REPORT TO NEAFWA VULNERABILITY ASSESSMENT EXPERT PANEL: EXPOSURE INFORMATION

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Introduction

Over the last 3-4 years a formal organizational framework has been developed for evaluating the vulnerabilities of species and ecological systems to climate change (Glick et al., 2011). This framework assumes that the vulnerabilities of species or systems are a function of three main components – their exposure, sensitivity, and adaptive capacity (Figure 1):

Exposure – an estimate of how much change in climate (or other stressors) a species or system may be exposed to.

Sensitivity – the extent to which a species or system is likely to be responsive to or affected by changes in exposure.

Adaptive capacity – the ability of a species or system to adapt to and accommodate changes in exposure to stressors.

Downscaled analyses for the Northeast Region have shown that there is likely to be a degree of intraregional variation in how the climate may change over this century (e.g., Hayhoe et al. 2006). Exposures of systems or species will, therefore, also vary geographically. If the vulnerabilities of ecological resources are to be understood, this variation in exposure must be taken into account. This report presents information from the literature describing how the exposures of northeastern species and systems may change and vary geographically over this century. This is not intended to be an exhaustive analysis of future climate change. Rather, it uses existing data to provide expert panel and habitat workgroup members who are assessing vulnerabilities with background information describing likely climate futures. As they build or evaluate vulnerability assessments for selected habitats across the region, workgroup members can use the figures and tables presented in this report to asses how climatic changes and exposures may vary within and across the region.

The data have been gathered from two sources – the Northeast Climate Impacts Assessment (NECIA), and the web-based tool, ClimateWizard. NECIA (2006) was a major effort to describe plausible climate futures in the Northeast by statistically downscaling 3 Global Circulation Models (GCMs) to a $1/8^{o}$ scale. The results were presented in a project report (NECIA, 2006), several scientific papers (e.g., Hayhoe et al 2006 and 2007), and in an interactive website (http://www.northeastclimatedata.org/). ClimateWizard is a web-based interactive tool (http://www.climatewizard.org/) developed by The Nature Conservancy and the Universities of Washington and Southern Mississippi. It uses various combinations of the output of 16 GCMs to statistically downscale information to a 12km grid scale. Both sources provide the most recent and thorough downscaled analyses of how the climate may change in the Northeast Region over the remainder of this century.

The southern boundary of the NECIA study area included the southern states of the NEAFWA area. However, for some variables (temperature, precipitation, evapotranspiration, soil moisture, snow cover days, drought, runoff, and stream flow) it excluded the southern portions of Virginia and West Virginia. ClimateWizard was used to fill this gap in coverage for the first two variables.

The temperature and precipitation metrics that can be addressed using ClimateWizard do not exactly match those that can be derived from the NECIA data-set (for example, the NECIA upper emissions estimates (Nakienovi et al. 2000) are based on the A1Fi emissions scenario, while ClimateWizard generally uses the A2 scenario). However, they are close enough for an acceptable match for the purposes of vulnerability assessment. Furthermore, the NECIA analyses cover a wider range of variables (temperature, precipitation, growing seasons, stream flow, snow cover, etc.) than are available in ClimateWizard, which is restricted to temperature and precipitation. We used both analytical tools to develop a comprehensive appraisal of how northeastern climatic and climate-related parameters will likely change over this century.

The data presented in this report do not include sea level rise estimates for the region. These will be provided in a separate document.

Exposure Information

The results of both downscaling analyses for the northeastern region are shown in Table 1 and in Figures 2 through 24. Table 1 presents the key, biologically relevant findings of the NECIA study for the region. Figures 2 through 6 describe how temperature and precipitation regimes are expected to alter over the next decades assuming low and a high (or medium-high) emissions scenarios. Figures 7 and 8 present NECIA results on how growing season and plant hardiness zones may alter. Figures 9 and 10 describe anticipated changes in evapotranspiration and soil moisture content. Figures 11 and 12 show projected changes in the characteristics of future snow cover in the region and Figure 13 projects future drought frequencies. Figures 14 through 19 project future changes in stream flow, runoff and low flow periods over the remainder of the century, while Figures 20 through 24 use ClimateWizard analyses to project temperature and precipitation changes for the states of Virginia and West Virginia.

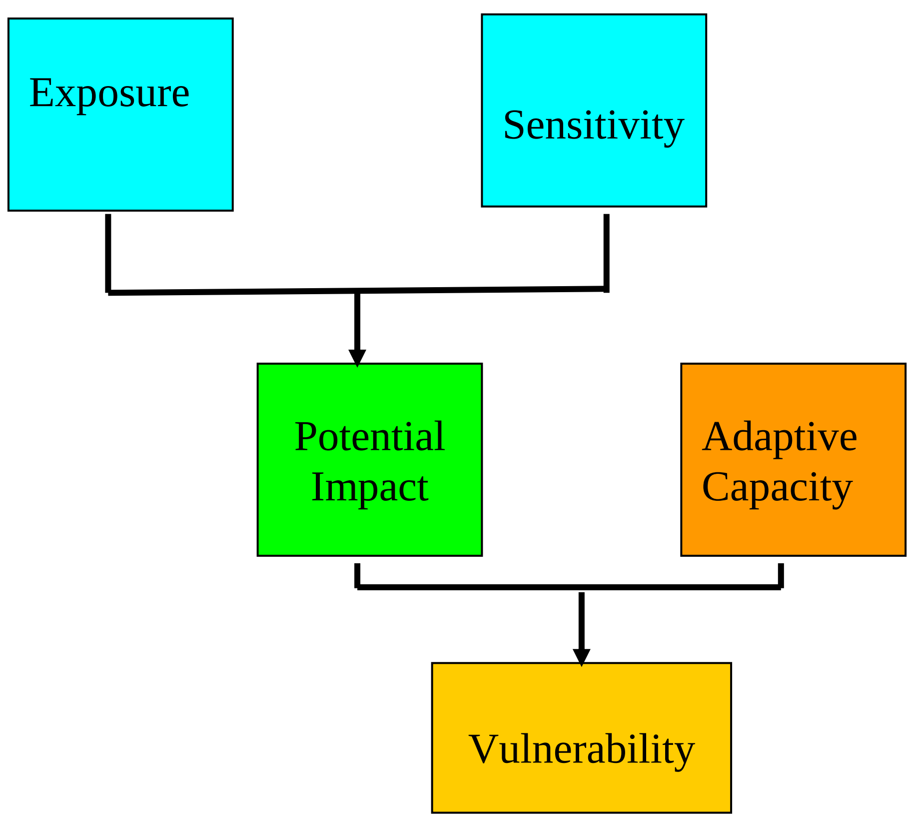


Figure 1. Vulnerability assessment organizational framework.

Table 1. Projected changes in key climate indicators for the periods 2035-2064 and 2070-2099 (NECIA, 2006).

		1961-1990	2035-2064			2070-2099		
	UNITS	20C3M	B1	A2	A1FI	B1	A2	A1FI
Temperature								
Annual	°C	7.8	+2.1	+2.5	+2.9	+2.9	+4.5	+5.3
Winter (DJF)	°C	-4.8	+1.1	+1.7	+3.1	+1.7	+3.7	+5.4
Summer (JJA)	°C	20.0	+1.6	+2.2	+3.1	+2.4	+4.3	+5.9
Precipitation								
Annual	cm (%)	102.9	+5%	+6%	+8%	+7%	+9%	+14%
Winter (DJF)	cm (%)	20.95	+6%	+8%	+16%	+12%	+14%	+30%
Summer (JJA)	cm (%)	28.03	-1%	-1%	+3%	-1%	-2%	0%
Sea Surface Temperatures[1]								
Gulf of Maine	°C	11.6[1]	+1.3[1]	+1.5[2]	–	+1.9[1]	+3.3[2]	–
Gulf Stream	°C	23.4[1]	+0.9[1]	+1.3[2]	–	+1.2[1]	+2.3[2]	–
Terrestrial Hydrology								
Evaporation	mm/day	1.80	+0.10	–	+0.16	+0.16	–	+0.20
Runoff	mm/day	1.14	+0.12	–	+0.09	+0.21	–	+0.18
Soil Moisture	% sat	55.0	+0.4	–	+0.02	+1.0	–	-0.07
Streamflow								
Timing of spring peak flow centroid	days	84.5	-5	–	-8	-11	–	-13
Low flow days (Q<0.0367 m3/s/km2)	days	65.5	-14	–	-1.5	-26	–	+22
7-Day low flow amount	%	100%	-4	–	-1	-4	–	-11
Drought Frequency								
Short	no. of droughts per 30 years	12.61	+5.12	–	+7.19	+3.06	–	+9.99
Med	no. of droughts per 30 years	0.57	+0.03	–	+0.51	+0.39	–	+2.21
Long	no. of droughts per 30 years	0.03	+0.03	–	+0.11	+0.04	–	+0.39
Snow								
Total SWE	mm	11.0	-4.4	–	-5.5	-5.9	–	-9.3
Number of snow days	days/mnth	5.2	-1.7	–	-2.2	-2.4	–	-3.8
Growing Season[2]								
First frost (autumn)	day	295	+1	+16	–	+6	+20	–
Last frost (spring)	day	111	-8	-14	–	-16	-23	–
Length of growing season	days	184	+12	+27	–	+29	+43	–
Spring Indices[2]								
First leaf	day	98.8	-3.0	-5.2	-3.9	-6.7	-15	-15
First bloom	day	128.8	-3.7	-6.0	-5.6	-6.3	-15	-16

[1] Based on SST output ("tos") from HadCM3, MIROC, CGCM CCSM, and PCM only

[2] Time periods restricted by output availability to 2047-2065 and 2082-2099.

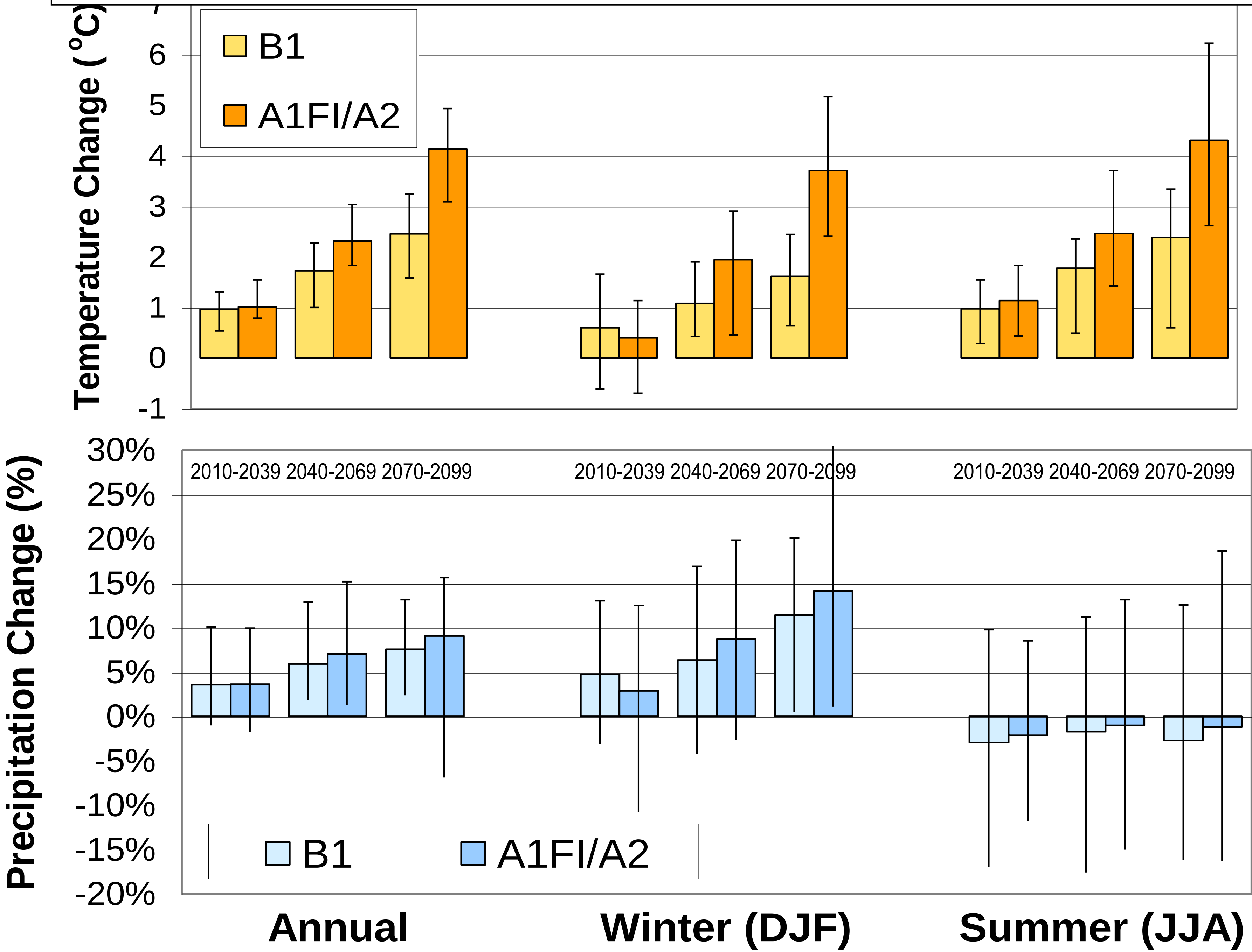


Figure 2. Projected mean annual temperature and precipitation change across entire NE Region. From NECIA.

