

NAVY/NSF-UNOLS Scientific Committee on Oceanographic Aircraft Research (SCOAR) Meeting,

Aug. 22,23, 2018, NASA Ames

US Coast Guard Manned & Unmanned Aircraft Operations Review

Dr. Phil McGillivary, USCG PACAREA & Icebreaker Science Liaison

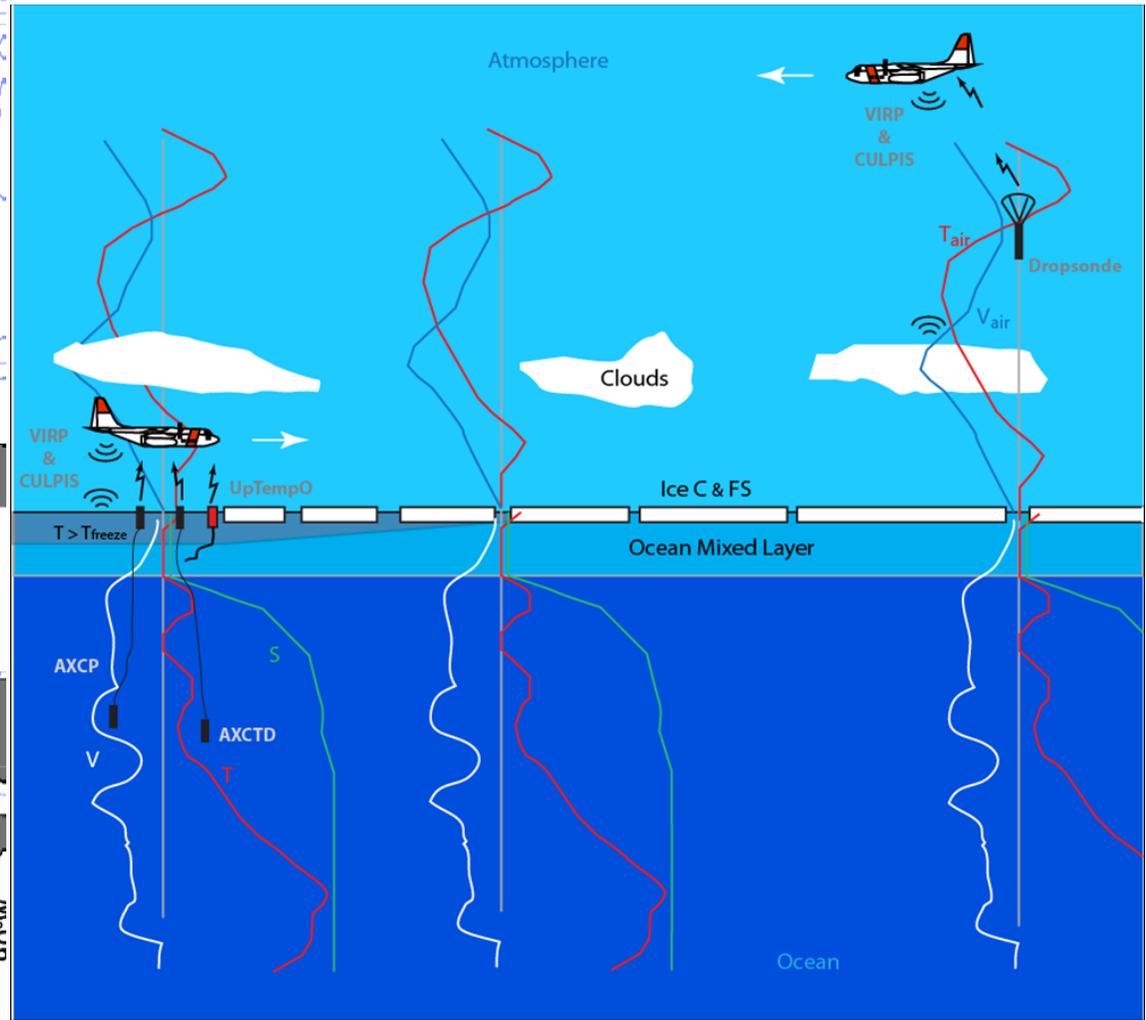
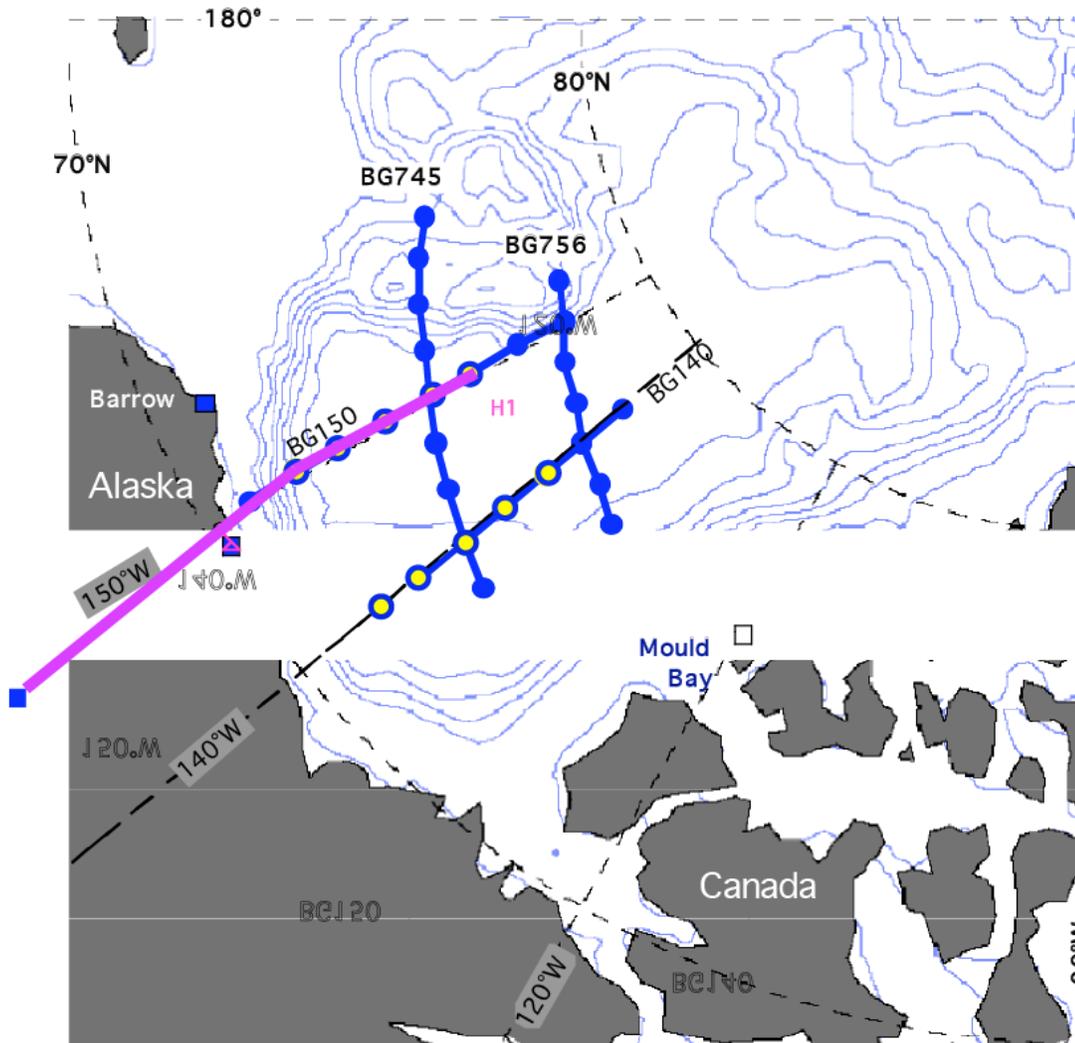
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USCGC POLAR STAR, McMurdo Sound, Ross Sea, Antarctica, 2018

