UAS Activities at Lamont-Doherty Earth Observatory of Columbia Universityms

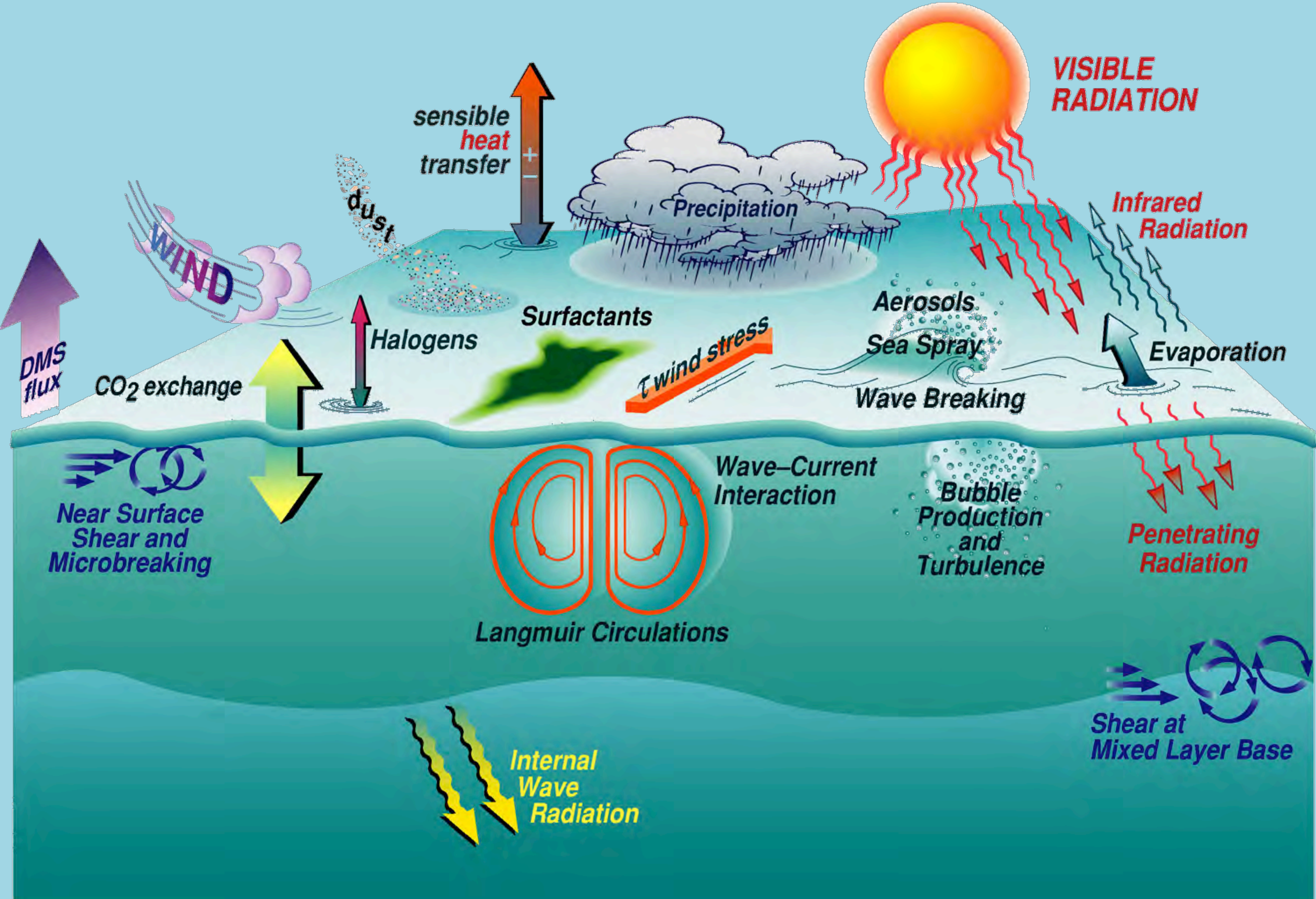
Christopher J. Zappa
Lamont-Doherty Earth Observatory, Columbia University

LDEO Team: S. Brown, T. Dhakal, C. Bertinato, N. Frearson.

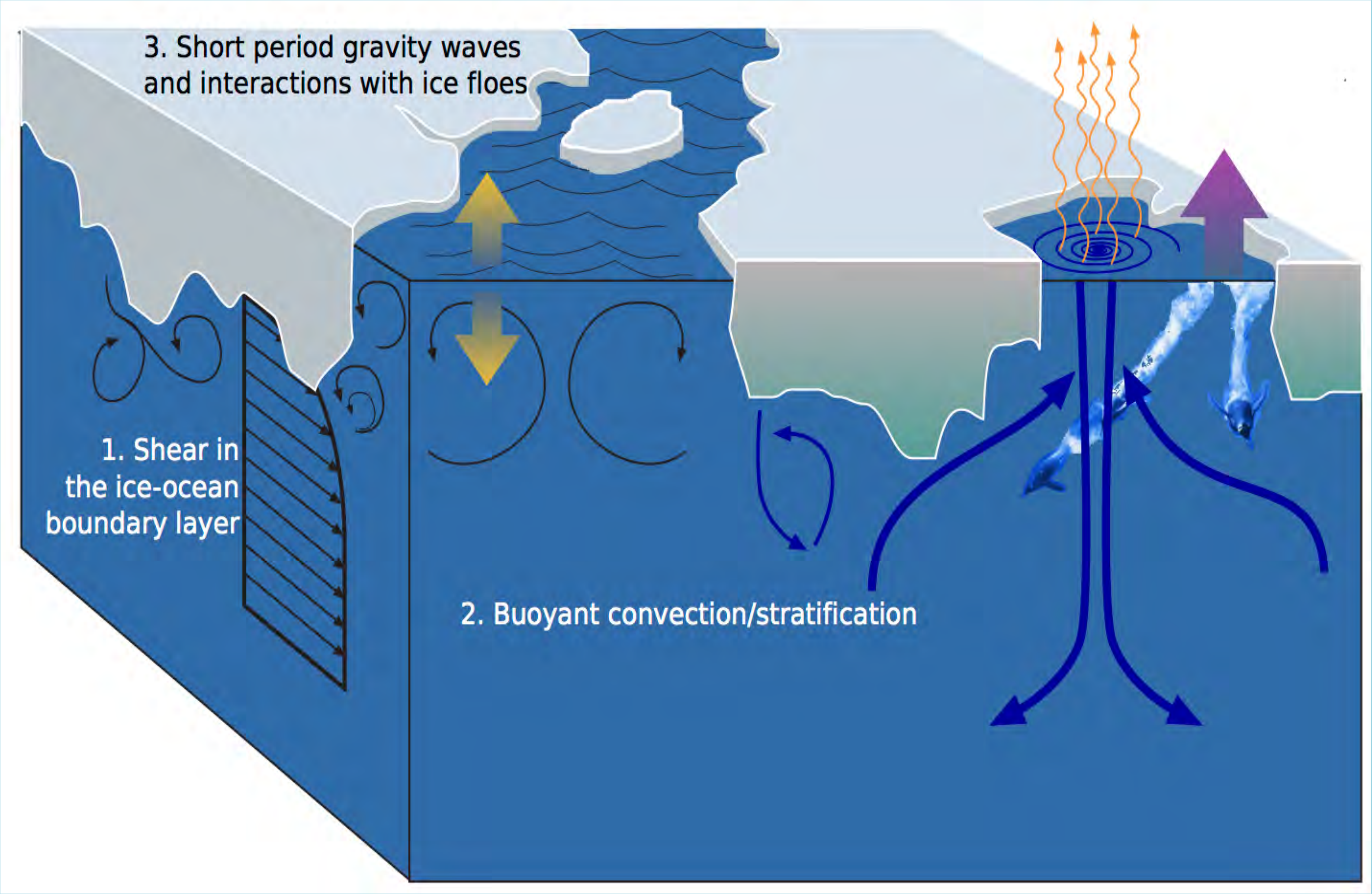
Acknowledgment to NASA UAS Program, NSF Polar Programs, the Moore Foundation, and Schmidt Ocean Institute.

2016 SCOAR Meeting, CIRPAS, Marina, CA June 28, 2016

Air-Sea Interaction Processes



Turbulence Mechanisms in Polar Systems

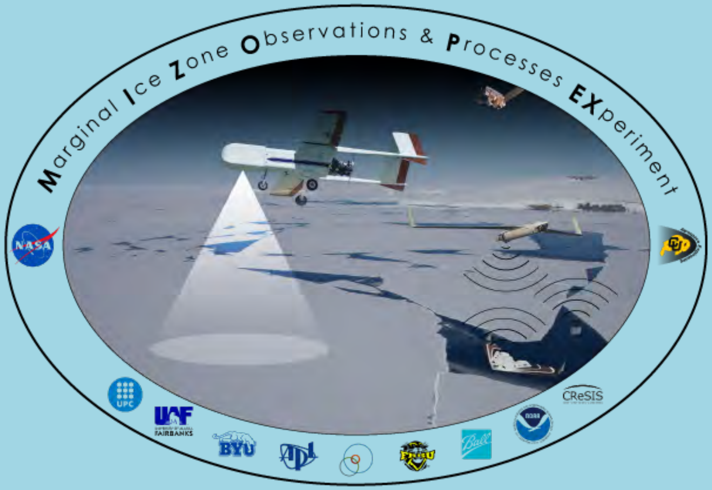


- Three mechanisms for mixing / turbulence that are not prevalent in low-latitude environments.
- Compare the structure of circulation and mixing of the influx of cold skin SST driven by surface currents and wind.

MIZOPEX 2013

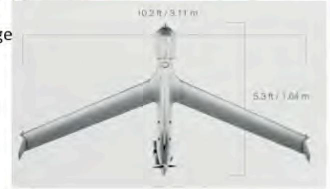
Goals:

- Assess ocean and sea ice variability in the Alaskan Arctic Ocean (Beaufort Sea/Prudhoe Bay area).
- Demonstrate potential for research using multiple unmanned aircraft systems (UAS) in polar regions.
- Determine best practices for safe, reliable operations in the National Air Space.



Overview of the UAF-Operated InSitu ScanEagle UAS

- Wingspan: 10.2 ft, Length: 4.5 ft
- Weight: 29 lbs (empty), 44 lbs (max takeoff wt.)
- Gas engine (1.9 hp), rear propeller, onboard generator for electric power
- 48 knot airspeed (cruise)
- Catapult launch, wing tip capture via cable
- Autonomous flight control with GCS control while in line of sight radio range (approx 40 km)
- Iridium satcom for over the horizon operations
- Endurance: 20+ hours
- Ceiling: 19,500 ft.
- Payload: up to ~6 lbs.
- Has received numerous FAA Certificates of Authorization, thousands of flight hours achieved.



The "Marginal Ice Zone Observations and Processes EXperiment" (MIZOPEX)

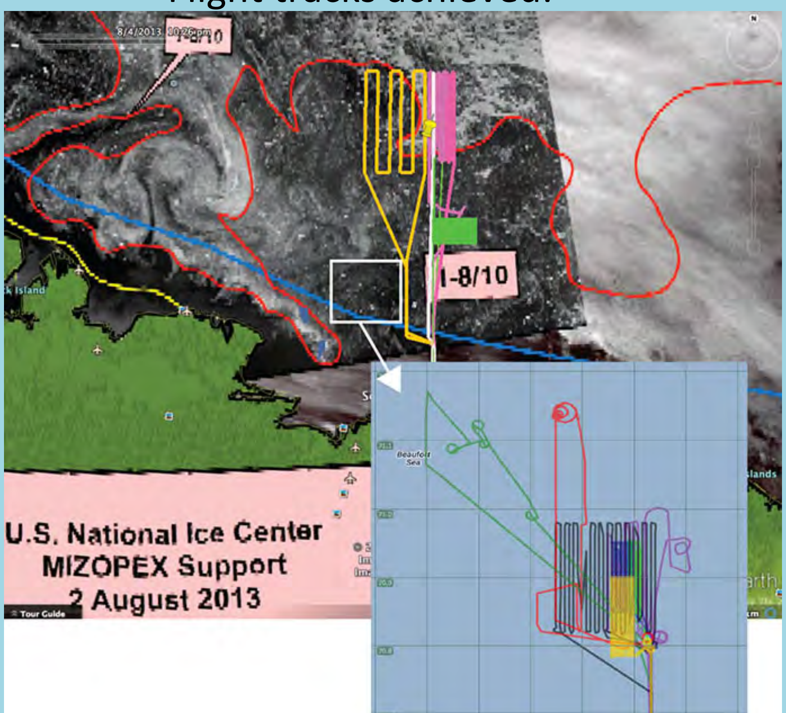
Goals:

- Assess ocean and sea ice variability in the Alaskan Arctic Ocean (Beaufort Sea/Prudhoe Bay area).
- Demonstrate potential for research using multiple unmanned aircraft systems (UAS) in polar regions.
- Determine best practices for safe, reliable operations in the National Air Space.

