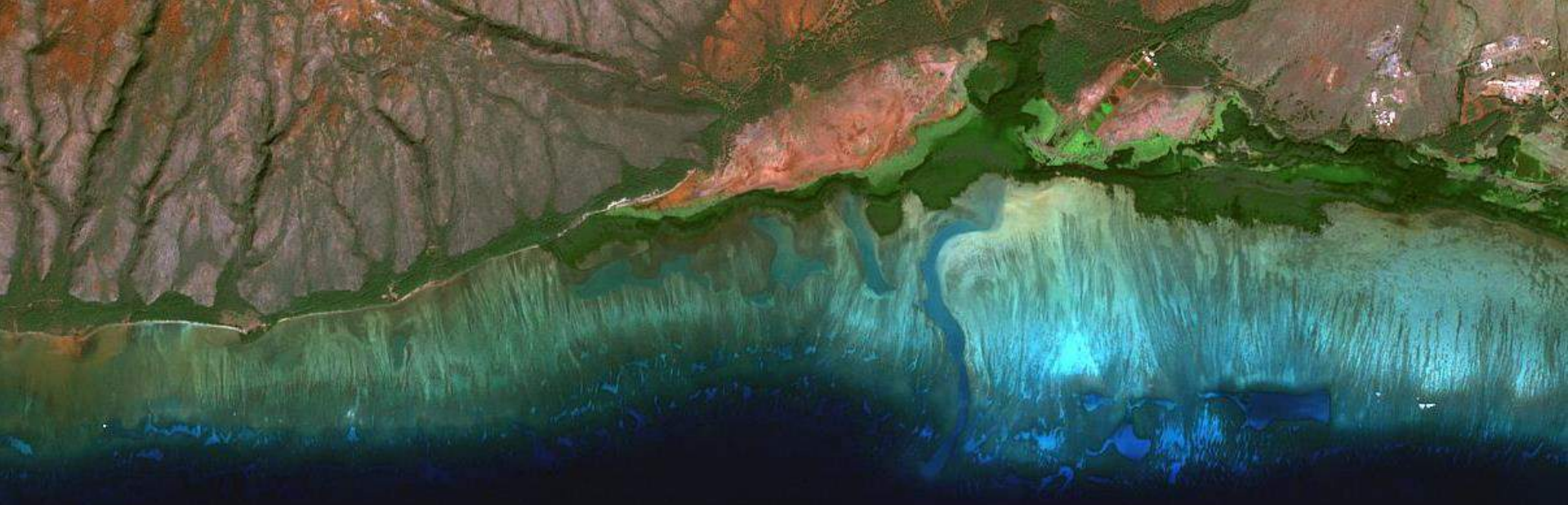


Coral Reef Remote Sensing Through Space and Time:
Implications for Global Monitoring and Assessment

James Goodman | HySpeed Computing
Paul Haverkamp (PI), Mui Lay, Susan Ustin | UC Davis
Luis Ramirez | Nova Southeastern University

NASA Award 80NSSC18K0124

2019 NASA Biodiversity and Ecological Forecasting Team Meeting

Project Objectives

This project will identify changes in coral, sand, and algae in Kaneohe Bay, the south coast of Molokai, and the French Frigate Shoals by comparing benthic classifications from the early 2000s and 2017.

To meet this goal, we will:

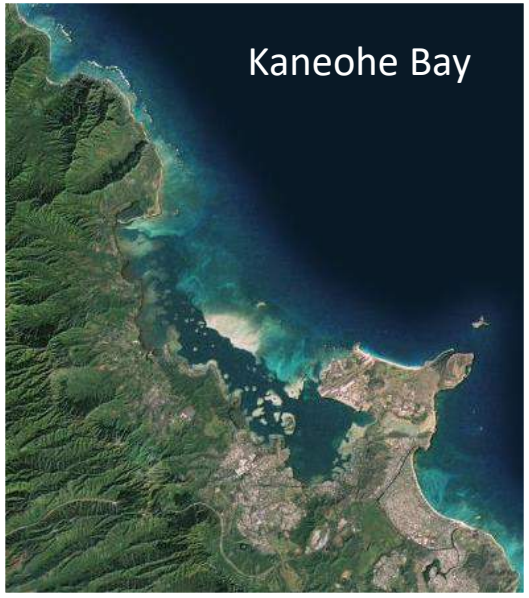
- Develop **workflows** for processing future satellite and AVIRIS benthic scenes.
- Investigate how different **image resolutions** impact benthic classification.
- Identify **environmental factors** that influence benthic habitat change.

