THE SATELLITE DERIVED CHART

(1983 – 2012)

Part 1

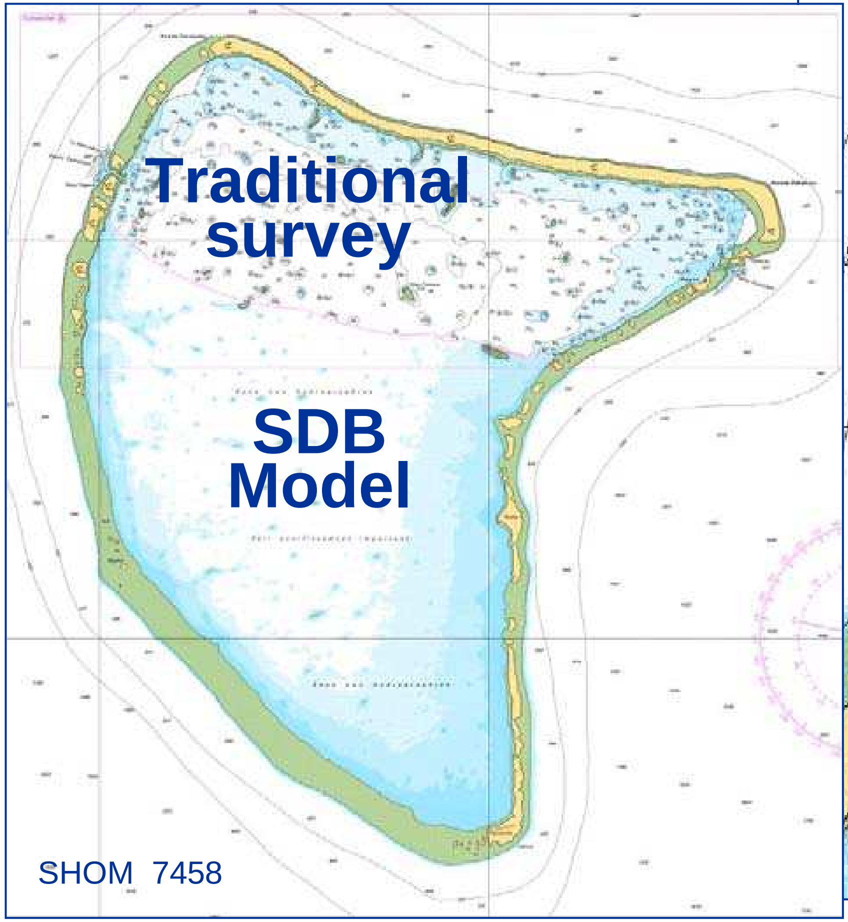
Revolution in Marine cartography: The impact of satellite

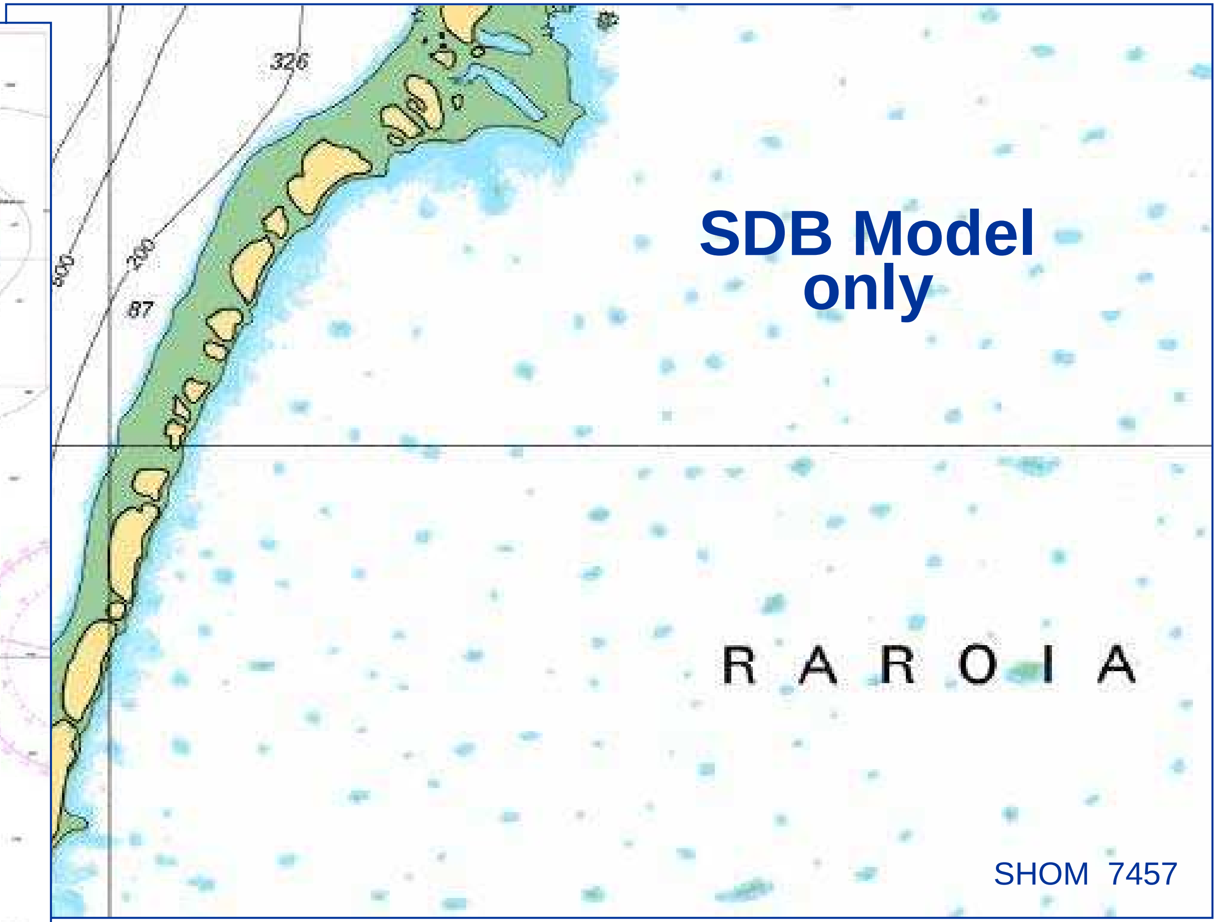
SDC/SHOM Timeline (an old story…)

1983 : Spot SDB simulation with a CASI radiometer in New Caledonia
1986 : First SPOT SDB test in the Uvea lagoon
1987 : First presentation of the SDC concept at the 13th IHC
1995 : First SDC publication in the French chart series
2004 : Evaluation of the ESA radar capacity (Coastchart project)
2006 : Termination of the Coastchart Project
2011 : Implementation of a S-57 catalogue of satellite derived objects
2012 : - 100th SDC publication in the French chart series
- Reassessment of radar capacity (TerraSAR-X) in West Africa

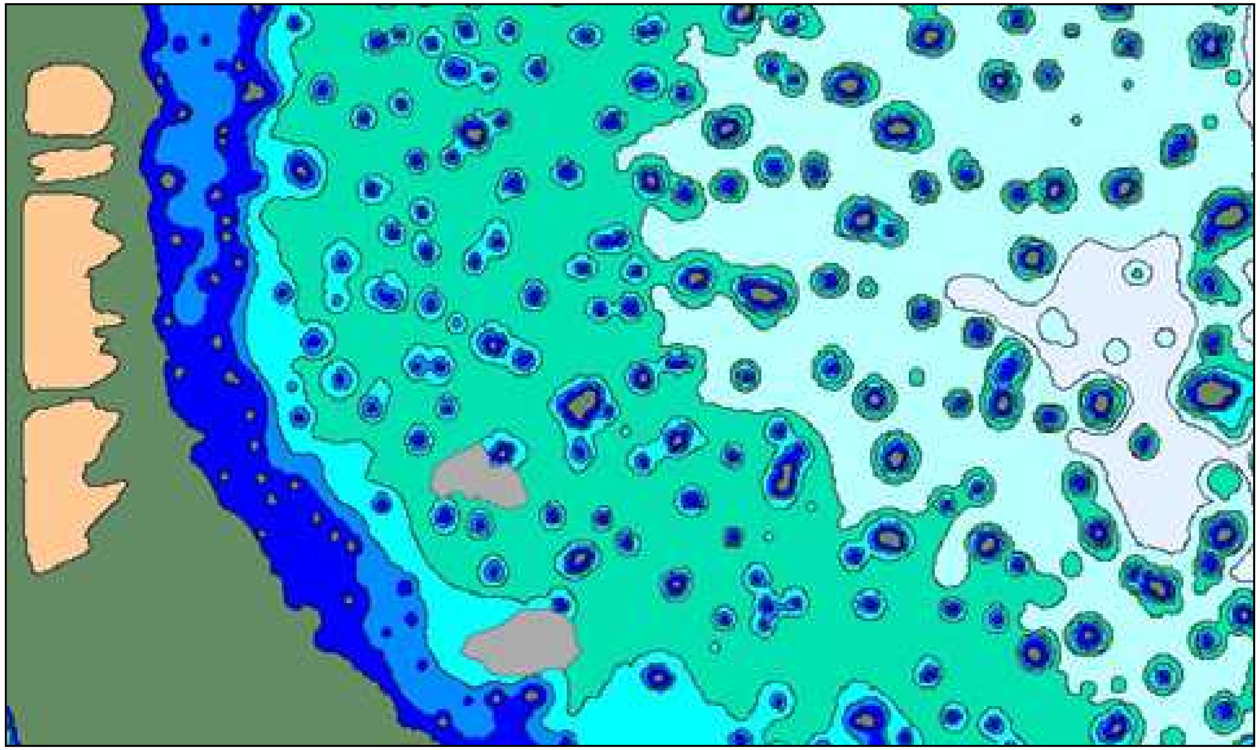
Oct 2011 : 1st SDB Seminar at UKHO
Mar 2012 : SHOM/UKHO/CSIRO discussions in Taunton
Sep 2012 : HSSC 4

As of today, SHOM has produced over 100 SDCs *("Spatiocartes")* supported by satellite field surveys, and conducted about 250 kinds of expertise to meet User's requirements…





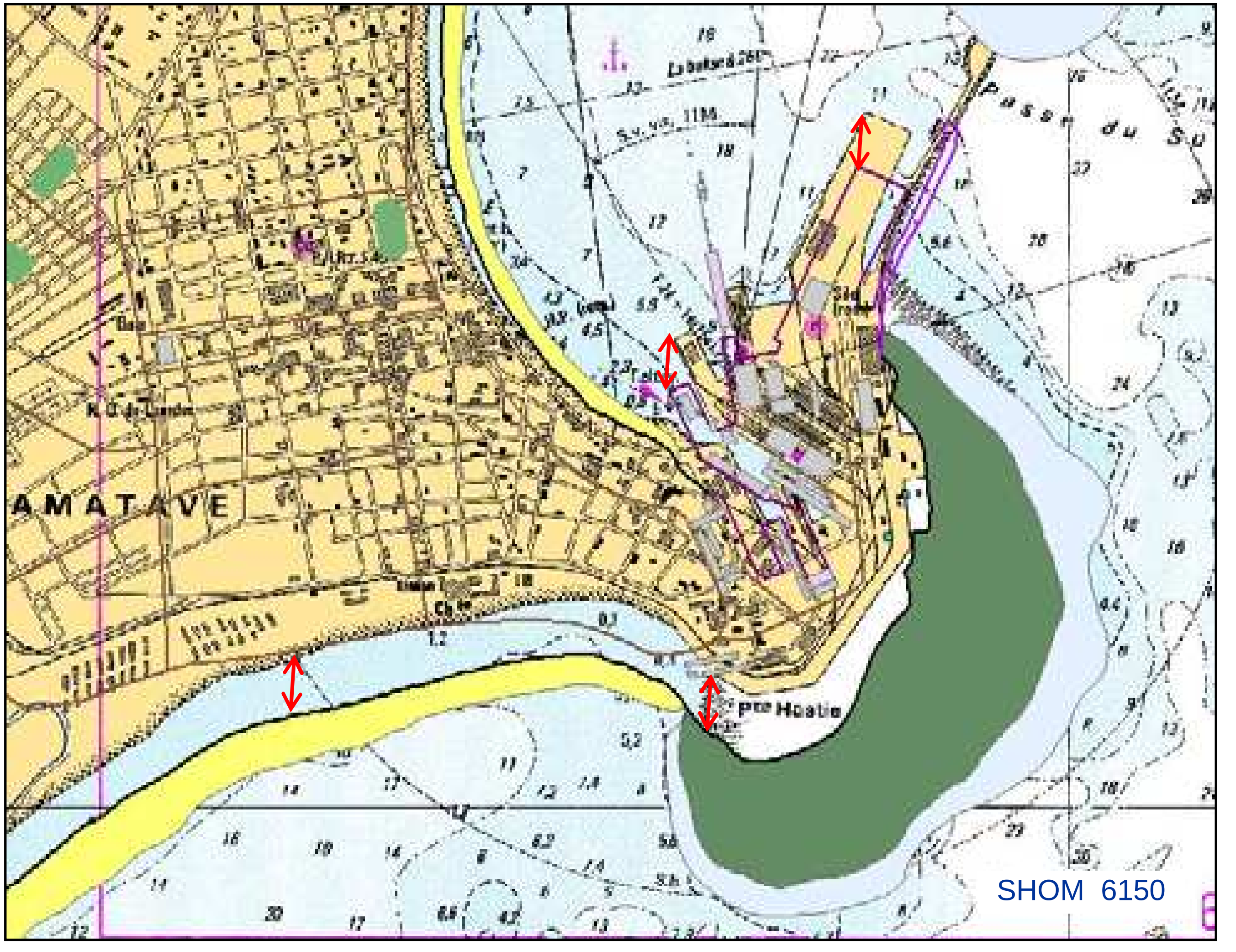
…covering a wide range of uses such as the Standard Product, a quality controlled SDC,



