Use of remote sensing technologies in coastal mapping process

Perspectives and challenges

Sophie Loyer & Nathalie Leidinger

Shom general overview

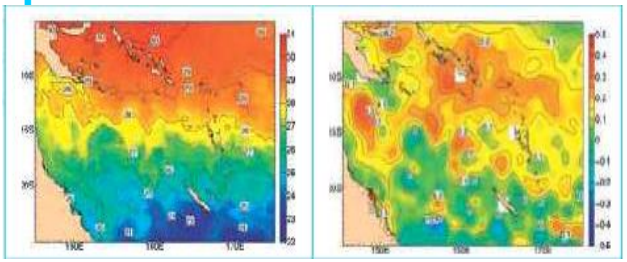
Coastal mapping process challenged by remote sensing survey

- Lidar
- SDB
- Hyperspectral

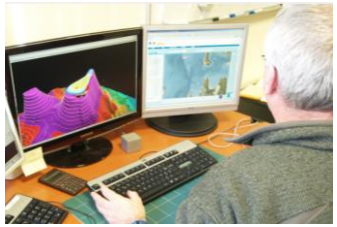
Challenges & Perspectives

A public administrative institution under the supervision of the Departement of Defence

➔to ensure **the safety of navigation**
➔to meet **Defence requirements** with regards to assessing the aero-maritime environment
➔to support **government maritime and coastal policies**



Description and prediction of the maritime and coastal environment
areas of expertise :
bathymetry,
sedimentology,
coastal hydrodynamics,
oceanography,
engineering of data acquisition and geographic information



Resources

500 staff except for the crew of specialised vessels
Annual budget : 58 M€ (2018)
Hydro-oceanography squadron :

- Ocean Survey *Beautemps Beaupré*

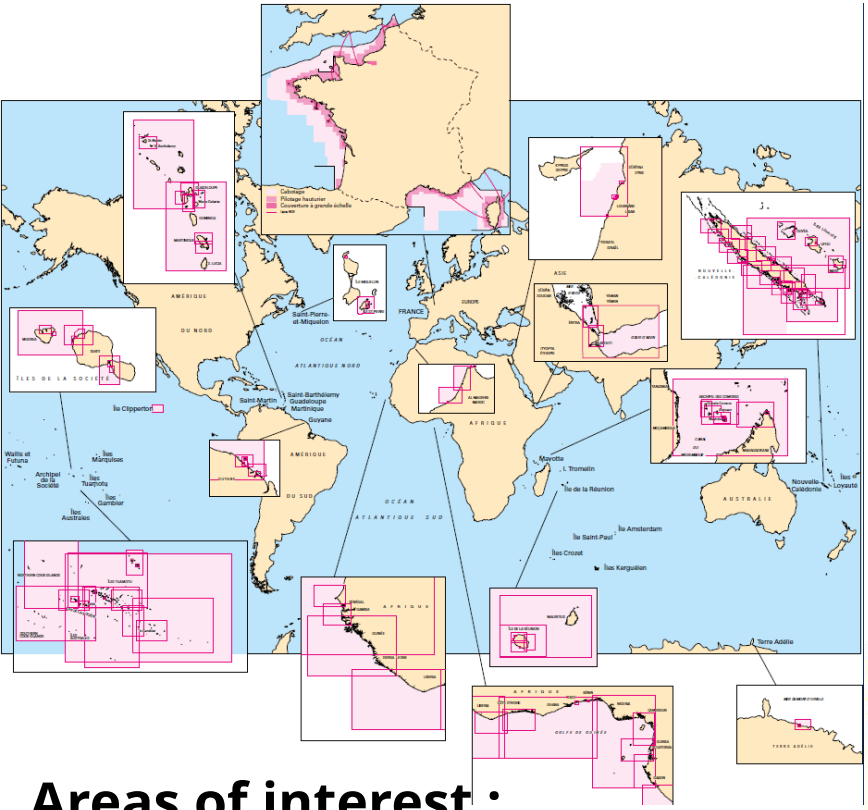
Operated by Shom (95%) &Ifremer (5%)

- Ocean research *Pourquoi pas ?*

Operated by Ifremer (55%) & Shom (45%)

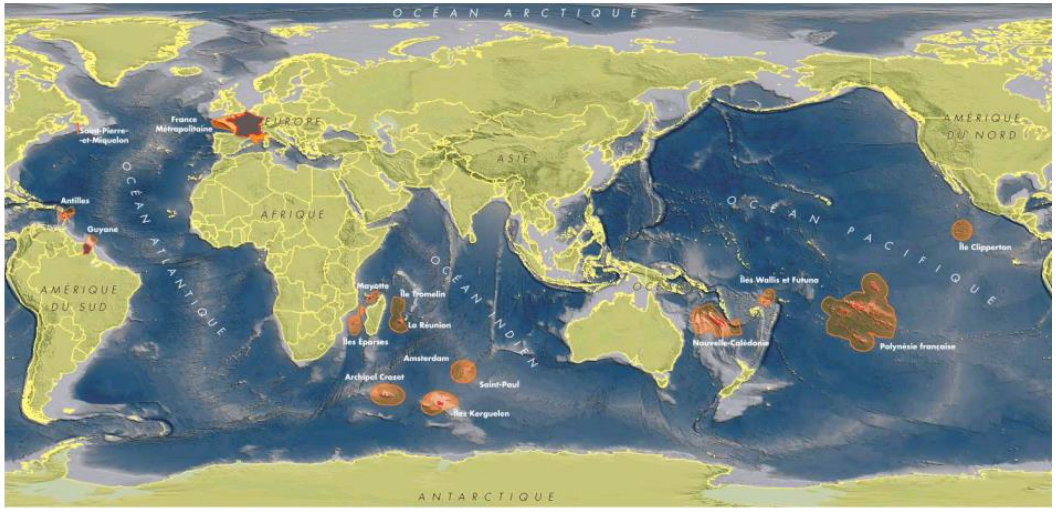
- Coastal Survey *Borda, Laplace, La Pérouse*

Shom ENC coverage



Shom chart portfolio :

- 890 paper charts (580 original charts, 260 fac-simile, 50 compilation charts)
- 620 ENCs for a complete portfolio of 900 (mainland France, overseas territories and areas where France is the charting authority)



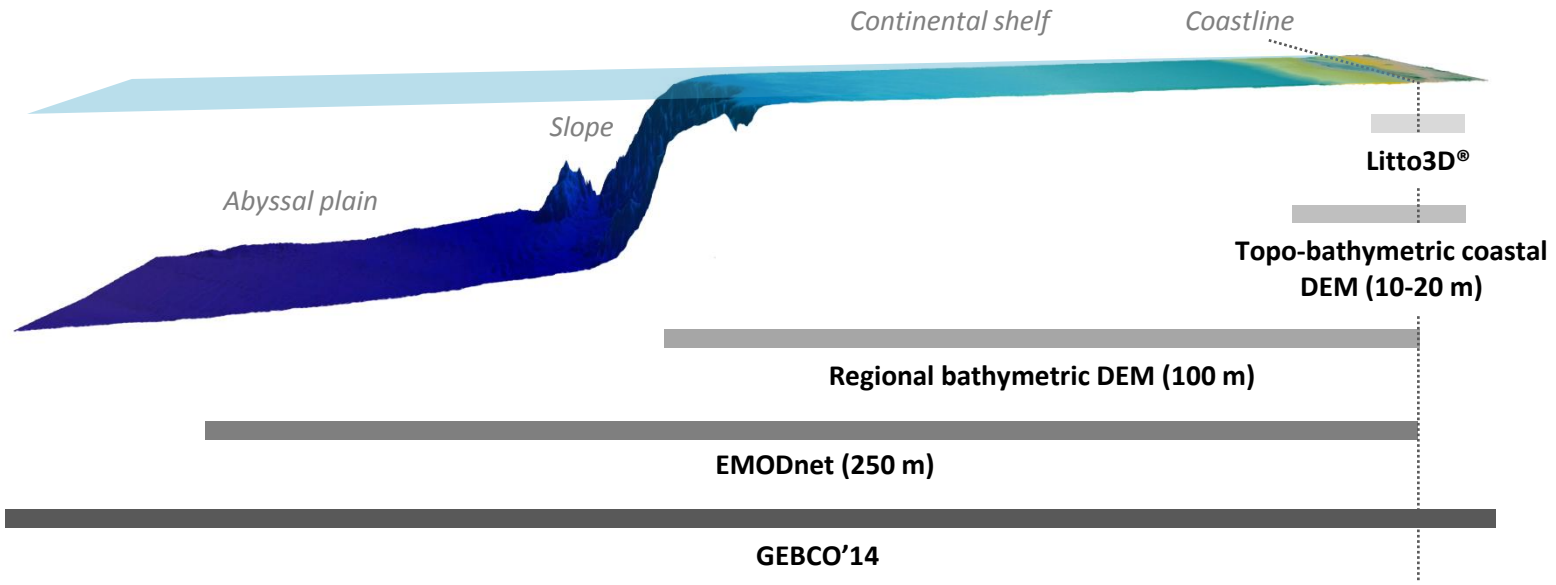
Areas of interest :

French EEZ (11 million sq. km);

and other areas of historical responsibility

For other uses than navigation, principally:

- Hydrodynamic modelling
- Marine submersions
- Morphology, seabed characterisation
- …



