



## FK180731 30-day Post Cruise Report

1. **Ship name:** Falkor
2. **Cruise Dates - Day Departed:** 7/31/2018
3. **Cruise Dates - Day Returned:** 8/16/2018
4. **Cruise Number:** FK180731
5. **Departure Port:** Astoria, OR, USA
6. **Arrival Port:** Astoria, OR, USA
7. **Mid-Cruise Port Call (if any):** None
8. **Mid-Cruise Port Call (if any):** None
9. **Participating Organizations, Institutions, Foundations, Government Agencies, etc.:**  
University of Southampton, The University of Tokyo, Kyushu Institute of Technology, The University of the Balearic Islands, Tokyo University of Marine Science and Technology, University of Sydney, University of Aberdeen, National Oceanography Centre, Sonardyne International Ltd, Greybits Engineering LLC.
10. **Funding Sources:** Cross-Ministerial Strategic Innovation Program (Japan), Next-generation Technology for Ocean Resources Exploration - Development of ecosystem survey and long-term monitoring technologies; Natural Environment Research Council (United Kingdom), NE/P020887/1, BioCam - Mapping of Benthic Biology, Geology and Ecology with Essential Ocean Variables; Natural Environment Research Council (United Kingdom), NE/R01227X/1, RamaCam - In situ holographic imaging and chemical spectroscopy for long term scalable analysis of marine particles in deep-sea environments; Engineering and Physical Sciences Research Council (United Kingdom), EP/S001182/1, Mapping in the Background: Scalable capabilities using low-cost passive robotic systems for seafloor imaging
11. **Describe all of the geographical area(s) where the science occurred:** Hydrate Ridge, Cascadia Margin, Eastern Pacific
12. **Name of Chief Scientist:** Blair Thornton  
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- 13. Cruise Objectives:** This is an engineering development cruise to demonstrate adaptive mission planning of multiple underwater robots when surveying dynamically changing gas hydrate environments at Hydrate Ridge. The objective is to demonstrate how efforts in seafloor observation can be focused using algorithms to visualise, explore and interpret large volumes of seafloor imagery and chemical measurements in operationally relevant time-frames. The effectiveness of this approach will be shown by generating multi-parameter and multi-resolution seafloor data products that have increased levels of detail and information in the regions that are of most scientific value. The focus is on advancing robotic survey technology rather than oceanographic exploration.

**14. Cruise Summary:**

More than 2TB of seafloor imagery (1.3 million images), chemical sensor data and multibeam data were collected using 4 underwater robotic platforms (IIS UTokyo Autonomous Underwater Vehicles (AUVs) AE2000f, Tuna-sand, Tuna-sand 2 and the SOI Remotely Operated Vehicle (ROV) Subastian) and the RV Falkor. A total of 19 AUV dives, including 8 multi-vehicle dives, and 13 ROV dives were carried out. Since small boats were used to assist the recovery of the AUVs, operations were restricted to daylight hours. The AUVs were launched and recovered using the aft deck starboard crane and their position was monitored using an over-the-side USBL and modem setup that was lowered from the ship's CTD crane. The ROV was launched and recovered using the aft-deck A-frame.

A 2 phase strategy was employed for data collection, where in phase 1, the AE2000f acted as our scout to identify areas of interest for more detailed observation. AE2000f was deployed at 2 sites (Southern summit at a depth of 780m and Northern summit at a depth of 680m) to collect ~17.4 hectares of dense grid 3D seafloor imagery at a resolution of approximately 1 cm. This data (consisting of ~620,000 images) was processed during the cruise to generate colour corrected 3D visual reconstructions with overlaid seawater pH and temperature plots and the results of unsupervised clustering algorithms to summarise the observations and highlight the broad-scale patterns in the observations. Overnight multibeam bathymetry surveys of the study sites were also carried out in the regions surrounding these 2 sites using the RV Falkor.

