Hakai

Science on the Coastal Margin

Hakai's Mission

Develop the tools, systems, people and insights we need to understand our coastal ecosystems in the context of climate change, and to deal with the consequences that are coming.

The Hakai Institute is part of the Tula Foundation.

Independent, BC-based, self-funded.

The Coastal Margin

Where the Pacific Ocean
meets the
Coastal Temperate Rainforest

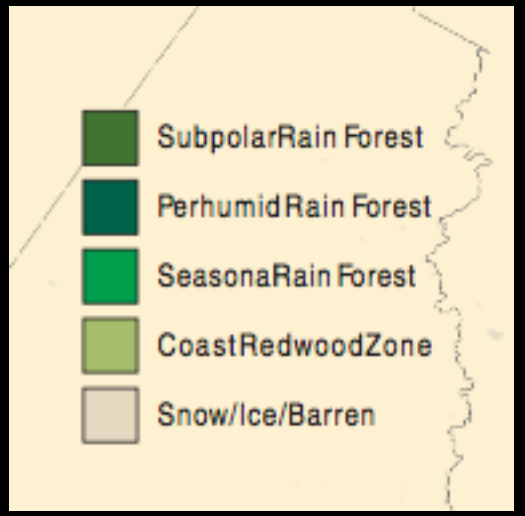
We ignore political boundaries and concentrate on science.

A mixture of our own work plus regional partnerships.

Established research centers as of 2010.

Hakai's ecological observatories filled part of the void.

We'd like to see an expanded network.



Hakai's Calvert Observatory

At the heart of the Great Bear Rainforest

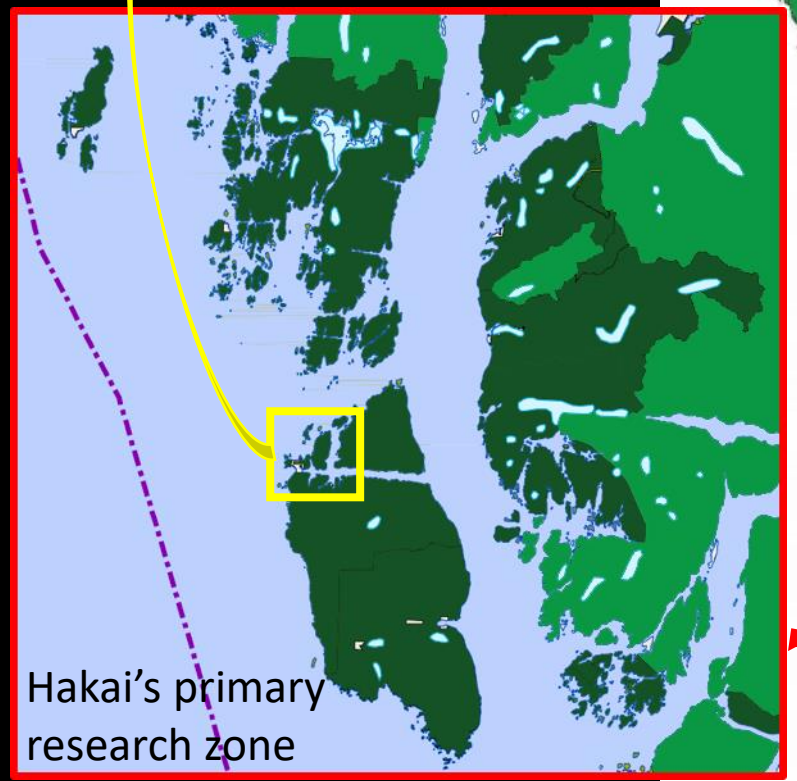
Protection varies across the Great Bear Rainforest. The most sensitive areas are set aside as conservancies, and protected 100%.

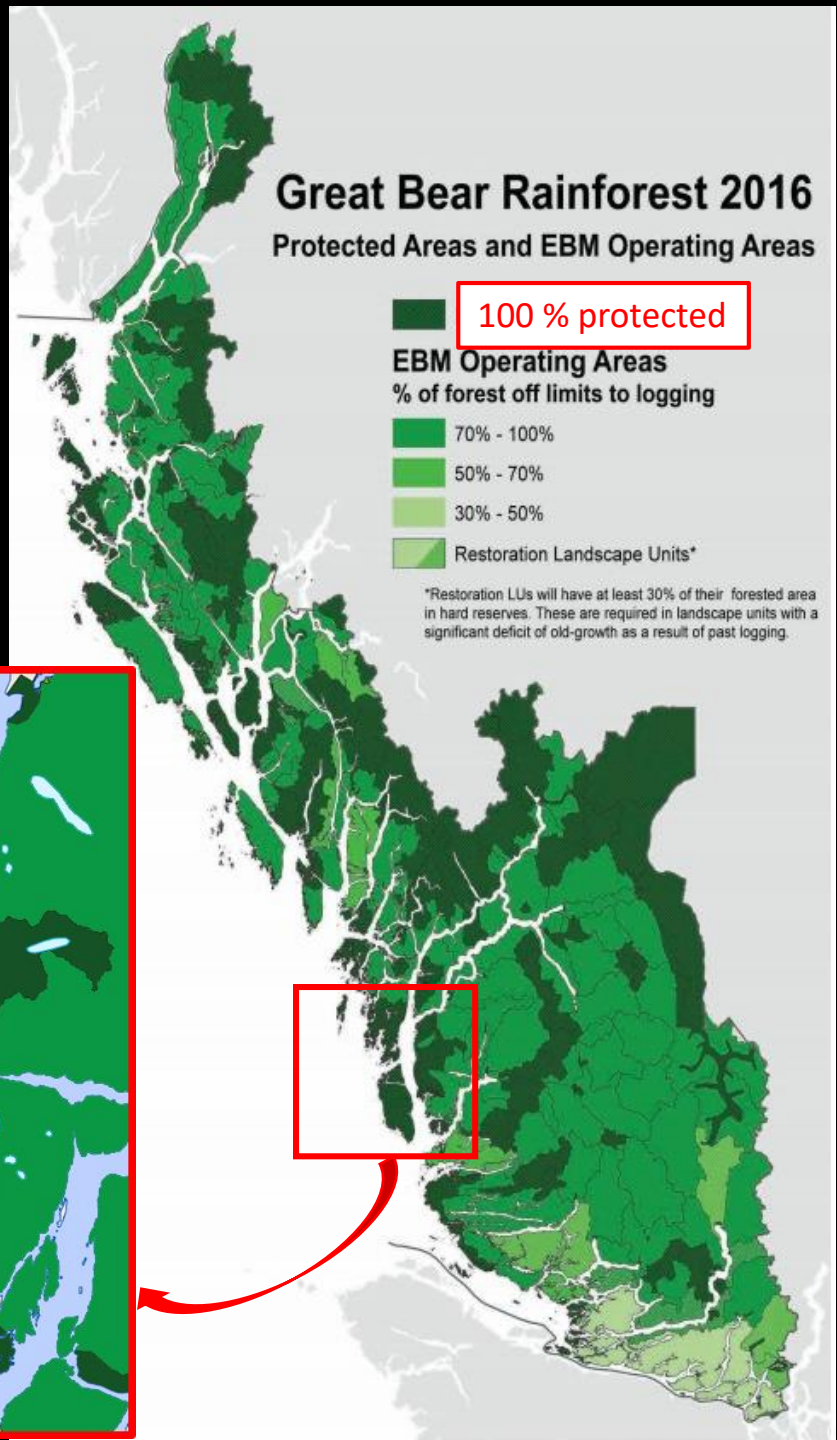
Hakai's Calvert Island Observatory is the de facto headquarters of the main cluster of coastal conservancies.

There are no other settlements or services within the zone marked in red. The town of Bella Bella is 80 km to the north.

Research runs from the ocean up the fjords and watersheds to the icefields.

Hakai is therefore uniquely favored in a strategic part of the coastal margin—a world-class, long-term, scientific asset.

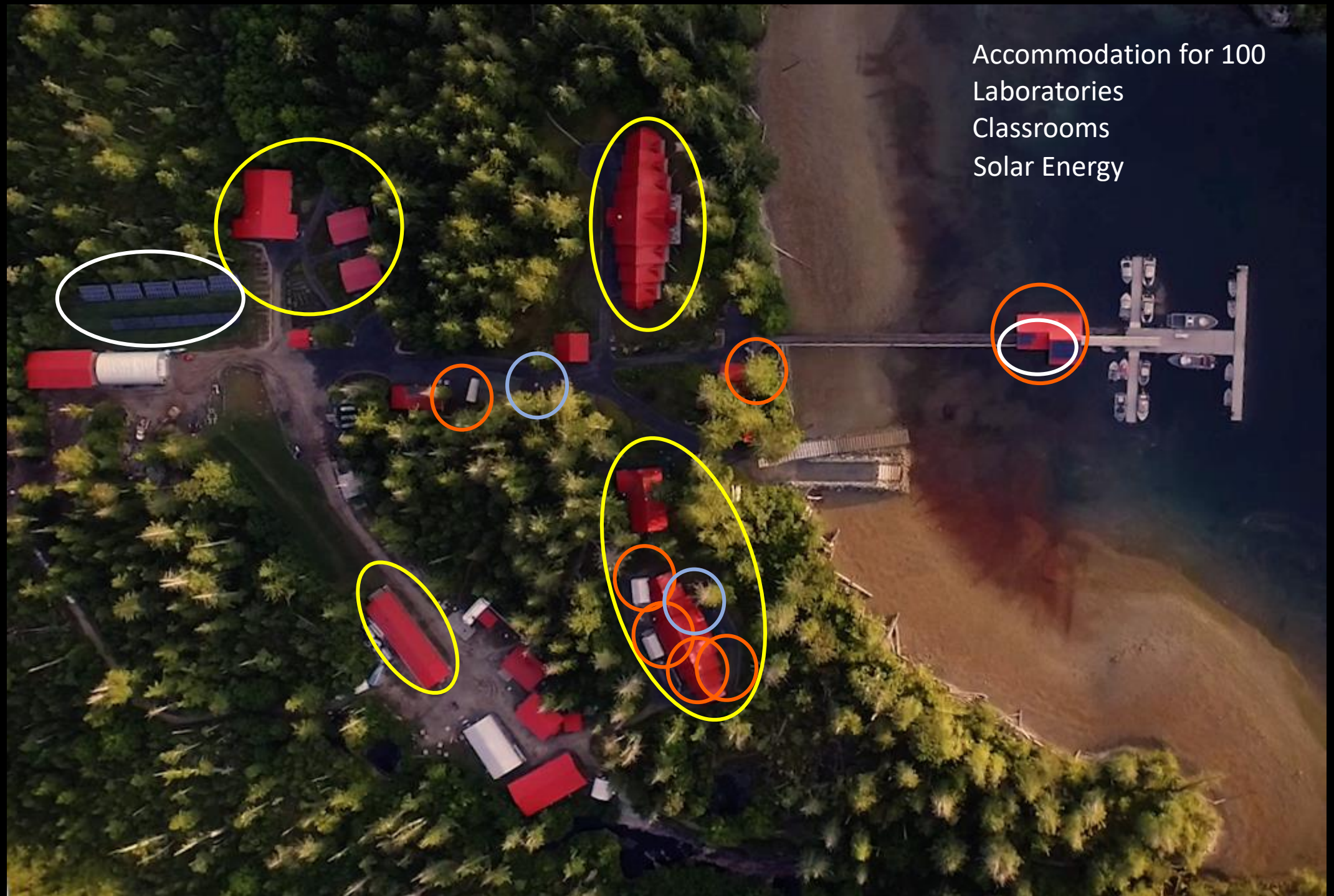




Hakai's Calvert Observatory

Icefields

Open Pacific Ocean


Accommodation for 100
Laboratories
Classrooms
Solar Energy

Living Off the Grid: Infrastructure

Research Partners

Academic:

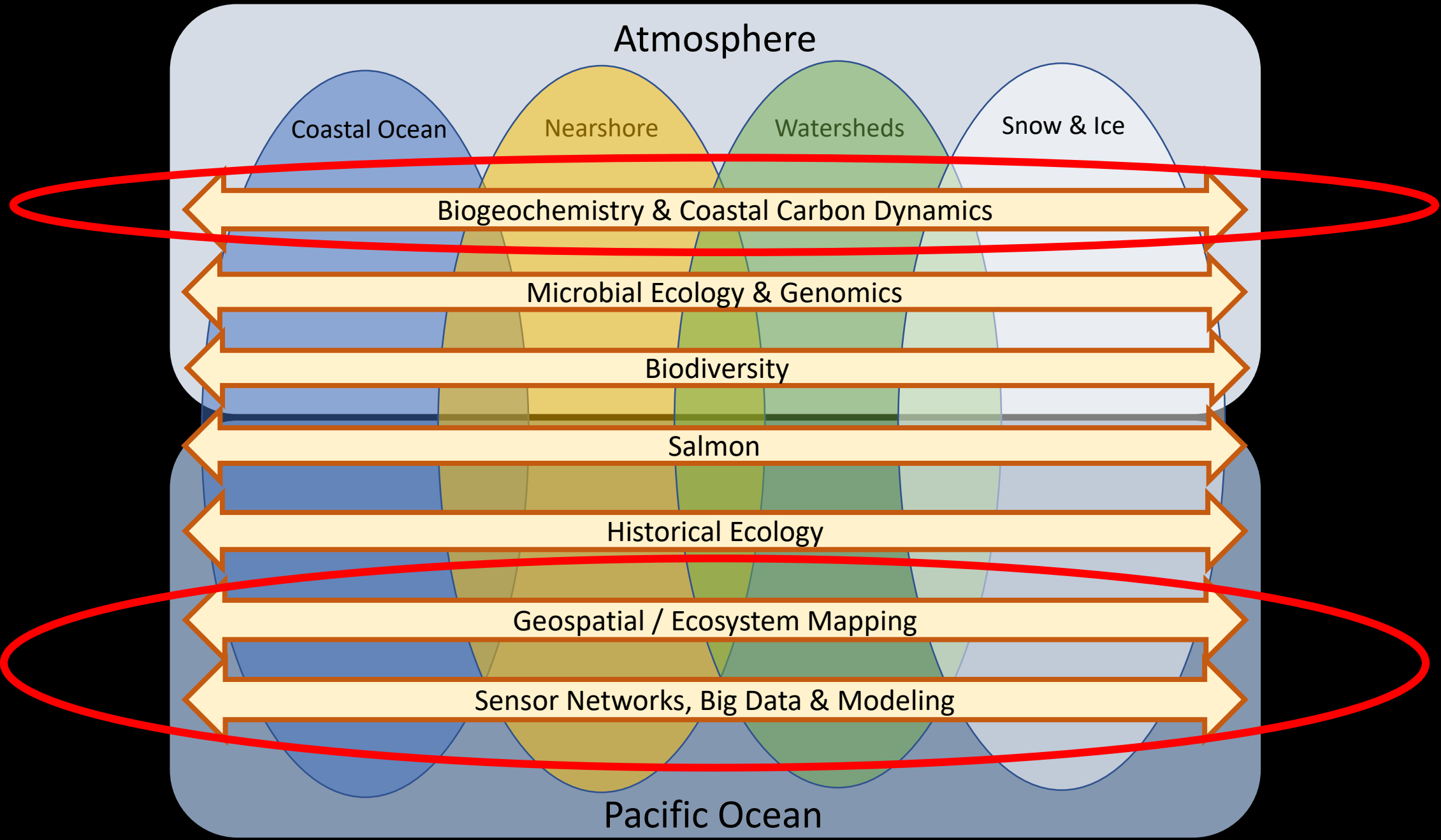
All BC Universities
University of Alberta
Dalhousie
University of Washington
University of Alaska
Oregon State University
UC Davis
UC Santa Cruz
UC Santa Barbara
Tulane

Government:

DFO (IOS, PBS, St Andrews)
Environment Canada
Parks Canada
BC Agriculture (Shellfish)
BC Parks / Environment
BC FLNRO
NOAA
Smithsonian Institution
Alaska State Ferries

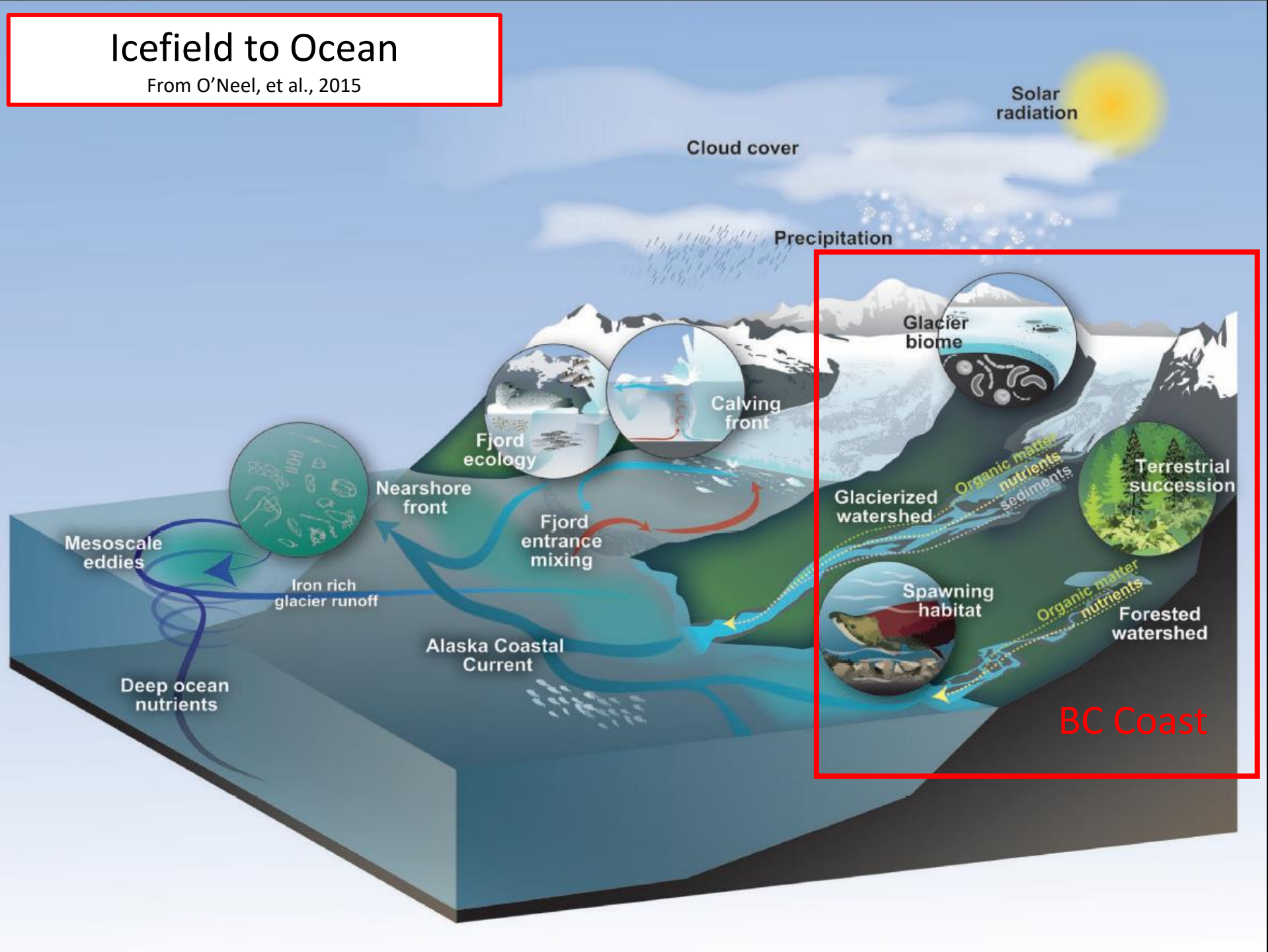
Other:

BC First Nations
Alaska Tribes
Shellfish Growers
Ocean Networks Canada
Pacific Salmon Foundation
Bamfield MSC
Friday Harbor Labs
Moore Foundation

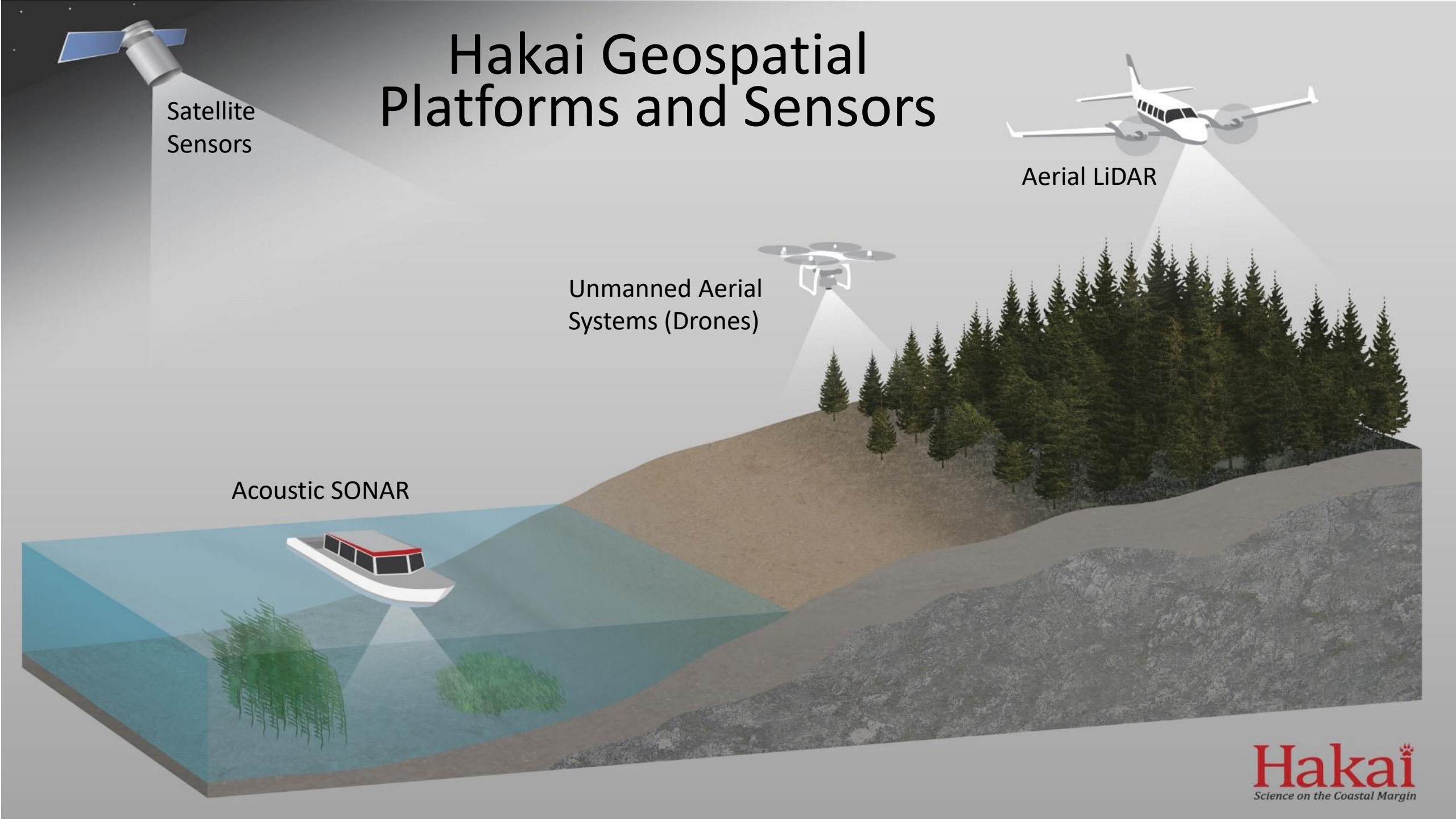

Atmosphere
Coastal Ocean
Nearshore
Watersheds
Snow & Ice
Biogeochemistry & Coastal Carbon Dynamics
Microbial Ecology & Genomics
Biodiversity
Salmon
Historical Ecology
Geospatial / Ecosystem Mapping
Sensor Networks, Big Data & Modeling
Pacific Ocean

Icefield to Ocean

From O'Neel, et al., 2015



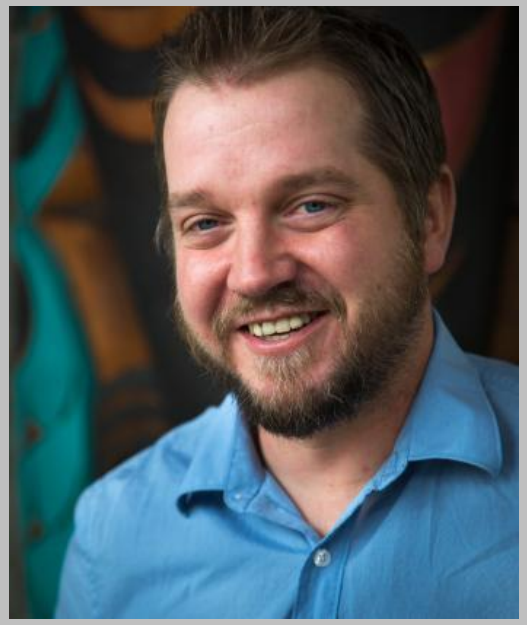
Hakai Geospatial Platforms and Sensors



Hakai
Science on the Coastal Margin

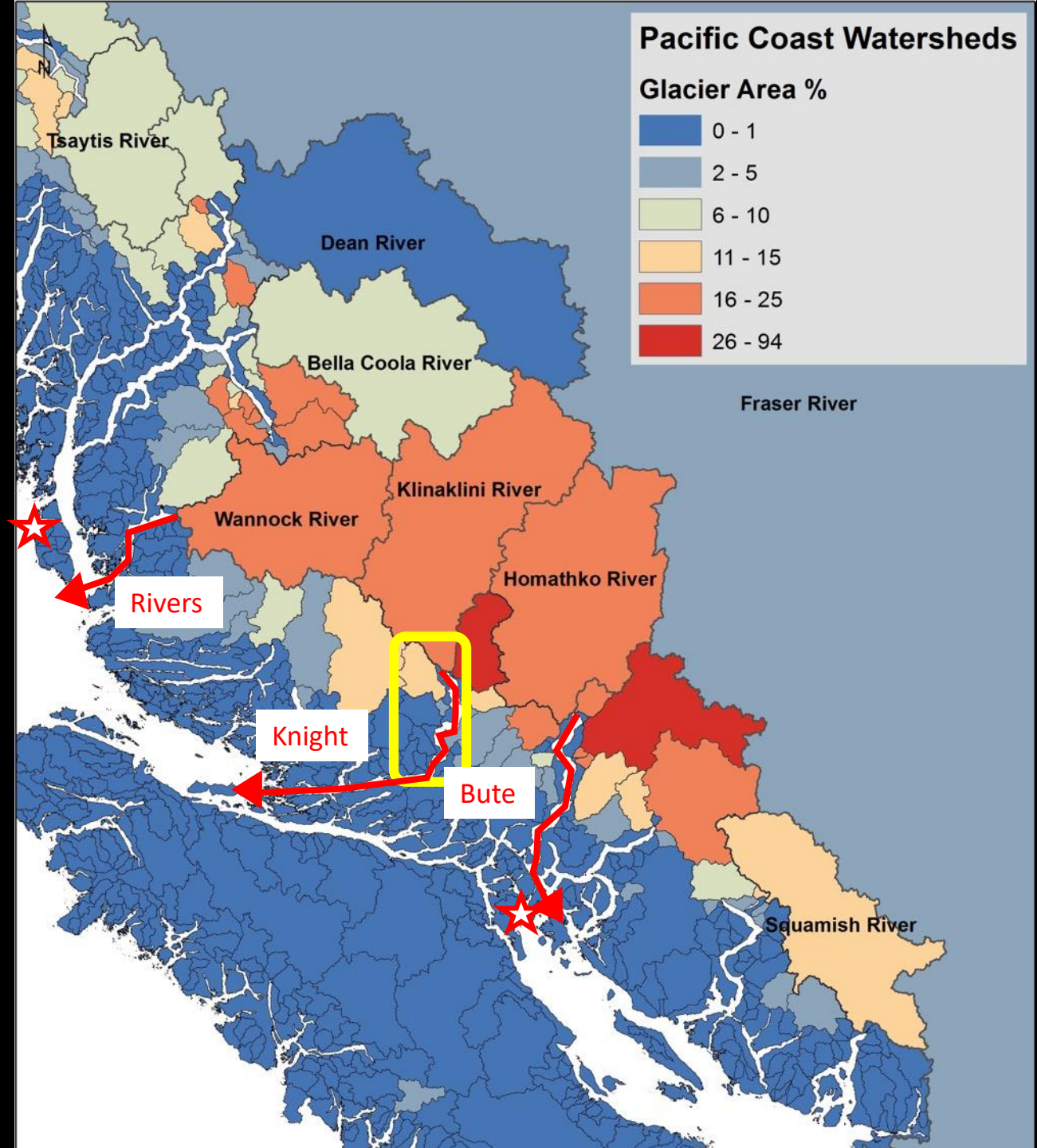
Ice & Snow

Brian Menounos, University of Northern BC
Bill Floyd, BC Govt & Vancouver Island University



BC’s coastal glaciers flow into the ocean via three major systems that are bracketed by the two Hakai facilities.

- Bute Inlet is fed by the Homathko & Southgate.
- Knight Inlet is fed by the Klinaklini & Franklin.
- Rivers Inlet is fed by the Wannock via Owikeeno Lake.