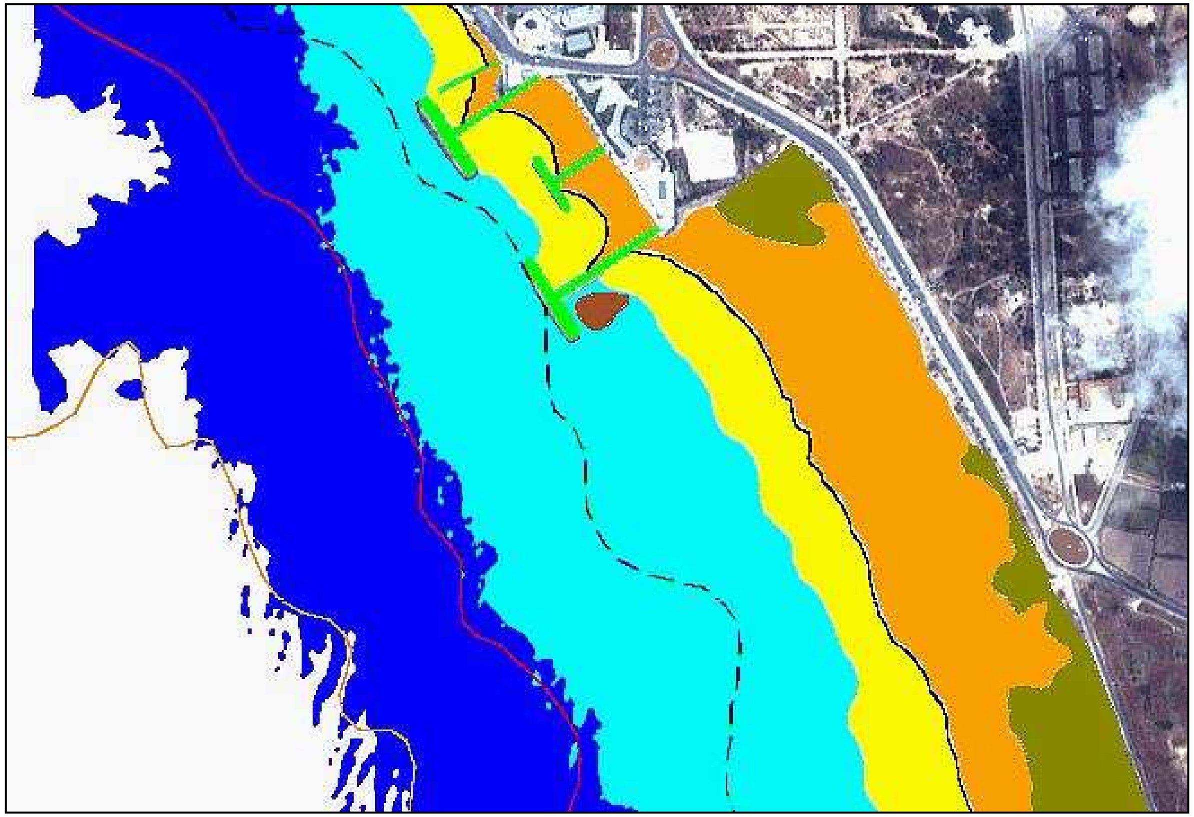
Tahanea atoll's GIS vector layer

...QC Chart updating,

50 years after the last survey, the new chart of Toamasina, Madagascar, will be rendered in WGS 84 and all discrepancies corrected

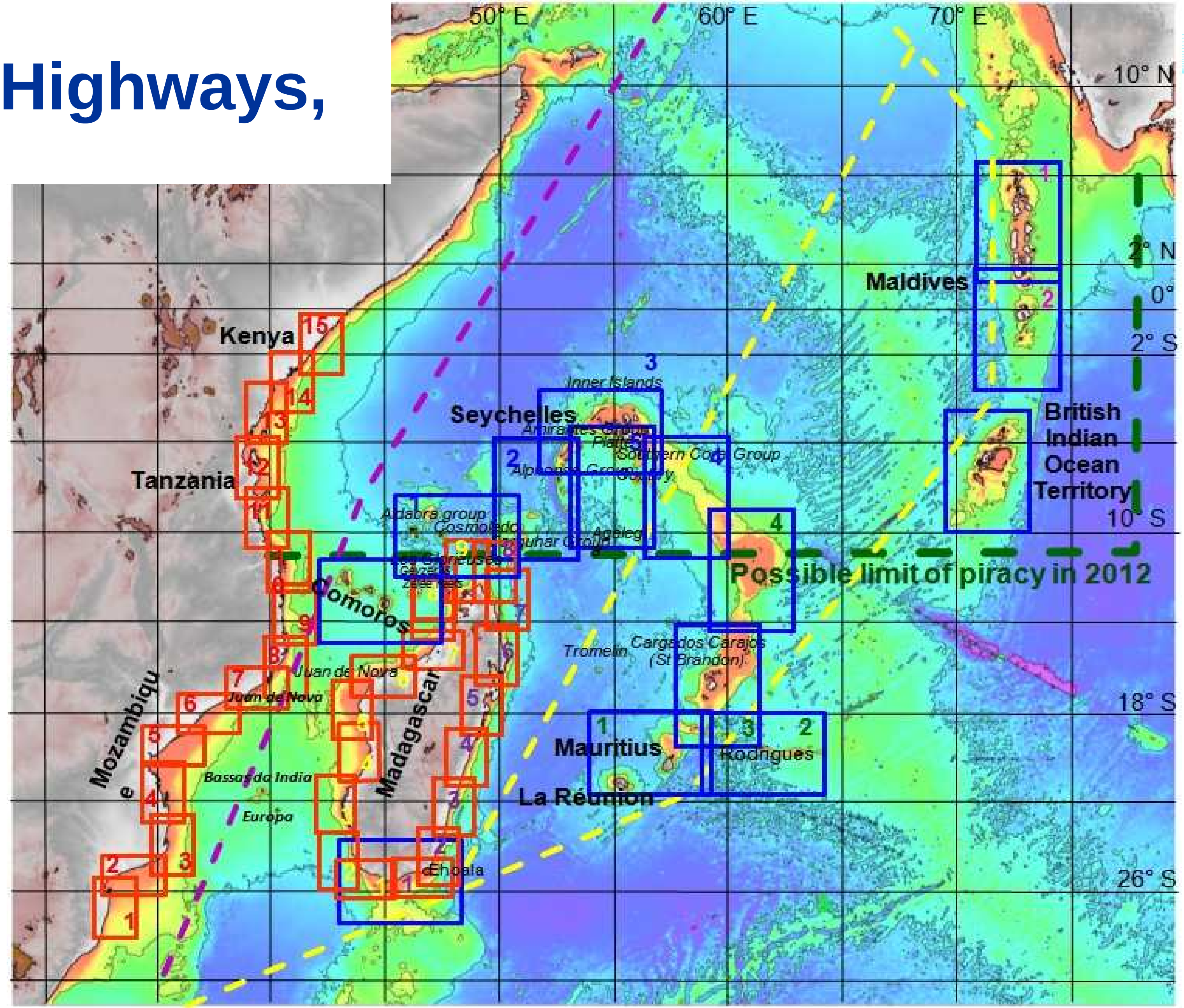


…Products of the Future: the S-100 digital SDC,



…Marine Highways,

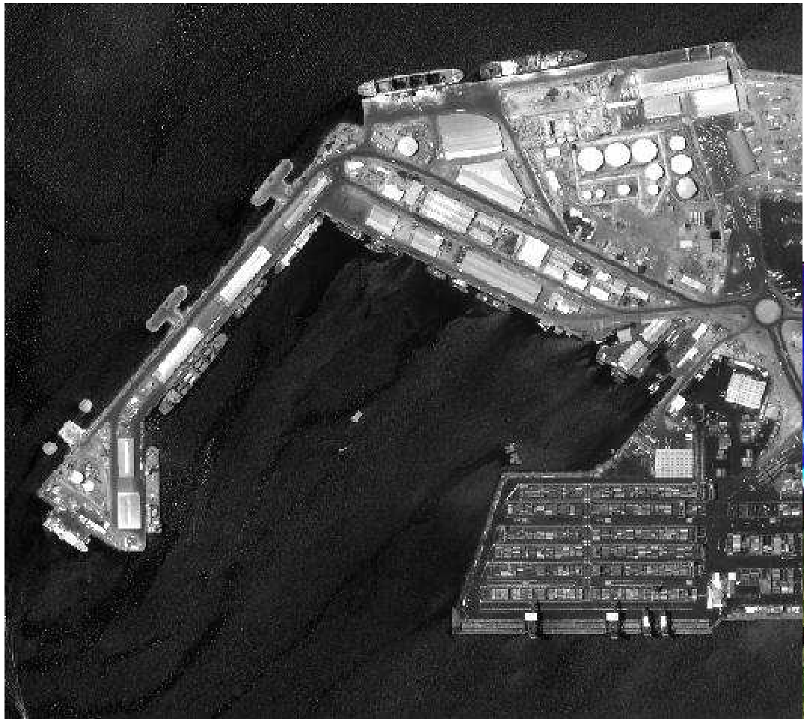
Production of SDCs ~~is~~ was considered by the World Bank for inclusion into the WIOMHP, Phase II



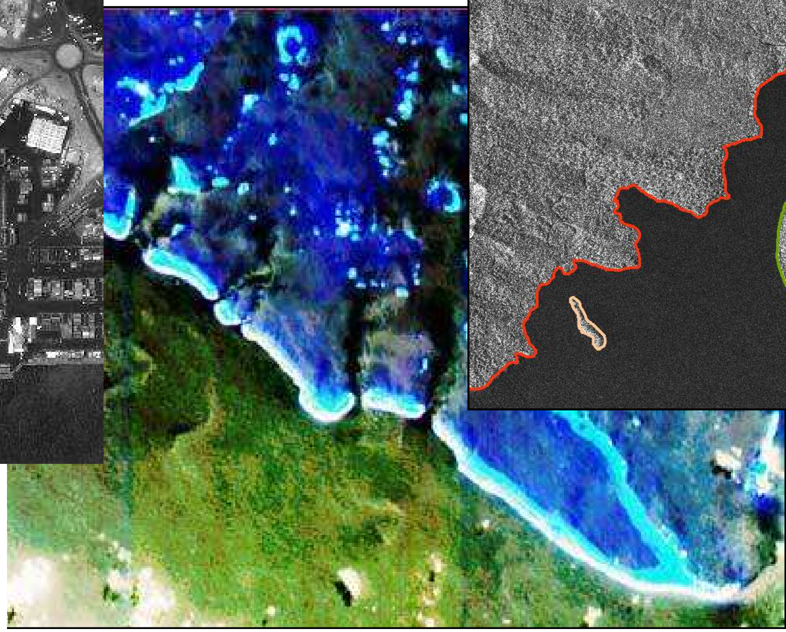
…Survey planning, etc.

Part 2
The seven steps of Quality Controlled Satellite Derived Bathymetry (SDB)

