The USA climate classification school – Hungarian aspects

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Budapest, 28th January, 2019

Climate classification schools

- In our days, the German and the USA climate classification schools are most frequently used, though German school is more popular.
- Development of the German school can be seen via works of Köppen, Geiger and Rubel.
- Development of the USA school can be seen via works of Thornthwaite, Mather, Willmott and Feddema.

Climate classification schools -- Hungary

- The climate structure on mesoscale in Hungary can be better characterized by the USA than by the German climate classification school!

- So, in Hungary the USA school is MORE POPULAR than the German school, that is there is more student and scientific work related to USA than to German school.

Some chosen student works

- Breuer H, 2007: Climatological modelling of evapotranspiration, soil water content and soil respiration in Hungary (original: A parolgas, a talajviztartalom és a talajlégzés klimatologiai modellezése Magyarorszagon. *MSc thesis*, ELTE, 93 pp.
- Skarbit N, 2012: Sensitivity of Feddema's climate classification method to the parameterization of potential evapotranspiration (original: Feddema éghajlat-osztályozási módszerének érzékenysége a potenciális evapotranszspiráció parametrizálására), *Scientific student paper*, Eötvös Loránd University, 24 pp.
- Skarbit N, 2012: Climate of Hungary in the twentieth century according to Feddema (original: Magyarország éghajlata a XX. században Feddema módszere alapján). *BSc thesis*, Eötvös Loránd University, 34 pp.

Some chosen student works

- Skarbit N, 2014: The climate of the European region during the twentieth and twenty-first centuries according to Feddema (original: Európa éghajlatának alakulása a XX. és a XXI. században Feddema módszere alapján). *MSc thesis*, Eötvös Loránd University, 61 pp.
- Takács D, 2014: Comparison of Hungarian and Swiss climate using Feddema method (original: Magyarország és Svájc éghajlatának összehasonlítása Feddema alapján), *Scientific student paper*, Eötvös Loránd University, 21 pp.
- Takács D, 2016: Regional alpine climate classification according to Feddema: Central European applications (original: A hegyi éghajlat regionális osztályozása Feddema alapján: közép-európai alkalmazások), MSc thesis, Eötvös Loránd University, 74 pp.

Some chosen student works

- Szabó AI, 2017: Investigation of the Carpathian Basin’s climate by using different climate classification methods and CarpatClim dataset. MSc thesis, Eötvös Loránd University, 42 pp.

Some chosen papers

- Drucza M, Ács F, 2006: Relationship between soil texture and near surface climate in Hungary, Időjárás, 110, 135—153.
- Szász G, Ács F, Breuer H, 2007: Estimation of surface energy and carbon balance components in the vicinity of Debrecen using Thornthwaite's bucket model. *Időjárás*, **111**, 239—250.
- Ács F., Breuer H., Skarbit N., 2015: Climate of Hungary in the twentieth century according to Feddema. *Theor. Appl. Climatol.*, **Vo. 119**, 161--169, DOI 10.1007/s00704-014-1103-5.
- Breuer H., Ács F., Skarbit N., 2017: Climate change in Hungary during the twentieth century according to Feddema. *Theor. Appl. Clim.*, **Vo. 127**, 853--863. DOI 10.1007/s00704-015-1670-0.

Some chosen papers

- Ács F, Takács D, Breuer H, Skarbit N, 2017: Climate and climate change in the Austrian-Swiss region of the European Alps during the twentieth century according to Feddema. *Theor. Appl. Climatol.*, DOI 10.1007/s00704-017-2230-6.
- Skarbit N, Ács F, Breuer H, 2017: The climate of the European region during the 20th and 21st centuries according to Feddema. *Int. J. Climatol.*, DOI: 10.1002/joc.5346.
- Breuer H, Ács F, Skarbit N, 2018: Observed and projected climate change in the European region during the twentieth and twenty-first centuries according to Feddema. *Climatic Change* doi.org/10.1007/s10584-018-2271-6

Books

- Ács F, Breuer H, 2013: Biophysical climate classification methods. (In Hungarian),
  http://elte.prompt.hu/sites/default/files/tananyagok/
09_AcsFerenc-Biofiz_eghoszt_modszerek/index.html

- Ács F, 2017: On twenty-first century climate classification. European multiregional analyses.Lambert Academic Publishing, 92 pp.

Johannes (Johan) Feddema

- JJ Feddema is contemporary USA climate classification school scientist.

He is methodologically present with us since 2012, but now he is is also present in person!

Climate Classification systems as a tool for representing climate change

Johannes Feddema
Department of Geography
University of Victoria

Budapest, 28 January 2019

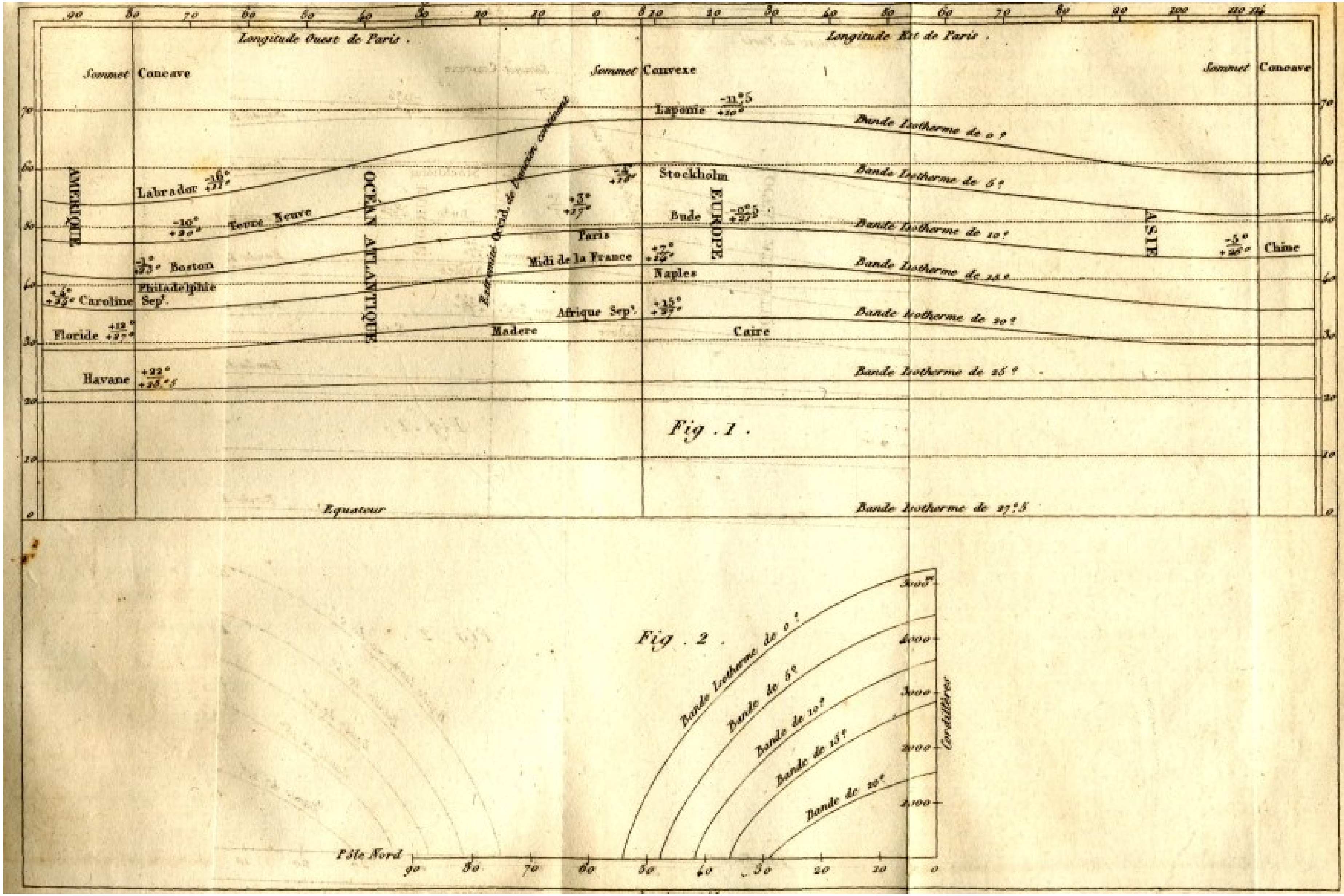
Outline

1. **Climate classification history**
    - Von Humboldt
    - Köppen
    - Thornthwaite
    - Others
    - Issues with current use for climate change detection
2. **A revised Thornthwaite system**
    - Revised moisture index
    - Use of PET
    - Seasonality
    - Causes of seasonality
    - Updates
3. **Uses in climate change detection and causes**
    - GHG climate projections
    - Urban climate simulation in the CESM
    - Case studies of climate change detection for combined GHG and Urban climates on select cities

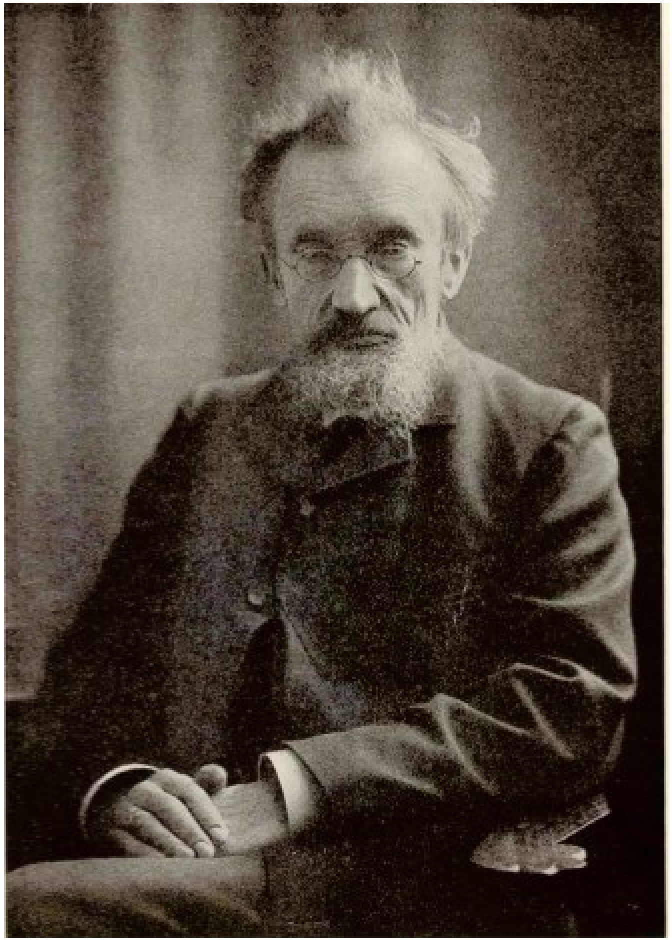
Key historical climate classification systems

Alexander von Humboldt (1769-1859), just after his return from the Americas (1799-1804).

Humboldt’s famous portrayal of **ecological zonation** by altitude using the Ecuadorian volcano Chimborazo as a model(1805).

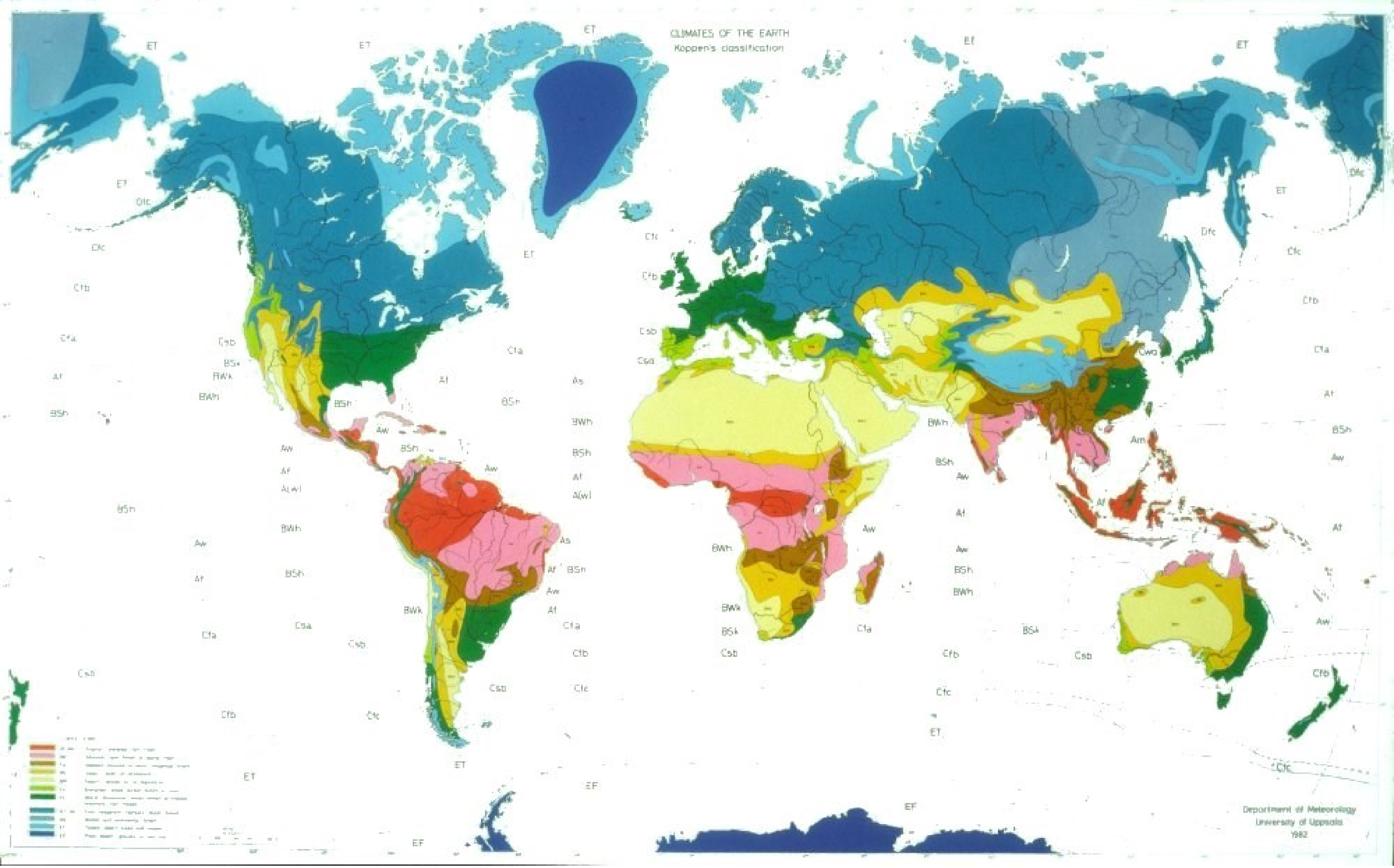


Isothermal lines by latitude and altitude (1817): a spatial abstraction of climate



Wladimir Köppen (1846-1940), Wladimir Köppen as an elderly man

Source: Thiede J. Wladimir Köppen, Alfred Wegener, and Milutin Milankovitch: their impact on modern paleoclimate research and the revival of the Milankovitch hypothesis. Vestnik of Saint Petersburg University. Earth Sciences, 2018, vol. 63, issue 2, pp. 230–250. https://doi.org/10.21638/11701/ spbu07.2018.207



Wladimir Köppen (1846-1940) used Humboldtian tools to classify the world's climate zones.

Köppen-Geiger criteria

Classification of major climatic types according to the modified Köppen-Geiger scheme			
letter symbol			
1st	2nd	3rd	criterion
A			temperature of coolest month 18 °C or higher
	f		precipitation in driest month at least 60 mm
	m		precipitation in driest month less than 60 mm but equal to or greater than 100 – (r/25)[1]
	w		precipitation in driest month less than 60 mm and less than 100 – (r/25)
B[2]			70% or more of annual precipitation falls in the summer half of the year and r less than 20t + 280, or 70% or more of annual precipitation falls in the winter half of the year and r less than 20t, or neither half of the year has 70% or more of annual precipitation and r less than 20t + 140[3]
	W		r is less than one-half of the upper limit for classification as a B type (see above)
	S		r is less than the upper limit for classification as a B type but is more than one-half of that amount
		h	t equal to or greater than 18 °C
		k	t less than 18 °C
C			temperature of warmest month greater than or equal to 10 °C, and temperature of coldest month less than 18 °C but greater than –3 °C
	s		precipitation in driest month of summer half of the year is less than 30 mm and less than one-third of the wettest month of the winter half
	w		precipitation in driest month of the winter half of the year less than one-tenth of the amount in the wettest month of the summer half
	f		precipitation more evenly distributed throughout year; criteria for neither s nor w satisfied
		a	temperature of warmest month 22 °C or above
		b	temperature of each of four warmest months 10 °C or above but warmest month less than 22 °C
		c	temperature of one to three months 10 °C or above but warmest month less than 22 °C

Köppen-Geiger criteria

D			temperature of warmest month greater than or equal to 10 °C, and temperature of coldest month –3 °C or lower
	s		same as for type C
	w		same as for type C
	f		same as for type C
		a	same as for type C
		b	same as for type C
		c	same as for type C
		d	temperature of coldest month less than –38 °C (d designation then used instead of a, b, or c)
E			temperature of warmest month less than 10 °C
	T		temperature of warmest month greater than 0 °C but less than 10 °C
	F		temperature of warmest month 0 °C or below
H[4]			temperature and precipitation characteristics highly dependent on traits of adjacent zones and overall elevation—highland climates may occur at any latitude

[1]In the formulas above, r is average annual precipitation total (mm), and t is average annual temperature (°C). All other temperatures are monthly means (°C), and all other precipitation amounts are mean monthly totals (mm).

[2]Any climate that satisfies the criteria for designation as a B type is classified as such, irrespective of its other characteristics.

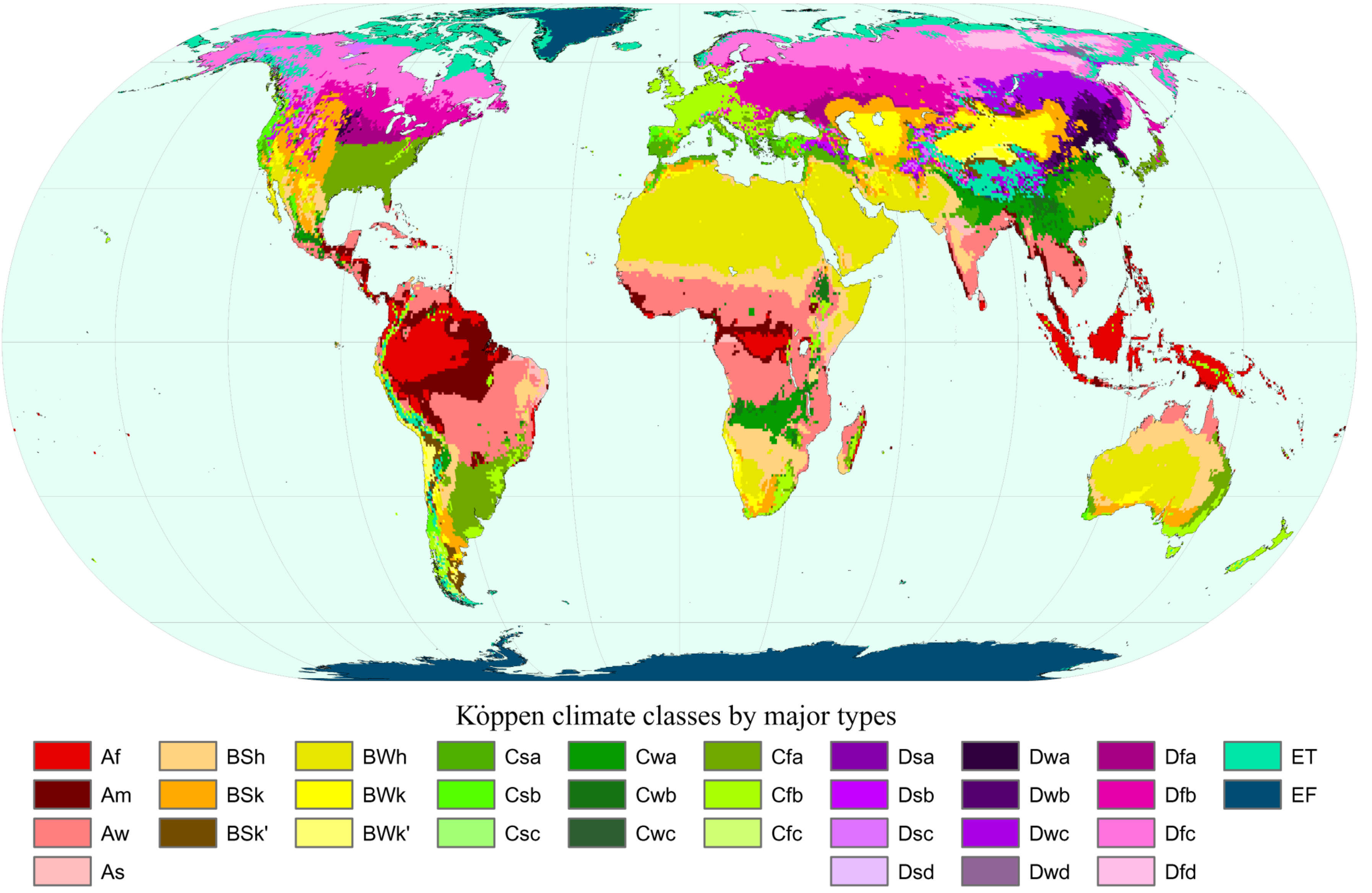
[3]The summer half of the year is defined as the months April–September for the Northern Hemisphere and October–March for the Southern Hemisphere.

[4]Most modern climate schemes consider the role of altitude. The highland zone has been taken from G.T. Trewartha, An Introduction to Climate, 4th ed. (1968).

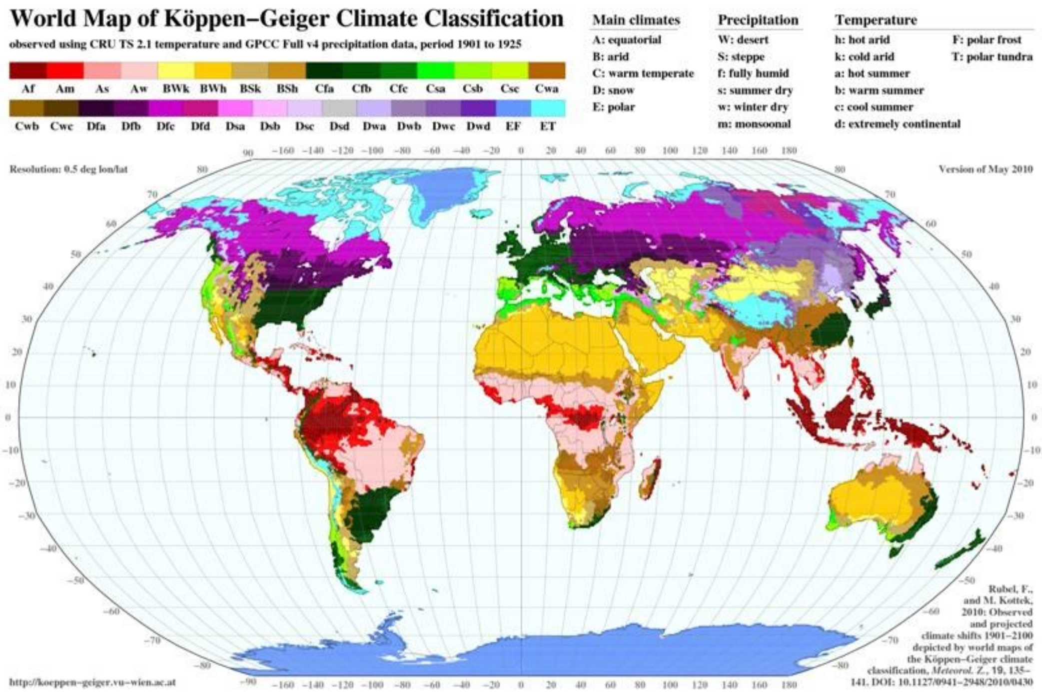
Data Sources: Adapted from Howard J. Critchfield, General Climatology, 4th ed. (1983), and M.C. Peel, B.L. Finlayson, and T.A. McMahon, "Updated World Map of the Köppen-Geiger Climate Classification," Hydrology and Earth System Sciences, 11:1633–44 (2007).