ONR SIZRS Program CG C130 Ops update (P.I.: Jamie Morison, UW APL)

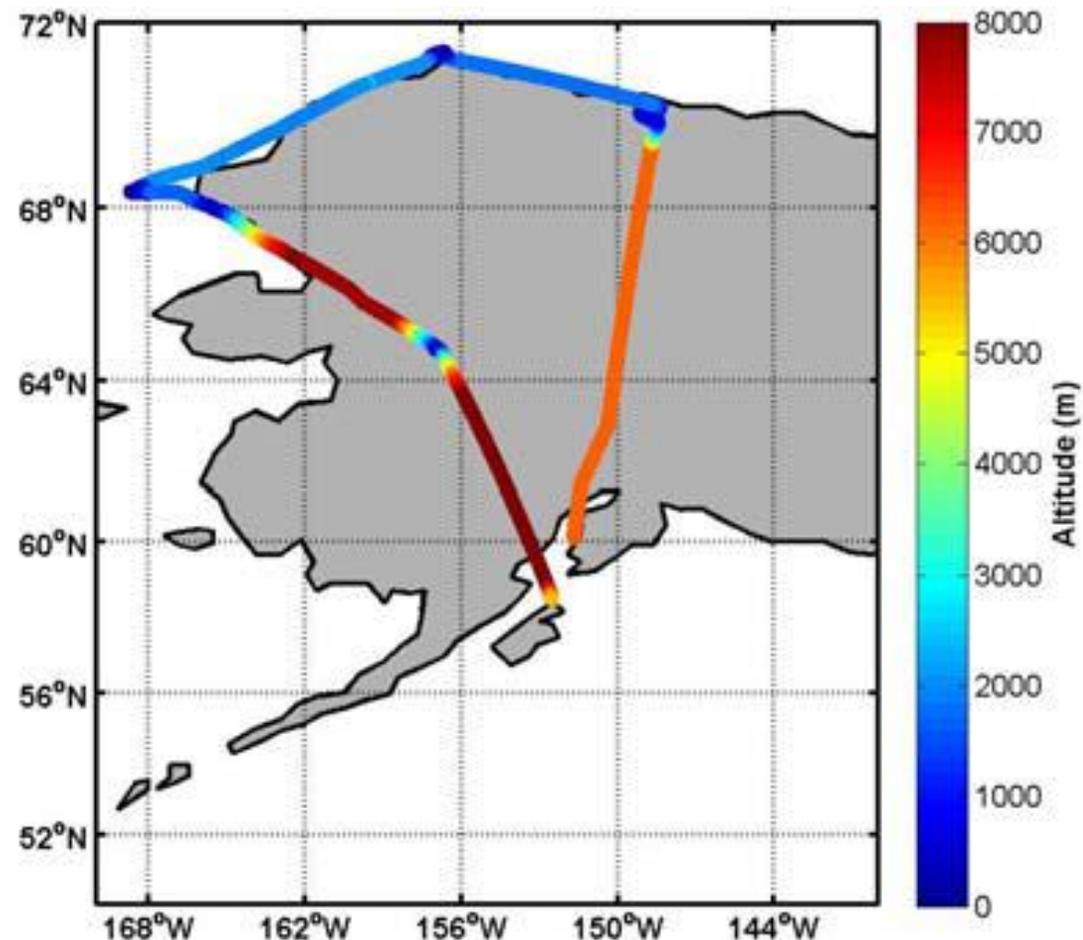
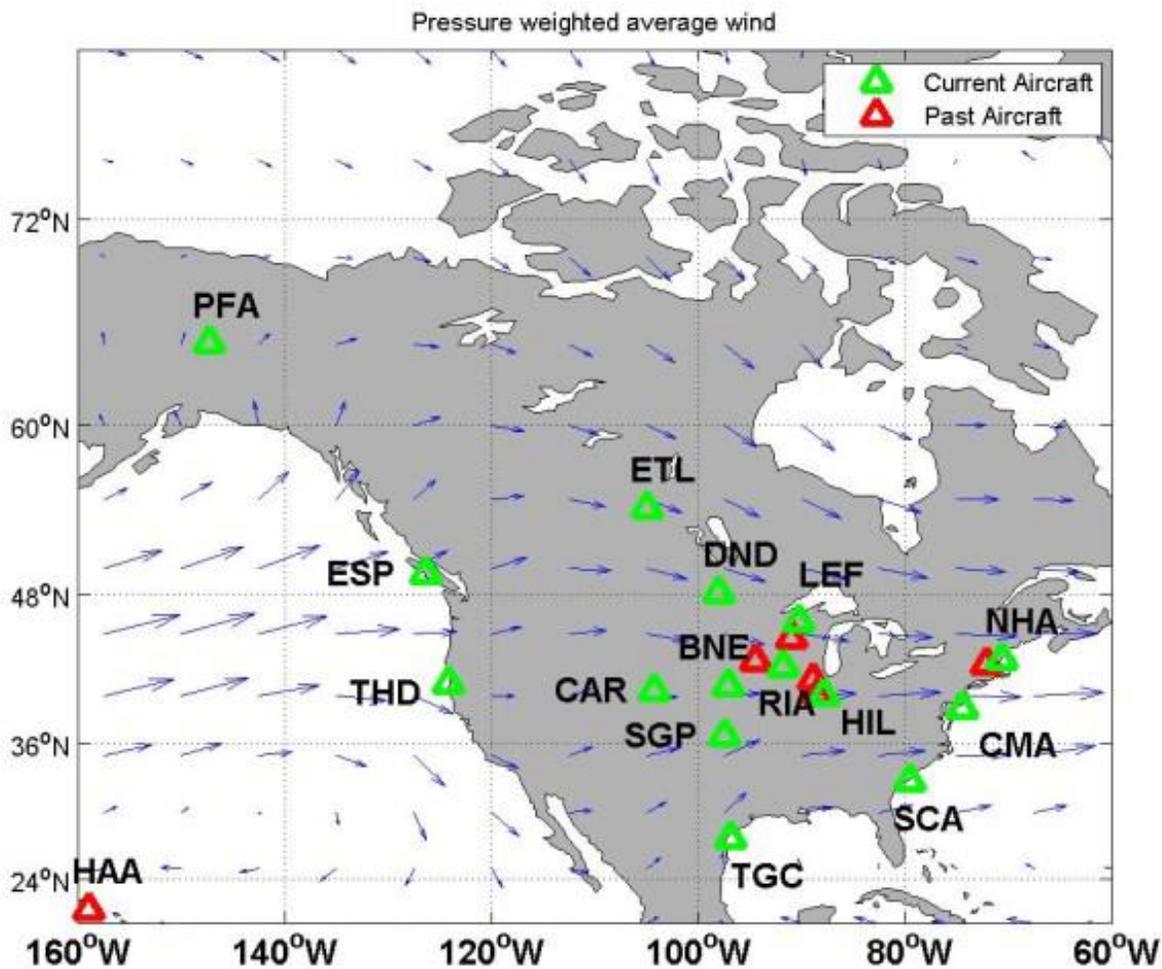
Left: map showing 140° & 150°W regular transect lines
Right: typical aircraft AXCTD, AXCP and dropsonde deployments



