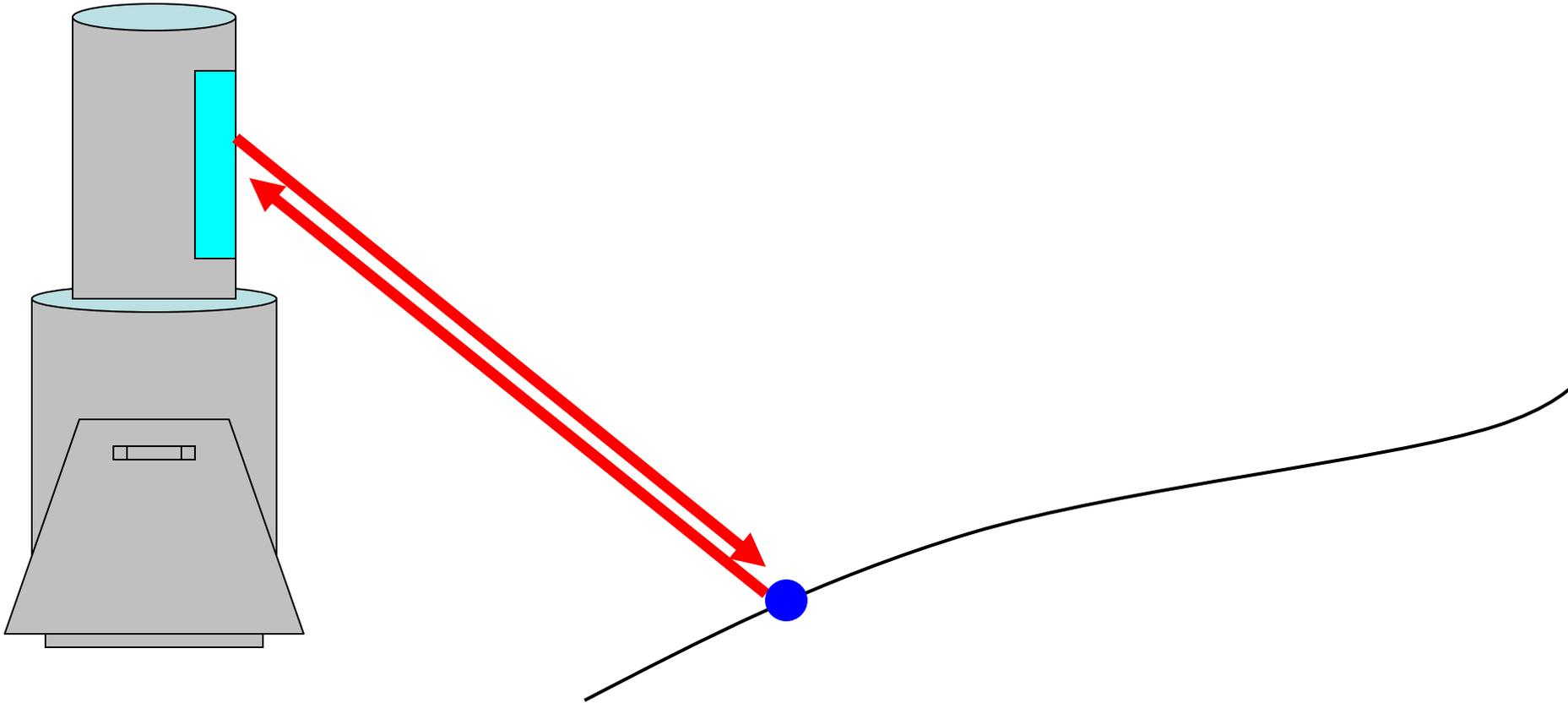


Monitoring Melt Pond Evolution with Surface Based LiDAR

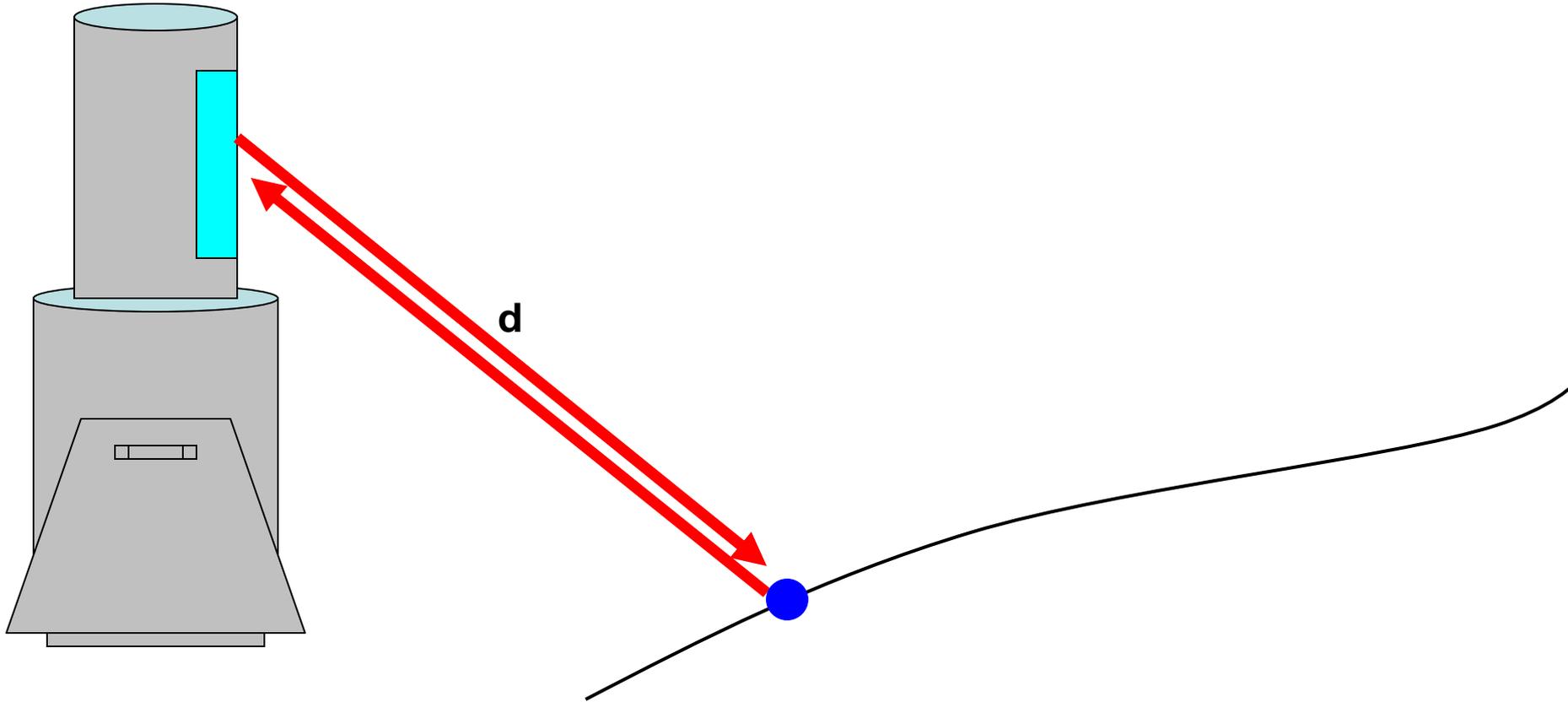


Chris Polashenski, Zoe Courville,
Don Perovich, Dave Finnegan

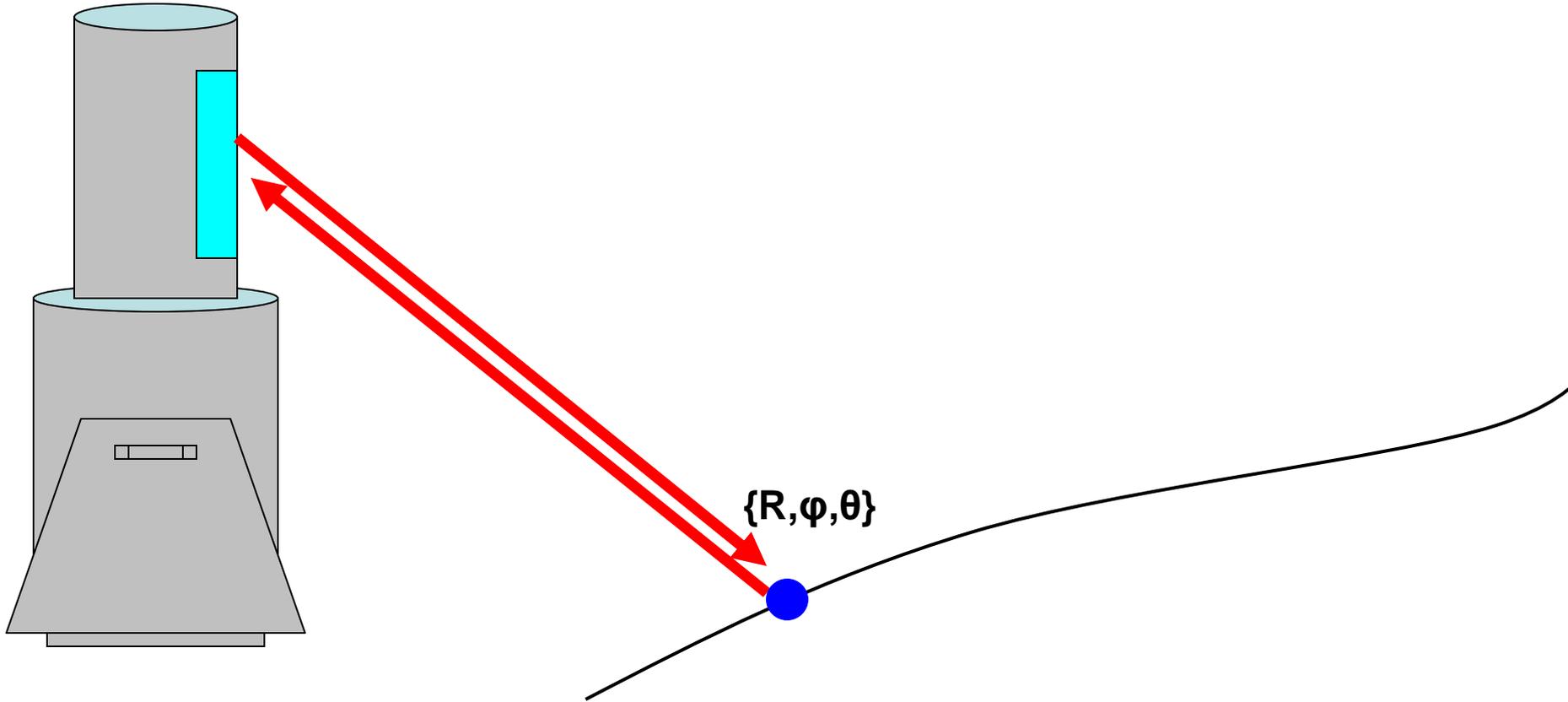
Light Distance And Ranging (LiDAR)



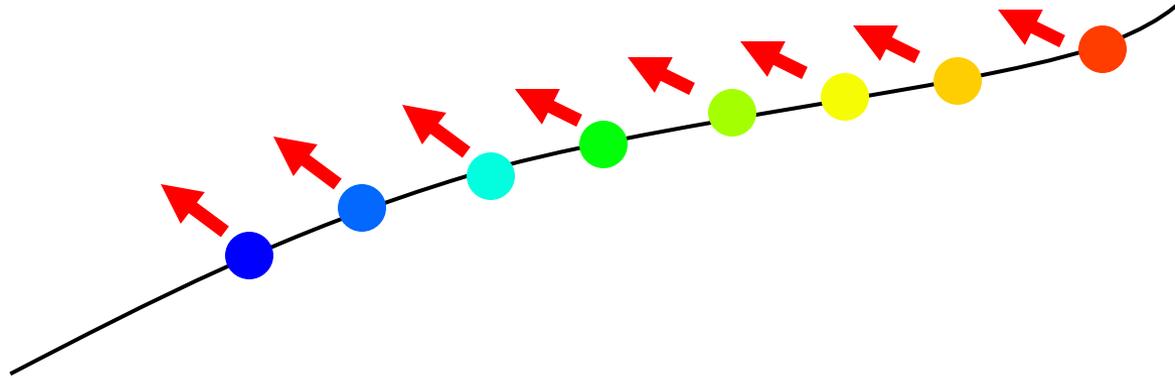
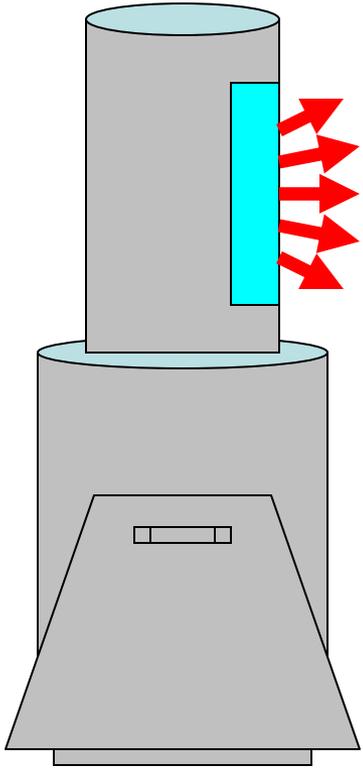
Light Distance And Ranging (LiDAR)



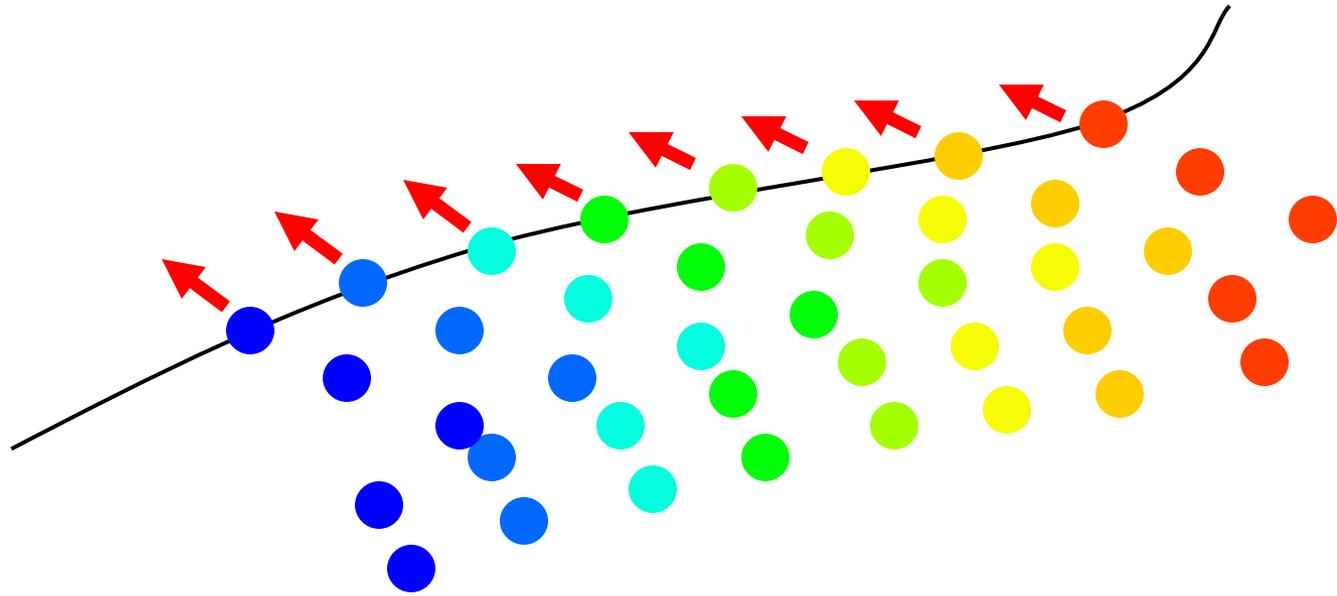
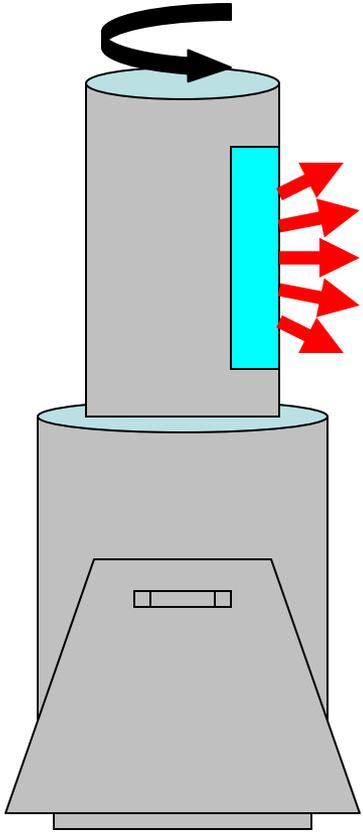
Light Distance And Ranging (LiDAR)



Light Distance And Ranging (LiDAR)

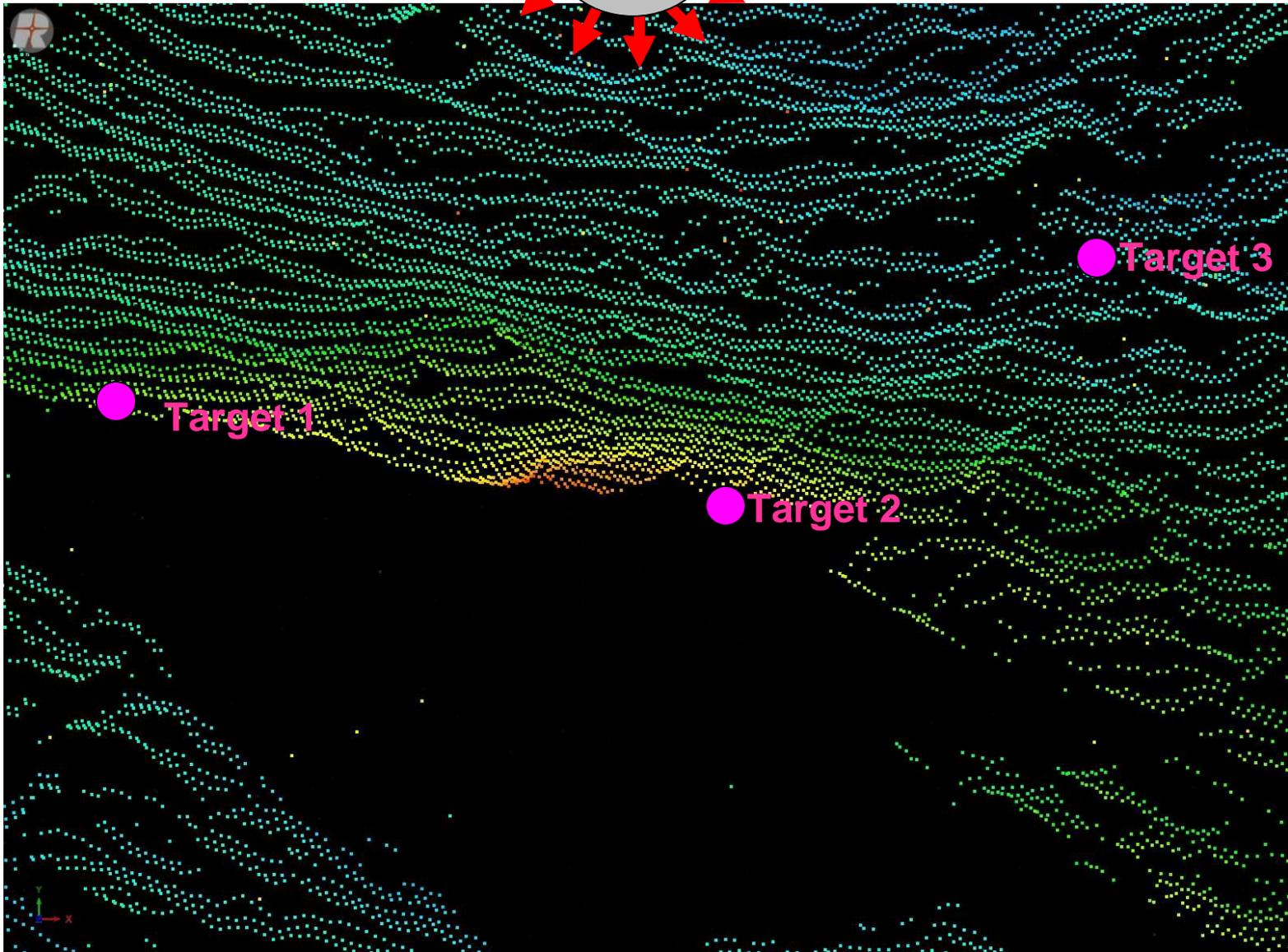


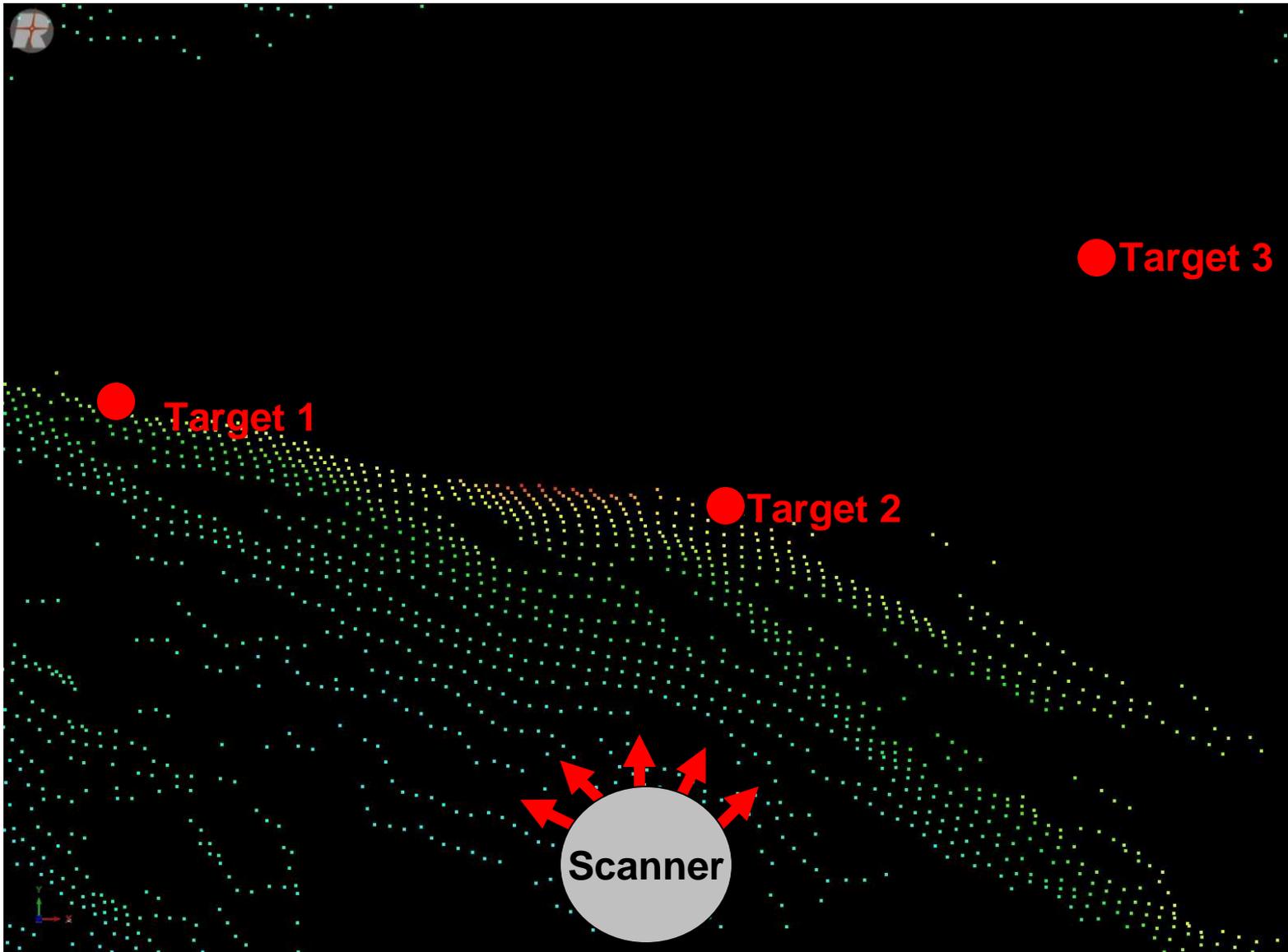
Light Distance And Ranging (LiDAR)