Data.shom.fr

Shom general overview

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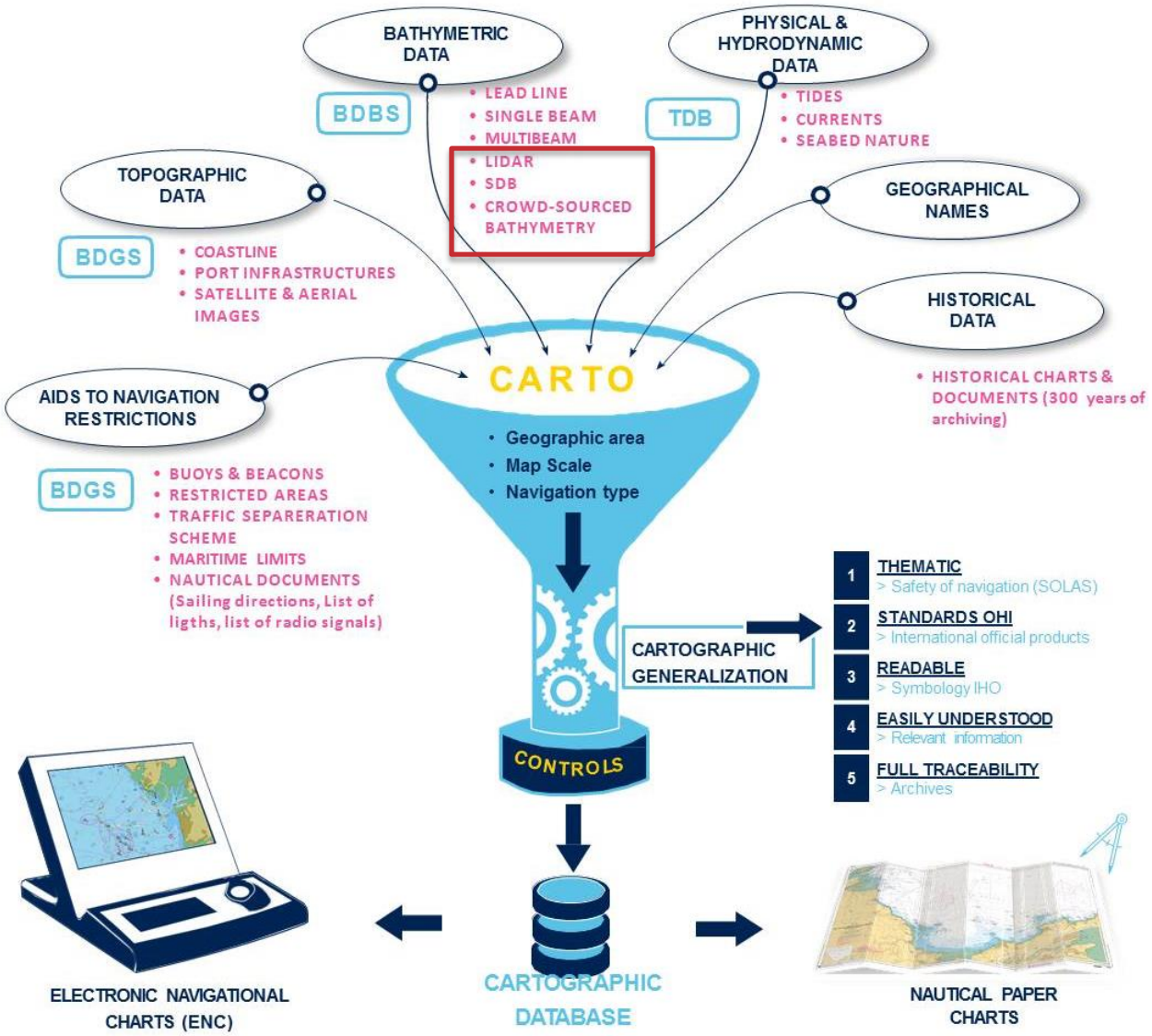
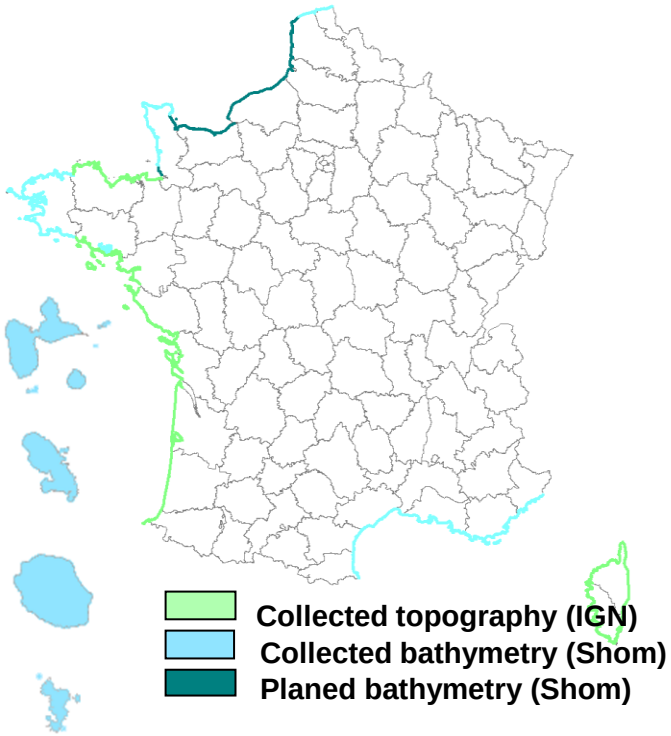
Challenges & Perspectives

MAPPING PROCESS



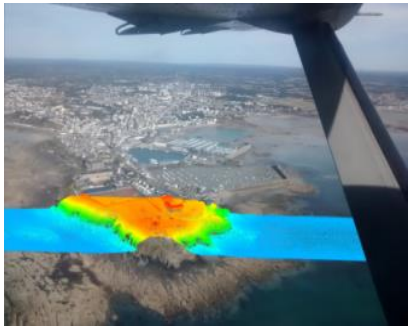
AIRBORNE LIDAR BATHYMETRY

FRENCH NATIONAL PROGRAM LITTO3D ® - COASTAL SURVEY



A major change in 2016 :

- "full service" contracted (at least for 3 years) with Leica Geosystems and CAE Aviation.
- Based on an ALB system = HawkEye III lidar + Cessna Grand Caravan + pilot(s) on a 2 months basis.
- Shom is in charge of the survey conduct.

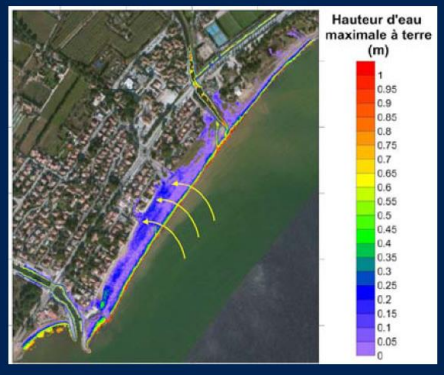


In mainland France:
41% of the coastline covered
52% planed for 2018
Overseas regions :
82% (excluding French Guiana)

LITTO 3D – COASTAL SURVEY

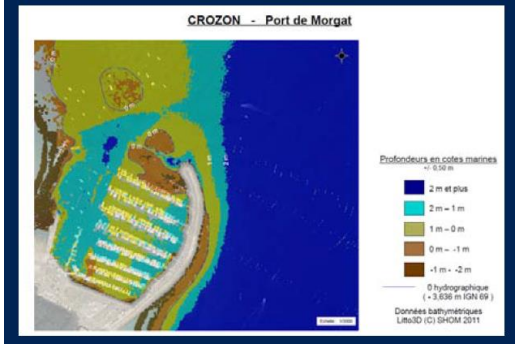
A PROGRAM TO SUPPORT GOVERNMENT POLICIES