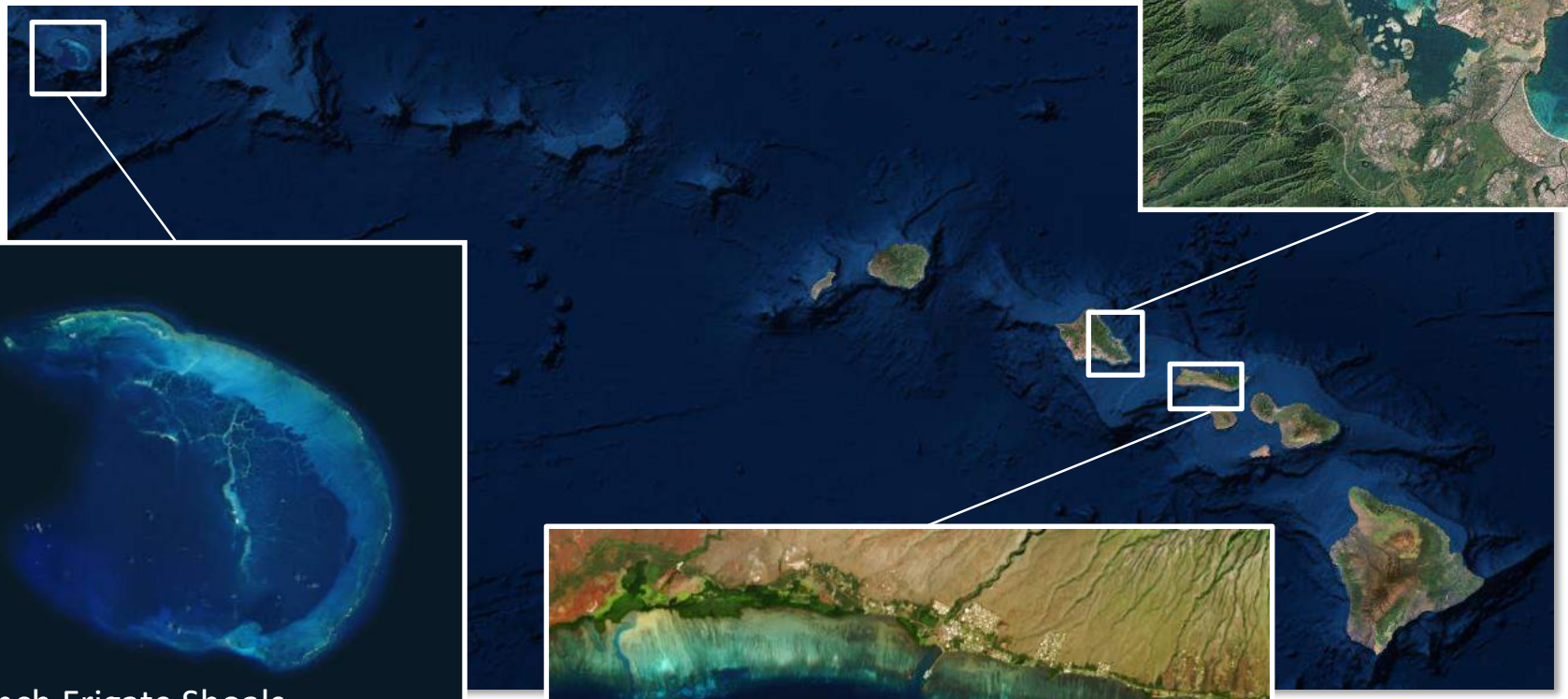
Credit: NOAA

Study Areas

Analysis focused on three areas of interest in Hawaii:

- Kaneohe Bay, Oahu
- South Coast Molokai
- French Frigate Shoals

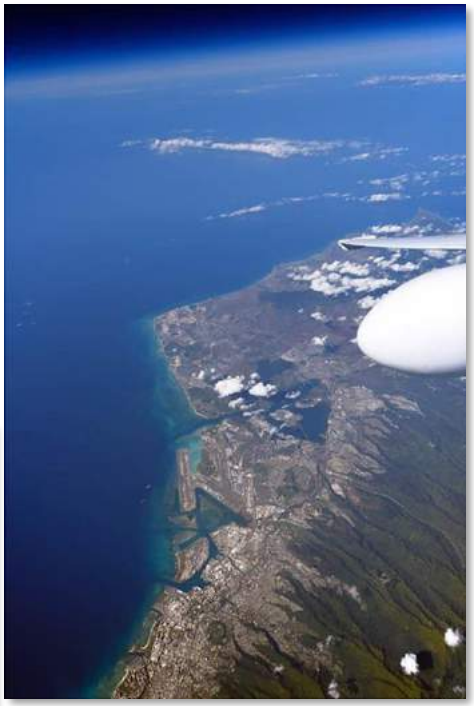




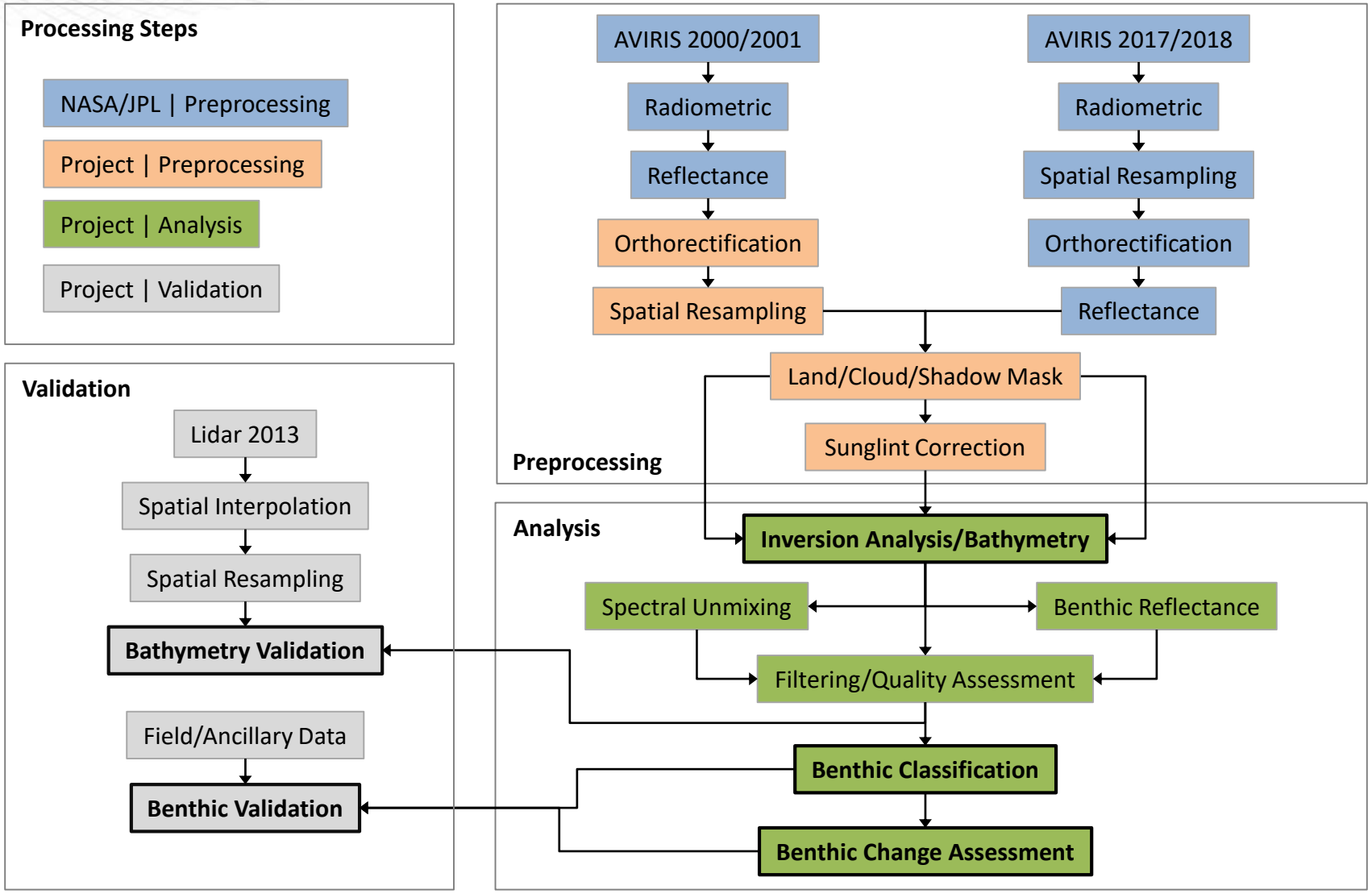
AVIRIS Missions

Project utilized data from four different AVIRIS missions:

- **2000** | Kaneohe Bay and French Frigate Shoals
- **2001** | Molokai
- **2017** | Kaneohe Bay, Molokai and French Frigate Shoals
- **2018** | Kaneohe Bay and Molokai

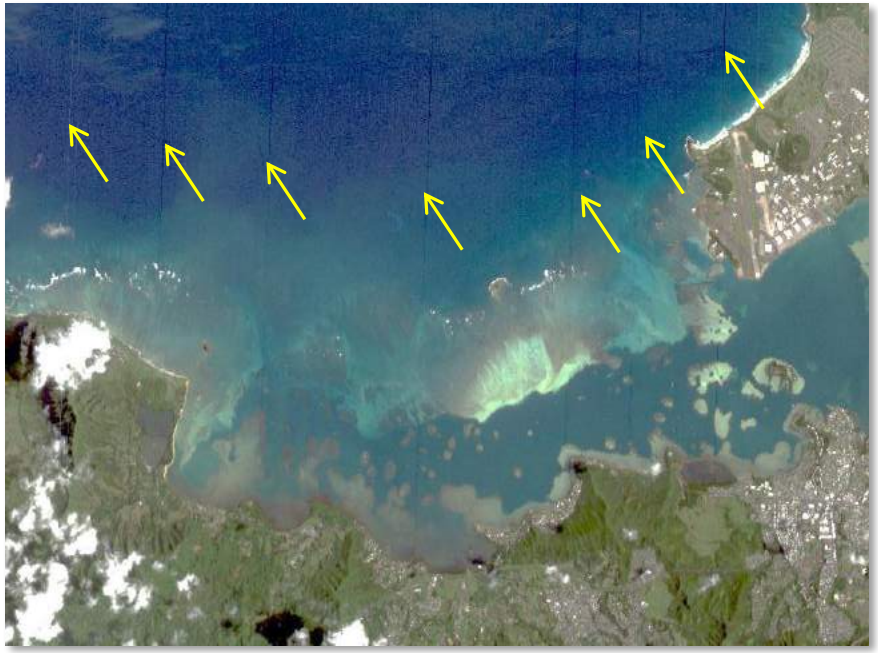


Data Analysis Workflow

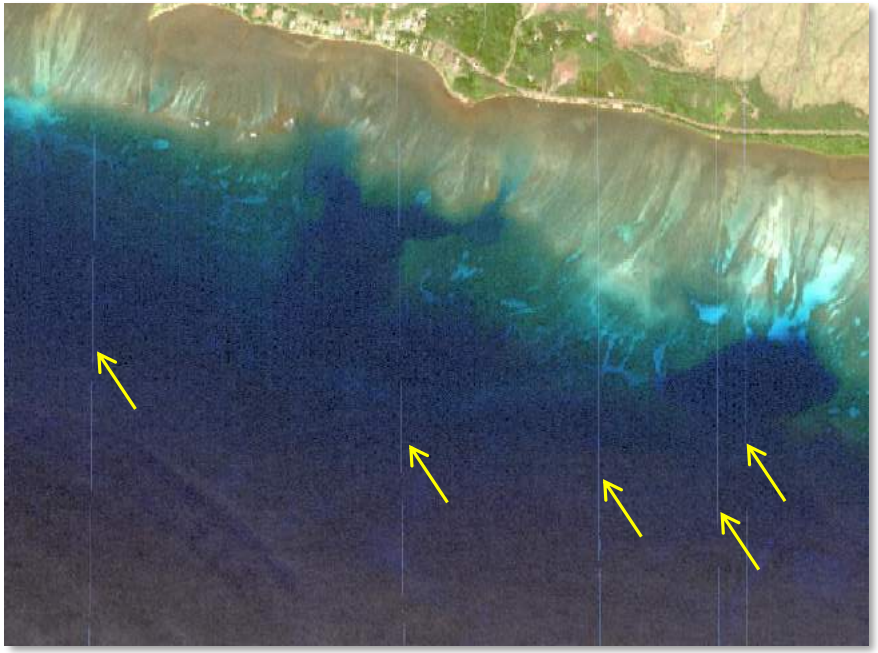


2018 Crosstrack Anomalies

- Unfortunately there are a series of crosstrack anomalies present throughout much of the 2018 data (erroneous linear spectral features).
- Fortunately data exists without these anomalies.



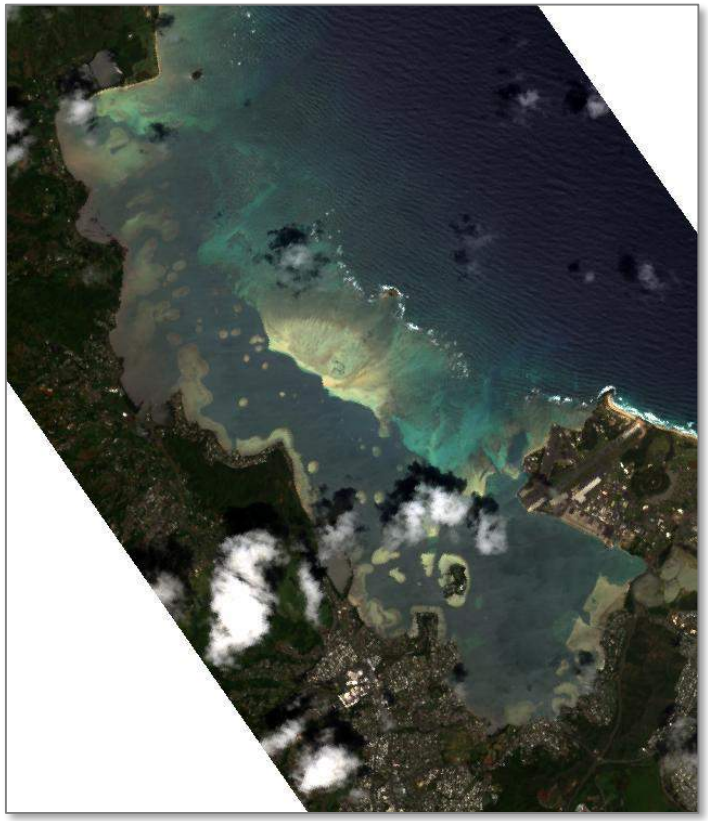
f180126t01p00r10_corr_v1i1_img
Kaneohe Bay

