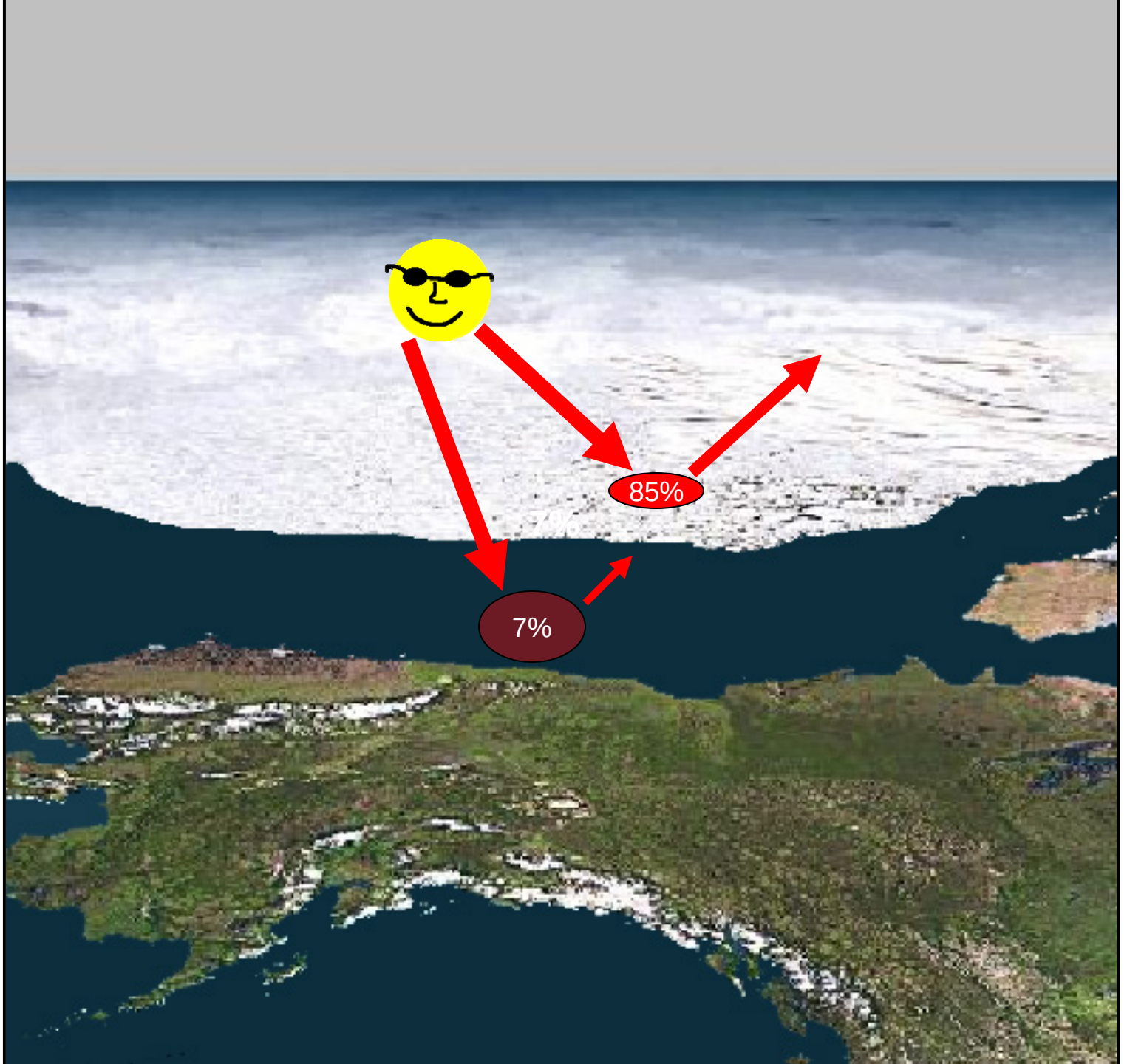
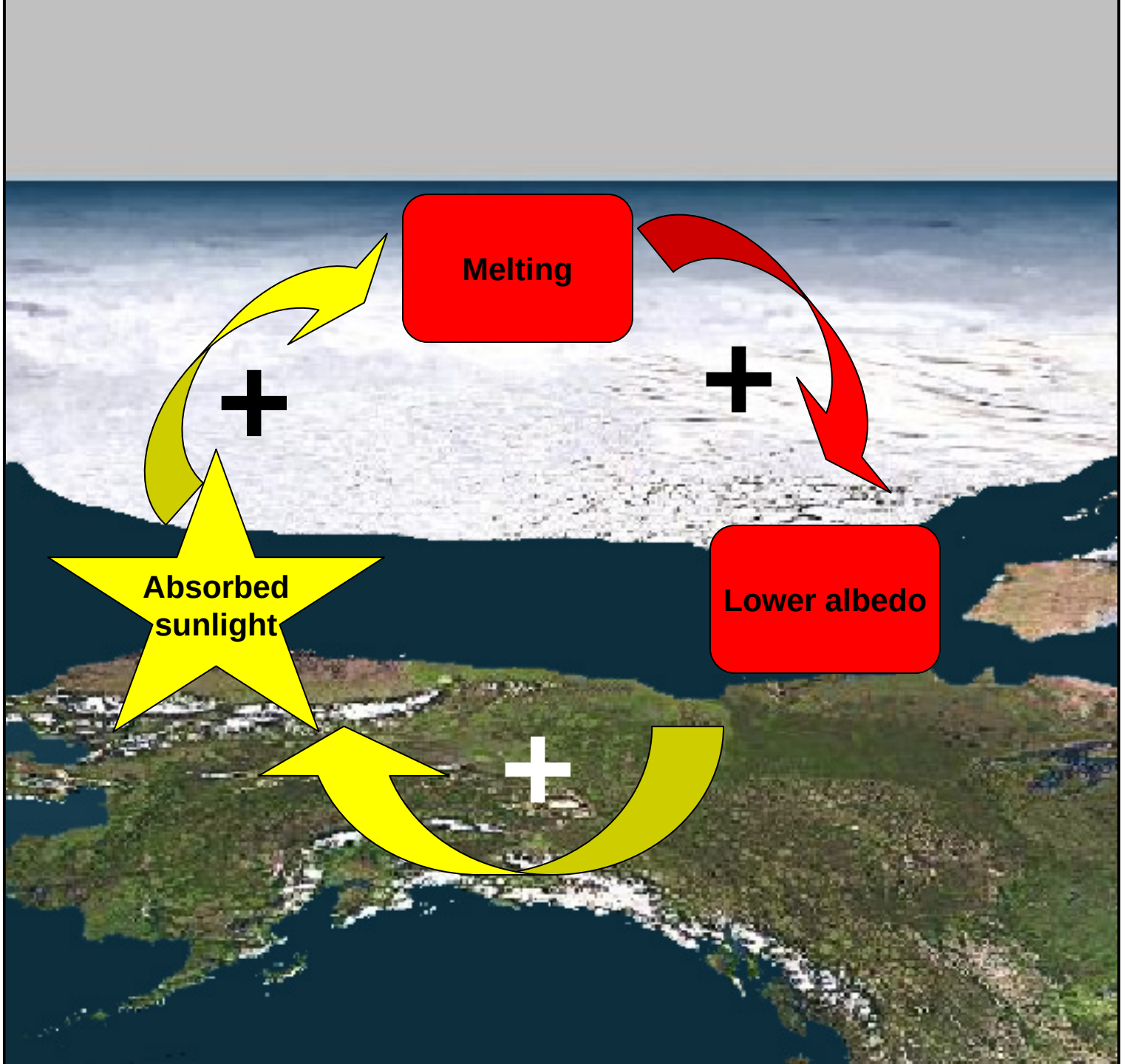
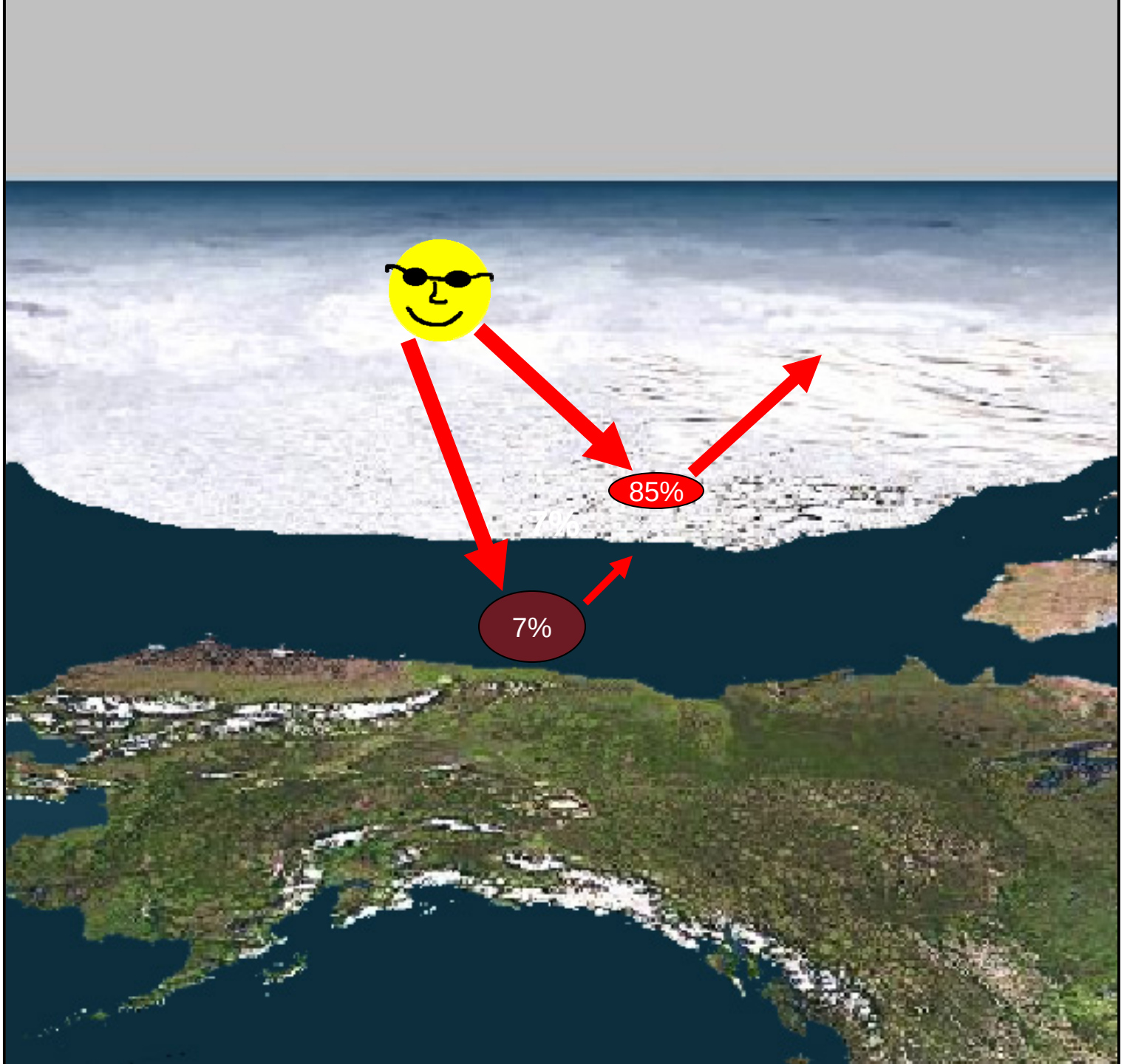
The Wonderful World Of Melt Ponds

Chris Polashenski

Photo: Chris Petrich


85%
7%

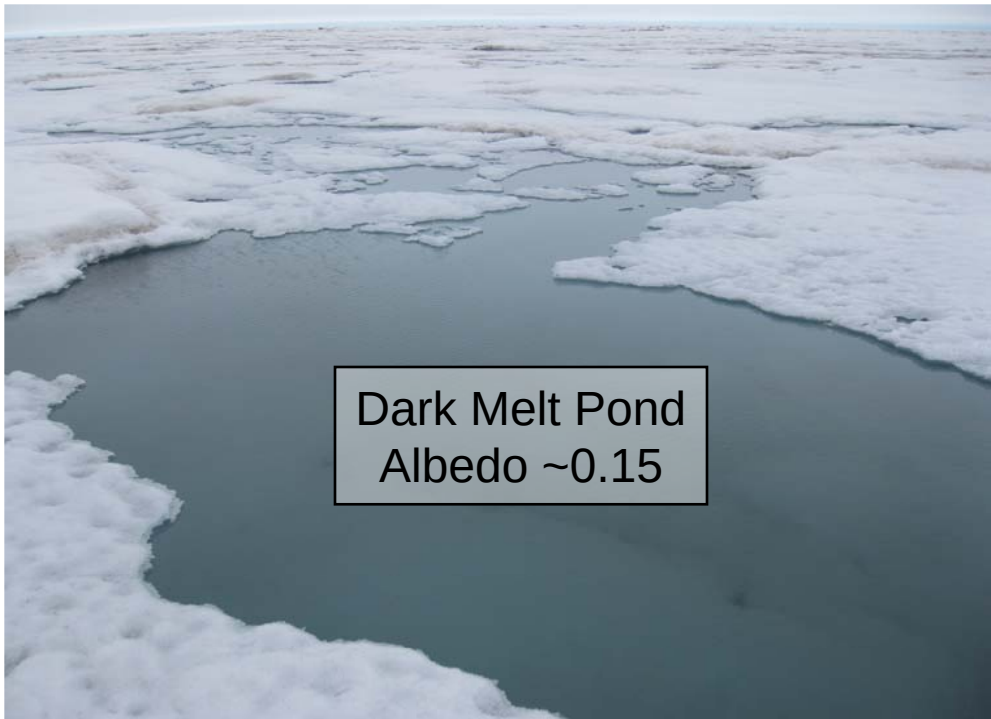

Melting
+
+
Absorbed sunlight
Lower albedo
+


85%
7%

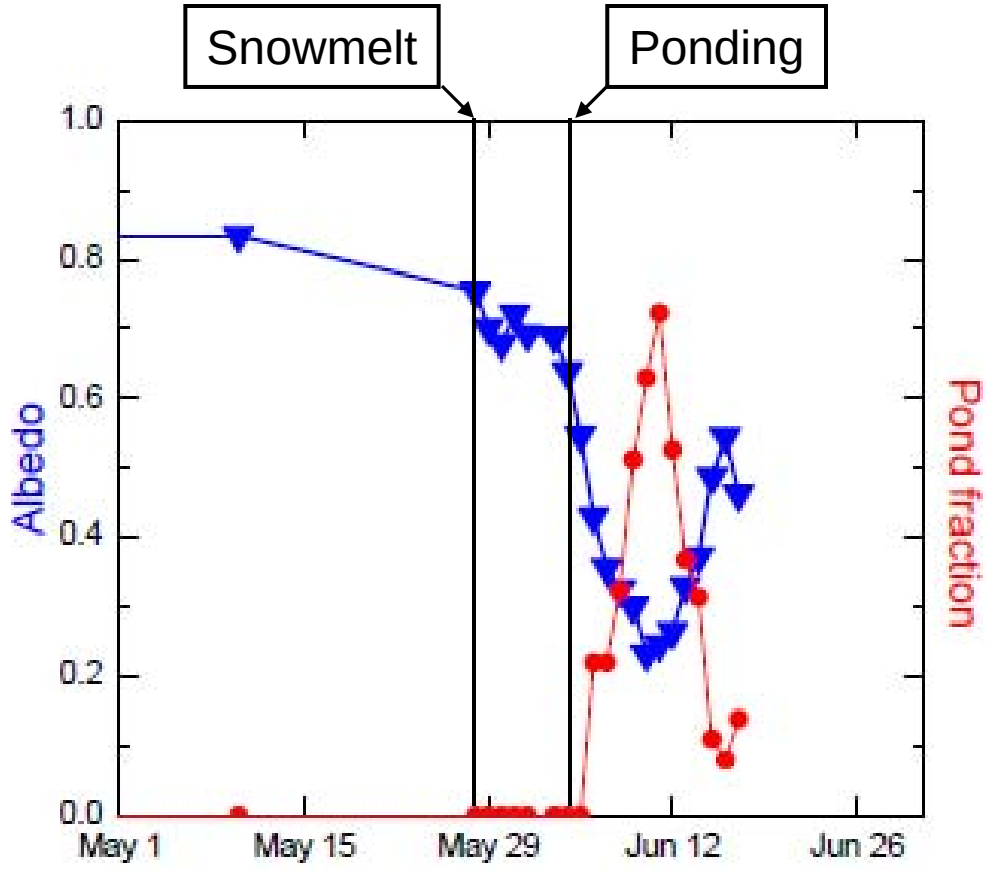

Dry Snow
Albedo ~0.85

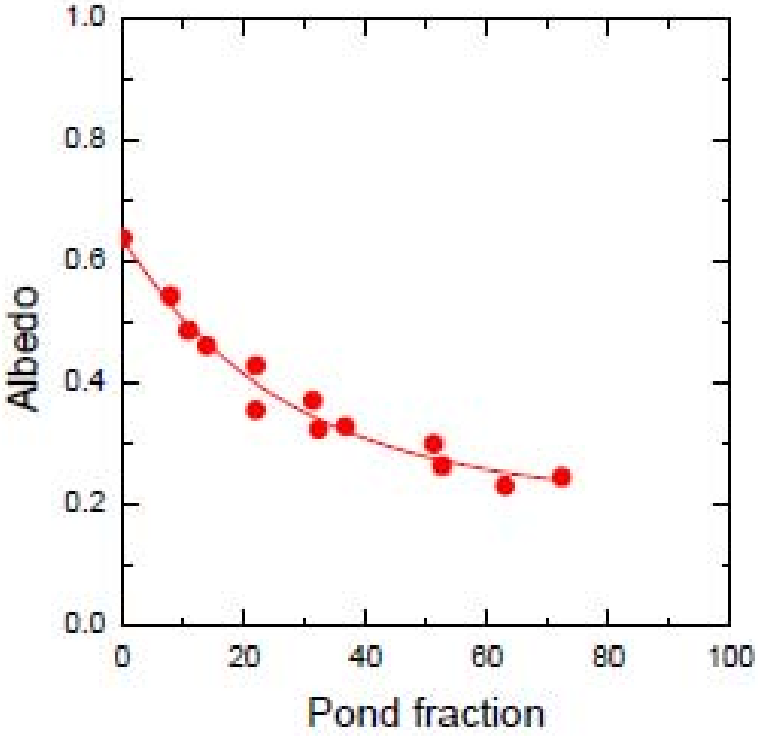

Wet Snow
Albedo ~0.75


Melting Snow-Free Ice
Albedo ~0.6


Dark Melt Pond
Albedo ~0.15

Melt Ponds are the Predominate Driver of Ice Albedo (and probably transmission too)

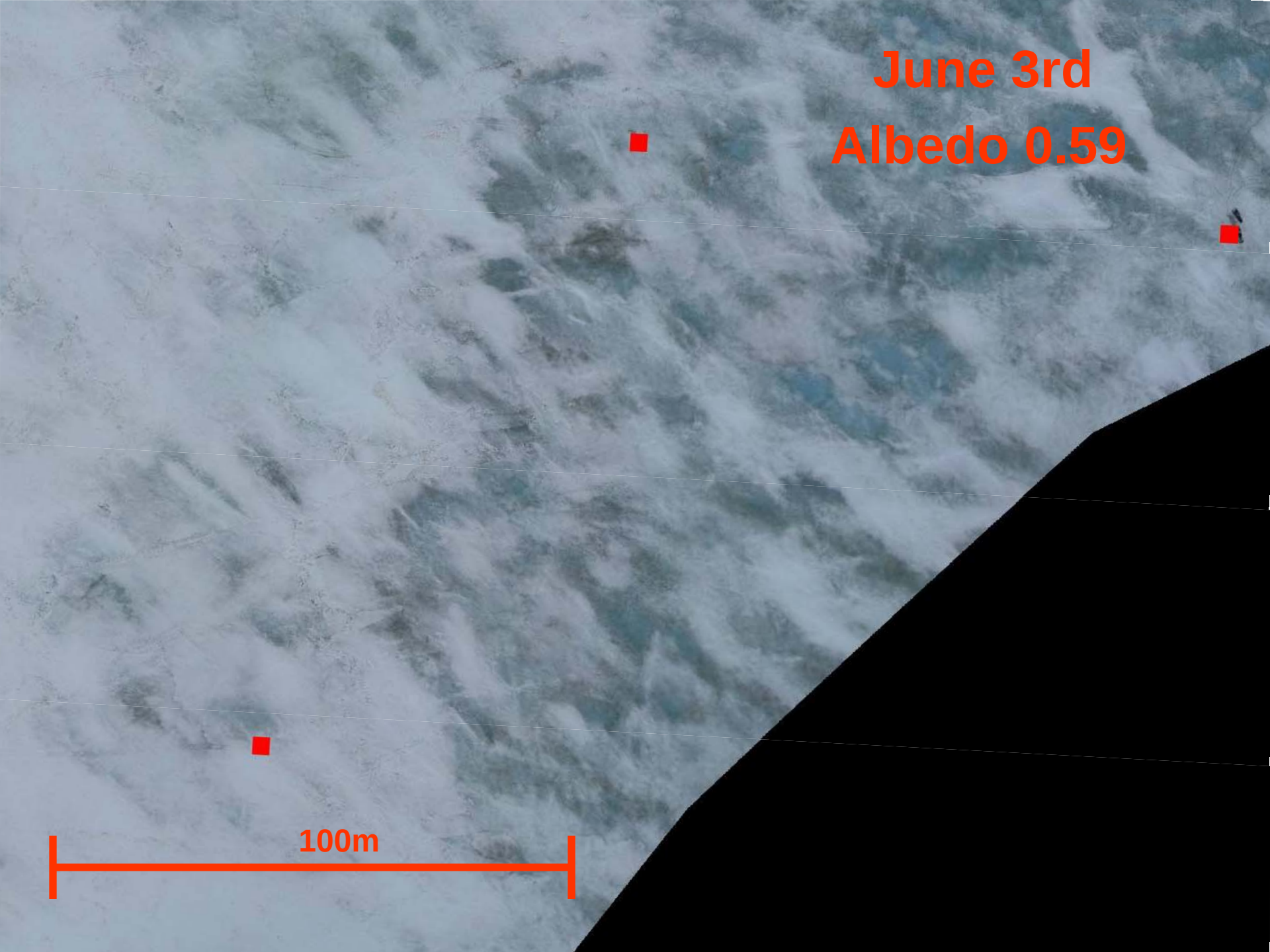


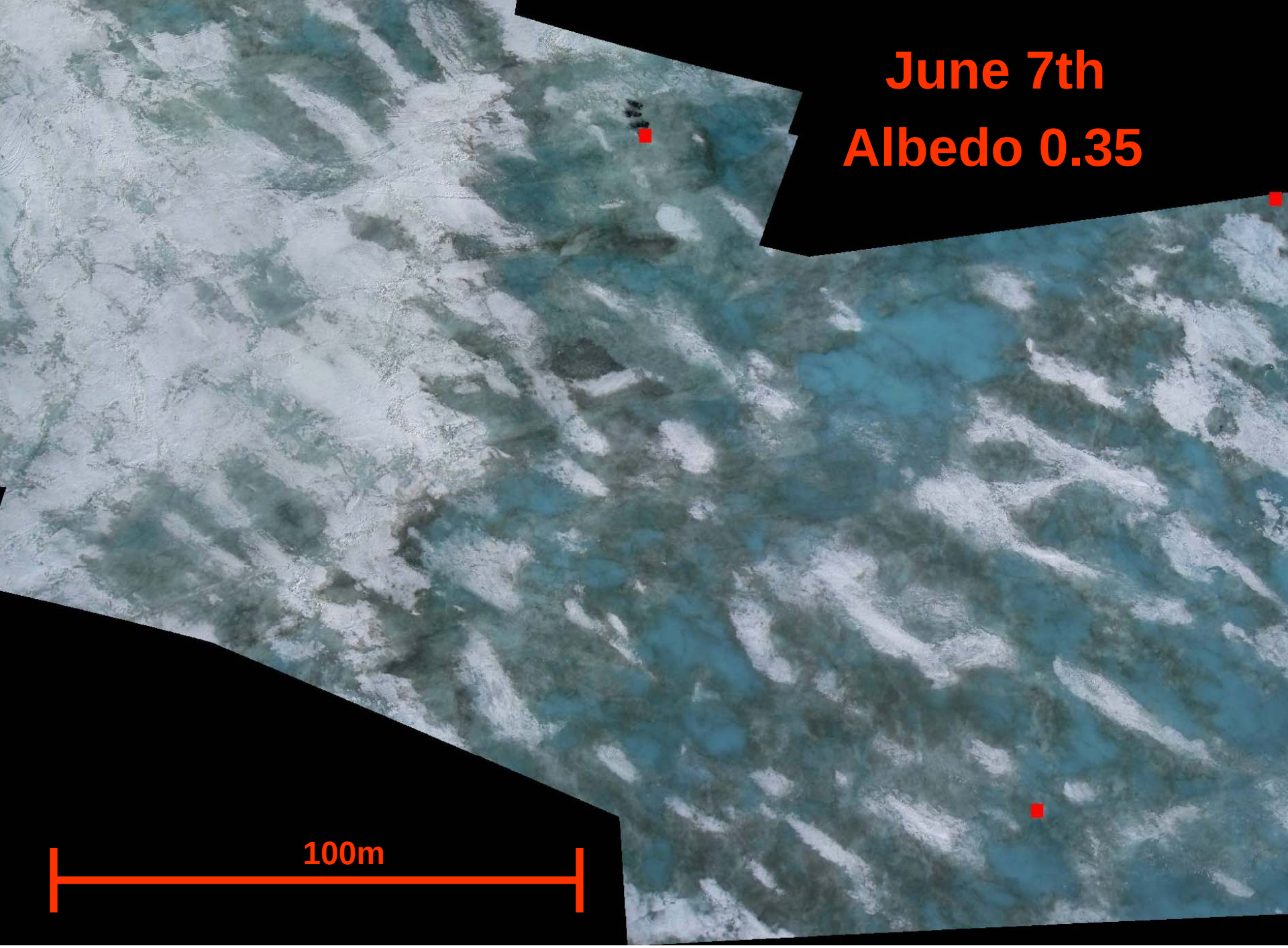


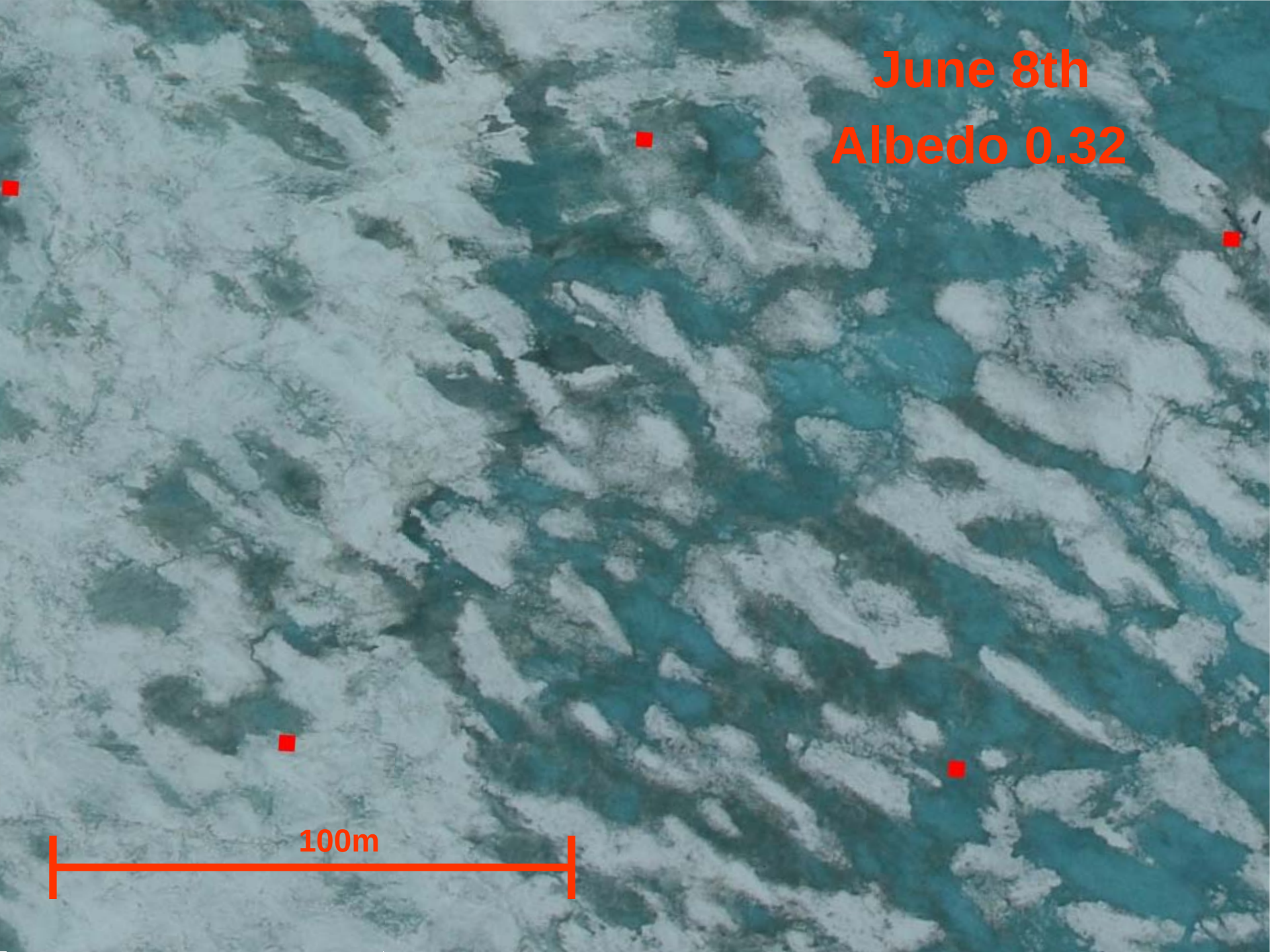
Ponds are Super Cool

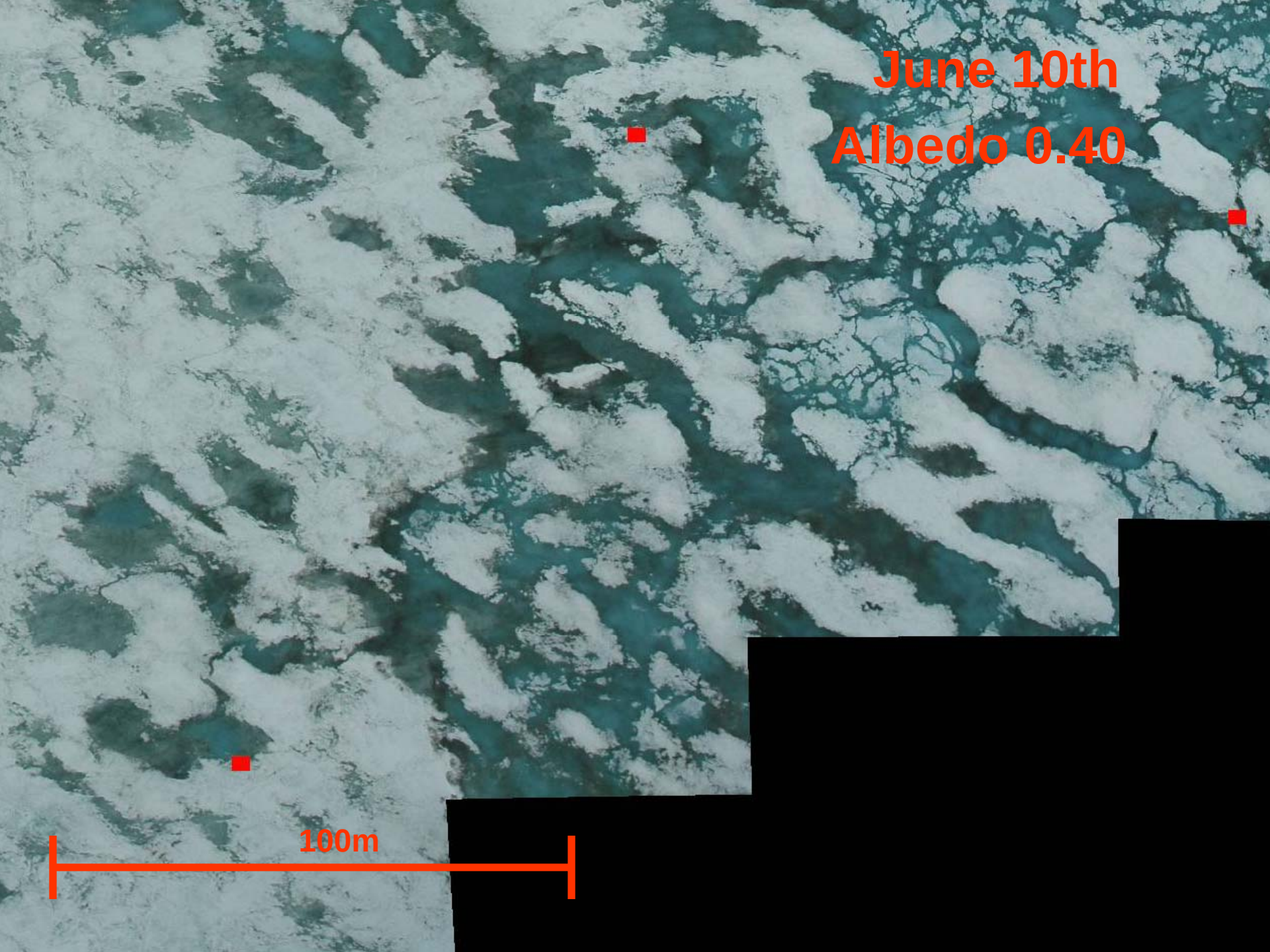
- Reason 1: Ponding dramatically changes the albedo of the ice.

