Climate Change Adaptation Plan

June 30, 2014

Climate Change Adaptation Policy Statement

The Social Security Administration touches the lives of virtually every person in America. We run one of the Nation's largest entitlement programs, as well as the Supplemental Security Income program, which provides financial support for the Nation's aged, blind, and disabled adults and children with limited income and resources. While the scope, severity, and pace of future climate change are difficult to predict, it is clear that potential changes could have important effects on our operations and programs. We agree that climate change adaptation is critical to complement climate change mitigation and both are necessary to address the causes and consequences of climate change.

Through climate adaptation planning, we will identify how climate change is likely to affect our ability to achieve our mission, operate our facilities, and meet our policy and program objectives. We will develop, prioritize, implement, and evaluate actions to mitigate climate change risks and develop new opportunities that climate change may bring. We will contribute to the Federal Government's leadership role in sustainability and pursue the vision of a resilient, healthy, and prosperous Nation in the face of a changing climate.

In our climate change adaptation planning and implementation, we will:

- Comply with all environmental and energy-related statutes, Executive Orders, and any applicable Federal, State, and local regulations;
- Consider climate change adaptation when making planning, purchasing, operating, and budgetary decisions;
- Conserve resources and prevent pollution by educating and encouraging employees and contractors to reduce energy consumption and water usage, reduce the amount of waste produced, and promote re-use and recycling whenever possible;
- Continue improving environmental stewardship by setting environmental goals, measuring progress, taking corrective action, when necessary, and communicating the results;
- Communicate and reinforce this policy throughout our agency; and
- Coordinate with other agencies, including the Interagency Climate Change Adaptation Task Force, on climate change adaptation.

Carolyn W. Colvin
Acting Commissioner

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Introduction and Summary

We have over 1,500 offices that include regional offices, field offices, teleservice centers, processing centers, hearing offices, the Appeals Council, and our headquarters in Baltimore, Maryland. However, for purposes of Federal reporting on matters relating to sustainability and climate change, we have been delegated responsibility for seven major facilities around the contiguous United States, in addition to our headquarters (HQ) campus in Woodlawn, Maryland:

- Wabash Avenue Building in Baltimore, MD
- Security West in Baltimore, MD
- Frank Hagel Federal Building in Richmond, CA
- Harold Washington Social Security Building in Chicago, IL
- Mid-Atlantic Social Security Center in Philadelphia, PA
- Addabo Federal Building in Jamaica, NY
- Wilkes-Barre Data Operations Center in Wilkes-Barre, PA

Our climate change adaptation planning focuses on the HQ campus and these delegated facilities.

Table 1 below depicts the results of the vulnerability and risk assessments we conducted in fiscal year (FY) 2013, and our resulting prioritization of issues. We ranked relevant issues in order of urgency, on a scale from 2 to 10 (very low to very high). So far, our vulnerability and risk assessments have considered only the agency as a whole, not specific locations.

Table 1. Results of Vulnerability and Risk Analyses, and Prioritization of Issues

Potential Problem Resulting from Climate Change	Vulnerability	Risk	Priority
Coastal Flooding: Increased flooding or inundation in coastal locations	**4** (high)	**4.5** (very high)	**8.5** (high)
Ozone: Impaired health due to elevated ground level ozone	**4** (high)	**4** (high)	**8** (medium-high)
Electricity: Increased disruptions to power supply from the electricity grid	**3** (medium)	**4** (high)	**7** (medium)
Non-Coastal Flooding: Increased flooding in non-coastal locations	**2.5** (medium-low)	**3.5** (medium)	**6** (medium)
Wildfire: Facilities damaged by wildfire	**3** (medium)	**3** (medium)	**6** (medium)
Water: Reduced water supply for facilities	**2.5** (medium-low)	**2.5** (medium-low)	**5** (medium)
Transportation: Increased disruptions and damage to transportation infrastructure	**2** (low)	**2.5** (medium-low)	**4.5** (medium-low)
Disease: Illness due to expanded range of vector-borne disease	**2** (low)	**2** (low)	**4** (medium-low)
Stormwater Runoff: Damage from erosion (on- and off-site); compliance with water discharge permits	**1.5** (low)	**2** (low)	**3.5** (low)

Table 2 provides a compilation of our adaptation goals and the actions under them, along with timeframes and lead offices. We describe our plans for how we will contribute to coordinated interagency efforts to support climate preparedness and resilience under Goal C in the next section. We provide the details of our climate change vulnerability and risk assessments in Appendices A and B, respectively. The planning process used to develop our Climate Change Adaptation Plan (Plan) is in Appendix C, and Appendix D summarizes the projected climate change impacts used to inform our assessments.

Table 2. Summary of Adaptation Plan Goals and Actions

#	ACTION	TImeframe	Lead
Goal A: Improve Our Understanding of the Risks Climate Change Poses to the Agency			
1	Survey the Delegated Facilities Regarding Their Climate Change Vulnerabilities	October 2014	DCBFQM
2	Analyze and Summarize Survey Information	December 2014	DCBFQM
3	Use Survey Results to Revise the Climate Change Adaptation Plan	January 2015	DCBFQM
Goal B: Climate Change Adaptation Planning Socialized and Integrated			
4	Vet the Adaptation Plan with the Delegated Facilities		
4a	Send the Adaptation Plan to the Delegated Facilities	February 2015	DCBFQM
4b	Synthesize Feedback into Recommendations for Future Revisions	March 2015	DCBFQM
5	Incorporate Adaptation Into Existing Headquarters Contingency Planning	November 2014	DCBFQM
Goal C: Improve Climate Change Adaptation Planning through Interagency Collaboration			
6	Continue Improving Our Understanding of Climate Change Risks through Interagency Initiatives	Ongoing	DCBFQM
7	Continue Improving Our Understanding of Climate Change Risks through Coordination with the General Services Administration	Ongoing	DCBFQM

Adaptation Plan Goals and Actions

Each action in the Plan consists of a description of the action, the timeframe for its completion (sometimes with intermediate steps), the lead agency component responsible for ensuring successful completion, and the performance metric(s) we will use to track progress on implementing the Plan.

