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Rethinking Typical Year Data Modeling for Solar Energy Application

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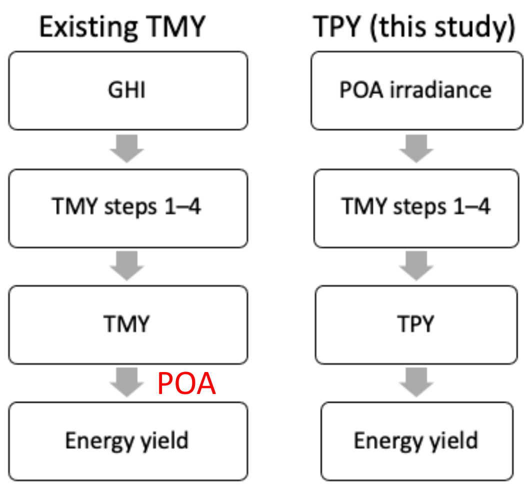
Motivation

- Limitation of the current TMY modeling: the current application of TMY datasets is prone to bias when converted to POA and can be significantly different from a new method to develop and generate a typical dataset.
  - This new approach considers the plane-of-array (POA) irradiance as the main driving variable for the selection of 12 typical months that make up the new dataset, referred to as Typical POA Year (TPY).
  - This study uses the NSRDB dataset (1998–2018) version 3 to produce both TPYs and TMYs for solar energy and various other applications.
  - Hypothetical solar systems information and POA irradiance data for both fixed-tilt and single-axis tracking are used to generate TPYs and associated generation capacity profiles for both TMYs and TPYs.

Method: TMY modeling Approach

Weighting parameters for the TMY and TPY data sets (modified from Wilcox and Marion 2008)

Index	TMY	TPY
Max dry bulb temp	1/20	1/20
Min dry bulb temp	1/20	1/20
Mean dry bulb temp	2/20	2/20
Max dew point temp	1/20	1/20
Min dew point temp	1/20	1/20
Mean dew point temp	2/20	2/20
Max wind velocity	1/20	1/20
Mean wind velocity	1/20	1/20
Global horizontal irradiance/POA	5/20	10/20
Direct normal irradiance	5/20	Not used



Modified from Wilcox and Marion 2008

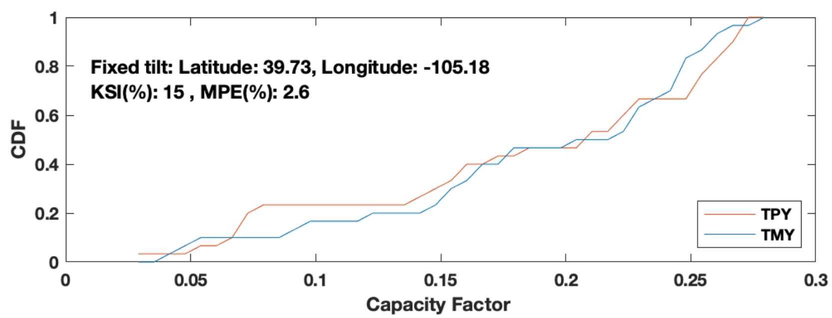
- Step 1
  - For each month of the calendar year, 5 candidate months with cumulative distribution functions (CDFs) for the daily indices that are closest to the long-term (21 years for the current NSRDB) CDFs are selected.
- Step 2
  - The 5 candidate months are ranked with respect to closeness of the month to the long-term mean and median.
- Step 3
  - The persistence of the meteorological parameters (as shown the weighting values in the left table) were evaluated by determining the frequency and run length above and below fixed long-term percentiles.
- Step 4
  - The 12 selected months are concatenated to make a complete year.

