ANNEX A

Puerto Morelos

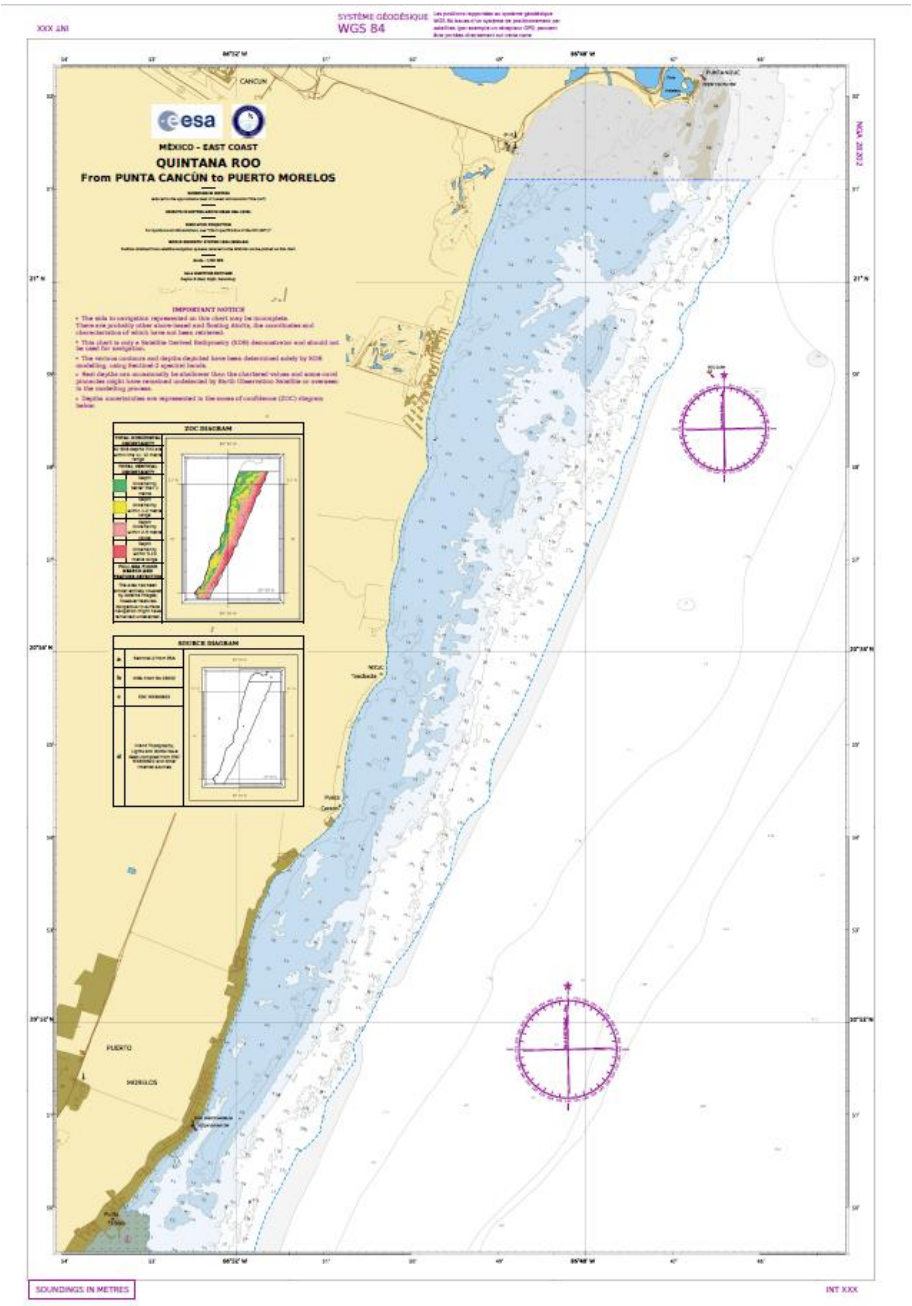
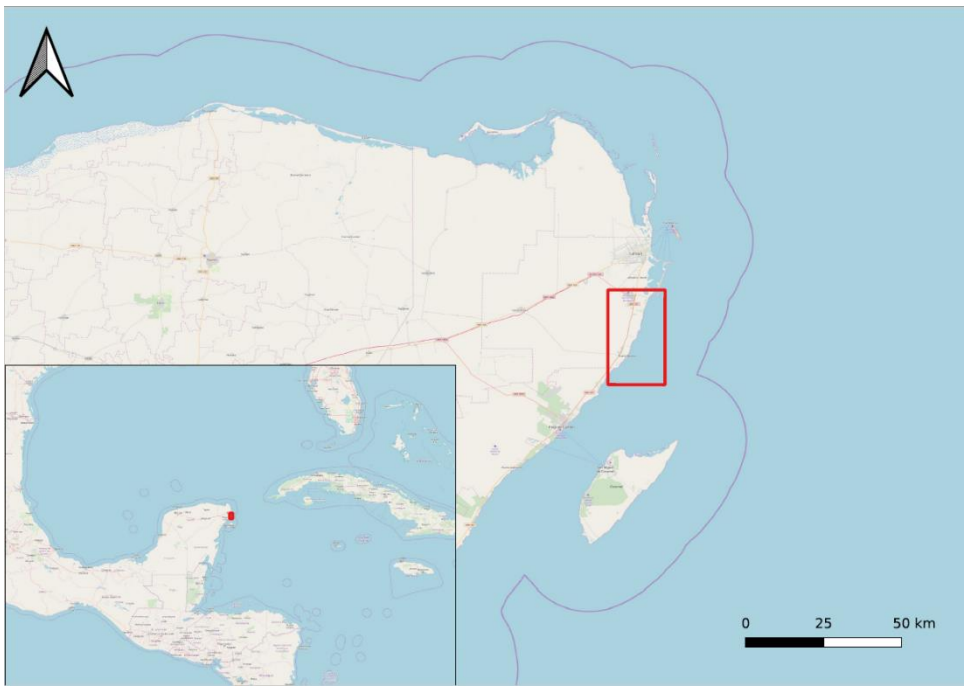


TABLE OF CONTENTS

1. Background Information

1.1 Overview

Puerto Morelos is a Mexican port town located on the Caribbean coast of the Yucatan Peninsula and home to the Great Mesoamerican Reef, the second largest reef in the world. This area is a large tourist location for Mexico and is a very popular diving location. The study area can be seen in the following figure.



Location of the Puerto Morelos study site. The red outline shows the study site where SDB was produced.

Puerto Morelos was chosen by ARGANS to compare the SDB results produced from Sentinel-2 10 m MSI with the existing SDB chart produced using KOMPSAT imagery taken in 2008 and 2009. This study aimed at assessing the capability of Sentinel-2 compared to VHR imagery.

1.2 Methodology

Using ESA Copernicus Sci-hub, 31 Sentinel-2 L1C images were downloaded for Puerto Morelos. These images were selected because of their minimal cloud cover, low glint and reduced suspended sediment loads. Once downloaded these images were assessed again before a final selection was made for satellite derived bathymetry to be produced. The final list of images was 6 Sentinel-2 images that met the high standard of criteria needed.

The 6 SDB models were then produced using IDA with comparisons being made to existing charts throughout the process to compare how the depth results differed between different sensors and the NGA chart made available. Once the 6 models had been computed and the final results were assessed, the "***Merge***" method was applied to these images. The *Merge* was only applied once all changes in the models had been assessed and it was deemed appropriate to merge the images together.

1.3 Main results

All *Merge* averaging methods were produced and assessed to identify which method produced the best results. This was done using a visual interpretation between the models and the pre-existing charts to find which model produced the closest results. Within this study the minimum distance weighted solution yielded the best results.

