



# **SATELLITE DERIVED BATHYMETRY (SDB)**

*Precautions to be taken when using SDB  
in support of Maritime Delimitations*

# SUMMARY

1. SDB current status
2. SDB models: Sambuca, ALUTs, Bomber, etc.
3. Applying SDB in Africa surf zones
4. Calibration and atmospheric corrections
5. Controls and field surveys
6. Tidal observations
7. Precision and final results
8. ARGANS / EOMAP challenge
9. Precision and final results
10. ITLOS views and arbitration

# 1. SDB CURRENT STATUS

- Since 1999, SDB is based on depth-log attenuation and Lee et al. physics based equations (1999) involving the absorption  $a$ , the scattering  $b$ , and the bottom reflectivity  $\rho$

$$\boxed{L = f(Z_{a, b, \rho})} \quad \text{or} \quad \boxed{Z = f^{-1}(L_{a, b, \rho})}$$

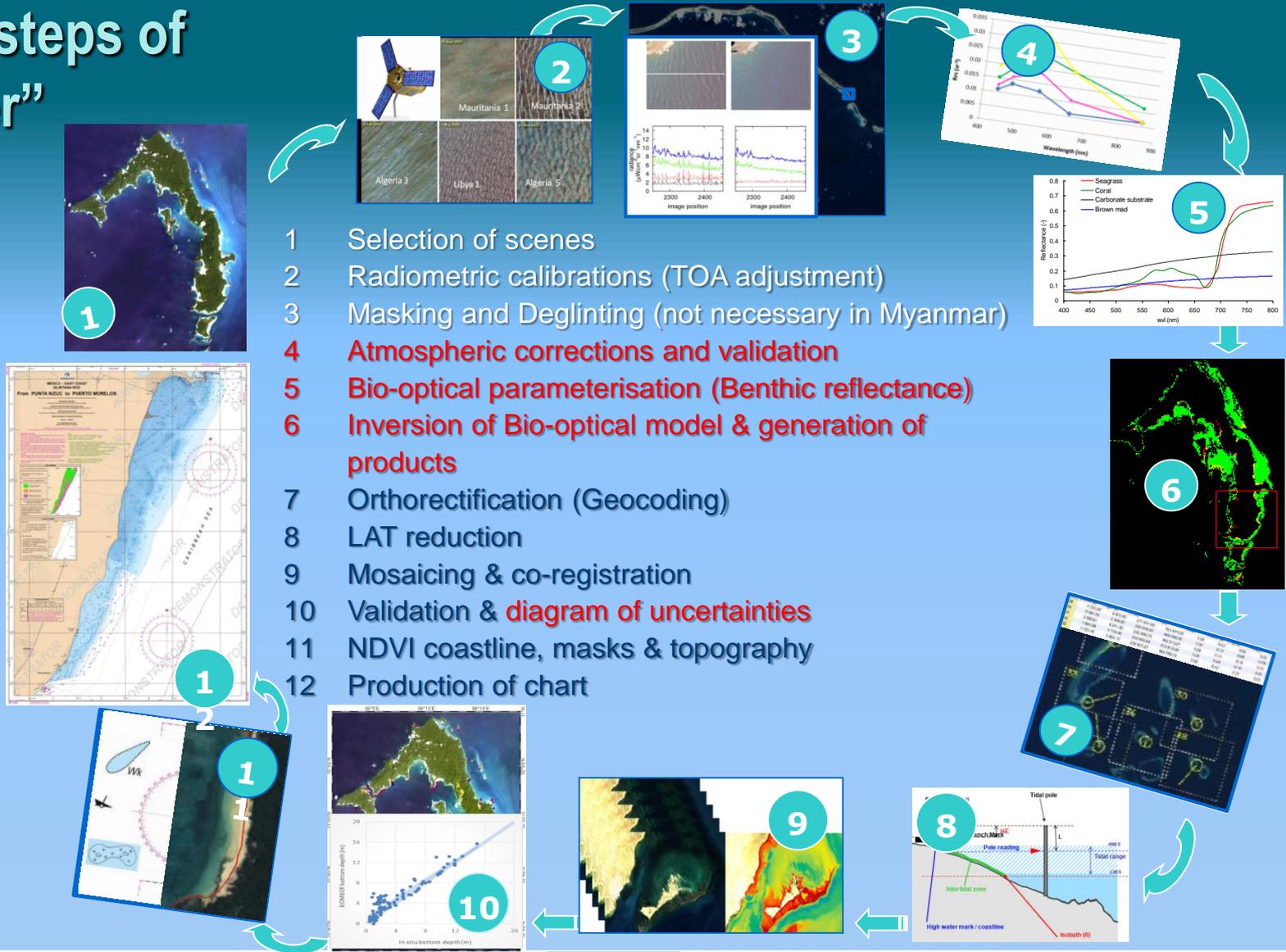
Lyzenga Forward model  Lee et al radiance inversion model