GOAL A Improve Our Understanding of the Risks Climate Change Poses to the Agency

Action 1 Survey the Delegated Facilities Regarding Their Climate Change Vulnerabilities

Action: The vulnerability and risk assessments we conducted in FY 2013 did not have the benefit of information from the field. To address this information deficit, we will send out a short survey to our delegated facilities to collect historical information on weather-related issues in their areas, and vulnerabilities they might already be experiencing, such as power outages or brown-outs occurring in storms or heat waves, threats or occurrences of flooding or wind damage, and wildfires known to be an ongoing threat. This information will enable us to determine how many of our facilities are located in areas with issues. We also plan to query facilities in coastal locations to assess which facilities are vulnerable to sea level rise and in what timeframe.

Timeframe: Deploy survey no later than October 2014.

Lead Office: Deputy Commissioner for Budget, Finance, Quality, and Management (DCBFQM)

Metric: Survey responses received from all delegated facilities.

Action 2 Analyze and Summarize Survey Information

Action: Analyze survey responses and generate a report discussing and summarizing the various vulnerabilities revealed by the survey.

Timeframe: December 2014

Lead Office: DCBFQM

Metric: Report completed.

Action 3 Use Survey Results to Revise the Climate Change Adaptation Plan

Action: Re-visit the prioritization of climate change issues for the agency based on the survey results, update Table 1 as needed, and revise the Plan, as appropriate, based on the new knowledge.

Timeframe: January 2015

Lead Office: DCBFQM

Metric: Agency Plan revised to incorporate information received from the delegated buildings.

GOAL B Climate Change Adaptation Planning Socialized and Integrated

Action 4 Vet the Adaptation Plan with the Delegated Facilities

Action: (a) Send the Plan to the delegated facilities. This has two purposes: 1) to increase their awareness of the agency's efforts to improve resiliency; and 2) to solicit any insights for proactively addressing projected climate change impacts based on their experience and best practices preparing for weather-related situations and emergencies.

(b) Comments from the delegated facilities received and synthesized into recommendations for future revisions, as appropriate.

Timeframe: (a) February 2015; (b) March 2015

Lead Office: DCBFQM

Metric: Final draft Plan generated for review at the Deputy Commissioner level, by incorporating feedback from other agency components.

Action 5 Incorporate Adaptation into Existing Headquarters Contingency Planning

Action: (a) DCBFQM directs the Office of Security and Emergency Preparedness (OSEP) to revise existing headquarters emergency contingency plan(s), as needed, to incorporate climate change considerations.

(b) OSEP updates the plan(s) as appropriate.

Timeframe: (a) October 2014; (b) November 2014

Lead Offices: (a) DCBFQM; (b) DCBFQM/OSEP

Metric: (a) Directive made to OSEP; (b) plan(s) managed by OSEP revised as needed.

GOAL C Improve Climate Change Adaptation Planning through Interagency Collaboration

Action 6 Continue Improving Our Understanding of Climate Change Risks through Interagency Initiatives

Action: Participate in inter-agency Federal Government initiatives to improve the accessibility and coordination of climate change science for decision-making, including the Interagency Climate Change Adaptation Task Force and the U.S. Global Change Research Program National Climate Assessment.

Timeframe: Ongoing

Lead Office: DCBFQM

Metric: Information useful for updating our Plan learned from participation in inter-agency initiatives of the Federal Government.

Action 7 Continue Improving Our Understanding of Climate Change Risks through Coordination with the General Services Administration (GSA)

Action: Coordinate with GSA to acquire knowledge relevant for planning, such as assessing vulnerabilities and risks and identifying space and infrastructure requirements for field offices, hearing offices, and data centers.

Timeframe: Ongoing

Lead Office: DCBFQM

Metric: Information useful for updating our Plan learned from coordinating climate change adaptation efforts with GSA.

Appendix A. Assessment of Vulnerability to Climate Change

Potential Problem Resulting from Climate Change	Climate Change Impacts Causing the Problem	SSA Functions Impacted	Assessment of Vulnerability to Problems Caused by Climate Change		
			Sensitivity of Problem to Climate Change	Capacity to Adapt to the Problem (high capacity corresponds to low score)	Vulner-ability
Increased disruptions to power supply from the electricity grid	1) Increased storm wind (downed power lines); and 2) extreme heat events (brown-outs due to inability of utility to meet cooling demands on hot summer afternoons).	1) Computing (organization-wide, including capacity to hear and decide disability cases); and 2) Facility electricity supply.	Overall High (4): Power outages have very high sensitivity to storms (wind), but there is only a medium sensitivity to brown-outs caused by high peak demand in hot weather.	High (2): Resiliency can be improved by diversifying power generation options (back-up generators and on-site renewables) and reducing demand through improved energy efficiency in facilities and data centers (e.g., hot aisle/cold aisle layout). Utilities can bury power lines and increase generation capacity. However, some measures carry fairly high upfront costs.	**3** (Medium)
Increased disruptions and damage to transportation infrastructure	Weather extremes (e.g., hot, cold, intense precipitation)	1) Customer interface at SSA offices; and 2) Employee health (icy surfaces)	Low (1): Damaged or disrupted transportation infrastructure (such as sidewalks, roads, and train tracks) can result from extreme weather, but sensitivity is relatively low.	Medium (3): Low capacity to adapt the transportation infrastructure itself, but telecommuting makes employee productivity less vulnerable. There is less adaptability for customer transportation to SSA offices, although telecommunications and the internet can substitute some of the in-person visits.	**2** (Low)
Reduced water supply for facilities	1) Reduced precipitation; 2) Sea level rise (seawater intrusion into groundwater); and 3) Reduced snow pack	Facility water supply	High (4): Very high sensitivity in certain regions of the country, but lower in those parts of the country that are less water-stressed.	High (1): Water demand by facilities can be greatly decreased through landscaping that requires little or no irrigation and efficient indoor plumbing fixtures. Some cost involved but water efficiency measures are often fairly cost-effective.	**2.5** (Medium-Low)
Damage from erosion (on and off-site) and compliance with water discharge permits	Increased precipitation intensity causing increased stormwater runoff from facilities	Managing facility grounds and stormwater runoff	Low (2): Sensitivity of SSA sites to erosion and stormwater runoff is highly dependent on the individual site. Assume overall low given the small size of many SSA facilities.	High (1): Low-cost options to increase stormwater retention, allowing more to percolate into the ground.	**1.5** (Low)