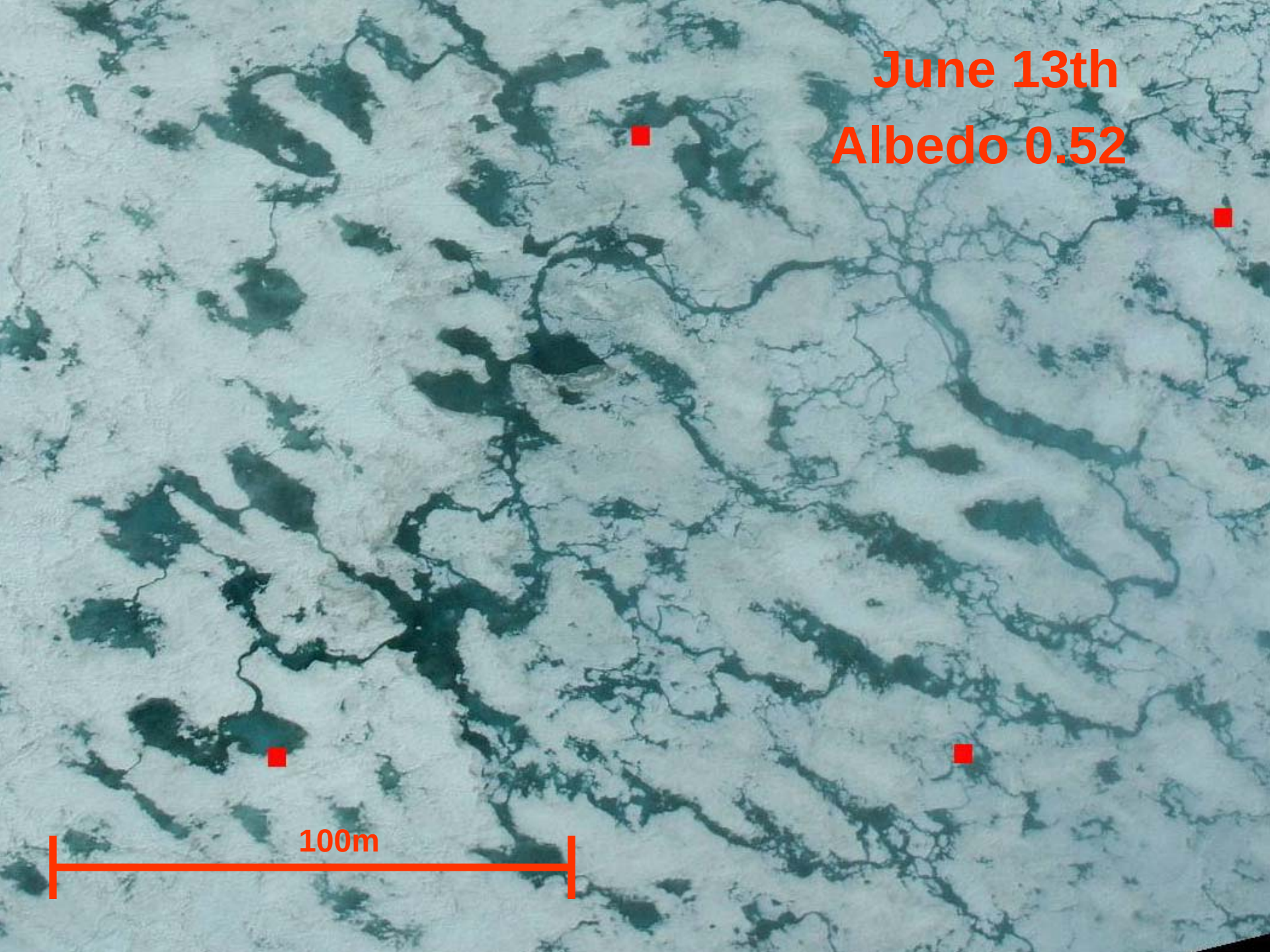

June 1st
Albedo ~0.79
100m


June 3rd
Albedo 0.59
100m

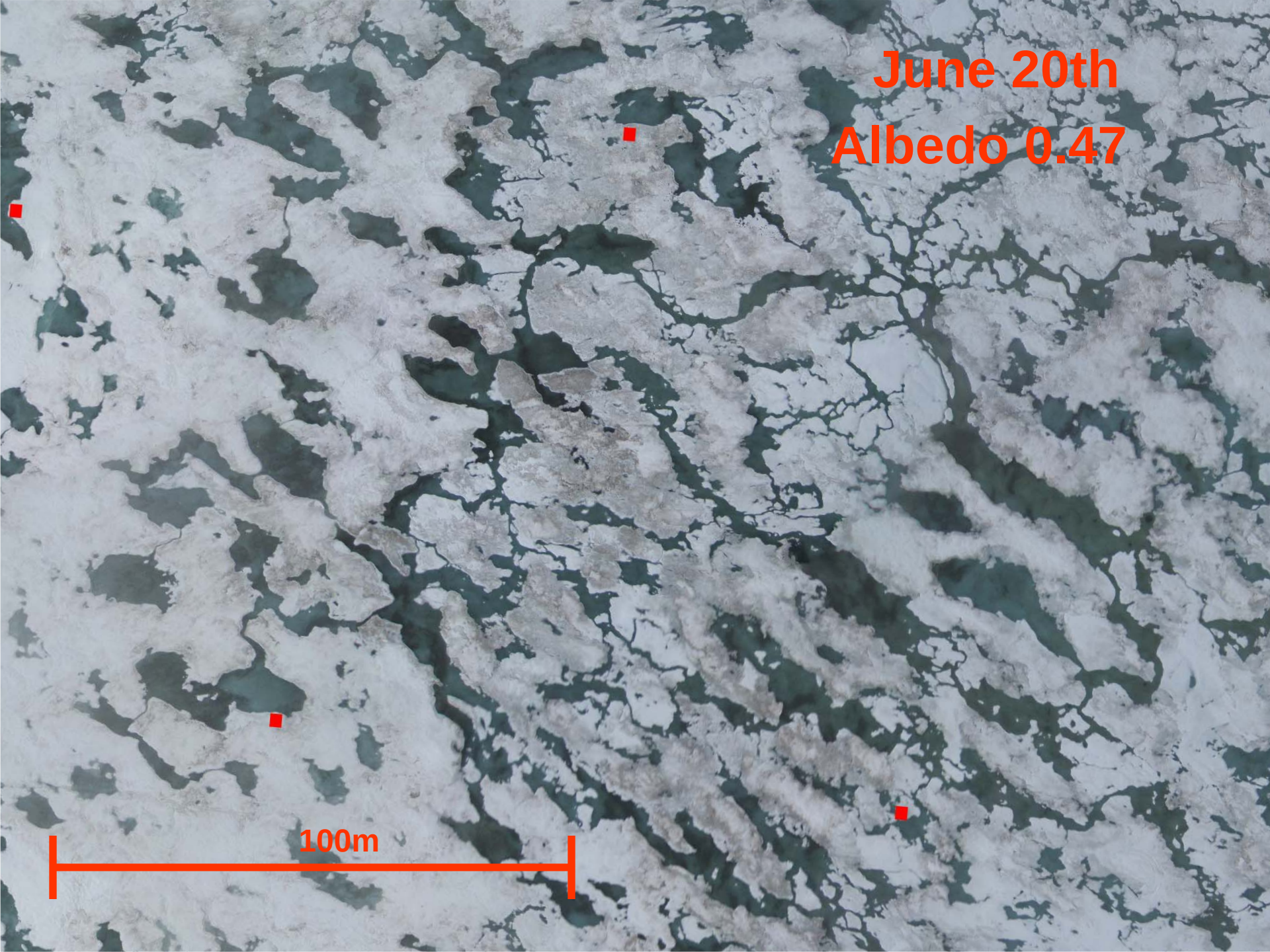

June 7th
Albedo 0.35
100m

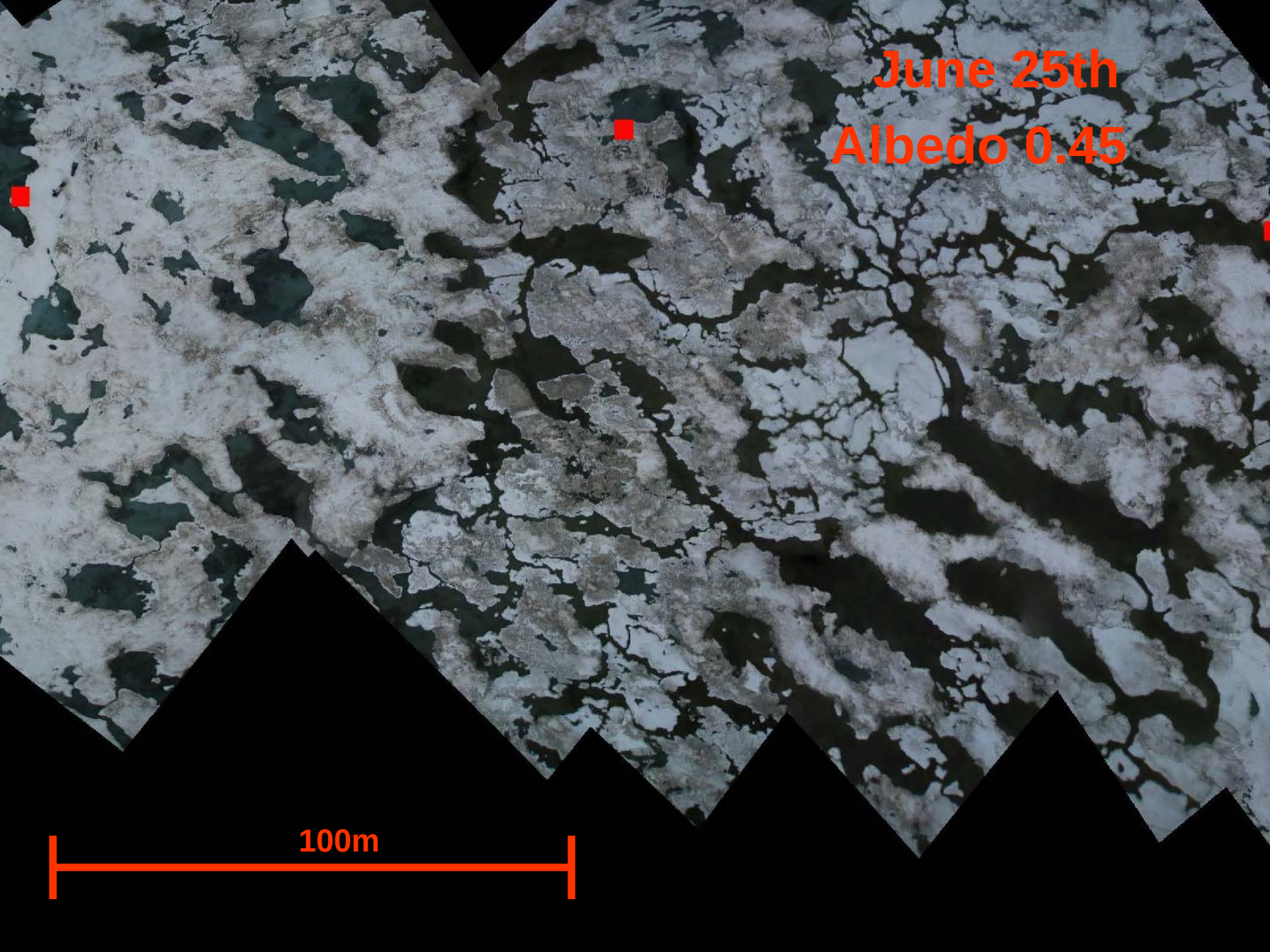

June 8th
Albedo 0.32
100m

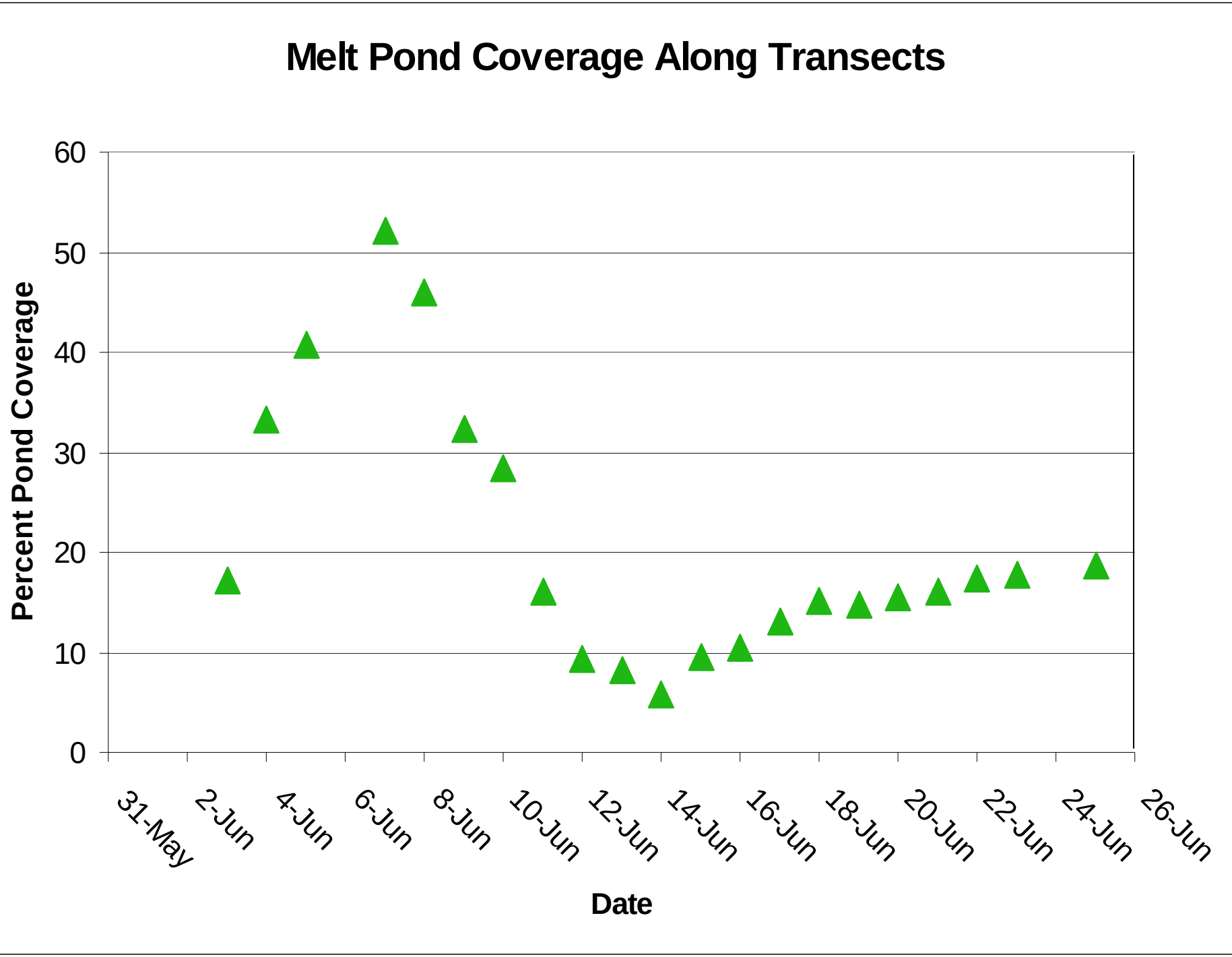

June 10th
Albedo 0.40
100m

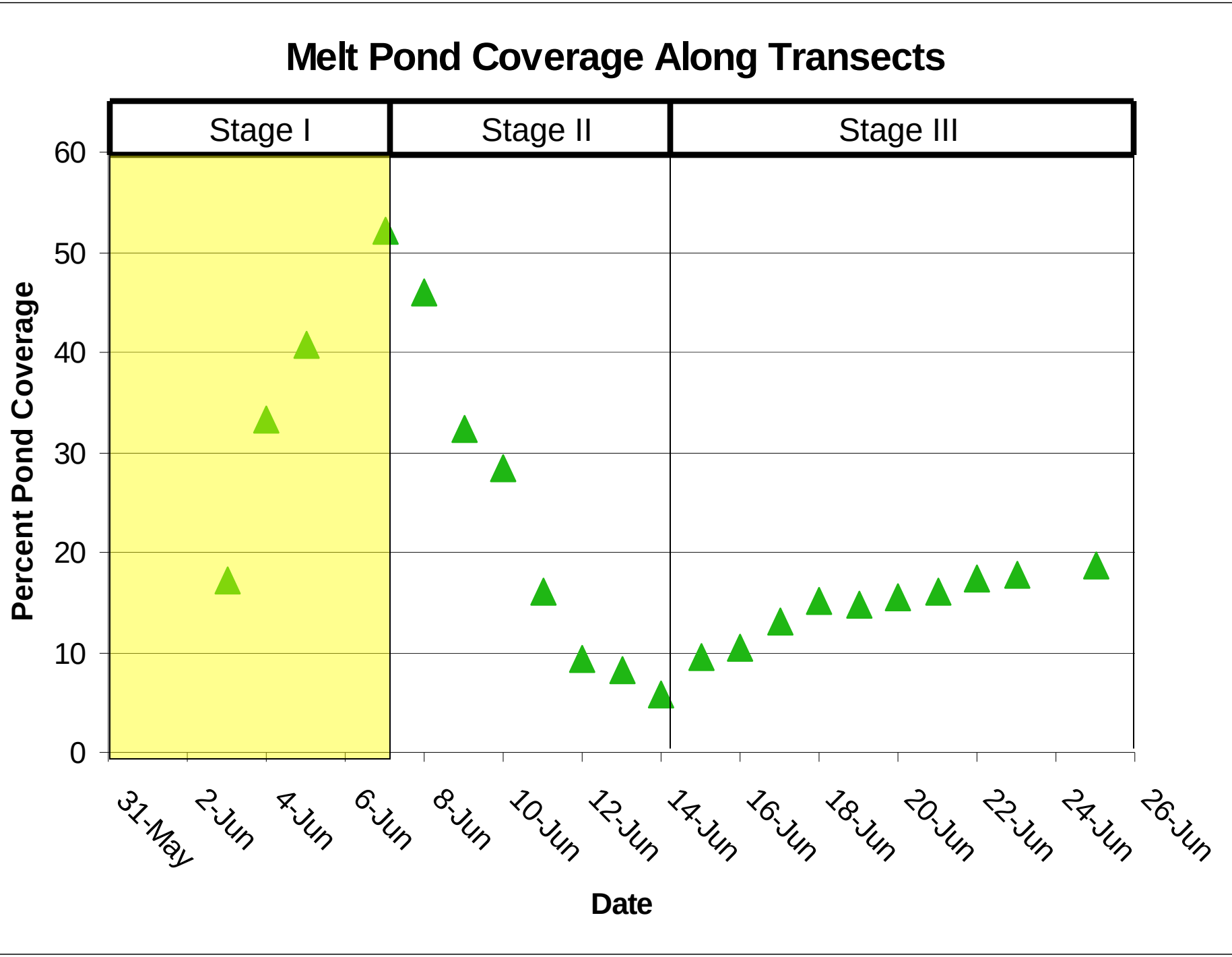

June 13th
Albedo 0.52
100m

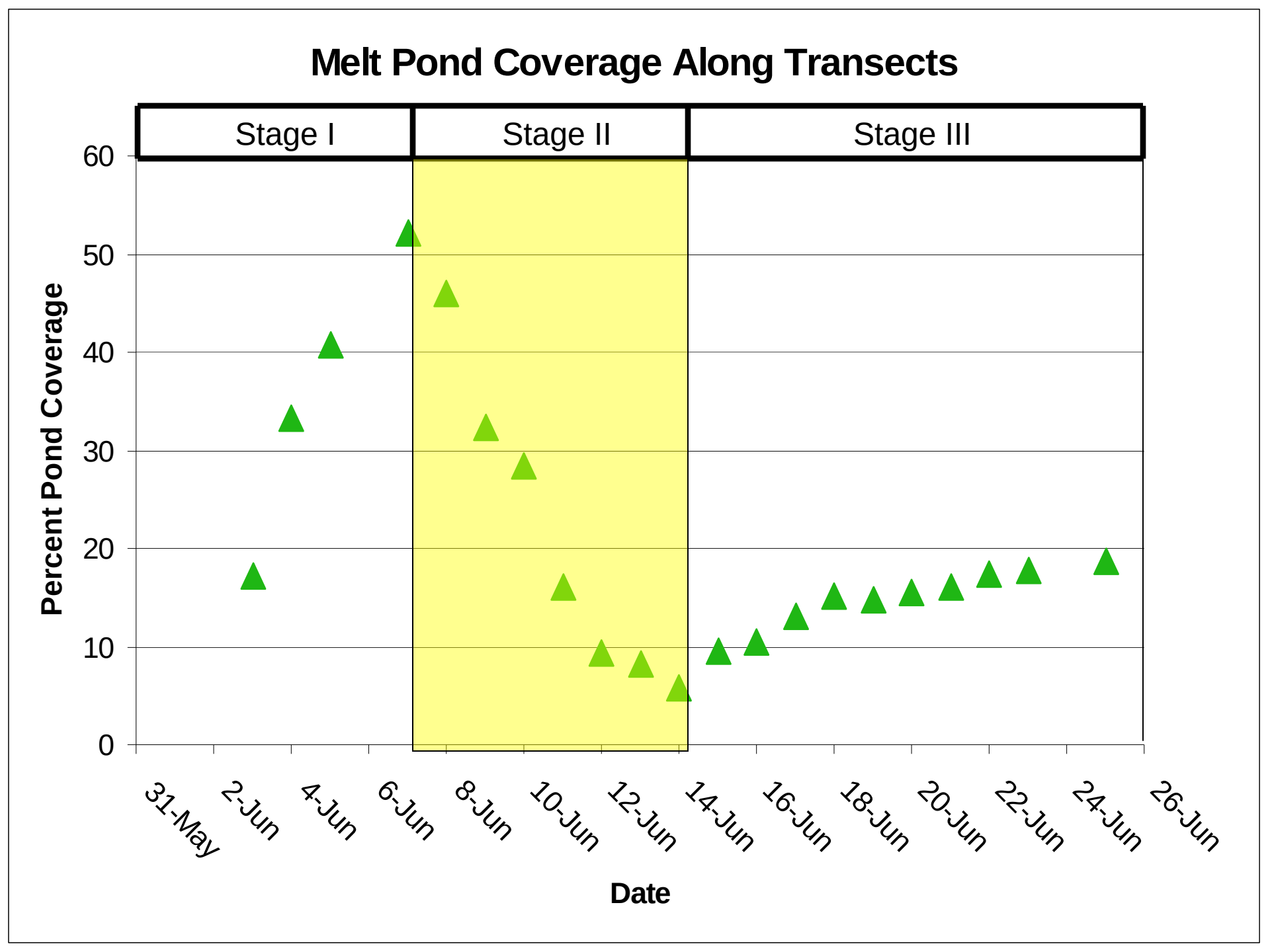

June 15th
Albedo 0.58
100m


June 20th
Albedo 0.47
100m


June 25th
Albedo 0.45
100m


Melt Pond Coverage Along Transects
Percent Pond Coverage
60
50
40
30
20
10
0
31-May
2-Jun
4-Jun
6-Jun
8-Jun
10-Jun
12-Jun
14-Jun
16-Jun
18-Jun
20-Jun
22-Jun
24-Jun
26-Jun
Date


Melt Pond Coverage Along Transects
Stage I
Stage II
Stage III
Percent Pond Coverage
60
50
40
30
20
10
0
31-May
2-Jun
4-Jun
6-Jun
8-Jun
10-Jun
12-Jun
14-Jun
16-Jun
18-Jun
20-Jun
22-Jun
24-Jun
26-Jun
Date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16-Jun
18-Jun
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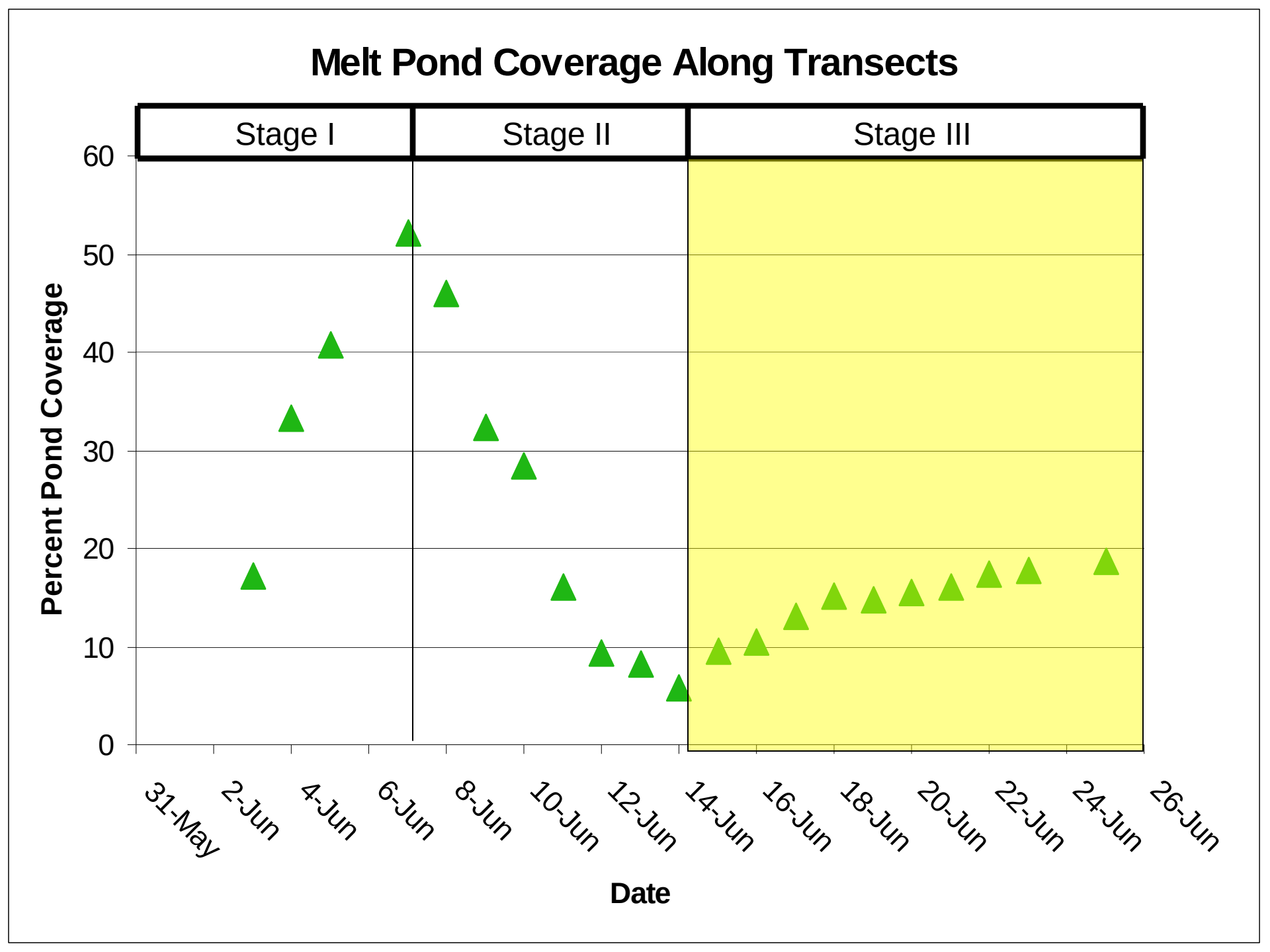
26-Jun
Date


Melt Pond Coverage Along Transects
Stage I
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Percent Pond Coverage
60
50
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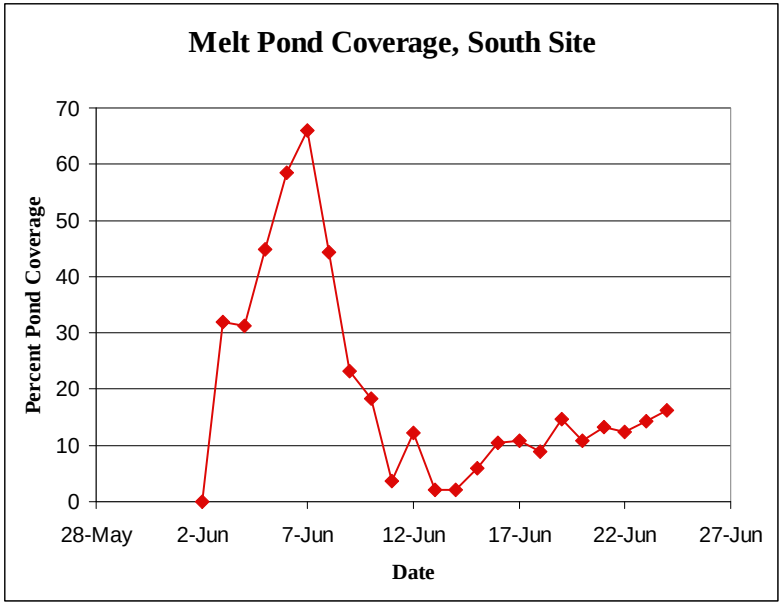
0
31-May
2-Jun
4-Jun
6-Jun
8-Jun
10-Jun
12-Jun
14-Jun
16-Jun
18-Jun
20-Jun
22-Jun
24-Jun
26-Jun
Date

Ponds are Super Cool

- Reason 1: Ponding dramatically changes the albedo of the ice.
- Reason 2: Ponds change a lot, forming and draining in a matter of days.



