Answer Sheet

LABORATORY 9: CLIMATE AND THE DISTRIBUTION OF BIOMES AND SOILS

Student Name _____

Student Number _____

QUESTION 1

Table 9.2 describes biome and soil type data for 80 locations scattered across our planet. This data has been plotted on **Figures 9.2** and **9.3** for you.

Table 9.2. Biome type, soil type, potential evapotranspiration (PE), moisture index (Im), Köppen climate type, and geographical coordinate data for 80 sampled locations.

No.	Weather Station Name	Location	PE	Im	Biome Type	Soil Type	Köppen Type
1	Tandil, Argentina	37°S, 57°W	1614	-48	G	6	Cfb
2	Rosario, Argentina	32°S, 60°W	2006	-51	G	6	Cfa
3	Santiago del Estero, Argentina	27°S, 64°W	2510	-77	S	7	BSh
4	Rio Preto da Eva, Brazil	3°S, 60°W	1526	51	T	4	Af
5	Santa Isabel do Pará, Brazil	1°S, 48°W	1789	34	T	4	Af
6	Buriti Cortado, Brazil	5°S, 42°W	2093	-26	T	4	Aw
7	Ciudad Bolivar, Venezuela	8°N, 63°W	1906	-50	S	4	Aw
8	Iquitos, Peru	3°S, 73°W	1776	61	T	4	Af
9	Iquique, Chile	20°S, 70°W	2243	-100	d	8	BWh
10	Altamira, Brazil	2°S, 53°W	1518	21	T	4	Am
11	Soledad de Graciano Sánchez, Mexico	22°N, 100°W	1890	-82	d	8	BSk
12	Apodaca, Mexico	25°N, 100°W	1981	-69	d	8	BSh
13	Port Isabel, Texas, USA	26°N, 97°W	1890	-63	S	7	Cfa
14	El Paso international Airport, Texas, USA	31°N, 106°W	2358	-91	d	8	BWk
15	Phoenix, Arizona, USA	33°N, 112°W	2633	-92	d	8	BWh
16	Yuma, Arizona, USA	32°N, 114°W	2472	-97	d	8	BWh
17	Imperial, California, USA	32°N, 115°W	2053	-97	d	8	BWh
18	Reno, Nevada, USA	39°N, 115°W	1917	-88	d	8	BSk
19	Olympia, Washington, USA	47°N, 123°W	980	27	E	2	Csb
20	Spirit Lake, Idaho, USA	48°N, 117°W	1136	-37	E	2	Dsb
21	Regina, Saskatchewan, Canada	50°N, 104°W	1184	-68	G	6	Dfb
22	Calgary, Alberta, Canada	51°N, 114°W	1128	-62	G	6	Dfb
23	Winnipeg, Manitoba, Canada	49°N, 97°W	1143	-55	G	6	Dfb
24	Anchorage, Alaska, USA	61°N, 149°W	655	-37	B	2	Dsb
25	Whitehorse, Yukon, Canada	60°N, 135°W	632	-57	B	2	Dfb
26	Fairbanks, Alaska, USA	64°N, 147°W	704	-54	B	2	Dfb
27	Barrow, Alaska, USA	71°N, 156°W	289	-61	tu	1	ET
28	Thunder Bay, Ontario, Canada	49°N, 89°W	948	-24	B	2	Dfb
29	Bonavista, Newfoundland, Canada	49°N, 53°W	846	25	B	2	Dfb
30	Duluth, Minnesota, USA	46°N, 90°W	1084	-34	De	2	Dfb
31	Caribou, Maine, USA	46°N, 68°W	913	3	De	2	Dfb
32	St. John, New Brunswick, Canada	45°N, 66°W	935	38	De	2	Dfb
33	Barrie, Ontario, Canada	44°N, 80°W	1084	-21	De	3	Dfb
34	Churchill, Manitoba, Canada	58°N, 94°W	595	-30	B	2	Dfb
35	Iqaluit, Nunavut, Canada	64°N, 69°W	416	1	tu	1	ET
36	Fargo, North Dakota, USA	46°N, 96°W	1264	-58	G	6	Dfb
37	Des Moines, Iowa, USA	41°N, 93°W	1399	-40	G	5	Dfa
38	Bolingbrook, Illinois, USA	41°N, 87°W	1304	-28	G	5	Dfa
39	Brentwood, Pennsylvania, USA	40°N, 80°W	1495	-34	G	3	Dfb
40	Asheville, North Carolina, USA	35°N, 82°W	1379	-18	De	4	Cfa