Accomplishments:

- 3 separate UAS deployed at Oliktok Point (USAF/DOE site; Alaskan coast) during 10 July – 9 Aug 2013
- 24 separate UAS flights carried out; 54 flight hours; visible and thermal imaging and microbuoy drops
- First beyond-line-of-sight flights, concurrent UAV ops., coincident remote and in-situ sensing, multi-agency coordination, use of ground-based radar for safety

Flight tracks achieved:



Unmanned aircraft used:

Overview of the UAF-Operated InSitu ScanEagle UAS

- Wingspan: 10.2 ft, Length: 4.5 ft
- Weight: 29 lbs (empty), 44 lbs (max takeoff wt.)
- Gas engine (1.9 hp), rear propeller, onboard generator for electric power
- 48 knot airspeed (cruise)
- Catapult launch, wing tip capture via cable
- Autonomous flight control with GCS control while in line of sight radio range (approx 40 km)
- Iridium satcom for over the horizon operations
- Endurance: 20+ hours
- Ceiling: 19,500 ft.
- Payload: up to ~6 lbs.
- Has received numerous FAA Certificates of Authorization, thousands of flight hours achieved.

Introduction

- Marginal ice zones (MIZ), or areas where the "ice-albedo feedback" driven by solar warming is highest and ice melt is extensive, may provide insights into the extent of changes in the Arctic Ocean.

- MIZ plays a role in setting the air-sea CO_2 balance making them a critical component of the global carbon cycle

- Incomplete understanding of how the sea-ice modulates gas fluxes renders it difficult to estimate the carbon budget in MIZ

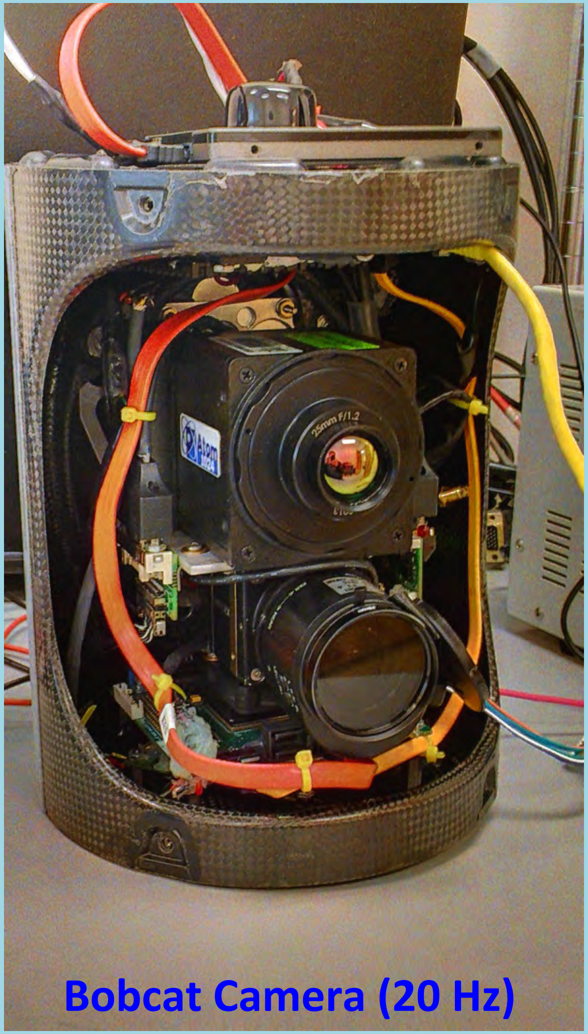
- Identify potential turbulent mechanisms that drive mixing and gas exchange in polar regions
  - Leads, Polynyas and in the presence of Ice Floes

- Field - UAV Flights that during MIZOPEX in August 2013
- Laboratory - GAPS in September-November 2012 at CRREL
- Field - UAV Flights that during ASIPBEX in April-May 2015 (New payload development)

IR / Visible ScanEagle Payload

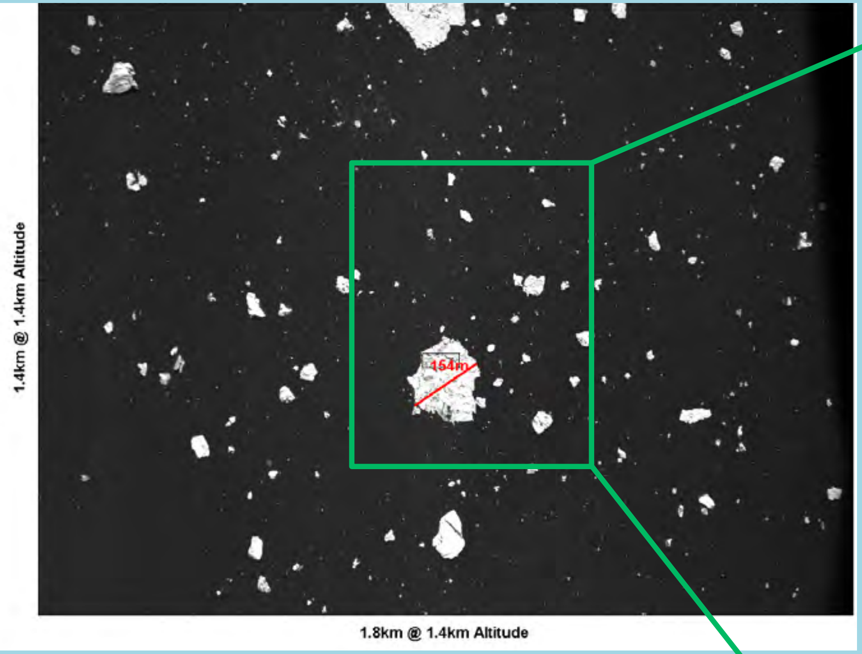
7 flights from 1-9 August, 2013;   10 hours of data

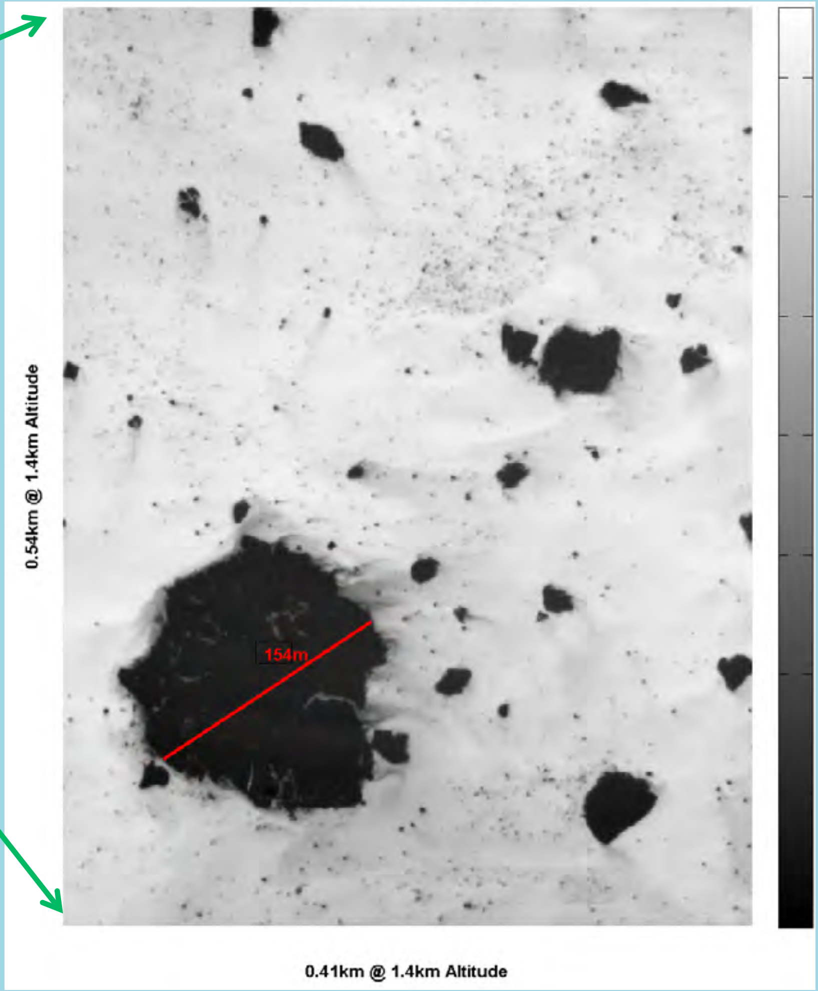
ATOM Camera (50 Hz)



MIZOPEX: Turbulence Mechanisms in Polar Systems

Measurements of Visible and Infrared Imagery from LDEO Payload on Scan Eagle



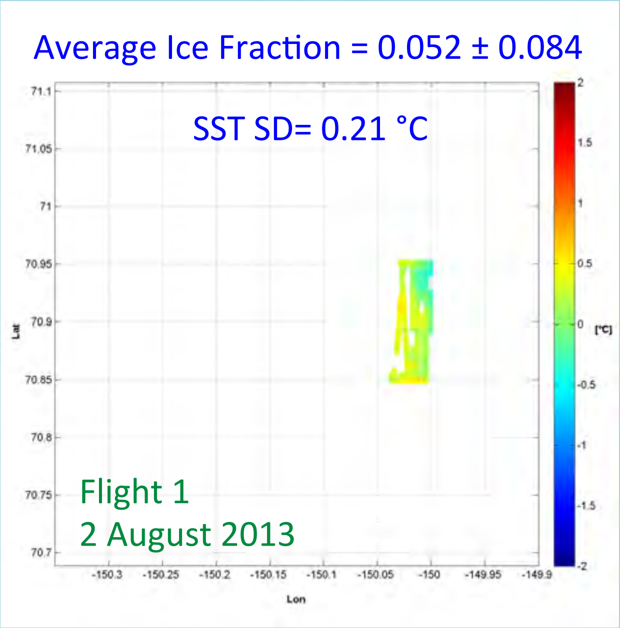


Visible (Left): 1.4 km x 1.8 km
Infrared (Right): 0.54 km x 0.41km

- Mechanisms for mixing / turbulence that are prevalent in polar environments.
  - Shear at the ice-ocean boundary layer
  - Interaction of ice floes with surface currents and waves
- Infrared imagery show cold wakes mixing near-surface ocean in the lee of ice floes.

