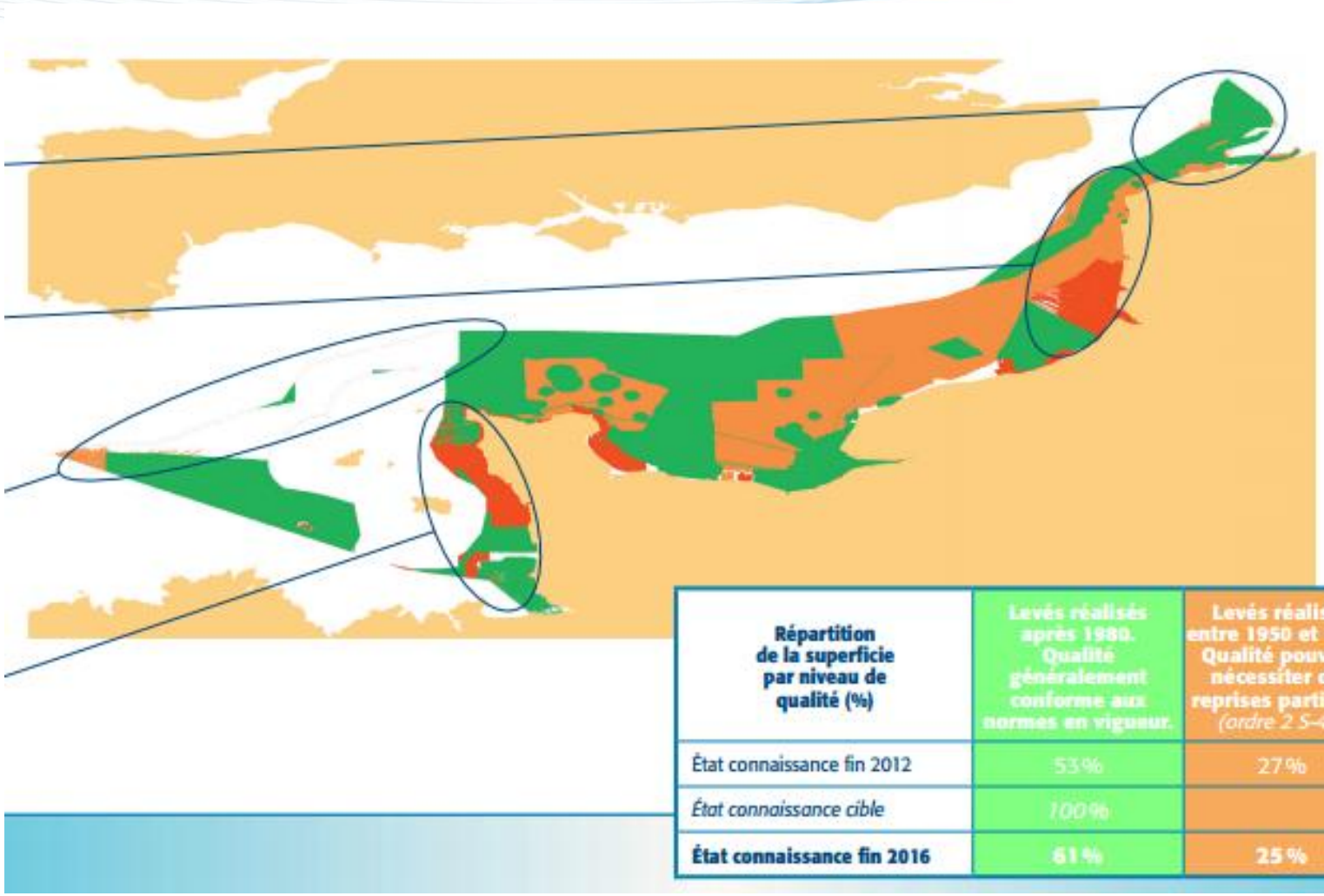
Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE
MINISTÈRE DE LA DÉFENSE

