NASA-NOAA Arctic UAS Projects

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NASA Headquarters

NOAA UAS Program Review

March 07, 2017

Key Points

NOAA has been a tremendous partner

- Our major campaigns would not have happened without NOAA
- Support was for campaigns and infrastructure development

Impacts of joint NOAA/NASA projects have been profound

- WISPR
- MIZOPEX

Your review must consider the context for these projects

When we started it was:

- UAS tools in search of scientific problems
- Significant administrative road blocks to Arctic UAS operation

Advancing Operational Readiness of High Altitude Dropsonde*

2009- 2010

NOAA/NSF develop Global Hawk dropsonde system

Concept in laboratory / relevant environment

2011

NOAA Winter Storms and Pacific Atmospheric Rivers (WISPAR)

First Global Hawk flights with dropsonde system

First Arctic Global Hawk flight

First dropsonde intercomparsion with NOAA G-IV

Results were published in peer-reviewed publication

Prototype in relevant environment

2012 - 2014

NASA Hurricane and Severe Storm Sentinel (HS3) /2011 - 2015

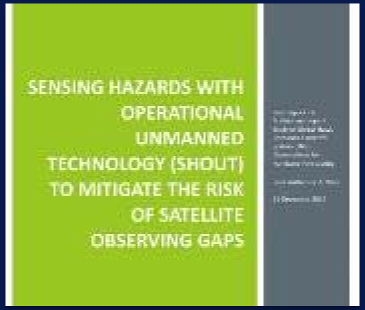
Dropsonde and remote sensing payload

Real-time dropsonde delivery to NOAA Global Forecast System and National Hurricane Center

Second dropsonde intercomparsion with NOAA G-IV

Prototype in relevant / operational environment

2014 – 2017



NOAA Sensing Hazards with Operational Unmanned Technology (SHOUT)

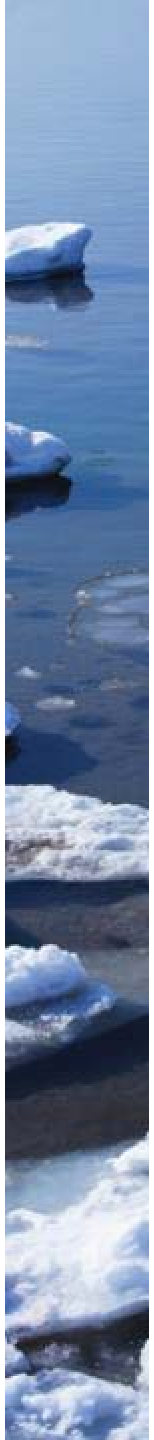
Flights over Atlantic, Gulf of Mexico, Pacific storms

12 missions, 288 flight hours, 738 dropsondes in 2016

Real-time dropsonde and remote sensing data delivery assimilate into NOAA Hurricane Weather Research Forecast Model

Prototype / System in operational environment

**Slide courtesy of R. Hood, NOAA*



The Unique Role of Unmanned Aircraft Systems (UAS) Observations at High Latitudes

The Arctic is

Courtesy of J. Intrieri, NOAA

- Remote and expansive
- Experiencing rapid change
- Logistically difficult to perform observations

The range, altitude and endurance capabilities of UAS in the Arctic fill a critical gap in a region where few observations exist above the surface

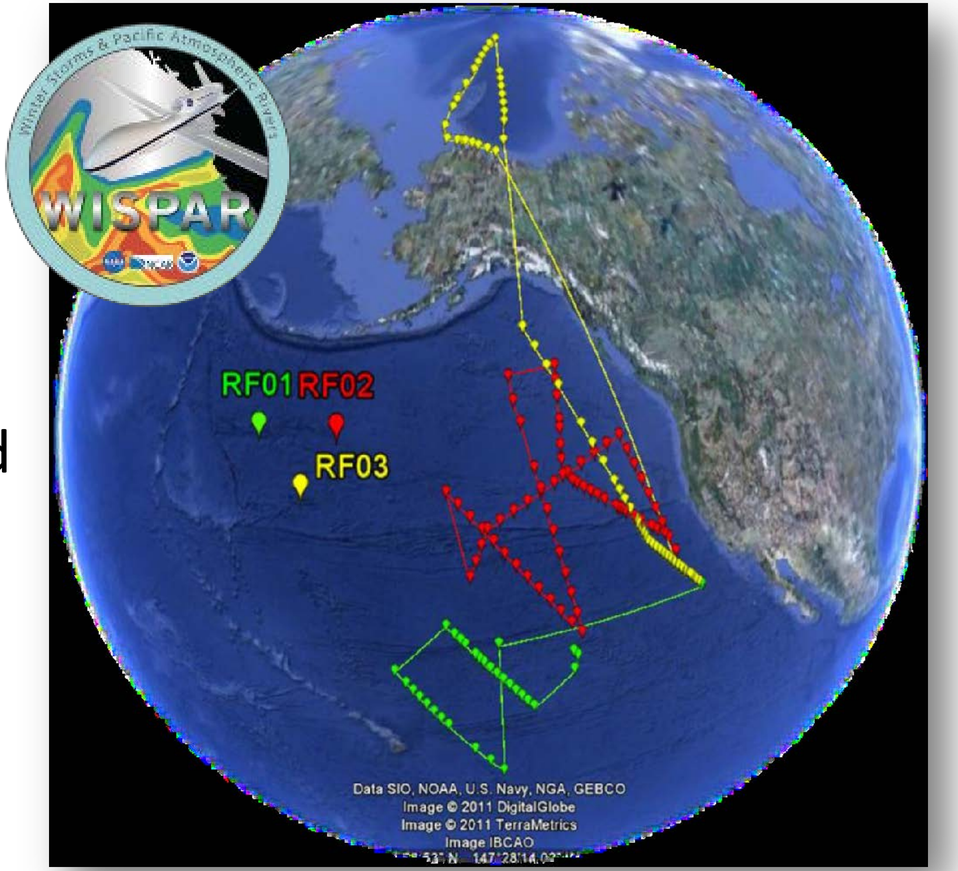
The meteorological and chemical observations in the Arctic will lead to important improvements in numerical weather prediction and coupled chemistry-climate models

WISPAR – Winter Storms and Pacific Atmospheric Rivers

WISPAR was conducted **Feb-Mar 2011** through a collaborative effort between **NOAA-NASA-NCAR**

