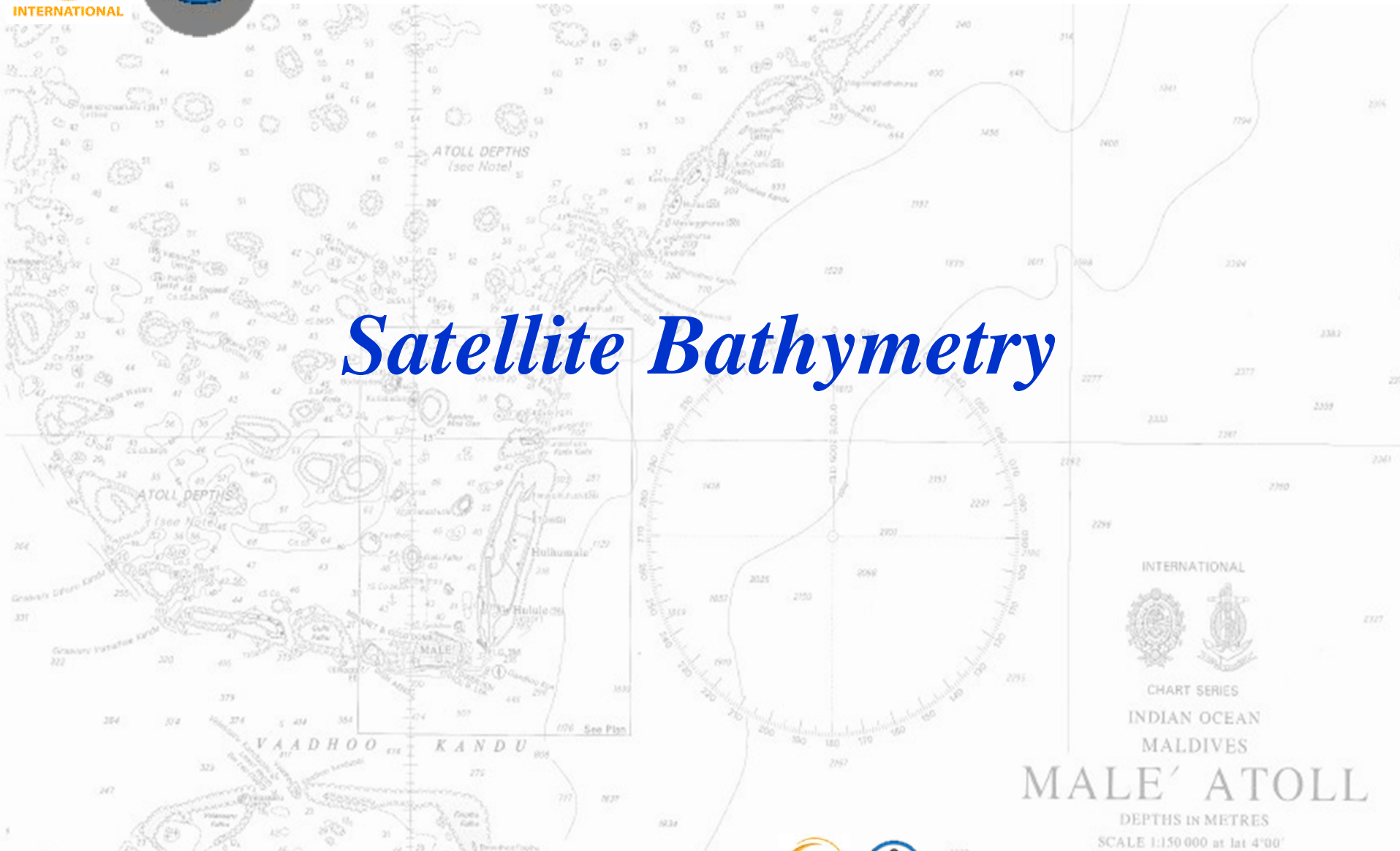




INTERNATIONAL



Satellite Bathymetry



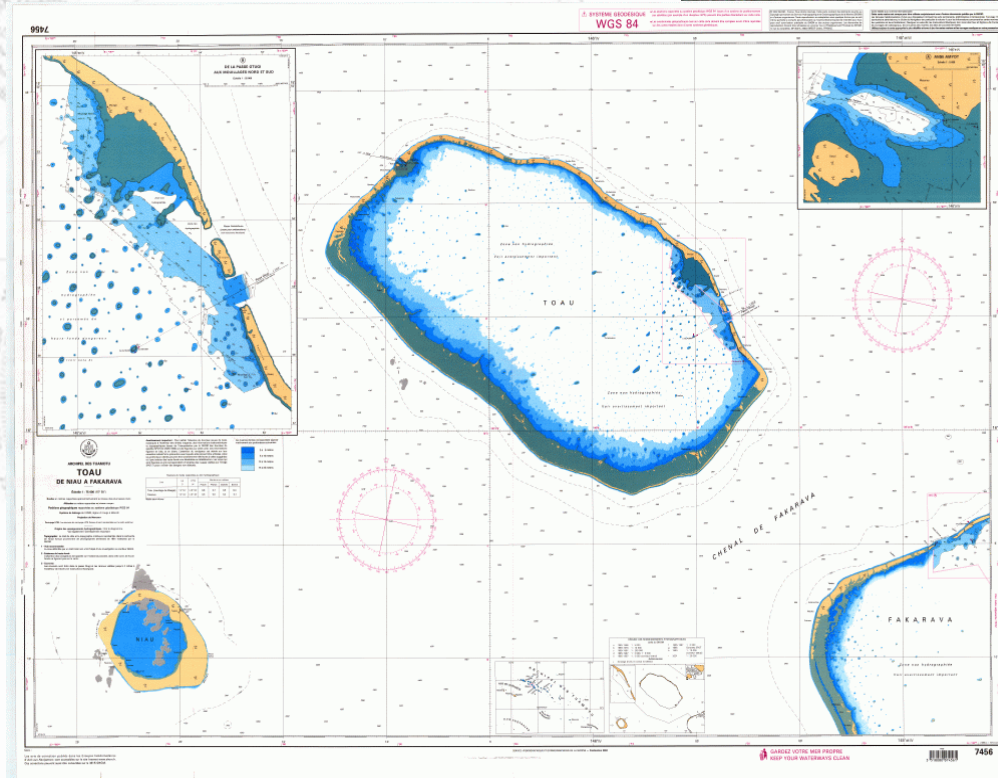
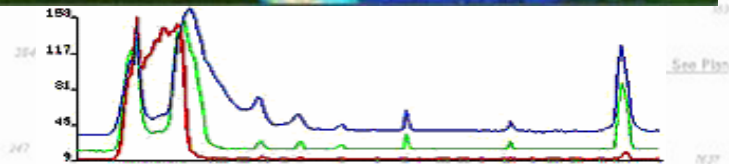
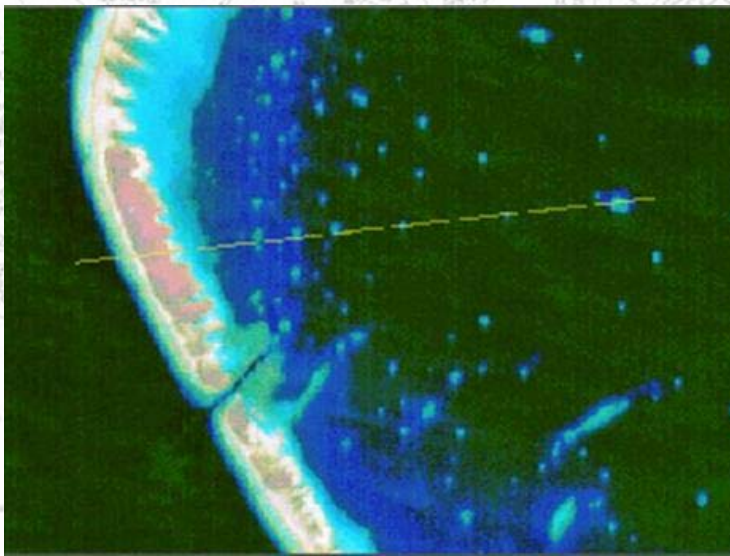
INTERNATIONAL
CHART SERIES
INDIAN OCEAN
MALDIVES

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

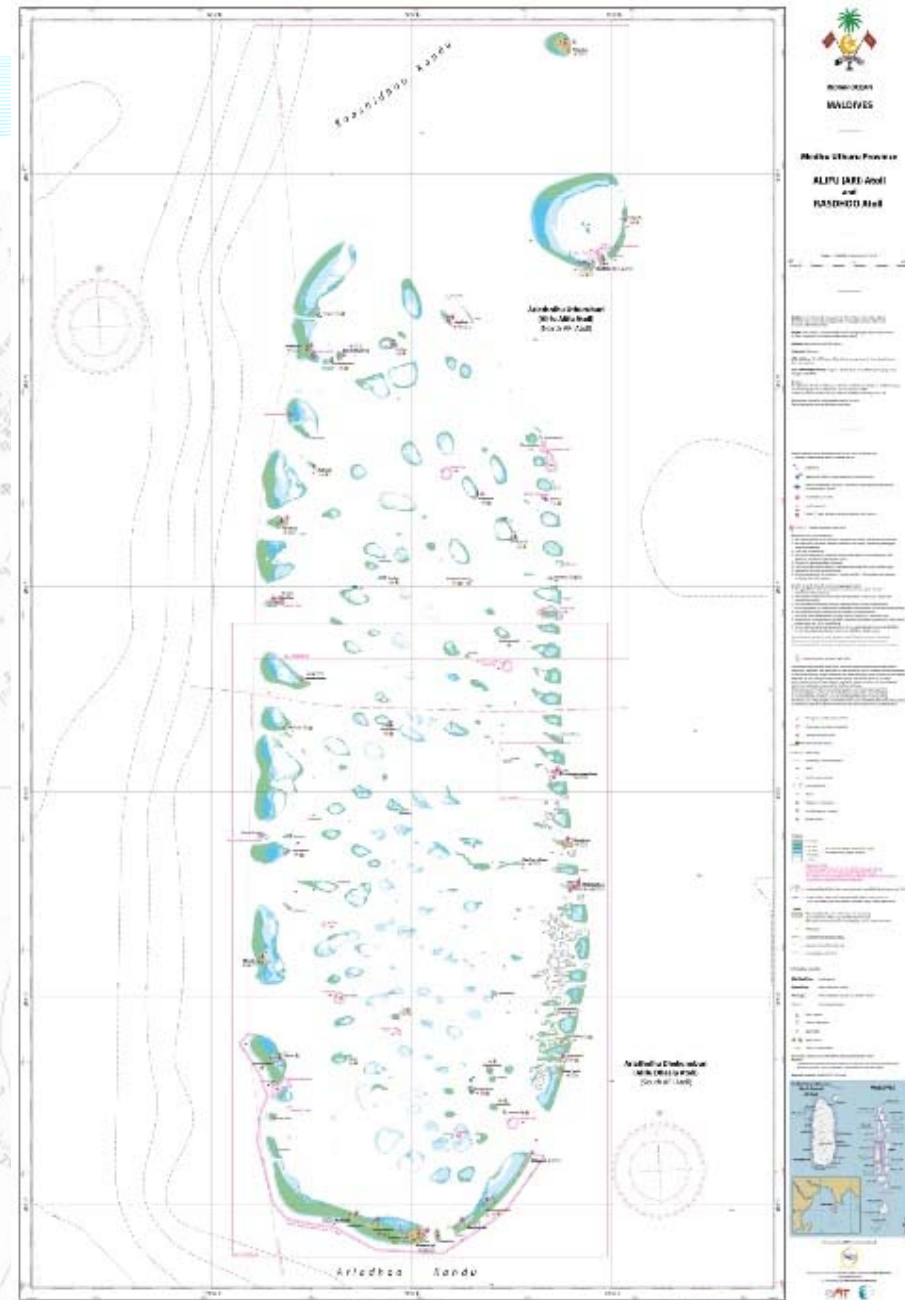
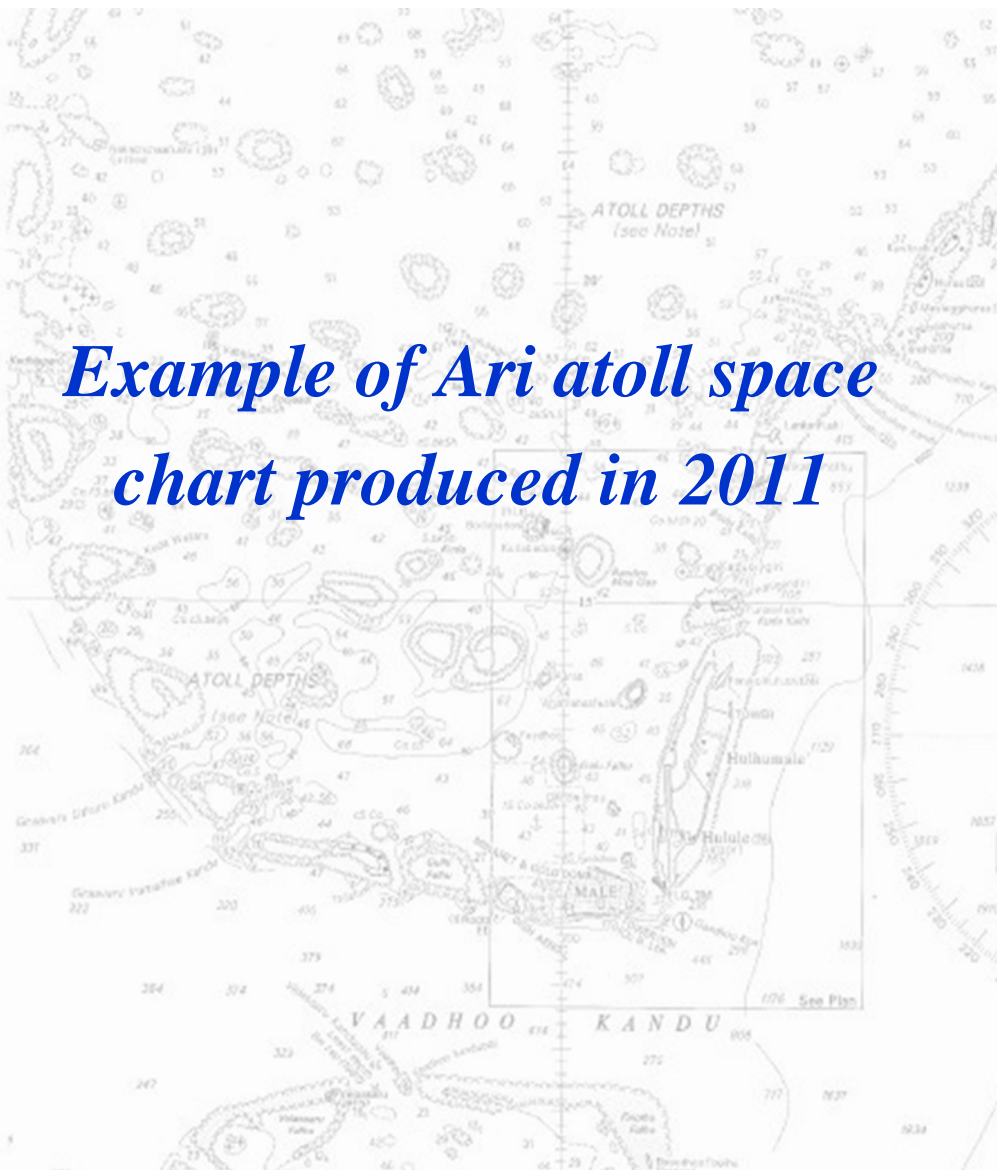


