Climate Change in the Hawkeye State

Technical Appendix
Climate Change Projections for Iowa

SUMMARY

Climatic trends in the Midwest are characterized by high variability on time scales of one to several years relative to long-term trends. It is not uncommon for temperature on a winter's day to vary by as much as 30°F (17°C) from the long term or century-scale mean, and for a summer's day temperature to vary by 15°F (8°C). For a given year, the annual temperature often varies by at least 3.5°F (2°C) from the long-term mean.

This high variability often makes it difficult to detect whether long-term trends are occurring and whether these trends can be attributed to human-induced change. However, careful analysis of historical long-term and short-term data reveals some significant trends in recent decades. For example, since the 1970s winter temperatures have ranged from near average to somewhat above average in comparison to earlier in the 20th century.

Using the IPCC 2000 standard emission scenarios, projected changes in climate have been determined relative to a baseline, taken as the average over the period 1961-1990. Confidence in annual average daily temperature increases falling within a range of 3-10°F (2-6°C) over the Great Lakes area during the next century is fairly high, as this spans the full range projected by the PCM and HadCM3 models and four SRES scenarios. On a seasonal basis, there is good agreement between models for greater summer temperature increases as compared to winter, although due to its lower climate sensitivity, the PCM model projects lower changes than the HadCM3 model.

In comparison to other models, both PCM and HadCM3 tend to predict a moderate to lower degree of change. In Table 1, projected change in seasonal average maximum temperature and precipitation for the period 2070-2099 for the PCM and HadCM3 models are compared to the range of projections for the SRES A2 and B2 scenarios obtained by seven GCMs (CCSRNIES, CGCM2, CSIRO, ECHAM4, GFDL, HadCM3 and PCM), as given in Ruosteenoja et al. (2003). Note that this comparison is for a region covering 'central North America', extending from 30°N to 50°N and 85°W to 105°W for the time period 2070-2099.

TABLE 1 – COMPARISON WITH OTHER MODELS

	Temperature (°C)			Precipitation (%)		
	PCM	HadCM3	All	PCM	HadCM3	All
Winter (DJF)	2-2.5	2.5-4	2-7.5	0 to +5	+6 to +7	-10 to +15
Spring (MAM)	2-2.5	2.5-4.5	2-7.5	+6 to +7	+6 to +9	+3 to +22
Summer (JJA)	2-3	5-7	2-7	+1 to +3	-10 to -17	-20 to +17
Autumn (SON)	2-2.5	4-5.5	2-5.5	+6 to +7	+7 to +10	-13 to +10

TABLE 2 – CLIMATE SUMMARY

Temperature, Precipitation & Soil Moisture

	By 2025-2030	By 2090-2099
Change in maximum daily temperature (^{o}C relative to 1961-1990 average)$^{+}$		
Winter (DJF)	0-3	3-8
Spring (MAM)	0-2	3-7
Summer (JJA)	1-4	5-12
Autumn (SON)	0-3	4-9
Change in average daily precipitation (% relative to 1961-1990 average)*		
Winter (DJF)	no sig. change (± 15%)	🡅 (-10 to +30)
Spring (MAM)	no sig. change (± 10%)	🡅 (-5 to +30)
Summer (JJA)	no sig. change (± 15%)	🡇 (-35 to –10)
Autumn (SON)	no sig. change (± 20%)	⇔ (-15 to +30)
Change in soil moisture (% relative to 1961-1990 average)*		
Winter (DJF)	no sig. change	🡅 (+30 to +50)
Spring (MAM)	no sig. change	🡅 (+5 to +20)
Summer (JJA)	no sig. change	🡇 (-30 to –5)
Autumn (SON)	no sig. change	🡇 (-30 to -5)

$^{+}$ Based on temperature projections from the PCM model for the SRES A2 & B2 scenarios and from the HadCM3 model for the SRES A1FI, A2, B2 & B1 scenarios.

* Based solely on HadCM3 projections for the SRES A2 & B2 (higher & lower mid-range) scenarios due to limitations on available data.

TEMPERATURE

Figure 1. Historical observed and HadCM3 model-calculated anomalies in daily average temperature (^oC) relative to the 1961-1990 average for Iowa. Historical data gridded from over 300 station records is plotted from 1900-2000 (Kunkel et al 1998) while future projections from 2001-2100 are plotted from 2001-2099. Changes in temperature are shown for the SRES A1FI (high), A2 (high mid-range), B2 (lower mid-range) and B1 (low) emissions scenarios. Bars show year-to-year variability, while solid lines indicate 10-year running means for temperature and 5-year running means for precipitation.

