NEMO-NET - THE FLUID LENSING NEURAL NETWORK FOR GLOBAL CORAL REEF ASSESSMENT

LAB FOR ADVANCED SENSING
NASA SILICON VALLEY, AMES RESEARCH CENTER

VED CHIRAYATH, JUAN TORRES-PEREZ, ALAN LI, MICHAL SEGAL-ROZENHAIMER, KAMALIKA DAS, JARRETT VAN DEN BERGH

NEMO-NET TEAM EXPANSION

OLD DOMINION UNIVERSITY

CORAL
COral Reef Airborne Laboratory

IUCN

Khaled bin Sultan Living Oceans Foundation

MISSION BLUE™
SYLVIA EARLE ALLIANCE

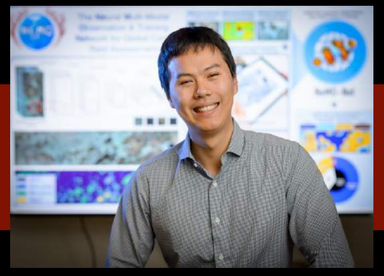
NEMO-NET TEAM

PI: DR. VED CHIRAYATH

SCIENCE

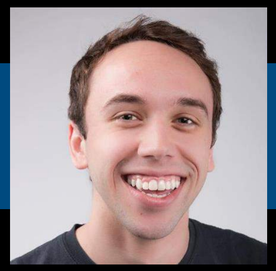
DR. JUAN TORRES-PEREZ, DR. SAM PURKIS

M/L



DR. ALAN LI, DR. MICHAL SEGAL-ROZENHAINMER, DR. KAMALIKA DAS

GAME



JARRETT VAN DEN BERGH, JOEY SCHUTZ, SIMON BENICHOU, YUVIKA DUBE, FERNANDO ZAMORA, ALYSSA DE LA TORRE

NEMO-NET SCIENTIFIC OBJECTIVES

1) *Develop the most accurate algorithm for identification of coral organisms from remote sensing at different scales.*
2) *Globally assess the present and past dynamics of coral reef systems through a large-scale active learning neural network.*
3) *Quantify coral reef percent cover and spatial distribution at finest possible spatial scale.*
4) *Characterize benthic habitats into 24 global hierarchical classes, resolving coral families with fluid lensing at finest scales.*

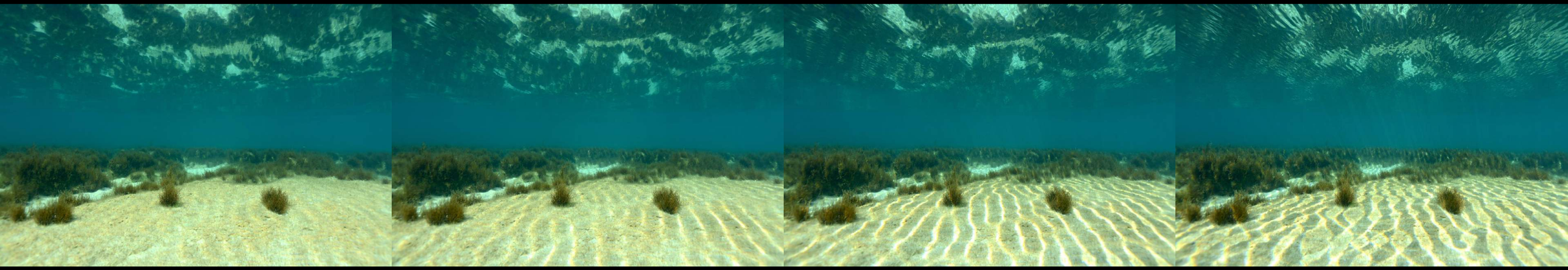
NEMO-NET TECH DEVELOPMENTS

1) *Developed malleable CNN architecture for scalable heterogenous computing architecture.*
2) *Created cloud masking CNN algorithm.*
3) *Implemented domain transfer learning for spectral and spatial resolution transfer learning (super resolution) across multiple sensors.*
4) *Created 3D active learning CNN training application in game interface for data training from multiple sensors.*