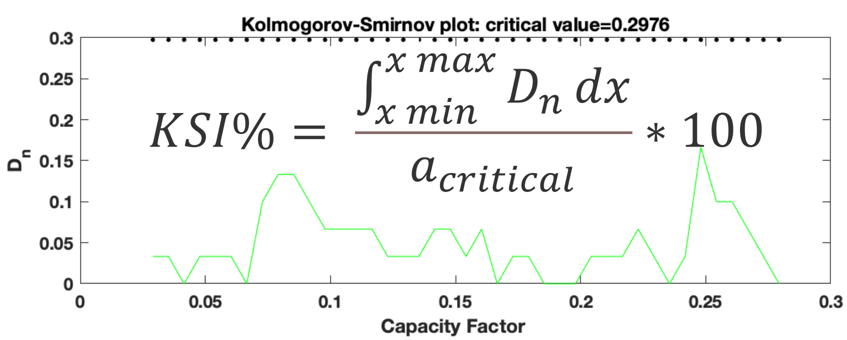
- Perez transposition model on long-term NSRDB time-series data was used to generate POA irradiance data for fixed latitude tilt and single-axis tracking (east-to-west tracking) orientations.
- Hourly data from the POA irradiance timeseries to generate a typical POA year (TPY) by changing the weight.

Method: Statistical Evaluation

Statistical Metrics

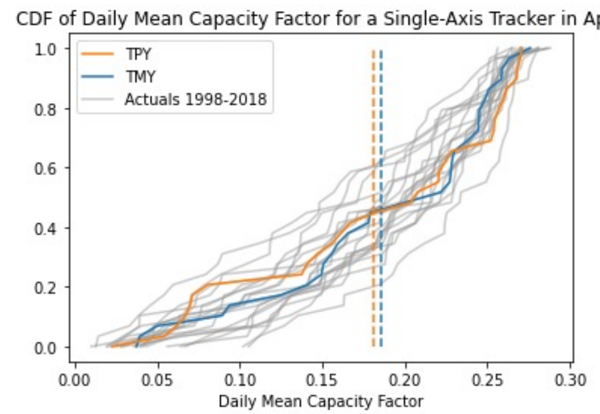
$$MBE\% = \sum_{i=1}^{n} \frac{(TMY_{cf_i} - TPY_{cf_i})}{TPY_{cf_i}}$$





$$KSI\% = \frac{\int_{x\,min}^{x\,max} D_n\,dx}{a_{critical}} * 100$$

CDF Differences between TPY and TMY



The figure demonstrates the daily averages of capacity factor (CF) (Y-axis) for one location/pixel for the month of April for single axis scenario for TPY and TMY. It is showing that the typical datasets have differences.

Method: Energy Yield and Evaluation

Energy Yield Simulation

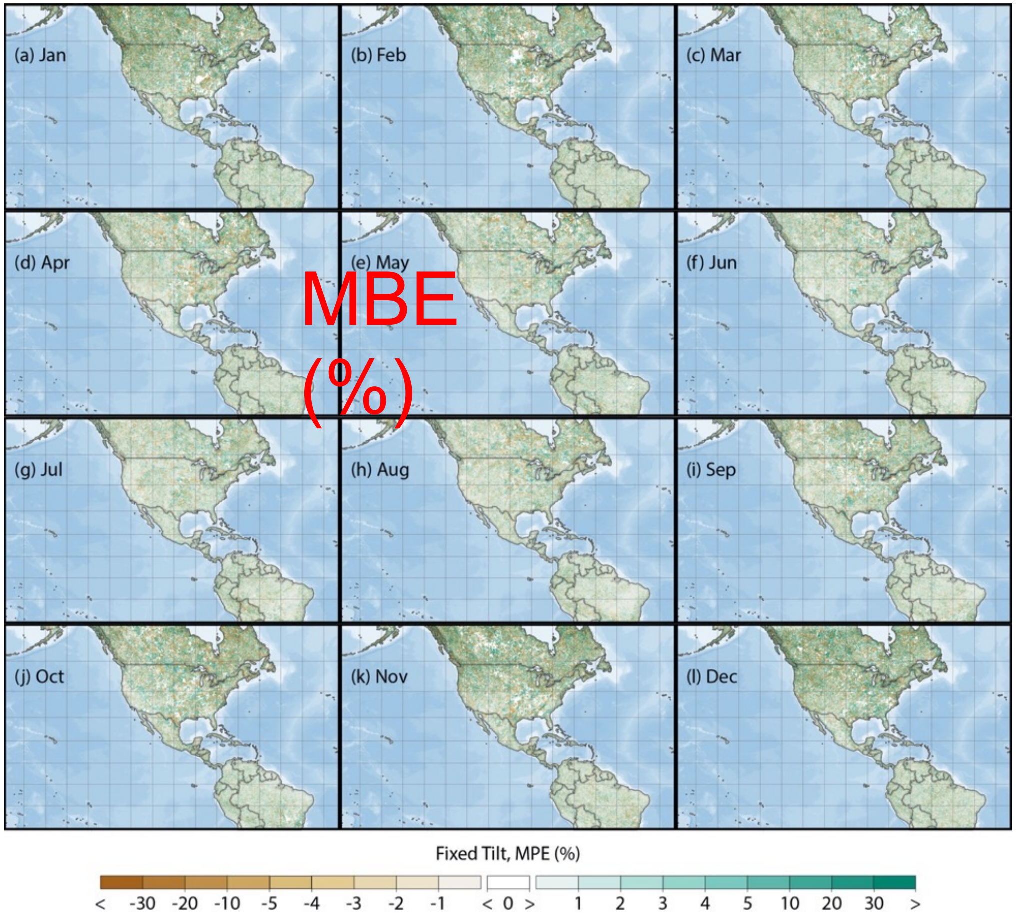
System model inputs for Energy yield simulation		
Input Description	Fixed	Single-Axis
Azimuth angle (degrees)	180	180
DC/AC ratio	1.1	1.1
Ground coverage ratio (GCR)(fraction)	0.4	0.4
Inverter efficiency (%)	96	96
System Losses (%)	14.0757	14.0757
System size (MW)	5	5
Tilt (degrees)	latitude	0
Software Module	pvwattsv7	pvwattsv7