SHOM nautical navigation canvas

- 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)

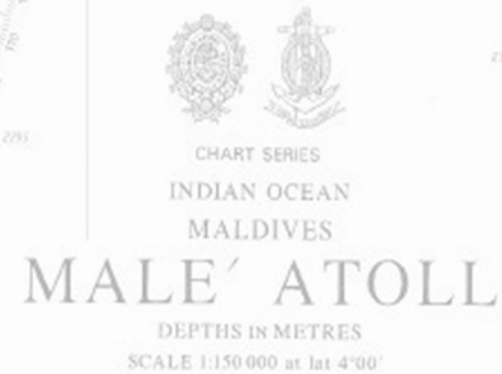
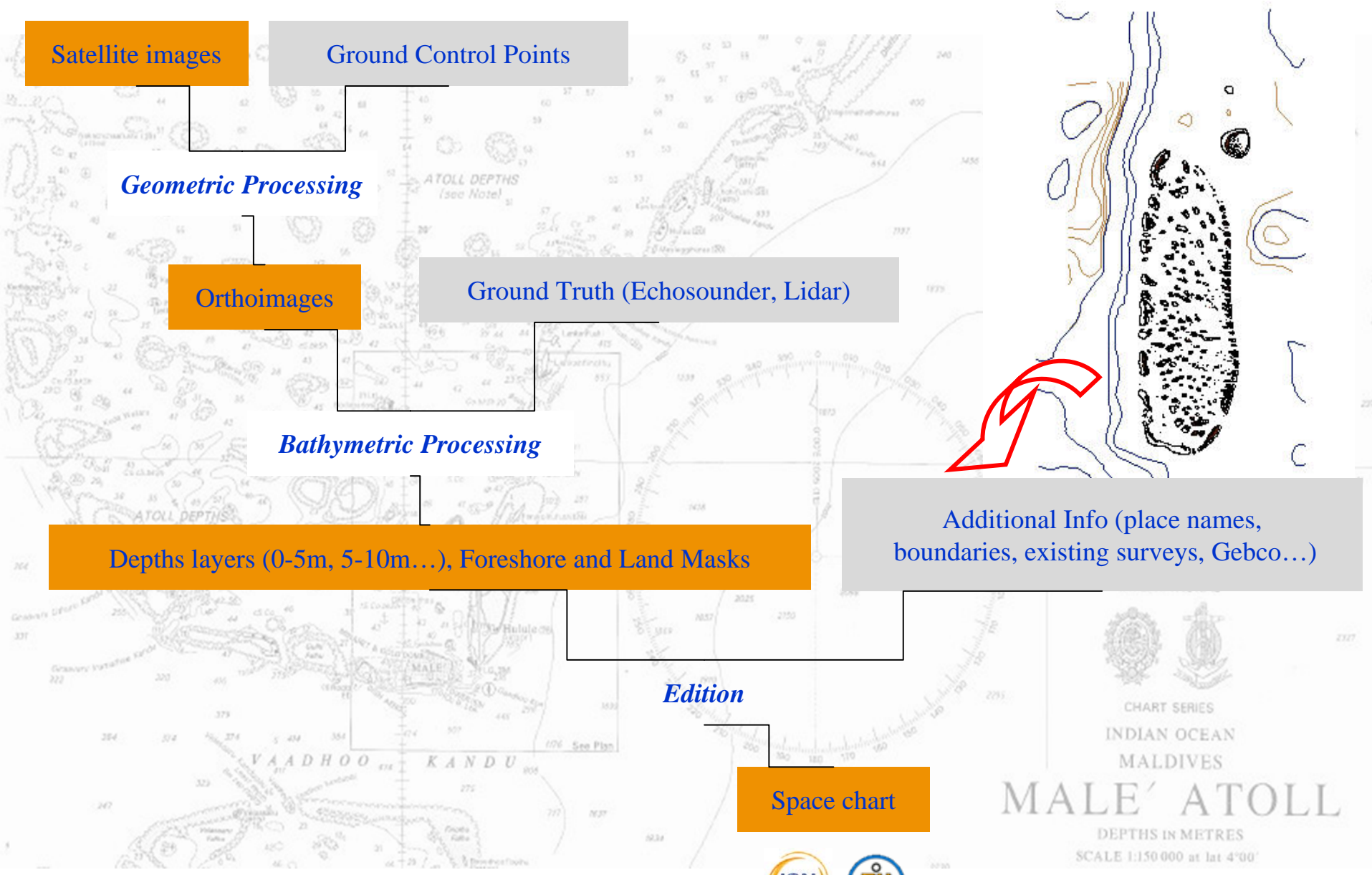
Bathymetric Processing

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

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

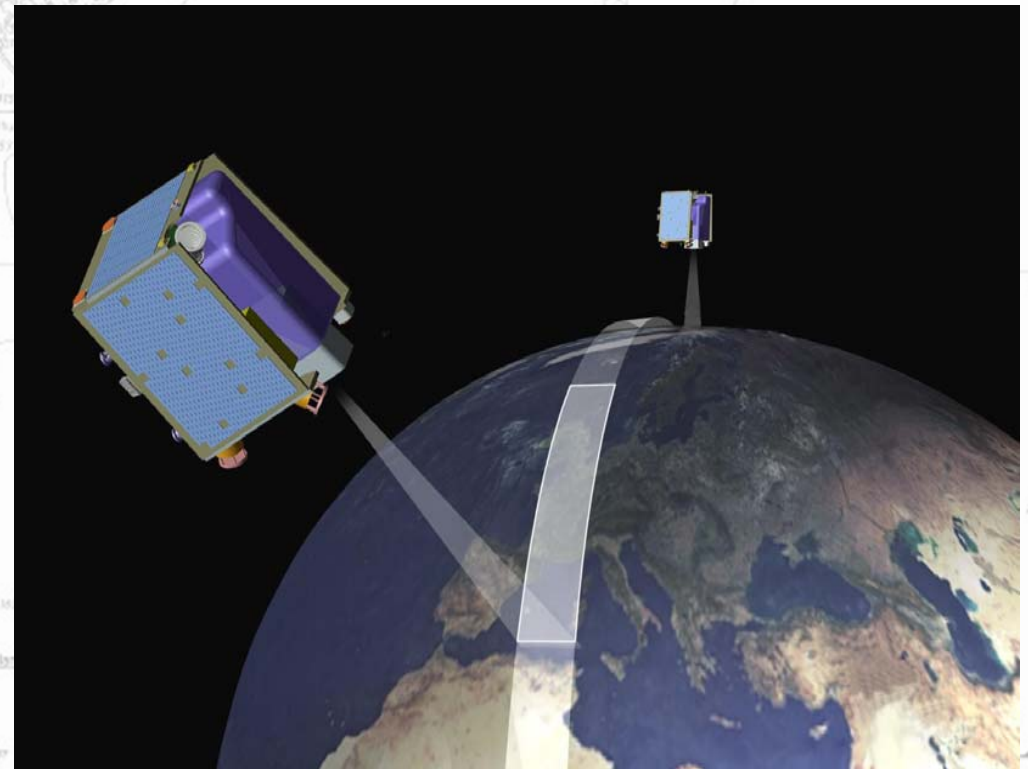
Edition

Space chart



The RapidEye constellation

- 5 identical satellites
- Orbital altitude: 630 km in sun-synchronous orbit



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

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

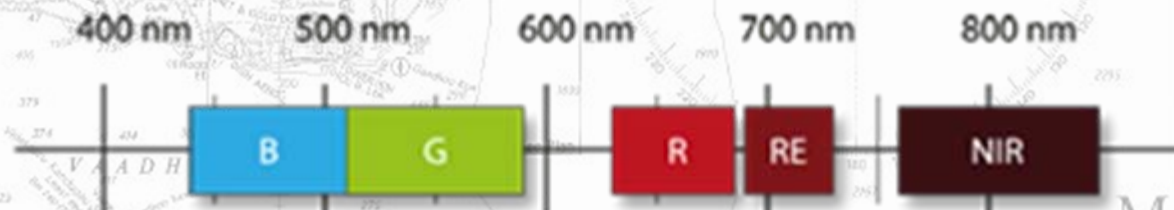


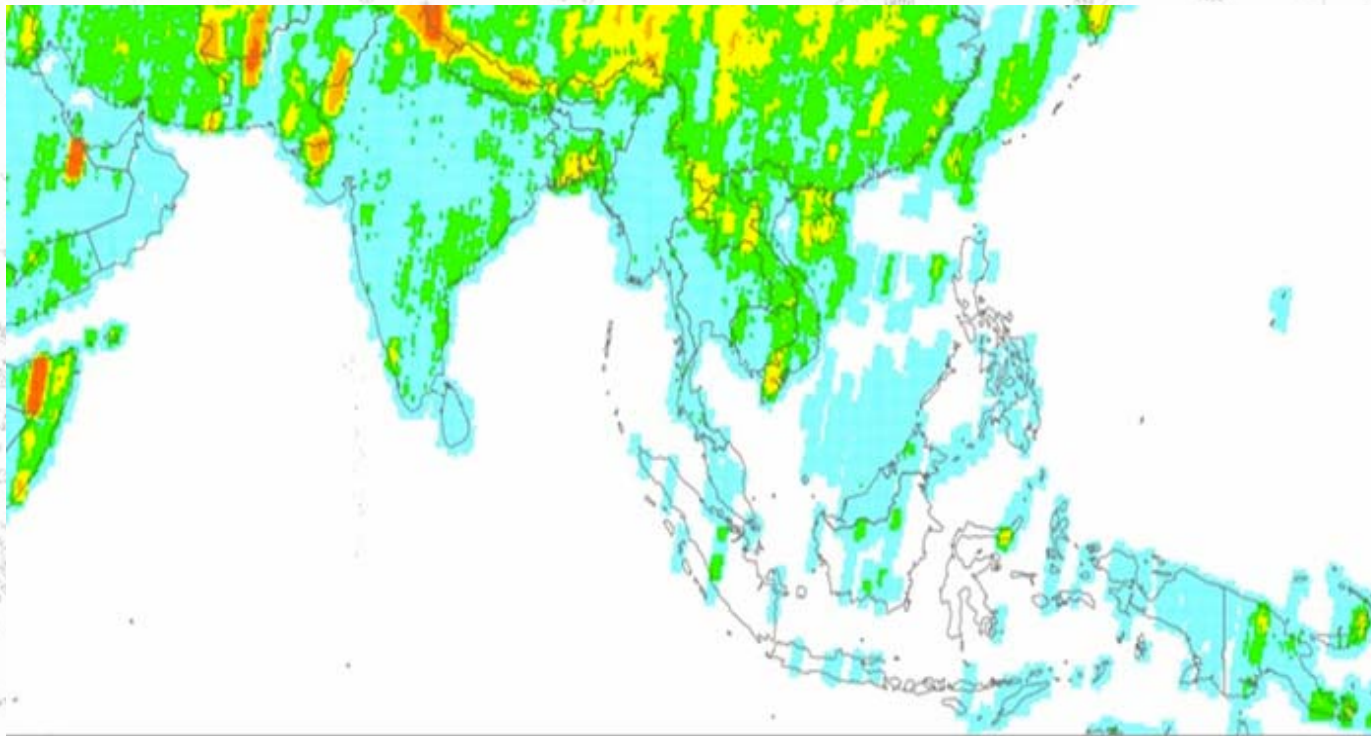
CHART SERIES
INDIAN OCEAN
MALDIVES

MALE' ATOLL

DEPTHS IN METRES

SCALE 1:150 000 at lat 4°00'

