# Two-in-one mapping of temperature and flow around microscale convective plumes

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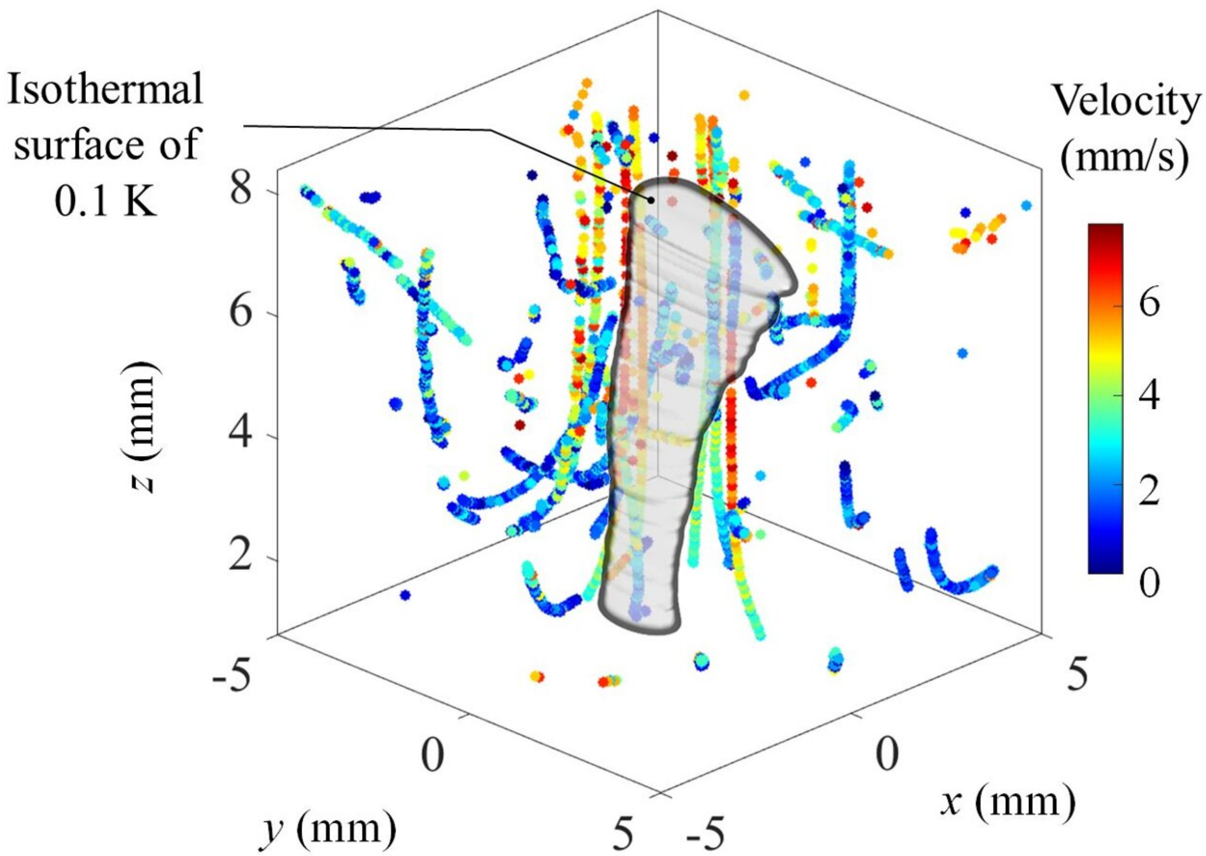


The team succeeded in mapping the fluid flow profile around a microscopic heat source in a body of water in three-dimensions. Credit: Tokyo Metropolitan University

Researchers from Tokyo Metropolitan University have devised a way to measure both the temperature and velocity profiles of fluid in a convective plume at millimeter length scales in 3D. They combined near-infrared absorption imaging and image processing to separate the motion of tracer particles from snapshots of how light is absorbed, producing both a smooth velocity and temperature map.

The technology, reported in the *Journal of Visualization*, promises new insights into optimizing the design of micro-heating and cooling devices.

Accurate maps of how heat and matter flow at the microscale are vital to the design of micro-heating and cooling devices. A classic example is in liquid-cooled microprocessors, where flow will directly affect how efficiently heat is carried away from chips.

Over the years, this has led to a wide range of techniques designed to map flow and temperature; for example, the video tracking of tiny "tracer" particles can yield an accurate flow map. But while methods exist to map different quantities separately, scientists are still looking for the best way to realize the mapping of multiple quantities at once, especially in three dimensions.

A team of researchers from Tokyo Metropolitan University led by Professor Naoto Kakuta have been studying the use of near-infrared imaging to capture maps of temperature in bodies of fluid. The absorption by water of light in the near-infrared (NIR) is temperature dependent. By mapping how much is absorbed in different parts of a sample with multiple NIR cameras, they can create an accurate 3D temperature map.

In previous work, they had succeeded in applying this to visualize tiny convective plumes, where heating of a microscopic portion of a volume of fluid creates a vertical, circulatory flow.

But while temperature could be mapped, it was not possible to map the flow profile at the same time. This is a significant drawback, since convective flows feature a complex coupling between heat transport and flow. But simply adding tracer particles and applying existing methods would require additional illumination by high-power LEDs or lasers.

The team had already noticed that tracer particles introduced into the same fluid cast a shadow against the NIR illumination used to create the temperature map. Preliminary work had helped make two-dimensional maps by simply watching how the shadows move.

Now, they have succeeded in creating fully 3D maps by using the same two camera system used for their NIR imaging. By manipulating the images, they could separate the shadows from the absorption profile, using the same data to extract a 3D map of both the flow and the temperature.

Applied to the same microscopic plumes, the team successfully mapped not only the temperature variation around their tiny heat source but the flow profile as well. They also confirmed close correspondence between their maps and heat and velocity profiles expected from numerical simulations.

Their new, simple method promises to deliver insights into the formation of convective plumes at the microscale, and how they might impact the performance of cutting-edge devices.

**More information:** The-Anh Nguyen et al, Simultaneous near-infrared measurement of temperature and flow fields of a thermal plume arising in water, *Journal of Visualization* (2024). DOI: 10.1007/s12650-024-00997-9

Provided by Tokyo Metropolitan University

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