

Le stockage S3

Un exemple pour la visualisation de cartes interactives

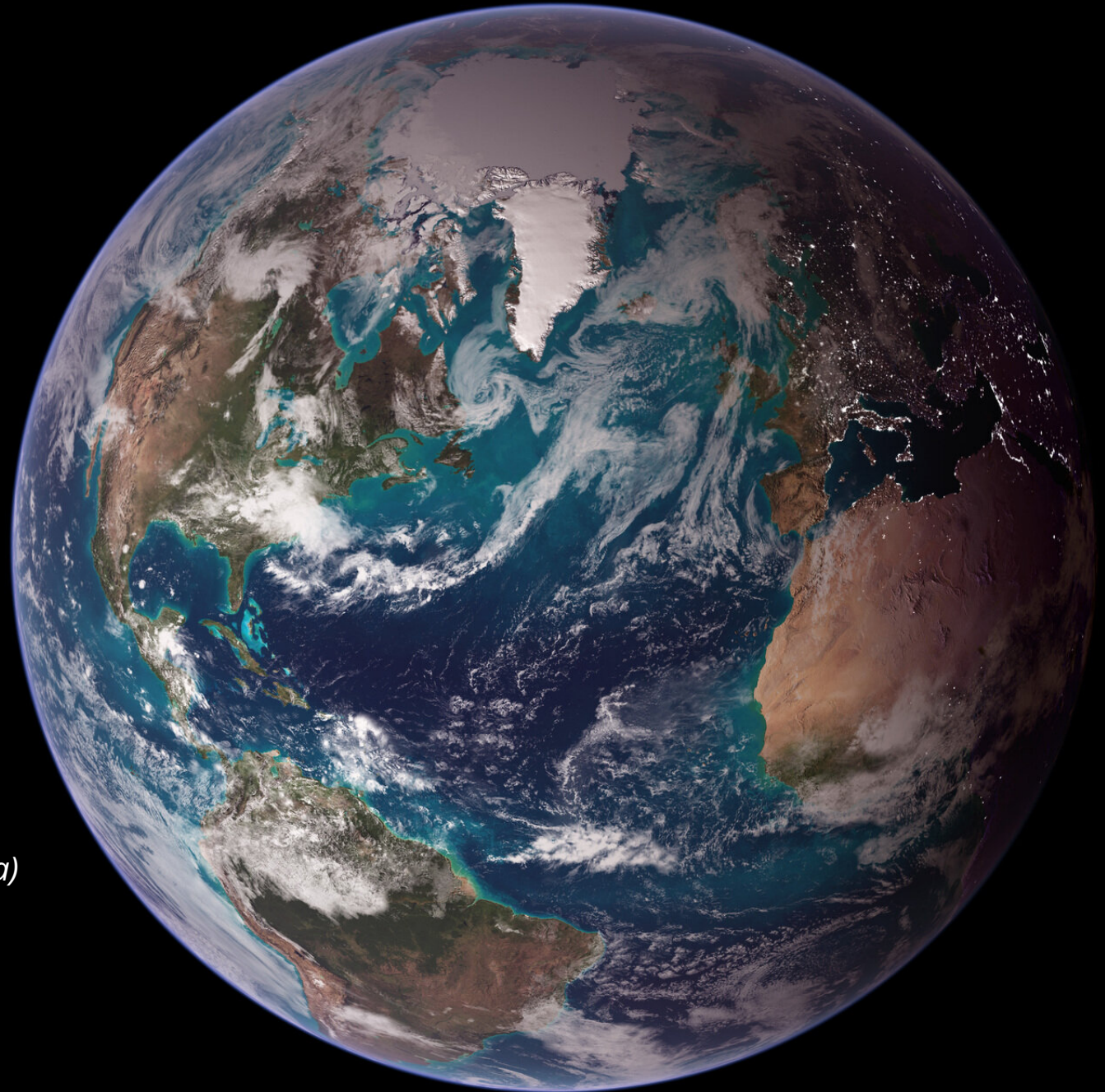
Benoît Seignovert

*Observatoire des Sciences de l'Univers Nantes Atlantique (Osuna)
Groupement Ligérien pour le Calcul Intensif Distribué (GLiCID)*