2018 ONR SIZRS Program CG C130 Ops update (P.I.: Jamie Morison, UW APL)

- 2017 ops: one-day SIZRS flights up 150°W to the ice edge (up to 76 or 77N) in June, July, August, and October. September mission scrubbed due aircraft/scheduling problems. Each mission involved typically 5 ocean AXCTD and AXCP stations, and up to 20 atmospheric dropsonde profiles.
- 2018 ops: June & July flights canceled by CG due to shortage of assets. Made up for those with shorter SIZR section flights on NOAA Twin Otter, including testing of new small NASA lidar. CG C130 August flight canceled due to mechanical problems; CG has OK'd Sept. and Oct. flights.
- Future SIZRS ops: USCG engineering center is adapting ACCB approvals for C130H to the C130J model: seems to be progressing well.
- Outyear SIZRS ops: writing ONR proposal for SIZRS after 2019.
- Other future ops: submitted DHS/CG Arctic Domain Awareness Center proposal to develop over ice aviation weather forecasts for use by CG aviators and for practice oil spill/ emergency survey exercises

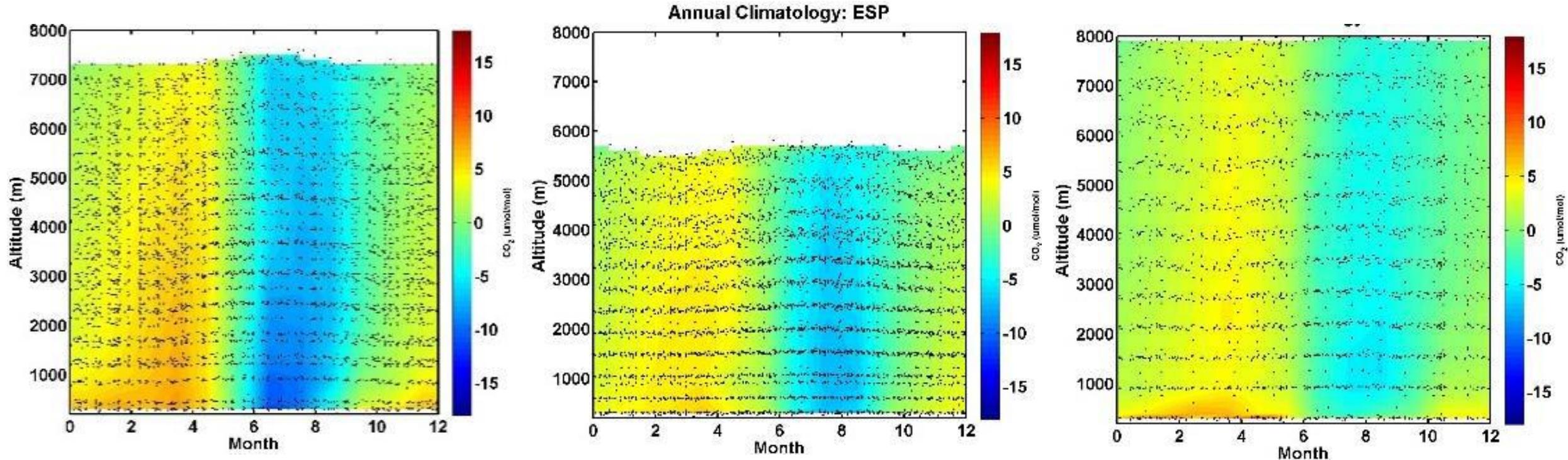
2018 NOAA ESRL Global Monitoring Division
CG C130 Aircraft Air Sampling Network (Colm Sweeney, PI) (left),
see: <http://www.esrl.noaa.gov/gmd/ccgg/aircraft.html> ,
and typical Alaska flight pattern (right)