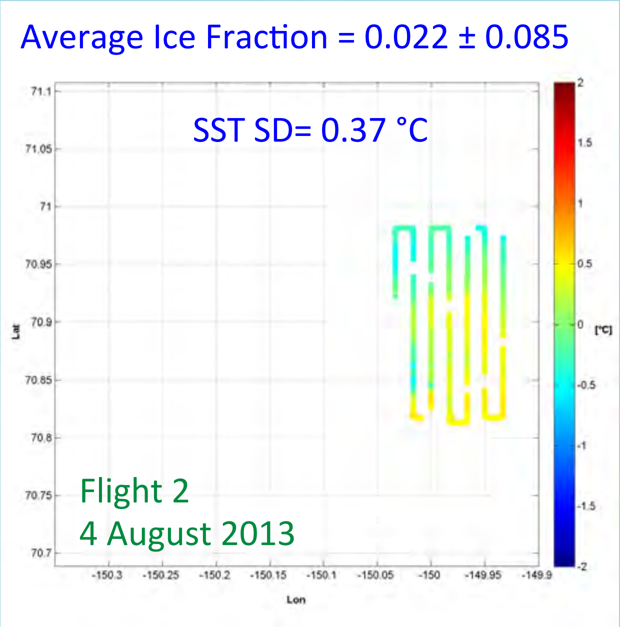
Christopher J. Zappa, Lamont-Doherty Earth Observatory, Columbia University

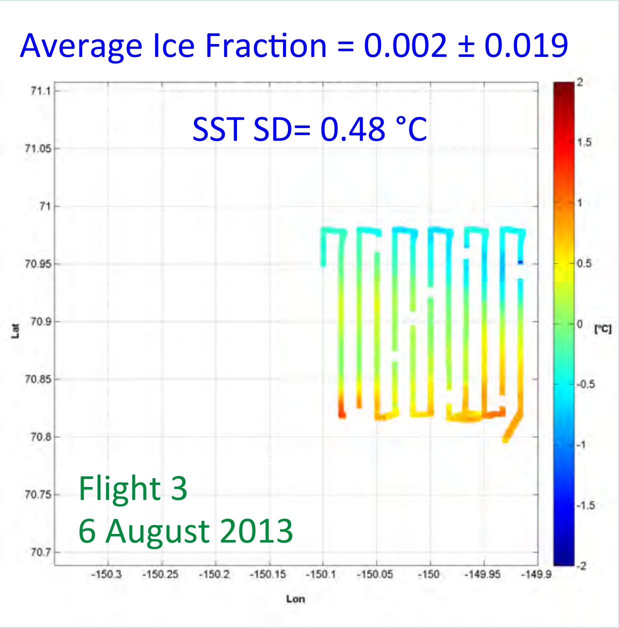
MIZ Transition Over Beaufort Sea



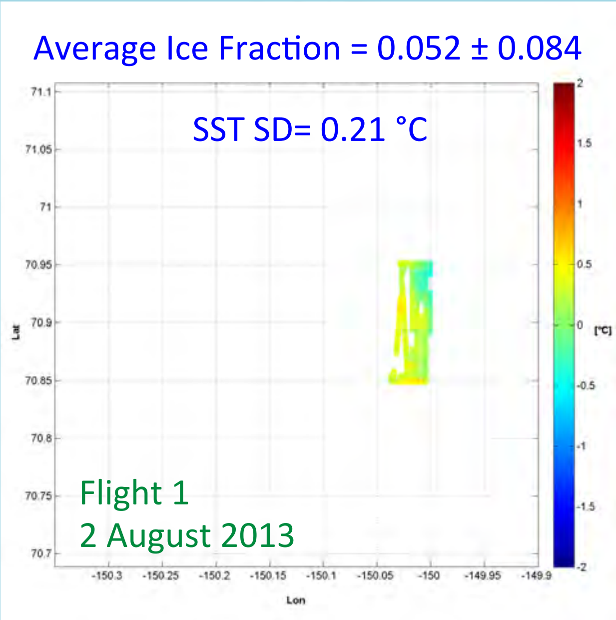
Presence of Sea Ice increases mixing that affects Skin Temperature Variability

- As the ice fraction decreases, the SST variability increases
- Increased ice fraction leads to enhanced mixing that erases gradients generated by ice melt
- As ice melts, mixing is reduced, the source for gradients is enhanced (melt), and gradients persist

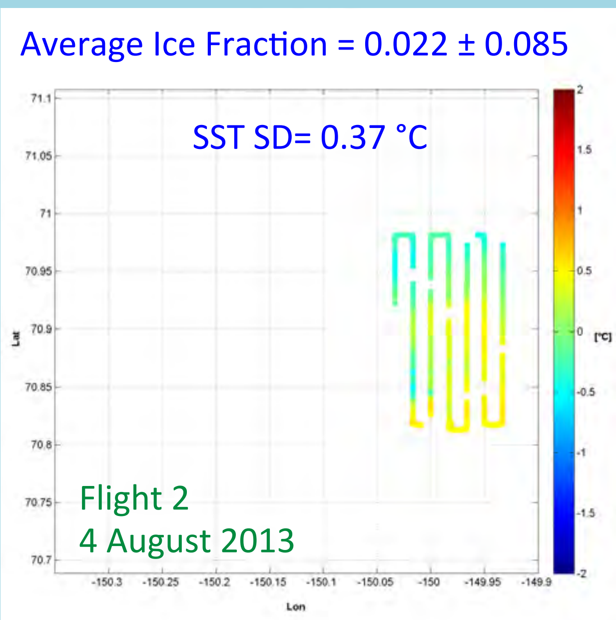


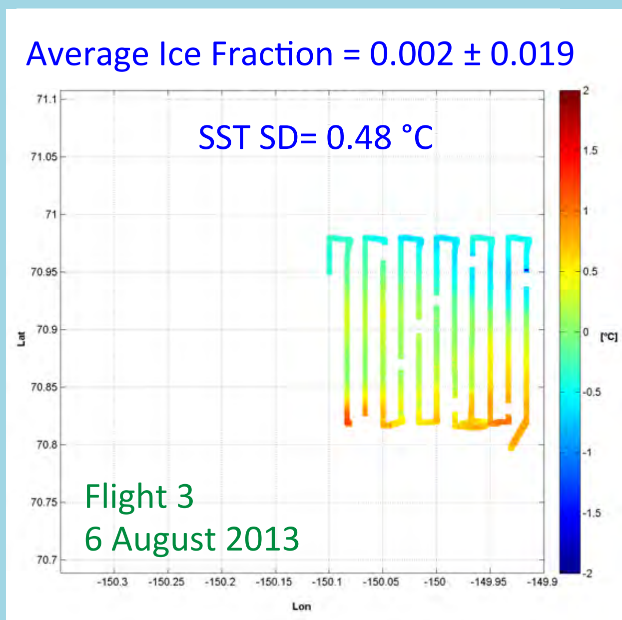


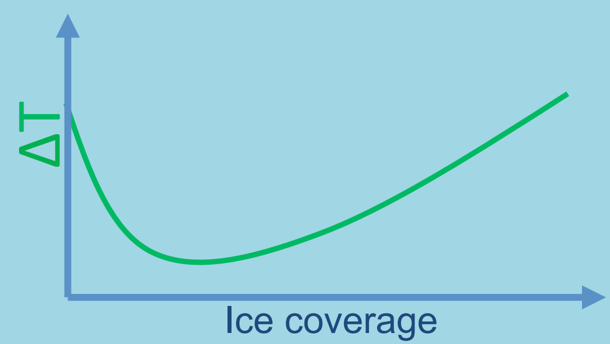
MIZ Transition Over Beaufort Sea



- Data suggests turbulence due to increased floe concentration enhances the mixing of skin SST variability
- We hypothesize that ΔT first decreases with floe concentration up to a certain point where concentration starts inhibiting turbulence and melt processes dominate.
  - Skin SST variability results during MIZOPEX are supported by measurements during experiments at CRREL.

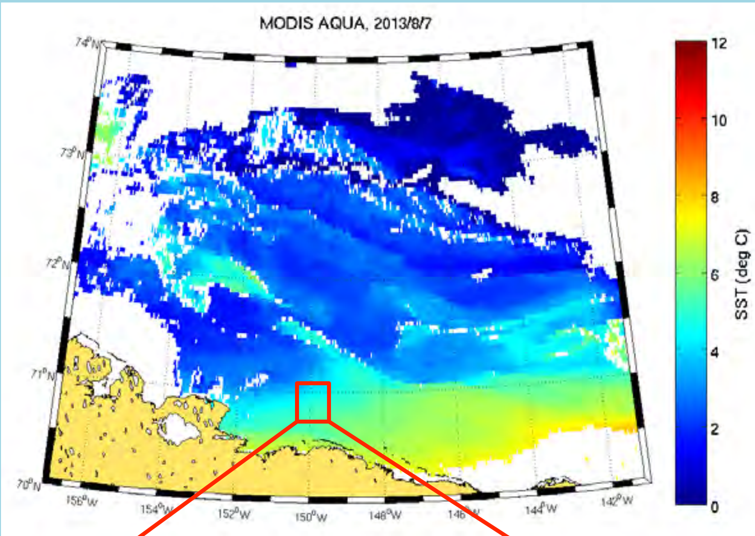


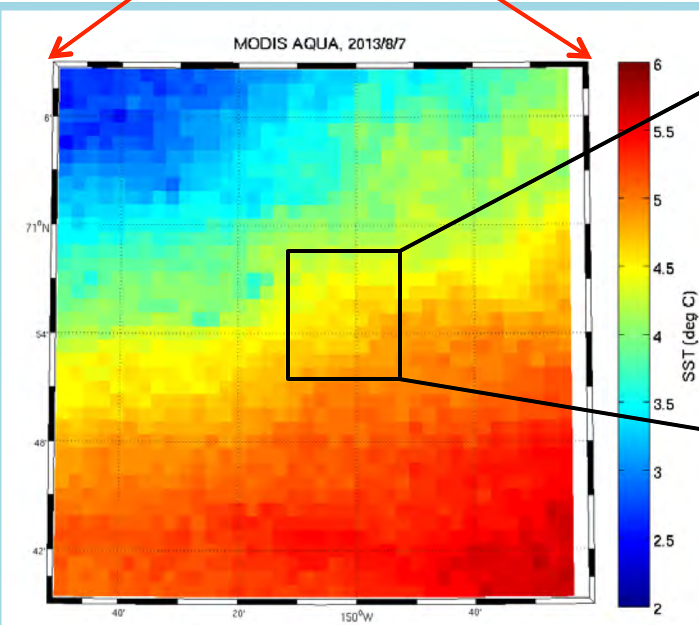




Satellite View of MIZOPEX Transition

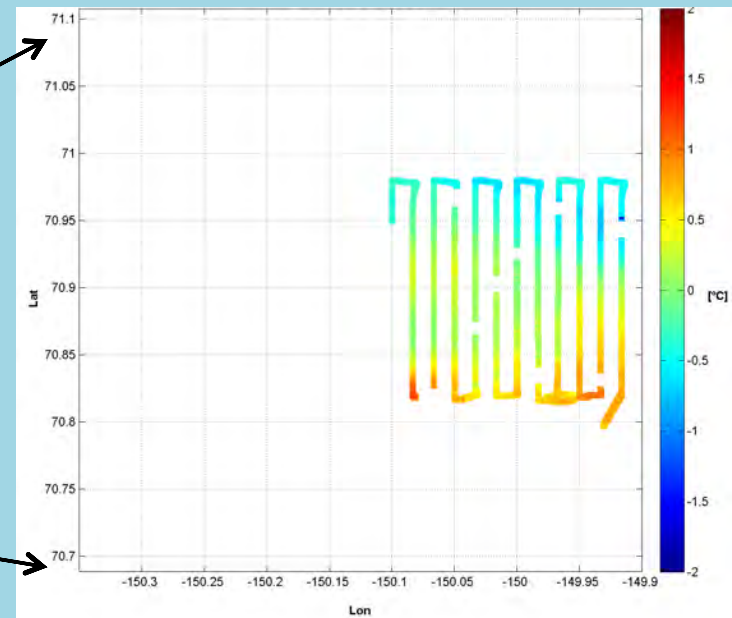
Measurements of Infrared Imagery from LDEO Payload on Scan Eagle





- Objective here to see if variability in the satellite SST fields is consistent with that observed in the airborne data as ice melts away (or if the satellite data is just too coarse to say anything).

- Image shows the similar N-S gradient observed in UAV data (roughly 1.5 °C).



MODIS Aqua image for 7-August 2013 (Top) and a Zoom in view (Bottom). The image is roughly a 50x50 km square. Unfortunately, we get just this one good satellite look due to cloud cover issues.