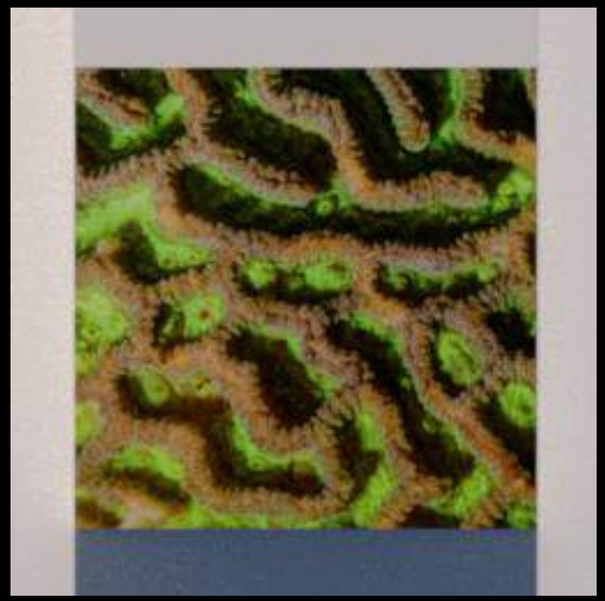
OCEAN WAVE FLUID LENSING PHENOMENON

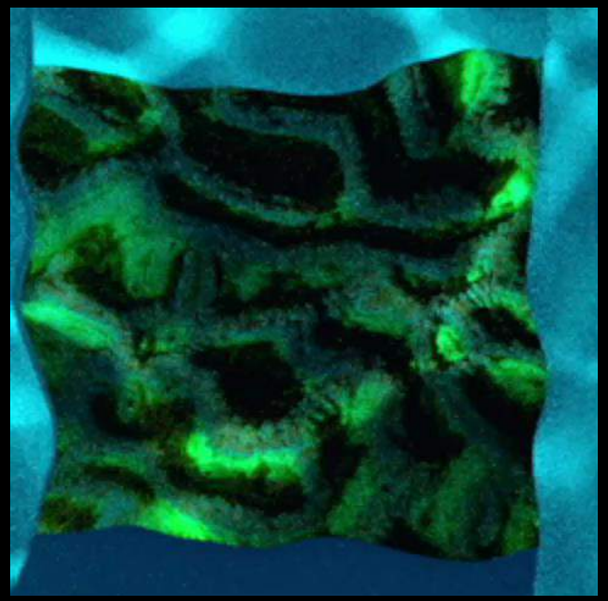
Caustics

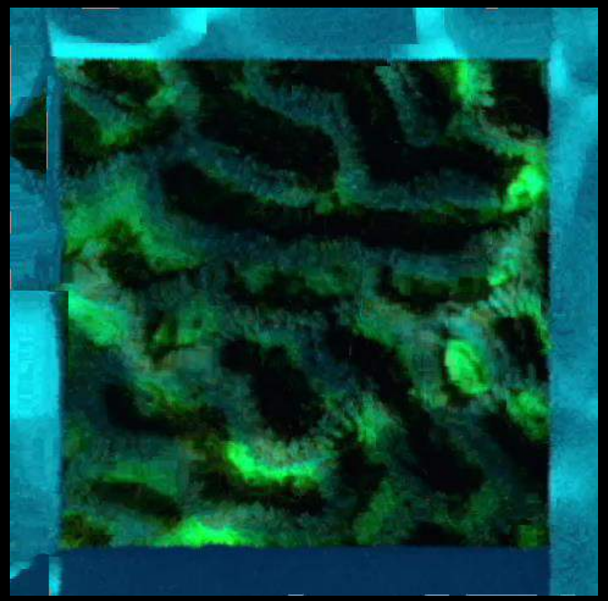
Fluid lenslets and evolution of caustics

