CREATING ACCURATE DIGITAL SURFACE MODELS USING UAV MOUNTED COMMERCIAL GRADE CAMERAS:

A PRACTICAL METHODOLOGY TO GENERATE MAP QUALITY GEOREFERENCED IMAGERY AND TOPOGRAPHY

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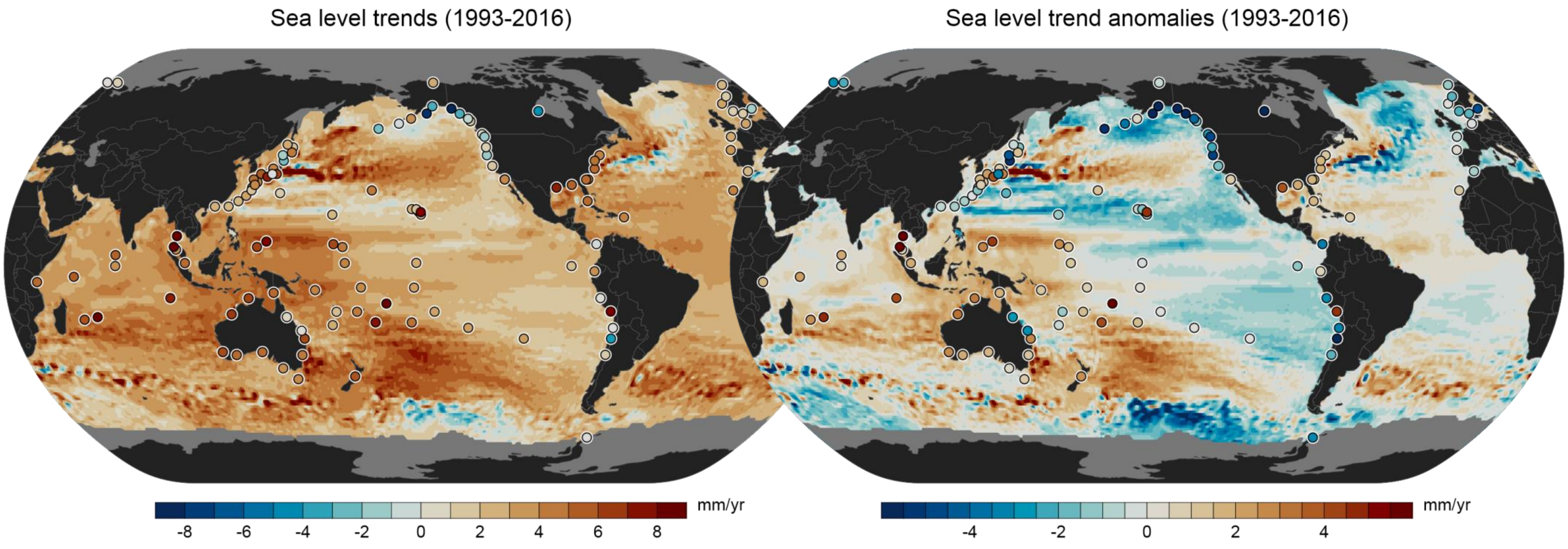
Need

- In the Pacific
  - Sea level rise variability
  - 27,000 small islands and islets
  - Insecure water resources
  - Few resources for resettlement

Climate Changes

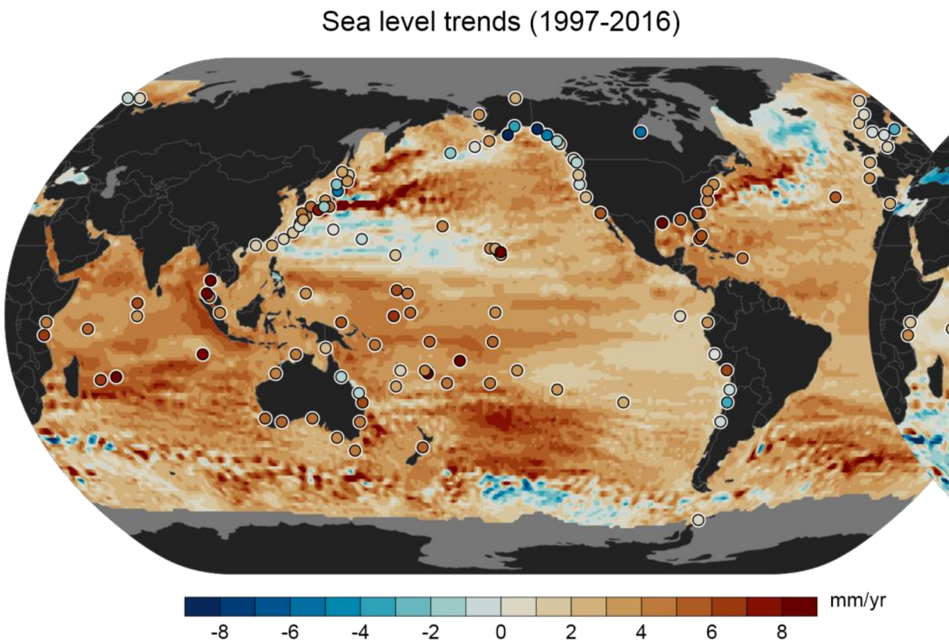
- Sea level changes are spatially variable

