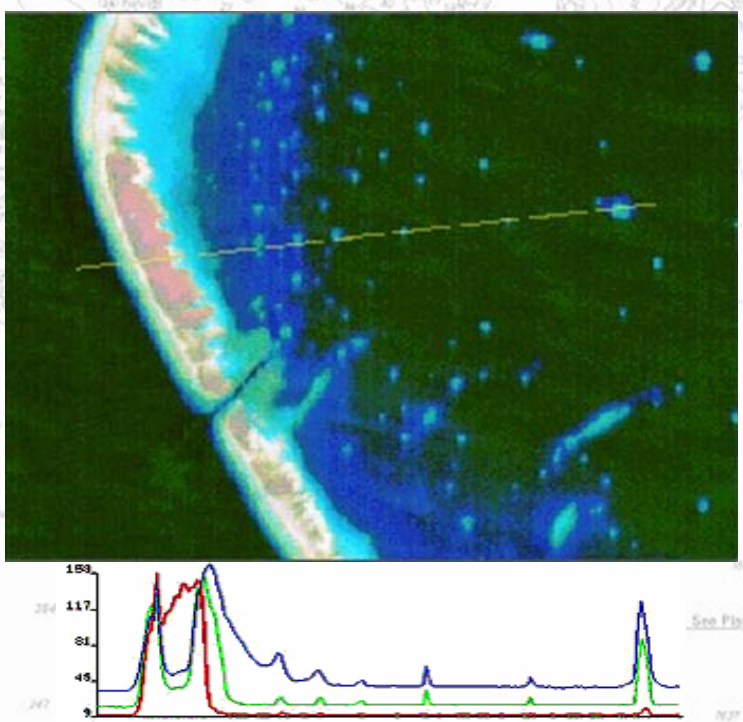
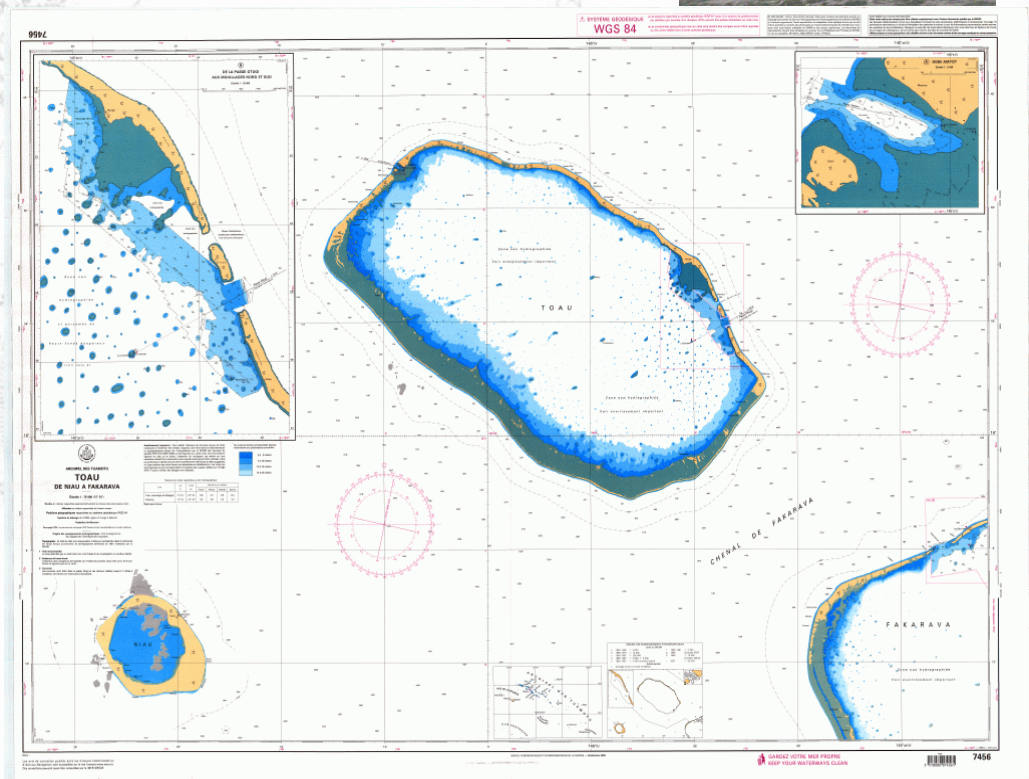
Satellite Bathymetry

Céline Roux

SHOM nautical navigation canvas

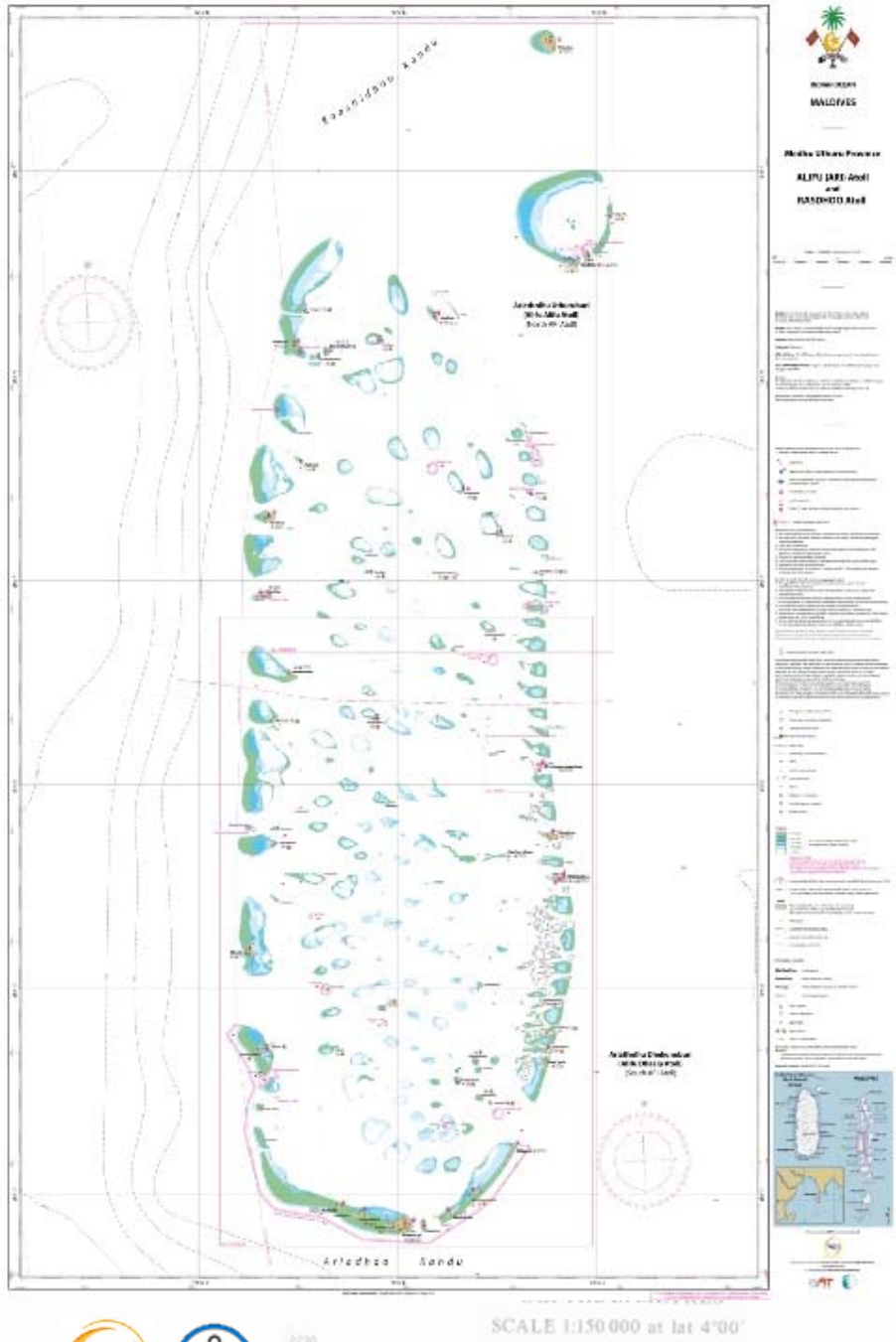
- *Charting coral reefs before 1982*
- *The Landsat Thematic Mapper breakthrough*
- *SHOM's « Spacechart » (from 1988 until today)*
- *Latest improvements*





Céline Roux

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

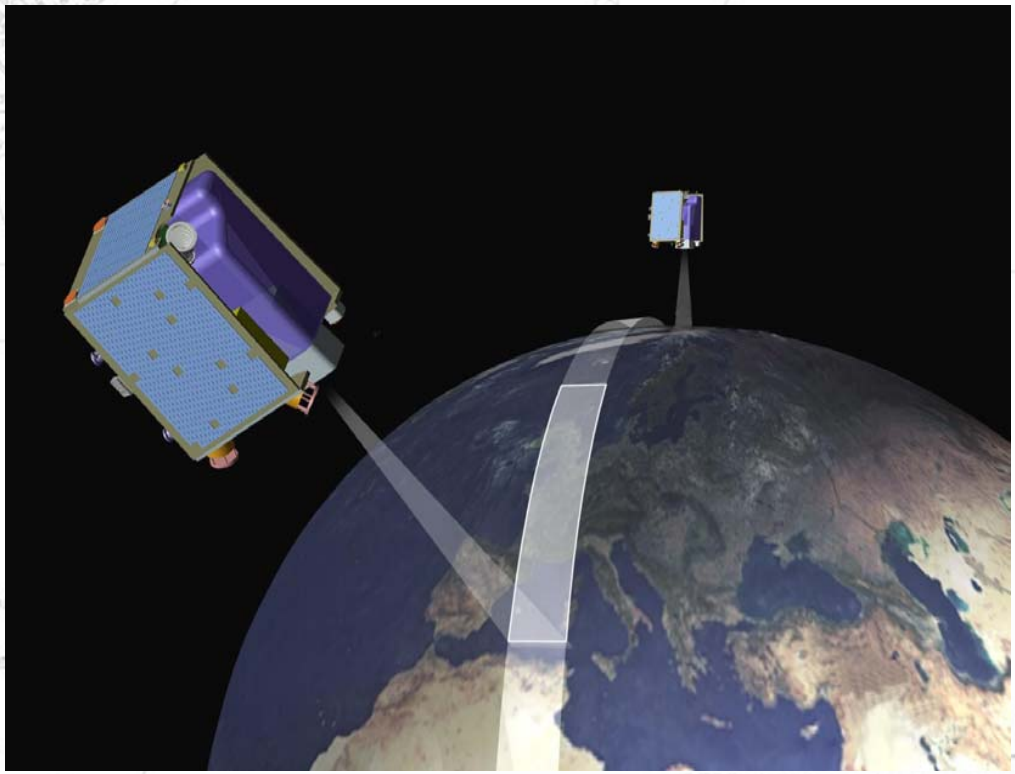
Additional Info (place names, boundaries, existing surveys, Gebco…)

