Global Biogeochemical Cycles

FEATURE ARTICLE
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GRAND CHALLENGES CENTENNIAL COLLECTION

Advancing Scientific Understanding of the Global Methane Budget in Support of the Paris Agreement

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Key Points:
- Despite rapid technological progress, major challenges still exist to diagnose the mechanisms that cause changes in atmospheric methane
- The capability must exist to determine whether emission reductions pledged as part of the Paris Agreement are actually occurring
- This study proposes improvements to methane science that could help scientists improve this capability in the coming decade

Supporting Information:
- Supporting Information S1
- Movie S1

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Abstract The 2015 Paris Agreement of the United Nations Framework Convention on Climate Change aims to keep global average temperature increases well below 2 °C of preindustrial levels in the Year 2100. Vital to its success is achieving a decrease in the abundance of atmospheric methane (CH_4), the second most important anthropogenic greenhouse gas. If this reduction is to be achieved, individual nations must make and meet reduction goals in their nationally determined contributions, with regular and independently verifiable global stock taking. Targets for the Paris Agreement have been set, and now the capability must follow to determine whether CH_4 reductions are actually occurring. At present, however, there are significant limitations in the ability of scientists to quantify CH_4 emissions accurately at global and national scales and to diagnose what mechanisms have altered trends in atmospheric mole fractions in the past decades. For example, in 2007, mole fractions suddenly started rising globally after a decade of almost no growth. More than a decade later, scientists are still debating the mechanisms behind this increase. This study reviews the main approaches and limitations in our current capability to diagnose the drivers of changes in atmospheric CH_4 and, crucially, proposes ways to improve this capability in the coming decade. Recommendations include the following: (i) improvements to process-based models of the main sectors of CH_4 emissions—proposed developments call for the expansion of tropical wetland flux measurements, bridging remote sensing products for improved measurement of wetland area and dynamics, expanding measurements of fossil fuel emissions at the facility and regional levels, expanding country-specific data on the composition of waste sent to landfill and the types of wastewater treatment systems implemented, characterizing and representing temporal profiles of crop growing seasons, implementing parameters related to ruminant emissions such as animal feed, and improving the detection of small fires associated with agriculture and deforestation; (ii) improvements to measurements of CH_4 mole fraction and its isotopic variations—developments include greater vertical profiling at background sites, expanding networks of dense urban measurements with a greater focus on relatively poor countries, improving the precision of isotopic ratio measurements of $^{13}CH_4$, CH_3D, $^{14}CH_4$, and clumped isotopes, creating isotopic reference materials for international-scale development, and expanding spatial and temporal characterization of isotopic source signatures; and (iii) improvements to inverse modeling systems to derive emissions from atmospheric measurements—advances are proposed in the areas of hydroxyl radical quantification, in systematic uncertainty quantification through validation of chemical transport