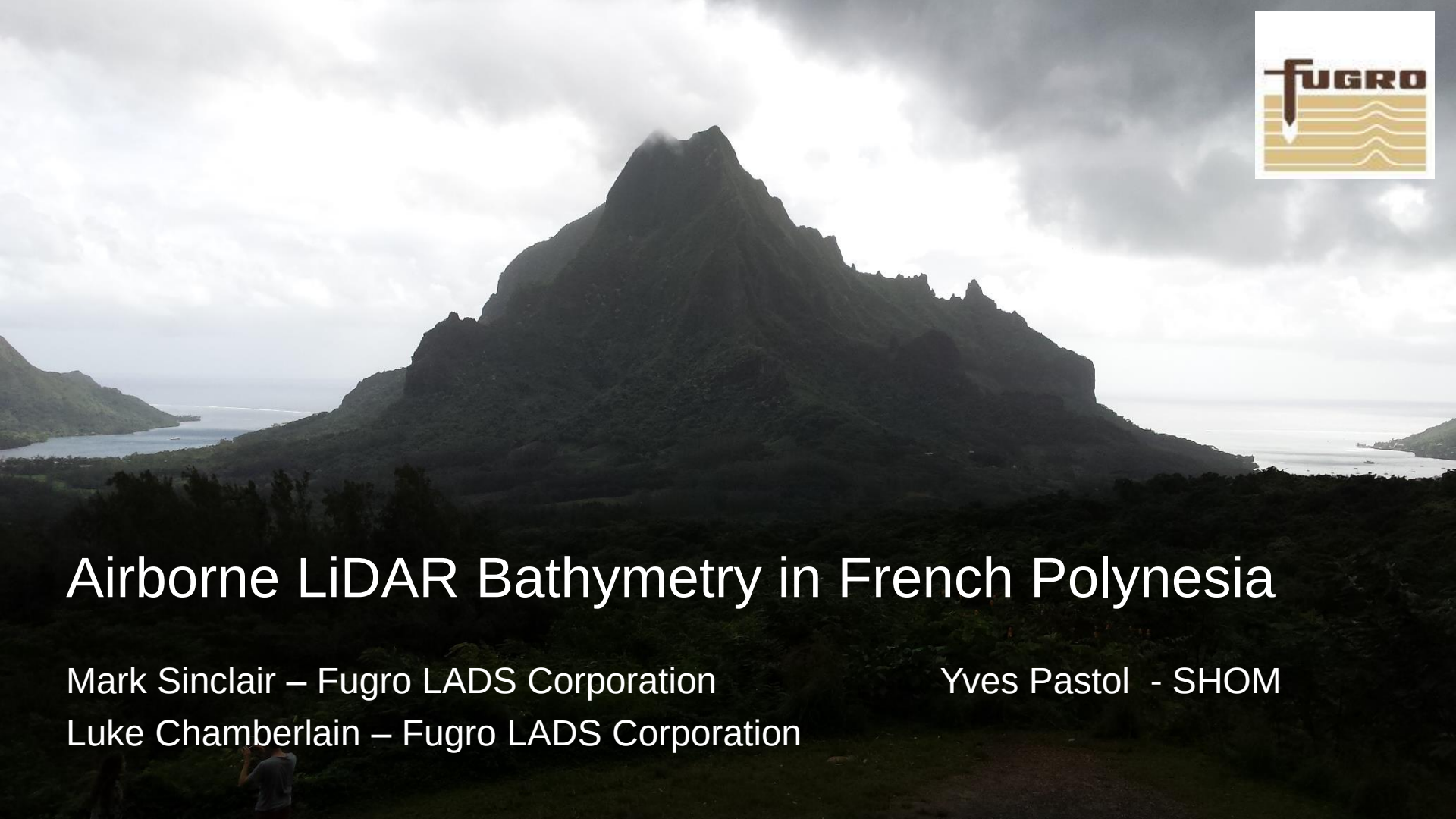
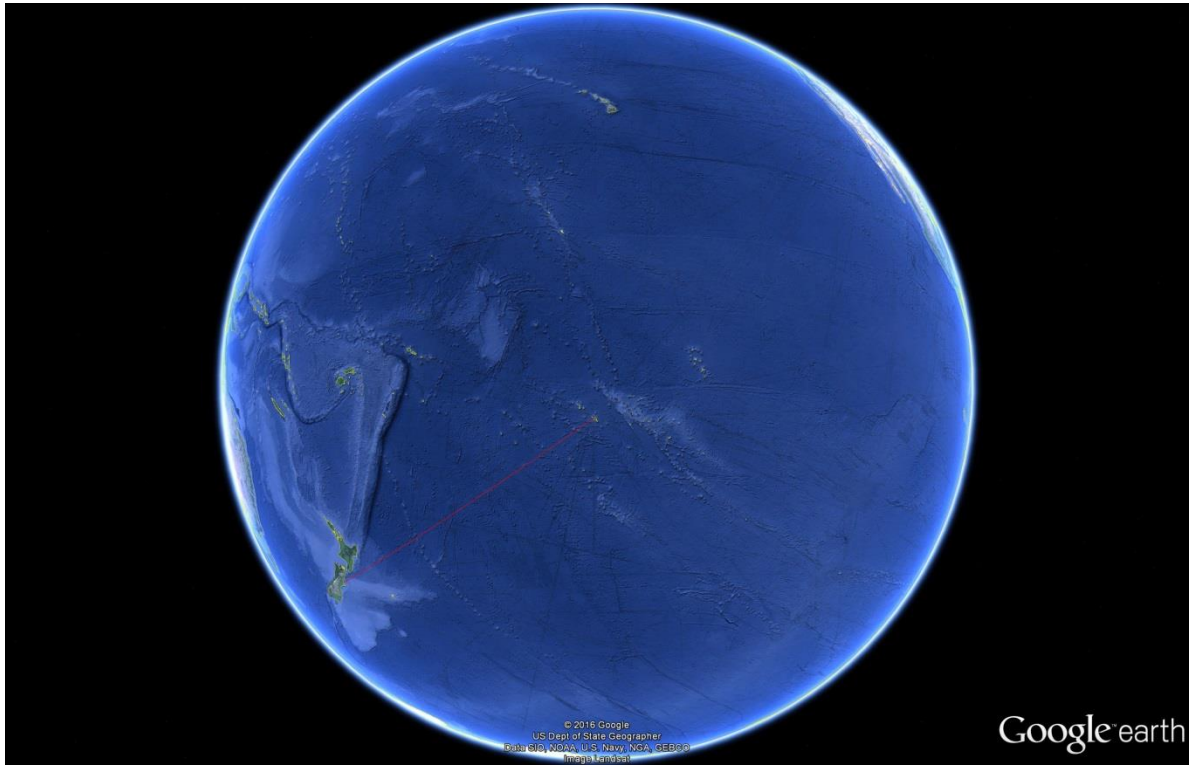


Airborne LiDAR Bathymetry in French Polynesia

Mark Sinclair – Fugro LADS Corporation
Luke Chamberlain – Fugro LADS Corporation
Yves Pastol - SHOM

A remote area:



Distance from Christchurch to Polynesia

~2,470 nm,

4,574 km.

Initial requirement

The French Polynesian Government Service de l'Urbanisme (SAU) needs to assess the vulnerability of land to climate change at a local level.

A project to produce a seamless, precise topographic and bathymetric model.

Uses:

