

MEETINGS

What Is the International Heliophysical Year?

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More than a celebration of the 50th anniversary of the International Geophysical Year (IGY), the International Heliophysical Year (IHY) planned for 2007 will be a program of coordinated research in the tradition of a long succession of international programs, of which the IGY is arguably the most famous. One might justifiably ask, "Yet another coordinated research program? Given all the others, what will IHY have to offer? Will it lead to better science or just more science?" To address these and other questions, nearly 60 scientists participated in the U.S. Planning Workshop for the IHY last April at the National Solar Observatory in Sunspot, New Mexico. The workshop, organized into four working groups on the Sun, the heliosphere, magnetospheres and ionospheres, and atmospheres and climate, took up the challenge posed by these critical questions.

While IHY was listed as one of several international year programs in a recent *Eos* article on the eGY (Electronic Geophysical Year), with NASA as its main sponsor, the sponsorship and roles of these programs relative to each other have been evolving. Initial ideas about the IHY were confined to solar-terrestrial physics, which could fit under the umbrella of the ICSU-sponsored International Polar Year (IPY). Strong voices on the workshop's scientific organizing committee, however, argued for a much broader purview of the IHY, out to the frontiers of heliophysical research in the same way that the IGY reached to the frontiers of geophysical research. At the workshop the broader purview was adopted as the starting point. It was agreed that the new word, "heliophysical," not to be confused with the more limited "heliospherical" (meaning primarily "solar wind"), should not only embrace atmospheric and solar-terrestrial physics but also include studies of other planets, the outer reaches of the heliosphere, and its interaction with the interstellar medium. The IHY can thus establish and foster interdisciplinary ties with astronomy and astrophysics.

Adopting the broader purview has important implications for structure and funding. Unlike many of the other programs, including the original IGY, the IHY will be a grass-roots, bottom-up rather than top-down, agency-sponsored program. While this means that funding must be sought as a separate effort, the grass-roots approach will afford the freedom to focus on science rather than on day-to-day mission-oriented activities. Adopting this approach also negates any perception that the IHY will be more U.S./NASA hegemony, a concern expressed at the workshop. Links with the international community will be nurtured through a variety of organizations including the International Astronomical Union, the International Space

Table 1. Processes Common to Various Solar Phenomena.

PROCESSES	CMEs & flares	solar wind	solar cycle	granulation	cosmic ray modulation irradiance	E: established S: speculative
	reconnection	E	E	S	S	
particle acceleration	E					
shocks & waves	E	E				E
dynamo			E	E		E
turbulence/convection	S	E	E	E		E
multi-scale structures	E		S			E
energy storage & release	E					
radiative transfer						E

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Science Institute, COSPAR, and the United Nations. At the workshop, N. Fox (NASA Goddard) reported on efforts to encourage projects involving scientists from emerging nations.

IHY Themes

A keynote address given by G. Siscoe (Boston University) made clear that international programs, beginning with the first International Polar Year in 1882, each leave legacies as a direct result of their focused efforts. They organize and coordinate data gathering and analysis, provide thematic emphases, and justify resource allocations under those themes. Their objectives have evolved from mapping phenomena on Earth to mapping in three dimensions, adding data first from the upper atmosphere and then space, to analyzing system complexity to recognizing systems as integrated and interactive. Data-gathering and analysis innovations have evolved from synoptic studies to coordinated data analysis workshops to numerical modeling and data assimilation.

Siscoe offered two suggestions for IHY themes that were subsequently adopted. The first is comparative heliophysical studies, for example, of planetary magnetospheres and ionospheres from the Hubble Space Telescope. Comparative studies are a niche not currently filled by mission-oriented projects and could provide opportunities for scientists from emerging nations to join teams proposing for viewing time or support for data analysis.

The second suggested IHY theme in a sense encompasses the first: in keeping with plans to foster ties with astrophysics, it is to work toward making a universal science out of what we do by focusing on physical structures and processes that cross discipline lines rather than focusing on individual phenomena as is traditional. For those who work in space physics, this second theme represents a basic physics counterbalance to space weather, and it defines a new movement described in a report, "Plasma physics of the local cosmos," recently published by the *National Research Council* [2004]. The motivation for this movement comes from a statement by E. N. Parker in his book, *Cosmical Magnetic Fields*: "It cannot be emphasized too strongly that the development of a solid understanding of the magnetic activity, occurring in so many forms in so many circumstances in the astronomical universe, can be achieved only by coordinated study of the various forms of activity that are accessible to quantitative observation in the solar system."

