Supercooling and freezing dirty water:

A laboratory investigation of thermally observable phenomena associated with cooling and freezing

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“If there is magic on this planet, it is contained in water.”

(Loren Eiseley, The Immense Journey, 1957)
I will start by showing magic that you may not have seen
Upside down convection

Heat in → ~700mW

Graph showing temperature changes over time with lines indicating different temperatures at the bottom of the tube.
Upside down convection  ON/OFF

Top at ~46°C

~1°C

-7.8°C

Latent heat released
A world record?

This vial was held at -15°C for 422 days

Checked >1 yr later and it still cooled to below -15°C
YES

Muddy pothole water will supercool

Typical cooling curve
As will all of these:
Magic

Divide - and each vial will release **latent heat** at a different temperature.

Time to freeze for a typical vial and supercooling temperature

For 138 cycles

\[-11.8 \pm 0.2^\circ C\]
Onset of freezing at 0°C and -5°C

The perfect ice nucleator

“Ice crystal”

Supercooling “On/Off” on demand

Anti-supercooling ON for both containers

Onset of freezing at 0°C

Anti-supercooling on for red container
Anti-supercooling off for green container

Onset of freezing at 0°C and -5°C

Supercooling “On/Off” on demand
Water escaping from a plastic water bottle
Polyethylene Terephthalate (PETE)
What happens when clean and dirty water begins freezing?
“An example of dirty water freezing and thawing”
Electrical activity and freezing

At End A

Back to End A

Now to End B

Voltage (mV)

Temperature (°C)

Time (sec)
Freezing supercool water

Freezing water in a large container

Water clusters?
End of show and tell

Now

Magic in Detail

Effect of:

Cooling from below
Rayleigh–Bénard convection
is a type of natural convection, occurring in a plane of fluid heated from below, in which the fluid develops a regular pattern of convection cells known as Bénard cells.

Heating water from below

This is a file from the Wikimedia Commons.
Mosaic Structures and Circulation

From G. Pollack’s The Fourth Phase of Water
Top of water column supercooled.
Stable vertical convection cells with respect to gravity

Vial tilted 15° West

Vial tilted 15° East

Vial tilted 15° North

Vial tilted 15° South
10ml of DD water in a 10 cm tall vial
Effect of 15° tilt from vertical

Tilt

Then back

Bath temperature
“Notice that the vertical ΔT around TC 6 is << than the horizon ΔT”
Now we induce thermal oscillations
By adding D$_2$O "Clusters"

Take a closer look
Thermal oscillations

~108 sec
Add $\text{D}_2\text{O}$ to $\text{H}_2\text{O}$

The effect
75uL of H₂O added (here in time) containing D₂O as indicated.
Smoothed by adjacent averaging
Thermal oscillation frequency vs. time
Water density vs. temperature

Density

Buoyancy

kg/m³

Temperature °C
No gradients

~20°C

~20°C

Density decreasing from 1 to .9

Density Maximum = 1

Density Decreasing from 1 to .9

ρ

~8°C

~4°C

>4°C

<4°C

Now we have a density and thermal gradient.
H₂O water clusters only

H₂O + D₂O water clusters

0% 12.5% 25% 50%
Metastable motion in a column of water cooled from the bottom

Temperature $\Delta T = 0$

Temperature $\Delta T = 2^\circ C$

H$_2$O Clusters

$\rho = 998.234 \text{ kg/m}^3$

$\rho = 998.681 \text{ kg/m}^3$

At $3.98^\circ C$

$\rho = 1000 \text{ kg/m}^3$

$-8^\circ C$

$\rho = 998.681 \text{ kg/m}^3$
24 hrs. in the life of a pond
Now ~No Thermal or Density Gradients
Water clusters

Fig. 2.3 Proposed structure of liquid water, from Rustum Roy and colleagues. Clusters are outlined in black.

From G. H. Pollack The Fourth Phase of Water
“Making D$_2$O water clusters in H$_2$O water”
“Experimental setup to measure the effect of D$_2$O clusters”

Heat flow
Time from a to b?

- 110 ml Water bottle
- Ice bath
- 7 Thermocouple(s)
“The 60sec time delay is a clear effect of D$_2$O water clusters in water”

The graph shows the temperature over time for different concentrations of D$_2$O. The black line represents the temperature without added D$_2$O, the red line with circle markers represents 0.23% added D$_2$O, and the green line with triangle markers represents 0.46% added D$_2$O.

The 60 sec delay is indicated by the horizontal line from the x-axis to the graph line, showing the time delay due to D$_2$O clusters.
110 ml Water bottle
Thermocouple(s)
6 TCs
Ice bath

Note: The effect of “no” clusters vs. clusters
“Effect of $\text{D}_2\text{O}$ water clusters on cooling curves”

Regular water

1.4% Not stirred

1.4% well mixed

$\text{D}_2\text{O}$ clusters broken apart
Thank you
Day

Sunrise

Surface ΔT ≥ 6°C

Night

Sunset

Bottom mud

Water temperature on a mostly “sunny day”

24 hrs. in the life of a pond

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