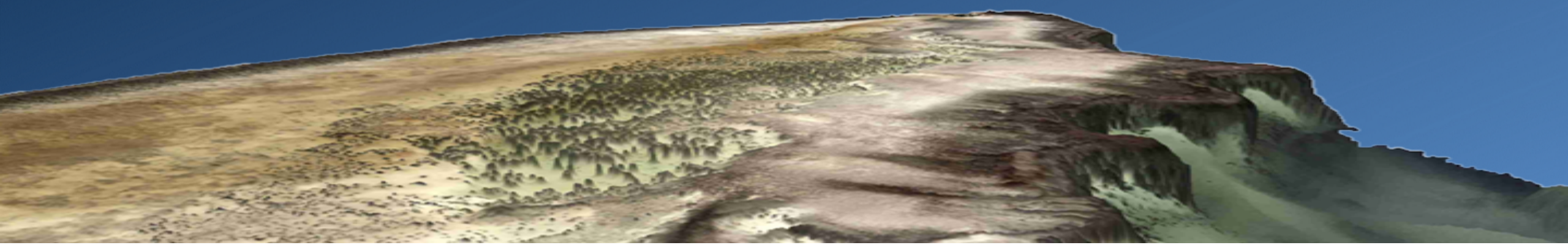
The Art of Satellite-Derived Bathymetry

International SDB Day

Lake Ammersee, June 7 2018

EOMAP
Germany, Australia



Let there be light

Aquatic parameters modulate the sunlight reflected from a water body.

Describe the modulation correctly and you can estimate the parameters.

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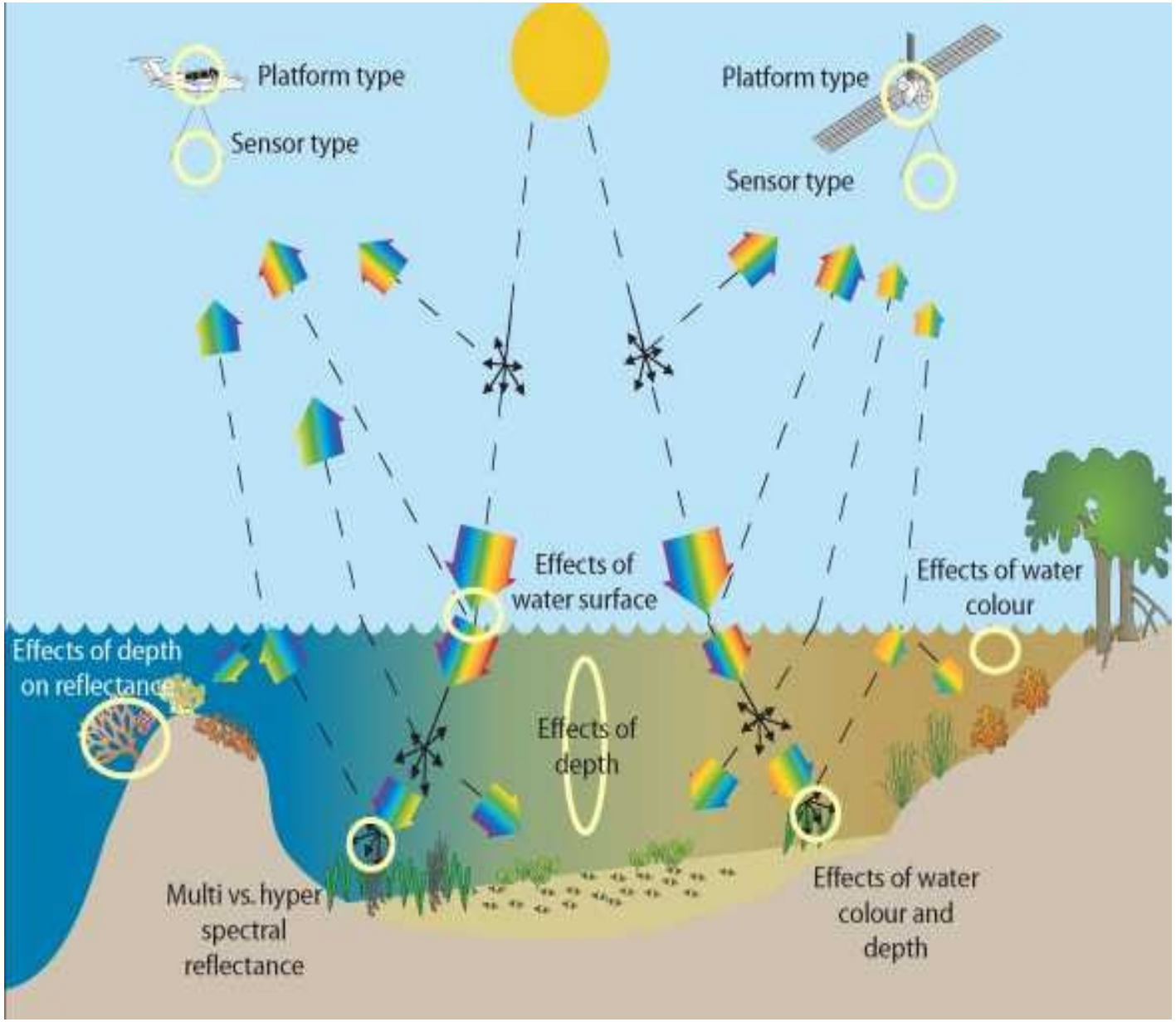
Simple.