Edition

Space chart

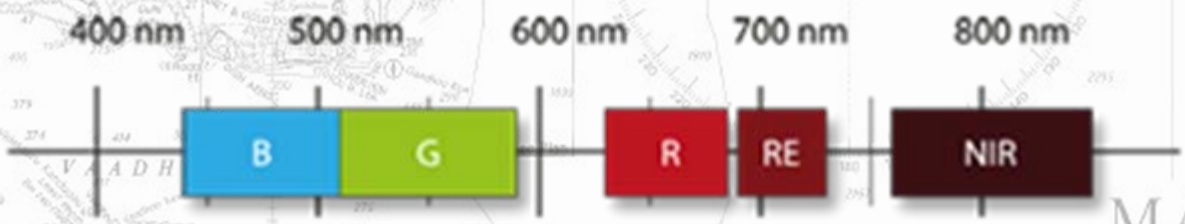
The RapidEye constellation

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

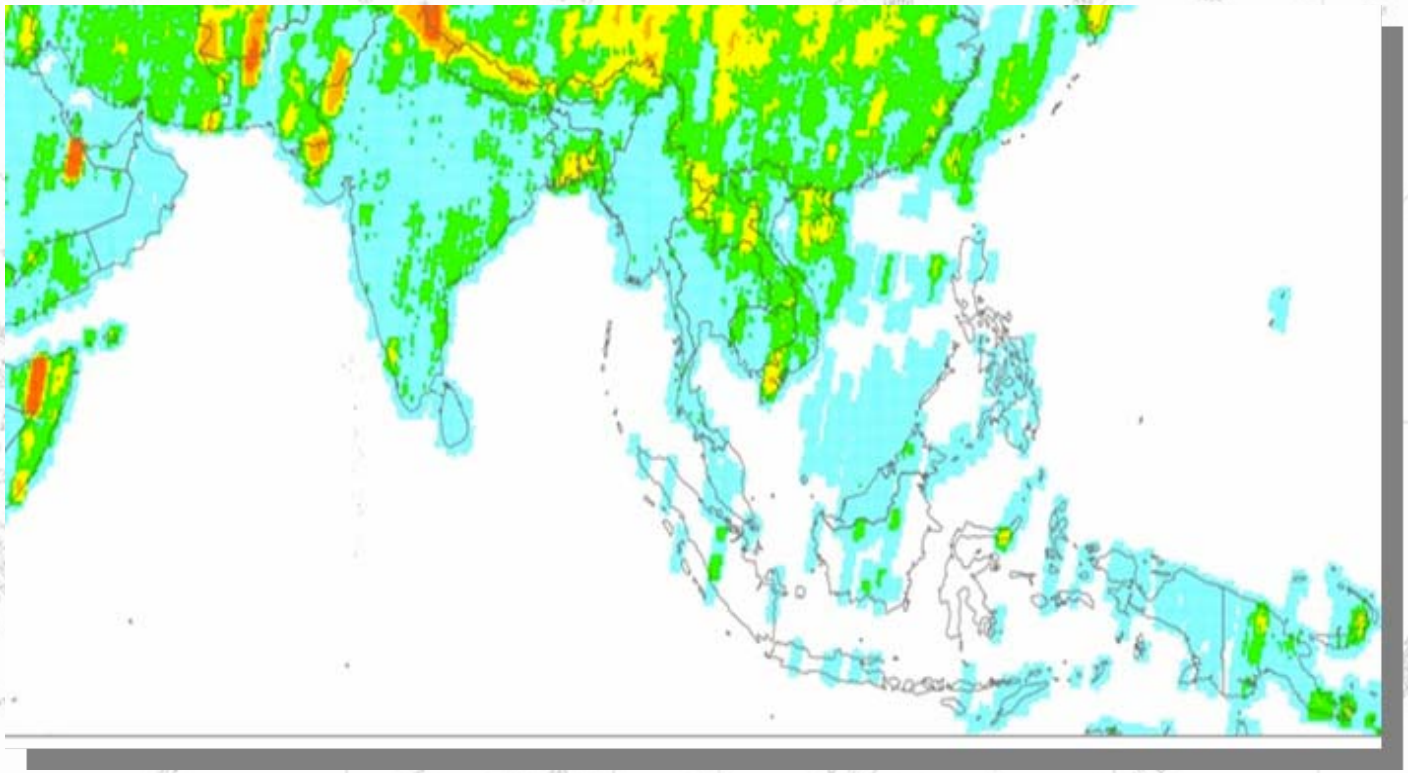


RapidEye satellite

- *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

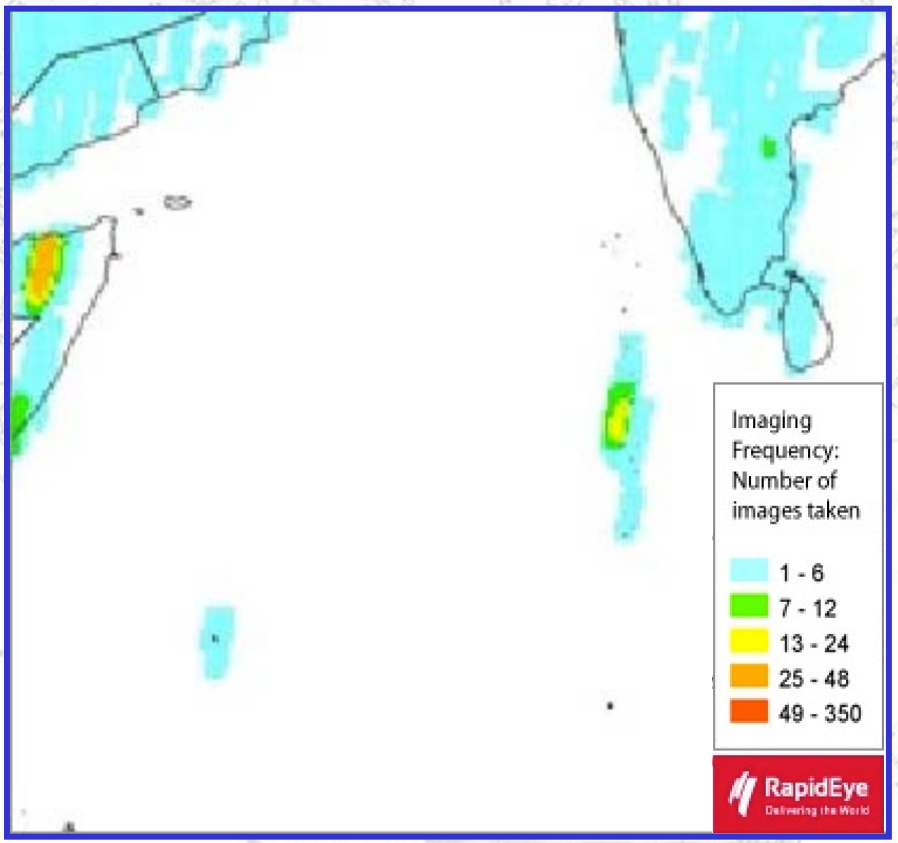


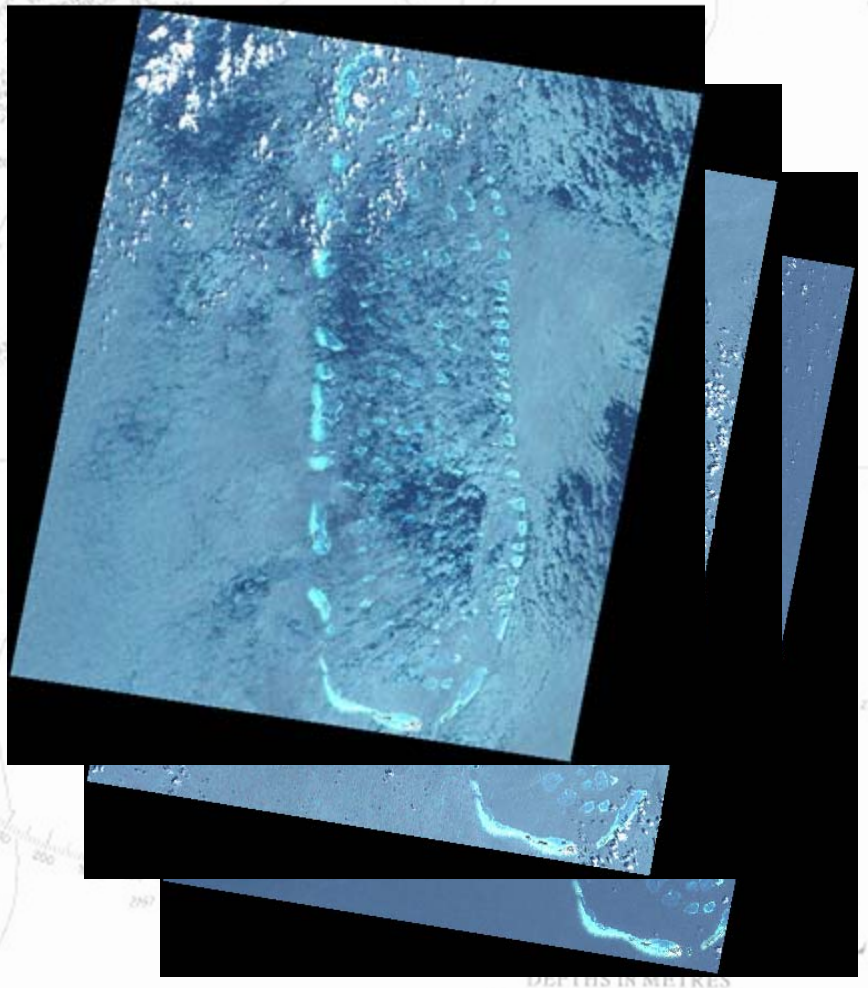
Initial attempt with Spot 5 Images

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

