Creating fTMY Weather Data From Climate Models for Building Simulation

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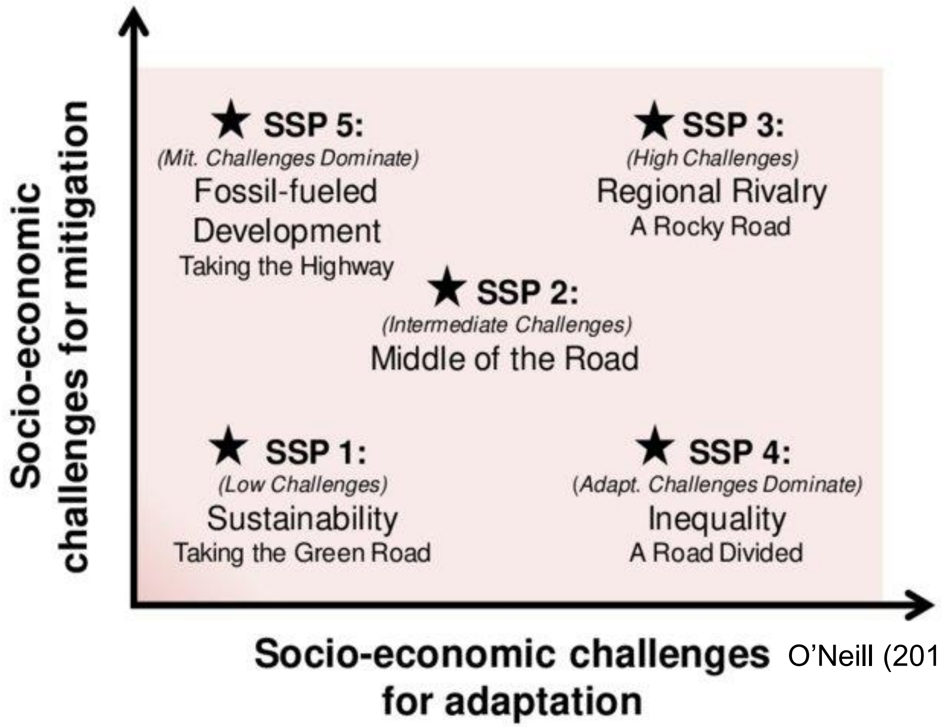
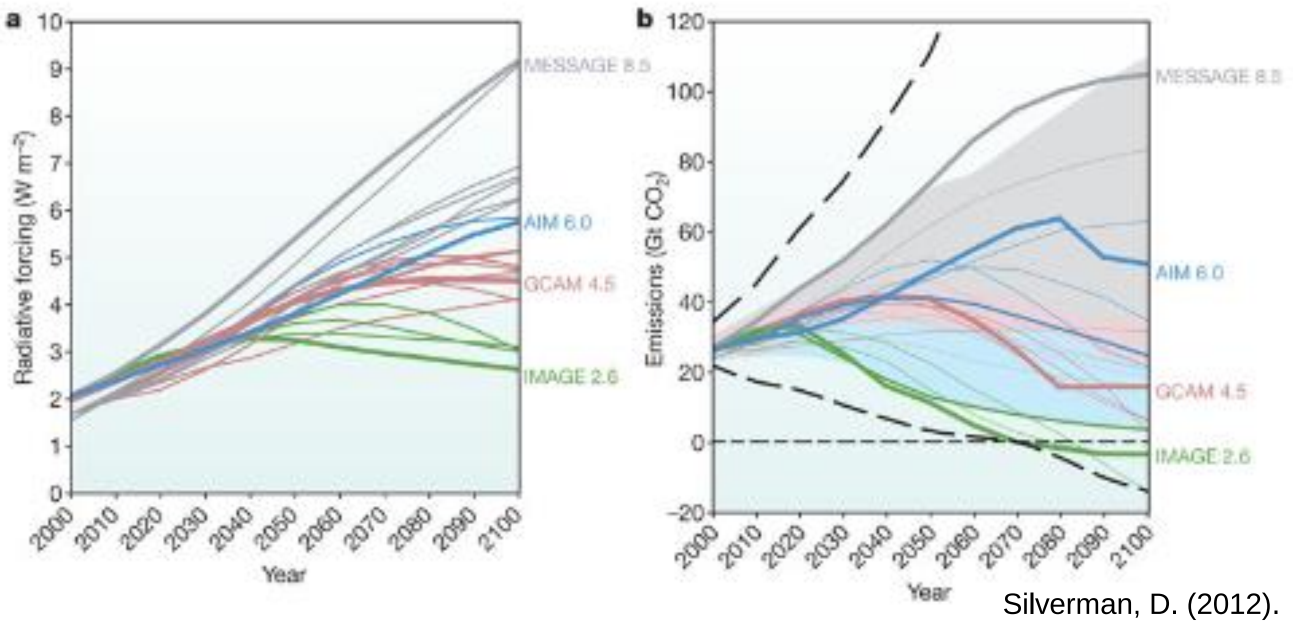
Visual summary of IPCC scenarios