Pond Volume Parameterization
CCSM CICE 4.0

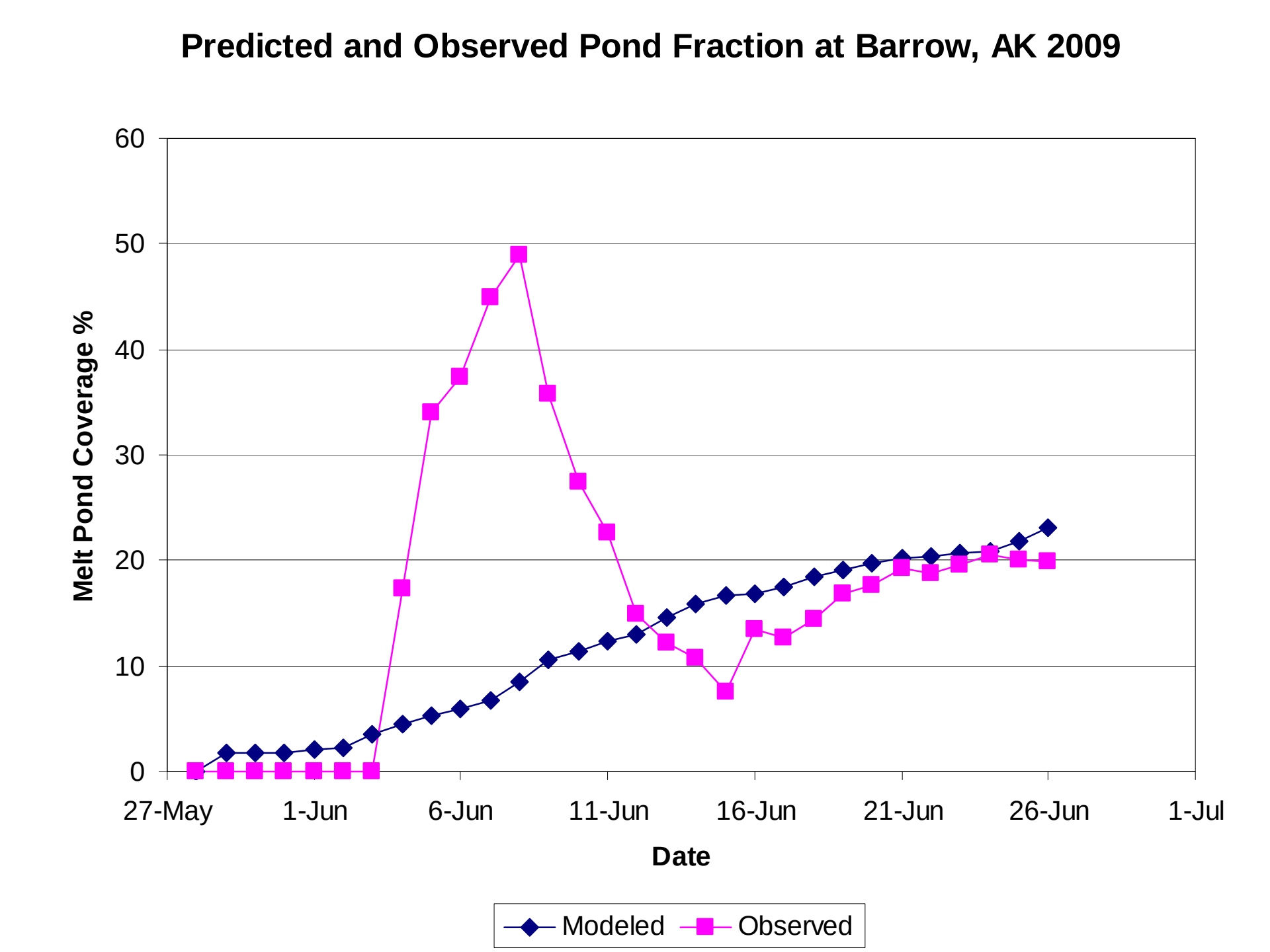
$$v_p^{'} = v_p(t) + 0.1(dh_i \frac{\rho_i}{\rho_w} + dh_s \frac{\rho_s}{\rho_w} + F_{rain} \frac{\Delta t}{\rho_w})$$

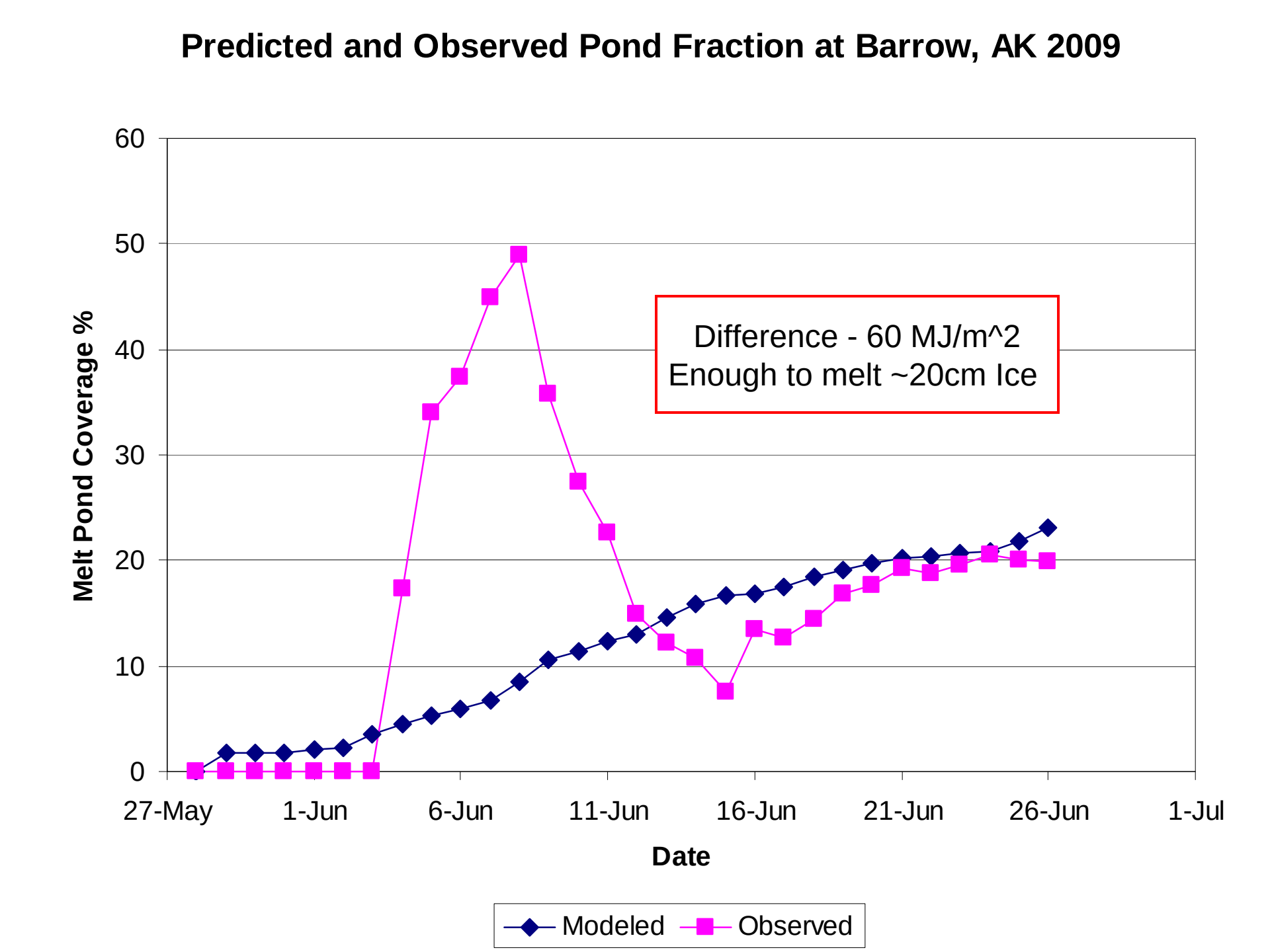
Keep Track of Pond Volume:
New pond volume =
old pond volume + 10% of the new melt water

$$h_p = 0.8 f_p$$

Pond fraction is related to pond depth by a factor of 0.8

CICE 4.0 Documentation


Predicted and Observed Pond Fraction at Barrow, AK 2009
Melt Pond Coverage %
60
50
40
30
20
10
0
27-May
1-Jun
6-Jun
11-Jun
16-Jun
21-Jun
26-Jun
1-Jul
Date
Modeled
Observed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Melt Pond Coverage %
60
50
40
30
20
10
0
27-May
1-Jun
6-Jun
11-Jun
16-Jun
21-Jun
26-Jun
1-Jul
Date
Difference - 60 MJ/m^2
Enough to melt ~20cm Ice
Modeled
Observed

Ponds are Super Cool

- Reason 1: Ponding dramatically changes the albedo of the ice.
- Reason 2: Ponds change a lot, forming and draining in a matter of days.
- Reason 3: Melt ponds are not that well understood.

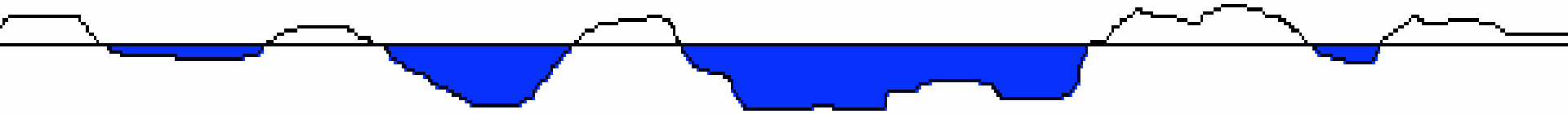
First Year

Multi Year

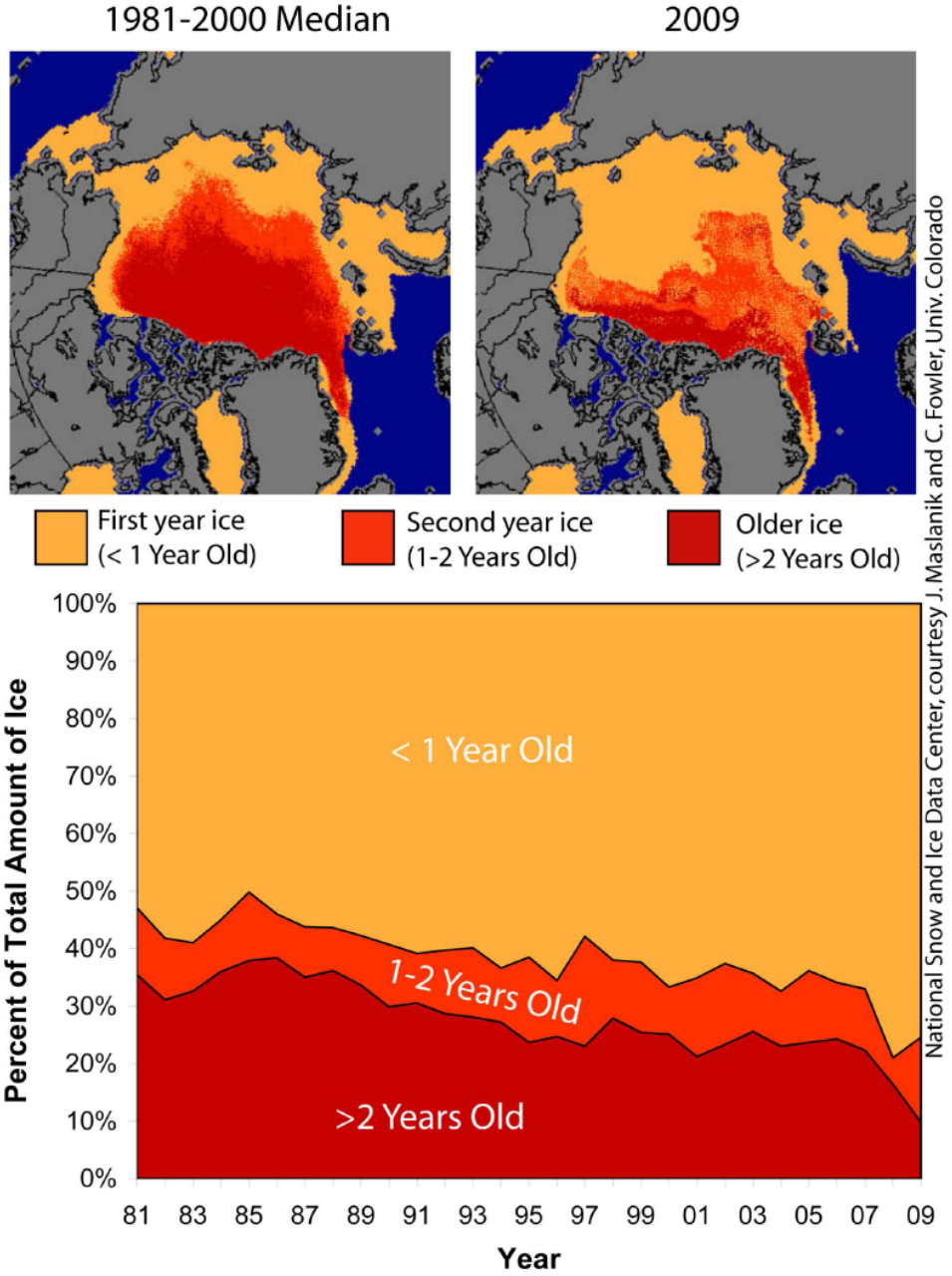
Melt Pond Coverage:

First Year Ice – Up to 90%+

Multi Year Ice – Rarely >40%



End of February Arctic Sea Ice Age



Ponds are Super Cool

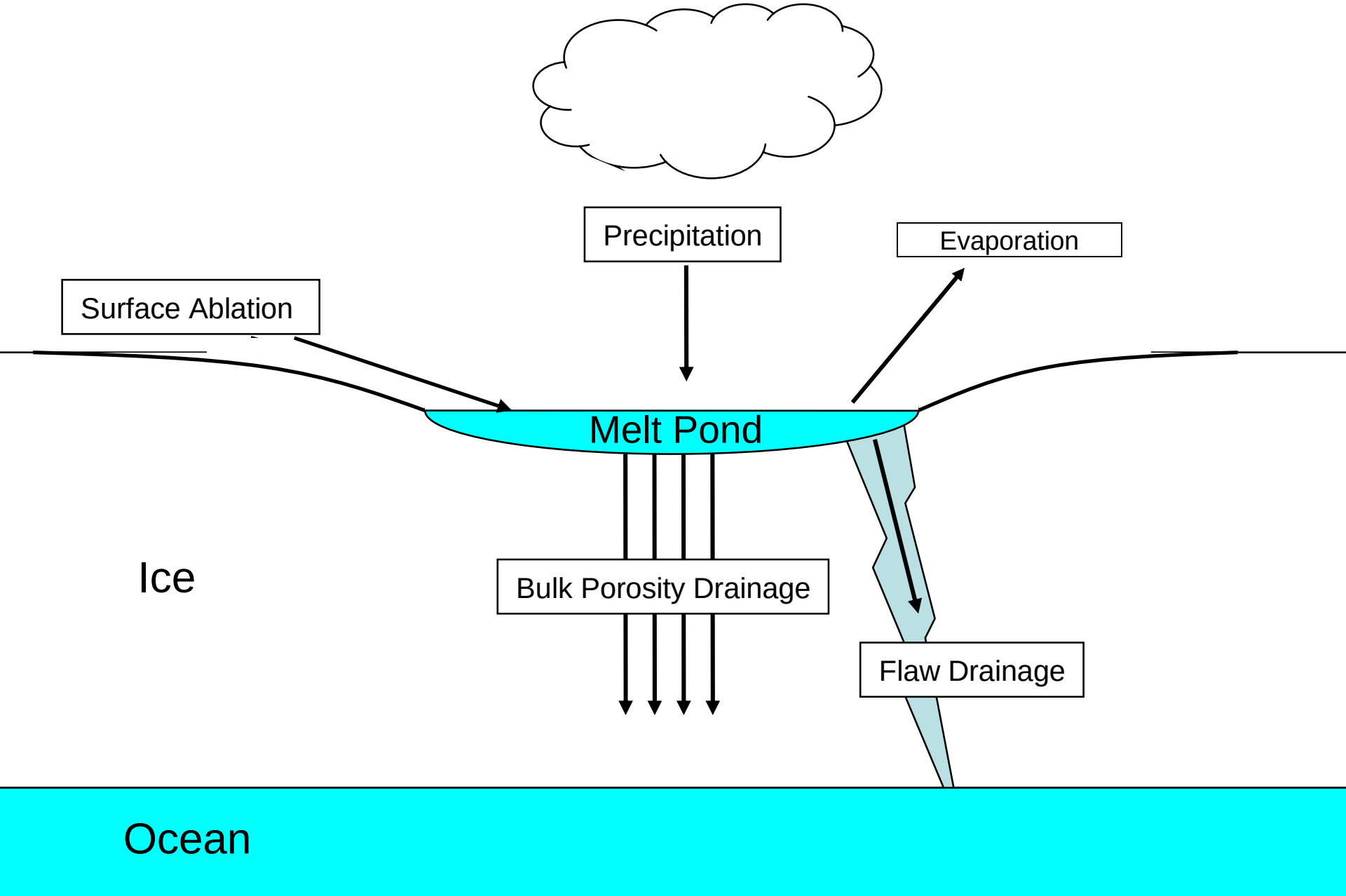
- Reason 1: Ponding dramatically changes the albedo of the ice.
- Reason 2: Ponds change a lot, forming and draining in a matter of days.
- Reason 3: Melt ponds are not that well understood.
- Reason 4: Melt ponds are something that may change significantly in a changing Arctic

Ponds are Super Cool

- Reason 1: Ponding dramatically changes the albedo of the ice.
- Reason 2: Ponds change a lot, forming and draining in a matter of days.
- Reason 3: Melt ponds are not that well understood.
- Reason 4: Melt ponds are something that may change significantly in a changing Arctic.
- Reason 5: Melt ponds are fun to drive through.

Photo: Chris Petrich

How do melt ponds work?



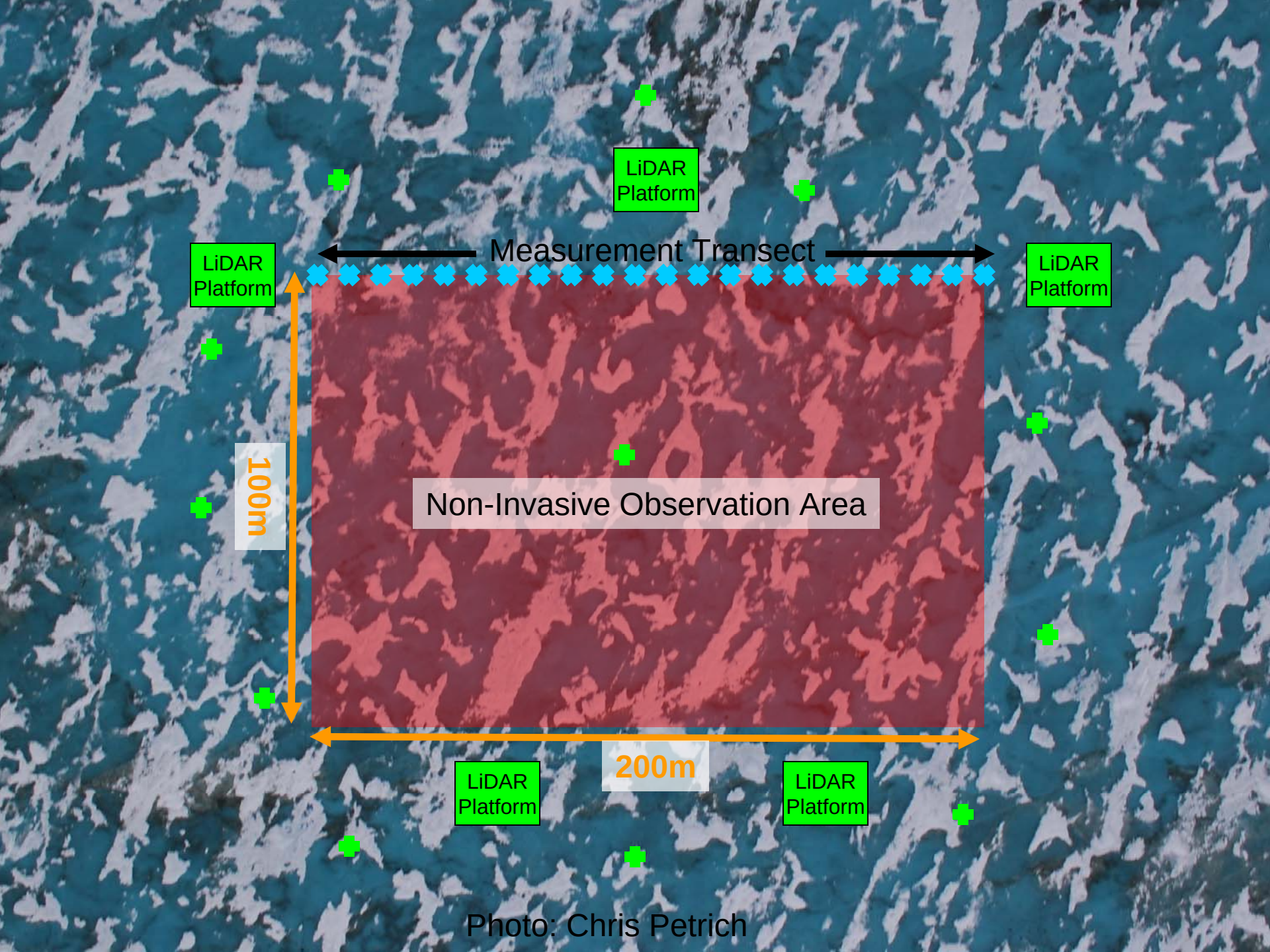


Photo: Chris Petrich

LiDAR Platform

LiDAR Platform

Measurement Transect

LiDAR Platform

Photo: Chris Petrich

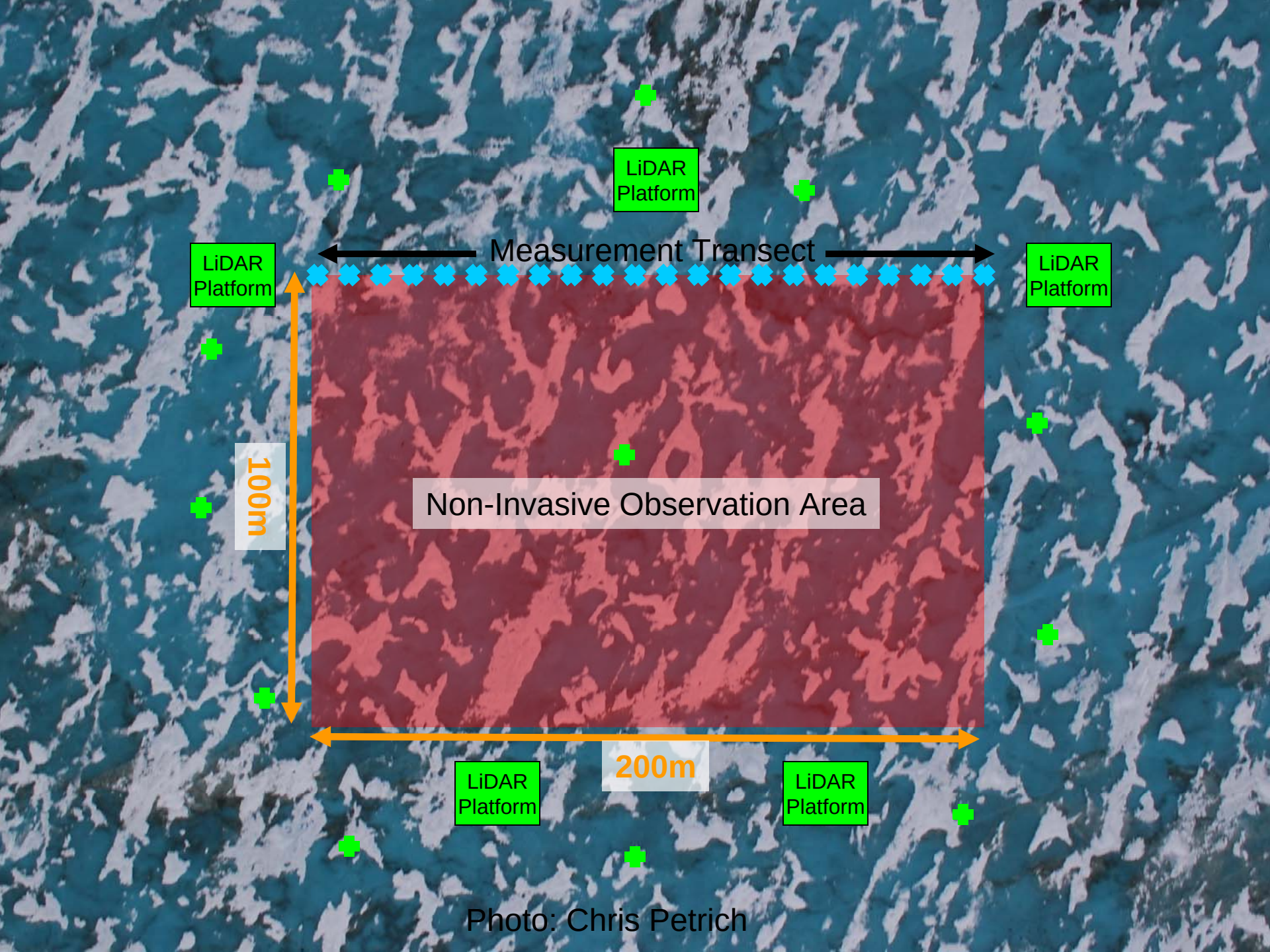
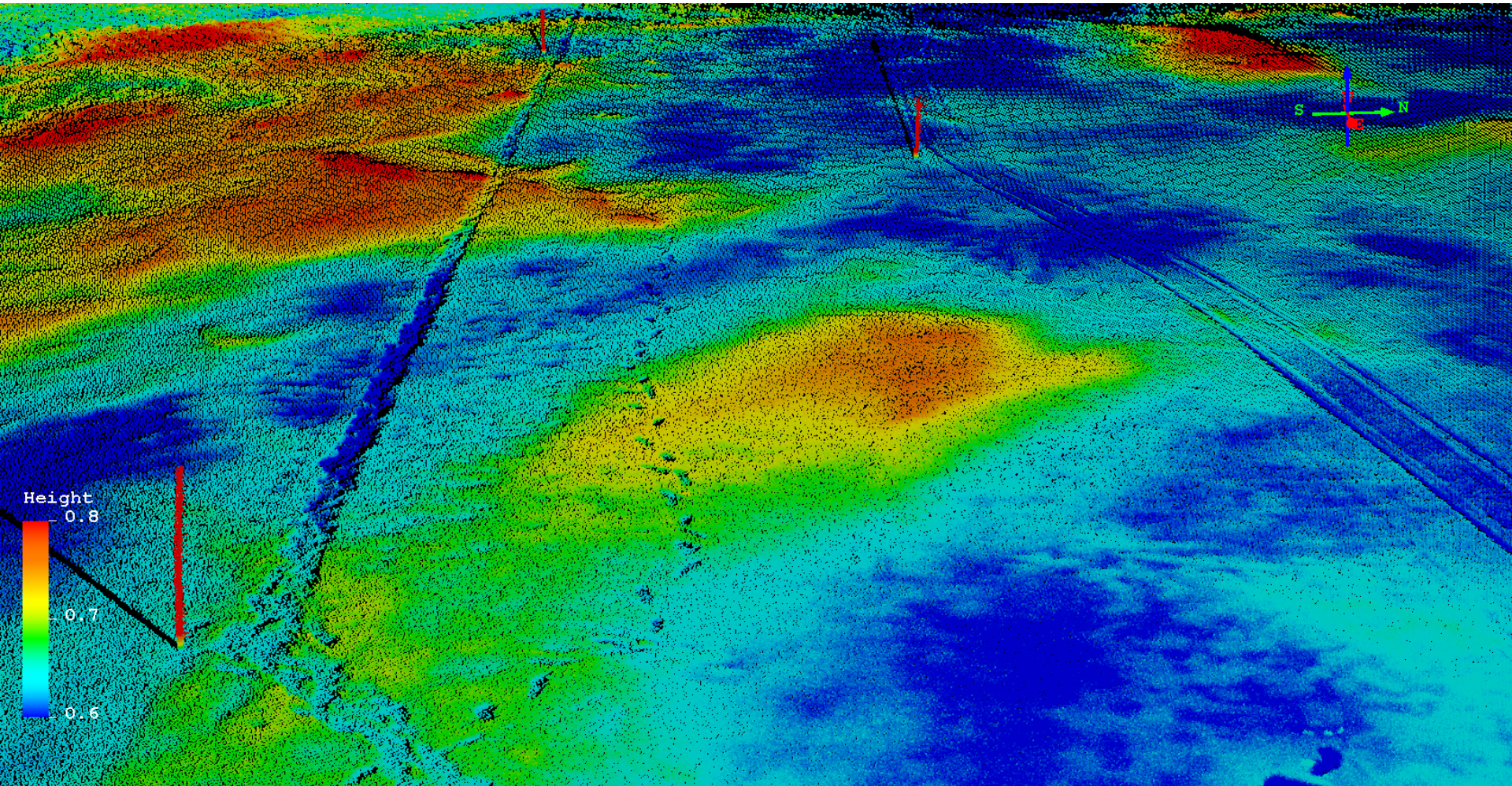
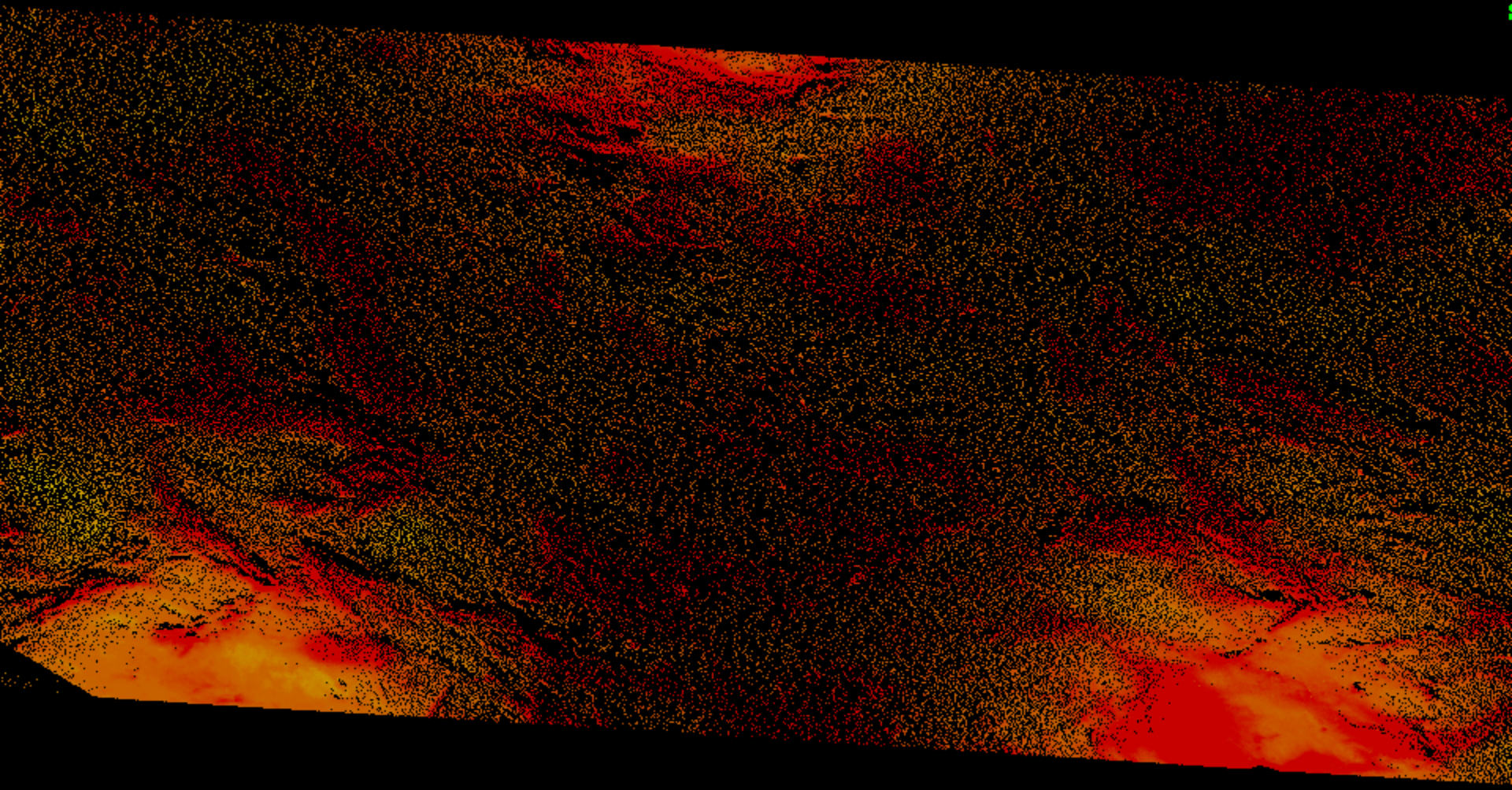


