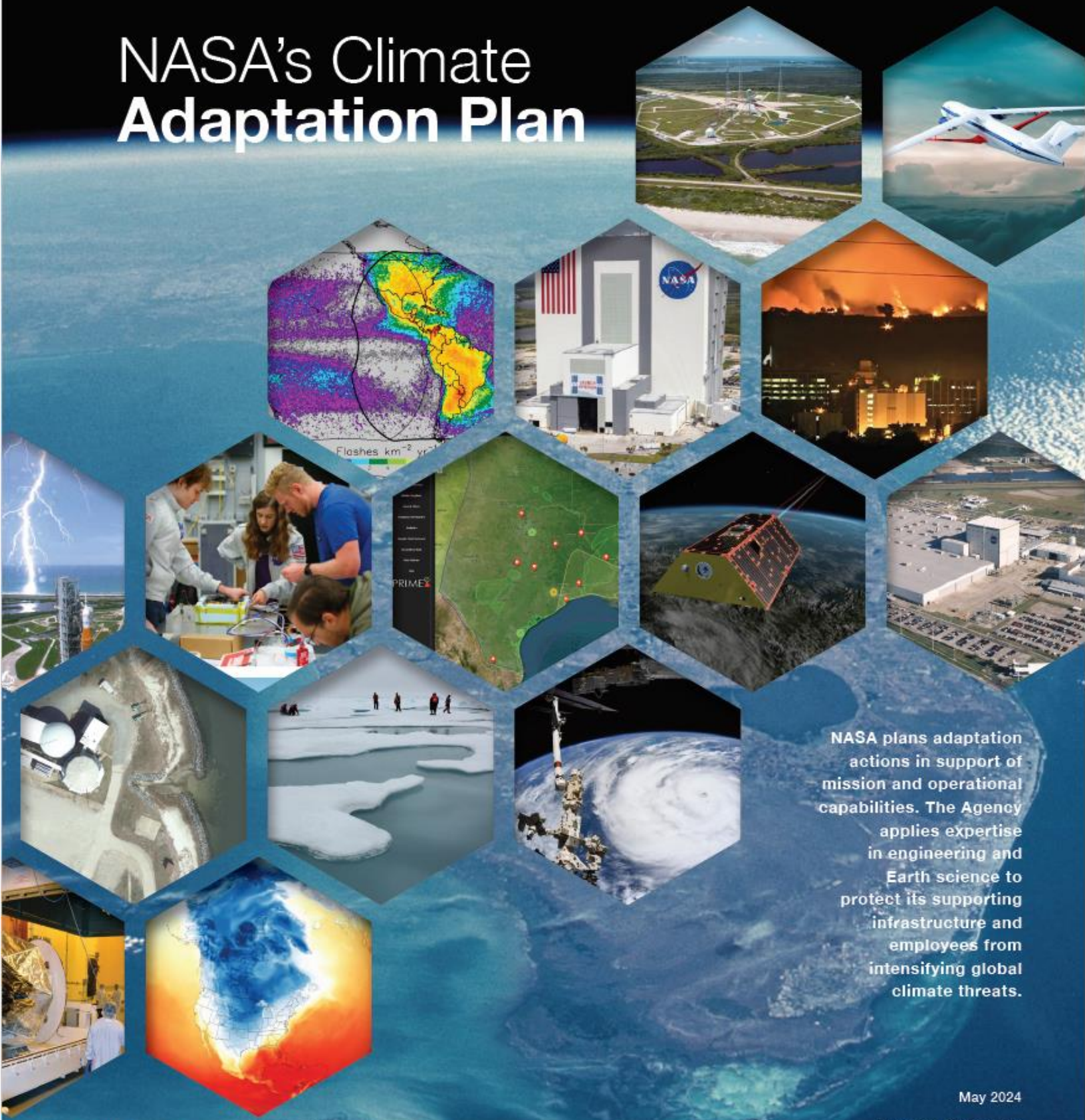
National Aeronautics and Space Administration

NASA's Climate **Adaptation Plan**



NASA plans adaptation actions in support of mission and operational capabilities. The Agency applies expertise in engineering and Earth science to protect its supporting infrastructure and employees from intensifying global climate threats.

May 2024

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NASA's Climate Adaptation Plan

May 2024

Points of Contact and Plan Approval

CAP Key Contacts

1. **Agency Climate Adaptation Official**
   Mr. Robert Gibbs
   Associate Administrator
   Mission Support Directorate

2. **Agency Climate Adaptation Action Officer**
   Mr. Joel Carney
   Assistant Administrator
   Headquarters Office of Strategic Infrastructure

Head of Agency Review and Approval

☒	Administrator has reviewed and approved the plan	**Bill Nelson**, Administrator 

It is NASA policy that integrating climate considerations into the Agency's policies, strategies, master plans, and partner engagements is mandatory.

To implement this policy, NASA commits to:

- Identify and implement adaptation strategies to avert potential mission impacts from climate change.
- Integrate climate adaptation planning and actions into the Agency Master Plans as well as Agency programs, policies, and operations.
- Minimize impacts to climate from Agency programs, policies, and operations.
- Execute priority climate scientific research, including climate observations, analysis, and modeling.
- Lead efforts and collaborate on climate change issues, sharing knowledge with a wide range of stakeholders.

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Section 1: Agency Profile

AGENCY PROFILE	
Agency Mission	NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.
Agency Bureaus Included in Climate Adaptation Plan	• Office of the Administrator • Mission Support Directorate (MSD) • Science Mission Directorate (SMD) • Aeronautics Research Mission Directorate (ARMD) • Space Operations Mission Directorate (SOMD) • Space Technology Mission Directorate (STMD) • Exploration Systems Development Mission Directorate (ESDMD) • NASA Centers and component facilities
Agency Climate Adaptation Official	Robert Gibbs Associate Administrator for MSD Joel Carney Assistant Administrator for the Office of Strategic Infrastructure (OSI)
Agency Risk Officer	Mary Skow Office of Safety and Mission Assurance (OSMA)
Point of Public Contact for Environmental Justice	Michelle Hawkins Program Manager for Climate Resilience and Community Action NASA Headquarters (HQ)/SMD/Earth Science Division (ESD)
Owned Buildings	Number: 5,031 Square Feet: 44,762,601 *(Facilities and Real Estate Division (FRED) Fiscal Year (FY) 2024 Report)*
Leased Buildings	Number Leased with Directly Measured Square Footage: 32 Square Feet Leased: 1,817,972 Number Leased Assets Alternatively Measured: 137 Estimated Square Feet for Leased Assets: 272,906 (*FRED FY 2024 Report*)
Employees	FY 2024 Federal FTE: 17,264 *(NASA FY 2025 President's Budget Request)* FY 2025 Federal FTE: 16,446 *(NASA FY 2025 President's Budget Request)* FY 2022 Contractors: 31,169 *(NASA Business Objects Report)* Includes onsite/near-site recurring work year equivalent; does not include major prime contractors.
Federal Lands and Waters	Owned: 134,964 acres Leased and Other Use Agreements: 264,877 acres *(FRED FY 2024 Report)*
Budget	FY 2022 Enacted: $24.04 billion (*Public Law 117-103*) FY 2023 Enacted: $25.38 billion (*Public Law 117-328*) FY 2024 Enacted: $24.88 billion (*Public Law 117-328*) FY 2025 President's Budget: $25.38 billion (*NASA FY 2025 President's Budget Request*)

Key Areas of Climate Adaptation Effort	• MSD, OSI
	  ○ FRED
	  ○ Environmental Management Division (EMD)
	  ○ Logistics Management Division (LMD)
	• SMD
	• NASA Centers

Climate variability and climate change have important impacts on NASA's ability to fulfill its mission and thus merit a proactive and integrated response. As such, NASA will continue to implement proactive measures to execute its mission and reduce the Agency's environmental, institutional, programmatic, and operational risks.

As a global leader in the field of Earth science, NASA also recognizes that it has a unique role in end-to-end Earth System Science, which includes observing and researching the climate system, as well as applying that knowledge for decision making and to inform the public about climate change. *NASA Strategic Plan 2022* underscores the priorities of the Biden-Harris Administration throughout our Agency's activities, including tackling the climate crisis. The Agency will continue to be a world leader in understanding, analyzing, and addressing climate change.

The Agency established the Senior Climate Advisor as a dual role for the Agency Chief Scientist in February 2021. This role was established in part to provide NASA leadership with critical insights and recommendations for the Agency's portfolio of programs related to climate, which encompasses NASA's efforts in climate observations, climate science, climate-related technology, sustainable aviation, climate policy support, environmental and climate justice, climate communications and public engagement, reducing its institutional carbon footprint and related resource use, and building institutional resilience to climate change. Through its Climate Strategy Working Group (CSWG), the Agency released *Advancing NASA's Climate Strategy* in Fiscal Year (FY) 2023 with four priorities: innovate, inform, inspire, and partner.

NASA approved its first Agency-wide comprehensive Agency Master Plan (AMP), which will result in recommended priorities for the mission-driven investment, sustainment, or divestment of NASA's facilities and infrastructure. AMP goals include risk mitigation and sustainability best practices and will allow NASA to focus investment on the highest mission-relevant facilities while aggressively reducing its footprint through demolition and divestment. For its remaining high-priority facilities, the modernization and revitalization of NASA's portfolio will be accomplished through the design of new construction and major renovations, which will include consideration of climate change, extreme weather, and associated adaptation needs.

In addition to the climate tools available to the Federal Climate Adaptation Plan (CAP) Network, NASA utilizes its scientific programs and research activities to support enhanced climate adaptation capabilities throughout the agency through the Climate Adaptation Science Investigators (CASI) Workgroup Program. A strong connection to the NASA Office of Strategic Infrastructure (OSI) is critical to the success of CASI. With OSI, CASI develops co-generated scientific and technical tools for use in climate adaptation and resilience decisions across the Agency. CASI's partnership of scientists with institutional managers brings together NASA's Earth science expertise and its culture of risk management attained through years of experience in space flight and other core missions. Stakeholder and workgroup meetings allow for development of CASI products tailored to Center needs and decisions.

NASA's Agency Resilience Framework (ARF) and Center Resilience Assessments (CRA) focus on risks to both institutional and mission operations. The Resilience Team includes a key partnership between NASA and the Department of Energy's National Renewable Energy Laboratory (NREL). This team has been working closely with CASI to develop and apply climate projection data and analyses and facilitate stakeholder engagement during the identification of Agency hazards, threats, and vulnerabilities. The team has leveraged these tools to assess risk mitigation options and develop resilience strategies in alignment with AMP goals and objectives.

In February 2021, NASA joined the National Climate Task Force established by President Biden, which encourages a government-wide approach to address climate change. As the world's premier Agency in space exploration and research, NASA will also prioritize cooperation with the international community, industry, and academia. In October 2021, NASA issued a Climate Action Plan that focused on averting mission impacts due to climate and continuing critical Earth science and climate research that inform and enable priority actions. Led by the Agency Climate Adaptation Official, this CAP expands upon NASA's previous plan, laying the foundation for efforts in FY 2024 through FY 2027.

Through its CAP, NASA is also able to advance environmental justice (EJ) as part of its mission, consistent with Executive Order (EO) 14008 and EO 14096 on *Revitalizing Our Nation's Commitment to EJ for All*. As NASA implements its CAP to increase the resilience of its facilities and operations, the Agency will apply its best efforts to, as appropriate and consistent with applicable law: address disproportionate and adverse environmental and health effects (including risks) and hazards, including those related to climate change and cumulative impacts of environmental and other burdens on communities with EJ concerns; and provide opportunities for meaningful engagement of persons and communities with EJ concerns.

Section 2: Risk Assessment

NASA manages more than two dozen satellites and instruments observing key climate indicators as the premier Agency in observing and understanding changes to Earth. NASA's Strategic Objective 1.1 is to understand the Earth system and its climate. NASA has an open information policy that makes its science data, software, and research freely and openly available to all, and current data systems are focused on disseminating data to the science community to support accelerating robust, transparent, and reproducible research. NASA also applies its internal climate expertise and enterprise data management systems to evaluate climate and extreme weather hazards and associated vulnerability and risk in a manner more robust than possible with public data available within these shared Federal toolsets.

