The Potential Impact of Climate Change on Building Energy Use in California and the US

Joe Huang

White Box Technologies

Moraga CA

SimBuild 2008

Berkeley CA

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What these studies are:

- Computer analyses of the effect of climate change on the HVAC energy use in the residential and commercial building stock in the US and California using simulations of prototypical buildings with modified weather files.

What these studies are not:

- no attempt to model or forecast any changes in the building stock, operations, or occupant behavior, i.e., these are NOT projections of future building energy use, only studies of the effect of climate change on building energy use, while holding everything else constant.

Work was done for two separate LBNL projects

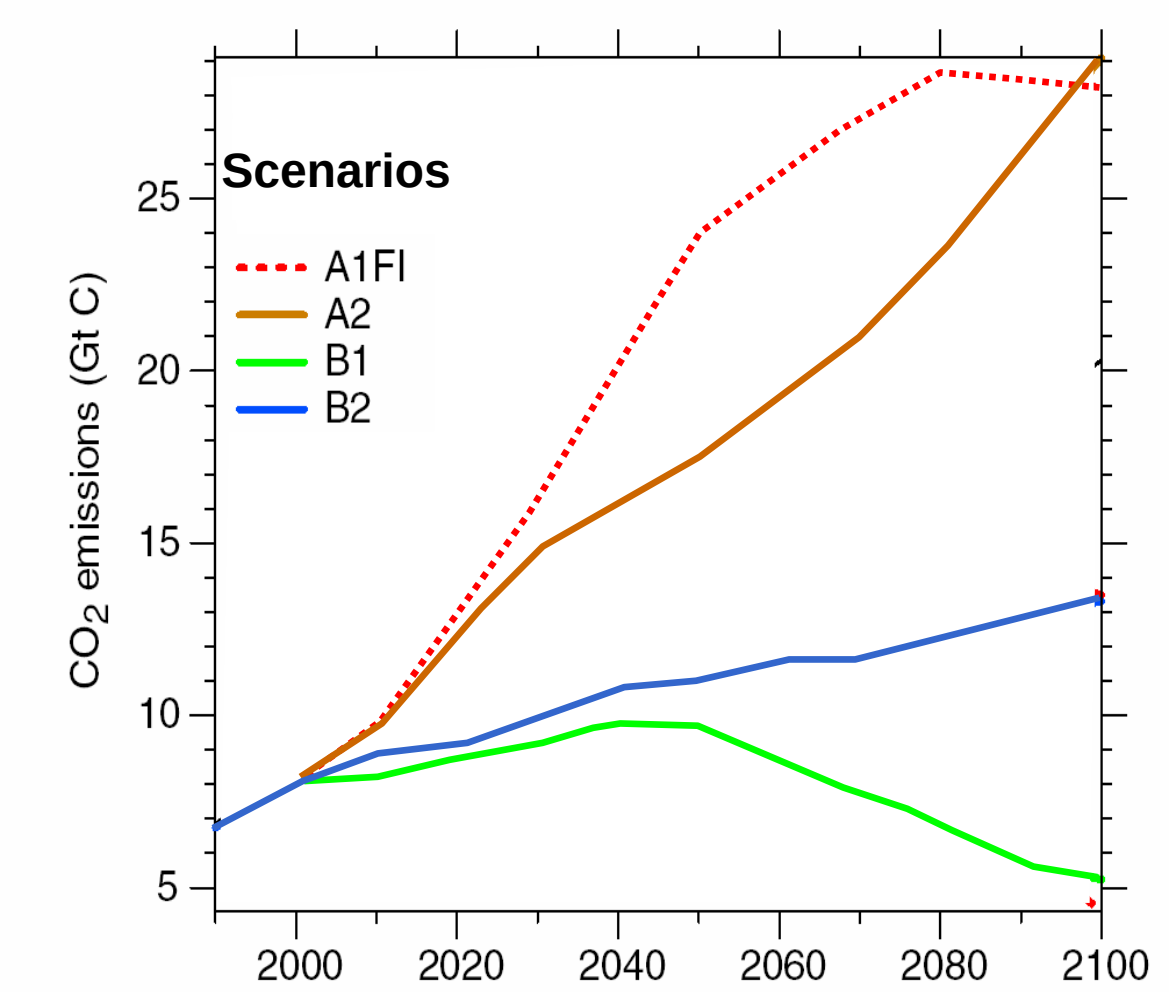
- ***Effects of climate change on energy production and use in the United States,*** multi-lab effort from 2005 through 2007 funded by DOE's US Climate Change Science Program, resulted in the *Synthesis and Assessment Product (SAP)4.5*, first draft Nov. 2006, second draft Mar. 2007
- ***Effects of global climate change on building energy consumption and its implications on building energy codes and policy in California***, funded by the CEC's Public Interest Energy Research (PIER) program 2007-2008, final report due July 2008 (!).

Scope of studies

Both projects used similar methodologies to estimate the impact of global climate change on bldg energy use in the US and California.

- **Obtained projected climate changes for various locations from Global Circulation Models (GCMs), either directly as in the SAP study for 18 US locations, or using downscaling techniques as just described by Norm Miller in the PIER project for 63 California locations.**
- **These projected changes are categorized as perturbations in monthly averages and daily ranges of temperature, humidity, and solar radiation for standard IPCC scenarios extending out to 2100.**
- **These perturbations are mapped on top of typical year weather files for different locations.**
- **Simulations are done using prototypical residential and commercial buildings (commercial only for the PIER project) to calculate the differences in heating and cooling energy use due to this projected climate change.**
- **The simulation results are multiplied by the floor areas represented by each prototypical building to calculate the net impact on energy use by building type, vintage, and time period.**

Climate Change Scenarios Defined by the IPCC WG III



A1FI rapid economic and pop. growth, fossil intensive energy sources, CO_2 conc. 970ppm

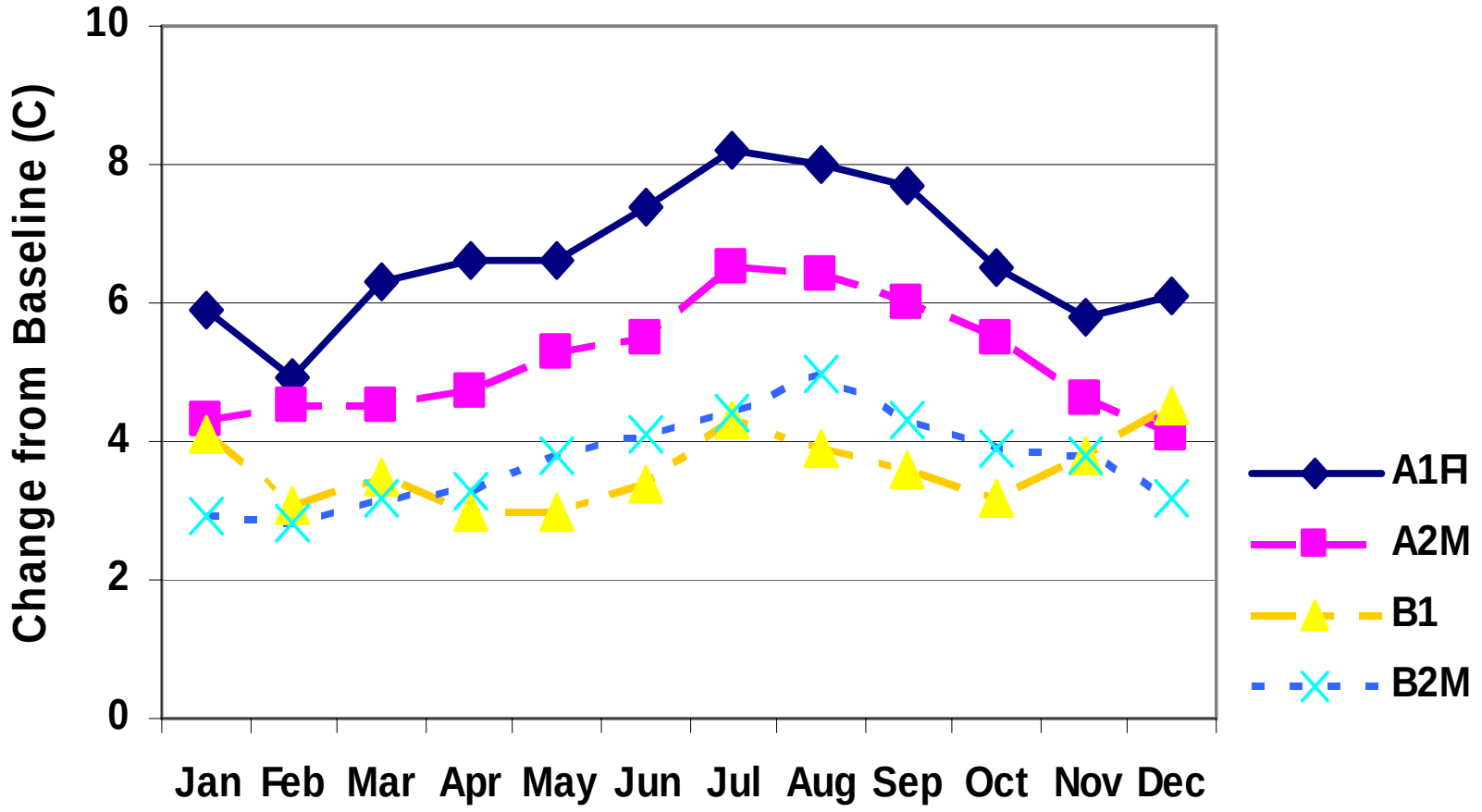
A2 continuous population growth, fragmented economic growth, CO_2 conc. 830ppm

B1 population peaks in mid-21st century, economic change towards service & information technologies and use of clean resource-efficient technologies, CO_2 conc. 550ppm

B2 local solutions to econo-mic, social and environmental sustainability; intermediate population and economic development, CO_2 conc. 600ppm

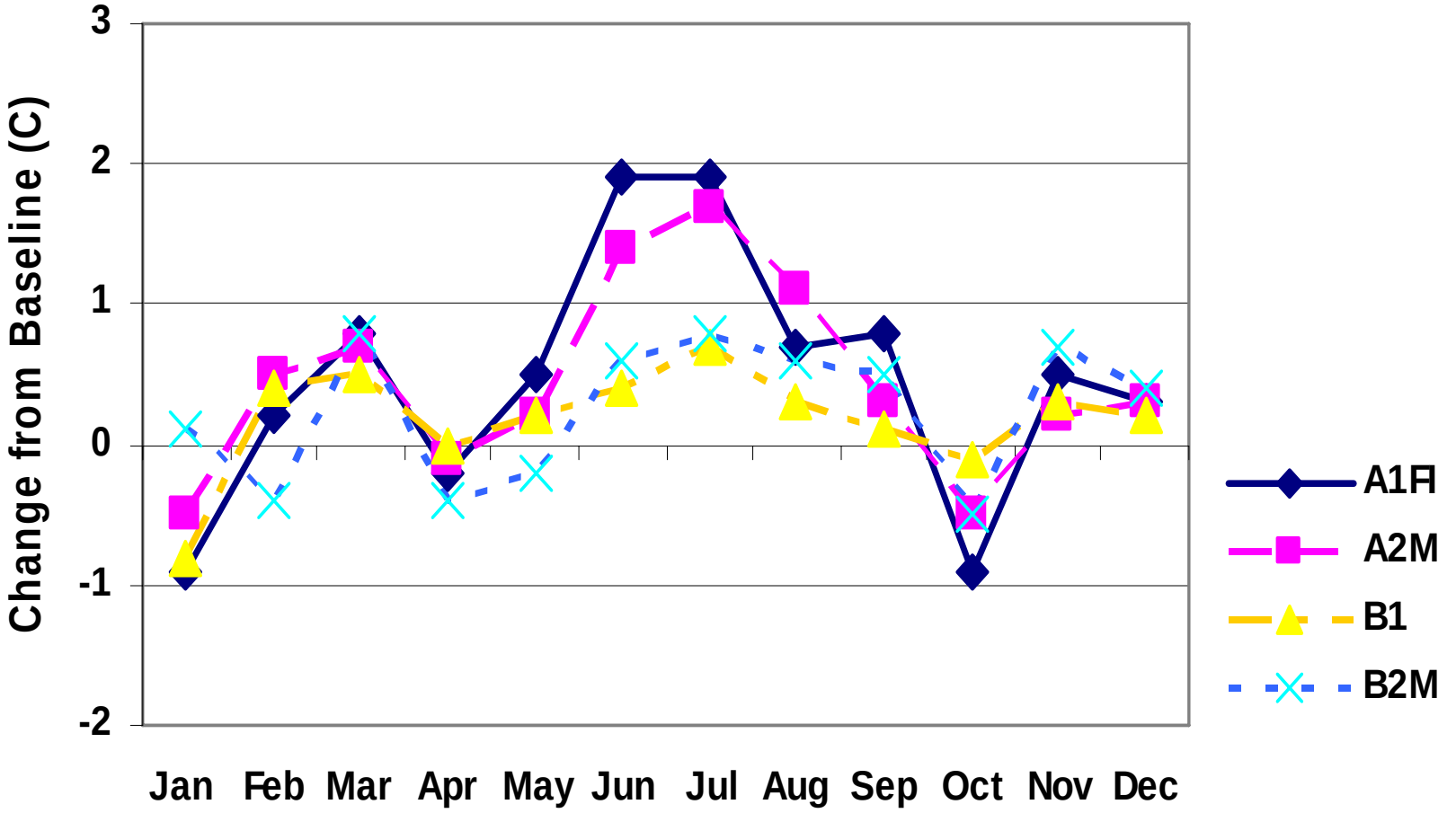
Predicted Changes in Monthly Average Temperature in Washington DC in 2080

(SAP study)



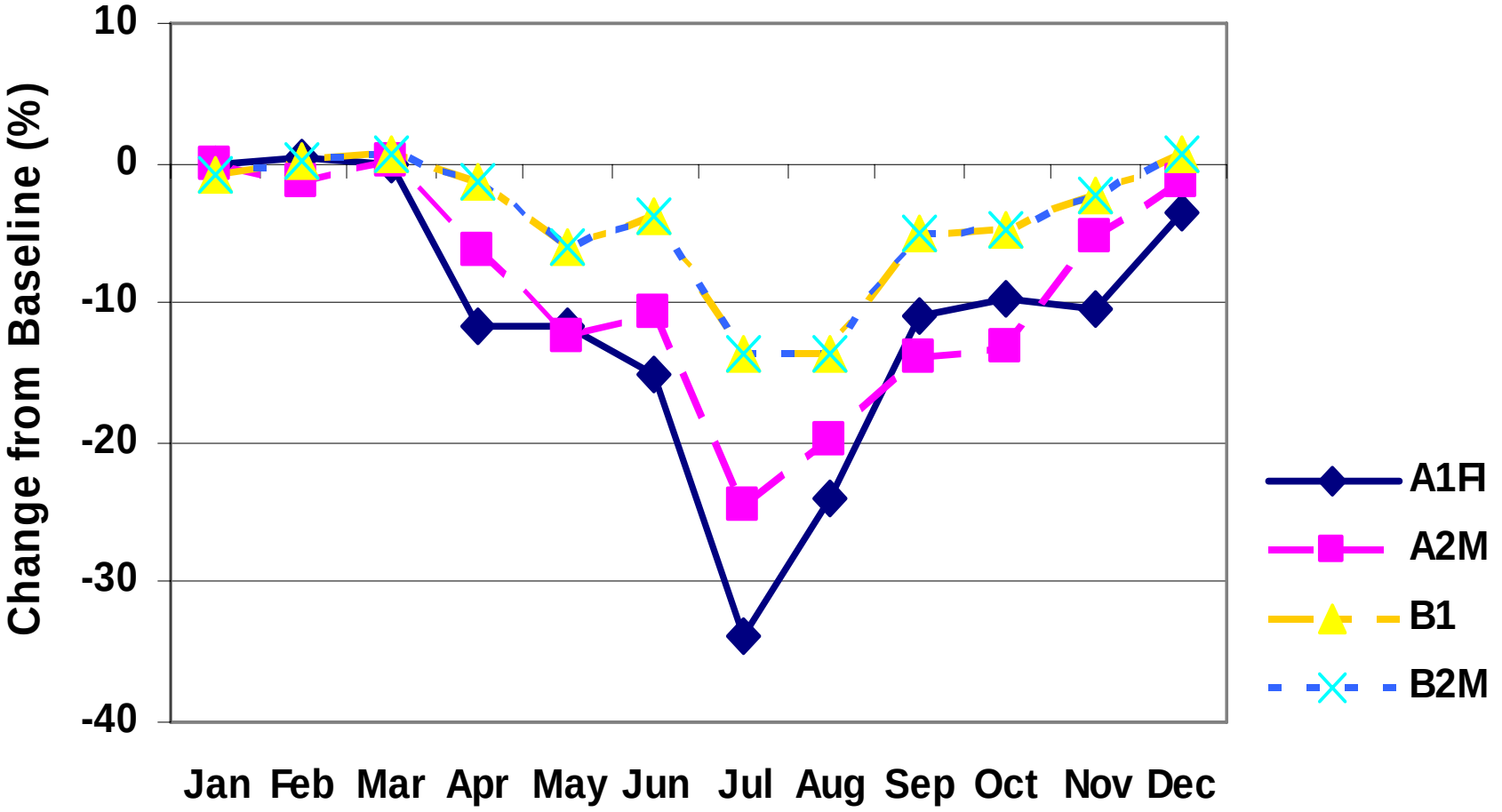
Predicted Changes in Monthly Diurnal Temperature Range in Washington 2080

(SAP study)