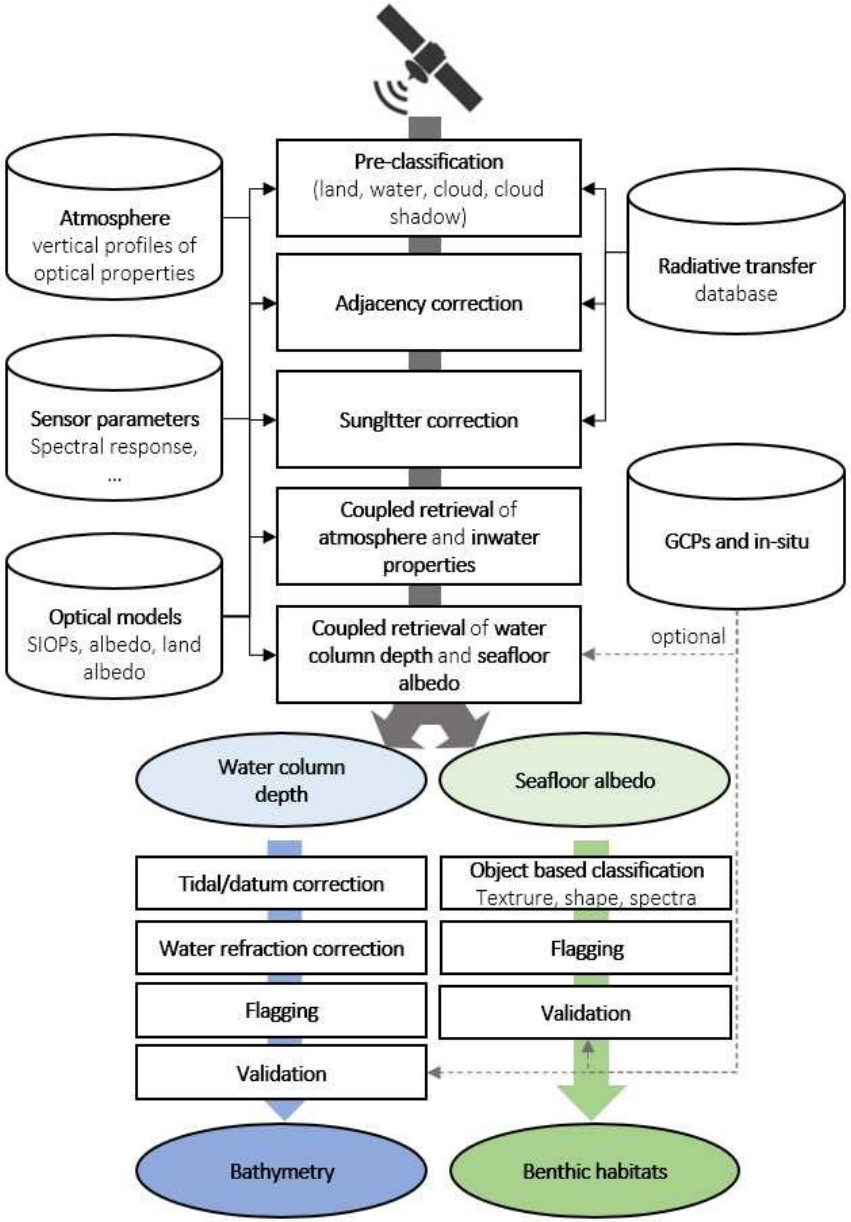
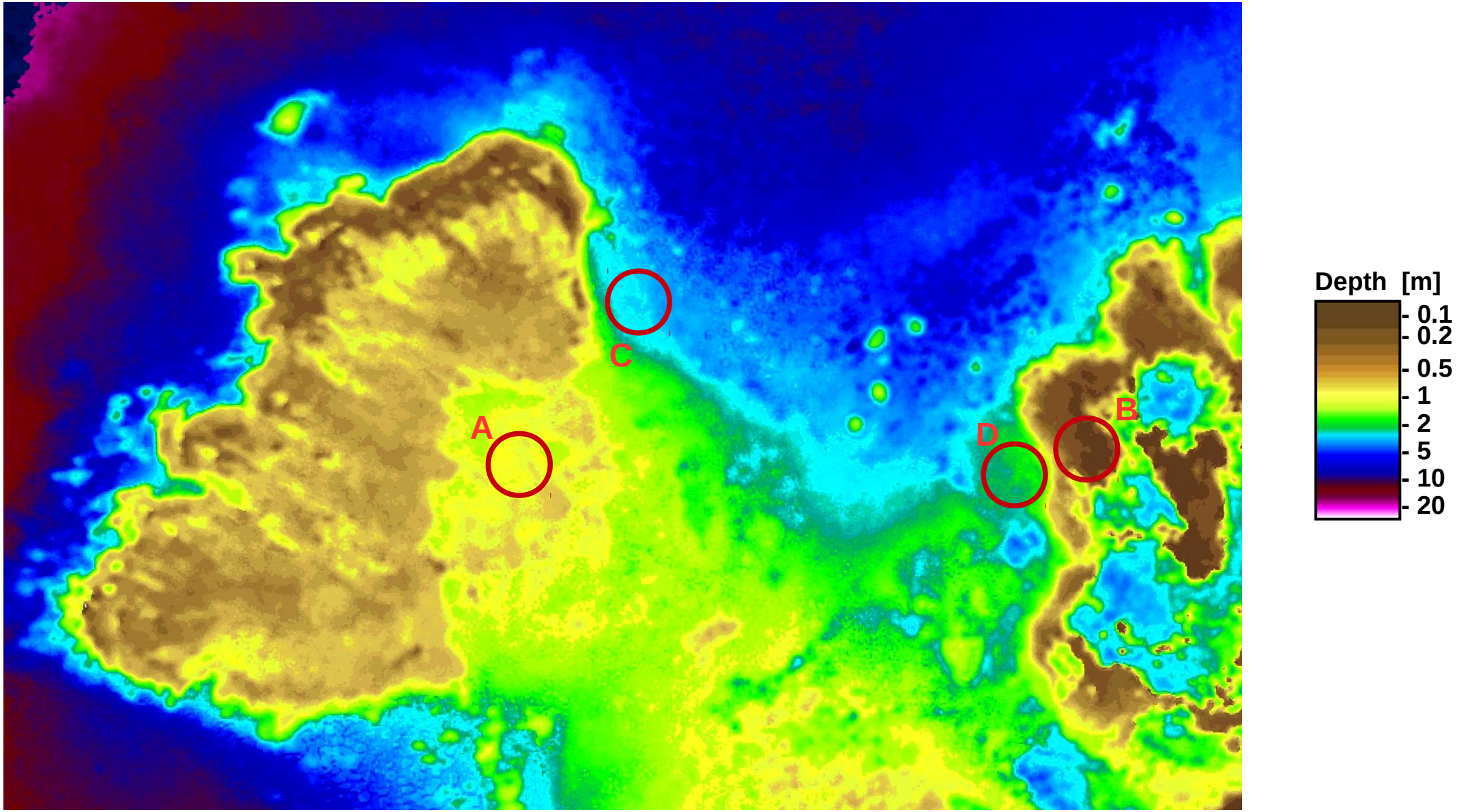


 Image courtesy of the Centre for Spatial Environmental Research, University of Queensland)

B
A
D
C



B
A
D
C

Origins of SDB - 1

Empirical methods

Lyzenga (1985), Clark et al (1987), Jupp (1988), Philpot (1989), Luczkovich et a1 (1993), Dustan et al, (2001), Stumpf et al (2003), ...

1) Depth data required a priori
2) Works for given sensor and given scene
3) Most popular: multiple linear regression

Modern implementation: GEBCO Cookbook

Origins of SDB -2

Radiative Transfer in the water column

Gordon et al (1975), Jerlov (1976), Morel and Prieur (1977), Aas (1987), Philpot 1987, Kirk (1983), Walker (1994), Mobley (1994)…….. Dekker et al 2001

$$\mu \frac{dL(\mathbf{s})}{dz} = -cL(\mathbf{s}) + b\int_{\Xi} L(\mathbf{s}')\tilde{\beta}(\mathbf{s},\mathbf{s}')d\Omega$$

$$K_d = \frac{a}{\overline{\mu}_d}\left(1 + r_d\frac{b_b}{a}\left(1 - \frac{r_u\overline{\mu}_d}{\overline{\mu}_u + \overline{\mu}_d}\frac{b_b}{a+kb_b}\right)\right), k = \frac{r_d\overline{\mu}_u + r_u\overline{\mu}_d}{\overline{\mu}_u + \overline{\mu}_d}$$

$$R(0-) = \frac{r_d\overline{\mu}_u}{\overline{\mu}_u + \overline{\mu}_d}\frac{b_b}{a+kb_b}, k = \frac{r_d\overline{\mu}_u + r_u\overline{\mu}_d}{\overline{\mu}_u + \overline{\mu}_d}$$

$$E_d(z) = E_d(0)e^{-K_d z}$$

$$R(0-,H) = R_\infty + (A - R_\infty)e^{-(K_d+\kappa)H}$$

$$E_u(0-) = E_u(0-)_C + E_u(0-)_B$$

$$E_u(0-) = R_\infty E_d(0-)\left(1 - e^{-(\kappa_C + K_d)H}\right) + AE_d(0-)e^{-(\kappa_B+K_d)H}$$

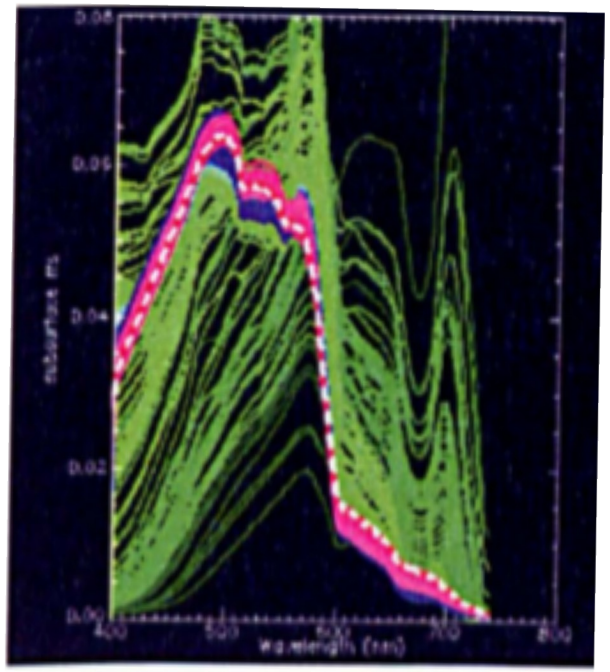
Origins of SDB - 3

Physics-based methods

Maritorena et al (1994), Lee et al, (1998-2001), Mobley (2005), ...