No.	Weather Station Name	Location	PE	Im	Biome Type	Soil Type	Köppen Type
41	Powder Springs, Georgia, USA	33°N, 83°W	1488	-10	De	4	Cfa
42	Reykjavik, Iceland	64°N, 15°W	515	69	B	2	Cfb
43	Dublin, Ireland	53°N, 6°W	919	-17	De	2	Cfb
44	Arkhangelsk, Russia	64°N, 40°E	597	-7	E	2	Dfb
45	Santander, Spain	43°N, 4°W	1191	-10	De	3	Cfb
46	Burgos, Spain	42°N, 4°W	1308	-56	M	7	Cfb
47	Verkhoyansk, Russia	67°N, 113°E	612	-71	B	2	Dfb
48	Turkestan, Kazakhstan	43°N, 68°E	1906	-89	G	7	BSk
49	Shanghai, China	31°N, 121°E	1489	-28	De	3	Cfa
50	Hong Kong	22°N, 114°E	1755	23	Td	4	Cfa
51	Singapore	1°N, 103°E	1571	51	T	4	Af
52	Hyderabad, Pakistan	25°N, 68°E	2754	-94	d	8	BWh
53	Nioro du Sahel, Mali	15°N, 9°W	2918	-81	S	8	BSh
54	Bamako, Mali	12°N, 7°W	2539	-62	S	7	Aw
55	Abidjan, Côte d'Ivoire	5°N, 4°W	1790	0	T	4	Aw
56	Swkopmund, Nambia	23°S, 15°E	2295	-100	d	8	BWk
57	Johannesburg, South Africa	26°S, 28°E	2170	-64	S	8	Cwb
58	Darwin, Australia	12°S, 130°E	2344	-28	S	4	Aw
59	Christchurch, New Zealand	43°S, 172°E	1263	-52	G	2	Cfb
60	Miami, Florida	29°N, 82°W	1694	-25	Td	4	Aw
61	Tantoyuca, Mexico	21°N, 98°W	1788	-32	Td	4	Aw
62	Mobile, Alabama	30°N, 88°W	1567	1	E	4	Cfa
63	Kano, Nigeria	12°N, 8°E	2691	-72	S	5	BSh
64	Giza, Egypt	30°N, 31°E	2258	-99	d	4	BWh
65	Waku Kungo, Angola	11°S, 15°E	2125	-47	gm	6	Cwb
66	Ewo, Democratic Republic of the Congo	6°S, 15°E	1842	0	S	4	Aw
67	Kabinda, Democratic Republic of the Congo	6°S, 24°E	2492	-43	S	4	Aw
68	Kisumu, Kenya	0°S, 34°E	2139	-38	S	4	Af
69	Juba, Sudan	5°N, 32°E	2688	-65	S	4	Aw
70	Jos, Nigeria	10°N, 9°E	1887	-30	gm	4	Aw
71	Abeche, Chad	14°N, 21°E	2959	-86	S	4	BWh
72	Kinshasa, Democratic Republic of the Congo	4°S, 15°E	1745	-22	S	4	Aw
73	Pemberton, British Columbia, Canada	50°N, 123°W	818	26	E	2	Dsb
74	Port Harcourt, Nigeria	5°N, 6°E	1528	77	T	4	Am
75	Campobasso, Italy	42°N, 4°W	1337	-51	M	7	Cfb
76	Crescent City, California, USA	42°N, 124°W	1273	42	E	2	Csb
77	Port Renfrew, British Columbia, Canada	49°N, 124°W	902	126	E	2	Cfb
78	Brewton, Alabama, USA	31°N, 87°W	1599	-1	E	2	Cfa
79	Sisimiut, Greenland	67°N, 54°W	456	-17	tu	1	ET
80	Dudinka, Russia	69°N, 86°E	325	23	tu	1	ET