NASA facilities are managed by OSI. The Agency organizes its internal climate assessments through the CASI team. The CASI Program, started in 2021, builds on the earlier CASI activity, which ran from 2009 to 2016. Information and tools developed by SMD's ESD support climate and extreme weather analyses to facilitate an exchange of scientific and infrastructure information with the objective of building resilience of NASA Centers. NASA structured CASI's primary goal around linking ESD climate and environmental products to decisions across three OSI divisions. Figure 1 provides examples of this coordinated effort and the linkage of CASI products to OSI decision-making needs. To advance this effort, ESD team members developed and conducted internal reviews of Center climate projections and interfaced with other NASA communities of practice (COP), such as the Geospatial Information System (GIS) COP, to assess further collaboration opportunities. CASI monthly meetings through FY 2023 focused on climate hazard exposure deep dives for each NASA Center and component facility. The Agency's Master Planning community provided a key entry point to link CASI with Center-level points of contact, allowing the CASI team to send data and products to relevant stakeholders ahead of each meeting.

	Division	Decision Areas	CASI Products	Decision Examples for CASI
Office of Strategic Infrastructure	**Environmental Management Division**	• Environmental Clean up and Restoration • Environmental Risk Management • NASA NEPA compliance • NASA CRM program for cultural assets • GHG reporting • Sustainability Program Management • Manage Natural Resources	• Center water budget • High tide levels • Extreme drought • Precipitation	• Wallops sedimentation study • Ames water reources • Irrigation management and stormwater system changes
	Facilities and Real Estate Division	• Design and Construction • Operations and Maintenance • Master Planning • Utilities Management	• RETscreen • Coastal inundation maps • Floods • Air Quality	• Energy usage at Langley • HVAC at Jet Propulsion Laboratory (JPL)
	Logistics Management Division	• Transportation and Fleet Management • Life Cycle Logistics Support and Supply Chain Management • Property Disposal Management • Equipment Management	• Extreme heat days • Wildfire	• Equipment management • Transportation network at Stennis

Figure 1. Linking initial CASI products to decision types and specific actions at NASA Centers.

Risk management strategies that accommodate potential future conditions include taking adaptation actions that perform well across multiple scenarios and objective measures of well-being. To support this endeavor, NASA climate scientists employ co-generation (or co-production)[1]—a form of knowledge production based on the dynamic interaction between scientists and stakeholders to develop useful, usable, and used information products—in product development. Assessing how products can be made more useful and usable, and inquiring how the user community would like to see the data presented, results in product capabilities directly linked to the decisions they will support. This process allows for a portfolio of key current and future climate risk information for Center managers and their regions.

The CASI team provided climate projections for each Center for temperature and precipitation and other variables for the 2020s through 2100 (see Section 2E and Appendix A for additional details on the approach). These projections include multiple scenarios based on those assessed by the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report. CASI sea level rise projections were aligned with those used for NCA5. The spatial scale of an approximately 27-kilometer (km) grid supports Center-level assessments, and the team will work toward higher resolution (an approximately 5–6-km grid) in later iterations. Tools include figures, maps, tables, and associated data tailored for NASA Centers resilience decisions. Figure 2 shows the breadth of hazard-specific products CASI has developed to date for 14 NASA Centers and component facilities.[2] Associated hazard working groups included temperature and precipitation, fires and air quality, extreme weather events, energy and water budgets, and sea level rise and coastal flooding. CASI continues addressing multiple scopes and scales in its current work and expanding assessments of some hazards, such as fires and air quality, to include additional Centers. CASI is extending beyond the NASA Centers to serve the data products for their regions, partners, and communities and working towards serving the CASI projections nationally. These groups align with the required Federal Mapper Application and include consideration of Agency exposure to additional climate and extreme weather hazards. Each group discussed potential impacts to the Agency's infrastructure, employees, natural environment, mission, operations, services, and supply chain.

Centers and Facilities	Temperature and Precipitation Projections	Fires and Air Quality	Extreme Weather Events	Energy and Water Budgets	Sea Level Rise and Coastal Flooding
1. Goddard Space Flight Center	✓		✓	✓	
2. Ames Research Center	✓	✓	✓	✓	✓
3. Jet Propulsion Laboratory	✓	✓	✓	✓	✓
4. Kennedy Space Center	✓		✓	✓	✓
5. Marshall Space Flight Center	✓		✓	✓	
6. Michoud Assembly Facility	✓		✓	✓	✓
7. Goddard Institute for Space Studies	✓		✓	✓	
8. Langley Research Center	✓		✓	✓	✓
9. Stennis Space Center	✓		✓	✓	✓
10. Glenn Research Center	✓		✓	✓	
11. Wallops Flight Facility	✓		✓	✓	✓
12. Johnson Space Center	✓		✓	✓	✓
13. White Sands Test Facility	✓		✓	✓	
14. Armstrong Flight Research Center	✓		✓	✓	

Figure 2. Center working groups and coverage for current CASI products.

[1] https://www.sciencedirect.com/science/article/abs/pii/S0959378010001093
[2] NASA Centers and Facilities - NASA

NASA used the Federal Climate Mapping for Resilience and Adaptation Application (Federal Mapping App), which was developed for Federal agencies by the White House Council on Environmental Quality (CEQ) and the National Oceanic and Atmospheric Administration (NOAA) to conduct a high-level screening of climate hazard exposure for Federal facilities and personnel. In addition to this high-level screening, NASA used Agency-specific CASI data and screening tools. Appendix A provides a detailed description of CASI methodologies and datasets.

NASA assessed the exposure of its buildings; employees; and lands, waters, and cultural and natural resources to five climate hazards: extreme heat, extreme precipitation, sea level rise, flooding, and wildfire risk.

Climate Data Used in Agency Risk Assessment

Hazard	Description	Scenario	Geographic Coverage
Extreme Heat	Measured as whether an asset is projected to be exposed to an increased number of days with temperatures exceeding the 99th percentile of daily maximum temperatures (calculated annually), calculated with reference to 1976–2005. Data are from high-resolution, downscaled climate model projections based on the Localized Constructed Analogs (LOCA) dataset prepared for the 4th National Climate Assessment.	Representative Concentration Pathway (RCP) 4.5	Contiguous United States (CONUS)
		RCP 8.5	CONUS
Extreme Precipitation	Measured as whether an asset is projected to be exposed to an increased number of days with precipitation amounts exceeding the 99th percentile of daily maximum precipitation amounts (calculated annually), with reference to 1976–2005. Data are from high-resolution, downscaled climate model projections based on the LOCA dataset prepared for the 4th National Climate Assessment.	RCP 4.5	CONUS
		RCP 8.5	CONUS and Alaska
Sea Level Rise	Measured as whether an asset is within the inundation extents from NOAA Coastal Digital Elevation Models and the 2022 Interagency Sea Level Rise Technical Report. Intermediate and Intermediate-High sea level rise scenarios used as proxies for RCP 4.5 and 8.5, respectively.	RCP 4.5	CONUS and Puerto Rico
		RCP 8.5	CONUS and Puerto Rico
Wildfire Risk	Measured as whether an asset is in a location is rated as high, very high, or extreme risk based on the U.S. Forest Service Wildfire Risk to Potential Structures (a data product of Wildfire Risk to Communities), which estimates the likelihood of structures being lost to wildfire based on the probability of a fire occurring in a location and likely fire intensity. Data reflects wildfires and other major disturbances as of 2014.	Historical	All 50 States
Flooding	Measured as whether an asset is located within a 100-year floodplain (1% annual chance of flooding) or 500-year floodplain (0.2% annual chance of flooding), as mapped by the Federal Emergency Management Agency National Flood Hazard Layer.	Historical	All 50 States and Puerto Rico

Exposure to extreme heat, extreme precipitation, and sea level rise were evaluated at mid- (2050) and late-century (2080) under two emissions scenarios, RCP 4.5 and RCP 8.5. Exposure to flooding and wildfire risk were only evaluated for the present day due to data constraints.

Climate Scenarios Considered in Agency Risk Assessment

Scenario Descriptor		Summary Description from 5th National Climate Assessment
RCP 8.5	Very High Scenario	Among the scenarios described in NCA5, RCP 8.5 reflects the highest range of carbon dioxide (CO_2) emissions and no mitigation. Total annual global CO_2 emissions in 2100 are quadruple emissions in 2000. Population growth in 2100 doubles from 2000. This scenario includes fossil fuel development.
RCP 4.5	Intermediate Scenario	This scenario reflects reductions in CO_2 emissions from current levels. Total annual CO_2 emissions in 2100 are 46% less than the year 2000. Mitigation efforts include expanded renewable energy compared to 2000.

Additional details about the data used in this assessment is provided in Appendix A.

2A. Climate Hazard Exposures and Impacts Affecting Federal Facilities

Indicators of Exposure of Buildings to Climate Hazards	RCP 4.5 2050	RCP 4.5 2080	RCP 8.5 2050	RCP 8.5 2080
Extreme Heat: Percent of buildings projected to be exposed to more days with temperatures exceeding the 99th percentile of daily maximum temperatures (calculated annually) from 1976 to 2005	100%	100%	100%	100%
Extreme Precipitation: Percent of buildings projected to be exposed to more days with precipitation amounts exceeding the 99th percentile of daily maximum precipitation amount (calculated annually) from 1976 to 2005	97%	100%	100%	100%
Sea Level Rise: Percent of buildings projected to be inundated by sea level rise	15%	15%	15%	25%
	High Risk	**Very High Risk**		**Extreme Risk**
Wildfire: Percent of buildings at highest risk to wildfire	15%	0%		1%
	100- or 500- Year Floodplain			
Flooding: Percent of buildings located within floodplains	17%			

In its 2021 Climate Action Plan, NASA reported over $1 billion in Disaster Recovery Expenditures from 2003 through 2020 based on publicly available information on hazard types and responses to disasters that have negatively impacted NASA's facilities and vulnerable communities. Since release of the 2021 plan, the Agency has tracked over $500 million in additional Disaster Recovery Expenditures through February 2024. NASA also established an Agency enterprise risk via our enterprise risk management (ERM) process titled "Infrastructure Impact Due to Climate Change." The enterprise risks are reviewed quarterly at the Mission Support Council meeting as part of the Baseline Performance Review (BPR). The BPR, led by the Associate Administrator, is a bottom-up review of performance against the Agency's strategic goals and other performance metrics, such as cost, schedule, contract, and technical commitments. This allows the Agency to consider all climate and weather hazards that impact its infrastructure from an Agency-wide viewpoint.

Guided by its AMP process, NASA is taking an Agency-wide and mission-driven approach to ensure critical capabilities and assets are mission ready, reliable, and affordable. At the same time, the Agency continues investing in the long-term asset health, sustainability, and physical footprint reductions that ensure NASA's future mission success. This mission-driven approach, utilizing data-driven and risk-informed methodologies, will ensure that NASA prioritizes sustainment when investing in mission-critical infrastructure and divestment of unneeded infrastructure. NASA will continue Agency right-sizing efforts by demolishing and eliminating obsolete facilities to reduce overall physical footprint, resource consumption, maintenance costs, and aging infrastructure risk, as well as enable the ability to renew and rebuild modern, sustainable, and climate resilient infrastructure to support future mission success. CASI has enabled a climate-informed ARF that aligns with Agency ERM and guides strategic investment for critical assets through the Planning, Programming, Budget, and Execution process. NASA will continue to incorporate climate risk management into the Agency ERM process in alignment with updated vulnerability assessments. Figure 3 shows AMP risk mitigation and sustainability best practice goals and their association to resilience and adaptation objectives, outcomes, and metrics.

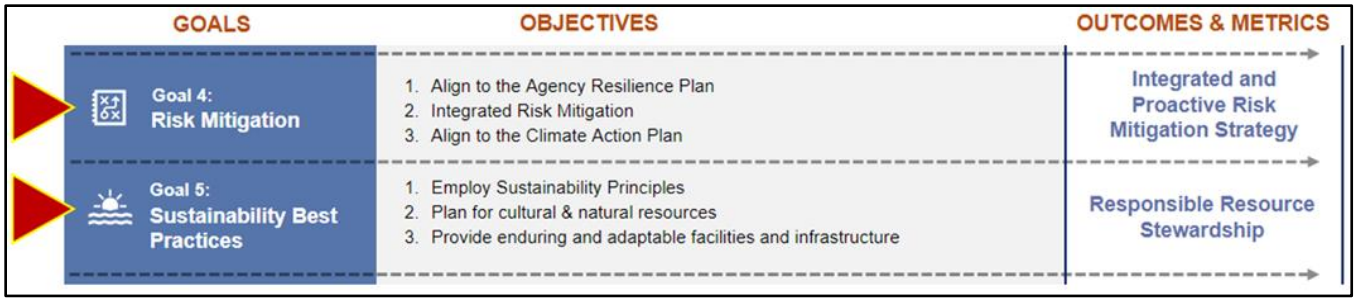

Figure 3. CAP Process Integration: AMP goals, objectives, outcomes, and metrics with ARF alignment.

