provided contributed greatly to the program's success. This research was funded by the Swedish Natural Science Research Council, the International Meteorological Institute, The Knut and Alice Wallenberg Foundation, the Nordic Arctic Research Programme, the Norwegian Research Council, the Austrian Federal Ministry for Education, Science and Culture, and the U.S. National Science Foundation's Office of Polar Programs.

References


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Over the past century, the geosciences have developed an impressive capability to understand and anticipate events occurring within the Earth system. The past decade has seen an explosion in quantitative geoscience. Progress is continuing to accelerate as advances in observational systems and computational tools are allowing simulations and predictions of geophysical processes with a temporal and spatial resolution unprecedented in human history. With these advances comes the necessity to reflect on the current state of geoscientific research, to reassess the direction in which research should be progressing, and to redefine the goals that can be realistically achieved.

The International Union of Geodesy and Geophysics (IUGG) formed a working group of young scientists charged with developing a vision for the future of the geosciences. The working group combined its expertise and enthusiasm to produce a report, "Geosciences: The Future" (www.iugg.org/geosciences.html), and symposium outlining its view of what is to come. Included in this vision are long-term goals for the major fields of geophysics; that is, plans for 50 years in the future; and short-term priorities, such as plans to address over the next decade. In addition, opportunities for interdisciplinary studies, proposals for the advancement of developing countries, and organizational recommendations for the geosciences are highlighted. The justification for this view of the future is based on the fundamental motivations and societal benefits underpinning geoscientific research.

The overriding aim of the geosciences is to reduce uncertainties as much as possible in predicting geoscientific events and, in so doing, to increase the value of the predictions to society. To this end, many specific short-term projects are discussed, ranging from seismic exploration of Mars, to measuring the water ice content of clouds. The majority of the projects are ultimately concerned with elucidating and understanding key processes, thus contributing to the primary scientific knowledge required to produce high-quality predictions. For example, modeling of volcanic magma-wall-rock interactions and ionospheric sounding are both process-oriented strategies designed to lead to high-quality predictions of eruptions and space weather, respectively.

Modeling and Observations

Impressive models already exist within each individual Earth science discipline and the models incorporate many major relevant components. Modeling often aims at computing the consequences of understood or proposed physics and is therefore complementary to activities that are focused on uncovering previously unknown physics. To improve our modeling ability, two basic strands of model development are required: improvements in model resolution (both spatial and temporal) and improvements in model parameterizations, including boundary and initial conditions.

The first strand allows finescale phenomena to be dealt with more realistically and models to be regionalized; the second allows modeling of elements and processes that cannot be treated independently. Critical scientific questions will focus on the interplay and exchanges of energy, momentum, and chemical constituents between individual components as we seek to consolidate our findings into the ultimate goal of an Earth system model. Recent advances in computational power, and the launch of projects such as the Earth simulator in Japan promises real progress in generating a unified Earth system model. The reconciliation of separate models on vastly disparate spatial and temporal scales is nevertheless non-trivial, and will demand the application of intellect and attention from the whole of the geosciences throughout the next decade and beyond.

Modeling is driven by observations from both the laboratory and the field. The most important development in observational systems will be the deployment of integrated global observing systems. Ultra-high temporal and spatial resolution data is becoming increasingly valuable as our ability to assimilate the data into models progresses. The global coverage possible from satellites is vital in addition to high-resolution in-situ measurements. For instance, satellite measurements of volcanic


Author Information

Caroline Leck and Michael Ternström, Stockholm University; Sweden; Patricia Matrai, Bigelow Laboratory for Ocean Sciences, McKown Point, West Boothbay Harbor, Maine; Erik Swietlicki, Lund University, Sweden; and Keith Bigg, Castle Hill, Sydney, Australia.

For additional information, contact C. Leck, Department of Meteorology, Stockholm University, SE-106 91 Stockholm, Sweden; E-mail: lina@misu.su.se

Fig. 1. This schematic shows the possible evolution of the major disciplines currently represented by the International Union of Geodesy and Geophysics. "Geosciences: The Future" recommends organizational changes to accommodate the decreased relevance of disciplinary boundaries. Original color image appears at back of volume.