Data modified from the publication Meentemeyer, V. 1979. Vegetation and climate: an exercise in map reading and graph interpretation. **Journal of Geography**. *78(5):181-187. Measurements of PE, biome type, Köppen climate type, and soil type were updated from* **ESRI's ArcGIS Online Living Atlas** *- https://livingatlas.arcgis.com/en/home/*

Visually analyze the distribution of the plotted biome data and identify obvious clusters on the graph. Note that in some cases, one type may overlap with another type, but in others only one group will be found in a particular part of the graph. On this graph, the following "colored letters" are used to identify the various biomes described below.

tu - *Tundra*
B - *Boreal Forests*
E - *Temperate Coniferous Forests*
De - *Temperate Broadleaf and Mixed Forests*
G - *Temperate Grasslands, Savannas and Shrublands*
gm - *Montane Grasslands and Shrublands*
d - *Deserts and Xeric Shrublands*
M - *Mediterranean Forests, Woodlands and Scrub*
S - *Tropical and Subtropical Grasslands, Savannas and Shrublands*
Td - *Tropical and Subtropical Dry Broadleaf Forests*
T - *Tropical and Subtropical Moist Broadleaf Forests*

Potential Evapotranspiration and Moisture Index Relationship with Biomes
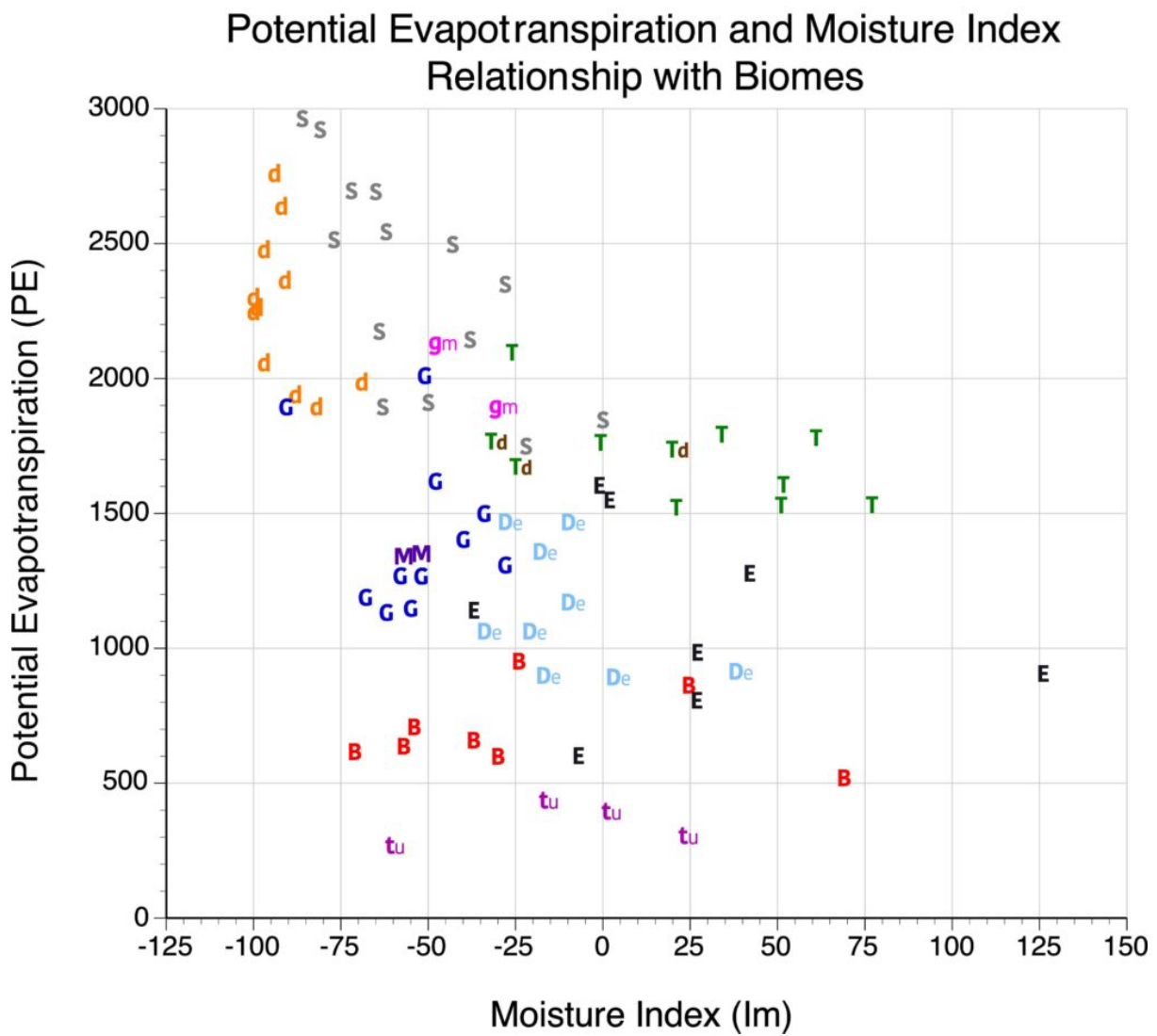
Figure 9.2. *Plot of 80 locations with biome types, and measurements of potential evapotranspiration and moisture index.*

