Site Representativeness and Sampling Network Design for the Next Generation Ecosystem Experiment (NGEE)-Arctic

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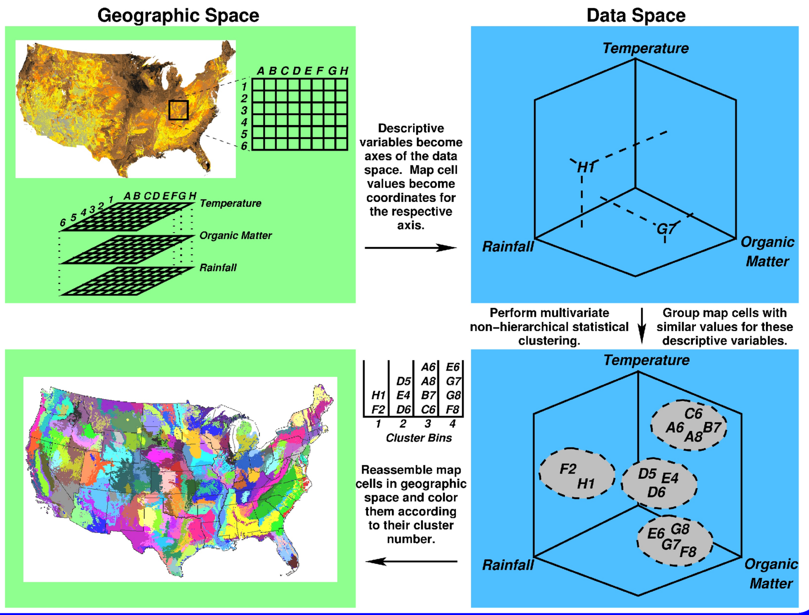
Introduction

NGEE-Arctic will use observations and models to understand how permafrost degradation in a warming Arctic will affect feedbacks to the climate system. To quantitatively delineate large-scale ecoregions and determine site representativeness in support of site selection, a statistical clustering methodology, developed by Hargrove and Hoffman, was applied to the analysis of modeled and observed environmental conditions for the state of Alaska at a resolution of 2 km^2 for the present (2000–2009) and a future (2090–2099) decade. The clustering algorithm is diagramed below.

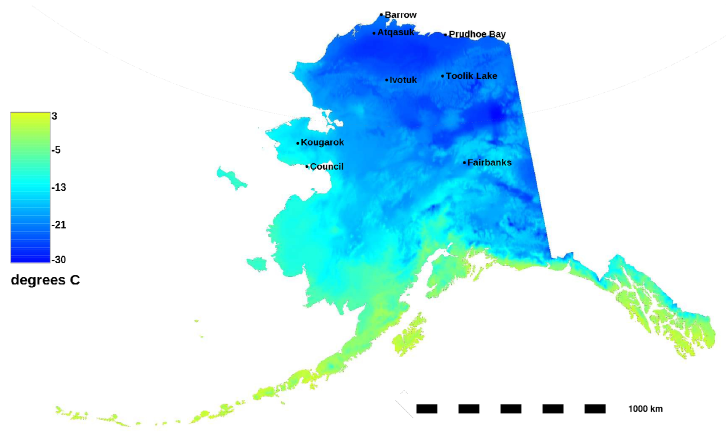
Two sets of input map layers for years 2000–2009 and 2090–2099 were used in the *k*-means cluster analysis:

- Monthly mean air temperature (12)
- Monthly mean precipitation (12)
- Length of growing seasons (mean & standard deviation)
- Day of freeze (mean & standard deviation)
- Day of thaw (mean & standard deviation)
- Maximum active layer thickness
- Warming effect of snow (ΔT_{sn})
- Mean winter snow depth (H_{sn})
- Mean annual ground surface temperature
- Mean annual ground temperature, bottom of active layer
- Thermal offset
- Limnicity
- Elevation