Josy Stockage S3 | Strasbourg | 2025-10-08

slid.es/seignovert/josy-s3

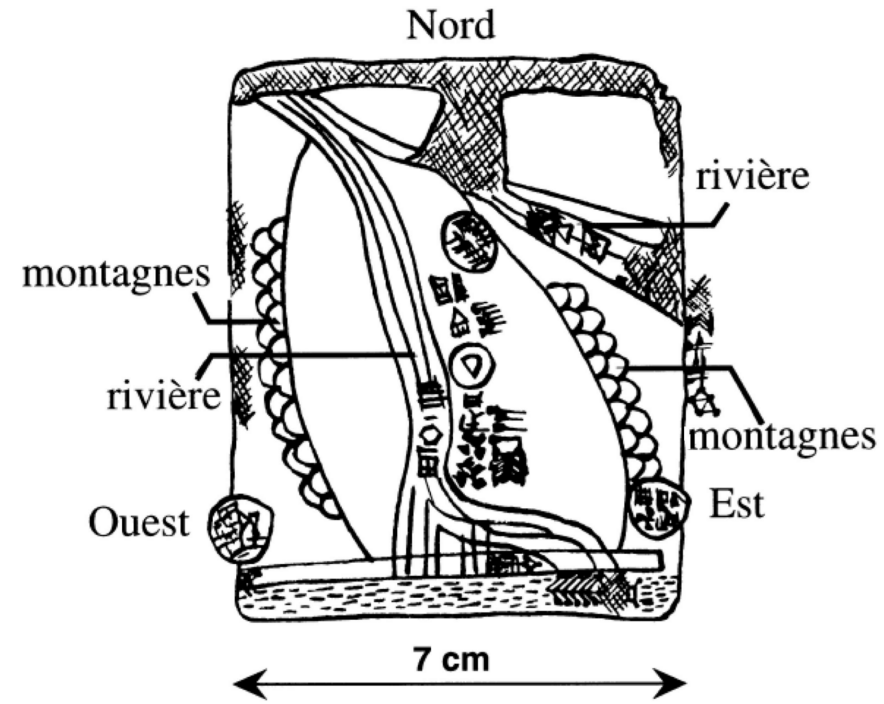
doi: 10.57745/DZGEQS



NASA/NOAA/R. Stöckli

Produire des cartes

une histoire millénaire



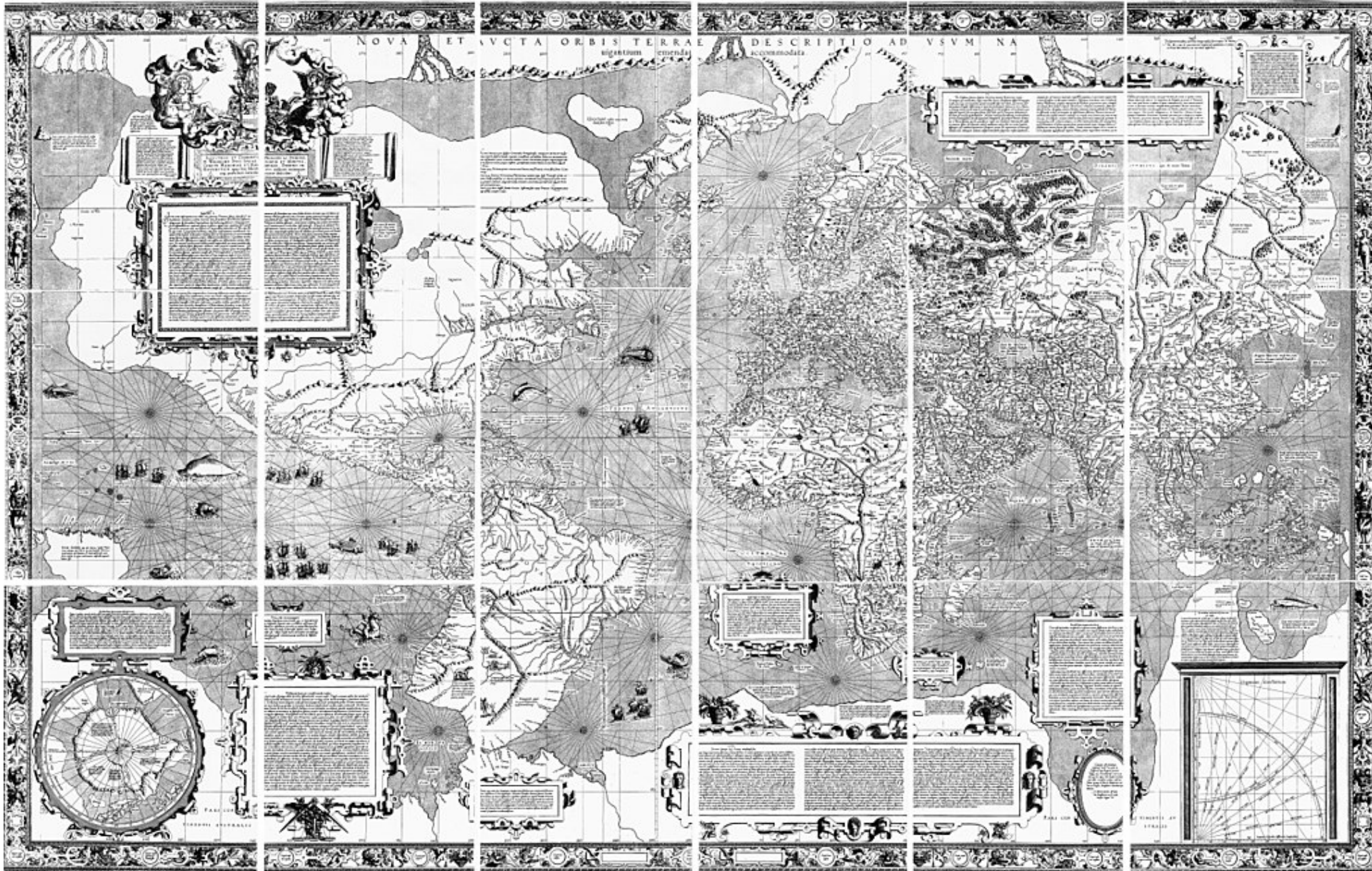
Carte Sumérienne | -2500



Tabula Rogeriana | 1154

70 feuillets

Global vs. détails



Carte de Mercator
1569

18 feuillets

1.2 m x 60 cm

Global vs. détails

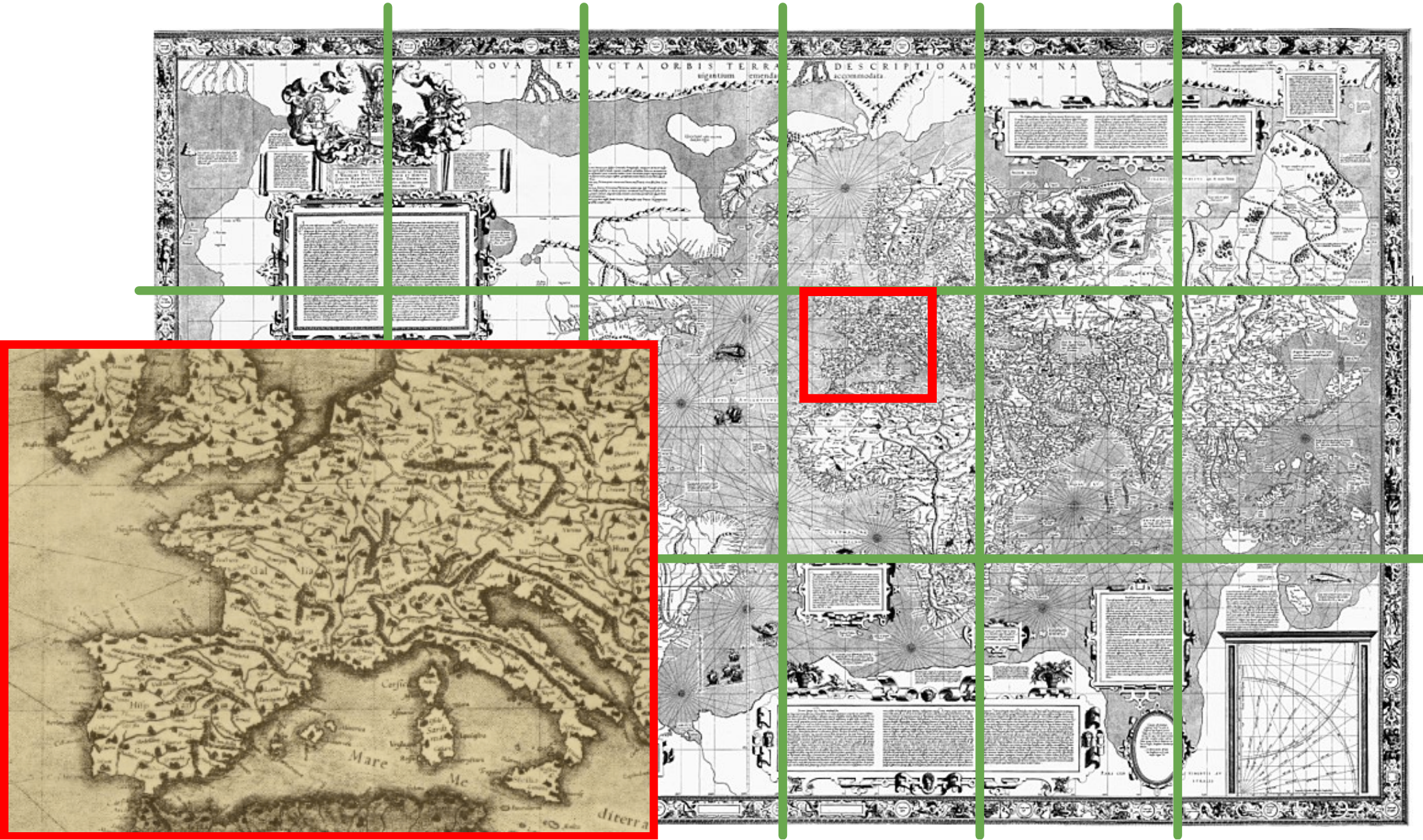


Carte de Mercator
1569

18 feuillets

1.2 m x 60 cm

Global vs. détails



Carte de Mercator
1569

18 feuillets

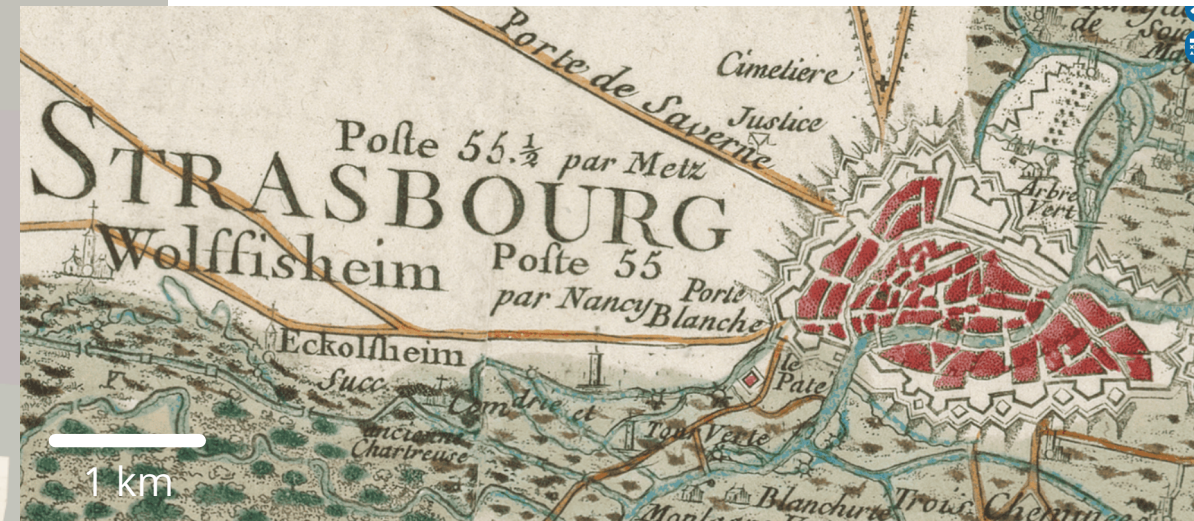
1.2 m x 60 cm

Carte de Cassini

1756 - 1815
(4 générations !)