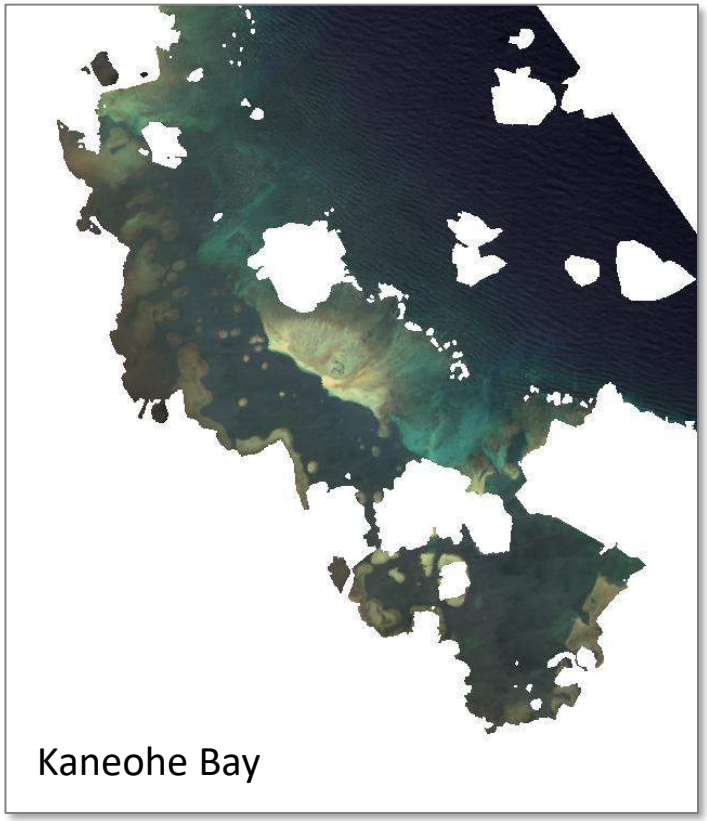


f180126t01p00r21_corr_v1i1_img
Molokai

Land, Cloud and Shadow Masks

- No single algorithm was found to be sufficiently robust to automate the process of delineating land, cloud and shadow versus water.
- We utilized a combination of band thresholds, spectral indices and manual editing to generate masks for each of the images.

