

Workshop Summary Report

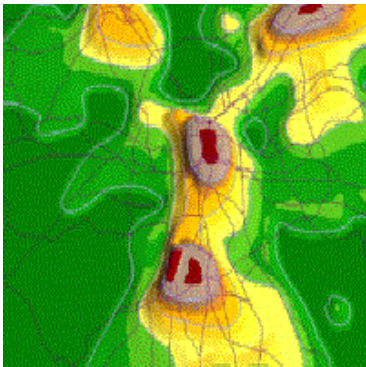
Houston Cool and Green!

A Workshop on Climate Variability in the Houston Region

New Technologies • New Opportunities

Houston Advanced Research Center, The Woodlands, Texas

May 24 and 25, 1999



Organized by:

Sustainable Enterprise Institute and HARC Center for Global Studies

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Rationale

Houston Cool and Green , a workshop held at the Houston Advanced Research Center in The Woodlands, Texas, May 24 and 25, 1999, brought 130 stakeholders together to discuss the uses of emerging technologies in documenting climate and other environmental changes and to plan mitigation strategies for the Houston region. In particular, the conference focused on environmental applications for remote sensing, planning applications and geographic information systems in a region dominated by an urban environment. Heat islands, habitat and greenspace conservation, flooding issues, meteorology, health and growth issues brought together a diverse audience to formulate plans to work across disciplines.

New technologies and planning tools can pinpoint the most urgent needs and quantify economic benefits and impacts. Because imagery can be used to show change graphically and quantitatively, it can be persuasive in demonstrating the extent of change. Digitized maps can be linked through a geographical information system (GIS) to show linked distributions of many types of statistics for the region.

Heat island reduction locating the hot spots , then planting trees and using reflective roofing and paving surfaces was presented as a way to cool the area, increase green space, reduce air pollution, and offer commercial opportunities. By relating the history of community involvement in areas where these ideas and technologies have been applied, presenters showed participants how these concepts and procedures might be applied in the Houston area. On the second day, interest groups met to devise plans for projects on the regional and local levels to use these ideas and technologies.

The United States Global Change Research Program

This workshop is one of several associated with the Southern Great Plains regional assessment of the United States Global Change Research Program (USGCRP), mandated by Congress under the Global Change Research Act of 1990 (P.L. 101-606). More than twenty such workshops have been held around the United States since 1990 in order to link research by scientists to specific needs of stakeholders in each region. The workshops are intended to provide planners, managers, organizations, and the public with information to cope with climate change, shaped to fit the unique priorities within each region.

Sponsorship

The Texas A&M Sustainable Enterprise Institute and Houston Environmental Foresight, a project of the Center for Global Studies at the Houston Advanced Research Center, produced the workshop under the sponsorship of the United States Department of Agriculture.

Support was also provided by Houston Environmental Foresight, whose current sponsors include:

Underwriter	Houston Endowment, Inc.
Benefactors	HARC, Compaq Computer Corporation, PriceWaterhouseCoopers, and The Harris and Eliza Kempner Fund
Contributors	City of Houston, San Jacinto River Authority, The Lyons Foundation

Cooperating Organizations

American Forests
Bayou Preservation Association
Center for Global Studies
City of Houston
HARC Environmental Information Systems Laboratory
Environmental Institute of Houston
GHASP (Greater Houston Association for Smog Prevention)
Gulf Coast Institute
Harris County Flood Control District
Houston-Galveston Area Council
NASA Johnson/ Houston Space Flight Center
NASA Marshall Space Flight Center
NASA Stennis Space Center
San Jacinto River Authority
Texas A&M Sustainable Enterprise Institute
Texas Forest Service
The Park People, Inc.
Trees For Houston
U.S. Department of Agriculture
U.S. Environmental Protection Agency

Planning Committee

Glenda Barrett

The Park People, Inc.

Richard Cate

MCCM Architects

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Citizens Environmental Coalition

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Katharine Lord

Trees For Houston

Jeff Taebel

Houston-Galveston Area Council

Mike Walters

Harris County Flood Control District

Mary Ellen Whitworth

Bayou Preservation Association

Background

The Houston Region

Greater Houston encompasses an ethnically diverse urban area of nearly 2,000 square miles with more than four million people. The region contains the nation's largest port, as well as one of the world's most extensive oil and petrochemical complexes. Houston has forged multiple links with the international economy through trade, industry, finance, and agriculture, and is the principal point of entry for trade with Mexico. The 8-county region around Houston includes agricultural, ranching, and timber lands, as well as an astonishing variety of ecosystem types: marine, barrier island, estuarine, bottomland forest, upland forest, prairie, and freshwater.

Houston Environmental Foresight and High Priority Environmental Issues

In 1995 the Houston Environmental Foresight Program published *Houston Environment 1995*,¹ a compilation of current scientific information about environmental issues in the region. A diverse group of stakeholders combined the evaluations by three science subpanels with community values to arrive at a comparative risk ranking for the Houston region *Seeking Environmental Improvement* (1996).² The highest priority issues were Outdoor Air Pollution, Indoor Air Contamination, Habitat Alteration and Loss, and the need for Parks and Open Space. Flooding and water pollution, issues rated as a High priority, were also addressed by this workshop. Foresight work groups are currently drafting recommendations to address these issues. The Foresight program has a wide variety of community stakeholders actively considering problems related to workshop issues. The Houston Cool and Green workshop widened the stakeholder group considering these issues and identified ways of working together to reduce impacts of several problems at the same time.

Highlights of Current Initiatives in the Region

Air pollution and the need for additional parks and green space, as well as the high priority issues of water pollution and flooding,³ have risen to prominence in the past year. The Houston region now ranks second to Los Angeles in ozone levels. A broad coalition of city, county, and regional stakeholders recently formed to suggest regional control measures for modeling in the Texas air quality State Implementation Plan. If the plan fails to demonstrate air quality attainment by 2007, the Houston region faces sanctions. The City of Houston recently commissioned a study of the human health effects of air pollution; preliminary results showed a cost of more than \$3 billion resulting from ozone and particulate effects. In addition, the City of Houston has signed a Heat Island Reduction Initiative agreement with the Environmental Protection Agency. Next year the Texas 2000 Southern Oxidant Study (SOS) will combine air chemistry research with remote sensing in an attempt to characterize the distribution and origins of ozone in a region with complex meteorology.

¹ Wilson, John D., Sabrina Strawn, and David Hitchcock, editors. *Houston Environment 1995*. Houston Environmental Foresight, Houston Advanced Research Center, Center for Global Studies, The Woodlands, TX. 1996.

² *ibid*

A draft parks plan for the City of Houston⁴ recognizes the need for additional parks and green space, and the COTSWOLD project incorporates trees and green space as a component of downtown revitalization. Dr. David Allen's research group at The University of Texas at Austin has recently completed a Leaf Biomass Density study for the Houston region.⁵ The Green Sector Initiative proposes a way, at least in Harris County, that through incentives development can be encouraged in less sensitive areas and discouraged in wetlands and floodplains and other environmentally sensitive areas. Around the region projects such as the Lower Trinity River Floodplain Habitat Stewardship Plan⁶ seek to stem the loss of habitat necessary to support biodiversity.

Climate Variability Issues

Rapid urbanization, subsidence, lack of elevation, extreme weather incidents, high precipitation rates, and development in the floodplain have led to a dramatic increase in flooding in recent years. Houston ranks near the top in repetitive flood loss claims in the recent National Wildlife Federation report, *Higher Ground*.⁷ In addition to remapping the floodplain, FEMA, the Harris Co. Flood Control District, and many other organizations are looking for ways to reduce losses from unwise development in the floodplain.

In contrast, prolonged heat and drought in 1998, with the promise of similar conditions in 1999 both in Texas and Mexico, have stressed existing trees and vegetation and led to rising danger of uncontrolled brush and forest fires. In 1998 persistence of smoke from fires in Mexico sounded a wake-up call to Texans about how little can be done once severe pollution exists.

⁴National Wildlife Federation, "Higher Ground: A Report on Voluntary Property Buyouts in the Nation's Floodplains. Washington, DC, National Wildlife Federation, July, 1998.

⁵Yarwood, Greg et al, ENVIRON International Corp., Novato, CA; Allen, David et al., Dept of Chemical Engineering, The University of Texas at Austin; and Guenther, Alex, National Center for Atmospheric Research, Boulder CO., "Leaf Biomass Density Data for South East Texas", February 12, 1999.

⁶U.S. Fish & Wildlife Service, "Lower Trinity River Floodplain Habitat Stewardship Program, March 1999.

⁷National Wildlife Federation, op. cit..

Workshop Presentations



The first day of the workshop included seven presentations on applications and technologies that could be applied in the Houston region. These presentations are summarized below.

Pictured to the left are some of the workshop speakers. From left to right are Dr. Kam Lulla, Dr. Jack Hill, Dr. Dale Quattrochi, Alice Ewen, Virginia Gorsevski, Wil Orr, and Ron Birk

Urban Applications of Remotely Sensed Data and Information

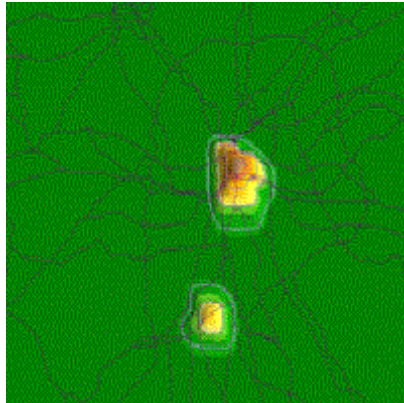
Dr. Dale Quattrochi and Dr. Jeff Luvall, NASA Marshall Space Flight Center

Although the primary mission of NASA has been to explore space, manned and unmanned spaceflights have also resulted in an enormous amount of data about the surface and atmosphere of the earth. Today the many NASA centers located throughout the United States are cooperating to learn more about the earth's environment and to share that knowledge with citizens in local and regional applications. The NASA Marshall Space Flight Center's Global Hydrology and Climate Change Center, located in Huntsville, Alabama, has recently been active in mapping urban heat islands and in teaming with NASA's Stennis Space Center in promoting commercial applications, Prescott College in Arizona in developing urban planning software tools, American Forests in urban applications through Project Atlanta (ATlanta Land use Analysis: Temperature and Air quality), and the U.S. Environmental Protection Agency in its Urban Heat Island Reduction Initiative Pilot Project (UHIPP).