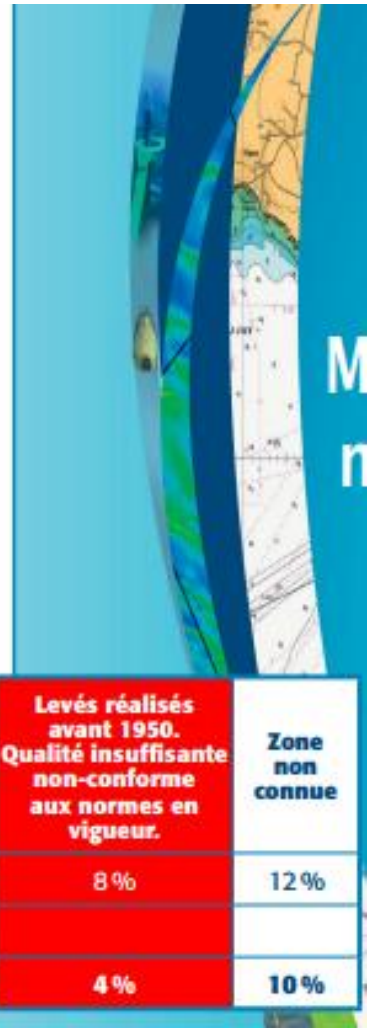
SHOM
L'océan à la carte

SATELLITE DERIVED BATHYMETRY

Coastal mapping update

Significant unexplored shallow waters





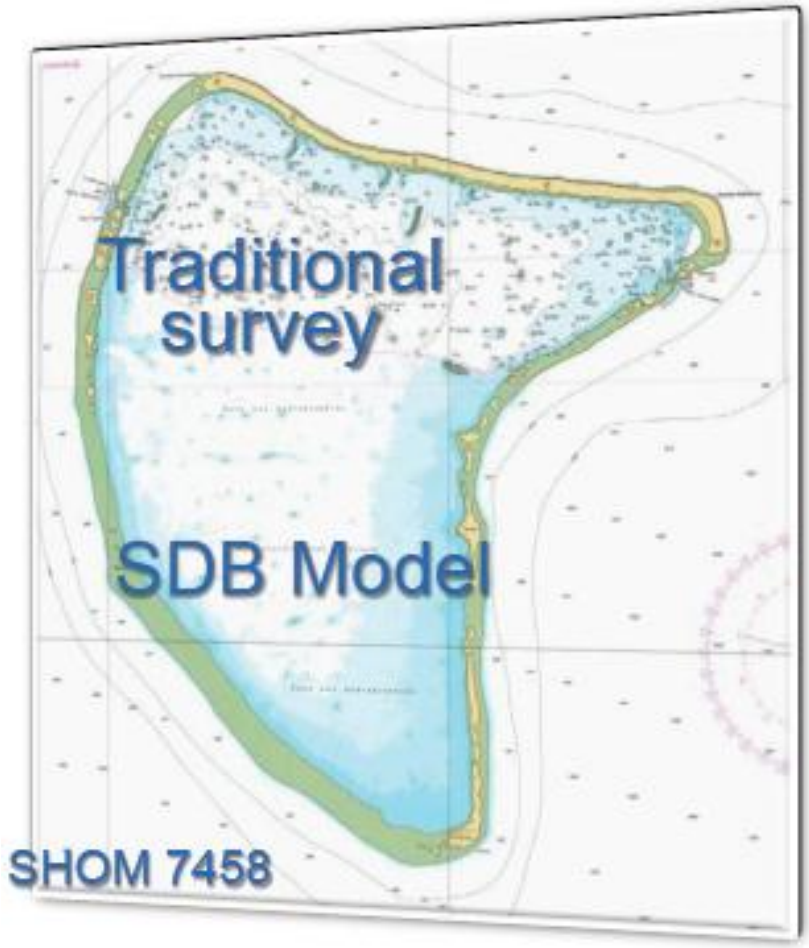
Répartition de la superficie par niveau de qualité (%)	Levés réalisés après 1980. Qualité généralement conforme aux normes en vigueur.	Levés réalisés entre 1950 et 1980. Qualité pouvant nécessiter des reprises partielles *(ordre 2 S-44)*	Levés réalisés avant 1950. Qualité insuffisante non-conforme aux normes en vigueur.	Zone non connue
État connaissance fin 2012	53%	27%	8%	12%
État connaissance cible	*100%*			
État connaissance fin 2016	**61%**	**25%**	**4%**	**10%**

What is Satellite Derived Bathymetry (reminder)?

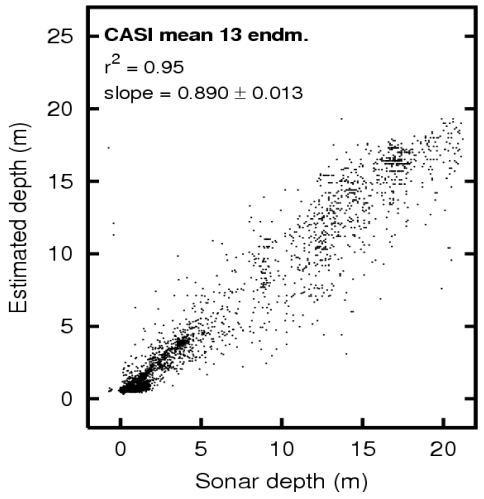
A survey method founded on analytical modelling of light penetration

…that can yield useful and inexpensive depth information in shallow water (< 30 m) in poorly surveyed areas

but still with uncertain compliance with IHO S-44



The two methods of SDB



1. In the **Empiric method** (Lyzenga 1978), based on the exponential attenuation of radiance, the model is warped to match in-situ measurements:

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

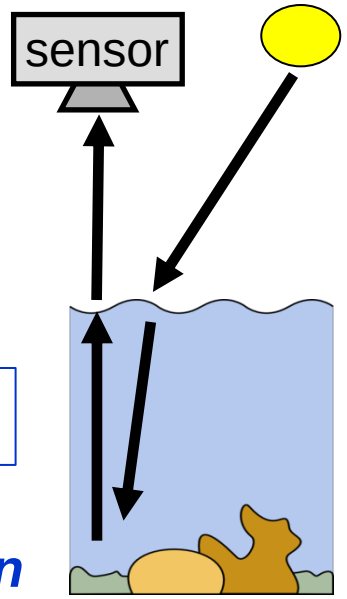
Depth Green Red

2. In the **Physics-based method**, depths are obtained by inverting the equation of radiance received by sensor:

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

Sensor receives this

Depth



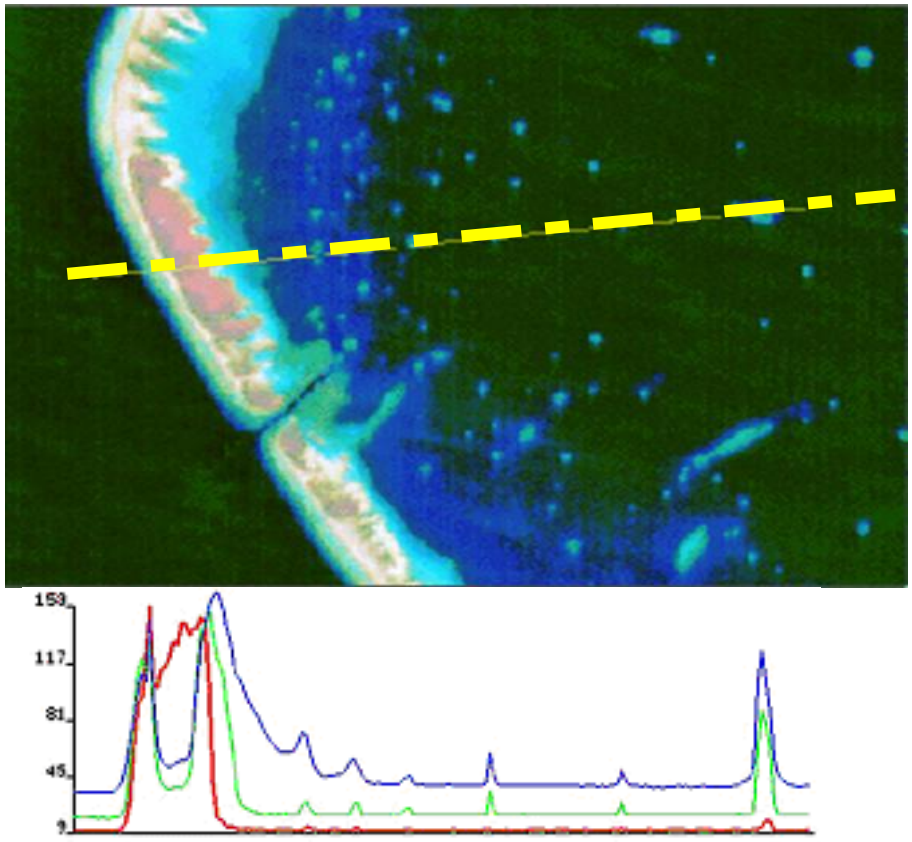
Courtesy
Dr John Hedley

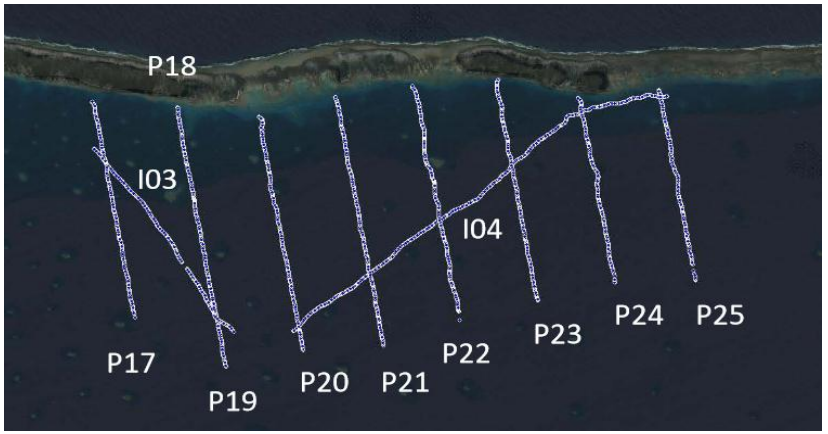
⇨ ***The Physics-based method is more robust & reliable, and (in theory at least) no longer depends on ground control.***

Published: Hedley & al. 2011, Remote Sensing of Environment 120, 145-1550, 145-155

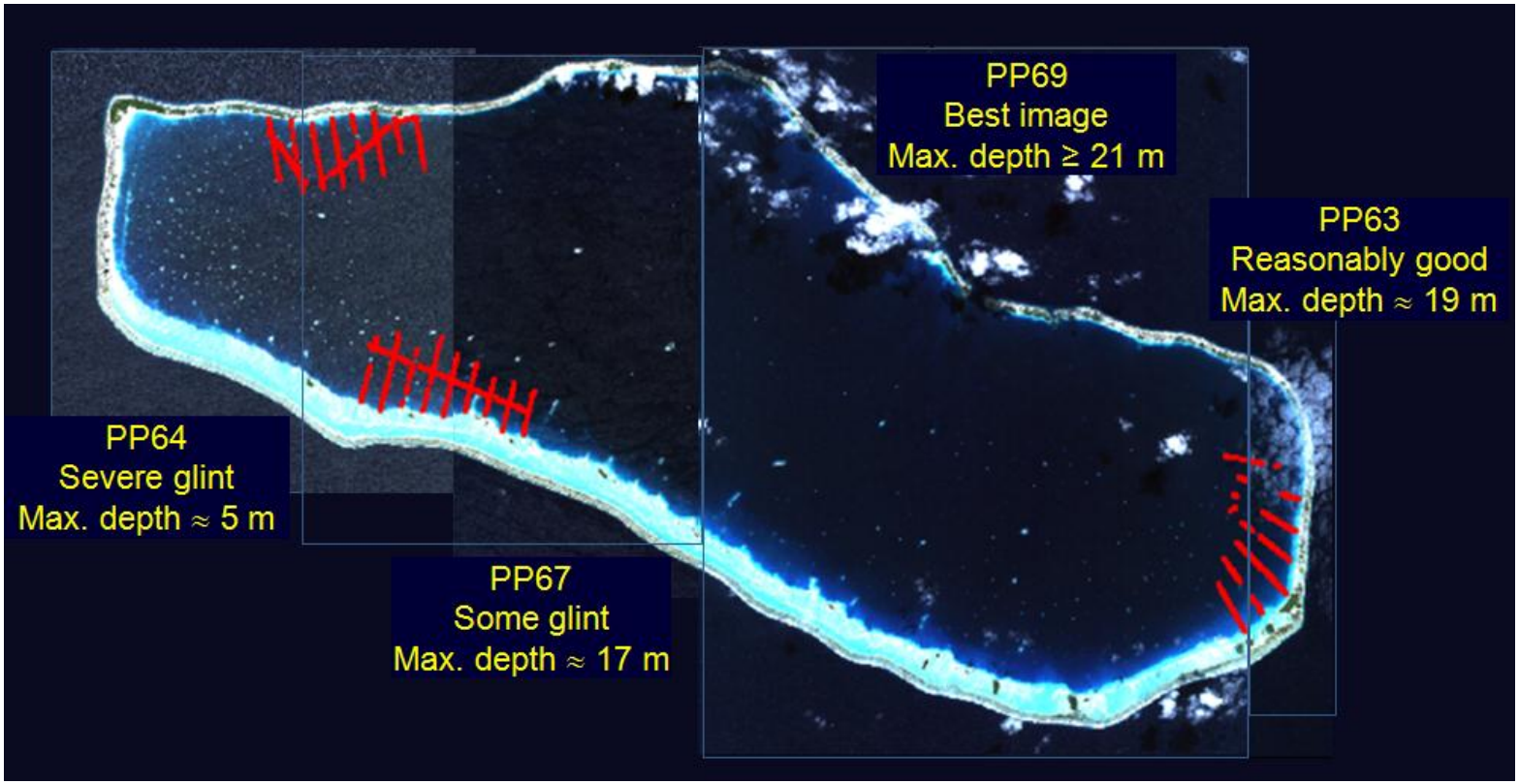
SDB early processing (Lyzenga 1978)