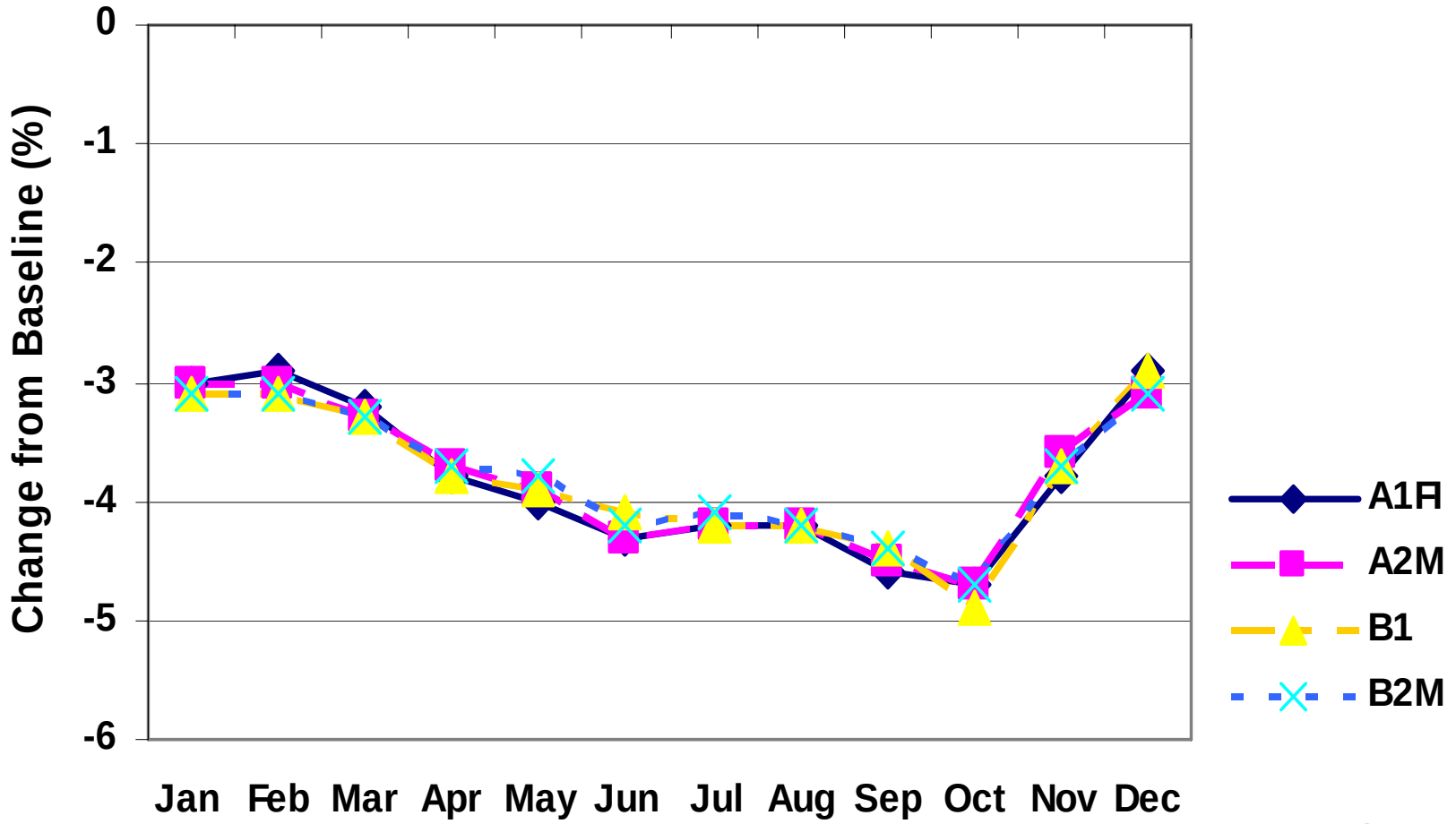
Predicted Changes in Monthly Average Relative Humidity in Washington 2080

(SAP study)

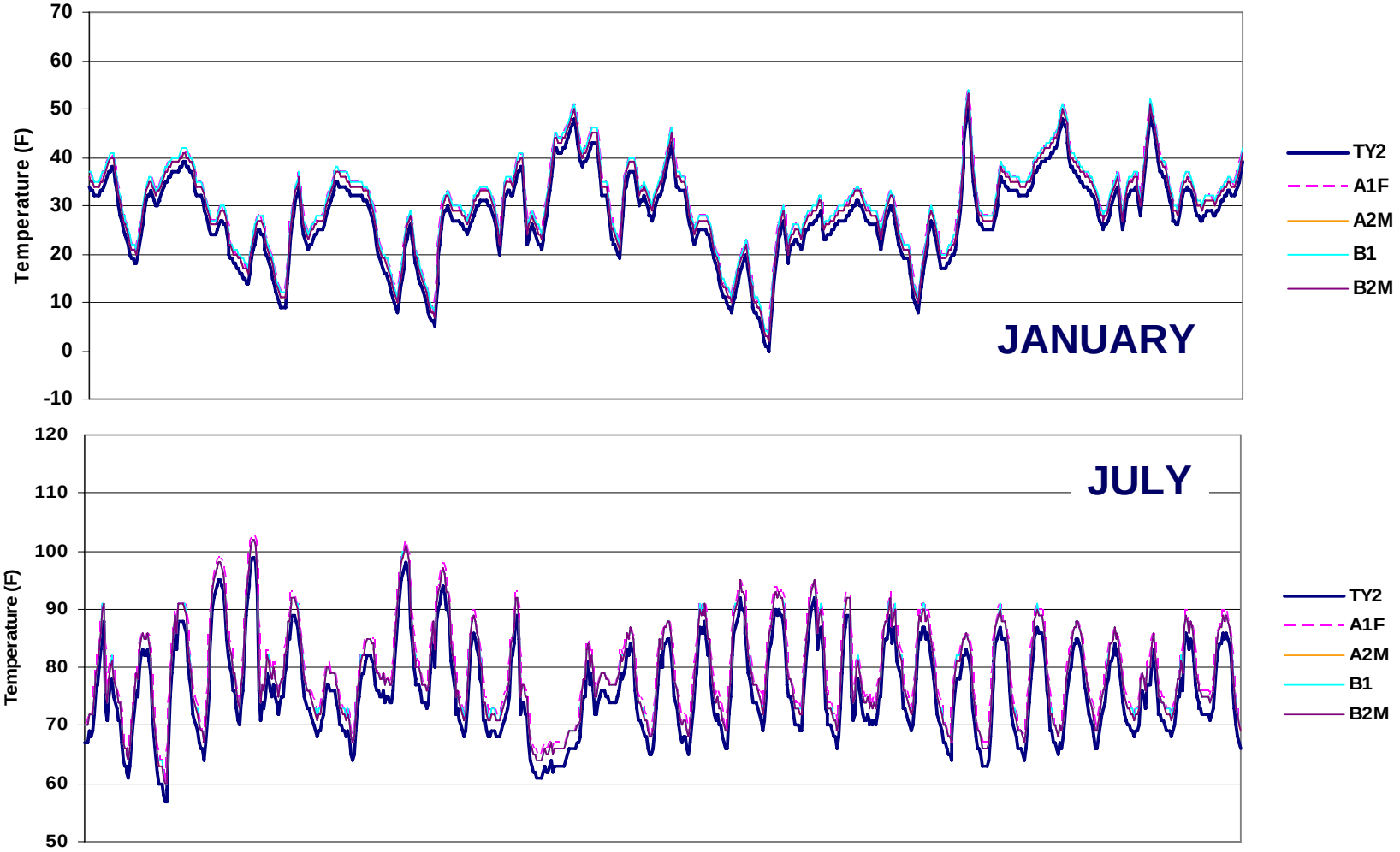


Predicted Changes in Monthly Average Cloud Amount in Washington 2080

(SAP study)



Temperatures in January and July for Washington TMY2 in 2020 (SAP study)



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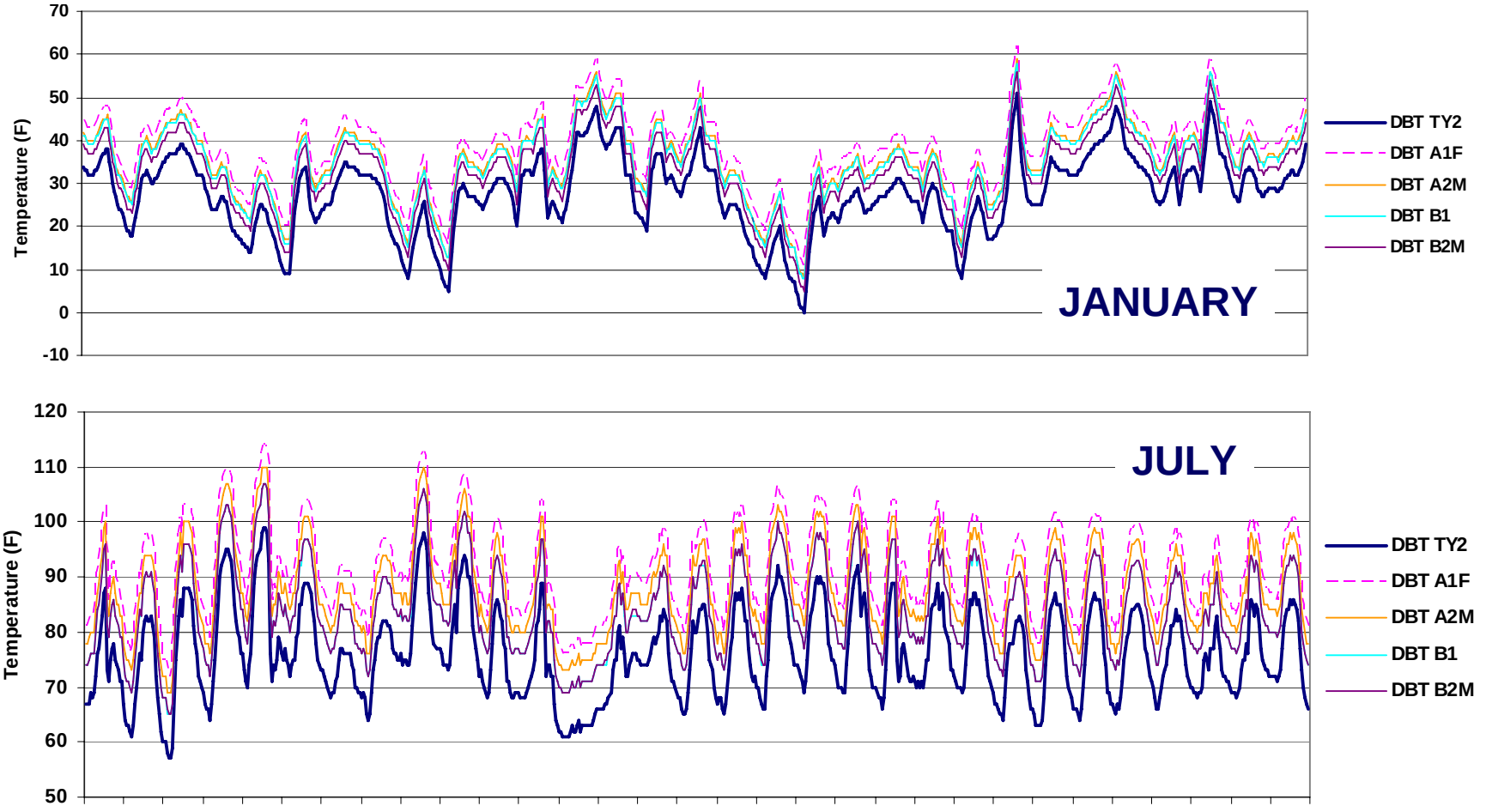
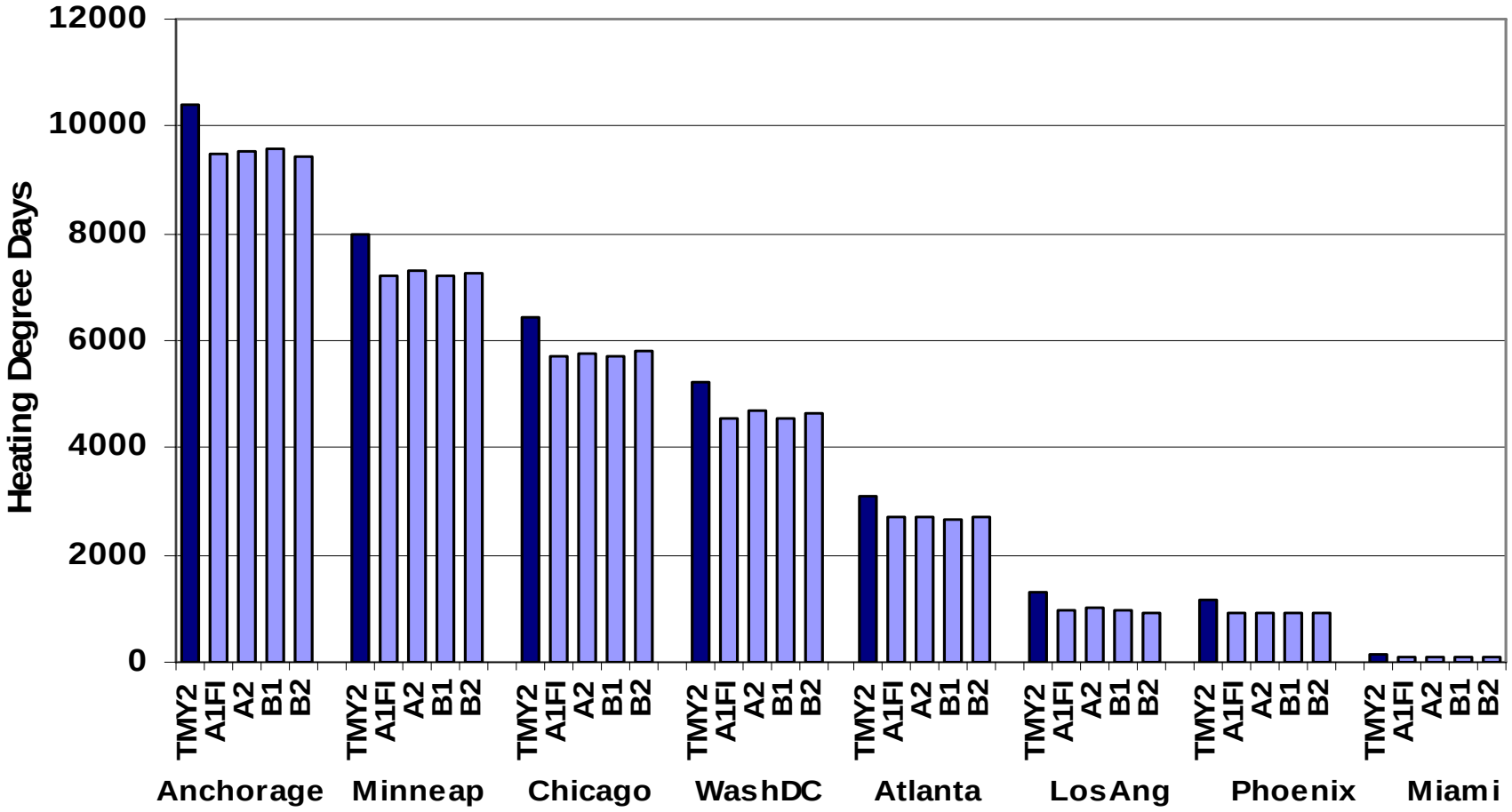


Cities considered in SAP study

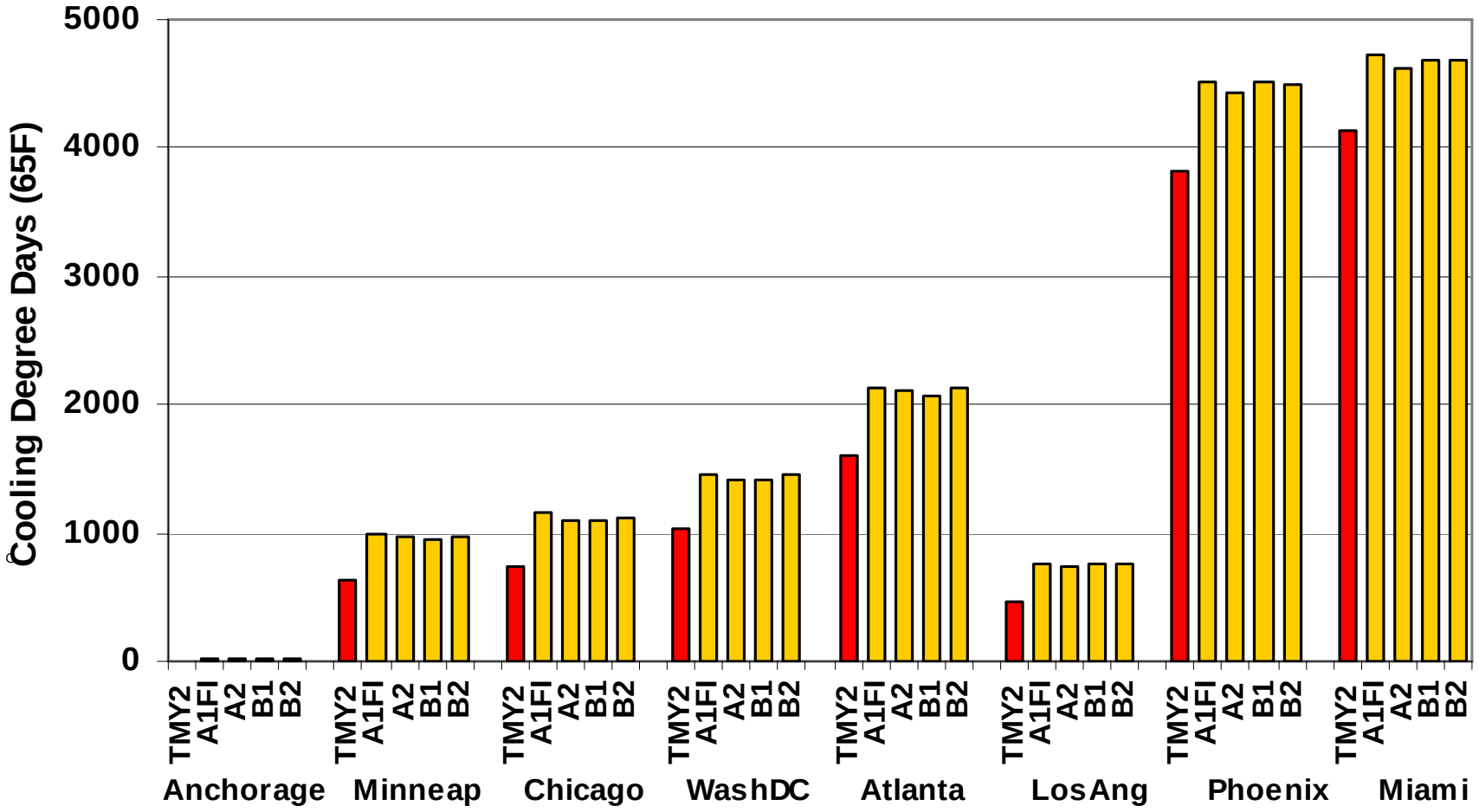
WESTERN		CENTRAL	EASTERN
Albuquerque	Los Angeles	Chicago	Atlanta
Boulder	Sacramento	Fort Worth	Boston
Phoenix	San Diego	Kansas City	Miami
Seattle	San Francisco	Lake Charles	New York
		Minneapolis	Washington

