

UAV Remote Sensing for Climate and Environmental Research

Stian Solbø, Norut

Norut — Northern Research Institute

- A national institute for applied research and commercializing
- 120 employees
- Special competence on the High North
- Close collaboration with University of Tromsø and Narvik University College



Main Research

Themes

Technology

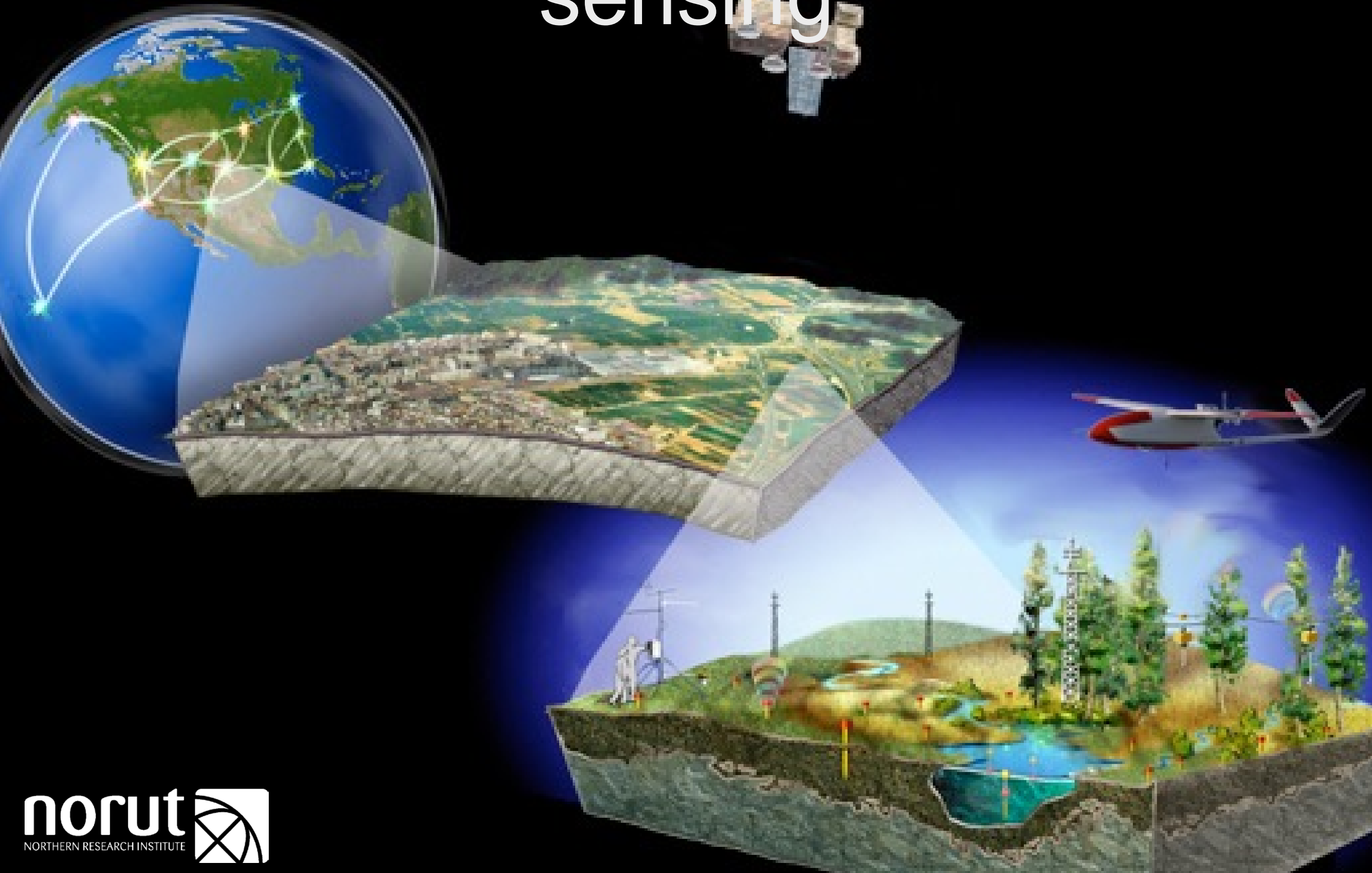
- Biotechnology
- Earth observation
- Renewable energy
- Cold climate technology
- Environmental and process technology
- ICT

Social science

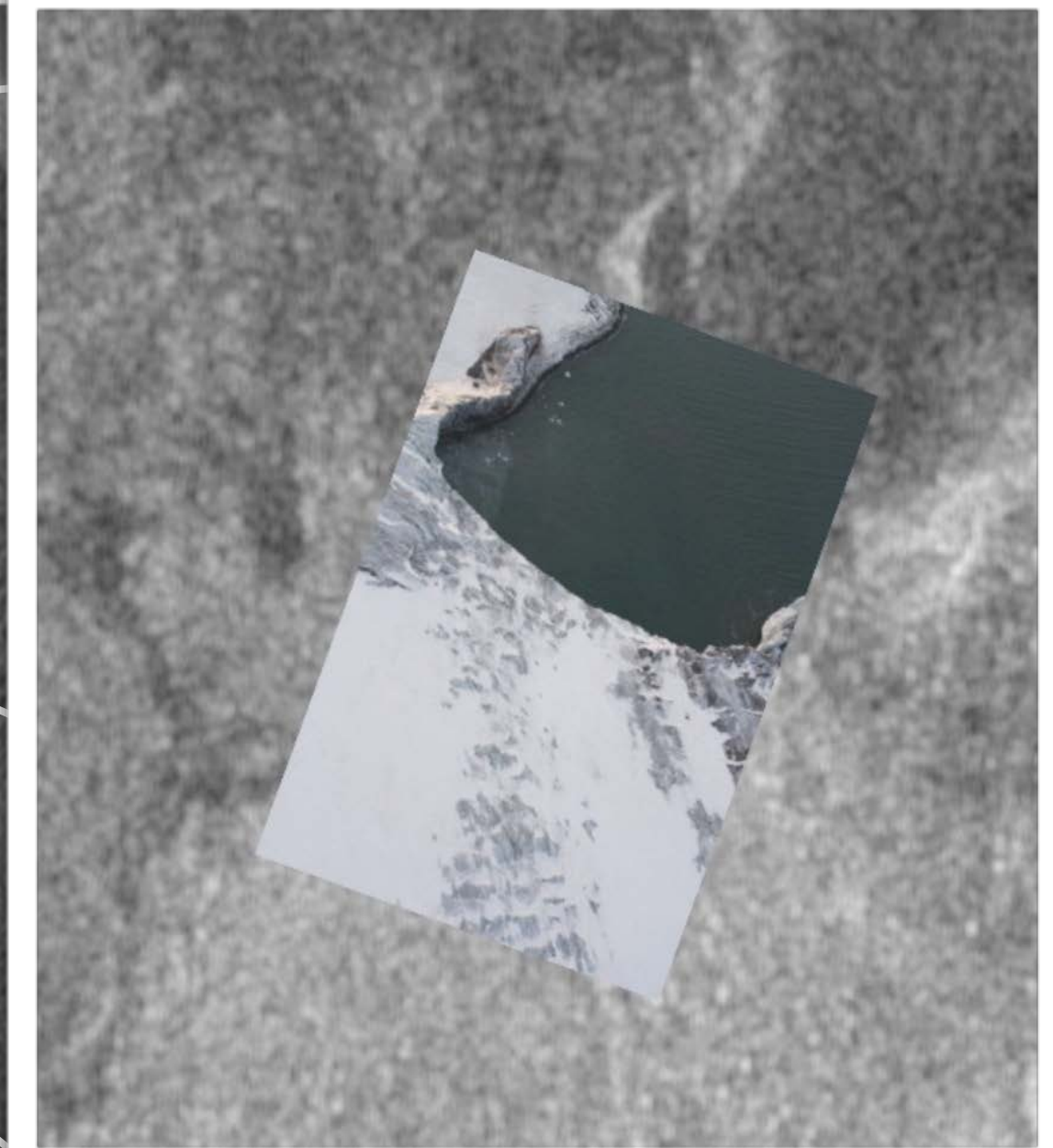
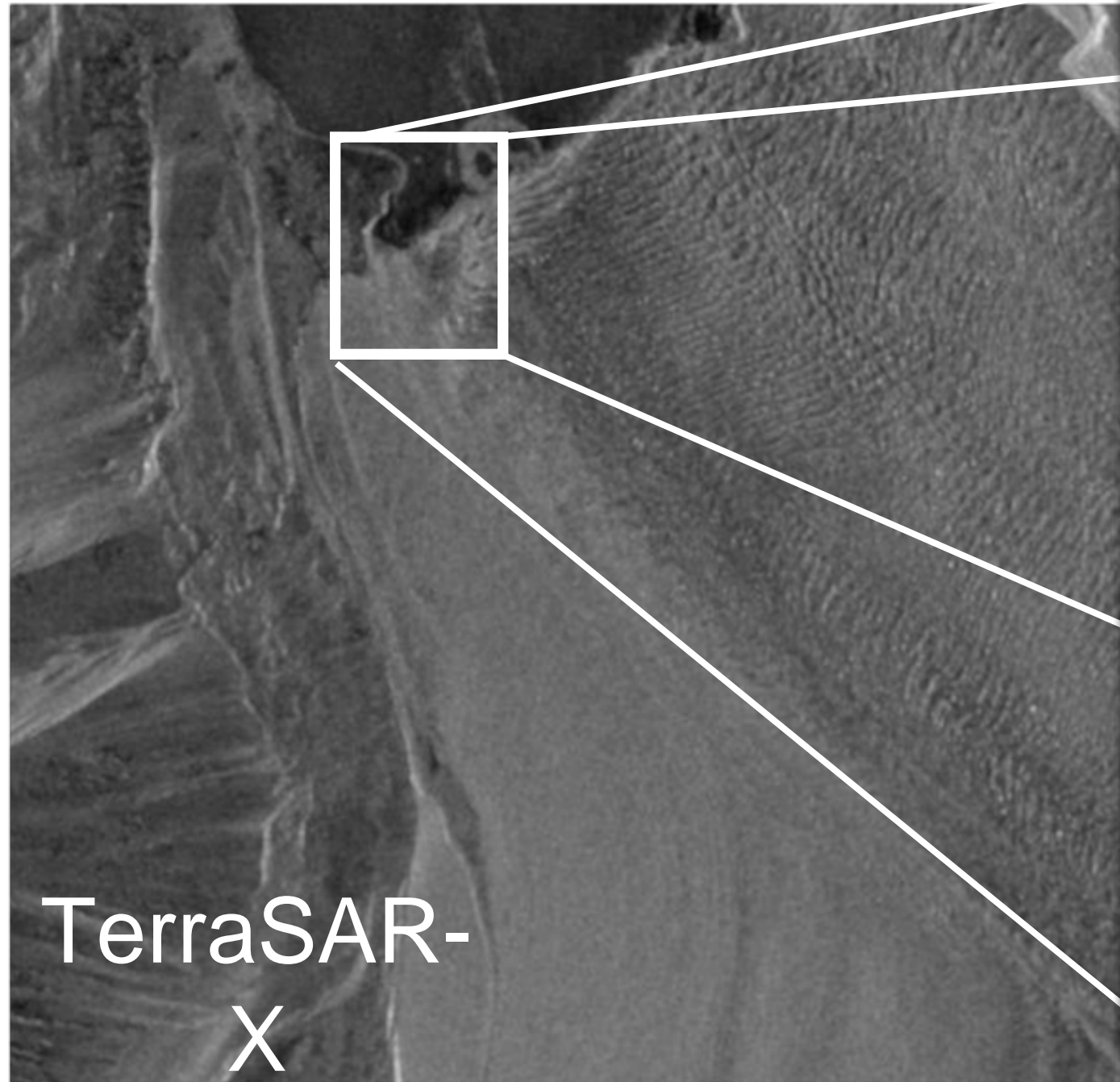
- The High North
- Industry and innovation
- Politics and society
- Regional development and territorial studies
- Technology and society



Satellite vs UAS remote sensing



Bridging the gap between satellite and in situ measurements



Some UAS Systems Previously Used in the Arctic

Global Hawk, NASA



ScanEagle, UAF



SUMO, Univ. of Bergen



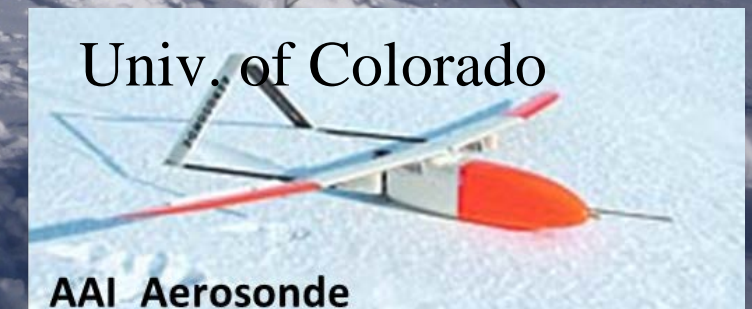
Cryowing, Norut



Cryowing Micro, Norut



Univ. of Colorado



Manta, NOAA



Eleron-10, AARI



Sierra, NASA



Noruts CryoWing UAS Fleet

CryoWing Micro (2012)
MTOW: 2-3 kg
Wingspan: 1,2 m
Range: 100 km
Telemetry: UHF
Payload Capacity: 0.8 kg
Fuel: Li-Pol Battery

CryoWing Mk 1 (2007)
MTOW: 32 kg
Wingspan: 3.8 m
Range: 400/800 km
Telemetry:
3G/GSM Iridium, UHF
Payload Capacity: 10 kg
Fuel Capacity: 4.5 kg petrol