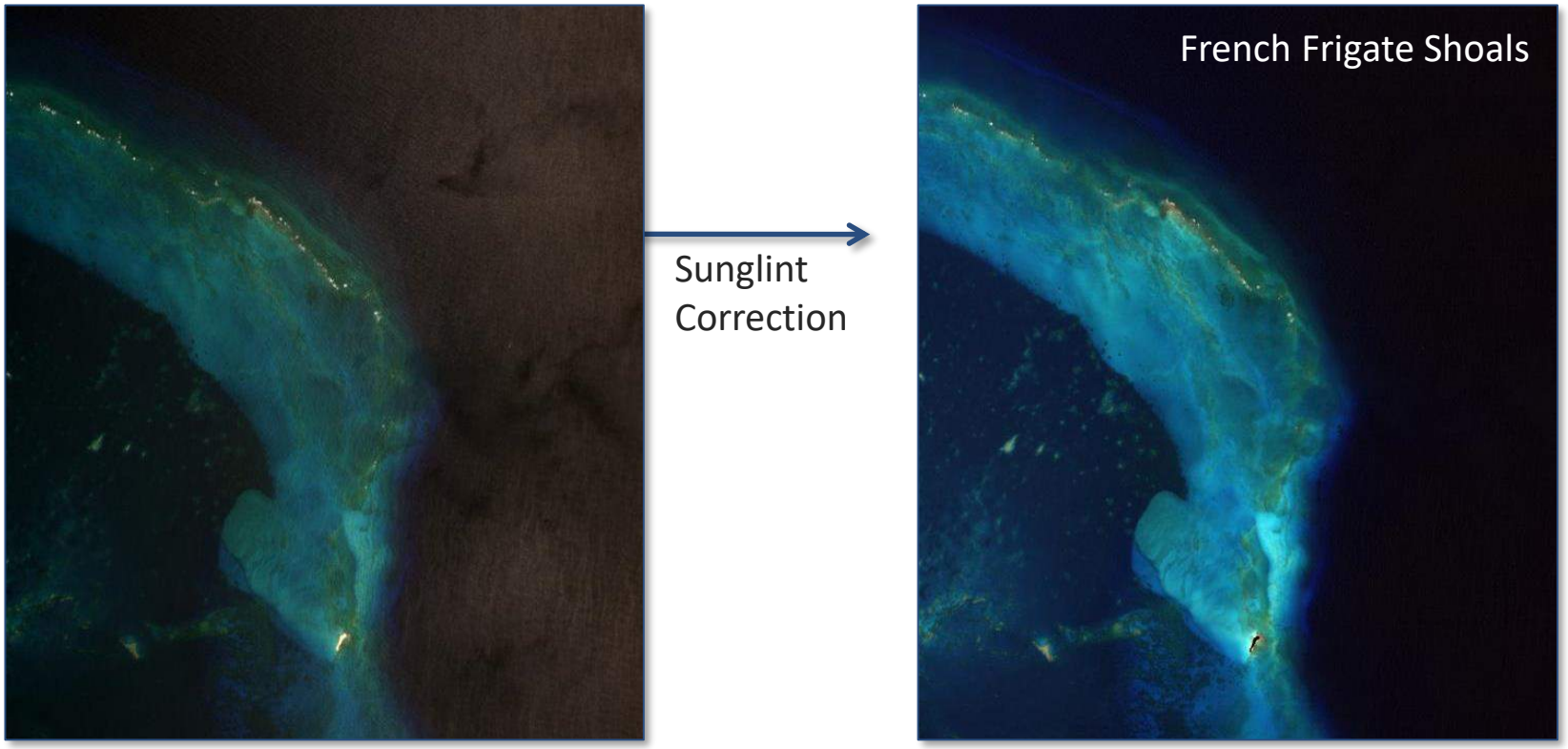




Kaneohe Bay

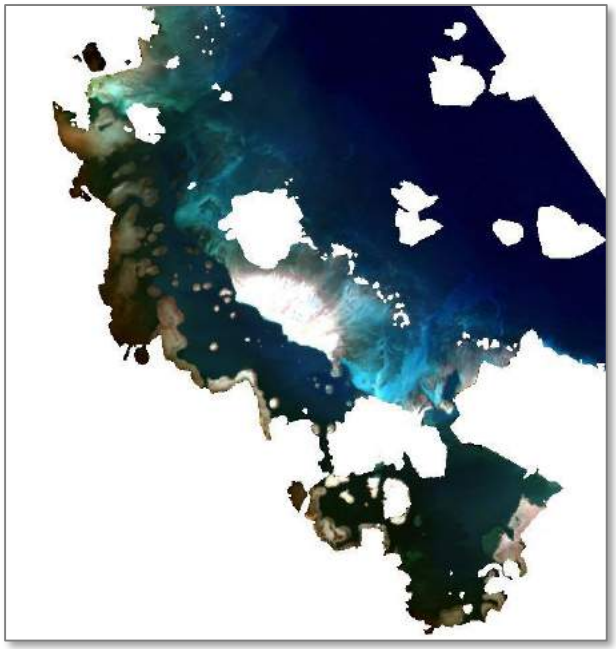
Sunglint Correction

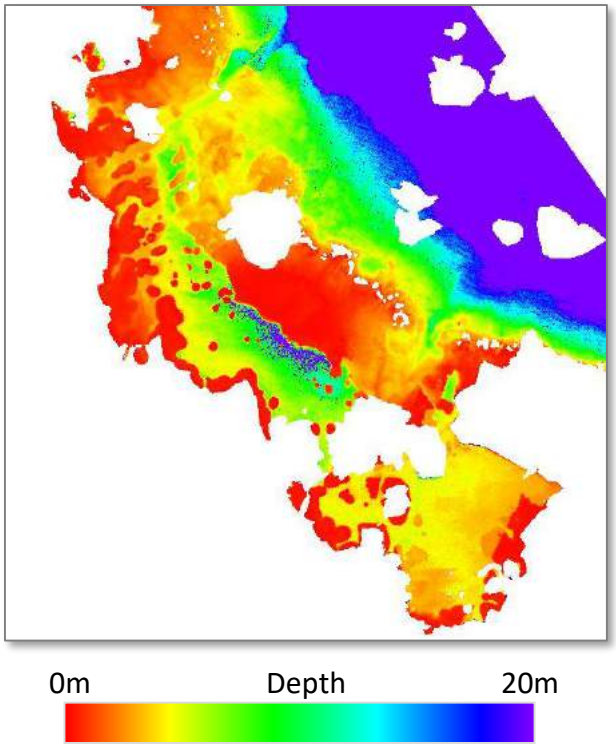
- Sunglint is significant in the 2000/2001 data, and minimal in the 2017/2018 data as a result of optimized acquisition parameters.
- A sunglint correction algorithm was used to minimize the impact of sunglint as well as help normalize surface reflectance between and within flightlines.

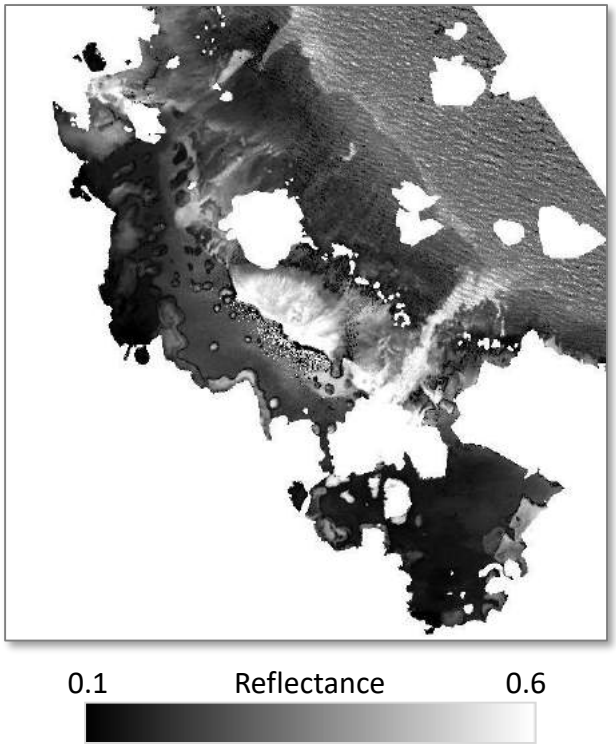


Inversion Model

- The hyperspectral inversion model provides an automated method for simultaneously deriving water depth, water properties and benthic albedo.
- Operates on a pixel-by-pixel basis with no need for any *a priori* information.



