



MINISTÉRIO DA  
CIÊNCIA, TECNOLOGIA  
E INOVAÇÃO



# Geographic information systems today: interoperability, services, ~~and processing platforms~~

SER-300-3 – Introdução ao Geoprocessamento – 2023

Author: Lúbia Vinhas

lubia.vinhas@inpe.br

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“Humanity today is faced with numerous challenges. The world we humans have created and in which we find ourselves is unlike any world of the past; and a return to the past is not a possibility. Many of these challenges can be addressed with **geospatial technology**, especially if that technology is built appropriately, is sufficiently comprehensive, and is open and accessible to all.”

<https://public.wmo.int/en/media/press-release/united-science-we-are-heading-wrong-direction>

*Building geospatial infrastructure*, Dangermond and Goodchild

<https://doi.org/10.1080/10095020.2019.1698274>

**Geodesy:** the science of measuring and representing the size and shape of Earth

**Mapping:** measurement of a position, na elevation, a perimeter or an area to define positional information on Earth

**Remote Sensing:** science related to obtaining data from distance using devices that detect emitted or reflected electromagnetic energy

**Cartography:** art and science of making maps to communicate geospatial information

**Geospatial Science** is a multidisciplinary field of research and application using geographic information and technology to answer scientific questions as they relate to both space and time

**Geographic Information Systems (GIS):** combines hardware, software, data and scientific methods to store, analyze, produce and display geospatial data

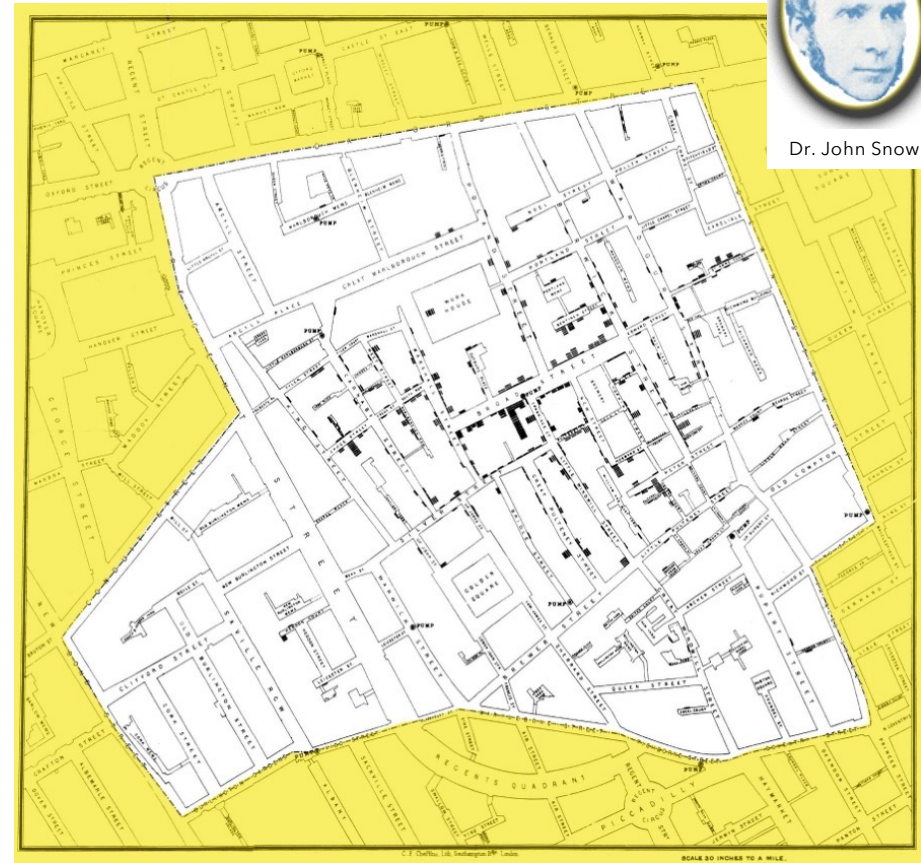
In 1854, Dr. John Snow used the power of mapping to identify the source of a cholera outbreak in London.

Beyond mapping, **Spatial Analysis** refer to transformation and manipulation of data, creating added value data.

“From data to Information to Knowledge to Wisdom” (Luc Anselin)



Dr. John Snow



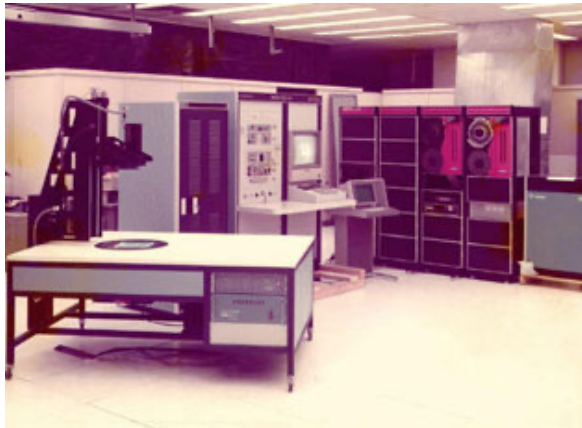
<https://www.ph.ucla.edu/epi/snow.html>



## Computer meet geography: decade of 1960

The electronic computer has in recent years increasingly demonstrated its ability to store, compile and assess statistical data. The staff of Spartan Air Services Limited with many years' experience in all phases of survey and mapping, and the personnel of International Business Machines Company Limited with their extensive facilities for computer research and development, have initiated studies regarding the application of computers to the storage, compilation and assessment of map data as well as statistical data, and to the production of accurate and specific correlations between the two types of data. These very preliminary investigations definitely indicate the feasibility of the use of computers in this field.

Source: An Introduction to the Use of Electronic Computers in the Storage, Compilation and Assessment of Natural and Economic Data for the Evaluation of Marginal Lands - Roger Tomlinson. 1962 (<https://gisandscience.files.wordpress.com/2012/08/4-computermapping.pdf>)

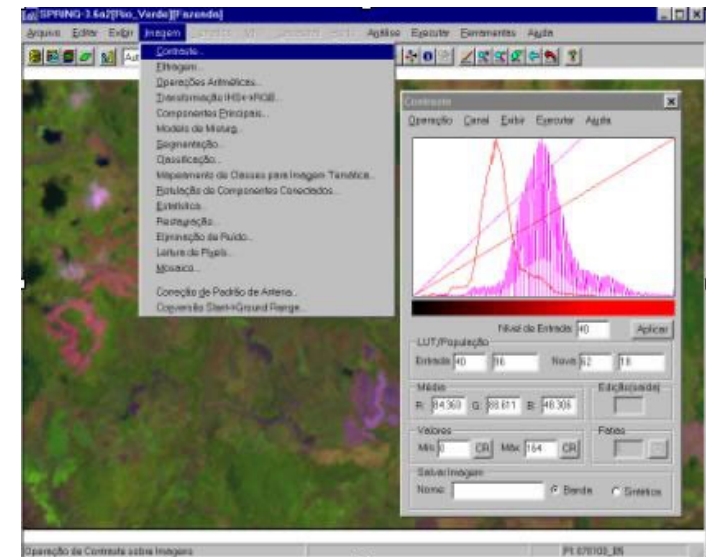


1974: IMAGE-100 (I-100) : US\$ 1 million.  
First image processing system in Brazil