Photo: Chris Petrich


Height
0.8
0.7
0.6
S
N
E

May 20



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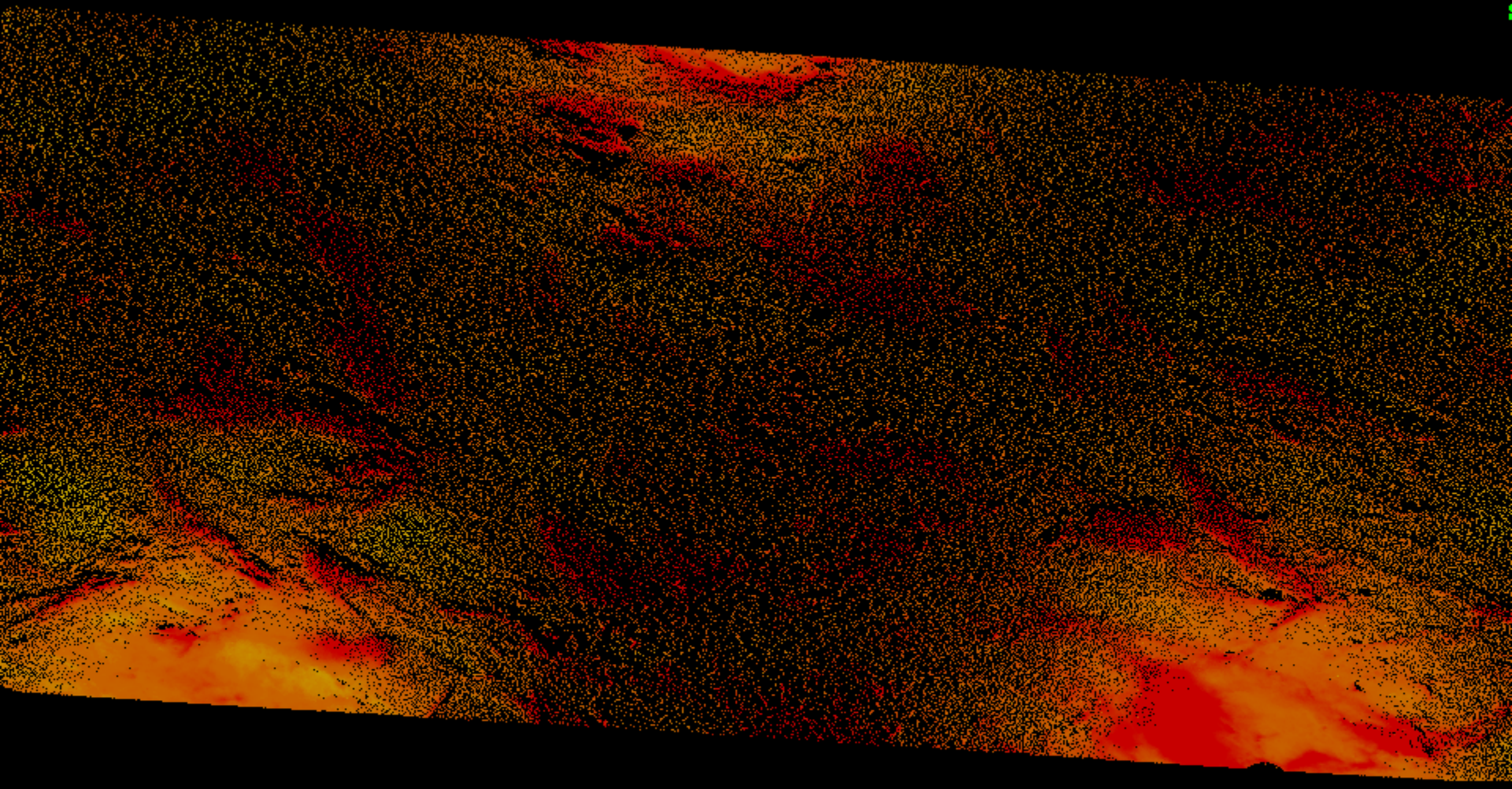
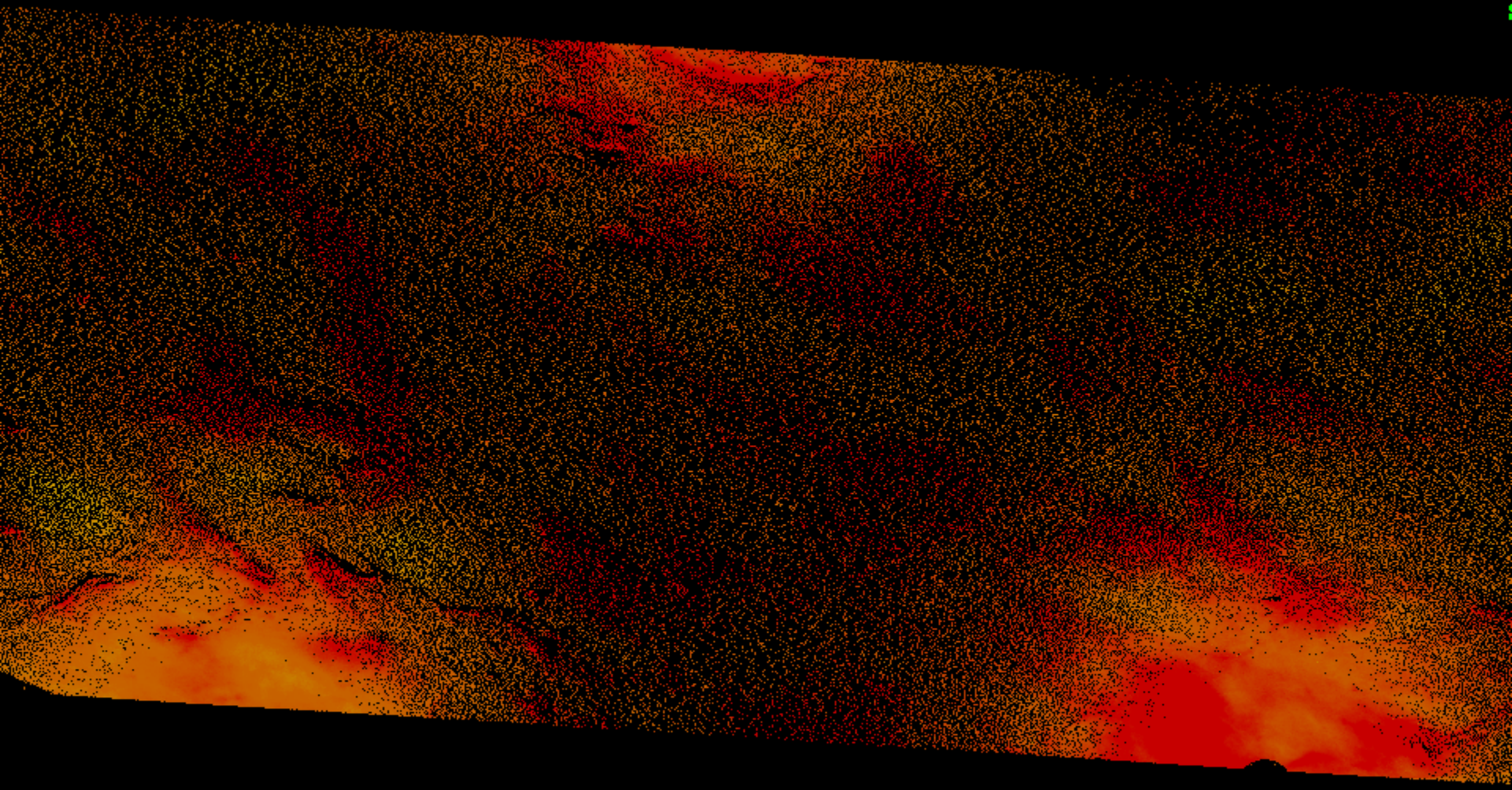
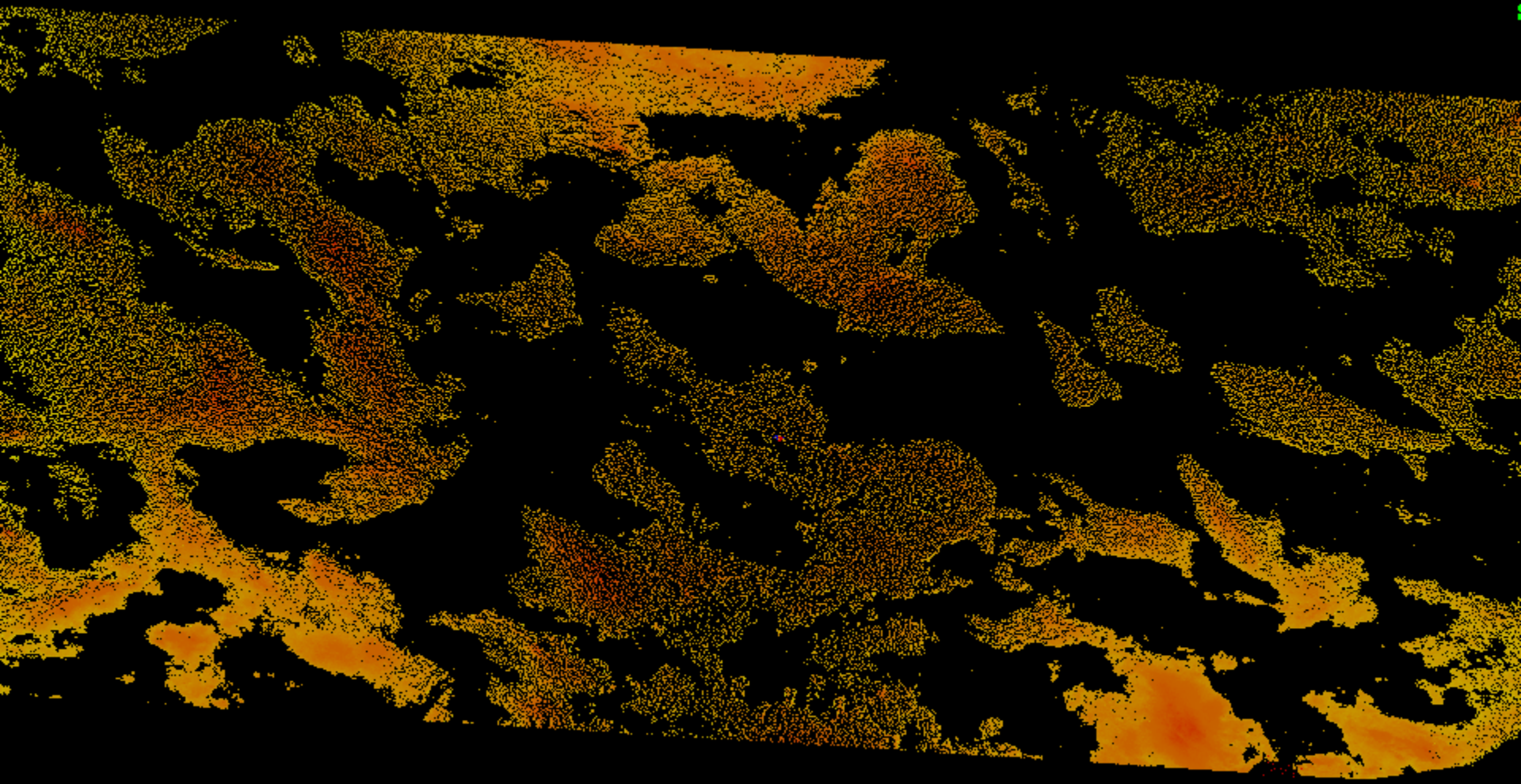


June 1



June 6



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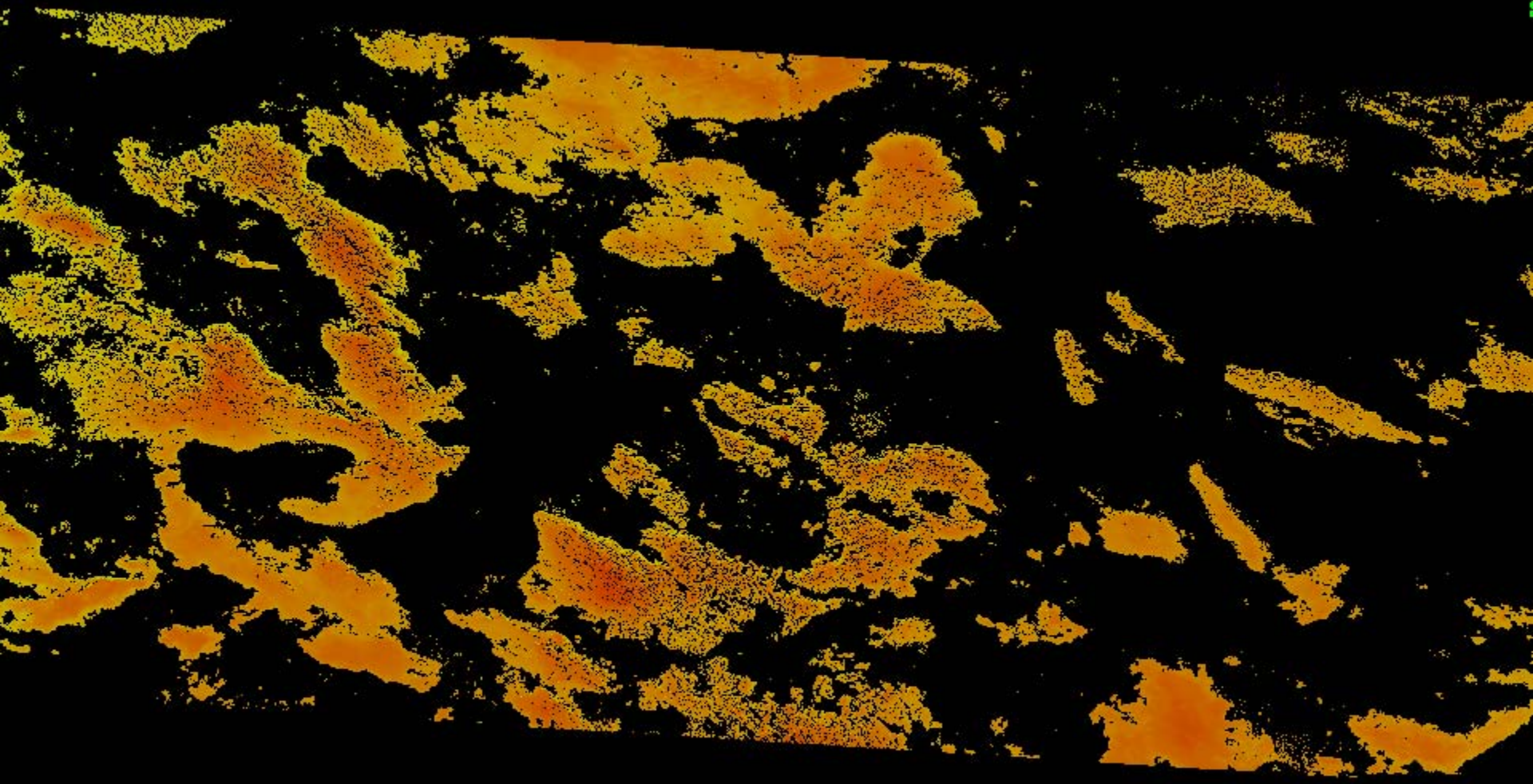
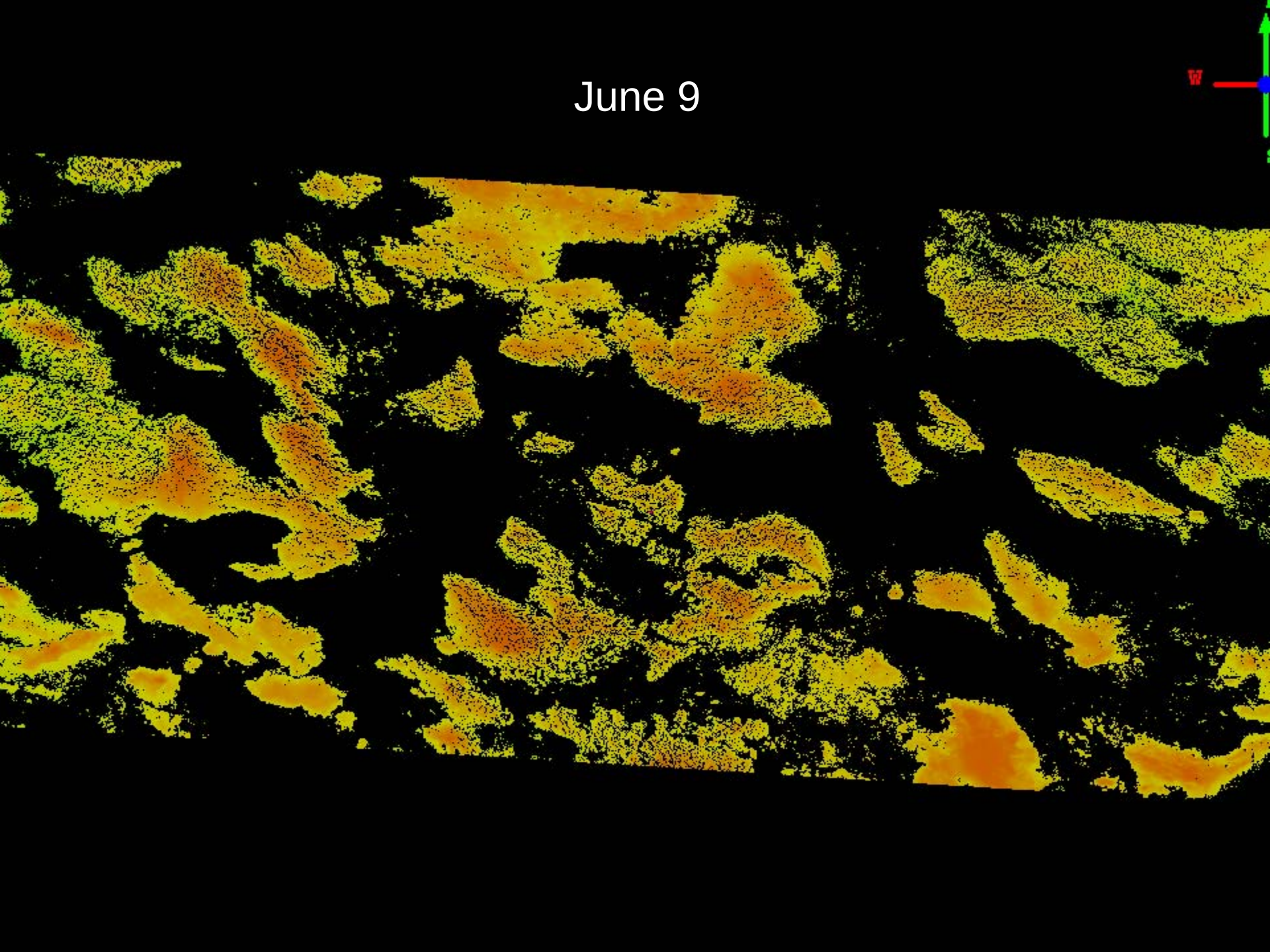
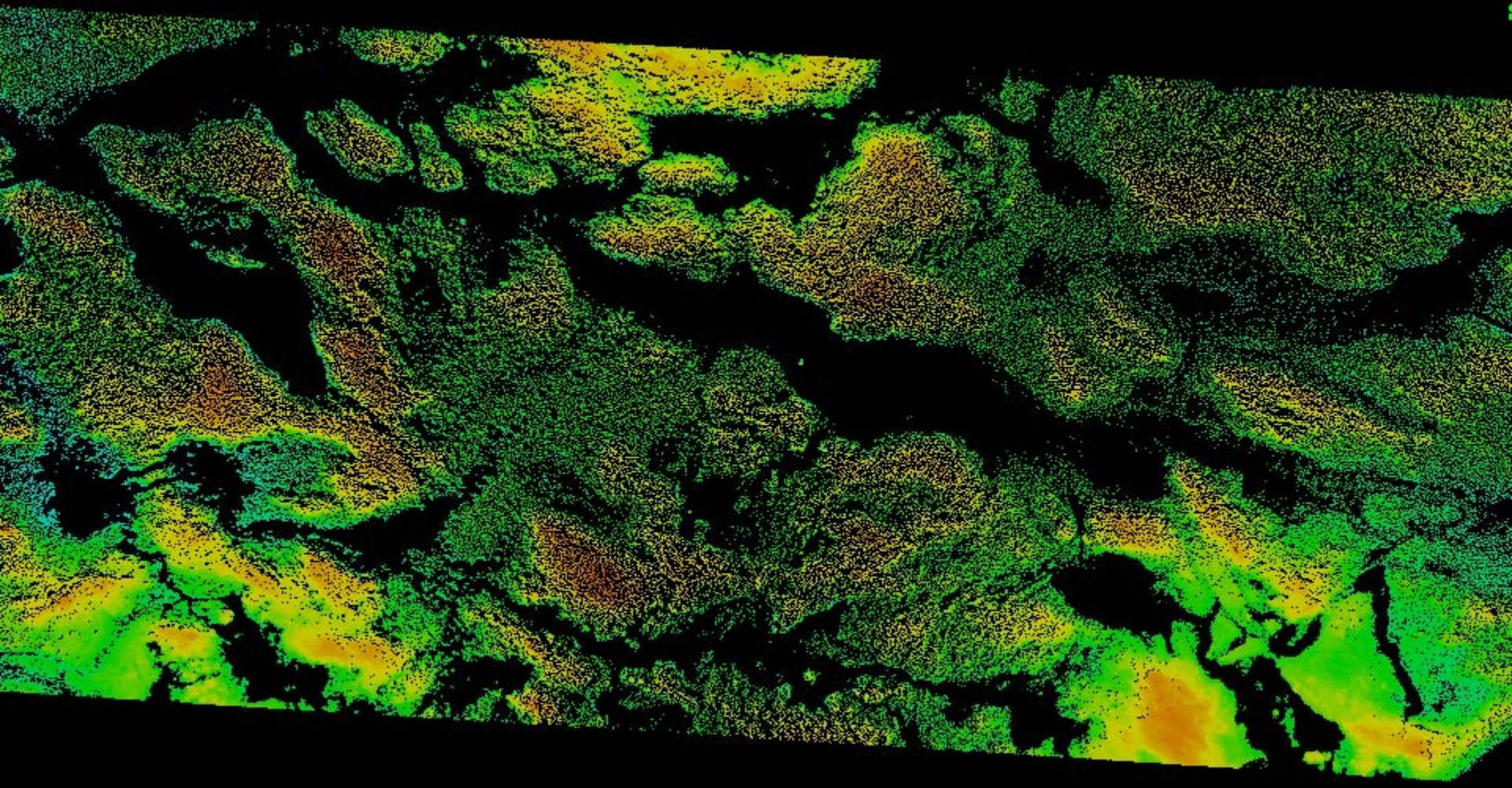


June 9



June 11



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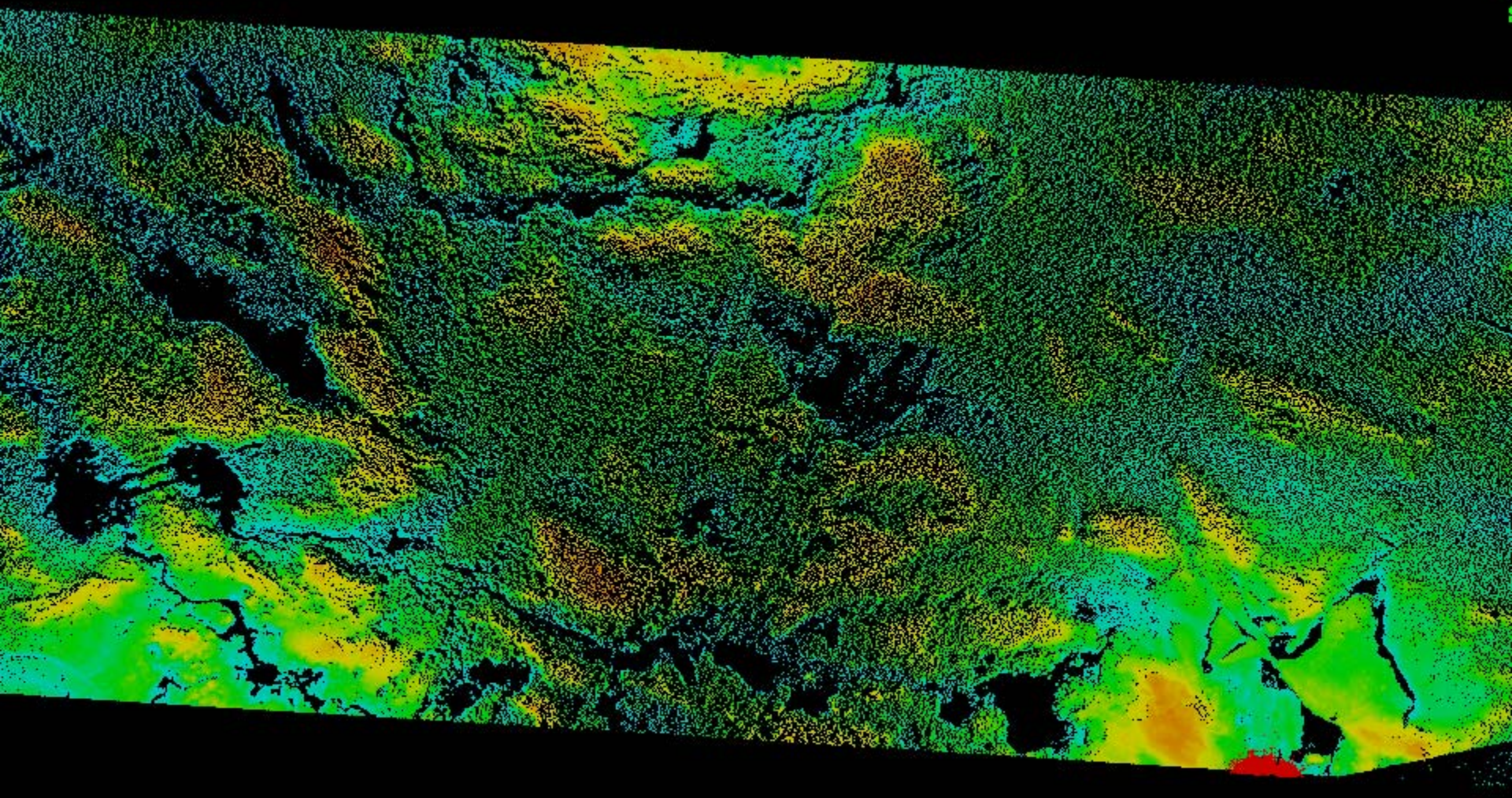

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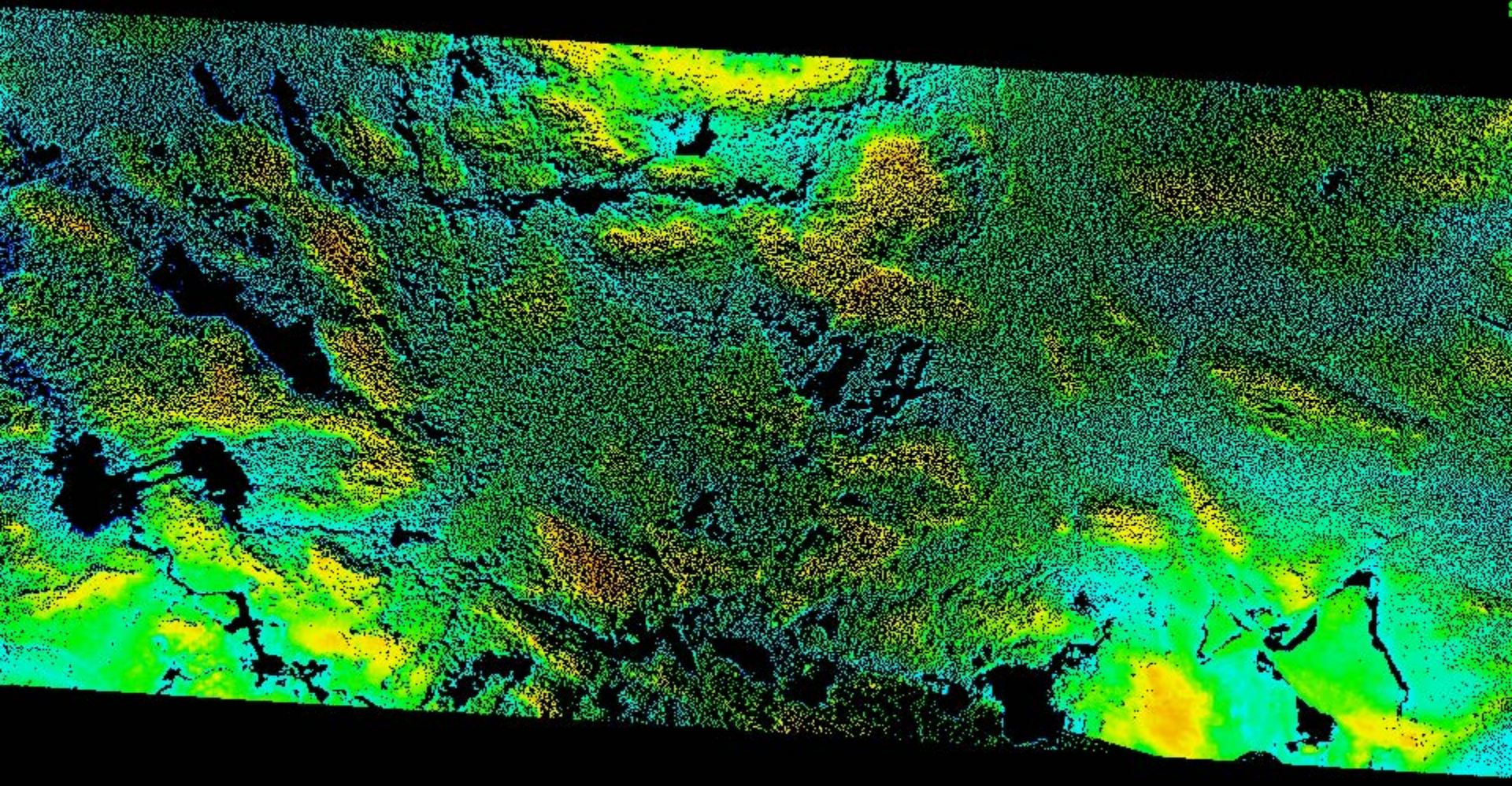

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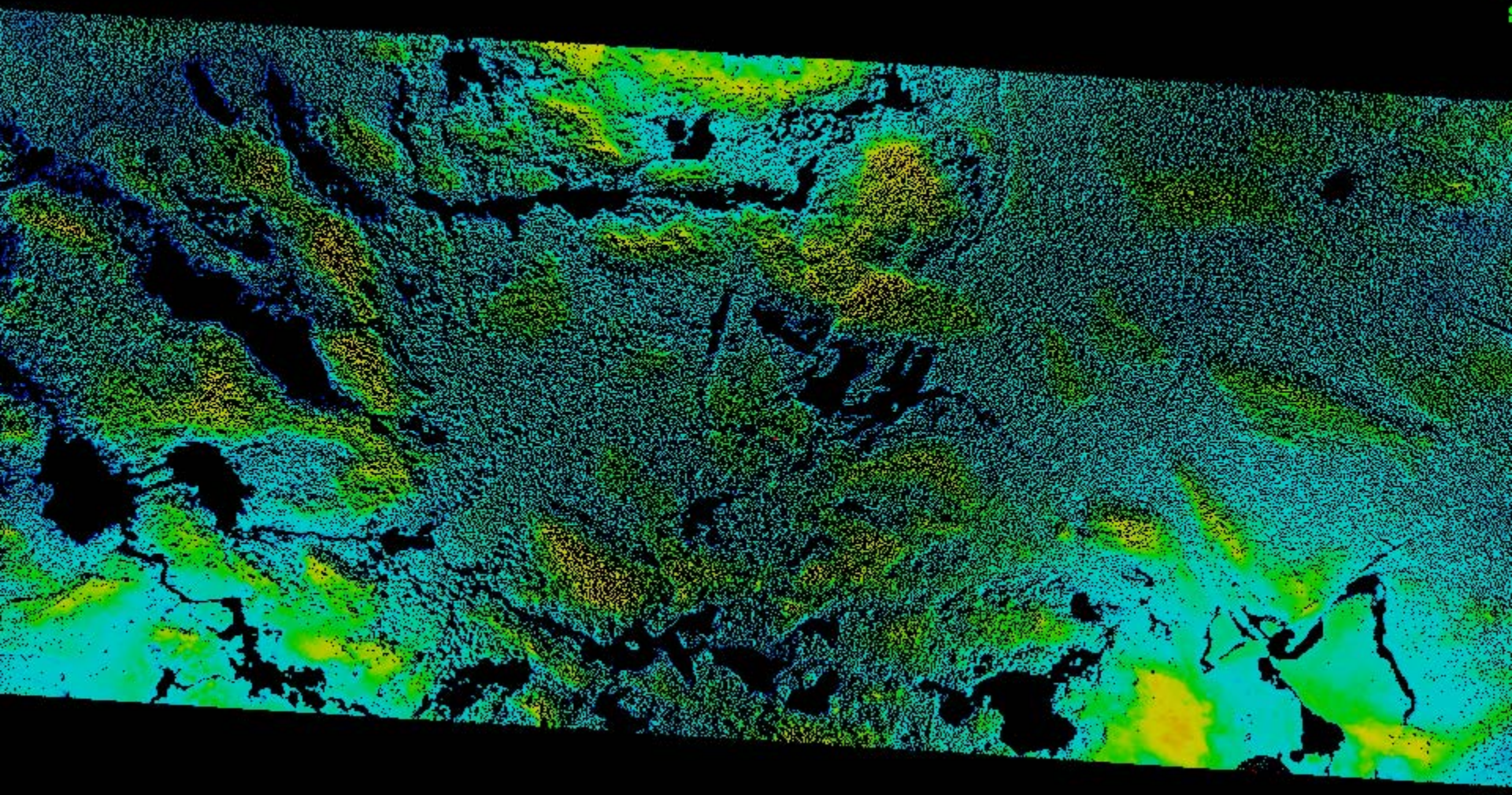