WISPAR science missions targeted 3 scientific objectives:

- Atmospheric Rivers
- Winter Storms Reconnaissance
- Arctic Atmosphere



Feb 11-12 – Atmospheric river (AR) with tropical-extratropical connection near Hawaii

Mar 3-4 – Targeted observations of an extratropical cyclone in the Gulf of Alaska and AR transect

Mar 9-10 – Arctic flight, dropsonde intercomparison with ground-based observations at Barrow, sampling within the Arctic stratospheric vortex, two AR transects in transit to Arctic

NASA Global Hawk UAS

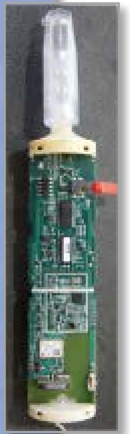
- High-altitude, long-endurance UAS: 55 – 65 kft, 28 hr duration
- Remotely operated from NASA Dryden Flight Research Center, Edwards AFB, CA

Global Hawk

Dropsonde System Launch Tube

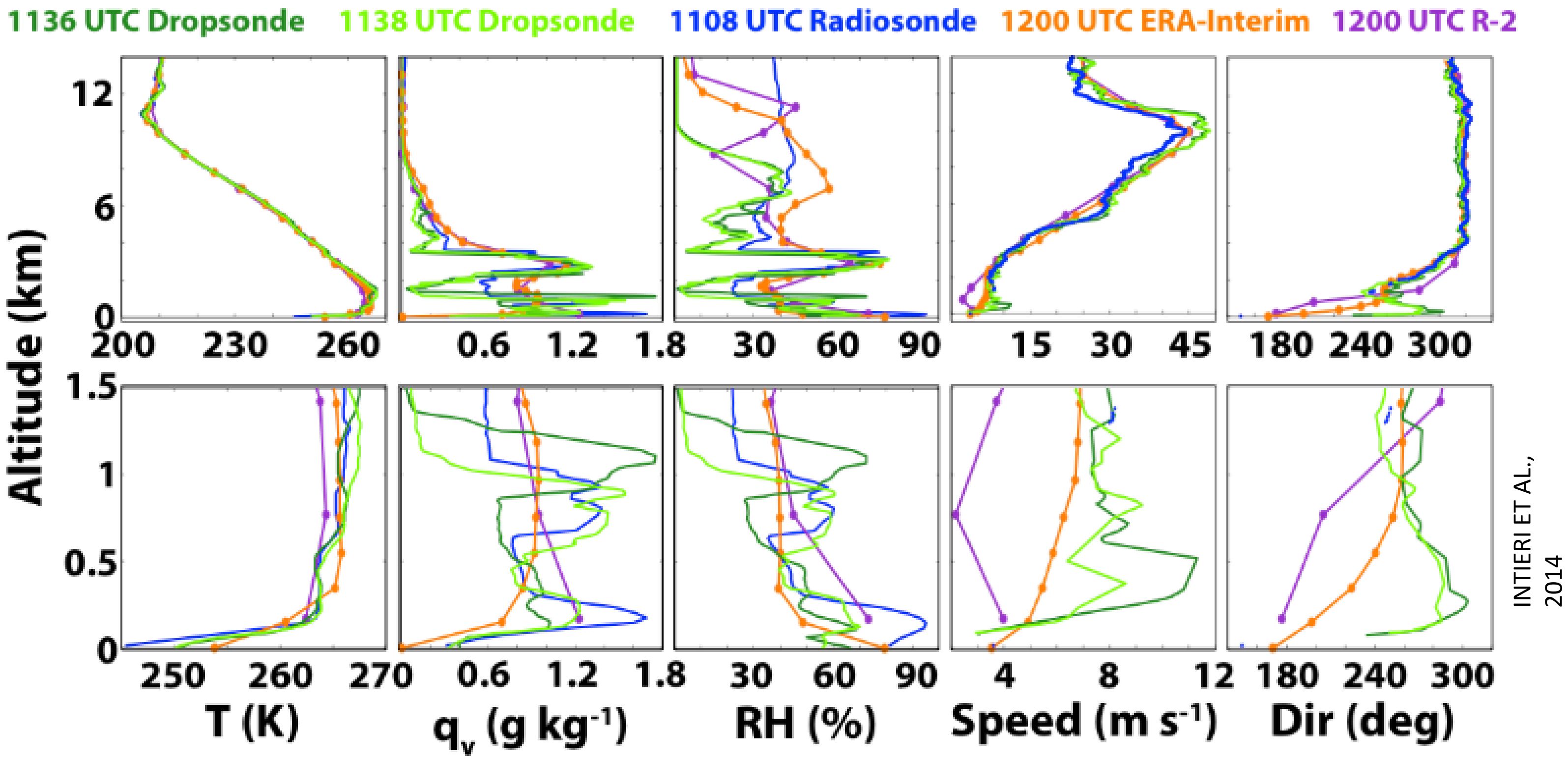
NOAA/NSF developed Global Hawk dropsonde system

Dropsonde Deployment



Dropsonde Launch Assembly

WISPAR showed that our satellite reanalyses are working well for upper atmosphere, which is critical for the Arctic