Heating Degree Hours 65F TMY2 and 2020 for 8 Selected Cities under 4 IPCC Scenarios



(SAP study)

Cooling Degree Days 65F TMY2 and 2020 for 8 Selected Cities under 4 IPCC Scenarios



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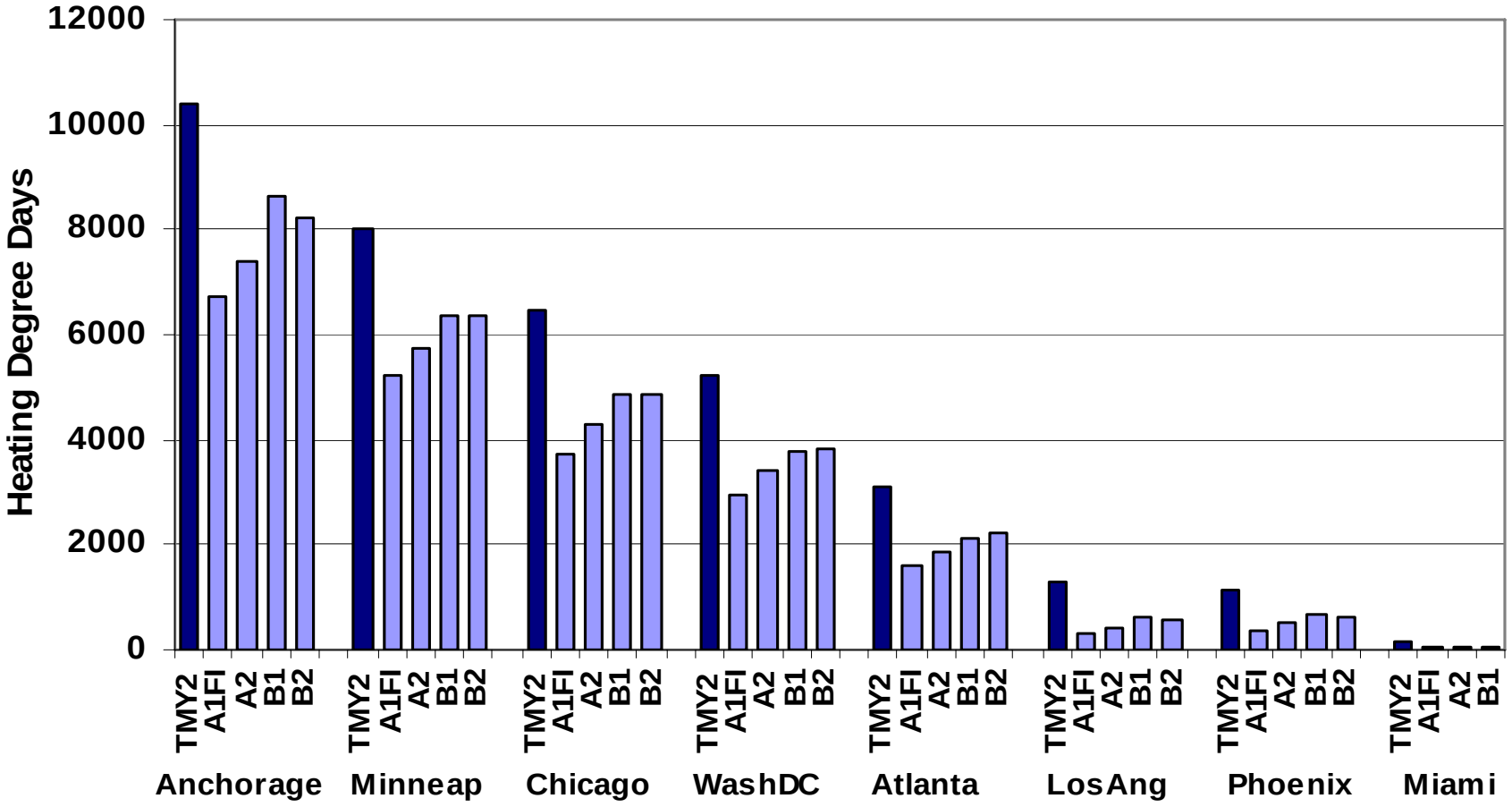
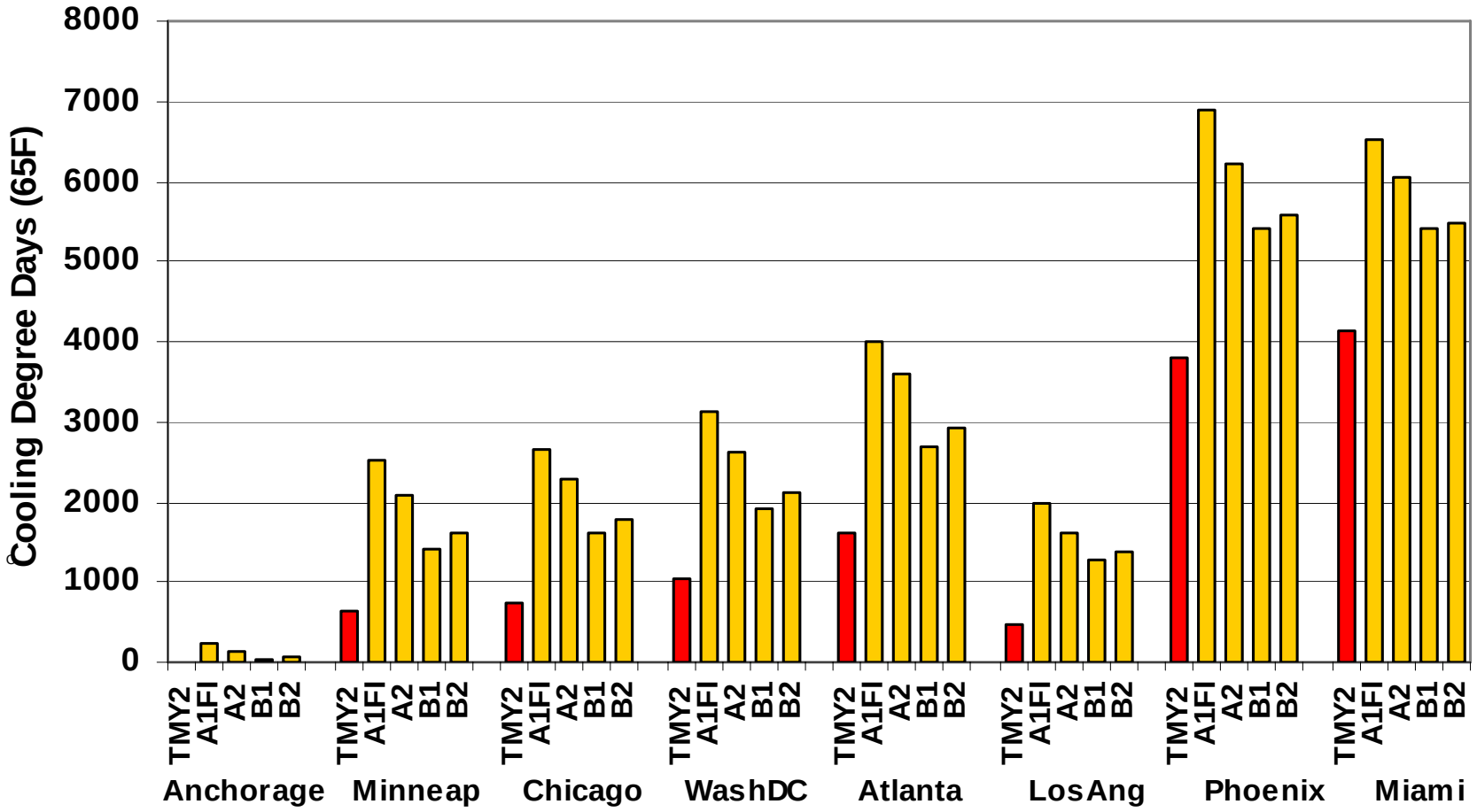
Heating Degree Hours 65F current and 2080 for 8 Selected Cities under 4 IPCC Scenarios



(SAP study)

Cooling Degree Days 65F TMY2 and 2080 for 8 Selected Cities under 4 IPCC Scenarios



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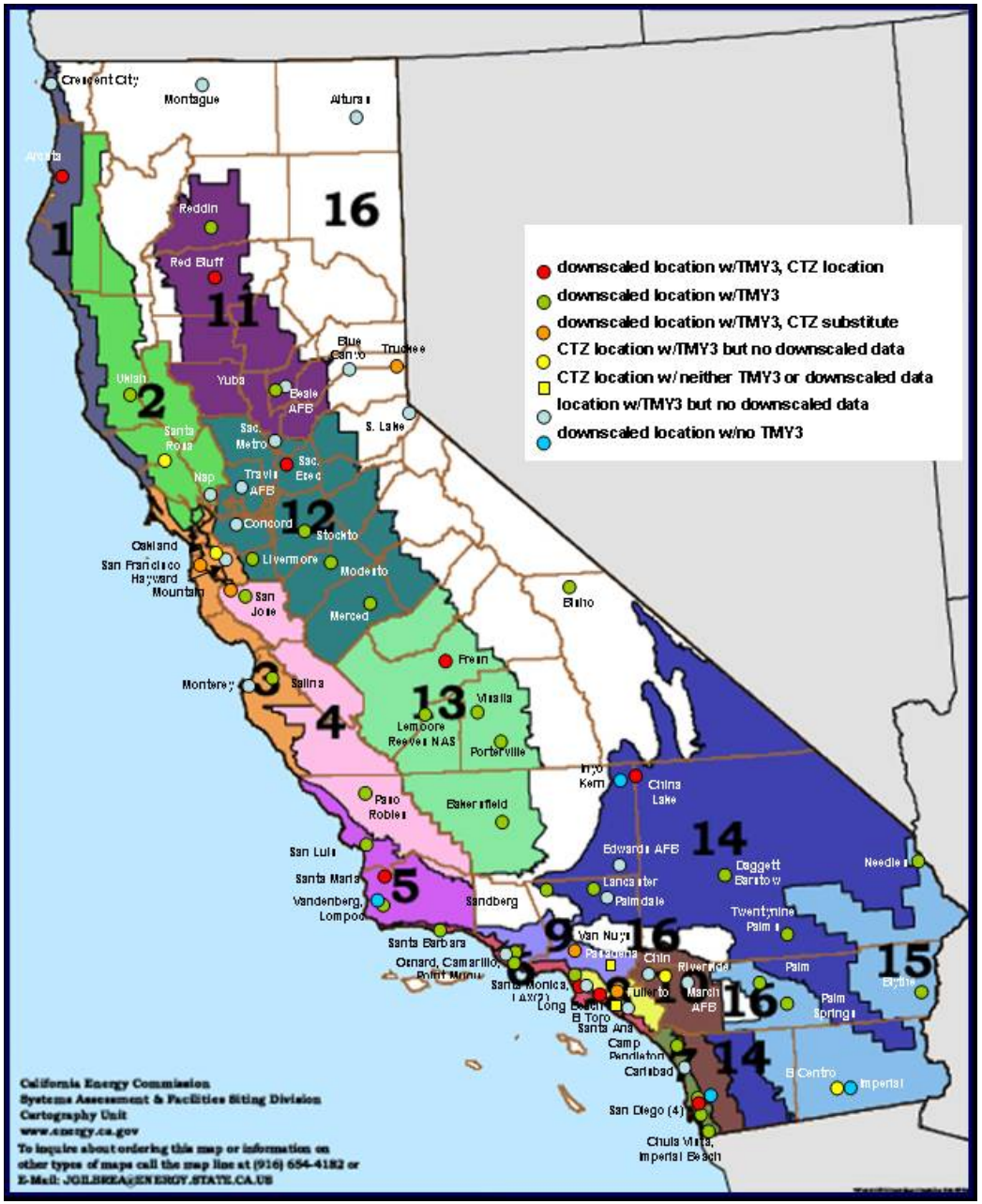
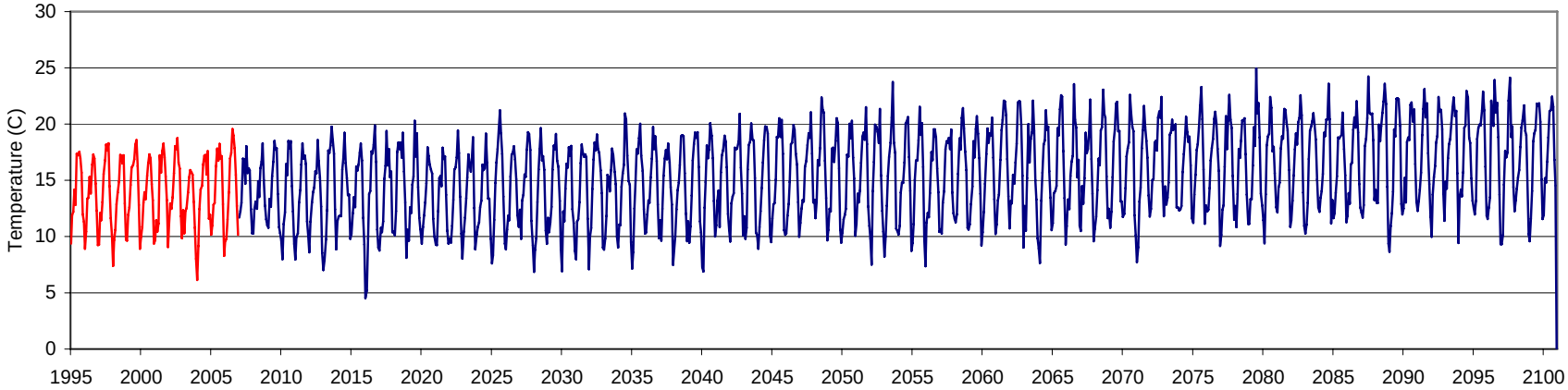


Downscaled weather data for 63 California locations 1995 -2100

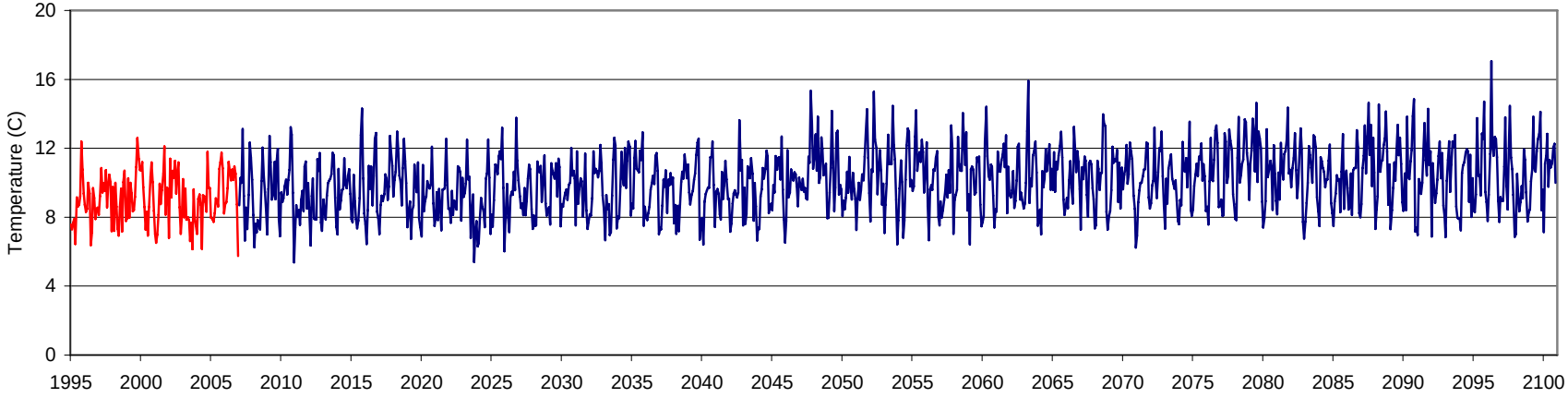
(PIER project)

Downscaled climatic data for Oakland 1995-2100 (PIER project)

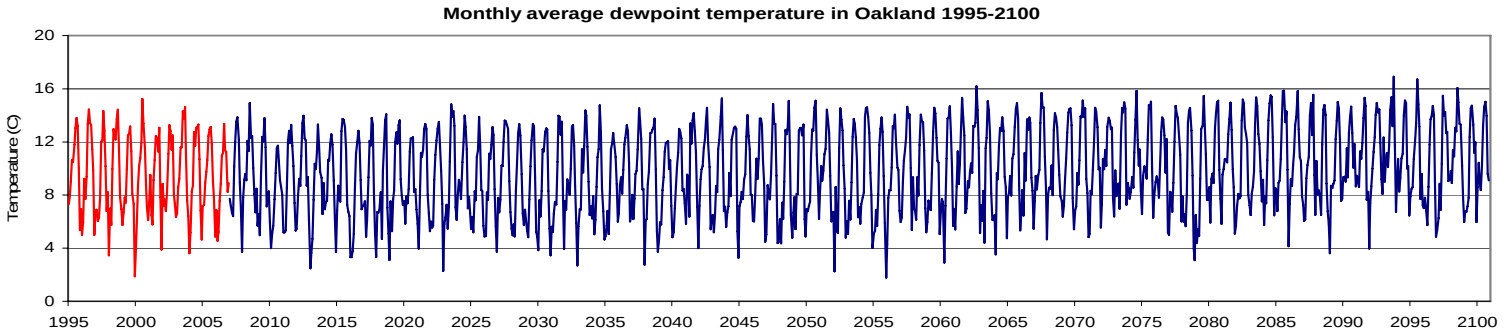
Monthly average dry-bulb temperature in Oakland 1995-2100