181 feuilles au 1:86 400

11 m x 11 m



Écran

32 000 x 32 000 pixels

1 000 Mpix ~ 3 Go

Papier

130 000 x 130 000 pixels

17 000 Mpix ~ 50 Go

Cartes IGN

1 200 cartes au 1:25 000

38 m x 38 m

Écran

110 000 x 110 000 pixels

12 000 Mpix ~ 33 Go

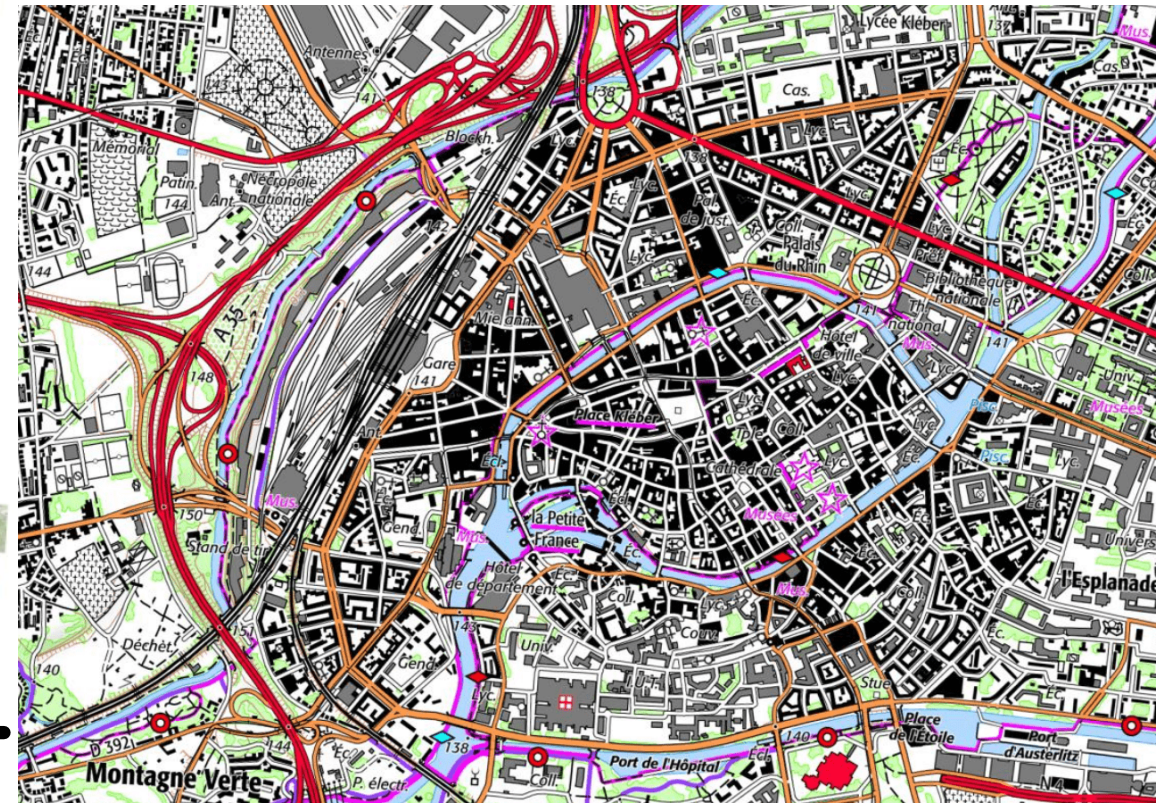
Papier

450 000 x 450 000 pixels

200 000 Mpix ~ 0.5 To



300 m



Global vs. détails aujourd'hui

Projection Mercator



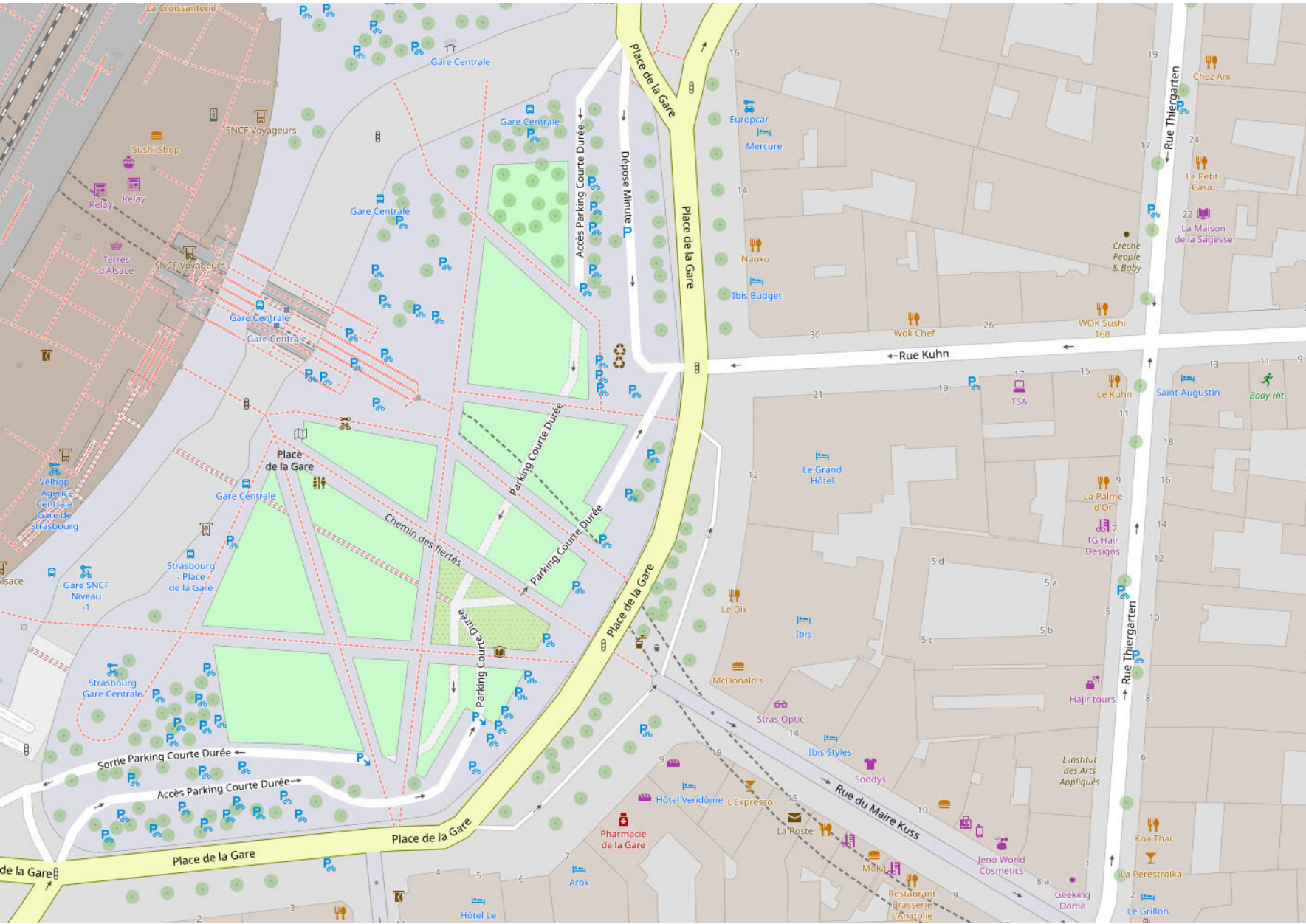
1:1 000
40 km x 20 km

Écran
110 000 000 x 55 000 000 pixels
6 000 000 000 Mpix ~ 18 Po

Papier
450 000 000 x 225 000 000 pixels
100 000 000 000 Mpix ~ 300 Po

Global vs. détails aujourd'hui

Strasbourg



1:1 000

40 km x 20 km

Écran

110 000 000 x 55 000 000 pixels

6 000 000 000 Mpix ~ 18 Po

Papier

450 000 000 x 225 000 000 pixels

100 000 000 000 Mpix ~ 300 Po

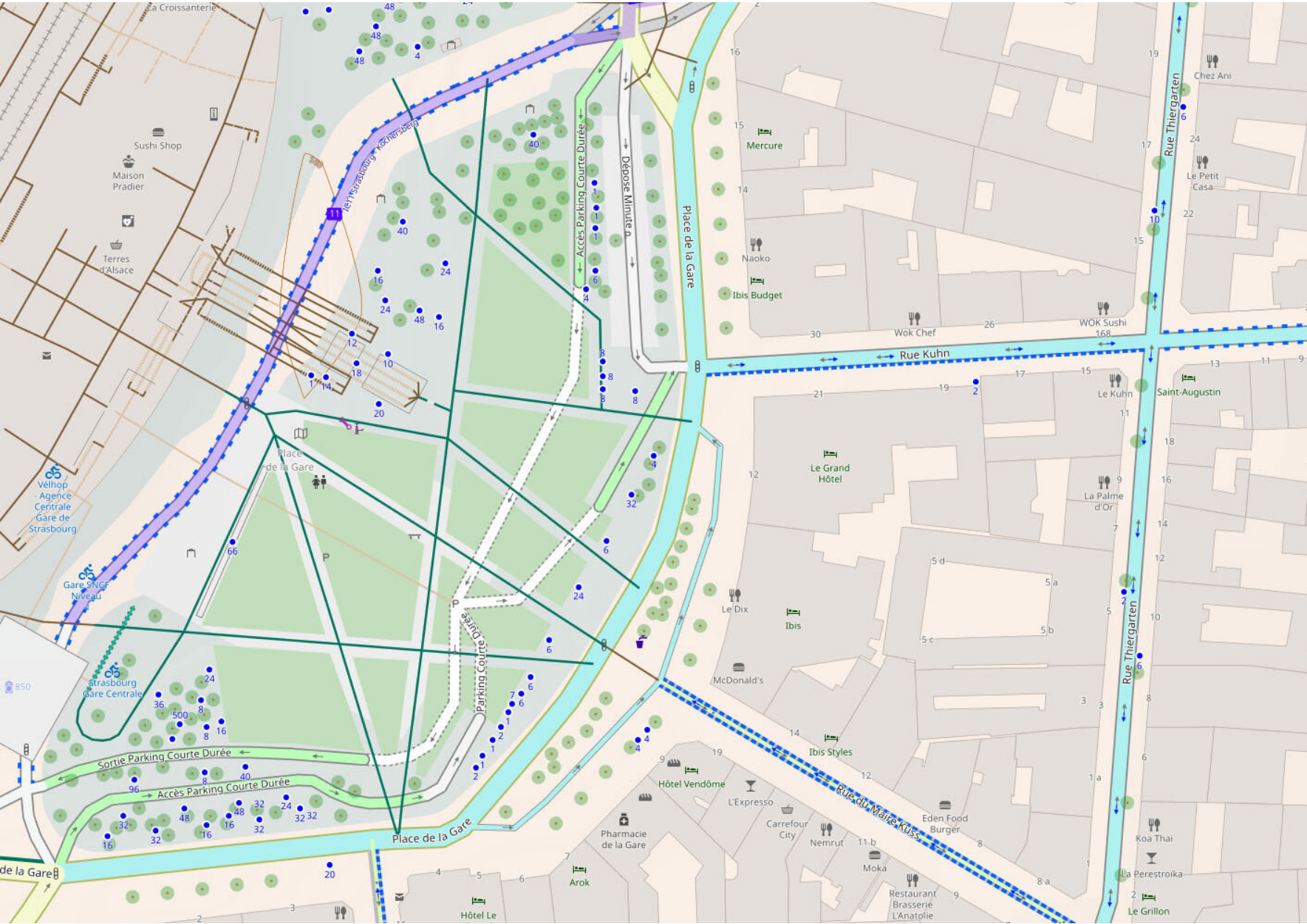
10 m

Open Street Map

Level 19

Global vs. détails aujourd'hui

Strasbourg



1:1 000

40 km x 20 km

Écran

110 000 000 x 55 000 000 pixels

6 000 000 000 Mpix ~ 18 Po

Papier

450 000 000 x 225 000 000 pixels

100 000 000 000 Mpix ~ 300 Po

10 m

Open Street Map

Level 19

**Comment
stocker tout ça ?**

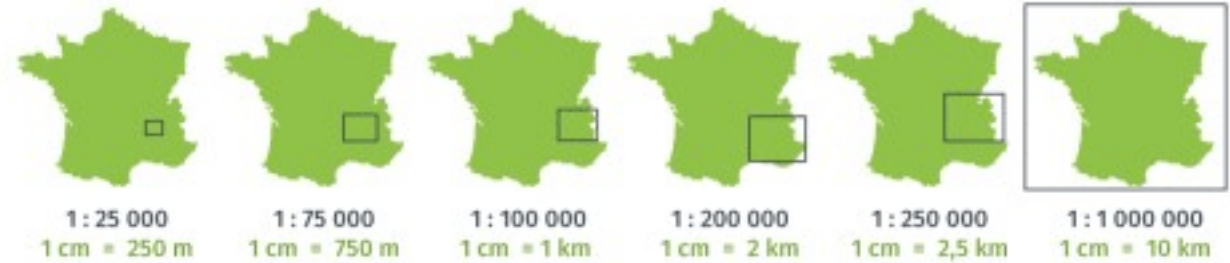


Oui mais ...

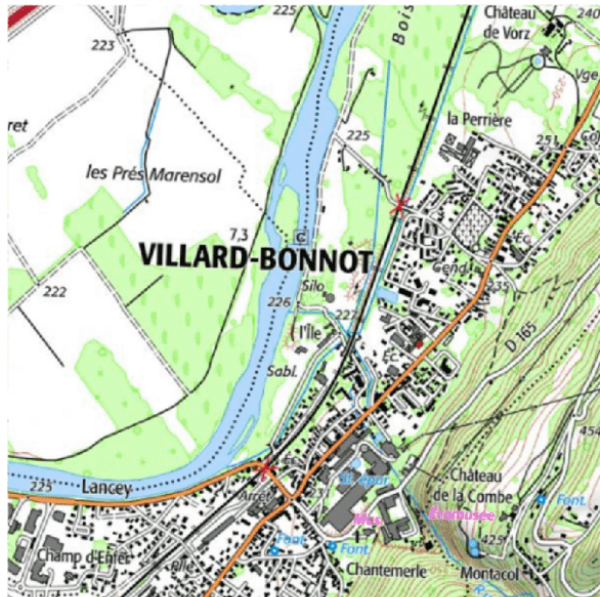
on n'a pas attendu S3 pour **distribuer** des cartes