Progress toward that end can be made with cross-disciplinary, intercomparative studies of processes like reconnection, explosive energy conversion, generation of energetic particles, cross-scale coupling, and turbulence; and of structures like flux ropes, current sheets, shocks, and waves. Following Parker, Siscoe noted that these processes and structures fall into the category of magnetically organized matter, as distinct from gravitationally organized matter like planets, stars, and galaxies.

Working Group Discussions

Speaking for participants in the working group on atmospheres and climate, M. Geller (State University of New York) noted they were the only group present addressing gravitationally organized matter. Nevertheless, the group became an integral part of the workshop effort and enthusiastically provided input for potential IHY projects on Sun-atmosphere connections. These fall into long- and short-term categories. Since climate studies rely on decadal or multidecadal data, long-term IHY projects cannot be data-gathering campaigns. Instead the group proposed much-needed assessments of scientific understanding in several areas, including irradiance reconstructions over multicentury timescales, the role of the Sun in producing tropospheric/stratospheric climate variability, the response of stratospheric ozone to solar variability over the solar cycle, and cosmogenic proxies as indicators of solar activity on timescales from a solar cycle to millennia. For short-term projects, the group made a list of eight candidate campaigns involving theoretical, observational, numerical, and laboratory studies, including, for example, a campaign on the effect of cosmic rays on ion nucleation, aerosols, clouds, and climate.

The working group on magnetospheres and ionospheres proposed to implement two major IHY initiatives that would integrate theory and modeling with observations, and leave as a legacy the elevation of modeling to a mature research tool. Supporting the concept of comparative planetary studies, one initiative would

focus on areas like auroral dynamics, storms, substorms, and radiation environments at different planets. The second initiative would focus on the end-to-end solar-terrestrial system. A prime example is the real-time global ionosphere campaign proposed by T. Fuller-Rowell (University of Colorado/NOAA Space Environment Center) to characterize global ionospheric variability as a function of season and geomagnetic activity. The campaign would reflect IHY priorities in several ways: it would cut across disciplines from solar to lower atmospheric physics, require data from many countries, address a global problem with high fidelity, have potential for discovery, and supply GPS systems to developing countries.

The suitability of global studies using widespread arrays of low-cost, ground-based instrument packages was echoed in other groups, notably in the working group on the heliosphere. Establishing a network of muon monitors and increasing neutron monitor coverage to gain latitudinal and longitudinal resolution were among the proposed possibilities. At the lowest end of the cost scale, J. Kasper described unique plans for thousands of low-frequency radio receivers. Like pixels in a snapshot, these could image the Sun and track evolving structures in the solar wind as they head toward Earth, while their Faraday rotation capabilities could map ionospheric parameters in unprecedented detail. Doing IHY science with widespread ground-based arrays has the added benefit of providing multinational educational opportunities. These would involve real-time data collection that could be incorporated into science programs around the globe.

The working group on the heliosphere also compiled a list of science questions concerning gaps in the overall understanding of our home star system, and designed potential IHY

campaigns to address those questions. Primary among them is a three-dimensional study of the upcoming solar minimum compared to the previous minimum of opposite magnetic polarity. Using data from the existing spacecraft fleet, which constitutes a formidable heliophysical observatory, and working synergistically with the proposed network of small ground-based facilities, the study would create an unprecedented legacy data set completing the 22-year solar cycle. Another campaign would create a link to proposed atmospheric campaigns on the role of cosmic rays both in creating signatures of long-term climate variations and in controlling atmospheric parameters. A campaign to understand solar wind signatures of reconnection at the Sun would create a link to solar physics and reflect the theme of universal processes.

The theme of universal processes became the centerpiece of the report from the working group on the Sun. T. Forbes and S. Gibson summarized their efforts in a chart, shown in Table 1, that indicates processes common to an array of solar-related phenomena. In addition, the group proposed a number of potential IHY campaigns, some calling for much-needed coordination among existing ground-based observing facilities. For example, R. Moore proposed using the widely available H- α telescopes to address the perplexing problem of why some filaments fail to erupt.

