Simulating flow from volcanoes and oil spills

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Some time around 37,000 BCE a massive volcano erupted in the Campanian region of Italy, blanketing much of Europe with ash, stunting plant growth and possibly dooming the Neanderthals. While our prehistoric relatives had no way to know the ash cloud was coming, a recent study provides a new tool that may have predicted what path volcanic debris would take.

"This paper provides a model for the pattern of the ash cloud if the wind is blowing past an eruption of a given size," said Peter Baines, a scientist at the University of Melbourne in Australia who did the study. He published his work in the journal *Physics of Fluids*.

Volcanic eruptions are an example of what Baines calls an "intrusion." Other examples include exhaust rising from a chimney, sewage flowing into the ocean, and the oil spilling underwater in the 2010 Deepwater Horizon disaster. In all these events, a fluid rises into a density-stratified environment like the atmosphere or the ocean. As the fluid rises, it is pushed by winds or currents, and this crossflow can cause the intruding fluid to disperse far from its origin.

Scientists have previously modeled intrusions into a completely calm environment, but before Baines nobody had ever attempted to introduce the effect of crosswinds, a necessary step toward making such models more realistic and useful.

Predicting Ash and Oil Flows

Baines thinks his work could be used to estimate how much ash is pouring out of a volcano, or how fast oil is gushing from a hole in the sea floor.

Baines is now working with volcanologists in Britain to apply his model to historic eruptions like the Campanian event and the catastrophic Toba supereruption that occurred around 73,000 years ago in Indonesia. The scientists are hoping to use ash deposits from these volcanoes to develop a sharper picture of the amount and speed of the ejected material.

"Most of what we know about prehistoric eruptions is from sedimentary records," said Baines. "You then have to try to infer what the nature of the eruption was, when this is the only information you've got."

Baines said his model can also help forecast the deposition patterns of future eruptions. And that should give us a big leg up on the poor Neanderthals.

How the Model Works

To understand how intrusions work in the presence of crossflows, Baines developed what he calls a semi-analytical model. He began with fluid dynamics equations, and then used numerical calculations to arrive at approximate solutions for specifics combinations of source flow and spread rates, and crosswind speed. He found that, under normal wind speeds, the intruding fluid reached a maximum thickness at a certain distance upstream from the source, and thinned in the downstream direction. The distance to the upstream stagnation point depended much more on the rate of source flow than the crossflow speed.

More information: The article, "The dynamics of intrusions into a density-stratified crossflow" by Peter G. Baines, appears in the Journal *Physics of Fluids*. dx.doi.org/10.1063/1.4811850

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