ARGANS

Remote Sensing and Earth Observation Specialists

Analyse Build Manage Deliver

Satellite Derived Bathymetry

Presentation to the HSPT

3rd December 2019

Jean Laporte, Henri Dolou and Joseph Avis

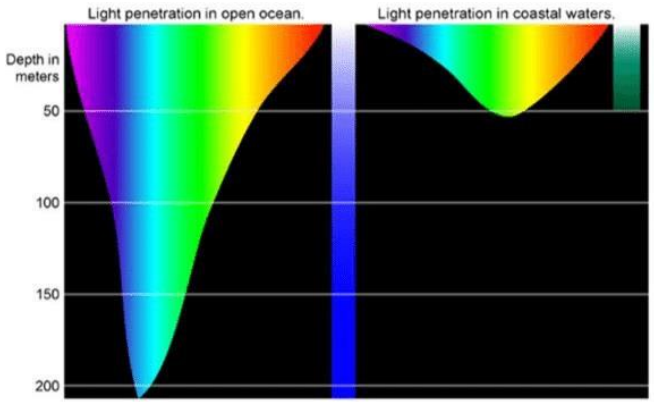
IHO

First part: State of the art, R&D and ongoing projects

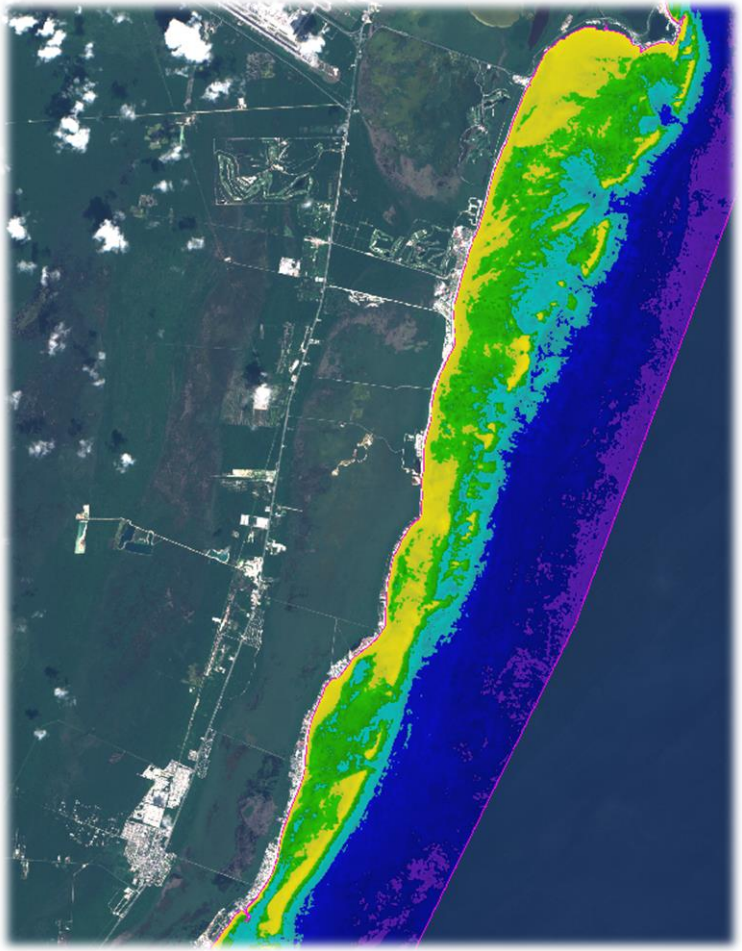
Joseph Avis, EO Scientist

Satellite Derived Bathymetry

Satellite Derived Bathymetry (SDB) is the estimation of ocean depth using multispectral sensors in the visible band.



- Cost effective.
- Fast production.
- High resolution results.
- Remote areas become accessible.
- Side products (seabed classifications).
- Effective down to 25 m (cut off depth).



Satellite Derived Bathymetry

SDB uses remote sensing passive sensors to measure the reflectance from the seabed.

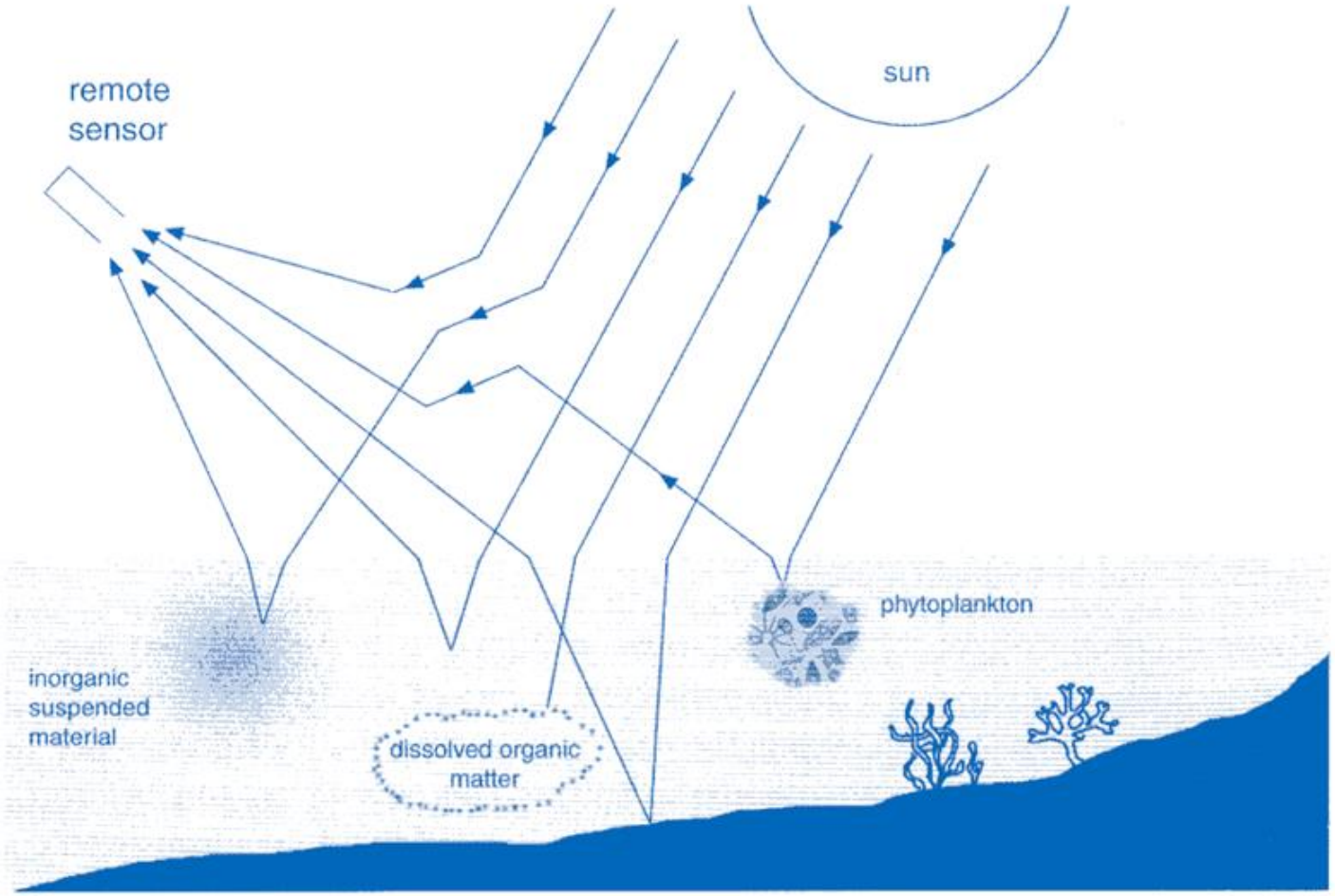
- Empirical:
  - Requires data set of known depths at the time of image acquisition.
  - Assumes estimated parameters across the whole image.
- Physics based:
  - Inversion model (which depth gives the closest match to reflectance).
  - Replaces empirical data with a more physically constrained model.

