National Aeronautics and Space Administration

Adapting Now to a Changing Climate

Johnson Space Center

the issue

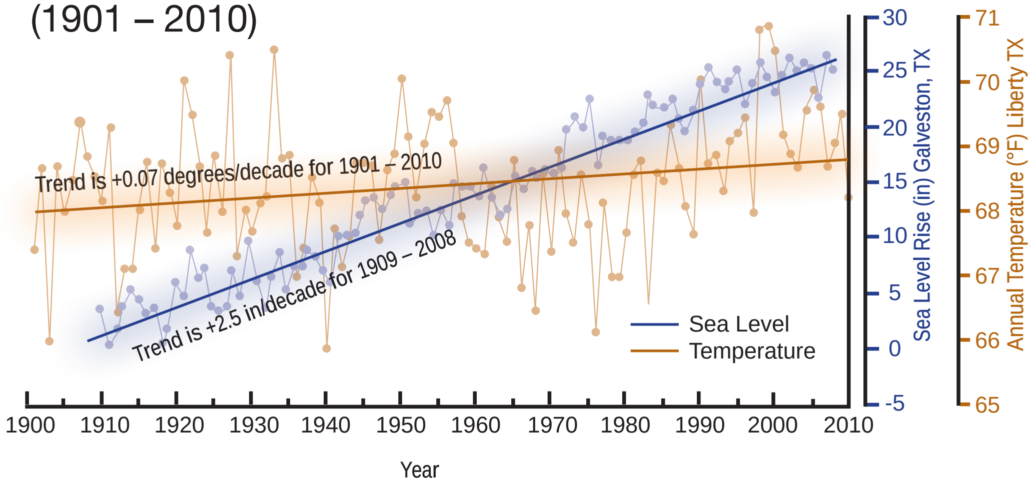
Climate data collected over the past 100 years in the Houston-Galveston area, for the entire U.S., and globally show a long-term pattern of sea level and temperature rise. Data from Liberty, Texas indicate that the average annual temperature has risen approximately 1 degree over the past century. Data from Galveston show that sea level has risen about 25 inches during this same time period, due in large part to the significant land subsidence occurring in the area.

Climate models project continued sea level rise and warmer temperatures in the region. Due to sea level rise, storm surges from hurricanes may increasingly make natural and built systems vulnerable to disruption or damage. Government agencies and other organizations, including utilities, planning commissions, and research institutions are currently assessing the potential of climate hazards to affect the region and their operations.

This handout can help area leaders (NASA together with its tenants, neighbors, and area partners) understand what they may expect in the future, and plan accordingly.

Observed Climate

Johnson Space Center
(1901 – 2010)



Temperature data are from Liberty, Texas; sea level rise data are from Galveston, Texas. These weather stations were chosen because they have long-term data records. All data are from the National Oceanic and Atmospheric Administration. See text above for note on subsidence and sea level rise.

the setting

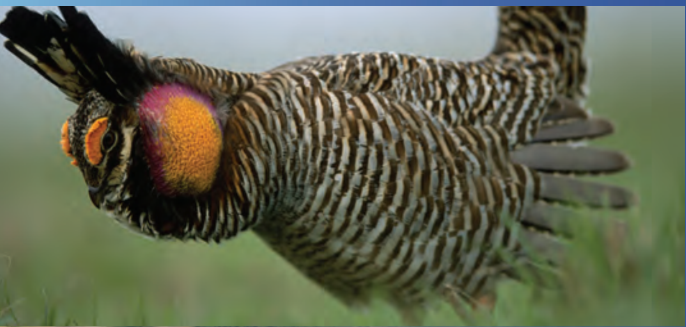
Johnson Space Center's Houston facility is located on nearly 1,700 acres in Houston, Texas. The Center borders Clear Lake to the east, which drains east to Galveston Bay and the Gulf of Mexico. Ellington Field lies northwest of the Center property. Armand Bayou Nature Reserve is at JSC's northern border. Another prominent feature in the Houston area, the nearby Port of Houston, generates $118B of statewide impact and more than $3.7B in state and local tax revenues from business activities related to the port.