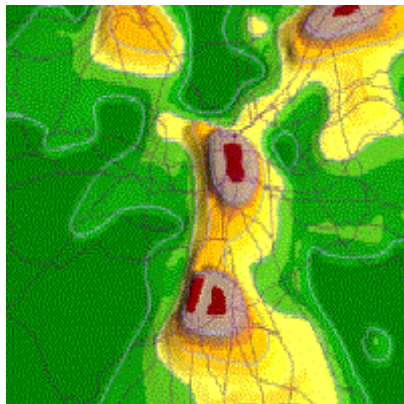
Types of Remote Sensing Useful in Urban Applications

Remote sensing has been useful in understanding the earth's surface since the Landsat series of satellites were launched in 1972. Remote sensing refers to obtaining information about an object without having direct contact with it (i.e., touching it). Remote sensing focuses on the collection of data from a variety of sources, such as aerial photography, radar, thermal imaging, and LIDAR. With the launch of the Landsat satellites in the early 1970s, remote sensing entered the era of multispectral data collection which refers to collecting quantitative data over a range of spectral band widths, as well as increasingly higher spatial resolution. When linked with other data through geographical information systems (GIS), remote sensing data becomes a powerful tool for understanding land use changes, climate changes, and

effects of thermal distribution. NASA remote sensing tools for urban applications fall into several categories:



1972 Atlanta temperature map



1993 Atlanta temperature map

Land use/land cover change through time-from satellites

- 1972-present —Landsat Multispectral Scanning System Thematic Mapper (MSS/TM) data, with a resolution of 80 meters on LANDSAT 1-3 and 30 meters on LANDSAT 4, 5, and 7
- 1982-present —Landsat Thematic Mapper and Landsat Enhanced Thematic Mapper Data (from Landsat 7) thermal data

Airborne Data from aircraft

<http://www1.msfc.nasa.gov/NEWMISFC/earth.html>

High spatial resolution **Advanced Thermal and Land Applications Sensor (ATLAS)** aircraft data NASA Marshall Space Flight Center hopes to be able to map the Houston area during the spring/summer 2000. This data can be collected on clear days with a 10-meter resolution between 11 a.m. and 3:00 p.m. to capture the highest incidence of solar radiation across the city landscape and show the distribution of heat islands. These are the maps that were used in Project Atlanta and in the EPA Urban Heat Island Initiative Pilot Projects in Sacramento, Salt Lake City, and Baton Rouge (see examples of ATLAS data collected over Atlanta, Georgia at <http://www.ghcc.msfc.nasa.gov/overview/urban.html>).

NASA ER2 MAS⁸ data (50m resolution) — NASA MSFC will include scanning spectroradiometer remote sensing imagery in its spring/summer 2000 proposal for the Houston area.

Coarse resolution satellite data

GOES /AVHRR for heat and land cover mapping ~1980-present

Geostationary Operating Environment Satellites (GOES) with Advanced Very High Resolution Radiometers (AVHRR) provide frequent images of the earth's surface at 5 different wavelengths, including a visible wavelength channel and four infrared channels. Thermal data can be obtained from the AVHRR at 1 km spatial resolution.

New satellite sensor data

TERRA (Earth Observing System(EOS)⁹) AM1) platform data (ASTER¹⁰, MODIS)¹¹

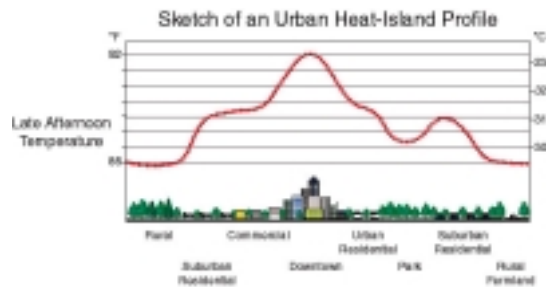
⁸ The MODIS Airborne Simulator (MAS) is an airborne scanning spectrometer that acquires high spatial resolution imagery of cloud and surface features from its vantage point on-board a NASA ER-2 high-altitude research aircraft. Data acquired by the MAS are helping to define, develop, and test algorithms for the Moderate Resolution Imaging Spectroradiometer (MODIS), a key sensor of NASA's Earth Observing System (EOS). The MODIS program will emphasize the use of remotely sensed data to monitor variation in environmental conditions for assessing both natural and human-induced global change". <http://ltpwww.gsfc.nasa.gov/MODIS/MAS/index.html>

⁹ http://eosps0.gsfc.nasa.gov/eos_homepage/description.html, <http://www.earth.nasa.gov/history/index40.html>

NASA's Terra spacecraft is scheduled for launch into polar orbit from Vandenberg Air Force Base on 27 August, 1999. It will contain ASTER and MODIS sensors as well as other instruments that can look at many aspects of the earth's climate and meteorology from several different angles. See <http://terra.nasa.gov/>, as well as the ASTER and MODIS websites. Terra is the flagship of NASA's coordinated effort to study the earth's total environment from space.

Other agencies such as NOAA and USGS have also been active in remote sensing and have mapping and photographic data available from archives. The National High Altitude Program (1980 to 1987) (http://edcwww.cr.usgs.gov/napp/napp_examples.html) produced an extensive series of black and white aerial photographs of the lower 48 states.

Urban Heat Islands



One of the most interesting and useful recent applications of remote sensing technology has been the study of urban heat islands. Remote sensing, when combined with meteorology information and other data through a geographical information system, can show how heat islands are distributed and help to explain why they develop. Heat islands are of interest to planners, elected officials, policy decision-makers, and the public because they affect energy consumption, public expenditure, air pollution, and health.

What Causes Heat Islands?

On warm summer days with calm winds, the air over a city can be 2-8° hotter than the surrounding countryside. In urban areas, there are fewer trees to provide direct shading and also additional cooling through evapotranspiration, the evaporation of water from the surfaces of leaves and soil. In addition, roof and paving materials with low reflectivity absorb more of the sun's rays, causing both surface temperature and overall ambient air temperature to rise. For example, roofs of tall buildings have been measured at temperatures as high as 60 °C. A typical profile of the urban heat island effect is shown to the left.

What are the Effects of Heat Islands?

Higher ambient air temperatures result in increased use of air conditioning in city buildings, causing higher energy use as well as higher energy costs in monthly utility bills. Whenever fuel is burned to produce electricity, the combustion results in release of CO₂, NO_x (oxides of nitrogen), and VOCs (volatile organic compounds). NO_x and VOCs combine in the presence of sunlight on hot, summer days to form ground-level ozone, or smog; the rate of ozone formation is accelerated when the temperature is

¹⁰ ASTER: Advanced Spaceborne Thermal Emission Radiometer. For some applications and an explanation, see the NASA Jet Propulsion Laboratory sites at <http://asterweb.jpl.nasa.gov/> and <http://asterweb.jpl.nasa.gov/asterhome/apps/urban/default.htm>

¹¹ See MODIS website reference footnote 1

higher. Thus, the urban heat island effect can precipitate higher incidences of ozone by adding additional heat to the overall chemical interactions that form ozone. In addition, stationary sources such as automobiles and machinery evaporate more fuel and other VOCs when the temperature rises. Higher temperatures exacerbate health problems, such as heat stress and asthma.

Project Atlanta



Infrared image of Atlanta

Atlanta, an urban area similar in many ways to the Houston area, has undergone tremendous growth in recent years. Without natural boundaries to contain its growth, Atlanta has sprawled out around a 110 square mile area. As development has occurred, American Forests estimates that Atlanta has lost over 60% of its tree canopy over the last 25 years and now has only 35% tree cover (Atlanta is still considered one of the greenest cities). American Forests considers 40% tree cover to be necessary to maintain cooling and erosion protection functions of trees in an urban area. NASA estimates from satellite remote sensing data that urban sprawl gobbled up 55 acres per day of tree cover around Atlanta between 1973 and 1992. As more and more land is clear-cut, temperatures and air pollution rise, and erosion and flooding increase, Atlanta recently passed a strict tree-preservation ordinance. Further motivation to cool the city comes from Atlanta's struggle to live with USEPA sanctions and loss of federal highway funding resulting from failure to meet national air quality standards.

NASA Marshall Space Flight Center has teamed with U.S. Department of Energy's Lawrence Berkeley Laboratory, American Forests, the U.S. Environmental Protection Agency, the University of Georgia, Georgia State University and other investigators in Project Atlanta to study how Atlanta's heat island can be cooled. By mapping the distribution of the heat islands and finding the hot spots, American Forests has helped city planners and other organizations to mobilize in targeting mitigation measures, such as tree surveys and strategic tree planting using volunteers, replacing dark absorptive roofs with more reflective ones, and exploring the use of reflective paving materials. School children helped in ground-truthing the thermal imaging, which led to a widespread educational initiative about heat islands and how to cool the city.

Results have been shared with Atlanta area with a wide variety of stakeholders. Significant progress has been made in translating scientific information into terms that citizens can understand. The steps have been:

- Educate stakeholders about the rationale for the study, describe results and data products, and suggest possible community benefits
- Ask the applications working group to work with the science team in developing an action plan
- Have periodic meetings with community stakeholders and the science team to provide project updates and review progress
- Develop data products in response to stakeholder priorities.

