Moorea Avatar – Physical Ecosystem Modeling of a Tropical Island

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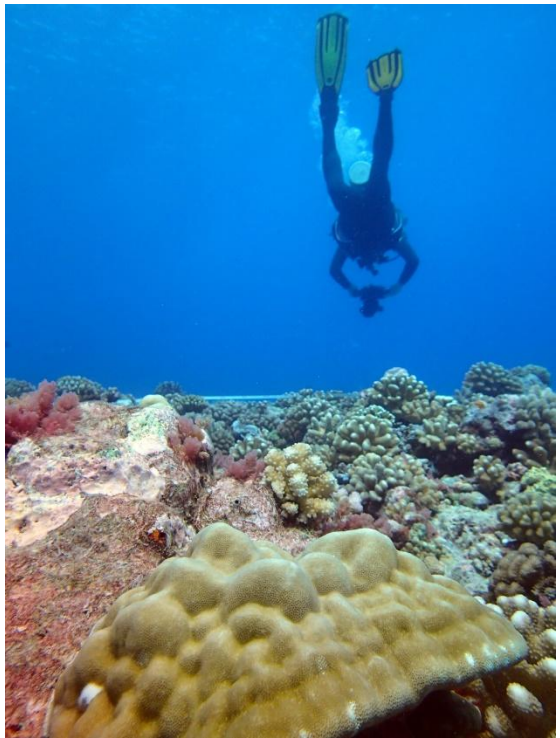
mooreaidea.org



The Island Digital Ecosystem Avatar (IDEA) Project

D'où venons-nous ? Que sommes-nous ? Où allons-nous ?
(Where Do We Come From? What Are We? Where Are We Going?)
Paul Gauguin, 1897, Oil on canvas 54 3/4 x 147 1/2 in. Museum of Fine Arts, Boston (source)

Can we model and predict the state of a (model) ecosystem?
What does the system look like today?
How did it get to this point?
What is its future under alternative scenarios of environmental change and human activity?

Scales of Complexity (Society Islands – Windward Islands)

- **Tetiaroa**
  - ~150 people
  - 6.5 km^2 (land)
  - Flat
- **Moorea**
  - ~17,000 people
  - 132 km^2
  - ~1,200m
- **Tahiti**
  - ~180,000 people
  - 1045 km^2
  - 2,200m

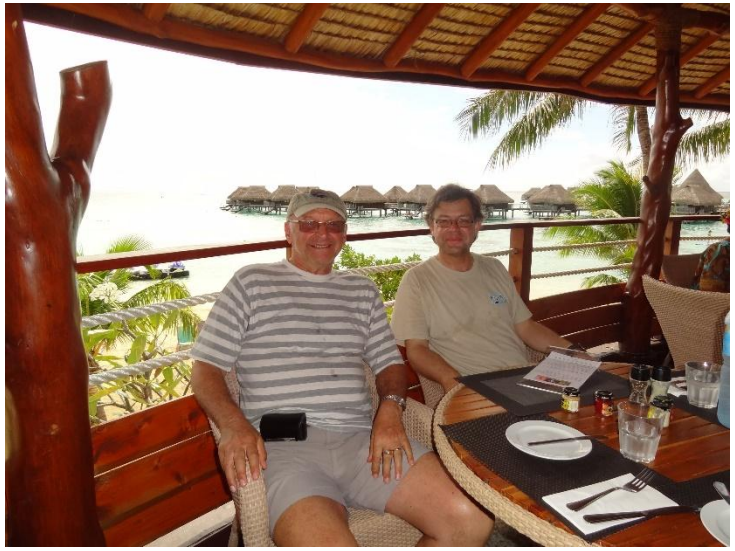
Moorea Landscape

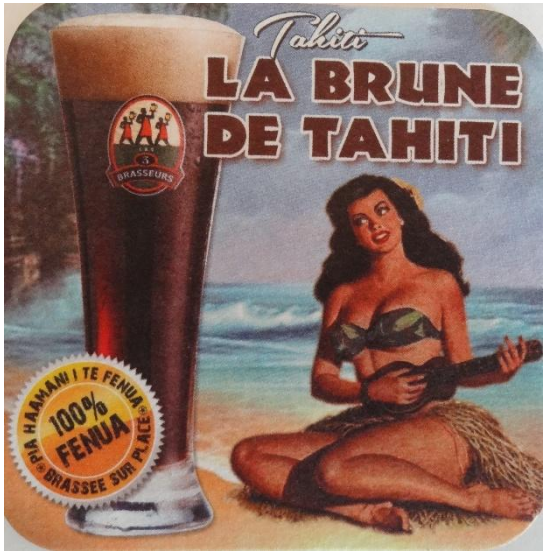
Cooks Bay

View from Belvedere

Tahitien culture

Tahitien culture



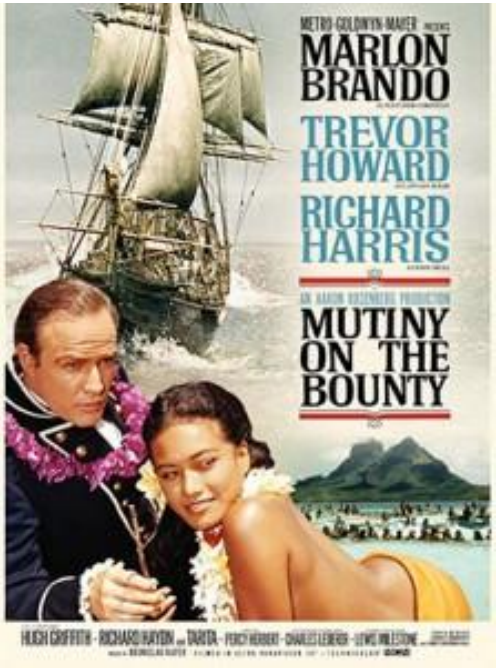


Tahitien nights

Tetiaroa - Island Avatar

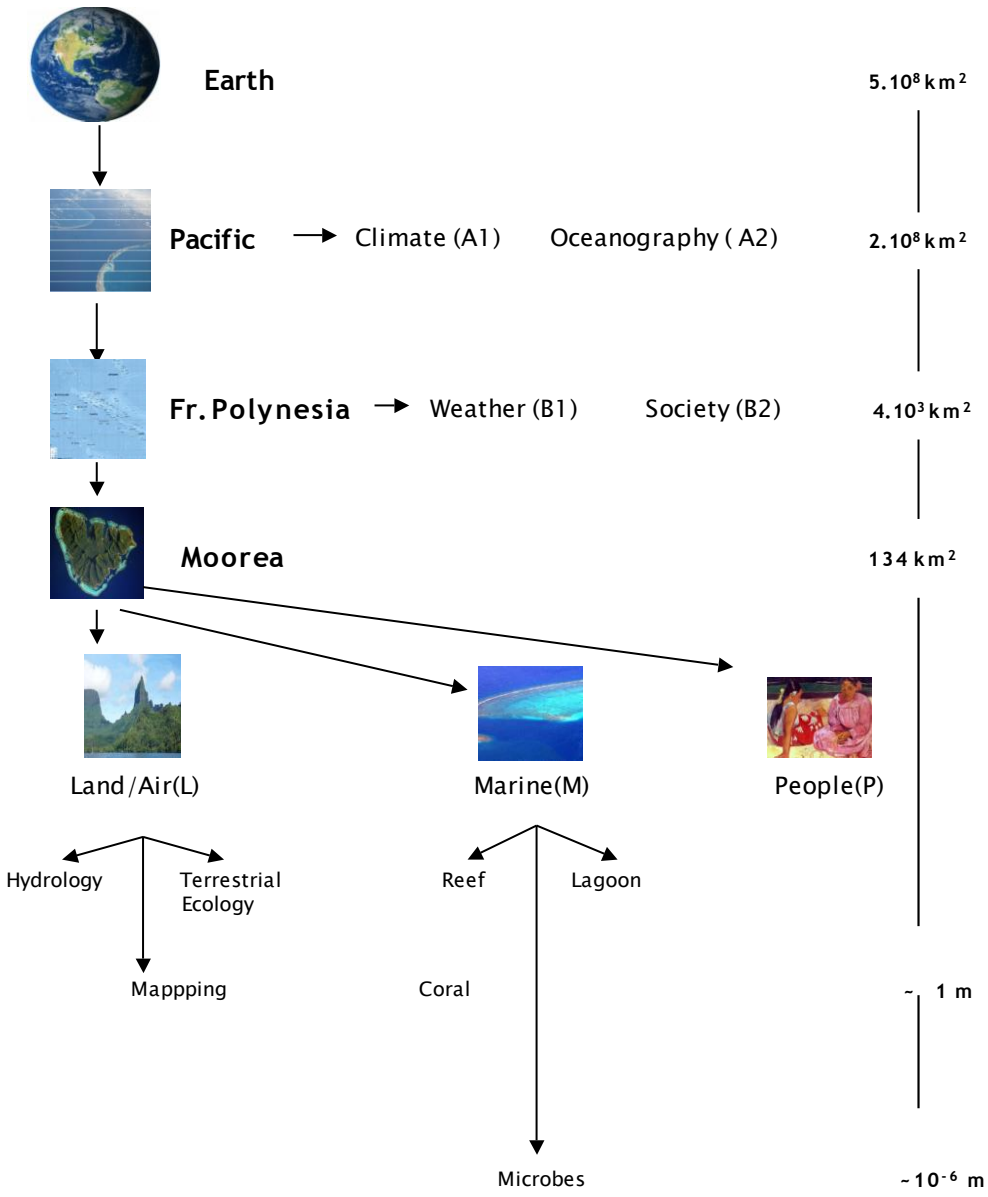
"Tetiaroa is beautiful beyond my capacity to describe. One could say that Tetiaroa is the tincture of the South Seas."

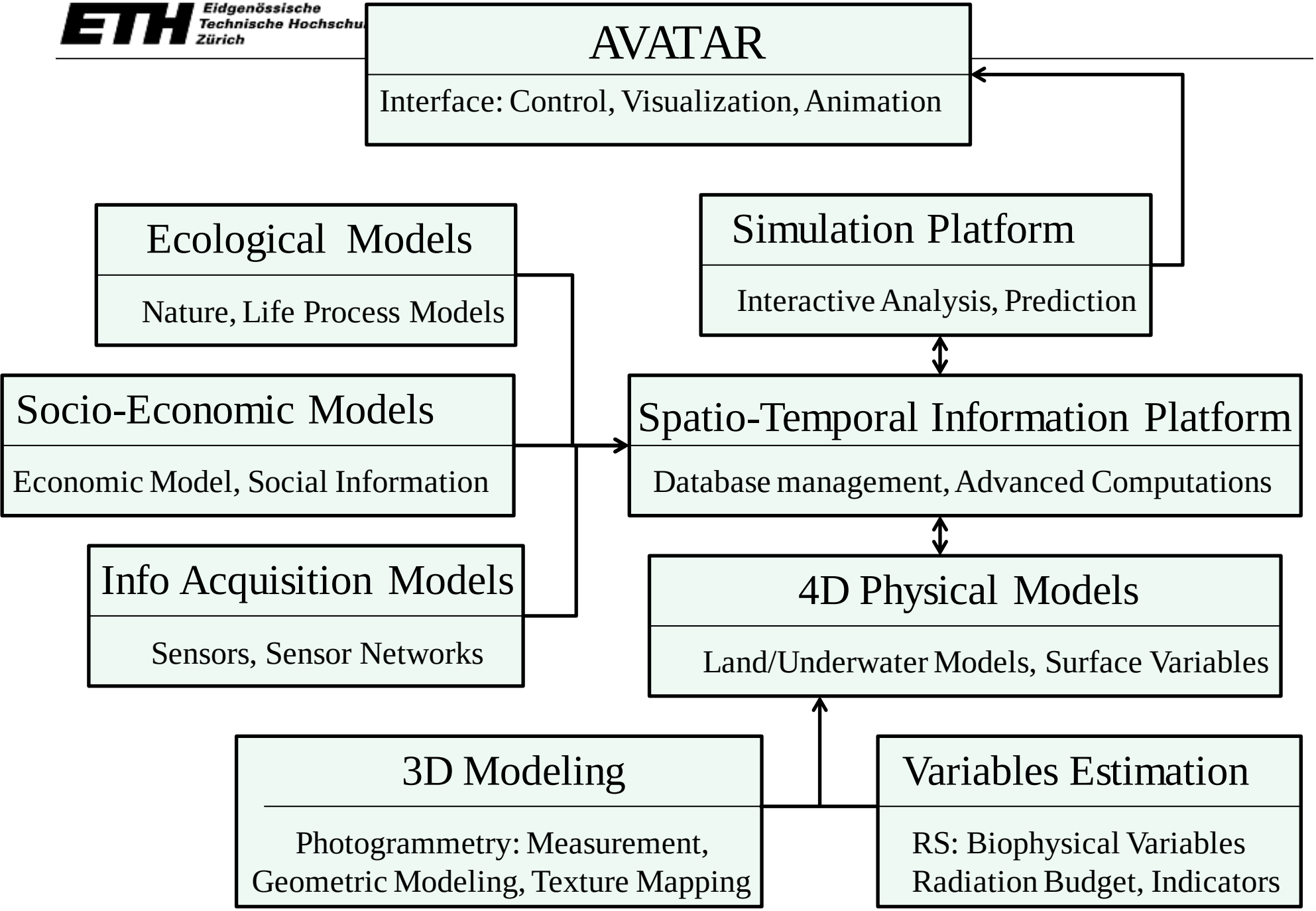
Marlon Brando



Modeling at many scales from globe to microbes

- Physical models are a foundation for ecological models
- Atmospheric models (M. Hopuare)
  - Climate, weather
  - micro-climate
- Water flows
  - ocean
  - lagoon
  - coral-scale
- Terrestrial hydrology




AVATAR
Interface: Control, Visualization, Animation
Ecological Models
Nature, Life Process Models
Simulation Platform
Interactive Analysis, Prediction
Socio-Economic Models
Economic Model, Social Information
Spatio-Temporal Information Platform
Database management, Advanced Computations
Info Acquisition Models
Sensors, Sensor Networks
4D Physical Models
Land/Underwater Models, Surface Variables
3D Modeling
Photogrammetry: Measurement,
Geometric Modeling, Texture Mapping
Variables Estimation
RS: Biophysical Variables
Radiation Budget, Indicators

Many research groups work already on Moorea

UNIVERSITÉ DE LA POLYNÉSIE FRANÇAISE

Richard B. Gump South Pacific Research Station

LE CRIOBE

MOOREA CORAL REEF LTER
Member of the NSF Long Term Ecological Research Network

École Pratique des Hautes Études

BIOCODE moorea
17 30S 149 50W

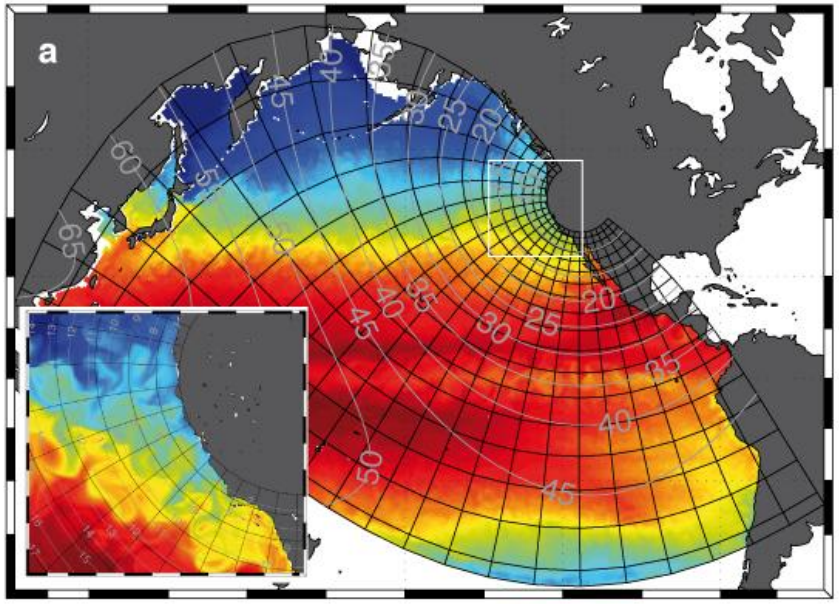
… and many more …

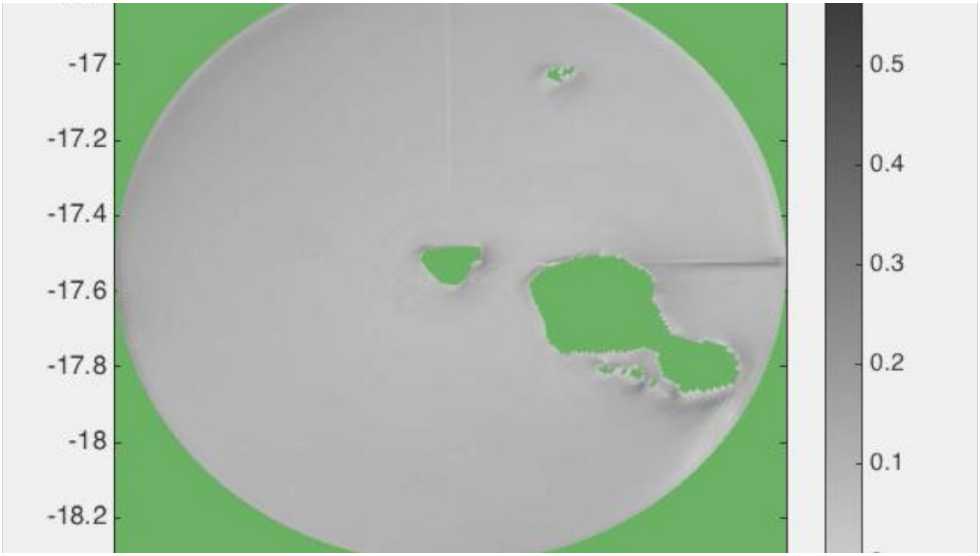
Thanks to the people helping build the Avatar