- Several models have been developed since; some are better performing than others, but all yield similar results.
- HOs are reluctant to implement SDB, which they find unreliable and insufficiently proven and invest little in R&D.
- Laboratories are confident but are not specially interested in reaching the cartographic world and meeting the IHO standards.
- Access to satellite images has improved significantly (Cal/Val, Big Data, HPC, frequent revisit, cost).

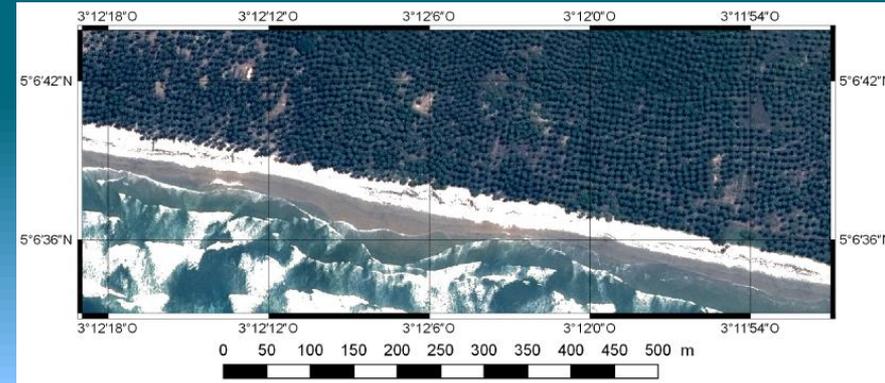
# 2. SDB MODELS: SAMBUCA, ALUTs, BOMBER, etc.

## The 12 steps of "Bomber"

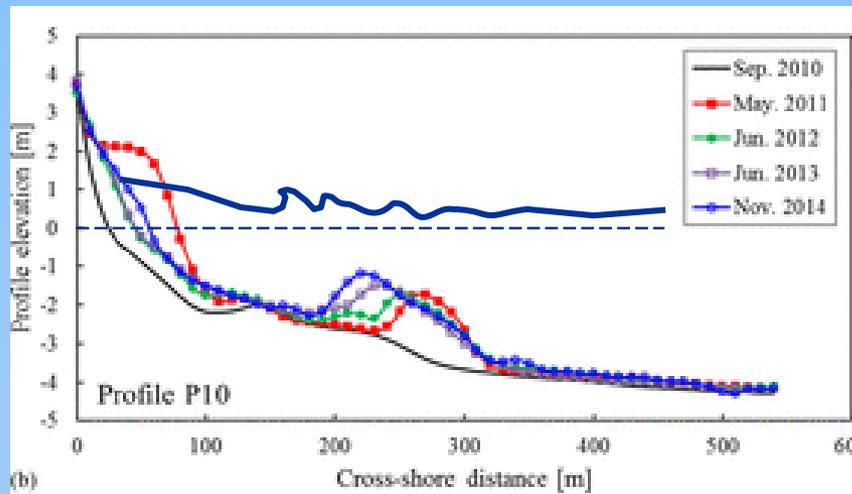
Most models are inspired by the CSIRO original