But exercise caution! As there are far more unknowns than equations, SDB models depend very much on parameterisation and interpretation

Satellite Derived Bathymetry

There are a range of multispectral sensors covering different spatial and spectral resolutions that are suitable for SDB production:

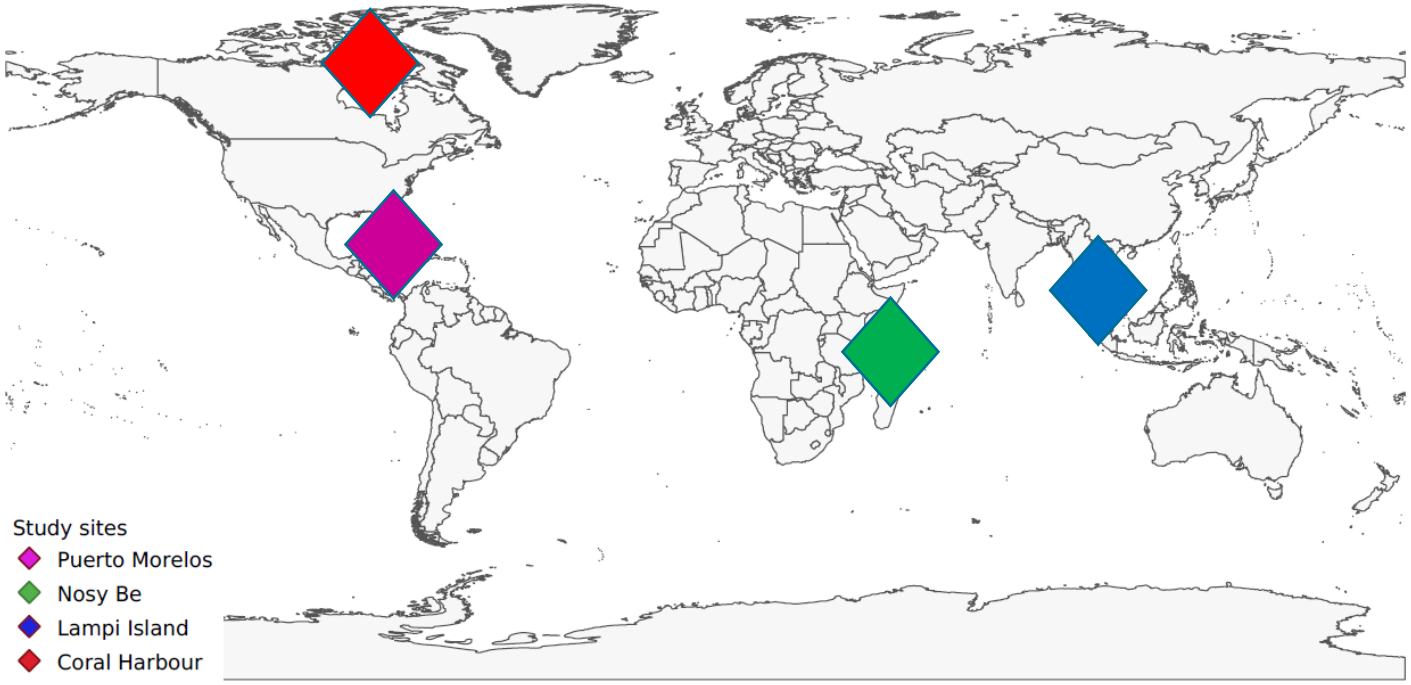
- Landsat (~30 m pixel resolution).
- Sentinel (~10 m).
- World-View/Pleiades (~2 m).



ARGANS collaboration with ESA

‘Sentinel Coastal Charting Worldwide’

- The objective of the project was to prove the capability of Sentinel-2 to produce IHO-compliant SDB chart demonstrators reducing coastal gaps at an affordable price.



Sentinel Coastal Charting Worldwide

Sentinel-2 for SDB production

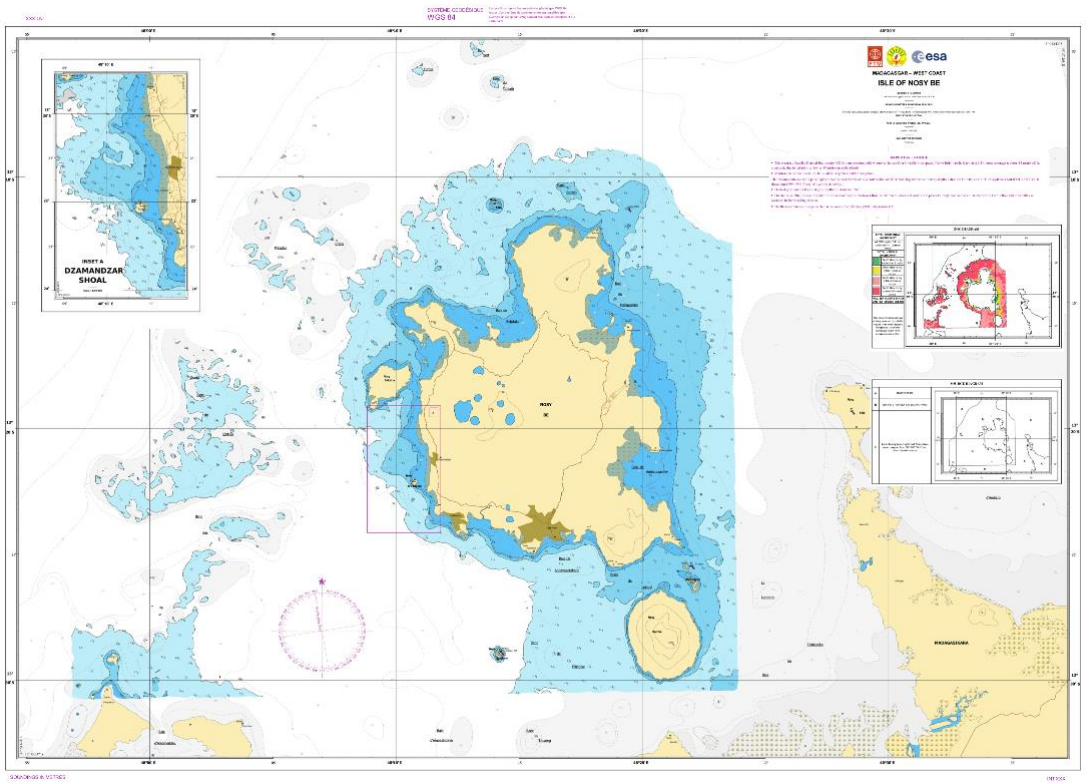
- 10 m spatial resolution.
- 13-band spectral resolution covering 443 – 2190 nm.
- High standard of image and sensor calibration.
- Co-registration of repeat image tiles offering a 12 m absolute horizontal precision, or metric with VHR co-registration
- High revisit time period (5 days at equator).
- Raw imagery is free open source.

ARGANS research findings

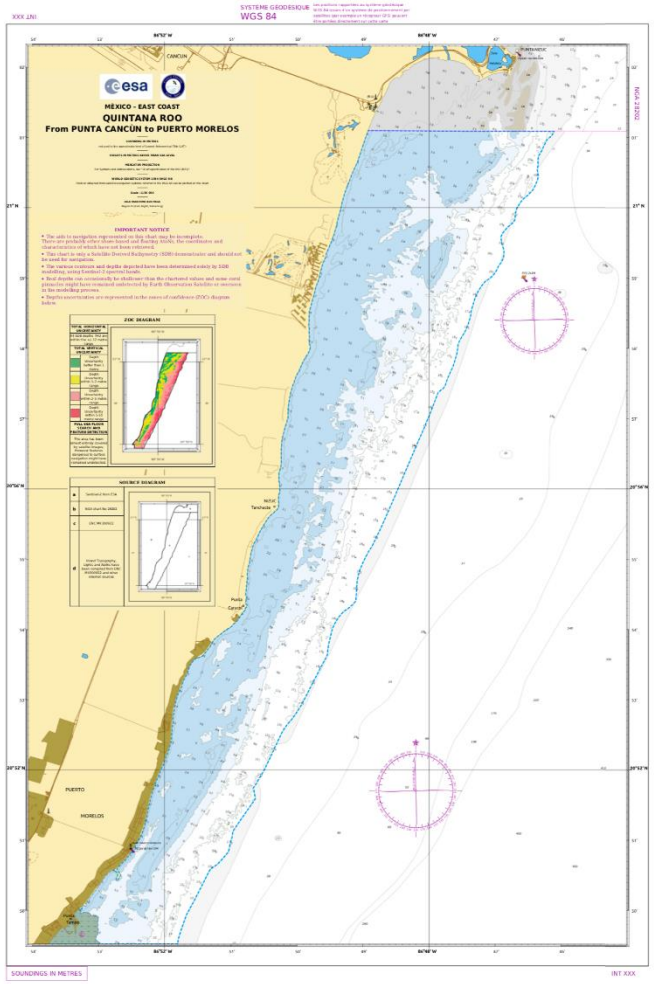
Results:

- ARGANS highlighted the quality of Sentinel-2 database and designed a ‘statistical approach’ to incorporate into our SDB workflow.
- Novel methodology allowing a combination of large datasets within a full statistical analysis.
- Results show that Sentinel-2 provides a higher accuracy at estimating depth when using a time series of images.