Potential Problem Resulting from Climate Change	Climate Change Impacts Causing the Problem	SSA Functions Impacted	Assessment of Vulnerability to Problems Caused by Climate Change		
			Sensitivity of Problem to Climate Change	Capacity to Adapt to the Problem (high capacity corresponds to low score)	Vulner-ability
Increased flooding or inundation in coastal locations	1) Sea level rise; and 2) Increased wind intensity (wind is a key factor in storm surges)	Facility infrastructure	High (4): Facilities located on the coast are potentially highly sensitive to flooding or inundation, but it depends on exact local conditions such as topography.	Medium-low (4): Protecting existing facilities from storm surges or inundation is very costly, although siting of future facilities can be controlled. *(Inundation differs from flooding in that it is a permanent condition.)*	**4** (High)
Increased flooding in non-coastal locations	Increased precipitation intensity	Facility infrastructure	Overall Medium (3): Facilities located near certain rivers and in areas that will become flood plains with climate change have a high sensitivity to increased precipitation intensity, but sensitivity is low otherwise.	Medium-high (2): Measures can be taken to protect facilities from temporary flood conditions, and siting of future facilities can be controlled.	**2.5** (Medium-Low)
Facilities damaged by wildfire	1) Reduced precipitation; and 2) Increased average temperature	Facility infrastructure	Medium (3): The frequency and severity of wildfires are very sensitive to climate change in certain regions of the country, but even within vulnerable regions, vulnerability depends on the specific location.	Medium (3): Although little if anything can be done regarding the siting of facilities, there are protective measures that can be taken in vulnerable areas.	**3** (Medium)
Illness due to expanded range of vector-borne disease	Increased average temperature (expands the range of vectors such as mosquitos carrying diseases; e.g., malaria and West Nile)	Employee and customer health	Medium (3): Warmer temperatures will make conditions more favorable for certain vectors, including allowing them to survive winters where previously they would not.	Very high (1): Due to ready access to advanced healthcare and pesticide options.	**2** (Low)
Impaired health due to elevated ground level ozone	Increased average temperature and more severe heat events (increase levels of ozone, which causes breathing problems)	Employee and customer health	Very high (5): Respiratory illness is very sensitive to ozone, and many metropolitan areas in the United States already experience more ailments, such as asthma, due to unhealthy ozone levels in the summer.	Medium (3): Ozone can be decreased by reducing air pollution and by reducing the urban heat island effect, although this requires large scale local action beyond SSA. Medical problems due to ozone can be treated to a certain extent.	**4** (High)

[a]Vulnerability on a scale from 1 to 5, corresponding to very low, low, medium, high, and very high vulnerability.

Appendix B. Assessment of Risks to Climate Change and Prioritization of Problems for Action

Potential Problem Resulting from Climate Change	Agency Functions Affected by the Problem	RISK ASSESSMENT			Adapt-ation Priority[b]
		Consequence of Problem (without adaptive measures)	**Probability the Climate Change Impact will Occur** (scientific **confidence** the impact will occur and the spatial and temporal **extent** of the impact)	**Risk**[a]	
Increased flooding or inundation in coastal locations	Facility infrastructure	Very High (5): Real property infrastructure damage or destruction.	High overall (4): There is a very high probability for sea level rise, which is a well understood phenomenon that is occurring now and will continue to do so. In terms of wind intensity, it depends on location. Research shows that while hurricanes might decrease in *frequency*, they might increase in *intensity*. However, in parts of North America where hurricanes are not an issue, there is not yet a clear correlation between climate change and storm intensity. Spatially, it depends where on the coast the facility is located.	**4.5** (Very High)	**8.5** (High)
Impaired health due to elevated ground level ozone	Employee and customer health	Medium (3): Lowered productivity in affected employees, and the possibility of more disability claims by customers	Very high (5): Very high scientific confidence in the: 1) Occurrence of higher temperatures with climate change; 2) Correlation between higher temperatures and ozone; and 3) Irritation caused by ozone on the human respiratory system.	**4** (High)	**8** (Medium-High)
Increased disruptions to power supply from the electricity grid	Computing and facility electricity supply	Very High (5): Intermittent absence of electricity to carry out the agency mission.	Overall medium (3): There is a very high probability of increased frequency and duration of extreme heat events, but the scientific evidence connecting increased storm activity in the U.S. to climate change is not strong at this point in time. The impact, if it occurs, will be fairly widespread across the U.S., but at any given point in time the occurrences will be localized.	**4** (High)	**7** (Medium)
Increased flooding in non-coastal locations	Facility infrastructure	Very High (5): Real property infrastructure damage or destruction.	Low (2): There is only a medium level of confidence that precipitation intensity will increase in the region of interest (continental U.S.). Also, most SSA facilities are not located in vulnerable areas.	**3.5** (Medium-High)	**6** (Medium)
Facilities damaged by wildfire	Facility infrastructure	Very High (5): Real property infrastructure damage or destruction.	Very Low (1): In certain areas, such as the West, there is very high scientific confidence that wildfires will increase in frequency and intensity due to drier soils, longer growing seasons, and expanding insect populations that kill trees. However, assigned low overall since most SSA facilities are not at risk in terms of location, and at any given point in time only a small sub-set will be affected.	**3** (Medium)	**6** (Medium)