1.4 References

Inputs and references are listed at the annex A for clarity. They include the following:

- References from 2014 :
    - Former (2014) **Kompsat** image (0.5 m resolution)
    - Former (2014) **SDB** results
    - Former **Mexican** charts collected in 2014 (NGA-NOAA)
    - Former **ARGANS** chart produced in 2014
- References of 2019 :
    - New SDB model : "MergeV2_60TM_Op3"
    - List of used Sentinel-2 images
- References of 2019: existing official charts

1.4.1 Project Data files

The Project data files listed at the annex A, e.g. "MergeV2_6DTM_Opt3 ".

1.4.2 SDB references

- SDB model reference “MergeV2_6DTM_Opt3” obtained by selecting 6 Sentinel-2 images
- List of Sentinel-2 images used by this demonstrator.

1.4.3 Existing official charts’ and ENCs’ references

- the only ENC is: MX300922 - 1: 90 000 - Coastal - Mexico.

2. Hydro-Cartographic Qualification of Demonstrator

2.1. Objectives (WP: 2, 6, 8, 9, 10)

⇨ Provide internal feedback to the SDB Analysts and

⇨ after replay, produce a final DTM and the associated ZOC information required to complete the Proposal’s charting. WPs.

2.2. Cartographic Qualification by comparison against ENCs

Method:

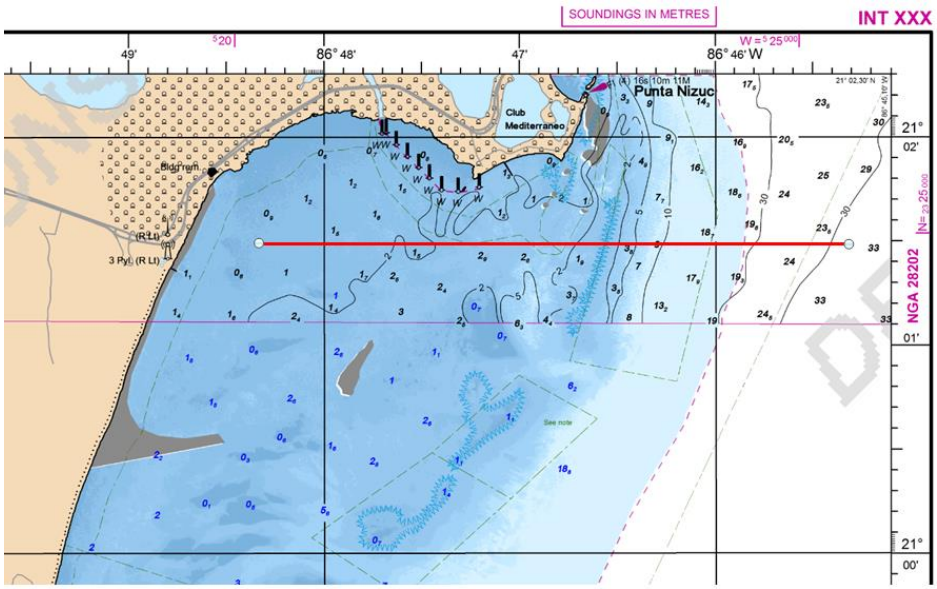
- Qualification was at first due to be only based on comparison with ENC MX300922 but there was not enough information because of this chart scale. It was then decided to use also the test chart produced with great care by ARGANS in 2014 (Puerto Morelos11). This early test chart already included the 1: 10 000 US survey exploited by the NGA chart No 28202 22nd edition of July 25, 1998, scale 1: 30 000

Limits of the method:

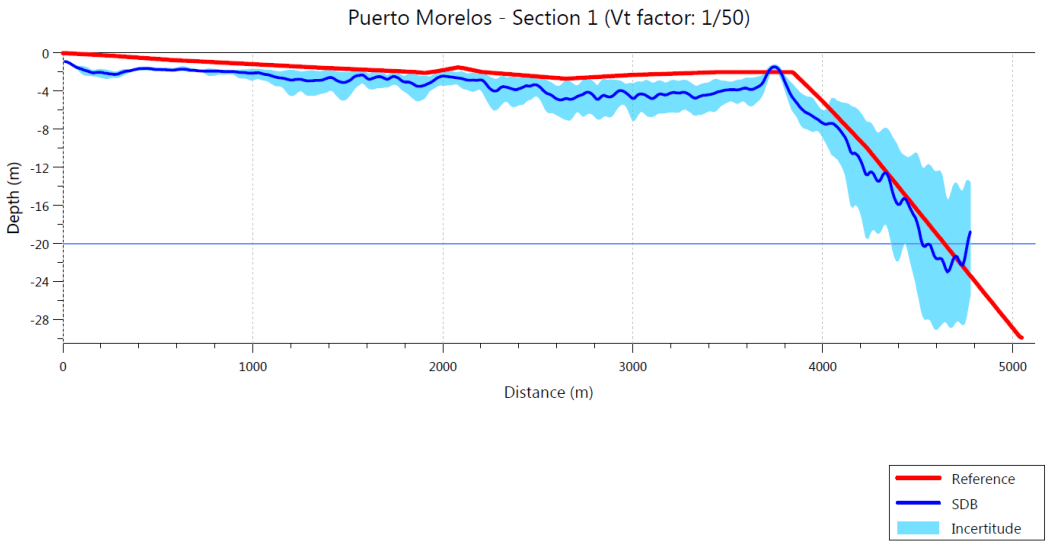
- Not as complete as a true comparison with raw survey data available on fair sheets;
- US survey covers only a small part of the demonstrator;
- ENC is at scale 1: 90 000. Contour lines are generalized accordingly and smoothed toward high sea.

Results: comparison with Puerto Morelos11 and NGA chart cross sections

Cross section (red line L= 21° 01’ 30’’ North, located inside the US MBES survey):

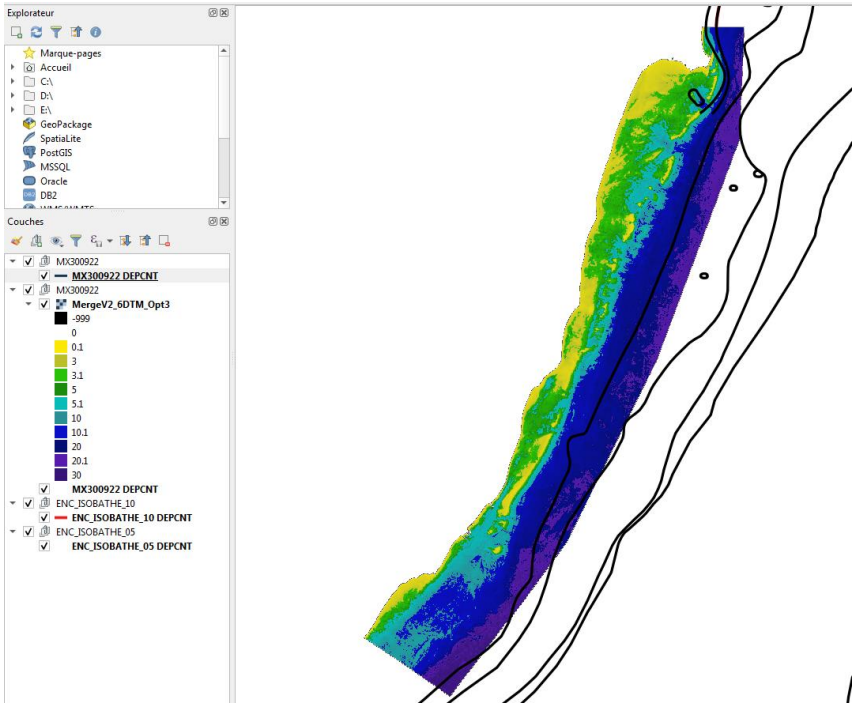


- Red line: reference = **Puerto Morelos11** (intersection with contour lines and some points interpolated from nearby soundings). The MX (Mexico) ENC precision is as follows: Horizontal = +/- 50 m - Vertical : +:- 1 m
- Solid blue line : SDB (V2)
- Light blue fuzz: model error-bars

