How is GIS applied to the scientific method?

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FORS350 / GPHY488
(Forestry) Applications of GIS
University of Montana
WA Franke College of Forestry & Conservation

Game plan

The Scientific Method

The Geographic Approach

Geographic Representation

How do we know things about the world?

How do we know things about the world?

Some ways of knowing:

- Personal experiences
- Cultural traditions
  - Education
  - Accumulation of historical and philosophical insights
- The Scientific Method
  - exploration
  - observation
  - experimentation
  - analysis

What is the scientific method?

What is the scientific method?

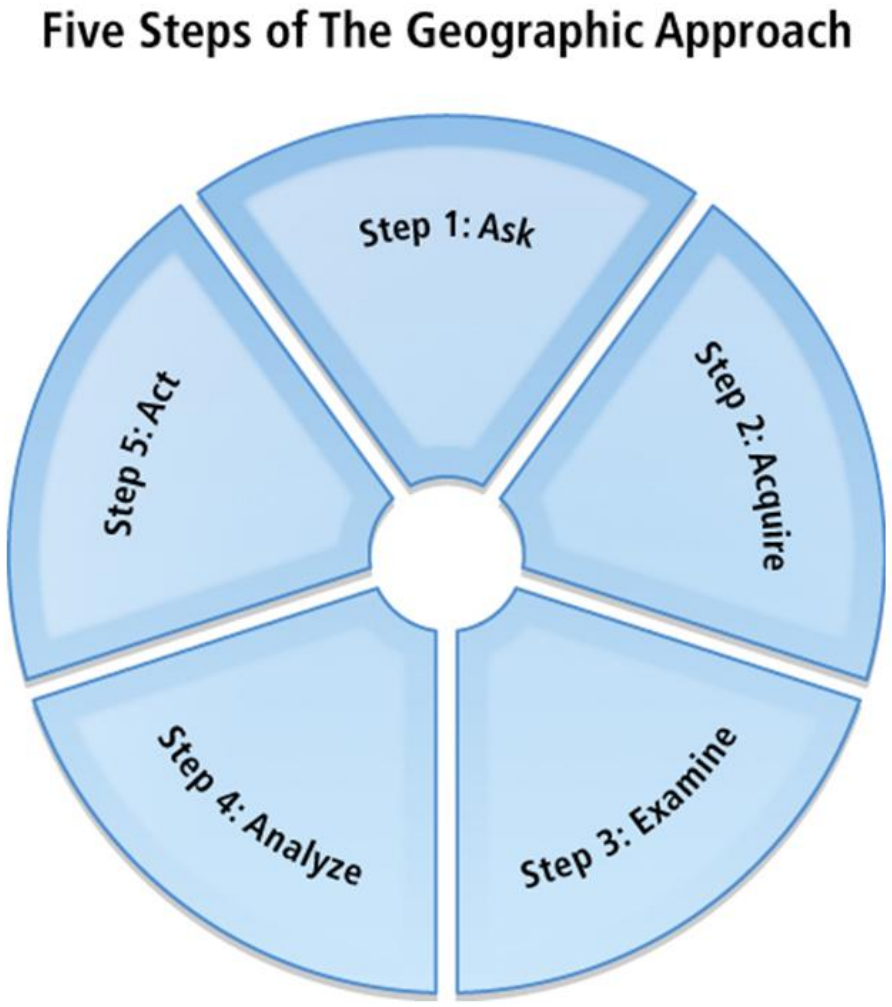
The modern scientific method is based on the work of René Descartes, one of the founders of contemporary Western science and philosophy.

Four rules of Cartesian inquiry:

1. Accept nothing as true that is not self-evident
2. Divide each problem into as many parts as possible
3. Proceed from the simplest to the most complex
4. Review everything to avoid errors

What is the scientific method?

What is the geographic approach?



What is the geographic approach?

Step 1: Ask

- What is the problem to solve to analyze?

Step 2: Acquire

- What data are needed to complete the analysis?

Step 3: Examine

- How is it organized (schema)?
- How does it relate to other data (topology)?
- Where is it from (metadata)?

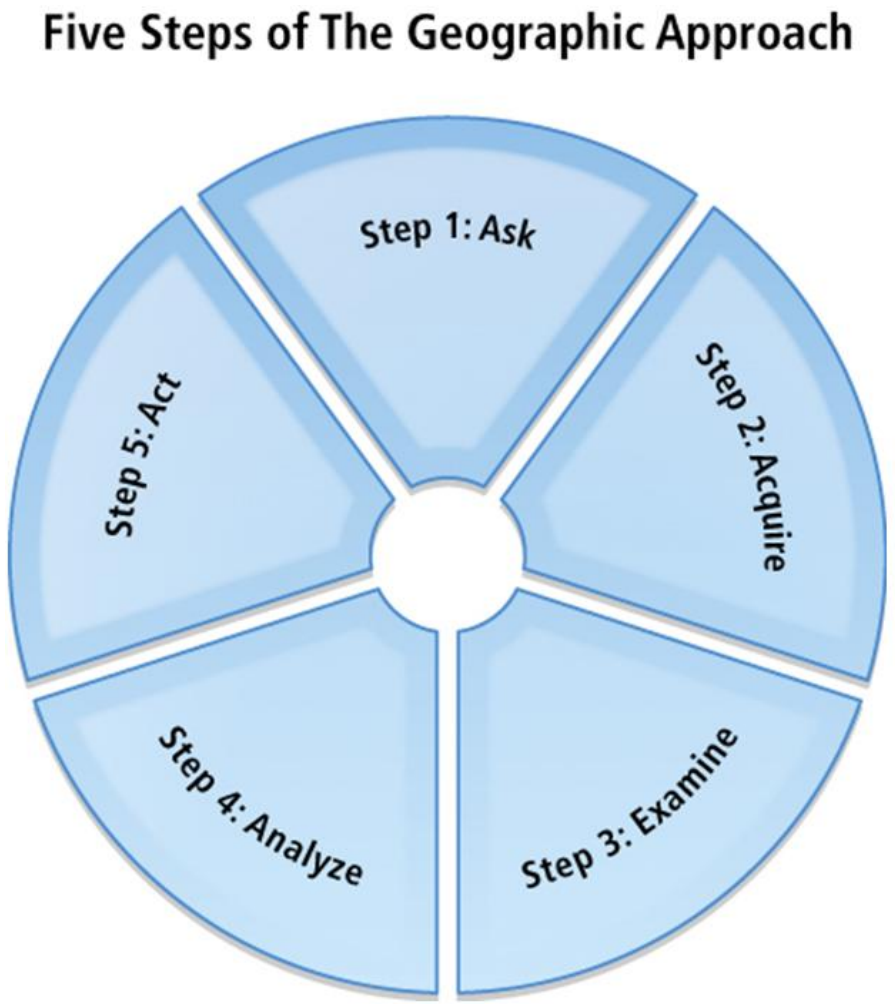
Step 4: Analyze

- Process and analyze data to achieve desired results.

Step 5: Act

- Present results as part of the decision-making process.

Data → Information → Knowledge!



How do we form **spatial** hypotheses?

It starts with an observation, which then leads to a question about what was seen.

- While most things have a spatial component, it is worth asking if your observation has nothing to do with location.
- Once you believe your question has a spatial component, you can convert it to a hypothesis to be tested with GIS.

The Geographic Approach can be thought to be nested within the hypothesis/experiment/analysis phase of the Scientific Method.

How do we form a spatial hypotheses?

1. OBSERVATION

Trees at the top of the slope are dying.

2. QUESTION

Does elevation have anything to do with tree health?

3. HYPOTHESES

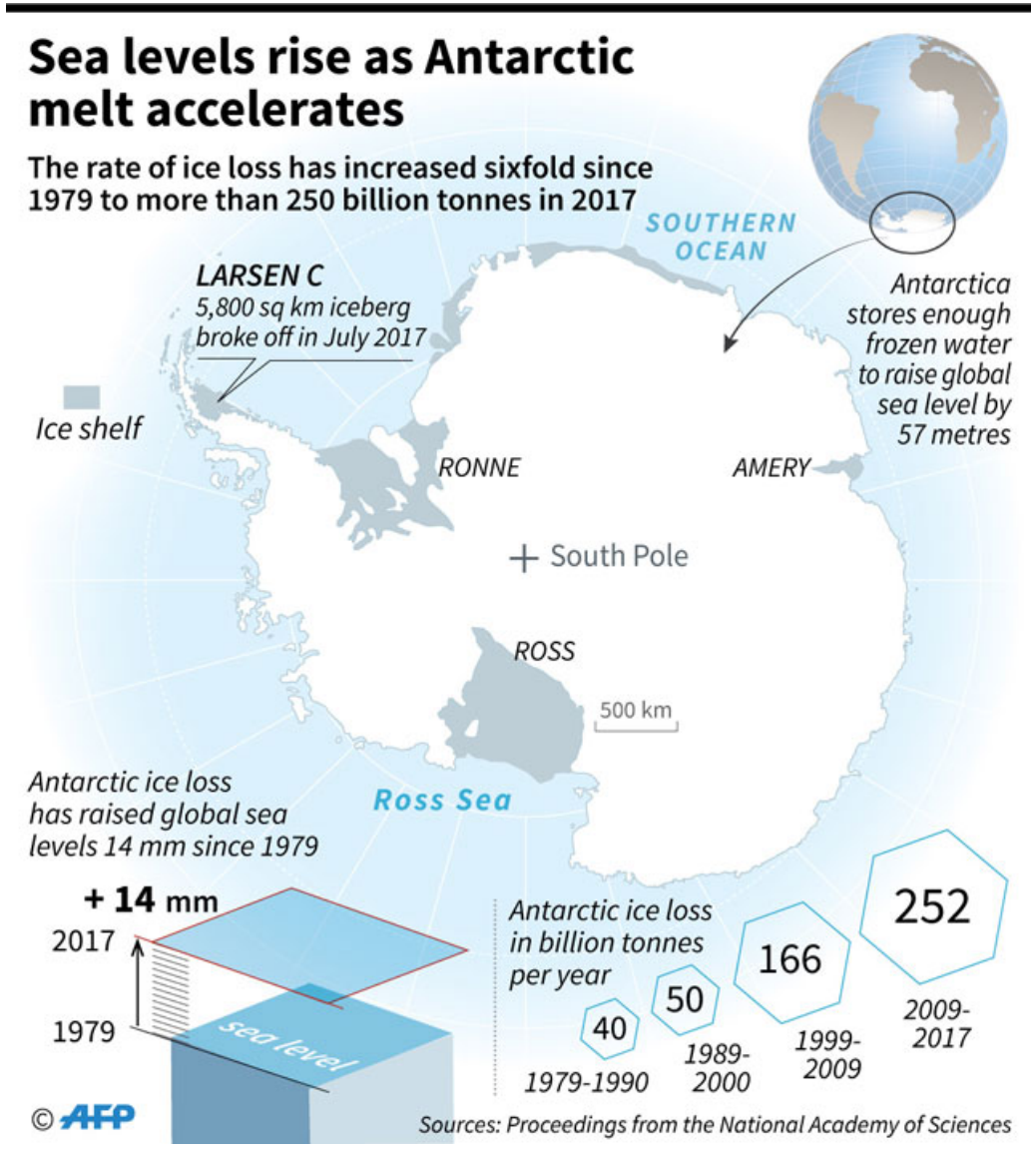
More trees die at higher elevations than at lower elevations.