A significant portion of NASA's infrastructure is in low-lying areas along coastal areas of the continental United States. Climate change is driving rising sea levels, which in turn exacerbates the impacts of storm surge and precipitation, ultimately contributing to higher water levels during major storm events. Information about these increasing risks are provided to the NASA coastal centers by CASI. The CASI team also monitors energy and water budgets. Drought is another hazard of concern. Mission activities such as launches, wind tunnel testing, engine testing, and other research and development activities have significant impacts on the Agency's water use, limiting NASA's ability to reach very low water use intensity. Currently, the Agency lacks adequate water metering capabilities to correlate water targets with the AMP. In FY 2023, NASA funded a critical water metering project across several sites, targeting the Agency's most significant water uses. Once these meters are installed, NASA will have a better analytical basis for setting water reduction targets. CASI has developed datasets to address these ongoing impacts and prepare for projected changes, such as shifting building climate zones as shown in Figure 4.

Center	Thermal Zone Change?	Moisture Zone Change?	Thermal Zone Change	Moisture Zone Change	When in SSP3?	When in SSP2?	When in SSP1?
Ames	No	No	3	3A	No change	No change	No change
Armstrong	Yes	Yes	3-->2	3A/3B-->2A /2B	after 2080	No change	No change
GISS	Yes	Yes	4-->3	4A-->3A	after 2070	after 2097	No change
Glenn	Yes	Yes	5-->4	5A-->4A	After 2030	After 2030	After 2030
Goddard	Yes	Yes	4-->2	4A-->2A	After 2028 (to 3) After 2085 (to 2)	After 2028 (to 3)	After 2028 (to 3)
Johnson	Yes	Yes	2-->1	2A-->1A	After 2045	After 2091	No change
JPL	Yes	Yes	3-->2	3A-->2A	after 2090	No change	No change
Kennedy	Yes	Yes	1-->0	1A-->0A	after 2068	No change	No change
Langley	Yes	Yes	3-->2	3A-->2A	after 2060	No change	No change
Marshall	Yes	Yes	3-->2	3A-->2A	after 2068	After 2088	No change
Michoud	Yes	Yes	2-->1	2A-->1A	after 2068	No change	No change
Stennis	Yes	Yes	2¤1	2A-->1A	after 2073	No change	No change
White Sands	Yes	Yes	3-->2	3B-->2B	after 2070	No change	No change

Figure 4. Projected building climate zone changes by Center (CASI Energy and Water Budgets Working Group).

2B. Climate Hazard Exposures and Impacts Affecting Federal Employees

Indicators of Exposure of Employees to Climate Hazards	RCP 4.5 2050	RCP 4.5 2080	RCP 8.5 2050	RCP 8.5 2080
Extreme Heat: Percent of employees duty-stationed in counties projected to be exposed to more days with temperatures exceeding the 99th percentile of daily maximum temperatures (calculated annually), from 1976 to 2005	100%	100%	100%	100%
Extreme Precipitation: Percent of employees duty-stationed in counties projected to be exposed to more days with precipitation amounts exceeding the 99th percentile of daily maximum precipitation amount (calculated annually), from 1976 to 2005	100%	100%	100%	100%
Sea Level Rise: Percent of employees duty-stationed in counties projected to be inundated by sea level rise	62%	62%	62%	62%

	High Risk	Very High Risk	Extreme Risk
Wildfire: Percent of employees duty-stationed in counties at highest risk to wildfire	12%	13%	0%

CASI provides climate exposure data for each of the hazards available in the Federal Mapper Application, as well as others, that can support NASA employee health and well-being at each of its Centers. NASA relies on these CASI datasets and tools to understand projected exposure to climate and weather hazards. NASA will continue to monitor projected hazards and exposure conditions Agency-wide and identify priority areas of concern to enable adaptation decision making.

Two hazards of particular concern to human health are wildfire and extreme heat. Air quality is already changing due to changes in wildfire conditions, where increasing incidence of poor air quality is linked to CASI's climate change projections of higher temperature and more frequent fire conditions. An increase in burned areas has led to related decreases in the air quality at most NASA facilities. Figure 5 shows that in 2021 surface-level smoke-related particles had increased at nearly all NASA facilities. The greatest increases occurred in the western United States, resulting from smoke emissions from wildfires and other types of biomass burning, which are significant source of carbon monoxide, nitrogen oxides, and other gases and particles. Smoke is a serious health hazard when small soot particles enter the lungs, and long-term exposure has been linked to higher rates of respiratory and heart problems.[3] Understanding the conditions driving large wildfires helps to link projections of future climate to smoke and air quality. In addition, if indoor air is not 100 percent recycled, smoke can cause even greater health risk indoors. Projections of future smoke exposure frequency and quantity suggest there is an increased need for repair, upgrade, monitoring, and maintenance of heating, ventilation, and air conditioning

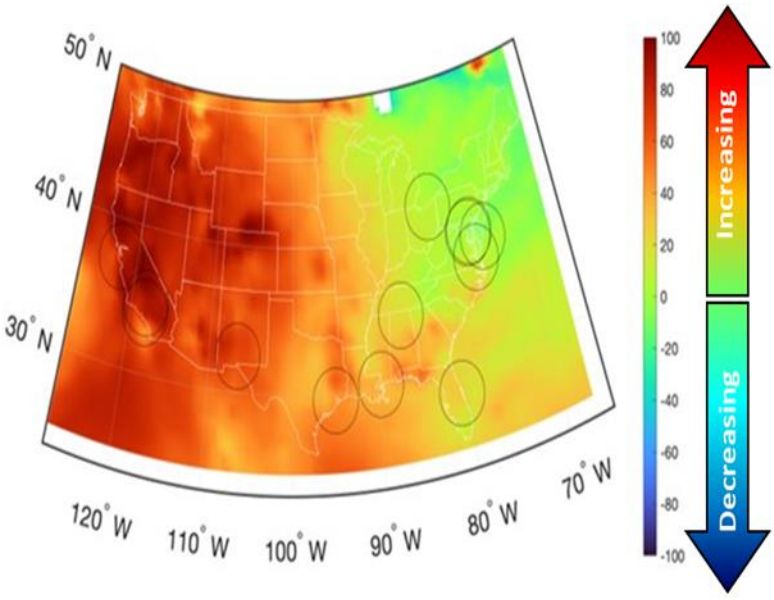

Figure 5. Percentage change in surface particulate matter in 2021 relative to 2000–2005, calculated as the sum of black carbon and organic carbon from NASA's Modern Era Retrospective Reanalysis (MERRA2) (CASI Fires and Air Quality Working Group).

[3] Satellite Data Record Shows Climate Change's Impact on Fires - NASA

systems to reduce smoke exposure to the NASA workforce. By the latter half of the century the extremely poor air quality experienced at NASA ARC in 2020, for example, will become commonplace based on CASI Fires and Air Quality Working Group datasets. Figure 6 displays a significant increase in projected annual extreme heat days at Langley Research Center (LaRC) by the end of the century. Extreme heat poses challenges to NASA employees, affecting not only their health through increased risk of heat stress and heat-related illnesses, but also complicating activities such as outdoor labor.

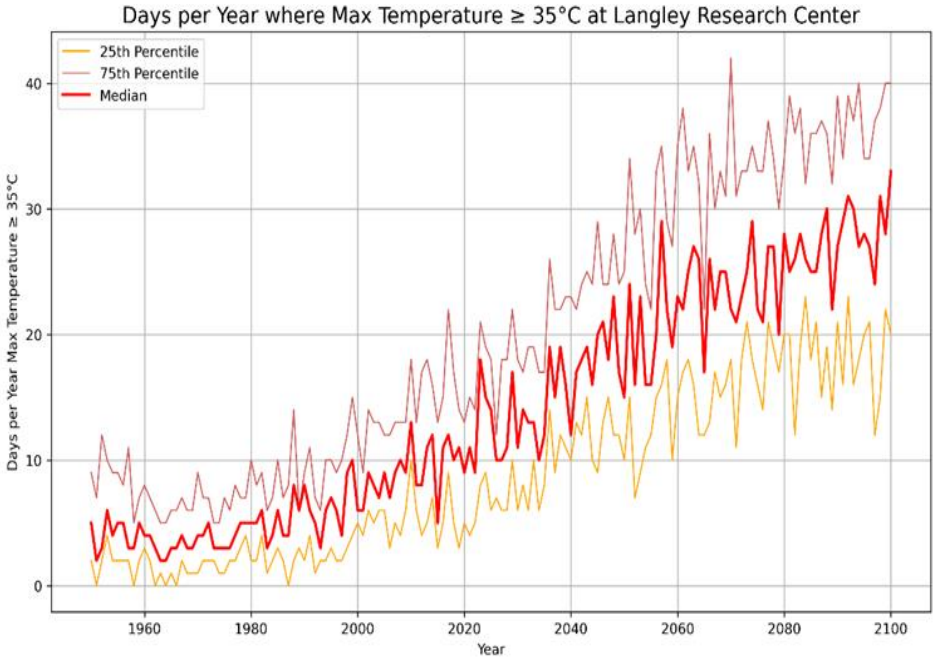

Figure 6. Days per year at LaRC when the maximum temperature reaches 35°C under an intermediate greenhouse gas scenario (CASI Extreme Weather Events Working Group).

2C. Climate Hazard Exposures and Impacts Affecting Federal Lands, Waters, and Cultural Resources

Federal lands and waters and cultural resources under NASA's stewardship have the potential to be adversely affected by climate change and extreme weather. The table below describes how NASA continues to review all climate and weather hazards from an Agency-wide viewpoint to identify vulnerabilities and inform adaptation decisions in alignment with responsible stewardship and management of Federal lands and waters. The table also provides a cross-cutting example of the potential linkage between climate impacts and legacy groundwater contamination.

Federal Asset	Current Climate Hazard Impact or Exposure	Future Climate Hazard Impact or Exposure
NASA is in the process of comprehensive exposure, impact, and vulnerability assessment as part of its ARF and CRA process, as described in the narrative section below.	All climate hazards are analyzed from an enterprise perspective, including all hazards available in the Federal Mapping Application, as described in the narrative section below.	NASA holistically assesses the Agency-wide Center impacts from climate and extreme weather, as described in the narrative section below.
Ongoing Agency-wide initiatives include investigating and addressing specific impacts.	Climate change drives changes in water budget that can impact groundwater levels and flows, including consideration of legacy soil and groundwater contamination.	CASI will continue site-specific investigations, such as how climate change may impact Agency-wide water budgets and associated groundwater flows.

Many NASA buildings are historically significant, including infrastructure covered in Section 2A. NASA is committed to responsible stewardship of cultural resources on lands that the Agency manages; these include historic buildings and structures, archaeological sites, and resources that are significant to Tribes. The Agency manages these resources and addresses associated risks in accordance with Federal and other requirements. NASA initiates relationships with all Federally recognized Tribes that have an interest in consulting on NASA actions in accordance with the National Historic Preservation Act (NHPA) of 1966, as amended, 54 United States Code (U.S.C.) 300101 et seq.; its implementing regulations (Protection of Historic Properties, 36 Code of Federal Regulations [CFR] Part 800); the National Environmental Policy Act (NEPA) of 1969 42 U.S.C. §§ 4321 and 4331; its CEQ regulations 40 CFR Part 1501; and EO 13175. In accordance with the NHPA and NEPA, NASA proactively engages Tribes that have historic or cultural ties to the area or are interested in NASA actions, and invites them to participate as consulting parties, to address any potential environmental or cultural impacts.

2D. Climate Hazard Exposures and Impacts Affecting Mission, Operations, and Services

SUMMARY OF KEY CURRENT AND PROJECTED CLIMATE HAZARD IMPACTS AND EXPOSURES		
Area of Impact or Exposure	**Identified Climate Hazard**	**Description**
NASA is in the process of comprehensive exposure, impact, and vulnerability assessment as part of its ARF and CRA process, as described in the narrative section below.	All climate hazards are analyzed from an enterprise perspective, including all hazards available in the Federal Mapping Application, as described in the narrative section below.	NASA holistically assesses the Agency-wide Mission, Operations, and Services impacts from climate and extreme weather, as described in the narrative section below.

NASA applies an enterprise approach and the AMP process for infrastructure management. NASA is coordinating closely at HQ and Center levels to ensure alignment between the programs and infrastructure that support mission, operations, and services. NASA continues to improve the data and tools needed to assess the impacts on and exposures to mission, operations, and services. The quantity of climate and weather data continues to grow rapidly from increased resolution and optimal data storage leading to a high degree of complexity. OSI, along with the other HQ and Center mission support organizations, manages institutional risk to mission. OSI focuses on four primary goals: readiness, affordability, sustainability, and workforce. These goals and related objectives focus on reducing risk to missions by using effective management strategies and operations and identifying and mitigating infrastructure risks to assure assets and capabilities are available to mission as needed. This has included advancing the AMP and ARF.