Ari Atoll – RapidEye images attempts

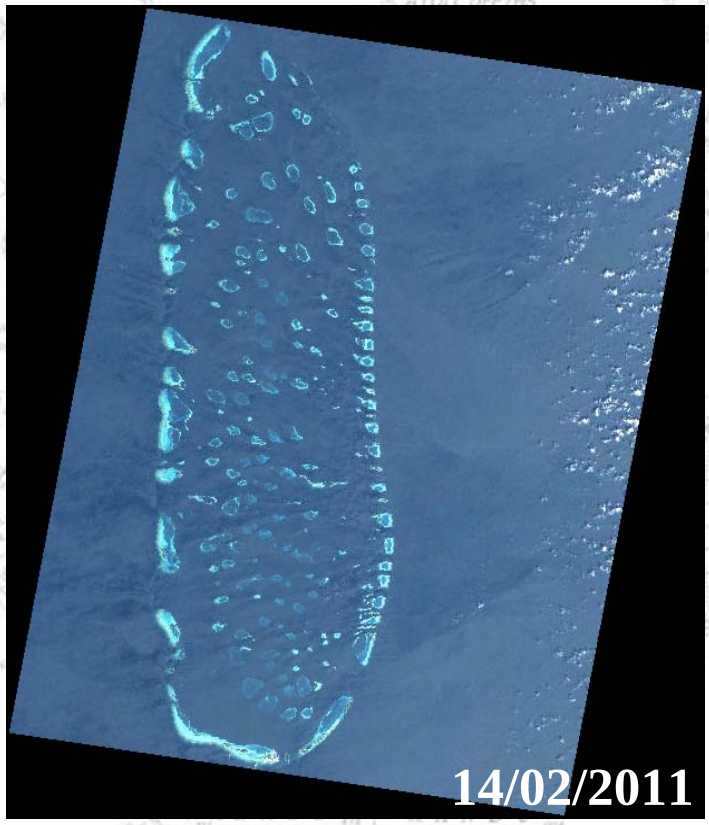
- *Several attempts made and rejected*

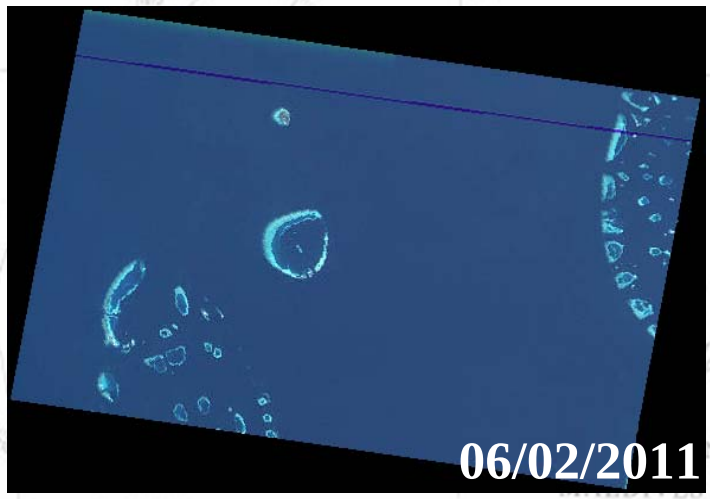




Final images selection

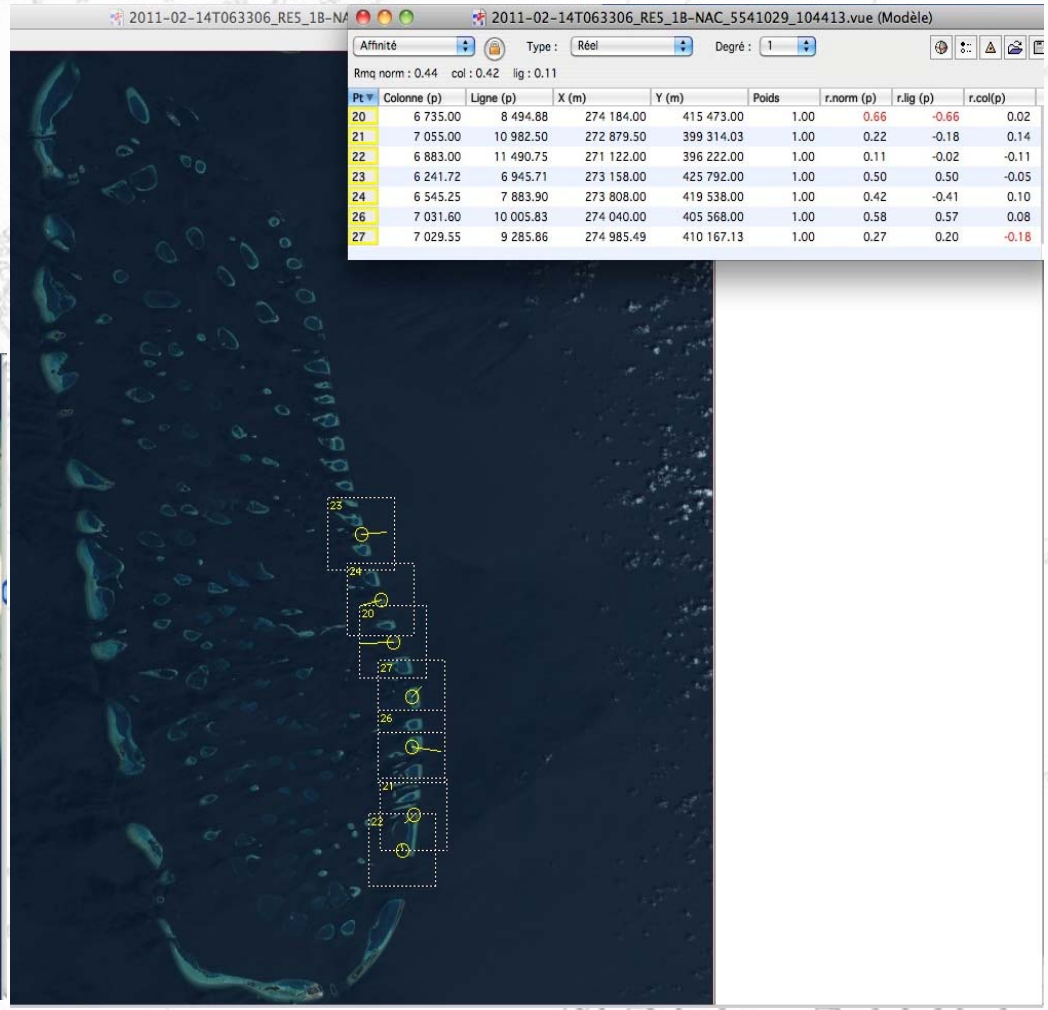
- *2 images selected*





Block Adjustment

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



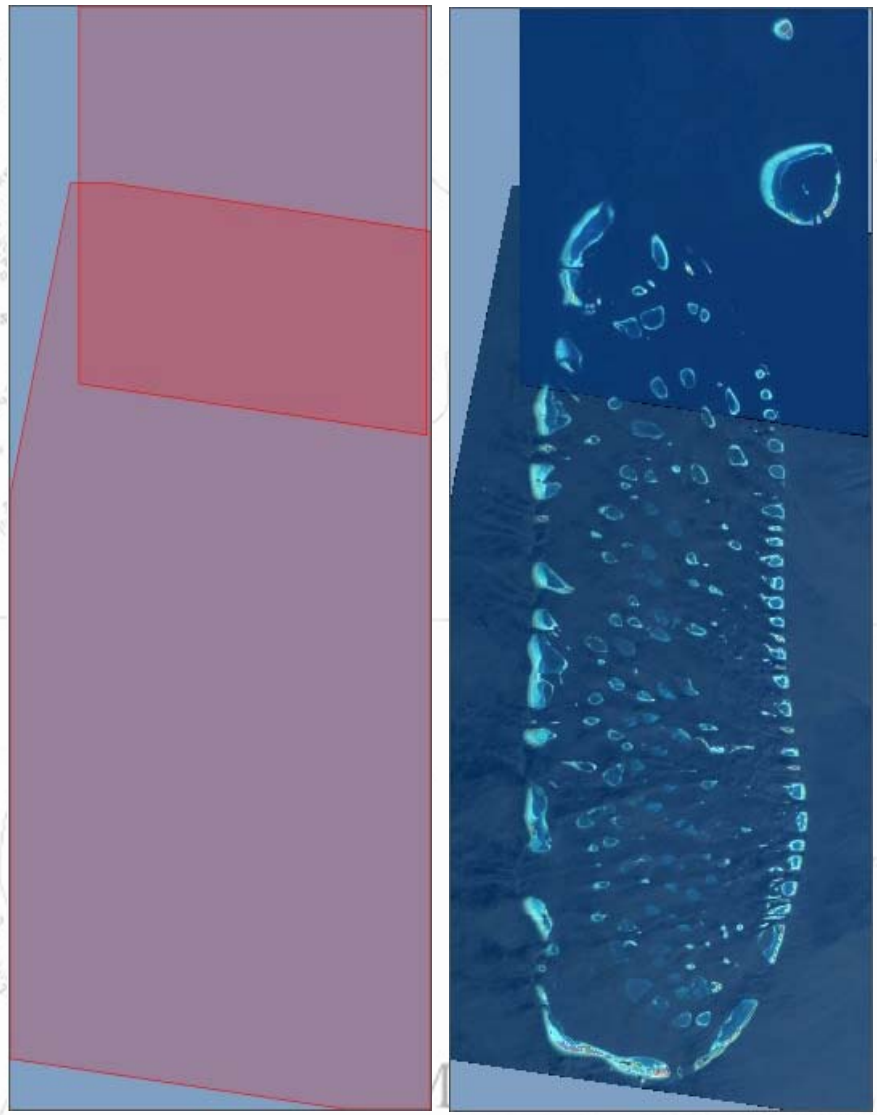
Orthorectification

Processing of the 2 orthoimages:

- *Images projected in Mercator WGS*

  84 to meet mariners' requirement

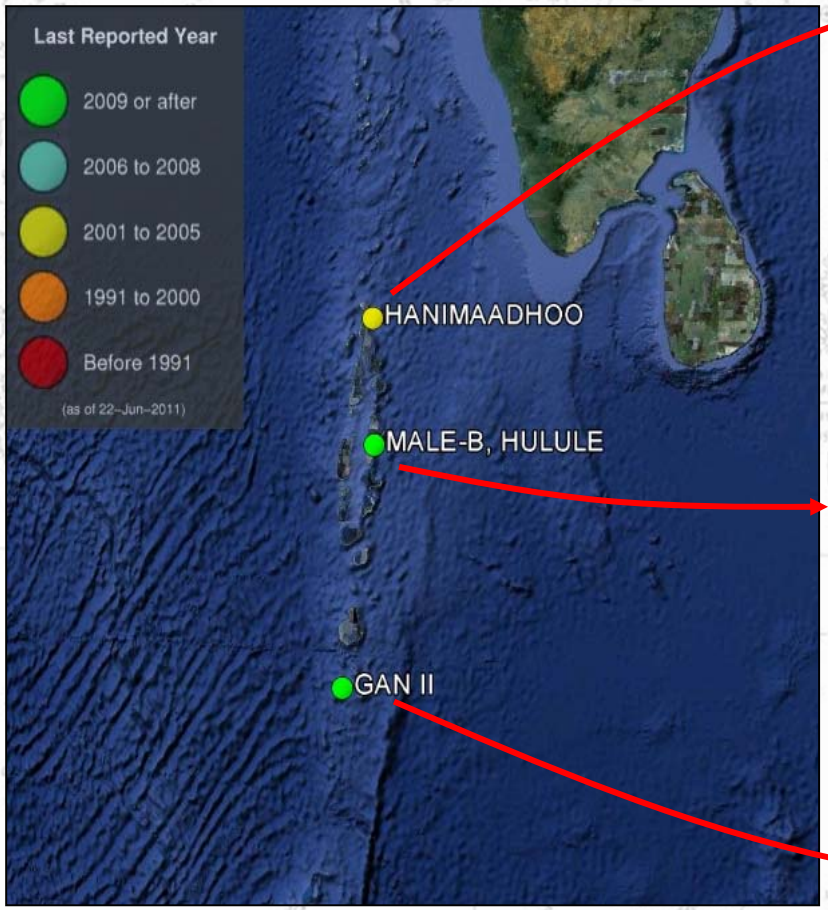
- *Pixel size = 5m*



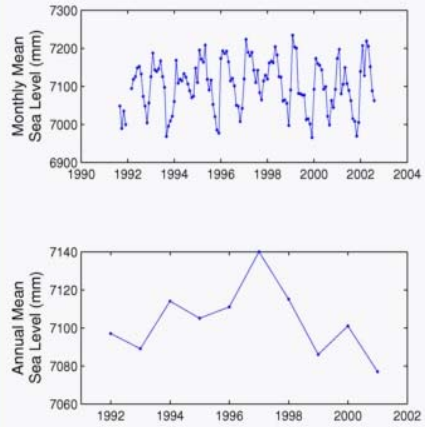
Overlaps check

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

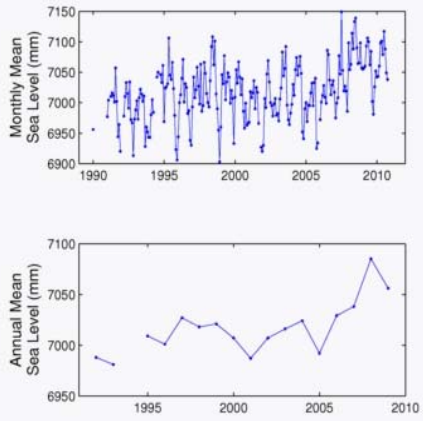
GLOSS tide gauges



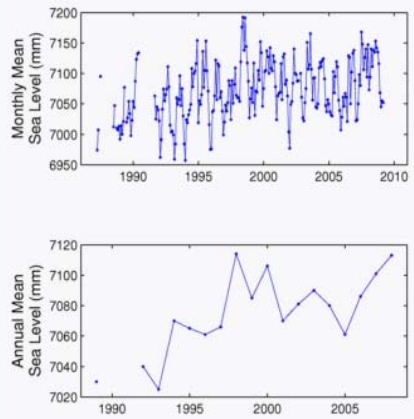
HANIMAADHOO
MALDIVES
PSMSL ID: 1779
Supplier: DEPT. OF METEOROLOGY, MALDIVES
PSMSL Coastline / Station Code: 454/021
Last Data: 2002



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

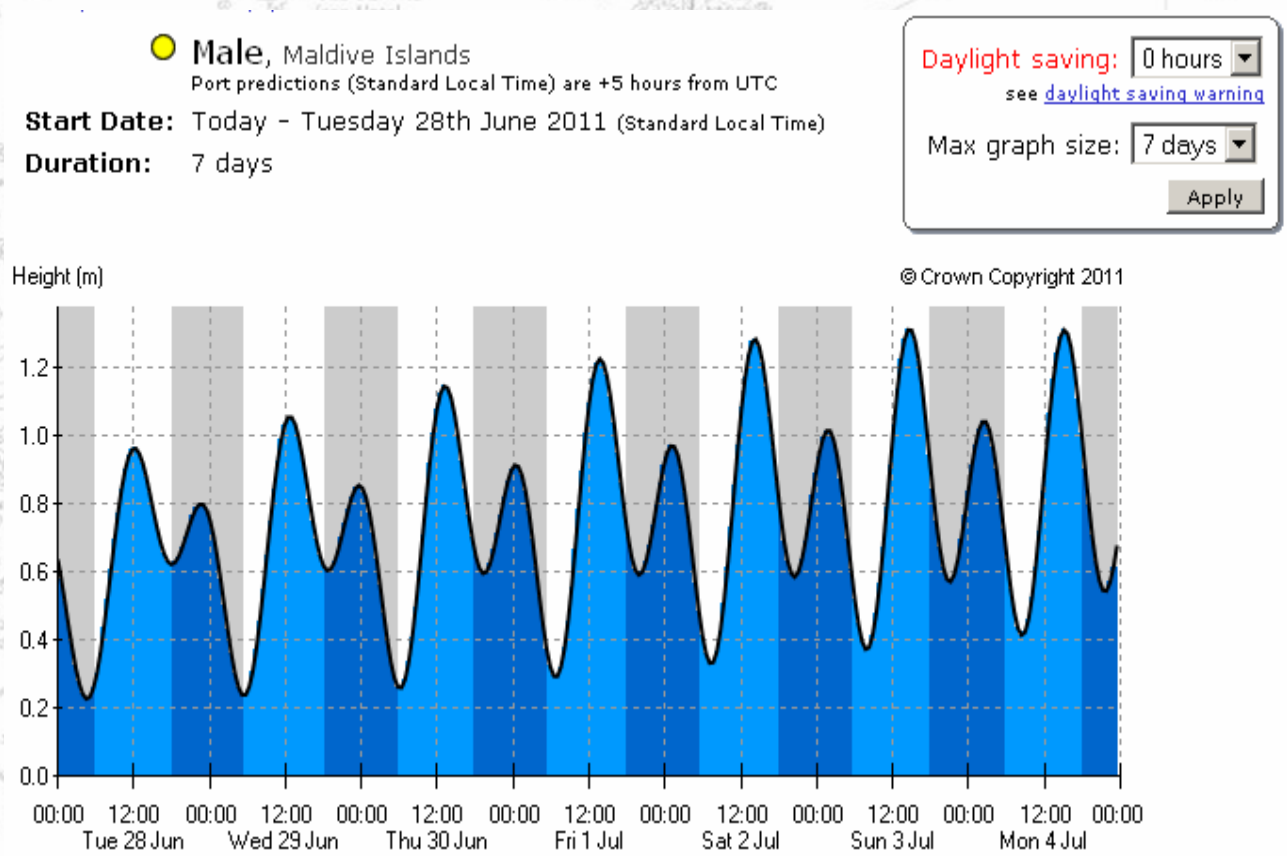


GAN II
MALDIVES
PSMSL ID: 1707
Supplier: METEOROLOGICAL STATION, GAN, MALDIVES
PSMSL Coastline / Station Code: 454/002
GLOSS Site Code: 27
Last Data: 2009

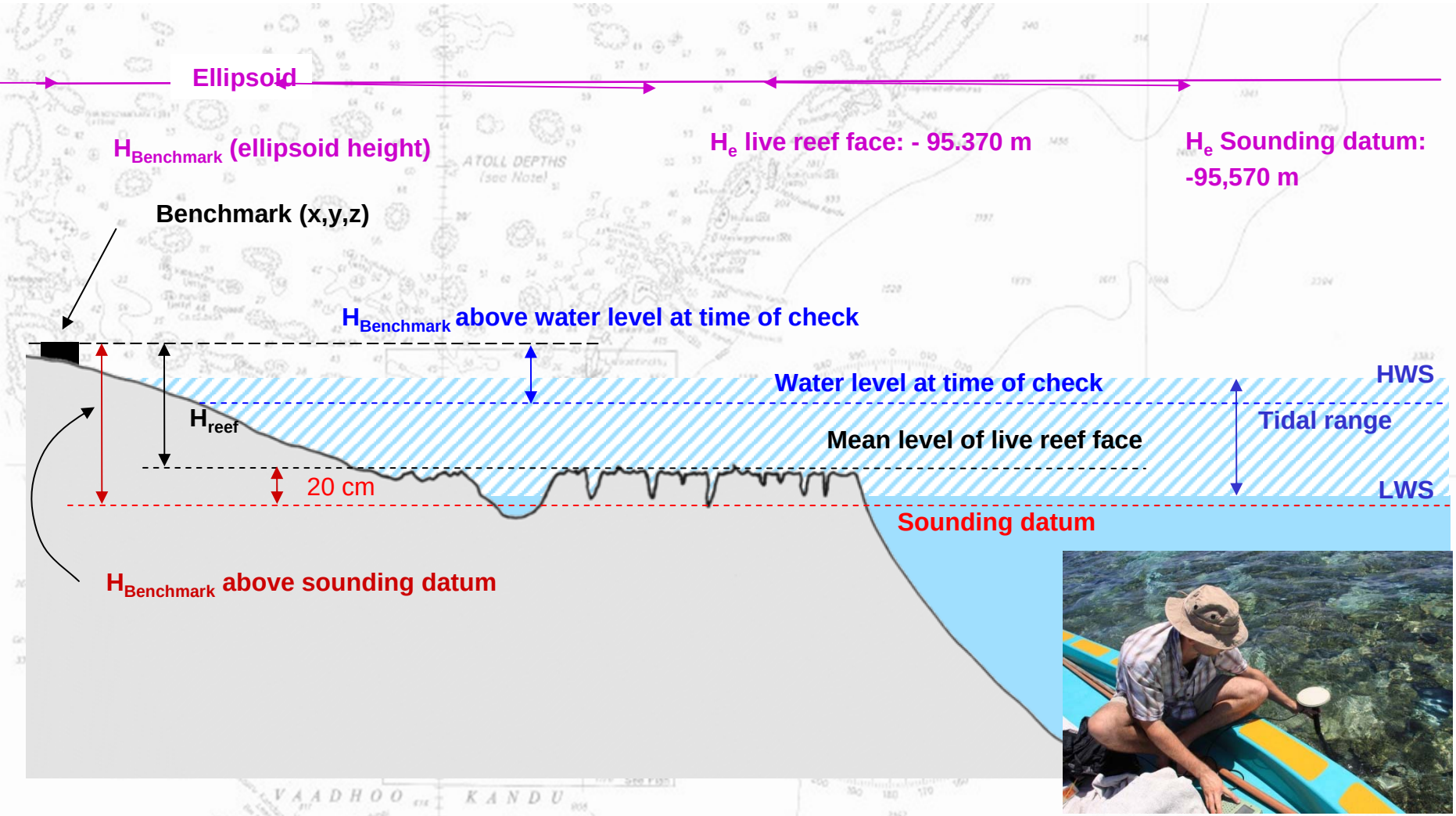


Tidal range determination

- <http://easytide.ukho.gov.uk/EASYTIDE/EasyTide/SelectPort.aspx>
- Mixed tide – maximum tidal range: 1.2 metre