4. EXPERIMENT

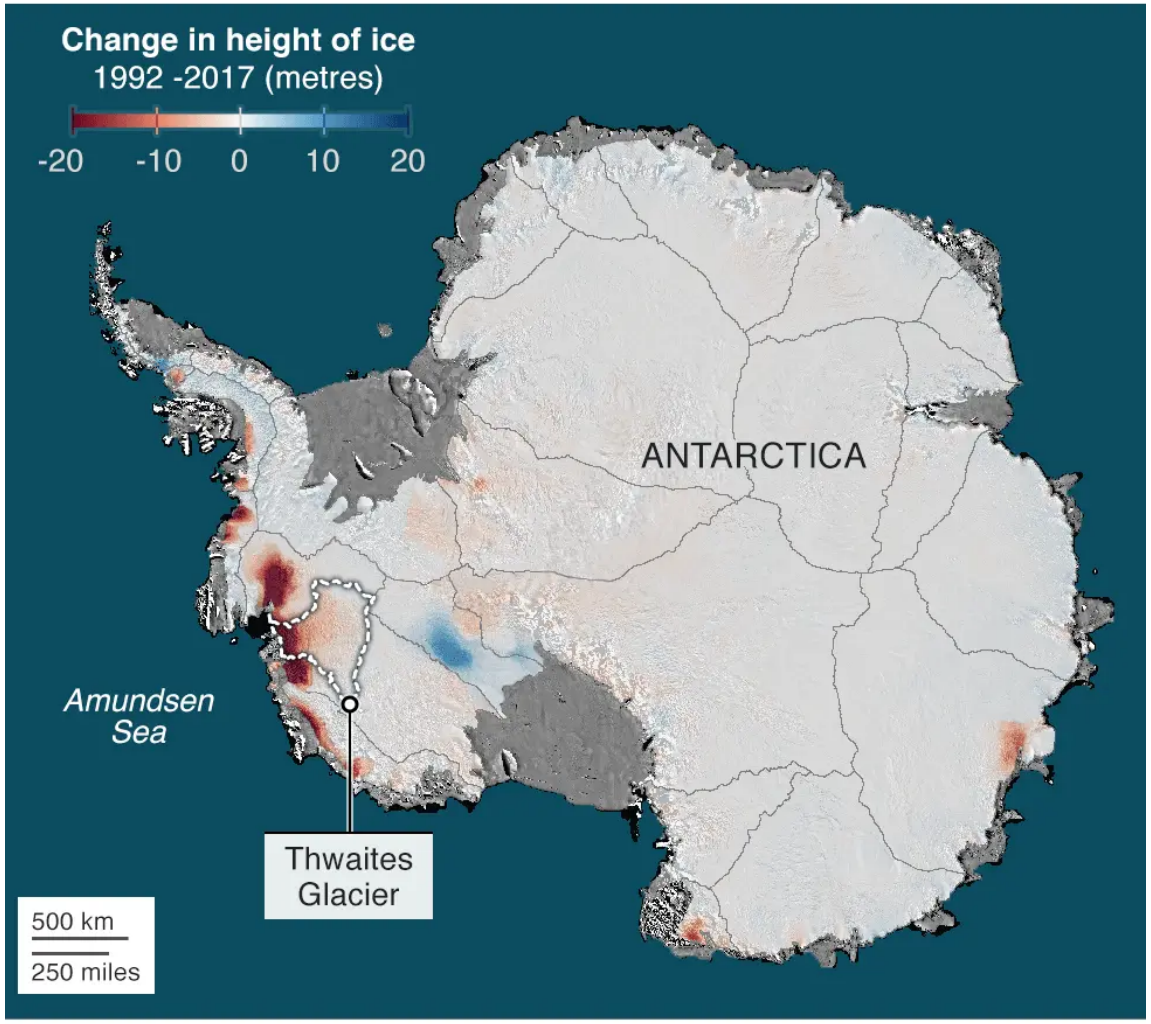
Randomly sample trees at different elevations to see if significantly more are dying on higher slopes.

Applications of GIS

What kinds of spatial problems can you use a geographic information system to answer?

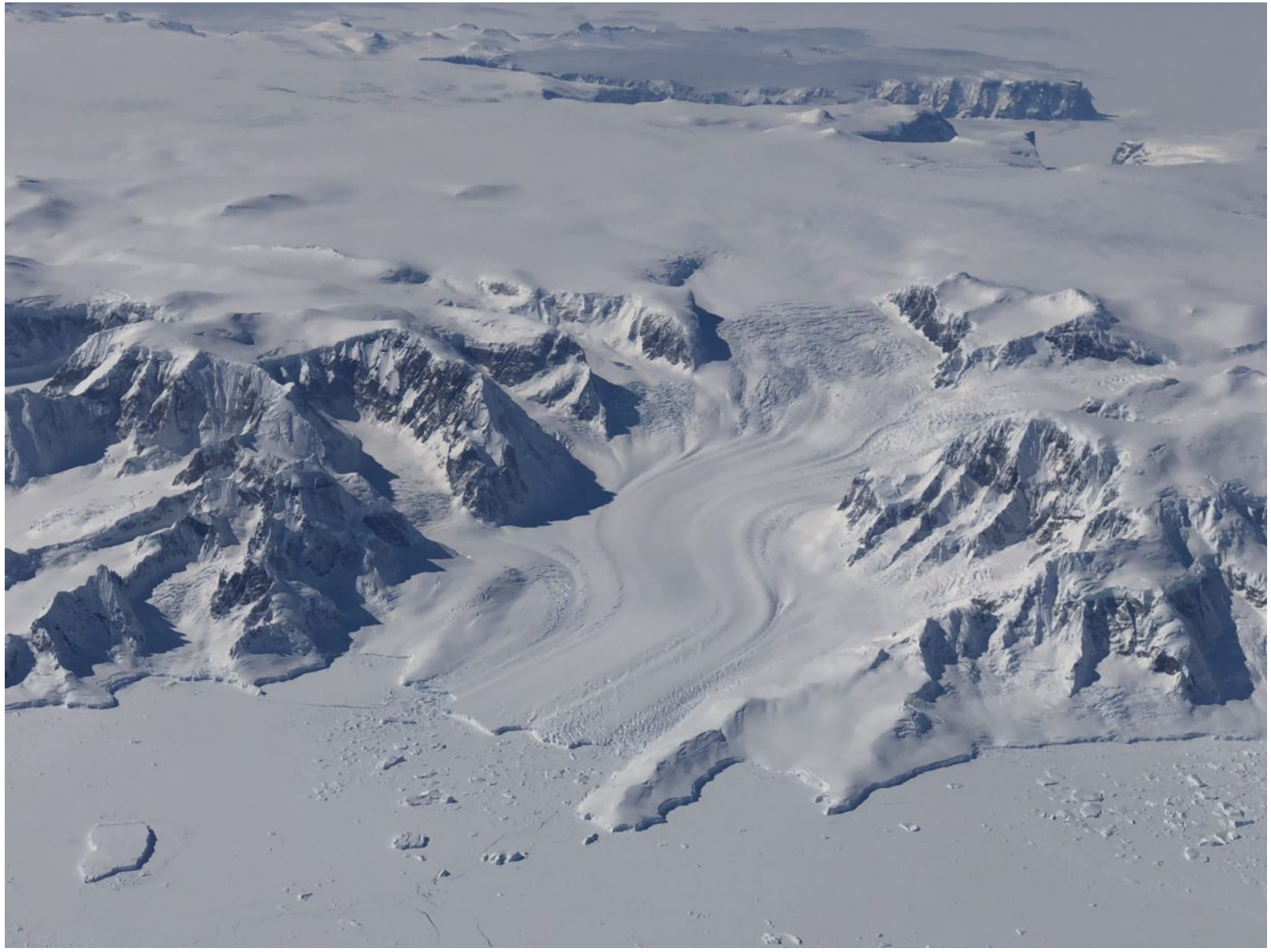

Sea levels rise as Antarctic melt accelerates
The rate of ice loss has increased sixfold since 1979 to more than 250 billion tonnes in 2017
SOUTHERN OCEAN
LARSEN C
5,800 sq km iceberg broke off in July 2017
Ice shelf
Antarctica stores enough frozen water to raise global sea level by 57 metres
RONNE
AMERY
South Pole
ROSS
500 km
Ross Sea
Antarctic ice loss has raised global sea levels 14 mm since 1979
+ 14 mm
2017
1979
sea level
© AFP
Antarctic ice loss in billion tonnes per year
40
1979-1990
50
1989-2000
166
1999-2009
252
2009-2017
Sources: Proceedings from the National Academy of Sciences

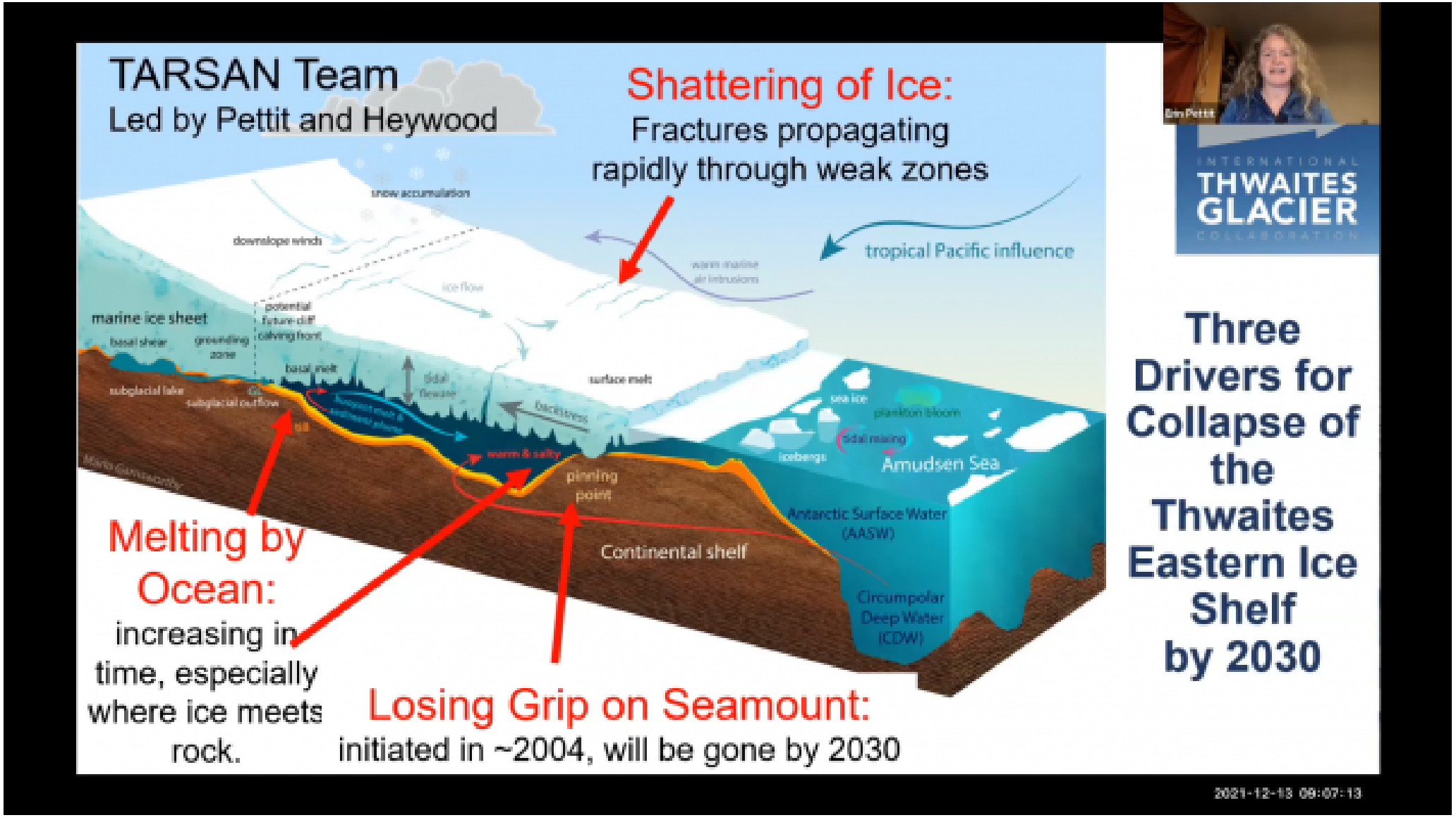
Ice sheets in West Antarctica have thinned the most