# 3. APPLYING SDB IN AFRICA SURF ZONES



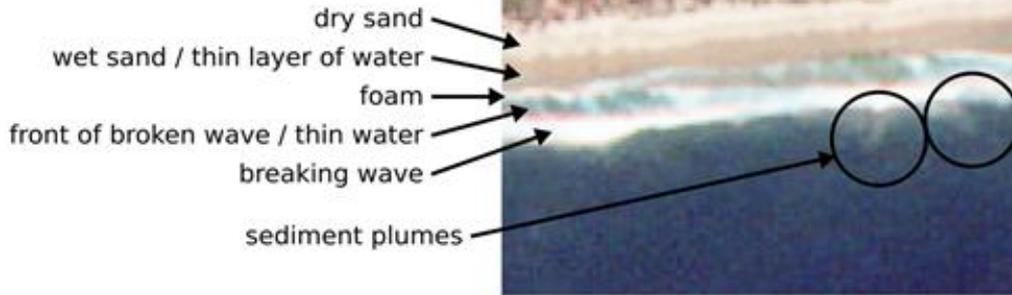
## Ivoirian surf zones



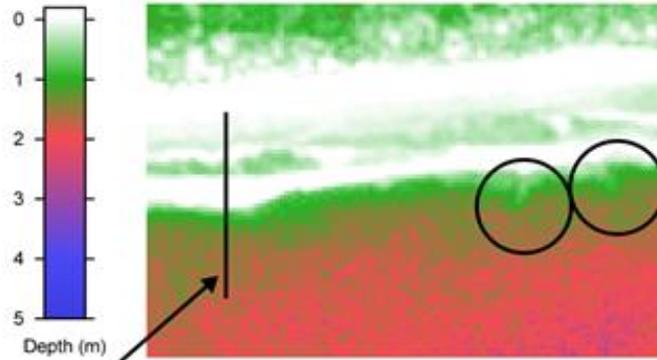
## Cross-shore profiles

- Full physics based SDB processing is used to determine profiles, not depth layers
- Between highly reflective foam bands, valid bathymetry can be retrieved
- Sediment plumes are detected by visual inspection
- Beach slope starts at the first point at which  $Z > 0$
- Most reliable depths are found behind the breakers
- No glint removal, no spatial filtering, independent pixel processing  $\Rightarrow$  pixel to pixel analysis can be noisy
- Ground truth is essential to post-calibrate the model