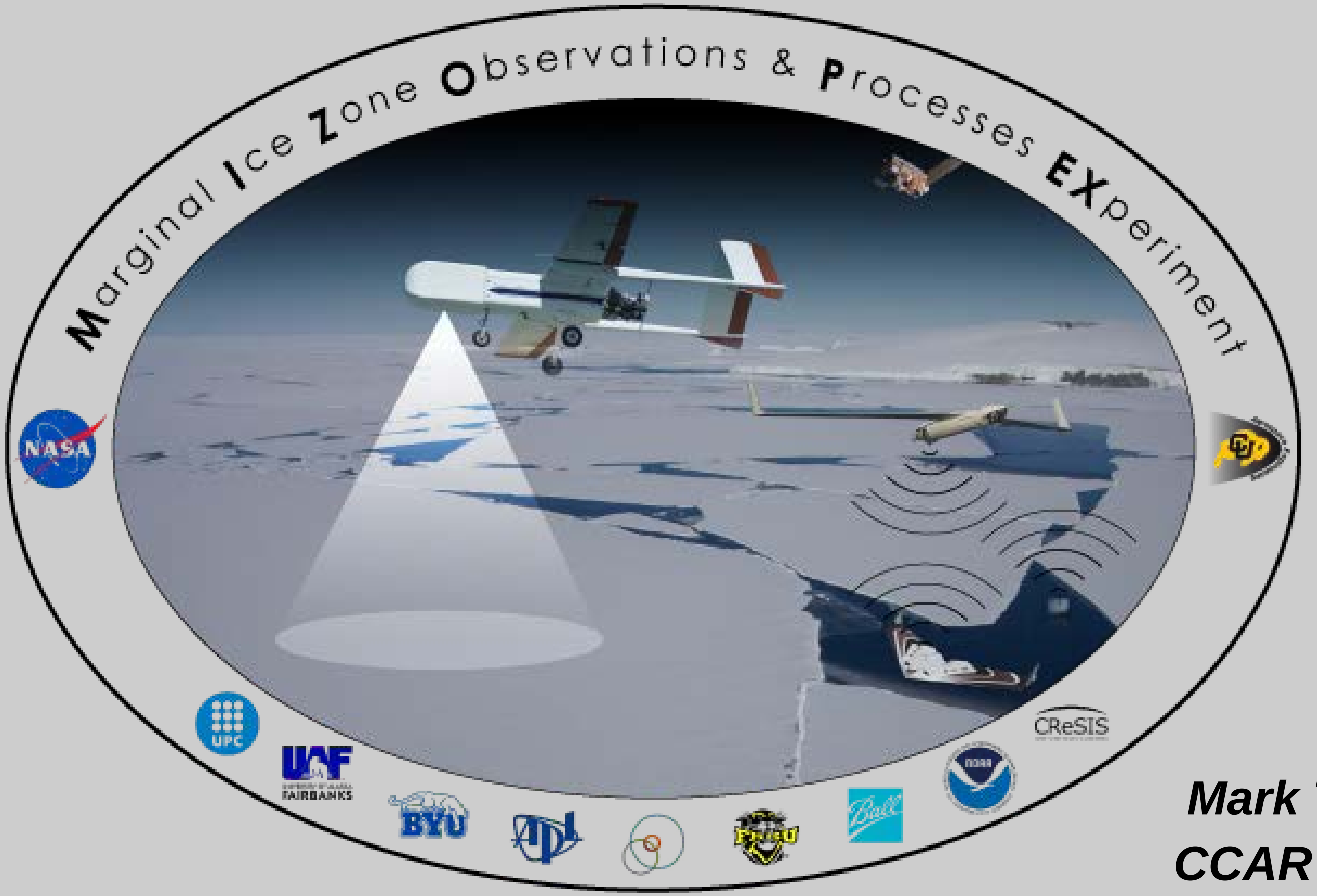


Barrow Weather Forecast Office radiosonde (blue line), Global Hawk dropsondes (green lines) and ERA-I (orange) and R-2 (purple) reanalysis profiles interpolated in space to the averaged dropsonde location for the entire profile depth (top) and lower atmosphere (bottom). From left to right: temperature (K), specific humidity (g/kg), relative humidity (%), wind speed (m/s), and wind direction (deg).

Figure courtesy of J. Intrieri, NOAA

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

Investigations of Spatial and Temporal Variability of Ocean and Ice Conditions In and Near the Marginal Ice Zone:



Mark Tschudi
CCAR
Univ. CO, Boulder

MIZOPEX Objectives

- Assess ocean and sea ice variability during the melt season within a key Marginal Ice Zone (MIZ) region.

  - Amount and distribution of heat in the ocean mixed layer

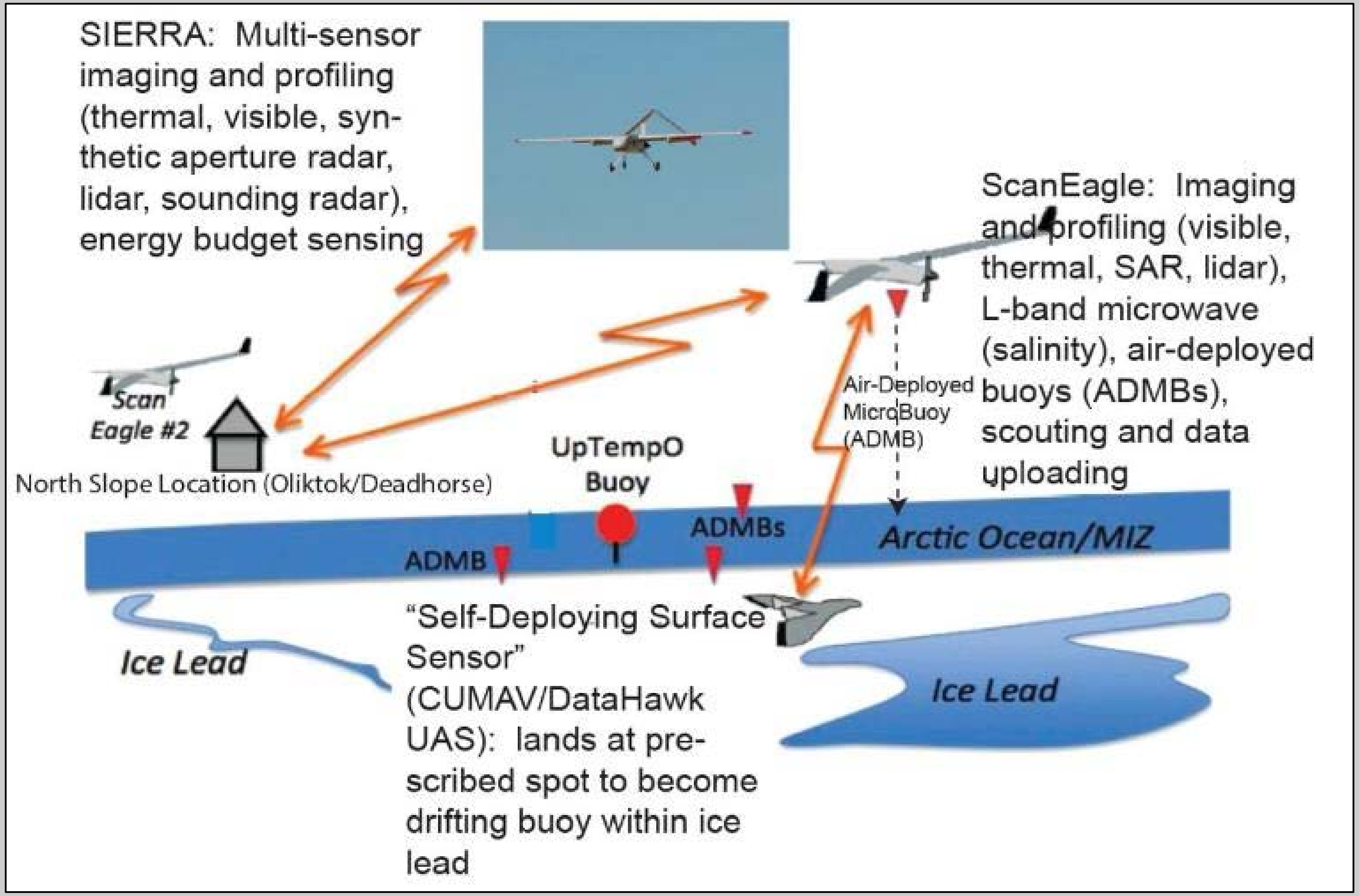
  - Relationships between atmospheric conditions and solar heating

