APPENDIX T

Literature Review

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LITERATURE REVIEW

This section briefly describes the results of a review of relevant peer-reviewed literature on climate change effects. This review includes summary descriptions of the literature reviewed, the greenhouse gas emissions scenarios considered and their applicability to the proposed Project, and an overview explanation of the methodological and analytical steps taken by the respective authors to develop climate change projections.

There is a variety of existing sources of downscaled climate research for the states, regions, and in some cases specific areas where the proposed Project would be constructed. The body of research on climate change is evolving in the United States. As part of this assessment, input from regional, state-designated climate experts was solicited to locate the most current and relevant sources. Though many projects are under development including dynamic downscaling,[1] much of that information has not yet been published. There is also a growing number of web-based platforms for generating downscaled climate impacts for user-defined geographies.

The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Intergovernmental Panel on Climate Change (IPCC 2007)

The Intergovernmental Panel on Climate Change (IPCC) predicts global climate change effects using a number of models and GHG scenarios. While uncertainty about the exact magnitude and rates of climate change exists, there is general agreement on expected climate and weather-pattern changes. This report includes the contributions of 676 authors and cites over 6,000 peer-reviewed scientific publications in an effort to present a comprehensive synthesis of predicted climate change.

Global Climate Change Impacts in the U.S., United States Global Change Research Program (USGCRP 2009)

The United States Global Change Research Program (USGCRP) provides downscaled model results for the United States from CMIP3-A (Coupled Model Intercomparison Project) and CMIP3-C. It also provides some general global projections, projections for all of the United States, and projections for some subregions with varying degrees of detail.

Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC 2012)

This report reviews existing studies, multiple global climate models, and multiple regional climate models. Confidence levels are conferred based on the reliability and relative agreement between the sources. In addition, likelihood assessments review the direction of change.

[1] Dynamic downscaling fits output from general circulation models into regional meteorological models. It uses numerical meteorological modeling to project how global patterns affect local weather conditions. This process generally achieves more accurate results, but is very data intensive.

High Resolution Interpolation of Climate Scenarios for the Conterminous USA and Alaska Derived from General Circulation Model Simulations (Joyce et al. 2011)

This report uses statistical downscaling to compare outputs from the following global circulation models for North America:

- CGCM31MR (Canadian Third Generation Coupled Global Climate Model, version 3.1, medium resolution);
- CSIROMK35 (the Commonwealth Scientific and Industrial Research Organisation Mk3.5 Climate Model);
- MIROC32MR (Model for Interdisciplinary Research on Climate, version 3.2, medium resolution); and
- NCARCCSM3 (U.S. National Center for Atmospheric Research Community Climate Model version 3.0).

The data were processed through the ANUSPLIN model to create gridded data for each variable. The report compares the outputs of each model and then averages the results from all the downscaled models. These results are displayed in Table 1. The report examines several subregions: the dry temperate climate region, prairie climate region, continental climate region, and subtropical climate region (see the Supplemental EIS, Figure 4.13.1-2). A summary of the average model outputs for each of the climate regions is presented in Tables 1 to 4.