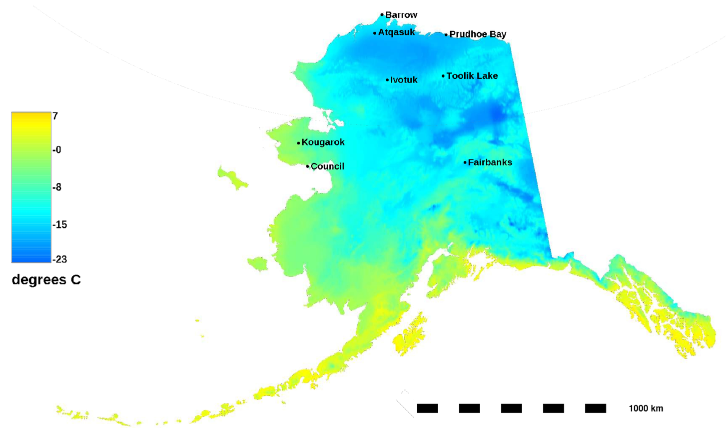


Sample Input Map Layers

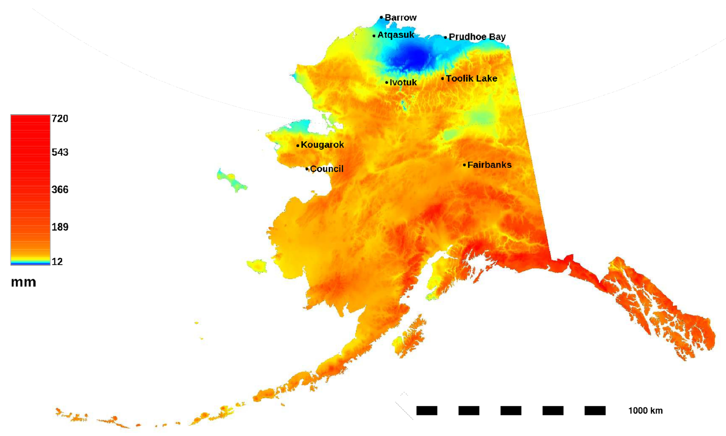
2000–2009 / 2090–2099



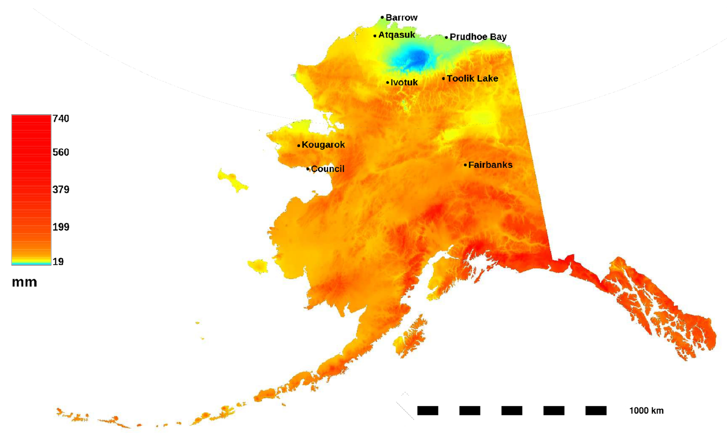
Monthly air temperature - January (2000–2009)
12 monthly air temperatures were used in the analysis.



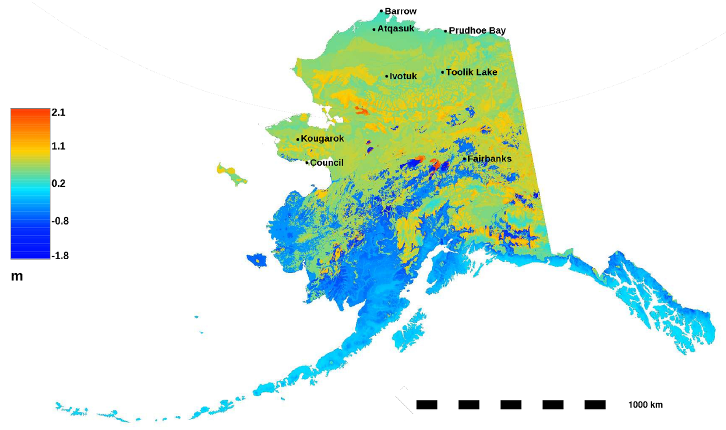
Monthly air temperature - January (2090–2099)
12 monthly air temperatures were used in the analysis.