- Intergovernmental Panel on Climate Change (IPCC) created Shared Socioeconomic Pathways (SSPs) to define different future baseline worlds
  - Varying factors such as population, technological, and economic growth



O'Neill (2016).

- IPCC created Representative Concentration Pathways (RCPs) to set pathways for greenhouse gas concentrations
  - Named for amount of radiative forcing by the year 2100
  - Based on future climate policies



Silverman, D. (2012).

Global Climate Model Variability

- Convert IPCC model data to meteorological variables for building simulation (2020-2100)
- Three levels of sophistication
  - Individual future years (as with historical years) may be outliers; how to account for multi-year/temporal variability?
  - There are many different climate models from institutions studying climate around the world; how to account for model variability?
  - There are many grid points that may not be within a region of interest or have multiple points within the area of interest; how to account for spatial variability?

Typical Meteorological Year (TMY)

- Typify weather conditions at a location over a period of time
- Representative month selection
  - Sandia Method
    - Considers statistical representation of several weather variables
      - Dry bulb, dew point, wind velocity, solar radiation
    - Cumulative Distribution Functions (CDFs) are calculated based on each weather variable/statistic combination
    - Each month's variable/statistic combination CDF is compared to the long-term CDF using Wasserstein Distance
    - A <u>weighted</u> sum of the distances is used
    - The months with the lowest weighted sum distances are selected and concatenated

Typical Meteorological Year (TMY)

2010	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2012	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2016	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2017	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2019	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

TMY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year	2011	2018	2014	2016	2016	2012	2017	2018	2015	2013	2019	2019

Future Typical Meteorological Year (fTMY): One Climate Model

2090	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2091	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2092	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2093	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2094	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2095	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2096	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2097	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2098	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2099	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

fTMY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year	2090	2094	2094	2096	2092	2090	2099	2093	2096	2098	2091	2092