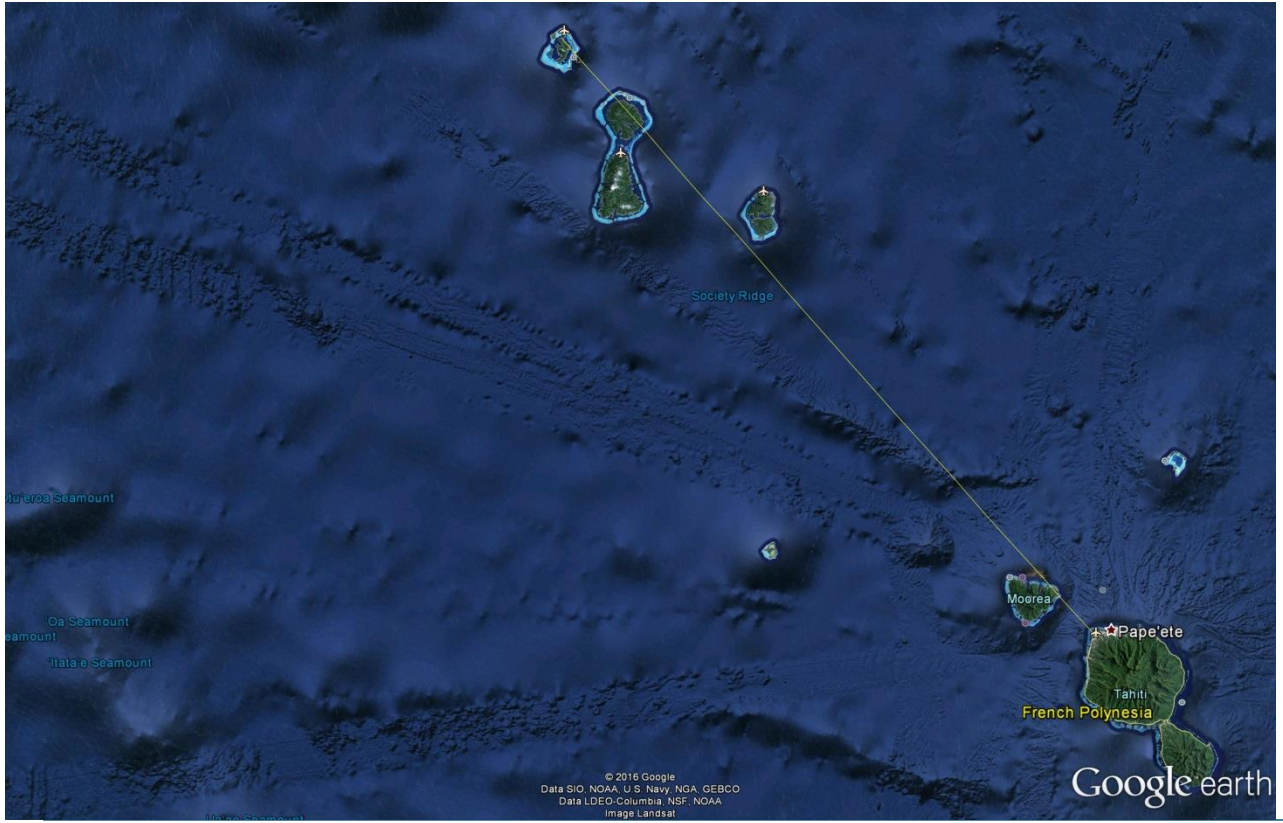
Understand risks from cyclonic swells to produce better risk management plans

Hazard & Risk assessment for tsunamis, floods, landslides & earthquakes (creation of Prevention Plans for Natural Hazards)

Support tourism initiatives – better nautical charting for cruise ship and diving industries

Other: planning for agriculture improvements, infrastructure upgrades, fisheries management …

Location of 2015 survey areas:

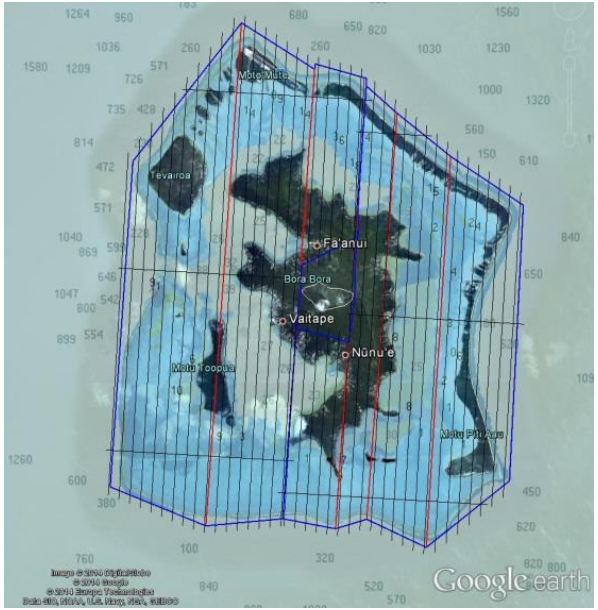


Distance from Papeete to Bora Bora is

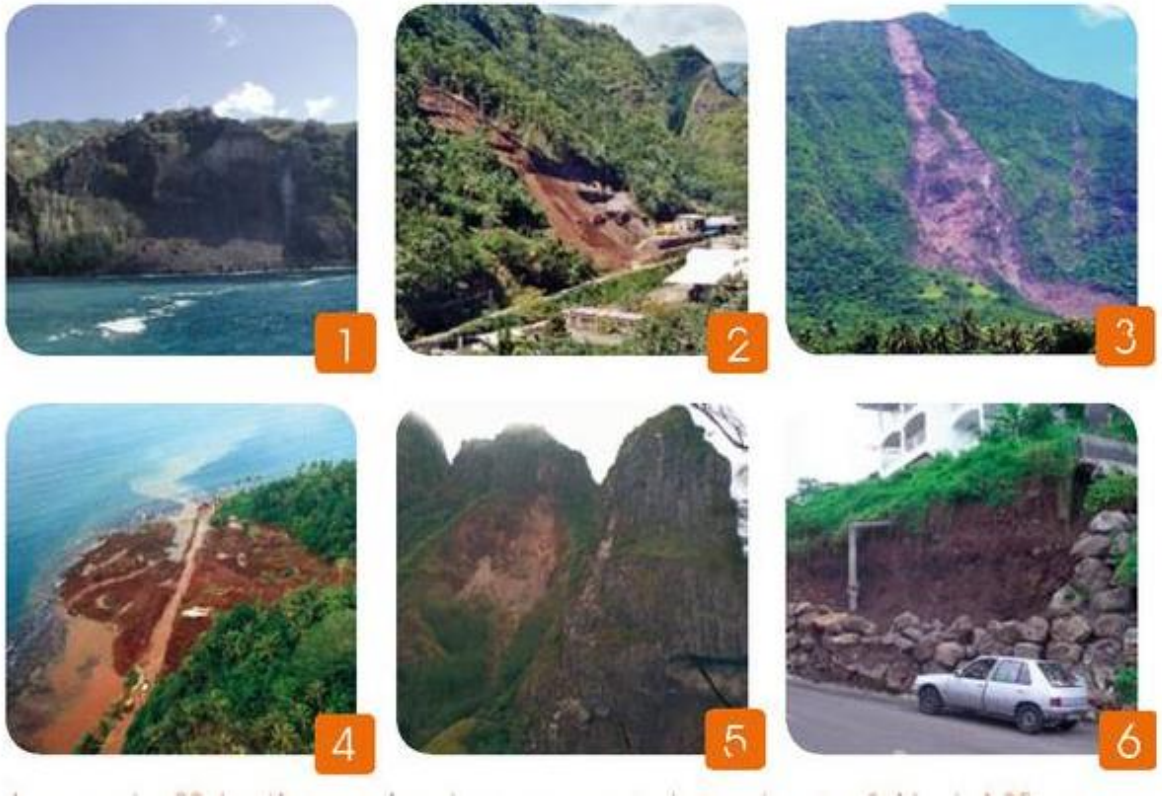
~ 140nm,

260 km.

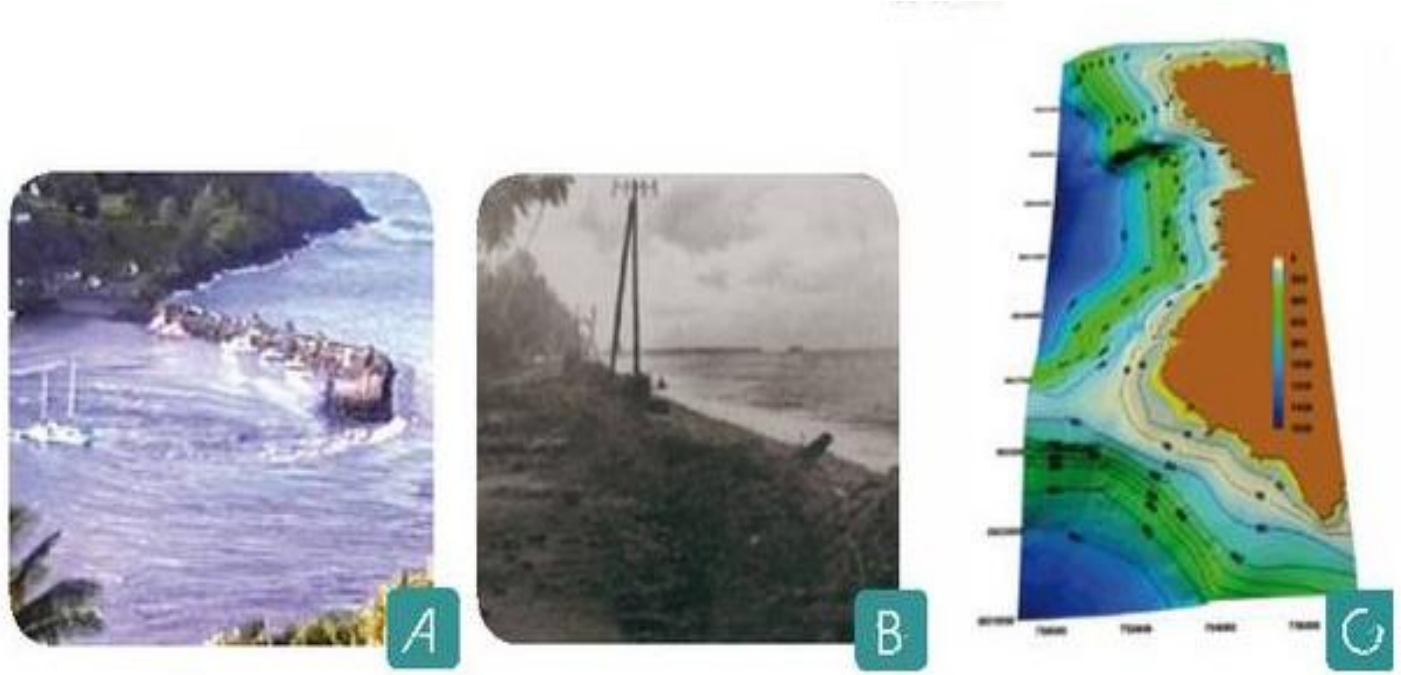
SAU: Bora Bora, Moorea & Tahiti survey areas