NOAA ESRL CG C130 trace gas inlet and aircraft sensing set-up



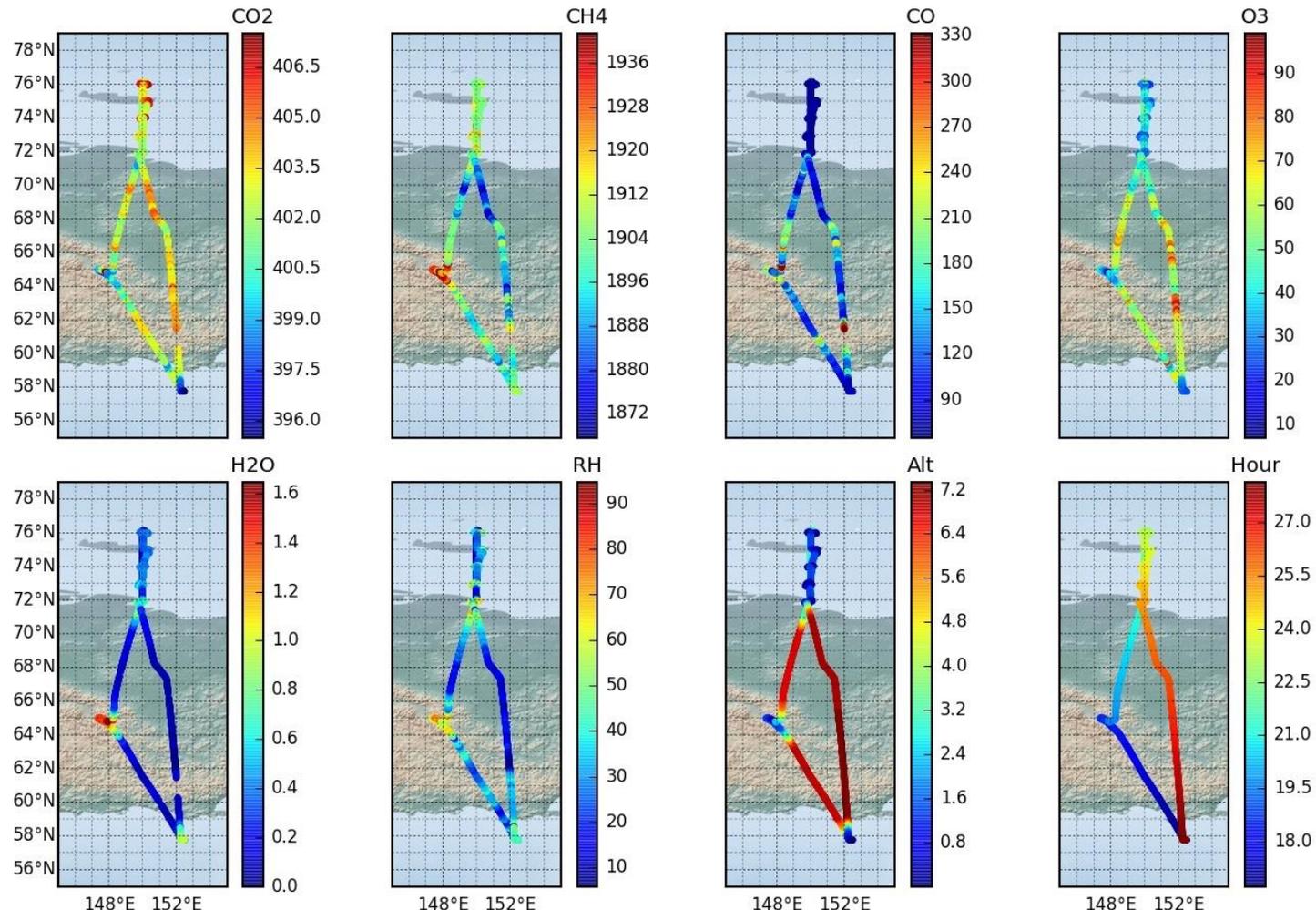
NOAA ESRL Aircraft [CO₂] Binned Data from Alaska, Seattle and California (left to right), showing the increasingly seasonal trend at higher latitudes



NOAA ESRL Global Monitoring Division

CG C130 Aircraft Air Sampling Data for Trace Gases from 7/11/2017 Flight

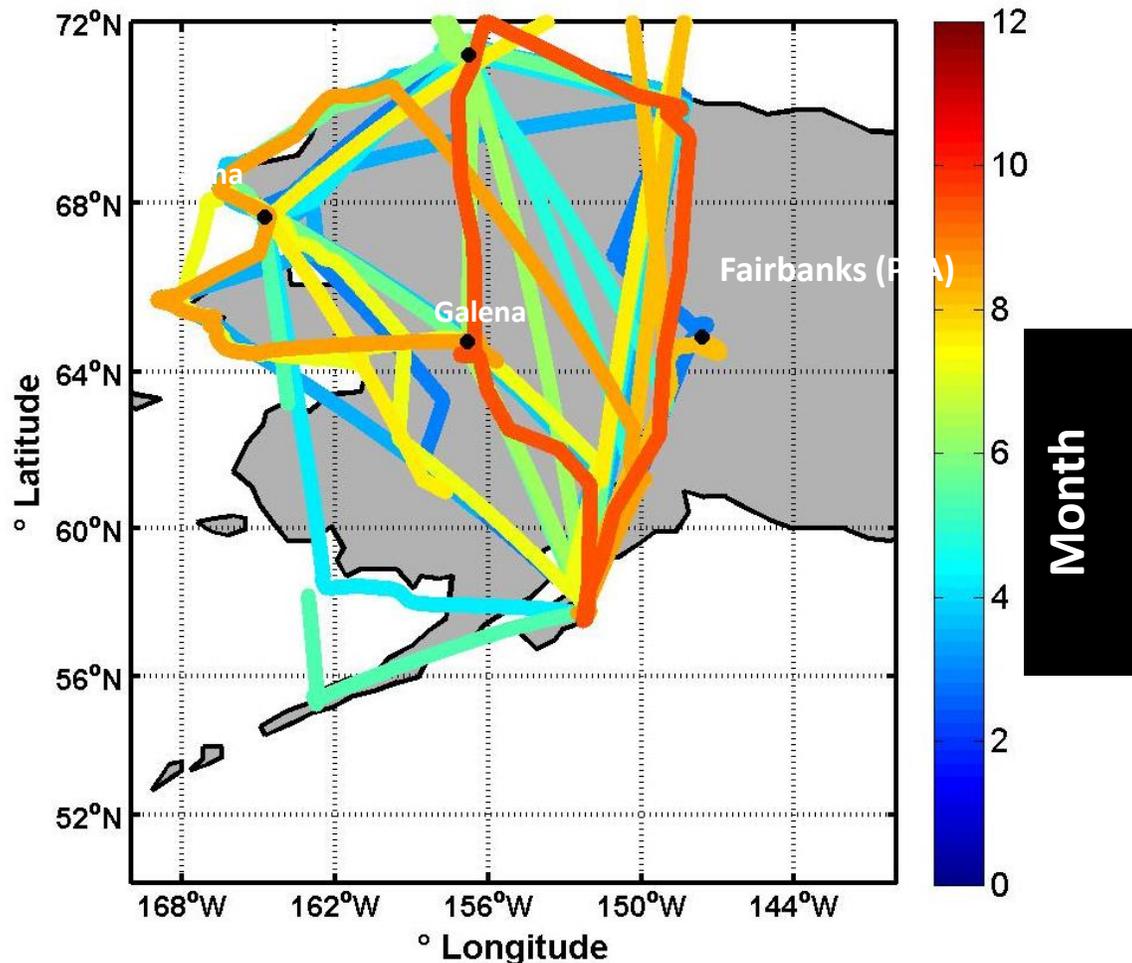
- Findings: -Late summer/early winter CO₂ & CH₄ emissions dominate Arctic C budget;
thus monitoring measurements should be made at that time of year
- Arctic CH₄ emissions haven't increased significantly but CO₂ emissions have



Spatial/temporal extent of NOAA measurements on CG C130 flights

2017: some flights cancelled, but completed 4 flights

2018/2019: flights cancelled to allow for changes to ACCB; will begin working on ACCB for C130-J and hope to resume operations in 2019



- 2009-2017
- March – November
- **> 65 flights so far**
- 1-3 vertical profiles / flight over interior and North Slope of Alaska
- Profiles over the Arctic Ocean have reached the North Pole
- A unique dataset of sustained and comprehensive atmospheric measurements in the Arctic