Des cartes à différentes résolutions



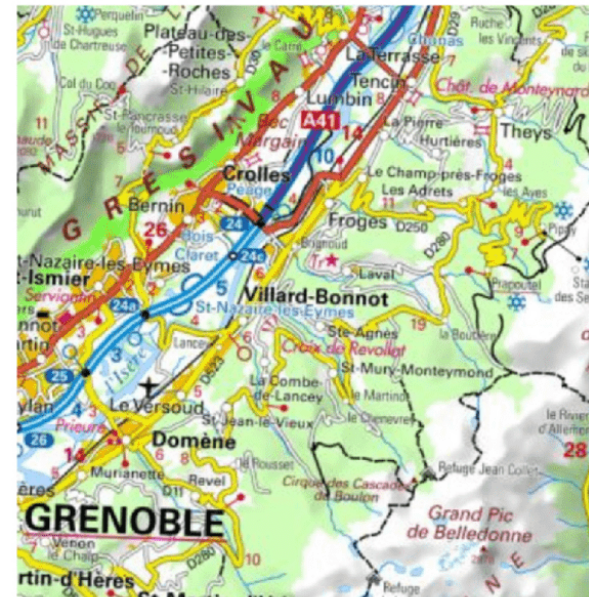
IGN



1 : 25 000



1 : 100 000



1 : 250 000



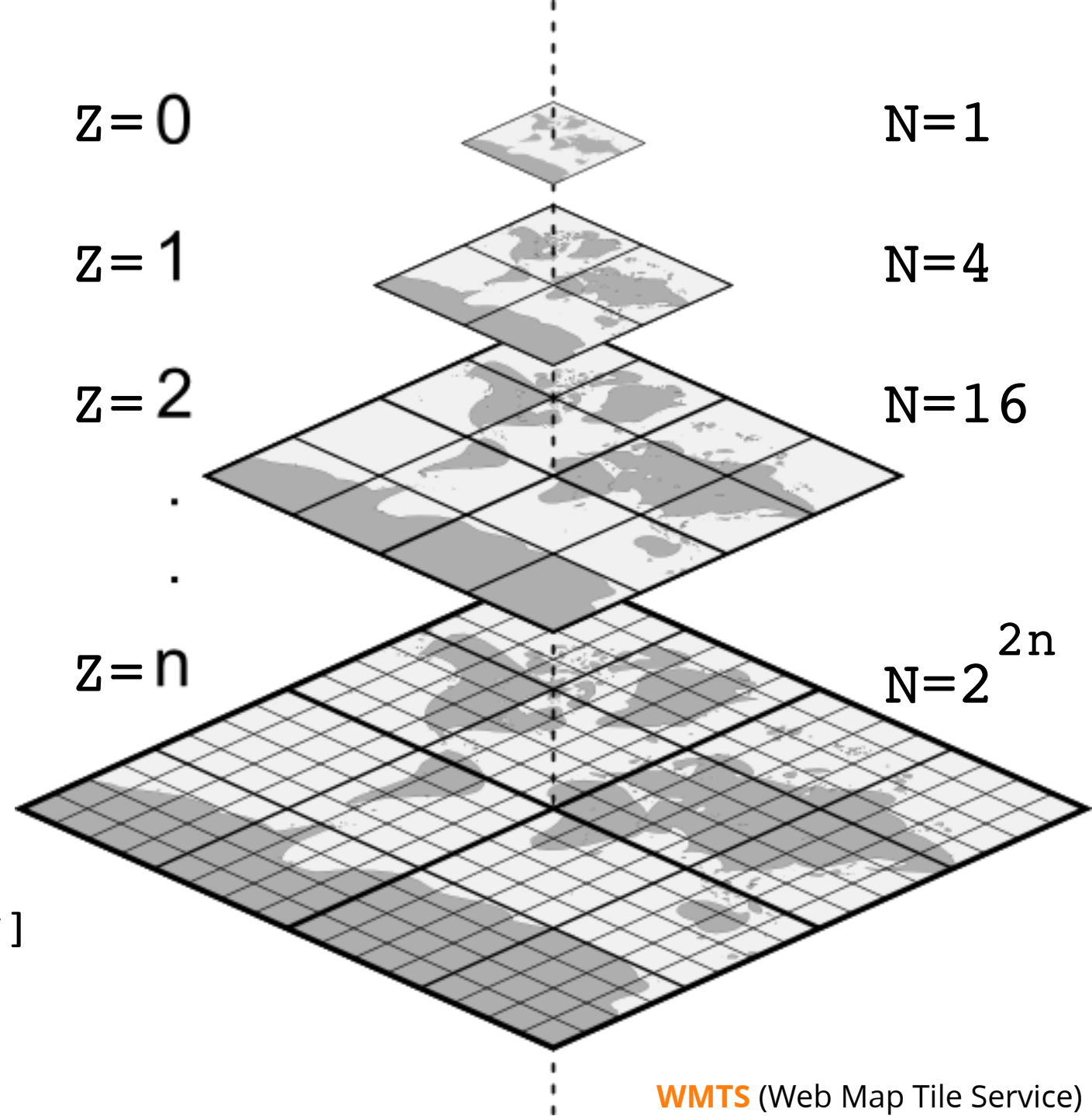
1 : 1 000 000

Méthode de Tuilage | Pyramidage

Taille des tuiles : 256 x 256 pixels
200 ko

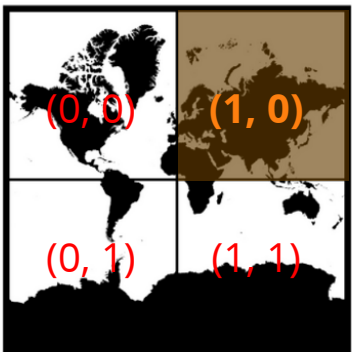
Nombre de tuiles : $N(Z) = 2^{2 \times Z}$

Indexation des tuiles : /Z/X/Y.[jpg|png]

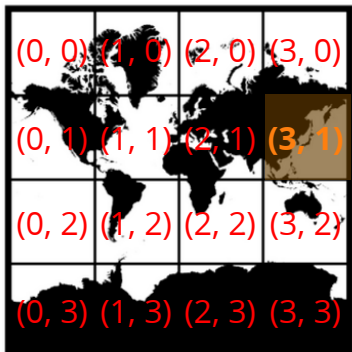




$Z = 0$



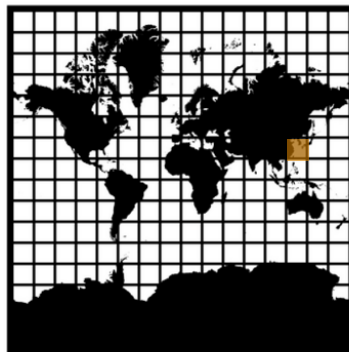
$Z = 1$



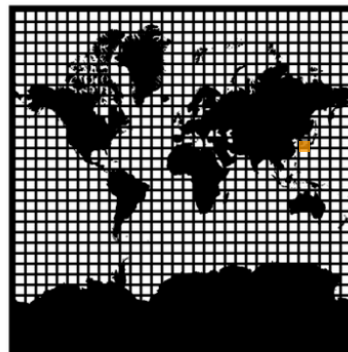
$Z = 2$



$Z = 3$



$Z = 4$



$Z = 5$

...



$(0, 0, 0)$



$(1, 1, 0)$



$(2, 3, 1)$



$(3, 6, 3)$



$(4, 13, 6)$



$(5, 27, 12)$ (Z, X, Y)

...

Coté server

1 x 256 x 256 pix
200 ko

4 x 256 x 256 pix
800 ko

16 x 256 x 256 pix
3.2 Mo

64 x 256 x 256 pix
13 Mo

256 x 256 x 256 pix
51 Mo

1024 x 256 x 256 pix
256 Mo

324 Mo
+26 %

Coté client

256 x 256 pix
200 ko

256 x 256 pix
200 ko

256 x 256 pix
200 ko

256 x 256 pix
200 ko

256 x 256 pix
200 ko

256 x 256 pix
200 ko

1.2 Mo
0.5%

Démo

```
1 <!DOCTYPE html>
2 <html lang="en">
3 <head>
4   <meta charset="UTF-8">
5   <meta name="viewport" content="width=device-width, initial-scale=1.0">
6   <title>Map tiles demo</title>
7   <link rel="stylesheet" href="https://unpkg.com/leaflet@1.9.4/dist/leaflet.css"/>
8 </head>
9 <body>
10   <div id="map" style="height: 800px"></div>
11   <script src="https://unpkg.com/leaflet@1.9.4/dist/leaflet.js"></script>
12   <script>
13     const map = L.map('map').setView([48.6056, 7.7095], 0);
14
15     const tiles = L.tileLayer('https://tile.openstreetmap.org/{z}/{x}/{y}.png', {
16       maxZoom: 19,
17       attribution: '© <a href="http://www.openstreetmap.org/copyright">OpenStreetMap</a>',
18     }).addTo(map);
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18     }).addTo(map);
19   </script>
20 </body>
21 </html>
```


Status	Method	Domain	File	URL	Initiator	Type	Transferred
200	GET	tile.openstreetmap.org	1.png	https://tile.openstreetmap.org/2/1/1.png	img	png	8,62 kB
200	GET	tile.openstreetmap.org	1.png	https://tile.openstreetmap.org/2/2/1.png	img	png	12,10 kB
200	GET	tile.openstreetmap.org	2.png	https://tile.openstreetmap.org/2/1/2.png	img	png	4,72 kB
200	GET	tile.openstreetmap.org	2.png	https://tile.openstreetmap.org/2/2/2.png	img	png	3,72 kB
200	GET	tile.openstreetmap.org	0.png	https://tile.openstreetmap.org/2/1/0.png	img	png	8,02 kB
200	GET	tile.openstreetmap.org	0.png	https://tile.openstreetmap.org/2/2/0.png	img	png	5,93 kB
200	GET	tile.openstreetmap.org	1.png	https://tile.openstreetmap.org/2/0/1.png	img	png	5,78 kB
200	GET	tile.openstreetmap.org	1.png	https://tile.openstreetmap.org/2/3/1.png	img	png	cached
200	GET	tile.openstreetmap.org	2.png	https://tile.openstreetmap.org/2/0/2.png	img	png	766 B
200	GET	tile.openstreetmap.org	2.png	https://tile.openstreetmap.org/2/3/2.png	img	png	4,18 kB
200	GET	tile.openstreetmap.org	3.png	https://tile.openstreetmap.org/2/1/3.png	img	png	2,14 kB
200	GET	tile.openstreetmap.org	3.png	https://tile.openstreetmap.org/2/2/3.png	img	png	1,47 kB
200	GET	tile.openstreetmap.org	0.png	https://tile.openstreetmap.org/2/0/0.png	img	png	5,48 kB
200	GET	tile.openstreetmap.org	0.png	https://tile.openstreetmap.org/2/3/0.png	img	png	3,71 kB
200	GET	tile.openstreetmap.org	3.png	https://tile.openstreetmap.org/2/0/3.png	img	png	1,54 kB
200	GET	tile.openstreetmap.org	3.png	https://tile.openstreetmap.org/2/3/3.png	img	png	1,64 kB
200	GET	tile.openstreetmap.org	1.png	https://tile.openstreetmap.org/2/3/1.png	lazy-img	png	7,20 kB
200	GET	tile.openstreetmap.org	3.png	https://tile.openstreetmap.org/3/3/3.png	img	png	5,77 kB
200	GET	tile.openstreetmap.org	3.png	https://tile.openstreetmap.org/3/4/3.png	img	png	15,24 kB
200	GET	tile.openstreetmap.org	2.png	https://tile.openstreetmap.org/3/3/2.png	img	png	5,69 kB
200	GET	tile.openstreetmap.org	2.png	https://tile.openstreetmap.org/3/4/2.png	img	png	15,78 kB
200	GET	tile.openstreetmap.org	4.png	https://tile.openstreetmap.org/3/4/2.png	img	png	1,35 kB
200	GET	tile.openstreetmap.org	4.png	https://tile.openstreetmap.org/3/4/4.png	img	png	10,19 kB
200	GET	tile.openstreetmap.org	4.png	https://tile.openstreetmap.org/3/2/3.png	img	png	6,27 kB
200	GET	tile.openstreetmap.org	4.png	https://tile.openstreetmap.org/3/5/3.png	img	png	10,13 kB
200	GET	tile.openstreetmap.org	4.png	https://tile.openstreetmap.org/3/2/2.png	img	png	10,18 kB
200	GET	tile.openstreetmap.org	4.png	https://tile.openstreetmap.org/3/5/2.png	img	png	6,44 kB
200	GET	tile.openstreetmap.org	4.png	https://tile.openstreetmap.org/3/2/4.png	img	png	8,56 kB
200	GET	tile.openstreetmap.org	4.png	https://tile.openstreetmap.org/3/5/4.png	img	png	1,22 kB
200	GET	tile.openstreetmap.org	4.png	https://tile.openstreetmap.org/3/3/1.png	img	png	5,06 kB
200	GET	tile.openstreetmap.org	4.png	https://tile.openstreetmap.org/3/4/1.png	img	png	5,40 kB
200	GET	tile.openstreetmap.org	4.png	https://tile.openstreetmap.org/3/3/5.png	img	png	899 B
200	GET	tile.openstreetmap.org	4.png	https://tile.openstreetmap.org/3/4/5.png	img	png	766 B
200	GET	tile.openstreetmap.org	2.png	https://tile.openstreetmap.org/3/6/2.png	img	png	6,90 kB
200	GET	tile.openstreetmap.org	4.png	https://tile.openstreetmap.org/3/1/4.png	img	png	861 B
200	GET	tile.openstreetmap.org	1.png	https://tile.openstreetmap.org/3/2/1.png	img	png	9,12 kB