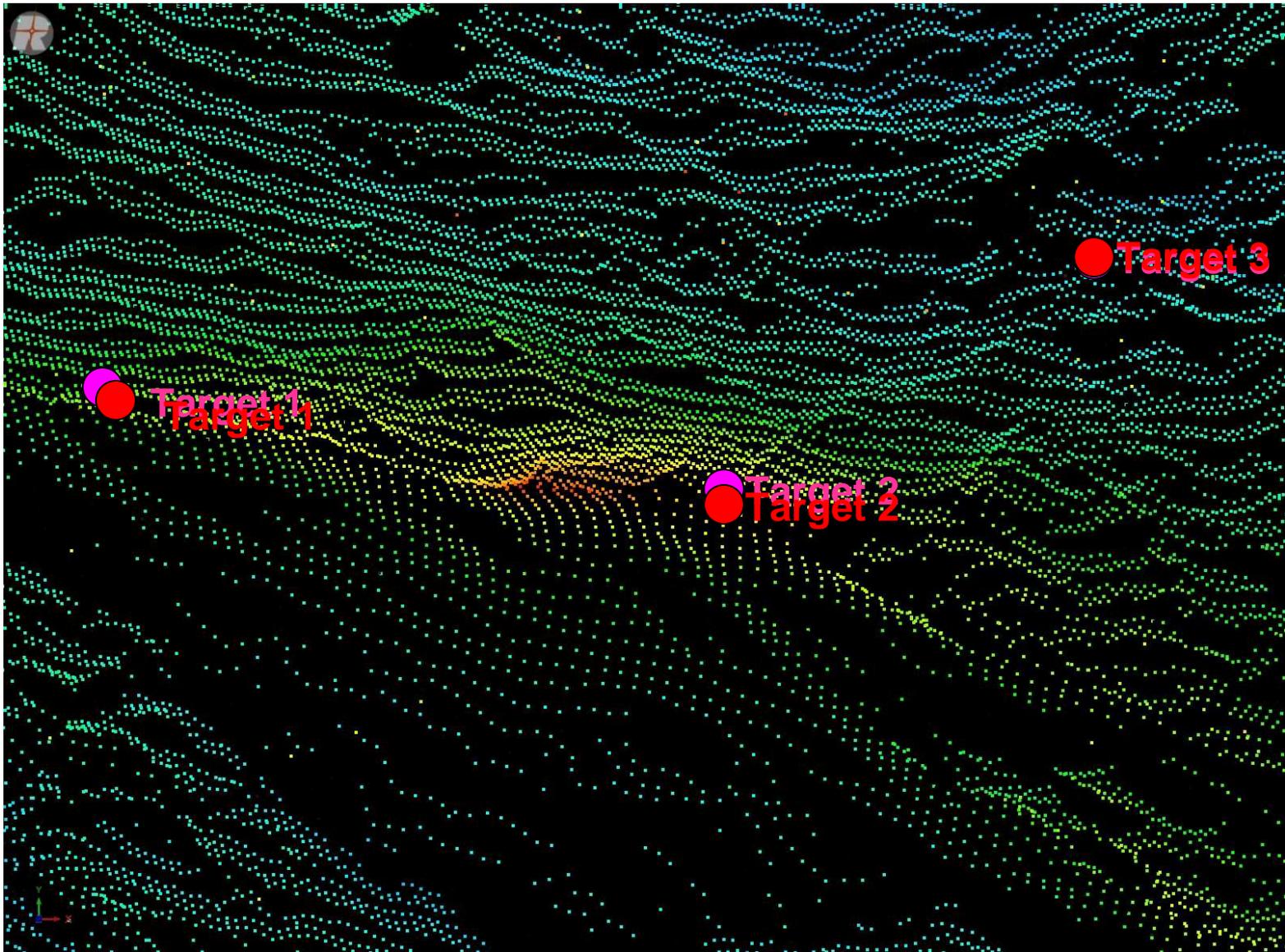


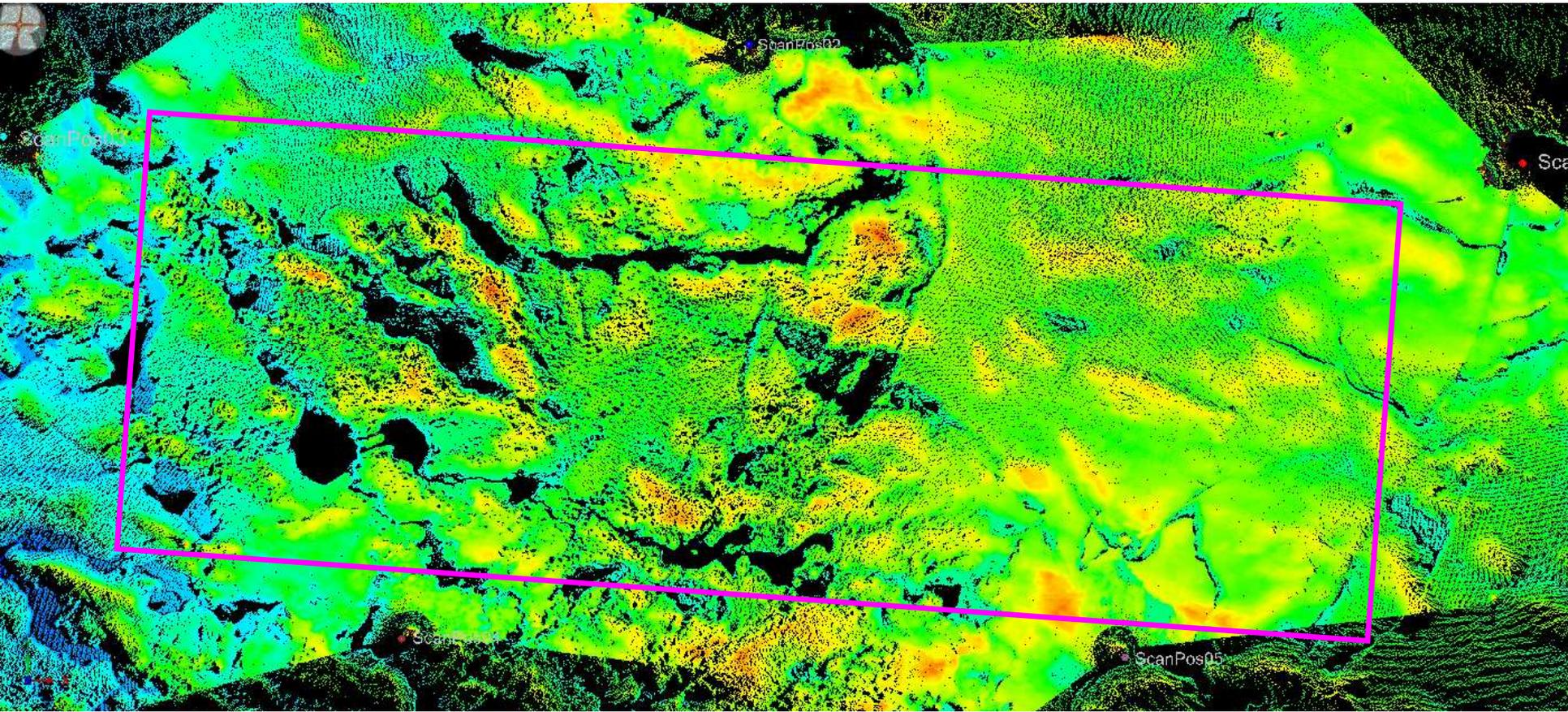


Scanner





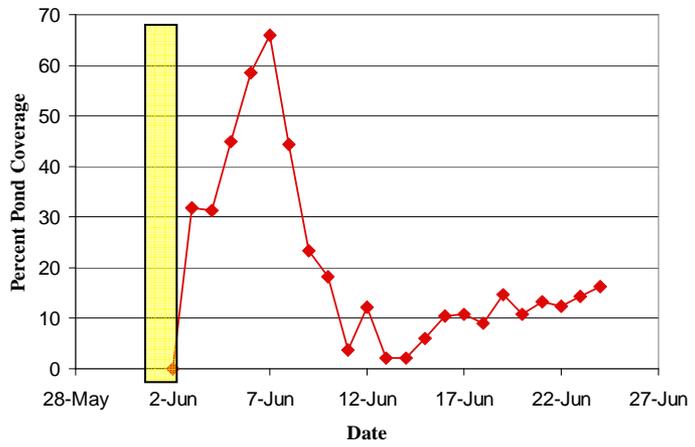




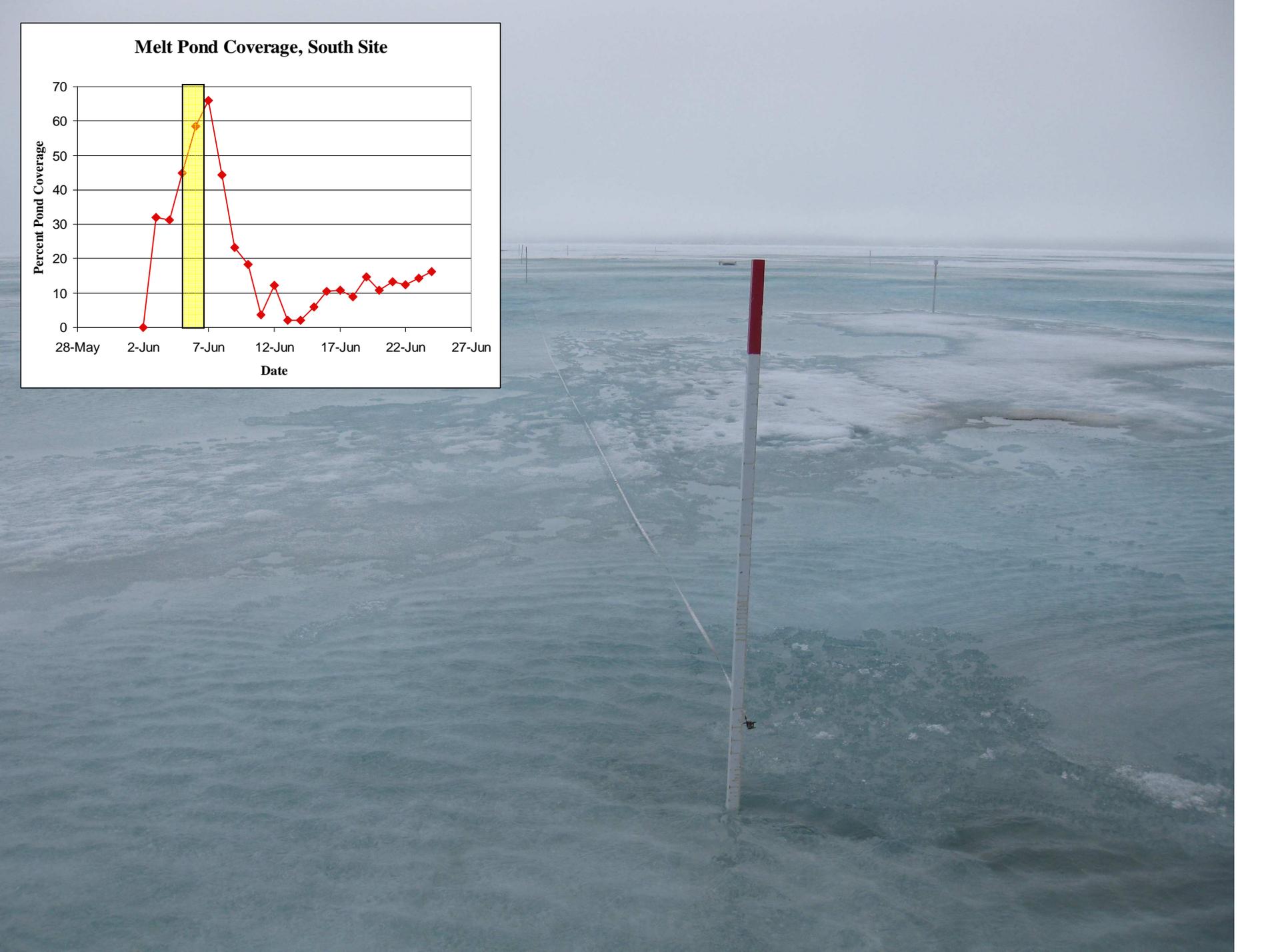
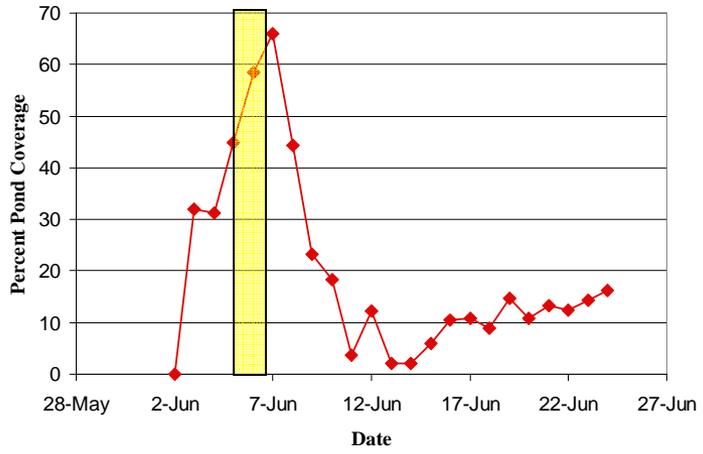
Melt Ponds



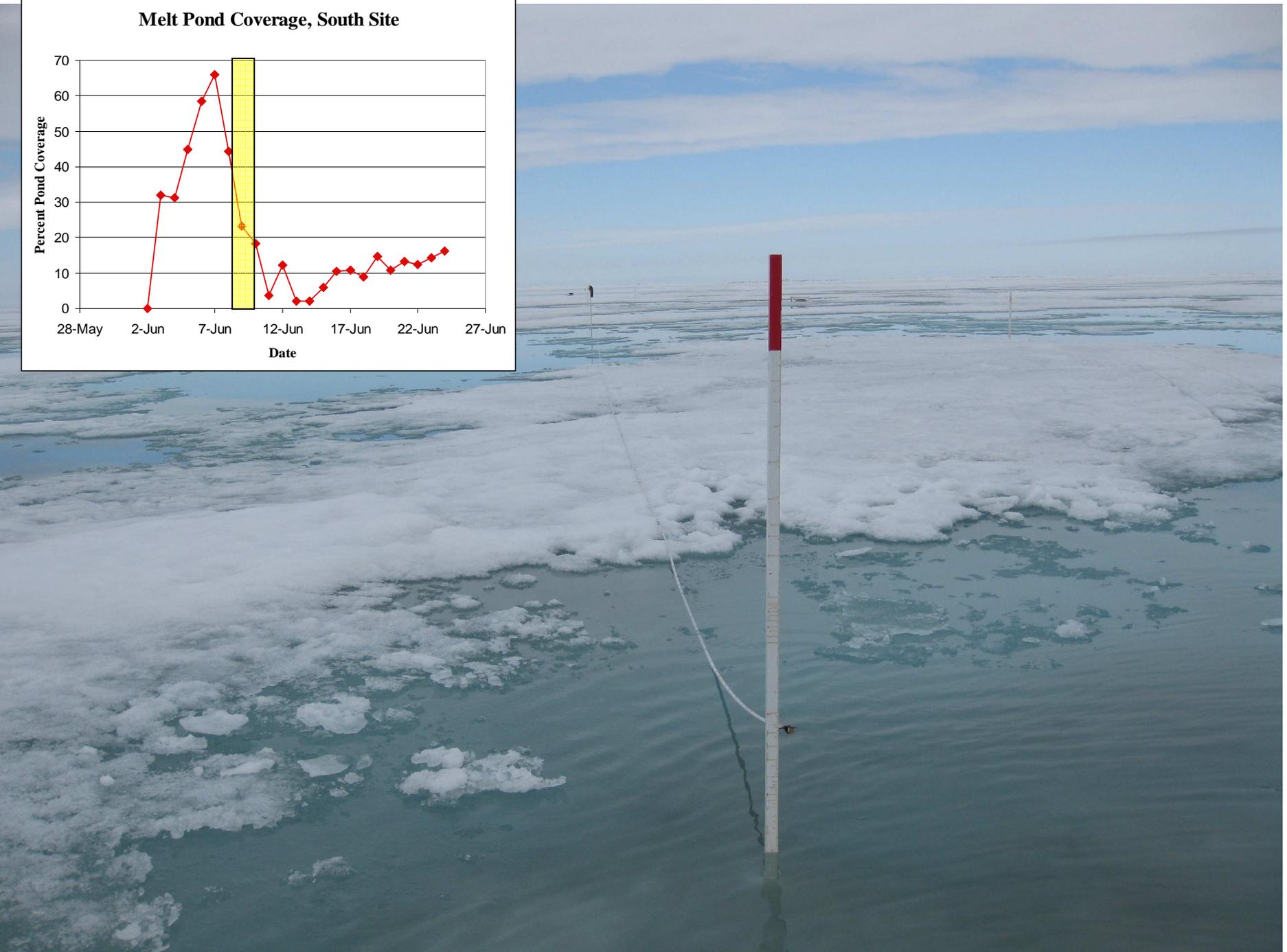
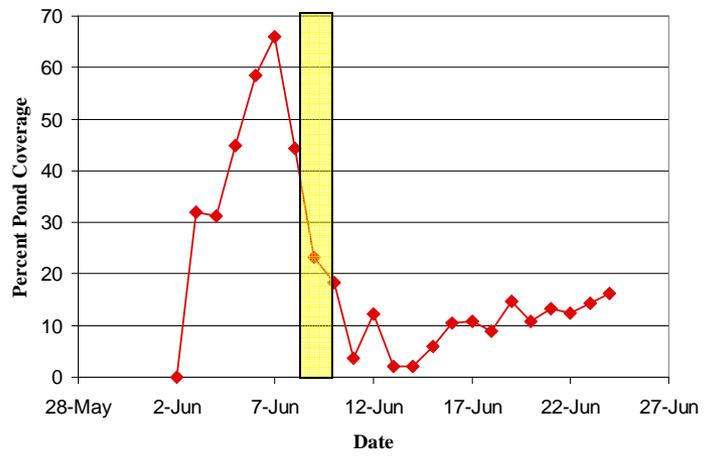
Melt Pond Coverage, South Site



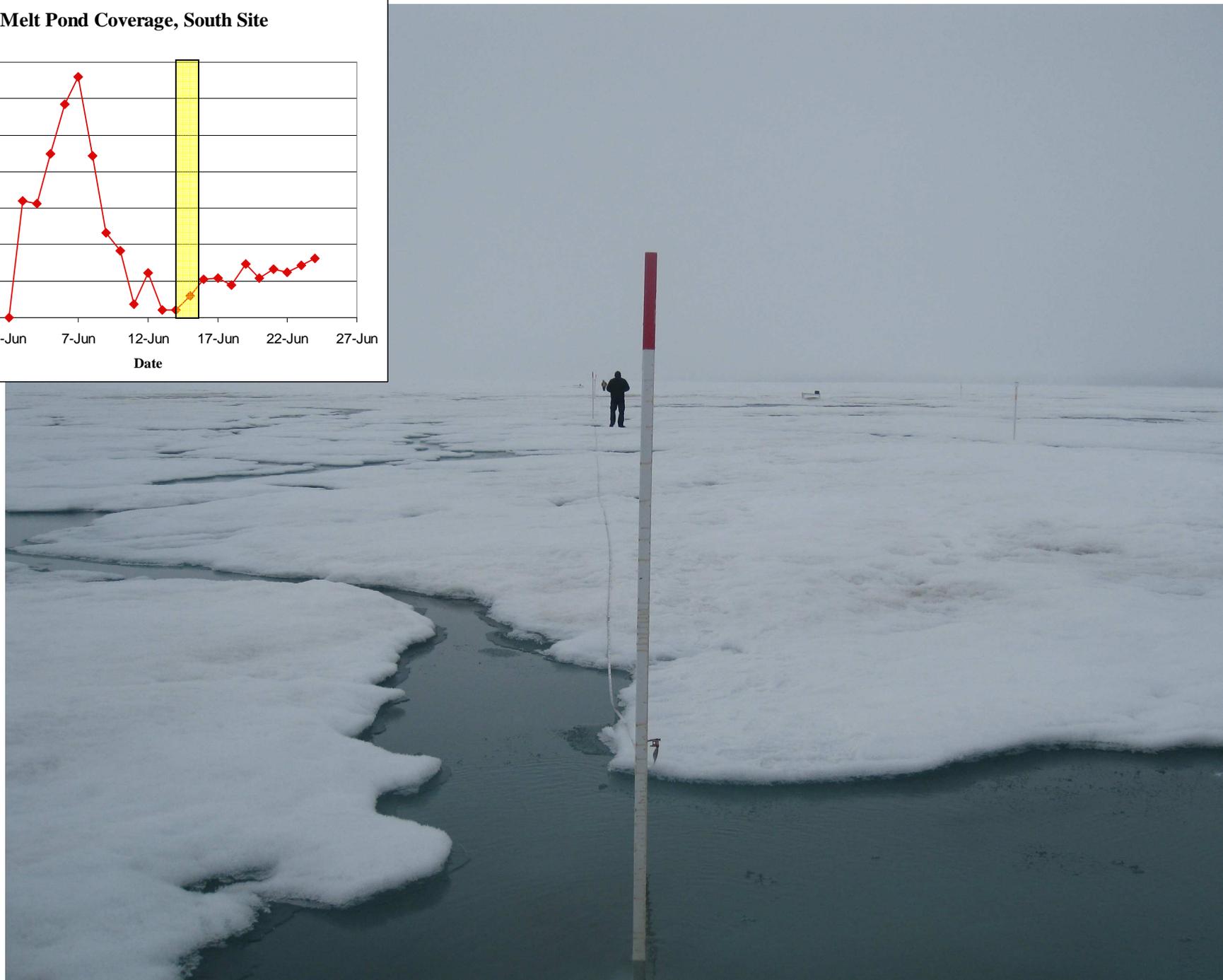
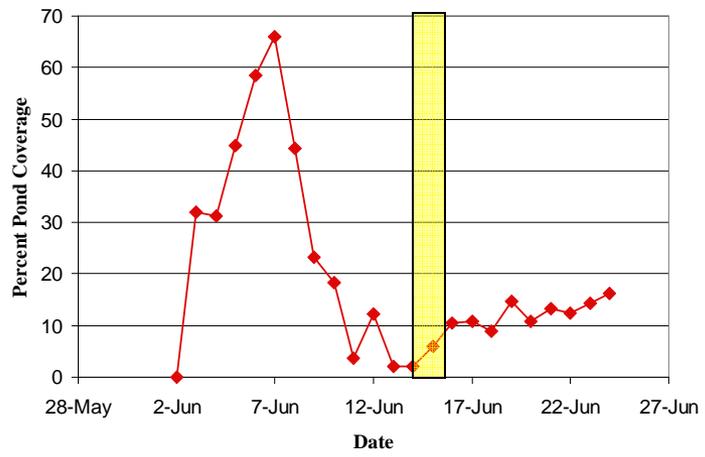
Melt Pond Coverage, South Site

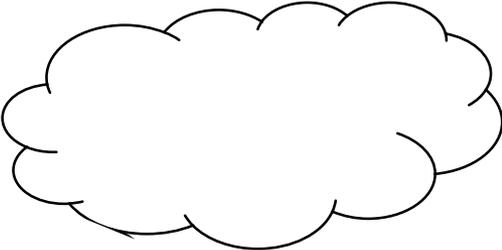
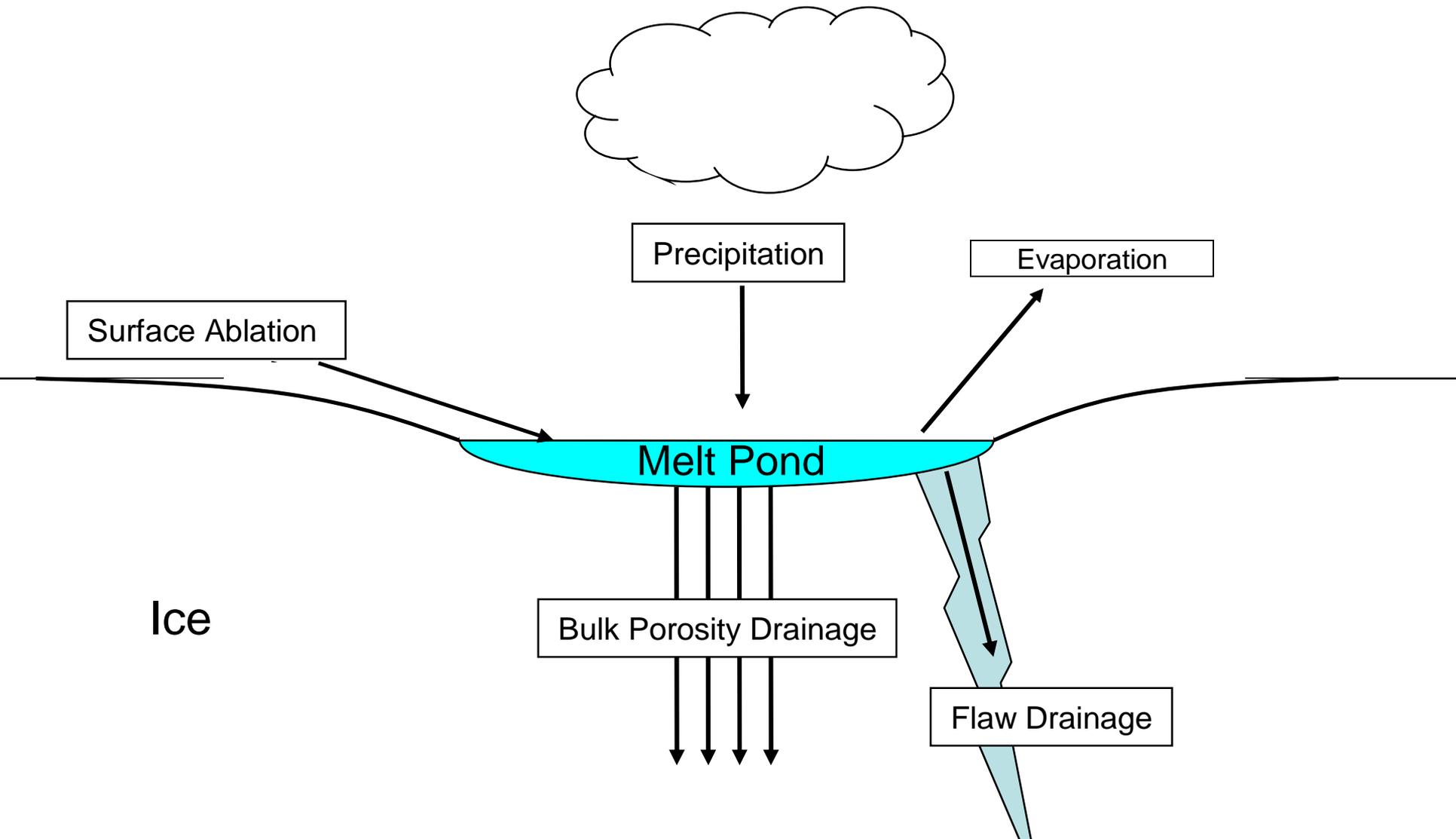