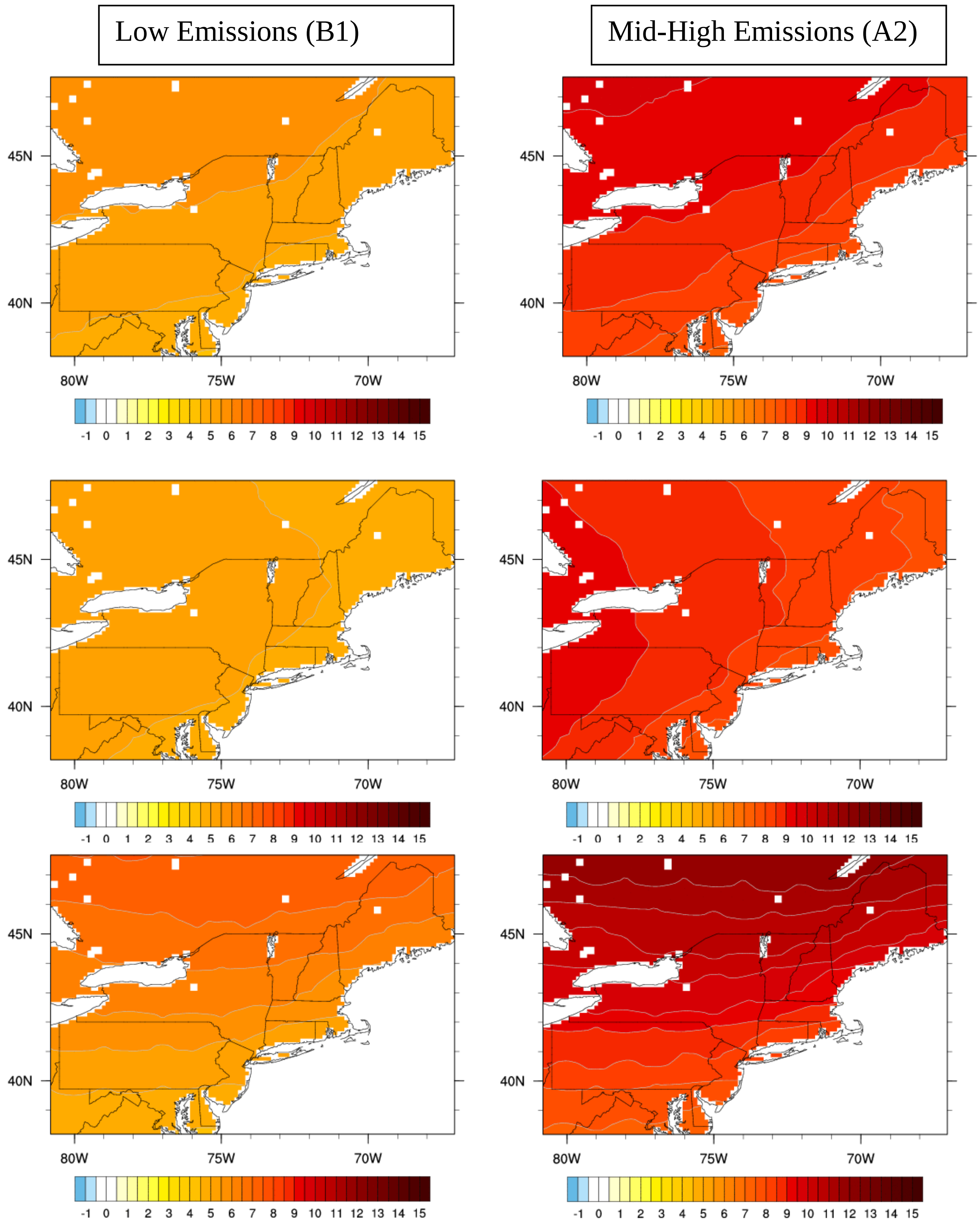


Figure 3. Average Temperature Change (^{o}F) by 2080-2099 Relative to 1971-2000. From NECIA.

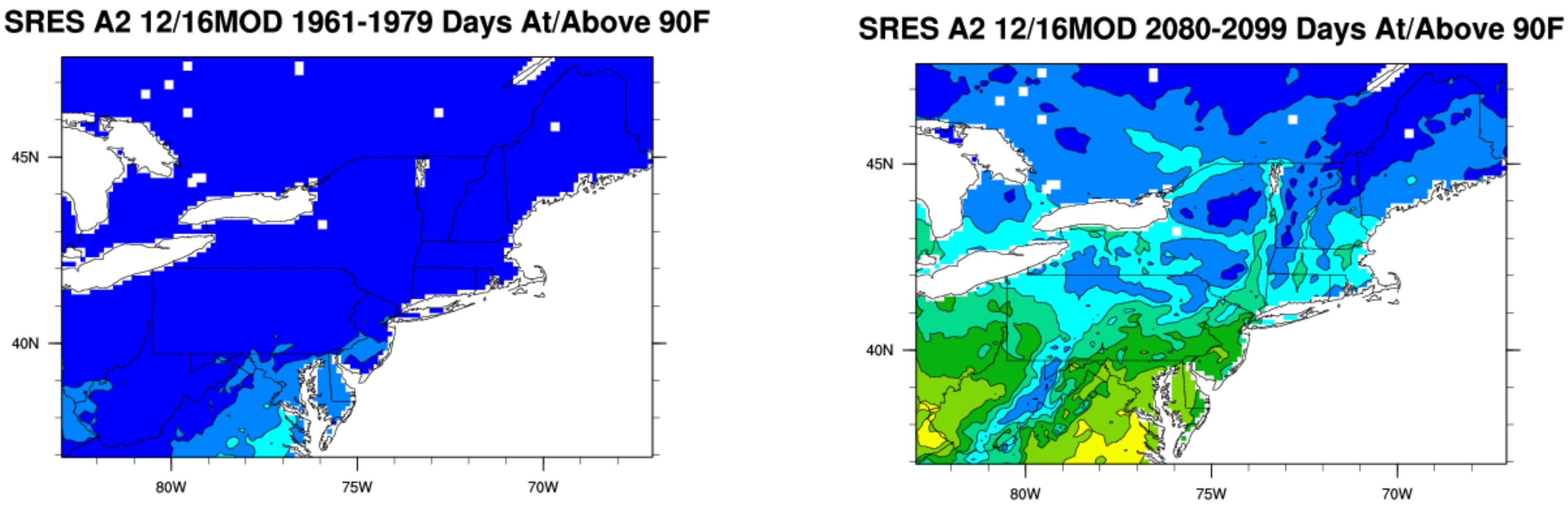


Figure 4. Extreme heat days (>90°F) Historic and Mid-High Emissions (A2). From NECIA.

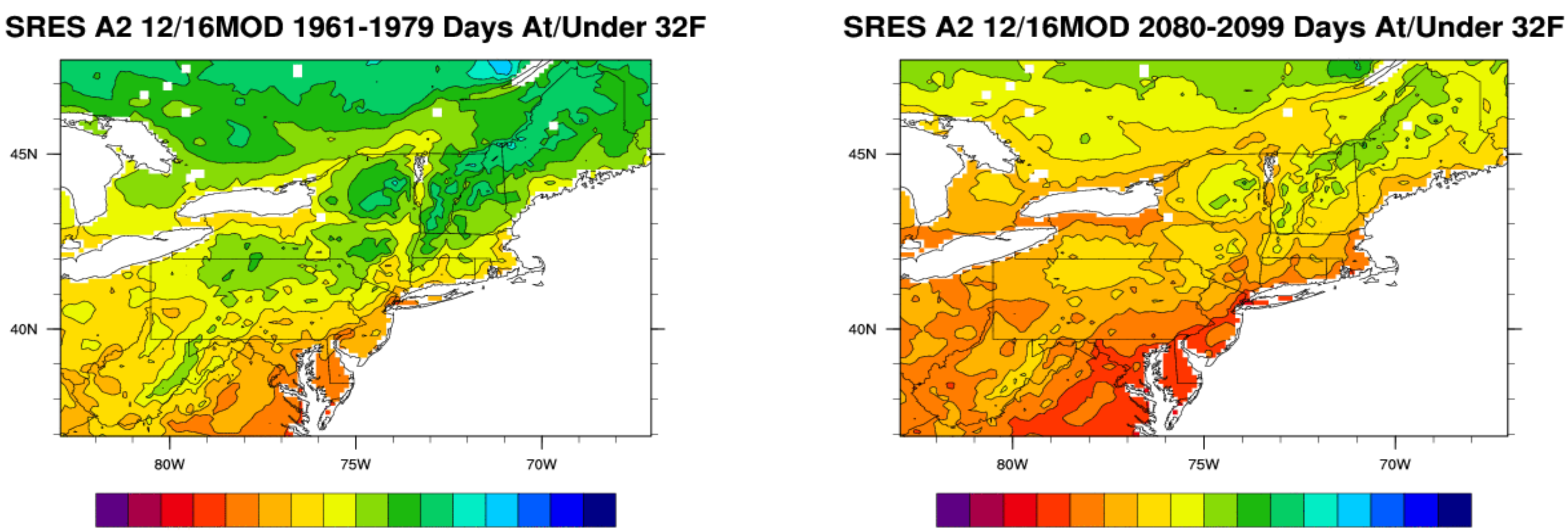
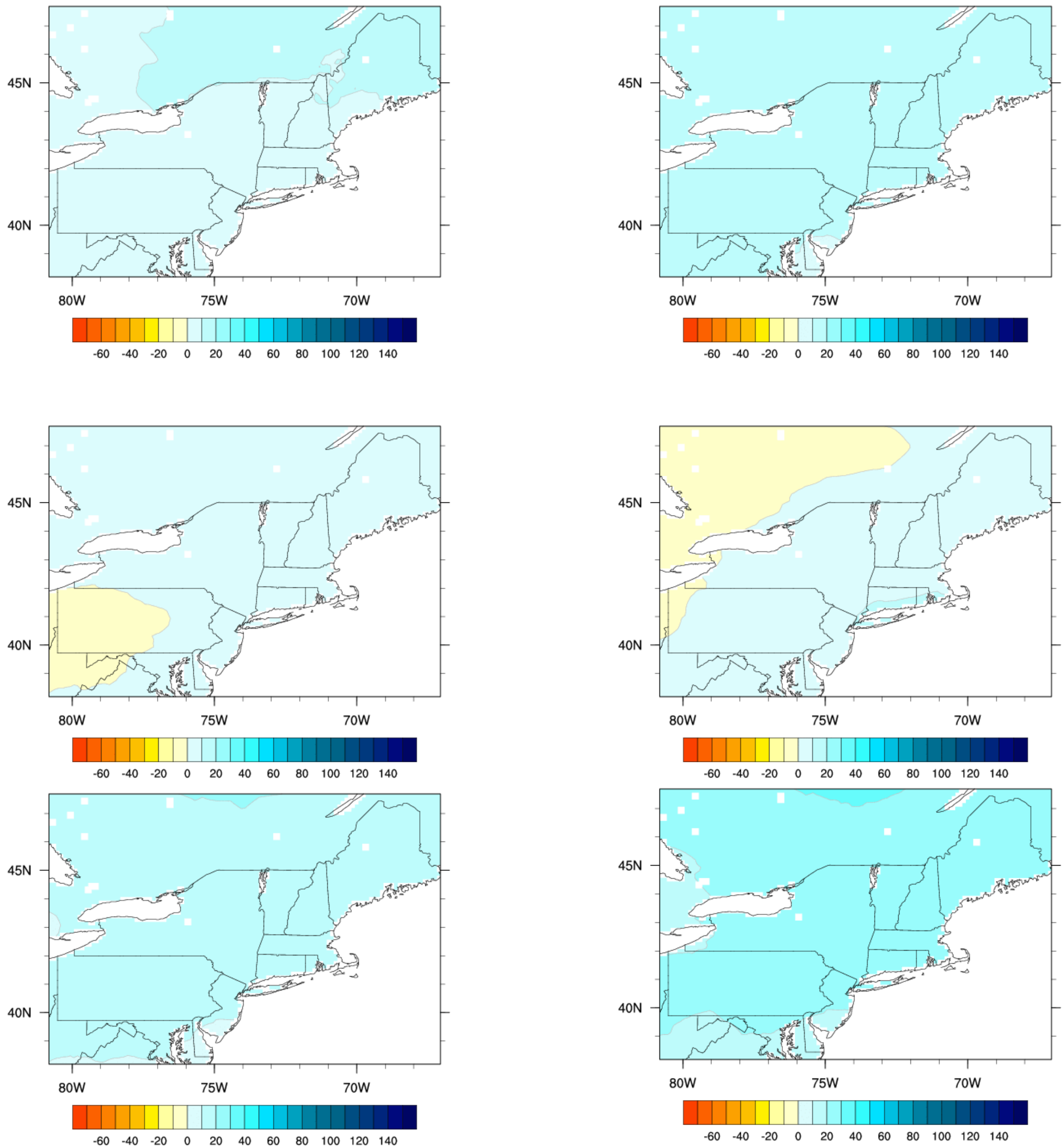