Final Charts



Nosy Be, Madagascar



Puerto Morelos, Mexico

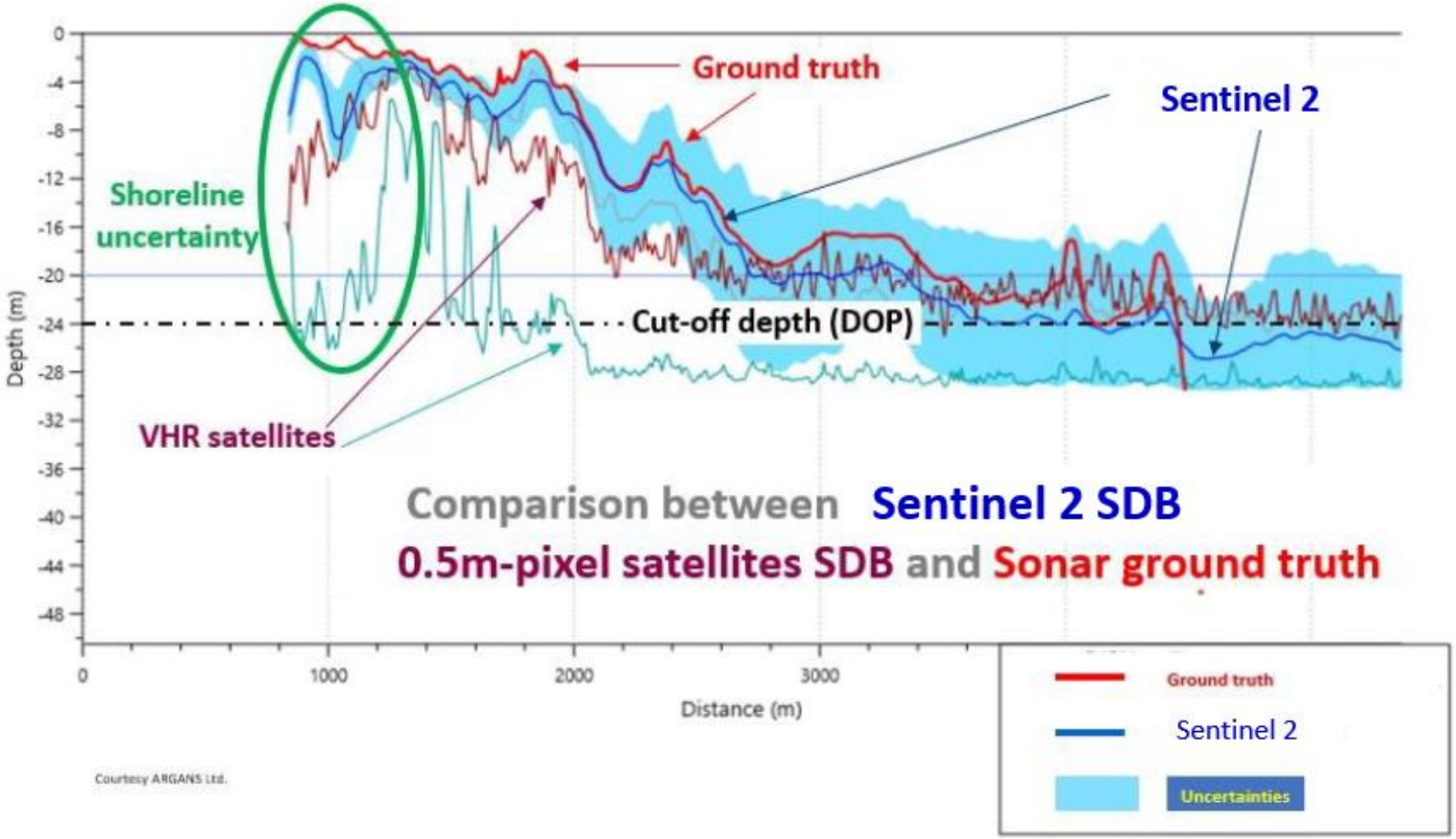
'Full report and final products can be freely downloaded from https://sdb.argans.co.uk/'

Collaboration with SHOM

ARGANS was contracted to push the boundaries of SDB methodologies that have been in place in Shom for 30 years

- Contrasting locations worldwide were used to compare SDB model performances and the effect of endmembers (changes to spectral responses of seabed).
- Varying image quality (glint, reflectance, viewing angle).
- Comparing the use of differing field data (charts from late 1800's, lead line and echo sounding data/or in situ observations/ or no field data).
- Comparison of different earth observation sensors.

Comparison of spatial resolution

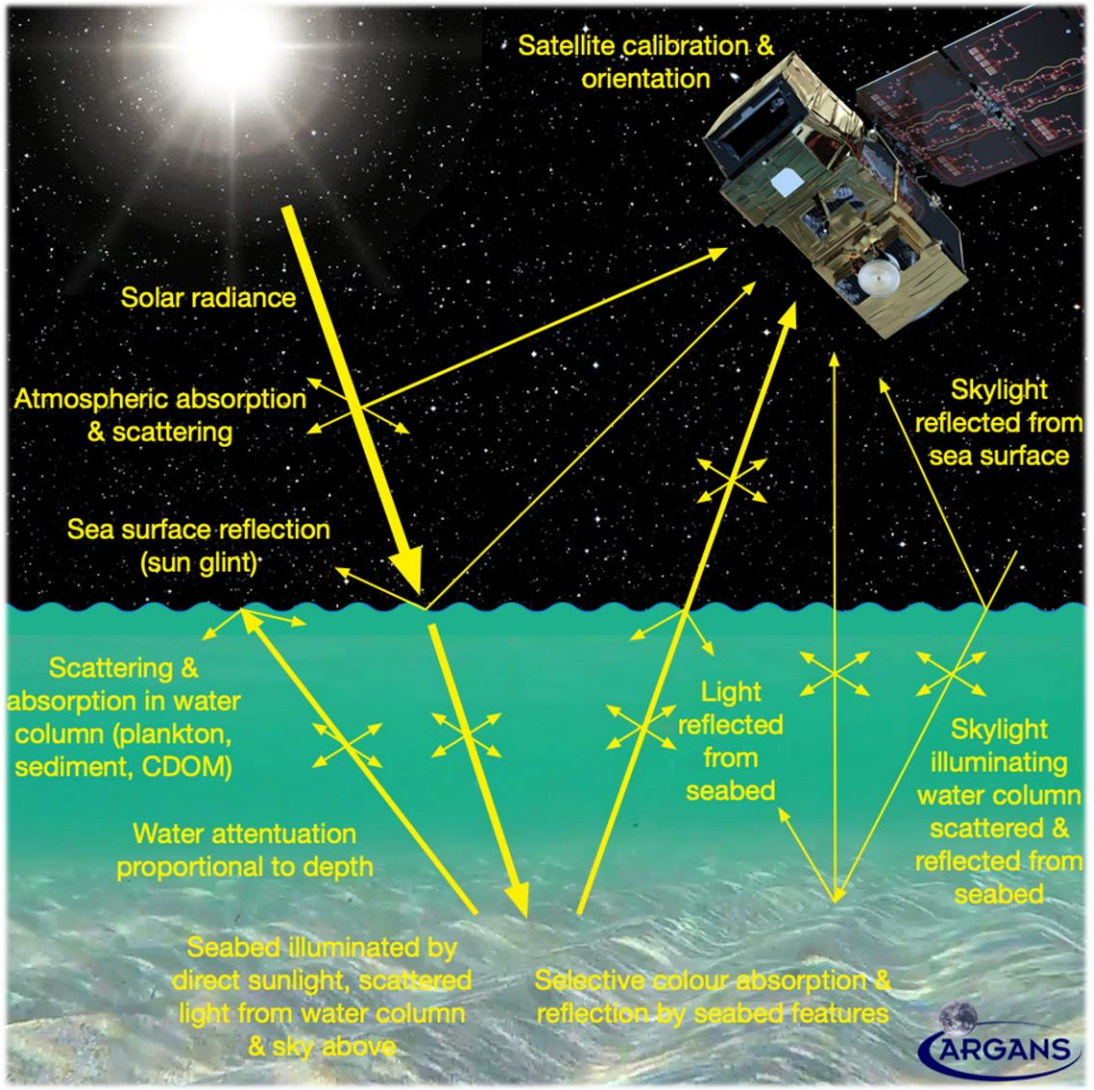


Uncertainties

Uncertainties associated to solar radiance:

- Atmospheric interactions.
- Sea surface interactions.
- Water column.
  - Inherent Optical Properties.
- Seabed.

- Tides, sensor (angles, glint…), sea state, end-members…



Future plans

- Reduce uncertainties.
  - Refine procedure for atmospheric correction.
  - Specific inherent optical properties.
- Site specific assessment.
  - Atmospheric correction per site.
  - Improve specific endmembers.
- Improve official, yet outdated, nautical charts.
- Implement Depth of Penetration (DOP) as an SDB validation tool and to complete the IHO C-55 with information on lidar and SDB feasibility

First conclusions

- SDB is a useful process for production of bathymetry due to the high revisit time and cost efficiency of Sentinel-2 satellite data.

- Sentinel 2 supersedes all known sensors to provide accurate assessment of seafloor bathymetry and an effective contribution to the IHO fundamental goal of Safety of Navigation worldwide.

- Although there are still issues regarding uncertainties, future work will provide an opportunity for SDB to become an IHO compliant source of navigational charts and Nippon Foundation/GEBCO coastal data.

Second part: Cartography

Henri Dolou, cat A Hydrographer

Technical recommandations to professionnal marine cartographers

- This presentation is addressed to Marine Cartographers whose trade is based on compilation, which consists of doing one's best with the information they have, relevant or not to the safety of navigation, according to their analysis of risks.
- SDB produces depths that may be useful for applications not limited to the Safety of Navigation (minimum depths depicted on the charts), but including other domains (marine environment, additional military layers, tidal and physical oceanography models, etc.).

