National Aeronautics and Space Administration

climate risks

Adapting Now to a Changing Climate

Langley Research Center

the issue

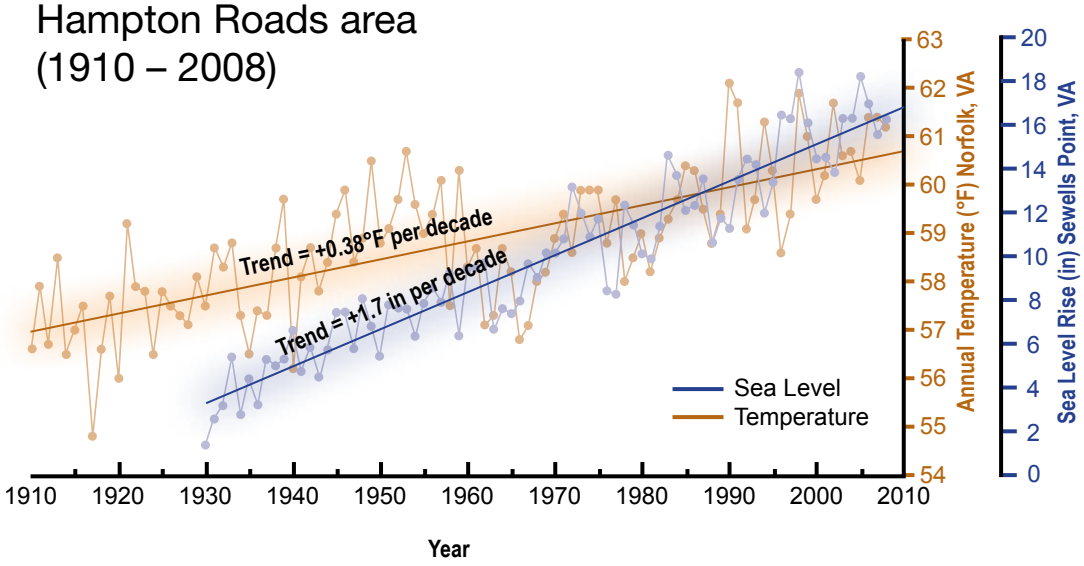
Climate data collected over the past 80 - 100 years in the Hampton Roads area clearly show a long-term pattern of sea level and temperature rise, accompanied by periods of shorter term variability.

Climate models project continued sea level rise and warmer temperatures in the Hampton Roads region. Along with sea level rise, storm surges from hurricanes or nor'easters may increasingly make natural and built systems vulnerable to disruption or damage. Government and other organizations, including utilities and planning commissions, 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

Hampton Roads area
(1910 – 2008)



Temperature data are from Norfolk; sea level rise data are from Sewells Point. These weather stations were chosen because they have long-term data records. All data are from the National Oceanic and Atmospheric Administration (NOAA).

the setting

NASA Langley Research Center (LaRC) occupies nearly 800 acres in Hampton, Virginia. The Center borders the Northwest Branch and Southwest Branch of the Back River, which flows east to the Chesapeake Bay. Most of the acreage of LaRC is located to the west of Langley Air Force Base (LAFB), with several small parcels to the east within Langley Air Force Base. Air Force runways lie between these West and East Areas.

At the mouth of the Chesapeake Bay, the Hampton Roads area is a bustling confluence of shipping, tourism, retail, arts, and industrial interests, with a strong federal presence including the Army, Navy, Air Force, Marines, Coast Guard, and NASA. The Port of Hampton Roads is the Nation's third largest seaport. Primary cities include Hampton, Newport News, Norfolk, Portsmouth, Poquoson, Chesapeake, Suffolk, Williamsburg, and Virginia Beach, together home to almost 2 million people. Temperatures in the area range from an average of 40°F (January) to 79°F (July). Annual average precipitation is 47 inches, with rain relatively evenly distributed throughout the year.

what's at stake?

NASA Langley Research Center generates an annual economic impact of approximately $900M and supports about 8,000 jobs beyond its gates. Approximately 3,800 people work within the Center, about half civil service employees and half contractors. LaRC's facilities are conservatively valued at $3.3B. Originally focused on aeronautics research, the unique skills (e.g., computational analysis) and research and testing facilities (e.g., Gantry and Wind Tunnels) at LaRC make critical contributions to the development of NASA's next generation of heavy-lift rockets and capsules for the upcoming phase of space exploration to the moon, Mars, and beyond. Aeronautical engineers and scientists continue to research ways to make aircraft greener, quieter, faster, and safer.