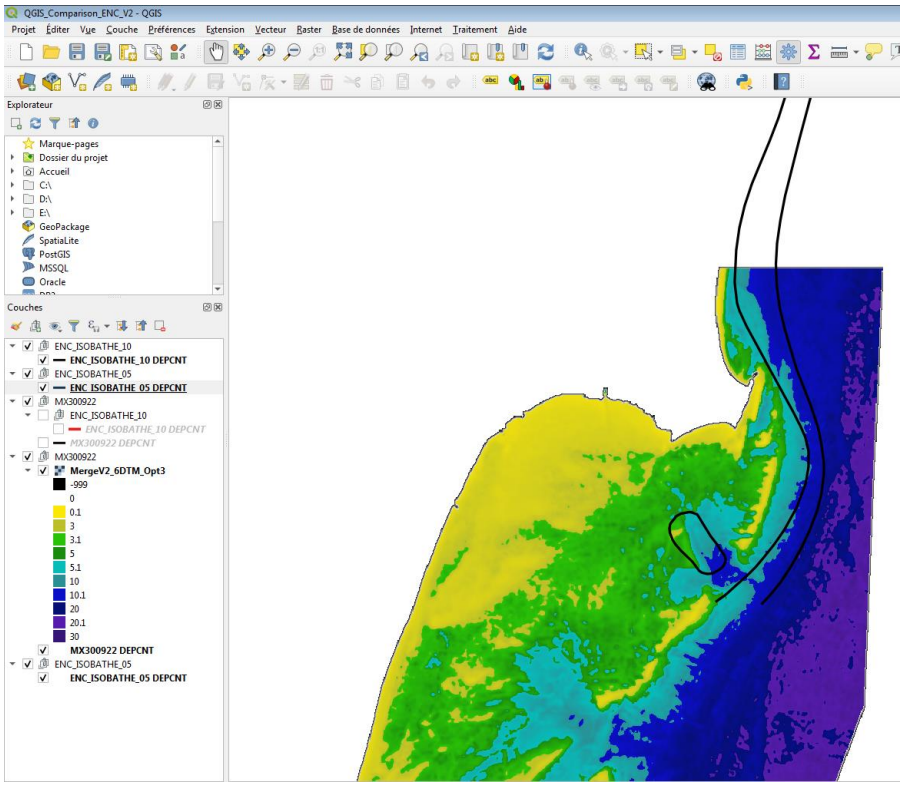


Results: comparison with ENC MX300922 (QGIS)

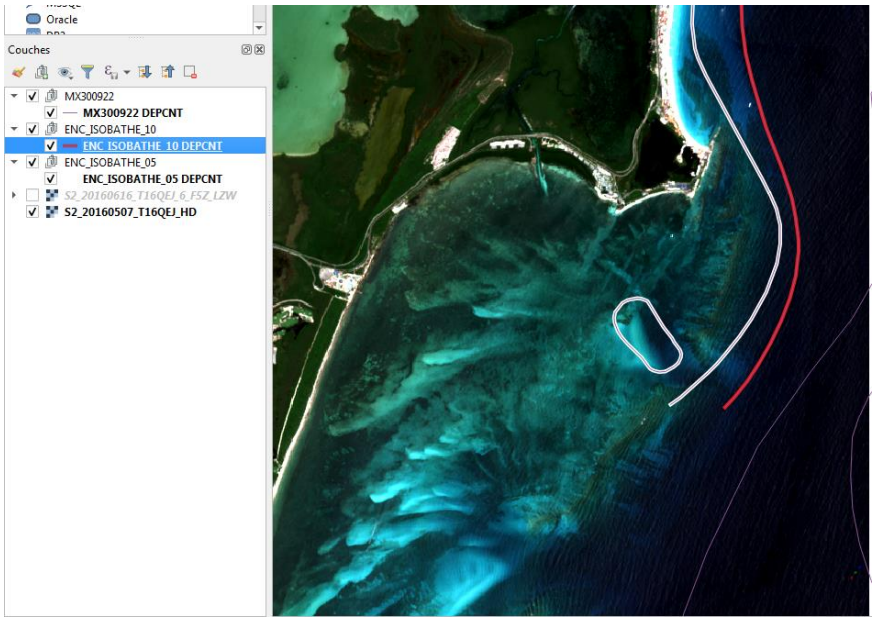
Nota: 5m and 10 m ENC contour lines are only available in the northern part


Explorateur
Marque-pages
Accueil
C:\
D:\
E:\
GeoPackage
SpatiaLite
PostGIS
MSSQL
Oracle
DB2
Couches
MX300922
MX300922 DEPCNT
MX300922
MergeV2_6DTM_Opt3
-999
0
0.1
3
3.1
5
5.1
10
10.1
20
20.1
30
MX300922 DEPCNT
ENC_ISOBATHE_10
ENC_ISOBATHE_10 DEPCNT
ENC_ISOBATHE_05
ENC_ISOBATHE_05 DEPCNT

SDB V2 / ENC


QGIS_Comparison_ENC_V2 - QGIS
Projet Éditer Vue Couche Préférences Extension Vecteur Raster Base de données Internet Traitement Aide
Explorateur
Marque-pages
Dossier du projet
Accueil
C:\
D:\
E:\
GeoPackage
SpatiaLite
PostGIS
MSSQL
Oracle
Couches
ENC_ISOBATHE_10
ENC_ISOBATHE_10 DEPCNT
ENC_ISOBATHE_05
ENC_ISOBATHE_05 DEPCNT
MX300922
ENC_ISOBATHE_10
ENC_ISOBATHE_10 DEPCNT
MX300922 DEPCNT
MX300922
MergeV2_6DTM_Opt3
-999
0
0.1
3
3.1
5
5.1
10
10.1
20
20.1
30
MX300922 DEPCNT
ENC_ISOBATHE_05
ENC_ISOBATHE_05 DEPCNT

5 m and 10 m contour lines (ENC)



Comparison Sentinel 2 / ENC contours in white / red)

Results:

- Pretty good up to 5 m
- Good enough down to 10 m in some places but comparison may not be relevant for limits explained above especially on the reef steep Eastern drop-off.

2.3. Comparison between Kompsat (2014) and Sentinel 2 (2019)

Objectives:

Make a comparison between the 2014 KOMPSAT DTM and the 2009 Sentinel-2 DTM to prove the Sentinel-2 suitability.

Inputs are :

- for 2014 : the DTM of that year
- for 2019 : the final version that has been exploited for charting: : « Merge_V2_6DTM_Opt3 »