Landslides – large or localised. Effects on marine areas



Tsunami Effects and modelling



Effects of Cyclones + Storm Surge

Other customers get onboard …

Moorea Coral Reef - Long Term Ecological Research (MCR-LTER)

The complex coral reefs and lagoons at the island of Moorea have been studied since 1970s from two international research stations and the main goal is to explore the effects of external drivers on the fate of coral reefs:

- Richard B Gump South Pacific Research Station
- CRIOBE - Centre de Recherches Insulaires et Observatoire de l'Environnement

Proposal was submitted by investigators from MCR-LTER to US National Science Foundation Long Term Ecological Research Program to fund additional survey of the entire coast of Moorea.

Why coral reefs?

A “massive jigsaw puzzle for scientists”, **coral reefs are the rainforests of the sea** and millions of people depend on them for food security and other ecosystem services, such as storm protection and sources of medicines. Indeed, it is said that: “no other habitat on Earth is of such importance to humans”.

Tropical island reefs, however, are under threat and represent **‘canaries in the mine’** due to their sensitivity to global change. Understanding interactions between island social systems and environments, and of differential cultural responses to ecosystem change, informs policies for sustainability and resilience. Such research is truly interdisciplinary and contributes to conceptual integration across the natural and social sciences.

Coral reefs represent one of the most diverse ecosystems on earth.

External drivers affecting coral reef decline include:

- Coastal Development
- Over Fishing
- Multiple factors associated with global climate change

The MooreaIDEA Project

Some researchers are organised into a broader research consortium MooreaIDEA. Acronym: Moorea Island Digital Ecosystem Avatars

Aim: construct advanced computational models of a range of complex socio-ecological systems, particularly islands (coupled natural-human systems) and cities (built environment) using Moorea as a template

Moorea is a natural laboratory spanning marine and terrestrial environments (to 1,207m) that is constrained enough to be tractable, but sufficiently large (132 sq. Km) to contain all the elements of a complex socio-ecosystem, including a sizable human population (~ 17,000).

Moorea IDEA – complete the island …

Line planning for remainder of Moorea funded by the US NSF.

& DEQ – part of south coast of Tahiti

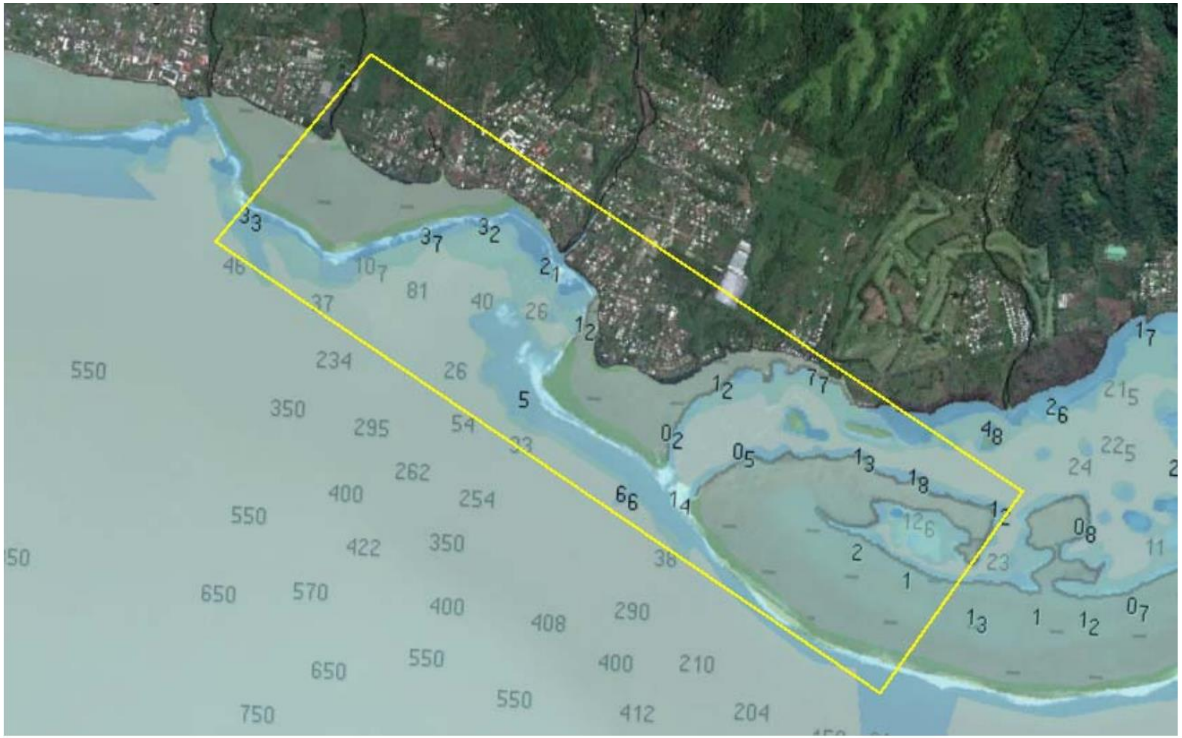


Figure 1: Proposed survey areaa for June 2015 capture for DLE (Yellow Polygon)

An additional area at the mouth of the Taharuu River was funded by local government department: Direction de l'Equipment

And don’t forget SHOM …

SHOM has 3 main missions:

National Hydrographic Service – to support marine navigation to discharge France’s obligations under SOLAS

Support to defence – to provide all necessary defence expertise and operational support in terms of knowledge of the aero-maritime environment

Support to government maritime and coastal policies - supports Government Action at Sea and provides expertise in work related to maritime limits and boundaries. It also helps collect and distribute digital data required for integrated management and sustainable development of coastal zones as well as government initiatives to reduce marine pollution.

SHOM's Litto3D® program:

An IGN-SHOM partnership for continuous representation of land-sea coast

The national program **Litto3D®** aims to produce a continuous reference digital elevation model of land-sea on the coastal fringe. This is to achieve relief of deep sea surveys and measures for accurate knowledge of the coastal area in mainland France and overseas territories.

The coastal strip is concerned: **- *at sea, to the depth contour continues to depth 10 m and at up to 6 miles offshore. - On land, up to 10 m altitude, and the least 2 km inland.*** In total, the influence of the program represents about 45 000 km ^{2}

Overview of the Litto3D® project

This is the Litto3D® coverage as of early 2015.

The Litto3D® product is released under an Open data licence .