NASA completed its ARF in 2023. CRAs at Johnson Space Center (JSC) (2020), Kennedy Space Center (KSC) (2022), Goddard Space Flight Center/Wallops Flight Facility (2022), and LaRC (2023) have been completed. NASA has used data from these assessments to prioritize its facility renewal and repair projects. Figure 7 depicts NASA's remaining Center resilience assessment schedule. The Agency is scheduled to gather updates from Centers that have completed their assessments in 2024, while kicking off GRC and Marshall Space Flight Center (MSFC) in February 2024 with a projected completion date of October 2024.

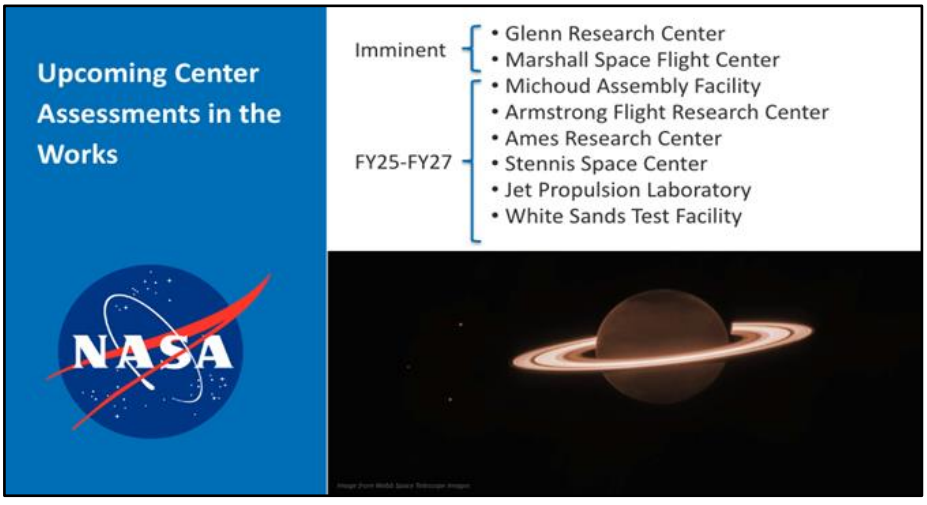

Figure 7. NASA Center Resilience Assessment Schedule.

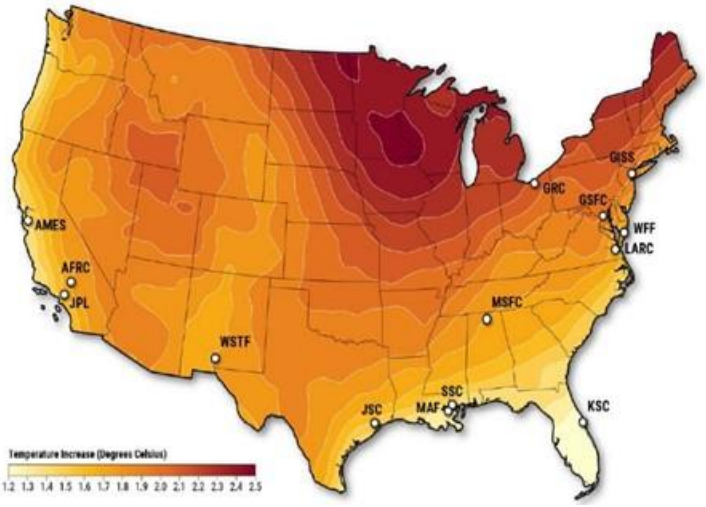

Figure 8. From NASA Agency Resilience Framework: Figure 5. Change in Temperature from Baseline (1981-2020) in the 2050s using SSP 2-4.5. Data created by CASI2 using NASA Earth Exchange's Global Daily Downscaled Projections; map created by the Department of Energy's NREL.

The NASA CRA focuses on risks to both institutional and mission operations and services. The Resilience Team (NASA and NREL) has been using climate projection data and climate analysis produced by NASA's CASI Workgroup and working with Agency stakeholders from OSI, including Master Planners, Facilities Managers, and Environmental Managers, as well as the Office of the Chief Health and Medical Officer (OCHMO), to identify hazards, threats, and vulnerabilities. Beyond temperature (see Figure 8), humidity, precipitation, coastal effects, fire, and extreme weather considerations, additional hazard considerations include subsidence, earthquakes, and human-caused or system design (e.g., cyberterrorism, accidental or planned utility outages, groundwater contamination, supply chain disruptions, and labor shortages). The Agency also considers climate impacts on external systems like utility infrastructure, which can impact NASA activities such as launches. Climate-related vulnerabilities identified include utility provider single point failure, corrosion of infrastructure, rising utility costs, and aging infrastructure. Therefore, regional collaboration and coordination with local and state officials is also critical for overcoming barriers to addressing climate risks, and NASA continues to partner with other entities (governmental or non-governmental) to find common solutions. Mitigation options have been developed to reduce associated risk to mission, operations, and services.

2E. Impacts from and Exposure to Additional Hazards

Assessments of extreme climate events are important for planning related to many applications, including ecosystem and agricultural health, economic development, and resiliency. The primary goal of the CASI Extreme Weather Events Working Group is to help in quantifying the changes in the risks and severity of relevant climate extremes at NASA Centers. The team develops estimates of heat- and moisture-related extremes (e.g., droughts, event-based flood risk, heat waves, and freeze/thaw risk) at spatial and temporal scales relevant to informing NASA Centers. NASA's infrastructure, workers, and any climate-sensitive systems will likely experience increased strain from extreme events by mid-century. Extremely cold days are projected to continue declining and are likely not as threatening as other hazards. Figure 9 shows the climate variable outputs from NASA's Land Information System (LIS) used in CASI and provided to NREL for the Center Resilience Assessments.

Water balance	***Rainfall*** ***Snowfall*** ***Evaporation*** ***Surface runoff Subsurface runoff***
Land surface states	***Temperature*** ***Snow water equivalent*** ***Snow depth*** ***Soil moisture*** ***Soil temperature*** ***Terrestrial water storage*** ***Groundwater storage*** ***Gross primary production***
Hydrology	***Streamflow*** ***River storage*** ***Flood storage*** ***Flooded area***

Figure 9. LIS climate variable outputs for hydrological extremes used by the CASI Extreme Weather Workgroup.

At WFF, for example, sea level rise will be concentrated in low-lying areas; however, hurricane storm surge can have major impacts through seasonal events and storm surges. In addition to immediate inundation impacts, these events can impact the ability of staff to reach the site and access to potable water. These events can also increase in severity due to sea level rise even in areas where permanent inundation is not projected. In addition, after Hurricane Isabel, LaRC realized significant pump house vulnerability. Given the challenges of managing corrosion and the continual degradation in LaRC's system of underground utility tunnels, the risk of flooding from heavy precipitation, or storm surge in addition to sea level rise could worsen this challenge. In a sanitary sewer project, the Center hardened the structure based on storm wrack lines and sea level rise protections. The primary hardening was an earthen berm structure and upgrades to the facility including a water-tight door system, water-proof surface coatings, and other building upgrades. The strategy for other susceptible areas of the campus includes planned retreat to the higher-elevation interior of the core campus. All new construction is required to be built at or above the 500-year floodplain, taking into consideration forecasted subsidence and sea level rise over the next 50 years. The team has also leveraged the hydrological modeling capabilities of NASA's LIS (lis.gsfc.nasa.gov) to develop climate-scale hydrologic projections for multiple scenarios, at 10-km resolution.

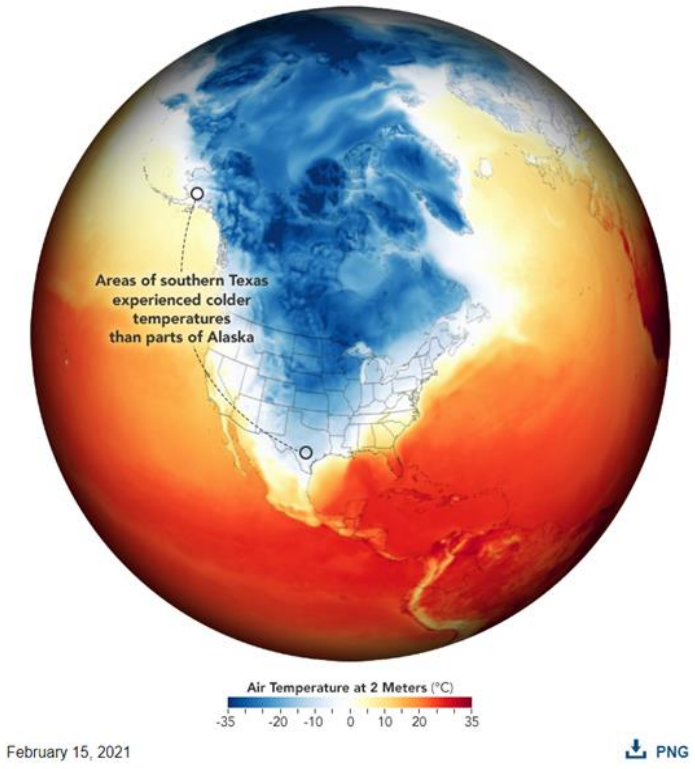

Figure 10. A deep freeze: During the second week of February 2021, cold air descended from the Arctic and covered much of North America with temperatures below freezing.

NASA also considers the interconnections among multiple hazards:

- Compound hazards – More than one hazard in the same place at the same time (e.g., heat/drought, river/coastal flood, tropical cyclone/heavy rainfall)
- Sequential hazards – Earlier hazard creates more vulnerable conditions for later hazard
(e.g., fire scar leads to mudslide; heat waves and cold spells crack cement)
- Simultaneous hazards – Hazards affect multiple, connected assets at same time (e.g., multiple launch facilities affected by tropical cyclone(s) at the same time)
- Systemic risks – Risks that are the result of, or are exacerbated by, co-dependencies between system elements
- Tipping points can lead to cascading risk that may be larger than initial impact, as evidenced by extreme electric utility price increases at JSC in the aftermath of a deep freeze in early 2021, as shown in Figure 10.[4]

[4] https://earthobservatory.nasa.gov/images/147941/extreme-winter-weather-causes-us-blackouts

Section 3: Implementation Plan

3A. Addressing Climate Hazard Impacts and Exposure

1. Addressing Climate Hazard Exposures and Impacts Affecting Federal Buildings

PRIORITIZED ACTIONS TO ADDRESS CLIMATE HAZARD EXPOSURES AND IMPACTS AFFECTING FEDERAL FACILITIES		
Climate Hazard Impact on and/or Exposure to Buildings	**Priority Action**	**Timeline for implementation (2024–2027)**
NASA is in the process of a comprehensive exposure, impact, and vulnerability assessment as part of its ARF and CRA process, as described in Section 2 and the narrative section below.	NASA is developing a prioritized list of assets for hardening, relocation, or identified needed redundancy. The Agency will align findings with the ARF, which will be integrated in findings and recommendations for the AMP.	NASA will prioritize and transform our asset management to ensure that our mission-critical infrastructure and facilities are available and reliable in the Artemis era and beyond. See Section 3D for additional information on the Agency timeline.

NASA prioritizes projects using multiple figures of merit including mission criticality, alignment with AMP priority infrastructure and facilities, relevance to NASA's strategic objectives, life-cycle cost, affordability, sustainable design principles, climate and extreme weather risk, and other risks and external factors. NASA's project prioritization method has proven successful at meeting mission requirements, modernizing and improving the resilience of the Agency's infrastructure, and reducing the overall footprint of the Agency's portfolio. It is the Agency's goal to continue to modernize and improve the climate resilience of mission-critical facilities and infrastructure in the implementation of the AMP and Real Property Capital Plan. The Agency understands the importance of assessing various implementation actions against both climate adaptation priorities and economic viability. Efforts to update NASA's AMP for FY 2024 include prioritizing sustaining assets and infrastructure through data-driven planning, affordability analysis, and the standardization of best planning practices.