1986: SITIM/SGL: hardware and software. Vector and Raster processing



1991: SPRING, reached 100.000 users. Free and open desktop GIS

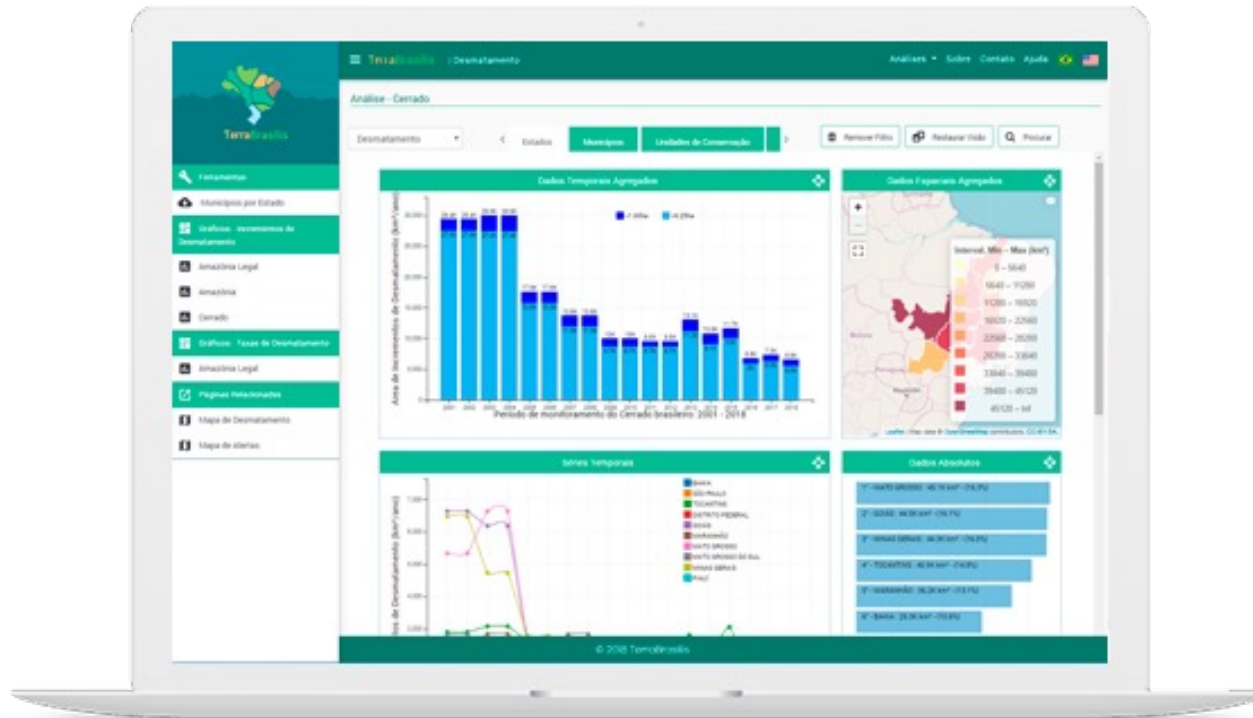


Source: <http://www.dpi.inpe.br/DPI/institucional/pessoal/historico>

2000: Library to develop geographical applications



## Use of internet to disseminate data



Source: <http://terrabrasilis.dpi.inpe.br/>



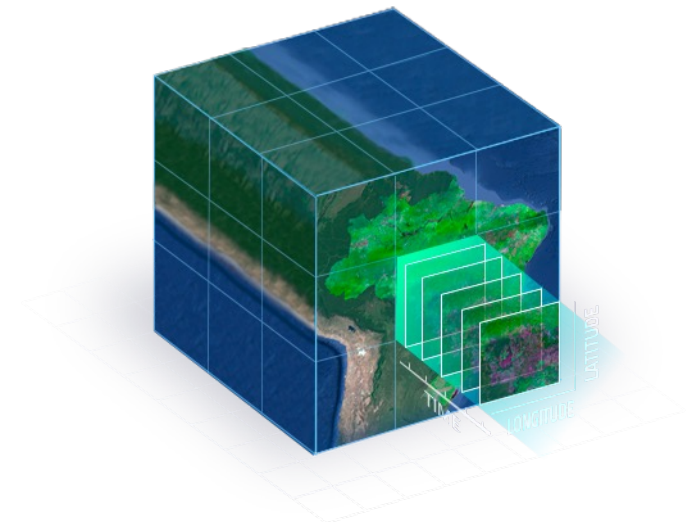
## High performance platforms for data processing



The screenshot shows a GitHub repository page for 'Brazil Data Cube Code Gallery'. The repository is licensed under MIT and includes badges for lifecycle, maturity, render, nbviewer, chat, and 18 online users. The description states: 'This repository contains a gallery of interesting Jupyter Notebooks, R Markdown and scripts based on Brazil Data Cube data and technologies.' The repository lists several services:

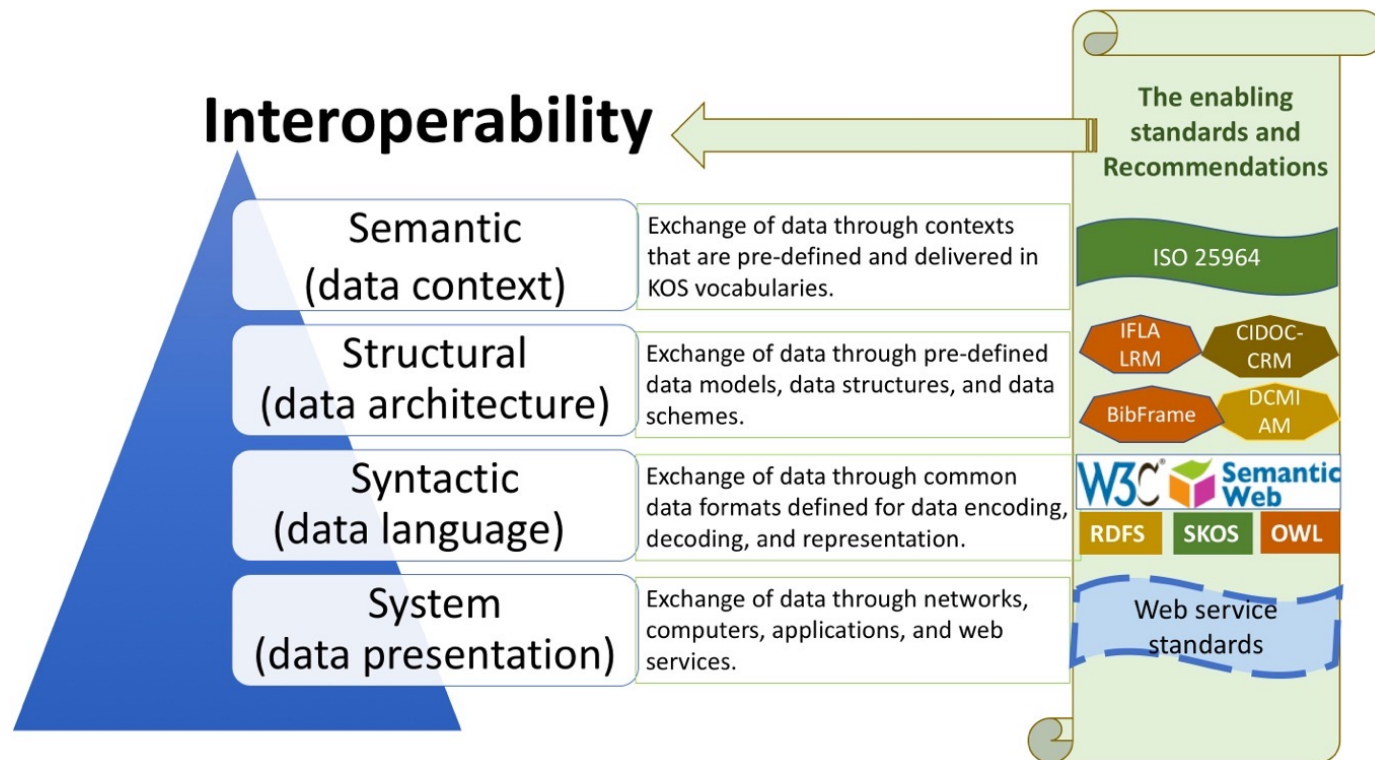
- Jupyter Notebooks**
- Data Access through SpatioTemporal Asset Catalog API (STAC)**
  - Introduction to the SpatioTemporal Asset Catalog. (Python, R)
  - Image processing on images obtained through STAC.
- Web Time Series Service (WTSS)**
  - Introduction to the Web Time Series Service (WTSS). (Python, R)
  - Web Time Series Service (WTSS) examples. (Python, R)
- Web Land Trajectory Service (WLTS)**
  - Introduction to the Web Land Trajectory Service (WLTS). (Python, R)
  - Web Land Trajectory Service (WLTS) examples. (Python)
- Tile Map Service (BDC-Tiler)**
  - Introduction to the Tile Map Service (BDC-Tiler). (Python)