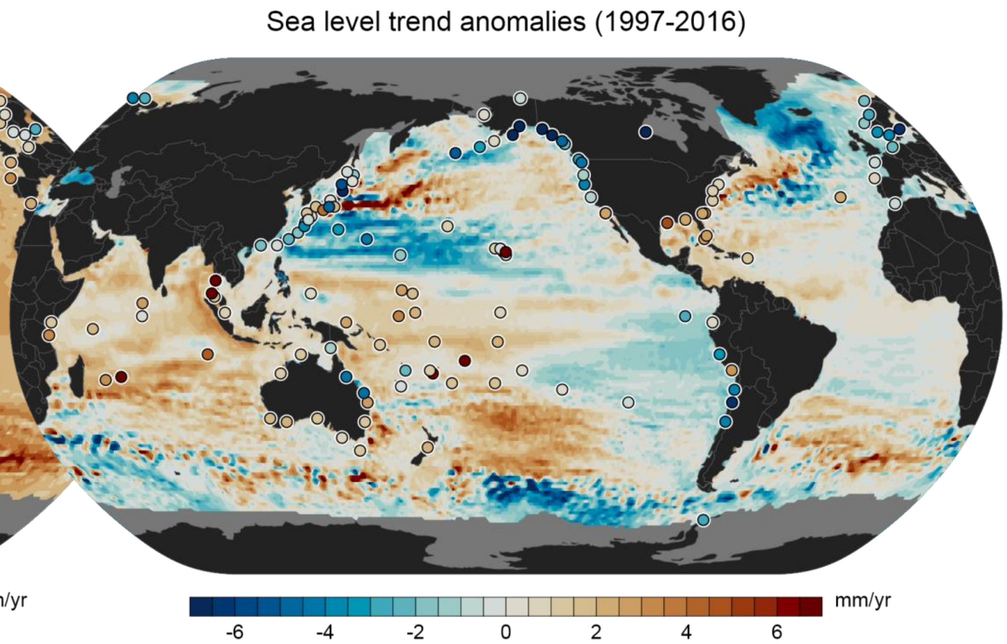


Source: UH sea level center

Climate Changes

- Sea level changes are spatially variable





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Climate Changes