- Hervé Bossin (ILM)
- Andrew Brooks (UCSB)
- Alessandro Capra (Modena)
- Antoine Collin (EPHE Dinard)
- Pascal Correia (Service de l'urbanisme)
- Neil Davies (Gump)
- John Deck (Berkeley)
- Gastil Gastil-Buhl (UCSB)
- Sultan Kocaman (ETH & Ankara)
- Armin Grün (ETH)
- Tao Guo (ETH)
- Sally Holbrook (UCSB)
- Matthias Troyer (ETH)
- Alex Kosenkov (ETH)
- Guillaume Le Port (CRIOBE)
- Chris Meyer (Smithsonian)
- Frank Murphy (Gump)
- Yves Pastol (SHOM)
- Serge Planes (CRIOBE)
- George Roderick (Berkeley)
- Russ Schmitt (UCSB)
- Gilles Siu (CRIOBE)
- Benoit Stoll (UPF)
- Hinano Teavai-Murphy (Atitia Center & Gump)

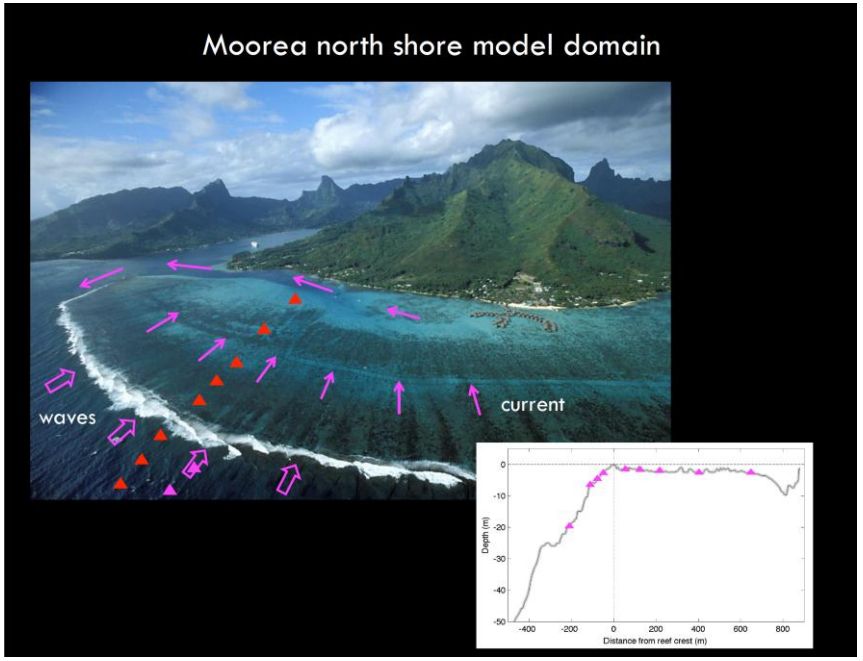
The Regional Oceanic Modeling System (ROMS)

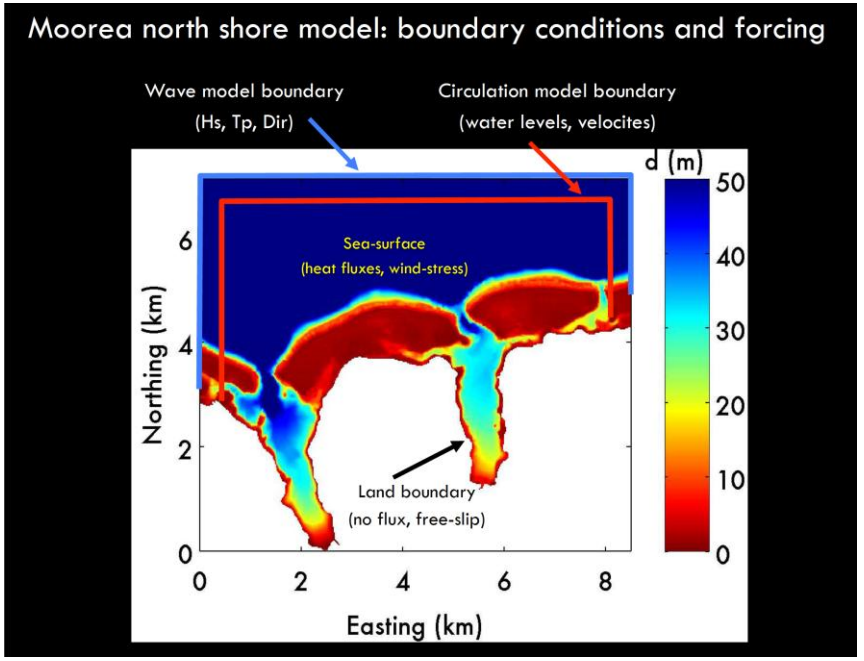
- Niki Gruber and Matt Münnich (ETH)
  - ocean-scale models solving simplified Navier-Stokes equations
  - plans to couple to local models around the island of Moorea





Water flows in the lagoon: Jim Hench (Duke)

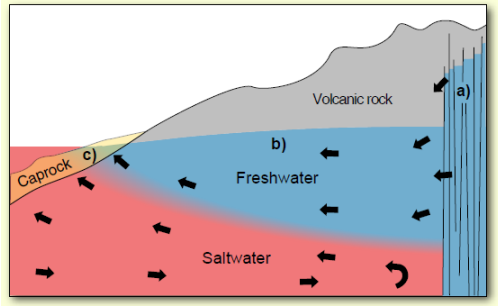




$$\underbrace{\frac{\partial U}{\partial t}}_{\text{time-varying}} + \underbrace{U\frac{\partial U}{\partial x} + V\frac{\partial U}{\partial y} + \frac{\omega}{h}\frac{\partial U}{\partial \sigma}}_{\text{advective acceleration}} - \underbrace{fV}_{\text{Coriolis accel.}} = \underbrace{-\frac{1}{\rho_0}P_x}_{\text{pressure gradient}} + \underbrace{F_{Dx}}_{\text{drag}} + \underbrace{M_x}_{\text{wave stresses}} + \underbrace{\frac{1}{h^2}\frac{\partial}{\partial \sigma}\left(A_v\frac{\partial U}{\partial \sigma}\right)}_{\text{momentum diffusion}}$$

Hydrology: Ana Barros (Duke)

- Hydrology simulations will need additional data to be collected and instruments to be deployed
  - rainfall gauges
  - stream gauges
  - geology
  - …



Hawaii aquifers can be categorized into
a) dike-intruded volcanic rock
b) dike-free volcanic rock
c) caprock.

Coastal sedimentary deposits form a caprock in some places that confines, attenuates tidal propagation into, and creates a thick freshwater lens within the volcanic-rock aquifer.

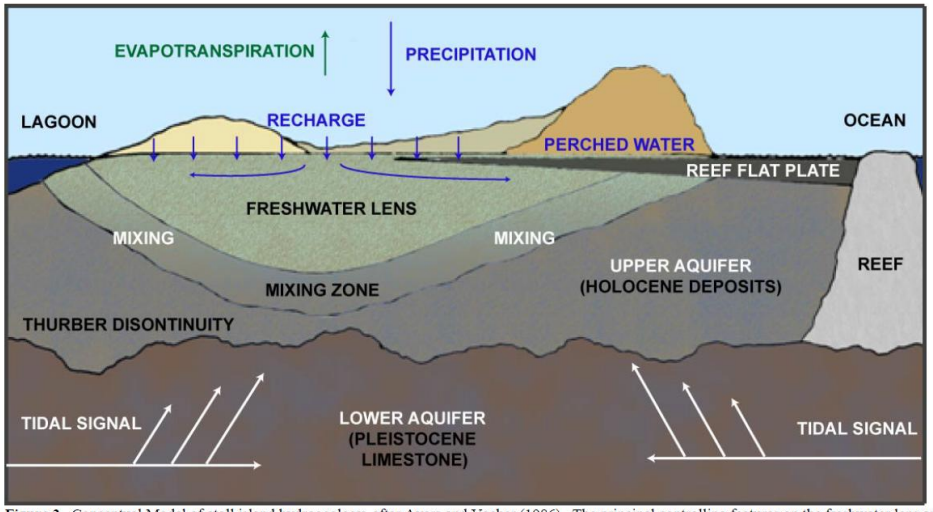
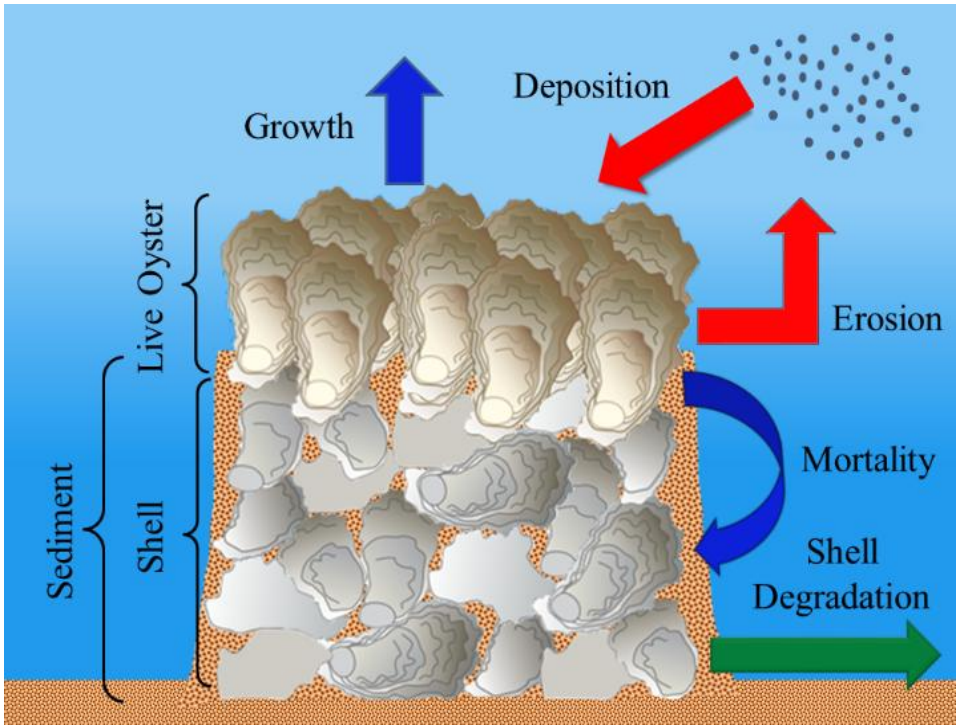


Figure 3. Conceptual Model of atoll island hydrogeology, after Ayers and Vacher (1986). The principal controlling features on the freshwater lens are (1) the width of the islands, (2) the recharge to the freshwater lens, (3) the hydraulic conductivity of the Holocene sediments, (4) the contact between the upper and lower aquifers, and (5) the reef flat plate.

Linking to biological models: Johanna Rosman

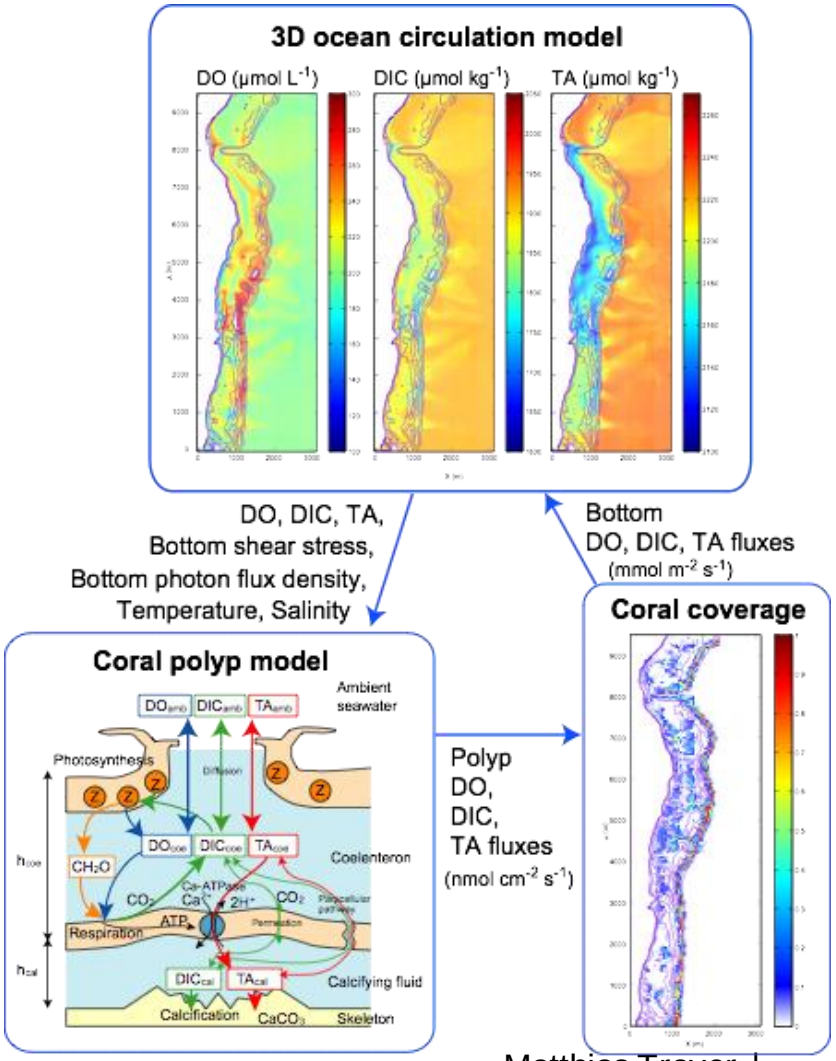
- A model to simulate effects of flow and sedimentation on reef development



Housego and Rosman 2015 (E&C)

Reef-scale modeling: Takashi Nakamura (Tokyo)

- Coral polyp model coupled with 3D ocean circulation model
- Polyp model evaluates evaluates the coral metabolisms (photosynthesis, respiration and calcification) in response to
  - flow condition,
  - material-limited situation and
  - ocean acidification.



Moorea IDEA - Data options for physical modeling

+ Existing data (maps, digital, statistical, social, etc.)
+ Highres satelite images
+ Aerial images
+ UAV; ultra-light airplane
+ Underwater photogrammetry
+ LiDAR (aerial)
+ Bathymetric data
  (sonar, sat. images, LiDAR)
+ SIS/DB platform
+ Visualization/animation

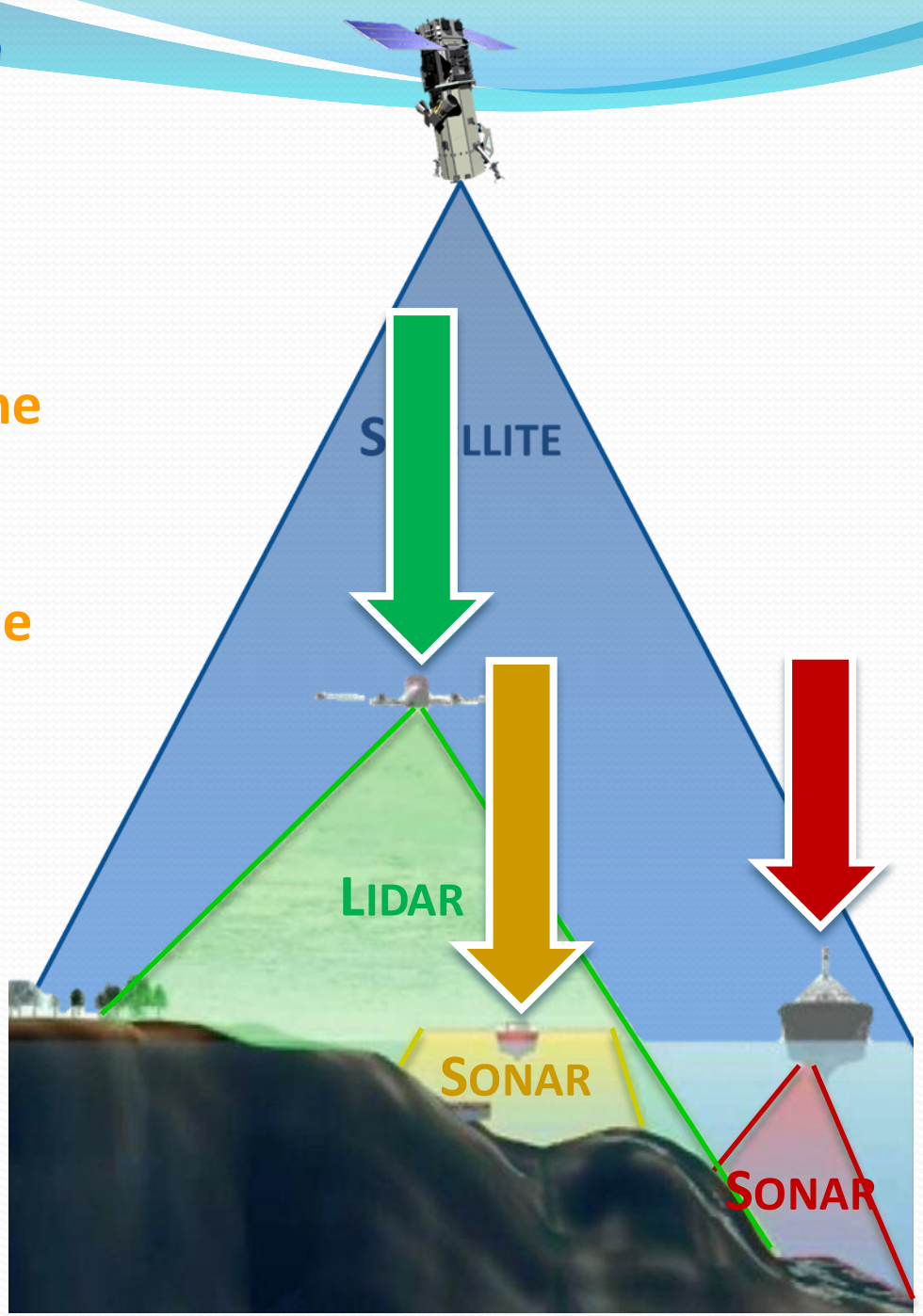
NEED FOR THE VERY SHALLOWS

Bathymetry mapping

How to map the bathymetry?