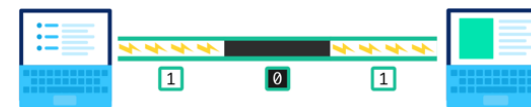
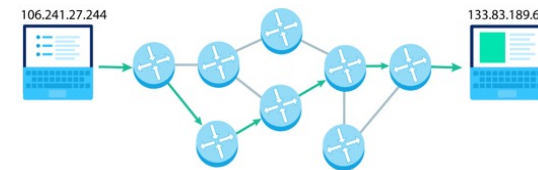
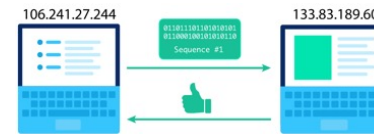
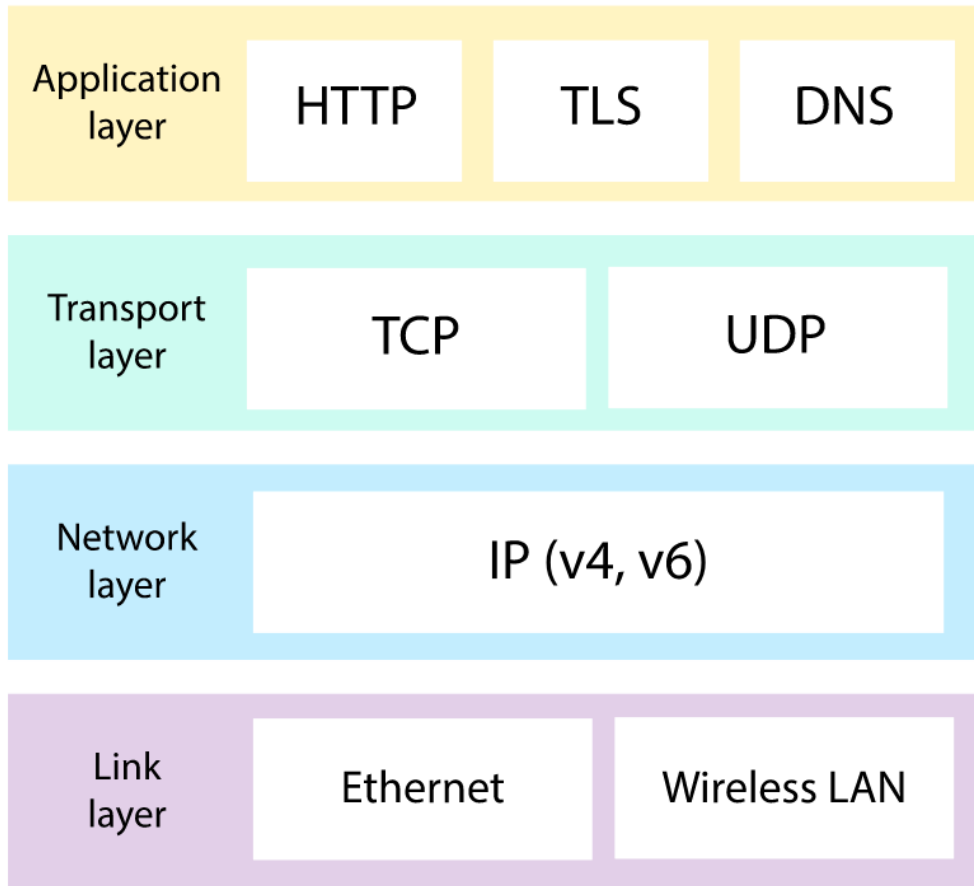
The right sidebar shows 'Packages' (No packages published), 'Contributors' (7), and 'Languages' (Jupyter Notebook 96.2%, R 3.8%). The GitHub logo is visible in the bottom right corner of the screenshot.



Source: <http://www.brazildatacube.org>

**Interoperability** can be defined as the capacity of heterogeneous and distinct applications to share procedures and data on distinct platforms. It is related to application collaboration regardless of the technologies used (methods, programming languages and, environments





There are many protocols on the Internet that operate at different layers, each building functionality on top of the layer below it.



The **World Wide Web (WWW)**, commonly known as the **Web**, is an [information system](#) enabling documents and other [web resources](#) to be accessed over the [Internet](#).

Documents and downloadable media are made available to the network through [web servers](#) and can be accessed by programs such as [web browsers](#). Servers and resources on the World Wide Web are identified and located through character strings called [uniform resource locators](#) (URLs).

([https://en.wikipedia.org/wiki/World\\_Wide\\_Web](https://en.wikipedia.org/wiki/World_Wide_Web))



The World Wide Web Consortium (W3C) is an international community where [Member organizations](#), a full-time [staff](#), and the public work together to develop [Web standards](#). (<https://www.w3.org/>)

## Networks (basics)

**Uniform Resource Locator (URL)** or hyperlink is a string that provides a reference to a resource on the Web.

A Web resource can be anything: a page, file, image, a service:

- <http://terrabrasilis.dpi.inpe.br>
- [https://data.inpe.br/data/S2\\_L2A\\_COG/v001/23/K/NQ/2023/2/S2A\\_TCI\\_20230220T131241\\_N0509\\_R138\\_T23KNQ\\_20230220T182156.tif](https://data.inpe.br/data/S2_L2A_COG/v001/23/K/NQ/2023/2/S2A_TCI_20230220T131241_N0509_R138_T23KNQ_20230220T182156.tif)
- <ftp://ftp.funet.fi/pub/standards/RFC/rfc959.txt>
- Mailto: [lubia.vinhas@inpe.br](mailto:lubia.vinhas@inpe.br)

## Networks (basics)

Encodings provide the format (arrangement of data elements) and syntax of the data and messages, or data send to and by a server

```
1 <?xml version="1.0" encoding="UTF-8"?>
2 <UP>
3   <nome>Instituto Nacional de Pesquisas Espaciais</nome>
4   <sigla>INPE</sigla>
5   <cidade>São José dos Campos</cidade>
6   <estado>SP</estado>
7   <fundacao>1971</fundacao>
8 </UP>
```

