Chapter for:
M. J. Schleppegrell & M.C. Colombi, Eds.
Developing Advanced Literacy in First and Second Languages
[Erlbaum]

Multimedia Genres for Science Education and Scientific Literacy

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Why Scientific Multimedia?

The acquisition of advanced literacy is a social process of enculturation into the values and practices of some specialist community. In the case of scientific literacy this is the community of professional scientists, and their literate practices are normally conducted in multimedia genres where meanings are made by integrating the semiotic resources of language, mathematics, and a variety of visual-graphical presentations. I want to consider here the nature and extent of the multimedia literacy demands of (1) the advanced secondary school curriculum in science, (2) the multimedia genres of traditional scientific print publication, and (3) the internet-based multimedia genres which professional scientists are developing to communicate with one another and to the public. A survey of these three domains of scientific literacy can provide a useful foundation for defining both the goals of advanced literacy in science and measures of proficiency in this globally significant literacy.

As writers and scholars we know that no discussion of such important and complex topics can be complete in itself. I will focus here on more recent explorations of internet-based multimedia science genres and only briefly summarize work reported elsewhere on science classrooms (Lemke, 1990a, 2000a) and scientific print publications (Lemke, 1998a). I will also cite other discussions of basic theoretical and conceptual issues in the analysis of literacies and semiotic practices which I have published over nearly twenty years. In those can be found extensive reference to the large literatures on these subjects, which can hardly be summarized here. Indeed, as bodies of scholarship grow in extent to unprecedented new scales, I believe we must abandon all pretense in individual works to exhaustive citation of the relevant literature. What I write here can only make full sense to those who read not only my cited references, but a substantial portion of the larger web of relevant literature which is in turn cited in those references. These vast webs of intertextuality are both powerful resources for meaning-making in general and specifically relevant to the nature of scientific literacies (Lemke,1985, 1990a, 1990b, in press-a).

Before looking in detail at specific examples of the multimedia literacy demands of scientific genres, I want to sketch in some general conceptual background which will inform what I say about the examples.

Literacy and Social Semiotics

For some time now I have been trying to develop a discourse about literate social practices that is informed by a theoretical perspective often referred to as social semiotics (e.g. Lemke, 1989, 1995; Halliday, 1978; Hodge & Kress, 1988). The basic principle of social semiotic analysis is that meanings are made by selective contextualization: each entity which we take to be a sign we make meaningful by considering its syntagmatic, paradigmatic, situational and intertextual contexts, both actual and potential (Lemke, 1985). We do this in relatively automated ways that represent the typical and repeated meaning-making practices of the communities to which we belong, and in ways that are specific to cultures and subcultures, topics, participants, and settings. Making meaning is a process that takes place in material systems that include but extend beyond ourselves as biological organisms; these systems include the material texts, tool, and artifacts of a community, as well as other persons and nonhuman participants, and extend over multiple spatial and temporal scales from the local setting and immediate moment to the whole history of a widespread community. The meanings we make on any occasion are both uniquely emergent and culturally typical; they depend both on local contexts and on other meanings made in other times and places.

In this view the broadest sense of ‘literacy’ is identical to meaning-making or semiosis in general. A narrower definition of literacy may be constructed by focussing on meaning-making in which complex configurations of artifacts or natural structures play a critical role, as ‘text’, in the meanings we make on some occasion. In this sense a geologist may ‘read’ the Grand Canyon as a text, just as s/he may ‘read’ a photo-montage of the canyon, a geological map of its strata and topography, or a verbal account of its stratigraphy. In fact the meanings made by such a geologist, and the typical genres of diagrammatic and verbal texts in geology, presume that verbal accounts are typically made sense of in relation to relevant maps, diagrams, photographic records, and personal field experience. Each of these is in turn to be interpreted in relation to all the others, including a large intertextual web of verbal and mutlimedia texts. Actual scientific texts are almost never in fact purely verbal (Lemke, 1998a; Roth et al., 1999).

The narrowest definition of literacy would focus solely on verbal literacy with written media, but this definition is intellectually untenable today. Efforts to say what distinguishes ‘writing’ (e.g. Harris, 1995; Lemke, 1997), unless they arbitrarily restrict themselves to signs interpreted only in terms of the semantics of the linguistic system, find that the boundaries between written text and mathematical or chemical symbolism are hard to declare or justify; indeed, both of these latter instances arguably descend from language historically and remain partially interpreted linguistically. From text to table, table to chart, chart to graph, graph to diagram, diagram to picture there are historical continuities and contemporary unities in practice (Lemke, 1998a). Developmentally, speech and gesture derive from common motor routines, pictures descend from the lasting traces of gestures, and writing is a differentiated form of expressive speech-accompanying gesture, not initially separated from depiction. Semiotically, we never in fact make meaning with only the resources of one semiotic system: words conjure images, images are verbally mediated, writing is a visual form, algebra shares much of the syntax and semantics of natural language, geometric diagrams are interpreted verbally and pictorially, even radio voices speak to us of individuality, accent, emotional state and physical health through vocal signs not organized by the linguistic code. All semiotics is multimedia semiotics; all meaning is made in the integration of resources from only analytically separable semiotic resource systems.

In the perspective of social semiotics, meaning making is social, and material, and semiotic, and so therefore is literacy. Because it is material, no actual phenomenon of literate practice can ever be exhaustively analyzed by specifying the formal relations by which it instances some one semiotic, or even all known semiotics (the consequence here has long been recognized by phenomenology, the cause is a bit more mysterious; Lemke, 2000b). Because it is semiotic, our accounts of what and how it means must consider the state of affairs it presents, how it orients itself in the system of intertextual alternatives, and what unifies it as a 'text' (Halliday's 1978, 1994 'ideational, interpersonal, and textual' linguistic meta-functions, and see generalizations in Lemke, 1998a; Kress & van Leeuwen, 1996; O'Toole, 1990, 1994). Because it is social, we must explicate its social functions, both local and immediate and larger-scale and longer-term, to understand its meanings in the widest sense.

Critical Literacy

Every literacy has evolved historically to fulfill some social function. Literacies in general assist cooperative activity in communities, and in particular they help us integrate short-term activities across longer timescales (Lemke, 2000c). A 'text' in the sense of some material artifact which survives on a timescale that is long compared to that of its production, and which circulates in a community over this longer timescale, comes to play a role in many specific short-term activities in which it is semiotically interpreted, and thereby functions most basically to tie together longer-term, larger-scale social processes and networks.

We can see, therefore, in texts the semiotic lifeblood of a community circulating through the body politic. We encounter in texts all the values and beliefs of that community, all its attitudes and orientations, alliances and conflicts, categories and classifications. We learn what it regards as normal and surprising, assured and doubtful, desirable and undesirable, necessary, permitted, forbidden and optional. But to understand the wider functions of the beliefs and values embodied in texts we must also study how they circulate: which activities, which settings, which persons and artifacts are connected by these texts. How are they used similarly and differently by those who typically handle them? And how is immediate behavior, and larger-scale social order, different because these texts with these beliefs and values circulated where they did rather than other texts with different beliefs and values?

A social semiotic perspective on literacy is explicitly political. Because it does not see meaning as inherent in texts, but rather in how they are used and interpreted in communities, it points outward to the social functions of texts and not just inward to their formal patterns. Because it sees meaning-making not as an interior mental process but as an ecological, material process in an emergent self-organizing system larger than the isolated organism, it poses questions about the social and material effects of texts and not just about the organismic physiology of their production or interpretation. Because it seeks to understand both the semiotic and material bases of social organization, it regards every text as having a political function on some social scale.

I believe the goal of education, all education, is to nurture the development of critical intellectual capabilities. The responsible exercise of the power which knowledge gives us requires that we assess the implications, consequences, and alternatives of our actions as best we can. Every text we make, every text in whose circulation we participate, every discourse formation or multimedia genre we adopt and use has larger political and social functions. Ethically and morally we must know what we do. Politically and personally we must learn enough to help our communities do better.

Advanced multimedia literacy in the genres of science and scientific education confers great power in our society. To empower a wider range of people, we need to understand the specific semiotic and social demands of this literacy. To empower them responsibly, we need to understand equally well its social and political consequences.

The Multimedia Literacy Demands of Scientific Education

For most of us our first encounters with the multimedia literacies of science comes in school. School science and its texts are not examples of the genres of professional science, not even in the advanced secondary school curriculum or in most of tertiary education (Lemke, 1994; Roth et al. 1999). They do however initiate students into its multimedia literacy demands (Lemke, 2000a). Science textbooks contain not just words in sentences and paragraphs, but tables, charts, diagrams, graphs, maps, drawings, photographs and a host of specialized visual representations from acoustical sonograms to chromatography strips and gene maps. In many cases they also contain mathematical formulas and algebraic derivations.