Coastal hazards and sea level rise

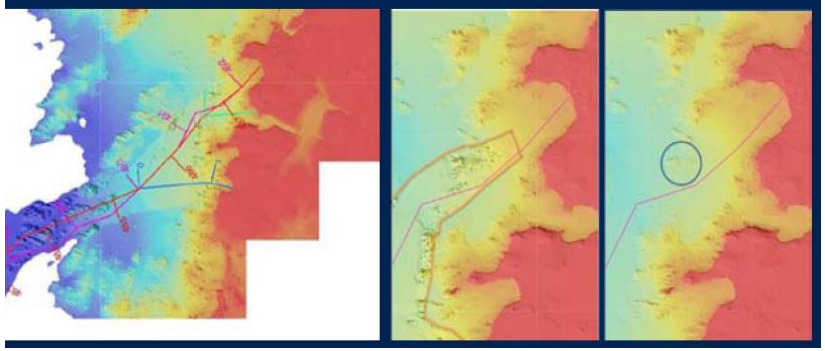


Coastline management

Management of the sedimentary stock



Marine renewable energy

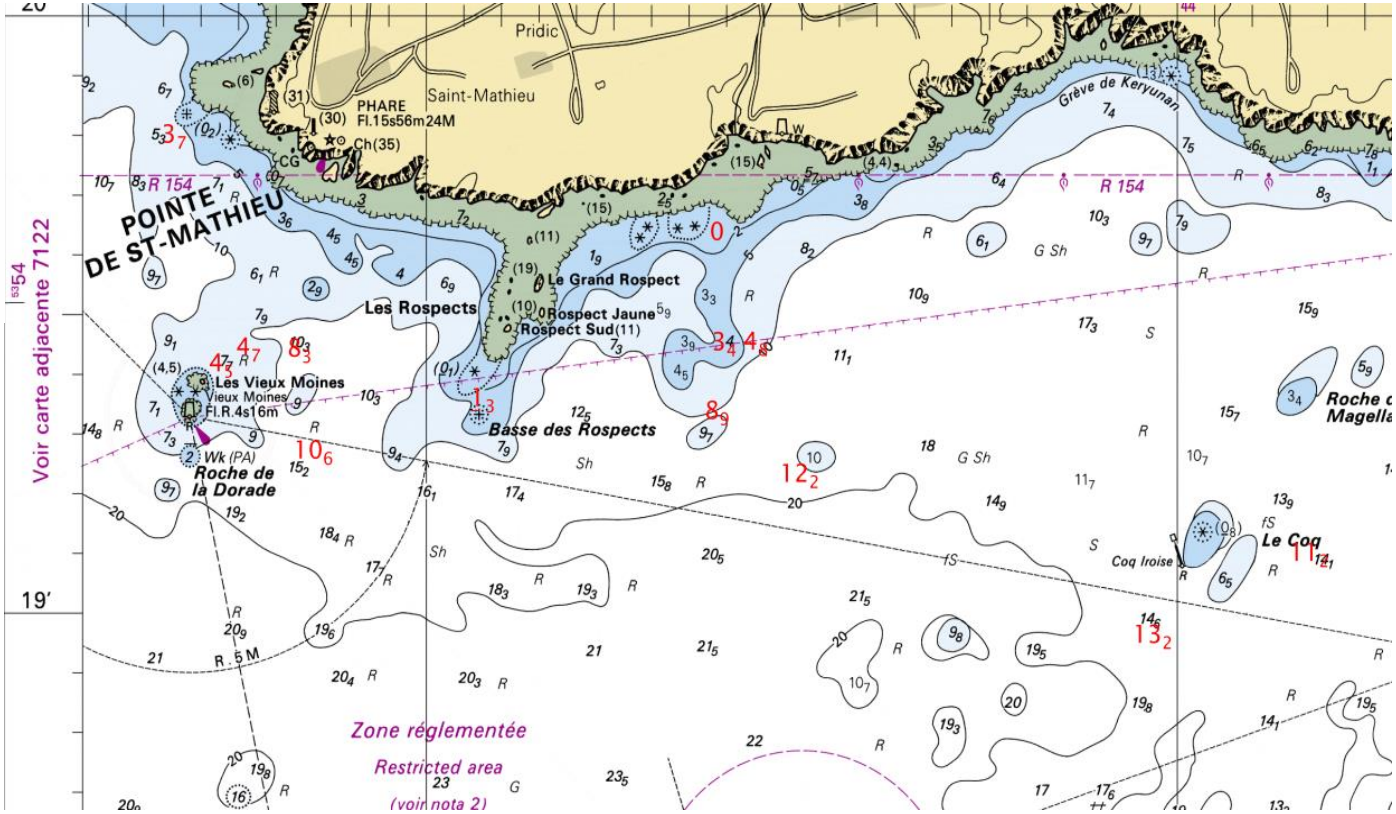


And a source of nautical information to update coastal charts

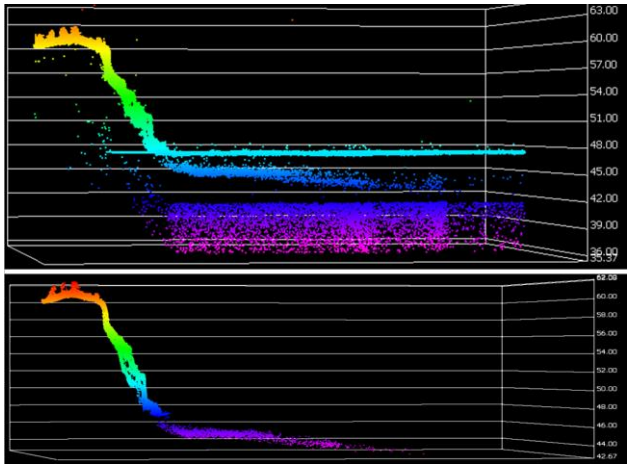
Survey « Finistère »

4 800 km2
1 060 km of coastline

Nautical charts impacted	Total soundings	Average number of new soundings / NC
28	> 2000	~ 62



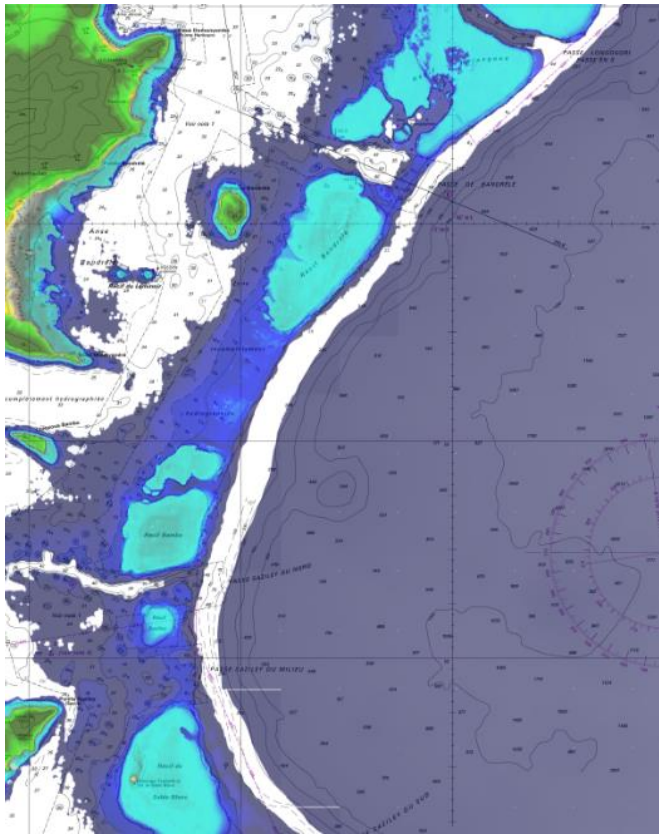
- Lidar return is a sum of multiple echoes :
  ➔ improve process to reduce noise,
  ➔ move towards more automated tools instead of manual review of high-density survey

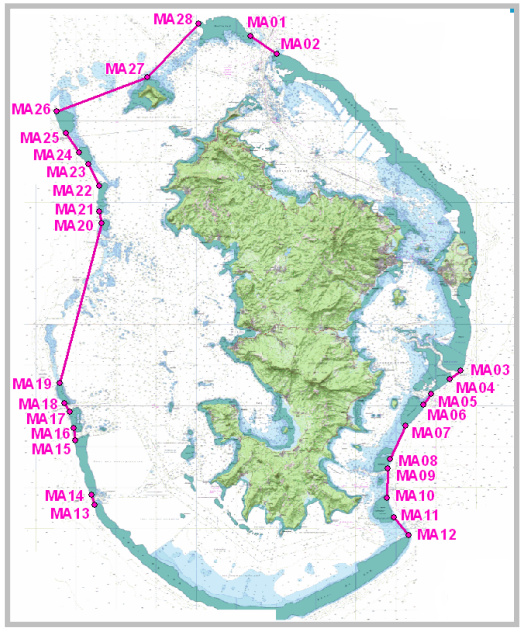


- Data Accuracy of lidar surveys is difficult to assess
- At Shom, lidar surveys always complements existing surveys

Shom cartographers used to say :
« With lidar, the most recent is not necessarily the best »