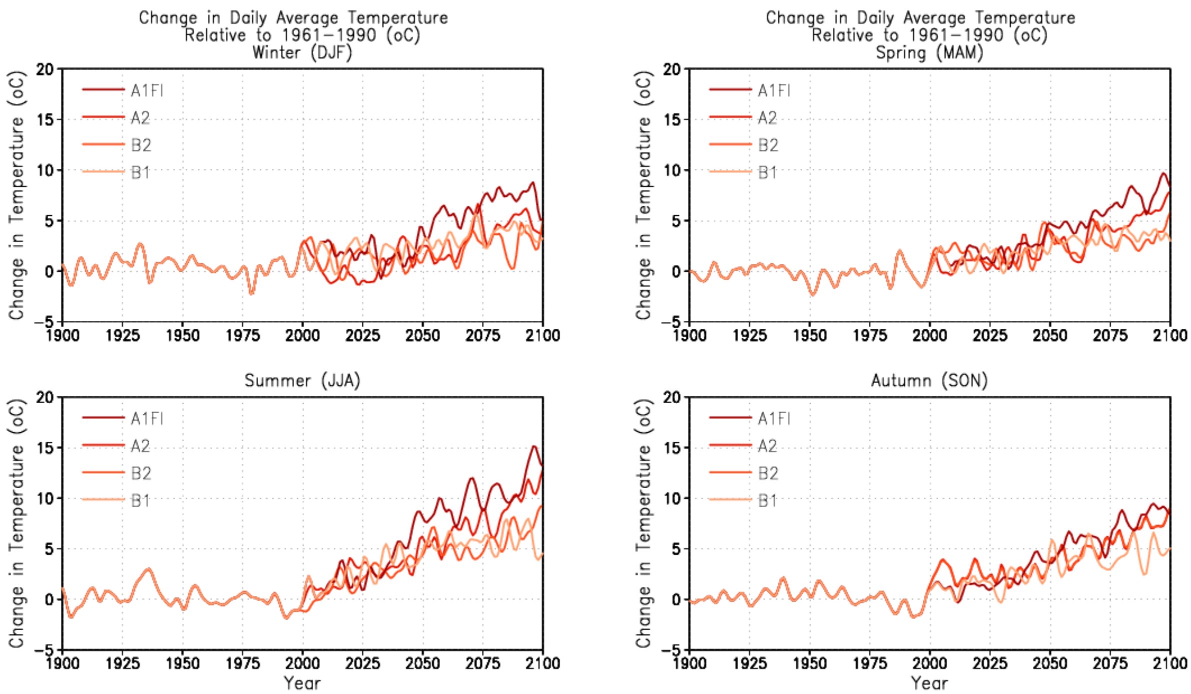


Figure 2. HadCM3 and PCM projections of change in winter and summer average maximum temperature (^{o}C) for 2070-2099 relative to 1961-1990. Results are shown here for the SRES A2 (higher mid-range) scenario. Other scenarios (not shown) also give a similar distribution of change for each model. Smaller projected changes in temperature are shown in peach while larger changes in temperatures range from orange to red.