But it is not just the print materials which make these demands. In a recent analysis of videotape data following one student through a day of advanced chemistry and physics classes (Lemke, 2000a, see also Cumming & Wyatt-Smith, 1997), I observed that in his chemistry lesson this student had to interpret a stream of rapid verbal English from his teacher; the writing and layout information on an overhead transparency; writing, layout, diagrams, chemical symbols and mathematical formulas in the open textbook in front of him; the display on his handheld calculator; more writing, layout, diagrams, symbolic notations, and mathematics in his personal notebook; observations of gestures and blackboard diagrams and writing by the teacher; observations of the actions and speech of other students, including their manipulation of demonstration apparatus, and the running by-play commentary of his next-seat neighbor. In fact he had quite often to integrate and co-ordinate most of these either simultaneously or within a span of a few minutes. There is no way he could have kept up with the content development and conceptual flow of these lessons without integrating at least a few of these different literacy modes almost constantly.

In one episode in the physics lesson, there is no role for the notebook, and not even a diagram, but a pure interaction of language and gestural pantomime, including whole-body motion. The teacher, Mr. Phillips, is standing just in front of the first (empty) row of student desktables, at the opposite end of the room from where the student, John, is sitting. John sees his teacher's hands cupped together to form a sphere, then the hands move a foot to the left and cup together to make another sphere. Then back to the first, and one hand and Mr. Phillips' gaze make a sweeping gesture from one to the other; then Mr. Phillips begins to walk to the left, repeating these gestures and walking down toward John's end of the room. Fortunately, Mr. Phillips is also talking and John is listening; by integrating the teacher's precise and conventionalized mime with his accompanying technical speech, John can interpret that the cupped hands are atoms, the sweeping hand a photon, emitted by the first, traveling to the second, absorbed there, re-emitted after a while, passing on down through a ruby crystal, producing a snowball effect of more and more photons of exactly the same energy. In other words, the crystal is a laser.

Mr. Phillips says he's going to add more complexity to the picture now. An atom might shoot out a photon in this direction -- gesture away from the axis of the room-sized imaginary ruby crystal toward the students -- or in this one -- gesture back toward the blackboard -- or ... -- oblique gesture. How do we get a laser beam then? He walks back and forth between the ends of his now lasing, imaginary ruby crystal, describing the mirrors he gestures into being at each end, but saying they differ in reflectivity and transmissivity, to build up and maintain the avalanche of photons, while letting some out in the form of the laser beam. John has seen mimes like this before; he has seen diagrams of atoms and crystals, of photons being absorbed and emitted by atoms. Intertextually, he can use the visual literacy of these past diagrams, together with his literacy in pantomime, and his verbal discourse literacy in atomic physics to synthesize a model of how a laser works.

John is lucky. He does appear to have the required literacies, and to be able to combine and synthesize them across media, events, and semiotic modalities. There is a great deal that John must already know in order to make sense of what he is learning in these lessons minute to minute. Not just language and verbally expressed discourse formations (such as the intertextual thematic formations I have described in Lemke, 1983, 1995 and elsewhere), but conventional diagrams of atomic arrangements in a crystal, standard graphs of energy levels of atoms, typical ways of gesturing directionality in space, and common notations for the algebraic and symbolic representation of chemical reactions and stoichiometric calculations of concentrations and the pH of solutions. His literacy extends to motor routines in operating a calculator, social discourse routines of question and answer in a classroom, and technical practices in manipulating a spectroscope and diluting a solution. He must constantly translate information from one modality to another: numerical to algebraic, algebraic to graphical, graphical to verbal, verbal to motor, pantomime to diagrammatic, diagrammatic to discursive. But simple translation is not enough; he must be able to integrate multiple media simultaneously to re-interpret and re-contextualize information in one channel in relation to that in the other channels, all in order to infer the correct or canonical meaning on which he will be tested. In most cases, the complete meaning is not expressed in any one channel, but only in two or more, or even only in all of them taken together (see detailed examples in Lemke, 2000a; Roth & Bowen, 2000; Wells, 2000).

Even if we restrict our attention to the interpretation of printed text, scientific genres remain highly multimodal.

Multimedia Genres of Scientific Print Publications

In another recent study (Lemke, 1998a), I examined the semiotic forms found in the standard genres of research articles and advanced treatises of professional scientific publication. In a diverse corpus, across disciplines and publication venues, the clear finding was that there is typically at least one and often more than one graphical display *and* one mathematical expression per page of running text in typical scientific print genres. There can easily be 3-4 each of graphics displays and mathematical expressions separate from verbal text *per page.*

In one prestigious journal of the physical sciences, each typical 3-page article integrated *four* graphical displays and *eight* set-off mathematical expressions. Some had as many as three graphical displays per page of double-column text, or as many as seven equations per page. In another journal, in the biological sciences, each typical page had two non-tabular visual-graphical representations integrated with the verbal text, and each short (average length 2.4 pages) article typically had six graphics, including at least one table and one quantitative graph.

To appreciate the absolutely central role of these non-verbal textual elements in the genres being characterized, it may help to ponder a few extreme (but hardly unique) cases:

- In one advanced textbook chapter, a diagram was included in a footnote printed at the bottom of the page.
- In one 7-page research report, 90% of a page (all but 5 lines of main text at the top) was taken up by a complex diagram and its extensive figure caption.
- The main experimental results of a 2.5-page report were presented in a set of graphs occupying one-half page and a table occupying three-fourths of another. The main verbal text did not repeat this information but only referred to it and commented on it.
- In most of the theoretical physics articles, the running verbal text would make no sense without the integrated mathematical equations, which could not in most cases be effectively paraphrased in natural language, even though they can be, and are normally meant to be read out as if part of the verbal text (in terms of semantics, cohesion, and frequently grammar).

A more detailed analysis in this study showed how absolutely normal and necessary it is to interpret the verbal text in relation to these other semiotic formations, and vice versa. It is not the case that they are redundant, each presenting the complete relevant information in a different medium; rather the nature of the genre presupposes close and constant integration and cross-contextualization among semiotic modalities.

Why? Why is science not content with verbal linguistic expression? Why have the forms of verbal expression it does use co-evolved so as to mainly make sense only when interpreted in close association with mathematics, diagrams, graphs, tables, maps, etc.? One reasonable hypothesis (for more discussion see Lemke, 1998a, in press-b) is that in attempting to describe the quantitative covariation of continuously variable phenomena (shape, temperature, velocity, angle, color, voltage, concentration, mass, etc., etc.) scientific discourse came up against the limitations of language as a semiotic resource. The semantics of natural language specializes in categorization -- in discretely nameable things and processes and in classifying their relationships. Language is not very good at describing complex shapes, shades of color, or degrees of temperature. For these purposes visual and spatial-motor representations are much better suited. To achieve precision however in relating one representation to another, the semantics of natural language also had to be extended historically to describe quantitative variation and relationships. Language remained the main tool of conceptualization and classification, but it was of use only when integrated with mathematical and visual representation. All these representations were and are themselves useful primarily as adjuncts to practical, technical, and experimental activity (see for example Lynch & Woolgar, 1990). The operational conventions of scientific procedures themselves constitute yet another semiotic modality to be integrated with the others.

Scientific Literacies and New Multimedia Genres

When we seek to educate students to use advanced scientific literacies, we are participating in their socialization into global communities. Scientific discourse formations and multimedia genres, at least in their print forms, are today international in their scope and global in their reach. In order to be perceived in the scientific and technical community as deploying them appropriately, students need to learn and adopt, even with reservations, certain values and identities. To ‘think like a physicist’ (or biochemist, or chemical engineer), to write like one, to make sense of technical genres as do those who create them authoritatively, students need to understand the larger value assumptions and subcultural conventions of the scientific community. They need to know what is regarded as of greater relative importance and how to signal such importance. They need to know how conflict and adversarial relationships are managed in this community. They need to understand how the texts of technoscience function not only to serve internal functions within the community, but how they link the community to its larger social, economic, and political functions in the wider society.

It is part of internal ethos or ideology of science about itself that it is an activity of pure human good, and that any discernable links to matters economic or political distances science from its ideal and is to that extent not truly science. Historically this isolationism arose from the conflicts between the grounds of scientific authority and those of religious and political authority (e.g. Shapin & Schaffer, 1985) in times of great social unrest and violence. We see its effects today in the restricted semantic register of scientific language, where evaluations of warrantability are manifold and explicit, but other dimensions of evaluative and expressive meaning (Lemke, 1998b) must be inferred on the basis of often distant or unwritten intertexts. Scientific texts are written as if they were only about matters of fact and explanation, when of course every text makes meaning about desirability, importance, permissibility, expectedness and all the other value dimensions.

From the viewpoint of social semiotics, scientific multimedia genres are as they are not just because they are fit to the internal functional needs of the scientific community, but also because they play a role in linking that community within the wider social, economic, and political institutions which make its continued existence possible.

It is more or less the case today that all professional science is ‘big science’; i.e. it is funded and supported by large-scale social institutions, whether universities, foundations, or increasingly (and always so historically) governmental and military agencies. One such agency, responsible for the support of a great deal of scientific research in the United States, is NASA, the National Aeronautics and Space Administration. It was created to separate secret and restricted military research from research that would potentially have wider economic impact and political support. In fact there is relatively little difference between a missile and a ‘launch vehicle’ so far as technology is concerned, and even less between a military spy sattelite and a civilian ‘earth observing platform’. NASA is increasingly driven by its potential economic impact and its need for the political support which derives from economic benefits to turn its technologies toward the earth rather than the stars.