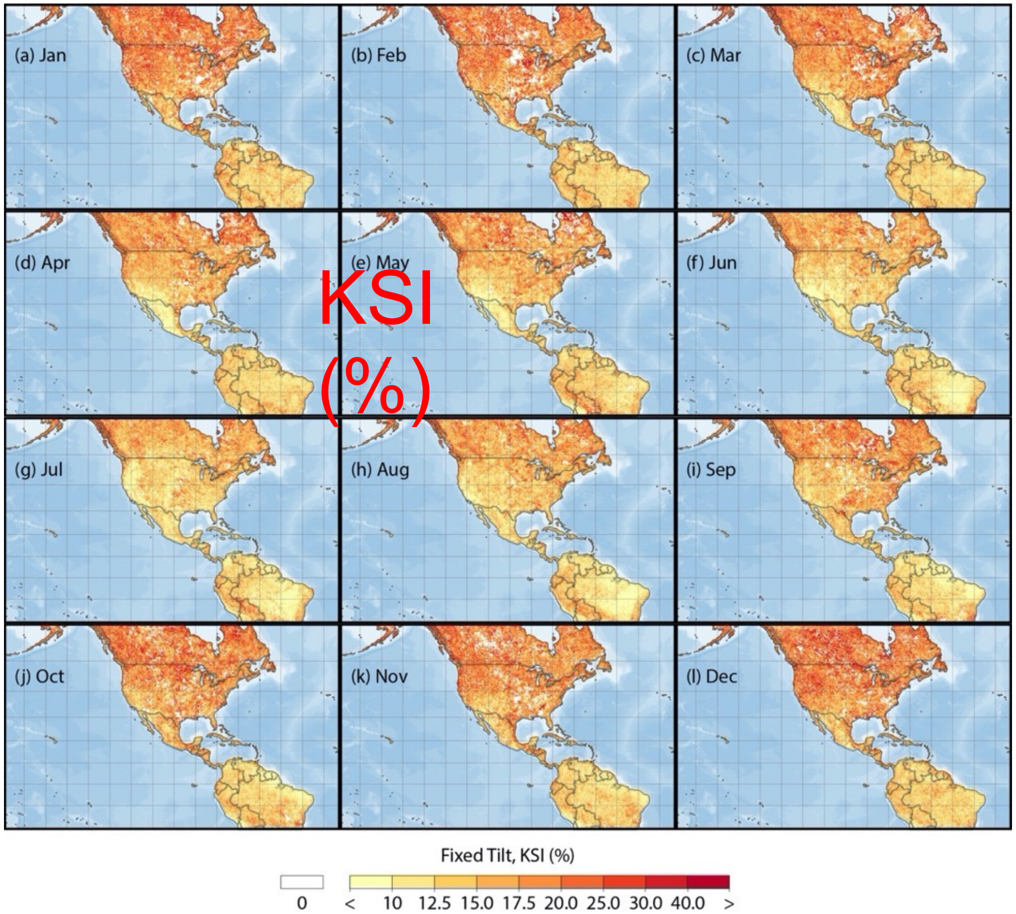
The analysis implemented Köppen-Geiger (KG) climate zones to provide insight into interpreting the results