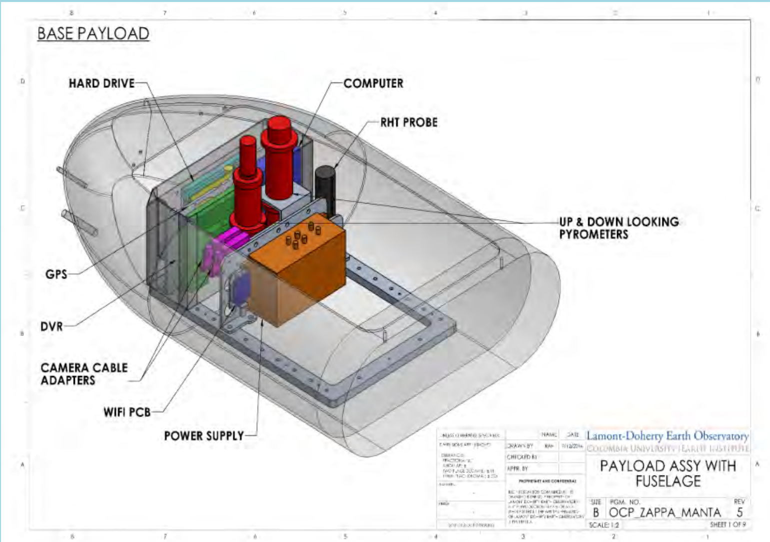
Christopher J. Zappa, Lamont-Doherty Earth Observatory, Columbia University

Moore Foundation: UAS Payload Development

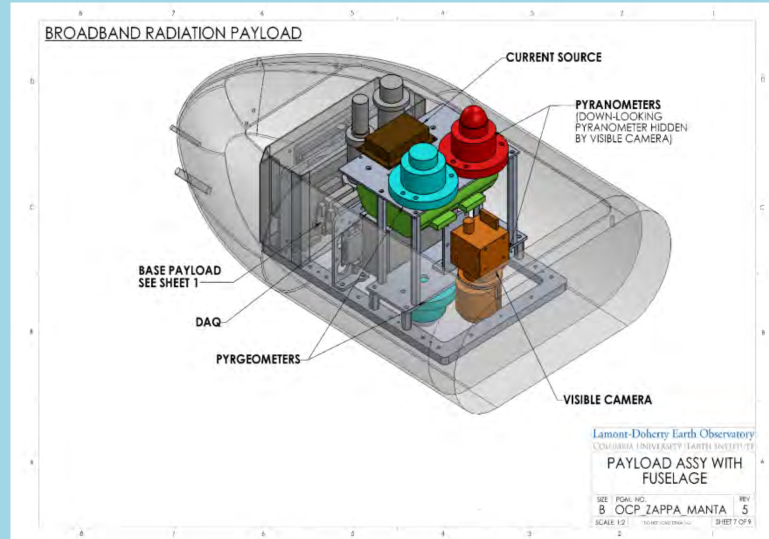

- Developed new payloads for UAVs (e.g., Scan Eagle, Manta, Aerosonde) funded by the Gordon and Betty Moore Foundation.
- Payloads include: i) VNIR hyperspectral imaging (400-1000 nm), ii) NIR hyperspectral imaging (900-1700 nm), iii) infrared imaging (8-9 microns), iv) Lidar scanner, v) air-sea-ice turbulent fluxes, radiative fluxes, vi) UAV-deployed combination dropsondes (q/T/P) and microbuoys (T/S).
- Culminated in airborne surveys over MIZ sea ice from Manta UAVs in Ny-Alesund Svalbard Norway during experiments April-May 2015 in collaboration with Tim Bates of NOAA PMEL (Seattle).

UAS Payload Development

BASE Payload

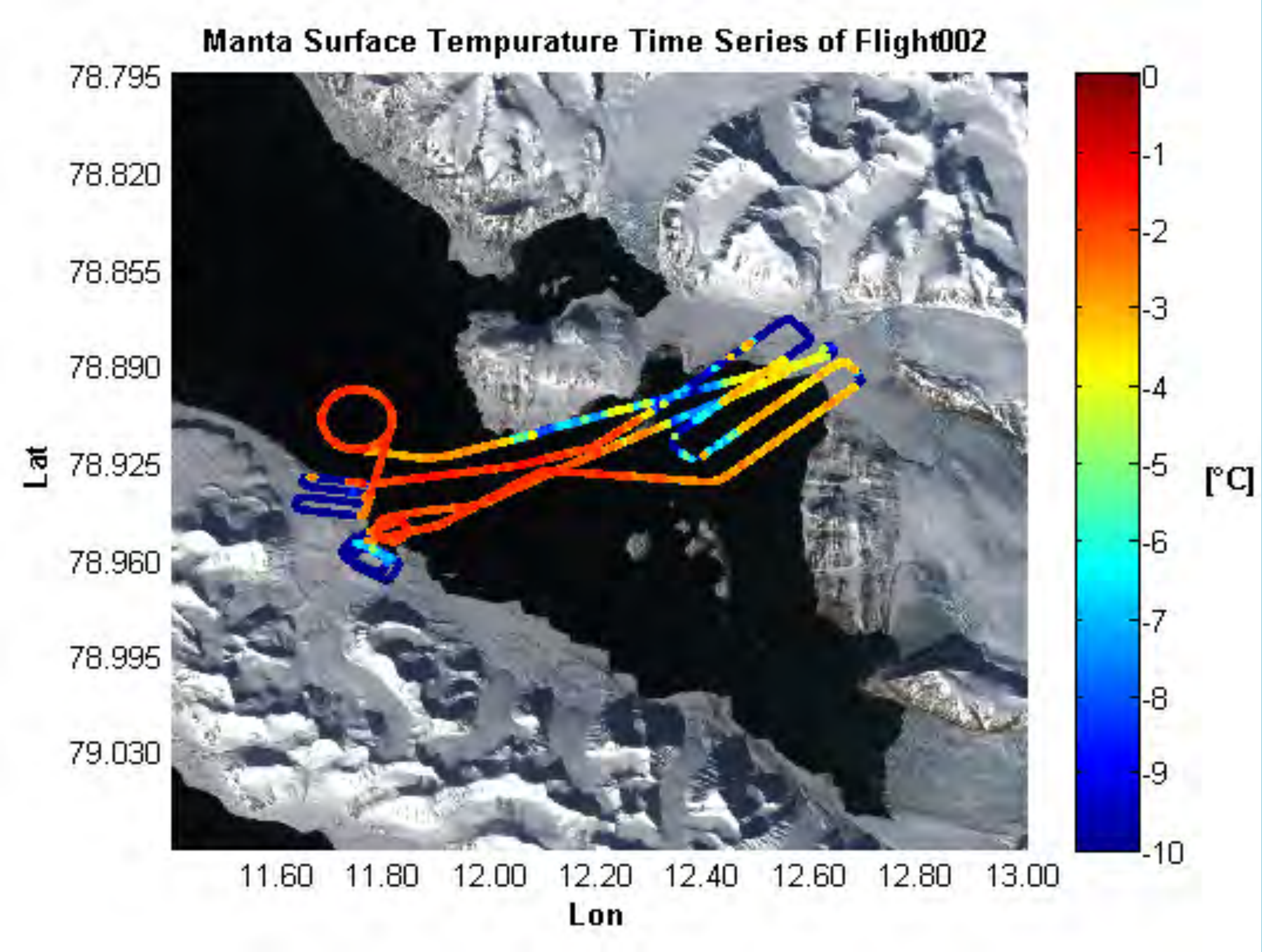


Sensor Module

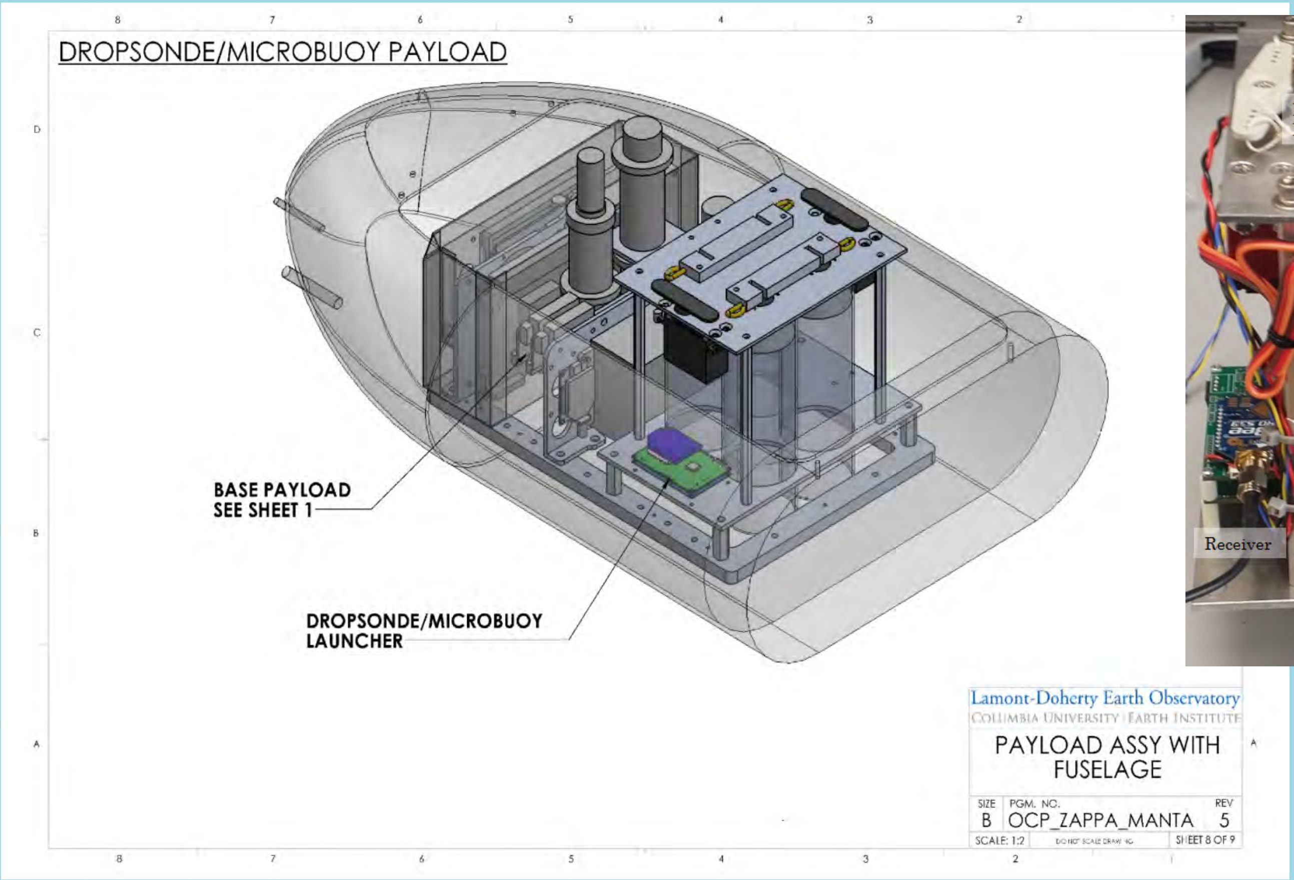


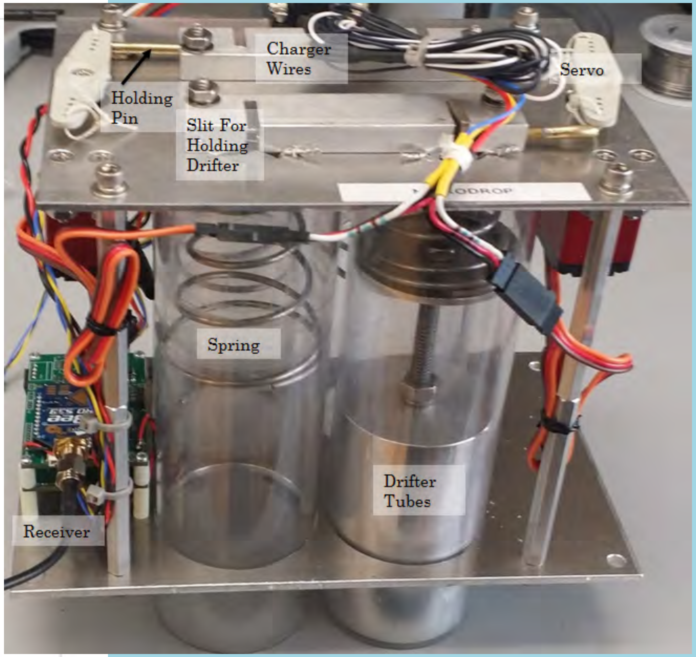
BASE payload allows for quick change between sensor payloads