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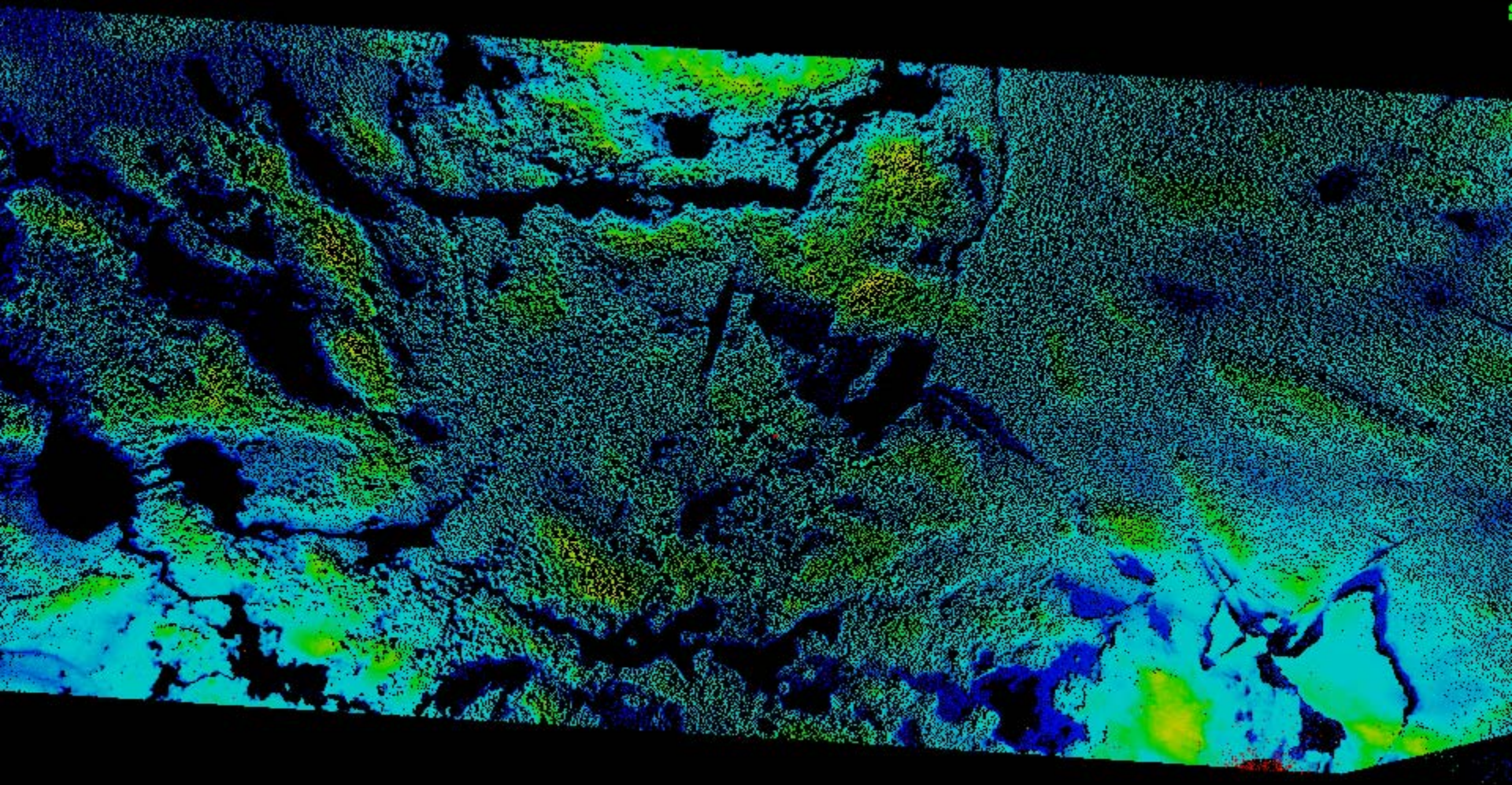

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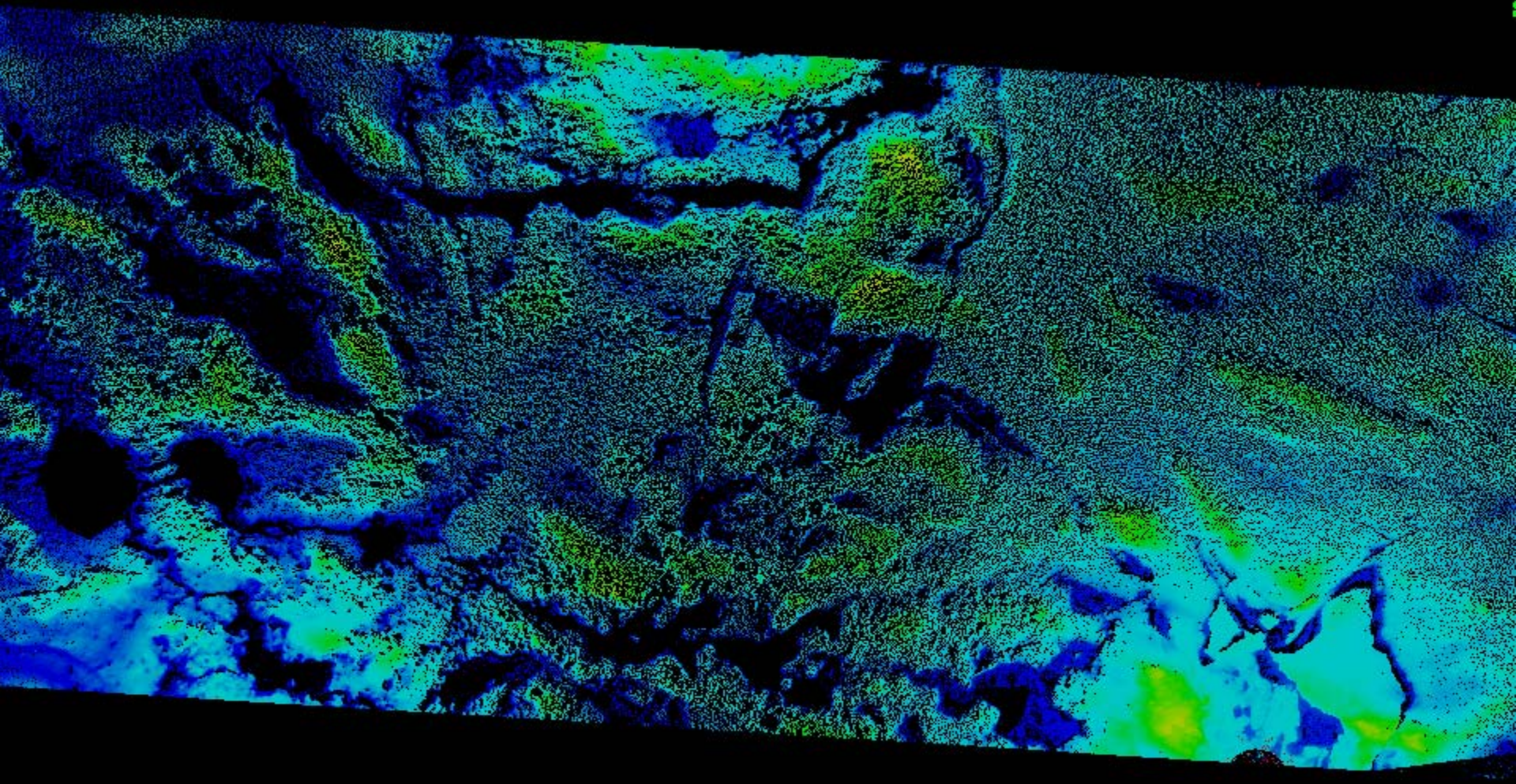
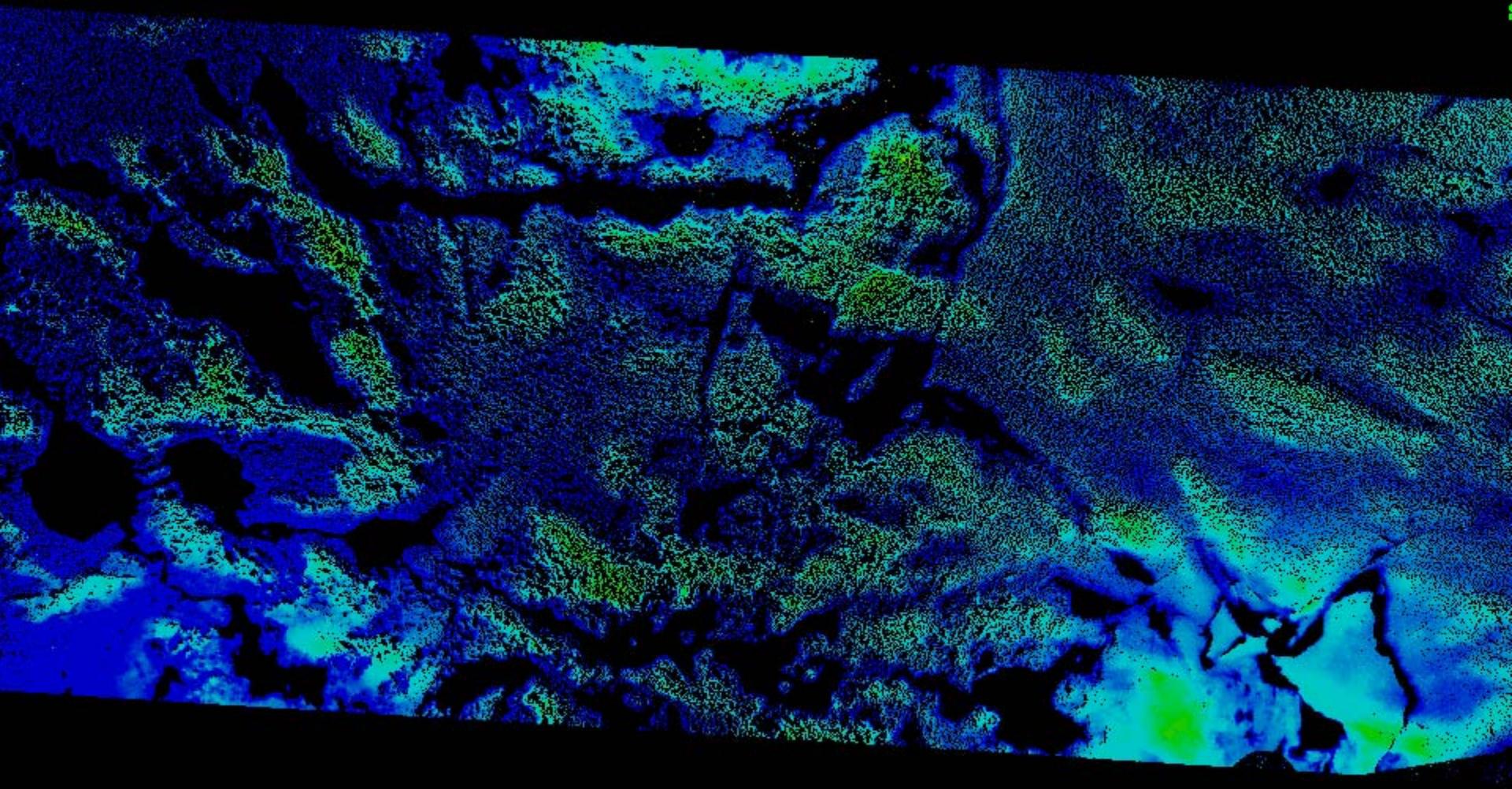
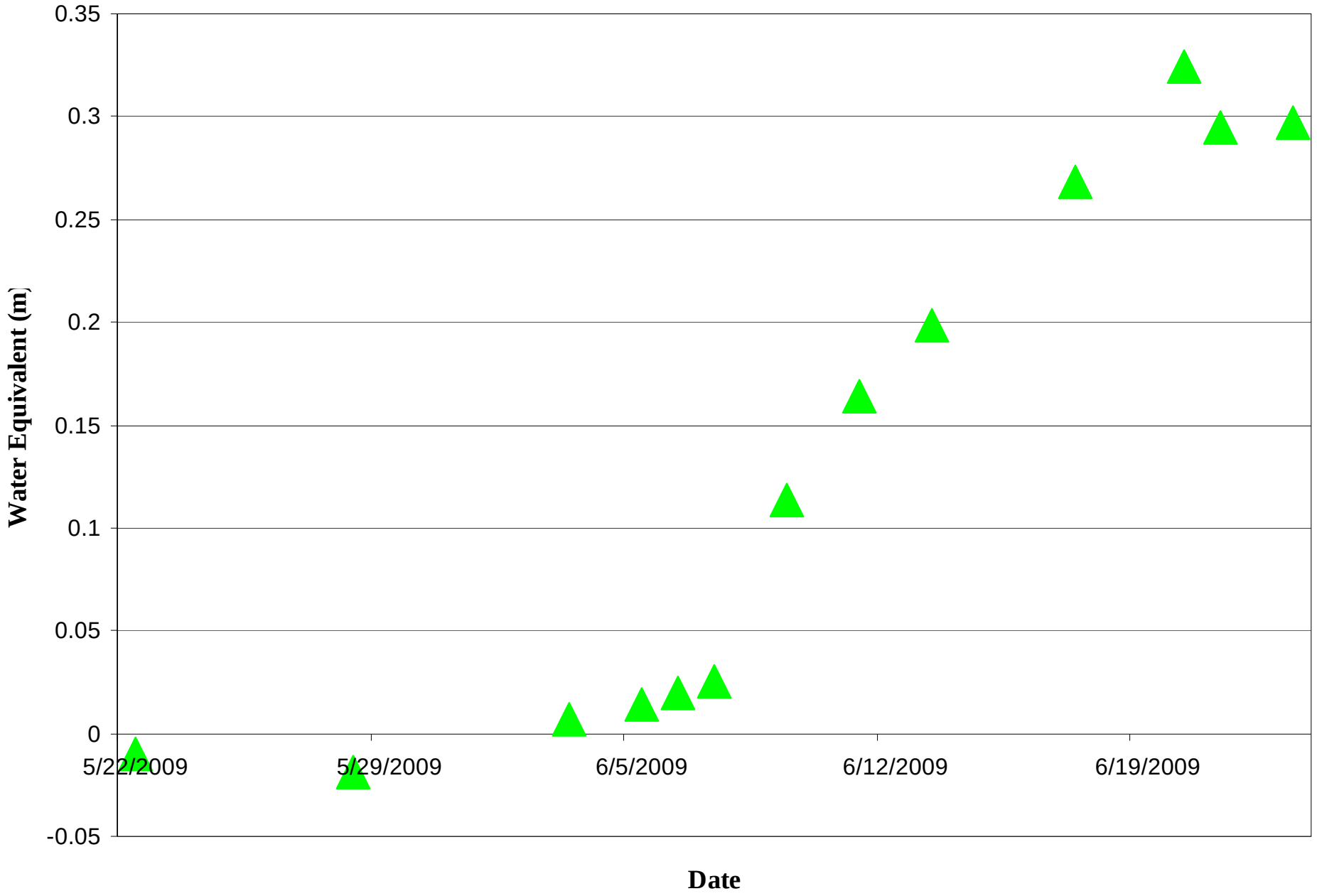


June 24



Cumulative Water Drainage (m) vs. Date



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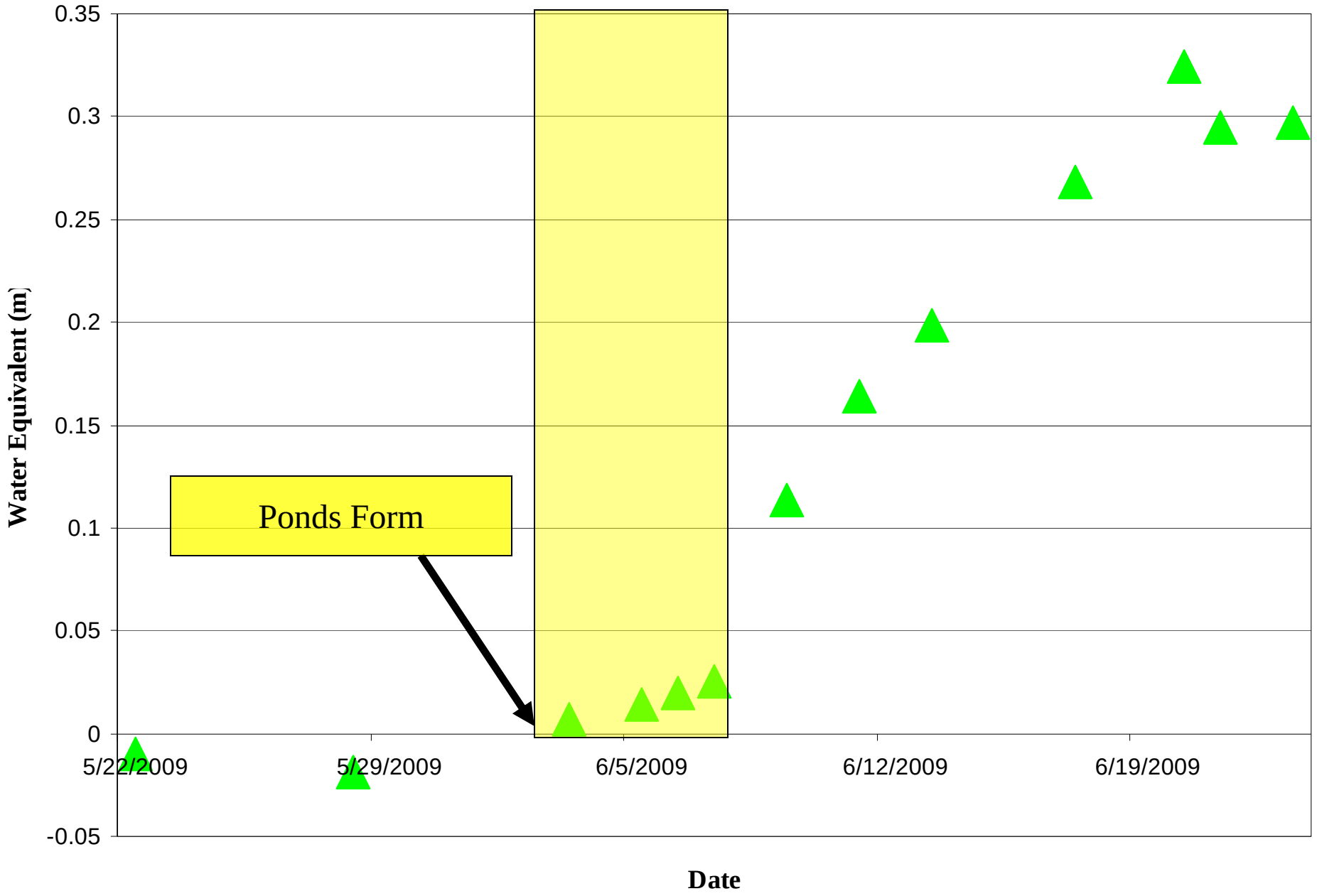

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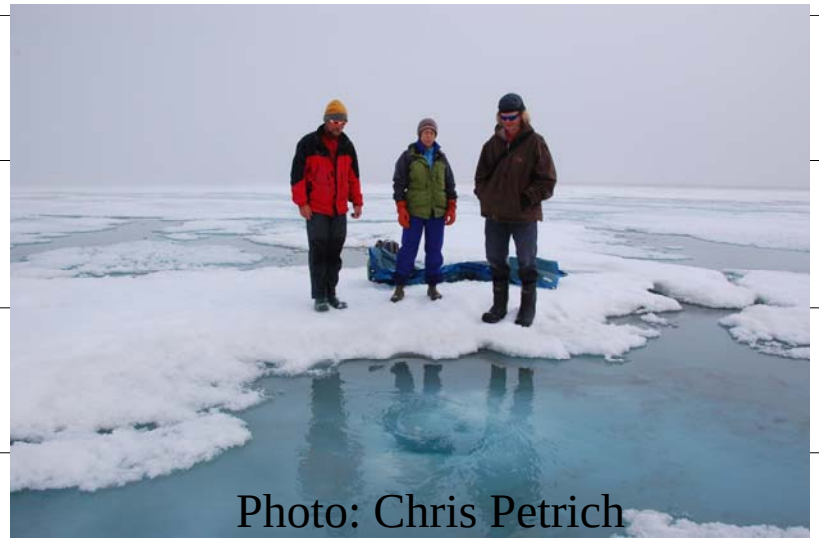


Photo: Chris Petrich

Maximum Pond Coverage
June 7th.

Drainage Holes Appear
June 7th

Water Equivalent (m)

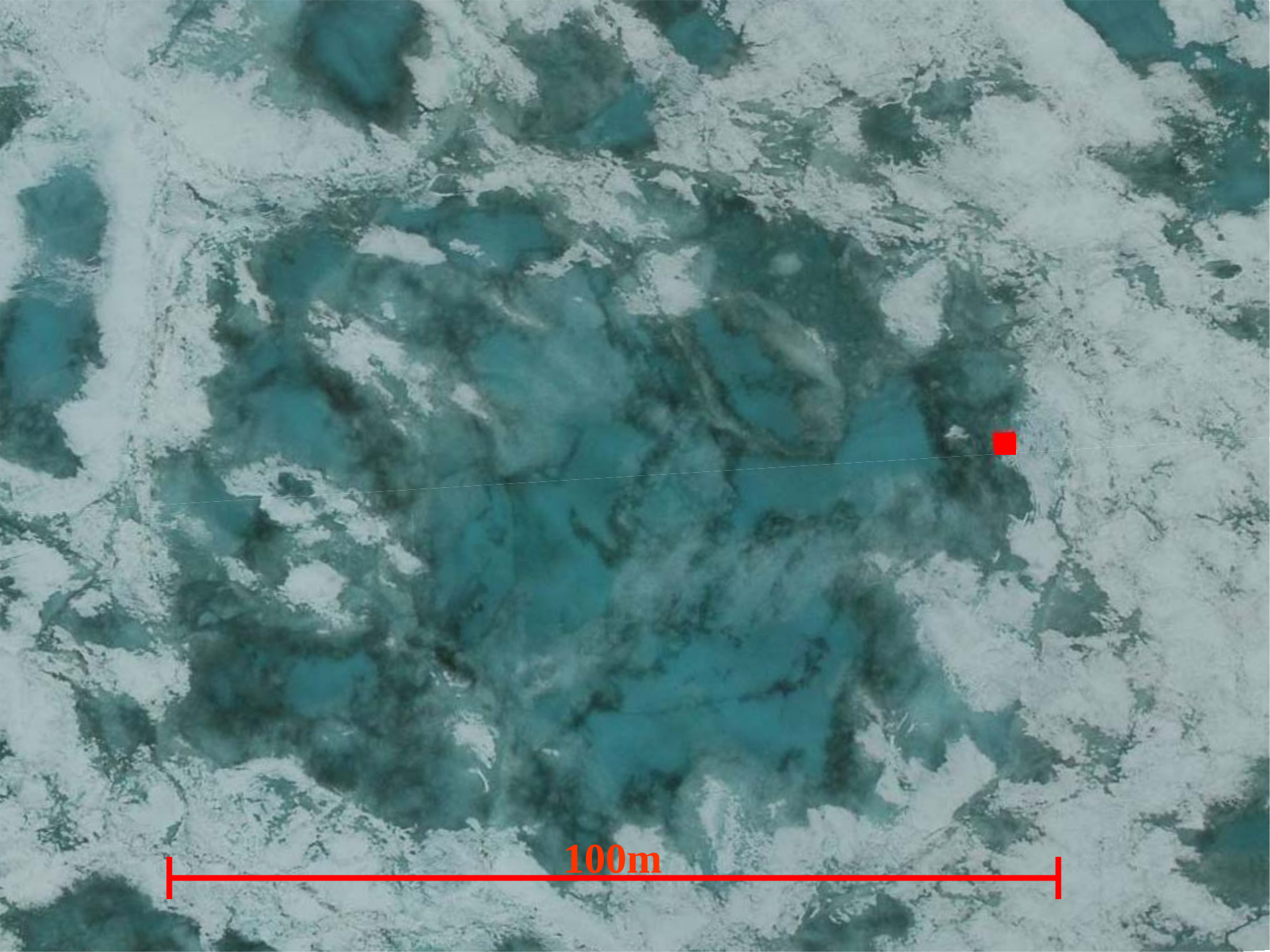
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05

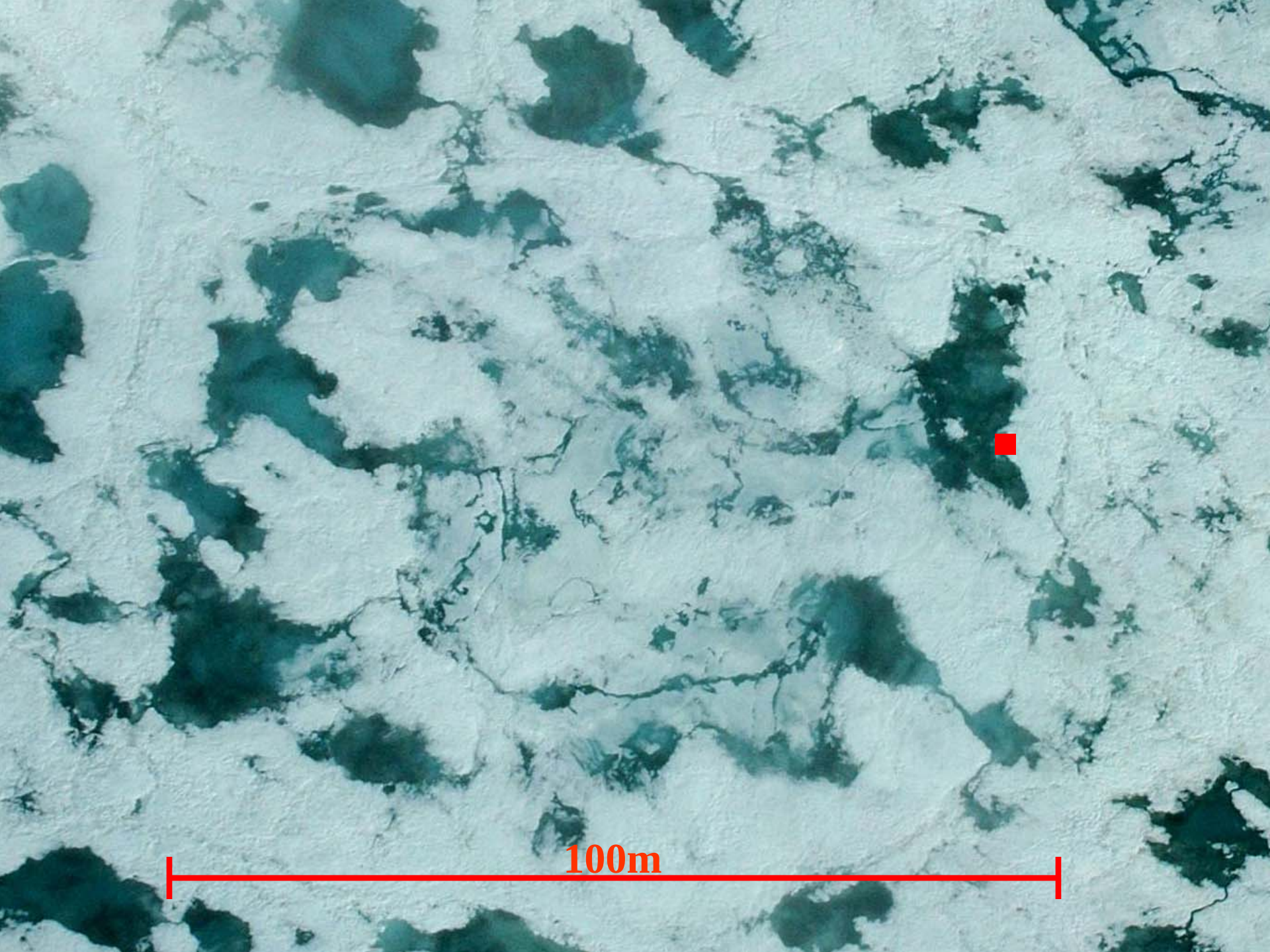
5/22/2009
5/29/2009
6/5/2009
6/12/2009
6/19/2009