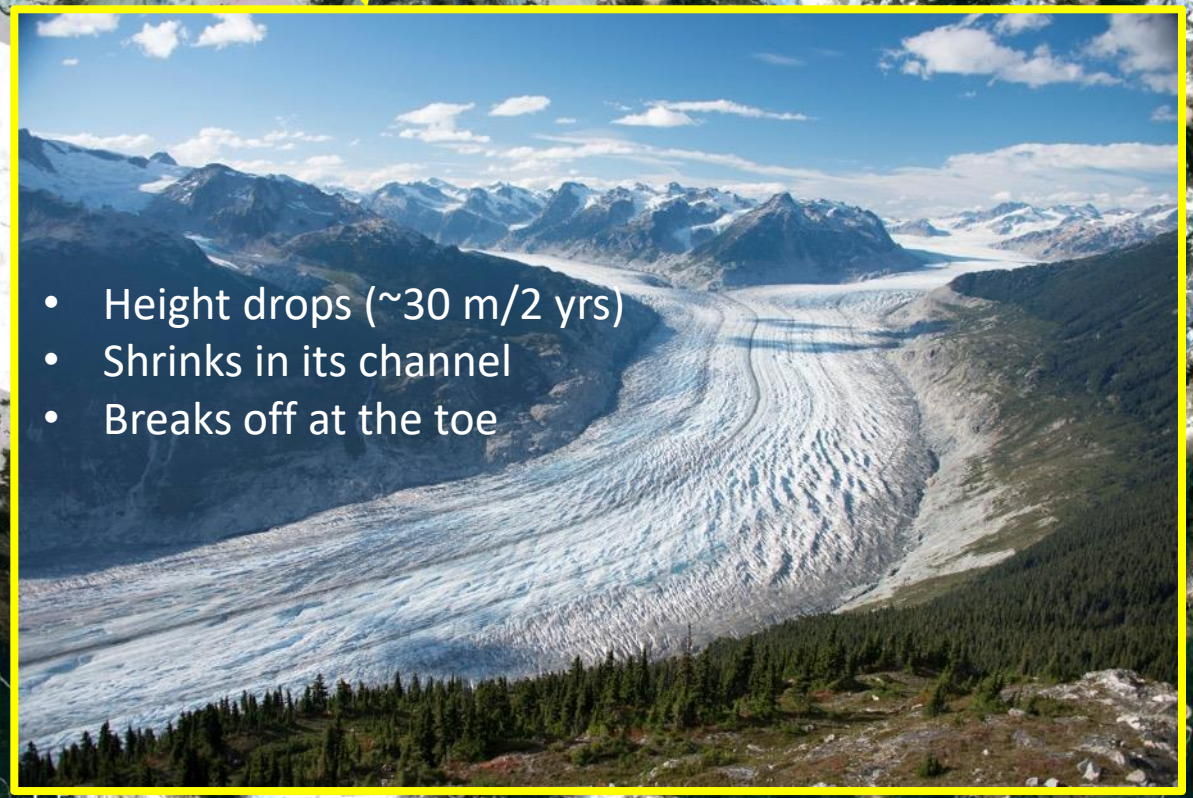
Icefields to Ocean

Klinaklini Glacier flows into Knight Inlet

Braided channels

Toe

Glacial plume



- Height drops (~30 m/2 yrs)
- Shrinks in its channel
- Breaks off at the toe

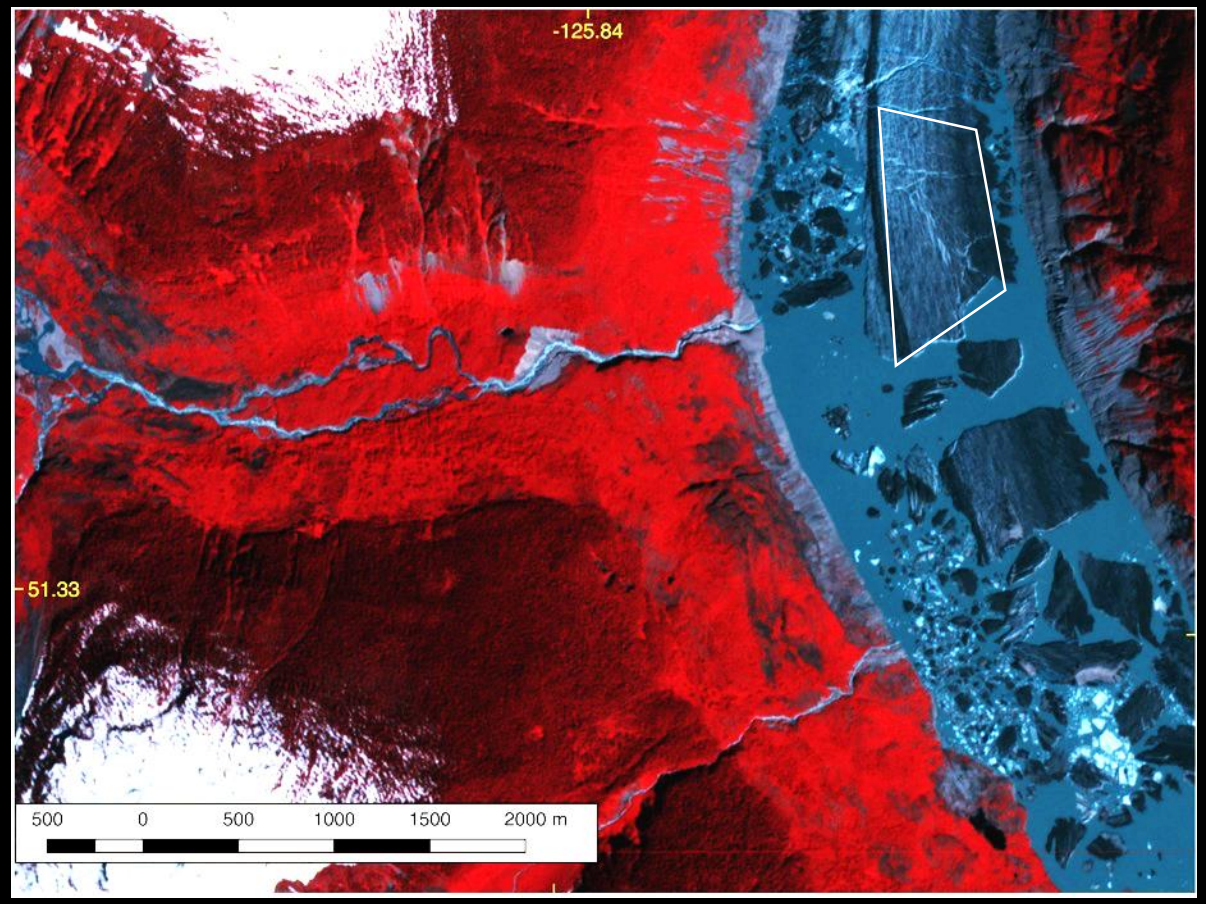
9 mi

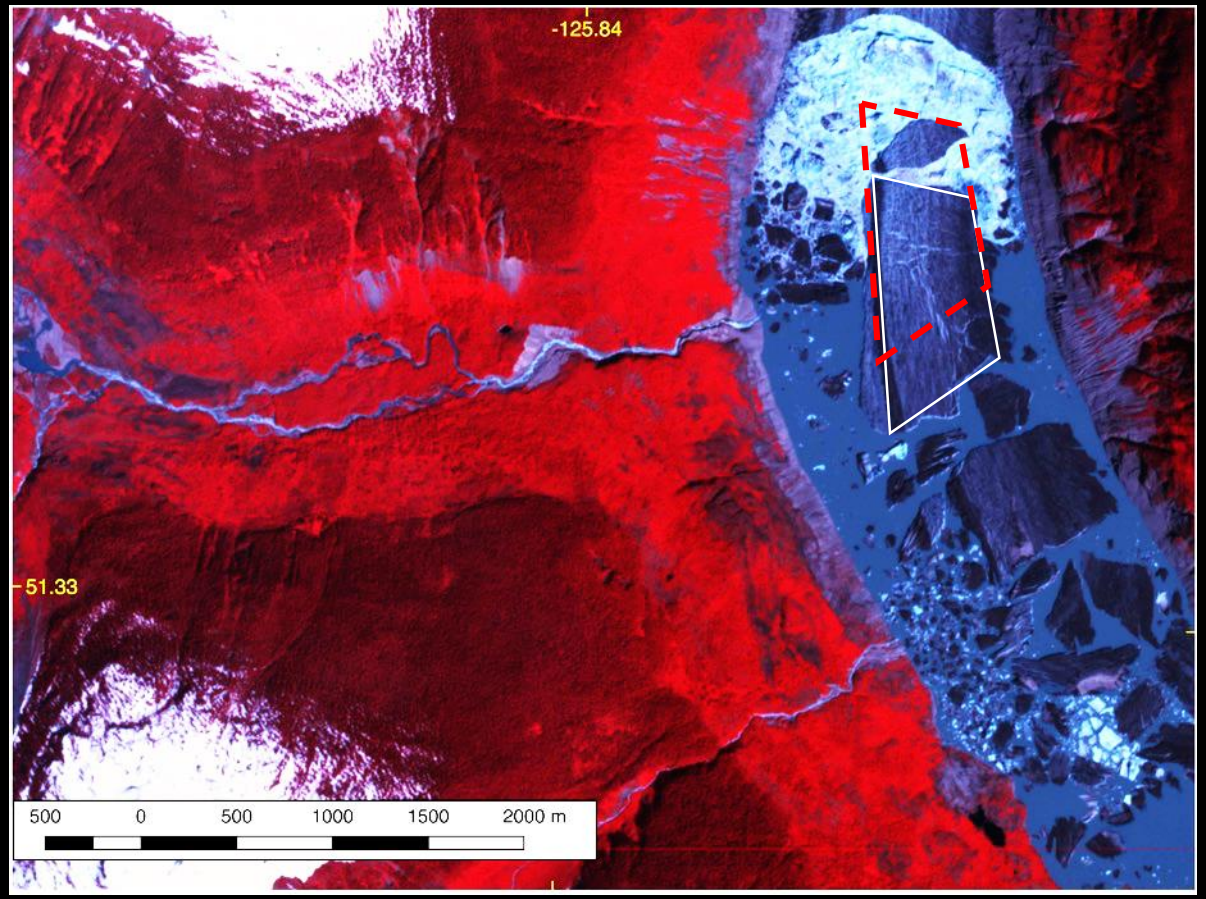
Our Glaciers are Receding Quickly
Klinaklini Glacier / Knight Inlet

July 4, 2017

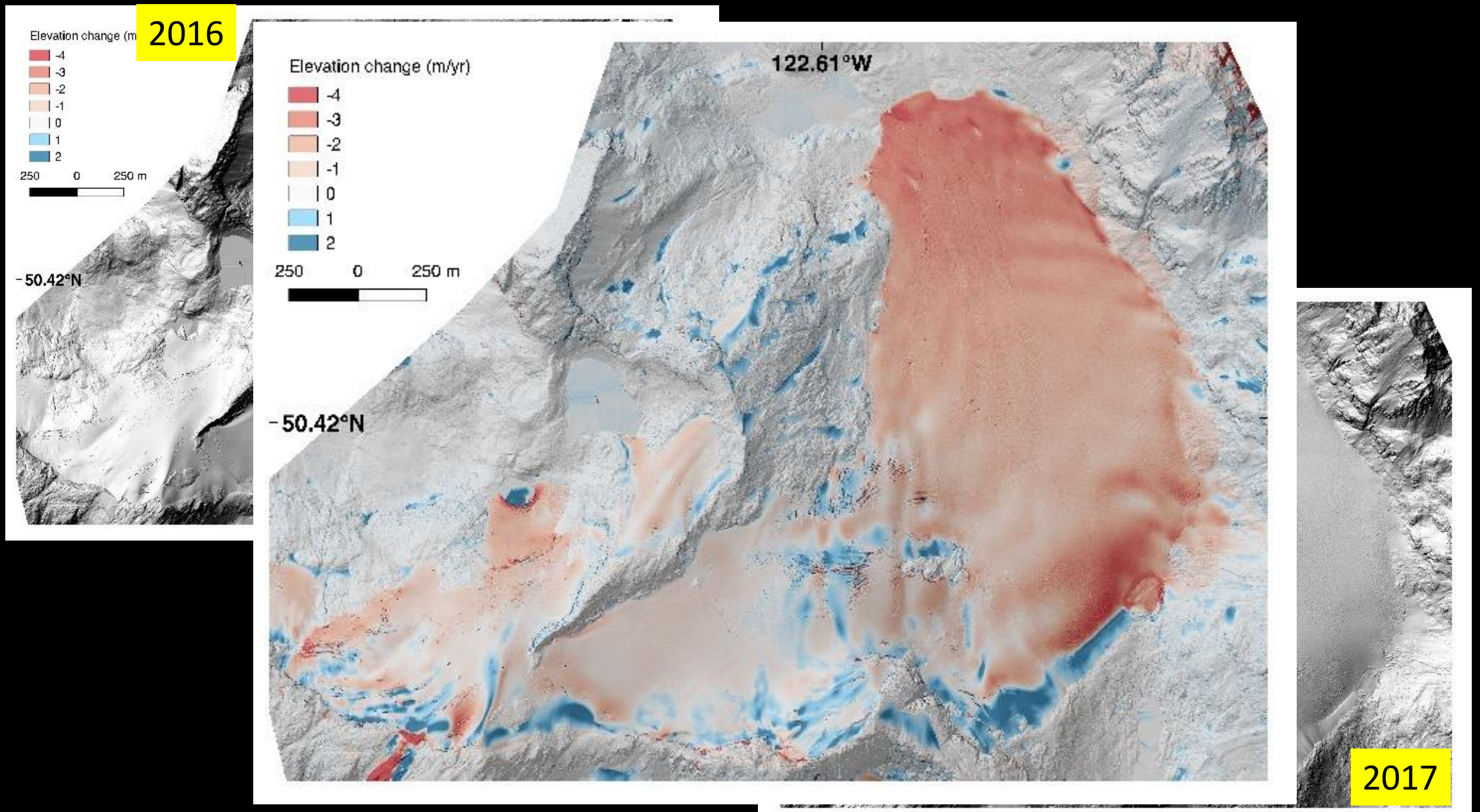
Planet Labs (satellite, false color)

July 6, 2017





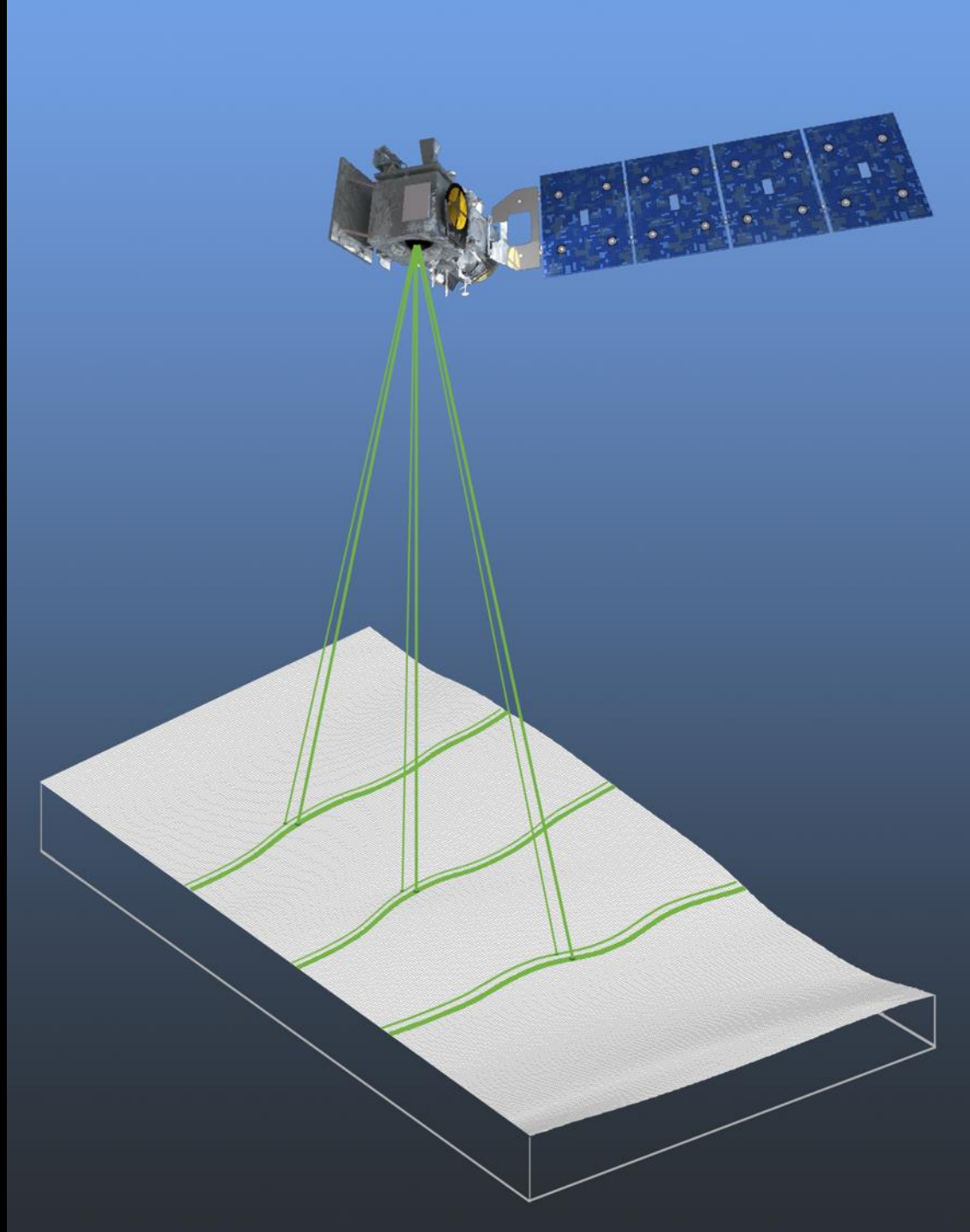
LiDAR: Hakai / UNBC's Riegl 780


2016
Elevation change (m
-4
-3
-2
-1
0
1
2
250 0 250 m
50.42°N
Elevation change (m/yr)
-4
-3
-2
-1
0
1
2
250 0 250 m
122.61°W
50.42°N
2017

IceSat-2: Satellite-Based LiDAR NASA/JPL (September 2018)

- First IceSat (2003-2009) looked only at polar ice.
- The IceSat-2 laser will emit green laser pulses at 532 nm wavelength.
- Six beams are arranged in three pairs, with the pairs 3.3 km apart.
- It fires at 10 Hz, taking elevation measurements every 70 cm along the satellite's ground path.
- Each pulse sends out about 20 trillion photons, almost all of which are dispersed or deflected as the pulse travels to Earth's surface and bounces back to the satellite.
- About a dozen photons from each pulse return to the instrument and are collected in a beryllium telescope.

Our lead Brian Menounos has been part of the science team for IceSat-2, so we will collaborate with JPL after the launch.

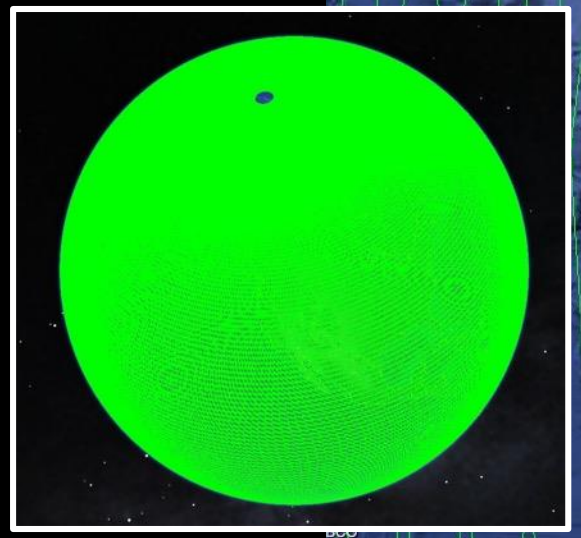


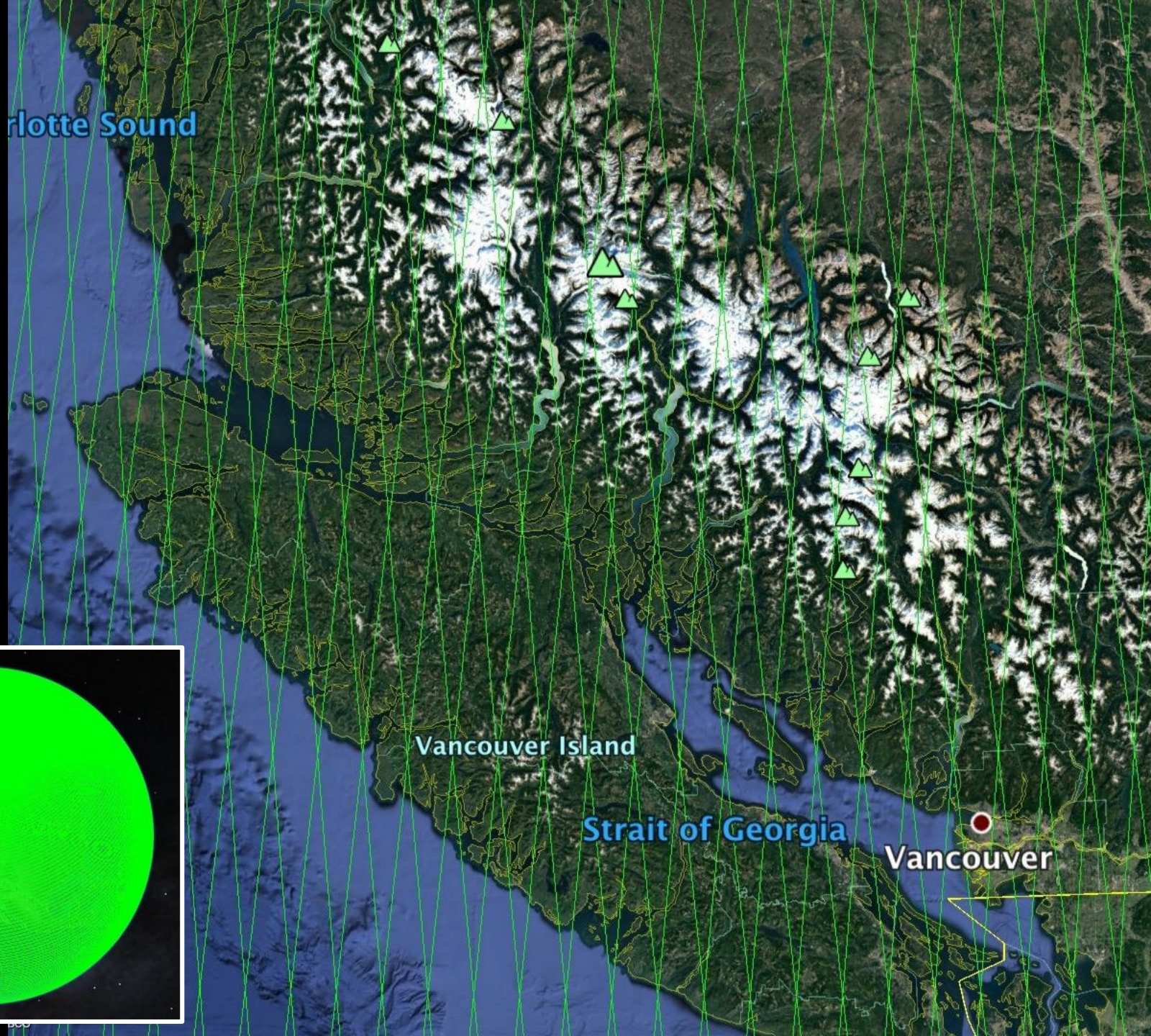
IceSat-2

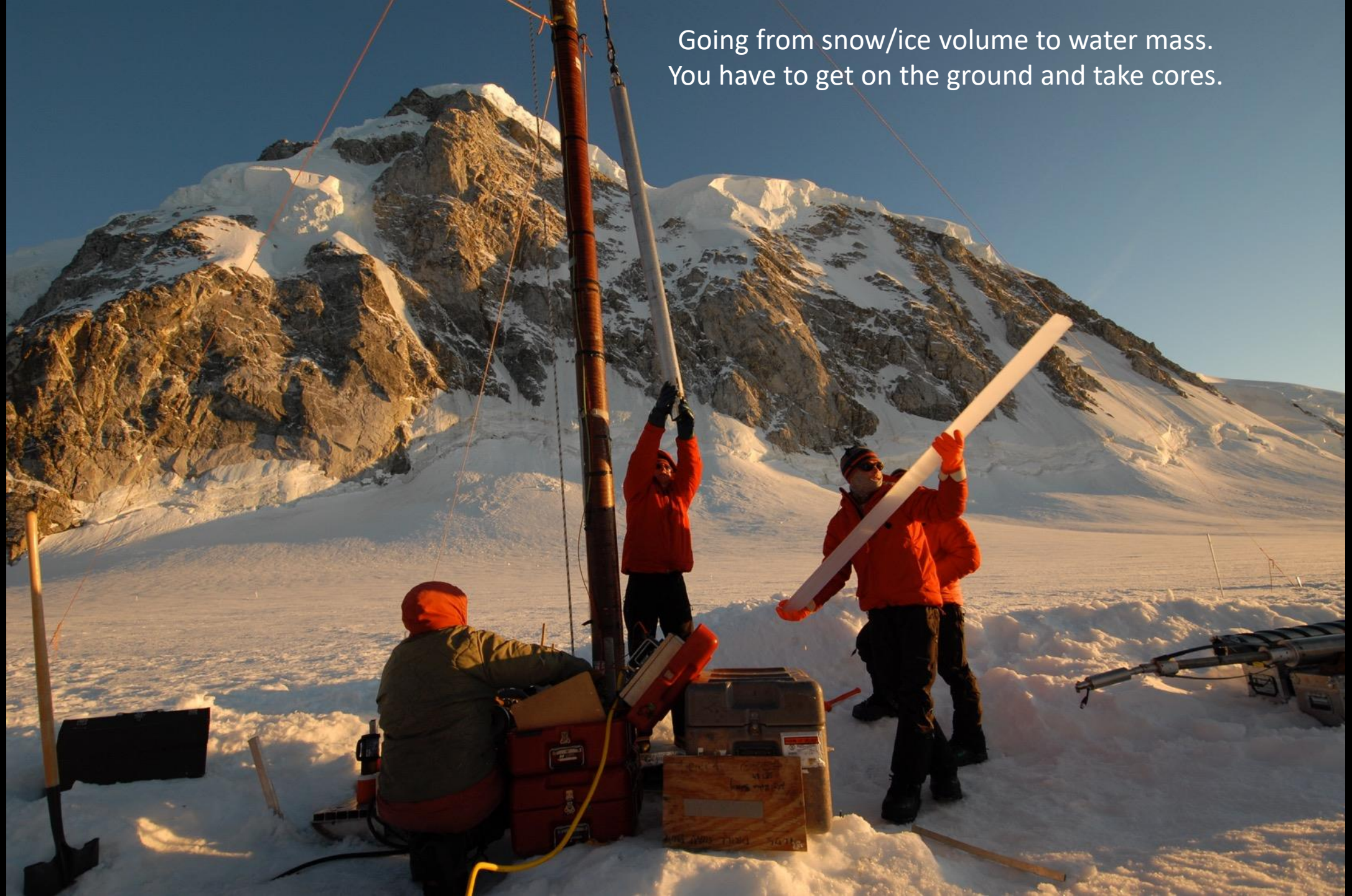
Near polar, near circular orbit.