  - Sea ice characteristics and relationships to melt rates and change

  - Satellite product validation (SST, ice concentration)

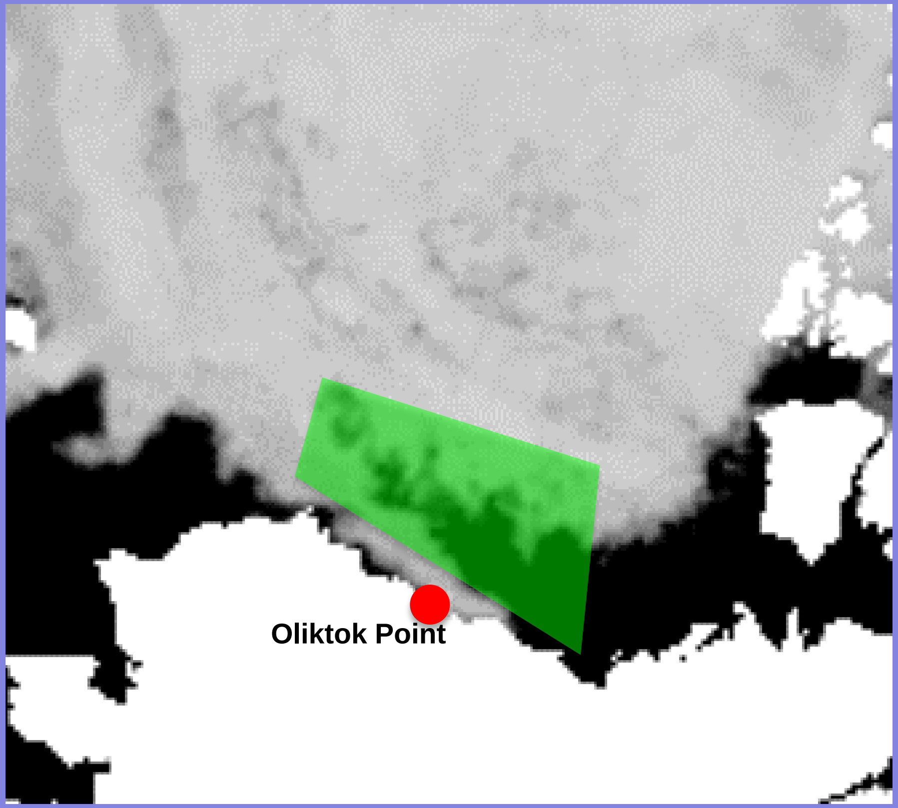
- Demonstrate potential for geophysical research using multiple unmanned aircraft system (UAS) types in polar regions.
- Determine best practices for collaborating with FAA regarding flight requirements and limitations.

MIZOPEX CONOPS

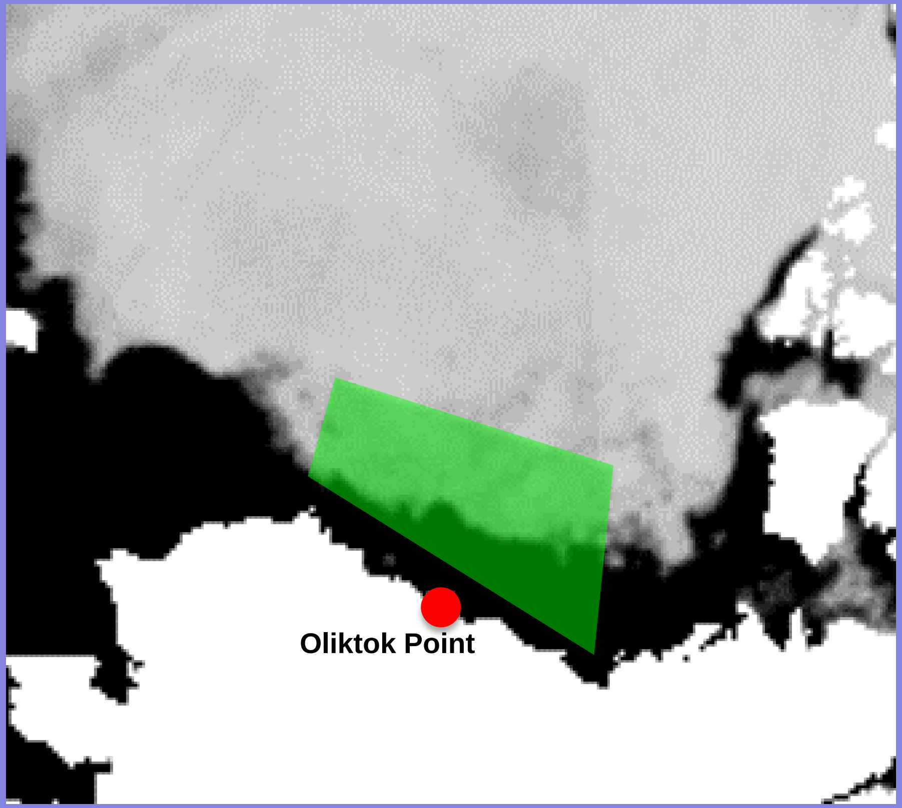


July Sea Ice Extent

15Jul2010



15Jul2011



Three UAS Platforms

CU
Datahawk
~ .8 hours

UAF
ScanEagle
~12.0 hours

NASA
Sierra
~6.0 hours

All UAS are flying lower-level missions:

> Below Cloud Cover

> Camera systems

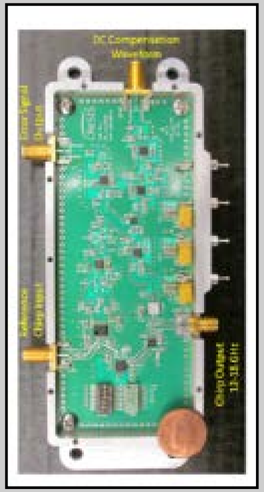
> Ocean skin temp

Sierra Systems

System Name	System Type	Geophysical Measurement	Affiliation
DMS	Visible Still Camera	Ice Concentration, Topography, Melt	NASA WFF
MIS	Pyrometers	Skin SST, Ice Surface Temperature	
	Spectrometers	Spectral Radiance, Albedo	
	Pyranometers	Solar Irradiance, Albedo	
Applanix	GPS, IMU	Aircraft Position, Attitude	
Bobcat	Visible Still Camera	Ice Concentration, Topography, Melt	LDEO
Jade	Thermal IR Still Camera	Skin SST, Ice Surface Temperature	
Shallow Ice Radar	L-Band Radar	Snow & Ice Thickness	
Snow Radar	Ultra-Wideband Radar	Snow Thickness	CReSIS
BESST	Thermal IR Still Camera	Skin SST, Ice Surface Temperature	Ball
SlimSAR	Imaging SAR	Ice Concentration, Roughness	Artemis
CULPIS	Profiling Laser Altimeter	Ice Thickness, Topography	CU
AIS	VHF Communications	Ship Identification and Tracking	NOAA

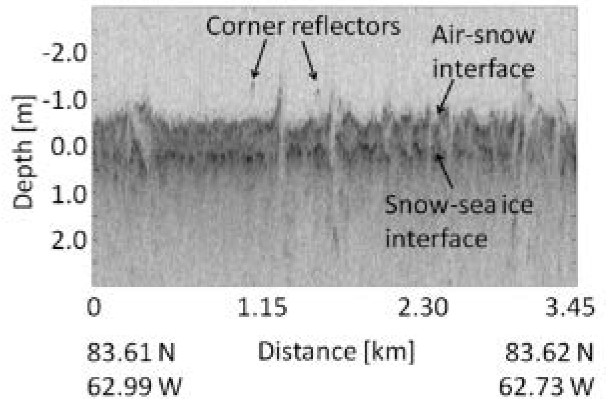
CRESIS Active Snow Radar

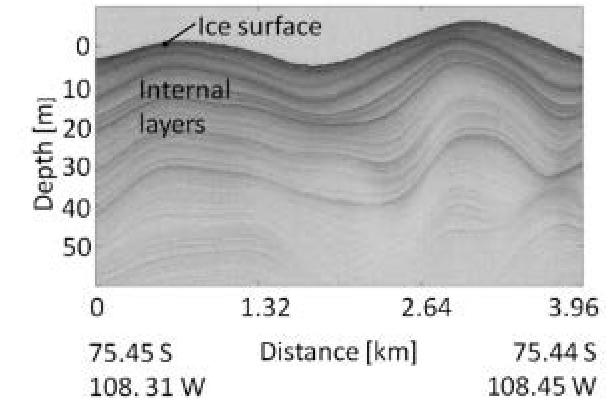
Parameter	Value
Operating Frequency	2-8 GHz (nominal)
Resolution	~5 cm
Output power	100-200 mW
Power consumption	<250 W
Weight	~16 kg
Measurement	Snow cover thickness (0.1-1m) over sea Internal layers over land ice



Data Samples

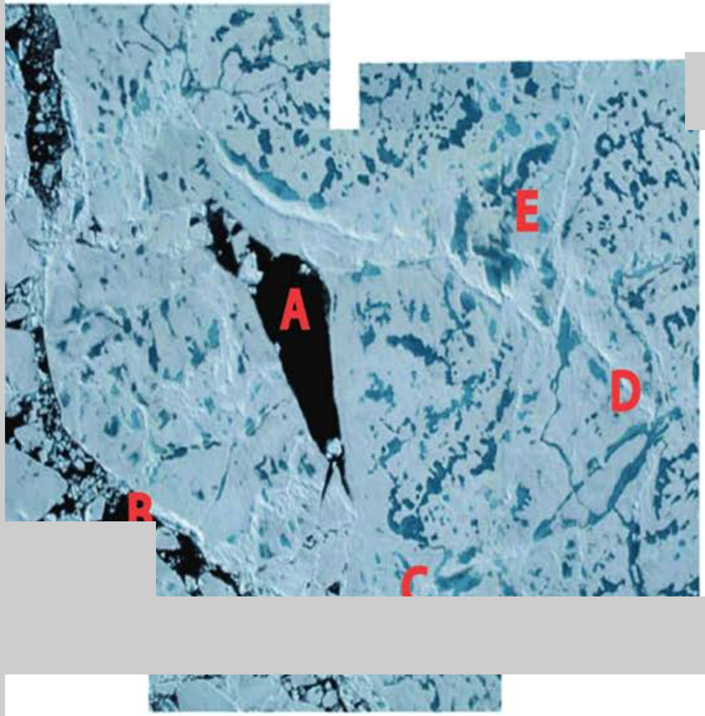
Snow Thickness (Lincoln Sea, Arctic, 2011)



