# Winter Limnology: Surface Cover Edition

## White Ice, Black Ice, Snow-on-ice, and what it all mean for lake productivity

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@dbinyyc

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- Drs Wrona (AEP/UofC), McCauley (UofC), Prowse (UVic)
- Aquatic Ecology lab (UofC) staff and students
- Environment and Climate Change Canada
  - Water and Climate Impacts Research Centre (UVic)
- NSERC
- Study conducted on the traditional territories of the people of the Treaty 7 region in Southern Alberta and the Métis Nation of Alberta, Region III

Photo: Sherwin Calaluan – Abraham Lake
https://www.cbc.ca/news/canada/calgary/frozen-bubbles-alberta-lakes-rivers-photography-1.4006704

Photo: Liu Yu – Canadian Geographic
https://www.canadiangeographic.ca/article/intriguing-photos-alberta-lakes-famous-bubbles

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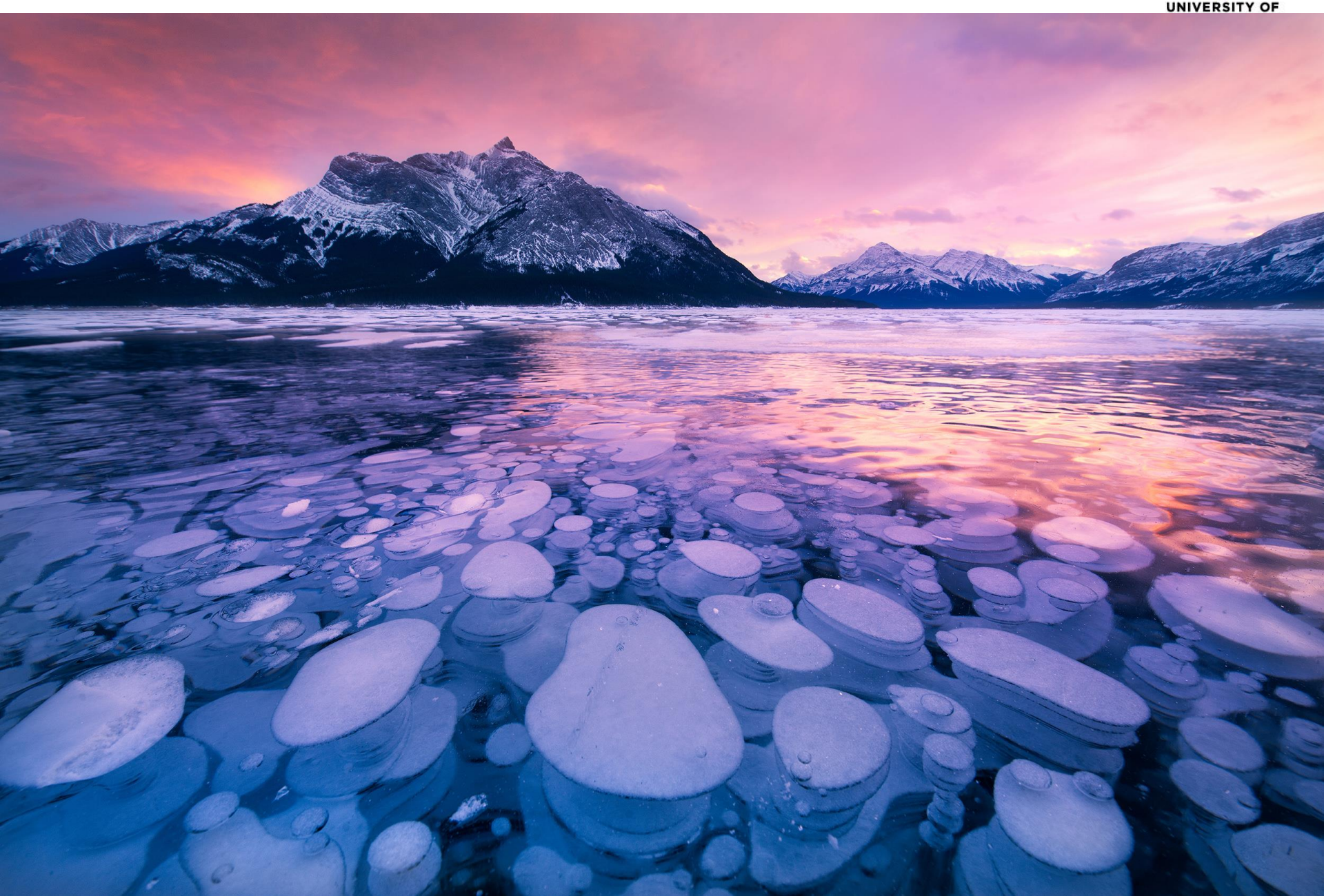

Climatic Change
DOI 10.1007/s10584-012-0470-0

## Variability and change in the Canadian cryosphere

C. Derksen · S. L. Smith · M. Sharp · L. Brown · S. Howell · L. Copland · D. R. Mueller · Y. Gauthier · C. G. Fletcher · A. Tivy · M. Bernier · J. Bourgeois · R. Brown · C. R. Burn · C. Duguay · P. Kushner · A. Langlois · A. G. Lewkowicz · A. Royer · A. Walker

# Winter Limnology as a New Frontier

*Stephen M. Powers and Stephanie E. Hampton*

ECOLOGY LETTERS
*Ecology Letters*, (2017) **20**: 98–111 doi: 10.1111/ele.12699

REVIEW AND SYNTHESIS

## Ecology under lake ice

Stephanie E. Hampton,[1]* Aaron W. E. Galloway,[2] Stephen M. Powers,[3] Ted Ozersky,[3] Kara H. Woo.[1] Rvan

**Abstract**
Winter conditions are rapidly changing in temperate ecosystems, particularly for those that experience periods of snow and ice cover. Relatively little is known of winter ecology in these systems, due to a historical research focus on summer 'growing seasons'. We executed the first global quan-

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RMetS
Royal Meteorological Society

## Simulation of North American lake-ice cover characteristics under contemporary and future climate conditions†

Yonas Dibike,[a]* Terry Prowse,[a,b] Barrie Bonsal,[c] Laurent de Rham[a] and Tuomo Saloranta[d]
[a] *Water and Climate Impacts Research Centre, Environment Canada at University of Victoria, Victoria, V8W 3R4, Canada*
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[c] *National Hydrology Research Centre, Environment Canada, Saskatoon, S7N 3H5, Canada*
[d] *Norwegian Institute for Water Research, Gaustadalléen 21, N-0349 Oslo, Norway*

HYDROLOGICAL PROCESSES, VOL. 11, 873–902 (1997)

# EFFECTS OF CLIMATE CHANGE ON THE FRESHWATERS OF ARCTIC AND SUBARCTIC NORTH AMERICA

WAYNE R. ROUSE,[1] MARIANNE S. V. DOUGLAS,[2] ROBERT E. HECKY,[3] ANNE E. HERSHEY,[4] GEORGE W. KLING,[5] LANCE LESACK,[6] PHILIP MARSH,[7] MICHAEL MCDONALD,[8] BARBARA J. NICHOLSON,[9] NIGEL T. ROULET[10] AND JOHN P. SMOL[11]

*J. Plankton Res.* (2015) 37(2): 277–284. First published online February 20, 2015 doi:10.1093/plankt/fbv002

HORIZONS

# Heating up a cold subject: prospects for under-ice plankton research in lakes

STEPHANIE E. HAMPTON[1]*, MARIANNE V. MOORE[2], TEDY OZERSKY[3], EMILY H. STANLEY[4], CHRISTOPHER M. POLASHENSKI[3] AND AARON W.E. GALLOWAY[1]

INVITED COMMENTARY

HP TODAY

HYDROLOGICAL PROCESSES
*Hydrol. Process.* **25**, 2767–2769 (2011)
Published online 25 April 2011 in Wiley Online Library (wileyonlinelibrary.com). DOI: 10.1002/hyp.8098

## Ice-covered lakes: environment and climate—required research

Lars Bengtsson*

Climatic Change
DOI 10.1007/s10584-012-0470-0

Variability and change in the Canadian cryosphere

## Simulation of North American lake-ice cover characteristics under contemporary and future climate conditions†

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*"changes in snow depth, in combination with reductions in black-ice growth, are projected to affect the effectiveness of snow loading, slushing, and ultimately white-ice growth"*