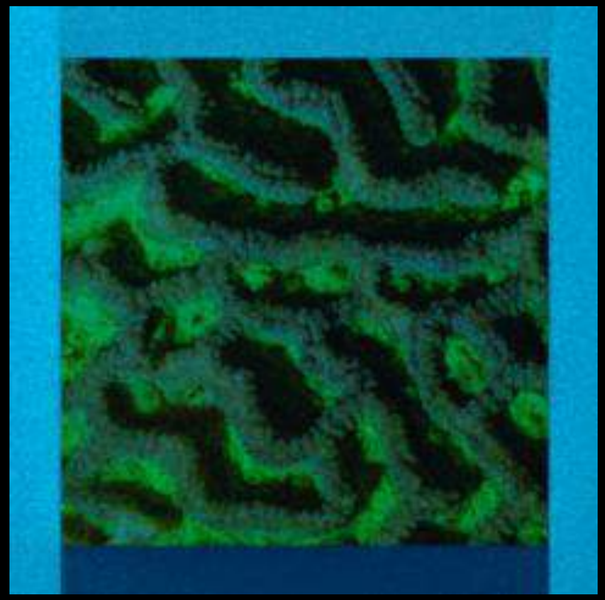


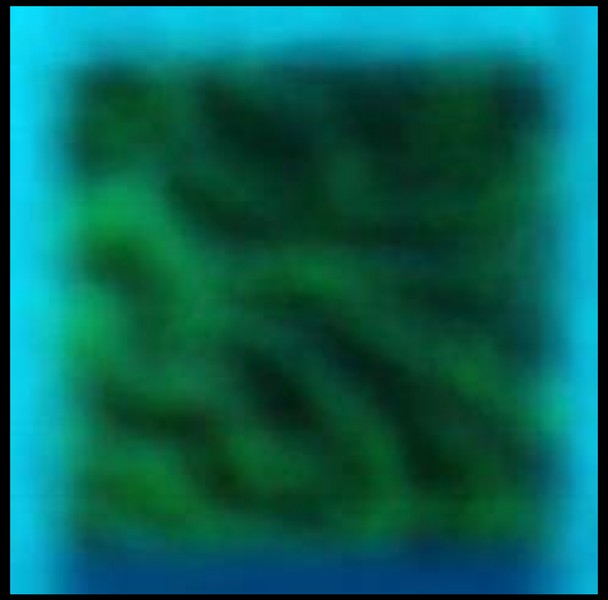
FluidCam





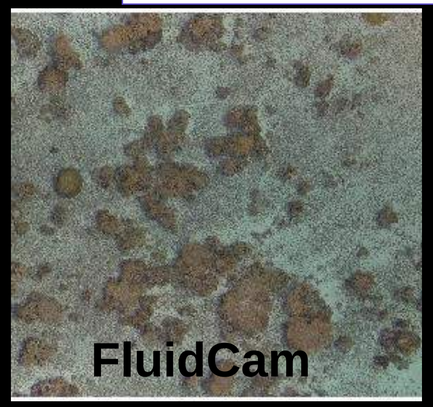


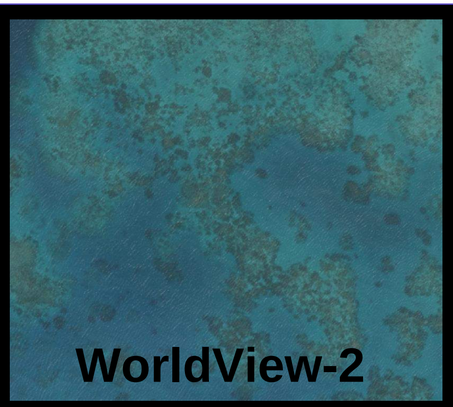


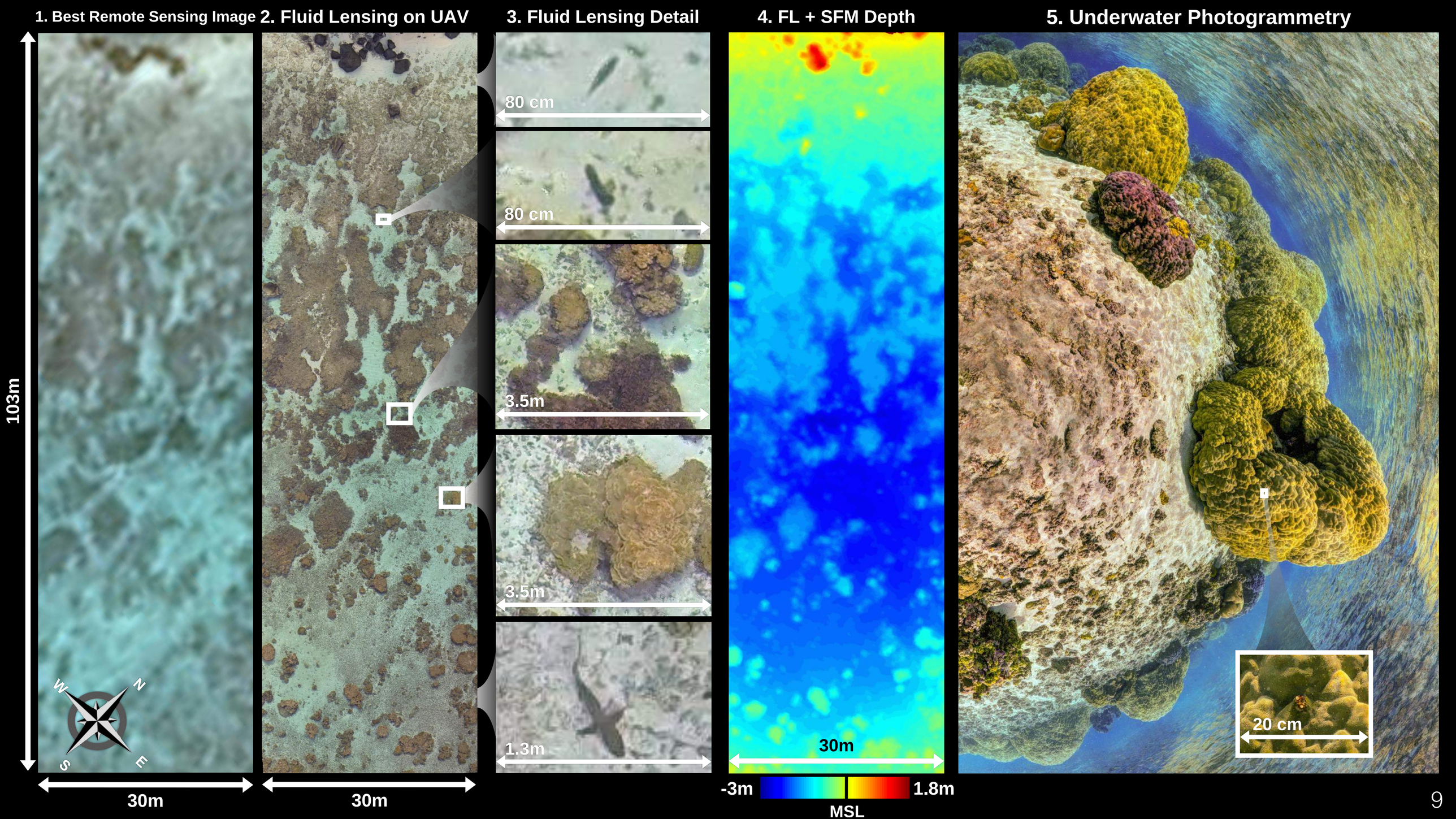


NEMO-NET DATA SOURCES

Sensor	Effective Spatial Resolution	3D	Spectral Bands	Locations
Underwater AUV	0.1 - 5 cm	YES	3	Australia, Great Barrier Reef, Pacific
FluidCam & MiDAR (NASA)	**0.1 ~ 2 cm**	YES	3-8	American Samoa, Guam, Western Australia, Puerto Rico, Indo-Pacfifc
QuickBird (USGS)	0.65 m	NO	4	US Territories
WorldView-2/3 (LOF)	0.5 - 3 m	NO	8	Global
CORAL PRISM (NASA)	7 m	NO	248	Hawaii, Mariana Islands, Palau, Guam, Great Barrier Reef
Landsat (USGS)	30 m	NO	11	Global

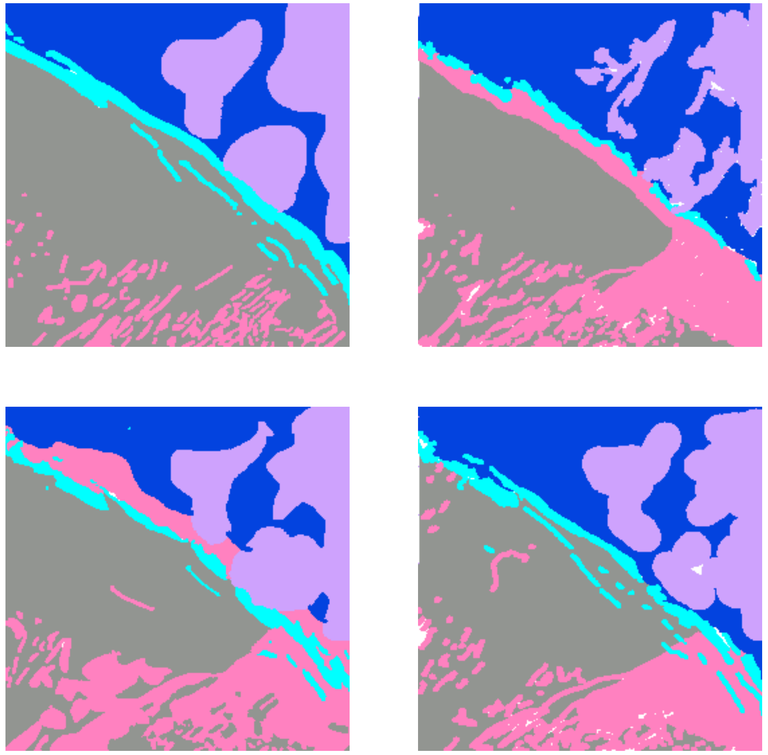




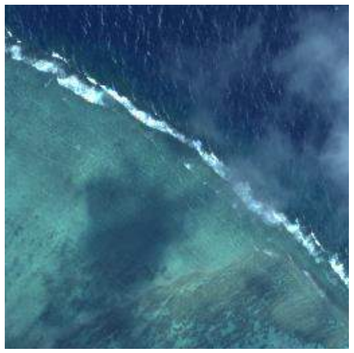

1. Best Remote Sensing Image
2. Fluid Lensing on UAV
3. Fluid Lensing Detail
4. FL + SFM Depth
5. Underwater Photogrammetry
103m
30m
30m
80 cm
80 cm
3.5m
3.5m
1.3m
30m
-3m
1.8m
MSL
20 cm
N
E
S
W