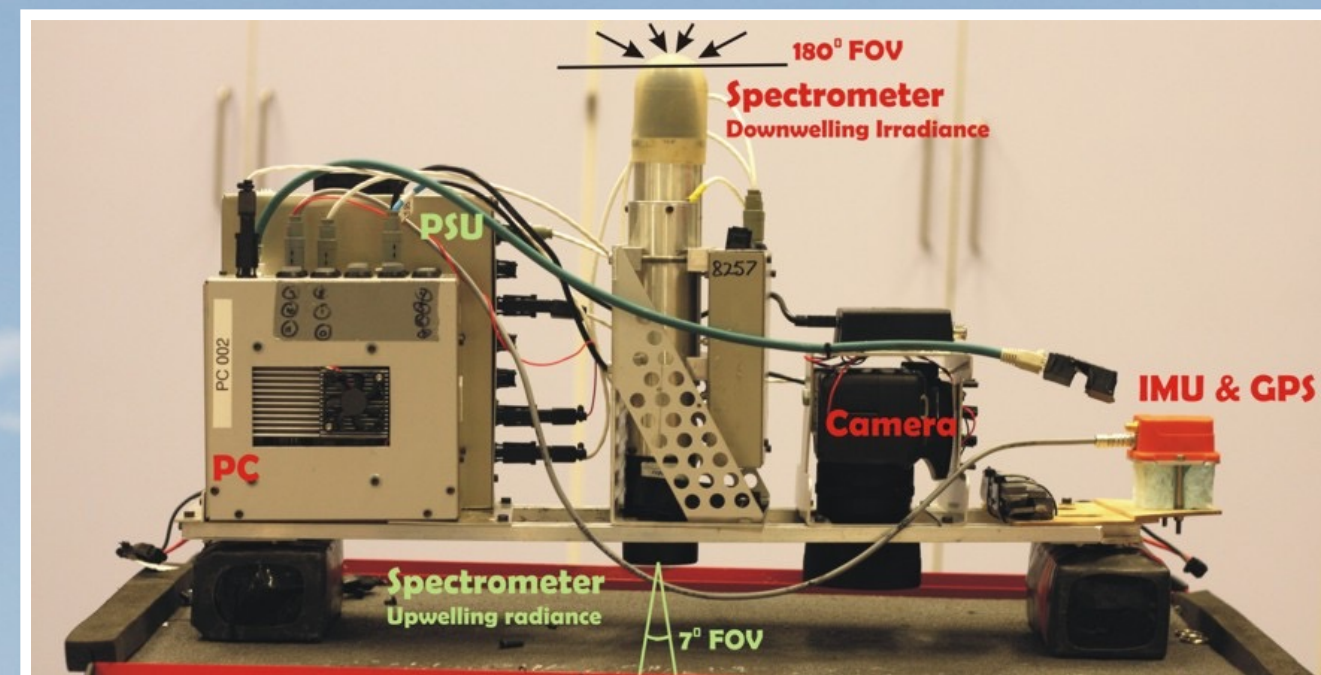
CryoWing Mk 2 (2012)
MTOW: 60 kg
Vingspenn : 5.2 m
Range: 1600 km
Telemetry:
3G/GSM, Iridium, UHF
Payload Capacity: 15 kg
Fuel Capacity: 15 kg petrol

CryoCopter (2013)
MTOW: 6-7 kg
Range: 2 km
Telemetry: UHF and C-Band
Payload Capacity: 3 kg
Fuel : Li-Pol Battery



Norut UAS Instrumentation

- Existing (owned by Norut):
 - Imaging spectrometer 256 channels 400-700nm wavelength(Fred Sigernes, UNIS)
 - Digitalcamera 18 MPX
 - IR Cameras FLIR Tau 320x240 and ICI-7640 640x480
 - C-band radar sounder (FFI)
 - Meteorological instr. package (temp, hum, press, wind)
 - Laser distance measurements
 - 2 antenna GPS for precision position and attitude measurements
 - Compass and IMU
 - IR-probe, SST
 - Turbulent flux sensor (Univ. Braunschweig)
 - Trios Spectrometer hyperspektral reflectance and albedo measurements
 - 2D Hyperspectral imager (Rikola)
- Planned and possible future sensors
 - Ku-band SAR (FFI, funded in work)
 - Drop Sonde
 - Methane sensor (Cryptophane based)
 - AEM (Airborne EM induction) sensor
 - UWB GPR (FFI HUBRA)



Earth Observation UAS vs. Satellite

Strengths:

- Selectable flight path
- Very high resolution
- Allow for rapid revisit rates
- Can fly below clouds
- Can do in-situ measurements
- Not limited to EM based sensors
- Low cost

Weaknesses:

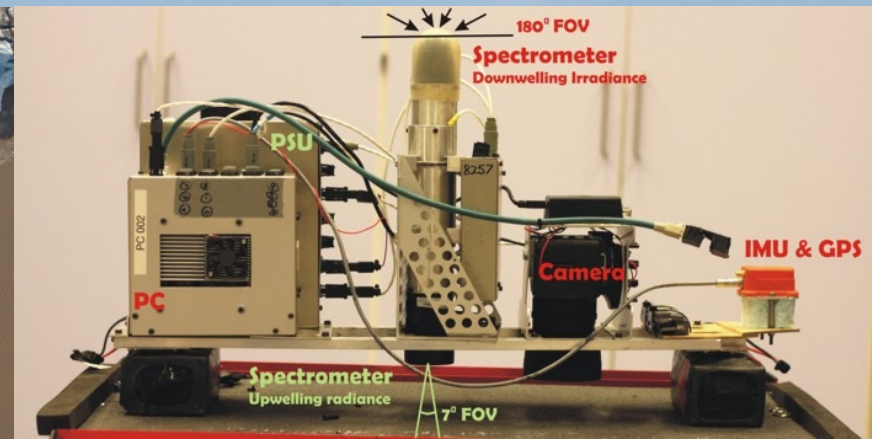
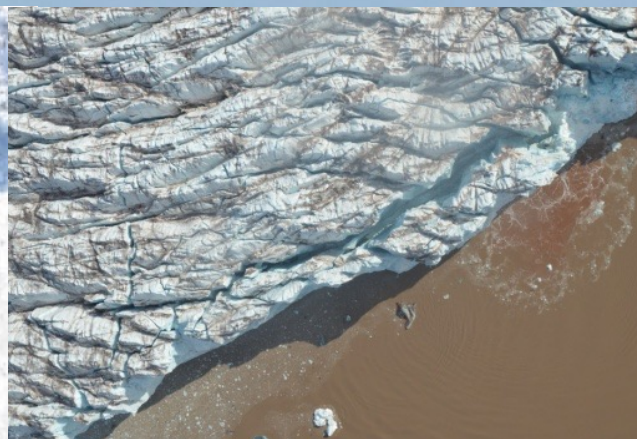
- Spatial coverage
- Repeatability
- Endurance
- Long time series 24/7/365



Key Arctic Science Topics

Where UAS could play a future vital role

- **Arctic lower atmosphere - boundary layer system; Dynamical and radiation feedback systems**
Aerosols and BC, clouds, surface energy fluxes, meteorology
- **Oceanic and sea-ice processes**
Ice fraction, ice thickness, ice albedo, melt pond fractions, ice mechanics, ice classification, snow on ice, ocean winds and waves.
- **Marine transport of energy, nutrients and pollution**
Ocean color (chlorophyll-A, algae), surface temperature and currents
- **Glacier and ice cap mass balance and dynamics**
Mass balance, glacier dynamics and facies characterization
- **Greenhouse gas processes and feedbacks in the Arctic climate system**
Measurements of methane, ozone, CO₂, N₂O and other trace gases
- **Arctic ecosystem resilience to climate variability and change**
Vegetation mapping, phenology and population estimation



Other Key "Arctic" Topics

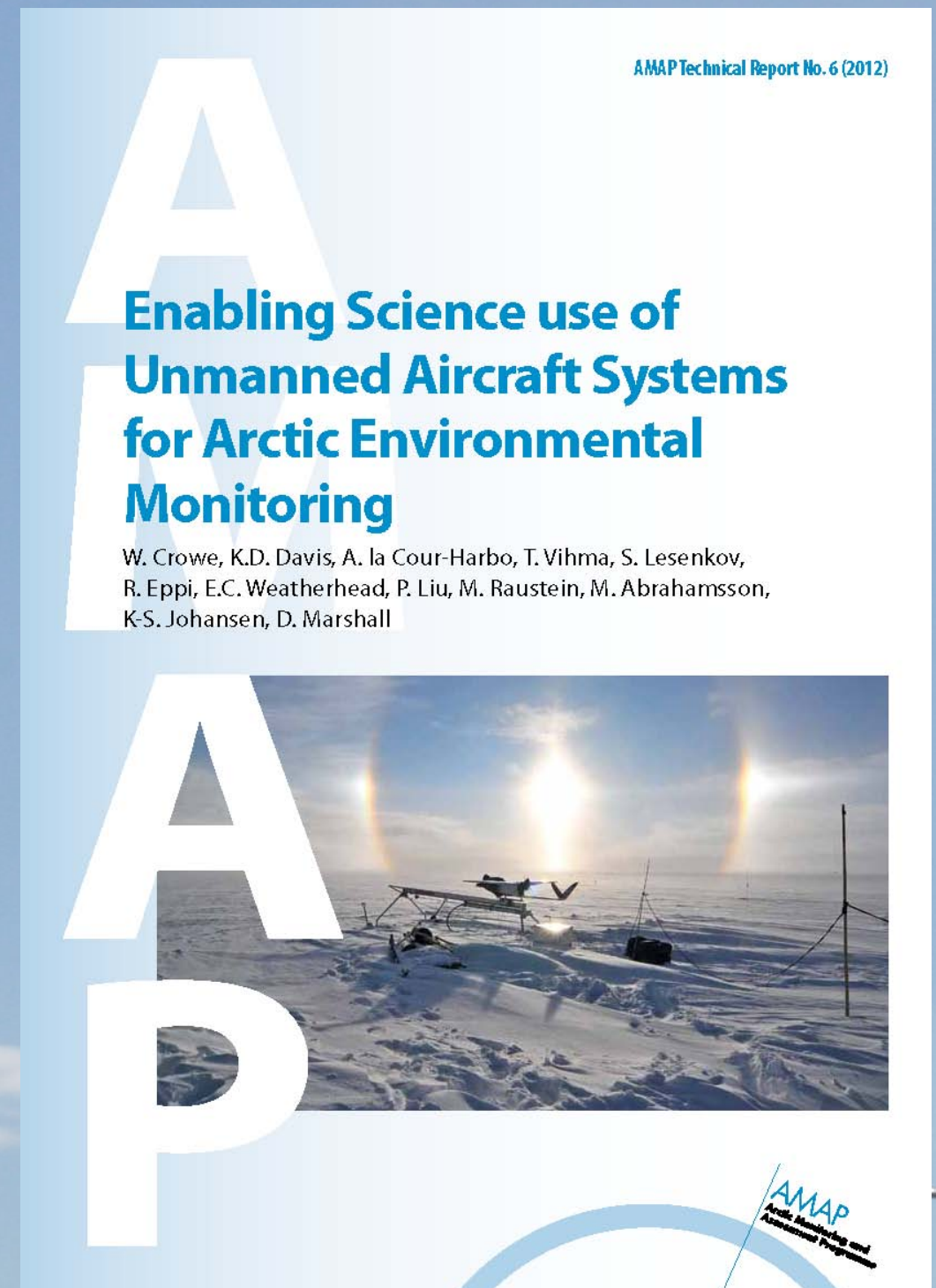
Where UAS will play a future vital role

- ***Search and Rescue***
Search part, MOB, Mountain Rescue, ship accidents.
- ***Operational Support Oil and Gas Industry***
Sea-ice surveillance
Ice-berg detection and tracking
Marine mammal detection
- ***Operational Support Maritime Industry***
Sea-ice properties, pirates, SAR
- ***Emergency Preparedness and Response***
Oil spill detection, distribution and tracking
Volcanic ash concentration
Plume monitoring industrial accidents (Nuclear, chemical)
- ***Resource management***
Marine mammal population estimation (seals, whales, polar bears)
Reindeer management (population management, food access)
- ***Renewable energy support***
Hydroelectric power
Wind power