Figure 5. Freeze Days (Tmin <32°F). Historic and Mid-High Emissions. From NECIA.

Figure 6. Average Precipitation: % Change Relative to 1971-2000 by 2080-2099. From NECIA.

Lower Emissions (B1) | Mid-High Emissions (A2)



Annual

Summer (JJA)

Winter (DJF)

Figure 7. Modeled growing season length (days) in 1961-1979 and 2080-2099. Mid-High Emissions (A2). From NECIA.

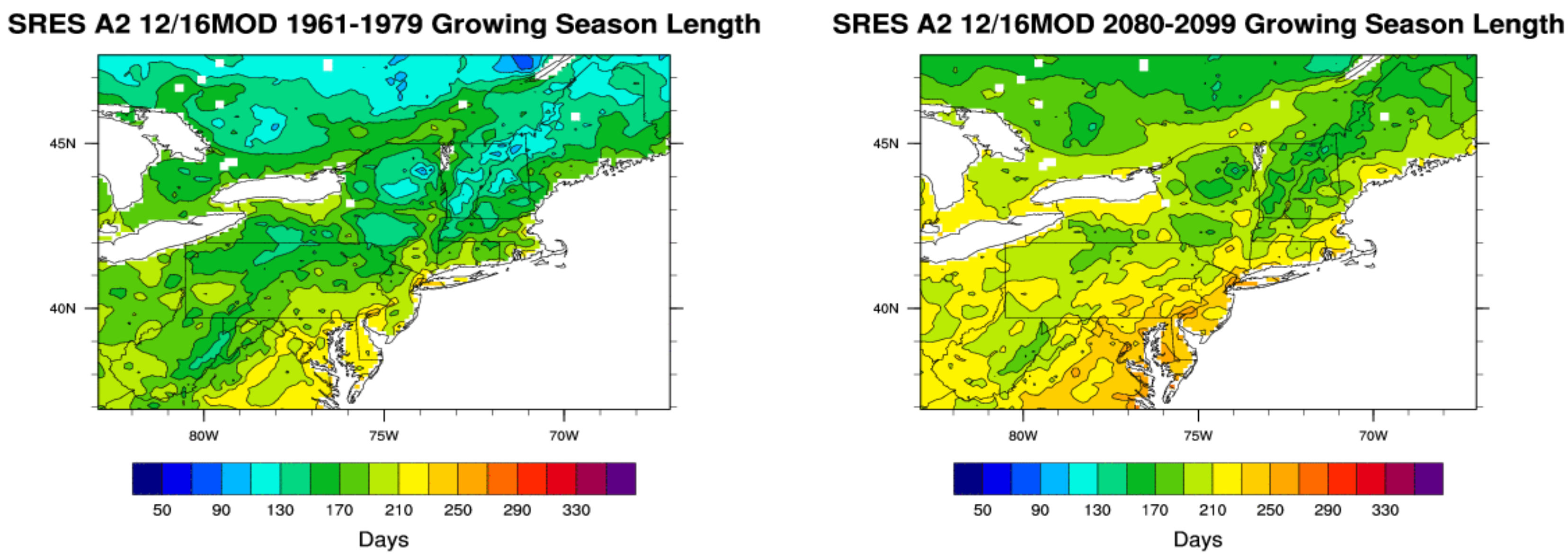


Figure 8. Modeled plant hardiness zones in 1961-1979 and 2080-2099. Mid-High Emissions (A2).

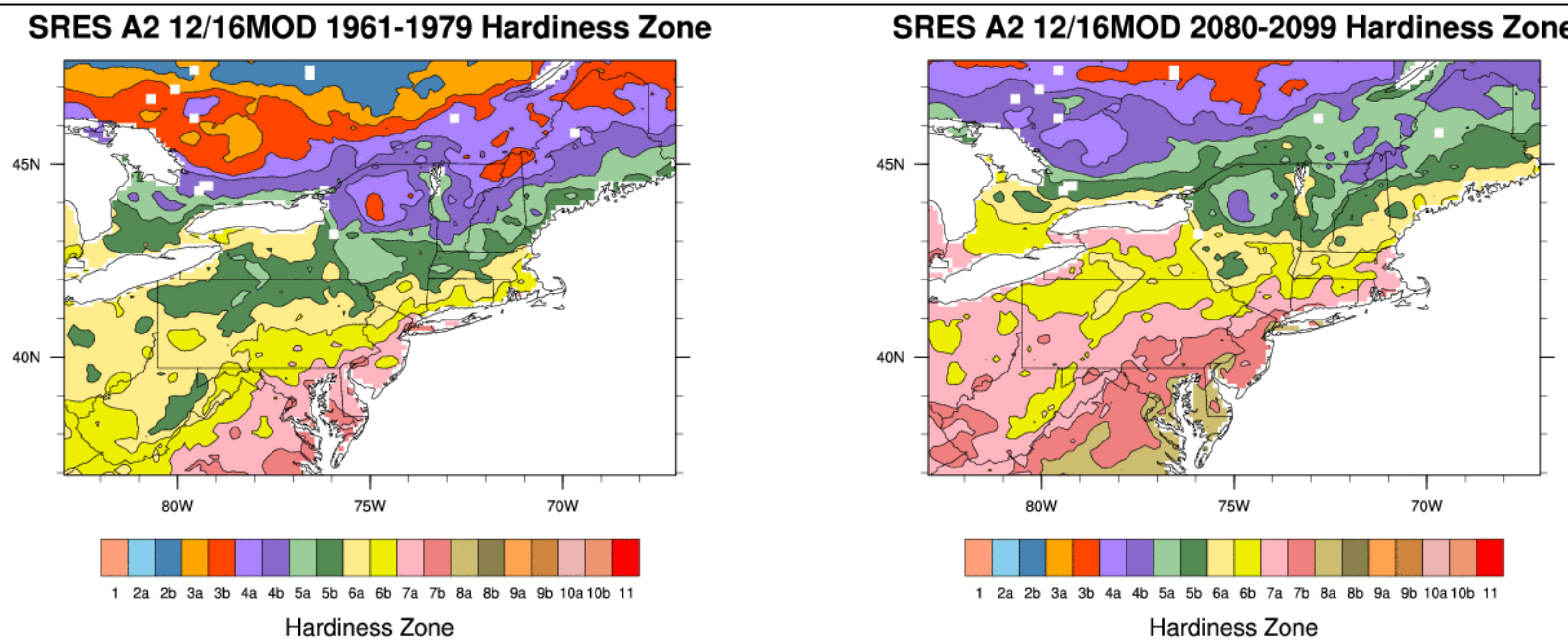


Figure 9. Projected percent seasonal changes in evapotranspiration. 2030-2060 relative to 1970-1999. B1 emissions scenario. From NECIA.