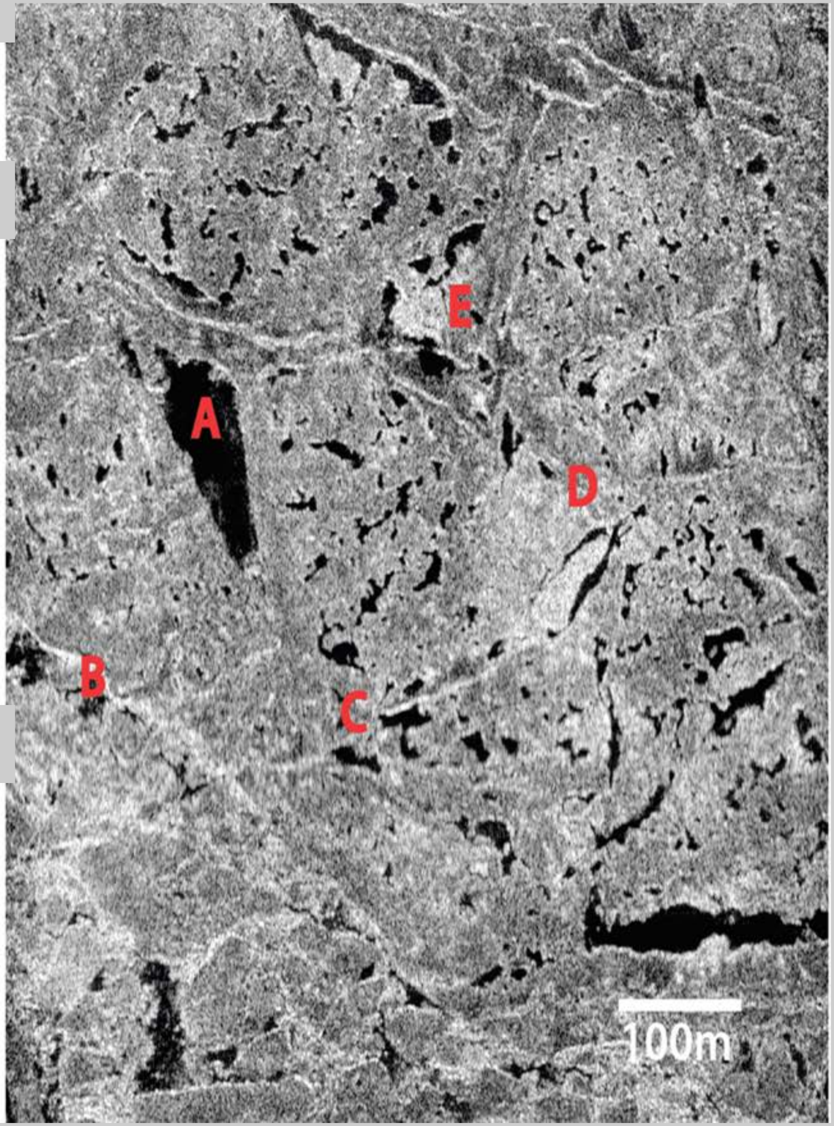


Land Ice (Thwaites Glacier, Antarctica, 2011)

Example Comparison of Optical and SAR images



C-band SAR image from CASIE microASAR. X-band SlimSAR will have higher spatial resolution and will better differentiate snow, water, and melt ponds.



ScanEagle & Buoy Systems

System Name	System Type	Geophysical Measurement	Affiliation
NanoSAR	Imaging SAR	Ice Concentration, Roughness	UAF
Gimbal	Visible Video Camera	Ice Concentration, Melt	
Bobcat	Visible Still Camera	Ice Concentration, Topography, Melt	LDEO
Atom	Thermal IR Still Camera	Skin SST, Ice Surface Temperature	
ADMB	Surface Buoy	Bulk SST	CU
CULPIS	Profiling Laser Altimeter	Ice Thickness, Topography	
Ariel	Microwave Radiometer	SSS	UPC
BESST	Thermal IR Still Camera	Skin SST, Ice Surface Temperature	Ball

System Name	System Type	Geophysical Measurement	Affiliation
SDSS	SRE UAS & Surface Buoy	Bulk SST	CU
UpTempO	Surface Buoy	Bulk SST	APL-UW

Air Deployed Micro-Buoy System

- Operates autonomously to launch 4 buoys per flight and search for/collect data from previously deployed buoys
- Buoy measures GPS location 1/hr and ocean temperature at surface, 1m and 2m depths 10/hr (0.1°C accuracy) = 2KB/day
- Expected buoy lifetime of 8-10 days
- Radio is an Xbee-PRO XSC 900 multipoint radio: 2-4km range (altitude dependent), 915MHz ISM band (FHSS 902-928MHz)
- Buoy radio sleep/wake cycle preserves battery. Data transfer occurs when buoy hears a “CQ” message from overflying receiver
- Radio data packets typically 40-100 bytes each (< 5sec to transmit 24 hours of data)

ScanEagle Payload Top

ScanEagle Payload Bottom

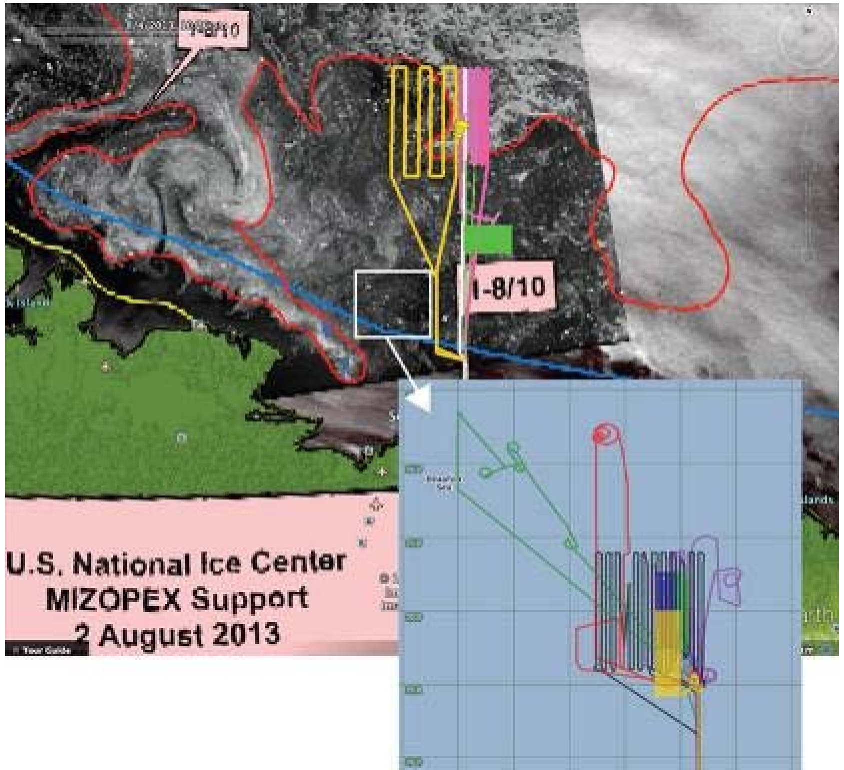
Buoy In Water

Accomplishments

- 3 separate UAS deployed at Oliktok Point (USAF/DOE site; Alaskan coast) during 10 July – 9 Aug 2013. Flights in national and International air space.
- 24 separate UAS flights carried out; 54 flight hours; visible and thermal imaging and microbuoy drops (900+ hours of data collected using 11 ScanEagle-deployed buoys)
- First beyond-line-of-sight flights, concurrent UAS ops., coincident remote and in-situ sensing, multi-agency coordination, use of ground-based radar for safety