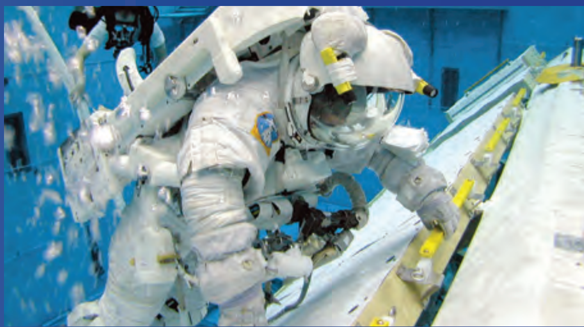
Temperatures in the area range from an average of 54°F (January) to 85°F (July). Annual average precipitation is around 54 inches (average from 1971 - 2000), with most rain falling between the months of June and November.

climate change

what's at stake?

Johnson Space Center (JSC) leads NASA's flight-related scientific and medical research efforts. JSC professionals direct the development, testing, production and delivery of all U.S. human spacecraft and all human spacecraft-related functions. More than $4.0B of federal aerospace contracts are managed out of JSC, providing a local payroll of more than $1.9B annually. Approximately 9,400 people work within the Center; about 3100 are civil servants. JSC's facilities are conservatively valued at $2.3B. JSC strives to make revolutionary discoveries and advances to benefit all humankind. Technologies developed originally for spaceflight are already applied in medicine, energy, transportation, agriculture, communications and electronics.





As the home of NASA's astronaut corps, JSC is the foundation of the area's human space exploration identity. The Center is responsible for training space explorers from the US and Space Station partner nations, including International Space Station crews. The Center's famed Mission Control Center is often referred to as the nerve center for America's human space program. A specialized pool at the Sonny Carter Training Center near Ellington Field simulates zero-gravity or weightless conditions experienced by spacecraft and crew during space flight. Beyond astronaut training, JSC endeavors to improve science, technology, engineering, and math education through many opportunities for students and educators. Education specialists prepare classroom materials, lead educational programs, and participate in partnerships to expand outreach to the community, touching the lives of students from kindergarten through university levels.

The natural resources on and around Johnson Space Center provide value as well. JSC biologists participate in an important breeding program for the critically endangered Attwater's prairie chicken. The Armand Bayou Nature Reserve, a 2500-acre preserve between JSC and the Bayport Industrial District, protects three Gulf Coast habitats – coastal flatwood forest, coastal tall grass prairie, and unchannelized estuarine bayou with surrounding wetlands. These local habitats host 370 species of birds, mammals, reptiles, and amphibians. The preserve is home to 220 species of birds, both permanent residents and migrating flocks.

The Climate Science Context

Scientists have collected weather and climate data and indicators of longer-term climate patterns (such as ice cores and tree rings) from the entire globe. Based on analyses of these data, plus a growing understanding of physical processes that control climate, scientists have developed sophisticated models that project future climate changes. Climate models consistently project that climate change will accelerate this century. The US Global Climate Change Research Program's report summarizes these results at www.globalchange.gov/publications/reports/scientific-assessments/us-impacts. NASA climate scientists are an important part of the international research effort. NASA is a key player in climate modeling and collection of both earth-based and space-based data used to develop and validate climate models and identify climate impacts.

Climate Scenarios

The United Nations Intergovernmental Panel on Climate Change (IPCC) developed three greenhouse gas (GHG) emissions scenarios based on differing sets of assumptions about economic growth, population growth, and other factors. The emissions scenarios range from "status quo" (i.e., minimal change in the current emissions trends) to more progressive (i.e., international leaders implement aggressive emissions reductions policies). From each of these three scenarios, a corresponding GHG atmospheric concentration is calculated and input into a global climate model. Scientists assess the range of model results to project future climate. The climate models include atmosphere, land surface, ocean, and sea ice components.