In 3 yrs it will carpet the globe.

Needs ground-truthing and calibration via local LiDAR and on-the-ground sampling.

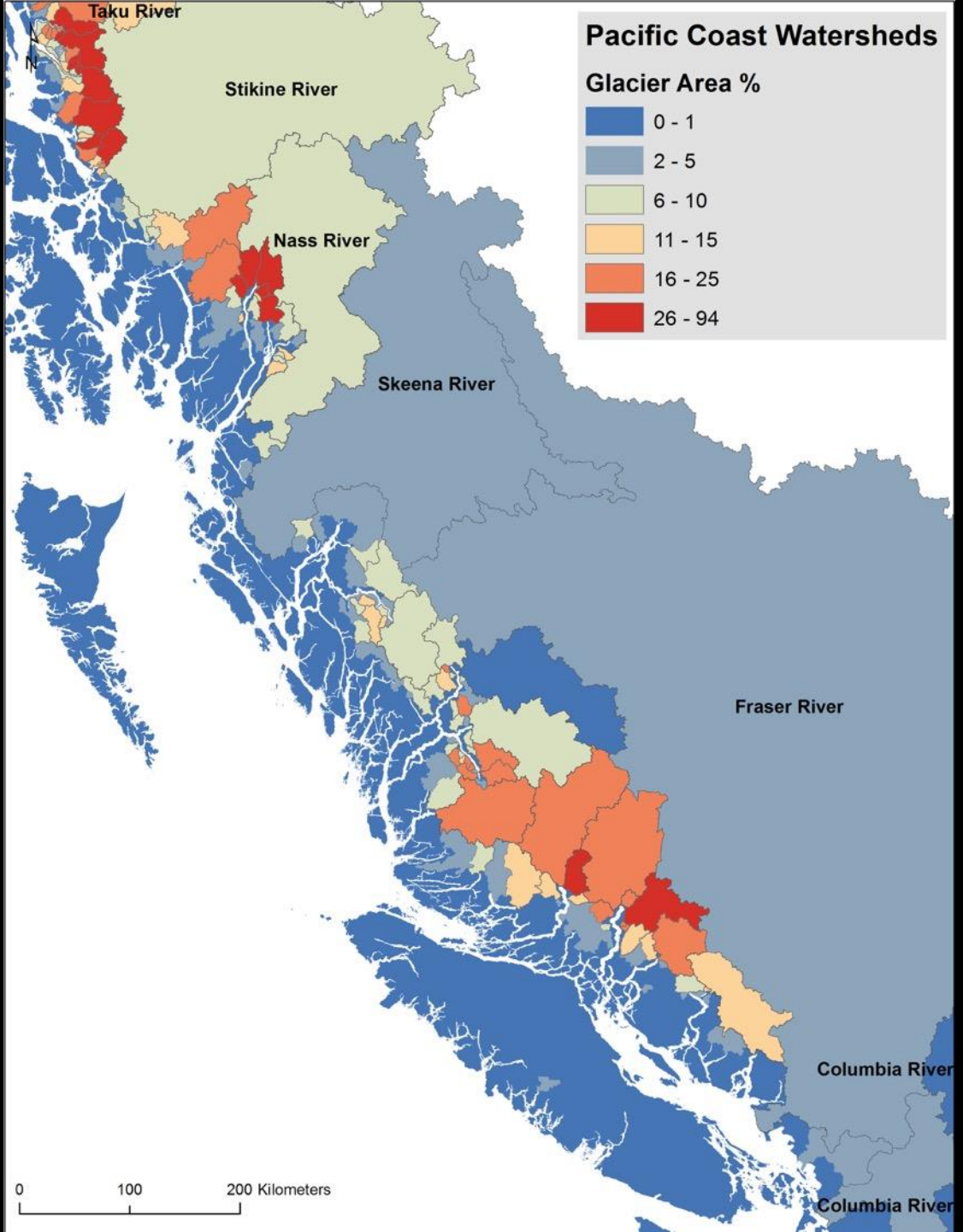


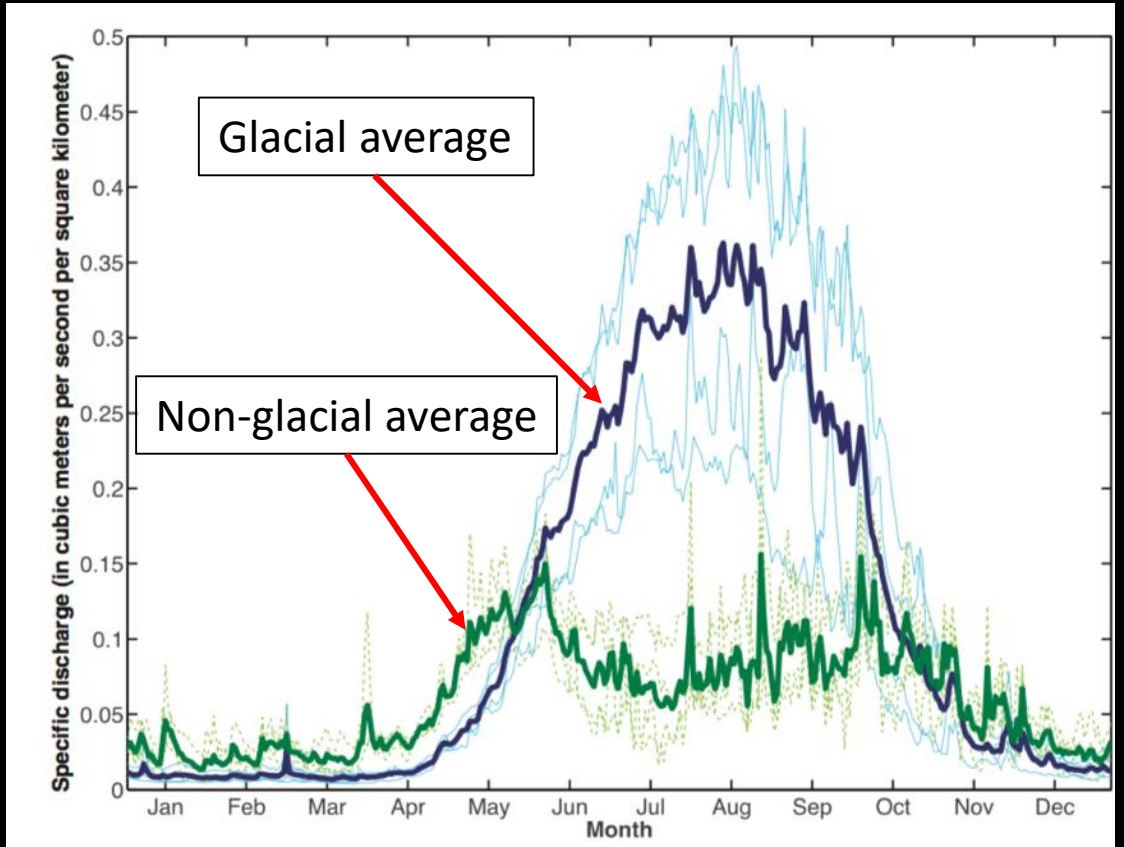



Going from snow/ice volume to water mass.
You have to get on the ground and take cores.

Glacial vs. non-glacial watersheds

Glacial watersheds yield far more flow per unit area. Glacial flow peaks in mid-summer. Non-glacial flow is bimodal, with snow melt in spring and rain in fall. Glacial flow: high inorganic transport, low in organics. Non-glacial is high in organics, esp. dissolved carbon.





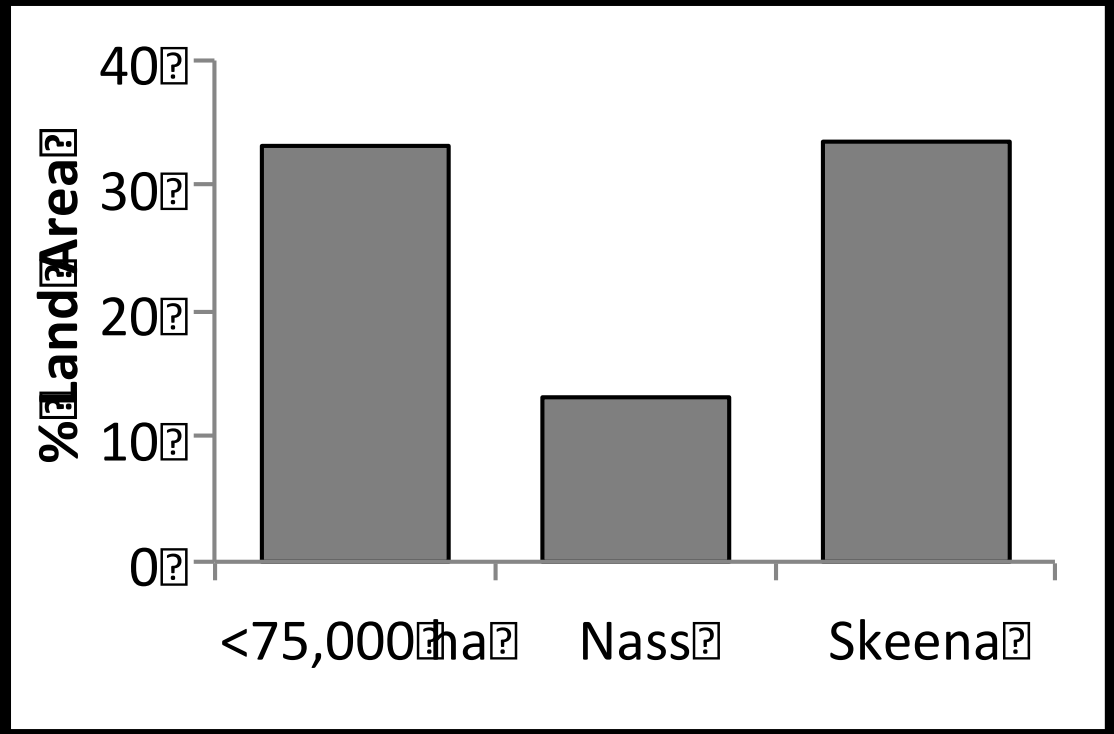
After O'Neel, et al., 2015 for SE Alaska

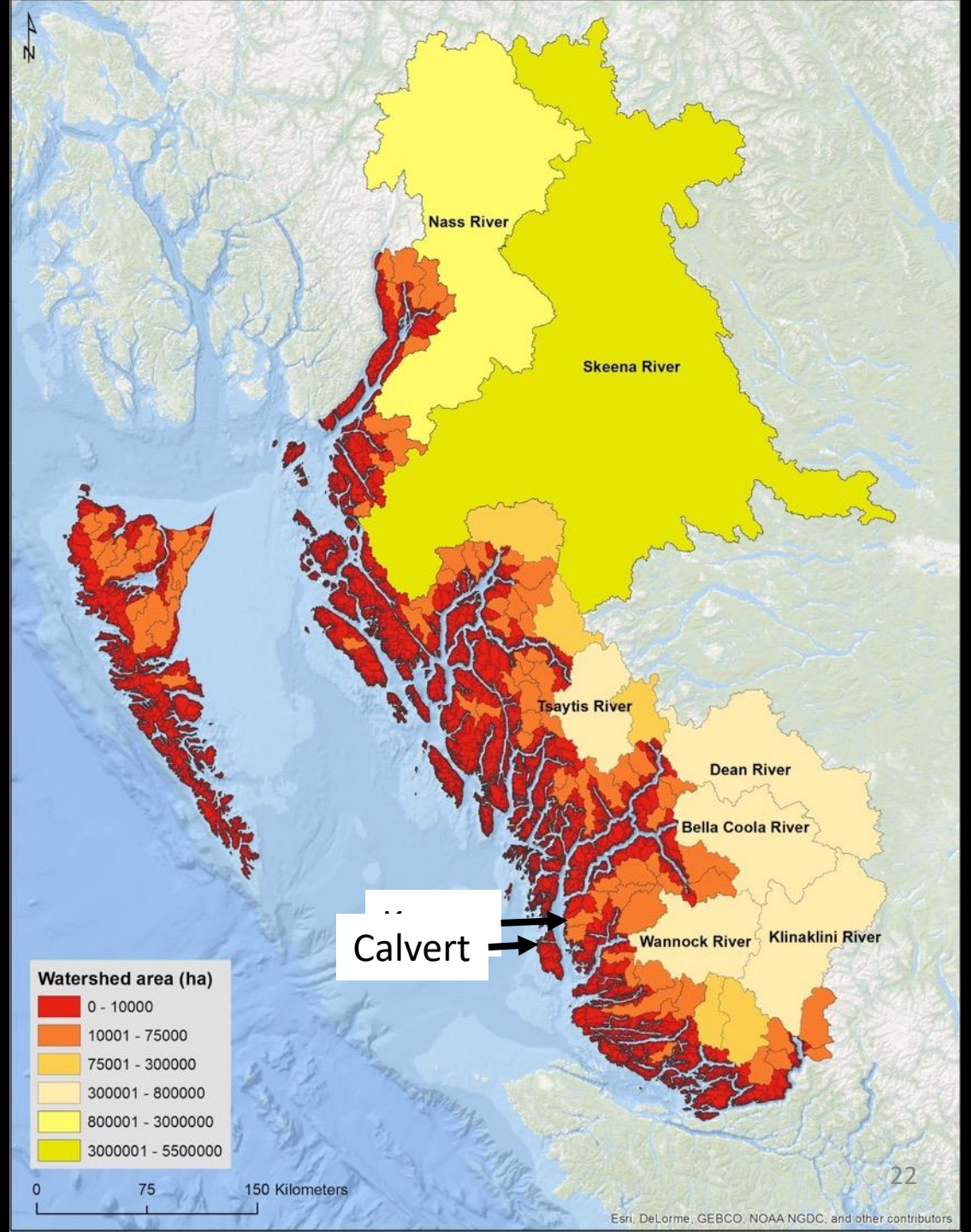
Large and Small Watersheds

Small watersheds add up. The aggregate area of watersheds less than 75,000 hectares matches that of the Skeena.

- ~ 100's of medium size like the Koeye
- ~ 10,000's of small ones like on Calvert

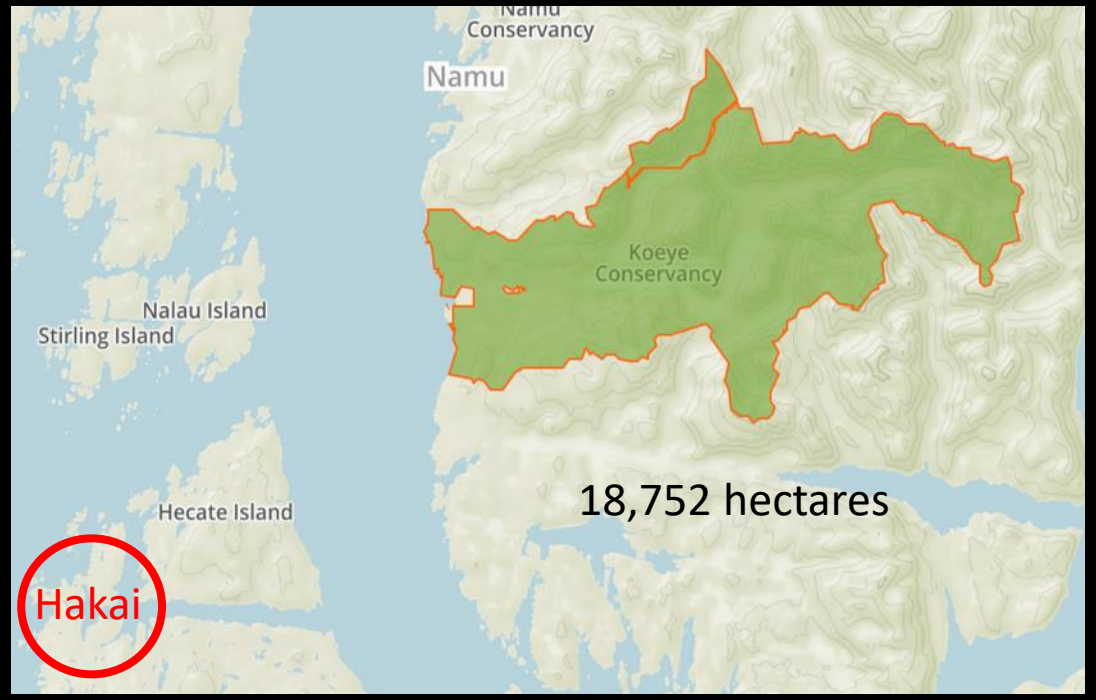
We can't study them all. We need to study a few representatives, then model & extrapolate.





Koeye Watershed

- Adjacent to our Calvert observatory and in effect an extension of it.
- We study it comprehensively, long term as a salmon ecosystem with the Heiltsuk First Nation.
- Like many medium sized watersheds it is strongly influenced by seasonal snow.
- We flew LiDAR pre-snow last fall to establish the bare earth topography (processing is just about done).
- We will monitor snow pack via annual winter LiDAR flights as with glaciers.



