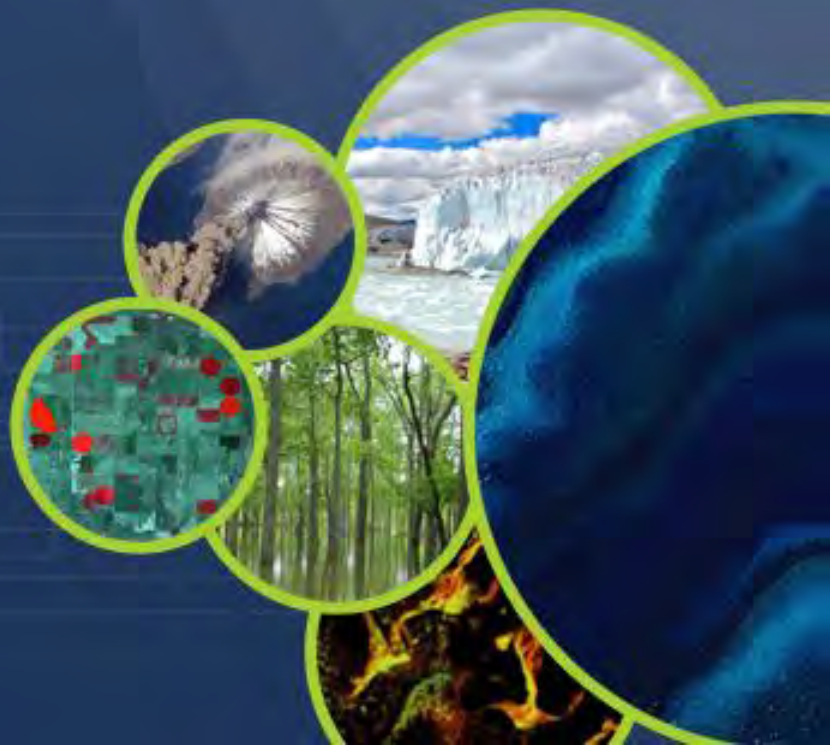
CEOS and the Australian Geoscience DataCube - Towards Integrated Earth Environmental Information Systems

DIAS Symposium
Tokyo, August 12016

Dr. Alex Held
2016 CEOS Chair Representative
CSIRO Canberra, Australia



What is CEOS?

www.ceos.org

The Committee on Earth Observation Satellites (CEOS) serves as a focal point for international coordination and data exchange to optimize societal benefit from space-based Earth observations. CEOS represents 22 countries through its 31 space agencies and 28 associate members.

CEOS Background

- Established in 1984 under auspices of G-7 Economic Summit of Industrialized Nations
  - Focal point for international coordination of space-related Earth Observation (EO) activities
  - Optimize benefits through cooperation of members in mission planning and in development of compatible data products, formats, services, applications, and policies
- Operates through best efforts of Members and Associates via voluntary contributions
- 31 Members (Space Agencies), 28 Associates (UN Agencies and other existing satellite coordination groups, scientific or governmental bodies that are international in nature, supporting ground facility programs)
- As the “space arm” of the intergovernmental Group on Earth Observations, CEOS is implementing high priority actions to support delivery of societal benefit

CEOS Members and Associates

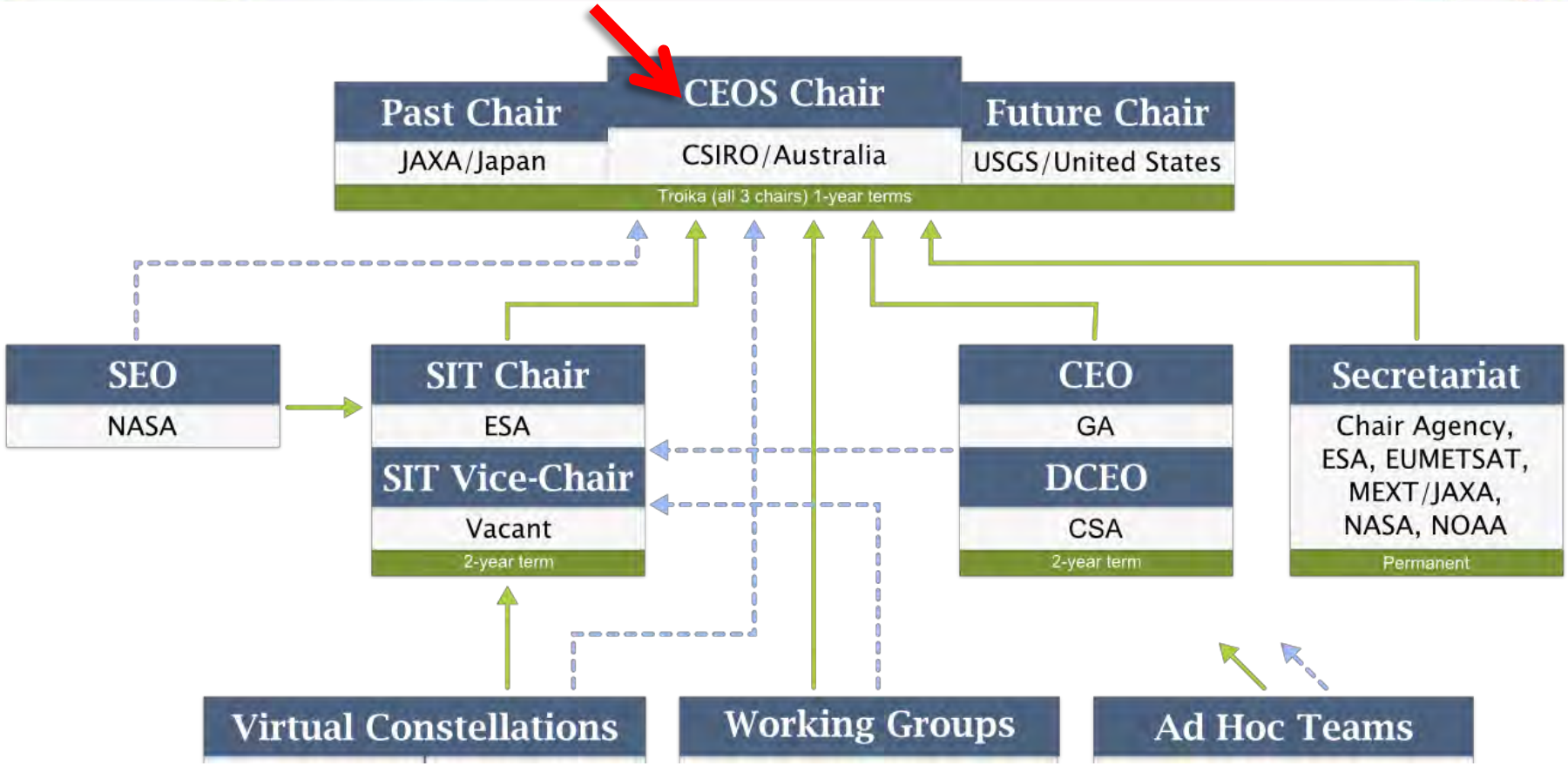
MEMBERS

Agenzia Spaziale Italiana (ASI)
Canadian Space Agency (CSA)
Centre National d'Etudes Spatiales (CNES), France
Centro para Desarrollo Tecnólogico Industrial (CDTI), Spain
China Center for Resources Satellite Data and Applications (CRESDA)
Chinese Academy of Space Technology (CAST)
Comisión Nacional de Actividades Espaciales (CONAE), Argentina
Commonwealth Scientific & Industrial Research Organisation (CSIRO), Australia
Deutsches Zentrum fürLuft-und Raumfahrt (DLR), Germany
European Commission (EC)
European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)
European Space Agency (ESA)
Geo-Informatics and Space Technology Development Agency (GISTDA), Thailand
Indian Space Research Organisation (ISRO)
Instituto Nacional de Pesquisas Espaciais (INPE), Brazil
Japan Aerospace Exploration Agency/Ministry of Education, Culture, Sports, Science, and Technology (JAXA/MEXT)
Korea Aerospace Research Institute (KARI)
National Aeronautics and Space Administration (NASA), USA
National Oceanic and Atmospheric Administration (NOAA), USA
National Remote Sensing Center of China (NRSCC)
National Satellite Meteorological Center/Chinese Meteorological Administration (NSMC/CMA)
National Space Agency of Ukraine (NKAU)
National Space Research Agency of Nigeria (NASRDA)
Netherlands Space Office (NSO)
Russian Federal Space Agency (ROSCOSMOS)
Russian Federal Service for Hydrometeorology and Environmental Monitoring (ROSHYDROMET)
South African National Space Agency (SANSA)
Scientific and Technological Research Council of Turkey (TÜBITAK)
United Kingdom Space Agency (UKSA)
United States Geological Survey (USGS)
Vietnam Academy of Science and Technology (VAST)

ASSOCIATES

Australian Bureau of Meteorology (BOM)
Belgian Federal Science Policy Office (BELSPO)
Canada Centre for Mapping & Earth Observation (CCMEO)
Crown Research Institute (CRI), New Zealand
Earth Systems Science Organisation (ESSO), India
South African Council for Scientific and Industrial Research (CSIR)/Satellite Applications Centre (SAC)
Gabonese Agency for Space Studies and Observations (AGEOS)
Global Climate Observing System (GCOS)
Geoscience Australia (GA)
Global Geodetic Observing System (GGOS)
Global Ocean Observing System (GOOS)
Global Terrestrial Observing System (GTOS)
Intergovernmental Oceanographic Commission (IOC)
International Council for Science (ICSU)
International Geosphere-Biosphere Programme (IGBP)
International Ocean Colour Coordinating Group (IOCCG)
International Society of Photogrammetry and Remote Sensing (ISPRS)
Malaysian National Space Agency (ANGKASA)
Mexican Space Agency (AEM)
Norwegian Space Centre (NSC)
Swedish National Space Board (SNSB)
United Nations Economic and Social Commission for Asia and the Pacific (ESCAP)
United Nations Educational, Scientific and Cultural Organization (UNESCO)
United Nations Environment Programme (UNEP)
United Nations Food and Agriculture Organization (FAO)
United Nations Office for Outer Space Affairs (UNOOSA)
World Climate Research Programme (WCRP)
World Meteorological Organization (WMO)

CEOS Organization



What is CEOS doing?