*"The relative increase in white-ice in the high northern latitudes sometimes exceeds 300%"*

HYDROLOGICAL PROCESSES, VOL. 11, 873–902 (1997)

EFFECTS OF CLIMATE CHANGE ON THE FRESHWATERS OF ARCTIC AND SUBARCTIC NORTH AMERICA

## The Relationship Between Winter Lake Cover, Radiation Receipts and the Oxygen Deficit in Temperate Lakes

Terry D. Prowse

*"…attenuation of solar radiation by snow and ice can reduce primary production to negligible levels."*

*"It is hypothesized that oxygen production can be accelerated by increasing radiation receipts through modification of albedo, cover thickness, cover composition or a combination of all three."*

under contemporary and future climate conditions†

Yonas Dibike,[a]* Terry Prowse,[a,b] Barrie Bonsal,[c] Laurent de Rham[a] and Tuomo Saloranta[d]
[a] Water and Climate Impacts Research Centre, Environment Canada at University of Victoria, Victoria, V8W 3R4, Canada
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Lars Bengtsson*

## Black ice – translucent

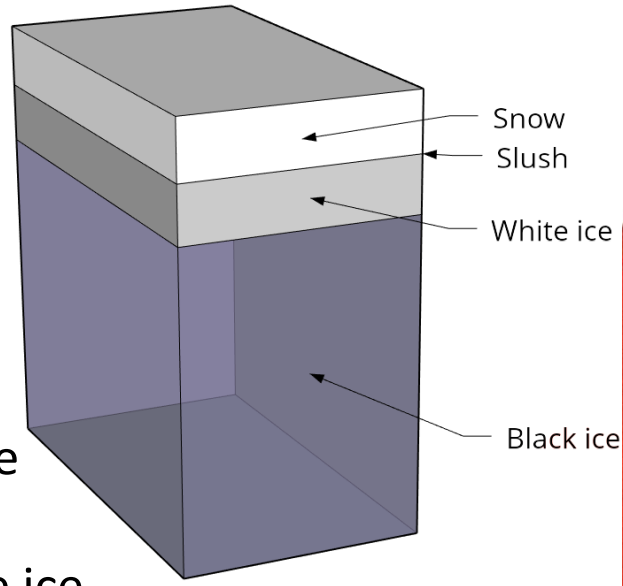
- High transmittance
- Low albedo
- Requires quick freeze and consistent temperatures
- Sometimes referred to as congelation ice

## White ice – opaque

- Low transmittance
- Medium-high albedo
- Results from freeze-thaw and slushing

## Snow

- Very low transmittance
- High albedo
- Deposited directly on ice surface
- Weight can cause slushing and creation of white ice



# Factors limiting phytoplankton growth

(adapted from McCombie 1952)

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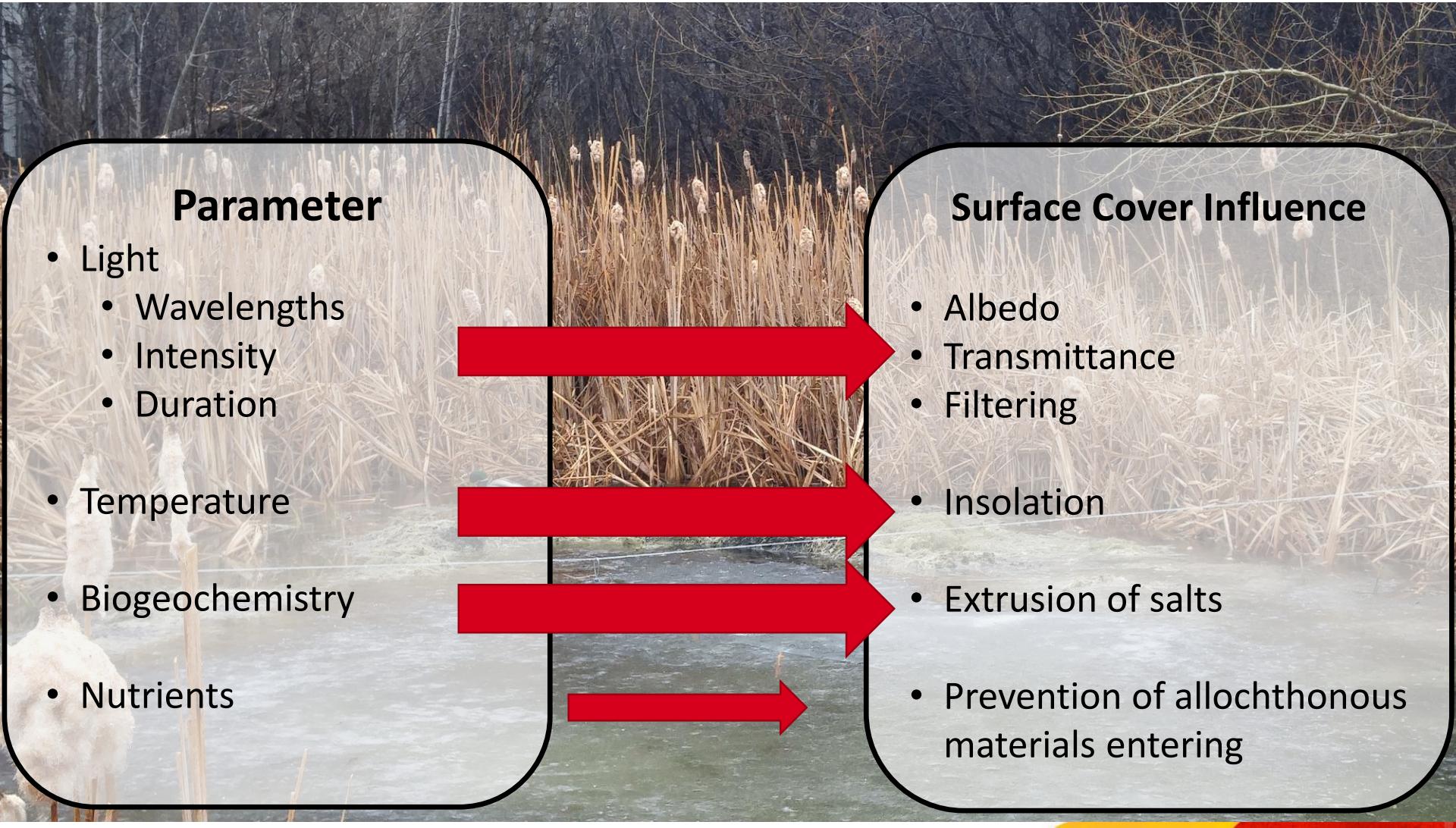


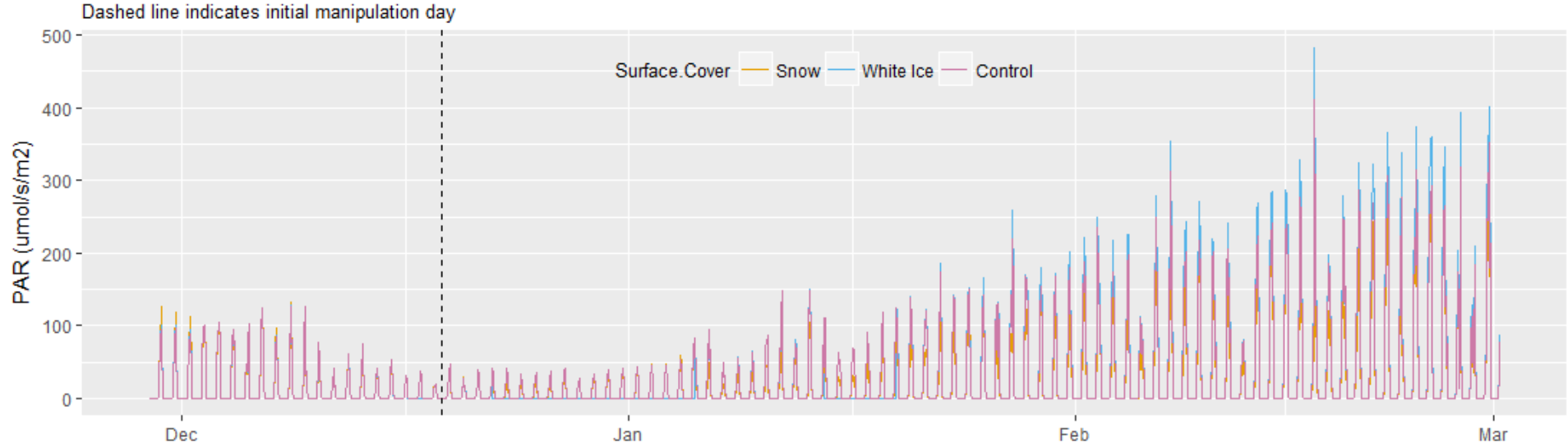
| Parameter | Surface Cover Influence |
| --- | --- |
| • Light<br>  • Wavelengths<br>  • Intensity<br>  • Duration | • Albedo<br>• Transmittance<br>• Filtering |
| • Temperature | • Insolation |
| • Biogeochemistry | • Extrusion of salts |
| • Nutrients | • Prevention of allochthonous materials entering |

