Overview of the NOAA Unmanned Aircraft Systems (UAS) Program

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National Marine Mammal Laboratory

and

NOAA UAS Program

21 May 2010

Road map

Overview of NOAA UAS Program

Operational successes

UAS in the virtual world

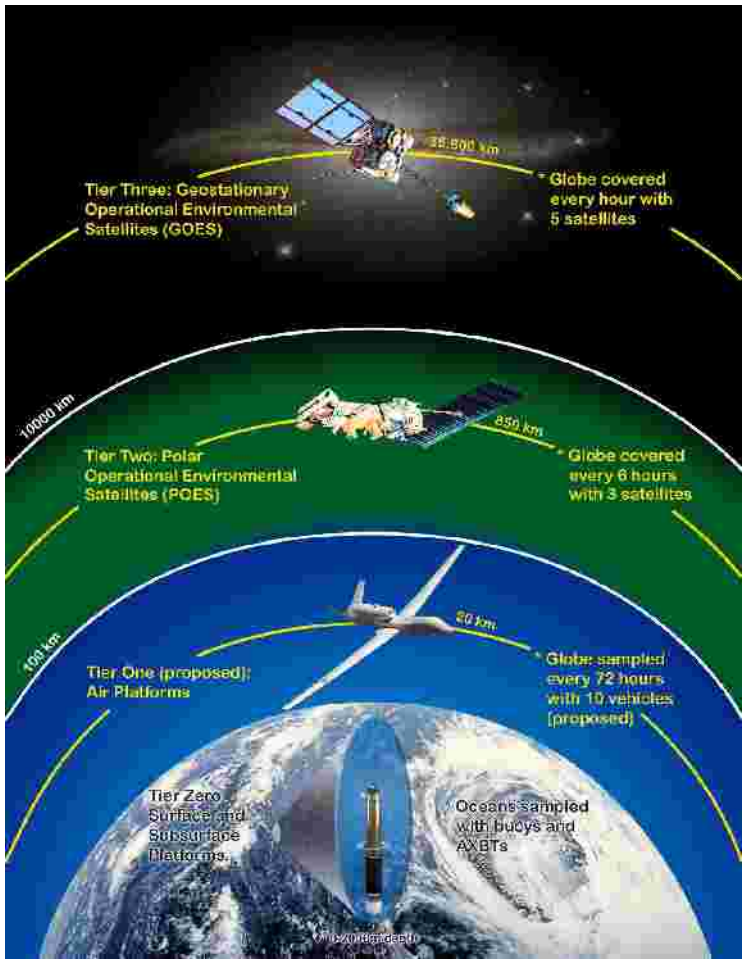
Platform/payload needs

Overview of NOAA UAS Program

The NOAA Unmanned Aircraft Systems (UAS) Program is evaluating the feasibility of UAS platforms to meet the NOAA Mission's goals for:

- ***Weather***
- ***Climate***
- ***Coasts***
- ***Oceans***

using a requirements-driven systems approach to assess technology readiness and operational feasibility



McDonald (2005): A global profiling system for improved weather and climate prediction. American Meteorological Society.

Unmanned Aircraft Systems
NOAA Position Statement

Unmanned Aircraft Systems (UAS) have the potential to and safely bridge critical information gaps in data sparse and remote locations of the global environment and advance the understanding of key processes in Earth systems. Optimizing the capabilities that UAS offer will advance NOAA's mission goals through improved understanding of oceanic and atmospheric exchanges, hurricanes, wildfires, marine ecosystems, polar regions, hazards, and other environmental and ecological processes, ultimately leading to improved climate and weather predictions and management of marine resources. NOAA is partnering with other civilian agencies, industry and the academic community to develop UAS operations, systems platforms that can be safely deployed, both nationally and globally, fill observational data gaps with increased efficiency and decreased risk to personnel.

NOAA UAS Regional Test Bases

- **Conceptual Science Studies**
- **Technology Demonstrations**
- **FAA Airspace Collaborations**
- **Regional Partnerships**

Operational Successes

High Impact Weather for Coastal Communities

- Low altitude land launched UAS flights for boundary layer sampling
- Aircraft launched UAS for boundary layer sampling
- High altitude UAS flight for remote sensing – Global Hawk 2010

Marine Monitoring

- High altitude UAS atmospheric chemistry and air quality remote sensing
- High and low altitude UAS studies of atmospheric rivers
- UAS surveillance

Polar Monitoring

- Low altitude sea-ice and meltpond mapping – Greenland glacier 2008
- Low altitude ship launched UAS marine mammal survey – Ice seals 2009
- High and low altitude UAS atmospheric chemistry and air quality sampling

Global Hawk Pacific (GloPac) Experiment – April 2010

A partnership between NASA , NOAA, and Northrop Grumman

7 April 2010 – 14 hrs – 4600 nm

Global Hawk over Mojave Desert

NASA Global Hawk Operations Center

Global Hawk Partnership Decal

13 April 2010 – 24 hrs – 8000 nm

GloPac objectives:

- **Evaluate performance of Global Hawk for science missions**
- **Observe ozone, greenhouse gases, ozone-depleting substances, aerosols, and constituents of air quality in the upper troposphere and lower stratosphere.**
- **Observe dust, smoke and pollution crossing the Pacific from Asia and Siberia with potential to impact U.S. air quality**
- **Collect validation information for Aura satellite**

Installation of NOAA Ozone Instrument

23 April 2010– 29 hrs – 9600 nm

Global Hawk High Definition Visible Imagery – 7 April 2010

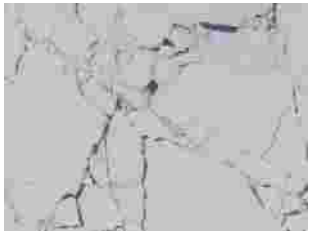
NOAA GloPac Team

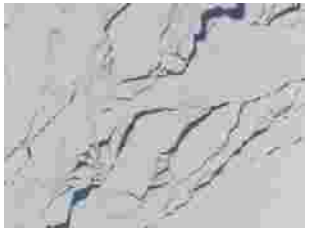
High definition visible images of sea ice captured by NASA Airborne Compact Atmospheric Mapper – 23 April 2010