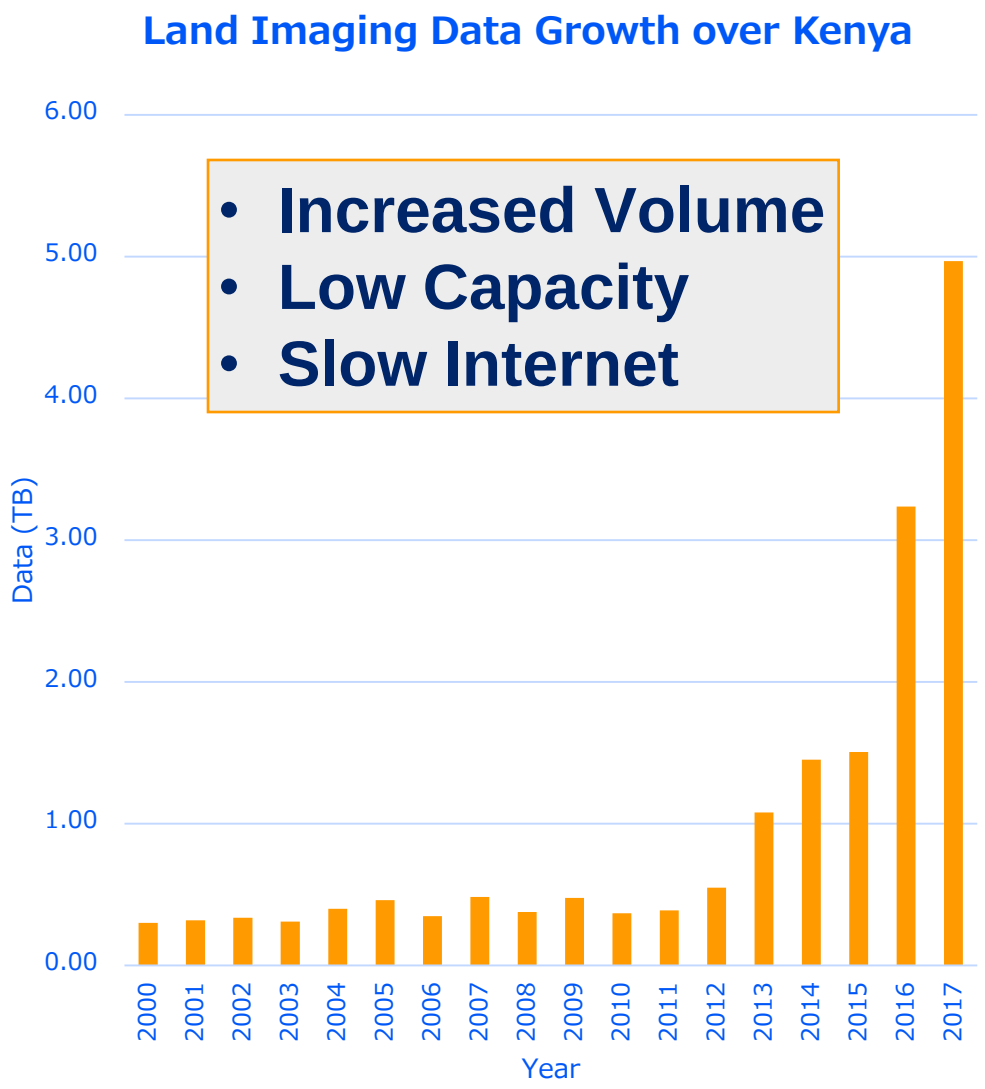
CEOS agencies collaborate on a variety of international projects that address key global issues ...

Data Access ... Promoting and improving space data use
Agriculture ... Global Food Security (GEOGLAM, UN-FAO)
Deforestation ... Carbon Stocks (GFOI, UN-REDD)
Climate Change ... Global Climate Change (GCOS, UNFCCC)
Disaster Management ... Floods, Earthquakes (UNISDR)

The latest trends in international geospatial & satellite data

- Free and open data
- Growing data volumes
- Improved computing technologies
- Open source software
- Pre-processed products

The Big-Data Challenge



- A significant growth in land imagery data (e.g. Landsat, Sentinel) will increase data volumes by >10x in the next few years.
- Many countries lack the knowledge, infrastructure, and resources to access and use space-based data.
- Countries have requested support from CEOS for data access, storage, processing, and analysis.
- The new CEOS Data Cube architecture provides a solution that saves countries time and money and reduces technical complexity.

As Chair of CEOS for 2016, CSIRO proposed to provide leadership and coordination on two new initiatives:

1. A study of Future Data Access and Analysis Architectures (co-chaired CSIRO and USGS)

2. A study of Non-meteorological applications for next generation geostationary satellites

Studies will draw upon expertise and capacity from existing CEOS WG's and VCs, as well as member agency experts.

ata Cube: National information infrastructure

Traditional Time-Series Analysis of Remote Sensing Data

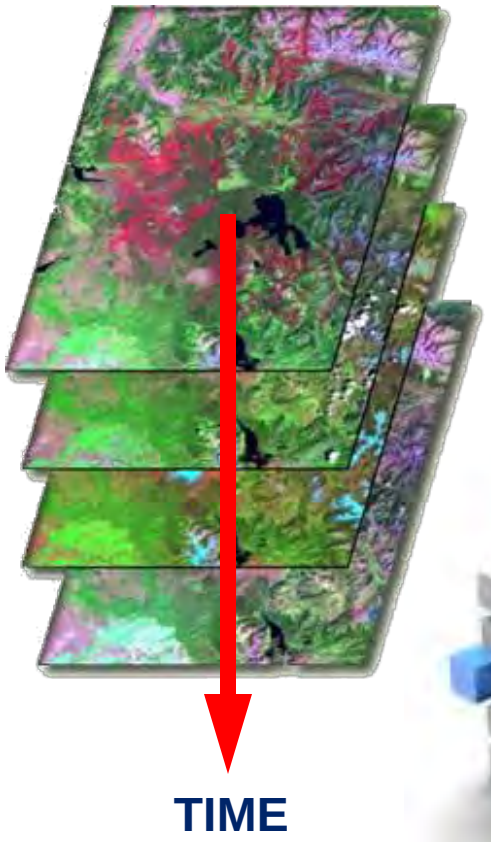
Can be repetitive, laborious, expensive and inefficient with large datasets.

What are Data Cubes?