- Better understanding of the interaction between surface cover and under-ice processes is needed
- Projected changes in environmental conditions in the northern mid-latitudes
- Controlled experiments help to understand relationships

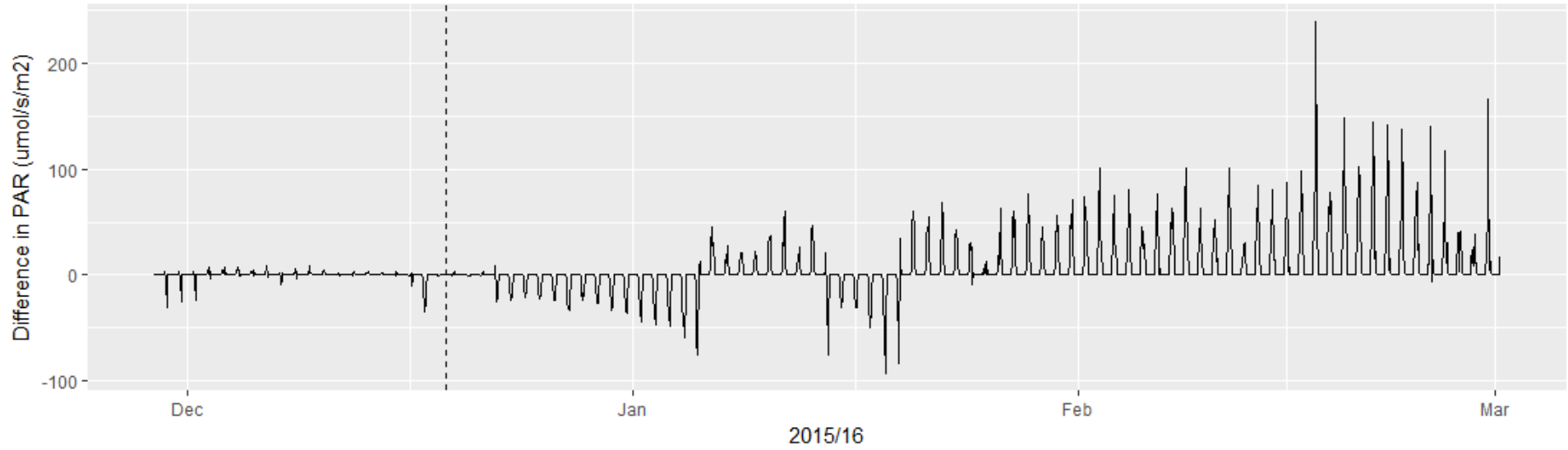
## Sample Collection

- Dissolved oxygen sensors deployed at multiple depths
- Grab water column samples analyzed for chlorophyll-*a*
- Solar radiation measurements
  - Incoming
  - Reflected
  - Surface
  - Under-ice
- Multisonde profiles recorded
- Biogeochemistry

# Under-ice PAR with varying surface cover manipulations




# Difference in under-ice PAR, between control and snow-on-ice



## Control (red)

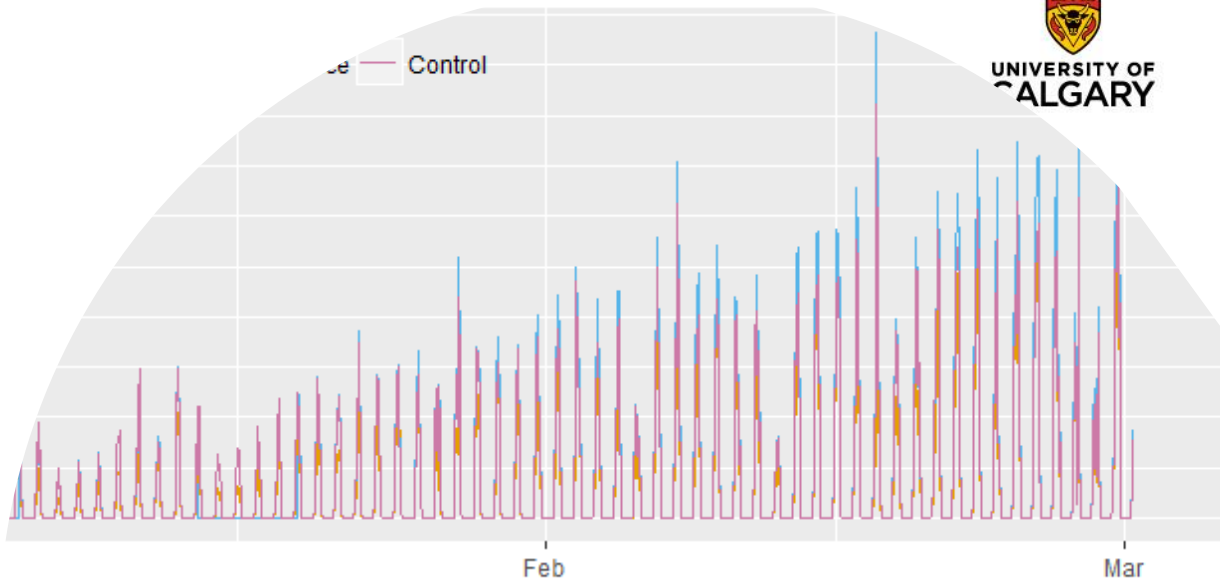
- Had a very mild winter
- Lots of freeze-thaw cycles
- Very similar in light transmission (and appearance) to white ice treatment

## White ice (blue)

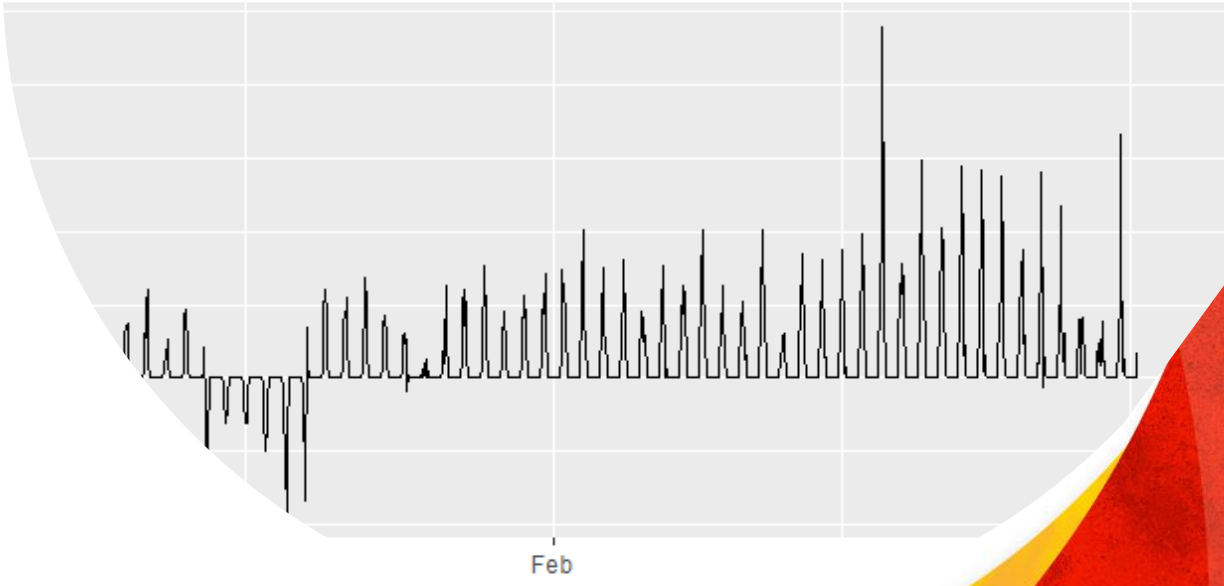
- Created by slushing snow
- Similar light properties to control for this year
- Some transmission