Climate Zones

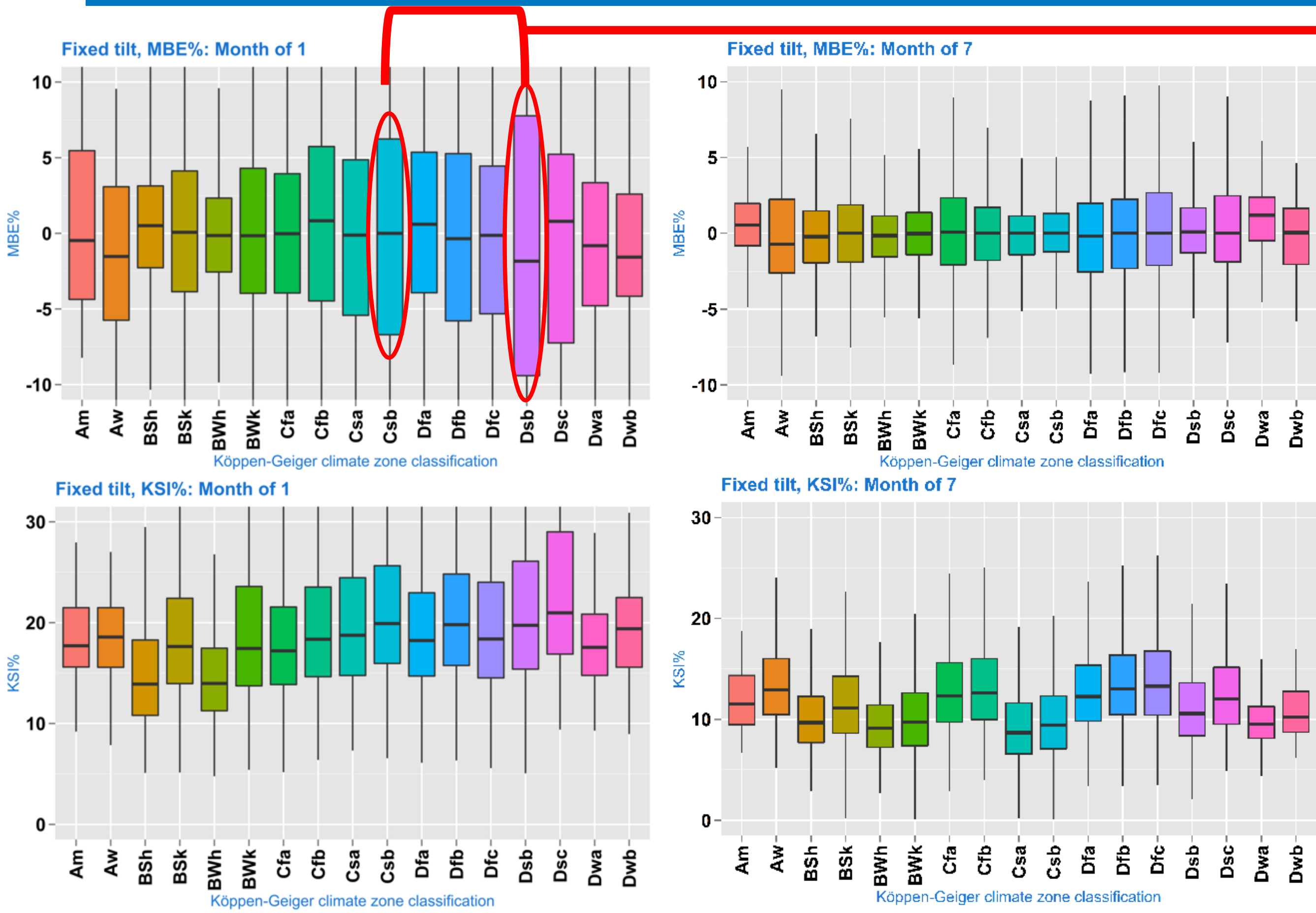
Climate zones based on Köppen-Geiger		
Main Climates	Precipitation	Temperature
A: equatorial/tropical	W: desert	h: hot arid
B: arid & semi-arid	S: steppe	k: cold arid
C: warm temperate	f: fully humid	a: hot summer
D: snow	s: summer dry	b: warm summer
E: polar	w: winter dry	c: cool summer
	m: monsoonal	d: extremely continental
		f: polar frost
		T: polar tundra