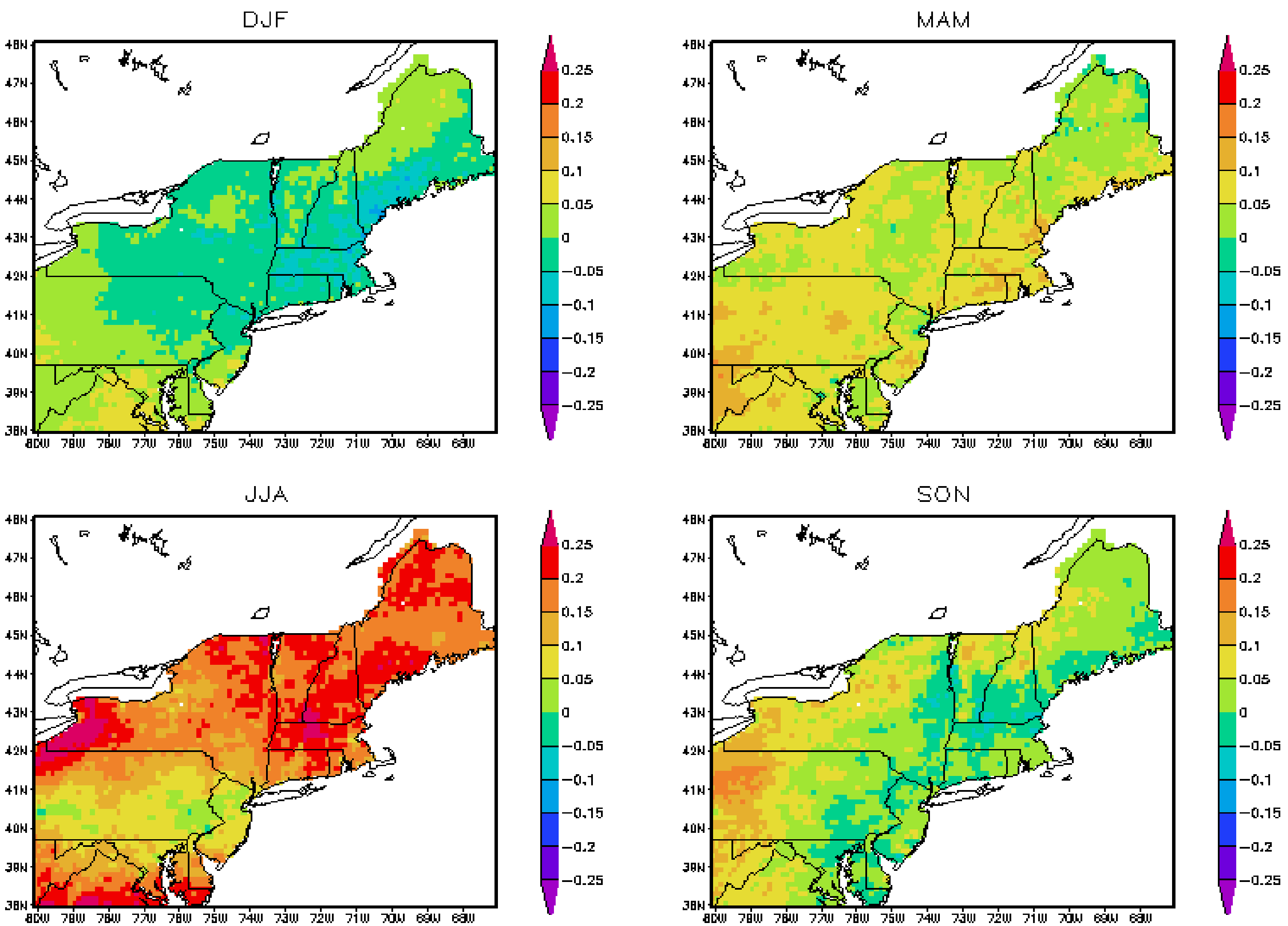


Figure 10. Projected percent seasonal changes in soil moisture. 2030-2060 relative to 1979-1999 (A1Fi emissions scenario). From NECIA.

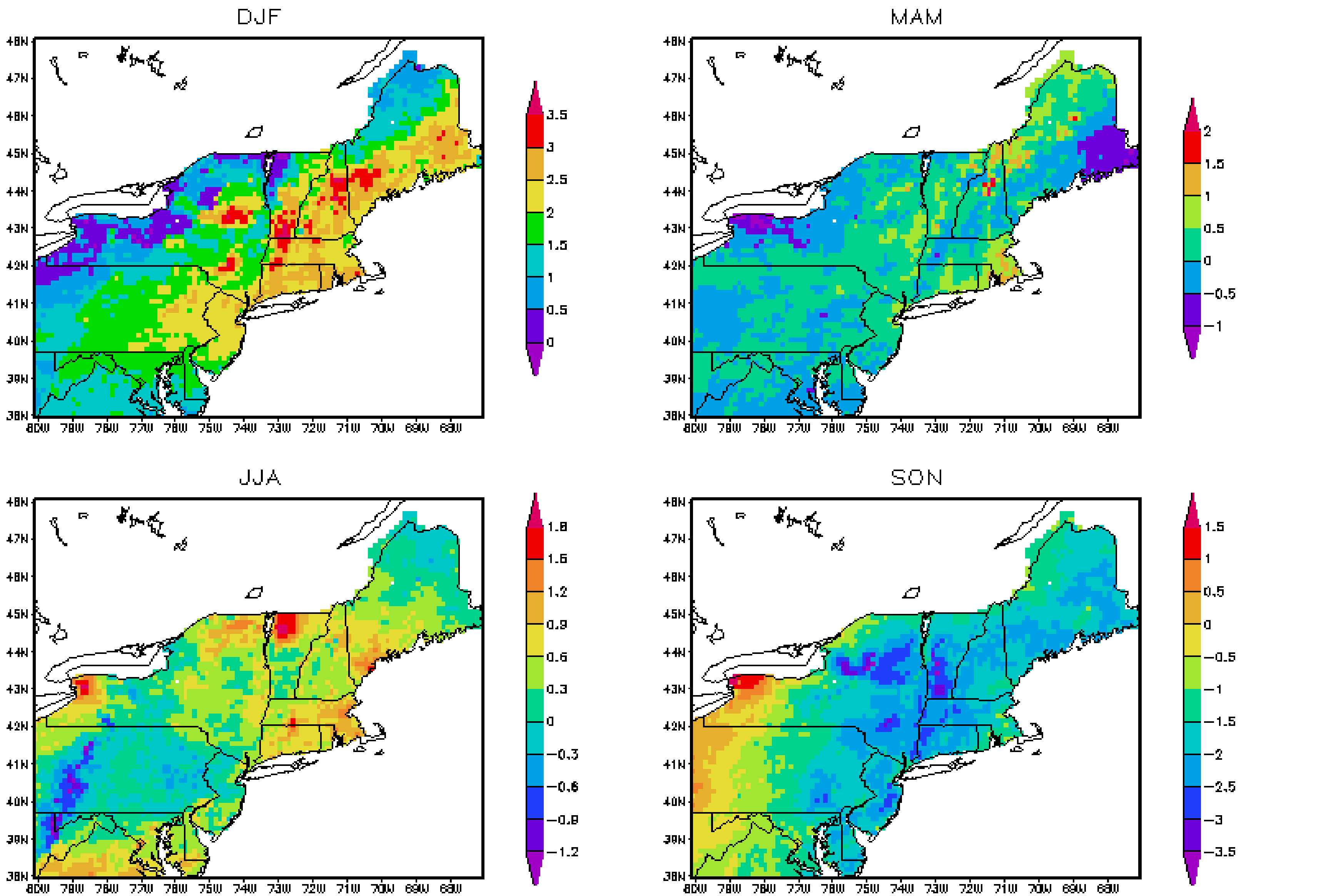


Figure 11. Number of Snow-covered days/month (Dec-Feb).
From NECIA.

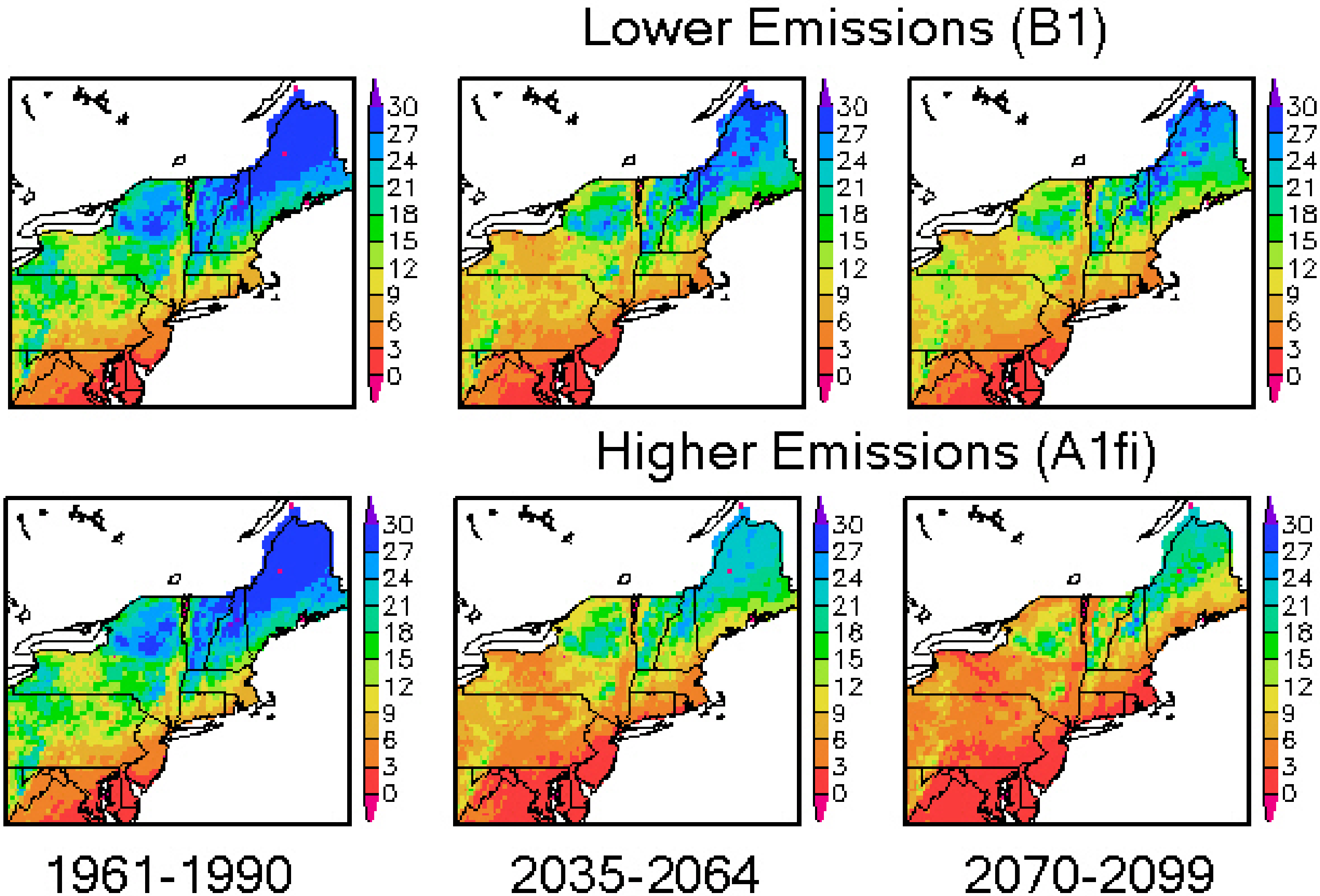


Figure 12. Red line encloses area of Northeast that historically has had at least a dusting of snow on the ground for 30 days or more during the winter. White area is that area that will continue to have snow cover by end of century. From NECIA.

Figure 13. Frequencies of Short-, Medium-, and long-term droughts during 1961-1990 and projected for the 30 year period 2070-2099. Values are the average of the HadCM3 and PCM models. From NECIA.