The cartography challenge

- Improve safety of navigation in critical waters
- Decide if and when charts have to be updated
- Check charted depths against satellite images
- Extend the charting potential for economic and social reasons by developing the “Good enough” concept

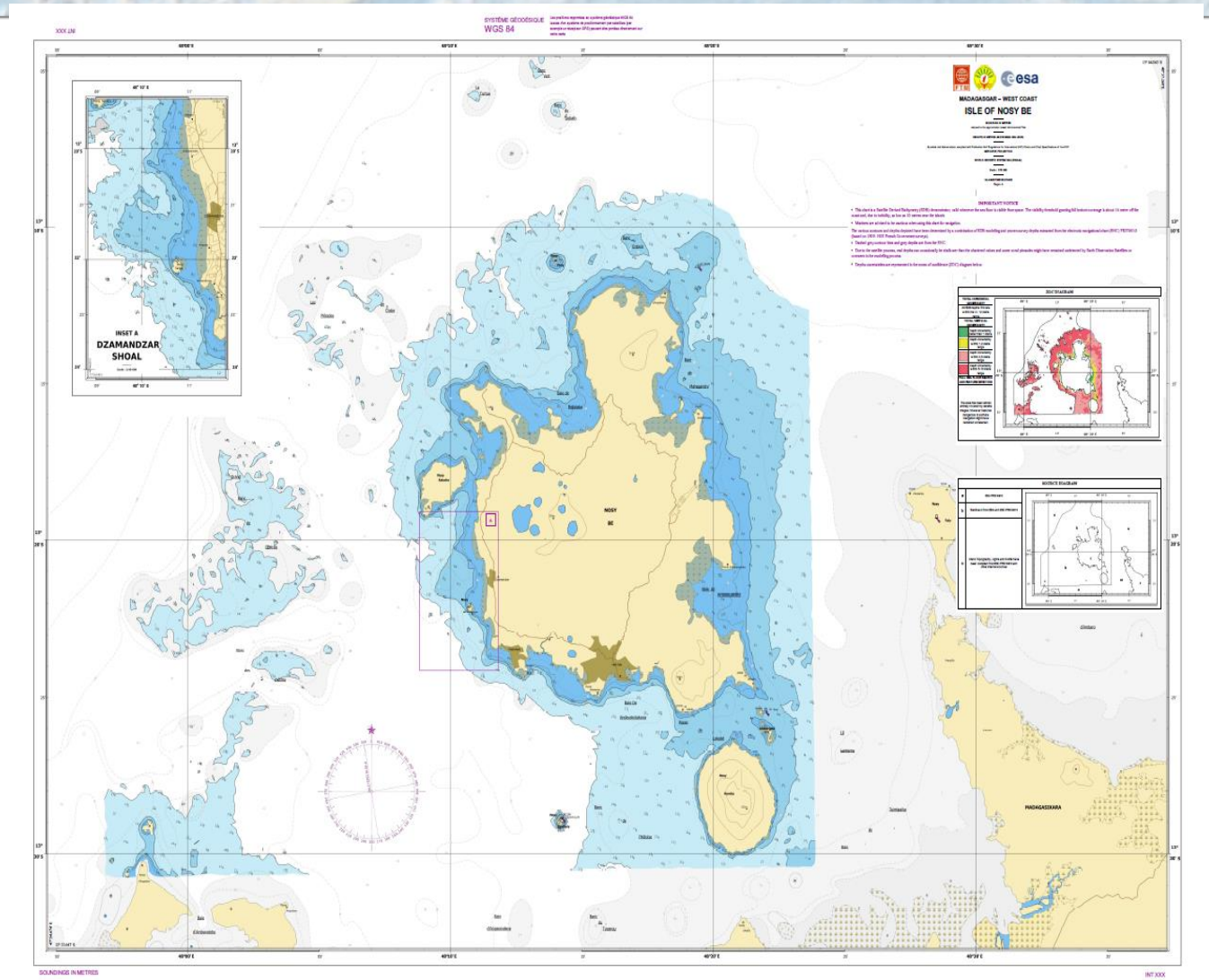
How should SDB experts and Cartographers relate with each other to optimise SDB results?

- Cartography, field experience and EO practice should be an obligation to SDB specialists.
- The cartographer does his best with what he is given … and in which he has concidence!
- EO specialists and SDB experts must be aware of the Cartographers' constraints and liabilities and must qualify their results in a way that cartographers can understand.
- Conversely, Marine cartographers must develop their understanding of Remote Sensing, extended to new solutions such as SDB.
- Both must be aware of the importance of standards such as S-44.
- Both must develop their control of SDB quantitative “uncertainties”

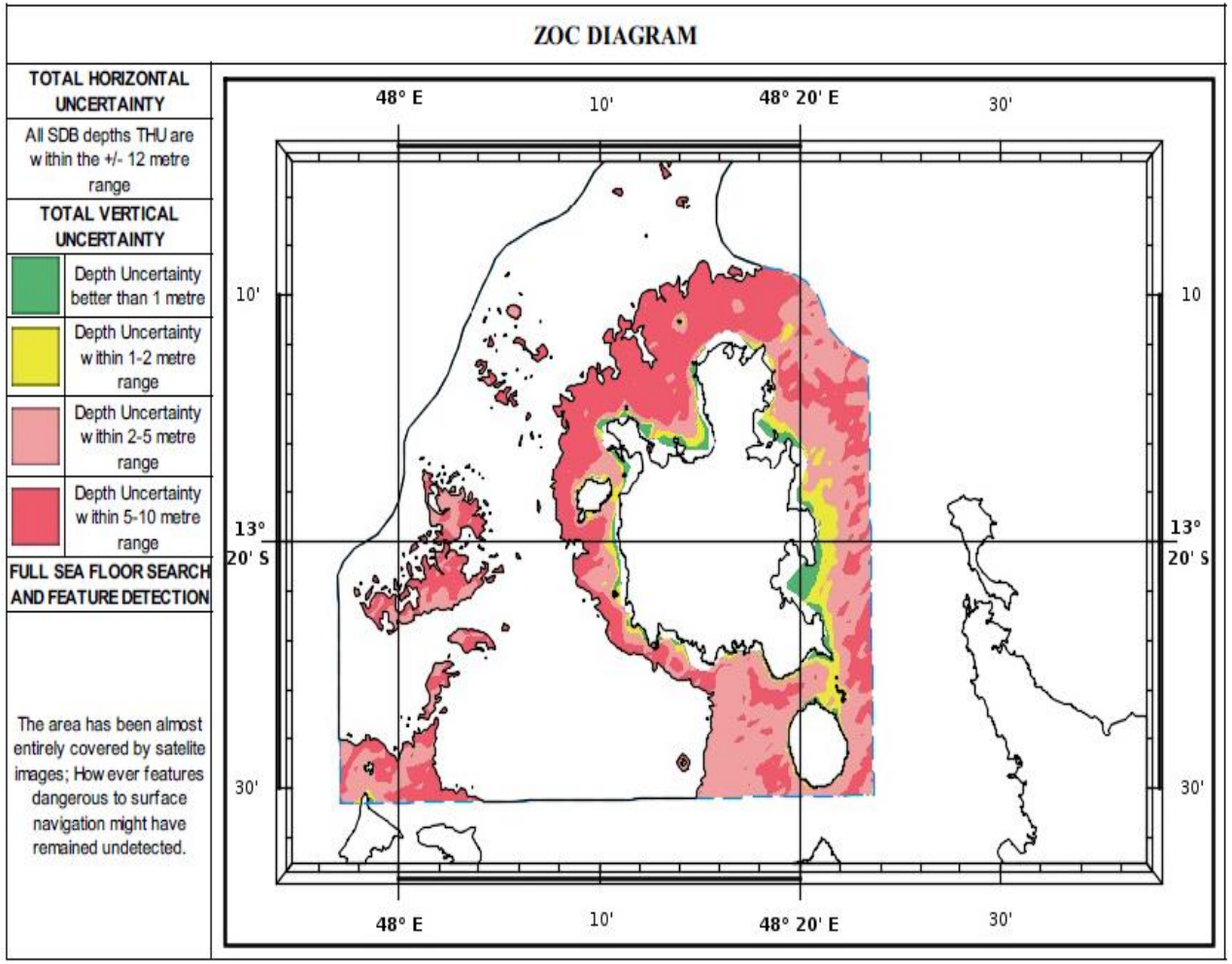
SDB pros and cons as seen by cartographers

- There is so much to do to improve coastal charting worldwide that Hydrographic Offices should not deprive themselves of this technique
- It has been possible for almost 30 years to produce SDB charts that already meet a number, if not all, IHO's standards, as long as they are produced professionally.
- Latest example: Nosy Be (a chart with ZOC and source diagrams).