Coast Guard GUPPI program (Group-1 UAS Prototype Program Initiative)



- Following FAA release of Part 107 UAS regulations, CG decided to set up a test and demonstration project to allow CG units to operate small UAS under Part 107 regulations. Currently four sectors are using these, and three more will be authorized by end of year.
- The program allows units to request use of small UAS for Living Marine Resource management, ice operations, pollution response, emergency response, ATON, small boat operations, and communications equipment & infrastructure inspections. Currently law enforcement, counter drug ops, and SAR ops are not authorized for UAS use, in part related to privacy issues, but it is expected these issues will be addressed in the coming year.
- The S-UAS used in GUPPI are not intended as permanent CG S-UAS solutions, but will be focused instead simply on demonstrating UAS capabilities.
- The GUPPI program is currently using the Yuneec Typhoon-H hexacopter, upper left (<http://us.yuneec.com/typhoon-h-overview>), but is considering adding the Autel Evo, upper right (<https://www.autelrobotics.com/evo/>), as it is smaller, more portable, easier to fly and has obstacle avoidance.
- CG UAS Program managers: LCDR Ryan Lande & CDR Zach Glass, CG HQ Aviation

Coast Guard GUPPI program (Group-1 UAS Prototype Program Initiative) SF Training Aug. 6,7, 2018



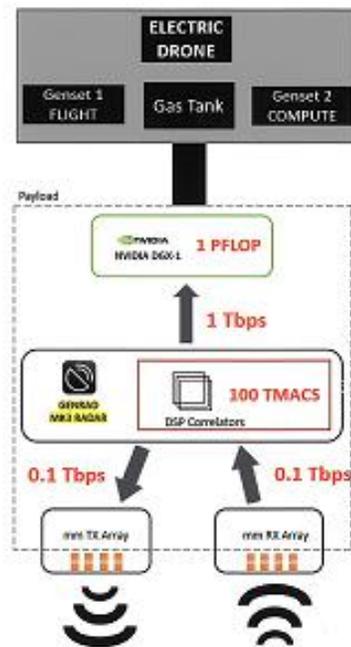
Other Coast Guard UAS Operations

- CG continues to use ScanEagle UAS under contract on one National Security Cutter (NSC).
- A CG multi-year contract for a similar mid-sized, long-range UAS for all NSCs is currently under review. These UAS will be likewise be operated under contract and not owned by the CG.
- CG R&D Center has 3 UAS projects underway:
 - 1 – RAMPS (Robotic Aircraft for Maritime Public Safety), demo Oct. 18, complete Jan/Feb. 2019
 - 2 – c-UAS – joint w/ other agencies, esp. DARPA, demos summer 2020
 - 3 – Long range, ultra-long Endurance UAS – demos fall 2019

CG PACAREA UAS Research Initiatives: Microwave Re-powered UAS for Persistent Surveillance

- Participated in OSD/DHS/NPS JiFX 18-04, Aug 6-8 at Camp Roberts (see: <https://my.nps.edu/web/fx/jifx-live>)
- Purpose: to demonstrate microwave re-powered UAS carrying comms node to act as flying cell phone tower/comms relay unit.
- Despite extensive prior collaboration, power supply was mirror image of what was needed, so will try again at future JiFX, or... NASA Ames has offered to possibly host demo there, still under discussion.
- Microwave system from Empower Earth, Inc. (Palo Alto), which developed thin, inexpensive flexible inter-connecting rectifying antenna segments (@4"x4") that can easily be attached to UAS underside.
- Caveat: UAS controls must be shielded from microwaves: tin foil works.

CG PACAREA UAS Research Initiatives: Mm-wave Radar UAS for Ice Ridge/Keel Mapping through Fog/clouds/rain/snow



This is a fully autonomous utility drone.

It's capable of 4hr flights without refueling

It carries a state of art Radar which allows it to reliably see and navigate around any obstacles.

In addition, it has 1 PFLOP of on-board compute which allows it to conduct a wide variety of tasks, ranging from Ground-Penetrating-Radar, navigation and path planning, to higher-level AI.

General Radar, Inc. UAS w/ mm-wave radar capable of measuring ice ridges with 1.5cm accuracy, with real-time and data processing via onboard 1 petaflop computer.

System can provide ice keel depth at an estimated 6-10' deep (TBD) while flying or much deeper if landed. Plans for field demo are in 2020.

CG PACAREA UAS Research Initiatives:

Gaze, Inc. (<http://www.gaze.ai>)

Solid State Lidar for
UAS Ice Ridge Mapping

gaze



- Gaze, Inc. is Anttoni Jaakkola from Finnish Geospatial Research Institute (FGI) and colleague whom I invited over to speak at Stanford in 2014 (see my 2014 SCOAR report which reviewed their earlier work). In spring 2018 they moved to SF to start Gaze, which makes solid state lidars, roughly the size of a pack of cigarettes with 50W power draw. The system is designed for 'smart' or unmanned cars, so currently has an @1000' range, and includes blue LEDs to improve performance in rain/fog, and will also be sold for infrastructure inspections.
- CG goal is to combine use of mm-wave radar and solid state lidar to allow both high accuracy ice ridge/ice topography measurements, as well as capability to measure through fog/snow and make ice keel measurements as well.

CG PACAREA Related UAS Research Initiatives:

Flightwave Edge VTOL UAS updates

- Univ. Hawaii Navy Applied Res. Lab has several Flightwave VTOL UAS (<https://www.flightwave.aero/>), and got NOAA Airworthiness Certification 8/14/18 for this airframe. They are pursuing additional (Navy or NASA) certifications to enable use on federal vessels.
- Flightwave Edge was part of an automated ASV-UAS-AUV front sampling program on RV FALKOR in June, 2018 in winds up to 25 knots, see:

https://schmidtocean.org/cruise/exploring_fronts_with_multiple_aerial-surface-underwater-vehicles/



CG PACAREA Related UAS Research Initiatives: Joint NASA-NOAA-CG Icing Studies

- NASA, NOAA and CG participated in UAS icing studies at the NASA Glenn Icing Tunnel in 2017. The principal goal was to test how well a new icing prediction software worked. The CG did not contribute any UAS, but merely helped define icing conditions relevant for CG ops (mostly in near freezing conditions, not extreme cold).
- In Nov. 2018 a second Ice Tunnel test will be done with a Flightwave Edge VTOL UAS half of which will be coated with the Ubiquaerospace D-Ice (<http://www.d-ice.tech/ubiq-aerospace/>) carbon nano-tube active anti-icing coating to determine coating efficacy.
- During the Nov. 2018 Ice Tunnel tests there will also be testing of one or two transparent anti-icing coatings for use on camera lenses or camera (or other instrument) housings.