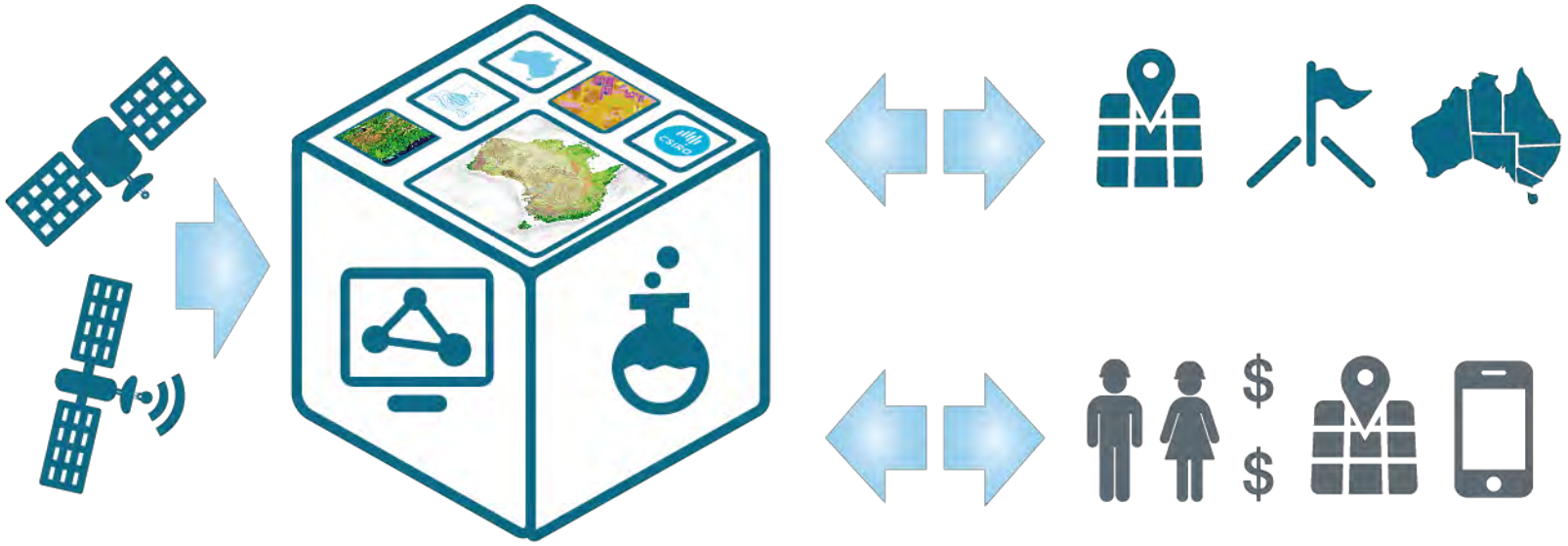
- **Data Cube** = Time-series multi-dimensional (space, time, data type) stack of spatially aligned pixels ready for analysis
- **Proven concept** by Geoscience Australia (GA) and the Australian Science Agency (CSIRO) and planned for the future USGS Landsat archive.
- **Shift in Paradigm** ... Pixels vs Scenes
- **Analysis Ready Data (ARD)** ... Dependent on processed products to reduce processing burden on users
- Supports an **infinite number of applications**, reduces data preparation time, allows time series analyses, increases interoperability of multiple datasets.
- **Open source** software approach allows free access, promotes expanded capabilities, and increases data usage.

Open Source Software

https://github.com/data-cube



New Data Cube remote sensing paradigm is to provide a single source of “analysis ready data” to



Basic Data Cube Architecture

Data

- Working with CEOS Space Agencies to develop plans for sustained provision of Analysis Ready Data (ARD)
- Landsat, Sentinels, MODIS, and more ....

Data Cube

- Open source software, developed and sustained by CEOS
- Support for diverse datasets and grid projections
- Deployment via local computers, regional hubs (e.g. SERVIR), or computing cloud (e.g. Amazon)
- Connections to common GIS tools (ArcGIS, QGIS)
- Advanced Programming Interfaces (APIs) for users

Users

- Prototypes in Colombia and Kenya
- Developing and testing user interfaces for custom mosaics and water management
- Investigating capacity building options (SilvaCarbon, **World Bank**)

Data Cube Detailed Architecture

UI & Application Layer

Forest | Economics | *App N*

SLEEK Integrating Tool | *Application / UI* | *Mobile App*

API

Data & Application Platform

Virtual Lab Platform

Data & Application Platform (Data Management, Access Controls, Job Management, Etc.)

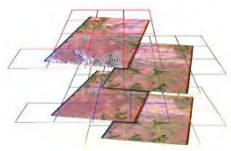
Database

Data Cube Infrastructure

AGDC Higher-level API | Data Presentation API | Visualization API | Analytics API

N-Dimensional Array

AGDC Low-level API



GA

AGDC Database

Metadata, Records, Etc.

GA + SEO

Datacube Files

GeoTIFF, HDF, NetCDF

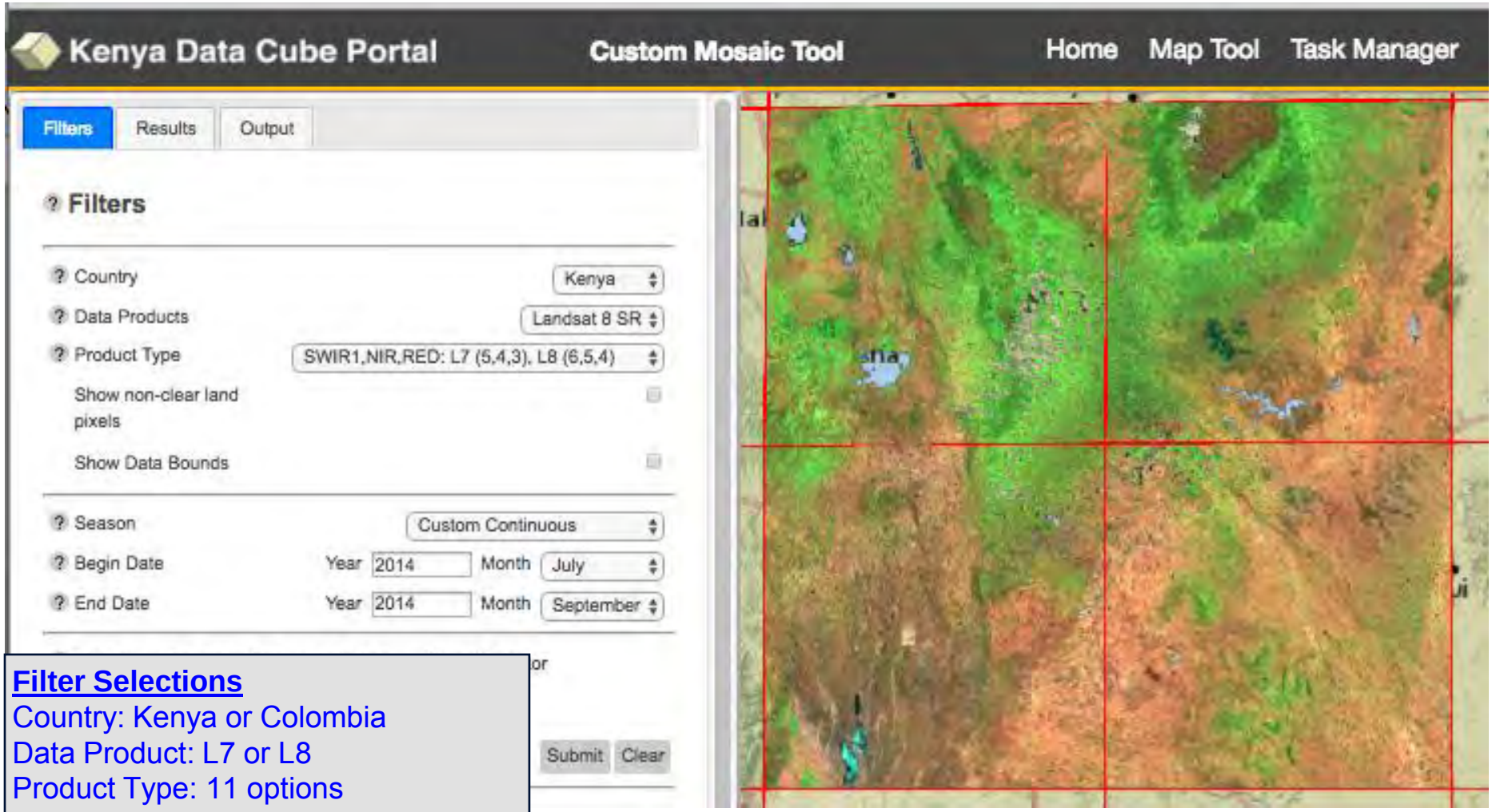
Architecture Considerations:

- Short-term vs. Long-term
- Flexible Deployment (Hybrid, AWS)
- Technology Decisions
- Performance vs. Flexibility
- AGDC API vs. Platform
- Resources / Timeline

Data Acquisition & Inflow

Space Segment/Ground Station Operation → Analysis-Ready Data Supply

GUI and Analytics Tools for DataCube
e.g. Custom Mosaicing

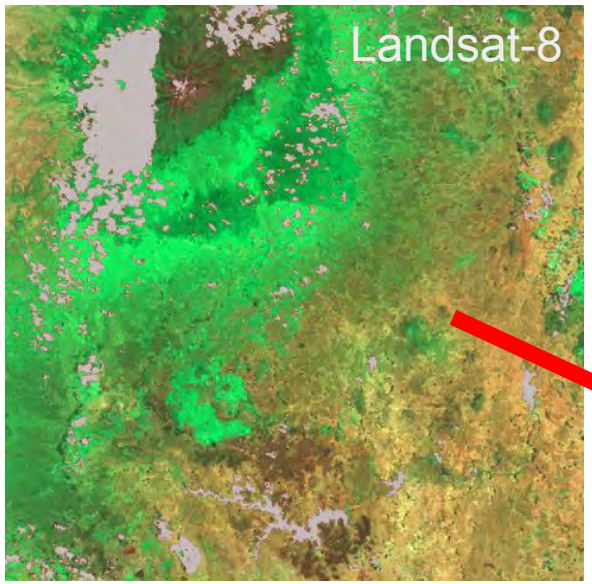


Filter Selections

Country: Kenya or Colombia
Data Product: L7 or L8
Product Type: 11 options
Non-clear pixels: RED flag
Dates: Continuous or Multiple Months
Bounding Box or Lat-Long