An interesting result of Project Atlanta has been discussions with EPA about the quantitative use of heat island mitigation results in State Implementation Plan (SIP) assessments for air quality standards attain-

ment modeling. This bears directly on developments in the Houston area. Other results are plans to use heat island project research in the development of a 20-year environmental plan for Atlanta and the redevelopment of a brownfields area. The National Park Service is experimenting with the use of porous paving materials for a parking area in North Atlanta. Georgia State University has replaced several roofs with reflective roofing materials, based on results from the Project ATLANTA study, and will assess quantitative effects as part of a student research program.

EPA/NASA - Urban Heat Island Mitigation Pilot Cities Project (UHIPP)

Dr. Jeffrey C. Luvall, PI, Dr. Dale Quattrochi, Co-PI, Marshall Space Flight Center

http://science.nasa.gov/newhome/headlines/essd20nov98_1.htm

Another project of the Marshall Space Flight Center, in cooperation with the U.S. EPA, has been the Urban Head Island Mitigation Pilot Cities Project (UHIPP). The goals of this project are to:

- Quantify the thermal and albedo structure of the selected cities using airborne scanner data in order to identify the "hot" and "cool" areas of the city. Relate the urban landscape structure to land use planning and how this affects the surface temperature of the city.
- Demonstrate the benefits of urban heat island mitigation measures on energy use and local air quality.
- Provide quantifiable data for making informed decisions in implementing urban heat island mitigation measures.
- Develop close working relationships with local planners, policy-makers, and non-profit groups within each city for the transfer of results and technology derived from analysis of high spatial resolution ATLAS data for the benefit of the community.

Two major strategies we are taking to reduce the urban heat island and improve air quality are strategic landscaping and albedo modification

Strategic Landscaping

- Shade buildings to directly reduce cooling demand
- Help lower ambient air temperature through evapotranspiration

Albedo Modification

- Install highly reflective surfaces on roofs and paved areas to reflect rather than absorb incoming solar radiation.

Lessons from Project Atlanta: Essential Aspects of a Local Stakeholder Heat Island Reduction Program

Lucie Griggs, American Forests, Atlanta



Involving the business community is essential. If you don't have the right people, no one will listen. Examples are local development and engineering companies, the Urban Land Institute, and the Chamber of Commerce. Consider the following positive aspects of a possible program area:

- Targets for cool communities programs
- Mid-size population centers, with a heat island effect
- Cross-section of communities based on climate and geography
- Local utility program with active public awareness outreach program
- Interested, active and committee municipal government agencies
- Significant corporate presence
- Relevant and diverse citizen organizations (i.e., non-profit organizations)
- New developments with potential to implement cool communities strategies
- Significant media opportunities
- Active state or local nursery organizations
- Strong state and local forestry programs, energy, extension, service presence
- University, college research presence
- Potential for minority/ non-traditional outreach
- Dedicated community leaders

One of the most important consequences of heat island reduction initiatives is that they produce quantitative, unbiased data that gets a variety of people together to work constructively on a common problem. In many cases, commercial applications make, as well as save, money. One of the key factors that must be understood in implementing a vibrant grass-roots urban heat island mitigation program is that efforts must be couched in economic terms; i.e., cost-benefit or other economic benefits. Otherwise community leaders, commercial enterprises, housing developers and others will not become stakeholders in heat island reduction efforts.

Other Heat Island Reduction Programs

The American Forests Cool Communities program helps communities plant trees strategically to cool urban areas. Volunteers are trained to do urban ecological analysis, and the information is entered into CityGreen software, an urban forest modeling program, to determine optimum tree planting species and locations. The U.S. EPA has a Heat Island Pilot Project (UHIPP) that has linked with NASA remote sensing imagery for pilot projects in several cities, including Sacramento, Baton Rouge, and Salt Lake City using high spatial resolution (ATLAS) thermal infrared imagery. Other cities that are being studied as part of this project using coarse resolution satellite (AVHRR) thermal infrared imagery include Los Angeles, Phoenix, Tucson, Chicago, Nashville and Houston. The Lawrence Berkeley National Laboratory has a testing program for roofing and pavement materials that rates their reflectivity and emissiv-

ity and hence their effectiveness in reducing heat absorption, surface temperature, and surrounding ambient air temperature.

Cooperation with meteorological researchers has shown that urban heat islands can produce unique weather for urban areas. Although further analysis of how urban heat islands impact local or even regional weather is necessary, understanding what the effects are of cities on weather will assist in helping build more habitable and sustainable urban environments.

Regional Land Use / Land Cover Applications

Dr. Kam Lulla, NASA Johnson / Houston Space Flight Center

NASA Houston/Johnson Space Flight Center is very interested in sharing the products of its scientific research with the Houston area community. The byproducts of both the manned and unmanned spaceflights provide useful resources for understanding environmental changes in the Houston area and for planning.

For example, earth observations from the human spaceflight platforms offer optical data about how the earth looks from space; these are important to bring people to the realization that all parts of the system are interconnected. The astronauts are intelligent people looking at the earth; they can document landscape change from episodic events such as flooding. An Internet-based photo database and catalog contains a vast number of digital images taken by astronauts from the space shuttle:

<http://images.jsc.nasa.gov/>

<http://spacelink.msfc.nasa.gov/Instructional.Materials/Curriculum.Support/Earth.Science/Earth.Images.From.Space/.index.html>

From.Space/.index.html

<http://earth.jsc.nasa.gov/lores.cgi?PHOTO=STS055-071-043>



Dr. Lulla speaking to workshop participants at HARC

Coastal communities are especially impacted by climate variability, population pressure, and the interaction of complex systems. For Houston several thousand images are available from spacecraft photos; these show the history of the landscape over the last 25 years. Detecting changes over the earth's surface through these photos can be useful for planners. The shuttle also contains earth-looking sensors. Window observations, astronaut-directed earth imaging, atmospheric sensors, and other payloads attached to the shuttle and the International Space Station can provide land use/ land cover data for this area. These images cover 75% of the earth's land and water, including the major urban areas, with 60, 30, and 10 meter resolution.

The United States Geological Survey (USGS) land use classification system is applied to the photographs obtained. Level 1 shows a profile of how urban / agricultural land uses have changed over the last 20 years. Level 2 can show different urban use classifications. When a census base map is overlaid, it can

graphically illustrate rapid change in this area. Overlays of the evolution of the transportation network or neighborhood analysis can further enhance this data. Using Natural Resources Conservation Service maps of natural landscape elements and watersheds, maps can show population density against stress to natural systems; for example, soil boundaries can be shown relative to increases in salinity. By combining layers, a GIS shows relationships.

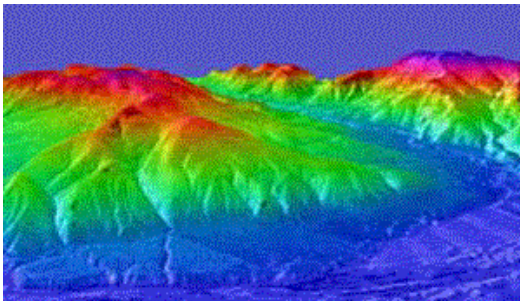
NASA Johnson wants to provide a local resource to the community. A recent study showed that 92% of taxpayers were concerned about earth's environmental condition. Human health is related to the health of natural ecosystems. Through our GIS spatial and image processing, we would like to expand our partnership with education. We have accurate land cover maps, remote sensing data that has been furnished to Texas state agencies from Landsat data, shuttle imagery, and future opportunities. Communities can propose data sources to target..

Commercial Applications of Remote Sensing

Dr. Bruce Davis, NASA Stennis Space Center

Dr. Ron Birk, Intermap Technologies

<http://www.crsp.ssc.nasa.gov>, <http://www.globalterrain.com>, <http://www.possys.com>



Radar generated terrain map

Commercial applications of remote sensing often involve ways to use geographical information systems (GIS) to improve understanding of possible impacts of different decisions. Planning possible transportation routes offers a good example. Cost and impact can be related visually. By iterating variations of weighting for contributing decision factors and then showing impacts and costs, various routes can be visualized with respect to traffic density, cost, surrounding atmosphere, and community impact. Other examples are:

- mapping coastal waterways to show impacts of ecotourism
- planning optimal routes for Emergency Response Vehicles
- real estate geographical information systems showing sewer lines, water lines, existing houses, electric lines, and percent shade on lots to plan optimum use of land during development
- monitoring natural disasters using a simulated fly-through of various neighborhoods with an on-line database of the natural and built features of the area.
- near real-time monitoring of all parts of a hurricane, showing the real destruction at all parts of the storm on the back side of the eye, making it possible to understand and prepare for storms

NASA enters into public/private partnerships with businesses in order to help businesses develop new capabilities. No money changes hands; the techniques developed become available to other companies.

Dr. Birk described two of the technology companies associated in partnership with NASA Stennis Space Center in development of new technologies, acquisition of data, and making it available to public and private companies and researchers Intermap Technologies and Positive Systems, Inc.

Intermap Technologies, a public company, prepares and offers for lease Digital Elevation Models (DEMs) based on various types of data ranging from precise airborne imaging to satellite derived images. These models can be flown through using computer imaging technology in which colors convey elevation and topography. These models are particularly useful for urban topography and mapping (radar is more often used for rural applications). Environmentally sensitive areas can be coded and can be seen in high resolution imagery using an urban 3-D flythrough. Examples of applications include:

- flood plain zonation maps
- contour maps
- avionics and flight safety applications
- hydrology maps
- agricultural mapping (fertilizer or pesticide application based on soil type, crop variety, and other micro-variables)
- cloud penetrations (where to seed)

Images are located precisely using a geodetic referencing system with one-meter resolution. Maps are sold by license, per tile. See price list on the <http://globalterrain.com> website.