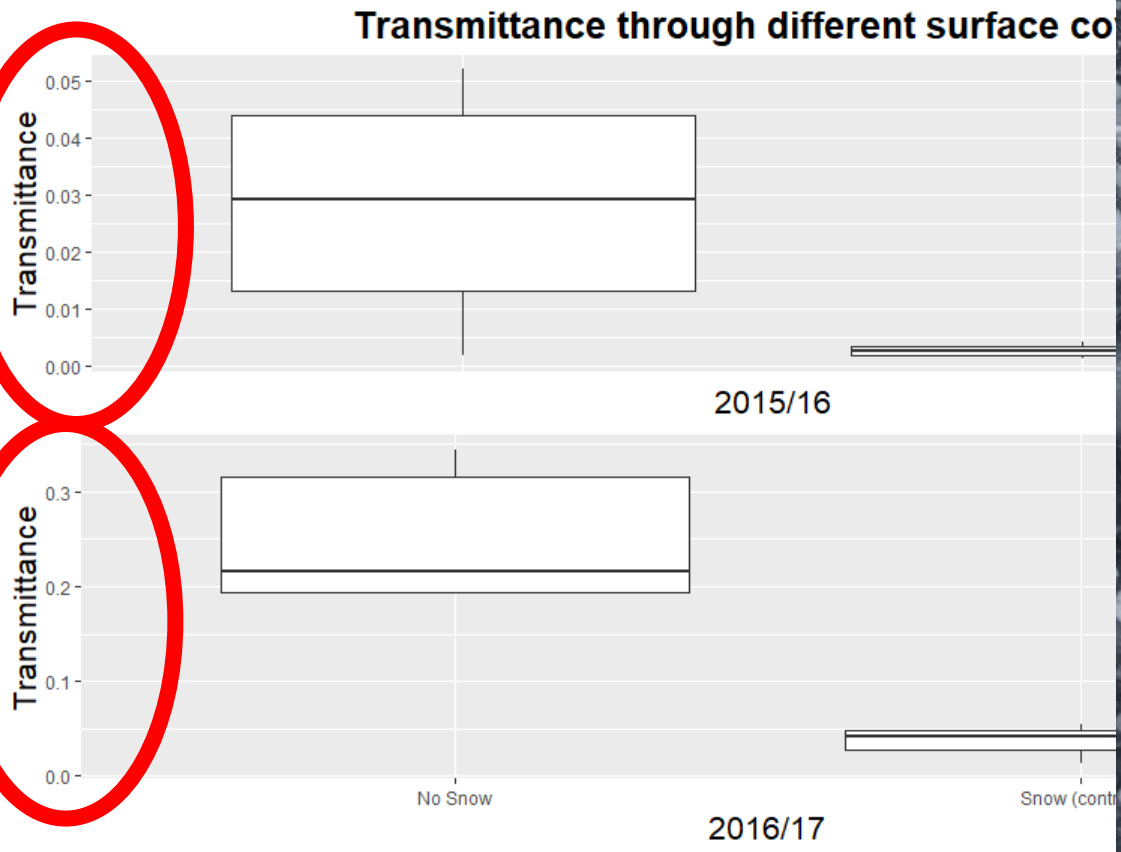
## Snow-on-ice (orange)

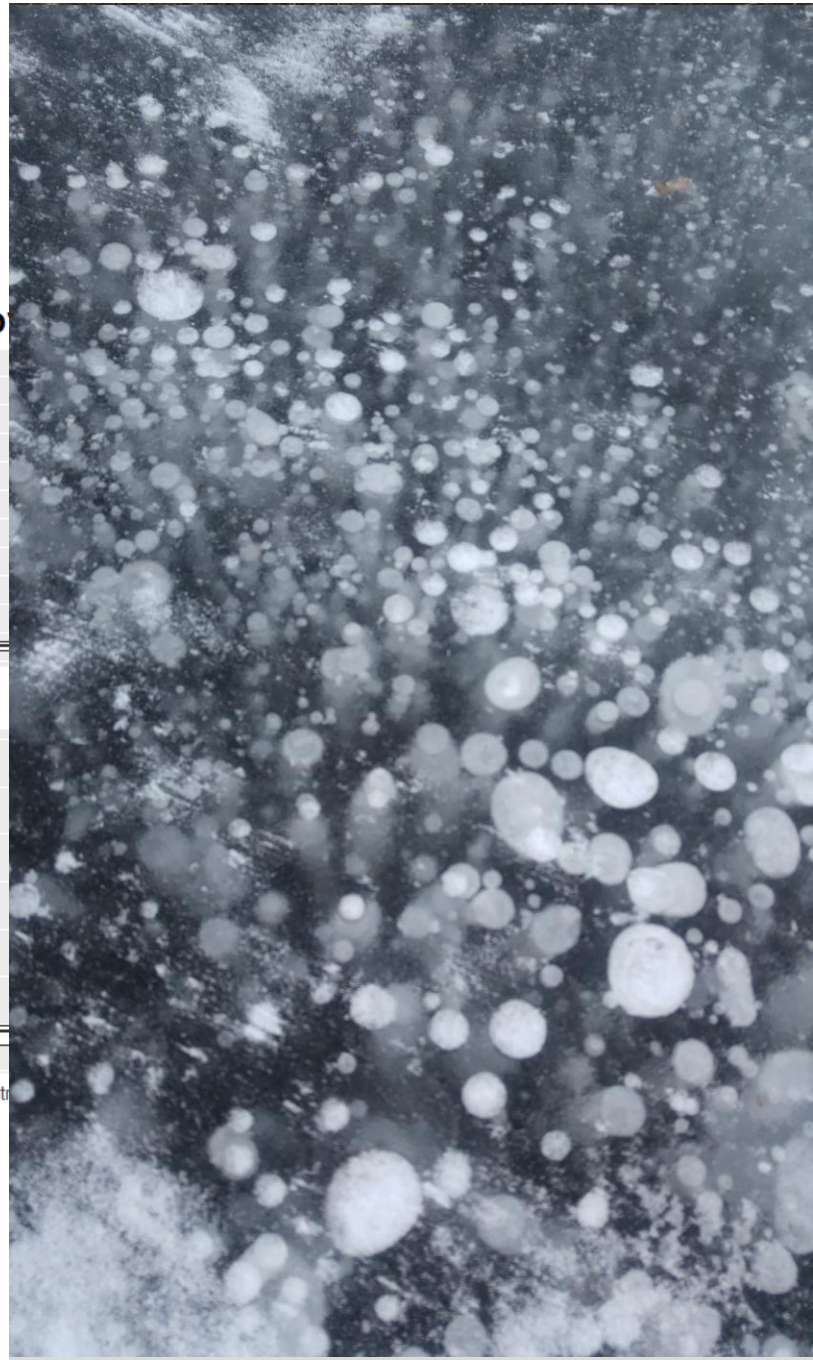
- Notably lower transmission than control or white ice treatment
- Limited PAR for under-ice biological activity




