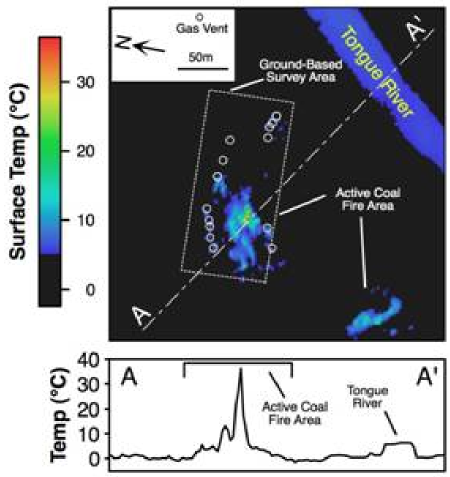
ELECTRIC POWER RESEARCH INSTITUTE

Environmental Impacts of Uncontrolled Coal Fires



One of several results of EPRI's Innovators Circle project on coal fires: an airborne infrared image of the Welch Ranch Fire[1] used to calculate the fire's heat flux ($W\ m^{-2}$).

Although little researched, thousands of uncontrolled coal fires occur in virtually all coal-bearing parts of the world, including more than 140 in the United States. These fires emit greenhouse gases and other potentially harmful toxic gases and prevent the use of a portion of these coal resources. As a first step to better understand the nature and extent of uncontrolled coal-fire emissions, EPRI initiated a research project to estimate air emissions from a relatively small fire, using airplane-based sensors in conjunction with surface measurements. The data can then be applied in large-scale models, providing a more accurate assessment of the contributions of these background emissions and their relative impacts to regional and global pollutant loading.

Introduction

Uncontrolled coal fires occur in virtually all coal-bearing parts of the world and may pose multiple threats to the global environment. These fires are often self-ignited (spontaneous combustion), due to natural ignition (such as lightning strikes), or result from human activities. The fires can persist for decades in underground coal mines, coal waste piles, and unmined coal beds. Direct hazards include emissions of pollutants, such as sulfur dioxide, carbon monoxide, and particulate matter; releases of air toxics such as arsenic, selenium, and mercury; and greenhouse gas emissions such as carbon dioxide (CO_2), methane, and nitrogen oxides. The contribution of coal fires to global atmospheric CO_2 and mercury is poorly known and highly uncertain, but potentially significant. In addition, such fires prevent the use of large quantities of coal for electricity production and other energy applications. Existing data on environmental impacts of uncontrolled coal fires suggest that:

- The amount of coal combusted by coal fires ranges between 300 and 600 Megatons per year (5–10% of global annual coal production).
- Coal fires in China alone may emit as much CO_2 annually as all U.S. motor vehicles.
- U.S. CO_2 and mercury emissions estimates from coal fires are 14 to 290 Megatons per year, and 0.6 to 11.5 tons per year, respectively; estimated global mercury emissions from coal fires are up to 32 tons per year. In comparison, U.S. coal-fired power plants annually emit approximately 2.4 Gigatons of CO_2 and 45 tons of mercury.

Spontaneous Combustion

Exposure of coal to atmospheric oxygen promotes heat-generating reactions–primarily oxidation of coal itself–and oxidation of pyrite (FeS_2) present in coal. In this process, carbon, the largest component of coal, combines with available oxygen to produce CO_2 and heat. Similarly, sulfur present in pyrite combines with oxygen and water forming sulfuric acid (H_2SO_4) and sulfur dioxide (SO_2), and releasing heat. Such heat-producing reactions—combined with the suppression of coal ignition temperatures at depth and the insulating capacity of coal overburden—can result in spontaneous combustion or sustain already-ignited underground coal fires. When exposed at the surface, coal beds can be ignited by lightning, wildfires, and human activities as well as by spontaneous combustion.

[1] A relatively small fire (~13 acres) of the 68 currently known and active fires in the Powder River Basin of Wyoming and Montana, some of which are hundreds of acres. Globally, thousands of fires are burning, many much larger in aerial coverage (km^2), coal volume, and fire intensity.

Scaling Up

Small coal fires present valuable study opportunities but do not provide a good estimate of emissions on a global scale. To determine the impacts of coal fire emissions on a regional, national, or global scale, gas fluxes measured at individual fire sites can be scaled up by the known extent of fires. Comparing emissions from a number of coal fires with similar attributes (for example, coal rank and type, energy content, composition, size, and intensity) and weighting them based on the size and intensity of the fire allows determination of an average emission rate per area or per volume of coal burned (that is, an emission factor). These emission factors are applied to estimated areas or volumes of burning coal to calculate emissions on larger scales. By making these scaling calculations, fires with the largest regional and/or global impact are identified as targets for further research.

Remote Sensing Techniques

Local areas of elevated temperatures, often referred to as surface thermal anomalies (or hot spots), are a precursor to coal mine fires. Temperature profiles across hot spots, when used as input in numerical models, help estimate the depth of underground fires. Thermal infrared (TIR) sensors are very effective in capturing such subtle hot spots. Satellite remote sensing using TIR offers a simple, cost-effective tool for detecting, mapping, monitoring, and characterizing fire areas. Unfortunately, with a spatial resolution of about 1 km and a revisit cycle of about a week or more, most current satellites with TIR have only limited potential to map hot spots on a regional scale. Lower-altitude remote sensing using aircraft is therefore more effective, accurate, and precise.

EPRI Research

EPRI initiated a research project to estimate air emissions from uncontrolled coal fires by using an airplane-based TIR sensor. The project is part of a larger "coal fire team" effort of academic, corporate, and governmental researchers that, in early 2009, used air and ground measurements to assess the fluxes at one such fire in the Powder River Basin of Wyoming and Montana[2]. EPRI's first-of-its-kind TIR results estimated burn rates of 1–3 tons of coal per day and daily CO_2 emissions of 3–6 tons. Assuming complete combustion, ground measurements estimated a total of 2–5 tons of coal were consumed per day resulting in 7-9 tons of CO_2 per day, with measured mercury emissions of less than 1 kg per year. Both assessments are in good agreement with each other. Differences between methods can be due to the limited sensitivity of TIR instruments, reducing the estimates of coal combustion rates obtained, or because of site access safety restrictions and the consequential reduced number of surface measurements.

More Research Needed

There are more than 140 known coal fires in the United States, but extrapolating the measured emissions from one small fire to a national, let alone global, scale is currently inadvisable since the significant uncertainties will only grow. Instead, focus should be on greatly reducing the uncertainties through improved measurements of more and—especially—larger fires.

The power sector is the single largest anthropogenic source of world-wide atmospheric mercury emissions, and a major contributor to CO_2 emissions. U.S. coal-fired power plants are expected to be regulated for mercury in the next 2–3 years and potentially CO_2 as well. However, coal fires will continue to emit mercury and CO_2, unless suppressed or extinguished, and based on current estimates and measurements, future coal fire emissions could match or exceed power plant emissions (at least in the United States). The implications for changes in mercury deposition as a result of reductions in coal plant emissions but continuing coal fire emissions remain unclear. Similarly, the current estimates and measurements of greenhouse gas emissions from coal fires warrant further studying of the exact magnitude of these fires on a global scale.

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[2] Airborne measurements provide the needed coverage of large areas, while ground-based measurements show small-scale variation and provide ground truth for airborne determinations.

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