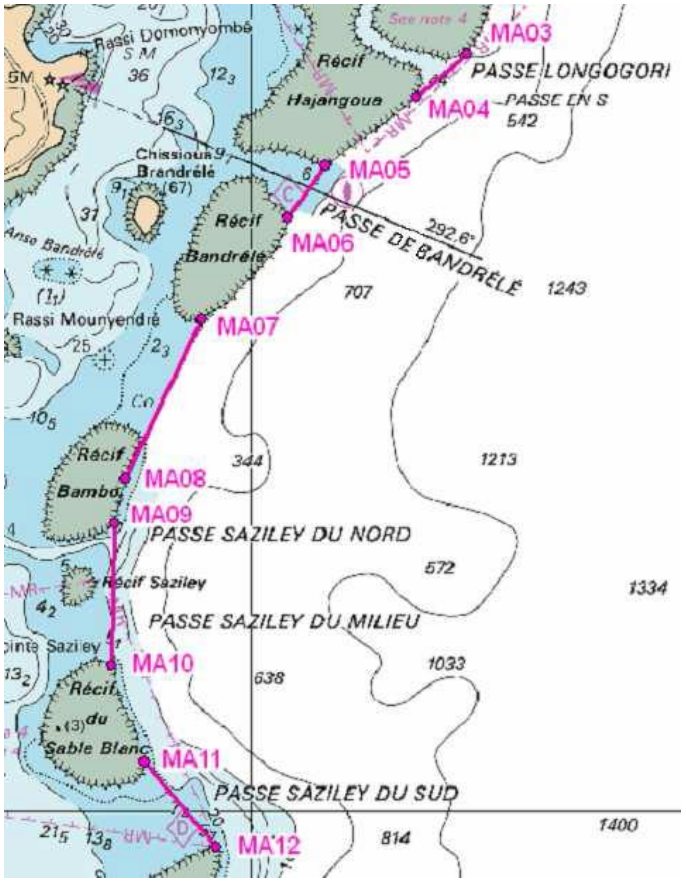
Exemple : Mayotte



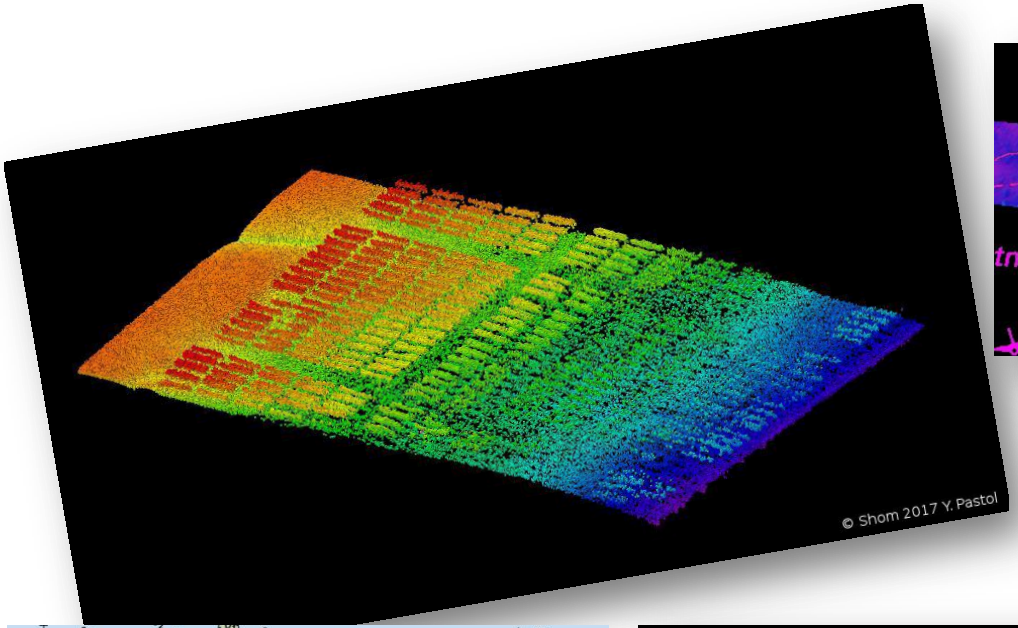


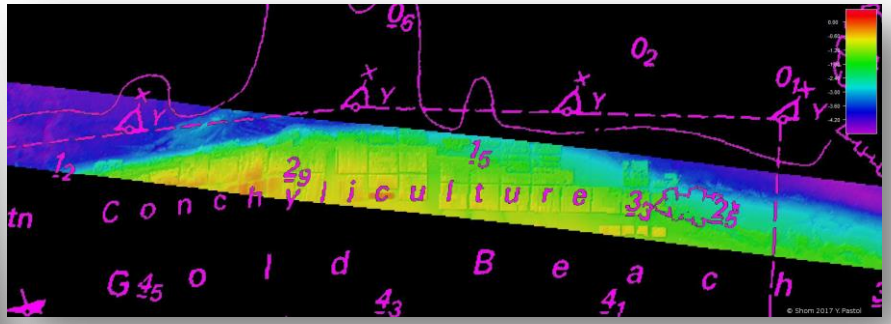
➔Normal baseline : intersection of Litto3D DTM with LAT

➔ determination of accurate base points

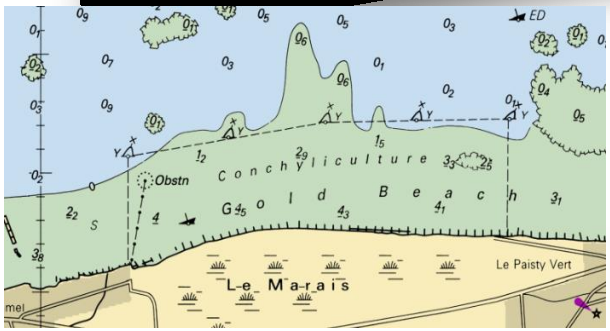


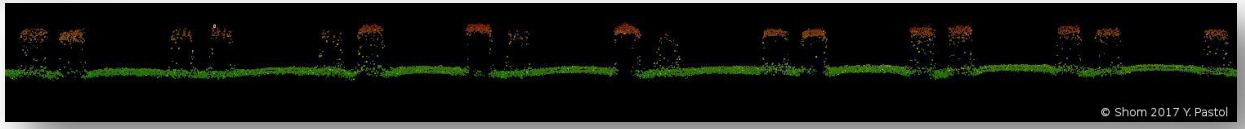
Collected lidar data for the management of shellfish parks (North of Vers-Sur-Mer)



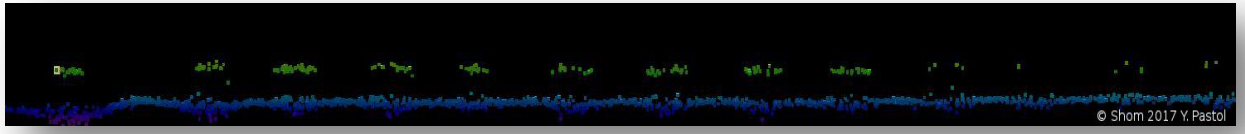


General view





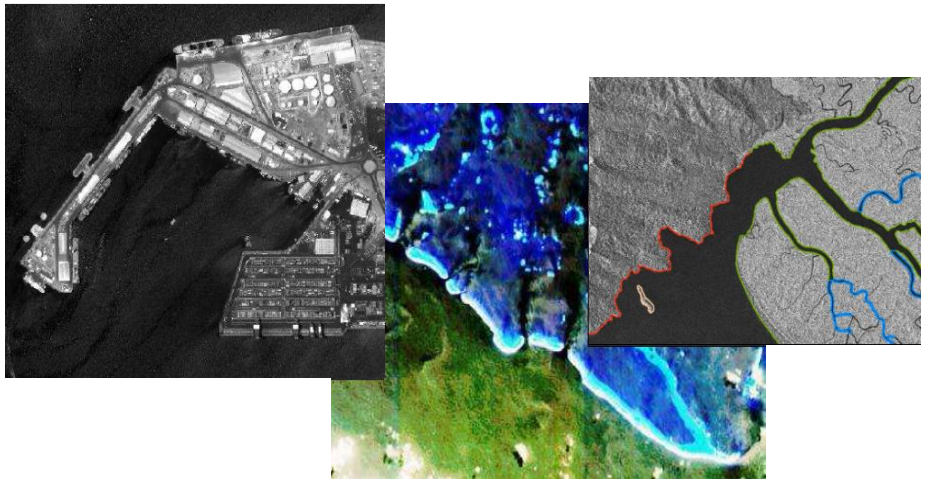
Oyster farms emerged : topographic lidar



Oyster farms immersed : bathy-shallow lidar

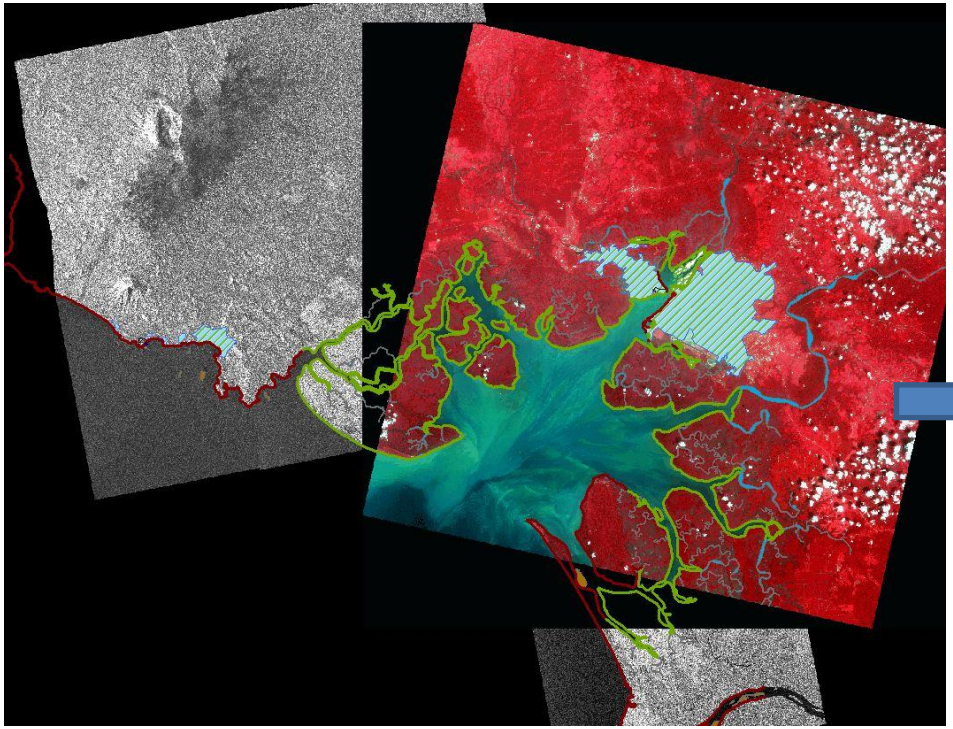
remote sensing concerns

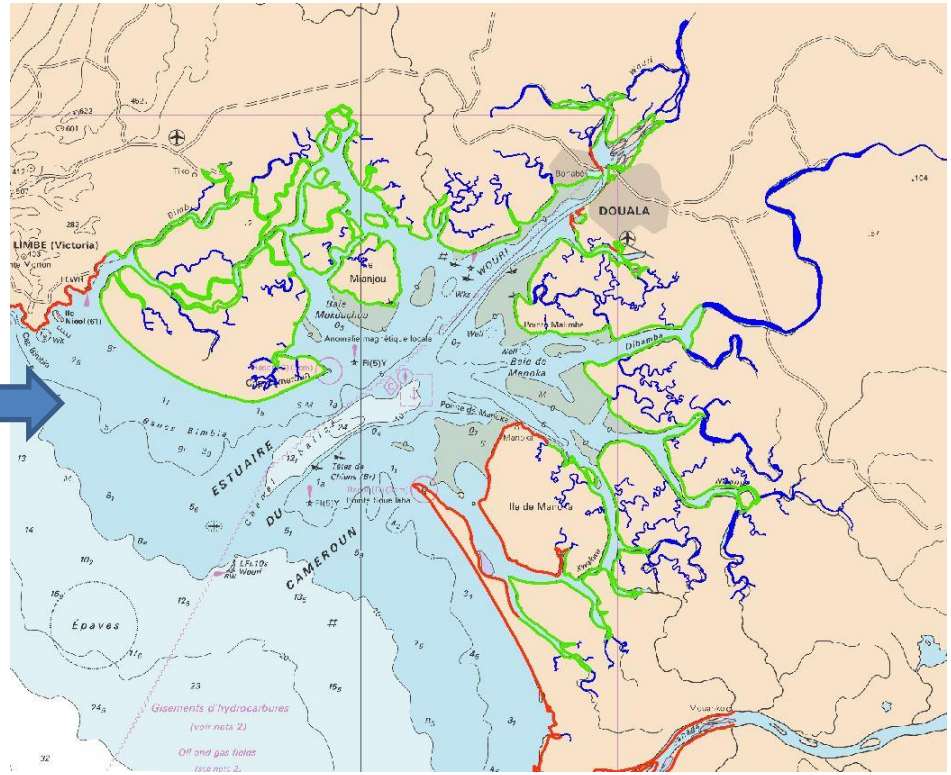
- ✓ Cartographic purposes :
  - To update and complete the charts with coastal topography and shallow water bathymetry
  - To update nautical informations (land informations)
- ✓ Specific Defense purposes