New Report Charts Course for Future of Geosciences

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BY SAM ADLEN, EMILY E. BRODSKY, TAIKAN OKI, AARON J. RILEY, LAURA SANCHEZ, CLAUDIA SIMIONATO, KAZUNORI YOSHIZAWA, AND URI SHAMIR

The International Union of Geodesy and Geophysics (IUGG) formed a working group of young scientists charged with developing a vision of the possible future of the geosciences. The working group combined its expertise and enthusiasm to produce a report, "Geosciences: The Future" (www.iugg.org/geosciences.html), and symposium outlining its view of what is to come. Included in this vision are long-term goals for the major fields of geophysics; that is, plans for 50 years in the future; and short-term priorities, such as plans to address over the next decade. In addition, opportunities for interdisciplinary studies, proposals for the advancement of developing countries, and organizational recommendations for the geosciences are highlighted. The justification for this view of the future is based on the fundamental motivations and societal benefits underpinning geoscientific research. The overriding aim of the geosciences is to reduce uncertainties as much as possible in predicting geoscientific events and, in so doing, to increase the value of the predictions to society. To this end, many specific short-term projects are discussed, ranging from seismic exploration of Mars, to measuring the water ice content of clouds. The majority of the projects are ultimately concerned with elucidating and understanding key processes, thus contributing to the primary scientific knowledge required to produce high-quality predictions. For example, modeling of volcanic magma-wall-rock interactions and ionospheric sounding are both process-oriented strategies designed to lead to high-quality predictions of eruptions and space weather, respectively.

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The first strand allows finescale phenomena to be dealt with more realistically and models to be regionalized; the second allows modeling of elements and processes that cannot be treated independently. Critical scientific questions will focus on the interplay and exchanges of energy, momentum, and chemical constituents between individual components as we seek to consolidate our findings into the ultimate goal of an Earth system model. Recent advances in computational power, and the launch of projects such as the Earth simulator in Japan promise real progress in generating a unified Earth system model. The reconciliation of separate models on vastly disparate spatial and temporal scales is nevertheless non-trivial, and will demand the application of intellect and attention from the whole of the geosciences throughout the next decade and beyond.

Modeling is driven by observations from both the laboratory and the field. The most important development in observational systems will be the deployment of integrated global observing systems. Ultra-high temporal and spatial resolution data is becoming increasingly valuable as our ability to assimilate the data into models progresses. The global coverage possible from satellites is vital in addition to high-resolution in-situ measurements. For instance, satellite measurements of volcanic
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to developing countries. The geosciences must look to the future: We must make efforts to review the Earth in ways ranging from anthropogenically-induced earthquakes, to global climate change. At the very least, we humans must control our own efforts aimed with some knowledge of the consequences of our actions. What geoscientists must remember is that our science is for survival and not just advancement, as is the case with many other fields of research. Despite the fact that advances made by geoscientists, there is an underlying obligation to society to provide the ability to improve humanity's chances of survival. Long-term goals include projects such as weather and climate modification, the precise prediction of volcanic eruptions, CO₂ sequestration in the oceans, and the scientifically-based allocation of groundwater resources. In the very long term, we may gain enough knowledge to not only prevent our actions from doing harm, but actually ameliorate our condition on the planet. We accept that it would be irresponsible in the extreme to begin the forcing of environmental systems while our knowledge is incomplete. Hence, we see that geosciences are in a position to begin actively pursuing theoretical and laboratory research based on these ideas of control. There is, of course, the real possibility that the geosciences will not be able to control fatal events. To this end, the group encourages projects to locate and/or develop other habitable environments as parallel undertakings. Projects searching for extra-planetary systems and terra-forming initiatives are just two examples highlighted in the report.

Society and Scientific Societies

In addition to the scientific problems to be addressed by the geosciences in the future, there are also several organizational and infrastructure issues that warrant attention. The onset of Earth system modeling has highlighted more clearly than ever the need for interdisciplinary studies. The traditional boundaries within in the geosciences are no longer wholly relevant, and a framework must be built that allows for the efficient study of the Earth system as a whole. The working group report anticipates that many of the existing disciplinary bound­

in the report.

Goals

In the very short term, it is probable that the next decade will largely be dominated by a continuation of existing research. Advances in computing power and observational resolution must be continually exploited as we aim to build on the considerable progress already made toward the goal of an Earth system model. The advances that have occurred, however, require that our realistic long-term goals be reassessed. The value of scientific research and the reasons for undertaking it are often best measured by its value to the end-user. In the case of the geosciences, the entire population that experience the variability of the Earth system, and are at the mercy of its extremes, could be considered end-users. Our short-term goals are all largely based on benefit to society through the ability to predict events. In the long term, we look beyond prediction to the control of events. We must build the capacity to mitigate extreme scenarios, or at least to provide contingency plans should they occur. Countless ethical and political issues are associated with exerting external control over our environment. However, the current planetary environment is no longer strictly natural. Human action is already affecting the Earth in ways ranging from anthropogenically-induced earthquakes, to global climate change. At the very least, we humans must control our own efforts aimed with some knowledge of the consequences of our actions.

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