RapidEye coverage



Imaging Frequency:
Number of images taken

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



INTERNAT



CHART SERIES

INDIAN OCEAN
MALDIVES

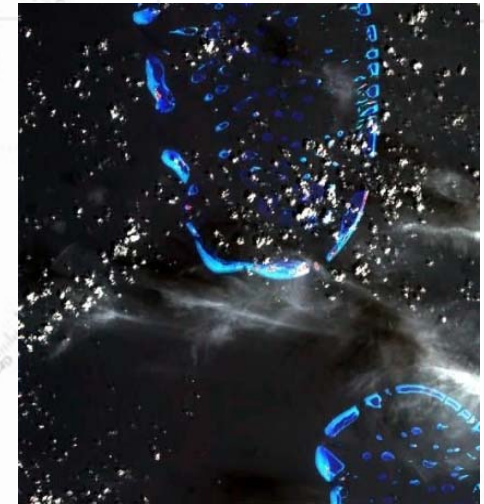
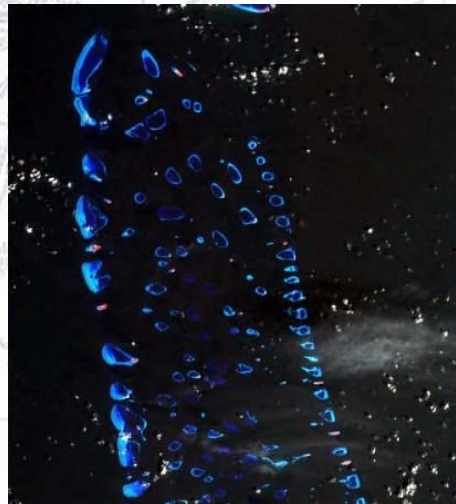
MALE' ATOLL

DEPTHS IN METRES

SCALE 1:150 000 at lat 4°00'

Initial attempt with Spot 5 Images

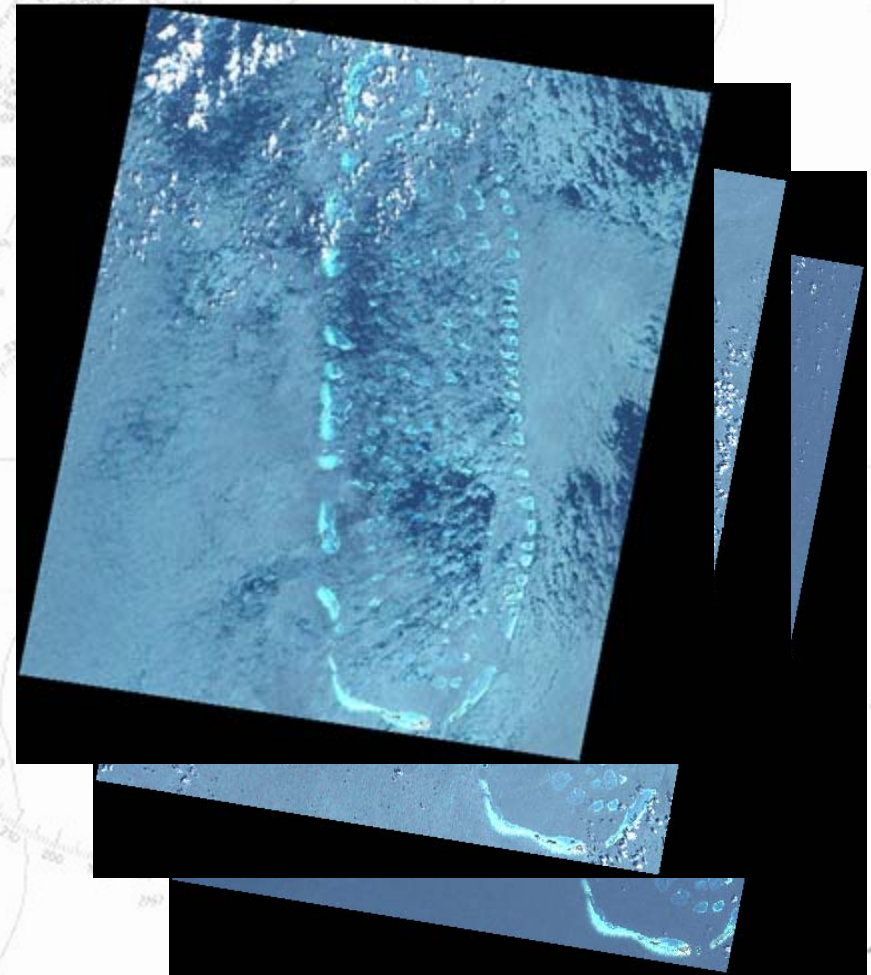
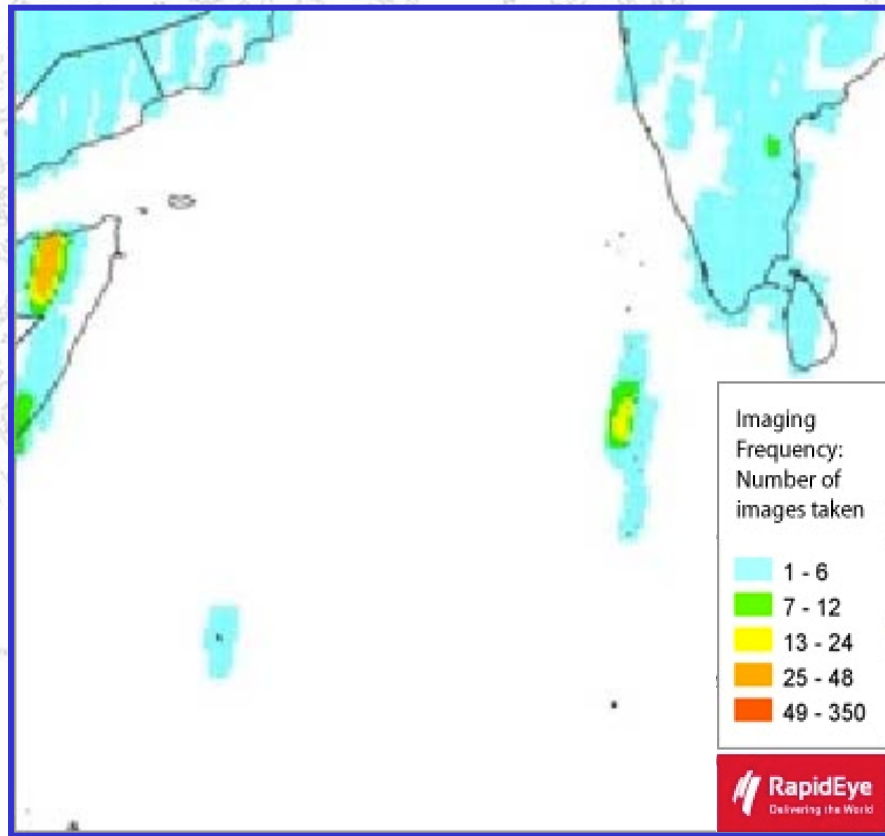
- *Tasking from 08/2010 to 01/2011*
- *No image available within SHOM stringent specifications*



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

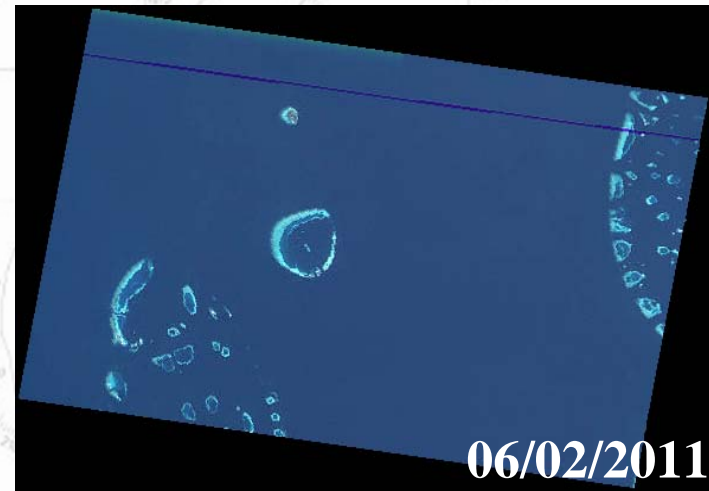
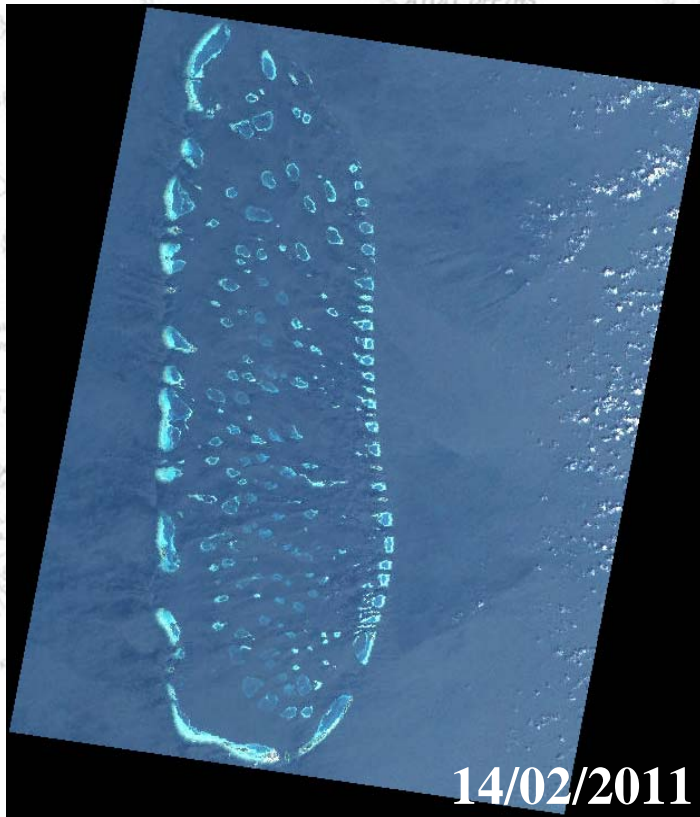
Ari Atoll – RapidEye images attempts

➤ *Several attempts made and rejected*



Final images selection

➤ 2 images selected



Block Adjustment

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



2011-02-14T063306_RE5_1B-NAC 2011-02-14T063306_RE5_1B-NAC_5541029_104413.vue (Modèle)