Available gratuit from diffusion.shom.fr

ALB survey in Polynesia - project risks

Need to manage:

- remoteness
- deployment and logistics
- poor survey control
- high mountains
- low cloud
- breaking swell
- low seabed reflectivity due to black sand

FP Survey Operations Summary 2015

27 May - Mobilise equipment & personnel to Papeete

03 June - Aircraft Arrival
Planning and control requirements for SW Pacific

04 – 09 June – remove bladder tank, install equipment, STW & calibrate Riegl & Fugro LADS ALB systems

10 – 26 June – 12 sorties including 7 weather days & 2 days internal mob

29 June - demobilisation


NISSAN

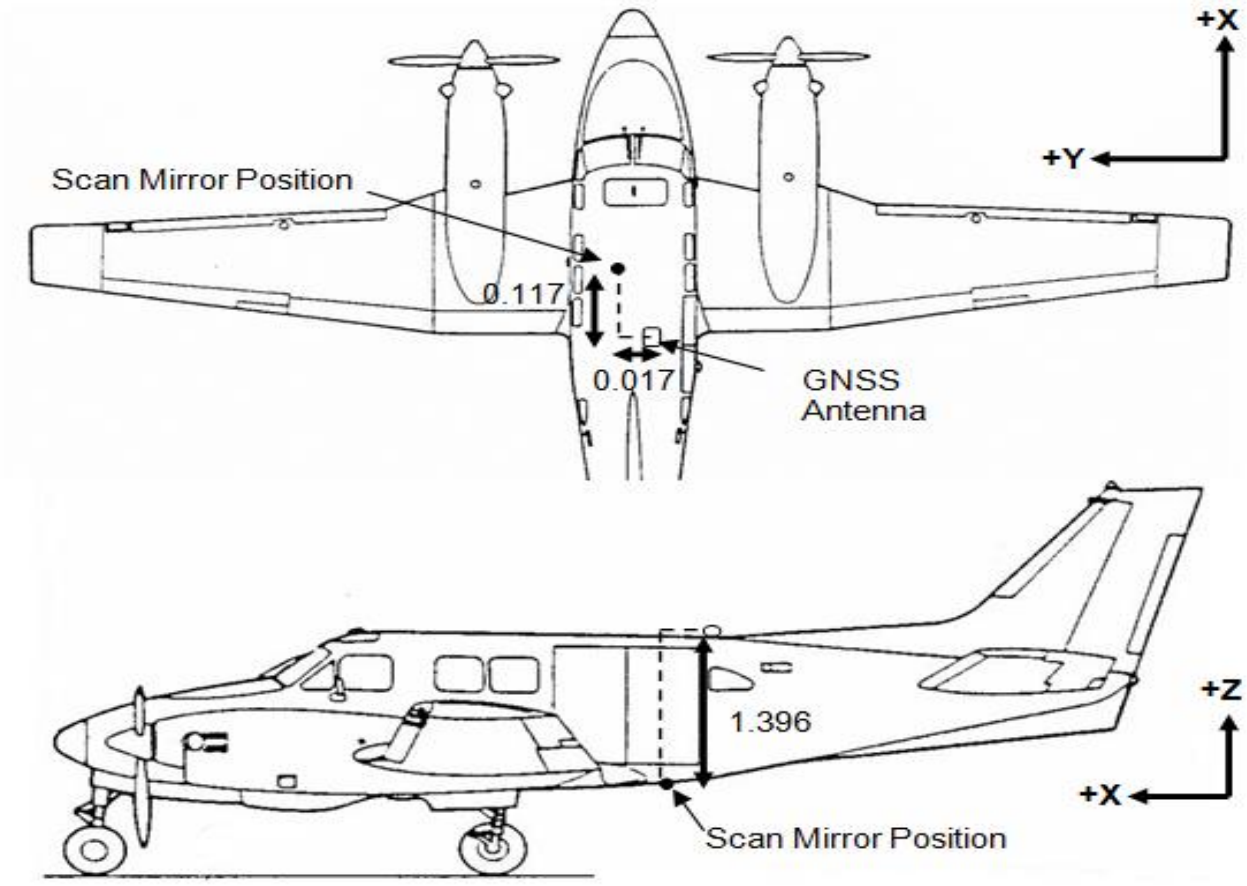


Figure 1 – Laybacks

Acquisition:

Fugro LADS Mk 3 Airborne System

RIEGL VQ-820-G Hydrographic Airborne Laser Scanner

Digital camera

Real-time positioning provided by Fugro Marinestar and post processing using GNSS PPP

POS AV with IMU and GNSS logger

Permanent GNSS base station in Papeete

Software:

Terramodel & Terrascan to review survey planning

Fugro LADS Mk 3 Ground System software

RIEGL RiProcess data processing software

Post Processed Kinematic (PPK) methodology using POSPac MMS software

MicroStation Terrascan for final merged data and export

Tech Specifications:

Sounding density:

- 4 points per sq m (on land & shallow water)
- IHO Order 1b (deep water) – 5 metre density

Tech Requirement:

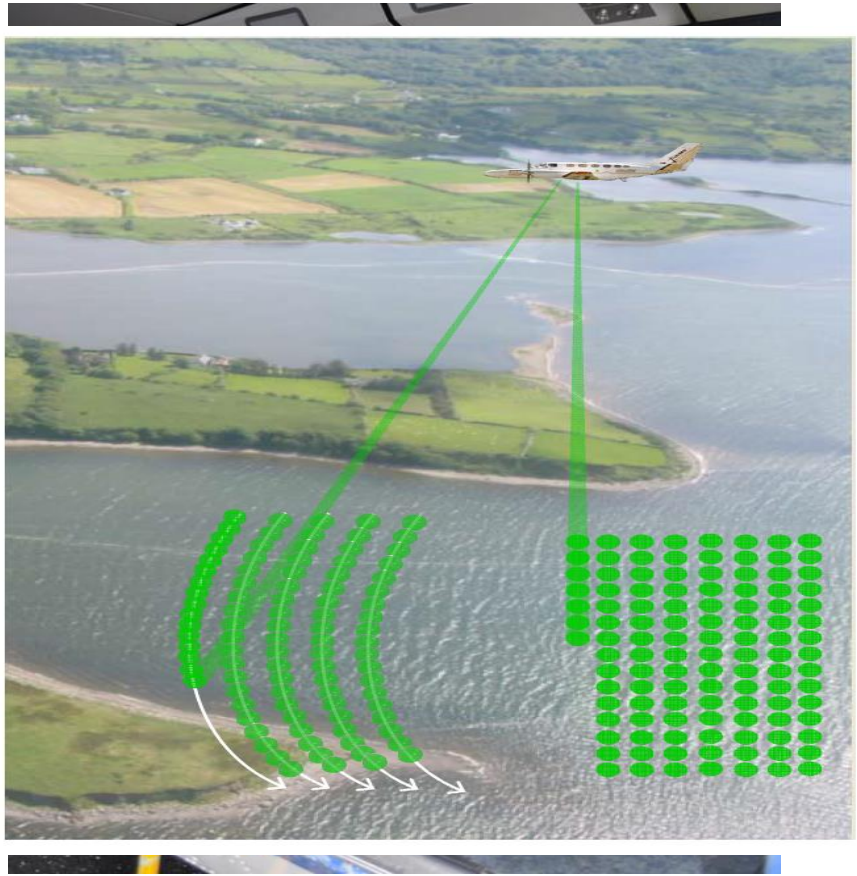
10m drying line to 40m nominal water depth

Minimum of 95% coverage in each survey area

Tahiti west coast

ALB Capture

- Sensor:
  - LADS ALB integrated with RIEGL VQ-820-G systems in the same aircraft
  - Both systems operate at 532nm
  - LADS system scans under the aircraft
  - RIEGL is angled 20 degrees fwd or aft
  - Systems complement each other providing coverage on the coast and offshore to deep water (LADS) and very high density coverage in very shallow water and on the beach and coast (RIEGL)



Geodetic Control

Coordinates:

- Tahiti and Moorea Survey Areas - UTM Zone 6 South, Central Meridian 147° West
- Bora Bora - UTM Zone 5 South, Central Meridian 153° West.

All collected data was post-processed relative to the International Terrestrial Reference Frame 2008 (ITRF08@2015.4) datum during the application of the PPK solution.

Final data was delivered to the Réseau Géodésique de la Polynésie Française (RGPF), which is based on ITRF92 (1993.0).

Bathymetry

The RIEGL system was operated at 251 kHz with a nominal swath width of 375m with a sounding density of nominally 4 points per square metre. Note the Riegl sensor can also operate at 500 kHz.

The LADS main lines of sounding were conducted using a 5x5 metre laser spot spacing with a swath width of 317 metres, at an aircraft ground speed of 160 knots. Main lines of sounding were flown at 290 metre spacing.

Bathymetry – Depth Benchmarks

A depth benchmark is typically a flat area of seabed which is used to verify the system accuracy.

Four benchmark areas were surveyed by MBES for comparisons in depths ranging from approximately 5 metres to 20 metres.

The benchmarks were re-surveyed on each sortie to check for correct system operation and correct application of tides or ellipsoidal heights in that area.