Science data gaps filled by UAS and associated challenges

Electronic copy at
www.amap.no



Glacier and ice cap mapping

UAS measurements of Kongsvegen/Kronebreen August 2014

Image © 2014 DigitalGlobe

Google earth

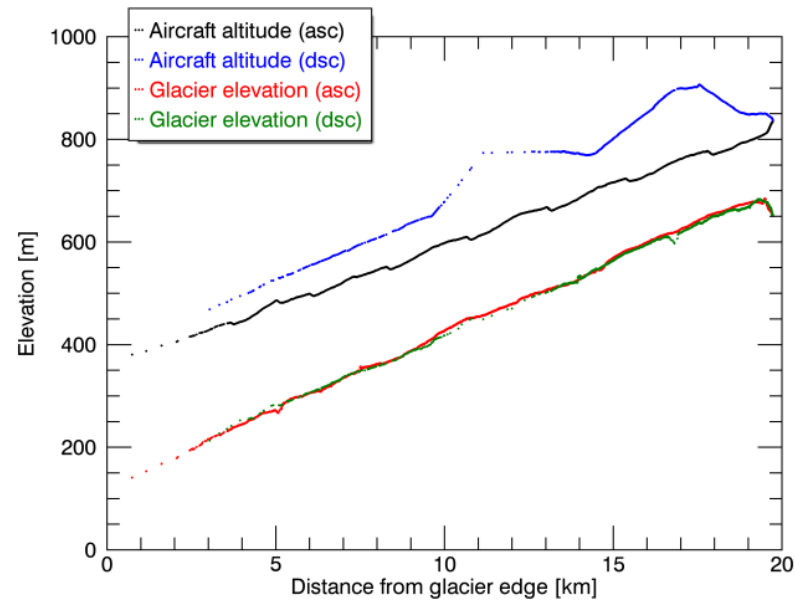
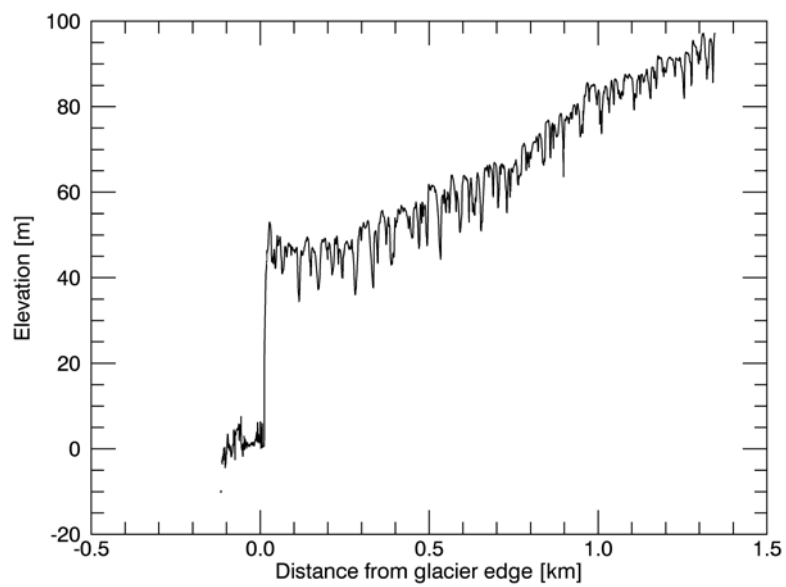
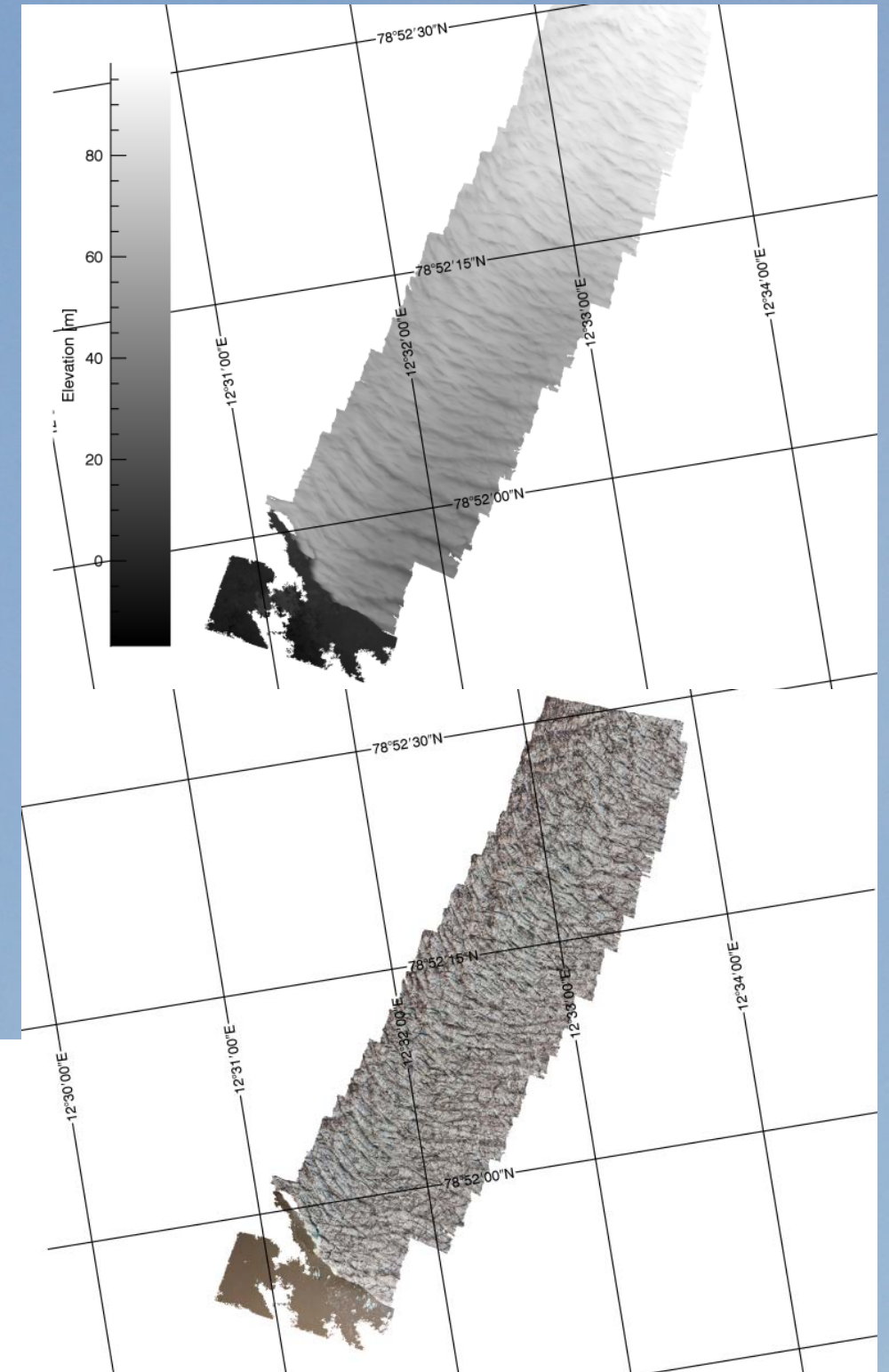
2009

78°51'50.77" N 12°36'49.14" E elev 183 m eye alt 4.97 km

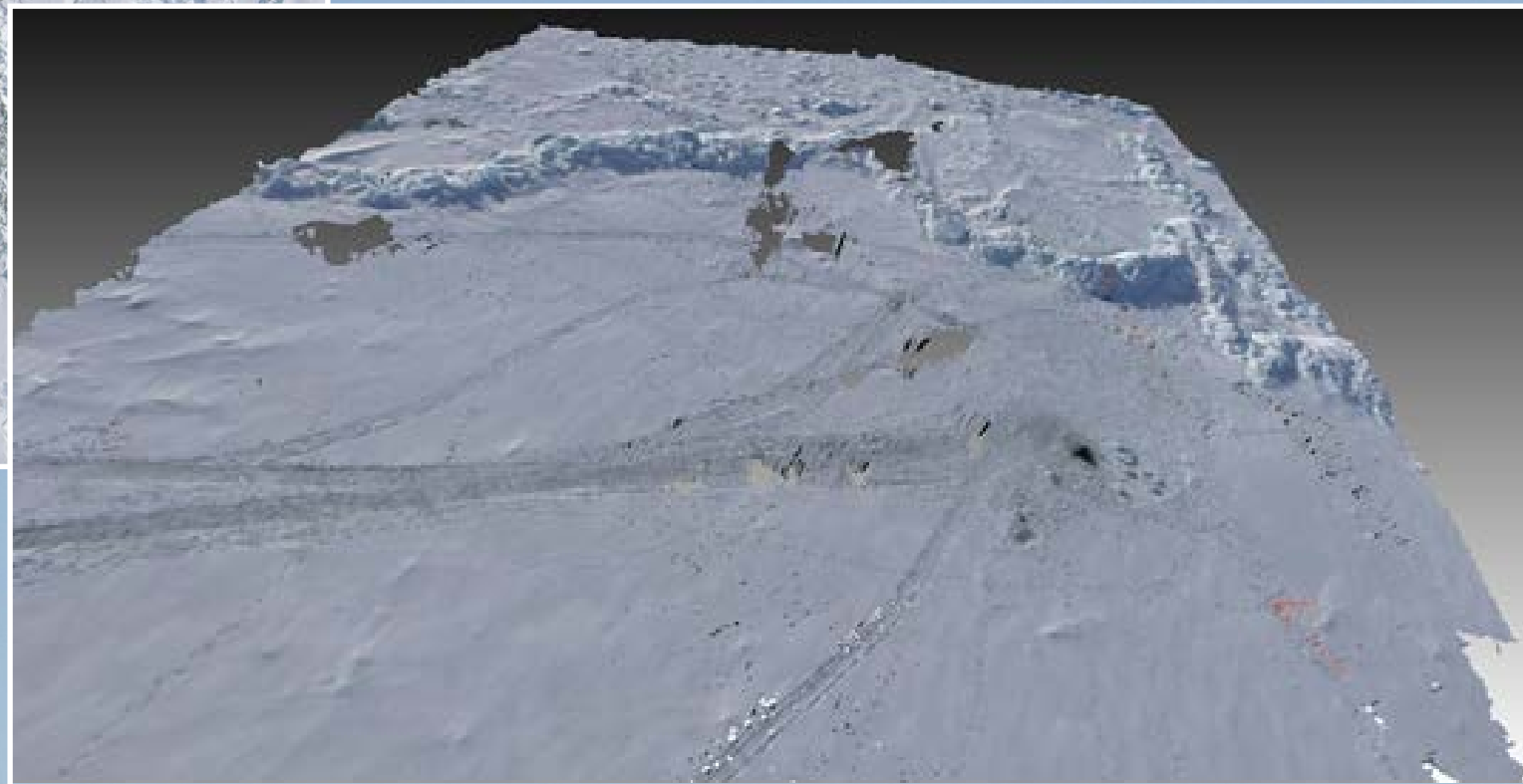
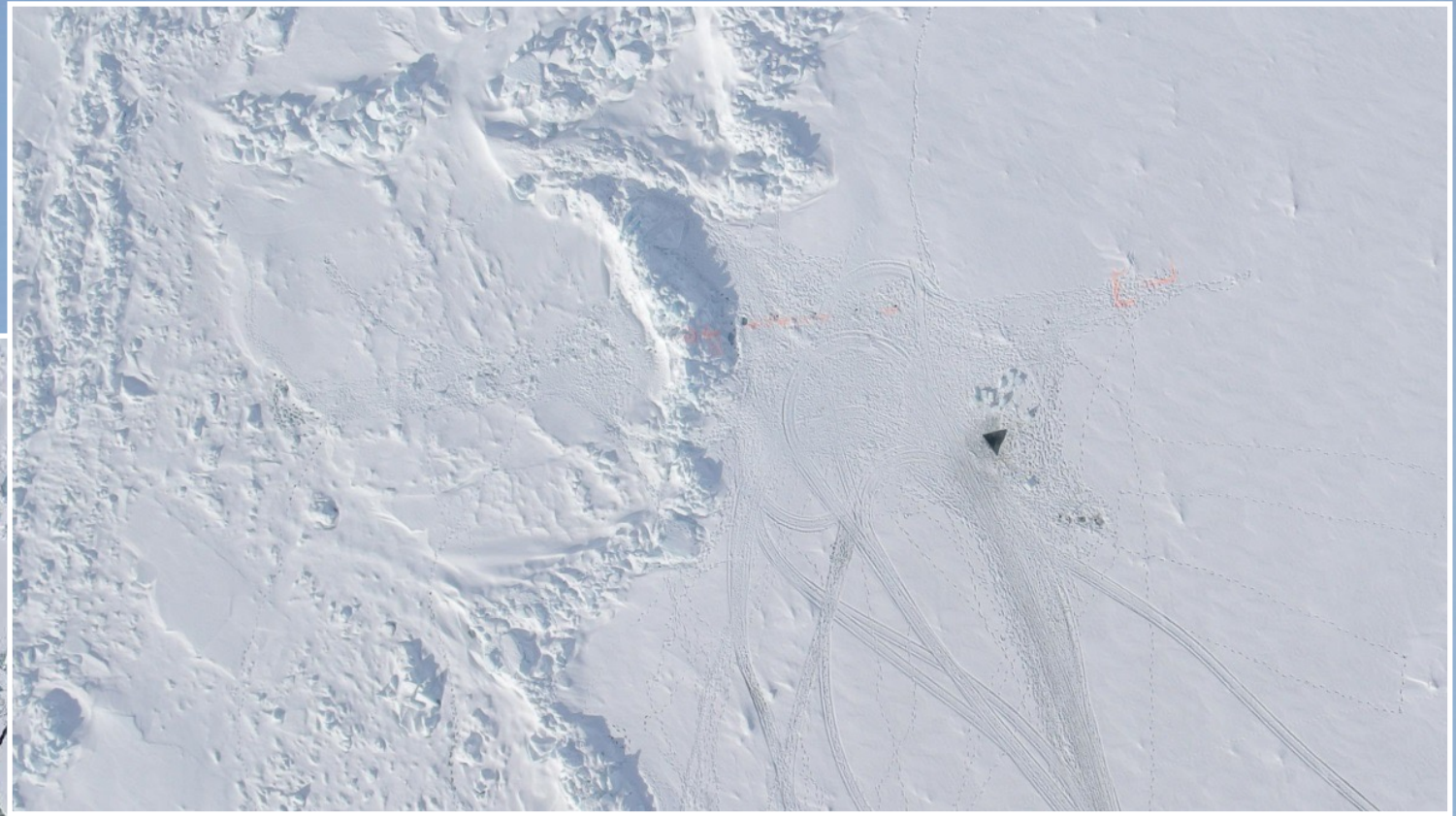
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Glaciology