Köppen Climate Classification

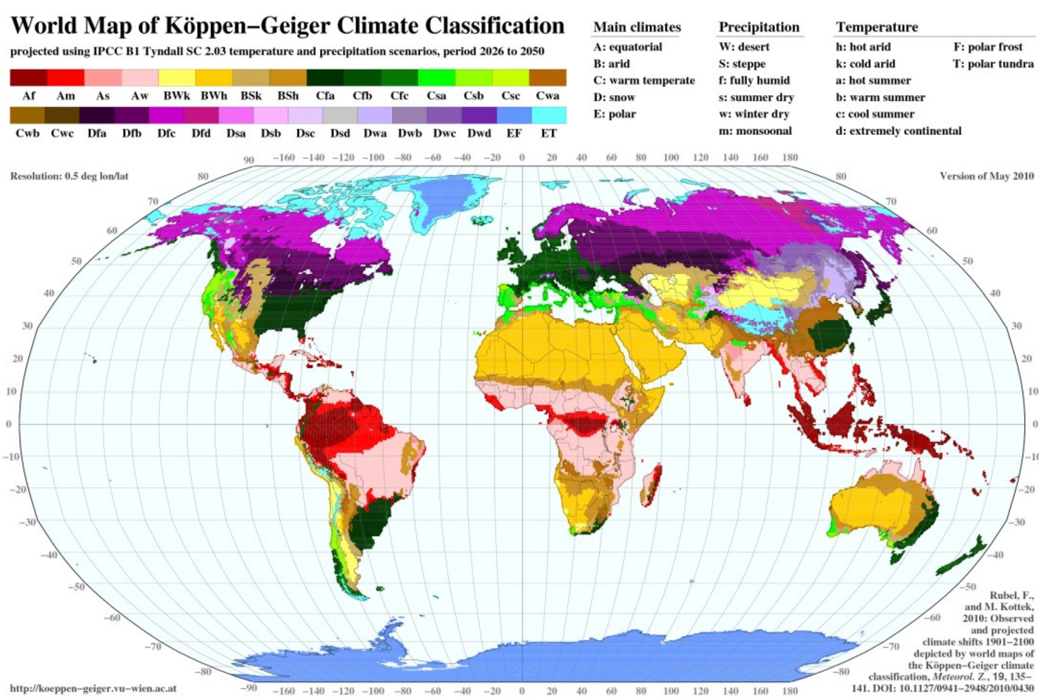
Climate Types



Current CRU Climatology



IPCC SRES B1 2026-2050 Climatology



Source: Rubel, F., and M. Kottek, 2010: Observed and projected climate shifts 1901-2100 depicted by world maps of the Köppen-Geiger climate classification. *Meteorol. Z.*, **19**, 135-141.

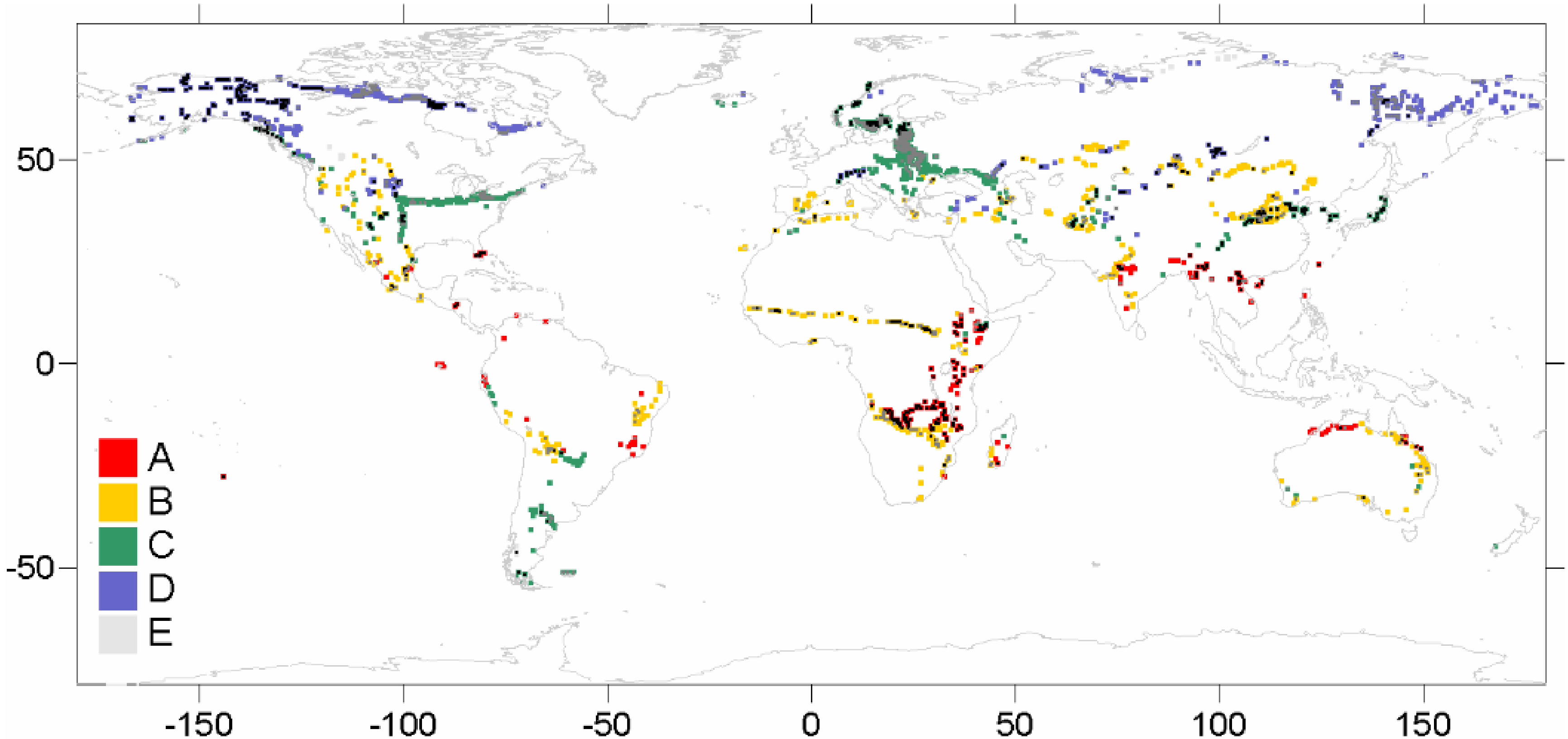


Figure 6: Köppen climate types for the period 1986 - 2000 for gridcells with different Köppen climates within the periods 1951 – 2000 and 1986 – 2000, respectively. Grey and black dots indicate gridcells for which a difference concerning the respective relevant climate parameter between the two periods can be determined on the 90% or 95% level of significance, respectively.

Source: Rubel, F., and M. Kottek, 2010: Observed and projected climate shifts 1901-2100 depicted by world maps of the Köppen-Geiger climate classification. *Meteorol. Z.*, **19**, 135-141.

C. Warren Thornthwaite (1899- 1963), with staff outside the “Laboratory of Climatology”.

American and Soviet geographers join forces for a better world. From left are (standing) Dr. John Mather, Dr. Aleksandr Krenke, Dr. Tatiana Bochareva and Dr. Cort Willmott, and (seated) Dr. Galina Sdasyuk and Dr. Gilbert White.

J. “Russ” Mather (1923- 2003), and Cort Willmott (1946-) at the University of Delaware

More rational divisions!

Thornthwaite 1931:

Useful stuff

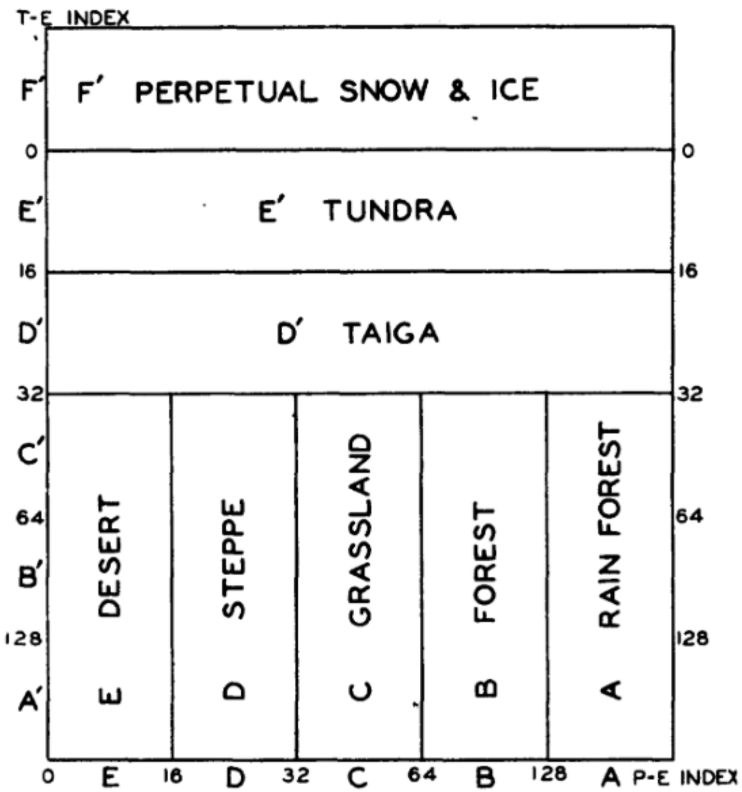


FIG. 9

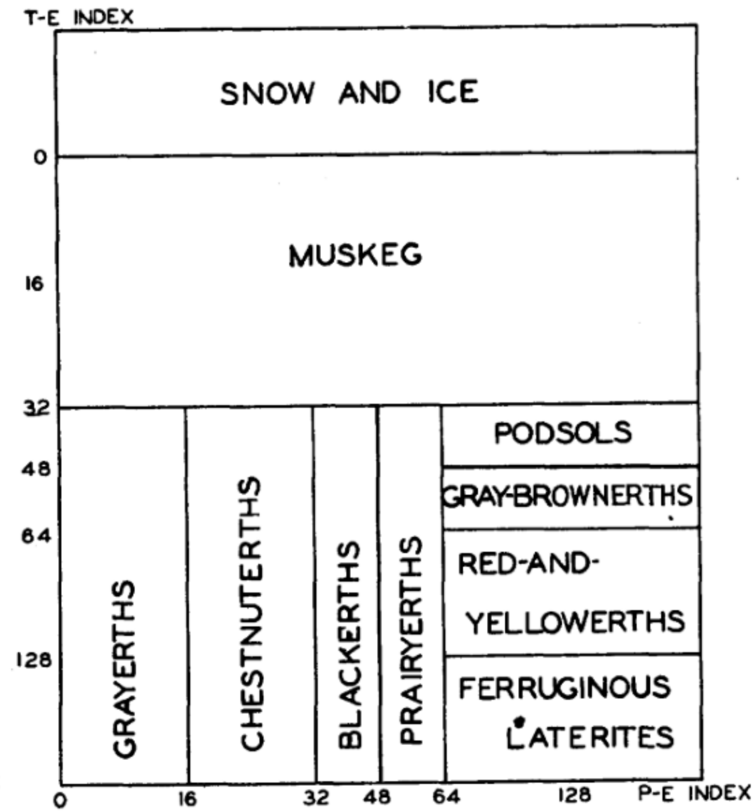


FIG. 10

FIG. 9—Graphical representation of the eight major climatic regions.
FIG. 10—Graphical representation of the climatic basis of soil development.

Some geographers in this country have shown a desire to adopt the Köppen system as an "official" climatic classification. Kesseli, for example, asserts that a certain innovation proposed by Russell and Ackerman "should be made part of the standard Köppen classification."[55] It would be a calamity if any current climatic classification were adopted as a standard. Climate is an extremely complex phenomenon, and any classification of it necessitates great oversimplification and involves the risk of serious error. Not

C. Warren Thornthwaite, 1943

Water balance

$$\Delta S = P - RO - ET - \Delta G$$

Where:

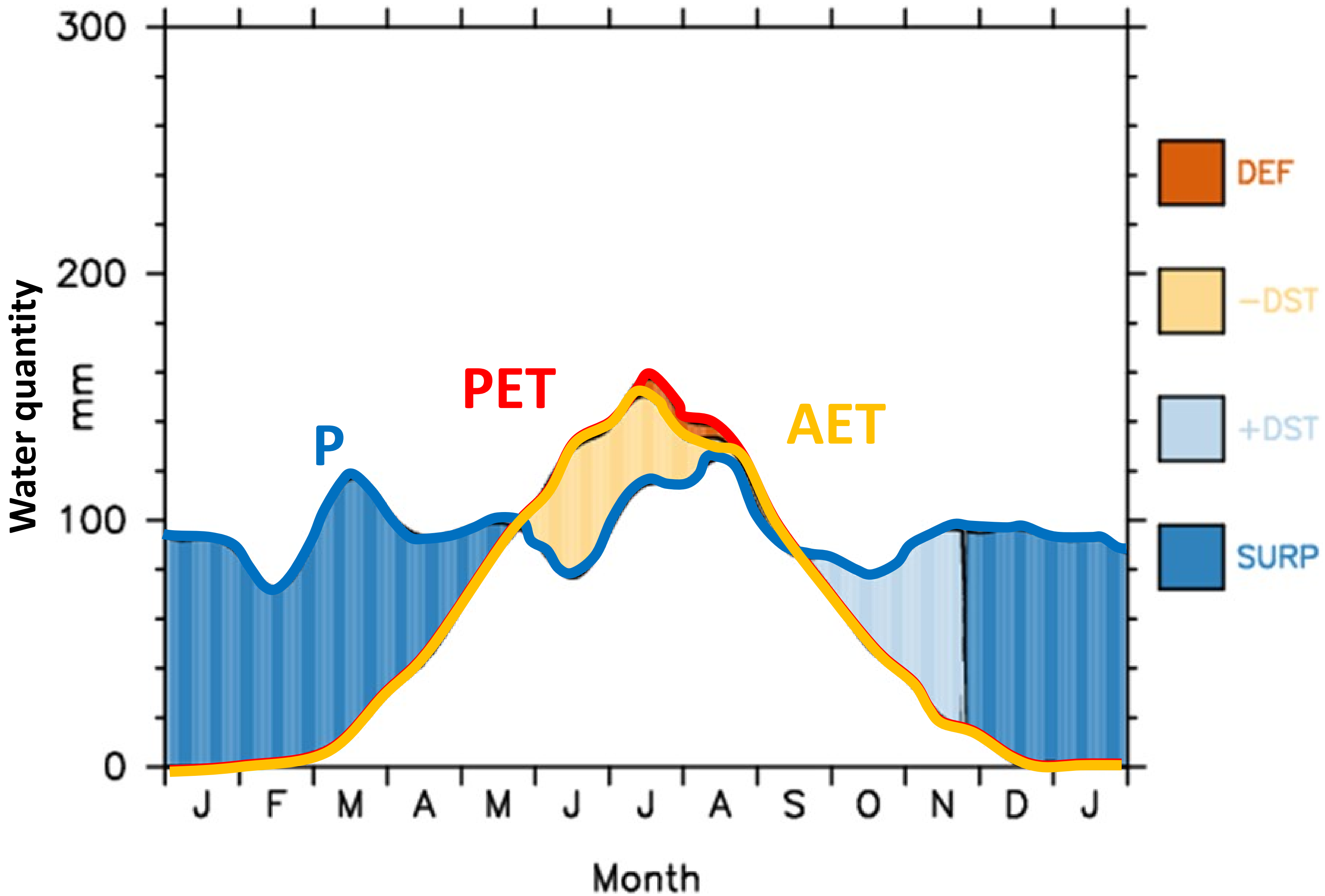
ΔS = Change in soil moisture

P = Precipitation (input)

RO = Runoff

ET = Evapotranspiration (transpiration + evaporation)

ΔG = Change in ground water storage


300
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Water quantity
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SURP

Thornthwaite 1948

AN APPROACH TOWARD A RATIONAL CLASSIFICATION OF CLIMATE

C. W. THORNTHWAITE

[With separate map, Pl. I, facing p. 94]

THE direction that the modern study of climate has taken has been dictated largely by the development of meteorological instruments, the establishment of meteorological observatories, and the collection of weather data. The catalogue of climatic elements consists of those that are customarily measured and usually includes temperature, precipitation, atmospheric humidity and pressure, and wind velocity. Increasingly, climatic studies have tended to become statistical analyses of the observations of individual elements. Because of this, climatology has been regarded in some quarters as nothing more than statistical meteorology.

Thornthwaite 1948

Thornthwaite's initial formulation

A moisture ratio that expresses the relative humidity or aridity of a month may be obtained by dividing the difference between precipitation and potential evapotranspiration by potential evapotranspiration,

$$\frac{p - e}{e} \text{ or } \frac{p}{e} - 1. \qquad (3)$$

Positive values of the ratio mean that the precipitation is excessive, negative values that it is deficient. A ratio of zero means that water supply is equal to water need.

Thornthwaite 1948

Developing the index further (percentage basis)

Where there is a water surplus and no water deficiency, the relation between water surplus and water need constitutes an index of humidity. Similarly, where there is a water deficiency and no surplus, the ratio between water deficiency and water need constitutes an index of aridity. Expressed as percentages these two indices are:

$$I_h = \frac{100s}{n} \quad \text{and} \quad I_a = \frac{100d}{n}, \tag{4}$$

where I_h and I_a are indices of humidity and aridity respectively, s is water surplus, d is water deficiency, and n is water need. The ultimate in the scale

Thornthwaite 1948

For this reason, a surplus of only 6 inches in one season will counteract a deficiency of 10 inches in another. Thus in an over-all moisture index the humidity index has more weight than the aridity index: the latter has only six-tenths the value of the former. The moisture index is:

$$I_m = I_h - .6I_a \quad \text{or} \quad I_m = \frac{100s - 60d}{n}. \tag{5}$$

Moist climates have positive values of I_m; dry climates have negative values. Figure 7 shows how climatic types are separated in terms of the moisture index, I_m, and makes clear how they are related to water surplus and water deficiency. The various climatic types together with their limits are as follows:

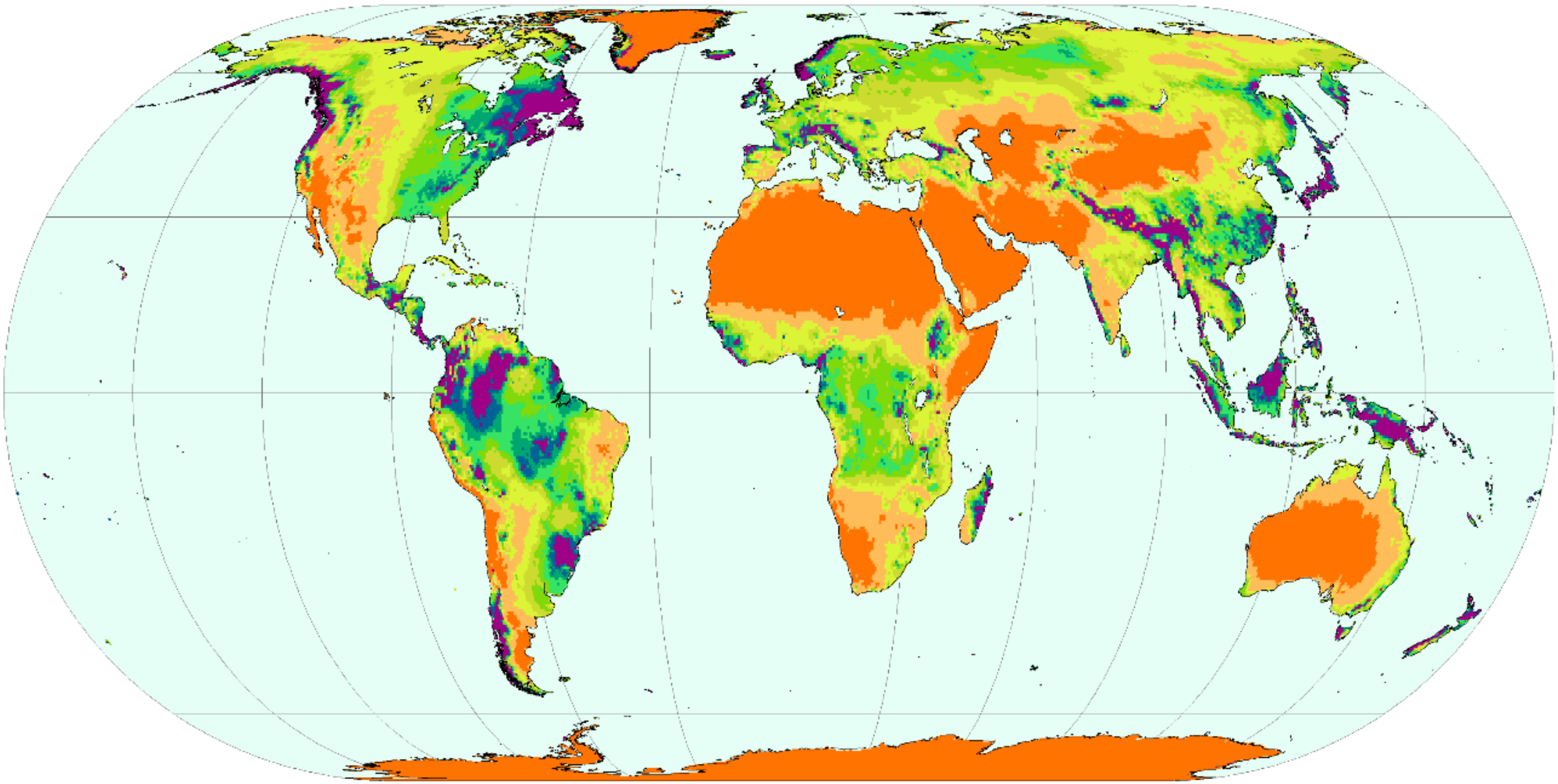
Climatic Type		Moisture Index
A	Perhumid	100 and above
B_4	Humid	80 to 100
B_3	Humid	60 to 80
B_2	Humid	40 to 60
B_1	Humid	20 to 40
C_2	Moist subhumid	0 to 20
C_1	Dry subhumid	−20 to 0
D	Semiarid	−40 to −20
E	Arid	−60 to −40

The index values −60, 0, and 100 are entirely rational limits of moisture regions. That the others are also may be seen in the nomograms of Figure

Thornthwaite's folly?