Madagascar: The Nosy Be SDB demonstrator



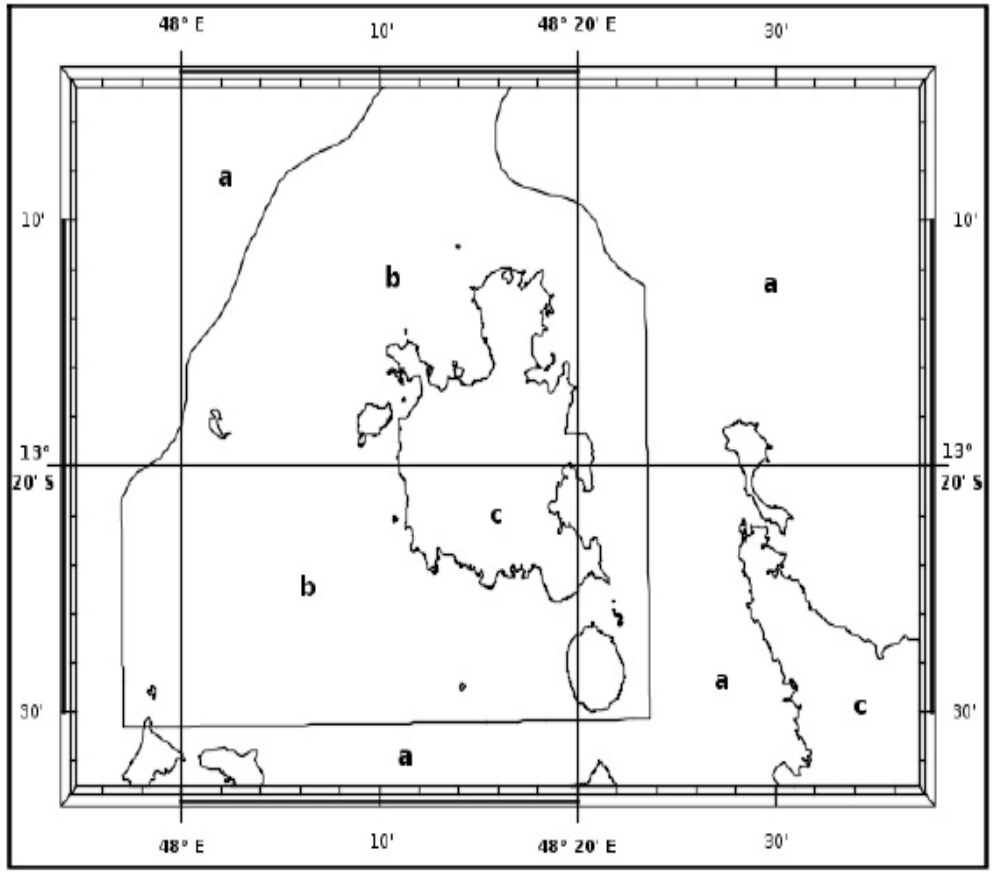
The Nosy Be ZOC (Zone Of Confidence)



….and source diagram

SOURCE DIAGRAM

a	ENC FR374910
b	Sentinel-2 from ESA and ENC FR374910
c	Inland Topography, Lights and AtoNs have been compiled from ENC FR374910 and other internet sources

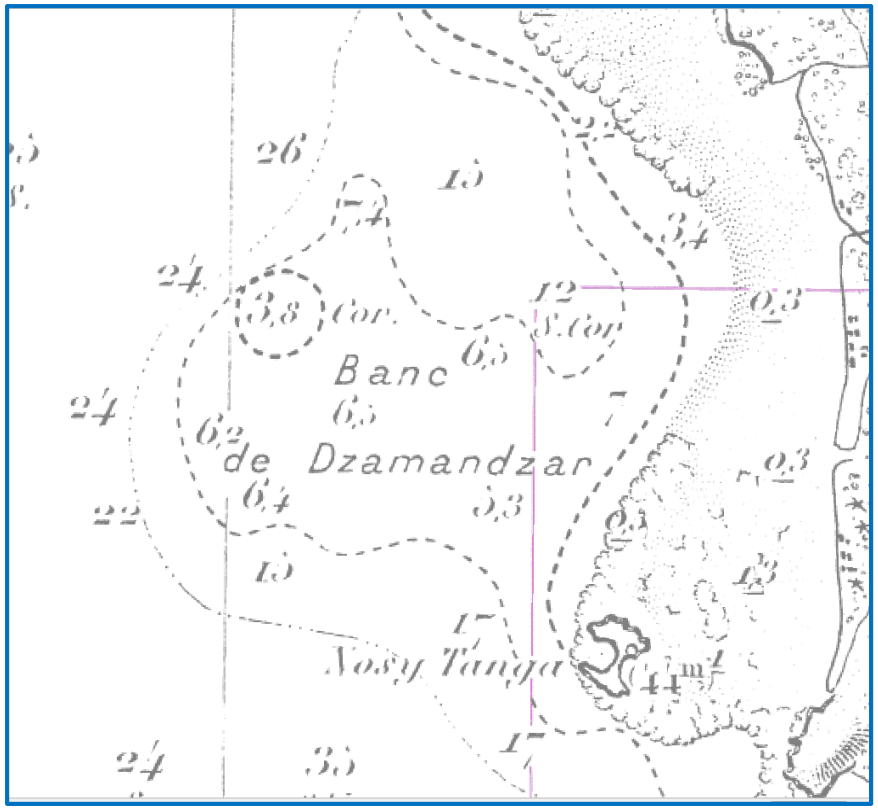


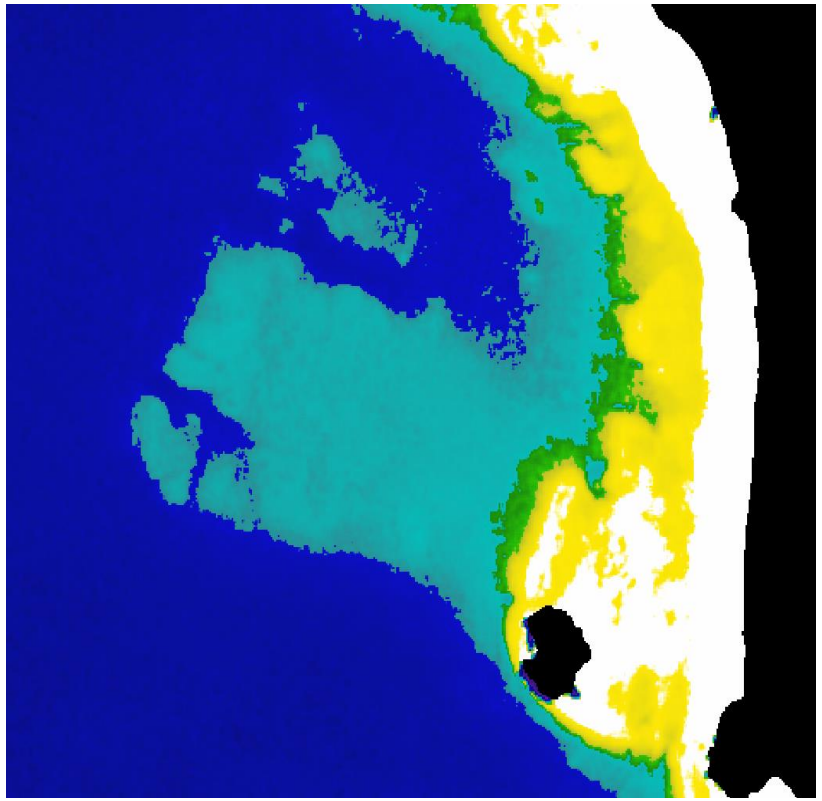
Q: Can SDB charts support Safety of Navigation?

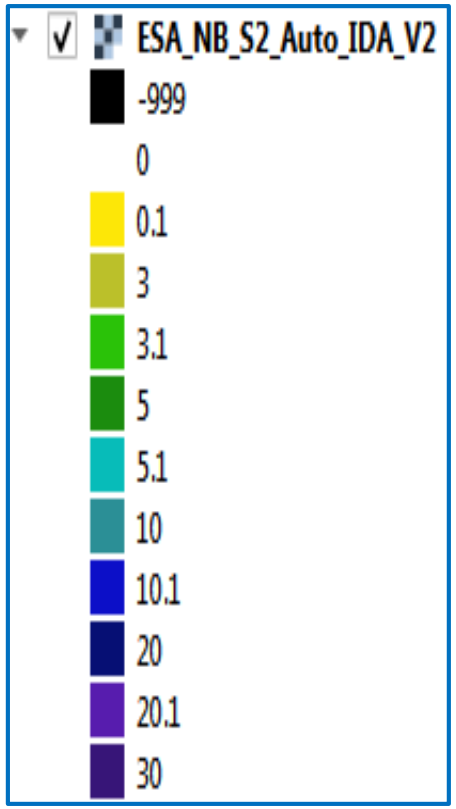
A: It depends on the cartographers' confidence in the available information

- To start with, some information is better than no information at all, re the IHO C-55 status of surveys and charts worldwide
- Ancient charts can be improved with visible coverage, e.g. Nosy Be
- Time series can be used to confirm or disprove shoal, e.g. the Thalia shoal in Andaman Sea