Bathymetry - Benchmark Results

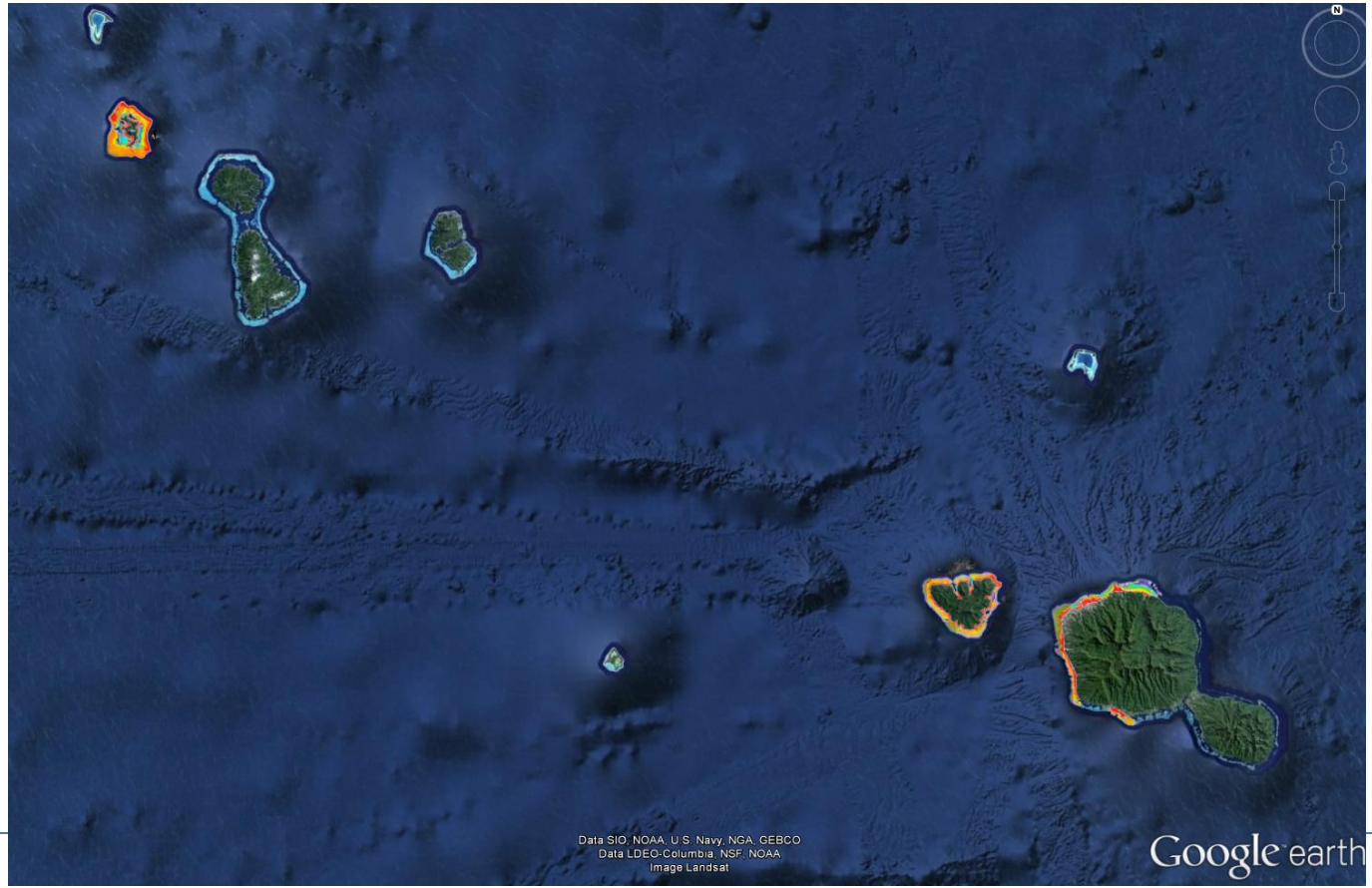
BM ID	Nominal Depth	Number of Comparisons	Average MDD	Average SD
1	5.8m	26351	0.10 +/- 0.07	0.12 +/- 0.01
2	15.4m	5067	0.08 +/- 0.00	0.13 +/- 0.00
3	18.2m	2552	0.06 +/- 0.14	0.15 +/- 0.01
4	14.2m	11889	0.51 +/- 0.00	0.10 +/- 0.03
	Total	45859	0.19 +/- 0.05	0.13 +/- 0.01

A total of fifty benchmark lines were compared using a total of 236,342 individual soundings. The average mean depth difference from all benchmark comparisons was -0.05 metres with an average standard deviation of ± 0.13 metres (1σ).

Bathymetry – Coverage

Area	Required SqKm (+10m drying to 40m depth)	Achieved SqKm (+10m drying to 40m depth)	Area percentage covered
Tahiti	77.20	73.16	96.81%
Moorea (Whole Island)	82.54	80.33	97.32%
Bora Bora	98.56	93.04	94.40%