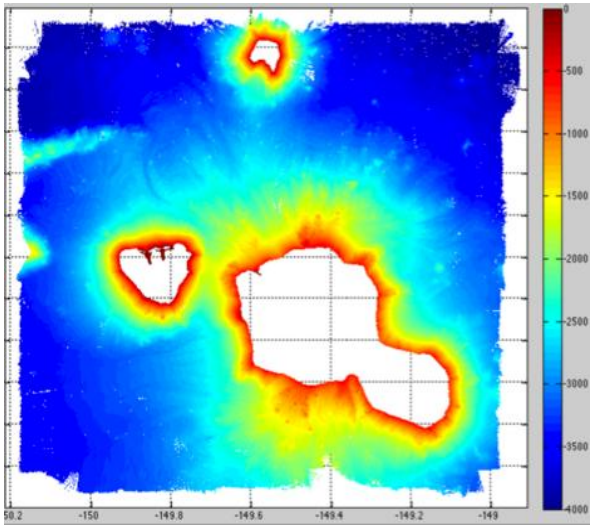
1. Waterborne
2. Airborne
3. Spaceborne

- Cost effective and budget adaptive
- Remote access to previously difficult and impractical areas
- Rapid project delivery
- No mobilizations or special permit requirements

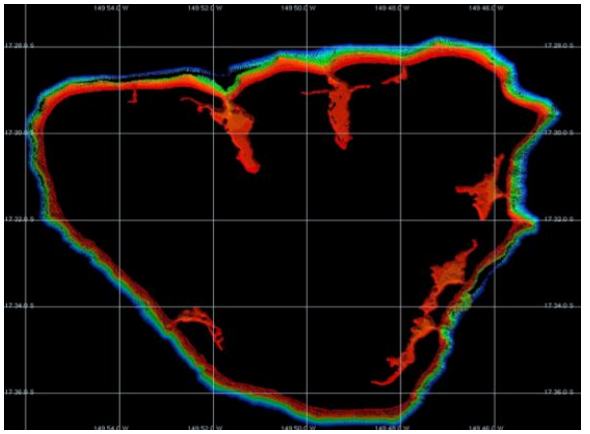


Bathymetry (water depth) from sonar

- Sonar cruise in July/August 2014, chief scientist Jim Hench
- R/V Kilo Moana
  - 20m x 20m grid
  - 100m - 4074m depth

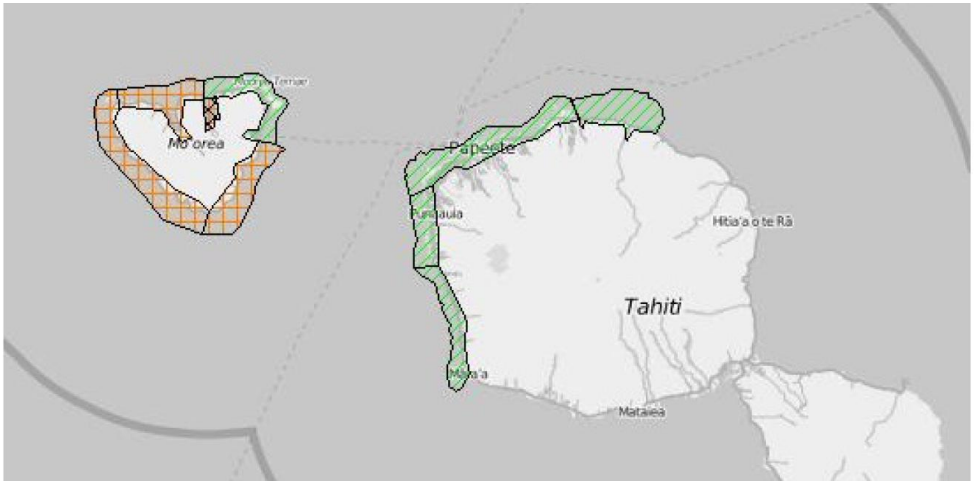


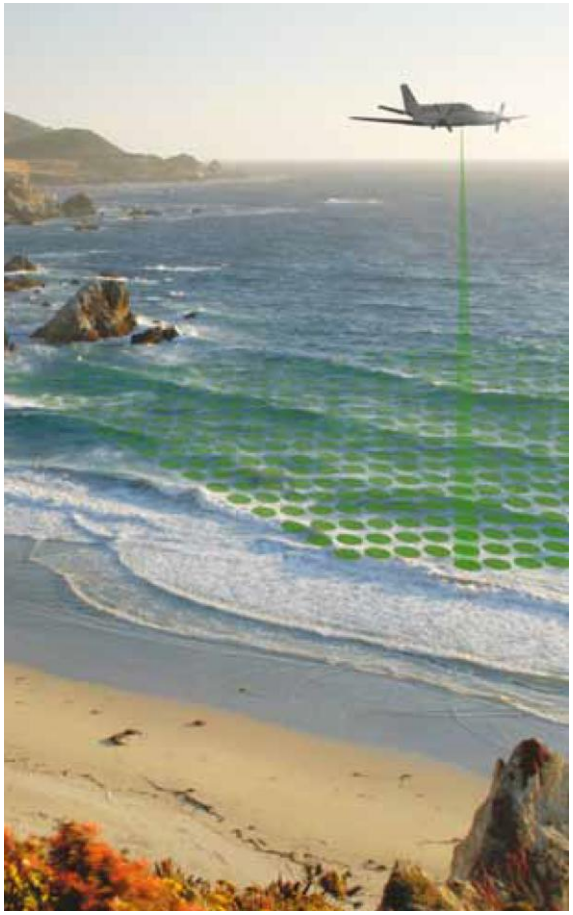
- R/V Ahi
  - 2m x 2m grid
  - 10m - 200m depth



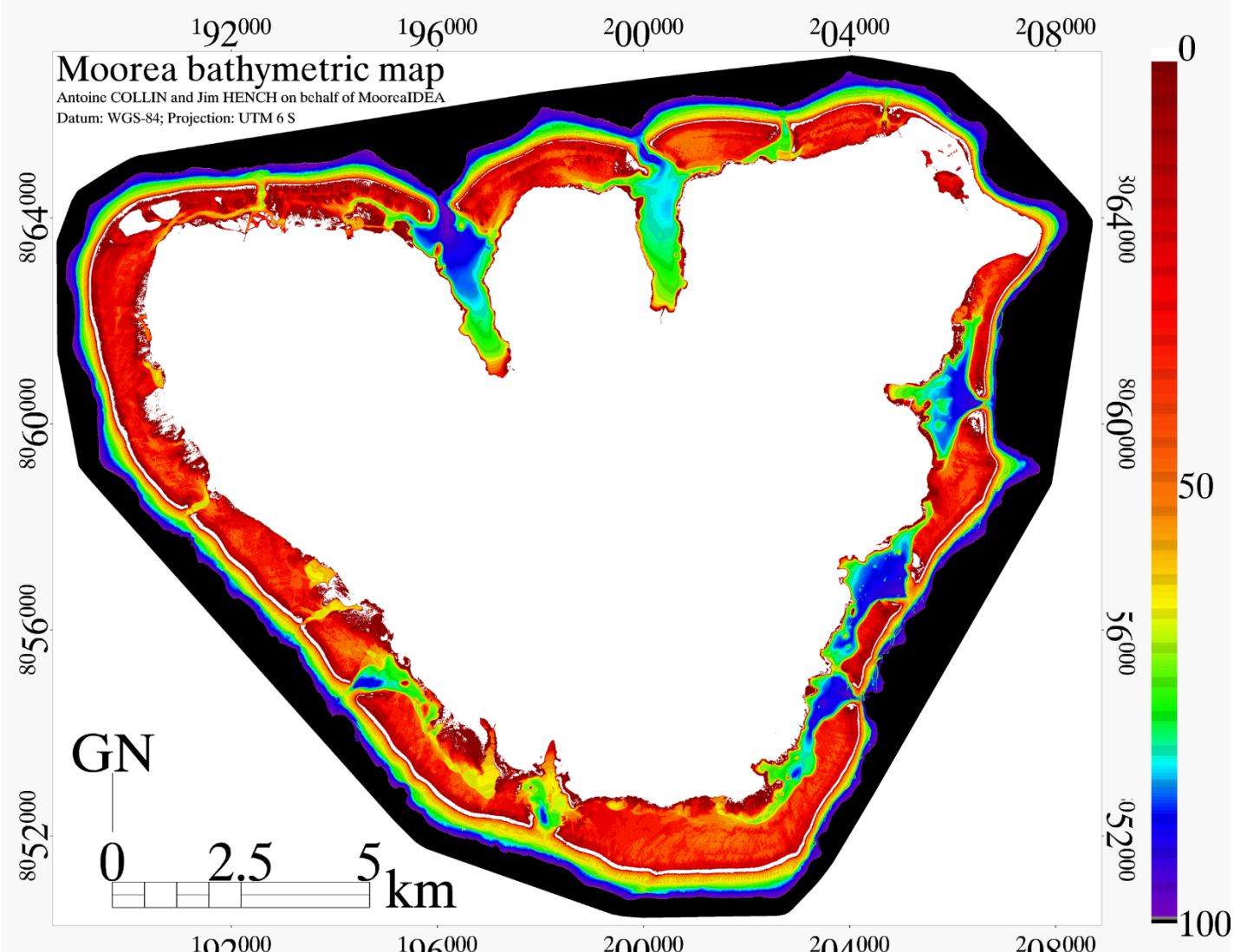
Lidar mapping of the lagoon and coast of Moorea

- Measure depth of the water by laser scanner from an airplane
- SHOM does north-east corner of Moorea and parts of Tahiti
- National Science Foundation of the USA pays for the rest of Moorea

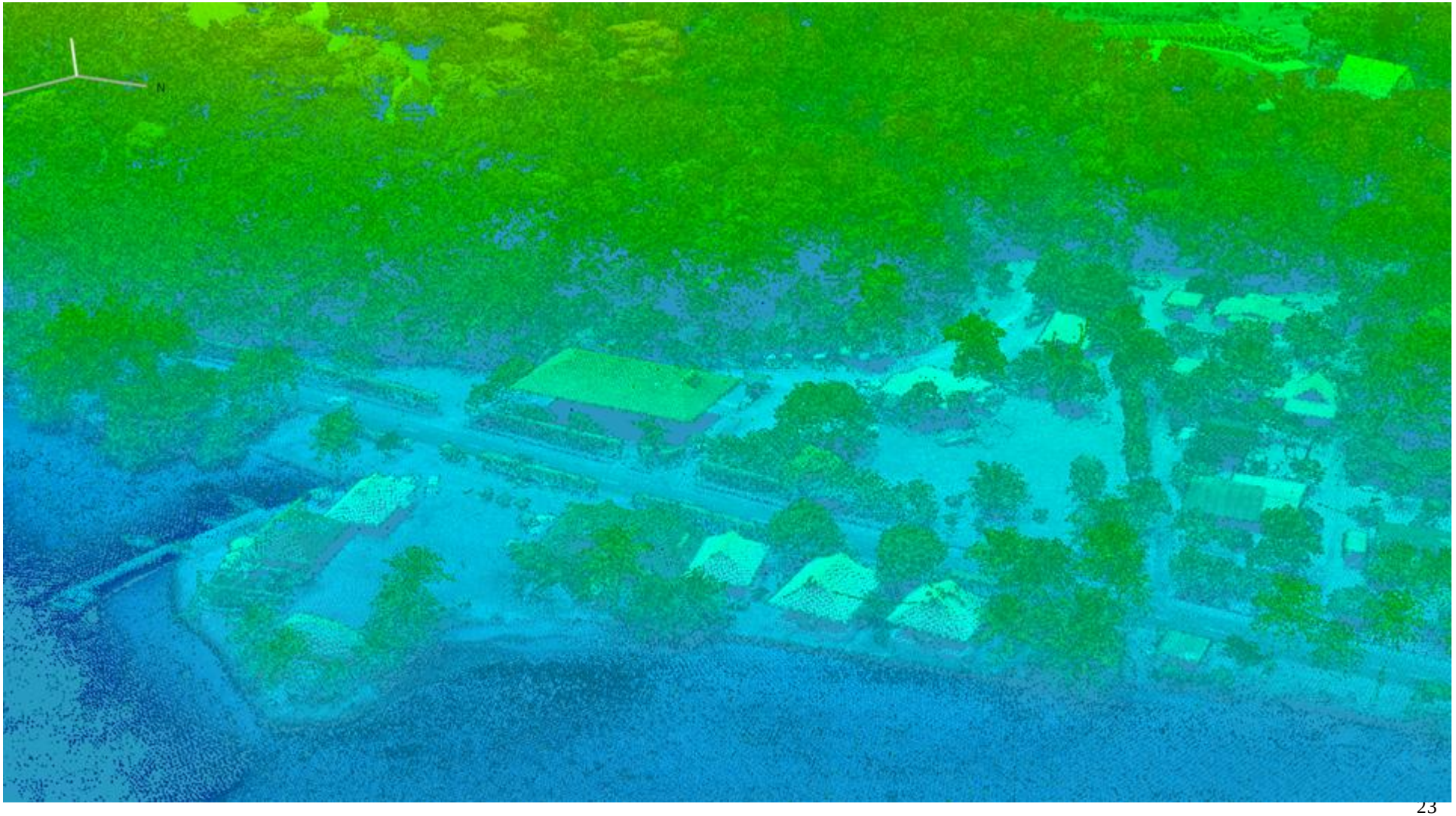




Moorea Bathymetry, Fugro LiDAR project 2015



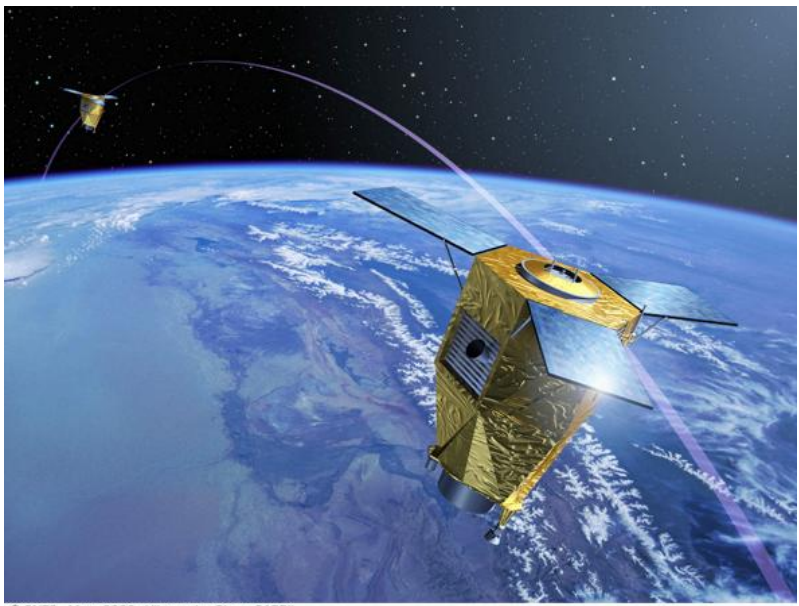
LiDAR pointcloud Gump Station



Pleiades

Two identical satellites: revisit time 1 day
4 gyros, 3 star trackers, location accuracy (without GCPs) < 12m
Telescope: 650mm, f = 13m
Panchromatic: 0.7m footprint
5 sensors (Lin. Array TDI) at 6000 x 20 pi, 13mue pi
Multi-spectral: 2.8m footprint
5 sensors at 1500 x 20 pi, 52 mue pi
4 lines assembly: RGB, NIR

20 km swath, full agility, anti-blooming



Moorea Pleiades image triplet

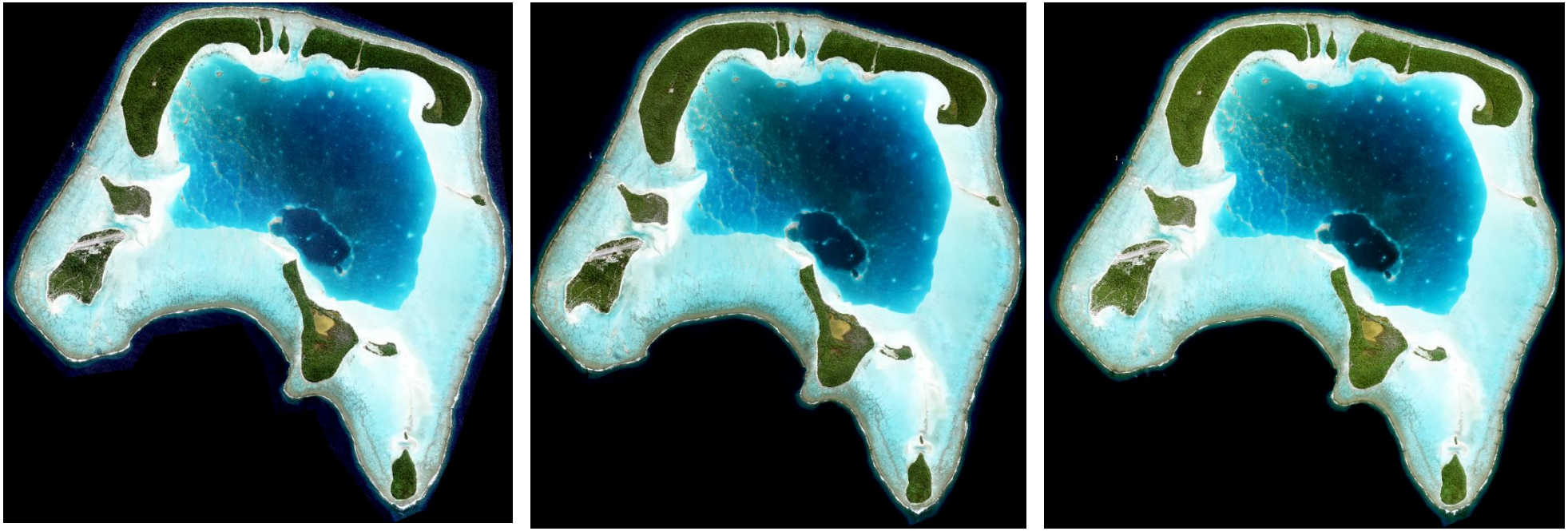


Acquisition date: 23 June 2014

Convergence angles along track. -13.5, 9.55, -2.2 degree

Coordinates: Geographical, WGS 84 (EPSG 4326)