Thornthwaite Climate Classification

Moisture Regions

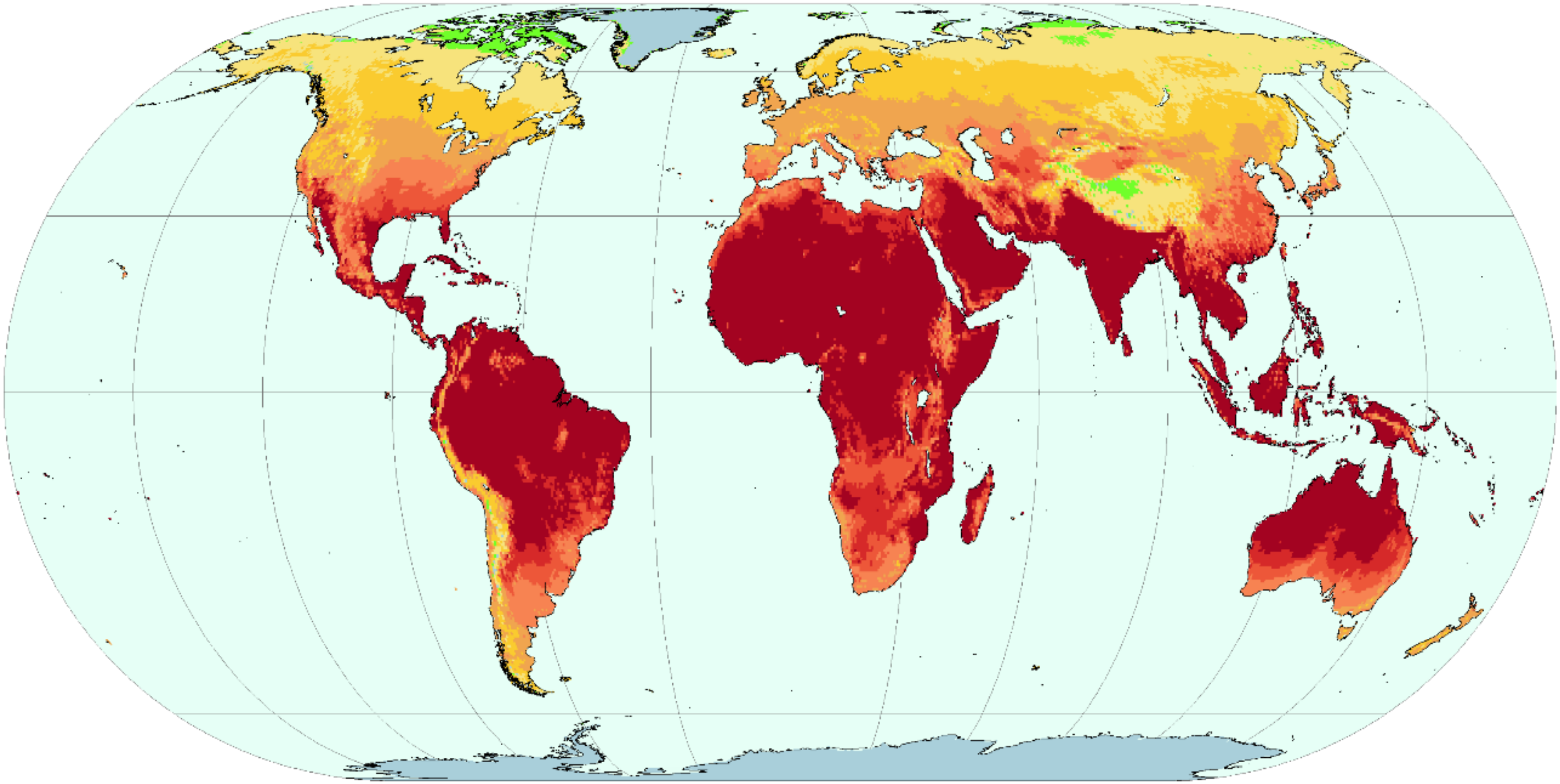


Climatic types based on the 1948 Thornthwaite moisture index

A - Perhumid	B2 - Humid	C1 - Dry subhumid
B4 - Humid	B1 - Humid	D - Semiarid
B3 - Humid	C2 - Moist subhumid	E - Arid

Thornthwaite Climate Classification

Index of Thermal Efficiency

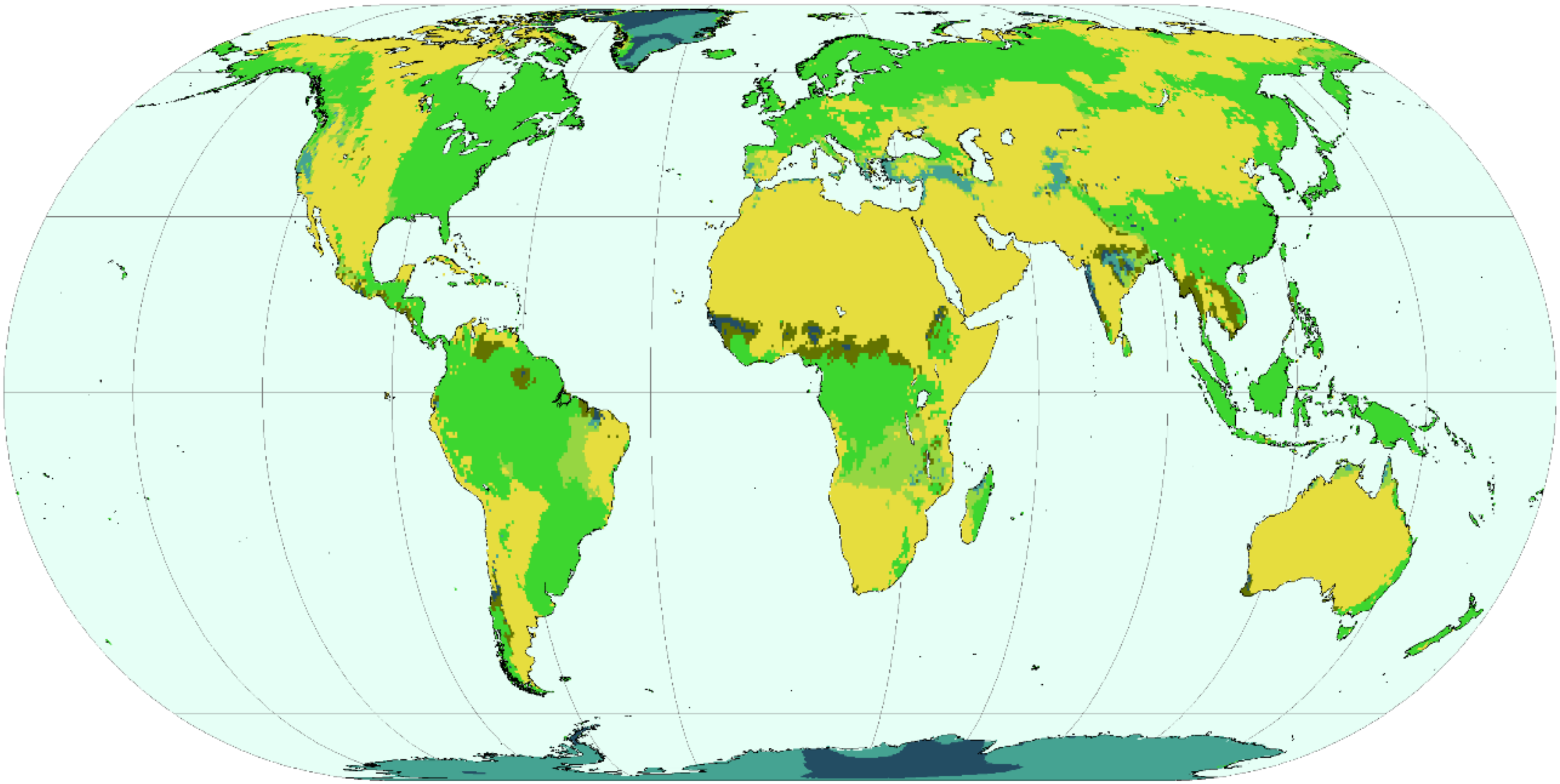


Thermal efficiency based on annual PE

A' - Megathermal	B'2 - Mesothermal	C'1 - Microthermal
B'4 - Mesothermal	B'1 - Mesothermal	D' - Tundra
B'3 - Mesothermal	C'2 - Microthermal	E' - Frost

Thornthwaite Climate Classification

Seasonal Variation of Effective Moisture

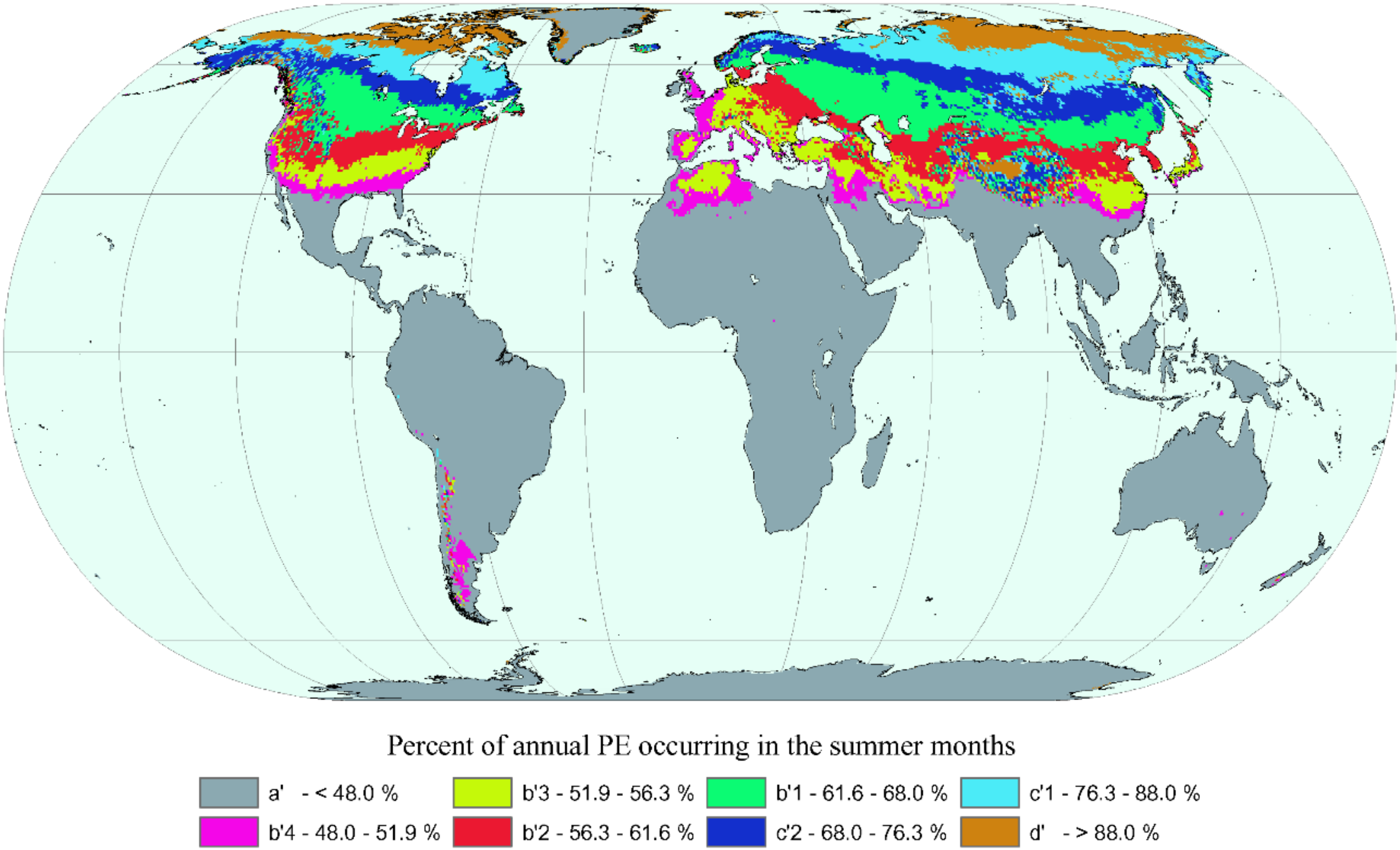


Seasonal Variation of effective moisture

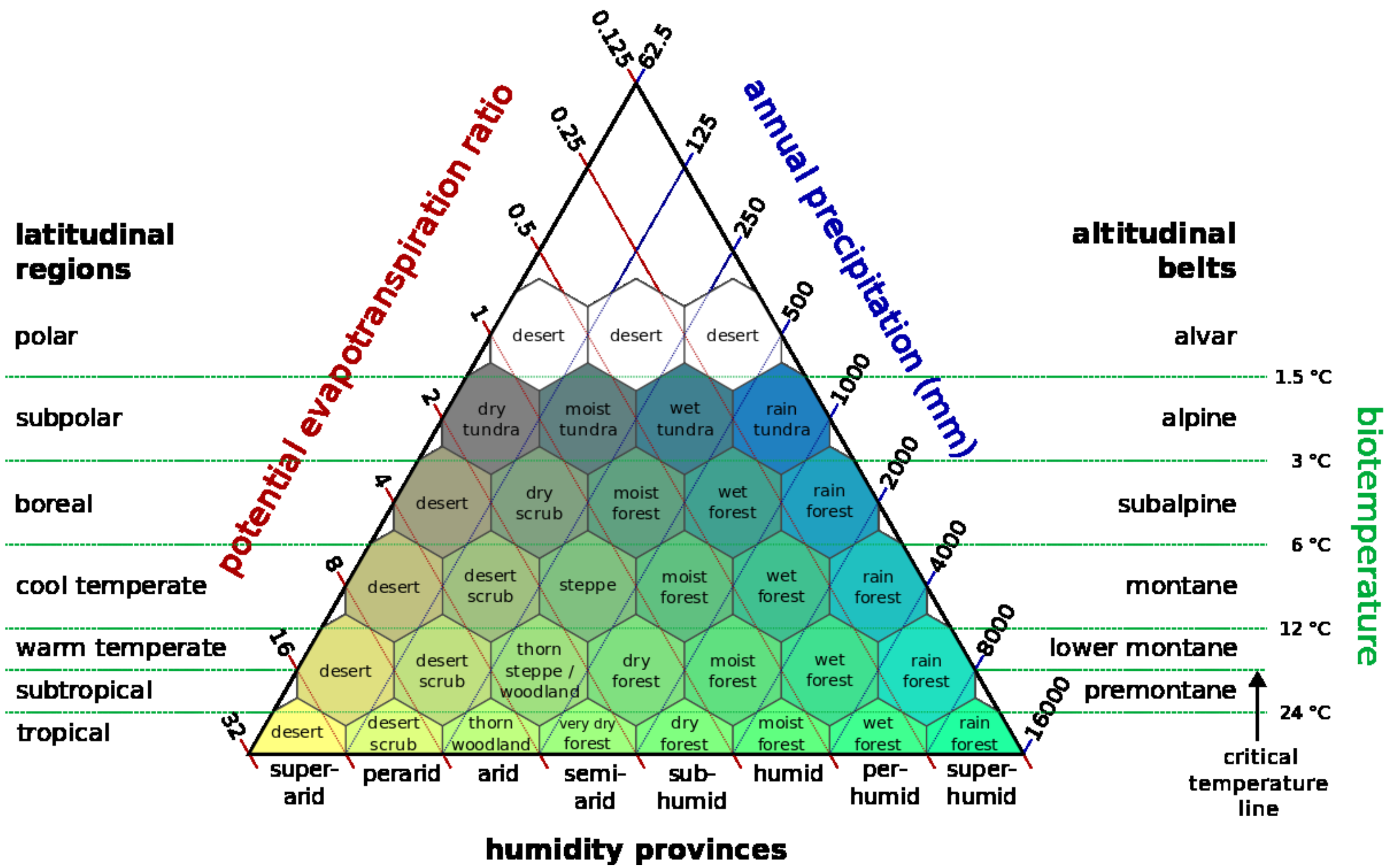
- r - Little or no moisture deficiency in any season (moist climates only)
- d - Little or no water surplus in any season (dry climate only)
- s - Moderate seasonal moisture variation with summer the driest season
- w - Moderate seasonal moisture variation with winter the driest season
- s2 - Large seasonal moisture variation with summer the driest season
- w2 - Large seasonal moisture variation with winter the driest season

Thornthwaite Climate Classification

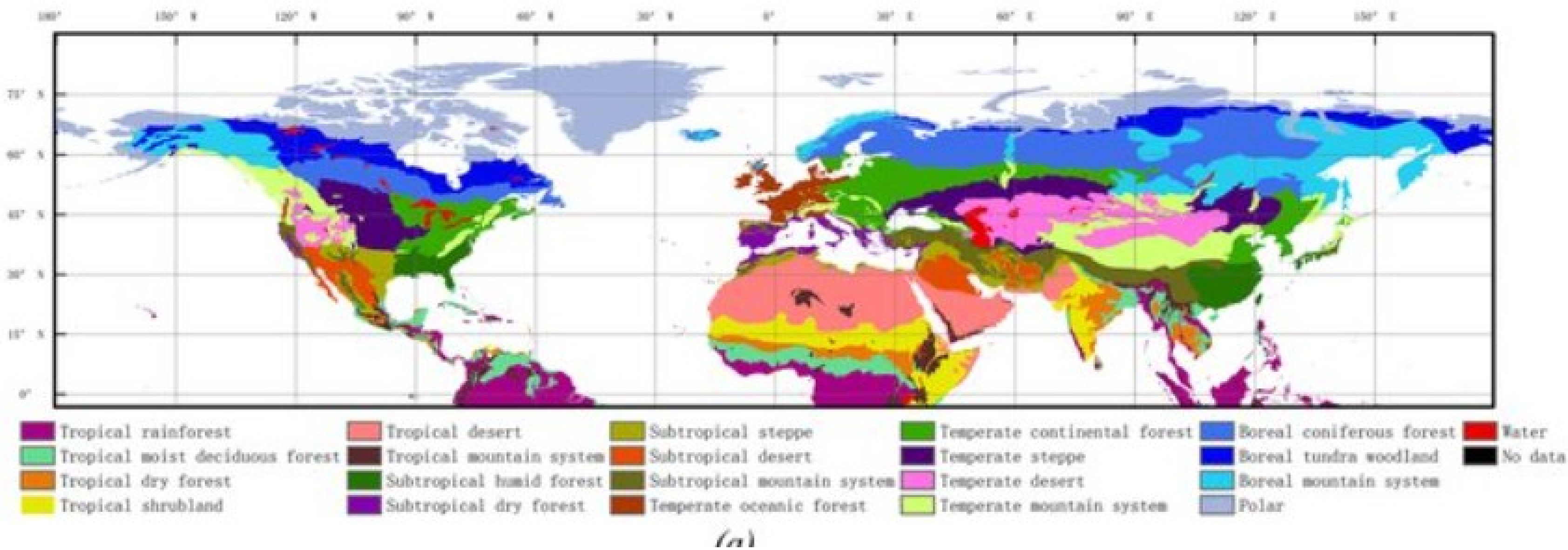
Summer Concentration of Thermal Efficiency



Follow up: Holdridge Life Zones

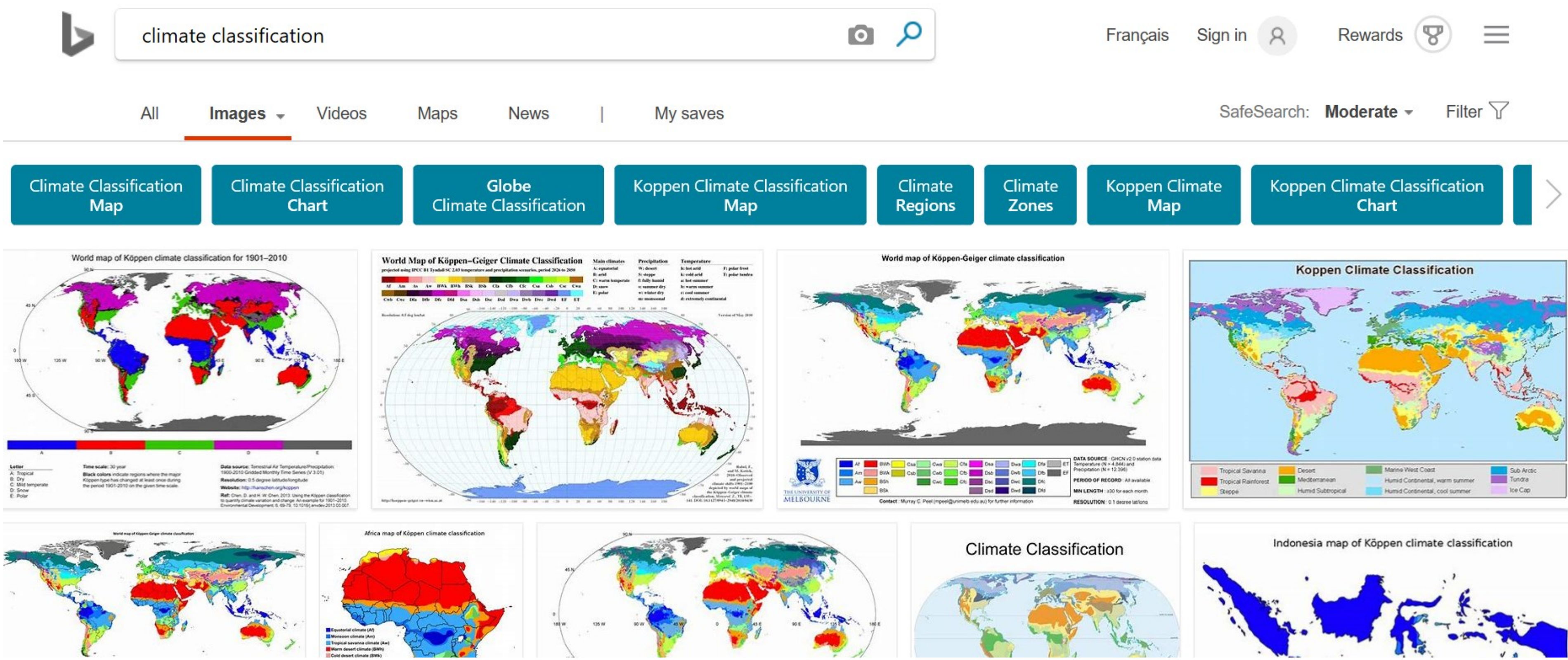


Holdridge Life Zones



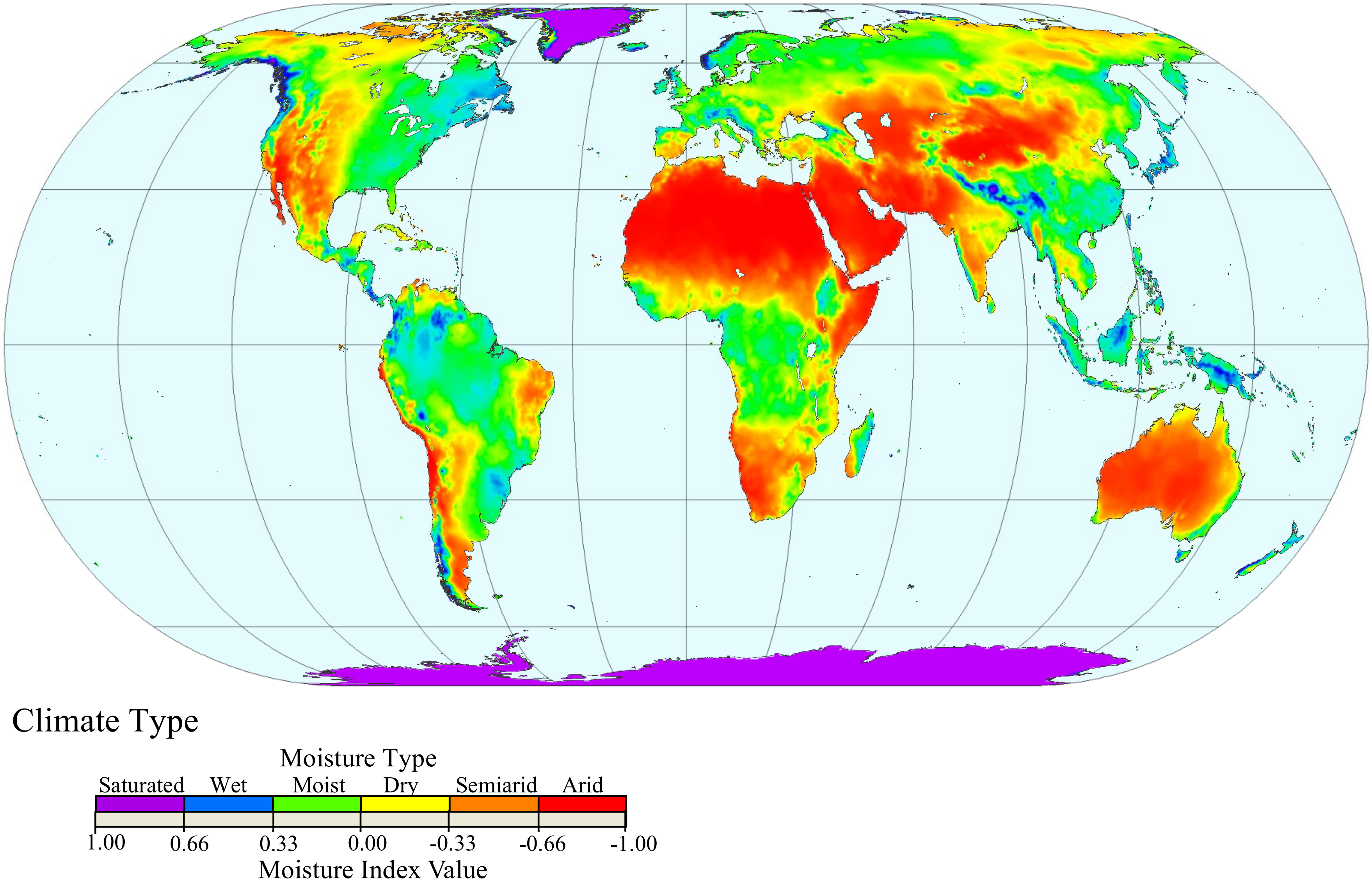
Source: Wang, Siyuan & Yang, Bojuan & Yang, Qichun & Lu, Linlin & Wang, Xiaoyue & Peng, Yaoyao. (2016). Temporal Trends and Spatial Variability of Vegetation Phenology over the Northern Hemisphere during 1982-2012. PLOS ONE. 11. e0157134. 10.1371/journal.pone.0157134.

