



# 1. EARTH AND ENVIRONMENT

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# *Introduction*

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**C**HANGE IS INEVITABLE—the Universe expands, nature adapts and evolves, and so must the scientific tools and technologies that we employ to feed our unrelenting quest for greater knowledge in space, Earth, and environmental sciences. The opportunities and challenges are many. New computing technologies such as cloud computing and multicore processors cannot provide the entire solution in their generic forms. But effective and timely application of such technologies can help us significantly advance our understanding of our world, including its environmental challenges and how we might address them.

With science moving toward being computational and data based, key technology challenges include the need to better capture, analyze, model, and visualize scientific information. The ultimate goal is to aid scientists, researchers, policymakers, and the general public in making informed decisions. As society demands action and responsiveness to growing environmental issues, new types of applications grounded in scientific research will need to move from raw discovery and eliciting basic data that leads to knowledge to informing practical decisions. Active issues such as climate change will not wait until scientists have all the data to fill their knowledge gaps.

As evidenced by the articles in this part of the book, scientists are indeed actively pursuing scientific understanding through the

use of new computing technologies. Szalay and Blakeley describe Jim Gray's informal rules for data-centric development and how they serve as a blueprint for making large-scale datasets available through the use of databases, leveraging the built-in data management as well as the parallel processing inherent in SQL servers.

In order to facilitate informed decisions based on reliable scientific evidence, Dozier and Gail explore how the applied use of technology and current scientific knowledge is key to providing tools to policy and decision makers. Hunt, Baldocchi, and van Ingen describe the changes under way in ecological science in moving from "science in the small" to large collaborations based on synthesis of data. These aggregated datasets expose the need for collaborative tools in the cloud as well as easy-to-use visualization and analysis tools. Delaney and Barga then provide compelling insights into the need for real-time monitoring of the complex dynamics in the sea by creating an interactive ocean laboratory. This novel cyberinfrastructure will enable new discoveries and insights through improved ocean models.

The need for novel scientific browsing technologies is highlighted by Goodman and Wong. To advance the linkage across existing resources, astronomers can use a new class of visualization tools, such as the WorldWide Telescope (WWT). This new class of tool offers access to data and information not only to professional scientists but also the general public, both for education and possibly to enable new discoveries by anyone with access to the Internet. Finally, Lehning et al. provide details about the use of densely deployed real-time sensors combined with visualization for increased understanding of environmental dynamics—like a virtual telescope looking back at the Earth. These applications illustrate how scientists and technologists have the opportunity to embrace and involve citizen scientists in their efforts.

In Part 1 and throughout the book, we see new sensors and infrastructures enabling real-time access to potentially enormous quantities of data, but with experimental repeatability through the use of workflows. Service-oriented architectures are helping to mitigate the transition to new underlying technologies and enable the linkage of data and resources. This rapidly evolving process is the only mechanism we have to deal with the data deluge arising from our instruments.

The question before us is how the world's intellectual and technological resources can be best orchestrated to authoritatively guide our responses to current and future societal challenges. The articles that follow provide some great answers.