Affinité Type : Réel Degré : 1

Rmq norm : 0.44 col : 0.42 lig : 0.11

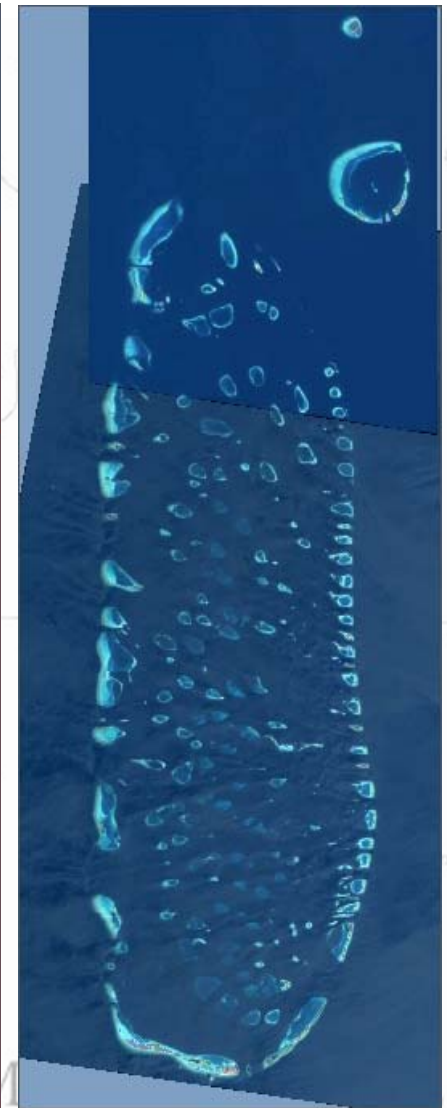
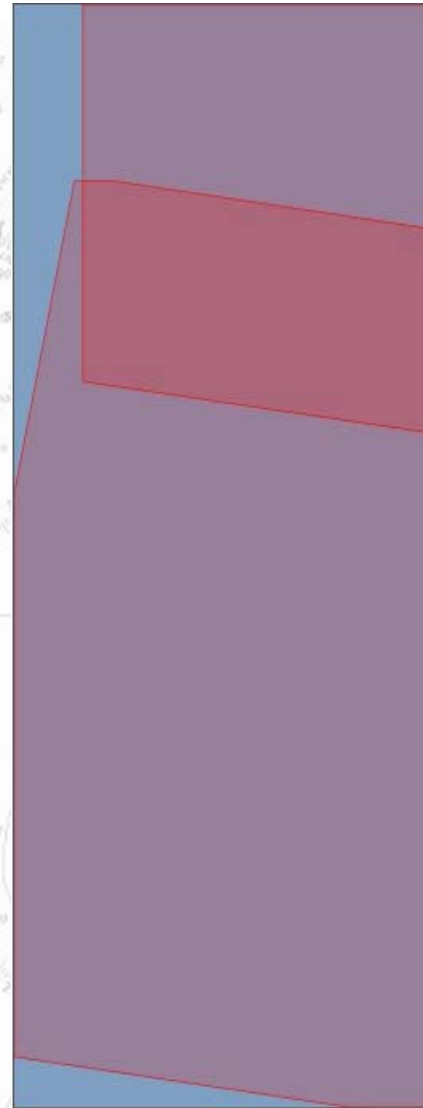
Pt	Colonne (p)	Ligne (p)	X (m)	Y (m)	Poids	r.norm (p)	r.lig (p)	r.col(p)
20	6 735.00	8 494.88	274 184.00	415 473.00	1.00	0.66	-0.66	0.02
21	7 055.00	10 982.50	272 879.50	399 314.03	1.00	0.22	-0.18	0.14
22	6 883.00	11 490.75	271 122.00	396 222.00	1.00	0.11	-0.02	-0.11
23	6 241.72	6 945.71	273 158.00	425 792.00	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

The image shows a dark aerial mosaic of the same coastal town. Several ground control points are marked with yellow circles and numbered 20 through 27, corresponding to the table above. The points are distributed across the town and harbor area.

Orthorectification

Processing of the 2 orthoimages:

- Images projected in Mercator WGS 84 to meet mariners' requirement
- Pixel size = 5m



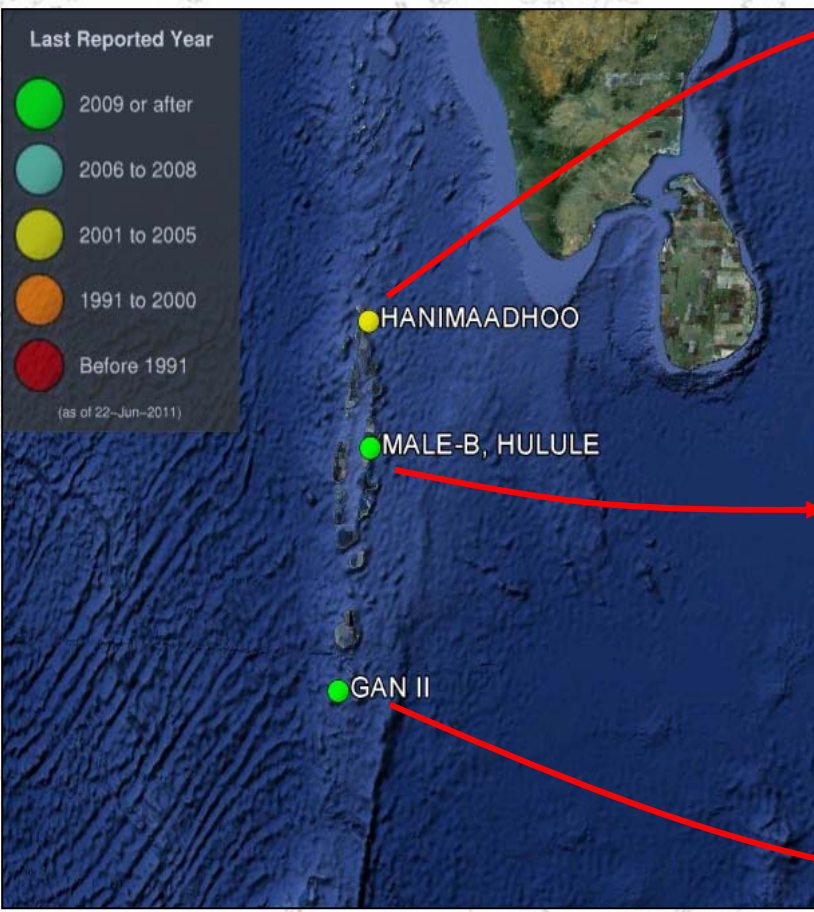
Overlaps check

- *Perfect superimposition of overlapping areas*
- *Final Accuracy = 2 m*



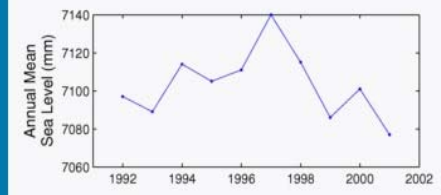
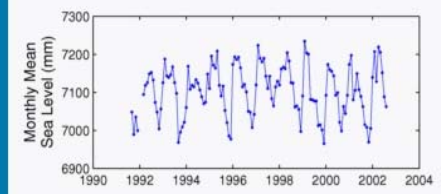
DEPTHS IN METRES
SCALE 1:150 000 at lat 4°00'

GLOSS tide gauges



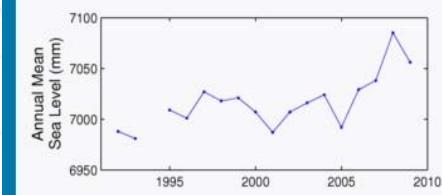
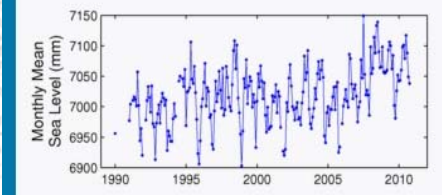
HANIMAADHOO MALDIVES

PSMSL ID: 1779
 Supplier: DEPT. OF METEOROLOGY, MALDIVES
 PSMSL Coastline / Station Code: 454/021
 Last Data: 2002



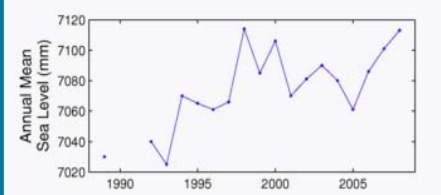
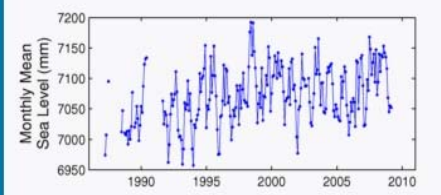
MALE-B, HULULE MALDIVES

PSMSL ID: 1753
 Supplier: DEPT. OF METEOROLOGY, MALDIVES
 PSMSL Coastline / Station Code: 454/011
 GLOSS Site Code: 28
 Last Data: 2010



GAN II MALDIVES

PSMSL ID: 1707
 Supplier: METEOROLOGICAL STATION, GAN, MALDIVES
 PSMSL Coastline / Station Code: 454/002
 GLOSS Site Code: 27
 Last Data: 2009



SCALE 1:150 000 at lat 4°00'



Tidal range determination

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

➤ *Mixed tide – maximum tidal range: 1.2 metre*

● Male, Maldives Islands

Port predictions (Standard Local Time) are +5 hours from UTC

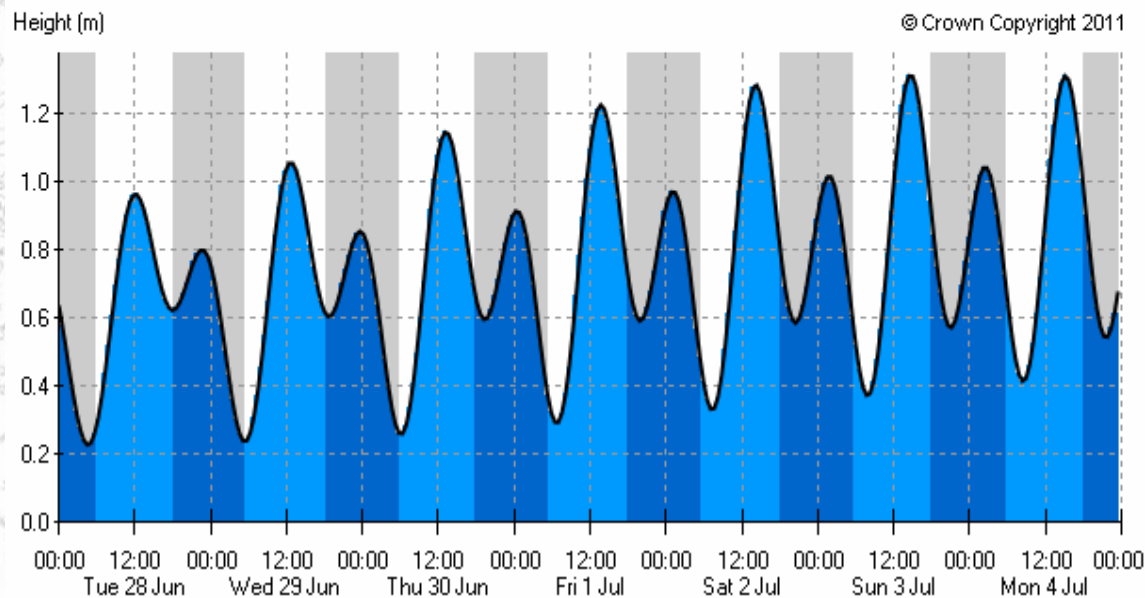
Start Date: Today - Tuesday 28th June 2011 (Standard Local Time)

Duration: 7 days

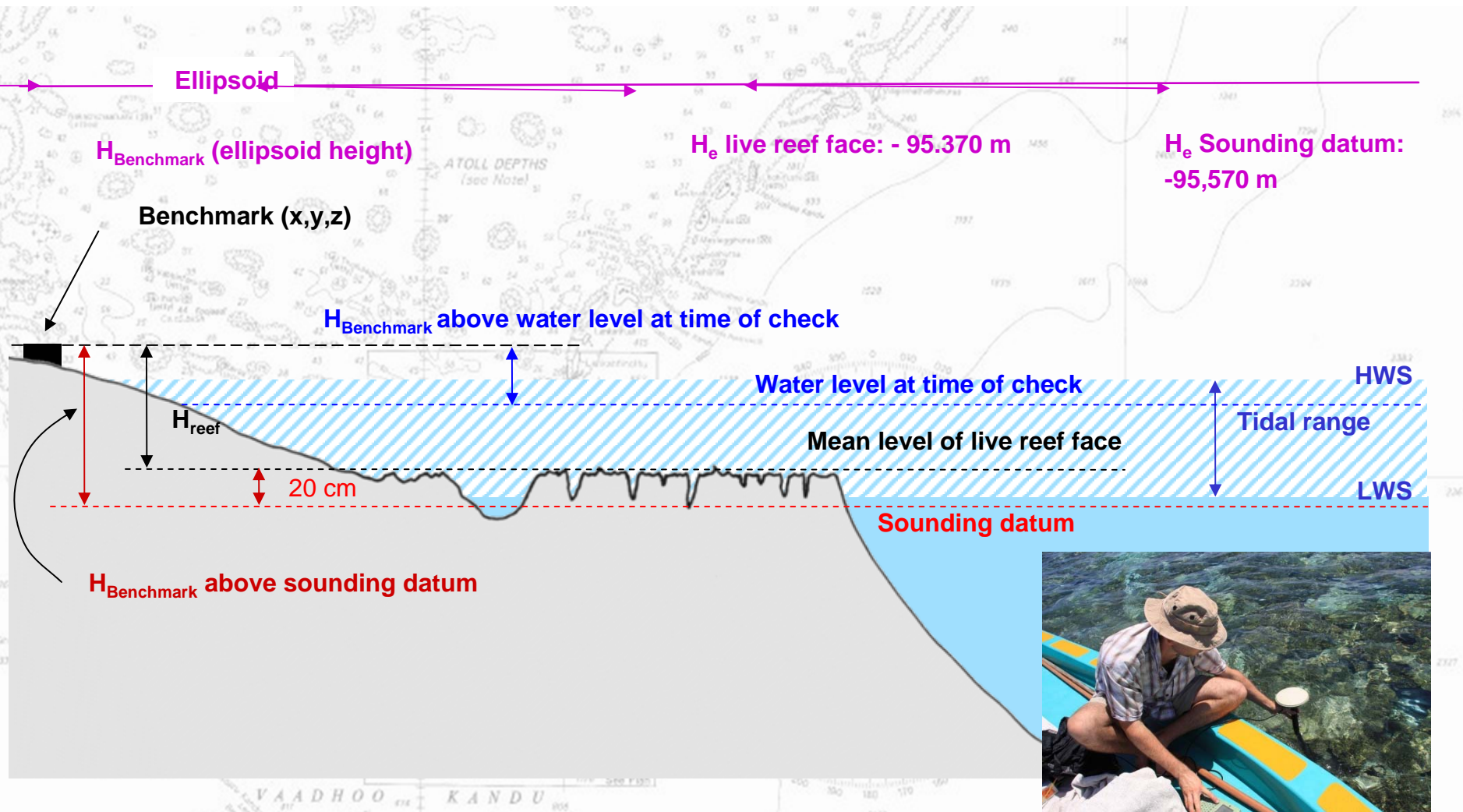
Daylight saving: 0 hours ▾
see [daylight saving warning](#)