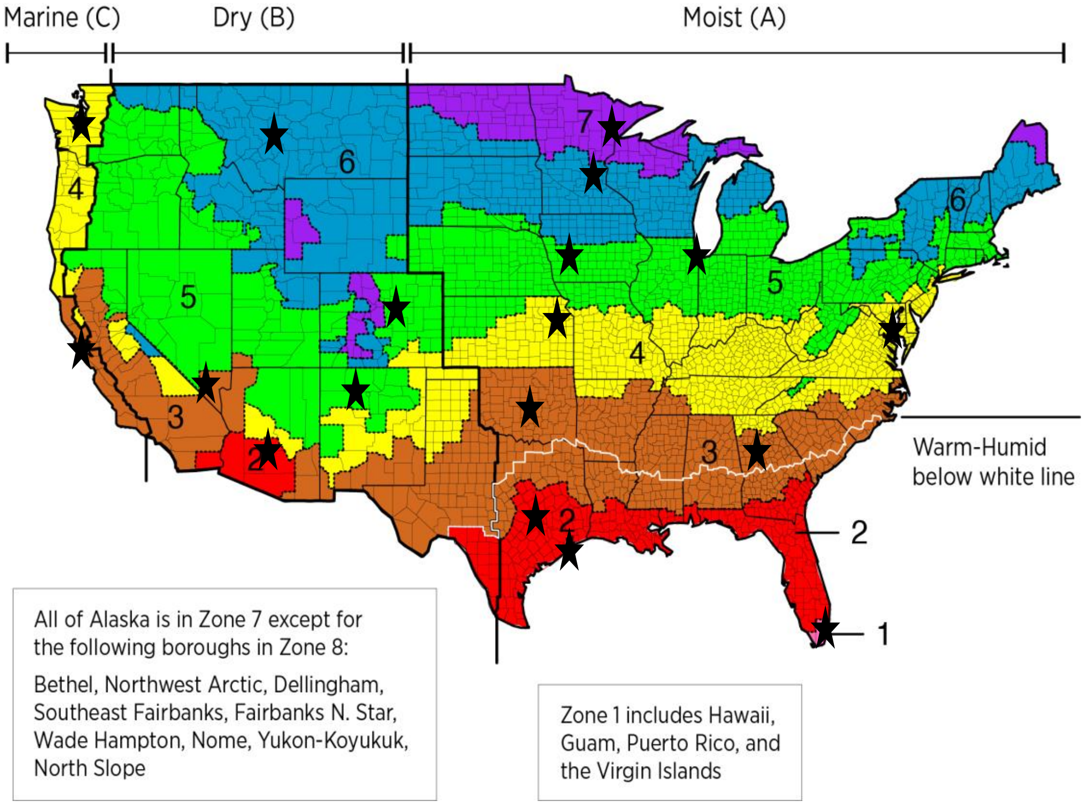
Future Typical Meteorological Year (fTMY): Multiple Climate Models

2090a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2090b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2091a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2091b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2092a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2092b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2093a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2093b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2094a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2094b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2095a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2095b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2096a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2096b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2097a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2097b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