Satellite Bathymetry

# SHOM nautical navigation canvas

- ➢ *Charting coral reefs before 1982*

- ➢ *The Landsat Thematic Mapper breakthrough*

- ➢ *SHOM's « Spacechart » (from 1988 until today)*

- ➢ *Latest improvements*
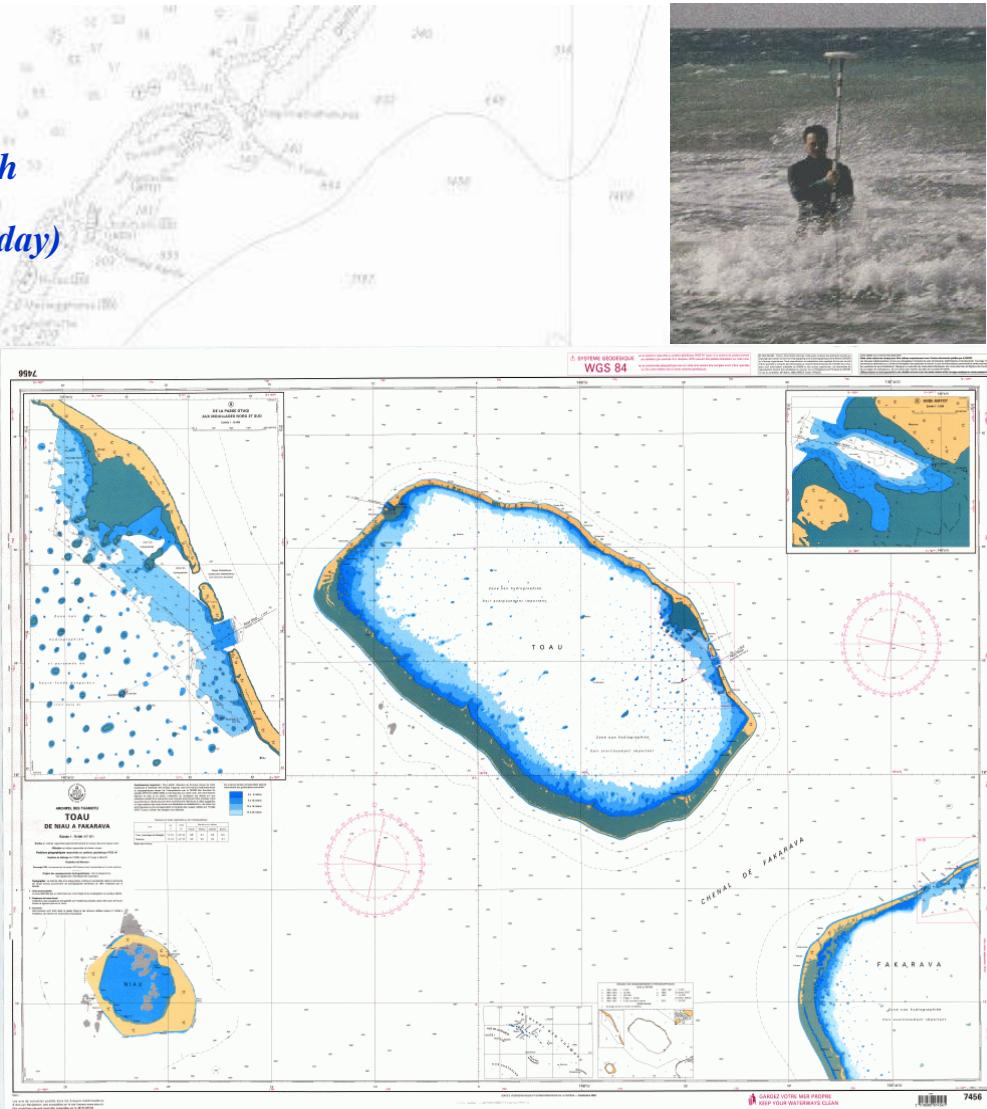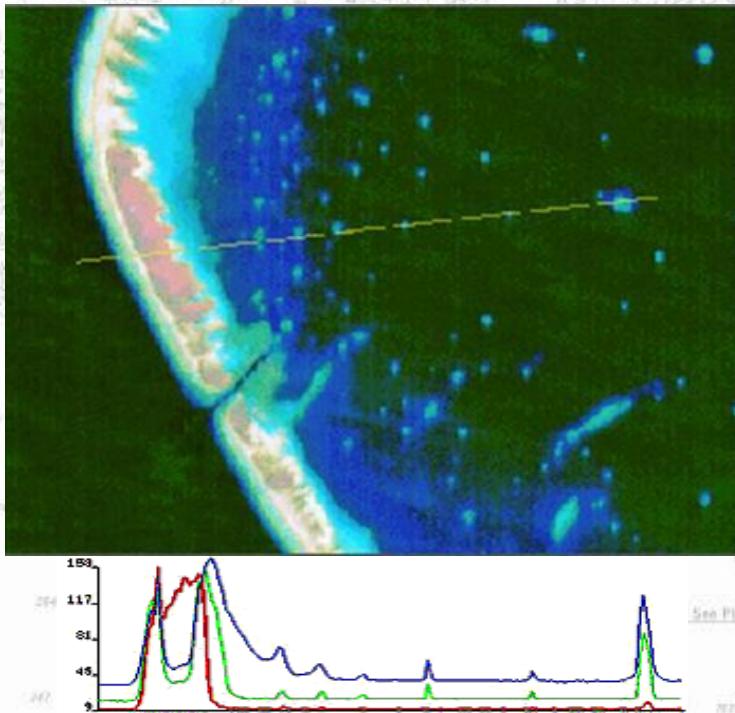
Example of Ari atoll space chart produced in 2011

Production flow chart

Satellite images

Ground Control Points

Geometric Processing

Orthoimages

Ground Truth (Echosounder, Lidar)

Bathymetric Processing

Depths layers (0-5m, 5-10m...), Foreshore and Land Masks

Additional Info (place names, boundaries, existing surveys, Gebco…)