- Needs survey lines and control points
- One image calibrated at a time - Generalisation uncertain





Model performances highly dependant on quality of images

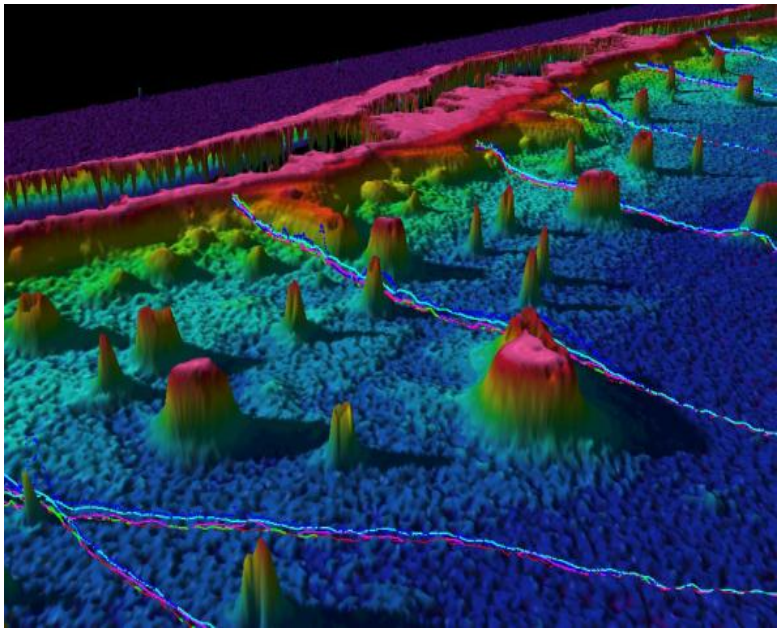


Same atoll, 4 Pleiades images, 4 different valid depth ranges

- Optimal performances require High Resolution images and suitable environment (wind, glint, current, sun, turbidity….)

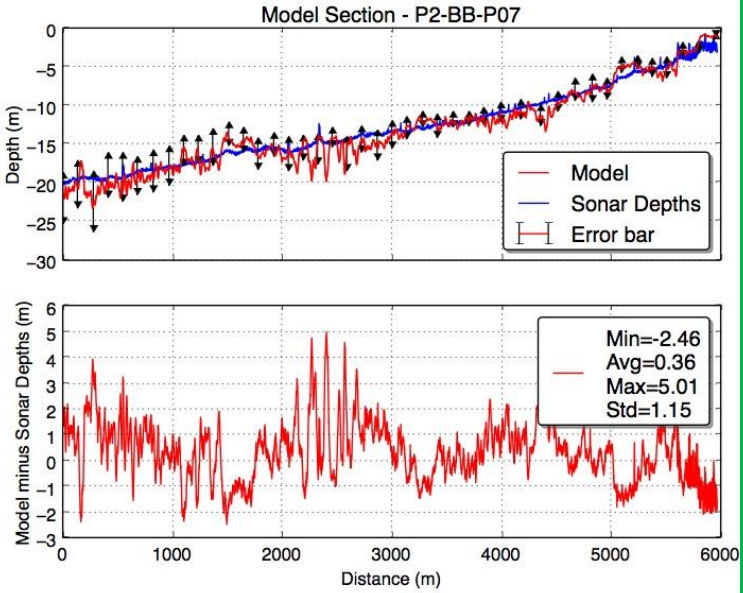
SHOM findings

- Physics-based model is best although S-44 orders 1 and 2 are well out of reach.

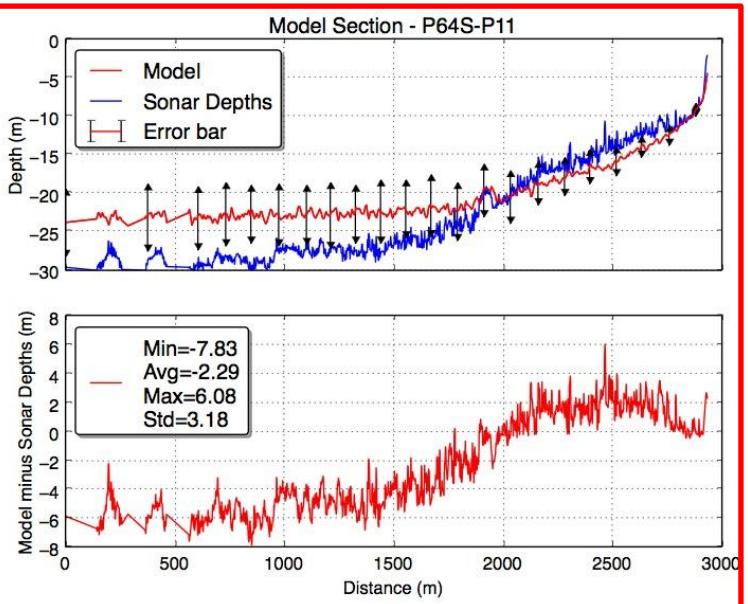


Physics-based model v. SBES

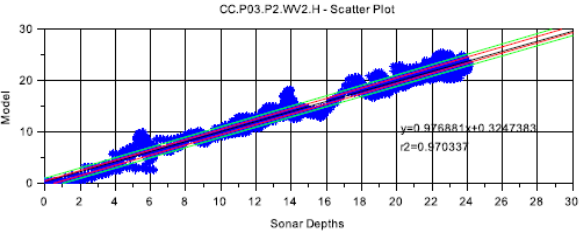
Good satellite image: the Hedley model and its error bars are consistent with the survey depths down to 25 metres