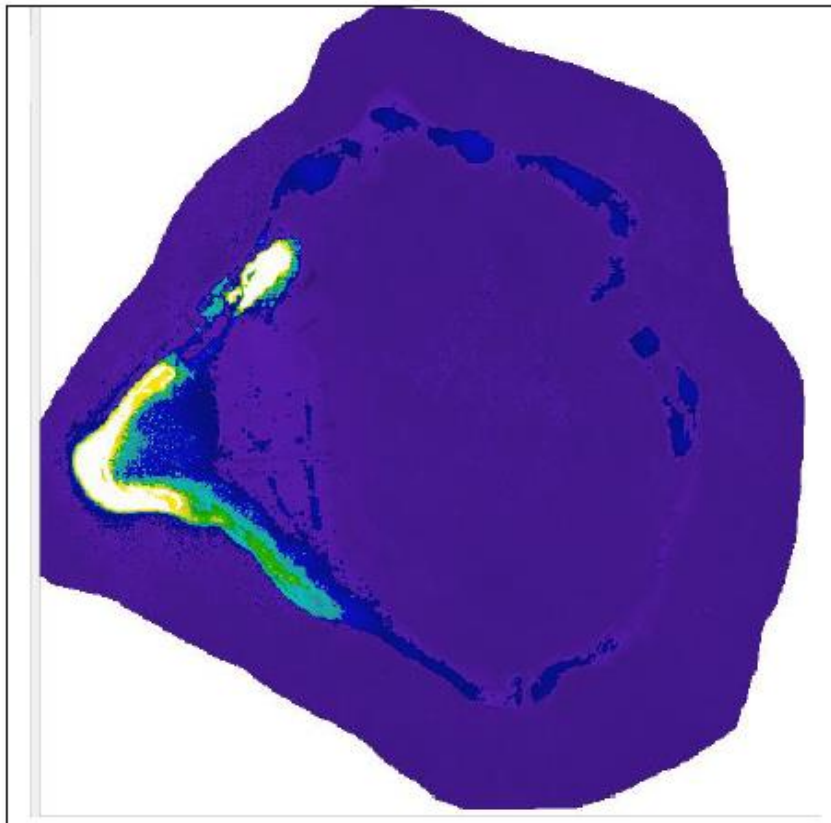
Madagascar/Nosy Be: Banc (shoal) Dzamandzar







Iles Eparses : Banc Geyser



-999
0
0.1
3
3.1
5
5.1
10
10.1
20
20.1
30

0.1 = de 0.1 à 3 (commence à 0.1 jusqu'à couleur suivante)

SDB potential and proven contributions

- Evaluation of existing chart to deliver Safety of Navigation
- Chart updating
- Identification of new navigation routes
- Filling C-55 charting gaps and populating the GEBCO database
- Help to decision and prioritise re-surveys
- Traditional survey planning and optimisation

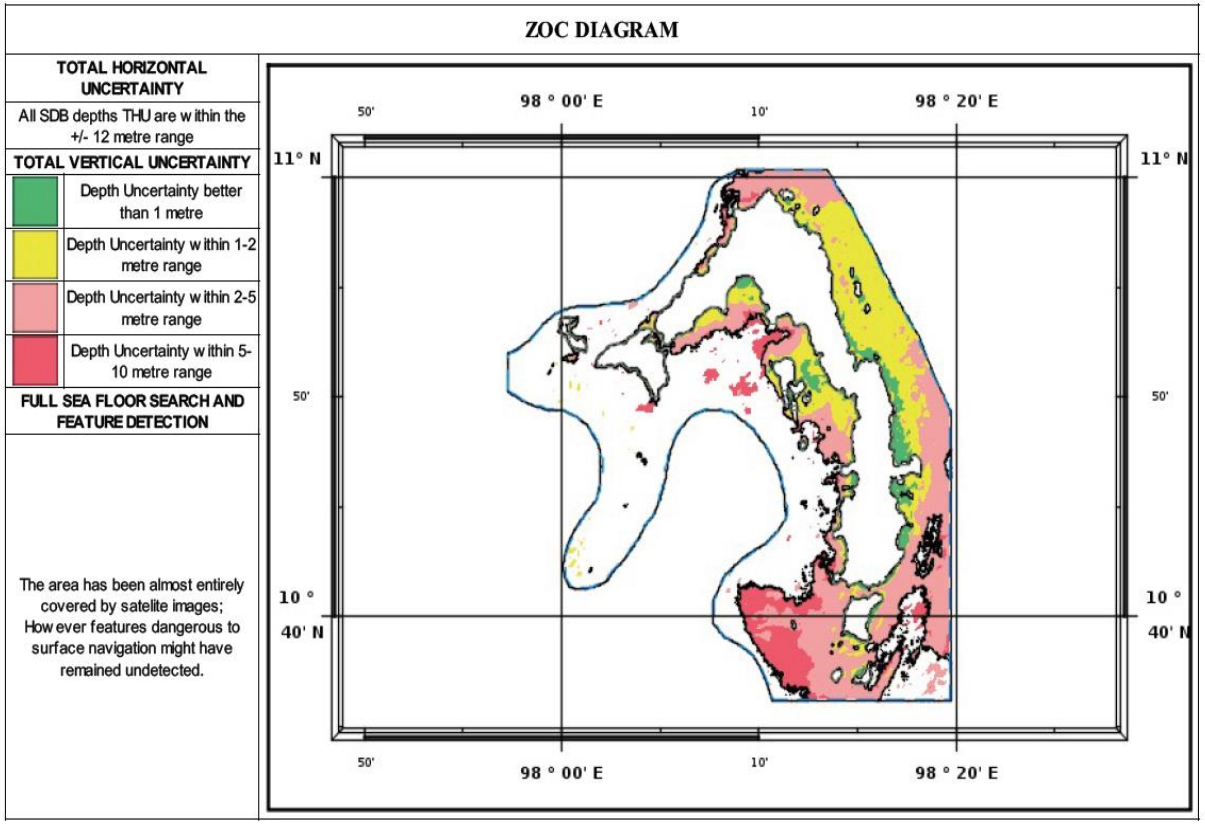
An important reminder to cartographers and analysts

- SDB produces DTMs that can easily be compared to charts, bathymetry databases or digital fair sheets
- Differences can be mapped <u>automatically</u> and discrepancies detected rapidly to plan further investigations.
- These comparisons can help confirming the chart validity and in turn, classify the SDB survey into either “good enough” or useless.

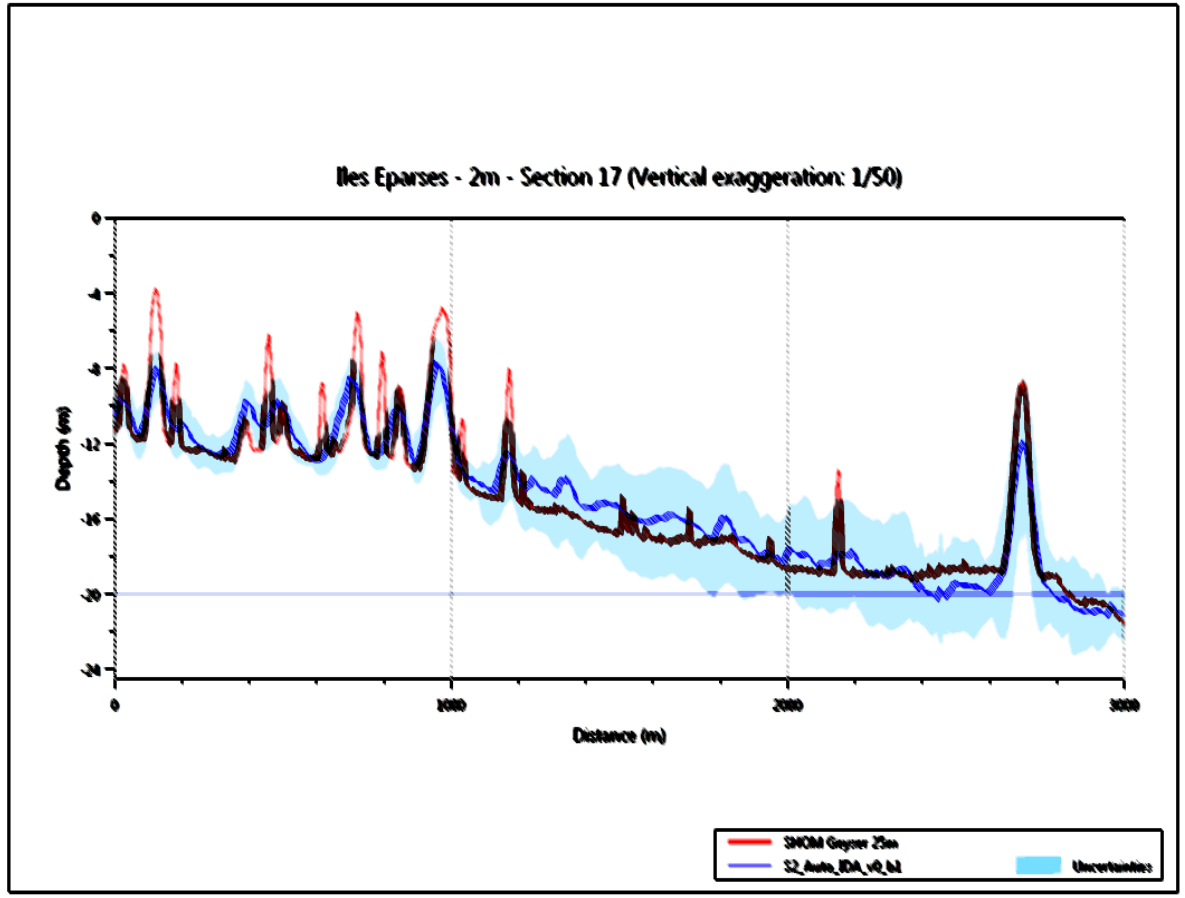
SDB Validation and qualification: professionalism, tools and experience