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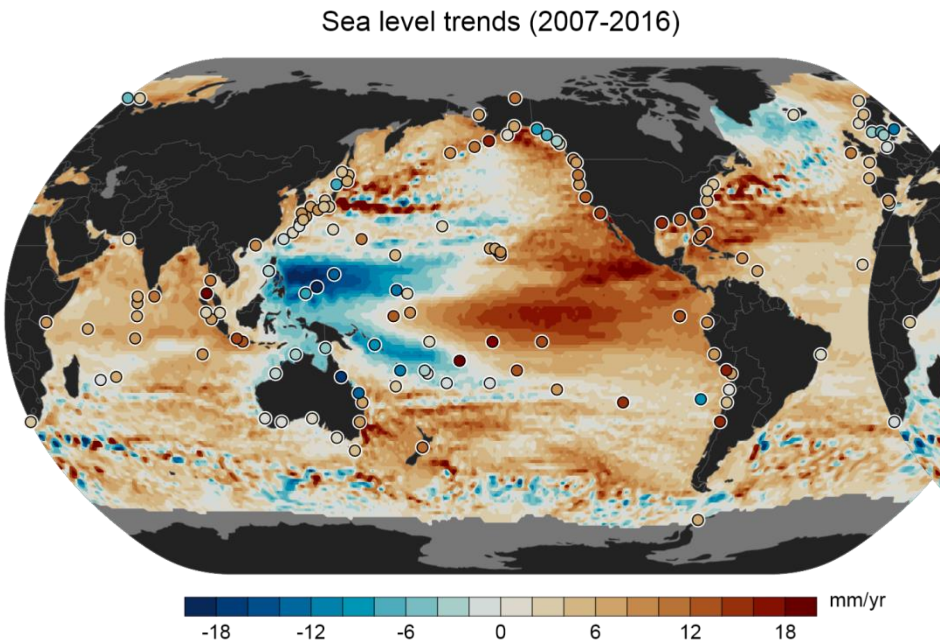
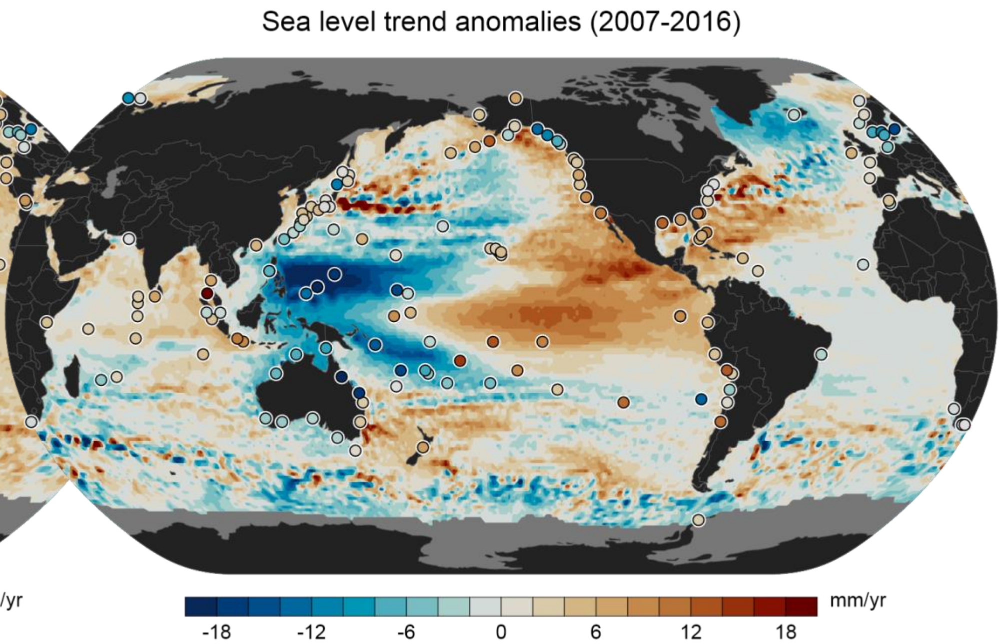
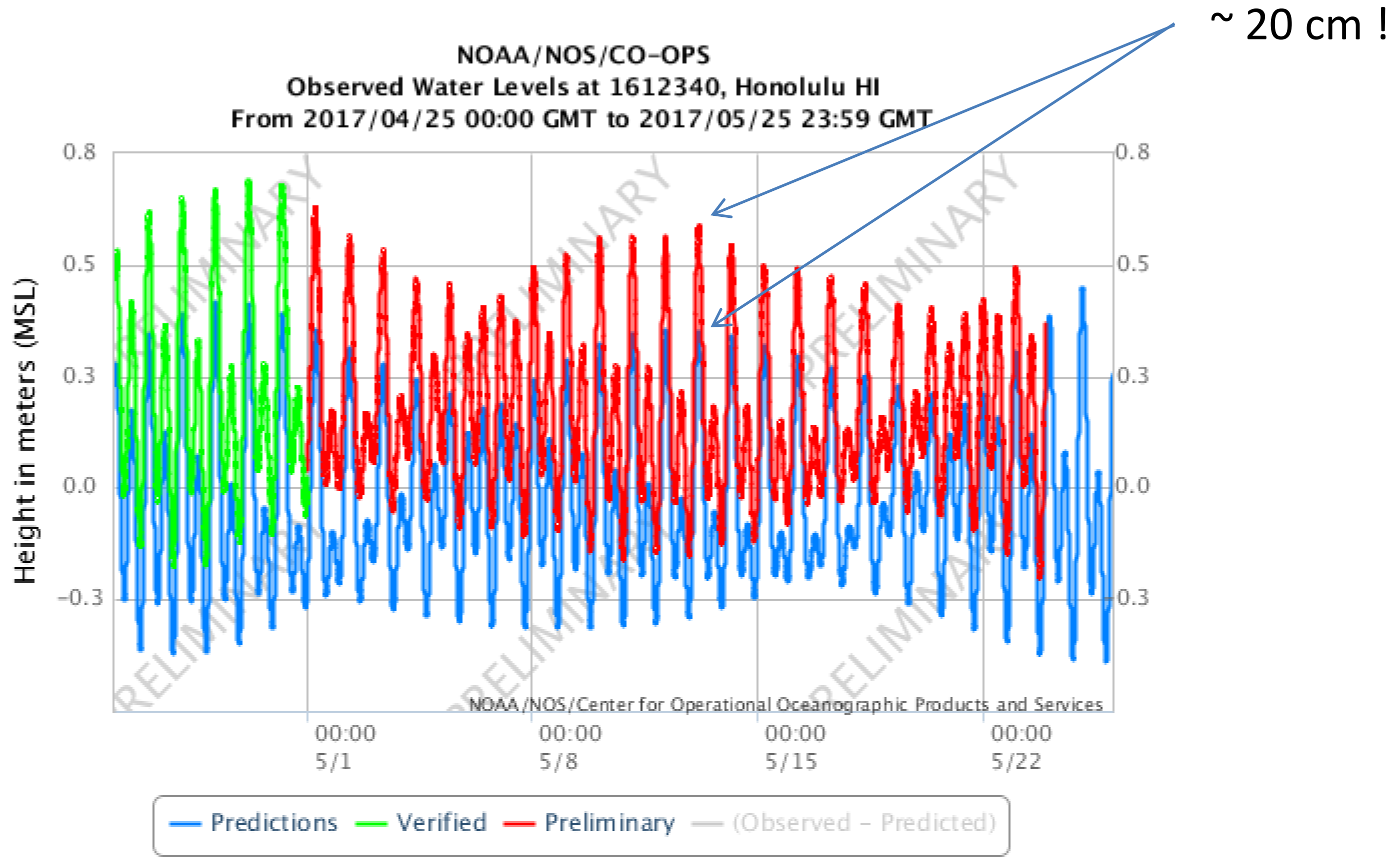