ACTIVE LEARNING FRAMEWORK

User Classified Data



Match with satellite data



Data Preparation

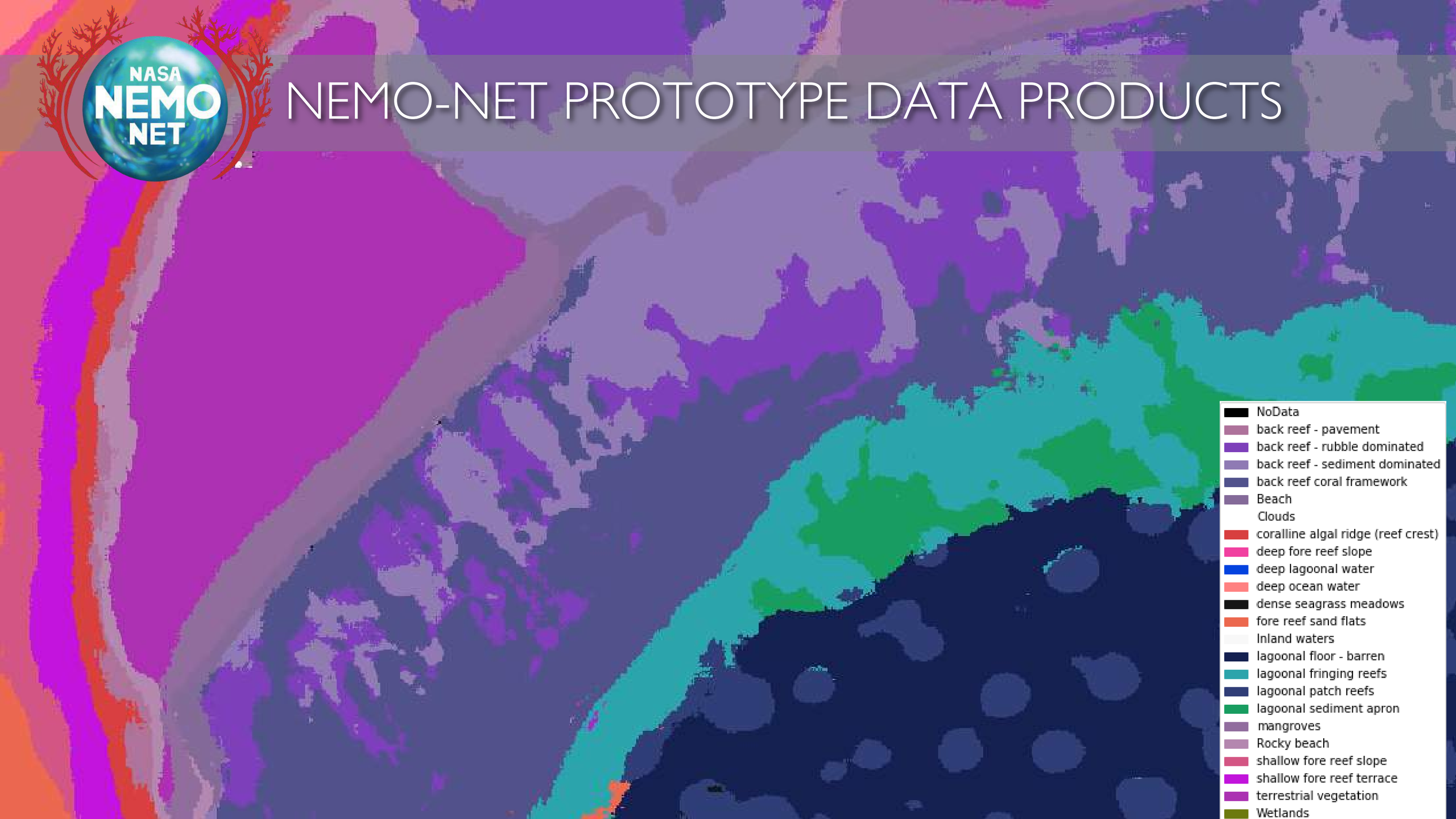
- Fill in gaps in user classified data (most common neighbor)
- Data normalization
- Label conversion
- Data randomization and augmentation
- Export image blocks to appropriate folders
- Export segmentation truth map

Prepared Data

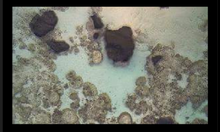
- Training Image Data
- Training Label Data
- Validation Image Data
- Validation Label Data

To CNN

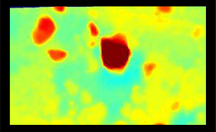
NEMO-NET PROTOTYPE DATA PRODUCTS



MM-Scale Airborne Fluid Lensing



MM-Scale Airborne Fluid Lensing DEM



M-Scale Airborne & Satellite Data

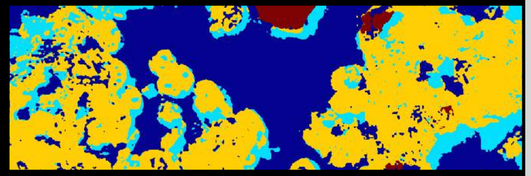
VR & App-based Active Learning & Interactive Training through IUCN, Mission Blue, & Partners

