Typical Meteorological Years for 33 locations in Greece: a handy tool for various applications

Basil Psiloglou[1], Harry Kambezidis[1], Dimitris Kaskaoutis[1], Dimitris Karagiannis[1], Kalliopi Petrinoli[1], Ariadne Gavriil[1], Kosmas Kavadias[2]

3rd ADAPTtoCLIMATE conference, 19-20 April, Athens, Greece

[1]Institute for Environmental Research and Sustainable Development, National Observatory of Athens, Athens, Palaia Penteli, Greece
[2]Laboratory of Soft Energy Applications and Environmental Protection, University of West Attica, Athens, Greece

Introduction

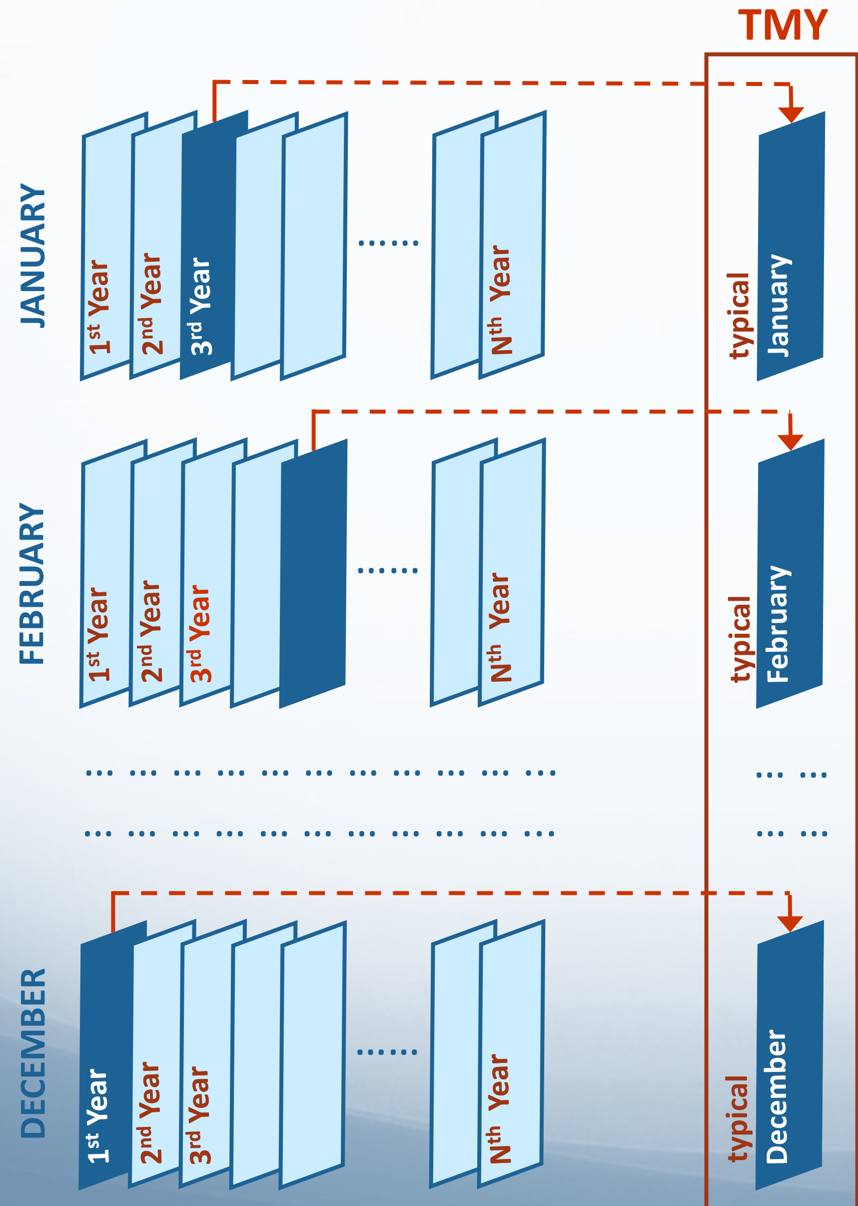
The concept of the Typical Meteorological Year (TMY) was firstly introduced in the late 1970s in USA (Crow 1970; 1980; 1983), as a design tool for approximating expected climate conditions at specific locations, at a time when computers were much slower and had less memory than today.

A TMY is a collation of selected weather data for a specific location, listing usually hourly values of meteorological and solar radiation elements for one-year period. The values are generated from a data bank of at least 10 years in duration.

It is specially selected so that it presents the range of weather phenomena for the location in question, while still giving annual averages that are consistent with the long-term averages for the specific location.