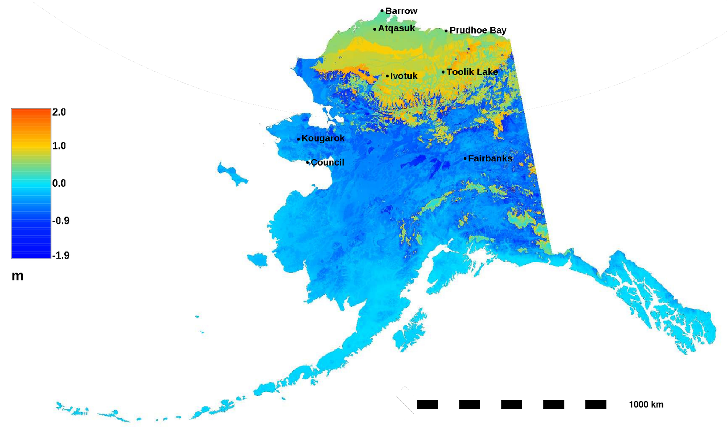
Monthly precipitation - July (2000–2009)
12 monthly precipitations were used in the analysis.



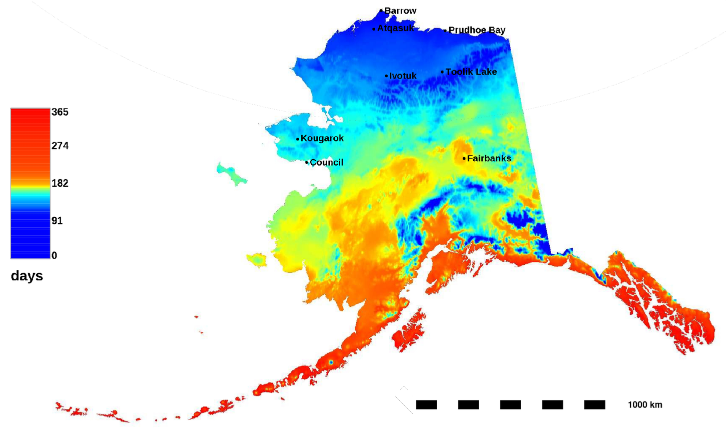
Monthly precipitation - July (2090–2099)
12 monthly precipitations were used in the analysis.



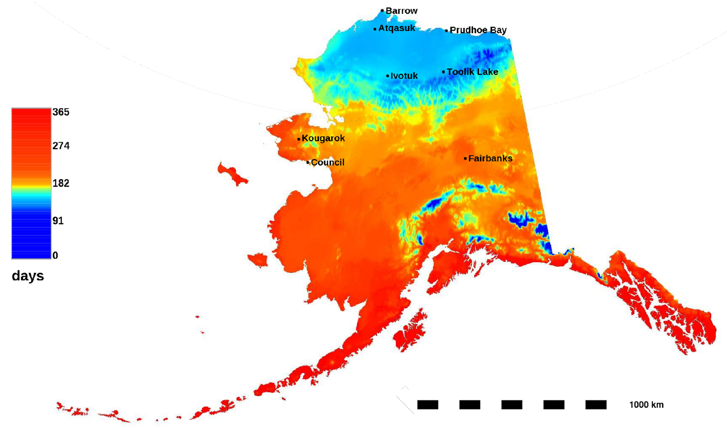
Mean active layer thickness (2000–2009)
Negative = seasonal freezing in absense of permafrost.



Mean active layer thickness (2090–2099)
Negative = seasonal freezing in absense of permafrost.



Mean growing season length (2000–2009)
Mean and standard deviation were used in the analysis.