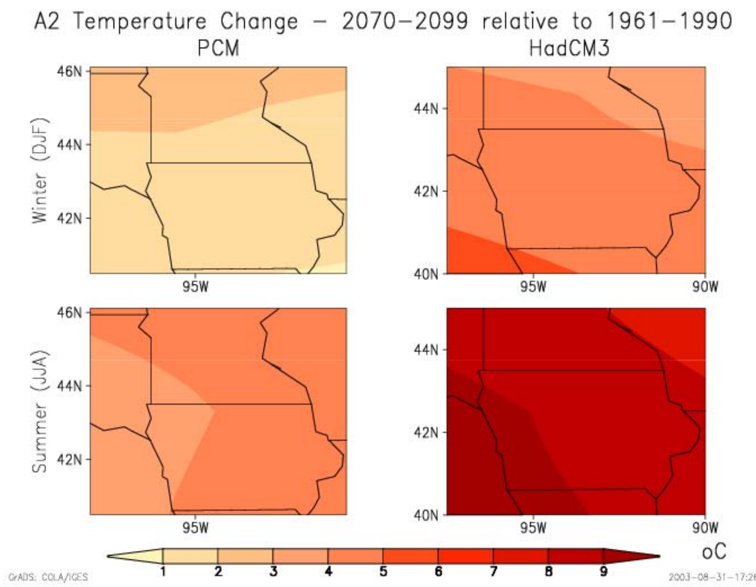
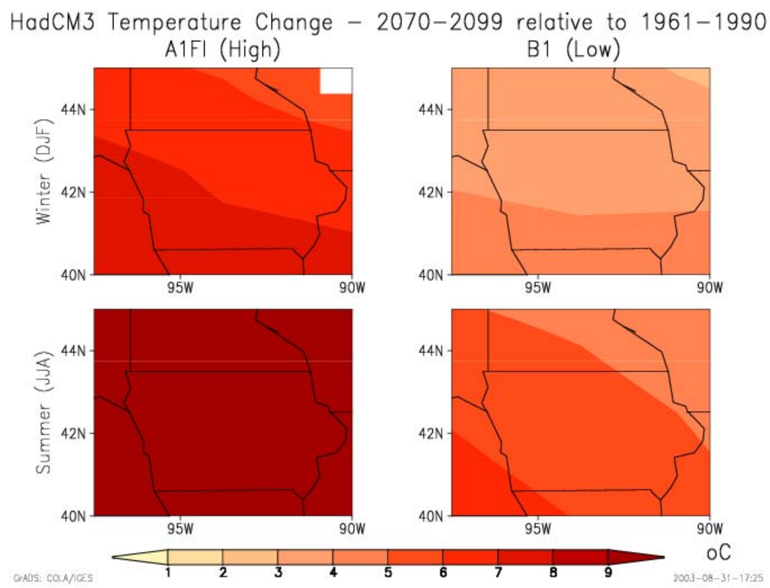
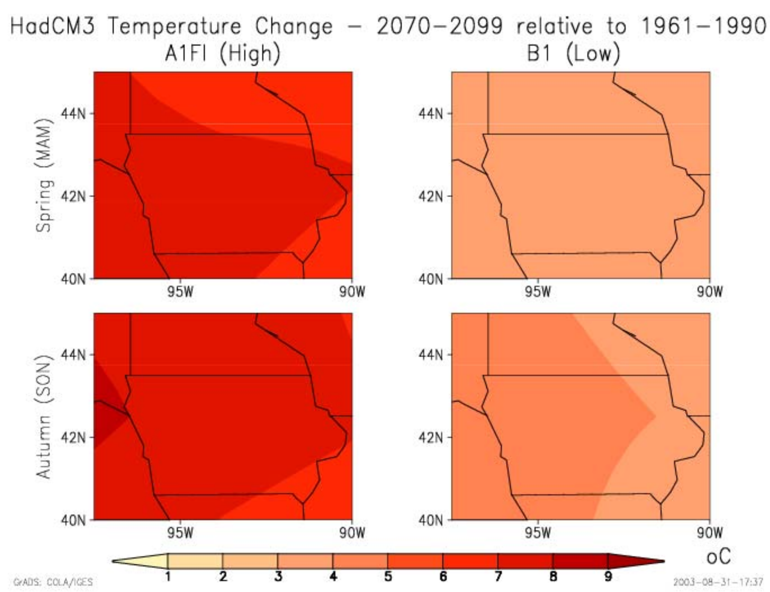


Figure 3. HadCM3 projections of change in average maximum temperature (^{o}C) for 2070-2099 relative to 1961-1990. Results are shown here for the SRES A1FI (highest) and B1 (lower) scenarios for (a) winter and summer, and (b) spring and fall. Smaller projected changes in temperature are shown in peach while larger changes in temperatures range from orange to red.

(a) Winter & Summer



(b) Spring & Fall



PRECIPITATION

Figure 4. Historical observed and HadCM3 model-calculated anomalies for changes in precipitation (%) relative to the 1961-1990 average for Iowa. Historical data gridded from over 300 station records is plotted from 1900-2000 (Kunkel et al 1998) while future projections from 2001-2100 are plotted from 2001-2099. Changes in precipitation are shown for the SRES A1FI (high), A2 (high mid-range), B2 (lower mid-range) and B1 (low) emissions scenarios. Bars show year-to-year variability, while solid lines indicate 10-year running means for temperature and 5-year running means for precipitation.