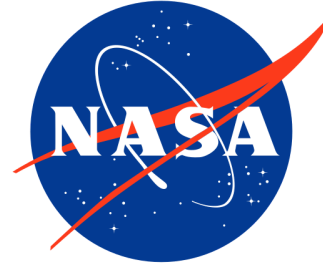
Quelques fournisseurs de tuiles



Open Street Map



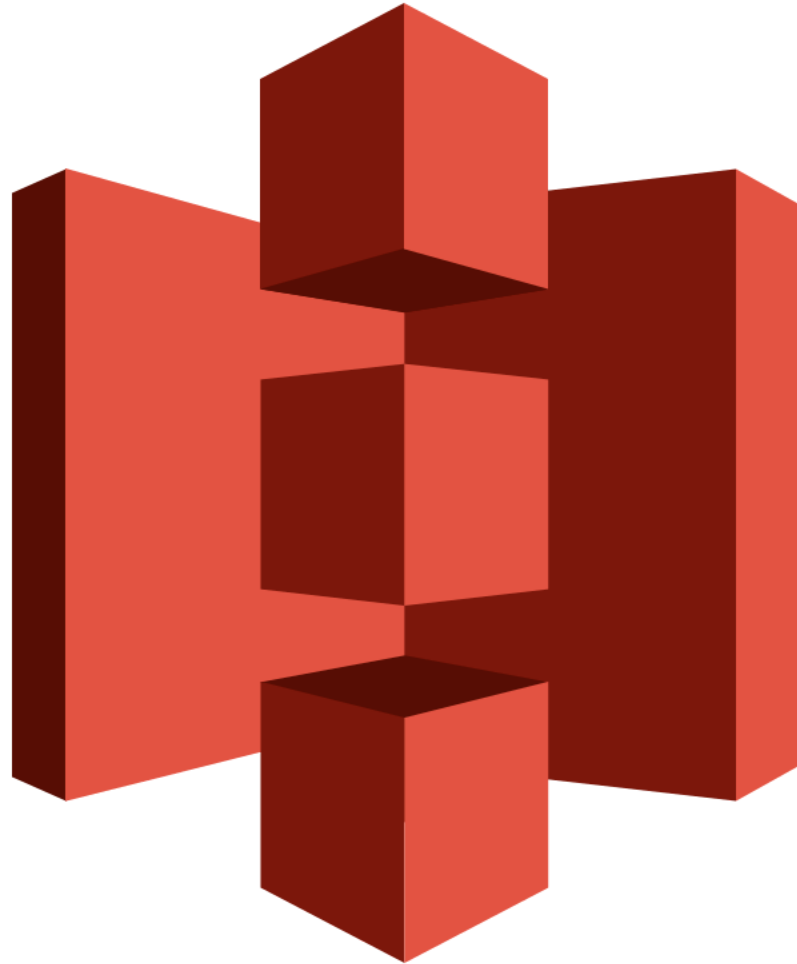
Google Maps



Apple Maps



Pourquoi faire du stockage sur S3 ?

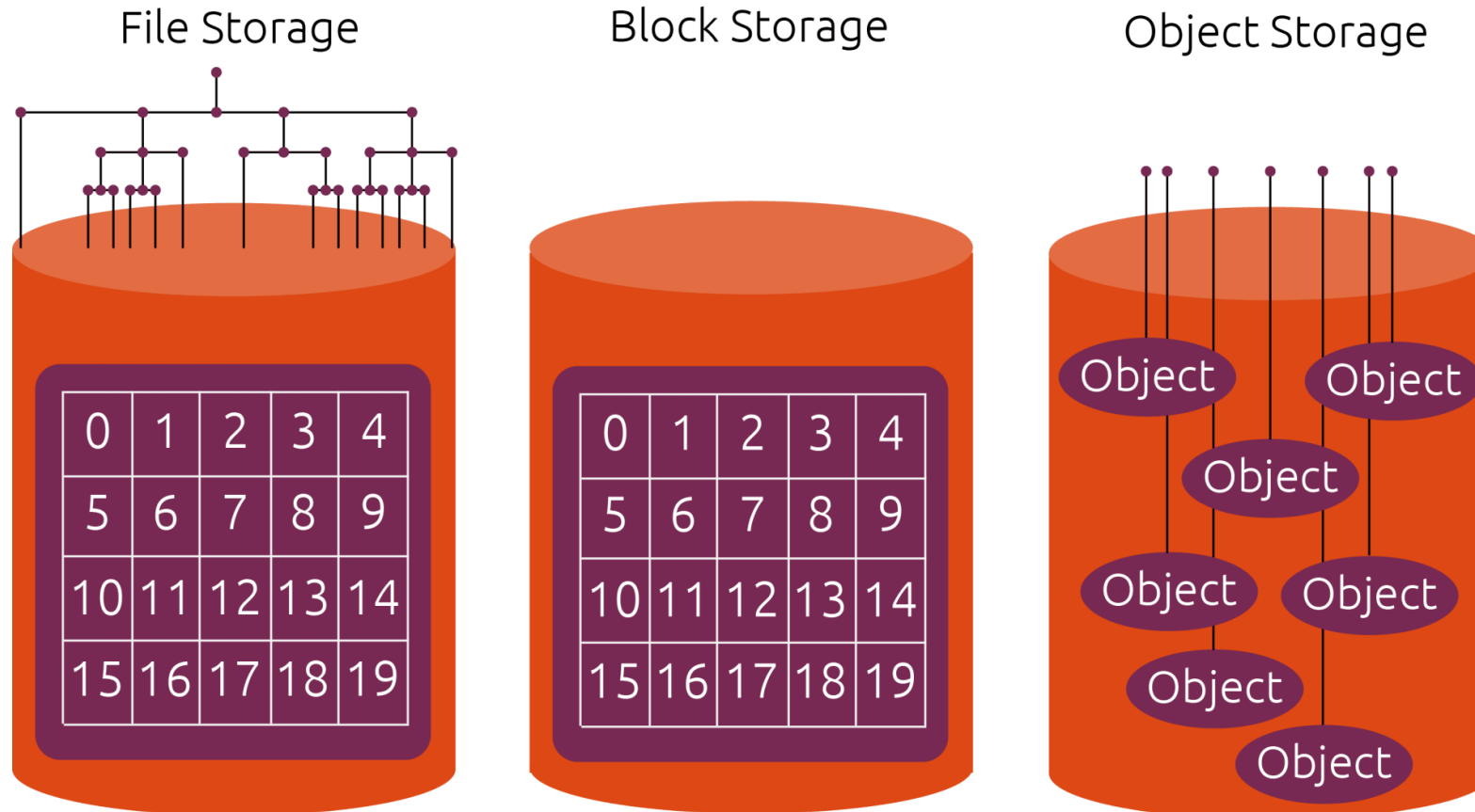


Tuilage à petite échelle...

256 x 256 pixels
200 ko

Level	# Tuiles	Taille du pixel	~ Échelle	Couverture	# dossiers / fichiers	Taille	
0	1	160 km	1:500 000 000	Globale	1 / 1 / 1	200 ko	😂
1	4	80 km	1:250 000 000		2 / 2 / 2	0.8 Mo	🌈
2	16	40 km	1:150 000 000	Continent	3 / 4 / 4	3.2 Mo	🦄
3	64	20 km	1:70 000 000		4 / 8 / 8	12 Mo	✨
4	256	10 km	1:35 000 000		4 / 16 / 16	50 Mo	👉
5	1 024	5 km	1:15 000 000	Pays	5 / 32 / 32	200 Mo	👏
6	4 096	2.5 km	1:8 000 000		6 / 64 / 64	0.8 Go	👍
7	16 384	1.2 km	1:4 000 000		7 / 128 / 128	3.2 Go	👉
8	65 536	600 m	1:2 000 000		8 / 256 / 256	12 Go	✌️
9	262 144	300 m	1:1 000 000		9 / 512 / 512	50 Go	👊
10	1 048 576	150 m	1:500 000	Métropole	10 / 1024 / 1024	200 Go	💪
11	4 194 304	75 m	1:250 000	Ville	11 / 2 048 / 2 048	0.8 To	🏆
...	...	...	...	...	...	...	
15	1 073 741 824	5 m	1:15 000	Route	15 / 32 768 / 32 768	200 To	💣
16	4 294 967 296	2.5 m	1:8 000		16 / 65 536 / 65 536	0.8 Po	💥
17	17 179 869 184	1.2 m	1:4 000	Adresse	17 / 131 072 / 131 072	3.2 Po	🔥
18	68 719 476 736	60 cm	1:2 000		18 / 262 144 / 262 144	12 Po	😵
19	274 877 906 944	30 cm	1:1 000	Passage piéton	19 / 524 288 / 524 288	50 Po	💀

Impossible de stocker des cartes à haute résolution sans **stockage objet** !





Faire des cartes interactives en S3 ☐

Capacité à stocker des très **grandes volumétries**

Capacité à stocker un très grand **nombre de fichiers** de petites tailles

Pas de limite de dossiers / fichiers

Stockage **web natif** (gateway)

Stockage **statique** (pas besoin de serveur)

Adressage par des objets par clé : **`/z/x/y.fmt`**

Parallélisation des requêtes: excellente performance

Utilisation en **CDN** : réplication / synchronisation / haute disponibilité / régionalisation