Date

Photo: Chris Petrich


http://www.alaska-in-pictures.com/picture-of-a-harbor-seal-8057-pictures.htm


100m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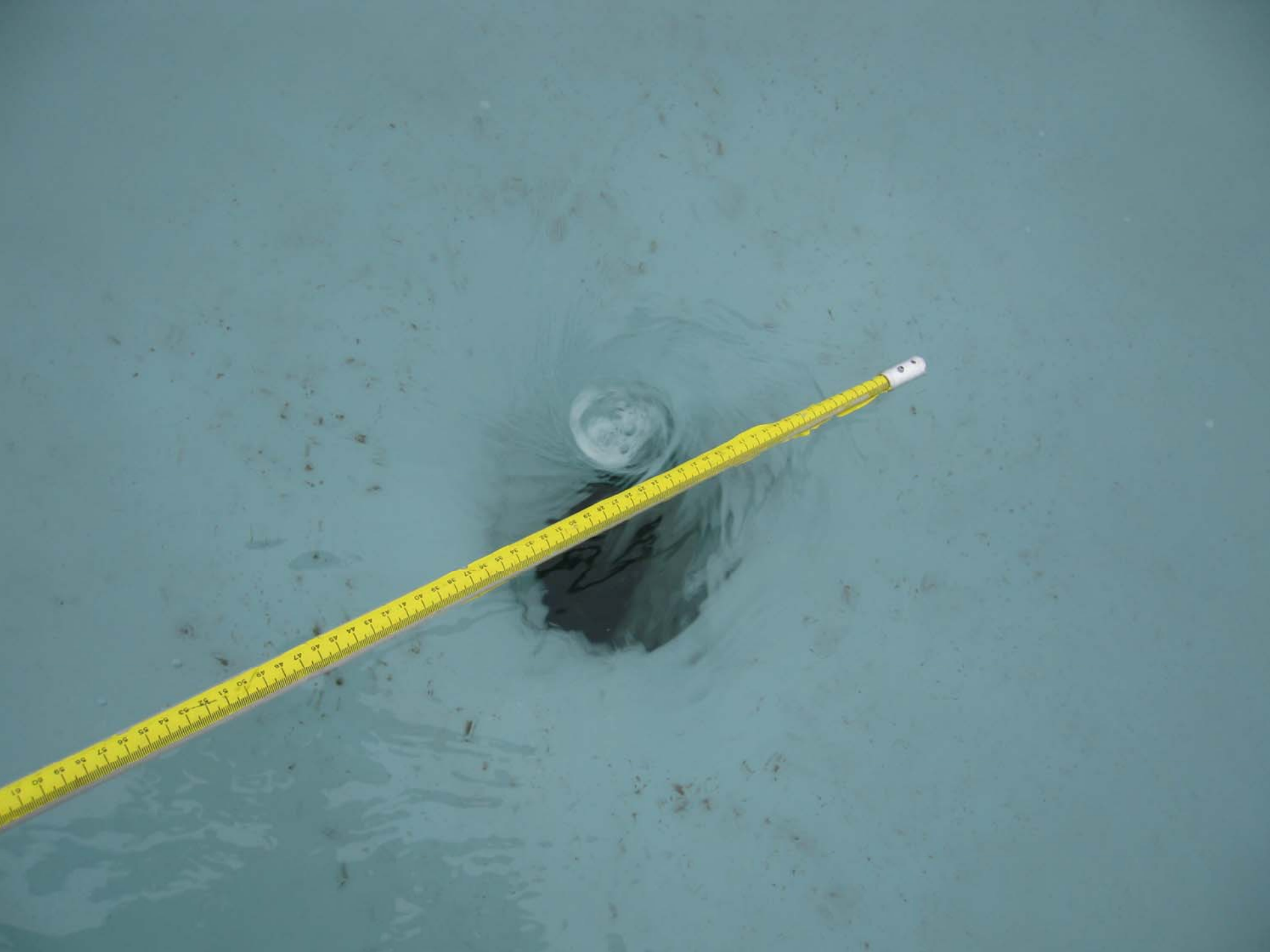
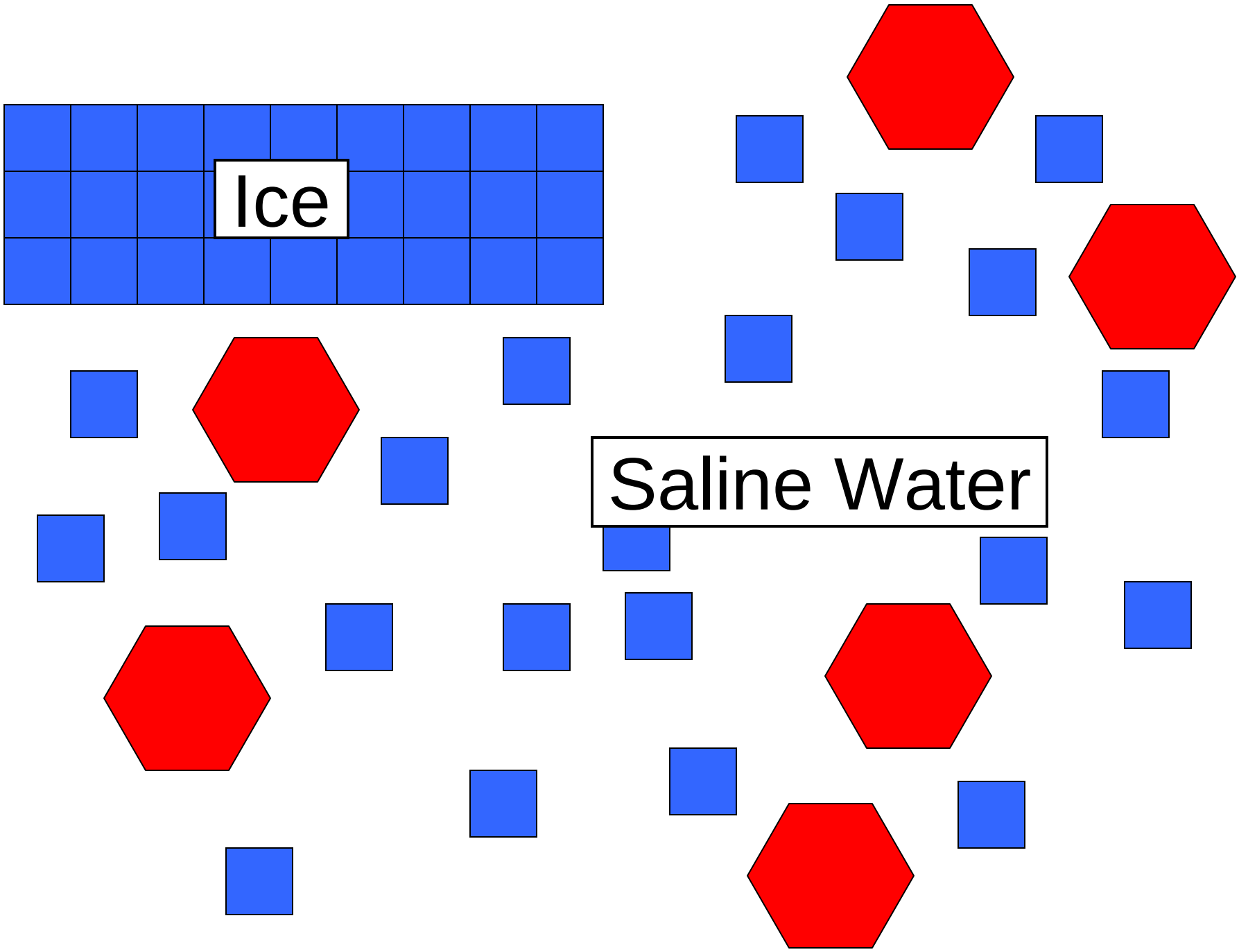
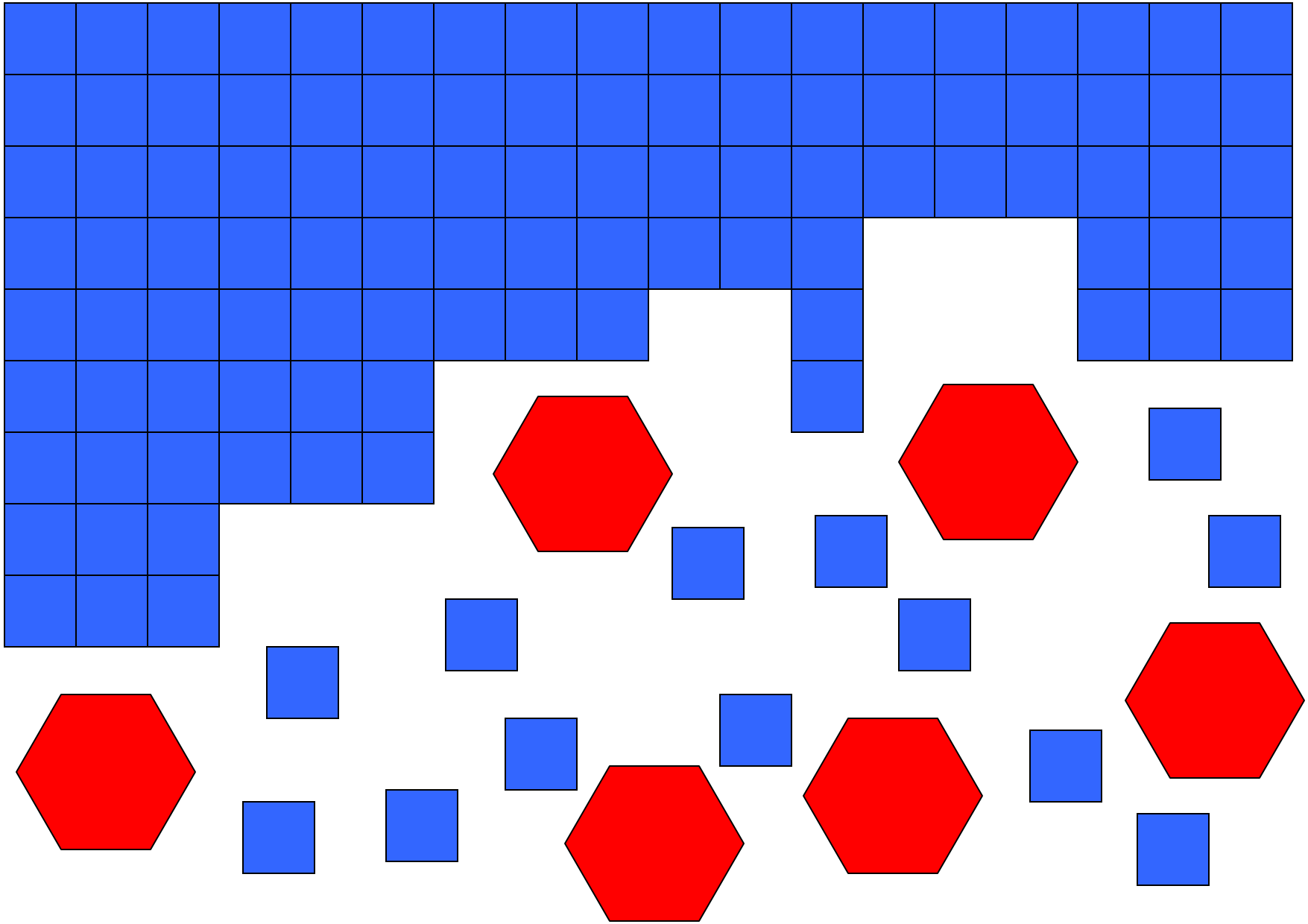
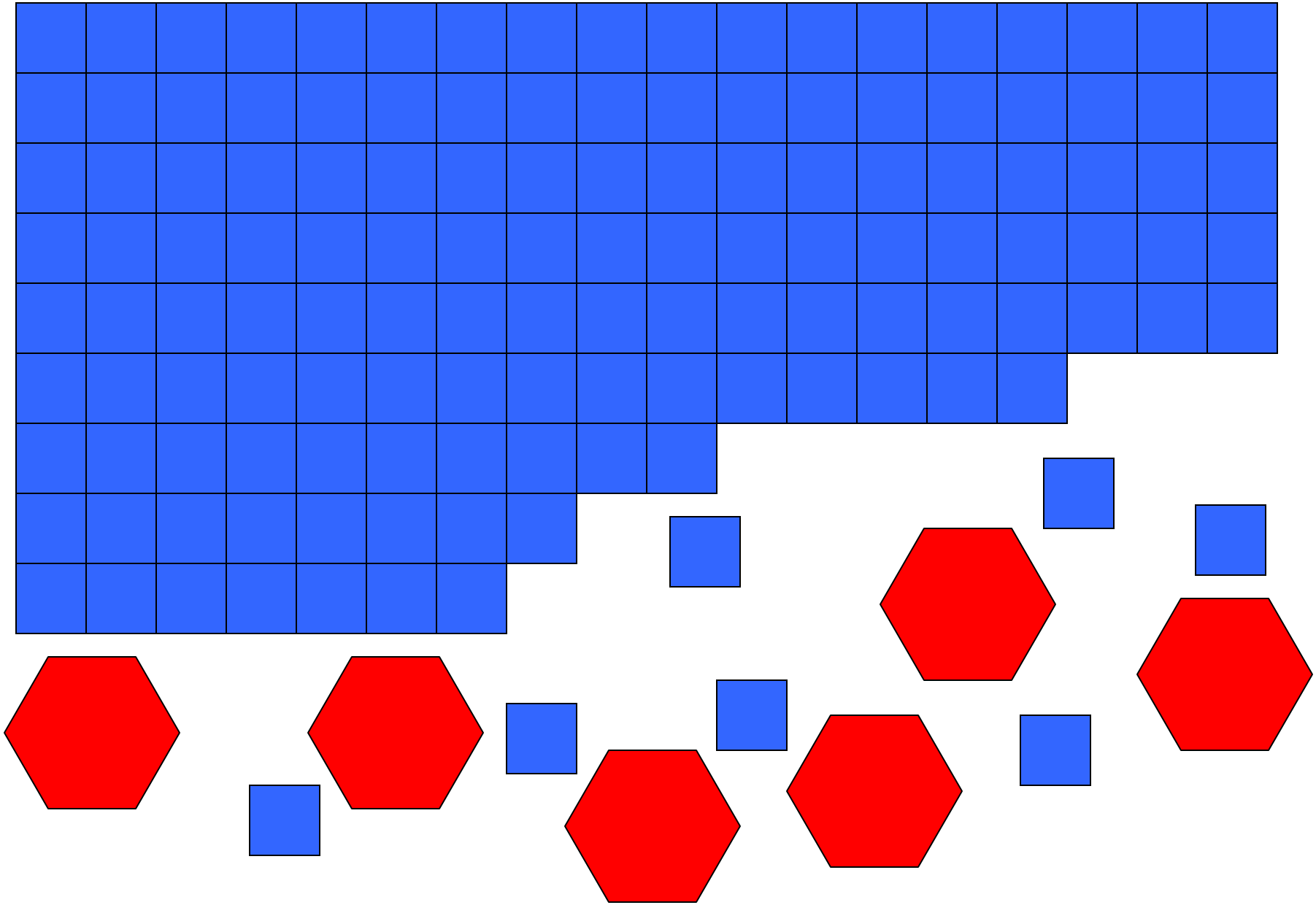
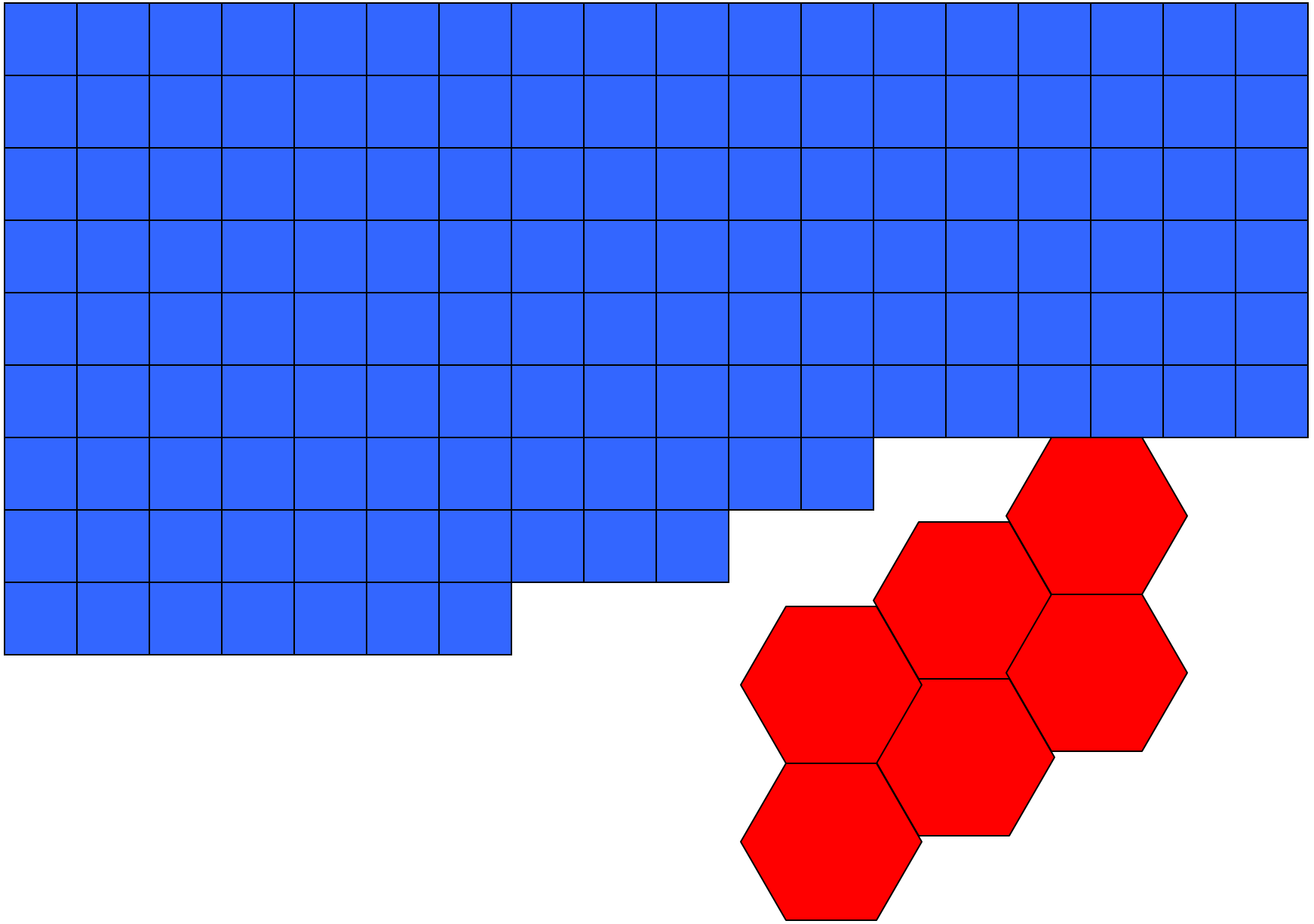
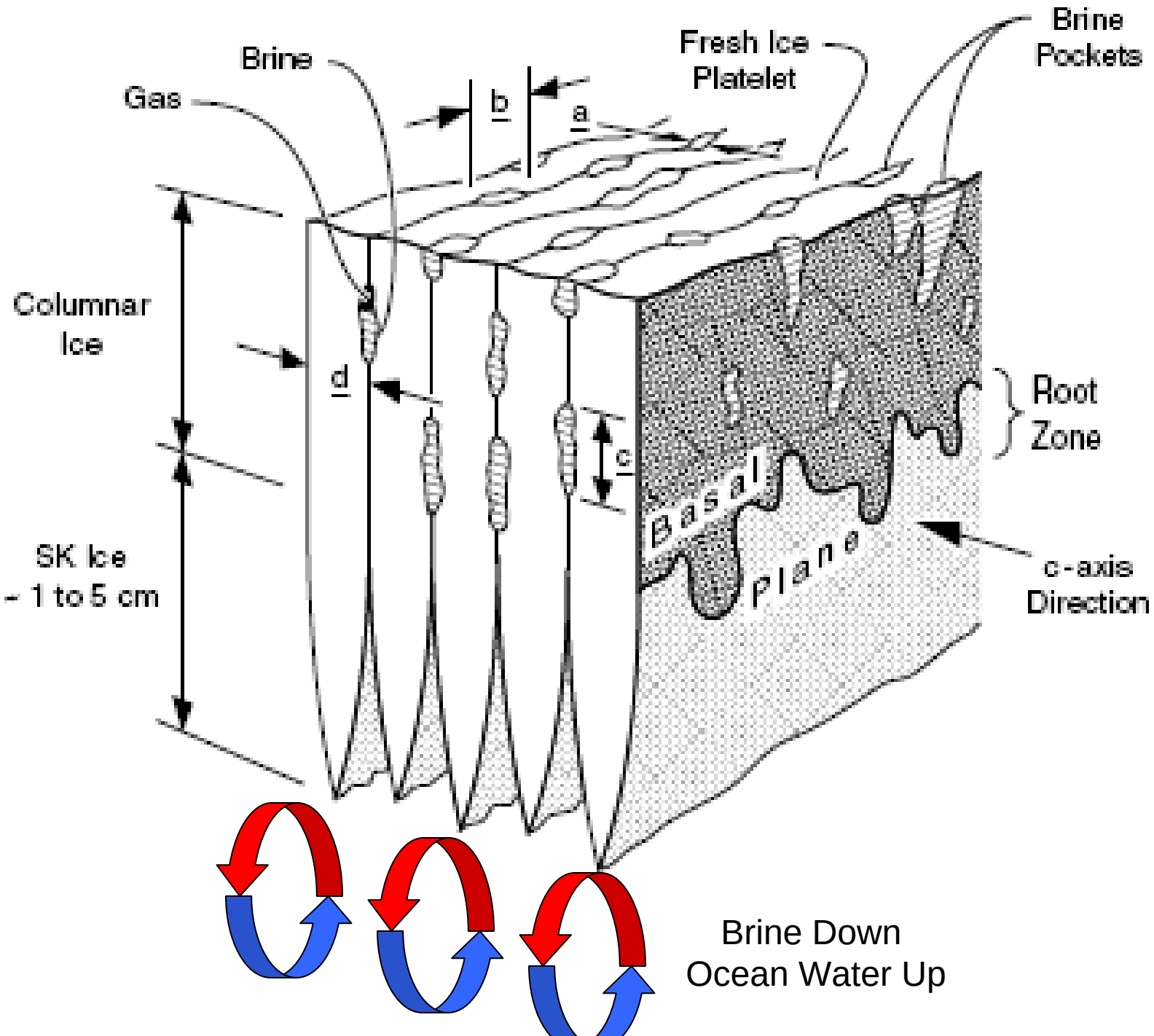


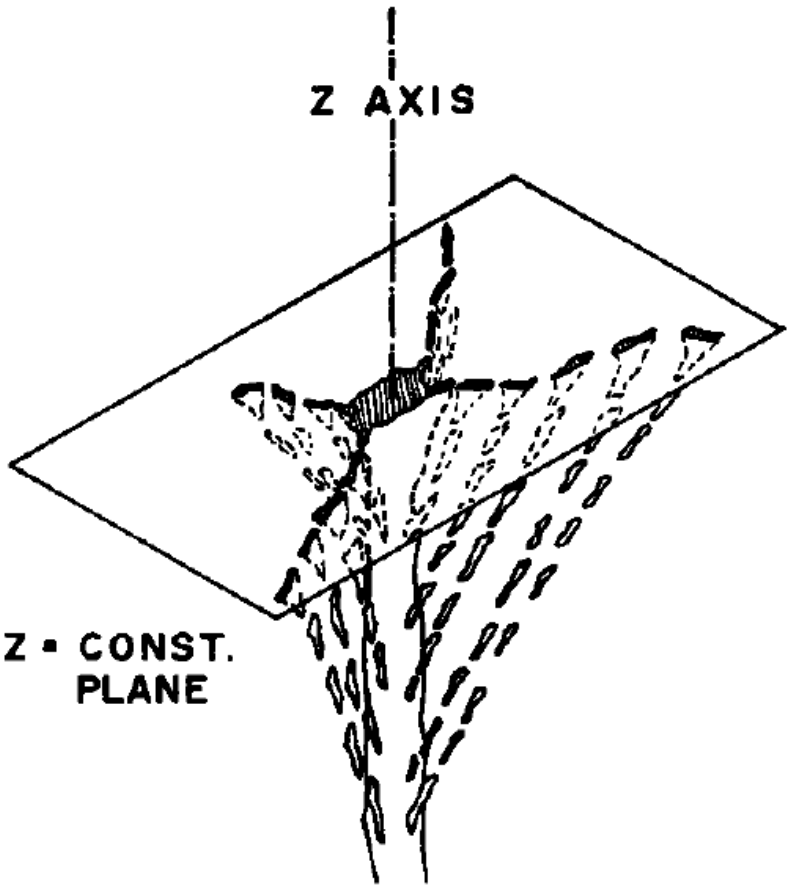

Ice
Saline Water

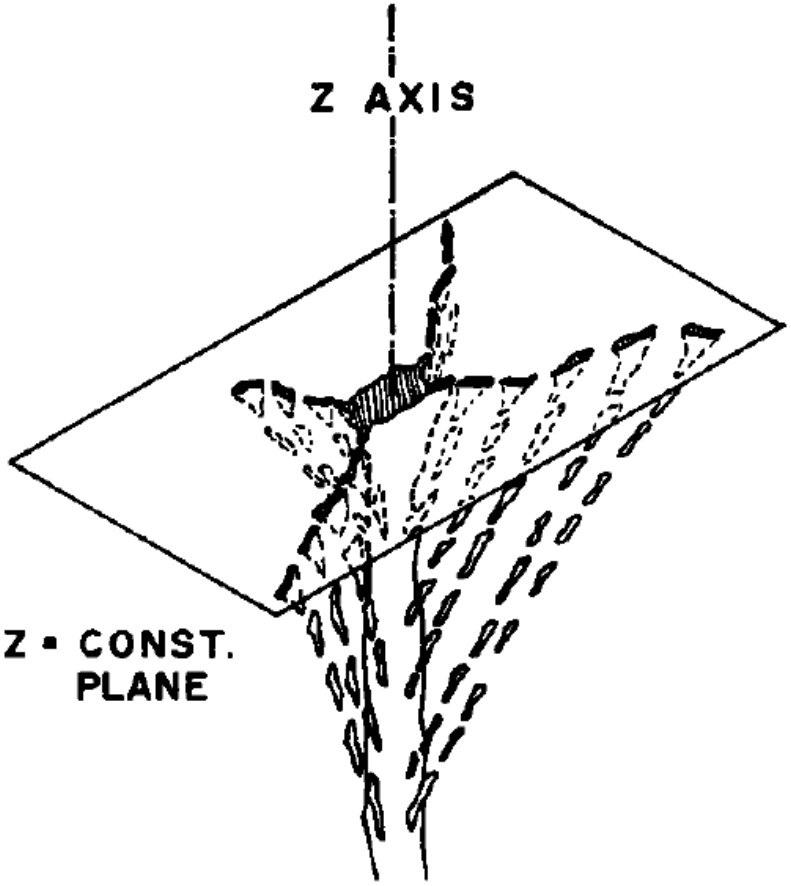




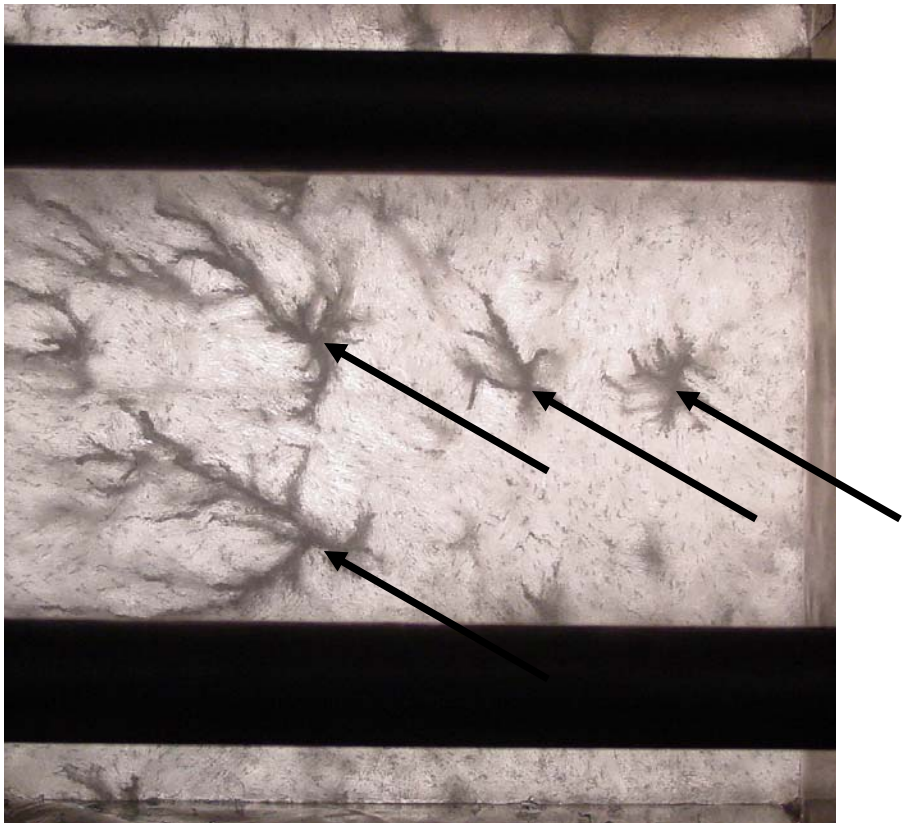



Brine
Gas
Fresh Ice
Platelet
Brine
Pockets
b
a
Columnar
Ice
d
c
Root
Zone
Basal
plane
c-axis
Direction
SK Ice
~ 1 to 5 cm
Brine Down
Ocean Water Up

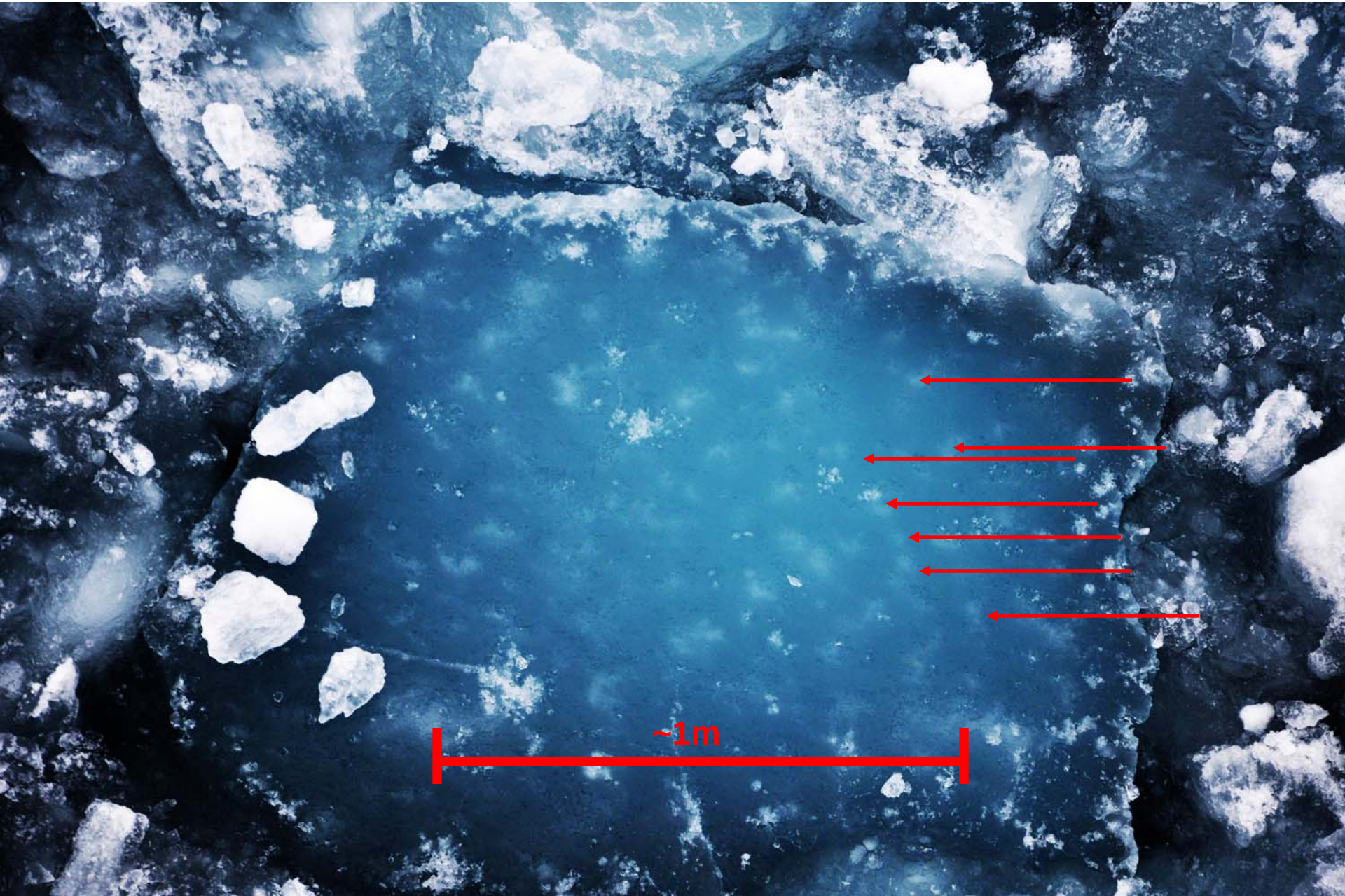

Z AXIS
Z = CONST.
PLANE



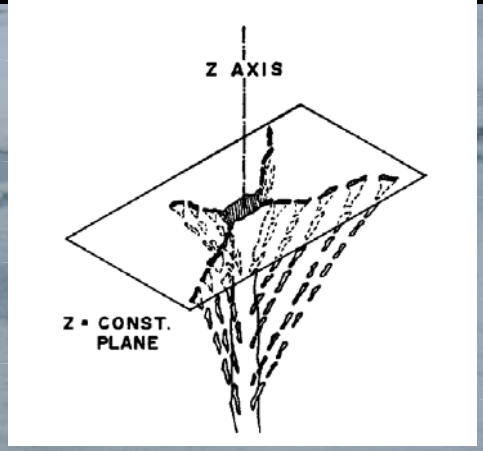
Horizontal Section



15 cm (about 6”)


~1m

a.



b.

c.

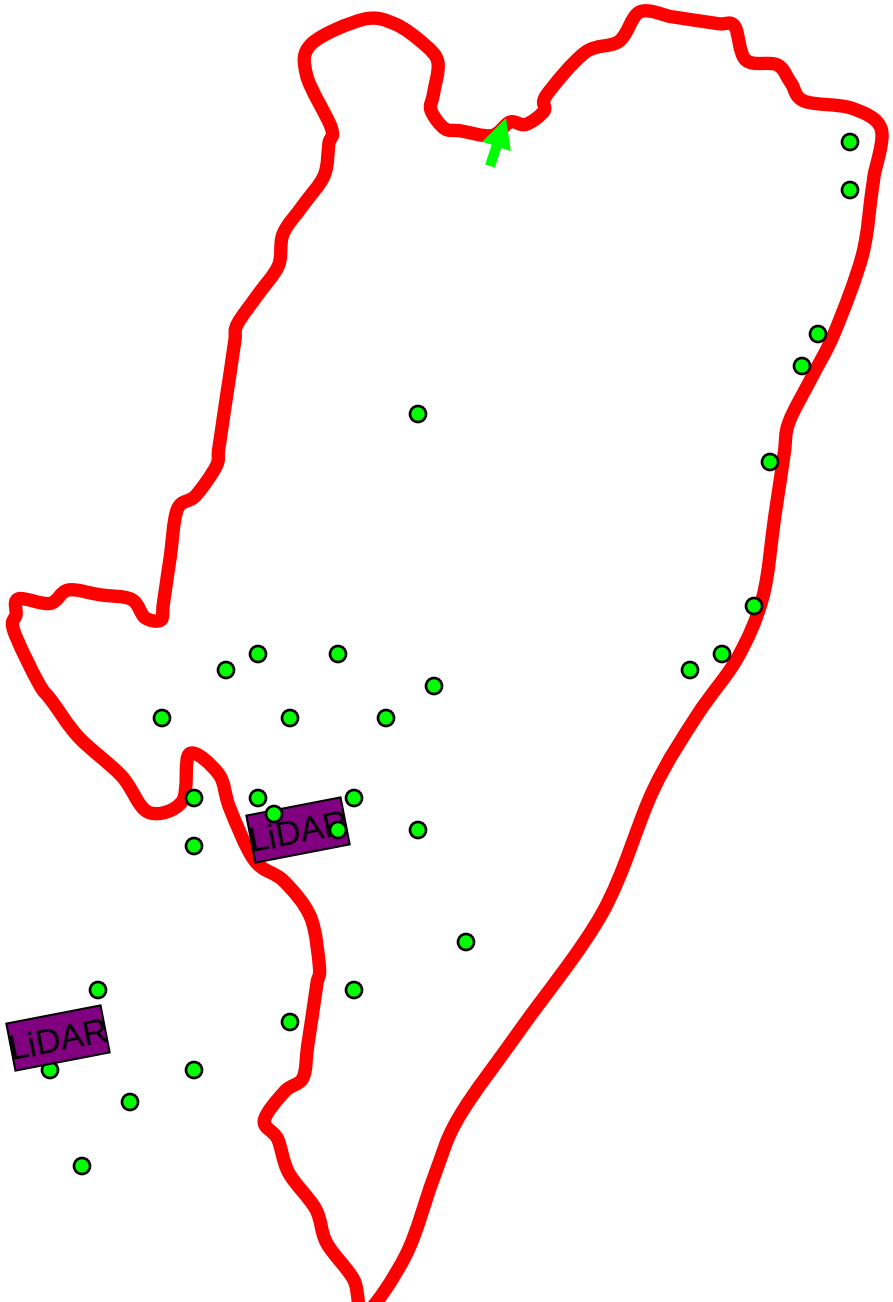
d.

e.

f.

