Supplementary Material

1 MATERIALS

The materials needed to conduct our table-top experiments are listed below and are also referred to in the three Experimental Sequences below.

1. LEGO SPIKE Prime robotics kit
2. Computer with LEGO SPIKE app installed
3. LEGO SPIKE light sensor
4. OXO turntable
5. Acrylic sidewall, or stand-alone tank
6. Colored tape
7. Spray bottle
8. 40 cm x 40 cm sheet of acrylic with centered 8 - 12 cm circular thru hole
9. Empty circular glass jar or aluminium can
10. Weights to keep the jar or can from floating away
11. Water
12. Food coloring
13. Ice
14. Dish soap
15. Salt

2 EXPERIMENTAL RECIPES

2.1 Convection Setup and Experimental Sequence

1. Assemble Materials 1-11, and attach blue tape to the side of the acrylic tank (see Figure 3b).
2. Secure the turntable onto the LEGO baseplate.
3. Place the rim of the OXO turntable in contact with the drive wheel. Place another weight atop the motor to ensure good contact between the drive wheel and the OXO rim.
4. Connect the computer to the LEGO SPIKE Hub, and open Scratch or Python to control the motor.
5. Fill the tank with 10 cm of water and place the acrylic sheet with centered thru hole atop the tank's sidewall.
6. Turn on the motor.
7. Spin up the fluid to solid body rotation, following Equation 1 and Figure 4.
8. After spin-up, spray a patch of dye atop the fluid layer through the open center of the acrylic sheet (Figure S1b), and then remove the sheet.
9. Upright convection will develop from there (we present late stage convection in Fig. 6 at $45\tau_\Omega \approx 4$ minutes).

