Use of NARCCAP Model Projections to Develop a Future Typical Meteorological Year and Estimate the Impact of a Changing Climate on Building Energy Consumption (GC13C-1104)

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Introduction

Typical climate conditions for the 20th Century may not provide adequate design parameters for the built environment of the 21st Century due to a rapidly changing climate. The conventional practice in the engineering community for incorporating climate data into building design is to use the "Typical Meteorological Year" (TMY), a site-specific database of typical hourly values of climate developed by Wilcox and Marion based on observed conditions from the National Solar Radiation Data Base and meteorological data for 1976-2005 from NCDC. This TMY database enjoys wide use in building design and alternative energy applications. We propose an alternative method that uses regional climate models under the North American Regional Climate Change Assessment Program (NARCCAP) to produce scenarios of future typical meteorological years for the middle of the 21st Century.

Data and Methodology

We first assessed whether the TMY data for our selected sites are indeed "typical" compared to observations. We computed monthly and hourly averages of each variable using the current TMY3 data set and compared them to the 1976 to 2005 base period of observations using NCDC data. *(Results not shown revealed that the differences were generally small – less than the monthly standard deviation in all months and all variables except relative humidity, pressure, and precipitation).*

Next we used reanalysis-driven runs of five NARCCAP regional climate models to evaluate their skill in reproducing TMY3 data. Data were compared through both monthly and 3-hourly averages. Comparing data in this way clearly shows the bias structure for each model.

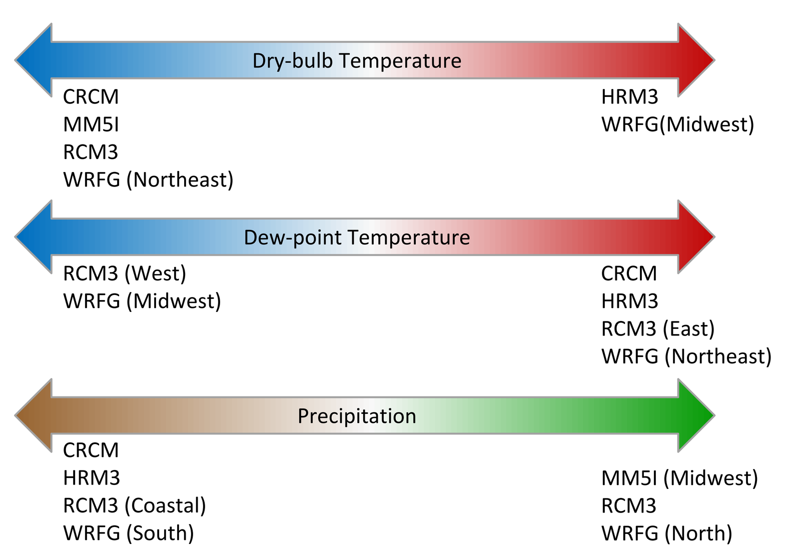

Figure 1: Average NARCCAP model biases for three selected variables.

We then used NARCCAP data to evaluate monthly climate change in nine meteorological variables used in building design. We examined nine different locations selected to represent a majority of the 16 different climate zones used in the creation of the U.S. Department of Energy (DOE) reference buildings

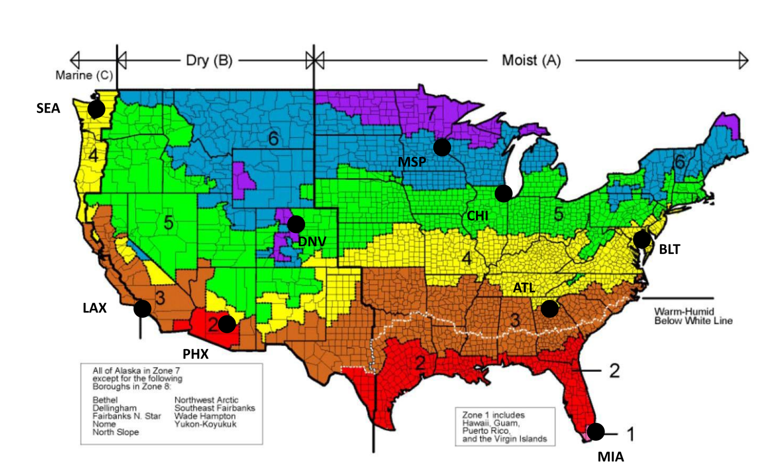

Figure 2: Locations selected for this study, shown on a climate zone classification map created by the DOE (Briggs et al. 2003)