Melt Pond Coverage, South Site



Melt Pond Coverage, South Site





Precipitation

Evaporation

Surface Ablation

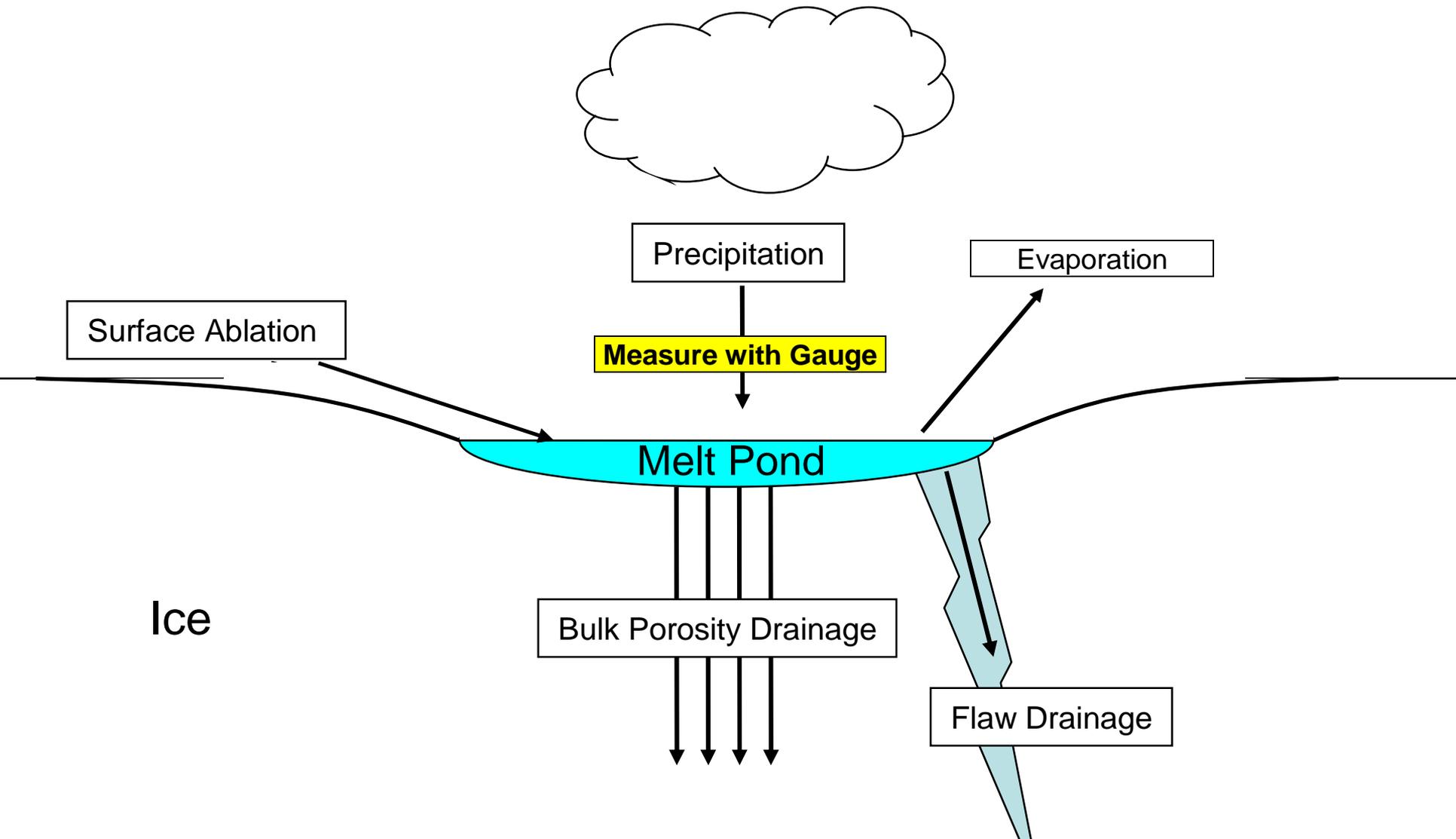
Melt Pond

Ice

Bulk Porosity Drainage

Flaw Drainage

Ocean



Surface Ablation

Precipitation

Evaporation

Measure with Gauge

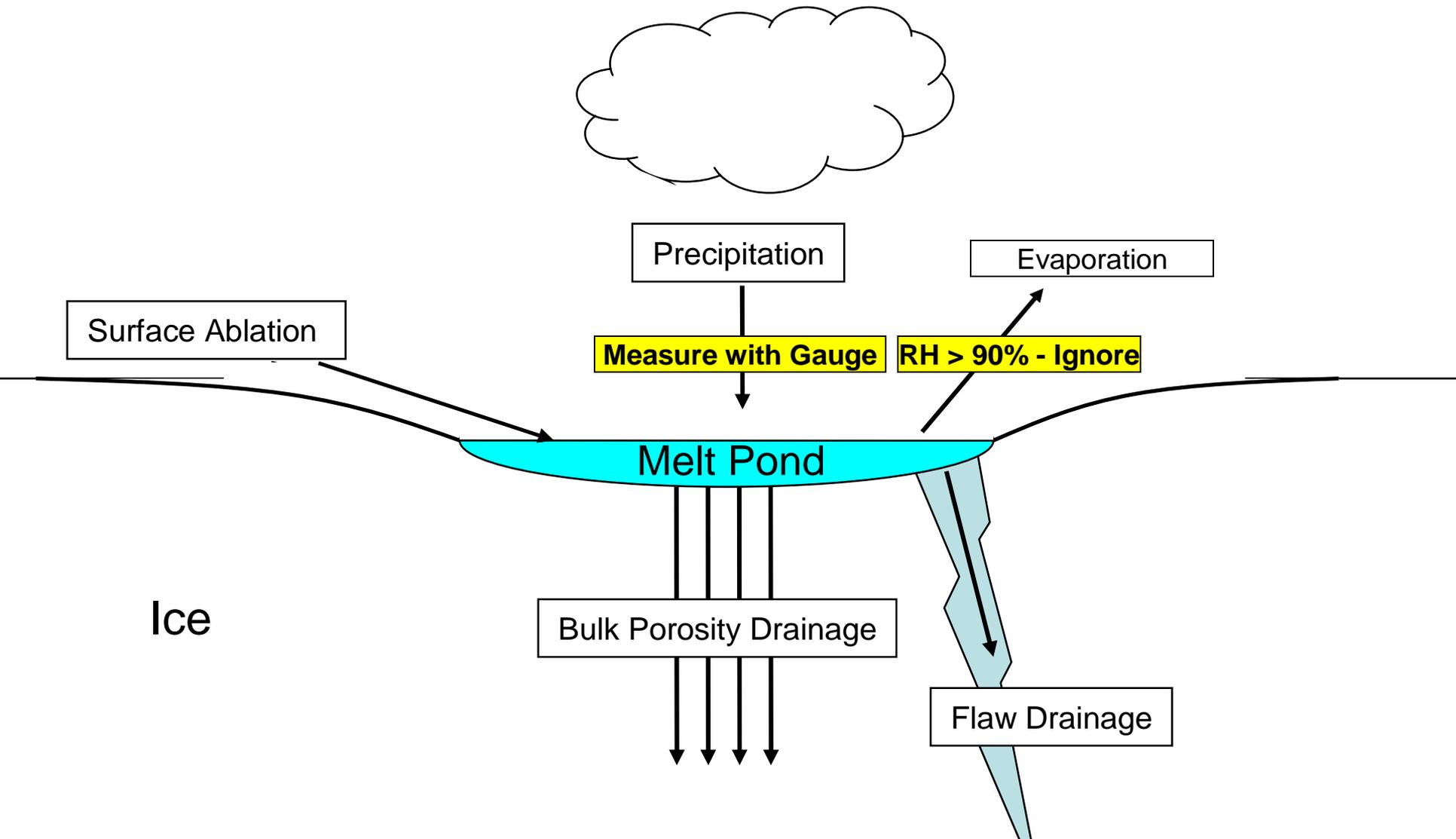
Melt Pond

Ice

Bulk Porosity Drainage

Flaw Drainage

Ocean



Precipitation

Evaporation

Surface Ablation

Measure with Gauge

RH > 90% - Ignore

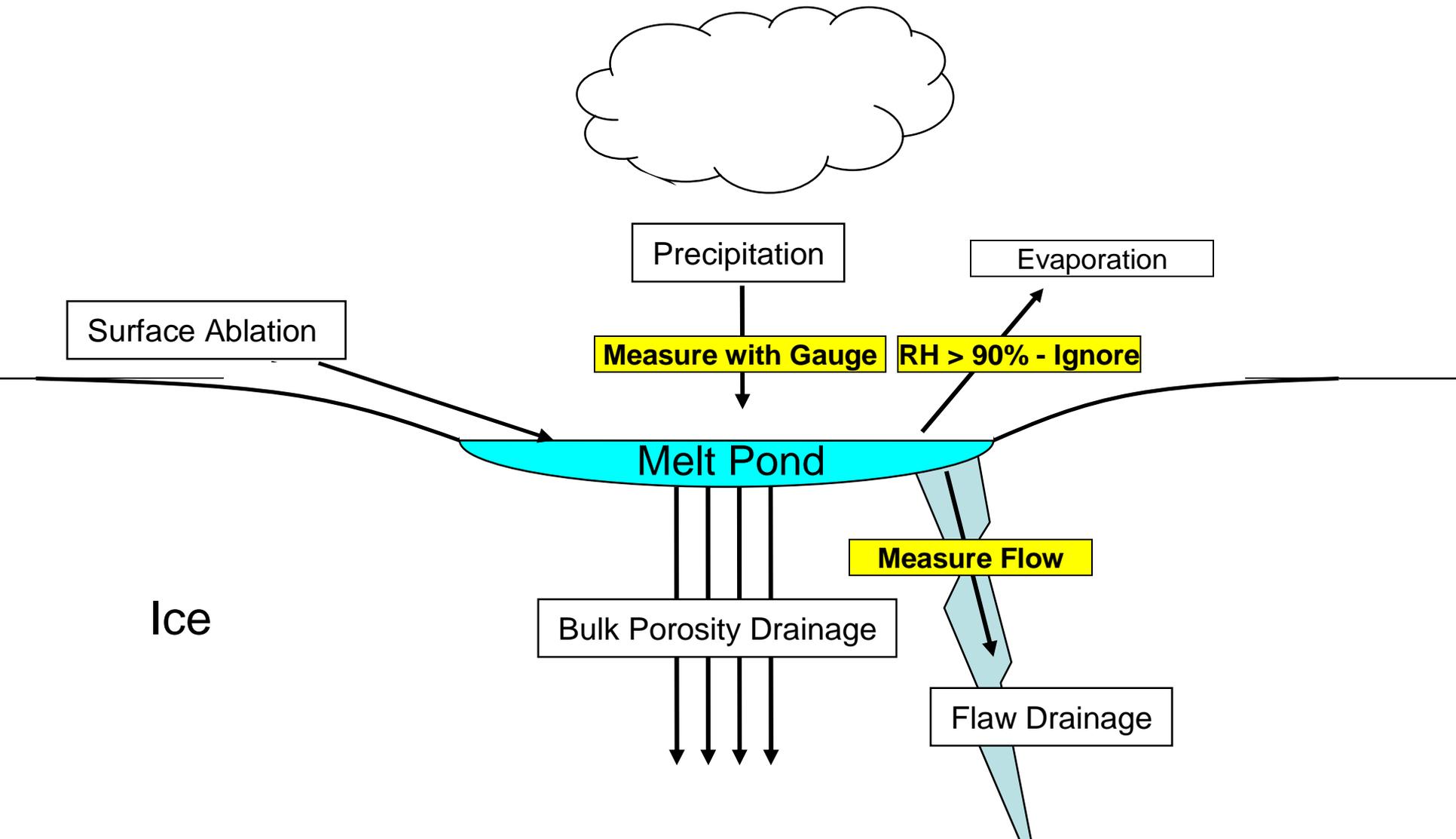
Melt Pond

Ice

Bulk Porosity Drainage

Flaw Drainage

Ocean



Precipitation

Evaporation

Surface Ablation

Measure with Gauge

RH > 90% - Ignore

Melt Pond

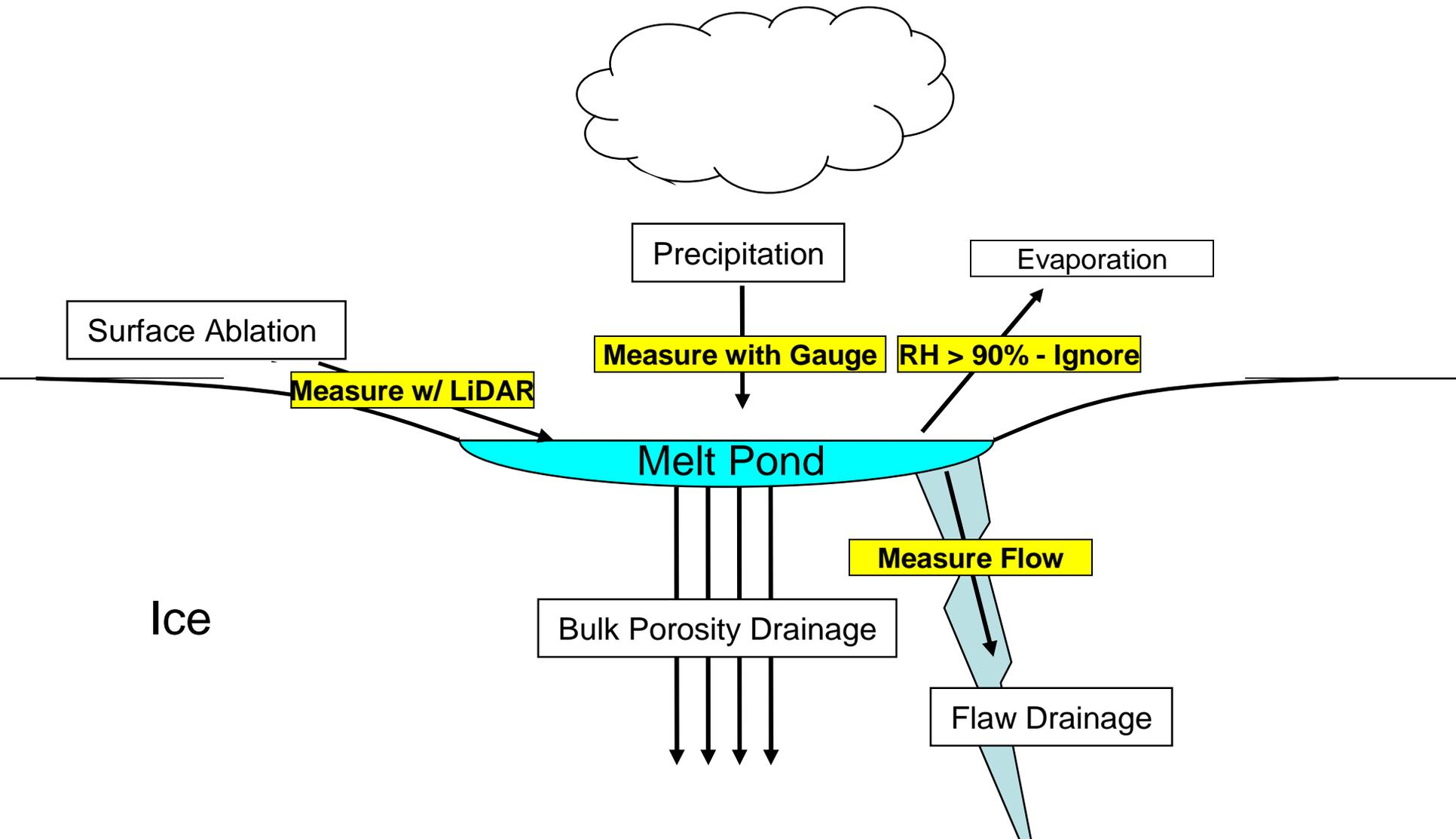
Bulk Porosity Drainage

Measure Flow

Flaw Drainage

Ice

Ocean



Precipitation

Evaporation

Surface Ablation

Measure with Gauge

RH > 90% - Ignore

Measure w/ LiDAR

Melt Pond

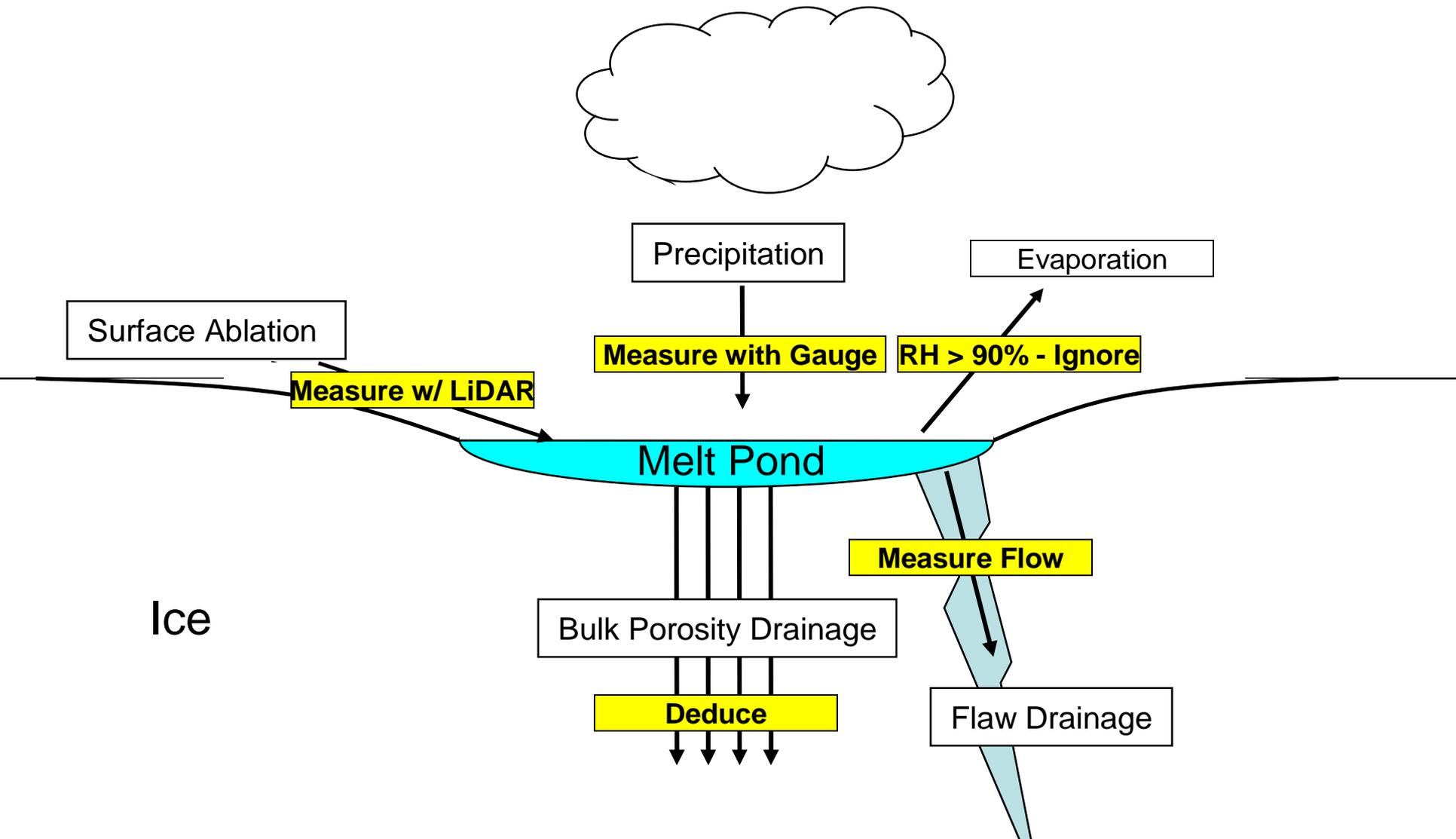
Measure Flow

Bulk Porosity Drainage

Flaw Drainage

Ice

Ocean



Precipitation

Evaporation

Surface Ablation

Measure with Gauge

RH > 90% - Ignore

Measure w/ LiDAR

Melt Pond

Measure Flow

Bulk Porosity Drainage

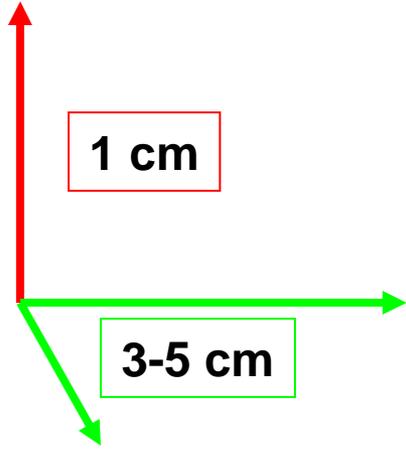
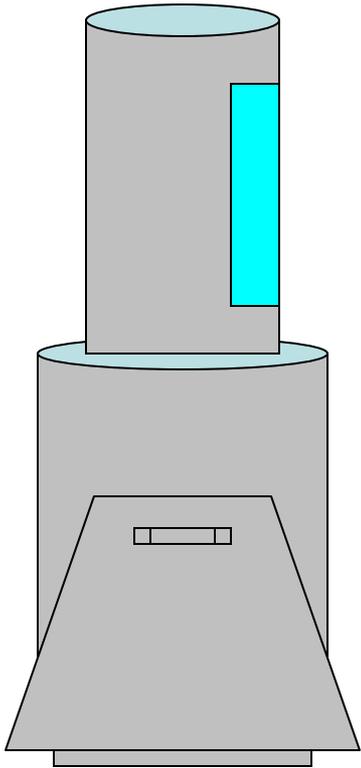
Deduce

Flaw Drainage

Ice

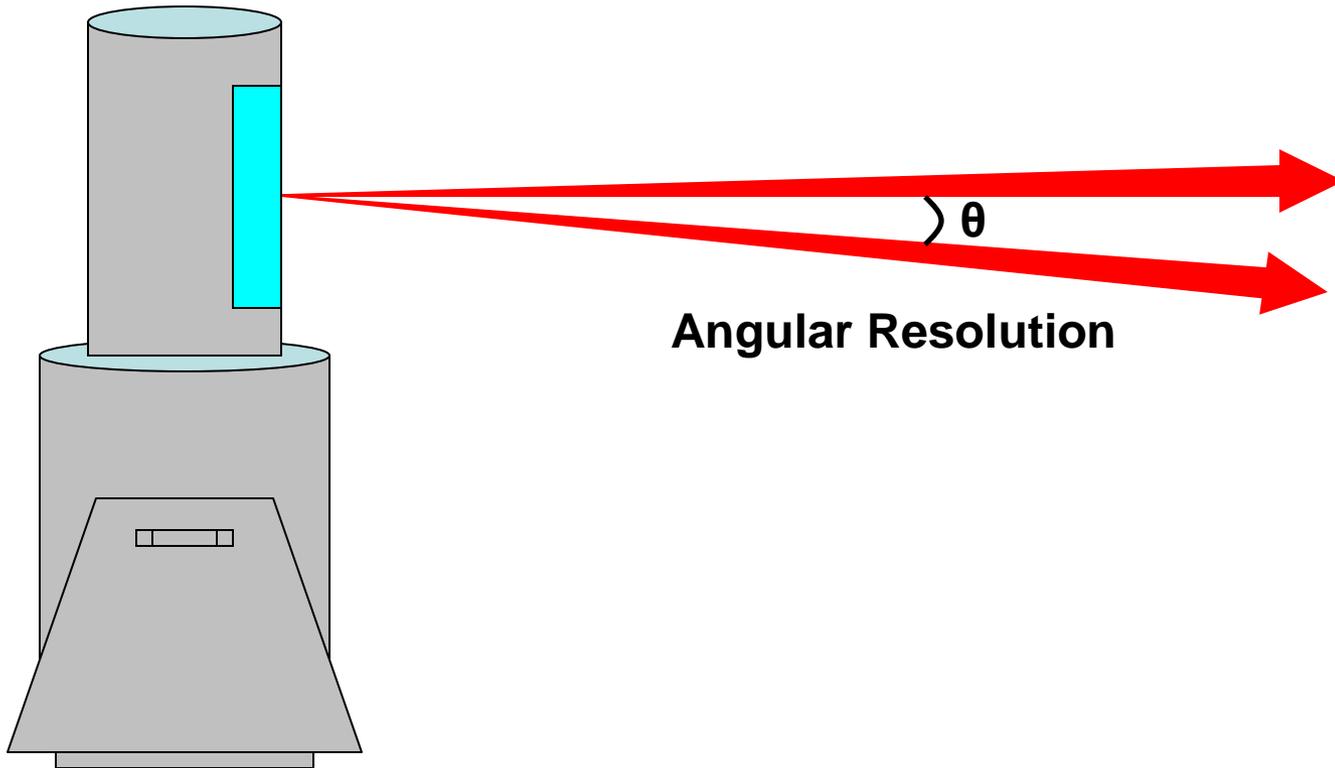
Ocean

Scan Resolution/Accuracy

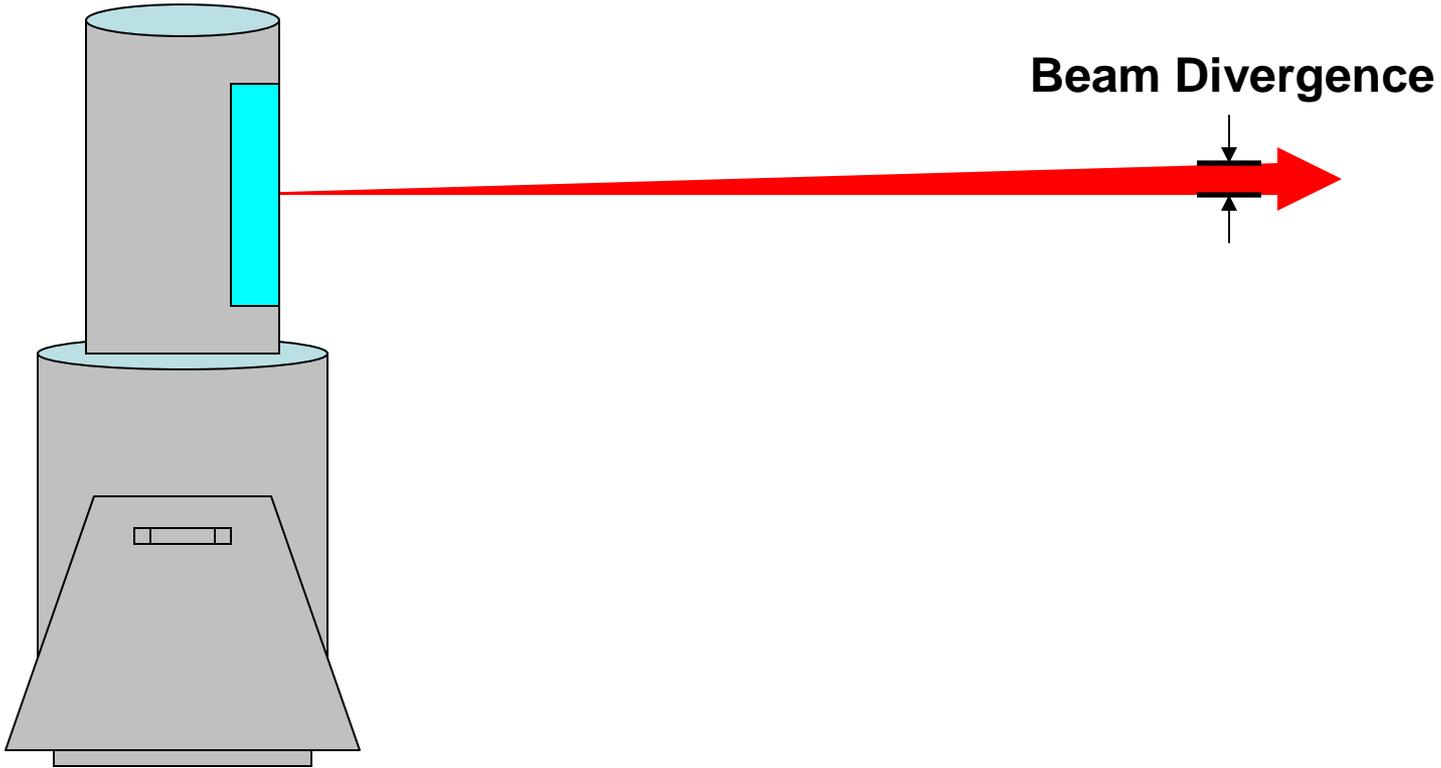


← 40m + →

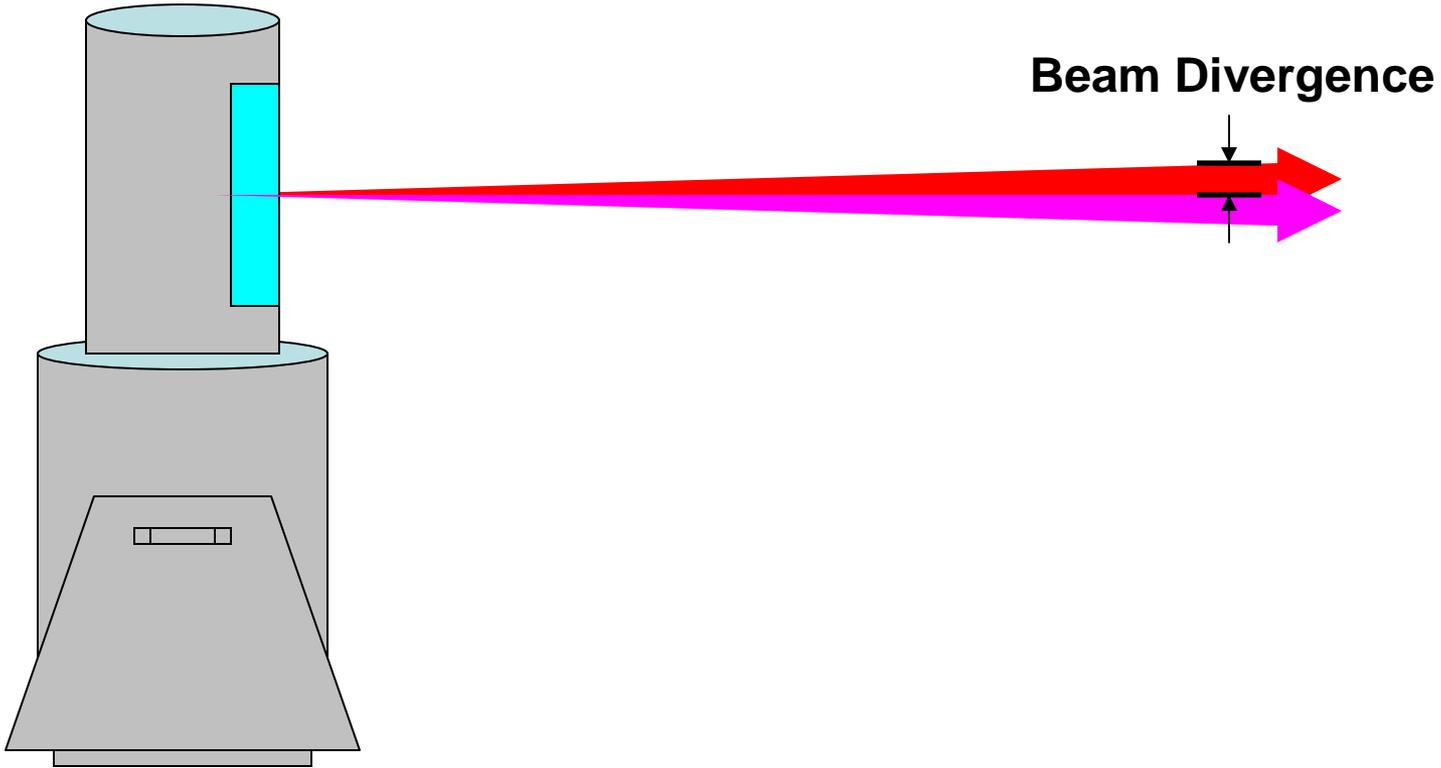
Angular Resolution



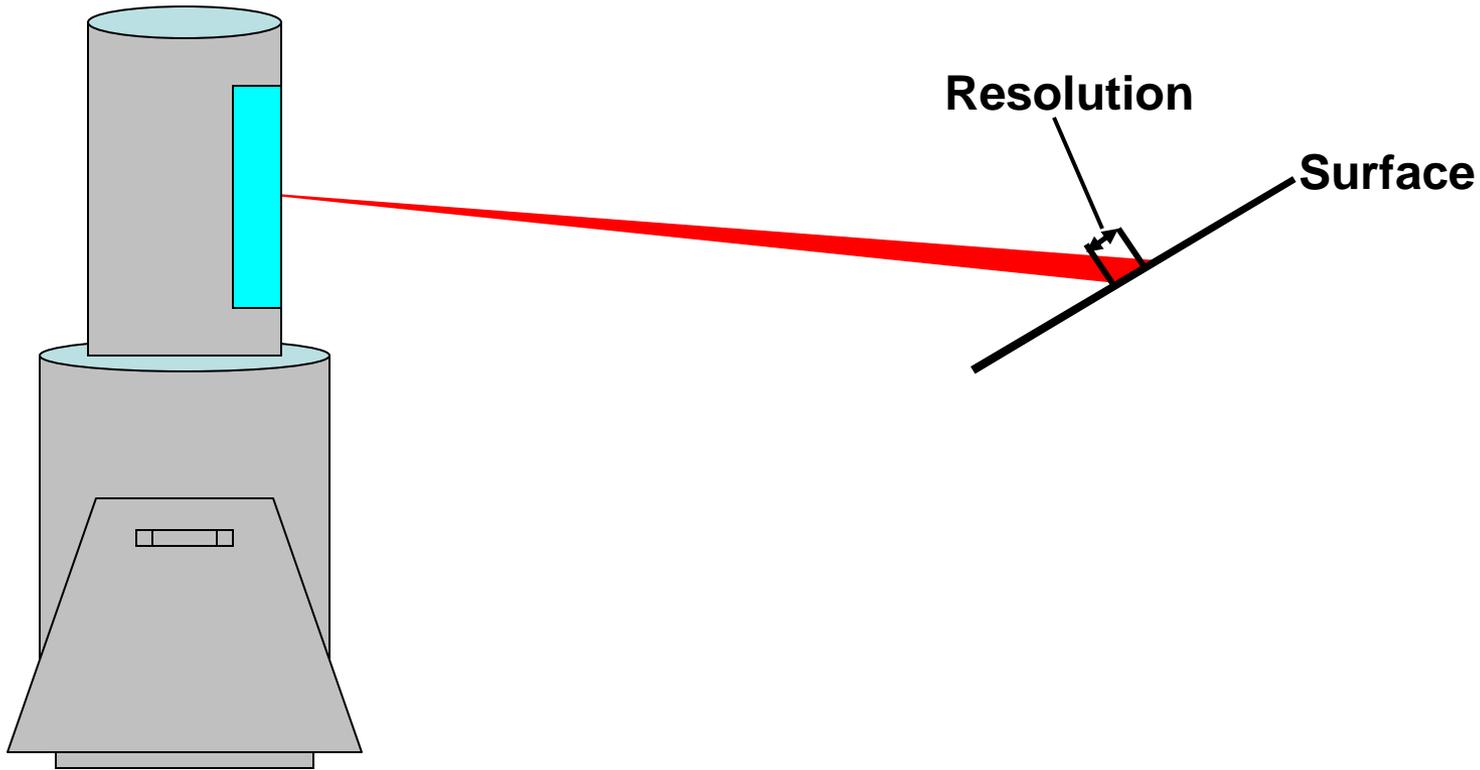
Beam Divergence



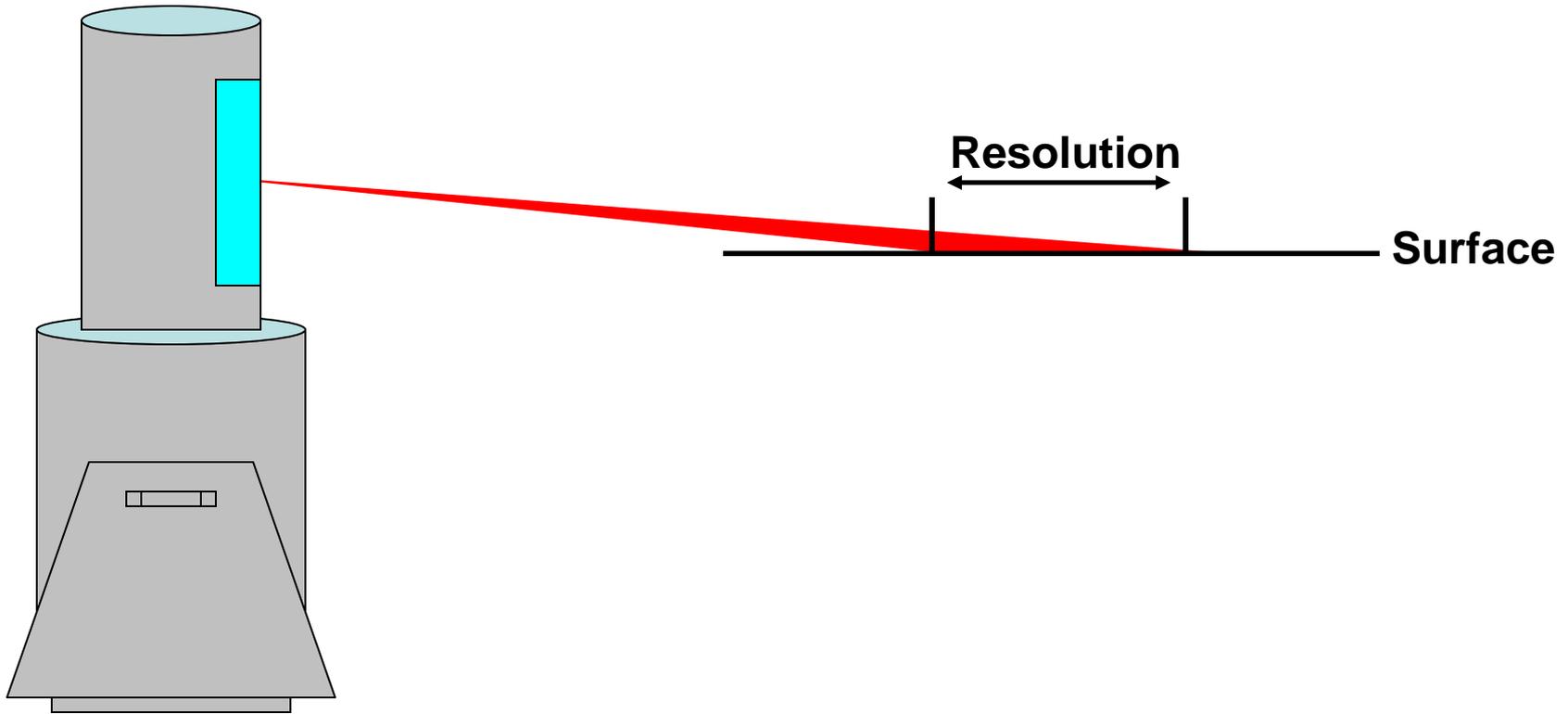
Beam Divergence



Angle of Incidence

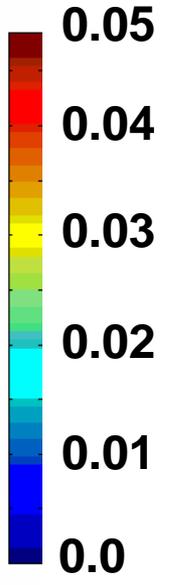
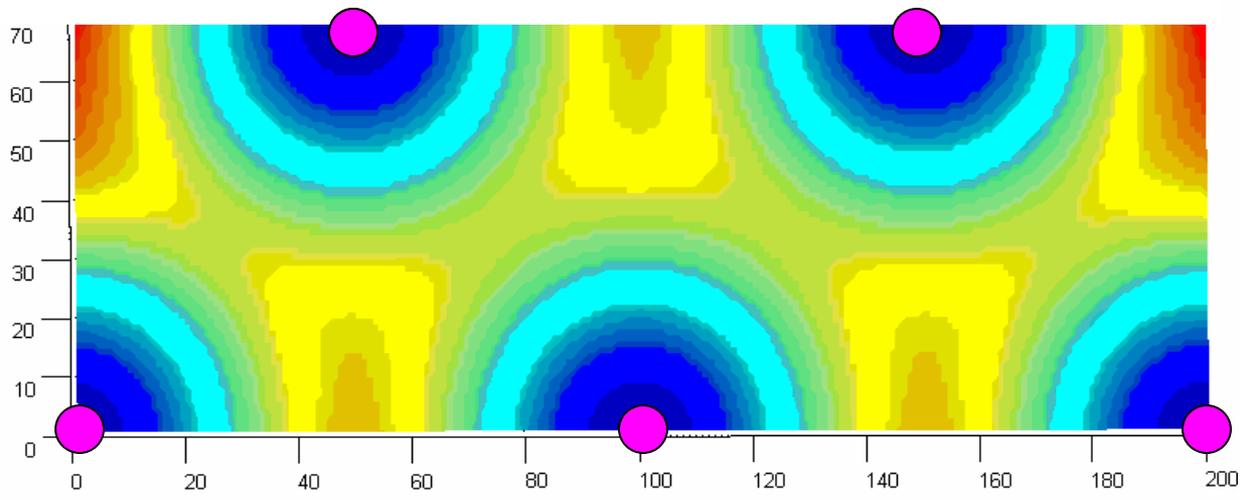


Angle of Incidence



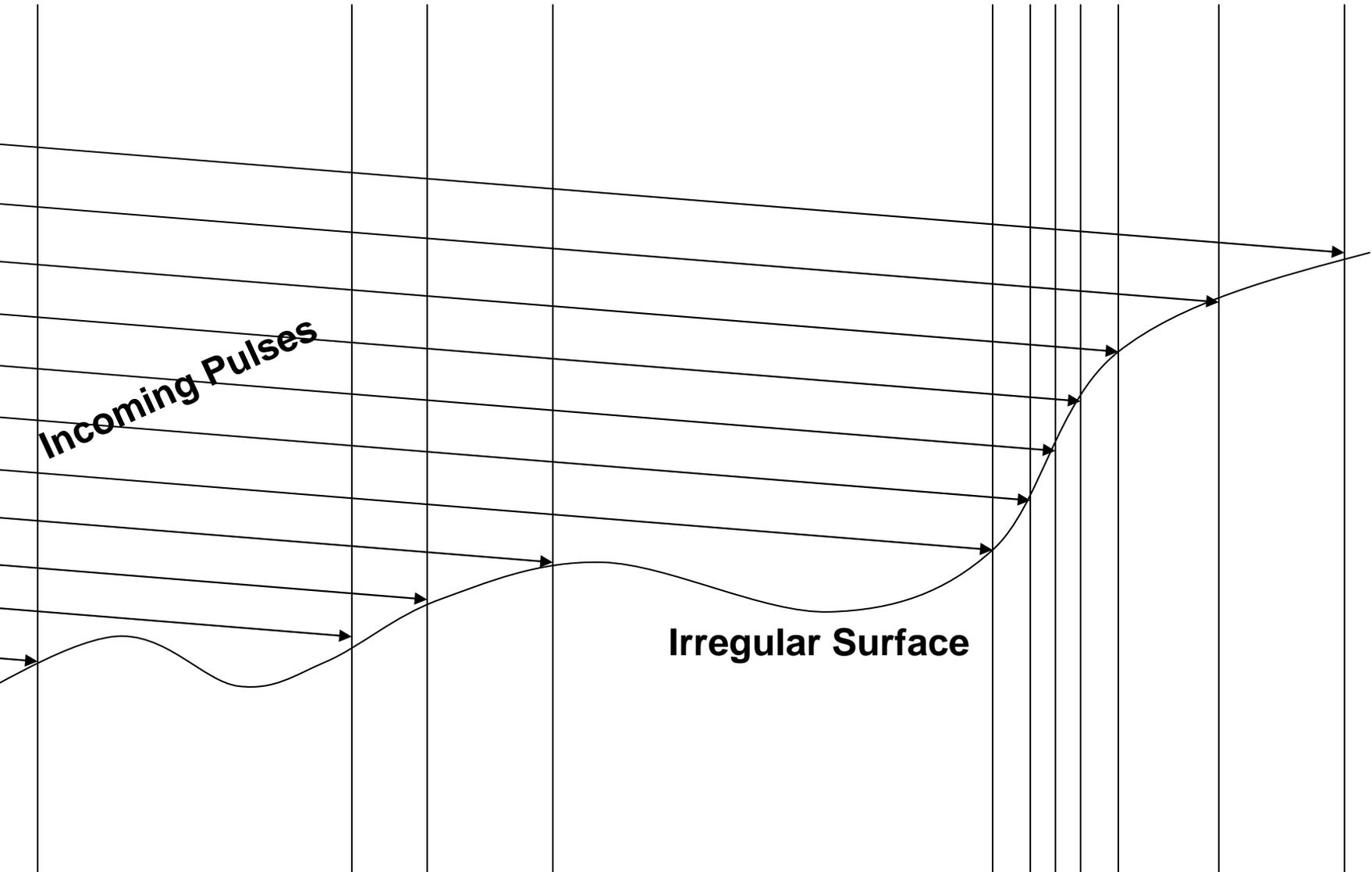
X-Y resolution (m)