Current day Status
Search for “Climate Classification”



A revised Thornthwaite type climate classification

New Classification: Climatic Moisture Types



Replace with Mean Annual Temperature?

Moisture Index (I_m) formulation

$$I_m = \begin{cases} \left(\frac{PET}{P}\right) - 1, & P < PET \\ 0, & P = PET = 0 \\ 1 - \left(\frac{PET}{P}\right), & P \geq PET \end{cases}$$

Where

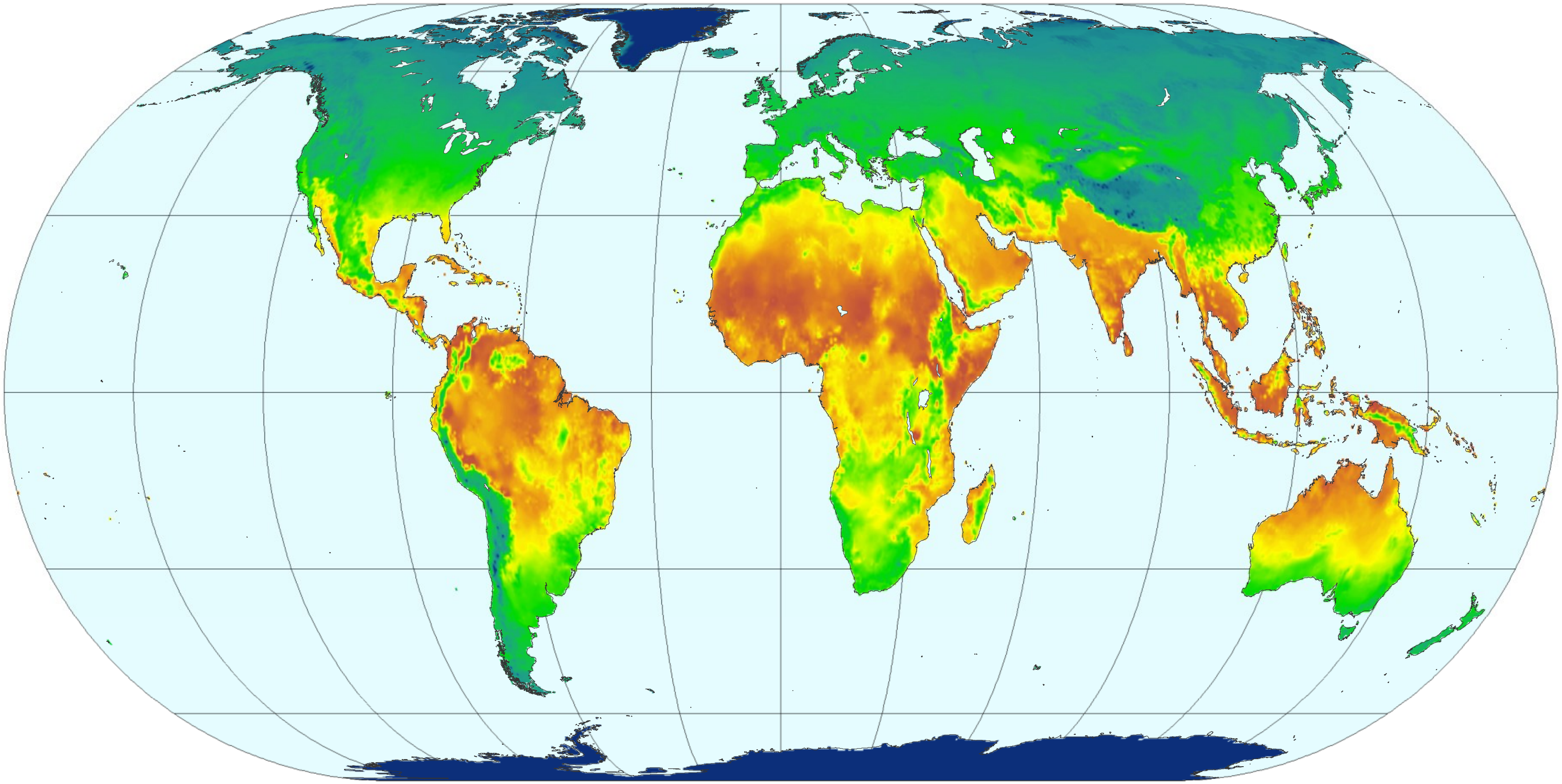
I_m = Moisture Index

E_p = Potential Evapotranspiration

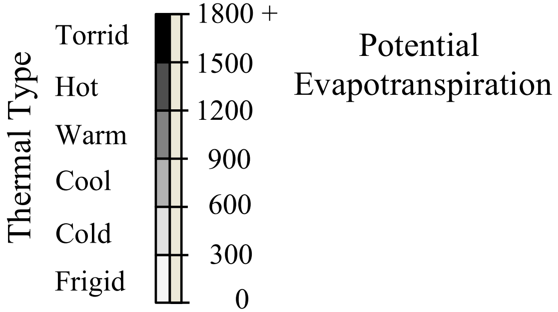
P_r = Precipitation

Source: Willmott and Feddema, 1992

New Classification: Climatic Thermal Types



Climate Type



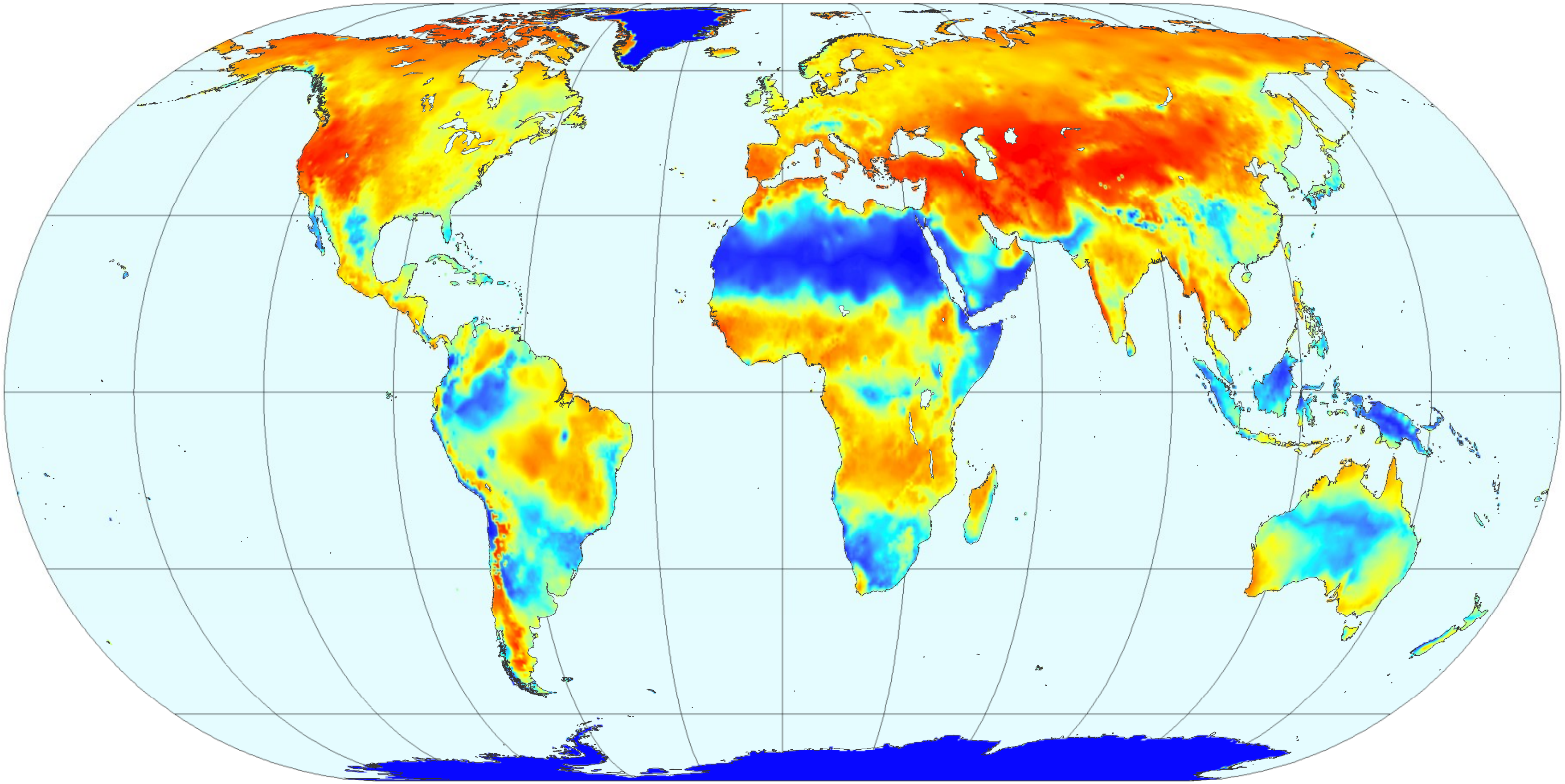
Seasonality (*S*) formulation

$$S = I_{m_{MAX}} - I_{m_{MIN}}$$

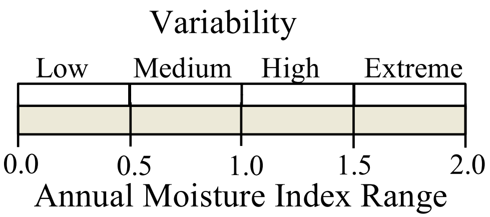
Where
$I_{m_{MAX}}$ = Annual maximum monthly Moisture Index
$I_{m_{MIN}}$ = Annual minimum monthly Moisture Index

Source: Feddema, 2005

New Classification: Climate Variability



Climate Variability



New seasonality (S_{Cause}) formulation

$$S_{Cause} = \left(\frac{P_{Range}}{PET_{Range}}\right)\begin{cases} < 0.5 = Temperature \\ -0.5 < Combined < 2 \\ > 2.0 = Precipitation \end{cases}$$

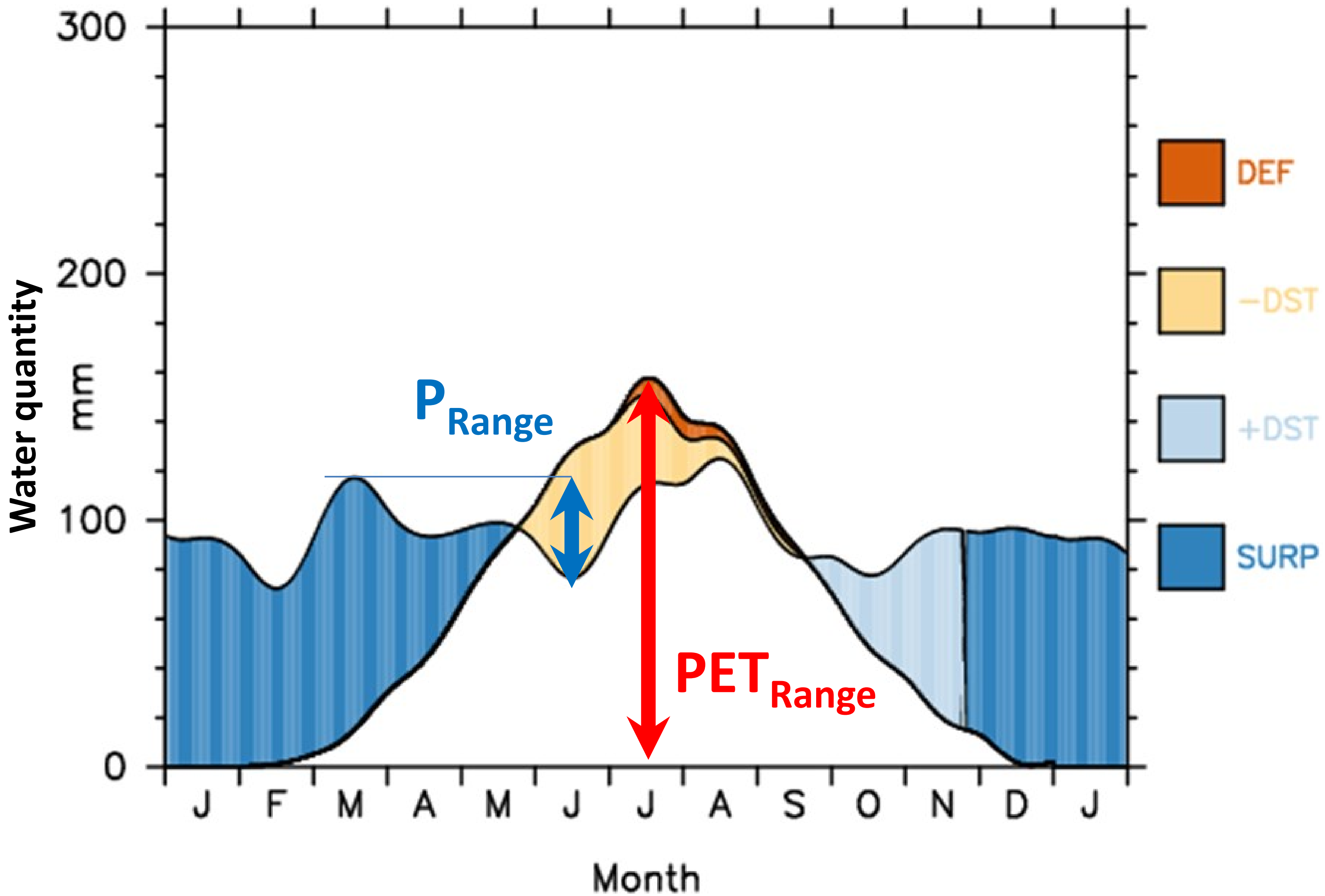
Where

S_{Cause} = Indication of proportion of seasonality caused by P, PET

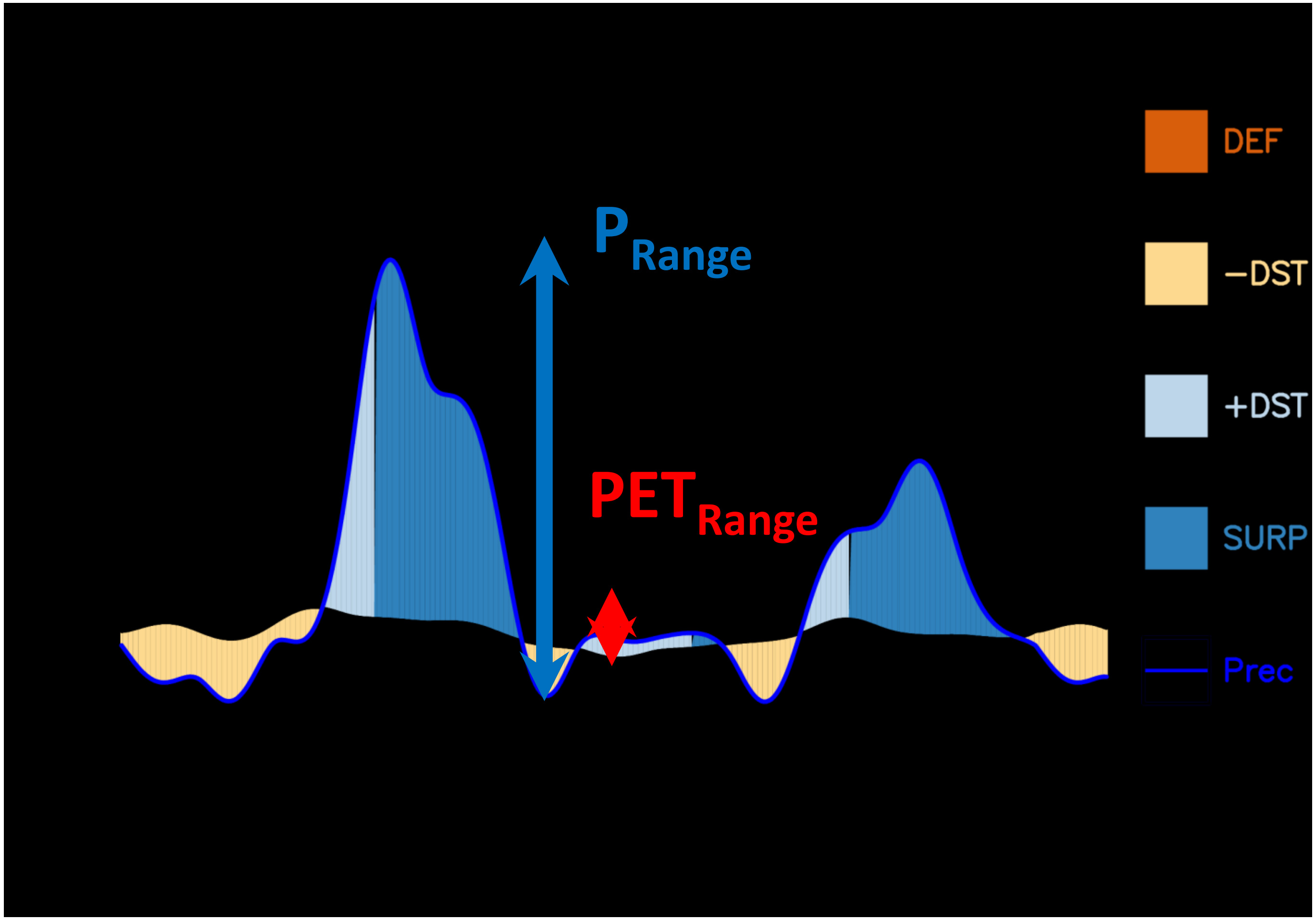
PET_{Range} = Annual Monthly Potential Evapotranspiration Range

P_{range} = Annual Monthly Precipitation Range

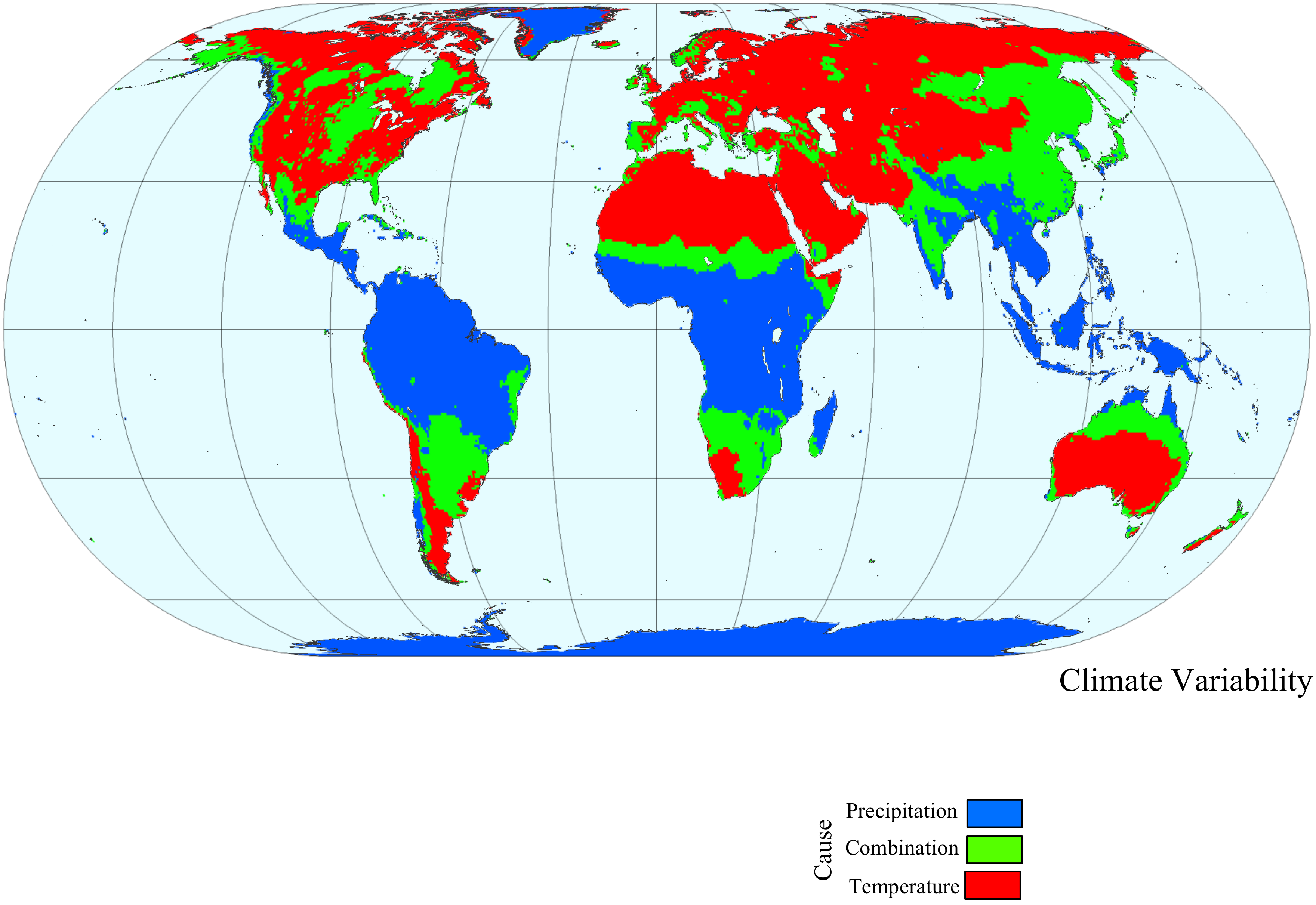
Newark, Delaware



Nakuru, Kenya



New Classification: Cause of Seasonality



New seasonality (S_{Cause}) formulation

$$S_{Cause} = \begin{cases} \left(\frac{P_{Range}}{PET_{Range}}\right) - 1, & P_{Range} < PET_{Range} \\ 0, & P_{Range} = PET_{Range} = 0 \\ 1 - \left(\frac{PET_{Range}}{P_{Range}}\right), & P_{Range} \geq PET_{Range} \end{cases}$$

$$S_{Cause} = \begin{cases} \succ -0.5 = Temperature \\ -0.5 < Combined < 0.5 \\ < 0.5 = Precipitation \end{cases}$$