Results

Model Projected Change

City	Totcld tens	Dry-bulb °C	Dew-point °C	Rhum %	Ahum g cm^{-3}	Pressure mbar	Wspd m s^{-1}	Wdir deg	Precip mm
Atlanta, GA	-0.21	2.30	1.88	-1.21	1.29	0.33	-0.05	-0.98	11.47
Baltimore, MD	-0.14	2.46	2.14	-0.77	1.25	0.27	-0.06	-5.85	3.75
Chicago, IL	-0.06	2.65	2.30	-0.70	1.06	0.23	-0.05	-3.88	22.50
Denver, CO	-0.05	2.67	1.77	-1.85	0.63	1.26	-0.10	-1.02	-37.45
Los Angeles, CA	0.04	1.89	1.82	0.10	1.08	0.09	-0.07	-5.63	-5.08
Miami, FL	-0.38	1.92	1.64	-0.92	1.71	0.27	0.02	-1.96	-129.56
Minneapolis, MN	-0.04	2.63	2.49	-0.02	1.02	0.28	-0.03	-5.02	28.72
Phoenix, AZ	-0.03	2.45	1.46	-2.09	0.67	0.40	-0.06	2.47	-51.03
Seattle, WA	-0.07	1.91	1.80	-0.11	0.83	0.42	-0.07	0.94	2.55

➡ Increasing temperatures from 1.5°C to 3.0°C

➡ Decreasing cloud cover, relative humidity and wind speed

Table 1: Annual average model projected changes for each location. These changes represent an average of all the available RCM-GCM combinations available in the NARCCAP dataset. Four global climate models (GCMs) and five regional climate models (RCMs) were used.

Global climate models used include the Community Climate System Model (CCSM), the Third Generation Coupled Global Climate Model (CGCM3), the Hadley Centre Coupled Model version 3 (HadCM3), and the Geophysical Fluid Dynamics Laboratory GCM (GFDL). Regional climate models used include the Canadian Regional Climate Model (CRCM), the Hadley Regional Model 3 (HRM3), the PSU/NCAR Mesoscale Model (MM5I), the Regional Climate Model version 3 (RCM3), and the Weather Research & Forecasting Model (WRFG).

Significance

Value	Totcld tens	Dry-bulb °C	Dew-point °C	Rhum %	Ahum g cm^{-3}	Pressure mbar	Wspd m s^{-1}	Wdir deg	Precip mm
Projected Change	-0.06	2.65	2.30	-0.70	1.06	0.23	-0.05	-3.88	22.50
SD of Model Change	0.11	0.47	0.39	2.00	0.24	0.53	0.08	1.98	51.31
SD of 20th C Obs	0.31	0.89	1.00	2.82	0.42	0.59	0.34	14.69	261.92

Table 2: Average annual projected changes for Chicago, IL, standard deviation between the available model combinations, and the standard deviation of 20th Century observations. Significance is shown (in red) for variables whose model projected change is greater than both the inter-model and inter-annual standard deviation.