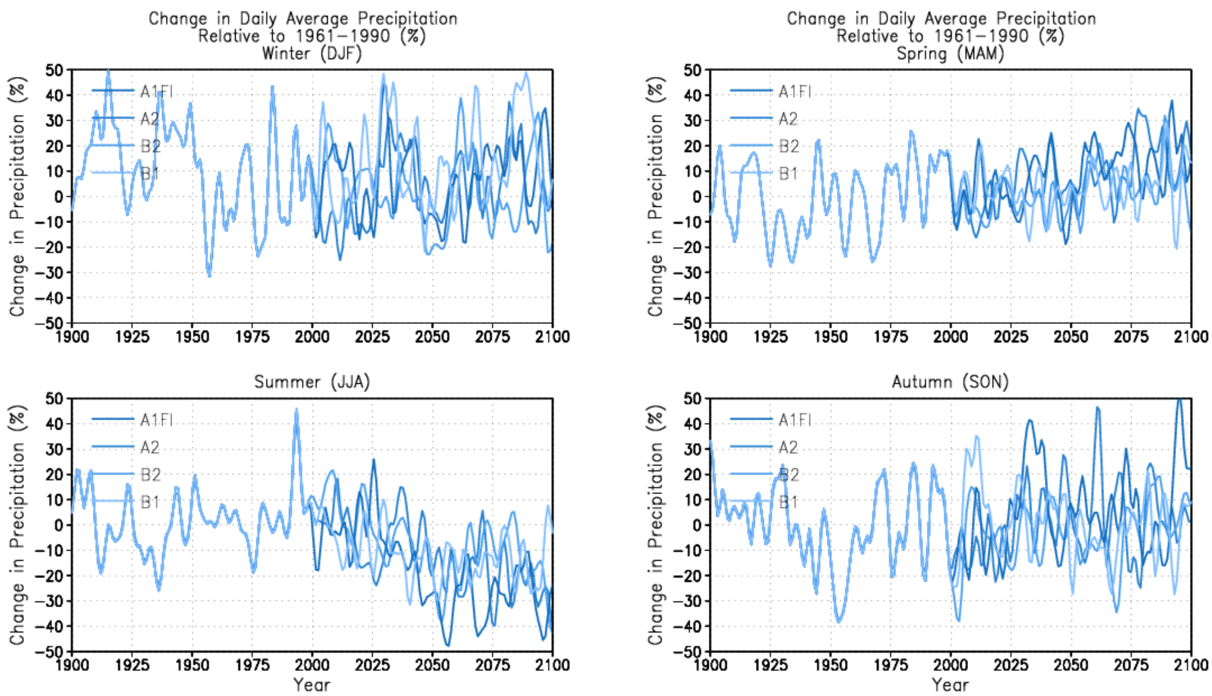


Figure 5. HadCM3 and PCM projections of change in winter and summer precipitation (%) for 2070-2099 relative to 1961-1990. Results are shown here for the SRES A2 (higher mid-range) scenario. Other scenarios (not shown) also give a similar distribution of change for each model. Yellow and orange shades indicate a projected decrease in future precipitation, while blue colors signify a projected increase, as shown in the color bars at the bottom of the plots.

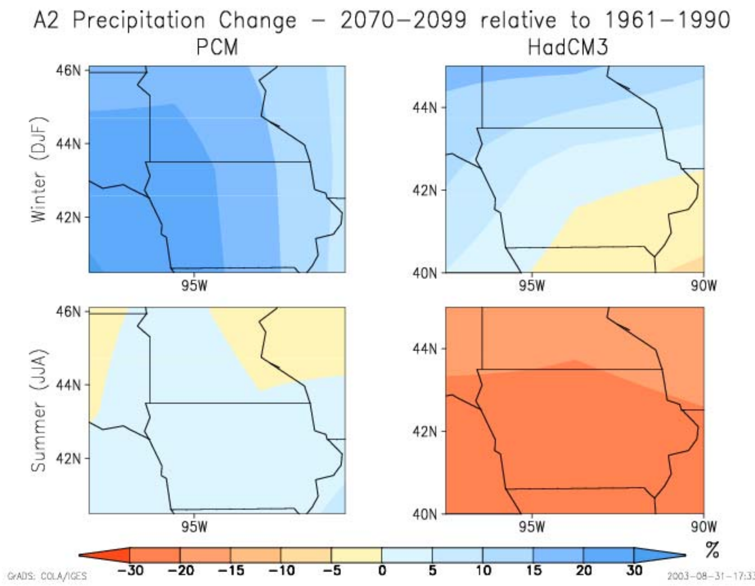
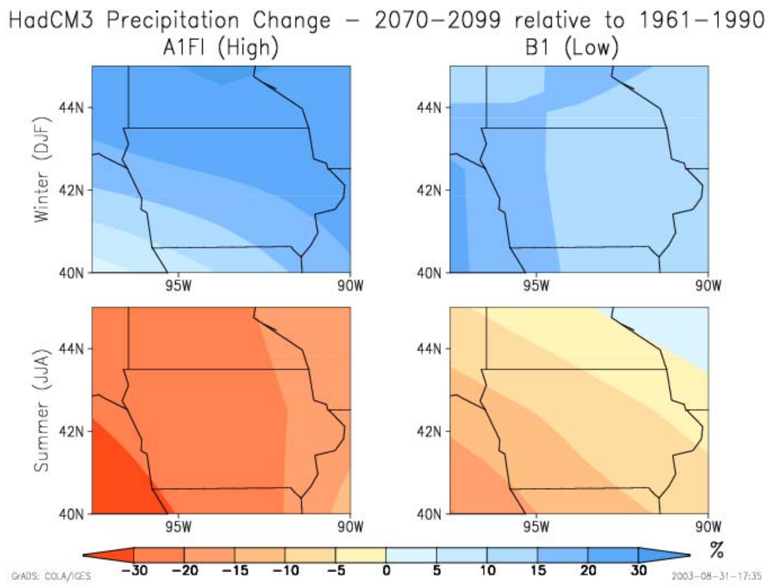