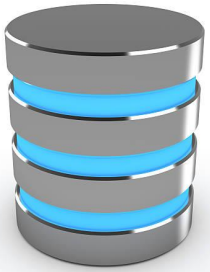


over 130 satellite derived charts (Topographic and bathymetric)

SATELLITE DERIVED BATHYMETRY FOR CARTOGRAPHIC PRODUCTION

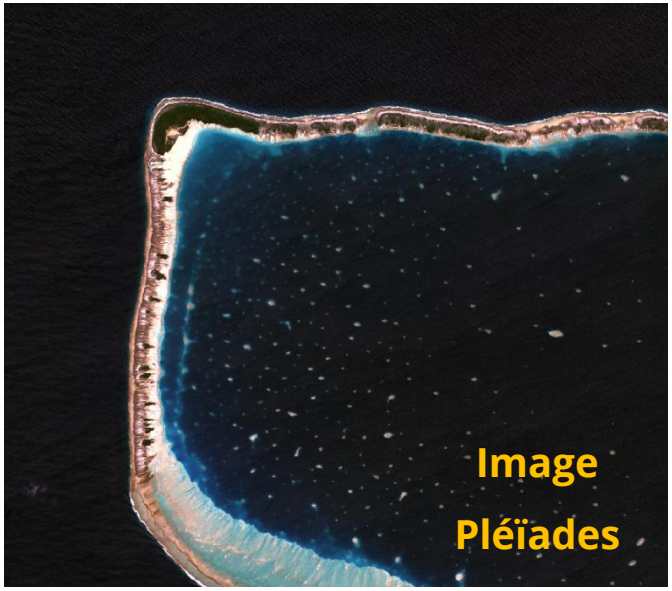


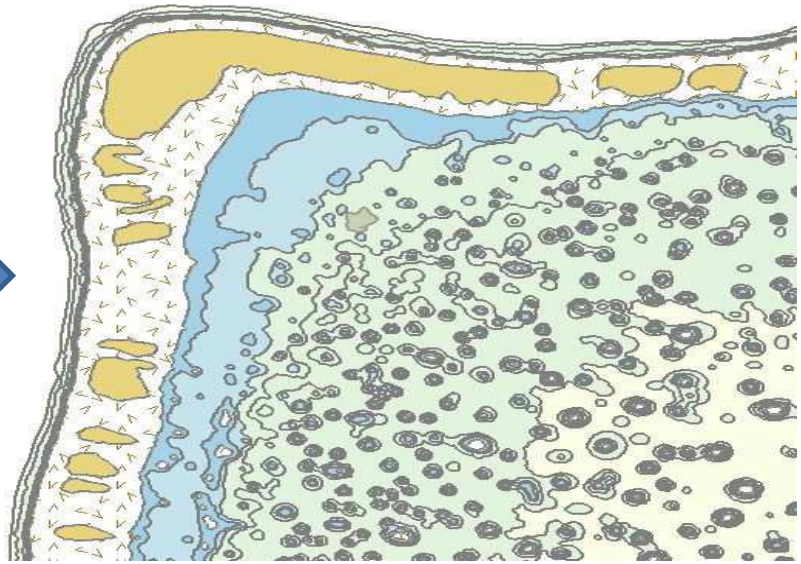


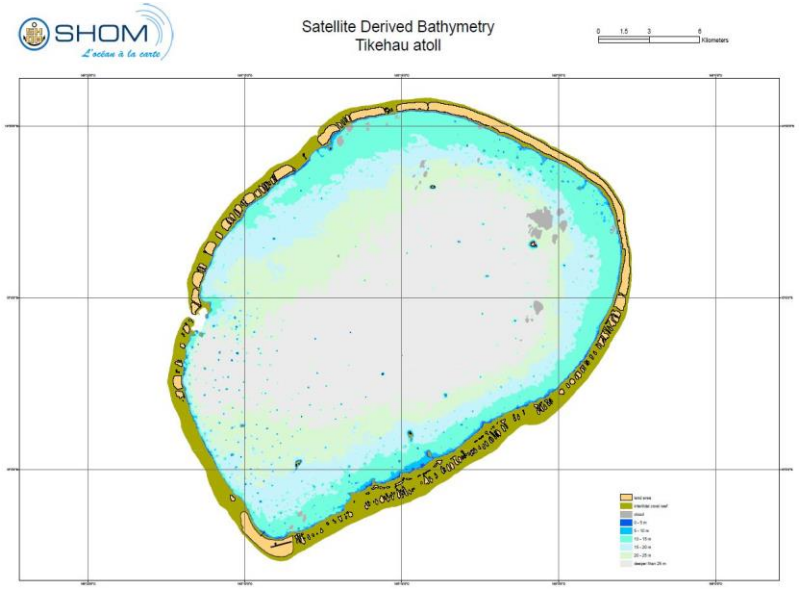


Topographic map

SATELLITE DERIVED BATHYMETRY => MARINE SPATIOCHART

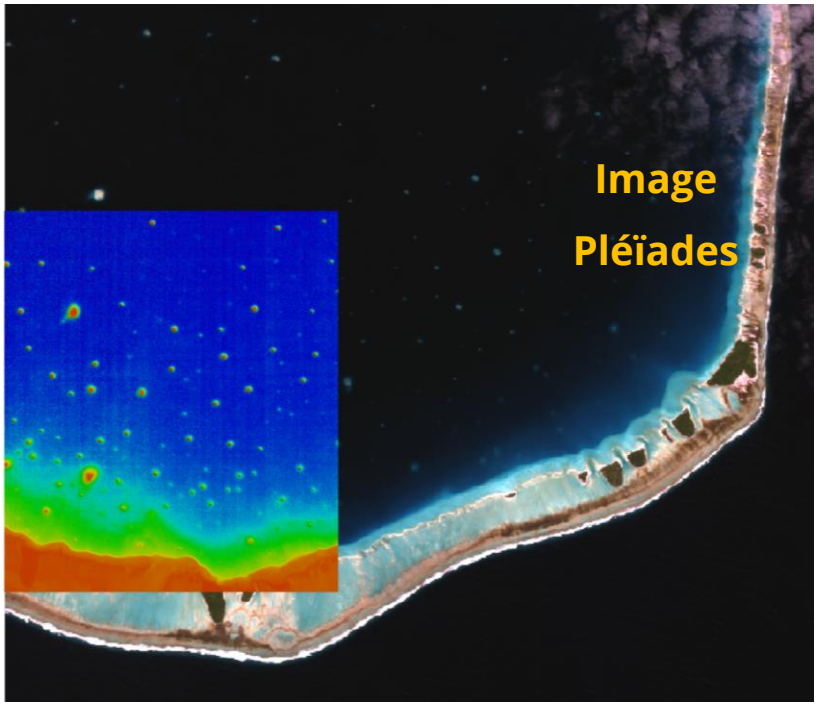


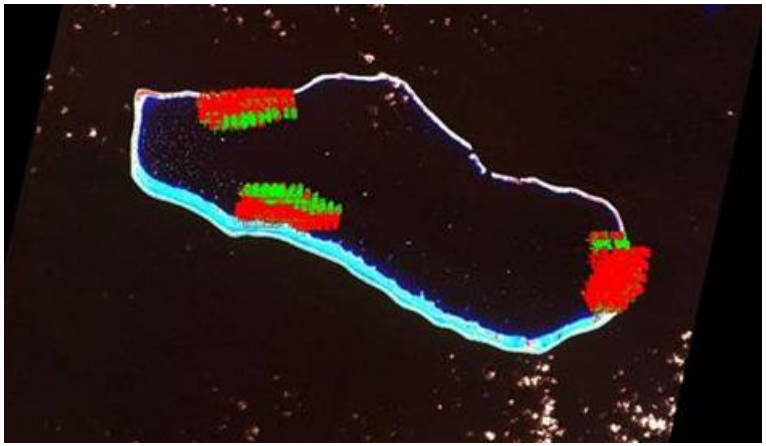


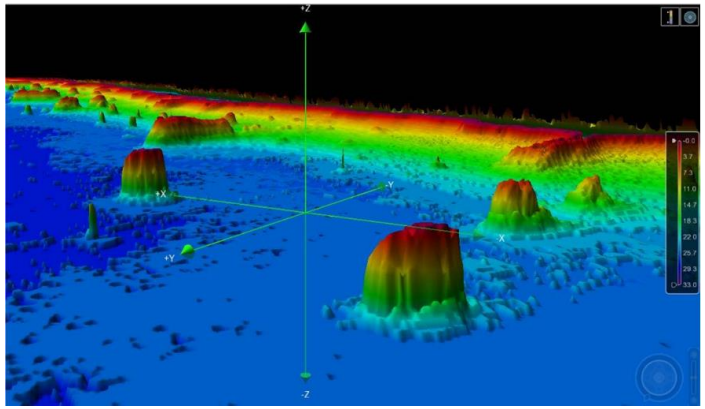


S-57 product

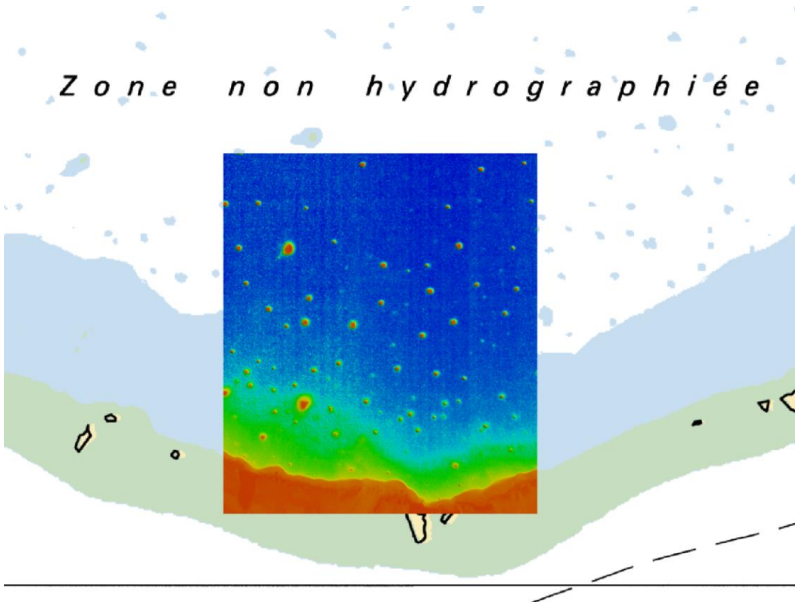
SATELLITE DERIVED BATHYMETRY : OVERVIEW

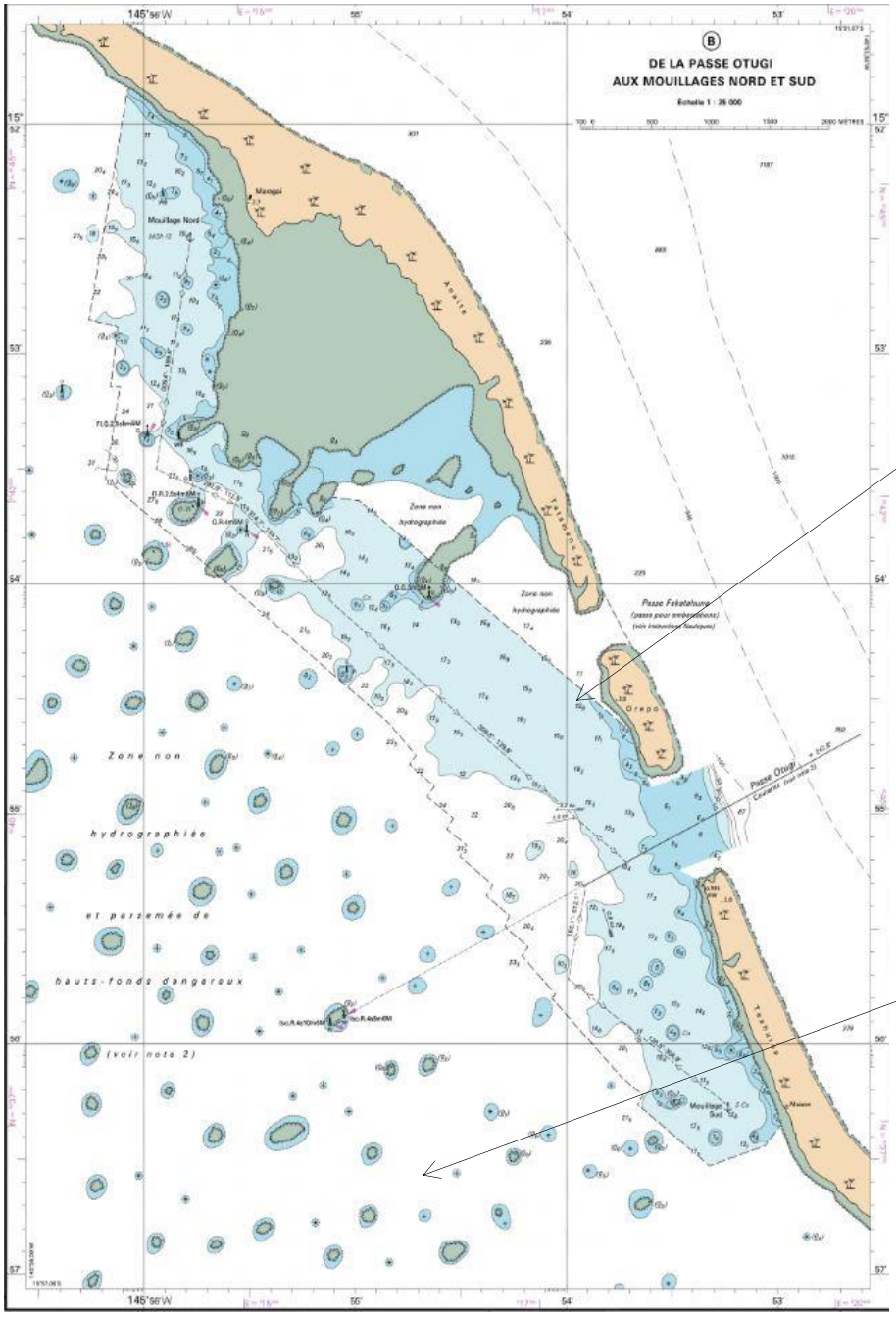






NOAA's Open House on Nautical Cartography



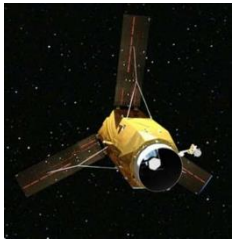


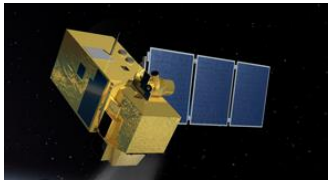
Echosounding survey

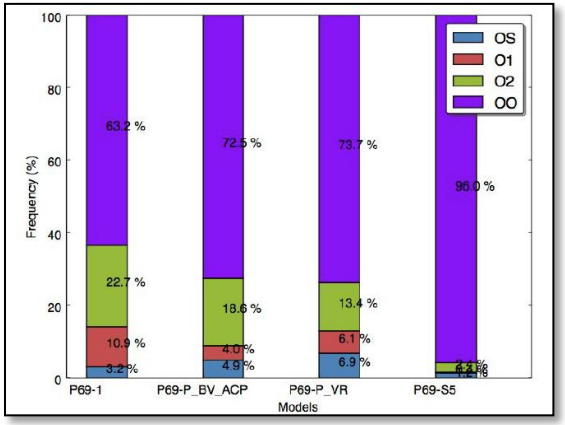
Satellite Derived Survey

Upgrade methodology and worflow

- Analytical physic-based modeling effciencies (?) – no absolute requirement of in-situ data (?)
- Evaluation of the contribution of different satellite imagery sources (… cost-benefit ratio)