(a) Composition of beach profile



(b) Bathymetry estimation

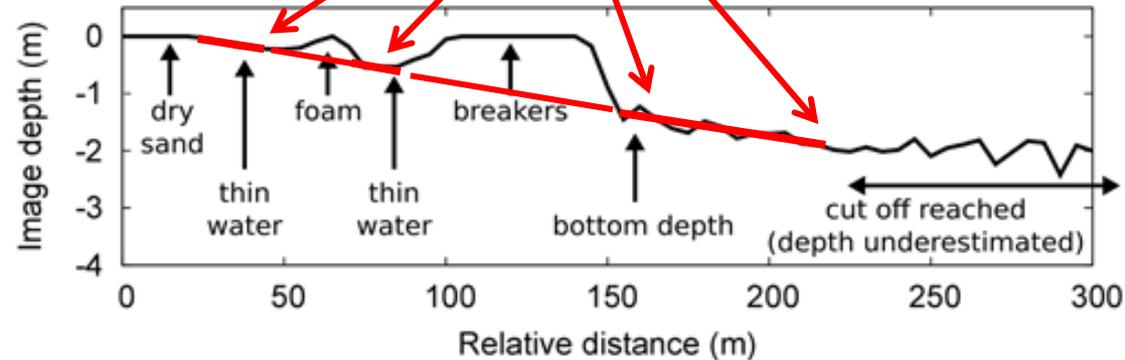


(c) Typical profile from beach to offshore avoiding sediment plumes

# Avoiding sediment plumes and foam

valid depths

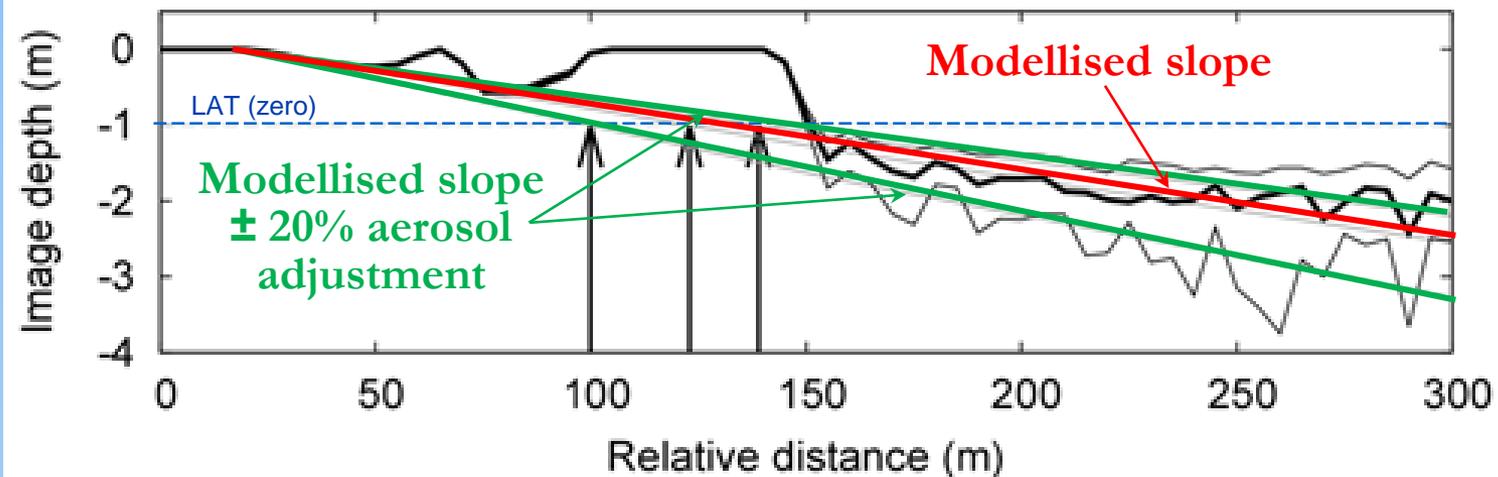
# Estimation of slope



# 4. CALIBRATION AND ATMOSPHERIC CORRECTIONS



Aerosols generated by breakers



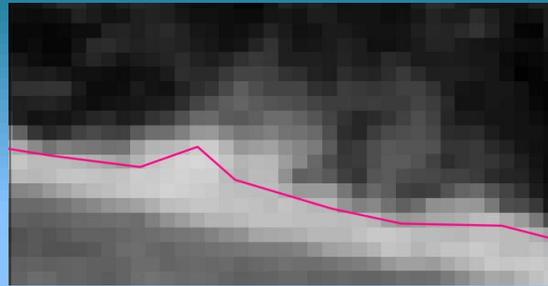
Influence of aerosol optical thickness

# 5. CONTROLS AND FIELD SURVEYS

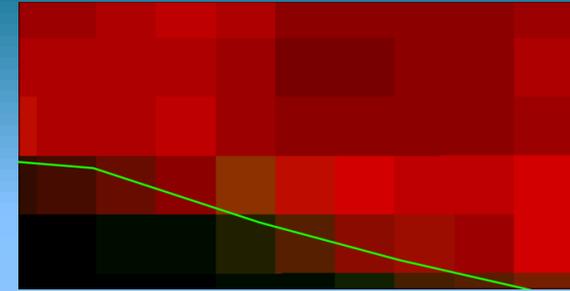
## ➤ Optimisation of satellite images



Pleiades (Pixel 0.5 m)