UAVs for Snow Measurement

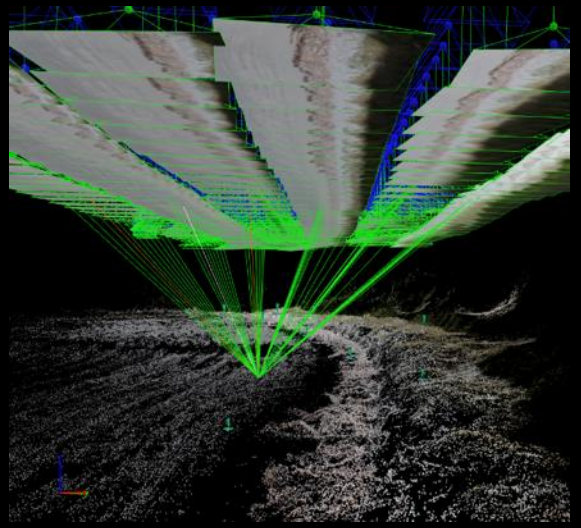
- LiDAR is the method of choice for measuring snow in medium size watersheds, particularly if they are inaccessible like Koeye.
- But LiDAR is costly and requires a lot of planning.
- For smaller, accessible systems UAVs (drones) may be practical for low-cost, on-demand measurement.
- 3D analysis is done via “structure from motion” modeling.
- Bill Floyd is testing this method at Mt Cain on Vancouver Island with our technical team.

UAV – Structure from Motion Workflow

Drone

Camera captures overlapping images while in motion.

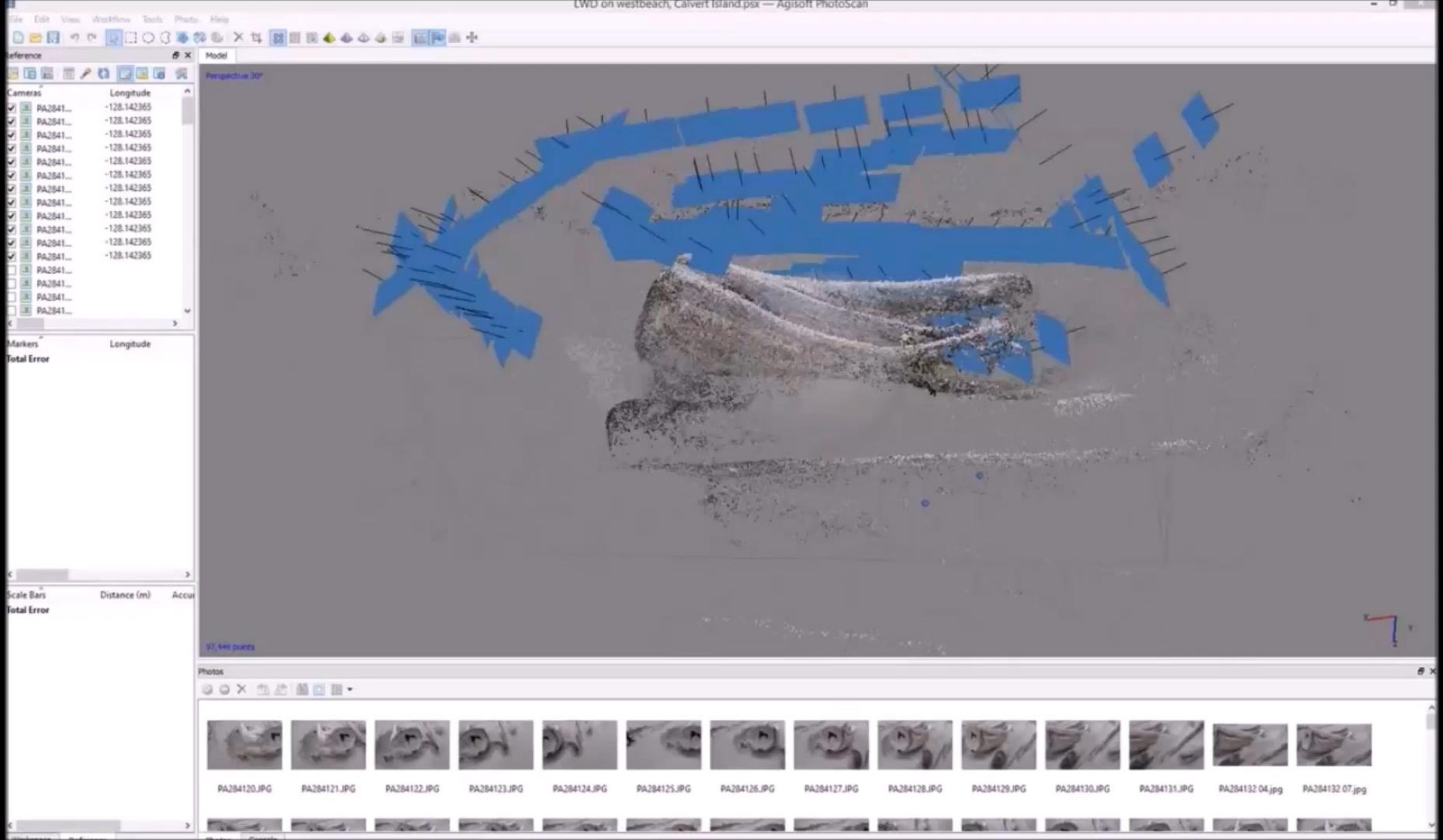
Computer Vision



Identifies and matches thousands of keypoints

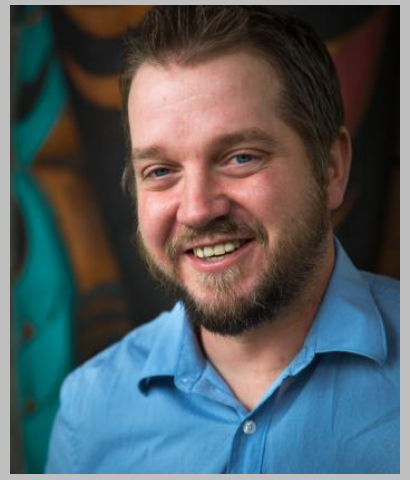
Photogrammetry

Extracts geometry to calculate position for generating accurate maps and 3D models

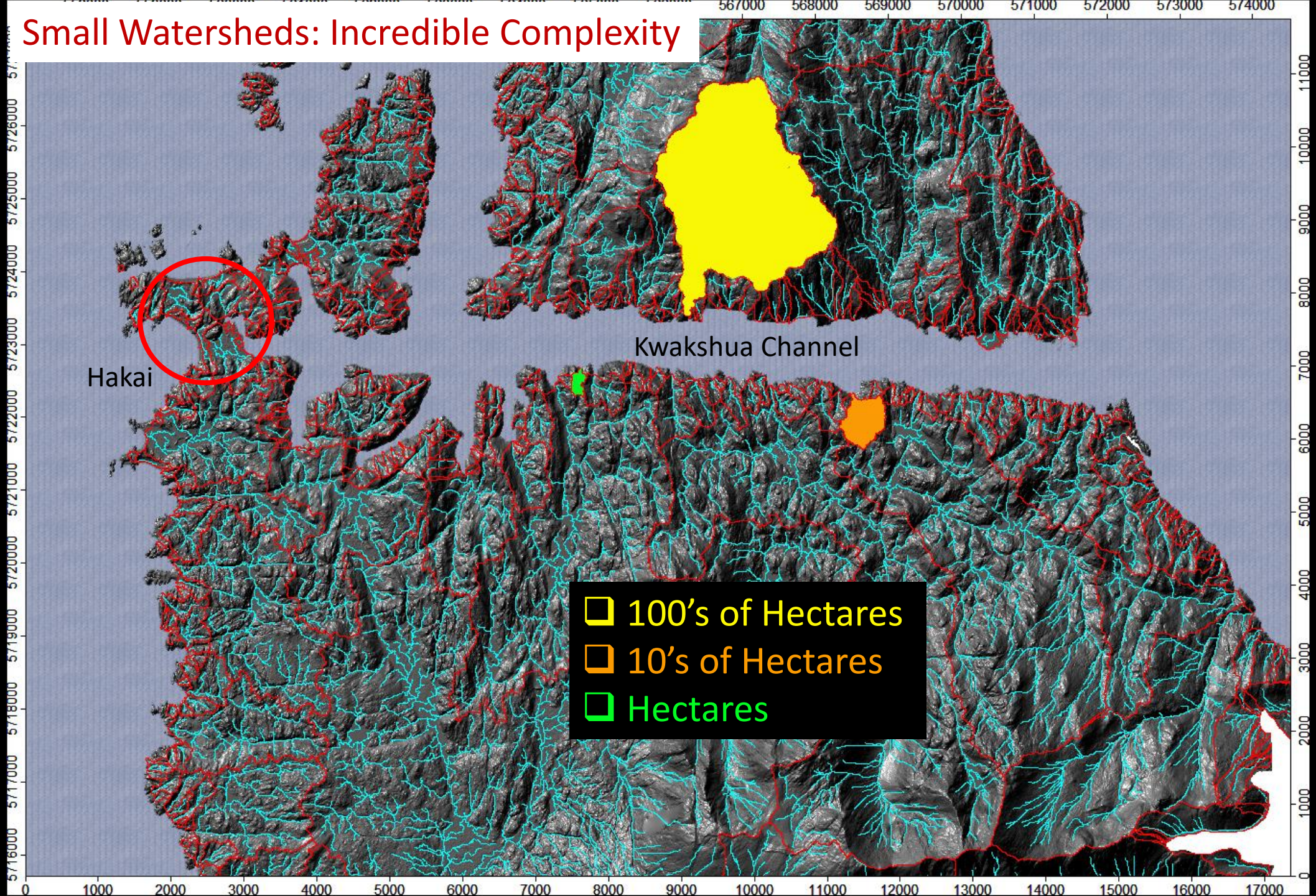

LWD on westbeach, Calvert Island.psx — Agisoft PhotoScan
Model
Perspective 30°
Cameras
Longitude
Markers
Total Error
Scale Bars
Distance (m)
Photos
PA284120.JPG
PA284121.JPG
PA284122.JPG
PA284123.JPG
PA284124.JPG
PA284125.JPG
PA284126.JPG
PA284127.JPG
PA284128.JPG
PA284129.JPG
PA284130.JPG
PA284131.JPG
PA284132 04.jpg
PA284132 07.jpg

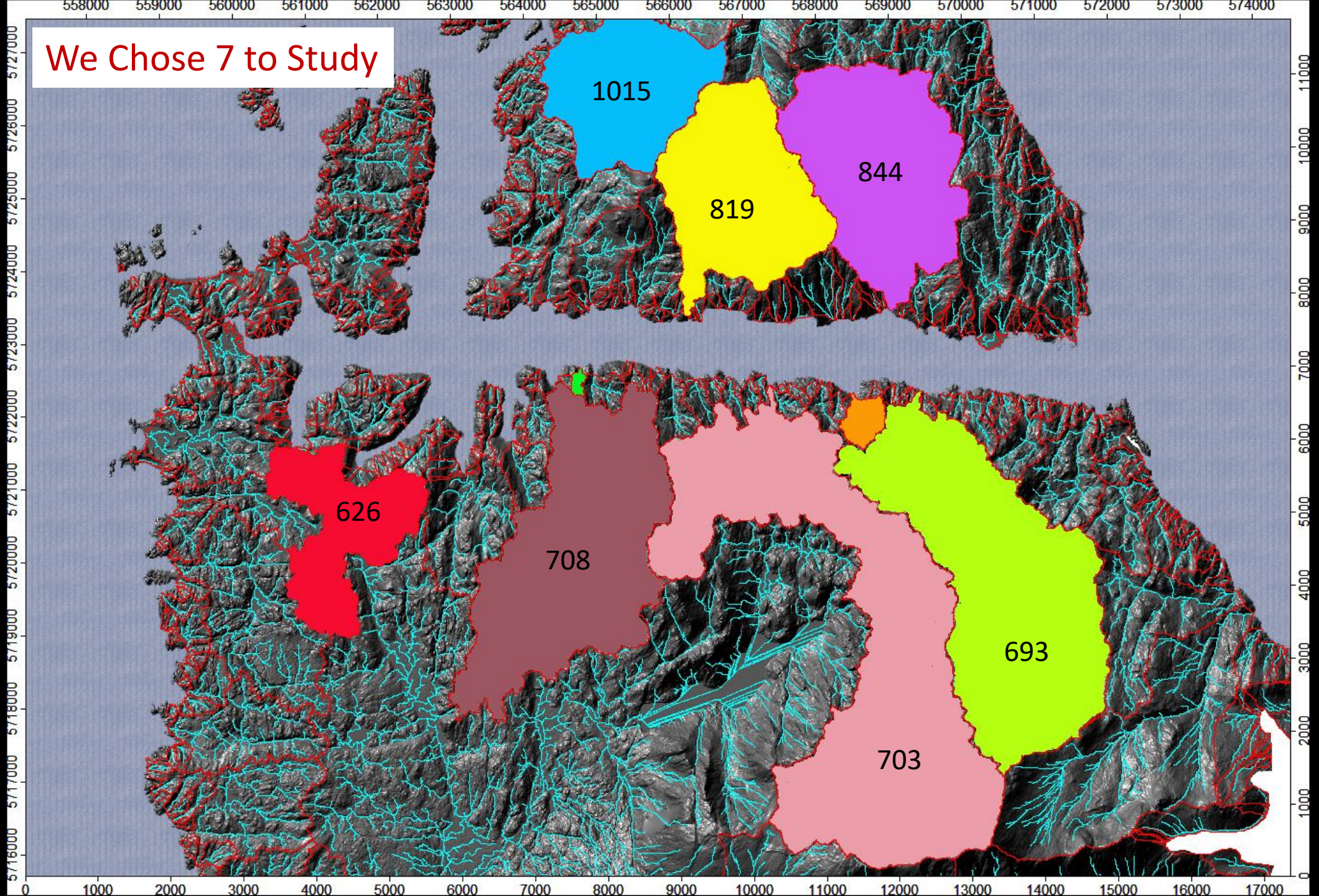
All Those Small Watersheds

Ian Giesbrecht (Hakai Institute), Bill Floyd (BC Govt. and VIU), Suzanne Tank (U of Alberta) and many others

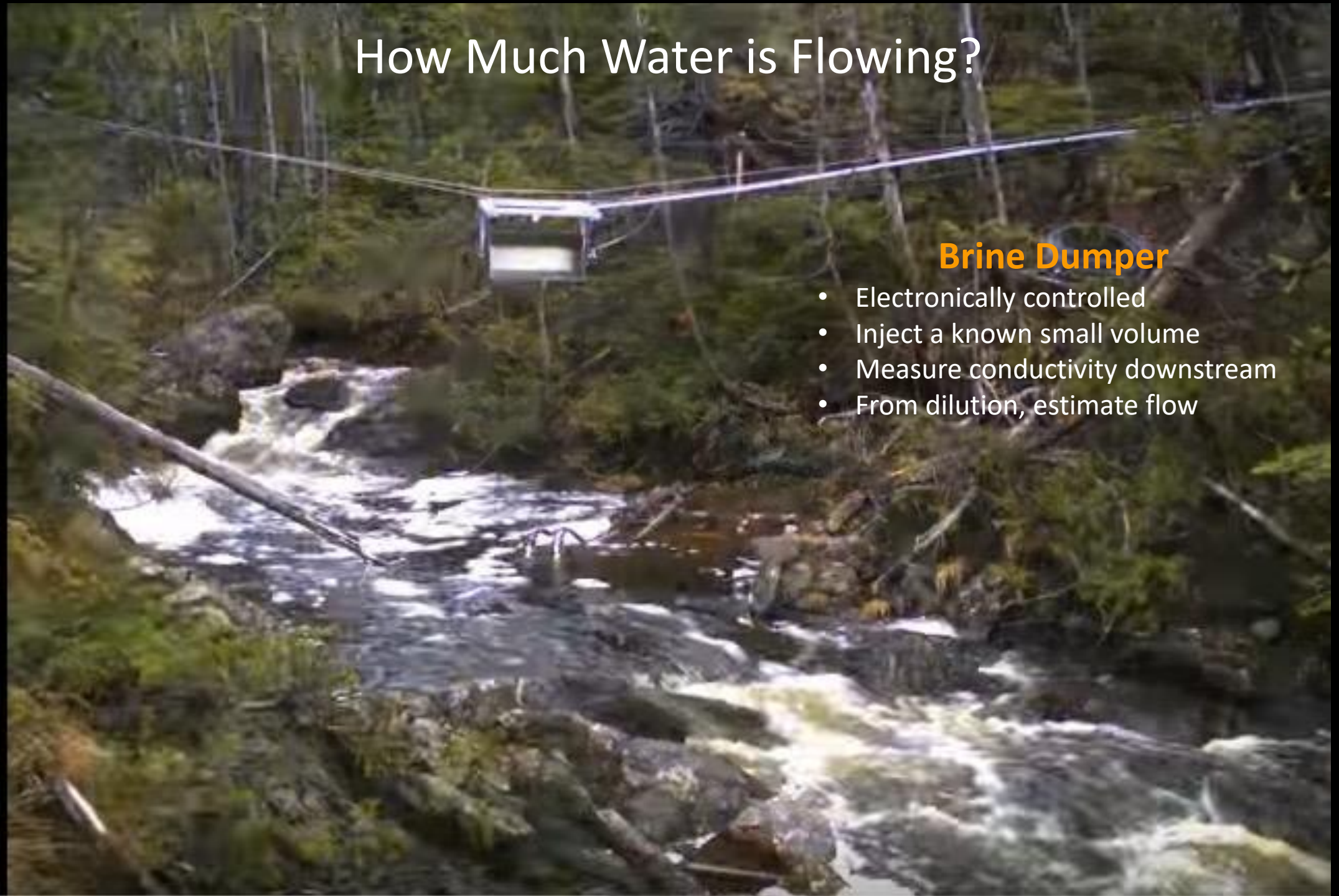




Small Watersheds: Incredible Complexity




We Chose 7 to Study
1015
819
844
626
708
693
703

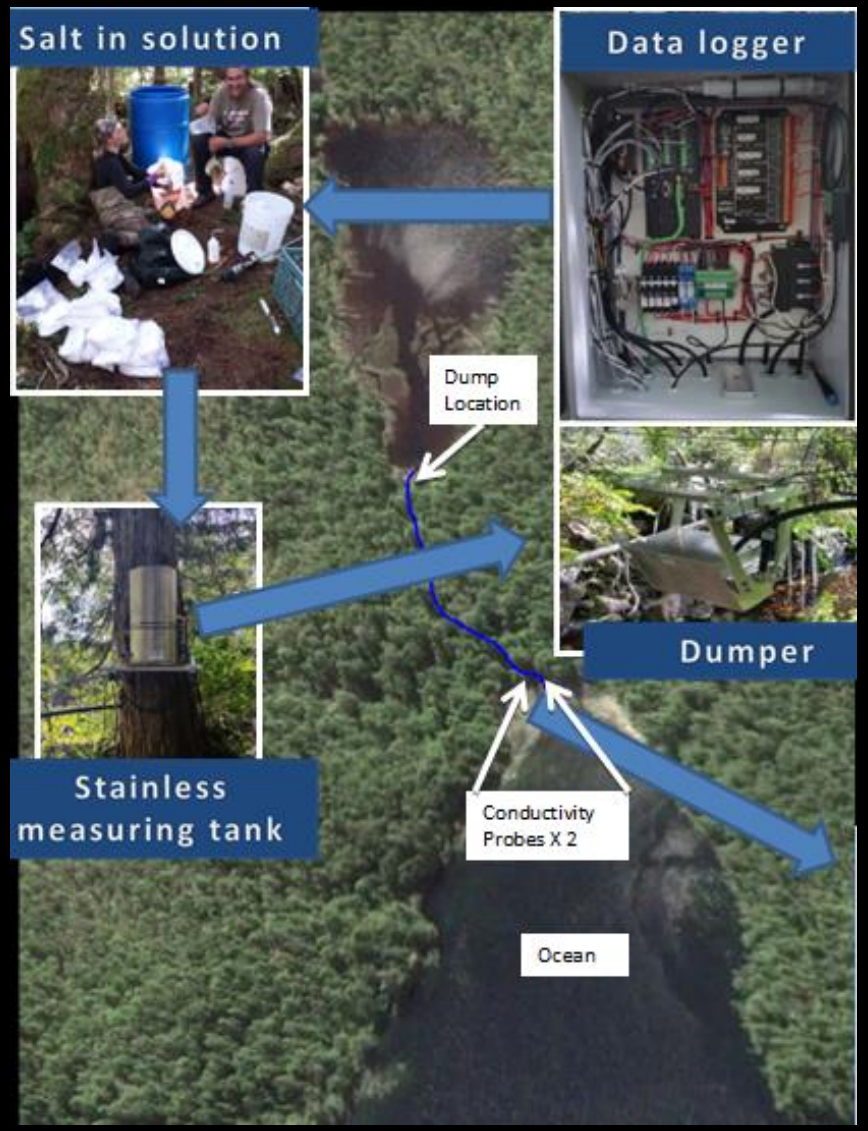
How Much Water is Flowing?