NASA also maintains one of the largest systems of scientific and technical communication and publicly available information databases in the world. Scientific teams and high technology companies look to NASA, as to its sister institutions (such as NOAA and the U.S. National Laboratories) to maintain the complex networks of non-print communication on which they depend, and to supply them with the results of taxpayer-supported scientific research. Indeed the global technoscience community, and not just the U.S., depends NASA’s networks of information.

The global communications and information technology infrastructure known as the internet was initially created to permit continuous military communications under conditions of nuclear warfare. It was then parasitized by the communication needs of scientists doing contract research for the U.S. military, and later by the wider scientific community whose research was funded by the U.S. government and seen to be in the national interest. For much longer than the commerical internet has been in the public eye, the scientific internet existed to permit rapid transmission of technical information among distant research centers doing related projects. The model of information on which it is based was designed to allow all forms of meaning: verbal, graphical, numerical to be exchanged with equal ease. Very powerful computing facilities were, and largely still are, needed to convert these information streams into forms of which humans can make sense (text, images, numbers), but in the last few years, as we all know, smaller computers have acquired the power to participate in this communications network and to transform at least small data streams into the beautiful text, images, animations, audio, and video of the WorldWideWeb.

NASA maintains a very large website as the primary interface to its enormous databases of sattelite-derived information and many other technical resources. Because it is a governmental agency, and so a political as well as a scientific institution, NASA also uses its website to build popular and business support for its agendas. Conveniently for researchers interested in the multimedia literacy demands of scientific information on the internet, its webpages are also in the public domain.

In a study I am currently engaged in, I am looking at the presentation of scientific information of essentially the same kind and from the same source in two different parts of the NASA website (actually it is a meta-site, a large number of interlinked websites spread across the component institutions in the nasa.gov domain). In one of these sites, the NASA Earth Observatory (http://earthobservatory.nasa.gov), data on conditions of the atmosphere, oceans, land, and biosphere of the earth as observed from space are presented for science teachers, students, and interested members of the educated public. In the other, the Goddard Space Flight Center's Earth Sciences (GES) Distributed Active Archive Center (DAAC, http://daac.gsfc.nasa.gov/DAAC_DOCS/gdaac_home.html) this same information is made available to professional scientists, in strikingly parallel fashion. (In fact I suspect the Earth Observatory site may have been modeled after Goddard's. For all web figures below, the original screen shots are archived in color at http://academic.brooklyn.cuny.edu/education/jlemke/webs/nasa/Davis-NASA.htm .)

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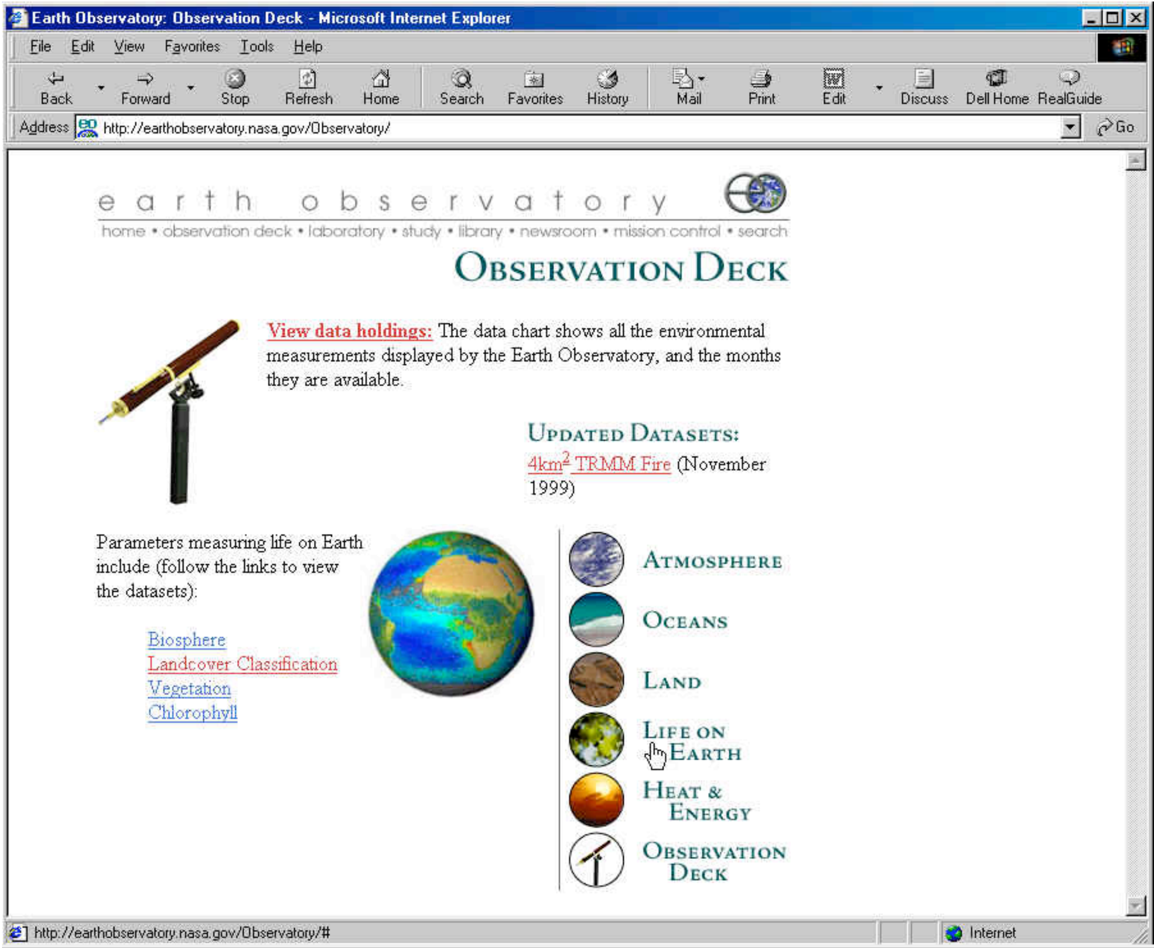
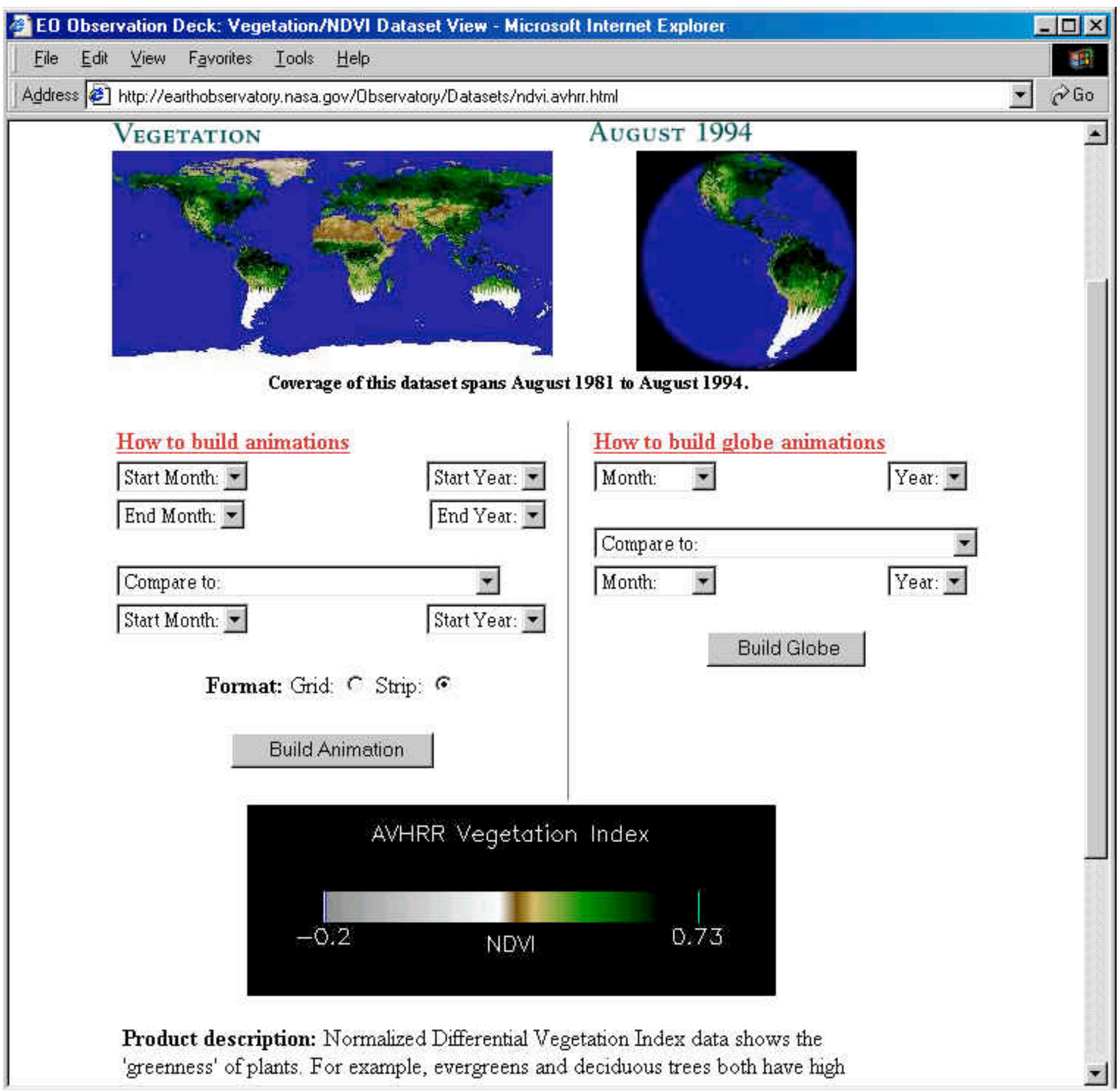