TMY sets remain in popular use until today consisting a handy tool between building designers and renewable energy systems engineers, providing them with a relatively concise set of data for system performance estimates, without the need of incorporating large amounts of data into simulation models.
Commercial software packages such as TRNSYS, Energy+, PV*SOL, PVscout and PVsystand support simulations using TMY data.

Each TMY data file consists of 12 months chosen as most "typical" among the years present in the long-term data set. *TMY is NOT the Average Meteorological Year*.



There are various methodologies to generate TMYs. The most well-known methods are :

(i) The **Danish method** (Andersen et al. 1977; Lund and Eidorff 1990; Lund 1995),

(ii) the **Festa-Ratto** (Festa and Ratto 1993) which is a modification of the Danish one, and

(iii) the **MSNL** (modified Sandia National Laboratories).

The Festa-Ratto methodology requires complicated statistical treatment of the data.

The **MSNL method** is a simpler statistical procedure and gives the opportunity to the user to select **Weighting Factors** for the parameters involved according to the application, and has **been selected in this study.**

The MSNL is an empirical method developed by Hall et al. (1978); it uses (i) the Finkelstein-Schäfer (FS 1971) method for arbitrary (non-Gaussian) cumulative distribution for testing the goodness of fit and (ii) the selection process proposed by Argiriou et al. (1999).

Advantages for TMY usage

- a TMY consists of "typical" months that contain REAL observations
- it presents the range of weather phenomena for the location in question, giving annual averages that are consistent with the long-term averages for the specific location
- TMYs are representative of the climatology at a location in the reference period
- useful tool for system performance estimates, without the need of incorporating large amounts of data into simulation models

Disadvantages for TMY usage

- TMY data sets are generated by first defining their "typical" months from a process of weighting various meteorological and solar radiation parameters and then gathering them to form a TMY
- TMY expresses essentially the 50th percentile of a parameter value expectancy, i.e. the probability that this value will be in the 50% confidence interval of the parameter.
- because of the way they have been created in, TMY data sets do not provide information about extreme events and do not necessarily represent actual conditions at any given time
- TMYs include also "filled" data values via statistical techniques, which otherwise would be missing due to lack of observations, thus reducing its accuracy.

Previous attempts to generate TMY for locations in Greece :

- **Pissimanis et al. (1988): TMY for Athens using data in the period 1966-1982**
  (17 YEARS)

- **Petrakis et al. (1996): preliminary results for Athens using data in 1977-1993.**
  (17 YEARS)

- **Argiriou et al. (1999): TMY for Athens using data in the period 1977-1996.**
  (20 YEARS)

- **Markou et al. (2007): created a DAYLIGHT Reference Year (DRY) for Athens**

- **Tsoka et al. (2018): Typical Weather Year (TWY) for building energy simulations that accounts for the Urban Heat Island (UHI) effect – application to Thessaloniki**

- **Kavadias et al. (2016, 2018): first attempt to generate TMYs across Greece, using HNMS data from 39 stations in the period 1989-2004 (during a PhD work), NOT published as that work resulted in the construction of a SOLAR MAP for Greece for application to energy saving in buildings and PV system design.**
  (16 YEARS)

In this Study

Data from 40 stations of the Hellenic National Meteorological Service (HNMS) network was initially obtained for the period 1985-2014 (30 YEARS).

With 30 years of data, all of the shorter-term weather variations are included, such as those caused by El Niño and La Niña episodes, or even the 11- or 22-year sunspot cycle. The short-cycle events that can last several years definitely influence the resulting means or persistence measures.

7 stations had availabilities of 60% or less for all parameters and were rejected from further analysis => finally 33 stations remain for TMY generation

Measurements :

- Dry-bulb temperature (T in °C)
- Relative Humidity (RH in %)
- Atm. Pressure at sea level (P_o in hPa)
- Wind Speed (in knots)
- Rainfall (R in mm)
- SunShine Duration (SSD in hours)

O_3 vertical column, Aerosol Optical Depth, Fine Mode Fraction, Total Cloud Fraction