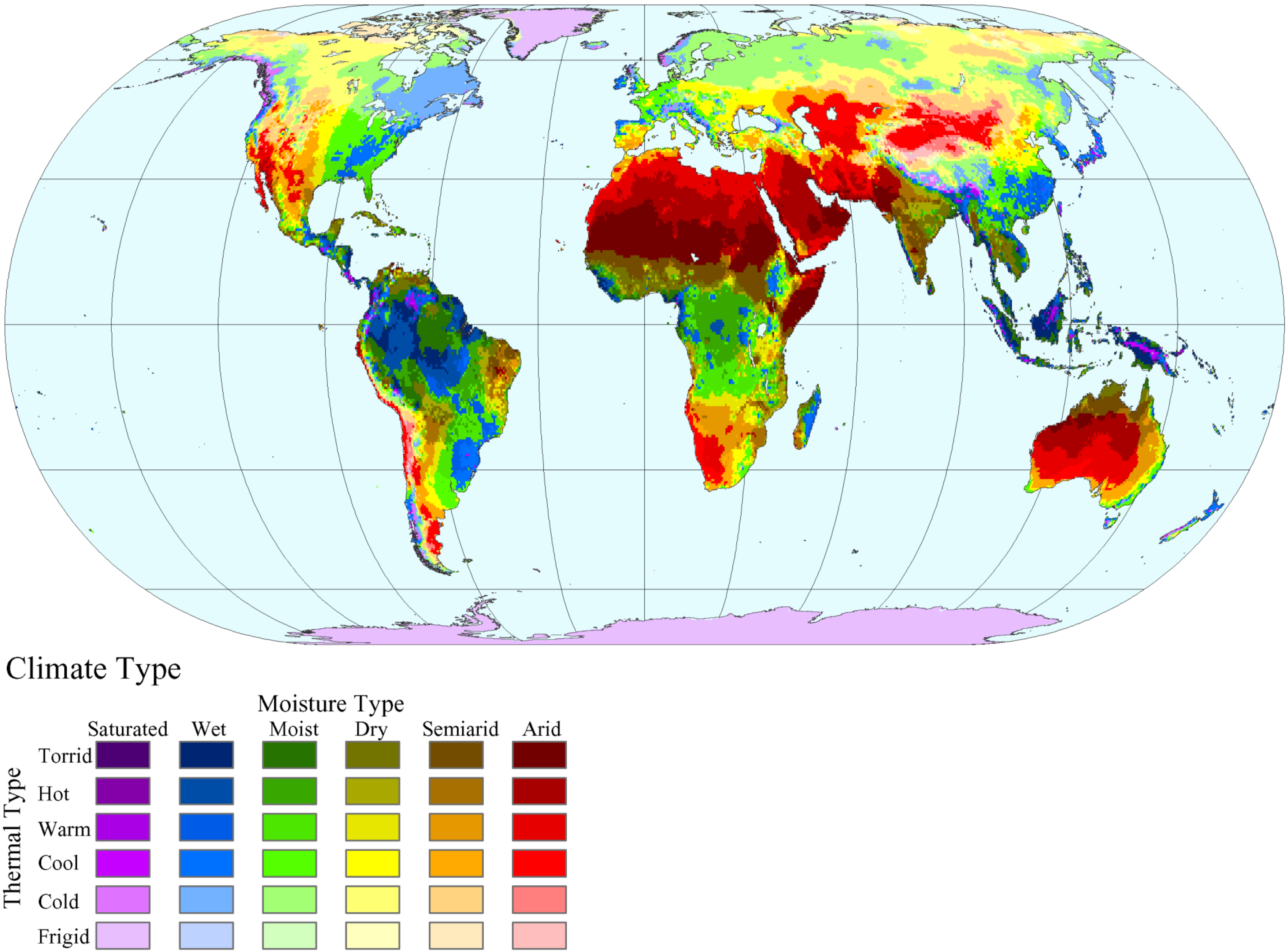
Where

S_{Cause} = Indication of proportion of seasonality caused by P, PET

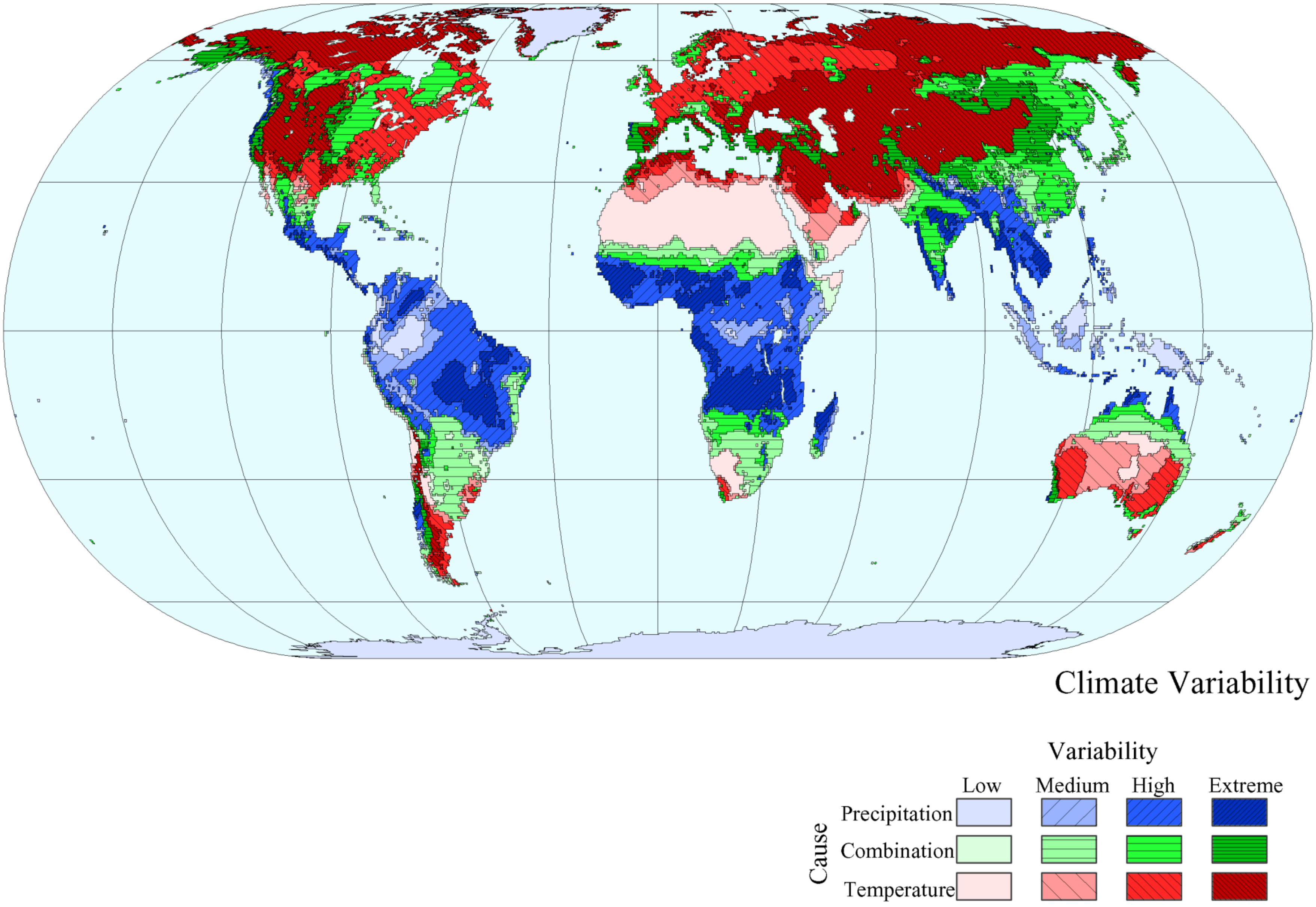
PET_{Range} = Annual Monthly Potential Evapotranspiration Range

P_{range} = Annual Monthly Precipitation Range

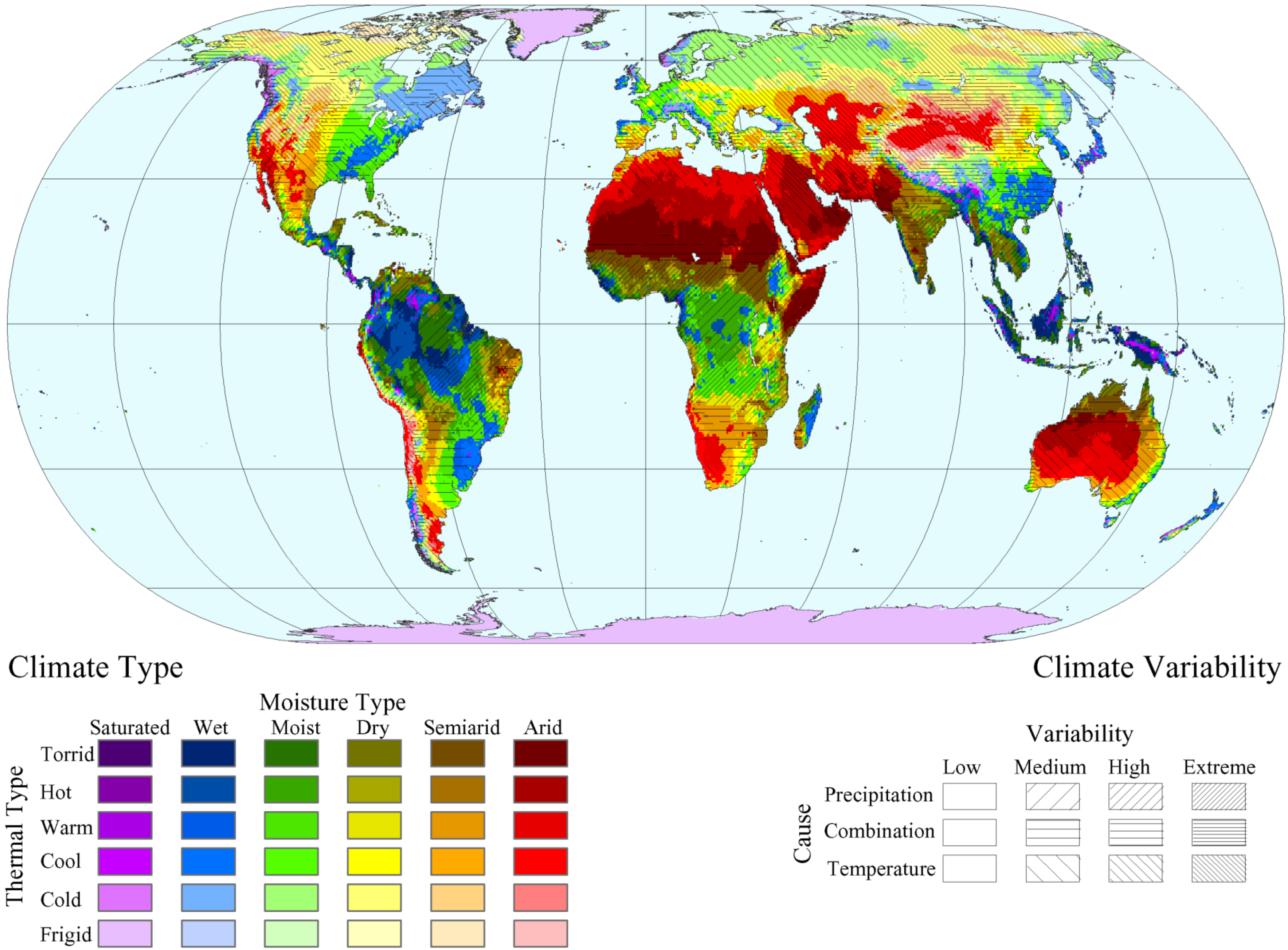
New Classification: Climatic Types



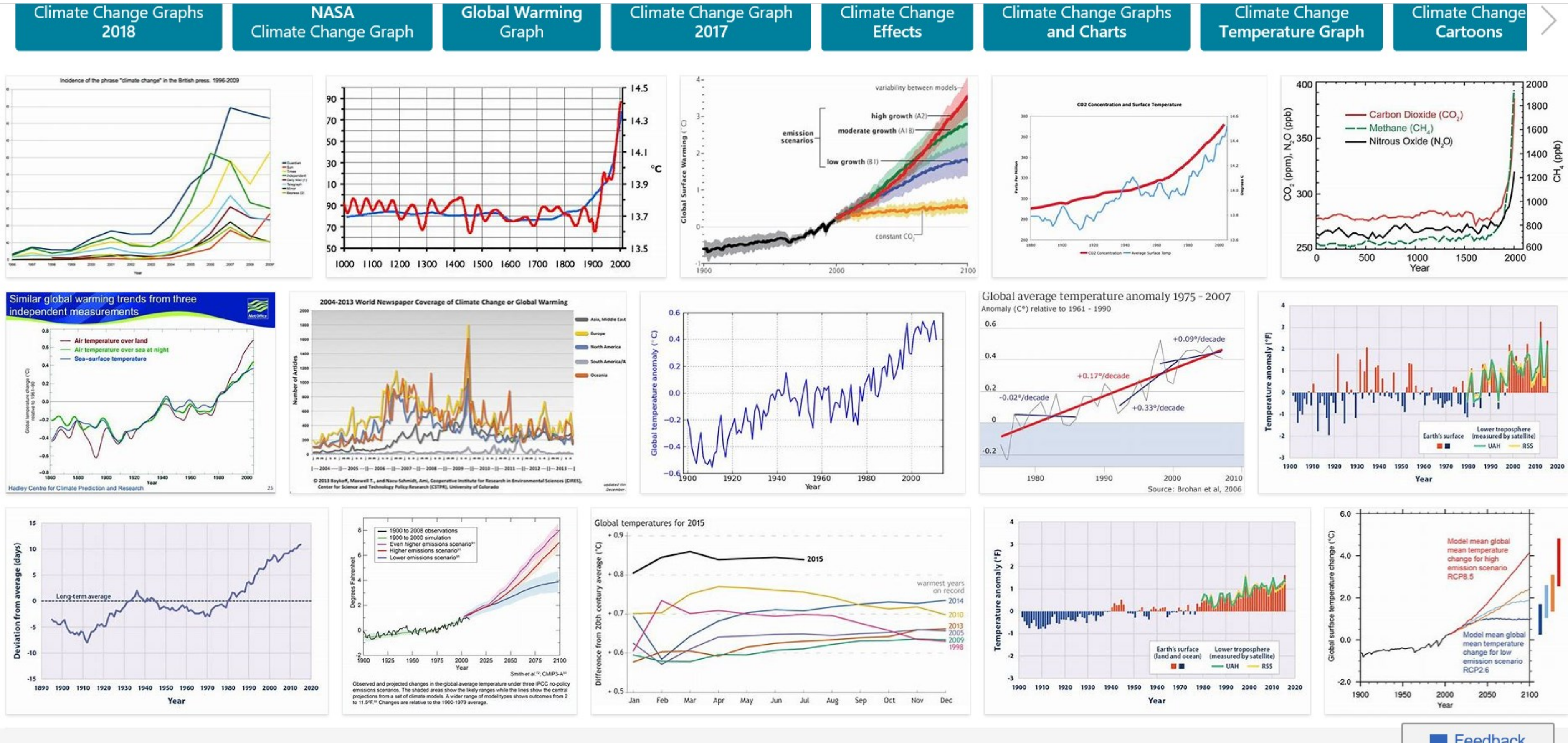
New Classification: Climate Seasonality by Cause



A revised Thornthwaite type climate classification



Search for “Climate Change”



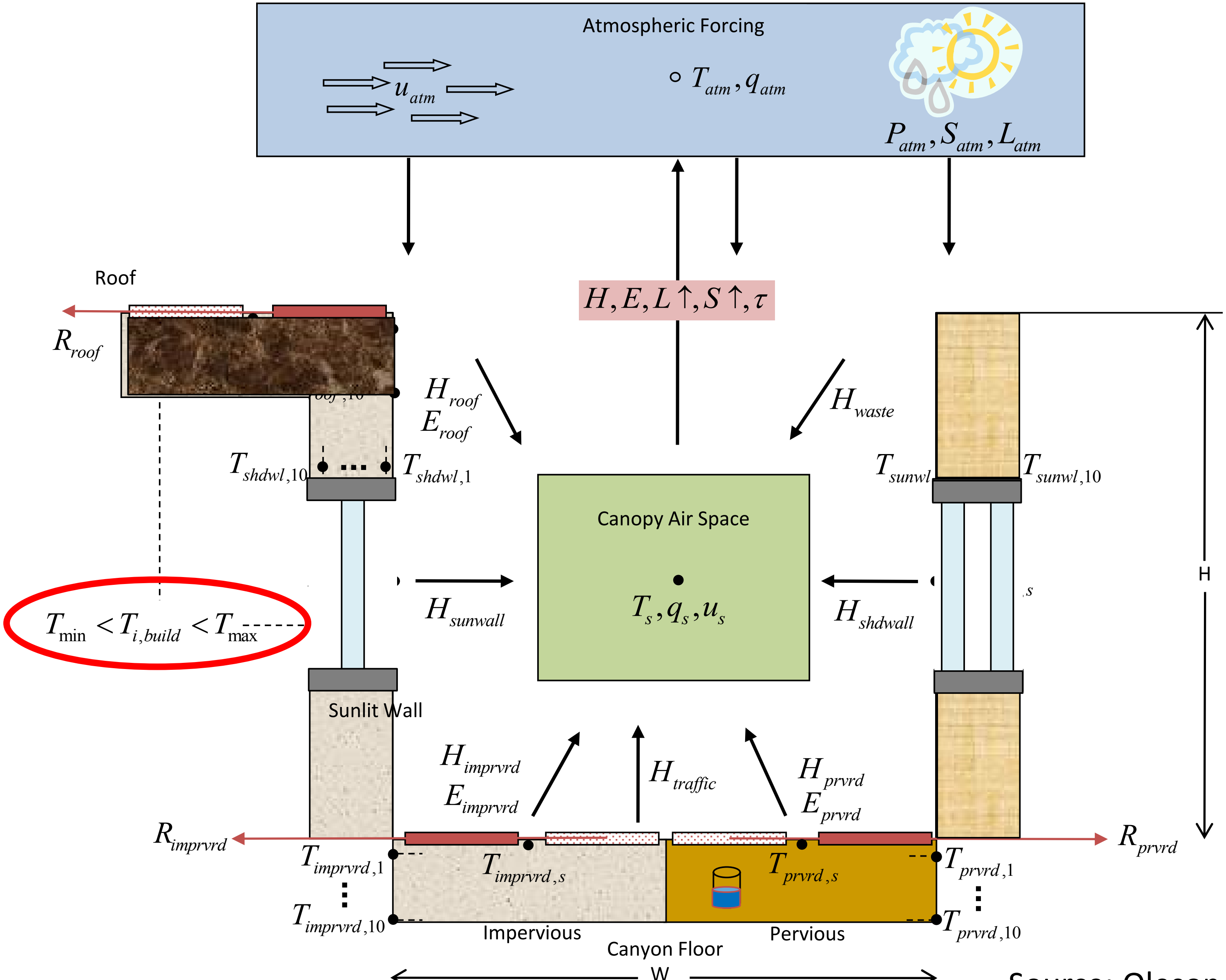
Using the revised classification to detect climate change

Simulate 2 climate change forcings:

1. GHG forcing based on RCP 8.5 average simulations in AR 5 (T and P)
2. Urban climate forcings at the local scale as simulated CESM (T only)

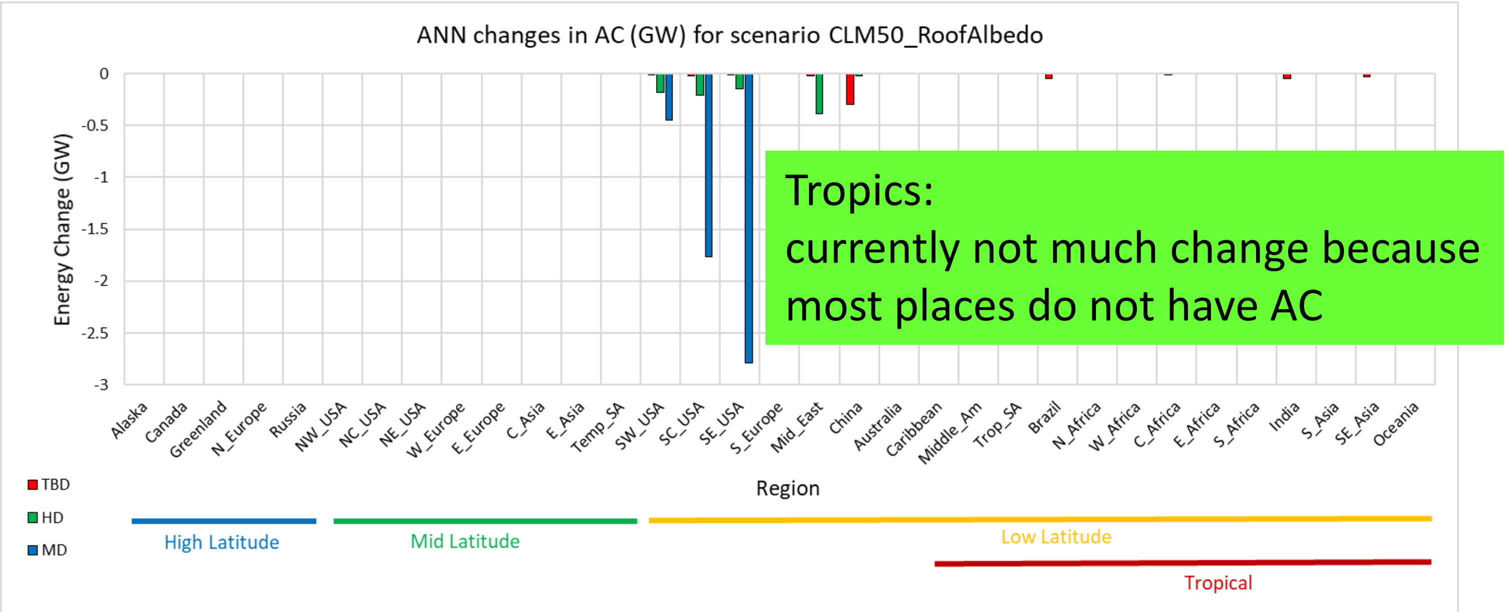
Urban climate simulations in the Community Earth System Model