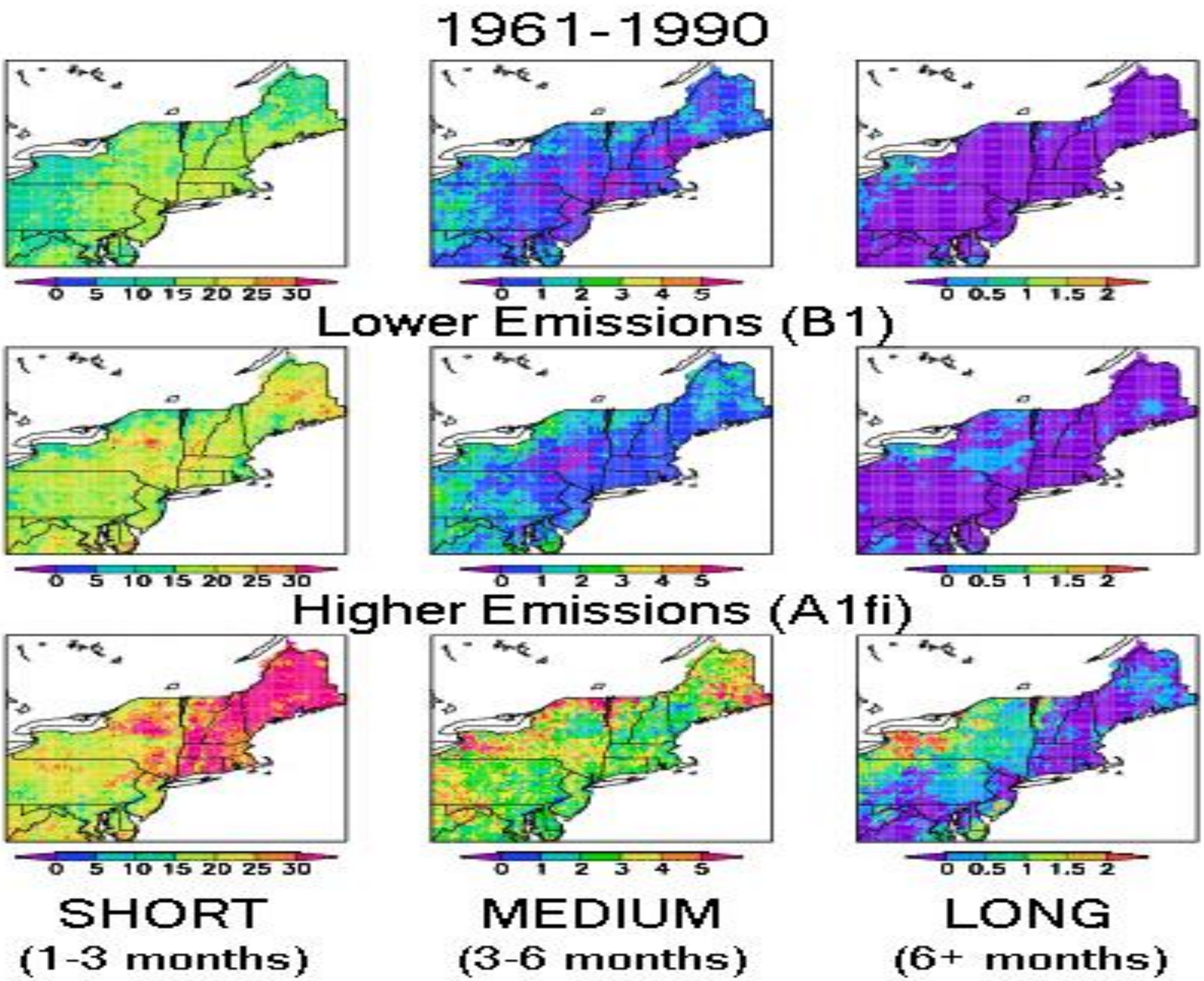
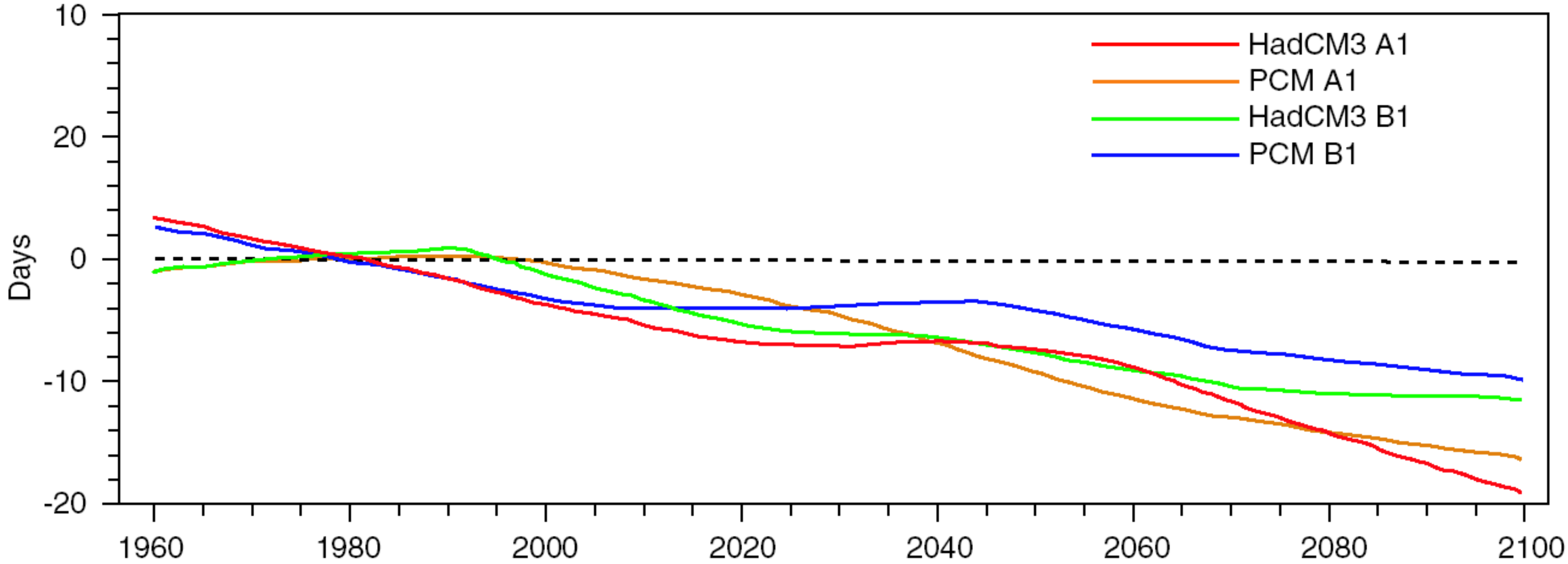
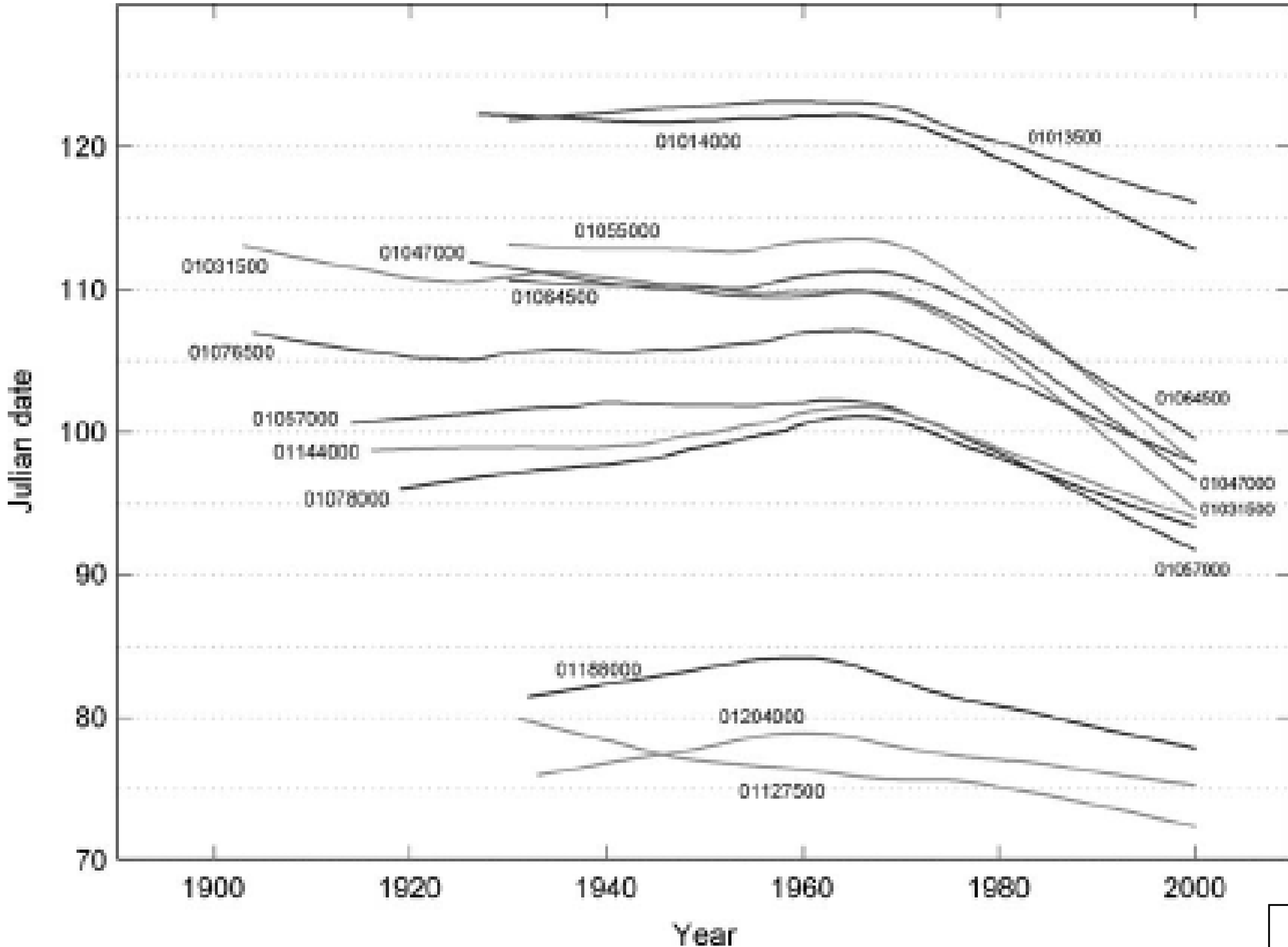


Figure 14. Projected Advance in Peak Spring Flow. From NECIA.



~ 1.5 to 2 weeks earlier (lower emissions, B1)
~ 2 to 2.5 weeks earlier (higher emissions, A1Fi) by 2100

Figure 15. Earlier Spring Peak Flow: observed. From NECIA.



Huntington et al. 2004

Figure 16. Projected average seasonal change in runoff (mm/day), 2030-2060 relative to 1970-1999. A1Fi emissions scenario. From NECIA.

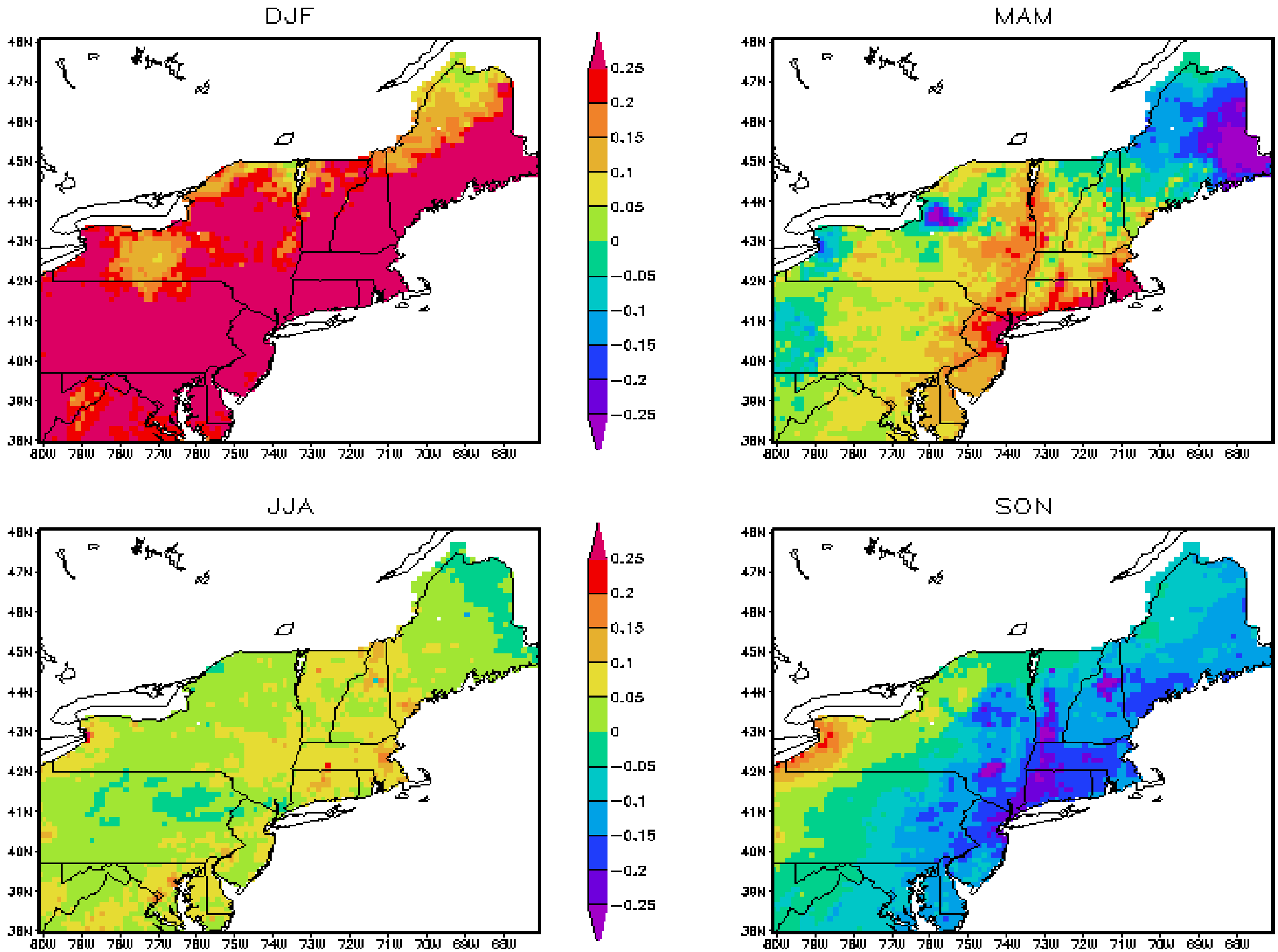


Figure 17. Increase in Duration of Summer Low Flow Periods. From NECIA.