Sea/Ice Surface Skin Temperature



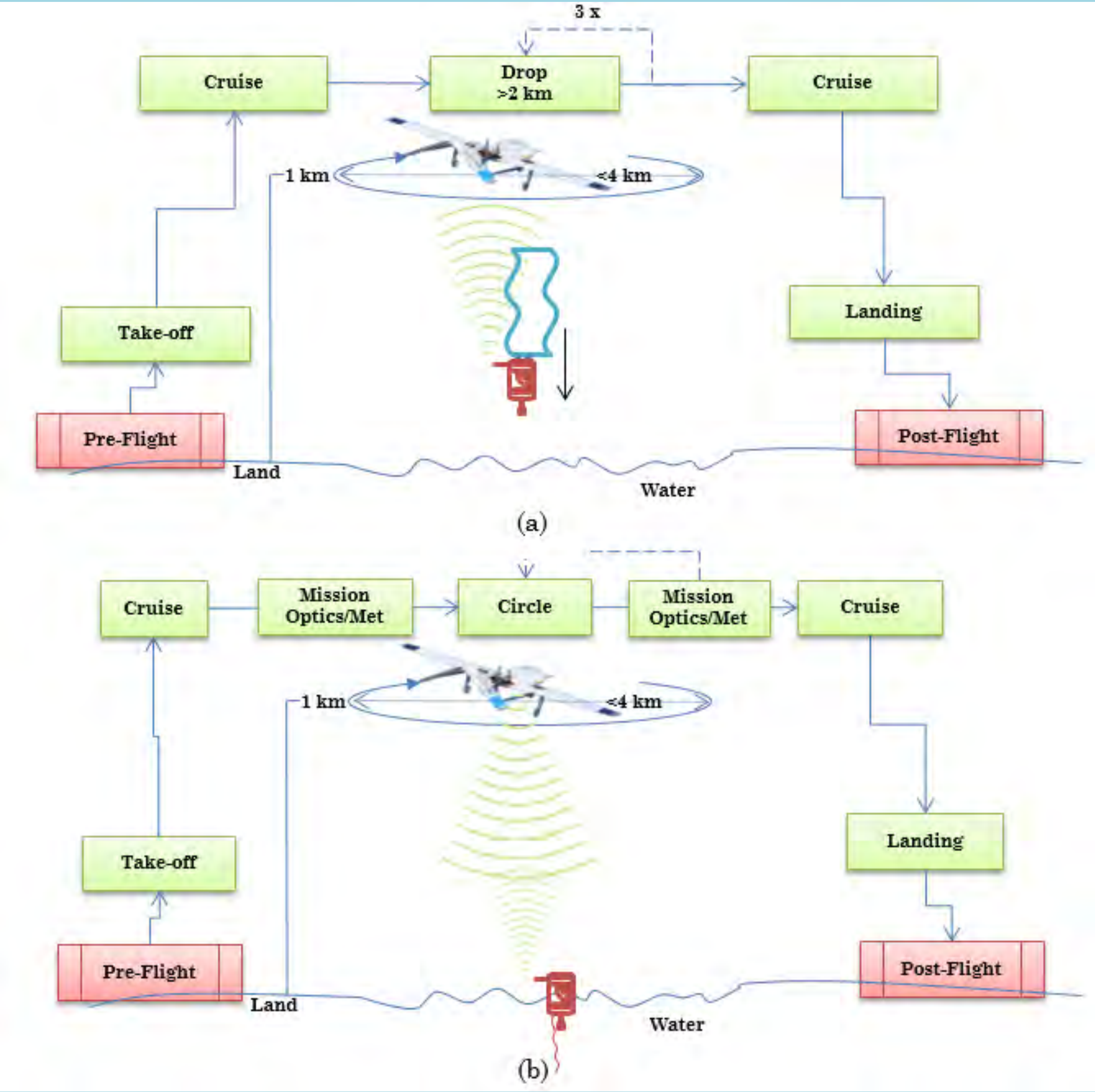
Dropsonde / Microbuoy Payload (DDmD)

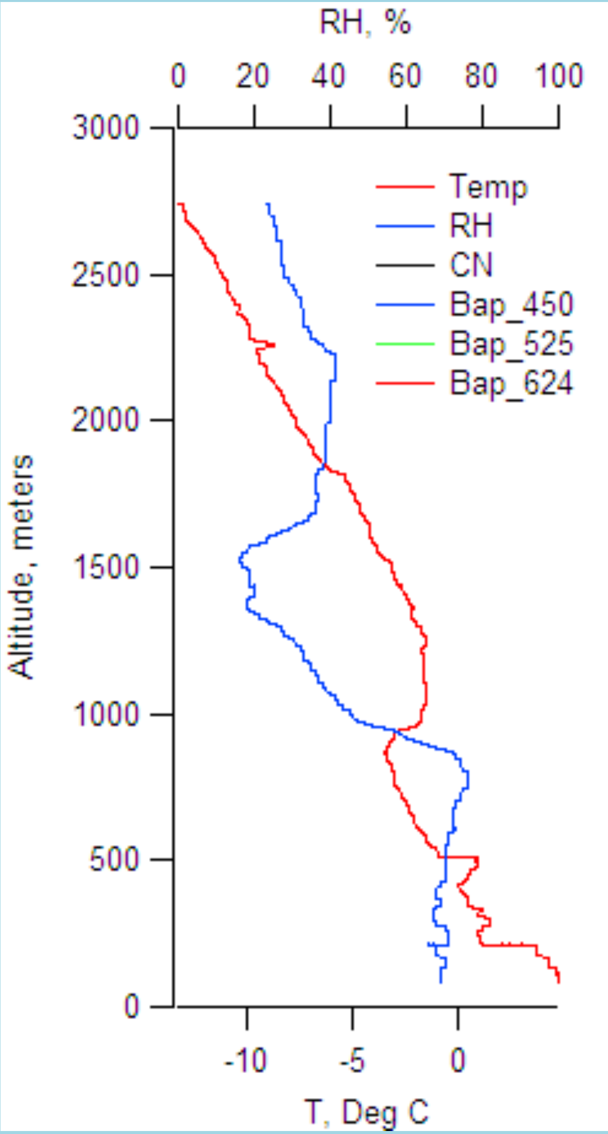




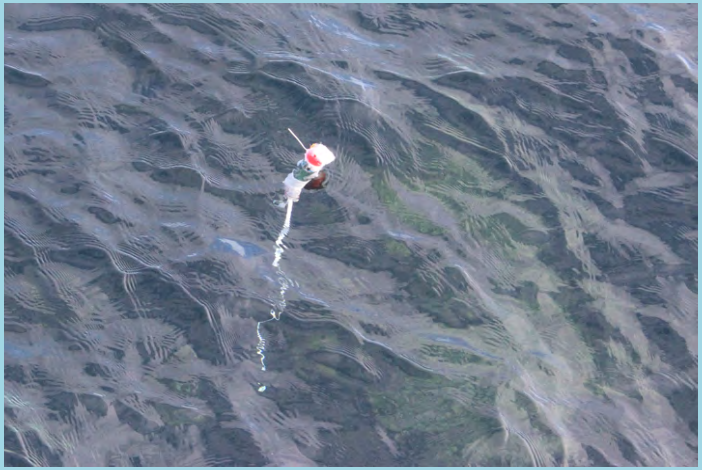
Dropsonde - Atmospheric Temperature, RH, and Pressure profiles
Microbuoy - upper ocean (1-m) temperature and salinity with telemetry

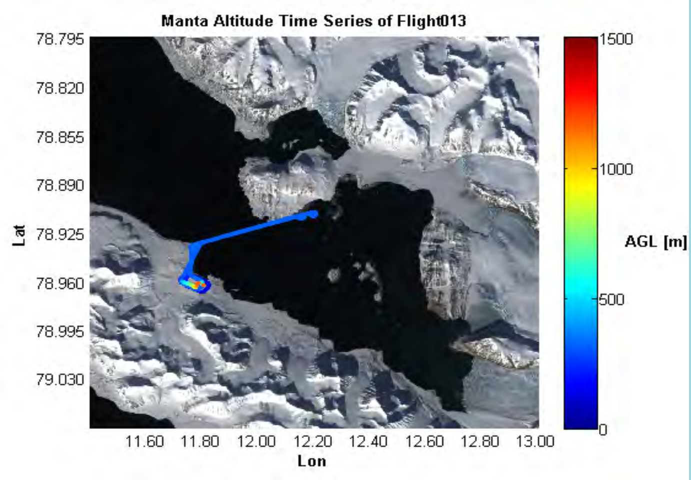
Dropsonde / Microbuoy Payload (DDmD)