Table 1 Climate Change Projection Summary for the Dry Temperate Climate Region

Climate Variable	A2 Emissions Scenario					A1B Emissions Scenario					B1 Emissions Scenario				
Mean Daily T_{min} (°C)	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year
Baseline 1980-2009	-1.13	10.30	0.20	-10.59	-0.32	-1.08	10.30	0.21	-10.60	-0.31	-1.14	10.33	0.11	-10.71	-0.36
Change by 2010-2039	0.74	1.20	0.96	0.98	1.00	1.25	1.39	1.08	1.33	1.28	1.04	1.06	1.03	0.99	1.04
Change by 2040-2069	2.27	2.77	2.53	2.59	2.52	2.36	2.81	2.49	2.65	2.58	1.66	1.86	1.89	2.14	1.89
Change by 2070-2099	3.88	4.63	4.16	4.14	4.22	3.07	3.80	3.58	3.62	3.52	2.12	2.46	2.53	2.84	2.49
100-year forcing	4.02	4.91	4.48	4.61	4.51	3.25	4.08	3.91	4.08	3.82	2.26	2.77	2.77	3.20	2.74
100-year variability (%)	1.14	76.08	30.36	0.44	47.74	-6.32	20.16	-14.51	0.17	-1.45	-21.79	7.72	-5.54	-5.79	-9.36
Mean Daily T_{max} (°C)	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year
Baseline 1980-2009	13.90	28.01	16.22	2.39	15.12	13.96	28.00	16.18	2.40	15.12	13.94	28.08	16.05	2.34	15.08
Change by 2010-2039	0.86	1.45	0.86	0.73	1.00	1.42	1.66	1.20	1.02	1.34	1.07	1.26	1.23	0.74	1.09
Change by 2040-2069	2.51	3.06	2.62	2.10	2.56	2.56	3.04	2.56	2.14	2.58	1.70	1.95	1.90	1.65	1.81
Change by 2070-2099	4.31	4.88	4.32	3.50	4.27	3.27	4.12	3.81	3.00	3.56	2.18	2.52	2.71	2.28	2.43
100-year forcing	4.48	5.23	4.73	3.85	4.57	3.51	4.46	4.18	3.36	3.86	2.39	2.94	2.94	2.58	2.70
100-year variability (%)	8.13	38.52	18.37	19.16	44.31	-3.83	5.19	-10.41	23.07	1.43	-13.36	8.34	-12.25	8.52	3.47
Total Precipitation (mm)	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year
Baseline 1980-2009	124	135	91	75	425	124	135	92	75	425	124	135	92	75	425
Change by 2010-2039	4	1	4	3	12	4	-2	2	2	6	6	0	-1	2	7
Change by 2040-2069	7	-2	2	6	12	6	5	4	7	22	10	5	4	6	25
Change by 2070-2099	6	3	3	12	24	10	0	2	11	23	10	6	0	8	24
100-year forcing	7	3	3	13	26	11	1	2	12	25	10	7	1	8	26
100-year variability (%)	10.52	4.74	12.62	13.86	2.72	-8.31	-2.21	5.72	4.77	-7.73	9.32	4.54	-1.26	20.03	7.40
Mean Windspeed (m s^{-1})	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year
Baseline 1980-2009	4.39	3.83	3.70	3.88	3.95	4.36	3.84	3.71	3.85	3.94	4.35	3.87	3.75	3.87	3.96
Change by 2010-2039	0.04	0.02	0.09	-0.01	0.04	-0.15	0.08	0.09	0.01	0.02	-0.14	0.03	0.02	-0.07	-0.03
Change by 2040-2069	0.01	0.13	0.06	0.02	0.05	-0.09	0.02	0.11	-0.02	0.01	-0.06	-0.06	0.02	0.03	-0.02
Change by 2070-2099	-0.01	0.20	0.07	-0.05	0.05	0.00	-0.01	0.06	0.03	0.03	-0.18	-0.07	-0.02	-0.02	-0.07
100-year forcing	0.02	0.19	0.04	-0.03	0.05	0.00	-0.01	0.05	0.02	0.02	-0.19	-0.03	0.01	-0.01	-0.06
100-year variability (%)	0.42	36.79	-18.66	-5.85	-16.26	-8.78	6.47	-22.23	-8.06	-20.87	5.37	9.38	-11.43	-3.67	-2.17

Source: Joyce et al. 2011.

Mean Daily Tmin (˚C) = the average minimum temperature each day. ˚C = degrees Celsius.

Mean Daily Tmax (˚C) = the average maximum temperature each day.
Change = average net change for the 30-year mean relative to the 1980-2009 baseline.
100-year forcing = the 100-year forcing is the changes in the means (for temperature and precipitation) of 1970-1999 and 2070-2099. This is the projected change in climate over 100 years.
100-year variability (%) = the change in the 30-year standard deviations relative to a 1970-1999 baseline.