NASA's OSI is within MSD and has overall responsibility for the oversight of real property management. OSI also collaborates with the NASA Centers responsible for the implementation of the Strategic Planning Guidance and for informing the development of Strategic Plan updates. OSI ensures that NASA Centers comply with Strategic Objective 4.2 from NASA's Strategic Plan, "Transform mission support capabilities for the next era of aerospace" to "ensure mission readiness and cultivate a reliable foundation for the future innovations in aerospace and science." NASA has designated OSI's Assistant Administrator as the Senior Real Property Officer, tasked with leading and directing the Agency's real property program and implementing real property functions. Within OSI, FRED manages the implementation of real property strategy, and it also identifies priorities to meet the strategy identified though NASA's Strategic Plan.

NASA's physical infrastructure supports our missions. However, much of NASA's physical infrastructure dates back to the Apollo era with over 80 percent of facilities beyond design life. NASA continually pursues renewal and repair projects through the Construction of Facilities (CoF) Program to modernize, consolidate, and enhance the resilience of the Agency's building portfolio. With the AMP now finalized and approved, NASA is much better positioned to understand what the future facility portfolio will look like, and this finalization also allows for the identification of candidate facilities for impactful projects that support climate adaptation priorities. An Agency-wide strategic approach and a building-level analysis are required to increase adaptive capacity and the approach will consider the need to prioritize projects in the most at-risk locations to achieve maximum benefits. The Agency has already implemented resilience projects at Centers where NASA has identified an enterprise risk. WFF Shoreline Beach Backpassing and Breakwater Installation Project, completed in 2021, provided localized shoreline protection and slowed near-shore erosion (see the additional discussion in Section 4B). KSC also continues to implement its Coastal Shoreline Project to address sea level rise impacts. In addition, KSC has added other climate-related projects to its institutional repair list, including roadway modifications and critical facility flood fortifications. As an added measure of protection against extreme storm events, the KSC CRA evaluated an alternative option of a hardened core

within the existing dune. While this option would not address the systemic erosion along the KSC shoreline, it would provide a barrier against extreme events, including for the most critically eroded and high energy areas. While this CAP does not address infrastructure outside of the United States, NASA also considers climate and weather risks to critical tracking stations and other overseas assets in its Agency-wide strategic approach.

2. Addressing Climate Hazard Exposures and Impacts Affecting Federal Employees

PRIORITIZED ACTIONS TO ADDRESS CLIMATE HAZARD EXPOSURES AND IMPACTS AFFECTING FEDERAL EMPLOYEES		
Climate Hazard Impact on and/or Exposure to Employees	**Priority Actions**	**Timeline for Implementation (2024–2027)**
NASA is in the process of comprehensive exposure, impact and vulnerability assessment as part of its ARF and CRA process, as described in Section 2.	All climate hazards analyzed from an enterprise perspective, including all hazards available for employees in the Federal Mapping Application; priority areas are described further in the narrative section below.	NASA will focus on evolving safety, health and medical, and engineering oversight policies and practices to protect Agency employees and the public from potential harm, while reaching mission success through innovative technical excellence.

Through the ongoing comprehensive vulnerability assessment process, the CASI team is exploring a partnership with OCHMO, which guides the Agency's Occupational Health Program. OCHMO establishes policy to ensure, to the extent possible, all NASA work environments, on Earth and in space, are safe, healthy, environmentally sound, and secure. Associated policy development and integration for the Agency includes consideration of indoor air quality and, more generally, occupational exposure assessment and management. OCHMO also collaborates with the Engineering and Safety & Mission Assurance Technical Authorities to assure integration of applicable OCHMO requirements. Initial discussion between CASI and OCHMO focused on extreme heat exposure and wildfire-driven air quality impacts for Agency employees, which are both concerns for NASA Centers. As an initial step in the CASI-OCHMO partnership is the calculation of future wet bulb globe temperature projections for all Centers and will undergo internal review. Wet bulb globe temperature is an indicator of human heat stress and can be used as the basis for heat stress prevention guidelines. These data are being requested by infrastructure stewards in addition to those responsible for employee protection. CASI is considering the need for user-established thresholds for decision making to accommodate the needs of multiple stakeholder groups. Differing thresholds can be developed, but user-defined thresholds lead to greatly increase computational intensity. In addition, ARC leads a combined aeronautics and science activity focusing on research, detection, prediction, and mitigation of wildfires, which will help the Agency address employee health risks from smoke exposure in addition to direct exposure to fires.

3. Addressing Climate Hazard Impacts on and Exposure to Federal Lands, Waters, and Cultural Resources

Type of Land or Water Asset	**Climate Hazard Impact on and/or Exposure to the Asset**	**Priority Action**
NASA is in the process of comprehensive exposure, impact, and vulnerability assessment as part of its ARF and CRA process, as described in Section 2.	All climate hazards analyzed from an enterprise perspective, including all hazards available for employees in the Federal Mapping Application.	NASA will focus on evolving safety, health and medical, and engineering oversight policies and practices to protect the Agency's managed lands and waters from potential harm, while reaching mission success through innovative technical excellence.

NASA's ability to view Earth from the unique vantage point of space provides a broad and integrated set of uniformly high-quality exposure data covering the Agency's managed lands, waters, and cultural resources. CASI's scope focuses on NASA Centers while currently extending scale to serve data products for surrounding

regions, partners, and communities and working toward national-scale products. CASI will continue to provide these data to help inform NASA decision makers for policy and operational decisions to address climate change.

NASA missions directly support Agency understanding of climate change impacts to its managed lands and waters and inform CASI toolset development. Landsat satellites provide an unparalleled record of Earth's varying landscapes through space-based observation, including for NASA Centers. The consistency of Landsat's digital image data from sensor to sensor and year to year makes it possible to trace land cover changes from 1972 to the present. Landsat's 30-meter resolution supports detailed measurement of climate impacts to NASA's managed lands and waters. Landsat data supports assessment of how land use affects climate change, tracking the impacts of climate change, and enabling adaptation to climate change. Figure 11 shows Landsat 9 photos that provide a preview of how the mission will help NASA understand the impacts of climate change on landscapes and coastlines to facilitate Agency decision making and asset protection.

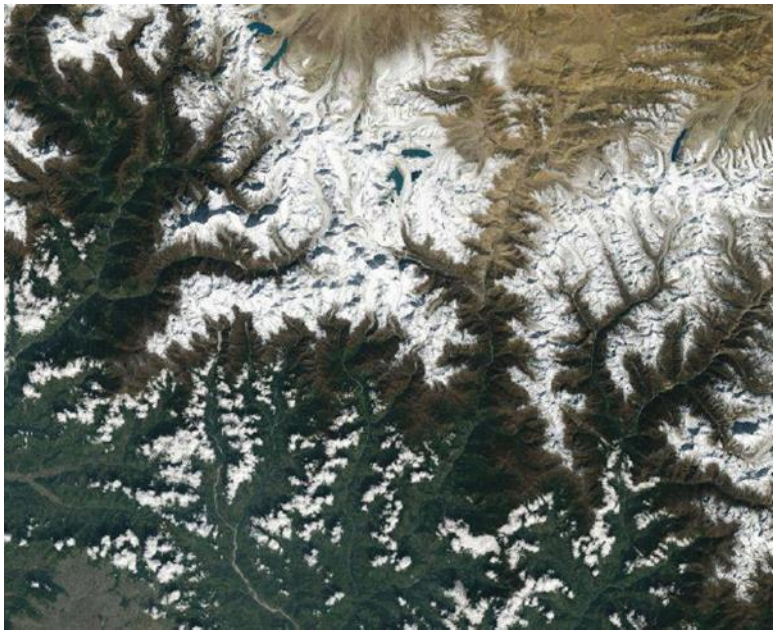

Figure 11. Landsat 9 photos (see text to the left for details).

3B. Climate-Resilient Operations

1. Accounting for Climate Risk in Planning and Decision Making

NASA's structured approach to managing climate risk at NASA Centers and facilities involves supporting decisions that reduce hazard exposure and sensitivity, while increasing adaptive capacity. The Agency, through coordination between internal climate scientists and institutional managers, is developing tools to help identify vulnerabilities and evaluate tradeoffs among adaptive pathways. NASA also promotes climate event recovery as an opportunity to improve, rebuild, replace, or retrofit infrastructure systems in a manner that accounts for a changing climate and improves resilience. The Agency works to enable opportunities such as efficient investment in sustainable development and collaboration with partner organizations to avoid maladaptive recovery.

Climate change and extreme weather events impact NASA's structures, managed lands, utility systems, roadways, and operations. NASA is assessing climate-related risks through a combination of qualitative and quantitative processes and continues to conduct resilience assessments to evaluate operating risks to climate-related hazards. Inputs include current vulnerability assessments, projected climatic changes, frequency and severity of events, and recovery time and cost. The objective of these resilience assessments is to examine the various vulnerabilities and threats that could interrupt operations, damage property, and threaten personnel, and could prevent the Agency from carrying out missions. Analyzing how vulnerabilities can result in interruptions to power, water, transportation, communications, and other assets or resources for NASA sites supports planning to invest in resilience.

NASA continues to analyze its portfolio through the resilience assessment process complimented by the Master Planning Asset Inventory Assessment. This combination of information allows the start of the short-term and long-term analysis of investments needed. Knowledge gained from the resiliency assessments is incorporated into the Agency Master Planning process as a focus to provide the best oversight of Agency and Center responsibilities and operations. In its 2014 Climate Risk Management Plan, NASA identified the need to periodically review existing efforts to ensure they reflect the latest knowledge on climate change when integrating

climate adaptation planning into NASA risk management and budget development processes.[5] To help meet this need, CASI is continually updating its data, projections, and tools. The current CRA processes represent a deeper dive as part of this ongoing process that includes continuous identification, analysis, planning, tracking, and management of risks.

2. Incorporating Climate Risk Assessment into Budget Planning

NASA's strategic planning and performance efforts are organized under the Office of the Chief Financial Officer (OCFO), ensuring that strategic planning is intimately linked with budget execution. The Strategic Planning Council, a top-level team chaired by the Administrator, develops the Agency-level multi-year plans and roadmaps, which are further developed by NASA's Mission Directorates and Mission Support offices. The strategic planning team within the OCFO then turns these plans and roadmaps into NASA's Strategic Plan. The Strategic Plan, released every three years to reflect organizational transformation, defines NASA's approach to achieving the Agency's vision and mission, which are the principles that support and drive research and development activities.

Coordination across OSI Divisions helps to ensure a shared, Agency-wide understanding of how climate adaptation and resilience considerations align to Agency budgetary considerations and the prioritization of investments to meet current strategy and goals. This process provides the necessary inputs to inform the development of future Strategic Plans by the OCFO that incorporate climate considerations. A growing understanding of Agency climate vulnerabilities and further integration into the ERM processes and BPR will allow for accurate materiality assessments and disclosures in annual Agency financial reporting and improve NASA's ability to manage associated climate-related financial exposure.

This CAP supports an Agency-wide effort to further incorporate climate considerations within ERM and BPR. NASA has identified climate change impacts as a key infrastructure risk through its structured ERM process. The need to maintain and replace aging critical infrastructure exacerbates this issue. These efforts will support the assessment of the Agency's financial capacity to adapt or otherwise protect against losses from low-probability, high-consequence events, aligning short-term expenditures and long-term investment plans. Through identification of threats and vulnerabilities, the NASA portfolio will be evaluated for Agency fiscal risk exposure due to climate change.

The Agency is further incorporating these risks in decision making to make climate change adaptation a routine part of program planning, execution, and evaluation. For example, the Agency considers climate risk in infrastructure project development through the CoF Program. The Agency further recognizes that managing climate risk supports its mission and efforts to reduce these risks must consider impacts to workforce, operations, and supply chain. NASA continues working toward the removal of barriers to climate risk reduction and has recognized a need to incorporate climate change expertise within integrated project teams and Agency review boards.