MRM v.6

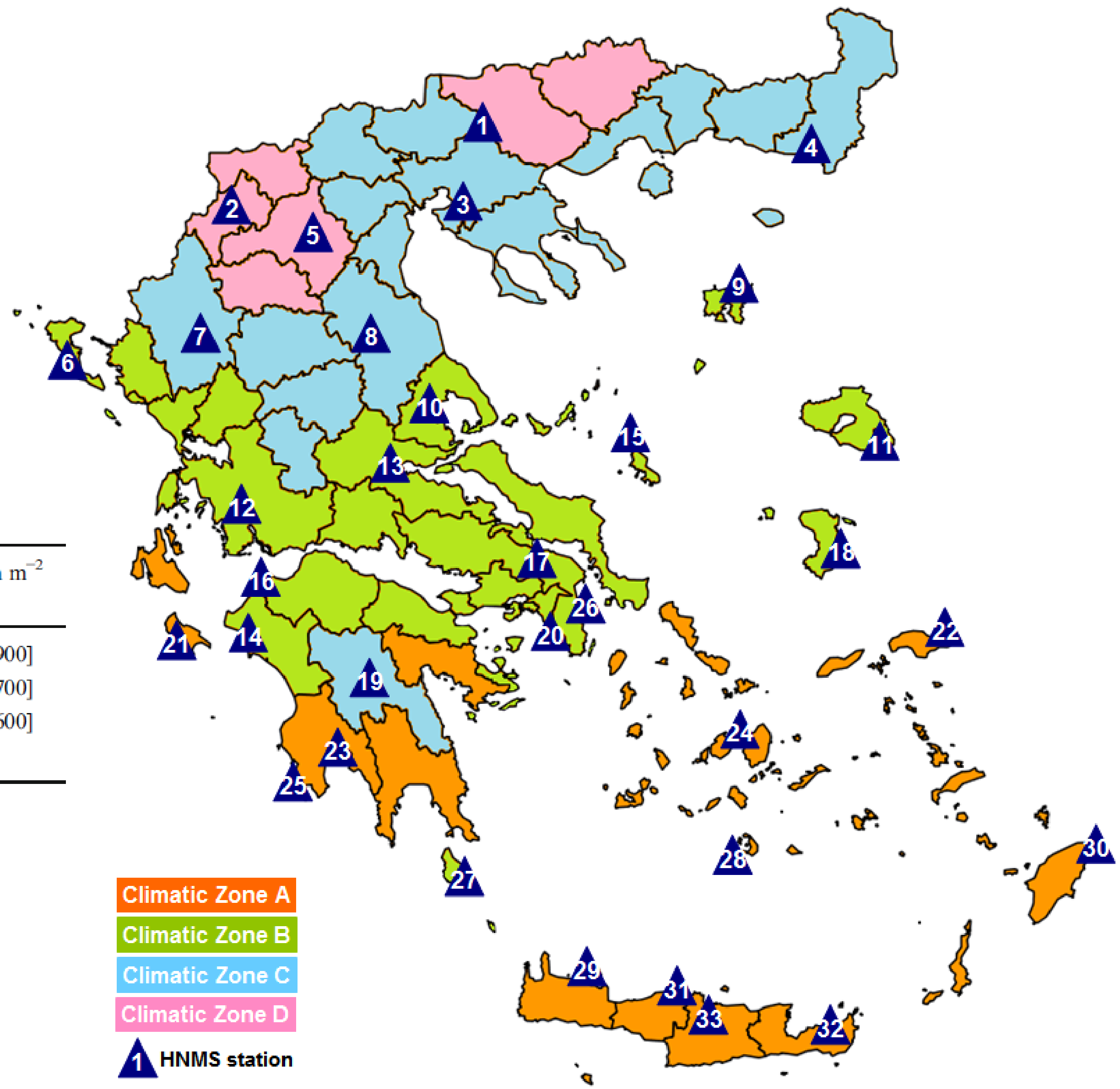
Calculations :

- Specific Humidity (Q in kg/kg)
- Atm. Pressure at station level (P_z in hPa)
- Global (G_e), Diffuse (D_e), Direct (B_e) solar radiation (in W/m^2), using MRM v.6 broadband radiation algorithm developed by the Atmospheric Research Team of NOA

Distribution of the 33 selected HNMS stations (blue triangles) across the 4 climatic zones of Greece for energy purposes.

Climatic zone	HDD (dimensionless)	CDH (dimensionless)	SR (kWh m^{-2} y^{-1})
A	< 1000	[1300, 4500]	[1700, 1900]
B	[1000, 1500]	[2200, 5500]	[1500, 1700]
C	[1500, 2000]	[1200, 3800]	[1450, 1600]
D	≥ 2000	≤ 1500	≤ 1500