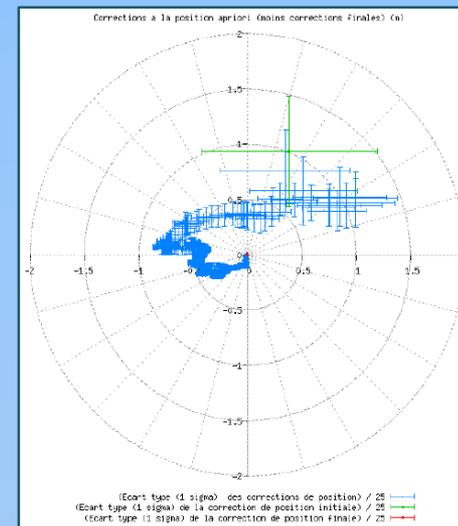


Spot 1 (Pixel 20 m)

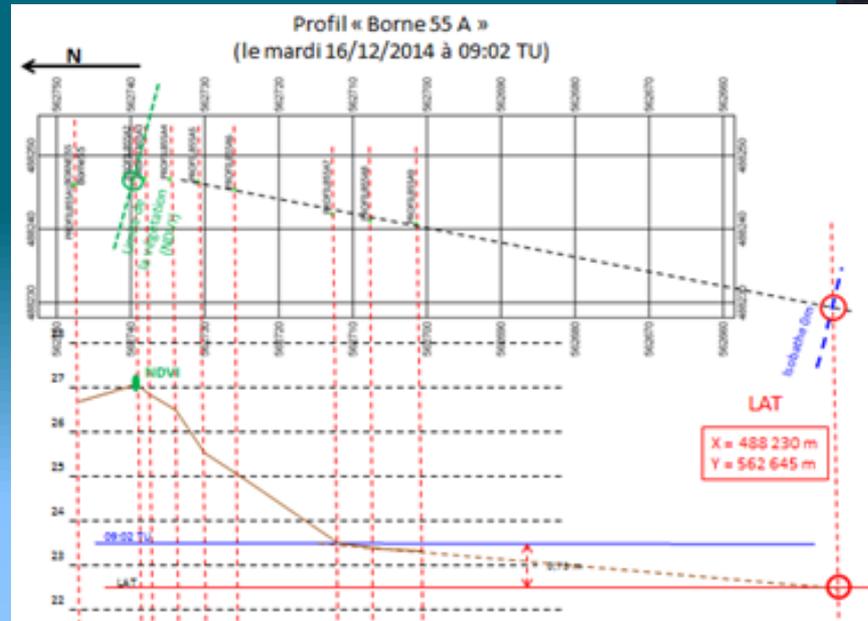


Spot 5 (Pixel 5 m)

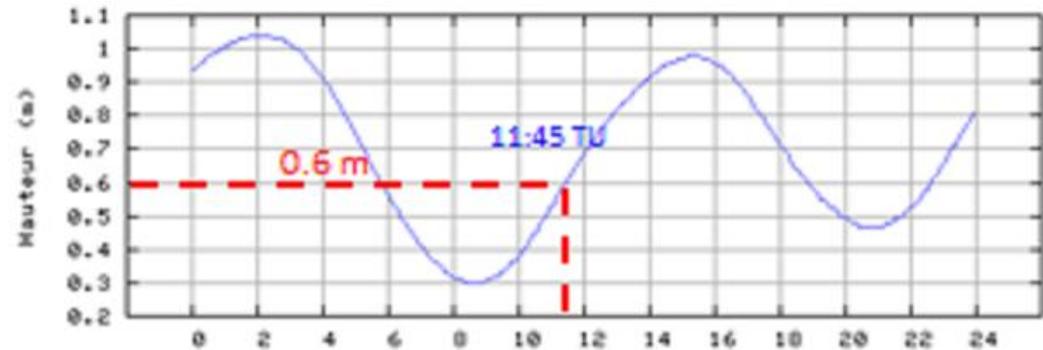
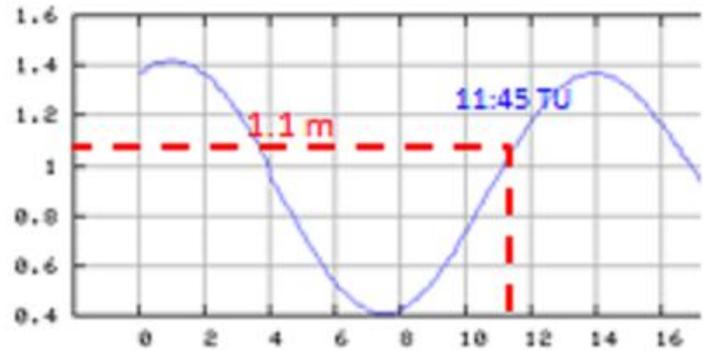
## ➤ Professional geodetic determinations