2098a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2098b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2099a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2099b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2100a	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2100b	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

fTMY	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Year	2091a	2096b	2093a	2098b	2091a	2100b	2090a	2095b	2093b	2098a	2091a	2099b

Developing fTMY Weather Files

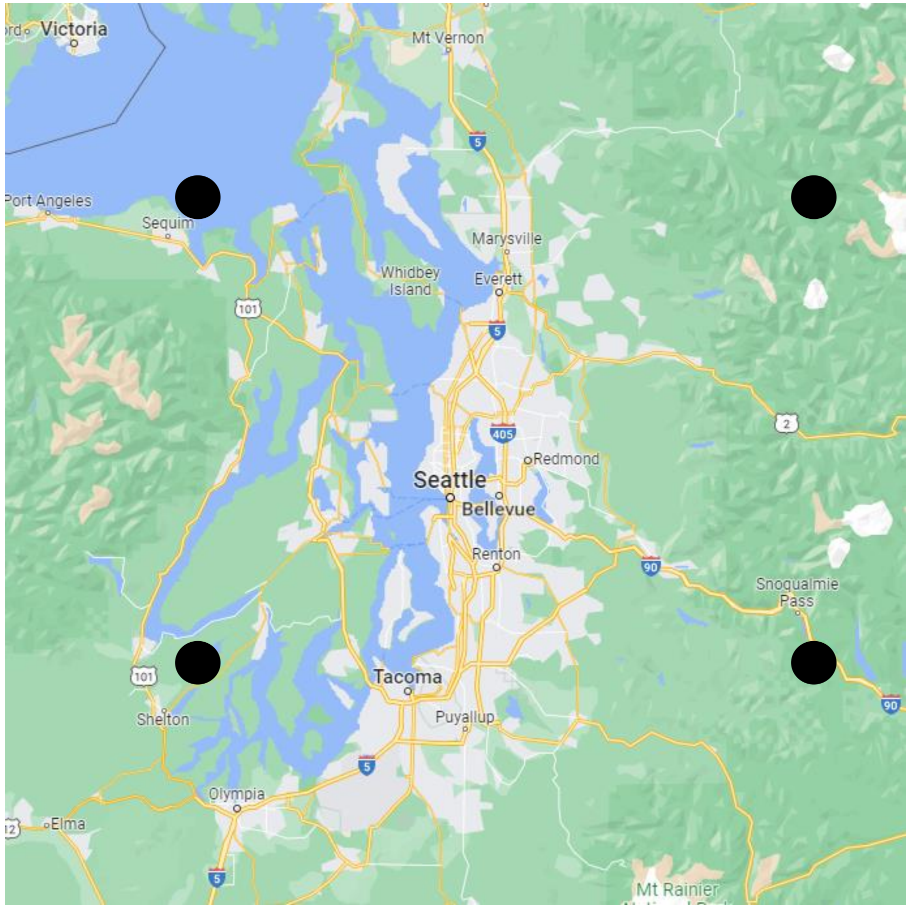
- SSP 5, RCP 8.5
- 2020-2100
- 18 cities in United States
  - Representative cities from each US climate zone
- 6 Climate Models from various climate institutions around the globe
  - ACCESS-CM2
  - BCC-CSM2-MR
  - CNRM-ESM2-1
  - MPI-ESM1-2-HR
  - MRI-ESM2-0
  - NorESM2-MM
- 9 Weather Variables
  - Air Temp
  - Longwave
  - Shortwave
  - Vapor Pressure
  - Vapor Pressure Deficit
  - Relative Humidity
  - Precipitation
  - Wind
  - Pressure