Coût du stockage faible mais... ⚠ au egress-cost 💰

Résolution temporelle



`/ {t} / {z} / {x} / {y} .fmt`



2025

Résolution temporelle



$\{/t\}/\{z\}/\{x\}/\{y\}.fmt$



2002

Résolution temporelle

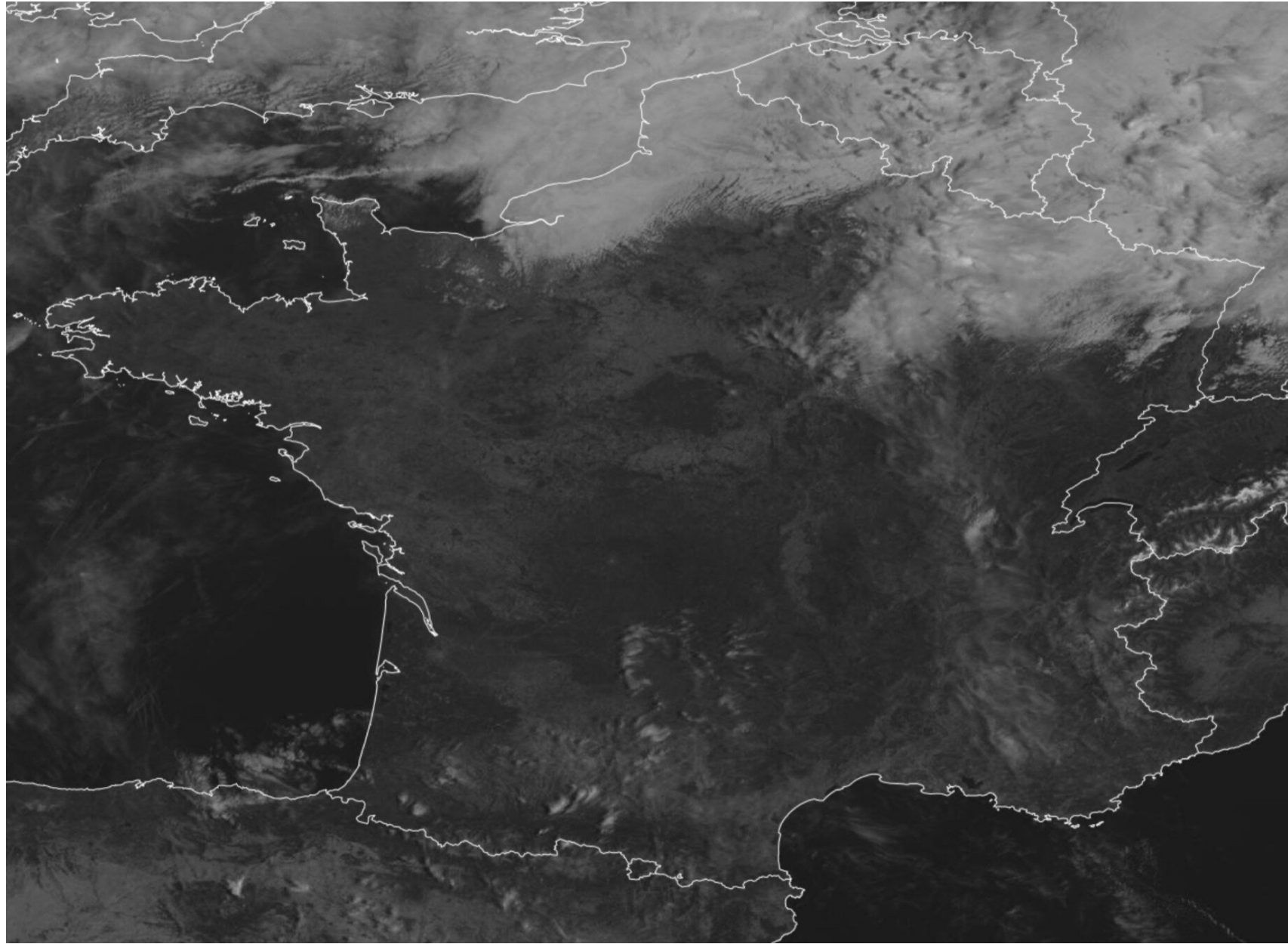


`/ {t} / {z} / {x} / {y} .fmt`



1943

Résolution multi/hyper-spectrale 🌈



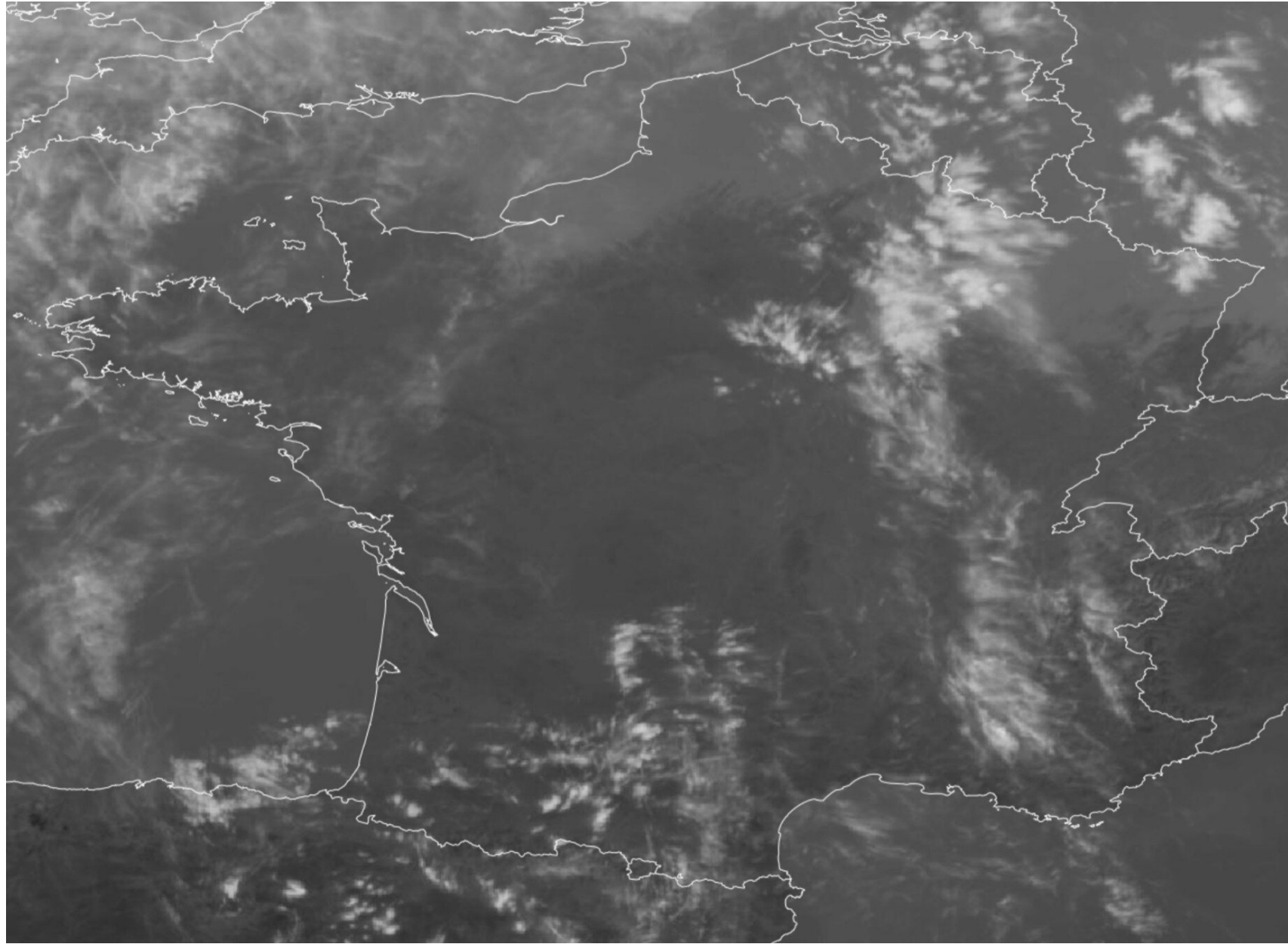
`/w/z/x/y.fmt`

0.6 μm

Eumetsat

Meteosat FCI

Résolution multi/hyper-spectrale 🌈



`/w/z/x/y.fmt`

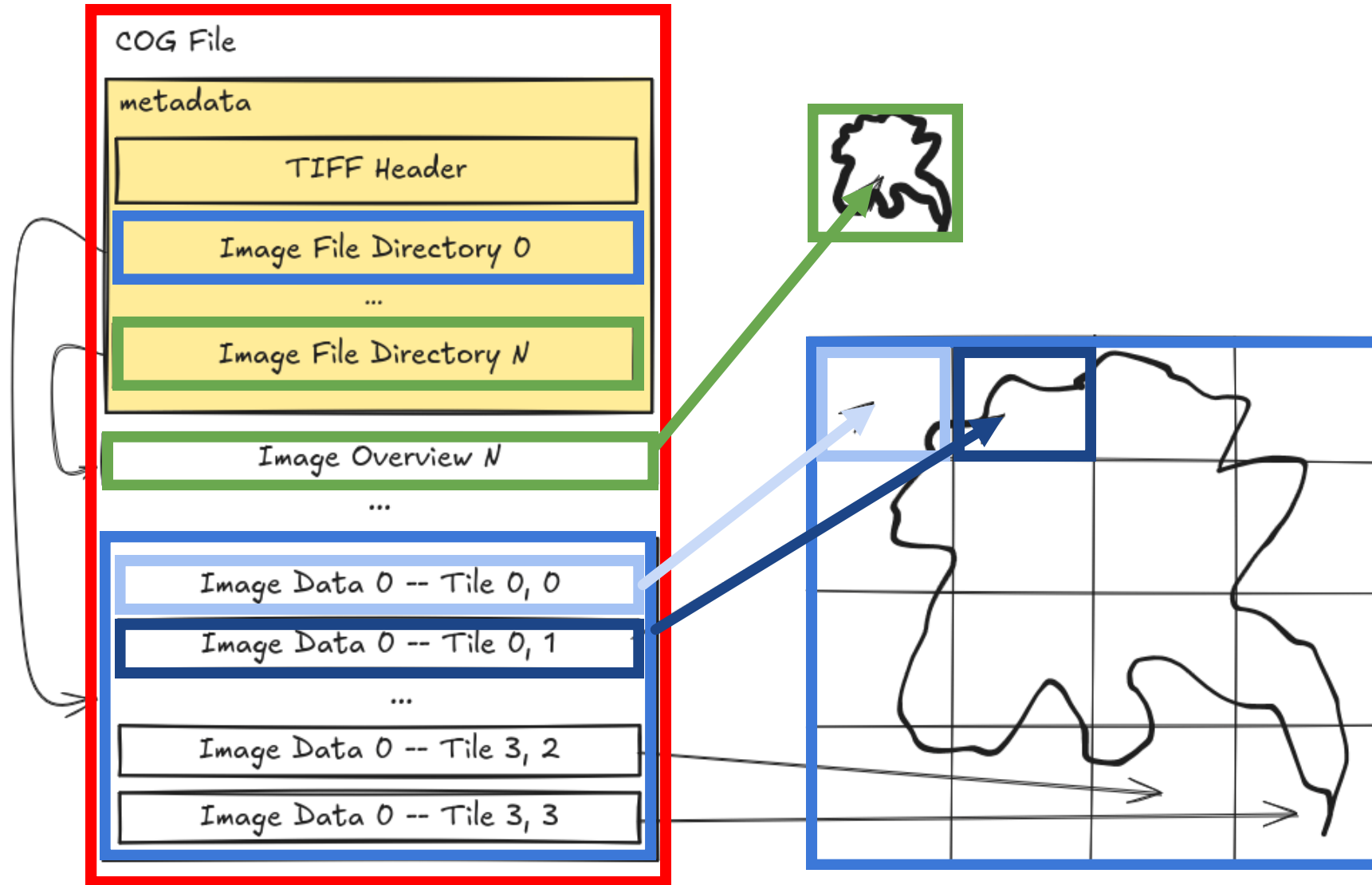
10.5 μm

Eumetsat

Meteosat FCI

Cloud Optimized GeoTiff ☁️

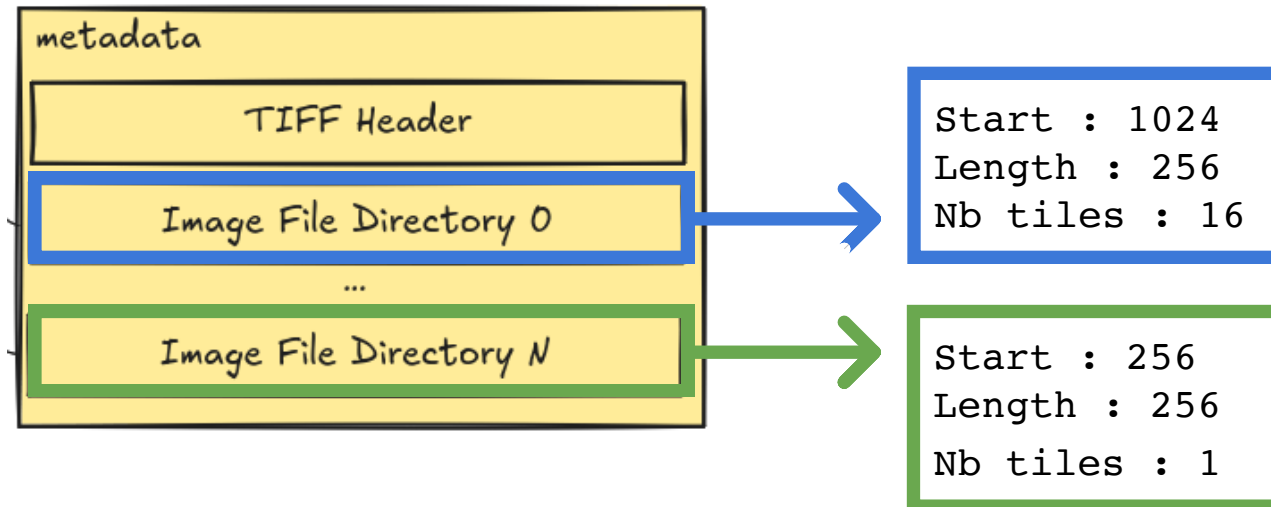
`/z/x/y.tif` ➡ `/cog.tif`



Cloud Optimized GeoTiff ☁

`/z/x/y.tif` ➡ `/cog.tif` + 🧑 HTTP range requests

```
$ curl -r 128 https://example.org/cog.tif
```