Level 1 Data & Existing Training Data Analysis

Active Learning Training of Coral Cover & Morphology Type

NASA NEMO NET

NeMO-Net Living Structure & Morphology Classification



IUCN

Khaled bin Sultan Living Oceans Foundation

MISSION BLUE™
SYLVIA EARLE ALLIANCE

NEMO-NET CLASSIFICATION HIERARCHY

Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
Zone	Major Geomorphological Structure	Detailed Geomorphological Structure	Biological Cover	Biological Morphology	Taxonomy
Reef Crest	Coral Reef and Hardbottom	Reef Crest/Coralline Algae Ridge	Live Coral	Branching Coral	Acroporidae
Fore-Reef		Fore-Reef Deep Slope	Algae	Massive Coral	Agariciidae
Reef Flat		Fore-Reef Shallow Slope	Higher Plants	Octocorals	Astrocoeniidae
Back-Reef		Fore-Reef Shallow Terrace	Prokaryotes	Macroalgae	Merulinidae
Lagoon		Fore-Reef Octocorals-dominated (Caribbean)	No Cover	Turf Algae	Montastraeidae
Bank/Shelf		Back-Reef Pavement	Unknown	Coralline Algae	Mussidae (Faviidae)
Escarpment		Back-Reef Coral Framework		Seagrasses	Poritidae
Channel		Back-Reef Coral Bommies		Mangroves	Siderastreidae
Dredged		Back-Reef Octocorals-dominated (Caribbean)		Cyanobacteria	Meandrinidae
Lagoon		Lagoon Pinnacle Reefs		Unknown	Pocilloporidae
Shoreline Intertidal		Lagoon Patch Reefs			Pectinidae
Salt Pond		Lagoon Fringing Reefs			Fungiidae
Inland Water		Lagoon Deep water			Caryophyliidae
Land	Unconsolidated Sediment	Fore-Reef Sand Flats			Dendrophyliidae
Unknown		Back-Reef Sediment-dominated			Gorgoniidae
		Lagoon Sediment Apron/Barren			Plexauridae
	Other	Deep Ocean Water			Alcyoniidae
		Seagrass Meadows			Nephtheidae
		Intertidal Wetlands			Phylum Chlorophyta
		Beach (Sand)			Phylum Phaeophyta
		Beach (Rock/Dark)			Phylum Rhodophyta
		Terrestrial Mangroves			Angiospermae
		Terrestrial Vegetated			Phylum Cyanophyta
		No Data/ Clouds/Unknown			Unknown

Branching Coral

Short description about branching coral.

These will be modified to L6 Classes

Mounding Coral

Short description about mounding coral.