The Houston-Galveston Area Climate and Weather Today

The subtropical climate of the area produces relatively mild winters and practically no snowfall. Summers are hot and humid. The climate of the region is heavily influenced by its location near the Gulf of Mexico. Tropical storms are fairly common, bringing heavy rainfall, strong winds, and coastal flooding. Heavy rainfall events (non tropical) are common throughout the year and can cause flash flooding. Two recent storms, Allison in June, 2001, and Ike in September, 2008 serve as reminders of the area's vulnerability to severe weather. The region is also vulnerable to severe droughts; in fact, extreme drought was experienced in the region during parts of 2011.

Future Climate Projections

NASA's Goddard Institute for Space Studies used site-specific climate data from Hobby Airport (temperature and precipitation) and Galveston (sea level rise) combined with climate model outputs to generate projections specific to the area.

Model results of projected changes

Climate Variables				
Variable	**Baseline**	**2020s**	**2050s**	**2080s**
Average Temperature	70.5°F	+1.5 to 2.5°F	+2.5 to 4.5°F	+3.5 to 7°F
Annual Precipitation	54 in	-5 to +5%	-15 to +5%	-15 to +5%
Sea Level Rise	NA	+2 to 3 in	+5 to 9 in	+11 to 20 in
Sea Level Rise – Rapid Ice Melt Scenario (See Rapid Ice Melt text box for more detail)	NA	~4 to 8 in	~17 to 26 in	~40 to 55 in

Temperature and precipitation projections reflect a 30-year average centered on the specified decade; sea levels are averages for the specific decade. The baseline for temperature and precipitation is the most complete 30-year data period centered around the 1980s; the baseline for sea level is 2000 – 2004. Temperature and precipitation data are for Houston, TX (Hobby Airport) and sea level data are for Galveston, TX. Temperatures are rounded to the nearest half degree, precipitation projections to the nearest 5%, and sea level rise to the nearest inch. Shown are the central range (middle 67% of values from model-based probabilities) across the GCMs and GHG emissions scenarios. Data are from the NOAA National Climatic Data Center.

changes

This "downscaling" process can provide a more precise projection for a specific location (in this case, the Houston-Galveston area) than modeling for an entire region, such as the southern US. Overall, the projections for Houston-Galveston indicate higher mean temperatures and rising mean sea levels. While little change is expected in average annual precipitation, individual precipitation events may become stronger, leading to increased risks of flash flooding.

The Case for Adaptation

Because of its location on the Gulf Coast, storm surge and sea level rise may be the biggest climate threats to JSC. The area has always been subject to hurricanes, and the associated high winds, storm surge, and flooding. Rising sea level will increase the risk of catastrophic storm surge impacts on JSC and the surrounding high profile infrastructure assets, human capital, and natural resources. Furthermore, land subsidence in the area worsens the impacts of rising seas and storm surges. Projected changes in the frequency of some extreme events like hot and cold days (see tables below) may also lead to large impacts. The Center's future is intricately connected with broader social, economic, and environmental trends expected throughout the Houston-Galveston Region, so JSC stewards developing adaptation strategies will also need to work together with regional decision-makers.

A Note on Interpreting Climate Projections

Do the projections in the Climate Variables chart mean it is appropriate to say, "In 2043, the average temperature at JSC will be 72.7°F."? No. Models do not provide this degree of certainty. Still, they suggest a significant and progressive long-term warming trend that could have considerable impacts on life and work in the Houston area; more specifically, it is appropriate to say that models suggest that between 2040 and 2070, temperatures may increase 2.5 to 4.5 degrees above the average baseline temperature.

Rapid Ice Melt Scenario

Because General Circulation Models do not capture all of the processes that may contribute to sea level rise, an alternative method that incorporates observed and longer-term historical ice-melt rates was developed. This "rapid-ice melt" approach includes the potential for rapid melting of some of the **land-based ice** in polar regions, such as that on Greenland or the Western Antarctic Ice Sheet. **This approach suggests that sea level could rise in the Houston-Galveston area by approximately 40 to 55 inches by the 2080s.**

Daily Temperatures	Baseline	2020s	2050s	2080s
Max temperature **at or above 90°F** (days)	90	100 to 113	116 to 136	126 to 164
Max temperature **at or above 100°F** (days)	0.9	2 to 3	3 to 11	7 to 35
Min temperature **at or below 40°F** (days)	37	24 to 29	17 to 26	12 to 21
Min temperature **at or below 32°F** (days)	9	4 to 6	3 to 5	2 to 4