Table 2 Climate Change Projection Summary for the Prairie Climate Region

Climate Variable	A2 Emissions Scenario					A1B Emissions Scenario					B1 Emissions Scenario				
Mean Daily T_{min} (°C)	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year
Baseline 1980-2009	6.22	18.13	7.53	-6.28	6.38	6.25	18.27	7.55	-6.36	6.42	6.29	18.30	7.53	-6.27	6.44
Change by 2010-2039	0.87	1.22	1.12	0.96	1.06	1.14	1.36	1.31	1.32	1.30	0.69	1.05	1.07	0.76	0.91
Change by 2040-2069	2.17	2.68	2.77	2.34	2.48	2.27	2.54	2.65	2.50	2.49	1.50	1.63	1.90	1.80	1.72
Change by 2070-2099	3.66	4.57	4.55	3.89	4.18	2.98	3.49	3.62	3.55	3.41	1.80	2.21	2.40	2.40	2.21
100-year forcing	3.80	4.78	4.91	4.38	4.46	3.17	3.83	4.00	3.96	3.73	2.02	2.59	2.76	2.90	2.55
100-year variability (%)	27.94	34.75	35.07	-7.48	36.13	-6.49	13.35	1.76	-8.01	-5.36	1.08	-2.32	10.48	-14.87	-9.71
Mean Daily T_{max} (°C)	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year
Baseline 1980-2009	18.92	30.95	20.34	5.09	18.81	18.98	31.20	20.37	5.04	18.89	19.04	31.28	20.26	5.09	18.90
Change by 2010-2039	1.00	1.50	1.22	0.82	1.15	1.14	1.52	1.55	1.16	1.36	0.74	1.17	1.35	0.66	1.00
Change by 2040-2069	2.22	2.91	2.92	2.21	2.56	2.43	2.61	2.76	2.45	2.56	1.45	1.48	2.20	1.72	1.73
Change by 2070-2099	3.90	4.79	4.71	3.85	4.33	3.19	3.60	3.88	3.49	3.54	1.82	2.17	2.77	2.31	2.27
100-year forcing	4.04	4.91	5.07	4.24	4.56	3.39	3.97	4.28	3.82	3.85	2.07	2.61	3.05	2.69	2.59
100-year variability (%)	15.26	20.78	27.28	14.83	39.52	-5.79	6.84	1.28	11.84	3.29	0.81	1.86	7.11	3.47	4.46
Total Precipitation (mm)	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year
Baseline 1980-2009	261	284	228	120	891	258	273	228	121	881	260	271	231	120	881
Change by 2010-2039	3	-6	5	1	4	10	-4	-3	2	5	12	-3	-9	-1	1
Change by 2040-2069	21	-13	8	-3	15	13	10	4	-7	20	22	24	-1	0	46
Change by 2070-2099	9	-5	9	0	14	25	15	3	-1	42	23	17	-7	-2	33
100-year forcing	15	7	9	2	33	28	17	4	2	50	28	17	-3	0	42
100-year variability (%)	-2.42	10.70	5.68	12.84	2.53	0.93	15.03	-1.33	13.92	-10.87	4.57	8.35	-6.56	3.75	4.10
Mean Windspeed ($m\ s^{-1}$)	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year
Baseline 1980-2009	4.75	3.85	4.06	4.53	4.30	4.71	3.86	4.10	4.53	4.29	4.72	3.84	4.11	4.56	4.30
Change by 2010-2039	0.27	0.03	0.17	0.07	0.13	0.08	0.17	0.00	0.05	0.08	0.05	0.12	0.07	-0.05	0.05
Change by 2040-2069	0.34	0.17	0.14	0.18	0.20	0.23	0.14	0.19	0.10	0.17	0.18	0.11	0.07	0.12	0.13
Change by 2070-2099	0.55	0.38	0.32	0.20	0.37	0.29	0.15	0.18	0.07	0.18	0.11	0.21	-0.03	0.04	0.08
100-year forcing	0.58	0.41	0.34	0.23	0.39	0.27	0.19	0.23	0.11	0.20	0.10	0.23	0.03	0.10	0.11
100-year variability (%)	4.48	17.44	8.04	5.69	5.12	-11.18	12.89	-0.38	-4.47	-11.19	2.24	21.88	13.55	-0.45	9.81

Source: Joyce et al. 2011.

Mean Daily Tmin (˚C) = the average minimum temperature each day. ˚C = degrees Celsius.
Mean Daily Tmax (˚C) = the average maximum temperature each day.
Change = average net change for the 30-year mean relative to the 1980-2009 baseline.
100-year forcing = the 100-year forcing is the changes in the means (for temperature and precipitation) of 1970-1999 and 2070-2099. This is the projected change in climate over 100 years.
100-year variability (%) = the change in the 30-year standard deviations relative to a 1970-1999 baseline.