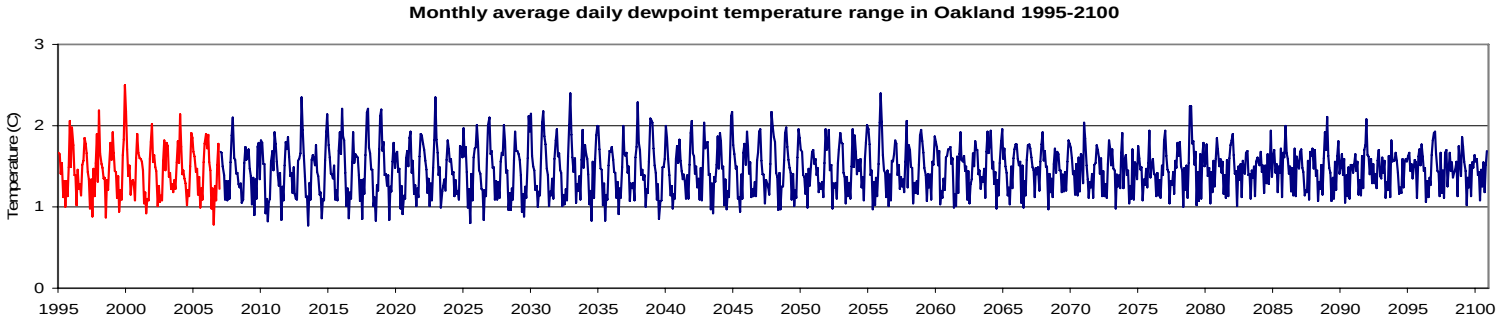


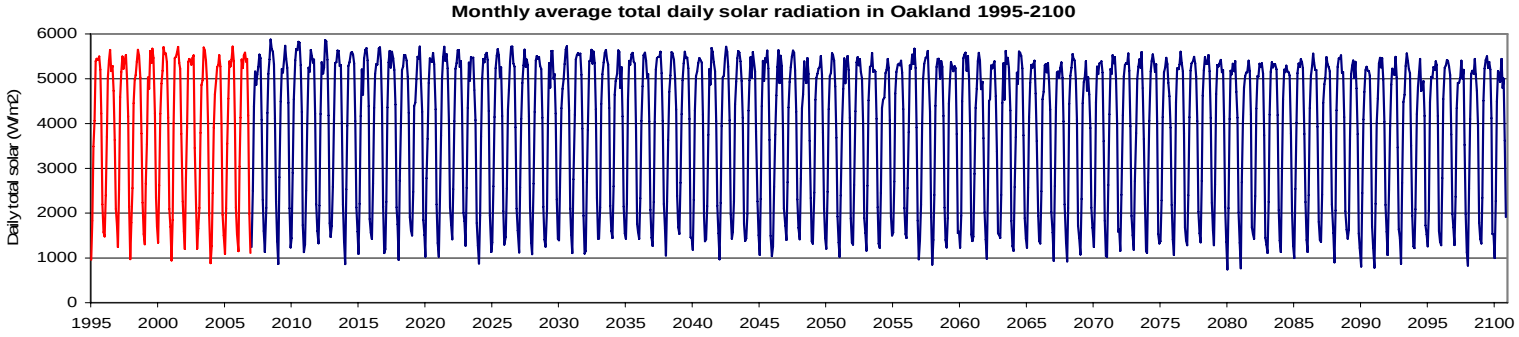
Monthly average daily dry-bulb temperature range in Oakland 1995-2100



Downscaled climatic data for Oakland 1995-2100 (PIER project)

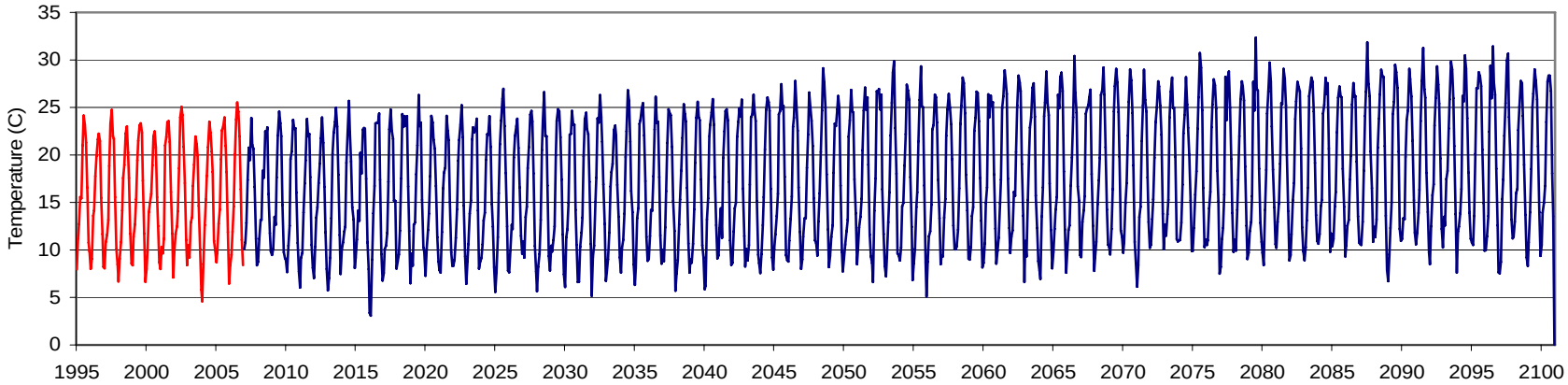






Downscaled climatic data for Sacramento 1995-2100 (PIER project)

Monthly average dry-bulb temperature in Sacramento 1995-2100



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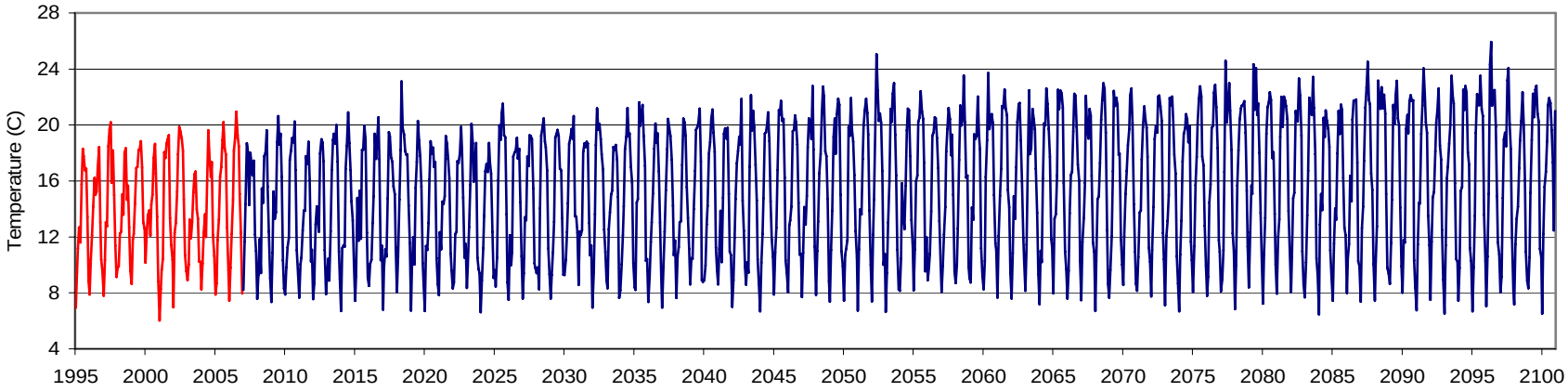

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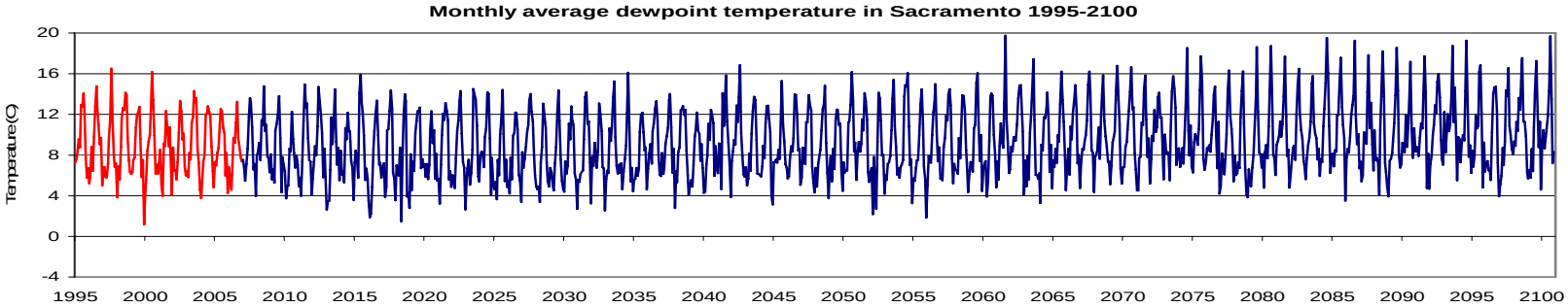
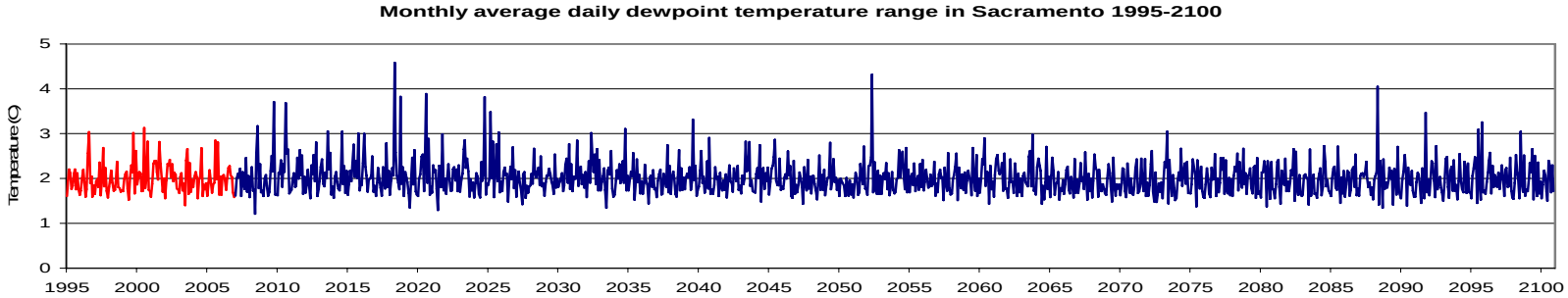
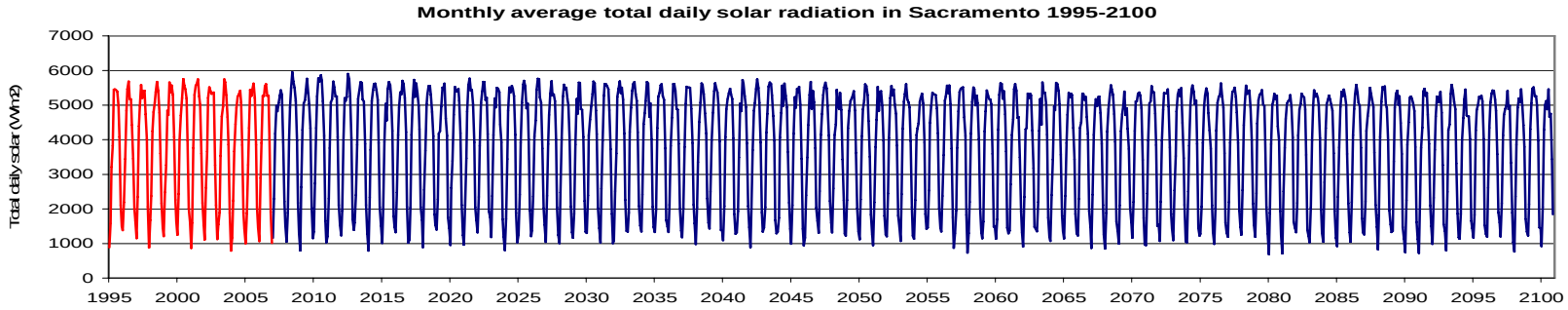
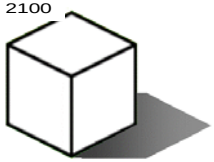


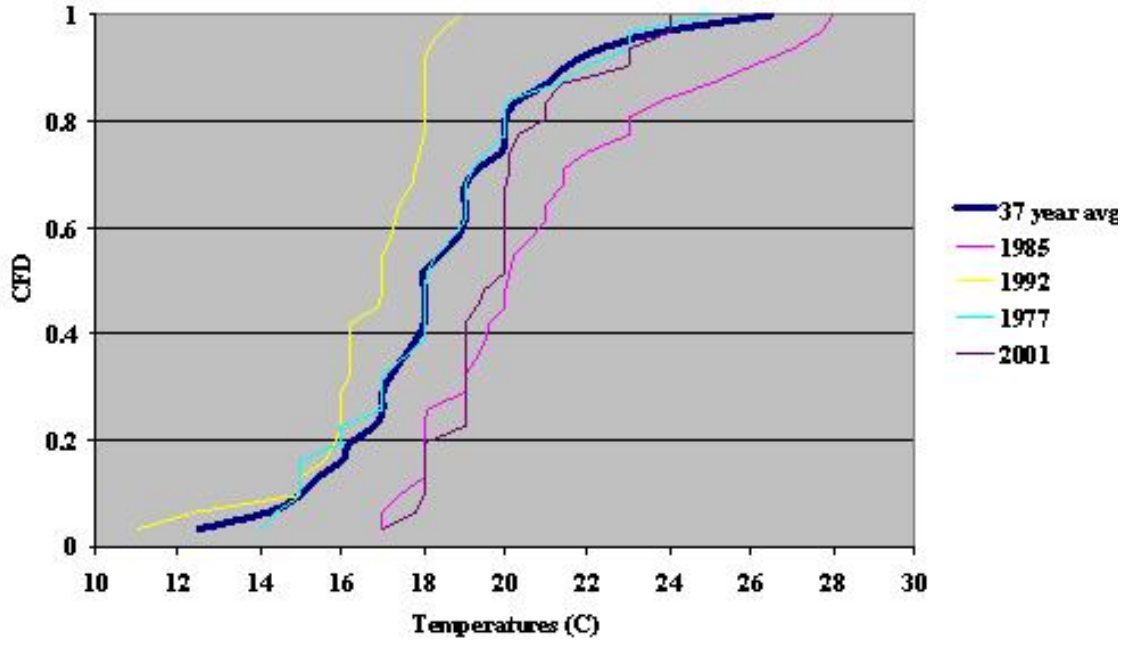






Creating “typical year” weather from multi-year historical weather data

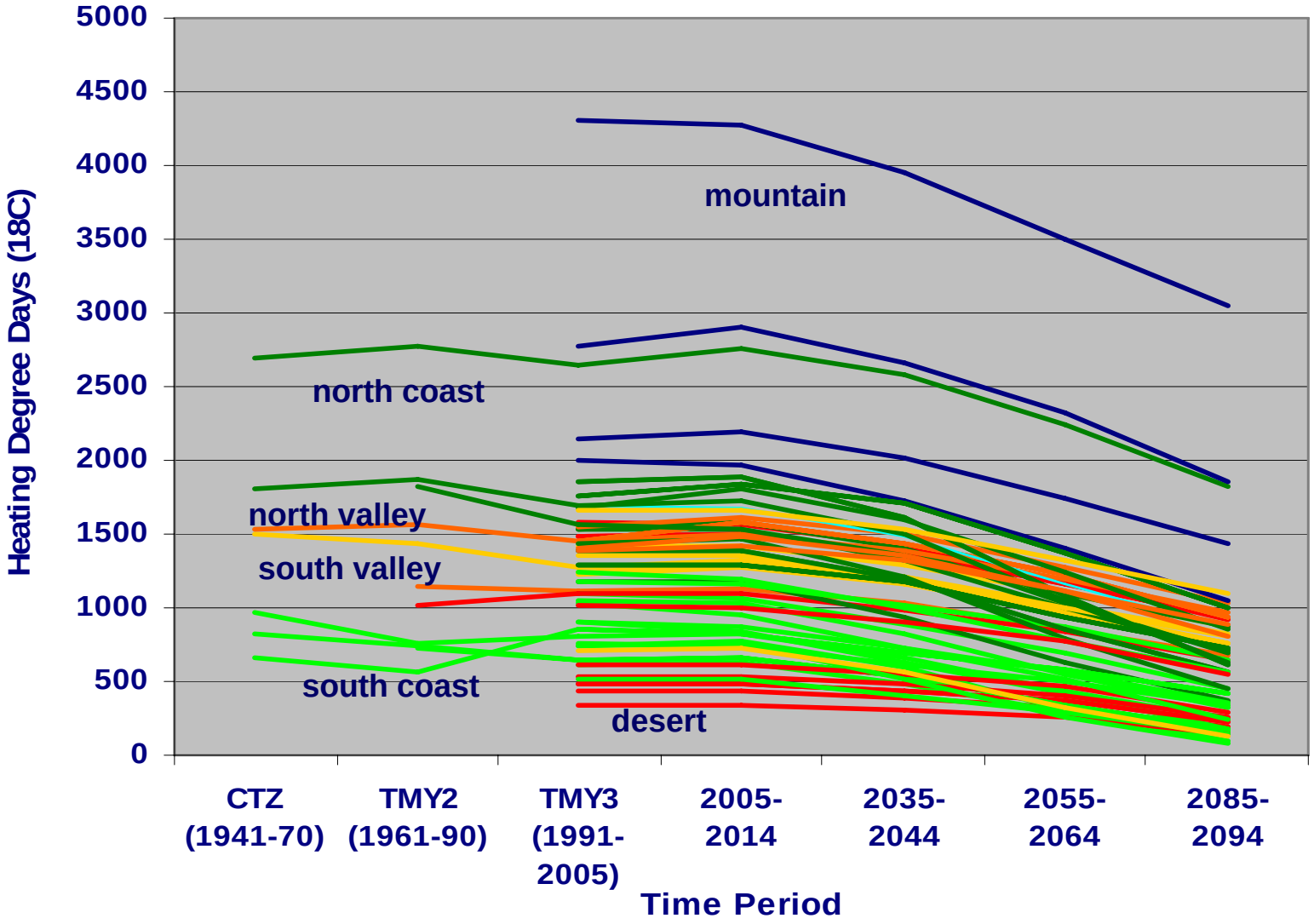
- 12 calendar months from the historical period of record are selected as the representative months based on various criteria and weighting.
- The Typical Meteorological Year (TMY) method developed by NREL compares the Cumulative Distribution Function (CDF) of each climate variable, and picks the month with the closest fit.