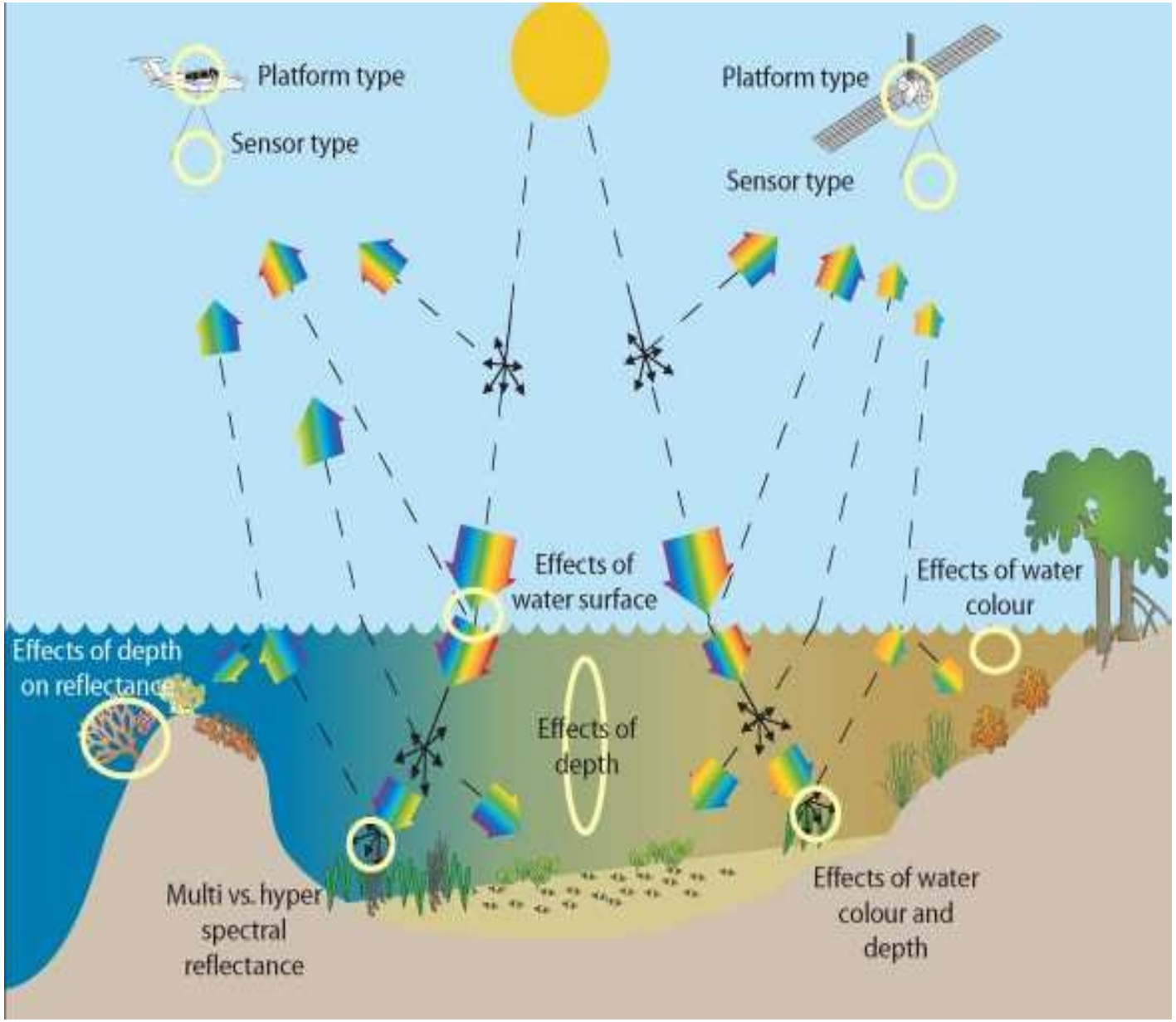
1) No data required a priori
2) Sensor agnostic, location independent
3) semi-analytical inversions, Look-up-Tables, fully analytical solutions

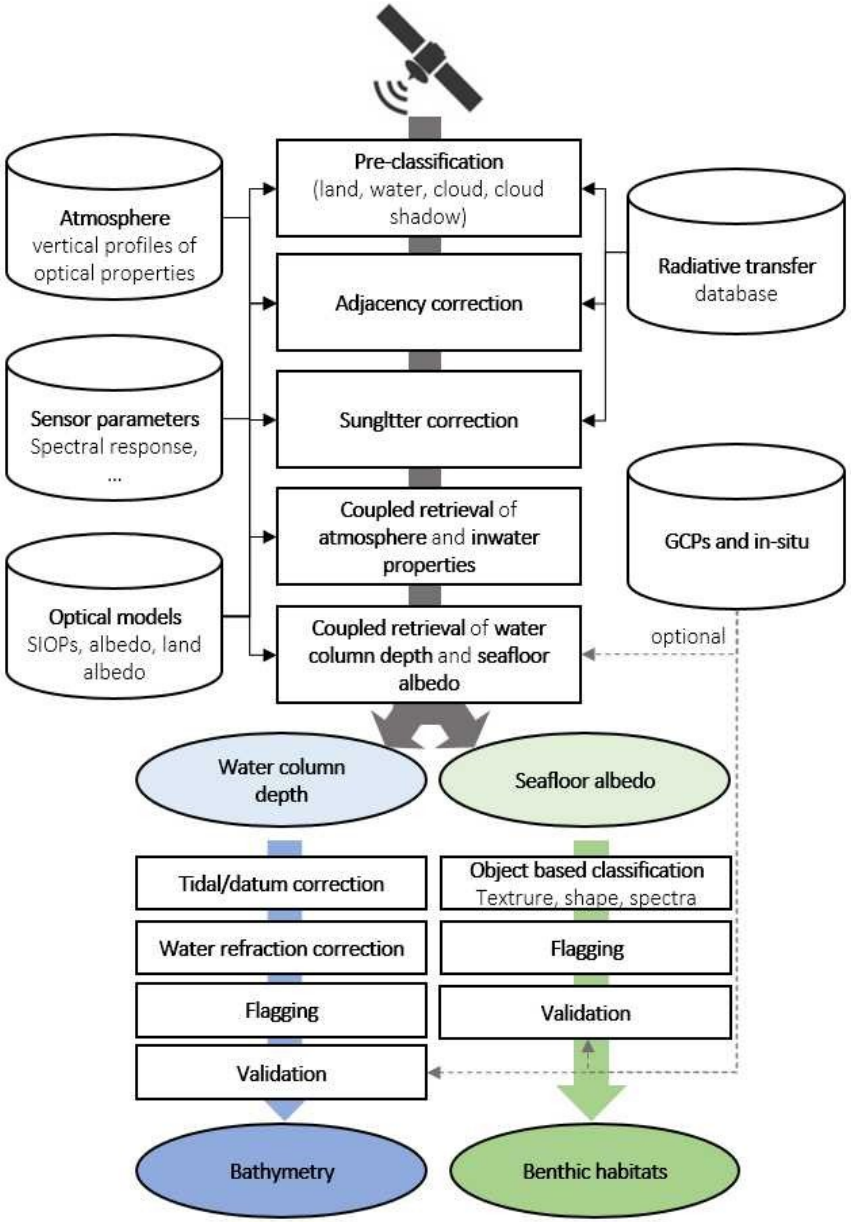
Modern implementations:
HOPE (Lee), SAMBUCA (Brando & Wettle), SMLUT (Mobley), WATCOR (EOMAP)



A tale of two methods

	(Semi-) Empirical	Physical
Setup & investment	Easy	Sophisticated
Location independent (In situ data not necessary)	No	Yes
Uncertainties traceable (independent of in-situ data)	No	Yes
Production capability	Dependent on in-situ data	Highly automatable
Methods	Relating brightness or log-ratios to depth (e.g. Lyzenga et al. , Stumpf….)	Resolving the light transfer equation (CSIRO SAMBUCA, EOMAP WATCOR,)





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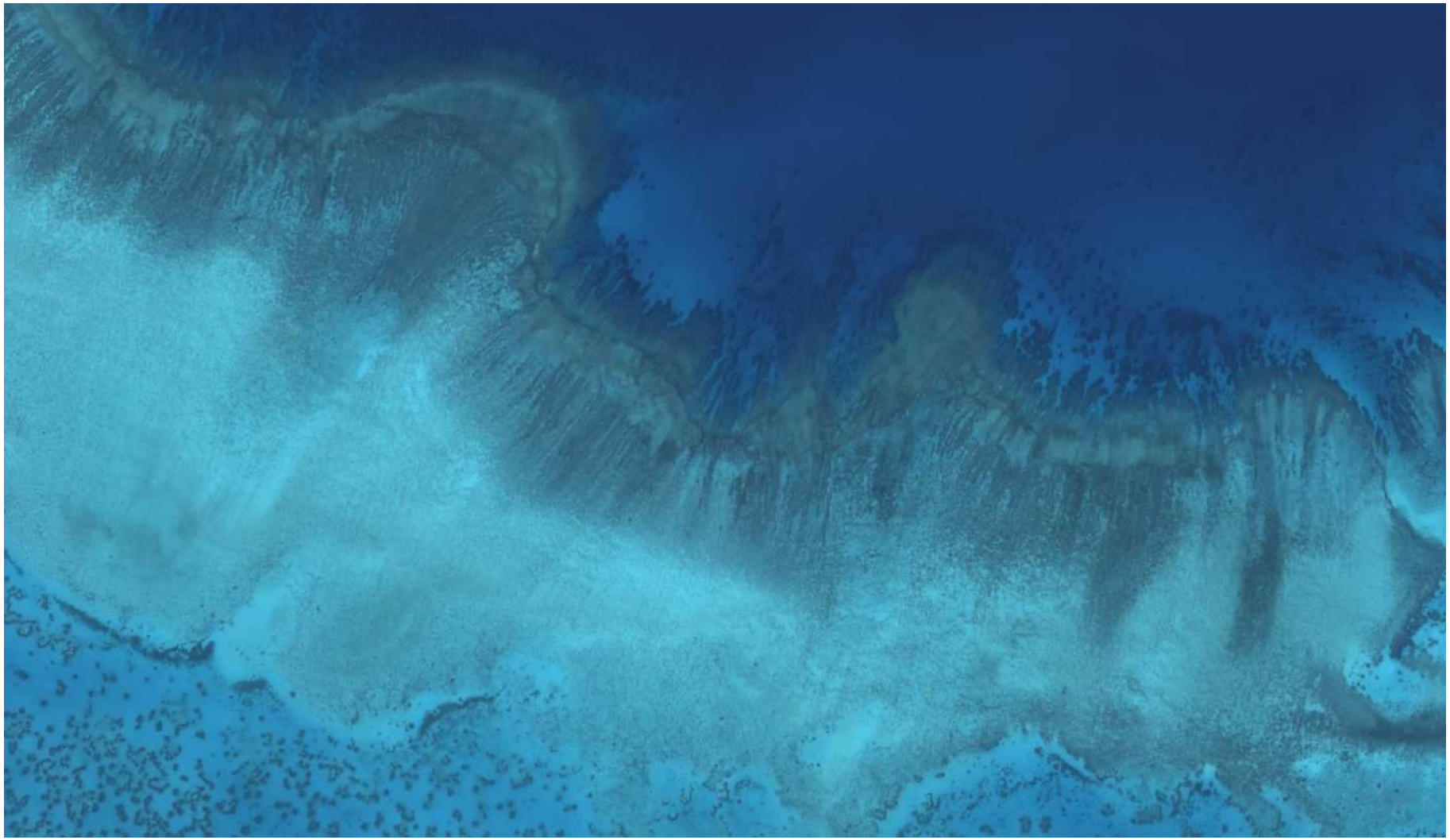
At-sensor radiance