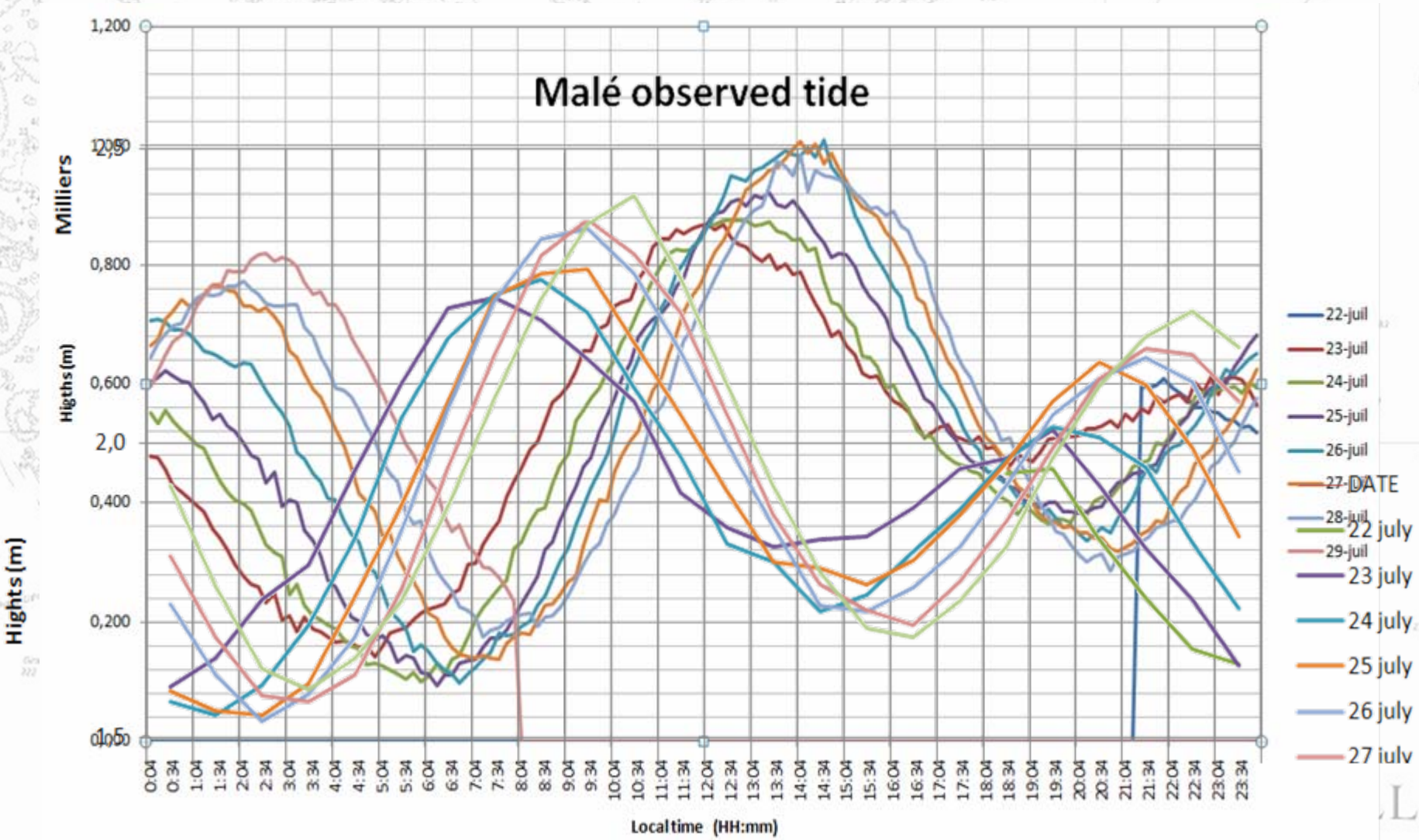


Field determination of chart datum



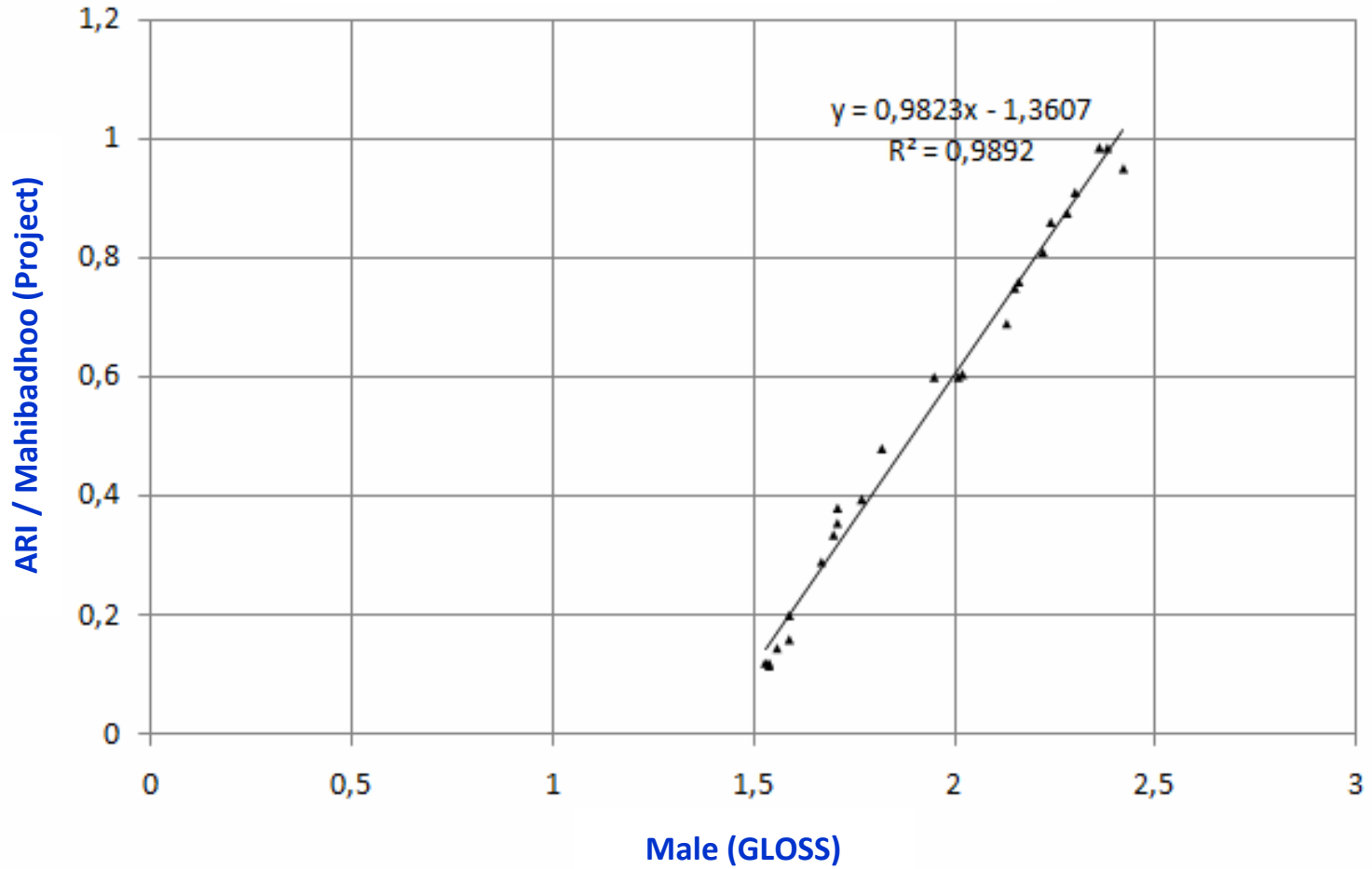
➢ *Mean level of live reef face (after 38 measurements): - 95.37 m (**σ** = 0.057 m)*

ARI ~ Mahibadhoo observed tide



Tide-by-tide simultaneous comparison

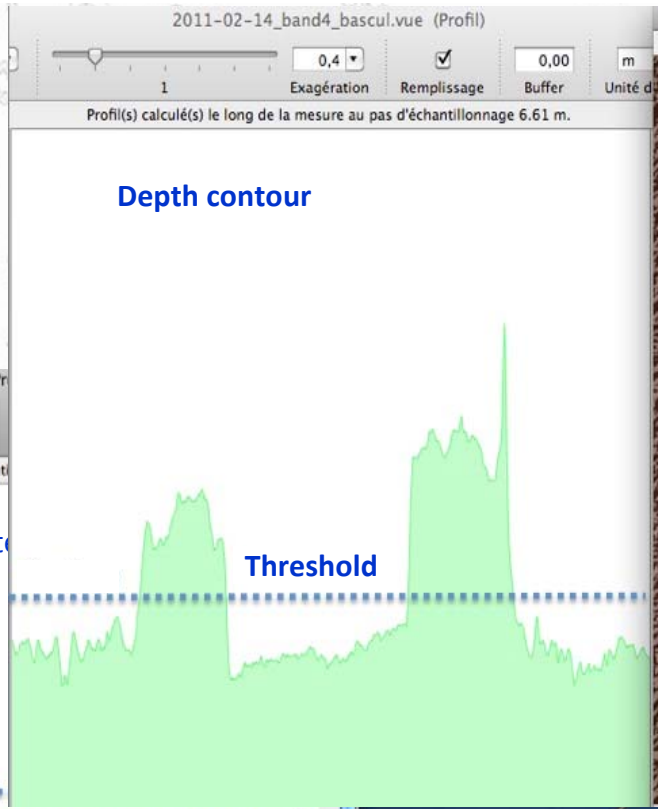
- *22nd to 29th July 2010 – Heights in metres*