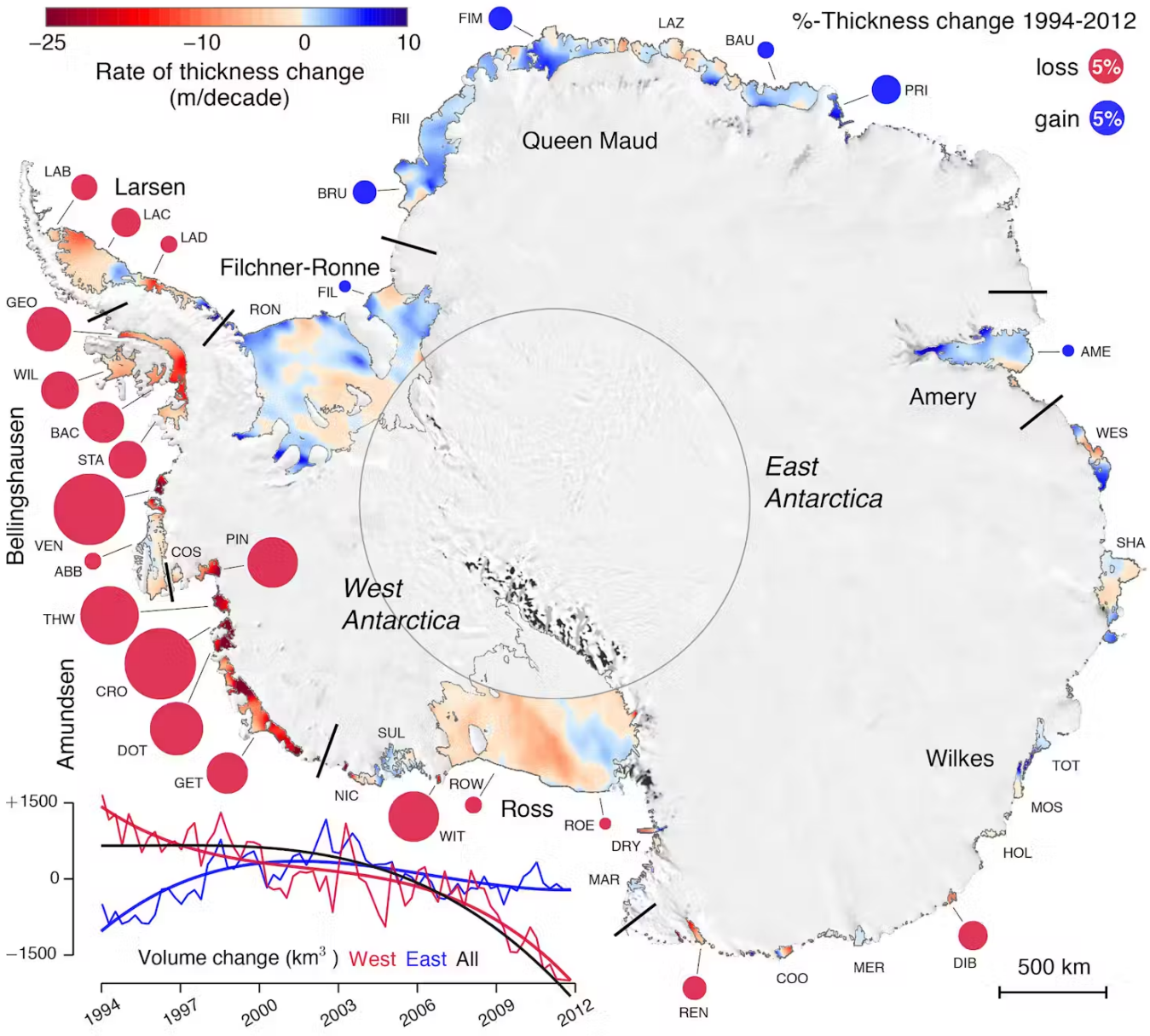


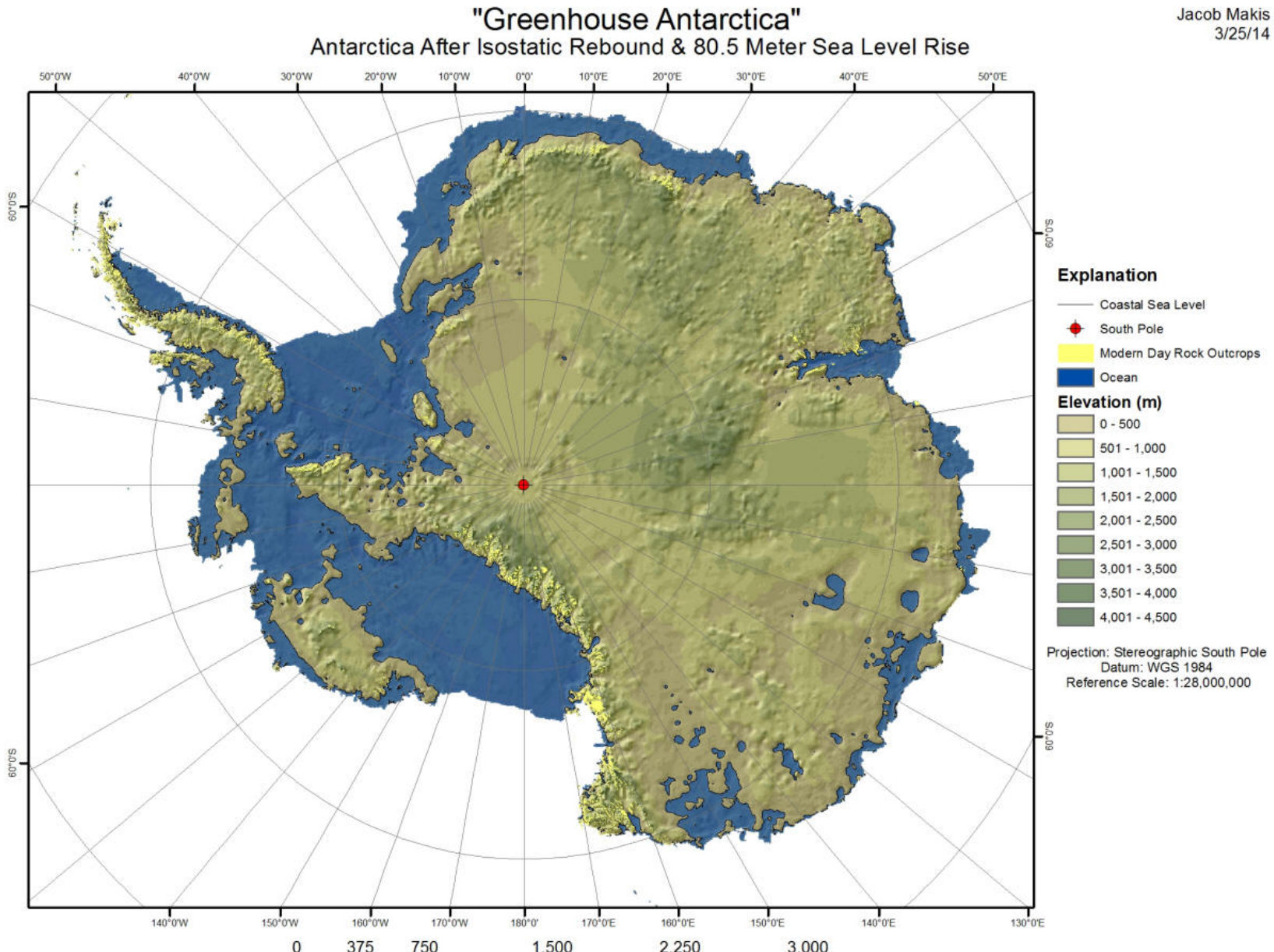
Source: Tom Slater, CPOM

BBC



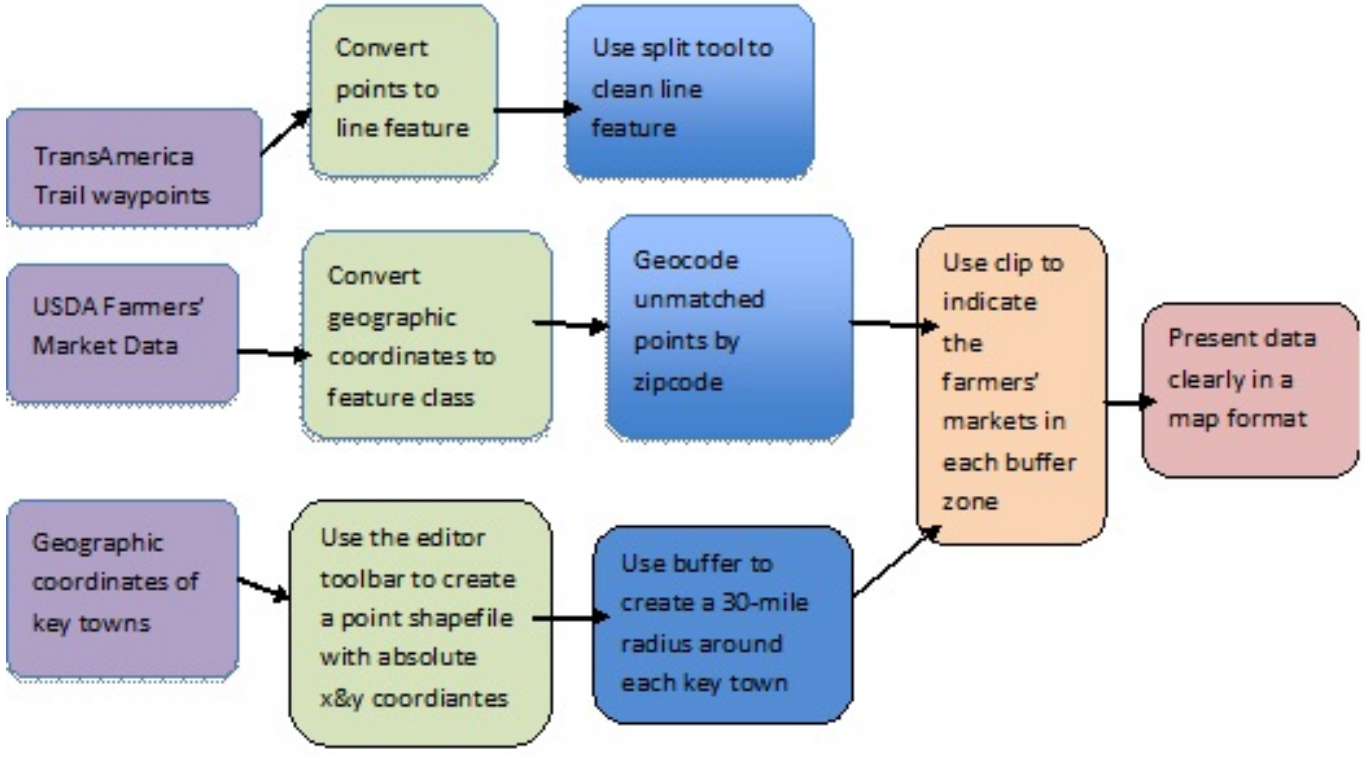

TARSAN Team
Led by Pettit and Heywood
Shattering of Ice:
Fractures propagating rapidly through weak zones
tropical Pacific influence
Three Drivers for Collapse of the Thwaites Eastern Ice Shelf by 2030
Melting by Ocean:
increasing in time, especially where ice meets rock.
Losing Grip on Seamount:
initiated in ~2004, will be gone by 2030
snow accumulation
downslope winds
ice flow
warm marine air intrusions
marine ice sheet
basal shear
grounding zone
potential future calving front
basal melt
tidal flexure
surface melt
subglacial lake
subglacial outflow
darkness
warm & salty
pinning point
sea ice
plankton bloom
tidal mixing
icebergs
Amundsen Sea
Antarctic Surface Water (AASW)
Continental shelf
Circumpolar Deep Water (CDW)
INTERNATIONAL THWAITES GLACIER COLLABORATION
2021-12-13 09:07:13