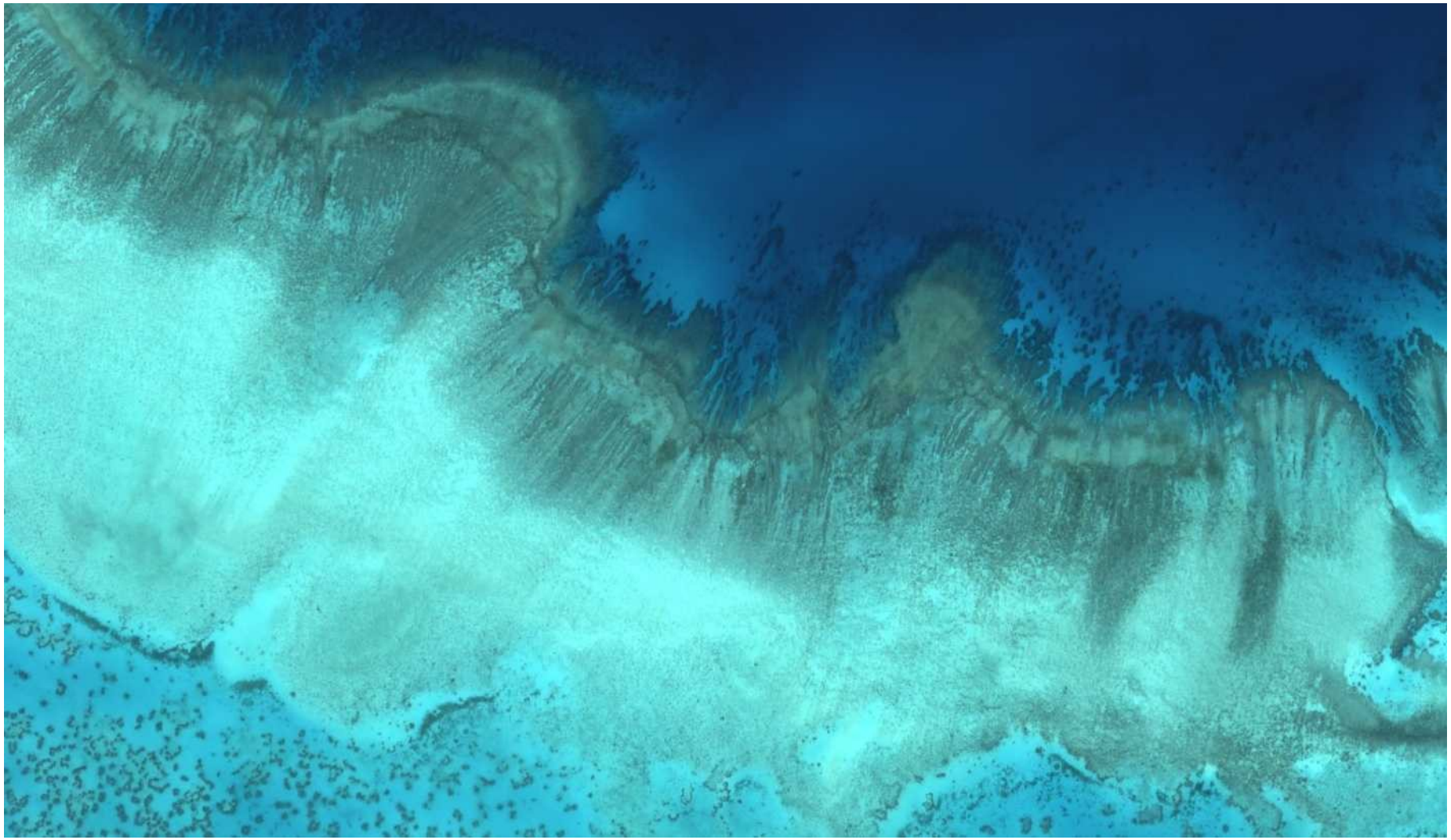


Heron Reef
Great Barrier Reef
Australia

DigitalGlobe
WorldView-2

2m resolution

Sub-surface reflectance



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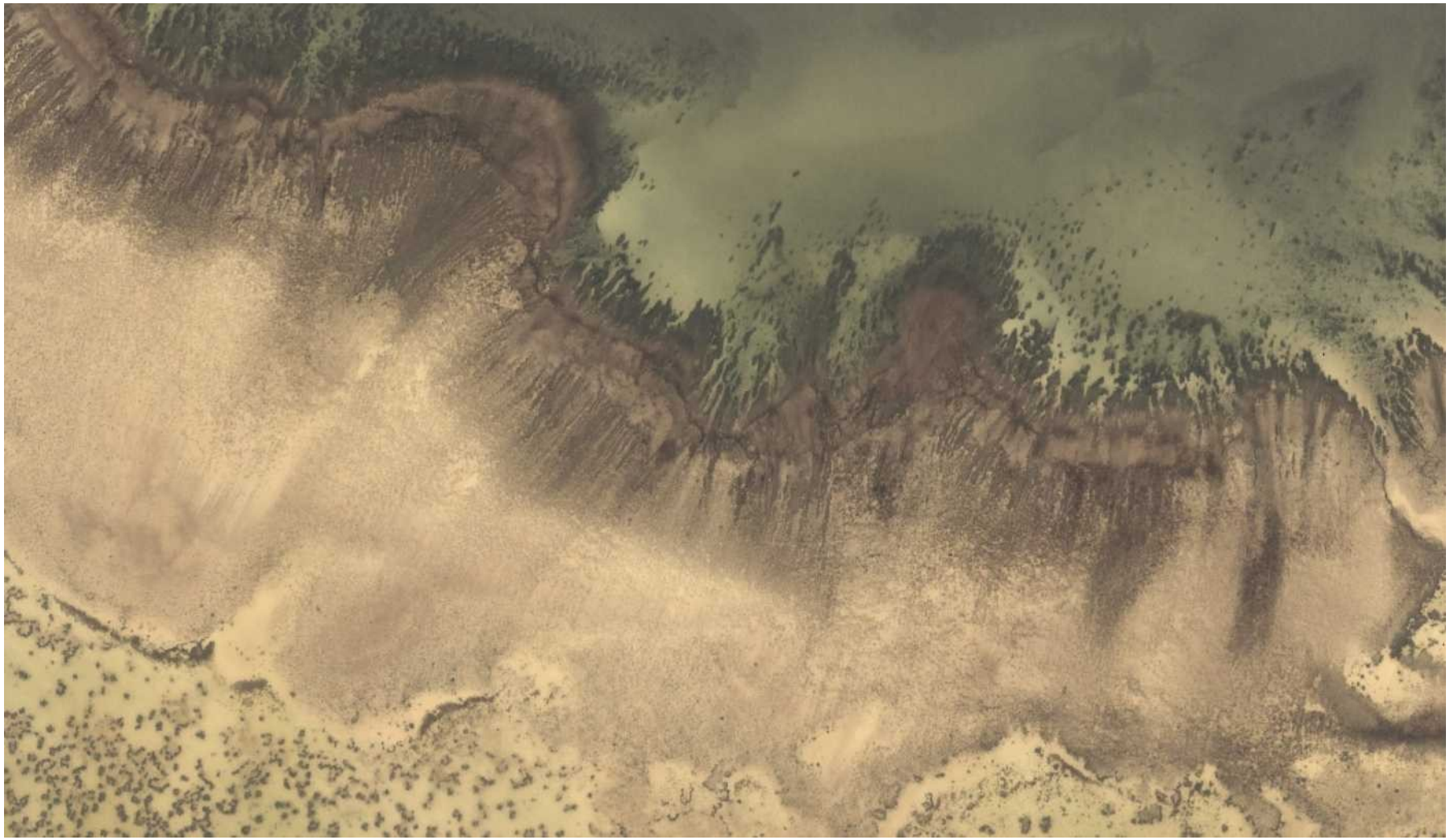
Seafloor reflectance