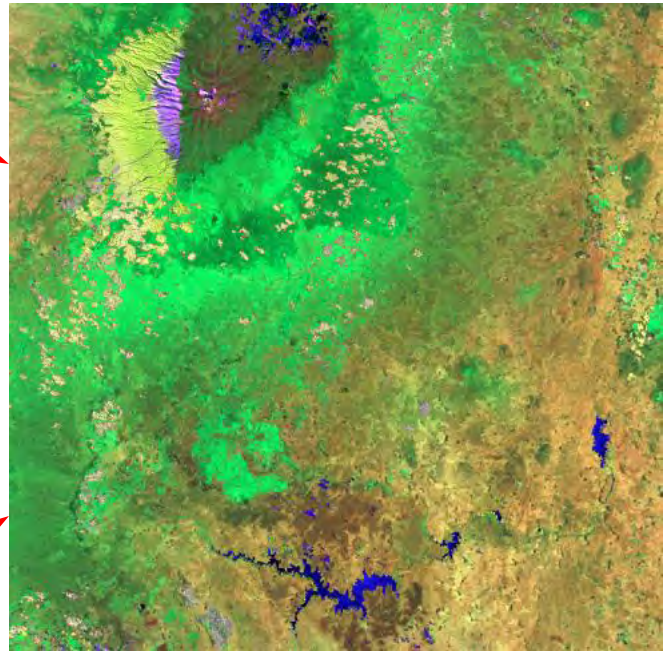
CESIUM

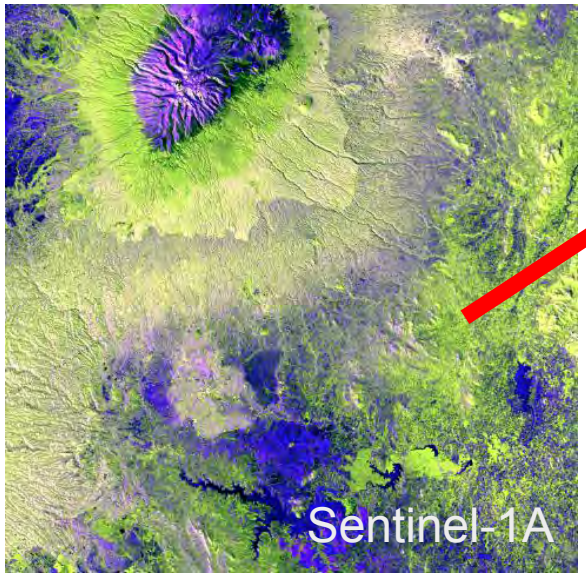
Landsat-Sentinel-1A Example



Masked clouds and water

Combined Mosaic Product





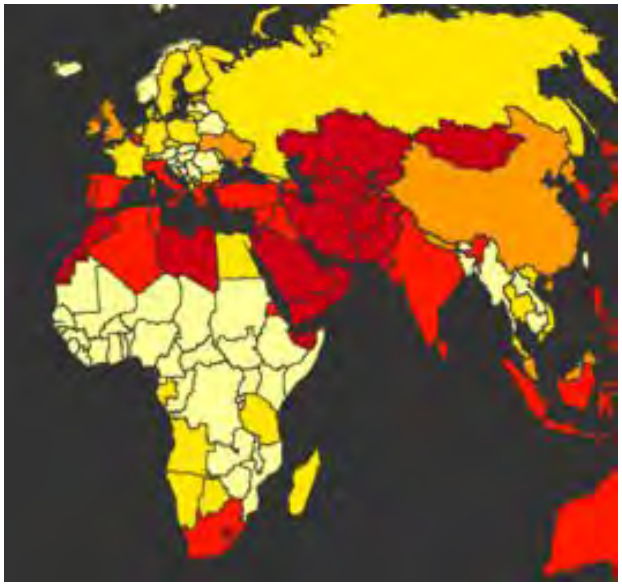
Complements of Norut VV-VH-NDI product

An integrated mosaic was created with the Data Cube over central Kenya for Oct-Dec 2014 using Landsat-8 and a Oct 2014 to Oct 2015 Sentinel-1A mosaic.

Sentinel-1A data can be used to fill areas of cloud cover within the Landsat-8 imagery for improved forest classification.

Example 2: Water Management

Water is one of the world's most valuable resources. Water supply, water quality and the risk of droughts and flooding can all be studied from space.



Water Stress by Country

WRI Aqueduct
Gassert et al., 2013

The CEOS **Data Cube** provides a unique method to utilize time series data for water management and assessment.

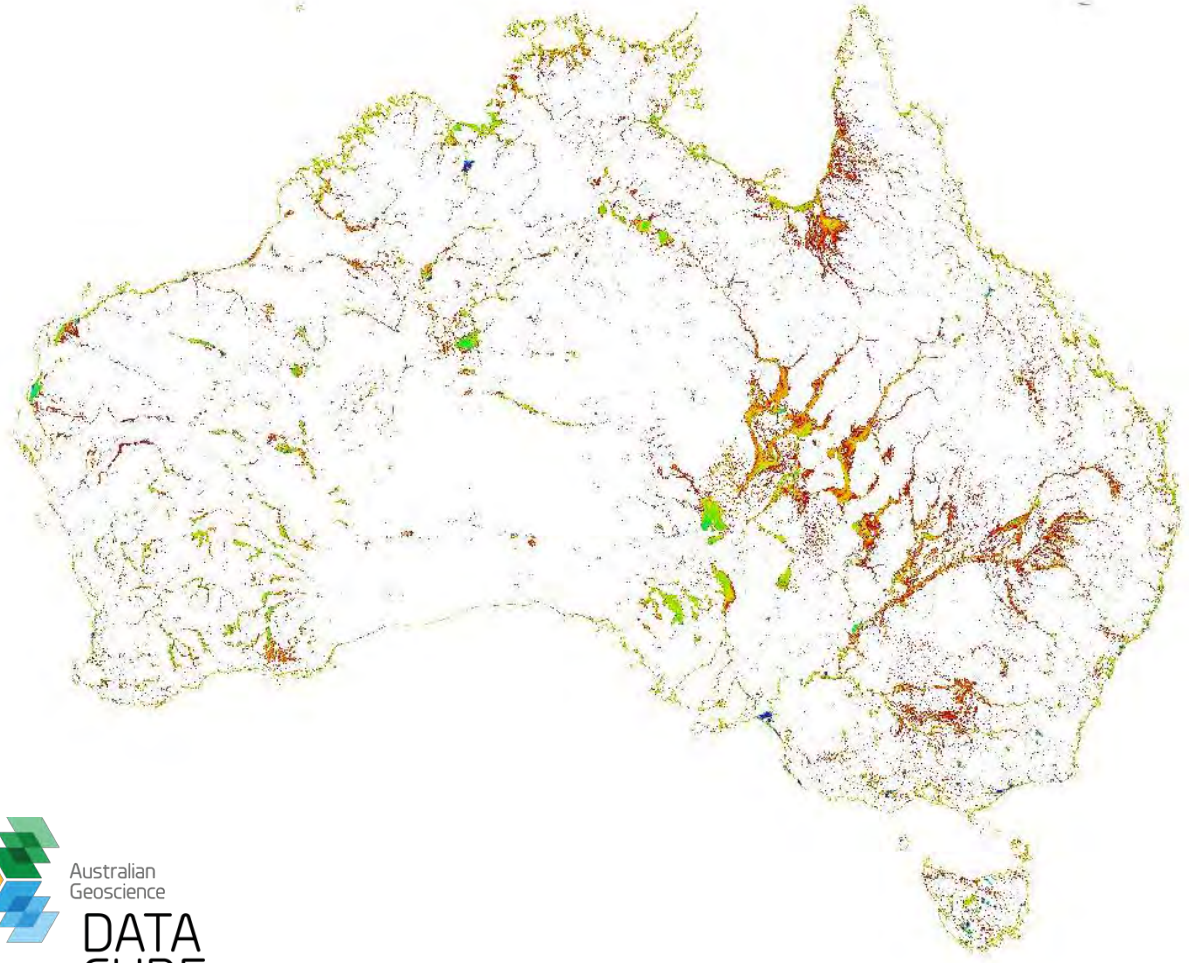
Data Access and Analysis

National Flood Risk Information Portal Australia

Source: Geoscience Australia

Data Access and Analysis

Continental surface water



- Water detection
- 15 Years of data from LS5 & LS7(1998-2012)
- 25m Nominal Pixel Resolution
- Approx. 133,000 individual scenes in ~12,400 passes
- Entire archive of 1,312,087 tiles => $21x10^{12}$ pixels visited
- 3 hrs at NCI (elapsed time) to compute