- **Professionalism**: first of all, prove that, as a hydrographer, the SDB specialist understands validation (where is it acceptable ?) and qualification (what is it worth ?) of his results.
- **The tools** are :
  - The Uncertainties yielded by SDB models
  - The maps of differences between SDB models and existing information
- **Experience** is certainly the heart of the matter

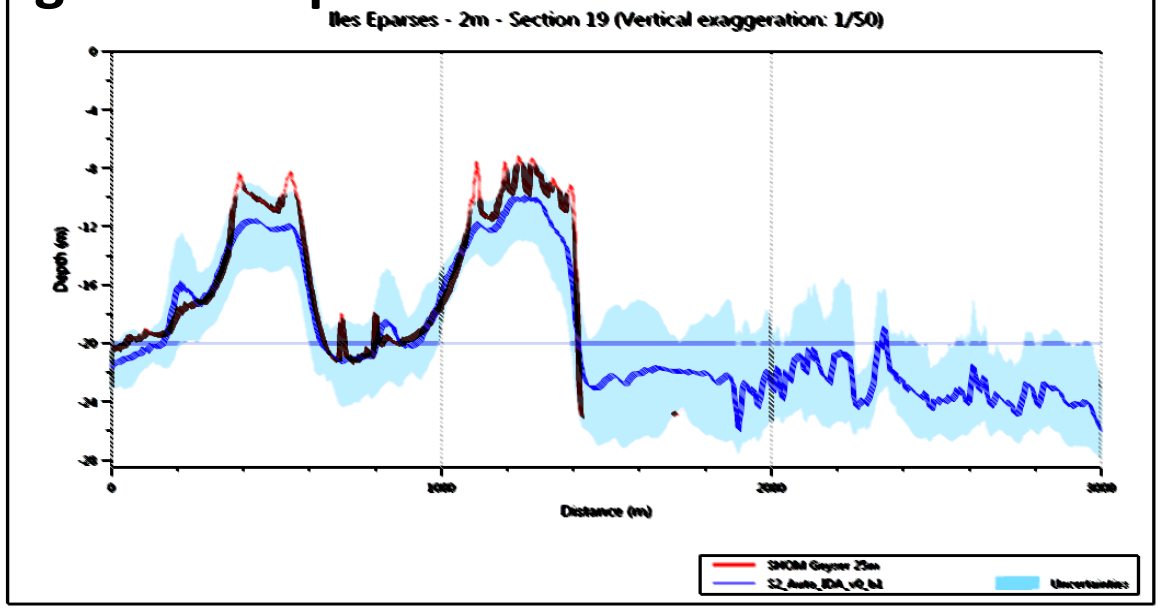
Models: uncertainties may be represented by CATZOC (Myanmar – Lampi Island)



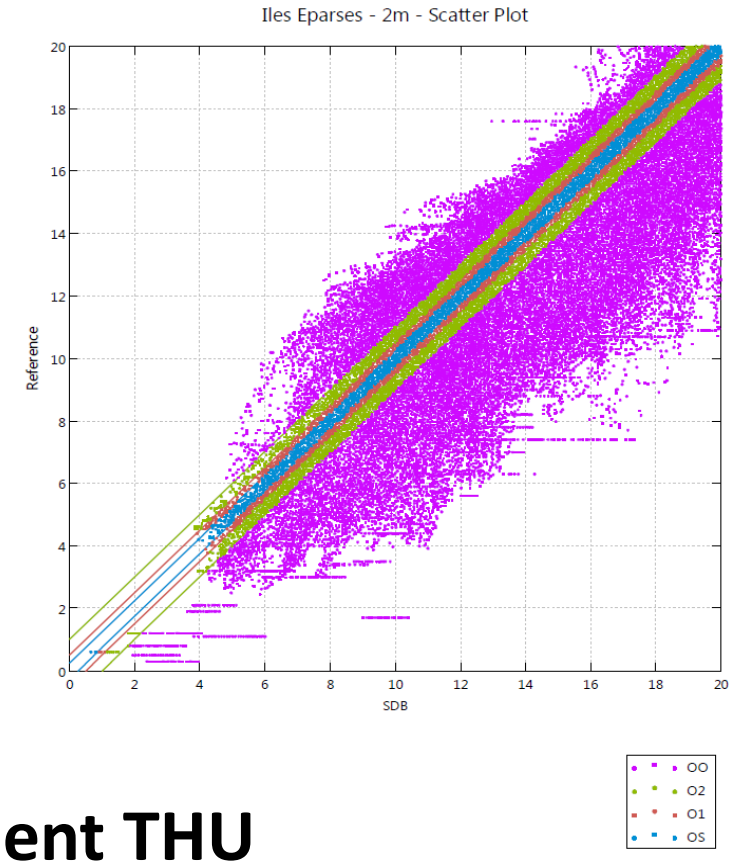
Comparison with existing data: cross sections

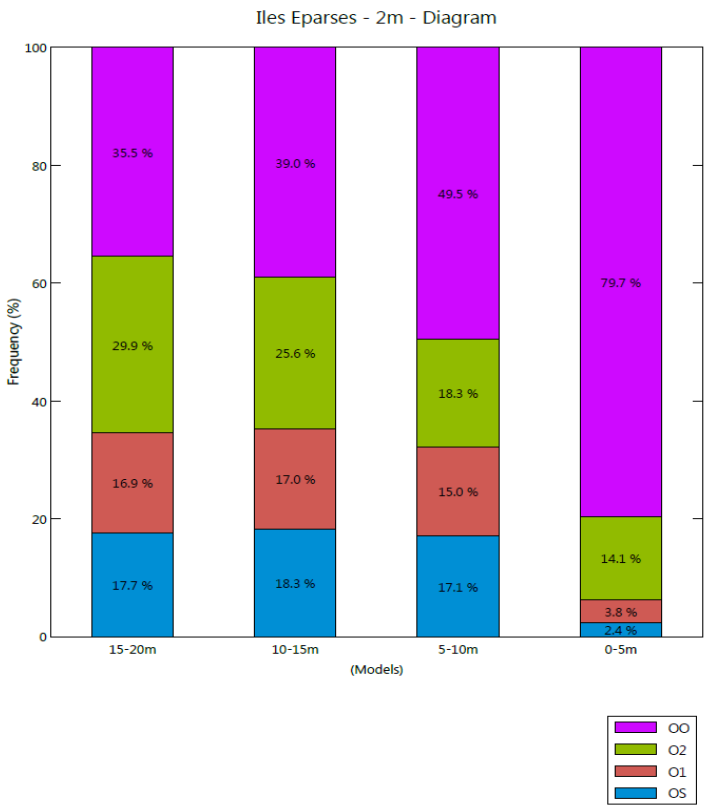


- **Comparison with existing data (experience : it is important to know the results already obtained in similar circumstances - environmental)**
- **Note that depths of small features such as coral pinnacles are selected however with a greater depth.**



How does SDB stand againt IHO's S-44 surveys orders (Special, 1 and 2)?