Max graph size: 7 days ▾

Apply

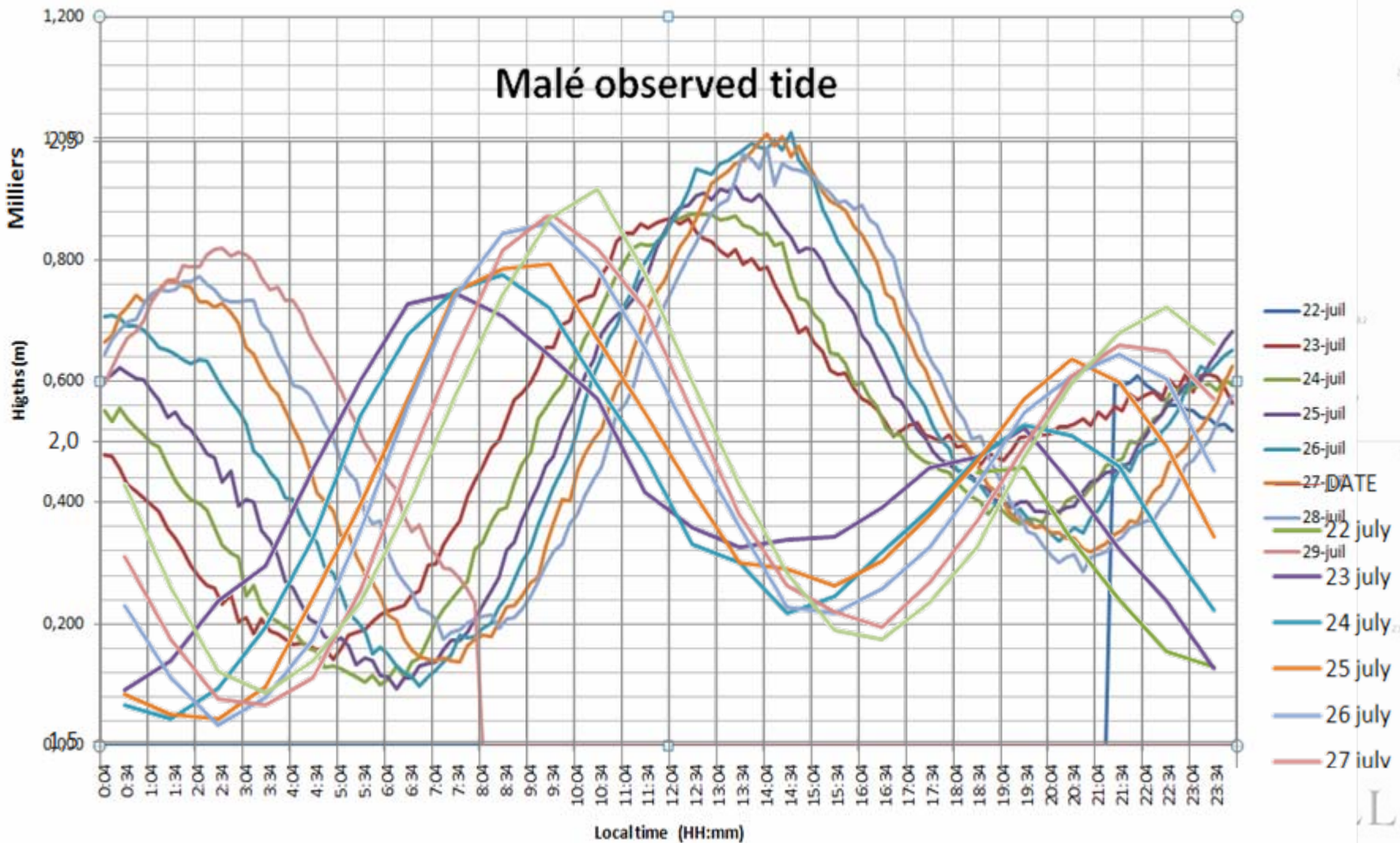


Field determination of chart datum



➤ Mean level of live reef face (after 38 measurements): - 95.37 m ($\sigma = 0.057$ m)

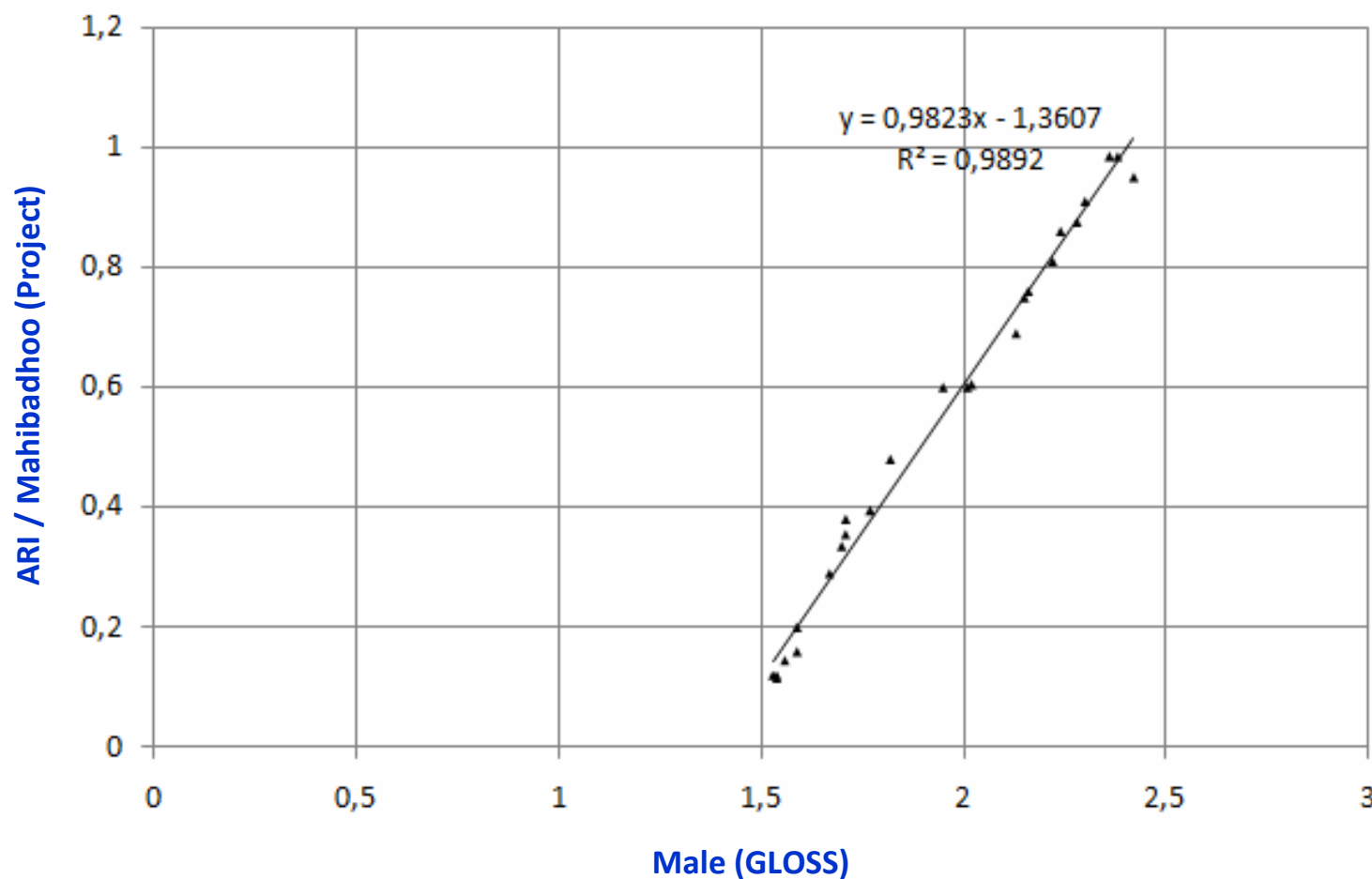
ARI ~ Mahibadhoo observed tide



SCALE 1:150 000 at lat 4°00'

Tide-by-tide simultaneous comparison

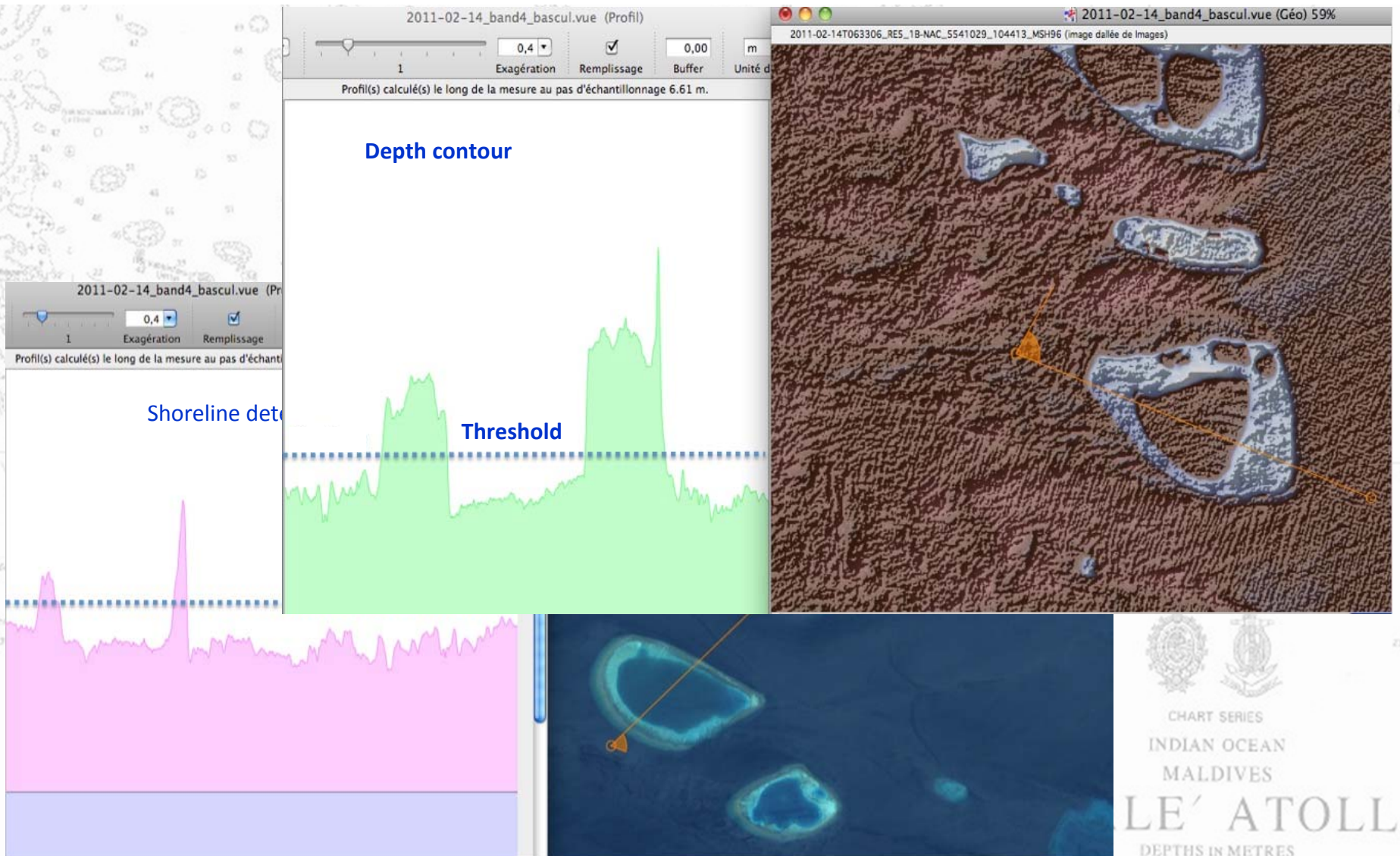
➤ 22nd to 29th July 2010 – Heights in metres