Australian Geoscience DATA CUBE

Source: Geoscience Australia

Australian Government Geoscience Australia

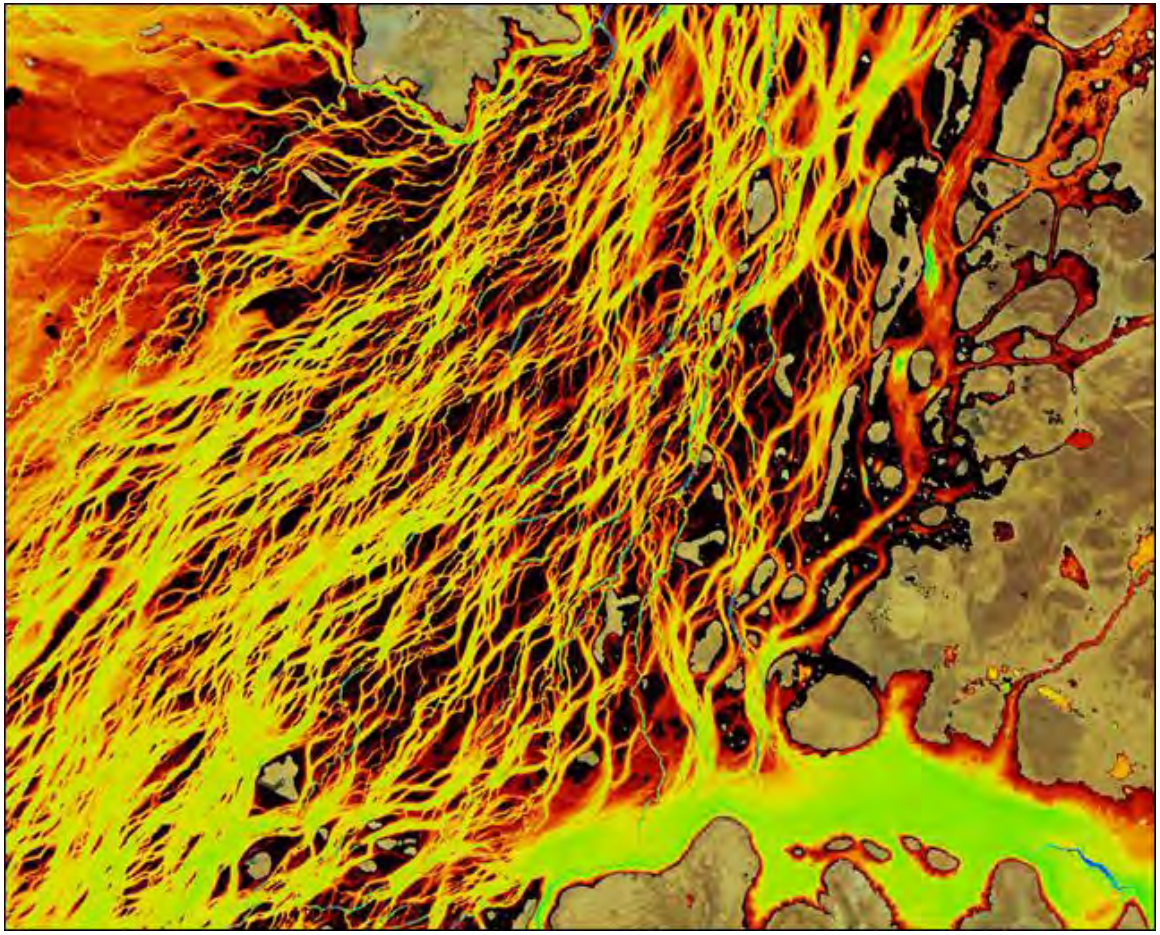
CSIRO

NCI

Australian WOFS Algorithm

WOFS = Water Observations from Space

Braided river network of Coopers Creek in Queensland, Australia



Blue = permanent water

Red/Yellow = infrequent flood events

CEOS has implemented the 23-step WOFS algorithm to produce results similar to those shown here

Braided river networks and flood extent is very difficult to map with traditional methods

Water Detection Tool

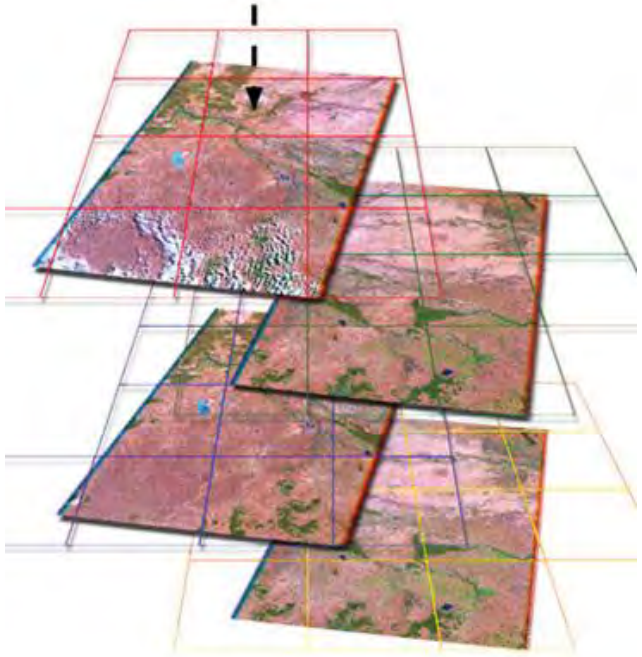
Kenya

Lake Baringo National Park

Preparation and Analysis

Data Preparation

- Landsat 7, January 2005 to April 2016
- 169 original scenes (202 GB of data)
- 1x1 degree Data Cube “stack” with annual storage unit “chunks”
- 3710 x 3710 x 169 = 2.3 billion pixels total
- 37 GB NetCDF data volume (~ 5:1 compression)

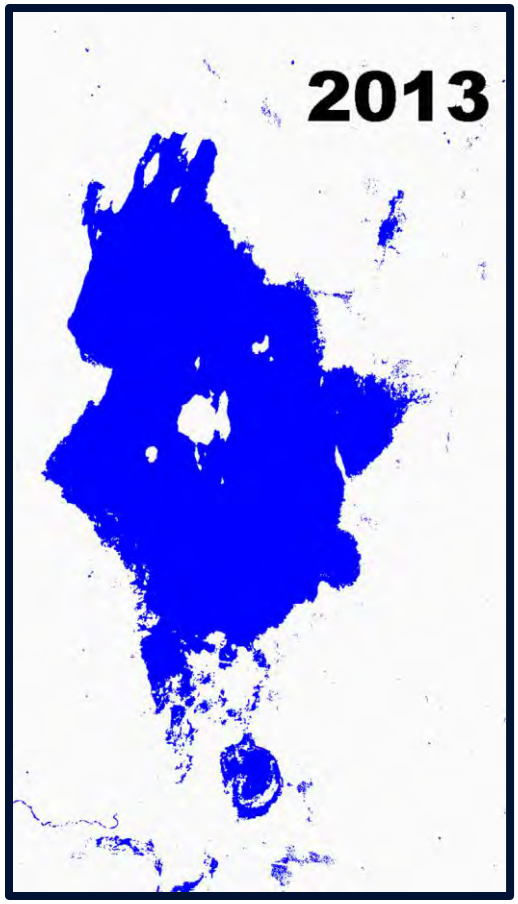


Data Analysis

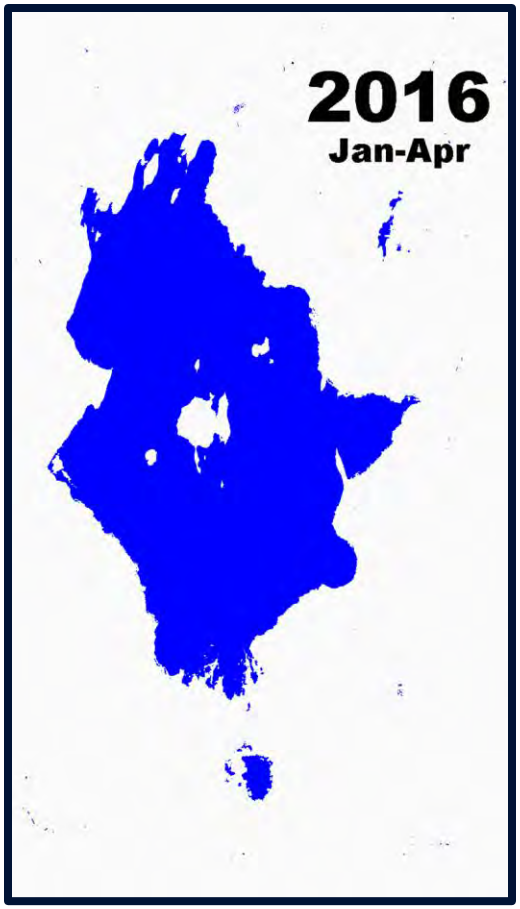
- 3.5 GHz Intel processor (4-core), 64GB RAM, Linux computer
- Modified Australian water detection algorithm uses multiple Landsat bands for 97% accuracy
- 1-2 minutes for an annual analysis and ~30 minutes for a full time series (11+ years) analysis

Lake Baringo, Kenya Annual Water Extent Analysis

Extreme droughts in the Baringo region in 2009 had severe impacts on pastures and farming