Qualitative Changes in Extreme Events During This Century

Event	Direction of Change	Likelihood
Heat Stress	↑	Very Likely
Intense Precipitation Events	↑	Likely
River Flooding	↑	Likely
Drought	↑	Likely
Intense Winds	↑	More likely than not

Based on global climate model simulations, published literature, and expert judgment

The number of days per year exceeding 90°F is projected to rise dramatically in the coming century, and the number of days with temperatures below 40°F is projected to decrease. More hot days would affect outside work, energy use, agricultural practices, and habitats.

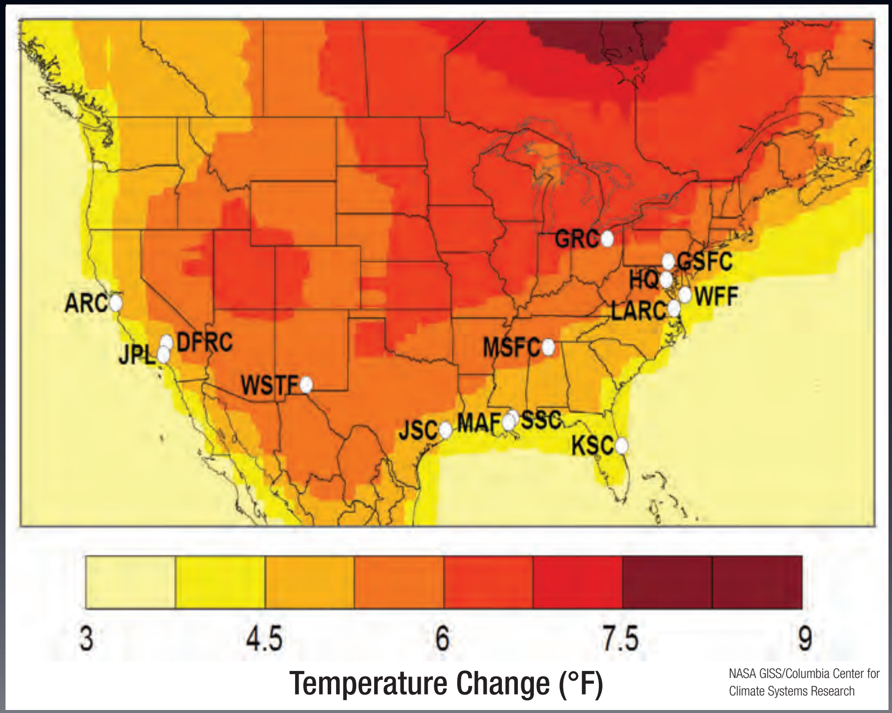
our responsibility

The time to develop and implement adaptation strategies is now. Executive Order 13514 directs federal agencies to assess and manage the effects of climate variables on their operations and mission in both the short and long term. A changing climate in the Houston-Galveston area will impact facility operations (e.g., water management, energy demands), natural resources (e.g., wetlands habitat changes, increase in invasive species, increase in pest species), infrastructure that is vital to mission success (e.g., flooded buildings), quality of life in the community (e.g., increased number of hot days), and the region's economy (e.g., increased percentage of public funds for utility costs, property damage). By considering these impacts during existing planning and decision-making cycles at Johnson Space Center, impacts to their missions may be abated or reduced. Recent construction initiatives at JSC in the wake of Hurricane Ike provide a good example of adaptation measures (e.g., buildings designed to withstand higher wind speeds) that take the increasing risks of climate impacts into account. Adaptation strategies developed for the Center may also prove beneficial to the local community as planners implement short-term tactical changes now, while simultaneously planning for longer-term strategic adaptation measures. Some of these potential impacts are listed in the chart below.

Building 20, LEED Office Facility for Transition, is one of JSC's six completed LEED certified buildings and was the first NASA building to earn the Platinum certification. This building and the other LEED buildings incorporate energy and water conservation techniques, daylighting, renewable materials and other sustainable characteristics in their design and construction.