Seasonal Changes

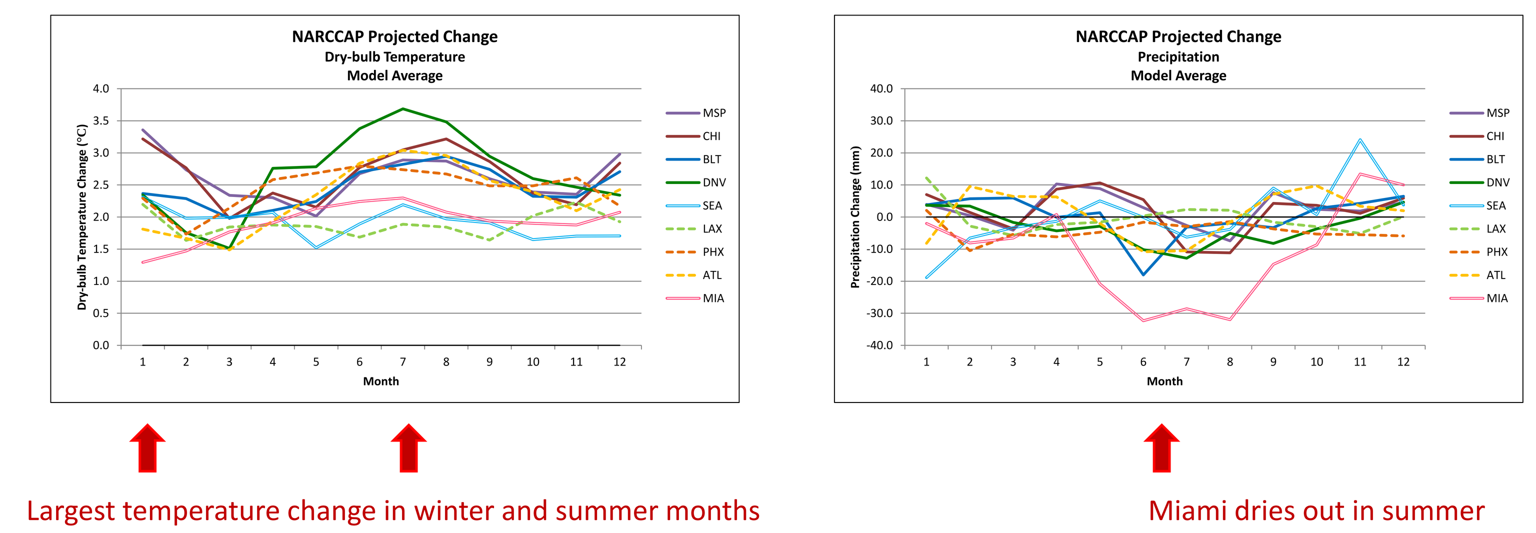

Figure 3: An example of seasonal projected model change in dry-bulb temperature and precipitation for each location. These seasonal patterns represent an average of all available model combinations.

Impact on Building Energy Consumption

We used a selection of the 16 commercial reference buildings created by the U.S. Department of Energy (DOE) to evaluate the impact of projected changes in climate on building energy consumption. Future TMY data files were constructed by adding the model projected changes to the existing TMY data files, at an hourly level. We used the energy performance software EnergyPlus to run simulations using first the original TMY data files and then the future TMY data files we created. We calculated the differences between these two simulations to show the impact of projected climate change on the energy consumption of medium office, secondary school, and stand-alone retail building types.