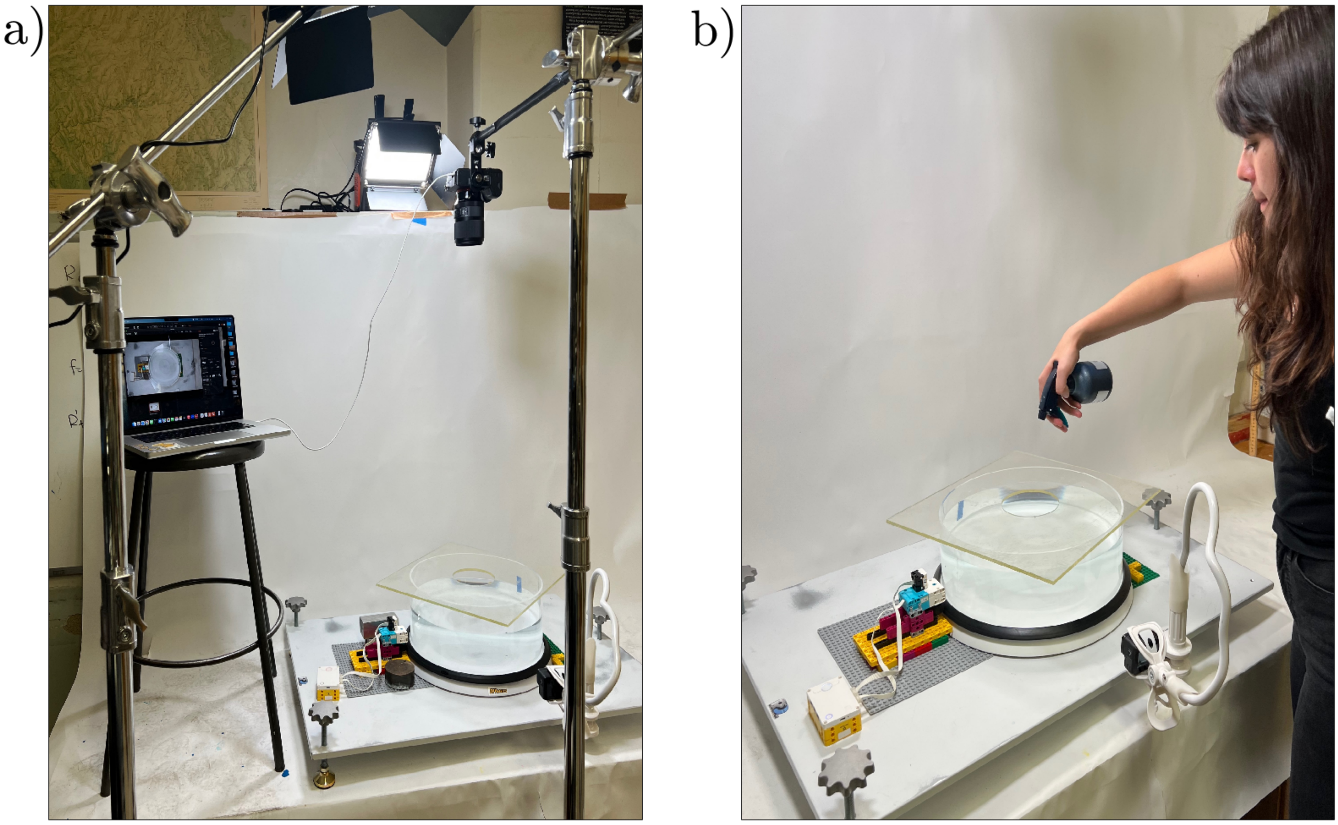

Figure S1. a) Lab setup for the convection experiment. b) Dye being sprayed in a local patch atop the surface of the fluid layer. Note that the cutout in the overlaying acrylic sheet control the location and size of the dye patch. This acrylic sheet is carefully removed from atop the rotating system immediately after spraying in the dye.

2.2 Thermal Wind Setup and Experimental Sequence

1. Assemble Materials 1-10 and 12-14, and attach the blue tape to the side of the acrylic tank (see Figure 3b).
2. Secure the turntable to the LEGO baseplate.
3. Place the rim of the turntable in contact with the drive wheel. Place another weight atop the motor to ensure good contact between the drive wheel and the OXO rim.
4. Connect the computer to the LEGO SPIKE Hub, and open Scratch or Python to control the motor.
5. Place the can in the center of the tank and use weights to hold it in place.
6. Fill the tank with 10 cm of water, adding more weight to the can as necessary.
7. Place cameras for viewing (begin recording if in the rotating frame; if not, record after step 12).
8. Turn on the motor. Tune the motor speed so that the tank spins at 1-2 RPM, per Equation 23.
9. Spin up the fluid to solid body rotation, following Equation 1. At low RPM, this takes about 20 minutes in a 10 cm layer of water.
10. During spin-up, combine 1 cups of water with 1 tablespoon of salt. Surf the web, aimlessly, for the rest of spin-up.
11. After the fluid has spun up, carefully fill the aluminum can with ice (Figure S2b).
12. Add the salt water mixture to the can to increase the thermal coupling between the ice, can, and the working fluid.