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 Processing

5 layers:

- Land
- Inter-tidal
- 0-5 m
- 5-10 m
- 10-15 m

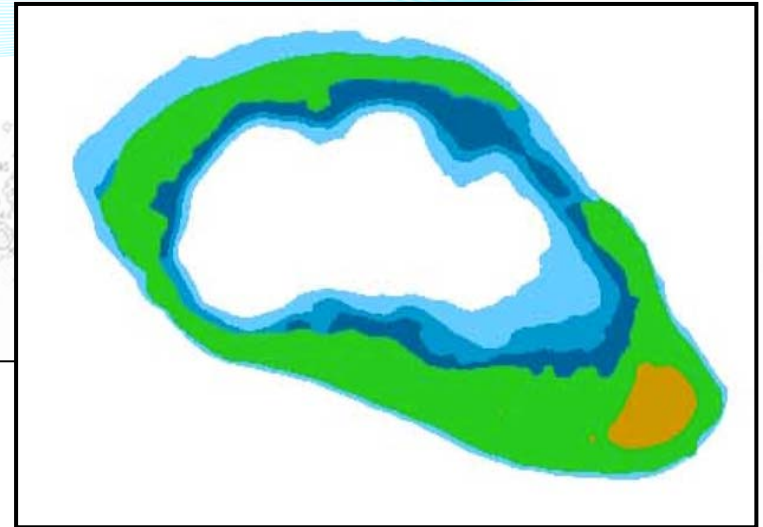
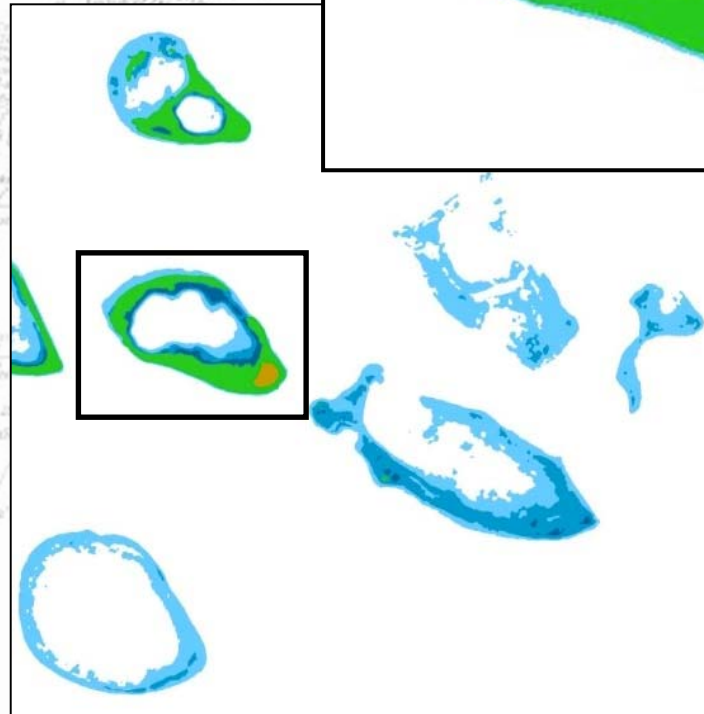
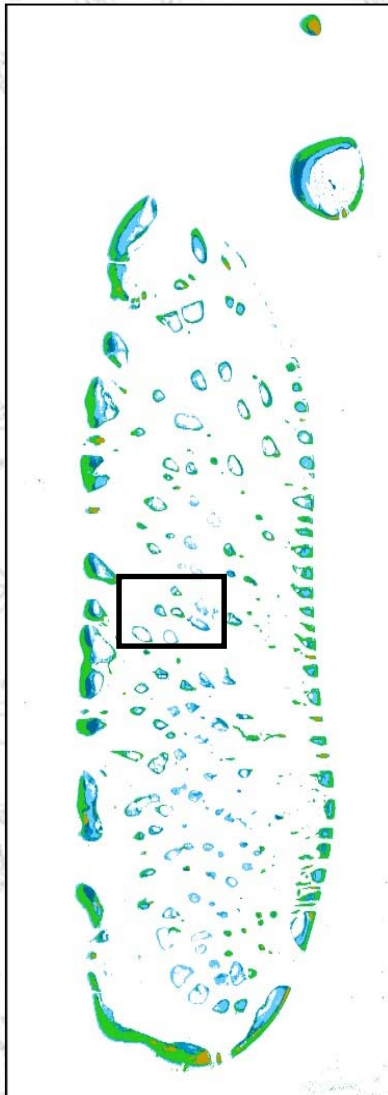


CHART SERIES
INDIAN OCEAN
MALDIVES

MALE' ATOLL

DEPTHS IN METRES

SCALE 1:150 000 at lat 4°00'

Resulting space charts

➤ 1/100 000 chart covering

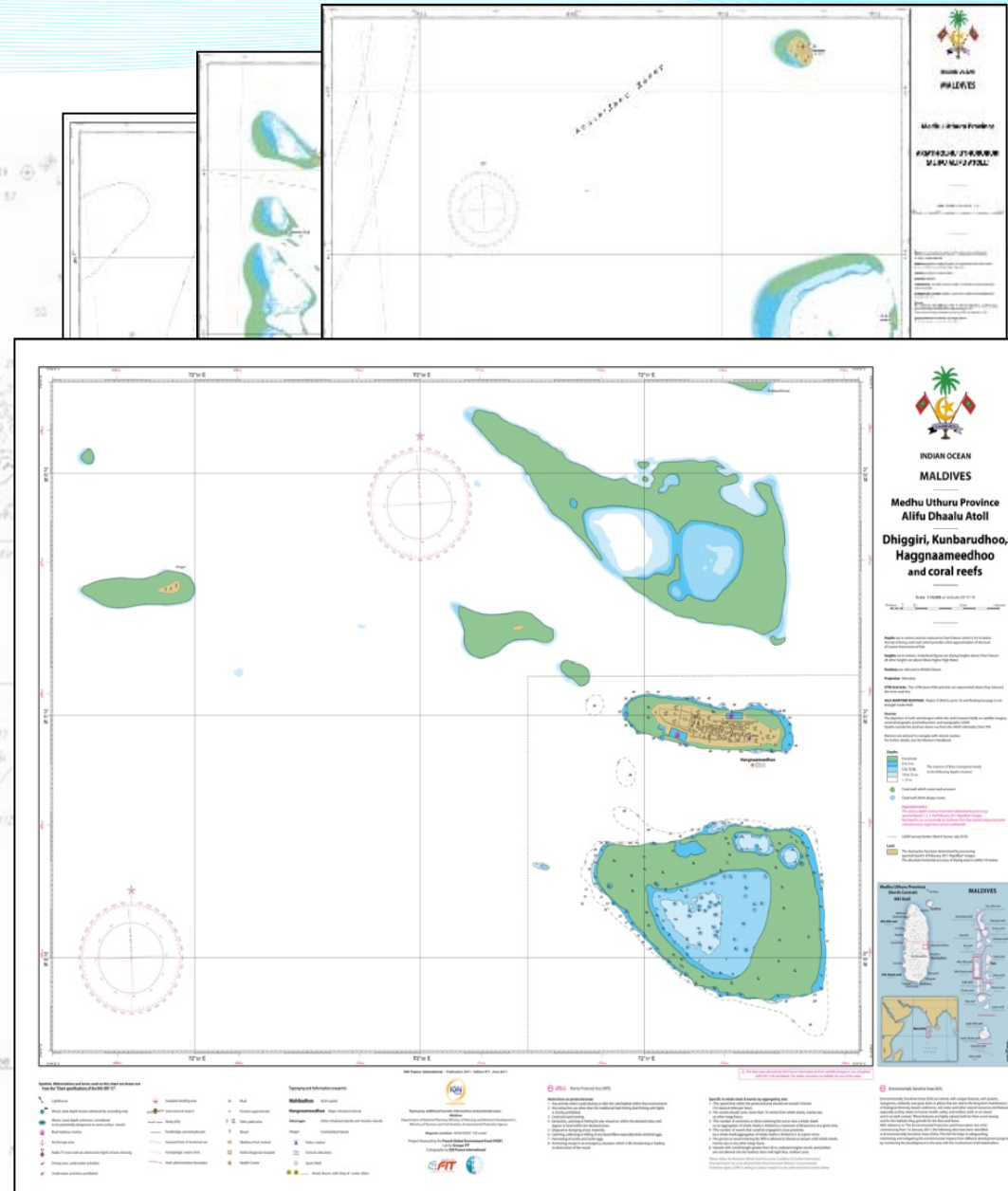
Alifu & Rasdhoo atolls

➤ 1/50 000 chart of South Alifu

➤ 1/50 000 chart of North Alifu &

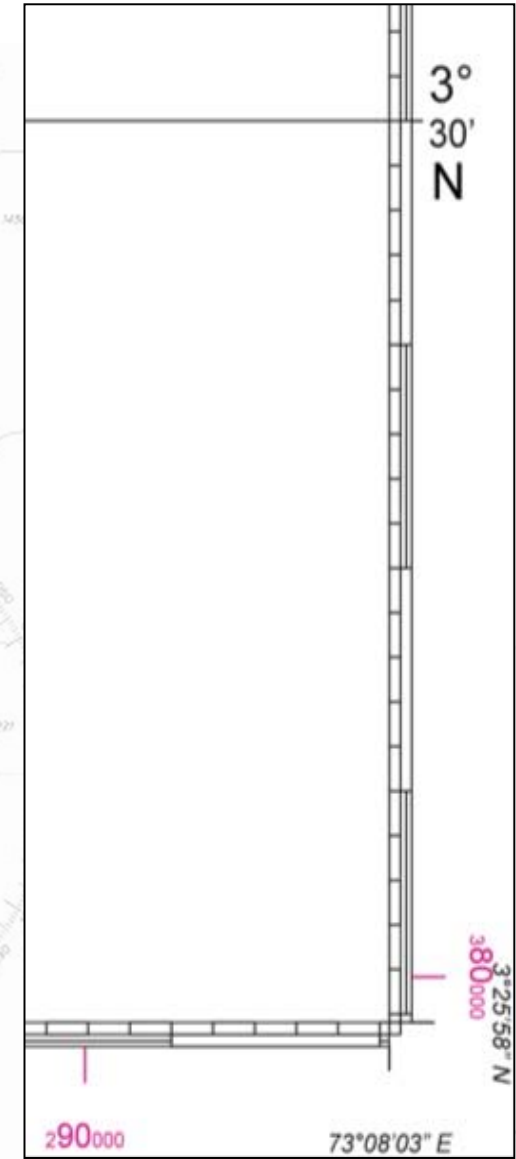
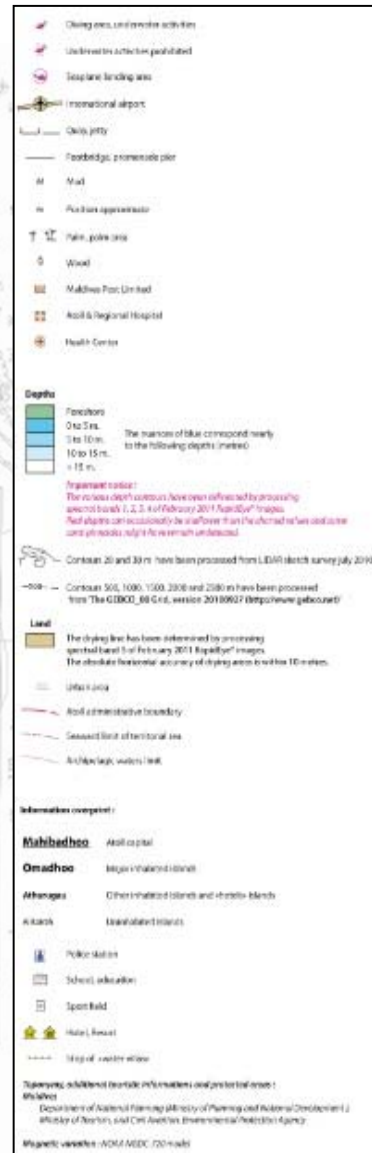
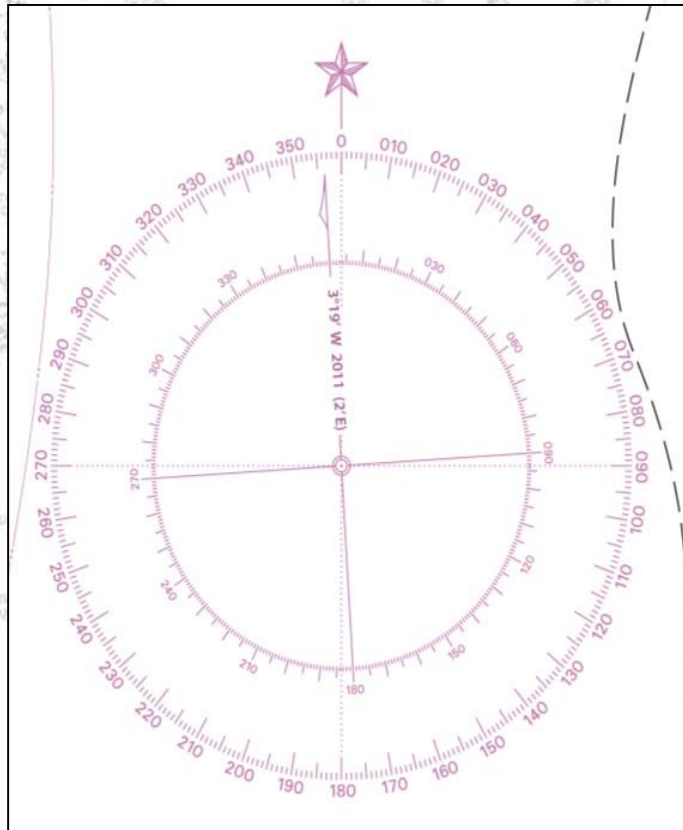
Rasdhoo