One Mission – Two Oceans

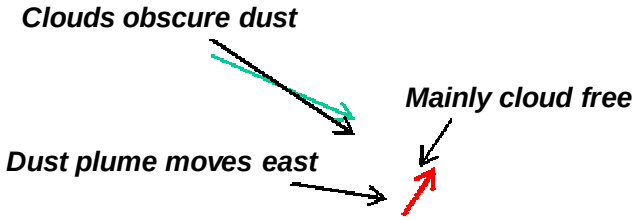
23 April 2010 Global Hawk Accomplishments

- **Flight endurance – 28.6 hrs; Flight range – 9700 nm;**
- **Maximum altitude – 19.9km; Maximum latitude – 85N**
- **First time any Global Hawk has ever traveled north of 70 latitude**
- **Collected, recorded, and relayed real-time readings of *in situ* stratospheric ozone, water vapor, methane, carbon monoxide, nitrous oxide, hydrogen, and sulfur hexofluoride concentrations along entire flight track**
- **Captured high definition visible imagery of sea ice**
- **Cloud Physics Lidar remotely sensed dust concentrations crossing the Pacific Ocean from 31 March 2010 Gobi Desert dust storm**

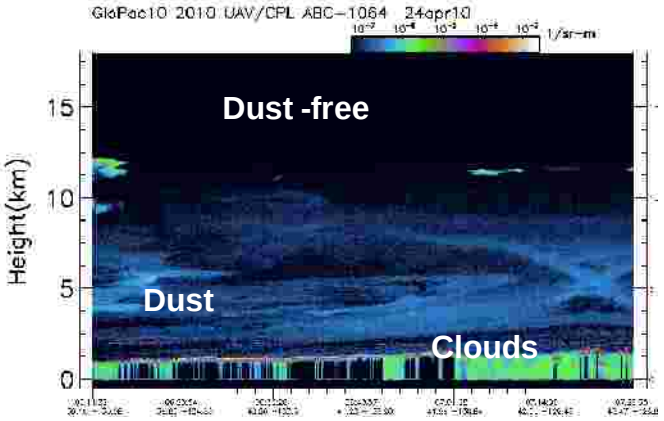




High definition visible images of sea ice captured by NASA Airborne Compact Atmospheric Mapper



NASA aerosol model forecast and Global Hawk flight track



Aerosol vertical profile observed by Cloud Physics Lidar along red arrow of flight track above

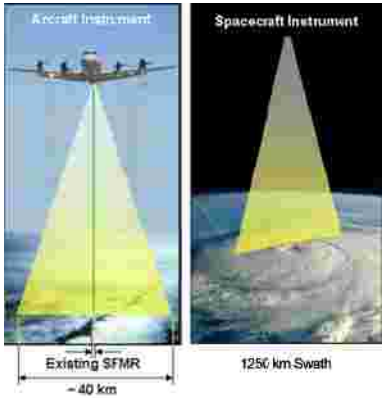
High Impact Weather Concept Study

Previous Aerosonde flights in collaboration with NASA

Global Hawk Hurricane Missions in collaboration with NASA

Exploring options for manned aircraft-launched UAS expendables.

HIRAD



Hurricane Imaging Radiometer development for ocean wind sensing in collaboration with NASA

Global Hawk dropsonde development in collaboration with NSF and NCAR

Atmospheric river air-sea flux study

Objective: Demonstrate the capability of small unmanned aircraft to accurately measure air-sea fluxes in severe weather conditions including atmospheric rivers

Collaborators: Scripps Institution of Oceanography, BAE

Results:

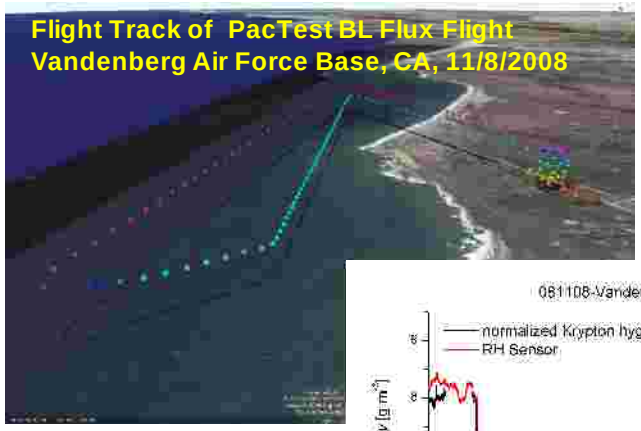
Initial testing at Vandenberg AFB in Oct-Nov 2008

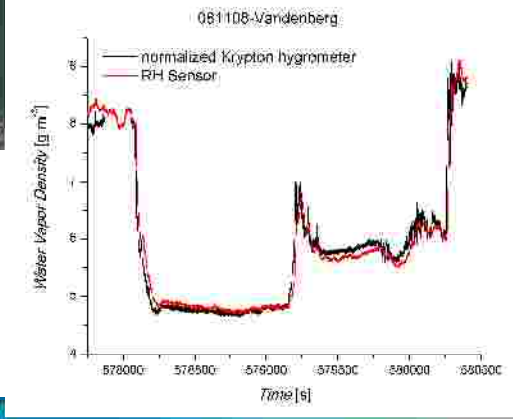
- Verified performance of high frequency moisture measurements
- Identified problem with inertial navigation system requiring return to manufacturer

Further flight testing at NASA Dryden next week

- Deploying ground-based direct covariance flux system for validation of airborne sensors
- 4 flights over 2 days planned

Overwater testing planned for San Nicholas Island, July 2010





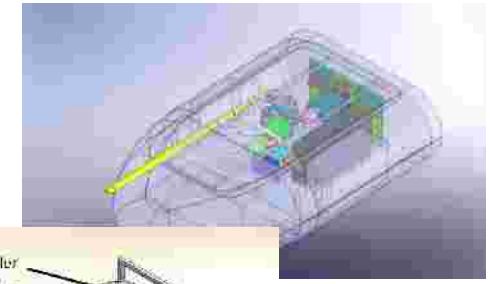
Contact: Gary Wick, gary.a.wick@noaa.gov

