Demonstrating an inversion with boiling water and ice

Materials and preparation:

- Find these in the trunk or your lab supplies:
  - Two 1-qt freezer containers or two 500-ml beakers
  - Digital thermometer with thermocouple wire. Make sure the thermometer’s battery works. Have a spare on hand.
- On the day before the activity, fill one of the containers half full with water and freeze it. If you forget, use ice cubes.
- On the day of the activity, have boiling water ready to fill the other container half-way. Keep it hot until you need it.
- Set up your lab bench or demonstration table with the container of ice on the right side (facing the class) and the empty container on the left. Make two signs (“Ice cold” and “Boiling”). Place them next to the appropriate containers. Place the digital thermometer and boiling water on the table too.
- Write the following table on the board:

<table>
<thead>
<tr>
<th>Classroom temperature (°C):</th>
<th>Ice</th>
<th>Boiling water</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C, level with top of container, above center</td>
<td></td>
<td></td>
</tr>
<tr>
<td>°C, inside container, 0.1 cm above ice or water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Is the air right above ice/water surface warmer or colder than air above?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Procedures:

1. Explain: To understand how smoke moves around and how it can get stuck in valley bottoms, making it hard for us to see and breathe, we have to understand the daily movement of air. Every day, sunlight reaches the earth’s surface, heats it up, and heats the surface air as well. Every night, the earth cools off because the sun isn’t heating it anymore, and the surface air cools off too. We’re going to investigate how air behaves – how it moves around – above hot and cold surfaces.

2. Get 3 students to help with the demonstration and begin:
a. Have one student turn on the digital thermometer and hold its display up so the class can see it. Measure in degrees C.

b. Have another student hold the thermocouple tip at shoulder level. Have the class call out the temperature, discussing until they agree on it.

c. Have a third student record that temperature in the top row of the table on the board.

d. In the “ice” container, have students measure and record temperatures at these 2 locations:
   - Level with top of container, over its center (see photos)
   - Inside container, about 1 mm above surface of ice (not touching ice/water). If the thermocouple touches the ice/water, you’ll know because the temperature will changes very fast. Just dry it off and try again.

e. In the “boiling” container, do the same thing. (It may be hard for the class to decide what the temperatures really are because the air above the water should be very turbulent. That’s OK.)

f. Ask: For each container, is the temperature 1 mm above the ice/water “warmer” or “colder” than the temperature at the top of the container?

Here is an example of the information that should be in the table when you’re done:
| Classroom temperature (°C): 20 |
|-----------------------------|----------------|
|                            | Ice | Boiling water |
| °C, level with top of container, above center | 19  | 25  |
| °C, inside container, 1 mm above ice or water | 7   | 83  |
| Is the air right above ice/water surface warmer or colder than air above? | colder | warmer |

3. Discuss:
   - How would you describe what the air is doing above the two surfaces? Use pairs of “contrast” words, such as quiet vs. wild, still vs. busy, unmoving vs. moving, or peaceful vs. turbulent.
   - For each container, would you call the air above the ice/water surface stable or unstable?
   - Explain: If the air is stable, there is an inversion present. That is, the usual daytime pattern of warm air on the bottom and cooler air on top is now upside-down, trapping the cold air at the bottom. That’s how smoke can get stuck and make the air murky and hard to breathe. The same thing can happen with dust and automobile exhaust on winter days.

4. Summarize or return to remainder of lesson plan.