At the Northern summit, drill holes and infrastructure at Ocean Drilling Program (ODP) site 892 and an anomalous region of the seafloor were identified by the algorithms. At the Southern summit, a number of bacterial mats, drill holes at ODP site 1249 and

cabled arrays of the Ocean Observatories Initiative (OOI) were identified. These sites formed the focus of the next phase (phase 2) of operations to collect more detailed information at higher resolution. For this, the AUVs Tuna-sand and Tuna-sand 2 were used. During one of the early deployments of Tuna-sand 2, an issue occurred with the vehicle's main CPU that could not be addressed while on-board the RV Falkor, preventing useful data from being collected by this AUV. Tuna-sand was therefore deployed to the locations of interest identified in AE2000f's data. Tuna-Sand successfully carried out 10 dense 20 x 20m grid surveys (consisting of ~730,000 images) with water-column pH and temperature overlays. These datasets were also processed to generate colour corrected 3D visual reconstructions with overlaid seawater pH and temperature plots and unsupervised clustering algorithms were used to summaries their observations. Tuna-Sand was deployed simultaneously with AE2000f on several occasions in order to fill in gaps and extend its wide-area mapping data.

As part of phase 2, the ROV Subastian was also deployed to make detailed visual observations using its forward looking camera, collect water-column CTD, pH and temperature data, and also carry out Laser Raman spectroscopic measurements of sub-surface sediment pore water at depths of 10, 20 and 30 cm below the sediment surface. In order to achieve this at key points of interest identified in the data collected by AE2000f and Tuna-Sand, a Geographic Information System (GIS) populated with the observational data of the AUVs and their interpreted summaries was generated, with the real-time location of the ROV overlaid onto it. This allowed the ROV pilots to navigate to regions of interest, avoid known hazards such as cables and infrastructure, and visit specific locations, such as bubble plumes, particular rocks and areas with discoloured seafloors, to efficiently perform precisely targeted measurements. A mechanical issue with the pump system used by the Laser Raman probe prevented useful data from being collected during the initial deployments. These mechanical issues were addressed during the cruise, allowing sub-surface chemical measurements to be obtained at a number of key locations during the latter stages of the cruise.

- 15. Did you collect Measurements or Samples, including biological specimens?** Seafloor imagery, pH, CTD, temperature, sub-surface Raman spectra, sub-surface temperature
- 16. Did you deploy and/or recover any Moorings, Bottom Mounted Gear, or Drifting Systems?** A seafloor camera calibration board was deployed and recovered during the cruise.
- 17. Equipment Used:** AE2000f, a 2000m depth rated flight-style AUV instrumented with a high-altitude (8m range) 3D imaging system and a water-column pH and temperature sensor. AE2000f operates at approximately 2knots at an altitude of 8m, allowing it to visually map the seafloor at a rate of up to ~40,000m<sup>2</sup>/h at ~8mm pixel resolution. AE2000f is 3m long and weighs 370kg in air.

Tuna-sand, a 1500m depth rated hover-capable AUV equipped with a high-resolution 3D imaging systems and a water-column pH and temperature sensor. Tuna-sand operates at approximately 0.4knots from ~2m altitude to map the seafloor at a rate of ~800m<sup>2</sup>/h at ~0.8mm pixel resolution. Tuna-Sand is 1.1m long and weighs 280kg in air.

Tuna-sand 2, a 2000m depth rated hover-capable AUV equipped with high-resolution 3D imaging systems and a water-column pH and temperature sensor. Tuna-sand 2 operates at approximately 0.4knots from ~2m altitude to map the seafloor at a rate of ~800m<sup>2</sup>/h at ~1.2mm pixel resolution. Tuna-Sand 2 is 1.4m long and weighs 380kg in air.

Laser Raman probe, a 2000m depth rated chemical analytic device consisting of a main bottle (containing a 532nm laser, spectrometer, detector and control CPU) coupled through a 6m long fibre optic cable to a focusing optic that can be held by an ROV manipulator. During this cruise, the focusing optic was coupled to a pump to draw in sub-surface sediment pore water to the measurement region of the device. The main body of the device is 0.8m without the fibre, and weighs 75kg in air.

QGIS mission progress visualisation and data processing tools.

**18. Station Plots:** *upcoming*

**19. Other:** Outreach activities consisting of ship to shore video live feed events and ask-me-anything discussions were carried out on the following dates:

31st July 2018, Ship to Shore: Secondary school students participating in the Smallpiece trust summer school programme at the University of Southampton.