3. Incorporating Climate Risk into Policy and Programs

Agency Policies Reviewed		
Climate Adaptation and Resilience	NASA hosts the NASA Online Directives Information System (NODIS) Library, which is a searchable database of NASA directives, documents, and historical records. Using this resource, NASA applies an enterprise approach (see Section 1, Agency Profile for contributing entities) to review potential policies for incorporation of climate considerations to improve adaptive capacity and climate resilience in programs and ensure that investments strategically consider future conditions and are climate smart. These reviews cover a wide range of policies including NASA Policy Directives (NPD), NASA Procedural Requirements (NPR), NASA Interim Directives (NID),	*NPD 1001.0D* *NASA Strategic Plan 2022* Includes top-level agency strategies tied explicitly to climate and extreme weather. *NPD 8500.1C* *NASA Environmental Management* Mitigate environmentally driven mission risks to improve climate resilience of critical Agency assets. *NPR 8831.2F - Chapter 9* *Facilities Maintenance and Operations*

[5] 2014 Climate Risk Management Plan - NASA

Agency Policies Reviewed		
Climate Adaptation and Resilience (continued)	NASA Policy Instructions (NPI), and NASA Advisory Implementing Instructions (NAII). Led by the Agency Adaptation Official, NASA will work toward further coordination of these cross-functional policy review efforts with the Agency Risk/Resilience Officer.	*Management* Discusses facility service life dependance on many factors, including climate. *NPD 1800.2E NASA Occupational Health Program* This directive establishes policy to ensure, to the extent possible, all NASA work environments are safe, healthy, environmentally sound, and secure. This includes consideration of climate impacts such as indoor air quality and, more generally, occupational exposure assessment and management.
Nature-Based Solutions	NASA continues to review NODIS to determine the extent of policies that do or should address nature-based solutions.	*NID_8500_100_* *Floodplain and Wetlands Management* Document references floodplain management throughout, including re-establish a setting or environment in which the natural functions of the floodplain can again operate, and the restoration, preservation and protection of the natural and beneficial values served by floodplains and wetlands. *NPR 8800.15C - Chapter 1* *Real Estate Management Program* NASA's land management policy requires Centers to consider flooding risks when making plans and agreements regarding land use and investment decisions on facilities projects. To implement this policy, NASA established an elevation-based zoning system. The Agency may consider increasing focus on potential nature-based solutions in updating this NPR, which expires 31 December 2024.
EJ	NASA uses the environmental review process under the National Environmental Policy Act to confirm that NASA's proposed actions will not disproportionately affect low income or minority populations. NASA provides opportunities for early and meaningful public involvement in a manner that is consistent with EO 12898, 14096, as well as NASA's Language Access Plan established per EO 13166.	The NASA EJ point of contact supports coordination of EJ considerations in relation to climate adaptation policies. The following policies guide NASA's EJ considerations more broadly. *NPS_3713_101_* *Policy Statement on Diversity, Equity, Inclusion, and Accessibility for NASA's Workforce and Workplaces* *NPI_2081_79_* *NASA Language Access Plan*
Tribal Nations	NASA initiates Government-to-Government relationships with all Federally recognized Tribes that may have an interest in consulting on NASA actions in accordance with the NHPA of 1966, as amended, 54 U.S.C. 300101 et seq.; its implementing regulations (Protection of Historic Properties, 36 CFR Part 800); the NEPA of 1969, 42 U.S.C. §§ 4321 and 4331; its CEQ	NASA is developing a Nationwide Programmatic Agreement (NPA) to meet its requirements under Section 106 of the NHPA. NASA has been consulting on the NPA with Tribes since 2022, and those consultations have informed sections of the NPA to ensure early and meaningful

Agency Policies Reviewed		
Tribal Nations (continued)	regulations 40 CFR pt. 1501; and EO 13175. In accordance with the NHPA and NEPA, NASA proactively engages Tribes that have historic or cultural ties to the area or are interested in NASA actions, and invites them to participate as consulting parties to address any potential environmental or cultural impacts. NASA Centers are the leads for Tribal consultation under NEPA and NHPA, and Center-specific consultation practices are documented in Center Integrated Cultural Resources Management Plans (ICRMPs). The NASA EO 13175 Officer reviews all proposed NASA rules for potential Tribal implications, and if potential implications are identified, develops a process for consultation. Some example policies to be considered for enhancing climate resilience include the following: *NPR 8510.1A* *NASA Cultural Resources Management* *NPR 8580.1A* *Implementing the National Environmental Policy Act and EO 12114* *NPR 8715.2B* *NASA Emergency Management Program Procedural Requirements* *NPR 9090.1C* *Partnership Agreements – Financial Requirements and Administration* *NAII_1050_3B_* *NASA Advisory Implementing Instructions: NASA Partnerships Guide*	consultation with Tribes when an undertaking may affect a tribal cultural resource. NASA intends to execute the NPA to align with the finalization of the AMP, which links directly to climate resilience in the ARF and CRAs. The Office of Strategic Infrastructure approved the 2023 Plan of Action for the Implementation of EO 13175, *Consultation and Coordination with Indian Tribal Governments*. This plan was developed based on feedback received from Tribal leaders during a consultation meeting in 2023 and through submitted written comments. The Implementation Plan for Tribal engagement includes a review of current Agency policies based upon Tribal input to determine opportunities to strengthen consultation and implementation. NASA has developed Standard Operating Procedures for inadvertent discoveries of archaeological materials and/or Native American human remains. NASA Centers submit Draft ICRMPs to Consulting Tribes for review and comment.
Co-Benefits of Adaptation	NASA continues to execute multiple greenhouse gas emission reduction activities. Starting with projects entering the design phase in 2022, all new construction projects entering the design phase are net-zero emission capable unless mission requirements dictate otherwise. In addition, CoF Program energy savings investment projects include an AMP alignment requirement, including those entering the design phase beginning in 2023. NASA has also modified existing projects to support Agency sustainability and resilience, including by leveraging grant funding available through other Federal agency programs.	*NPR 8570.1B* *NASA Energy and Water Management Program* Promotes mitigation of energy and water-related climate change risks and impacts and use of lower impact energy sources. *NPR 8820.2H - Chapter 6* *Facility Project Requirements* References Clean Air Act Amendments of 1990 Title VI (Stratospheric Ozone and Global Climate Protection), 42 U.S.C. § 7401 et seq.

NASA incorporates climate and resilience considerations into Agency risk management and investments and into Center-level processes. Ongoing efforts include continual Agency policy and process reviews at regular intervals, as well as addressing new Federal policy requirements. NASA uses climate projections to manage risk and inform short- and long-term investment decisions through various workflows. In the Master Planning community, for example, climate data are used to strengthen the risk-based analytic framework to ensure

decisions are consistent with the Agency goals and the AMP. Procedure and guideline reviews will continue to include the addition of needed climate-related details and clarifications, as well as the modification of policies and directives that require more thorough incorporation of climate adaptation efforts. Sustainability efforts and focused climate risk analysis will continue to be a part of current and future processes, and NASA will continue to make updates, as needed, based on internal needs and Federal or other regulatory mandates.

Much of NASA's work is conducted within fenced Centers and component facilities located in six states. NASA's research and development programs are typically conducted onsite; however, NASA also operates rocket launch sites and uses runways where spacecraft and aircraft operations extend into surrounding airspace over the surrounding communities. NASA maintains Center-specific EJ plans that are updated every five years. These serve to provide community information cited in all NASA NEPA documents. EJ provides NASA with a platform to ensure the neighboring community is informed of projects and helps maintain strong relationships to work collaboratively on shared adaptation priorities. At the Community Day during the CASI Workshop held at LaRC in November 2023, CASI shared climate risk information with local groups from the Hampton Roads, one of the most vulnerable areas to sea level and coastal flooding in the country. CASI will hold a similar Community Day at its 2024 Workshop and is exploring how it can further share NASA climate change information with communities near its facilities to address climate-related EJ concerns in surrounding communities.

4. Climate-Smart Supply Chains and Procurement

LMD and the NASA Aeronautics Research Institute have partnered to develop a supply chain resiliency tool set to analyze risks and address impacts from climate change and real-time disaster disruption on NASA's supply chain. The flagship capability is a software suite called PrimeE. The software is a web-based Government tool designed to assist NASA teams with industrial analysis and supply chain assessments. The toolset is being updated in FY 2024 to operate in the NASA cloud hosting environment. The Agency's Supply Chain Risk Management Program also established a Supply Chain Resiliency Board.[6]

NASA has worked to evolve its supply chain resiliency modeling and simulation capability, which will provide agency planners with capabilities to evaluate program and project supply chain risks for flood, drought, and other risk areas. The Agency has formed partnerships with the Department of Defense and specifically the Defense Contract Management Agency to explore supplier risk data sharing. LMD is working to develop and share future information technology tools that will focus on supply chain illumination and visibility.

Over the past year, LMD has focused on evaluating readiness of the Agency's logistics and transportation operations to climate change and extreme weather events. This has included evaluating warehouse and supply infrastructure to assess and formulate a strategy for addressing resilience gaps in logistics infrastructure. This involves collaboration with FRED to begin planning consolidation of logistics infrastructure and infrastructure modernization where possible in consideration of climate and extreme weather impacts.

At-Risk Supplies/Services	Outline Actions to Address Hazard(s)	Identify Progress Toward Addressing Hazard(s)
NASA evaluates its entire supply chain risk inclusive of multiple hazards, including climate and extreme weather. LMD has focused on drought, flood, thunderstorm,	NASA has established three priorities for analyzing climate risk to its supply chain. • Priority 1: Logistics Infrastructure Optimization • Priority 2: Supply Chain Climate Risk Analysis	LMD has expanded supply chain climate analysis capabilities to now include: • Supplier hierarchal relationships of NASA programs • Sole source, alternate source to functional capability identification • Multi-functional relationships between programs and subsystems

[6] NC_1000_56_.pdf (nasa.gov)

At-Risk Supplies/Services	Outline Actions to Address Hazard(s)	Identify Progress Toward Addressing Hazard(s)
and earthquake, among other hazards in its recent critical supply chain risk analyses. The Agency continues reviewing risks holistically to specifically identify its top at-risk supply chains and services.	• Priority 3: Partnership Growth for Transportation Climate Risk Evaluation Descriptive examples of the actions taken under these priorities are provided in the narrative section below.	• Committed Federal budget by supplier, program or congressional district • Geographic mapping expands beyond Earth-based sources • Aggregated data collaboration with Government and industry suppliers NASA continues to make progress on prioritizing climate adaptation and associated planning for its supply chain. This includes three priority areas of focus discussed in the narrative section below.

Priority 1 focuses on Logistics Infrastructure Optimization. In partnership with the Stennis Space Center (SSC), LMD will be piloting and consolidating three Logistics Operations facilities into a single climate-resilient distribution center. The new location on SSC will provide a single robust storage solution. The new location will also provide surge capability for disposition and disposal of materials and scrap. This surge capability will help the agency process damaged or inoperable property as part of normal utilization or future climate events. This effort will be the model to consolidate or evaluate other opportunities throughout the Agency.

Priority 2 focuses on Supply Chain Climate Risk Analysis. LMD continues to evolve the PrimeE Tool Set, which houses the Agency's supply chain climate-resilience and risk assessment capabilities. In Figure 12, PrimeE outlines all states with NASA facilities overlaid with RS-25 program suppliers in those states along with earthquake, drought, and flood risk areas. The figure inset in the lower right quadrant shows shipping suppliers in the Southeastern United States overlaid with thunderstorm, drought, and flood risk areas. NASA continues to engage in active discussion to host these capabilities on classified and unclassified Department of Defense IT digital infrastructure. NASA continues to evaluate the dataset for security considerations and are pursuing a partnership to prevent aggregated data from being compromised or accessed by unauthorized users. Plans also include maturing supplier economic forecast models to evaluate financial impacts due to climate change for Agency suppliers.

Figure 12. PrimeE Tool Set showing an RS-25 program supplier hazard analysis.

Priority 3 focuses on Partnership Growth for Transportation Climate Risk Evaluation. LMD will be working in the next year to develop new partnership with agencies to evaluate best practices in transportation planning and climate change. We are looking for ways the Agency can plan to reduce transportation and supply disruption due to climate change. We have started working with the Department of Transportation to discuss multimodal transportation risks and their plans for increasing resilience.

LMD is further partnering with industry transportation and freight providers to develop new strategies to reduce freight emissions and environmental impacts. Strategy focus areas include low/zero greenhouse gas (GHG) emission calculation in transportation route and carrier planning and decision making, adopting verified GHG calculator toolsets and NASA Freight Tool digital modernization. LMD continues working to model and optimize shipping while reducing NASA GHG emissions.

In addition to supply chain risk, NASA also considers climate change in its procurement activities. The Agency has developed a series of "Sustainability Moments," including a brief tutorial on embodied carbon that can inform procurement decisions. NASA also set a goal to increase integration and the utilization of contractors and businesses from underserved communities to expand equity in its procurement process.

The Agency is in the process of updating its Federal Acquisition Regulation Supplement to require adherence to the NASA Carbon-Pollution Free Electricity (CFE) Strategic Plan during utility service contract procurements and strengthen coordination between stakeholders during acquisition planning to ensure Agency goals are reached, including participation in aggregated Federal procurements. Additionally, the Agency has incorporated EO 14057 goals into project evaluation criteria with the expectation that new construction, third-party financed projects, and real estate actions will emphasize onsite CFE generation for NASA consumption and progress toward 100 percent CFE by 2030.