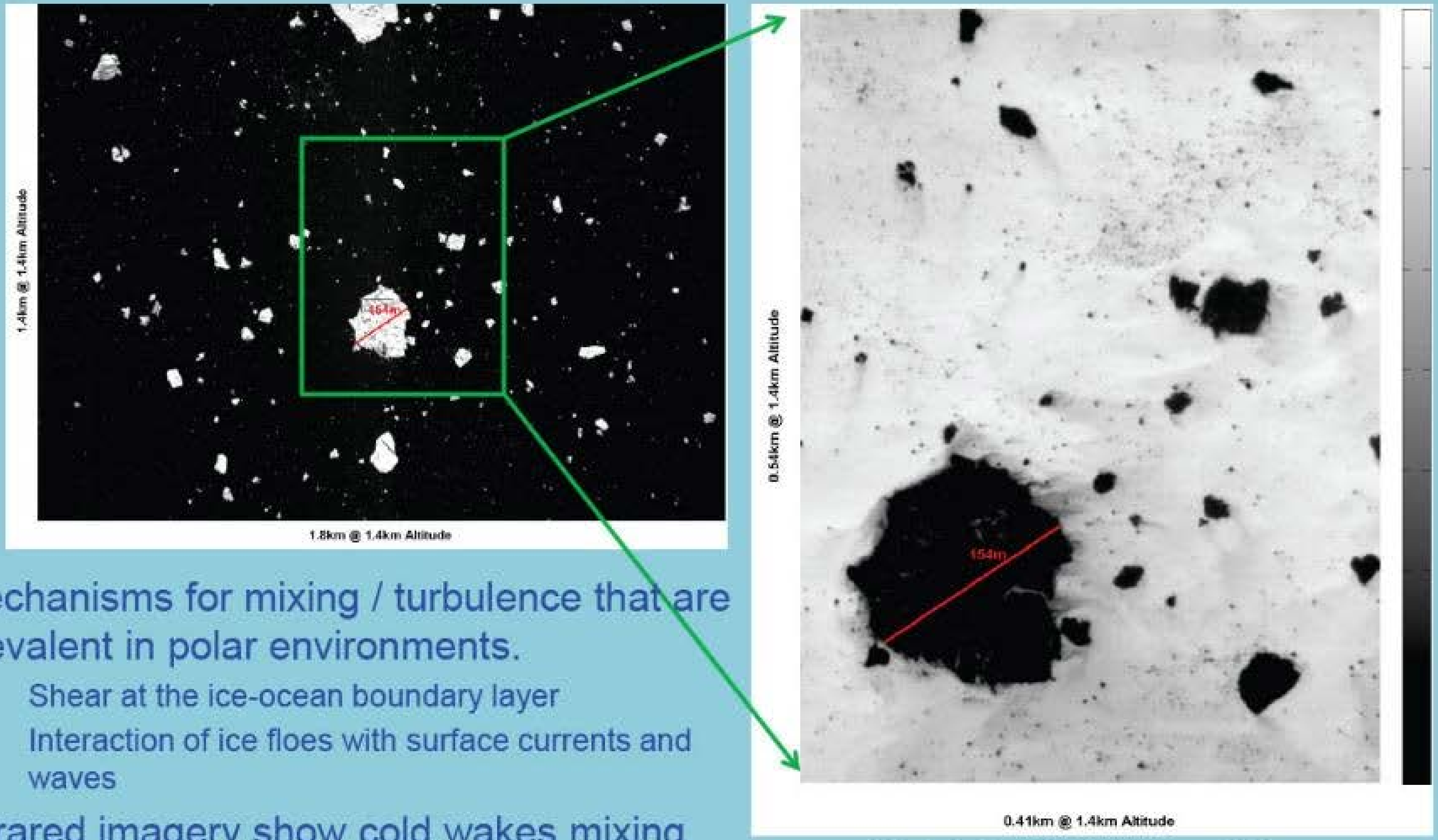
Unmanned aircraft used:

Flight tracks achieved:



MIZOPEX: Turbulence Mechanisms in Polar Systems

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

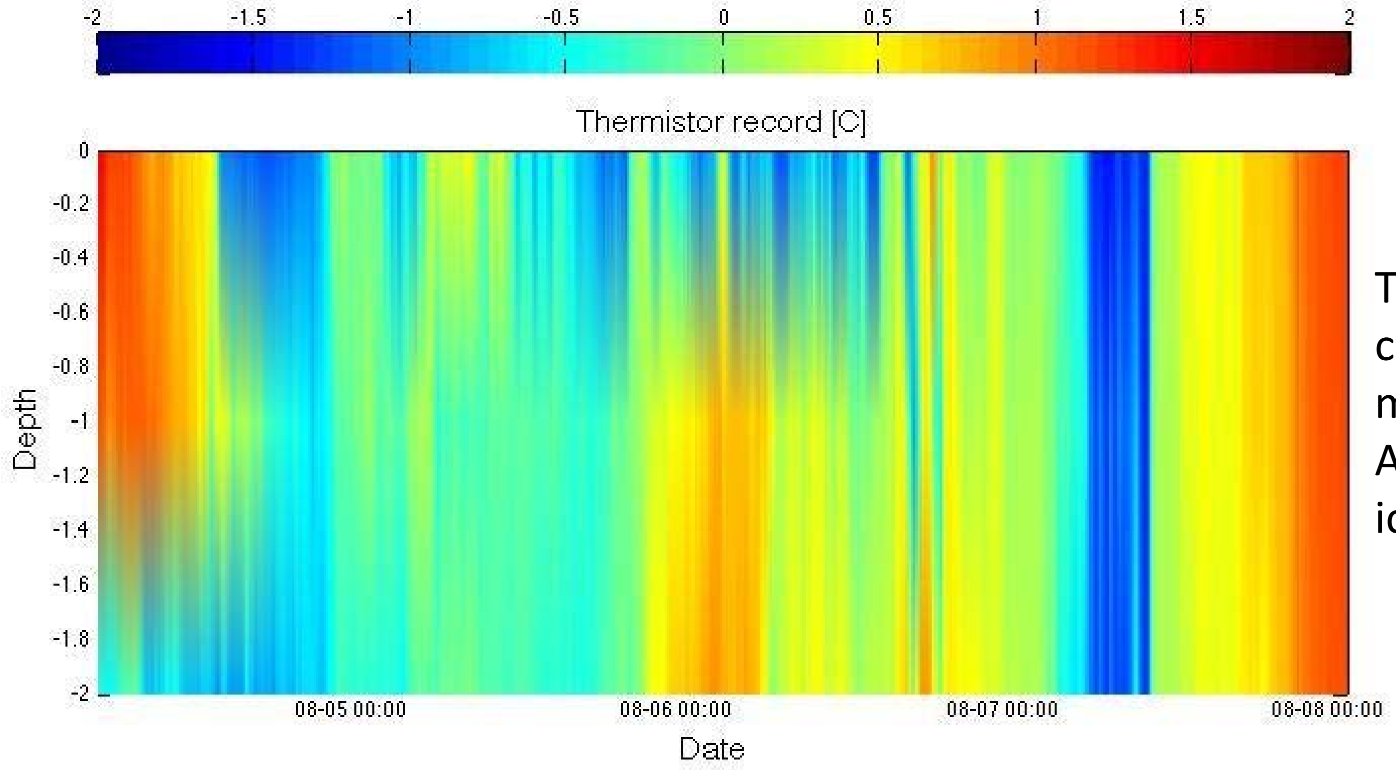


- Mechanisms for mixing / turbulence that are prevalent in polar environments.
  - Shear at the ice-ocean boundary layer
  - Interaction of ice floes with surface currents and waves
- Infrared imagery show cold wakes mixing near-surface ocean in the lee of ice floes.

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

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

Temperature data from ADMB deployed in MIZ

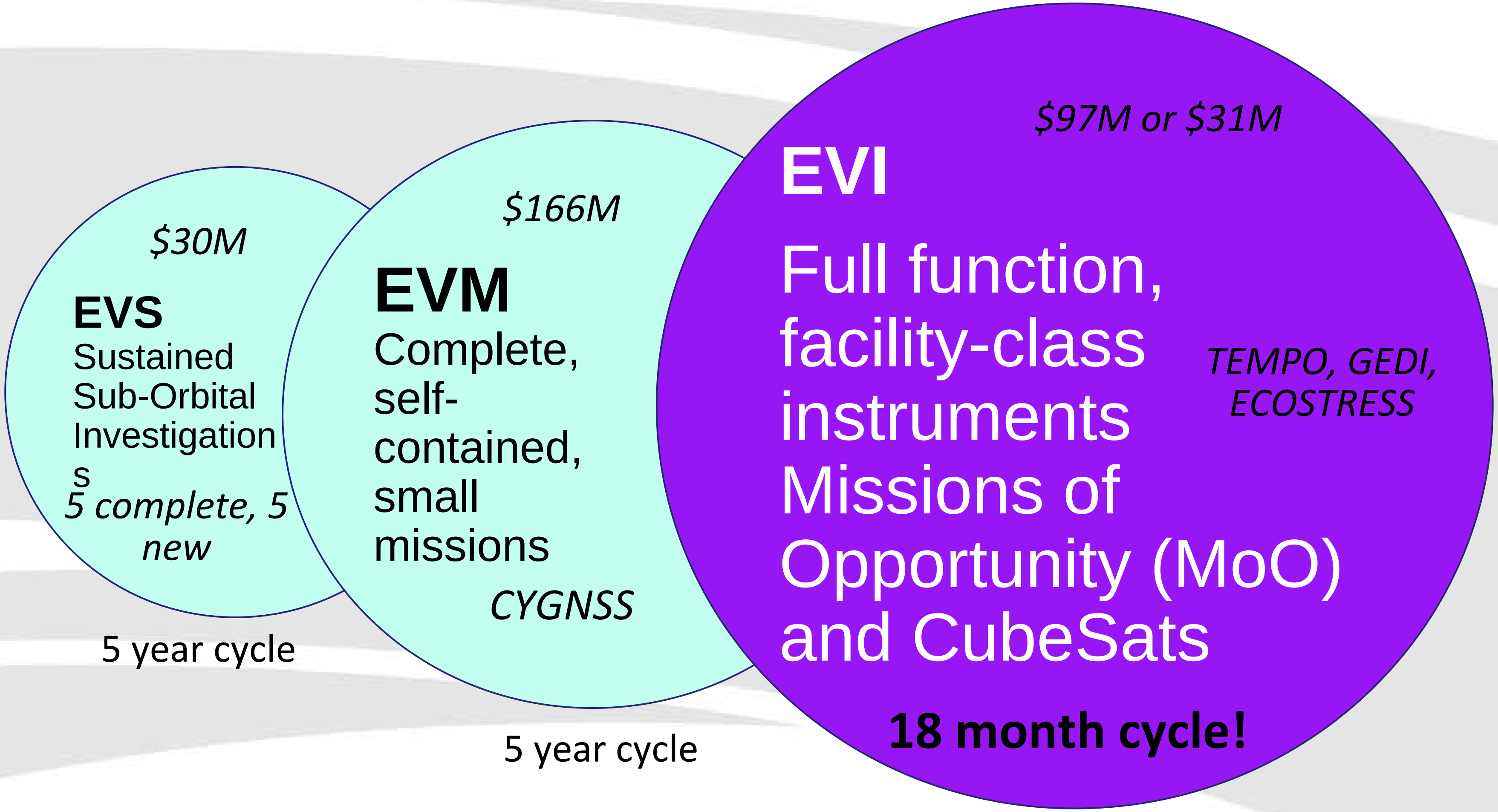


Temp. measurements collected at 0, 1, and 2 meter depths by one ADMB in the marginal ice zone.

- Skin temperature is not reliable measure of ocean temperature at 1 or 2 m depth.
- Cold water can be suspended over warmer sub-surface temperatures.
- High winds induce mixing in the upper ocean.

Lessons Learned

- Large UAS pose unique challenges
  - MIZOPEX was a pathfinder with FAA and the lessons learned document is fascinating
- We have an amazing array of instruments and systems that work (it’s not just cameras)
- UAS operations are still a challenge relative to piloted aircraft
- There are other unique aspects of UAS that remain to be exploited, e.g. swarms



- EVI-3 continues to support the Earth Science Division’s goal to develop capable instruments for flights on NASA or partner missions