[Figure 1a. NASA Earth Observatory Observation Deck Webpage

(January 2000, http://earthobservatory.nasa.gov/Observatory/)

ABOUT HERE]

The level of multimedia literacy demands at the Earth Observatory (EO) site is hardly minimal. Users of these webpages confront the complexities of not just simplified scientific text, but an interactive glossary function, links to background information in documents accessed from a Library page, links to closely related websites documenting research projects on related scientific topics (the Study), and most notably the option of linking to an interactive system for scientific visualization of relevant sattelite data (the Observation Deck, Figure 1a). It is the main Observation Deck page which is organized along strikingly parallel lines with the Goddard GES DAAC main page. By selecting a 'parameter' (i.e. type of data derived from sattelite sensors, e.g. Vegetation) and a time range (see Figure 1b), users can display, in the form of color-coded maps (Figure 1c), an animated display that shows changes in the values of this parameter worldwide over the chosen time range, and even display side by side for comparison maps coded for two different parameters. Users have the choice of three display modes: mercator-like projection maps in an animated strip (Figure 1c, rather like cartoon frames that can be flashed by quickly to show a single dynamically changing image), a grid or matrix table of maps each for a different fixed time within the range, and a globe which shows only a single time frame, but can be rotated to show the color-coded values of the paramter(s) at all points on the earth, or as seen from any direction in space above the earth.



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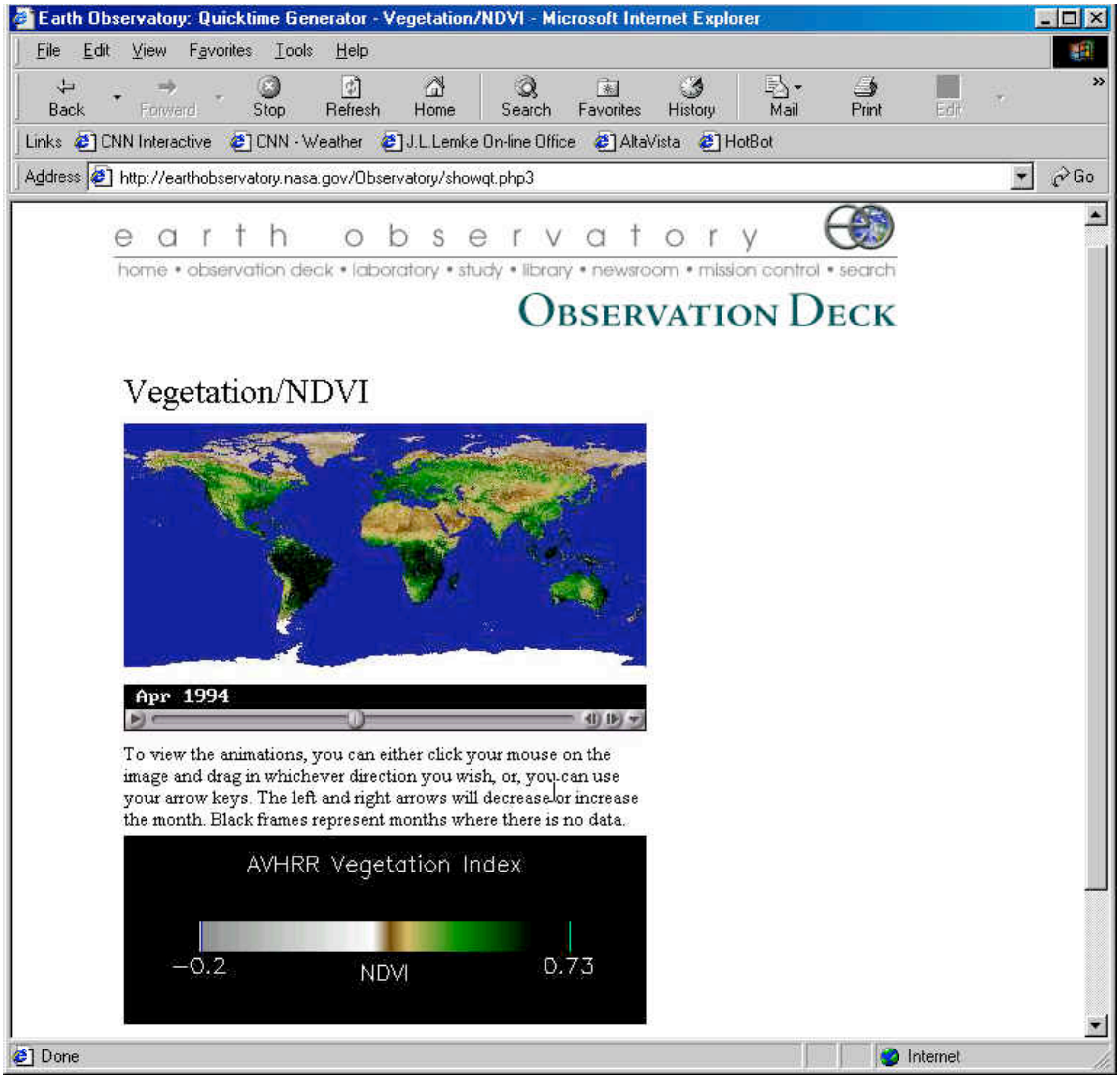
[Figure 1b. NASA Earth Observatory: Life on Earth, Vegetation Dataset Webpage (January 2000, http://earthobservatory.nasa.gov/Observatory/Datasets/ndvi.avhrr.html) ABOUT HERE]

Moreover, the color-coding is quantitatively based, and a key is provided that shows a continuously variable color-spectrum and the corresponding numerical values (Figures 1b, 1c). Along with this is an explanatory paragraph discussing what the color-coded image maps show that is of scientific importance, and in some cases what the technical nature of the parameter is and from what sattelite instrument it is derived (e.g. Figure 1b, truncated at bottom). These latter facts are not usually fully explained, even if they are mentioned.



[Figure 1c. Display of Vegetation NDVI Data in Animated World Map with Key (January 2000, http://earthobservatory.nasa.gov/Observatory/showqt.php3) ABOUT HERE]

The Earth Observatory site in fact also includes a 'Style Sheet' for potential contributors, and this makes it clear that its genre conventions, at least verbally, are journalistic. It aspires to something like the level of sophistication and public accessibility of a print publication such as *Scientific American*. There is almost no mathematics in the EO site, but regular use of both numerical values and visual representation of quantitative information and relationships. In making use of the Observation Deck's scientific visualization facility, visitors must integrate scientific language, specialized visual display genres, quantitative values, and time-dependent animation. The latter is also interactive; the user employs a motor routine to control the animations by dragging the mouse over the images while a counter changes to show the month and year of each frame.

The demands of the EO site represent the minimal goals of scientific multimedia literacy in the current school curriculum, according to generally agreed on national standards (American Association for the Advancement of Science, 1996; National Research Council, 1996). They would not be sufficient for tertiary study of a scientific or technical field, or even for the work that John was doing in his advanced science classroom in a secondary school. They do show us, however, how print genres of sophisticated popularized science are evolving to take advantage of the new computational possibilities of internet-based multimedia.

To gain a better sense of the dimensions of increasing semiotic sophistication that are needed beyond the EO site's level, we can turn to its sister site for professional scientists. It is not in fact easy for the casual visitor to the NASA website to find the GES DAAC. Most of the pages that are readily accessed from the NASA homepage (www.nasa.gov) are oriented to informing the general public and have the production values of a newsmagazine or advertising poster. You can get to the EO site by looking through the prominently displayed 'Cool NASA Sites' on the homepage. EO can be reached by just two hypertext jumps from the NASA homepage. GES DAAC on the other hand took quite a lot of hunting to find in the absence of knowledge of the correct specialized search terms. A relatively direct path, seeking information on earth sciences data, takes six such jumps, most of them far from obvious choices in menus with several other plausible options. A slightly shorter path leads to a search engine, which, if one knows the correct technical terms, would bypass the GES DAAC and lead directly to the possibility of downloading the raw data which the GES DAAC pages describe. There is also information available on how to turn this raw data into useful visualizations, but only for those using high-end scientific workstation computers.