All groups stressed the importance of working through existing programs like CAWSES (Climate and Weather of the Sun-Earth System) and groups like CEDAR (Coupling, Energetics, and Dynamics of Atmospheric Regions), GEM (Geospace Environment Modeling), and SHINE (Solar Heliospheric Interplanetary Environment), of maintaining existing spacecraft missions, and of promoting the development of

comprehensive, long-term databases. All agreed to incorporate eGY as an intrinsic legacy tool. While the IHY will focus on campaigns that can be carried out during the celebratory year 2007, just as in previous international years, IHY activities will leave a foundation for future science and understanding.

Immediate follow-up to the workshop will include three special sessions at the 2004 AGU Fall Meeting on universal processes and structures, low-cost distributed instrument arrays, and education outreach opportunities.

The U.S. Planning Workshop for the IHY was held 20–22 April 2004 at the National Solar Observatory in Sunspot, New Mexico.

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References

- Committee on Solar and Space Physics, National Research Council (2004), *Plasma physics of the local cosmos*, 96 pp., National Academy of Sciences, Washington, D.C.
- Parker, E. N. (1979), *Cosmical Magnetic Fields*, p. 788, Oxford University Press/Clarendon Press, Oxford.
- N. U. CROOKER, Center for Space Physics, Boston University, Mass.; E-mail: crooker@bu.edu

The Ocean in a High CO₂ World

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It is now 25 years since the first papers appeared documenting by direct measurement the buildup of fossil fuel CO₂ in the ocean. In the past quarter century the situation has changed enormously. What was at first a controversial detection of a signal above a large natural oceanic background is now a huge and easily recognizable geochemical perturbation on a scale not matched for a large part of Earth's history. Earth's atmospheric concentration of CO₂ is now higher than experienced during at least the last 400,000 years.

The accumulated oceanic burden of fossil fuel CO₂ is now >400 billion metric tons. The net CO₂ gas invasion rate across the air-sea interface, driven by the growing global mean pCO₂ difference between air and sea, is now about 1 million metric tons CO₂ per hour, and the decrease in surface water pH is now about 0.1 pH units. The signal is detectable worldwide, and has penetrated to >1000-m depth. And simple extrapolations based upon well-recognized energy use scenarios, such as the Inter-

governmental Panel on Climate Change (IPCC) IS92A "Business as Usual" projection, lead to oceanic pCO₂ levels of ~600 ppm, and a pH change of about 0.3, in the second half of this century with far greater changes possible in the future. Without the benefit of this massive disposal in the upper ocean of mankind's artifact of energy use, the world would face an overwhelming atmospheric CO₂ problem.

Yet the oceanic uptake blessing comes at a price, and that price may be paid by oceanic ecosystems facing changes in oceanic chemistry of unprecedented scale.

About 120 scientists met last spring at UNESCO headquarters, in Paris, under the auspices of the Scientific Committee on Oceanic Research (SCOR) and the Intergovernmental Oceanographic Commission (IOC) to review this problem, pose questions, and devise research strategies for the future. What are the possible oceanic consequences of no emissions control? Can oceanic iron fertilization strategies sequester significant quantities of CO₂? What might be the cost/benefit of direct deep-ocean

CO₂ disposal as opposed to indirect surface disposal today? Finally, is the fundamental knowledge in place to provide wise counsel to society on these matters?

The Once and Future Context

M. Parry presented the projected climate impacts of no/some/much emissions control and sequestration (reflecting the wide range of policy options available), with a special focus on the impact of rising sea levels on human populations. J. Edmonds presented the daunting economic challenge of providing energy services throughout this century while reducing atmospheric emissions. L. Bopp reviewed the climate-driven physical changes projected for the ocean. Once change has occurred, it does not quickly go away. D. Archer noted that full consumption of fuel reserves will produce temperature and CO₂ changes from which the deep ocean will take 10⁶ years to recover. The paleoperspective (E. Boyle) indicates that we are already beyond the still poorly understood 90 ppm glacial-interglacial CO₂ changes, and can soon enter a state not experienced on Earth for millions of years.