# Determination of beach profiles and image setting by traditional topographic surveys



## 6. TIDAL OBSERVATIONS



Sassandra and Abidjan predicted tides (SHOM tide tables, although Admiralty tide tables could do)

- Field observations must be reduced to the LAT
- Predicted tides should be sufficient
- However an even better precision can be obtained by observing water level at local tide stations

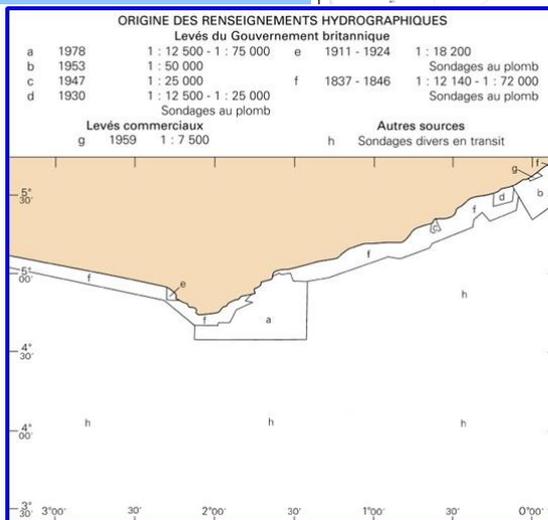
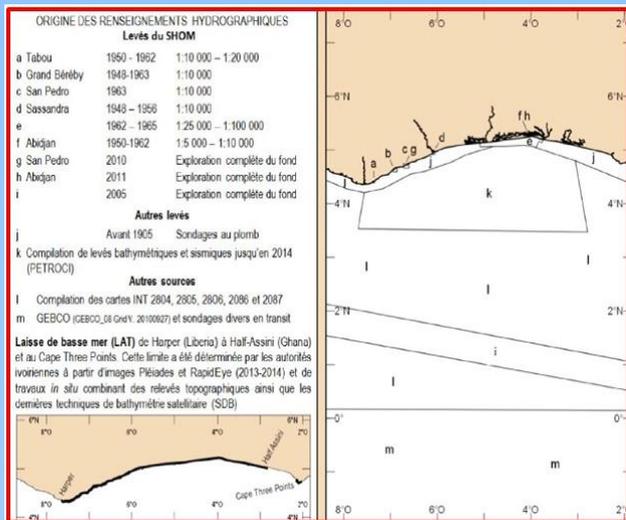