**PAR, between control and snow-on-ice**



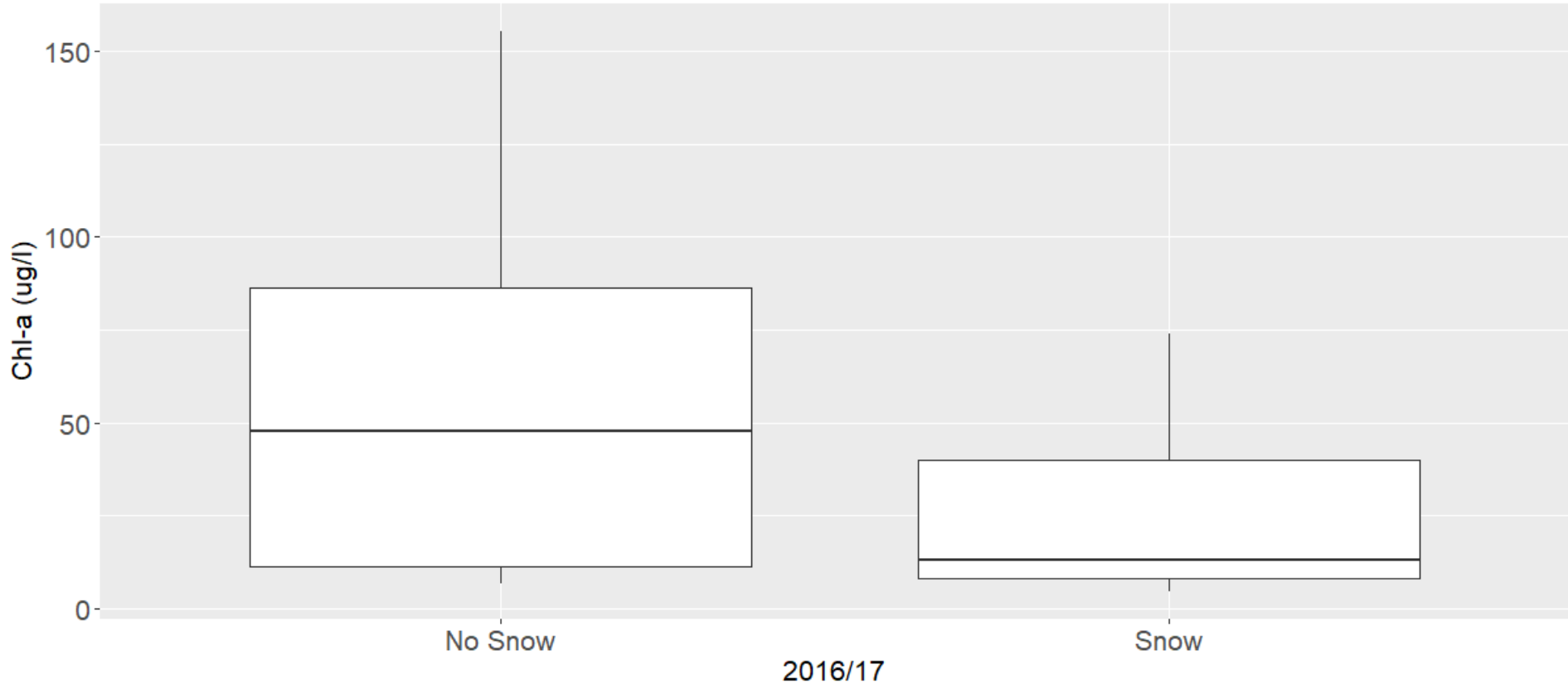

Transmittance through different surface co
Transmittance
0.05
0.04
0.03
0.02
0.01
0.00
2015/16
Transmittance
0.3
0.2
0.1
0.0
No Snow
Snow (contr
2016/17