Step 1: Image selection

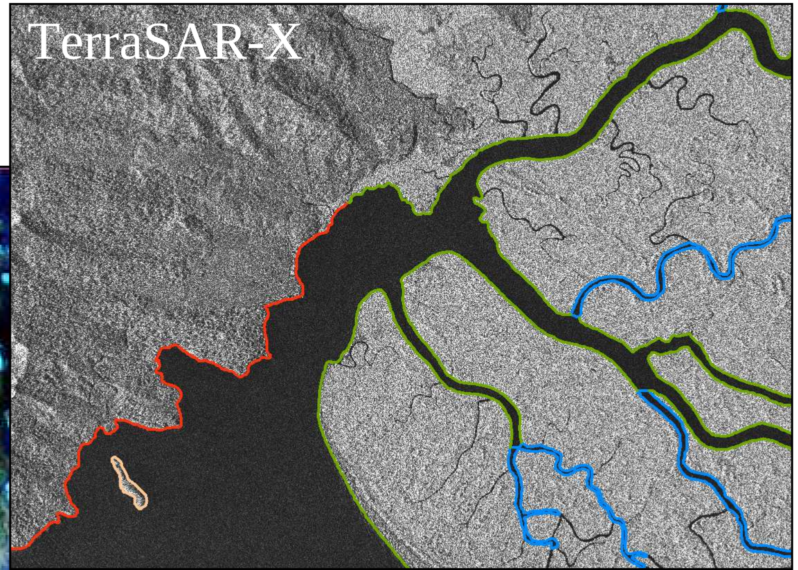


Panchromatic for high topographic definition

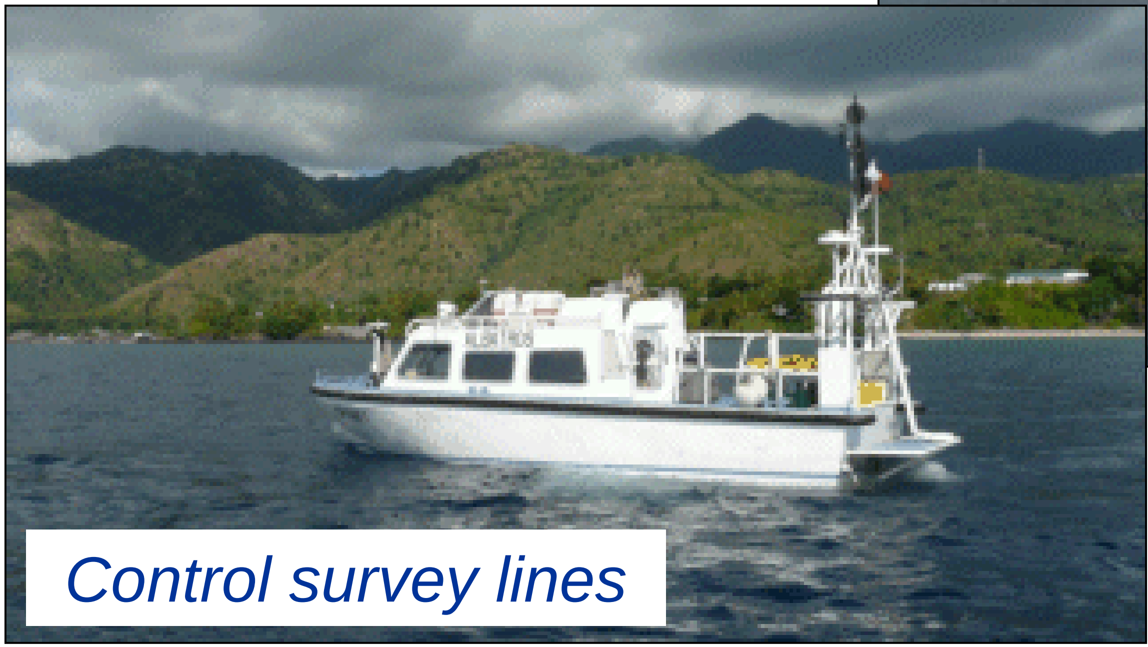


Blue, green & red channels for bathymetry and bottom structure

Radar to see through clouds



Step 2: Ground control

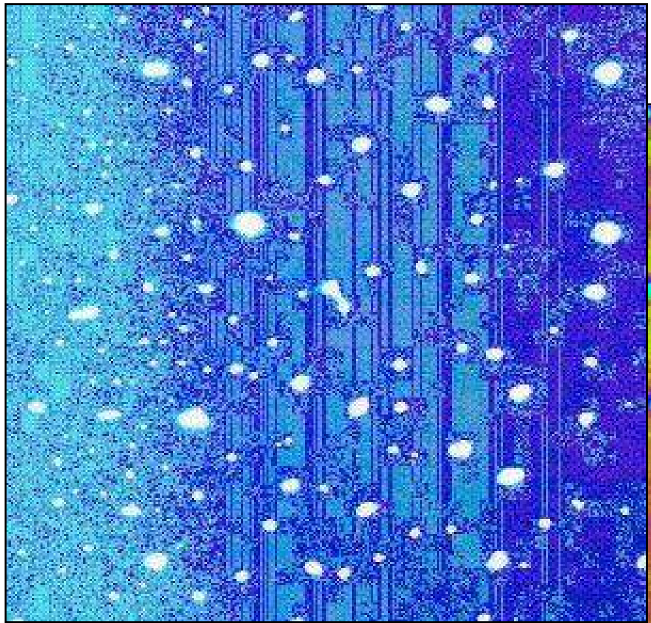


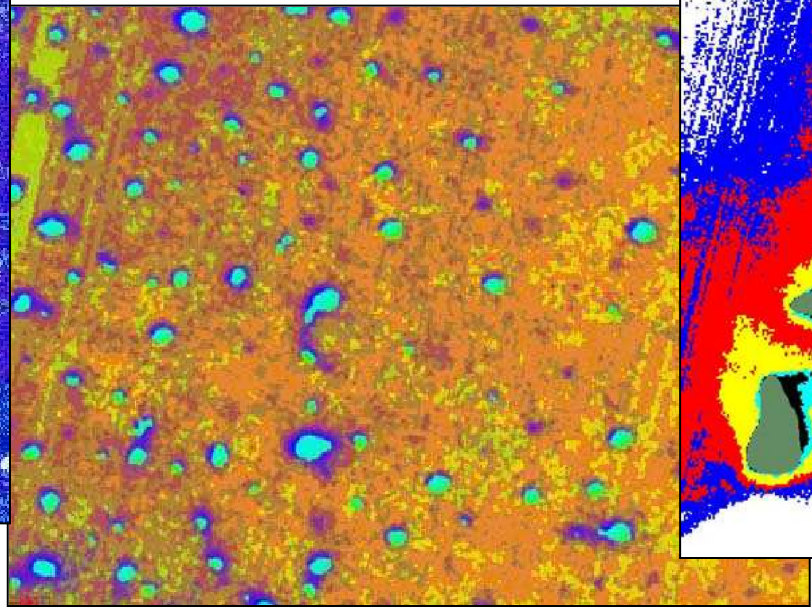
Step 3: Orthorectification

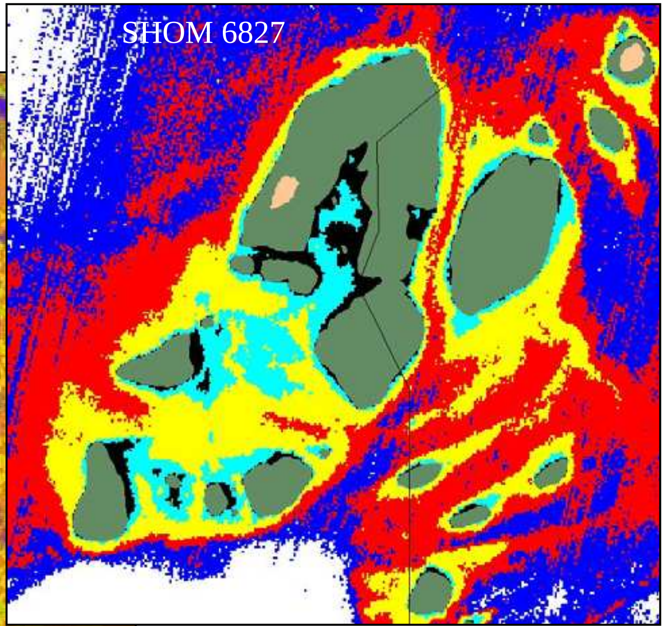
Errors of unrectified images can be up to several km

Step 4: Destriping & Enhancement

12 runs of home-made software to enhance bottom structures)



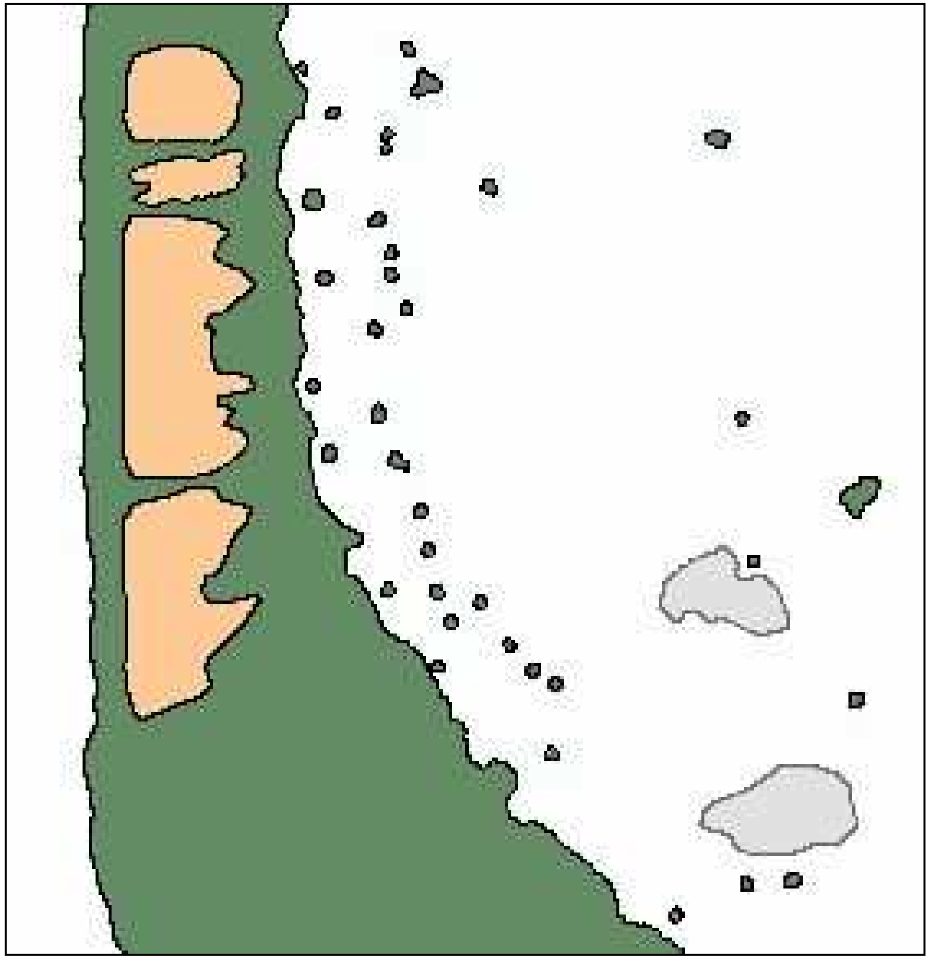




Careful destriping to avoid suppressing relevant details

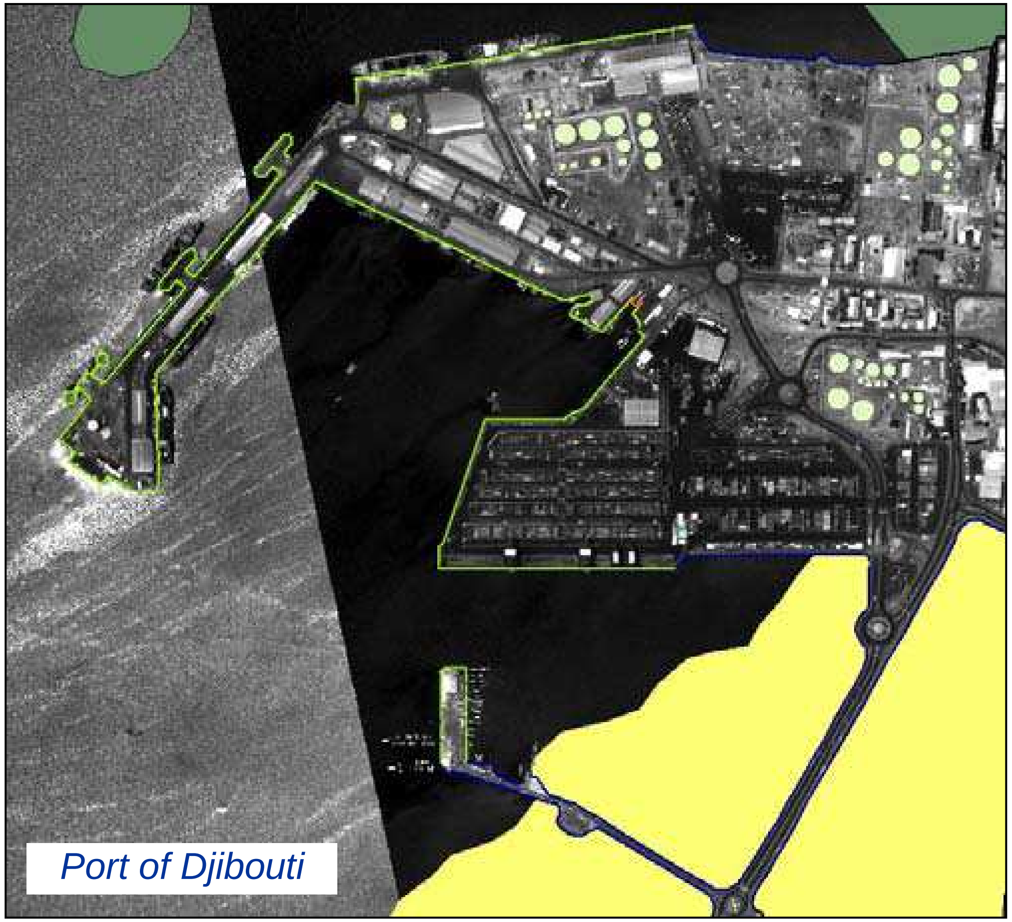
Image PCA

Step 5: Determination of vector masks



Land, Dries and Cloud masks are performed under hydrographic surveyor supervision (not fully automatic) and then automatically vectorised

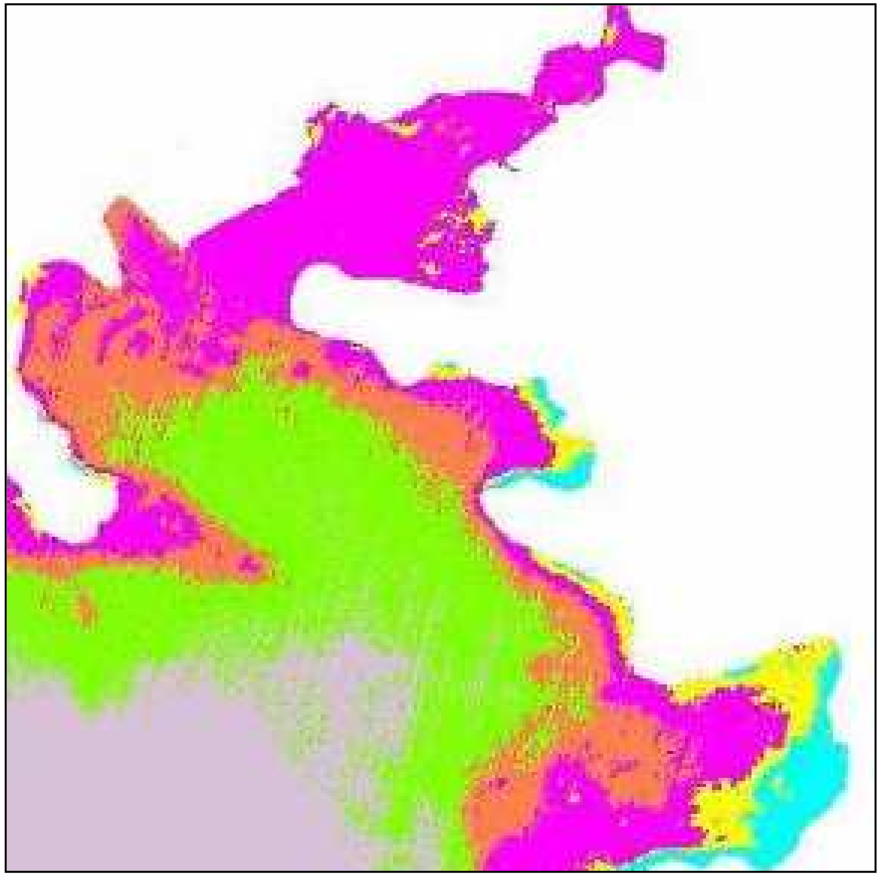
Step 6: Capture of objects



Port of Djibouti

The cartographer uses automated and/or manual data capture methods, whichever are the fastest

Step 7: Bathymetric modelling



Raw Satellite Derived Model

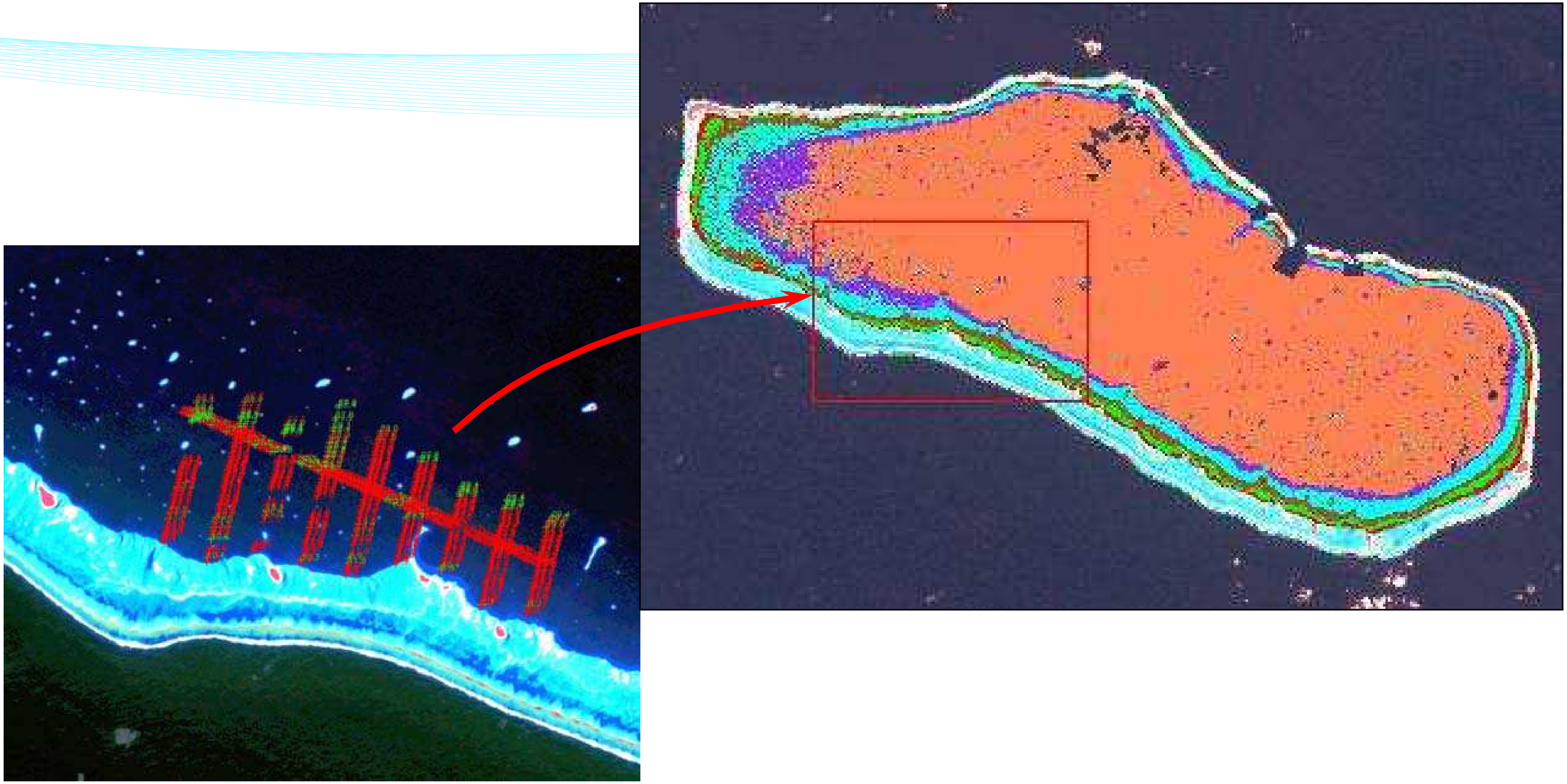
Lyzenga regressional equation:

$$Z = A.\ln(V_1 - V_{1inf}) + B.\ln(R_2 - R_{2inf}) + C$$

Depth

Green

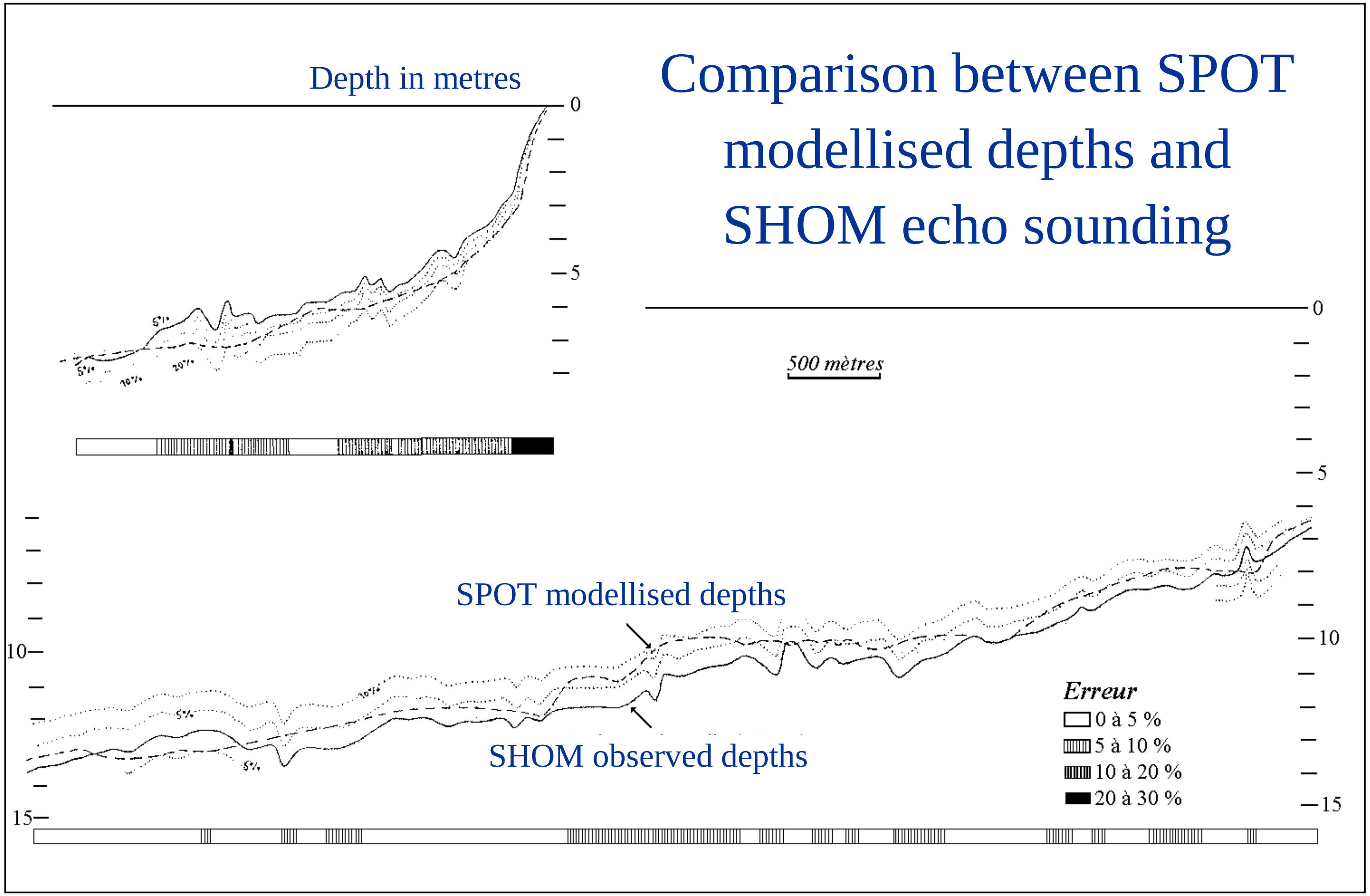
Red



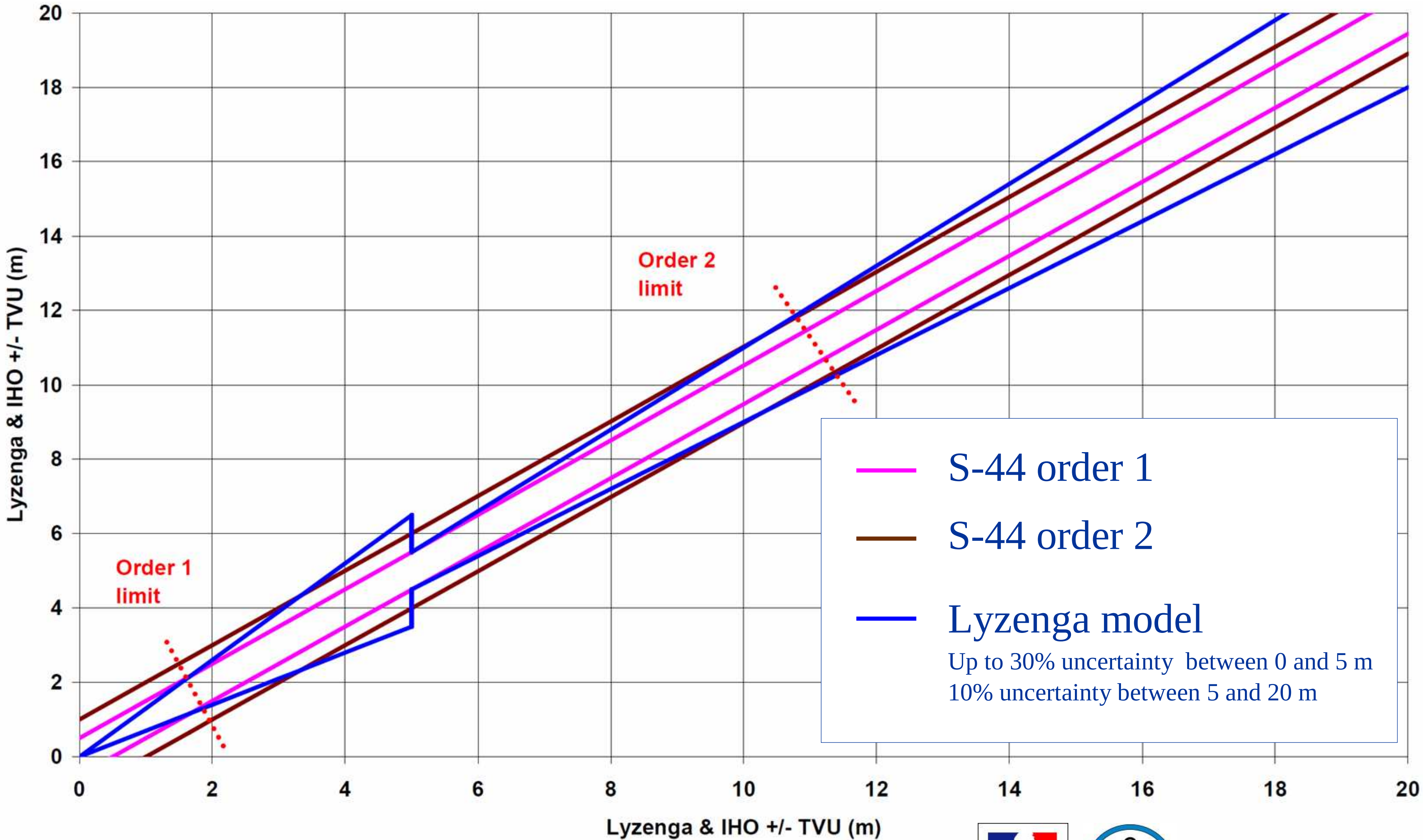
The A, B & C Lyzenga coefficients are determined by comparison with tide corrected, well distributed, control survey lines, then extrapolated to the entire model .

Part 3
SDB performances

Early tests (Uvea, New Caledonia – 1987)



Lyzenga model performances against IHO S-44
as observed on 99 SDCs



Performance Feedback

(Facts of life as opposed to Labs' claims)

Horizontal precision:

- **10 m average,** *in the case of spatiotriangulated contiguous blocks without GPS control points*
- **10 m average,** *in the case of an orthorectified image with GPS control points*
- **2 m locally,** *with HR images and dense network of control points*

Vertical precision:

(with properly calibrated Lyzenga model)

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

Performance Shortcomings

Bottom investigation remains incomplete:

- *Features not always detected and/or difficult to determine (bottom roughness badly replicated by the model)*

Depth of penetration: 20 m on average, exceptionally 30 m

- *Difficult or impossible to detect and measure 2m objects at 40 m depth (S-44 order 1a)*

Processing time:

- *Manual checks of automated processes and data validation are painstaking and still require hydrographic surveyor supervision.*

Ground control (Control points & Control survey lines):

- *Indispensable and relatively costly.*

Statement of facts

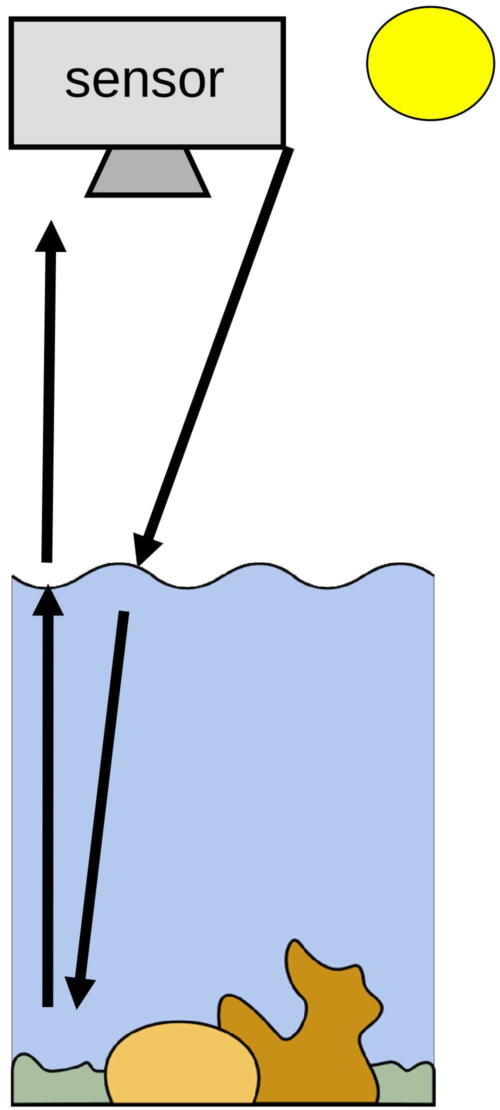
- SDC is a standard product, catalogued in the French chart series since 1995.
- SDB is a well-proven process that must be refined continuously.
- SDC production is routine and accessible to all.
  (the SHOM Lyzenga-based ENVI software has actually been commercialised to EXELIS Inc.)
- Nonetheless, final SDC production must be supervised by qualified hydrographers who are aware of the limits of the method.
- The obligation of Quality Control, a consequence of HOs' liability, remains a costly commitment.

SHOM Way ahead

- Test Inversion methods, in production, against Lyzenga's (ongoing). Benchmarking and implementation if proven better.
- Test & implement new captors and processes (ongoing).
- Keep track of latest developments in France and abroad (permanent).
- Develop S-100 satellite objects in support of ENCs (continued).
- Develop new S-44 standard in liaison with IHO in order to cater for SDB.
- List User's requirements against costs & performances and consolidate product line.
- Etc.

The physics-based Inversion Method may work without in-situ data

- Also can cope better with variation in water constituents
- Is based on physical geometry and radiative transfer theory
- Other unknowns are estimated in the process



A set of equations predict what the sensor receives – they are 'inverted' to estimate depth from sensor data:

$$r_{\mathrm{rs}}(\lambda) \approx r_{\mathrm{rs}}^{\mathrm{dp}}(\lambda)\left(1 - \exp\left\{-\left[\frac{1}{\cos\theta_{\mathrm{w}}} + \frac{D_{\mathrm{u}}^{\mathrm{C}}(\lambda)}{\cos\theta}\right]\kappa(\lambda)H\right\}\right) + \frac{1}{\pi}\rho(\lambda)\exp\left\{-\left[\frac{1}{\cos\theta_{\mathrm{w}}} + \frac{D_{\mathrm{u}}^{\mathrm{B}}(\lambda)}{\cos\theta}\right]\kappa(\lambda)H\right\}$$

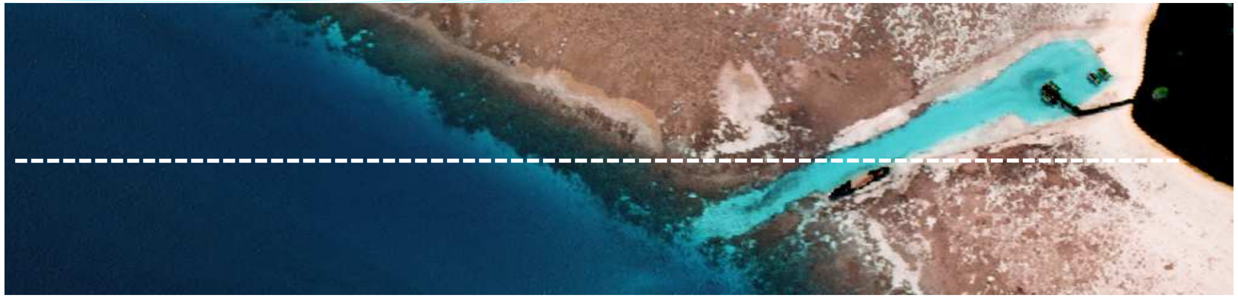
Sensor receives this

depth in metres

By courtesy of ARGANS Ltd.