[Figure 2a. NASA Goddard Space Flight Center Earth Sciences Distributed Active Archive Homepage, Cursor over Atmospheric Chemistry link, Displaying Ozone Depletion (January 2000, http://daac.gsfc.nasa.gov/DAAC_DOCS/gdaac_home.html) ABOUT HERE]

At the Goddard Earth Sciences DAAC homepage, we find a marvelous analogue of the EO Observation Deck page. Both contain menus of links to information on topics such as the earth's atmosphere, oceans, biosphere, etc. The respective menus are:

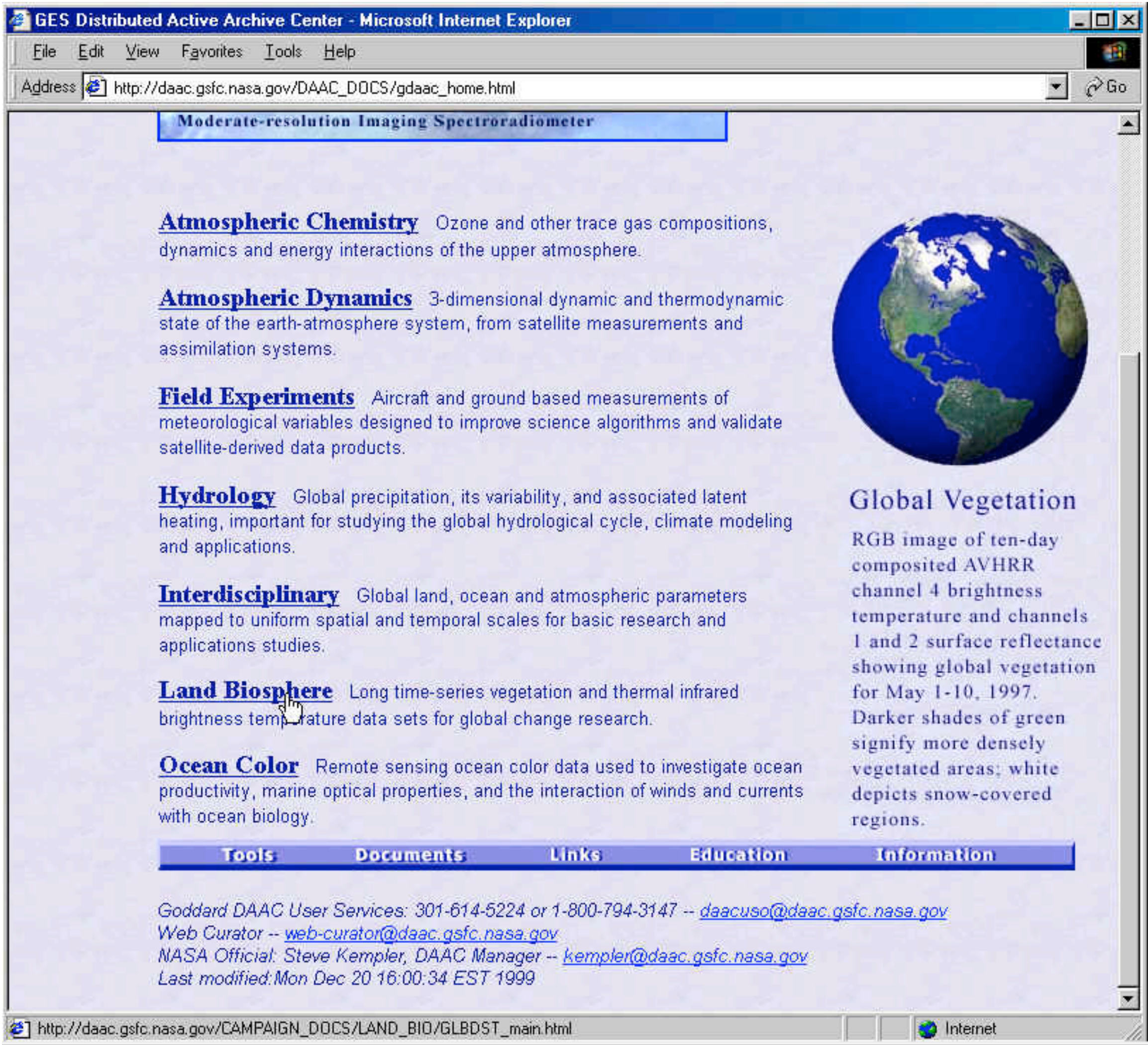
Earth Observatory Observation Deck:

Atmosphere – rainfall, ozone, cloud fraction
Oceans – chlorophyll, sea temperature
Land – vegetation, fires, surface temperature
Life on Earth – biosphere, vegetation, chlorophyll
Heat and Energy – surface temperature, outgoing radiation

GSFC Earth Science DAAC:

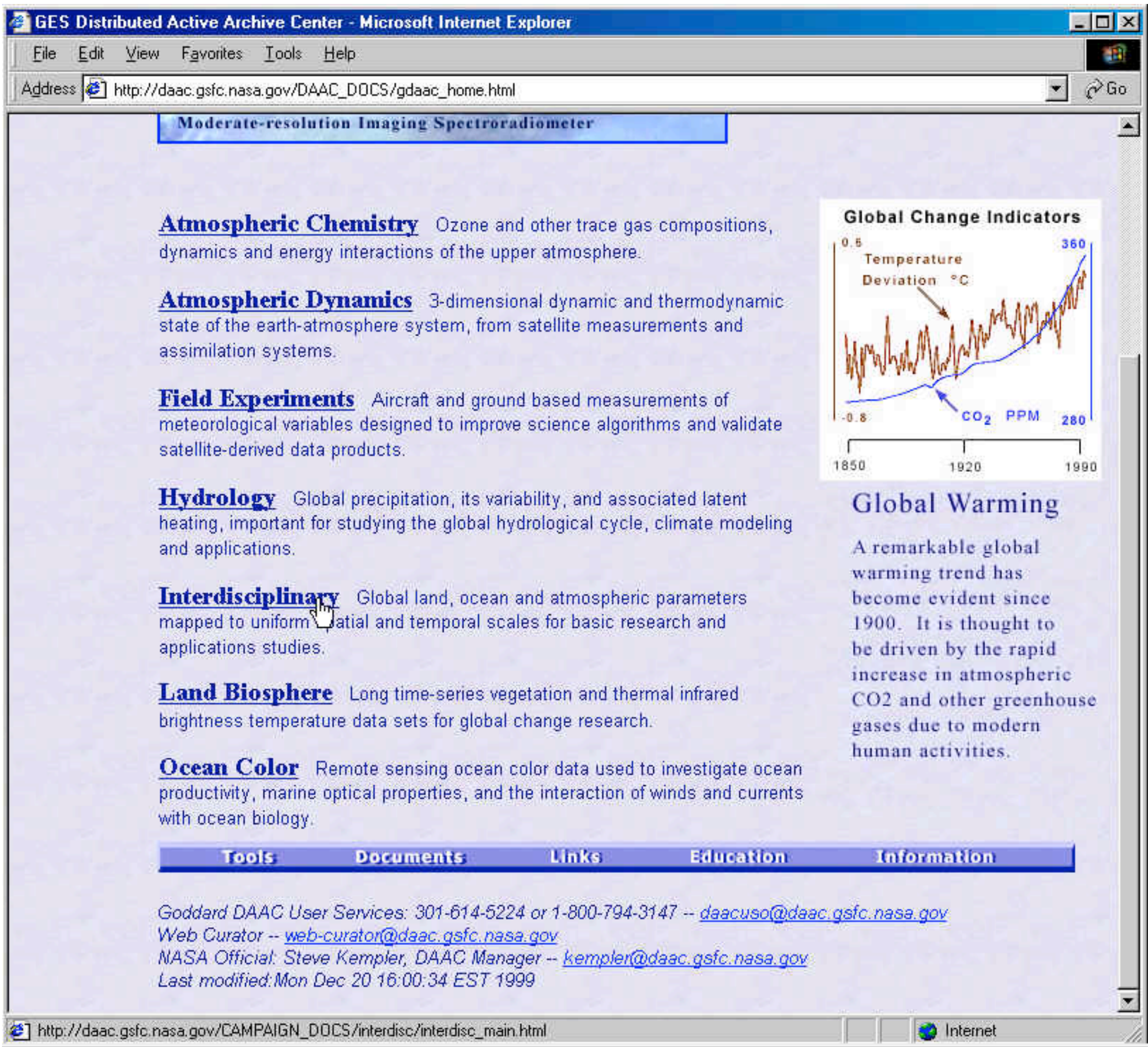
Atmospheric Chemistry
Atmospheric Dynamics
Field Experiments (meteorological variables)
Hydrology (global precipitation)
Interdisciplinary (global land, ocean, and atmospheric parameters)
Land Biosphere (vegetation and infrared brightness)
Ocean Color

On the EO page, passing the cursor over each menu item heading (at right) leads to the appearance of a colored (2-D) globe of the earth showing a typical pattern for one of the parameters under that heading and beneath it a list of links to the visualization engine for various specifically related data parameters. (See Figure 1a.)