Field Y
Dimension
(m)

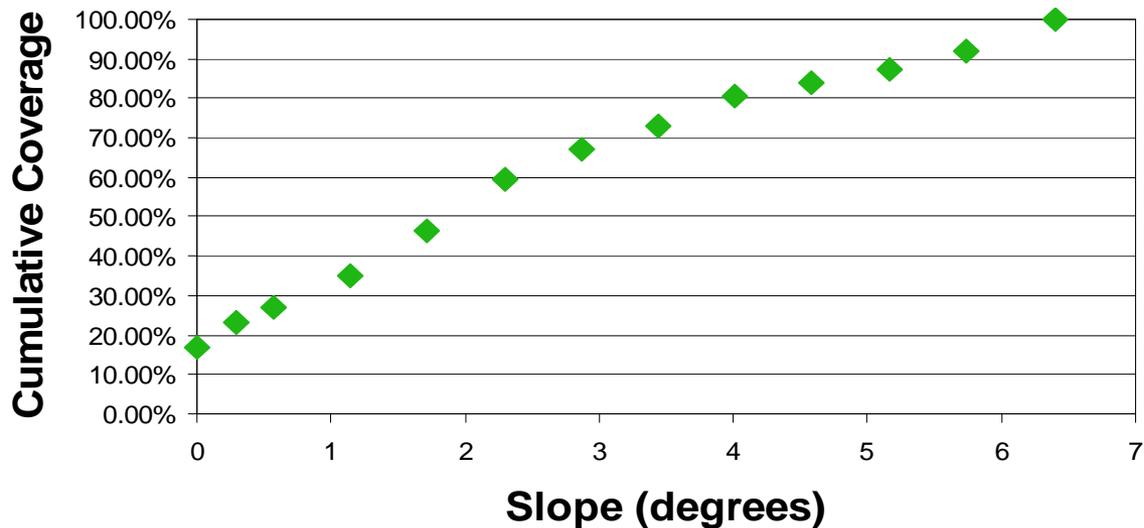


Field X Dimension (m)

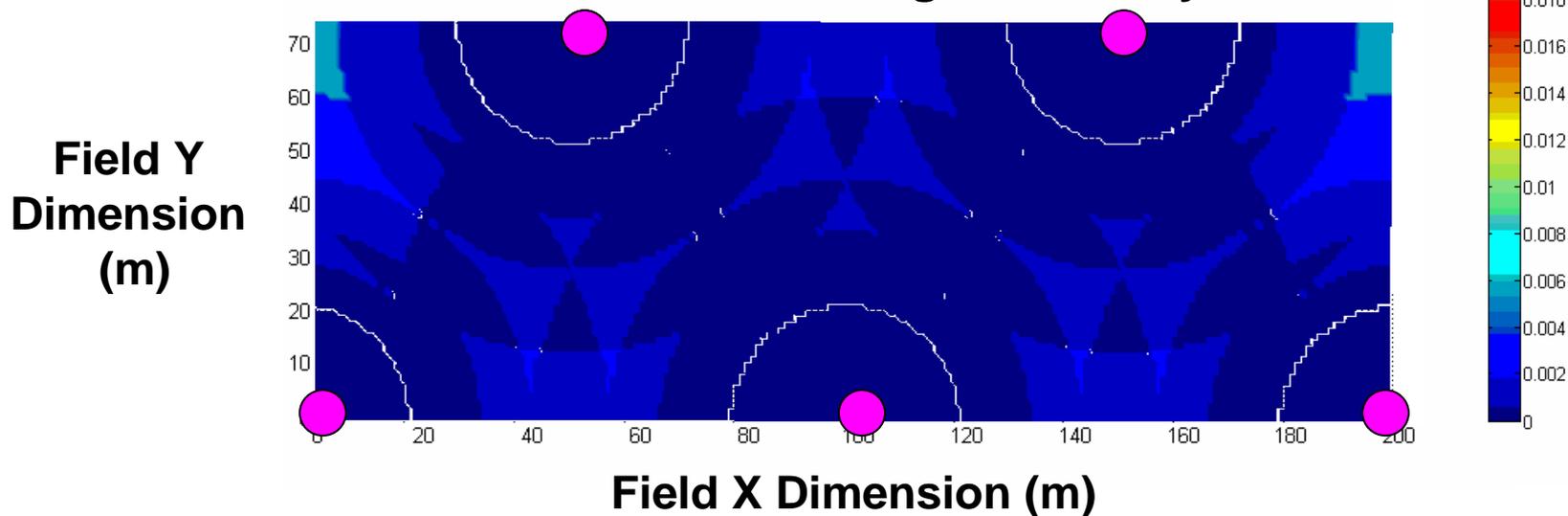
Uneven Sampling/Shadowing Biases High

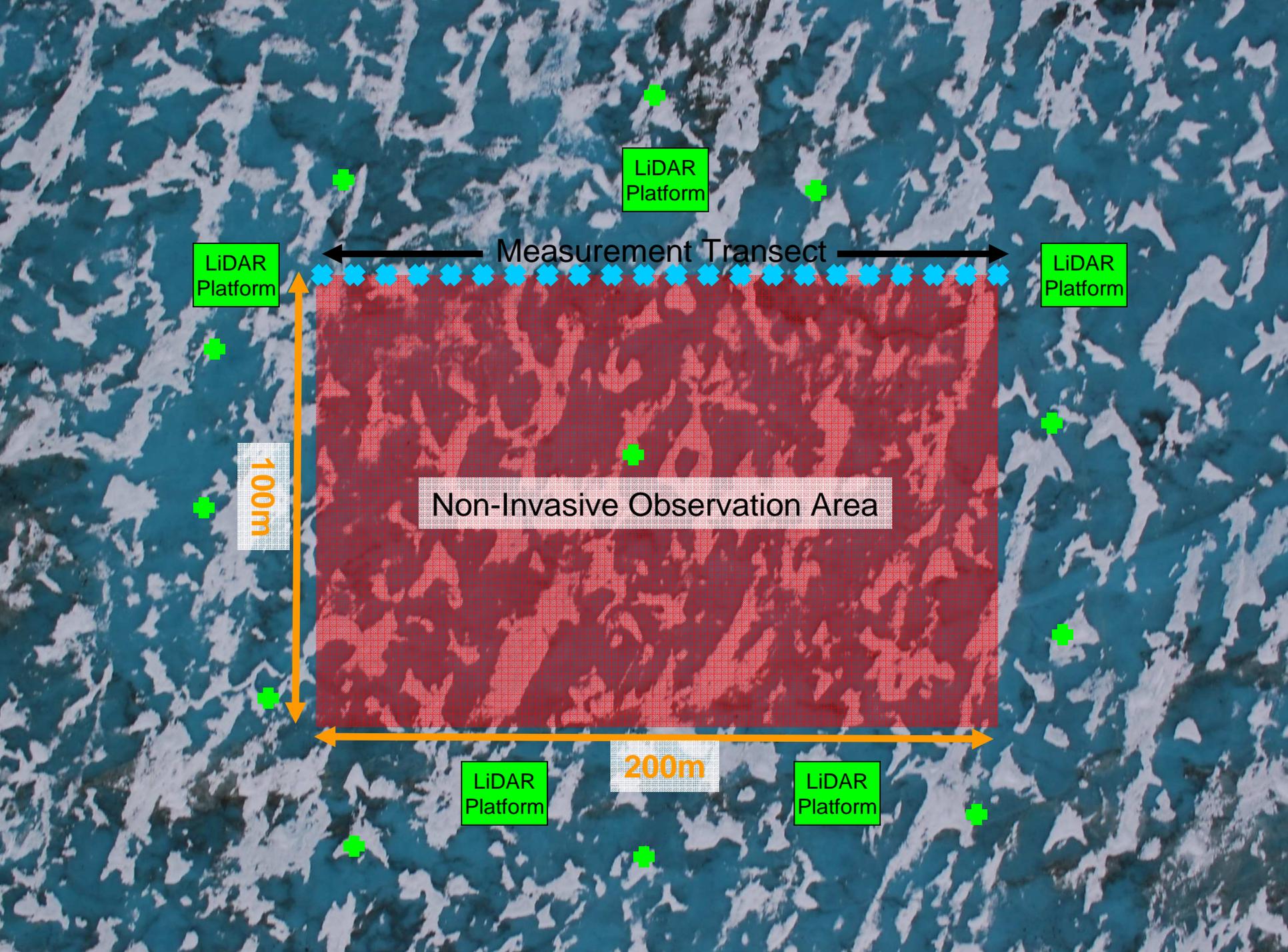


Surface Slope Distribution (25cm)