Uncertainty as error bars at every point in an image

Example:
Heron fore reef
and boat channel



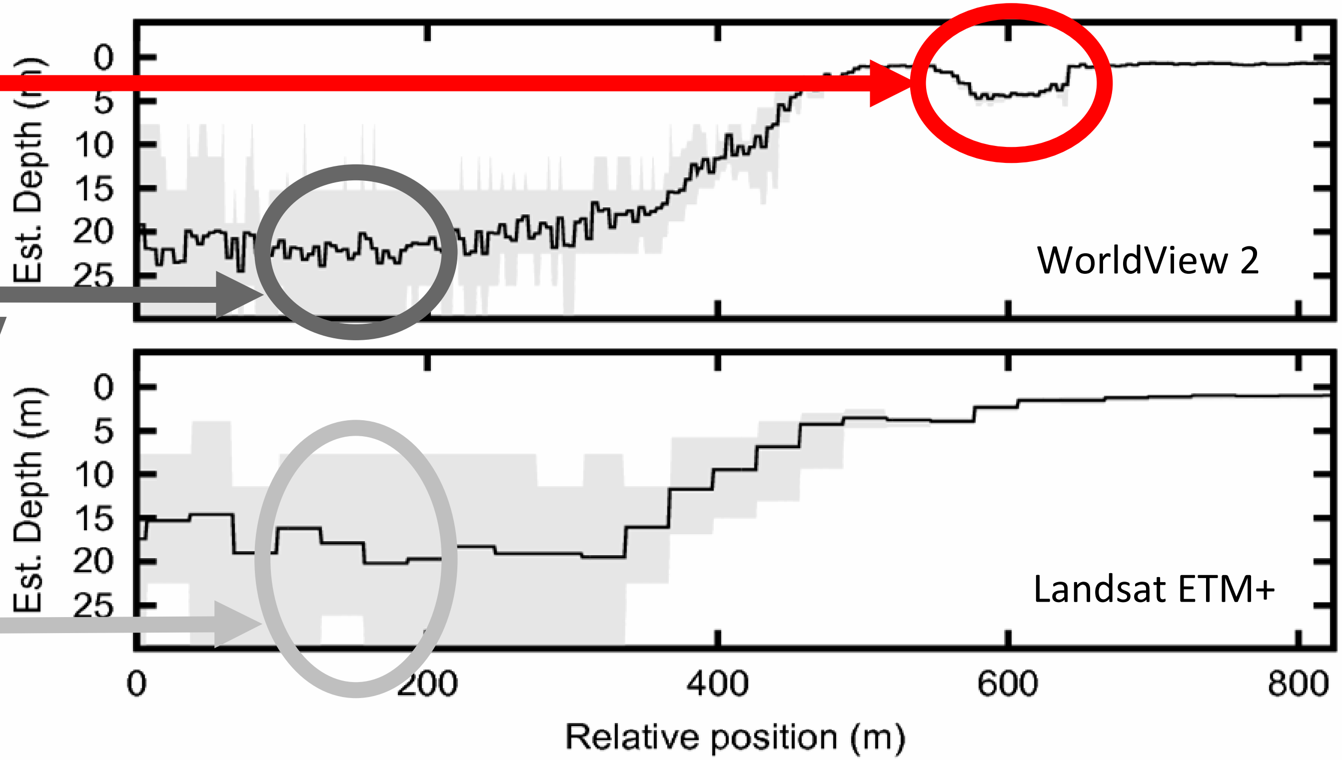
Estimate

Range

Boat channel depth of 5 m - low uncertainty

Deeper areas around 20 m - higher uncertainty

Depends on imagery, Landsat is usable but has higher uncertainty



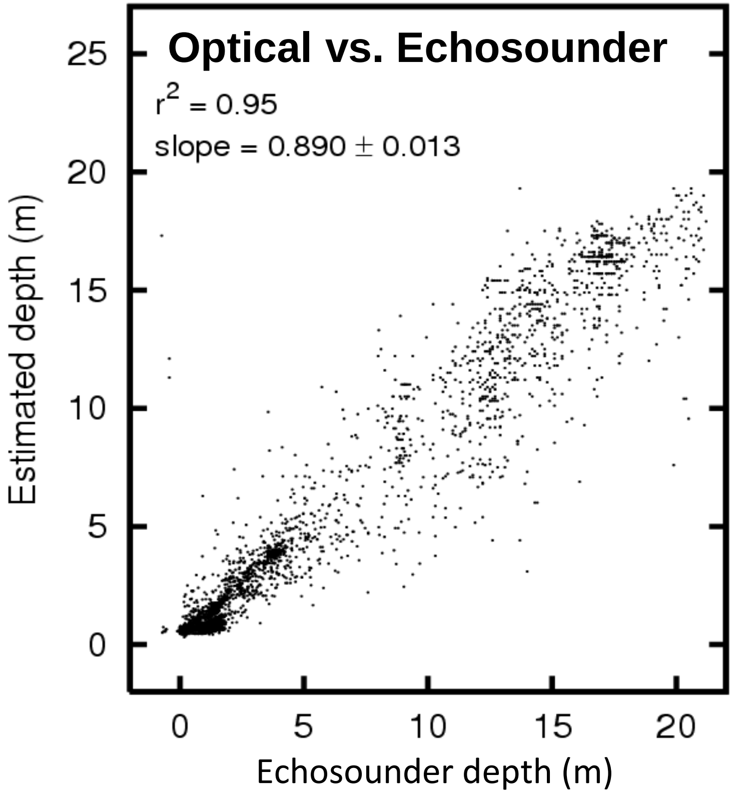
Published: Hedley & al. 2011, *Remote Sensing of Environment* 120, 145-155

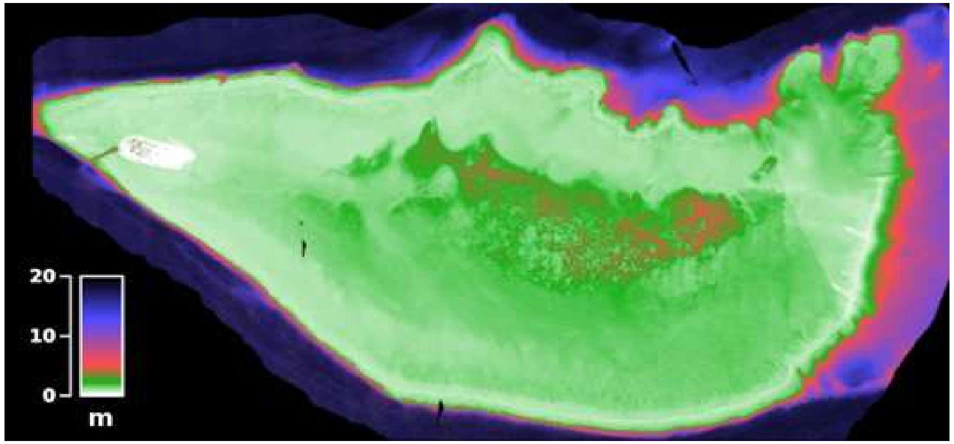
By courtesy of ARGANS Ltd.

Bathymetry from images without in-situ surveys

Example:
Heron reef, Australia

1 m spatial resolution bathymetric map from hyperspectral data





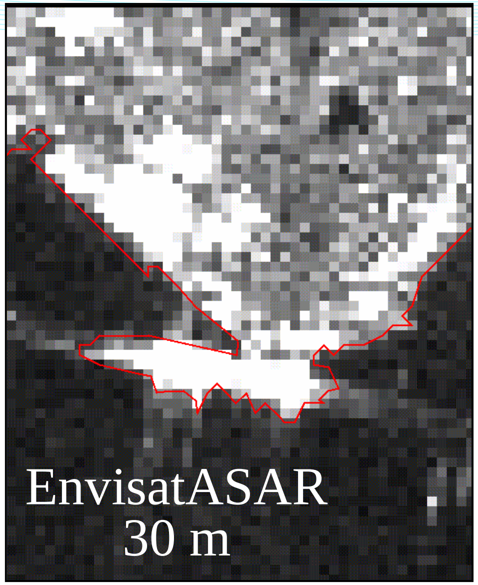
11 km, image total is ≈ 50 million pixels

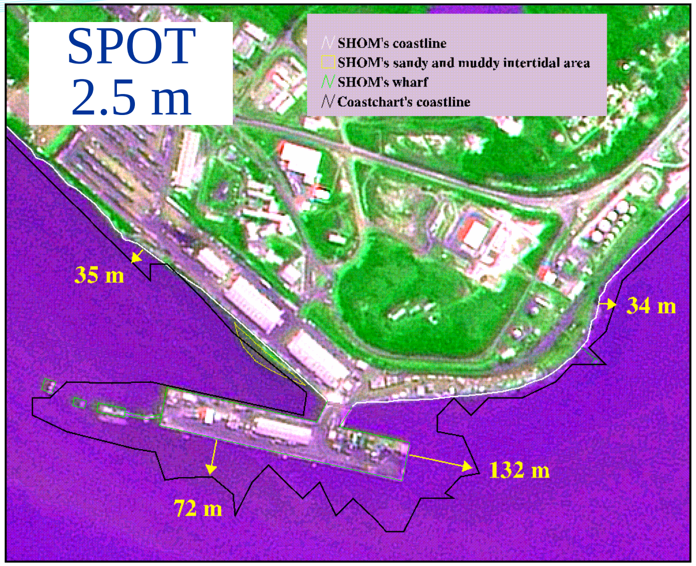
Published: Hedley et al. 2009, *Remote Sensing of Environment* 113, 2527-2532
Dataset available: Hedley et al. 2012, *Pangaea*, doi:10.1594/PANGAEA.779522

By courtesy of ARGANS Ltd.

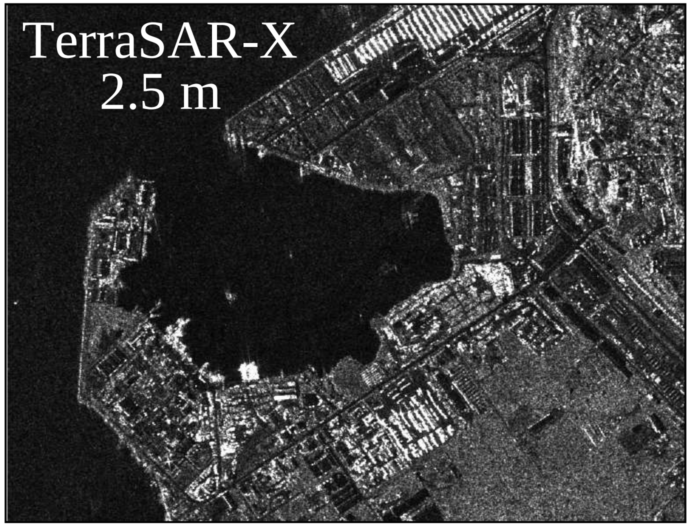
Test & implementation of radar satellites

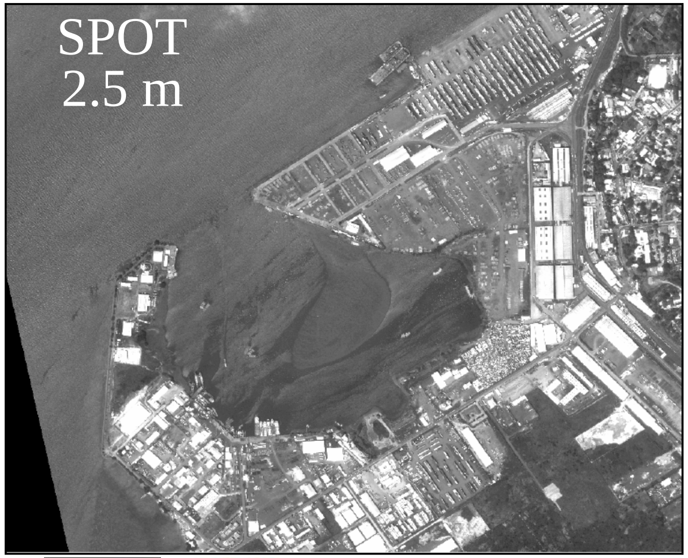
From the 2004 - 2006 aborted Coastchart project…





…to the 2012 precision





Development of a catalogue of S-100 satellite objects in support of ENC production

Vecteurs issus de la télédétection satellitaire	Géométries (Point, Line, Area)	acronyme	attribut 1	attribut 2	attribut 3
appontement, jetée / pier, jetty	L, A	SLCONS	CATSLC 4	INFORM	NOBJNM
barrage / dam	L, A	DAMCON	CATDAM 2	INFORM	NOBJNM
base navale (militaire) / naval base	P, A	HRBFAC	*CATHAF 6*	INFORM	NOBJNM
bassin de radoub (cale sèche) / graving dock (dry dock)	A	DRYDOC	INFORM	NOBJNM	OBJNAM
bâtiment remarquable (hangar, entrepôt, …) / conspicuous building (warehouse, storehouse, …)	A	BUISGL	convsh 5	INFORM	NOBJNM
brise-lames / breakwater	L, A	SLCONS	CATSLC 1	INFORM	NOBJNM
brise-mer / seawall	L, A	SLCONS	CATSLC 10	INFORM	NOBJNM
cale de construction / slipway	L, A	SLCONS	CATSLC 13	INFORM	NOBJNM
cale, cale de halage / ramp	L, A	SLCONS	CATSLC 12	INFORM	NOBJNM
canal (de navigation) / canal, slough	L, A				
canal de drainage des eaux excédentaires / canal to drain excess water from surrounding land	L, A				
canal d'irrigation / flume	L, A				
chantier naval / shipyard	P, A				
château d'eau / water tower	P, A				
construction isolée / single building	P, A				
désert rocheux (rocailleux) / rocky desert (stony desert)	A				
désert sableux / sandy desert	A				
digue / dyke	L, A				
dock flottant / floating dock	L, A				
duc d'albe / dolphin	L, A				
émissaire, égout / outfall pipe, discharge pipe, sewer	L				
épave / wreck	A				
épi / groyne	L				
estran (de nature indéfinie) / unknown intertidal area	A				
estran corallien (récif corallien couvrant et découvrant) coral reef, which covers and uncovers	A				
estran rocheux / rocky intertidal area	A				
estran sableux et/ou vaseux, banc de sable, banc de vase sandy and/or muddy intertidal area, sandbank, mudbank	A				
ferme marine / marine farm	L, A				
fond corallien (récif corallien immergé) / coral seabed	A				
fond rocheux / rocky seabed	A				
fond sableux et/ou vaseux / sandy and/or muddy seabed	A				
gazoduc / overhead pipeline to transport gaz	L				
glacier / glacier	A				

OBJECTS

trait de côte / coastline	L	COALNE	INFORM	NOBJNM	OBJNAM
tranche bathymétrique [Zmin-Zmax] m (modèle calculé) / [Zmin-Zmax] meters depth area	A	DEPARE	*DRVAL1 Zmin*	*DRVAL2 Zmax*	INFORM
tranche bathymétrique 0-5 m (modèle calculé) / 0-5 meters depth area	A	DEPARE	*DRVAL1 0*	*DRVAL2 5*	INFORM
tranche bathymétrique 5-10 m (modèle calculé) / 5-10 meters depth area	A	DEPARE	*DRVAL1 5*	*DRVAL2 10*	INFORM
tranche bathymétrique 10-15 m (modèle calculé) / 10-15 meters depth area	A	DEPARE	*DRVAL1 10*	*DRVAL2 15*	INFORM
tranche bathymétrique 15-20 m (modèle calculé) / 15-20 meters depth area	A	DEPARE	*DRVAL1 15*	*DRVAL2 20*	INFORM
tranche bathymétrique 20-25 m (modèle calculé) / 20-25 meters depth area	A	DEPARE	*DRVAL1 20*	*DRVAL2 25*	INFORM
voie ferrée / railway	L	RAILWY	INFORM	NOBJNM	OBJNAM
zone arborée (bois, forêt, bosquet) / woodland, woods	A	VEGATN	*CATVEG 6*	INFORM	NOBJNM
zone bâtie / build up area	A	BUAARE	INFORM	NOBJNM	OBJNAM
zone de bathymétrie supérieure à 20 m (modèle calculé) / deeper than 20 meters depth area	A	DEPARE	*DRVAL1 20*	*DRVAL2 50*	INFORM
zone de bathymétrie supérieure à 25 m (modèle calculé) / deeper than 25 meters depth area	A	DEPARE	*DRVAL1 25*	*DRVAL2 50*	INFORM
zone de bathymétrie douteuse (modèle calculé douteux) / doubtful depth area (from bathymetric model)	L, A	DEPARE	*DRVAL1 Zmin*	*DRVAL2 Zmax*	QUASOU 3
zone de déferlement (sur une plage, à la côte, …) / surf zone, breakers	A	WATTUR	*CATWAT 1*	INFORM	NOBJNM
zone de petits fonds vaseux / muddy shallow waters	A	SBDARE	NATSUR 1	*WATLEV 3*	INFORM
zone de pipelines / pipelines area	A	PIPARE	PRODCT	INFORM	NOBJNM
zone de travaux en cours / under construction area (works in progress)	L, A	SLCONS	CONDTN 1	INFORM	NOBJNM
zone d'élevage de coquillages (conchyliculture) / shellfish beds	L, A	MARCUL	CATMFA 2	INFORM	NOBJNM
zone dunaire, dunes / sandhills, dunes	A	SLOGRD	*CATSLO 3*	NATSUR 4	INFORM
zone humide (marais, marécage, …) / wetlands (swamp, marsh, …)	A	LNDRGN	*CATLND 2,12*	INFORM	NOBJNM
zone industrielle / industrial area	A	PRDARE	*CATPRA*	PRODCT	INFORM
zone masquée (nuage, ombre, …), télédétection impossible / masked area (cloud, shadow, …), impossible to remote sense	A	UNSARE	INFORM	NOBJNM	OBJNAM
zone terrestre / land area	A	LNDARE	INFORM	NOBJNM	OBJNAM