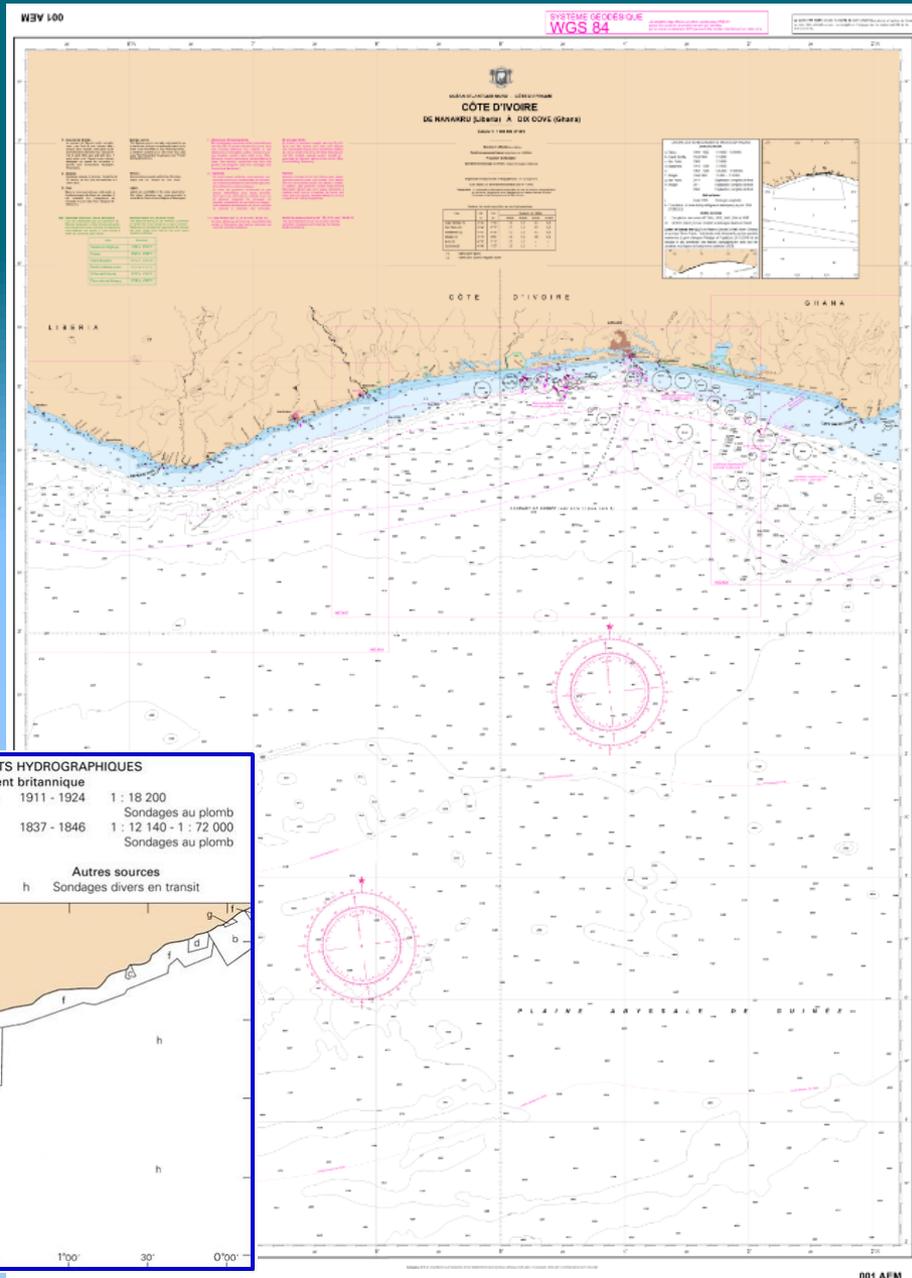
# 7. PRECISION AND FINAL RESULTS

Precision of baseline:

± 5 m with Pleiades image (Cote d'Ivoire)

± 10 m with RapidEye images

± 15 m with RapidEye images, without ground control (Ghana)



## 8. ARGANS / EOMAP CHALLENGE

### According to EOMAP:

- SDB is not applicable due to the turbidity
- ARGANS did not provide the full data as required
- All ARGANS results challenged (charts, beach profiles, baselines, tides, etc.)