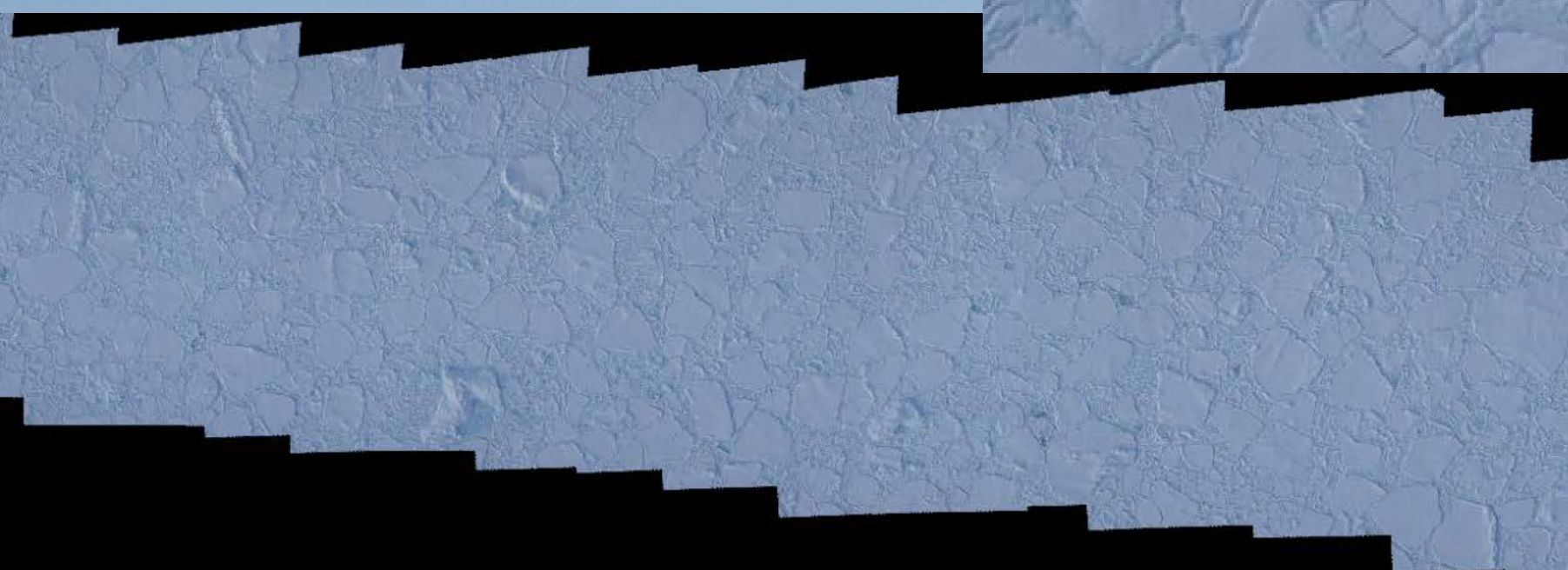
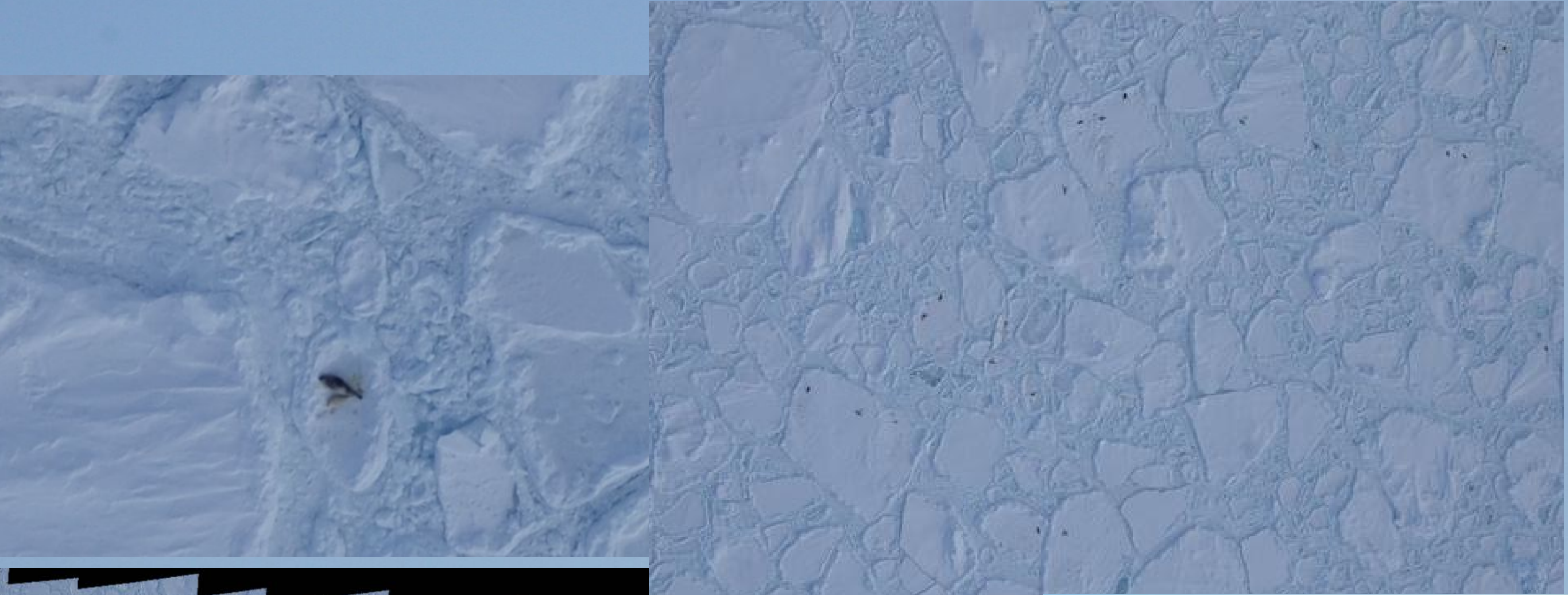
Kronebreen and Kongsvegen Glaciers



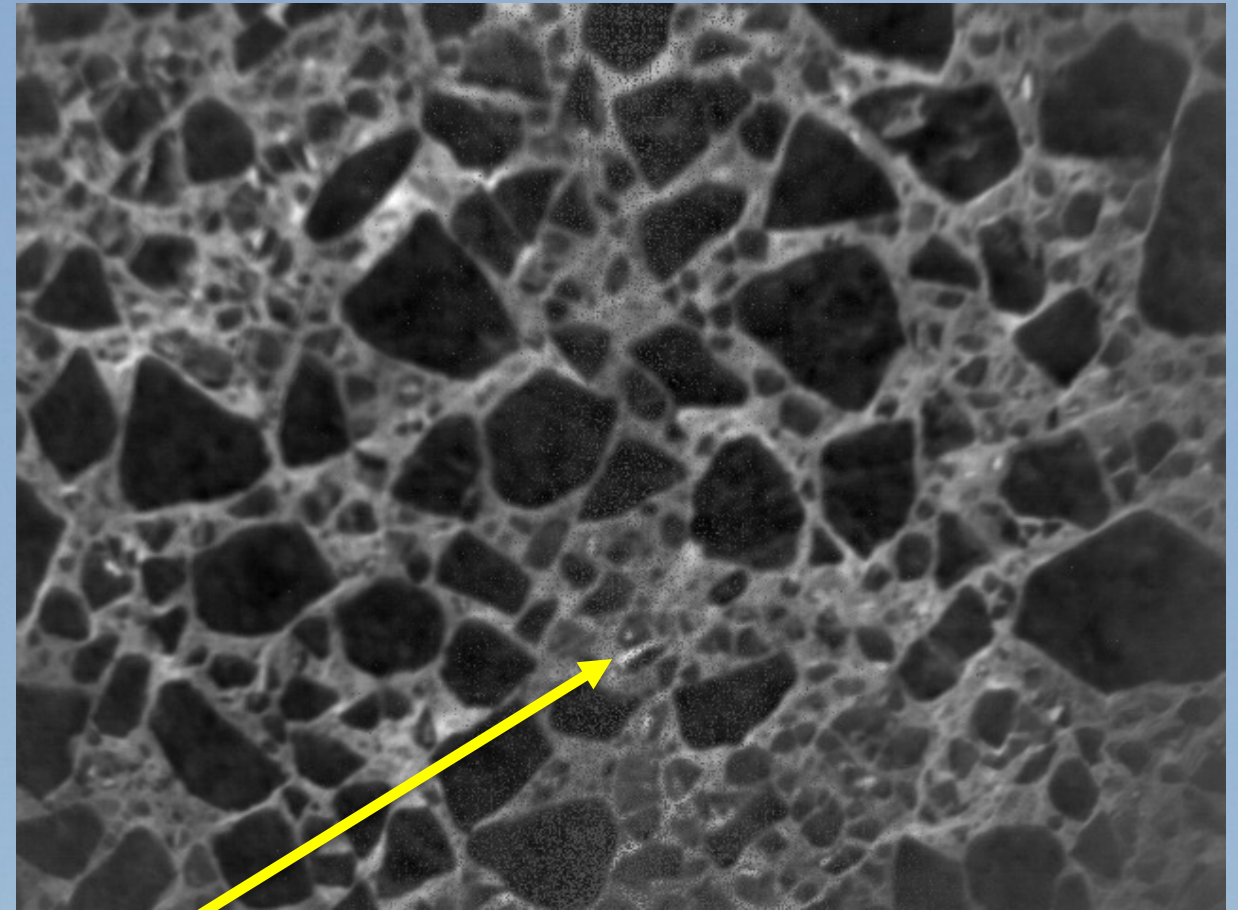
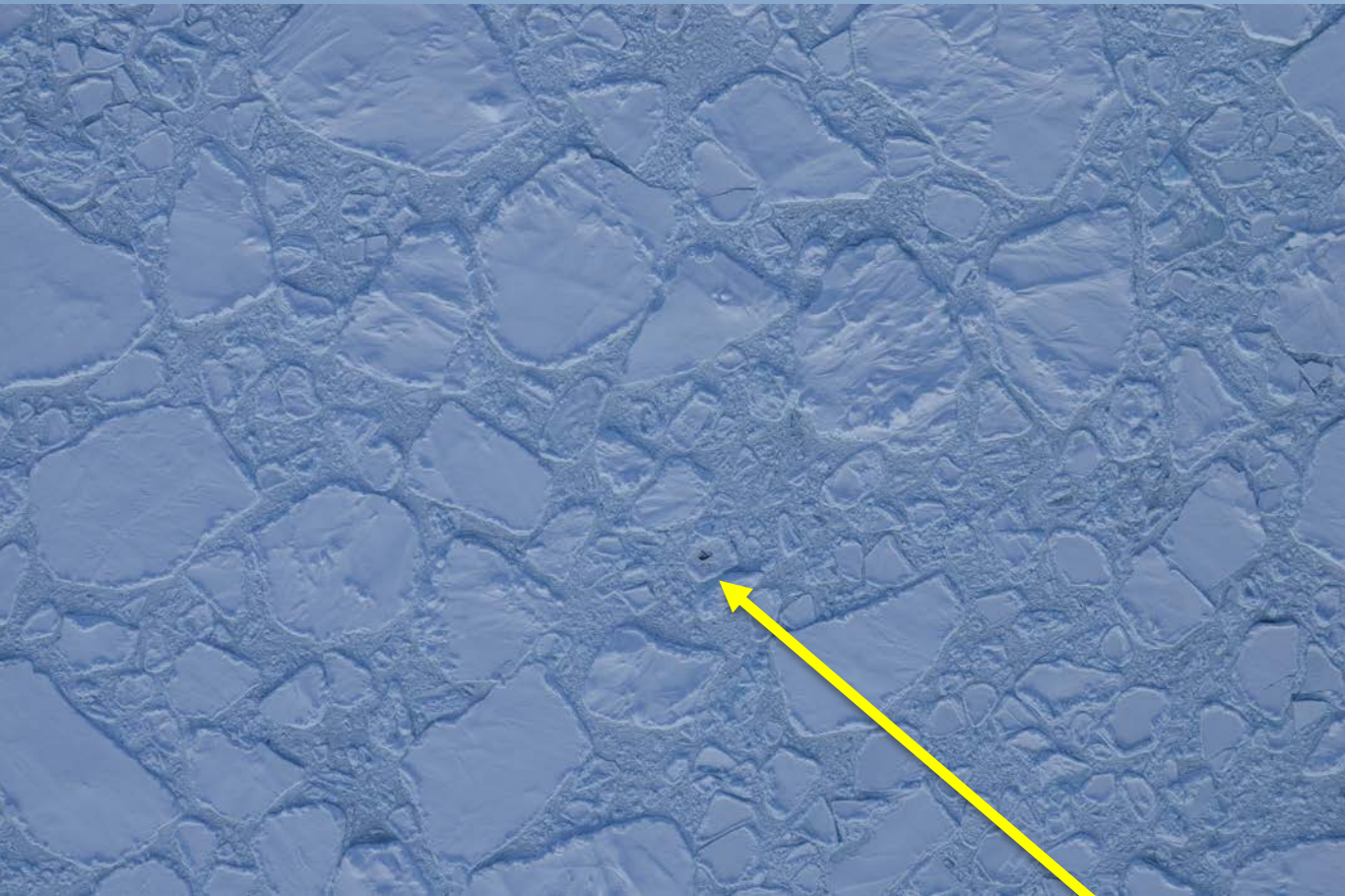
KV Svalbard April-May 2013



