SUPPLEMENT

ENHANCING CLIMATE RESILIENCE AT NASA CENTERS

A Collaboration between Science and Stewardship

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CLIMATE PROJECTION METHODS FOR NASA CENTERS. Comparison of mean change and extreme event projections are based on the North American Regional Climate Change Assessment Program (NARCCAP) regional climate models (RCMs) (Mearns et al. 2007, 2009); these regional climate model simulations are available for the A2 emissions scenario for a hindcast period and for a 30-yr period centered around the 2050s.

Statistically downscaled projections from 16 GCMs and three emissions scenarios were generated for the 2020s, 2050s, and 2080s, with each time period defined as the 30-yr average centered on the specified decade. Methods for the temperature and precipitation projections are as described in Horton et al. (2011), except that the 12-km Bias Corrected and Spatially Downscaled (BCSD) World Climate Research Programme Coupled Model Intercomparison Project phase 3 (CMIP3; available online at http://gdo-dcp.ucllnl.org/) dataset was substituted for GCM gridbox output (Maurer et al. 2007).

Sea level rise projections (Table ES1) are regionalized using the method described in Horton and Rosenzweig (2010) and Horton et al. (2011); this approach, which includes regional and global terms, produces lower GCM-based projections (Solomon et al. 2007) as well as a rapid ice-melt scenario that is consistent with recent higher-end projections (e.g., Pfeffer et al. 2008, NRC 2012, Parris et al. 2012; Perrette et al. 2013; Slangen et al. 2014.).

Table ES1. Sea level rise (SLR) projections for the 2050s at NASA Centers.

NASA Center	2050s GCM-based SLR*	2050s rapid ice-melt SLR**
Ames Research Center	15–23 cm	46–64 cm
Johnson Space Center	13–23 cm	43–66 cm
Kennedy Space Center	13–20 cm	43–61 cm
Langley Research Center	18–28 cm	48–69 cm
Stennis Space Center	15–25 cm	46–69 cm

* Projections are based on 7 GCMs and 3 emissions scenarios. Presented are the central range (middle 67%) of values from model-based probabilities. Data are rounded to the nearest cm.

** The rapid ice-melt scenario is based on acceleration of recent rates of ice melt in the Greenland and West Antarctic ice sheets and paleoclimate studies.

MEAN TEMPERATURE AND PRECIPITATION. For the BCSD ensemble, projected annual mean temperature changes averaged across the 10 NASA Centers (2050s relative to the 1980s) range from an increase of 0.9°C for a B1 BCSD simulation to an increase of 2.9°C for an A1B simulation. Most of this range is due to climate model sensitivity, not the choice of greenhouse gas emissions scenario (Nakicenovic et al. 2000); the 16 BCSD ensembles for the B1, A2, and A1B scenarios respectively range from 1.6° to 2.1° to 2.2°C. Projected precipitation changes by the 2050s for the NASA Centers are generally small compared to historical variability; for example, annual mean precipitation projections for the 16 GCM ensemble for the A2 scenario span from −4% at the Jet Propulsion Laboratory to +6% at Goddard Space Flight Center.

EXTREME EVENTS BASED ON BCSD. Table ES2 shows how the frequency of extreme temperature events (defined as the number of days per year when a temperature threshold is met or exceeded) that currently are used for Center planning are projected to change under the BCSD 1/8° monthly projections. The delta method (whereby monthly mean changes based on multiyear timeslices are applied to daily historical data) is used to convert the projected mean monthly changes from BCSD to daily station data (e.g., Gleick 1986; Arnell 1996; Wilby et al. 2004). The extreme event thresholds are not uniform, since the Centers span multiple climate zones. While there is some variation in these projections, many Centers experience approximately a doubling of the frequency of extreme heat events, and approximately a 50% reduction in the probability of extreme cold events by the 2050s.

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

1) Levels of future greenhouse gas concentrations and other radiatively important gases and aerosols,
2) Sensitivity of the climate system to greenhouse gas concentrations and other radiatively important gases and aerosols,
3) Climate variability, and
4) Changes in local physical processes (such as afternoon sea breezes) that are not captured by global climate models.

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

Table ES2. Annual average number of days of observed and projected maximum and minimum temperatures above and below prescribed thresholds for NASA Centers. The baseline data for temperature are for the most complete set of 30 years centered on the 1980s at the specified weather station. Projected values are for the 30-yr period centered on the 2050s decade, using the central range (middle 67% of values from model-based probabilities) across the 16 statistically downscaled (BCSD) GCMs and three GHG emissions scenarios.

Baseline	Projected	NASA Center	Observed station	Baseline	Projected
At or below 40°F				**At or above 90°F**	
20	11–15	Kennedy Space Center	Titusville, FL	82	102–134
26	5–12	Jet Propulsion Laboratory	Pasadena, CA	66	87–107
37	17–26	Johnson Space Center	Houston, TX	90	116–136
48	26–34	Langley Research Center	Norfolk, VA	34	49–64
55	24–36	Ames Research Center	San Jose, CA	20	28–41
65	40–50	Stennis Space Center	Poplarville, MS	82	106–131
129	89–105	Dryden Flight Research Center	Edwards Air Force Base, CA	109	122–133
At or below 32°F				**At or above 90°F**	
63	35–46	Marshall Space Flight Center	Huntsville, AL	48	73–100
110	71–84	Goddard Space Flight Center	Beltsville, MD	26	46–65
121	77–94	Glenn Research Center	Cleveland, OH	9	19–37