Cloud Optimized GeoTiff ☁️

`/z/x/y.tif` ➡ `/cog.tif` + 🧑 HTTP range requests

Start : 256
Length : 256



```
$ curl -r 256-512 https://example.org/cog.tif
```



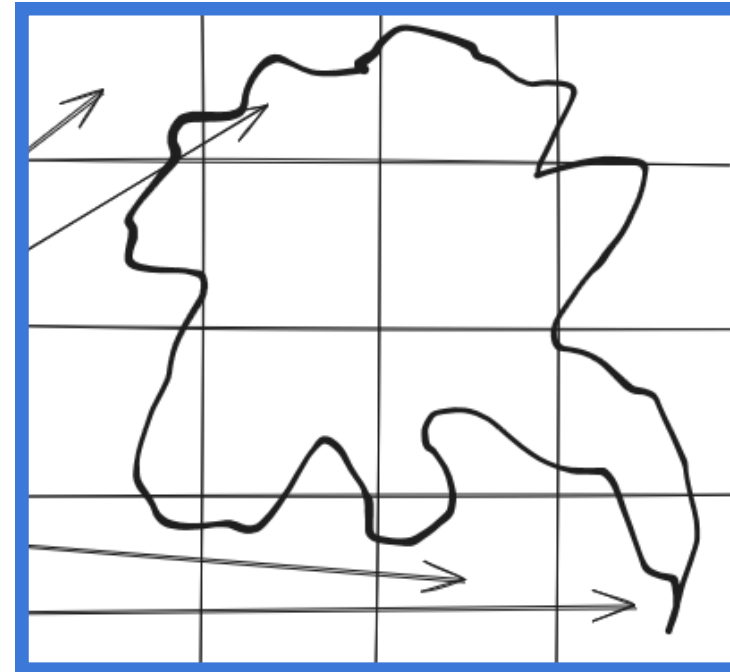
Cloud Optimized GeoTiff ☁️

`/z/x/y.tif` ➡ `/cog.tif` + 🧑 HTTP range requests

```
$ curl -r 1024-5120 https://example.org/cog.tif
```



Start : 1024
Length : 16 * 256 = 4096



Cloud Optimized GeoTiff ☁️

`/z/x/y.tif` ➡ `/cog.tif` + 🧑 HTTP range requests

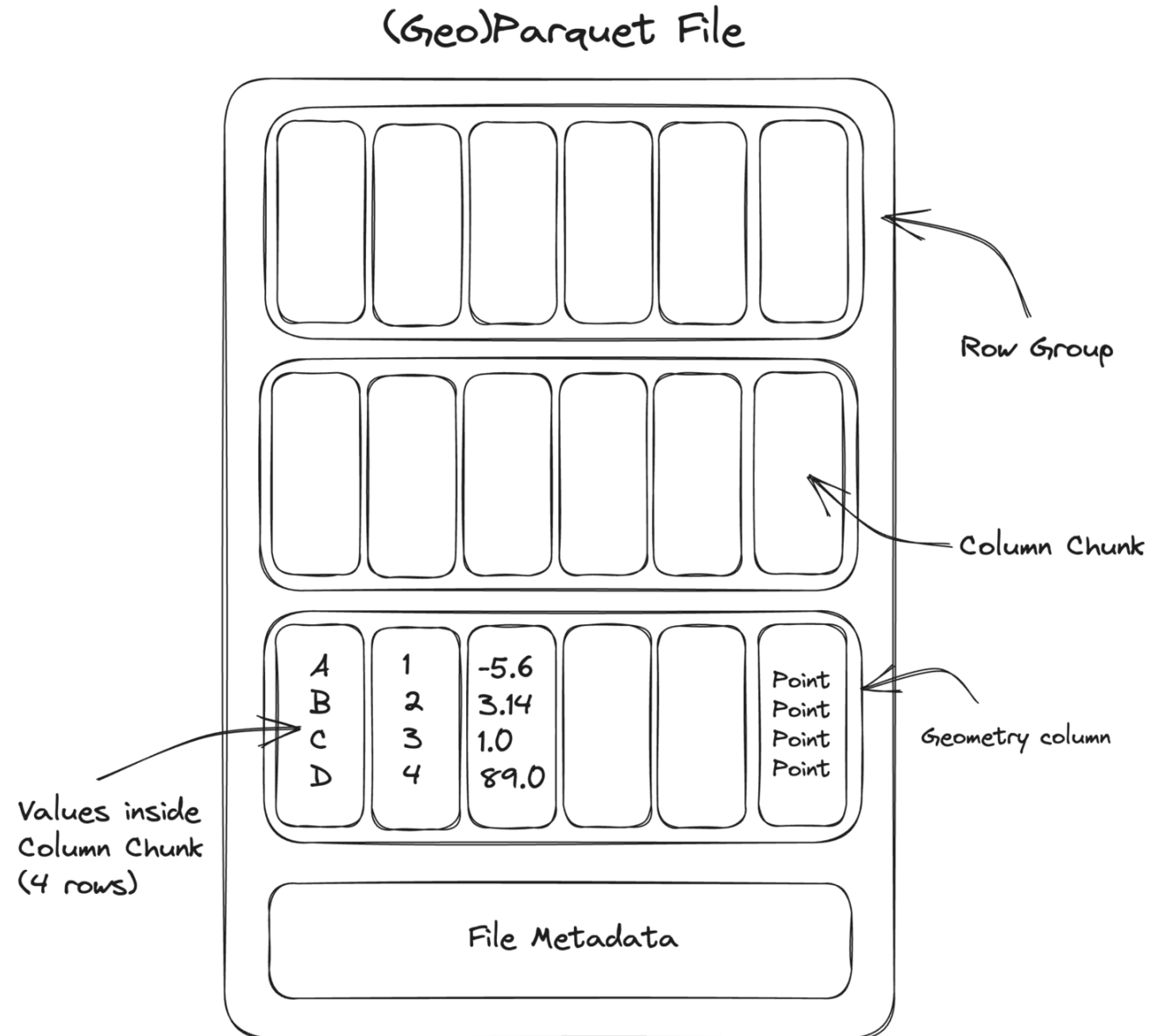
```
$ curl -r 1280-1536 https://example.org/cog.tif
```



Start : 1024
Length : 1 * 256 = 256
Offset : 1 * 256 = 256

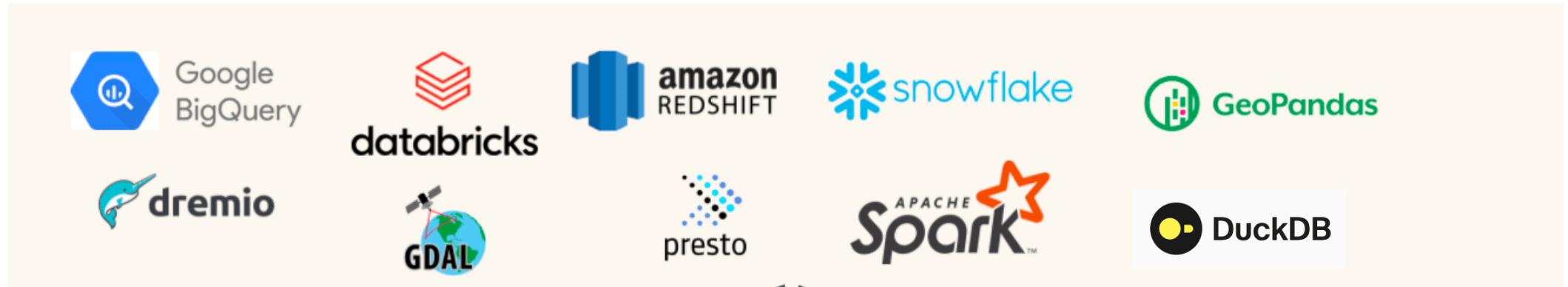


Base de données géographique native S3 📌



Base de données géographique native S3 📌

COMPUTING
ENGINES &
LIBRARIES



```
SELECT data FROM myTable JOIN providerTable
```



CLOUD
STORAGE



Base de données géographique native S3 📍



```
ATTACH 's3://example.org/stations.duckdb' AS stations_db;  
  
SELECT count(*) AS num_stations FROM stations_db.stations;
```

num_stations
578



```
SELECT PARCEL_ID, geometry FROM stations_db.stations  
WHERE ST_Contains(ST_Point(0, 45), geometry) LIMIT 100;
```