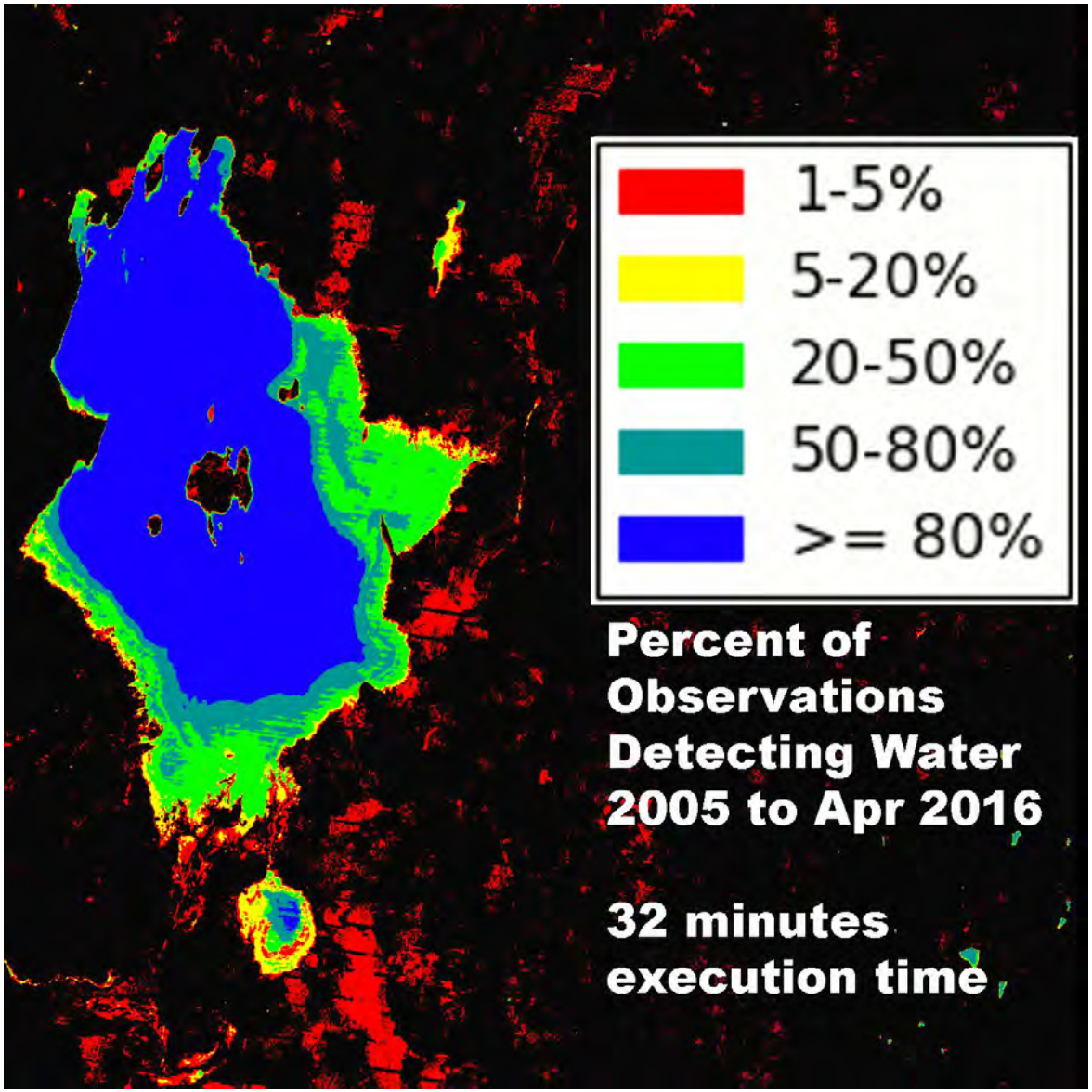


Extreme floods displaced 600 families and swept away livestock near Lake Baringo in 2013



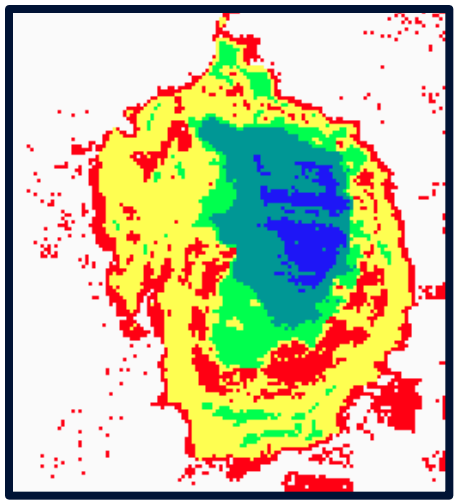
4 months of dry season data resulted in little water detected outside the lake boundary

Lake Baringo, Kenya
11-year Time Series Results



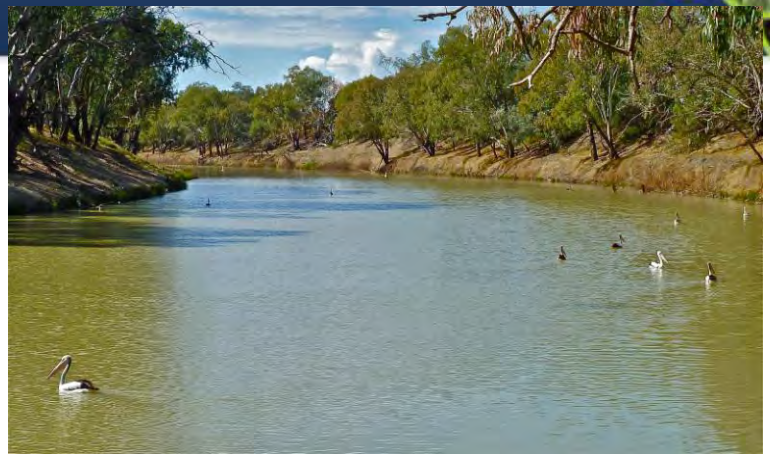
Blue = frequent water
Red/Yellow = infrequent flood events

Flood risk can be easily inferred from WOFS analysis results. 30-meter Landsat resolution allows detailed assessments that are far better than MODIS (250-m).



Water Quality Tracking

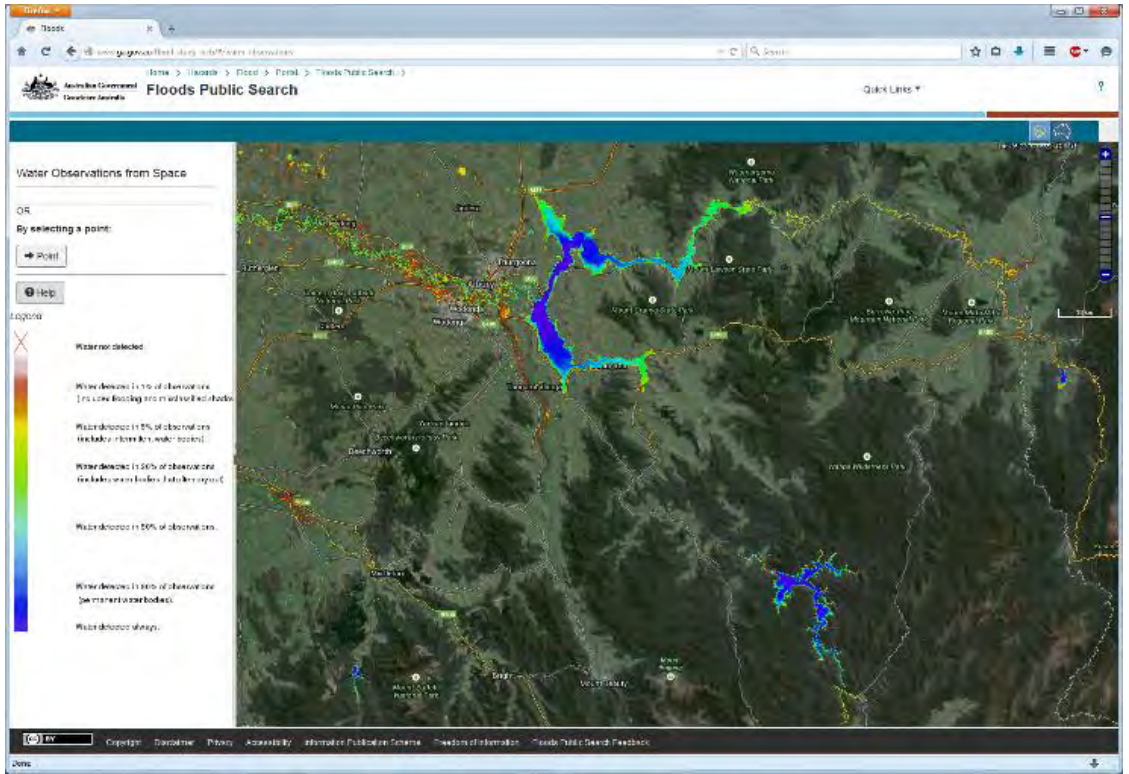
- An increasing global problem
- Systems under pressure
- Human and animal health impacts