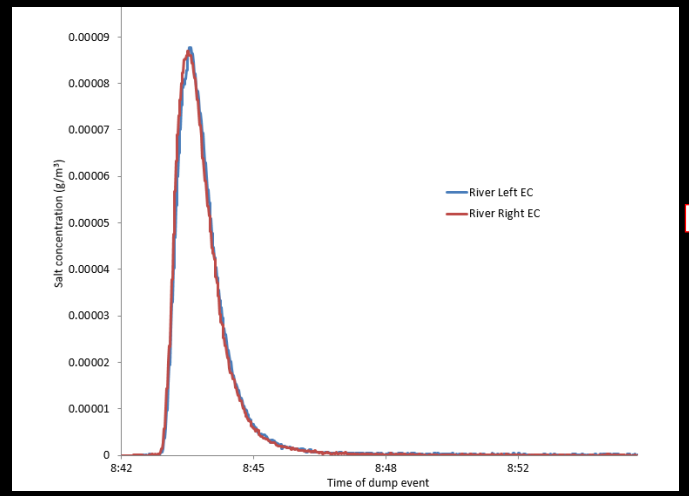


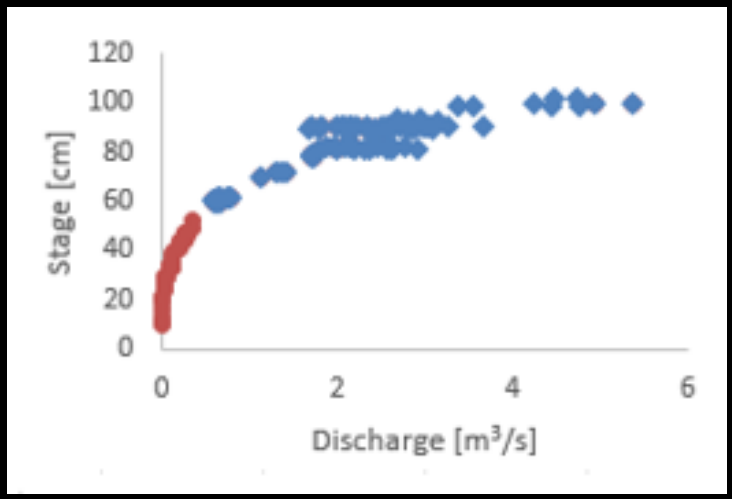
Brine Dumper

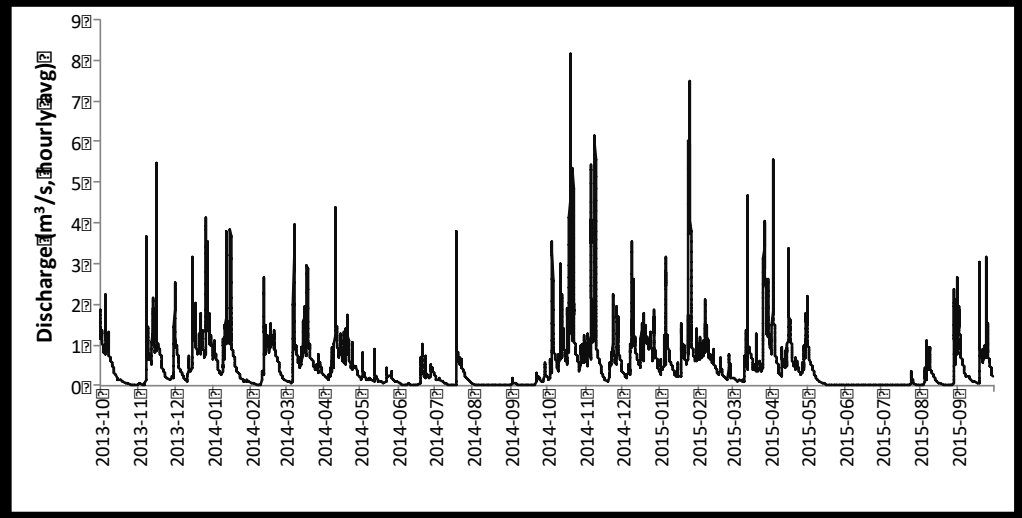
- Electronically controlled
- Inject a known small volume
- Measure conductivity downstream
- From dilution, estimate flow

Automation to Measure Stream Flow at High Frequency



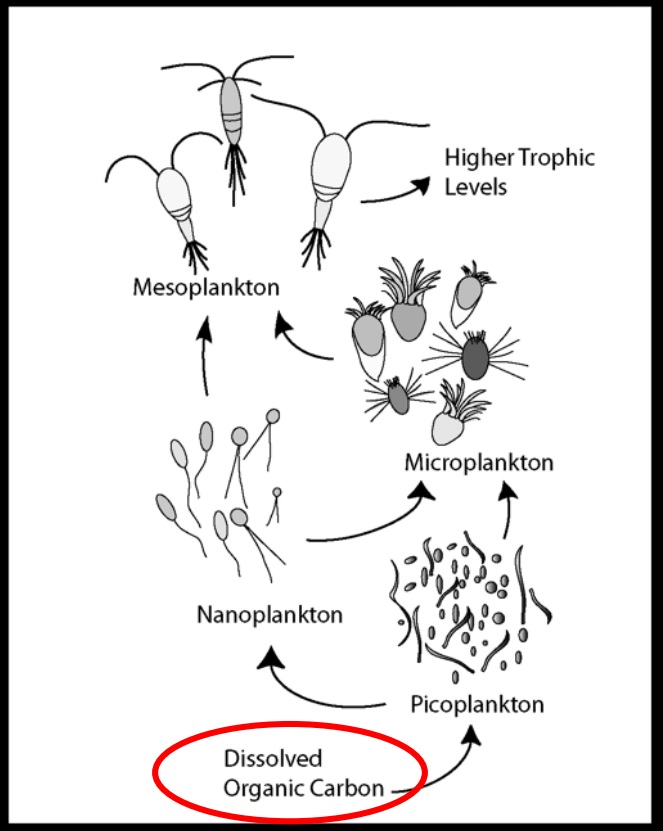




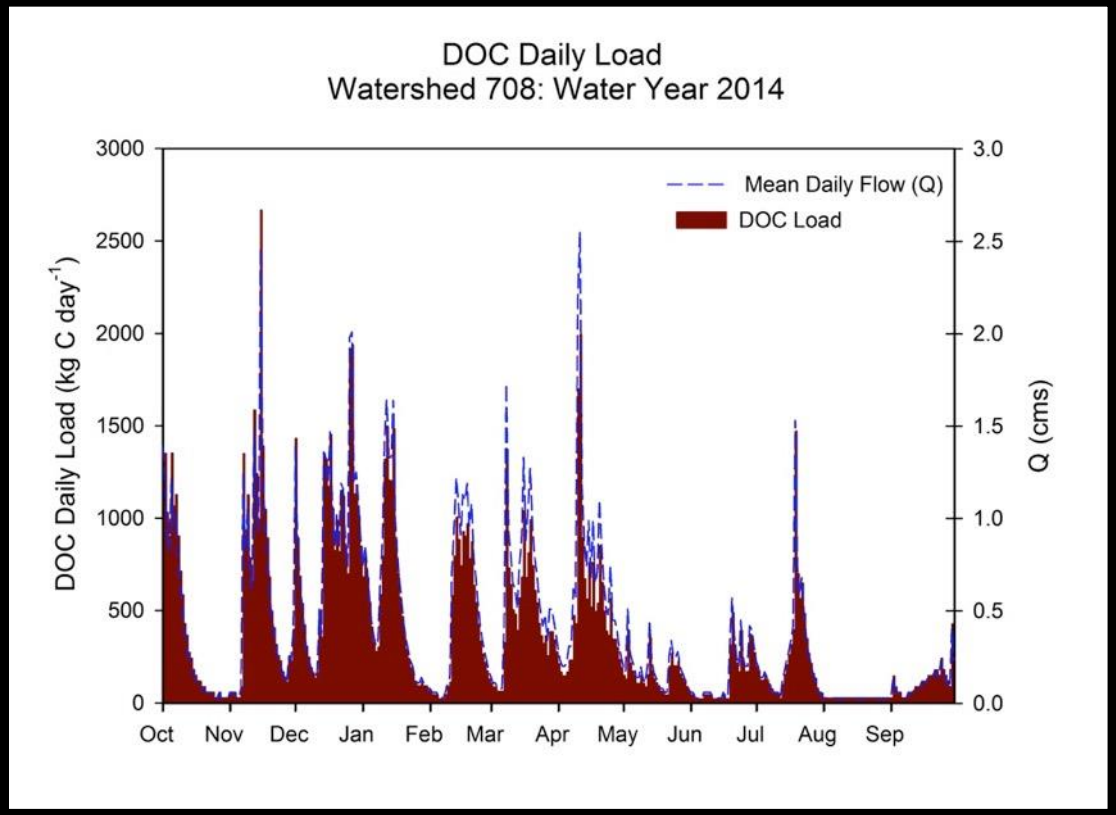


Dissolved Organic Matter

- Organic carbon, nitrogen, phosphorus.
- Breakdown products.
- Some protein, nucleic acids, sugars.
- Tannins from decaying vegetation and peat bogs very high in our streams.
- Dissolved organic carbon (DOC) fuels the microbial loop at the base of ocean food webs.



Kwakshua Watersheds: Very high DOC export



- High precipitation
- Highly organic soils flush quickly
- Short, steep watersheds

⇨ Rapid stream response to rain events

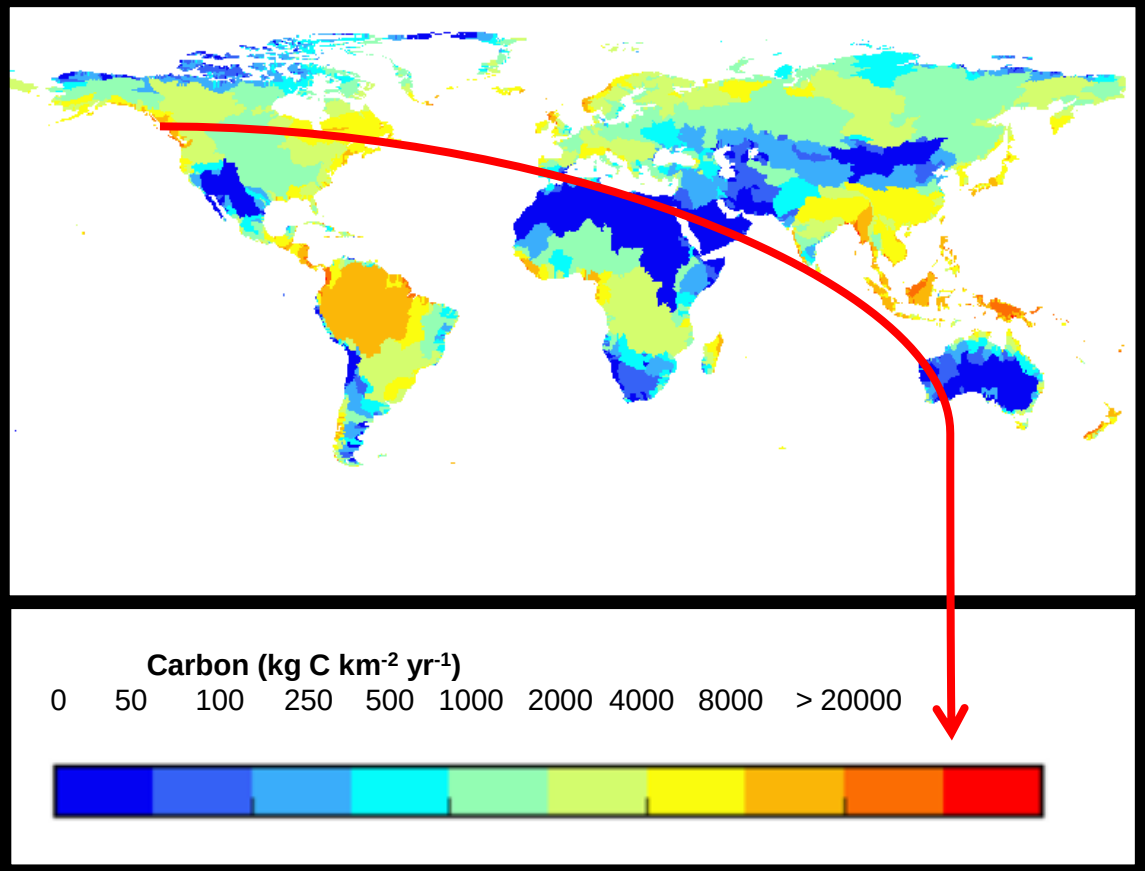
DOC Very High by Global Standards

(kg of carbon per square km per year)

Global Average: 5,890

North Pacific Average: 3,684

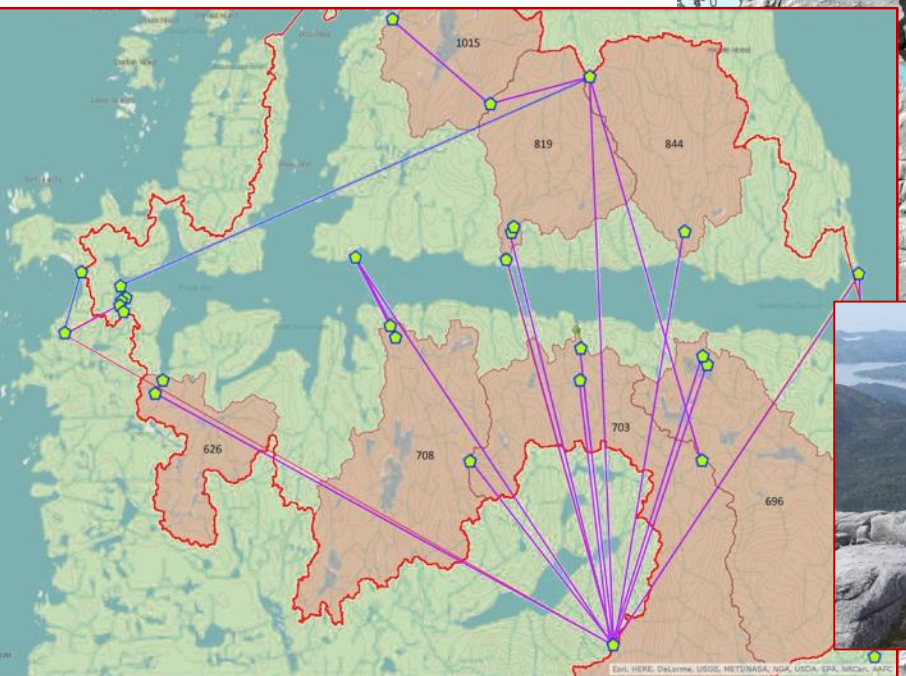
Kwakshua: 19,050 ± 4200



Mayorga et al. 2010, Beusen et al. 2009

Sensor Network: Kwakshua Watersheds

- Hydrology
- Biogeochemistry
- Weather
- Cameras
- Real time
- On the Internet



LiDAR-Based Ecosystem Classification

Inputs:

- LiDAR
- Multispectral data (RapidEye 5m)