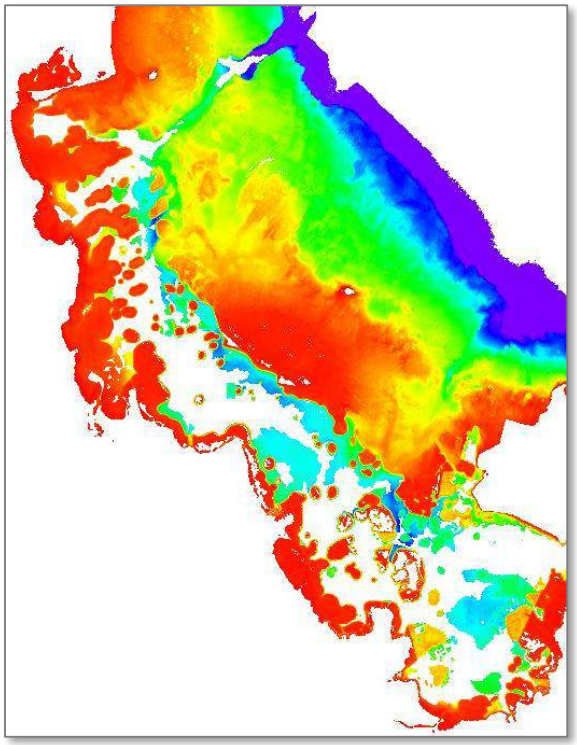




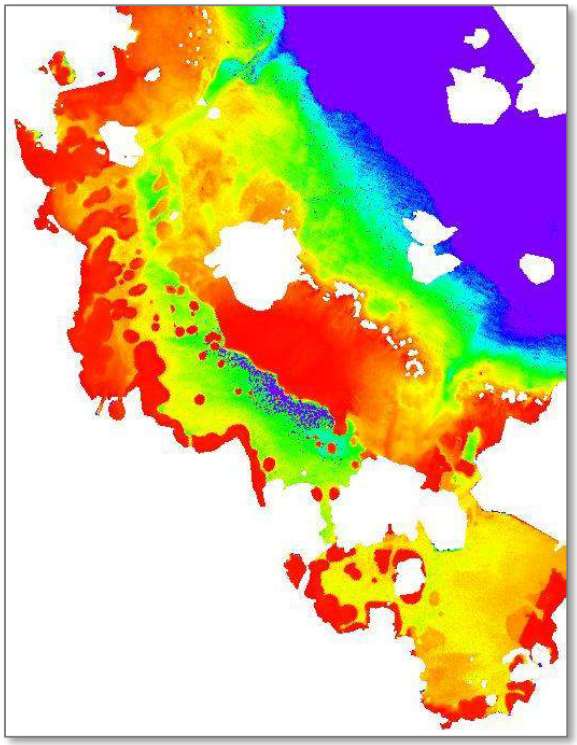
Bathymetry

- Derived water depth is one of the key output products that can be readily validated against measured lidar data.

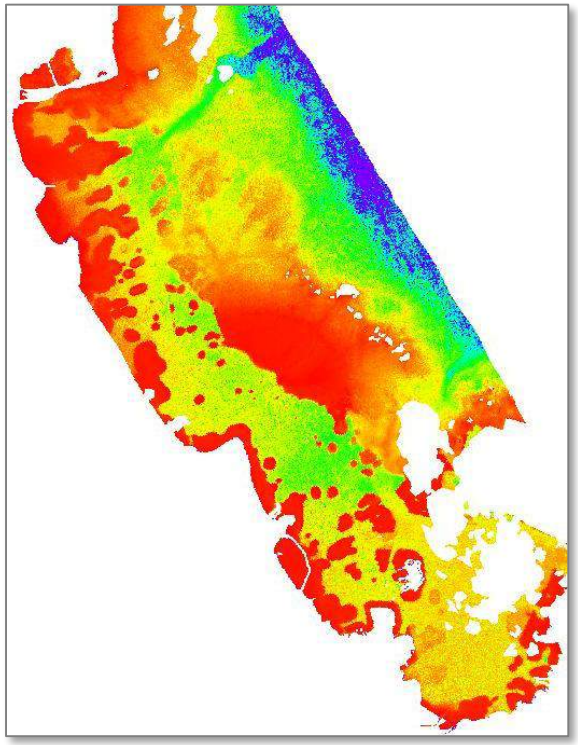
2013 Lidar



2000 AVIRIS

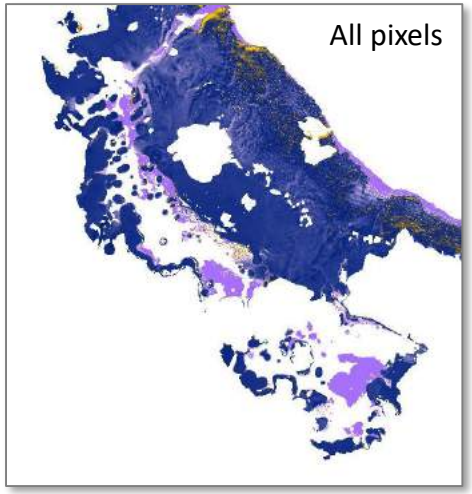


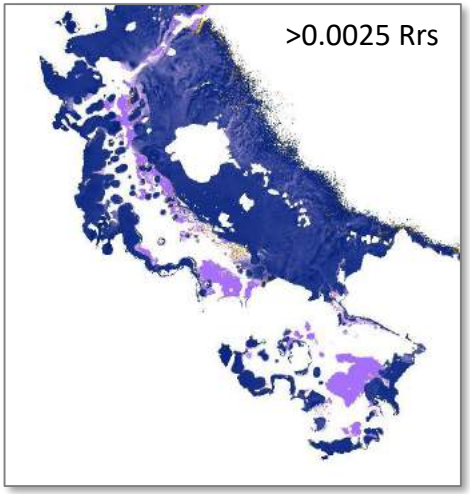
2017 AVIRIS

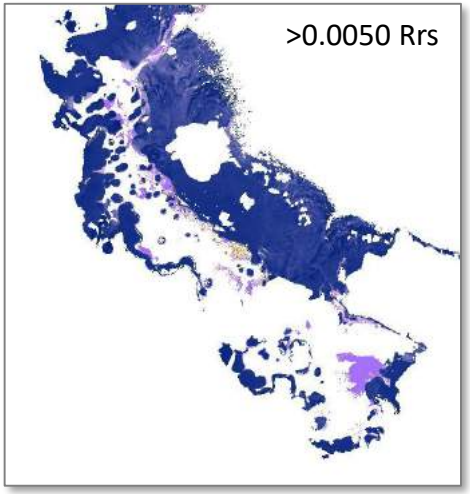


Confidence Levels

- Utilized derived bathymetry to determine confidence levels of inversion output based on surface reflectance and model metrics.



