Lewis Thomas, Global Habitability, and Earth Satellites

by S. I. Rasool

S. Ichtiaque Rasool is currently Distinguished Visiting Scientist at Caltech's Jet Propulsion Laboratory and a visiting associate in planetary science on the campus. He also holds a Fondation de France chair at the Ecole normale supérieure in Paris and previously spent 17 years with NASA, his last position there being Chief Scientist for Space and Terrestrial Applications at NASA headquarters in Washington, D.C. For the past few years he has been particularly interested in promoting the use of space information for earth sciences and, as chairman of the International Committee on Space Research (COSPAR) Commission on Studies of the Earth's Surface, Meteorology and Climate, has been instrumental in organizing the international workshops and program of research described below.

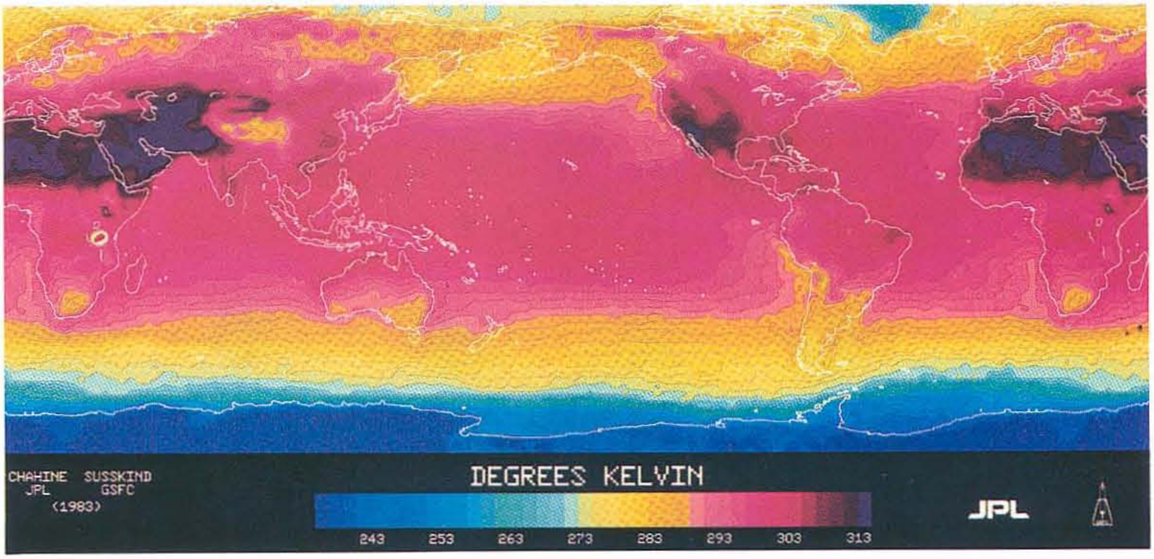
On reading Lewis Thomas's discussion of the Global Habitability project in the last issue of E&S, *he was inspired to respond on the state of the program and why it's not as simple a task as it may sound. Born in India and educated in France (PhD in atmospheric physics), he is as interested in the questions of "international politics" that Thomas raises as in the technical problems.*

IN HIS ESSAY ("Science and Social Science," *E&S,* March 1984) Lewis Thomas eloquently and convincingly argues that NASA as an agency should begin to apply the sophisticated space technology it developed for planetary exploration to monitor and study the "anatomy, physiology, and pathology of the earth itself." He writes of his hope that the Global Habitability project stands high on NASA's list of priorities and urges its funding.

Dr. Thomas is quite right — the problems of earth are fundamental, and satellites and the imaging technology developed for space exploration can help us understand and in some cases even solve these problems. He writes: "It is possible now to begin monitoring this planet, spotting early on the evidences of trouble ahead for our species or for others, especially the kinds of trouble for which we humans are responsible. I cannot think of a better work for the international science community on the ground or out in space, and I hope we will get on with it."