These will be modified to L6 Classes

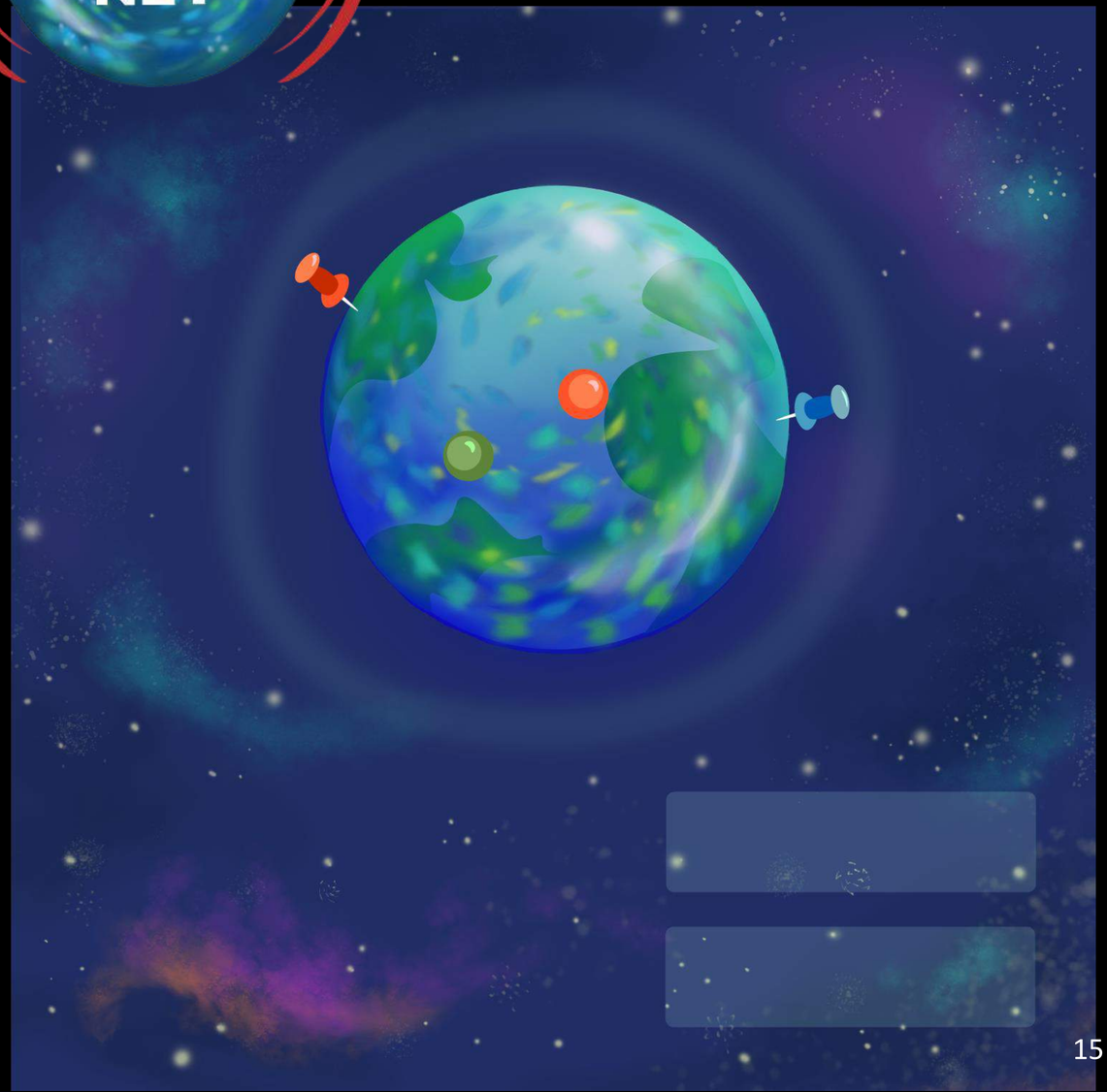
Rock

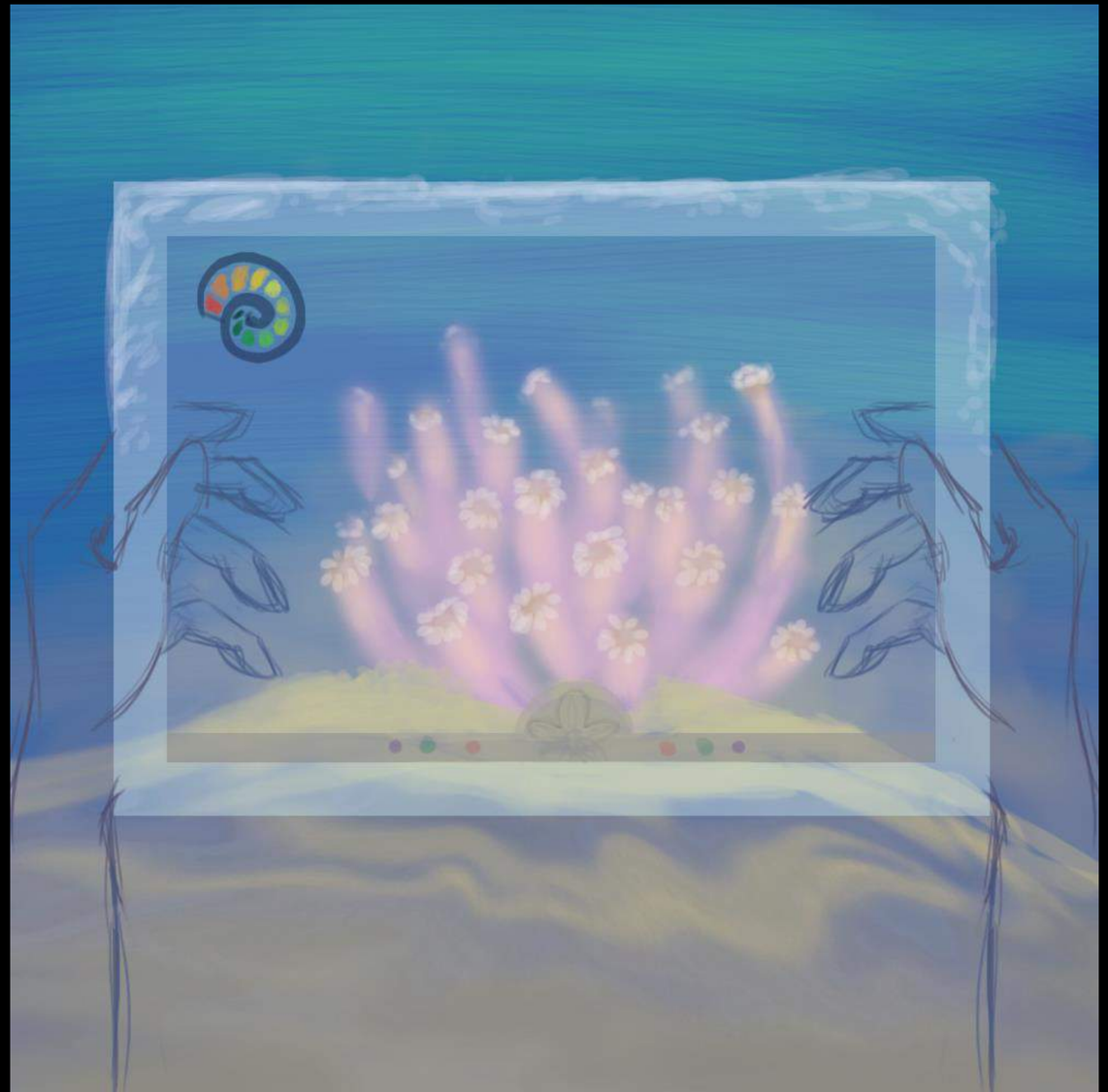
Short description about rocks.

In-game field guide

- Each class label will contain photos of typical species/genera
- May vary depending on the geographical location of the image to be processed (e.g., Atlantic/Caribbean vs Indo-Pacific)