Counting Seals



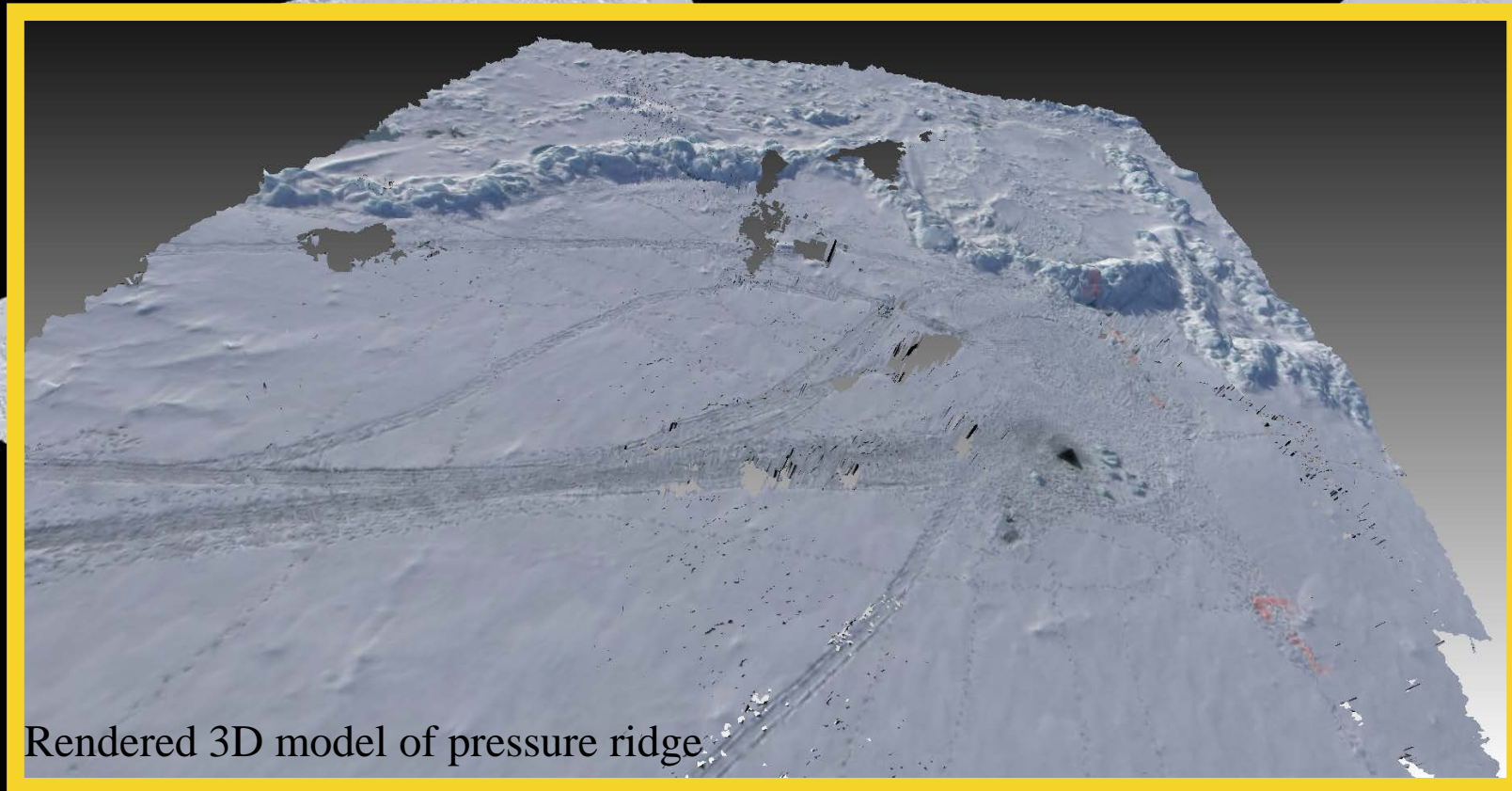
Simultaneous visible and IR



Seal on ice floe



Sea ice mapping



Rendered 3D model of pressure ridge

Marine Mammals

Marine Mammals

Seismic and sonar activities might impact whales and seals

- *Monitoring for whales is required*
- *Impact poorly understood, huge differences in requirements*
- *Behavioral studies needed*

Measurements

- *Detection (IR and visible imagery)*
- *Identification, size estimation*



Marine Mammals





Currently a Norut team is counting penguins in Antarctica!



Cultural heritage mapping

Ny-London Svalbard, mapped July
2014

Cultural heritage mapping

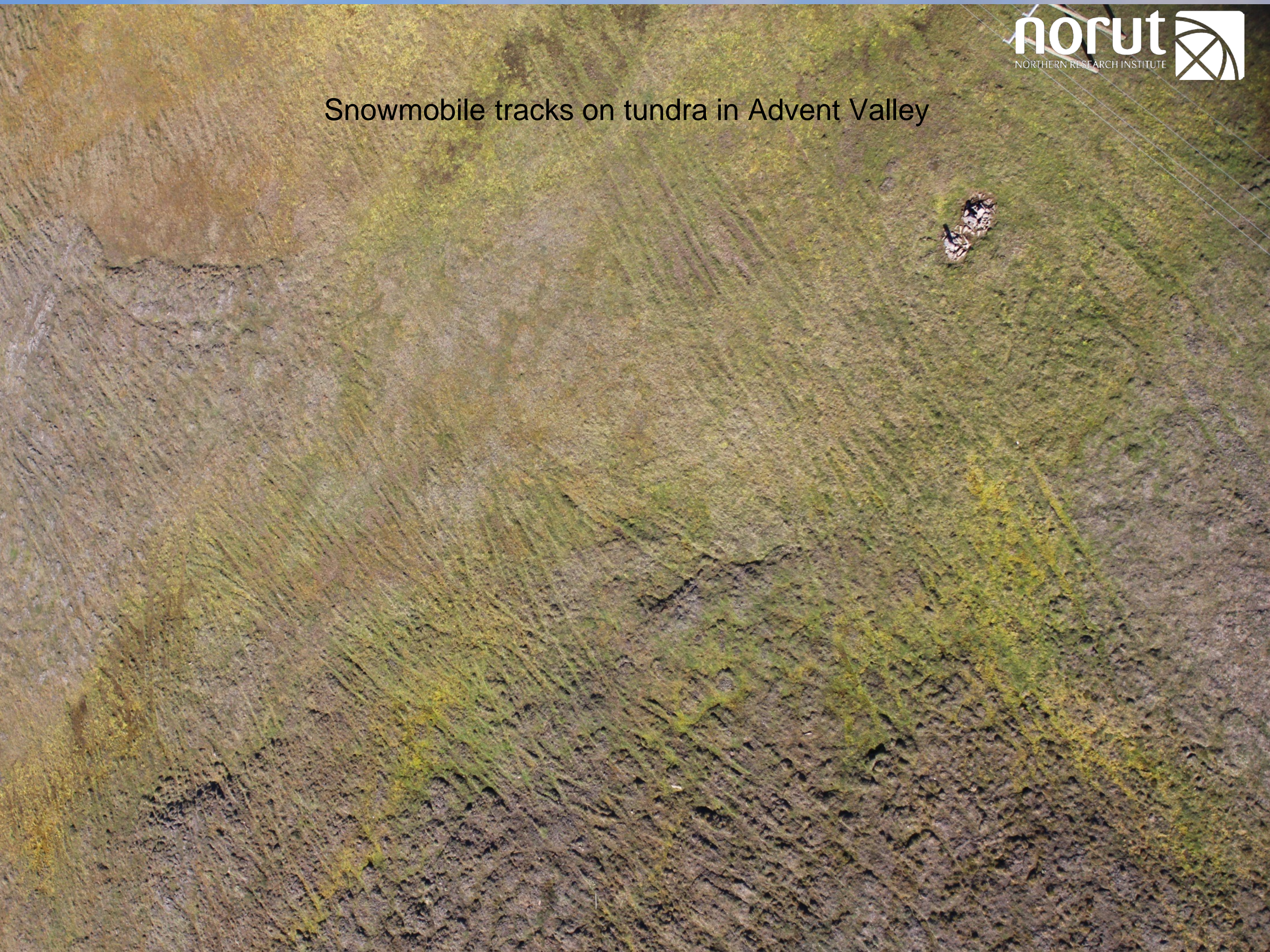
Old steam engine



Mapping vegetation stress due to ATV traffic. Breivikeidet



Snowmobile tracks on tundra in Advent Valley



Vegetation Mapping and Scaling

Svalbard Science forum project 2013/14

Low impact measurements for mapping of vegetation, biomass and phenology

Sensors:

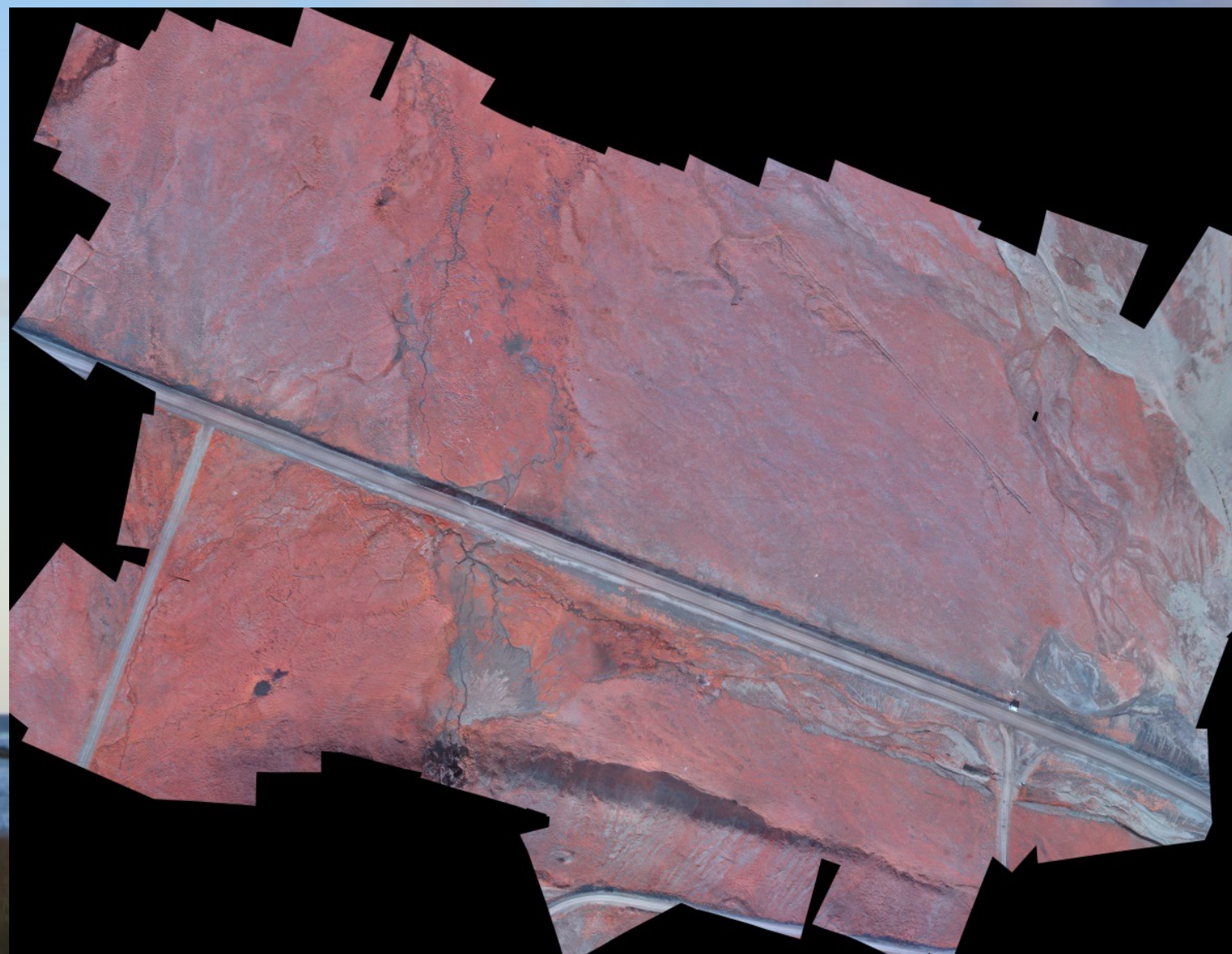
Camera, Visible and NDVI

Challenges:

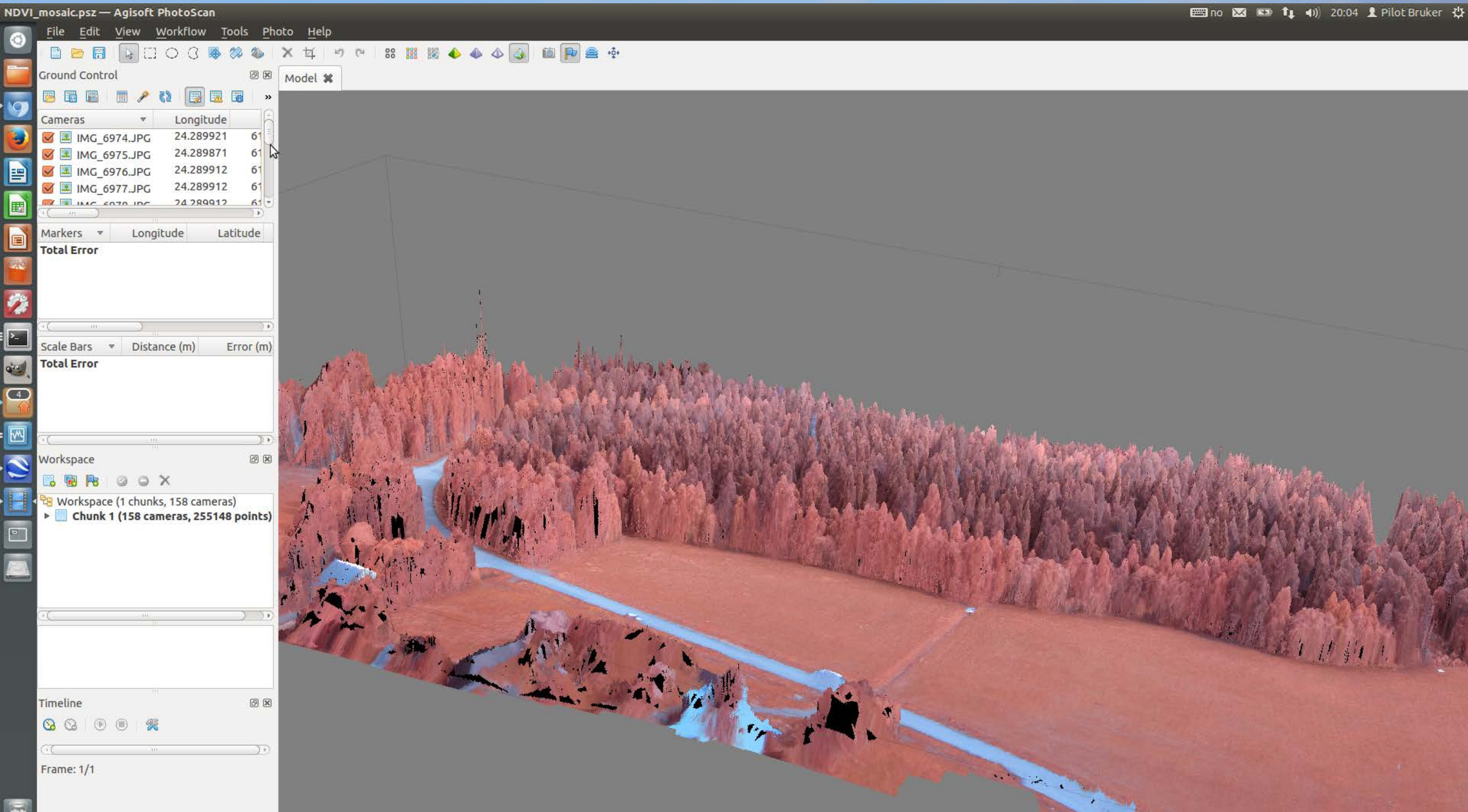
Very high resolution may be required for some applications.