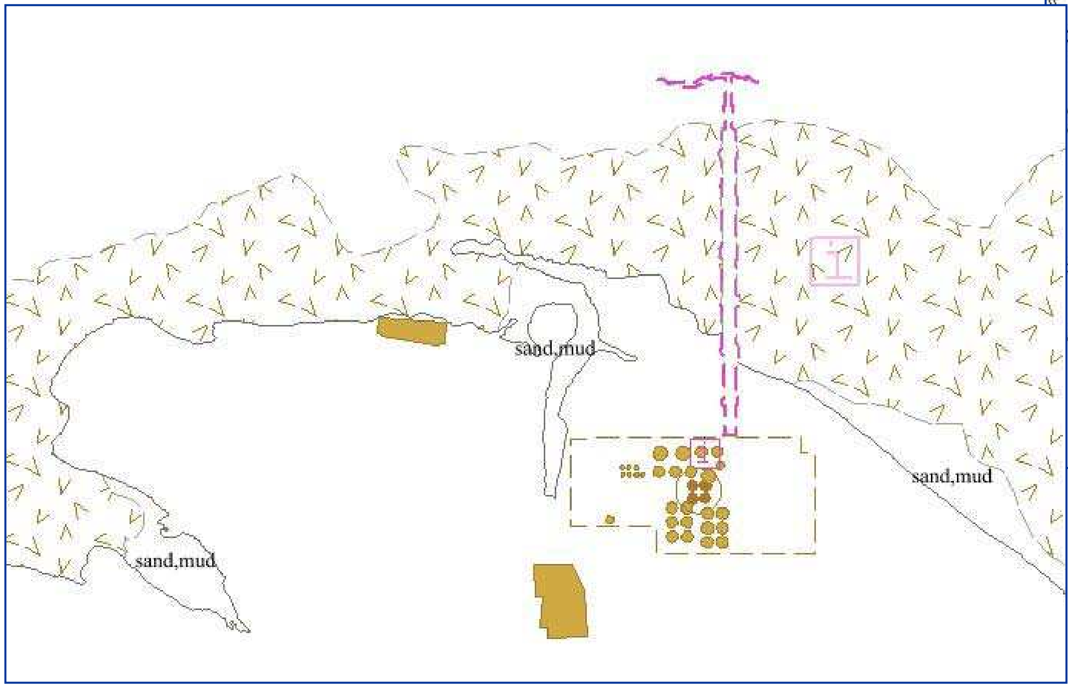
LAYERS

Excerpt of BDTIS (the SHOM images' database)

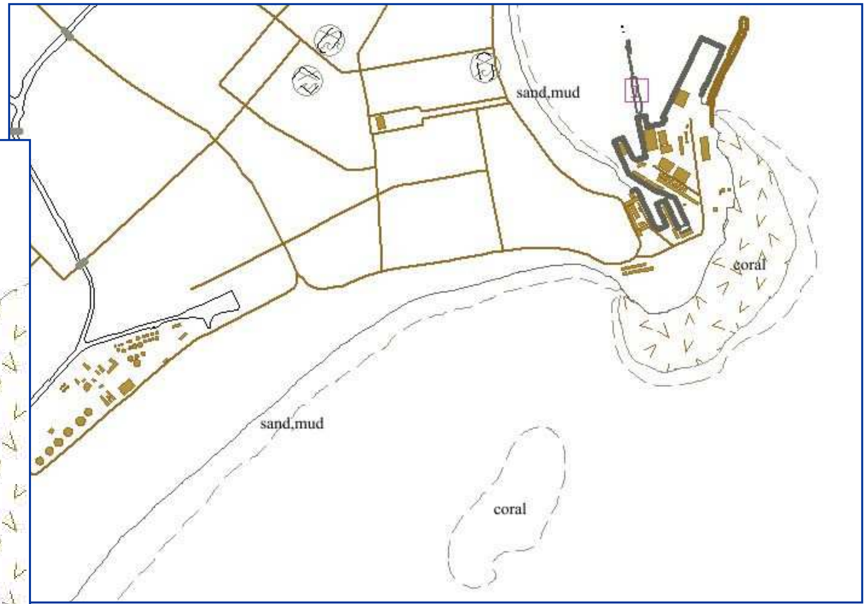
Part 4

SHOM new line of products

Vector Database (CARIS HPD)



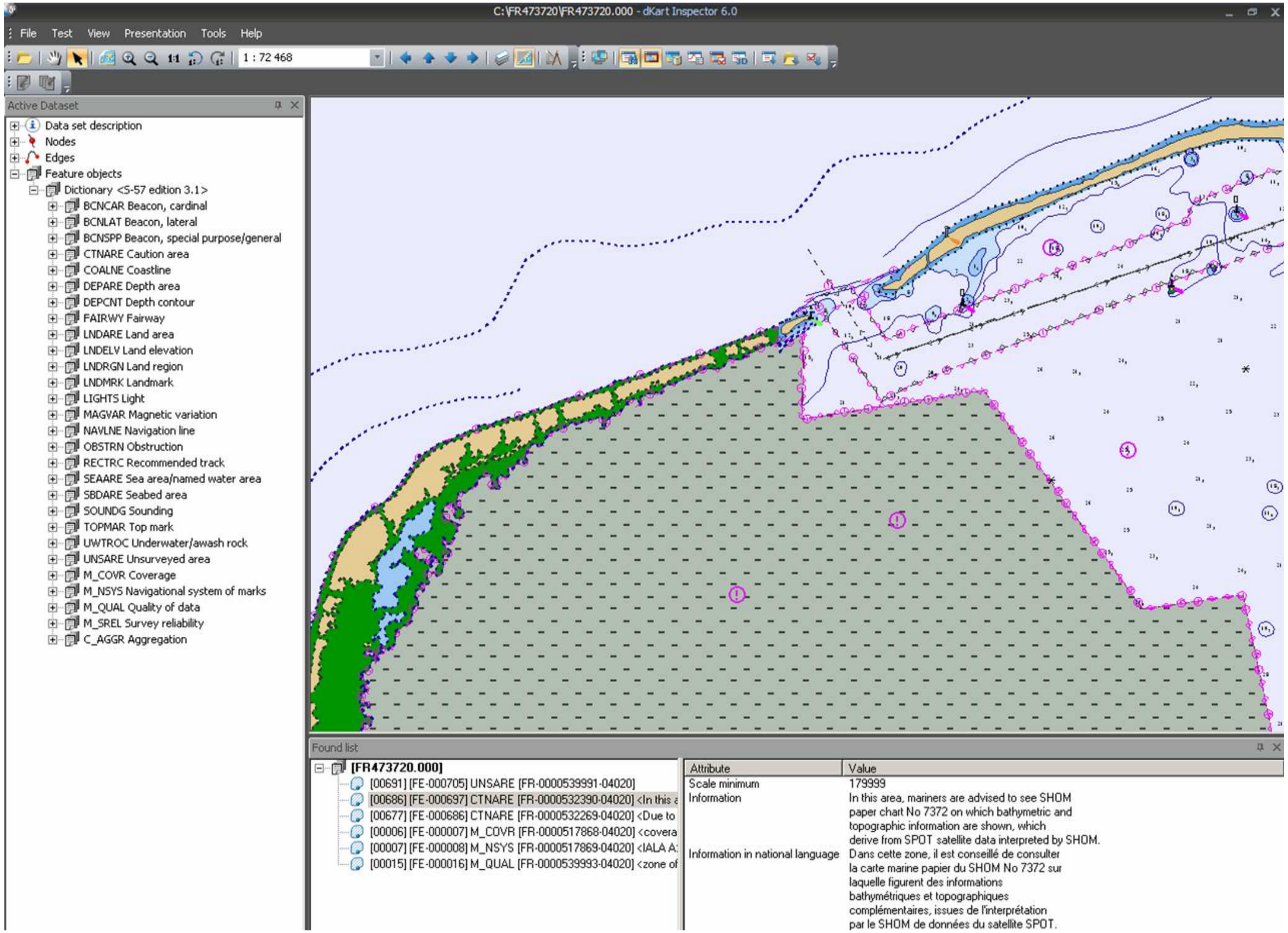
Doralé (Djibouti) oil terminal



Port of Toamasina, Madagascar

Satellite Derived ENC in the S-10* format

(suited to all GIS and Editors)



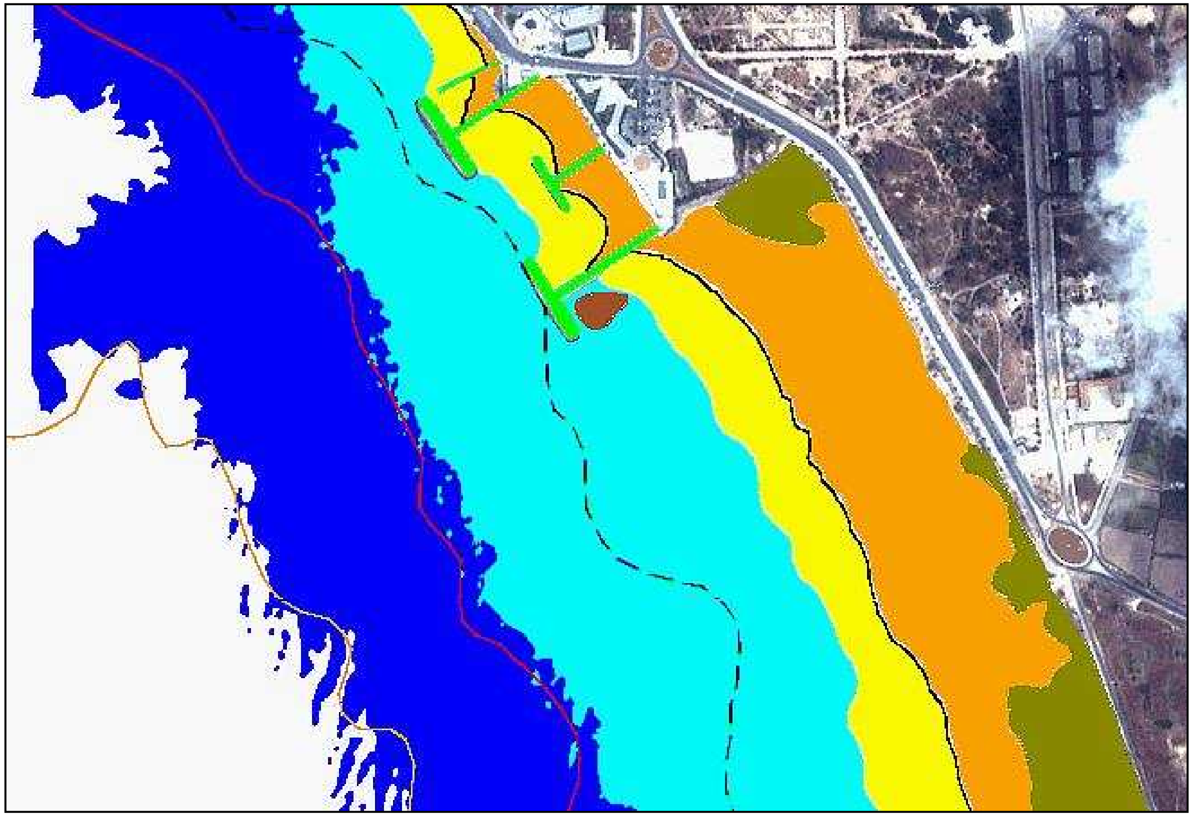
Digital Topographic SDC

(suited to all GIS and Editors)

Designed to comply
with shore requirements

Digital Nautical SDC

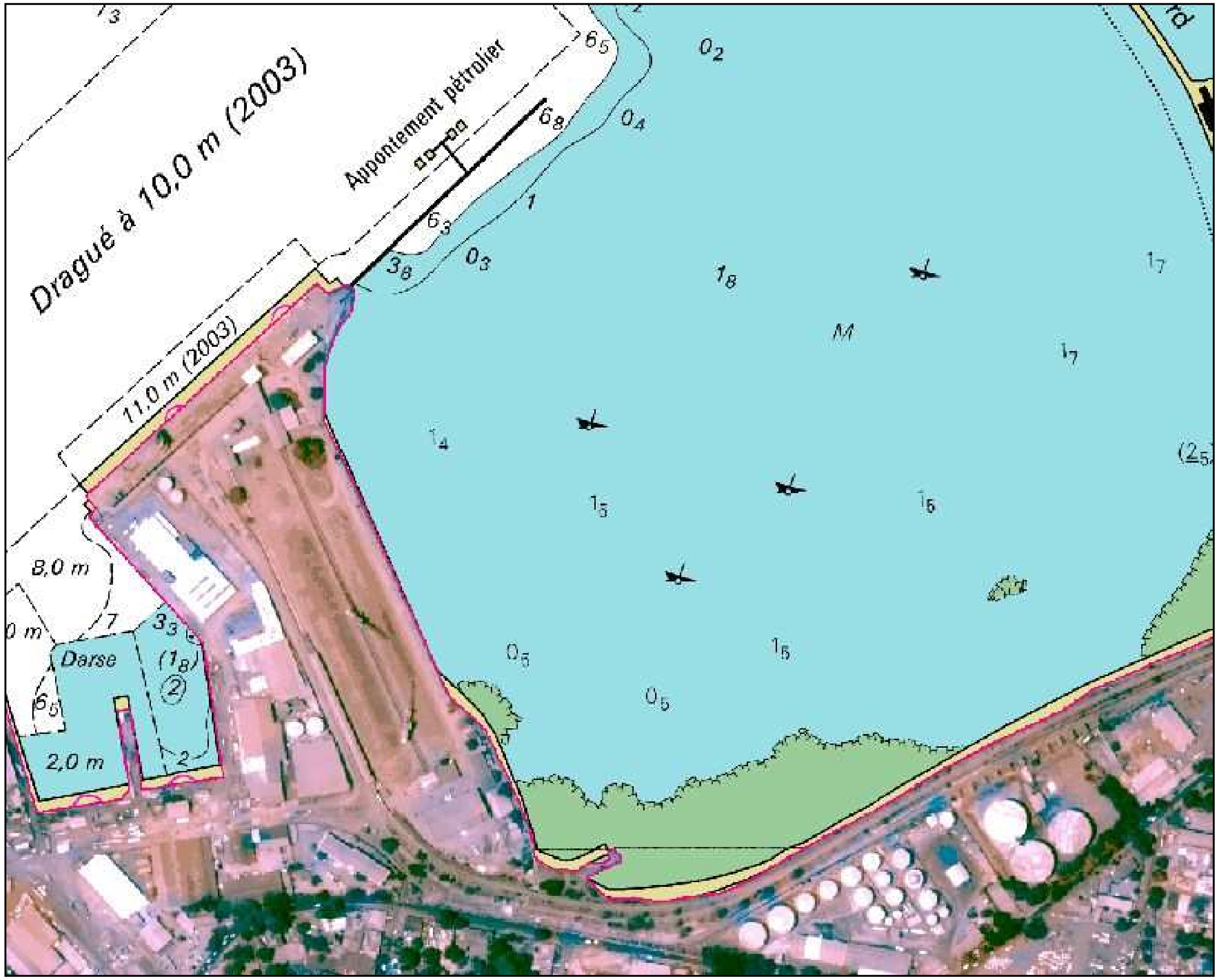
(suited to all GIS and Editors)



Designed to comply with
Marine requirements

Seamless Land-Sea SDC

(suited to all GIS and Editors)



Designed to comply with Operational deployments, ICZM requirements, etc.