CG PACAREA Related UAS Research Initiatives: US-Canada-UK-Australia Quantum Navigation Studies

- AUSMIN talks were held between US SecDef & SecState and Australian equivalents at Stanford July 23,24, 2018.
- Among issues discussed were the Joint International Quantum Navigation program, which, per request, we will be coordinating on with USN NPS & Australian Defence Force.
- Further details on the program will be released in Sept. 2018 for development of a quantum PNT (position, navigation and timing) system by 2022.
- This effort is linked to the US National Quantum Initiative Act brought to the floor of both House and Senate on July 26, 2018 which directs DoD to establish a consortium on the topic managed out of OSTP and including DHS, NSF, NASA and others.
- This effort may include coordination with the Canadian Quantum Satellite Mission, Quantum Encryption and Science Satellite (QEYSSAT), for which initial contract was let Aug. 3, 2018.

CG PACAREA UAS Research Initiatives:

ONR ICE-PPR* Workshop, Rovaniemi, Finland, June 11-13, 2018 (Intl. Collaborative Engagement Program for Polar Research)

- Army Jaeger Brigade (arctic specialists: crisis response and SAR) use Israeli Orbiter-2 UAS (see: <https://aeronautics-sys.com/home-page/page-systems/page-systems-orbiter-2-mini-uas/>), similar to ScanEagle: long-endurance, electric, catapult launch, net or parachute recovery; meets NATO standards.
- Finnish Air Force uses UAS for border security to supplement jets during winter darkness and heavy snowfall.
- Dr. Juha Roning, Univ. Oulu, is Dir. Arctic Drone Lab (<https://www.arcticdronelabs.com/>) and organized Allied ICT Finland (<https://alliedict.fi/>) so groups could work together. Work includes U. Tampere (Jussi Aaltonen: work on joint UAS and AUV inspections), U. Turku (forestry, agriculture, river flooding), and others, including drone journalists. Hold a tele-meeting every two weeks. Current focus is on drone swarms. Have a large test area near Oulu, but...no lakes! Another UAS test site they use is at Rena, in SE Norway.
- “Hy-Fliers” program combines flying and controlling robots for inspection, as for Chevron and Total pipeline inspections, etc., including inspections at plants. For this built UAS w/ a round bottom that lands on pipes for inspections. UAS not yet working in winter as most COTS drones not good to -20oC. Their UAS worked OK at -20oC if you kept batteries warm, but batteries didn’t last as long in cold = their biggest problem. Their UAS also cannot tolerate water and so if it is below freezing and it rains, that is a problem.

CG PACAREA UAS Research Initiatives:

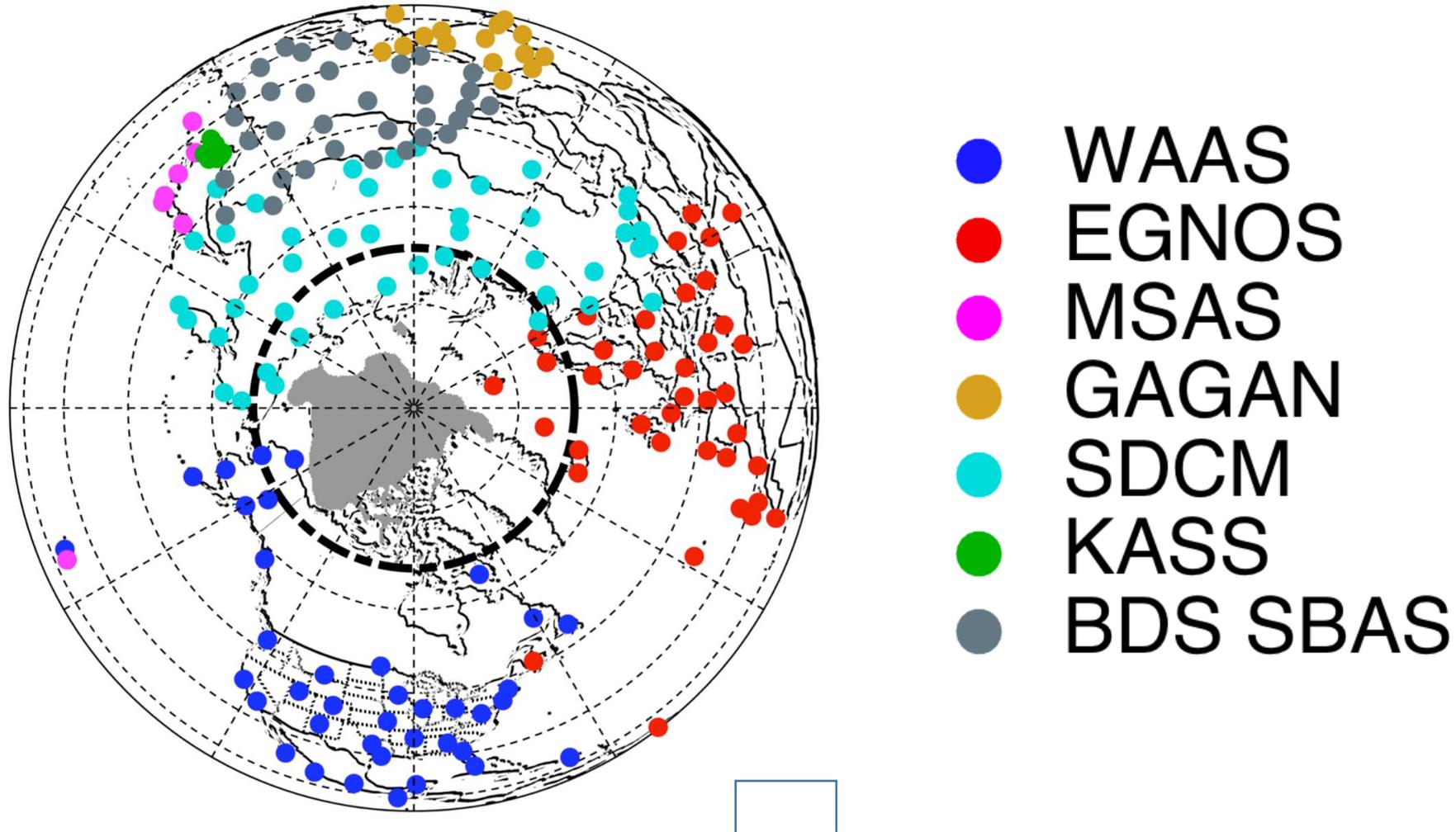
ONR ICE-PPR* Workshop, Rovaniemi, Finland, June 11-13, 2018 (Intl. Collaborative Engagement Program for Polar Research)

- Dr. Laura Ruotsalainen—Finnish Geospatial Res. Inst. (FGI) in National Land Survey
- Focus on accuracy of Global Navigation Satellite System (GNSS) positioning at high latitudes.
- Main problem w/ GNSS data in arctic for UAS is vertical altitude; if you are trying to use GPS for automated landings of UAS on a deck, you will probably crash land due to vertical position errors.
- Neither Galileo nor Chinese Beidou satellites help with satellite coverage gap that starts 72-76oN; GLONAS is closest to Pole, so helps some.
- Augmentation improves GNSS accuracy, but few land-based stations in the arctic. Ground stations monitor sat signal quality and send corrections before it is sent out. But you need to see three stations at once to do this; that is hard in arctic. Currently can use EGNOS (European Geostationary Navigation Overlay Service) in EU part of Arctic; similar system in US/Canada, but still gaps.
- SPACE NORWAY plans to launch 2 satellites in 2022, but you need three to do this, and they don't have funds for that. Russia plans to launch 4 satellites which solves the problem for them, but they will not be sharing that data.
- SEE GRAPHICS NEXT SLIDES...