CLMU



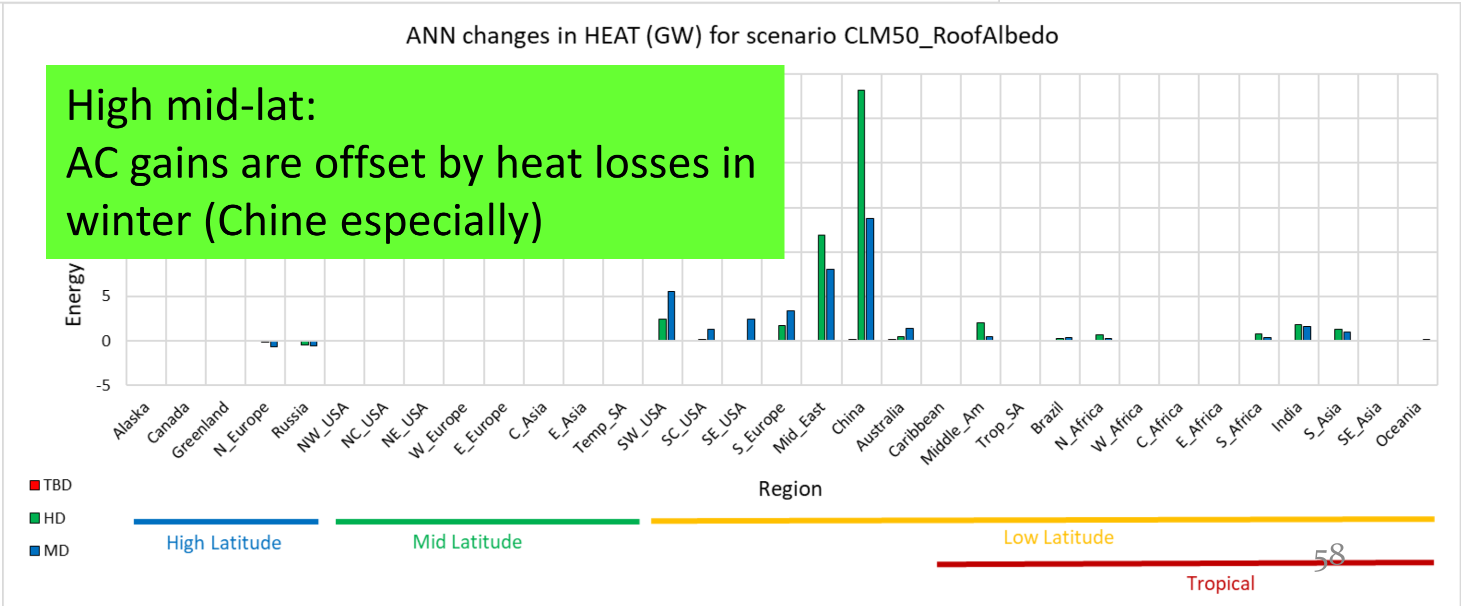
Source: Oleson et al. 2008a,b

Roof Albedo: annual energy change

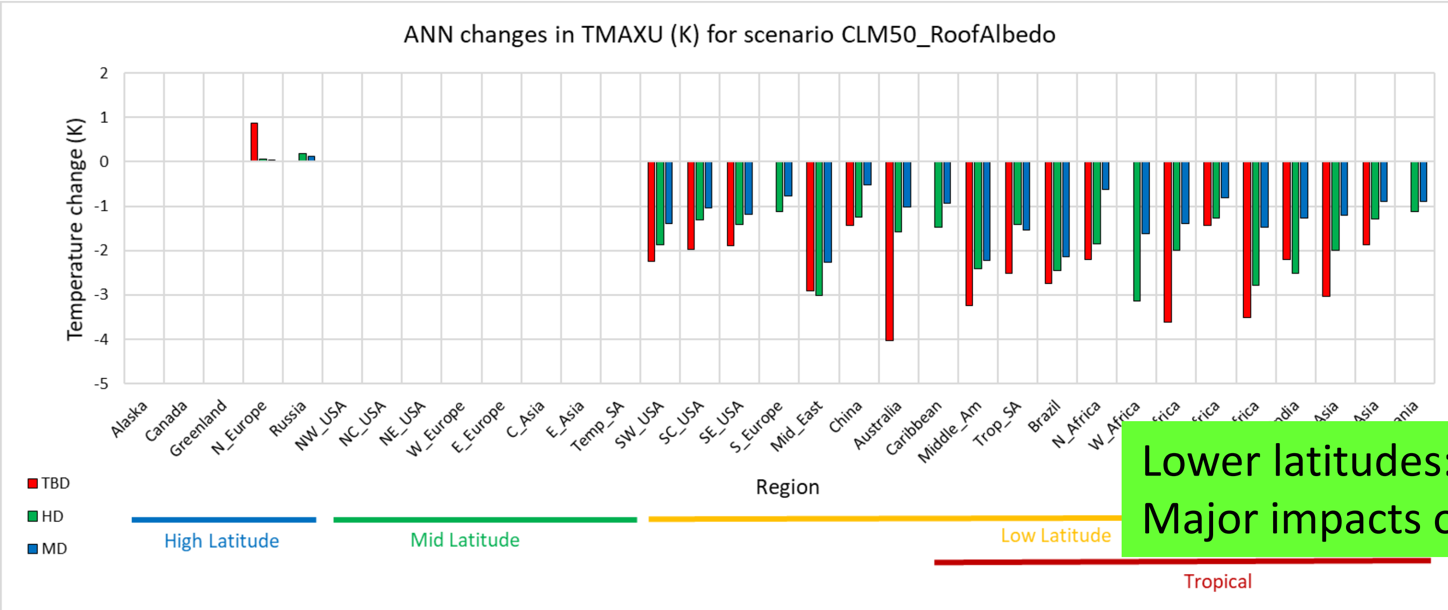


AC related energy use

Heating related energy use



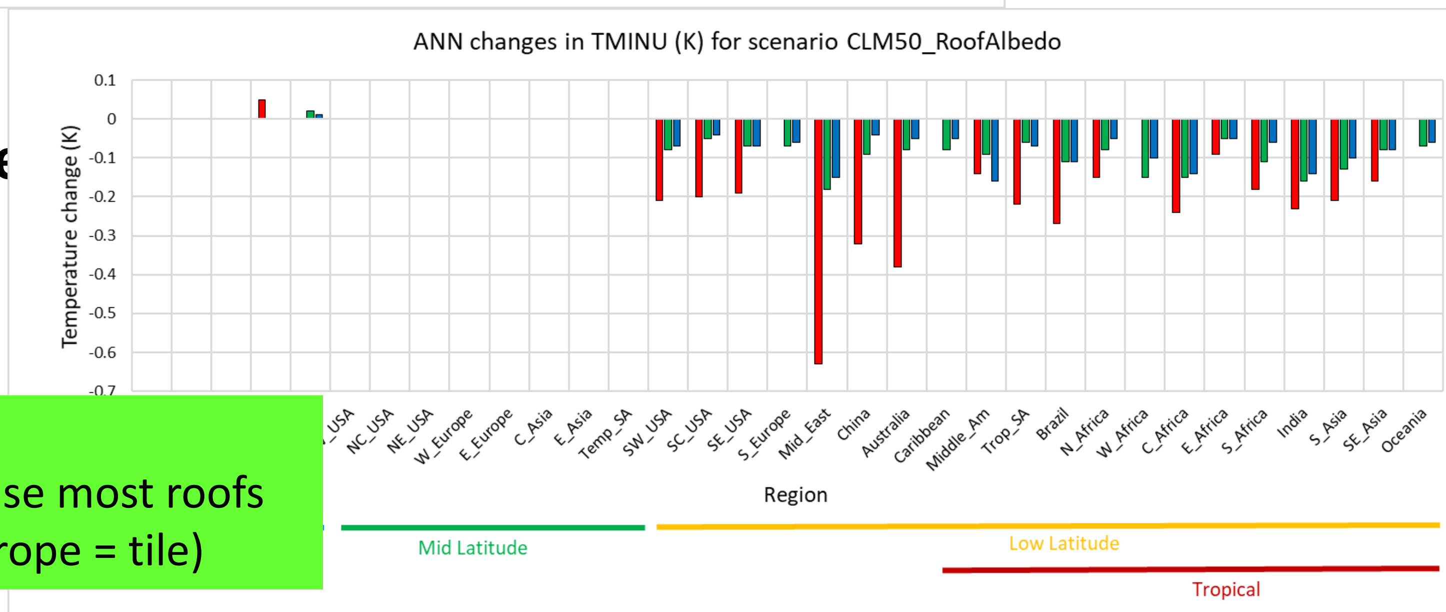
Roof Albedo: annual temperature change



T-max change

Lower latitudes:
Major impacts on UHI

T-min change

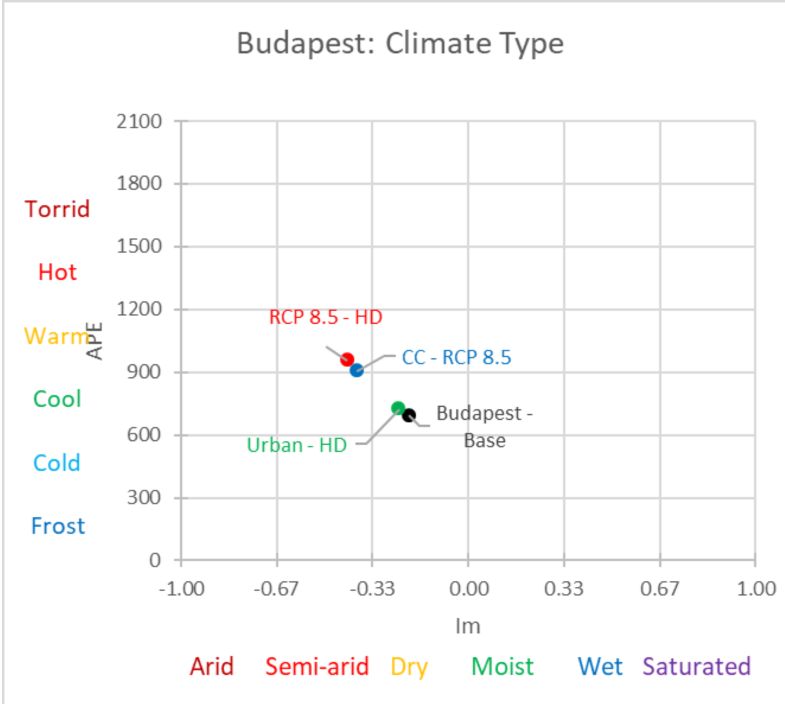


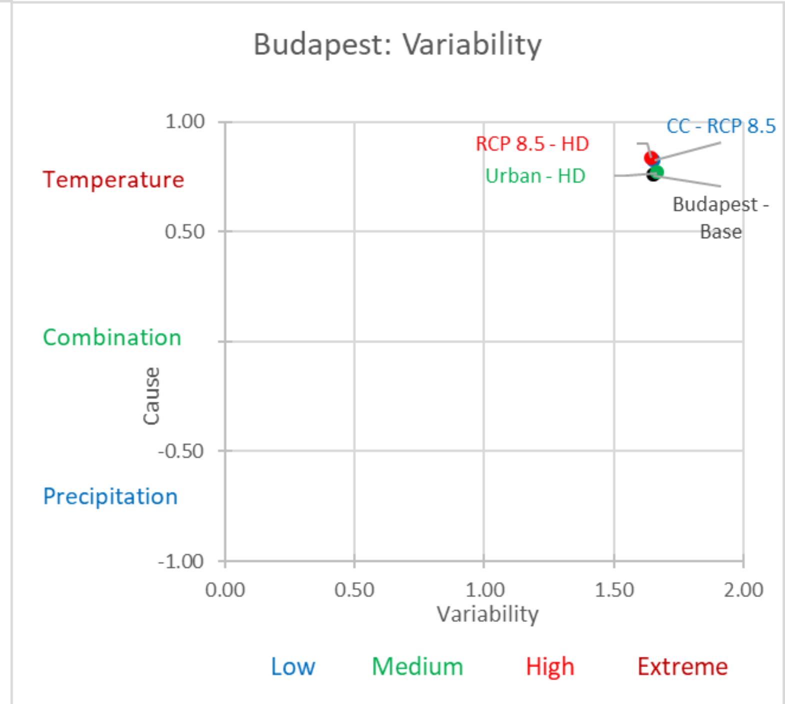
High lat:
Minor change because most roofs are dark asphalt (Europe = tile)

Outcomes for select cities

A potential modification

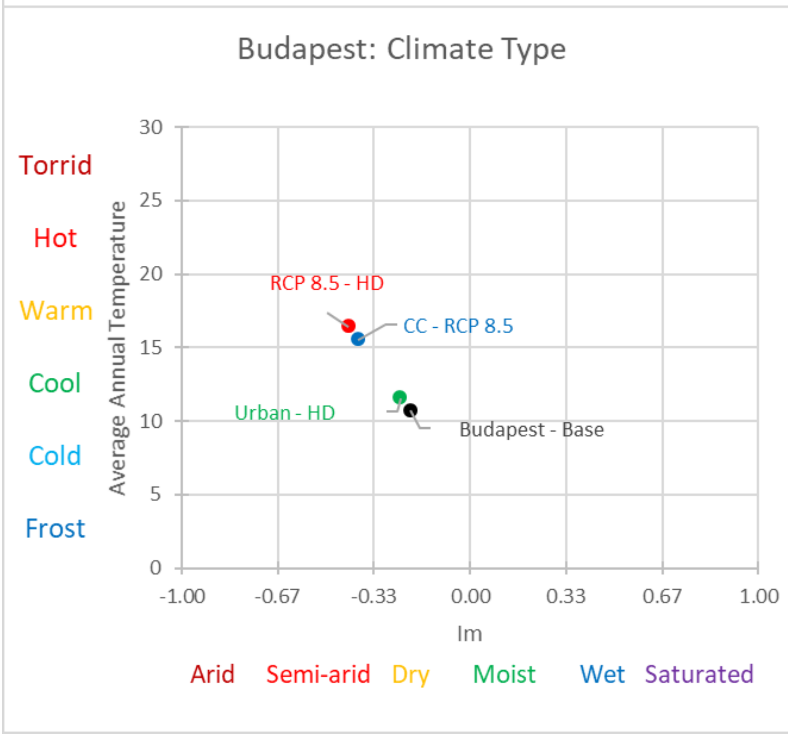
PET

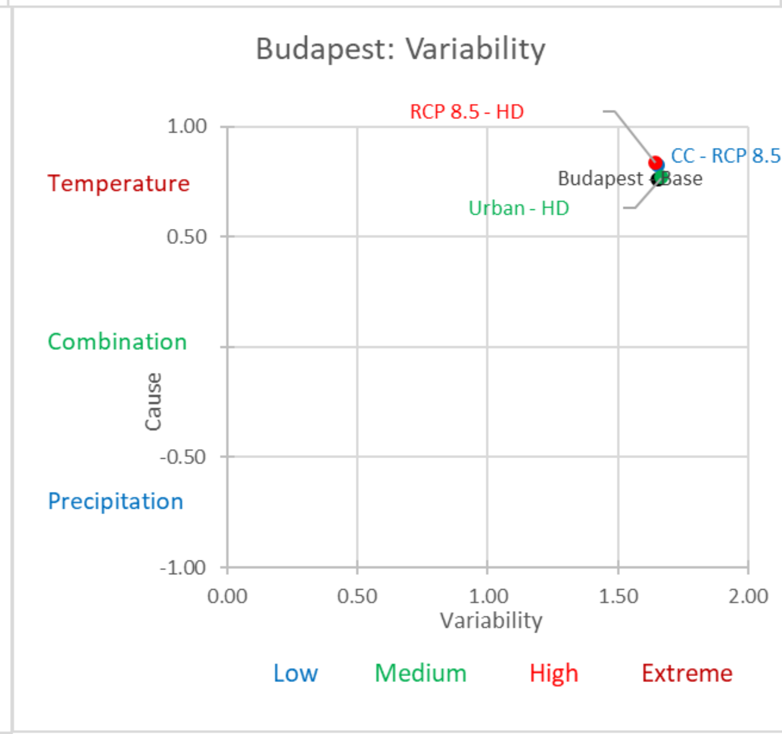


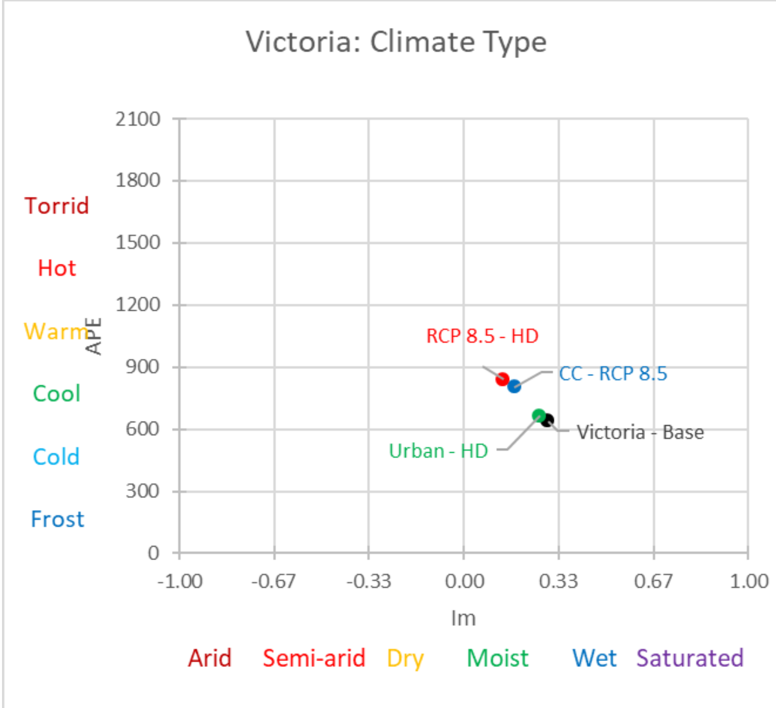


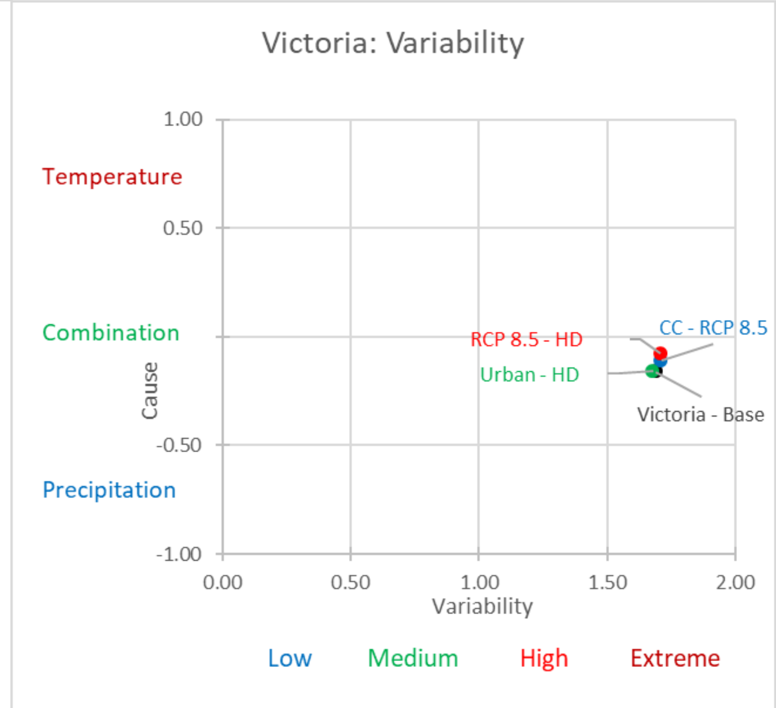
Vs

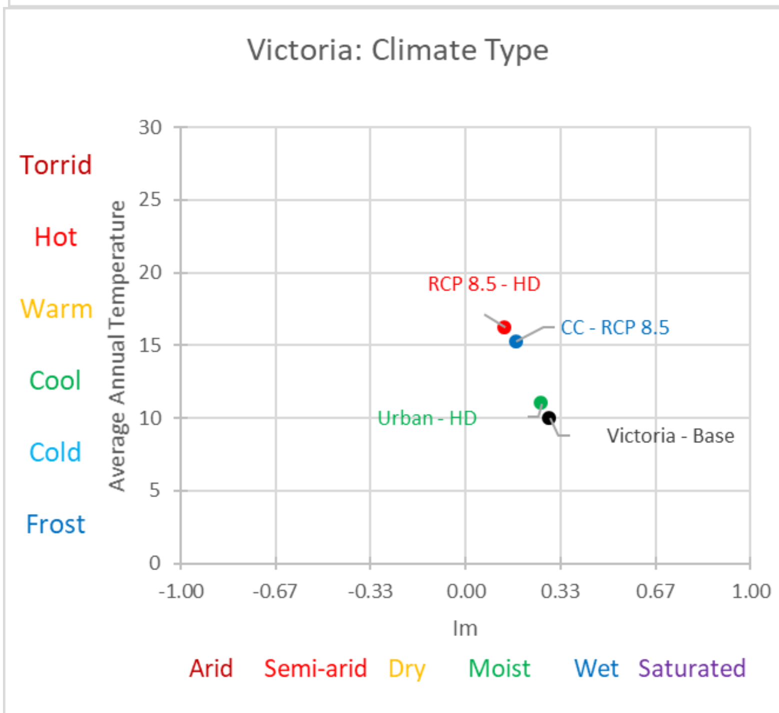
Mean annual Temperature






Victoria: Climate Type
Torrid
Hot
Warm
Cool
Cold
Frost
APE
2100
1800
1500
1200
900
600
300
0
RCP 8.5 - HD
CC - RCP 8.5
Urban - HD
Victoria - Base
-1.00
-0.67
-0.33
0.00
0.33
0.67
1.00
Im
Arid
Semi-arid
Dry
Moist
Wet
Saturated


Victoria: Variability
1.00
Temperature
0.50
Combination
Cause
-0.50
Precipitation
-1.00
RCP 8.5 - HD
CC - RCP 8.5
Urban - HD
Victoria - Base
0.00
0.50
1.00
1.50
2.00
Variability
Low
Medium
High
Extreme


Victoria: Climate Type
Torrid
Hot
Warm
Cool
Cold
Frost
Average Annual Temperature
30
25
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15
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RCP 8.5 - HD
CC - RCP 8.5
Urban - HD
Victoria - Base
-1.00
-0.67
-0.33
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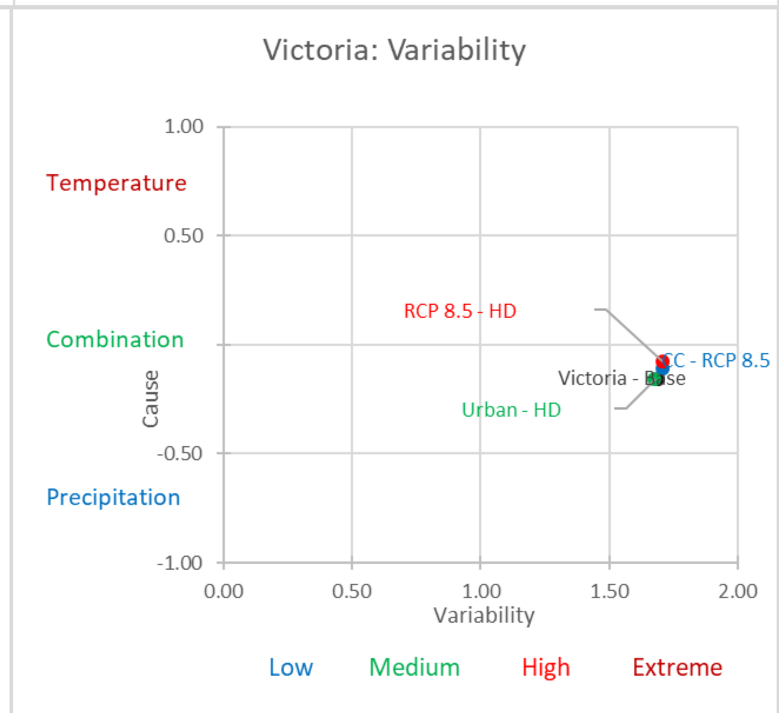
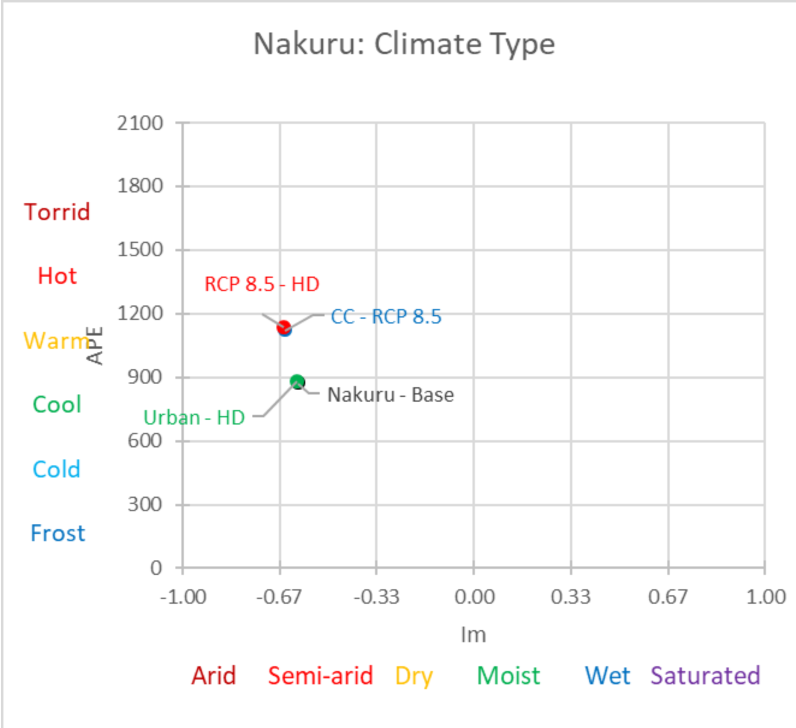
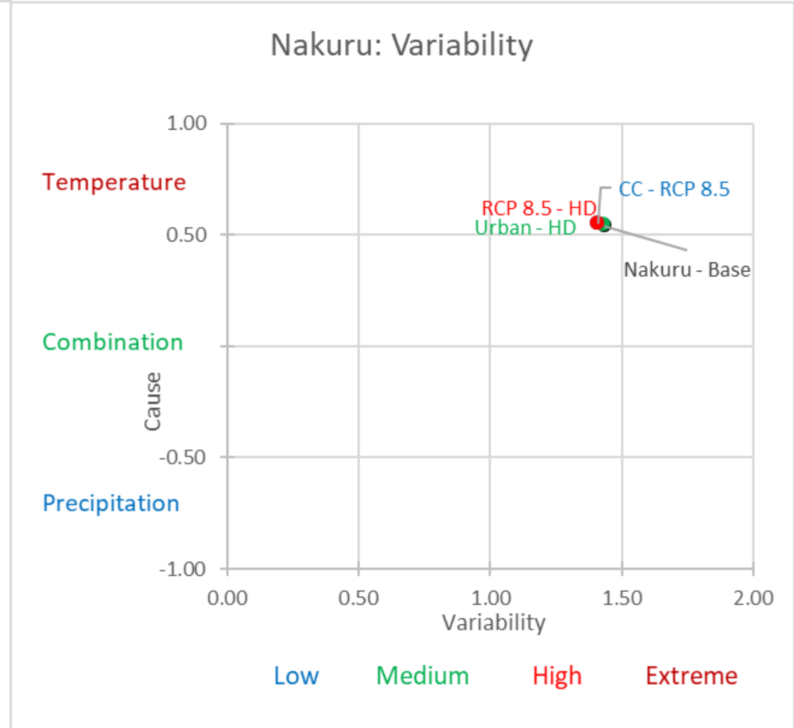
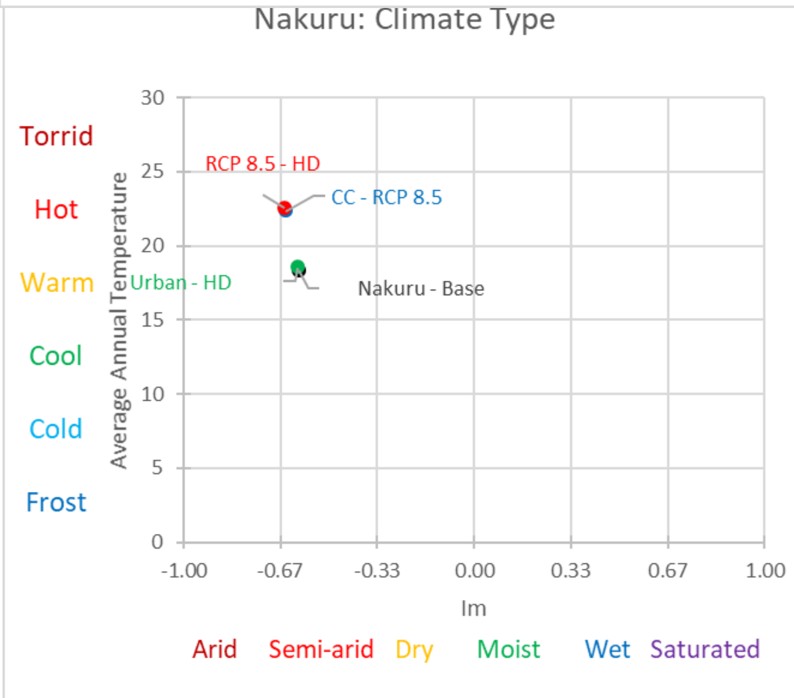
0.67
1.00
Im
Arid
Semi-arid
Dry
Moist
Wet
Saturated