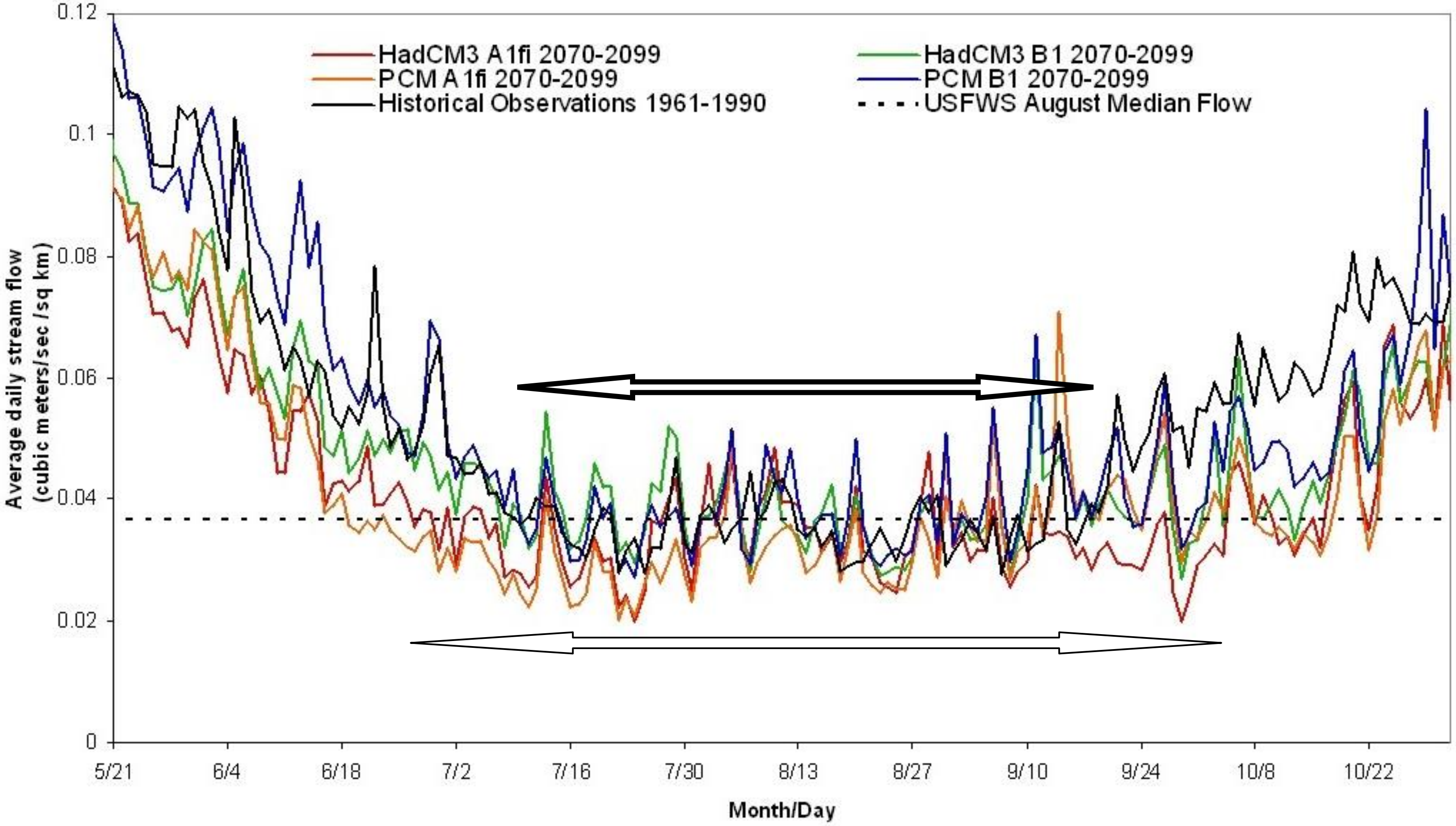


Figure 18. Projected change in the probability of low (10%) flows from the historic (1961-1990) to the future (2070-2099) periods for winter (DJF) for selected basins. Indicates a decreased probability of low flow events across much of the northern part of the NE under the A1FI scenario as compared with B1. From NECIA.

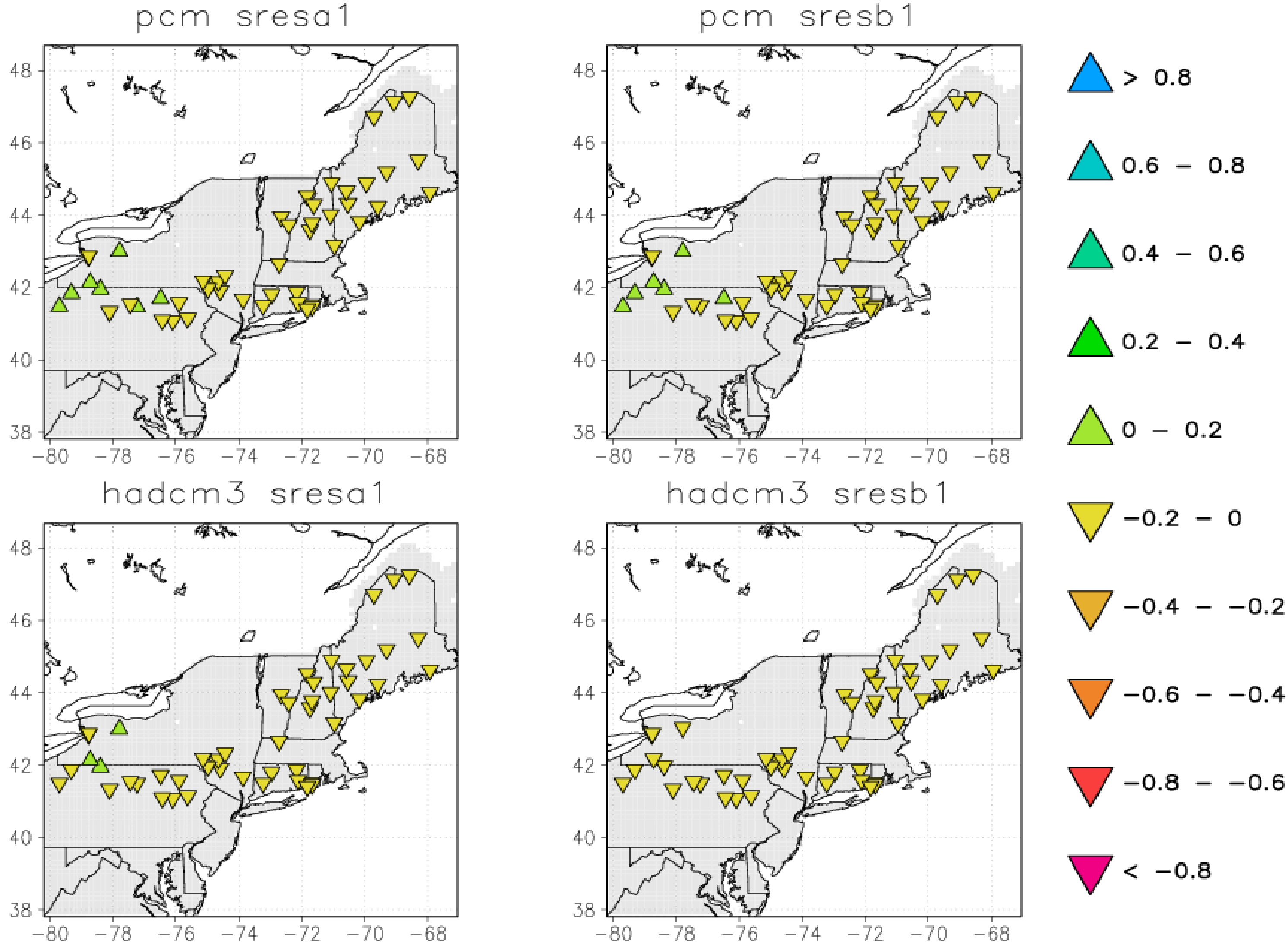


Figure 19. Projected change in the probability of high (90%) flows from the historic (1961-1990) to the future (2070-2099) periods for winter (DJF) for selected basins. Simulations indicate an increased probability of high flow events across much of the northern part of the NE under the A1FI scenario as compared with B1. From NECIA.