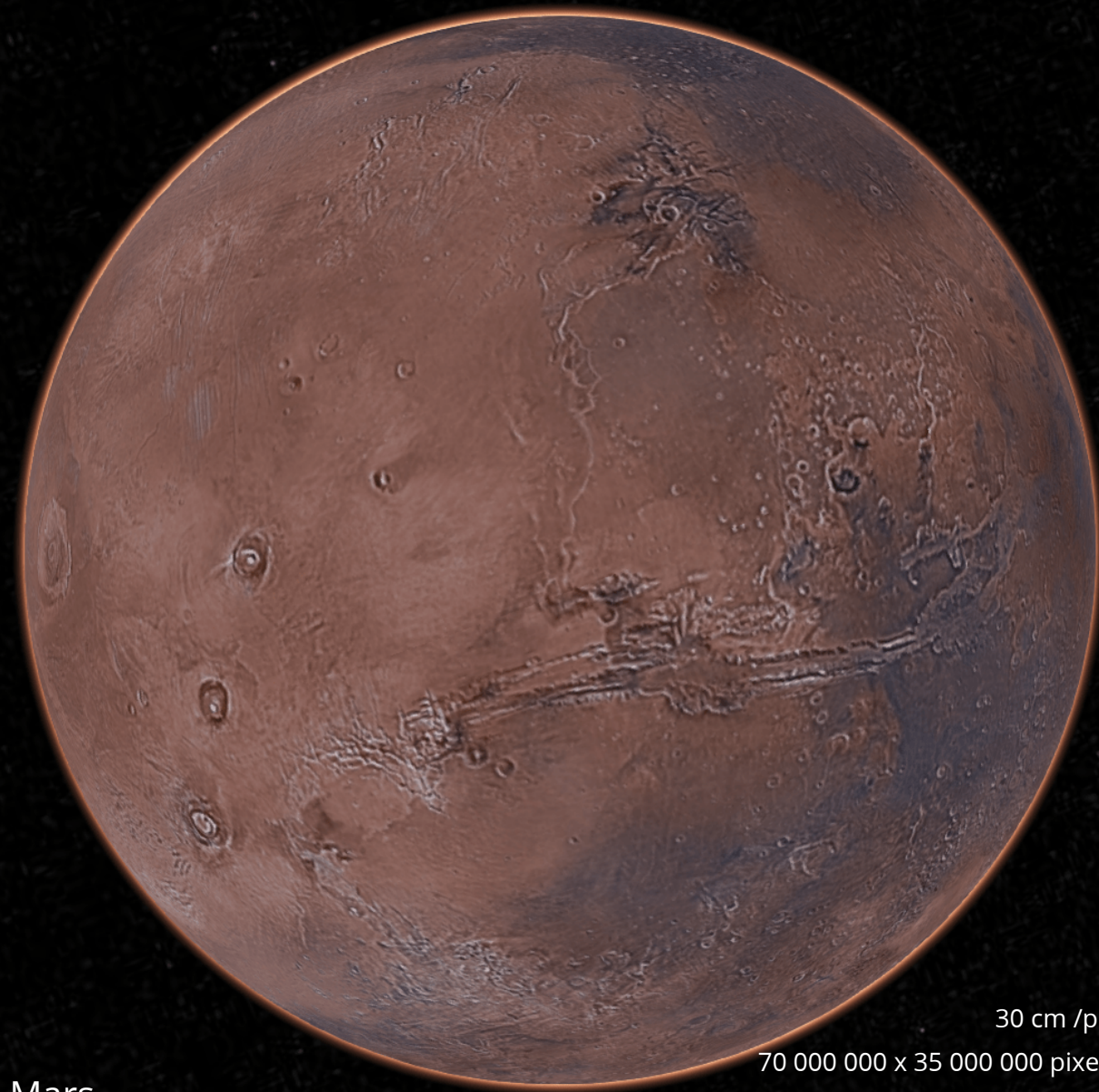
ID_PARCEL	geometry
123563	POLYGON ((3.33896 49.84122, 3.33948 49.8...
5527076	POLYGON ((-1.44483 49.61280, -1.44467 49...
11479241	POLYGON ((2.87821 46.53674, 2.87820 46.5...
...	...

Quelques exemples dans le système solaire 🌍



Lune

50 cm /pix
22 000 000 x 11 000 000 pixels
240 000 000 Mpix ~ 720 To



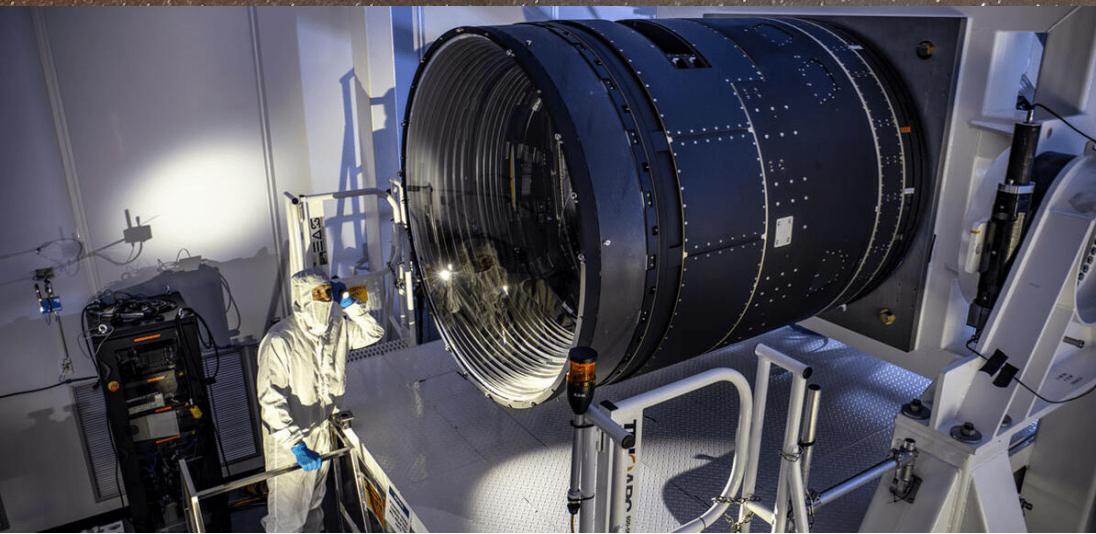
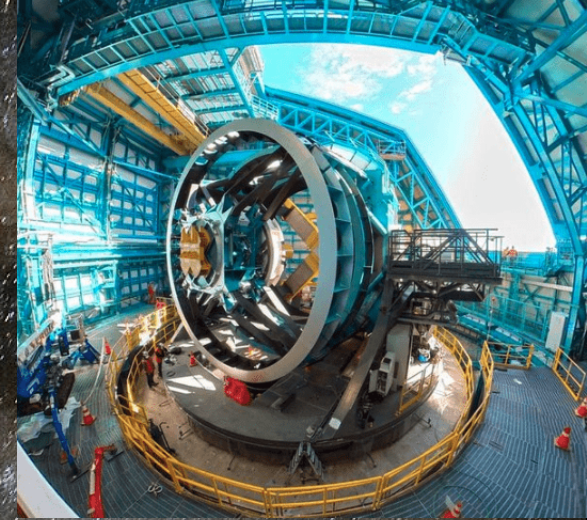
Mars

30 cm /pix
70 000 000 x 35 000 000 pixels
2 500 000 000 Mpix ~ 7 Po

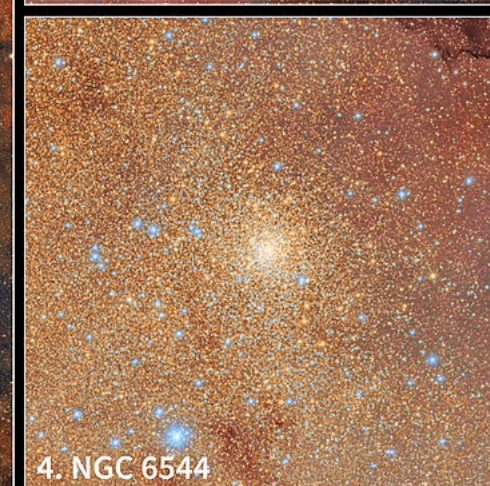
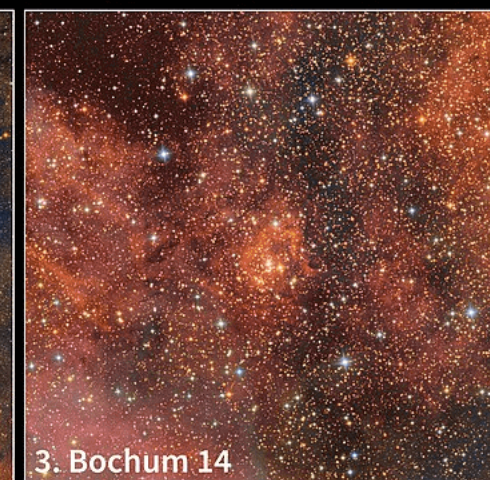
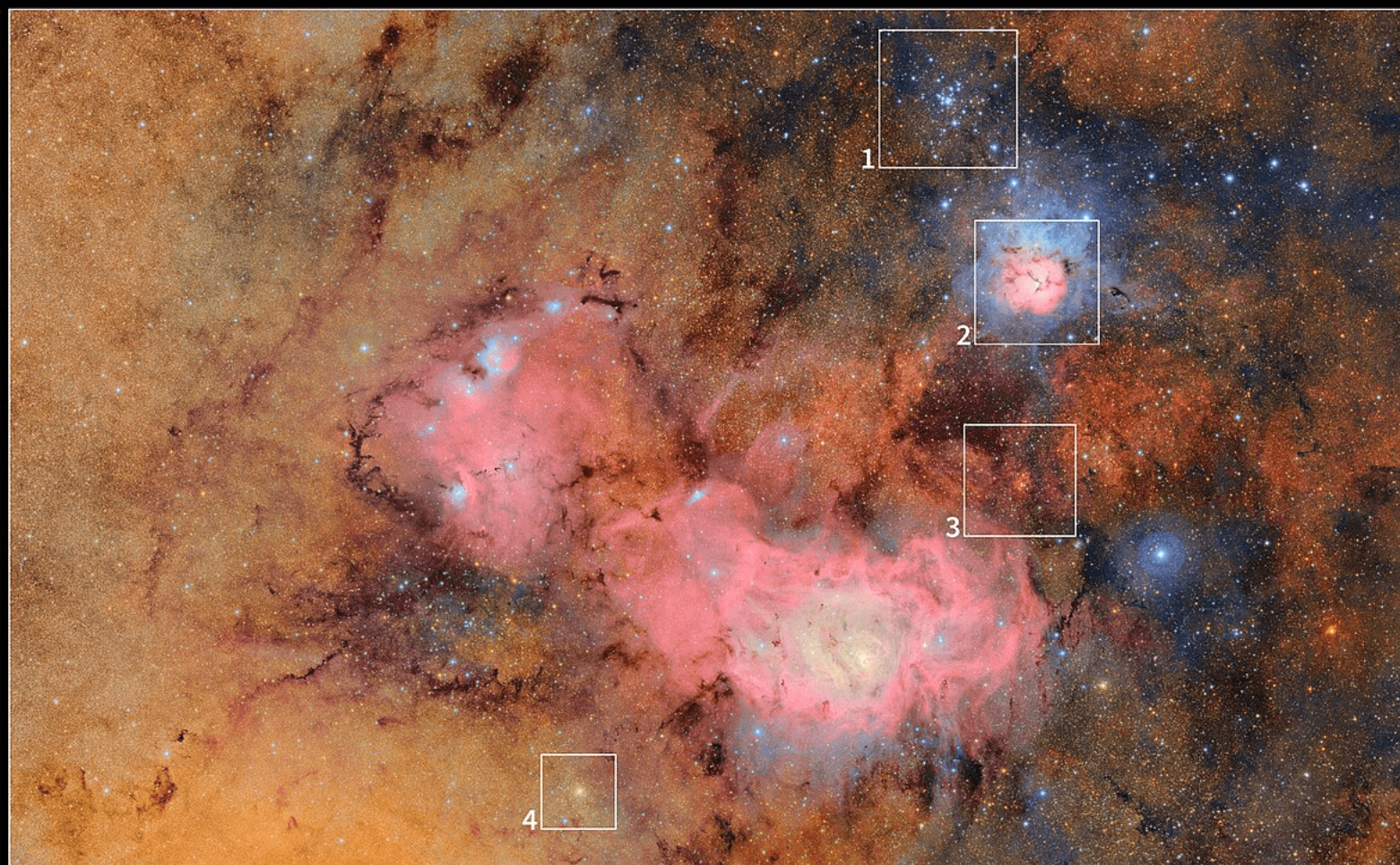
<https://murray-lab.caltech.edu/CTX/V01/SceneView/MurrayLabCTXmosaic.html>

Carte du ciel ✨

8.4 m miroir
3 200 Mpix / image
200 000 images / an
20 To / jour
~ 6 Po / an



Observatoire Vera Rubin (LSST) - 2025



Nébuleuses Trifide et la Lagune

<https://noirlab.edu/public/images/noirlab2521b/zoomable/>