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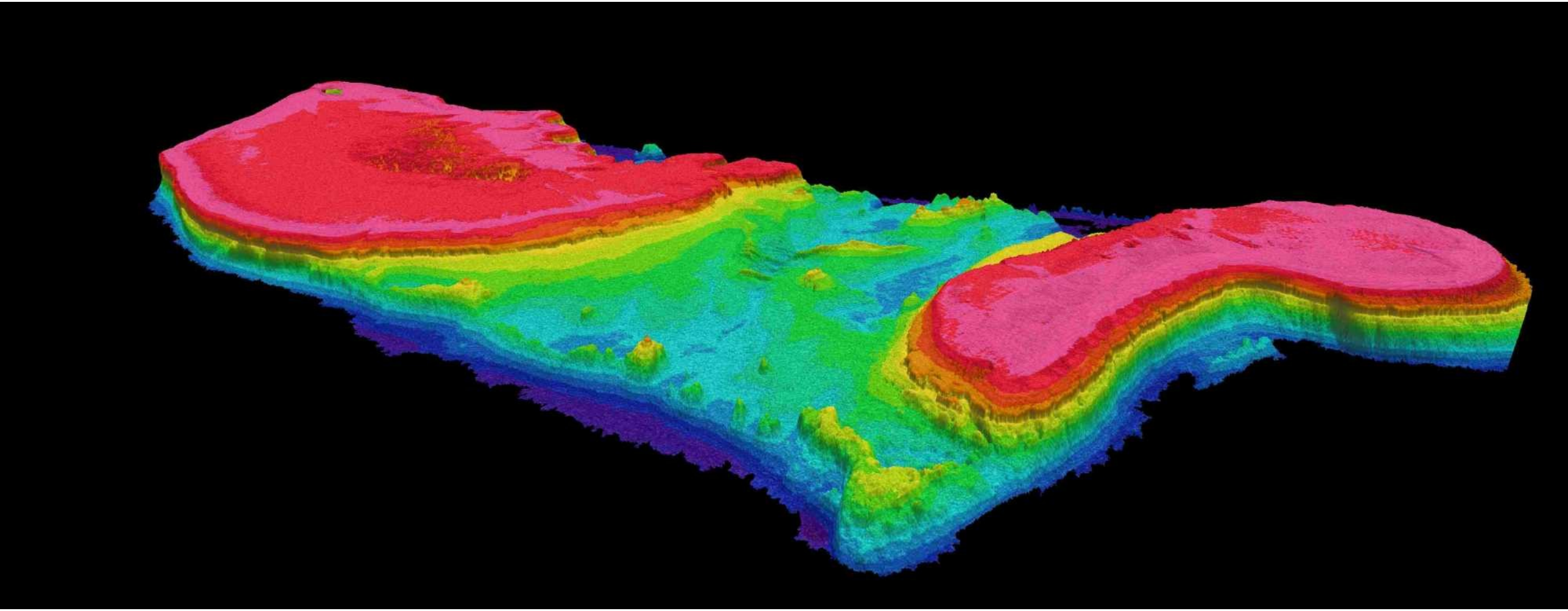
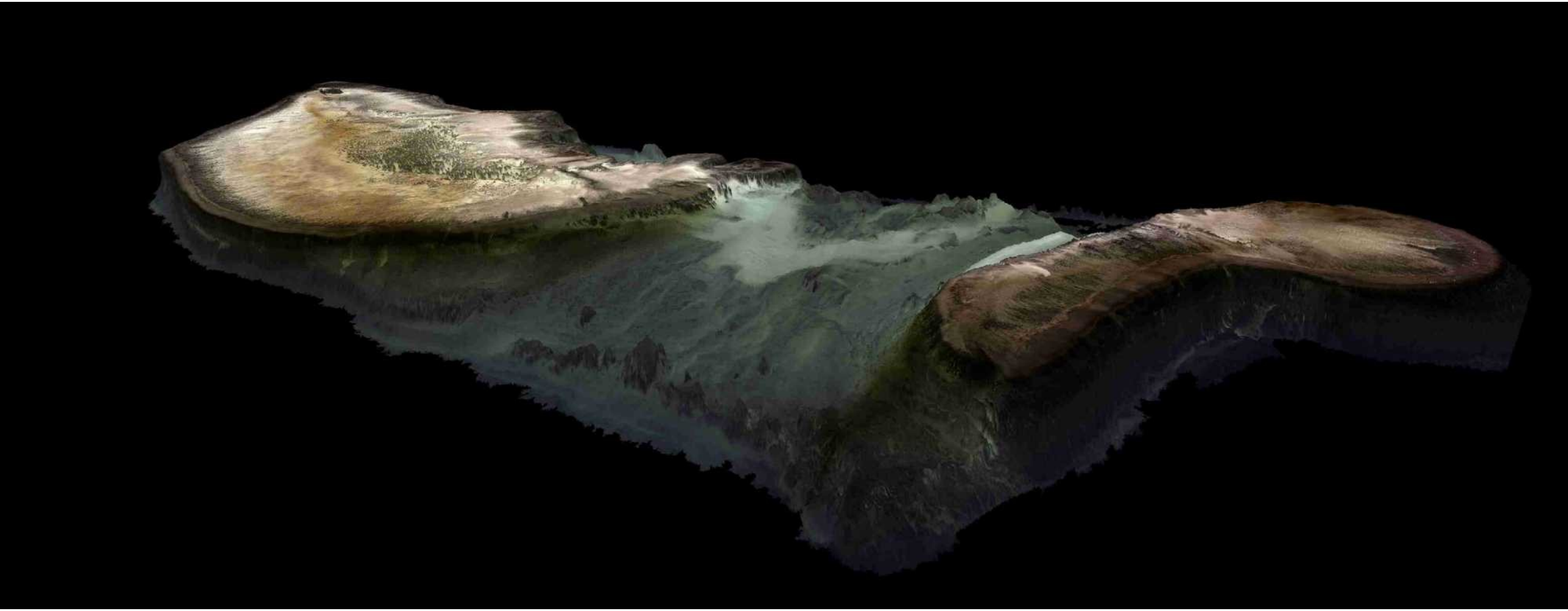
SDB of Heron and Sykes Reef, 2m resolution