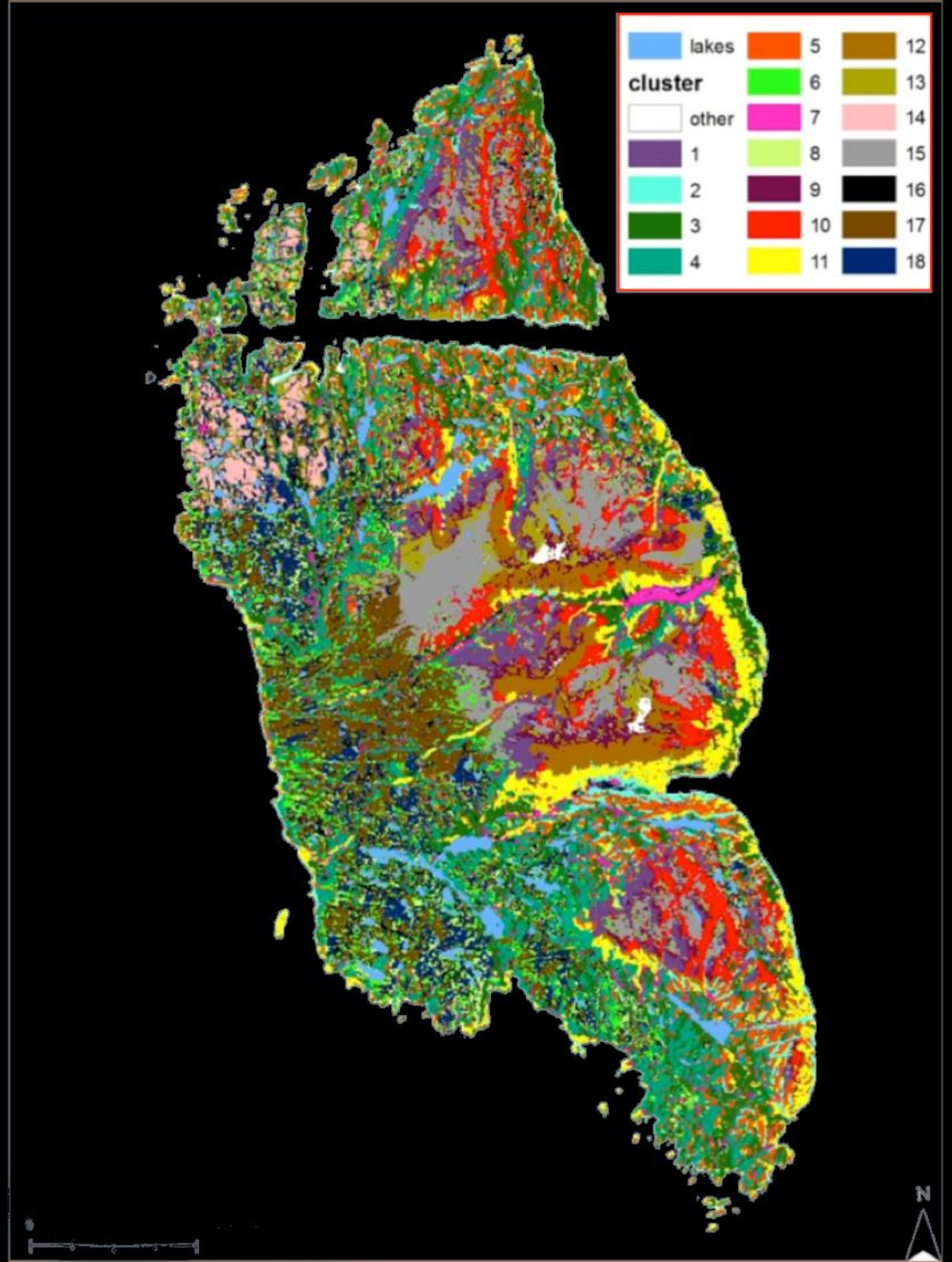
Analysis:

Input metrics for topography and soil drainage (TPI, TWI, etc.), productivity (NDVI), and forest structure.

Results:

- 6 non-forested types
- 12 forest types
- Statistical summary of each

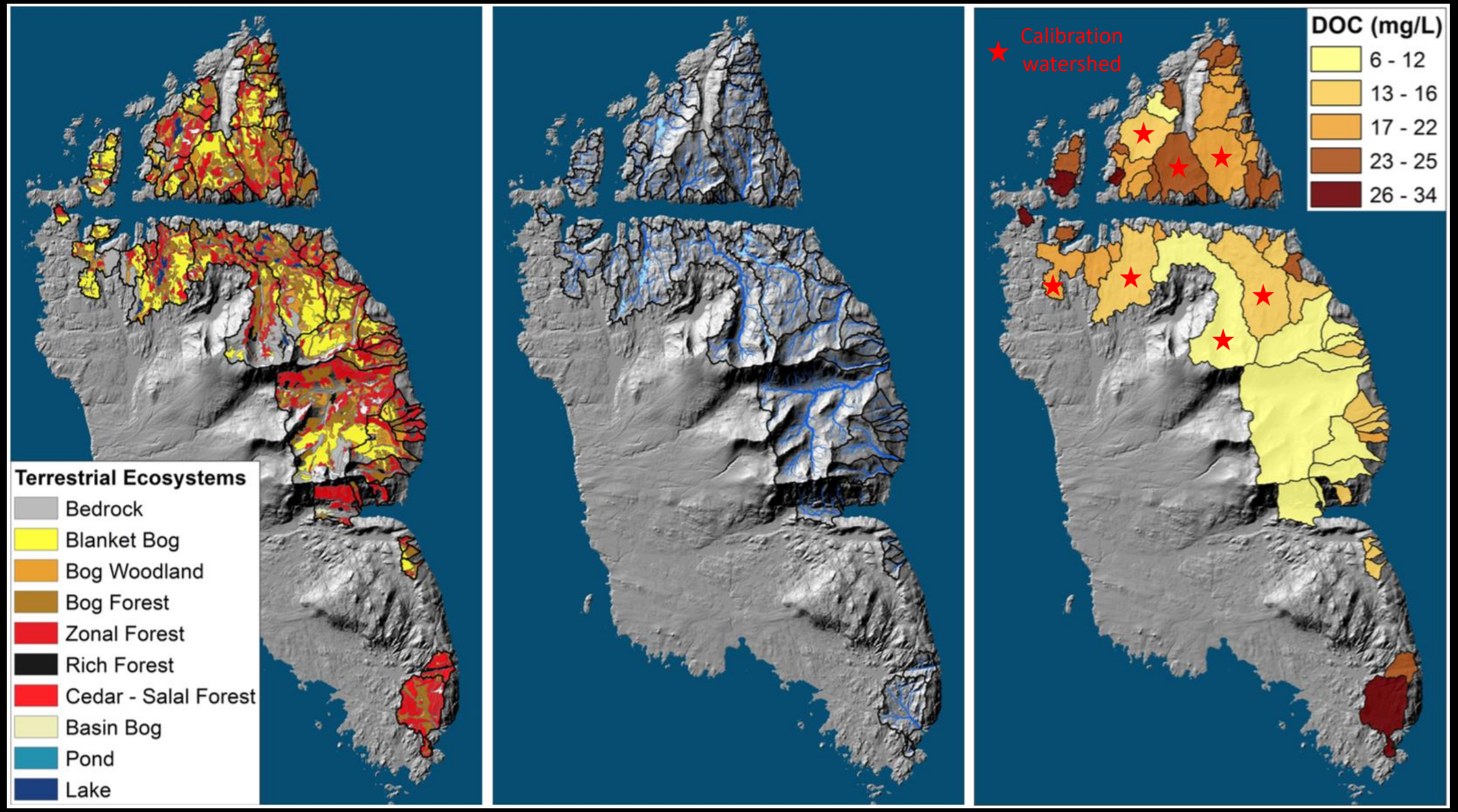
(e.g. red/yellow is productive forest; grey is alpine; pink is exposed bedrock.)



Spatial Pattern Analysis & Research Laboratory

Hakai
A Tula Foundation Program

Carbon Flux: Measure, Model, Predict, Test Locally, Rinse, Repeat



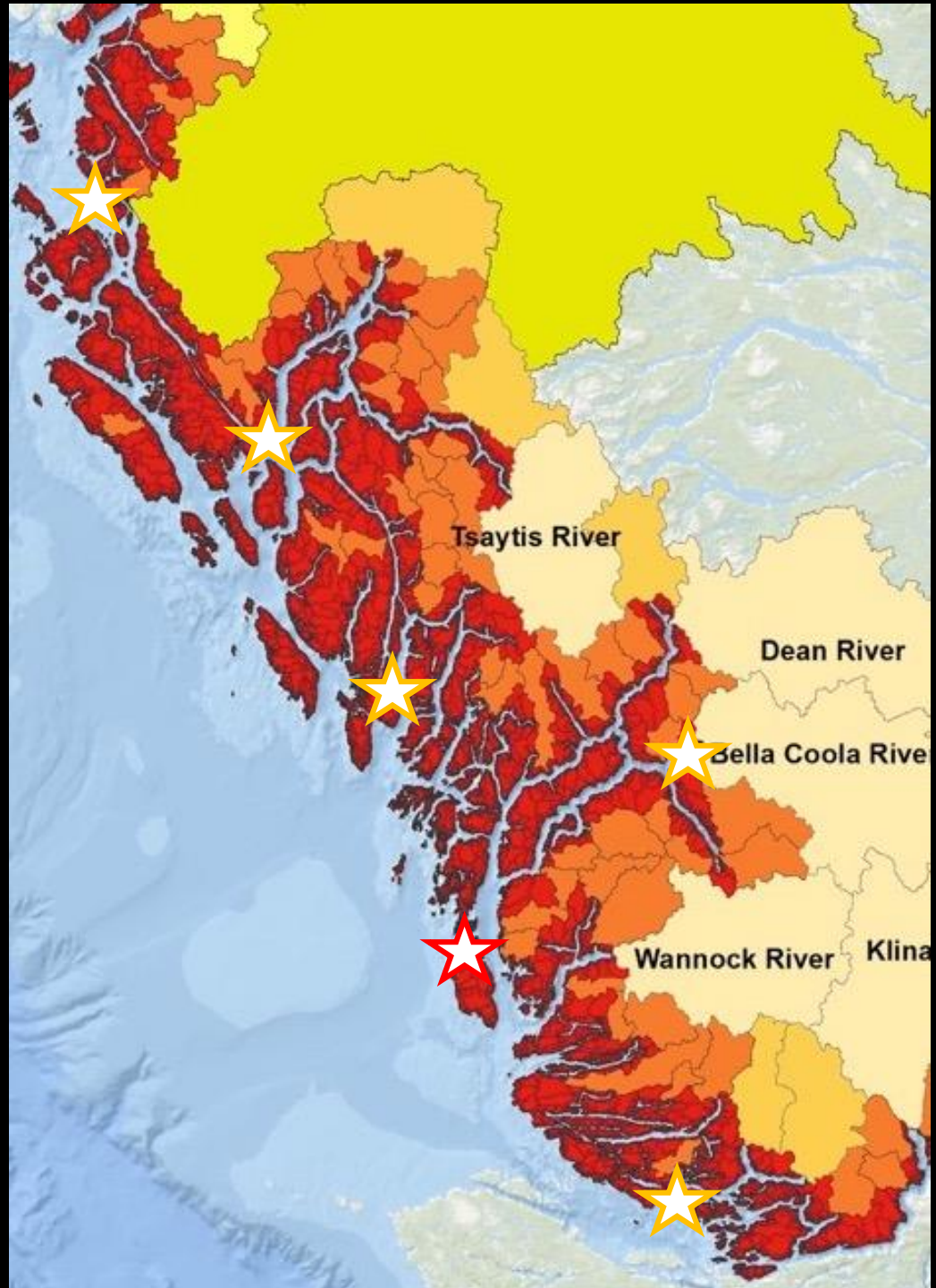
Thinking on a Regional Scale

Extending the model:

- More calibration watersheds
- More synoptic sampling

Can’t do it alone:

- Have a partner scientific group in Alaska.
- Recruiting capable local organizations on the BC coast to help with sampling, local instrumentation, ground-truthing.

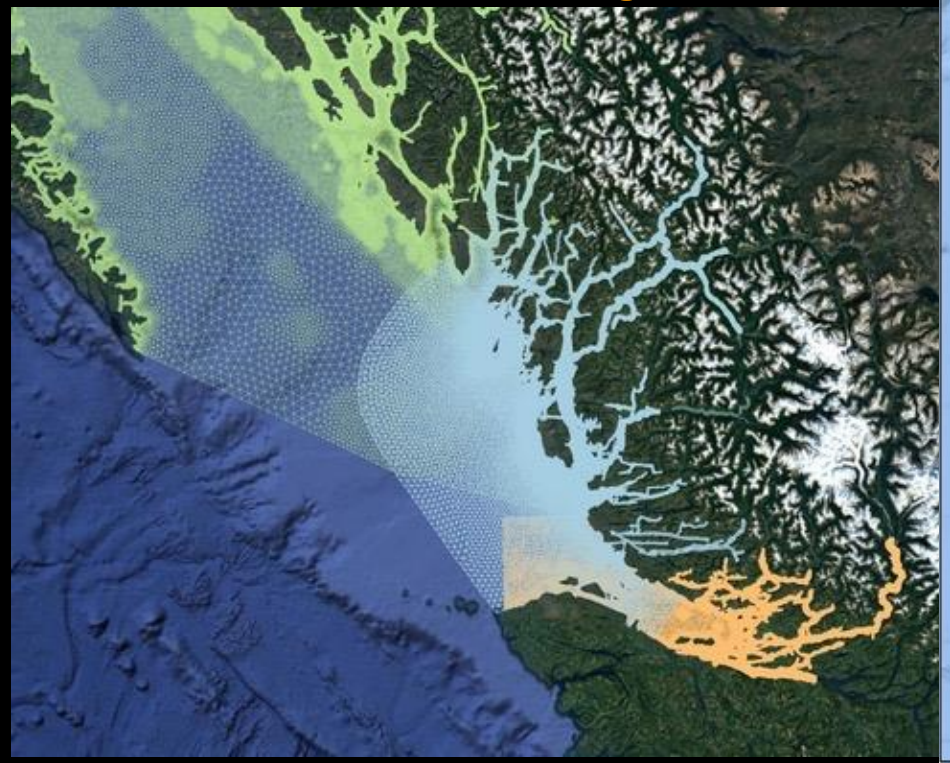


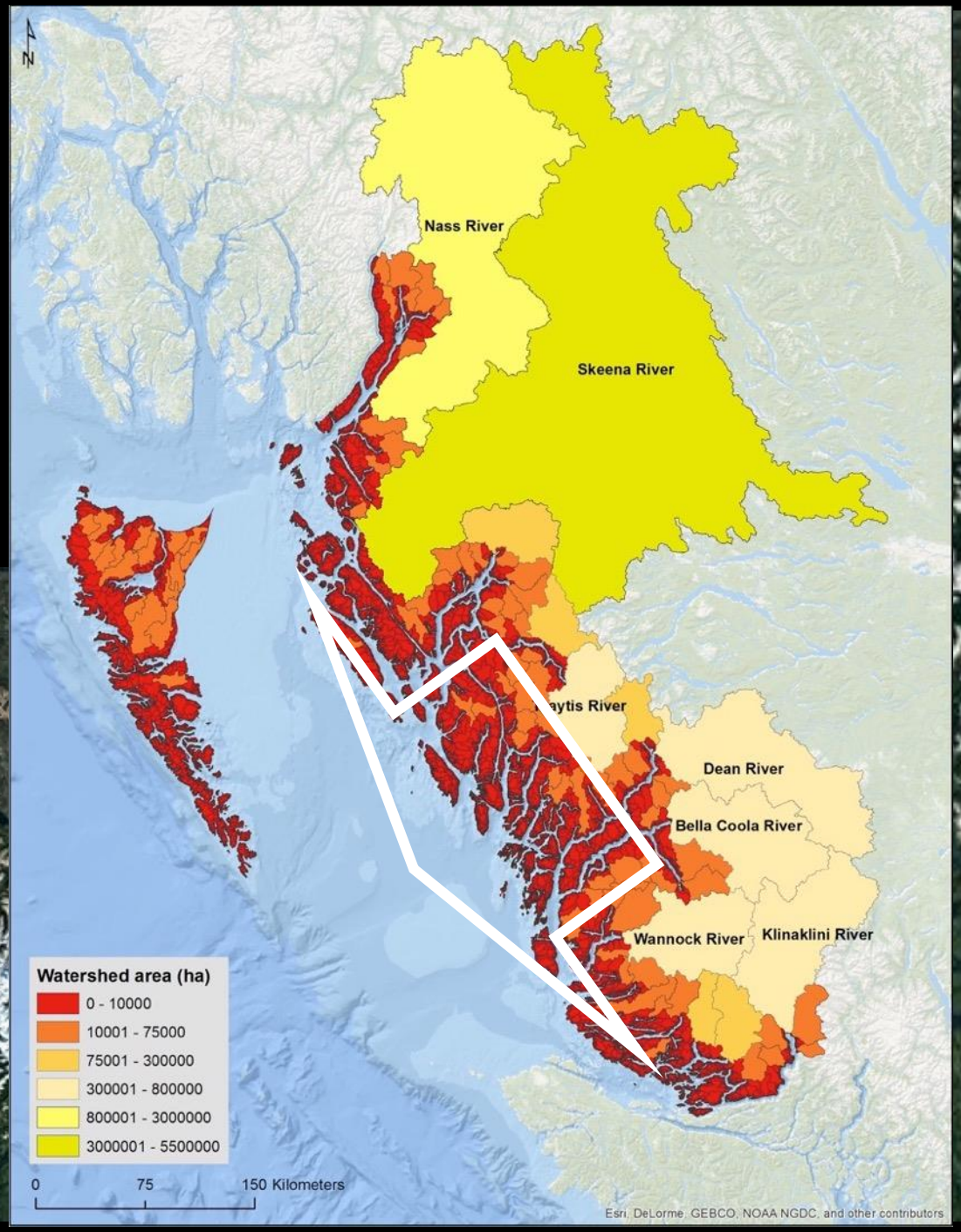
Hydrodynamic Modelling

Partners: DFO Institute of Ocean Sciences (Sidney).