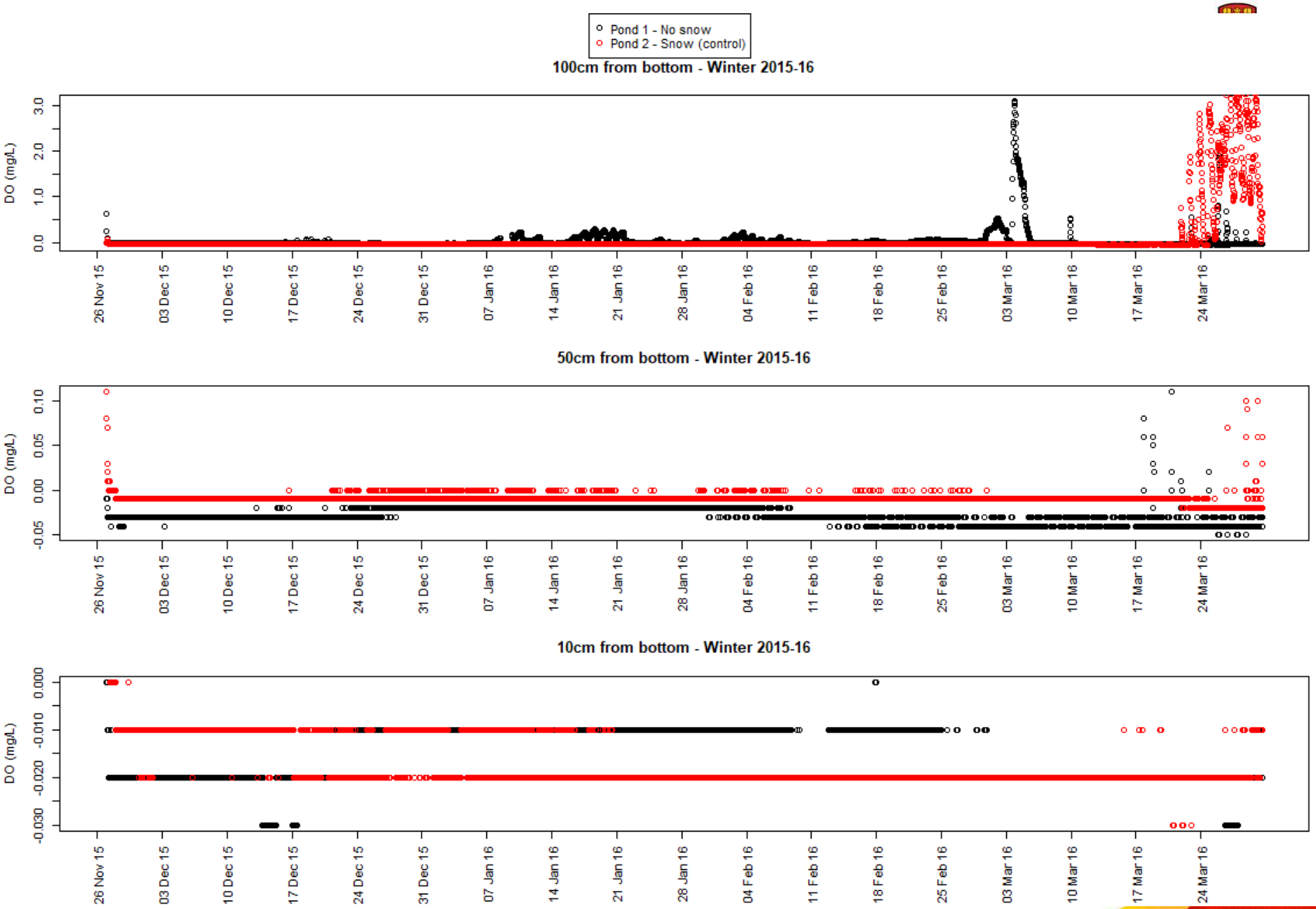


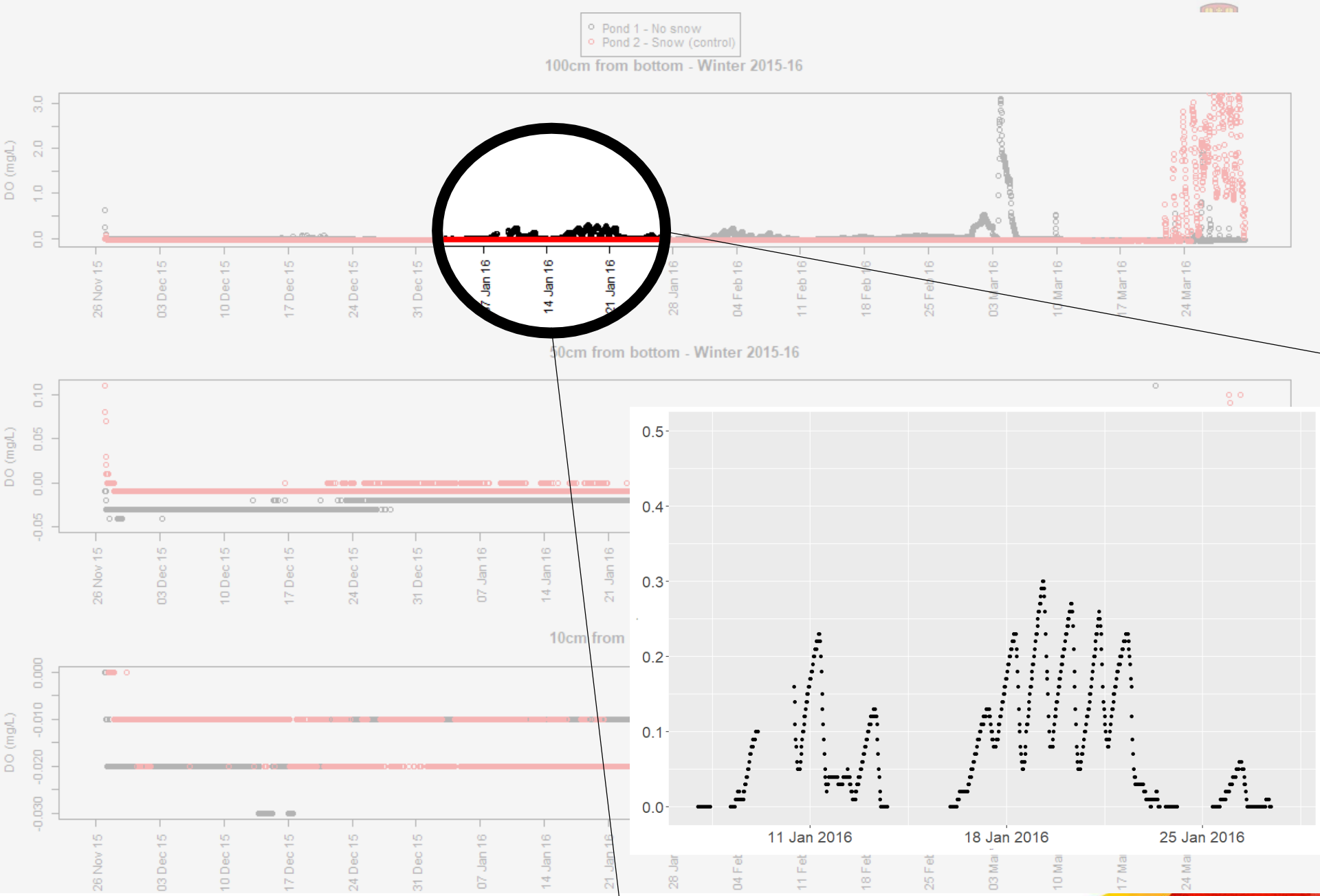
2016/17

# Chlorophyll-a

- Significant difference between snow-on and snow-removed
- No-snow values comparable to other literature – max of 155 µg/L *in winter*
- Noticeable colour shift between in control pond
  - Snow covered – green to red
  - No snow - green




Pond 1 - No snow
Pond 2 - Snow (control)
100cm from bottom - Winter 2015-16
DO (mg/L)
0.0
1.0
2.0
3.0
26 Nov 15
03 Dec 15
10 Dec 15
17 Dec 15
24 Dec 15
31 Dec 15
07 Jan 16
14 Jan 16
21 Jan 16
28 Jan 16
04 Feb 16
11 Feb 16
18 Feb 16
25 Feb 16
03 Mar 16
10 Mar 16
17 Mar 16
24 Mar 16
50cm from bottom - Winter 2015-16
DO (mg/L)
-0.05
0.00
0.05
0.10
10cm from bottom - Winter 2015-16
DO (mg/L)
-0.030
-0.020
-0.010
0.000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10cm from
DO (mg/L)
26 Nov 15
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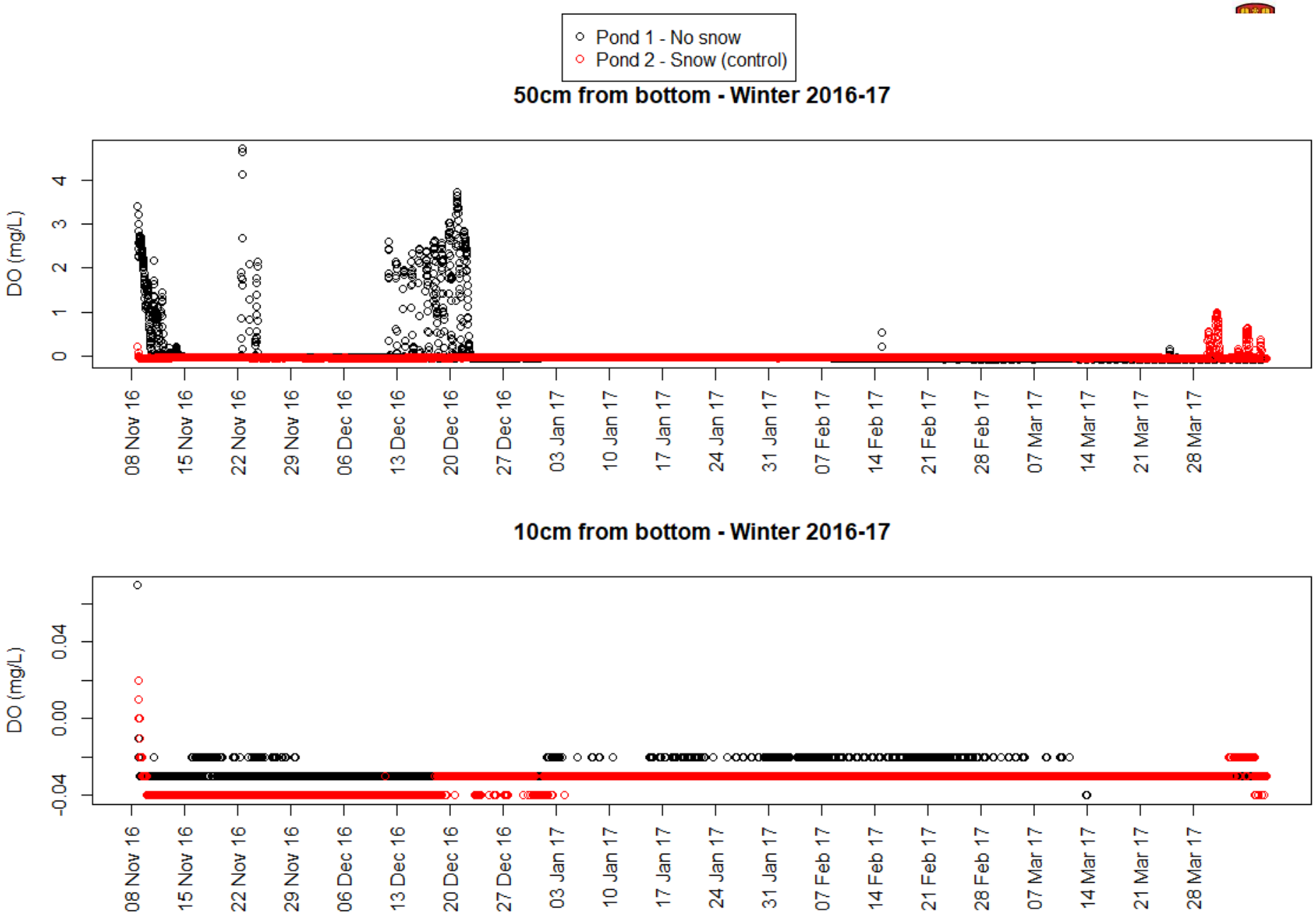
10 Dec 15
17 Dec 15
24 Dec 15
31 Dec 15
07 Jan 16
14 Jan 16
21 Jan 16
28 Jan 16
04 Feb 16
11 Feb 16
18 Feb 16
25 Feb 16
03 Mar 16
10 Mar 16
17 Mar 16
24 Mar 16
11 Jan 2016
18 Jan 2016
25 Jan 2016