Answer the questions that follow:

1.1) The Tundra (tu) biome has Potential Evapotranspiration values that range from

    A 250-500.
    B 500-1000.
    C 1000-1500.
    D 1500-2000.

1.2) Geographically, where is the Tundra (tu) biome found?

    A Poleward of 65° North.
    B Between 55 and 65° North.
    C Central Greenland.
    D Central Antarctica.

1.3) After carefully examining **Table 9.2**, what Köppen climate classification type is usually associated with the Tundra (tu) biome?

    A A climate type.
    B BW and BS climate type.
    C C climate type.
    D D climate types
    E E climate type.

1.4) What value for PE would serve as a good boundary between the Boreal Forests (B) and Tundra (tu) biomes?

    A 250
    B 500
    C 750
    D 1000

1.5) Which biome replaces the Temperate Broadleaf and Mixed Forests (De) biome when moisture becomes less available?

    A Temperate Coniferous Forests (E).
    B Mediterranean Forests, Woodlands and Scrub (M).
    C Deserts and Xeric Shrublands (d).
    D Temperate Grasslands, Savannas and Shrublands (G).

1.6) After carefully examining **Table 9.2**, what two Köppen climate classification types are usually associated with the Temperate Broadleaf and Mixed Forests (De) biome?

      A A climate type.
      B BW and BS climate type.
      C C climate type.
      D D climate types.
      E E climate type.

1.7) Which biomes replaces the Boreal Forests (B) biome when energy (Potential Evapotranspiration) becomes more available? (Multiple answers are accepted for this question)

      A Temperate Broadleaf and Mixed Forests (De).
      B Mediterranean Forests Woodlands and Scrub (M).
      C Deserts and Xeric Shrublands (d).
      D Temperate Grasslands Savannas and Shrublands (G).

1.8) At approximately what values of the Moisture Index (Im) do places become so dry that desert vegetation becomes common?