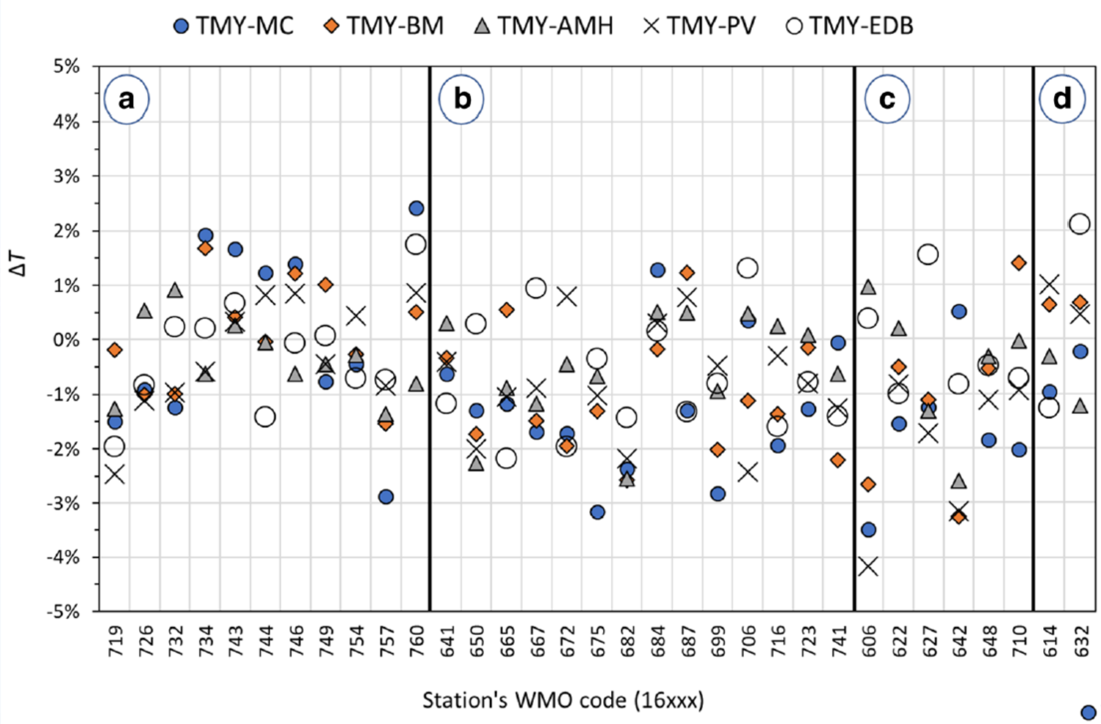
Range of annual HDD, CDH, and SR values to define the climatic zones in Greece for energy saving in buildings according to the Technical Chamber of Greece report (Tech. Guideline No. 20701-1, 2010)



HDD : number of days during the cold period of the year needed to heat a building from the aver. ambient T to 18°C
CDH : number of hours during the warm period of the year needed to cool a building from the aver. ambient T to 26°C
SR : available solar radiation per year

Weighting Factors of the selected parameters used for the generation of TMYS for 5 applications across the 33 locations in Greece.

Parameter	TMY Meteorology Climatology	TMY Bio-Meteorology	TMY Agro-Meteorology Hydrology	TMY Photo-Voltaics	TMY Energy Design of Buildings
$Tair_{ave}$	0.09	0.25	0.20	0.10	0.25
$Tair_{max}$	0.04			0.05	
$Tair_{min}$	0.05			0.05	
RH_{ave}	0.08	0.25	0.15	0.10	
RH_{max}	0.04			0.05	
RH_{min}	0.04			0.05	
Q					0.25
P_z	0.04				
G_e	0.50	0.30	0.15	0.25	0.50
B_e			0.15	0.25	
WS_{ave}	0.08	0.20	0.15	0.05	
WS_{max}				0.05	
R	0.04		0.20		
SUM	1.00	1.00	1.00	1.00	1.00
	Based on Pusat et al. (2015) and Sepúlveda et al. (2014).	After advice from Prof. A. Matzarakis, DWD	Proposed for the first time by the research team	Based on Cebecauer and Suri (2015)	Based on Sun et al. (2017)