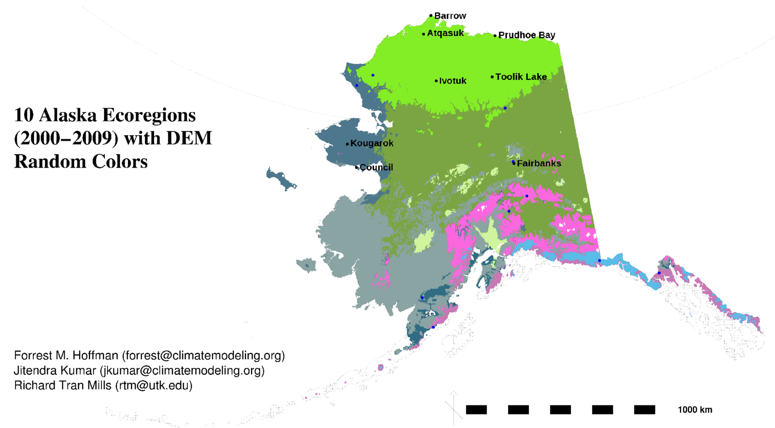


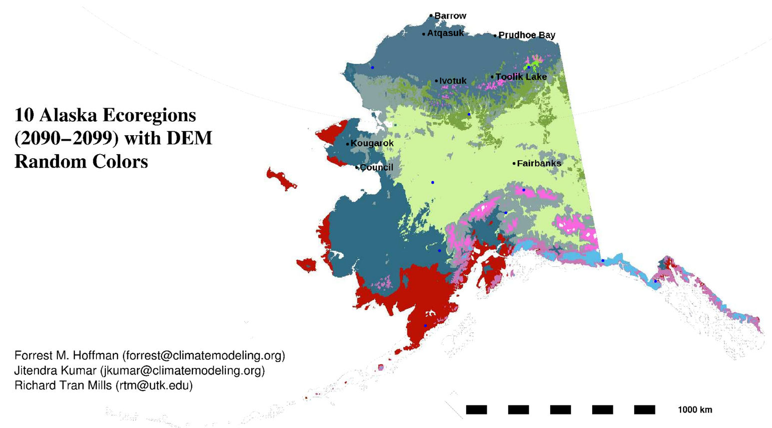
Mean growing season length (2090–2099)
Mean and standard deviation were used in the analysis.