Table 3 Climate Change Projection Summary for the Continental Climate Region

Climate Variable	A2 Emissions Scenario					A1B Emissions Scenario					B1 Emissions Scenario				
Mean Daily T_{min} (°C)	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year
Baseline 1980-2009	2.75	14.80	5.11	-8.45	3.54	2.79	14.89	5.12	-8.50	3.56	2.91	14.89	5.18	-8.32	3.64
Change by 2010-2039	1.00	1.08	1.16	1.10	1.10	1.13	1.18	1.31	1.43	1.28	0.61	0.93	0.91	0.74	0.82
Change by 2040-2069	2.34	2.54	2.63	2.63	2.52	2.40	2.45	2.60	2.76	2.55	1.67	1.64	1.78	1.92	1.77
Change by 2070-2099	3.87	4.29	4.35	4.28	4.21	3.23	3.29	3.39	3.91	3.46	1.99	2.20	2.21	2.39	2.21
100-year forcing	4.07	4.50	4.67	4.71	4.48	3.48	3.60	3.72	4.29	3.76	2.35	2.50	2.60	2.95	2.59
100-year variability (%)	17.22	17.80	25.65	-6.08	26.31	-17.73	-10.29	4.27	-10.09	-7.63	-11.76	-21.56	6.12	-15.03	-15.21
Mean Daily T_{max} (°C)	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year
Baseline 1980-2009	15.51	27.60	17.15	2.21	15.60	15.55	27.78	17.18	2.16	15.66	15.68	27.83	17.21	2.31	15.74
Change by 2010-2039	1.06	1.17	1.16	0.77	1.05	1.14	1.24	1.41	1.07	1.23	0.68	1.01	1.06	0.44	0.82
Change by 2040-2069	2.36	2.80	2.80	2.13	2.52	2.49	2.51	2.65	2.24	2.47	1.59	1.46	1.84	1.53	1.62
Change by 2070-2099	4.01	4.55	4.50	3.69	4.20	3.25	3.39	3.49	3.34	3.37	1.94	2.23	2.39	1.99	2.15
100-year forcing	4.21	4.65	4.85	3.99	4.41	3.49	3.67	3.86	3.59	3.64	2.30	2.56	2.79	2.39	2.50
100-year variability (%)	23.32	13.30	30.83	20.34	40.54	-11.59	1.92	5.01	10.74	5.43	2.18	-5.47	4.24	2.37	-1.64
Total Precipitation (mm)	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year
Baseline 1980-2009	288	311	252	203	1054	289	304	253	204	1050	287	300	254	203	1044
Change by 2010-2039	9	-1	6	5	17	11	3	7	3	26	7	1	-1	2	12
Change by 2040-2069	18	-11	4	16	28	11	7	8	8	35	23	23	11	8	65
Change by 2070-2099	18	-5	18	23	55	28	10	6	23	70	29	10	2	15	58
100-year forcing	25	7	18	24	74	36	16	8	25	85	35	12	5	15	67
100-year variability (%)	15.89	4.81	17.79	27.27	19.52	0.60	-2.87	0.24	34.85	-3.04	5.66	-6.56	-3.41	23.17	1.56
Mean Windspeed (m s^{-1})	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year
Baseline 1980-2009	4.07	3.15	3.52	4.15	3.72	4.04	3.20	3.54	4.15	3.73	4.05	3.13	3.55	4.19	3.73
Change by 2010-2039	0.24	-0.06	0.01	0.14	0.08	0.00	0.02	-0.07	0.11	0.02	0.00	-0.02	-0.06	-0.05	-0.03
Change by 2040-2069	0.23	0.01	-0.02	0.26	0.13	0.14	-0.07	-0.06	0.11	0.04	0.12	0.02	-0.03	0.11	0.06
Change by 2070-2099	0.41	0.01	-0.01	0.28	0.18	0.23	-0.05	-0.05	0.13	0.07	0.05	0.02	-0.10	0.09	0.02
100-year forcing	0.44	0.00	0.01	0.33	0.19	0.23	0.00	-0.01	0.20	0.10	0.06	0.00	-0.04	0.18	0.05
100-year variability (%)	5.64	-8.38	23.57	5.51	-0.24	-1.18	-2.16	8.19	2.38	-6.17	-0.12	-1.59	14.14	6.17	5.96

Source: Joyce et al. 2011.