Operationalisation of a water quality alert system

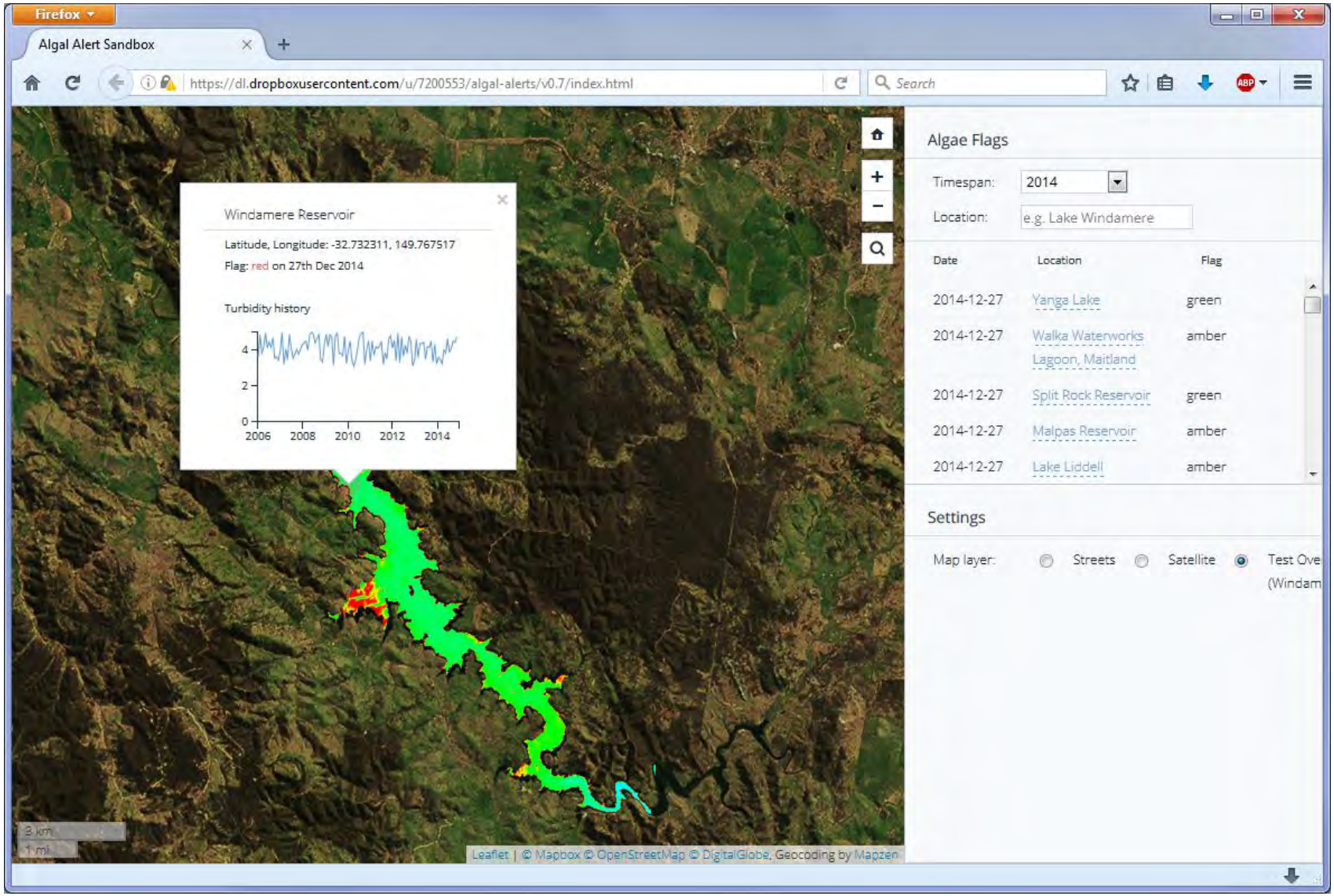
Design Principles:

- **Rapid turnaround of satellite data**
- **Built to use the Australian Geospatial DataCube**
- **Software framework / Product delivery system**
- **Able to accommodate new sensors and data streams (GCOM-C, S2/S3), new algorithms**

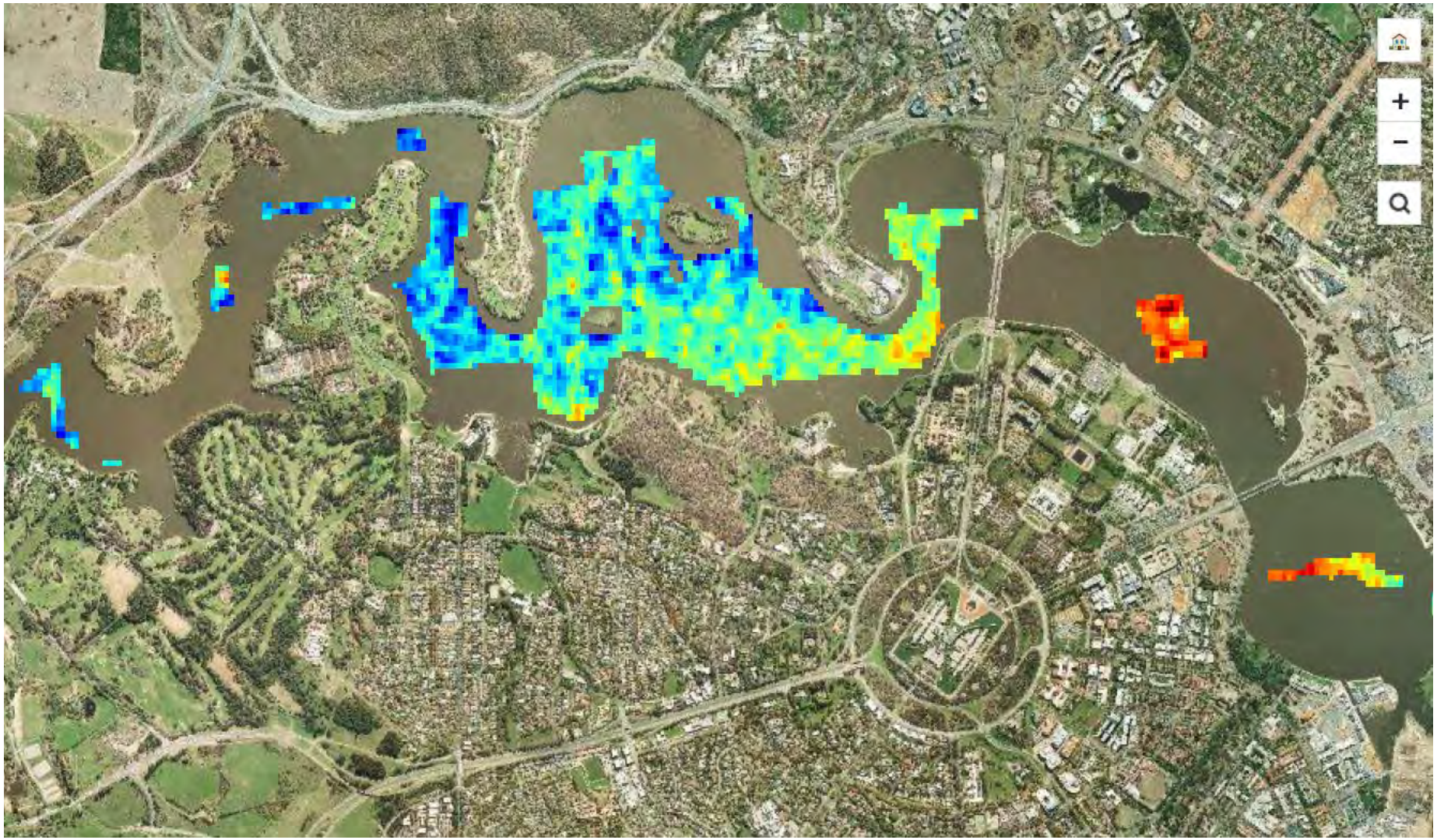


Water observations from space example (GA)

