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Grand challenges in environmental informatics

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We live in an era of environmental deterioration through depletion and degradation of resources such as air, water, and soil; the destruction of ecosystems and the extinction of wildlife (Kondratyev, 1998; Kondratyev et al., 2004; Cracknell et al., 2009; Hansen et al., 2013; Freedman, 2014). As a matter of fact, environmental degradation is one of three main threats identified in 2004 by the High Level Threat Panel of the United Nations, the other two being poverty and infectious diseases. In particular, air pollution ranked seventh on the worldwide list of risk factors, contributing to approximately three million deaths each year. Air pollution is especially considerable in growing and emerging economies (Ramanathan and Feng, 2009; Rao et al., 2013) (see, for instance, **Figure 1**). Therefore, environmental studies are of great importance and they stand at the forefront of modern science (http://www.ipcc.ch/). Environmental research is a multi-disciplinary science because it comprises various branches of studies like chemistry, physics, medical science, life science, agriculture, public health, sanitary engineering, etc.

Environmental informatics is an integrator of science, methods and techniques for serving environmental engineering needs. It provides the information processing and communication infrastructure to the interdisciplinary field of environmental sciences aiming at data, information, and knowledge integration, the application of computational intelligence to environmental data as well as the identification of environmental impacts of information technology. The important tasks of the environmental informatics are the data interpretation, their collection, storage, processing, and display (Hilty et al., 1995).

One important area of environmental informatics is the acquisition of data related to remote sensing of atmosphere, vegetation, and ocean using optical, thermal infrared and microwave instruments (ground/ship-based, airborne, and satellite). Satellite remote sensing is of particular importance (Burrows et al., 2011). Environmental problems being global need global observation systems, which can only be achieved by using observations from satellite platforms. A great number of instruments have been installed on satellite platforms since satellite technology begun with the launch of Sputnik in 1957. They enable a much better understanding of the patterns of global atmospheric pollution by aerosol particles and also by various trace gases, land use, etc.

Despite significant scientific progress in the last decade, many domains of uncertainty still remain. In particular, the methods for the estimation of aerosol load using space-borne instrumentation must be greatly improved using multi-angular spectropolarimetry. The algorithms for the current spectrometers and radiometers require a number of a priori assumptions, which could potentially bias retrievals and lead to the under-estimation (or overestimation) of the aerosol impact on the environment and climate.

Considerable improvement of the methods for the determination of atmospheric pollution from space is needed (Kokhanovsky and de Leeuw, 2009). The influence of trace gases, aerosol, and especially clouds (including polluted ice and water clouds) on the weather and climate requires more thorough studies based on the analysis of a large volume of data. Here, environmental informatics plays an important role. Mathematical methods must also be further improved for the solution of inverse problems (Rodgers, 2000), systems modeling, and

FIGURE 1 | The pollution in Beijing (www.marketplace.org).

optimization. The new approaches should be developed. Computer graphics and visualization for environmental decision support must be used on a far larger scale. It is anticipated that further developments will lead to the creation of better tools for environmental monitoring and control using both ground and satellite observation systems. This will enable more thorough decision and risk analysis for the environmental management (Gunderson and Holling, 2002; Folke et al., 2005).

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