Potential Problem Resulting from Climate Change	SSA Functions Affected by the Problem	RISK ASSESSMENT			
		Consequence of Problem (without adaptive measures)	**Probability the Climate Change Impact will Occur** (scientific **confidence** the impact will occur and the spatial and temporal **extent** of the impact)	**Risk**[a]	**Adapt-ation Priority**[b]
Reduced water supply for facilities	Facility water supply	Very low (1): Even severe water shortages, although devastating in ways, will likely not impact the ability to operate facilities enough to impair SSA's mission.	Overall High (4): There is very strong scientific evidence that climate change will reduce the availability of water in certain regions of the country.	**2.5** (Medium-Low)	**5** (Medium)
Increased disruptions and damage to transportation infrastructure	1) Customer interface at SSA offices; and 2) Employee and customer health (icy surfaces)	Low (2): Given the already existing prevalence of telecommunications and the Internet in the day-to-day conduct of business.	Overall medium (3): There is a very high probability of extreme heat events, but confidence in precipitation intensity projections is not as high. With regard to more frequent extreme cold, there are indications that a decline in Arctic sea ice caused by climate change could cause colder winters along the East Coast due to changes in the Arctic Oscillation, but evidence is not yet strong.	**2.5** (Medium-Low)	**4.5** (Medium-Low)
Illness due to expanded range of vector-borne disease	Employee and customer health	Low (2): Lowered productivity in affected employees, and the possibility of more disability claims by customers.	Low (2): Scientific projections of expanding disease range have a high degree of confidence, but there are other factors at play that should limit the actual occurrence of disease.	**2** (Low)	**4** (Medium-Low)
Damage from erosion (on and off-site) and compliance with water discharge permits	Managing facility grounds and stormwater runoff	Low (2): Expense of adding low impact development features to manage runoff, or non-compliance with local regulations or lawsuits by property owners downstream.	Low (2): Increased precipitation intensity is projected as a possible impact from climate change, but not yet with high confidence. The impacts, if they occur, will presumably be limited to a small sub-set of facilities at any given point in time.	**2** (Low)	**3.5** (Low)

[a]Risk on a scale from 1 to 5, corresponding to very low, low, medium, high, and very high risk.

[b]Ranking calculated as the sum of vulnerability and risk scores, ranging from 2 (very low) to 10 (very high).

Appendix C. Process for Climate Change Adaptation Planning and Evaluation

Our Climate Change Adaptation Planning Team (Adaptation Planning Team) has defined the agency's vision for adaptation planning: **to improve our capacity to assess and build resilience to climate change risks**. This document lays out the process we will use to develop and continually improve our Climate Change Adaptation Plan and annually evaluate our progress on it.

STEP 1 Assess Future Climate Change Impacts for Different Regions of the Country

While we conduct adaptation planning on an agency-wide level, knowledge of projected impacts on a *regional* scale provides the Adaptation Planning Team with a better understanding of the full set of potential impacts we face. From scientific modeling conducted on different regions in the contiguous United States, we consider recent scientific projections with regard to the primary climate drivers:

- Sea level rise;
- Increased temperature, especially any projected increases in extreme heat events;
- Change in the quantity and patterns of precipitation; and
- Increased intensity and frequency of other extreme weather events, such as hurricanes and droughts.

If available for the region, we also consider projections for secondary indicators relating to hydrology (such as snow pack and stream flow) and growing seasons. We synthesize the information into an overall narrative for what the future likely holds in terms of impacts compared to the historical record, and the projected timeframe over which these impacts are to occur.

STEP 2 Analyze Climate Change Vulnerabilities and Risks

We face a number of potential problems due to the impacts of climate change. **Figure 1** below depicts the primary **impacts** projected by scientists to result from climate change; the main **problems** these impacts could cause for an agency such as ours (whose operations are essentially confined to office space, and transportation to and from that space); and which **functions** would be affected as a result. We determine which of the potential problems are the most serious by assessing the vulnerability of each potential problem to climate change, and the risk that the agency faces due to each of these problems. Vulnerability is the combination of the sensitivity of a potential problem to climate change and the capacity to improve our resilience to the problem. Risk is a function of two factors: the known or estimated consequence of a given problem caused by climate change and the probability that the climate change impact causing that problem will occur.

The Adaptation Planning Team begins the vulnerability and risk assessments by identifying all potential critical problems or issues for the agency that can be caused by climate change. Figure 1 illustrates some of the potential impacts of climate change on our critical functions. For each potential problem, the Adaptation Planning Team describes the climate change impact causing the problem, the function impacted, the sensitivity of the problem to climate change, and the capacity to adapt to the problem. We assigned a score from 1 to 5 (very low to very high) for both the sensitivity and the capacity to adapt, and average these scores to arrive at a ranking for vulnerability. For the risk assessment, we assign a score from 1 to 5 characterizing the consequence of the problem in the absence of any intervention, and similarly assign a score that conveys the degree of scientific confidence that the impact will occur, and the spatial and temporal extent of the impact across the agency.