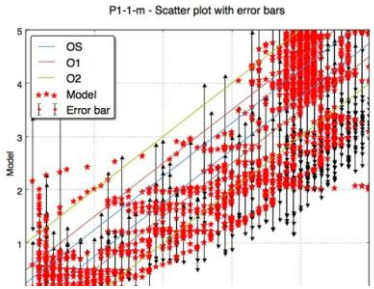
Poor satellite image: the Hedley model and sonar survey split at around 12 metres while the module of error bars increases significantly

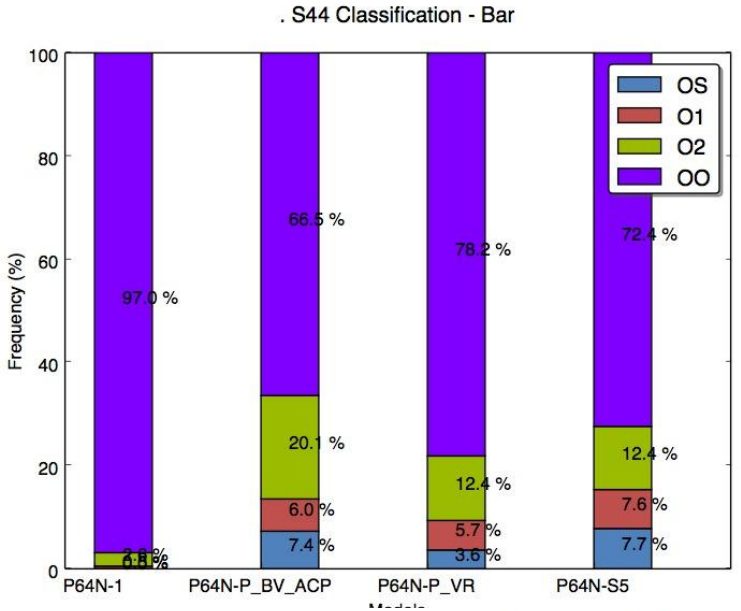


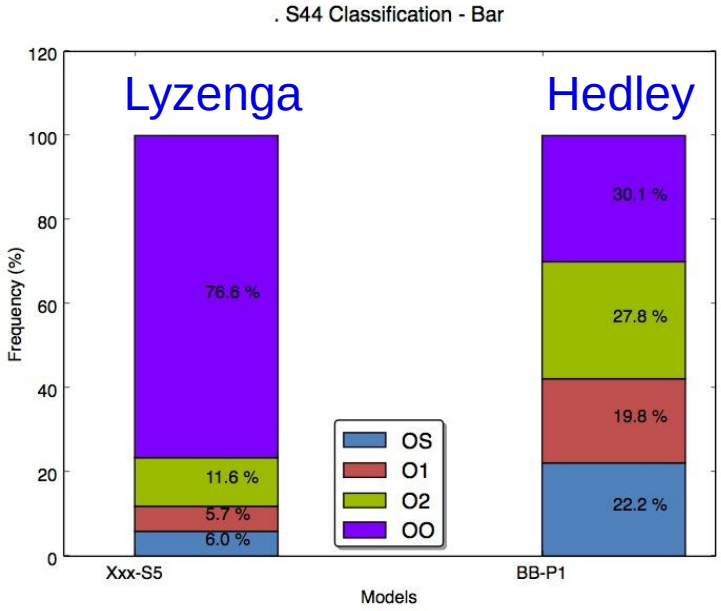
Physics-based model against S-44 Compliancy