SBAS (Satellite Based Augmentation Systems) Reference Stations from Tyler Reid, et al., 2015:

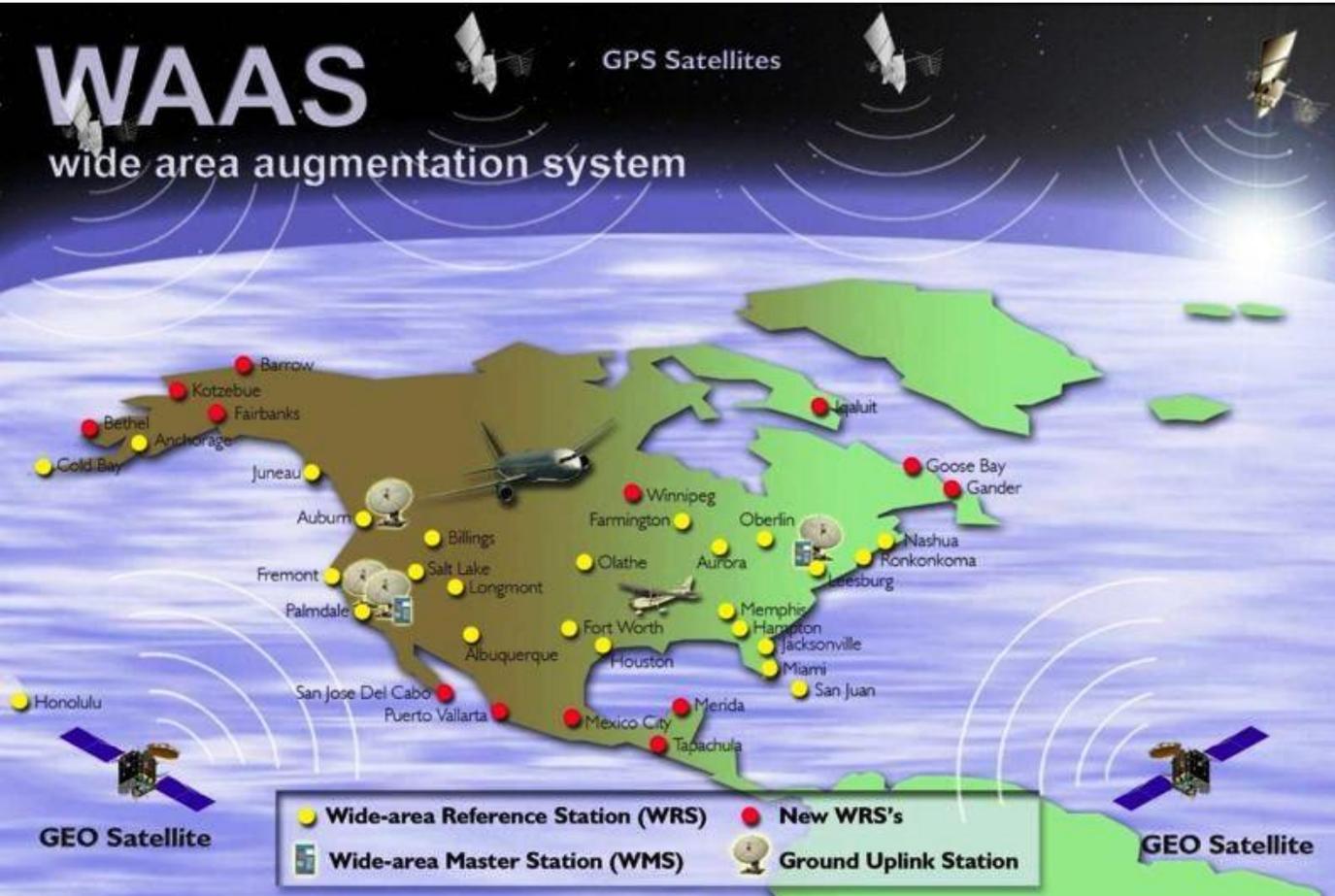
Tyler Reid, et al., 2015:

<https://gps.stanford.edu/research/current-research/arctic-navigation>

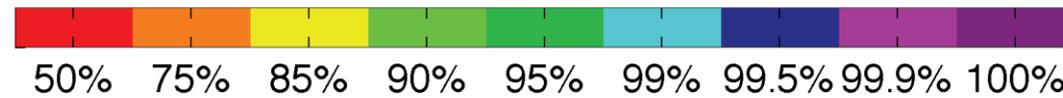
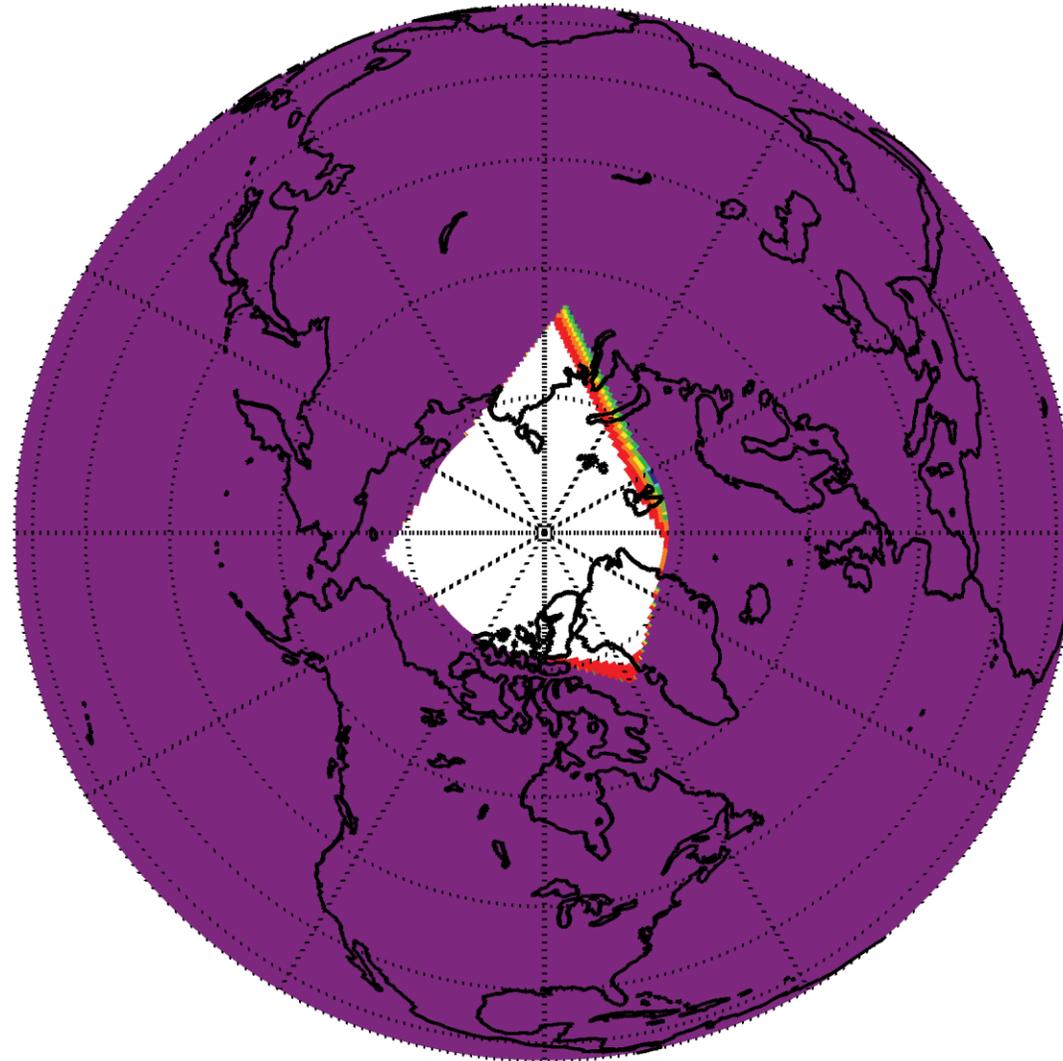