−25
−10
0
10
Rate of thickness change
(m/decade)
%-Thickness change 1994-2012
loss 5%
gain 5%
FIM
LAZ
BAU
PRI
RII
Queen Maud
BRU
LAB
Larsen
LAC
LAD
Filchner-Ronne
FIL
RON
GEO
WIL
BAC
STA
Bellingshausen
VEN
ABB
COS
PIN
THW
CRO
DOT
GET
Amundsen
West
Antarctica
East
Antarctica
AME
Amery
WES
SHA
SUL
NIC
ROW
WIT
Ross
ROE
DRY
MAR
Wilkes
TOT
MOS
HOL
DIB
COO
MER
REN
500 km
+1500
0
−1500
Volume change (km^3) West East All
1994
1997
2000
2003
2006
2009
2012

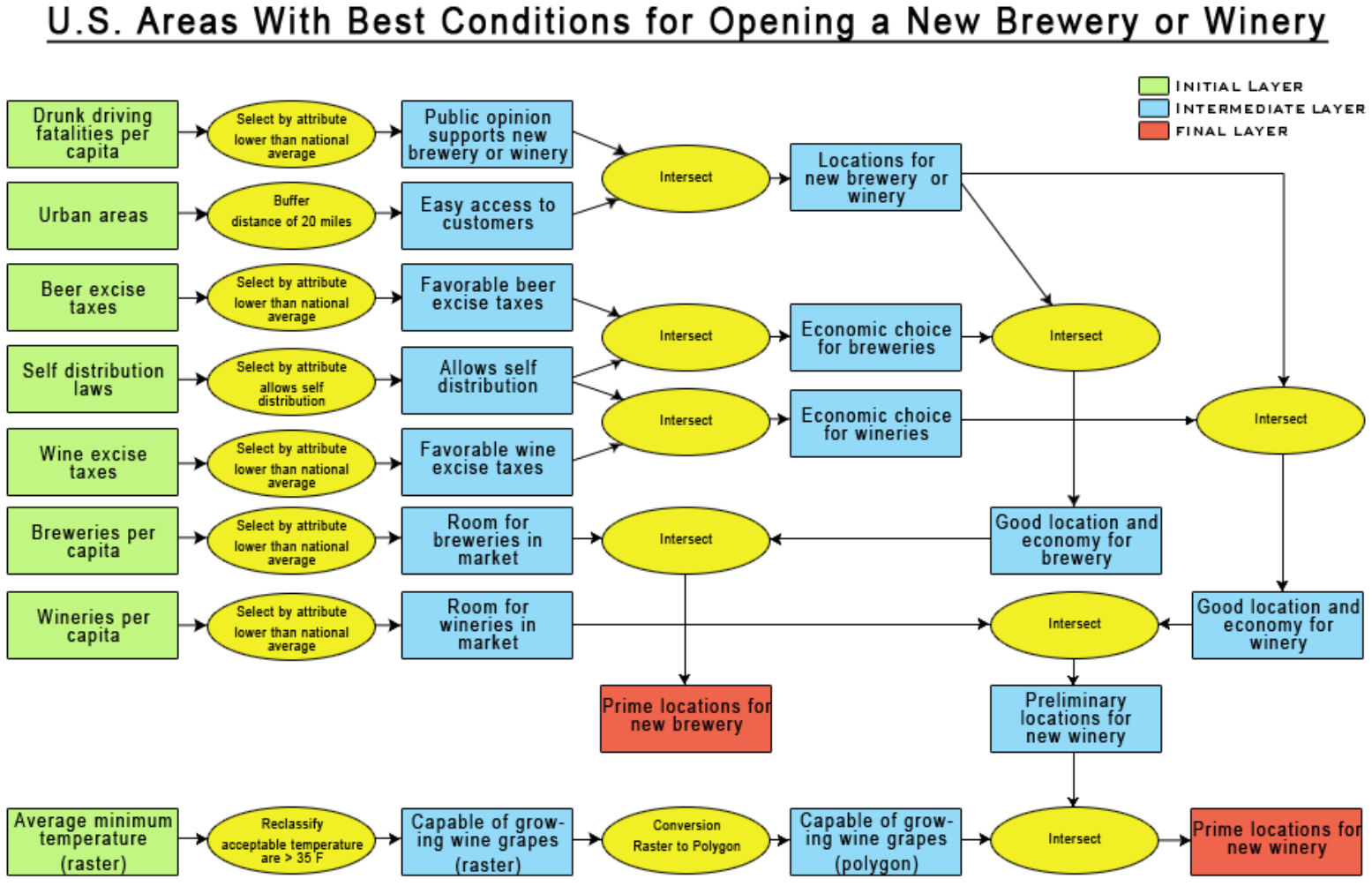

"Greenhouse Antarctica"
Antarctica After Isostatic Rebound & 80.5 Meter Sea Level Rise
Jacob Makis
3/25/14
50°0'W
40°0'W
30°0'W
20°0'W
10°0'W
0°0'
10°0'E
20°0'E
30°0'E
40°0'E
50°0'E
60°0'S
140°0'W
150°0'W
160°0'W
170°0'W
180°0'
170°0'E
160°0'E
150°0'E
140°0'E
130°0'E
Explanation
Coastal Sea Level
South Pole
Modern Day Rock Outcrops
Ocean
Elevation (m)
0 - 500
501 - 1,000
1,001 - 1,500
1,501 - 2,000
2,001 - 2,500
2,501 - 3,000
3,001 - 3,500
3,501 - 4,000
4,001 - 4,500
Projection: Stereographic South Pole
Datum: WGS 1984
Reference Scale: 1:28,000,000
0
375
750
1,500
2,250
3,000

How is the Scientific Method applied with GIS ?

What farmers markets are within 30 miles of the Trans America Trail?



How is the Scientific Method applied with GIS ?

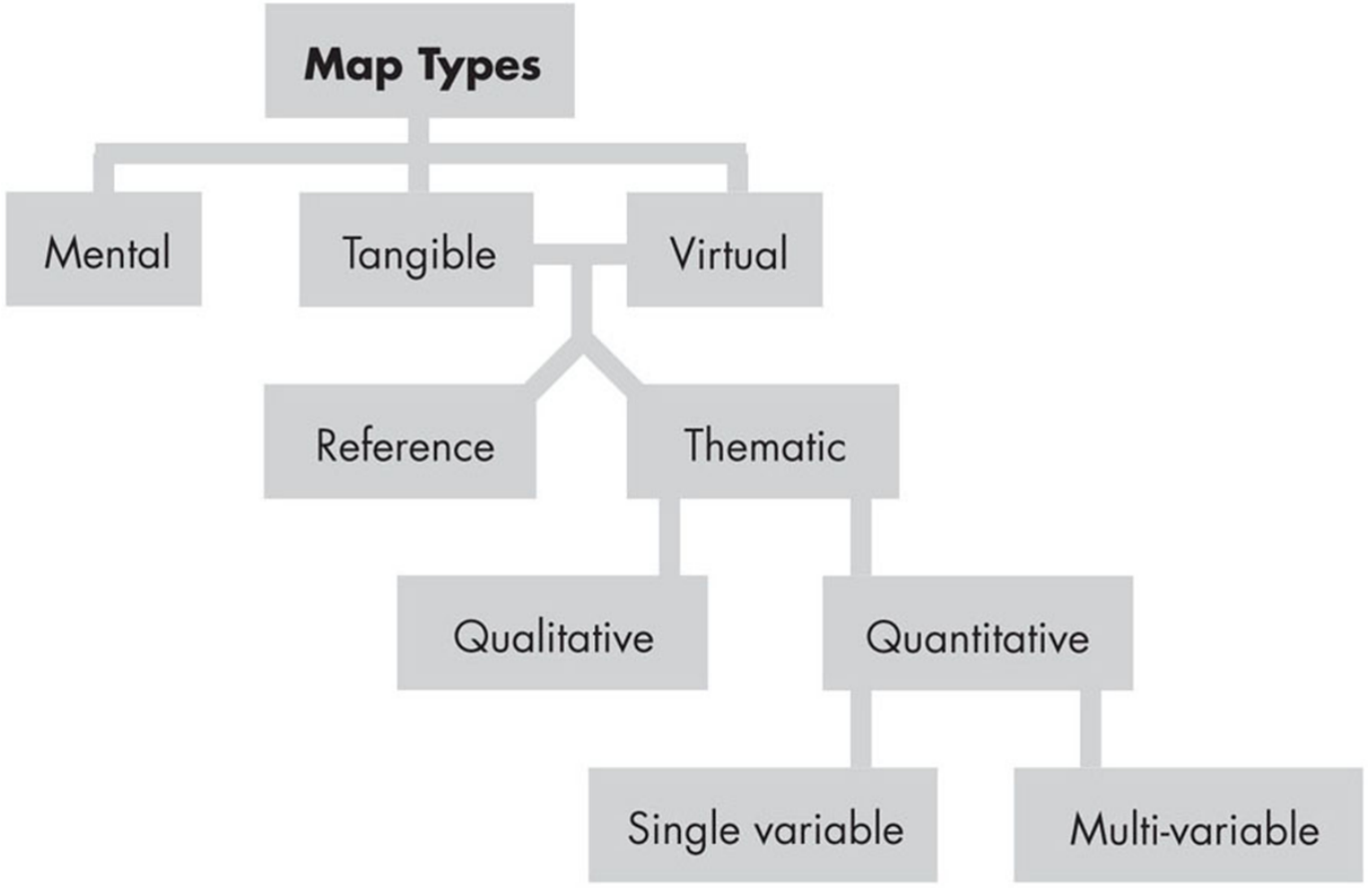


Can Missoula meet its electricity needs with roof-top solar?

The earth at sea level receives about 1,000 Watts per square meter.

How can we use GIS to answer this question? What data do we need?

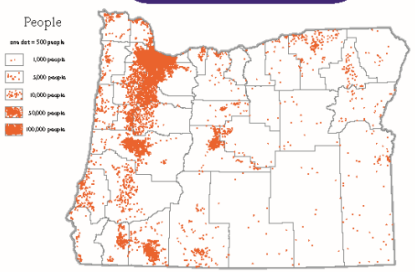
What is Thematic Cartography?