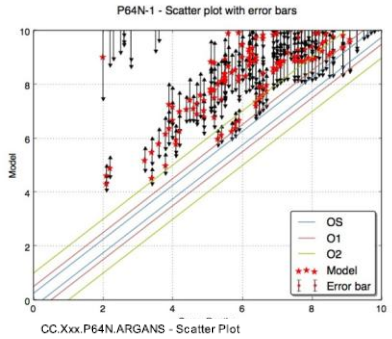


Best image out of 6:
≈ 70 % compliant

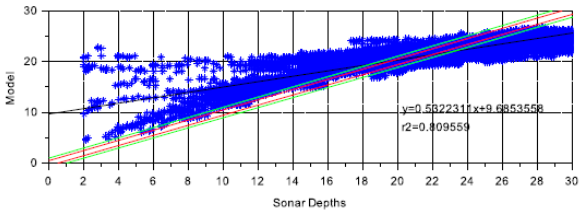




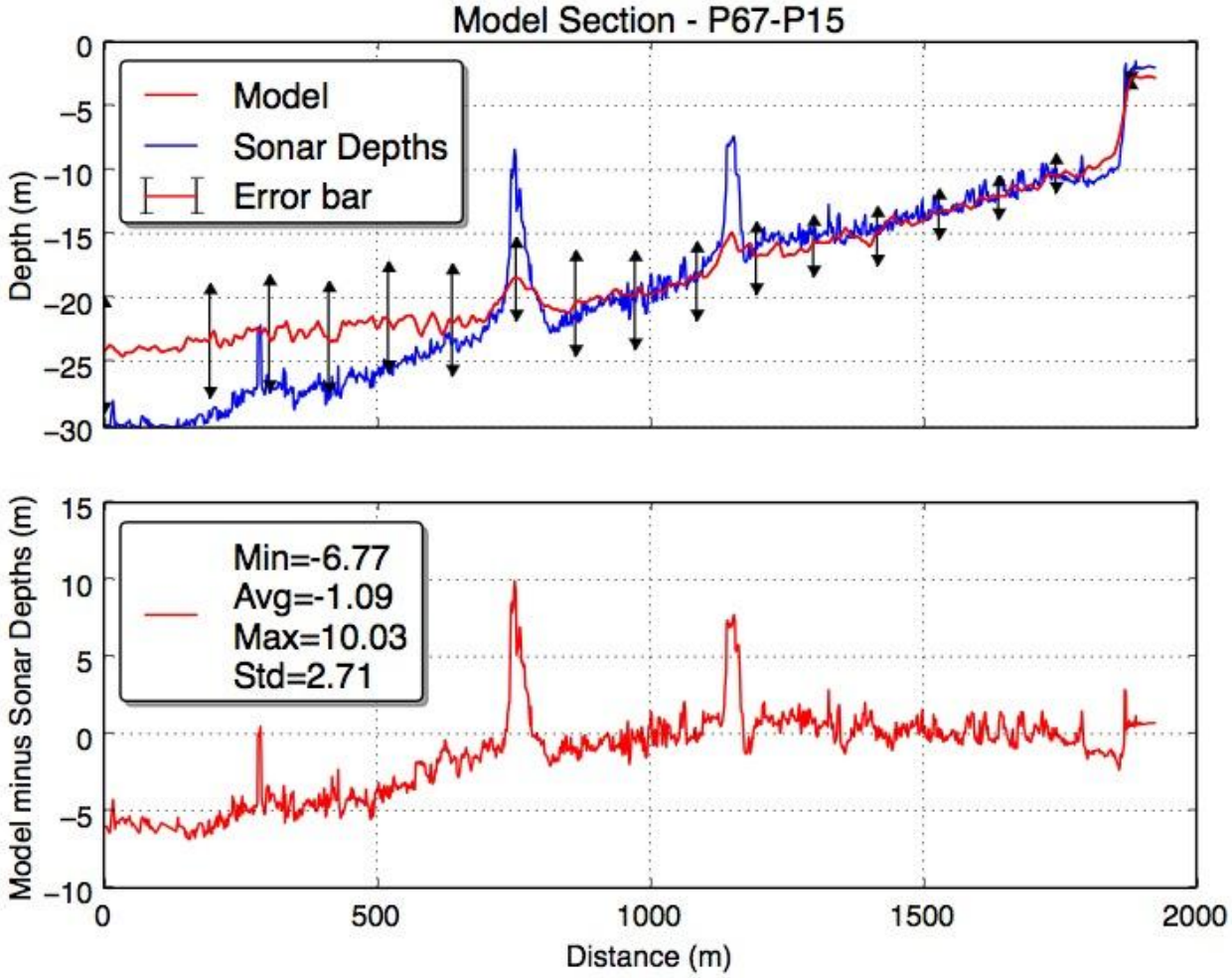




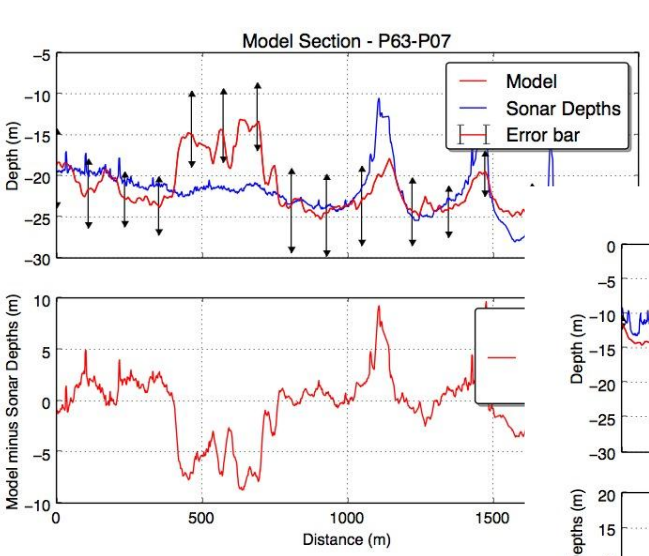
Worst image out of 6:
≈ 28 % compliant

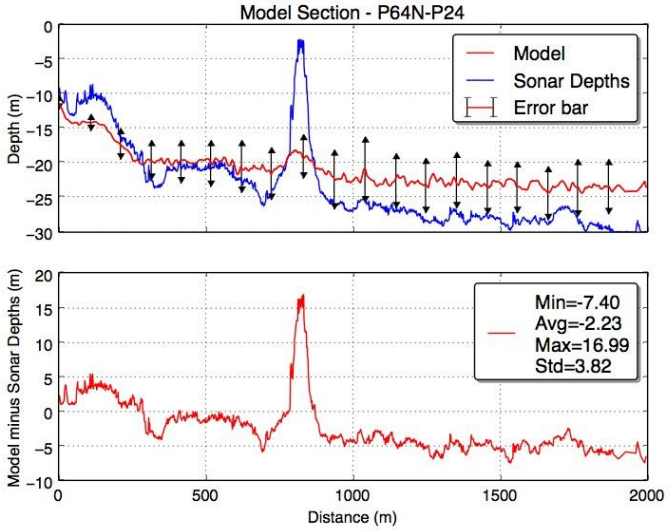


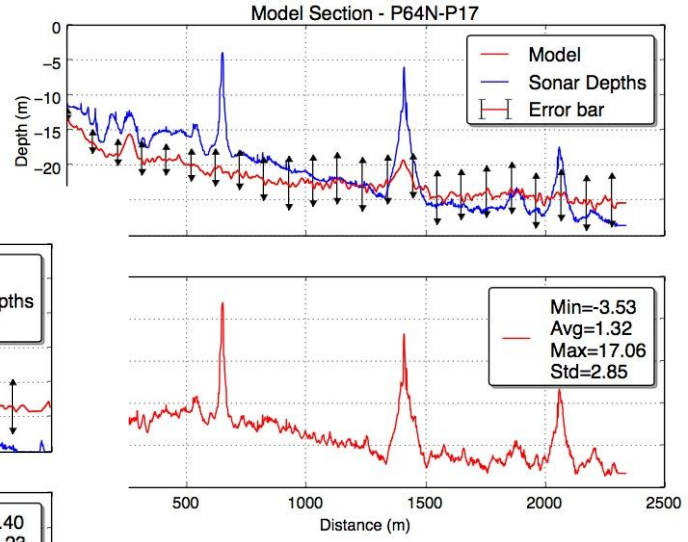
Shoals' detection

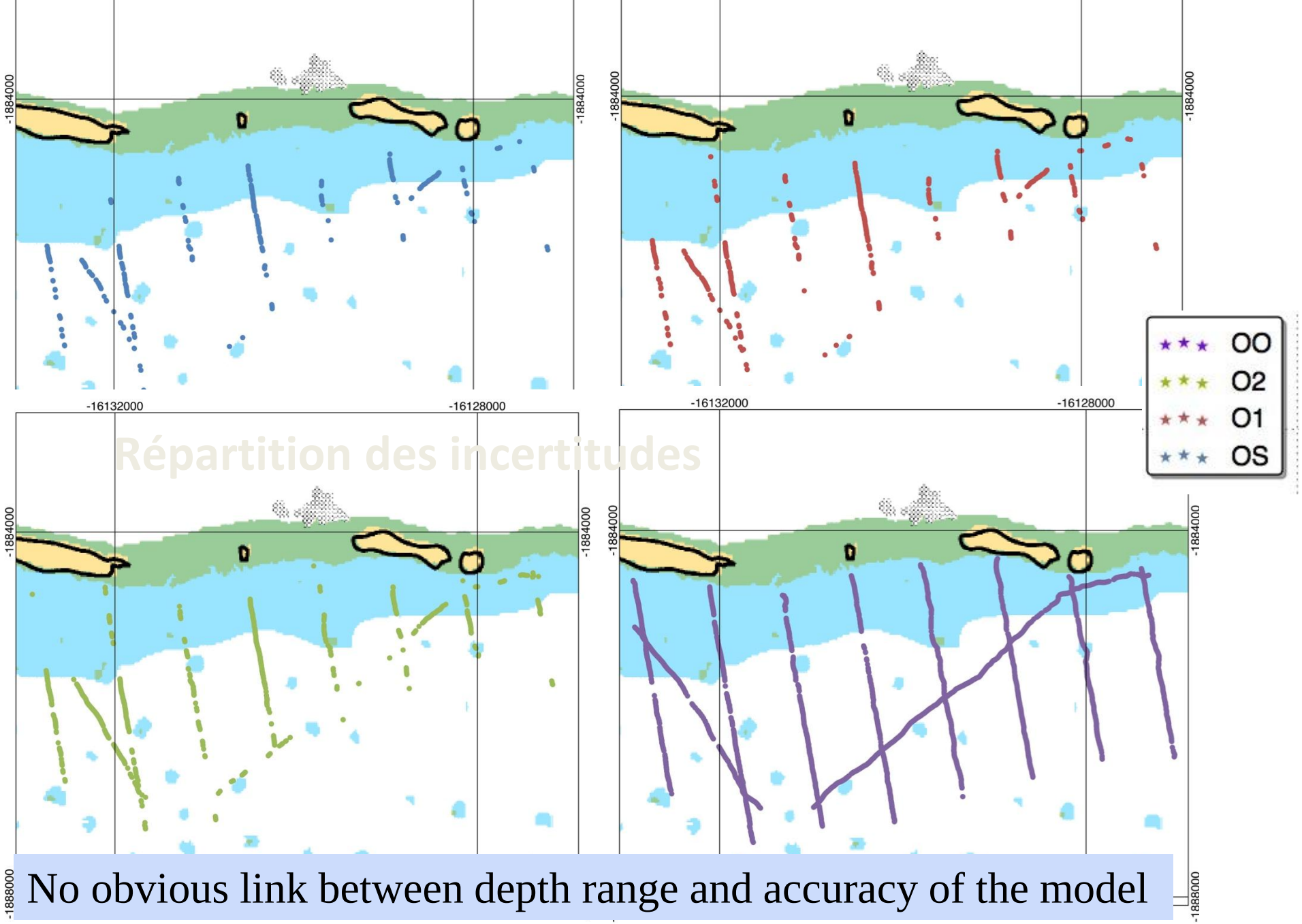


Some shoals not properly measured, not detected, or wrongly detected





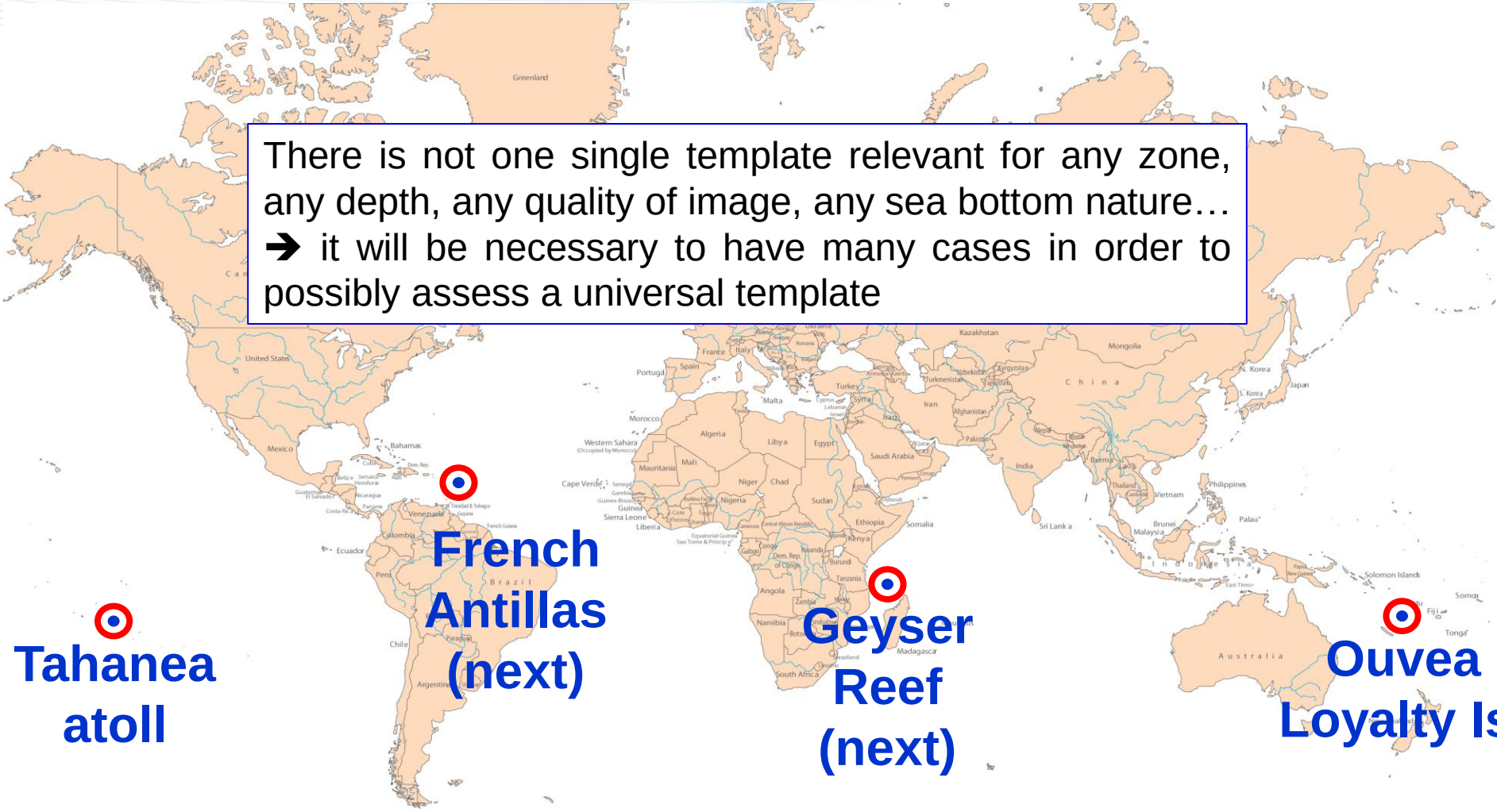




Répartition des incertitudes

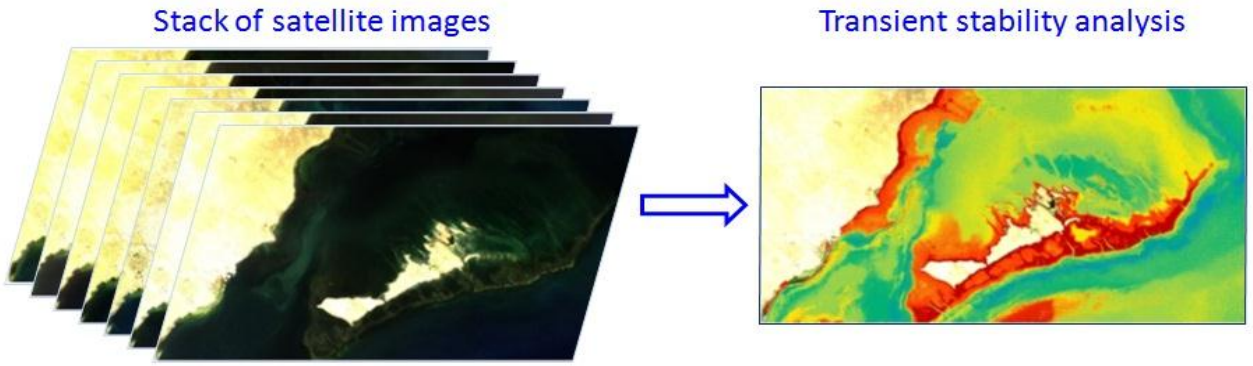
No obvious link between depth range and accuracy of the model