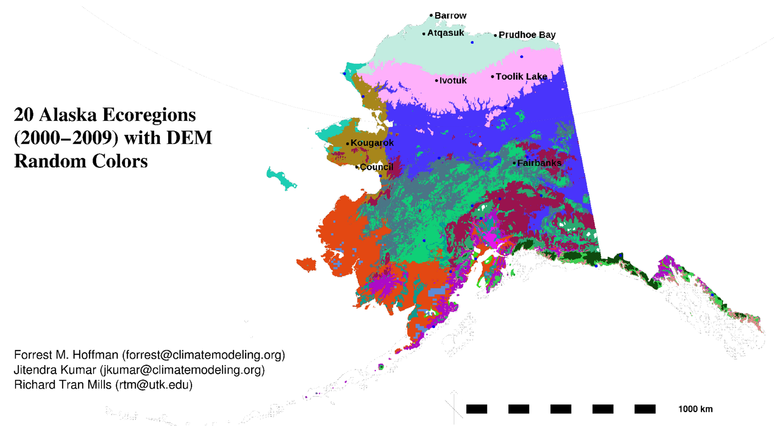
Quantitatively Derived Ecoregion Maps

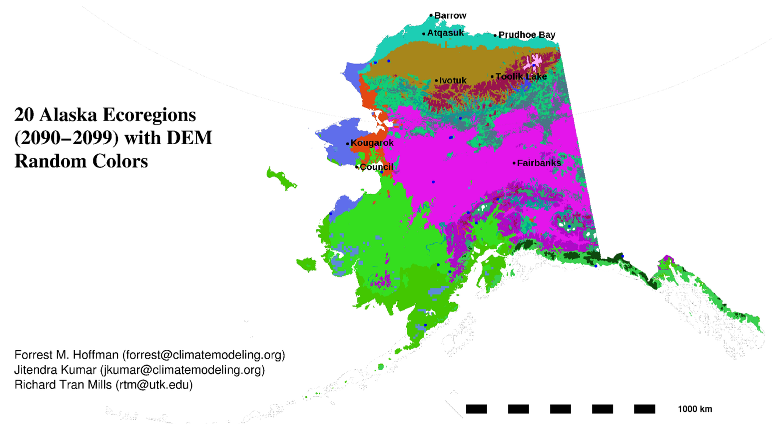
Cluster analysis of all input data layers, both contemporary and future, was performed for k = 5, 10, 20, 100, 200, 500, and 1000. This yields multiple maps of Alaska ecoregions for the present and future. Since the same random colors are used for present and future maps for every level of division, comparison of the maps broadly shows how environmental conditions change. Blue circles identify the cell closest to the mean conditions of the ecoregion in which it resides. The tables shown below the 10 and 20 ecoregion maps enumerate the mean environmental conditions for each ecoregion, along with the land area and percent land area that ecoregion occupies.