UPCOMING NASA NEMO-NET APP - 2019



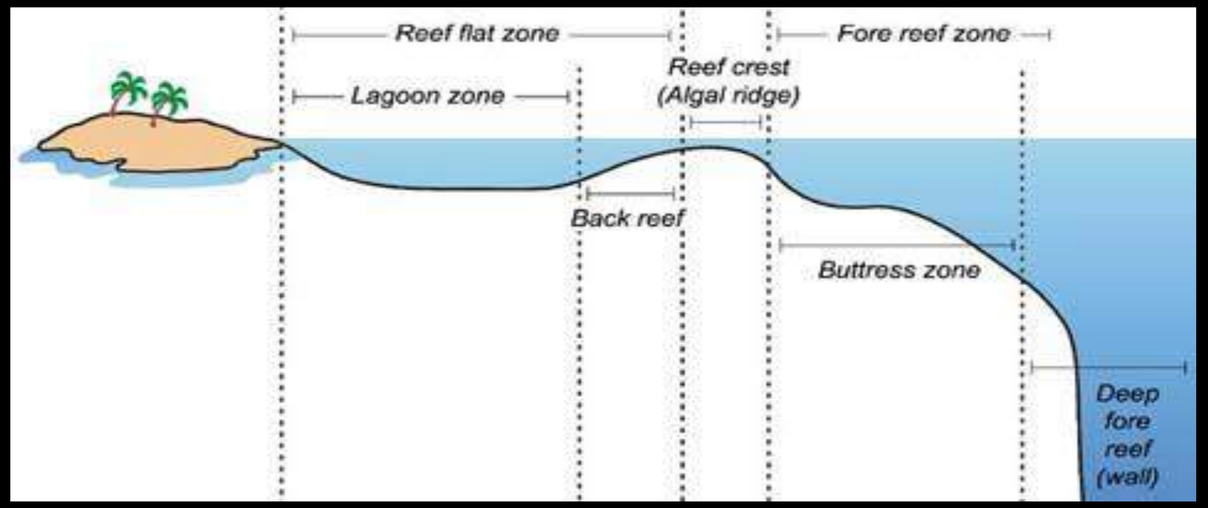


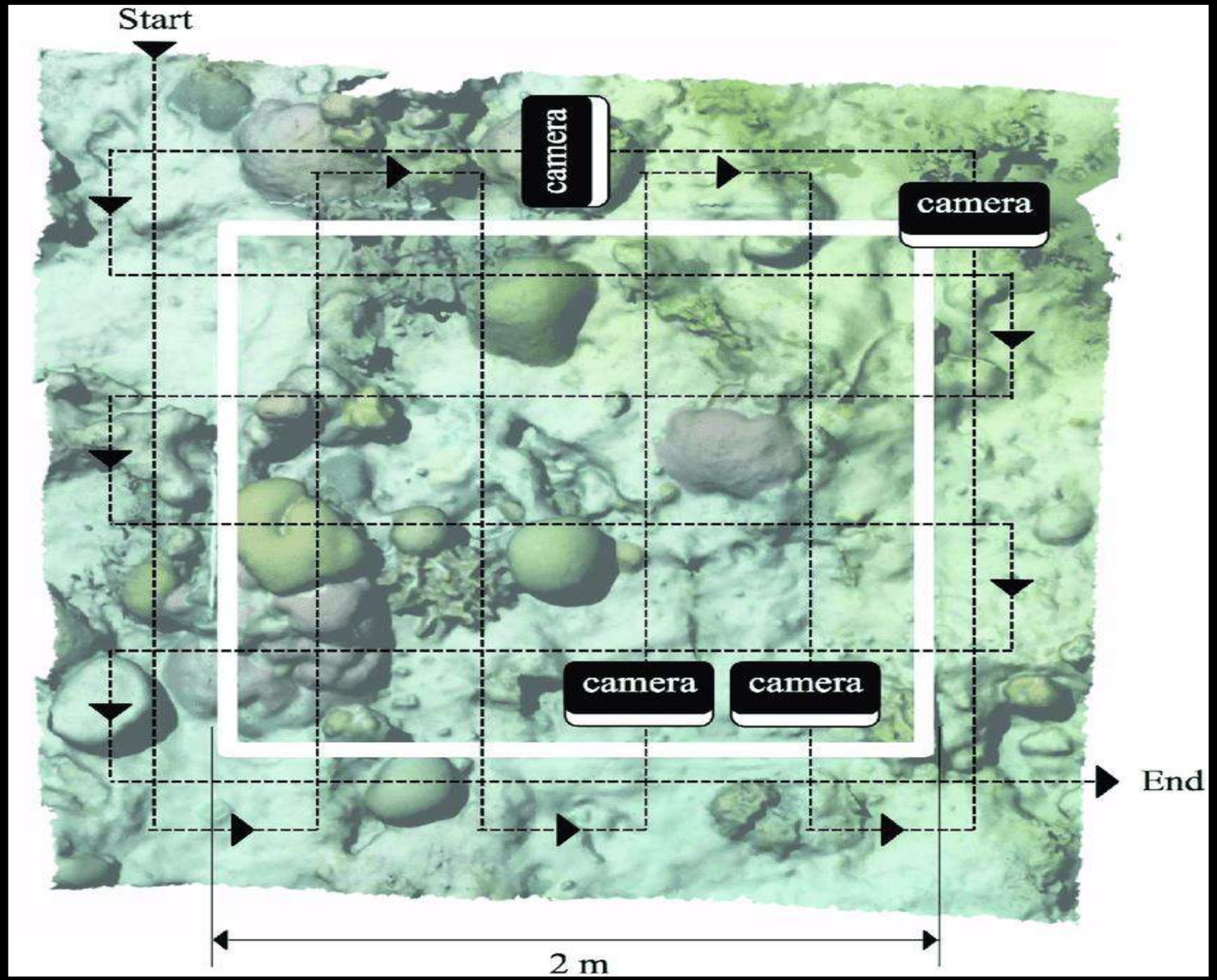
NEMO-NET NEWS

PUERTO RICO FIELD CAMPAIGN!

Puerto Rico Field Mission

- March 6-18, 2019
- Concentrated on the southwest coast (La Parguera Natural Marine Reserve)
- 3 reef sites (legacy sites for previous NASA campaigns: 2004-2009; HICE-PR; CoralBASICS)
- Coordination with the University of PR – Department of Marine Sciences – Bio-optical Oceanography Laboratory (Dr. Roy Armstrong, Director)
- Collection of high resolution camera data for NeMO-Net