Seafloor reflectance draped on SDB



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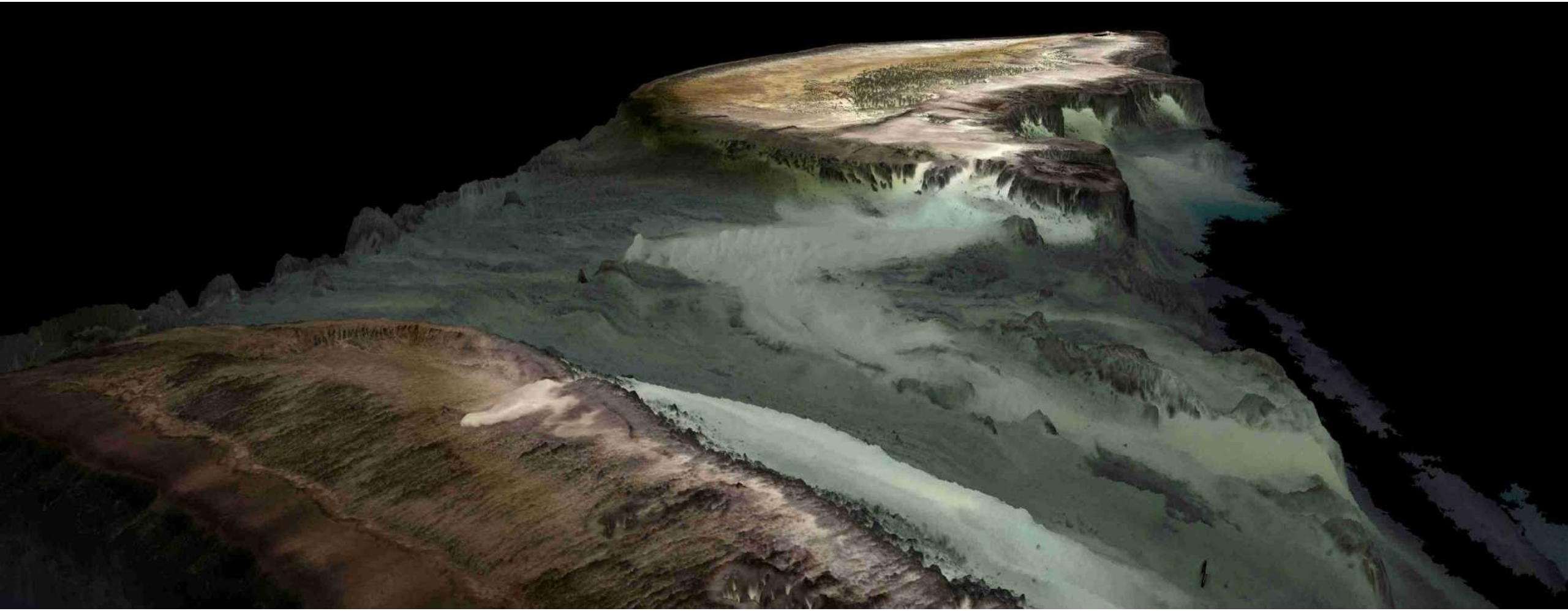
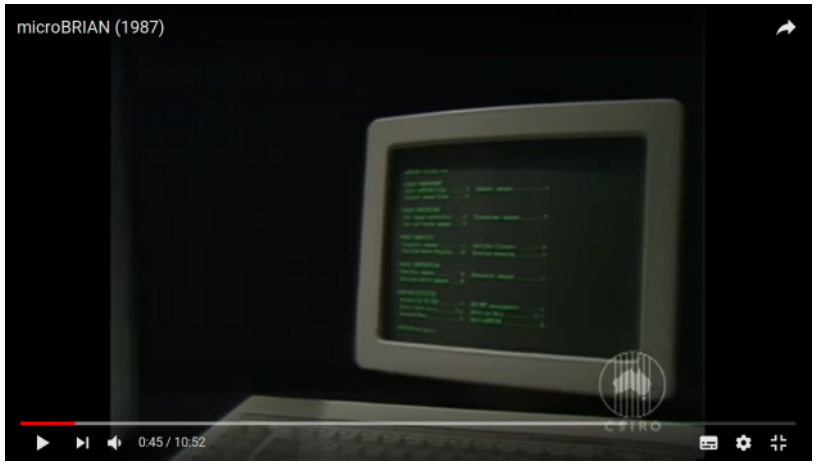


Evolution of SDB

- Empirical methods (1980’s): R&D, localised sites
MicroBRIAN: Mapping the Great Barrier Reef**:** depth-of-penetration

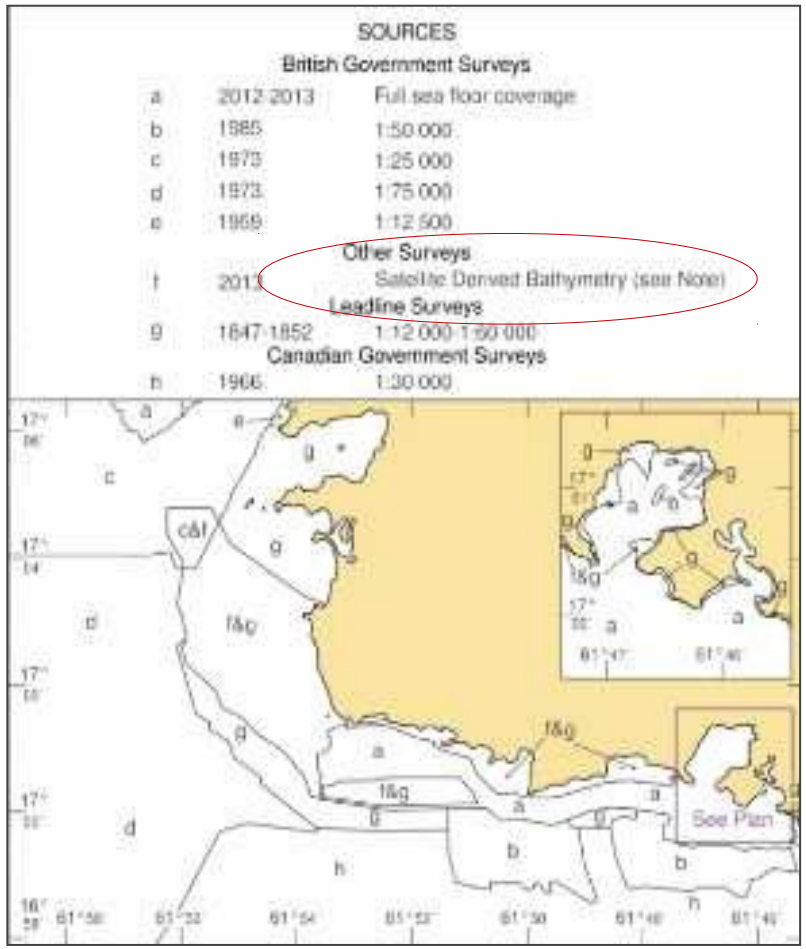


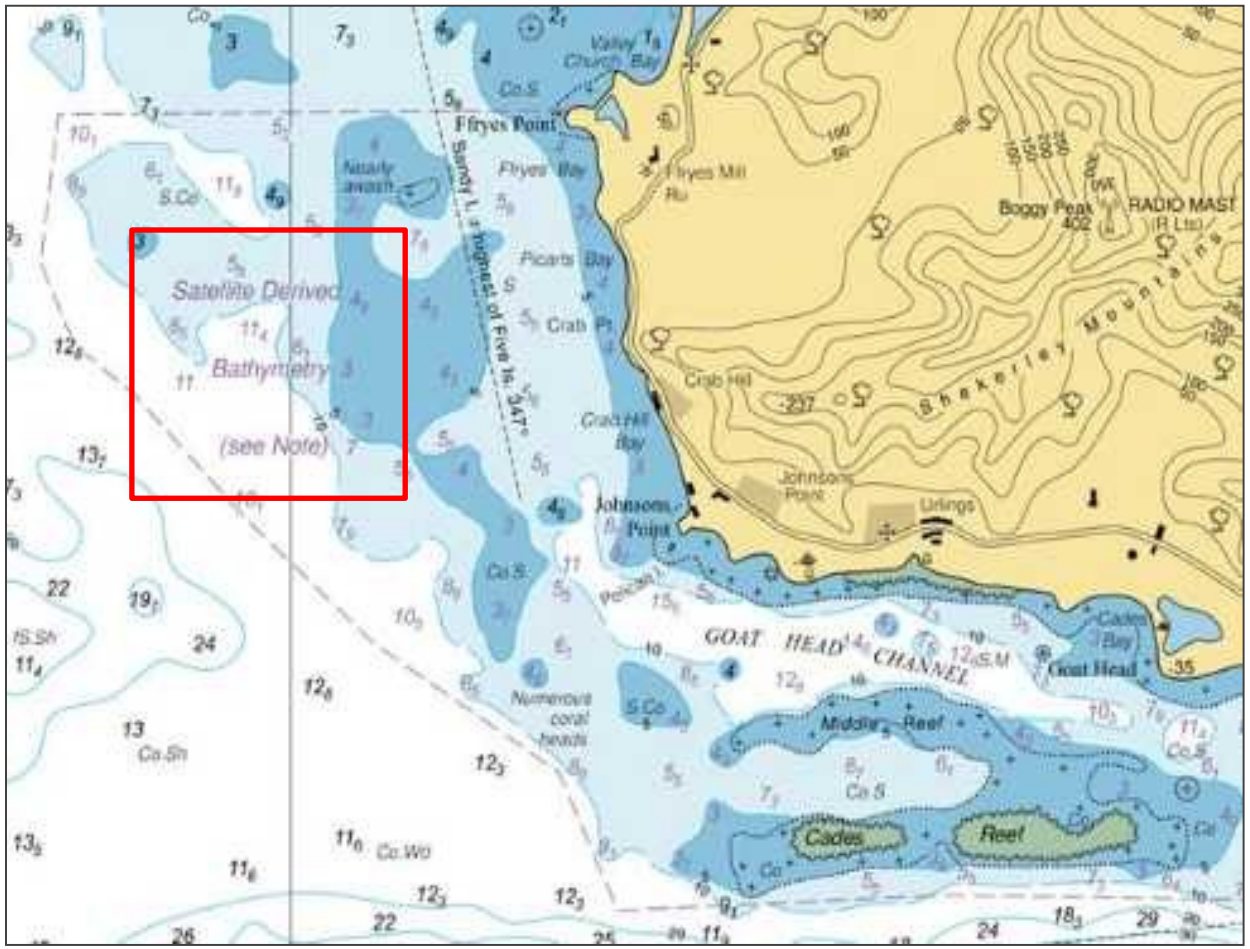
- Decades of R&D (physics-based), some over-promising, gradual uptake