Part 5

Cost considerations

Surveys, Processing and Charts

(costs based optionally on SHOM Dec 2011 figures)

- Ocean-survey vessel: 63 510 € per 24 hrs day (survey team not included)
- Coastal-survey ship: 52 241 € per 24 hrs day (survey team not included)
- Survey/Post-processing by 16-strong team: about 10 000 € per day
- Time ratio Post-processing / Deep sea survey: 3.5 (more if shallow)
- Survey of port and access: about 0.5 M€ per port
- Chart production costs (2009 figures, without printing):
  - Publication: 79 500 €
  - Edition: 46 000 €
  - ENC: 16 500 € (to be added to the publication cost)

- “Commercial” geophysical vessel (14 arrays – 57 crew) : US $ 280 000 per day

Costs of surveys per sq. km

	Litto3D preliminary assessment (2004)	2011
Lidar	1 000 € (French coasts)	Average: 1 500 to 2 000 € Greatly variable. Depends on survey and quality of post-processing
MBES	1 000 to 1 400 €	Average: 1 000 to 1 400 € Up to 10 times these figures in the worst cases
Satellite		25 to 45 € (depends on quality of product)

Satellite images & Processing

(based on SHOM 2011 figures)

✓**Cost of satellite images: anything between 0.02 and 40 € per sq. km, depending on quality, amongst other considerations**

SATELLITE	*Spatial resolution (m)*	*Cost per sq. km (€)*
Quickbird	*2.4 x 2.4*	*22*
Pleïades	*2.8 x 2.8*	*5 (SHOM guess)*
TerraSar-X Strip Map	*1.25 x 1.25*	*2.64*
Spot View	*10 x 10*	*1.07*
RapidEye	*5 x 5*	*0.95*
DMC	*22/32*	**0.02 to 0.12**

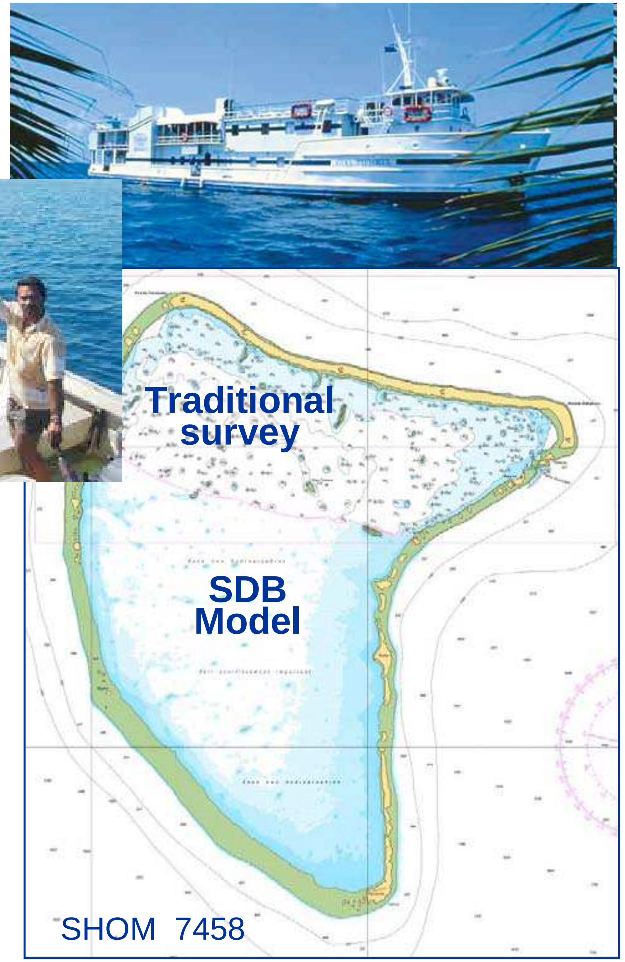
✓**Cost of image processing (20 x 20 km): 15 000 € without ground control**

Ultimately, how should we spend our money?

1 000 to 2 000 € per sq. km for this?

+

Or 40 € per sq. km for that?



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THE SATELLITE DERIVED CHART

(1983 – 2012)

Thank you for your attention.

Do you have any questions?

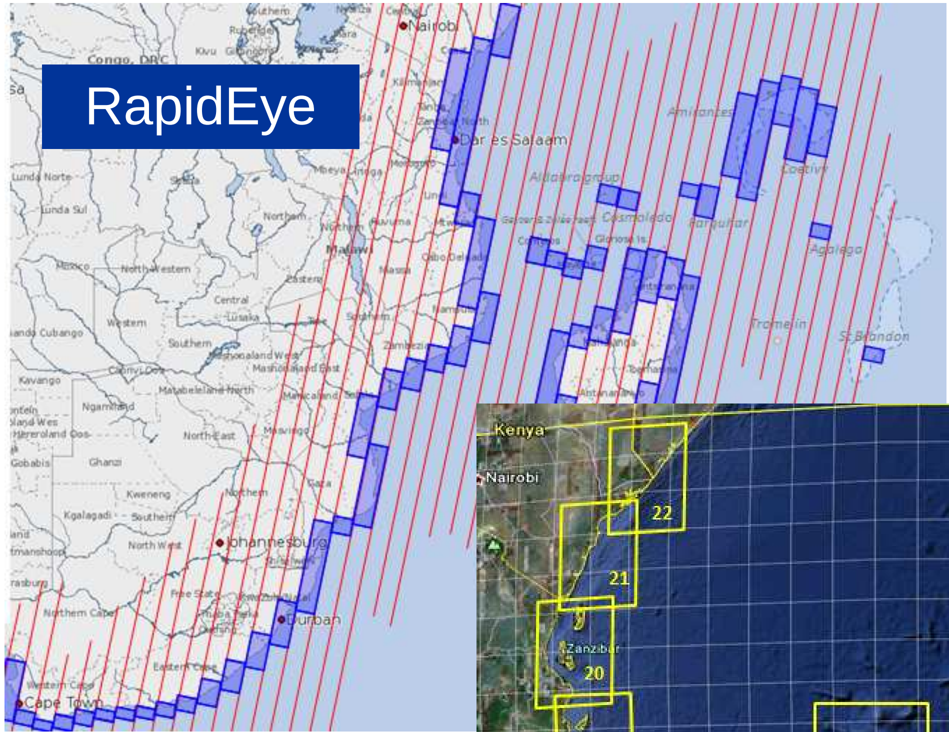
Addendum:

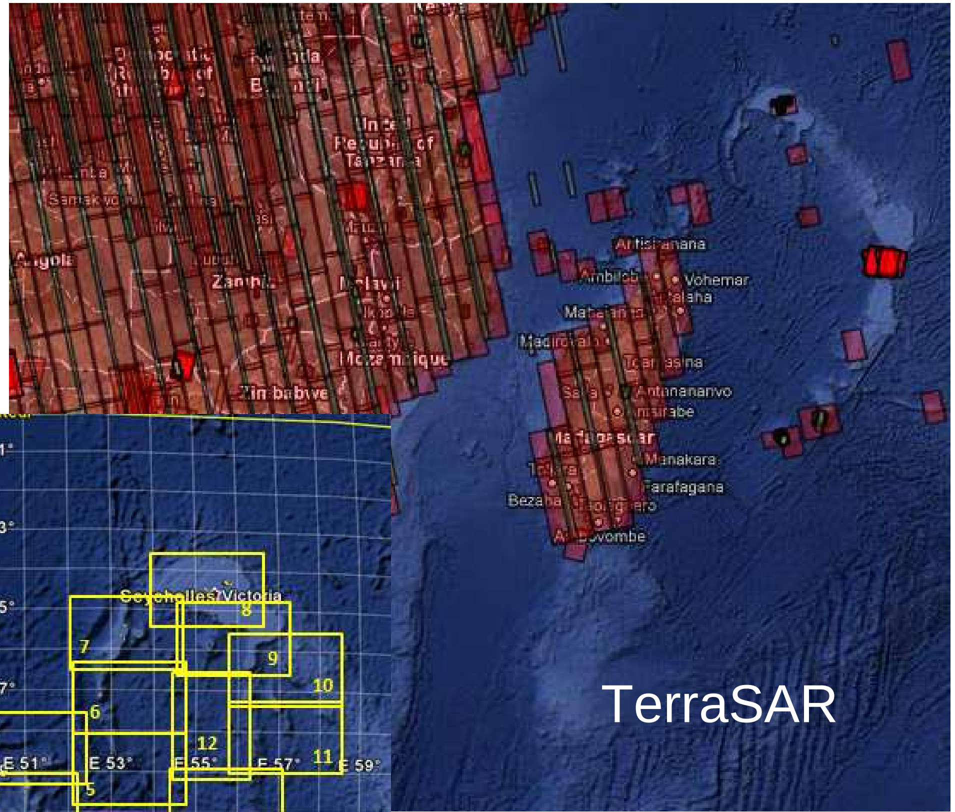
SHOM vision of the future
&
Examples of SDC applications

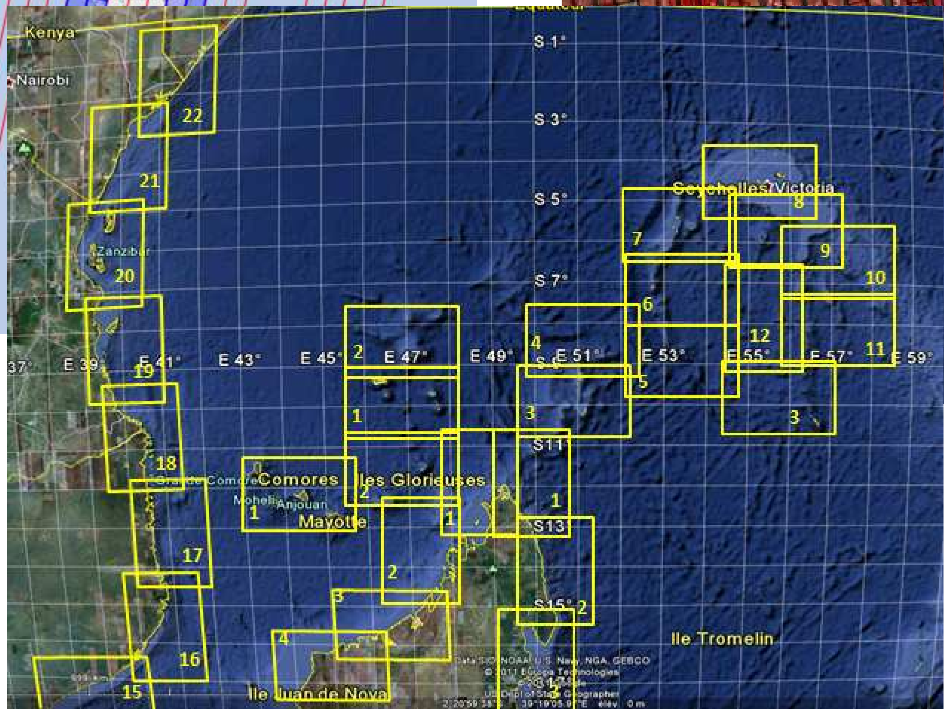
SHOM goals and vision of the future

- *Influence the development of SDB technologies with a view to improve the world existing chart series and depict poorly surveyed areas.*
- *Bridge the gap between R&D and effective production of SDCs, and receive funding for the qualification and benchmarking of valid SDB technologies.*
- *Develop a new S-44 standard in liaison with IHO to cater for SDB.*
- *Expand the Manual on Hydrography (C-13) to address SDB technologies.*
- *Develop partnership with those HOs that share SHOM concern about the bleak future of some segments of the existing chart series.*
- *Transpose the SDB technology directly applicable to Capacity Building in developing HOs.*

South West Indian Ocean



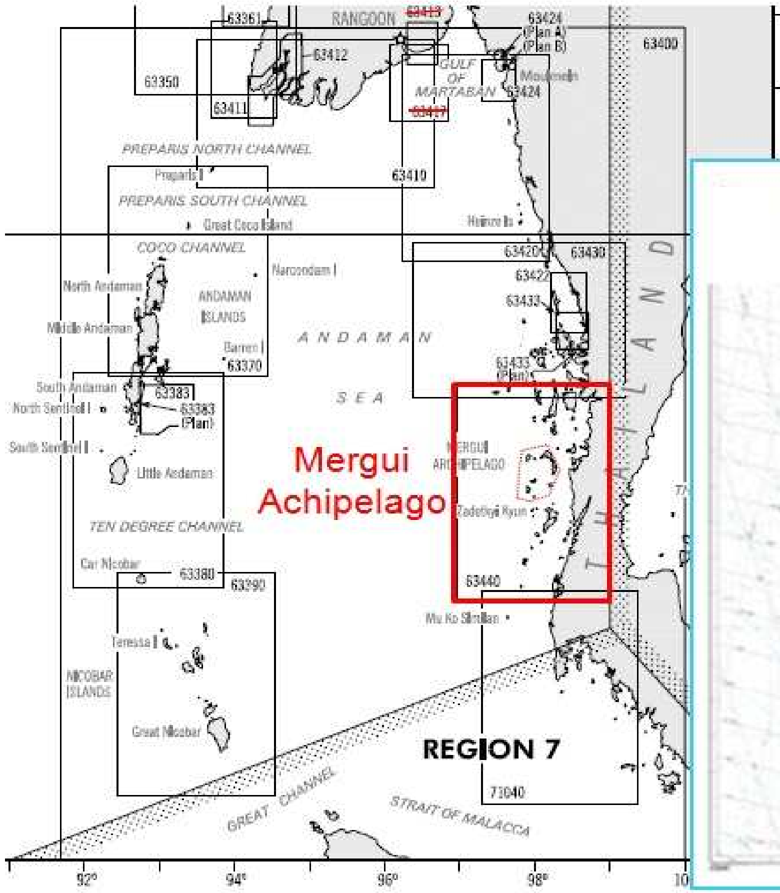


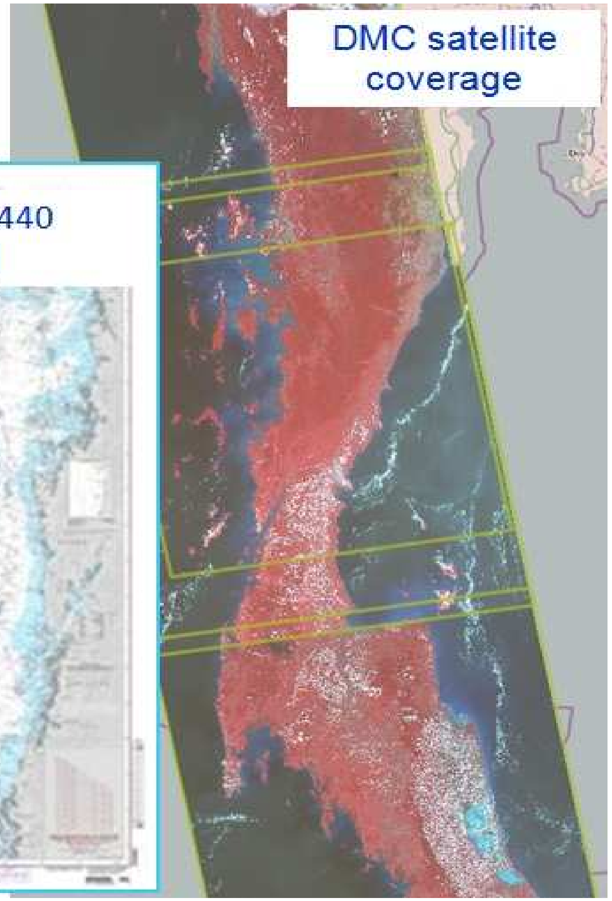


With special thanks to Pierre Mouscardes Consulting

Myanmar and Thailand ICZM

A tourist heaven, the Mergui archipelago comprises 800 islands and covers a 36 000 sq. km uncharted area and a National Park