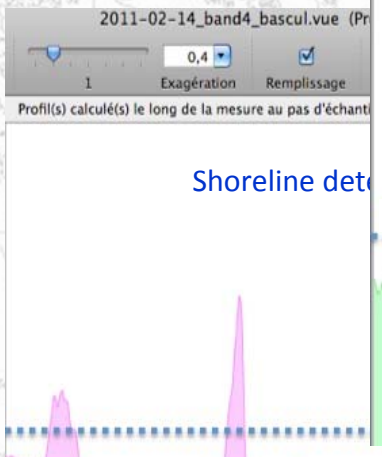


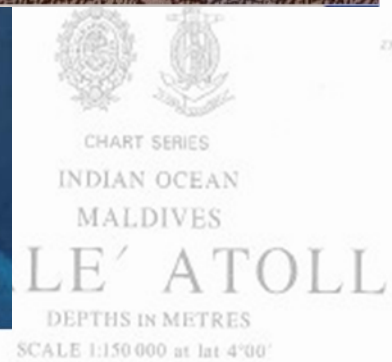
Processing

- ***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



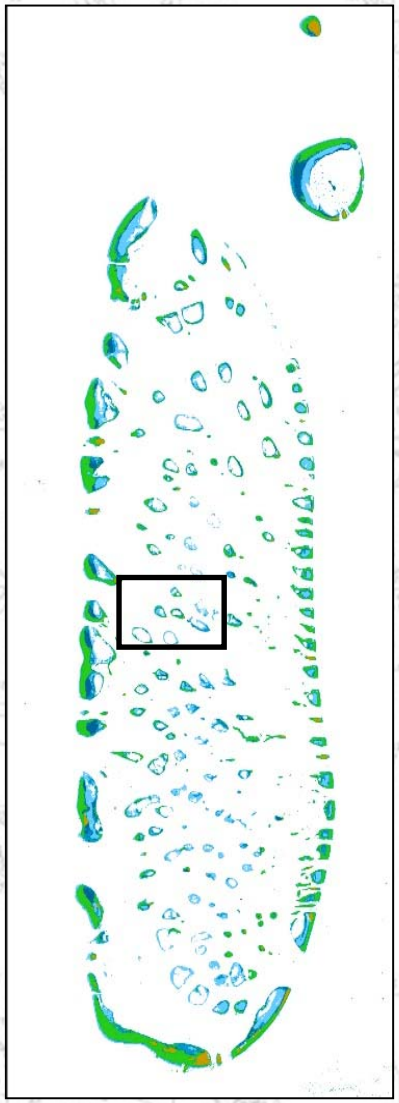


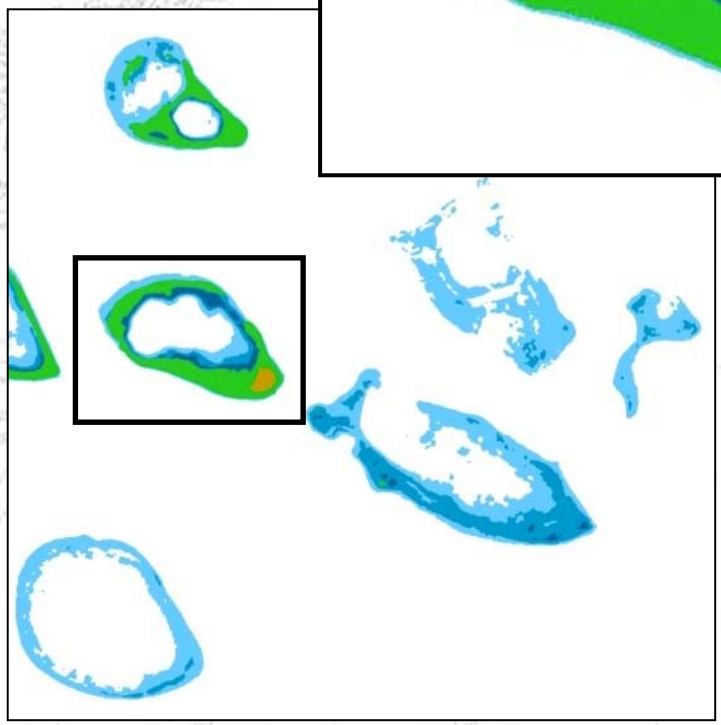


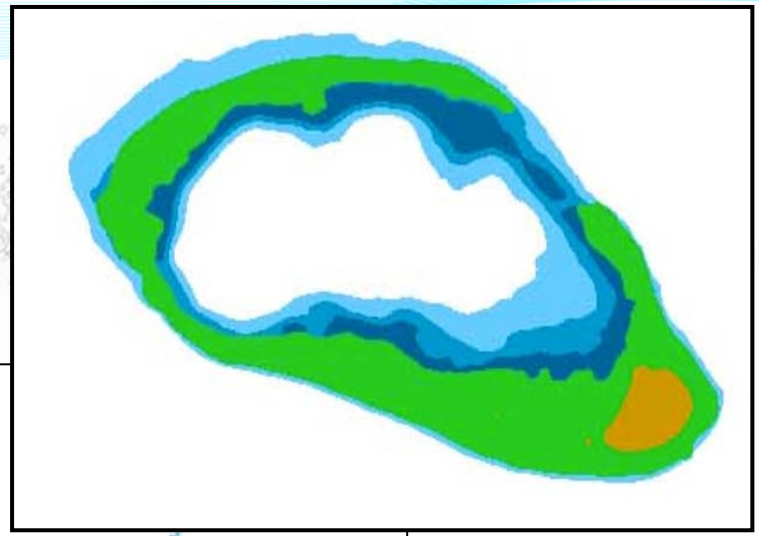
Depth Processing

5 layers:

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

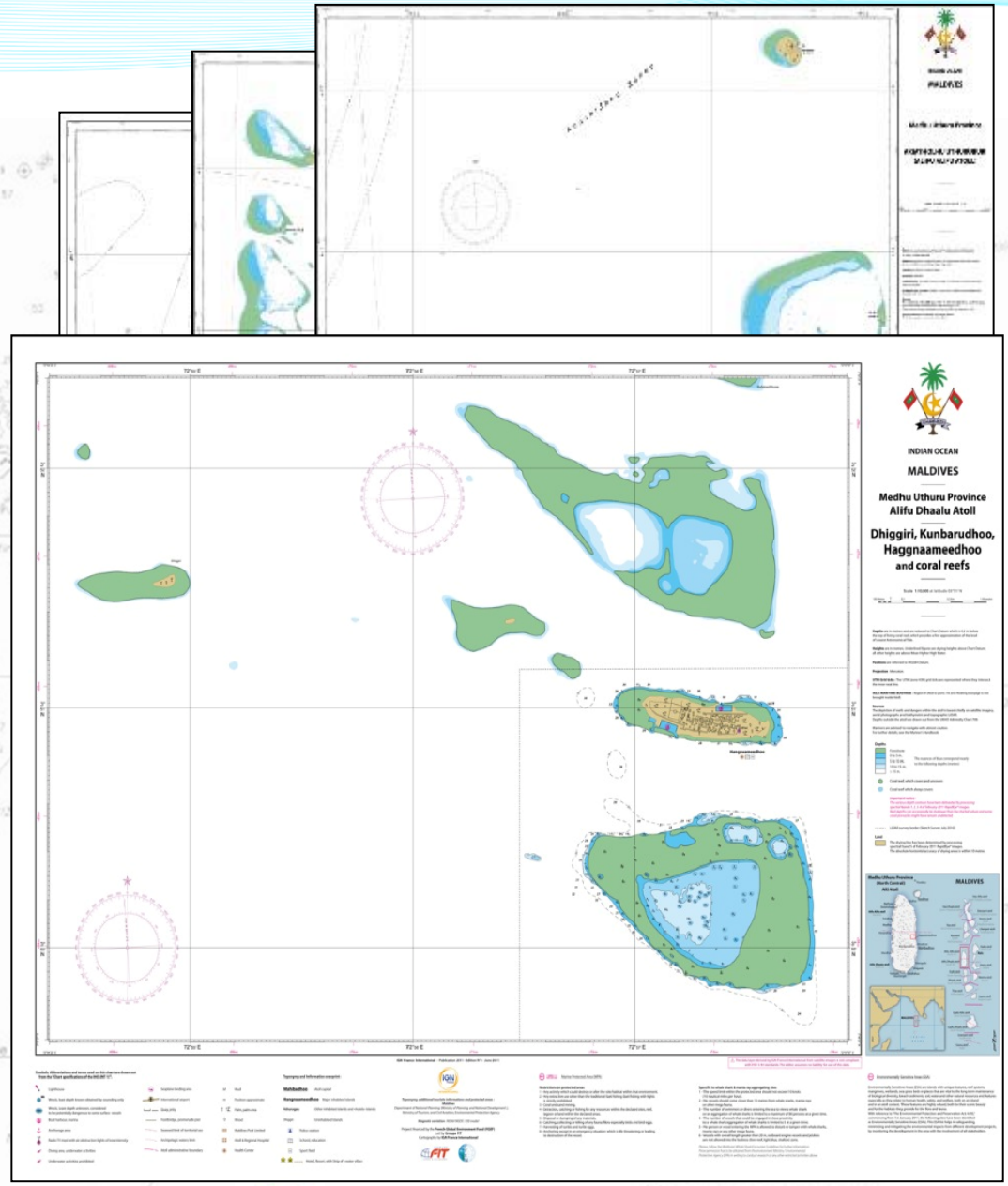






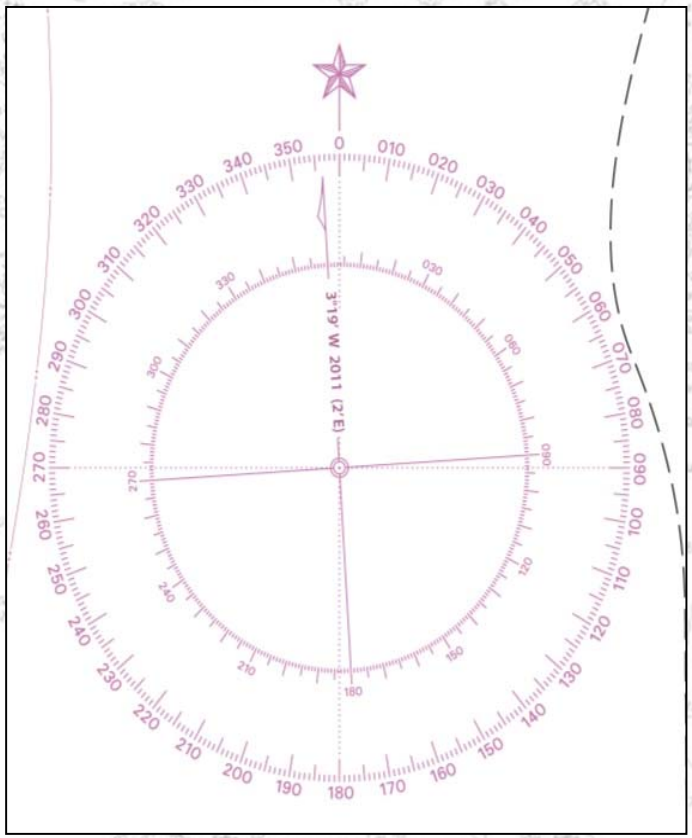
Resulting space charts

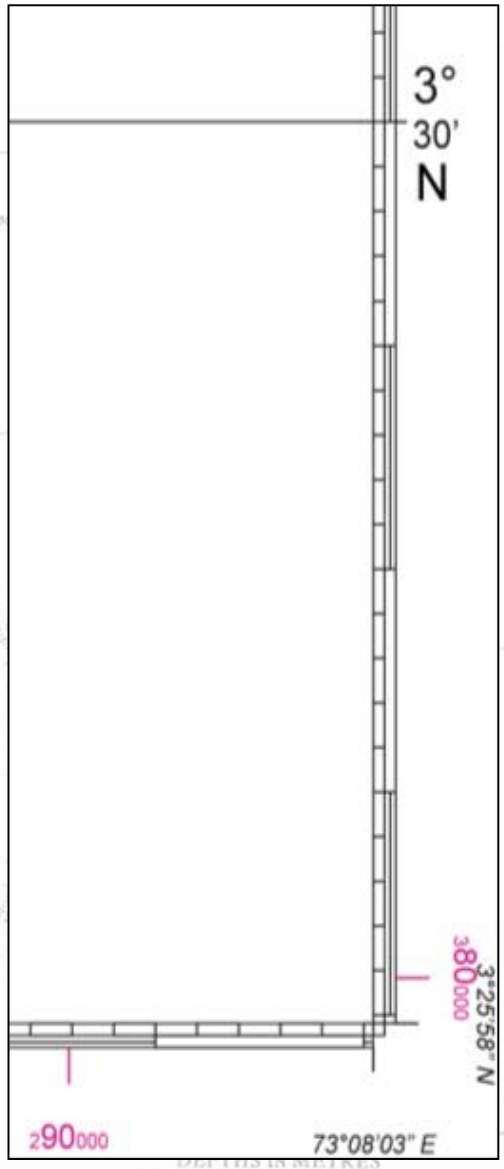
- *1/100 000 chart covering Alifu & Rasdhoo atolls*
- *1/50 000 chart of South Alifu*
- *1/50 000 chart of North Alifu & Rasdhoo*
- *1/10 000 chart of Hangnaameedhoo*