Types of Thematic Maps

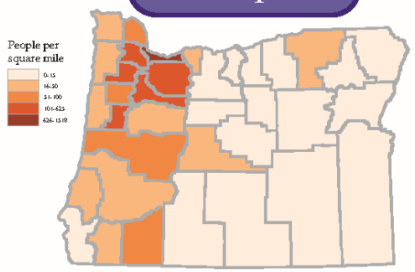
All five thematic maps show where people live in Oregon, but each map uses a different way to show that distribution.

Dot Density



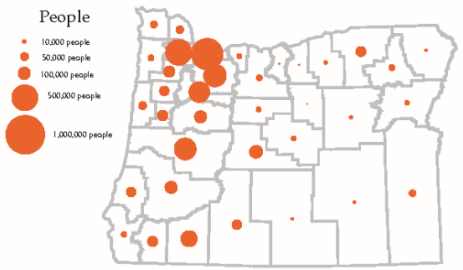
- One dot equals a certain number of people
- If dots are close together, lots of people live in one area
- If dots are spread out, not very many people live in one area

Choropleth



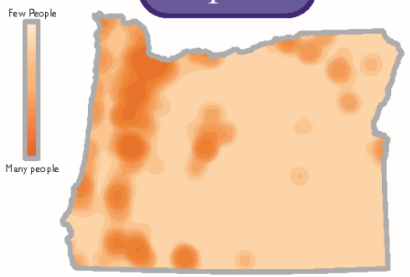
- Each county is shaded a color to show density or number of people per square mile
- The symbol covers an entire county, but it does not mean that people live everywhere inside the county

Graduated Circle



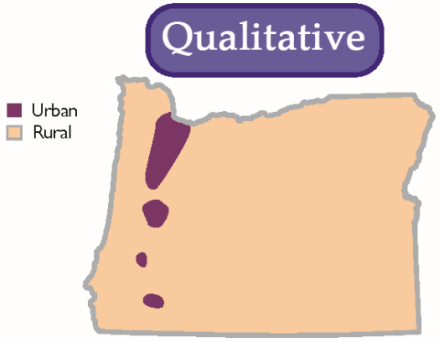
- One circle represents how many people live in that county
- The size of the circle is proportional to the number of people that live in a county - the more people that live in a county, the larger the circle

Isopleth



- This map shows a continuous distribution of population
- Because we do not know how many people live in every single place in Oregon, we take an average of two cities in an area to estimate the number of people in that area

Qualitative



- This map draws boundaries around different groups of people (for example, urban residents and rural residents)
- The map does not show how many people are in each group, just where each group is located

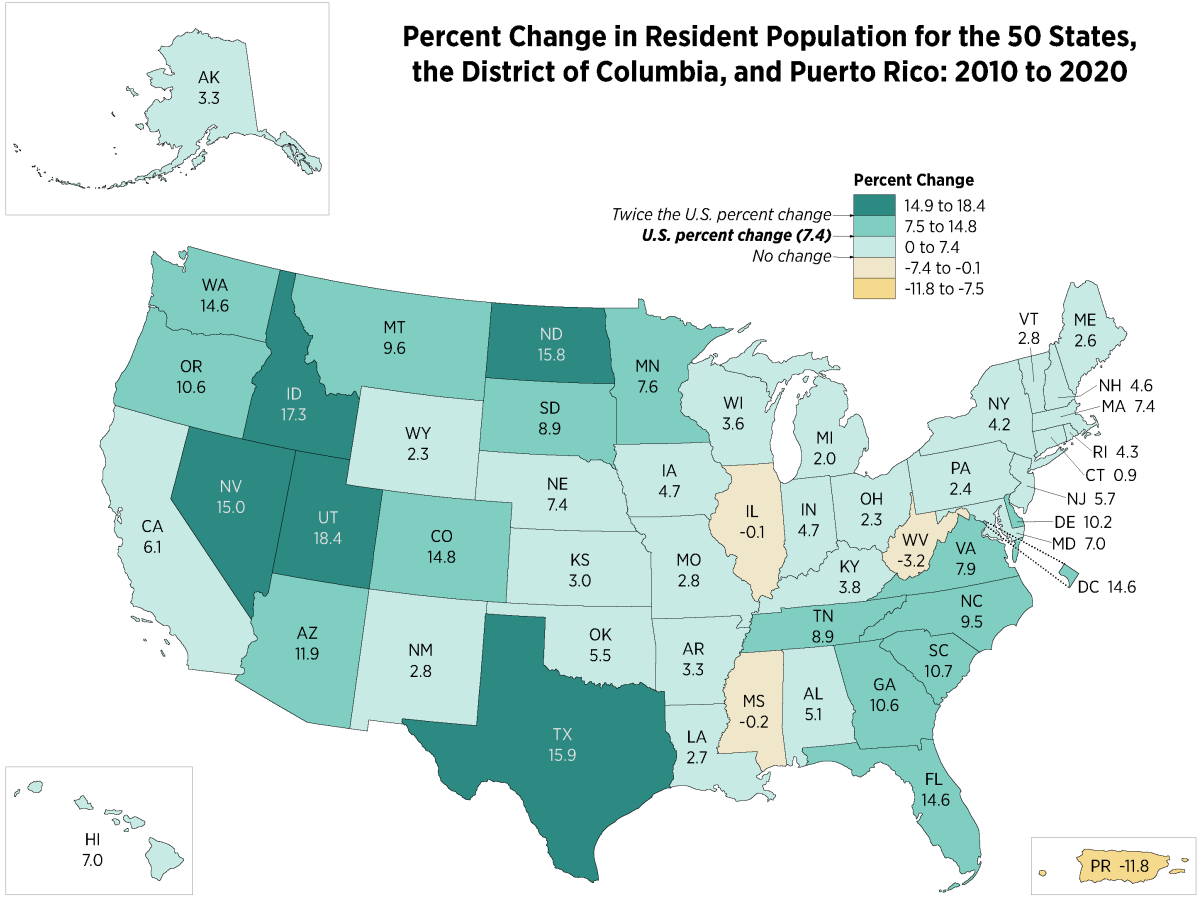
The Point... is to turn this:

Attributes of Places Final Index

FID	Shape *	OBJECTID	NAME	ST	DISTANCE	INDEX_	POP2000	X_COOR	Y_COOR	FINAL_INDX	POS
185	Point	18460	Barlow	OR	59.988426	-35	140	-1285.462617	720.661807	-1133.23	7339080
55	Point	2261	Muir Beach	CA	2.606149	-40	295	-1420.835027	225.495873	-1449.41	7338760
300	Point	23622	Custer	WA	4.903329	-40	299	-1212.00738	961.410374	-1496.38	7338710
186	Point	18475	Butteville	OR	54.454017	-35	293	-1290.716408	722.460785	-1995.89	7338210
190	Point	18511	Donald	OR	54.615992	-35	608	-1291.518863	720.240573	-3887.51	7336320
78	Point	2540	Stinson Beach	CA	0.559769	-40	751	-1423.265452	228.999046	-4164.9502	7336050
197	Point	18577	Johnson City	OR	66.471862	-35	634	-1275.873906	728.823598	-4162.0698	7336050
184	Point	18456	Aurora	OR	58.467762	-35	655	-1287.571291	719.645833	-4208.0298	7336000
199	Point	18607	Maywood Park	OR	67.3765	-35	777	-1272.246319	738.424133	-5029.1099	7335180
7	Point	1704	Bolinas	CA	0.961137	-40	1246	-1425.876018	229.855613	-7138.96	7333070
189	Point	18495	Columbia City	OR	55.500253	-35	1571	-1277.288955	764.461119	-9674.3496	7330540
302	Point	23682	Friday Harbor	WA	1.904217	-40	1989	-1237.388102	941.733429	-11606.4	7328600
310	Point	23897	Ridgefield	WA	60.233845	-35	2147	-1274.299846	757.580641	-13177.7	7327030
303	Point	23685	Geneva	WA	4.268151	-40	2257	-1204.810523	947.391127	-13238	7326970
27	Point	1924	Fairbanks Ranch	CA	4.767205	-25	2244	-1212.532145	-177.67016	-13285	7326930
62	Point	2427	Ross	CA	2.38753	-40	2329	-1417.659585	231.705251	-13651.2	7326560
93	Point	5204	Brussels	IL	1414.08675	10	141	288.55275	109.069075	-15040.2	7325170
191	Point	18514	Dundee	OR	45.997264	-35	2598	-1298.353999	726.101148	-15741.3	7324470
110	Point	6120	Sauget	IL	1432.138511	10	249	312.650316	85.366149	-15868.7	7324340
99	Point	5395	East Carondelet	IL	1427.444402	10	267	308.687665	81.567052	-15929.8	7324280
61	Point	2419	Rollingwood	CA	2.322631	-40	2900	-1405.619249	228.372475	-17076.6	7323130
212	Point	18748	Wood Village	OR	74.223451	-30	2860	-1265.975813	735.424913	-17635.6	7322570
104	Point	5532	Grafton	IL	1422.978676	10	609	297.098654	111.554476	-17937.1	7322270
101	Point	5428	Elsah	IL	1426.401856	10	635	300.952341	110.206355	-18127.4	7322080
92	Point	5198	Brooklyn	IL	1432.729163	10	676	312.215009	89.980211	-18436.6	7321770
20	Point	1892	East Richmond Heights	CA	2.785772	-40	3357	-1405.156128	226.773795	-19823.199	7320390
252	Point	19266	Haysville	PA	1974.303794	5	78	823.180929	279.564613	-20224.4	7319990
253	Point	19288	Hookstown	PA	1958.294985	5	152	806.012252	281.795164	-20508.301	7319700
286	Point	19878	Shippingport	PA	1961.102294	5	237	808.334848	283.964001	-21046.4	7319160
248	Point	19216	Glenfield	PA	1975.43521	5	236	824.411909	279.337465	-21183.699	7319030
307	Point	23788	Marietta-Alderwood	WA	2.057488	-40	3594	-1210.570008	952.429767	-21237.9	7318970
238	Point	19089	Eastvale	PA	1967.6651	5	293	812.208697	294.702564	-21448	7318760
244	Point	19146	Fallston	PA	1967.506644	5	307	812.868852	291.698334	-21530.4	7318680
179	Point	17662	Waite Hill	OH	1920.151574	5	446	748.246729	343.956618	-21890.9	7318320
224	Point	18832	Ben Avon Heights	PA	1978.506677	5	392	827.600736	279.295403	-22150.4	7318060
298	Point	23557	Blaine	WA	2.201293	-40	3770	-1214.871754	967.250518	-22295.4	7317910
278	Point	19801	Rosslyn Farms	PA	1977.102314	5	464	827.813375	272.973154	-22568.4	7317640
292	Point	19973	Thornburg	PA	1977.445926	5	468	827.938431	273.851931	-22595.801	7317610
313	Point	24031	Woodland	WA	58.582706	-35	3780	-1273.949733	764.954748	-22959.199	7317250
287	Point	19906	South Heights	PA	1970.444662	5	542	818.491256	282.17202	-22969.801	7317240
268	Point	19665	Osborne	PA	1973.701274	5	566	822.512506	279.733783	-23146.4	7317060
237	Point	19084	East Rochester	PA	1969.596619	5	623	815.400491	290.361105	-23447.301	7316760
283	Point	19855	Sewickley Hills	PA	1976.062678	5	652	824.179518	282.647879	-23686	7316520
269	Point	19682	Patterson Heights	PA	1966.914521	5	670	811.989496	292.667324	-23702.5	7316510
106	Point	5569	Hartford	IL	1438.677929	10	1545	315.535583	102.022453	-23710.1	7316500
109	Point	6094	Roxana	IL	1441.103042	10	1547	317.881286	102.641398	-23746.4	7316460
119	Point	14017	Fairview	NJ	73.354727	-30	3942	1136.559949	331.230368	-24118.9	7316090
228	Point	18884	Bridgewater	PA	1967.986291	5	739	813.650523	290.657452	-24127.199	7316080
272	Point	19695	Pennsbury Village	PA	1976.53993	5	738	827.154352	273.2699	-24206.699	7316000
35	Point	2023	Highlands-Baywood Park	CA	1.324286	-40	4210	-1414.793925	198.947512	-24926.6	7315280
71	Point	2486	Santa Venetia	CA	1.604584	-40	4298	-1413.806567	233.616457	-25457.4	7314750
282	Point	19854	Sewickley Heights	PA	1974.656643	5	981	822.941839	281.833043	-25645.9	7314560
111	Point	6174	South Roxana	IL	1440.244514	10	1888	317.269961	101.48997	-25783.801	7314430
136	Point	15026	Hewlett Bay Park	NY	2311.074539	-10	484	1151.806381	354.070811	-25908.1	7314300
138	Point	15028	Hewlett Neck	NY	2310.902884	-10	504	1151.813153	353.362258	-26026.4	7314180
18	Point	1849	Del Mar	CA	0.113269	-25	4389	-1217.316923	-178.65374	-26108.5	7314100
171	Point	16805	Bratenahl	OH	1908.394084	5	1337	737.711308	338.241636	-27119.301	7313090
257	Point	19392	Leetsdale	PA	1971.531379	5	1232	819.740042	281.709201	-27120.699	7313090
195	Point	18553	Happy Valley	OR	68.723202	-35	4519	-1272.92333	731.011625	-27494.6	7312720
150	Point	15282	North Lynbrook	NY	2312.254914	-5	742	1152.358885	356.631731	-27507.9	7312700
167	Point	15657	Woodsburgh	NY	2310.465429	-10	831	1151.445456	353.037733	-27984	7312230