WAAS (Wide Area Augmentation System) & EGNOS (European Geostationary Navigation Overlay Service)

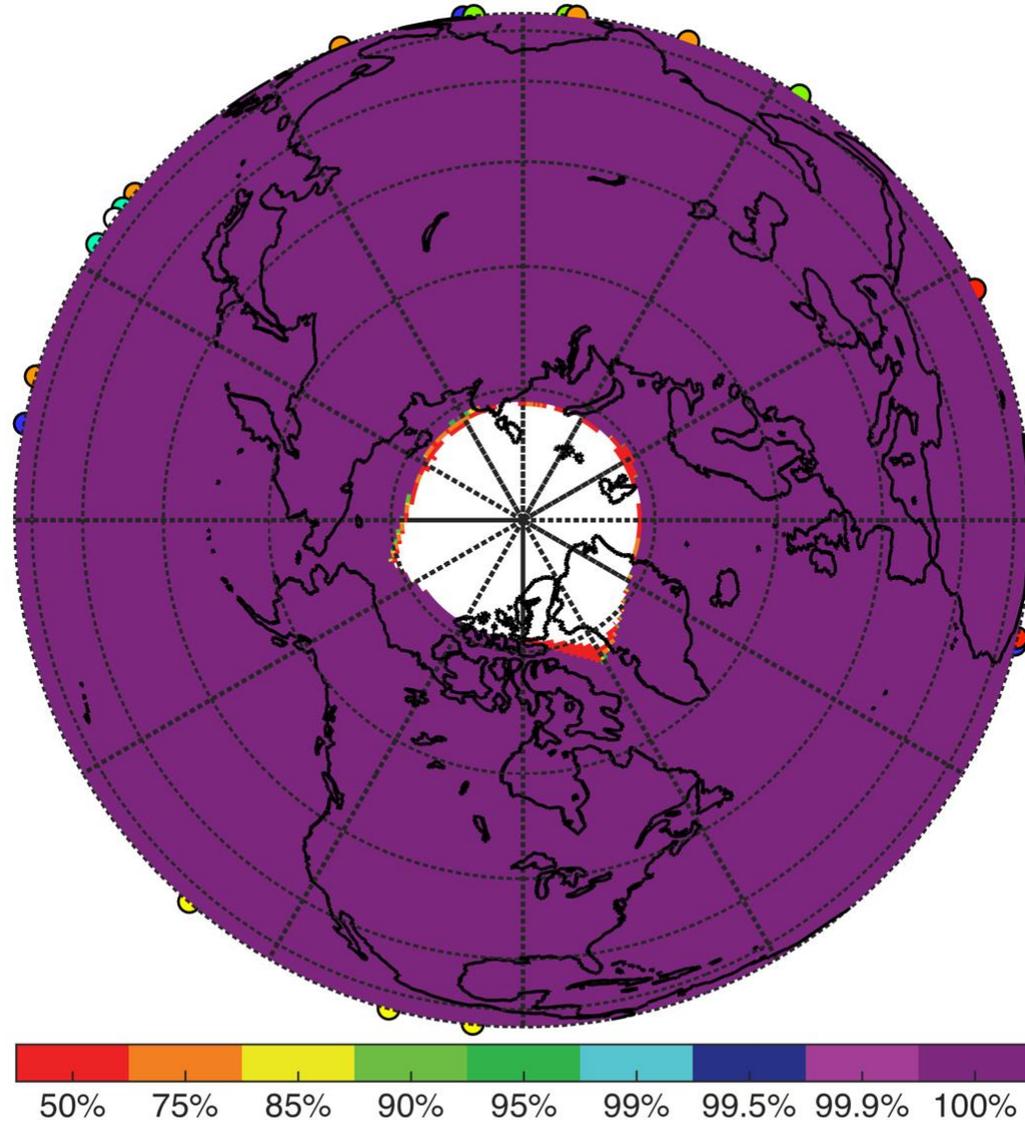
Reference Stations showing gap for much of polar region



Coverage of SBAS GEOS (Reid, et al., 2015)



Availability of SBAS (Reid, et al., 2015)



Practical Limit (72°N)

5° Elevation Mask (76°N)

Additional: Greg Asner – Carnegie Airborne Observatory run out of Stanford. Hyperspectral imaging spatially pinpointed with dual laser waveform lidar, initially used for forests, now coral reefs to id tree/coral cover to species, c.f.: <https://reefscape.carnegiescience.edu/homepage>. System details in: “Supplementary Materials for: Airborne laser-guided imaging spectroscopy to map forest trait diversity and guide conservation.” G. P. Asner et al., *Science* 355, 385 (2017). DOI: 10.1126/science.aaj1987. And: “Carnegie Airborne Observatory: in-flight fusion of hyperspectral imaging and waveform light detection and ranging (wLiDAR) for three-dimensional studies of ecosystems.” G.P. Asner, et al., *Journal of Applied Remote Sensing*, Vol. 1, 013536 (13 September 2007).