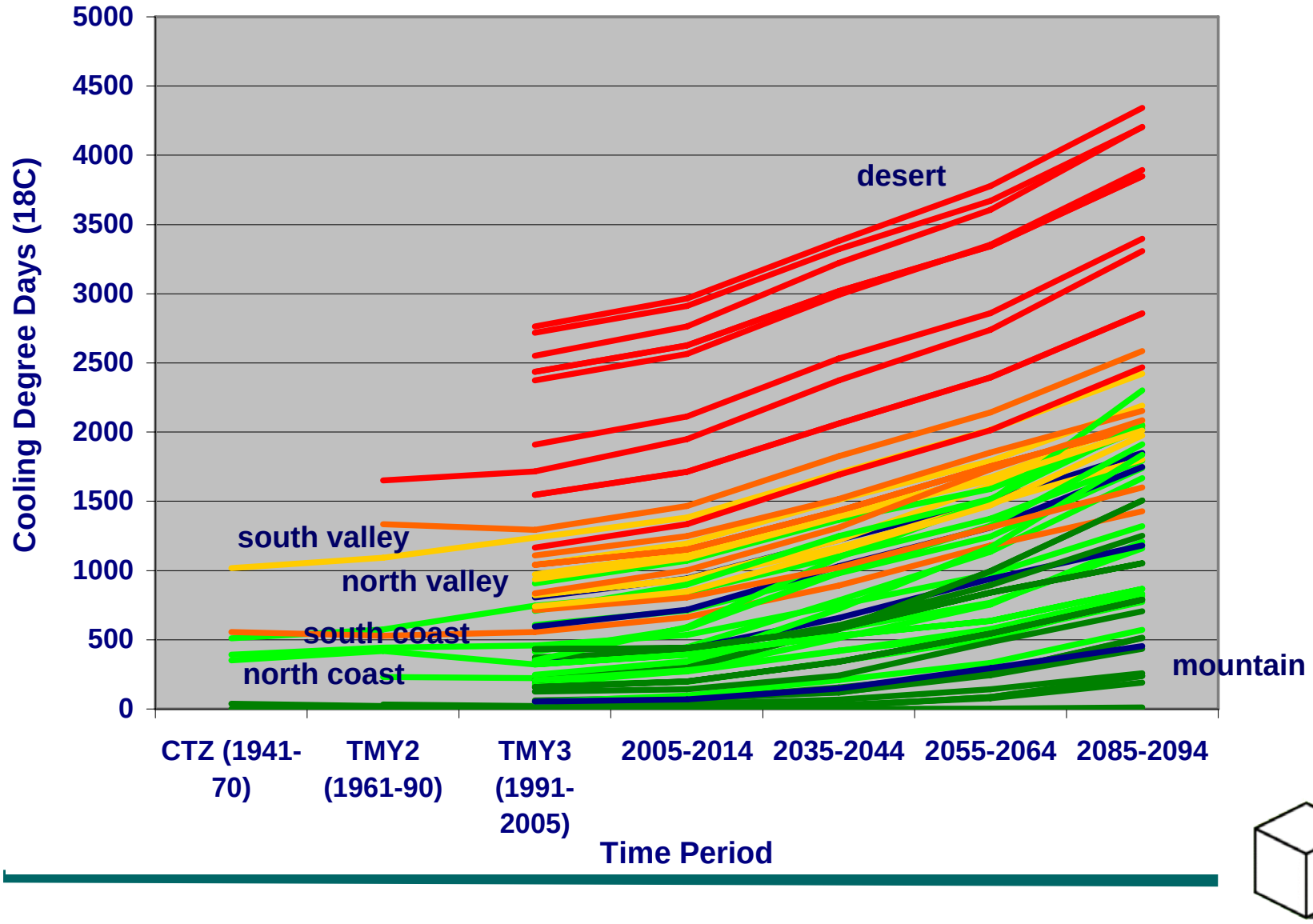
Three ways to create typical year weather from future year weather projections

- Consider the downscaled data the same as historical data to select typical months and build from them “typical year” weather files for future periods.
- Obtain the long-term CDF from the downscaled data, but use the historical data set to select the typical months.
- Compute the average changes in climate variables, i.e., temperature, humidity, solar, etc., in the downscaled data over time, and then map those changes onto existing “typical year” weather files such as the CTZ, TMY2, and TMY3 data sets.

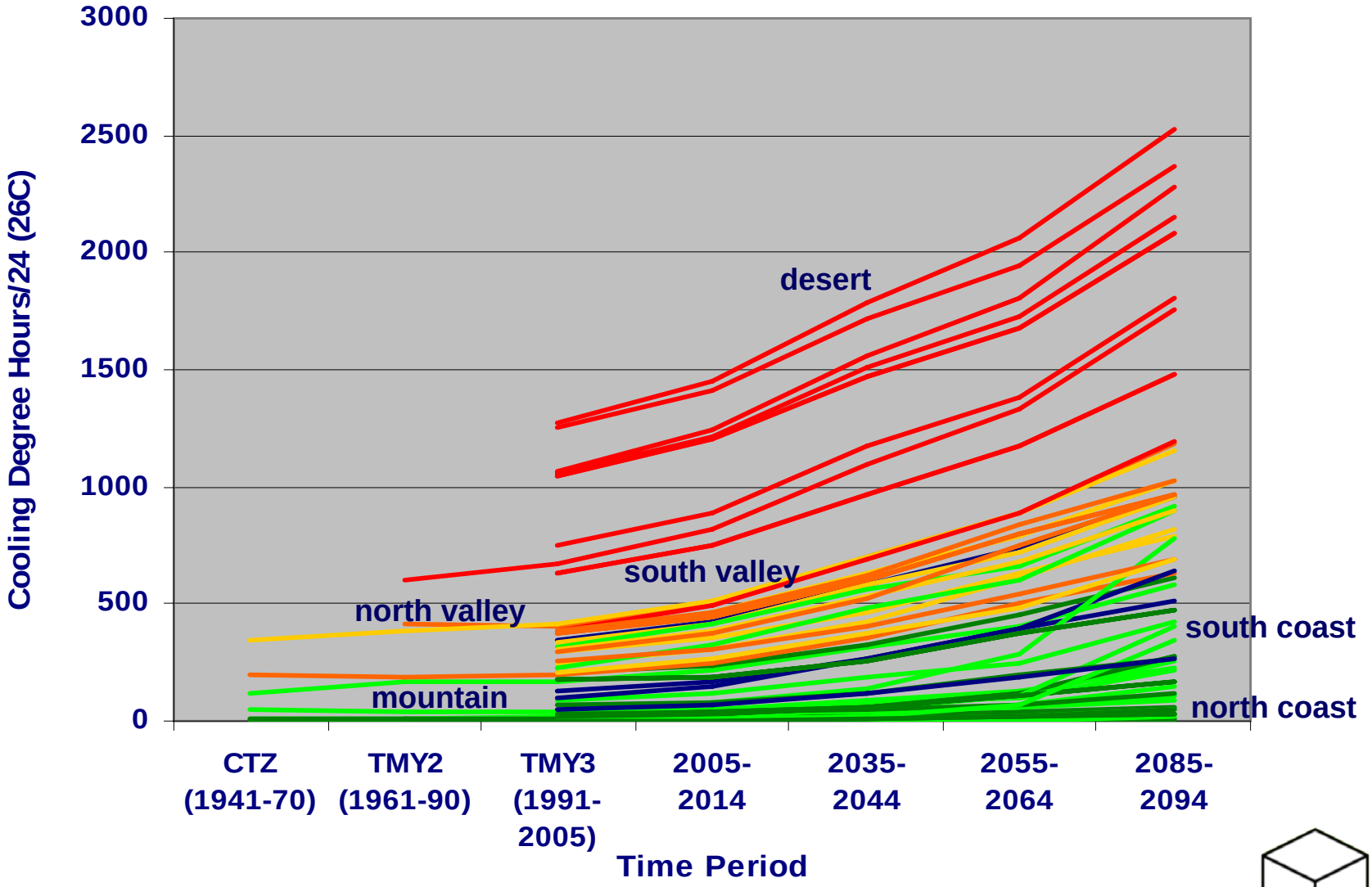
California Heating Degree Days 1941-2100
A1FI Scenario (Base 18C)



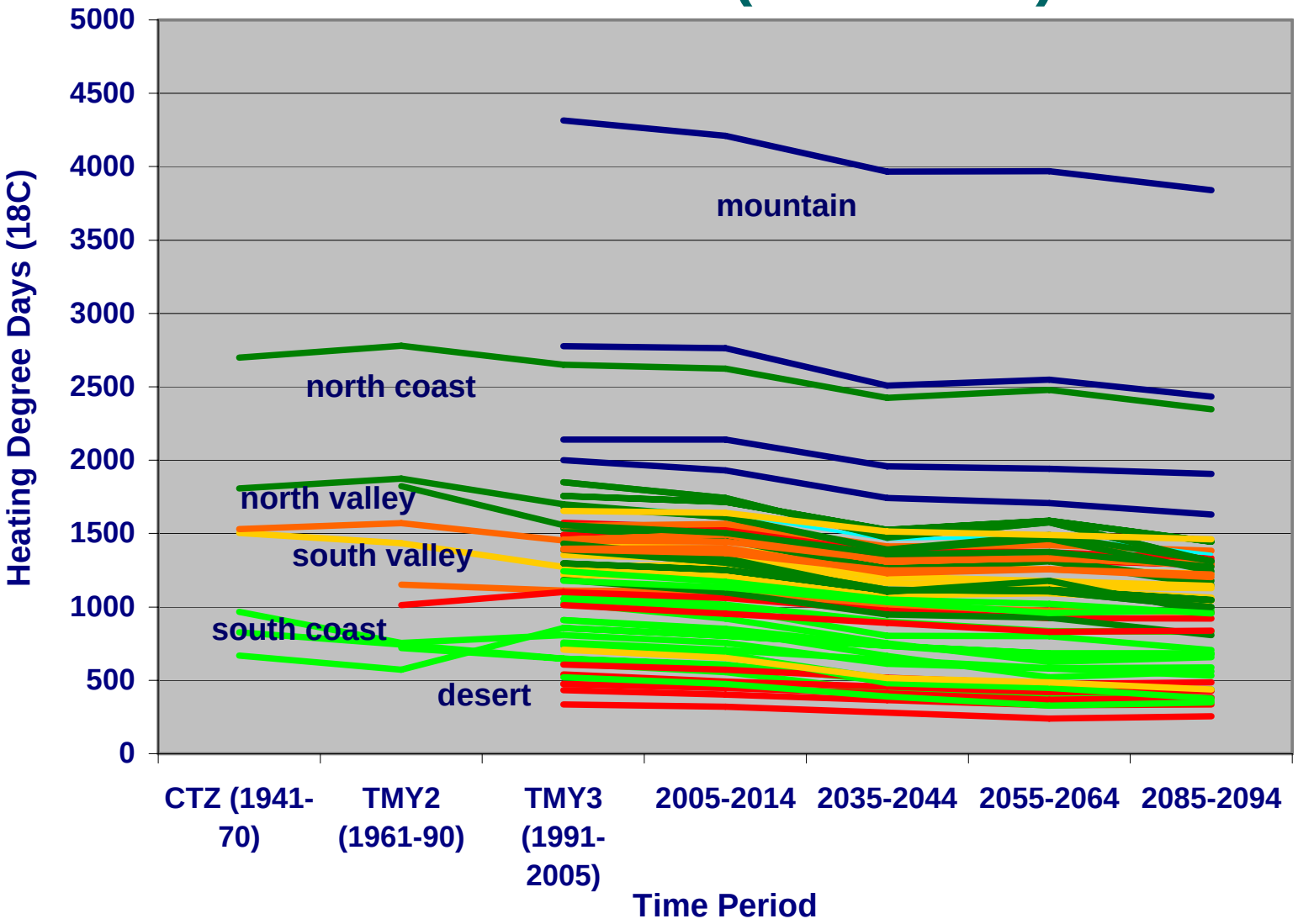
California Cooling Degree Days 1941-2100
A1FI Scenario (Base 18C)



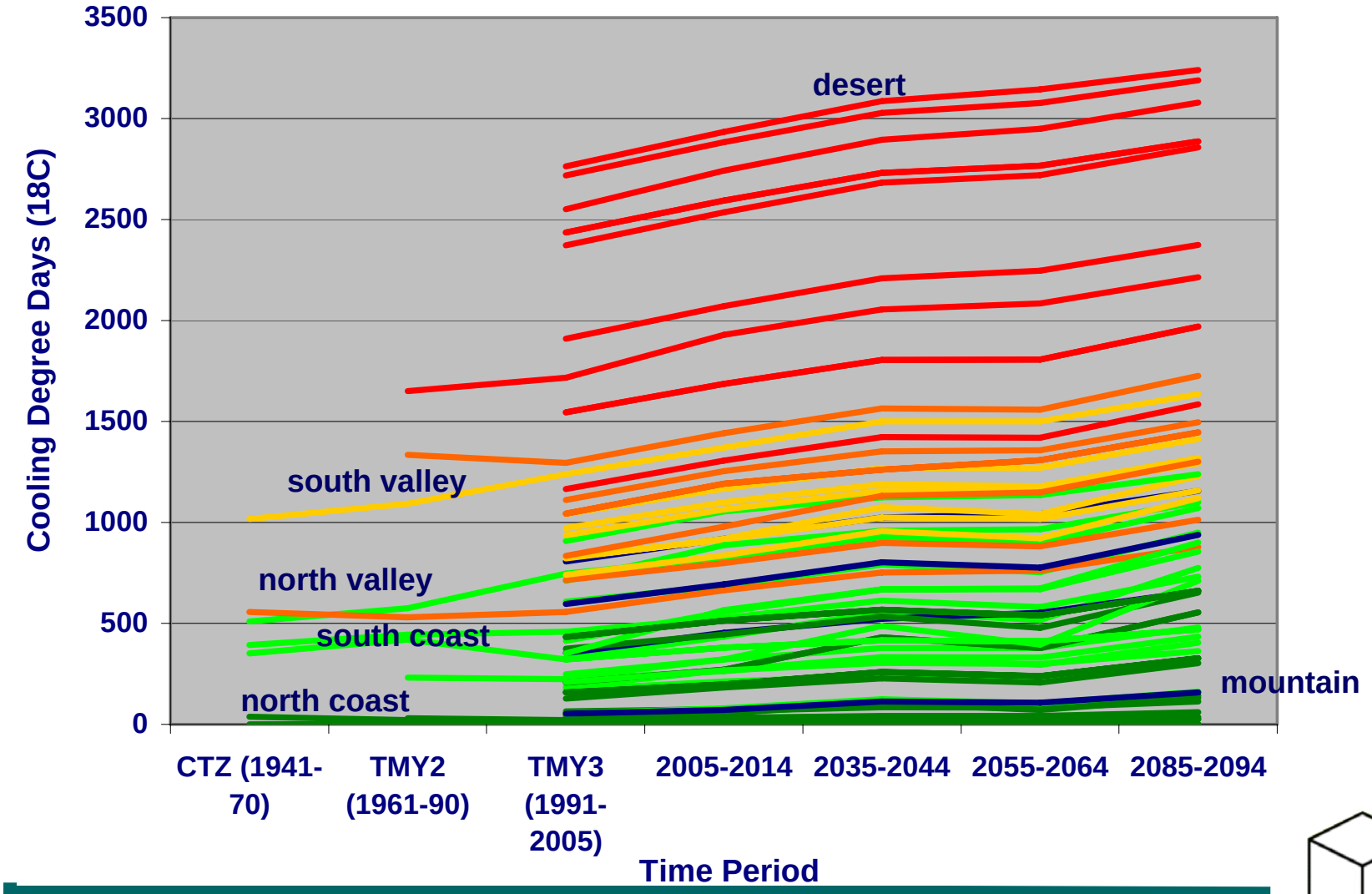
California Cooling Degree Hours/24 1941-2100
A1FI Scenario (Base 268C)