      A -120 to -100.
      B -100 to -70.
      C -70 to -40.
      D -40 to 0.

1.9) Which biome replaces the Tropical and Subtropical Grasslands, Savannas and Shrublands (S) biome when moisture becomes less available?

      A Tropical and Subtropical Moist Broadleaf Forests (T).
      B Mediterranean Forests, Woodlands and Scrub (M).
      C Deserts and Xeric Shrublands (d).
   **D** Temperate Grasslands, Savannas and Shrublands (G).

1.10) After carefully examining **Table 9.2**, what Köppen climate classification type is usually associated with the Deserts and Xeric Shrublands biome?

        A A climate type.
        B BW and BS climate type.
        C C climate type.
        D D climate types.
        E E climate type.

QUESTION 2

Visually analyze the distribution of the plotted soil type data and identify obvious clusters on the graph. Note that in some cases, one type may overlap with another type, but in others only one group will be found in a particular part of the graph. On this graph, the following "colored letters" are used to identify eight general soil types described below.

1 - Tundra Soils
2 - Podzols
3 - Gray-Brown Forest Soil (Podzol Variant)
4 - Tropical and Subtropical Red and Yellow Soils
5 - Prairie Soils
6 - Chernozem Soils
7 - Brown Steppe Soils
8 - Desert Soils
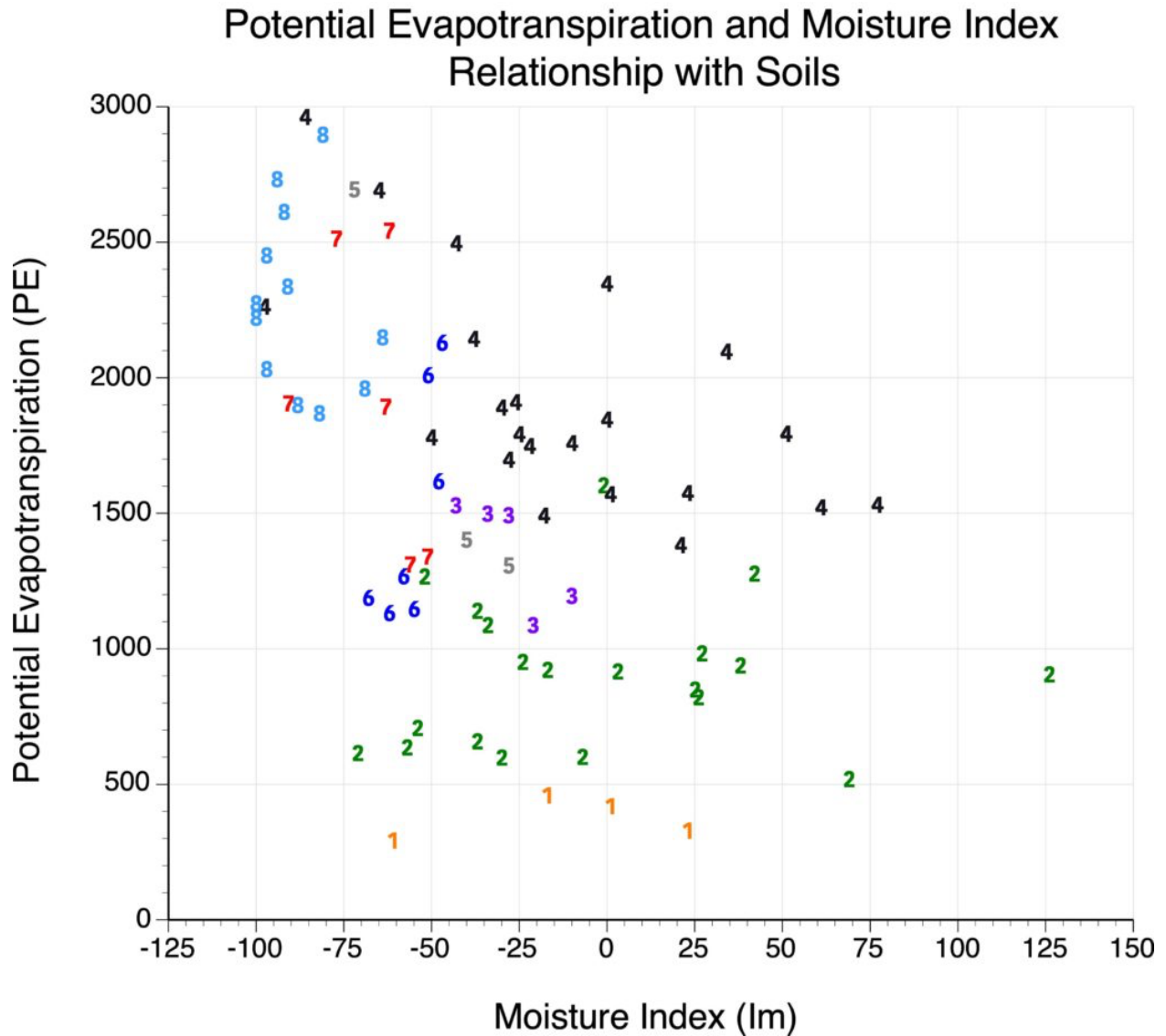
Figure 9.3. *Plot of 80 locations with soil types, and measurements of potential evapotranspiration and moisture index.*