Atmospheric Chemistry - Climate Studies

Objective: Vertical profiles of atmospheric aerosol properties in remote locations (above ships at sea and in the Arctic)

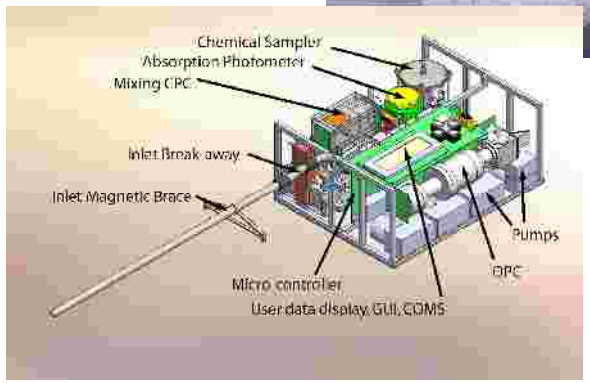
Operation details: Aerosol package will include total particle number, particle size, particle light absorption (soot), and particle chemical composition.

Collaborators: Tim Bates & Trish Quinn, NOAA/PMEL Atmospheric Chemistry Group
Christian Meinig & Scott Stalin, NOAA/PMEL Engineering Development Division
Fred J. Brechtel & Andy Corless, Brechtel Mfg. Inc.



Results:

Currently field testing aerosol instrumentation aboard R/V Atlantis (not with UAS).
Currently developing a shipboard net capture system for the UAS



Contact: Tim.Bates@noaa.gov

Applications of UAS to surveillance of Marine Protected Areas and fisheries

Objective: Test/evaluate use of AeroVironment Puma AE & Wasp UAS for maritime law enforcement

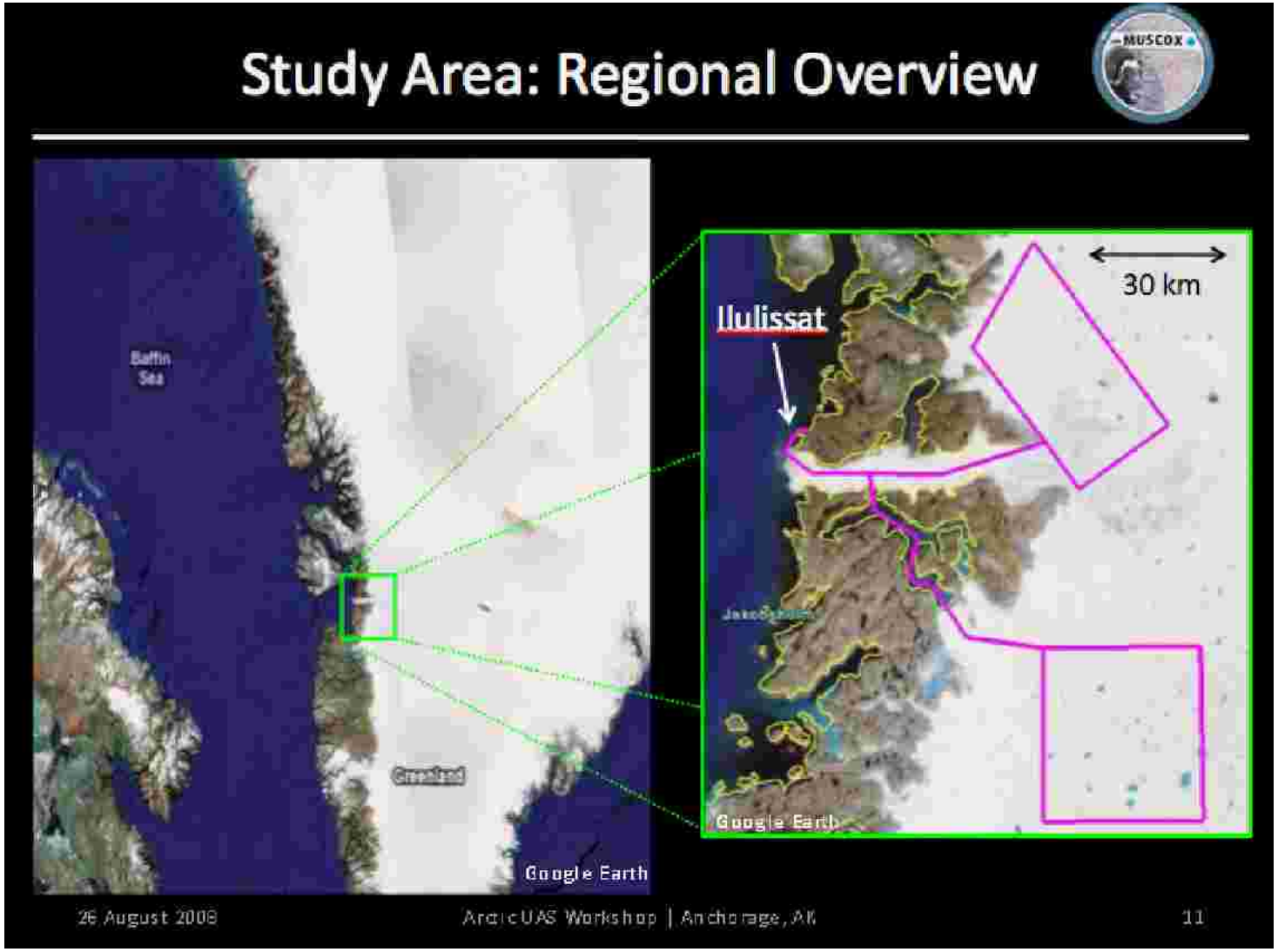
Collaborators: Coast Guard, Navy, Cal. Fish & Game

Results:

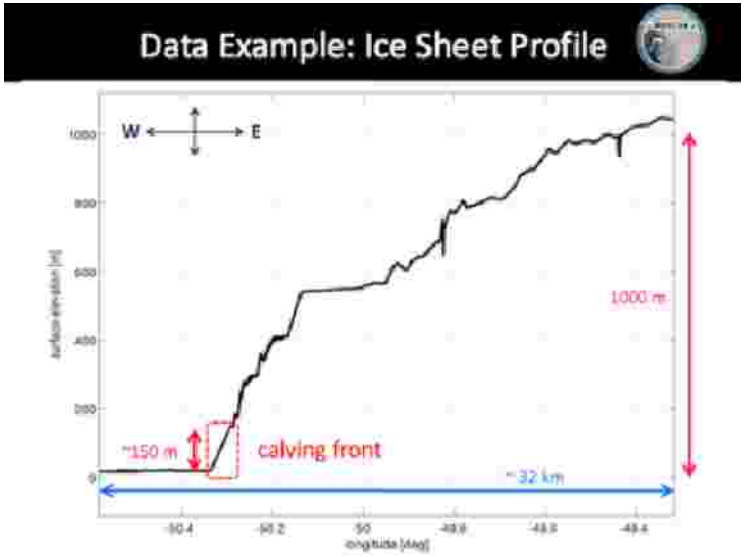
- Successful real-time video feed
- Successful in identifying vessel name, numbers, deck activity

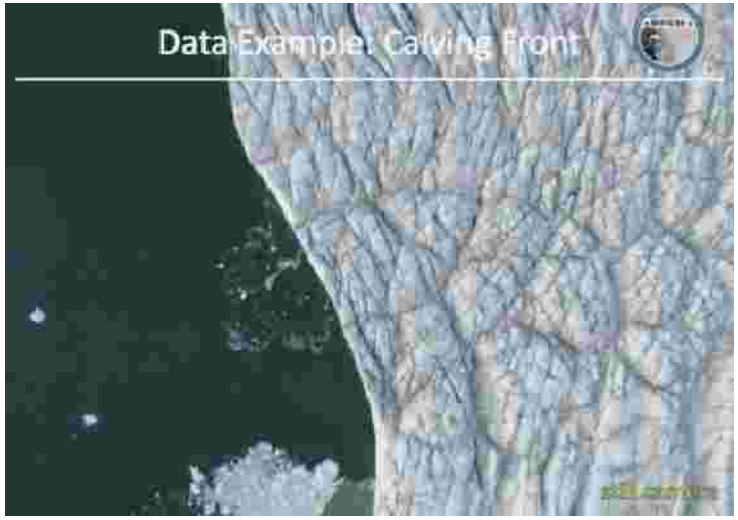
Contact: Todd.Jacobs@noaa.gov

Greenland glacier study - 2008



Greenland glacier study - 2008





Objectives:

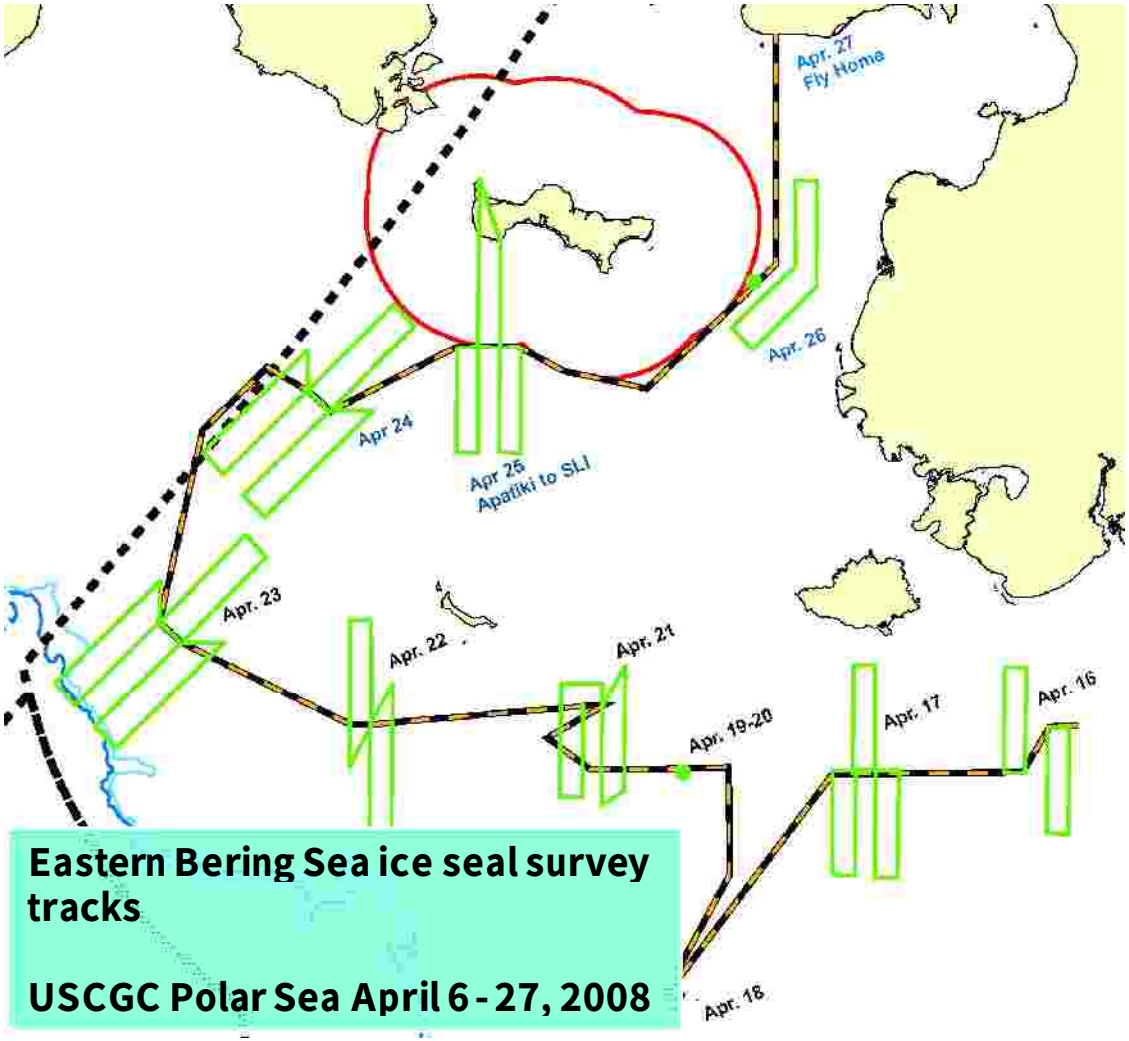
- Measurement of the volume of surface melt-water pools on a fast-moving glacier
- Assess ACR “Manta” for Arctic missions
- Evaluate Iridium for beyond-line-of-sight missions

PI: John.Adler@noaa.gov
Collaborators: ACR, CU-Boulder

Marine wildlife surveys

Line transect sampling of disperse wildlife

- Ice seals
- Bowhead whales



Eastern Bering Sea ice seal survey tracks

USCGC Polar Sea April 6 - 27, 2008

Bering Sea ice seal study

2009 Bering Sea UAS objective

Evaluate the ability of small UAS to effectively collect sightings data in a sub-Arctic environment.

