of CO_2 concentrations in streams and rivers are now practical. It is essential to make these measurements if well-constrained calculations of efflux are to be made on a continental scale.

The findings of Butman and Raymond[3] are founded on extensive data and a careful assessment of uncertainties in CO_2 efflux, and so provide a template for the type of analyses that are needed in other regions. They also highlight the importance of often undervalued monitoring programmes for assessing environmental conditions and changes, such as those coordinated by the US Geological Survey. It is apparent that the efflux of carbon to the atmosphere from streams and rivers can substantially exceed fluvial transport of organic and inorganic carbon to the ocean[4]. The interpretation of these fluxes in the context of the global carbon cycle remains ambiguous, however, and questions remain regarding the source of the carbon released and the influence of anthropogenic perturbations, such as acidification, erosion and damming, on efflux.

Carbon fluxes from inland waters, as derived by Butman and colleagues[3], could play an important role in the terrestrial carbon budget, even if mainly by relocating terrestrial respiration. If this effect is important, then the terrestrial CO_2 sink may prove smaller than thought. ❐

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References

1. Cole, J. J. *et al. Ecosystems* http://dx.doi.org/10.1007/s10021-006-9013-8 (2007).
2. Aufdenkampe, A. K. *et al. Front. Ecol. Environ.* **9,** 53–60 (2011).
3. Butman, D. & Raymond, P. A. *Nature Geosci.* **4**, 839–842 (2011).
4. Richey, J. E., Melack, J. M., Aufdenkampe, A. K., Ballester, V. M. & Hess, L. *Nature* **416,** 617–620 (2002).

PLANETARY SCIENCE

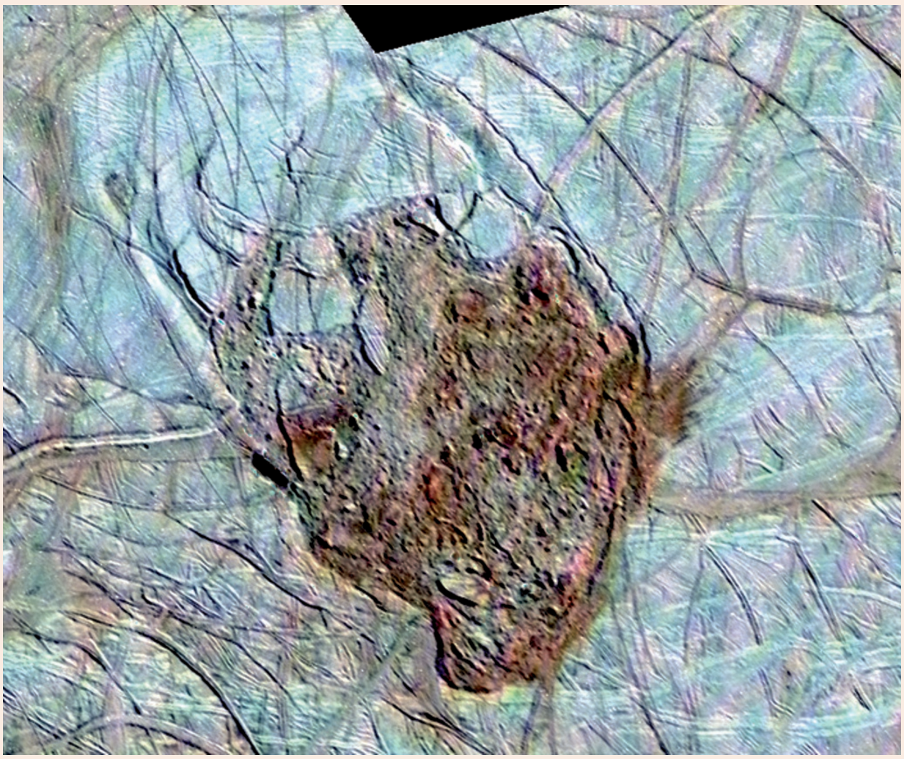
Chaos and water

Europa, the smallest of Jupiter's four Galilean satellites, has intrigued generations of planetary scientists. Its thick shell of ice is thought to cover a liquid ocean, kept from freezing by tidal energy. Where there is liquid water, there might be life. Not surprisingly, this moon has enjoyed much attention from astrobiologists, as well as from NASA.

Despite the widespread interest, it has been difficult to determine how Europa's relatively young surface developed its distinct cracks and streak. The provenance of more morphologically complex regions, termed chaos terrains, has also not yet been fully explained. In these regions, crustal blocks of ice — interspersed with different materials — resemble icebergs in a frozen ocean.

Now Britney Schmidt and colleagues re-interpret archival images from the Galileo probe that met its fate in Jupiter's atmosphere in 2003 (*Nature* **479,** 502–505; 2011). They focus on two regions of chaos on Europa's surface, and analyse them in the light of current understanding of ice, brine and water dynamics in Earth's volcanic craters and ice shelves.

Schmidt and colleagues propose that ascending plumes of relatively warm ice induce subsurface melting and the formation of ice-enclosed lenses of meltwater. Because ice melt leads to a reduction in volume, the overlying ice surface collapses and fractures. Subsequent brine injection and refreezing can explain the observed surface morphology in the chaos terrains. If so, lenses of liquid water should exist at depths of only about 3 km within the satellite's icy crust. According to this interpretation, one of the studied chaos terrains on Europa, Thera Macula, is currently actively deforming.



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Compared with earlier estimates of 10–30 km of ice above any of Europa's liquid water, a frozen crust of only 3 km may sound almost penetrable and may give hope to those searching for life in the extraterrestrial Universe. Long before sampling of Europa's liquid water comes within reach, however, we should be able to test the proposed model for chaos formation: extensive surface modification in the active chaos terrain should already have produced noticeable changes in the morphology at Thera Macula since the Galileo images were taken.

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