Edition
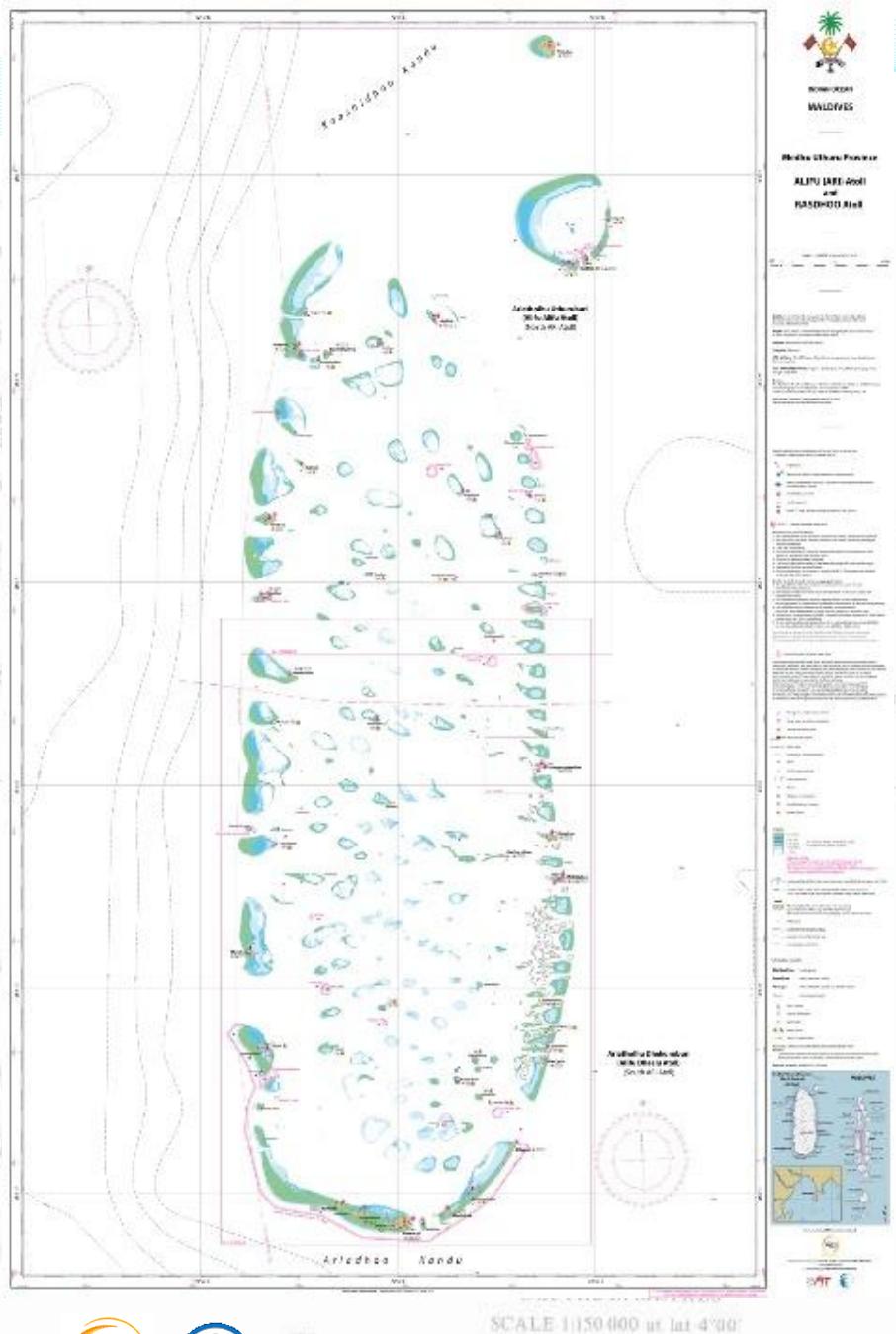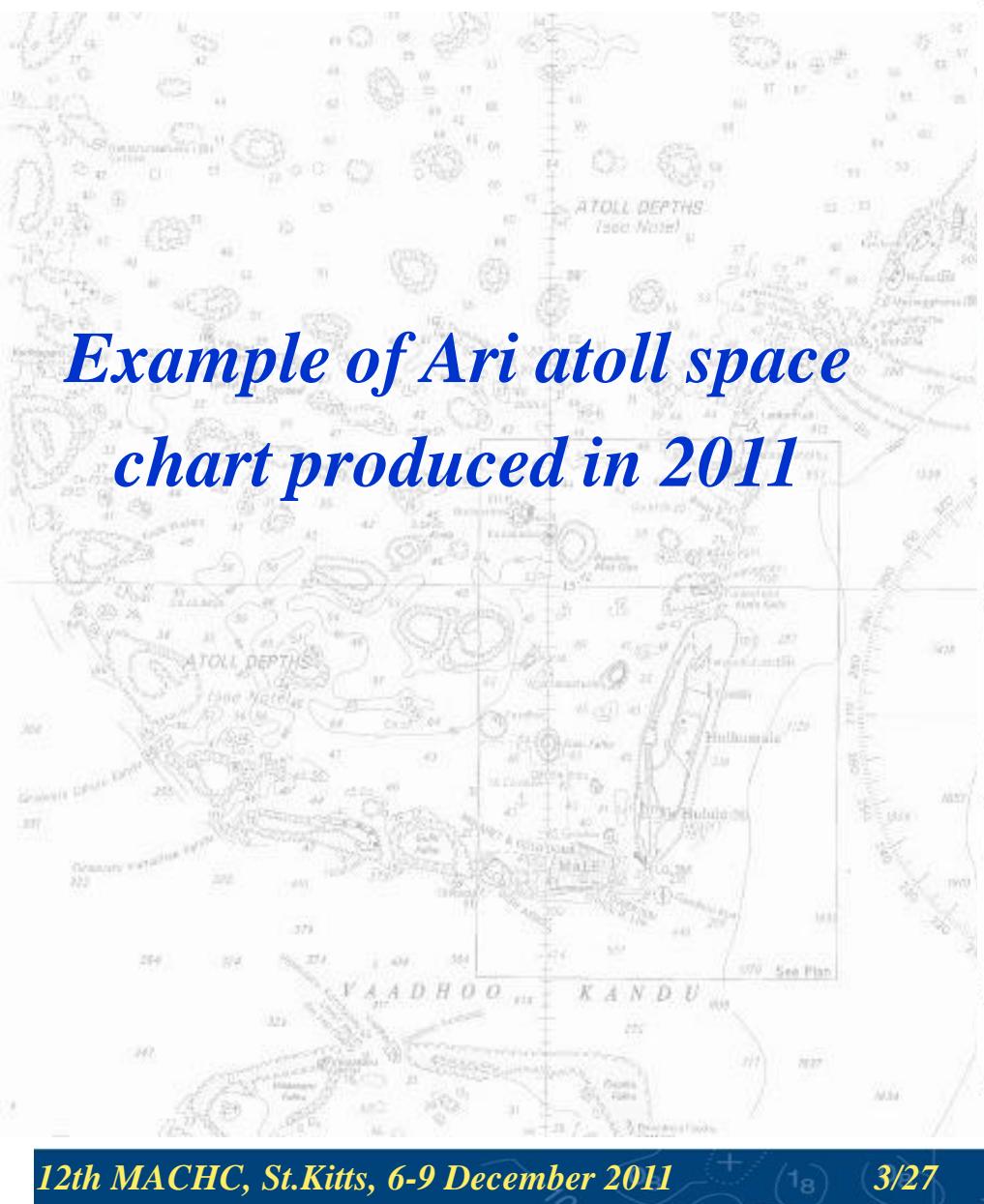
Space chart
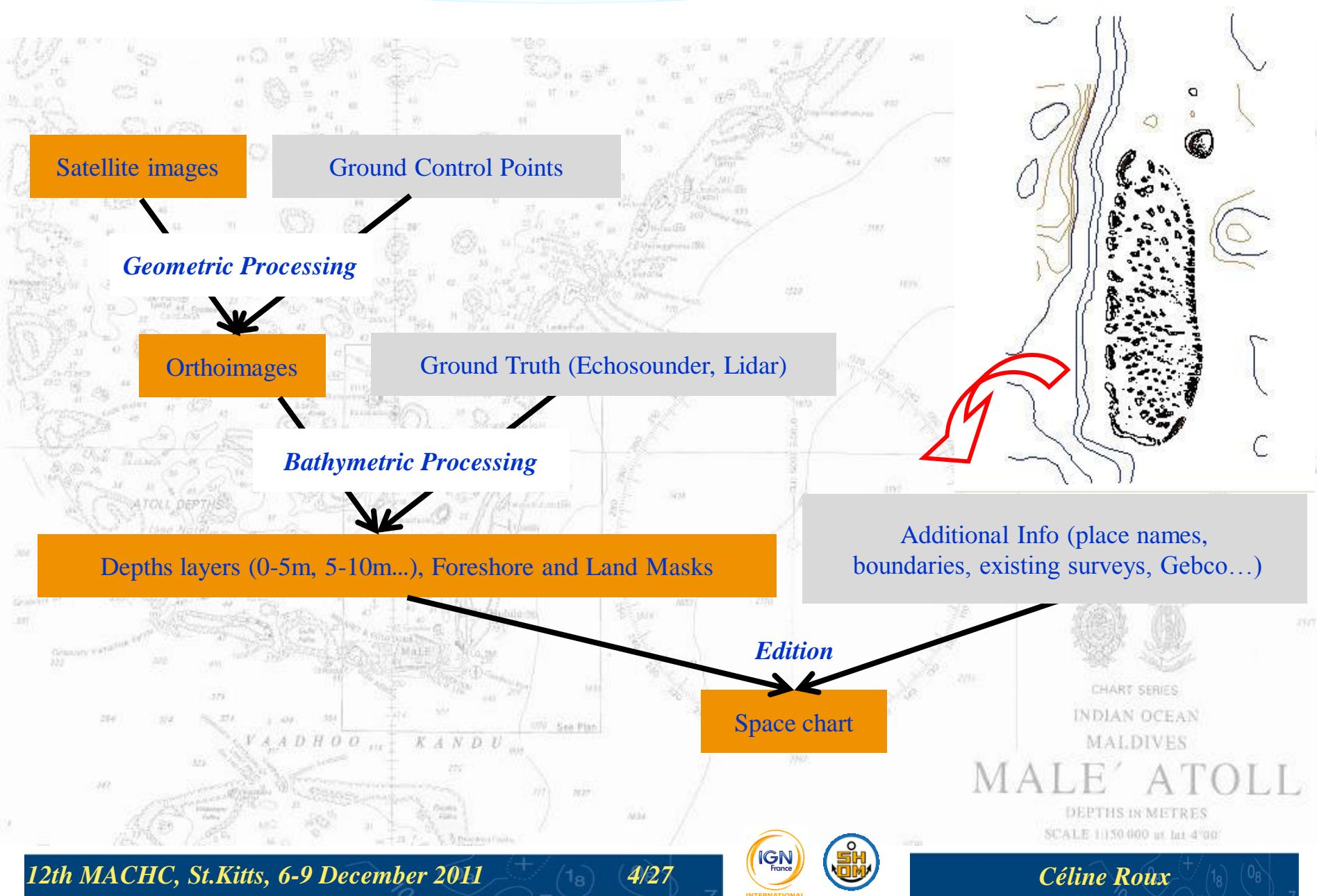
The RapidEye constellation

➢ *5 identical satellites*

➢ *Orbital altitude: 630 km in sun-synchronous orbit*
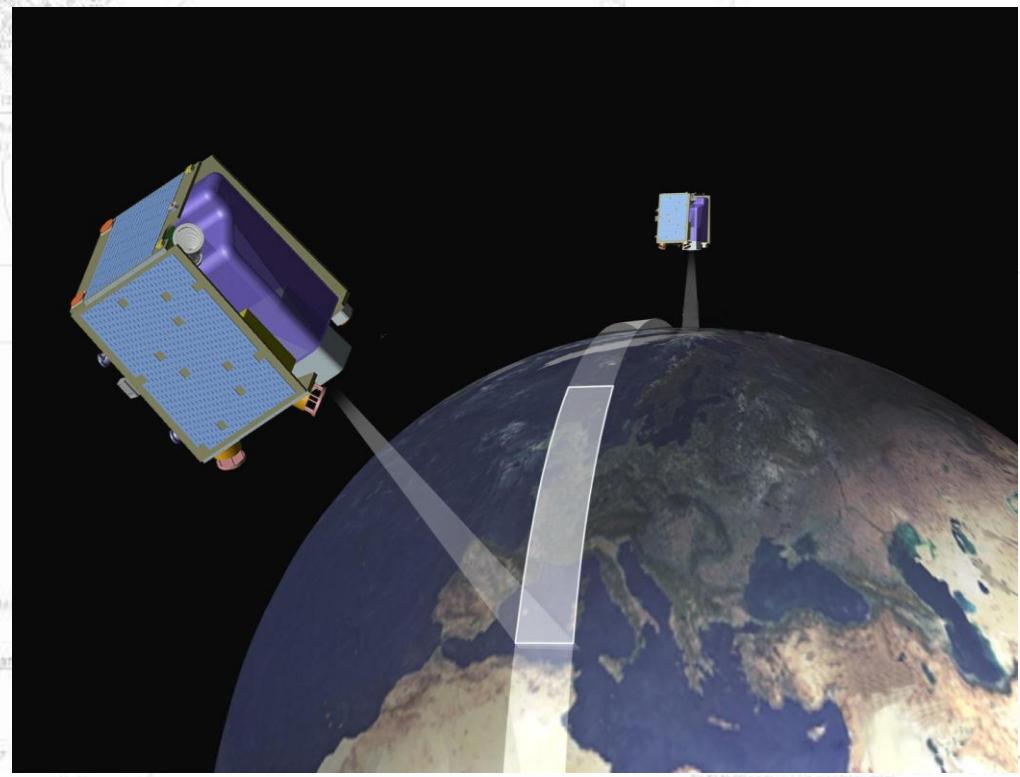
RapidEye satellite

- Ground sampling distance (nadir): 6.5m
- Pixel size (orthorectified): 5m
- Dynamic range: up to 12 bits (4096 levels, instead of SPOT's 255 DN)
- 5 spectral bands
- Swath width: 77 km
- Image up to 1 500 km long
- Spacecraft roll angle: +/- 25 degrees
- Revisit time: Daily off-nadir / 5.5 days at nadir
- Image capture capacity: 4 million km2/day
- 2 billion km2 archived since launch in 2009
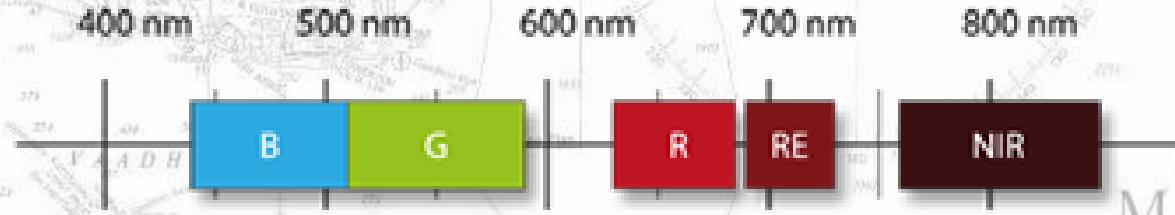
RapidEye coverage