6th August 2018, Ask-me-anything: Underwater Robotics in Oceanography

9th August 2018, Ship to Shore: Smithsonian National Museum of Natural History

15th August 2018, Ship to Shore: Smithsonian National Museum of Natural History





Platforms



AE2000f  
Wide area imaging: SeaXerocks  
Chemistry: pH, temperature



Tuna Sand  
Detailed imaging: Unagi 6k  
Chemistry: pH, temperature

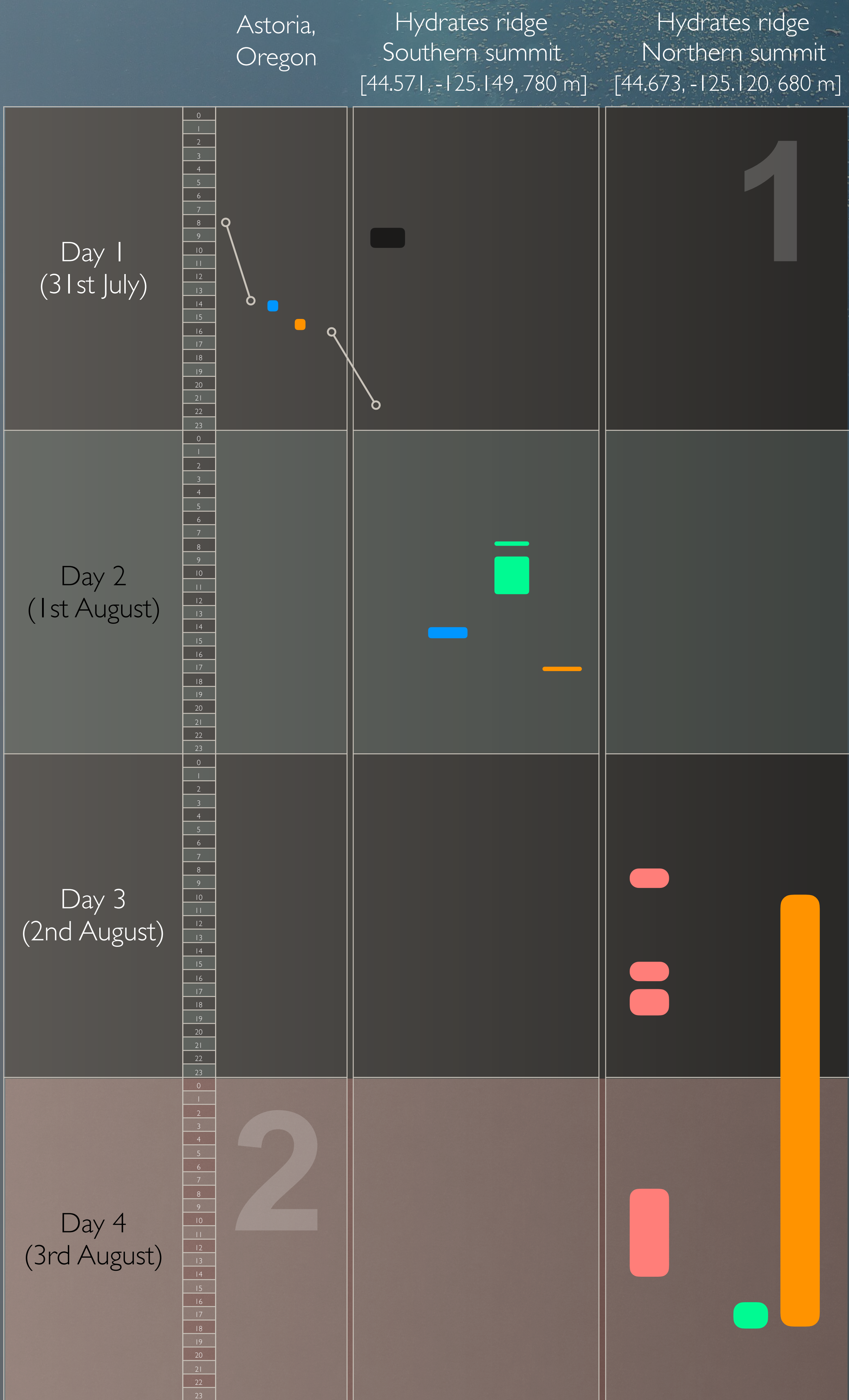


Subastian  
Subsurface chemistry: Raman spectroscopy  
Chemistry: pH, temperature, CTD



Tuna Sand 2  
Imaging: SeaXerocks LED 1.5-3 m altitude  
Chemistry: pH, temperature

Timeline



Paths from root data directory

\$qgis = qgis/fk180731/trajectories  
\$raw = raw/2018/fk180731  
\$proc = processed/2018/fk180731