Cartographic overlay

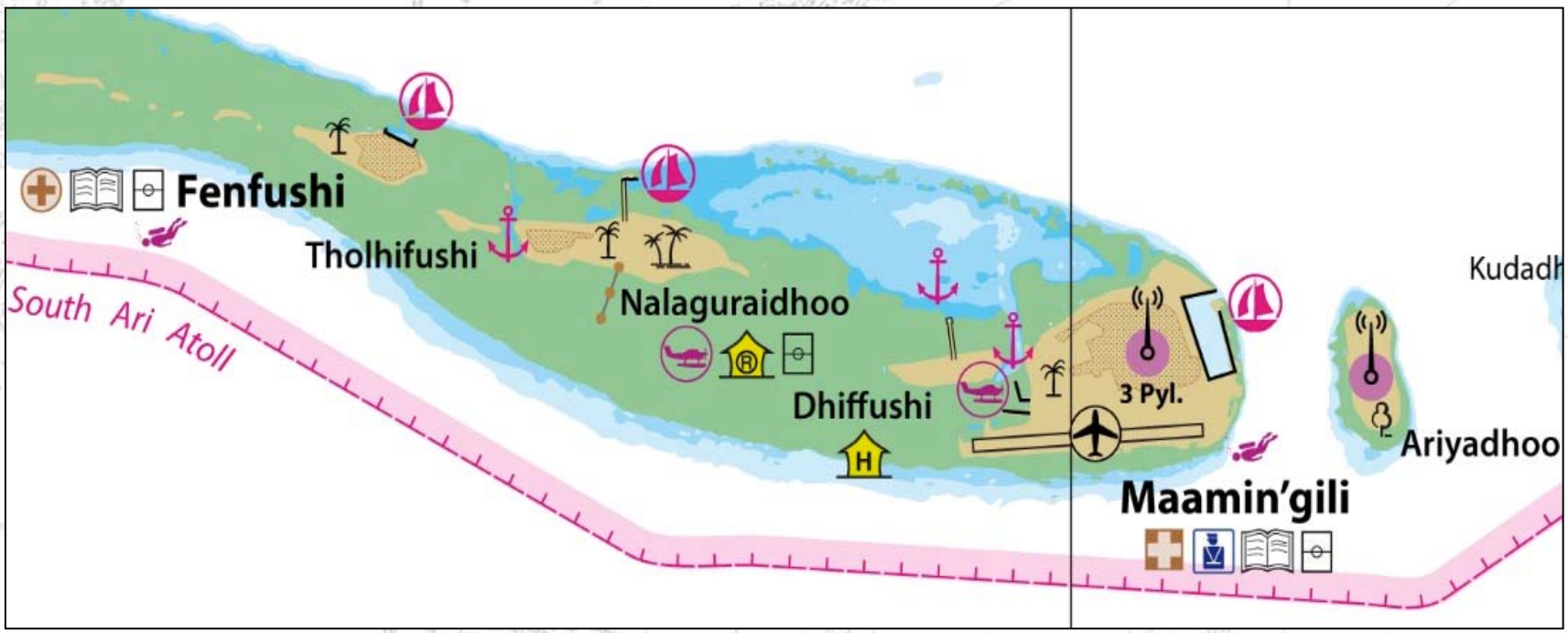
- *Latitude, longitude & UTM 43 N*
- *Detailed chart legend*
- *Compass rose & magnetic variation*





Conspicuous objects & topography

- *Using IHO publication 1 D*



Example of Admiralty chart BA700

Surface to be covered : 32 200 km²

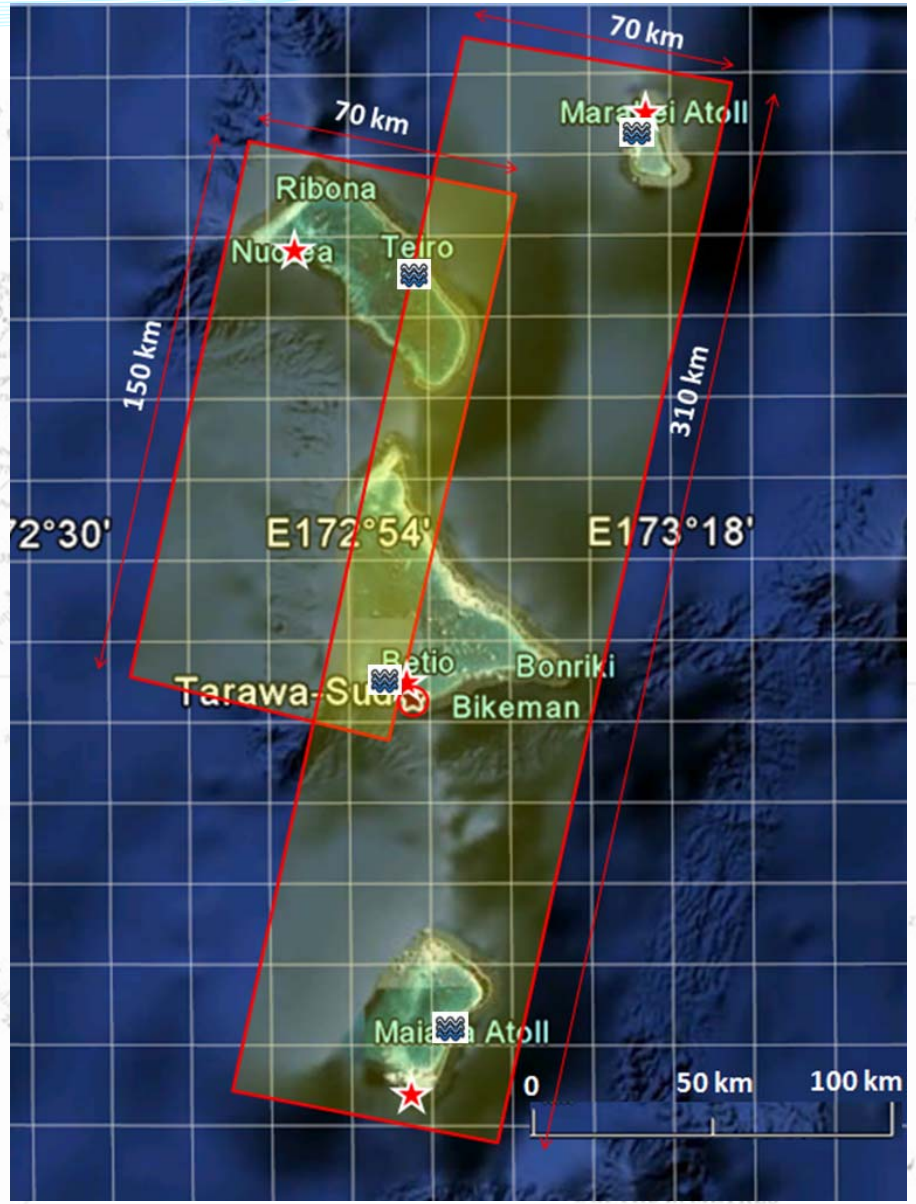
➢ ***Step 1: Choice of satellite***

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

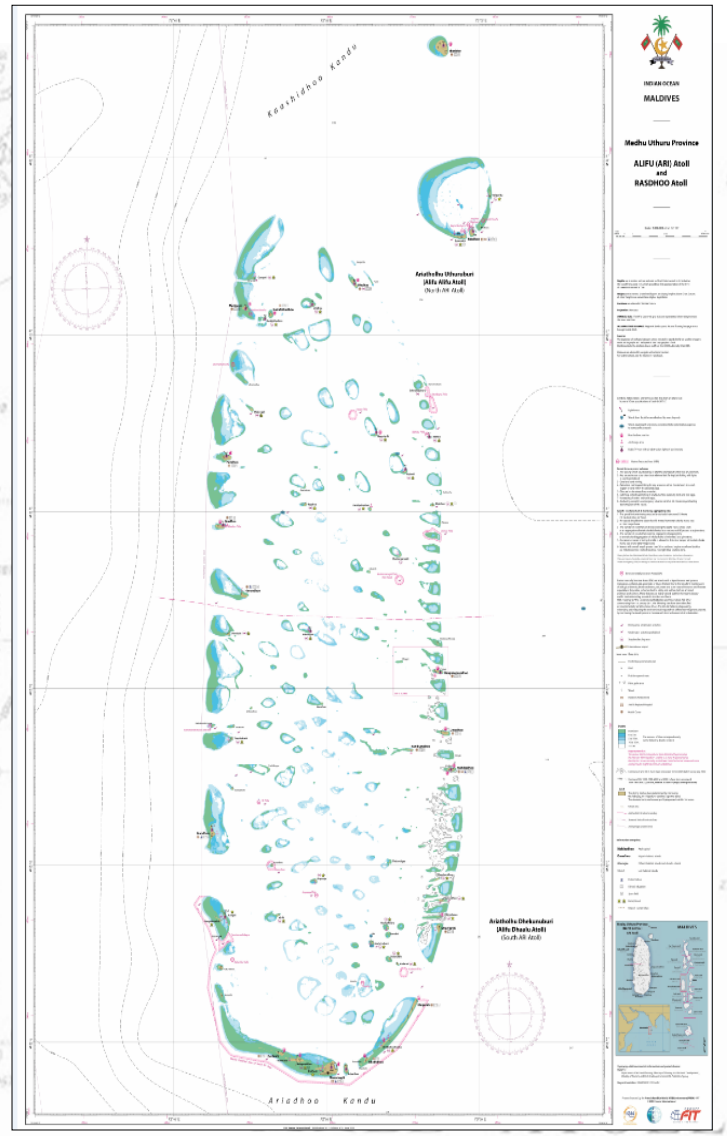
➢ ***Step 3: Production of a minimum cartographic base***