Imaging Frequency: Number of images taken

- 1 - 6
- 7 - 12
- 13 - 24
- 25 - 48
- 49 - 350

RapidEye
Delivering the World

# Initial attempt with Spot 5 Images

➢ *Tasking from 08/2010 to 01/2011*

➢ *No image available within SHOM stringent specifications*

Céline Roux
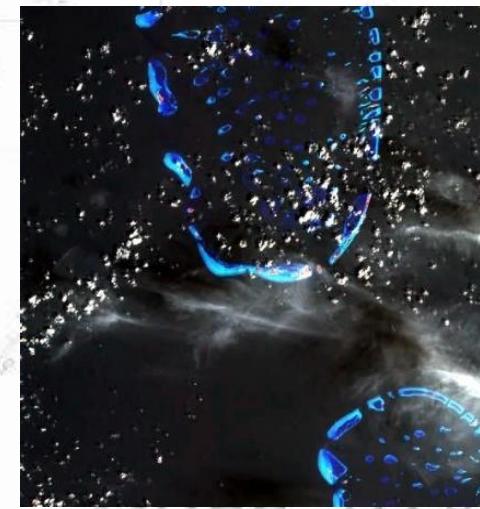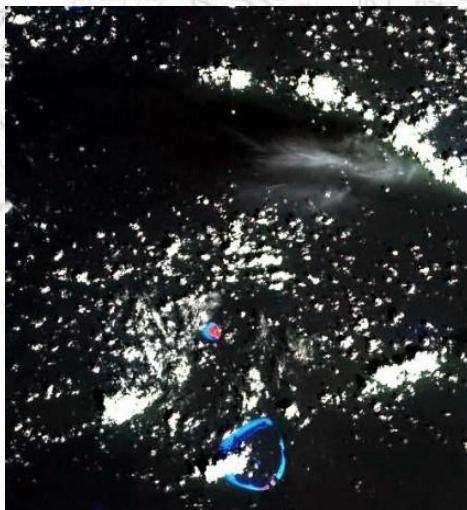
Ari Atoll – RapidEye images attempts

> *Several attempts made and rejected*
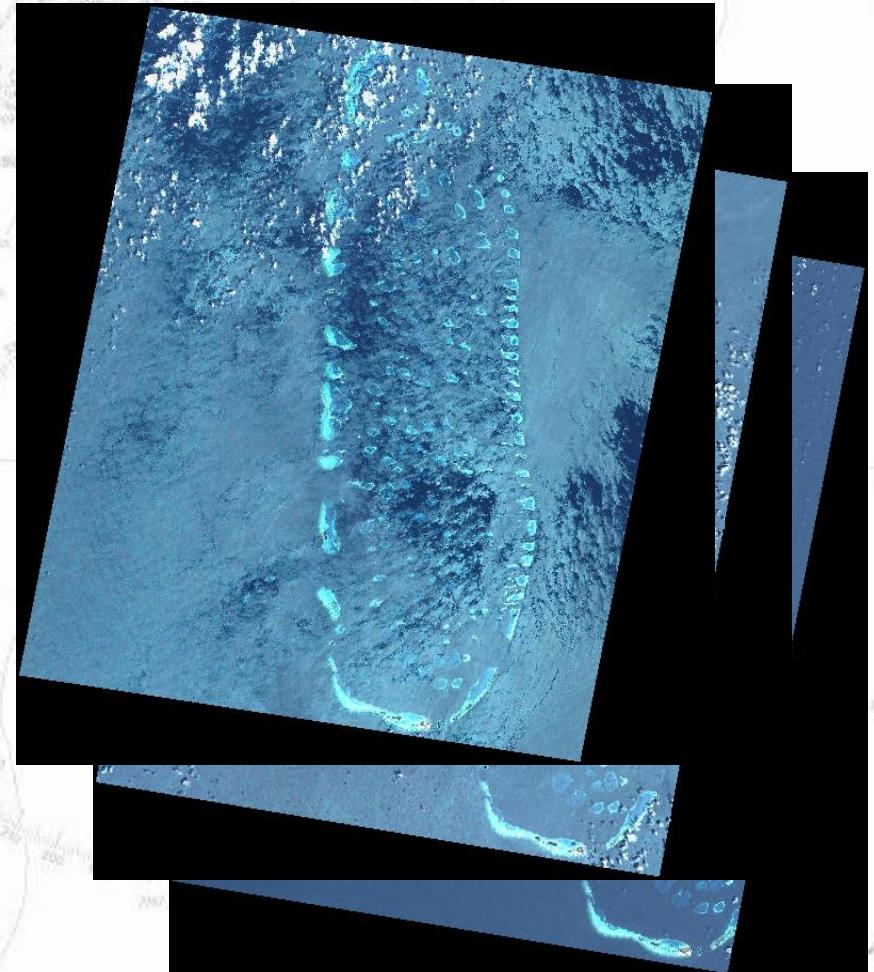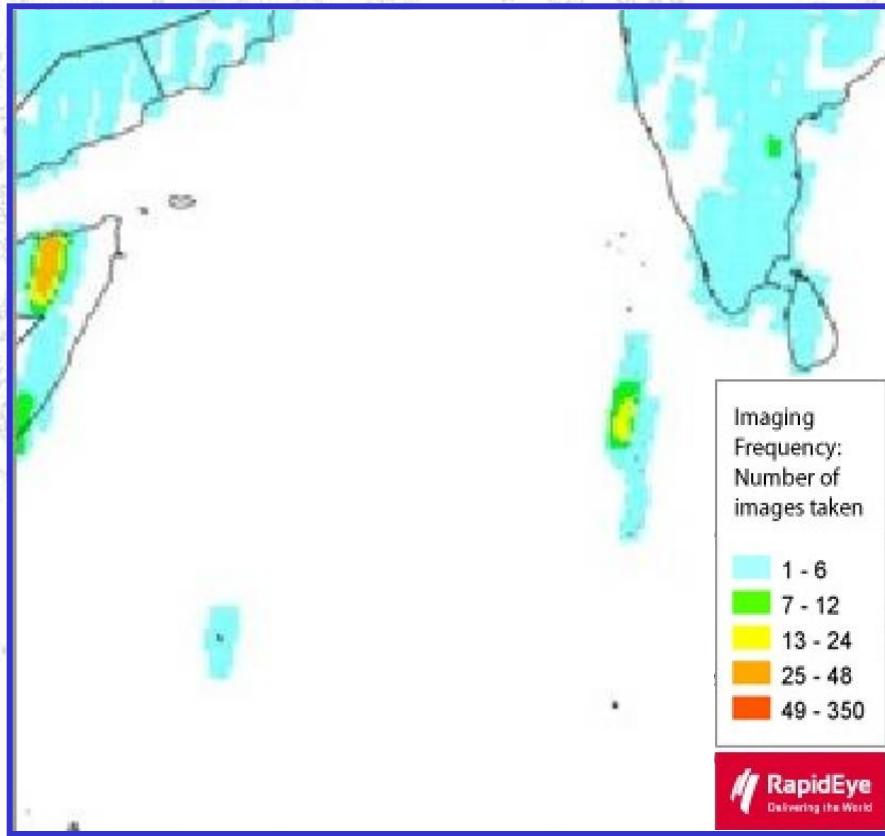
Final images selection

➤ *2 images selected*

14/02/2011

06/02/2011

MALE' ATOLL

DEPTHS IN METRES

SCALE 1:150 000 at lat 4°00'
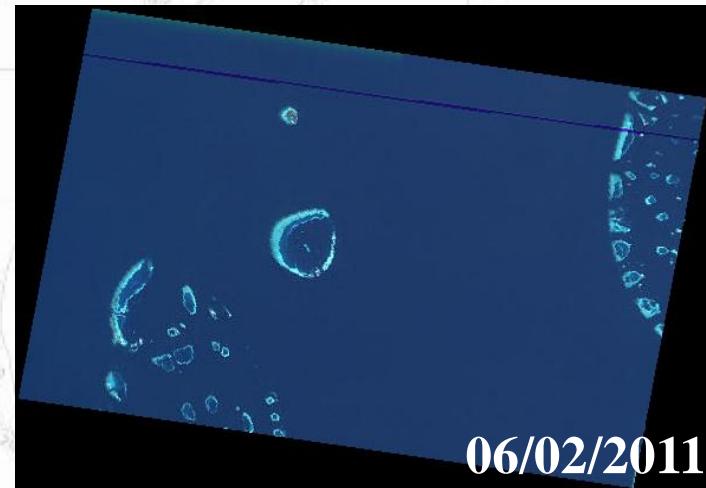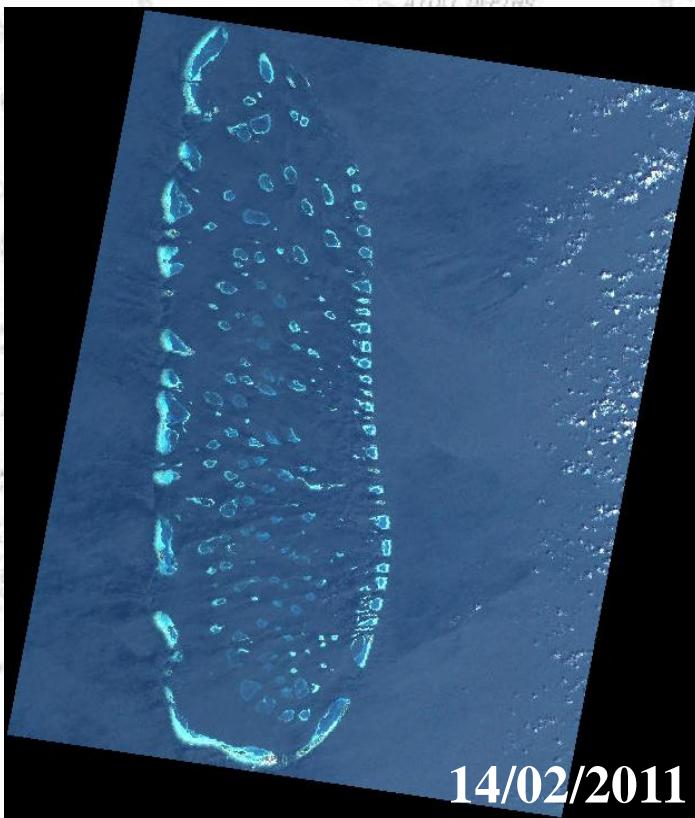
Block Adjustment

➤ *Ground control points on existing mosaic of aerial images*

Pt	Colonne (p)	Ligne (p)	X (m)	Y (m)	Poids	r.norm (p)	r.lig (p)	r.col(p)
20	6 735.00	8 494.88	274 184.00	415 473.00	1.00	0.66	-0.66	0.02
21	7 055.00	10 982.50	272 879.50	399 314.03	1.00	0.22	-0.18	0.14
22	6 883.00	11 490.75	271 122.00	396 222.00	1.00	0.11	-0.02	-0.11
23	6 241.72	6 945.71	273 158.00	425 792.00	1.00	0.50	0.50	-0.05
24	6 545.25	7 883.90	273 808.00	419 538.00	1.00	0.42	-0.41	0.10
26	7 031.60	10 005.83	274 040.00	405 568.00	1.00	0.58	0.57	0.08
27	7 029.55	9 285.86	274 985.49	410 167.13	1.00	0.27	0.20	-0.18