- Evaluation of the accuracy (vertical uncertainty) : meet standard OHI requirements







- **Vertical precision**
  - Up to 30% depth uncertainty in the [0-5m] layer
  - 10% depth average uncertainty in the [5-20m] layer

Depth	Special Order	Order 1A	Order 1B	Order 2
5m (16.4')	0.25m (0.8')	0.50m (1.6')	0.50m (1.6')	1.01m (3.3')
10m (32.8')	0.26m (0.8')	0.52m (1.7')	0.52m (1.7')	1.03m (3.4')
20m (65.6')	0.29m (1.0')	0.56m (1.8)	0.56m (1.8')	1.10m (3.6')
50m (164.0')	0.49m (1.6')	0.82m (2.7')	0.82m (2.7')	1.52m (5.0')

Use of hyperspectral technology in the shallow water

Ability to collect remotely sensed bathymetric data from airborne hyperspectral imagery

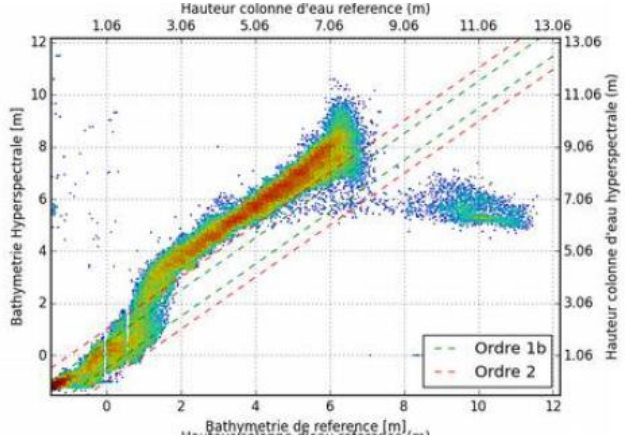
➔ Study made by Hytech-Imaging to evaluate :

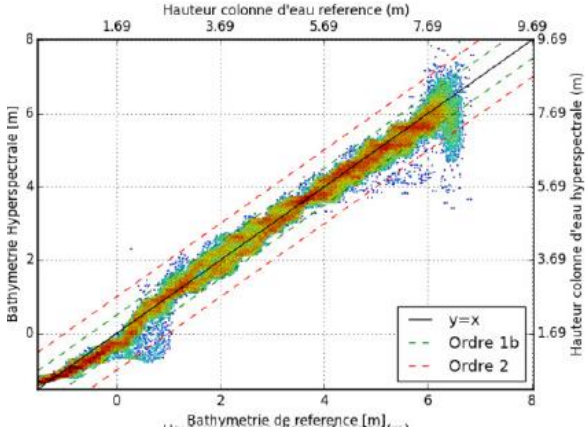
Capacity to obtain depth measurements that will support nautical chart : self-sufficient or must be assisted (by a bathymetric laser profiler to collect data in the center of the « swath »)?