Absolute reflectance measurements are challenging due to high attitude dependency and BRDF effects

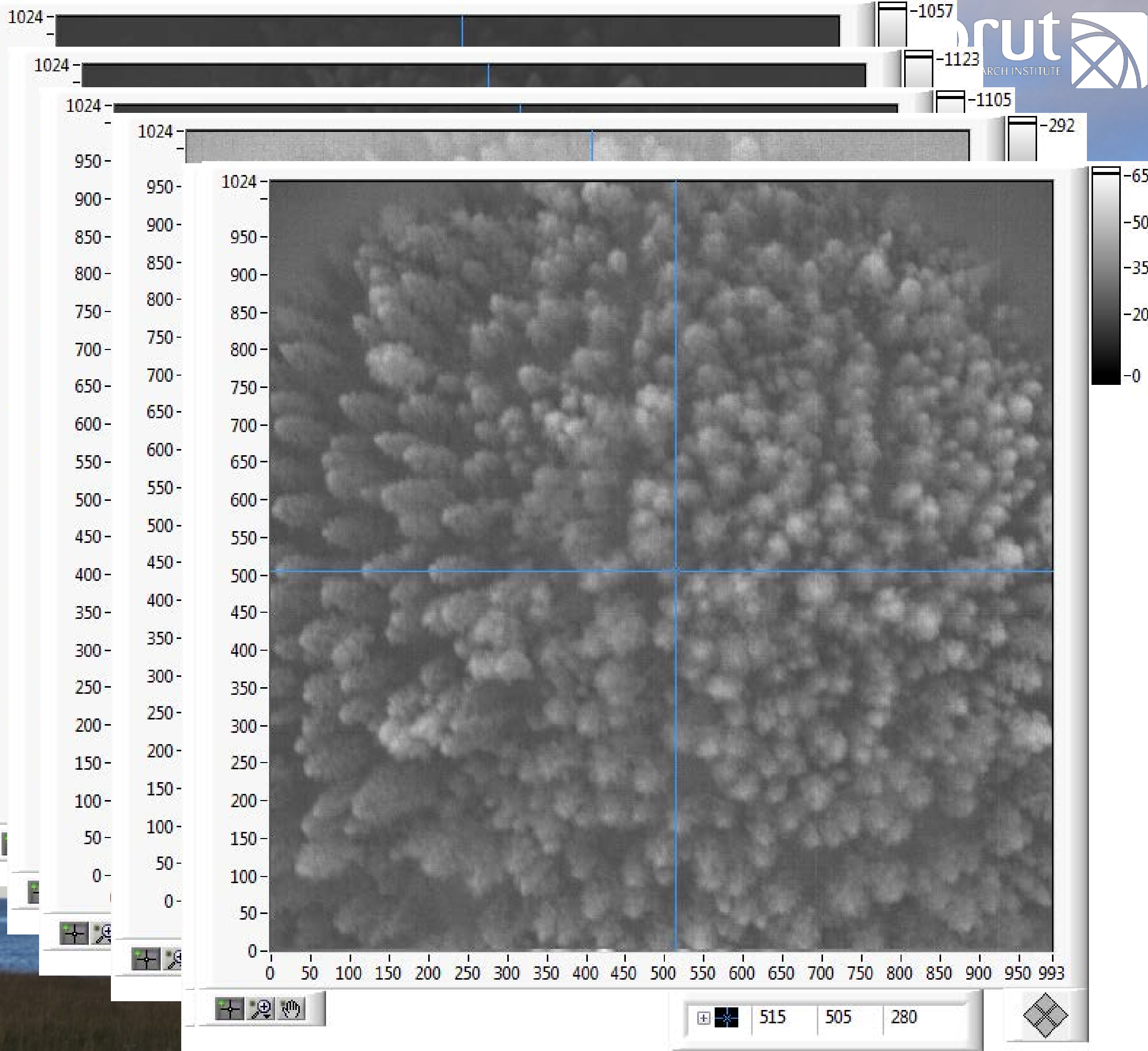
NDVI mosaic Adventdalen



3D processing of NDVI data



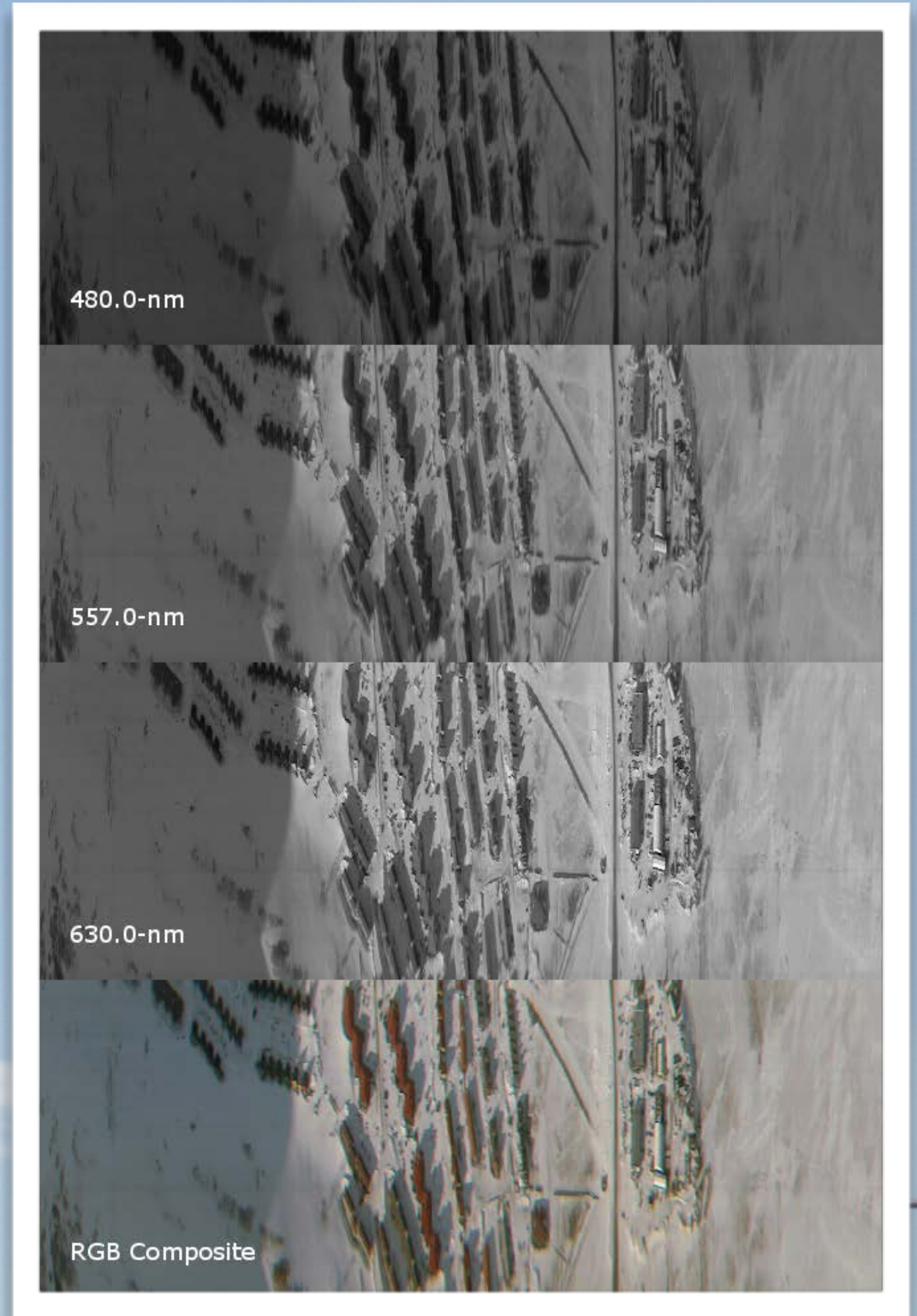
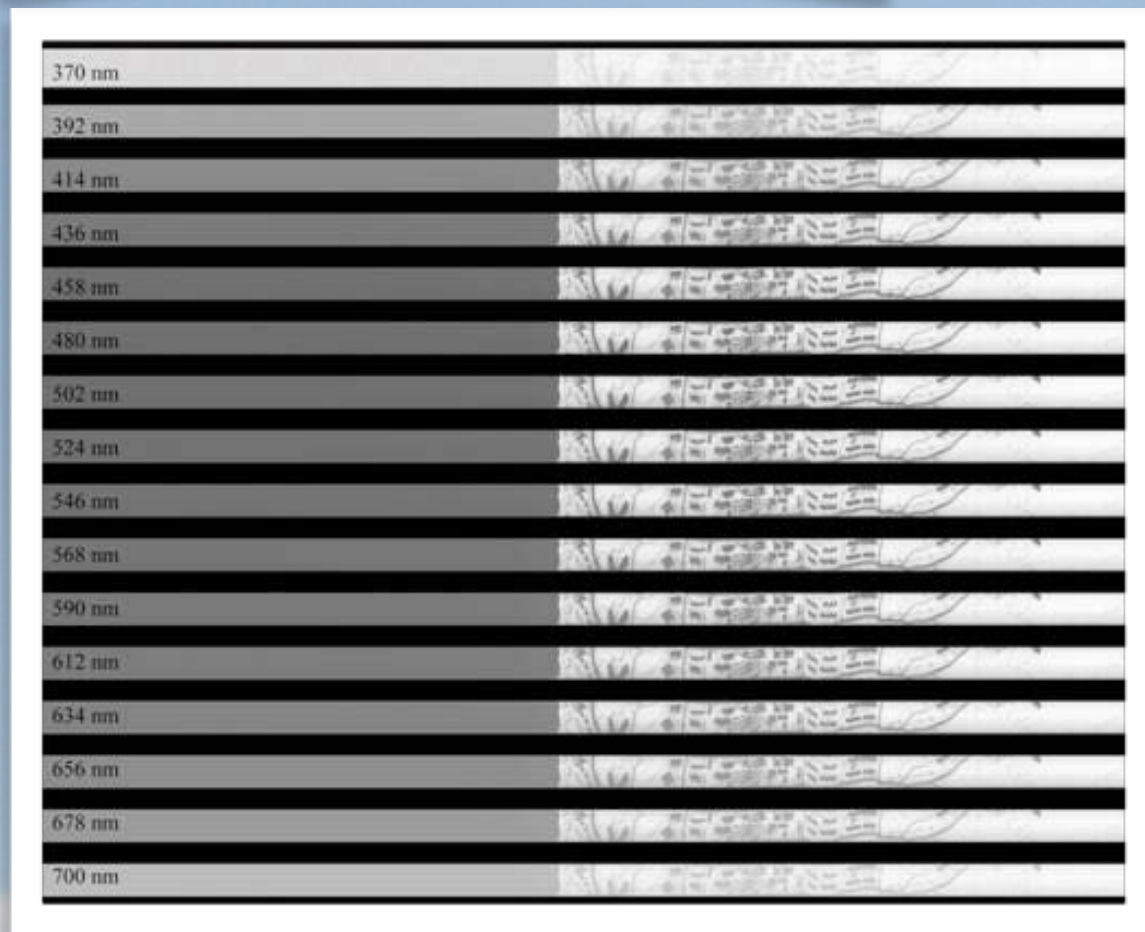




Channels

- 500
- 510
- 531
- 570
- 645
- 700
- 710
- 720
- 730
- 745
- 750
- 760
- 775
- 790
- 858
- 5ms int