Positive Systems, Inc. (<http://www.possys.com>) develops and markets airborne image acquisition systems (ADAR) and custom imaging services. This orthorectified high resolution multispectral imagery is particularly useful for detecting and analyzing change, since resolution is 100-1000 times higher than that of satellites. Areas of application include

- environmental monitoring
- precision agriculture
- forestry
- industry
- regulatory compliance
- urban planning

Q: How ready are city governments to take these technologies and use them?

A: It varies. Cities that have major universities with GIS expertise and good geography departments are more likely to be interested and have access to the expertise to interpret the images. By nature this kind of analysis is multi-jurisdictional. City bureaucracy tends to be departmentalized; so bureaucratic structure can be a problem. Funding is not so much a problem as is having people on the city or regional staff who can interpret and work with the data as well as charter and mandates. Making decisions may require use

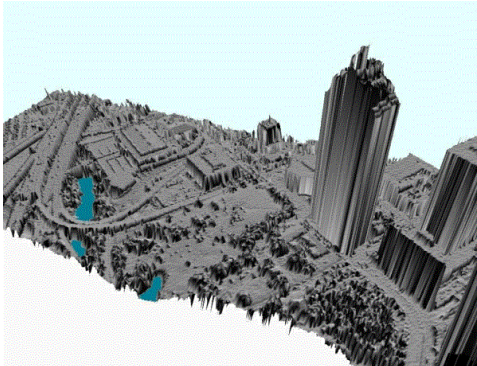
of many data sets, integrating across jurisdictions and disciplines. Governments need to consider the costs of *not* planning vs. paying for tools that help in planning wisely.

Q: Does every community need high level expertise to accomplish this?

A: NASA Stennis helps with creating the prototype for new developmental technologies. These are stimulated by partnerships between the federal government, universities, and local or regional governments, who cooperate to do demonstration projects. The results of these projects can be shared with other governments.

LIDAR Imaging and Applications

Dr. Jack Hill, Houston Advanced Research Center, Environmental Information Systems Laboratory



LIDAR image of Galleria/Uptown area of Houston

The Environmental Information Systems Laboratory (EISL) uses advanced computer technologies to integrate, visualize, and analyze spatial data for a variety of environmental projects. EISL operates on the forefront of a number of technologies that have been used to address area environmental issues. By combining technologies and databases as appropriate, EISL can deliver answer maps that show distribution and extent of statistical and geographical information visually. To prepare these maps, EISL uses appropriate combinations of aerial photography, aircraft or satellite imagery, archive maps, textual or statistical databases, ground-based sensors, mathematical models, and expert knowledge.

Overlapping layers of data can be viewed, referenced to common address correlates, to show current situations and the development of situations over time. An example of an overlay prepared for the Federal Emergency Management Agency (FEMA) shows a graphic overlay of development in the last ten years with the floodplain shown in a contrasting color. Since increased development leads to more impervious areas and therefore less opportunity for runoff and increased flooding, showing this truth map with development in the flood plain can deliver a compelling message.

LIDAR shows terrain and earth features three dimensionally by reflecting laser beams every ten feet toward the surface of the earth from different angles and timing their return. The airplane, which usually flies at night to avoid shadows, has gyroscopic pitch and roll corrections and a ground positioning system (GPS). LIDAR data is overlaid with USGS maps and other GIS data and ground-truthed with aerial photography.

EISL has been particularly active in the Houston area in its use of LIDAR imagery to show three-dimensional maps verified by video photography. For example, EISL used airborne laser imaging to assist Project Impact, a FEMA project designed to increase emergency preparedness and target resources for emergency response. EISL technology is also being used to track pipelines involved in widening the Port of Houston and to search for industries that might be causing a spill.

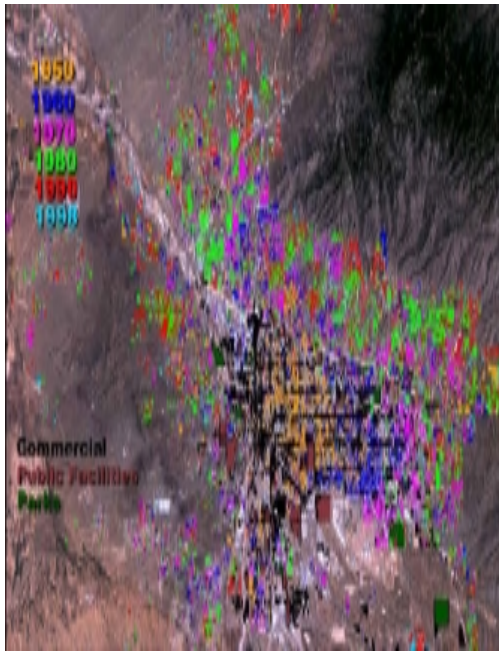
EISL has used LIDAR for the Harris County Flood Control District (HCFCD) and the Federal Emergency Management Agency (FEMA) to map floodplains more accurately, using three-dimensional imagery. This information is being put into digital insurance maps.

LIDAR imagery would be useful in showing three-dimensional implications of heat islands, for example, height of buildings. Different applications, with their varying resolutions, work better for different applications. Although radar works better for most rural applications, LIDAR works better in urban applications because of the density of information. You can see, for example, which streets, houses, and buildings flood.

Beginning with baseline information, GIS technology can be used to forecast various scenarios of the future and suggest what effects modifying the landscape might have before we do it. These technologies help in bridging the gap between science and engineering and policy makers by making information visible and easy to comprehend.

Responses: Integrating Technologies for Community Planning

Wil Orr and Hoyt Johnson, Prescott College, Tucson, AZ and NASA



Development history of Tucson, Arizona produced with GIS

The Environmental Planning and Information Center (EPIC) develops decision support software that provides three-dimensional visualization as well as two-dimensional GIS-based predictive models. This project, which is funded by NASA, provides a useful tool for planners and decision-makers for making decisions in an environment of uncertainty.

Consequences of growth or of proposed economic, transportation, or development programs can be modeled years into the future. Factors such as sprawl, water supply, air quality, traffic congestion, heat island formation, stormwater runoff, flooding and others can be visually developed over time according to parameters which the planners themselves wish to enter into the model.

The model can show visually how different management strategies might materialize over time, based on what planners Do Know, Don't Know, and what is Predicted. The model can help cities to build resilience in the face of economic extremes, weather extremes and population pressure by making wise decisions.

Climate change is one of the environmental issues that the model has addressed. Research data shows that the oceans are getting warmer both in their warm phases and cool phases that alternate annually. Temperatures are increasing, and communities need to plan for more episodes of extreme weather. Although in the history of the earth, there have been many periods when the climate would have been uncomfortable for us, we expect the amount of water (flood vs. drought) and the temperature to stay within a fairly narrow range. The Urban Growth Model relates local sustainability issues to global change. It forecasts long term consequences and provides a single metric for sustainability.

Inputs for the Urban Growth Model include historical data, previous trends, policies, climate change information, and extreme weather occurrences. Outputs include vehicle miles traveled, per capita income, land use by type housing density, number of businesses and unemployment rates, ecological footprint, and climate change under different scenarios. The program is designed to run on an ordinary computer.

According to the Urban Growth Model, heat island reduction strategies can have a maximum of up to 15-20% reduction of temperature, with 10 degrees C. average, through a maximum possible reduction of albedo and increase of tree canopy over a period of 10-15 years.

The Ecological Footprint provides the best single measure of sustainability. This represents the amount of productive land necessary to support all the resource and waste disposal needs of a community. Modeling the consequences of different development policies in terms of the ecological footprint can be shown spatially with two-dimensional GIS images.

Using remote sensing imagery you can portray growth visually over time. Three-dimensional visualization with video imaging can allow you to travel through a model.

These techniques allow planners to bring some order, process, and an electronic record to a public meeting. Many environmental problems are related; these technologies can help to show the complex interrelationships in ways that decision-makers and the public can understand.

CityGreen Software Applications

Alice Ewen, American Forests. Washington, DC



CityGreen analysis of site map.

American Forests, founded in 1875, is the nation's oldest nonprofit citizen conservation organization. American Forests through its Global Releaf program plants millions of trees each year and promotes good urban forestry practices through its Urban Ecosystem Analysis program. Active support of rural forest policy is another cornerstone of American Forests' efforts.

Urban ecosystem analysis uses computer technology to interpret the urban ecosystem and to communicate urban forest values. The urban ecosystem consists of manmade elements of the city plus tree canopy. The baseline state of the urban forest focuses on current tree inventory and the percent tree canopy. For example, Austin has 34% canopy cover, Milwaukee 18%, and Atlanta 27%. For a city to have adequate benefit from its trees, the goal should be to have 40% canopy cover. This varies depending on the part of the city: for the business district, 15% should be achievable; for suburban areas, 50% or more, and for urban residential areas 25%. In Atlanta 60% tree loss has resulted in 12 degrees increase in temperature and 12% more air pollution.

City Green

CityGreen is an ArcView-based GIS software program produced by American Forests. By entering the species composition, tree size, number of trees and % canopy cover, planners can derive the dollar costs and value of tree canopy. For example, in Atlanta removing 60% of the tree canopy has resulted in a loss of \$1 billion in stormwater management benefits, \$15 million in air pollution costs, and an increase of \$4.6 million in energy use from increased air conditioning demand.

In Puget Sound, rapid growth has led to a 37% decrease in natural habitat and 50% increase in urban area. CityGreen shows 1.2 billion square feet of water leading to a 29% increase in stormwater runoff as a consequence of the loss of tree cover.

Around the Chesapeake Bay American Forests is studying canopy cover losses on a watershed basis. The LANDSAT region level forest canopy cover records can be incorporated into the program and overlapped



with land uses. This shows high canopy areas decreasing from 47% to 27%, low canopy increasing from 45 to 68%, average canopy decreasing from 44 to 30%, and runoff increasing by 28%.