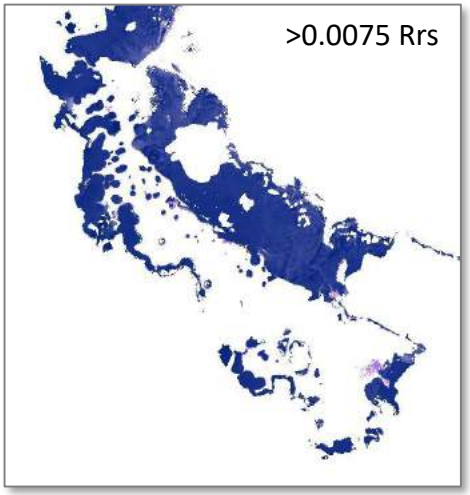


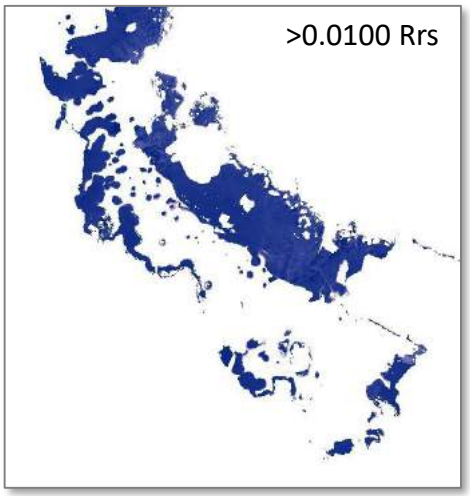


Bathymetry Difference
Derived - Measured

-5m 0m 5m

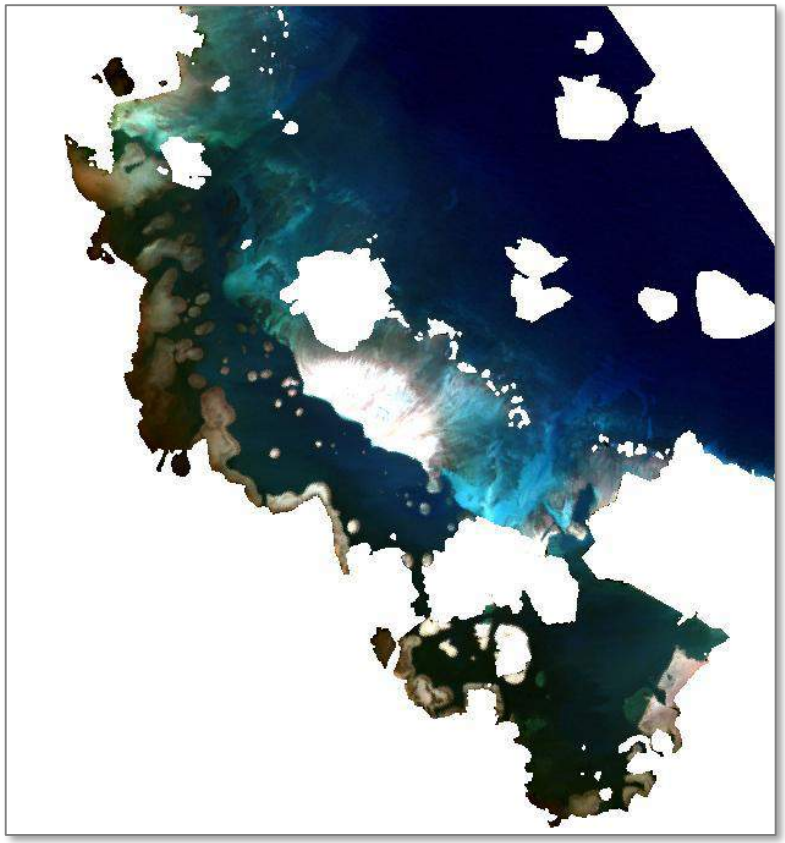
Difference

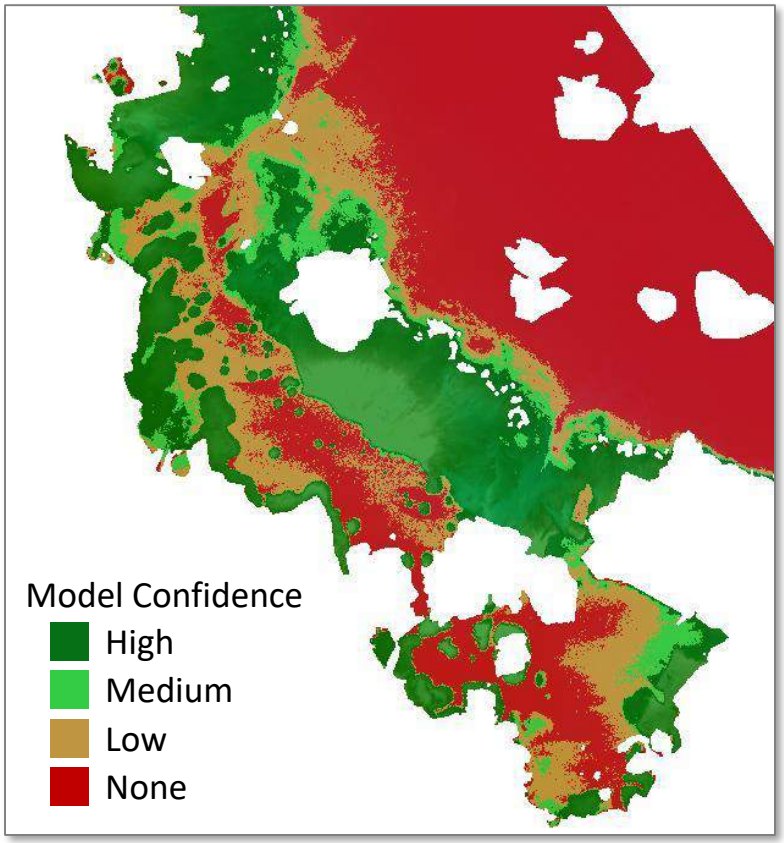




Confidence Levels

- Applied the derived confidence levels to model output in order to better inform subsequent analysis of benthic classification and change detection.