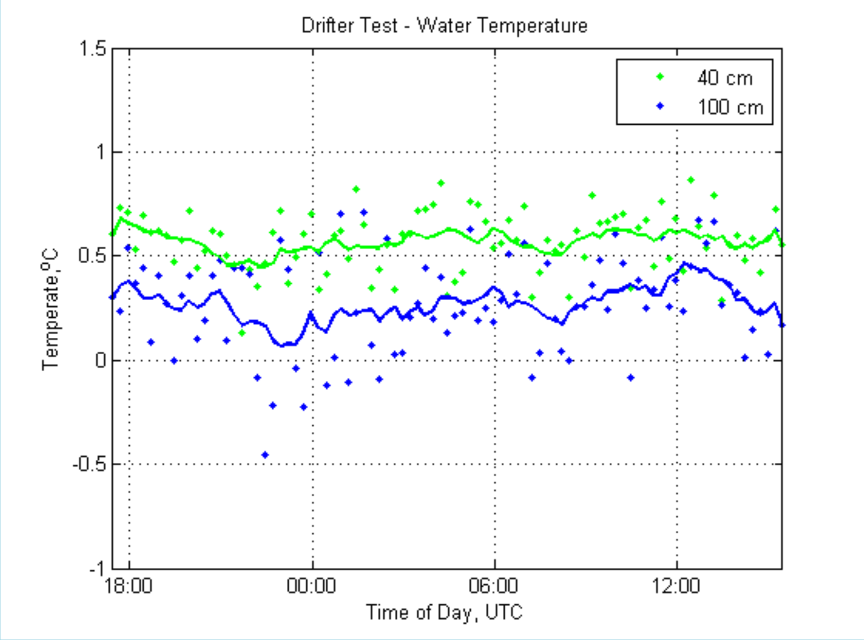


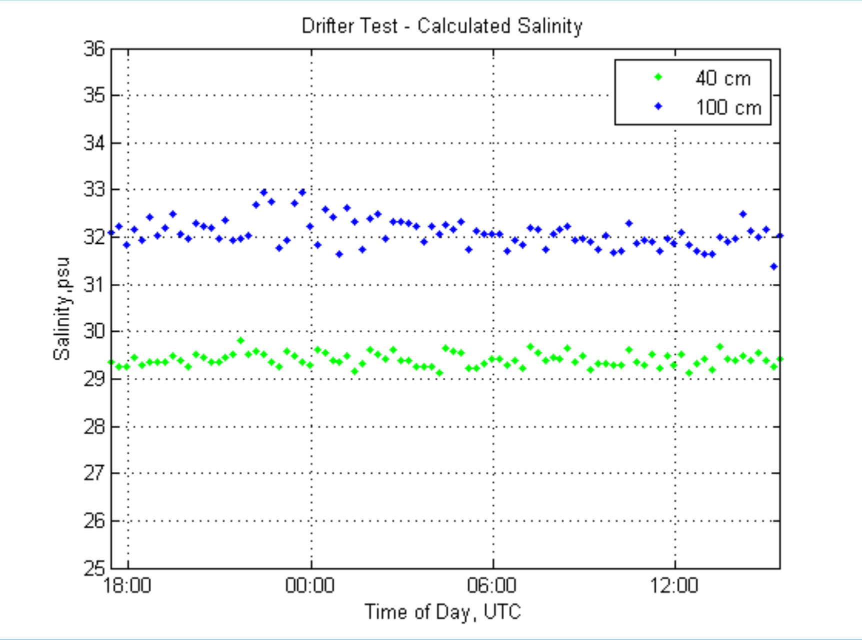


Dropsonde / Microbuoy (DDmD) Payload



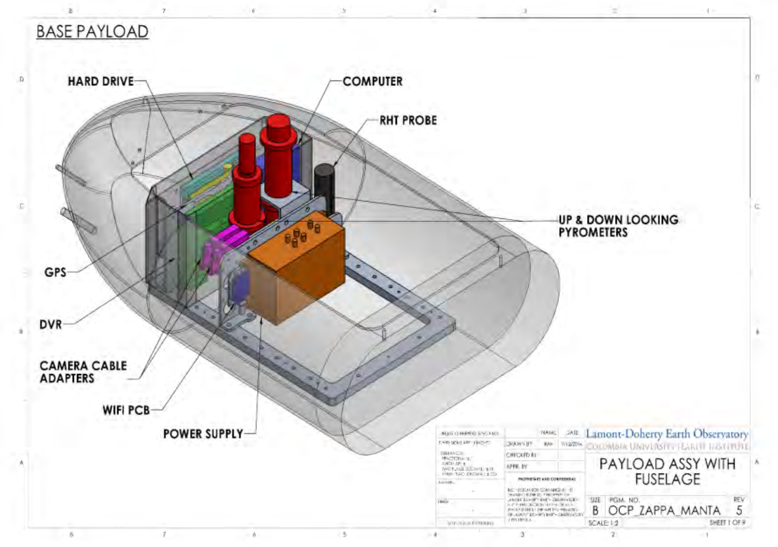




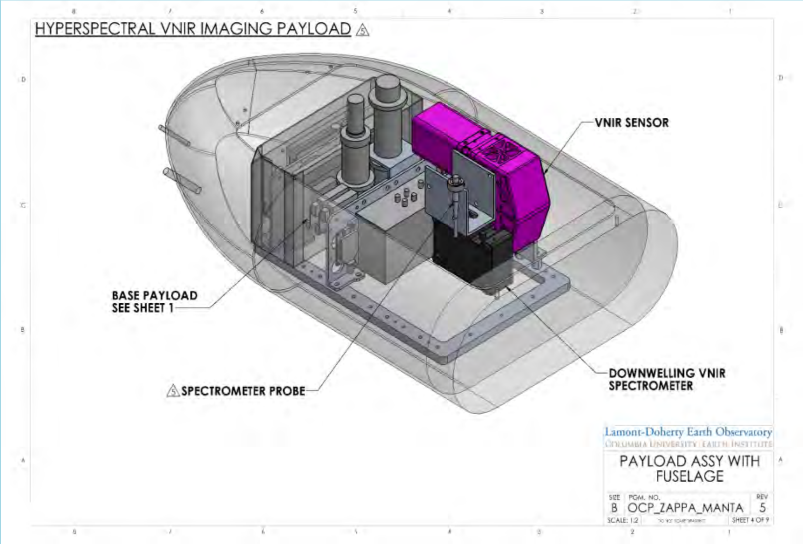


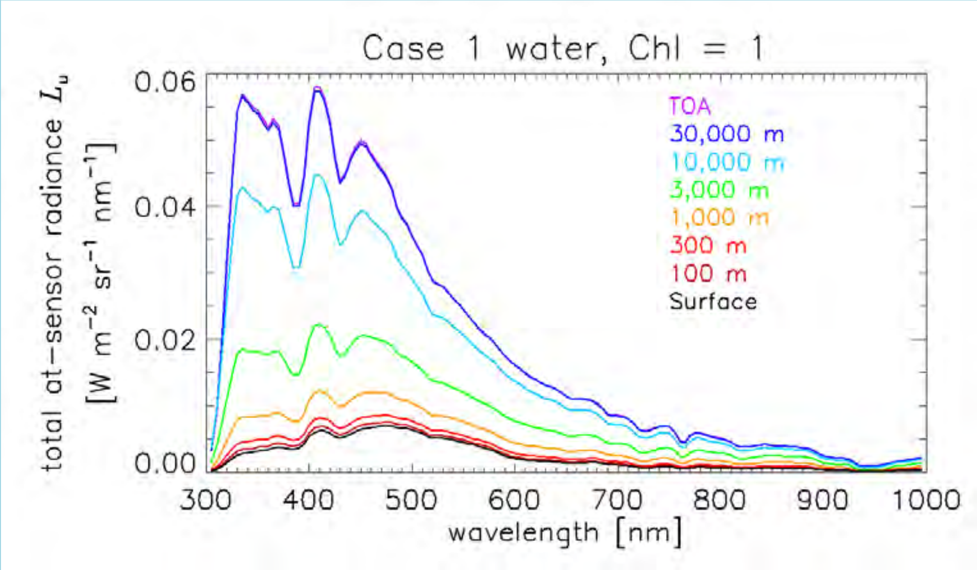
Hyperspectral Payload Development

BASE Payload

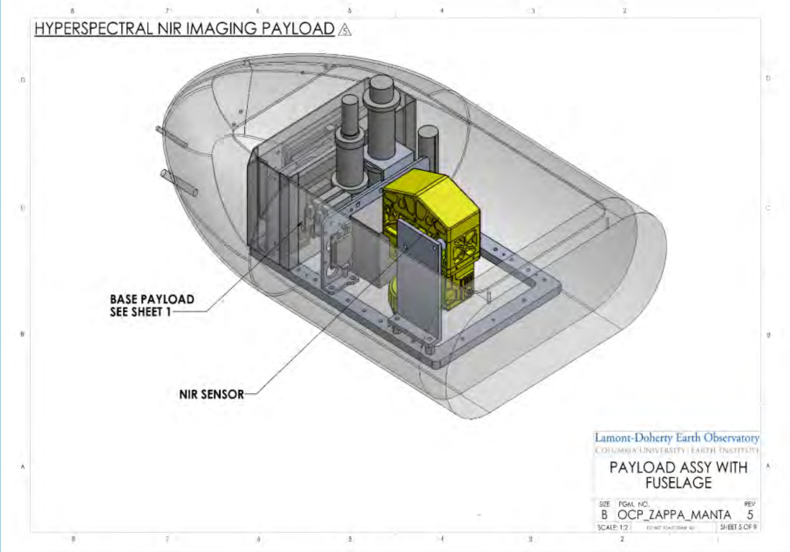


VNIR Module

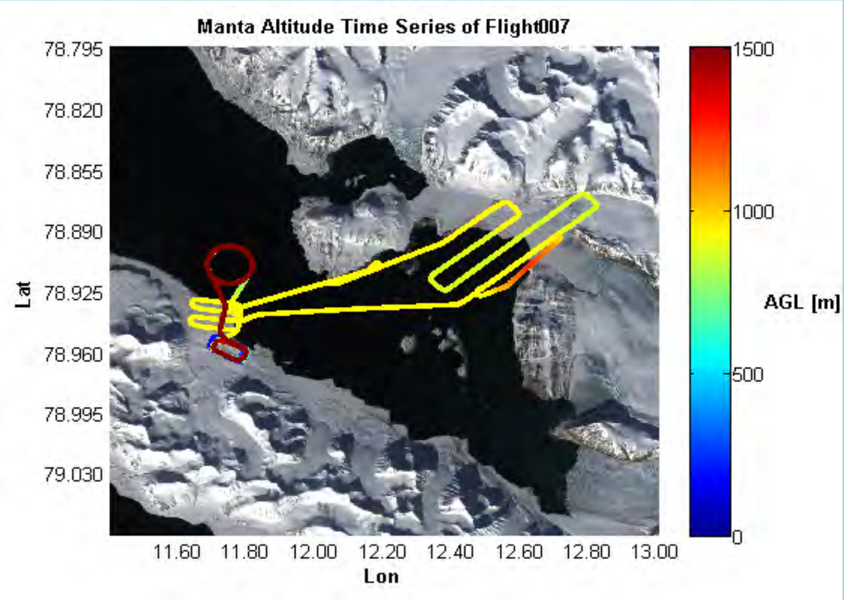


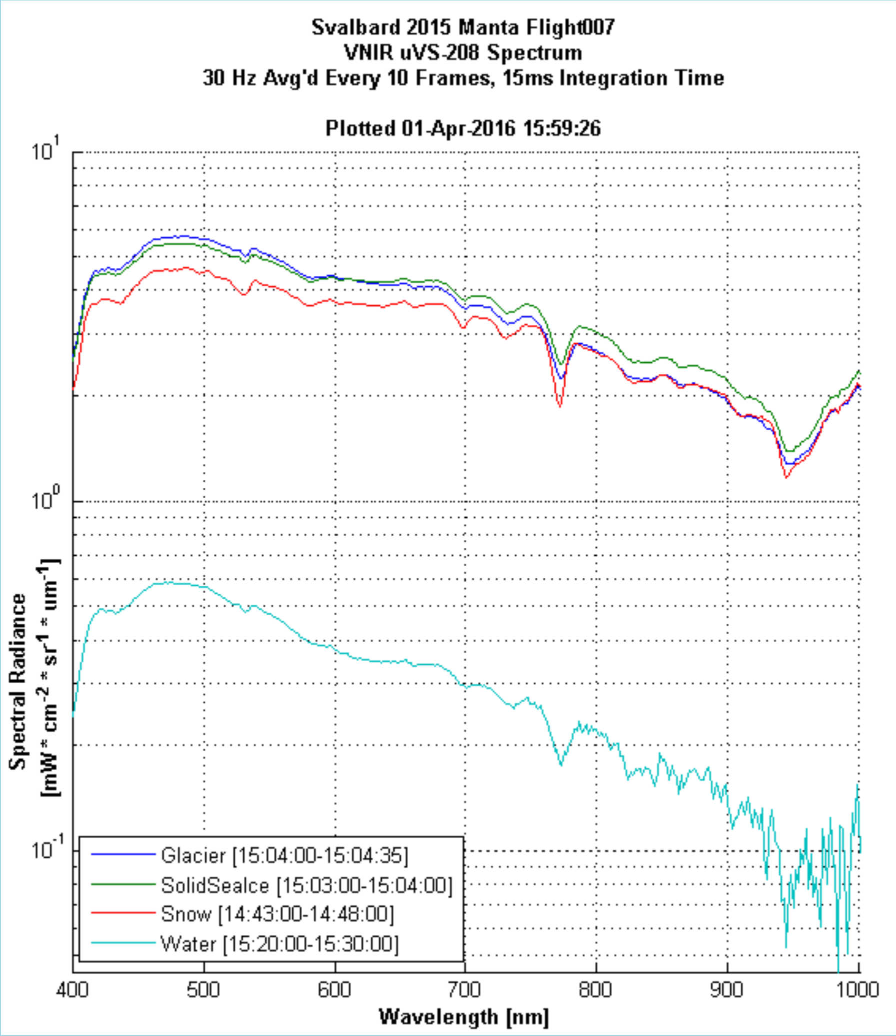


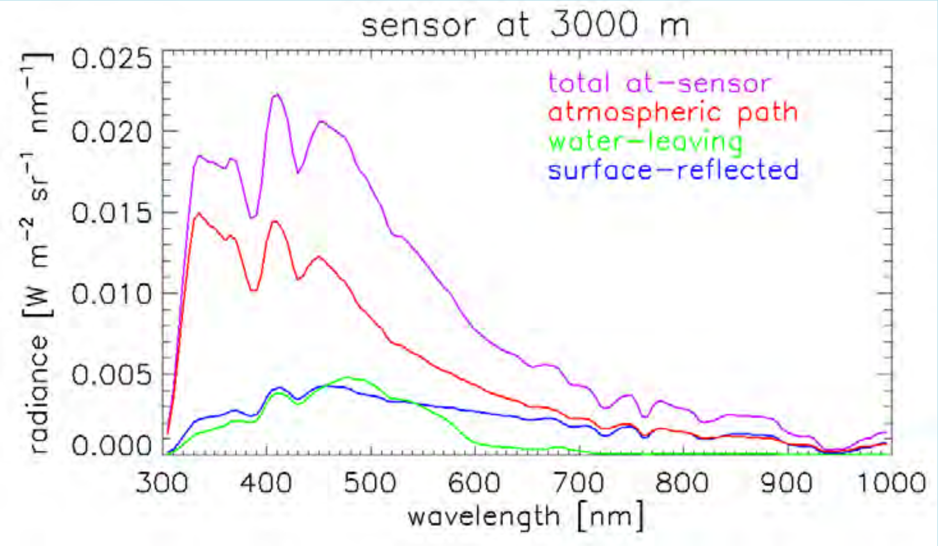
NIR Module



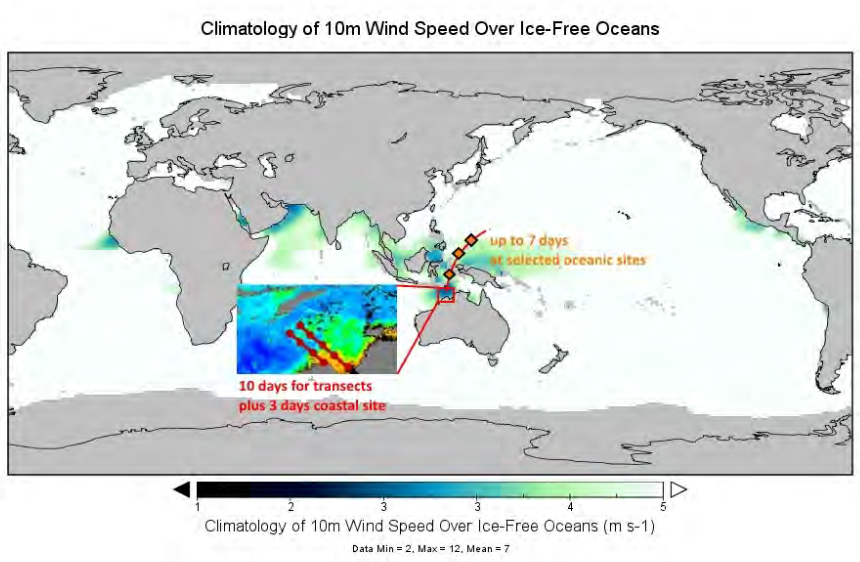
Hyperspectral Payload Development







Future Directions – R/V Falkor



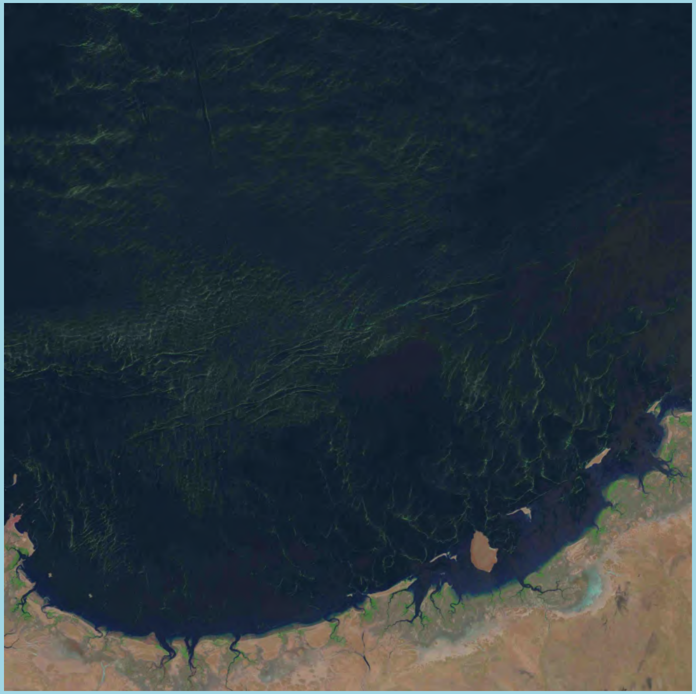
- Upcoming Cruise from R/V Falkor in the Northwest Australian Continental Shelf
- Payloads developed for Manta UAS will be integrated onto Latitude Engineering HQ-60.
- Airborne surveys of the Sea Surface Microlayer from Latitude UAVs as well as in situ measurements of the SSM chemistry and biology from catamaran, drifters, and buoys.
- Measurements: ocean surface gravity-capillary wave spectra (*O*(1-0.001)m) using LIDAR and polarimetric imaging; complete chemical and biological quantification and characterization of the biogenic slicks from autonomous catamarans; and quantification and characterization of the near-surface ocean temperature, salinity, TKE dissipation rate, and currents from a drifting spar buoy and in the mixed-layer from autonomous sub-surface profiling