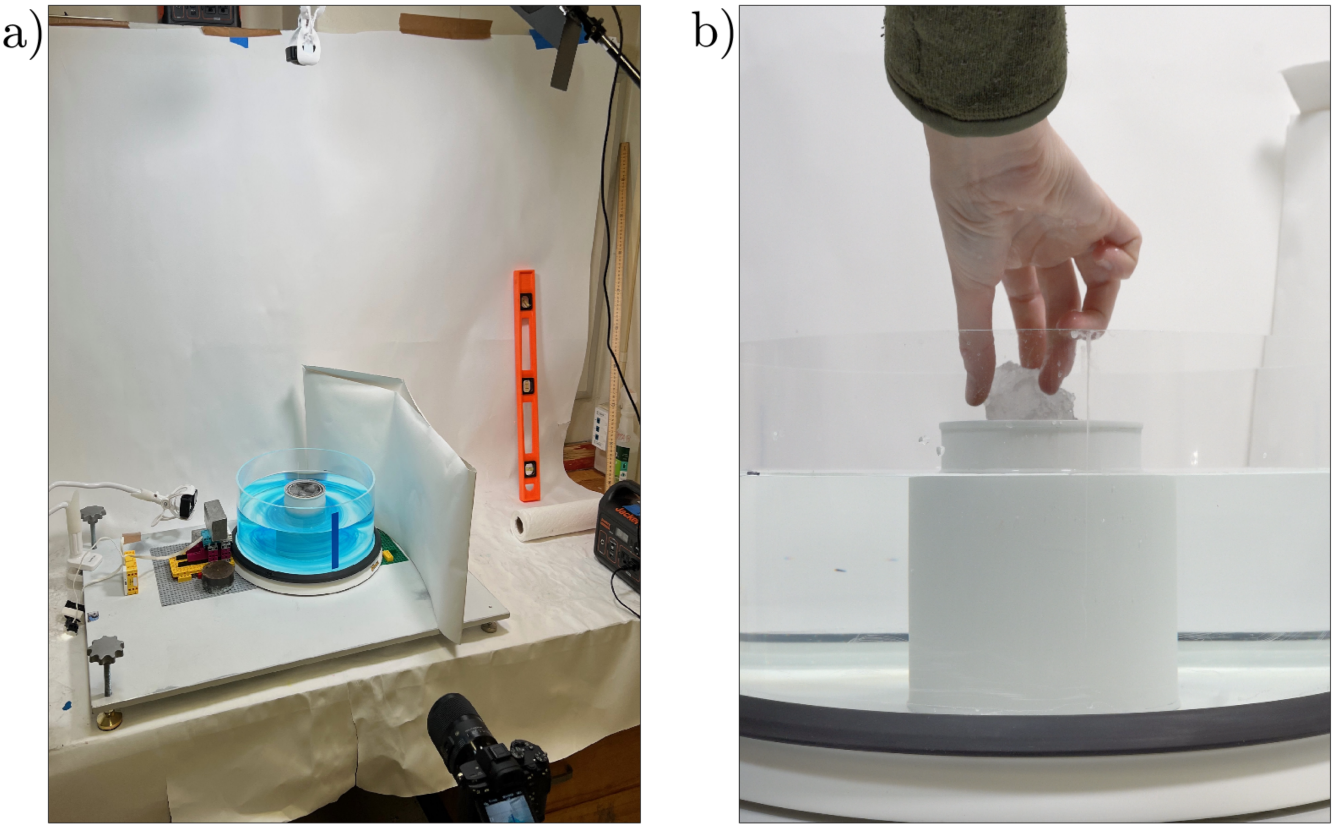

Figure S2. a) Lab setup for the thermal wind and baroclinic instability experiments. b) Ice being added to the central can.

13. Optional: Wait a few minutes for thermal gradients to build in the fluid annulus.
14. Place a few drops of dye near the side of the can.
15. The thermal wind shear flow should develop from there (Figure S3a).

2.3 Baroclinic Instability Setup and Experimental Sequence

1. Follow the steps listed above in 2.2.
2. However, the rotation rate of the tank should be set above ≈ 3 rpm, per equation (23) in the main text.
3. Place a few drops of one color dye near the side of the cold can. Place a few drops of another color dye near the outer radius of the tank.
4. The set up should allow for the visualization of baroclinic instabilities in the fluid annulus (Figure S3b).