Céline Roux

Orthorectification

Processing of the 2 orthoimages:

➤ *Images projected in Mercator WGS 84 to meet mariners' requirement*

➤ *Pixel size = 5m*
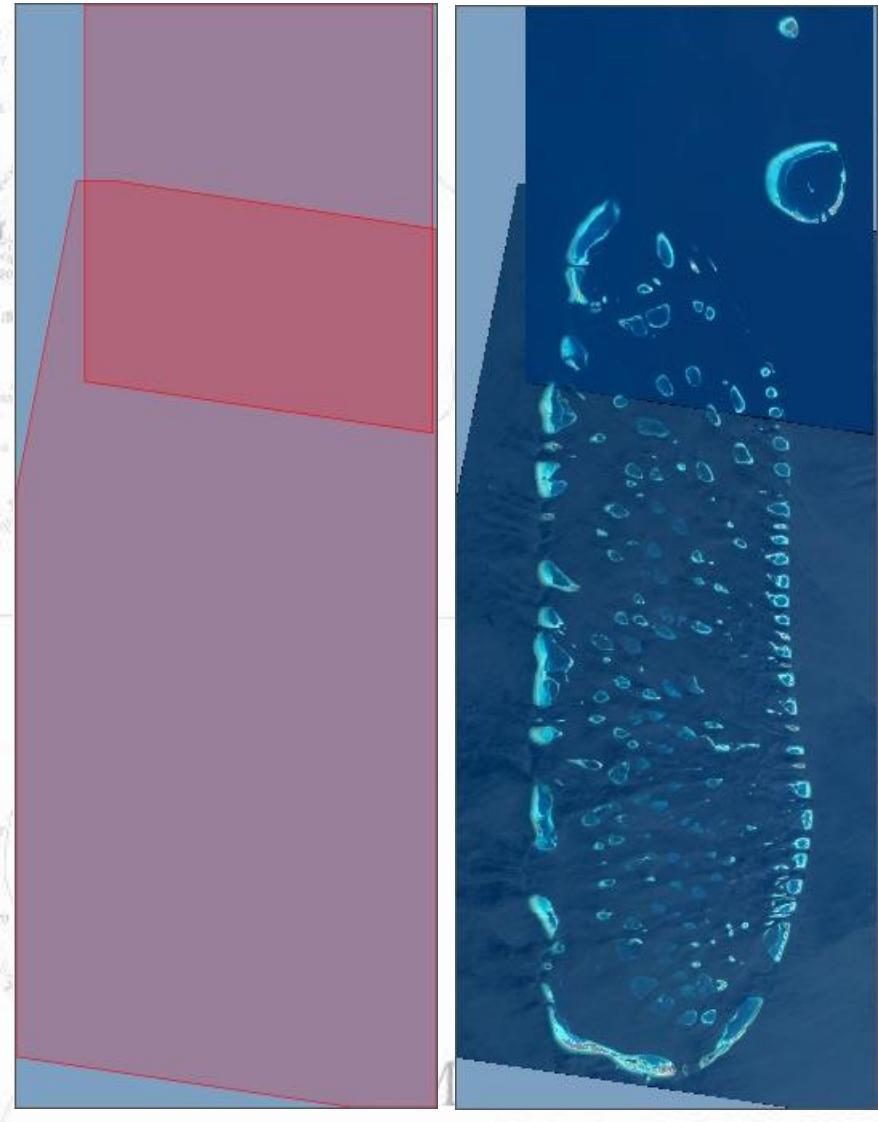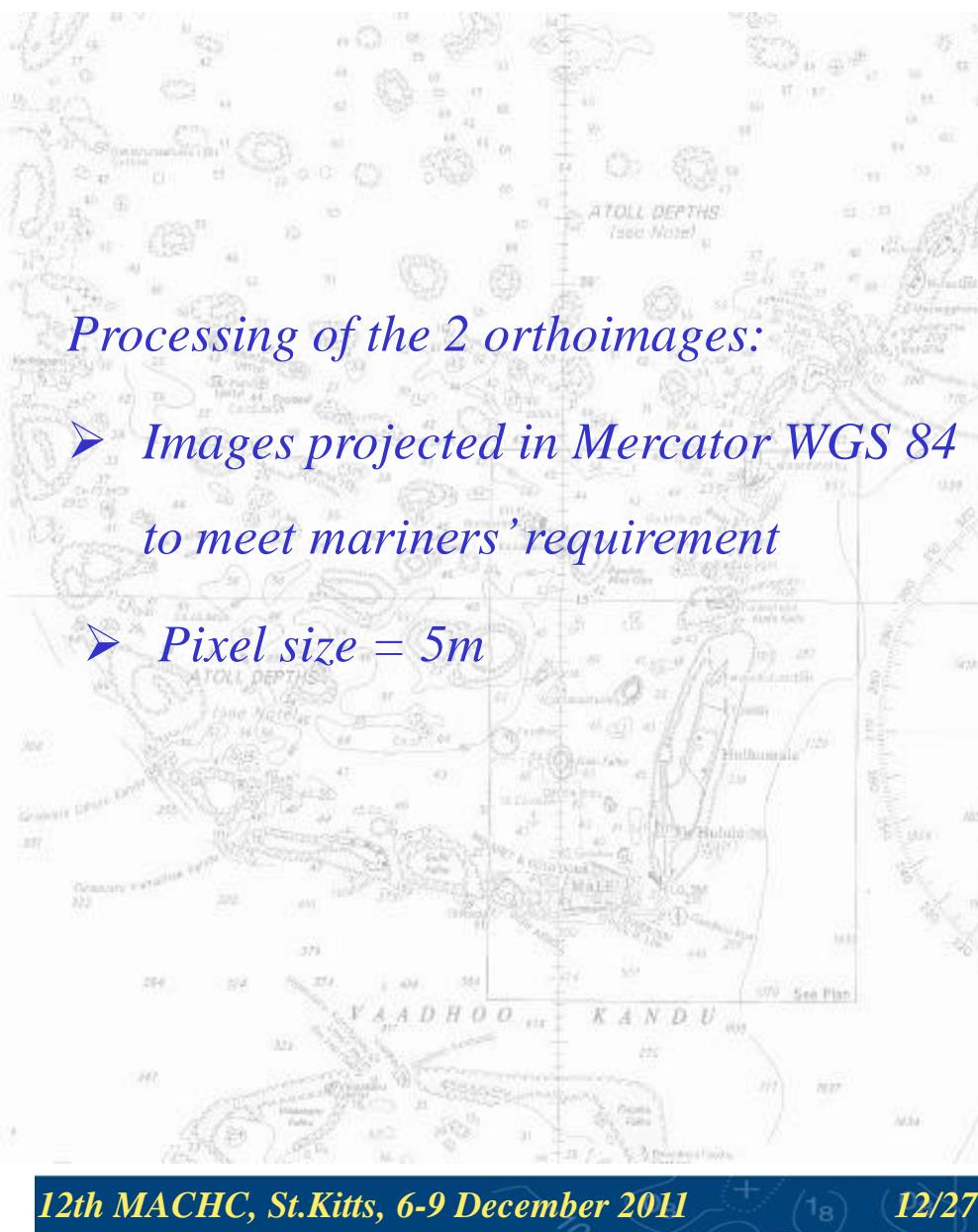
# *Overlaps check*

> *Perfect superimposition of overlapping areas*

> *Final Accuracy = 2 m*

GLOSS tide gauges
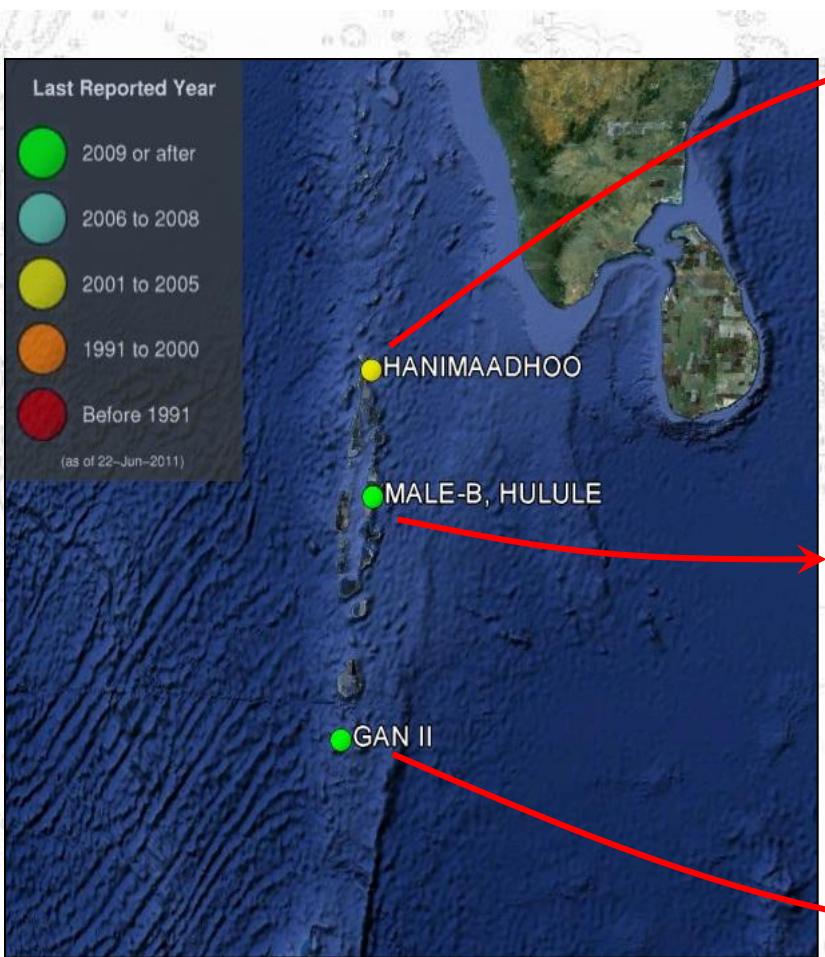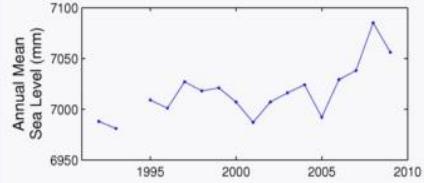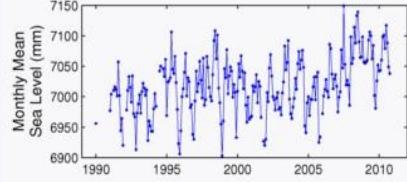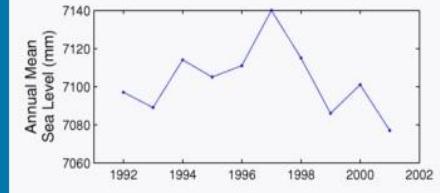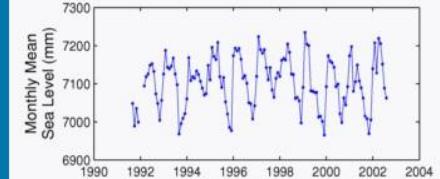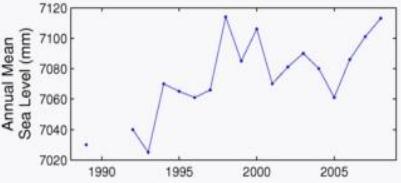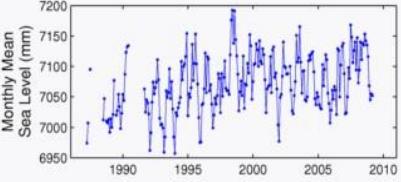
Tidal range determination