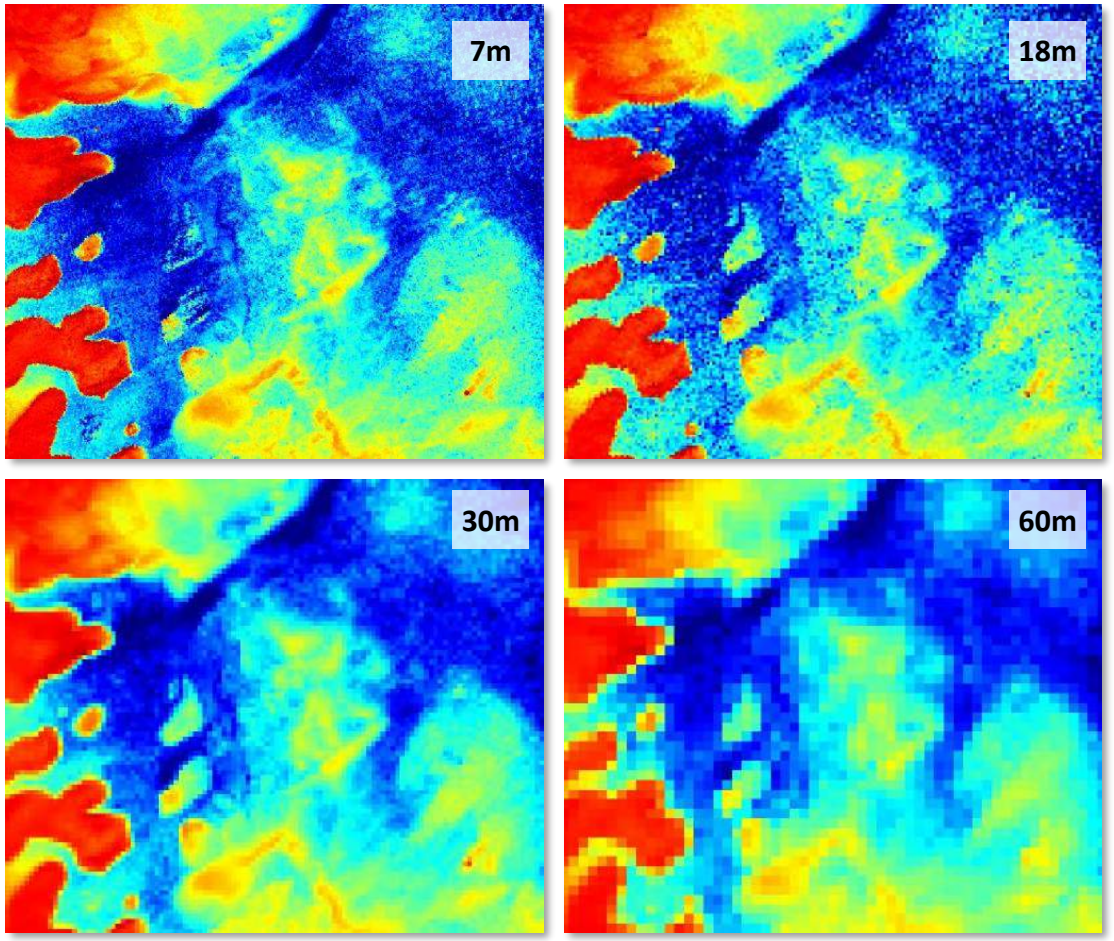
Bathymetry

Bathymetry validation was performed for each confidence level, as well as comparing output with and without sunglint corrections.

		>0.0025 Rrs			>0.005 Rrs			>0.0075 Rrs			>0.0100 Rrs		
	Deglint	r	mean	std dev	r	mean	std dev	r	mean	std dev	r	mean	std dev
Kaneohe Bay													
f000412t01p03r08	yes	0.90	-0.29	1.24	0.89	-0.21	0.94	0.94	-0.10	0.45	0.95	-0.08	0.32
f170303t01p00r07	no	0.89	-0.12	0.85	0.92	-0.04	0.34	0.94	-0.03	0.20	0.94	-0.03	0.16
	yes	0.88	-0.20	0.99	0.91	-0.08	0.40	0.94	-0.05	0.23	0.94	-0.04	0.18
f180212t01p00r07	no	0.61	-0.78	2.41	0.63	-0.38	1.52	0.86	-0.12	0.47	0.87	-0.07	0.30
	yes	0.73	-0.63	2.05	0.67	-0.37	1.48	0.86	-0.12	0.47	0.88	-0.07	0.30
f180129t01p00r07	no	0.76	-0.84	2.46	0.87	-0.22	0.80	0.93	-0.10	0.36	0.91	-0.06	0.26
	yes	0.86	-0.76	2.17	0.88	-0.22	0.78	0.93	-0.10	0.36	0.91	-0.07	0.27
Molokai													
f011102t01p03r07	yes	0.92	-0.11	0.32	0.92	-0.10	0.29	0.93	-0.09	0.26	0.94	-0.09	0.24
f170127t01p00r26	no	0.90	-0.02	0.90	0.92	-0.10	0.35	0.97	-0.08	0.21	0.97	-0.08	0.19
	yes	0.89	-0.20	0.90	0.91	-0.11	0.37	0.95	-0.10	0.23	0.95	-0.09	0.22
f180126t01p00r11	no	0.72	-0.49	1.94	0.72	-0.40	1.61	0.76	-0.19	0.61	0.79	-0.16	0.44
	yes	0.82	-0.46	1.08	0.79	-0.39	1.51	0.83	-0.20	0.57	0.84	-0.16	0.42

Spatial Resampling

- AVIRIS data was resampled to 18m, 30m, and 60m.
- Analysis was repeated at each different resolution.



Conclusions

Overall

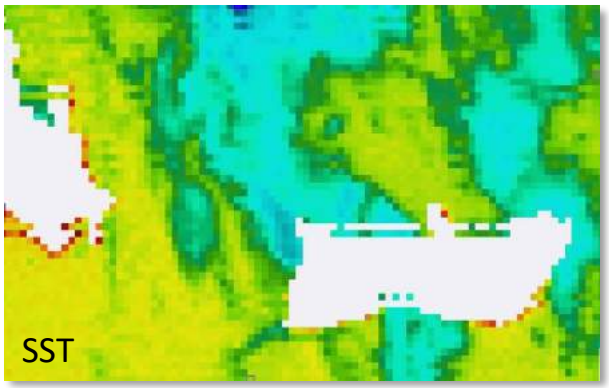
- The combined 2000/2001 and 2017/2018 AVIRIS datasets represent an invaluable resource for exploring hyperspectral remote sensing of coral reefs through space and time.
- Acquisition at higher solar angles, which facilitates higher signal, are an important consideration when balancing the tradeoffs associated with minimizing sunglint, which can be algorithmically mitigated.
- Inversion models can be used to simultaneously retrieve estimates of water depth and benthic albedo without need for any *a priori* information.

Processing Specific

- Operational applications require further development of supporting algorithms, such as cloud and cloud shadow masks.
- Filters can be used to establish different confidence levels in model output.
- Sunglint correction can effectively minimize the impacts of specular reflection from the water surface.

Future Directions

- Incorporate field data and existing benthic habitat maps to classify images.
- Identify areas of change between 2017/2018 and 2000/2001.
- Utilize random forest models to determine the influence of environmental parameters on benthic habitat change:
  - MODIS sea surface temperature
  - MODIS Chlorophyll-a and irradiance
  - Terrestrial landcover
  - Rainfall
  - Sedimentation loads
  - Wave power



- Investigate the influence of human development on benthic change based on highly developed area (Kaneohe Bay), minimally developed area (south coast of Molokai), and undeveloped area (French Frigate Shoals).

Thank you!

For questions and additional information:

- James Goodman | jgoodman@hyspeedcomputing.com
- Paul Haverkamp (PI) | pjhav@ucdavis.edu