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Natural emissions of methane from geothermal and volcanic sources in Europe

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Abstract

It has recently been demonstrated that methane emission from lithosphere degassing is an important component of the natural greenhouse-gas atmospheric budget. Globally, the geological sources are mainly due to seepage from hydrocarbon-prone sedimentary basins, and subordinately from geothermal/volcanic fluxes. This work provides a first estimate of methane emission from the geothermal/volcanic component at European level.

In Europe, 28 countries have geothermal systems and at least 10 countries host surface geothermal manifestations (hot springs, mofettes, gas vents). Even if direct methane flux measurements are available only for a few small areas in Italy, a fair number of data on CO_2, CH_4 and steam composition and flux from geothermal manifestations are today available for 6 countries (Czech Republic, Germany, Greece, Iceland, Italy, Spain). Following the emission factor and area-based approach, the available data have been analyzed and have led to an early and conservative estimate of methane emission into the atmosphere around 10,000 ton/yr (4000–16,000 ton/yr), basically from an area smaller than 4000 km^2, with a speculative upper limit in the order of 10^5 ton/yr.

Only 4–18% of the conservative estimate (about 720 ton/yr) is due to 12 European volcanoes, where methane concentration in volcanic gases is generally in the order of a few tens of ppmv. Volcanoes are thus not a significant methane source. While the largest emission is due to geothermal areas, which may be situated next to volcanoes or independent. Here inorganic synthesis, thermometamorphism and thermal breakdown of organic matter are substantial. Methane flux can reach hundreds of ton/yr from small individual vents. Geothermal methane is mainly released in three countries located in the main high heat flow regions: Italy, Greece, and Iceland. Turkey is likely a fourth important contributor but the absolute lack of data prevents any emission estimate.

Therefore, the actual European geothermal–volcanic methane emission could be easily projected to the 10^5 ton/yr levels, reaching the magnitude of some other natural sources such as forest fires or wild animals.

Keywords: methane; natural emissions; geothermal systems; volcanoes; greenhouse-gas inventory

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1. Introduction

Atmospheric trace gases from natural sources contribute to atmospheric changes in the same way as those stemming from anthropogenic sources. Information on trace gas emissions from anthropogenic sources has greatly improved over recent decades as a consequence of countries' reporting requirements. The knowledge of natural emission still has large uncertainties (Simpson et al., 1999). As control activities have proved successful in decreasing anthropogenic emissions in many sectors over time, the relative importance of natural sources even increases. Thus, it is essential to improve our knowledge of all natural emissions.

Methane is both a greenhouse gas and reacting in the troposphere. An assessment of its natural emissions is thus important not only to understand its ozone forming potential, but also its greenhouse-relevant properties.

Gas seepage from geological origin has traditionally not been considered an important source significantly contributing to the atmospheric concentrations (e.g., Lelieveld et al., 1998; IPCC, 2001). Also in a European study (Simpson et al., 1999) gas seeps are not considered a major source. However, since 2001 there has been a growing body of evidence on the importance of geological seeps as global contributors of methane. New studies suggest that a wide class of geological sources, including onshore macro-seeps (e.g., mud volcanoes), microseepage, submarine seepage and geothermal seeps, are responsible for a surprisingly high global gas emission, in the order of 40–60 Tg/yr (Etiope and Klusman, 2002; Etiope, 2004; Etiope and Milkov, 2004; Etiope et al., 2004; Etiope, 2005; Kvenvolden and Rogers, 2005). Among the natural sources, only wetlands are considered more important. This increasing evidence also leads to consideration by organisations supporting a policy process: the UNECE Task Force on Emission Inventories and Projections (http://www.tfeip-secretariat.org), in a current revision of the UNECE/EMEP Atmospheric Emission Inventory Guidebook (EEA, 2004), is about to include geological sources with a new description and emission factors.

On the global scale, methane emission from geothermal and volcanic manifestations, which will be covered in this paper, seems to be less than 10% of total geological sources. The majority of geological emissions derives from the seepage from hydrocarbon-prone sedimentary basins (Etiope and Klusman, 2002). A first global geothermal emission was estimated to be in the range 1.7–9.4 Tg/yr by Lacroix (1993). Etiope and Klusman (2002) evaluated provisionally a continental geothermal (non-volcanic) source strength in the range 2.5–6.3 Tg/yr, on the basis of global heat flow data and a small data set of methane fluxes. On a country, regional or continental scale, the sedimentary/geothermal emission ratio can vary greatly depending on the geo-tectonic setting: in the regions of crustal rifting and plate subduction, geothermal and volcanic methane emission can be dominant.

The main constituents released by geothermal and volcanic manifestations are H_2O and CO_2. CH_4 occurs in very low amounts (from some ppmv to a few % units), produced either by inorganic reactions (like Fischer–Tropsch), magma degassing and/or thermal breakdown of organic compounds in crustal sediments (Welhan, 1988; Taran and Giggenbach, 2003; Fiebig et al., 2004). The total gas flux into the atmosphere however can be so high (orders of thousands of tonnes per year from individual gas vents) that also CH_4 fluxes may also become significant.

In Europe, 28 countries have geothermal systems (Lund and Freeston, 2001) and at least 10 countries host surface geothermal manifestations (hot springs, mofettes, gas vents). Data on gas composition and flux from these manifestations are available today for 6 countries (Italy, Iceland, Greece, Germany, Czech Republic and Spain); they are interpreted here to provide an early estimate of geothermal methane emission at European scale. This is the main task of this work. This emission was not considered by previous European inventories, neither by Simpson et al. (1999), nor the CORINAIR Inventory (see EEA, 2004). In this respect, specific emission and up-scaling calculation methods are proposed, following the concept of the EMEP/CORINAIR Guidelines, based on total gas flux data (CO_2 or steam) and on the amount of CH_4 occurring in the released gas.

2. Definitions

A discrimination of sources will be relevant only when abatement measures can be applied to specific sources, or when this discrimination allows for a better characterization of underlying physico-chemical processes and consequently also to improved assessment of fluxes into the atmosphere. In the context of anthropogenic emissions, the question of abatement and the application of measures to a specific source are of primary interest. For natural emissions as described here, the discrimination focuses towards a possibility to obtain better information on the underlying processes.

The geological sources considered in this work include both volcanoes and geothermal areas, which may be associated with, or independent of volcanoes.