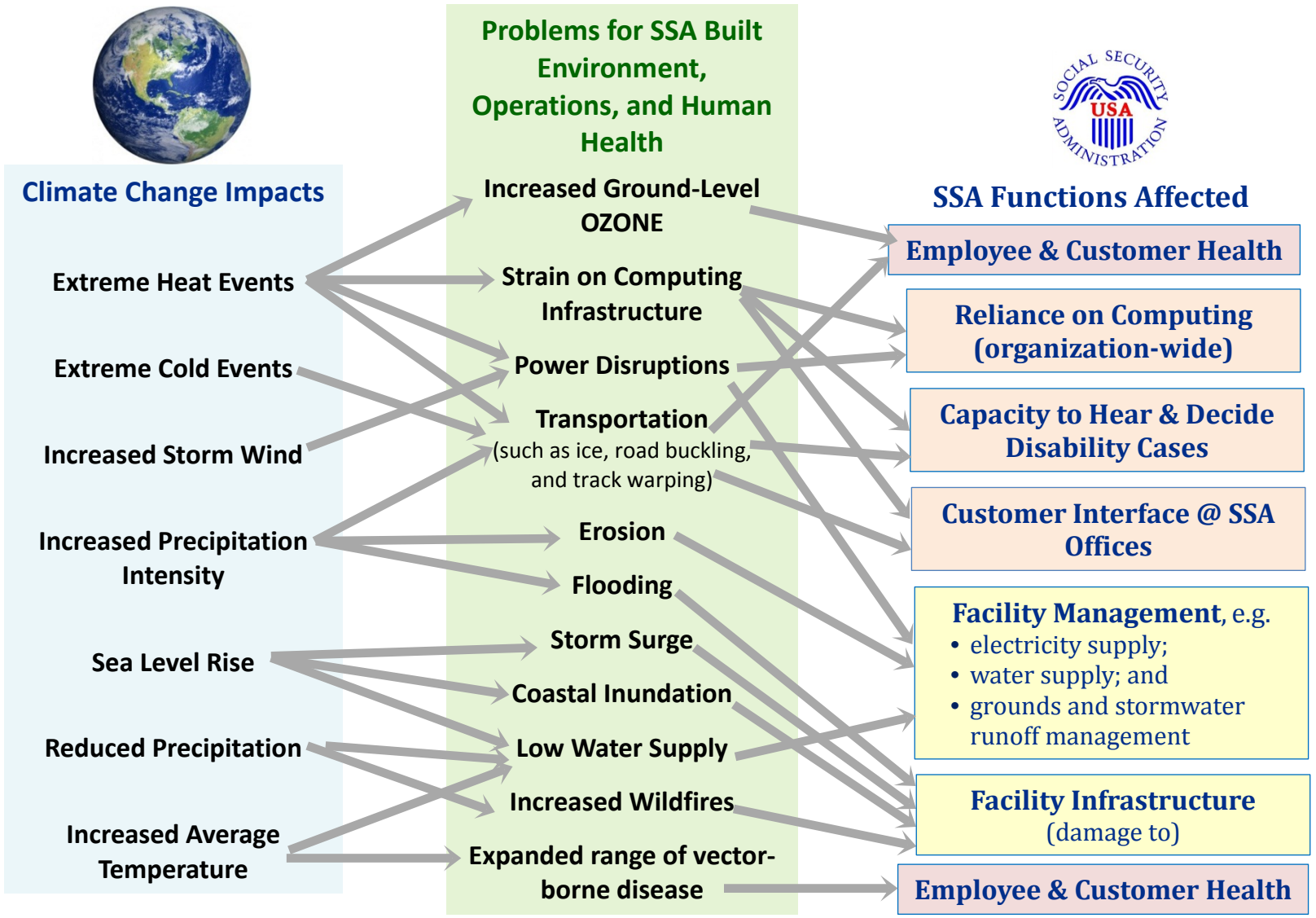

Figure 1. Some Potential Impacts of Climate Change on Critical Agency Functions

STEP 3 Prioritize the Timeframes for Addressing the Vulnerabilities and Risks

An assessment of both vulnerability and risk allows the Adaptation Planning Team to rank the potential problems according to how serious they are and how difficult it will be to improve resilience to them. For each potential problem addressed by the analysis, we add the scores for risk and vulnerability to generate a ranking from very low to very high priority for action, as illustrated by **Figure 2**.

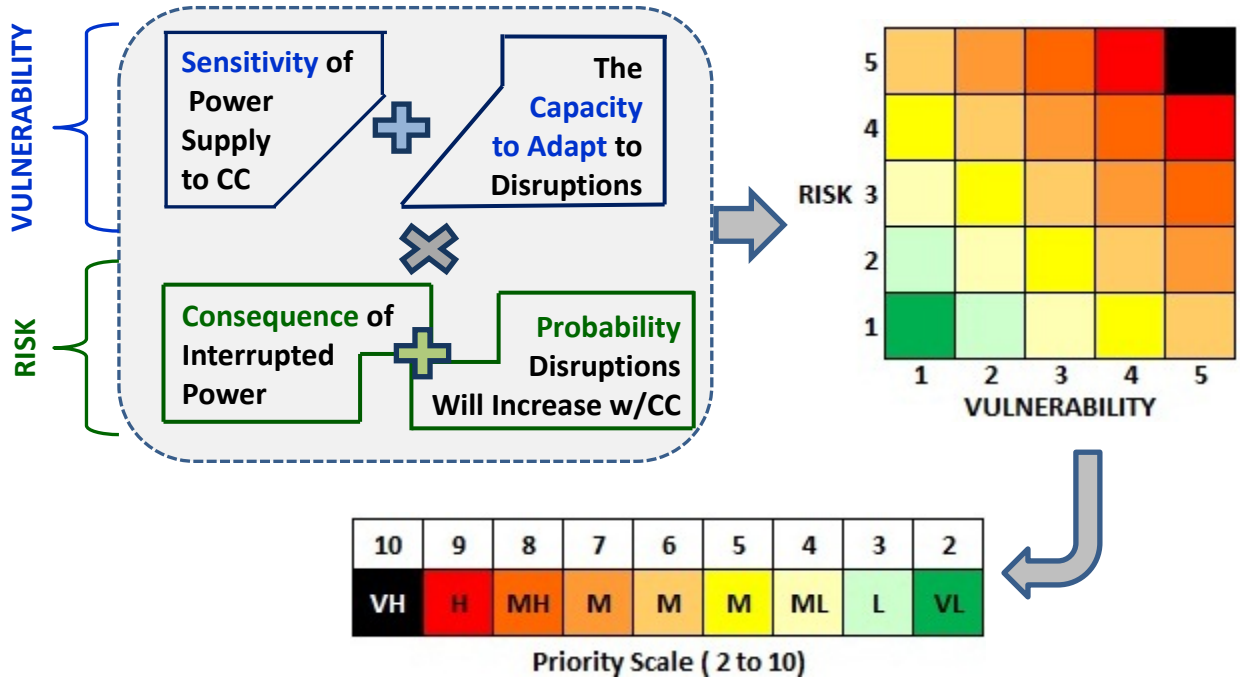

Figure 2. Vulnerability Plus Risk: Evaluate Adaptation Priorities By Looking at the Whole Picture
(using example of power supply disruption)

STEP 4. Develop the Action Plan and the System to Monitor and Evaluate Progress on It

Using the priorities established in Step 3, the Adaptation Planning Team develops a set of goals for improving the agency's resiliency to climate change, including one or more concrete actions for achieving the goal. A goal describes what the agency wants to accomplish and an action describes a measure to do so. The Adaptation Planning Team will precisely articulate each goal and action so they are not subject to interpretation at a later time or by a different set of people. The action plan will also identify the component responsible for the successful implementation of each action. Based on the prioritizations, the action plan will include a timeframe for implementing each action. Finally, the agency will generate a built-in system for monitoring, evaluating, and reporting progress on the adaptation action plan by developing one or more performance indicators or metrics for each action. The Plan is a living document that we will refine over time, based on regular evaluations of progress and continued improvements in the science of climate change projections.