XML

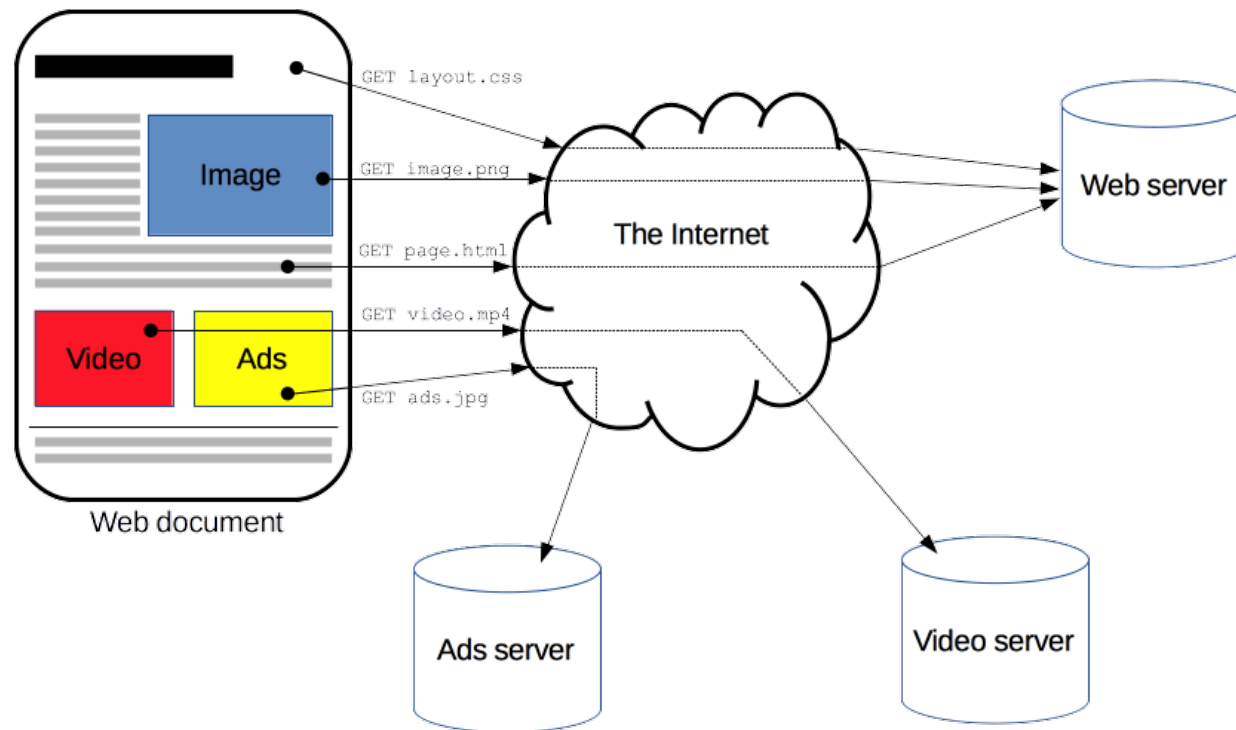
An XML Schema describes the structure of an XML document.

```
{
  "UP": {
    "nome": "Instituto Nacional de Pesquisa Espaciais",
    "sigla": "INPE",
    "cidade": "São José dos Campos",
    "estado": "SP",
    "fundacao": "1971",
  }
}
```

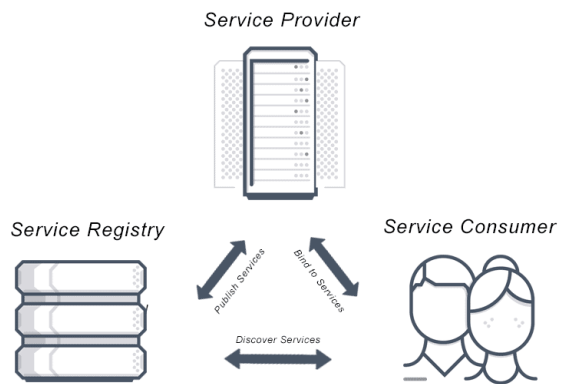
JSON

JSON Schema is a grammar language for defining the structure, content, and (to some extent) semantics of JSON objects.

**HTTP** is a protocol for fetching resources such as HTML documents. It is the foundation of any data exchange on the Web and it is a client-server protocol.



*The Service Oriented Architecture Triangle*



## Service

A Service is a set of interfaces provided by an entity. The service provides a functionality that distinguishes the entity from other entities. In this context, an entity is a server on the web, that provides a service, in most cases via HTTP.

## Interface

An interface specifies a set of calls to an object (i.e. server) to execute a process (e.g., transformation or query). Usually, it defines the name of the operations, the list of parameters and allowed values.

## Operation

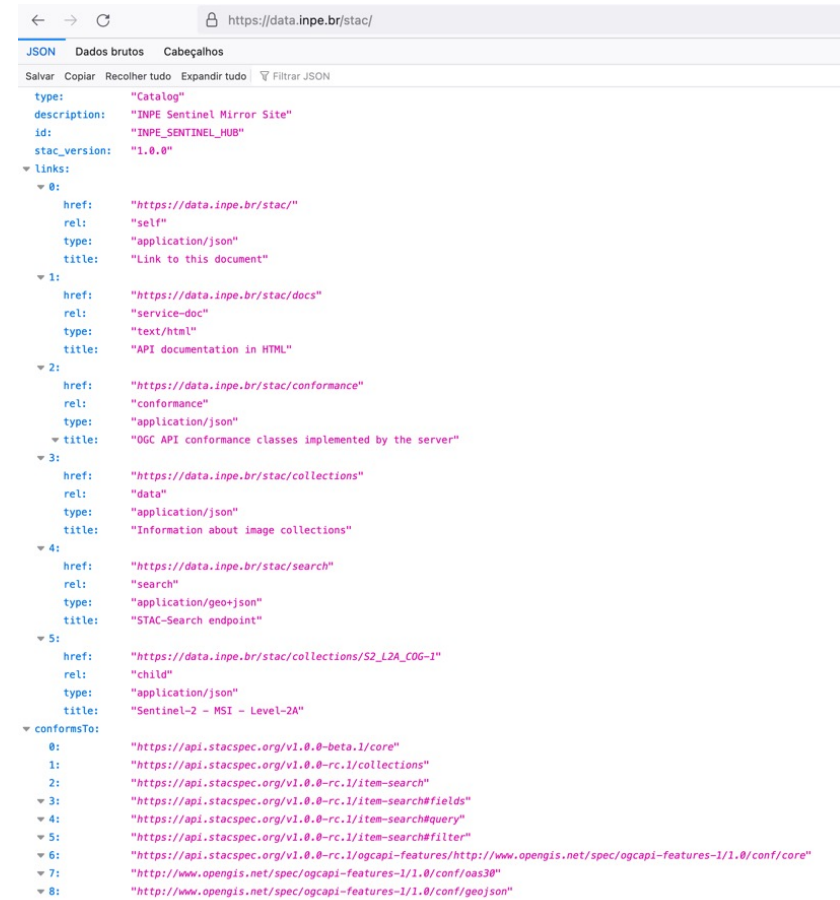
In the context of Web services, an operation is a request to a server. For example, an HTTP request is a specific operation. An operation is defined by a service interface.