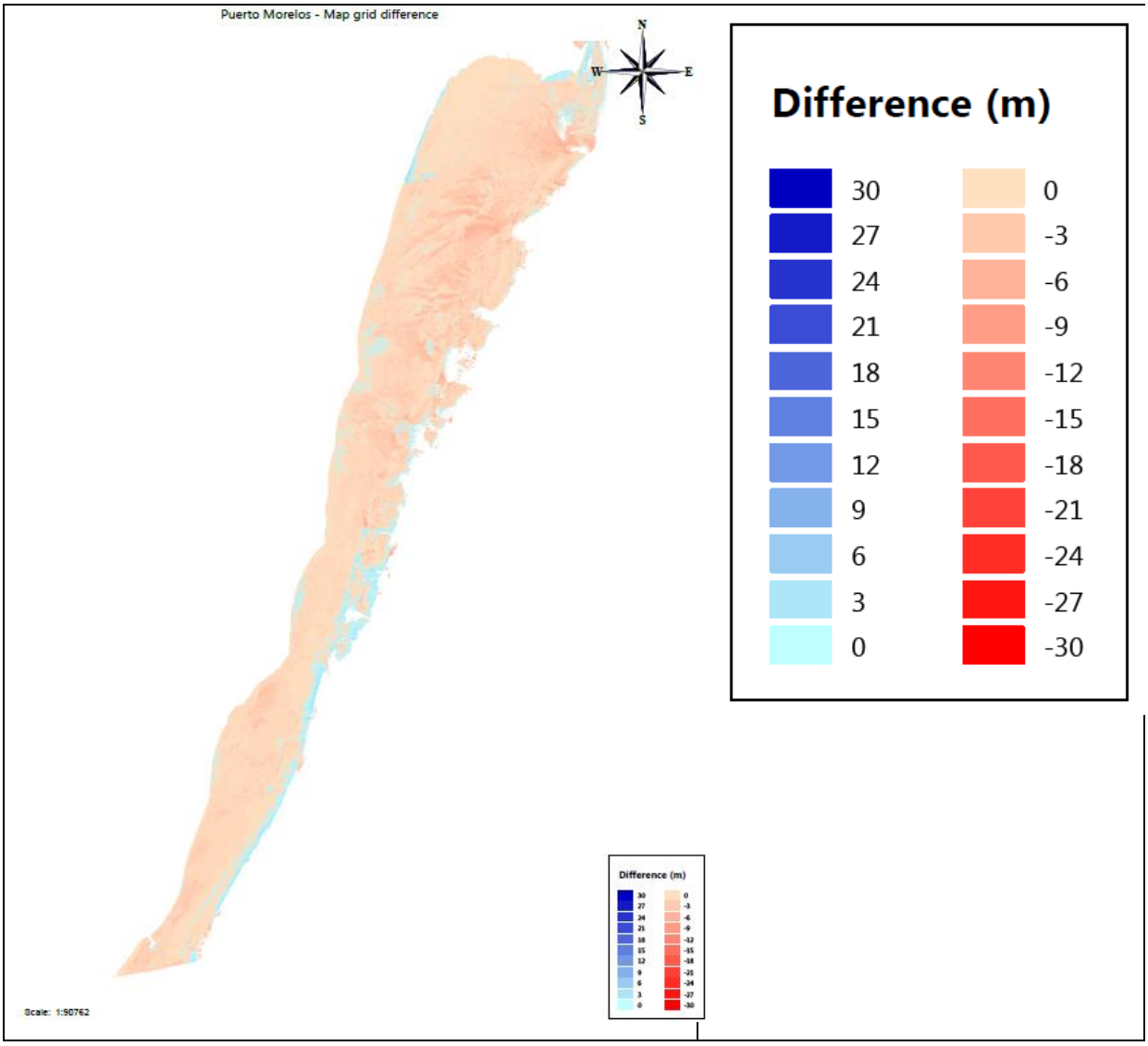
It must be acknowledged that there are no other references such as fair sheets to consolidate the study. There are only soundings coming from a chart (US) in the northern part that have already been exploited during the qualification (see previous paragraph).

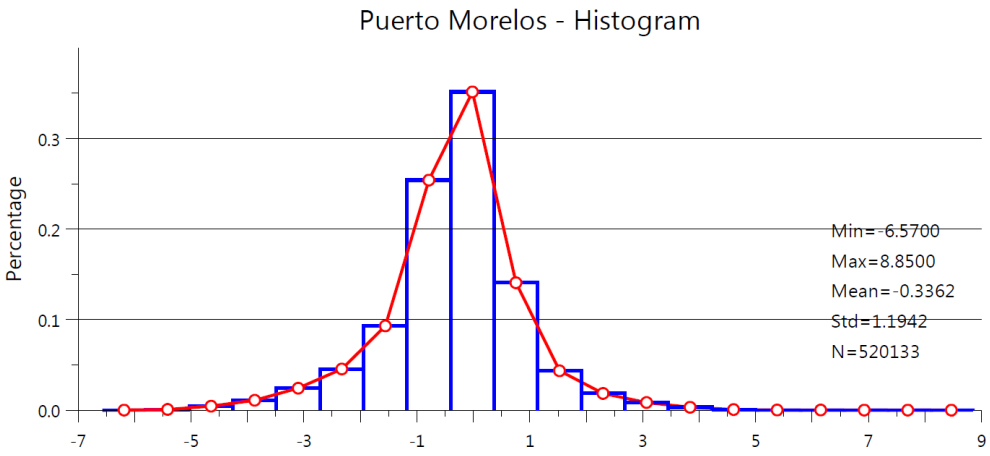
Results

A difference model 2014 – 2019 has been done

- 2019 : MergeV2_6DTM_Opt3_b1 (resolution : 10 m)
- 2014 : 2014 yuc_ksU6_all_zpl_pair6_dist_Z_5M_mean3x3_b1 (0.5 m KOMPSAT resolution averaged to 10 m)

Results for depths from 0 to 10 m:





Remarks – "conclusion": Sen-2 images are just as good as VHR Kompsat to determine depths.

- on average, differences are within 0.3 m
- Differences of up to 1 metre can be found where there are large model uncertainties , especially in area where depth gradients are steep)