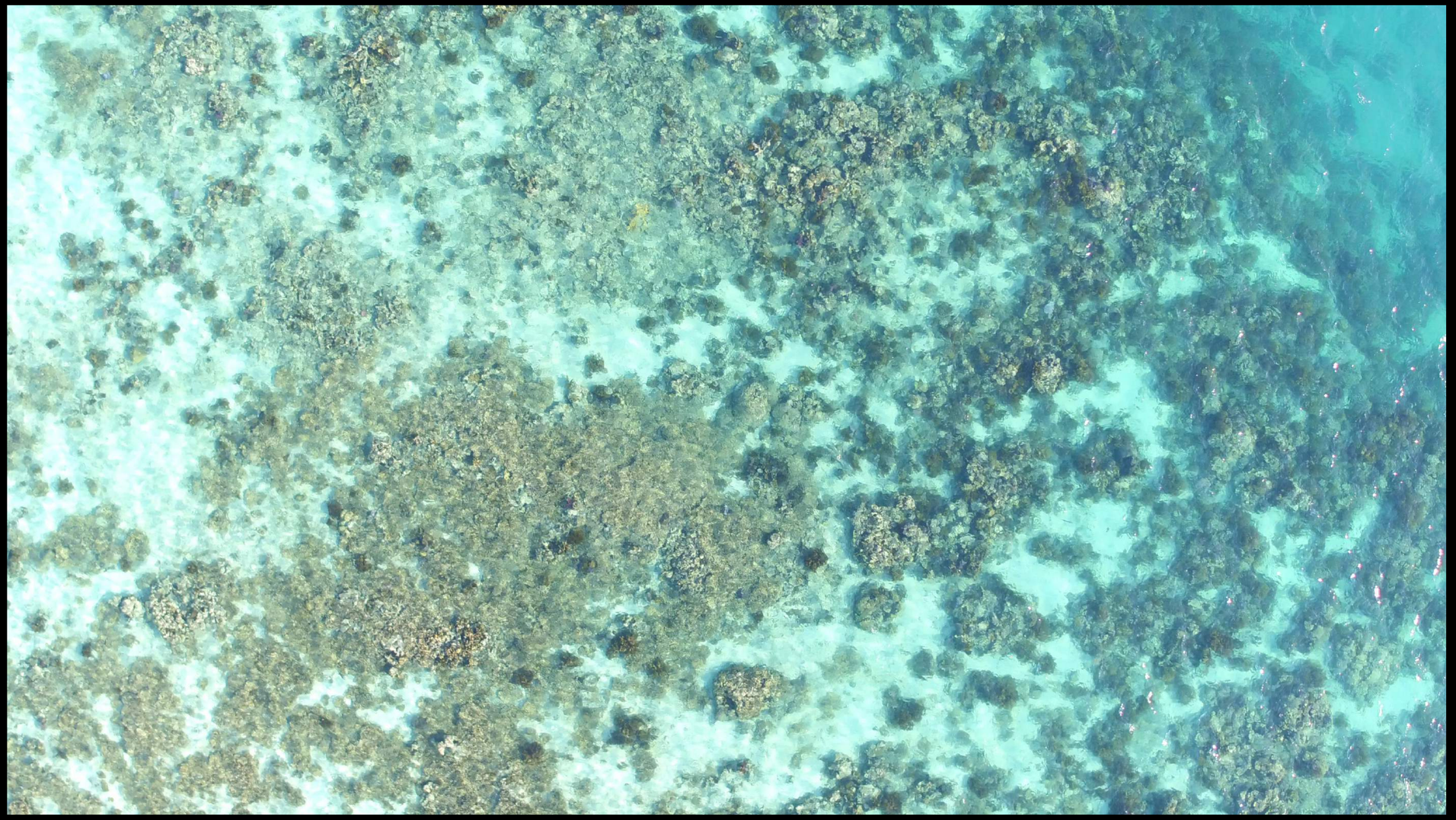




- Actually… 10x10m phototransects
- ~80% overlapping between photos
- > 5 phototransects per reef site
- Capture uniform and mixed areas

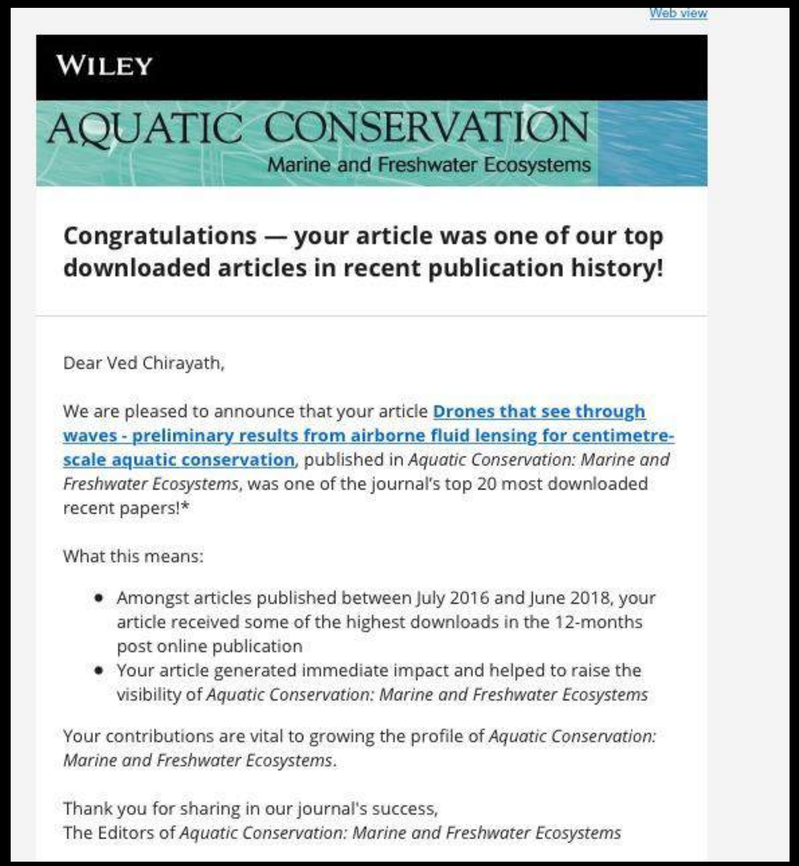
WP
RTK 15
Zenmuse X5R
72%(47.65V)
98%
23:22
2D
50.0 M
Progress: 4%
Waypoints: 23/600
Speed
2.7 M/S
LAT 17.944295091
LON -67.080147885
Height
74.9 M

Typical waypoint sampling - video



- ~ 500-800 waypoints per reef
- ~ 1GB of data per waypoint
- ~ 2.3 cm spatial resolution

PUBLICATIONS AND NEXT STEPS …



Web view

WILEY

AQUATIC CONSERVATION
Marine and Freshwater Ecosystems

Congratulations — your article was one of our top downloaded articles in recent publication history!

Dear Ved Chirayath,

We are pleased to announce that your article **Drones that see through waves - preliminary results from airborne fluid lensing for centimetre-scale aquatic conservation**, published in *Aquatic Conservation: Marine and Freshwater Ecosystems*, was one of the journal's top 20 most downloaded recent papers!*

What this means:

- Amongst articles published between July 2016 and June 2018, your article received some of the highest downloads in the 12-months post online publication
- Your article generated immediate impact and helped to raise the visibility of *Aquatic Conservation: Marine and Freshwater Ecosystems*

Your contributions are vital to growing the profile of *Aquatic Conservation: Marine and Freshwater Ecosystems*.

Thank you for sharing in our journal's success,
The Editors of *Aquatic Conservation: Marine and Freshwater Ecosystems*

1) *Accepted, 2019. Remote Sensing of Environment. Fluid Lensing and Machine Learning for Automated Centimeter-Resolution Airborne Assessment of Coral Reefs in American Samoa without Ocean Wave Distortion.*
2) *In review, 2019. Cloud Detection Algorithm for Multi-Modal Satellite Imagery using Convolutional Neural-Networks (CNN).*
3) *In review, 2019. Special Issue, Frontiers in Marine Science.Next-Generation Optical Sensing Technologies for Exploring Ocean Worlds - NASA FluidCam, MiDAR, and NeMO-Net.*
4) *Guam Field campaign – May 2019 (last week!)*
5) *Palau Field Campaign – Sept 2019 before the 42nd US Coral Reef Task Force meeting*
6) *Several other publications under development*

Thank you!