To use CityGreen for an urban ecological analysis, you begin with an aerial photo at a low level and digitize land features, tree canopy, grass and pervious surfaces, and roads and buildings. Volunteers can be employed to gather field data on trees: size, species, health, trunk diameter. These data are incorporated through an Excel spreadsheet. The tree data are georeferenced according to their relationship to buildings. From this you can derive stormwater benefits¹², air quality benefits¹³, and energy conservation benefits.

Growth of trees several years into the future can be incorporated into the model to show effects later. If you already have GIS files for roads and buildings, you can use them in the model. Volunteers will need training in data collection and species identification.

In Dade Co. the model showed how much energy savings could be accomplished just by planting one tree at each single family home. This was enough to influence passing an ordinance to plant trees.

The chief value of CityGreen is in communicating with the public and decision makers about the value of trees. You can show the value of parking lot landscaping and retention strategies for soil conservation.

In Gainesville Florida a local developer is using CityGreen to find solutions to be able to keep more trees. Although there was a 10% mandate in the ordinances, he managed to keep 35% after realizing that preserving tree canopy would reduce stormwater runoff and require less investment in having to build retention ponds.

The new version of CityGreen should be available in mid-summer 1999; it will incorporate the growth rates of various trees vs. mortality factors. American Forests website is <http://www.americanforests.org>.

¹² Requires % impervious cover vs. tree canopy, precipitation rates, average slope, and TR55 formula for urban hydrology from a small watershed model.

¹³ Requires carbon storage, rate of sequestration, pollution removal by trees, ozone, SO₂, and particulate removal rates.

U.S. Environmental Protection Agency (EPA) Heat Island Reduction Initiative (HIRI)

Virginia Gorsevski, U.S. EPA

What is an urban heat island?

In urban areas on hot summer days the city can be as much as 8 °F. hotter than surrounding rural areas. This urban heat island effect occurs because buildings and pavement which have replaced natural vegetation over decades of development, absorb rather than reflect much of the incoming solar radiation. The overall effect is to increase ambient air temperature.

In addition, development reduces the amount of tree canopy in a given area. The loss of cooling when trees are cleared results not only from the absence of shade, but also because vegetation serves to cool ambient air temperature through a process known as evapotranspiration which occurs as moisture is released naturally into the air.

Why reduce heat islands?

Higher urban temperatures in the summer lead to greater use of air conditioning and therefore increased energy consumption for cooling. Saving energy by reducing the necessity for air conditioning not only saves money but also reduces the amount of NO_x (oxides of nitrogen) released into the air. Since NO_x and elevated temperature are two of the primary factors that influence the formation of ozone (smog), reducing ambient heat levels can significantly and measurably reduce smog and therefore improve air quality.

In addition to increasing smog on a local level, higher demand for cooling energy also affects the global environment by increasing the amount of carbon dioxide (CO₂) in the atmosphere due to the burning of fossil fuels. Elevated temperatures can affect weather patterns and increase the number of precipitation events. In an area like Houston, where flooding is a long-term problem that is currently growing more serious, reducing ambient heat levels can have regional as well as global effects.

High heat levels also produce health problems, such as heat stress, aggravated asthma and other respiratory symptoms, particularly in children and older adults. Cooling the city improves overall livability.

In summary, cooling the city will:

- Improve air quality
- Save money
- Save energy
- Reduce CO₂ levels, contributing toward less global warming and climate change
- Reduce extreme weather events, including flooding
- Reduce incidence of heat-related illness and fatalities
- Increase overall livability and comfort level

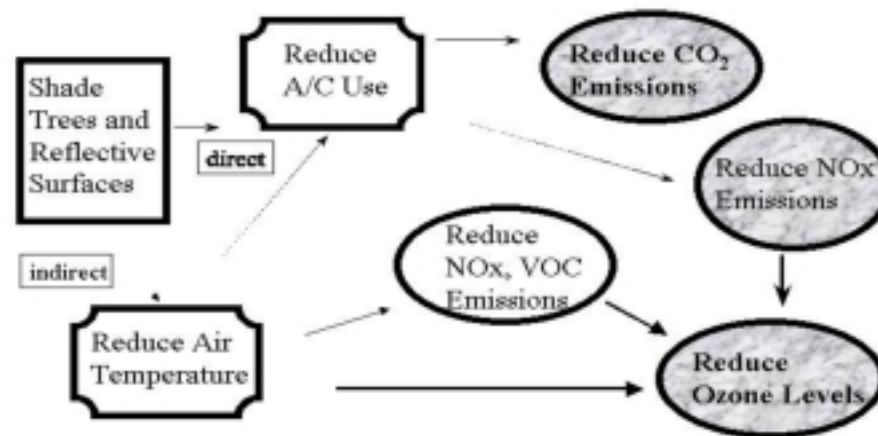
How can cities reduce heat islands?

Plant shade trees

Planting of shade trees in strategic locations not only blocks incoming radiation to keep buildings cooler, but also cools the surrounding air by evapotranspiration. Placement of trees, size and species of trees, and number of trees all affect the amount of benefit. Studies show that shade trees can reduce the peak cooling loads for residential buildings about 30% annually.

In addition, heat island mitigation measures can result in net savings of money and energy for individuals and communities

How Trees and Reflective Surfaces Affect Air Pollution



Use highly reflective surfaces on roofs and paint that absorbs less heat

Reflective roofs can save up to 50% of the cooling energy used in buildings; this is especially effective in commercial buildings. For the Houston area, this could mean

- \$17/1000 ft² savings for residential buildings
- \$20/1000 ft² savings for commercial buildings, for a possible total of
- \$27 million annually if everyone did it.

In northern areas, this benefit is reduced somewhat by a winter heating penalty, which would not be a problem in the Houston area.

Use highly reflective surfaces for pavement and parking lots

Research is still in progress about the quantitative energy-saving and heat reduction benefits of reflective pavement, but it is clear that some materials (e.g., concrete rather than dark asphalt) have superior reflective qualities and initial studies reveal that lighter-colored material can be cost-effective when factoring in the lifecycle costs of materials, including maintenance, etc.

So why isn't everybody doing it?

Heat island reduction is still a new idea for most people, and there is a lack of information about the problem, mitigation strategies, and benefits. Institutional and political barriers, such as deed restrictions and building codes, offer another obstacle. Lack of established models for action, lack of planning tools, and the absence of heat island reduction as a city — community — specific issue are other reasons.

The Urban Heat Island Pilot Project (UHIPP)

The U.S. Environmental Protection Agency has worked in Sacramento, Baton Rouge, and Salt Lake City in cooperation with NASA Huntsville thermal imaging to quantify potential benefits of heat island mitigation strategies.

See http://www.ssl.msfc.nasa.gov/NEWHOME/headlines/essd19may98_1.htm



Installing highly reflective roofing in Atlanta

Working with the Lawrence Berkeley National Laboratory's (LBNL) heat island project, the EPA UHIPP project uses tree planting and Energy Star products for roofing and pavement to educate consumers about their benefits in temperature reduction. LBNL uses models to quantify benefits for energy use, dollar savings, and pollution prevention results. This allows further evaluation of products in actual applications. The Energy Star program (for example, <http://www.epa.gov/appdstar/roofing/> and <http://www.energystar.gov>) labels energy-efficient products and enlists industry partners to promote them. EPA works with LBNL in technical and economic analysis of roofing materials such as metal roof products, reflective coatings, single ply membranes, and lighter colored shingles, and of paving materials.

EPA also works with city planners to develop tools and model action plans for heat island reduction. A guidebook for heat island reduction mitigation is currently under development; this will contain model ordinances and codes. EPA is also investigating heat island reduction initiatives as long-term air quality planning strategies, since benefits have been demonstrated to be significant and measurable enough for possible inclusion in State Implementation Plans (SIP).

In summary, the Urban Heat Island Pilot Project forms community partnerships to:

- Investigate opportunities
- Develop action plans and tools
- Implement strategies and
- Measure results

Project Workgroup Reports



Five workgroups were organized the second day of the workshop to develop ideas for specific projects that could utilize remote sensing data and concepts discussed during the first day of the workshop. The five groups include:

- Regional Issues
- Strategic Planning
- Air Quality
- Human Health
- Education

The results of their efforts are described below:

Regional Issues Work Group

I. Goals

To encourage cool, green development practices

Currently the eight-county area around Houston experiences random and largely unplanned development, increased flooding, and habitat fragmentation and loss. Regional applications of remote sensing data and geographical information systems can help to influence new development and redevelopment in a cool, green way.

By encouraging the city to use these principles in existing projects, we can encourage other municipalities, developers, and planners to adopt strategies that can cool the urban area, protect sensitive habitat, reduce flooding, and preserve tree cover. Since remote sensing and GIS can show the area as a whole, spatial data may be helpful in enhancing regional planning.

To increase energy efficiency

To identify habitat and wetland communities in order to have an accurate visual survey and to establish a baseline for future ecological studies

To study correlation between species immigration and heat islands

To conserve and increase habitat and increase green space

The Houston area is home to a variety of habitat types marine, barrier island, estuary, riverine, bottomland forest, prairie, and upland forest. An accurate visual and measurable record of land use, habitat distribution and fragmentation over time can provide information to groups and individuals that work to conserve the ecological wealth of the region. One example is Texas Parks and Wildlife's Wildscapes program.

Land use and land cover patterns impact habitat and community distribution. The Green Sector Initiative, recently passed by the Texas Legislature for Harris County, will need land use/land cover maps showing bayous, wetlands and other sensitive environmental areas in order to identify sensitive vs. non-sensitive areas for permitting.