➤ 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

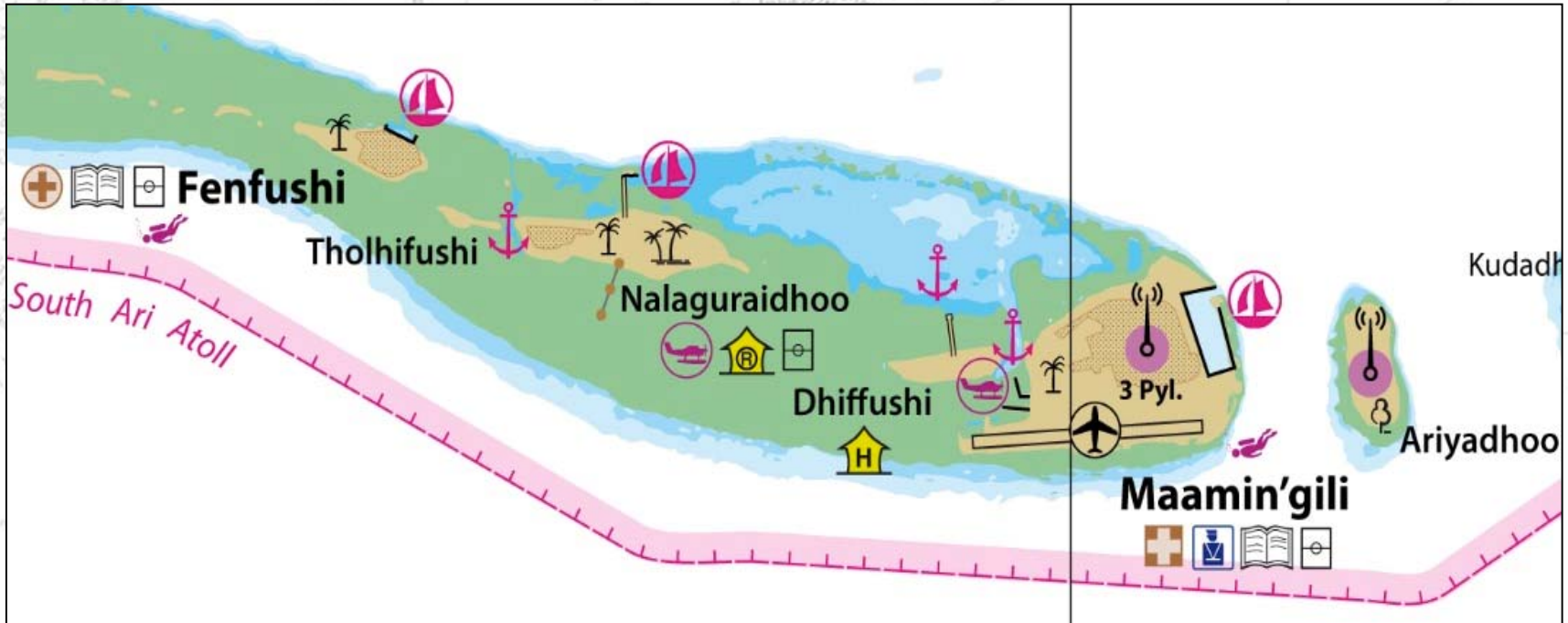


CHART SERIES
INDIAN OCEAN
MALDIVES
MALE' ATOLL
DEPTHS IN METRES
SCALE 1:150 000 at lat 4°00'

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 ★

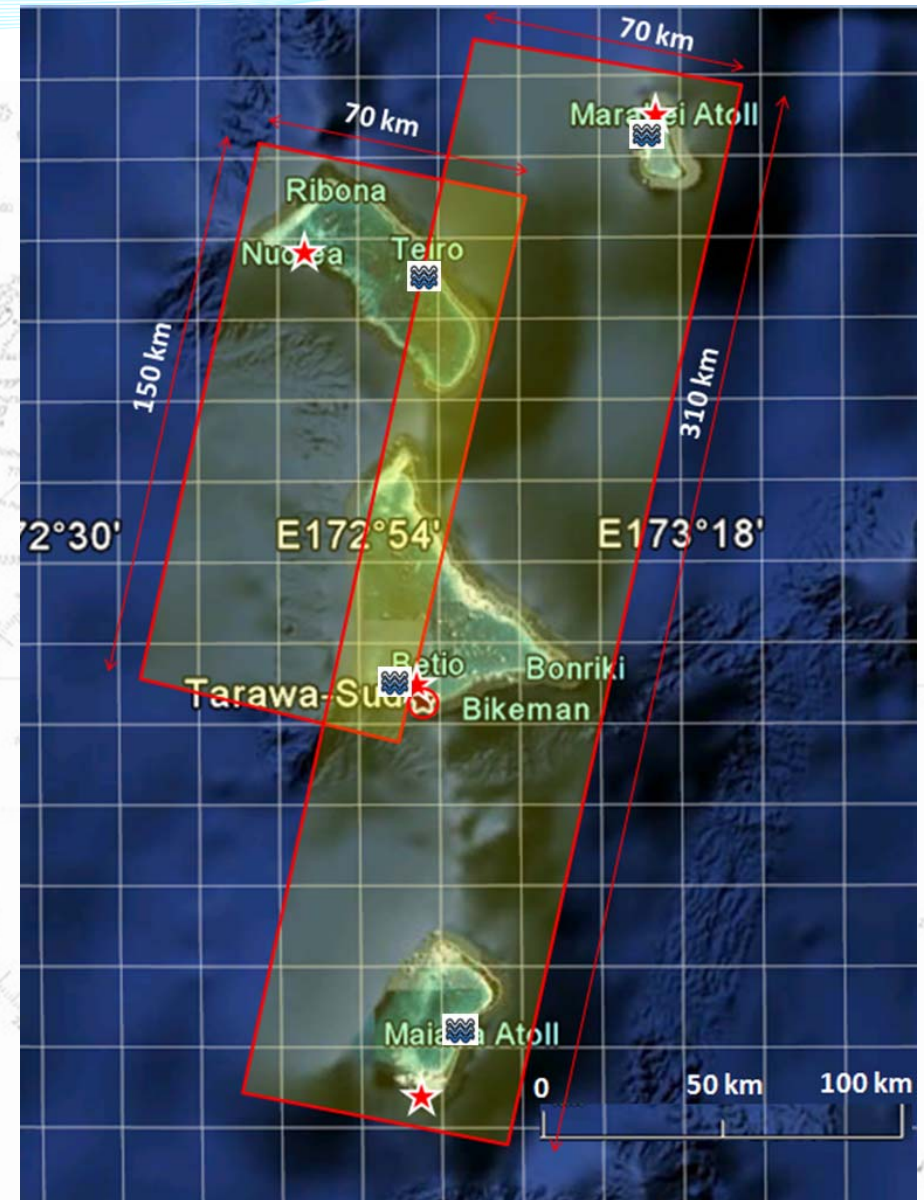
Reference stations & control points (WGS 84)

Reference : Betio/DORIS

• Tide 🌊

Reference : Betio Tide Gauge

Tide by tide simultaneous comparison with temporary tide gauges



Example of Ari atoll

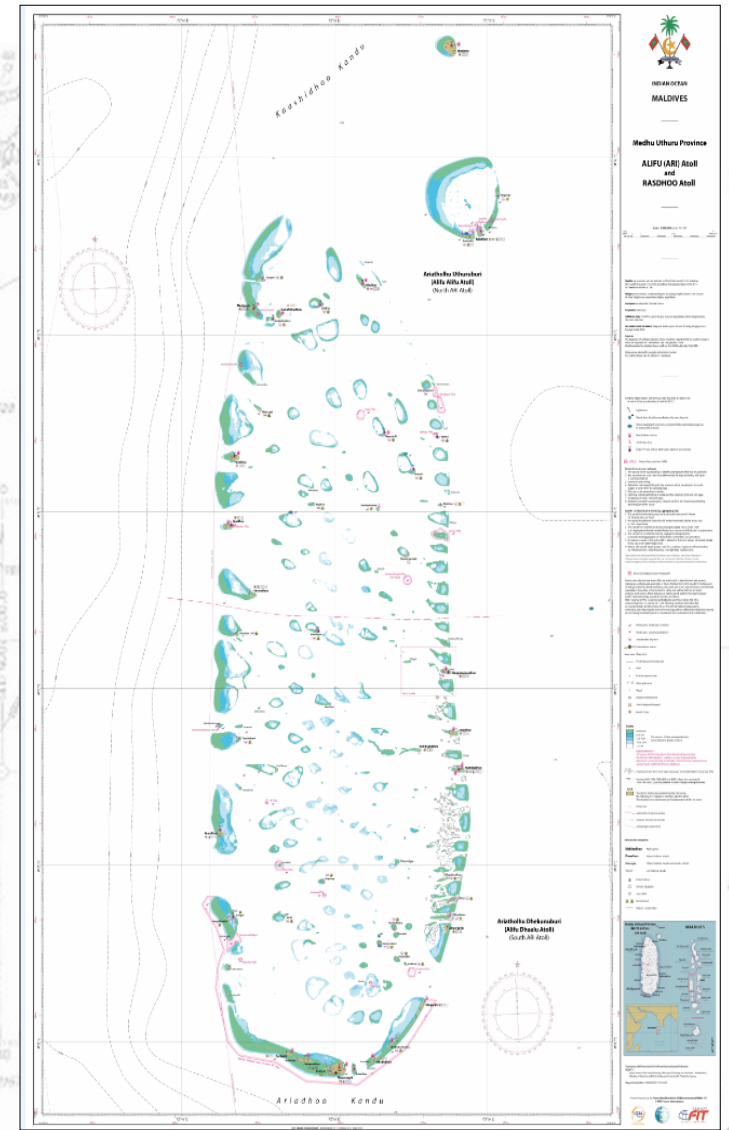
➤ Step 3: Production of a minimum cartographic base