Pond 1 - No snow
Pond 2 - Snow (control)
50cm from bottom - Winter 2016-17
DO (mg/L)
0
1
2
3
4
08 Nov 16
15 Nov 16
22 Nov 16
29 Nov 16
06 Dec 16
13 Dec 16
20 Dec 16
27 Dec 16
03 Jan 17
10 Jan 17
17 Jan 17
24 Jan 17
31 Jan 17
07 Feb 17
14 Feb 17
21 Feb 17
28 Feb 17
07 Mar 17
14 Mar 17
21 Mar 17
28 Mar 17
10cm from bottom - Winter 2016-17
DO (mg/L)
-0.04
0.00
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08 Nov 16
15 Nov 16
22 Nov 16
29 Nov 16
06 Dec 16
13 Dec 16
20 Dec 16
27 Dec 16
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07 Mar 17
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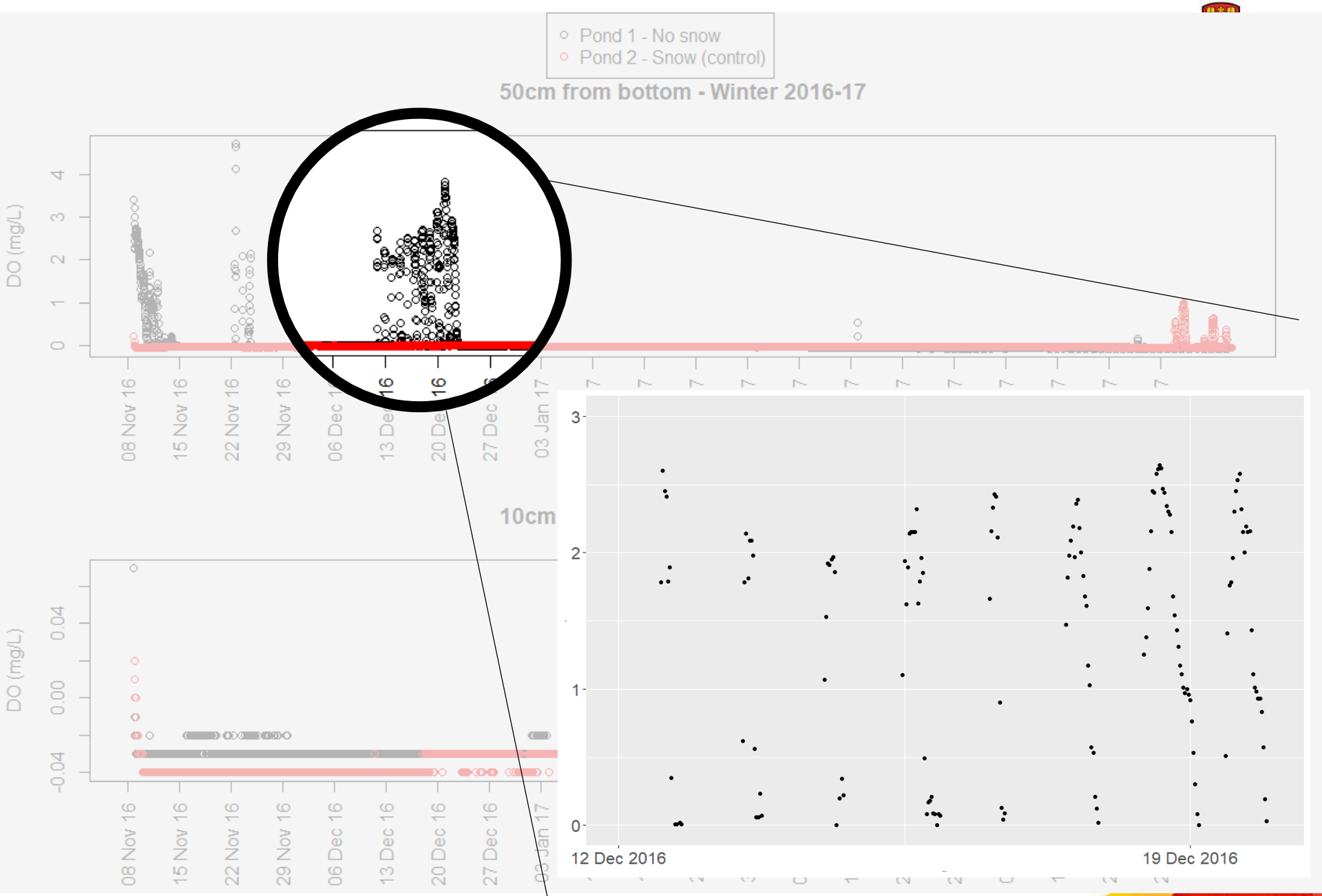
21 Mar 17
28 Mar 17


Pond 1 - No snow
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50cm from bottom - Winter 2016-17
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0
1
2
3
4
08 Nov 16
15 Nov 16
22 Nov 16
29 Nov 16
06 Dec 16
13 Dec 16
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27 Dec 16
03 Jan 17
10cm
DO (mg/L)
-0.04
0.00
0.04
08 Nov 16
15 Nov 16
22 Nov 16
29 Nov 16
06 Dec 16
13 Dec 16
20 Dec 16
27 Dec 16
03 Jan 17
0
1
2
3
12 Dec 2016
19 Dec 2016

# Factors affecting phytoplankton growth

(adapted from McCombie 1952)

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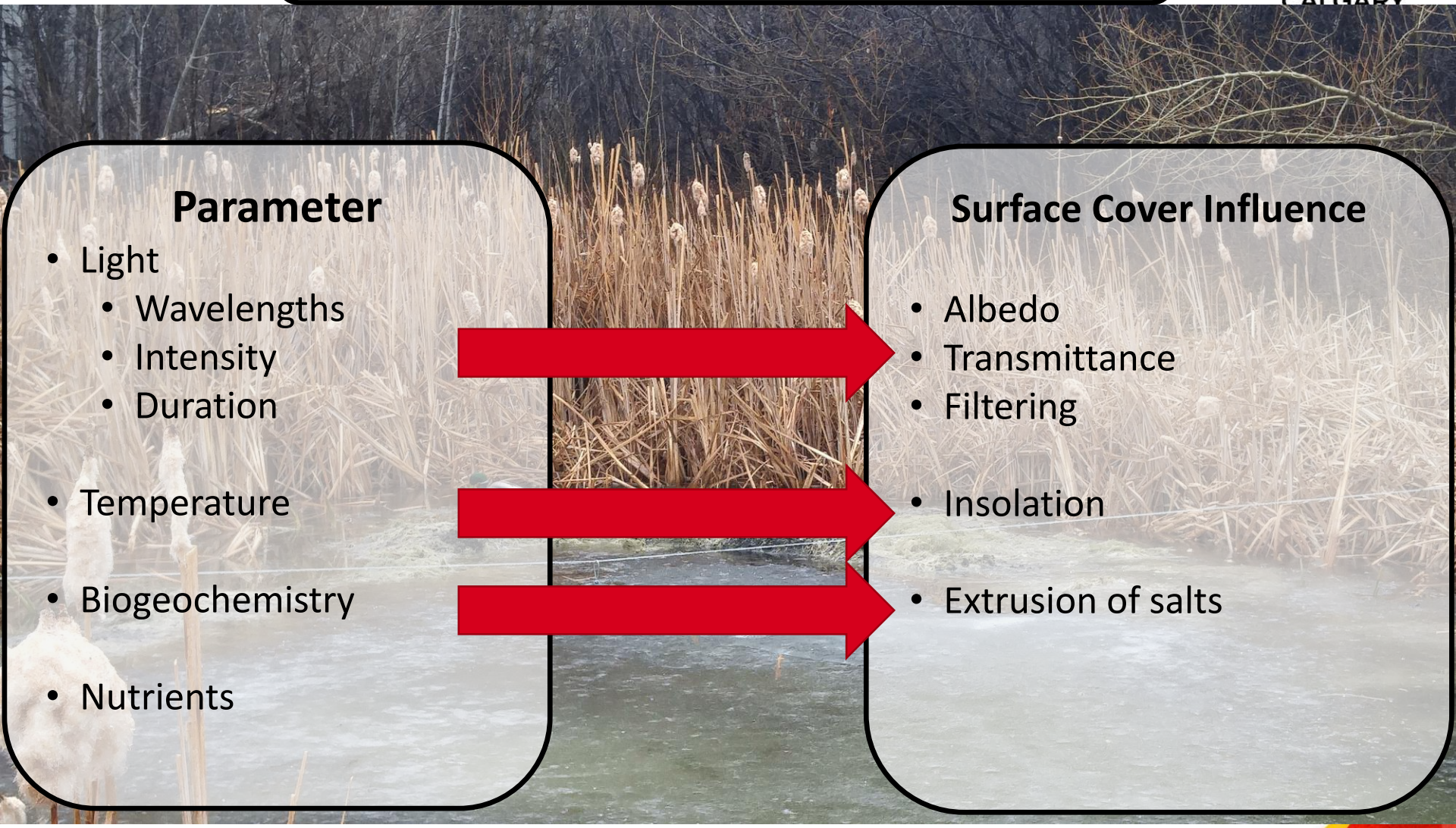