08:00 depart Astoria  
08:25 to 08:45 Ship to shore with Small Piece

14:15 to 15:06  
• 45.616, -124.857, 1375 m \$qgis/waypoints/ctd\_unagi6k\_20180731\_141500.csv  
• Unagi 6k pressure test to 900 m

15:41 to 16:05  
• 45.609, -124.880, 1375 m \$qgis/waypoints/subastian\_20180731\_154100.csv  
• ROV sensor test at 50 m

22:00 arrive at survey site

08:23 to 08:30  
• ROV ground fault  
09:23 to 12:02  
• Seawater density profile \$qgis/waypoints/subastian\_20180801\_092300.csv  
• Set calibration board \$raw/subastian/20180801\_092313\_sub\_ram  
• Confirm Marum sonar towers

14:44 to 15:04  
• Buoyancy and communication check with 20m rope and buoy \$qgis/waypoints/ts\_20180801\_144400.csv

17:18 to 17:4  
• Buoyancy and communication check with 20m rope and buoy \$qgis/waypoints/ts2\_20180801\_171800.csv

08:36 to 09:57  
• Buoyancy and communication check with 20m rope and buoy \$qgis/waypoints/ae2000f\_20180802\_083600.csv

10:42 to 18:23 (+1 day)  
• Seafloor observation test \$qgis/waypoints/ts2\_20180802\_104200.csv  
• OS crash requiring rescue

15:25 to 16:42  
• Error; Glide mode set  
17:25 to 19:12 \$raw/ae2000f/20180802\_172527\_ae2000f\_sx3  
• Laser calibration

08:19 to 14:20  
• Wide area mapping \$qgis/localisation/20180803\_065749\_ae2000f\_sx3/  
• 108,530 images csv/dead\_reckoning/auv\_dr\_Xviii\_Cam51707923.csv  
\$raw/ae2000f/20180803\_065749\_ae2000f\_sx3  
\$proc/meshes/hydrate\_ridges\_north\_ae2000f  
\$proc/mosaics/20180803\_065749\_ae2000f\_sx3.tiff

16:34 to 18:23  
• Visual confirmation of TS2  
• Recovery to surface



		Astoria	Hydrates ridge Southern summit	Hydrates ridge Northern summit
Day 5 (4th August)	0			
	1			
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	19			
	20			
	21			
	22			
	23			
Day 6 (5th August)	0			
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Day 7 (6th August)	0			
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Day 8 (7th August)	0			
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	21			
	22			
	23			
Day 9 (8th August)	0			
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Day 10 (9th August)	0			
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	23			
Day 11 (10th August)	0			
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	23			

\$qqis = qqis/fk180731/trajectories
\$raw = raw/2018/fk180731

\$proc = /processed/2018/fk180731

08:07 to 13:54

- Wide area mapping
- 76,768 images

\$qqis/localisation/20180804\_093404\_ae2000f\_sx3/csv/dead\_reckoning/auv\_dr\_Xviii\_Cam51707923.csv
\$raw/ae2000f/20180804\_093404\_ae2000f\_sx3
\$proc/meshes/hydrate\_ridges\_south\_ae2000f
\$proc/mosaics/20180804\_093404\_20180804\_143258\_20180805\_123456\_20180809\_083837\_ae2000f\_sx3.tiff

14:17 to 19:21

- Wide area mapping
- 98,030 images

\$qqis//localisation/20180804\_143258\_ae2000f\_sx3/csv/dead\_reckoning/auv\_dr\_Xviii\_Cam51707923.csv
\$raw/ae2000f/20180804\_143258\_ae2000f\_sx3
\$proc/meshes/hydrate\_ridges\_south\_ae2000f
\$proc/mosaics/20180804\_093404\_20180804\_143258\_20180805\_123456\_20180809\_083837\_ae2000f\_sx3.tiff

09:08 to 12:50

- Vertical thruster failure abort

13:30 to 19:30

- Wide area mapping
- 133560 images

\$qqis/localisation/20180805\_123456\_ae2000f\_sx3/csv/dead\_reckoning/auv\_dr\_Xviii\_Cam51707923.csv
\$raw/ae2000f/20180805\_123456\_ae2000f\_sx3
\$proc/meshes/hydrate\_ridges\_south\_ae2000f
\$proc/mosaics/20180804\_093404\_20180804\_143258\_20180805\_123456\_20180809\_083837\_ae2000f\_sx3.tiff