Tetiaroa Pleiades images



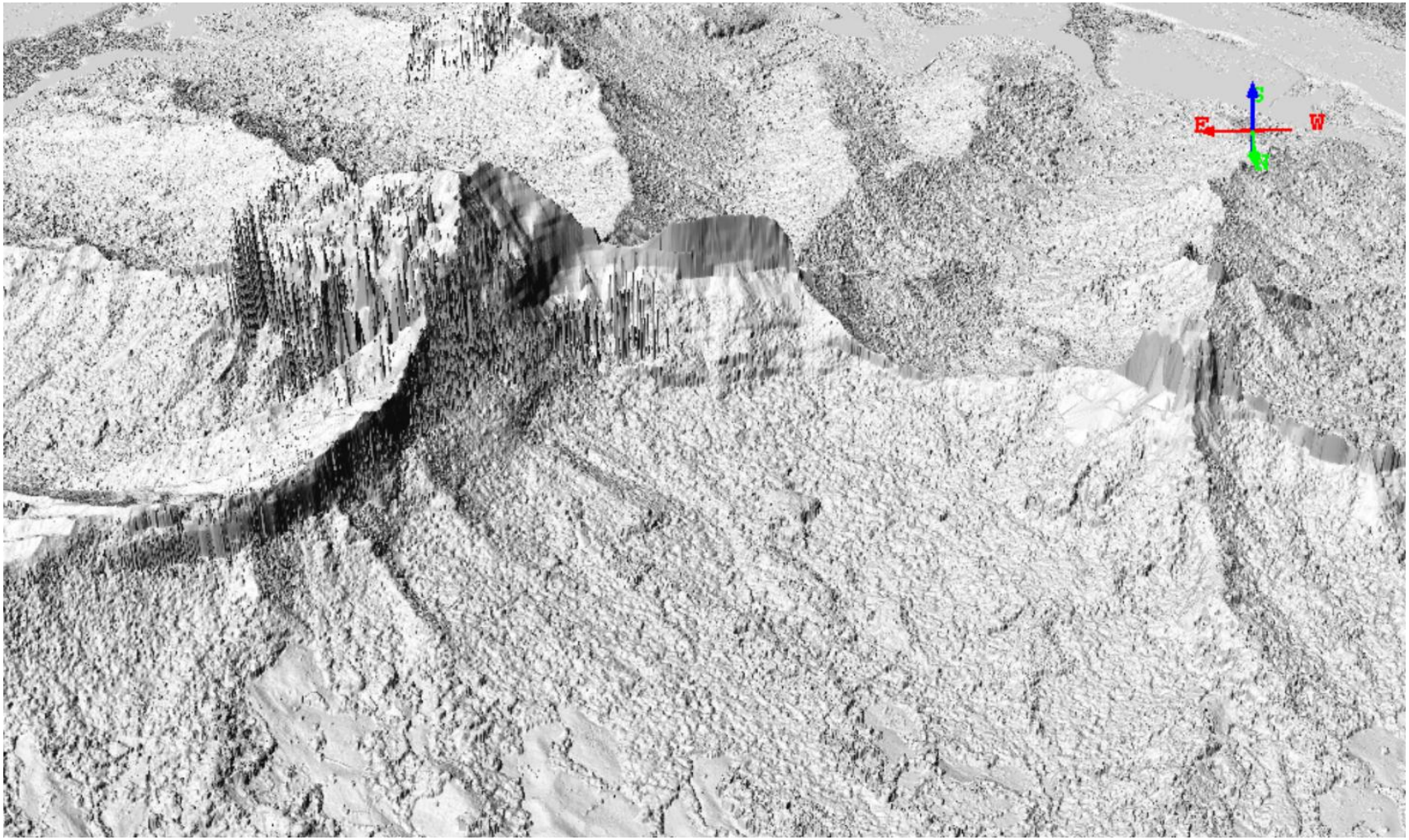
Acquisition date: 30 June 2014

Convergence angles along track: 0.4, -12.0, 10.4 degree

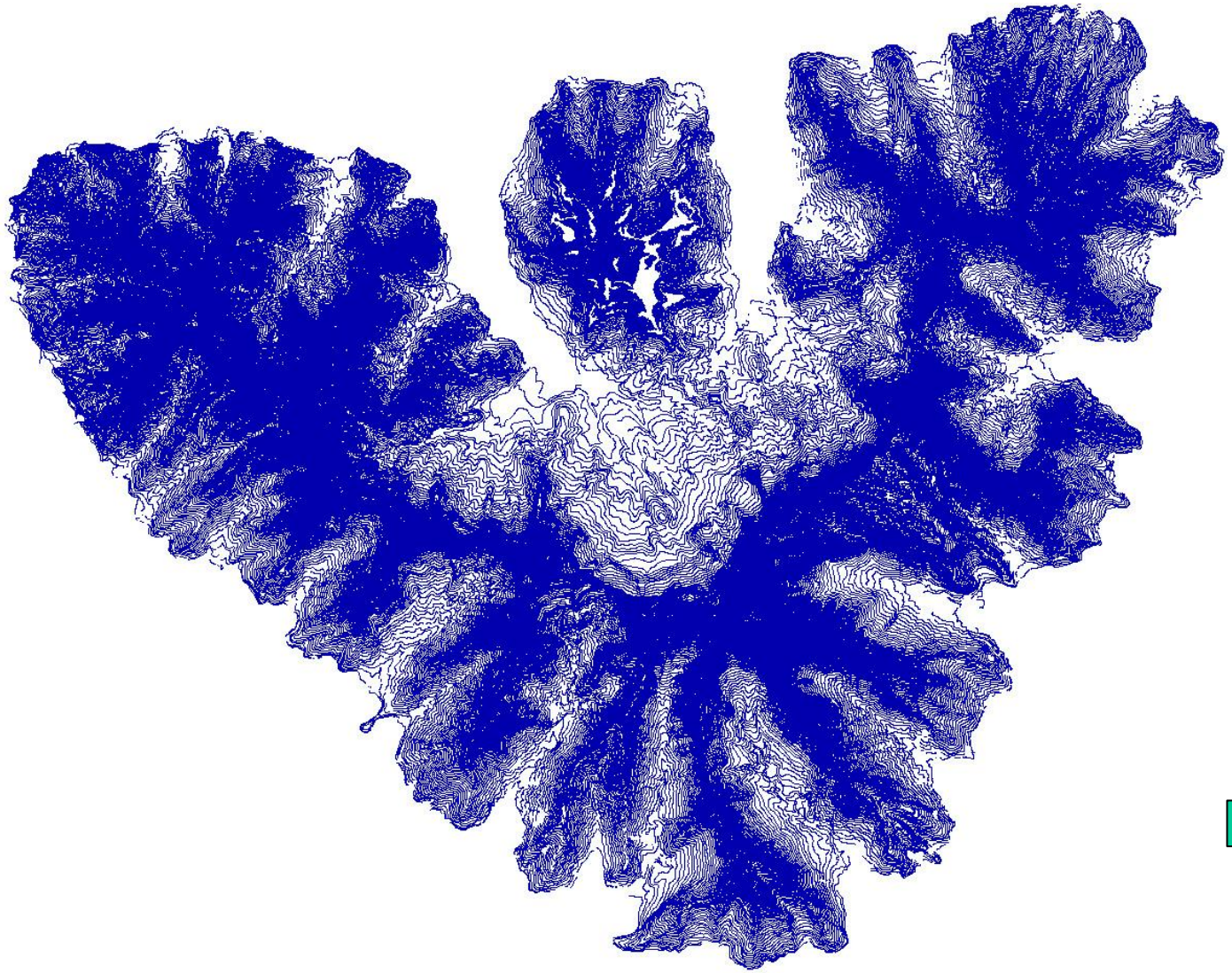
Moorea 3D model

DSM generation through image matching (LPS)

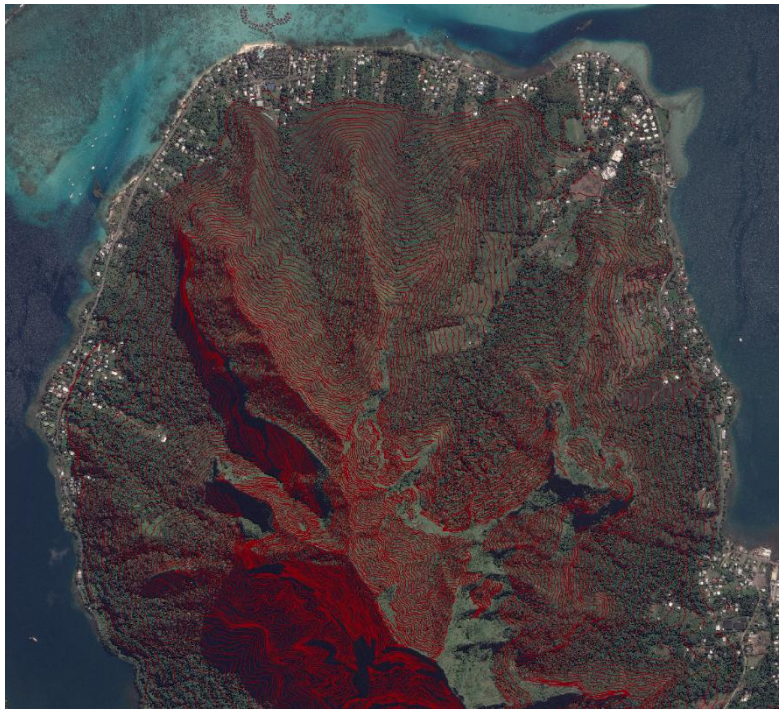
Problem: Blunders. Requires manual editing

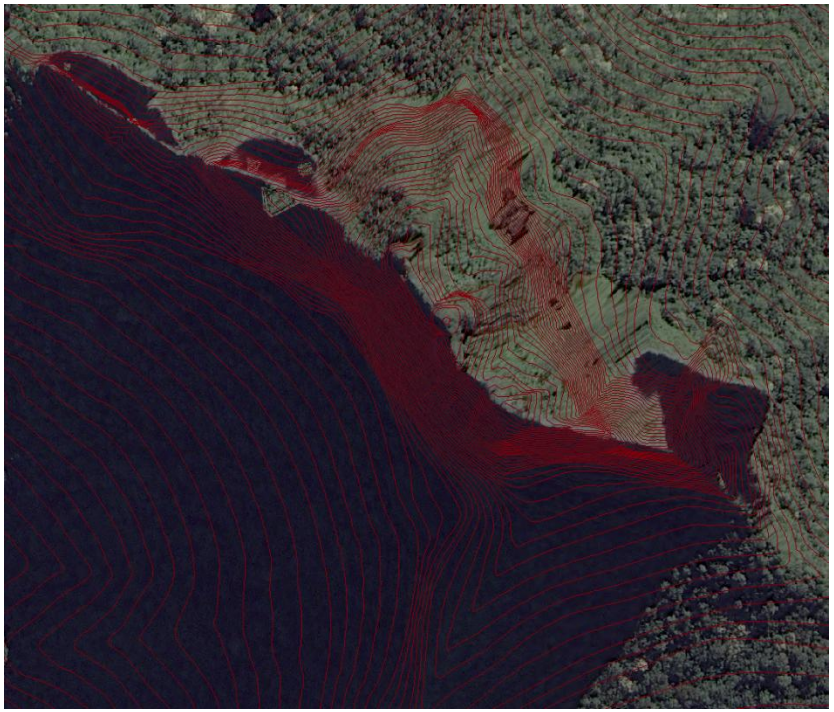


DTM (from map)

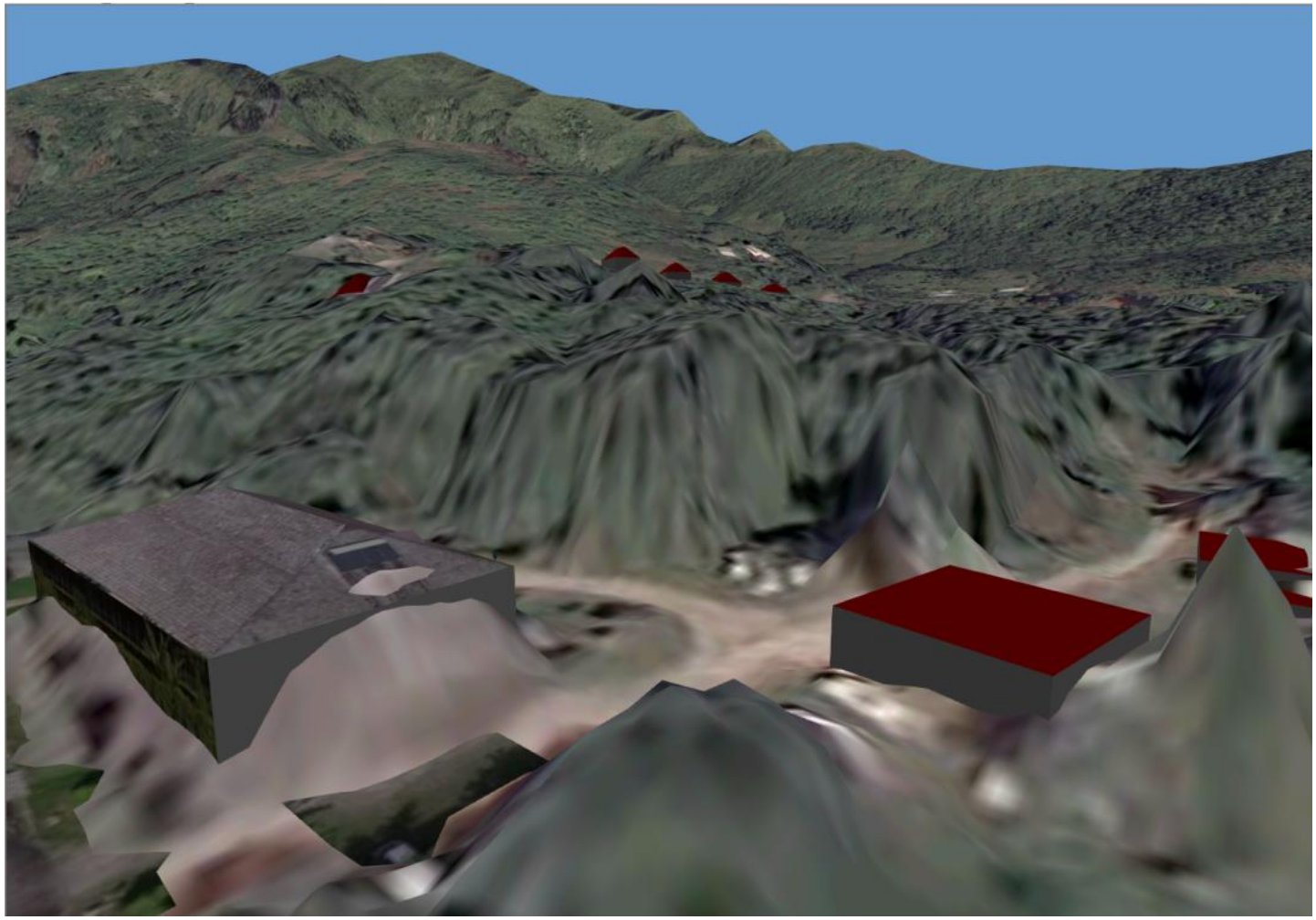


Contours (ortho overlay)





Building modeling – inaccurate DTM



Phantom 2 quadrocopter

Maoea take-off

Maoea take-off2

UAV images landscape overview

(Courtesy: CRIOBE Station)

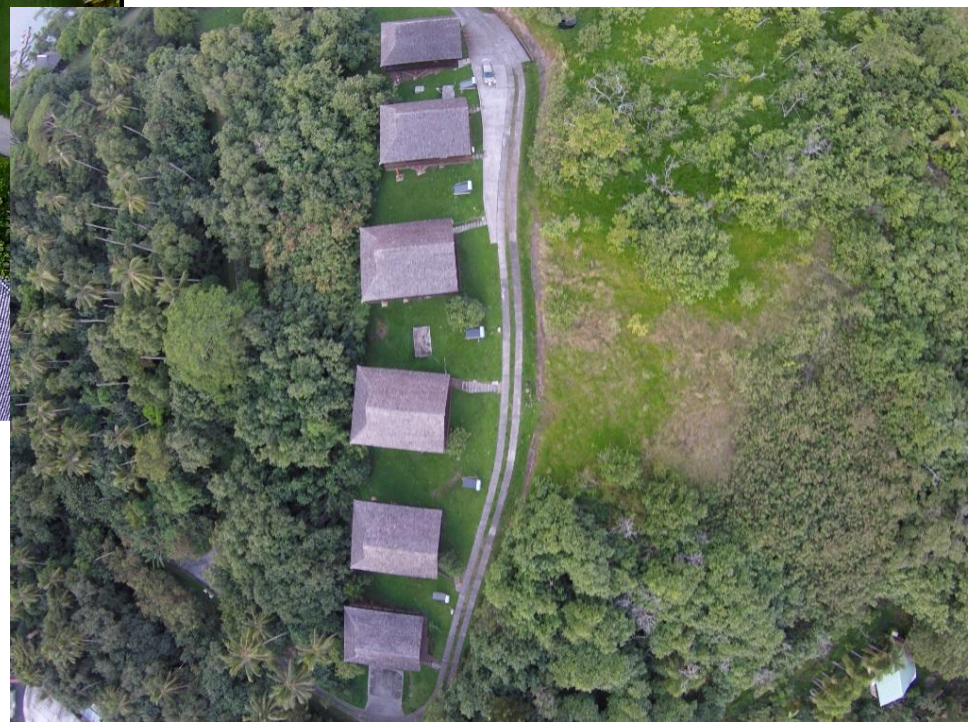
UAV image Cook´s Bay

(Courtesy: CRIOBE Station)