[Figure 2b. NASA GSFC DAAC Homepage, Cursor over Land Biosphere link, Displaying Global Vegetation (same URL as for Figure 2a, different cursor position) ABOUT HERE]

On the DAAC page, passing the cursor over each menu item (at left) leads to the appearance in a frame on the right of a colored graphic image and paragraph long caption. The images are in two cases color-coded earth globes (Figures 2a and 2b), exactly as on the EO page, but other images include a complex data graph showing atmospheric carbon dioxide and global temperatures as a function of time (years and decades, Figure 2c) and a topographic visualization of the vector flow of air and ocean currents in a monsoon (Figure 2d). Beneath one of the globe images is a color-spectrum quantitative key for ozone concentrations (Figure 2a). The captions tend to give more technical descriptions of the nature of the data as well as of its scientific importance. On this one DAAC page the multimedia literacy demands are already in excess of those for the entire sequence on the EO site leading to interpretation of the visualized coded data maps. These users begin already past the point where the EO users end.



[Figure 2c. NASA GSFC DAAC Homepage, Cursor over Interdisciplinary link, Displaying Global Warming (same URL as for Figure 2a, different cursor position) ABOUT HERE]

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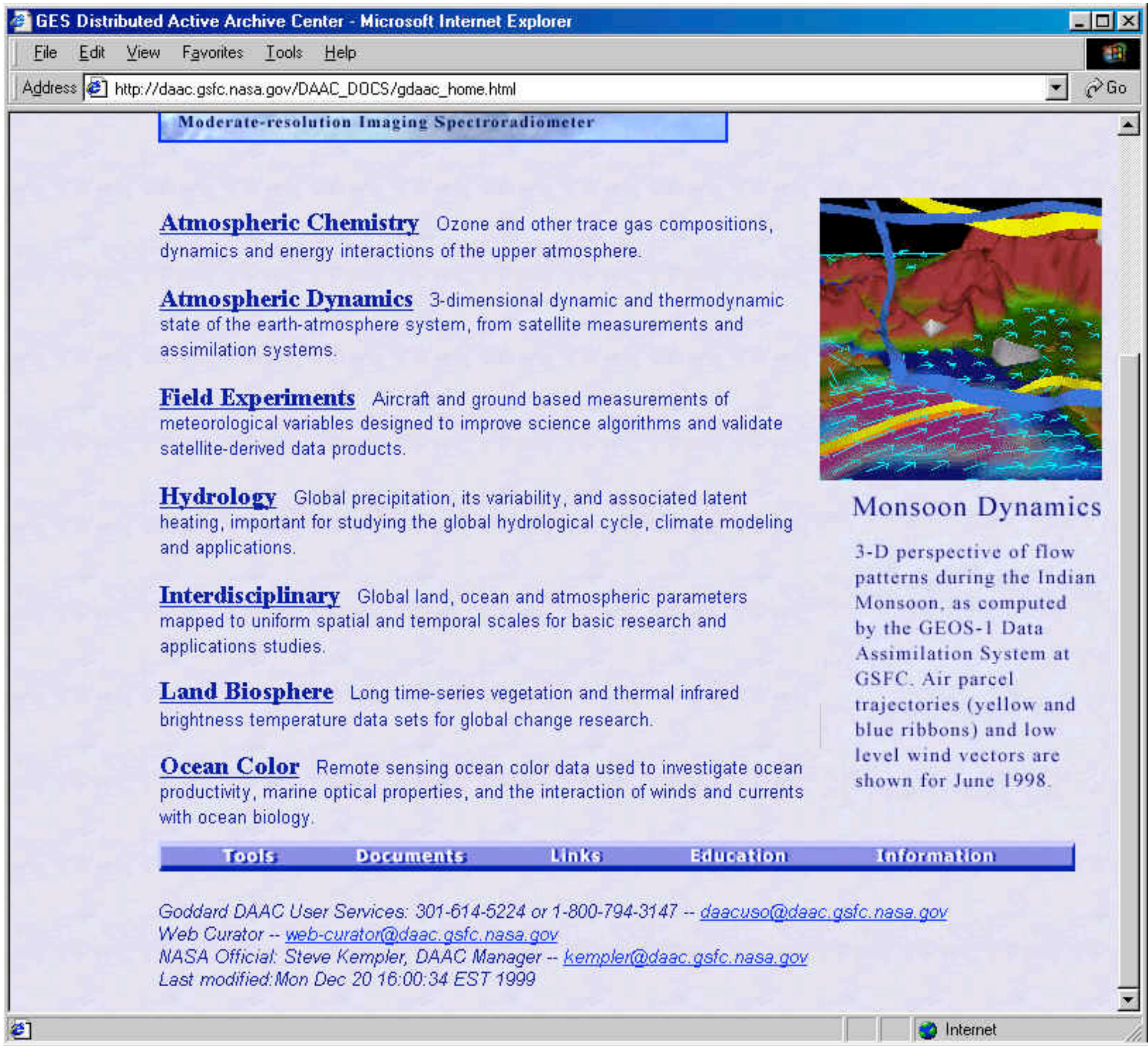
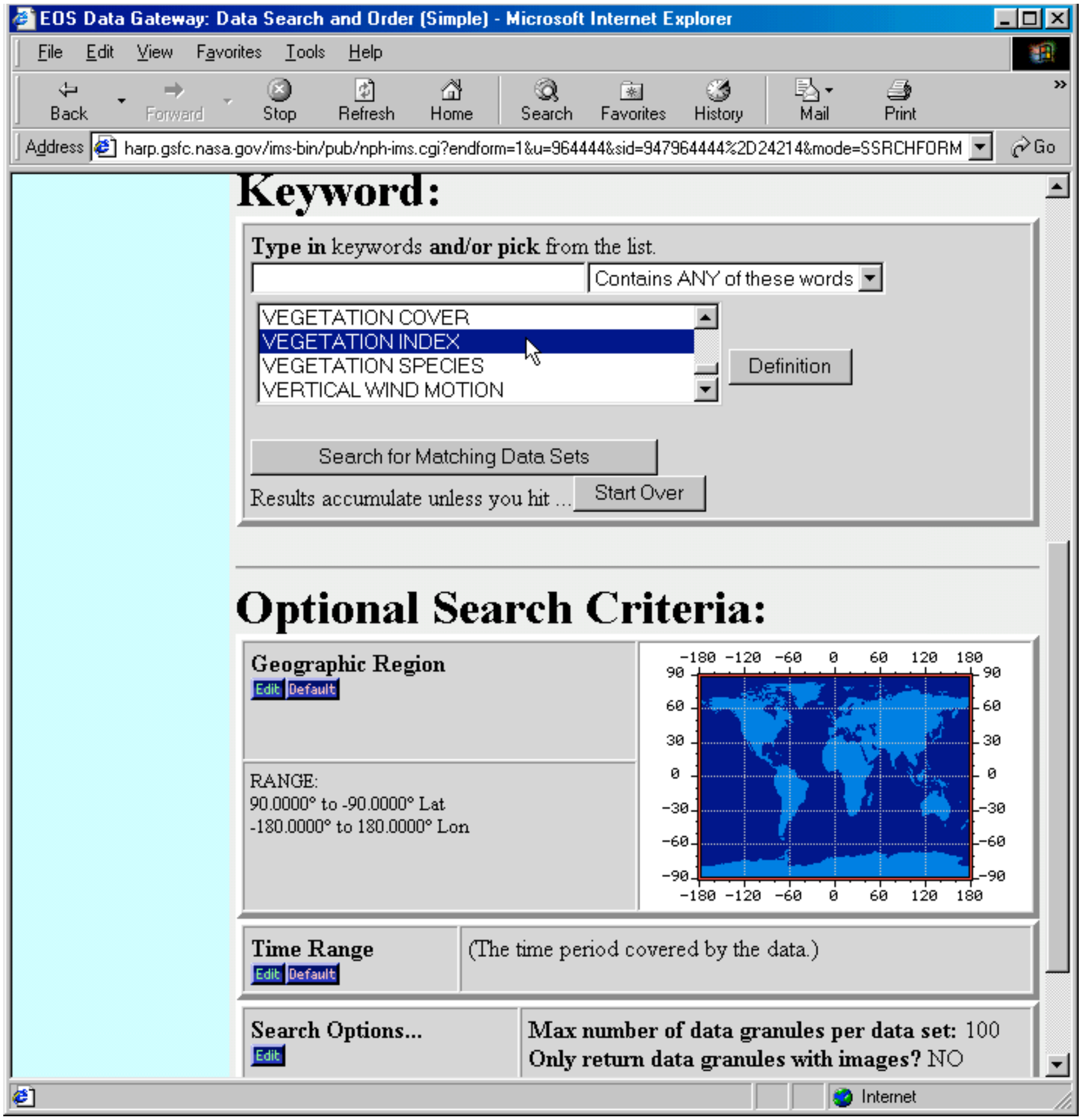