To improve flood mitigation strategies by increased accuracy in locating flood prone areas

Current flood plain maps used for development planning, issuing building permits, and determining flood insurance eligibility are based on statistical estimates that in many cases are inaccurate and out of date. The US Federal Emergency Management Agency (FEMA) is working with local flood control authorities to remap the floodplains to reflect actual flood plains more accurately (FIRMS). Since flooding does not respect political boundaries, this information needs to be available regionally. With an 8-county study area showing basins and regional landscapes 3-dimensionally, it will be easier to plan effective mitigation strategies.

To understand the causes of flooding in order to introduce appropriate mitigation strategies

As rapid development and increased impervious cover in the Houston area have led to more flooding episodes, it is also important to track land use and land cover as they impact drainage basins and flooding.

To study tree species, their energy budgets and water budgets in relation to their effectiveness in heat island mitigation

Both water and trees can mitigate the heat island effect. By correlating a thermal distribution map against water and canopy cover / trees studied over time as mitigation strategies for heat island effects, their effectiveness can be compared.

To be able to visualize how surrounding land use and growth patterns affecting land cover and land use over time affect development of heat islands; to compare land use / land cover for the region over time.

Looking at the history of growth visually, especially when the maps are overlaid with economic activity distribution and transportation features, would be very effective in planning. Understanding the consequences of development in new vs. established areas would be easier with this kind of visual tool.

A comparison of heat island formation in a canopied population area like The Woodlands with a clearcut developed area would be instructive. Perhaps the NASA flight pattern could be molded to include such a comparison.

To support new nonpoint source pollution mandates (NPDES)

II. Strategy

Planning

To maintain the momentum generated by the workshop, a point person or group with appropriate expertise needs to coordinate a regional (8-county) response to the opportunities for new information. This response might include:

- Formation of a core team of stakeholders and expansion to include a wide representation of organizations and interest
- Acquisition of City Green software (pilot projects) and planning simulation software to compare different development scenarios (regional)
- Preparation of a needs assessment
- Preparation of funding proposals
- Formation of a data sub-committee that would conduct a survey of existing data for the region and assess existing data sets and technologies
- Examination of similar heat island and long-term ecological assessment studies in other regions and summary of lessons learned
- Preparation of a strategic plan, coordinating with clients, Houston Foresight Program, Gulf Coast Institute, City of Houston, Houston-Galveston Area Council and others
- Preparation of project milestones and critical path
- Preparation of a plan for motivating stakeholders and public audience

Activities

Demonstration projects at the local level (six months to one year)

- Downtown city demonstration of tree planting and landscaping, such as the COTSWOLD project
- Differential thermal and energy conservation effects of dark vs. reflective roofing materials
- Comparison of developments or plots with trees vs. no trees using CityGreen quantitative cooling and stormwater runoff benefits
- Working with developers.¹⁴

Creation of a database for baseline conditions of tree canopy and vegetation

¹⁴ Note: A developer in Sugar Land has already indicated willingness to participate in a demonstration as a result of this workshop.

Creation of program visuals and marketing materials

- Spatial data creating visuals to show regional change (every 10 years), urban change for Houston (every 5 years), and effects of local short-term demonstration projects (6 months-1 year)
- Preparation and support for possible NASA thermal imaging project in the Houston area (initial thermal data could be prepared using economical commercial thermal sensors before NASA comes back in 2000).

Motivators

- Visuals of trends showing facts and figures can show a story and help to leverage funding
- Marketing visits to most influential share holders to get their involvement; invitations to all meetings
- Quarterly newsletter and periodic press releases
- Web page
- Project / Alliance Champion(s)

Benefits

A series of remote sensing / GIS-based regional projects to reduce heat island effects, conserve habitat, understand regional causes and mitigation strategies for flooding would include many direct and indirect benefits:

- Energy savings
- Aesthetic improvements and improvement in quality of life
- Reduction of health costs
- Improvement of air quality and contribution toward compliance with National Air Quality Standards
- Reduction in flooding
- Enhancement of biodiversity
- Attraction of technology and research: by serving as a role model community we can drive technology development in a positive way, since this area has a strong capability in technology
- Attraction of new business and ecotourism
- Creation of a viable market for sustainable technologies, reflective roofing materials, and other appropriate technologies; this would also benefit regional Trade Associations

Stakeholder Groups

A. Government

- Texas Department of Transportation-TX DOT,
- City of Houston and other area municipal governments
- Houston-Galveston Area Council (H-GAC)
- Harris County Flood Control (HCFC) and other flood control districts
- METRO

- County governments
- Texas Water Development Board
- Texas Parks and Wildlife
- U.S. Fish and Wildlife
- Taxing and Investment Zones
- Extension Services
- Texas Forest Service
- Others

B. Organizations and Associations

- Garden clubs
- Civic associations and neighborhood groups
- Educators and researchers
- Environmental organizations
- Non-governmental associations (NGOs)

C. Business

- Real estate brokers and agents
- Trade Associations: Roofers, Builders, Paving Contractors, Architects and Landscape Planners
- Media
- Developers
- Utilities
- Chambers of Commerce
- Financial Institutions

Strategic Planning Work Group

Toward a Regional Urban Heat Island Reduction Initiative

The strategic planning group opted to write a general document describing the heat island issue and the elements of implementing a regional plan to address it. The intended audience would be policy makers and concerned citizens. A first step would be to a regional public/private partnership entity to serve as an organizing umbrella group. It was suggested that HARC or H-GAC be the convener of such a group.

How to Create a Cooler Greener City: A Guidance Document

I. Introduction

Executive Summary

The Problem

- air quality, urban heat islands, costs of doing nothing, health costs

History

- urbanization, population, pollution

II. Science of Air Quality and Heat Islands

(in layman s language)

III. Data Needs for Planning

Mapping data

- Remote sensing visual imagery (Satellite imaging, LIDAR, ADAR , aerial photography. At least some should be at a resolution that will show watersheds, bayous, wetlands and green space)
- Thermal mapping

GIS databank

- A regional GIS databank where all GIS information is kept i.e. one stop shopping ; one suggestion was that a GIS council be set up to oversee this

Chemical Inventories

- Pollutant inventories, atmospheric chemistry research, air toxics, CO2, NOx

Meteorologic Data

- Daily heat fluctuations, weather patterns

Historical Information

- Urbanization, paving, tree loss

IV. Available Information Resources

NASA, USEPA, USFS, DOE NRCS, TNRCC, TNRIS, COG, County & City Offices, LEPC, H-GAC. HARC, list of online resources

V. Heat Island Reduction Project Ideas

Use of trees and vegetation for cooling

- (e.g. rooftop vegetation, increase canopy, wetland restoration)

Changes in the built environment

- (e.g. roofing, paint, insulation, and paving alternatives)

Cost benefit analysis

VI. Community Education

- Schools
- Construction industry
- Residential associations
- Chambers of commerce

VII. Organization and Management

- Involve stakeholders
- Interdisciplinary teams

VIII. Making it Happen

- Funding resources
- Government relations
- Getting the public involved

Problems our Region Faces

- Air quality needs to come up to USEPA standards. The region must address ozone, particulates, toxics and greenhouse gases.
- Water quality and quantity must be assured. We need to protect watersheds and have problems with runoff and flooding.
- More greenspace is needed, and it continues to disappear. To support the increase of greenspace we need a parks inventory and need to protect canopy and urban forest
- We need to protect sensitive and rare habitat areas, particularly wetlands such as prairie potholes
- Transportation: We need to relieve congestion
- Energy consumption: We need effective conservation measures

Information Needs Particular to Our Region:

Air

- Thermal imaging over all 8 country region: where are urban heat islands?
- LIDAR: monitor Nox, ozone, criteria pollutants (look for concentrations over different time sequences)
- Atmospheric chemical footprinting
- Visual classification of air toxics

Water, greenspace and transportation

- Pull together all historical visual information to track over time, want temporal sequence of development of built environment, tree cover changes, watershed changes, building in floodplains, channelization, want to calculate rate of paving,
- Daily fluctuations: map daily transportation cycles and map onto heat fluctuations

Energy consumption

- Per capita power use and by whom, daily fluctuations

Map brownfields and pipelines

Local Demonstration Projects for Heat Island Reduction

I. Rationale

Although strategies for heat island reduction must be regional to result in significant temperature reduction, local demonstration projects can be effective in gaining public interest and support. Demonstration projects work by showing local benefits instead of telling about success in other cities.

II. Goals

The goals of local demonstration projects would be to create public / private partnerships, to use visualization tools to make heat island reduction measures easier to understand, to generate a body of data about heat radiation and effects on ambient temperature under various circumstances, and to change the mind set about the usual way of developing and building.

II. Types of demonstrations

Demonstrations might involve:

- design and construction of a parking lot with reflective or porous paving and tree plantings
- targeted tree planting throughout a neighborhood
- temperature measurements on different kinds of rooftops, paved areas, and vegetated areas throughout a neighborhood to demonstrate differences in temperature
- ground-truthing for remote sensing thermal mapping

- a neighborhood development that demonstrates heat island mitigation and energy conservation measures.
- comparison of two developments, one with heat island mitigation measures and one without, or one with trees preserved and one beginning with clearcut lots.
- long term temperature monitoring on the ground and on flyovers
- projects that involve schools, scouts, and other youth groups
- tree planting at public institutions

III. Site selection

Site selection could be based on hot spots on thermal maps, or on sites that might be available to use for demonstrations. For example, it might be possible to use a reflective roof on the proposed new City of Houston jail building or on other government buildings. Residential or commercial sites could be chosen.

IV. Strategy

1. Form alliances to sponsor and conduct the project

The Mayor's new Super Neighborhood focus might provide a starting point, along with alliances involving the schools, the Boy or Girl Scouts, utility companies, Habitat for Humanity, government organizations like the Texas Forest Service, volunteer organizations, medical schools, meteorology stations and university researchers, schools of public health, businesses, developers, roofing contractors, paving landscapers, and others.