Record: 0 | Show: All | Selected | Records (10 out of 314 Selected) | Options

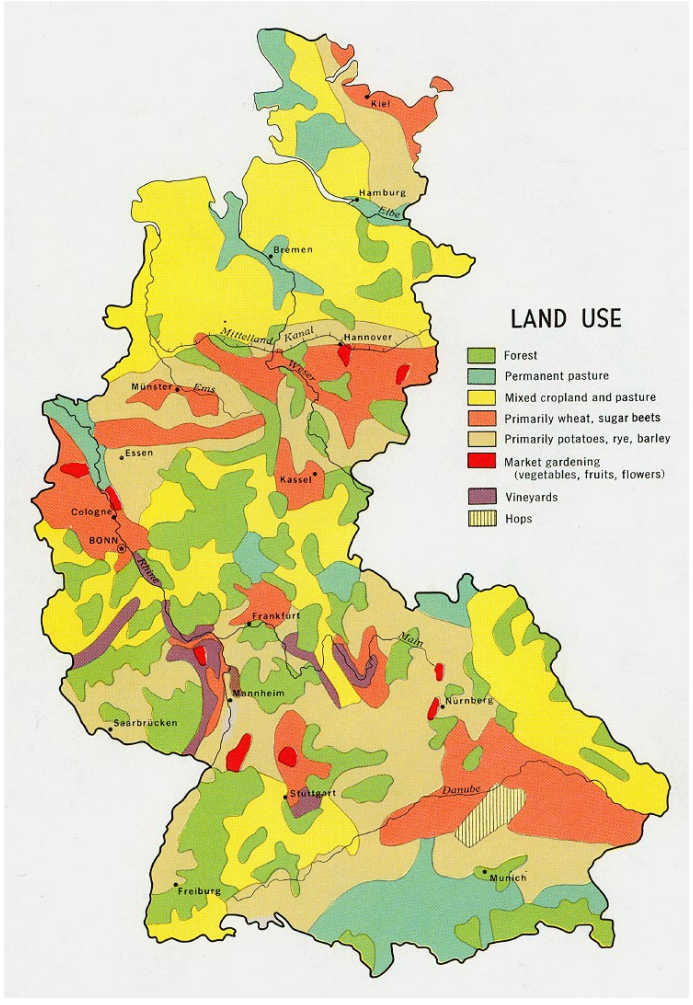
Into This!


Percent Change in Resident Population for the 50 States, the District of Columbia, and Puerto Rico: 2010 to 2020
Percent Change
Twice the U.S. percent change
U.S. percent change (7.4)
No change
14.9 to 18.4
7.5 to 14.8
0 to 7.4
-7.4 to -0.1
-11.8 to -7.5
AK 3.3
HI 7.0
WA 14.6
OR 10.6
CA 6.1
ID 17.3
NV 15.0
MT 9.6
WY 2.3
UT 18.4
AZ 11.9
CO 14.8
NM 2.8
ND 15.8
SD 8.9
NE 7.4
KS 3.0
OK 5.5
TX 15.9
MN 7.6
IA 4.7
MO 2.8
AR 3.3
LA 2.7
WI 3.6
IL -0.1
MS -0.2
MI 2.0
IN 4.7
KY 3.8
TN 8.9
AL 5.1
OH 2.3
WV -3.2
GA 10.6
FL 14.6
SC 10.7
NC 9.5
VA 7.9
PA 2.4
NY 4.2
VT 2.8
ME 2.6
NH 4.6
MA 7.4
RI 4.3
CT 0.9
NJ 5.7
DE 10.2
MD 7.0
DC 14.6
PR -11.8
United States Census Bureau
U.S. Department of Commerce
U.S. CENSUS BUREAU
census.gov
United States Census 2020

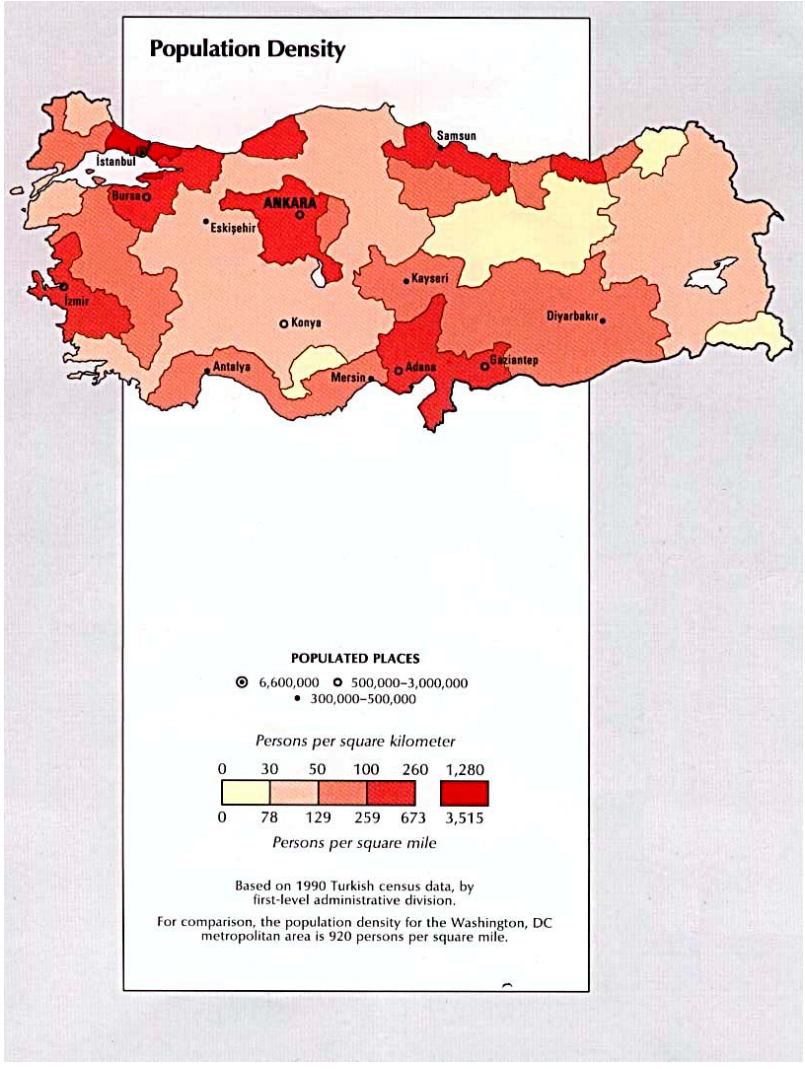
REFERENCE

Iran
International boundary
Province (ostān) boundary
National capital
Province (ostān) capital
Railroad
Road
0
250 Kilometers
0
250 Miles
Lambert Conformal Conic Projection, SP 12N/38N
Boundary representation is not necessarily authoritative.
ARMENIA
Yerevan
AZERBAIJAN
Baku
TURKEY
Van
Türkmenbashi
Nebitdag
TURKMENISTAN
Gyzylarbat
UZBEKISTAN
Charjew
Amu Darya
Caspian Sea
Ashgabat
Mary
Tejen
Sarakhs
Saragt
Gushgy
Herāt
Harīrūd
AFGHANISTAN
Farāh
Helmand
Daryā-ye
PAKISTAN
Nok Kundi
Gwadar
Arabian Sea
Gulf of Oman
Muscat
OMAN
UNITED ARAB EMIRATES
Abu Dhabi
Dubai
Doha
QATAR
BAHRAIN
Manama
Persian Gulf
Strait of Hormuz
KUWAIT
Kuwait
SAUDI ARABIA
IRAQ
Baghdad
Irbīl
Karkūk
An Nāşirīyah
Al Başrah
Umm Qaşr
Tigris
Euphrates
Shatt al Arab
Tabrīz
Ardabīl
Āstārā
Orūmīyeh
Lake Urmia
ĀZARBĀYJĀN-E SHARQĪ
ĀZARBĀYJĀN-E GHARBĪ
ARDABĪL
Rasht
GĪLĀN
Zanjān
ZANJĀN
Mahābād
Qazvīn
Bandar-e Torkeman
Sārī
Gorgān
MĀZANDARĀN
Bojnūrd
Rūd-e Atrak
Mashhad
Shāhrūd
Tehrān
Eslāmshahr
TEHRĀN
Semnān
SEMNĀN
KHORĀSĀN
Dasht-e Kavīr (salt desert)
Kavīr-e Namak
Qom
Sanandaj
KORDESTĀN
HAMADĀN
Hamadān
KERMĀNSHĀHĀN
Bākhtarān
Arāk
MARKAZĪ
Kāshān
Īlām
ĪLĀM
Khorramābād
LORESTĀN
EŞFAHĀN
Eşfahān
Dezfūl
Shahr-e Kord
CHAHĀR MAHALL VA BAKHTĪĀRĪ
KHŪZESTĀN
Ahvāz
Khorramshahr
Ābādān
Bandar-e Khomeynī
Yāsūj
KOHKĪLUYEH VA BOYER AHMADĪ
Yazd
YAZD
Bāfq
Bīrjand
Kermān
KERMĀN
Sīrjān
Bam
Zāhedān
Shīrāz
FĀRS
BŪSHEHR
Bandar-e Būshehr
Kangān
HORMOZGĀN
Bandar-e 'Abbās
Bandar-e Lengeh
Jāsk
Bandar Beheshtī
Bazman
SĪSTĀN VA BALŪCHESTĀN
alignment approximate
railroad u/c
Administrative Line
no defined boundary
De Facto Boundary