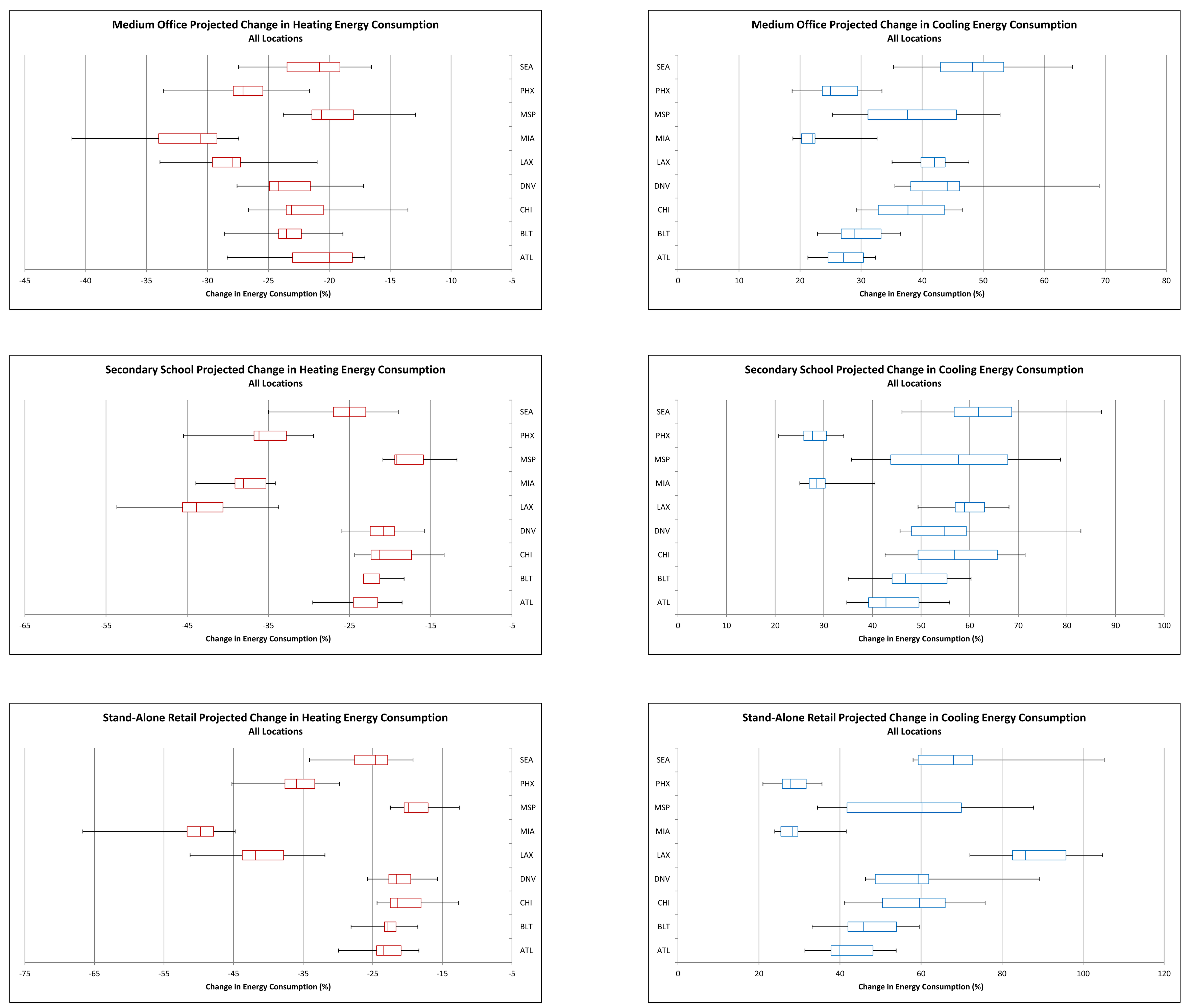

Figure 4: Percentage change in heating and cooling energy consumption for each location. The range and average of the NARCCAP model combinations used in this study are represented by the box and whisker plots.

Conclusions

- TMY3 data is representative of (except for relative humidity, pressure, and precipitation) the 30-year observed conditions.
- While each model and variable has its own unique bias, the NARCCAP models are generally able to reproduce the TMY3 data.
- The NARCCAP models produce significant changes in dry-bulb temperature, dew-point temperature, and absolute humidity.
- Additional significant changes in climate variables occur when examining model projections on seasonal and diurnal levels.
- Heating energy consumption is expected to decrease; cooling energy consumption is expected to increase.
- Total annual energy consumption may increase, decrease, or remain steady depending on the balance between heating and cooling
- With different systems and sources for heating and cooling, the costs of changing energy consumption or the costs of installing adequate systems likely will not balance.
- For those regions having significant changes in energy consumption and patterns, future typical meteorological year data can be prepared for risk analysis of a changing climate

References

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