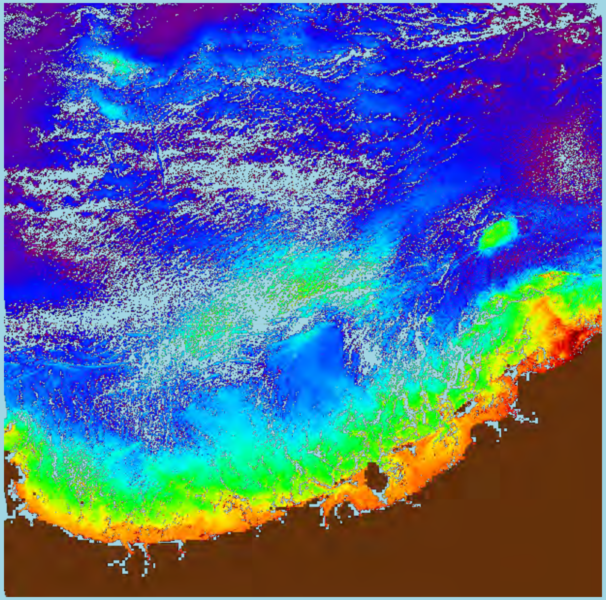
Future Directions – R/V Falkor

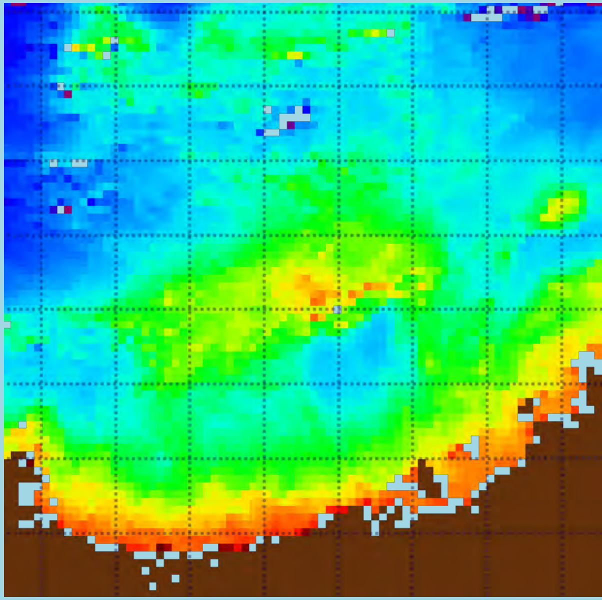
Future Directions – R/V Falkor

Dense internal wave field

- **Effects of biogenic slicks on albedo, near-surface heat flux, diurnal warm-layer processes and mixing.**

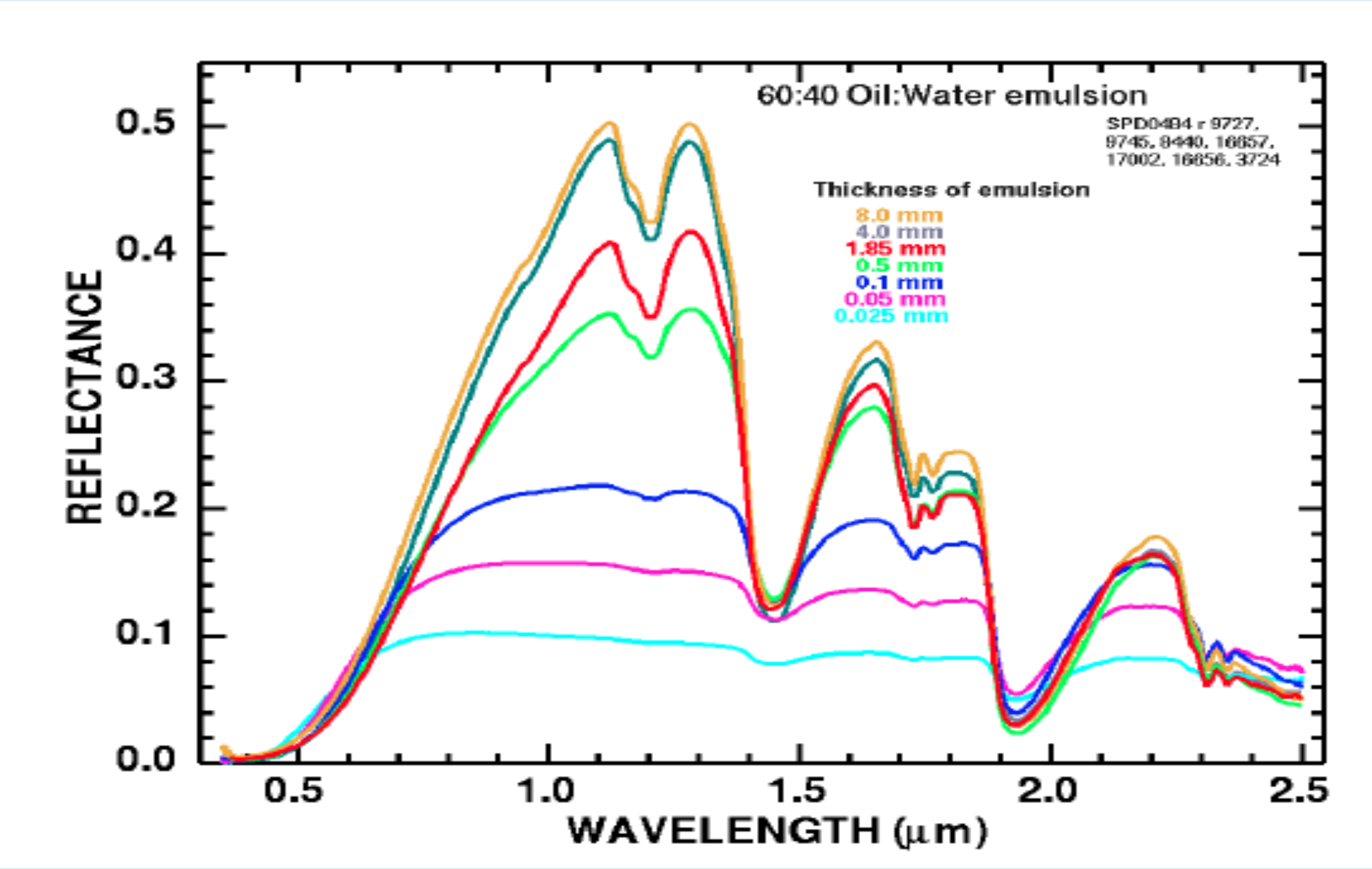




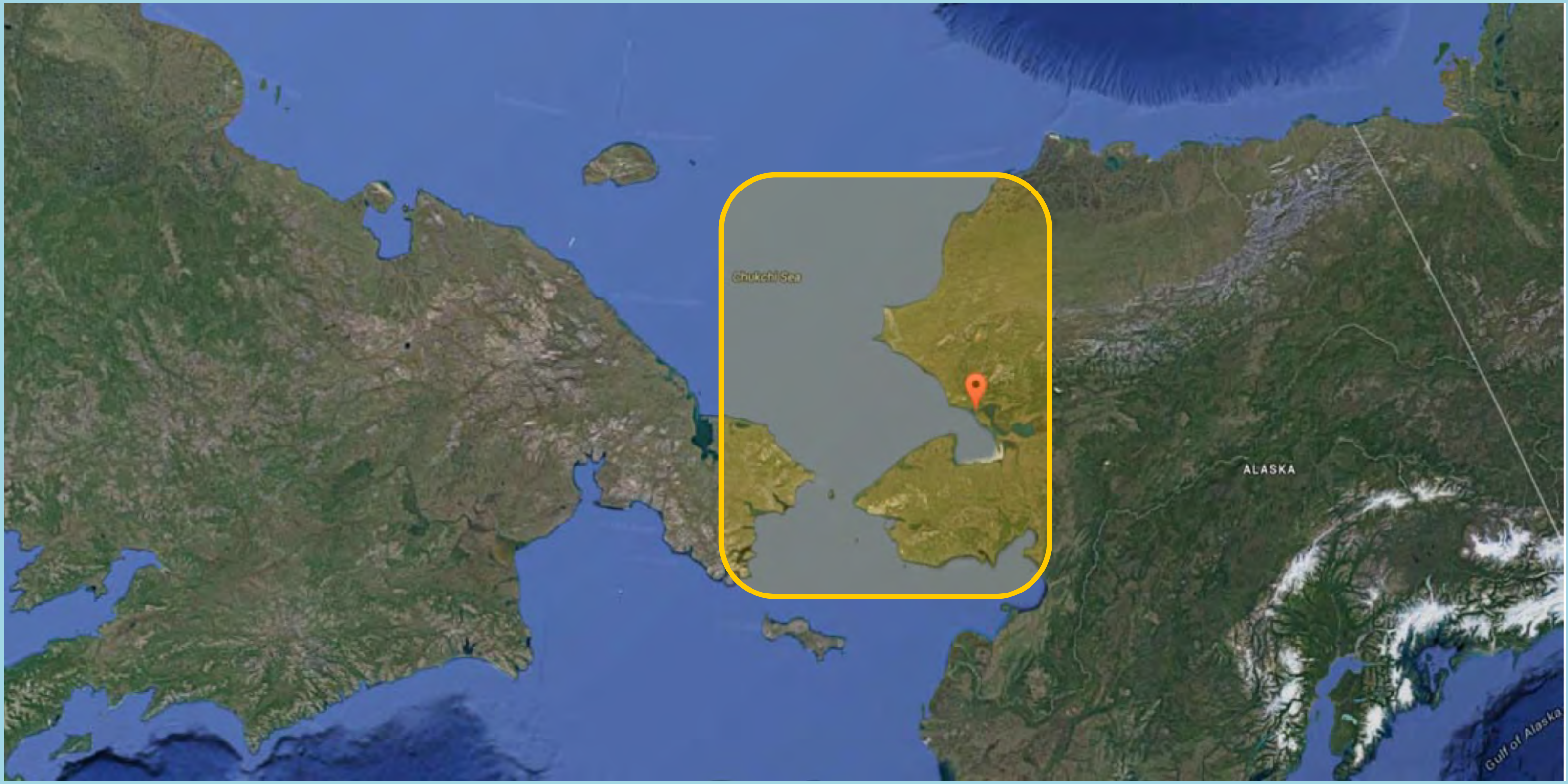


(Top) True color image captured by the Landsat satellite on Novermber 17, 2014, of the coast of Northwestern Australia, east of Point Samson. *Trichodesmium* is known to bloom extensively in this region [*Creagh*, 1985] and the slicks are presumably due to accumulation of this organism in the surface microlayer. The slicks are dense enough to accumulate along the wake of a ship (north/south lines seen to top left of true color image. (Bottom Left) 30 m resolution chlorophyll map obtained from the Landsat data. The high albedo from the dense surface slicks trigger the cloud mask (white). The wake of the ship can be seen in this image to the top left. (Bottom Right) MODIS Aqua map of chlorophyll for the same day. The 1 km resolution image does not show any “clouds” since the fine structure of the surface slicks are averaged out with the intervening waters and the albedo is not high enough to trigger the cloud mask.