➤ *<http://easytide.ukho.gov.uk/EASYTIDE/EasyTide/SelectPort.aspx>*

➤ *Mixed tide – maximum tidal range: 1.2 metre*
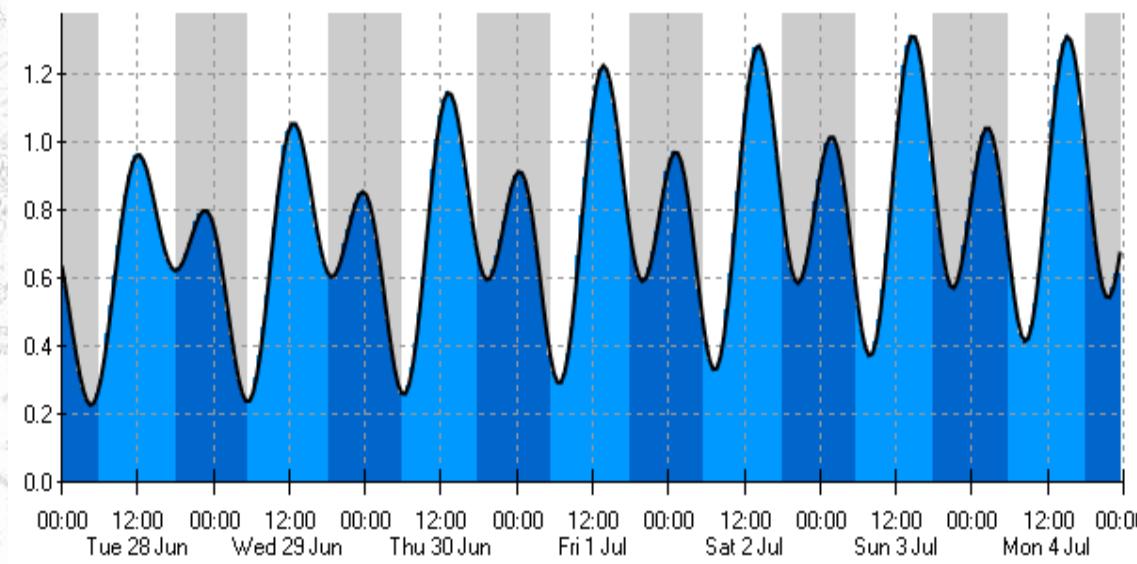
Field determination of chart datum

Ellipsoid

$H_{Benchmark}$ **(ellipsoid height)**

H_e **live reef face: - 95.370 m**

H_e **Sounding datum: -95,570 m**

Benchmark (x,y,z)

$H_{Benchmark}$ **above water level at time of check**

HWS

Water level at time of check

Tidal range

H_{reef}

Mean level of live reef face

20 cm

LWS

Sounding datum

$H_{Benchmark}$ **above sounding datum**
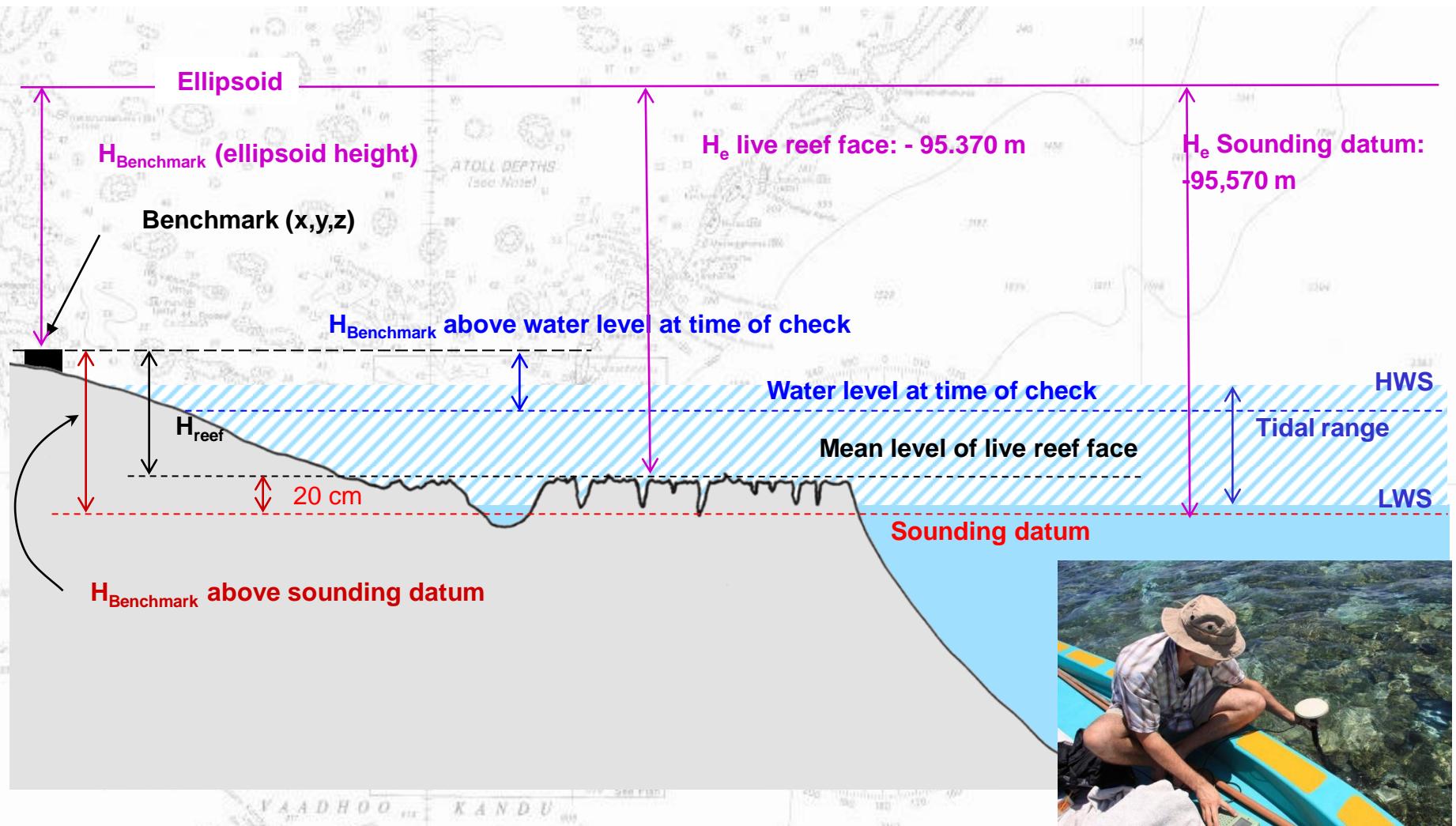
➢ *Mean level of live reef face (after 38 measurements): - 95.37 m (σ = 0.057 m)*

Malé observed tide
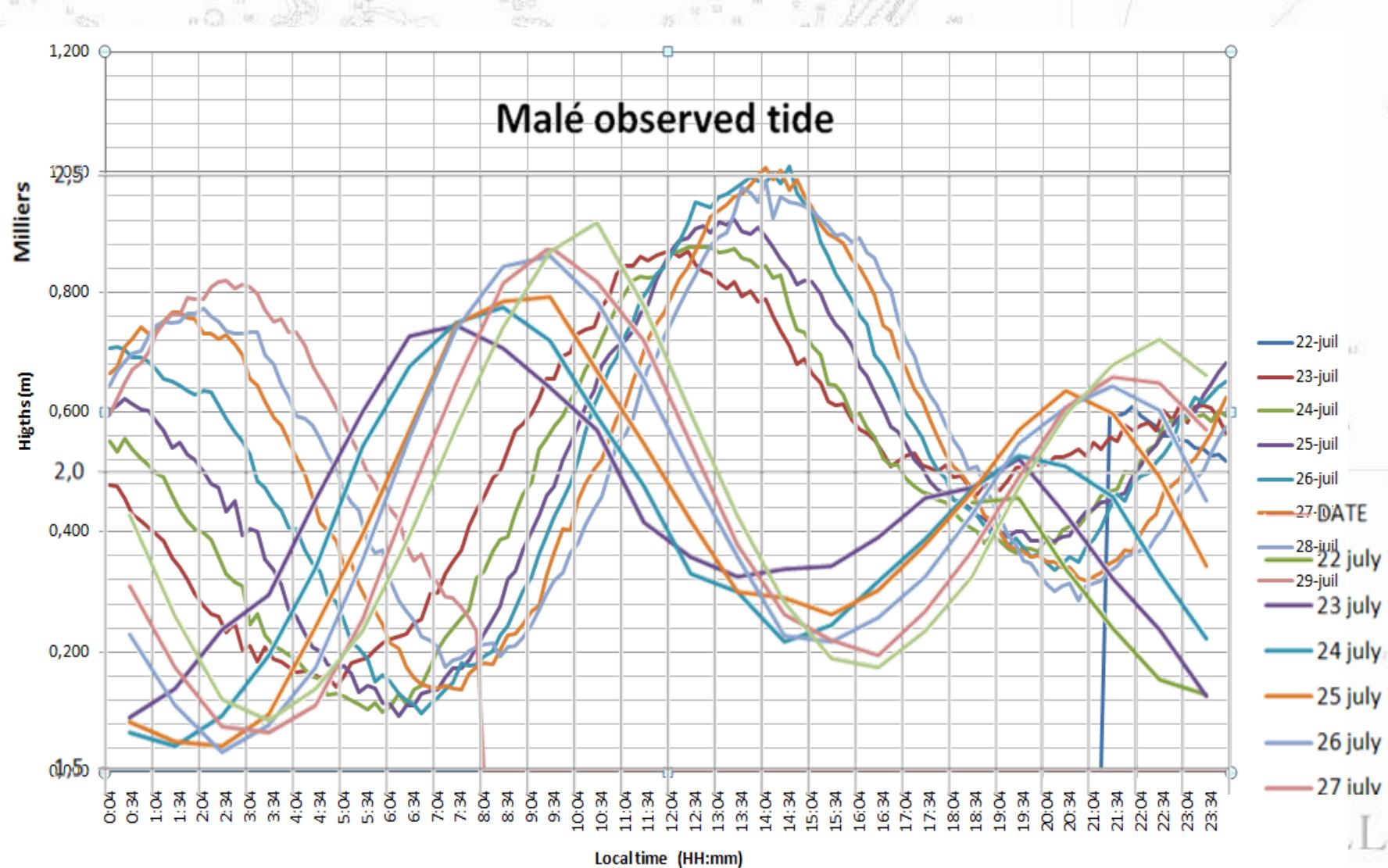
Tide-by-tide simultaneous comparison