0.25m Shadowing Probability





LiDAR Platform

LiDAR Platform

LiDAR Platform

Measurement Transect

Non-Invasive Observation Area

100m

200m

LiDAR Platform

LiDAR Platform









ScanPos02

ScanPos03

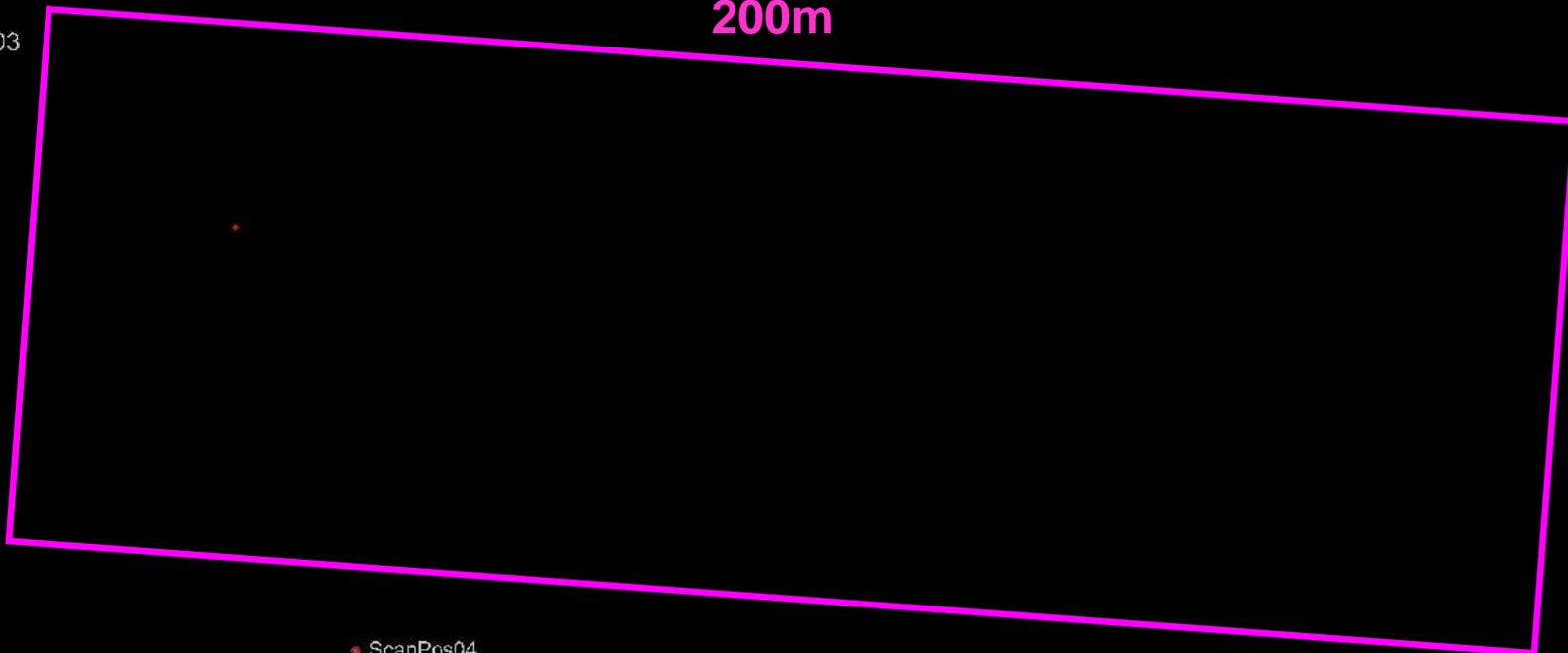
200m

ScanPos05

70m

ScanPos04

ScanPos05





ScanPos03

ScanPos02

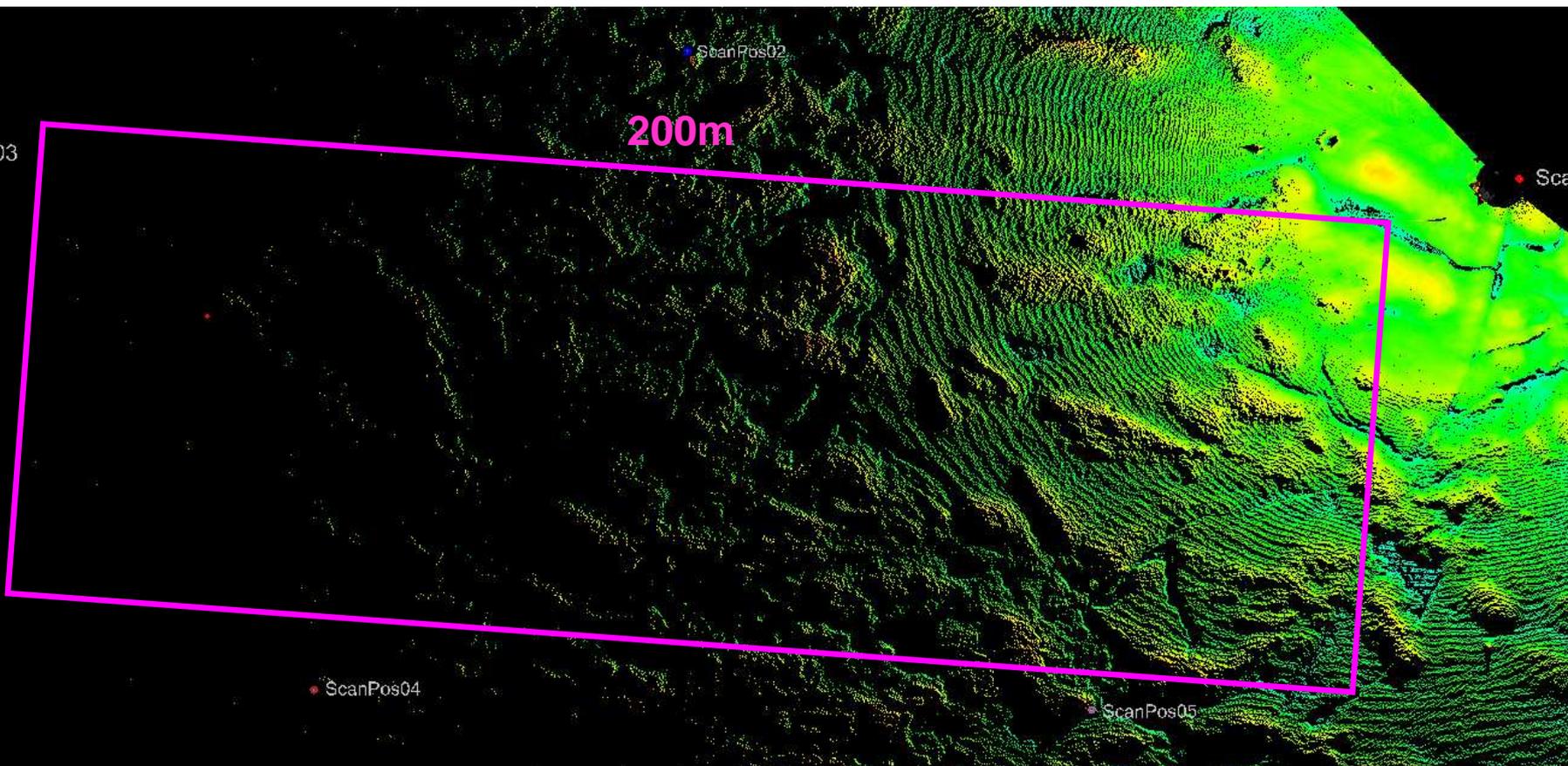
ScanPos01

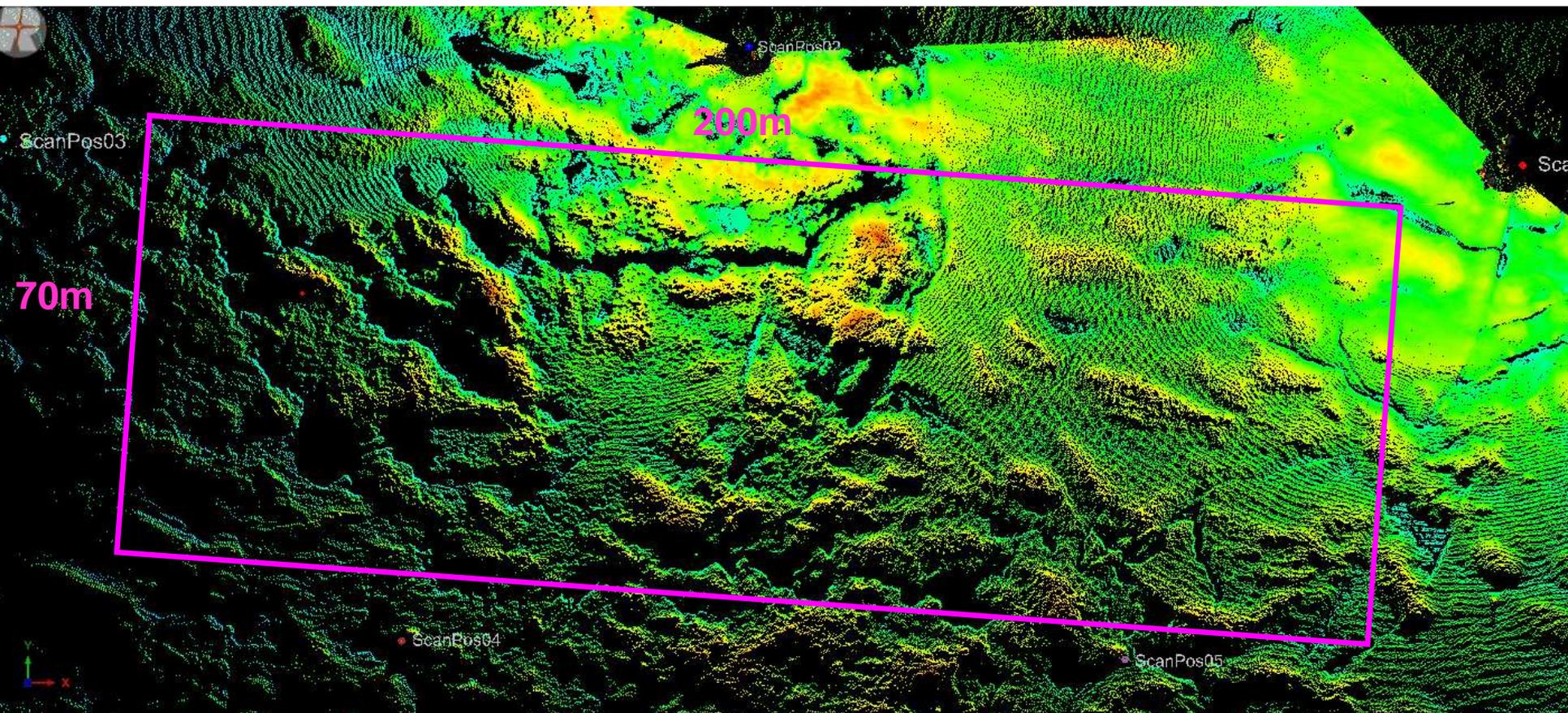
200m

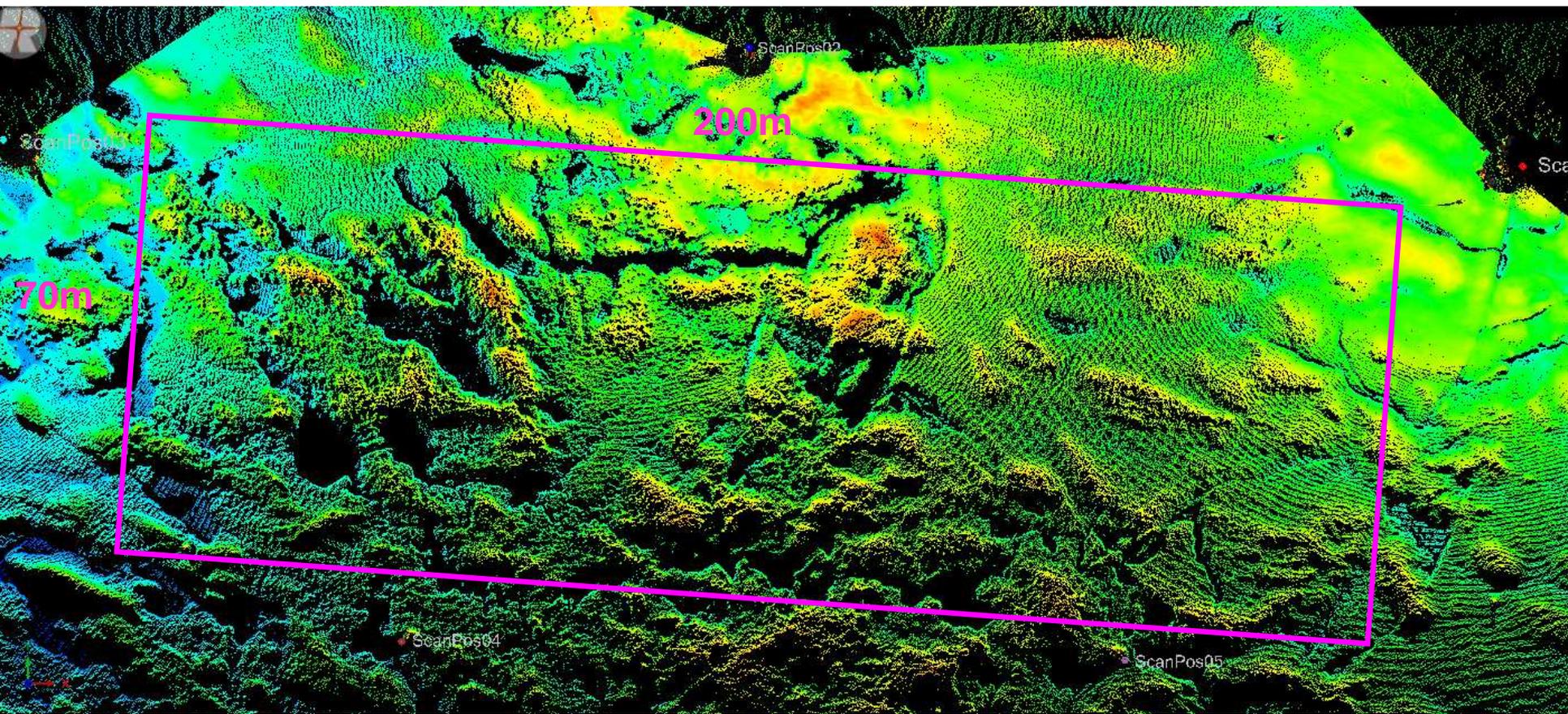
70m

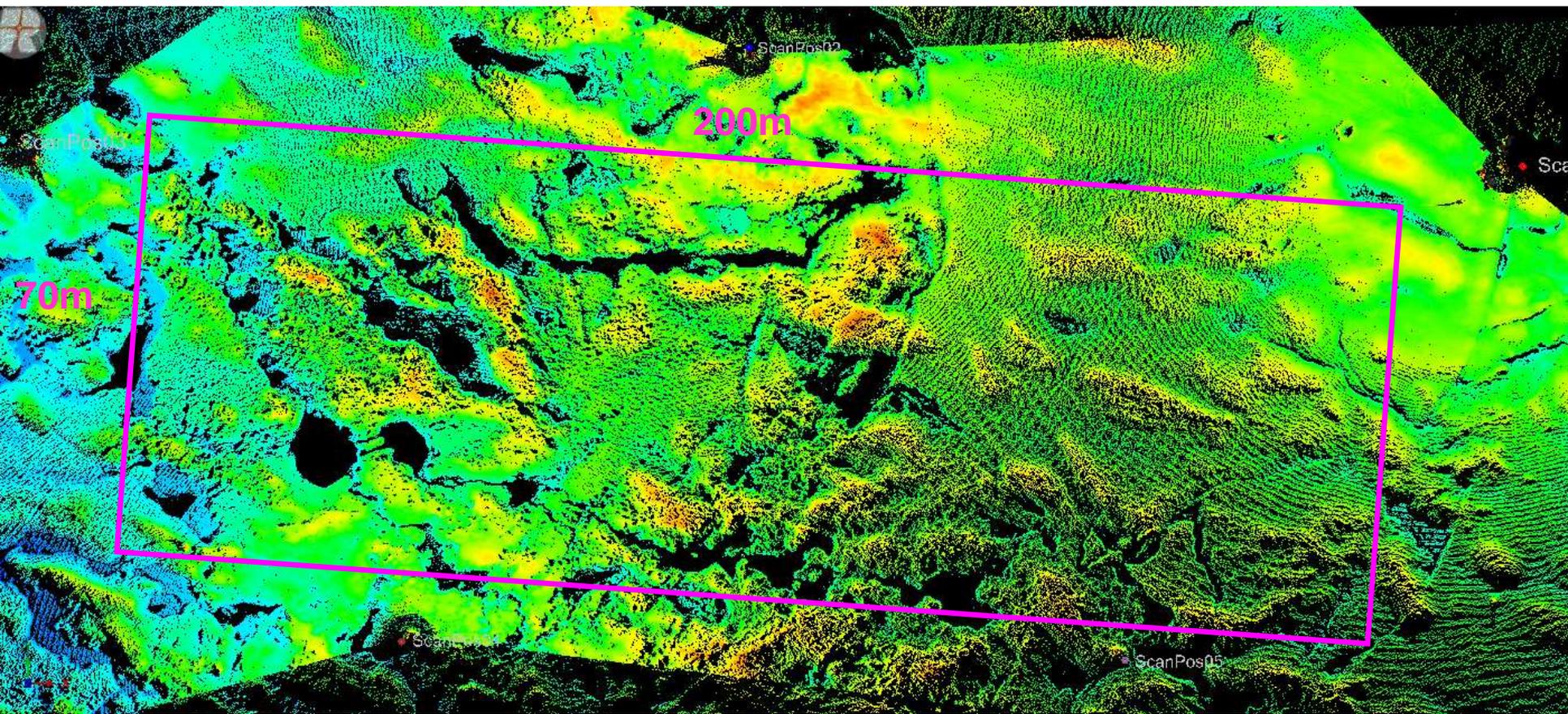
ScanPos04

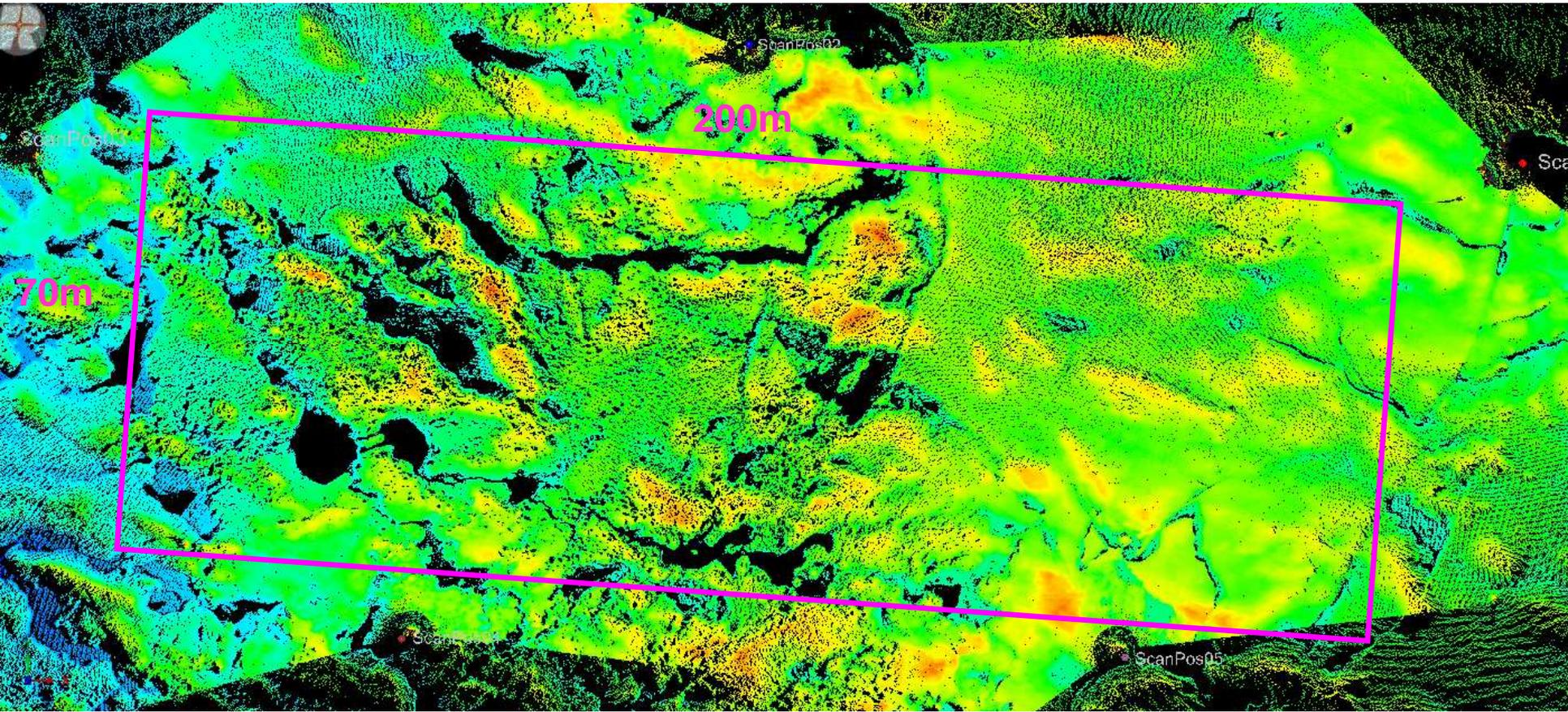
ScanPos05

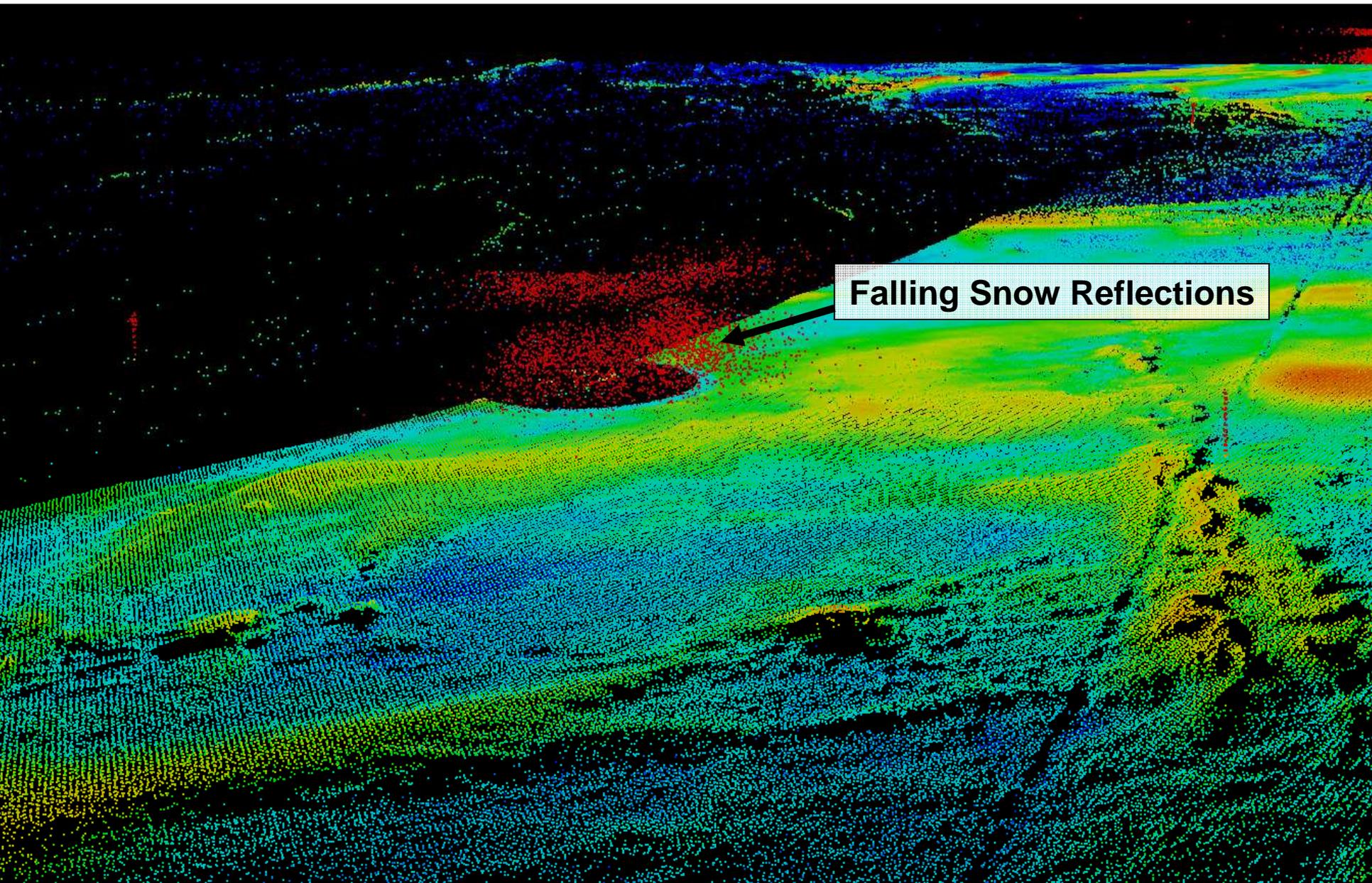




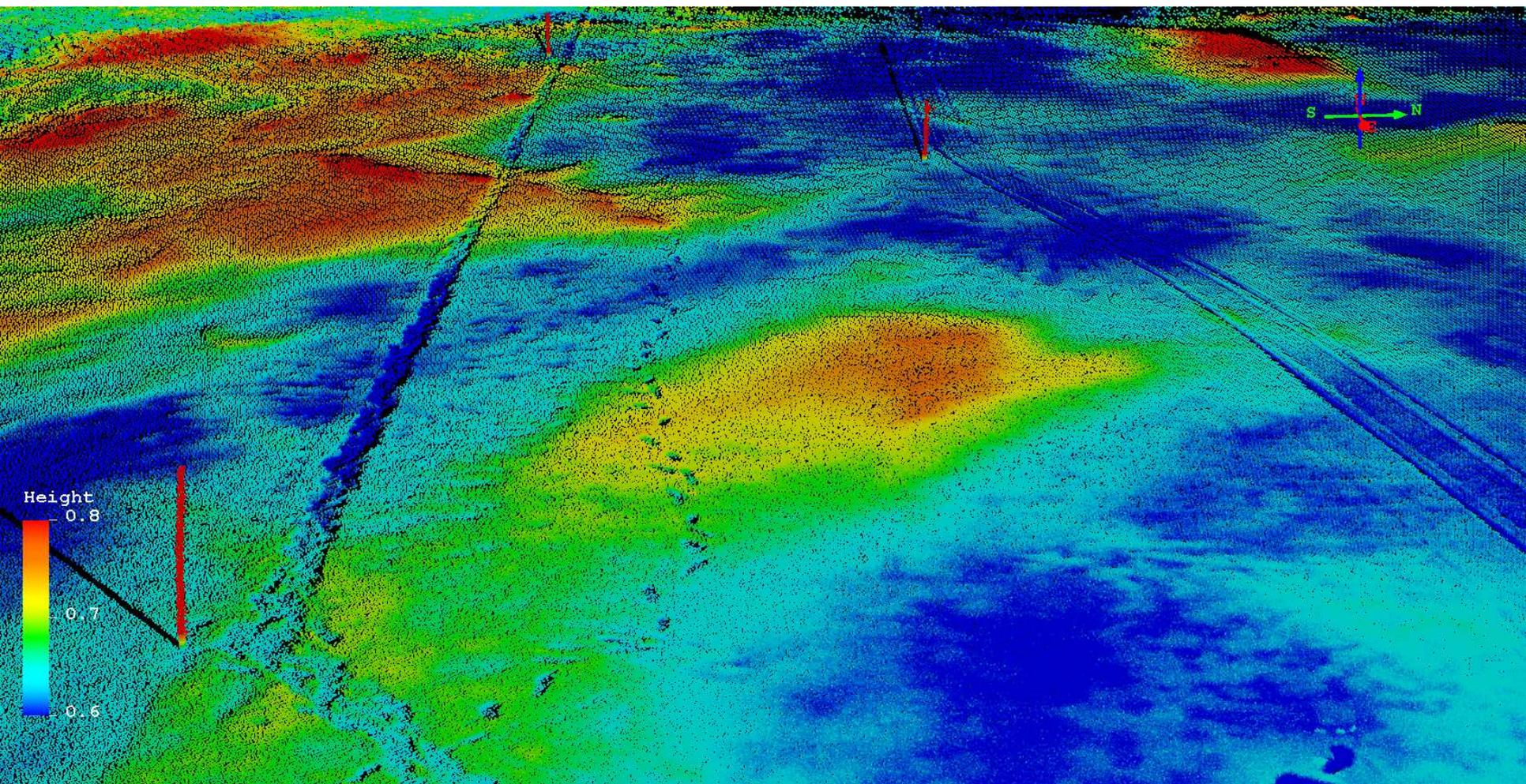






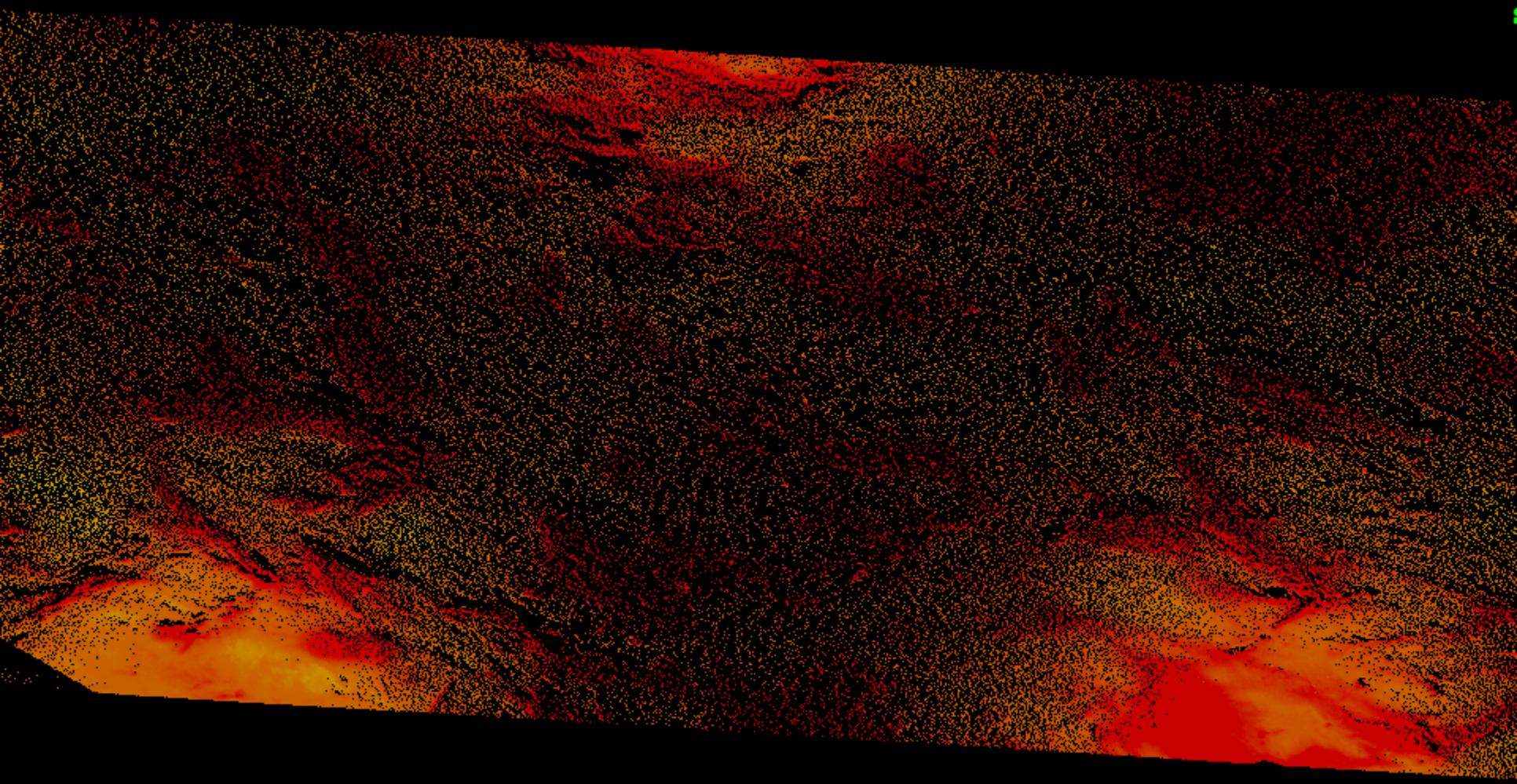
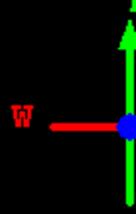


Falling Snow Reflections

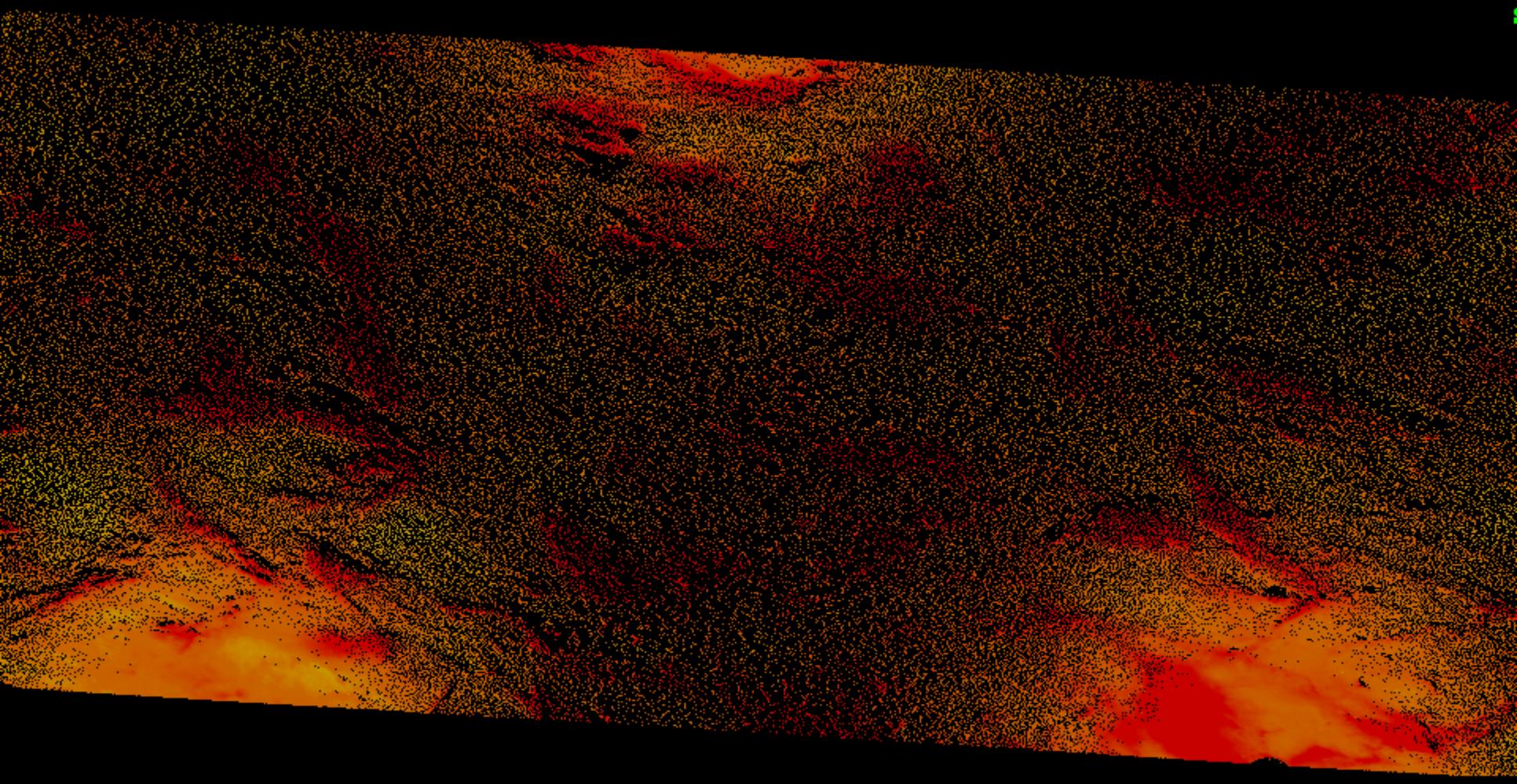
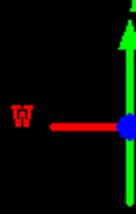


Height
0.8
0.7
0.6

May 20

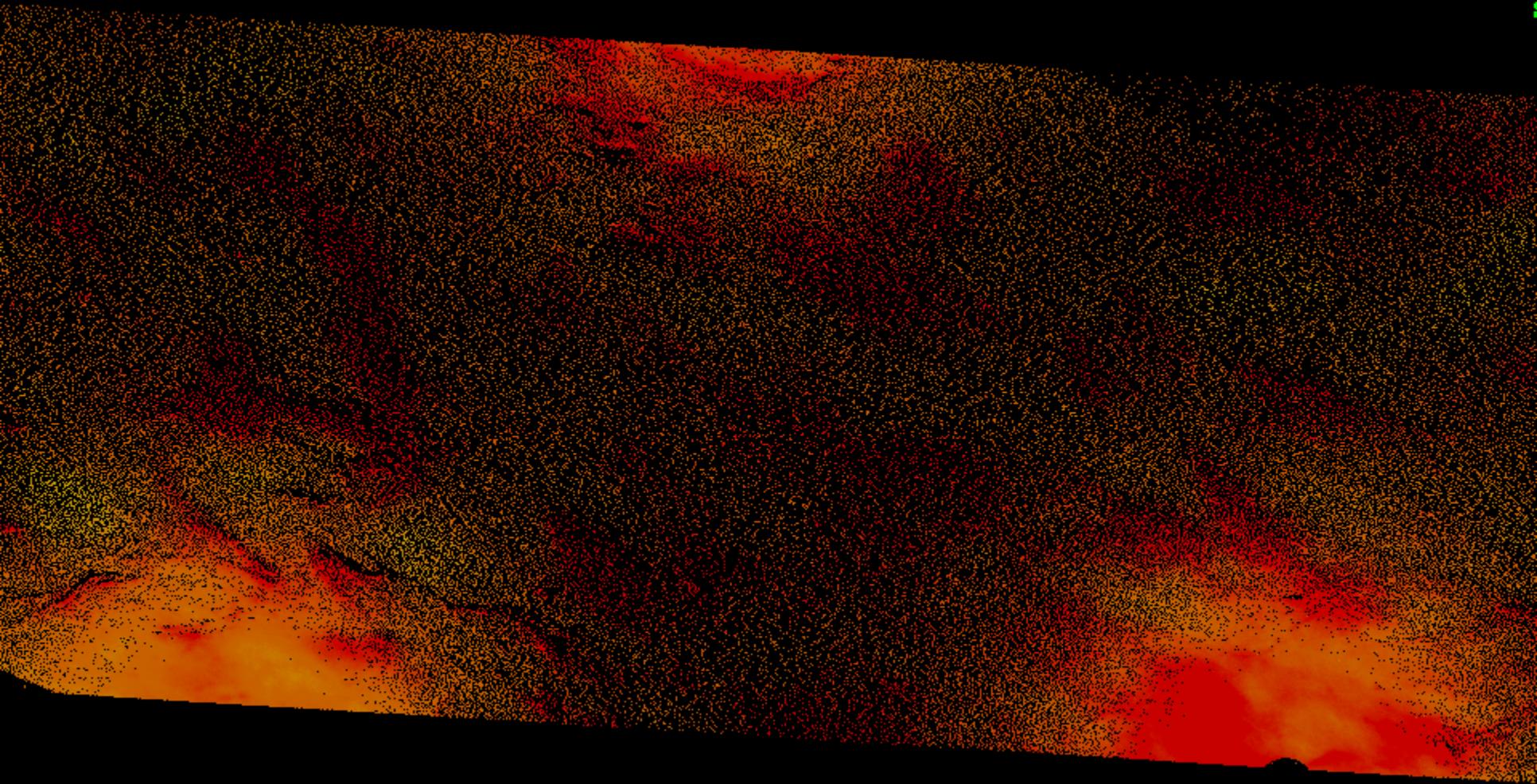


May 29



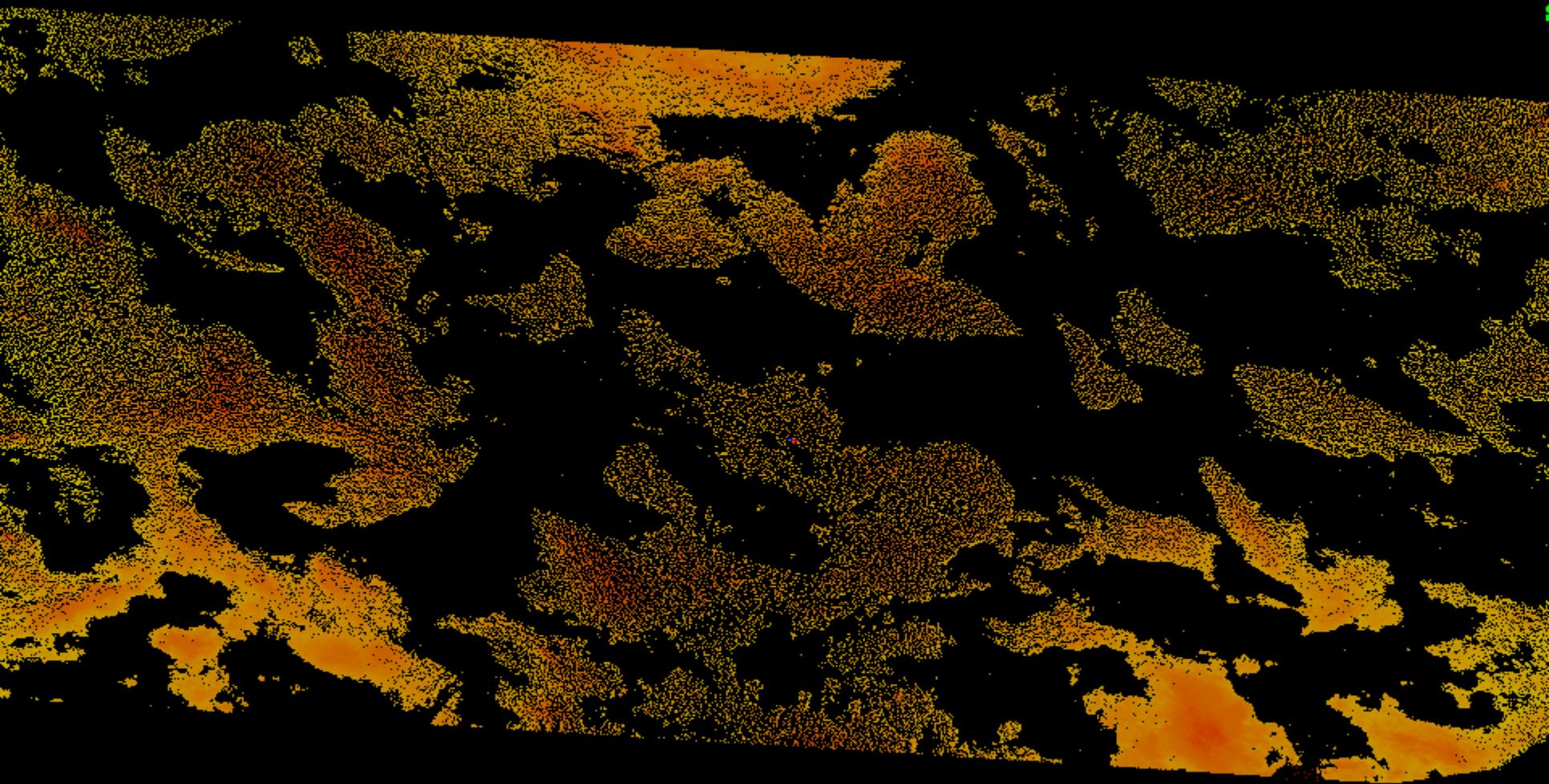
June 1

W

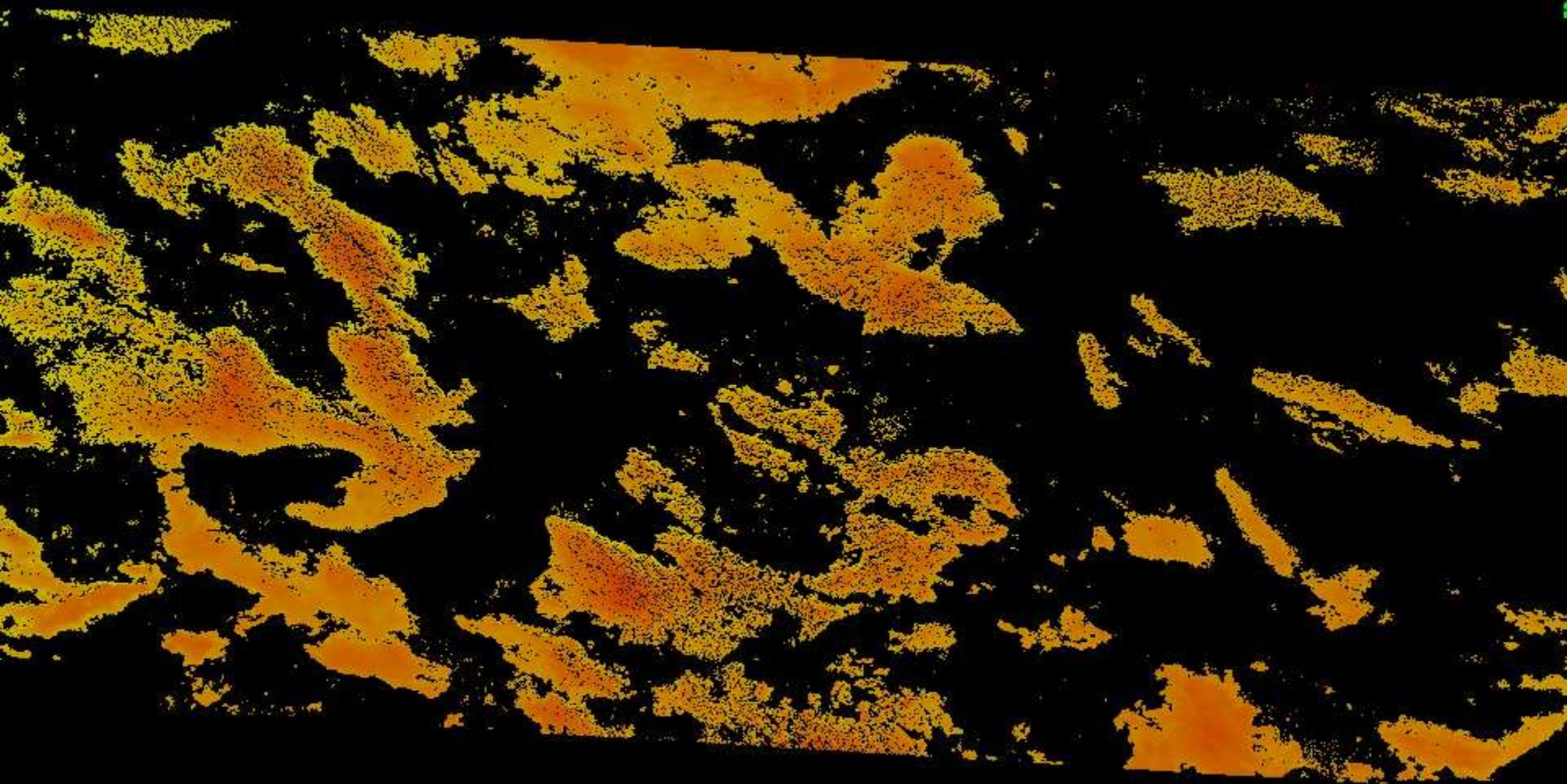


June 6

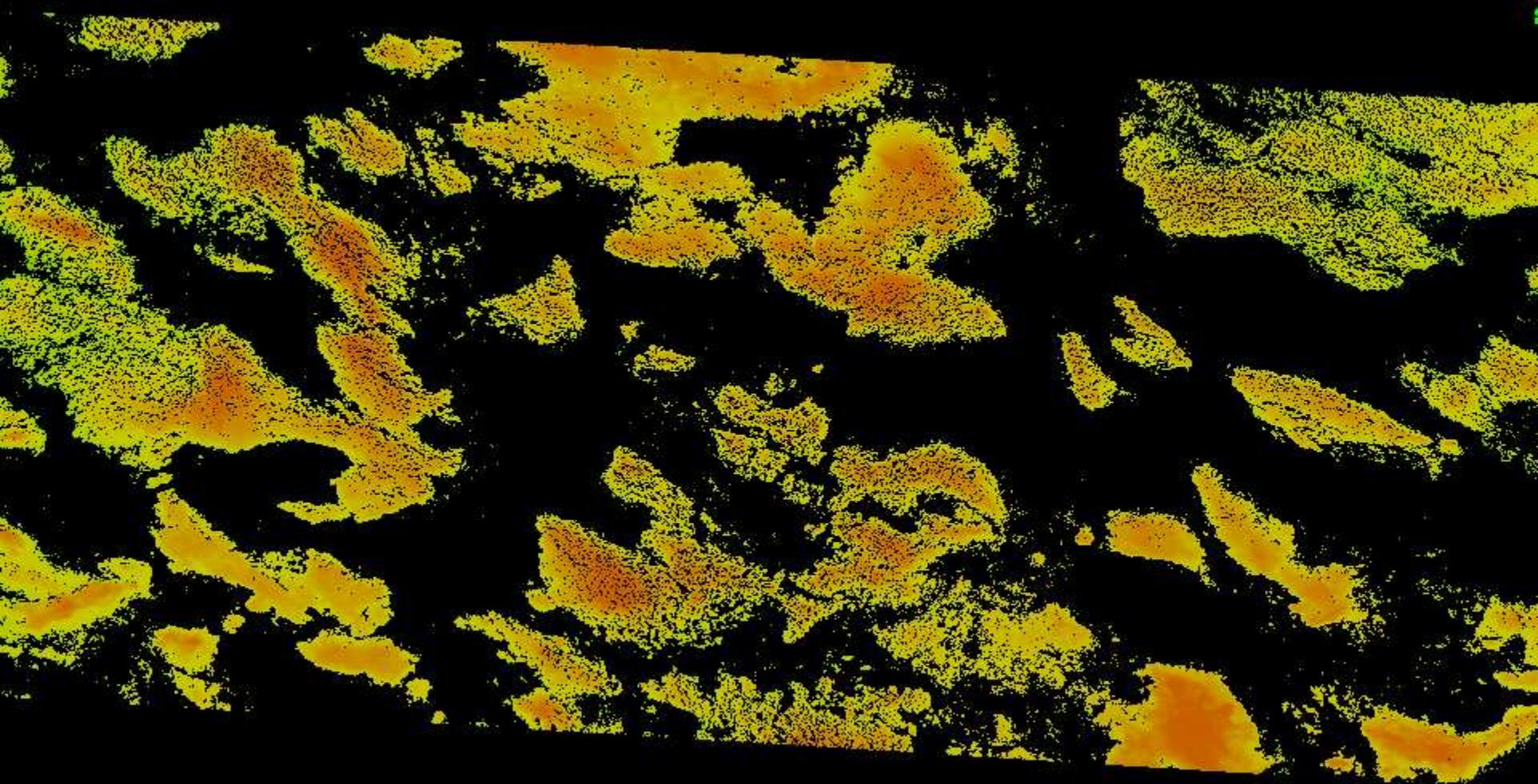
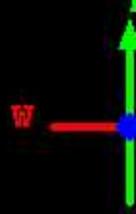
W