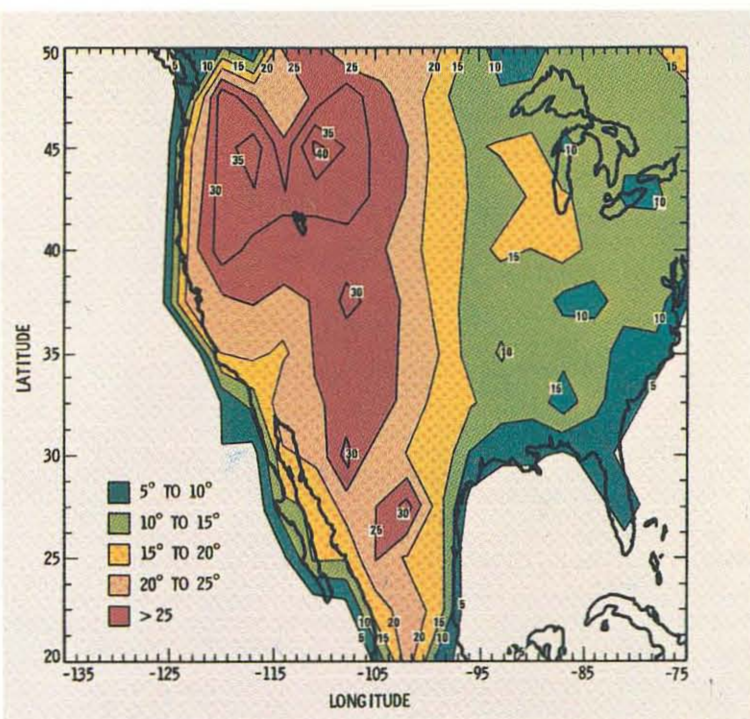
We are indeed getting on with it. But whether it is "possible now to begin monitoring this planet" is another question. There is still a lot of homework to do before the current space technology can really be used to observe consistently the seasonal or year-to-year changes in the character of the earth's surface on a global scale. Even though the imaging from space is constantly improving, and we can "see" more and more clearly, we still very often don't know exactly *what* we are seeing and what it means, especially in the case of the earth's surface. We have to be able to convert images into meaningful and quantitative scientific data over time, and this presents some real problems. Images taken by satellites in the visible, infrared, and microwave regions of the spectrum will first have to be validated with ground "truth"; that is, teams of researchers will have to compare what the satellite sees from space with what can actually be confirmed on the ground. For example, what are we really seeing in a "vegetation index" determined by a satellite? Is it the leaves, the humidity of the plants and soil, the chlorophyll in the biomass, or what?

The physical, chemical, and biological state of the whole globe cannot be monitored all the time by a hypothetical Global Habitability satellite. Also, NASA isn't going to be able to do it alone. To start with, we will have to use the satellite systems that exist today and that are already scheduled for the rest of the decade.



A NOAA satellite provided temperature data that, when corrected to remove interference from clouds and atmosphere, yields this image (made by Chahine/Susskind at JPL) of the mean "skin" temperature (averaged over day and night) of the earth in July 1979. To determine whether the earth as a whole is warming or cooling over time, at least 10 years of such data would need to be analyzed.

For any new system we will have to wait until the early 1990s. But what does already exist are the weather satellites operated by the National Oceanic and Atmospheric Administration (NOAA), which observe mainly the cloud and storm systems and measure atmospheric temperatures and moisture but have some capability to look at the surface; the land-observing satellites, such as NASA's Landsat and the French SPOT (to be launched next year), whose task is to map the geology and monitor the health and acreage of crops; and NASA's research satellites, which attempt to measure the chlorophyll in the oceans, the dust in the stratosphere, and the extent of the polar ice.



Using the same satellite data that generated the world map above, S.I. Rasool plotted the difference between day and night temperatures for the United States, dark green representing the smallest difference and dark brown the greatest. Since moist soil retains the day's heat while deserts do not (and consequently grow colder at night), this map can be seen as a "wetness" index, which could also have something to say about vegetation. Before this could have any real meaning, however, it would have to be verified on the ground.

Today six different nations launch these kinds of satellites with very specific, and often only local, objectives in mind. The *immediate* challenge, therefore, is to use these existing systems and try to extract from them information on global changes in biomass over the last decade, so that we can understand, for example, as Thomas describes it, "the cyclic exchanges of carbon, nitrogen, phosphorous, and sulfur between land and oceans," the year-to-year fluctuations in global rainfall patterns, variations in soil humidity and in surface temperatures on a continental scale, changes in ocean productivity, and, of course, attempt to resolve the big question of whether the earth as a whole is warming up or cooling down.

Because these satellites are multinational and because any one of them lasts only two or three years on the average, calibrating the different systems into a standardized interpretation over a decade is a major task. But it's not impossible. Dr. Thomas writes that the Global Habitability program will involve more than just congressional wrangling over NASA's budget. "It will require, as well, collaborated efforts by researchers from many different disciplines in science and engineering and from virtually every country on the face of the earth, which means international politics at its most difficult."

These collaborated efforts have already begun with the blessing of NASA, NOAA, the French Space Agency (CNES), the European Economic Community, and the United Nations Environment Program (UNEP). Following are excerpts from an article about these preparations from the February 1984 (Vol. 65, No. 2) *Bulletin of the American Meteorological Society*, which I wrote with H. J. Bolle, president of the International Association of Meteorology and Atmospheric Physics. (Since this was published, NASA has sponsored another workshop in March in Washington, D.C., bringing the total of international scientists involved in the project to more than 200.)