Survey Results



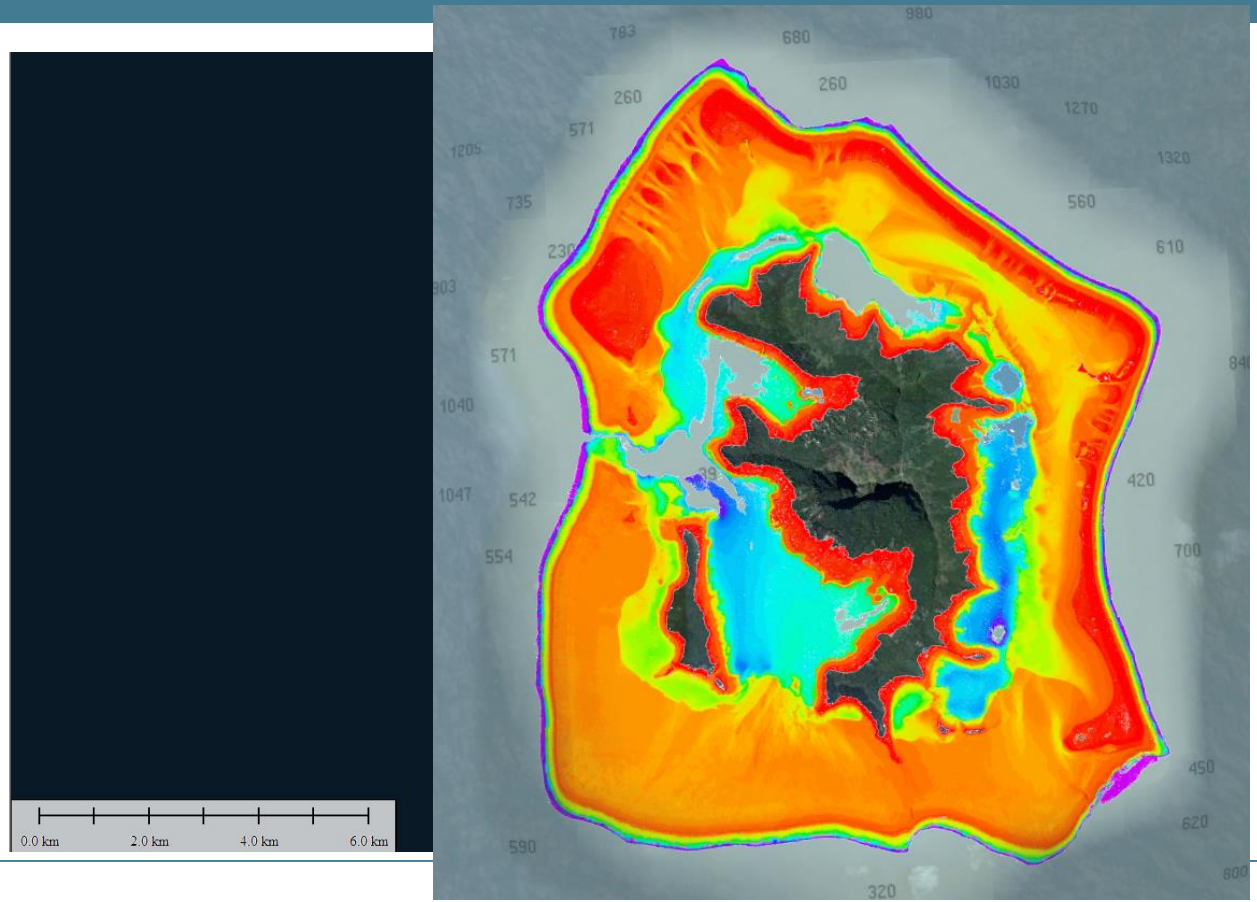
Survey Results

Ridge to outer Reef

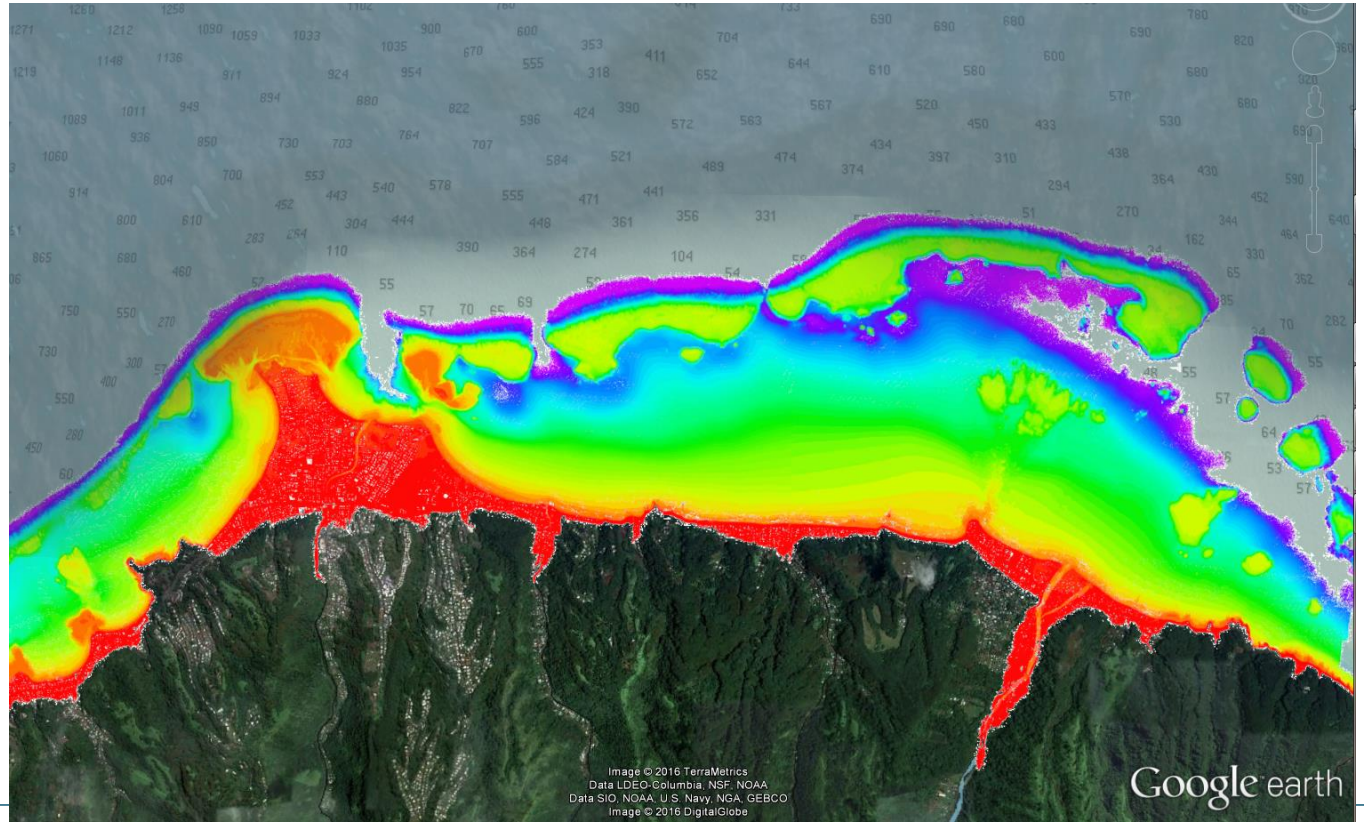
30m ASL to -60m below

(Note this achieves the specification of 10m ASL to -40m below)