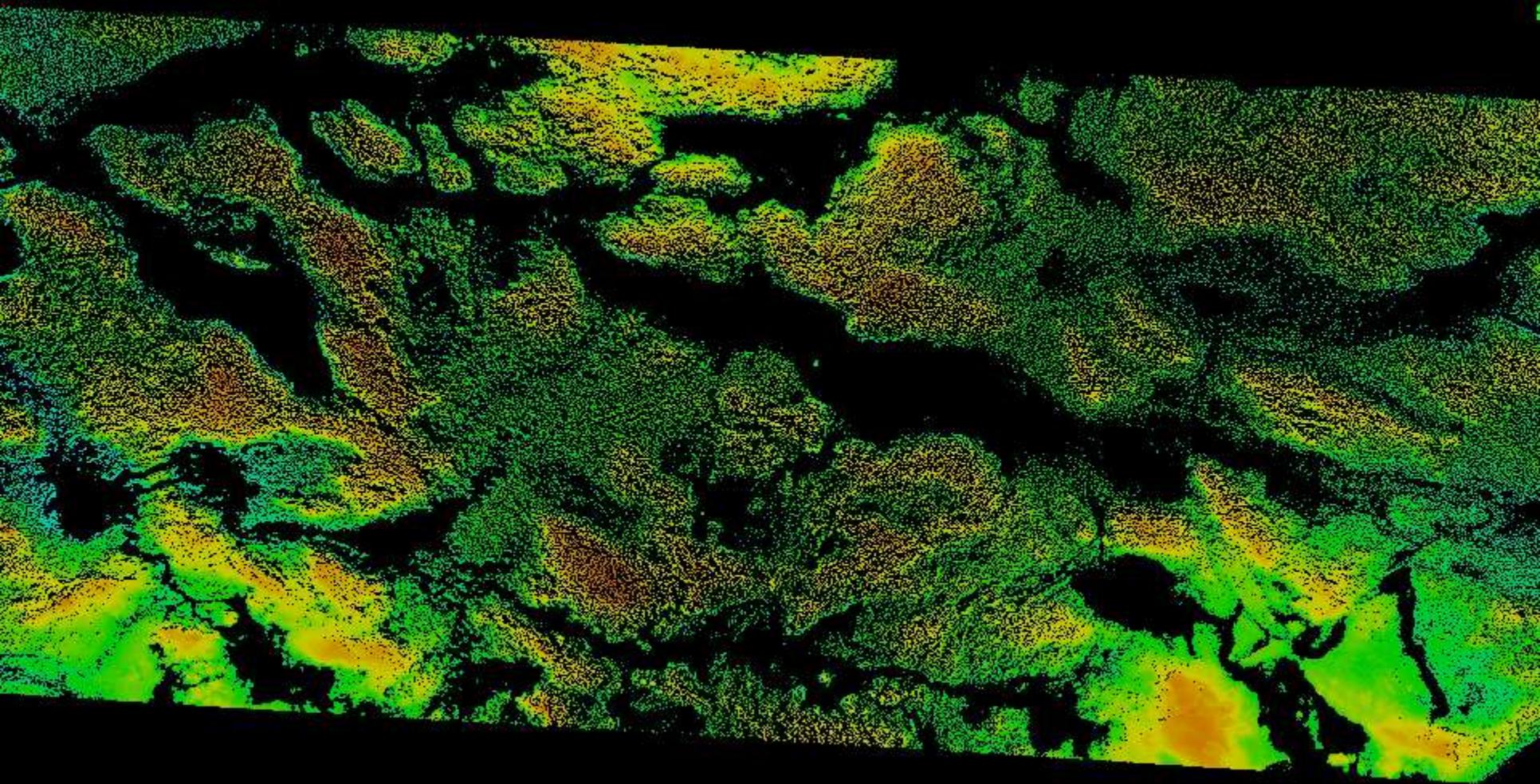
June 7



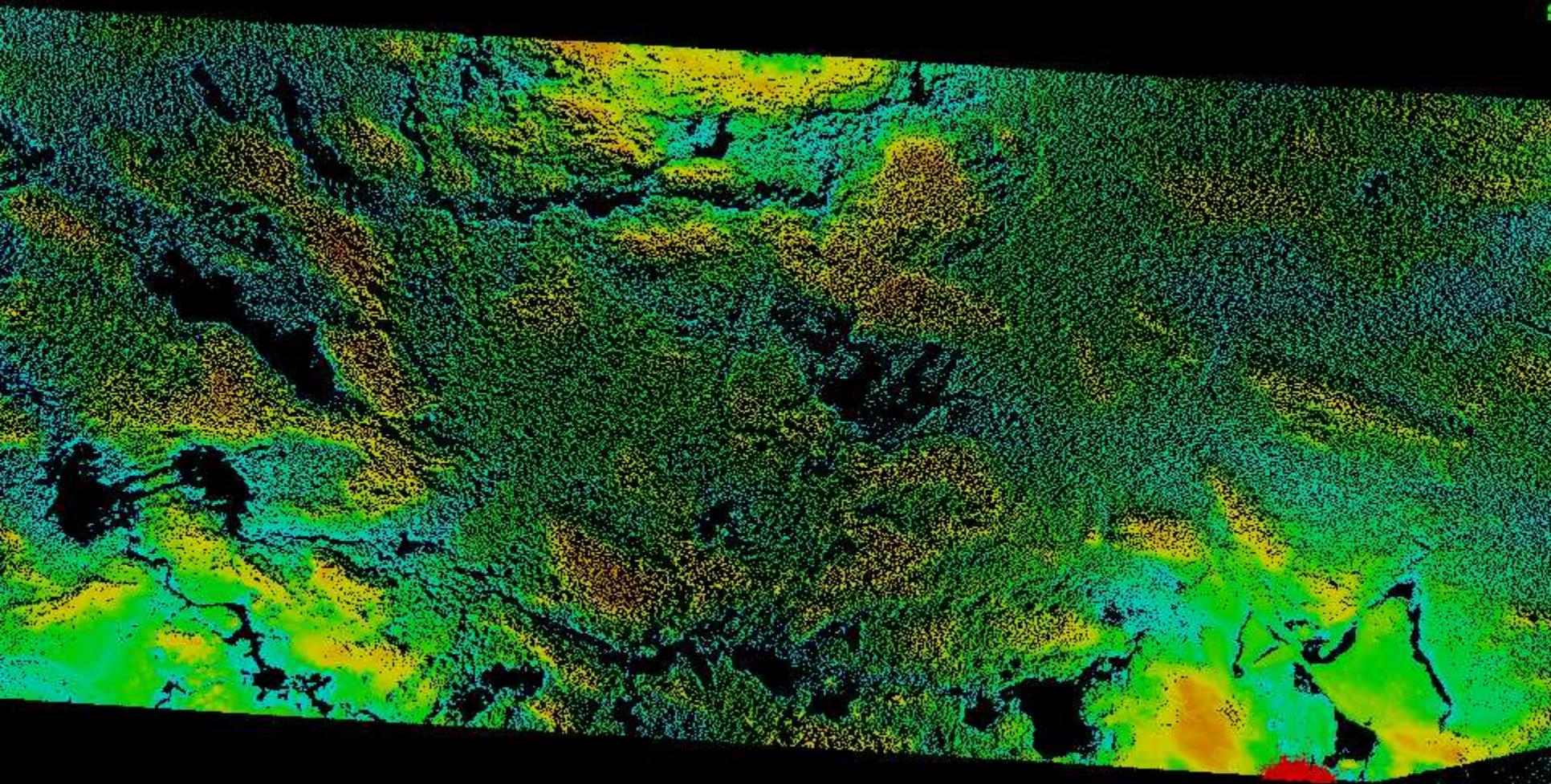
June 9



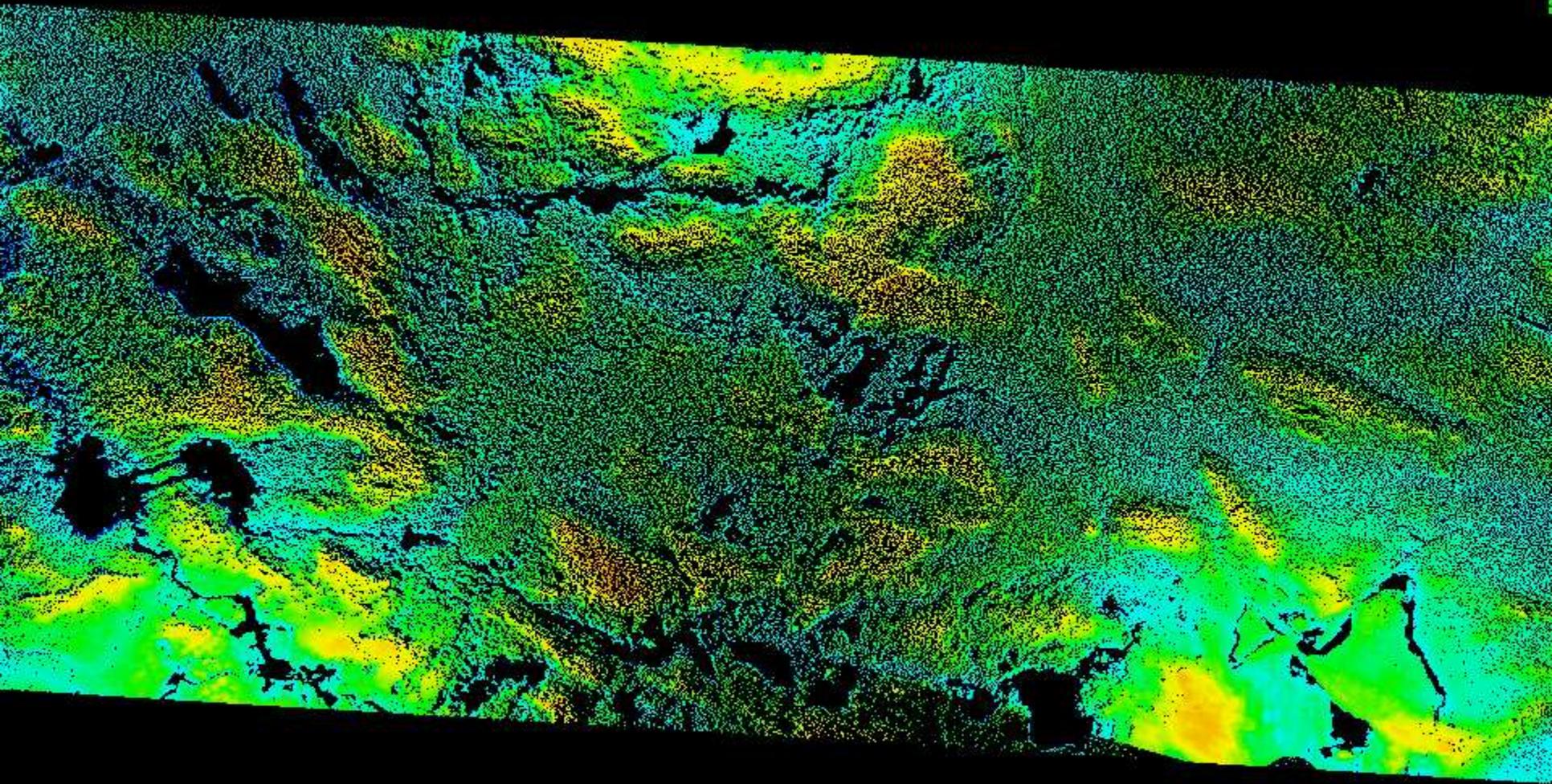
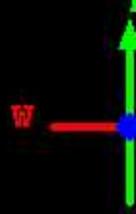
June 11



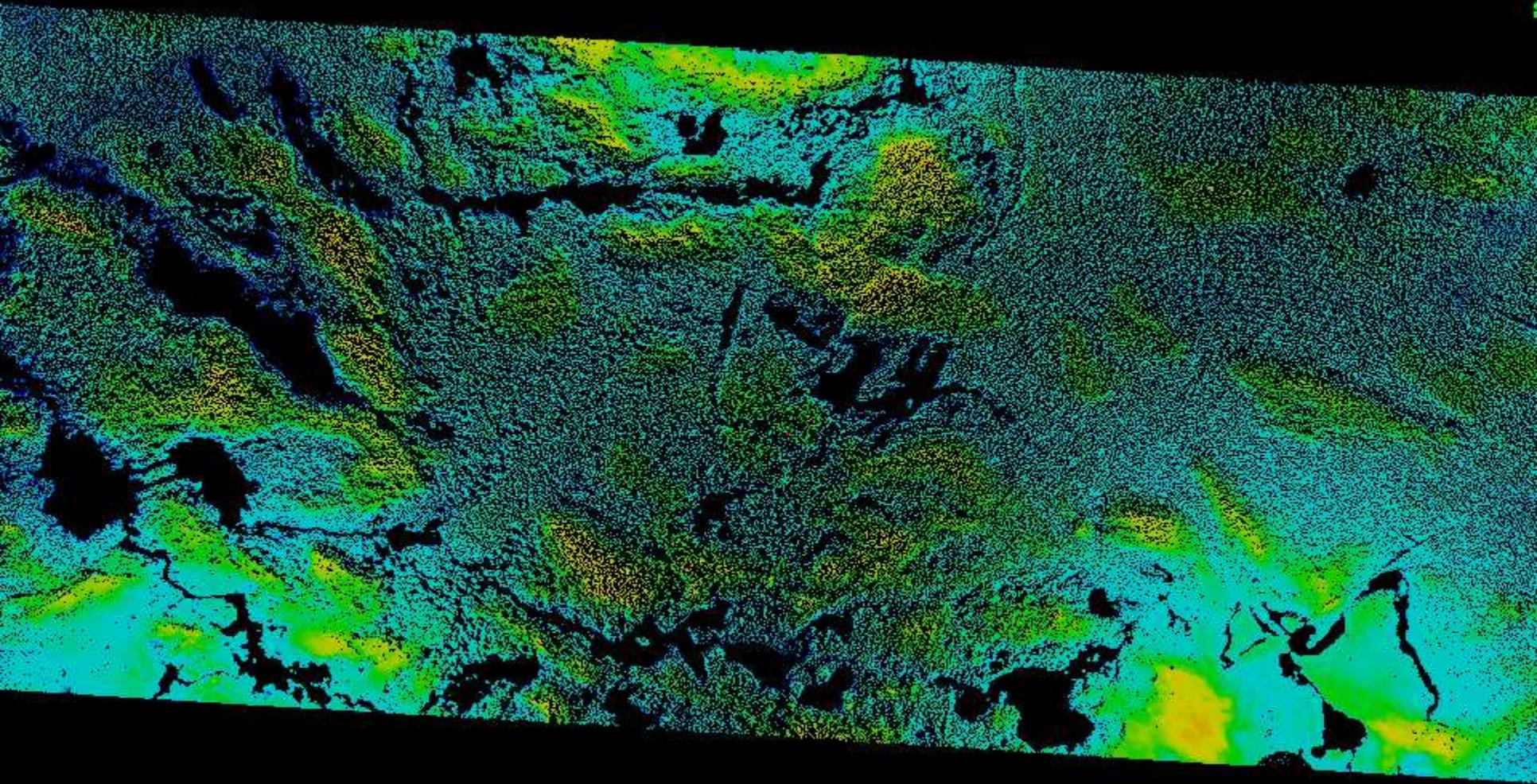
June 13



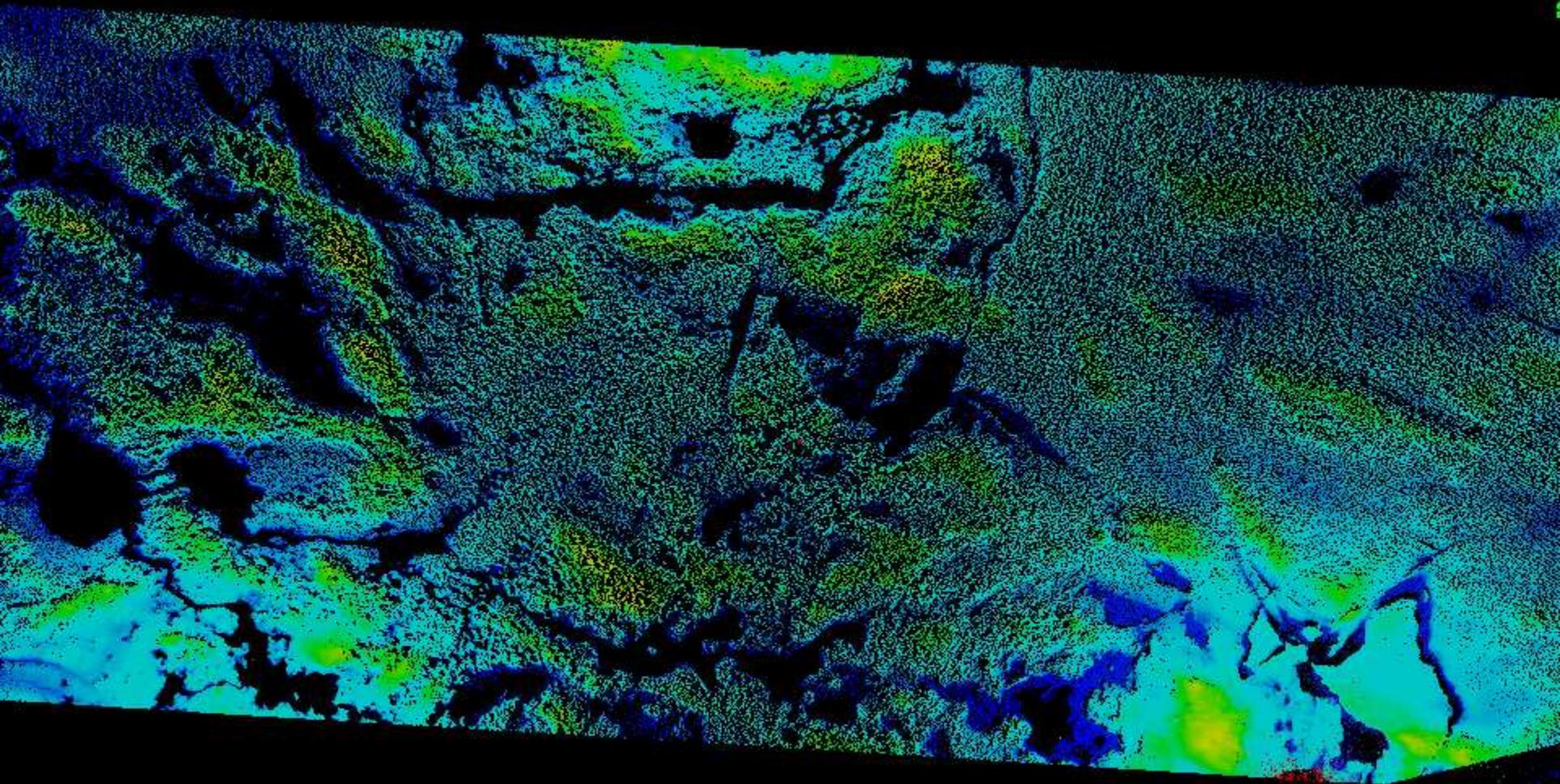
June 15



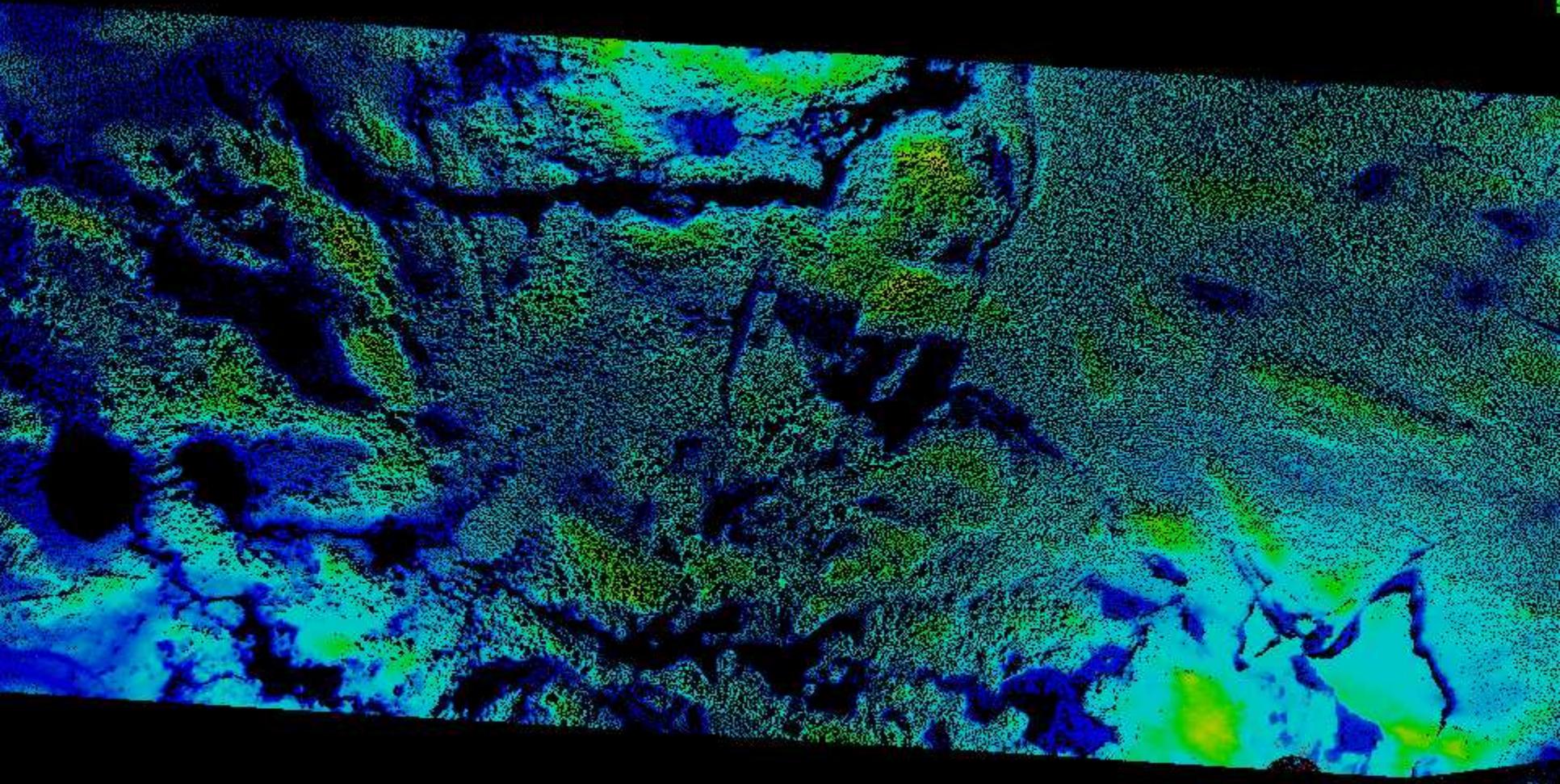
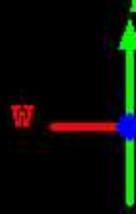
June 16



June 19

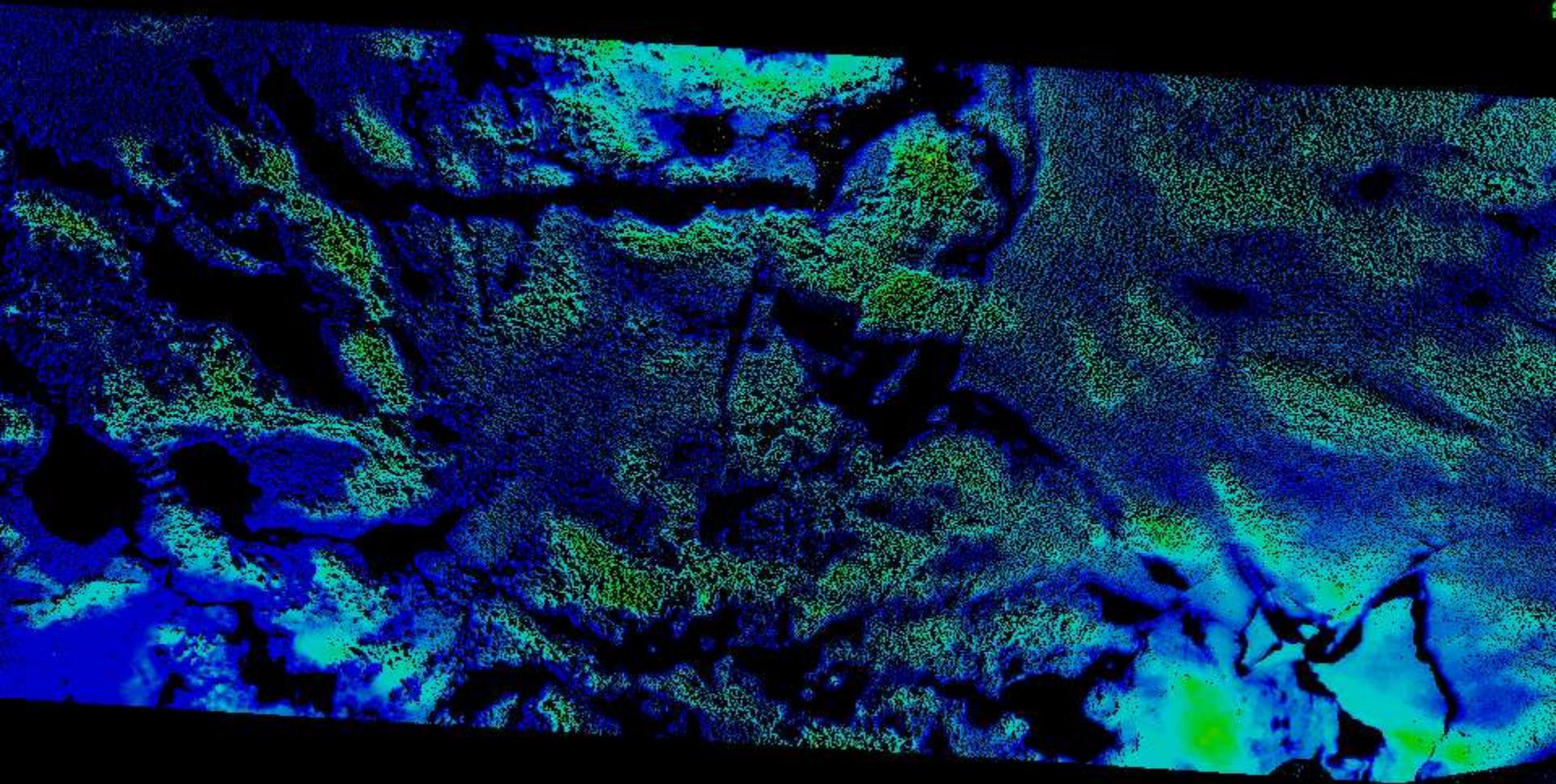


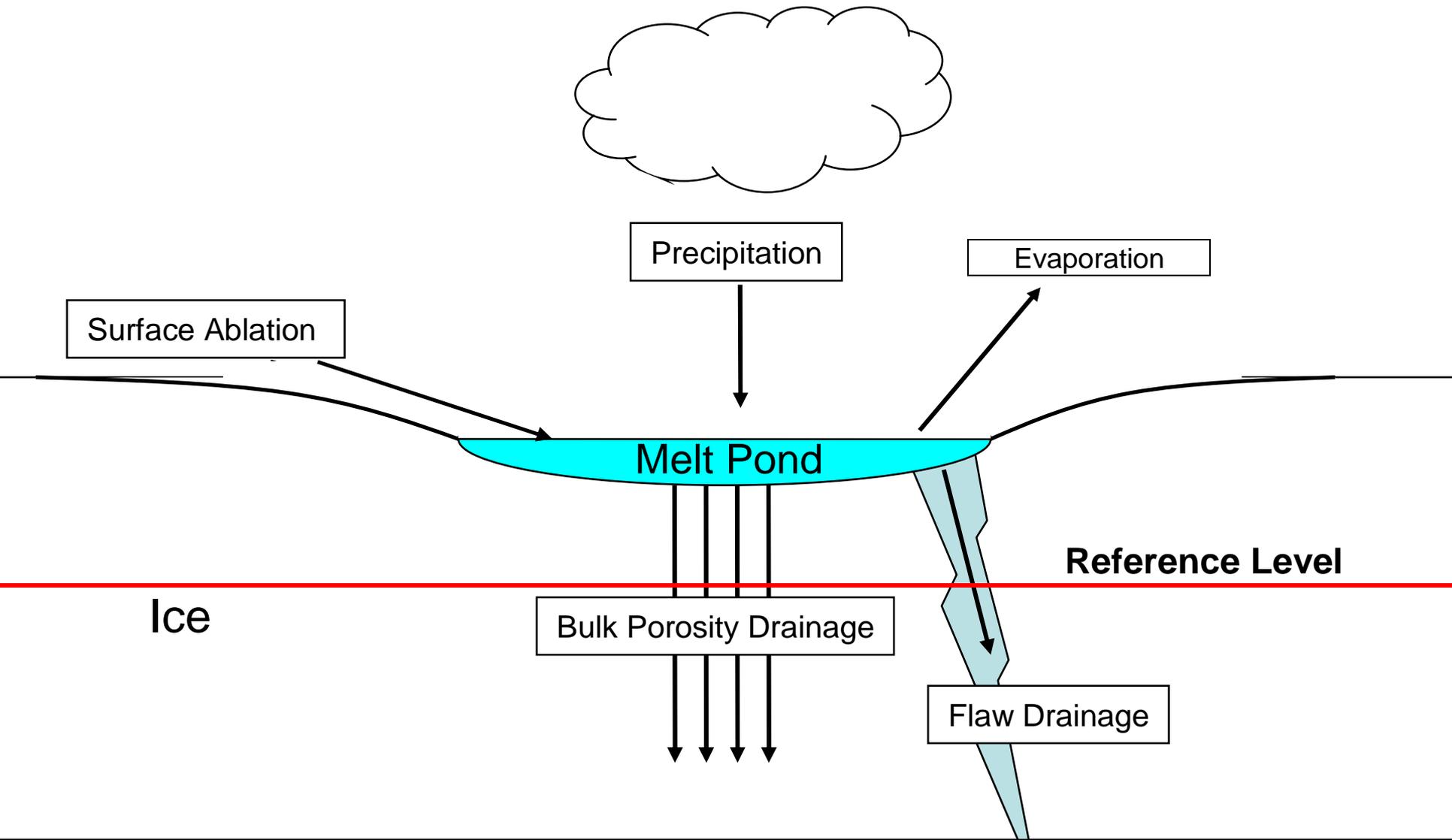
June 22



June 24

W





Surface Ablation

Precipitation

Evaporation

Melt Pond

Reference Level

Ice

Bulk Porosity Drainage

Flaw Drainage

Ocean

Measured by Probing along Transect

Measured by LiDAR

$$h_{total} = h_{ice} + h_{snow} + h_{water}$$

Solve for

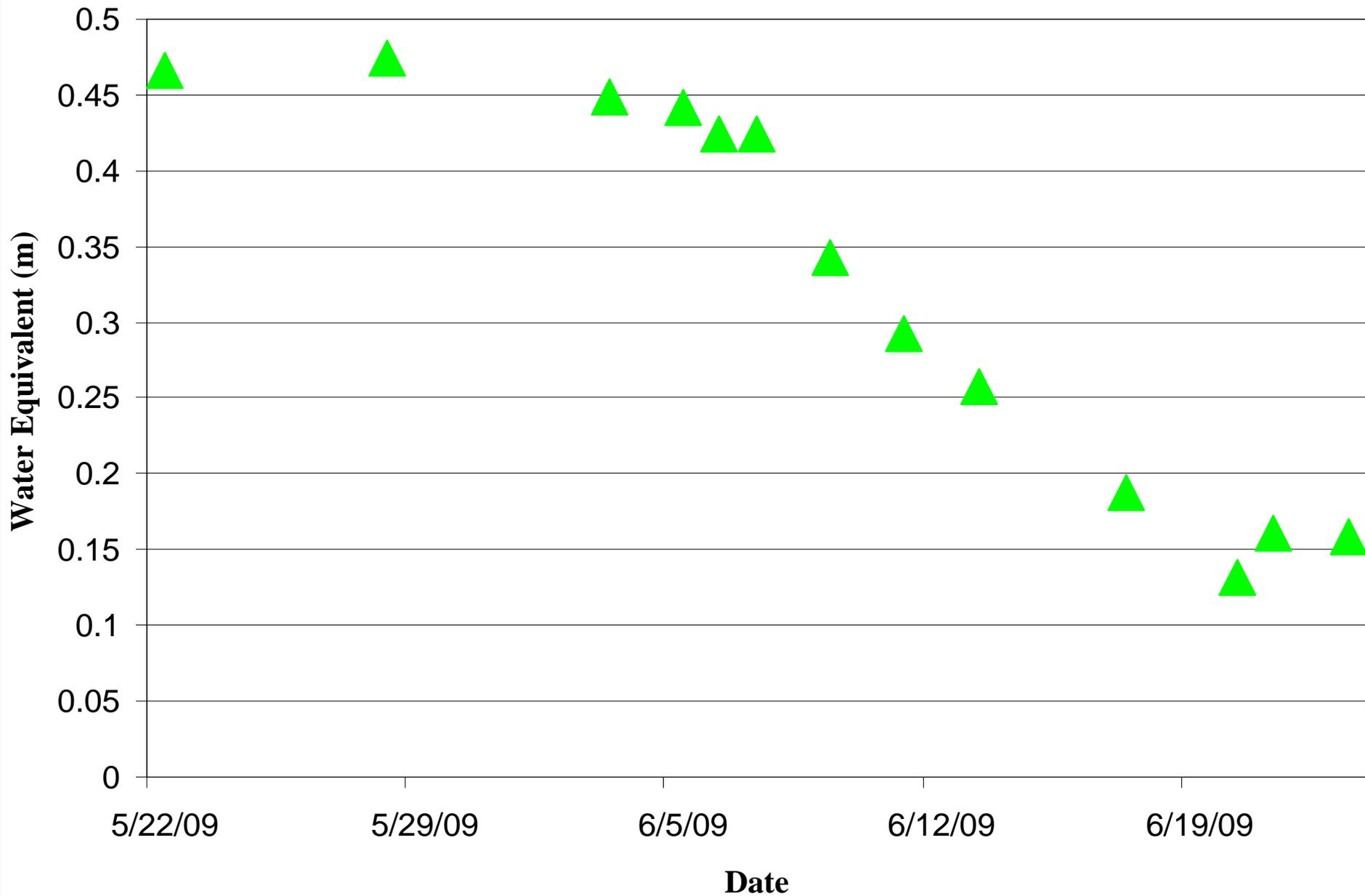
$$h_{water} = \frac{\rho_{ice} h_{ice} + \rho_{snow} h_{snow} + \rho_{water} h_{water}}{\rho_{water}}$$