> More than 100 geophysicists and space scientists, drawn from a variety of disciplines and from 22 countries, deliberated in two week-long workshops held in Boulder, Colorado, and Innsbruck (Austria) and in a two-day briefing session in New Delhi (India) this summer as part of the United Nations Environment Program (UNEP) supported International Satellite Land-Surface Climatology Project, within the World Climate Impact Studies Program.
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> The principal motivation for such a project comes from three important considerations: 1) both climate induced and man-made changes on the earth's surface are known to be large and of profound significance; 2) satellites are ideally suited to measure these changes globally and over long-time scale (years, decades); 3) but there is currently no uniform methodology to derive consistent surface cover information from radiances measured by currently operating satellites.
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> The purpose of the workshops was to define a program of research which would lead, within five years, to agreed upon methodologies for converting satellite measured radiances into quantitative data concerning the earth's surface . . .
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> . . . Vegetation cover is the variable which is of greatest susceptibility both to the climatic fluctuations and human activities. Vegetation cover also has a direct bearing on the life of man on earth . . . Climatic fluctuations also change the extent of snow cover and ice sheets; natural climatic fluctuations along with human activity also affect the soil humidity and the boundaries of the desert. At the same time, these very changes on the earth's surface can themselves influence the climate of a region or even the globe. They certainly affect the energy and momentum transfer between surface and atmosphere as well as the soil hydrology . . .
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> . . . Currently, satellites appear to be capable of measuring a few of these land-surface variables with some precision; none of the parameters, however, is determinable with high enough consistency and accuracy that a long-term history of changes on the earth's surface can be documented. A careful assessment of the state-of-the-art of space technology at the workshops indicated that although the satellite sensors have become quite sophisticated, many important fundamental problems have yet to be solved satisfactorily before the radiances measured at the satellite could be adequately interpreted in terms of changes in surface properties of the earth . . . In spite of the fact that some ten years of quantitative satellite observations are available, these problems have not been solved to the extent required. It was the conclusion of the workshops that now we understand the problems well enough to plan an initial program to solve them . . .
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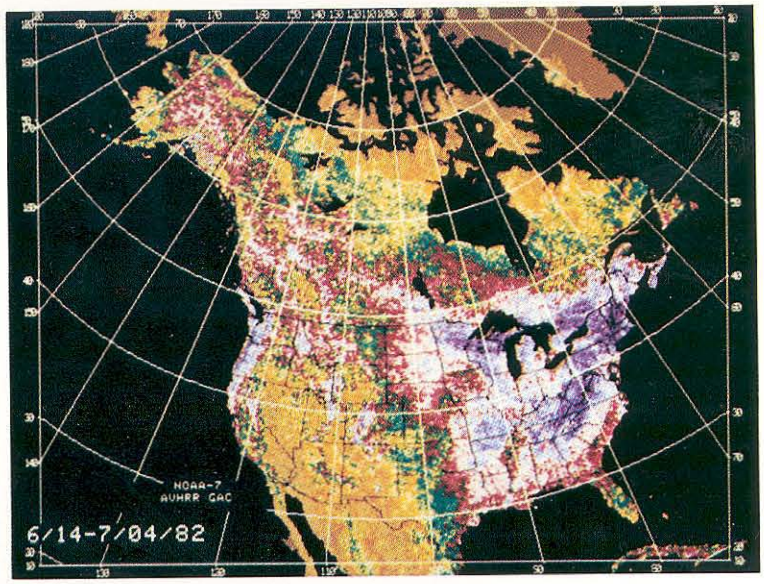
> . . . In summary, at this set of three workshops, it was abundantly clear that satellites can be a major tool to really assess globally the impact of climate and of man's activity on the character of the surface of the earth. It was also clear that if the satellites are to be an adequate tool, then one has to "calibrate" them with ground "truth" repeatedly in time and in space, and one scientist's interpretation of the measurement has to be compared with that of other workers. Only then can one visualize a homogeneous and authentic data set which can be used to assess quantitatively key parameters for climate studies. It was agreed that if this objective is to be accomplished before the end of the decade, the evaluation and validation studies as described briefly here must start at once because all the ingredients to initiate such a program are available now: more than a decade of satellite data, improved models of land surface-atmosphere interactions, ground observations at key locations, competent scientists and, very importantly, the motivation of appropriate international agencies to coordinate such an activity on a global scale. □



This "greenness" index for June 1982, using data from another satellite instrument, was made by Samuel Goward and colleagues at the University of Maryland and Goddard Space Flight Center. Since the map shows the amount of green, or chlorophyll (actually represented by colors ranging from purple to yellow), it might also be considered a vegetation index. But, like the wetness index, this too is really a measure of radiation, and, although the pattern is strikingly similar to the wetness index, such interpretations will have to be correlated and authenticated over a long period of time in order to be useful for habitability planners.