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

Total production time = 7 months

Average cost per spacechart = 100 k€

**Cost per km² = 40 €
(vs 1 000 € with other survey methods)**



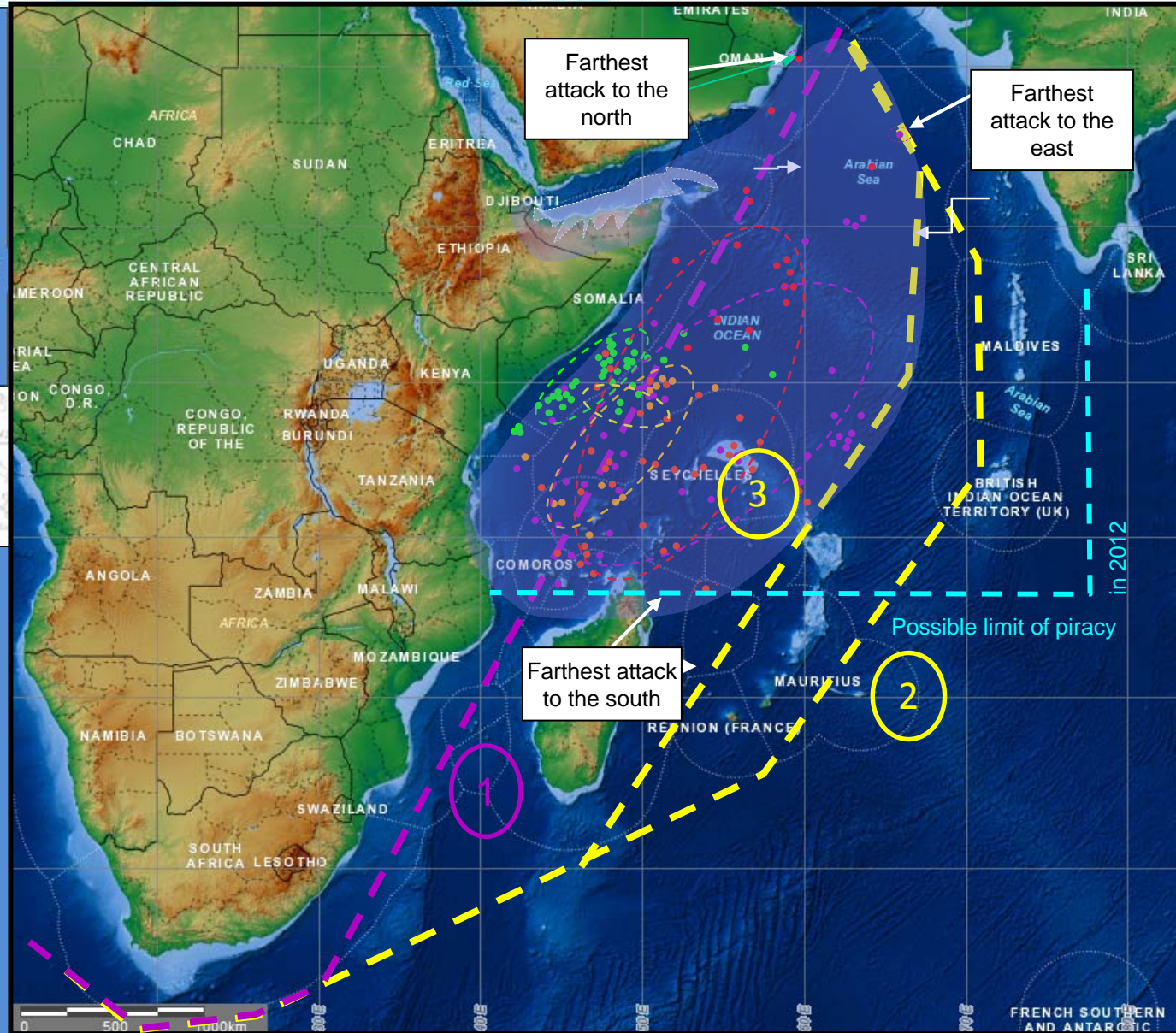
Spacecharts for the marine highways

Piracy affected areas (2005 -2009)

- 2005 - 2007
- Mav 2008
- November 2008
- Mav 2009
- November 2009

Gulf of Aden attacks 2005 - 2009

Dangerous Area 2009

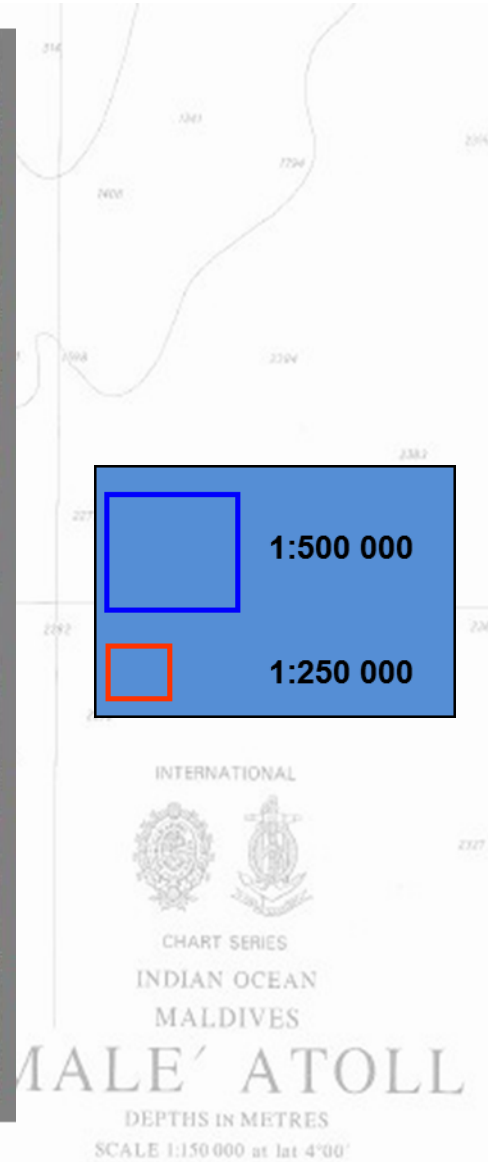
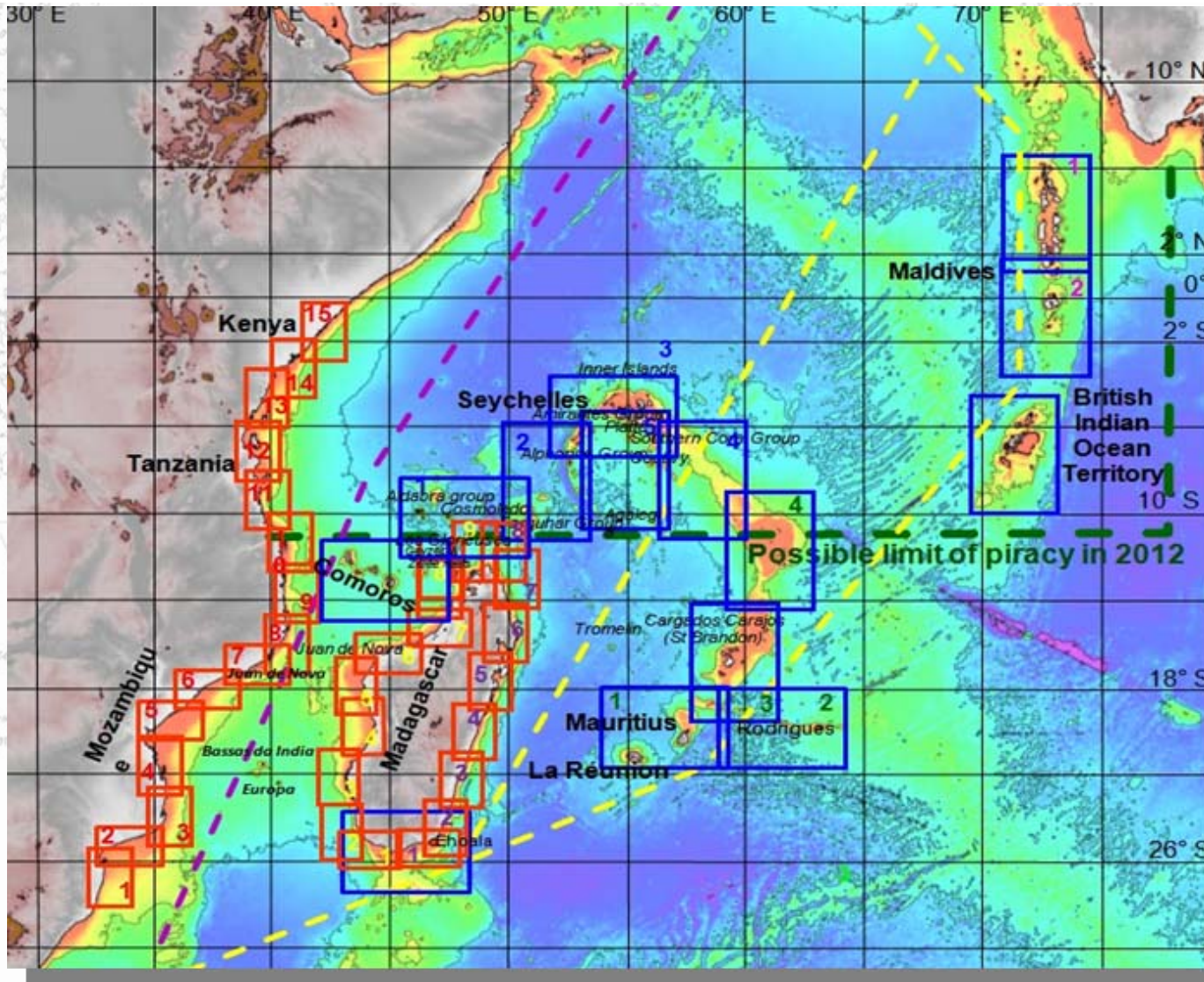


1- Main tanker route before piracy

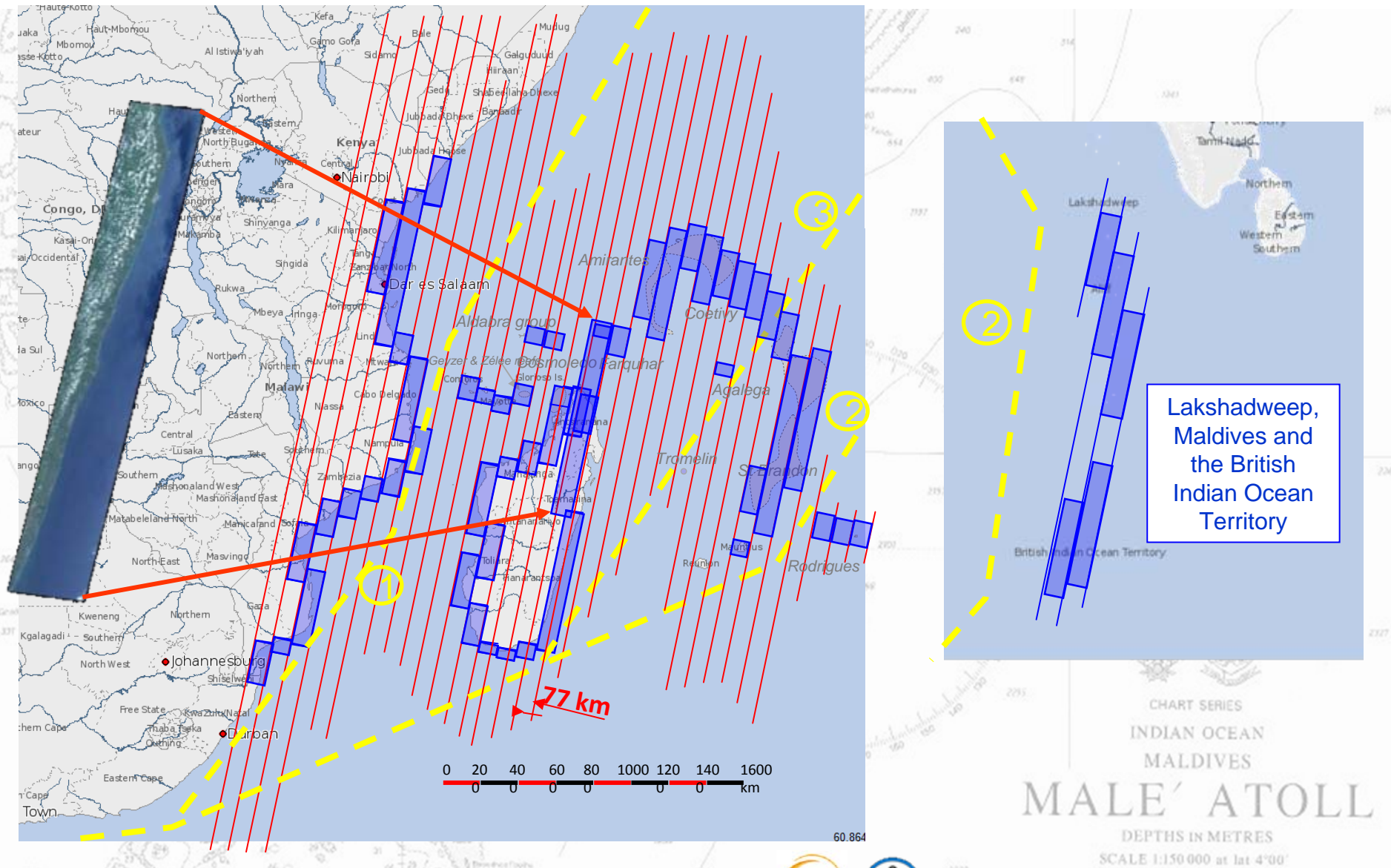
2 - Diverted route used by tankers and bulk traffic in case of persistent piracy

3 - Route variant in case of stable or declining rates of piracy

Spacecharts index



Available satellite images for the marine highways





Thank you for your attention.



INTERNATIONAL
CHART SERIES
INDIAN OCEAN
MALDIVES

MALE' ATOLL

DEPTHS IN METRES

SCALE 1:150 000 at lat 4°00'