International Code Council (2012)

fTMY Weather File Development

- Spatial resolution of climate models created need for downscaling
- Data was statistically downscaled to increase to better represent city (Rastogi 2022)
- Hourly data was obtained using Mountain Microclimate Simulation Model (MTCLIM)

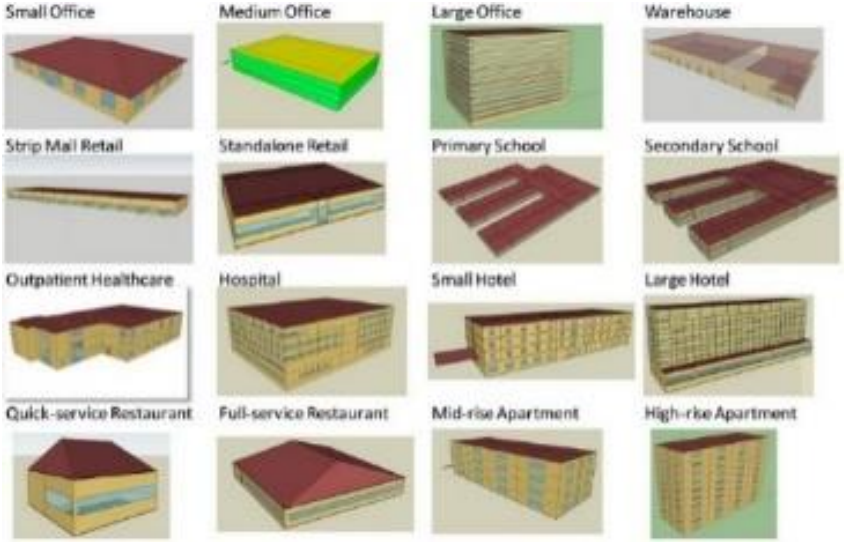


Global Climate Model Grid Points

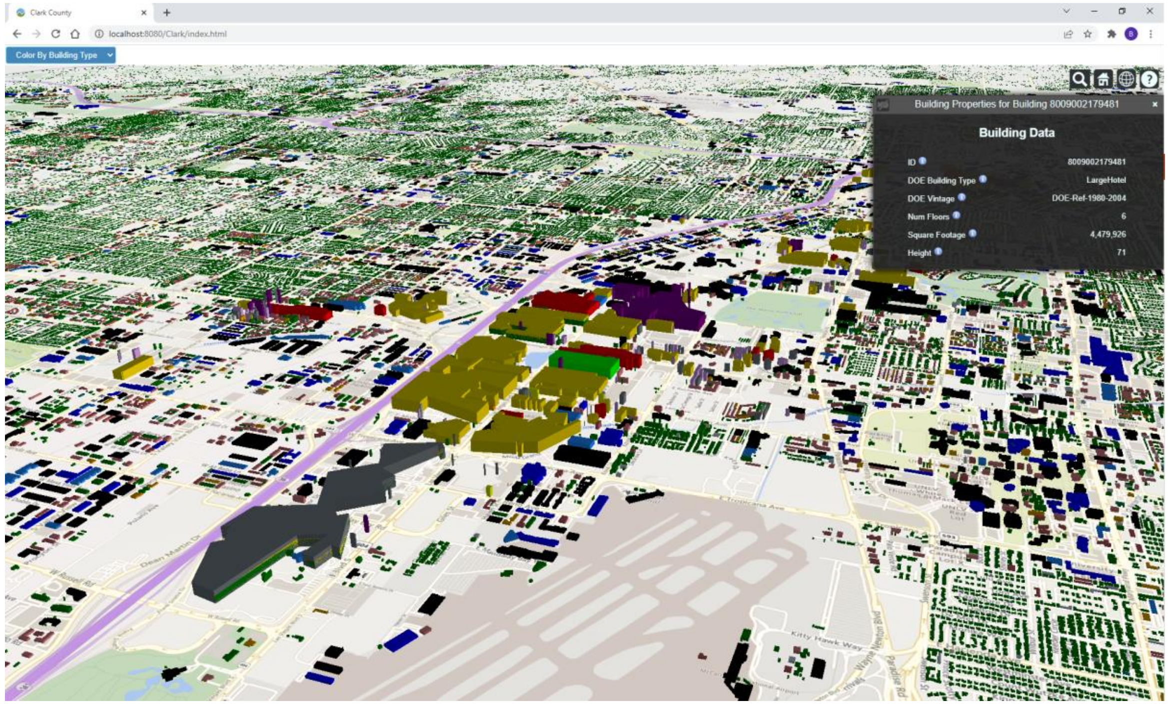
AutoBEM

- AutoBEM takes set of building properties as inputs
  - Building Footprint
  - Building Height
  - Building Type
  - Building Age
- AutoBEM develops building energy models using OpenStudio and simulates Models using EnergyPlus
- Internal characteristics and other building properties (occupancy, equipment, insulation, etc.) determined non-intrusively by building type and year built

OpenStudio



DOE Prototype Buildings



Clark County (Las Vegas) Modeling Example

Maricopa County Case Study

- 144 fTMY weather files were developed
- 20-year periods
  - 2020-2040
  - 2040-2060
  - 2060-2080
  - 2080-2100
- Formatted as Energy Plus Weather (EPW) files for use in EnergyPlus building simulation
- Can be used to assess how climate projections will impact building energy use in future years
  - Initial evaluations of Maricopa County, Arizona

Scenario	Average Dry Bulb Temperature (°F)
2020-2040	24.1
2040-2060	25.8
2060-2080	26.6
2080-2100	29.1

Scenario	Total Energy	Electricity	Natural Gas
2020-2040	0.24 Quads	0.20 Quads	0.04 Quads
2040-2060	4.4%	5.5%	-2%
2060-2080	5.7%	7.9%	-7%
2080-2100	12.7%	17%	-11.3%

Scenario	Total Costs	Total Emissions
2020-2040	$ 8.5 Billion	26 Million Tons CO2
2040-2060	5%	4.4%
2060-2080	6.9%	5.7%
2080-2100	15%	12.7%

Scenario	July Total Energy
2020-2040	0.03 Quads
2040-2060	9%
2060-2080	12.3%
2080-2100	20.7%

Conclusions

- GCM provide estimations of future weather under various socioeconomic and climate scenarios
- TMY are used to select a year of typical weather for a location by selecting representative months from various years
- fTMY data can be created based on the output climate model weather projections, reducing individual year variance
- fTMY data are representative of several different climate models, reducing individual model bias
- fTMY data can be used to assess how the built environment will be impacted by climate change

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Questions?

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