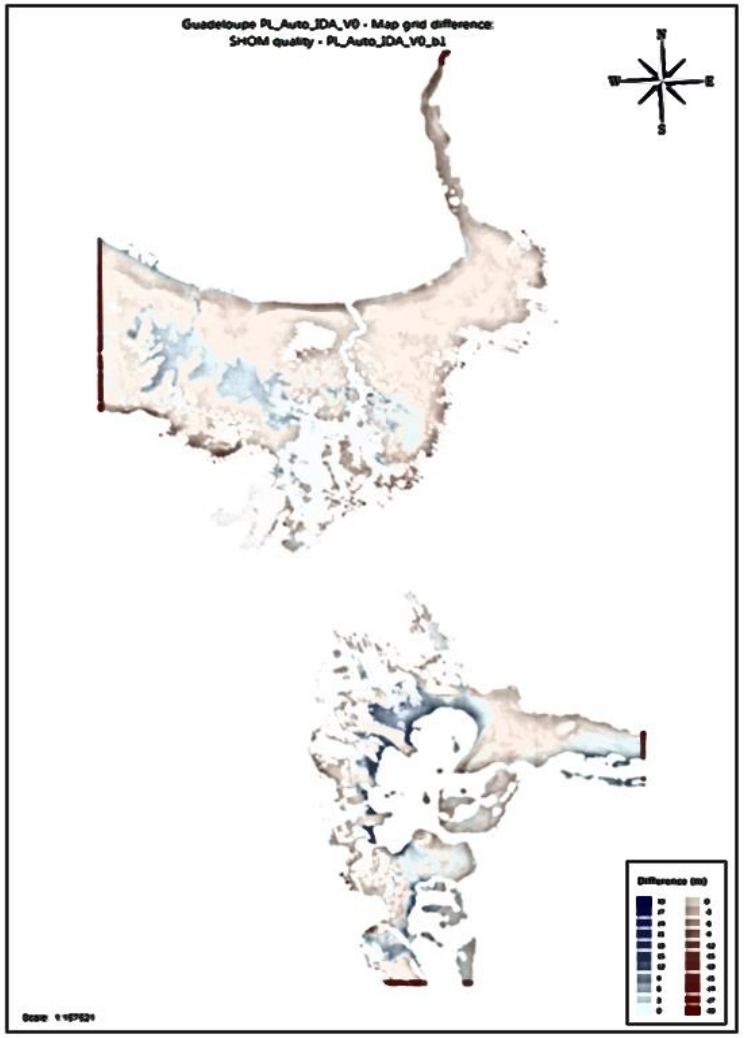


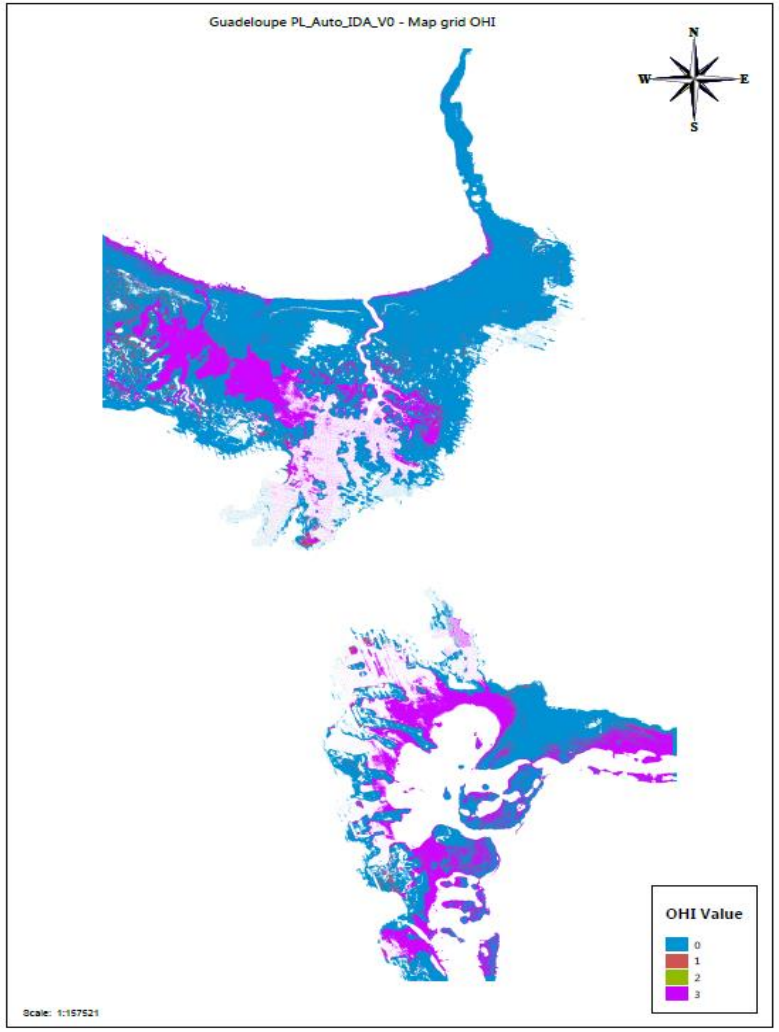


Excellent THU

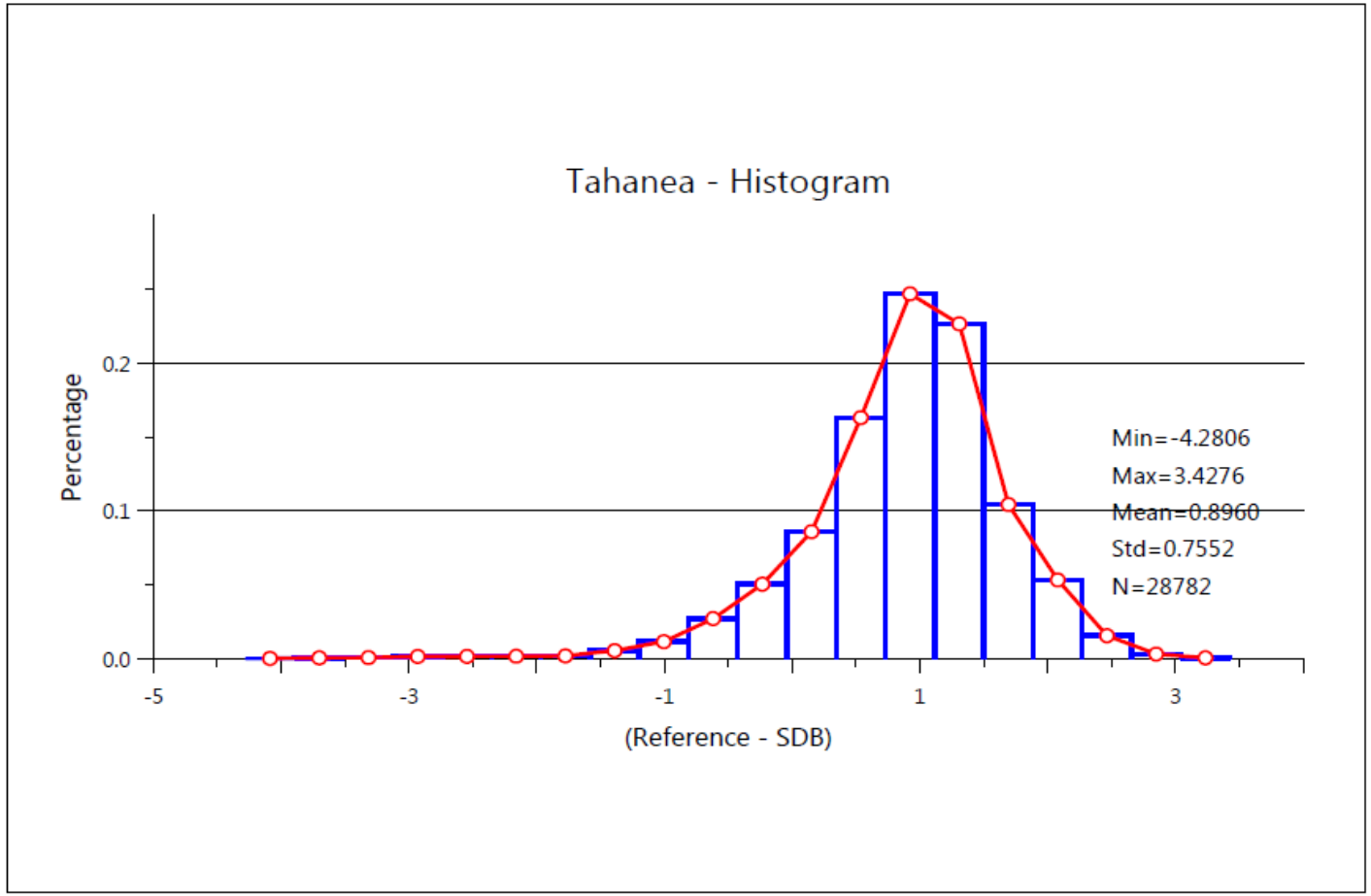
Mediocre TVU, cluttered with systematic and random errors

Maps of differences
Statistics of IHO's S-44 compliancy





Statistics: histograms



Third part: Standards

Jean Laporte, Cat A Hydrographer

S-44 SDB standards (Overall considerations)

- EO and RS techniques, i.e. SDB, Wave Derived Bathymetry, etc. can no longer be ignored.
- EO Remote sensing applies indifferently to satellite, lidar and hyperspectral. All share in common that the bottom must be seen (passive) or reached (active), hence the importance of including a DOP criteria.
- Hydrographic Qualification is essential to SDB for the two following reasons:
  - SDB is not a rigorous science, but depends on parameterisation
  - Interpretation is supreme and has consequence on safety of navigation
- Standards applicable to other scientific usages (environment, habitat, etc.) can be relaxed as they do not entail Government liability.

Tentative S-44 SDB standards (The Matrix)

	Parameter / Data Type	1	2	3	4	5	6	7	8	9	10	11	12
R	EARTH OBSERVATION AND REMOTE SENSING												
a	Capability of system to measure Depth [range in m]	>50	50	20	15	10	5	2	1	0.5	0.4	0.1	
b	DOP (Depth of Light Penetration) [m]	Optional	Optional	Optional	15	10	5	2	1	0.5			
c	Resolution (e.g. pixel size) [m]	>50	50	20	15	10	5	2	1	0.5	0.5	<0.5	<0.5
d	Revisit period [days, hours]	>15 d	>15 d	>15 d	10 to 15 d	5 to 9 d	1 to 4 d	<1 d	<12 h	<1 h	<0.1 h	<0.01 h	**<0.001 h**
e	Overall validation and expertise [FIG/IHO category, other credentials]	Optional	Optional	Cat B	Cat B	Cat B	Cat A	Cat A	Cat A	Cat A	Cat A	Cat A	Cat A

End of presentation

ARGANS

About ARGANS:

- ARGANS, is a UK-registered company with headquarters based in Plymouth UK, offices in Sophia-Antipolis and Brest, and staff located in London and Southampton.
- We are specialists in satellite-based Earth Observation, remote-sensing applications and services, IHO-compliant cartography and geographical information systems used to map and monitor the marine, atmospheric and terrestrial environments.
    - https://argans.co.uk/proj-sdb.html