2. Publicize the project through the media

3. Interest university interns and volunteer organizations to help with implementation

4. Use visual data to show heat island distribution

Correlate with humidity and other weather parameters, and find ways to link with a human health and discomfort index, with warnings for particularly hot areas. An Internet site could pinpoint heat stress areas, with a supplemental phone number for those without Internet.

5. Examine ways to overcome obstacles of deed restrictions, existing legislation, and need for test sites

Air Quality Work Group¹⁵



Dr. Robert Harriss, Texas A&M Sustainable Enterprise Institute, talks with Dr. John Nielsen-Gammon and Dr. Gary Sickler of Texas A&M Department of Meteorology and Texas MesoNet.

Ozone and heat islands

In the Western states, modelers are seeing a positive impact of the heat island effect on the formation of ozone. The Southern Oxidant Study planned for next summer will use a 2km grid in the Houston core area to model ozone

Effects of heat islands on air quality¹⁶

The following is a summary of interactions between heat islands and ozone formation that can be used in modeling.

1. Decrease temp. - change in ozone and PM formation
2. Decrease temp - decrease biogenic emission rate.
3. Decrease temp - decrease energy consumption yields NOX reduction
4. Decrease temp - decrease fugitive emissions, evaporative VOC emissions
- 5.* Increase tree cover - increase dry deposition rate

¹⁵ Partial List of Attendees: Air Quality Group

Jeff Luvall, NASA Marshall

Gene McMullen, Asst. Chief, BAQC, City of Houston

Larry York, GIS Specialist, BAQC, City of Houston

John Williams, Harris Co. Dept. of Public Health

Dick Flannery, TNRCC Region 12 - Houston

Mark Estes, TNRCC - Air Quality Planning & Assessment, Austin

Christine Wiedmeyer - Grad Student, UT Austin

Diane Bailey - HGAC, Office of Air Quality

Pamela Berger, City of Houston

- 6.* Increase leaf biomass - increase biogenic emissions
 - 7.* Change albedo - change photolysis rates?
 8. Change thermal mixing of pollutants
 9. Change in partition between latent and sensible heat.
- * Input parameters

Impacts of unique area meteorology on pollutant formation

We need a better understanding of how the land-breeze sea-breeze cycles impacts formation of pollutants. Another part of the problem is regional: we need to understand the impact of Galveston Bay / Beaumont-Port Arthur on ozone formation in the Houston area. Could pollutants from the B/PA area be blown over Galveston Bay at night and transported into the Houston area in the morning? Dick Flannery reports having seen the highest ozone levels at Smith Point and Seabrook early in the morning.

Currently we have the capability of measuring ozone at levels up to 150 feet with portable towers. Low level winds and upper level winds set up a unique circulation; VOCs are released at lower levels, and NOx at upper levels. The Southern Oxidant Study ought to be able to address the question of whose VOCs are mixing with whose NOx.

Unique heat island challenge posed by industry concentration

What is the magnitude of the heat island over the Houston Ship Channel industries? Those that try to do point source modeling suspect that there is a heat island over the channel. Surface radiant temperature may lead to the mixing of pollutants and reactions among them. Since many sources in the refinery/petrochemical industry operate at very elevated temperatures their impact may be substantial. There is a hand-held IR (infrared radiometer) for measure of temp for calibration.

Would there be a possibility of any specialized instrumentation for the SOS study to measure rise of the plume (Mark Estes)? Concentrated thermal plumes in an area can pipeup emissions into an area where reactions can take place. NOAA's LIDAR technique can measure pollutants and wind and mixing depth. Airplane-based LIDAR can be used.

Participants in such a study would include NOAA, Brookhaven, SOS. NOAA has ground based LIDAR. TNRCC will have funding. Baylor can do air craft monitoring if they can replace their aircraft which burned a couple of months ago. Dave Allen and Matt Fraser have proposed studies for the SOS and are working on a proposal for a fine particulate matter (PM) super-site.

Resources

- Dave Allen, University of Texas at Austin
- Texas A&M University Meteorology

¹⁶ Mark Estes, TNRCC

- Matt Fraser, Rice University
- Texas Natural Resource Conservation Commission (TNRCC)
- Southern Oxidant Study - Texas 2000 Study
- Environmental Protection Agency
- City of Houston
- SONOMA Tech., Inc. Study (commissioned by City of Houston)
- Houston Regional Monitoring (HRM)
- LBL - Lawrence Berkeley National Laboratory
- LIDAR - HARC flew plan and mapped out area - Surface Roughness
- Extension Services
- NASA
- Reliant Energy (was HL&P)

Priority Research Areas

- Partitioning of NOx/VOC sources
- Quantify [heat island effects on ozone formation?] in models
- Modeling of regional / urban meteorology
- How are the dynamics of [heat islands? Ozone formation?] at the sub-grid level affecting meteorology? Air quality ?
- How would the overall level of heat emission be impacted by reducing vehicle miles traveled (VMT) through mass transit? Reduced heat from vehicles, reduced need for additional parking lots, less hot soak all should result- what would be the impact on ozone formation? There seems to be general reluctance to address this issue.
- What is the difference in impact between roofs with solar panels and coating?
- What is the magnitude and impact of the petrochemical/refining heat island magnitude?
- Get surface roughness from LIDAR.

Short Term Planning

- Organize liaison between researchers for modeling, coordinating especially with the Southern Oxidant Study (SOS)
- Look at surface resources of Houston.
- Add to the tree inventory.¹⁷
- Survey building information for City of Houston.

Long Term Planning

Integration of data into MMS ,UAM, and SOS database.

¹⁷ See Urban Ecosystem Analysis in regional planning group report.

Human Health Work Group¹⁸

Prepared by Dale Quattrochi, NASA Marshall Space Flight Center

Available Data Resources

Remote Sensing Data

- Land use/land cover change through time
- 1972-present —Landsat MSS/TM data
- 1982-present —Landsat TM thermal data
- Airborne Data
 - Spring/summer 2000? — high spatial resolution ATLAS aircraft data
 - NASA ER2 MAS data (50m resolution) — spring/summer 2000?
- Coarse resolution satellite data
 - GOES/AVHRR for heat and land cover mapping ~1980-present
- New satellite sensor data
 - TERRA (EOS AM1) platform data (ASTER, MODIS)
- Aerial photos
 - National High Altitude Program (~1970 s to present?)
 - Others
- LIDAR data (i.e., Jack Hill — HARC)

Meteorological Data

- Meteorological station data (National Weather Service and Texas A&M)
- NWS Radar data (e.g., NEXRAD)
- Precipitation data (NWS)
- Humidity (NWS)
- Climatic Regimes (National Climatic Data Center, Texas A&M)

Human Health Data

- Crime data (for relating heat events to incidences of crime)
- Mortality by ZIP code
- Mortality by diagnosis (heart attack, etc.)
- Emergency room visits by diagnosis codes (e.g., respiratory infections)
- Demographics (current up to 1997 for Houston)
- Socioeconomic (1990/2000 Census data)
- Individual human health/stress monitors (e.g., like what Emory University is doing on a per-person basis in Atlanta)

¹⁸ Dale Quattrochi, NASA MSFC, facilitator; Anita Hagan, University of Houston Clear Lake Environmental Institute; Virginia Gorsevski, USEPA Heat Island Reduction Initiative; Richard Somerville, City of Houston; Jacqueline M. Lentz, Bureau of Air Quality, Dept of Health and Human Services, City of Houston; Juan Londoño, Harris Co. Health Department, Bebe Lising; Winifred J. Hamilton, Baylor College of Medicine/ GHASP; Chris Caudell Sagstetter, City of Houston, Environmental Health; Elisabeth Castro Power, Chemical / Environmental Specialist; Gary L. Sickler, Dept of Meteorology, Texas A&M University; Hoyt Johnson, NASA / Prescott College.

- Statistical samples of specific neighborhoods for input into a human comfort index
- Infectious disease data? (e.g., encephalitis?) [epidemiological data]
- Allergen/mold spore count information
- Inhaler usage by K-12 school children
- Occupational health records (e.g., time loss from work due to heat stress problems on the job)

Potential Projects

Urban Ecological Analysis [Human Comfort/Sustainability]

- Look at the entire 8 county metropolitan area
- Perform sampling in representative ecosystems across the metro area [approximately 5 areas]
- Relate to pollutants (streams, runoff, etc.), surface heat as identified from remote sensing data
- Canopy closure [shade index]
- Project would potentially be an early and easy success story at relatively low cost, e.g., \$50-75,000
- Focus on areas in metro Houston where we (i.e., community groups, decision-makers, etc.) want to make changes in the local neighborhoods and communities

Participating Organizations

- GHASP
- Trees for Houston
- HARC (GIS/Remote Sensing)
- TNRCC
- HGAC (Regional Council of Governments)
- University of Texas (emissions data)
- Texas Forest Service
- City of Houston Urban Forester
- NASA
- American Forests
- Civic and neighborhood organizations
- CEC (Citizen Environmental Coalition)

Mortality and Human Health Effects from Heat and Pollution Events

Participating Organizations

- Drug stores
- Clinics/hospitals
- University of Houston School of Public Health
- Health Departments (both city and county)