Answer the questions that follow:

2.1) What two biomes are associated with Tropical and Subtropical Red and Yellow Soils (4)? (Multiple answers are accepted for this question)

    A Tropical and Subtropical Moist Broadleaf Forests (T).
    B Mediterranean Forests Woodlands and Scrub (M).
    C Deserts and Xeric Shrublands (d).
    D Temperate Grasslands Savannas and Shrublands (G).

2.2) What two biomes are associated with Podzol Soils (2)? (Multiple answers are accepted for this question)

      A Boreal Forests (B).
      B Mediterranean Forests Woodlands and Scrub (M).
      C Tundra (tu).
      D Temperate Coniferous Forests (E).

2.3) What biome is associated with Desert Soils (8)?

      A Tropical and Subtropical Moist Broadleaf Forests (T).
      B Mediterranean Forests, Woodlands and Scrub (M).
      C Deserts and Xeric Shrublands (d).
      D Temperate Grasslands, Savannas and Shrublands (G).

2.4) What biome is associated with Chernozem Soils (6)? (Multiple answers are accepted for this question)

      A Tropical and Subtropical Moist Broadleaf Forests (T).
      B Mediterranean Forests Woodlands and Scrub (M).
      C Temperate Broadleaf and Mixed Forests (De).
      D Temperate Grasslands Savannas and Shrublands (G).