Source: UH sea level center

Local short-term climate variability



Source: NOAA Tides and Currents

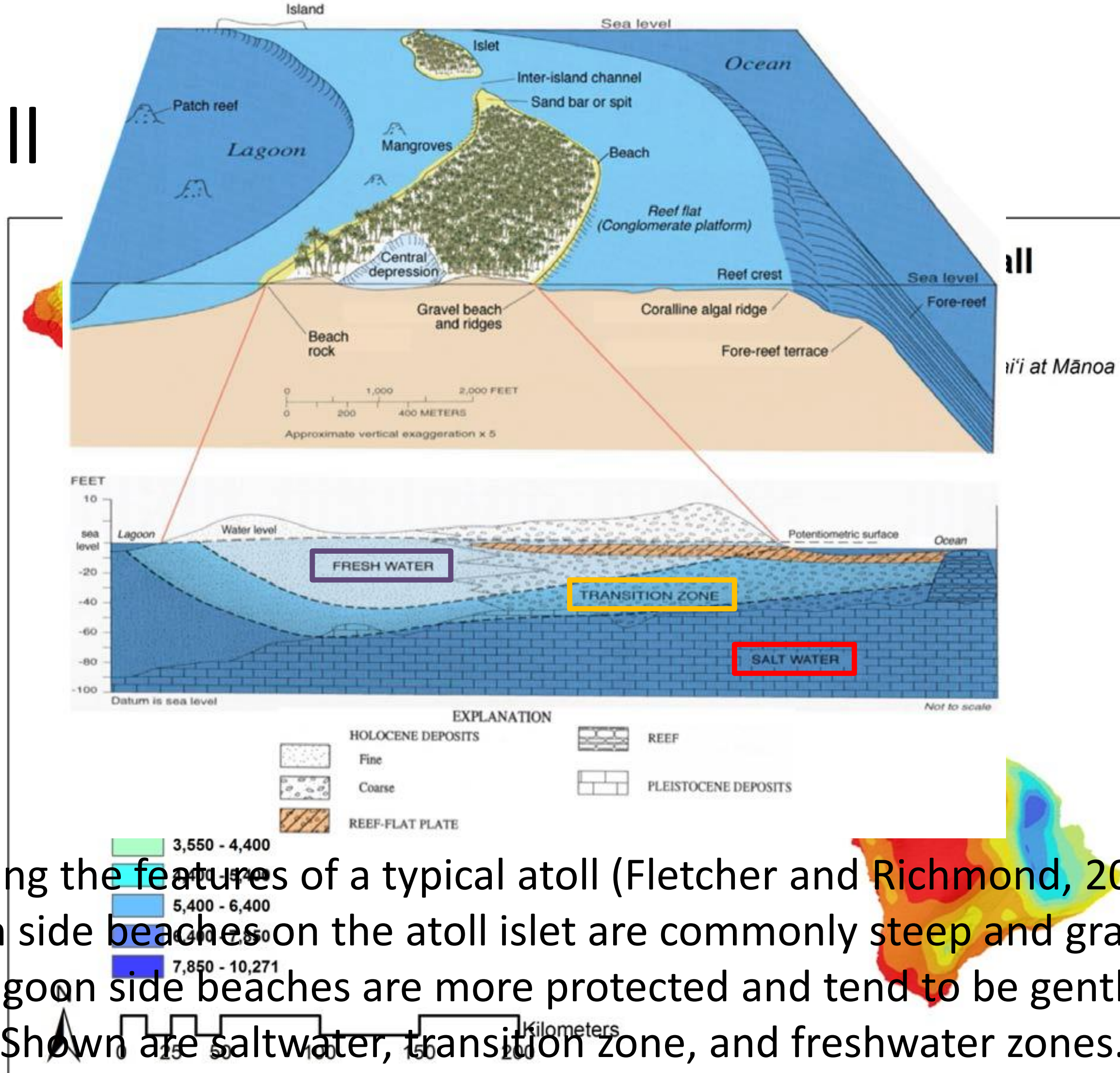
Short-term climate variability

- King tides

Sources: Hawaii News Now and Aljazeera America

Fresh Water

- Rainfall



Drawing showing the features of a typical atoll (Fletcher and Richmond, 2010). The exposed ocean side beaches on the atoll islet are commonly steep and gravel rich, whereas the lagoon side beaches are more protected and tend to be gently-sloping and sand rich. Shown are saltwater, transition zone, and freshwater zones.

Source: Hawaii Rainfall Atlas

Islands and atolls

- ~27,000 islands in the Pacific!
- Most are low islands (> 3 m) and part of atolls
- Most have vulnerable fresh water resources
- Most development is near the ocean and its resources

Source: UH sea level center

Mapping an atoll

- LiDAR is too expensive and requires airports and infrastructure for planes
  - Processing and cost exceed the means of small island nations
- We know that UAV may offer a solution
  - Cost effective and cheaper to deploy
- Need to develop a workflow for imagery and product quality assessment

The Marshall Islands

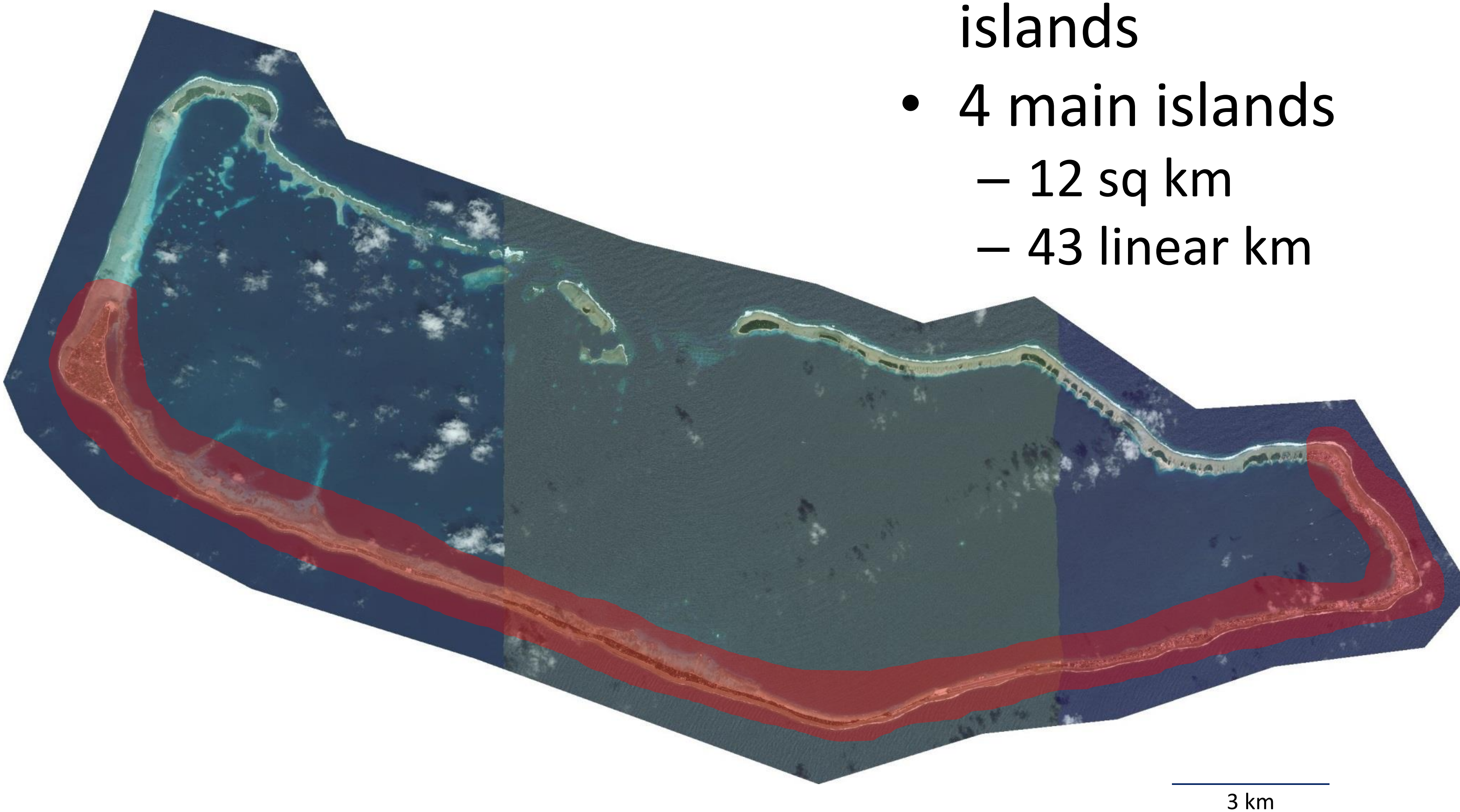
- 29 atolls with ~1100 islands and islets
- Majuro, the capital is home to over half of the ~53000 people in the republic
- History of flooding on both the lagoon and ocean sides from king tides and sea level anomalies
- Only a small portion of the atoll has been mapped better than 30 m resolution

Goal

- Develop a method to provide a 1 m resolution DSM to local government and resource managers
  - Utilize existing equipment
  - Utilize experience mapping coastal environment to maximize the possibility of success
  - Expose local surveyors to methodology

Majuro

- Comprised of 64 islands
- 4 main islands
  - 12 sq km
  - 43 linear km



Field tools

- GPS kinematic and static
- Total Station
- Ground targets
- 2 Phantom off-the-shelf UAVs
- 10 people
- Knowledge of the ground
- Access to property