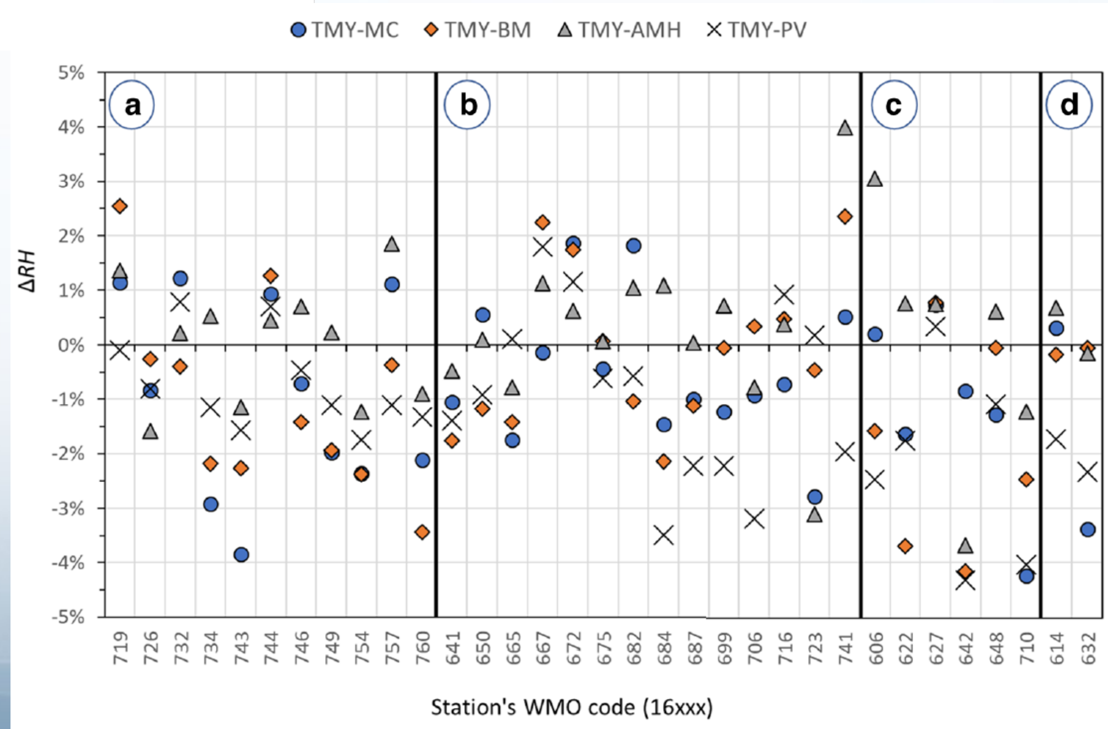


Representativeness of the derived TMYs

The validity of the various TMYs was assessed by calculating the % difference between the time series of every meteorological parameter in each TMY and its corresponding average value (climatic mean) of the 30-years period.

$$\Delta x_p = \frac{\overline{X_{p,TMY,st}} - \overline{X_{p,1985\text{-}2014,st}}}{\overline{X_{p,1985\text{-}2014,st}}} \times 100$$

p : the parameter (e.g. T, RH, P, R)
st : the station (of the 33 available)
TMY : a TMY application
1985-2014 : the period available



The comparison shows that the errors (differences) do not usually exceed 5%, supporting the fact that the derived TMYs are representative of the sites selected

Conclusions

The present work presents the derived TMYs for 33 locations in Greece distributed all over the country, covering its 4 climatic zones defined for energy purposes.

TMYs are based on meteorological data collected from the Hellenic National Meteorological Service network in Greece in the period 1985–2014.

This is the first time that TMYs cover all 4 climatic zones of Greece for energy purposes, based on data over a long period (30 complete years).

Derivation of 5 different versions for each of the 33 TMYs, i.e. TMY-Meteorology-Climatology (TMY-MC), TMY-Bio-Meteorology (TMY-BM), TMY-Agro-Meteorology-Hydrology (TMY-AMH), TMY-PV applications (TMY-PV), and TMY-Energy Design of Buildings (TMY-EDB) for the first time worldwide.

The validity of the various TMYs was assessed in accordance with the climatic mean of the 30-years period.

The comparison shows that the errors (differences) do not usually exceed 5%, supporting the fact that the derived TMYs are representative of the sites selected.

More details for TMYs can be found in:

Theoretical and Applied Climatology (2020) 141:1313–1330
https://doi.org/10.1007/s00704-020-03264-7

ORIGINAL PAPER

Check for updates

Generation of typical meteorological years for 33 locations in Greece: adaptation to the needs of various applications

Harry D. Kambezidis[1] • Basil E. Psiloglou[1] • Dimitris G. Kaskaoutis[1] • Dimitris Karagiannis[1] • Kalliopi Petrinoli[1] • Ariadne Gavriil[1] • Kosmas Kavadias[2]

Received: 13 July 2019 / Accepted: 6 May 2020 / Published online: 3 June 2020

TMY analysis was carried out in the frame of a Greek National funded project: “Development of synergistic and integrated methods and tools for monitoring, management and forecasting of environmental parameters and pressures”
KRIPIS-THESPIA-II

Thank you for your attention

Contact E-mail: bill@noa.gr