Victoria: Variability
1.00
Temperature
0.50
Combination
Cause
-0.50
Precipitation
-1.00
RCP 8.5 - HD
CC - RCP 8.5
Victoria - Base
Urban - HD
0.00
0.50
1.00
1.50
2.00
Variability
Low
Medium
High
Extreme


Nakuru: Climate Type
Torrid
Hot
Warm
Cool
Cold
Frost
APE
2100
1800
1500
1200
900
600
300
0
RCP 8.5 - HD
CC - RCP 8.5
Nakuru - Base
Urban - HD
-1.00
-0.67
-0.33
0.00
0.33
0.67
1.00
Im
Arid
Semi-arid
Dry
Moist
Wet
Saturated


Nakuru: Variability
Temperature
Combination
Precipitation
Cause
1.00
0.50
-0.50
-1.00
CC - RCP 8.5
RCP 8.5 - HD
Urban - HD
Nakuru - Base
0.00
0.50
1.00
1.50
2.00
Variability
Low
Medium
High
Extreme


Nakuru: Climate Type
Torrid
Hot
Warm
Cool
Cold
Frost
Average Annual Temperature
30
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0
RCP 8.5 - HD
CC - RCP 8.5
Urban - HD
Nakuru - Base
-1.00
-0.67
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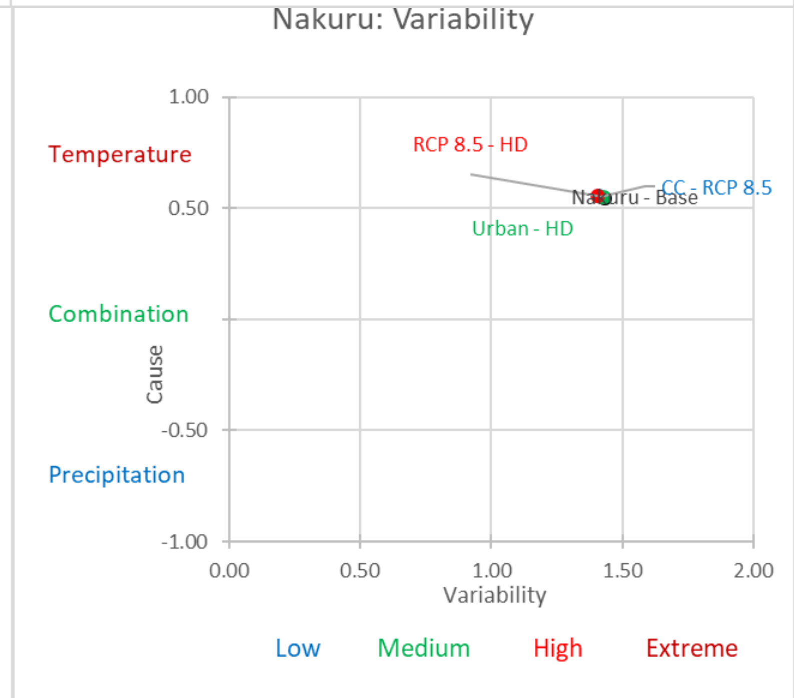
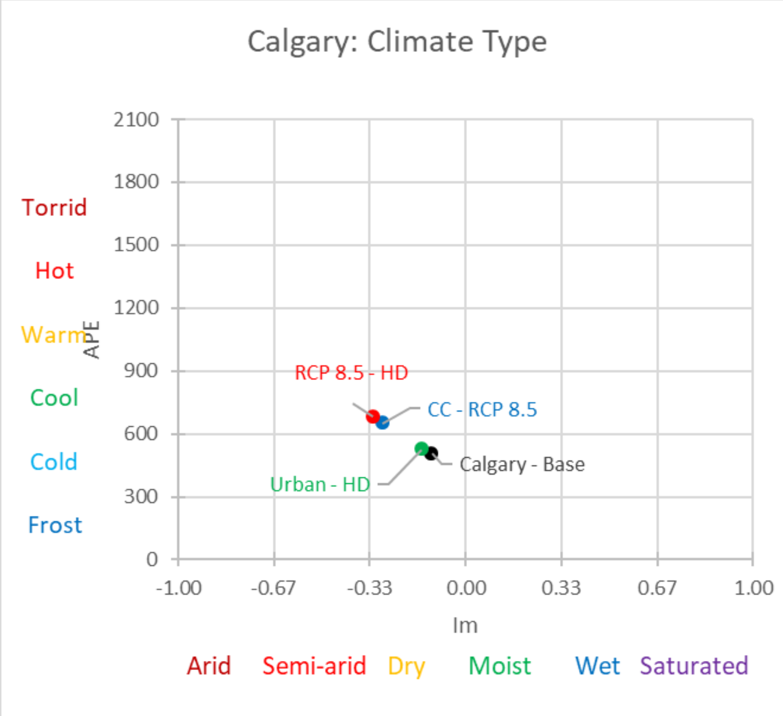
Im
Arid
Semi-arid
Dry
Moist
Wet
Saturated

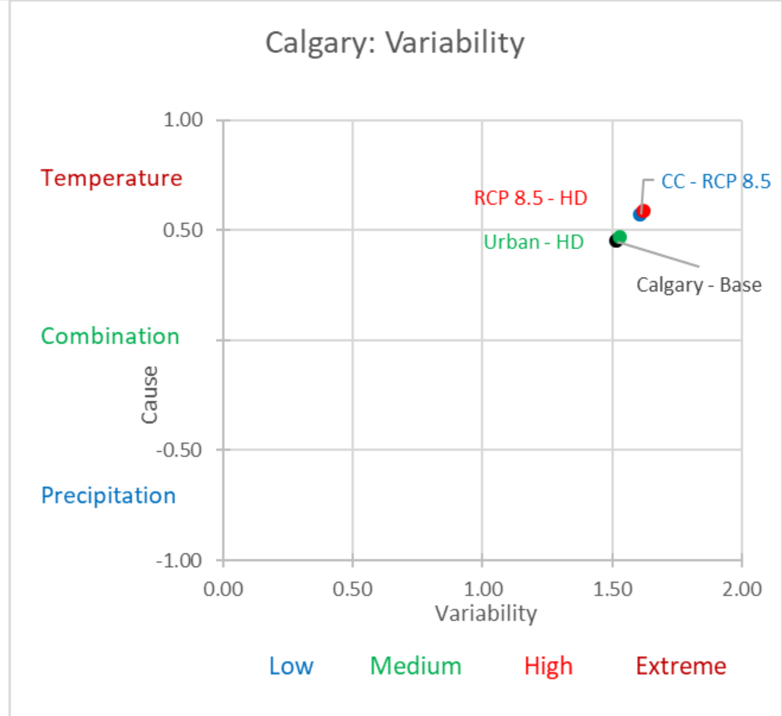

Nakuru: Variability
Temperature
Combination
Precipitation
Cause
1.00
0.50
-0.50
-1.00
RCP 8.5 - HD
Nakuru - Base
CC - RCP 8.5
Urban - HD
0.00
0.50
1.00
1.50
2.00
Variability
Low
Medium
High
Extreme

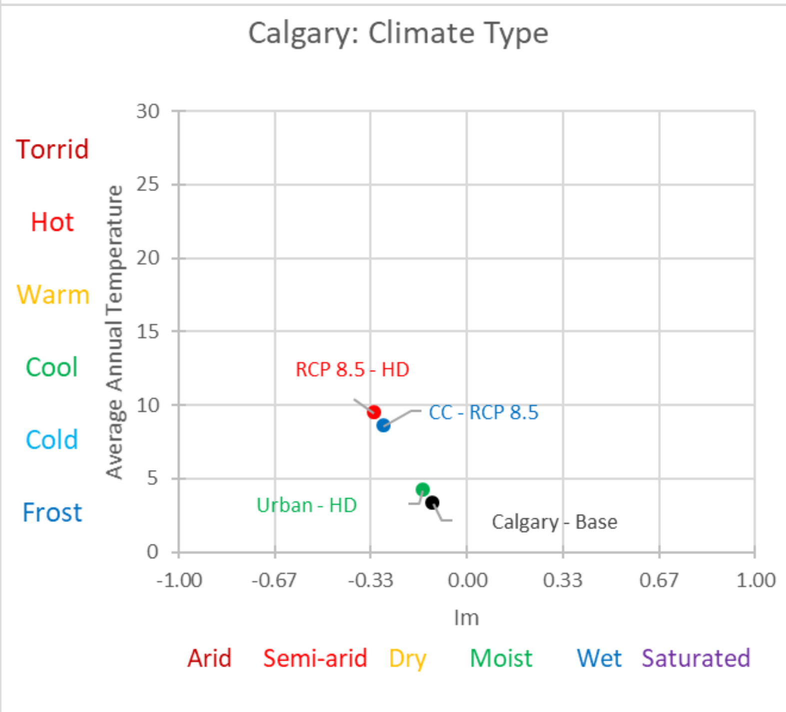
Will need to draw new thermal efficiency boundaries

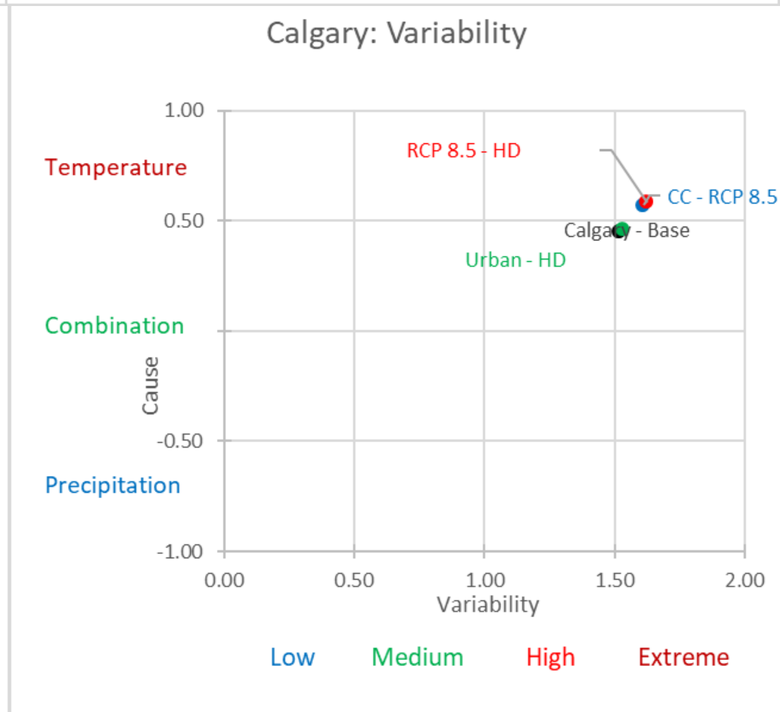
--

if boundaries are essential





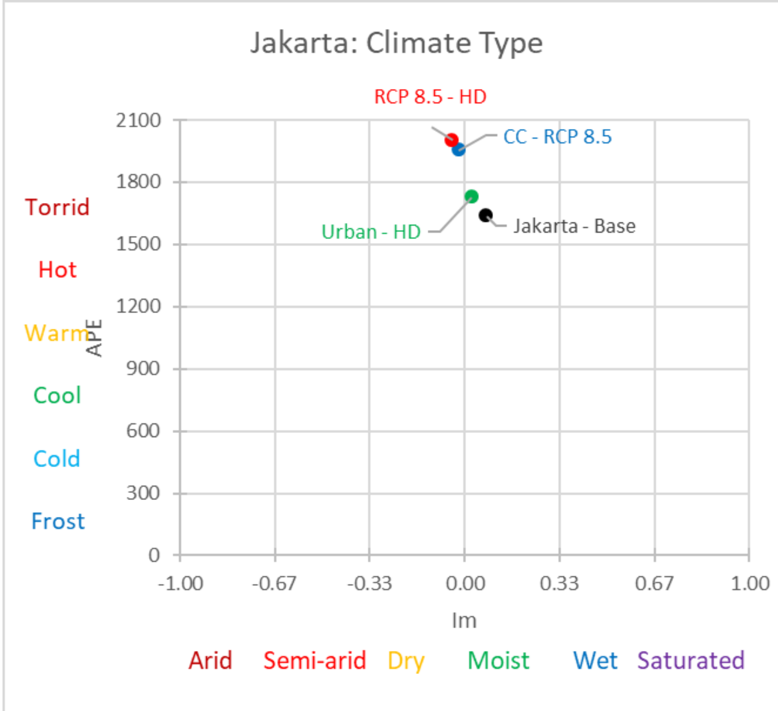


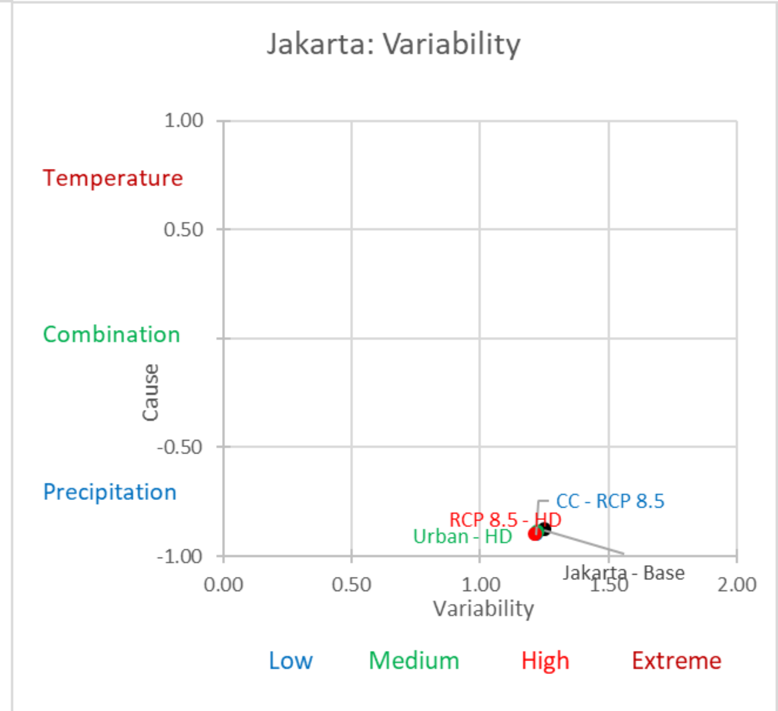


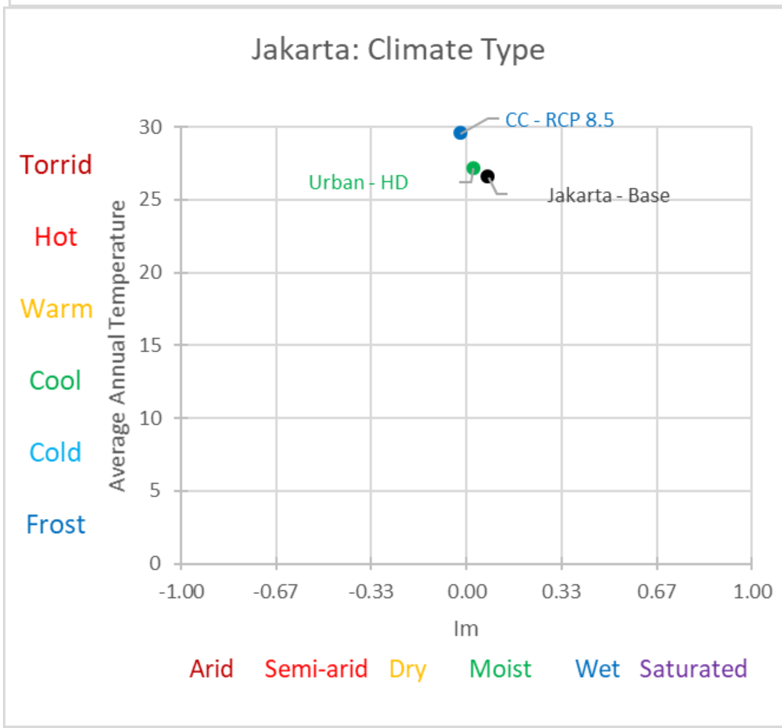
Next steps: Calculating Integrated Climate Change and Map

Proposed methodology:

1. For each variable calculate:
   – Long-term or base period mean
   – Mean absolute deviation (MAD)
   – Create a z-score equivalent from these
2. Map z scores for period of interest show relative magnitude of change in each location
3. Calculate a Euclidian distance for all 4 variables to represent integrated climate impact


Jakarta: Climate Type
RCP 8.5 - HD
CC - RCP 8.5
Urban - HD
Jakarta - Base
Torrid
Hot
Warm
Cool
Cold
Frost
APE
2100
1800
1500
1200
900
600
300
0
-1.00
-0.67
-0.33
0.00
0.33
0.67
1.00
Im
Arid
Semi-arid
Dry
Moist
Wet
Saturated


Jakarta: Variability
Temperature
Combination
Precipitation
Cause
1.00
0.50
-0.50
-1.00
CC - RCP 8.5
RCP 8.5 - HD
Urban - HD
Jakarta - Base
0.00
0.50
1.00
1.50
2.00
Variability
Low
Medium
High
Extreme


Jakarta: Climate Type
CC - RCP 8.5
Urban - HD
Jakarta - Base
Torrid
Hot
Warm
Cool
Cold
Frost
Average Annual Temperature
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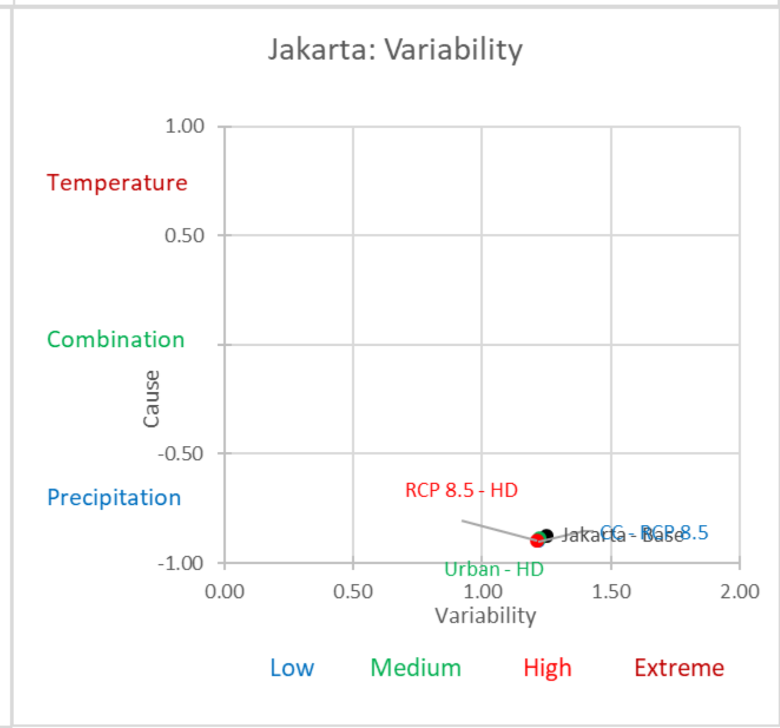
Semi-arid
Dry
Moist
Wet
Saturated


Jakarta: Variability
Temperature
Combination
Precipitation
Cause
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RCP 8.5 - HD
Jakarta - Base
CC - RCP 8.5
Urban - HD
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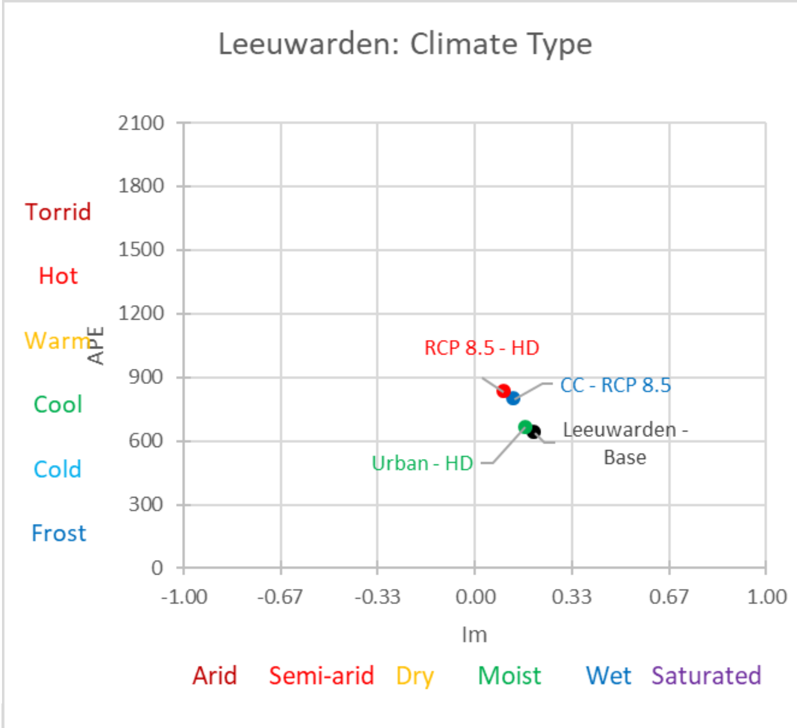
1.50
2.00
Variability
Low
Medium
High
Extreme