# Web Application



# Web Service



The Open Geospatial Consortium (OGC), an international voluntary consensus standards organization for geospatial content and location-based services, sensor web and Internet of Things, GIS data processing and data sharing. It originated in 1994 and involves more than 500 commercial, governmental, nonprofit and research organizations in a consensus process encouraging development and implementation of open standards:

- Freely and publicly available: free of charge and unencumbered by patents and other intellectual property.
- Nondiscriminatory: available to anyone, any organization, any time, anywhere with no restrictions.
- No license fees: no charges at any time for their use.
- Vendor neutral: in terms of their content and implementation concept and do not favor any vendor over another.
- Data neutral: independent of any data storage model or format.
- Based on Consensus: defined, documented, and approved by a formal, member driven consensus process. The consensus group remains in charge of changes and no single entity controls the standard



<http://terrabrasilis.dpi.inpe.br/geoserver/prodes-legal-amz/wms?>

**REQUEST**=GetMap&

**SERVICE**=WMS&

**LAYERS**=yearly\_deforestation&

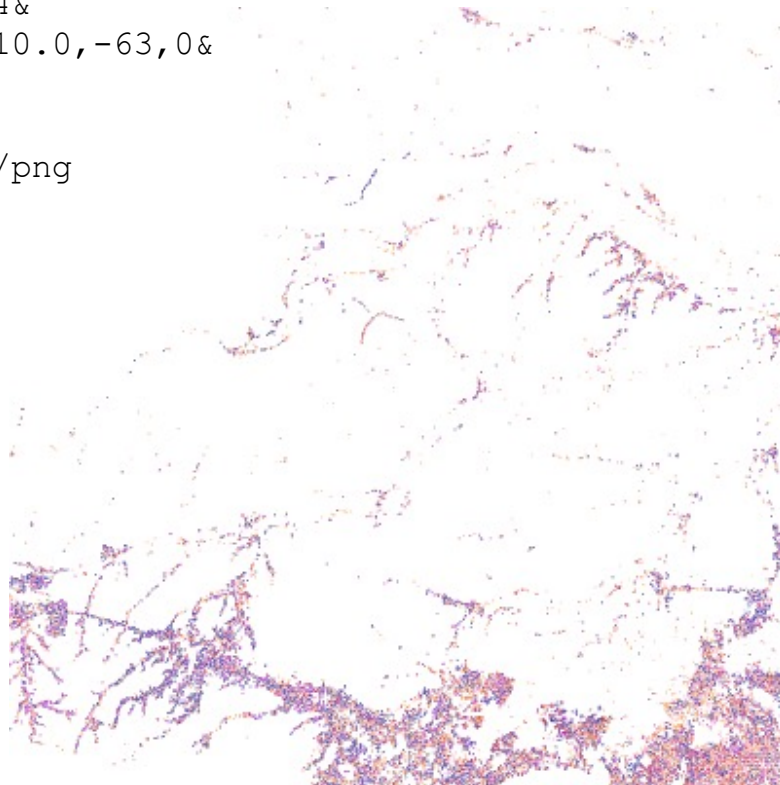
**CRS**=EPSG:4674&

**BBOX**=-73.0,-10.0,-63,0&

**WIDTH**=400&

**HEIGHT**=400&

**FORMAT**=image/png



## OGC - Web Map Service

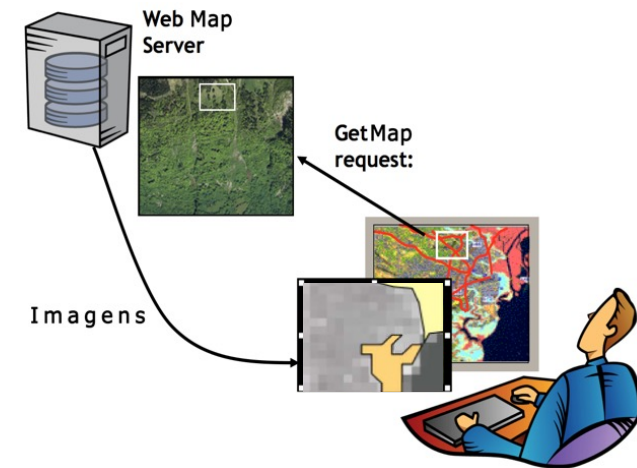


Figure: [https://geocatalogo.com.br/servicos\\_ogc.php](https://geocatalogo.com.br/servicos_ogc.php)

<http://sistemas.anatel.gov.br/geoserver/ANATEL/ows?service=wfs&version=1.3.0&request=GetCapabilities>

The screenshot shows the QGIS interface with a map of red points. A data table window is open, displaying the following data:

id_plano_basico	numfistel	nomefase	siglauf	nomemunicipio	nomeentidade	numservico	
1	79155376	01030101655	Licenciada	RJ	Rio de Janeiro	TV O DIA S/A	167
2	79155429	05030339876	Licenciada	PR	Curitiba	TELEVISÃO T...	167
3	79155939	50417090765	Outorgada	RJ	Rio de Janeiro	RIO METRO ...	167
4	79156311	03030158616	Licenciada	RS	Porto Alegre	RBS-EMPRES...	167
5	79156448	50417090846	Outorgada	SP	São Paulo	PAULISTA ME...	167
6	79156644	24000003950	Licenciada	ES	Vitória	TV 2000 LTDA	167
7	79156684	10030035910	Licenciada	CE	Fortaleza	RAIMUNDO A...	167
8	79157375	11030035008	Licenciada	DF	Brasília	RBC-REDE B...	167
9	79157743	04030147941	Licenciada	MG	Belo Horizonte	RÁDIO ITATIA...	167
10	79158060	11030035180	Licenciada	DF	Brasília	MCI TV DO B...	167

### OGC - Web Feature Service

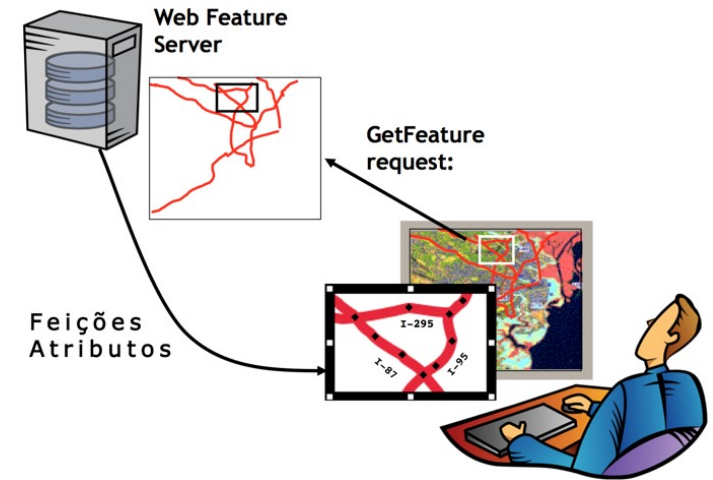
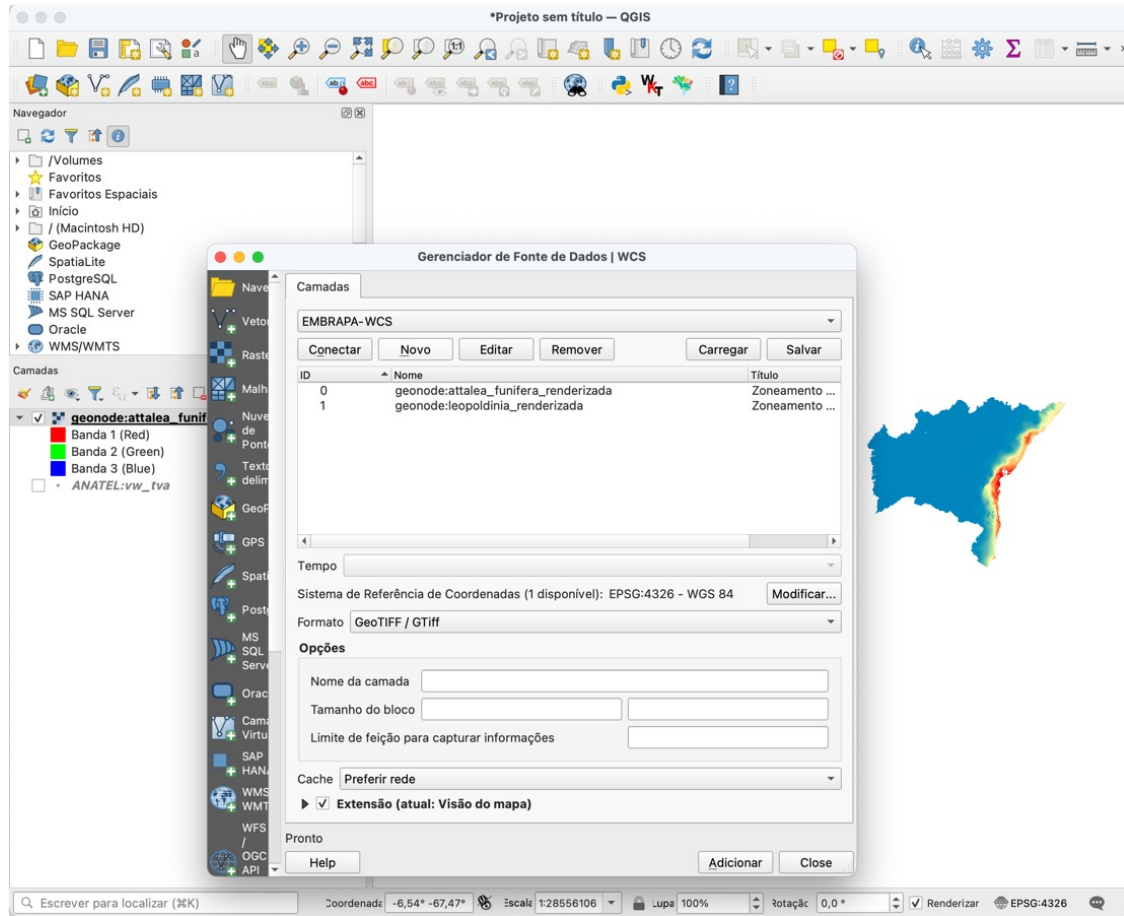