2000–2009 / 2090–2099



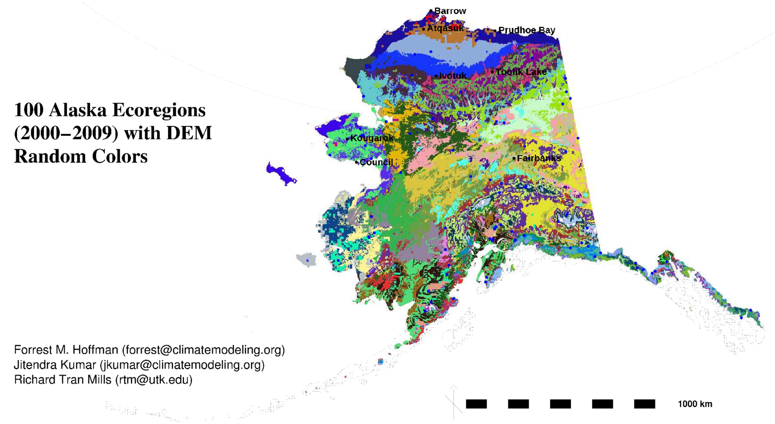


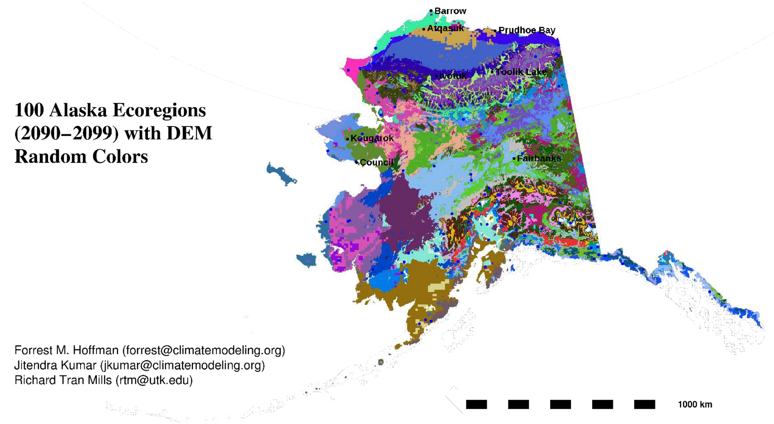


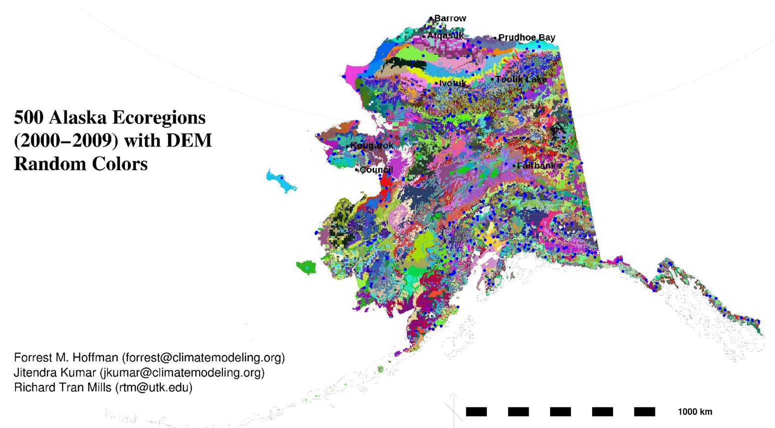


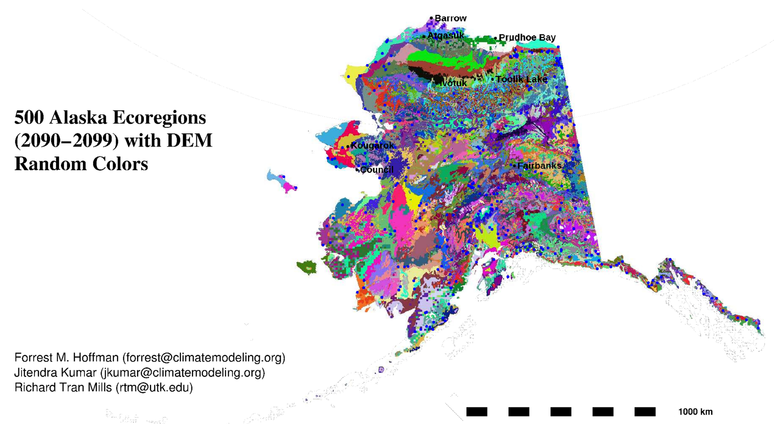
Environmental conditions of 19 exist only in the future