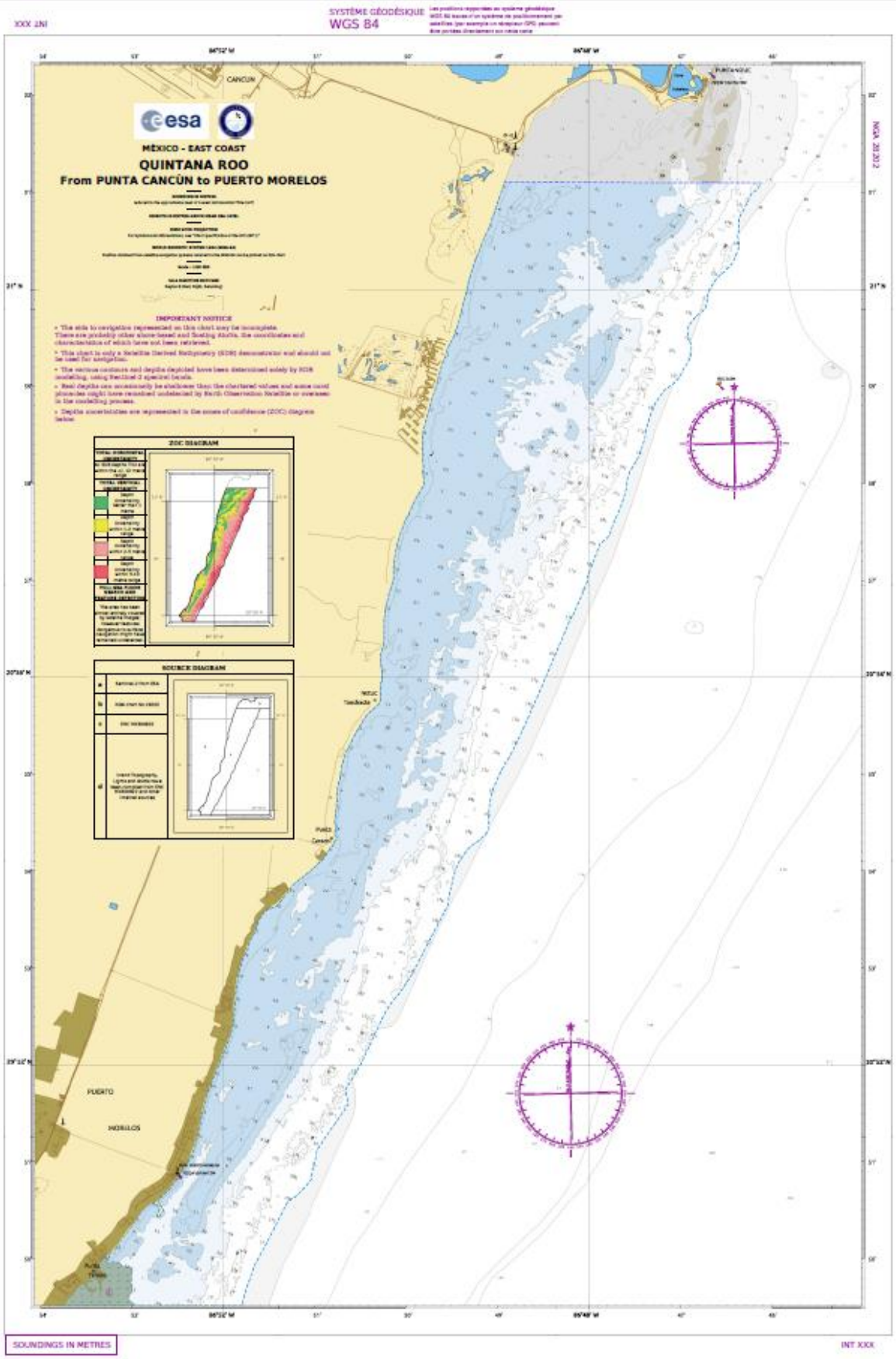
3. Production of the SDB Demonstrator

3.1. Objectives (WP: 6, 8)

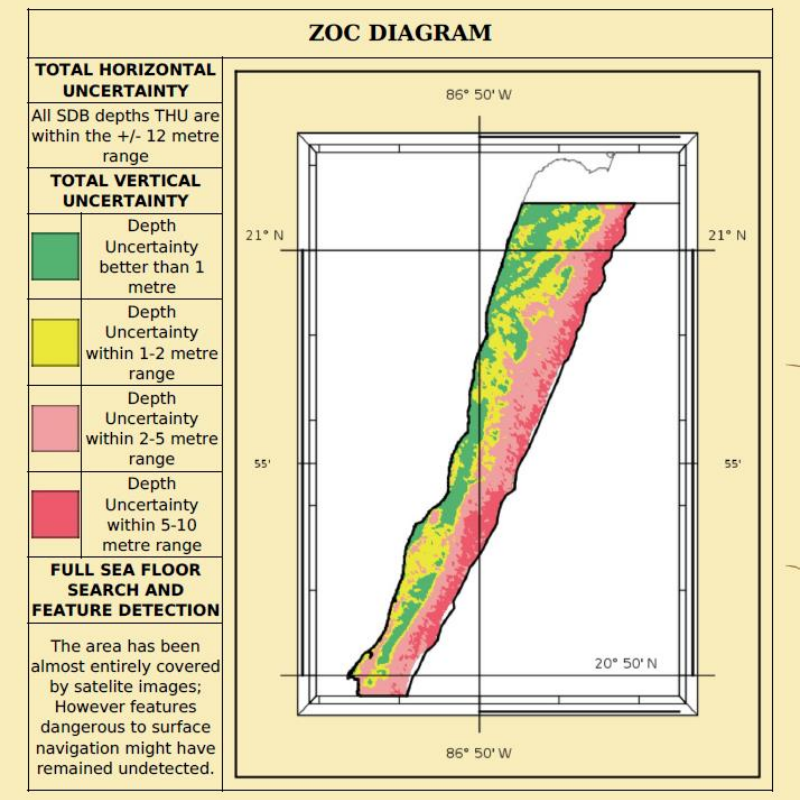
⇨ Produce a high-quality paper chart proving the compatibility between the IHO S-4 standards and the SDB model outputs.

⇨ Adapt the diagram of sources and ZOC to cater for SDB

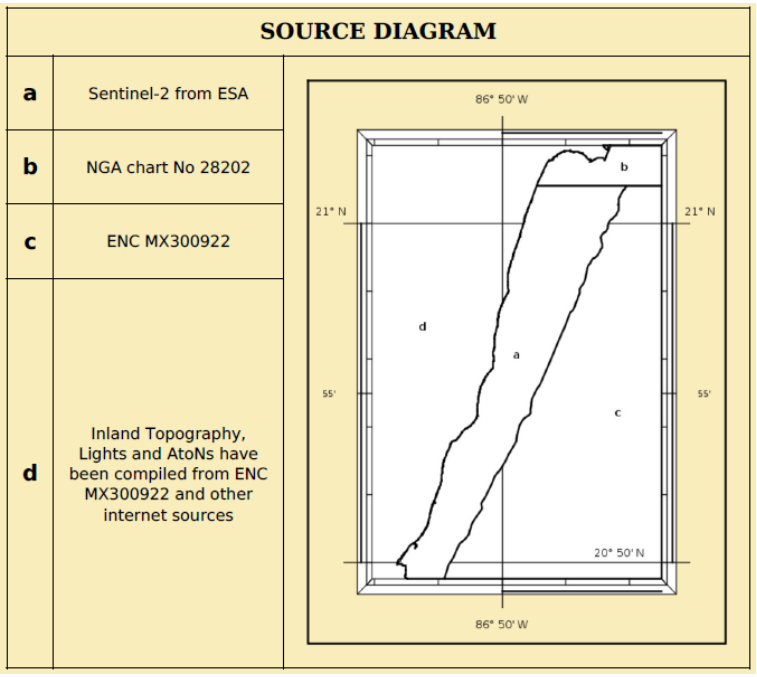
3.2. Demonstrator : "PuertoMorelos_2019-08-16"


SYSTÈME GÉODÉSIQUE
WGS 84
CANCUN
esa
MÉXICO - EAST COAST
QUINTANA ROO
From PUNTA CANCÚN to PUERTO MOROLOS
IMPORTANT NOTICE
ZOC DIAGRAM
SOURCE DIAGRAM
PUERTO
MORELOS
SOUNDINGS IN METRES
INT XXX

ZOC :



Source diagram



4. Deliverables

Object	File's name
DTM	MergeV2_6DTM_Opt3
Chart in "pdf" format (Adobe Acrobat Document)	PuertoMorelos_2019-08-16
Chart in "GeoTiff" format (Image TIFF)	PuertoMorelos_2019-08-16