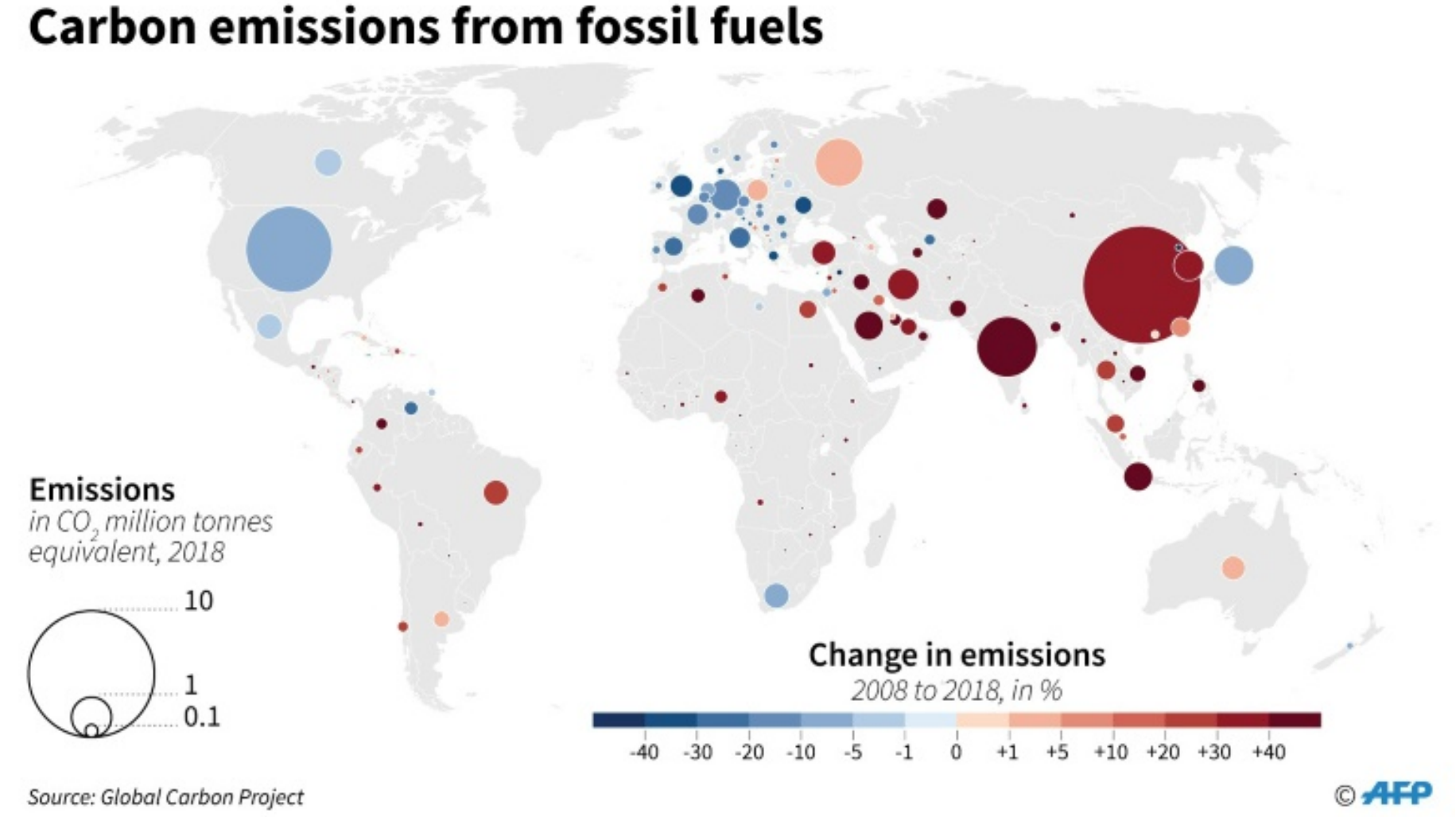
QUALITATIVE



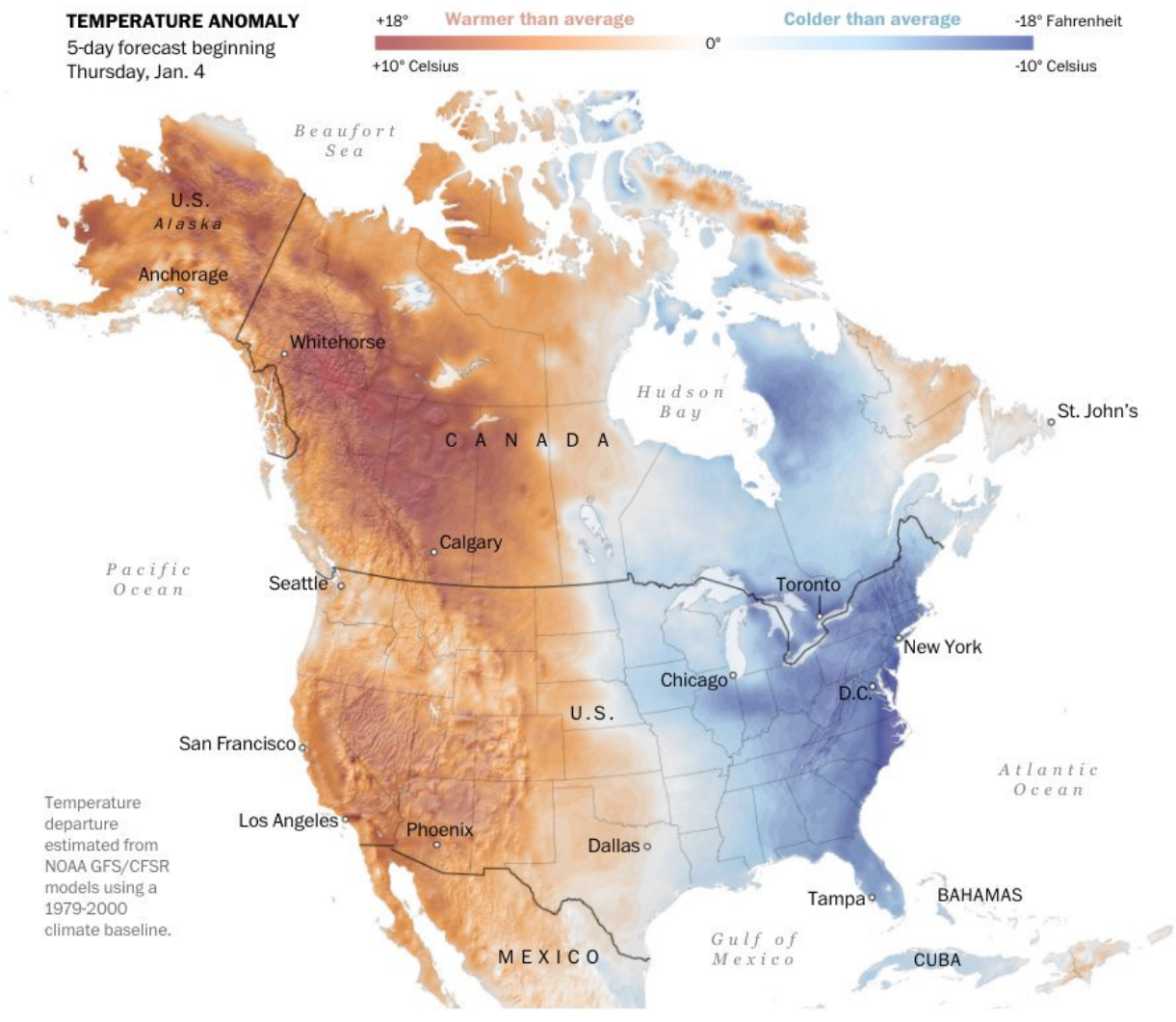
QUANTITATIVE CHOROPLETH



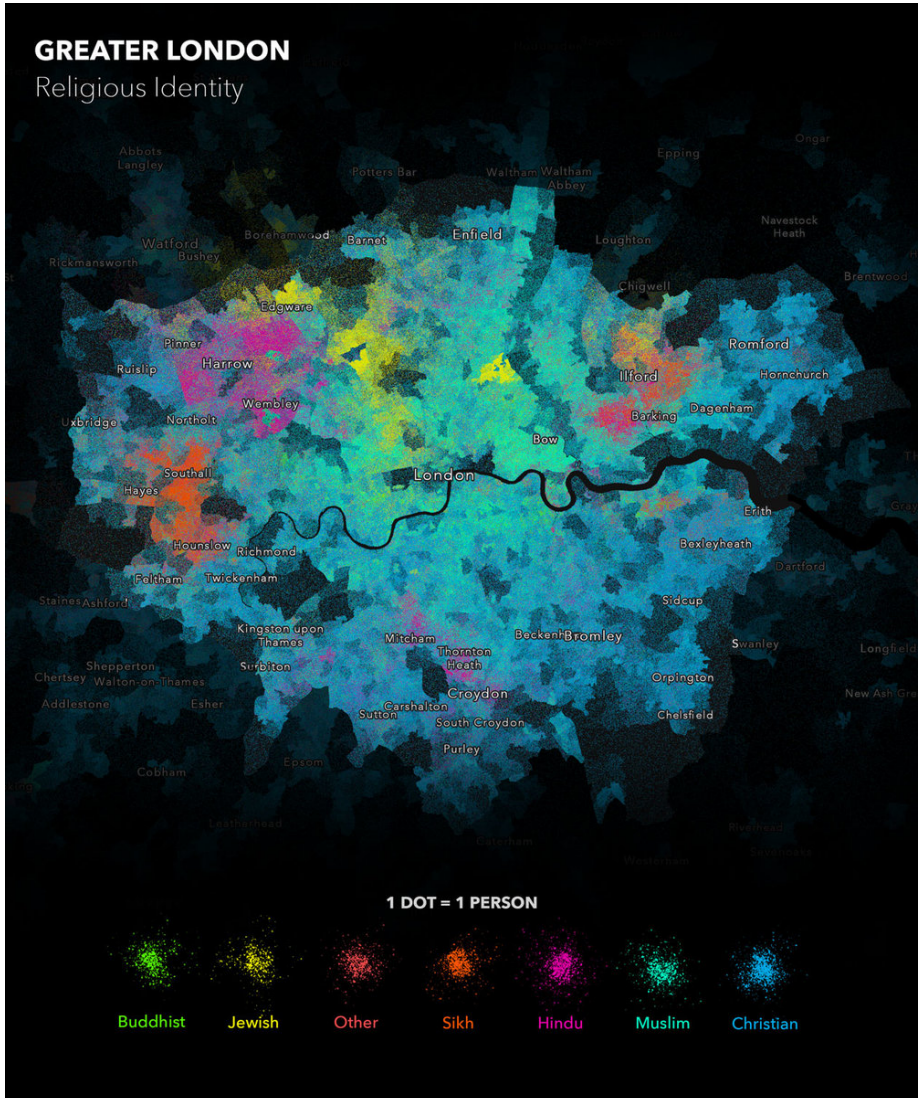
QUANTITATIVE PROPORTIONAL SYMBOL



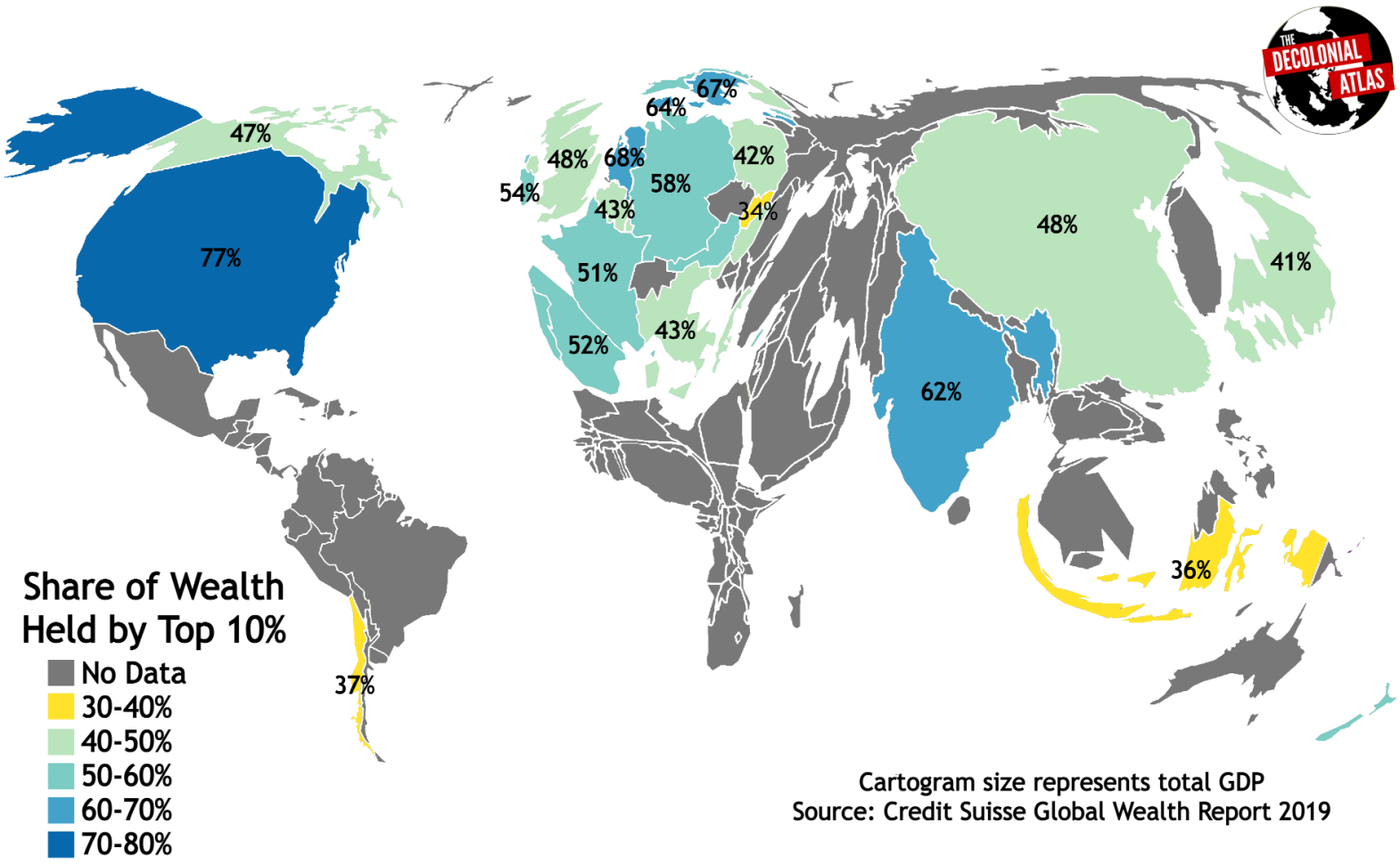
QUANTITATIVE ISARITHMIC



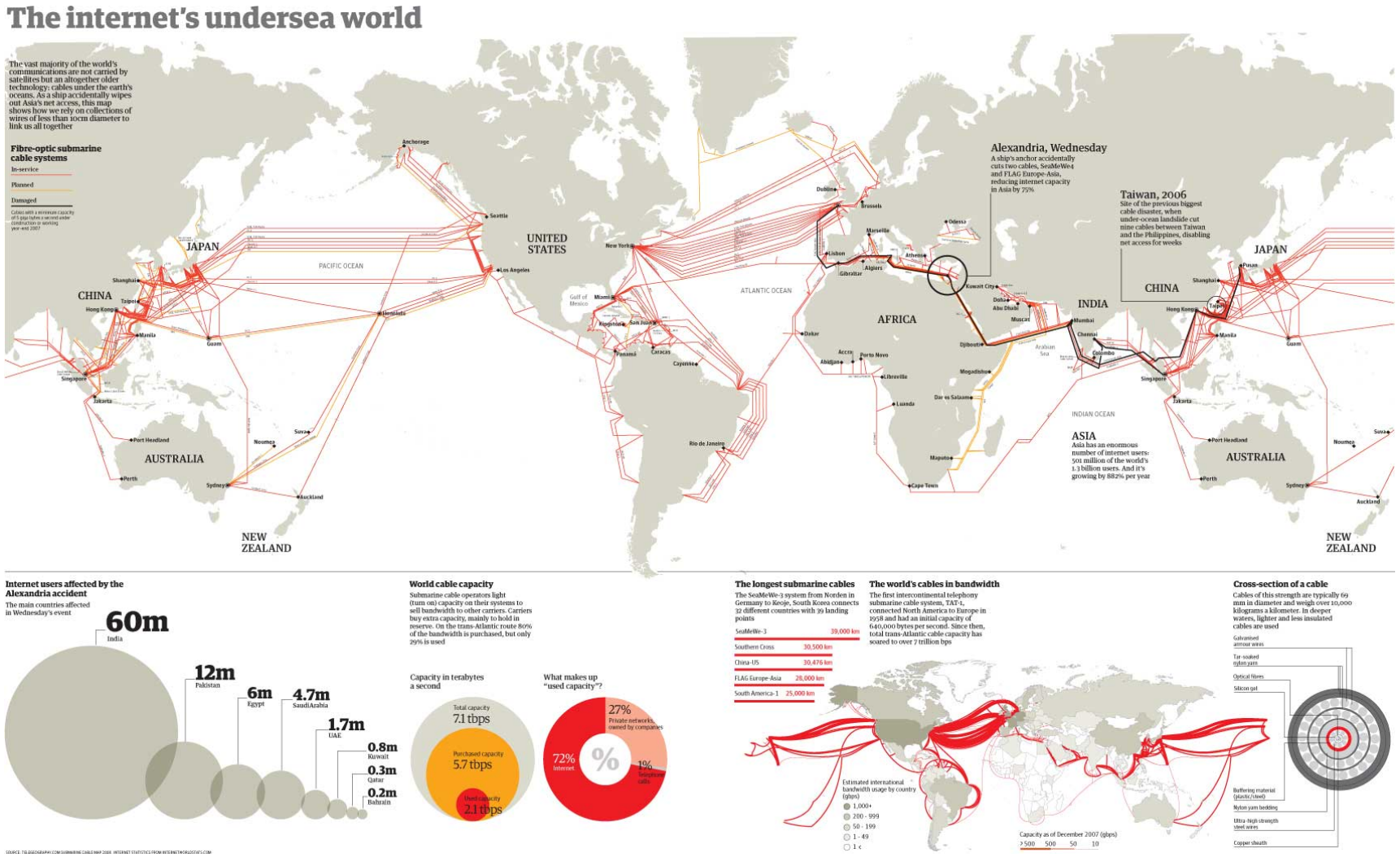
QUANTITATIVEDOT DENSITY



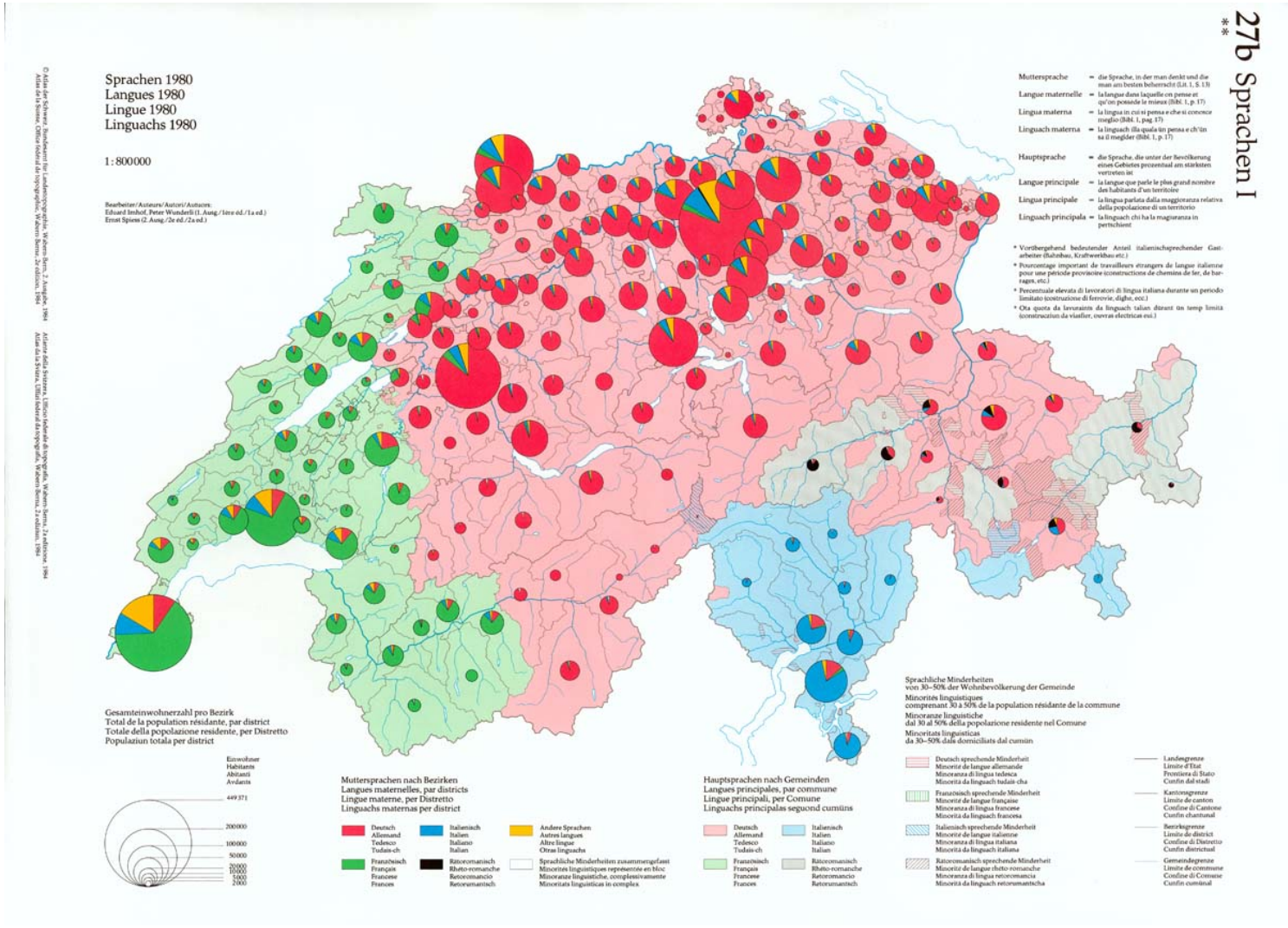
QUANTITATIVE CARTOGRAM



QUANTITATIVE FLOW



QUANTITATIVE MULTIVARIATE



SO WHAT's IMPORTANT?

Make maps people want to look at!

A good Map gives the user access to the data that is not readily available in the table. GIS answers questions that only spatial analysis can!

(It also should keep their eyes from rolling back in their heads as they drift off to a happy place!)