> *22nd to 29th July 2010 – Heights in metres*
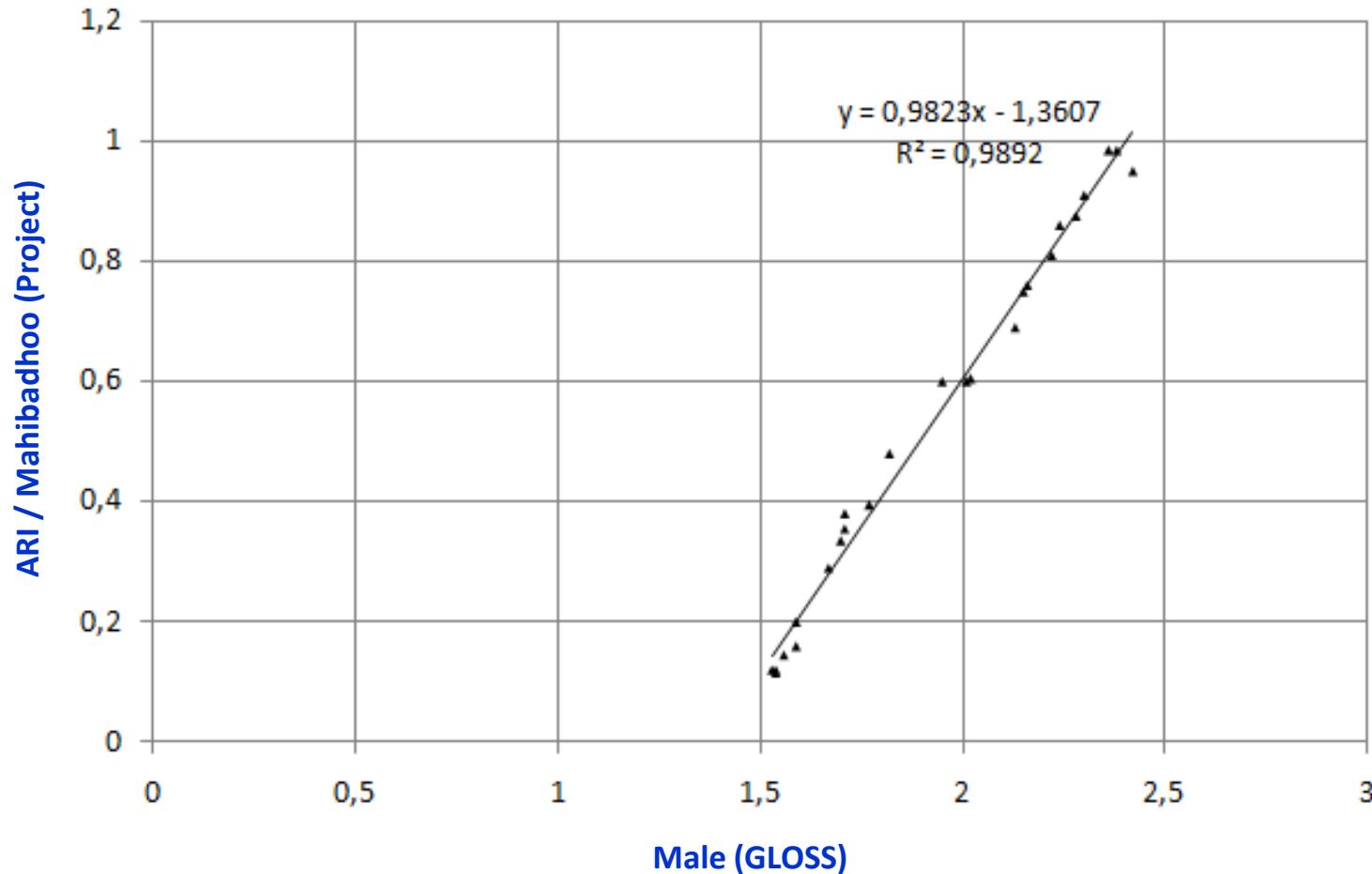
Processing

➢ *Harmonizing Image radiometry* ⇨ *same colour of deep water everywhere*

➢ *Generating Land Mask and coastline* ⇨ *RapidEye band 5 (NIR)*

➢ *Generating Inter-tidal Mask* ⇨ *RapidEye band 4 (RedEdge)*

➢ *Computing the Bathymetric Model (depth contours):*

    ➢ *Processing performed by applying thresholds to RapidEye band 2 (Green)*

    ➢ *Transformation of image by using the Lyzenga algorithm (elimination of influence of water column) : $Z = A \cdot \ln(R - R_{inf}) + B$, where Z: calculated depth, R: pixel value, R_{inf}: deep water value*

    ➢ *Model calibration by using precise sensors (Lidar or echosounders)*

Threshold Contour determination

Depth contour

Threshold

Shoreline det...
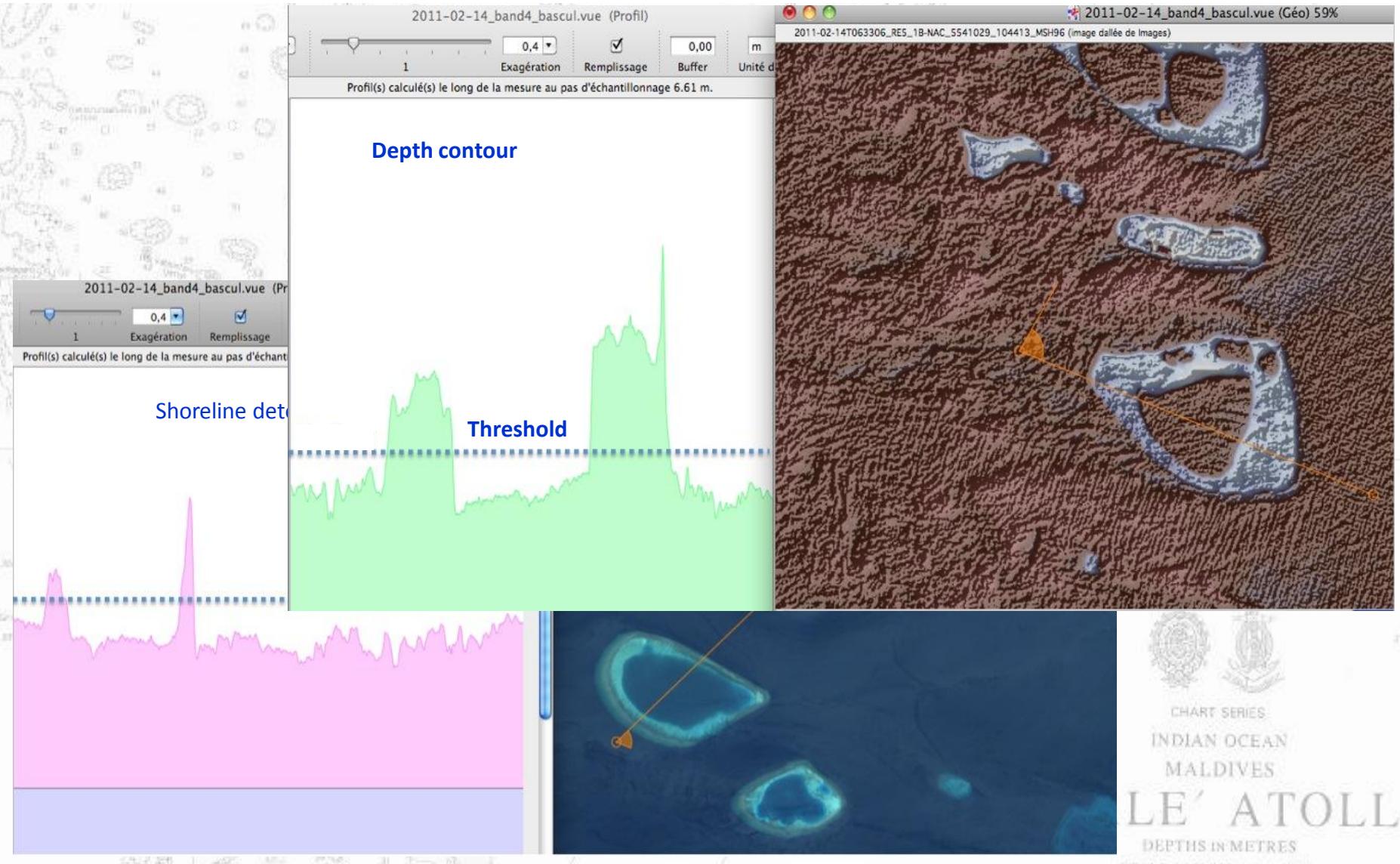
Depth Processing

5 layers:

➢ *Land*

➢ *Inter-tidal*

➢ *0-5 m*

➢ *5-10 m*

➢ *10-15 m*
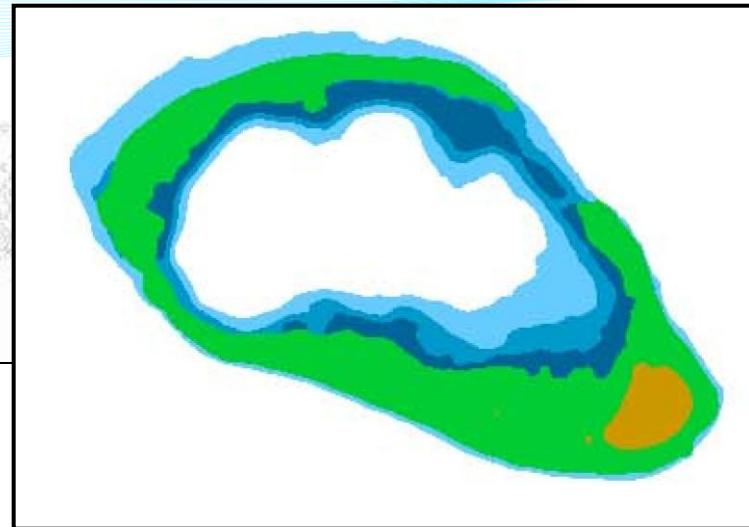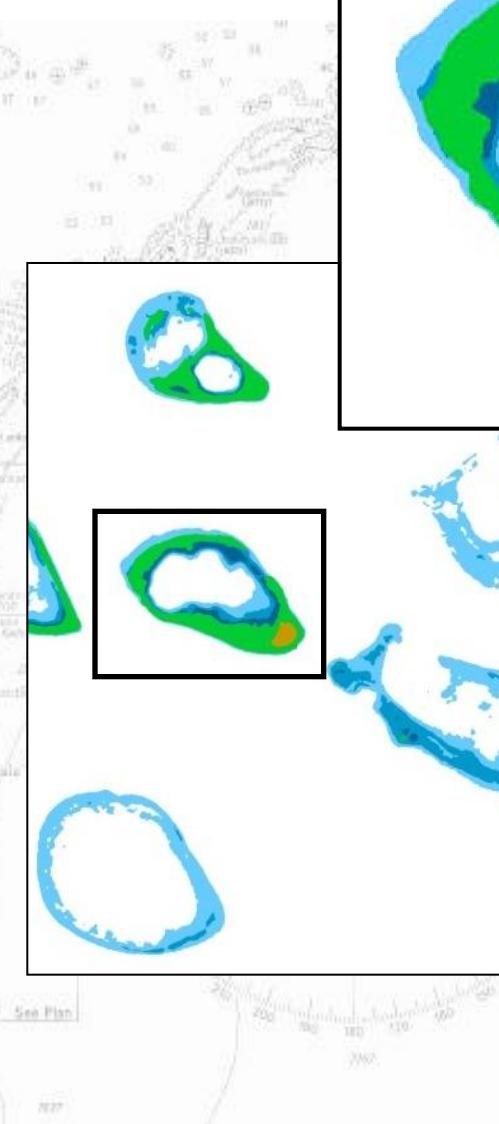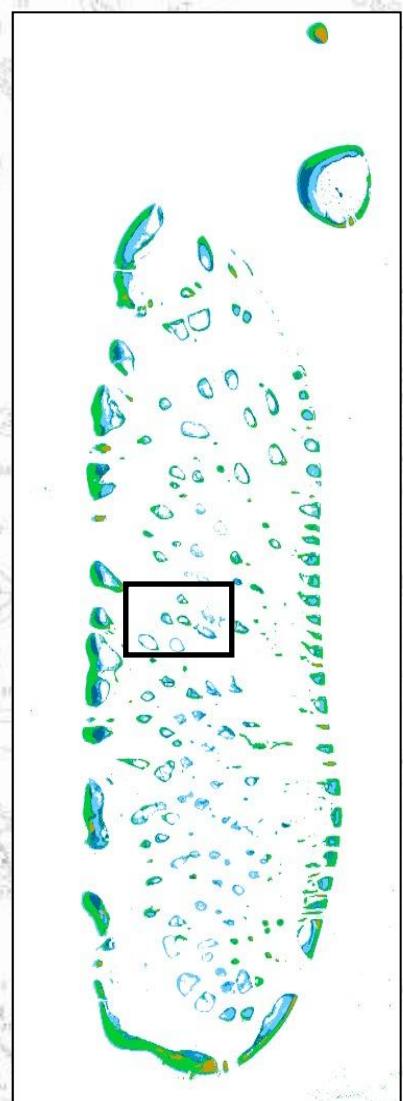
Resulting space charts

- *1/100 000 chart covering*

   Alifu & Rasdhoo atolls
- *1/50 000 chart of South Alifu*
- *1/50 000 chart of North Alifu &*

   Rasdhoo
- *1/10 000 chart of Hangnaameedhoo*
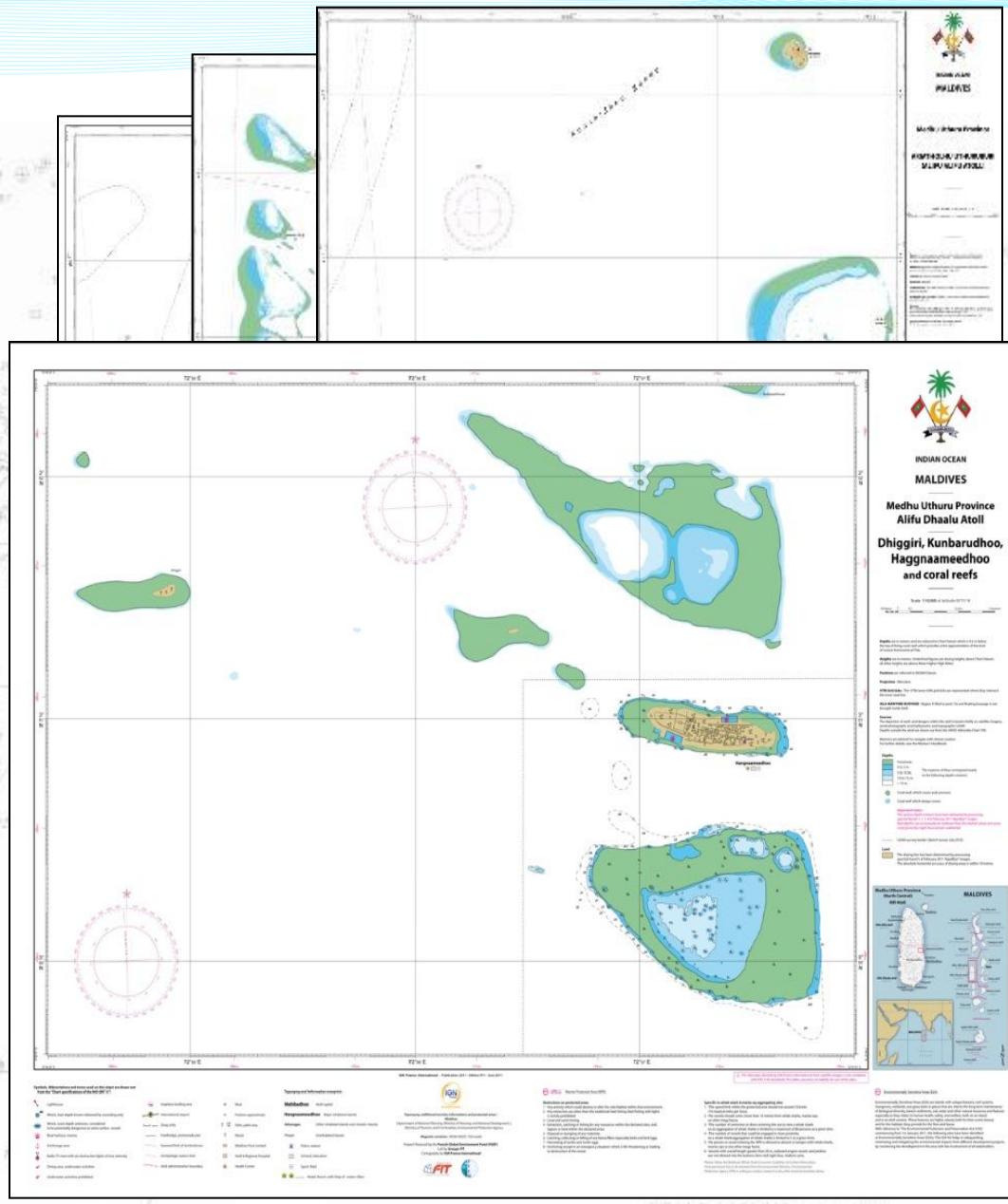
Cartographic overlay

➤ *Latitude, longitude & UTM 43 N*

➤ *Detailed chart legend*

➤ *Compass rose & magnetic variation*
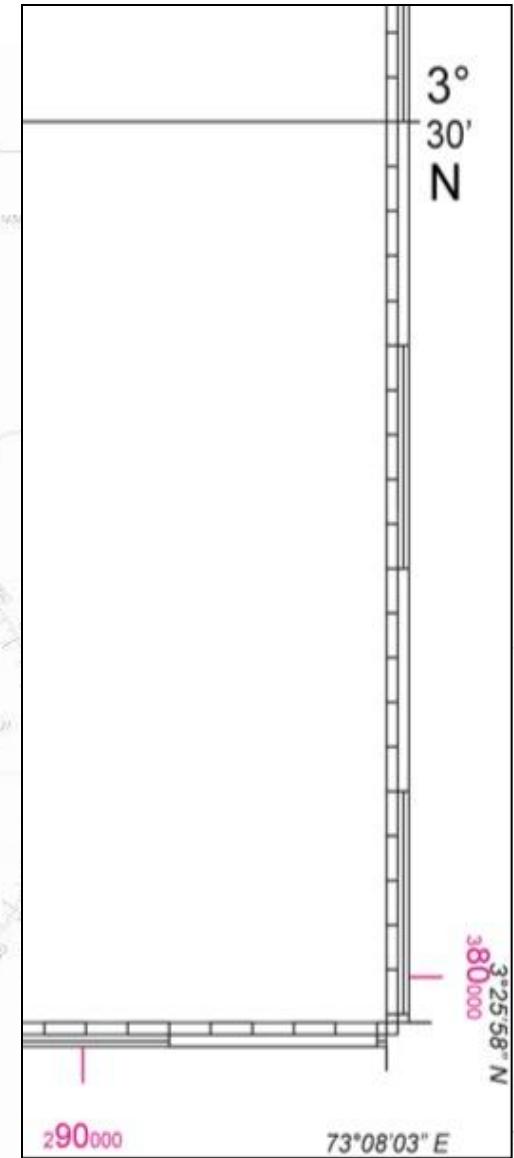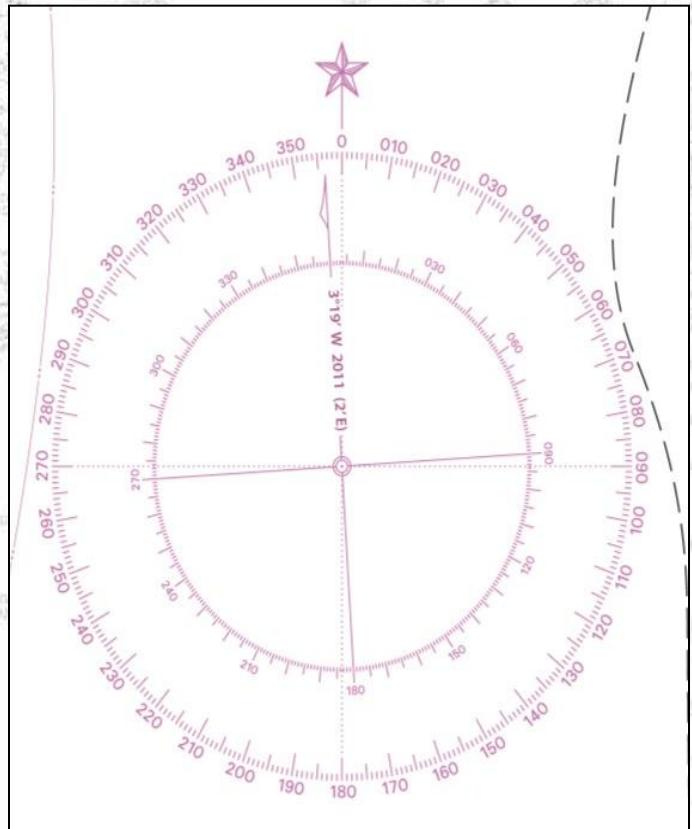
Conspicuous objects & topography