GPS

- Survey grade Kinematic backpack mounted and car mounted rovers
  - – Collect reef-top points
  - – Collect road points
- Survey grade static survey
  - – Collect target locations

Total station surveys

- TS16 smart station to collect under canopy coverage missed by UAVs and GPS rovers
  - Very labor and time intensive

Ground Targets

- Two sizes and configurations
  - Based on planned flight altitude(s)
  - B/W and Y/B squares ~ 1 m

UAVs

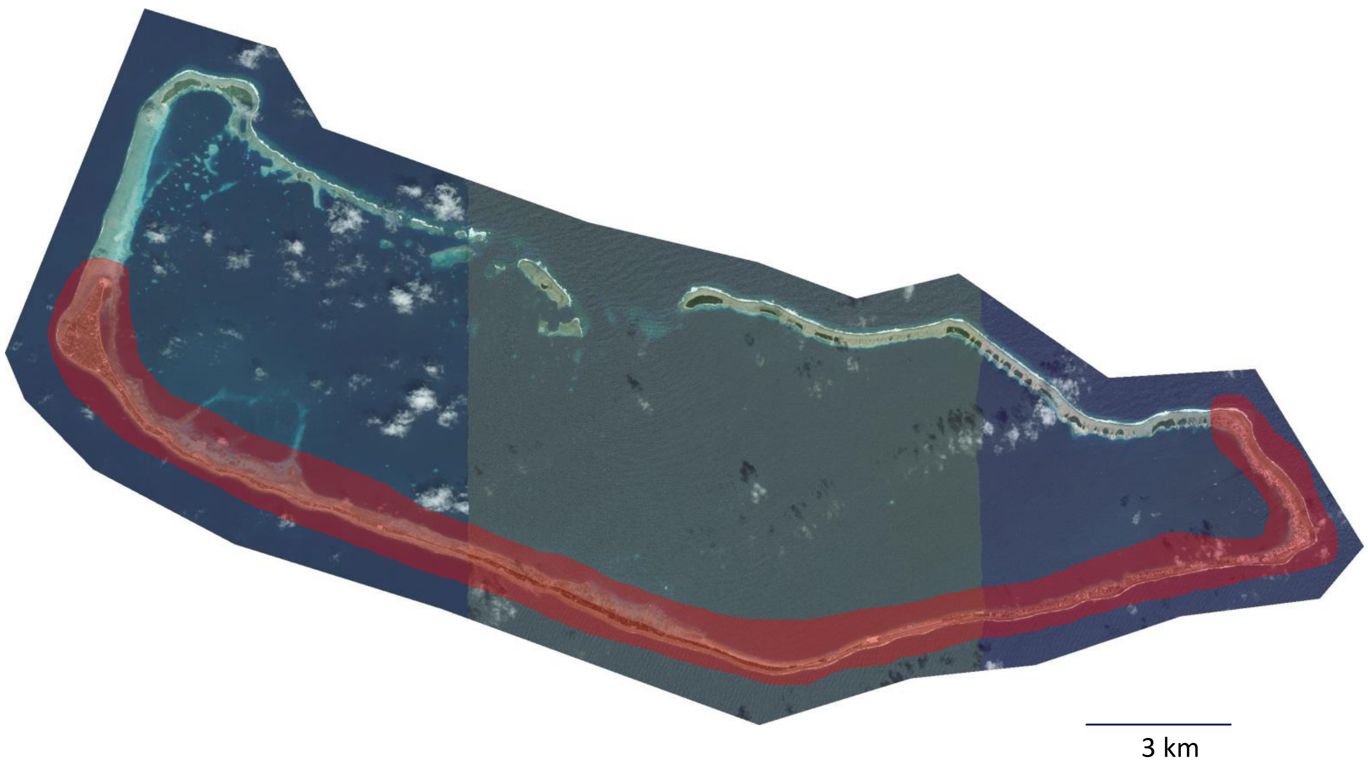
- Off-the-shelf quadcopters
  - Phantom 3 pro (2015)
  - Phantom 4 (2016)
- Flight planning software
  - Drone deploy (Phantom 4)
  - Altizure (Phantom 3 pro)

Ground survey crews

- Kinematic GPS crew
  - Jeff, Dean, Cindy, Monica, Maxim, Bill
- Static GPS crew
  - Ed, Scotty, Bill
- UAV pilots
  - Andrea, Maria, Scotty, Maxim, Matt

Data collection

- 10 days of flying 6 – 8 hrs per day = 120 flights
- 120 linear km
- 34,000 oblique and nadir photos taken