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| • Nutrients | |

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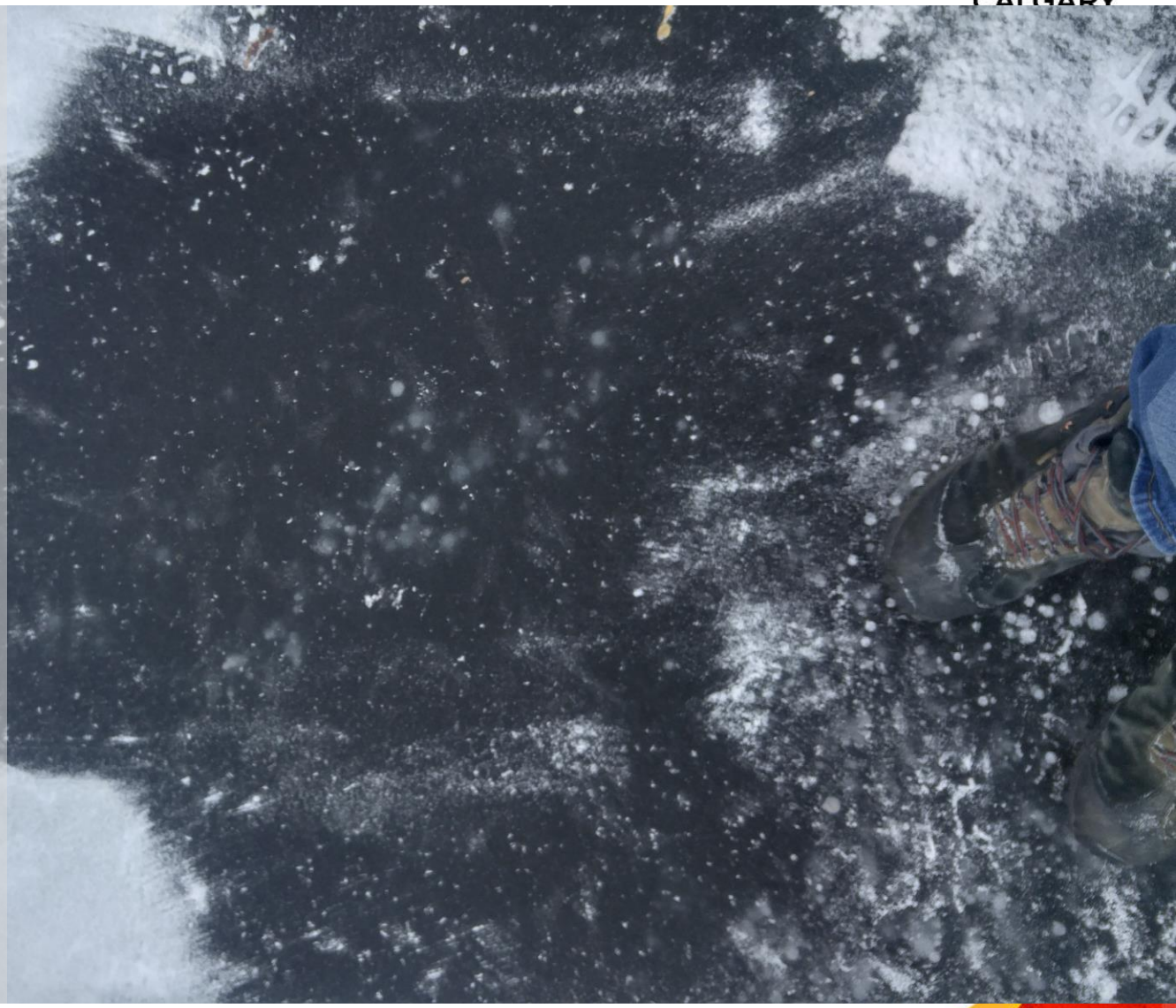
# Conclusions

- Biological activity **is** occurring under-ice
- Surface cover controls under-ice activity and is expected to change under future projected climate conditions
- Influence of carbon on under-ice activity relatively unknown
- Single spot sampling would not detect some diurnal fluctuations
  - More continuous monitoring needed

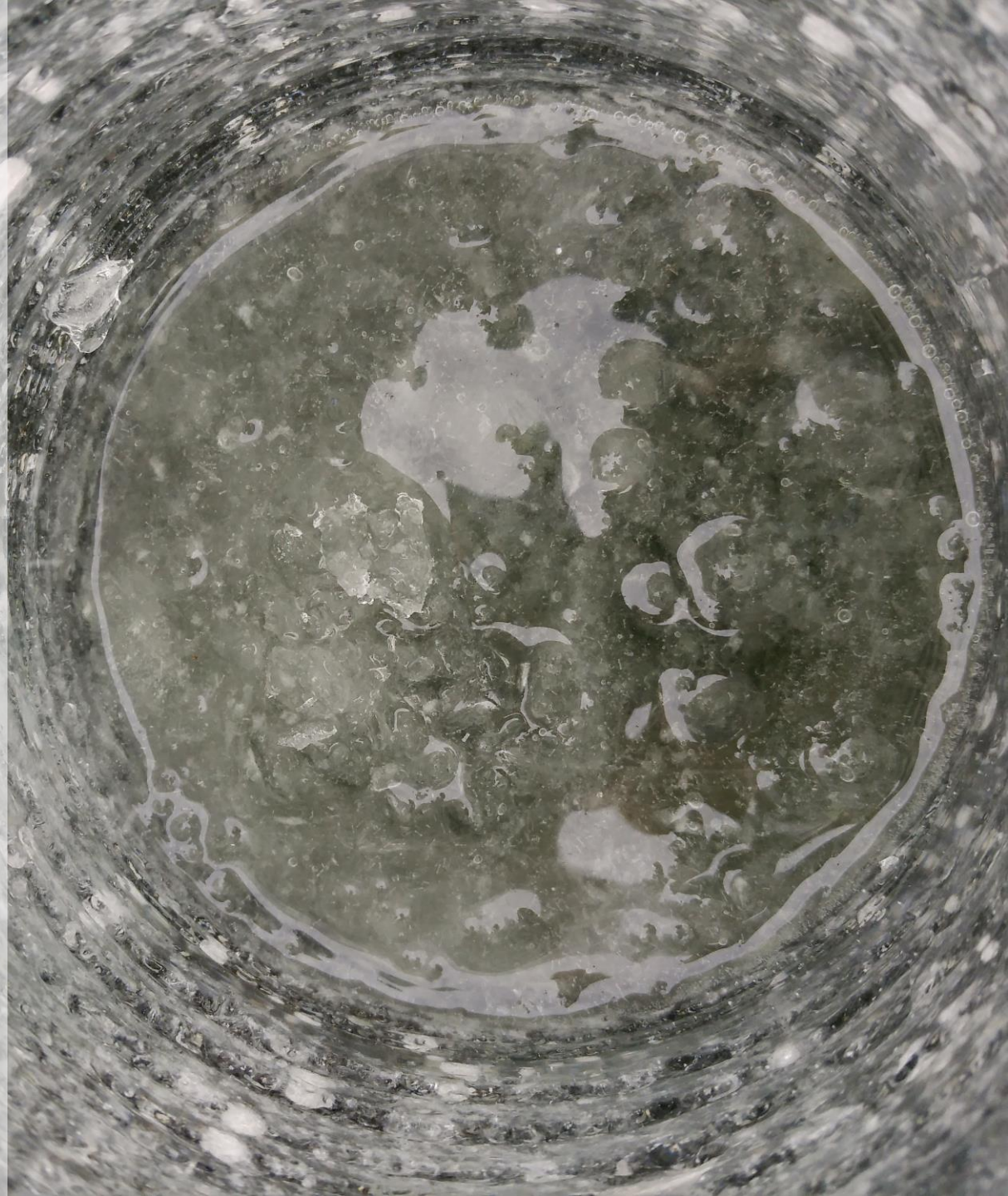


# Relevance to lake management

- Inter-seasonal relationships
- Shallow systems in particular
  - Especially when combined with eutrophication
- Potential of building predictive model for timing of algal blooms
  - More data required

## Future Work

- Evaluating relationship of productivity to biogeochemistry under-ice
- Assessing the influence of DOC in under-ice productivity using experimental mesocosms
- Determining connection between winter surface cover conditions and ice-off biological activity (ie. Algal blooms)
- Integration of additional data sources (citizen science?)



# Specific projects

- Nakamun Lake Research program with AEP – EMSD

- Historical data analysis linking ice conditions / timing and bloom prevalence / timing

Nakamun Lake – Facebook

# Questions

- Any questions?

- Want to discuss further?
  - david.barrett@ucalgary.ca