Visualisation Water Quality



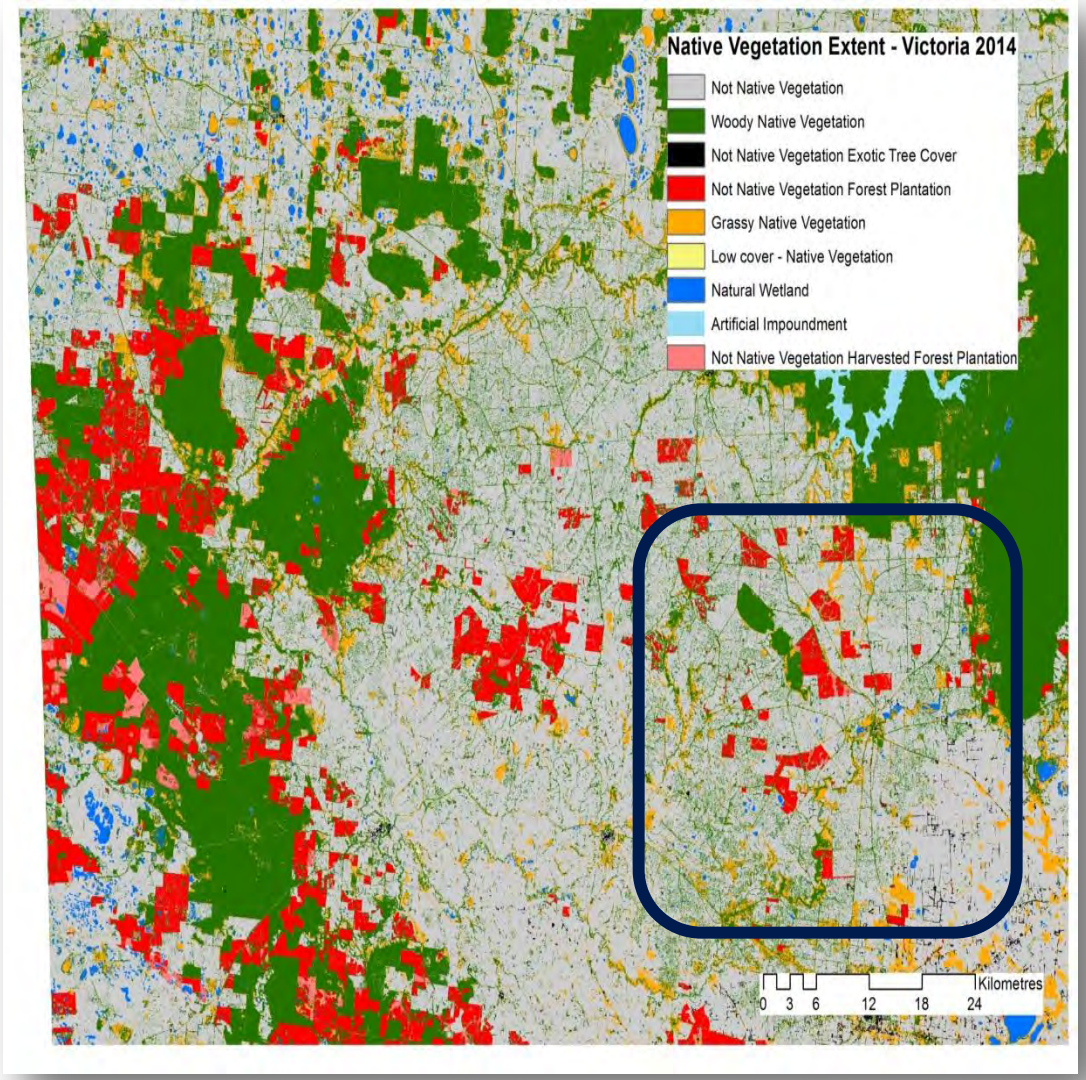
Visualisation of initial results over Canberra



Tracking agricultural production and land-use change

Vegetation Cover Change Mapping

Re-mapping vegetation in Victoria

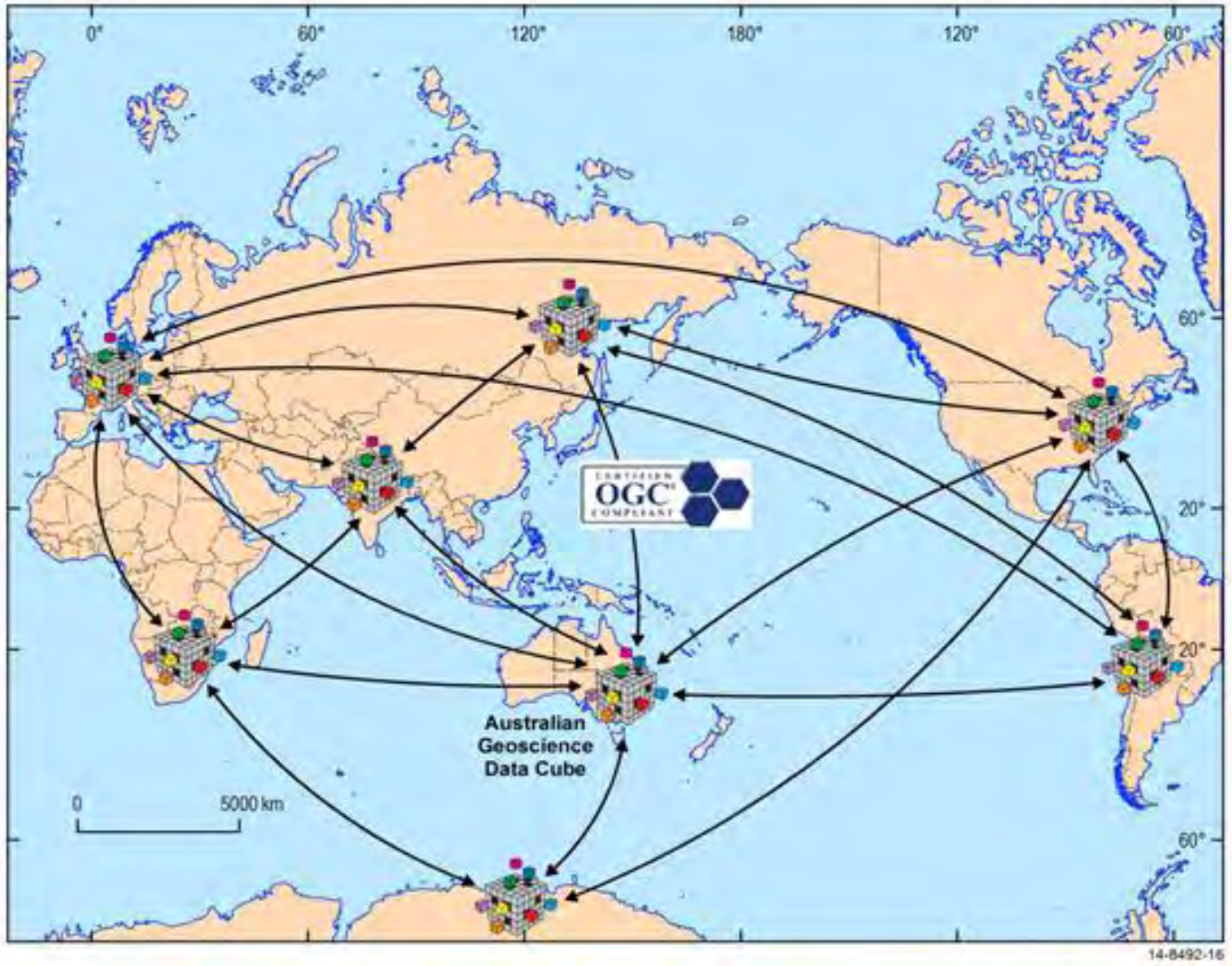


Country Demonstrations

- Prototype Data Cube projects are under development in **Colombia and Kenya**
- Major focus is on interoperable operation of network of DataCubes
- The Colombia project is supported by CSIRO and IDEAM (Institute of Hydrology,
- The **Colombia** team is growing capacity ... They have demonstrated use of the software to expand the data in their mini-cube and they have modified the user interface to add mosaics, change detection and NDVI-based forest/non-forest maps. They are interested in more applications such as water resource management.

- The **Kenya** project is supported by the Australian Government and the Clinton Foundation (CCI and SLEEK). Versions of the full-country Data Cube (11TB of data, 7500 scenes) are located locally and on the Amazon cloud.
- The Kenya team is currently utilizing scene-based methods to complete historic forest maps for UN reporting and will move to a Data Cube implementation in 2017.

Vision of a Global Network of Interoperable DataCubes



- Different national/regional/ global applications;
- BUT consistent standards, formats and interoperability.
- The Data Cube tackles a problem that is not peculiar to Australia
- It supports addressing global challenges – Sustainable Development Goals

Opportunities for engagement by different users, clients and service providers

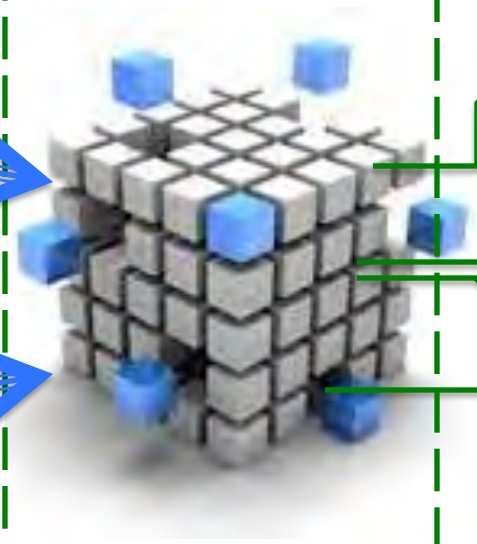
Public or Commercial Satellite Data

Data "Ingestors"

Landsat	Sentinel-1
Sentinel-2	MODIS
ALOS	GCOM-C
WV-2/3	CBERS
SMAP	Etc.

Other Data

DataCube Platform



Publicly funded or commercial infrastructures

Application Tools

API

Commercial APP

Commercial APP

API

Public APP

Commercial APP

API

Public APP

Public APP

Public APP

R&D APP

Users & Services

Government Agencies

Private Customers

Researchers

Globally Interoperable
under eg OGC and ISO Standards

Closing thoughts …

- Satellite data can play a major role in building capacity and new industries in developing countries
- Data Cubes can bring satellite data to many more people and to remote areas without good internet
  - Once there, local scientists and engineers can be trained and educated on how to analyze the data
  - For example, time series analyses would be valuable to the study of urbanization, agriculture, forests and natural resource management
- Through partnerships among space agencies, UN and governments, we can stretch this capacity to all corners of the globe!