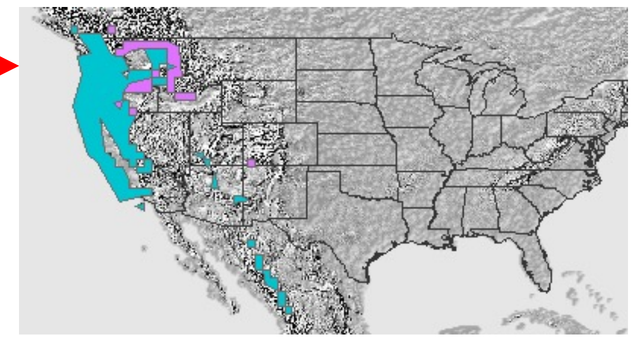
Result at the Regional Scale (Latitude Tilt)





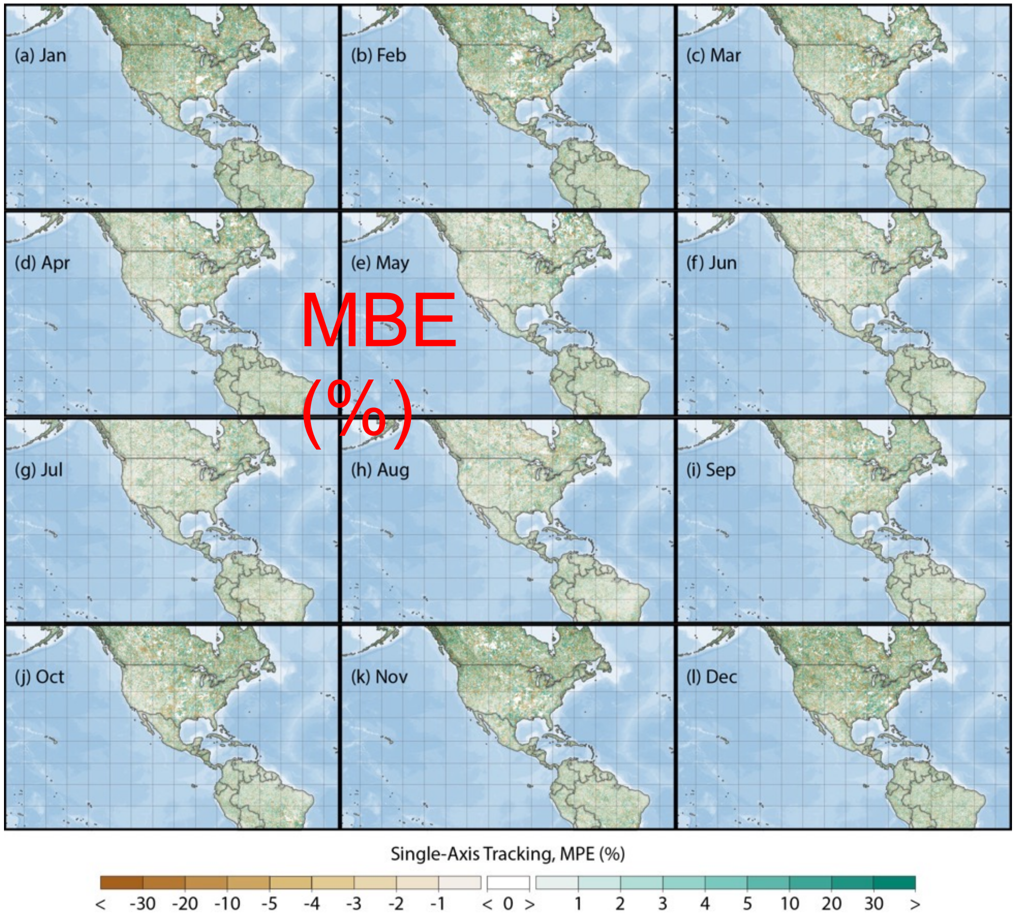
Result by Climate Zones (Latitude Tilt)