- Evaluate camera performance and seal response to UAS
- Evaluate platform performance in icing conditions

Operations:

- Downward looking DSLR camera collects images every 4 seconds
- Collect images from various altitudes (300 – 1000 ft)
- Conduct limited surveys of pack ice (within 5 Nmi radius of ship)

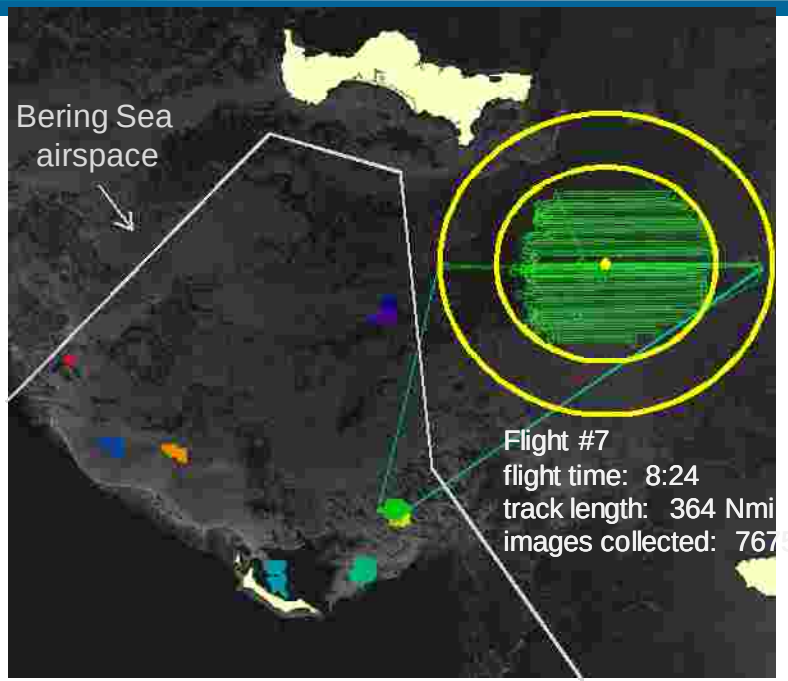
Collaborators: Greg Walker, UAF; Boeing/Insitu, Evergreen

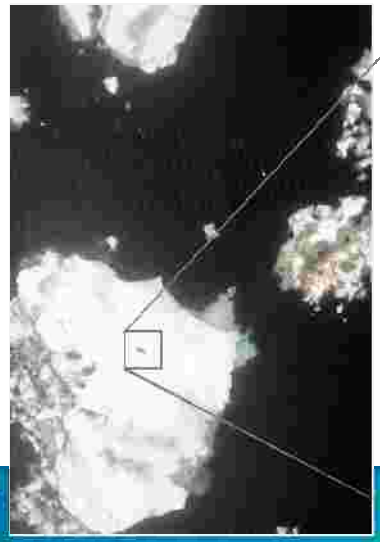
Bering Sea ice seal study

Results: Ten successful flights from the NOAA ship *McArthur II* in the Bering Sea

- No lost aircraft or lost comms
- Recovered in light rain, fog, and snow
- Total flight hours: 42
- Longest flight: 8.5 hours
- Total transect length: 1200 Nmi
- Total images collected: 27,000

