Application of Independent Component Analysis to geochemical records of the Eocene hyperthermals in the Indian Ocean

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Multiple transient global warming episodes occurred during the early Paleogene (ca. 56–52 Ma). These events, called 'hyperthermals', commonly accompanied rapid and pronounced negative excursions in carbon isotopic composition ($\delta^{13}C$) and ocean acidifications, indicating massive injections of ^{13}C-depleted greenhouse gas to the ocean-atmosphere system.

Here we have constructed a new, high-resolution geochemical data set including major- and trace-element contents, $\delta^{13}C$, and $CaCO_3$ content of 249 deep-sea sediments taken from two cores drilled in the Indian Ocean and the Indian sector of the Southern Ocean. The sediments of these cores clearly record the multiple hyperthermals including the Paleocene-Eocene Thermal Maximum (PETM), the Eocene Thermal Maximum 2 (ETM2), H2, I1/I2, and the ETM3.

Then we statistically analyzed the high-dimensional geochemical data matrix by applying Independent Component Analysis, which can extract original independent source signals from observed multivariate data (i.e., chemical compositions of sediment samples) on the basis of intrinsic non-Gaussian data structures attributable to individual materials or processes. We extracted four geochemical independent components (ICs) that collectively account for 85.6% of the total sample variance. One of the components involving Ba and $\delta^{13}C$ indicates a signature of a negative feedback process via an enhanced biological pump [1]. Downhole (i.e., time-series) profiles of the IC scores demonstrate that the productivity feedback commonly functioned and efficiently sequestered the excess carbon in recovery phases of not only the PETM but also the other minor hyperthermals.

[1] Ma, Z. et al., *Nature Geoscience* **7**, 382-388 (2014).