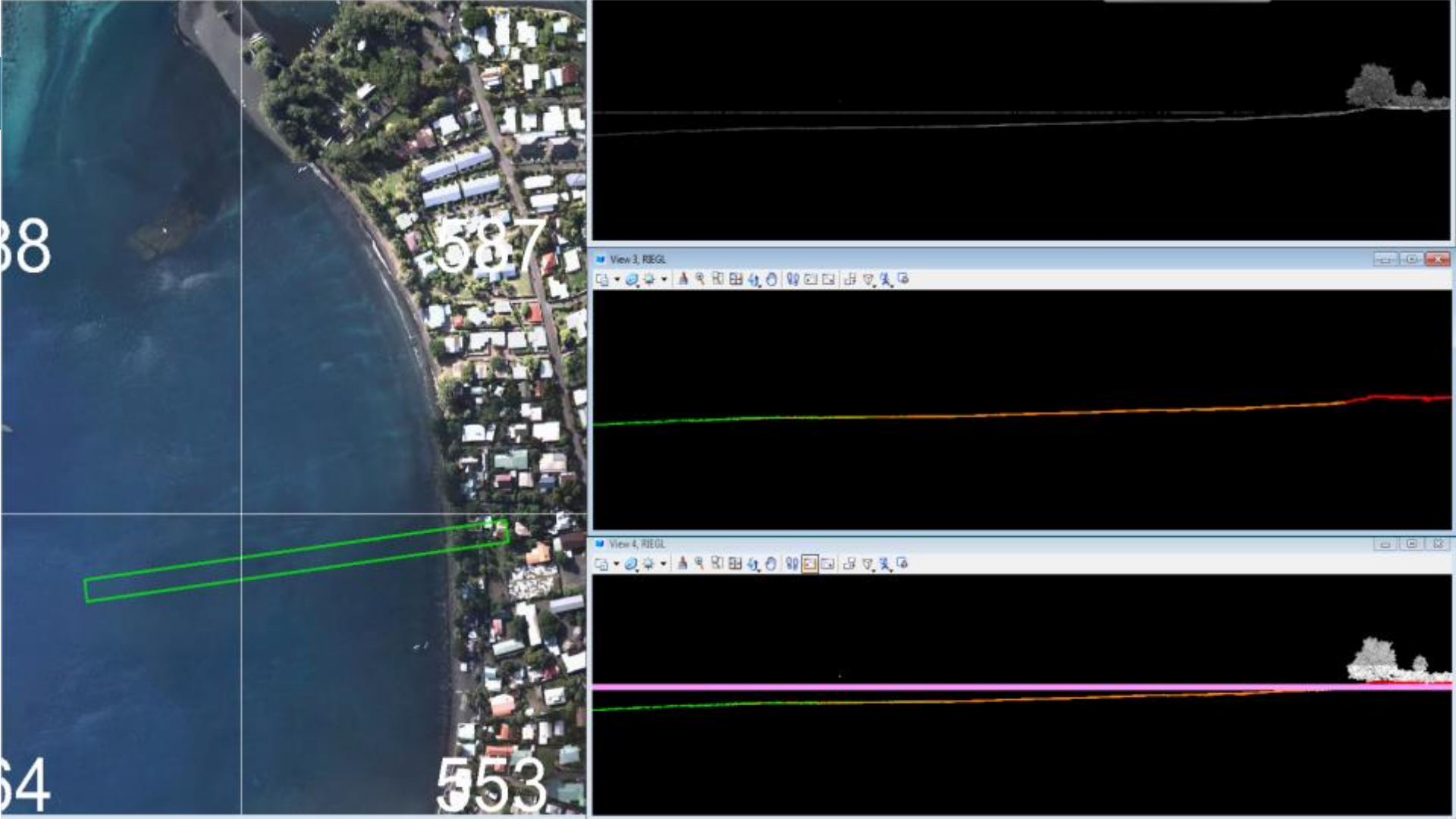
Survey Results



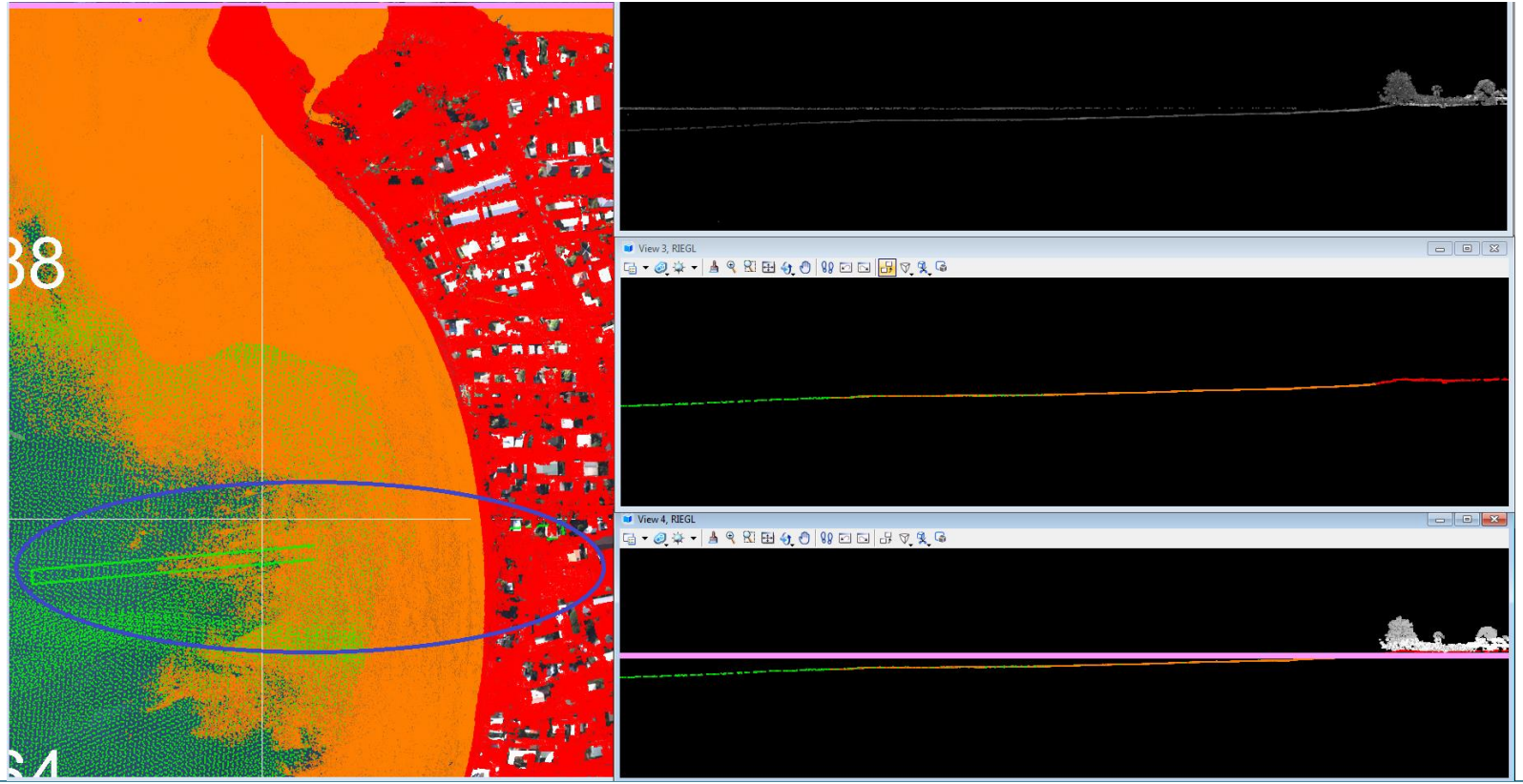
Survey Results



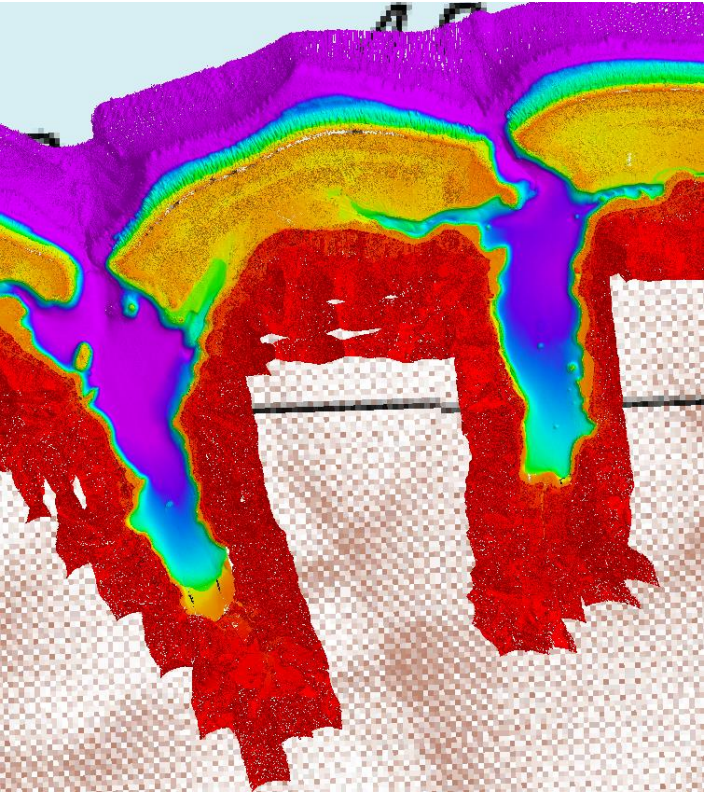
Target Detection – 1m Cube in 15m water

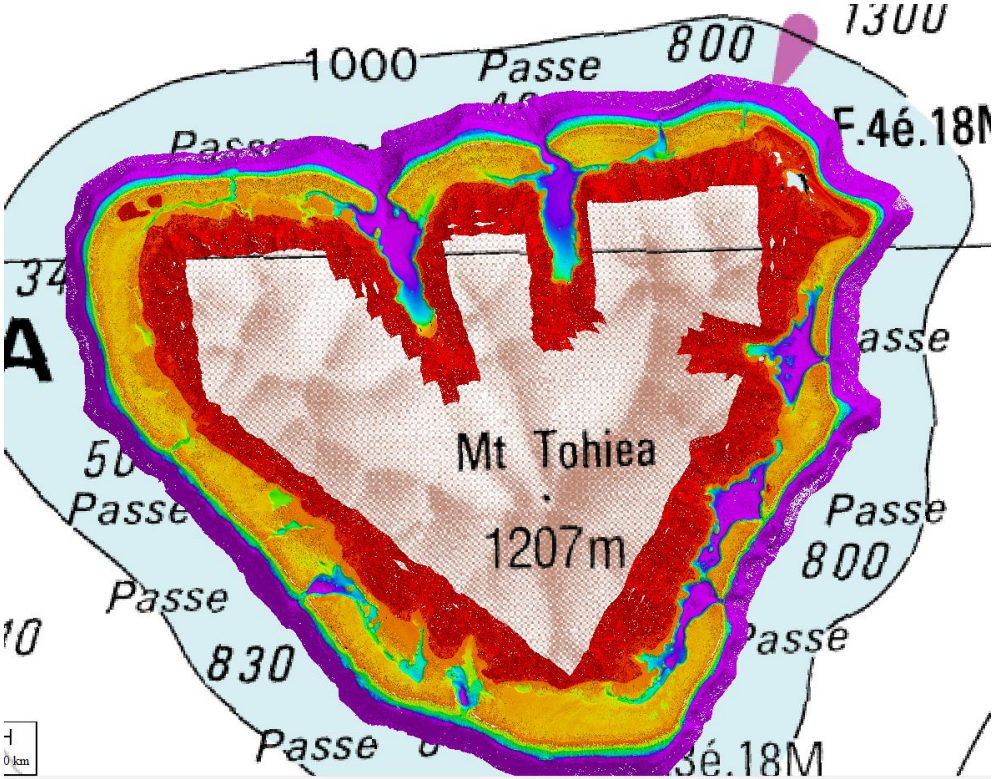

View 3, RIEGL
View 4, RIEGL

LADS + Riegl data over black sand …

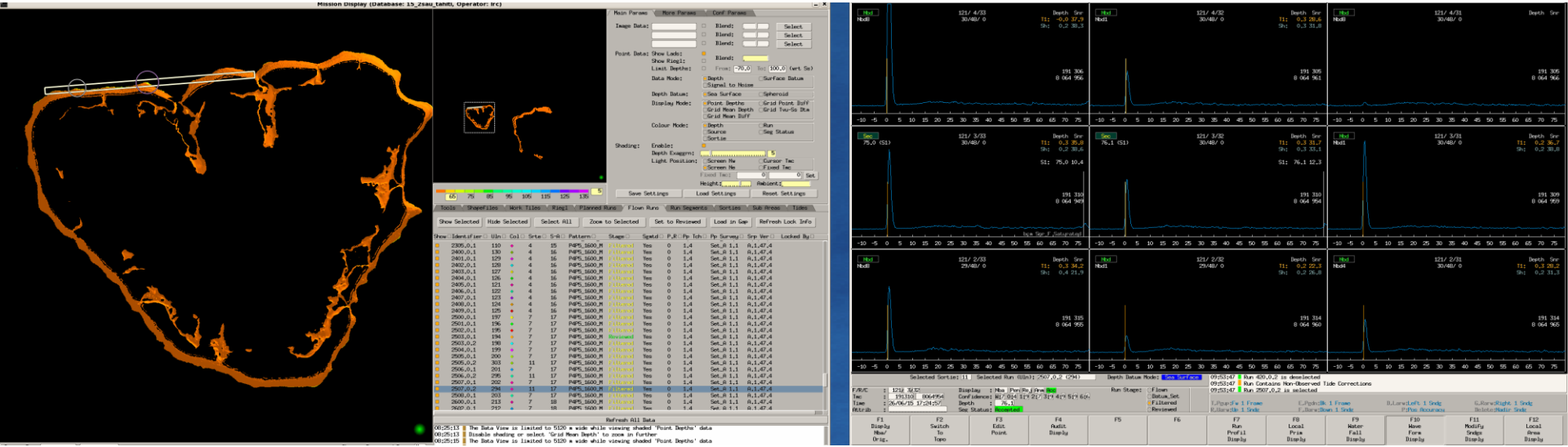


Final ALB + MBES coverage

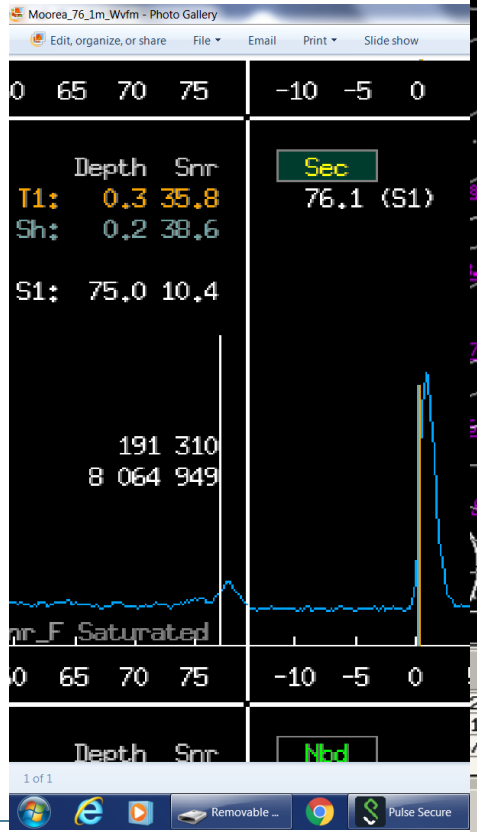


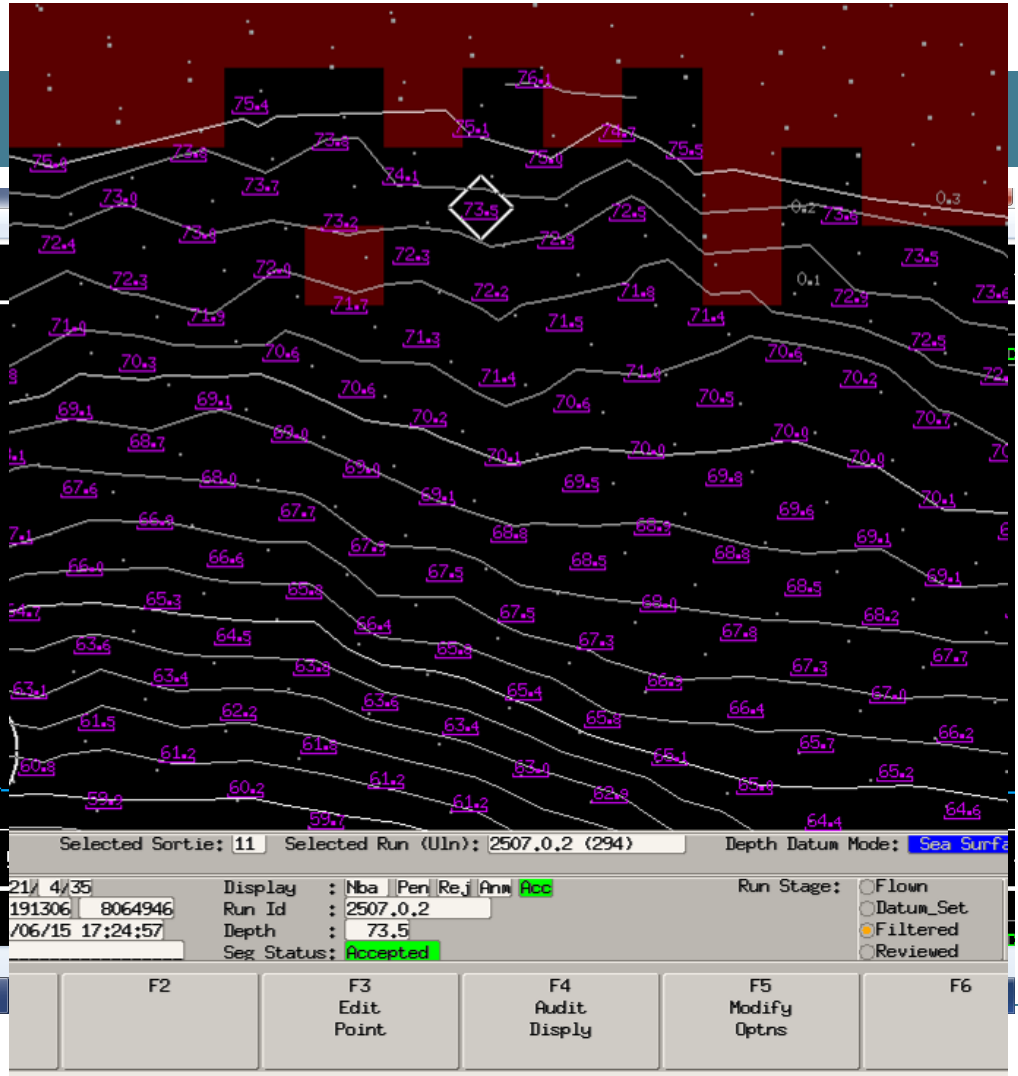


Max depth 76.1m

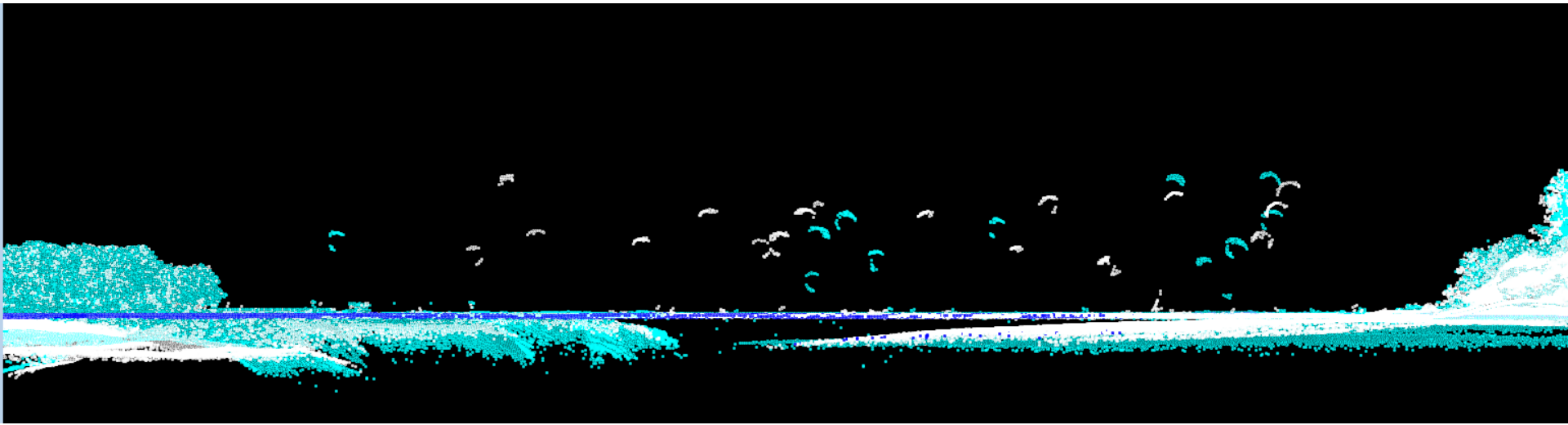


Max depth 76.1m





Fort Venus



Pointe de Venus, where Captain Cook undertook the first observations of the transit of Venus on 3 June, 1769

Conclusion

French Government is a well prepared organisation evidenced by:

- Recognise land/sea interface as critical & prioritises projects (since 2005)
- Documentation for standards (since 2005)
- Open data licencing (since 2005)
- Data download direct from website (since March 2014)
- Make technical updates available to regional managers (ongoing)
- Using compliant data for coastal zone management & updating nautical charts (since 2005)
- Understanding of limitations and benefits (ongoing)

Digital Avatars – new generation of CZM

The ALB data from this survey is also expected to benefit a substantial international scientific user base.

Acknowledgements

SHOM – Yves Pastol – co-author
SAU – Mr. Bernard AMIGUES
DEQ – Tahiti Local Government
MCR-LTER – Moorea Coral Reef Long Term Ecological Research
Jim Hench – Duke University Marine Laboratory

Fugro LADS - Luke Chamberlain, SW Pacific Campaign Project Manager

Thank you

Any Questions?