Figure: [https://geocatalogo.com.br/servicos\\_ogc.php](https://geocatalogo.com.br/servicos_ogc.php)

<https://atlas.geoinfo.cnpm.embrapa.br/geoserver/ows?service=WCS&version=1.3.0&request=GetCapabilities>



## OGC - Web Coverage Service

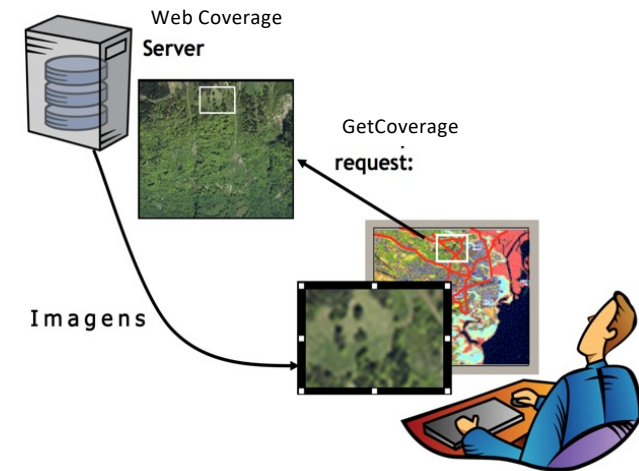


Figure: [https://geocatalogo.com.br/servicos\\_ogc.php](https://geocatalogo.com.br/servicos_ogc.php)

# Example: data.inpe.br/geonetwork

data.inpe.br/geonetwork/srv/por/catalog.search#/search?resultType=details&sortBy=relevance&from=1&to=30

BIG Catalogue Pesquisar Mapa Entrar Portuguesa

Pesquisar ...

Nada na cesta

Ordenado por relevância

Canal 12 - Dados GOES-16/ABI

Canal 02 - Dados GOES-16/ABI

Canal 10 - Dados GOES-16/ABI

Canal 09 - Dados GOES-16/ABI

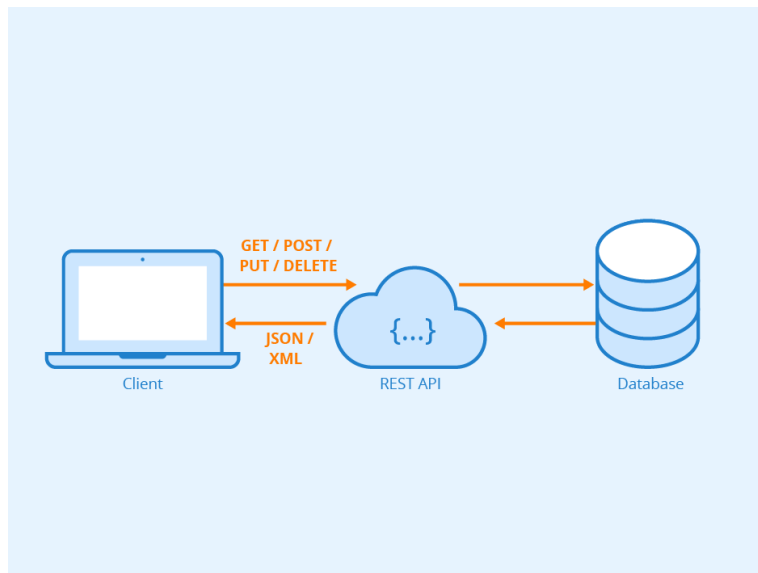
Filtro

- TIPOS DE RECURSOS
  - Conjunto de dados (196)
  - Serviço (10)
  - Service-OGC:WMS (5)
  - Service-COG-GeoTIFF Raster File (5)
- AÇÕES DISPONÍVEIS
  - Transferível (89)
  - Visível (61)
- TÓPICOS
  - Mapas de base, Coberturas Aéreas, i... (71)
  - Climatologia, Atmosfera (71)
  - Ambiente (43)
  - Informação geocientífica (42)
  - Águas interiores (16)
- PALAVRAS-CHAVE
  - Mapas de base, Coberturas Aéreas, i... (71)
  - Radiação Solar (71)
  - Energia Renovável (71)
  - Climatologia, Atmosfera (71)
  - Prodes (66)
- CONTATO PARA O RECURSO
  - INPE/MCTI (86)
  - Divisão de Processamento de Image... (74)
  - Divisão de Processamento de Image... (53)
  - INPE/MCTIC (41)
  - Fundação de Ciência, Aplicações e T... (22)



[https://bibliotecadigital.economia.gov.br/bitstream/123456789/310/1/Perfil\\_MGB.pdf](https://bibliotecadigital.economia.gov.br/bitstream/123456789/310/1/Perfil_MGB.pdf)

**Representational state transfer (REST)** is a software architectural style that defines a set of constraints to be used for creating Web services. RESTful Web services allow the requesting systems to access and manipulate textual representations of Web resources by using a uniform and predefined set of stateless operations



In programming terms, there is an **endpoint (a URL)** that the server is waiting to get a request. We connect to that endpoint and send in some data about us (remember, REST is stateless, no data about the request is stored) and the server responds with the correct response.

[https://official-joke-api.appspot.com/random\\_joke](https://official-joke-api.appspot.com/random_joke)

```
type: "general"
setup: "What did the ocean say to the shore?"
punchline: "Nothing, it just waved."
id: 181
```

The STAC specification is a **common language to describe geospatial information**, so it can more easily be worked with, indexed, and discovered.

**STAC Item** is the core atomic unit, representing a single spatiotemporal asset as a GeoJSON feature plus datetime and links.

**STAC Catalog** is a simple, flexible JSON file of links that provides a structure to organize and browse STAC Items. A series of best practices helps make recommendations for creating real world STAC Catalogs.