- Commercial deployments around 2005, environmental applications

Evolution of SDB

Admiralty Chart BA2066: 2015





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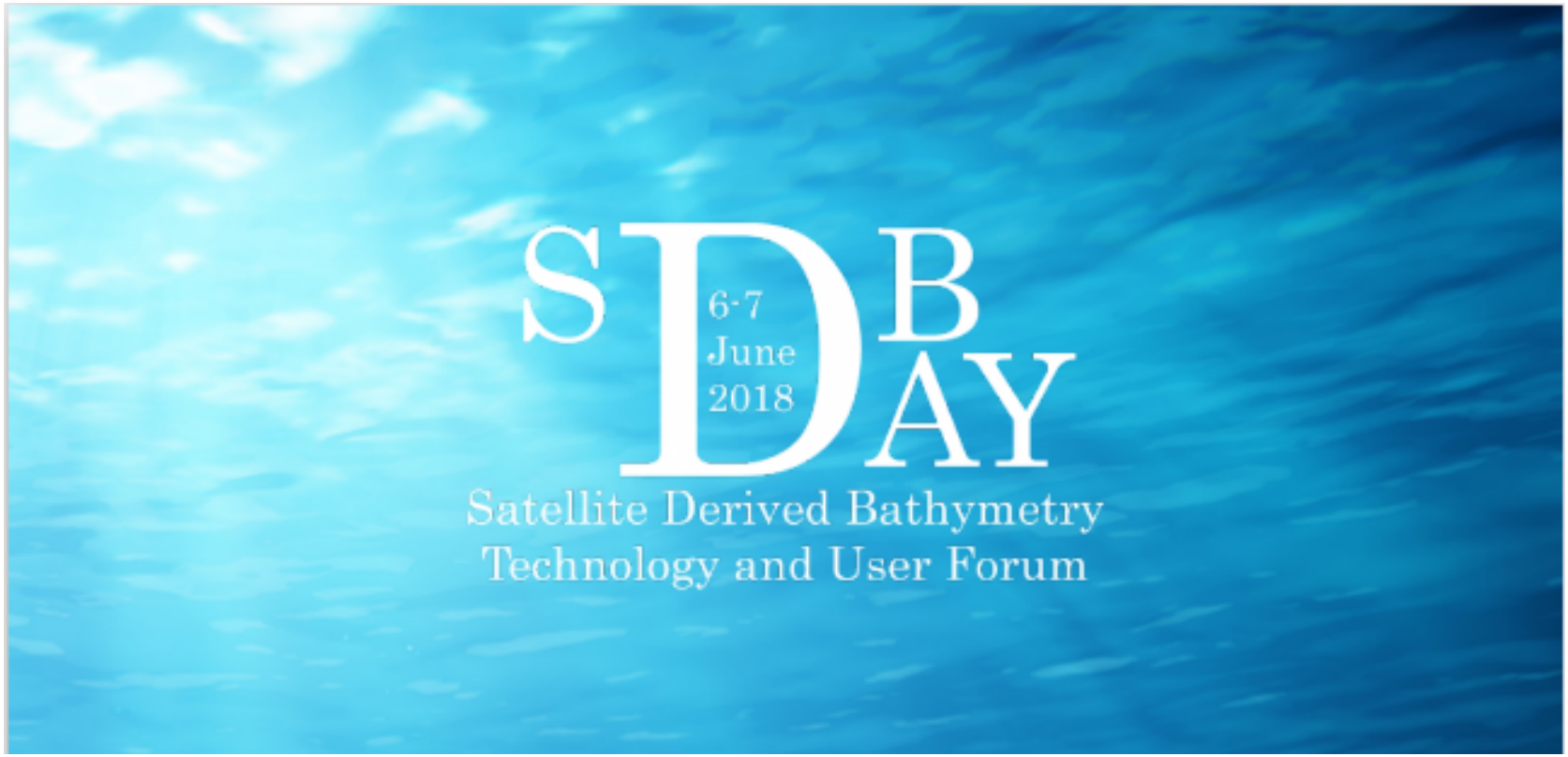

Drivers of SDB quality

Sensors
spatial resolution, radiometric calibration/stability, signal-to-noise, re-visit frequency...

Algorithms
implementation of physics, speed, assumptions....

Production workflows (including QC procedures)
manual vs. automation, robustness, speed, accuracy assessment, quality control...

The Art of SDB

1. Image pre-processing is critical
Atmospheric correction: robust and rapid
Adjacency effect
Bi-directional Reflectance Distribution Function (BRDF)
And more….

2. Accuracy, validation and uncertainty estimation
Mapping remote, unknown area: no absolute accuracy
Model-based uncertainty measures +
World-wide experience/database

The Art of SDB- image pre-processing

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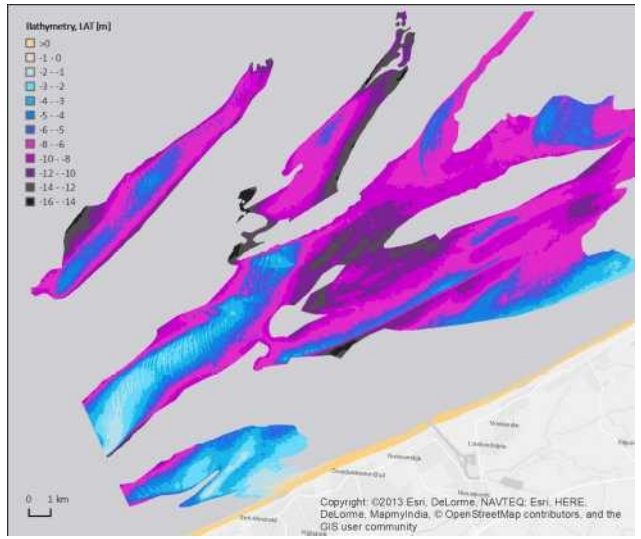
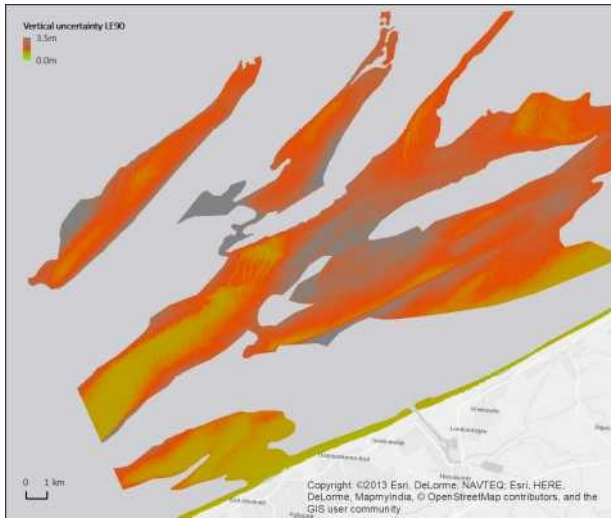
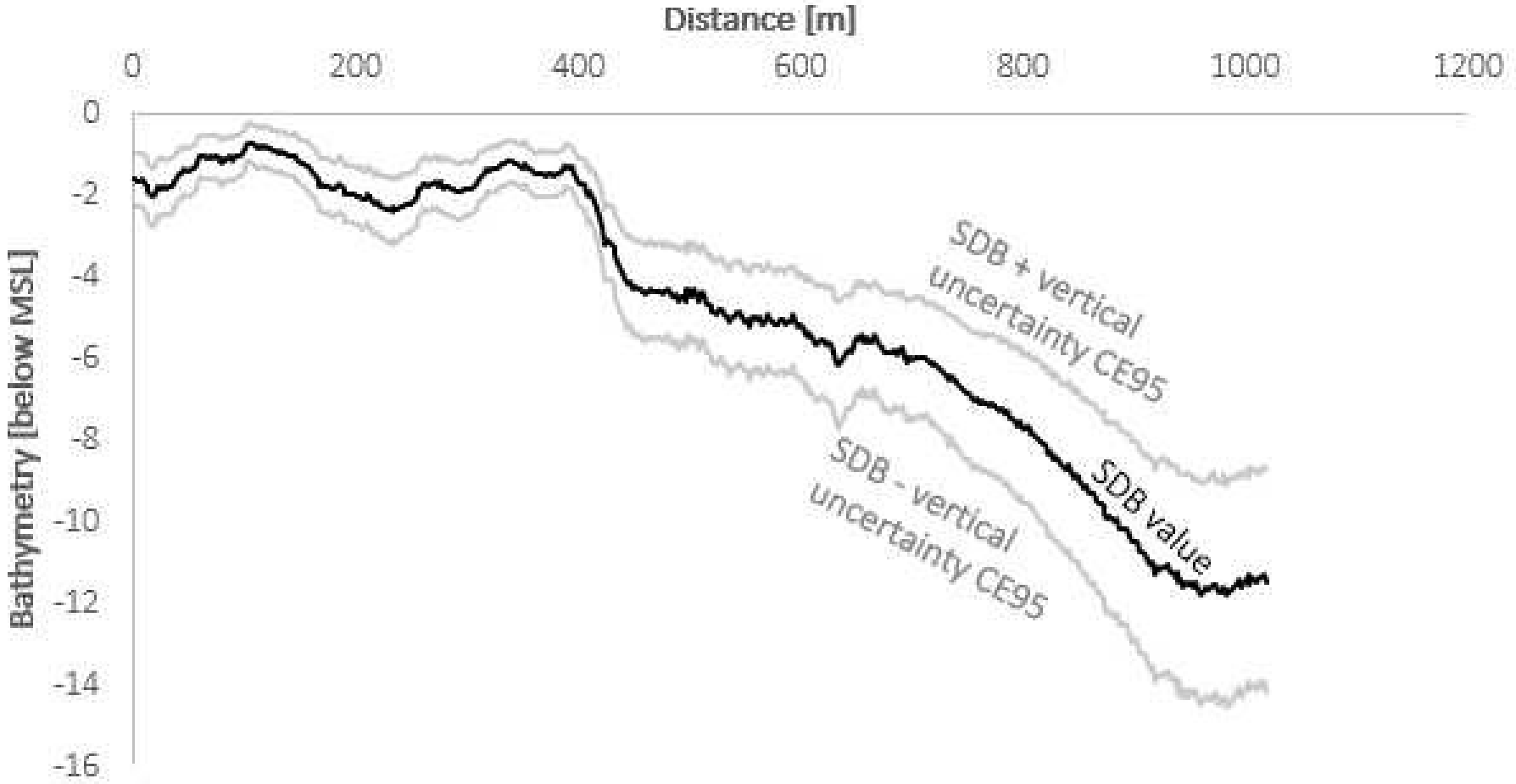
The Art of SDB – quantifying uncertainty