14:25 to 17:17

- Detailed mapping
- 91,396 images

\$qqis/localisation/20180805\_123456\_ae2000f\_sx3/csv/dead\_reckoning/auv\_dr\_Xviii\_Cam51707923.csv
\$raw/tuna\_sand/20180805\_215810\_ts\_un6k
\$proc/meshes/20180805\_213810\_ts\_un6k
\$proc/mosaics/20180805\_215810\_ts\_unk6k.tiff

08:25 to 08:45

Ask-me-anything: Robotics in Oceanography

08:03 to 11:08

- Detailed mapping
- 113,392 images

\$qqis/localisation/20180806\_153714\_ts\_un6k/csv/dead\_reckoning/auv\_dr\_LC.csv
\$raw/tuna\_sand/20180806\_153714\_ts\_un6k
\$proc//meshes/hester\_site\_tuna\_sand
\$proc/mosaics/20180806\_153714\_ts\_un6k.tiff

13:36 to 17:29

- Detailed mapping
- 126,462 images

\$qqis/localisation/20180806\_210350\_ts\_un6k/csv/dead\_reckoning/auv\_dr\_LC.csv
\$rawtuna\_sand/20180806\_210350\_ts\_un6k
\$proc/meshes/20180806\_210350\_ts\_un6k\_2
\$proc/mosaics/20180806\_153714\_ts\_un6k.tiff

08:00 to 11:32

- Subsurface chemistry

\$raw/subastian/20180807\_075440\_sub\_ram

16:36 to 19:33

- Subsurface chemistry

08:19 to 15:30

- Subsurface chemistry

\$raw/subastian/20180808\_075158\_sub\_ram

16:36 to 19:33

- Subsurface chemistry

08:19 to 15:30

- Subsurface chemistry

\$raw/subastian/20180808\_075158\_sub\_ram

16:36 to 19:33

- Subsurface chemistry

08:19 to 15:30

- Subsurface chemistry

\$raw/subastian/20180808\_075158\_sub\_ram

16:36 to 19:33

- Subsurface chemistry

08:25 to 08:45

Ship to shore with the Exploratorium

09:41 to 18:44

- Wide area mapping
- 206,842 images

\$qqis//localisation/20180809\_083837\_ae2000f\_sx3/csv/dead\_reckoning/auv\_dr\_Xviii\_Cam51707923.csv
\$raw/aae2000f/20180809\_083837\_ae2000f\_sx3
\$proc/meshes/hydrate\_ridges\_south\_ae2000f
\$proc/mosaics/20180804\_093404\_20180804\_143258\_20180805\_123456\_20180809\_083837\_ae2000f\_sx3.tiff

11:06 to 14:54

- Detailed mapping
- 126,748 images

\$qqis/localisation/20180809\_183741\_ts\_un6k/csv/dead\_reckoning/auv\_dr\_LC.csv
\$raw/tuna\_sand/20180809\_183741\_ts\_un6k
\$proc/meshes/20180809\_183741\_ts\_un6k\_2
\$proc/mosaics/20180809\_183741\_ts\_un6k\_2.tiff