**STAC Collection** is an extension of the STAC Catalog with additional information such as the extents, license, keywords, providers, etc that describe STAC Items that fall within the Collection.

**STAC API** provides a RESTful endpoint that enables search of STAC Items, specified in OpenAPI, following OGC's WFS 3.

<https://stacspec.org/en>



Example: a STAC Catalog for EO Imagery

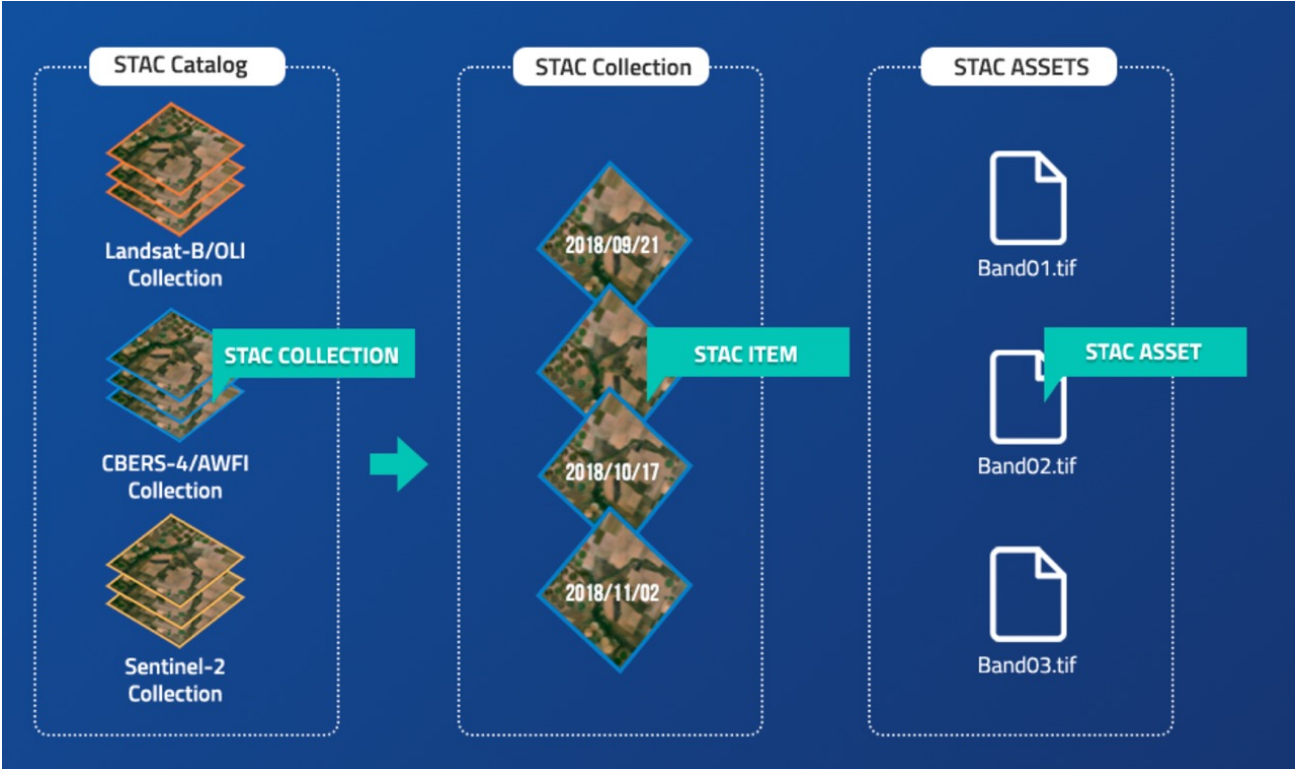
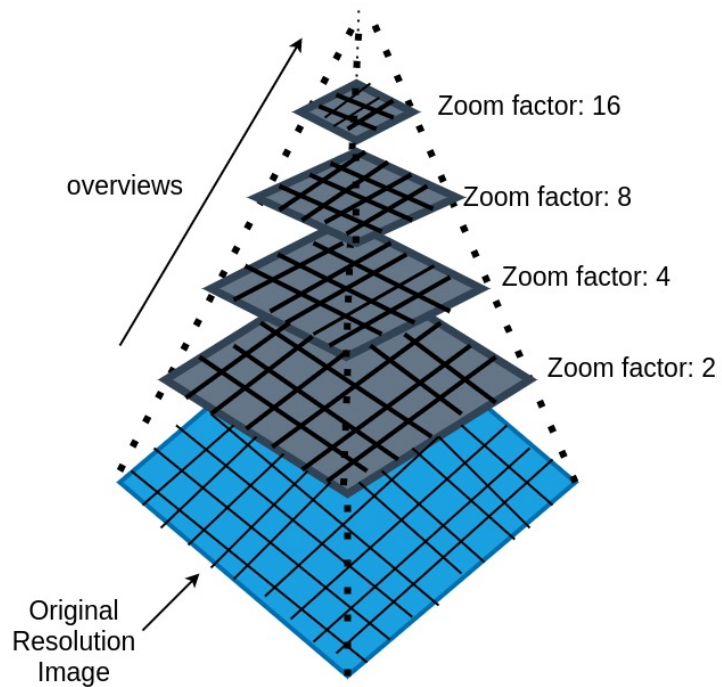


Figure: <http://www.brazildatacube.org/stac-spatiotemporal-asset-catalog/>

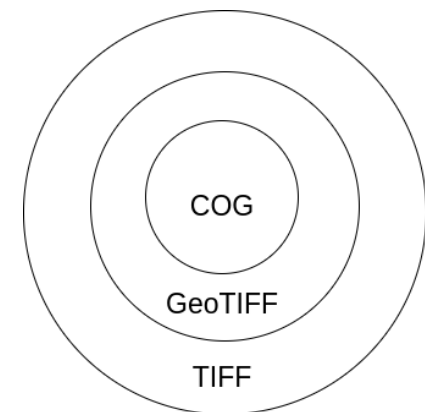
A **Cloud Optimized GeoTIFF (COG)** is a regular GeoTIFF file, aimed at being hosted on a HTTP file server, with an internal organization that enables more efficient workflows on the cloud.



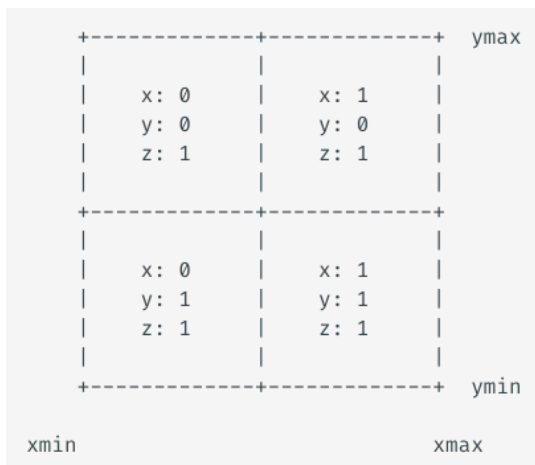
<https://www.cogeo.org/map>



[https://data.inpe.br/data/S2\\_L2A\\_COG/v001/21/L/YG/2023/3/S2A\\_TCI\\_20230304T134701\\_N0509\\_R024\\_T21LYG\\_20230304T192754.tif](https://data.inpe.br/data/S2_L2A_COG/v001/21/L/YG/2023/3/S2A_TCI_20230304T134701_N0509_R024_T21LYG_20230304T192754.tif)