Contact: Peter.Boveng@noaa.gov, Michael.Cameron@noaa.gov

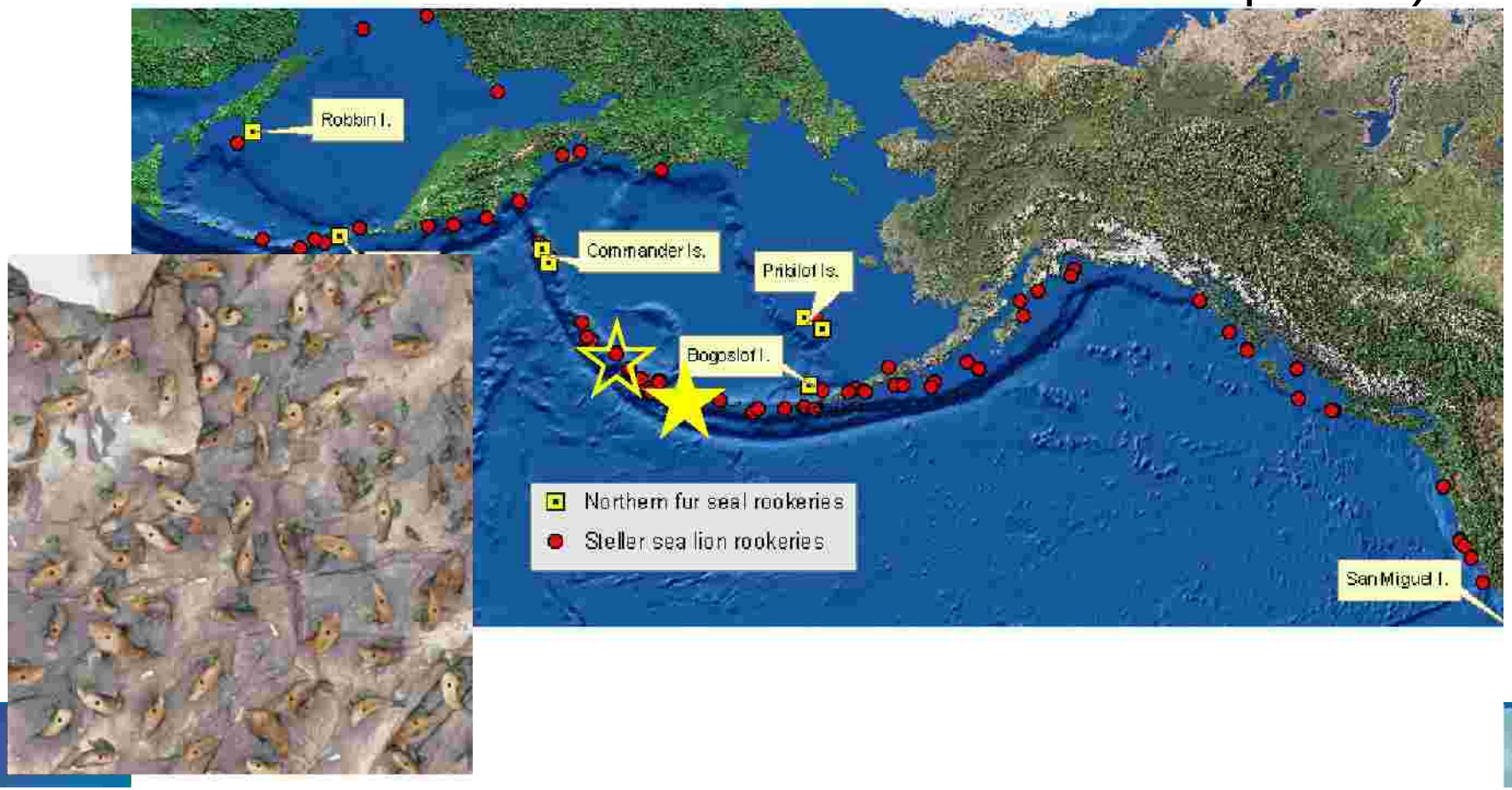




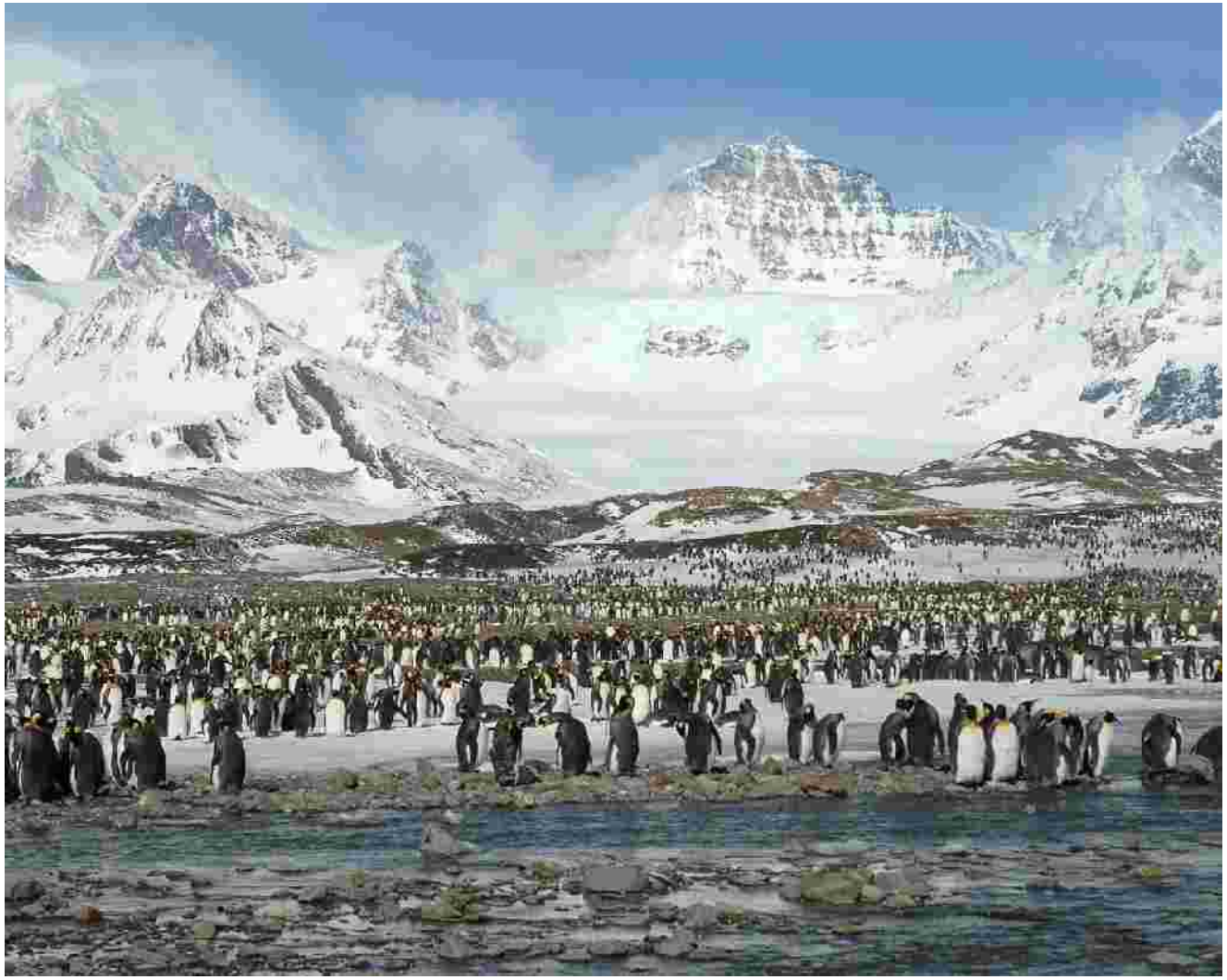
Marine wildlife surveys

Collecting data on wildlife at known locations

- Harbor seals
- Penguins
- Steller sea lions
- Dolphin schools (find using vessel-based spotters)



Antarctic Mission: Penguins & Antarctic fur seals



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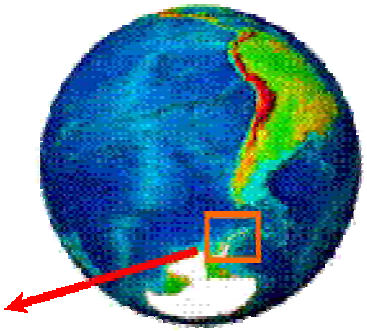