Data processing

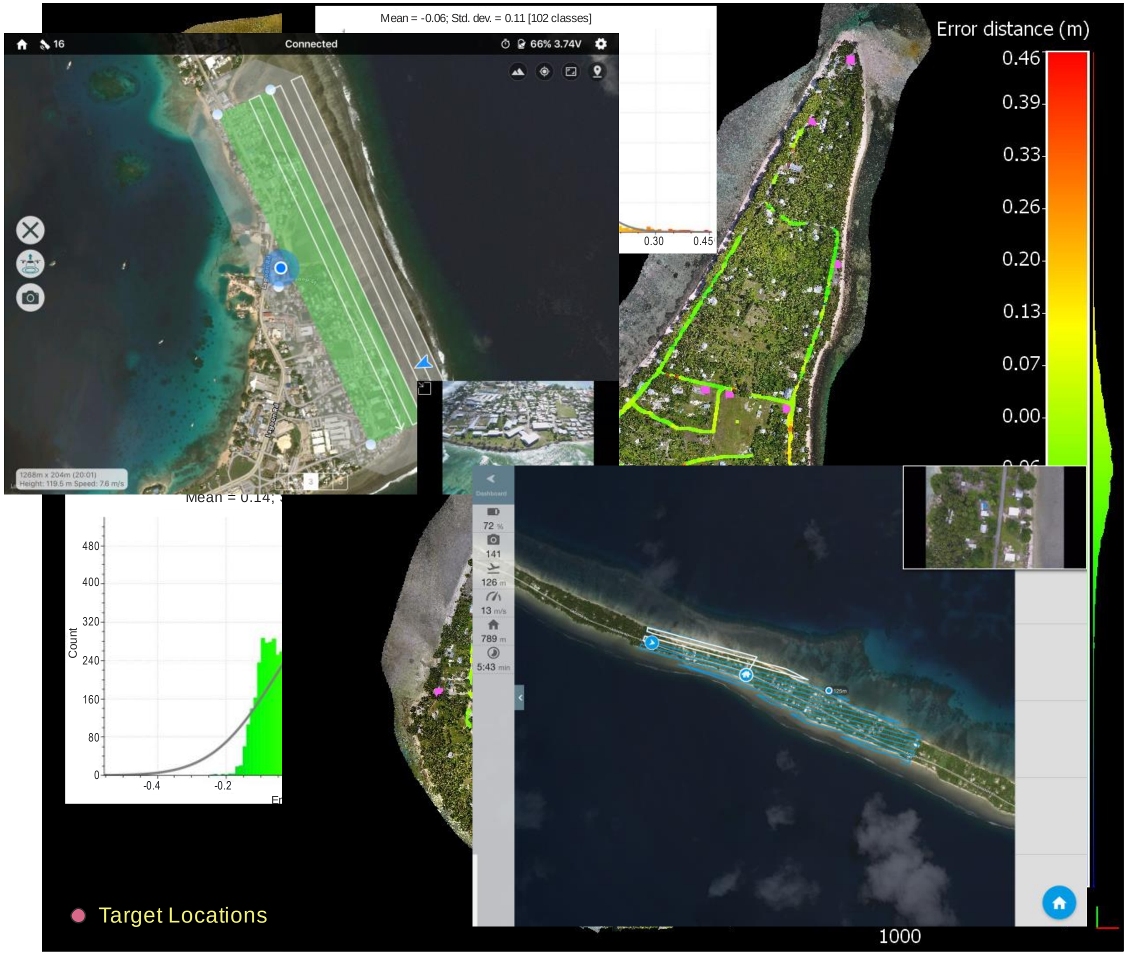
- GPS data post-processed with base station data
- Target locations post processed with CORS – Aus site on Majuro
- Only nadir imagery chosen for first processing
  - 7,000 images cover whole island except airport

Image Processing

- Agisoft Photoscan
  - Uses camera GPS to derive sparse point cloud
  - Targets identified and post-processed GPS locations used rather than camera GPS for 'real' alignment
  - Iterative error refinement to remove inaccurate points in point cloud
- Output surface model processed to classify 'bare earth', structures and vegetation
- QA/QC'd using processed kinematic GPS

Results

- 103 targets collected and located
- 34,000 images
- 1.3 million GPS points
- 200 hrs of processing