Climate Variable	Potential Impacts
Sea Level Rise	Exacerbated flooding from storm surges; reduced emergency response capabilities. Increased salinity impacts to drinking water resources and habitats
Coastal Flooding	Impacts to wastewater treatment plants on the coast; damage to infrastructure; changes in shoreline habitats; overloading of stormwater management system
Overall Increased Temperature	Increased cooling costs in the summer; decreased heating costs in the winter. Changes in plant and animal cycles, including pest and disease vector species
Increased Number of High Temperature Days	Potential for damage to infrastructure materials; potential for limiting work and recreation outdoors; increased health problems related to heat stress
Precipitation Changes	Increased flooding from extreme precipitation events; increased risk of drought as temperatures rise; habitats affected by fluctuating groundwater levels

Projected Temperature Change (°F), 2080s minus 1980s, A1B Emissions Scenario*



*Average projected temperature change across sixteen global climate models for the A1B emissions scenario. The A1B scenario, one of several developed by the IPCC, assumes high CO2 levels for first the half of the 21st century, followed by a gradual decrease after 2050. Each time period (the 2080s and 1980s) reflects a 30-year average, not a specific point in time. ***The precise values shown in the map should not be interpreted as the most likely outcome.*** *The patterns of future climate change will depend on a range of factors, including the climate system, population, economics, technology, and policy.*

A Note about Downscaling Climate Data Specifically for Individual NASA Centers

The quantitative climate projections in this document are based on global climate model simulations conducted for the IPCC Fourth Assessment Report (2007) from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project Phase 3 (CMIP3) multi-model dataset. The simulations provide results from sixteen global climate models that were run using three emissions scenarios of future greenhouse gas concentrations. The outputs are statistically downscaled to 1/8 degree resolution (~12 km by 12 km) based on outputs from the bias-corrected (to accurately reflect observed climate data) and spatially-disaggregated climate projections derived from CMIP3 data. Results provide a more refined projection for a smaller geographic area. This information is maintained at: **http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections** and described by Maurer, et al. (2007)[1].

The **rapid ice melt scenario** and qualitative projections reflect a blend of climate model output, historical information, and expert knowledge. For more information about rapid ice melt models, see a paper and references at **http://www.nature.com/climate/2010/1004/pdf/climate.2010.29.pdf**.

Key Uncertainties Associated with Climate Projections

Climate projections and impacts, like other types of research about future conditions, are characterized by uncertainty. Climate projection uncertainties include but are not limited to:

1) Levels of future greenhouse gas concentrations and other radiatively important gases and aerosols,

2) Sensitivity of the climate system to greenhouse gas concentrations and other radiatively important gases and aerosols,

3) Climate variability, and

4) Changes in local physical processes (such as afternoon sea breezes) that are not captured by global climate models.

Even though precise quantitative climate projections at the local scale are characterized by uncertainties, the information provided here can guide resource stewards as they seek to identify and manage the risks and opportunities associated with climate variability/climate change and the assets in their care.

[1]Maurer, E.P., L. Brekke, T. Pruitt, and P.B. Duffy (2007), 'Fine-resolution climate projections enhance regional climate change impact studies', Eos Trans. AGU, 88(47), 504.

Authorization for NASA's climate risk management efforts, which began in 2005, includes:

- Federal Managers' Financial Integrity Act of 1982, supported by:
  - GAO (1999) Standards of Internal Control in the Federal Government
  - OMB Circular A-123 (2004) Management's Responsibility for Internal Control
- National Security Directive 51 and Homeland Security Presidential Directive 20: National Continuity Policy (9 May 2007) on localized acts of nature
- Presidential Policy Directive 8 – National Preparedness (30 March 2011) for catastrophic natural disasters
- Executive Order 13514 (8 October 2009) Leadership in Environmental, Energy and Economic Performance
- 2010 National Aeronautics and Space Act (51 USC Sec 20101 et seq)
- 2010 National Space Policy of the United States of America

Members of NASA's Climate Adaptation Science Investigator (CASI) Work Group contributed to this document.

Spring 2012
www.nasa.gov
NP-2012-02-838-HQ