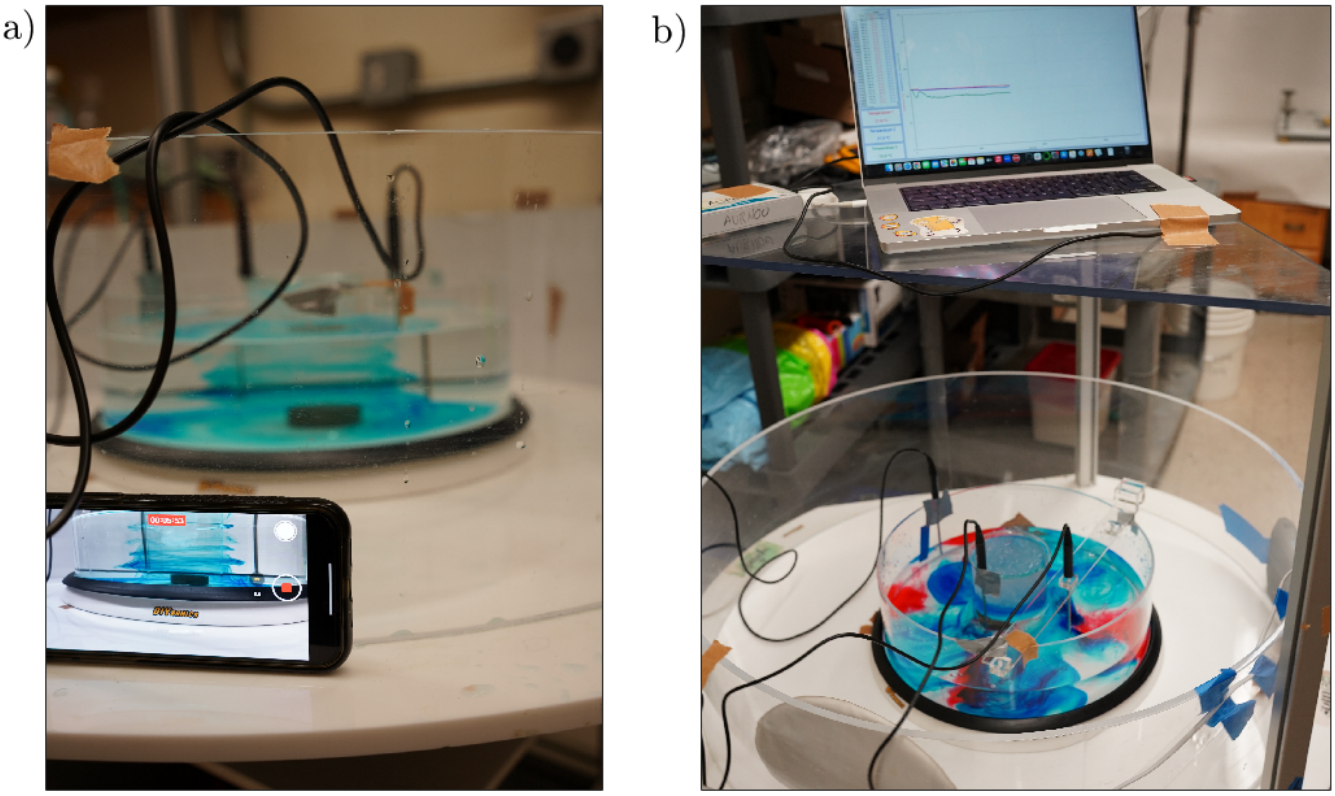

Figure S3. Thermometry experiments made on the HT3. Three thermistors are situated just exterior to the inner boundary at R_i; at mid-radius, $R_{mid} = (R_o + R_i)/2$; and at just interior to the outer boundary at R_o. The thermistors are all located approximately 1 cm above the tank bottom. a) Sideview of the thermal wind experiment ($\mathcal{N}_{RPM} \approx 1$; $H \approx 10$ cm). b) Oblique view of the baroclinic instability experiment ($\mathcal{N}_{RPM} \approx 11$; $H \approx 5$ cm). The thermal data was acquired on the laptop situated on the HT3's acrylic top deck.