Figure 6. HadCM3 projections of change in winter and summer precipitation (%) for 2070-2099 relative to 1961-1990. Results are shown here for the SRES A1FI (highest) and B1 (lower) scenarios for (a) winter and summer, and (b) spring and fall. Yellow and orange shades indicate a projected decrease in future precipitation, while blue colors signify a projected increase, as shown in the color bars at the bottom of the plots.

Winter & Summer



Spring & Fall

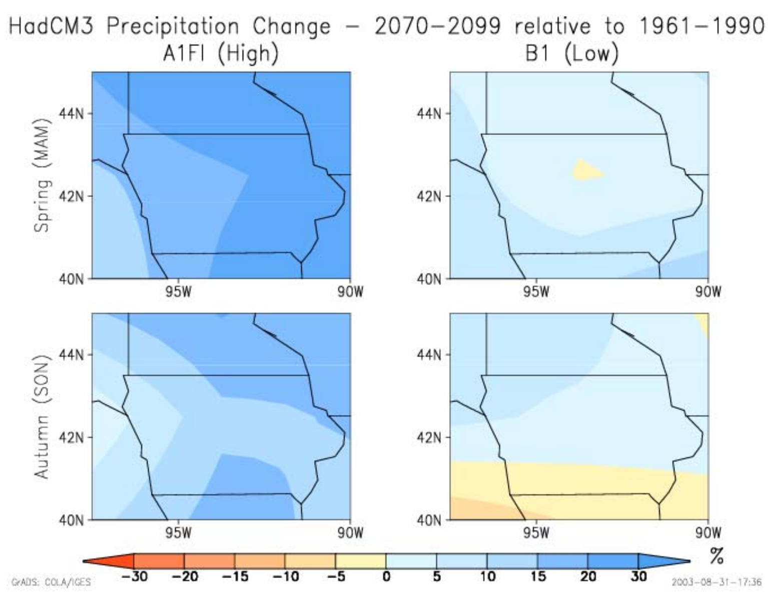


Figure 7. Changes in length of frost-free season and dates of last spring and first autumn frost over Iowa. Historical data on the frost-free season is shown from 1900-2000, based on daily minimum temperature records gridded from over 300 stations around the Midwest (Kunkel et al., 1998). HadCM3 projections from 2001-2099, based on daily minimum temperature outputs calibrated to historical growing season lengths over the reference period 1961-1990, are shown in red for the higher A1FI scenario and blue for the lower B1 SRES emission scenario. Bars show year-to-year variability while solid lines indicate 10-year running means.