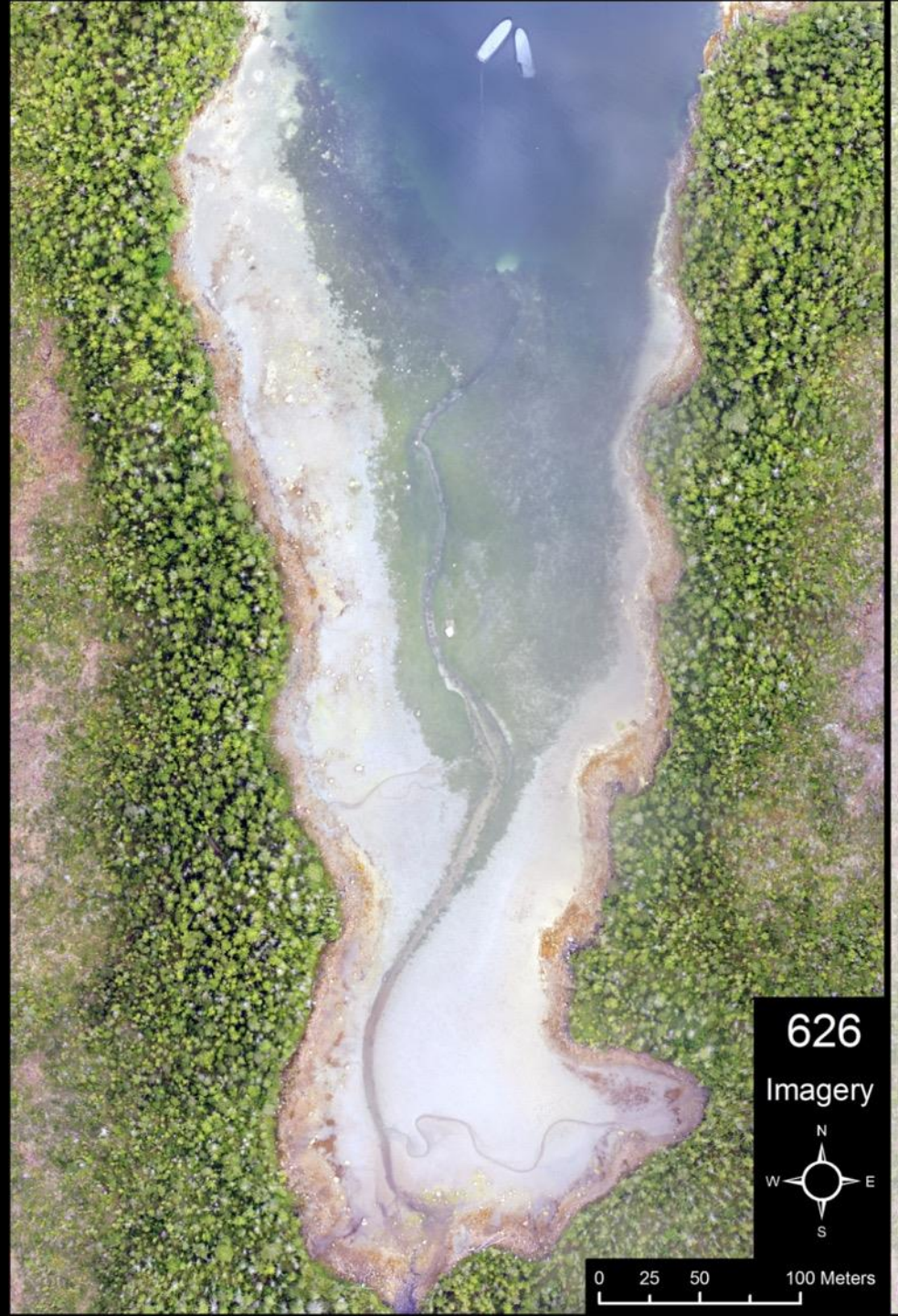
Hakai is responsible for modelling the Central Coast, filling the gap left by previous work.

Hakai is also harmonizing these





Estuaries & Nearshore


626
Imagery
N
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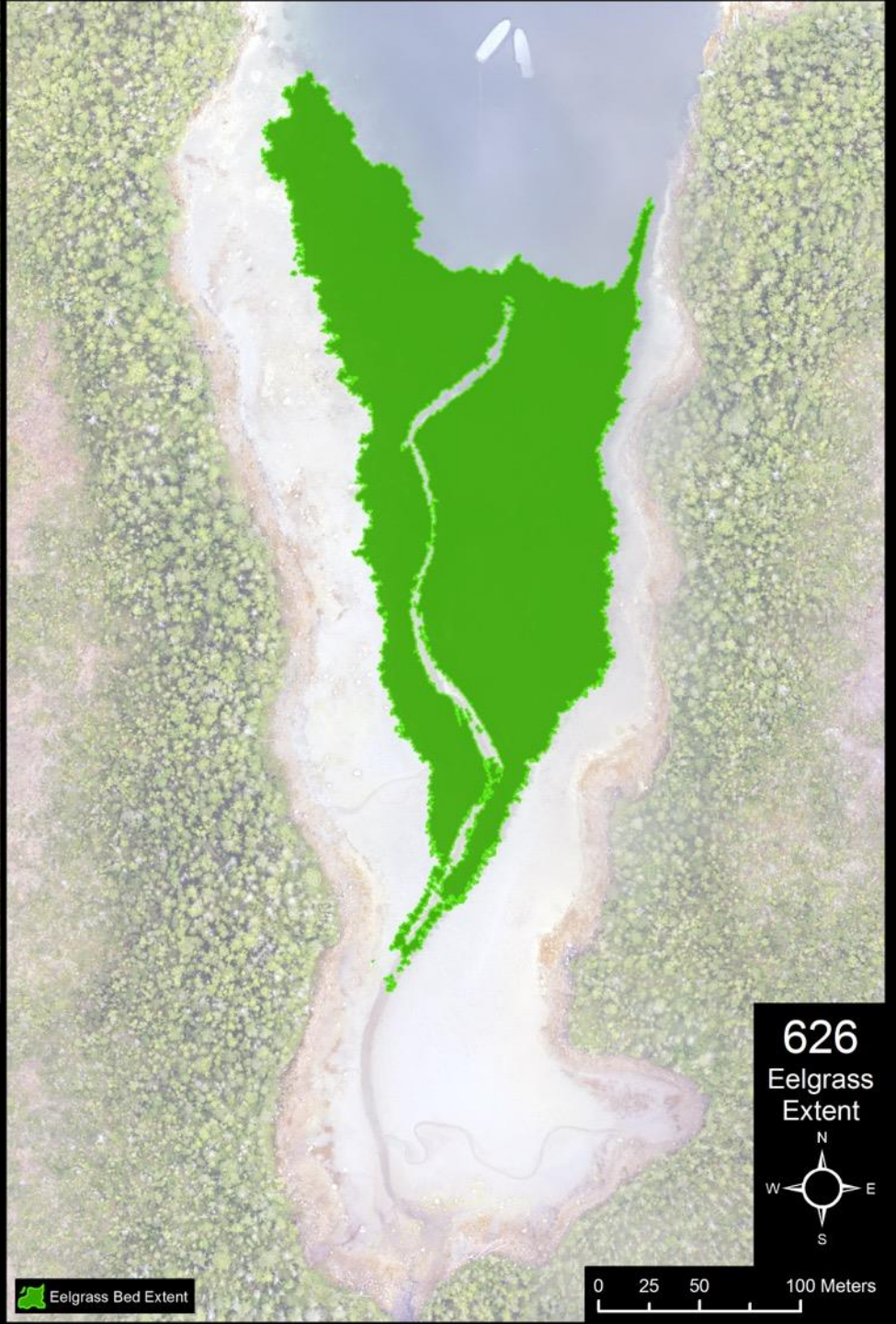
S
0 25 50 100 Meters

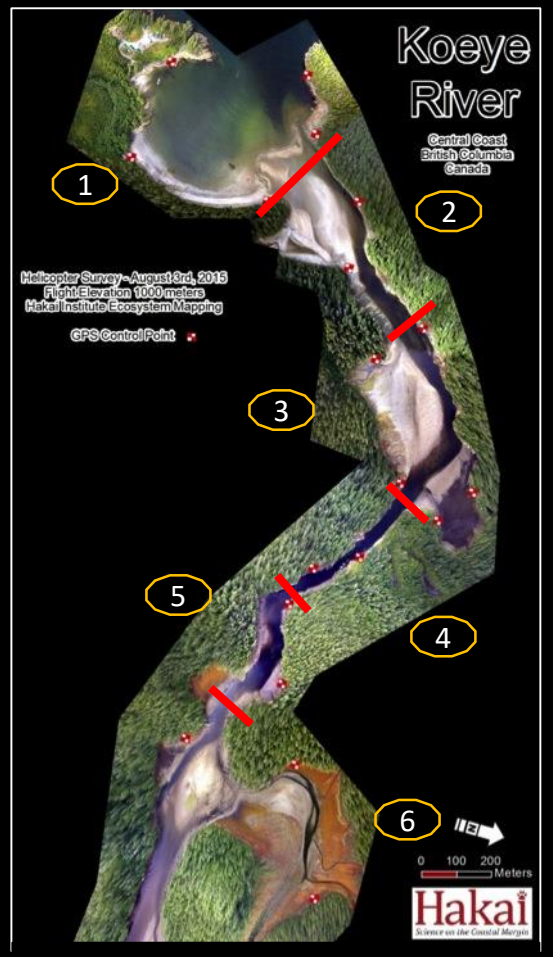

Eelgrass Bed Extent
626
Eelgrass Extent
N
W
E
S
0 25 50 100 Meters

UAV-Derived 2D Model of the Koeye River Estuary

1: Bay (sand)

3: Mud flat/eelgrass

5: Pools (rock/mud)

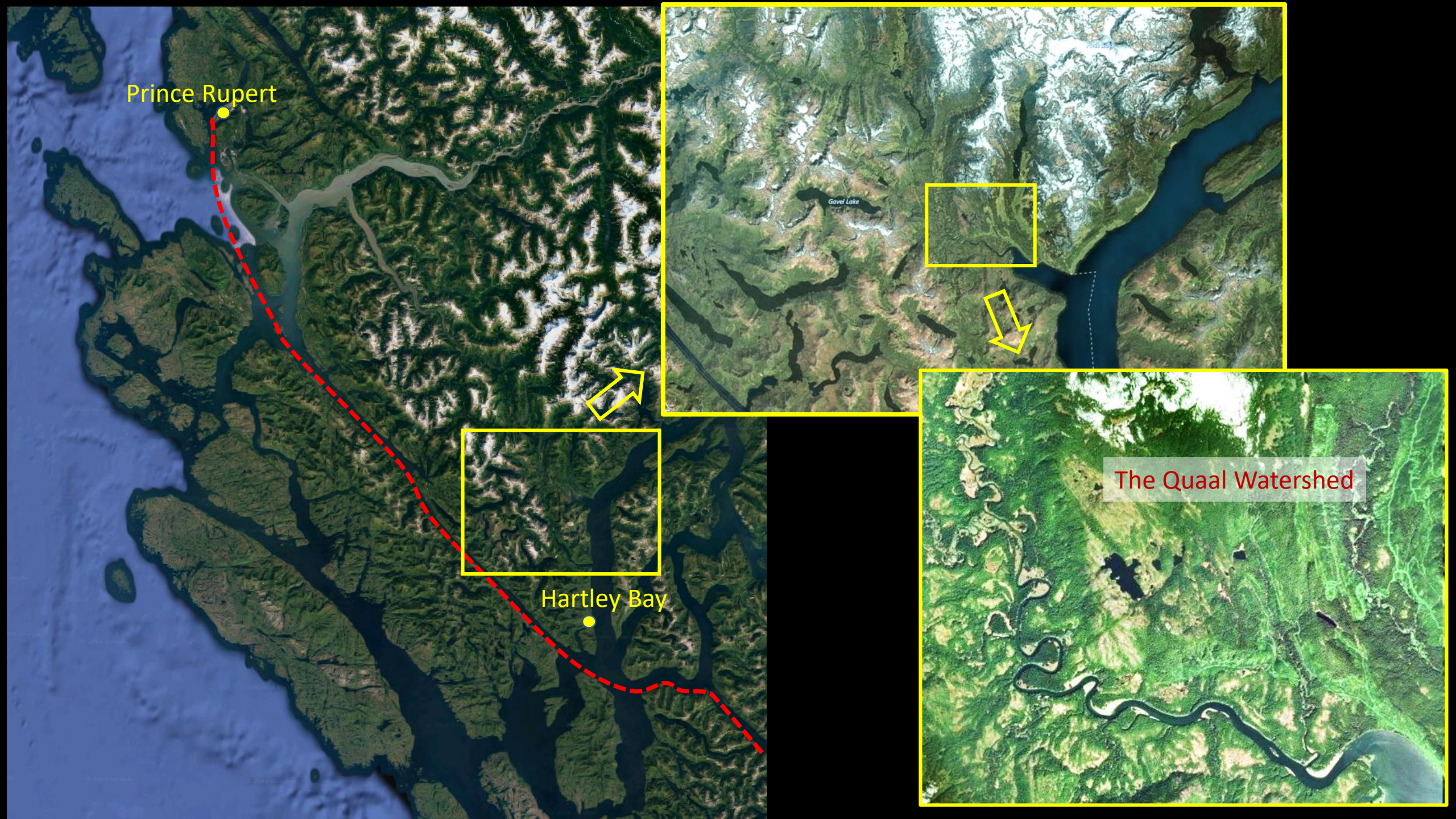


Thanks to the Geospatial and Habitat Mapping team.

2: River mouth (sand)

4: Narrows (rock)

6: Marsh flats

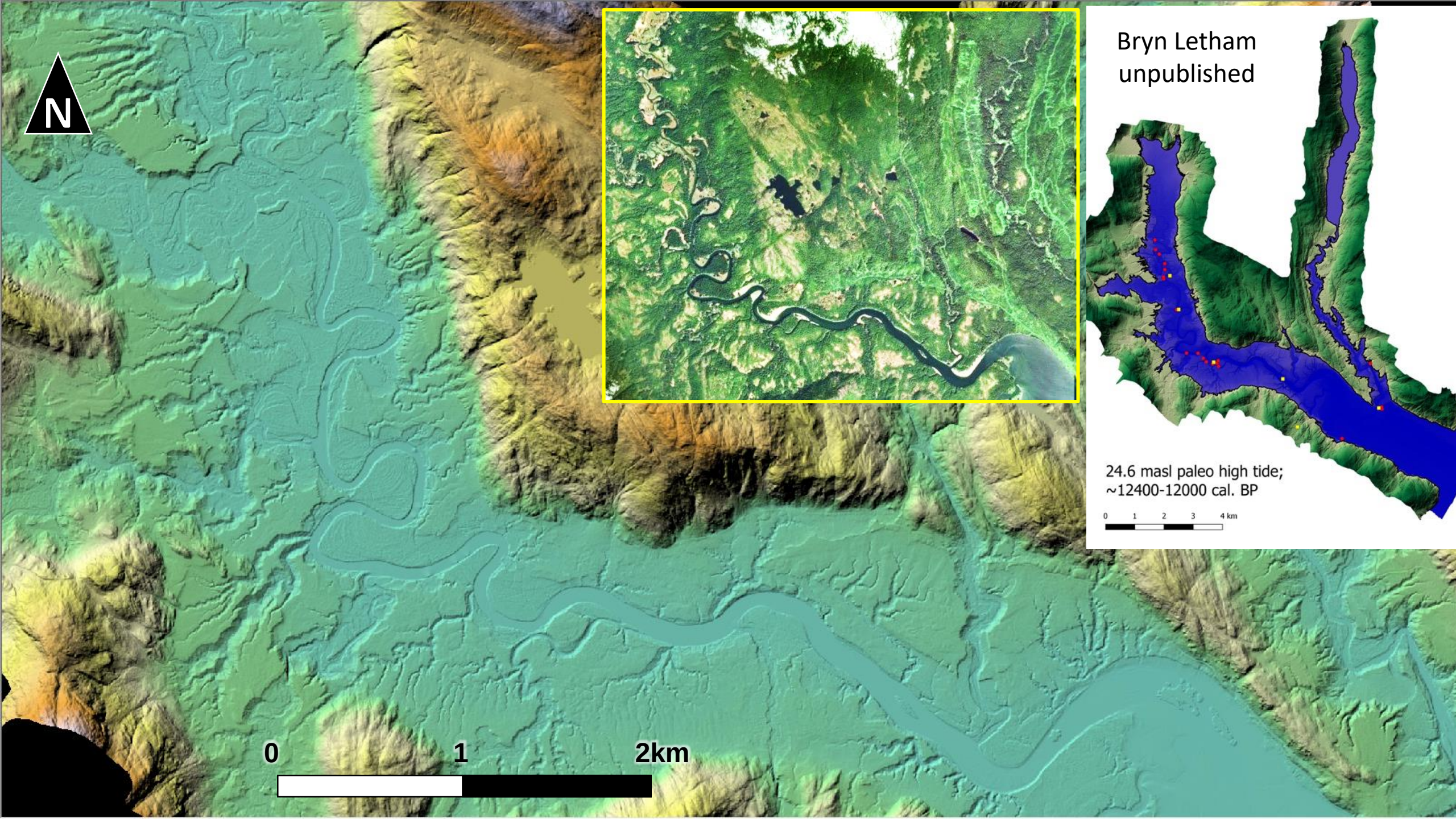

Prince Rupert
Hartley Bay
Gavel Lake
The Quaal Watershed

Bare Earth LiDAR

In support of ecological and archeological research by the Gitga'at First Nation, and Bryn Letham & Dana Lepofsky from Simon Fraser Univ.

N

0 1 2km


N
0
1
2km
Bryn Letham
unpublished
24.6 masl paleo high tide;
~12400-12000 cal. BP
0 1 2 3 4 km

Bathymetry

Ultra-High Resolution Multibeam Echosounder
Reson Seabat T50R and Hakai Blue

- Ideal for shallow water, nearshore surveys
- Seabed mapping and classification
- Integrated INS (Pitch, Roll, Heading)
- Agile Frequency = improved swath performance
  - (190 – 420 kHz)
  - Lower freq. = greater depth, lower resolution
  - Higher freq. = shallow depth, high resolution

	200 kHz	400 kHz
Typical Depth (m)	0.5 - 375 m	0.5 - 150 m
Max Depth	550 m	250 m

Bathymetry of Lake 892 (H5)
Watershed 693, Calvert Island, B.C

Hakai
Science on the Coastal Margin

128°0'0"W

51°38'30"N

Legend

Survey Benchmark

1m depth contours

Full Lake Surface Area (m^2)	101,535
Full Lake Maximum Depth (m)	35.13
Full Lake Average Depth (m)	12.14
Full Lake Volume (m^3)	**1,232,831**

Lake bathymetry was surveyed on June 1 and 11 2016 using a canoe-mounted, location-aware depth sounder and by taking random manual depth measurements. All depth recordings are referenced to a survey benchmark and have been processed and checked in a 3D GIS environment. Lake bathymetry has been modeled by means of 1m Natural Neighbours raster generated from a Triangulated Irregular Network (TIN) using survey data. The high water mark is used as reference for full lake volume calculations. The lake outline has been manually digitized from a high resolution orthophoto.

For further information contact data@hakai.org or visit Hakai's metadata repository.

Map projection: UTM Zone 9 Datum: NAD83
Lake IDs are internal to Hakai Research Institute; the 3 character ID number corresponds to the BC Waterbody Identifier.

N

0 25 50 100 150 200 250 Meters

Hakai

Science on the Coastal Margin