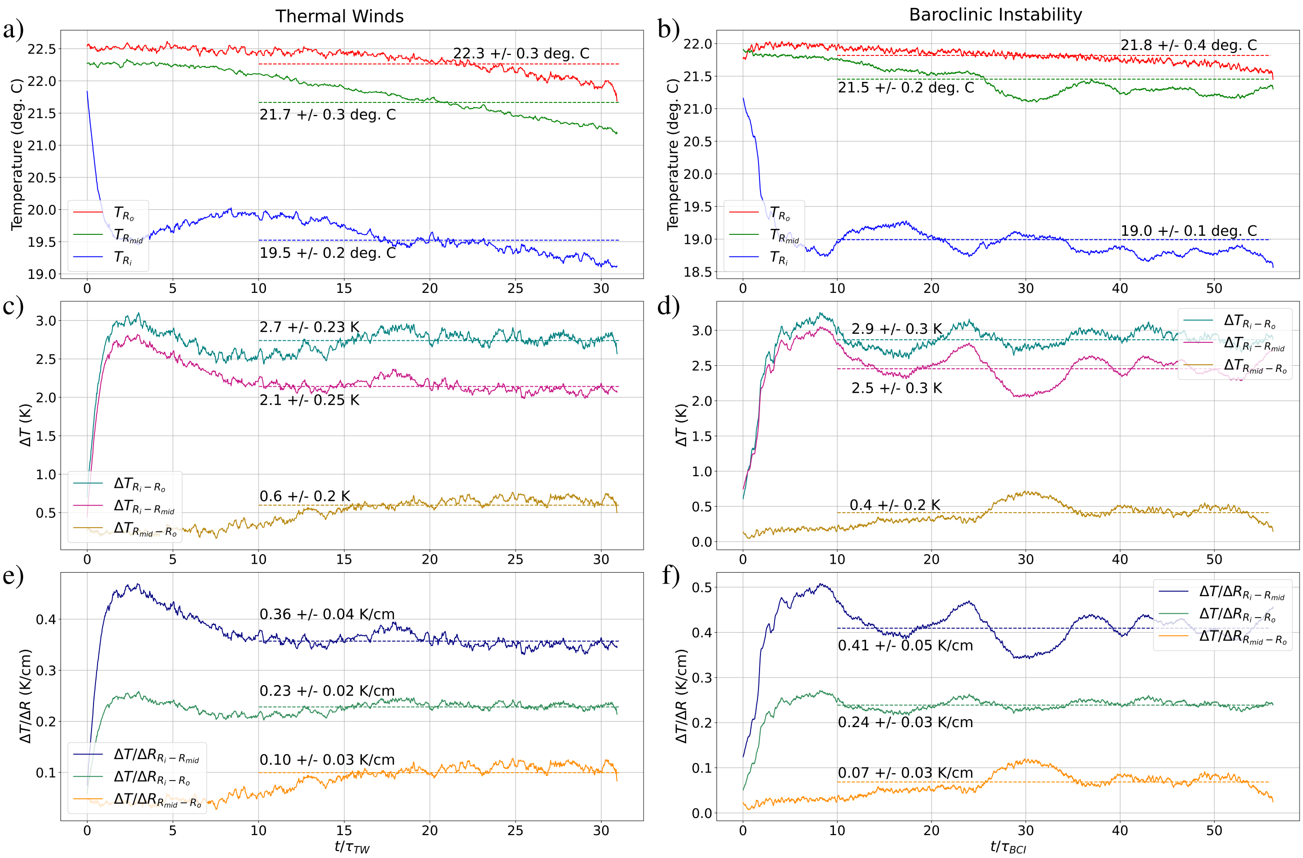

Figure S4. Temperature time series data for the thermal wind (left column; $\mathcal{N}_{RPM} \approx 1$; $H \approx 10$ cm) and the baroclinic instability experiments (right column; $\mathcal{N}_{RPM} \approx 11$; $H \approx 5$ cm) shown in Figure S3. Panels a) and b) show temperature data, T. Panels c) and d) show radial temperature differences, ΔT. Panels e) and f) show radial temperature gradient estimates, $\Delta T/\Delta R$. The horizontal dashed lines denote time-averaged values.

3 LABORATORY TEMPERATURE FIELD MEASUREMENTS

More often than not, qualitative, dye-visualization based experiments are made with our *DIY*namics hardware. Here we have also made a set of thermal measurements to quantitatively estimate the characteristic temperature scales that develop in our experiments. Figure S3 shows the set up for these thermal measurements. The OXO turntable was placed in the center of our 80 cm diameter HT3 table. We placed three Vernier temperature probes at the edge's of the fluid annulus and at its midpoint. The tips of the probes were all set approximately 1 cm above the bottom of the fluid layer (Figure S3a). The probes were connected to a Vernier LabQuest Stream interface, which was connected to a laptop situated in the rotating frame atop the HT3's acrylic top deck (Figure S3b).

Note that access to a larger-diameter rotary table is not needed to make these measurements. Similar thermal measurements could be made on any of our kits by making use of use wireless thermometers, such as Pasco's wireless temperature sensors or Vernier's 'Go Direct' temperature probes.

Figure S4a shows the temperature time series data from the TW experiment carried out with $\mathcal{N}_{RPM} = 1$ and $H = 10$ cm. Figure S4d shows the temperature time series data from the BCI experiment carried out with $\mathcal{N}_{RPM} = 11$ and $H = 5$ cm. The mean temperature differences across the fluid annulus was near 2.7

K in both experiments. Interestingly, the thermal vacillations in the BCI data elegantly show the thermal signatures of the baroclinic eddies as they slowly drift past the thermometers. The mean values of the temperature differences across the fluid gap and the temperature gradients are given in Table 1. and are used in testing the theoretical predictions against the observed structures in our dye-visualization movies.