The Art of SDB

"In theory, practice and theory are the same. In practice, they are not."

3. Full parameterisation: towards diminishing returns

- Algorithm complexity affects speed and robustness
- Fieldwork (SIOPs / benthos) defeats the point!

4. All variables are not created equal

- e.g. SDB *can* be relatively stable vs. e.g. seafloor composition
- There is more…..

Future of SDB

Sensors

Options and capabilities will only increase

A dedicated shallow water sensor?

(UAVs)

Algorithms

Aquatic RT physics is more or less fully understood

Number of implementations continue to grow, continual improvements

No dramatic step change?

Production workflows (including QC procedures)

Increasing automation > stand-alone software

Accuracy and reliability tracking

Speed

Uptake of SDB

Advantages and limitations

Affordable, rapid, non-intrusive (discrete)
Limited by optical depth, cloud cover
Complementary to e.g. MBES, ALB

Fit-for-purpose - Applications

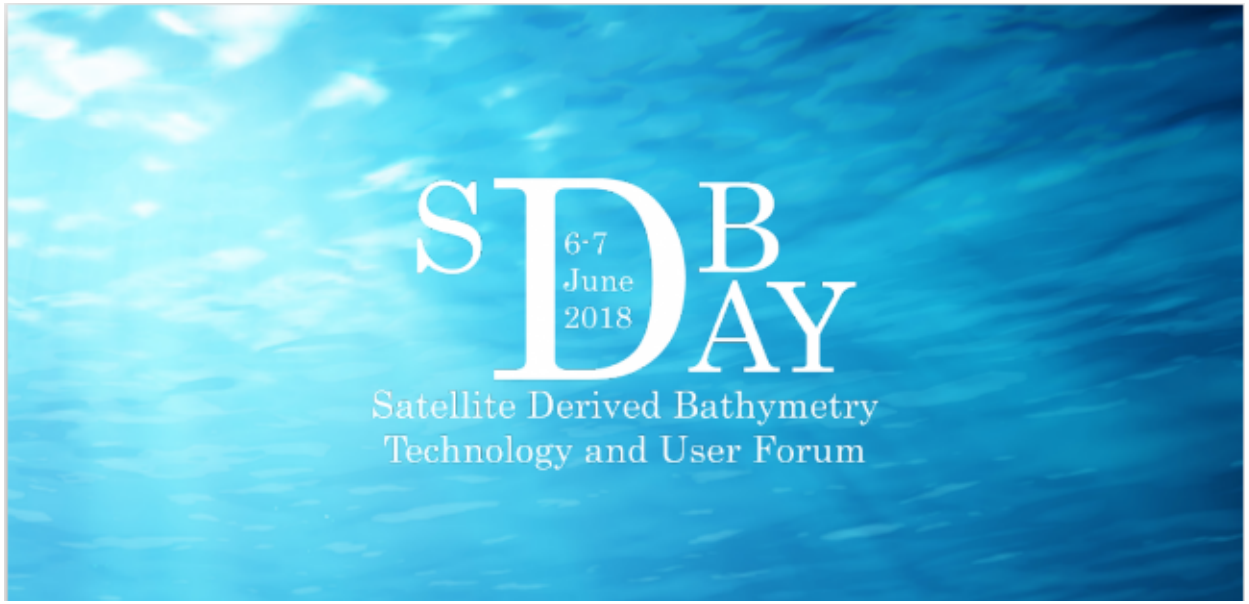
Hydrodynamic modelling vs. charting/navigation vs. emergency vs. environmental monitoring vs. treasure hunting vs. shark attack prediction vs.....

Accessibility and Integration

Standards

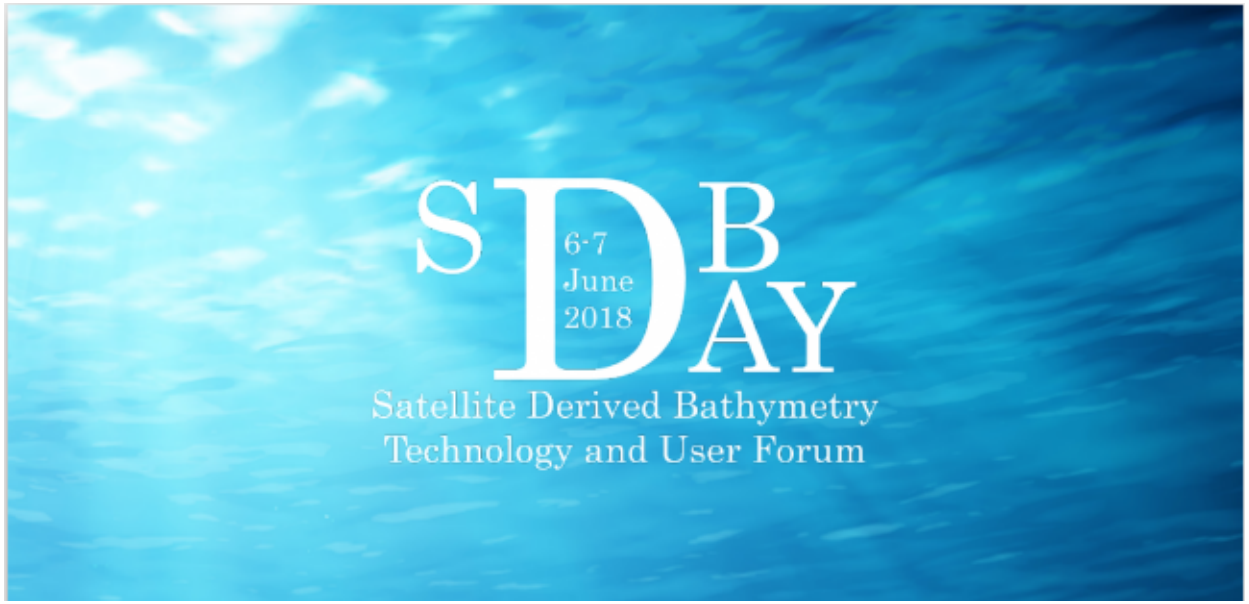
Hydrographic…..others?
Accuracy and quantifiying error

Uptake of SDB



When and how to leverage SDB
Understanding SDB quality
Standards and integration
Requirements (end-users)

Uptake of SDB



Welcome.