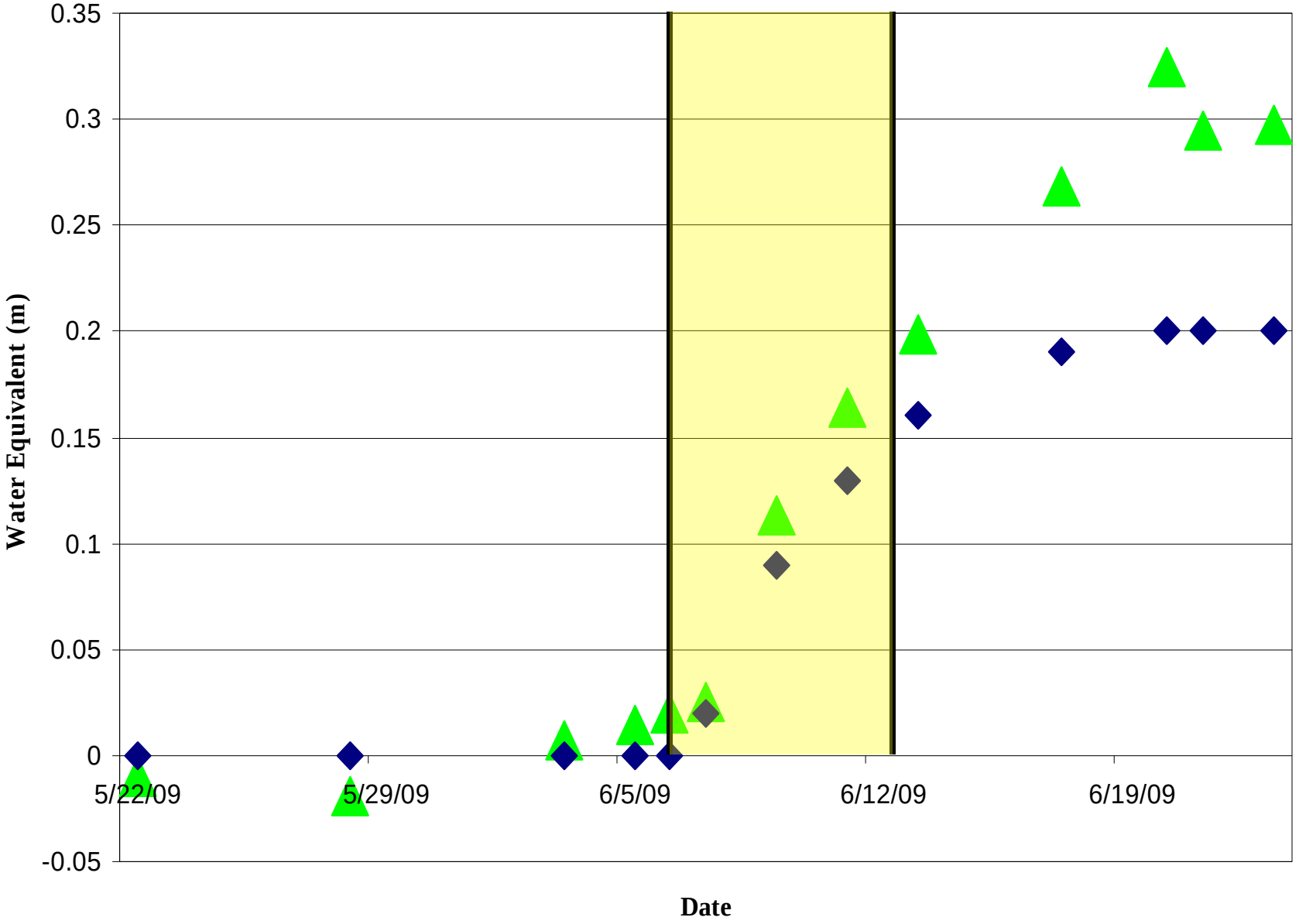
g.

June 10th

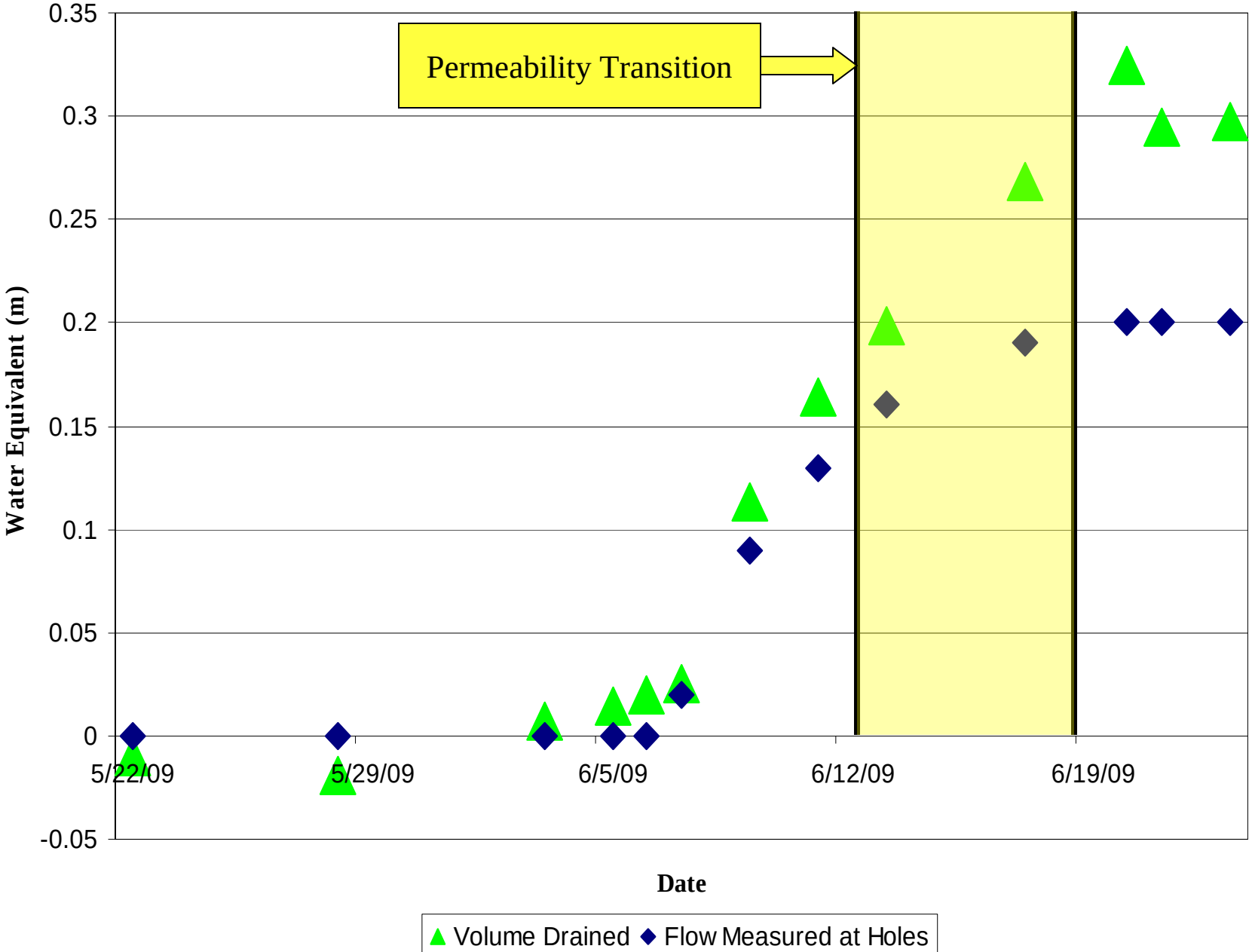


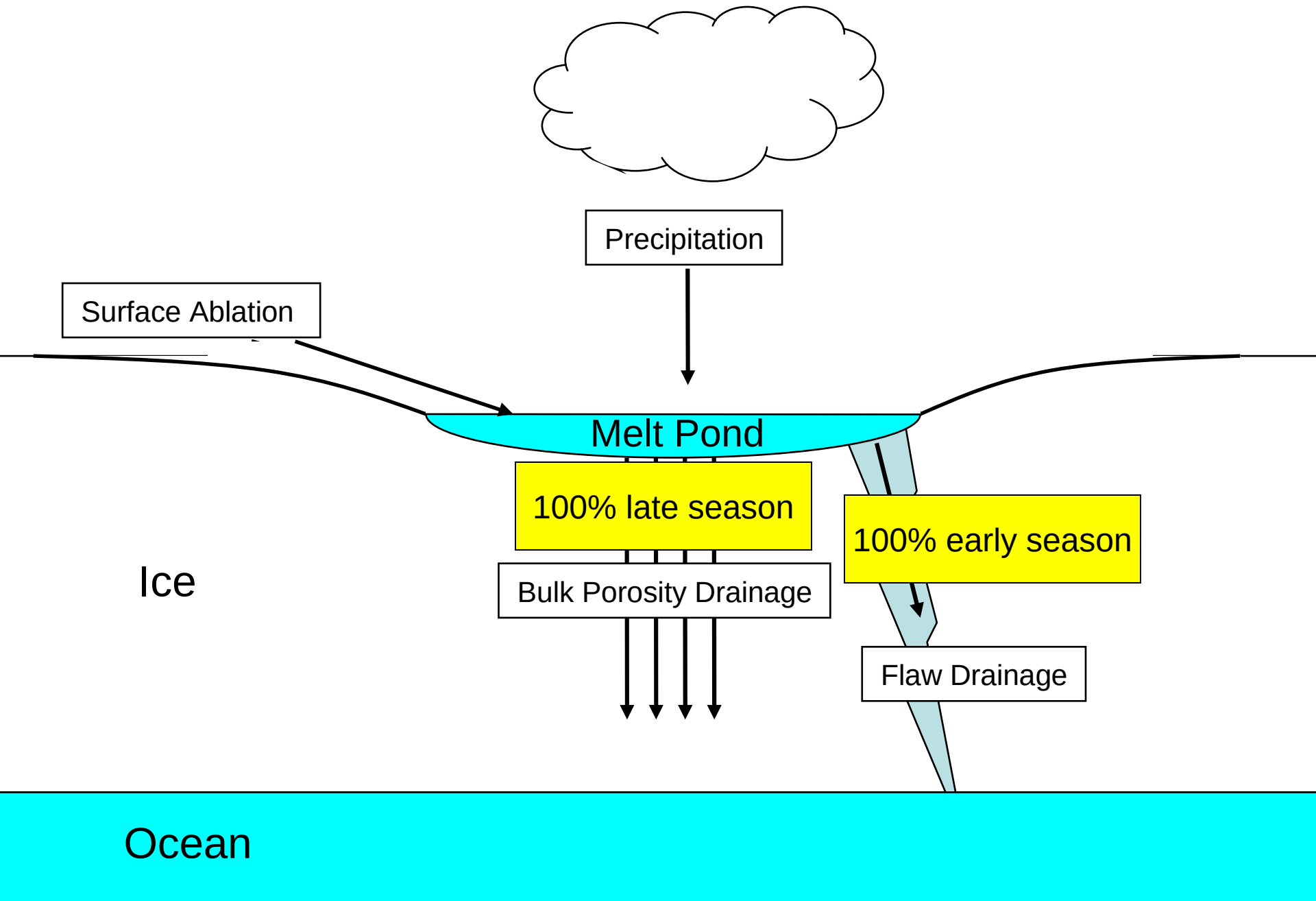
1km

Cumulative Water Movement

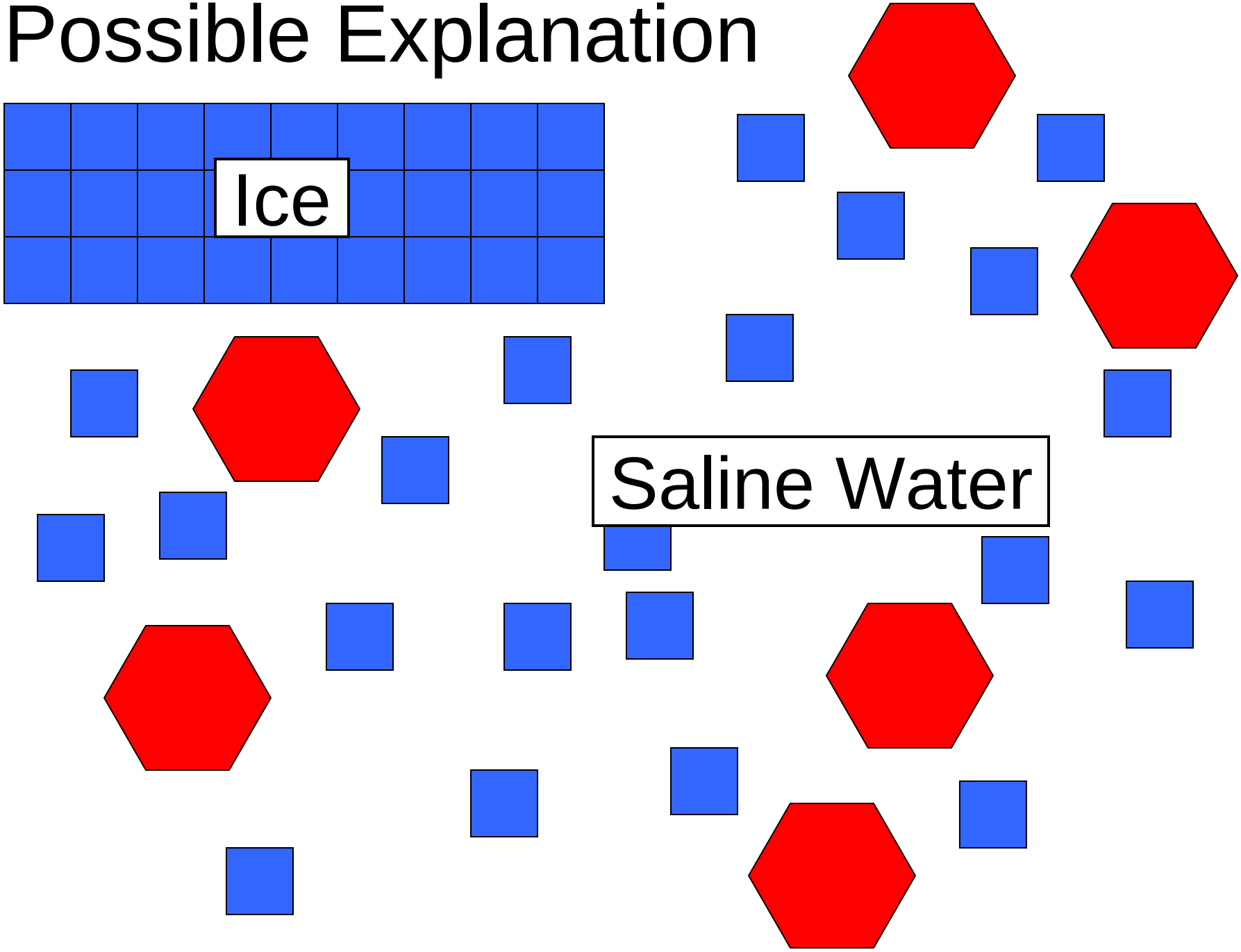


Cumulative Water Movement

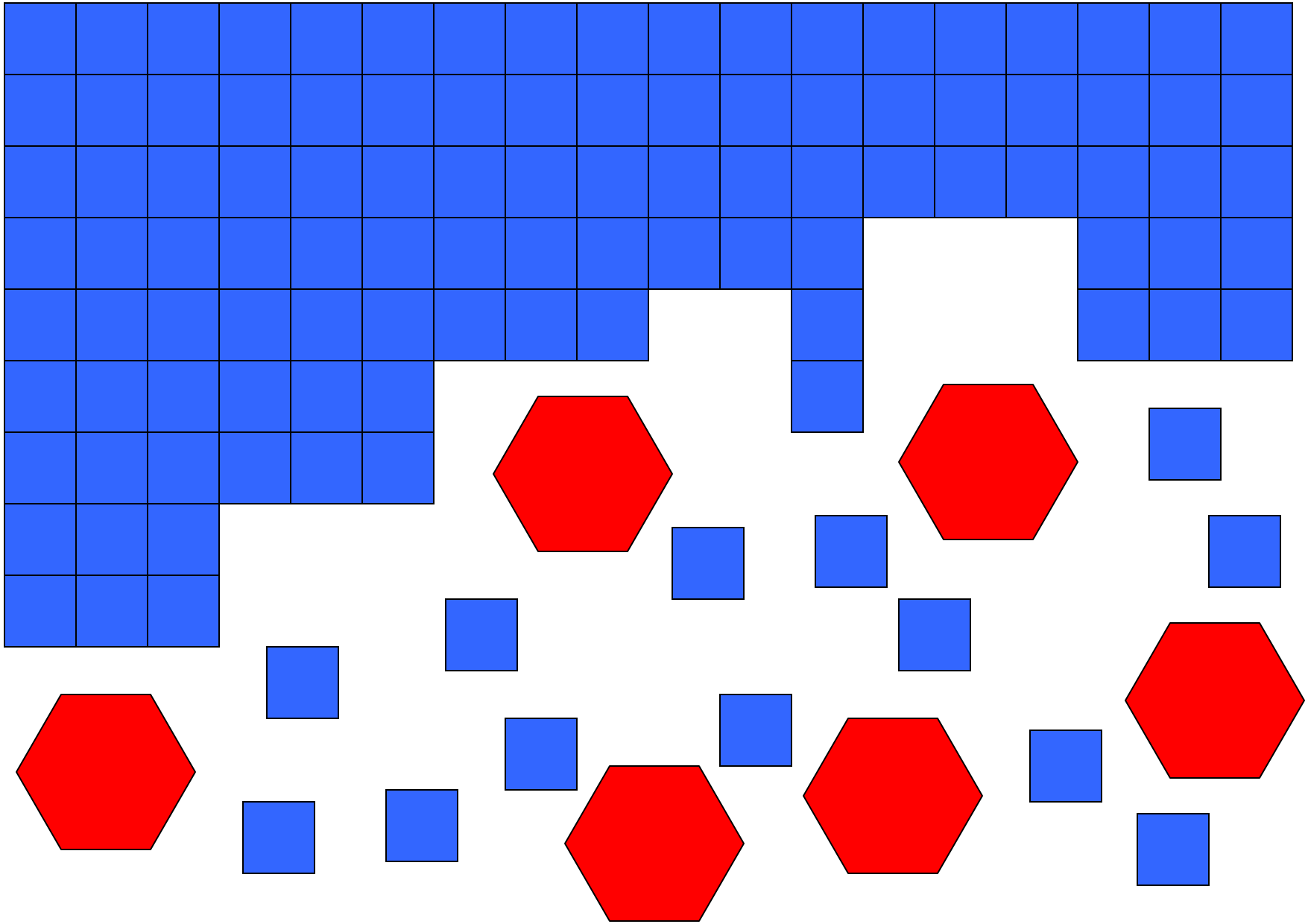



Precipitation
Surface Ablation
Melt Pond
100% late season
100% early season
Ice
Bulk Porosity Drainage
Flaw Drainage
Ocean