Mean Daily Tmin (˚C) = the average minimum temperature each day. ˚C = degrees Celsius.
Mean Daily Tmax (˚C) = the average maximum temperature each day.
Change = average net change for the 30-year mean relative to the 1980-2009 baseline.
100-year forcing = the 100-year forcing is the changes in the means (for temperature and precipitation) of 1970-1999 and 2070-2099. This is the projected change in climate over 100 years.
100-year variability (%) = the change in the 30-year standard deviations relative to a 1970-1999 baseline.

Table 4 Climate Change Projection Summary for the Subtropical Climate Region

Climate Variable	A2 Emissions Scenario					A1B Emissions Scenario					B1 Emissions Scenario				
Mean Daily T_{min} (°C)	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year
Baseline 1980-2009	11.06	20.39	12.18	2.30	11.47	11.11	20.46	12.20	2.23	11.49	11.10	20.47	12.21	2.30	11.51
Change by 2010-2039	0.89	1.05	1.06	0.57	0.90	0.99	1.05	1.28	0.81	1.04	0.64	0.92	0.93	0.38	0.74
Change by 2040-2069	2.01	2.31	2.47	1.51	2.08	1.95	2.21	2.39	1.57	2.03	1.49	1.45	1.73	1.05	1.44
Change by 2070-2099	3.23	3.92	4.15	2.74	3.52	2.73	3.04	3.15	2.53	2.87	1.79	1.97	2.14	1.43	1.85
100-year forcing	3.39	4.10	4.44	3.00	3.73	2.95	3.29	3.46	2.73	3.10	1.99	2.24	2.47	1.70	2.10
100-year variability (%)	22.75	36.98	32.24	26.36	53.39	-1.67	2.43	7.16	3.85	9.85	4.22	-0.45	11.09	-0.13	3.11
Mean Daily T_{max} (°C)	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year
Baseline 1980-2009	24.49	32.39	25.32	14.77	24.23	24.58	32.56	25.40	14.71	24.31	24.61	32.64	25.43	14.77	24.35
Change by 2010-2039	0.97	1.20	1.06	0.54	0.95	0.96	1.06	1.20	0.69	0.98	0.57	0.99	0.89	0.33	0.71
Change by 2040-2069	2.06	2.72	2.51	1.51	2.20	2.06	2.32	2.30	1.62	2.07	1.32	1.26	1.57	1.06	1.31
Change by 2070-2099	3.40	4.42	4.16	2.85	3.72	2.68	3.22	3.17	2.58	2.91	1.65	1.92	2.13	1.50	1.81
100-year forcing	3.55	4.47	4.42	3.07	3.87	2.91	3.43	3.51	2.74	3.14	1.91	2.22	2.50	1.72	2.08
100-year variability (%)	20.75	9.47	37.75	15.99	37.14	-5.84	-2.47	7.12	1.34	-3.13	8.53	8.96	8.86	-3.31	6.17
Total Precipitation (mm)	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year
Baseline 1980-2009	354	376	287	334	1351	346	368	281	335	1329	347	363	280	334	1324
Change by 2010-2039	-16	-17	6	-3	-28	-4	-11	20	-5	2	10	-10	8	-8	4
Change by 2040-2069	-10	-44	5	-2	-49	-3	-16	12	-13	-20	16	10	20	-2	45
Change by 2070-2099	-13	-51	6	-28	-84	26	-13	5	-10	11	26	-7	17	-5	33
100-year forcing	-1	-42	8	-26	-61	30	-12	1	-7	13	30	-11	12	-4	29
100-year variability (%)	12.34	-16.95	-5.07	7.01	-3.34	1.82	-6.78	3.28	16.61	-13.07	22.02	2.78	1.17	19.33	-0.66
Mean Windspeed (m s^{-1})	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year	Spring	Summer	Fall	Winter	Year
Baseline 1980-2009	3.74	2.77	3.11	3.68	3.33	3.74	2.79	3.11	3.68	3.33	3.78	2.78	3.11	3.69	3.34
Change by 2010-2039	0.13	0.06	0.03	0.01	0.06	0.08	0.05	-0.02	-0.05	0.02	-0.10	0.04	0.00	-0.04	-0.02
Change by 2040-2069	0.17	0.13	0.07	0.02	0.09	0.11	0.09	0.07	0.05	0.08	0.07	0.12	-0.04	0.08	0.06
Change by 2070-2099	0.26	0.24	0.10	0.13	0.18	0.09	0.12	0.01	0.02	0.06	-0.01	0.09	-0.02	0.05	0.03
100-year forcing	0.27	0.24	0.15	0.19	0.21	0.11	0.14	0.06	0.09	0.10	0.05	0.10	0.03	0.13	0.08
100-year variability (%)	-6.32	-20.45	1.09	-2.86	-27.61	-8.37	-11.92	6.57	-3.94	-14.94	-2.69	4.19	5.37	-5.46	-20.64