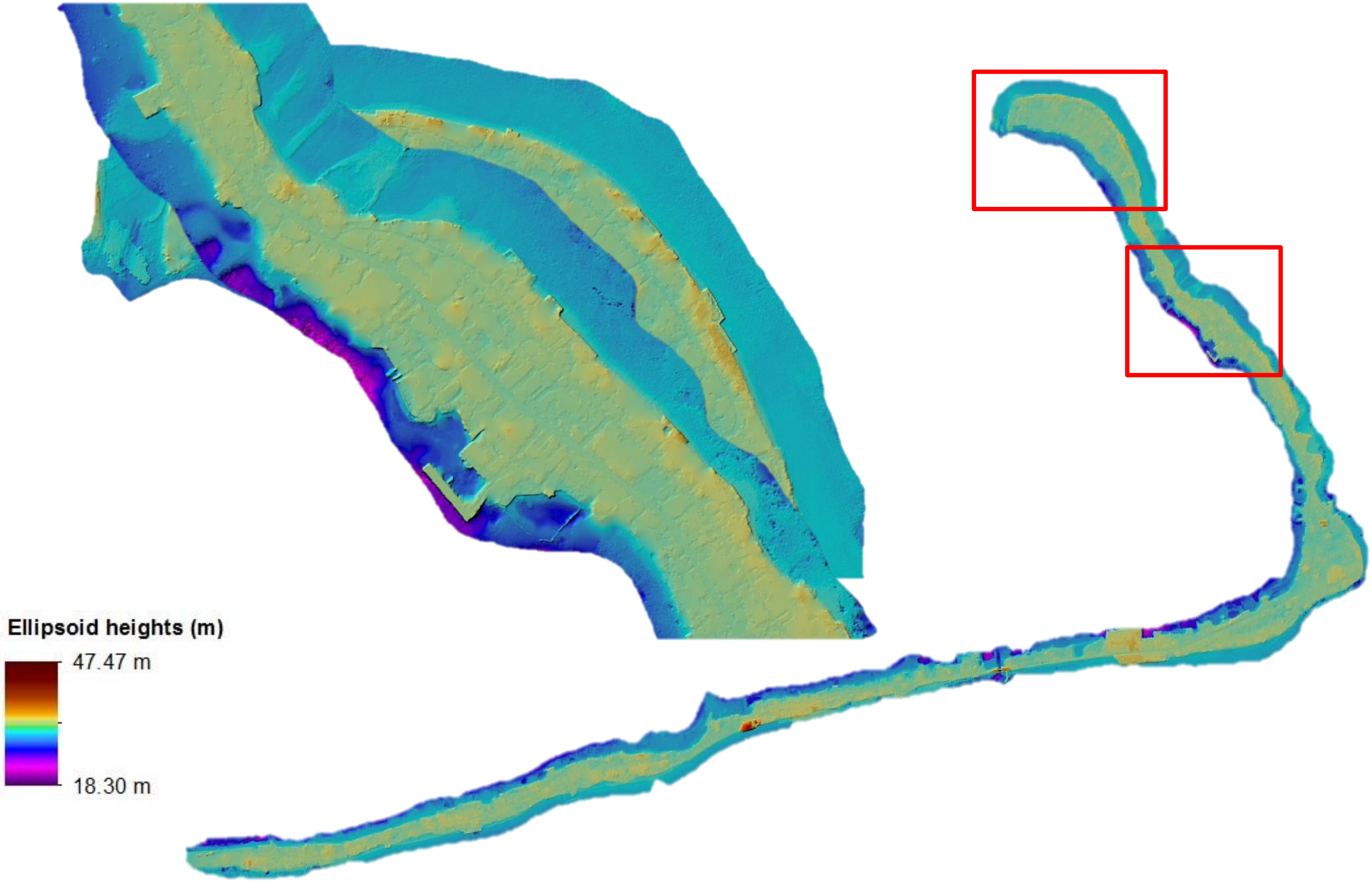


Errors

Date	RMSE (m)	MAE (m)	MdAE (m)	No. Pts.	Date	RMSE (m)	MAE (m)	MdAE (m)	No. Pts.
Sep. 14, 24, 26	0.23	0.16	0.10	14,720	Sep. 20	0.16	0.12	0.09	3,814
Sep. 15	0.21	0.17	0.16	19,229	Sep. 21	0.13	0.10	0.08	842
Sep. 16	0.16	0.12	0.08	15,729	Sep. 22, 23	NA	NA	NA	NA
Sep. 17	0.22	0.19	0.18	4,930	Sep. 24 Peace Park	0.20	0.16	0.12	45
Sep. 19	0.13	0.10	0.07	10,337	Sep. 24 Reef Flats	0.47	0.45	0.46	2,301

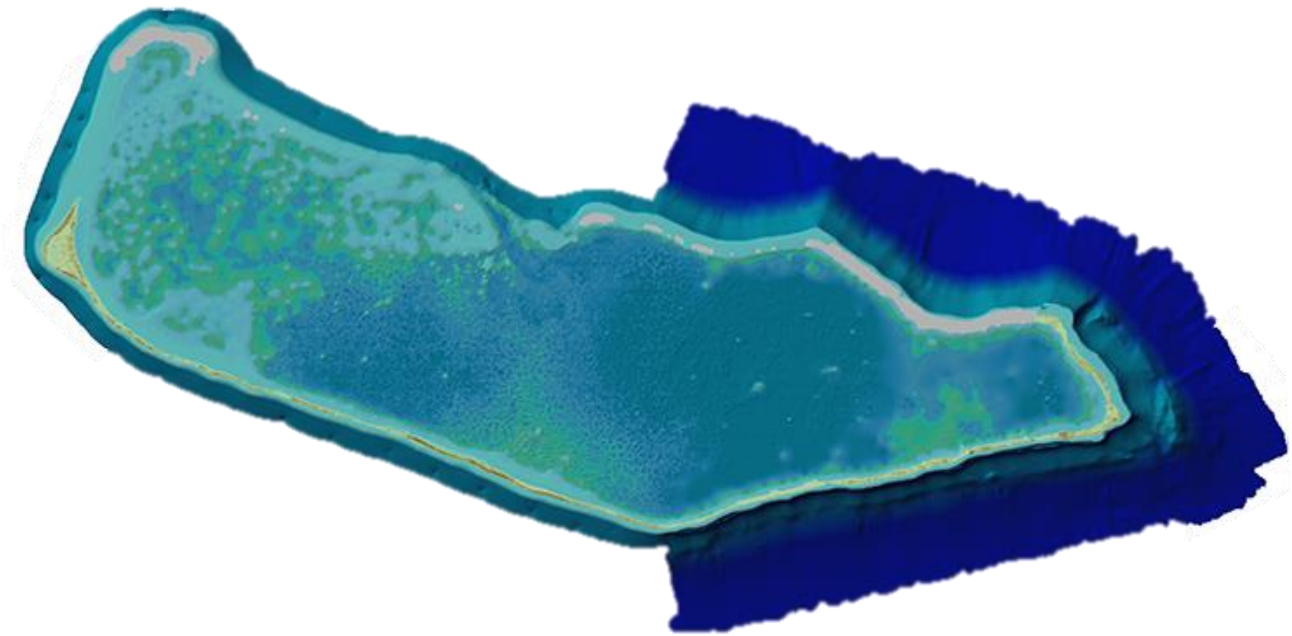
RMSE = Root mean square error (vertical)
MAE = Mean absolute error (much better than mean error in my opinion)
MdAE = Median absolute error