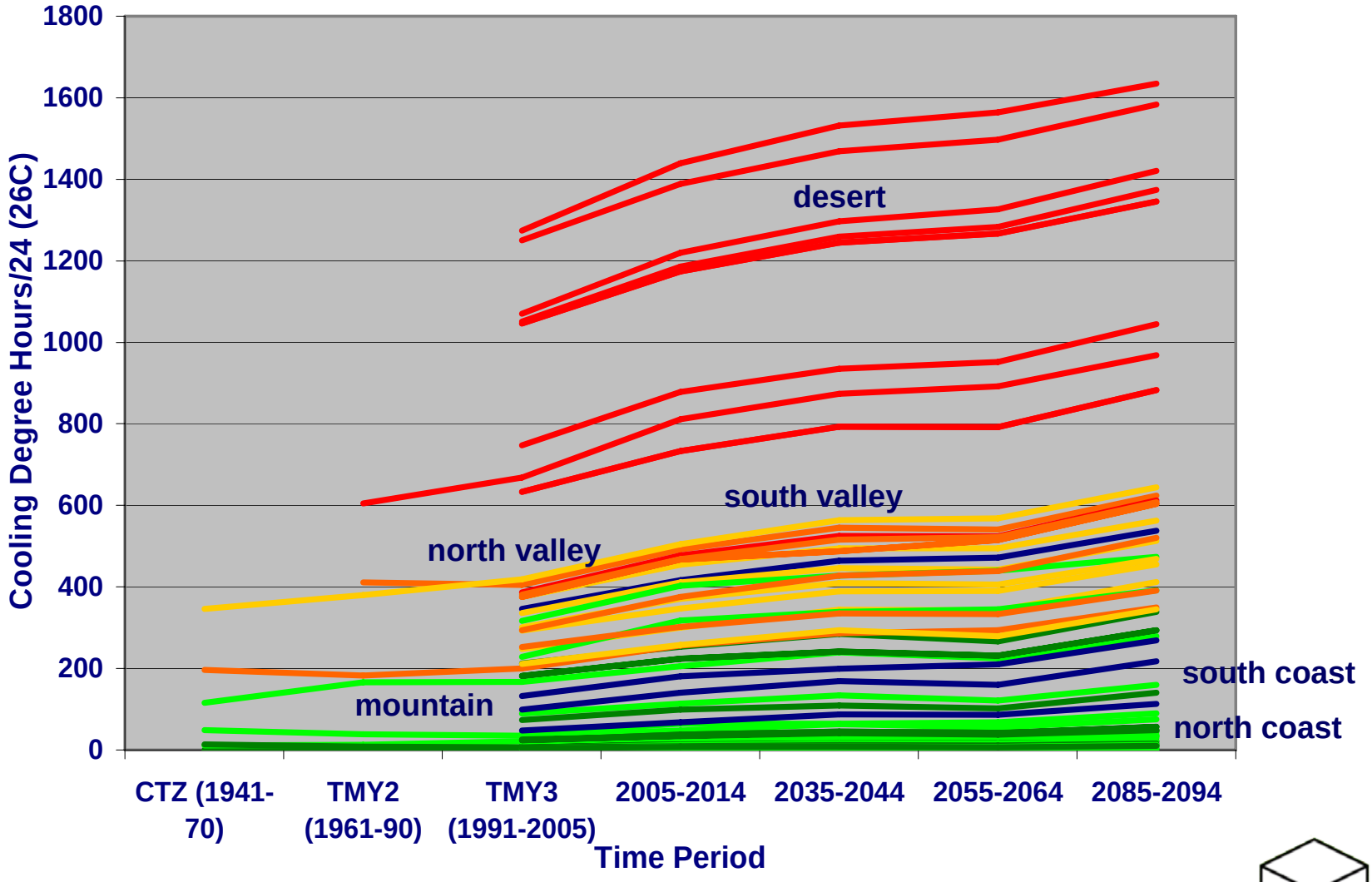
California Heating Degree Days 1941-2100
BI Scenario (Base 18C)



California Cooling Degree Days 1941-2100
BI Scenario (Base 18C)



California Cooling Degree Hours/24 1941-2100
BI Scenario (Base 26C)



Equivalent current climate Locations to projected Climates in 2100 (A1FI Scenario)

(PIER project)

Equivalent current climate Locations to projected Climates in 2100 (B1 Scenario)

(PIER project)

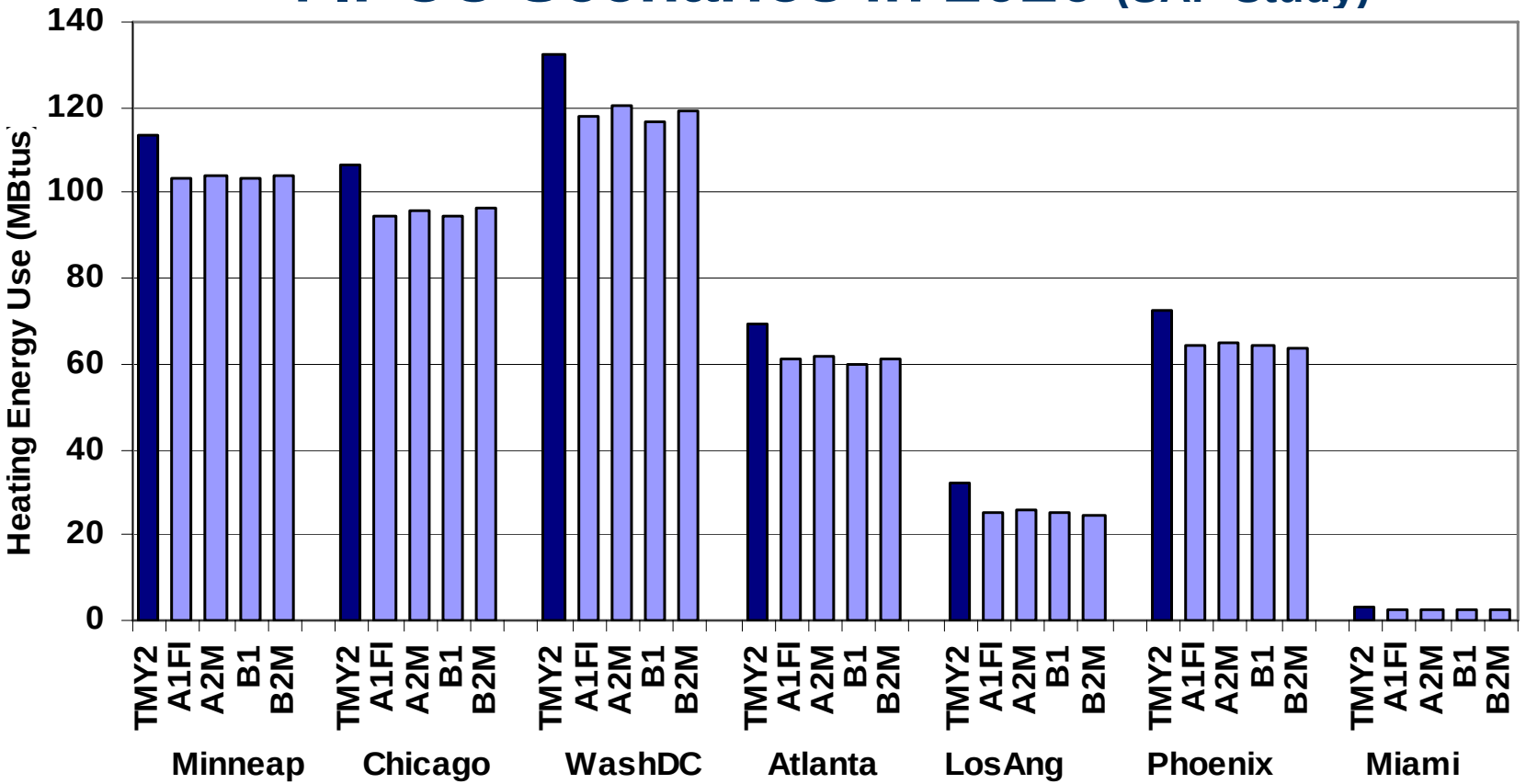
Prototypical buildings to represent the US residential and commercial building stock

- **Work began in 1986 to develop prototypical multifamily buildings for the Gas Research Institute**
- **100 single-family and 66 multi-family prototypes for 16 climates**
- **150 commercial prototypes for 17 building types of 3 vintages in 3 US regions (last version completed 2007, available from NREL or LBNL web sites)**

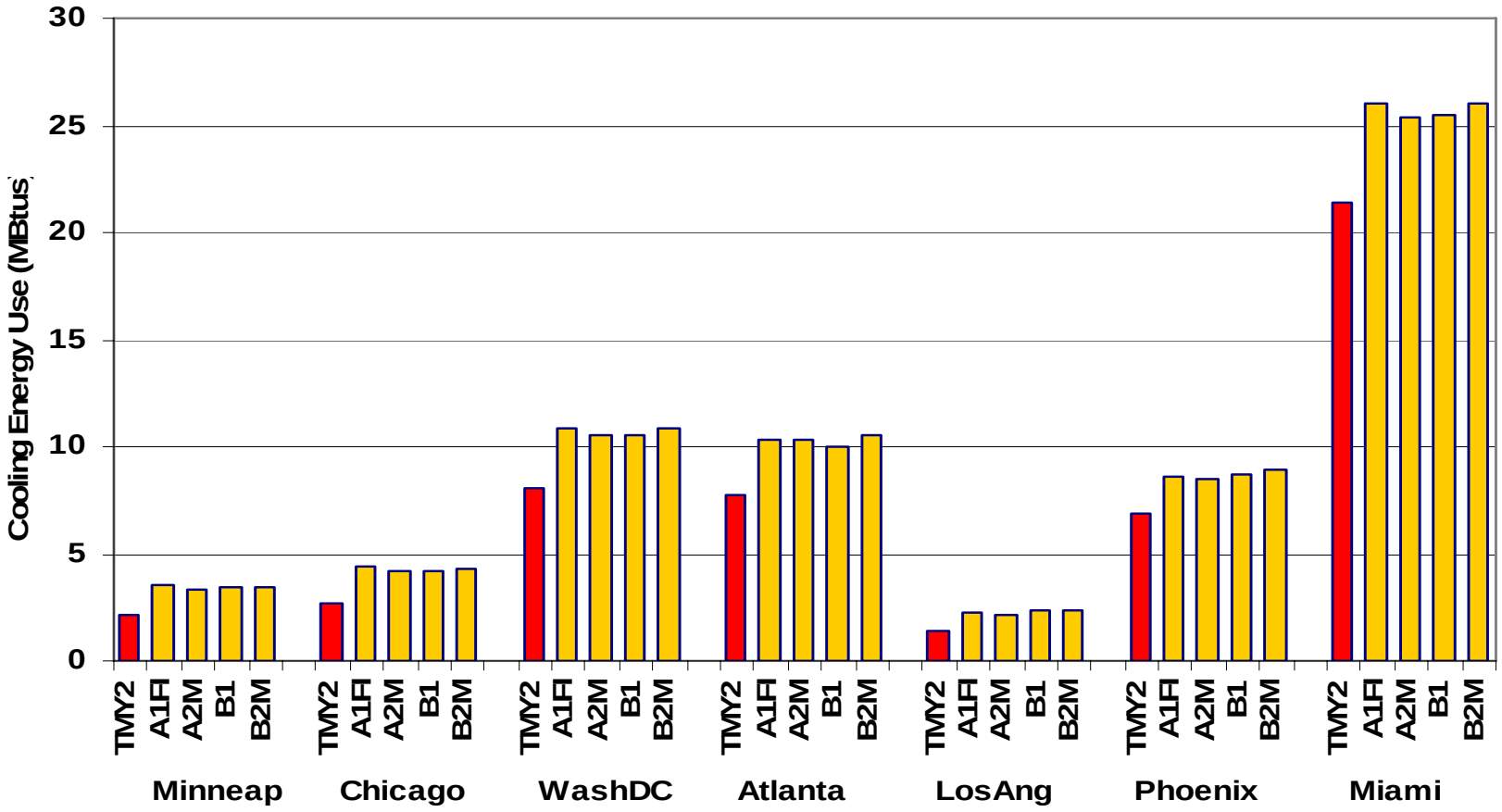
Large Office	OutPatient Clinic	Fast-Food Restaurant	Primary School East
Medium Office	Large Hotel	Sit-Down Restaurant	Primary School West
Small Office	Small Hotel	Supermarket	Secondary School East
Hospital	Stripmall Store	Retail Store	Secondary School West
		Warehouse	

- **Prototypical buildings combine survey data from DOE/EIA or the housing industry, code requirements, studies of building operations and internal conditions, with system performance and operating conditions based on engineering judgment**
- **Region-wide energy use intensities and fuel/electric ratios calibrated against DOE/EIA surveys.**

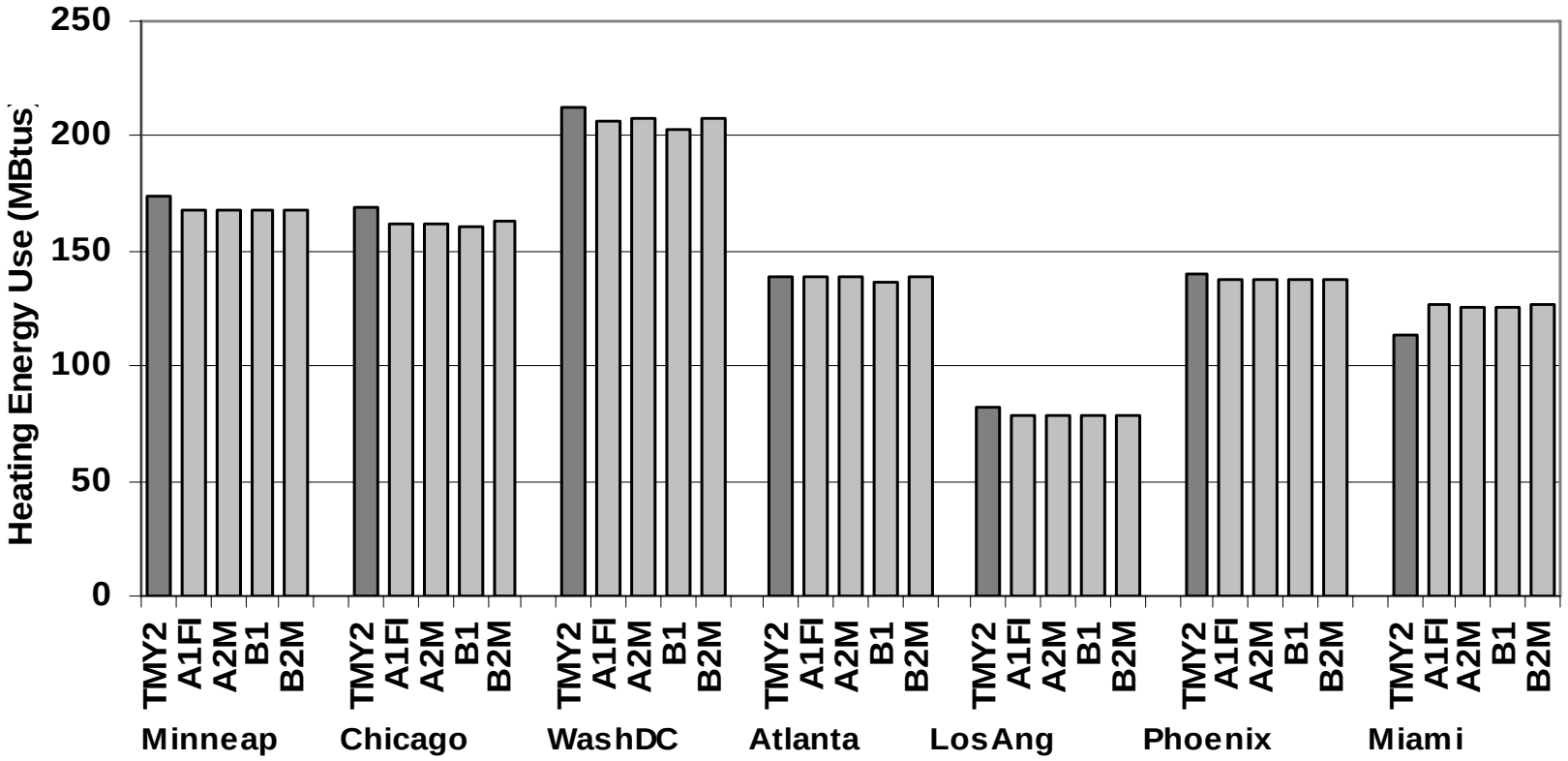
Heating Energy Use for Old Single-family Houses for 7 Selected Cities with 4 IPCC Scenarios in 2020 (SAP Study)



Cooling Energy Use for Old Single-family Houses for 7 Selected Cities with 4 IPCC Scenarios in 2020 (SAP Study)



Total Energy Use for Old Single-family Houses for 7 Selected Cities with 4 IPCC Scenarios in 2020 (SAP Study)



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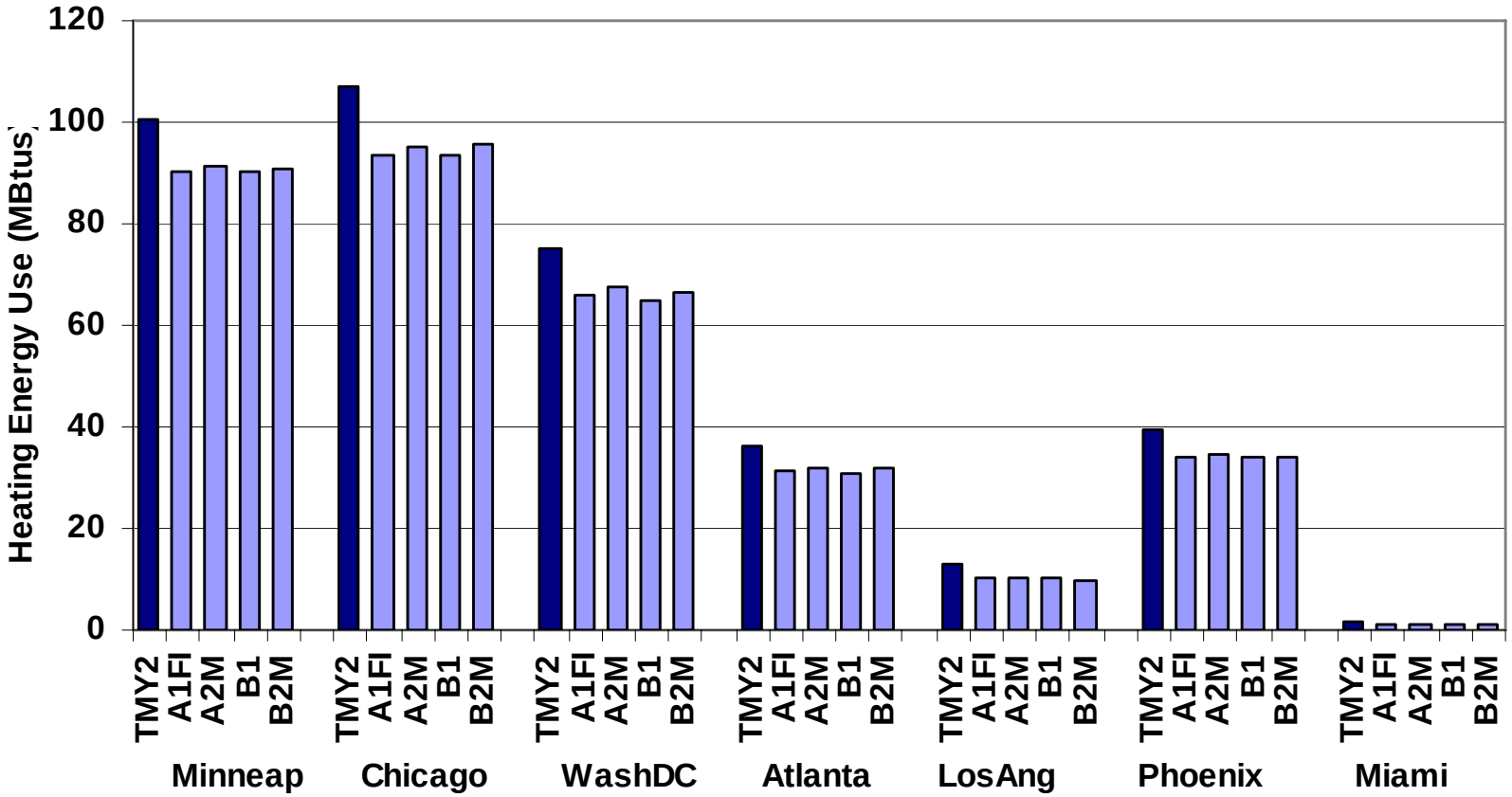