[Figure 2d. NASA GSFC DAAC Homepage, Cursor over Atmospheric Dynamics link, Displaying Monsoon Dynamics (same URL as for Figure 1a, different cursor position) ABOUT HERE]

If we try to locate comparable information to that in the EO site, e.g. its Life on Earth: Vegetation data, which shows the greening of the earth with the seasons and the extent of polar snowfields in the north and south year by year, we select Land Biosphere from the DAAC menu and are taken first to the option to browse and select the data we want by means of a search page that has drop-down boxes like those on the EO visualization page (Figure 3a, compare Fig. 1b) listing the various parameters available (in DAAC these are datasets, but classified by their typical scientific uses) and similarly, again like EO, for the time ranges. In the DAAC site, time can be specified to the day, not just the month as in EO, and geographical regions can also be isolated. But once a data set is selected, our choice is either to download it by FTP (the faster forerunner of HTTP on the web), typically 35 megabytes, or to browse it … but this is only possible if we have a unix-based workstation computer, not an ordinary PC. True scientific users would then have a comparable experience to the EO visitor. Further technical literacy is required to make use of the instructions given on how to set up the browser function on the workstation.

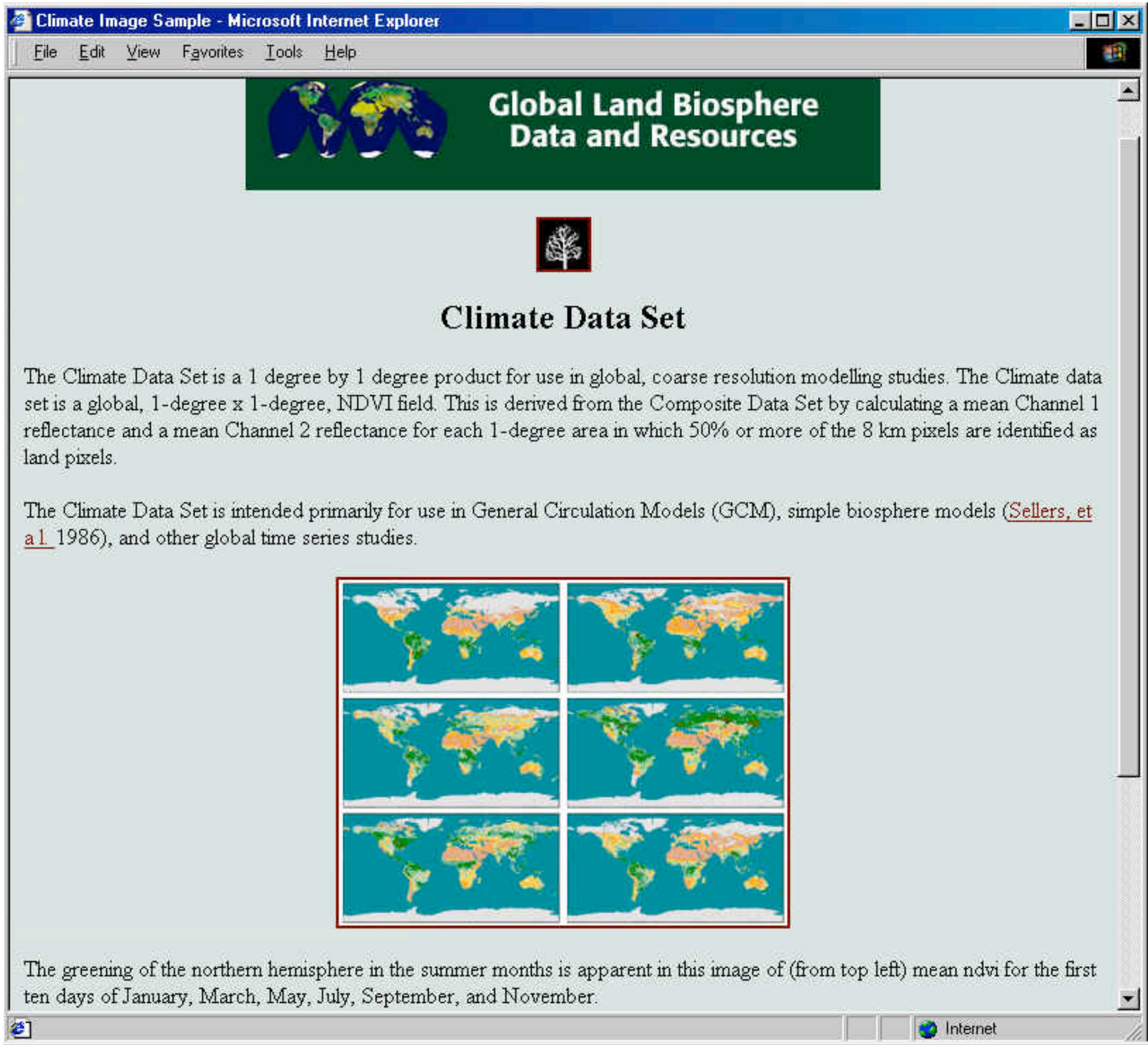


[Figure 3a. NASA EOS Data Gateway: Data Search and Order Form Page (Access via link: Enter as Guest from http://harp.gsfc.nasa.gov/~imswww/pub/imswelcome/plain.html) ABOUT HERE]

Unlike at the EO site, browsable images here do not include brief color-key codes and an explanatory paragraph. Rather, there is an entire menu of resources and documentation to assist the technical user in interpreting the data displays. In some cases this includes links to the researchers who have created the datasets; and in all cases links to the published scientific literature describing all aspects of the production of the data. If we in fact look at some of this documentation (there is a 96-page printable manual you can download for the data we are interested in here on vegetation cover), we find after three more jumps a sample of the displays of our data, in low resolution, as a grid of maps, very similar to what we can get in the EO visualization (see Fig. 3b). It is accompanied by a reference to the published literature, and the key explanation:

> The Climate Data Set is a 1 degree by 1 degree product for use in global, coarse resolution modelling studies. The Climate data set is a global, 1-degree x 1-degree, NDVI field. This is derived from the Composite Data Set by calculating a mean Channel 1 reflectance and a mean Channel 2 reflectance for each 1-degree area in which 50% or more of the 8 km pixels are identified as land pixels.

-



[Figure 3b. NASA GSFC Global Land Biosphere Data and Resources, Climate Data Set Webpage (January 2000, http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/LAND_BIO/Climate_ds.html)ABOUT HERE]

There is no automatic glossary function here as there is in the EO site, but we can use the online documentation to unpack the meaning of much of the technical language. In doing so, we get some sense of the multimedia literacy demands of professional scientific genres. For example, 'composite data set' leads back to 'daily data set' and its description is primarily in the form of a table:

```
Daily Data Set Layers
```

Layer	Units	Range
NDVI	-	-1 to +1
CLAVR flag	-	0 to 31
QC flag	-	0 to 31
Scan Angle	radians	-1.047 to +1.047
Solar Zenith Angle	radians	0 - 1.396
Relative Azimuth Angle	radians	0 - 6.283
Ch1 Reflectance	%	0-100
Ch2 Reflectance	%	0-100
Ch3 Brightness Temps	Kelvin	160-340
Ch4 Brightness Temps	Kelvin	160-340
Ch5 Brightness Temps	Kelvin	160-340
Date and Hour of Obs	DDD.HH	1-366.23

[http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/LAND_BIO/Daily_ds.html]

The actual parameter in the data set which underlies the images of interest to us, and which is in fact identified, but not explained, even in EO is 'NDVI'. Following on to the basic documentation for this we find:

> The Normalized Difference Vegetation Index (NDVI), which is related to the proportion of photosynthetically absorbed radiation, is calculated from atmospherically corrected reflectances from the visible and near infrared AVHRR channels as:
>
> (CH2 - CH1) / (CH2 + CH1)
>
> Where CH1 is the reflectance in the visible wavelengths (0.58-0.68 um) and CH2 is the reflectance in the reflective infrared wavelengths (0.725-1.1 um). The principle behind this is that Channel 1 is in a part of the spectrum where chlorophyll causes considerable absorption of incoming radiation, and the Channel 2 is in a spectral region where spongy mesophyll leaf structure leads to considerable reflectance (Tucker 1979, Jackson et al.1983, Tucker et al. 1991).

-

[http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/LAND_BIO/ndvi.html]

This paragraph is perfectly typical of mathematical-scientific register: the set-off algebraic formula expression, followed by the 'Where …' definitions, the citations to the literature, as well as the use of technical terms, and embedded numerical expressions with units of measure. Note the hypertext link on 'reflectances' which is a new feature of this medium. It leads in fact not to a simple text definition, but to a complex page dominated by black-and-white images showing the differences between the channel 1 and channel 2 data used in NDVI calculations; this reflectances page also contains embedded quantitative data with measure units and a link to the published literature.