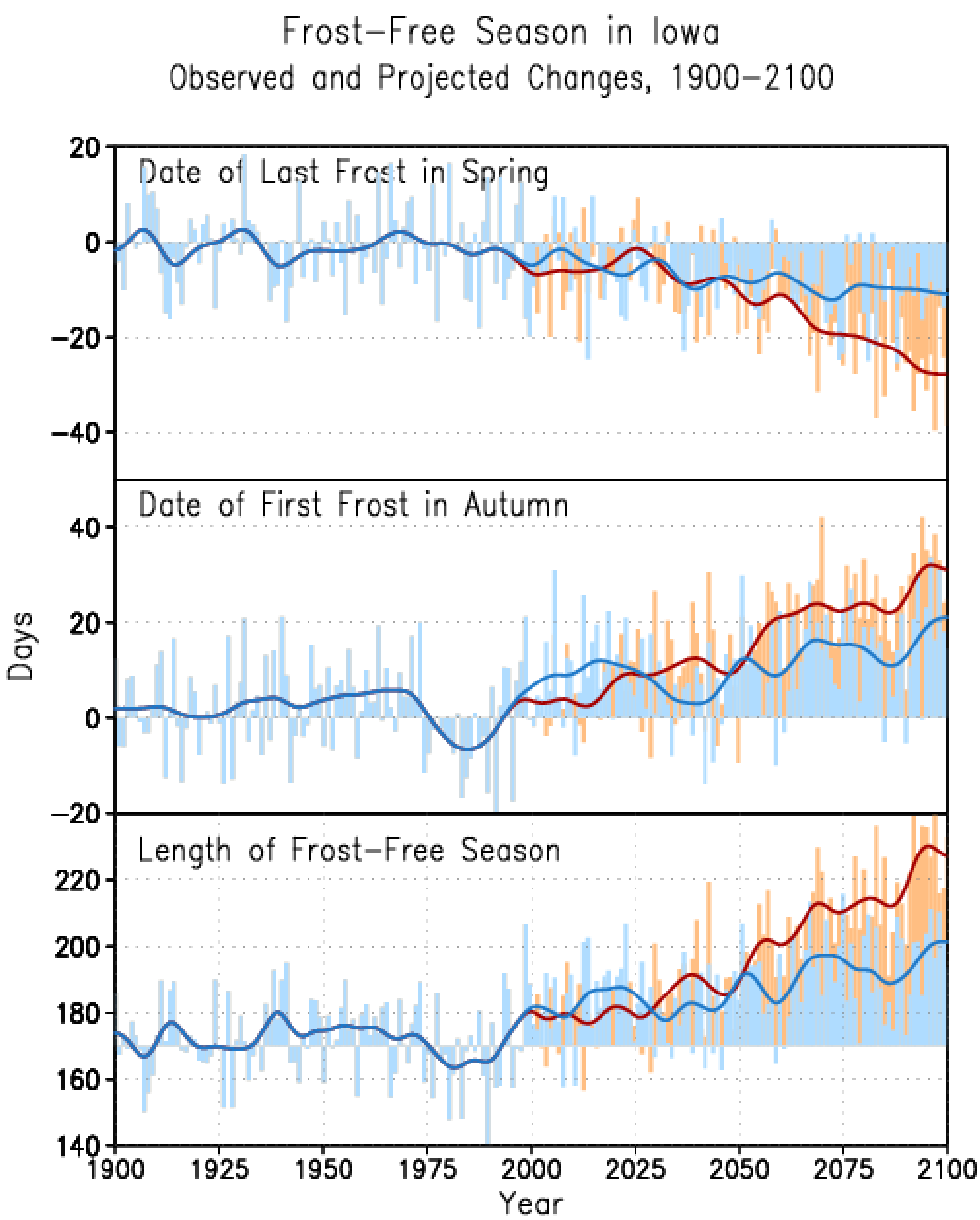


Figure 8. Analysis of historical observed (1900-2000) and HadCM3 mid-range A2 (dark) and B2 (light) projections (2001-2099) shows that (a) 24-hour heavy precipitation events are becoming more frequent in the region, while a smaller increase has also been observed in (b) 4-day and (c) 7-day events. Frequency of historical events was determined by locating the 101 largest events from 1900 to 2000, such that the average was one event per year. In some years, this meant that were no events in certain areas while in other years there could be multiple events. The events were then averaged over Iowa and plotted according to the year in which they occurred. Frequency of future events was determined by counting the number of model-projected events based on model daily precipitation output that lay within the range of the 101 historical events previously located. The model event threshold was then normalized by the difference between modeled vs. observed historical event frequencies, and the number of future events exceeding the normalized threshold calculated. Bars show the yearly averages while the solid lines indicate the 10-year running mean. Results from two different climate scenarios show similar trends of 24-hr event frequencies remaining well above average for the next few decades and doubling by the end of the century, while a smaller change is projected for events of longer duration.