Environmental conditions of 1 and 5 exist only in the past





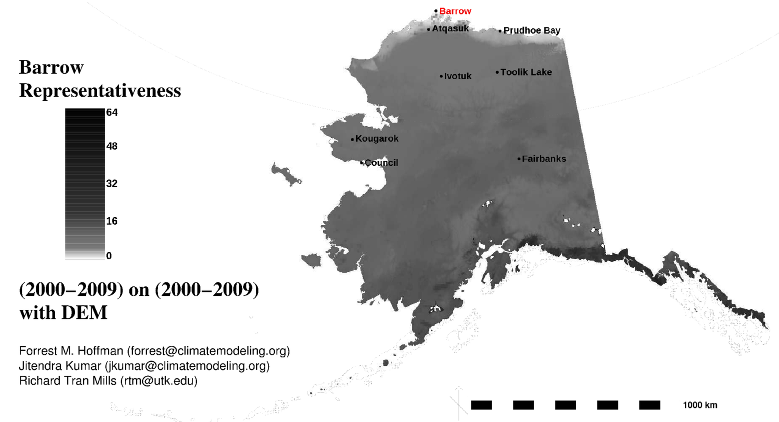


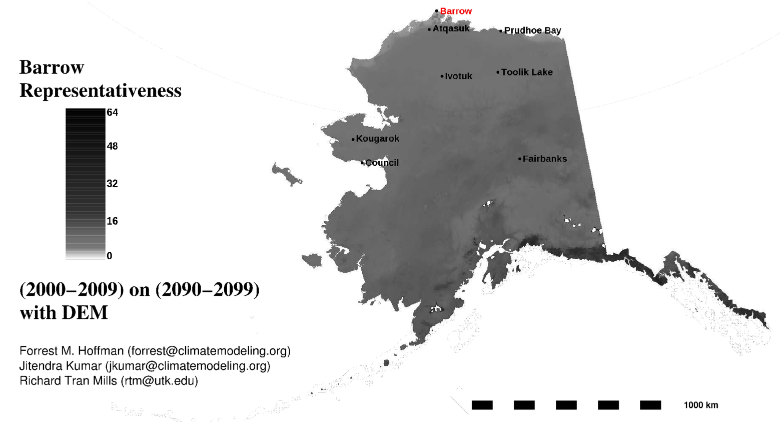


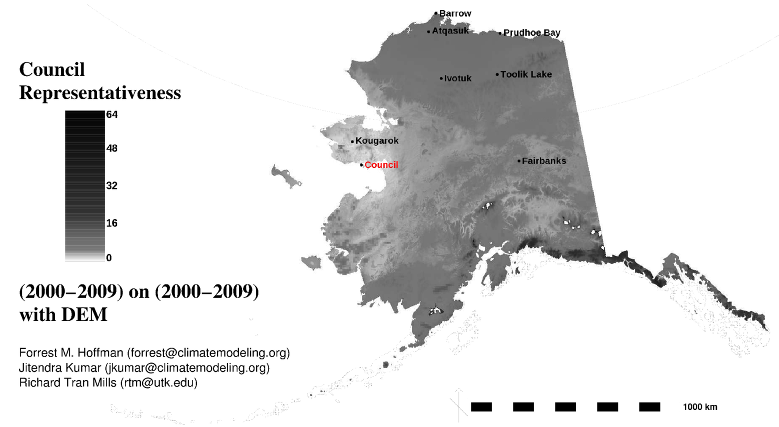
Site Representativeness Maps

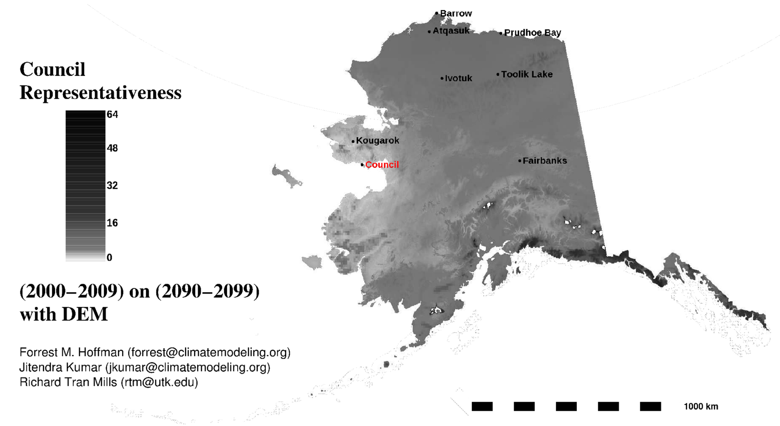
Because the quantitative environmental factors form a high-dimensional data space in which both present and future land cells are located, the Euclidean distance between cells provides a relative measure of representativeness for any site. By picking a single site, like present-day Barrow, maps of “Barrow-ness” for the present and the future can be computed, as shown in the first row below. White and light gray locations have environmental conditions similar to Barrow, while dark gray to black areas are poorly represented by the enviornmental conditions at Barrow. Similarly, the second row shows maps of present-day “Council-ness”. The third row contains maps of representativeness considering both Barrow and Council simultaneously.

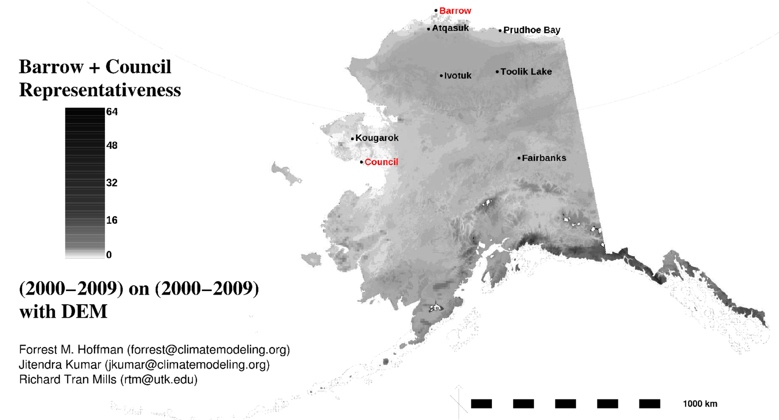
2000–2009 on 2000–2009 / 2000–2009 on 2090–2099