The literacy demands here are quite comparable to those of scientific print publications (Lemke, 1998a), but go beyond them in the specific matter of hypertext (or hypermedia) literacy. In print genres, the scientific citation is a standard intertextual referring device; to make use of it requires not just language literacy skills to interpret the citation, but also the activity skills needed to physically locate the printed text referred to. That latter demand is being simplied by the hypertext links of web-based genres (although it is still present here; the links to the citations lead not to the original papers but only to the detailed citation information in an online bibliography). At the same time, it becomes easier in the new medium to increase the density of links, and so the complexity of the intertextual web that users must integrate in order to make full sense of any part of it.

Hypertext literacy is a large subject in itself (e.g. Rouet & Levonen, 1996; Reinking et al., 1998), raising basic questions of how people navigate through large hypertextual webs, and how we make meaning across both short-term, small-scale trajectories of sequentially linked webpages and also longer-term, larger-scale trajectories which may eventually include a large fraction of all the locally linked pages at a site (or within a meta-site). Hypertext literacy is feature of the emerging extended literacy of computer-based multimedia (Lemke, 1998c), which happens to have its leading developmental edge in the domain of scientific communication.

Conclusions and Initiatives

It is too early in my on-going studies of web-based multimedia genres to draw firm conclusions about the dimensions and directions of advanced literacy beyond what carries over, transformed, from print literacies. It will be important to compare not just public-interest vs. professionally-oriented websites, but also scientific websites (which are somewhat conservative in conserving the substantial cultural capital already invested in scientific print literacies) vs. more *avant garde* experiments with the semiotic affordances of web-based media. It is typical in the evolution of any medium that it first seeks to replicate familiar genres (e.g. early live television and theatre, photography and painting, email and office memos, web chat and conversation), but then creates new genres of its own (music videos, strobe photographs, listgroups, the emerging distinctive CHAT register). The webpage itself is a new proto-genre, evolving away from its antecedents in printed-page composition, and it will likely diverge into many new genres fitting specialized functional niches.

Meanwhile, analysis of web-based scientific genres continues to show us the institutional connections of scientific texts in ways that may be more obvious on the web than in print. The NASA homepage shows ample evidence of political intentions (e.g. its anti-drug message), and elsewhere in the site it is easy to trace the new emphasis on ‘doing business’ that has been added to the original mission of ‘doing science’. It would be interesting to know how many links there are from webpages in the .mil (military) domain to those in nasa.gov. The site also shows the many means by which different kinds of users are differentiated, from ‘kids’ to ‘educators’ to ‘business’ and ‘commercial technology’, from the general public to professional scientists. Institutionally, and ecologically, all these different actors and activities form a single system. We have already seen briefly here how similar presentations can be for technical and non-technical audiences; it is obvious that one is in some sense derived from the other, and it is likely that in a larger view intertextual influences circulate full-circle and the forms of technical genres take into account -- even in their reactions to or efforts at distinguishing themselves from -- less technical genres. While the differences between pages for ‘kids’ and those for professional scientists may be striking, contrasts with pages for businesses are likely to be less so, and it may be quite difficult to distinguish messages for the general public, messages for scientists as citizens, and messages for political sponsors of the NASA budget. Accordingly it becomes more and more likely that genre and register conventions, or rhetorical means, will tend to diffuse between sets of pages designed for these different user groups.

Studying a complex web domain such as *nasa.gov* also provides the opportunity to follow the connections, and disconnections, among materials created for the entire gamut of users from children to professional scientists, all within a single institutional framework. This is not possible, for example, with the print publishing industry; there are probably not very many institutions that span this range. Government science agencies in the U.S. may be unique in addressing such a broad spectrum of reader-users. Social semiotics emphasizes the institutional contexts of literate practices, and if we wish to understand how our society constructs degrees of literacy, from elementary to advanced, within a single domain such as science, it may be more useful to examine various examples all within a single discernable institutional framework, rather than institutionally unconnected instances.

Finally, any enumeration of the contexts of use of these multimedia texts must include not just those of production and circulation, but also those of the local end-users. A complete social semiotic analysis would therefore add, as additional and for some purposes privileged intertexts, interview reports and on-site fieldnotes and recordings of how people actually make use of and interpret NASA webpages. In what institutional contexts (school, business, military R&D, scientific research) do people with various science literacy backgrounds make use of these pages, and for what purposes? Whom do these pages' designs and contents serve well, and for whom are they difficult or intractable?

Many users of NASA webpages are located outside the U.S. (for the Earth Web Server, mainly nontechnical, but with links to technical data: about 15% of all accesses were from Europe, 4% from Asia, 2% from Latin America; for comparison 8% were from U.S. university domains, 16% from U.S. commercial domains which include most private individuals connecting to the internet; comparable data for a more exclusively technical website at GSFC was not recently available). Technical users presumably have no difficulty accessing the pages in English, which is the dominant language of international science and technology, but those less proficient in either or both the English language and the thematic formations of relevant scientific subfields in any language, will have particular difficulty. There are webpage translation engines, but they are general-purpose and do not do well with technical registers, even though for a specialized translation engine these predictable and routinized registers are rather easily translated. I suspect that familiarity with the conceptual semantics of the relevant scientific field in any language is more relevant to successful understanding of a scientific text in English than is general English proficiency, at least beyond a very rudimentary skill in the language. If this is true, then teachers of science may be better prepared to teach scientific English than are teachers of the English language, at least in the sense that they could acquire the necessary language concepts in far less time than language teachers would require to master the necessary scientific ones. (In fact, New York State will now require six credits of study in language acquisition and literacy development for all teachers, including all secondary school teachers of science. New York State Education Department, 1999.)

It is commonly believed that the presence of mathematical and visual-graphical elements also aids scientific comprehension in a second language. Whether this is so may depend not so much on the debatable ‘universality’ of the nonlinguistic semiotics (they are in any case internationally standardized in science across languages) as on whether students have learned their conventional forms and meanings by having previously integrated them with verbal text in any language.

It is presumably easier, especially at later ages, to teach students the necessary multimedia forms and conventions in a language in which they are proficient and otherwise experienced in dealing with scientific topics, and then assist them to make similar connections of mathematical formulas, diagrams, graphs, etc. to English text, once the combined meanings of text and image have initially been grasped. In a social semiotic perspective there is far less difference between 'learning science' and 'learning scientific English' (Lemke, 1990a) than in theories which describe language entirely as a matter of forms, separable from semantic content and function, or which regard 'science' or 'scientific knowledge' as objective or mental realities separable from using language and other semiotic resources in social practices. There is no science without language, and no mastery of scientific English separate from the comprehension of some set of scientific concepts.

If we extend this view to the integrated deployment of multiple semiotic modalities, then scientific 'concepts' are themselves multimedia entities (Lemke, 1998a). What it means to understand a scientific concept is to be able to mean with it, and we normally make scientific meaning only in some combination of words, images, and mathematical and graphical signs. Advanced scientific literacy means both using advanced literacy skills specific to scientific activity and making specialized scientific meanings that cannot be made without using some language, in conjunction with other semiotic resources. It is particularly clear in the domain of scientific activity that language skills as such are not separable in practice from the particular kinds of meanings to be made, nor from the other semiotic resources needed to do so.

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Figure Titles/Captions

Figure 1a. NASA Earth Observatory Observation Deck Webpage (January 2000, http://earthobservatory.nasa.gov/Observatory/)

Figure 1b. NASA Earth Observatory: Life on Earth, Vegetation Dataset Webpage (January 2000, http://earthobservatory.nasa.gov/Observatory/Datasets/ndvi.avhrr.html)

Figure 1c. Display of Vegetation NDVI Data in Animated World Map with Key (January 2000, http://earthobservatory.nasa.gov/Observatory/showqt.php3)

Figure 2a. NASA Goddard Space Flight Center Earth Sciences Distributed Active Archive Homepage, Cursor over Atmospheric Chemistry link, Displaying Ozone Depletion
(January 2000, http://daac.gsfc.nasa.gov/DAAC_DOCS/gdaac_home.html)

Figure 2b. NASA GSFC DAAC Homepage, Cursor over Land Biosphere link, Displaying Global Vegetation (same URL as for Figure 2a, different cursor position)

Figure 2c. NASA GSFC DAAC Homepage, Cursor over Interdisciplinary link, Displaying Global Warming (same URL as for Figure 2a, different cursor position)

Figure 2d. NASA GSFC DAAC Homepage, Cursor over Atmospheric Dynamics link, Displaying Monsoon Dynamics (same URL as for Figure 1a, different cursor position)

Figure 3a. NASA EOS Data Gateway: Data Search and Order Form Page
(Access via link: Enter as Guest from
http://harp.gsfc.nasa.gov/~imswww/pub/imswelcome/plain.html)

Figure 3b. NASA GSFC Global Land Biosphere Data and Resources, Climate Data Set Webpage (January 2000,
http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/LAND_BIO/Climate_ds.html)

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