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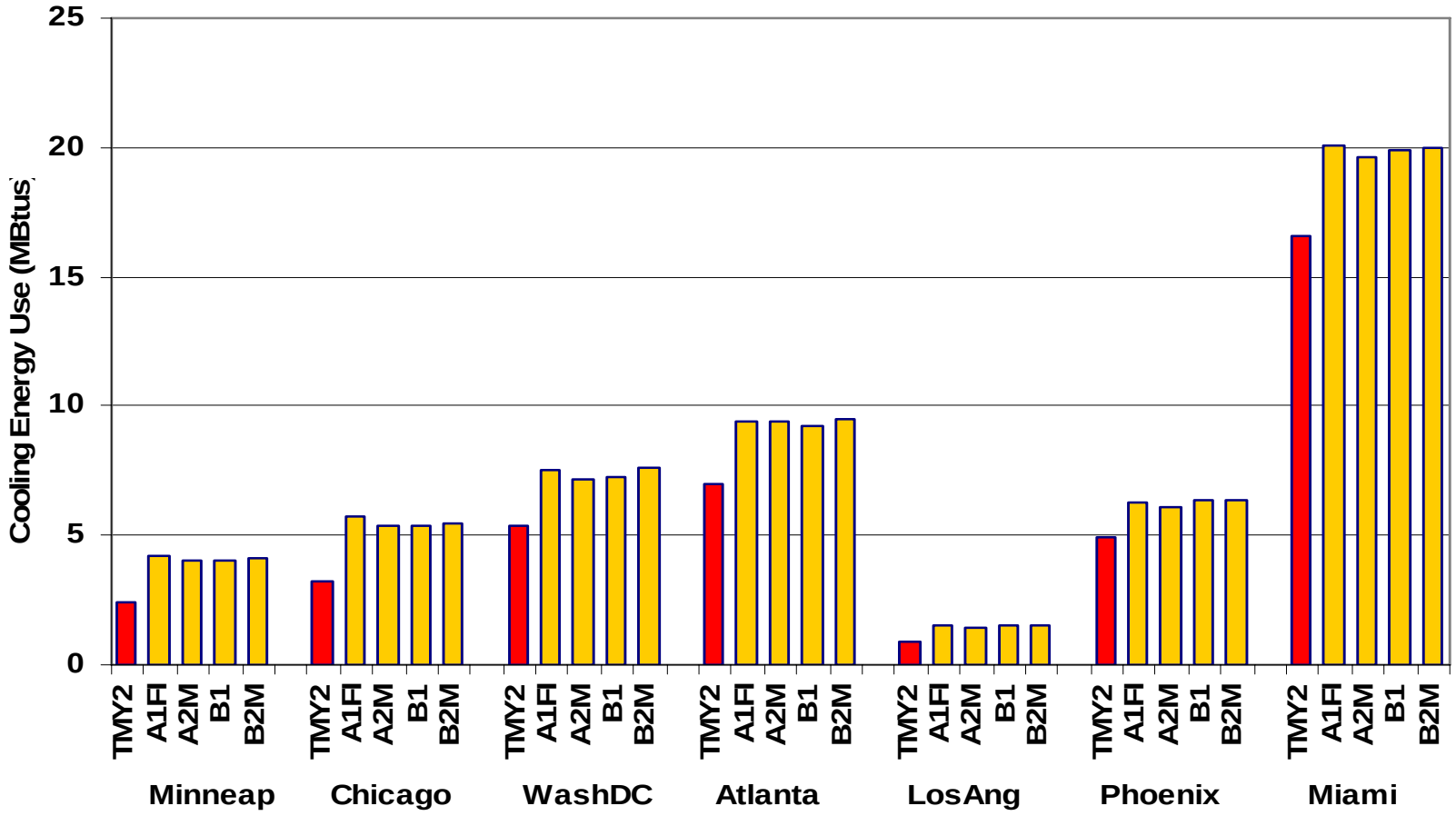

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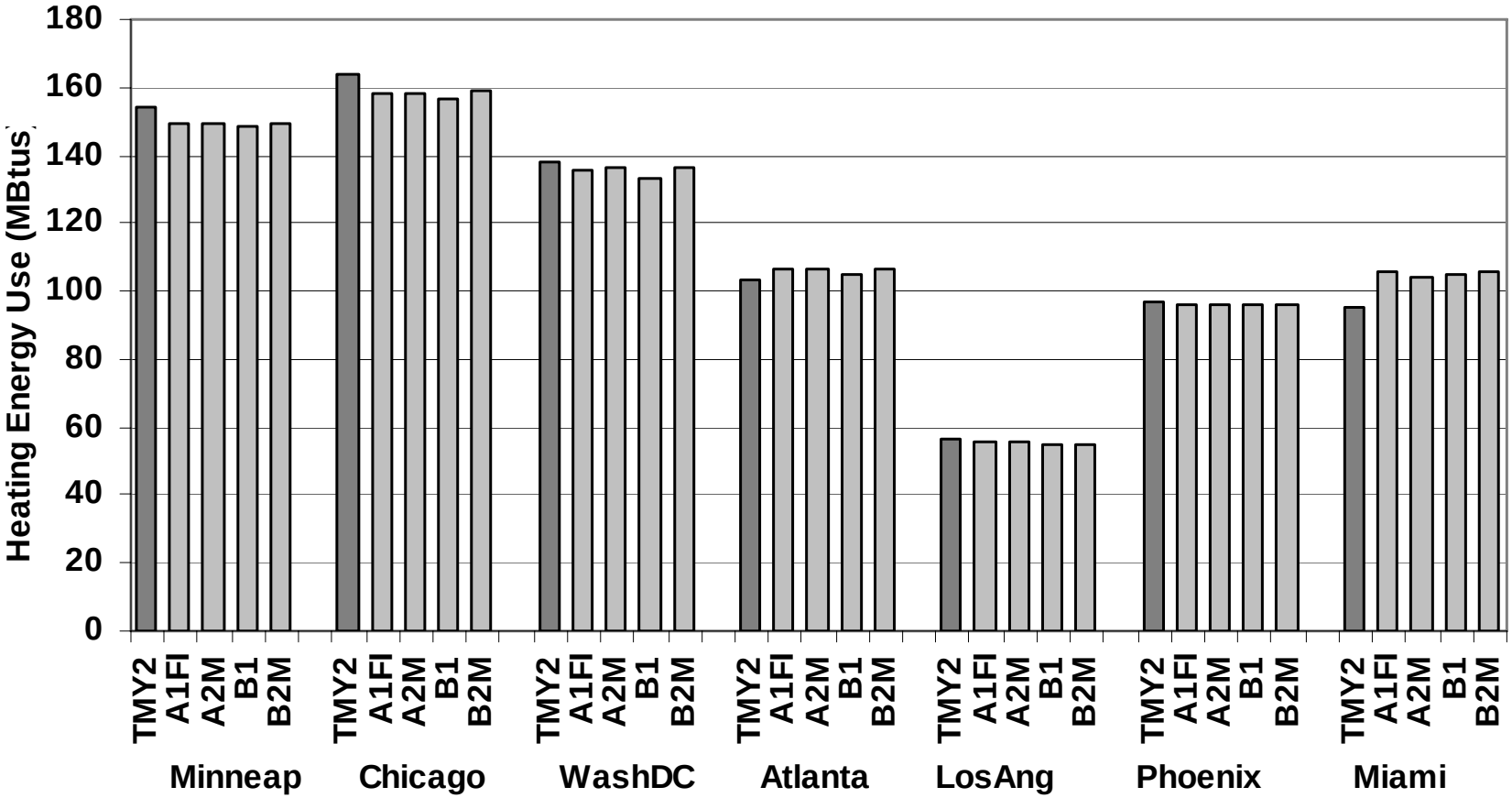
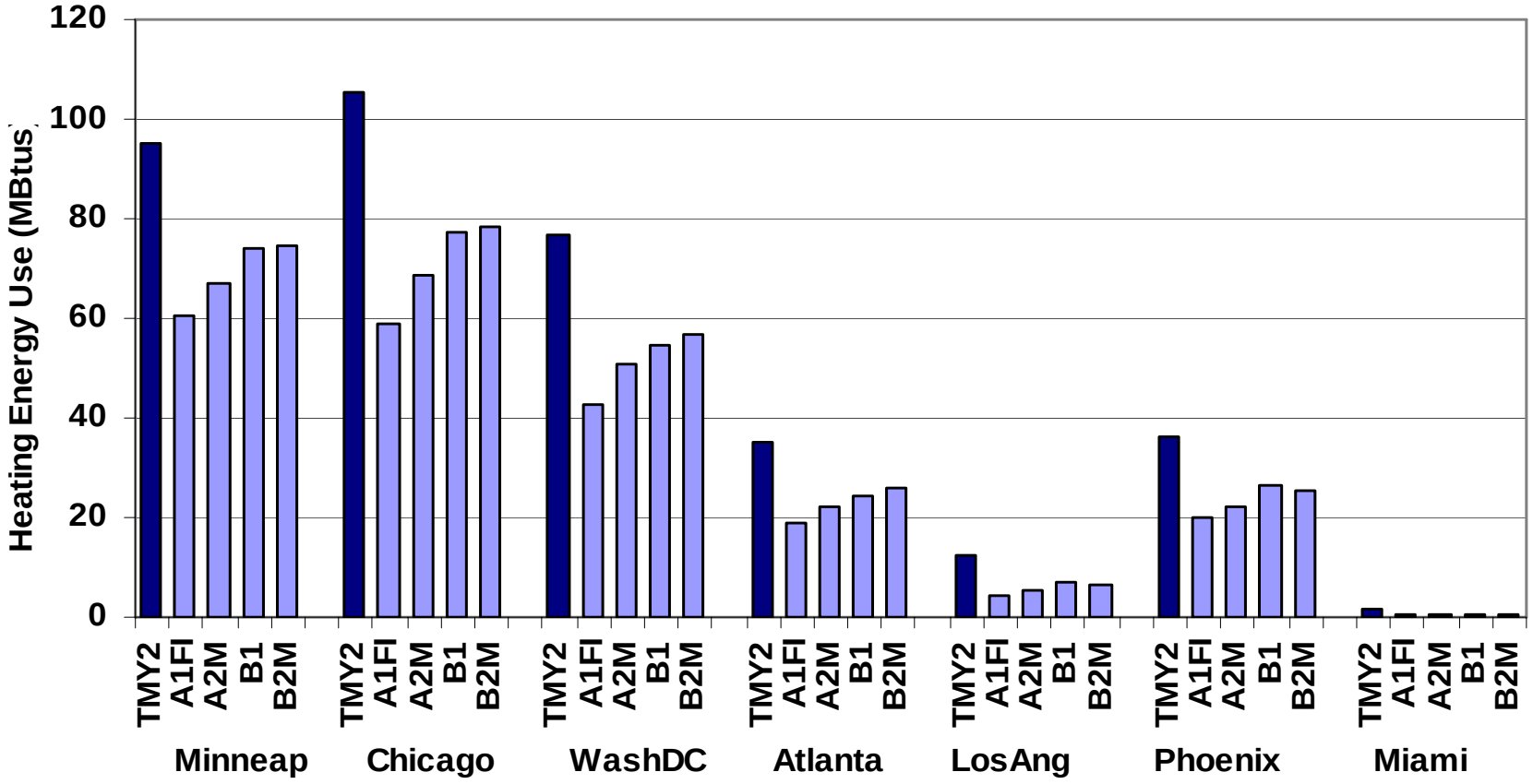
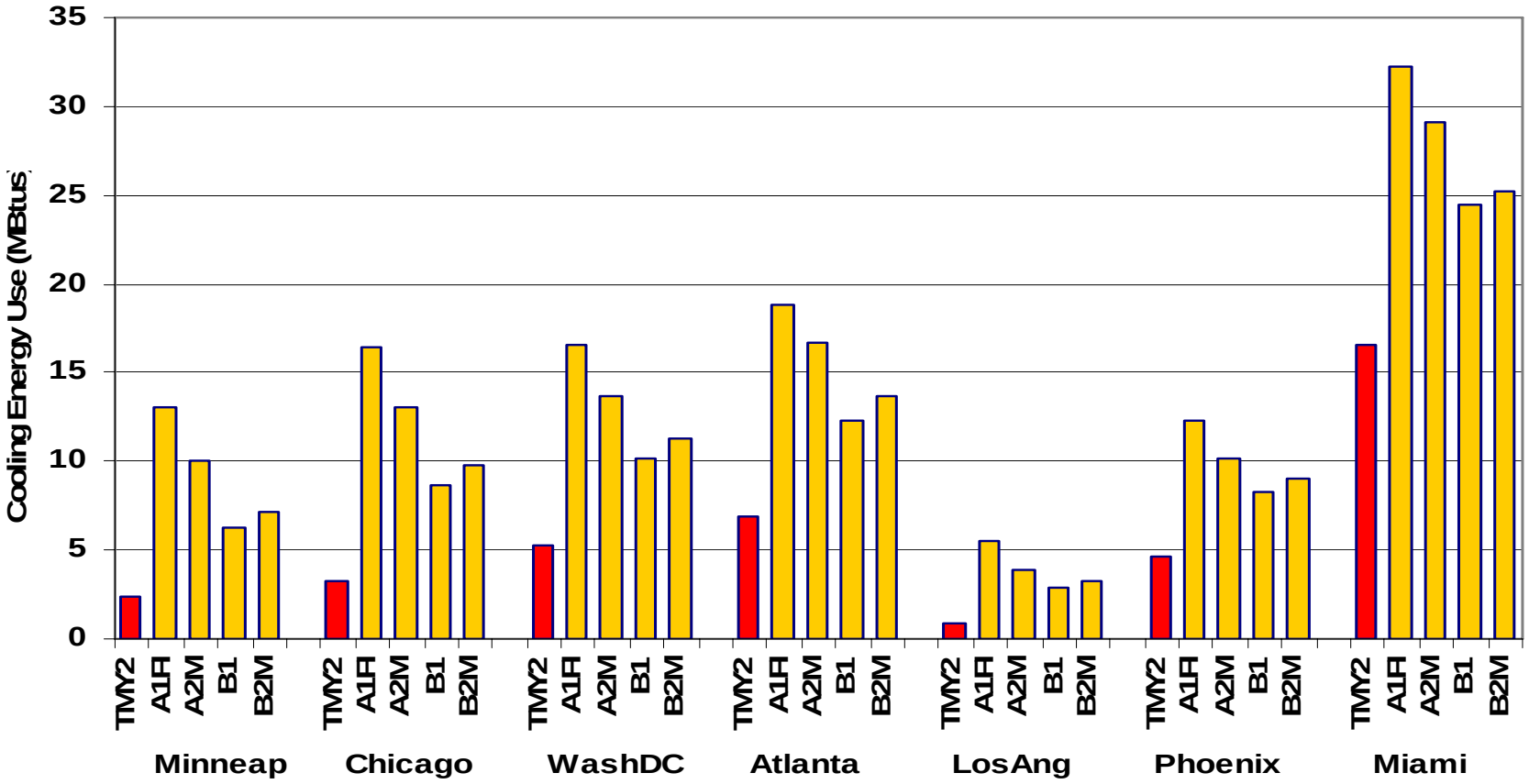


Heating Energy Use for New Single-family Houses for 7 Selected Cities with 4 IPCC Scenarios in 2080 (SAP Study)



Cooling Energy Use for New Single-family Houses for 7 Selected Cities with 4 IPCC Scenarios in 2080 (SAP Study)