APPENDIX – PUERTO MORELOS – MEXICO

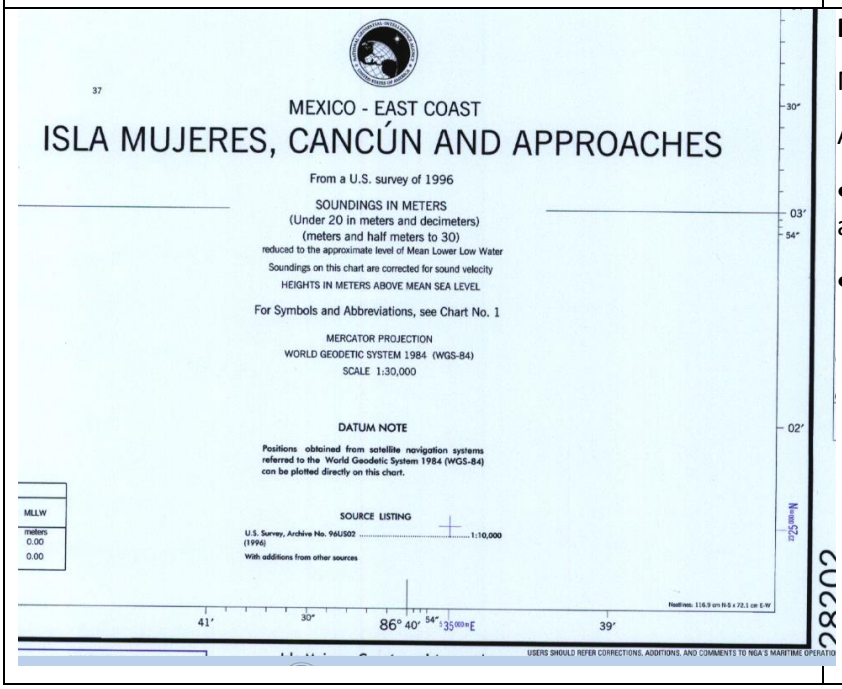
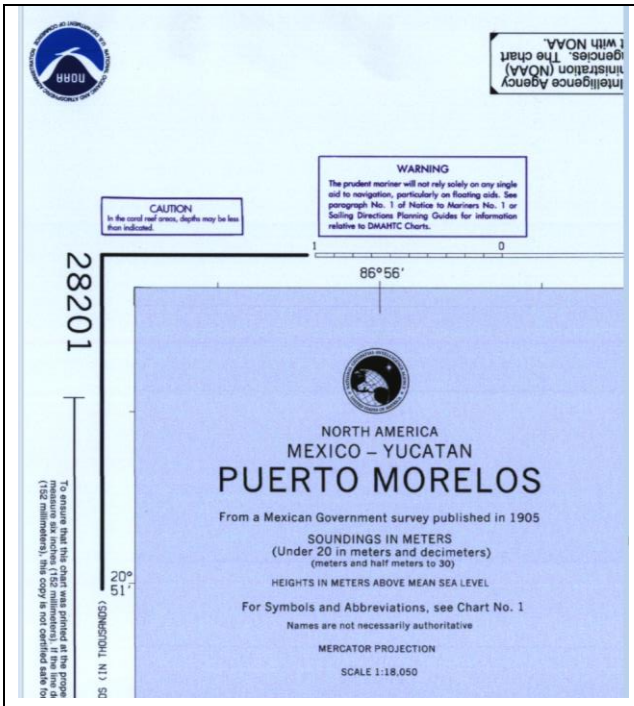
APPENDIX-1: References of 2014

APPENDIX-1_A: list of references of 2014: SDB and chart based on KOMPSAT images

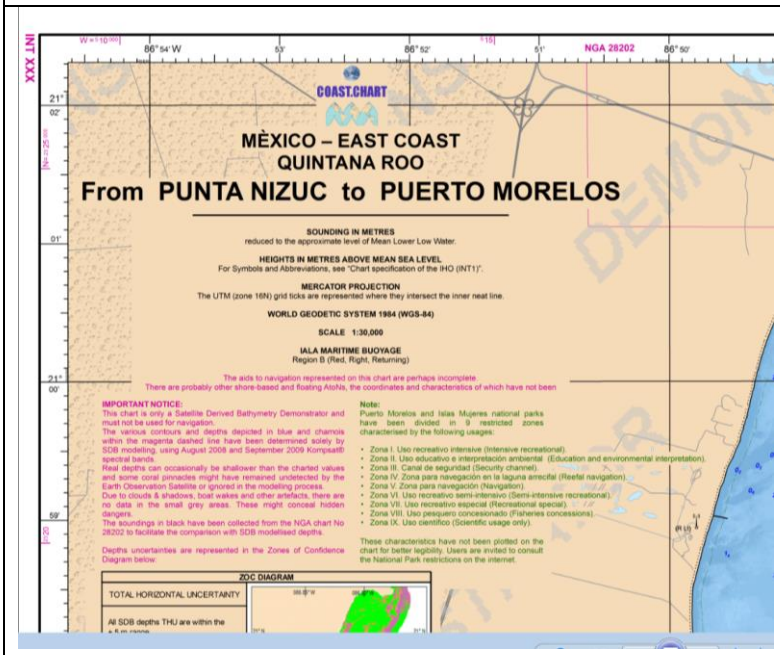
These references are those collected the Pierre Mouscardes' disk.

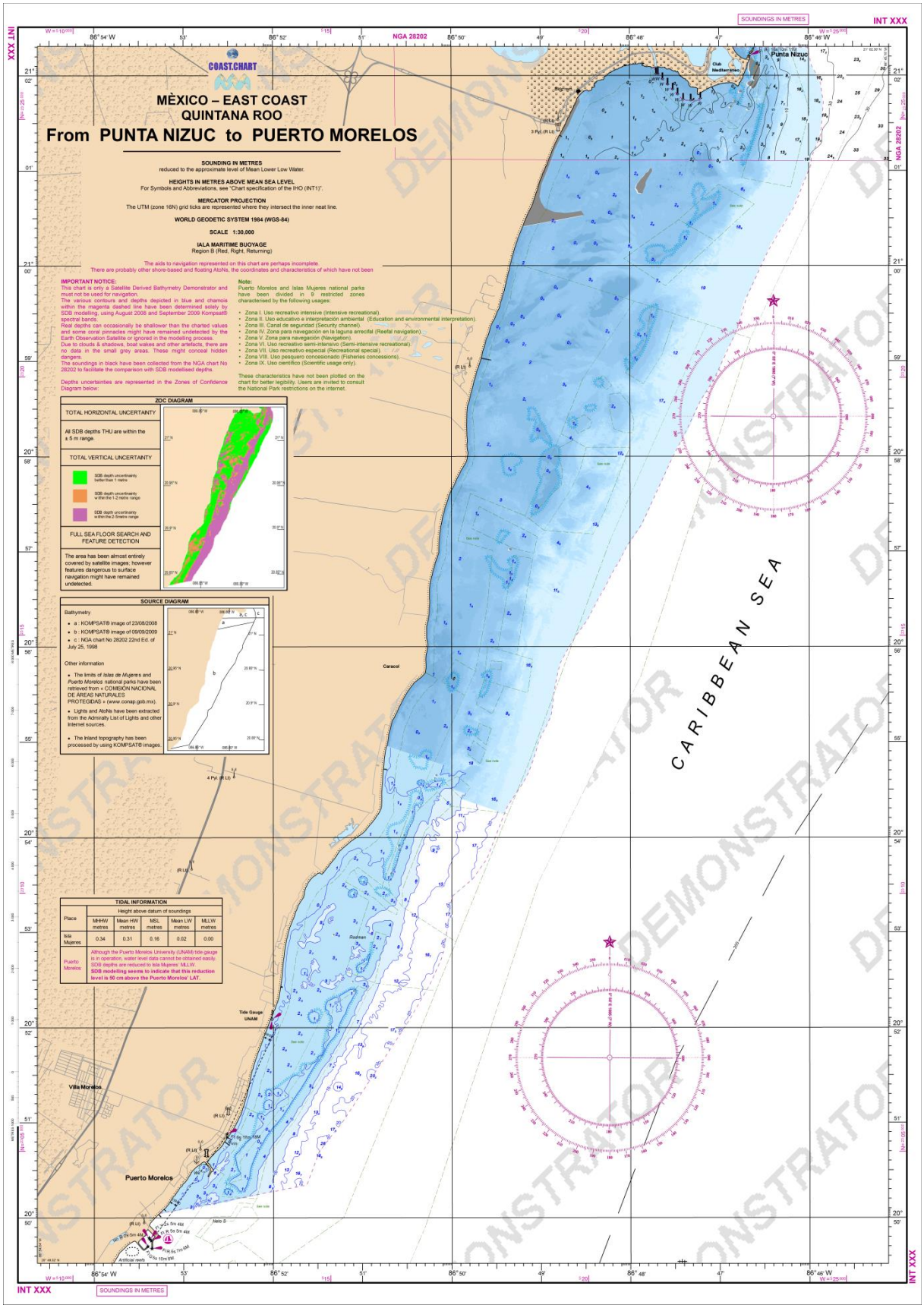
Objet	Directory	Files
• Former (2014) **Kompsat** image	ESA_Puerto Morelos_REF_2014_DTM_ARGANS_JH	○ « **yuc_200X_ks2_gc.tif »** (Kompsat image)
• Former (2014) **SDB** results (DTM: John Hedley)	ESA_Puerto Morelos_REF_2014_DTM_ARGANS_JH	○ "**yuc_ksU6_all_zpl_pair6_dist_Z_5M_mean3x3.tif"** (2014 SDB model) ○ "**yuc_ksU6_all_zpl_pair6_dist_Z_5M_unc_mean3x3"** (Incertitude of 2014)
• Former **Mexican** charts collected in 2014 (see Annex – NGA-NOAA)	ESA_Puerto Morelos_REF_2014_Charts_NOAA	Mainly: ○ **"ArgansLtd chart1_zone-utile_georef.tif"** ○ **"ArgansLtd chart2-1_georef.tif"**
• Former **ARGANS** chart produced in 2014 (see Annex)	ESA_Puerto Morelos_REF_2014_DTM_ARGANS_JH	○ First version: **"Puerto Morelos"** ○ Last version: **"Puerto Morelos11"** ○ Last version georeferenced by Valentin: so to be given by Valentin) **"Puerto Morelos11_Geo"**