NASA is pursuing six potential energy performance contracts from FY 2024 through FY 2026. Associated audits will focus on identifying energy and water conservation measures including opportunities for photovoltaic (PV) generation and storage. Strategic priorities and objectives include advancing the efficiency of Center operations and reducing reliance on traditional carbon-based energy sources. These projects bundle a diverse mixture of energy and water conservation measures. They can also address strategic infrastructure resilience priorities, even in demanding environments with uninterruptible missions and highly technical requirements. Through creative use, refinement, and enhancement of the performance contract process, NASA has provided energy savings and improved efficiency, while also improving resilience for facilities that support critical NASA missions.

NASA has developed zero-emission vehicle (ZEV) implementation guidance approved by the Agency's Chief Sustainability Officer. Implementation is directed by the LMD. Each Center's Transportation Officers coordinate electric vehicle supply equipment and ZEV deployment with assistance from LMD and the NASA Transportation Manager. NASA's Strategic Plan for transforming from a petroleum-powered fleet to a zero-emission-powered fleet focuses on building infrastructure and identifying high-value charging station locations through FY 2027. These stations will support NASA's fleet inventory of the future. NASA plans to invest heavily in infrastructure through FY 2027 and replace the sedan subset of its projected fleet inventory with ZEVs.

5. Climate-Informed Funding to External Parties

NASA provides grant funding that supports climate- and weather-related adaptation and resiliency goals. NASA grant funding is primarily disseminated through SMD, and the Agency has recently focused on opportunities to align climate-related grants with EJ. Success in these efforts will benefit NASA and its surrounding communities by bringing the best minds and talent to understand, innovate, and tackle challenging issues like climate change.

NASA ESD recognizes a need to develop and learn from relationships with underserved and overburdened communities, as well as organizations familiar with working alongside these communities. ESD also recognizes a need to expand awareness, accessibility, and use of Earth science information to advance equity and environmental justice (EEJ) as well as to combine this information with social science information. In 2021, ESD released the first EEJ opportunity through Research Opportunities in Space and Earth Science (ROSES; ROSES-21 A.49 NASA Equity and Environmental Justice) and selected 39 projects that began in late 2022 and early 2023. This portfolio included three types of projects: landscape analysis projects, community-based feasibility study projects, and data integration projects. These projects explore a variety of topics and geographies, such as urban heat islands and extreme heat, wildfire risk and smoke, greenspace, agriculture, and disaster risk. Example projects can be seen at https://appliedsciences.nasa.gov/what-we-do/capacity-building/environmental-justice.

In 2023, NASA released solicitation A.47 Earth Action: Community Action for Equity and Environmental Justice to support protection from disproportionate and adverse human health and environmental effects (including risks) and hazards, including those related to climate change. NASA seeks to advance the creation of geospatial tools that integrate Earth science and socioeconomic information, expand the COP that use Earth observations to address climate-related EJ issues, and inform action. NASA is especially interested in proposals from or partnered with domestic non-Federal organizations from community-based non-profit institutions, Tribal Governments and academic institutions, indigenous-supporting organizations, local governments, and academic institutions active in addressing climate-related EJ issues that would benefit from the insights offered by NASA Earth science information. NASA is intentional about meaningful engagement with communities and requested proposals developed in collaboration with underserved and overburdened communities, that involve a co-design process to address community interests to use Earth science information in decisions, actions, and policies.

In 2023 NASA also released solicitation A.67 Earth Action: Supporting Climate Resilient Communities with a focus on supporting communities in building their resilience to climate impacts through the application of NASA Earth observations. This call for proposals aims to increase the use of NASA Earth observations to support community resilience, expand the COP who use NASA Earth observations to develop climate-informed community resilience decisions, demonstrate the value of using NASA Earth observations to prepare for and respond to climate change, and inform NASA's future strategic engagement and activities on climate resilience.

In 2023 NASA selected proposals in response to solicitation A.28 Research and Analysis Interdisciplinary Research in Earth Science with seven sub-elements (Nitrogen, Ocean-Atmosphere, Fire, Environmental and Climate Justice, Land-Ocean, Ocean Worlds, and Earth-Moon connections. This solicitation required that investigations meet the following criteria to ensure a strategic and data-informed approach to adaptation and resilience research:

- offer a fundamental advance to our understanding of the Earth system;
- be based on remote sensing data, especially satellite observations, but including suborbital sensors as appropriate;
- go beyond correlation of data sets and seek to understand the underlying causality of change through determination of the specific physical, chemical, and/or biological processes involved;
- be truly interdisciplinary in scope by involving traditionally disparate disciplines of the Earth sciences.

Many of these programs promote climate adaptation and resilience, while also helping to advance EJ because they are covered programs within the Justice40 Initiative, which sets a goal that 40 percent of the overall benefits of certain Federal climate and other investments flow to disadvantaged communities that are marginalized by underinvestment and overburdened by pollution. Additional information on related NASA programs can be found at Applied Sciences: Climate Resilience.

3C. Climate Training and Capacity Building for a Climate-Informed Workforce

Training and Capacity Building	
Agency Climate Training Efforts	*Percent of the Agency's Federal staff who have taken a 60+ minute introductory climate training course (e.g., Climate 101)*: Approximately 10%
	Percent of the Agency's senior leadership (e.g., Sec, Dep Sec, SES, Directors, Branch Chiefs, etc.) who have completed climate adaptation training: Not yet tracked
	Percent of budget officials who have received climate adaptation-related training: Not yet tracked
	Percent acquisition officials who have received climate adaptation-related training: Not yet tracked
	Additional efforts the Agency is taking to develop a climate-informed workforce: The NASA Chief Scientist and Senior Climate Advisor leads climate literacy initiatives for the Agency, which has included Agency-wide coordination through the CSWG. NASA has also continued internal climate education and training by focusing on existing COPs. This allows the Agency to address critical climate literacy requirements specific to employee's day-to-day responsibilities and operational and mission support duties. The topic of climate risk is also captured

Training and Capacity Building	
Agency Climate Training Efforts (continued)	in Master Planning activities as well as Sustainability Program information sharing. NASA's CSWG led planning and execution of a two-day Climate Summit in 2022. This included a 1-hour "Climate 101" training session. OSI developed and presented a climate and sustainability video for presentation at the 2022 Climate Summit. The video helped to illustrate how climate events can affect mission and how, alongside sustainability efforts, NASA climate adaptation efforts can make a difference for the Agency, its surrounding communities, and the world. See the Section 3C narrative for further Climate Summit details. NASA is also hosting science and climate town halls across its Centers, which focus on keeping the workforce informed about NASA's climate work and progress, climate science integration across the Agency and NASA's efforts to foster a climate-informed workforce and enable adaptation efforts. NASA plans to conduct town hall events that focus on education for general workforce as well as those in roles with a direct climate function. NASA utilizes its internal Learning Management System, System for Administration, Training, and Educational Resources for NASA (SATERN) to host training, education, and career development modules. The Agency is considering development of one or more modules for climate-focused training, including introductory and advanced education materials. Agency-wide and Center-specific trainings occur throughout the year. In addition to Agency-led trainings within EMD University or the NASA SATERN Training platform, EMD works with NASA Centers to extend education opportunities across the Agency and beyond. Beginning in September 2023, the Agency began working with Centers and colleagues to identify events that could be extended across the Agency. As a result of these efforts, the Agency developed a mailing list. Anyone interested can subscribe to this mailing list (NASA employee, contractor, or external individuals) and allows NASA to promote educational events. Between September 2023 and January 2024, 8 Agency-wide events were coordinated with 1,887 attendees.
Agency Capacity	*Number of full-time Federal staff across the Agency who have tasks relevant to climate adaptation in their job description*: NASA has not completed its analysis of this job specific measurement

Climate Summit participants were invited Agency-wide. Figure 13 shows day one primarily focusing on information delivery and Climate 101 with an opportunity for moderated questions to presenters and panelists.

Figure 13. NASA's 2022 Climate Summit; Day 1 Agenda.

Day two focused on understanding climate and weather challenges more clearly, including gathering input from subject matter experts and the workforce on the problem and potential solutions. The participants also identified actions items (e.g., inform the Climate Strategy implementation plan, CSWG Actions, and next Climate Summit). These sessions on day two covered a wide range of topics, including:

- Safeguarding NASA's mission
- A whole-of-government approach to climate change
- Actionable information for underserved, vulnerable communities
- Breaking down stovepipes for collaboration on climate activities
- Rethinking NASA technologies to address climate challenges
- New public-private partnership models for NASA climate action
- Developing the climate-savvy workforce of the future
- Empowering, inspiring and equipping NASA climate ambassadors
- From NASA data to decision support.

NASA also provides training on its Earth-observation information through the Applied Remote Sensing Training (ARSET) program.[7] ARSET offers online and in-person trainings for beginners and advanced practitioners on a range of datasets, web portals, and analysis tools covering topics such as air quality, agriculture, disaster, land, and water resources management. Since 2009, the program has reached more than 100,000 participants from 180 countries and more than 17,000 organizations worldwide. In 2023, ARSET developed an online, instructor-led introductory training, "Building Climate Risk Assessments from Local Vulnerability and Exposure." This training describes climate risk assessment approaches that originate with stakeholder expertise in the fundamental climate vulnerability and exposure of their system. By identifying at-risk assets and the types of climate conditions that drive problematic responses, stakeholders and scientists can co-develop risk information targeting specific climatic impact drivers and utilizing climate observations and projections sets selected to suitably address those risks. The training provided an assessment and engagement framework and utilized examples from the CASI Program.

3D. Summary for Major Milestones

The table below summarizes NASA's timeline for major milestones discussed throughout Section 3 and related elements of Section 2.

Section of the Implementation Plan	Description of Milestone	Climate Risk Addressed	Indicators for Success
Section 2	Higher resolution CASI datasets and tools	All hazards	Approximately 5–6-km grid resolution complete
Section 2D	Center Resilience Assessments complete	All hazards	Completion of individual Center assessments
Section 3A1	Continue ongoing coastal resilience and hardening	Sea level rise and storm surge impacts to launch facilities	Access to space through further integration of climate in ERM process
Section 3A2	Expand CASI and OCHMO collaboration	Heat- and fire-related air quality impacts to employees	Establish partnership and produce heat stress and air quality projections
Section 3B4	Expand application of PrimeE capabilities	All hazards; focus on earthquake, drought, and flood risk areas	Top at-risk supply chains and services identified
Section 3B5	Climate-informed funding	All hazards	Explicit climate consideration metrics
Section 3C	Completion of training framework	All hazards	Expanded training metrics

[7] ARSET Climate Trainings | NASA Applied Sciences

Section 4: Demonstrating Progress

4A. Measuring Progress

Key Performance Indicator: Climate adaptation and resilience objectives and performance measures are incorporated in planning and budgeting of Agency programs by 2027.		
Section of the CAP	**Process Metric**	**Agency Response**
3A – Addressing Climate Hazard Impacts and Exposure	Step 1: Agency has an implementation plan for 2024 that connects climate hazard impacts and exposures to discrete actions that must be taken. (Y/N/Partially) Step 2: Agency has a list of discrete actions that will be taken through 2027 as part of their implementation plan. (Y/N/Partially)	Step 1: Y Step 2: Partially
3B1 – Accounting for Climate Risk in Decision-making	Agency has an established method of including results of climate hazard risk exposure assessments into planning and decision-making processes. (Y/N/Partially)	Partially
3B2 – Incorporating Climate Risk Assessment into Budget Planning	Agency has an Agency-wide process and/or tools that incorporate climate risk into planning and budget decisions. (Y/N/Partially)	Y
3B5 – Climate-Informed Funding to External Parties	Step 1: By July 2025, Agency will identify grants that can include considerate and/or evaluation of climate risk. Step 2: Agency modernizes all applicable funding announcements/grants to include a requirement for the grantee to consider climate hazard exposures. (Y/N/Partially)	Step 1: Partially Step 2: Partially
Key Performance Indicator: Data management systems and analytical tools are updated to incorporate relevant climate change information by 2027.		
Section of the CAP	**Process Metric**	**Agency Response**
3A – Addressing Climate Hazard Impacts and Exposure	Agency has identified the information systems that need to incorporate climate change data and information and will incorporate climate change information into those systems by 2027. (Y/N/Partially)	Partially
Key Performance Indicator: Agency CAPs address multiple climate hazard impacts and other stressors, and demonstrate nature-based solutions, equitable approaches, and mitigation co-benefits to adaptation and resilience objectives.		
Section of the CAP	**Process Metric**	**Agency Response**
3B3 – Incorporating Climate Risk into Policy and Programs	By July 2025, 100% of climate adaptation and resilience policies have been reviewed and revised to (as relevant) incorporate nature- based solutions, mitigation co-benefits, and equity principles. (Y/N/Partially)	Partially
Key Performance Indicator: Federal assets and supply chains are evaluated for risk to climate hazards and other stressors through existing protocols and/or the development of new protocols; response protocols for extreme events are updated by 2027.		
Section of the CAP	**Process Metric**	**Agency Response**
3B4 – Climate- Smart Supply Chains and Procurement	Step 1: Agency has assessed climate exposure to its top five most mission-critical supply chains. (Y/N/Partially) Step 2: By July 2026, Agency has assessed services and established a plan for addressing/overcoming disruption from climate hazards. (Y/N/Partially)	Step 1: Partially Step 2: Partially