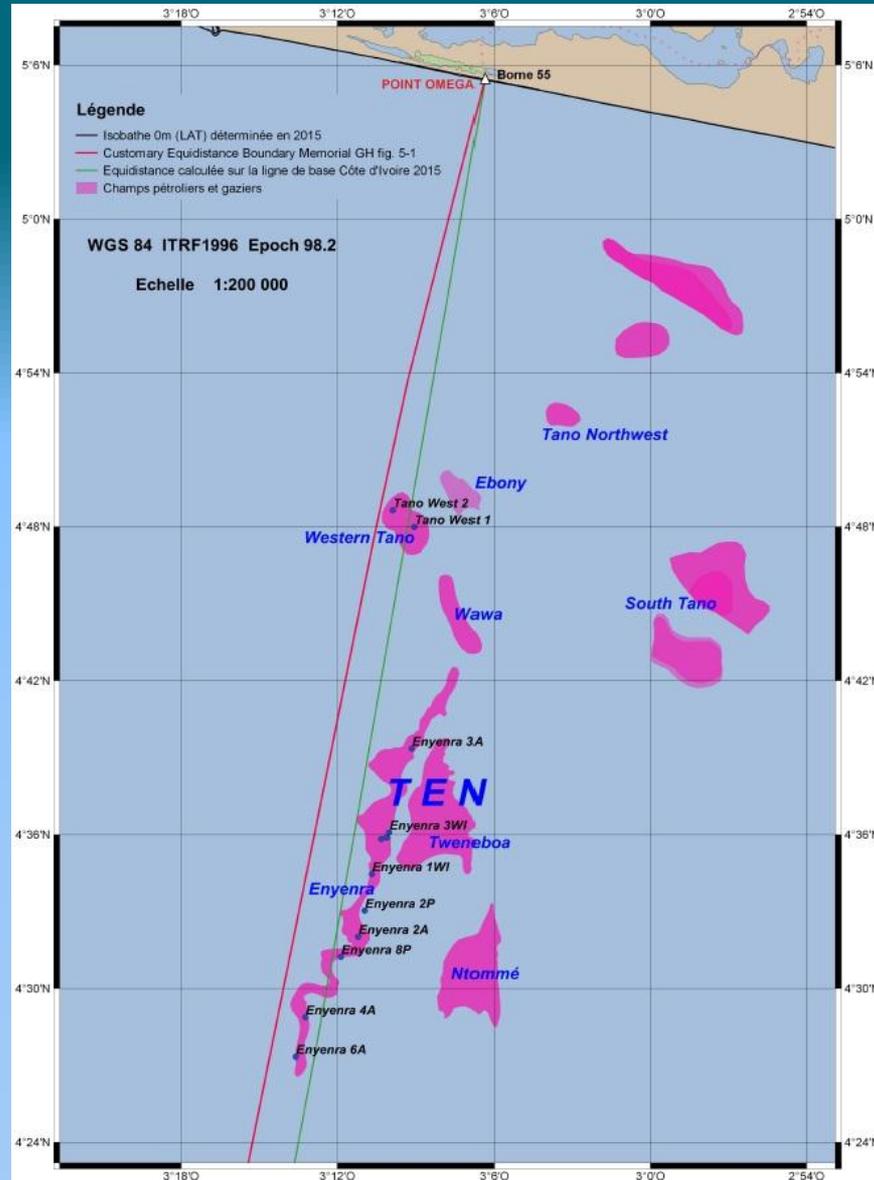
### According to ARGANS:

- The operators were all experienced Cat A FIG/IHO
- SDB has been validated and field-proven
- Because of lack of ground controls, EOMAP's images and conclusions are irrelevant

## 9. ITLOS VIEWS AND ARBITRATION

- Although more recent and precise, the Cote d'Ivoire chart is discarded as it would create two equidistances.
- Using an 1837 coastline was not discussed as the INT chart series BA 1383 / SHOM 7786 were used by both Parties until 2014.
- ITLOS calculated a simplified equidistance based on INT chart.
- The Court neither objected, nor approved the validity of SDB.
- The Court did not address the EOMAP/ARGANS challenge.
- All other Cote d'Ivoire relevant circumstances (concavity, Jomoro dog's leg, coastal instability, consequences on Togo/Benin delimitations, location of hydrocarbons) have been rejected.
- Apart legal issues (Estoppel...) of no practical consequences, Cote d'Ivoire loses all chances to gain access to the oil fields.

# OBJECT OF THE EXERCISE



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KLH

FIG/IHO/ICA Cat. A

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**Any Questions?**