LaRC research leads to possible applications of innovative technologies to sectors beyond NASA including transportation, public health, and recreation. The Innovative Partnerships Program at LaRC promotes the progression of LaRC technologies from the lab to the marketplace.

LaRC, together with Langley Air Force Base, is the foundation of the area's space exploration and aeronautics identity. These federal agencies, plus the National Institute of Aeronautics and the Virginia Air & Space Center, mentor, educate, entertain, and inspire citizens in the surrounding communities, and draw millions of visitors every year. The science and engineering presence within the community results in many science, technology, engineering, and mathematics educational opportunities for students of all ages.

Like so many Chesapeake Bay neighbors, LaRC works to steward the diverse natural resources of the Nation's largest estuary. The Back River and its tributaries are important sources of shellfish, crabs, and fish to local fisheries. The area falls within the Atlantic Flyway for migratory birds and is home to many water fowl, song birds, and raptors. Three types of wetlands on the northern and eastern boundary – Forested, Emergent, and Scrub-Shrub – serve as habitat for wetlands species.

projected changes

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. LaRC researchers use these satellite- and ground-based data to examine the role of the atmosphere in climate change.

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 Hampton Roads Climate Today

The subtropical climate of the area produces relatively mild winters and little snowfall. Summers are hot and humid. The climate of the region is heavily influenced by its location near the Atlantic Ocean. Temperatures in coastal locations are moderated by the ocean and the close proximity of the Gulf Stream. Tropical storms and nor'easters are fairly common along the east coast of the US, bringing heavy rainfall, strong winds, and coastal flooding. Ocean/land breezes and thunderstorms, which are most frequent in the summer, also contribute to area climate patterns.

Future Climate Projections

NASA's Goddard Institute for Space Studies used site-specific climate data (temperature and precipitation) from the Langley Air Force Base and Norfolk International Airport stations and Sewells

Model results of projected changes

Climate Variables				
Variable	**Baseline**	**2020s**	**2050s**	**2080s**
Average Temperature	59.9°F	+1.5 to 2.5°F	+2.5 to 4.5°F	+3.5 to 6.5°F
Annual Precipitation	46.8 in	0 to +10%	0 to +10%	0 to +15%
Sea Level Rise	NA	+2 to 5 in	+7 to 11 in	+12 to 21 in
Sea Level Rise – Rapid Ice Melt Scenario (See Rapid Ice Melt text box for more detail)	NA	~5 to 10 in	~19 to 28 in	~41 to 53 in

Temperature and precipitation projections reflect a 30-year average centered on the specified decade; sea levels are averages for the specified 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. The baseline temperature and precipitation is an average of baseline data from the Langley Air Force Base and Norfolk International Airport stations. Sea level rise projections are for Sewells Point, Virginia, and include the impacts of subsidence in the area. Temperatures are rounded to the nearest half degree, precipitation projections to the nearest 5%, and sea level rise to the nearest inch. Data are from the NOAA National Climatic Data Center.

projected changes

Point (sea level rise) combined with climate model outputs to generate projections specific to the Hampton Roads area. This "downscaling" process can provide a more precise projection for a specific location (in this case, Hampton Roads) than modeling for an entire region, such as the southeast US. Overall, the projections for Hampton Roads indicate higher mean temperatures and rising mean sea levels, with little change expected in annual precipitation.