SHOM tests of physics-based method



Further developments & foreseeable improvements

- Validation of the Physics-based method against MBES / lidar / hyperspectral HR surveys (Indian Ocean – 2016).
- Implementation of semi-automated data cleaning & decimation tools.
- Thorough comparison with S-44 orders of precision.
- Tests of image stability using co-registration.



Courtesy *Groupe ACRI*

Effective performances

	Acoustic (EM 2040)	Lidar (CZMIL)	Satellite (Pleïades XS)
Spatial XY resolution (m)	0.2	0.5	2
Spatial Z resolution (m)	0.1	0.2	1
Density (measures /m²)	**25**	4	0.25
Total Horizontal Uncertainty (m)	**0.5**	1	10
Total Vertical Uncertainty (m)	**0.2**	0.3	30% to 10% of depth

Costs *

- In very shallow waters < 10m

	Acoustic (EM 2040)	Lidar (CZMIL)	Satellite (Pleïades XS)
Survey (k€ per sq. km)	2.5	1.5	0.01
Duration (hour per sq. km)	7	0.08	0
Processing (hour per sq. km)	21	4	3
Total Cost (k€ per sq. km)	**3.3**	**1.7**	**0.1**
Total Duration (hour per sq. km)	28	4	3

**Rough estimates*

Conclusions

- SDB can help filling the world's charting gaps at reasonable cost.
- There is no ideal technique that can do everything: SDB is very cost effective for first guess and global picture, Lidar and/or MBES is needed where high accuracy is required.

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