➤ *Using IHO publication 1 D*
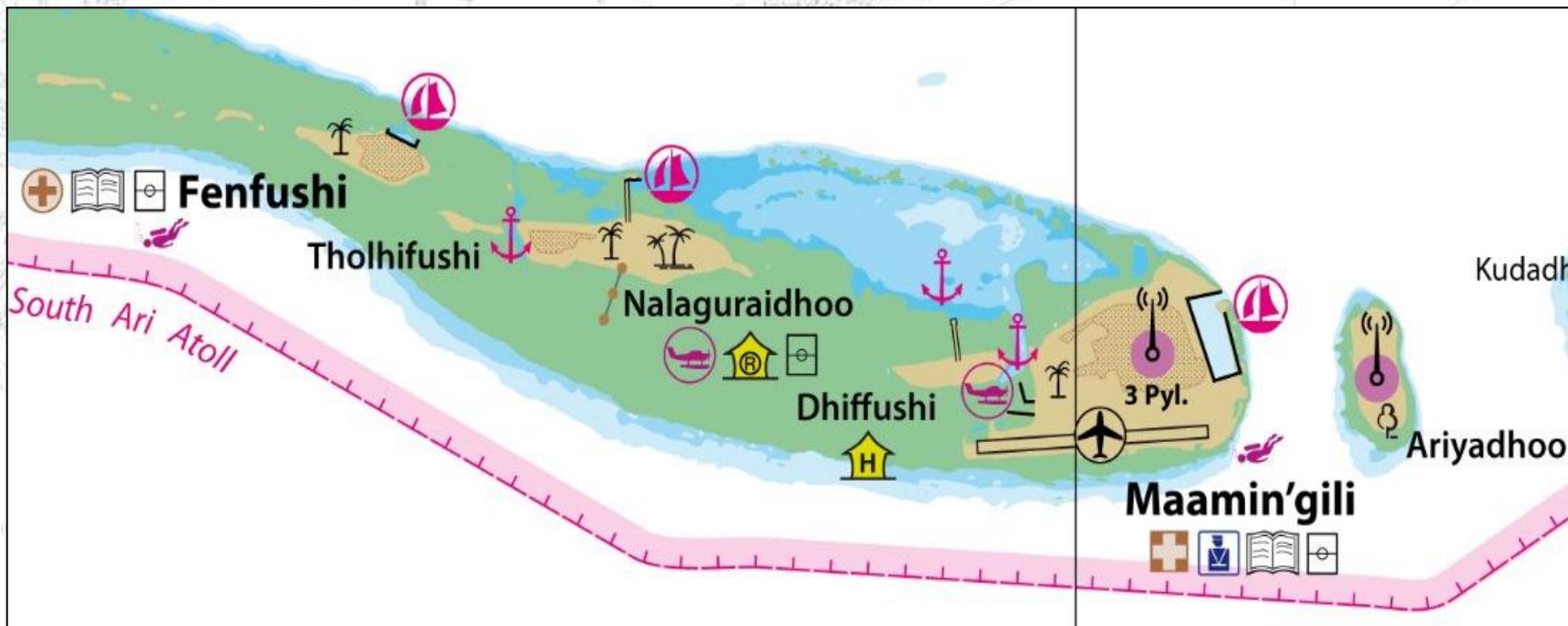
Example of Admiralty chart BA700

Surface to be covered : 32 200 km²

➤ **Step 1: Choice of satellite**

*RapidEye*
definition = 5m
1 pixel = 0.03 mm
(for chart scale 1:175 000)

➤ **Step 2: Fieldwork**

• *GPS* ★
Reference stations & control points (WGS 84)
Reference : Betio/DORIS

• *Tide* 〰
Reference : Betio Tide Gauge
Tide by tide simultaneous comparison with
temporary tide gauges
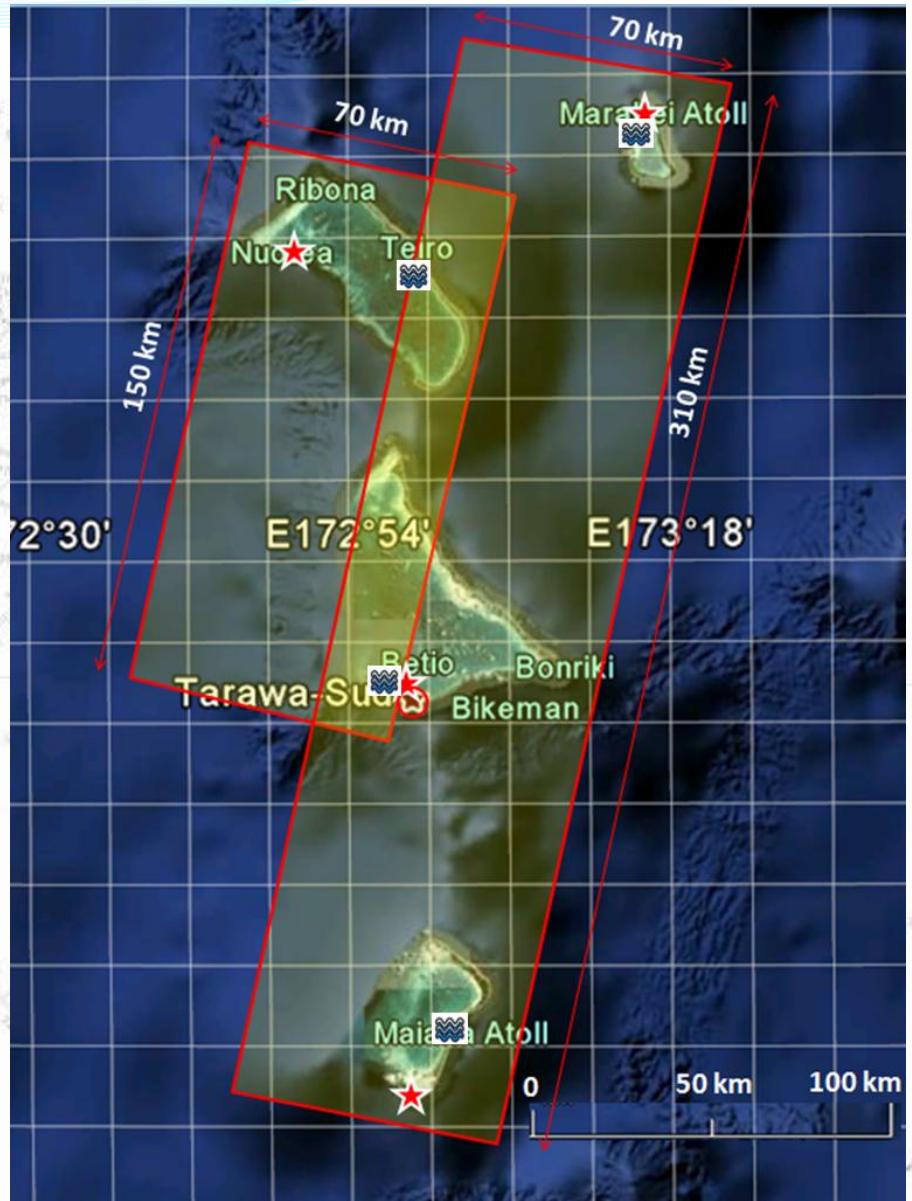
Example of Ari atoll

> *Step 3: Production of a minimum cartographic base*

- *Geometric processing*
- *Bathymetric processing*
- *Overlaying additional information*
- *Quality checks*

Total production time = 7 months

Average cost per spacechart = 100 k€

Cost per km^2 = 40 €
(vs 1 000 € with other survey methods)

DEPTHS IN METRES
SCALE 1:150 000 at lat 4°00'

Céline Roux
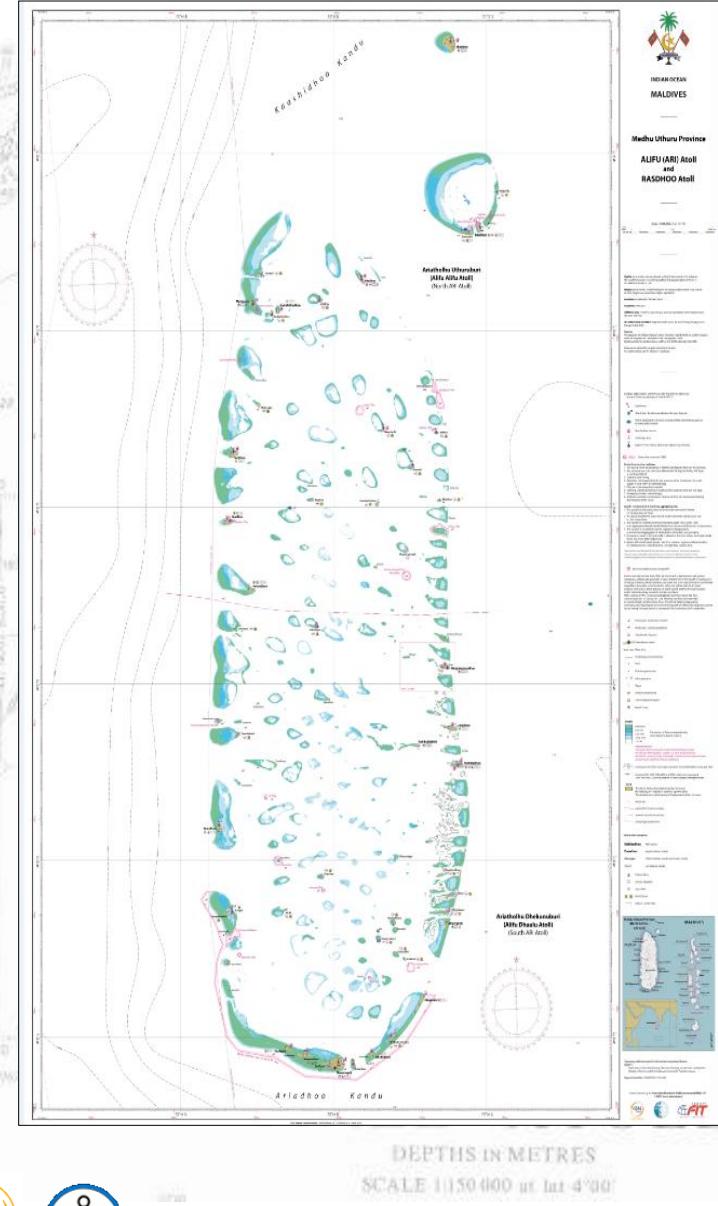
Thank you for your attention.