The Case for Adaptation

Because of its location on the Back River/Chesapeake Bay, sea level rise and storm surge may be the biggest climate threats to LaRC. The area has always been subject to nor'easters and hurricanes, and the associated high winds and flooding. The combination of rising sea level and severe storms could produce catastrophic impacts on LaRC 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. Langley's future is intricately connected with broader social, economic, and environmental trends expected throughout the Chesapeake Region, so LaRC 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 LaRC will be 63.4°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 Hampton Roads 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 Hampton Roads area by approximately 41 to 53 inches by the 2080s.**

Daily Temperatures	Baseline	2020s	2050s	2080s
Max temperature **at or above 90°F** (days)	34	40 to 47	49 to 64	55 to 86
Max temperature **at or above 100°F** (days)	0.7	1 to 3	3 to 7	5 to 16
Min temperature **at or below 40°F** (days)	102	83 to 89	71 to 83	59 to 77
Min temperature **at or below 32°F** (days)	48	34 to 39	26 to 34	19 to 30

Extreme Events: 2020-2090		
Event	**Direction of Change**	**Likelihood**
Heat Stress	↑	Very likely
Intense Precipitation Events	↑	Likely
River Flooding	↑	Likely
Drought	↑	More likely than not
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 32°F is projected to decrease. More hot days would affect outside work, energy use, and habitats.

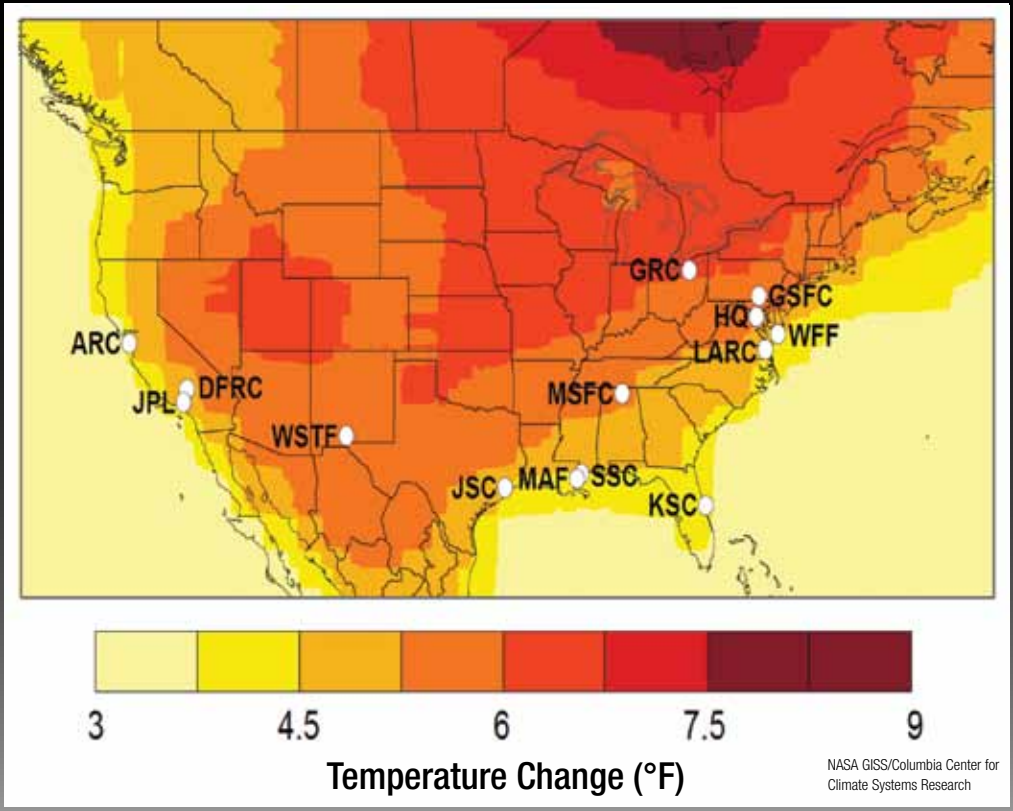
our responsibility

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 Hampton Roads area will impact facility operations (e.g., water management, energy demands), natural resources (e.g., salt marsh 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). By considering these impacts during existing planning and decision-making cycles at Langley Research Center, impacts to their missions may be abated or reduced. 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.

The first phase of LaRC's renovation initiative called New Town – the Administrative Office Building – was completed in 2011 and earned a Platinum Rating from the US Green Building Council's Leadership in Energy and Environmental Design (LEED) program. The building incorporates energy and water conservation features such as a green roof, photovoltaic panels, daylighting, and geothermal ground-source heating and cooling.

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

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



* A1B scenario, one of several developed by the IPCC, assumes high CO_2 levels for first half of the 21st century, followed by a gradual decrease in emissions after 2050

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**.

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.

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