UAV images lagoon and reef

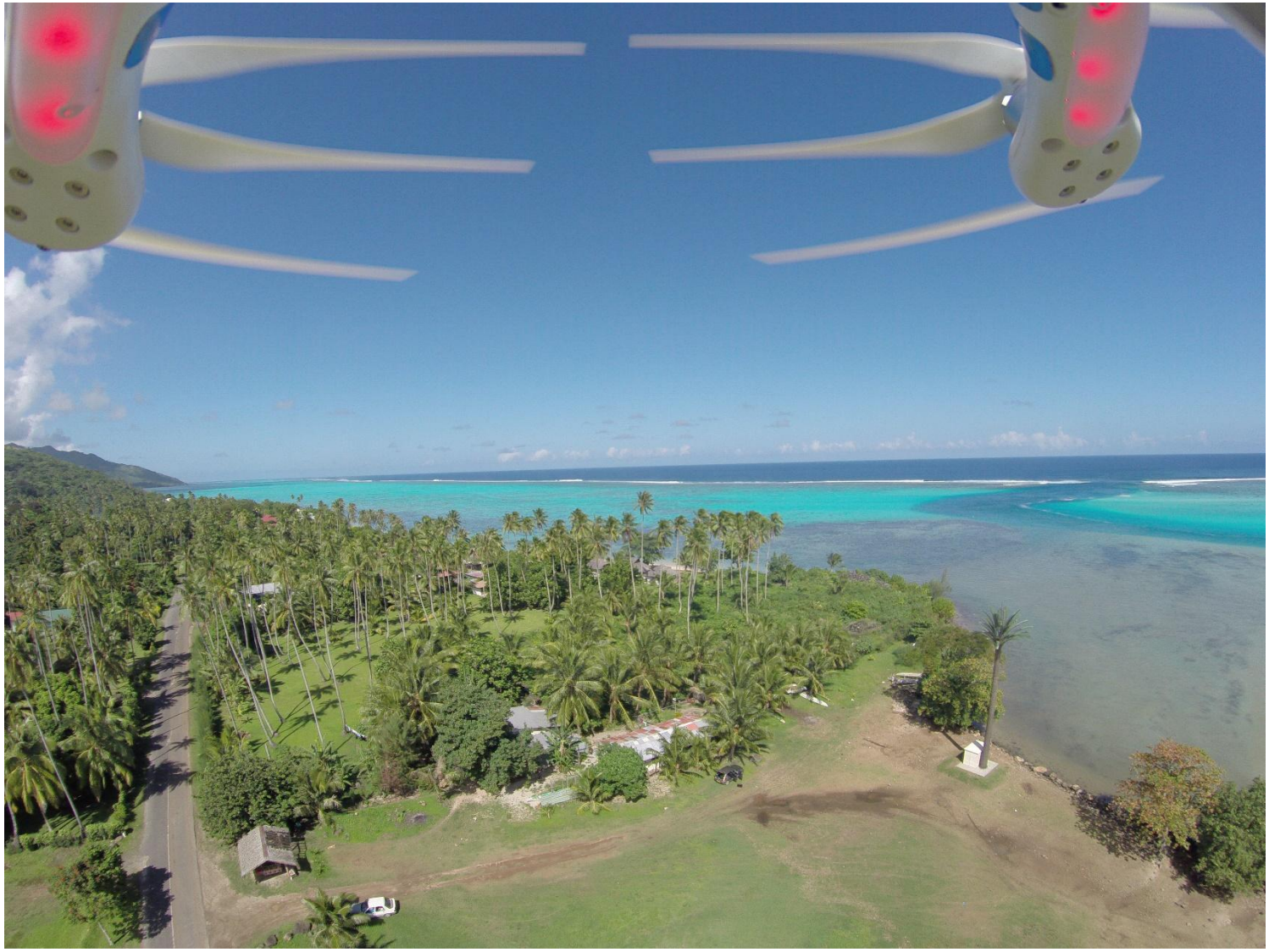
(Courtesy: CRIOBE Station)

Views from UAV



Archaeological sites (Marae, Temple)

UAV images arch. site (Marae Nuu Roa)

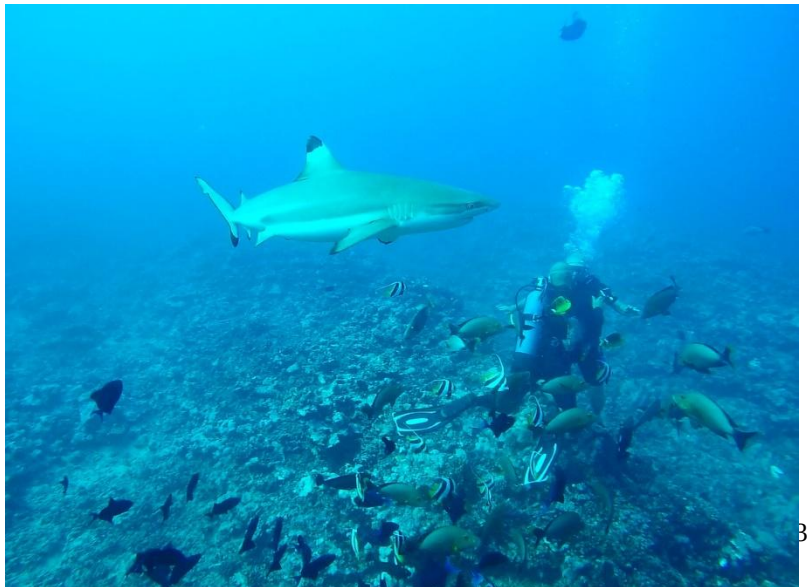


UAV images arch. site (Marae Nuu Roa, 6.2015)

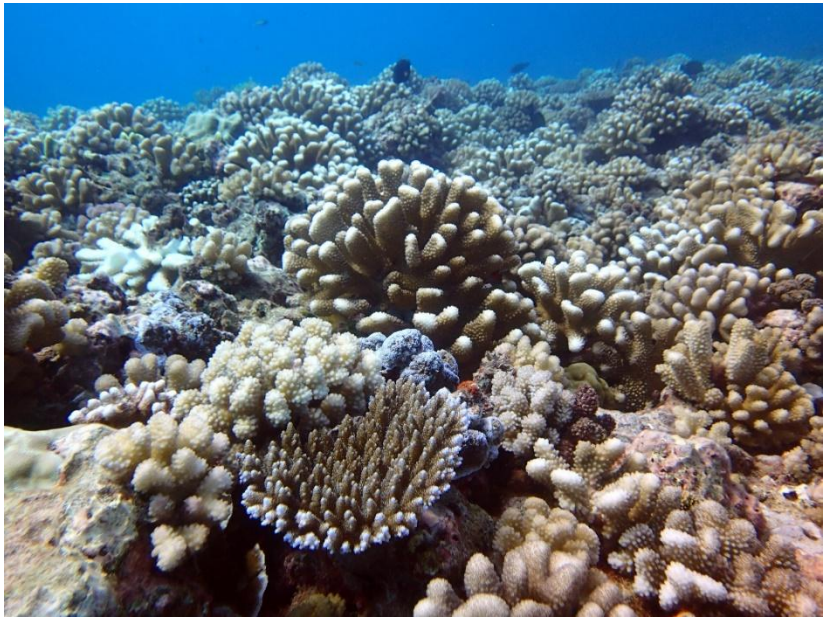
Diving the Moorea reef – morning at Cooks Bay