Appendix D. Scientific Projections of Climate Change by Region for the Contiguous United States

Larger Scale Phenomena

- **Global Sea Level Rise**: Not counting local variations that affect the magnitude of sea level rise, such as subsidence of land and regional variations in ocean circulation, estimates for sea level rise are in the vicinity of about **1 foot by 2050** and **3 feet by 2100**.
- **Temperate Storms:** There is no scientific consensus yet on temperate storms (meaning storms in the contiguous U.S. that are not hurricanes or tropical storms). Some research results predict significantly greater quantities of precipitation, but some do not.
- **Winters:** Parts of the U.S. could experience colder winters due to climate change, by causing changes in the Arctic Oscillation. The Arctic Oscillation is an index used to describe the state of atmospheric circulation over the Arctic. Conditions over the Arctic oscillate between two states, a negative phase and positive phase. During the negative phase, high pressure is maintained over the North Pole. In its positive phase, air pressure over the ocean shifts, with lower pressure over the Pole and higher pressure at mid-latitudes around 45 degrees North. During positive phases of the Arctic Oscillation, cold air from the Arctic moves southward into the U.S. Research into the effects of climate change on the Arctic Oscillation is still in its early stages, but there are indications that climate change will alter the Arctic Oscillation, with ramifications for weather in the U.S., Canada, Europe, and Asia.

Northeast

- **Heat:** Science projects the number of days with extreme heat will increase by about 50 percent by mid-century. It projects humidity will increase as well, resulting in a projected 350-400 percent increase in the number of days with heat index values exceeding 90°F, which is the heat index value designated as "extreme caution" by the National Weather Service. The Environmental Protection Agency states, "Northeastern cities are likely to experience some of the highest numbers of heat-related illnesses and deaths, compared with the rest of the nation" because "the region is generally not as well adapted to heat as warmer regions of the country." Science projects average annual temperatures to be about 4°F higher by mid-century.
- **Precipitation:** Science projects heavy precipitation to occur more frequently and with greater intensity.
- **Stream Flow:** Projections are for greater variability in stream flow, with more high flow events in the winter, carrying with it a greater risk of flooding, and more frequent low flow events in the summer, increasing the risk of drought.
- **Local Sea Level Rise:** Sea level is rising faster than the global average off the Northeast coast (south to about New York), and it is expected to accelerate due to the effects of ocean circulation (a weakening of the Atlantic meridional overturning circulation).
- **Winters:** Parts of the U.S., including the eastern seaboard, could experience colder winters due to climate change, by causing changes in the Arctic Oscillation, an index used to describe the state of atmospheric circulation over the Arctic. Conditions over the Arctic oscillate between two states, a negative phase and positive phase. During negative phases of the Arctic Oscillation, cold air from the Arctic moves southward into Canada and the U.S. The harsh winter of 2009/2010 corresponded to a record persistence of the Oscillation in its negative phase. Research into the effects of climate change on the Arctic Oscillation is still in its early stages, but there are indications that climate change will alter the Arctic Oscillation.

Mid-Atlantic

- **Heat:** Projections include an increase in the occurrence of days exceeding 90°F, from about 30 now to 50 by mid-century, and the number of days over 100°F is projected to quadruple, with the annual temperature about 4°F higher by mid-century.
- **Precipitation:** Science projects that the amount and intensity of precipitation will increase.
- **Hurricanes:** For those areas of the region subject to hurricanes, although scientists have not yet projected with high confidence a correlation between climate change and the frequency and intensity of hurricanes, the general consensus is that the frequency of hurricanes might decline, but they are likely to become stronger. One recent study predicts that the frequency of category 4 and 5 hurricanes will nearly double by the end of the century.
- **Local Sea Level Rise:** Sea level is rising faster than the global average due to post-glacial subsidence, combined with a high confidence projection that the ocean circulation effect will accelerate sea level rise in this region.
- **Winters:** Parts of the U.S., including the eastern seaboard, could experience colder winters due to climate change by causing changes in the Arctic Oscillation, an index used to describe the state of atmospheric circulation over the Arctic. Conditions over the Arctic oscillate between two states, a negative phase and positive phase. During negative phases of the Arctic Oscillation, cold air from the Arctic moves southward into Canada and the U.S. The harsh winter of 2009/2010 corresponded to a record persistence of the Oscillation in its negative phase. Research into the effects of climate change on the Arctic Oscillation is still in its early stages, but there are indications that climate change will alter the Arctic Oscillation.

The South

- **Heat:** Although the rise in average annual temperatures will be modest (about 2°F by mid-century), the problem will be a marked increase in extreme heat events. By the middle of the century, for example, hot days currently viewed as rare are likely to occur at least every other year, and there is a better than 50/50 chance 21 days per year will be hotter than 100°F.
- **Precipitation:** It is uncertain whether the total annual amount of precipitation will increase or decrease, but there are indications that intensity could increase.
- **Hurricanes:** Although scientists have not yet projected with high confidence a correlation between climate change and the frequency and intensity of hurricanes, the general consensus is that the frequency of hurricanes might decline, but they are likely to become stronger. One recent study predicts that the frequency of category 4 and 5 hurricanes will nearly double by the end of the century.
- **Local Sea Level Rise:** Certain areas are experiencing rapid subsidence, especially in Louisiana and East Texas, causing local sea level rise to be appreciably higher in the affected areas.

Southwest (not including California) and Interior West

- **Heat:** Projections are for extreme heat events to increase in frequency and duration, with the length of heat waves expected to increase more than they will in other regions of the country. Projections include an increase in the average annual temperature by about 4 to 5°F by mid-century.
- **Precipitation:** There is a scientific consensus that precipitation will decrease in the arid Southwest, although the magnitude of the decrease is still uncertain. For the Mountain West,

there is insufficient data to provide clear trends for precipitation, though there are some indications of more extreme precipitation in the mountains in some areas.