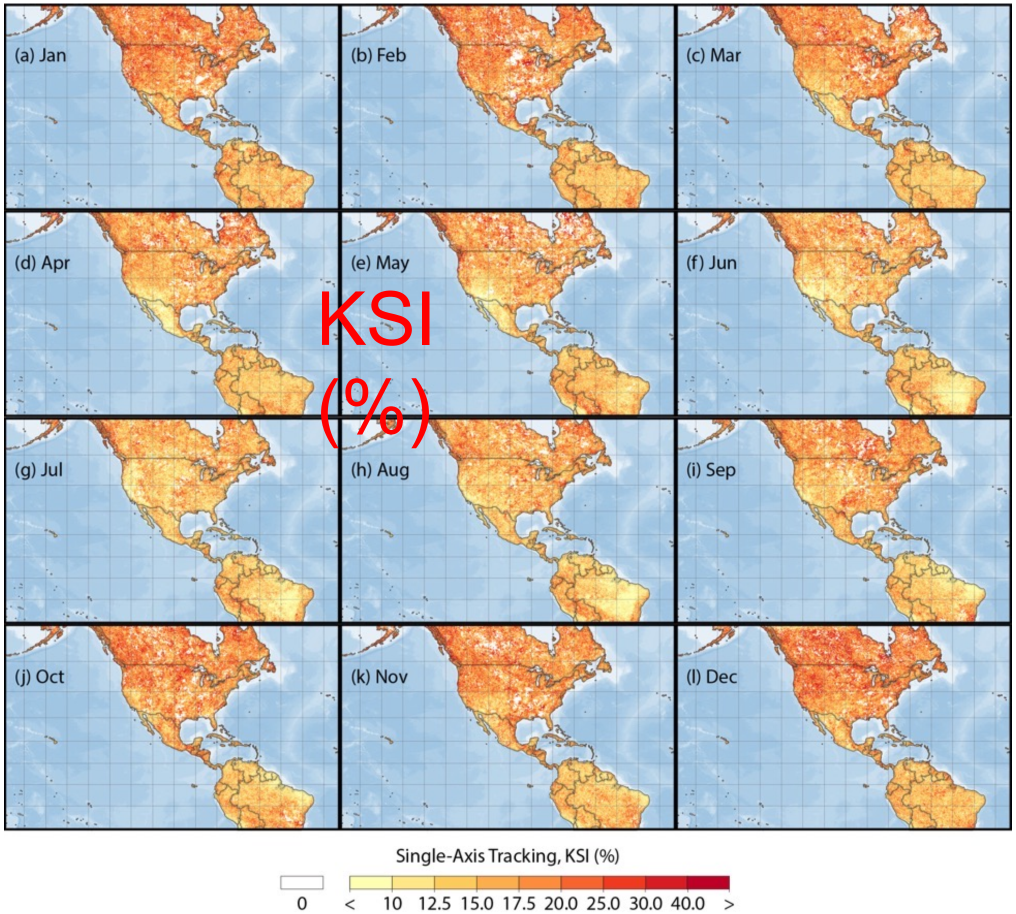




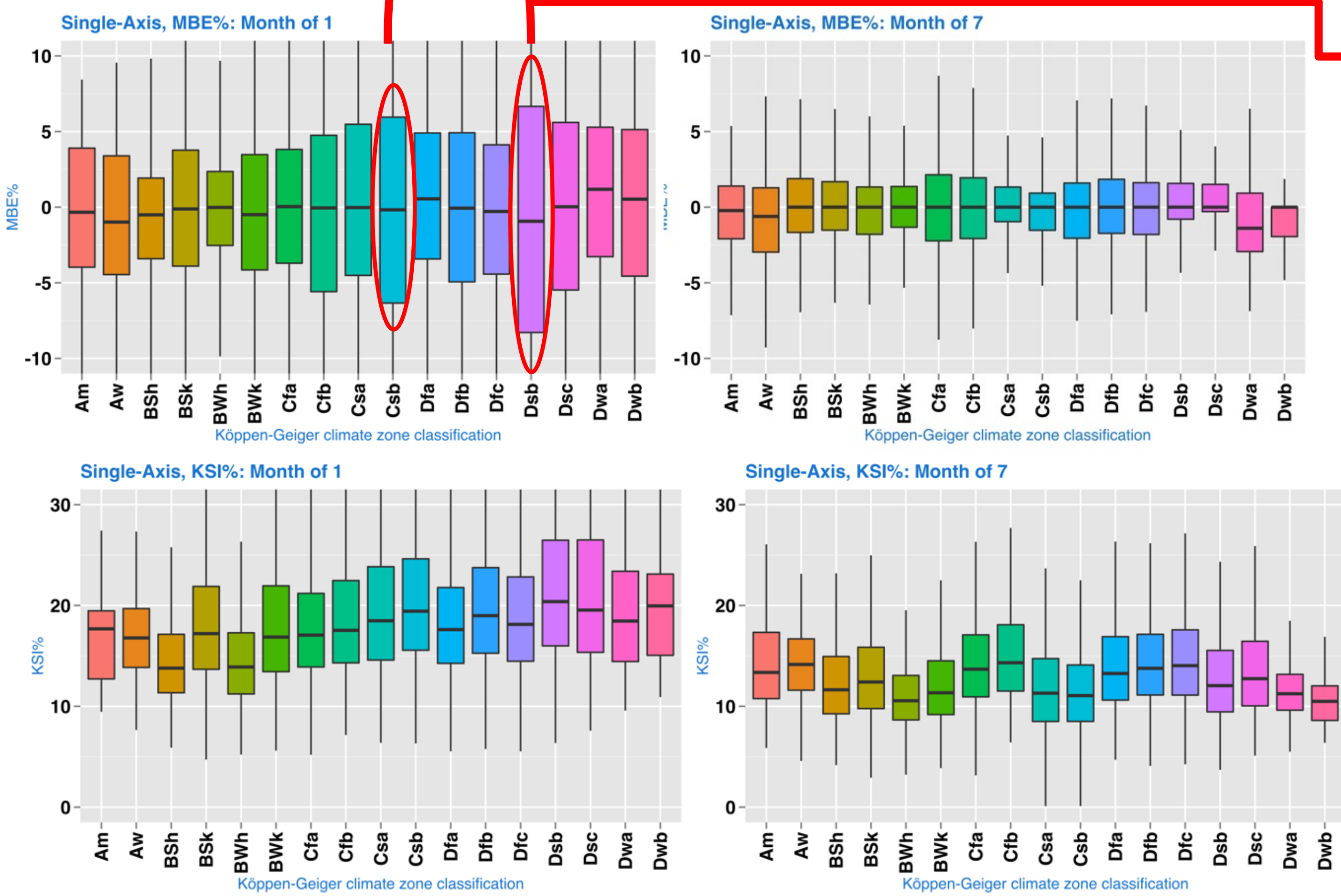
The figures demonstrated the existing TMY dataset overestimates energy yield by about ±5 % as shown by the MBE statistic as compared to TPY for most of climate zones. However, the snow or continental and warm temperate climate zones labeled as 'Dsb' and 'Csb' demonstrated higher differences in the winter months and slightly higher in the summer months.

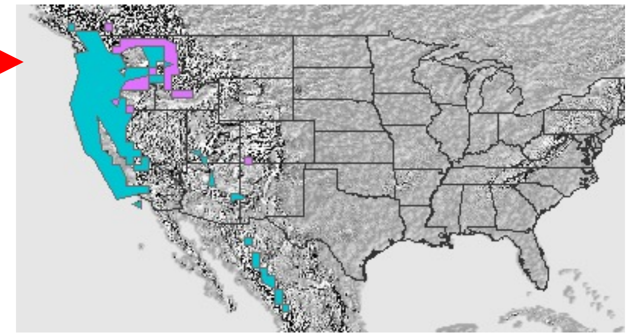
Result at the Regional Scale (Single Axis)





Result by Climate Zones (Single Axis)





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Summary

- TMY datasets are used during the design phase of many projects, such as roof top PV.
- This paper describes a rigorous approach to remove the main limitations of the current TMY formulation and develop a methodology that is better adapted to solar applications.
- This new approach, which results in a TPY file, demonstrated significant differences over the Americas, with the magnitude depending on climate zone and season, when compared to the corresponding TMY dataset.
- The conventional TMY datasets typically mis-predict the energy yield of PV systems by about ±5% over the interquartile range, as compared to TPY. That difference can even reach up to ±30% in some areas, particularly in winter.

Thank You!

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