Partners: **NOAA National Marine Fisheries Service / Southwest Fisheries Science Center**

Enerdyne

Aerial Imaging Solutions

Wayne.Perryman@noaa.gov

Objective: Collect vertical images of penguin colonies and fur seal rookeries that can be used for population assessment studies

- Testing system at California sea lion rookery July 2010 – compare ground-based counts, traditional aerial survey counts, and counts from UAS imagery
- Aircraft will be taken aboard ship and will stage from vessel to sample otherwise inaccessible sites in Antarctica, January 2011

Testing UAS in the "model world": Weather

OSSE – Observing System Simulation Experiment

- An OSSE is a modeling experiment used to evaluate the of new observing systems on operational forecasts when actual observational data are not available

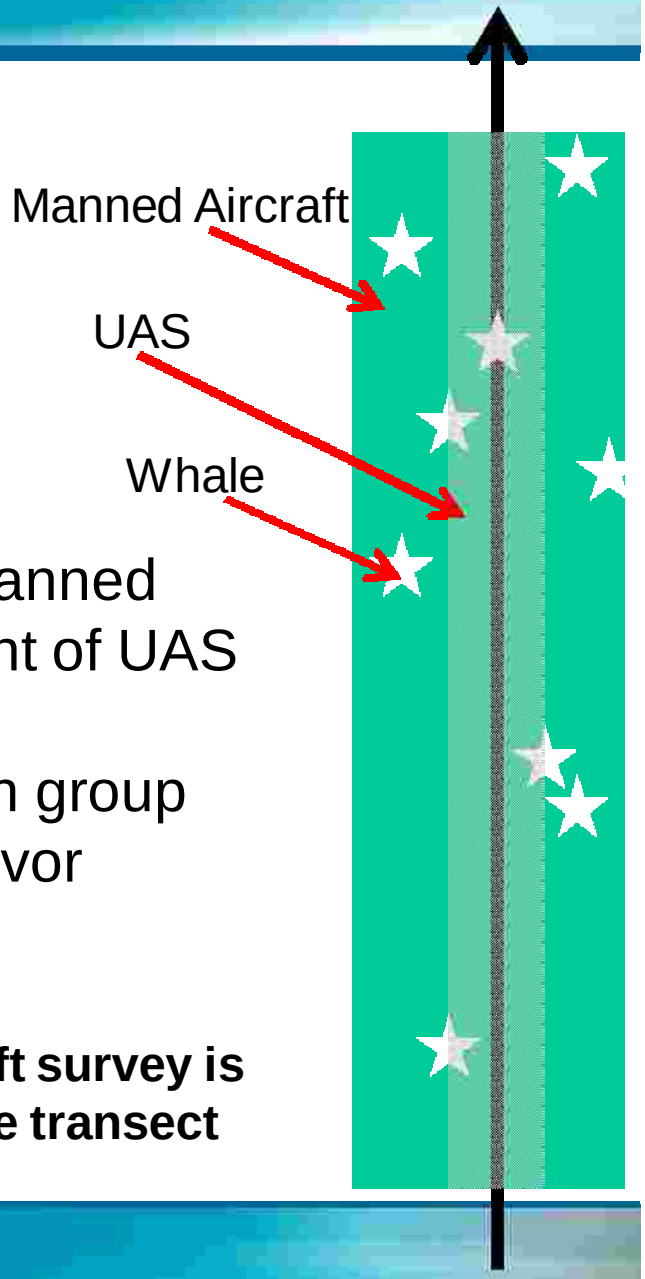
- UAS OSSE will be used to guide acquisition, flight planning, sensor development decisions

- Current efforts include global weather OSSE to evaluate hurricane tracking improvements and regional hurricane OSSE to evaluate hurricane intensity improvements

Testing UAS in the "model world": Whale surveys

- Results

Field of View	UAS Survey Distance	UAS Survey Time
400 m	2 – 5x	5 – 12.5x
600 m	1.5 – 4x	3.75 – 10x



- Detection probabilities for UAS relative to manned aircraft have considerable effects on the amount of UAS effort required
- Incorporating the uncertainty associated with group size estimation into this analysis would likely favor manned aircraft over UASs

A direct field comparison of a UAS vs. manned aircraft survey is the essential next step to understanding utility for line transect surveys.

Platform Needs

- **Long & short endurance**
- **Low, medium, and high altitude**
- **Beyond line of sight operation**
- **Flexible payload integration**
- **Deployable from other platforms**
- **Dependable communication and data transfer**
- **Quiet noise levels for wildlife surveys and law enforcement**

Payload Needs

- **Synthetic aperture radars**
- **Temperature and humidity profiling radiometers**
- **All weather ocean wind speed, sea surface temperature, precipitation, ice edge imaging radiometers**
- **Precipitation and wind profiling radars**
- **Wind and aerosol lidars**
- **Dropsonde systems**
- **Hyperspectral imagers**
- **Lightning and electric field sensors**
- **Radar and laser altimeters**
- ***In situ* samplers of aerosols, gases, and hydrometeors**

Challenges

- **Airspace access**
- **Technologically mature payloads and information products ready for operational applications**
- **Need new compact and lightweight sensors**
- **On-board processing and real-time information products**
- **Efficient information management and visualization**

Growing NOAA Priority - Interim Report of the Interagency Ocean Policy Task Force

- **National Policy and Implementation Strategy for 9 Priority Objectives:**
  - ***Ecosystem-Based Management***
  - ***Coastal and Marine Spatial Planning***
  - ***Inform Decisions and Improve Understanding***
  - ***Coordinate and Support***
  - ***Resiliency and Adaptation to Climate Change and Ocean ication***
  - ***Regional Ecosystem Protection and Restoration***
  - ***Water Quality and Sustainable Practices on Land***
  - ***Changing Conditions in the Arctic***
  - ***Ocean, Coastal, and Great Lakes Observations and Infrastructure***
- **Implementation Strategy should:**
  - ***"Identify specific and measureable near-term, mid-term, and long-term actions, with appropriate milestones, performance measures, and outcomes to fulfill each objective"***
    (Pages 7 & 28)
- **Ocean, Coastal, and Great Lakes Observations and Infrastructures should include:**
  - ***"The use of unmanned vehicles and remote sensing platforms and satellites to gather data on the health and productivity of the ocean, our coasts, and Lakes" (Page 38)***