FINAL DSM

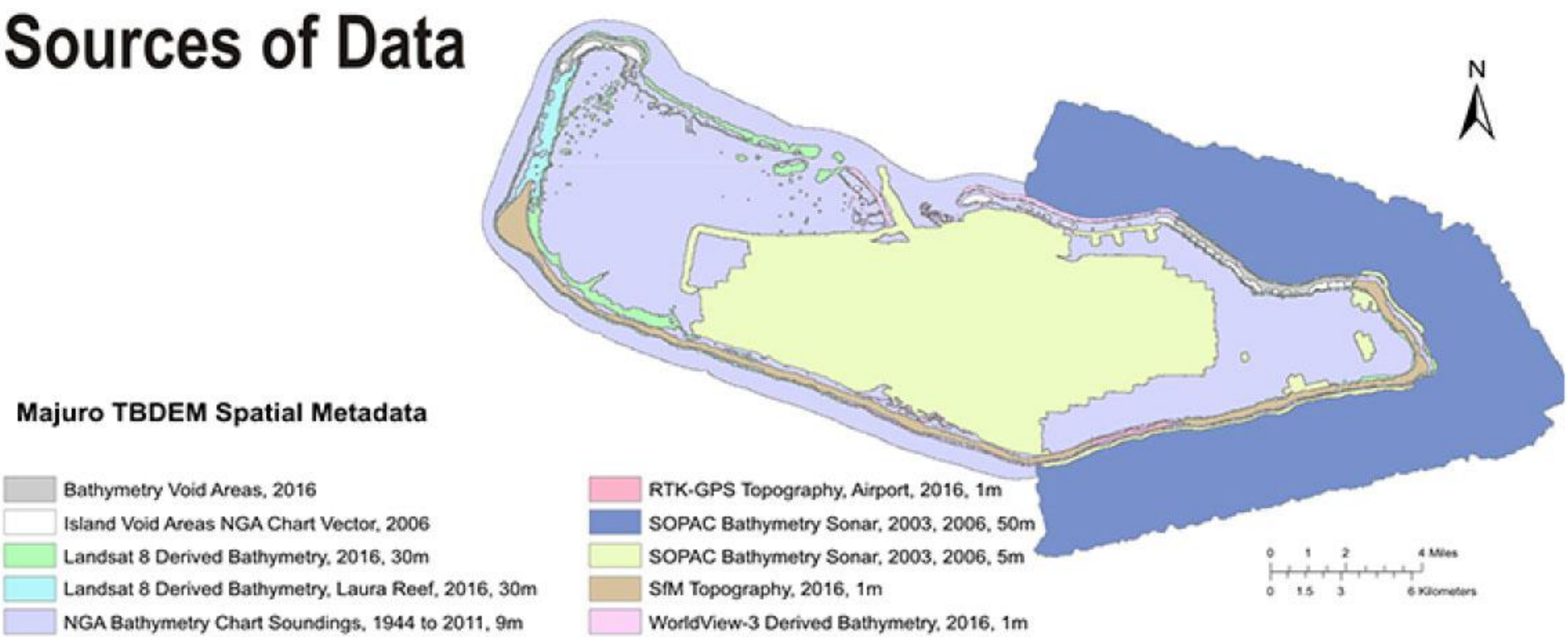


Final Terrain/Bathy DEM

- A mosaic of data sources



- Link to USGS data products:
  – https://topotools.cr.usgs.gov/coned/majuro_atoll.php



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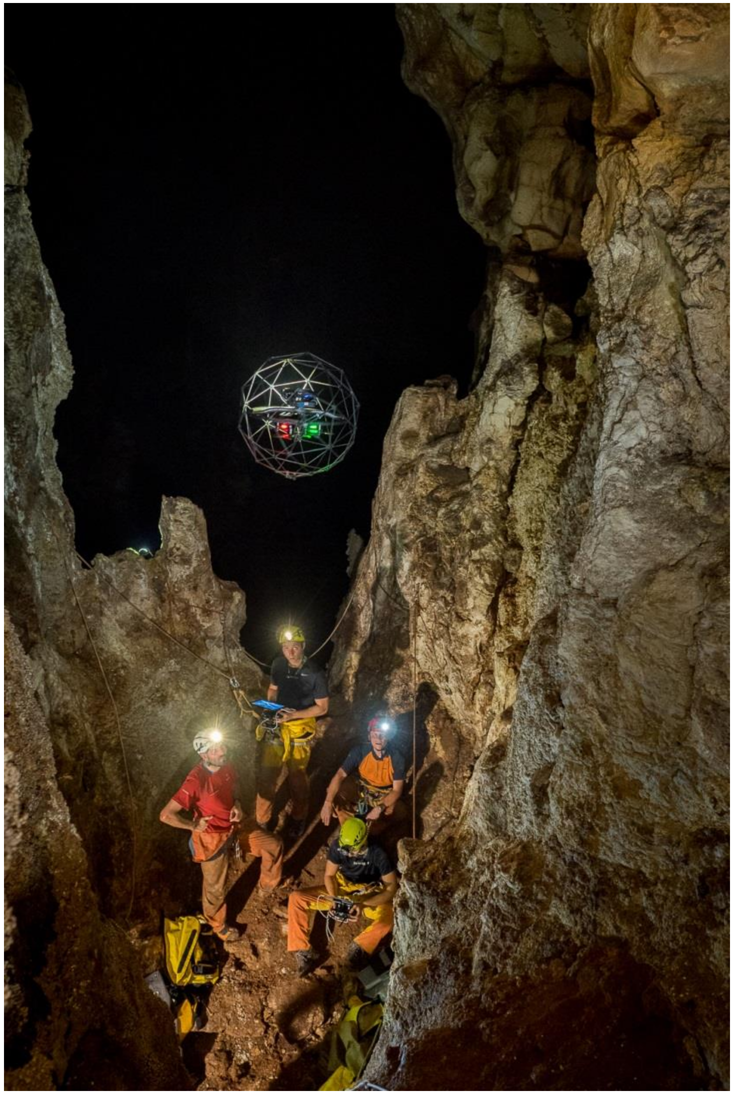
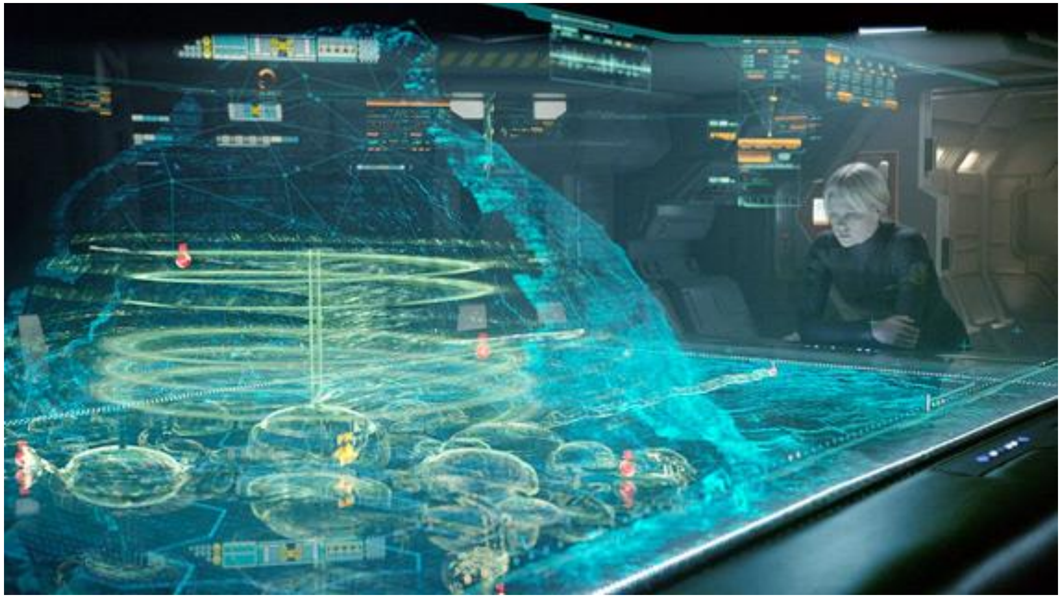
Next steps

- Process oblique imagery collected
- Collect reef-top/shallow water points for validation and calibration
- Re-collect portions of the atoll where image quality may have reduced accuracy
- Account for tides if possible

The future



- New applications are emerging everyday
- Creating new cartographies to navigate and reference space and all of the information collected



Thank you