Science and Culture: Dissecting the *Great Wave*

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The Great Wave off Kanagawa, a 19th century woodcut by Japanese artist Hokusai, depicts *oshiokuri-bune,* or cargo boats, navigating a monstrously rough sea within sight of a snow-capped Mt. Fuji. The woodcut is among the best-known works of Japanese art, yet in the last few years scientists have argued that it suffers under an enduring misconception. The wave itself, featured on t-shirts, textbooks, and emoticons, is often described as a tsunami, a wave born of a powerful event—like an underwater volcano or earthquake—that traverses the deep sea with low amplitude and long wavelength but swells to destructive proportions in shallows near the shore.

However, the woodcut's wave doesn't fit the profile of a tsunami, physicists argued in a 2009 paper (1). The behemoth in the *Great Wave,* by some estimates, looms as tall as 10 m over the boats and is in the process of breaking. Tsunamis break when they're nearer the shore and not in deep water. The woodcut suggests other tall waves followed the big one; the primary tsunami waves spread out over long distances. The scientists proposed that Hokusai's masterpiece more likely depicts a rogue wave called a plunging breaker.

Rogue waves were once the stuff of legend: walls of water that came from nowhere and swamped boats without warning. However, in recent decades, ocean physicists have documented the waves' existence and explored natural mechanisms that could plausibly govern rogues. Rogues may result from linear processes, which means the heights of colliding waves sum to the height of the resulting, single wave. However, they likely also have a nonlinear driving mechanism, in which the height of the rogue far exceeds the sum of the waves that made it.

In a paper published April 2013 (2), French and Irish physicists show that a linear process called directional focusing could have spurred the *Great Wave*. Under this model, turbulent conditions focus the energy of a system of water waves like a lens focuses light.

"Wind patterns are so variable, with swirling gusts and so on, that wave trains moving in different directions can spontaneously merge and be focused together at one point," says lead author John Dudley, a physicist at the Franche-Comté Electronique, Mécanique, Thermique et Optique - Sciences et Technologies Institute in Besançon, France.

To bolster their argument that Hokusai's wave is likely a rogue, Dudley and his coauthor enlisted ocean photographer V. Sarano, who supplied a photograph of a giant breaking wave in sub-Antarctic waters. The waves in the photograph and woodcut are nearly identical in size and formation.

"Nature has this wonderfully rich behavior, and artists have noticed this for many years and recorded it as best they could," says Dudley. "Now we have the science to provide more insight into what's going on."

The Great Wave off Kanagawa woodcut by Hokusai depicts a rogue wave rather than a tsunami, researchers have concluded.

1 Cartwright JHE, Nakamura H (2009) What kind of a wave is Hokusai's Great wave off Kanagawa? *Notes Rec R Soc Lond* 63(2): 119–135.
2 Dudley JM, Sarano V, Dias F (2013) On Hokusai's Great wave off Kanagawa: Localization, linearity and a rogue wave in sub-Antarctic waters. *Notes Rec R Soc Lond* 67(2):159–164.