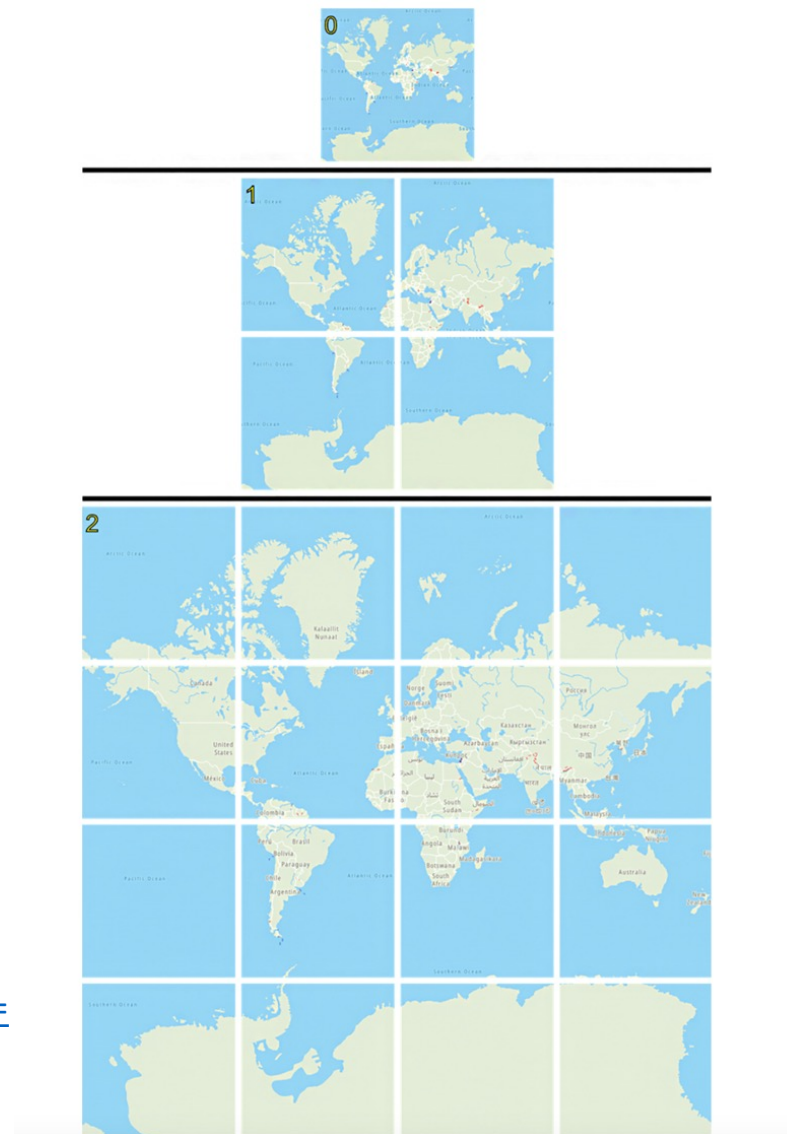


**TMS** is a protocol created by OSGeo that allows tiles to be requested using integer indices. It also provides metadata for discovery and configuration. It is based on the concept of TileMatrixSets

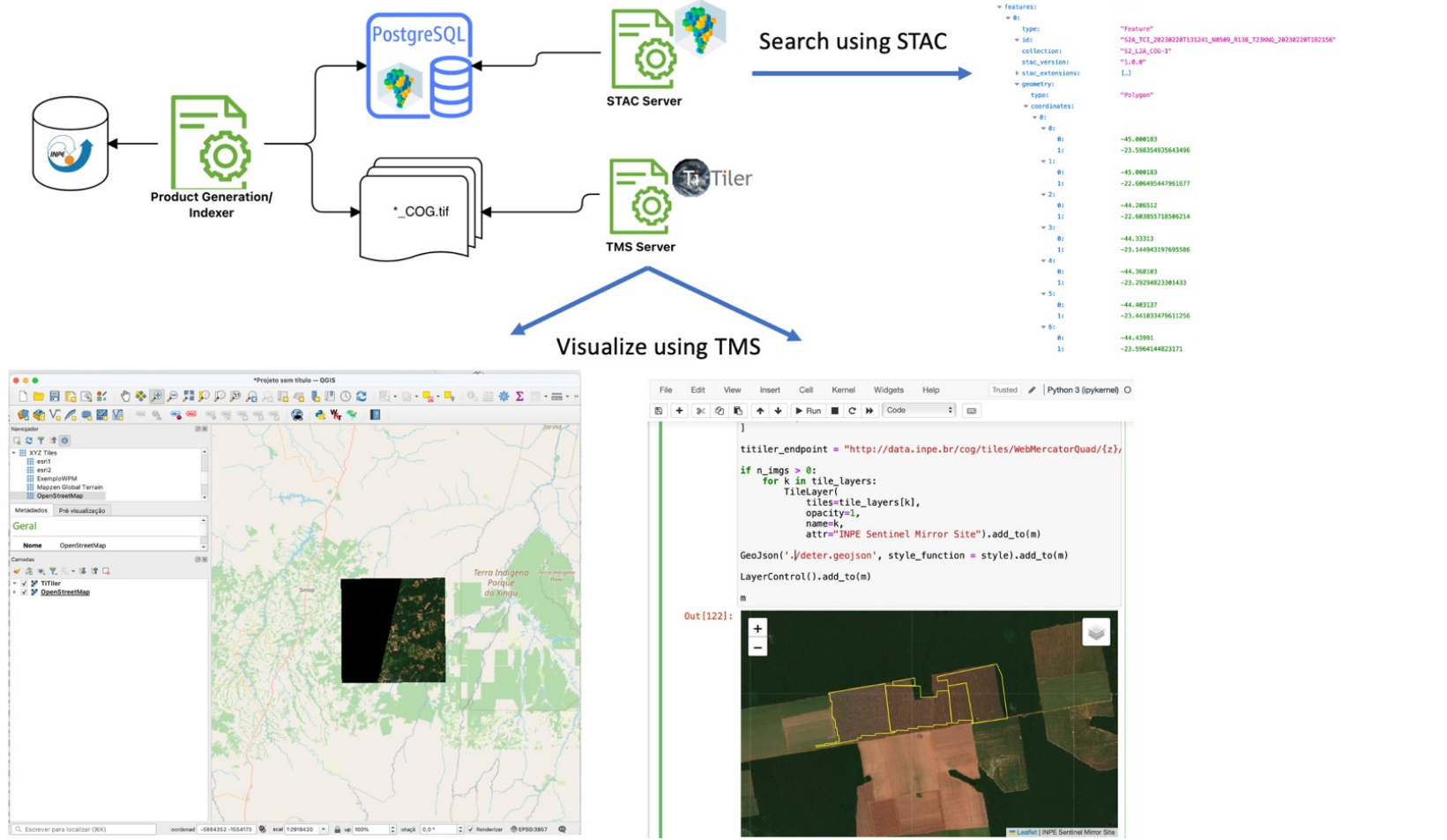


The [Web Mercator grid](#) is the **de facto standard** for Web maps.

<http://data.inpe.br/cog/tiles/WebMercatorQuad/{z}/{x}/{y}@1x?url=>



# Example



# Exercício

- Buscar (ex. Catálogo da INDE) pelo menos dois conjuntos de dados de interesse para o seu trabalho indicando como estão disponíveis para acesso
  - Quais serviços? Quais as URL's dos serviços?
- Interagir com o serviço STAC do catálogo CBERS4 e Amazônia disponível em:  
[www2.dgi.inpe.br/inpe-stac/](http://www2.dgi.inpe.br/inpe-stac/)

Identificar quais as coleções são oferecidas

- Onde você pode encontrar as Bases cartográficas contínuas – Brasil, do IBGE? Para download e por serviços.