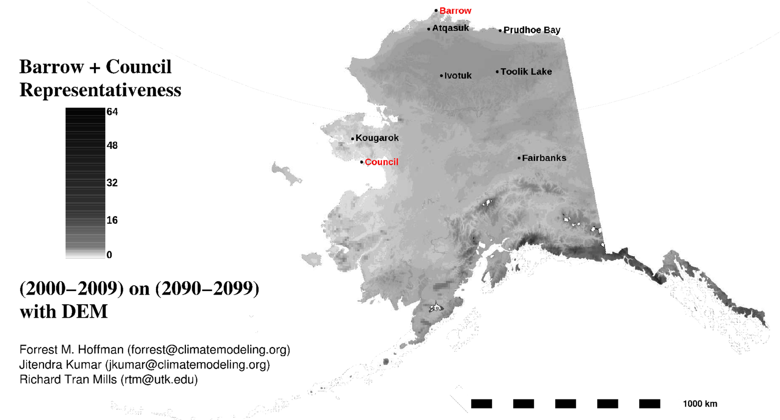












“Mileage Charts” of Representativeness

Standardized Euclidean distances in the data space formed by these environmental variables provides a relative measure of similarity between individual candidate sampling sites for NGEE-Arctic, providing clues into the environmental gradients that span the geographic space between them. These relative similarities are shown in the style of old-fashioned mileage charts below. Similarities between sites for the present are shown in the table at left and those for the future are shown in the table at right.

Present (2000–2009)

Sites	Council	Atqasuk	Ivotuk	Toolik Lake	Kougarok	Prudhoe Bay	Fairbanks
Barrow	9.16	4.55	5.91	6.43	8.01	3.58	12.27
Council		8.70	6.40	7.24	2.29	8.16	5.12
Atqasuk			5.18	5.69	7.80	1.75	10.74
Ivotuk				3.01	5.85	4.48	8.03
Toolik Lake					6.77	5.21	8.76
Kougarok						7.26	5.66
Prudhoe Bay							10.47

Future (2090–2099)

Sites	Council	Atqasuk	Ivotuk	Toolik Lake	Kougarok	Prudhoe Bay	Fairbanks
Barrow	8.87	4.89	6.88	7.69	8.04	4.18	11.99
Council		8.83	6.93	8.45	2.44	8.24	5.75
Atqasuk			5.87	6.62	8.15	2.30	10.19
Ivotuk				3.85	7.27	4.75	7.56
Toolik Lake					8.45	5.93	8.66
Kougarok						7.89	6.47
Prudhoe Bay							9.85

The relative similarity between sites in the present and in the future is shown below. For example, present-day conditions at Council are more representative of conditions at Barrow in the future than the present, as suggested by the 10 ecoregions maps.

Present (2000–2009) \ Future (2090–2099): Sites	Barrow	Council	Atqasuk	Ivotuk	Toolik Lake	Kougarok	Prudhoe Bay	Fairbanks
Barrow	3.37	9.68	4.71	6.09	6.98	9.05	3.77	11.77
Council	8.38	1.67	8.10	5.91	7.56	3.10	7.45	5.44
Atqasuk	6.01	9.33	2.46	5.47	6.36	8.98	2.66	10.20
Ivotuk	7.07	7.18	5.87	1.59	4.26	7.27	4.90	7.52
Toolik Lake	7.46	7.95	6.33	3.17	1.82	7.94	5.56	8.23
Kougarok	7.29	3.05	6.93	5.57	7.13	2.51	6.54	5.82
Prudhoe Bay	5.30	8.80	3.12	4.76	5.95	8.49	2.00	9.89
Fairbanks	12.06	5.59	10.40	7.89	9.03	6.31	10.14	1.96

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