Future Directions – R/V Falkor



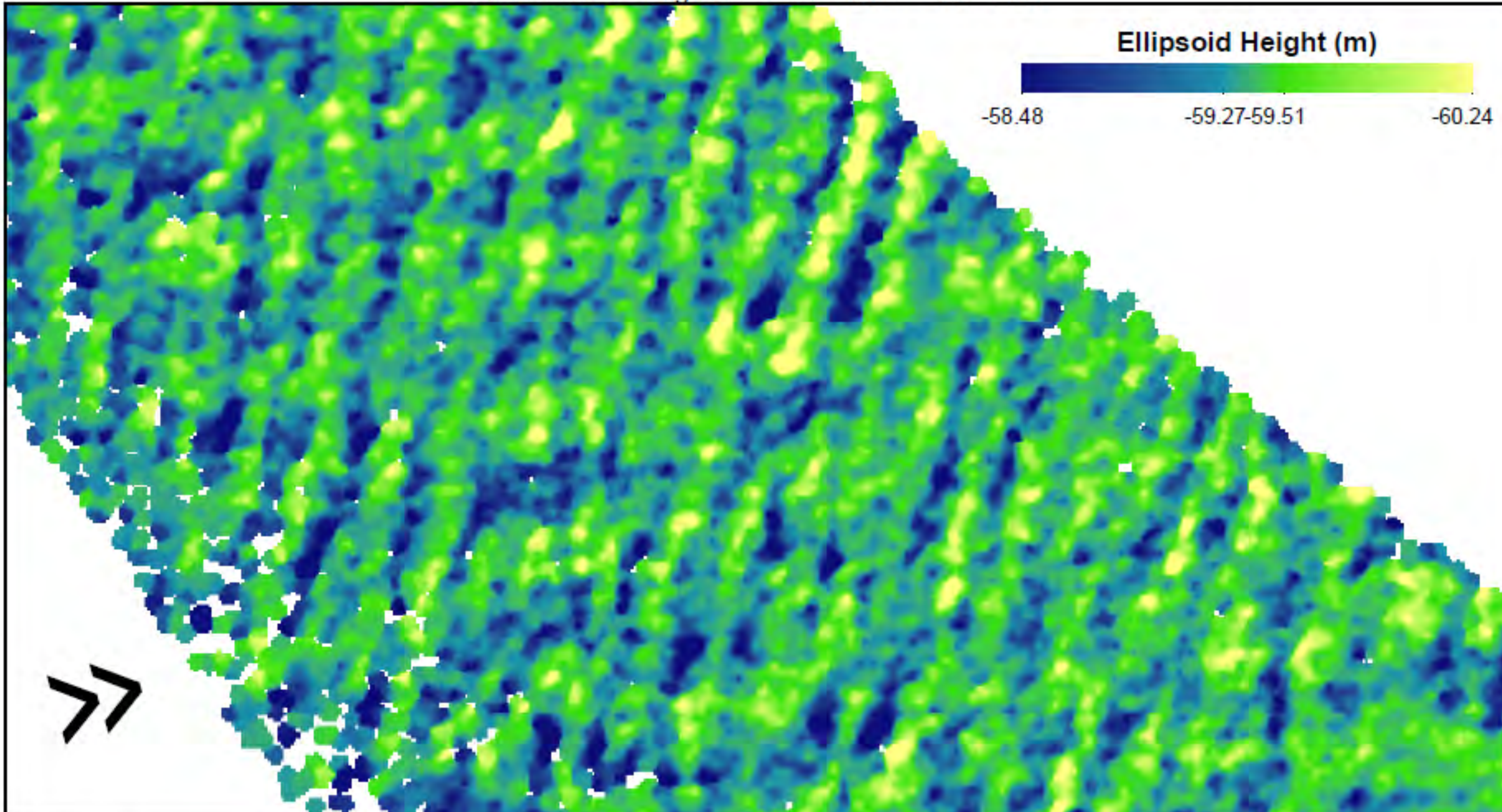
Future Directions – Back To Alaska



This proposed project will help answer critical questions directly related to changes in the Arctic that are important both to global climate and to Arctic communities that are already being impacted by the loss of sea ice. The ability of this project to put global science in service of communities in which sea ice is a critical part of daily life and local culture adds a dimension to the ongoing work. The goal of this project is to elucidate a basic question that is significant for the entire Earth system. Have these regions passed a tipping point, such that they are now essentially acting as sub-Arctic seas where ice disappears in summer, or instead whether the changes are transient, with the potential for the ice pack to recover?

Surface Ellipsoid Height from LIDAR Over Waves - IDW Grid

Antarctica 1 - Flight 6 - Dec. 1 2014 - 08:49:23

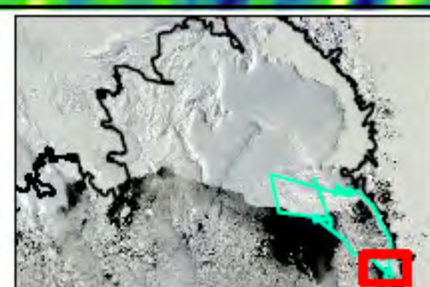


50
Meters

Angle gate filter applied
(only +/- 10 degrees from nadir)

Grid Method: Inverse Distance Weighted
Cell Size: 1m
Search Radius: 3m

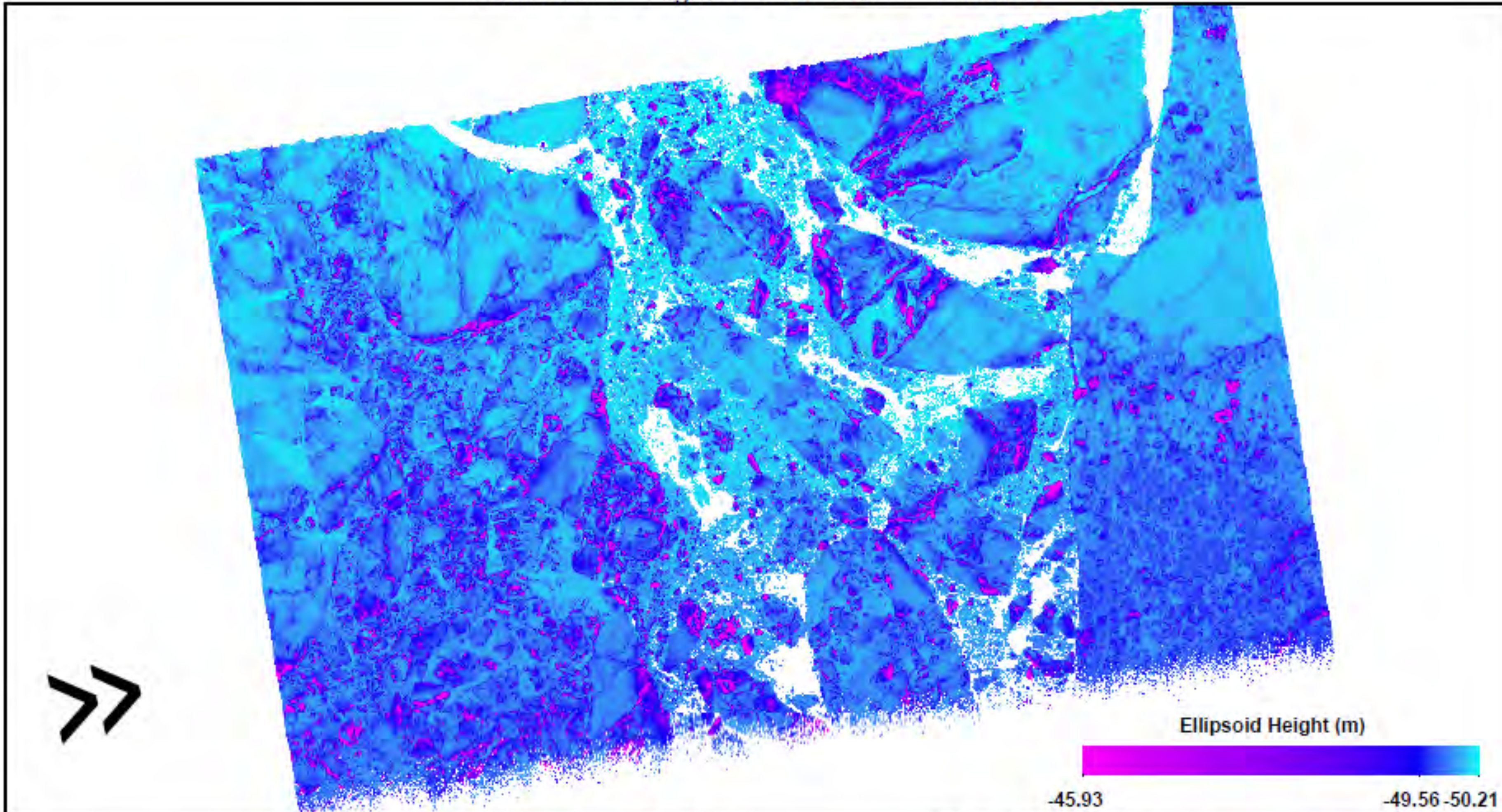
MODIS Terra 12/1/2014 - 250m



MODIS Terra 12/1/2014 - 1km

Surface Ellipsoid Height from LIDAR Over Sea Ice - IDW Grid

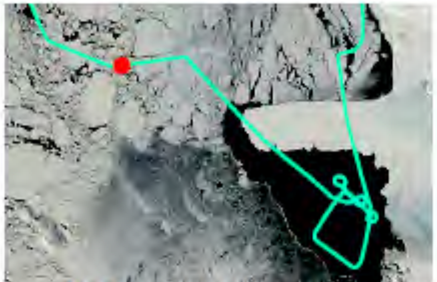
Antarctica 1 - Flight 6 - Dec. 1 2014 - 08:26:23



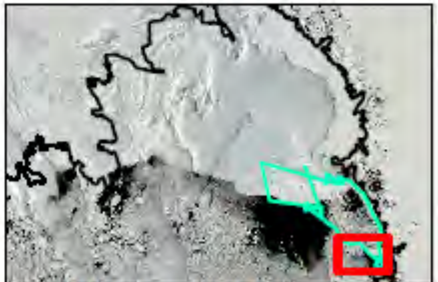
200

Meters

Grid Method: Inverse Distance Weighted
Cell Size: 20cm
Search Radius: 80cm



MODIS Terra 12/1/2014 - 250m



MODIS Terra 12/1/2014 - 1km

Operations in Alaska During MIZOPEX

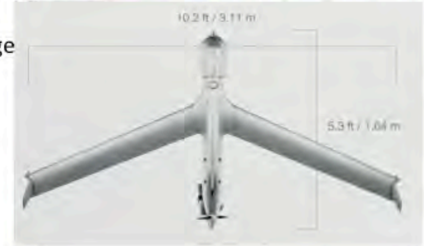
Marginal ice zones (MIZ), or areas where the "ice-albedo feedback" driven by solar warming is highest and ice melt is extensive, may provide insights into the extent of Arctic Ocean changes.

The goal of these and future analyses of the MIZOPEX data set is to elucidate a basic question that is significant for the entire Earth system. Have these regions passed a tipping point, such that they are now essentially acting as sub-Arctic seas where ice disappears in summer, or instead whether the changes are transient, with the potential for the ice pack to recover?

ScanEagle in Alaska During MIZOPEX

Overview of the UAF-Operated InSitu ScanEagle UAS

- Wingspan: 10.2 ft, Length: 4.5 ft
- Weight: 29 lbs (empty), 44 lbs (max takeoff wt.)
- Gas engine (1.9 hp), rear propeller, onboard generator for electric power
- 48 knot airspeed (cruise)
- Catapult launch, wing tip capture via cable
- Autonomous flight control with GCS control while in line of sight radio range (approx 40 km)
- Iridium satcom for over the horizon operations
- Endurance: 20+ hours
- Ceiling: 19,500 ft.
- Payload: up to ~6 lbs.
- Has received numerous FAA Certificates of Authorization, thousands of flight hours achieved.



Longer durations and with longer flight range.
Proven operation in polar environments.
Ability to fly at low altitudes.

Flights Over Beaufort Sea During MIZOPEX