Leeuwarden: Climate Type
Torrid
Hot
Warm
Cool
Cold
Frost
APE
2100
1800
1500
1200
900
600
300
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RCP 8.5 - HD
CC - RCP 8.5
Leeuwarden - Base
Urban - HD
-1.00
-0.67
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1.00
Im
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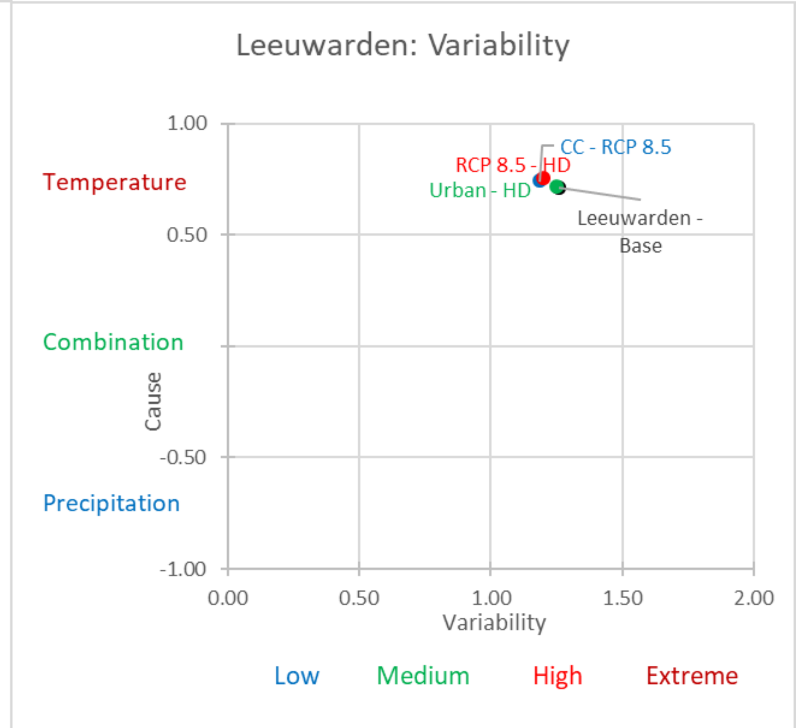
Semi-arid
Dry
Moist
Wet
Saturated


Leeuwarden: Variability
Temperature
Combination
Precipitation
Cause
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CC - RCP 8.5
RCP 8.5 - HD
Urban - HD
Leeuwarden - Base
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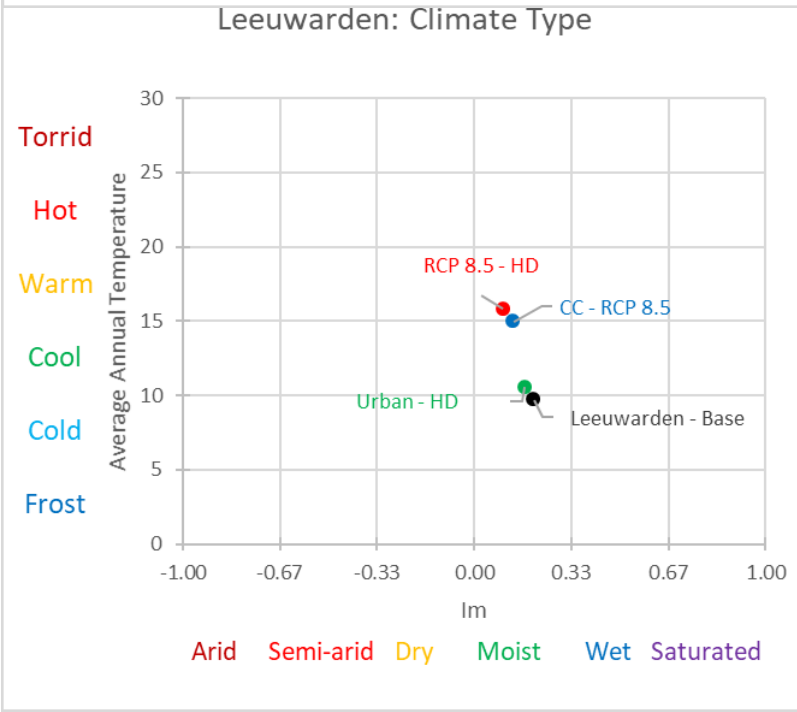
1.50
2.00
Variability
Low
Medium
High
Extreme


Leeuwarden: Climate Type
Torrid
Hot
Warm
Cool
Cold
Frost
Average Annual Temperature
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RCP 8.5 - HD
CC - RCP 8.5
Urban - HD
Leeuwarden - Base
-1.00
-0.67
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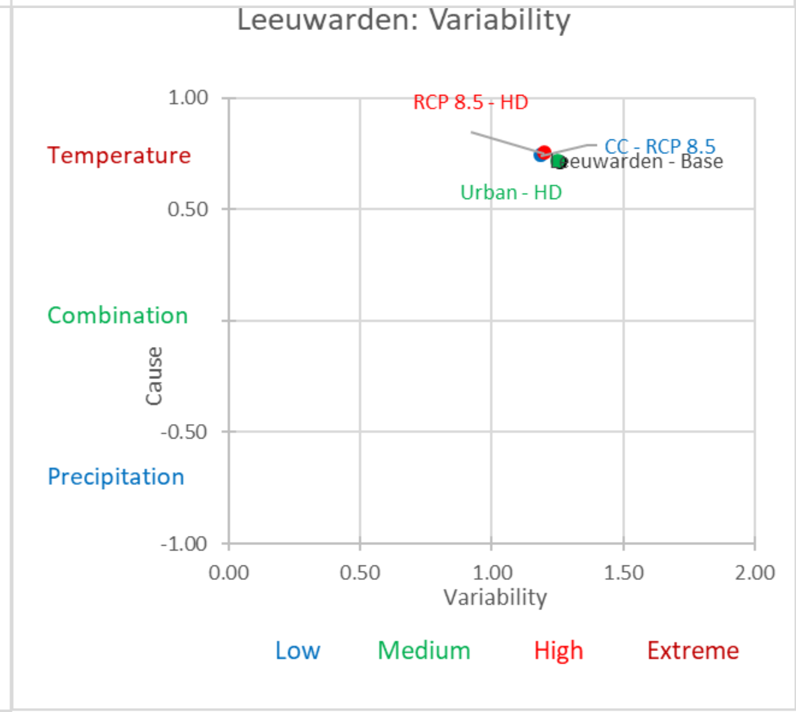
Im
Arid
Semi-arid
Dry
Moist
Wet
Saturated


Leeuwarden: Variability
Temperature
Combination
Precipitation
Cause
1.00
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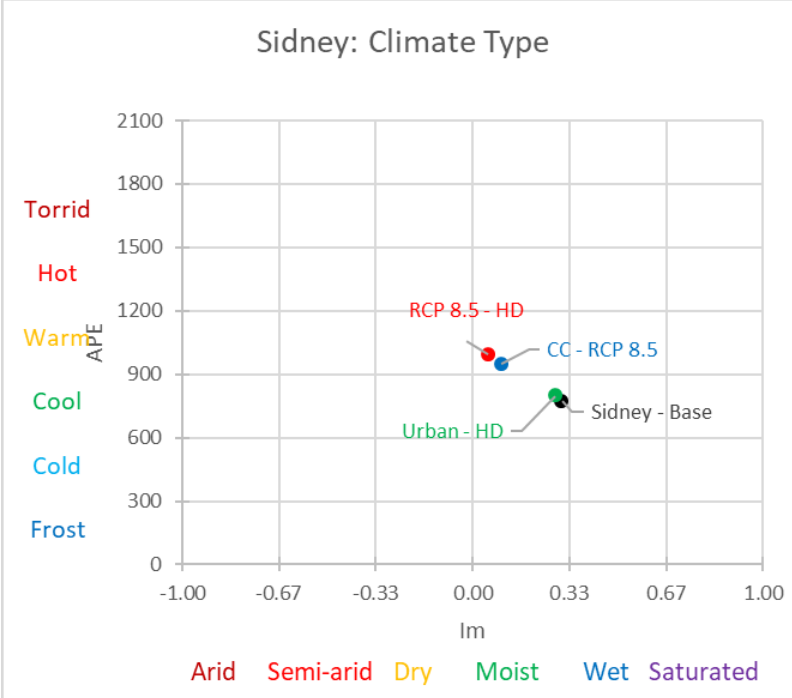
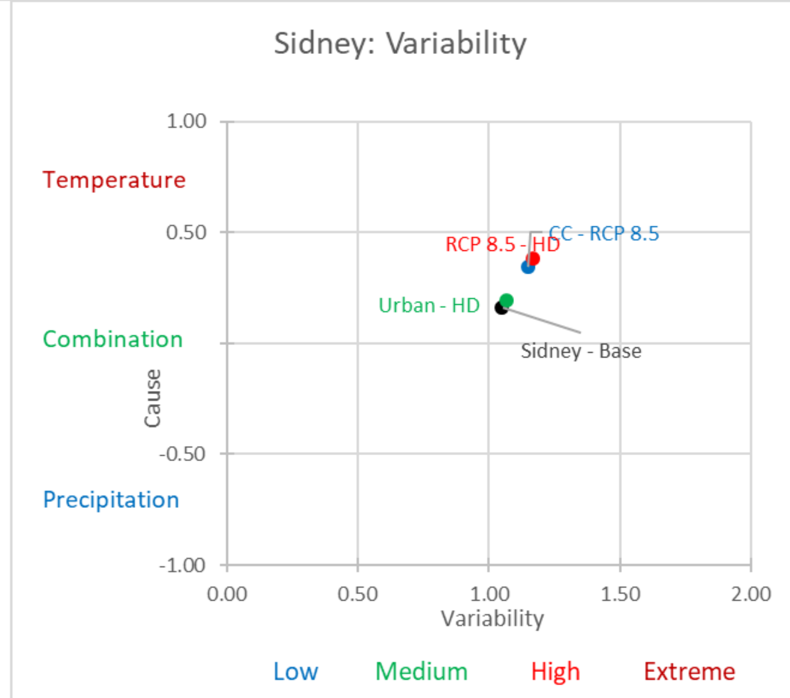
-0.50
-1.00
RCP 8.5 - HD
CC - RCP 8.5
Leeuwarden - Base
Urban - HD
0.00
0.50
1.00
1.50
2.00
Variability
Low
Medium
High
Extreme


Sidney: Climate Type
Torrid
Hot
Warm
Cool
Cold
Frost
APE
2100
1800
1500
1200
900
600
300
0
RCP 8.5 - HD
CC - RCP 8.5
Urban - HD
Sidney - Base
-1.00
-0.67
-0.33
0.00
0.33
0.67
1.00
Im
Arid
Semi-arid
Dry
Moist
Wet
Saturated


Sidney: Variability
Temperature
Combination
Precipitation
Cause
1.00
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-1.00
RCP 8.5 - HD
CC - RCP 8.5
Urban - HD
Sidney - Base
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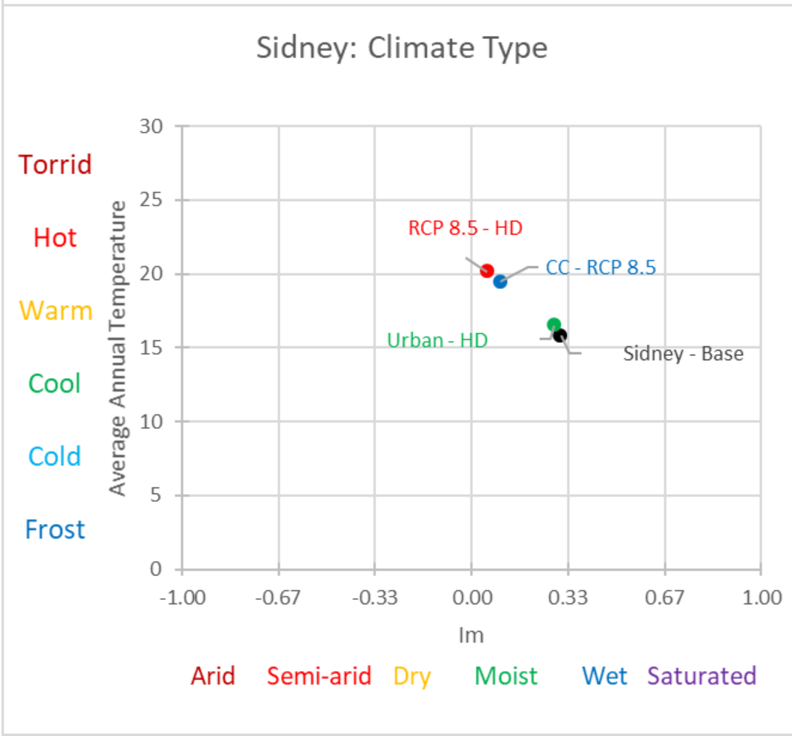
2.00
Variability
Low
Medium
High
Extreme


Sidney: Climate Type
Torrid
Hot
Warm
Cool
Cold
Frost
Average Annual Temperature
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RCP 8.5 - HD
CC - RCP 8.5
Urban - HD
Sidney - Base
-1.00
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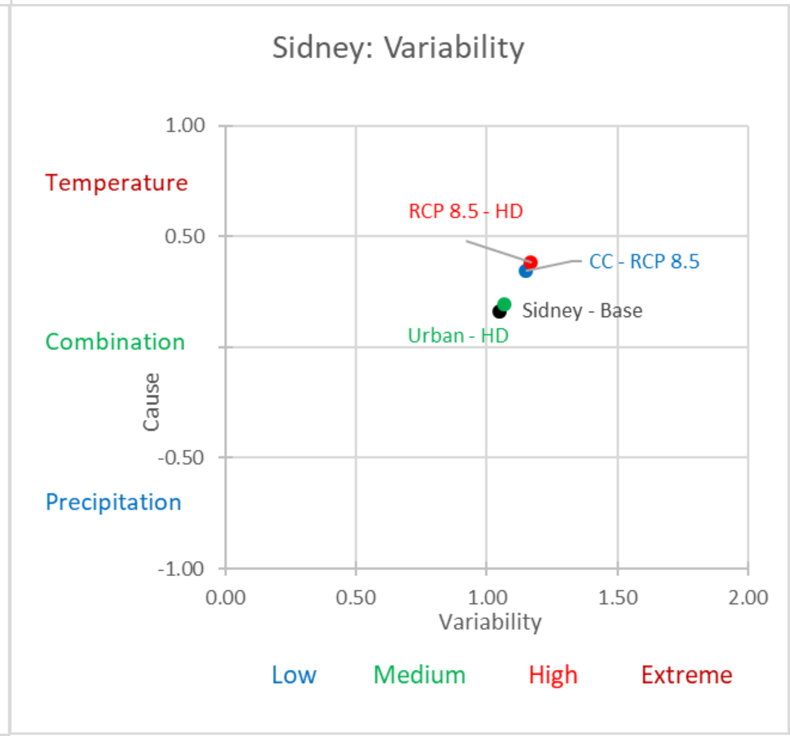
Arid
Semi-arid
Dry
Moist
Wet
Saturated


Sidney: Variability
Temperature
Combination
Precipitation
Cause
1.00
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-1.00
RCP 8.5 - HD
CC - RCP 8.5
Sidney - Base
Urban - HD
0.00
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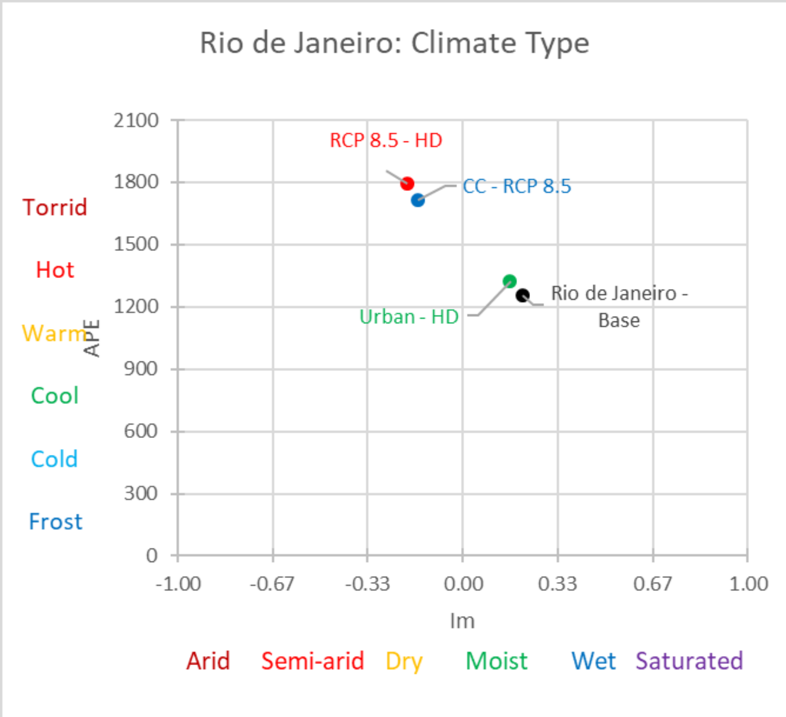
2.00
Variability
Low
Medium
High
Extreme


Rio de Janeiro: Climate Type
RCP 8.5 - HD
CC - RCP 8.5
Urban - HD
Rio de Janeiro - Base
Torrid
Hot
Warm
Cool
Cold
Frost
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-0.67
-0.33
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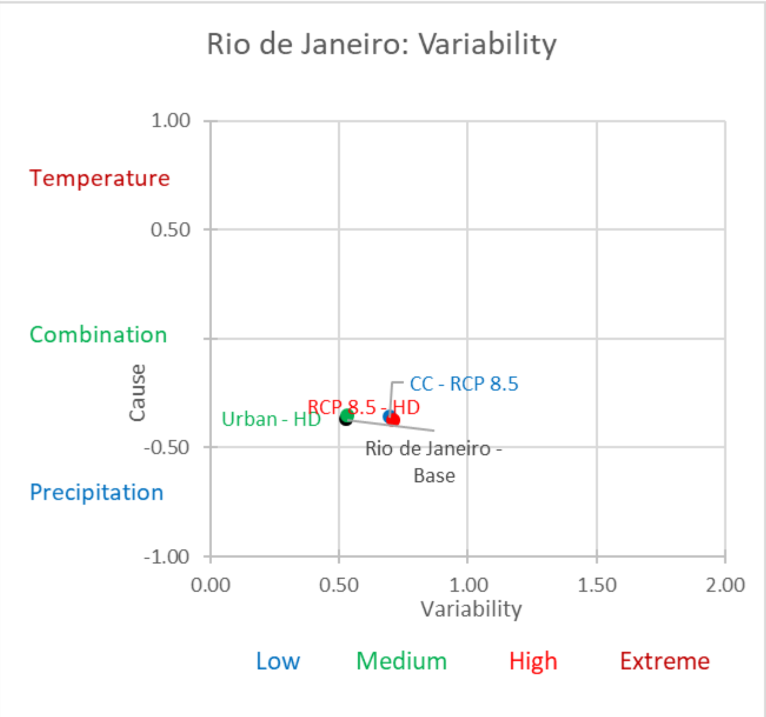
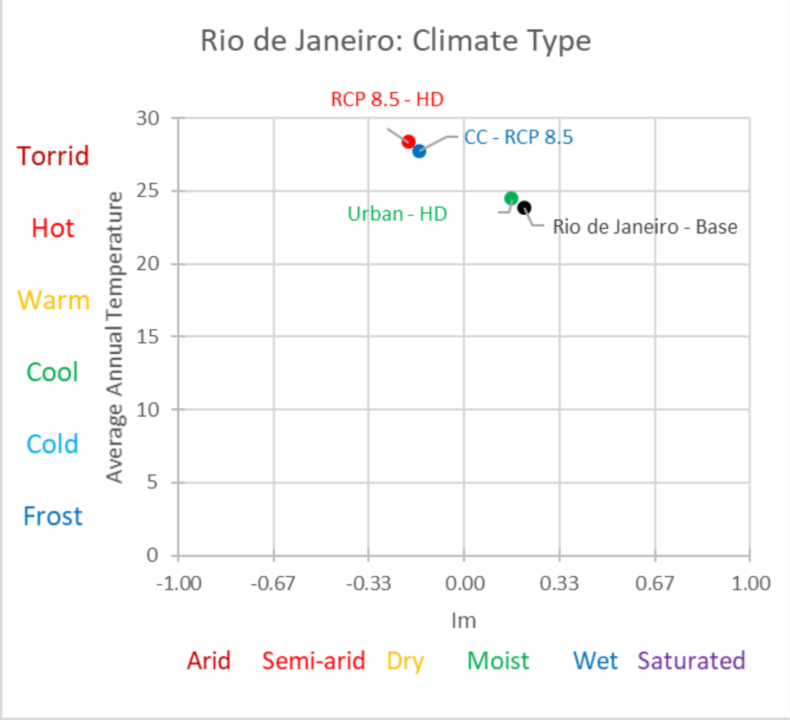
1.00
Im
Arid
Semi-arid
Dry
Moist
Wet
Saturated


Rio de Janeiro: Variability
1.00
0.50
-0.50
-1.00
Temperature
Combination
Precipitation
Cause
CC - RCP 8.5
RCP 8.5 - HD
Urban - HD
Rio de Janeiro - Base
0.00
0.50
1.00
1.50
2.00
Variability
Low
Medium
High
Extreme


Rio de Janeiro: Climate Type
RCP 8.5 - HD
CC - RCP 8.5
Urban - HD
Rio de Janeiro - Base
Torrid
Hot
Warm
Cool
Cold
Frost
Average Annual Temperature
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-1.00
-0.67
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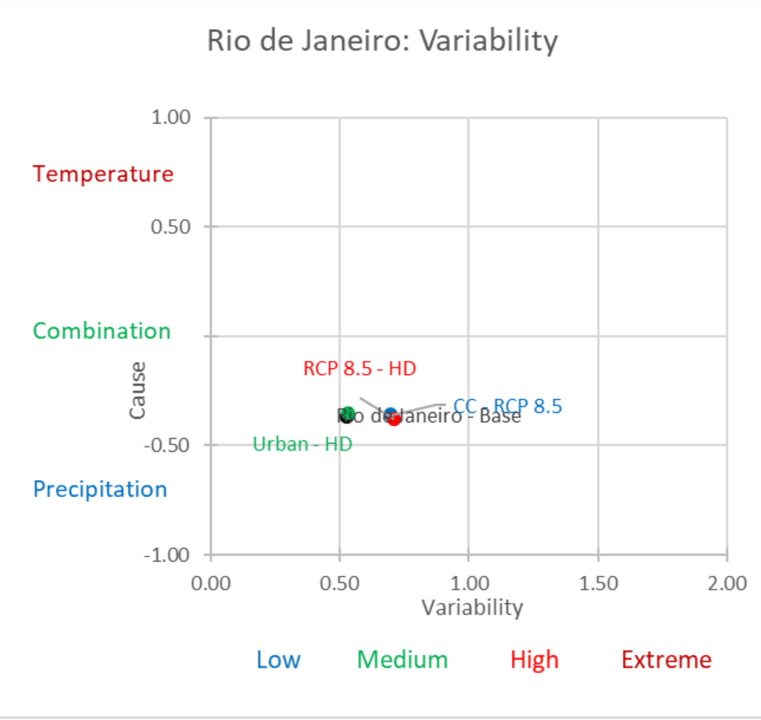
0.67
1.00
Im
Arid
Semi-arid
Dry
Moist
Wet
Saturated


Rio de Janeiro: Variability
1.00
0.50
-0.50
-1.00
Temperature
Combination
Precipitation
Cause
RCP 8.5 - HD
CC - RCP 8.5
Rio de Janeiro - Base
Urban - HD
0.00
0.50
1.00
1.50
2.00
Variability
Low
Medium
High
Extreme

VOTE: **PET** or **MAT**?

Questions