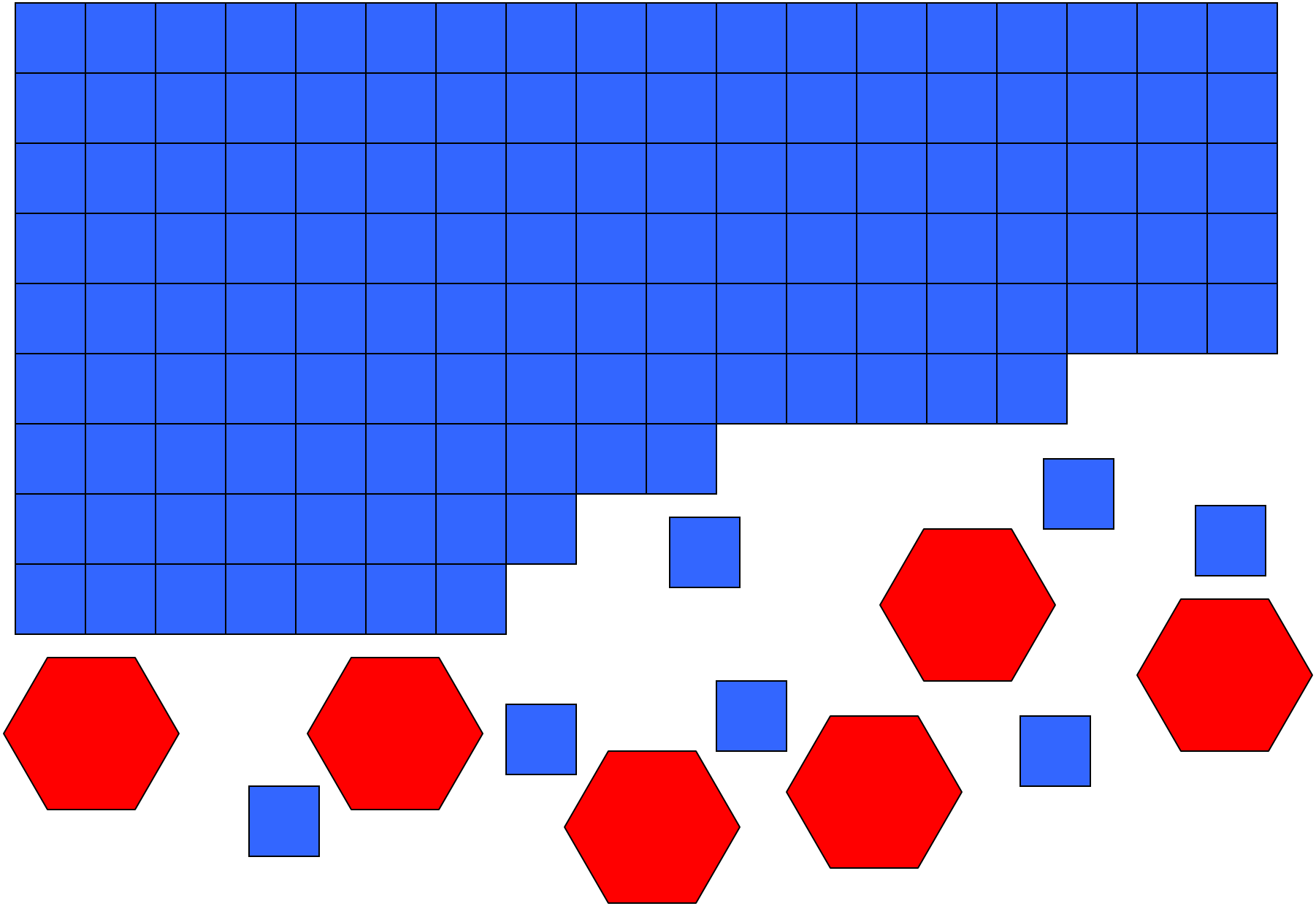
Possible Explanation



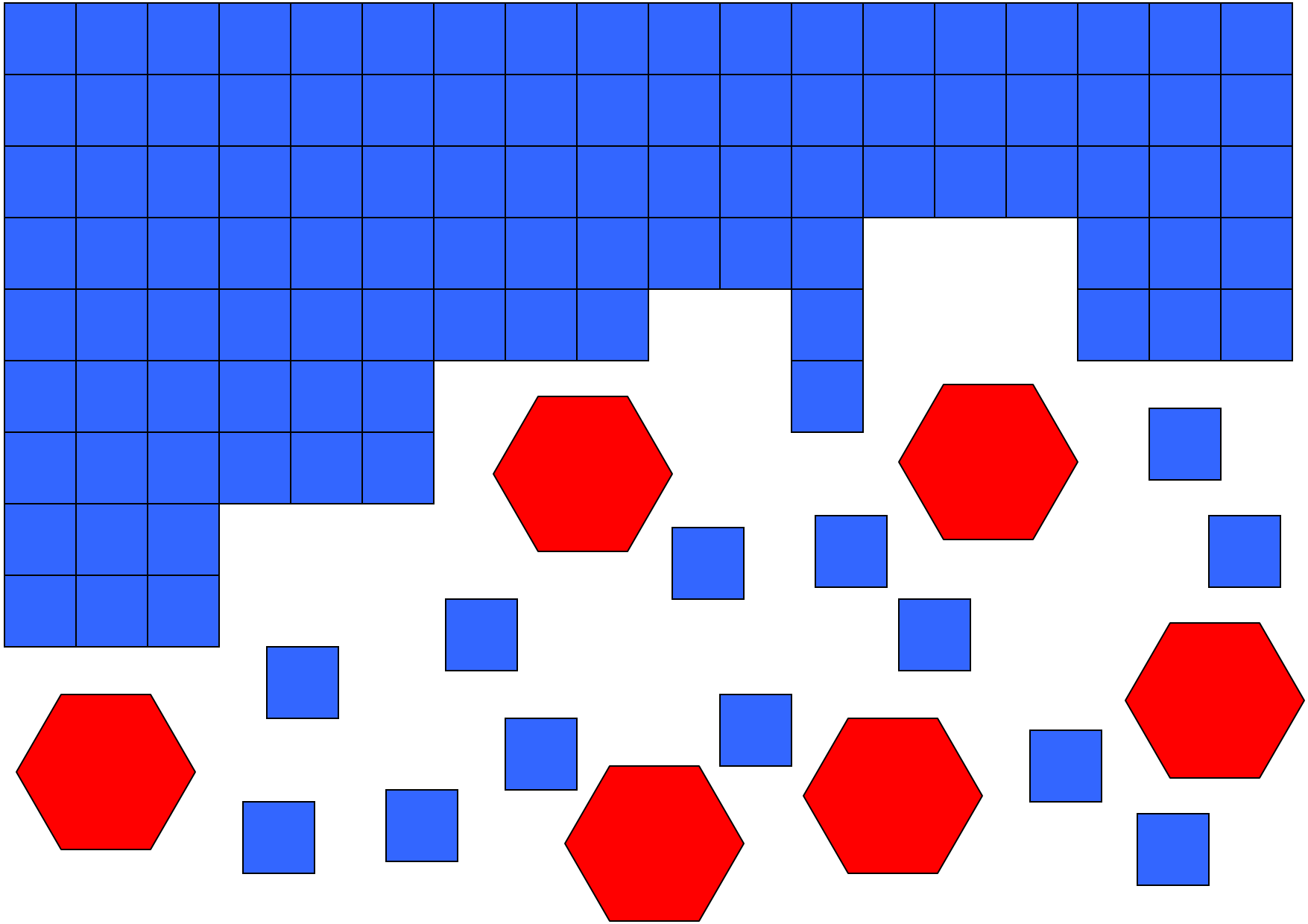
Possible Explanation



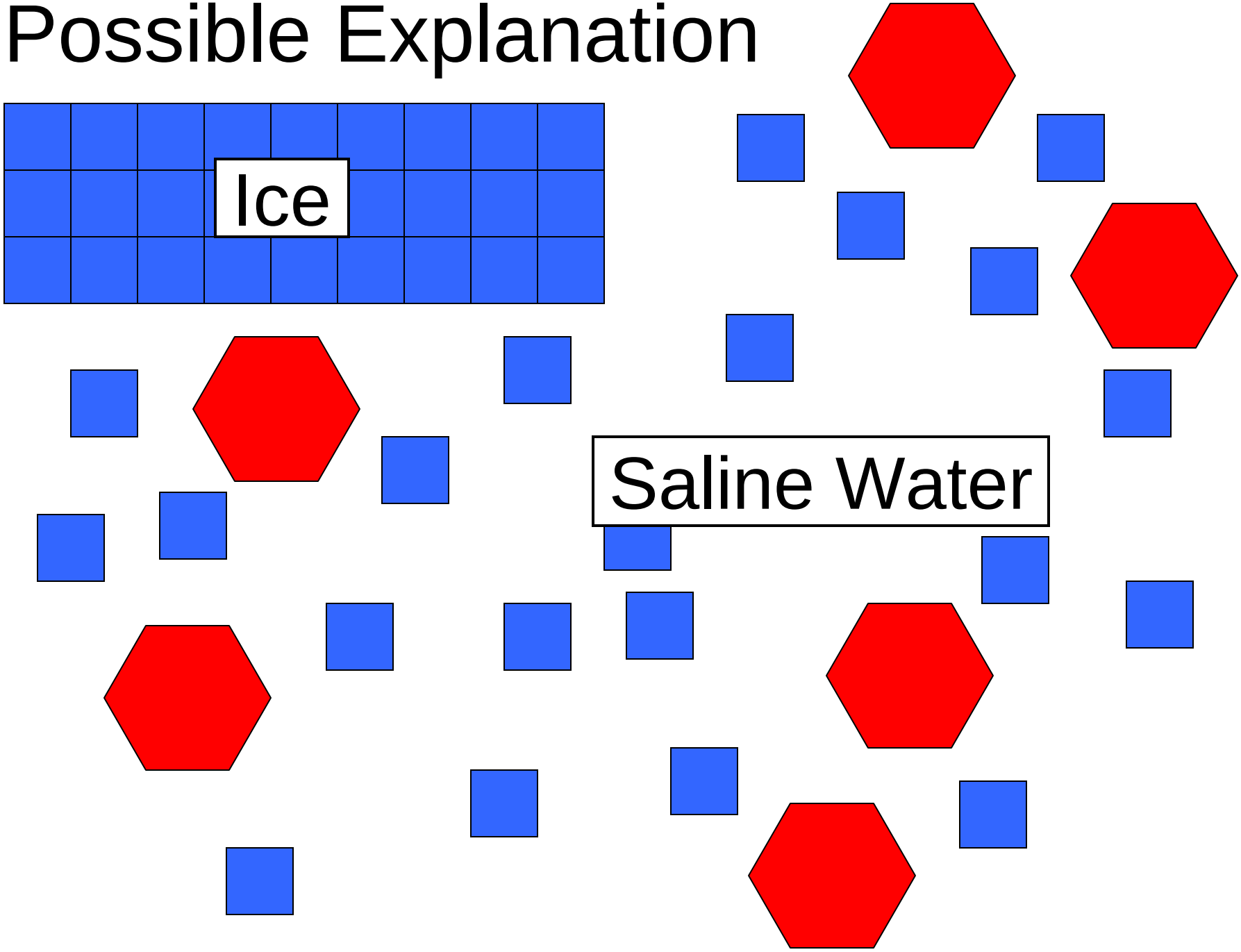
Possible Explanation



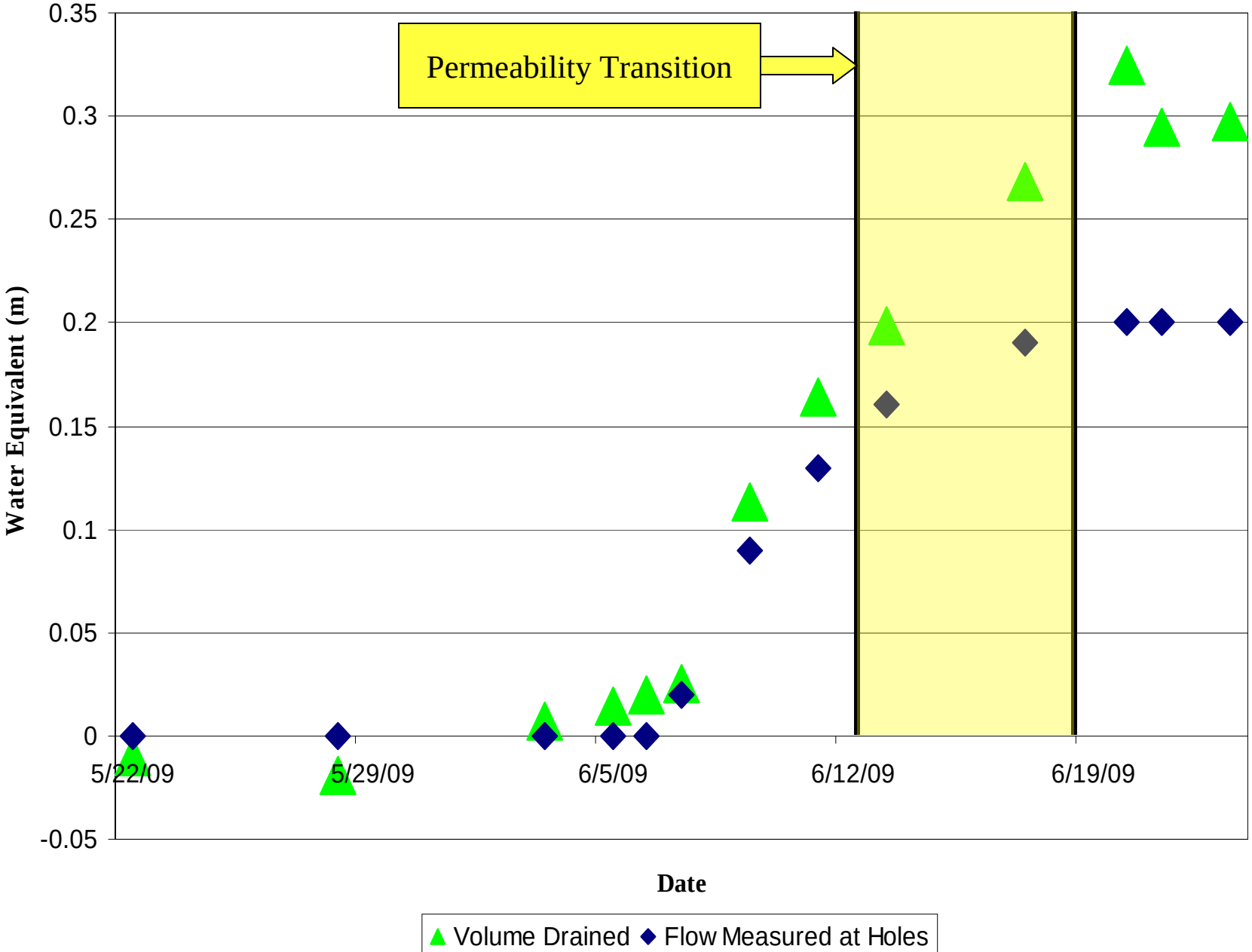
Possible Explanation



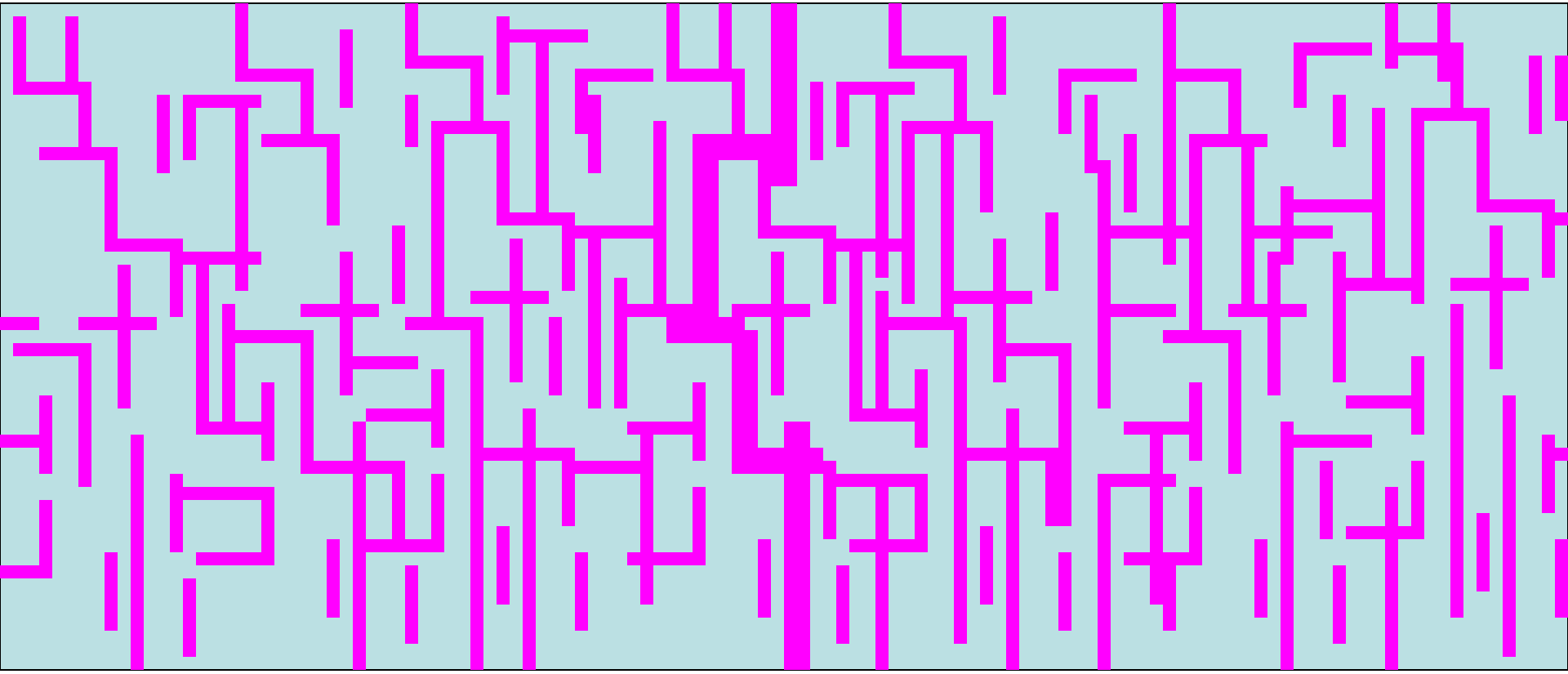
Possible Explanation



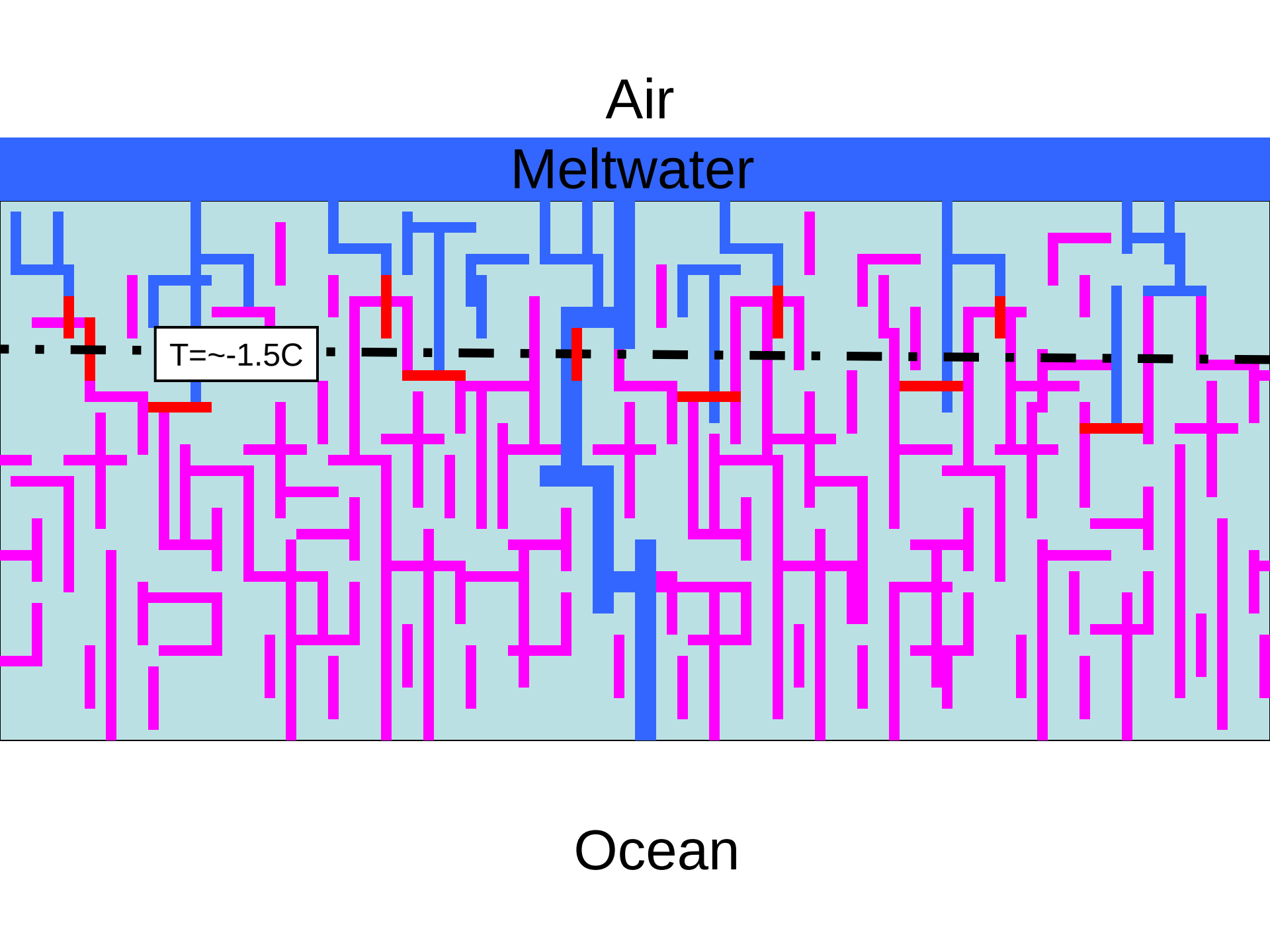
Cumulative Water Movement

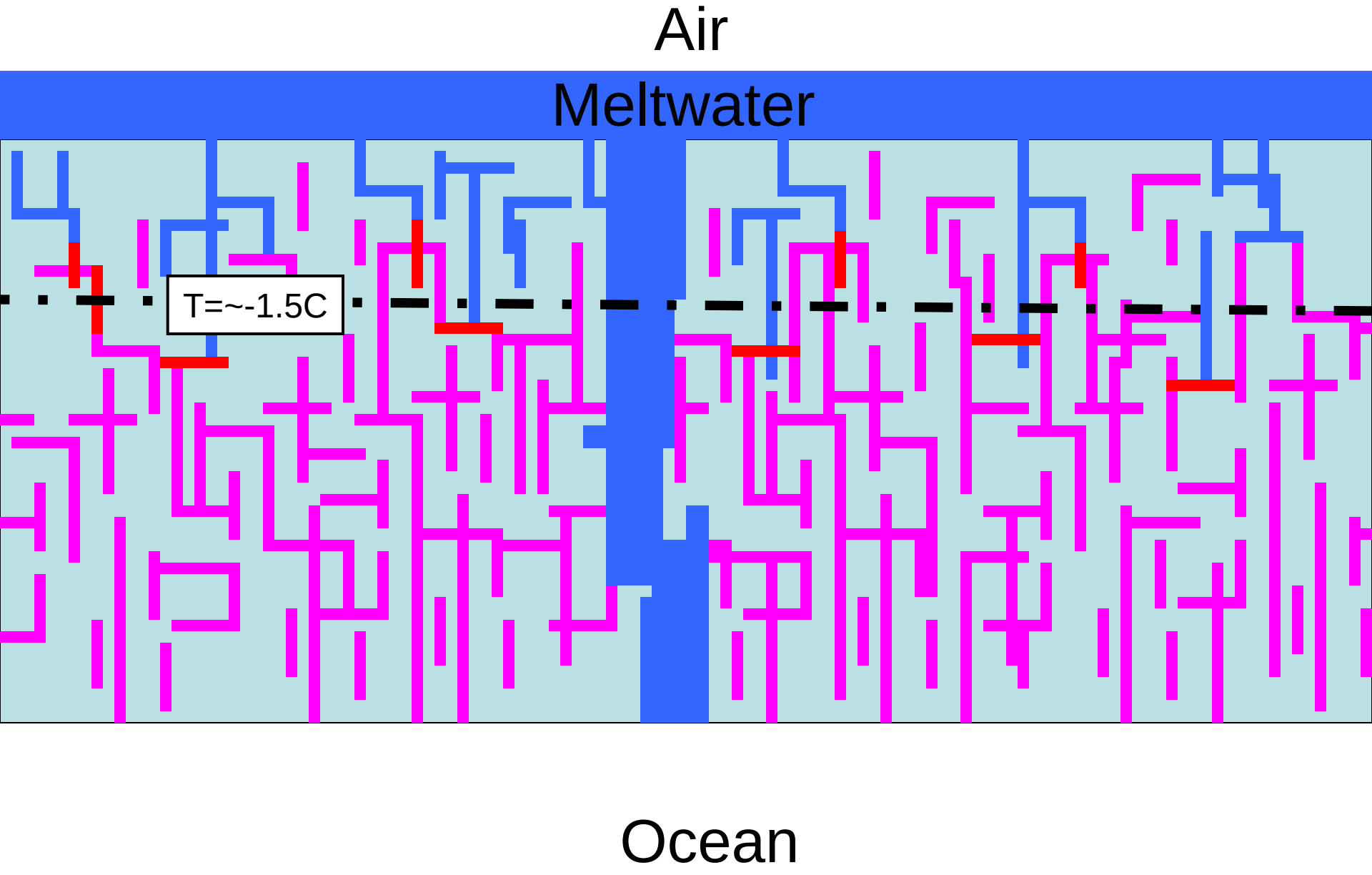


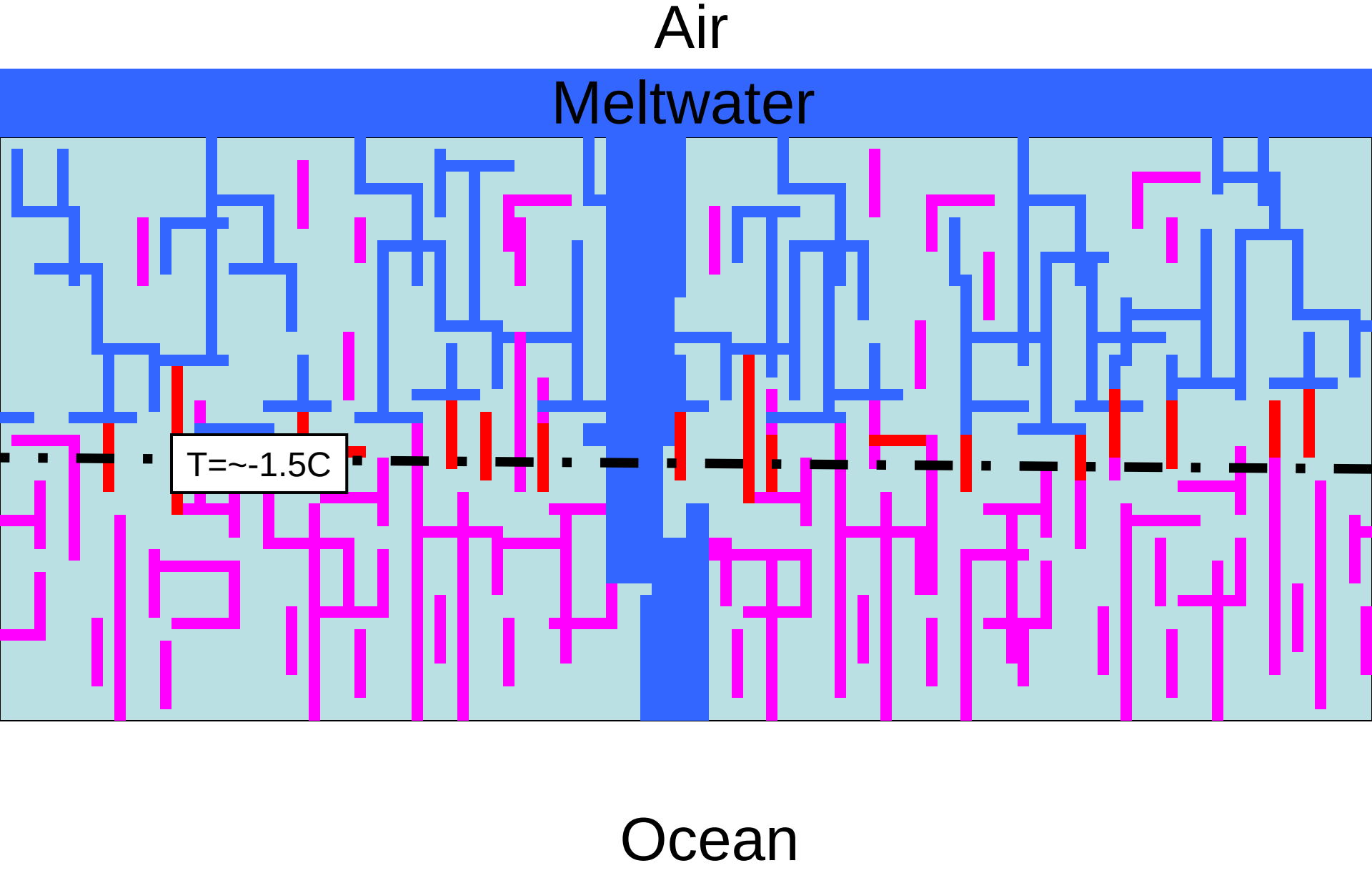
Air

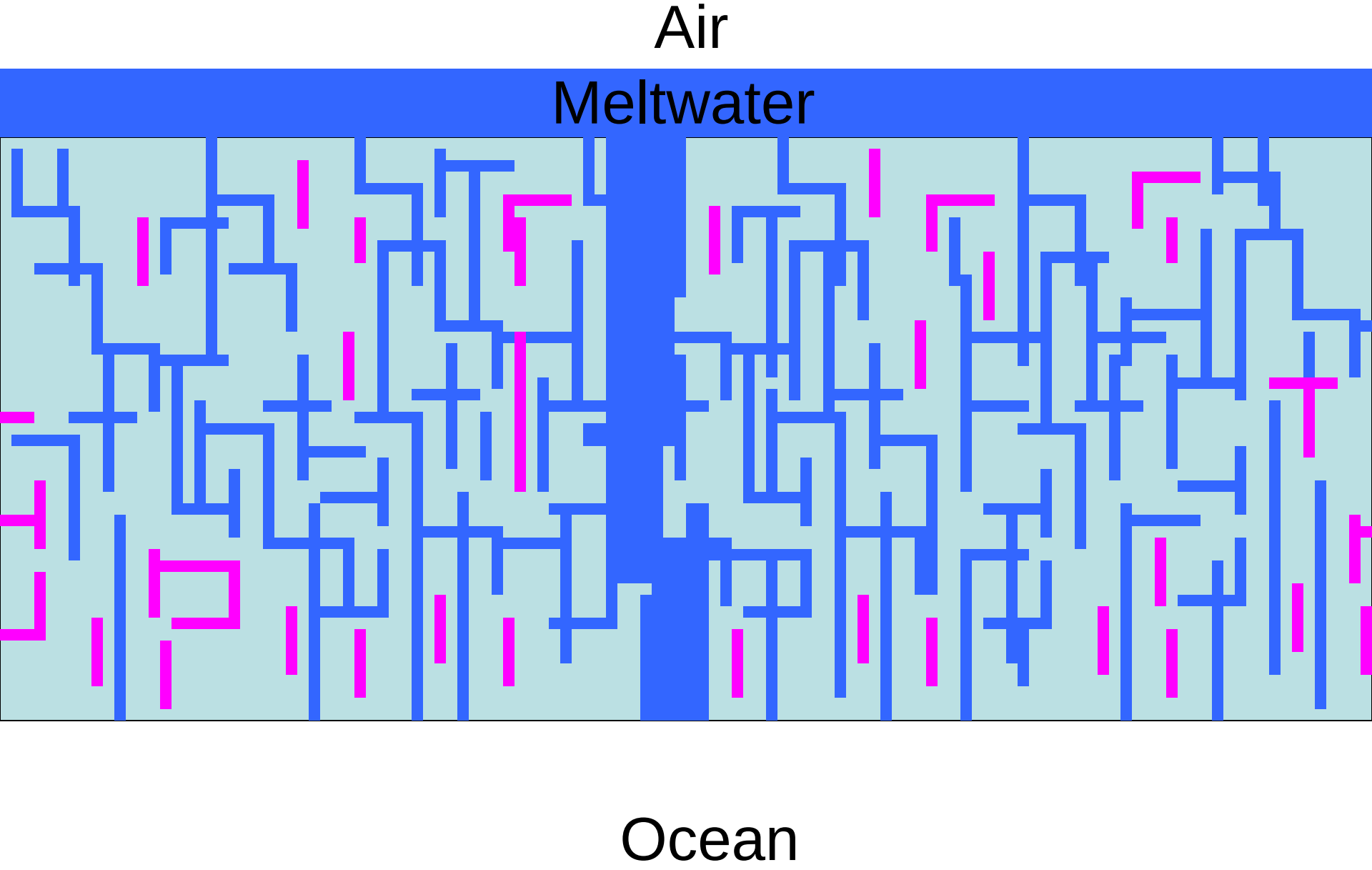


Ocean


Air
Meltwater
T=~-1.5C
Ocean


Air
Meltwater
T=~-1.5C
Ocean

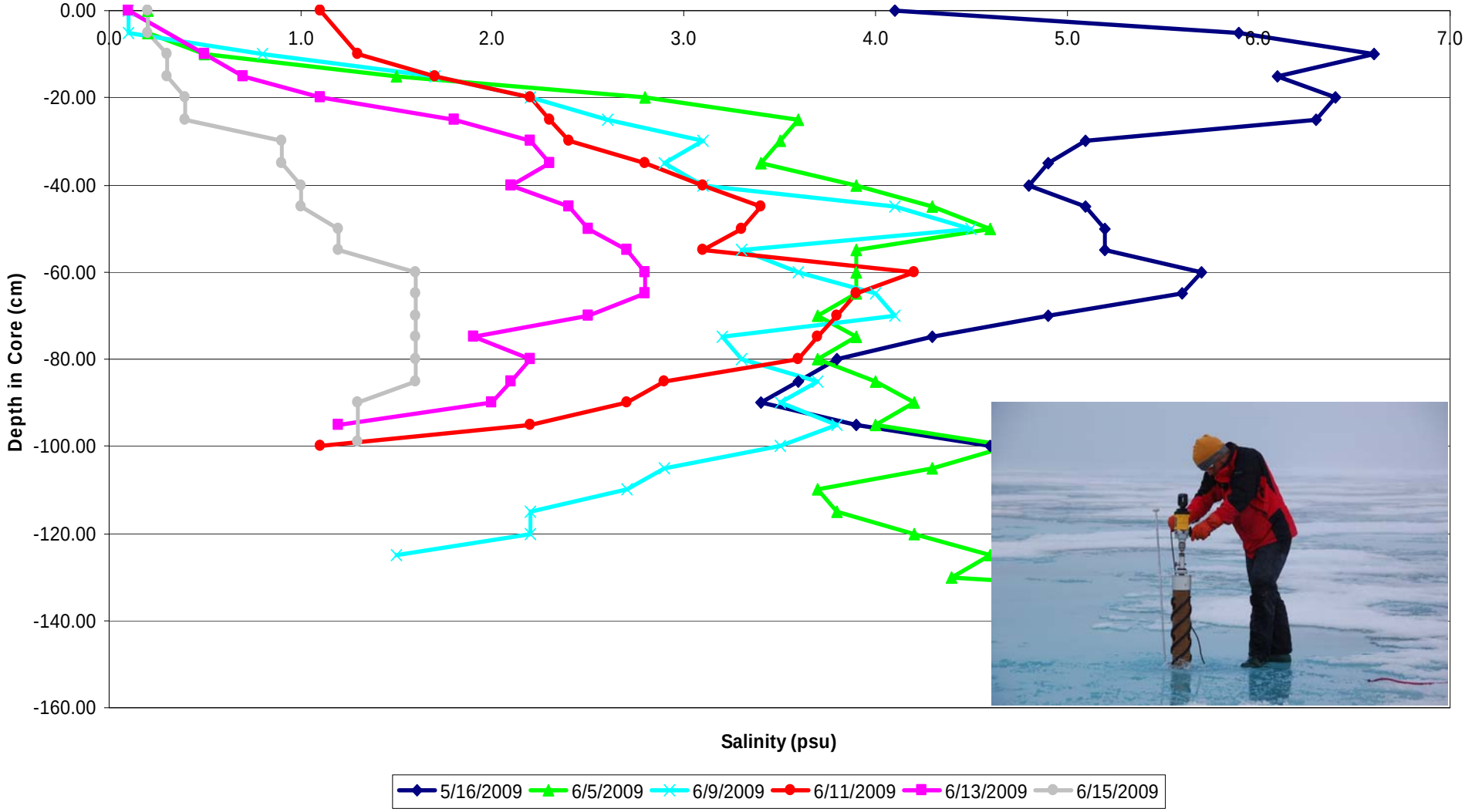

Air
Meltwater
T=~-1.5C
Ocean

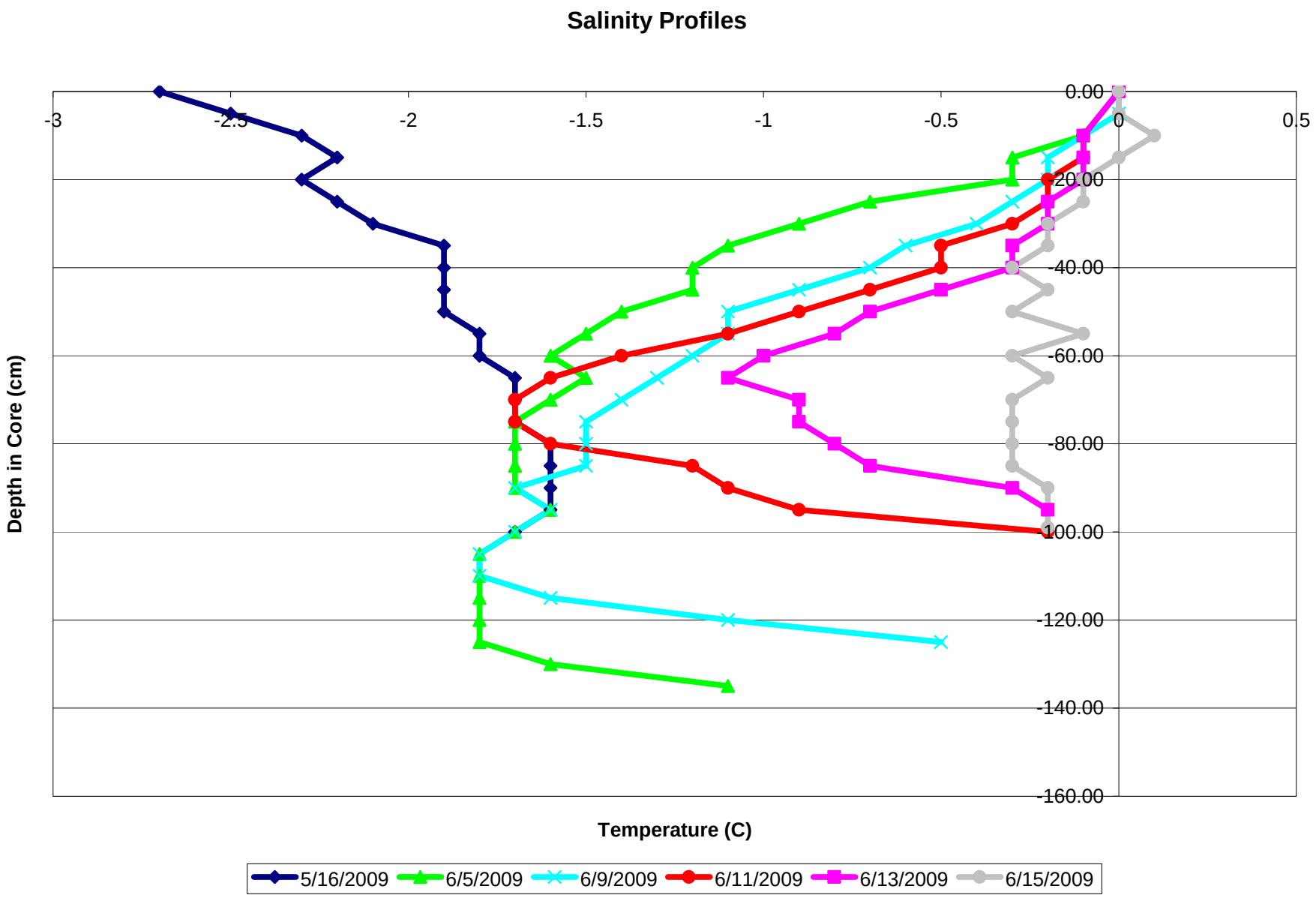

Air
Meltwater
Ocean

The Unified Theory of Sea Ice Permeability

- Ice is impermeable due to fresh meltwater intrusions refreezing in pores that are otherwise connected through to the ocean.
- The ice remains impermeable as long as it is cold enough to refreeze fresh water intruding from above.
- Pores above a critical size (such as well organized brine channels or core barrel holes) cannot be plugged by refreezing because heat cannot be conducted away quickly enough to overcome heating from the freshwater flow and, therefore break through earlier.

Salinity Profiles




Salinity Profiles
Depth in Core (cm)
0.00
-20.00
-40.00
-60.00
-80.00
-100.00
-120.00
-140.00
-160.00
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
Temperature (C)
5/16/2009
6/5/2009
6/9/2009
6/11/2009
6/13/2009
6/15/2009

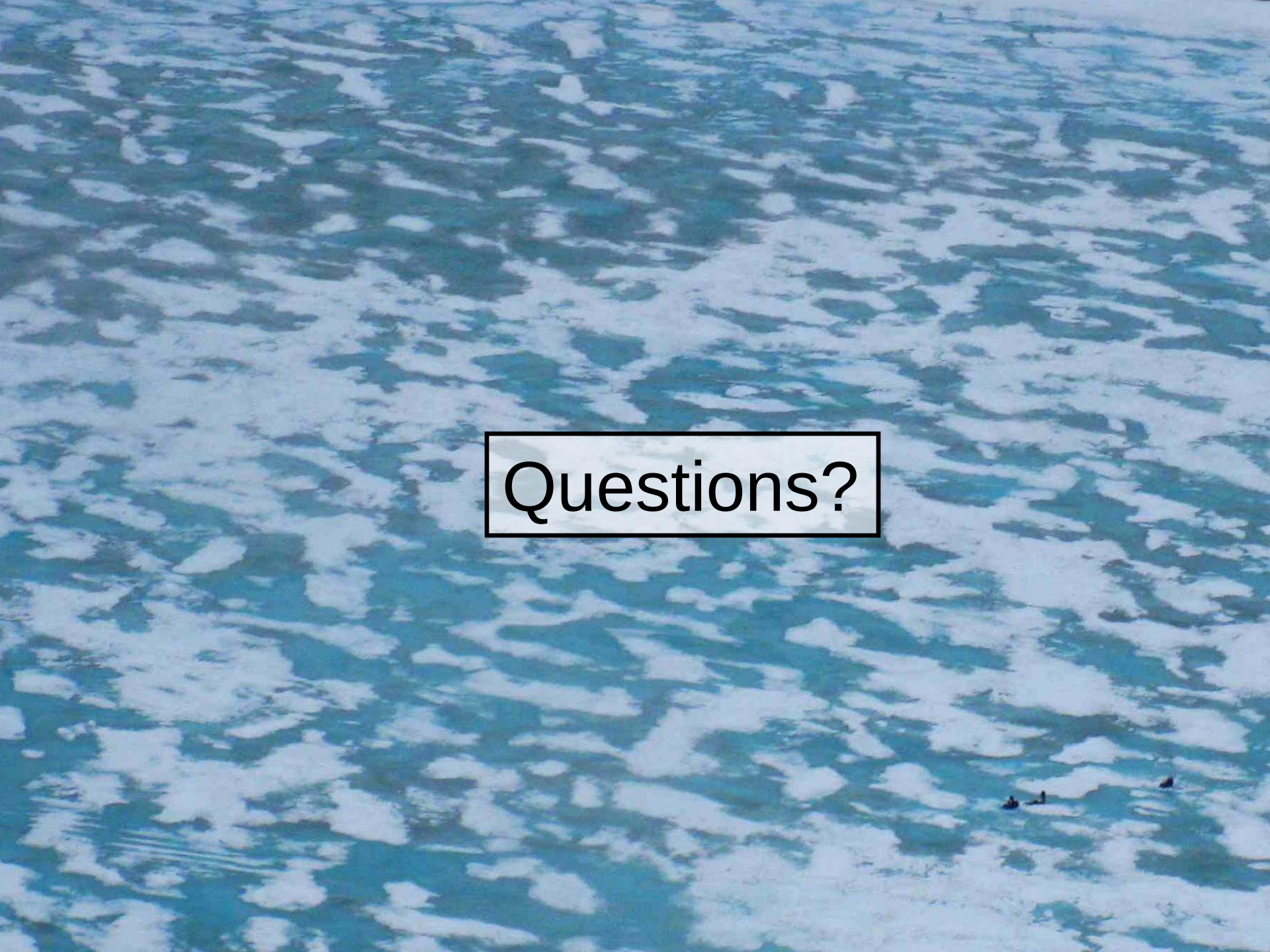
On ICESCAPES….

On Ice:

- Determine if ponds are above sea level.
- Take cores to measure temperature, salinity, and O18, tracking propagation of meteoric water in impermeable pond bottoms.
- Investigate relationship between pond color, depth, and underlying ice type.
- Measure size and shape of drainage features which may contribute to floe breakup.

On board:

-Confirm generality of the Barrow observations in other places.
-Look for size and distribution of drainage holes and signs of flow
-Estimate connectivity of melt ponds for drainage.
-Talk with the rest of you to determine what significance melt ponds may have to the biological system.


Questions?