- **Water Supply**: There is a consensus among the scientists who have been modeling flow in the Colorado River that it will decline by roughly 10 percent. The Colorado River is a critical source of water supply for much of the region, and is already over-subscribed. Mountain snowpack will decline.
- **Wildfires:** Predictions are for large wildfires to become more frequent and more intense.

California

- **Heat:** Projections are for *very* hot days (those exceeding the historical 95th percentile) to become much more common. Projections are for *extended* heat waves, which almost never occurred historically, to become much more common. (Extended heat waves are heat waves consisting of five or more consecutive days exceeding the 95th percentile.) Projections include an increase in the average annual temperature of about 2°F by mid-century, with summer expected to warm by about 2°F more than winter.
- **Precipitation:** Although projecting future precipitation in California is still an active area of research, it appears fairly likely that precipitation will decline by an alarming degree.
- **Water Supply**: The average decline in snowpack in the Sierra Nevada over all elevations is about 40 percent by mid-century. In California, as in much of the West, snow in the mountains—especially in the spring—is a key source of fresh water. Combined with the projected decline in overall precipitation, water supply in this already water stressed region will become a more pressing issue.
- **Wildfires**: Projections are for the occurrences of large wildfires to increase by about 30 percent in the middle of the century. California is prone to flash flooding and landslides due to its distinct wet and dry seasons, and fires exacerbate the impacts by burning stabilizing vegetation.
- **Local Sea Level Rise**: South of Cape Mendocino (in Northern California), sea level rise along the California coast will be somewhat greater than the global average.

Pacific Northwest

- **Heat:** Projections are for heat waves to become more frequent, with the average annual temperature rising about 3°F by mid-century.
- **Precipitation:** Projections are for increases in extreme high precipitation over the next half-century.
- **Water Supply**: Projections are for a 40 percent decline in snowpack in the mountains by mid-century. This has important ramifications for water supply in some regions (such as the densely populated Puget Sound) that depend on water released from the snowpack into streams and reservoirs later in the spring and summer. Another problem is the timing of the melt: as winter and spring precipitation increasingly becomes rain rather than snow, and the snow melt occurs earlier in the year, water available from snow melt will shift dramatically over the course of the century, from summer to spring to winter.
- **Local Sea Level Rise**: Parts of the region are subsiding and parts are being uplifted, but projections are for overall rates of sea level rise on the coasts of Oregon and Washington to be somewhat *lower* than the global average.

MidWest and the Plains

- **Heat:** Projections are for heat waves and higher humidity to plague the region. Projections are that the heat waves with the severity of the 1995 heat wave, which historically occur about once every 30 years, could occur roughly once a year by mid-century and twice a year late in the century. Projections are for the number of days over 90°F to increase from only 15 currently to 42 days by mid-century, and days exceeding 100°F could be six times as common by mid-century.
- **Precipitation:** Projections are for precipitation to become more intense, increasing the likelihood of flooding and disruptions to travel. Given the size of the region, other precipitation trends such as seasonal variations will likely vary by sub-region, and more research is needed to provide this granularity. Modeling on the four state block of Michigan, Indiana, Illinois, and Wisconsin projects declining rainfall in the summer, making drought even more of a problem in the southern portion of this region than it is now.
- **Winters:** Parts of the U.S. could experience colder winters due to climate change, by causing changes in the Arctic Oscillation, an index used to describe the state of atmospheric circulation over the Arctic. Conditions over the Arctic oscillate between two states, a negative phase and positive phase. During negative phases of the Arctic Oscillation, cold air from the Arctic moves southward into Canada and the U.S. The harsh winter of 2009/2010 corresponded to a record persistence of the Oscillation in its negative phase. Research into the effects of climate change on the Arctic Oscillation is still in its early stages, but there are indications that climate change will alter the Arctic Oscillation.

BIBLIOGRAPHY

Key references used in making summaries of projected climate change impacts

Sea Level Rise

Cayan, D., M. Tyree, M. Dettinger, H. Hidalgo, T. Das, E. Maurer, P. Bromirski, N. Graham, and R. Flick. 2009. Climate change scenarios and sea level rise estimates for the California 2008 Climate Change Scenarios Assessment, Public Interest Energy Research Program Reports, Publication # CEC-500-2009-014-D, California Energy Commission, Sacramento, CA, 62 pp.

Pfeffer, W.T., J. T. Harper, S. O'Neel. 2009. Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise. *Science* **321**, 1340 (2008); DOI: 10.1126/science.1159099.

Shepherd, A. et al. 2012. A Reconciled Estimate of Ice-Sheet Mass Balance. *Science* **338**, 1183, DOI: 10.1126/science.1228102.

Vermeer, M. and Stefan Rahmstorf. 2009. Global sea level linked to global temperature. *Proc. Natl. Acad. Sci. U.S.A.*, **106**(51), 21527–21532, doi:10.1073/pnas. 0907765106.

Storms – Tropical Cyclones

Bender, M.A., T.R. Knutson, R.E. Tuleya, J.J. Sirutis, G.A. Vecchi, S. T. Garner, I.M. Held, 2010, Modeled Impact of Anthropogenic Warming on the Frequency of Intense Atlantic Hurricanes, *Science* 22 January 2010: Vol. 327. no. 5964, pp. 454 – 458, DOI: 10.1126/science.1180568.

Bengtsson, L., K. I. Hodges, M. Esch, N. Keenlyside, L. Kornbleuh, J.-J. Luo, and T. Yamagata, 2007: How may tropical cyclones change in a warmer climate? *Tellus* 59A, 539–561.

Emanuel, K.A., 2007: Environmental factors affecting tropical cyclone power dissipation. *Journal of Climate* 20(22), 5497- 5509.

Emanuel, K., R. Sundararajan, and J. Williams, 2008: Hurricanes and global warming: results from downscaling IPCC AR4 simulations. Bulletin of the American Meteorological Society, 89(3), 347-367.

Trenberth, K.E., 2010. "Changes in precipitation with climate change", *Climate Research Special 25* 'Climate services for sustainable development', doi: 10.3354/cr00953.

Storms – Temperate

Bengtsson, L., K. I. Hodges, N. Keenlyside. 2009. Will Extratropical Storms Intensify in a Warmer Climate?. *J. Climate*, 22, 2276–2301. doi: http://dx.doi.org/10.1175/2008JCLI2678.1.