APPENDIX-1_B: Reference of charts (2014) from NGA - NOAA (origine: Pierre Mouscardès's disk)

Chart reference	File
	**Repertory:** ESA_Puerto Morelos_REF_2014_Charts_NOAA • "ArgansLtd chart1" and • "ArgansLtd chart1_zone-utile"
	**Repertory:** ESA_Puerto Morelos_REF_2014_Charts_NOAA • "ArgansLtd chart2" and • "ArgansLtd chart2-1" And ArgansLtd chart2-1_georef

APPENDIX-1_C: Reference of chart (2014) from ARGANS (source: Pierre Mouscardès ')

Chart reference	File
	**Repertory:** ESA_Puerto Morelos_REF_2014_Chart_ARGANS • "Puerto Morelos" and • "Puerto Morelos11" (final version" • « *cahier des charges simplifié pour la cartographie_PIERRE* »

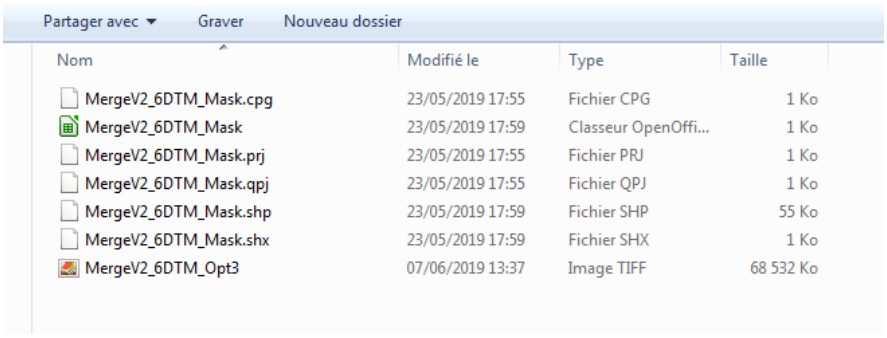

COAST.CHART
MÈXICO – EAST COAST
QUINTANA ROO
From PUNTA NIZUC to PUERTO MORELOS
SOUNDING IN METRES
reduced to the approximate level of Mean Lower Low Water.
HEIGHTS IN METRES ABOVE MEAN SEA LEVEL
For Symbols and Abbreviations, see "Chart specification of the IHO (INT1)".
MERCATOR PROJECTION
The UTM (zone 16N) grid ticks are represented where they intersect the inner neat line.
WORLD GEODETIC SYSTEM 1984 (WGS-84)
SCALE 1:30,000
IALA MARITIME BUOYAGE
Region B (Red, Right, Returning)
The aids to navigation represented on this chart are perhaps incomplete.
There are probably other shore-based and floating AtoNs, the coordinates and characteristics of which have not been
IMPORTANT NOTICE:
This chart is only a Satellite Derived Bathymetry Demonstrator and must not be used for navigation.
The various contours and depths depicted in blue and chamois within the magenta dashed line have been determined solely by SDB modelling, using August 2008 and September 2009 Kompsat® spectral bands.
Real depths can occasionally be shallower than the charted values and some coral pinnacles might have remained undetected by the Earth Observation Satellite or ignored in the modelling process.
Due to clouds & shadows, boat wakes and other artefacts, there are no data in the small grey areas. These might conceal hidden dangers.
The soundings in black have been collected from the NGA chart No 28202 to facilitate the comparison with SDB modelised depths.
Depths uncertainties are represented in the Zones of Confidence Diagram below:
Note:
Puerto Morelos and Islas Mujeres national parks have been divided in 9 restricted zones characterised by the following usages:
Zona I. Uso recreativo intensivo (Intensive recreational).
Zona II. Uso educativo e interpretación ambiental (Education and environmental interpretation).
Zona III. Canal de seguridad (Security channel).
Zona IV. Zona para navegación en la laguna arrecifal (Reefal navigation).
Zona V. Zona para navegación (Navigation).
Zona VI. Uso recreativo semi-intensivo (Semi-intensive recreational).
Zona VII. Uso recreativo especial (Recreational special).
Zona VIII. Uso pesquero concesionado (Fisheries concessions).
Zona IX. Uso científico (Scientific usage only).
These characteristics have not been plotted on the chart for better legibility. Users are invited to consult the National Park restrictions on the internet.
ZOC DIAGRAM
TOTAL HORIZONTAL UNCERTAINTY
All SDB depths THU are within the ± 5 m range.
TOTAL VERTICAL UNCERTAINTY
SDB depth uncertainty better than 1 metre
SDB depth uncertainty within the 1-2 metre range
SDB depth uncertainty within the 2-5 metre range
FULL SEA FLOOR SEARCH AND FEATURE DETECTION
The area has been almost entirely covered by satellite images, however features dangerous to surface navigation might have remained undetected.
SOURCE DIAGRAM
Bathymetry
a : KOMPSAT® image of 23/08/2008
b : KOMPSAT® image of 09/09/2009
c : NGA chart No 28202 22nd Ed. of July 25, 1998
Other information
The limits of Islas de Mujeres and Puerto Morelos national parks have been retrieved from « COMISION NACIONAL DE ÁREAS NATURALES PROTEGIDAS » (www.conap.gob.mx).
Lights and AtoNs have been extracted from the Admiralty List of Lights and other Internet sources.
The Inland topography has been processed by using KOMPSAT® images.
TIDAL INFORMATION
Height above datum of soundings
Place
MHHW metres
Mean HW metres
MSL metres
Mean LW metres
MLLW metres
Isla Mujeres
0.34
0.31
0.16
0.02
0.00
Puerto Morelos
Although the Puerto Morelos University (UNAM) tide gauge is in operation, water level data cannot be obtained easily. SDB depths are reduced to Isla Mujeres' MLLW. SDB modelling seems to indicate that this reduction level is 50 cm above the Puerto Morelos' LAT.
NGA 28202
Punta Nizuc
Club Mediterraneo
CARIBBEAN SEA
Caracol
Roatan
Tide Gauge UNAM
Villa Morelos
Puerto Morelos
Artificial reefs
INT XXX
SOUNDINGS IN METRES

APPENDIX-2: 2019 References

APPENDIX-2_A: 2019 References : SDB model – Sentinel-2 images

V2: References:

- WeTransfer: on 07 June 19 (from Valentin Schmitt)
- File :



This file has 3 bands, based on exchange format:

- Z-Avg : the depth
- Z-Min : the minimum depth
- Z-Max : the maximum depth

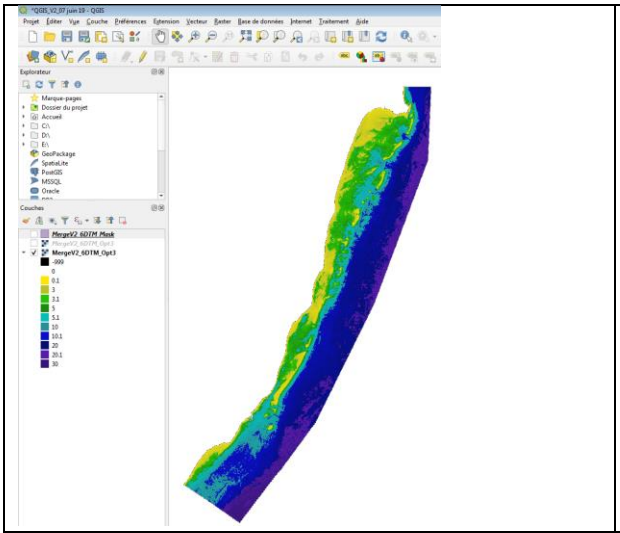
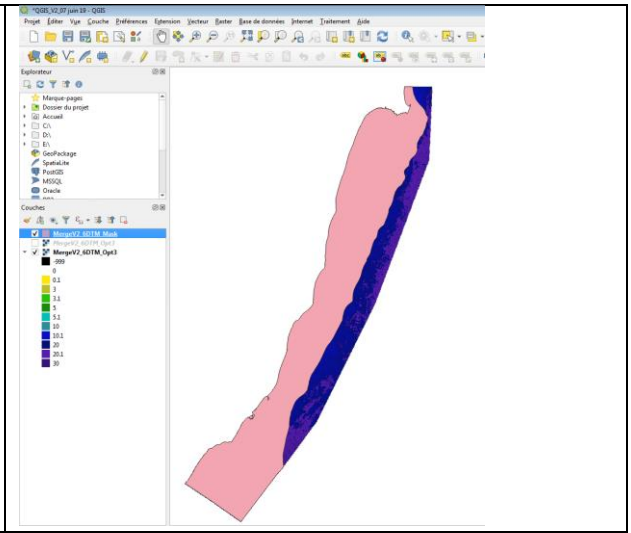
The folder contains:

MergeV2_6DTM_Opt3.tif: merged DTM included 6 different DTM.

The image list is:

- S2_20160507_T16QEJ
- S2_20160616_T16QEJ
- S2_20161223_T16QEJ
- S2_20171014_T16QEJ
- S2_20180914_T16QEJ
- S2_20190226_T16QEJ

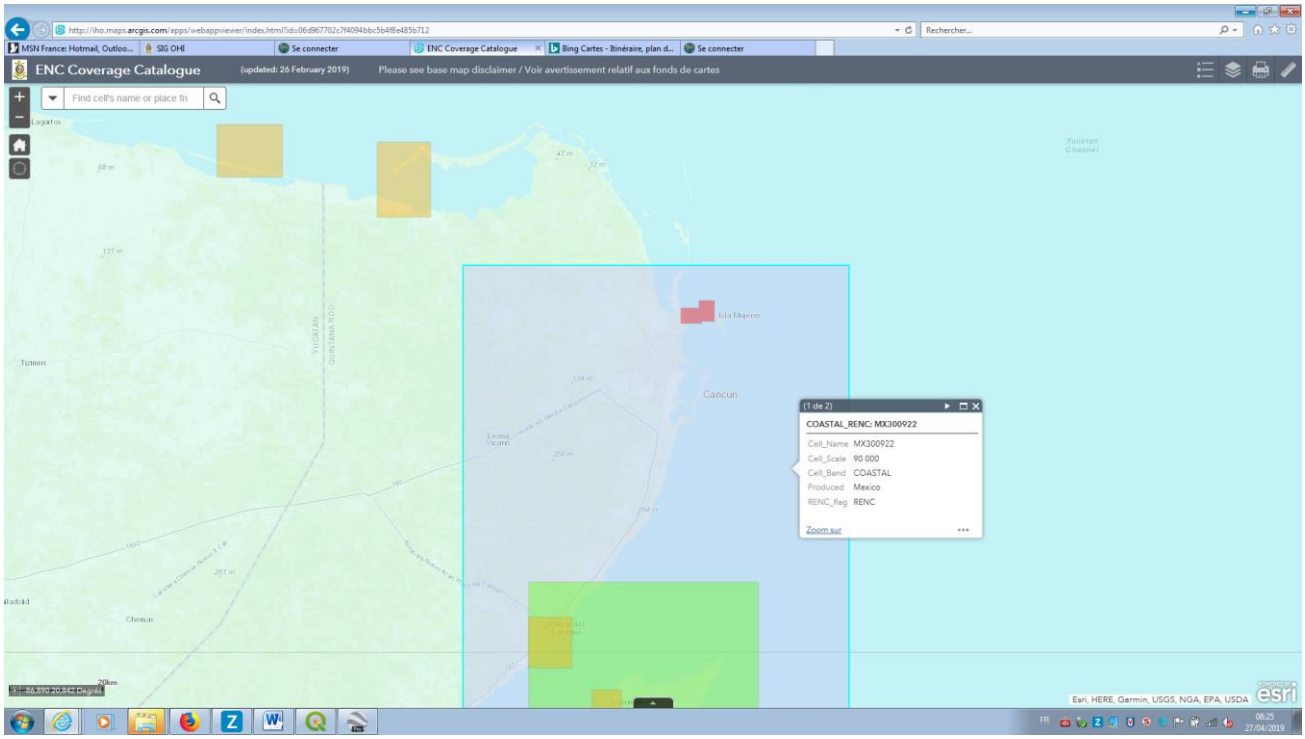
MergeV2_6DTM_Mask.shp: The mask highlighting the selected area.

	
Without mask	**With mask**

APPENDIX-2_B: 2019 Existing official charts: ENC MX300922

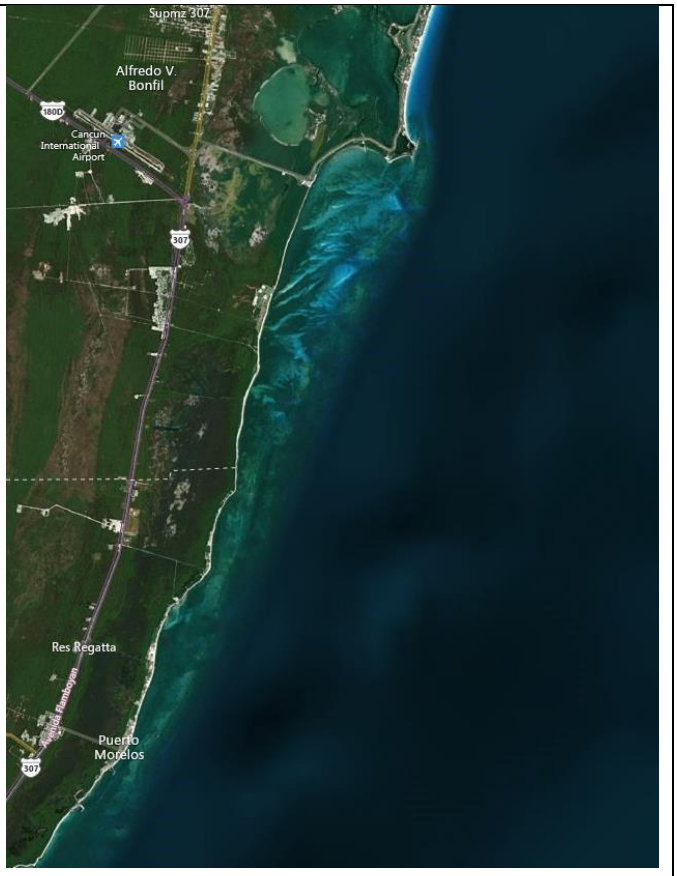
According to IHO and Primar catalogue the only ENC is: **MX300922 - 1: 90 000 - Coastal** - Mexico.

Note: scale **1: 90 000** to be compared to the chart to be done: **1: 30 000**



APPENDIX-2_C: Bing map – Google Earth (2019)

Bing Map



Bing Map