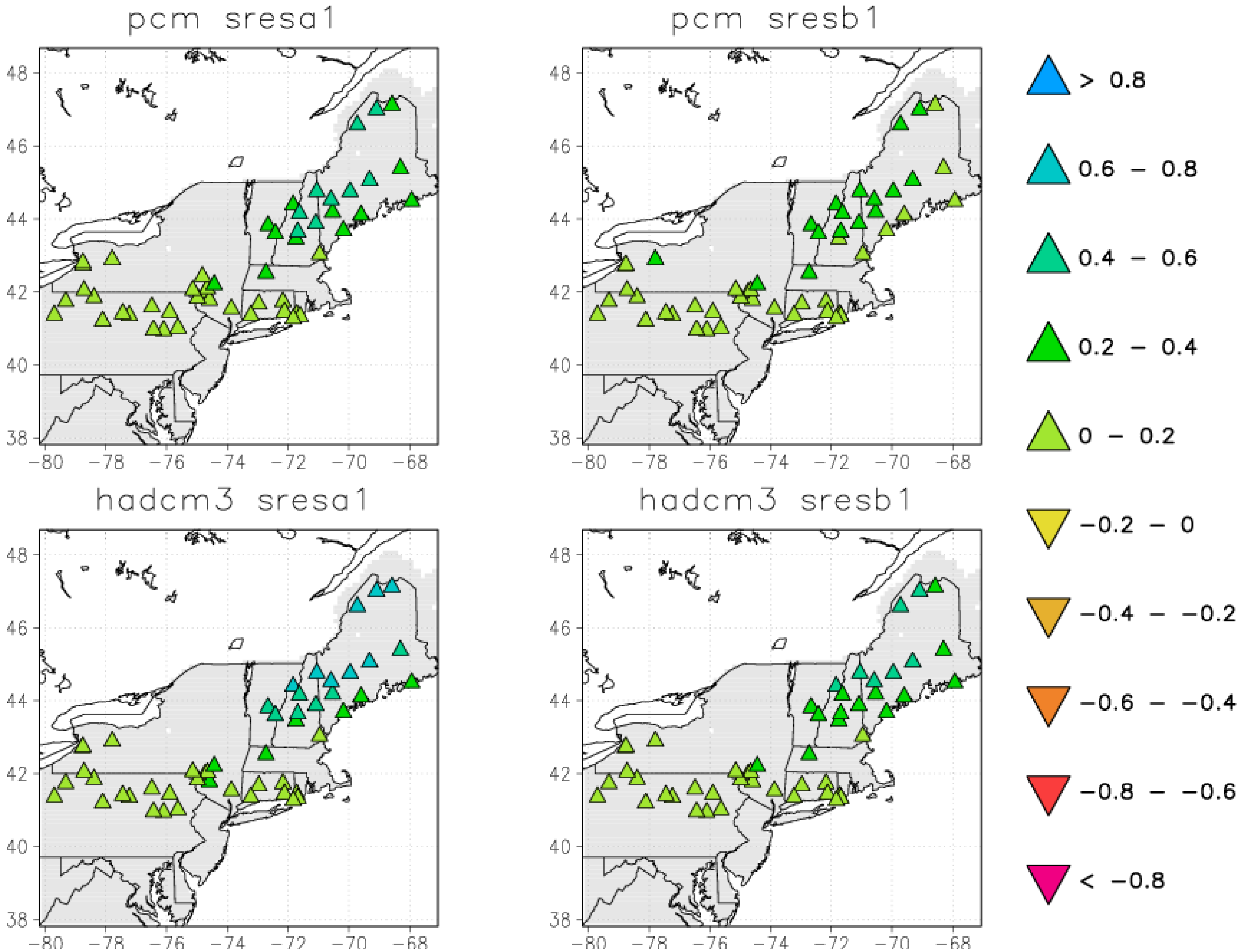


Figure 20. Current and projected annual mean temperatures in Virginia under the B1 and A2 emissions scenarios. Data are means of 16 GCM predictions (analyses from ClimateWizard).

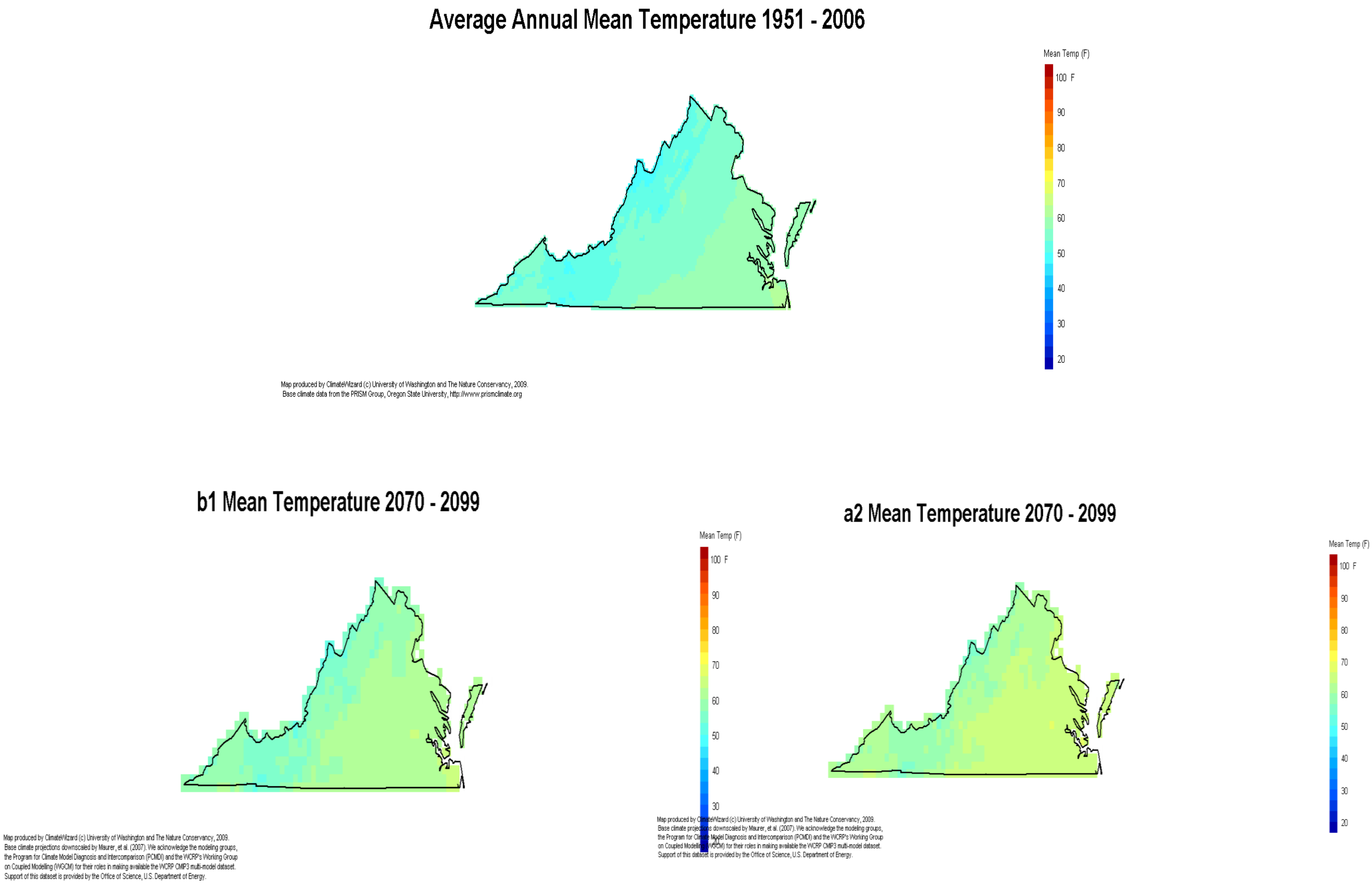
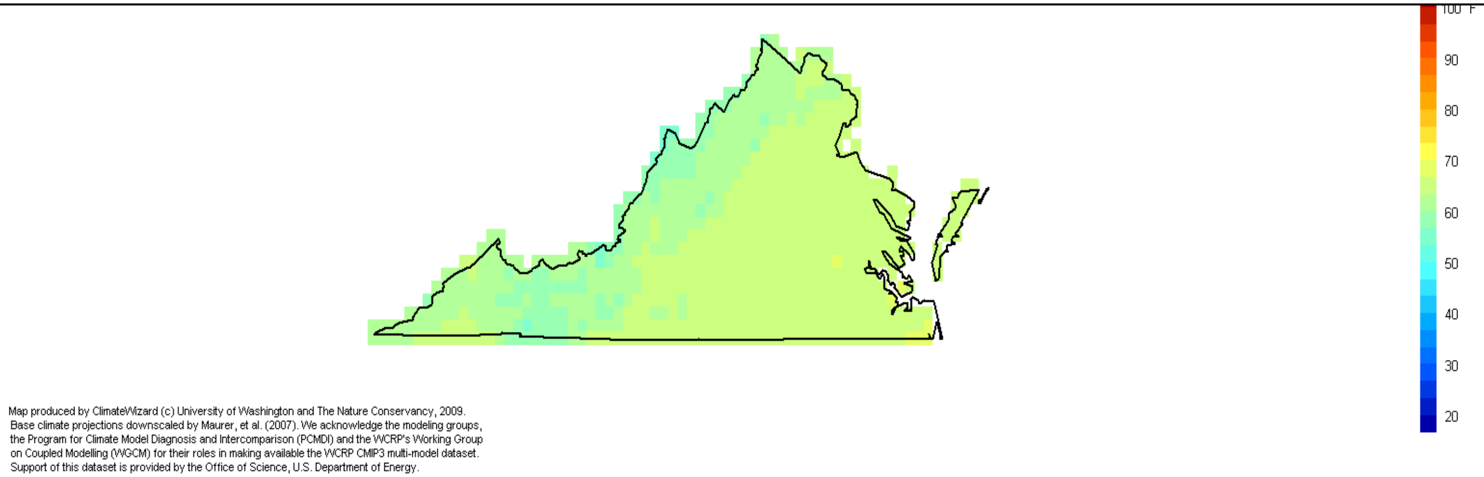


Figure 21. Projected mean annual temperatures in Virginia by 2070-2099. Upper is temperature change where 80% of the climate models project a greater temperature increase, and 20% of the climate models project less of a temperature increase. Lower is where 20 of the 16 models predict a greater temperature increase. Analyses from ClimateWizard.



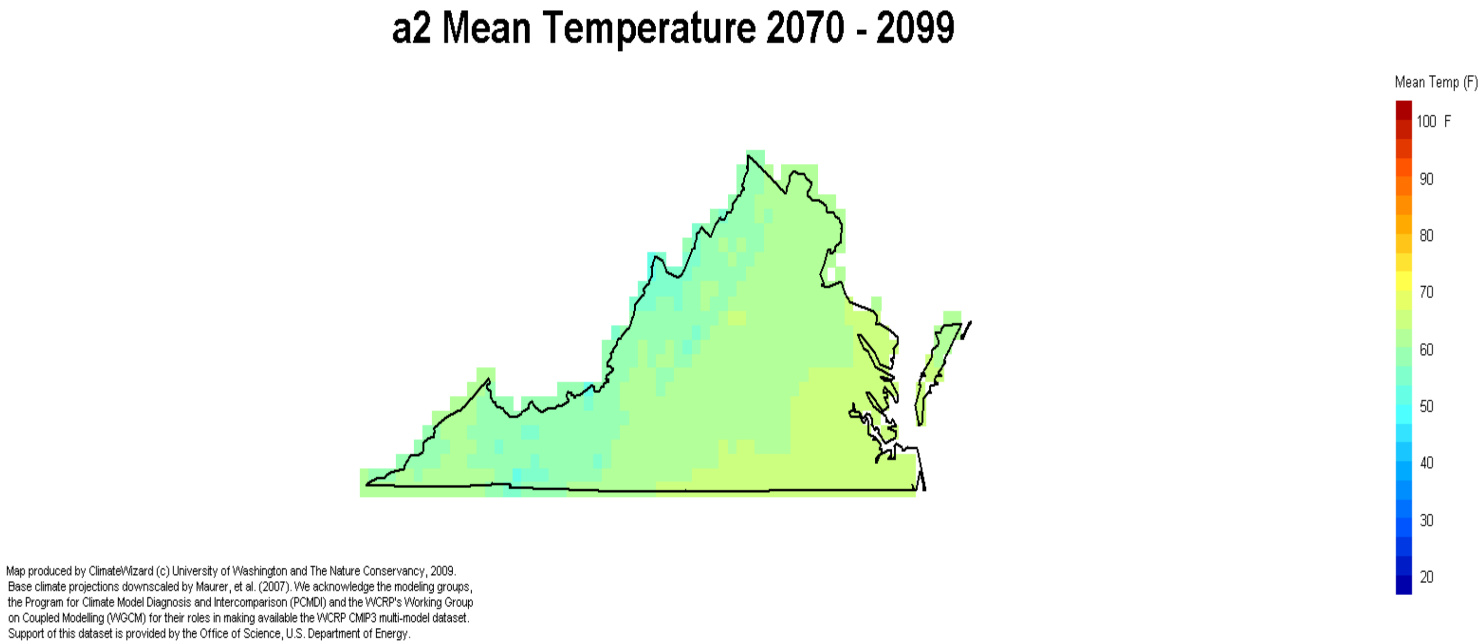


Figure 22. Current and projected annual mean precipitation in Virginia under the B1 and A2 emissions scenarios. Data are means of 16 GCM predictions. Analyses from ClimateWizard.