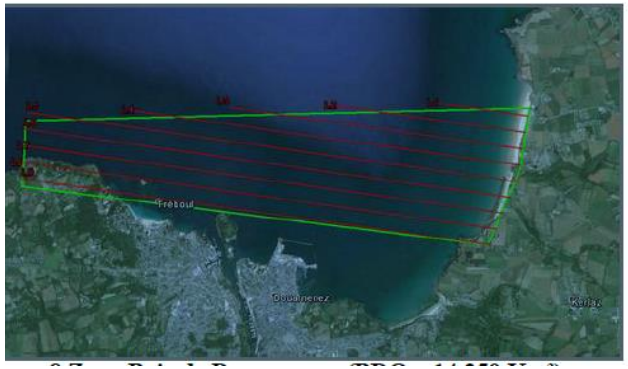
Assessment of bathymetric potential with regard to hydrography requirement ?

Comparative analysis of two methods : self-sufficient and assisted mode

Main results in terms of bathymetric achievement

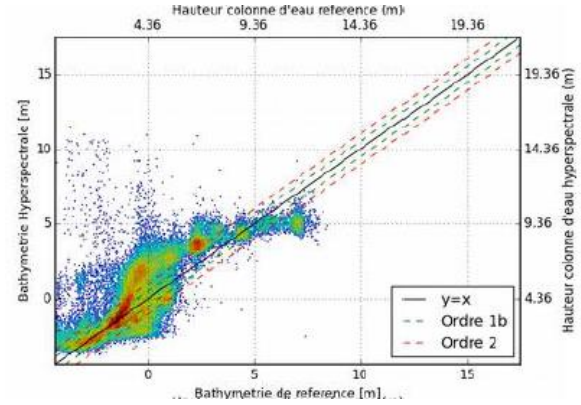


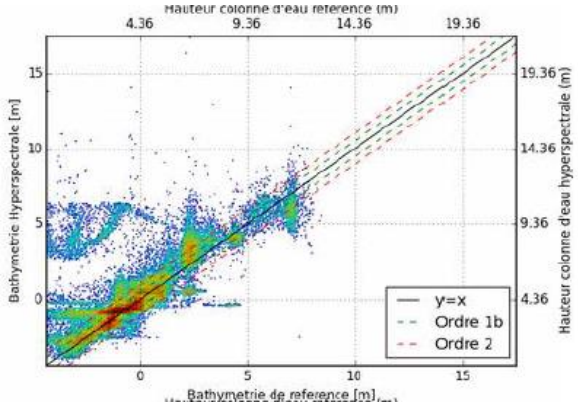




self-sufficient

assisted mode





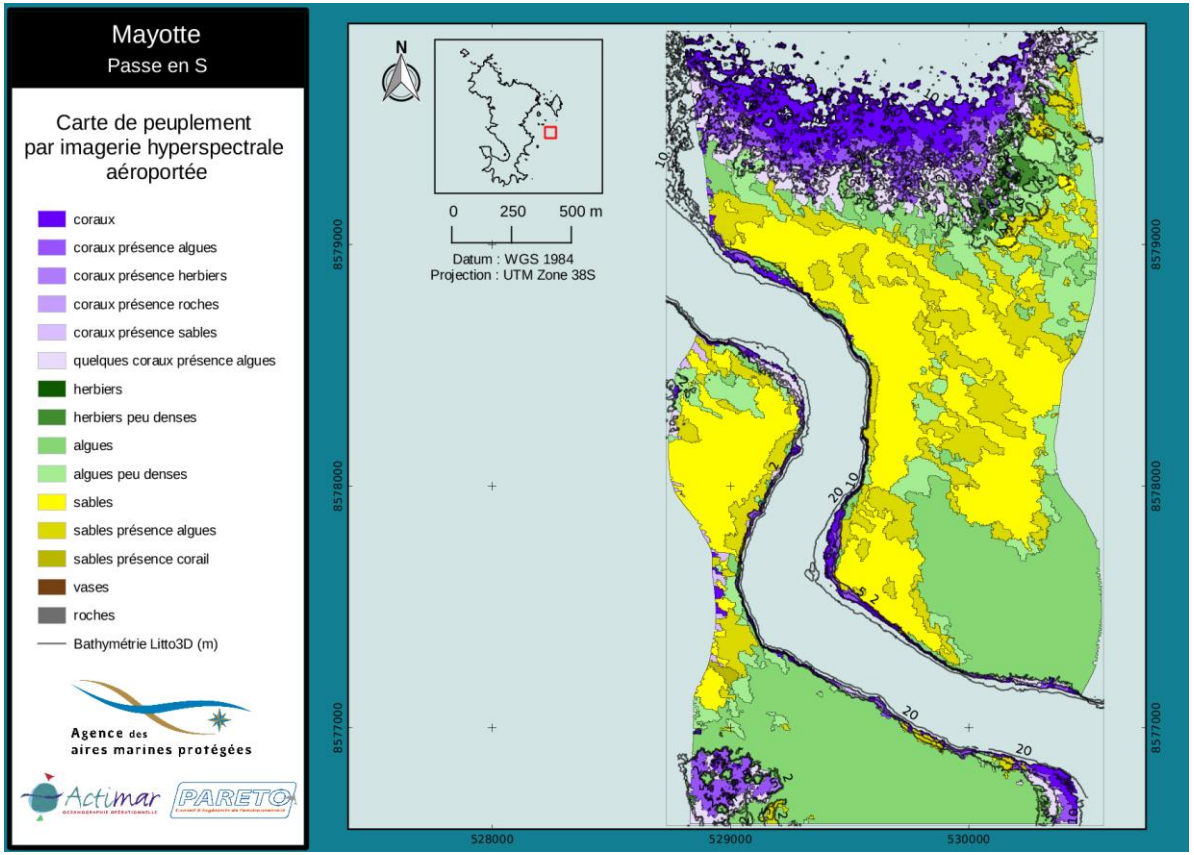
- **Advantages**
  - Great resolution (spectral and planimetric resolution)
  - Powerful to remove contributions due to sea-surface sunglint, atmosphere, bottom reflectance
  - IHO qualification order 2 achievable under some conditions

- **Shortcomings**
  - Limited by environmental conditions
  - Additional sensors have to be integrated for an operational use (bathymetric laser profiler)
  - Limited to very shallow water (Order 2 : 0-7m)

- **Acquisition of a processing software workflow…**

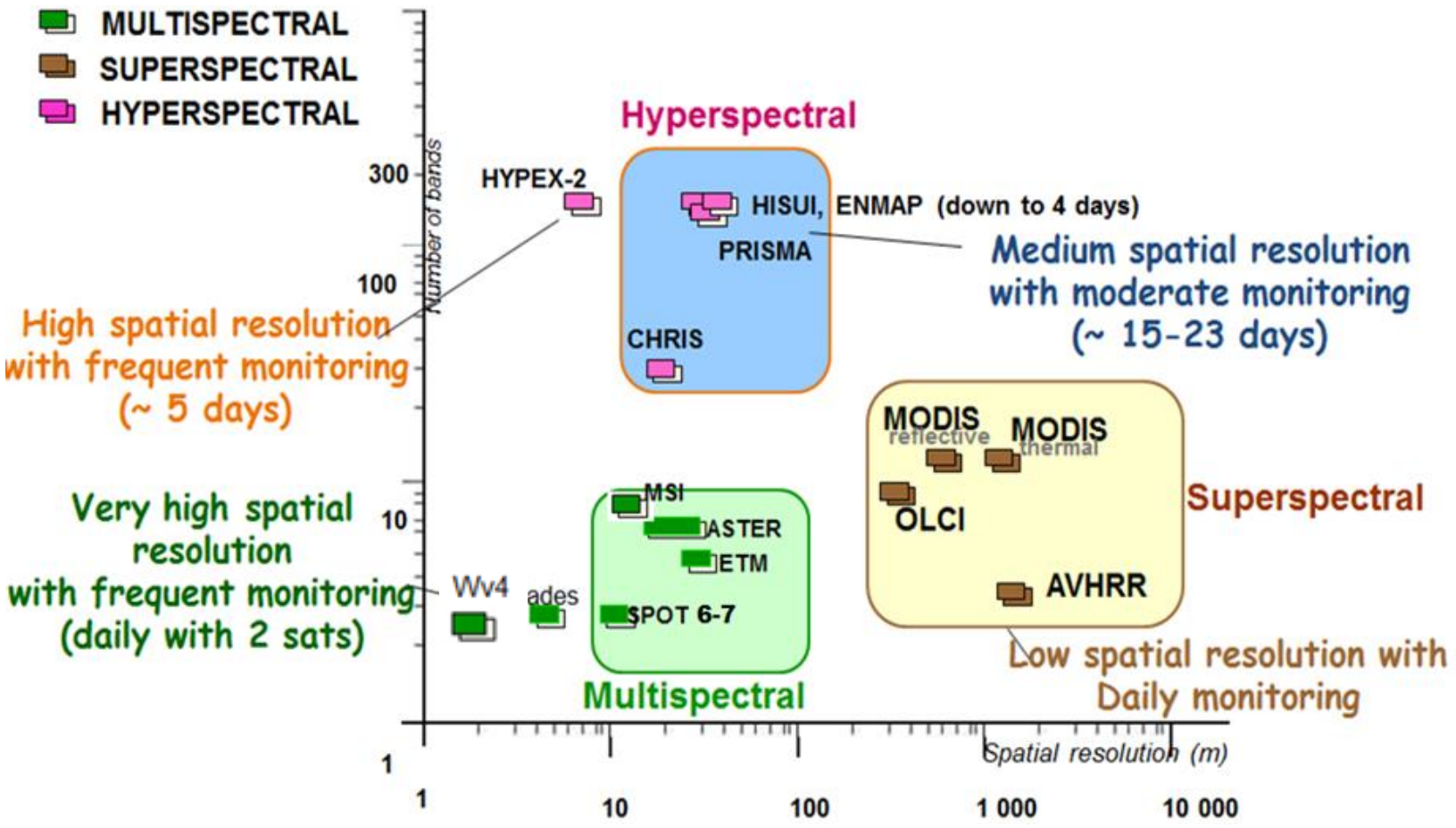
AIRBORNE HYPERSPECTRAL IMAGERY : PROSPECTS