2.5) Tundra and Desert soils are commonly recognized as immature soils with no or limited profile development. The particular environments they exist in add little organic matter to the soil profile and limit the chemical reactions necessary for pedogenesis. What climate factors are responsible and how do they limit these two important factors in soil development?
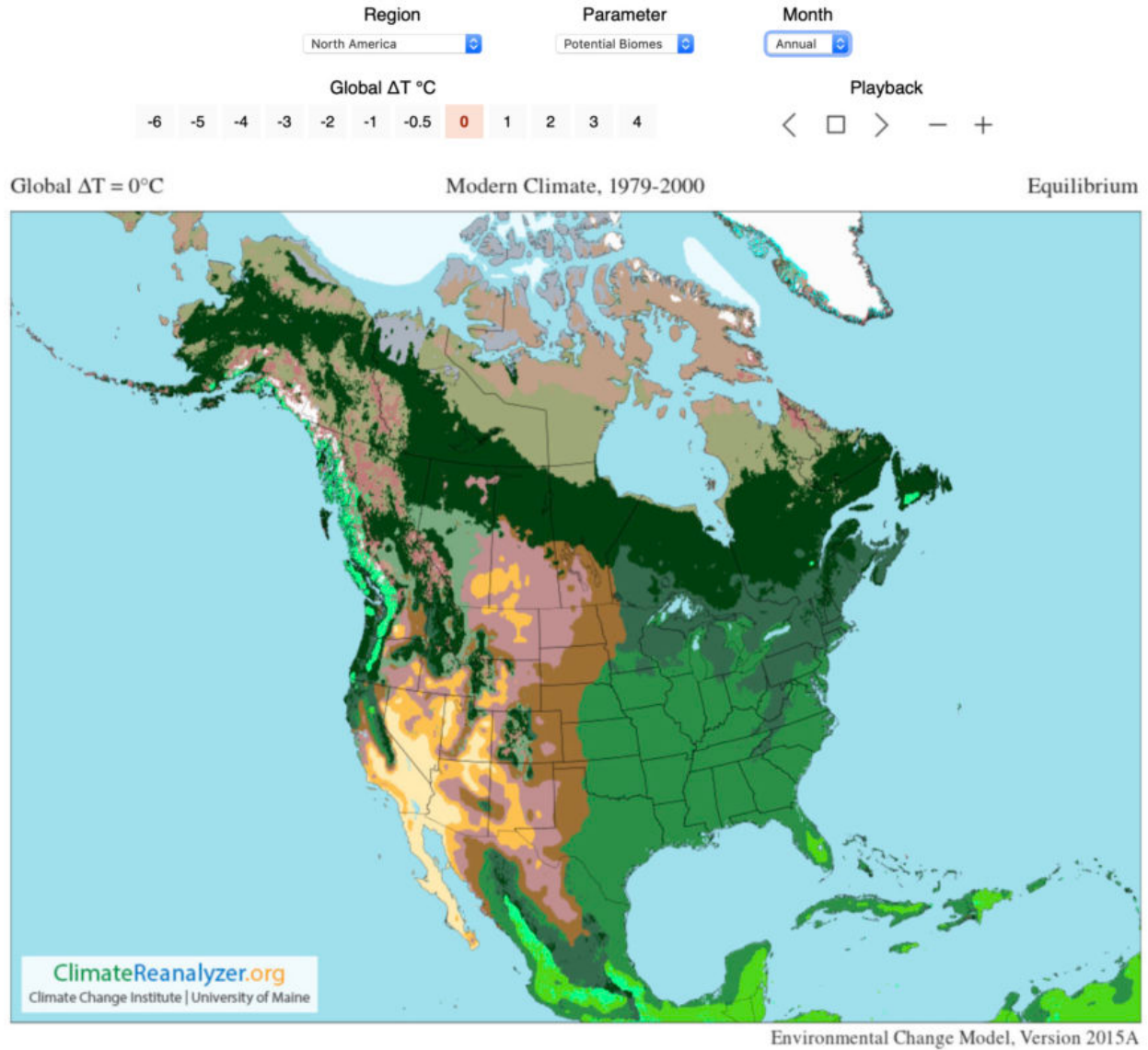
QUESTION 3

We are now going to use a computer model to investigate how future climate change will influence the spatial distribution of North America's biomes. This model is available on **Climate Reanalyzer** and is called the **Environmental Change Model** (ECM). Note that ECM uses a biome classification system that is slightly different and more complex than the one you are familiar with. The biomes displayed on ECM are (in brackets the roughly equivalent biome found in **Figure 9.1** is given):
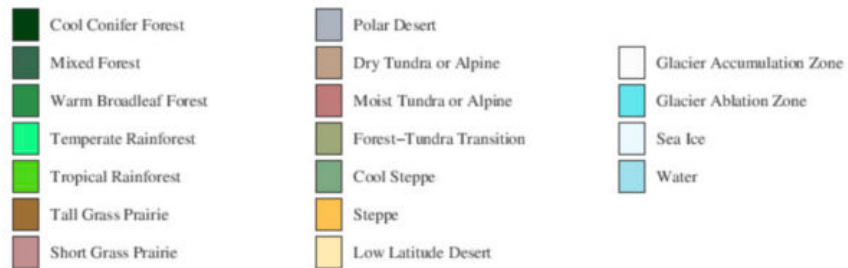
1. Cool Conifer Forest (Boreal Forest/Taiga)