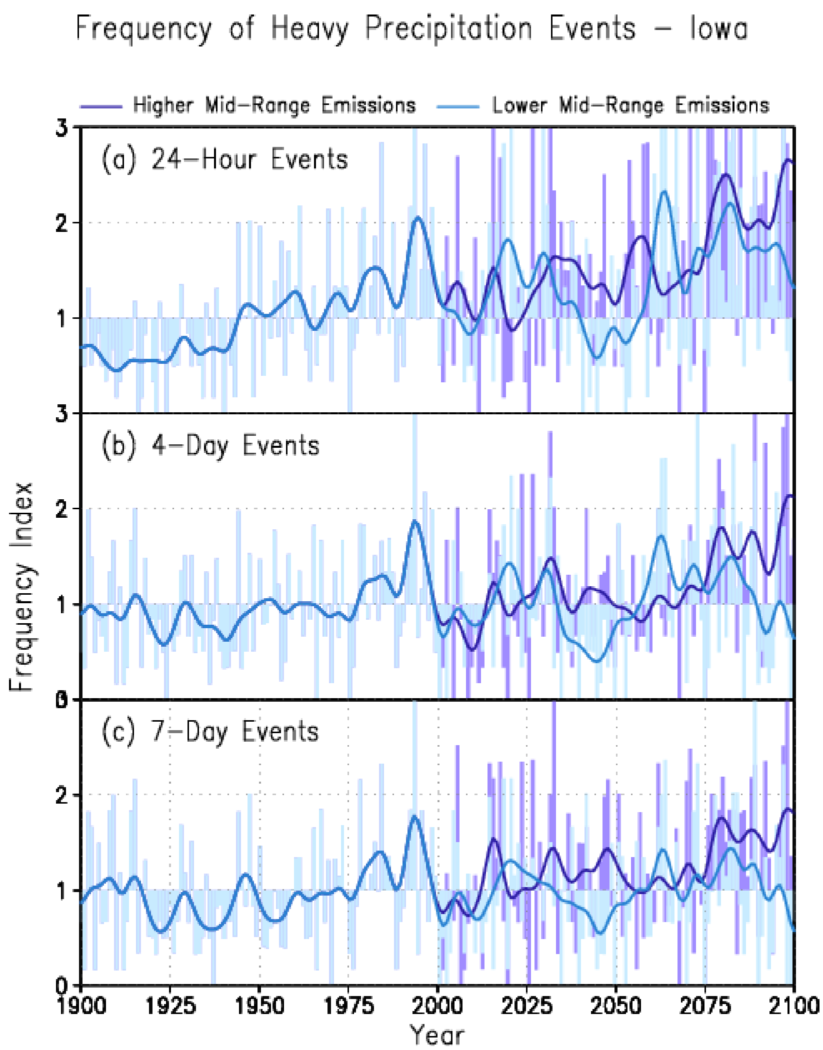


TABLE 3 – CLIMATE SUMMARY

Heat waves & Cold Spells

	By 2025-2030	By 2090-2099
Heatwaves*		
4-day	5 – 6 x more frequent	13 - 23 x more frequent
7-day	4 - 5 x more frequent	10 - 15 x more frequent
10-day	3 – 4 x more frequent	7-10 x more frequent
Cold spells*		
4-day	no significant change	decrease by 50-80%
7-day	no significant change	decrease by 50-80%
10-day	no significant change	decrease by 50-80%

* Based solely on HadCM3 projections for the SRES A2 & B2 (higher & lower mid-range) scenarios due to limitations on available data.

HEAT WAVES

Figure 9. Analysis of historical observed (1900-2000) and HadCM3 mid-range A2 (dark) and B2 (light) projections (2001-2099) shows that the frequency of multi-day heat waves lasting for (a) 4 days, (b) 7 days and (c) 10 days are projected to increase significantly over the next century, reaching levels similar to those observed during the 1930's within a few decades. Frequency of historical events was determined by locating the 101 highest consecutive daily *minimum* temperature occurrences from 1900 to 2000, such that the average was one event per year. In some years, this meant that were no events in certain areas while in other years there could be multiple events. The events were then averaged over Iowa and plotted according to the year in which they occurred. Frequency of future events was determined by counting the number of model-projected events based on model daily precipitation output that lay within the range of the 101 historical events previously located. The model event threshold was then normalized by the difference between modeled vs. observed historical event frequencies, and the number of future events exceeding the normalized threshold calculated. Bars show the yearly averages while the solid lines indicate the 10-year running mean.