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Red Sea

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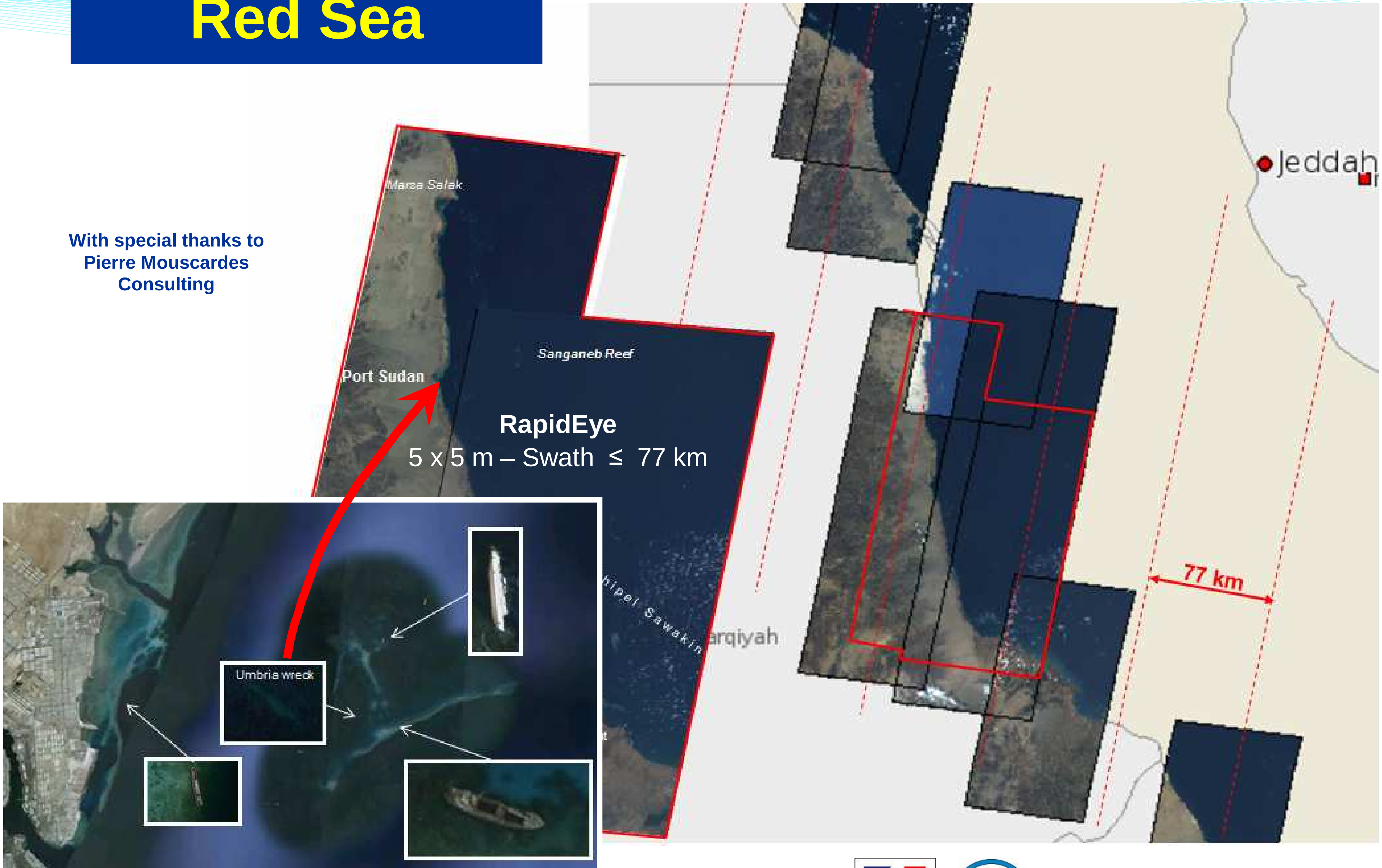
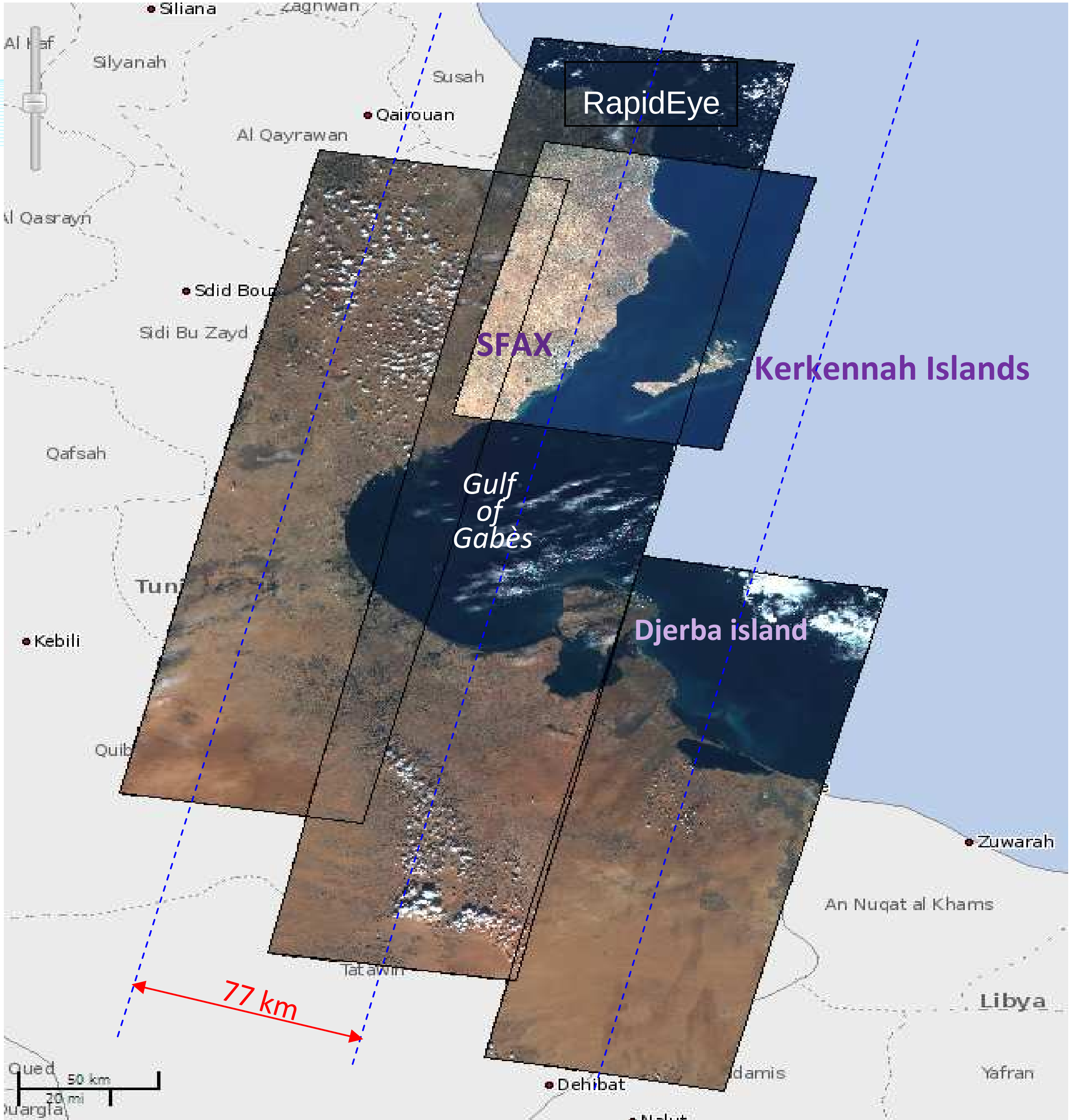


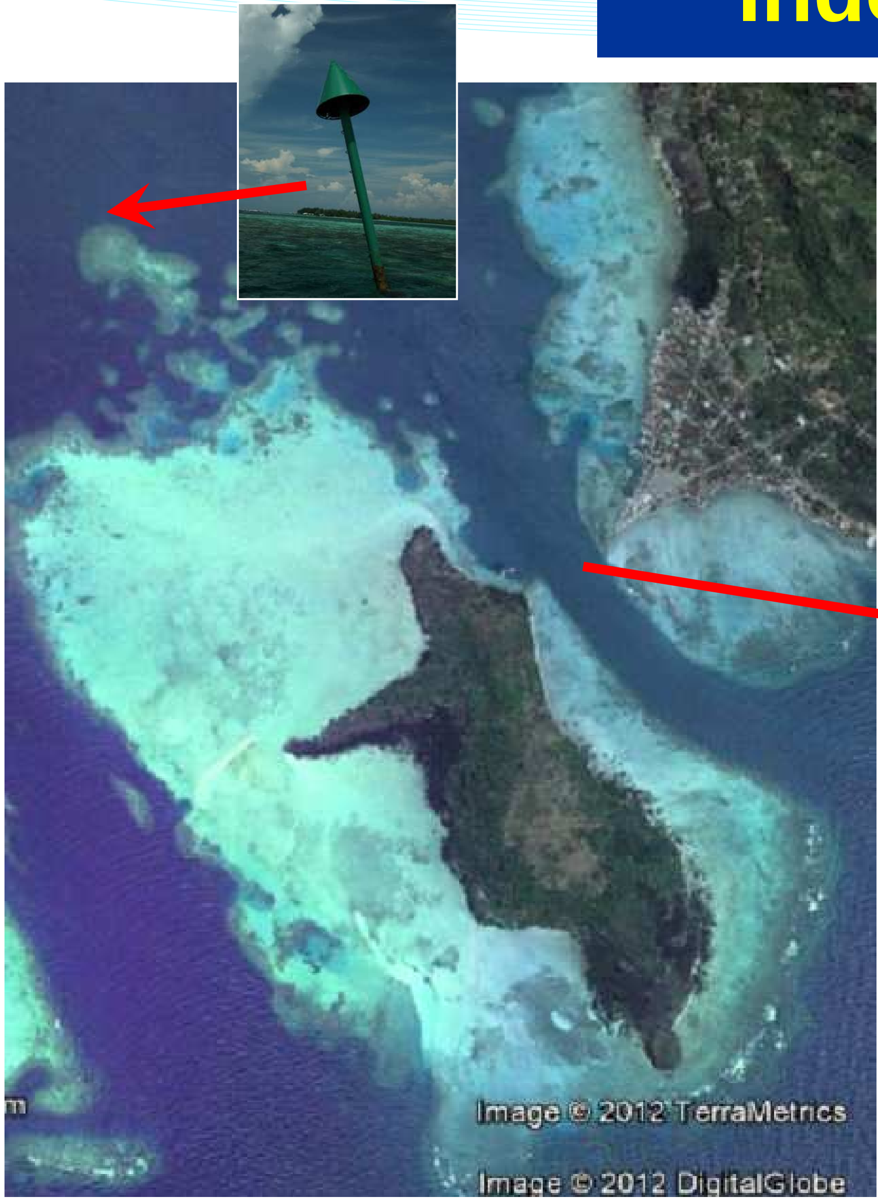
Mediterranean

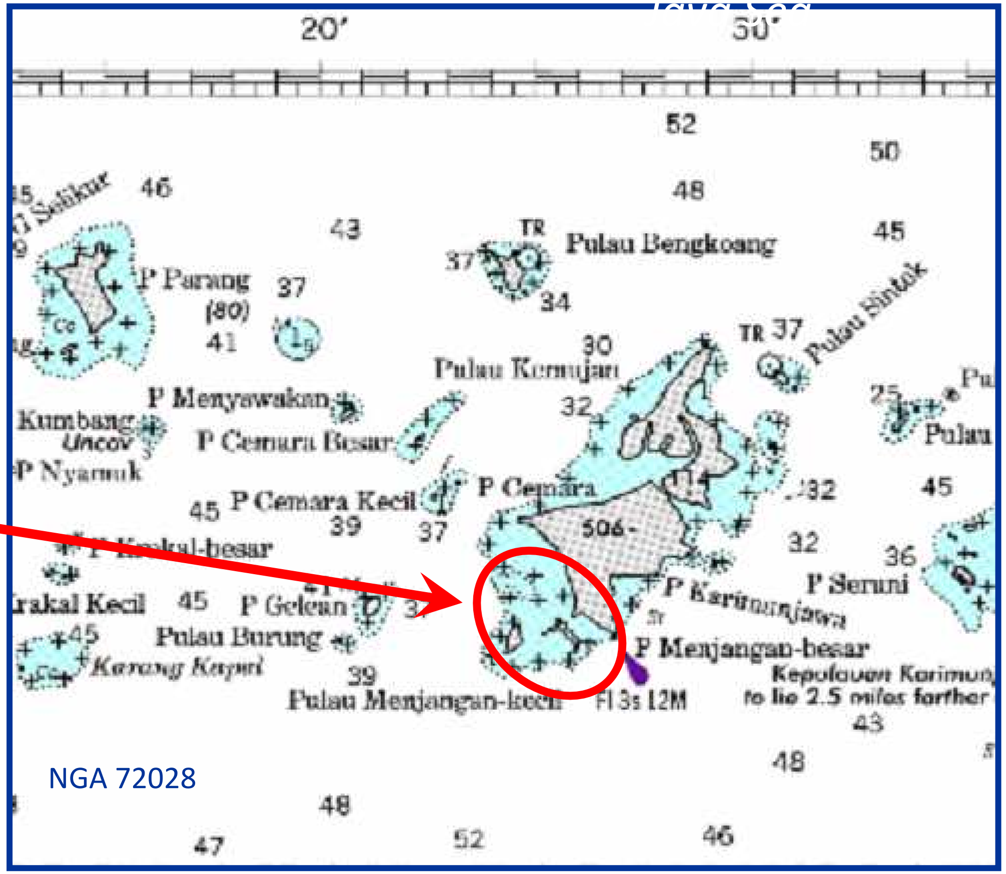


Updating of some Maghreb old charts is considered as a possible component of the future Southern Mediterranean Marine Highway

With special thanks to Pierre Mouscardes Consulting

Indonesia





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