2. Mixed Forest (Temperate Broadleaf & Mixed Forests)

3. Warm Broadleaf Forest (Temperate Broadleaf & Mixed Forests)

4. Temperate Rainforest (Temperate Conifer Forests)

5. Tropical Rainforest (Tropical & Subtropical Moist Broadleaf Forests)

6. Tall Grass Prairie (Temperate Grasslands, Savannas & Shrublands)

7. Short Grass Prairie (Temperate Grasslands, Savannas & Shrublands)

8. Polar Desert (Tundra)

9. Dry Tundra or Alpine (Tundra)

10. Moist Tundra (Tundra)

11. Forest-Tundra Transition (Boreal Forest/Taiga)

12. Cool Steppe (Temperate Conifer Forests)

13. Steppe (Temperate Grasslands, Savannas & Shrublands)

14. Low Latitude Desert (Desert & Xeric Shrublands)

The figure below from **Climate Reanalyzer's Environmental Change Model** shows the potential distribution of the 14 biomes under the climate typical for the period 1979-2000 – note the inputs used to produce this map, in particular Global $\Delta T°C = 0$.

In a separate browser window recreate the map above. In another browser window create a map of **North America** showing the potential distribution of the 14 biomes under a **worst case scenario** where Global $\Delta T°C = 4$. Examine the differences between the two maps and answer the following questions.

Potential Biomes

■ Cool Conifer Forest	■ Polar Desert	□ Glacier Accumulation Zone
■ Mixed Forest	■ Dry Tundra or Alpine	■ Glacier Ablation Zone
■ Warm Broadleaf Forest	■ Moist Tundra or Alpine	□ Sea Ice
■ Temperate Rainforest	■ Forest–Tundra Transition	■ Water
■ Tropical Rainforest	■ Cool Steppe	
■ Tall Grass Prairie	■ Steppe	
■ Short Grass Prairie	■ Low Latitude Desert	

3.1) Which forest biome listed below shows the greatest increase in surface coverage over North America under Global $\Delta T°C = 4$ when compared to Global $\Delta T°C = 0$?

      A Warm Broadleaf Forest.
      B Mixed Forest.
      C Cool Coniferous Forest.
      D Temperate Rainforest.

3.2) Which forest biome listed below shows the greatest decline in surface coverage over North America under Global $\Delta T°C = 4$ when compared to Global $\Delta T°C = 0$?

      A Warm Broadleaf Forest.
      B Mixed Forest.
      C Cool Coniferous Forest.
      D Temperate Rainforest.

3.3) Over the provinces of Alberta, Saskatchewan, and Manitoba surface coverage of Short Grassland, Tall Grassland, and Steppe combined increases by how much under Global $\Delta T°C = 4$ when compared to Global $\Delta T°C = 0$?

      A 10%
      B 30%
      C 50%
      D 100%

3.4) What two biomes replace Mixed and Cool Conifer Forests in Ontario under Global $\Delta T°C = 4$ when compared to Global $\Delta T°C = 0$? (Multiple answers are accepted for this question)

      A Warm Broadleaf Forest.
      B Tall Grass Prairie.
      C Short Grass Prairie.
      D Temperate Rainforest.

3.5) Do Texas, Louisiana, Mississippi, Florida, and Georgia see much change in their biomes under Global $\Delta T°C = 4$ when compared to Global $\Delta T°C = 0$?

      A Yes.
      B No.