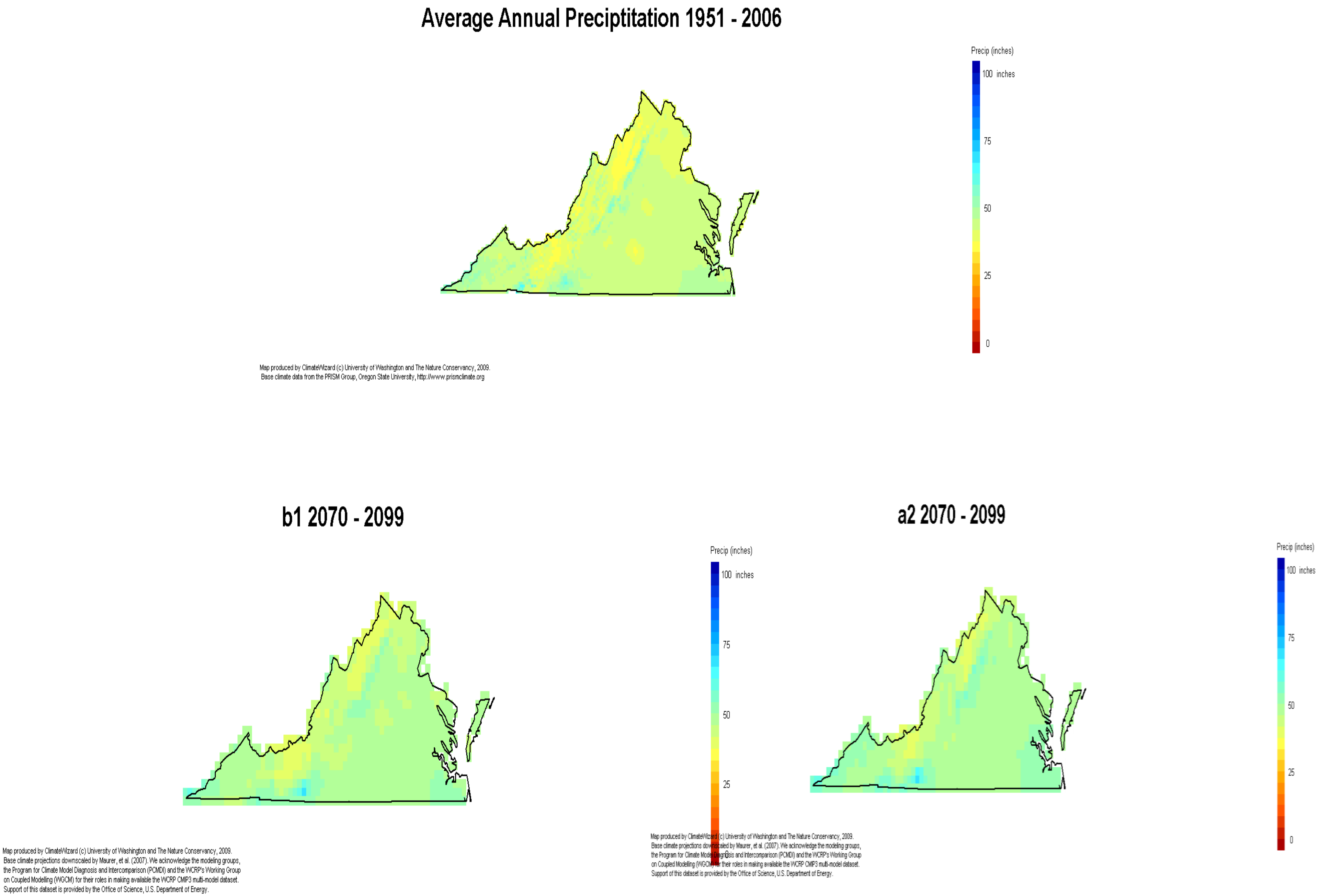


Figure 23. Current and projected annual mean temperatures in West Virginia under the B1 and A2 emissions scenarios. Data are means of 16 GCM predictions. Analyses from Climate Wizard.

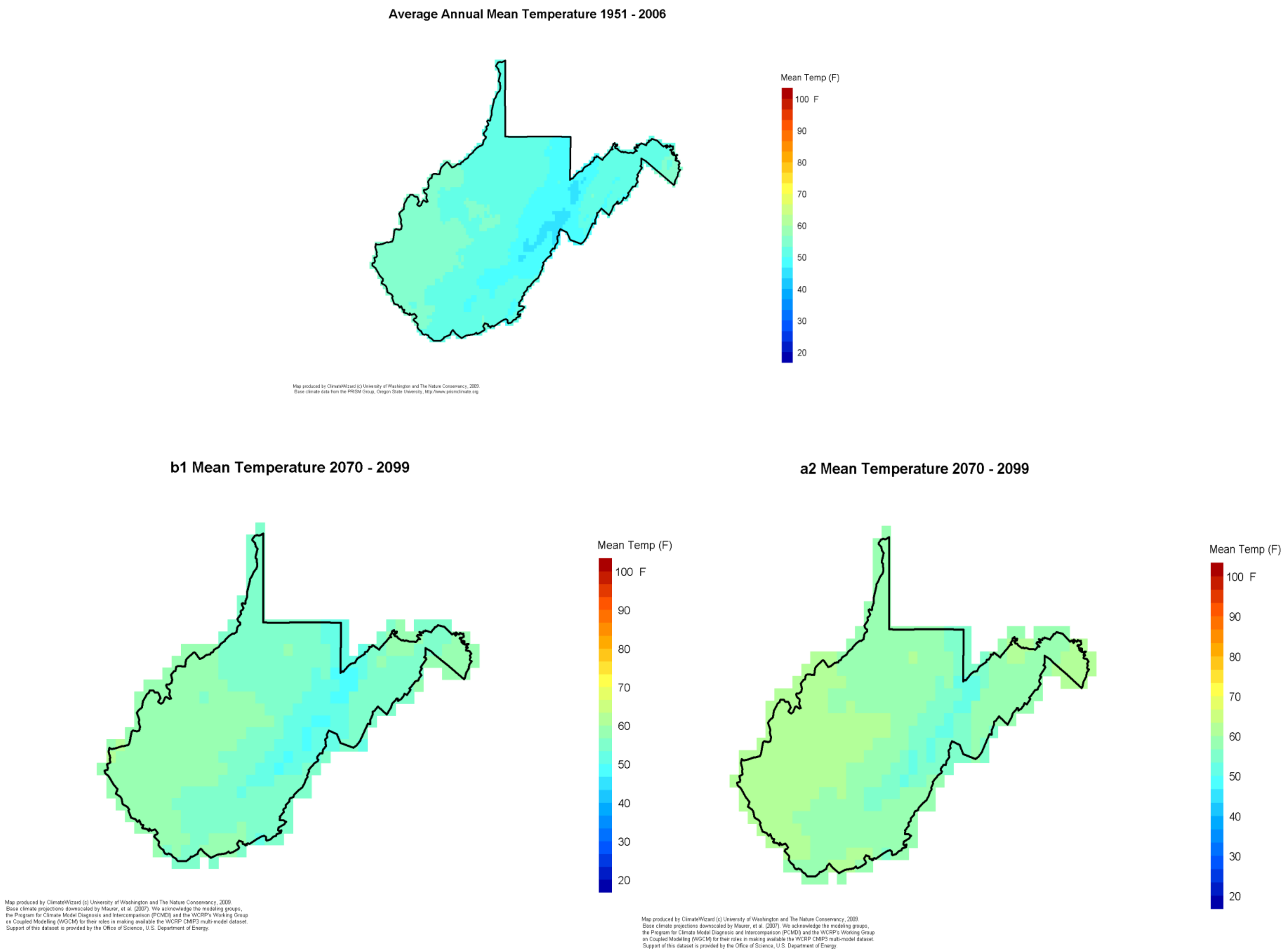
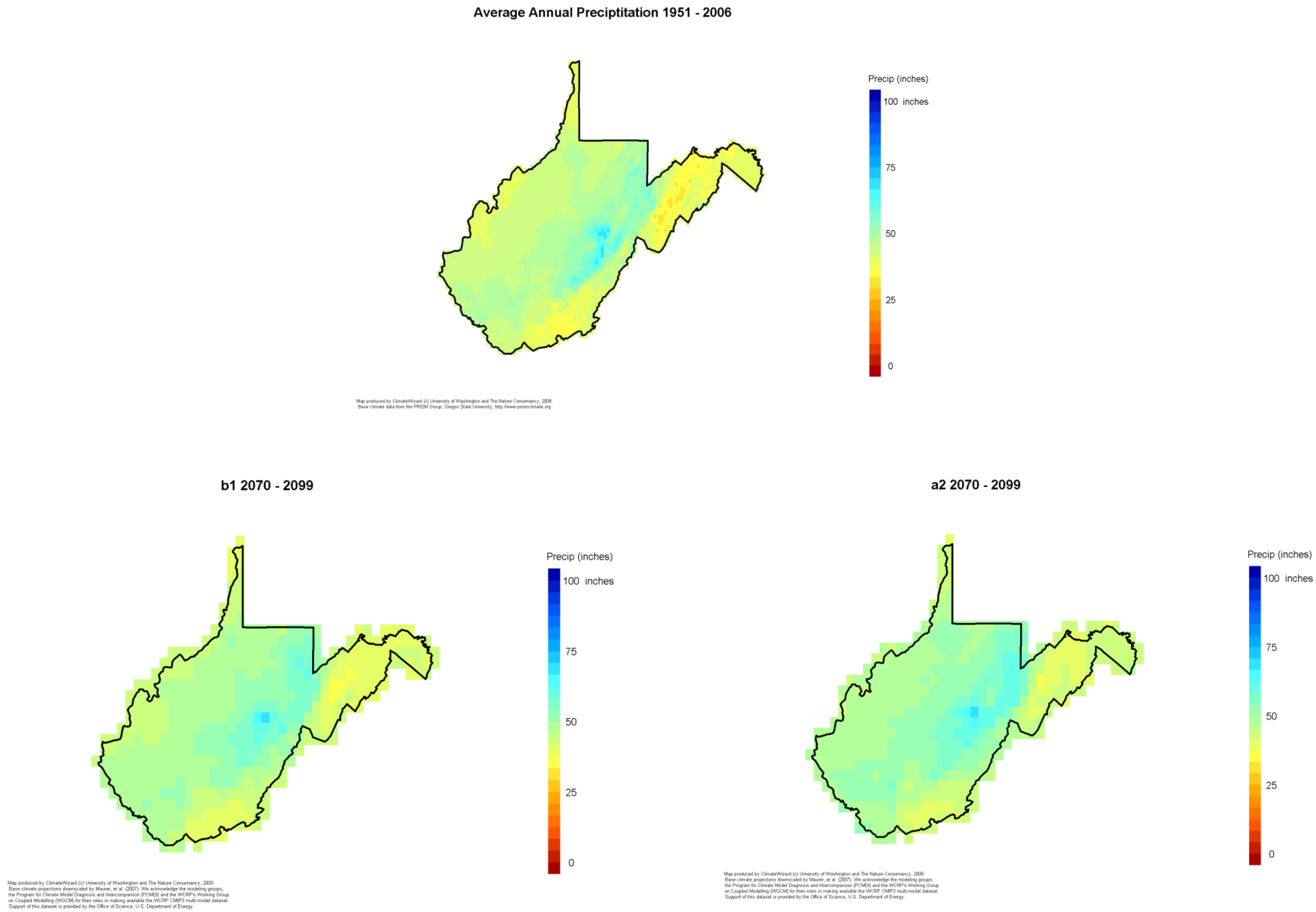


Figure 24. Current and projected annual mean precipitation in West Virginia under the B1 and A2 emissions scenarios. Data are means of 16 GCM predictions. Analyses from ClimateWizard.



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