0.9 g/cm³ below water
0.7g/cm³ above water

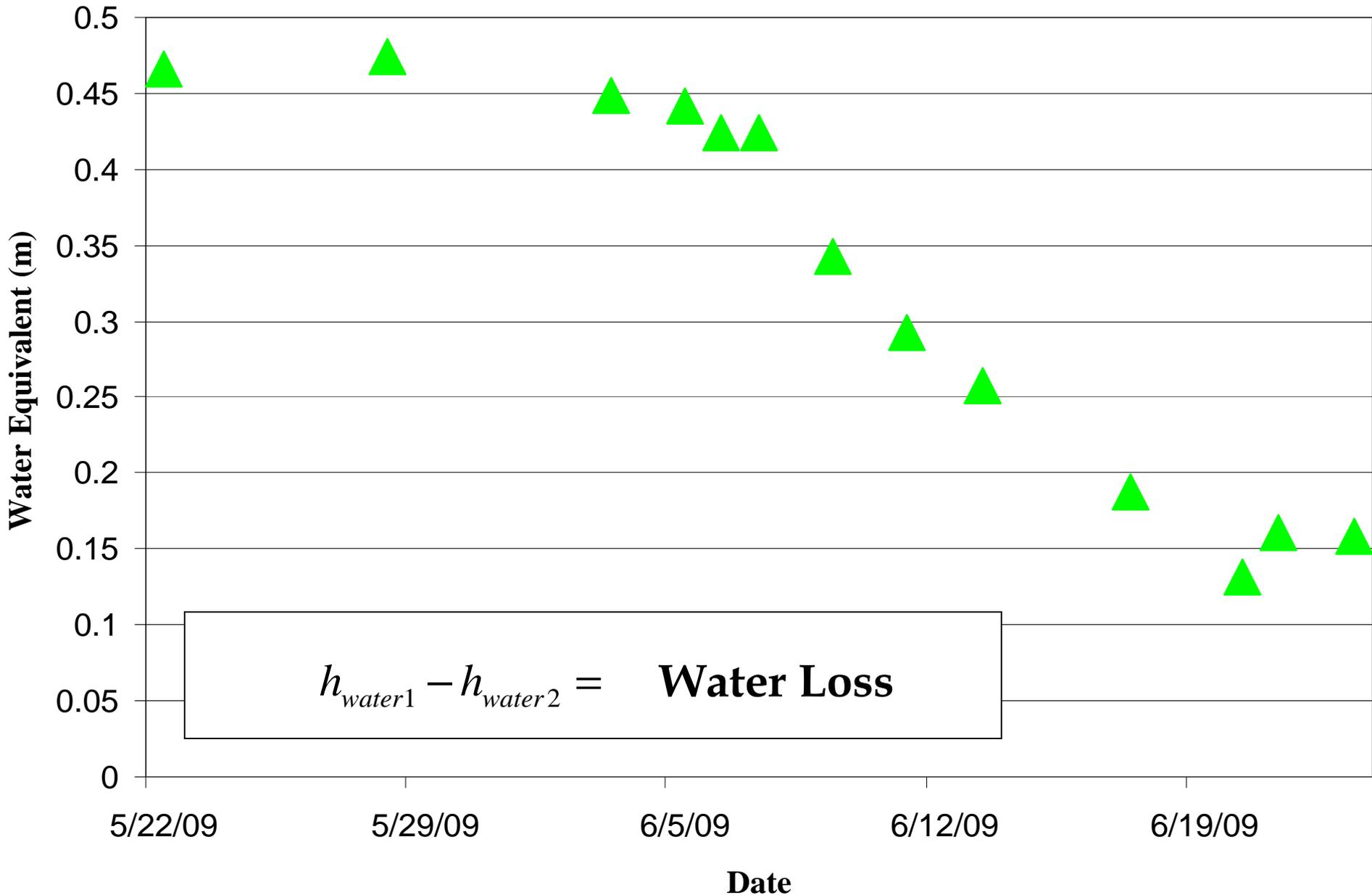
Measured using
SWE corer

1.0g/cm³

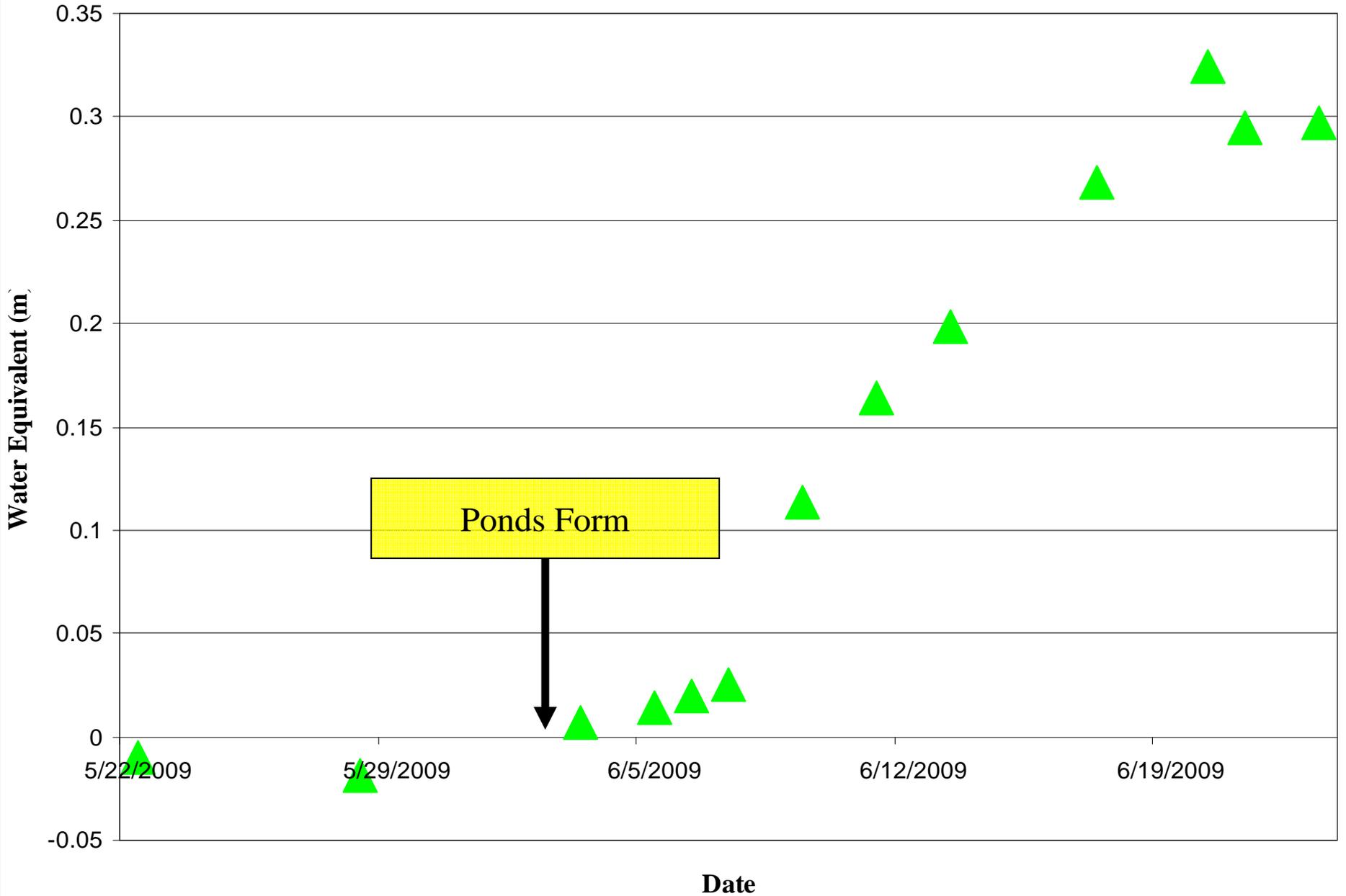
Meters of Water Equivalent Above Reference Plane, North Site



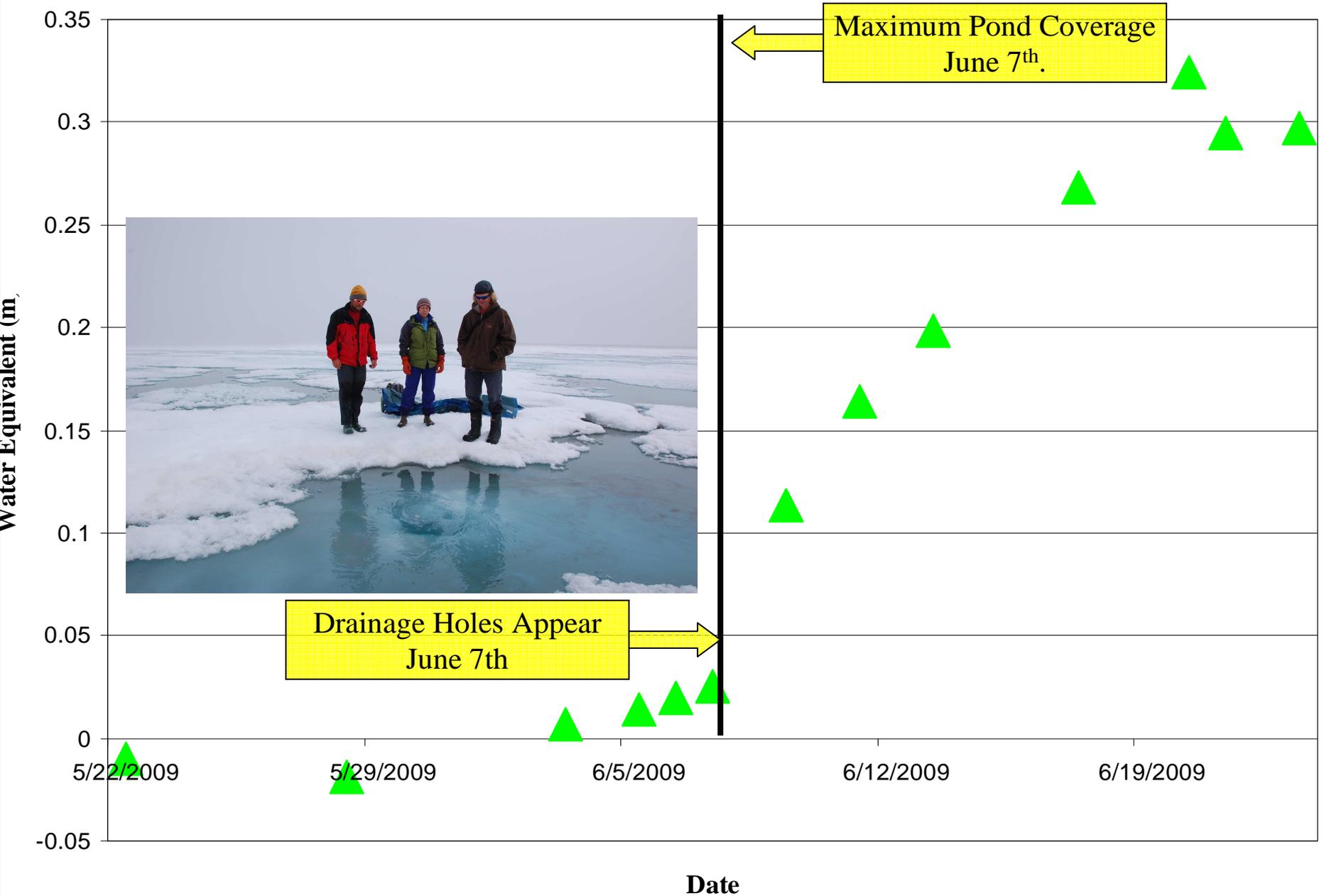
Meters of Water Equivalent Above Reference Plane, North Site



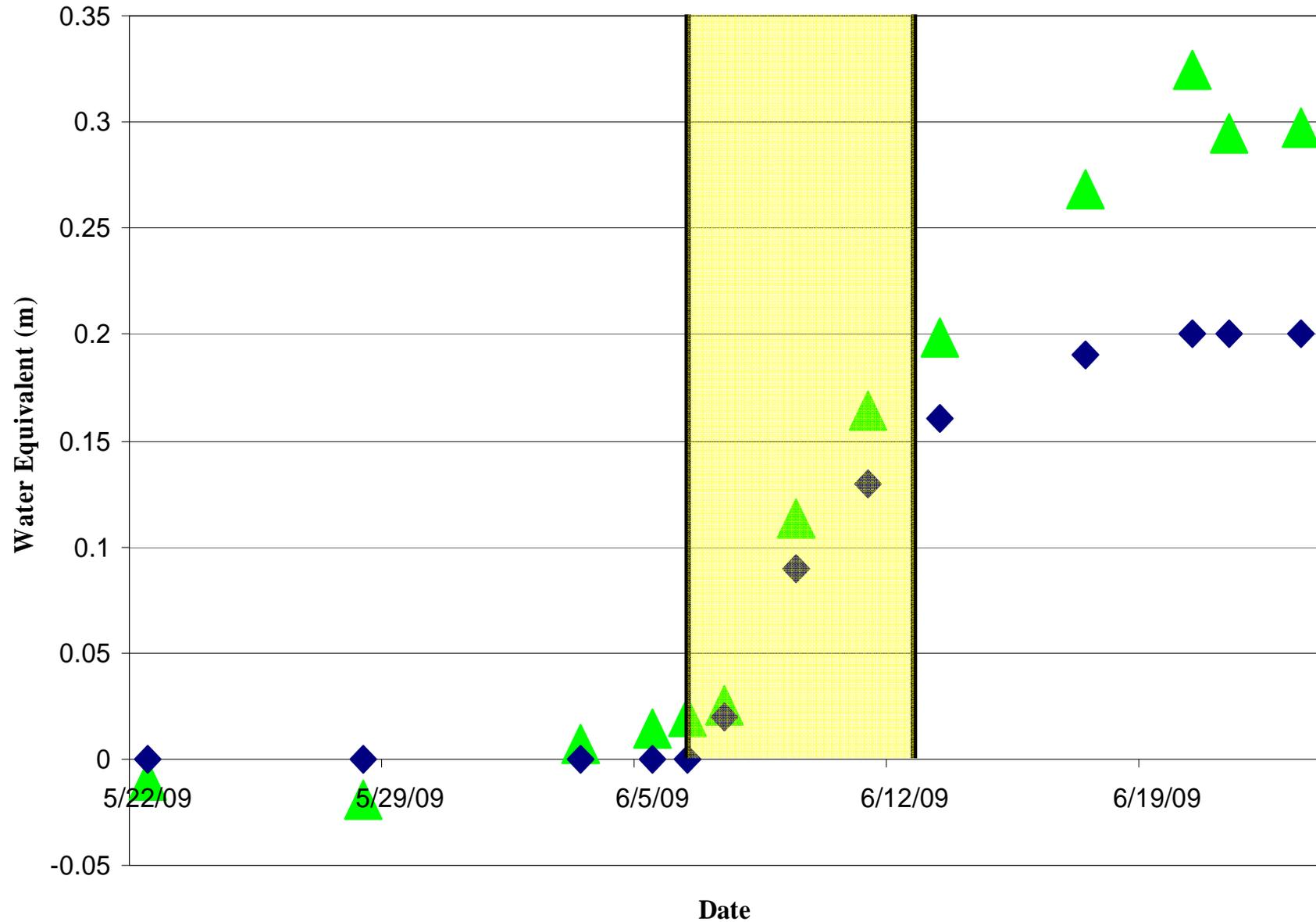
Cumulative Water Drainage (m) vs. Date



Cumulative Water Drainage (m) vs. Date

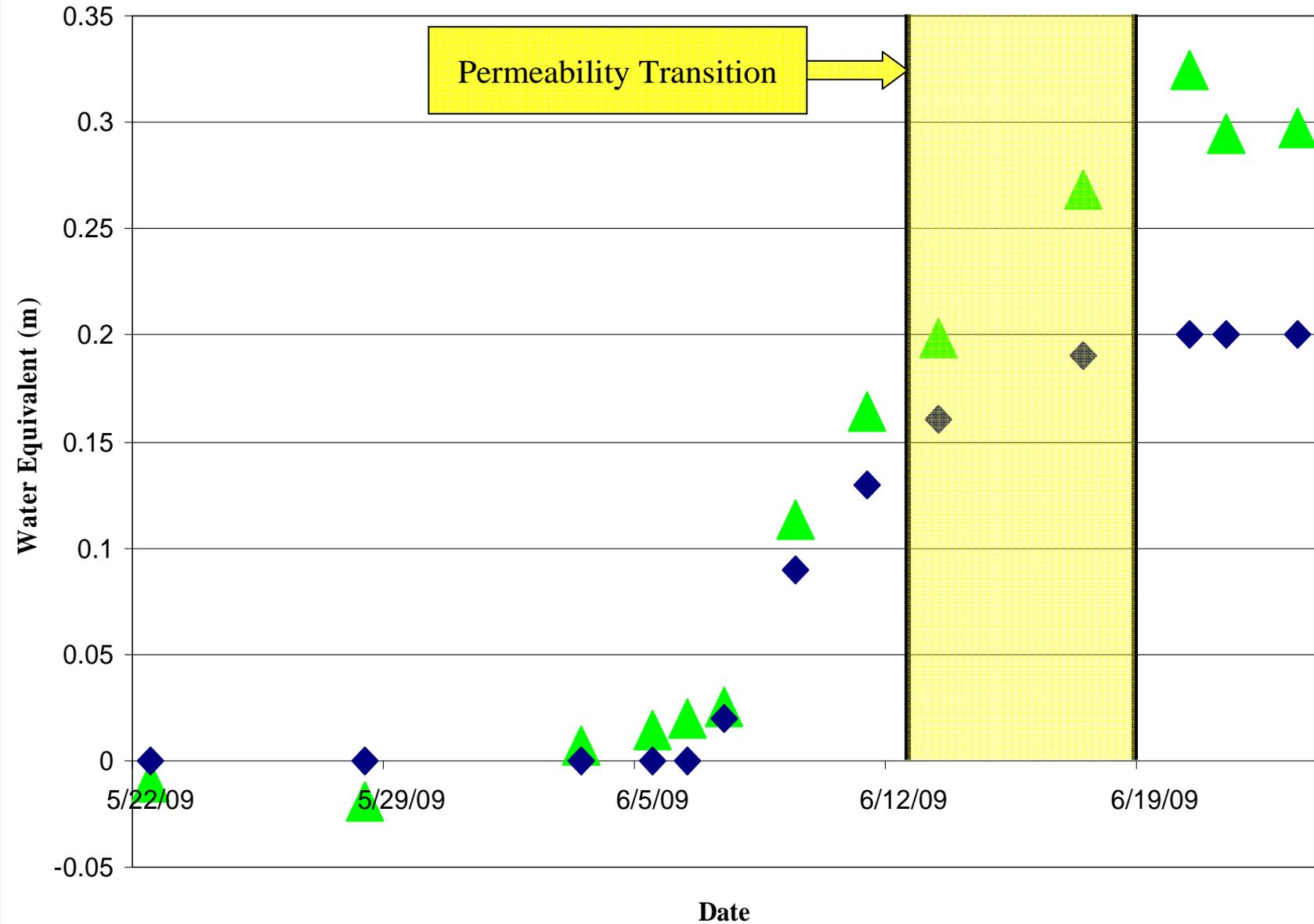


Cumulative Water Movement



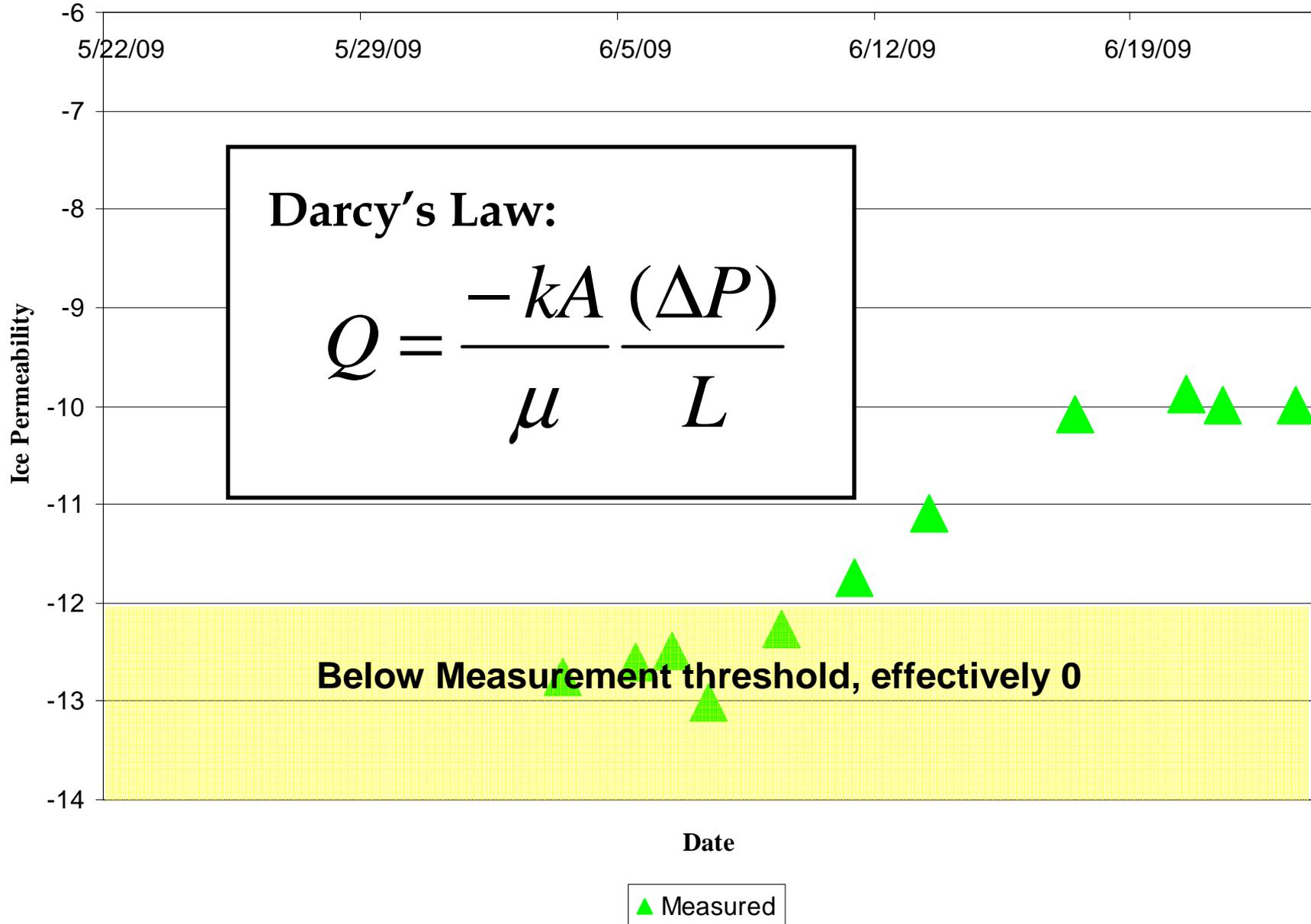
▲ Volume Drained ◆ Flow Measured at Holes

Cumulative Water Movement



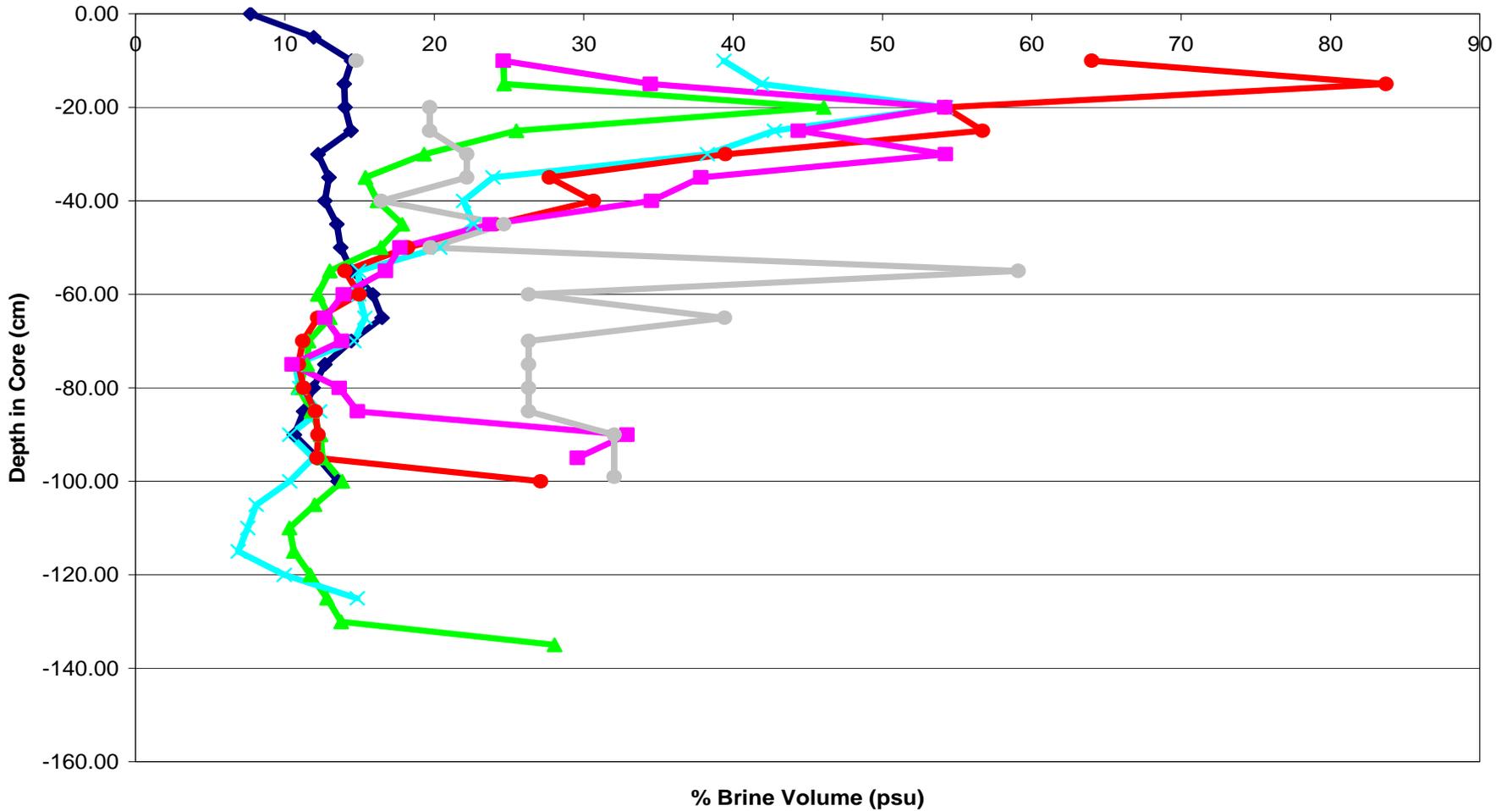
▲ Volume Drained ◆ Flow Measured at Holes

Ice Permeability



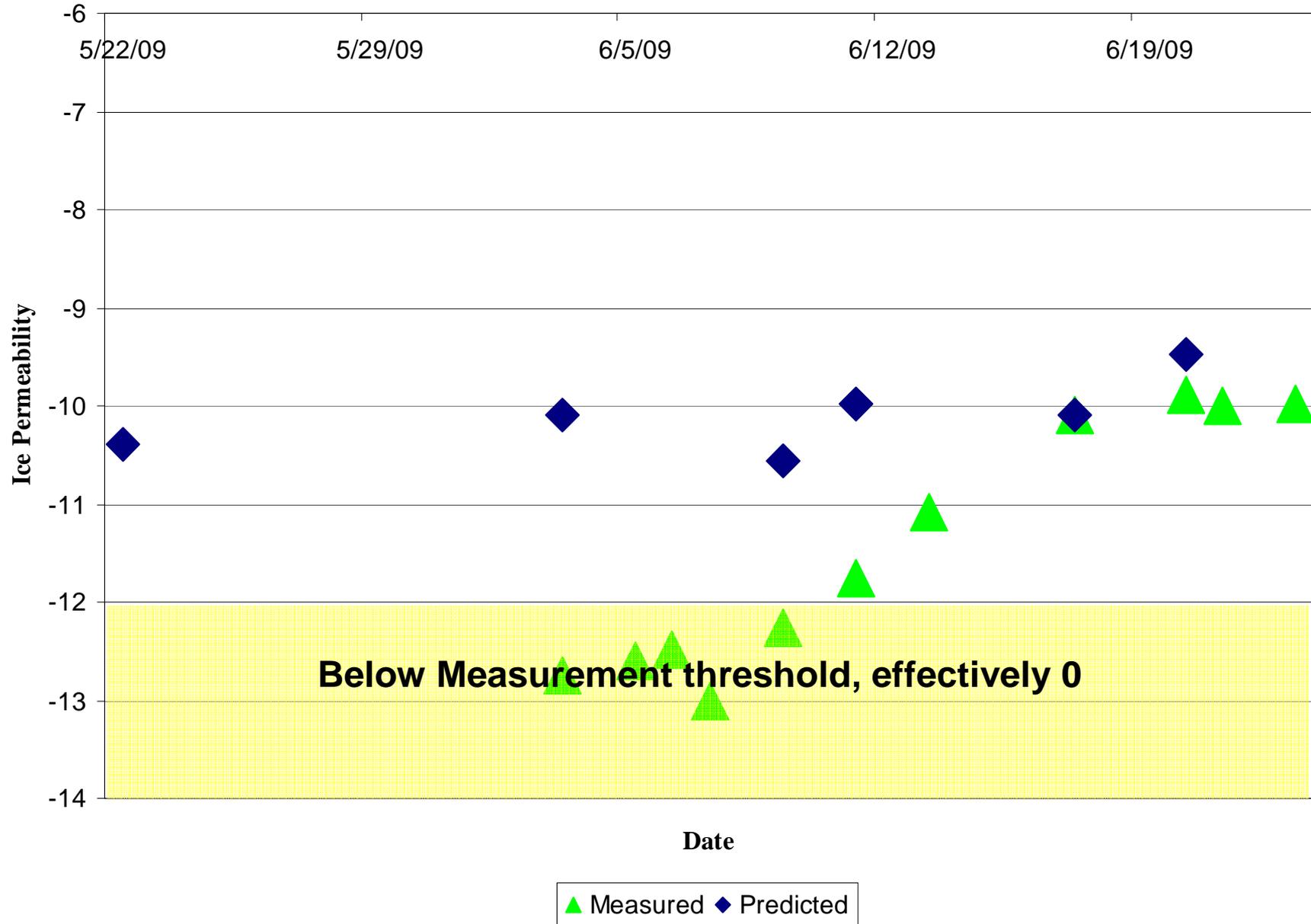
Brine Volume Profiles

$$v_b = S \left(0.0532 - \frac{4.919}{T} \right)$$



5/16/2009 6/5/2009 6/9/2009 6/11/2009 6/13/2009 6/15/2009

Ice Permeability



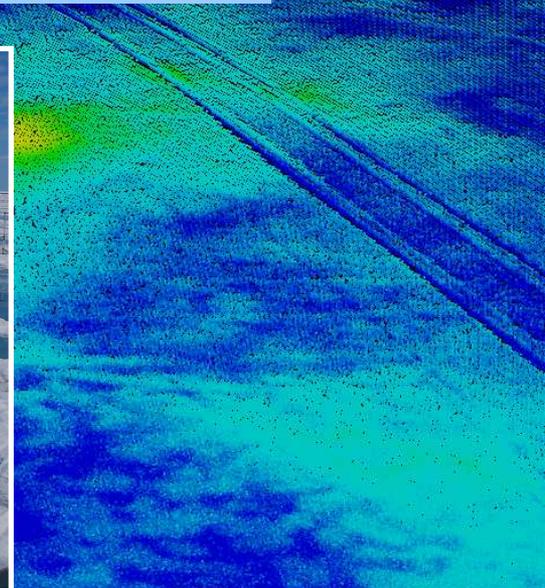
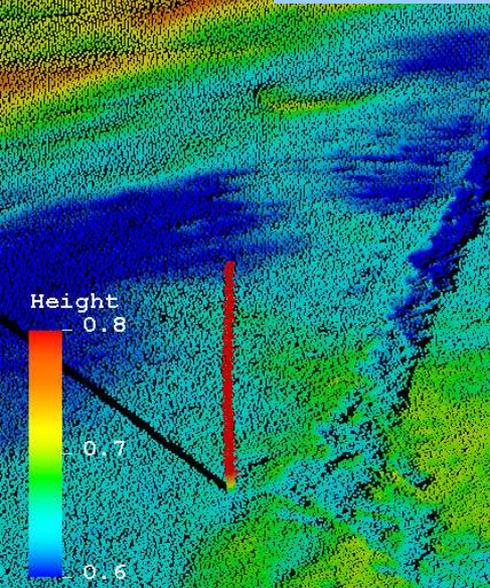
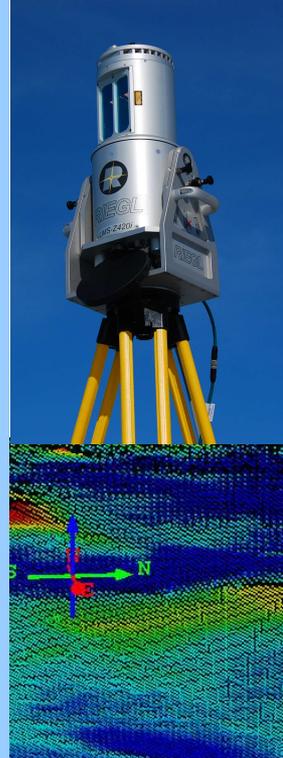
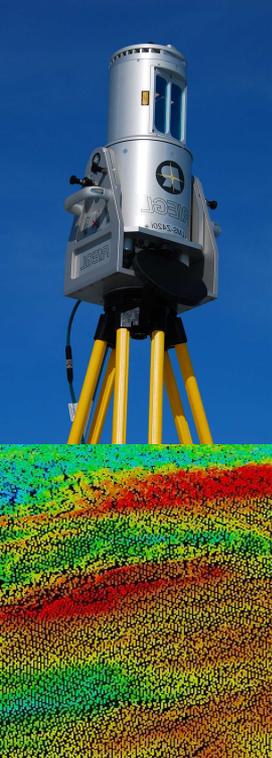
Conclusions

Continued Challenges:

- Deformation in the array
- Micro Shadowing/Surface Aliasing
- Lack of pond returns, no pond bottom returns.