Contact Information

NOAA UAS Web Site

http://UAS.noaa.gov

NOAA UAS Program Director

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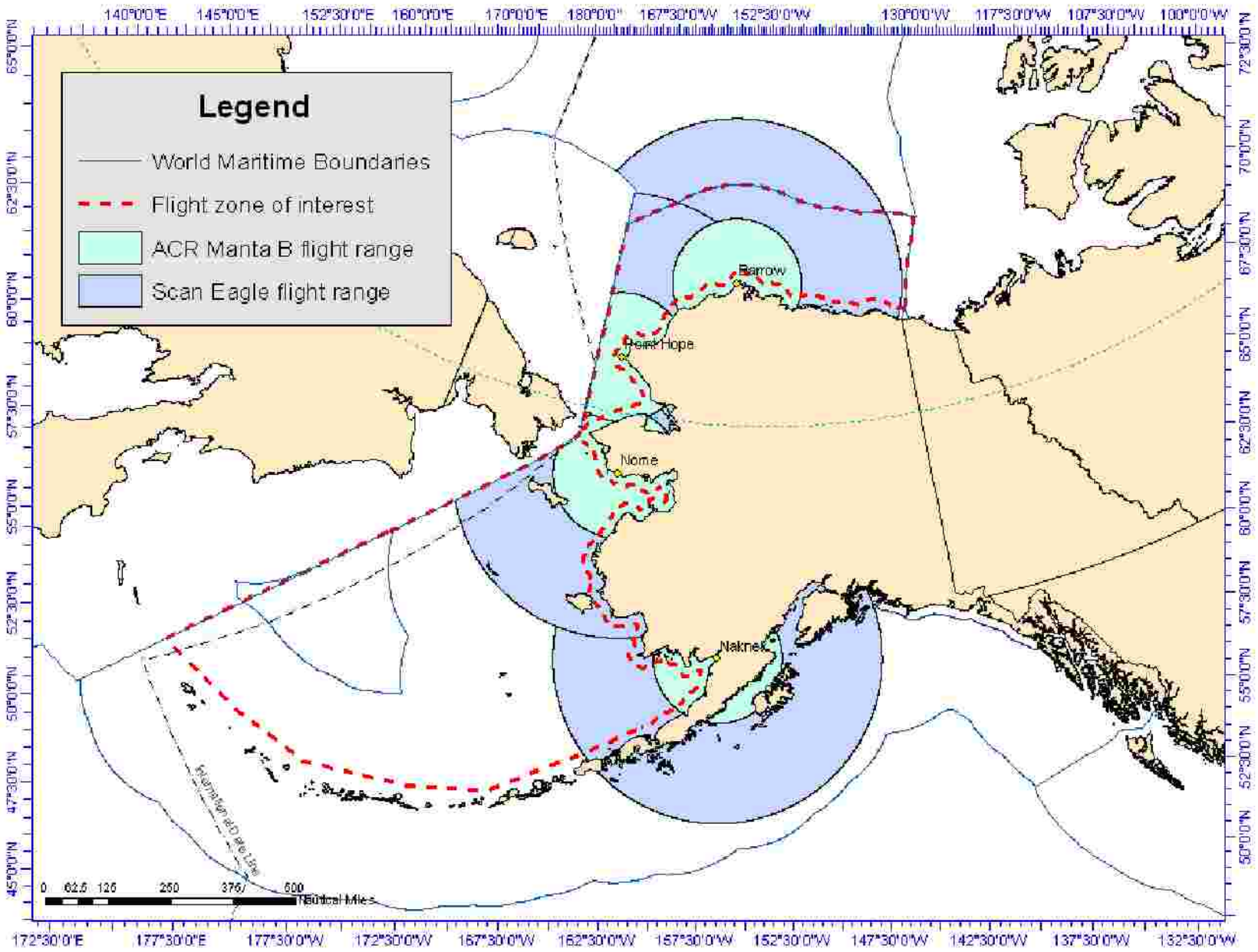
Back-Up Slides


Legend
World Maritime Boundaries
Flight zone of interest
ACR Manta B flight range
Scan Eagle flight range
Barrow
Point Hope
Nome
Naknek
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Nautical Miles
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107°30'0"W
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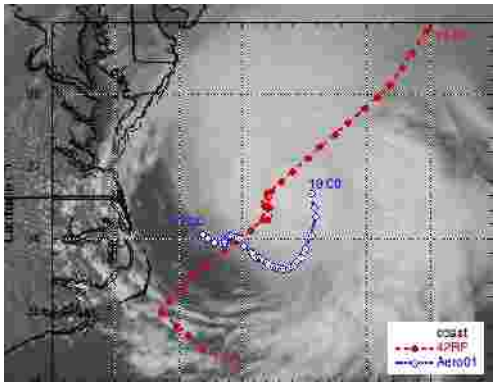
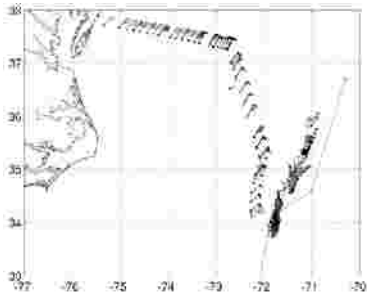
152°30'0"W
147°30'0"W
142°30'0"W
137°30'0"W
132°30'0"W

Gulf / Atlantic Testbed

- **Testbed Co-Leads: Dr. Joseph Cione (OAR/AOML) , Dr. Robert Rogers (OAR/AOML), and and Dr. Christopher Landsea (NWS/NHC)**
- **Past Emphasis has been LALE Hurricane Monitoring**



Hurricane Ophelia Imagery



Hurricane Noel Wind Data

LALE FLIGHTS

- ***2005 – Hurricane Ophelia***
- ***2007 – Hurricane Noel***