⇒ **Use for environnemental assessment (seafloor classification / detection of obstruction, water optics)**



HyTECH Imaging

➔ Still work to be done for a hydrographic use – but future outlooks with next generation of satellites, …



Shom general overview

Coastal mapping process challenged by remote sensing survey

- Lidar
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- Hyperspectral

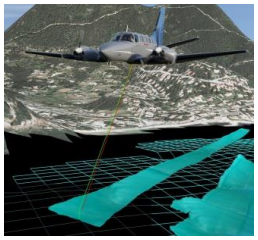
Challenges & Perspectives

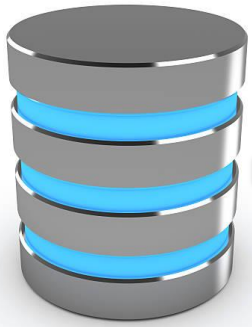
Lidar, satellite derived bathymetry … create massive amounts of data in minutes BUT it still takes weeks to derive the correct bathymetry :

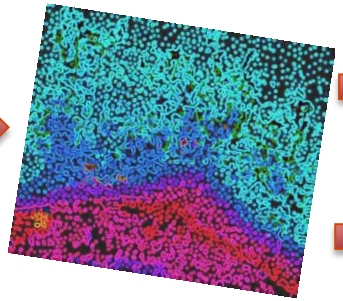
- Data volume
- Data complexity
- Data accuracy

Big data management is definitely a topic to be addressed in a better way and automated processing techniques have to be developped

New database approach ➔ bathymetric knowledge database / reference surface







Nautical charts production

Other products : DTM, …

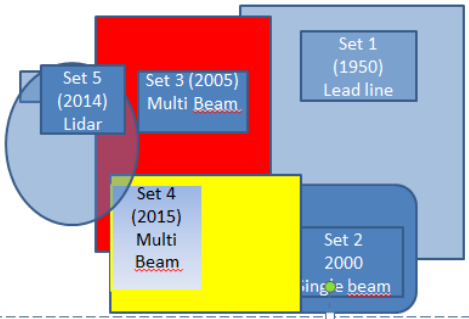
Bathymetric DataBase (BDBS)

Deconfliction & Fusion tools

Reference surface

- **Deconfliction :**
  - generate the « minimum surface including all the soundings of an homogeneous set in terms of hydrographic characterization »

  ➔ Relevant choice of information sources in overlapping areas

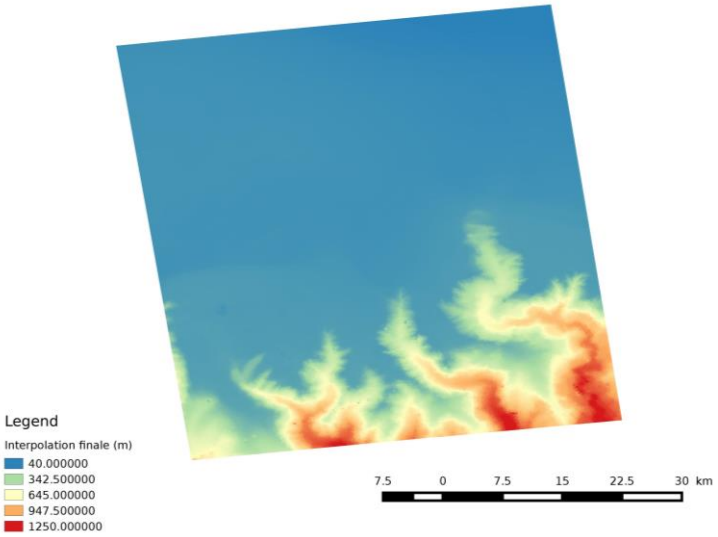


- Set 1 (lead line survey, 1950) is the oldest data in SHOM database for this region and is used for DTM and chart production.
- Set 2 (Single beam survey, 2000, caleva=0) removes and replaces all old sets (Set 1).
- Set 3 (Multi beam survey, 2005) removes and replaces all preceeding sets (Set 1 & Set 2).
- Set 4 (Multi beam survey, 2015, caleva=1) removes and replaces all survey data mentioned in caltxt (Set 1, set 2 & Set 3).
- Set 5 (Lidar surevy, 2010, caleva=2) complements set 1 and set 4 in overlapping zone.

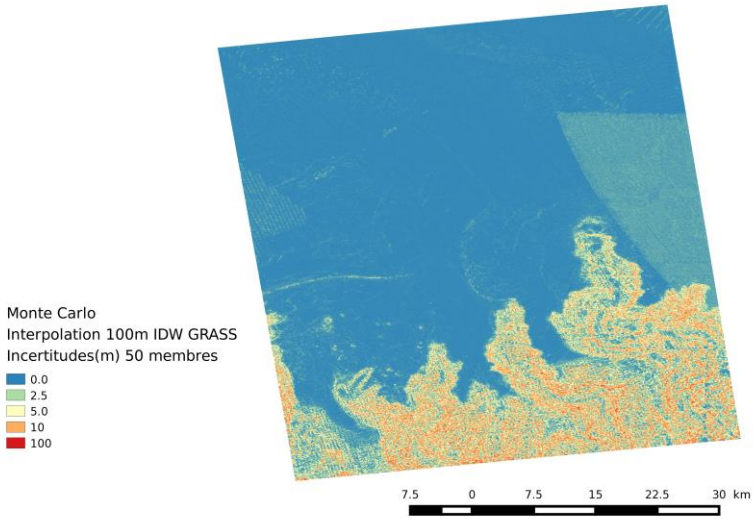
➔ Next step = test other methods of spatial indexing (Q-Tree) & take into account geospatial characteristics of data sets (density, spatial distribution, topographic variability, ...) to identify inconsistency and optimize the choice

- **Fusion, interpolation and estimation of uncertainty**
  - Interpolation nearest neighbor / spline / Kriging / Monte carlo

➔ Relevant strategy of interpolation and uncertainty estimation : which estimator ? For what kind of use (surface navigation ? Underwater nav ?)



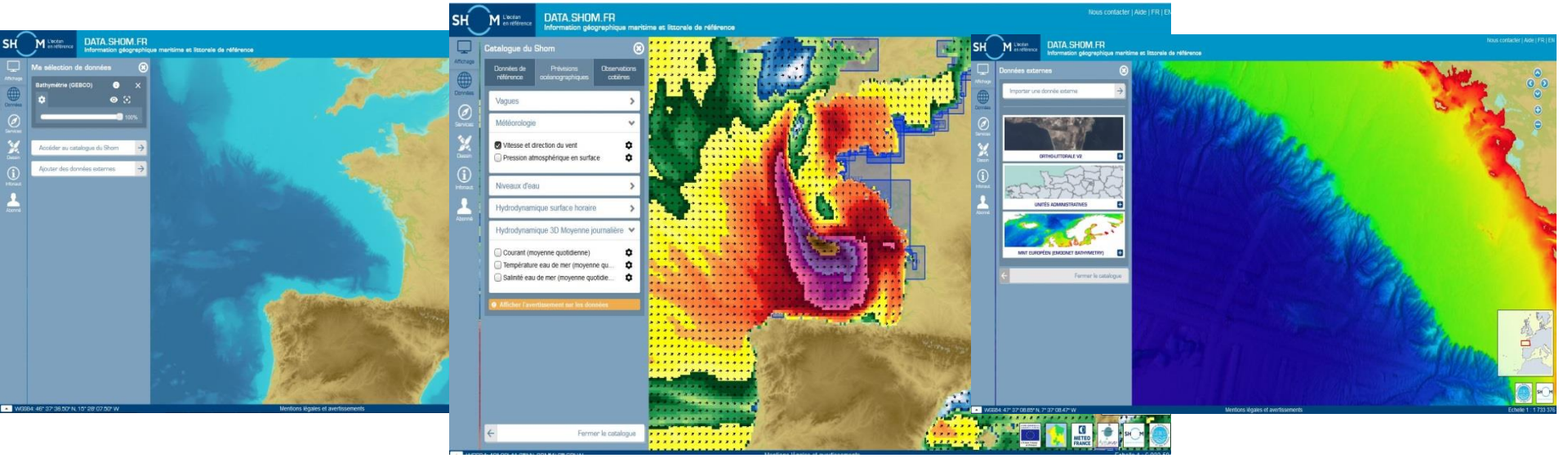
DTM generated by deterministic interpolation



Estimation of the associated uncertainty per grid node resulting from the Monte-Carlo method

- **Automation of the acquisition, processing and utilisation of the data**
  - Pydro/Hydroffice
  - Data management (Multi-resolution grids vs point clouds, …)
- **Data complementarity**
  - Within archived data (National/international Database)
  - Using different technologies
- **Smart data**
  - Artificial Intelligence for data processing (starting PhD Thesis « Machine learning for the optimisation of hydrographic data processing (MBES, Lidar)"
- **Smart users**
  - Providing the user with confidence (ZOC, but also quantitatively/physically based estimation of uncertainty)
  - Chart adequacy / Resurvey strategy (SDB, CSB)

THANK YOU !



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