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

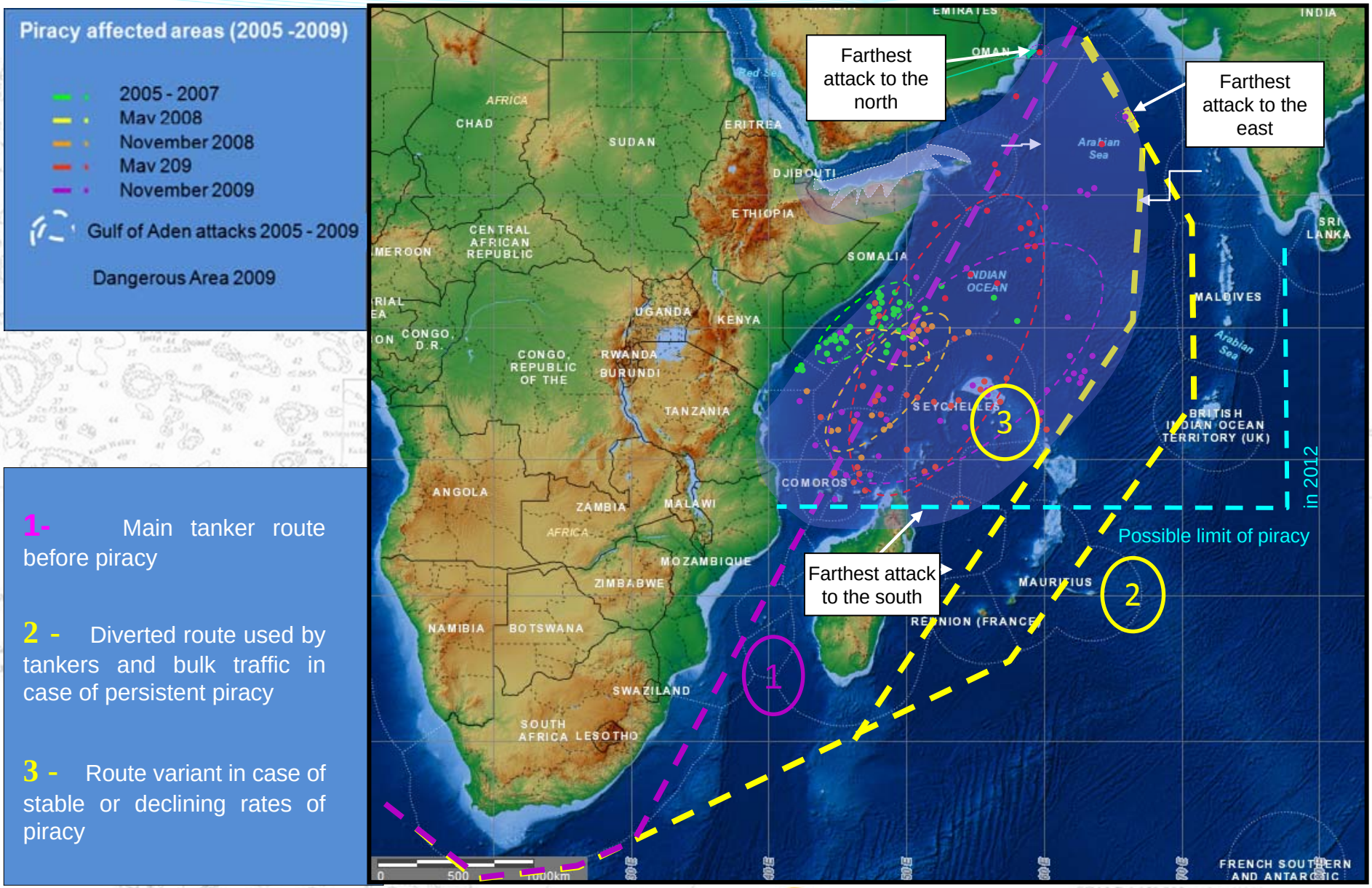
Total production time = 7 months

Average cost per spacechart = 100 k€

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



Spacecharts for the marine highways

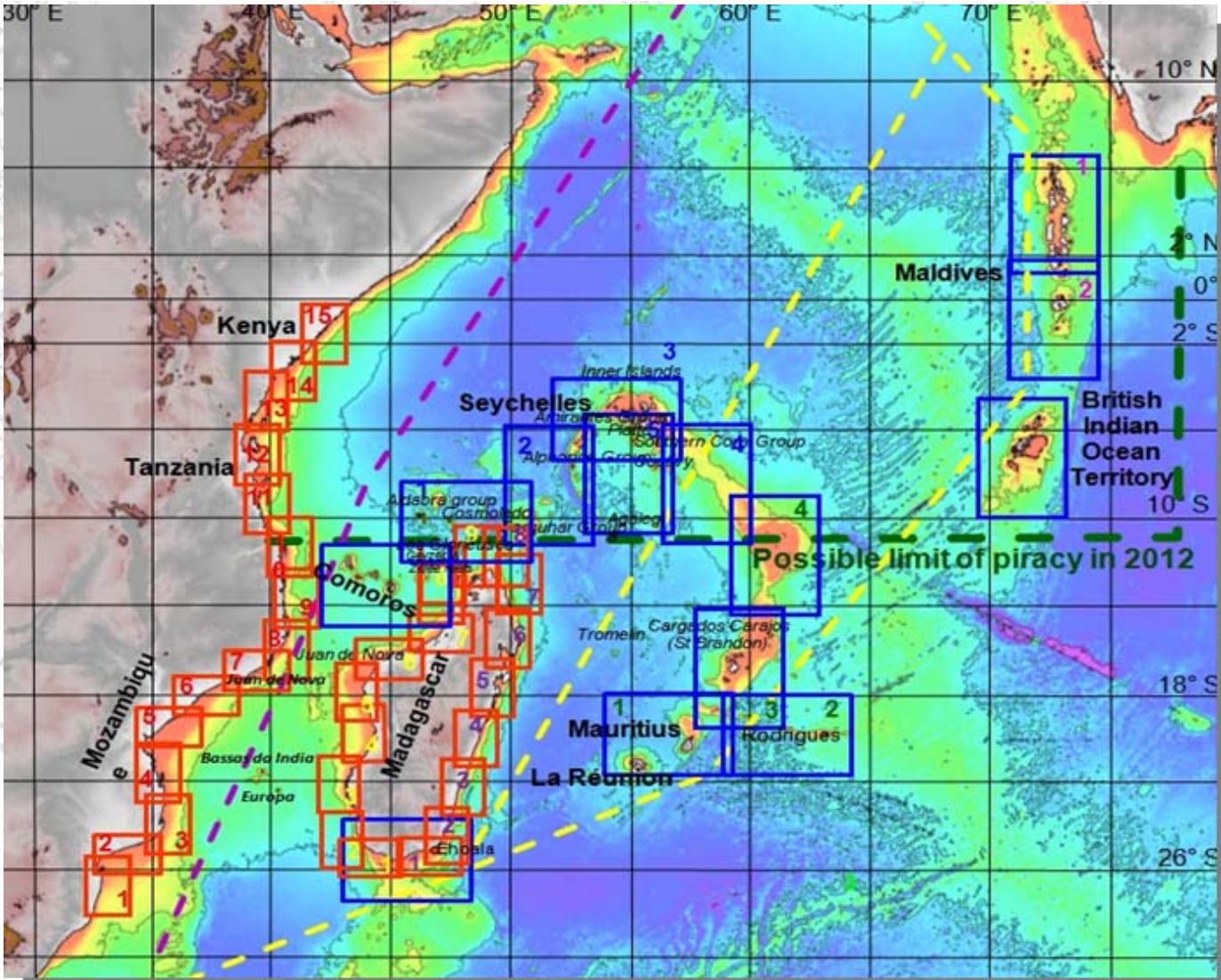


1- Main tanker route before piracy

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

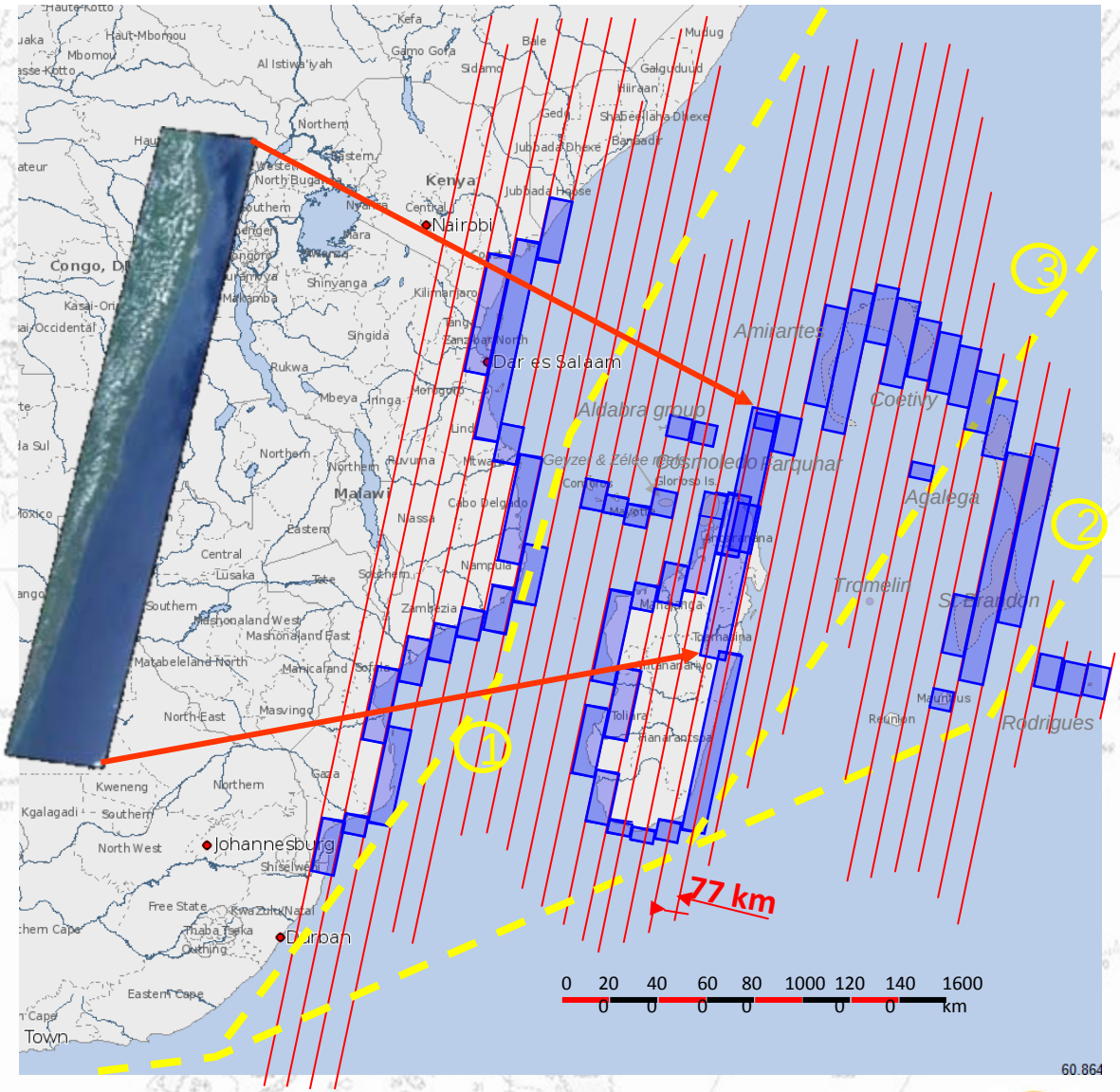
Spacecharts index

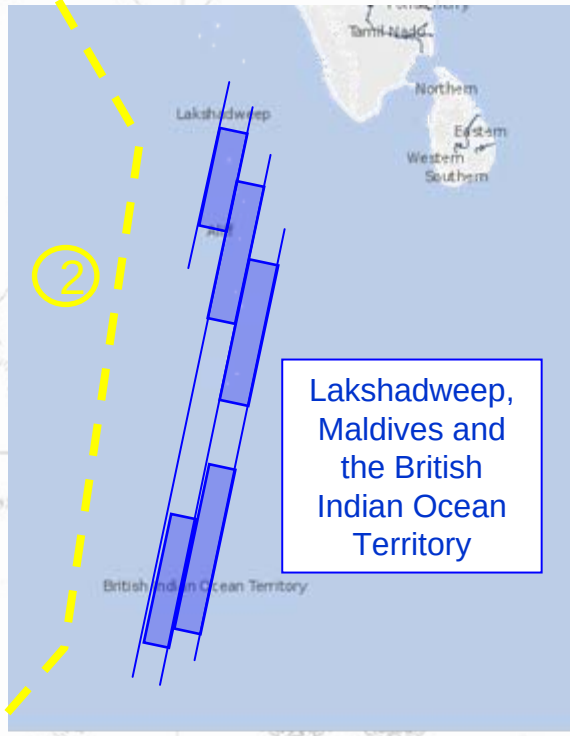


1:500 000

1:250 000

Available satellite images for the marine highways





Lakshadweep, Maldives and the British Indian Ocean Territory

Céline Roux

Thank you for your attention.