Diving the Moorea reef – leaving for the transects

Diving the Moorea reef

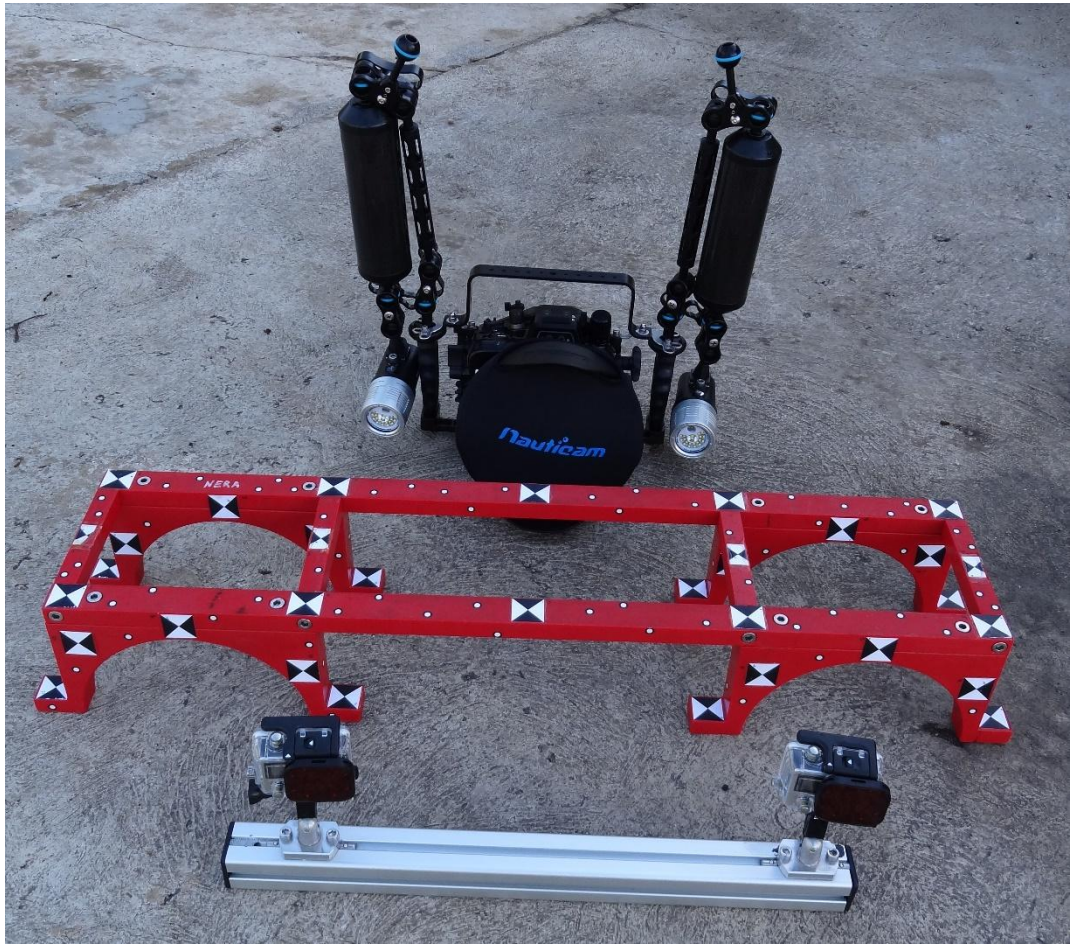


Diving the Moorea reef

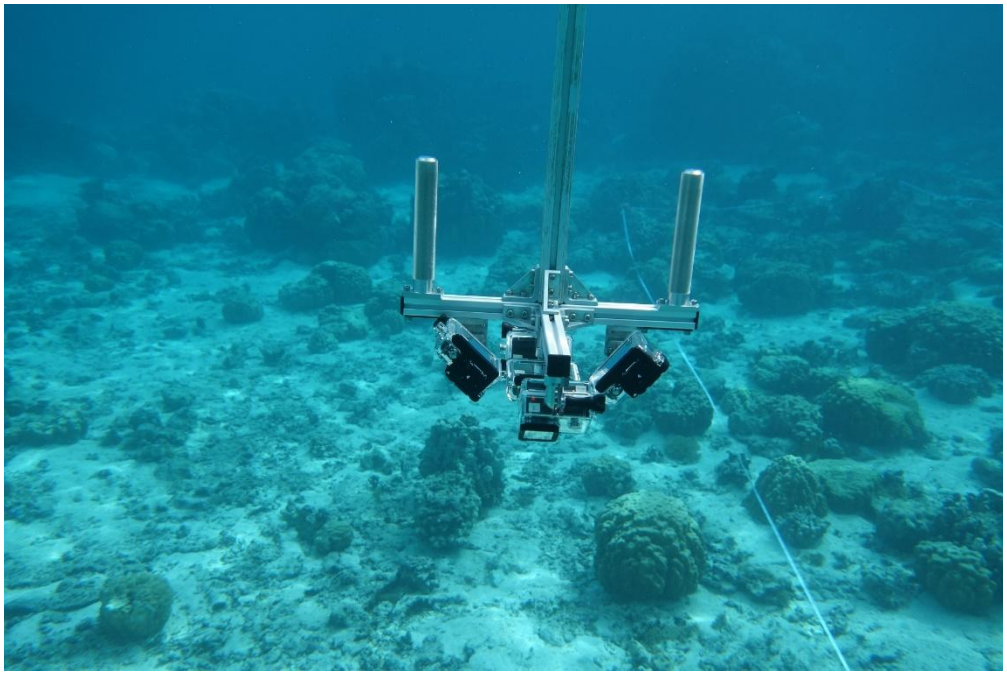


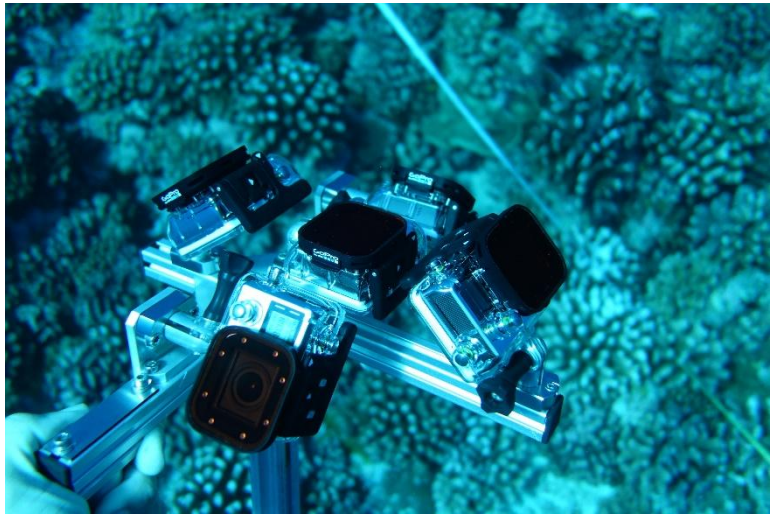
Alessandro
GoPro filming

Our Cameras

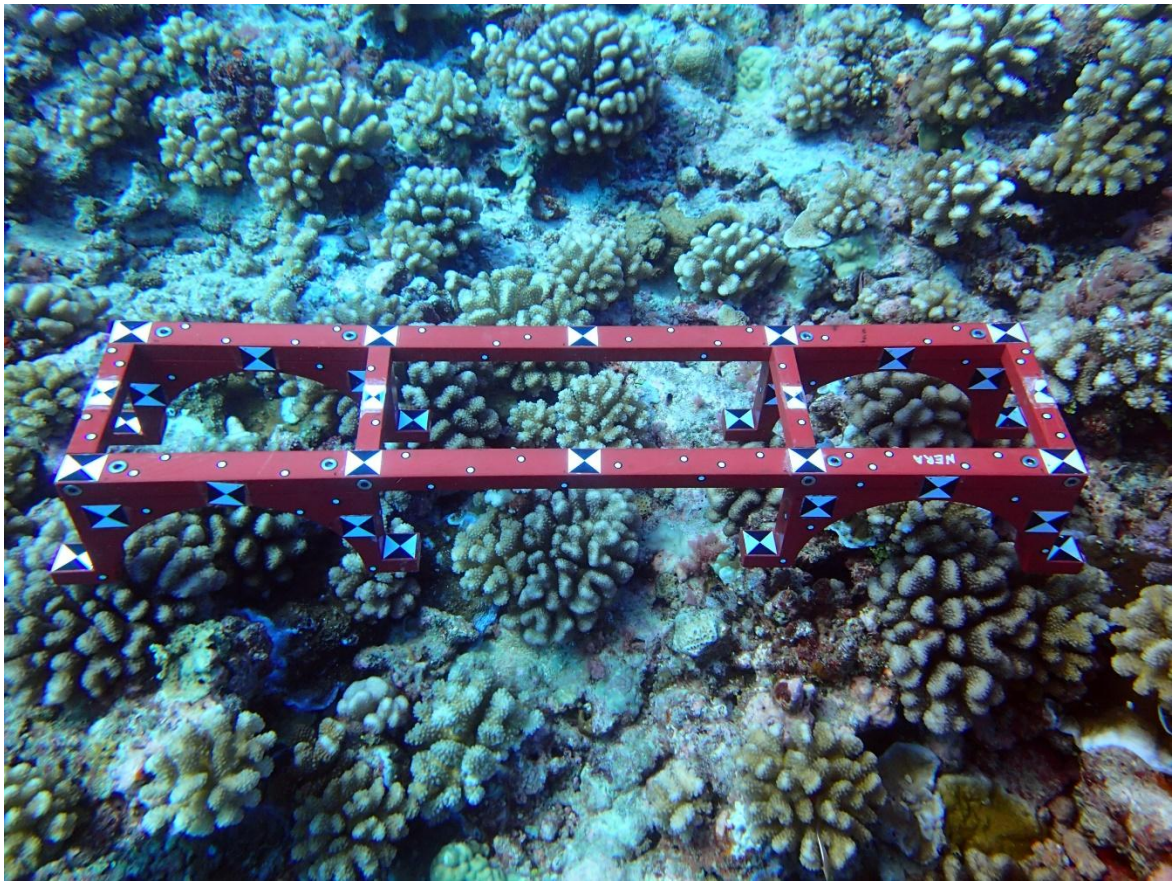


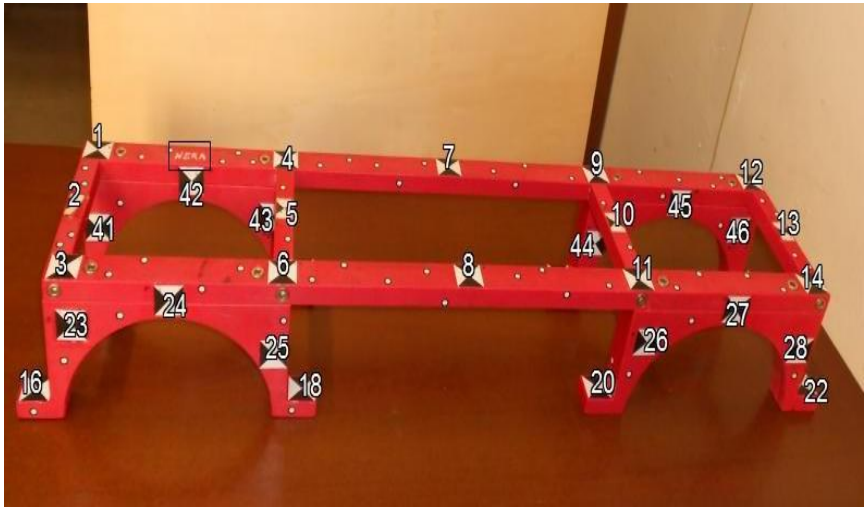
5-head GoPro camera system



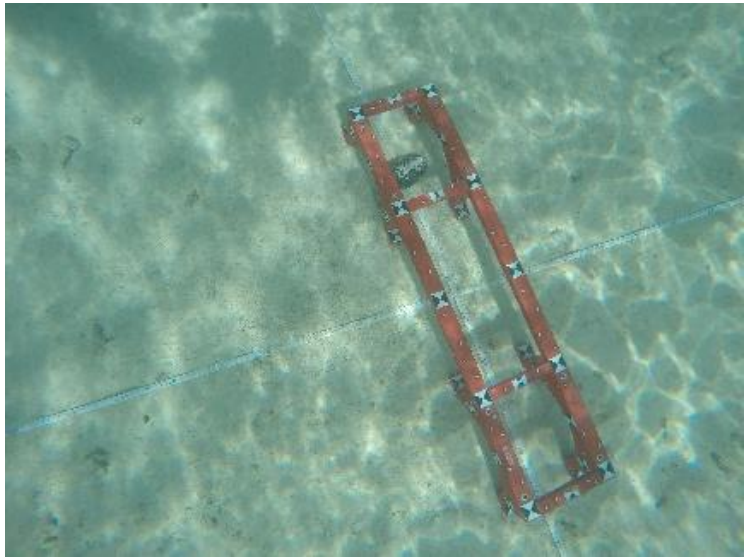


Calibration frame

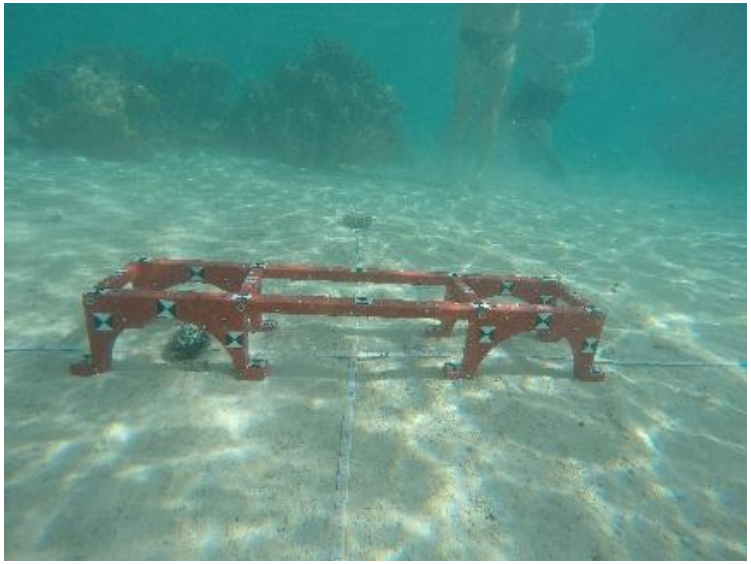


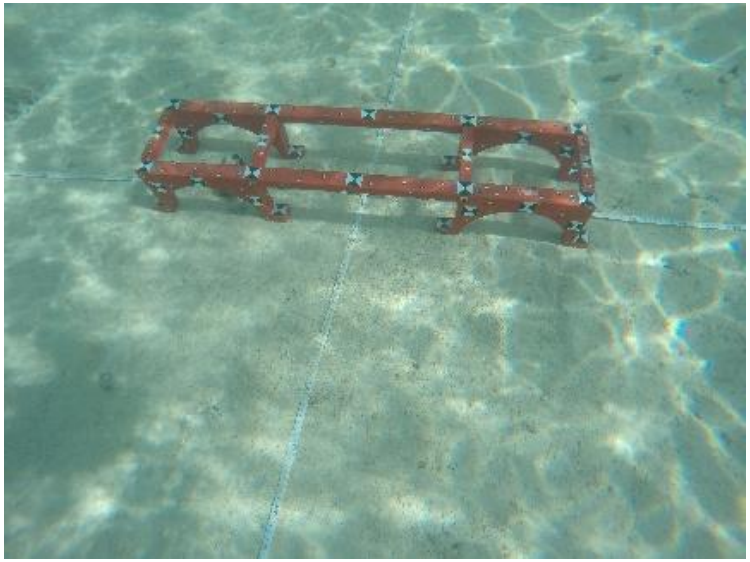


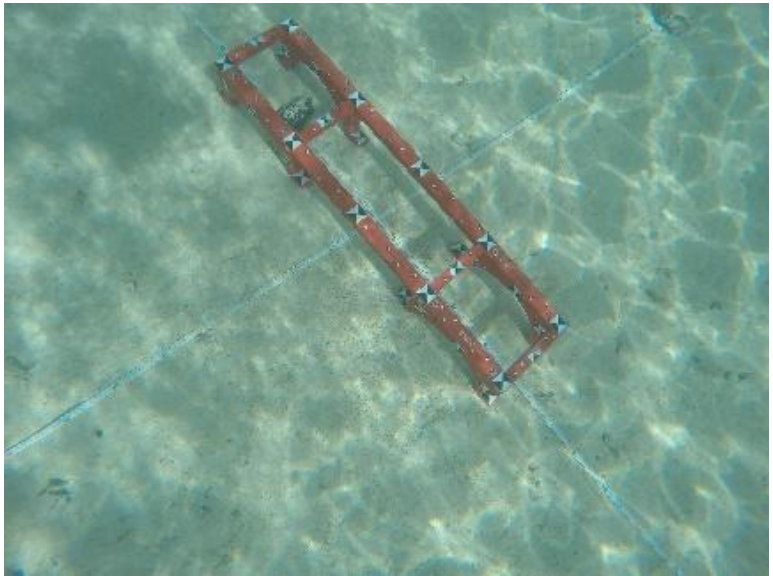
C1 calibration images



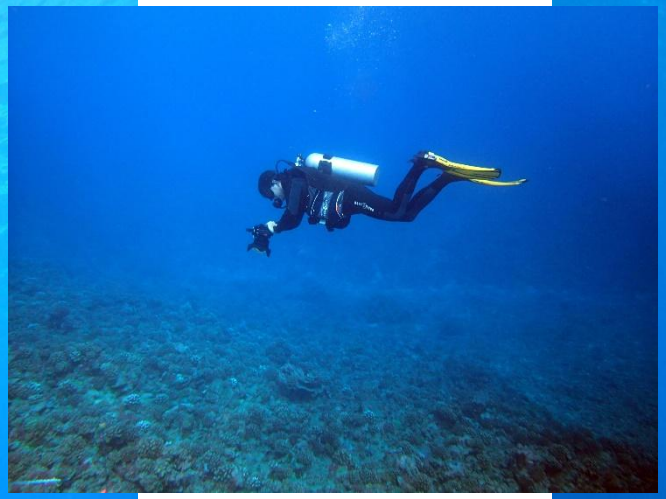
C1 summary

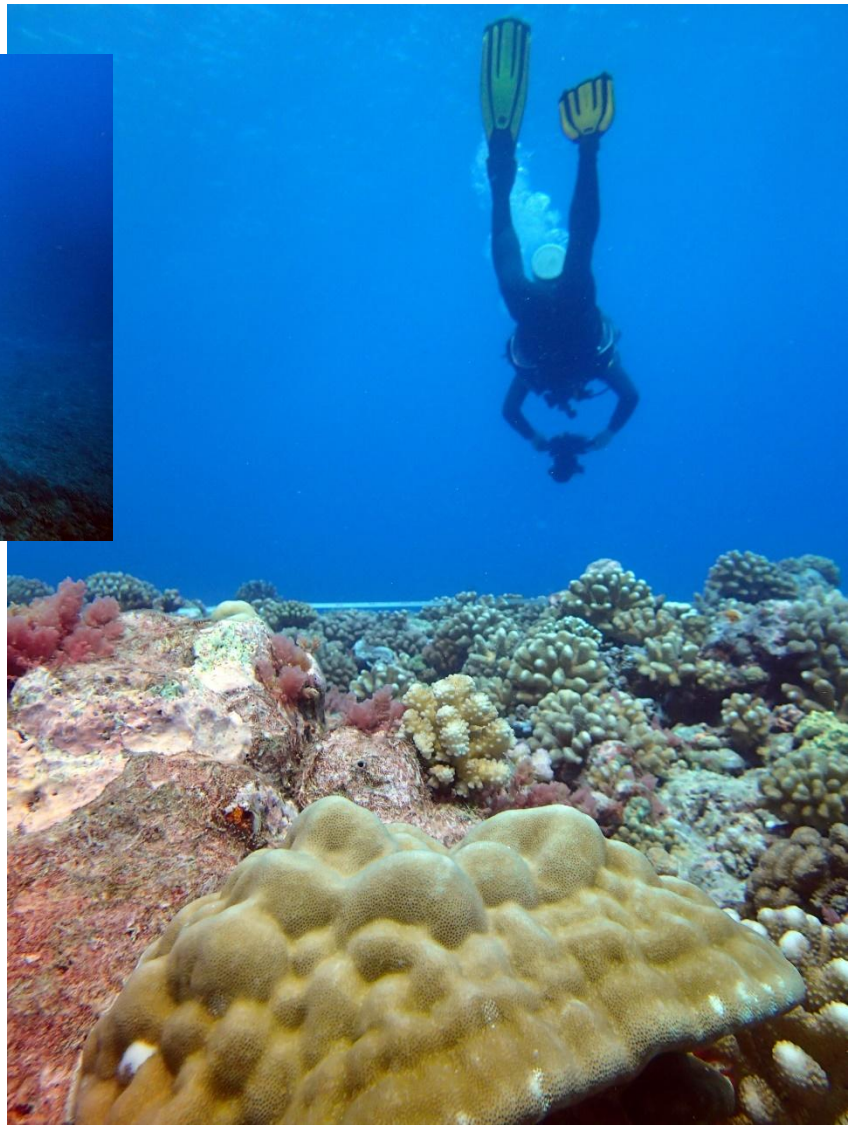