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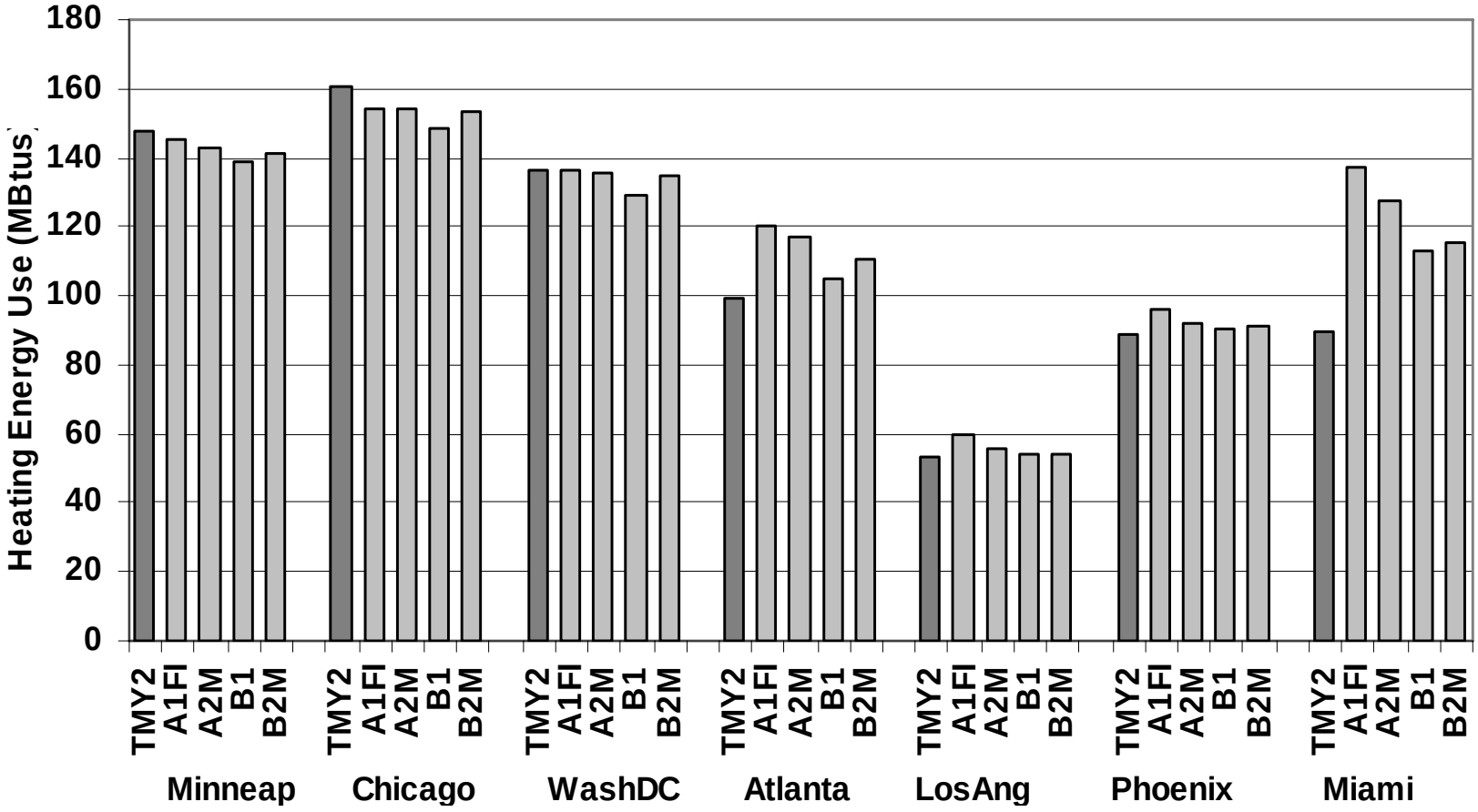
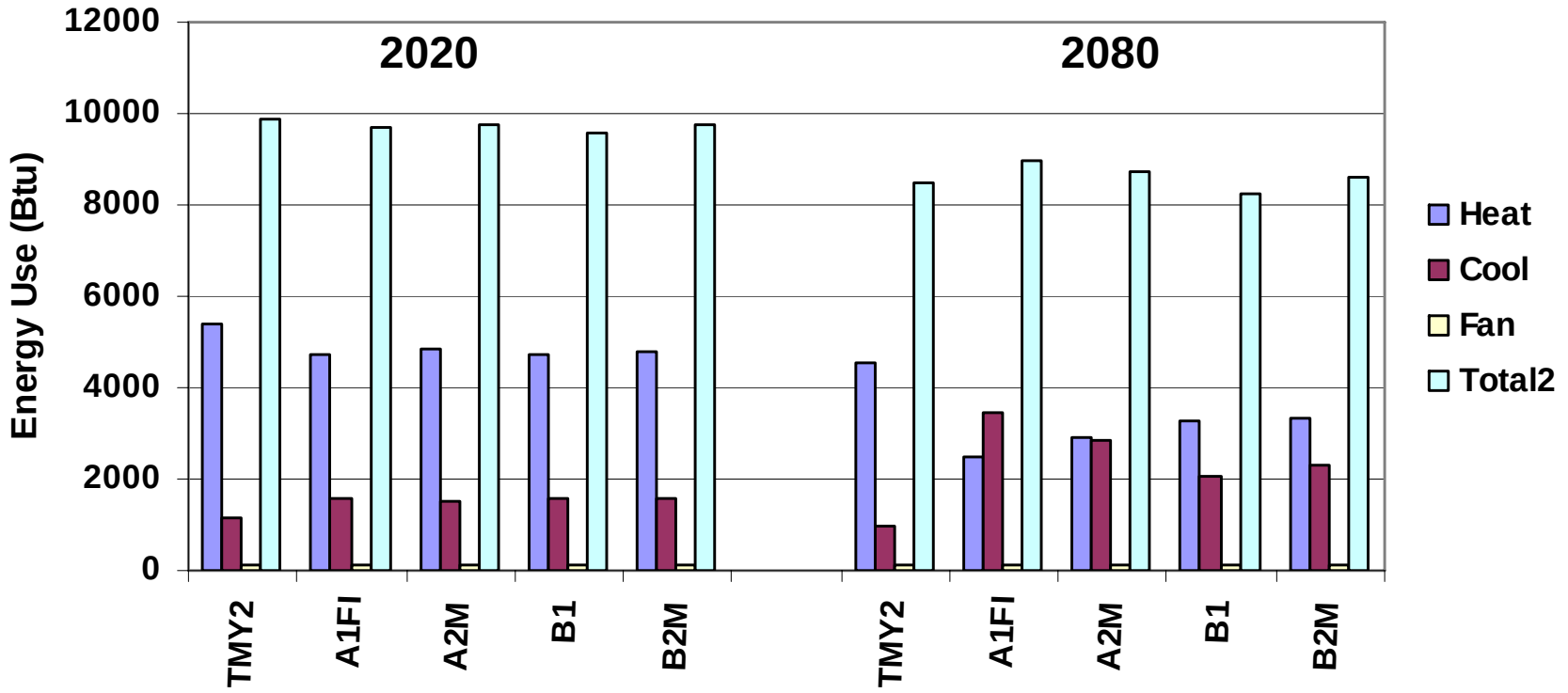
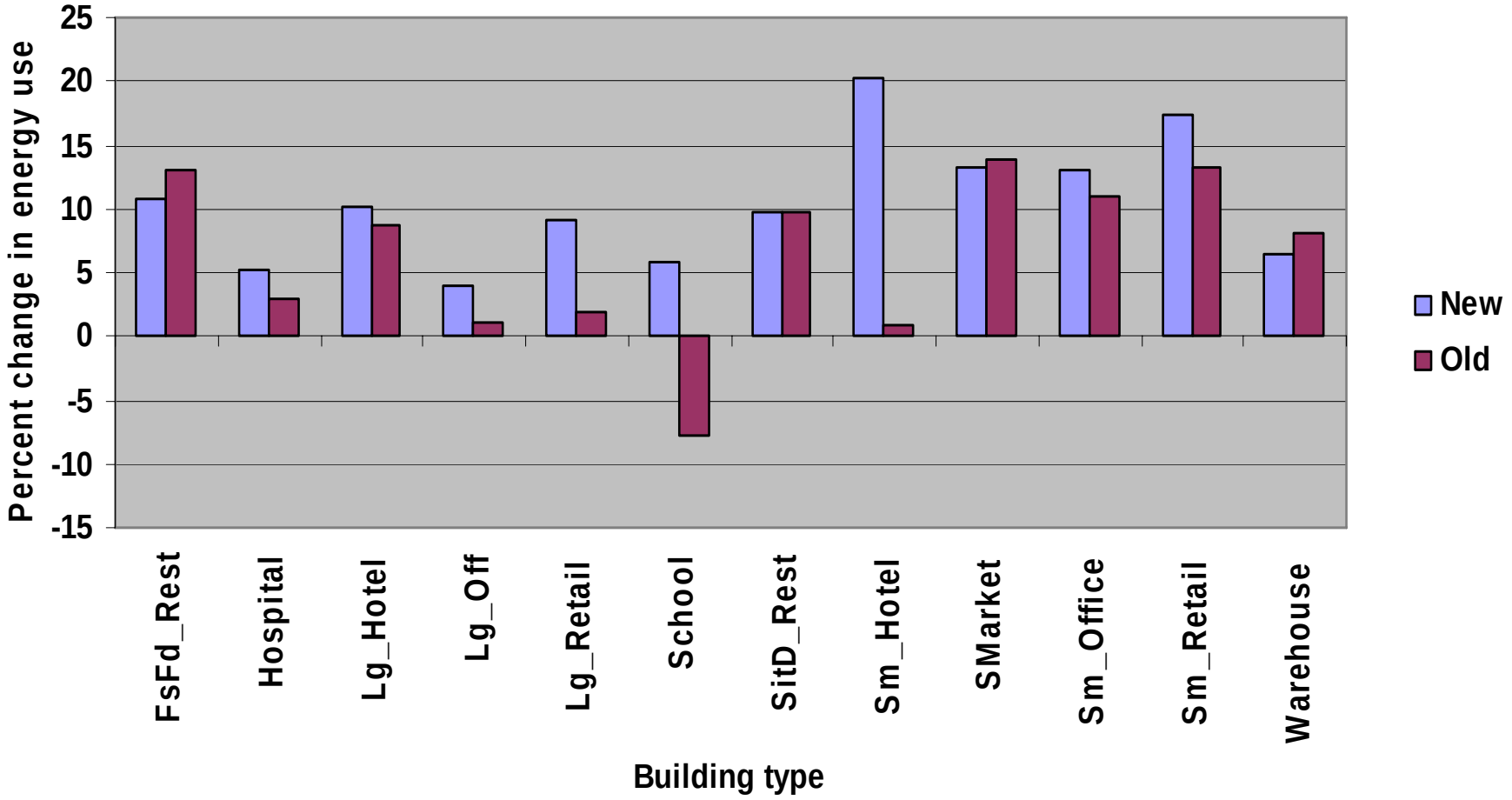


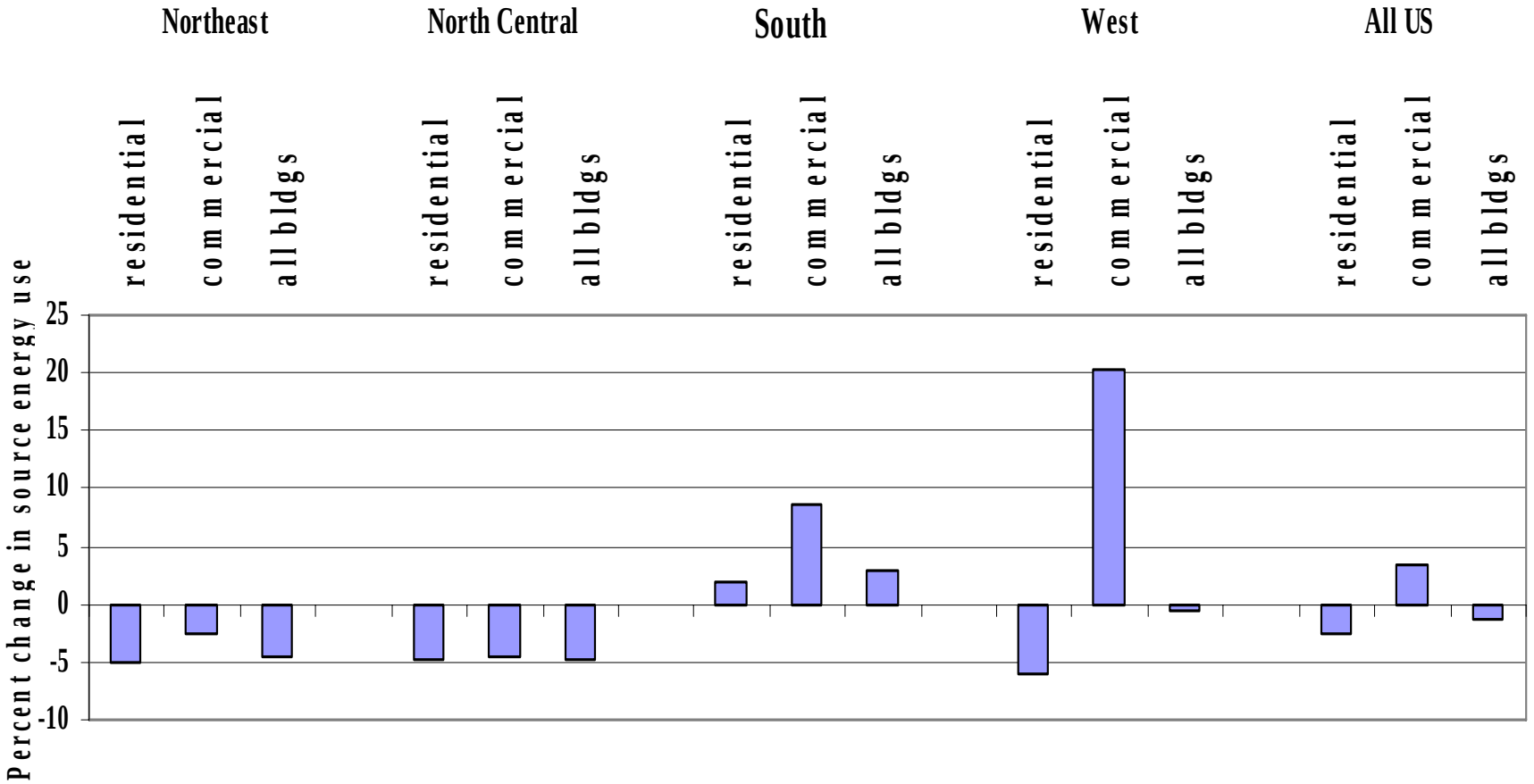
Overall impact on residential building energy use in 2002 and 2008 (SAP Study)



Percent Change in Total Energy Use for Prototypical Commercial Buildings in Los Angeles with IPCC A1FI Scenario in 2080 (SAP study)



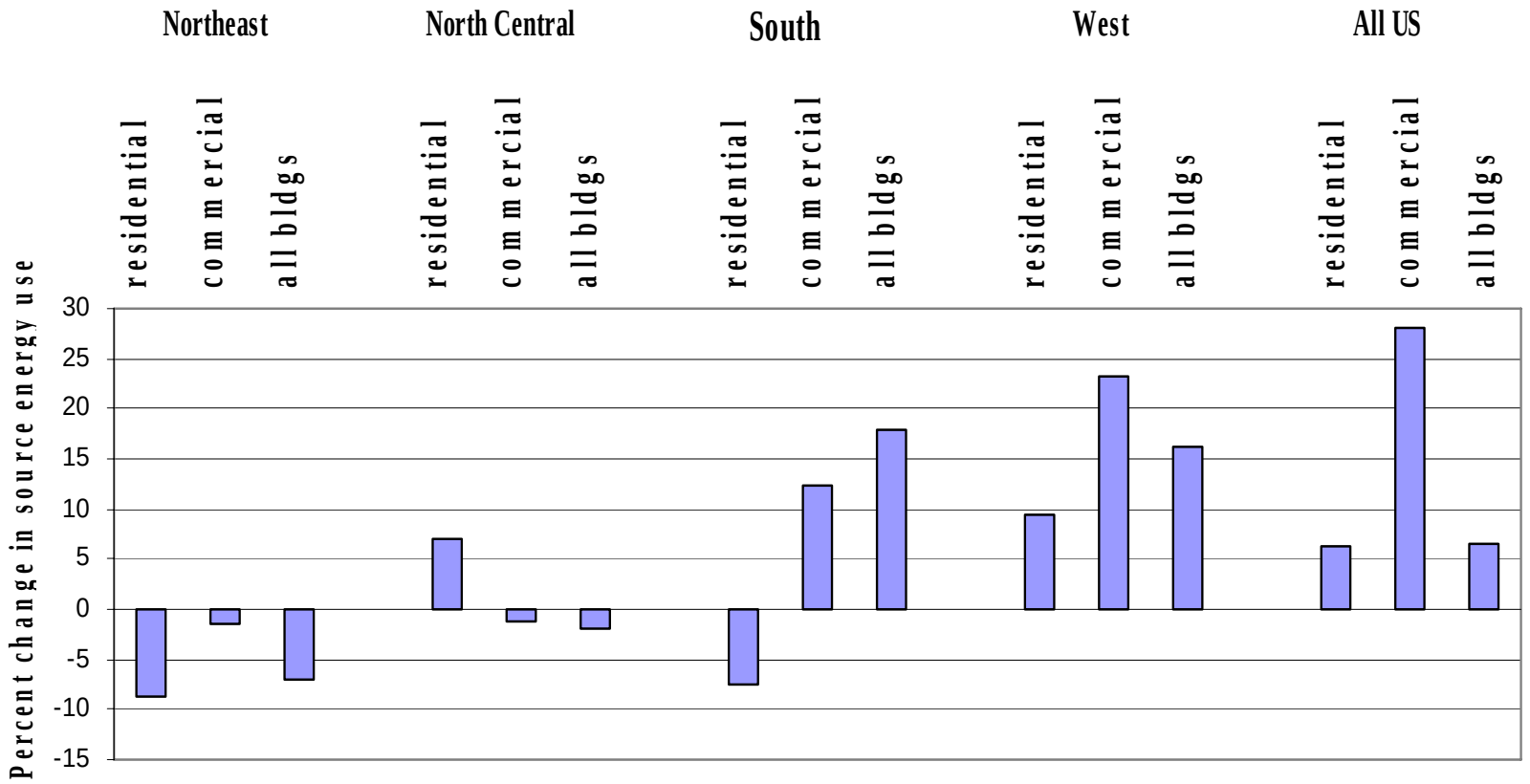
Overall impact of climate change on building energy use in 2020
(SAP Study, in source energy)



Nationally, 7% decrease in site energy use,
or 1-2% decrease in source energy use

Overall impact of climate change on building energy use in 2080

(SAP Study, in source energy)



Nationally, 18% decrease in site energy, or 6% increase in total source energy use .

Conclusions

- **The impact of climate change on building energy use may seem small in the beginning, or when aggregated for the entire building sector due to counteracting effects, but can be significant depending on the building, climate, and time period.**
- **In California, the impact is expected to be from moderate to significant increases in space conditioning energy use**
- **Cooling energy use is expected to increase substantially, particularly in the coastal areas of California.**
- **The Energy Commission should consider factoring in climate change in the weather data used for analysis in setting the Title-24 building energy requirements.**

Climate change impact reports:

- **SAP study report, "The impact of climate change on the energy use of the US residential and commercial building sectors", LBNL-60754, hard copy available from LBNL, PDF copy available on request to me at joe@drawbdl.com.**
- **PIER project report, "Effects of global climate change on building energy consumption and its implications on building energy codes and policy in California", will be available in one month.**

Weather data modification procedures

Program was written in Fortran 90. Please contact me for more details at joe@drawbdl.com

Prototypical building models

DOE benchmark building prototypes were released by NREL in Dec. 2007, please check with NREL for details

Draft LBNL commercial building prototypes in *EnergyPlus* and *DOE-2.1E* are available at http://windows.lbl.gov/staff/yjhuang/commercial.htm