	Step 3: Agency has identified priorities, developed strategies, and established goals based on the assessment of climate hazard risks to critical supplies and services. (Y/N/Partially)	Step 3: Partially
Key Performance Indicator: By 2027, Agency staff are trained in climate adaptation and resilience and related Agency protocols and procedures.		
Section of the CAP	**Process Metric**	**Agency Response**
3C – Climate Training and Capacity Building for a Climate-Informed Workforce	Step 1: By December 2024, 100 percent of Agency leadership have been briefed on current agency climate adaptation efforts and actions outlined in their 2024 CAP. (Y/N/Partially) Step 2: Does the Agency have a Climate 101 training for your workforce? (Y/N/Partially) If yes, what percent of staff have completed the training? Step 3: By July 2025, 100 percent employees have completed climate 101 trainings. (Y/N/Partially)	Step 1: Partially Step 2: Partially Approximately 10% Step 3: Partially

4B. Adaptation in Action

NASA has considered climate change risk to our mission over time, as shown in Figure 14, and continually advances efforts to further incorporate climate considerations within ERM processes. This process has included exploring new and continuing existing partnerships internally, as well as with Federal partners, state and local government, academia, and industry. The Agency continues sharing what it learns and learning from other organizations. Significant challenges remain, including workforce bandwidth to execute the CAP alongside management of other risks to mission. To assess progress and benefits, the Agency measures savings in maintenance, energy, water, and other costs, including in alignment with climate co-benefits through its net-zero operations goals.

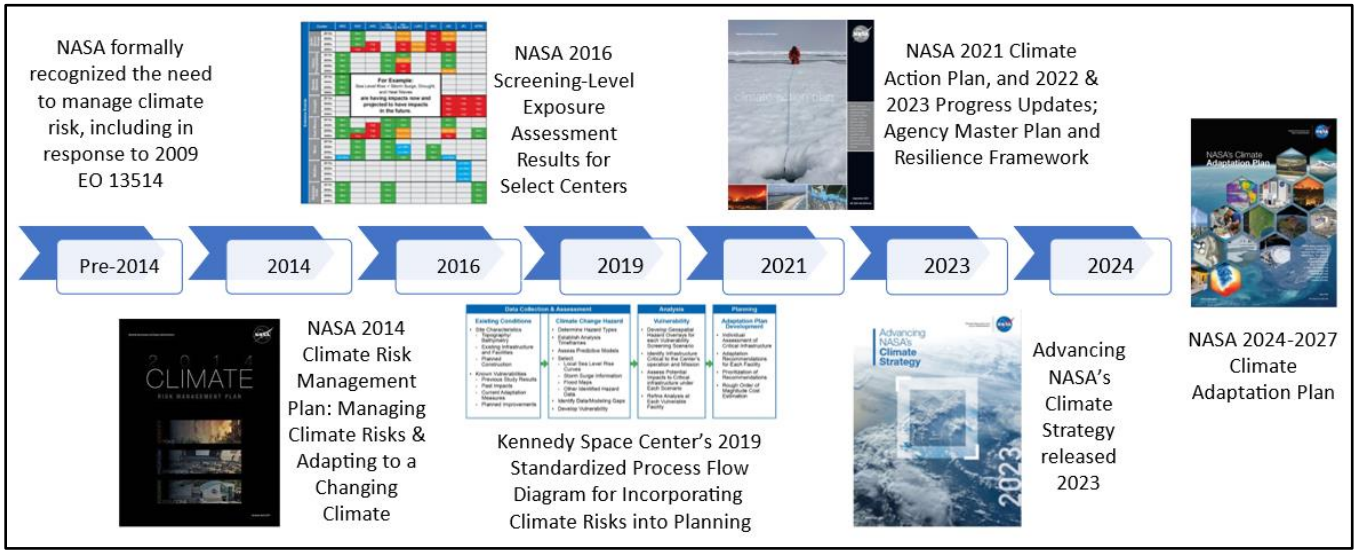

Figure 14. NASA's climate risk timeline.

In its 2021 Climate Action Plan, NASA established five priority actions. OSI focuses and leads on Priorities 1–3, with fellow Mission Directorates directly supporting Priorities 4 and 5. Priority Action 1 is to ensure access to space. Figure 15 shows NASA's 2021 shoreline protection with five breakwaters installed along with 1.2 million cubic yards of sand to protect launch assets. This was a joint effort with the Army Corps of Engineers. The breakwaters continue functioning well versus 1990's-era stone seawalls. The Agency plans to expand this approach at WFF and possibly apply a similar approach at KSC.

Figure 15. NASA's 2021 shoreline protection with five breakwaters.

NASA also develops internal awards to recognize accomplishments. For example, NASA added a climate and resilience category to its Blue Marble Award program, and KSC's Dune Survey Team was recognized for its efforts to protect KSC, its mission, and operations (see Figure 16). In addition to coastal shoreline protections, KSC has also added other climate-related projects to its institutional repair list, including roadway modifications and critical facility flood fortifications.

In FY 2023, the United States Department of Energy selected NASA's White Sands Test Facility to enter negotiations for a $700,000 Assisting Federal Facilities with Energy Conservation Technologies program 2022 cycle grant, which will add funding in FY 2024 to an ongoing direct-funded battery energy storage system (BESS) project. This project will provide a 2-megawatt BESS and a dynamic output control system in a larger solar PV project. The project reflects a connected focus on Priorities 2 (AMP) and 3 (ARF) by tying together mission assurance, energy security, efficiency, and resilience with energy conservation measures enabling load shifting, peak shaving, cost savings, and emergency power for the potable water system. NASA plans to replicate lessons learned to inform similar projects and share results with other Federal agencies.

Figure 16. MSFC awarded a Group Achievement Honor Award for Kennedy Space Center Protective Dune Survey Team.

Priority Action 4 focused on updating climate modeling to enable better understanding of Agency threats and vulnerabilities. Beyond CASI achievements, NASA's mission includes many other accomplishments in this area. For example, the Surface Water and Ocean Topography (SWOT) mission brings together two communities focused on a better understanding of the world's oceans and its terrestrial surface waters. United States (U.S.) and French oceanographers and hydrologists and international partners have joined forces to develop this satellite mission to make the first global survey of Earth's surface water, observe the fine details of the ocean's surface topography, and measure how water bodies change over time. Missions that monitor sea levels, including the

SWOT satellite and Sentinel-6 Michael Freilich, help to monitor El Niños in the near term. SWOT, in particular, collects data on sea levels right up to the coast, which can help to improve sea level rise projections. For example, an analysis by NASA's sea level change science team notes that with strong El Niño conditions, cities along the western coasts of the Americas could see an increase in the frequency of high-tide flooding that can swamp roads and spill into low-lying buildings. These details could aid NASA's coastal Centers in preparing for rising seas in the next decades at finer resolution and better enable partnership with policymakers and planners in surrounding communities that require higher resolution datasets to inform local decisions, which impact NASA's resilience.

Priority Action 5 included a focus on ARMD's Scalable Traffic Management for Emergency Response Operations (STEReO). Leveraging capabilities developed under the STEReO activity, ARMD formulated a new project to focus on wildfire aerial response. These efforts have been incorporated into Advanced Capabilities for Emergency Response Operations (ACERO); see Figure 17. The initial focus of the effort is to develop interagency concept of operations to ensure consistency of operational priorities, technology adoption, and programmatic alignment for national needs. The technical objectives of the project are to develop and demonstrate emerging airspace management technology to improve emergency responders' efficiency and safety during a disaster and to employ emerging aviation technologies that support 24-hour operations. These efforts will help NASA manage risk to facilities in high-risk wildfire areas, such as the Jet Propulsion Laboratory and Ames Research Center.

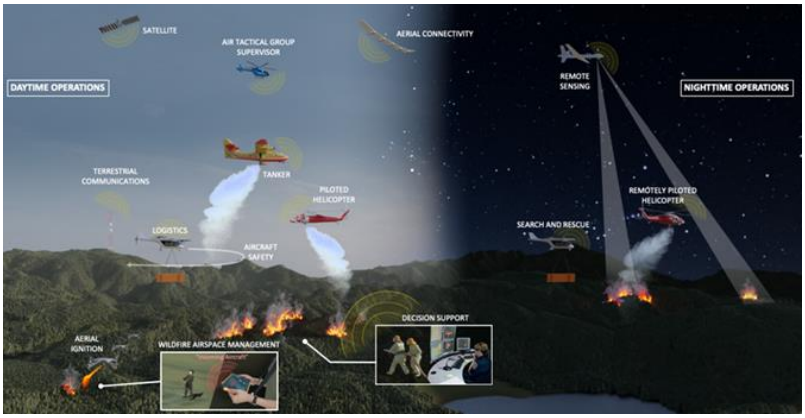

Figure 17. ACERO concept of operations.

Appendix A: Risk Assessment Data

The Federal Mapping App uses the following data:

Buildings
Buildings data comes from the publicly available Federal Real Property Profile (FRPP). The General Services Administration (GSA) maintains FRPP data and Federal agencies are responsible for submitting detailed asset-level data to GSA on an annual basis. Although FRPP data is limited—for example, not all agencies submit complete asset-level data to GSA, building locations are denoted by a single point and do not represent the entirety of a structure or could represent multiple structures, and properties may be excluded on the basis of national security determinations— it is the best available public dataset for Federal real property. Despite these limitations, this data is sufficient for screening-level exposure assessments to provide a sense of potential exposure of Federal buildings to climate hazards.

Personnel
Personnel data comes from the Office of Personnel Management's non-public dataset of all personnel employed by the Federal government that was provided in 2023. The data contains a number of adjustments, including exclusion of military or intelligence agency personnel, aggregation of personnel data to the county level, and suppression of personnel data for duty stations of fewer than five personnel. Despite these adjustments, this data is still useful for screening-level exposure assessments to provide a sense of key areas of climate hazard exposure for agency personnel.

Climate Hazards
The climate data used in the risk assessment comes from the data in Climate Mapping for Resilience and Adaptation (CMRA) Assessment Tool. When agency climate adaptation plans were initiated in 2023, CMRA data included climate data prepared for NCA4. Additional details on this data can be found on the CMRA Assessment Tool Data Sources page. Due to limited data availability, exposure analyses using the Federal Mapping App are largely limited to the contiguous United States. Additional information regarding Alaska, Hawai'i, U.S. Territories, and marine environments has been included as available.

In addition to this high-level screening, NASA used Agency-specific CASI data and screening tools:

CASI uses downscaled climate data from NASA Earth Exchange's Global Daily Downscaled Projections (Thrasher et al. 2022)[8,9] derived from CMIP6, as developed for the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (IPCC AR6). This is completed across four Tier-1 greenhouse gas (GHG) emissions scenarios [Shared Socioeconomic Pathways (SSPs)]; specifically, SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5. This is conducted at 0.25-degree spatial resolution, globally, with the historical data from 1950 to 2014 and future projections for 2015 to 2100. Daily data is generated by applying the Bias-Correction Spatial Disaggregation method to correct the global climate model (GCM) bias by using Princeton University's observational climate dataset Global Meteorological Forcing Dataset (GMFD)[10] and is further spatially disaggregated using GMFD data. This includes 35 GCMs. Further CASI analyses reduced this to a set of 22 GCMs after removing "hot" models, which CASI defines as the models within the IPCC AR6's "very likely" range of Transient Climate Response, which is a measure of climate model sensitivity (IPCC, AR6-WG1, TS).

[8] NASA Earth Exchange Global Daily Downscaled Projections (NEX-GDDP-CMIP6) | NASA Center for Climate Simulation
[9] https://www.nature.com/articles/s41597-022-01393-4
[10] Sheffield, J., Goteti, G., & Wood, E. F. (2006). Development of a 50-year high-resolution global dataset of meteorological forcings for land surface modeling. *Journal of Climate*, 19(13), 3088-3111.