Catto, J.L., Len C. Shaffrey, Kevin I. Hodges. 2011. Northern Hemisphere Extratropical Cyclones in a Warming Climate in the HiGEM High-Resolution Climate Model. *Journal of Climate* 24:20, 5336-5352.

Ulbrich, U., G. C. Leckebusch & J. G. Pinto. 2009. Extra-tropical cyclones in the present and future climate: a review. *Theor. Appl. Climatol.* 96:117–131, DOI 10.1007/s00704-008-0083-8.

Northeast

Hayhoe, K., C.P. Wake, T.G. Huntington, L. Luo, M.D. Schwartz, J. Sheffield, E. Wood, B. Anderson, J. Bradbury, A. DeGaetano, T.J. Troy, and D. Wolfe. 2007. Past and future changes in climate and hydrologic indicators in the US Northeast. *Climate Dynamics* 28:381-407.

Hayhoe, K., C.P. Wake, B. Anderson, X.-Z. Liang, E. Maurer, J. Zhu, J. Bradbury, A. DeGaetano, A. Hertel, and D. Wuebbles. 2008. Regional climate change projections for the Northeast U.S. *Mitigation and Adaptation Strategies for Global Change* 2008, vol. 13, issue 5, pages 425-436.

Yin, J., M.E. Schlesinger & R.J. Stouffer. 2009. Model projections of rapid sea-level rise on the northeast coast of the United States. *Nature Geoscience*, published online: 15 March 2009, DOI: 10.1038/NGEO462.

Mid-Atlantic

Boesch, D.F. (editor). 2008. *Global Warming and the Free State: Comprehensive Assessment of Climate Change Impacts in Maryland.* Report of the Scientific and Technical Working Group of the Maryland Commission on Climate Change. University of Maryland Center for Environmental Science, Cambridge, Maryland.

Hayhoe, K., C.P. Wake, T.G. Huntington, L. Luo, M.D. Schwartz, J. Sheffield, E. Wood, B. Anderson, J. Bradbury, A. DeGaetano, T.J. Troy, and D. Wolfe. 2007. Past and future changes in climate and hydrologic indicators in the US Northeast. *Climate Dynamics* 28:381-407.

Neumann, J.E. et al. 2000. *Sea Level Rise & Global Climate Change : A Review of Impacts to U.S. Coasts.* Pew Center on Global Climate Change.

Yin, J., M.E. Schlesinger & R.J. Stouffer. 2009. Model projections of rapid sea-level rise on the northeast coast of the United States. *Nature Geoscience*, published online: 15 March 2009, DOI: 10.1038/NGEO462.

The South

Keim, B.D., T.W. Doyle and V.R. Burkett, 2008. Chapter 3: How Is the Gulf Coast Changing? In: *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I.* Synthesis and Assessment Product 4.7 by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [Savonis, M.J., V.R. Burkett, and J.R. Potter (eds.)], Washington, DC, USA.

USGCRP 2009. Global Climate Change Impacts in the United States, Thomas R. Karl, Jerry M. Melillo, and Thomas C. Peterson, (eds.). Cambridge University Press.

Southwest and Interior West

Christensen, N. S. and D. P. Lettenmaier. 2007. A multimodel ensemble approach to assessment of climate change impacts on the hydrology and water resources of the Colorado River Basin. *Hydrol. Earth Syst. Sci.*, 11, 1417–1434.

Diffenbaugh, N.S., J.S. Pal, R.J. Trapp, and F. Giorgi. 2005: Fine-scale processes regulate the response of extreme events to global climate change. *Proc. Natl. Acad. Sci. U.S.A.*, 102(44), 15774–15778, doi:10.1073/pnas.0506042102.

Hoerling M., D. Lettenmaier, D. Cayan and B. Udall. 2007. Reconciling Projections of Colorado River Streamflow. *Southwest Hydrology*, May/June.

Hoerling, M. and J. Eischeid. 2007. Past Peak Water in the Southwest. *Southwest Hydrology*, Jan/Feb 2007.

Ray, A.J. et al. 2008. Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation, CU-NOAA Western Water Assessment.

Seager, R., Ting, M., Held, I., Kushnir, Y., Lu, J., Vecchi, G., Huang, H.-P., Harnik, N., Leetmaa, A., Lau, N.-C., Li, C., Velez, J., and Naik, N. 2007. Model projections of an imminent transition to a more arid climate in southwestern North America. *Science* **316**, 1181–1184, doi:10.1126/science.1139601.

California

Cayan, D., M. Tyree, M. Dettinger, H. Hidalgo, T. Das, E. Maurer, P. Bromirski, N. Graham, and R. Flick. 2009. Climate change scenarios and sea level rise estimates for the California 2008 Climate Change Scenarios Assessment. California Energy Commission, Public Interest Energy Research (PIER) Program. Publication #CEC-500-2009-014-D.

Gershunov, A., D.R. Cayan and S.F. Iacobellis. 2009. The Great 2006 heat wave over California and Nevada: Signal of an Increasing Trend. *J. Climate.*, **22**(23), 6181-6203. *(111)*.

National Resource Council. 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. National Academy of Sciences, Washington, D.C.

Westerling, A.L., B. P. Bryant, H.K. Preisler, T.P. Holmes, H.G. Hidalgo, T. Das, and S.R. Shrestha, 2009. Climate Change, Growth and California Wildfire. California Energy Commission, Public Interest Energy Research (PIER) Program. Publication #CEC-500-2000-046-F.

Pacific Northwest

Climate Impacts Group. 2009. The Washington Climate Change Impacts Assessment, M. McGuire Elsner, J. Littell, and L Whitely Binder (eds). Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, Washington.

National Resource Council. 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. National Academy of Sciences, Washington, D.C.

MidWest and the Plains

Cherkauer, K.A. and T. Sinha. 2010. Hydrologic impacts of projected future climate change in the Lake Michigan region, *Journal of Great Lakes Research* **36** (2010) 33–50.

Hayhoe, K. & D. Wuebbles. 2007. Climate Change and Chicago: Projections and Potential Impacts. Chapter 2 of the Chicago Climate Action Plan.