Instrumentation: Hyperspectral imager

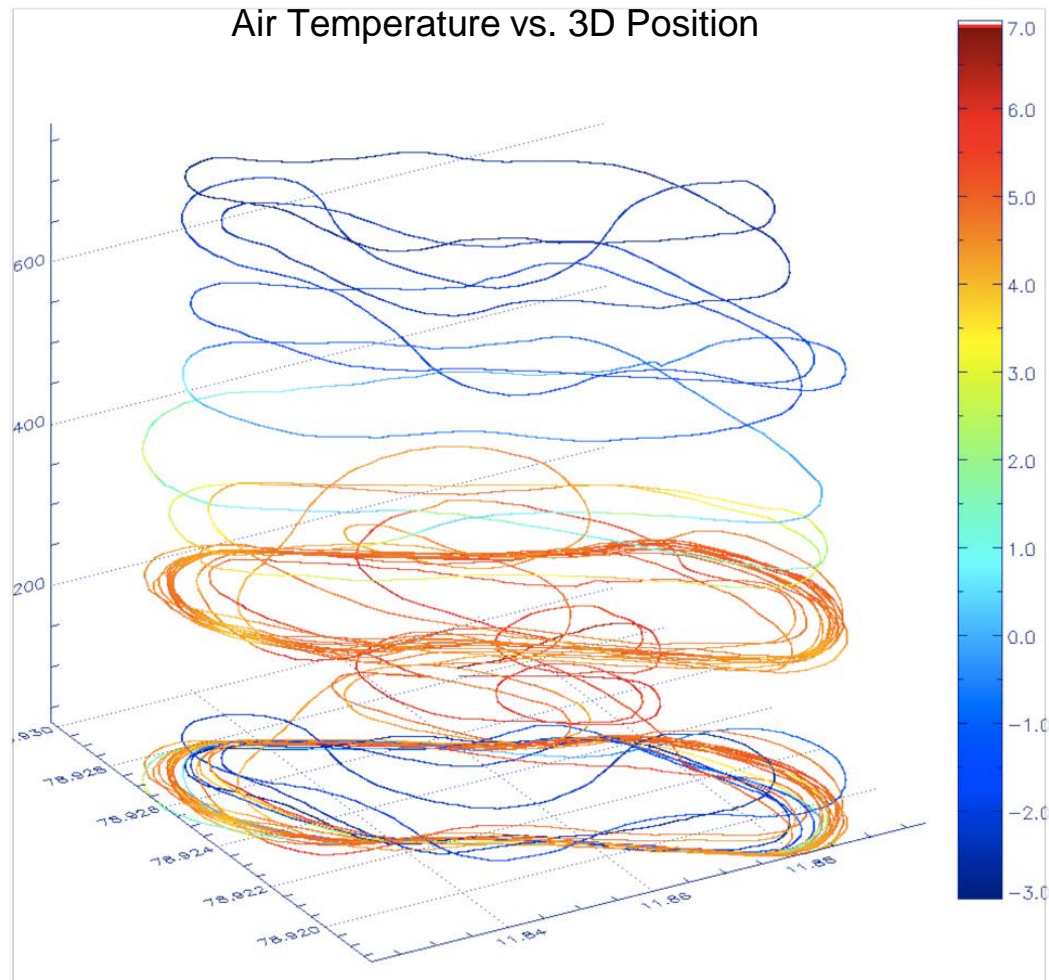


Courtesy: Fred Sigernes, UNIS

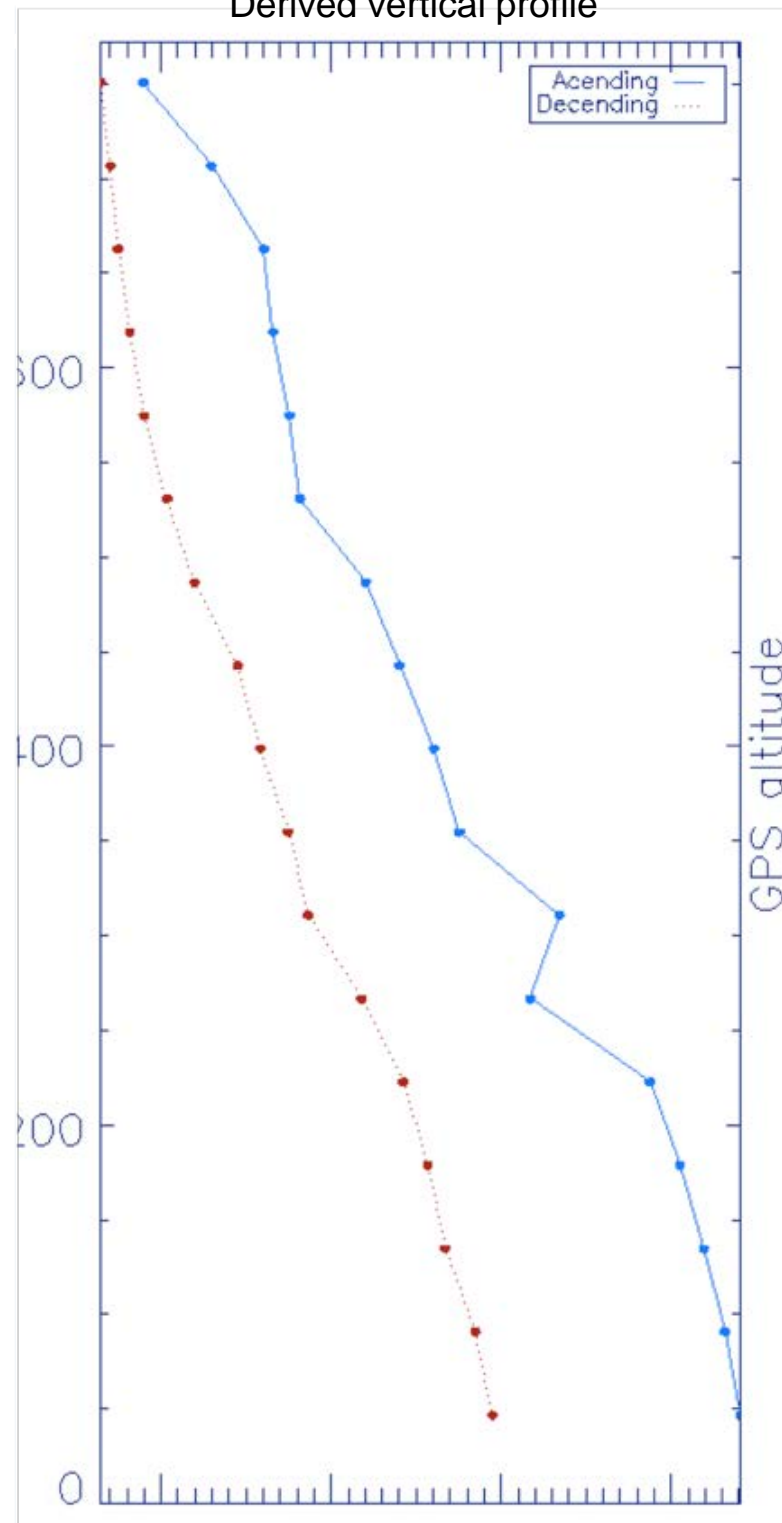
Instrumentation: Met Sensors



Air Temperature vs. 3D Position



Derived vertical profile

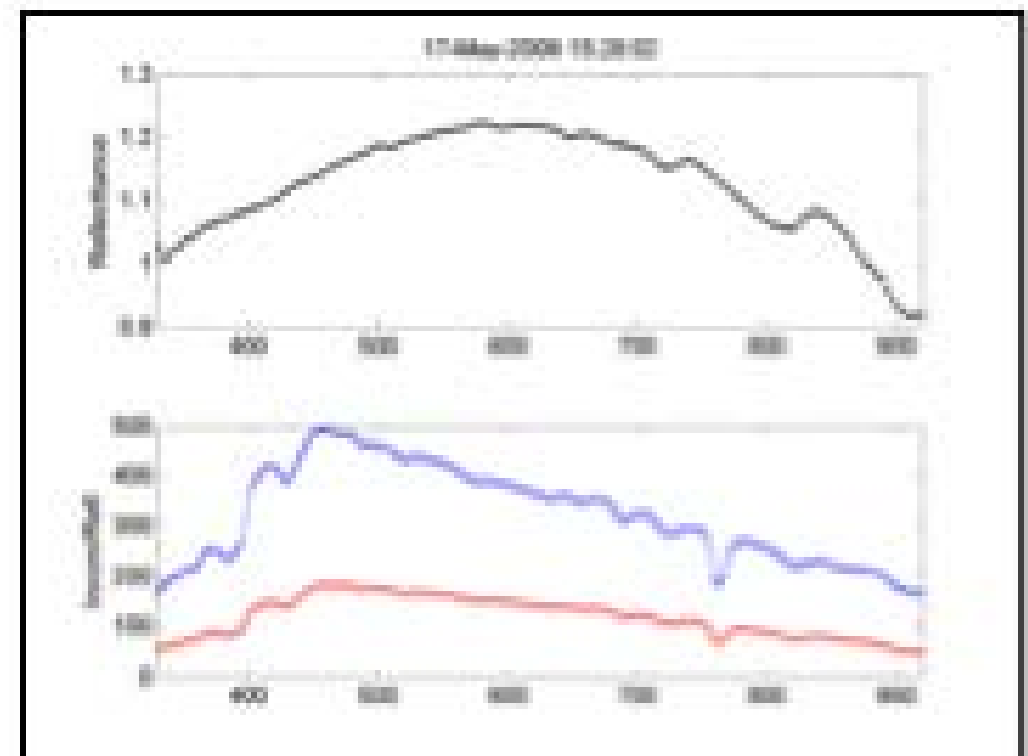
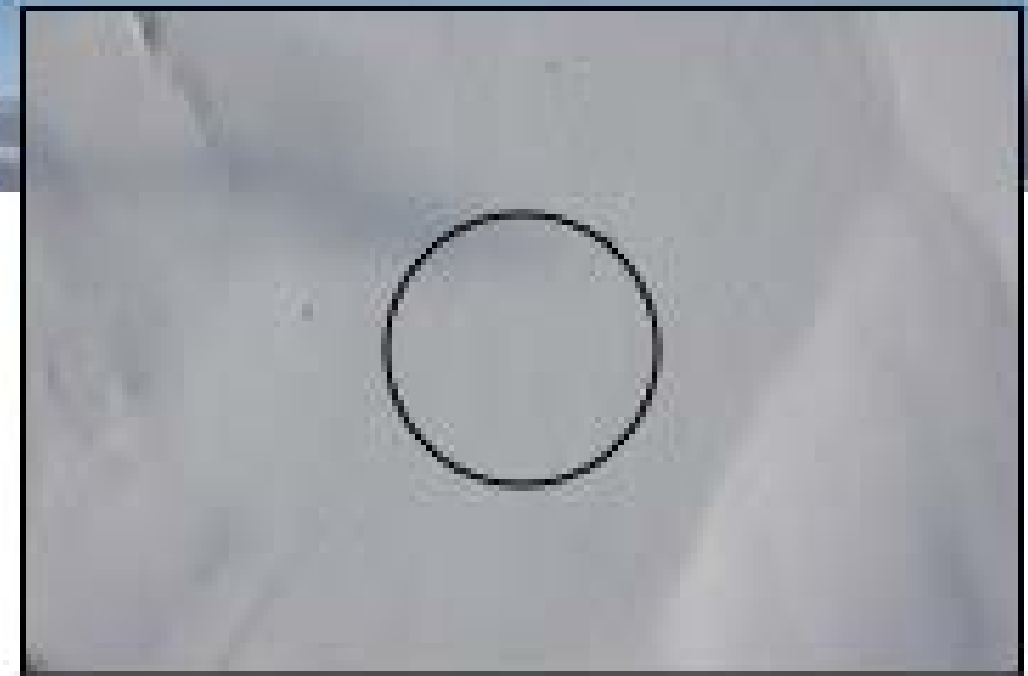