09:05 to 12:19

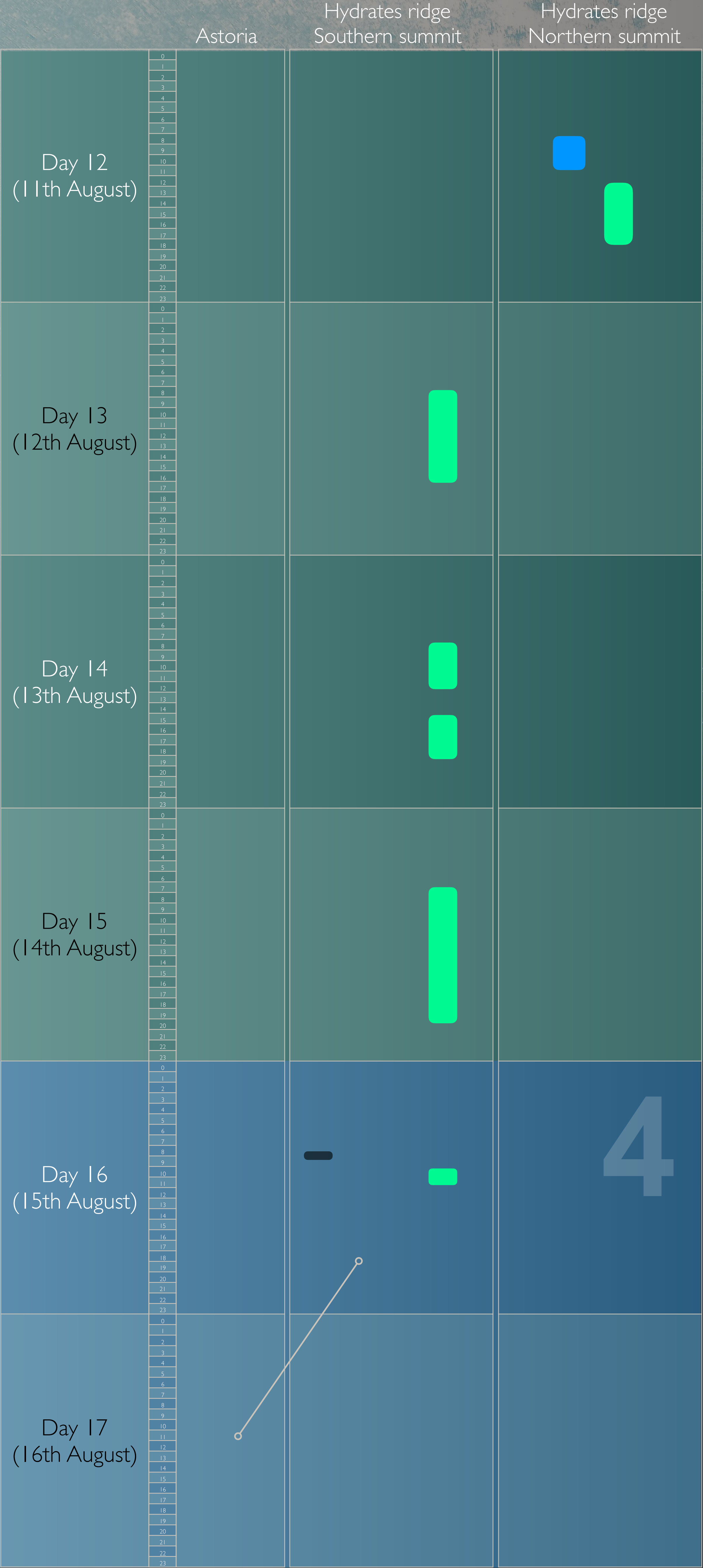
- Camera did not boot

13:44 to 17:13

- Detailed mapping
- 134,440 images

\$qqis/localisation/20180810\_211206\_ts\_un6k/csv/dead\_reckoning/auv\_dr\_LC.csv
\$raw/tuna\_sand/20180810\_211206\_ts\_un6k
\$proc/meshes/meshes/20180810\_211206\_ts\_un6k
\$proc/mosaics/20180810\_2111206\_ts\_un6k





\$qgis = qgis/fk180731/trajectories

\$proc = /processed/2018/fk180731

\$raw = raw/2018/fk180731

08:09 to 11:38

• Detailed mapping

• 135,116 images

\$qgislocalisation/20180811\_153727\_ts\_un6k/csv/dead\_reckoning/auv\_dr\_LC.csv

\$raw/tuna\_sand/20180811\_153727\_ts\_un6k

\$proc/meshes/whale\_fall\_tuna\_sand

\$proc/mosaics/20180811\_153727\_ts\_un6k.tiff

12:36 to 18:45

• Subsurface chemistry

\$raw/subastian/20180811\_121759\_sub\_ram

08:06 to 17:03

• Subsurface chemistry

\$raw/subastian/20180812\_080600\_sub\_ram

08:04 to 12:50

• Subsurface chemistry

15:06 to 19:13

\$raw/subastian/20180813\_062254\_sub\_ram

• Subsurface chemistry

07:20 to 20:20

• Subsurface chemistry

\$raw/subastian/20180814\_080257\_sub\_ram

08:25 to 08:45

Ship to shore with the Exploratorium

10:06 to 11:51

• Recover calibration board

18:00 depart from survey site

11:00 arrive at Astoria

# Achievements

- 19 AUV deployments (8 multi-AUV dives) and 13 ROV dives
- 1,351,284 images (623,730 wide area, 727,554 detailed)
- 17.4 ha of seafloor mapped at sub-centimeter resolution
- 0.4 ha of targeted mapping at sub-millimeter resolution