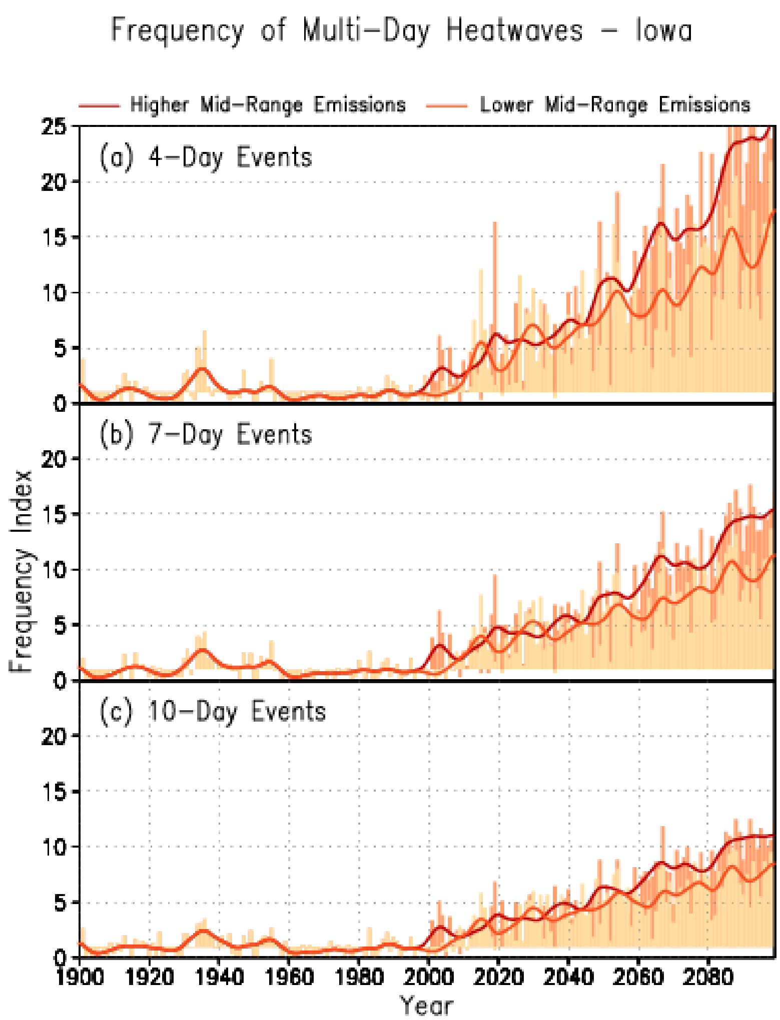
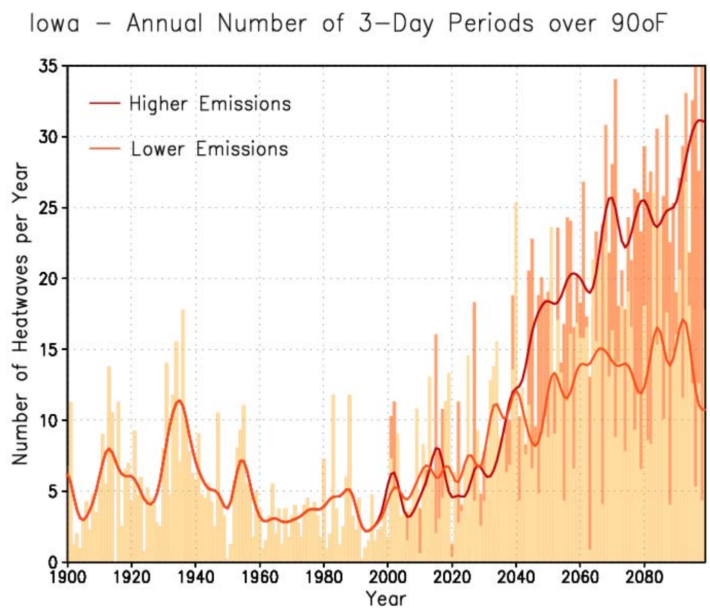


Figure 10. Analysis of the number of 3-day periods that exceeded 90oF for the historical observed (1900-2000) and HadCM3 mid-range A2 (dark) and B2 (light) projections (2001-2099)



COLD SPELLS

Figure 11. Analysis of historical observed (1900-2000) and HadCM3 mid-range A2 (dark) and B2 (light) projections (2001-2099) shows that the frequency of multi-day cold spells lasting for (a) 4 days, (b) 7 days and (c) 10 days are projected to decrease significantly over the next century. Frequency of historical events was determined by locating the 101 highest consecutive daily *maximum* temperature occurrences from 1900 to 2000, such that the average was one event per year. In some years, this meant that were no events in certain areas while in other years there could be multiple events. The events were then averaged over Iowa and plotted according to the year in which they occurred. Frequency of future events was determined by counting the number of model-projected events based on model daily precipitation output that lay within the range of the 101 historical events previously located. The model event threshold was then normalized by the difference between modeled vs. observed historical event frequencies, and the number of future events exceeding the normalized threshold calculated. Bars show the yearly averages while the solid lines indicate the 10-year running mean.