Conventional radiosonde



Remote Sensing Reflectance

**Sample data from VAUUA project.
Nilu/NP/Norut**



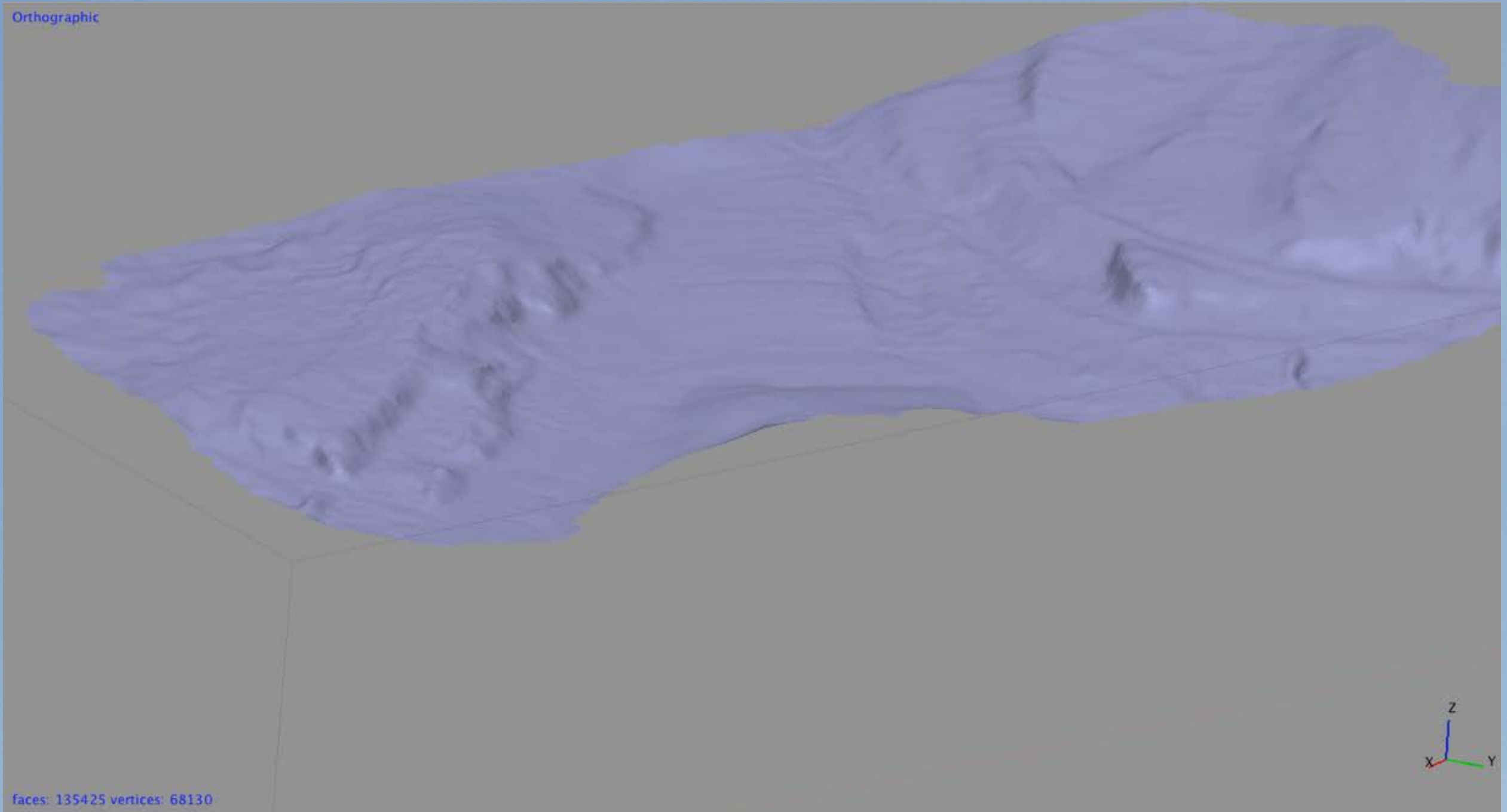
Examples from CryoWing micro

Ortophoto shown in Google Earth

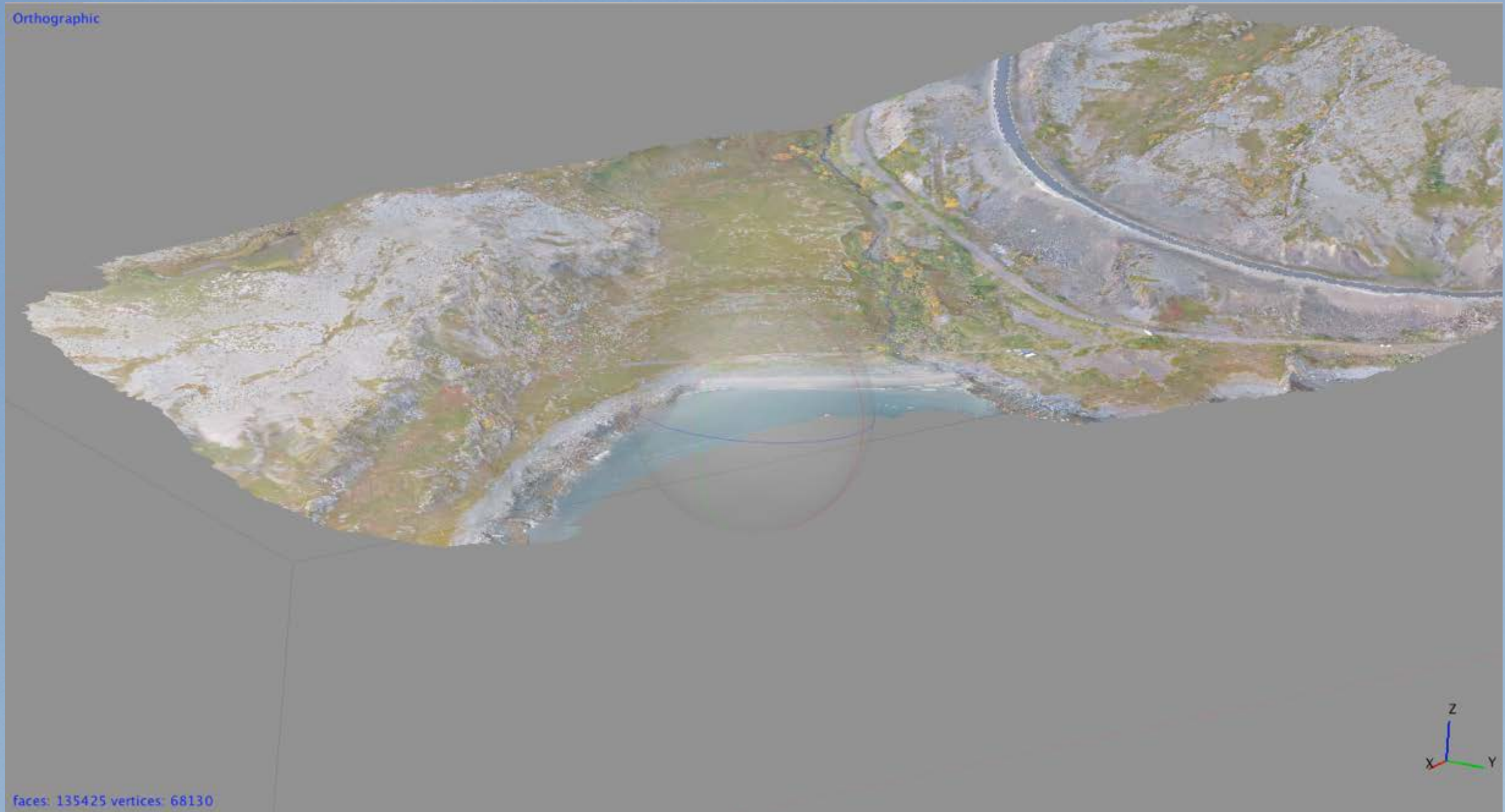
Textured DEM



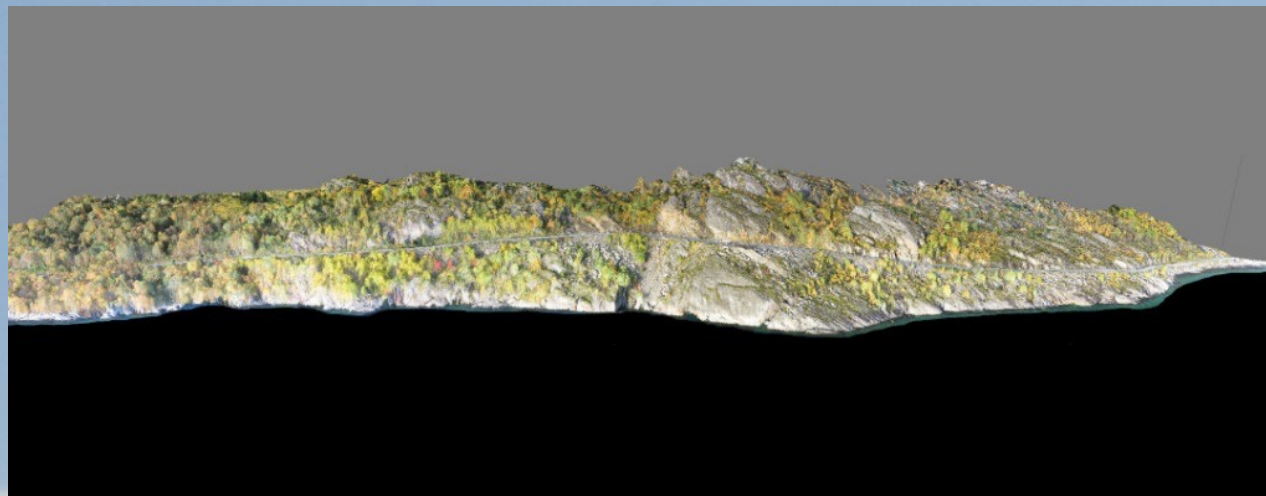
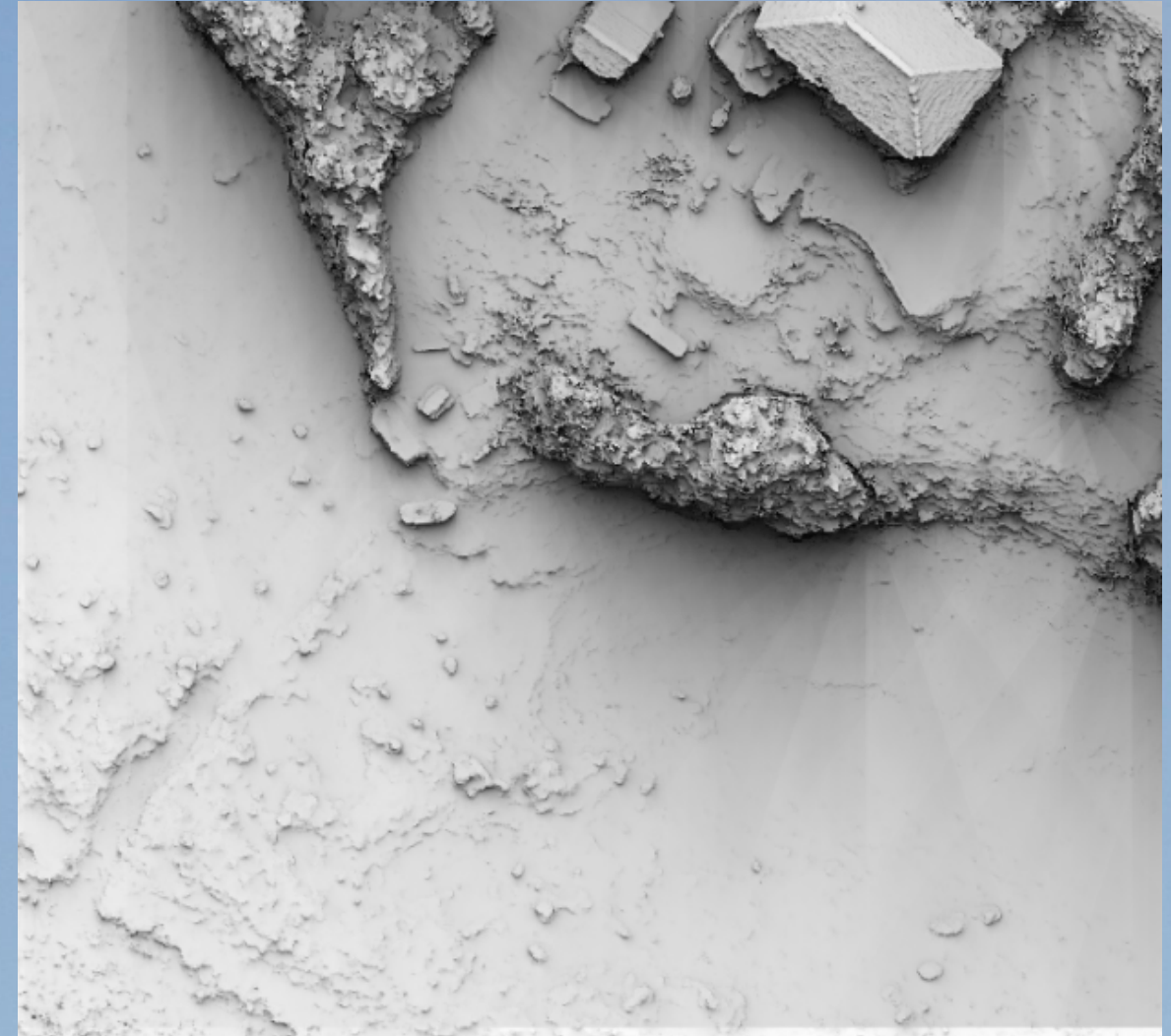
Solid 3D model




Textured 3D model



Håkøya buildings 3D



The “Drone revolution”

- 
- Small drones are big business in the consumer market
 - “Your neighbors” are drone pilots
 - SfM software that provide orthophoto and DEM are widely available:
 - Agisoft, Pix4D, Dronemapper, MICMAC, Mosaicmill, Pioneering, +++++
 - Turn-key solutions targeted for the construction industry: Trimble, Sensefly, Topcon/Mavinci, Bramour

The “Drone revolution”

- Currently there are 178 approved RPAS operators in Norway (1500 in the EU)
- Many of these are starting to provide orthophoto and DSMs
- In a few years: Scientific grade data on 1Km² scale available at low cost!

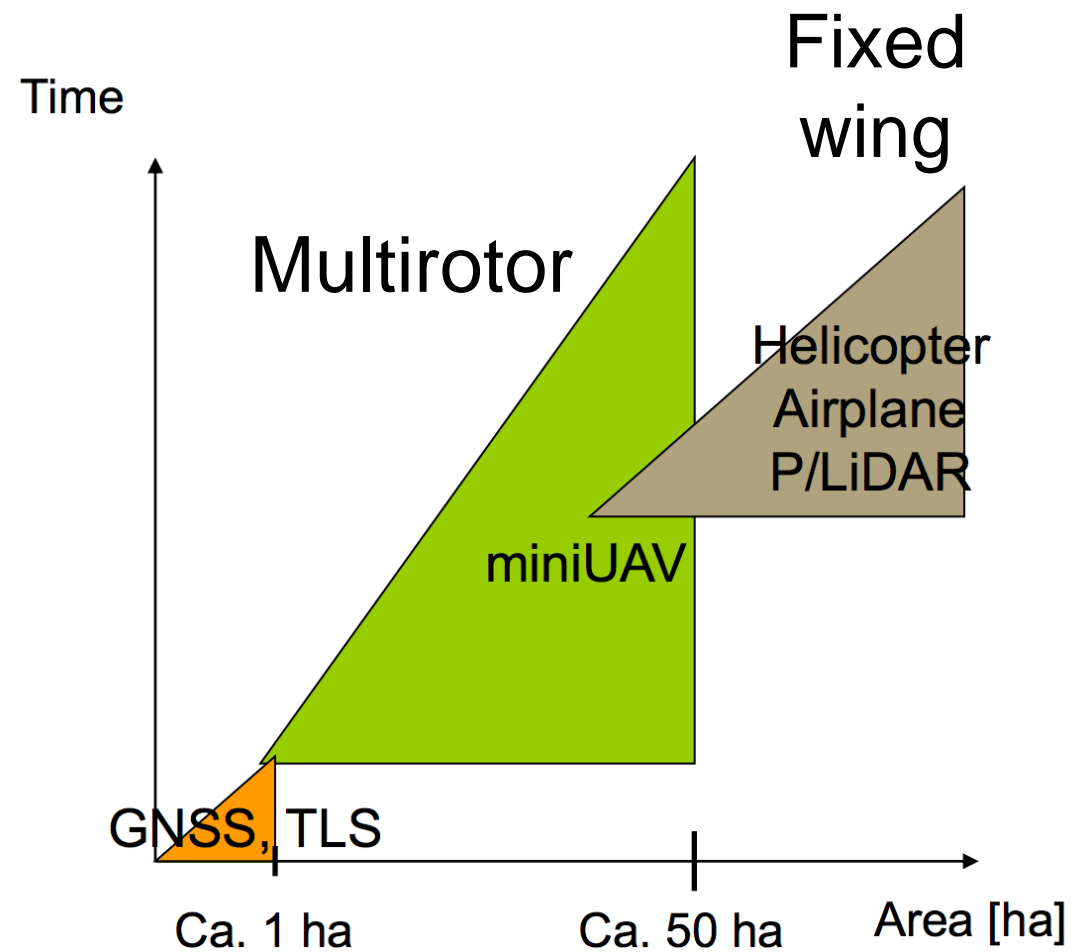
Area vs. Time (Cost)

Analysis and Discussion



Step of the workflow	Time effort in % of the total time required
Flight Planning	4.1
Data Acquisition	33
Setup of the Project in LPS	2
Aerial Triangulation	11.4
DSM Generation	41.2
Orthoimage Generation	1.4
Mosaicking	6.9
Total	100

Time effort required for the workflow



Thank you for you attention



Photos by: Torbjørn Houge,
Kjell Sture Johansen, Andreas Tøllef
Rune Storvold, Stian Solbø, et al.