Technology is moving rapidly

- waveform processing for multiple returns per pulse
- mobile scanners
- visible wavelength lasers to penetrate water



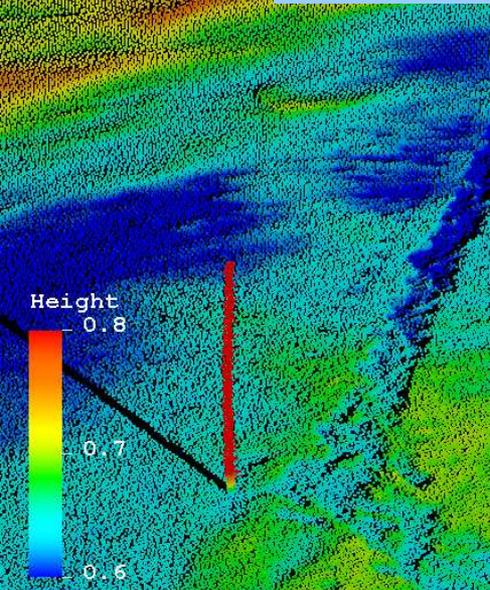
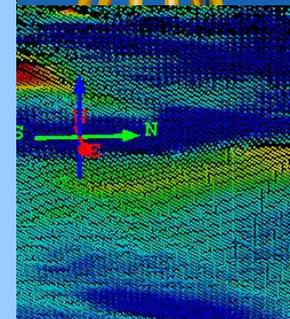
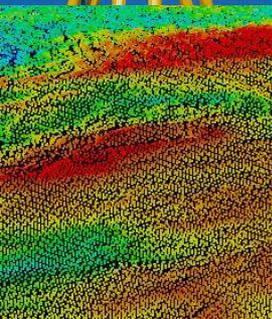
Thank you!

Collaborators

Zoe Courville, Don Perovich, Dave Finnegan, Matthew Sturm, Matthew Druckenmiller, Hajo Eicken, Chris Petrich

Barrow Arctic Science Consortium

National Science Foundation Grant No. ARC-0454900















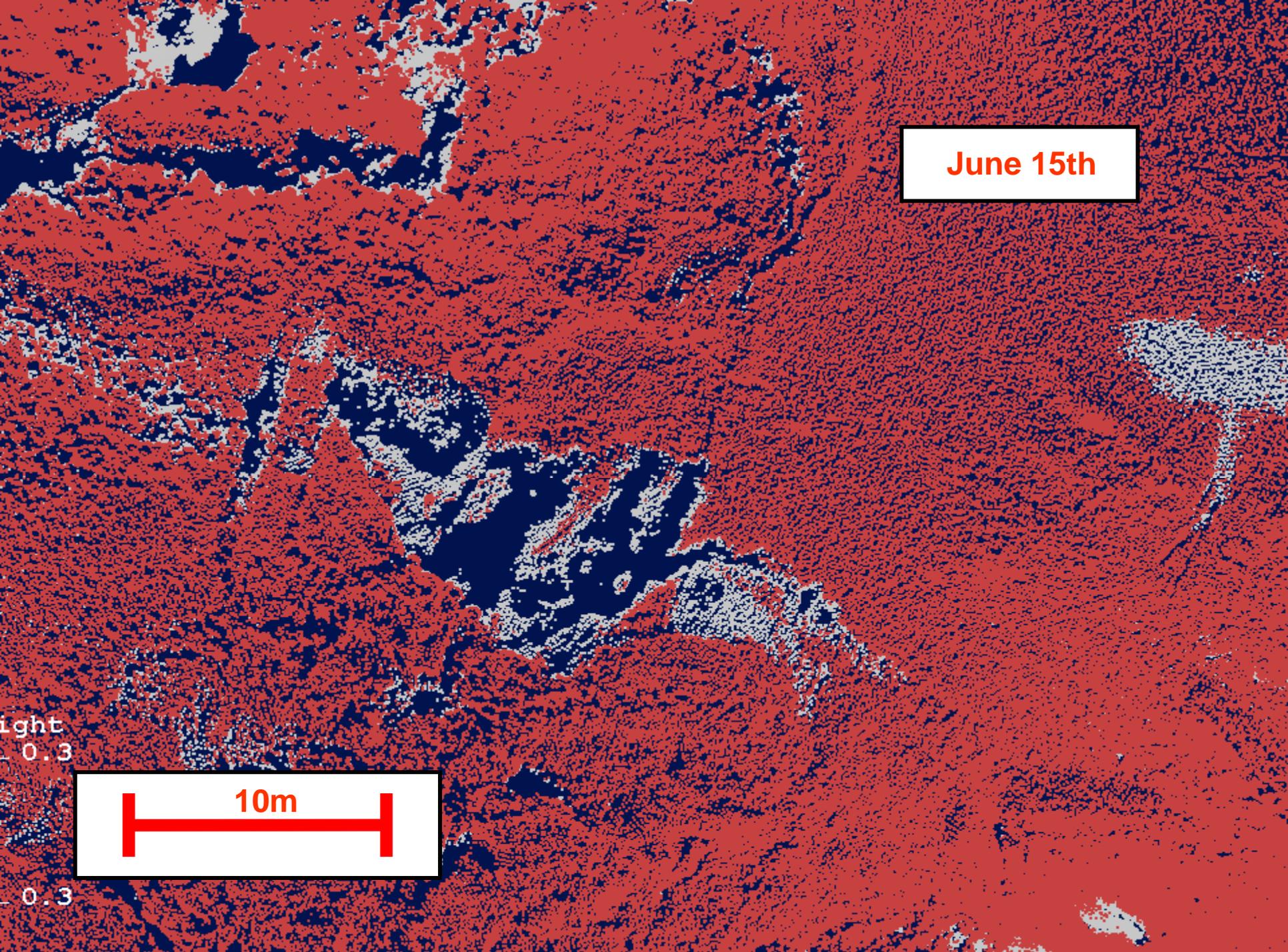


June 15th

Light
0.3

10m

0.3

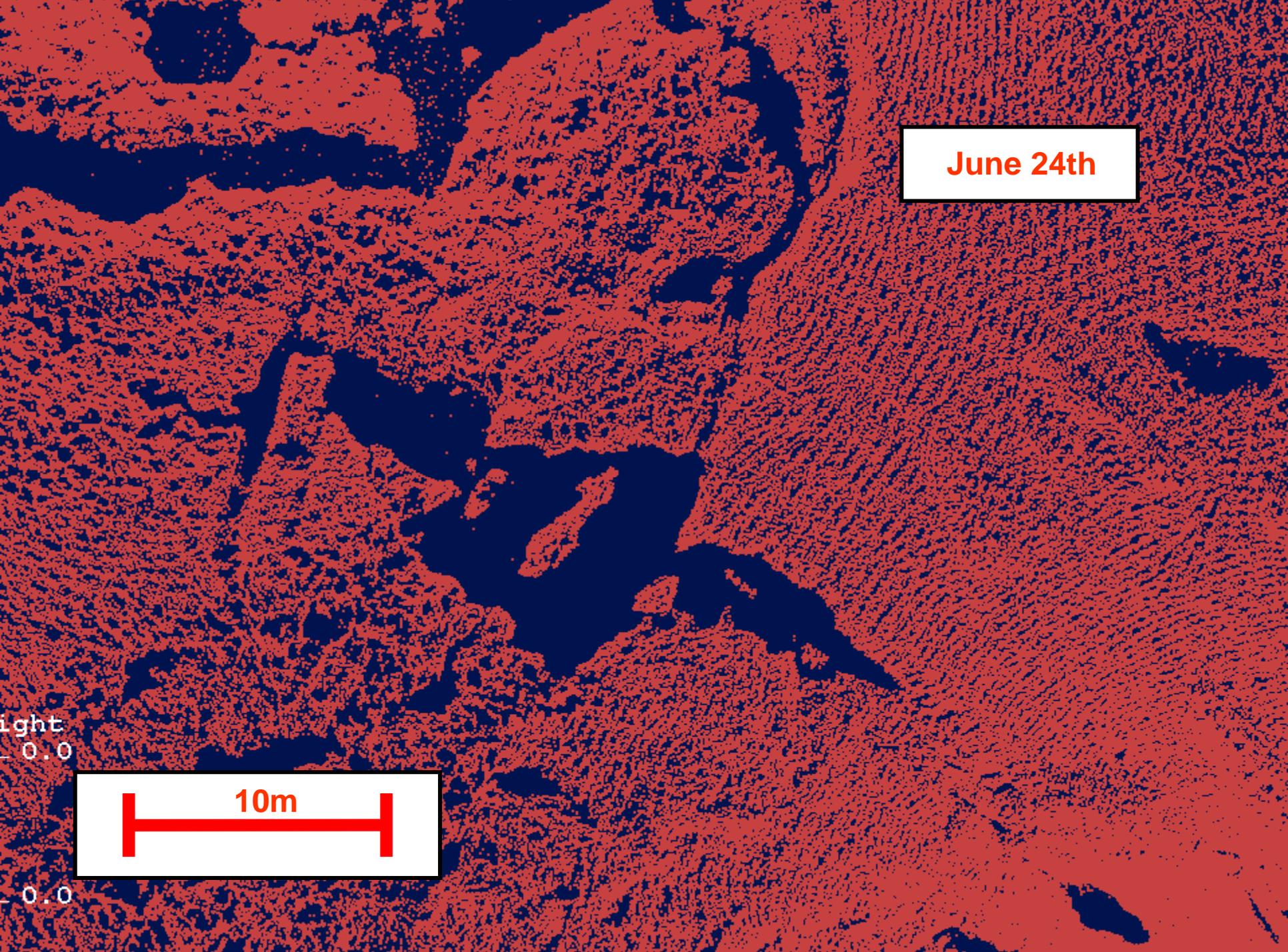


June 24th

Light
0.0

10m

0.0



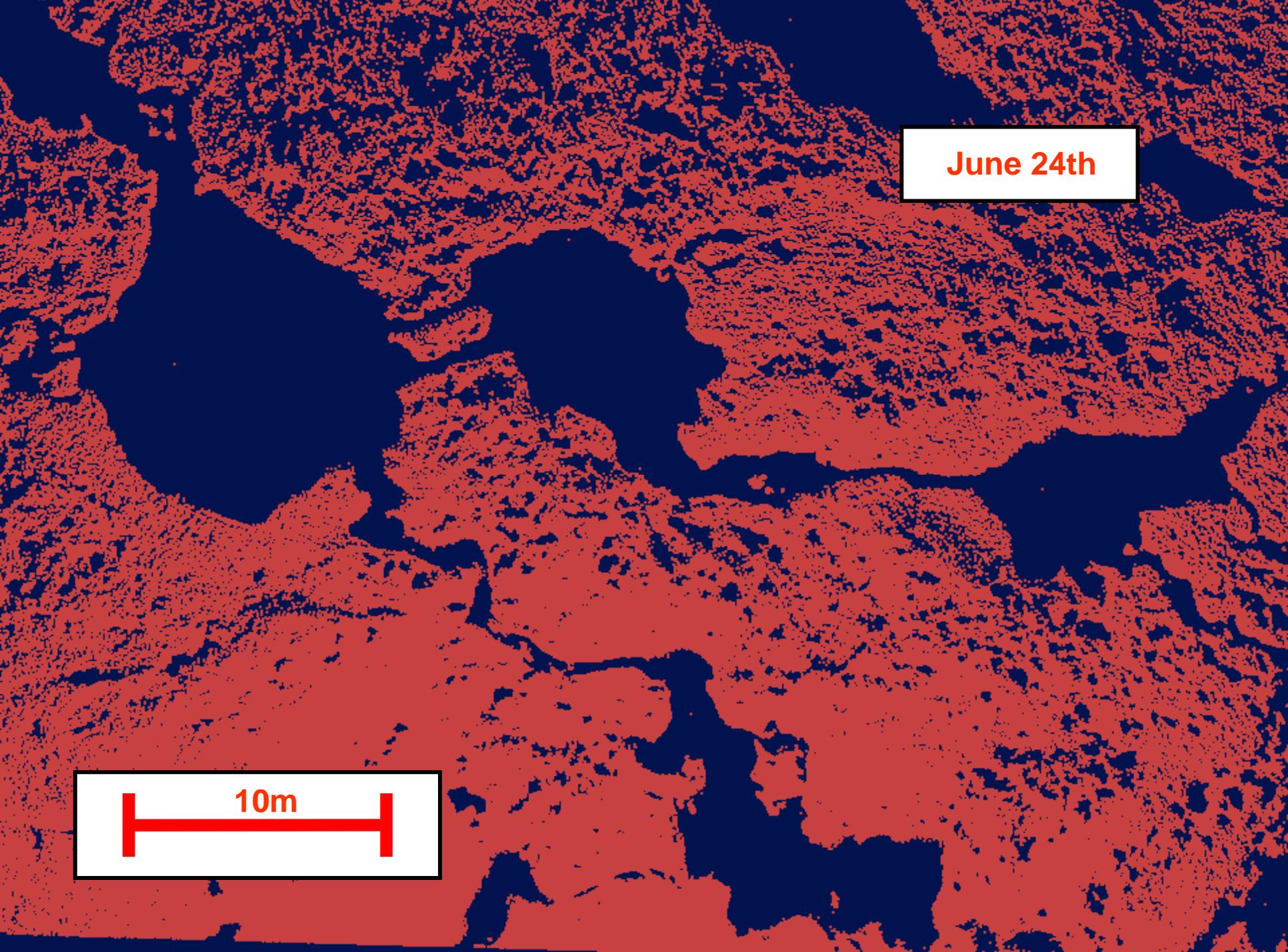
June 15th

10m

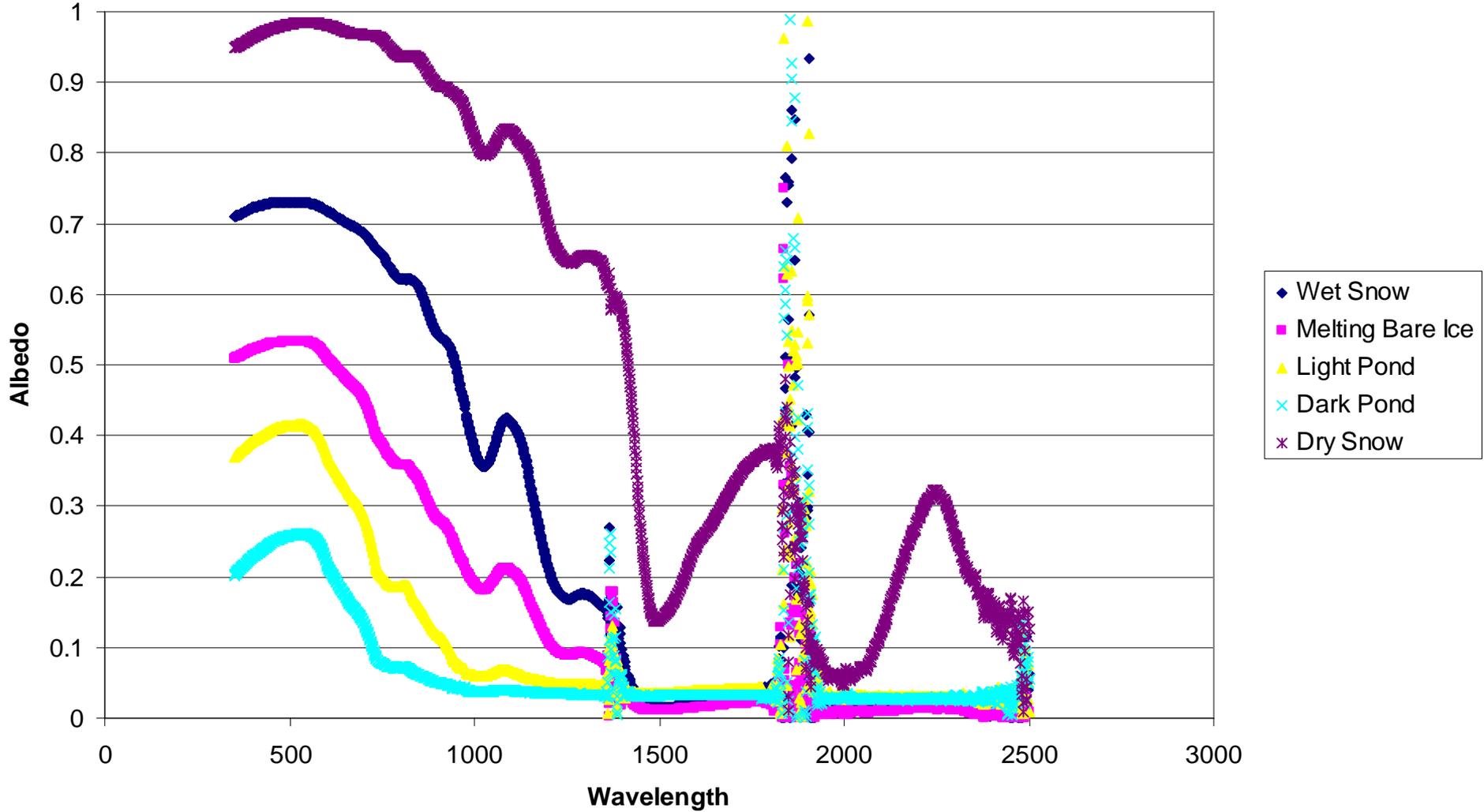


June 24th

10m

An aerial photograph showing a coastal area with a mix of green vegetation and brownish, possibly sandy or rocky, terrain. A scale bar in the bottom left corner indicates a length of 10 meters. A date label in the top right corner reads "June 24th". The terrain appears to be a mix of natural and possibly man-made or altered land.

Spectral Albedos of Various Surfaces

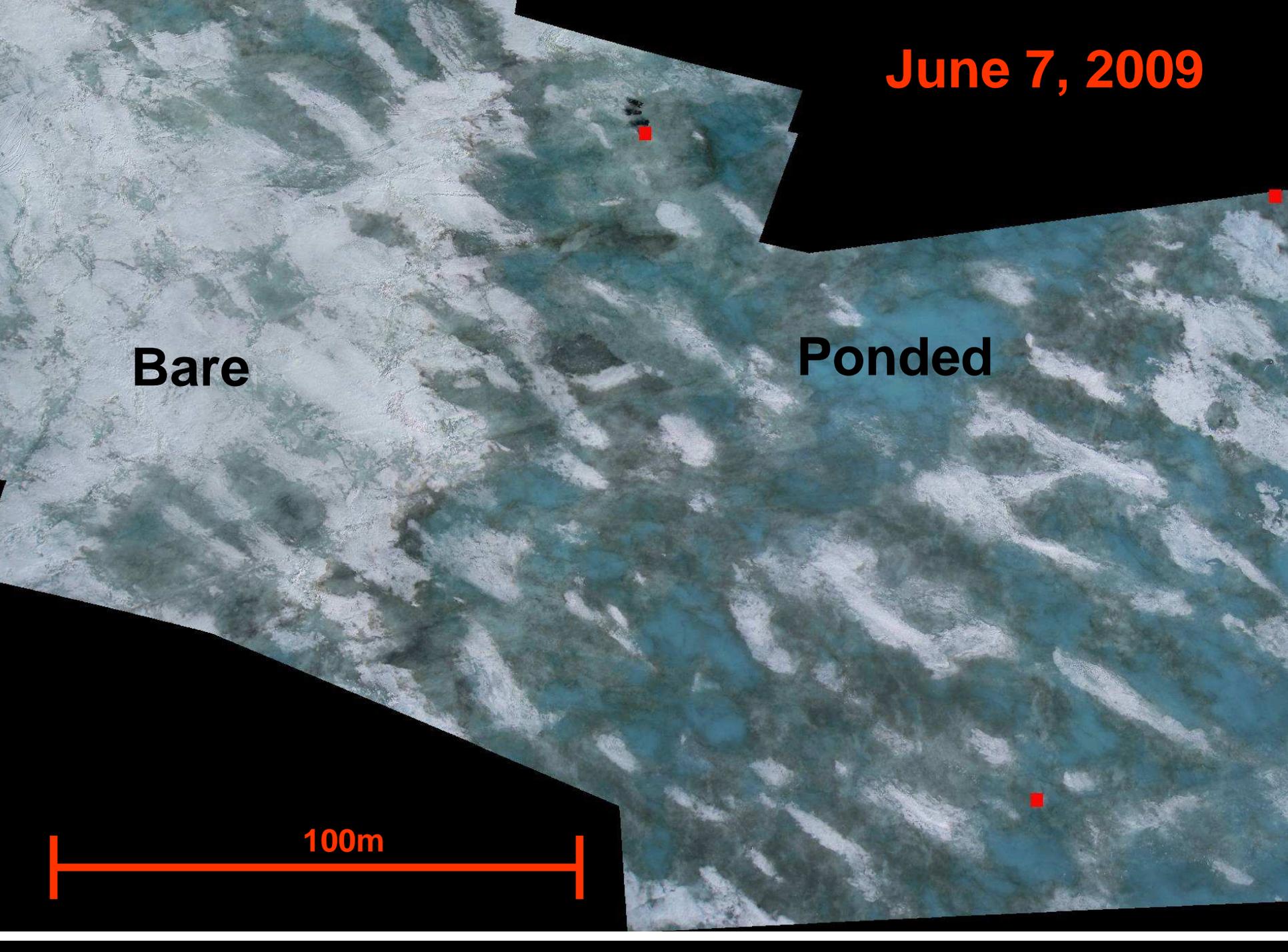


June 7, 2009

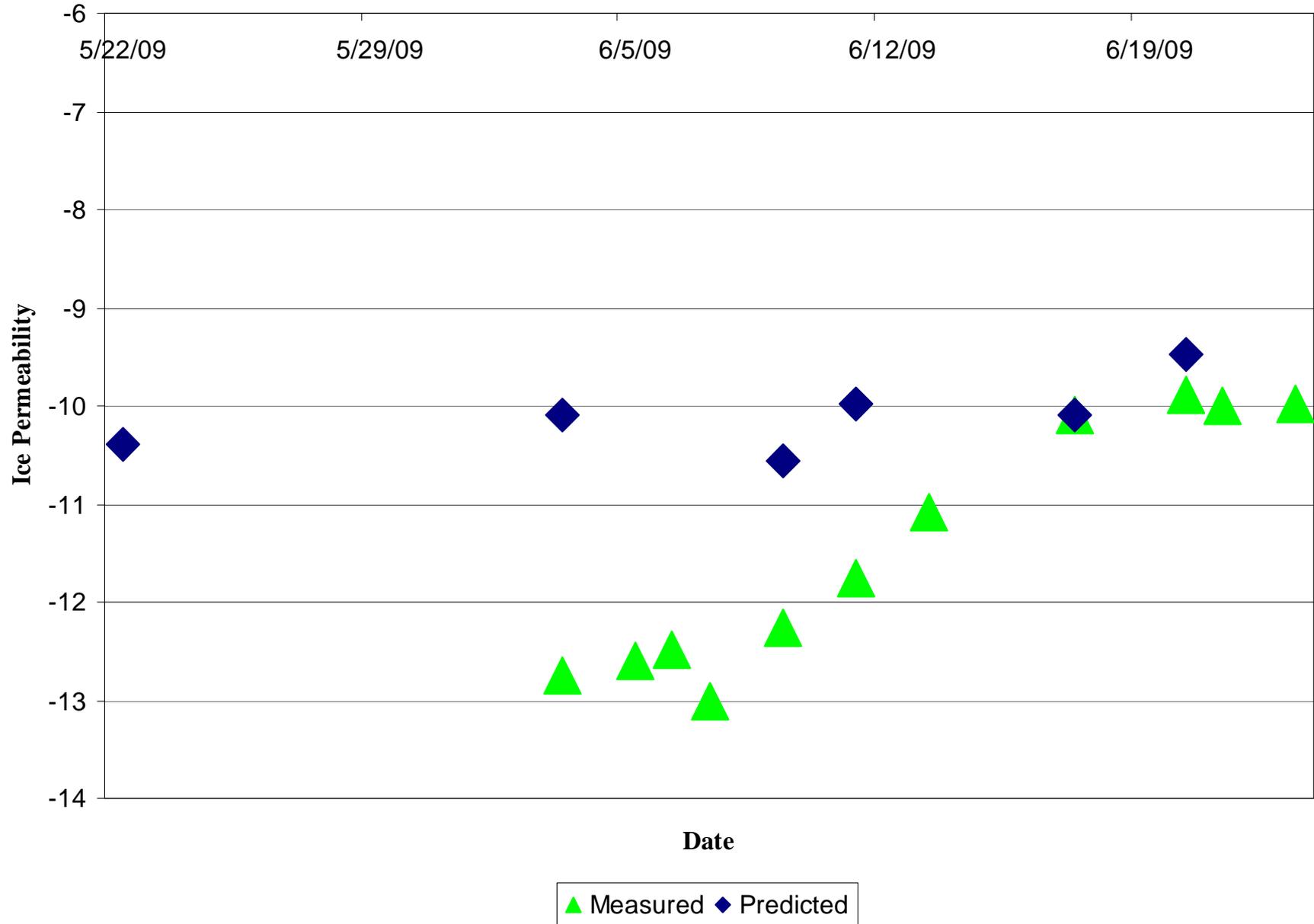
Bare

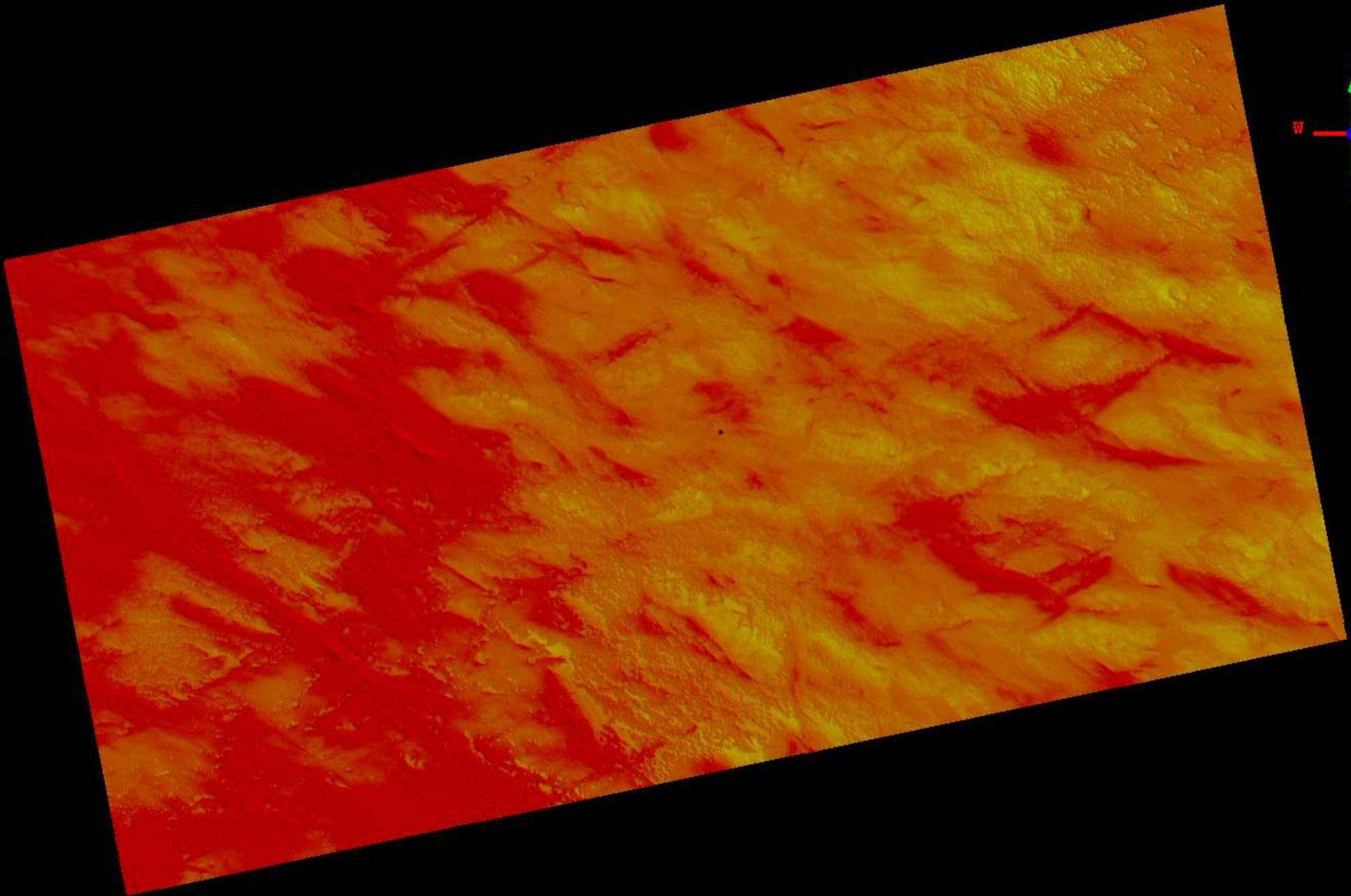
Ponded

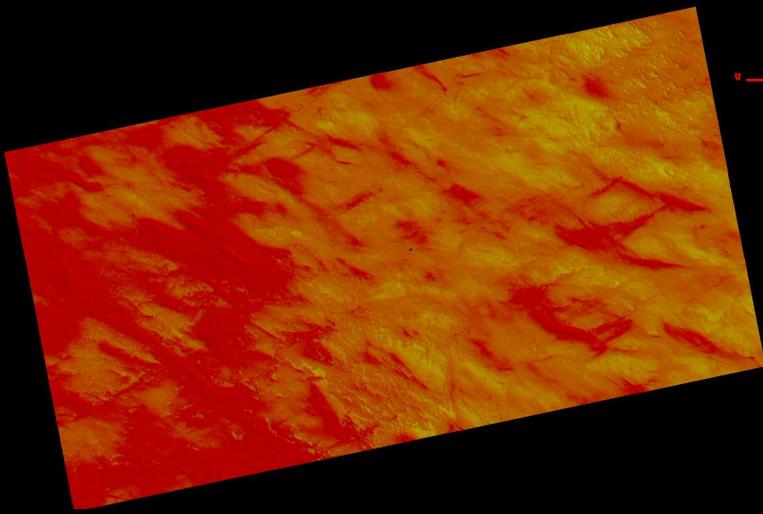
100m



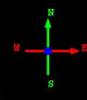
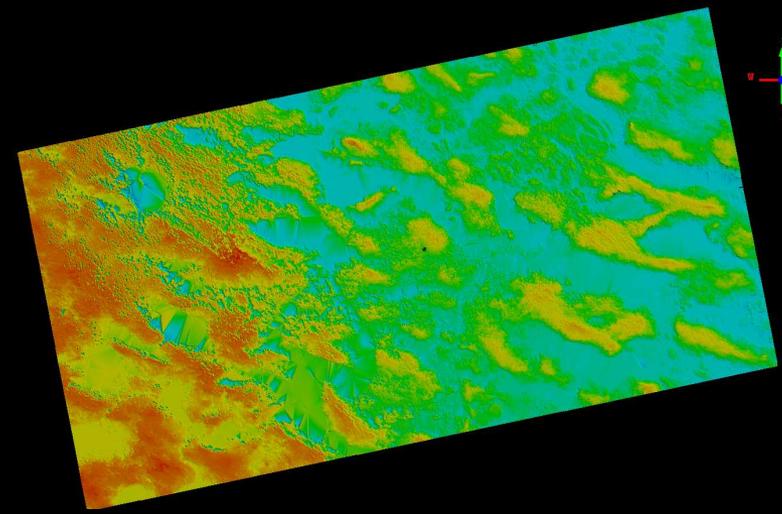
Ice Permeability







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