Visualization of Houston's Urban Heat Island

- Texas Department of Health
- HGAC (demographic data)
- Look at relationship of mortality as possible result of heat and pollutant events from a broad scale spatial and temporal perspective across the 8 county Houston metro area
- Zero in on specific target neighborhoods & communities according to demographics and socioeconomic parameters (and geographic parameters) as a function of correlation of possible deaths with heat and pollution (both ozone and particulates) events
- As another possible indicator of human health effects of heat/pollution events, survey pharmacy drug dispensing inventories (e.g., Eckerds) as related to respiratory distress — also include over the counter drugs (e.g., headache, congestion) as possible indicator?
- Survey of emergency room visits during high heat/pollution events to assess spatial distribution/demographics etc. of people experiencing distress
- Develop a mechanism for visualizing the development of the urban heat island effect over Houston (e.g., 3-D computer graphics)
- Present visualization of heat island predominance or persistence across the Houston metro area (e.g., 3-D heat island visualization draped over Houston landscape map)
- Show how the urban heat island changes on a daily basis in respect to intensity of incoming solar radiation and clouds
- Show how the urban heat island effect is compounded by humidity and prevailing weather regimes (e.g., persistent high pressure) during the dog days of summer
- Could lead to development of a human discomfort index that builds upon the already existing heat index that is used
- Could be used to impress upon the general public the ramifications on human health that exist from heat island effects and high pollution events (e.g., enhanced public awareness)
- Could be included as part of TV weather reports, much like the 3-D visualization of cloud cover that is now shown on TV

Mapping of Urban "Hot Spots" and Correlation of These with Human Health Problems or Discomfort

- Perform a ground survey by selected or targeted neighborhoods based on analysis of remote sensing heat island data
- Distribute individual human comfort/discomfort surveys or questionnaires to identify personal perceptions of comfort/discomfort by target neighborhoods
- Perform individual heat stress monitoring (e.g., unit carried by sampling of people in targeted neighborhoods to record heat stress on body temperature, perspiration, etc.)
- Establish an Internet site to provide data on heat/pollution discomfort zones as identified from remote sensing and meteorological data on a daily basis (e.g., site would provide indices for indicating How comfortable are you today? , by age, geographic location, etc. A phone call in site could also be established to do the same kind of survey of human comfort/discomfort by targeted neighborhoods

- Use the Houston Mayor's Office Super Neighborhoods as a foundation for establishing targeted neighborhoods for analysis
- Super Neighborhoods would be a focus for communities affected by heat and ozone events throughout the Houston metro area
- These neighborhoods could also be used to expedite urban sustainability measures (e.g., tree planting) and also attract positive media attention to both the problems and the prospects for these Super Neighborhoods
- Also serve as a comparative study between neighborhoods with differing demographic and socioeconomic conditions to see if the residents of these neighborhoods are affected differently by high heat/pollution events
- Develop stronger ties to universities and health departments through these surveys
- e.g., develop internship programs for students to go into these Super Neighborhoods to assess human health conditions, both during high heat/pollution events and on a regular basis

Participating Organizations (for the above two projects)

- NASA
- Power companies (e.g., Reliant)
- Meteorological information (e.g., National Weather Service)
- Local schools (e.g., school children to distribute ground surveys)
- Mayor's office
- Civic and neighborhood organizations
- University of Houston School of Public Health
- University internship programs
- TNRCC
- Media (TV, radio, newspaper)
- Businesses (e.g., roofing, paving, heating and air conditioning)
- Land developers/builders
- Landscaping companies

Education Work Group¹⁹

Ruth Milburn, Facilitator

Sue Runco, Recorder

Project Name	As a title for a region-wide education initiative about heat island effects and ozone, the group suggested Project <u>H</u> ouston <u>O</u> zone <u>T</u> emperature.
Goal	The primary goal of the project would be to establish techniques for convincing the community, including policy makers, that there is a heat island problem. By involving students in data collection and processing as well as creating analysis and display tools, the project could also create awareness of the dimensions of the heat island issue among students. In addition, by partnering with existing air pollution education programs, the school district(s), and the media, broad relationships can be fostered.
Project Description	<p>The Houston Independent School District already plans an ozone measurement project. Middle school teachers and students have been trained to collect ozone data in late August / early September 1999. Temperature measurements could be added with little additional effort.-data collection. Students could take temperature over asphalt and grass, under trees.</p> <p>This would initiate an idea of the distribution of temperature across various areas of the city. Since this represents tagging on to a program that already exists, it could increase community awareness at low cost. Texas A&M has agreed to post results on a website. Participants for ground truthing during the proposed NASA thermal imaging flyover in 2000 and the Texas 2000 Southern Oxidant Study could be recruited in the process.</p> <p>Other activities might include articles and interviews, booths at celebrations, and establishment of an educational website. Students might write an article about the relationship of temperature and air quality for the newspaper, make a video, have contests, write poetry, design a model subdivision that would minimize the heat island effect, or use a computer program to show the effects of trees on temperature</p>

¹⁹ Participants included:

Ruth Milburn, Houston Arboretum and Nature Center, Facilitator

Sue Runco, NASA Johnson Space Center, Recorder

Brian Shmaefsky, Kingwood College

Victor Cordova, Chief Urban Forester, Dept of Parks & Recreation, City of Houston

Irene Cravey, Texas State Tech College

John Nielsen-Gammon, Dept. of Meteorology, Texas A&M University

Linda Knight, Rice/HISD Model Lab

Ric Jensen, Information Systems, Texas Water Resources Institute

Bridget Jensen, Houston Homeowners Association / citizen actioneer

and air quality. Individual student projects or science fair projects could also be done on heat island effects.

To carry out the project, the facilitating group would build a series of related activities over the year. Press releases would make the connection between heat islands, ozone, human health, and energy costs. Daily measurements linked to the Texas 2000 study and the NASA project could be publicized on TV, with identification of student participants.

Indicators of Success

- diverse participation
- large number of participants
- initiation of change in policy
- website hits
- media interest
- participation in next phase

Resources

- Houston-Galveston Area Council Clean Air Coalition education program²⁰
- HISD program
- Proposed NASA Marshall Space Flight Center thermal imaging project
- Texas 2000
- Texas A&M meteorology program
- Urban Heat Island Reduction Program for Houston
- Non-profit organizations
- GLOBE program source of data
- Instructional modules for heat islands
- Eagle Scout projects

Obstacles

- Myths about trees
 - Trees produce VOCs that result in smog. There are biogenic emissions from trees, but the benefits outweigh the problems
 - Trees destroy the foundations of houses
- Cost of preserving trees related to development
- Difficulty of coordinating large number of students
- Lack of hard data on costs/ benefits
- This issue may be too complicated for the media to be interested in writing about
- Finding collection sites for data
- Communication with teachers and students
- Other possibilities are assisting in tree surveys and planting trees to reduce heat island effects.

²⁰ Need to coordinate with H-GAC Clean Air Action Program, which would be the logical place to implement these initiatives (Anne Mrok-Smith)

Glossary

Albedo	the fraction of light reflected by a body or surface.
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer. Used to obtain detailed maps of surface temperature and emissivity, reflectance, and elevation. Obtains high spatial resolution, global, regional and local targeted data in 14 channels from the visible through the thermal infrared wavelength regions.
ATLAS	Advanced Thermal and Land Applications Sensor (the sensor used for NASA MSFC thermal imaging)
EOS	Earth Observing System. Purpose: to understand the primary biogeochemical cycles of the planet, the nature of the coupling between the biogeochemical subsystem and the physical climate subsystem and the characteristics of the human portion of the biogeochemical system and hydrological cycle.
EPA	United States Environmental Protection Agency
FEMA	Federal Emergency Management Agency
GIS	Geographical Information System. A computerized mapping system that enables the user to visualize statistical information; allows information to be presently visually using maps. Information is keyed to geological locations, allowing multiple databases to be keyed to one central location. A system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data which are spatially referenced to the earth. A computer-based approach to interpreting maps and images and applying them to problem solving
GOES	Geostationary Operating Environment Satellites. Provide frequent images at 5 different wavelengths, including a visible wavelength channel and four infrared channels.
GPS	Global Positioning System. Operated by U.S. Department of Defense, utilizes 24 small satellites, each transmitting radio signals at the same two frequencies. Used to identify exact geographical locations to correlate with other data
HIRI	Heat Island Reduction Initiative
LANDSAT	Land Satellite. Take clear pictures of earth from 570 miles out in space. Follow instructions from computers on earth. Work in extremely cold temperatures in space. Last for many years.
LBNL	Lawrence Berkeley National Laboratory. One type of research improves the scientific basis of risk assessment; another calibrates energy conservation by the use of reflective roof and paving materials
LIDAR	Light Intensification Detection and Ranging. Uses laser interferometry in connection with airborne video to produce three dimensional remote sensing products
MODIS	Moderate Resolution Imaging Spectroradiometer. Measures biological and physical processes on land and the ocean using a cross-track scanning multispectral radiometer with 36 spectral bands, from visible to thermal infrared
NASA	National Aeronautics and Space Agency
NGOs	Non-governmental organizations
NMSFC	NASA Marshall Space Flight Center, Huntsville AL
NOAA	National Oceanic and Atmospheric Administration. Warns of dangerous weather, charts seas and skies, guides use and protection of ocean and coastal resources, and conducts research to improve understanding and stewardship of the environment.
NOx	nitrogen oxides, an important component of the reaction that results in the formation of ground-level ozone. Formed through combustion.
RADAR	Radio Detection and Ranging. A ranging device that measures distances as a function of round trip travel times of a directed beam of pulses spread out over specific distances.
SIP	State Implementation Plan.

SOS Southern Oxidant Study. Work to design and execute scientific research and modeling programs that will increase present understanding of ozone accumulation in the atmosphere. Strategic alliance of research scientists, engineers, and air quality managers from universities, federal and state governments, industry, and public interest groups. Texas 2000 is the portion of this study that will be done in the Houston region beginning next year.

TERRA NASA space satellite planned for deployment August 1999.

UHIPP Urban Heat Island Initiative Pilot Project (USEPA / NASA)

USGCRP United States Global Change Research Program. Provides the foundation for increasing the skill of predictions of seasonal to interannual climate fluctuations and long term climate change.

VOCs volatile organic compounds. Along with NO_x, combine in the presence of sunlight and heat to produce ground level ozone (smog)