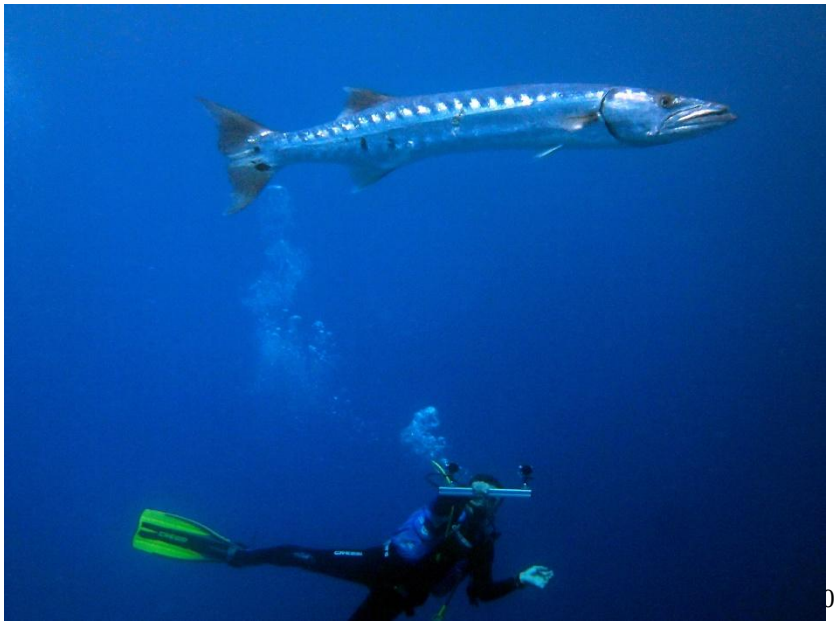


Matthias with Lumix single camera

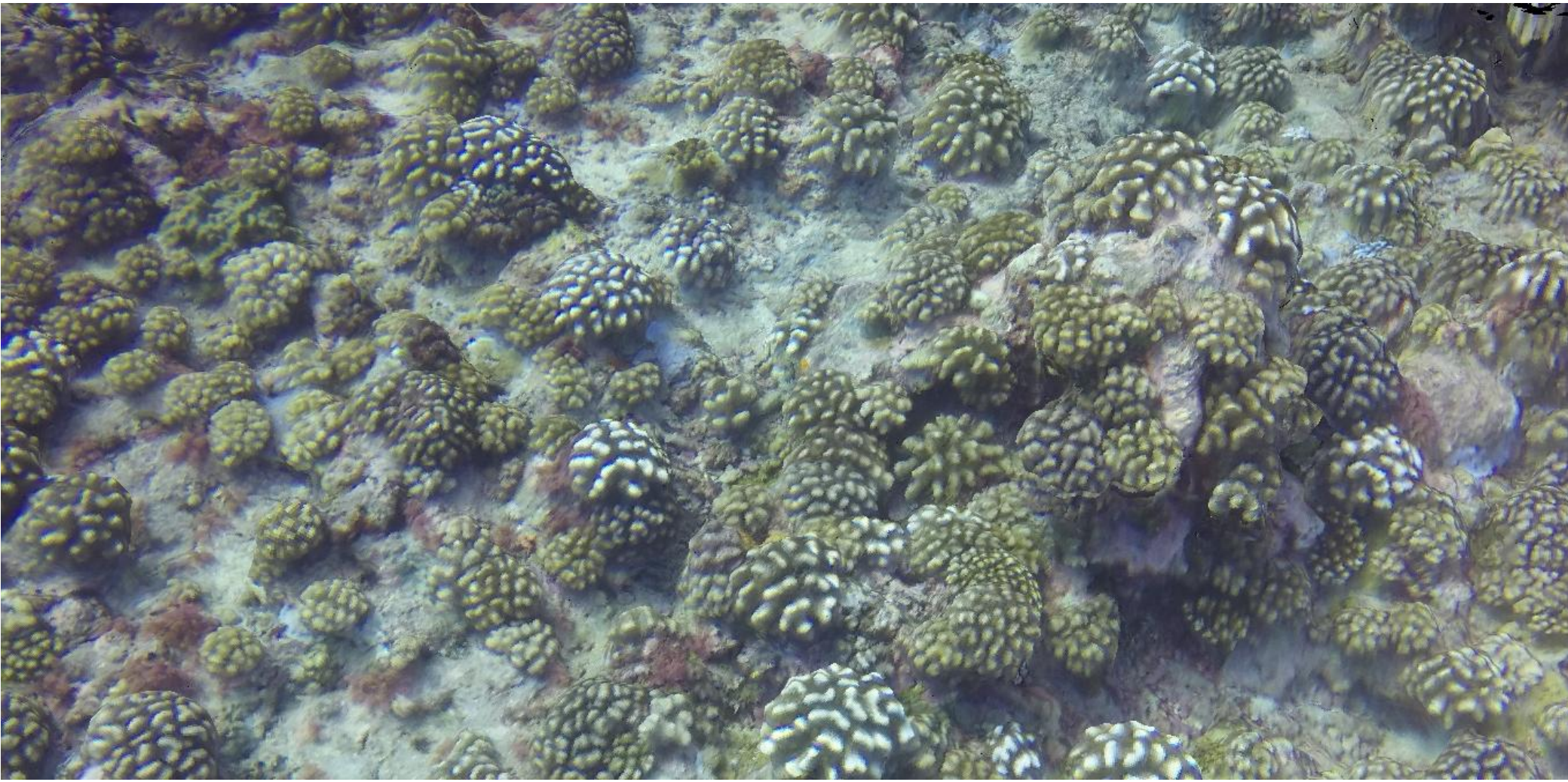




Alessandro with GoPro stereo rig

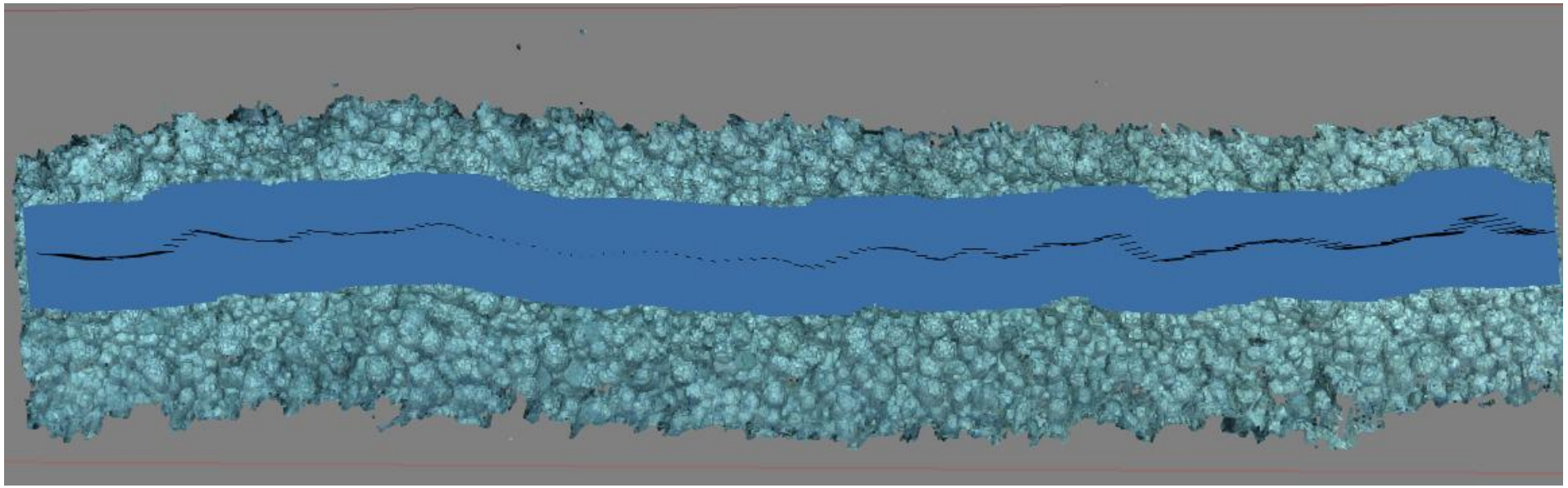


Underwater photogrammetry for 3D coral models

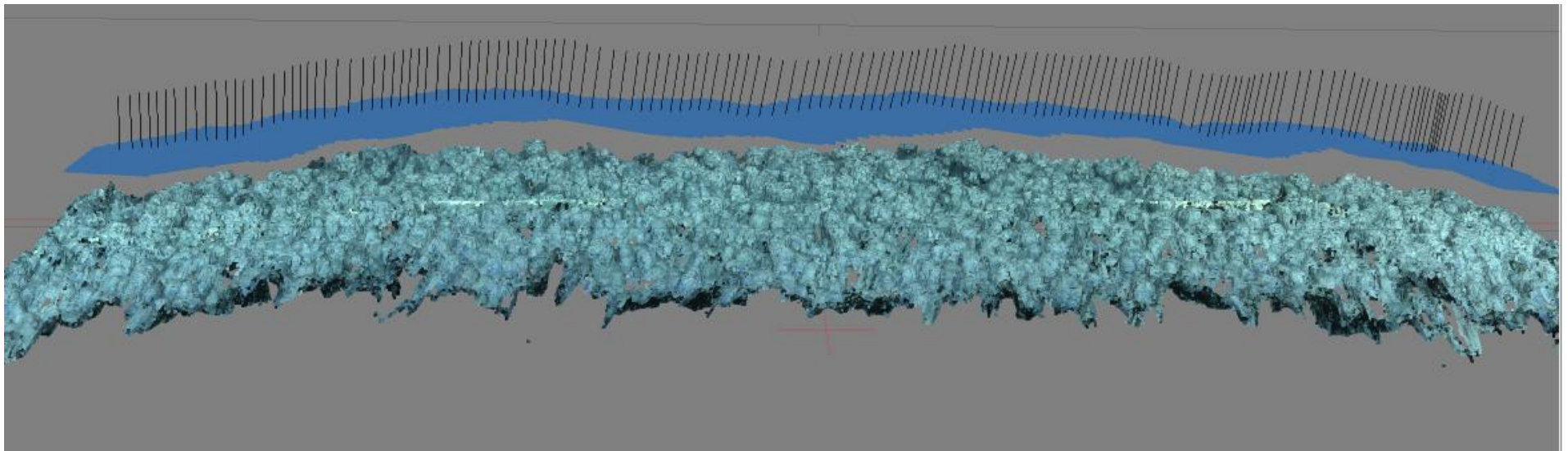


Forereef quick data processing, June 2016

Image sequence path



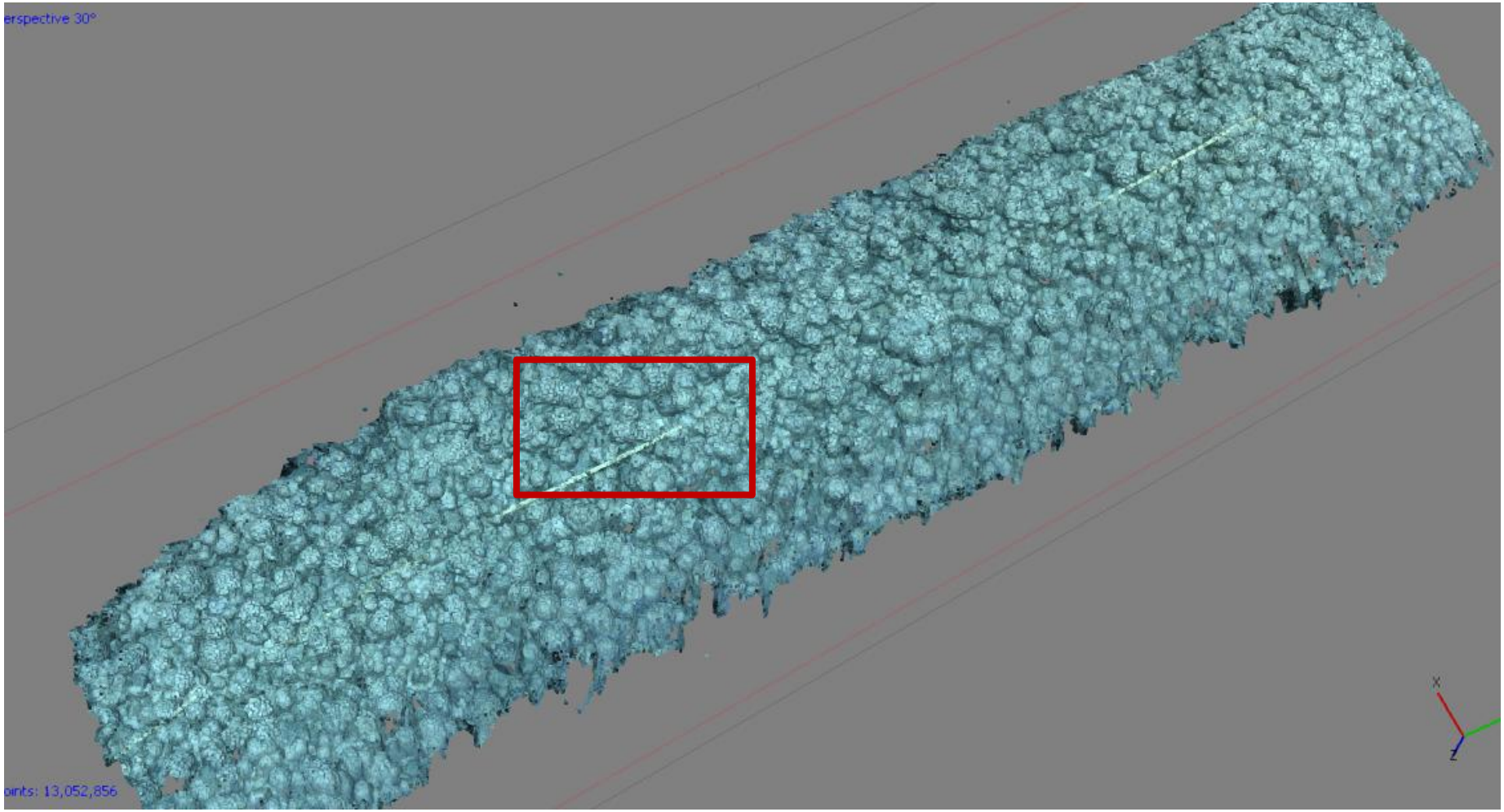
Top view



Side view

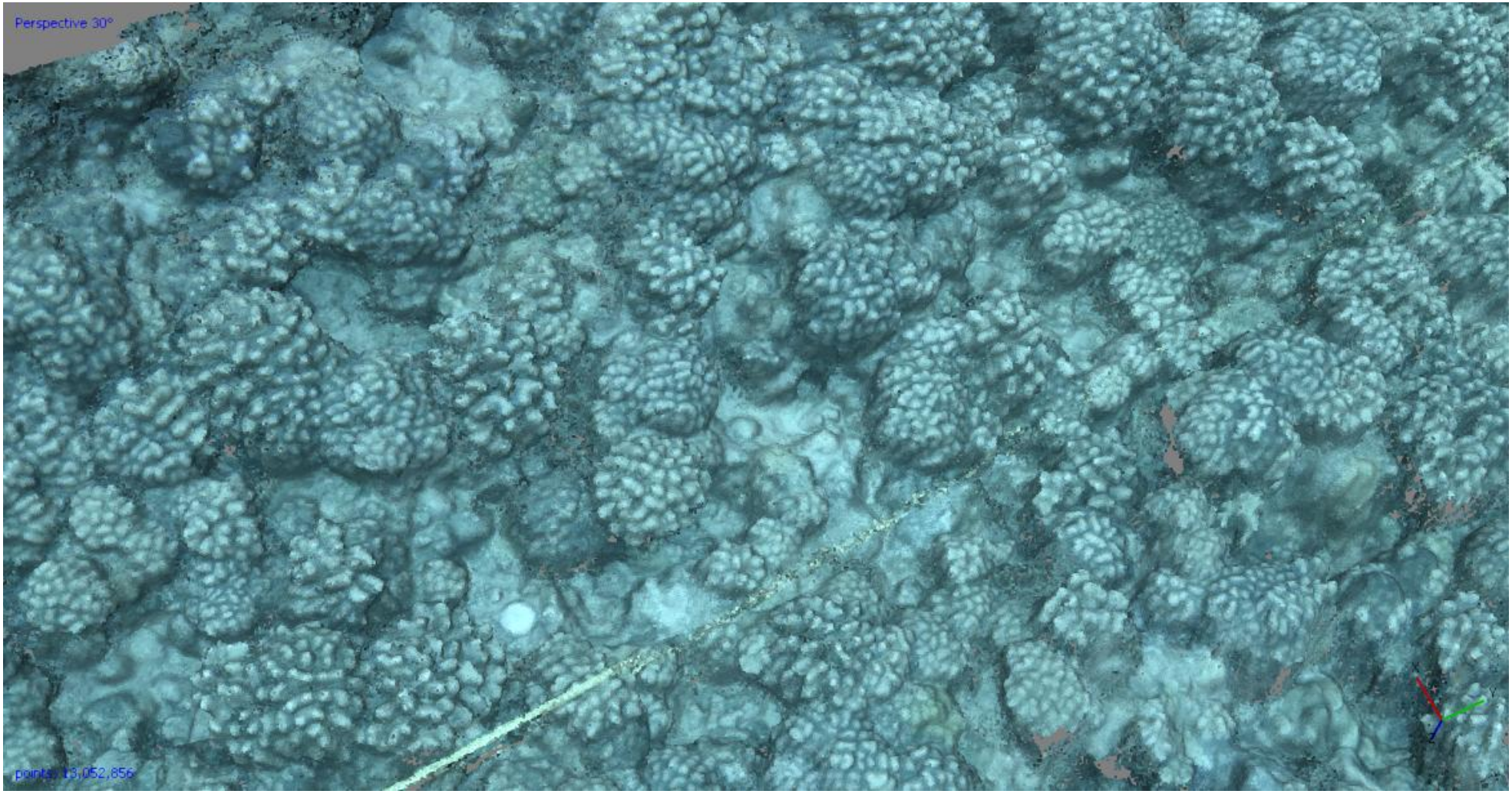
Forereef quick data processing, June 2016

3D point cloud



Forereef quick data processing, June 2016

Close view of 3D point cloud



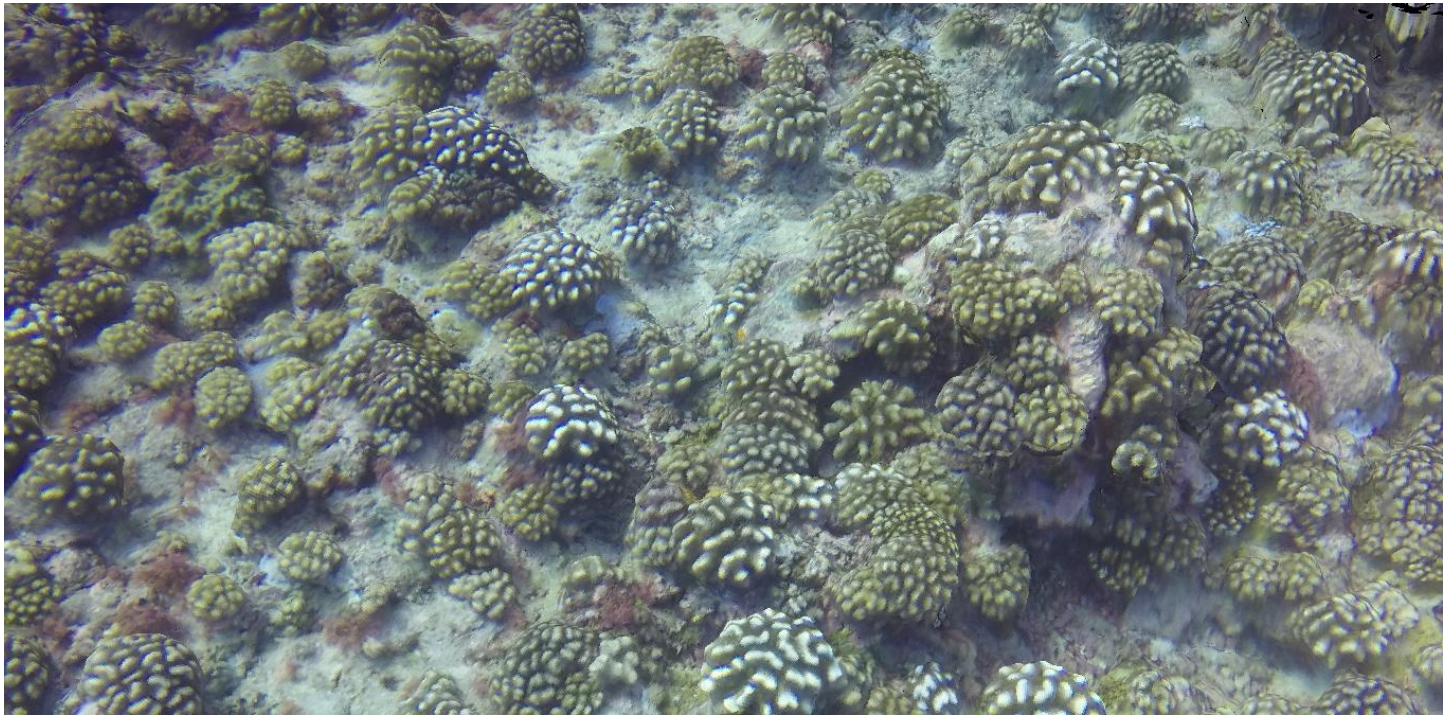
Underwater Photogrammetry for coral growth