Source: Joyce et al. 2011.

Mean Daily Tmin (˚C) = the average minimum temperature each day. ˚C = degrees Celsius.
Mean Daily Tmax (˚C) = the average maximum temperature each day.
Change = average net change for the 30-year mean relative to the 1980-2009 baseline.
100-year forcing = the 100-year forcing is the changes in the means (for temperature and precipitation) of 1970-1999 and 2070-2099. This is the projected change in climate over 100 years.
100-year variability (%) = the change in the 30-year standard deviations relative to a 1970-1999 baseline.

West-Wide Climate Risk Assessments: Bias-Corrected and Spatially Downscaled Surface Water Projections, United States Bureau of Reclamation (USBR 2011a and 2011b)

Sixteen global circulation models formed the basis of the climate projections used in this study. The study uses a downscaling technique known as the Bias Correction and Spatial Disaggregation approach, developed by Wood in 2002, to apply the CLIP3 projections at a watershed scale. This was done for the B1 (low), A1B (medium), and A2 (high) scenarios. This provided information on the extremes with lower probability but higher risk. The results focused on the Missouri watershed, which includes parts of the states of Montana, North Dakota, South Dakota, Nebraska, and Kansas.

CLIMATE MODELING

SCENARIOS

Current climate modeling to project future climate change effects uses scenarios of GHG emissions levels in the atmosphere. The IPCC created a number of scenarios for GHG emissions; these are dependent on assumptions regarding population and economic growth, as well as technology for fuel use and fuel production. These determine the degree and severity of predicted climate change effects. The four scenarios selected for this analysis in the 2007 IPCC report are described as follows:

- The A2 scenario is a heterogeneous world with high population growth rates and slow rates of economic development and technological innovation.
- The A1B scenario assumes rapid economic growth, and a world population that peaks around 2050. Technological innovation and adoption of energy-efficient technologies is balanced and does not rely on any one energy source.
- The A1F1 scenario assumes rapid economic growth, and a world population that peaks around 2050. Technological innovation and adoption of energy-efficient technologies is fossil intensive.
- The B1 scenario assumes very rapid economic growth, a world population that peaks around 2050, and a very fast innovation and adoption of energy-efficient technologies. The economy makes rapid changes toward services and information.

The IPCC has not assigned probabilities to any of these scenarios, but instead provides them for use in models to examine the entire range of possibilities and evaluate consequences based on the greenhouse gas emissions implicit in these combinations of population, economic activity, and technological innovation. The A2, A1B, and B1scenarios (Figure 4.13.1-1) were analyzed in various models presented in the studies reviewed. In the Fifth Assessment Report (expected in approximately 2014), the IPCC plans to provide a greater range of emissions scenarios.

GLOBAL CIRCULATION MODELS

Global Circulation Models are still in the domain of active research and are therefore the subject of further investigation and improvement themselves. Consequently, such models may vary in spatial and temporal resolution, the numerical methods employed to solve sets of coupled differential equations, the initial conditions, and sub-grid-cell parameterization of processes that are too small-scale for explicit numerical treatment.

DOWNSCALING

Climate change studies are based on global models that are downscaled for regional application. The global model results for temperature, precipitation, solar gain, and wind are disaggregated for the scale of interest and then refined based on topographical features and historical trends. The scale of interest for the downscaling determines the level of detail available from the study.

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