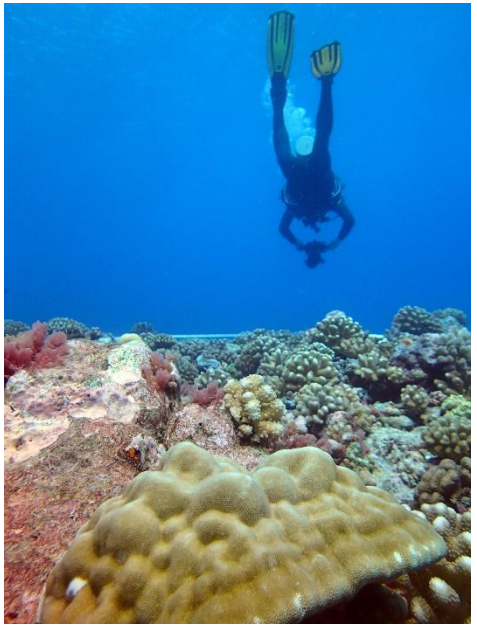
Moorea Island, June 2015

40 000 images

Alessandro GoPro

Image coverage



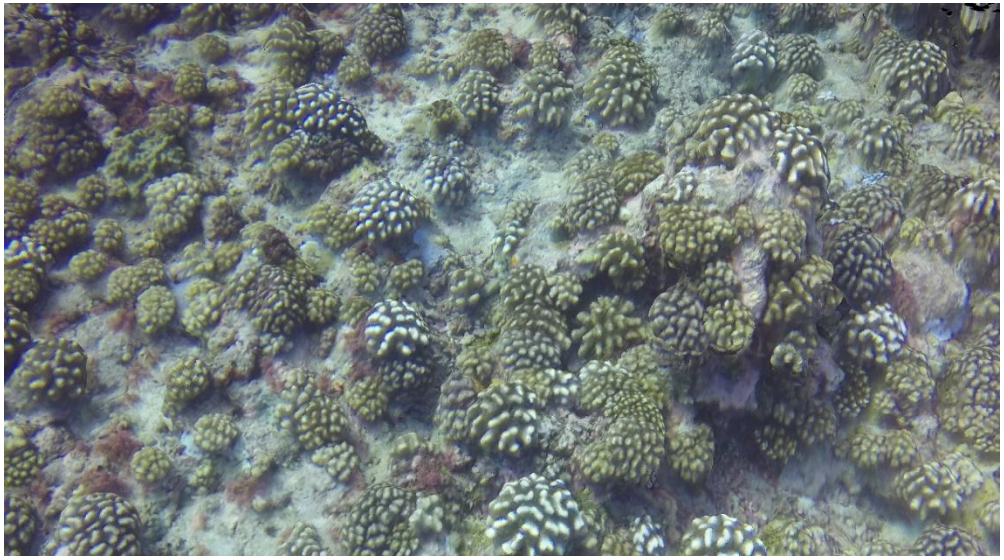


Underwater Photogrammetry for coral growth

Moorea Island, June 2015

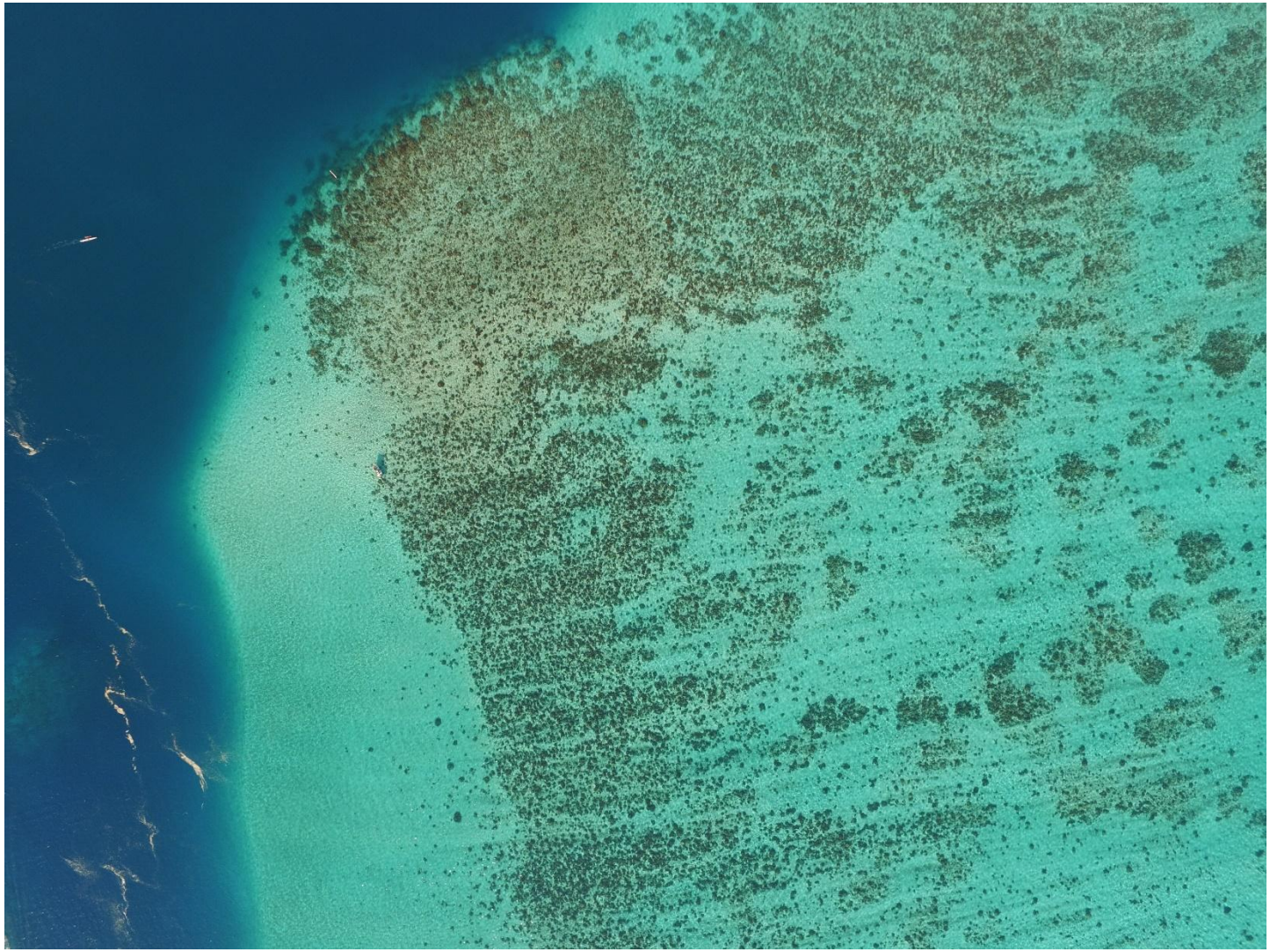
40 000 images, GSD = 1.2.mm

Coral model.1



Coral model Andy

Lagoon habitat mapping with UAVs

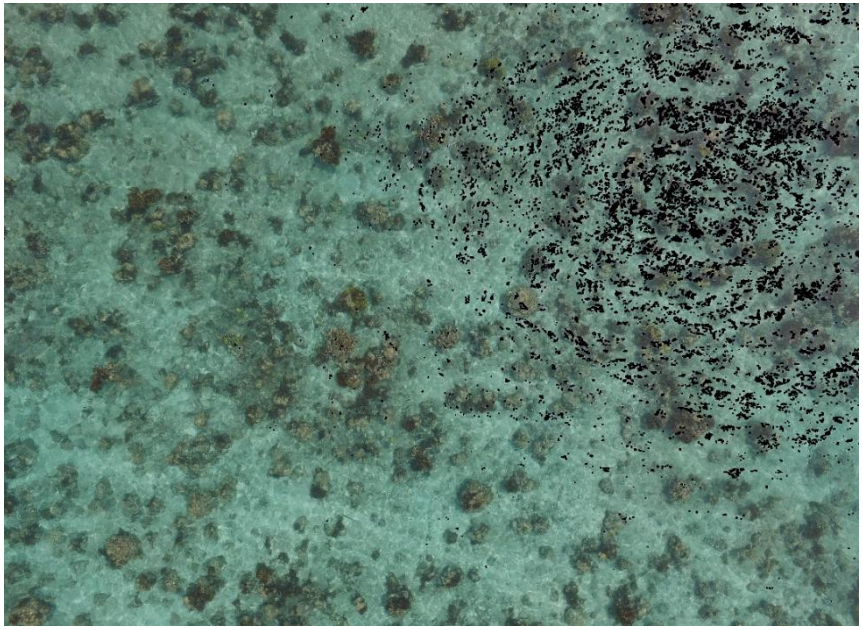


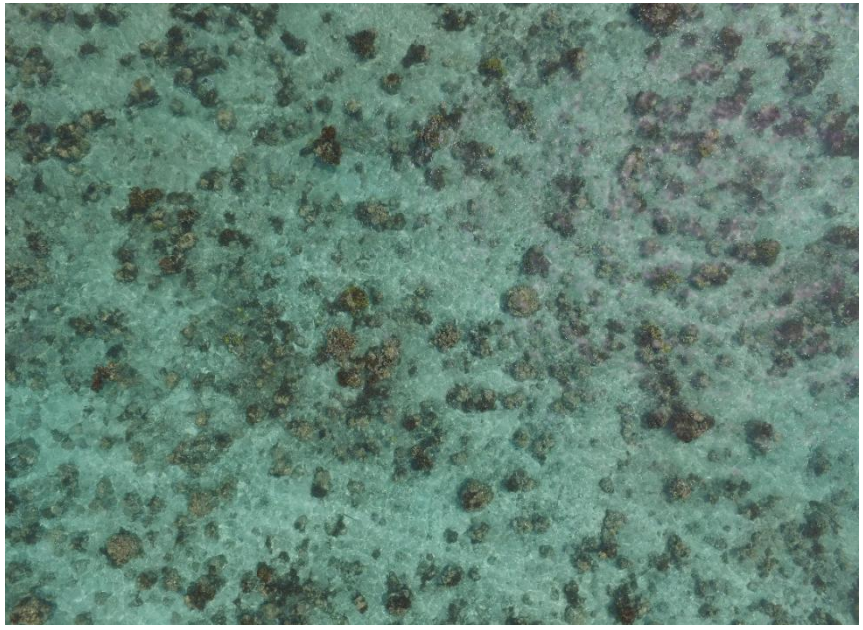
The imaging power of UAV videos

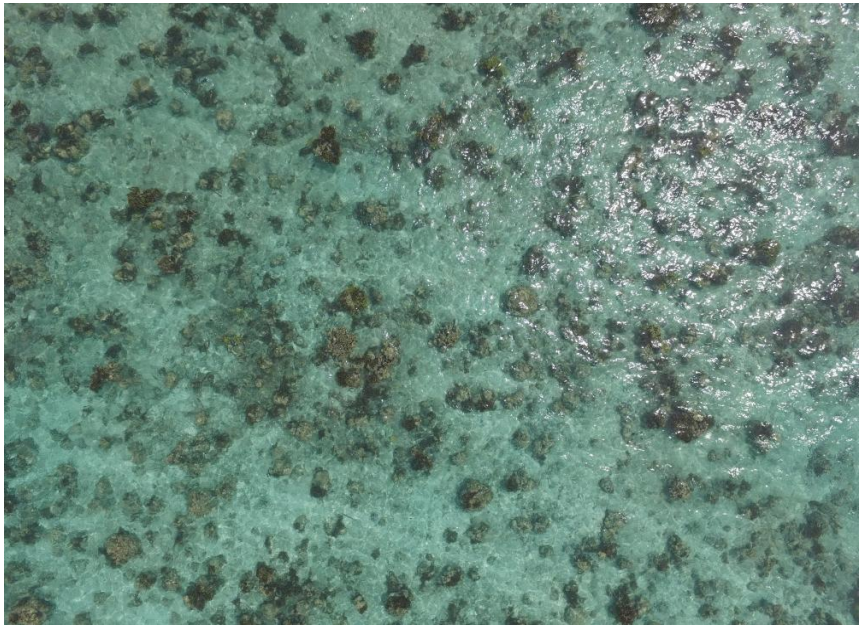
UAV take-off and landing from a boat

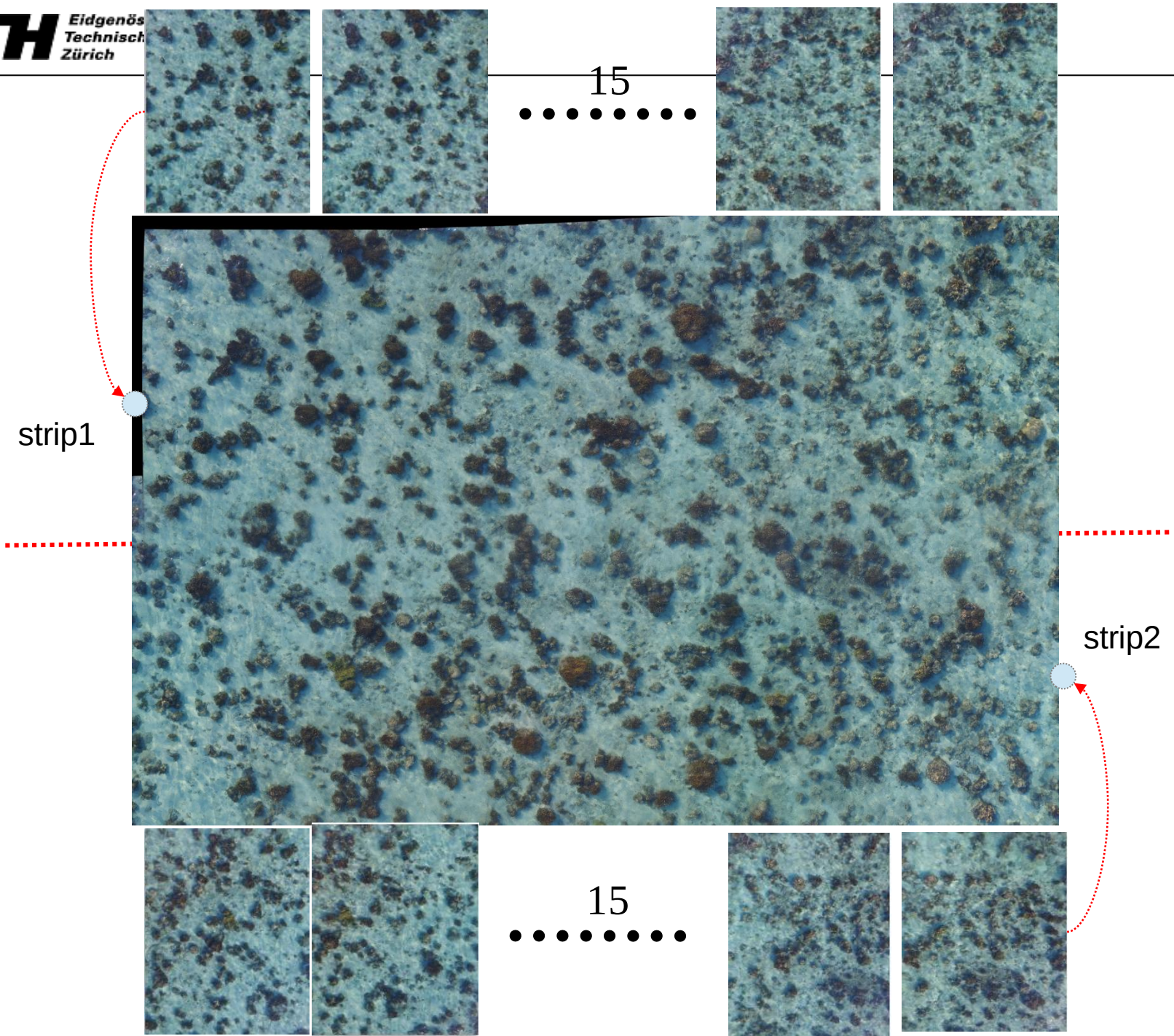
hg = 10m
GSD = 4.2mm

Glare removal

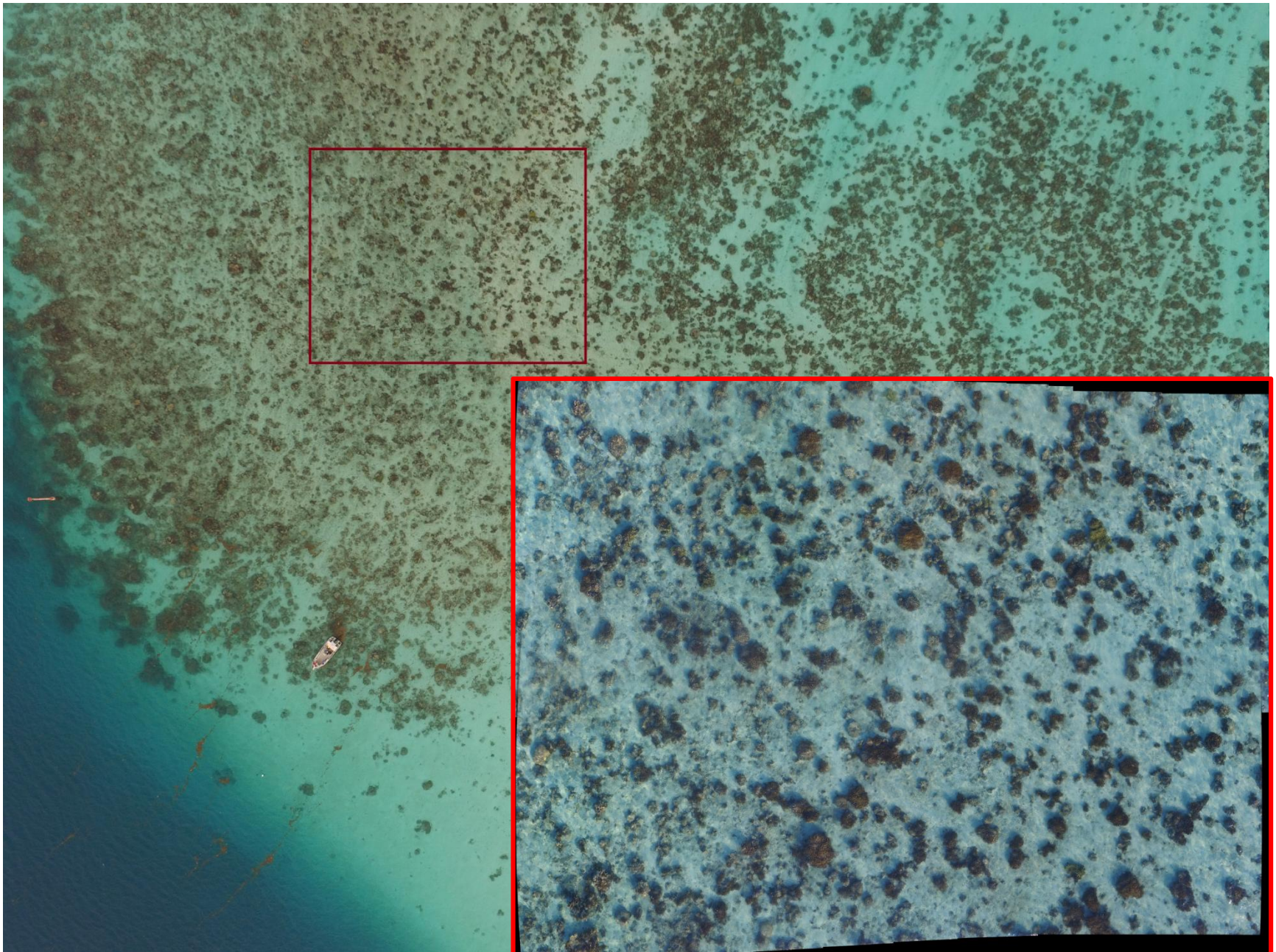







15
strip1
strip2
15

MRB at 200m



Opunahu Bay, James Cook memorial

Inspire car take-off

Rockcaves of Puhinu and Hatara

Marae Ti`i Rua

Archery Tahua Te'a

GSD = 2mm

Model: 66 images

On-site Processing – 3D Archaeological Sites

Temple relic

Archery field

Image Stripes Stitching	
Data	Video (4K) Image (4K X 3K)
Software	Agisoft Photoscan
Comments	*Merge of multiple blocks is need*

North Coast video

24 km HR video,
35 min

Gump Station

Conclusions

+ Big ambitious interdisciplinary project of environmental modeling

+ First step: Restriction to Moorea (plusTetiaroa) island.
  Transferable to other tropical islands

+ ***Avatar***: Concept beyond GIS. Extended functionality

+ Currently: Data driven. Research proposal stage

+ Physical modeling: Multi-sensor, multi-scale approaches. Image based and point cloud based methods very important

+ System „Raw data acquisition - Processing pipeline“ out-of-balance

+ Software used: Australis, I-witness, LPS, Agisoft, pix4D, Sure.
  Under development: multiple channel (RGB) calibration, UW-classifier, building extractor from point clouds, etc.