Modeling Climate Change in a Test Tube

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Teaching global warming is challenging …

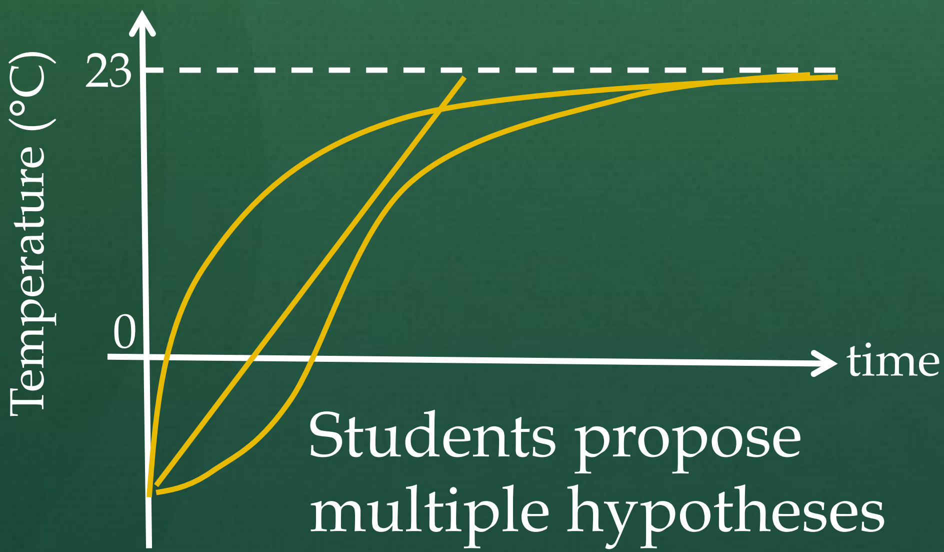
- It's a highly politicized topic
- Its multidisciplinary, abstract, complicated …
  - Global anything doesn't *fit* in the classroom
  - Cause and effect are often indirect, diffuse, …
- There's lots of (deliberate) misinformation and obfuscation
- The conclusions are depressing
- We cling to prior beliefs
  - The consequences of changing our minds are profound …
- …
- *Reviews aren't as good as for other classes*

Terminal Science

Many of my students are math/science phobic and this may be the last science class they ever take

Melting Ice Experiment

When we place a small piece of ice in the classroom and measure its temperature, what will the resulting graph look like?



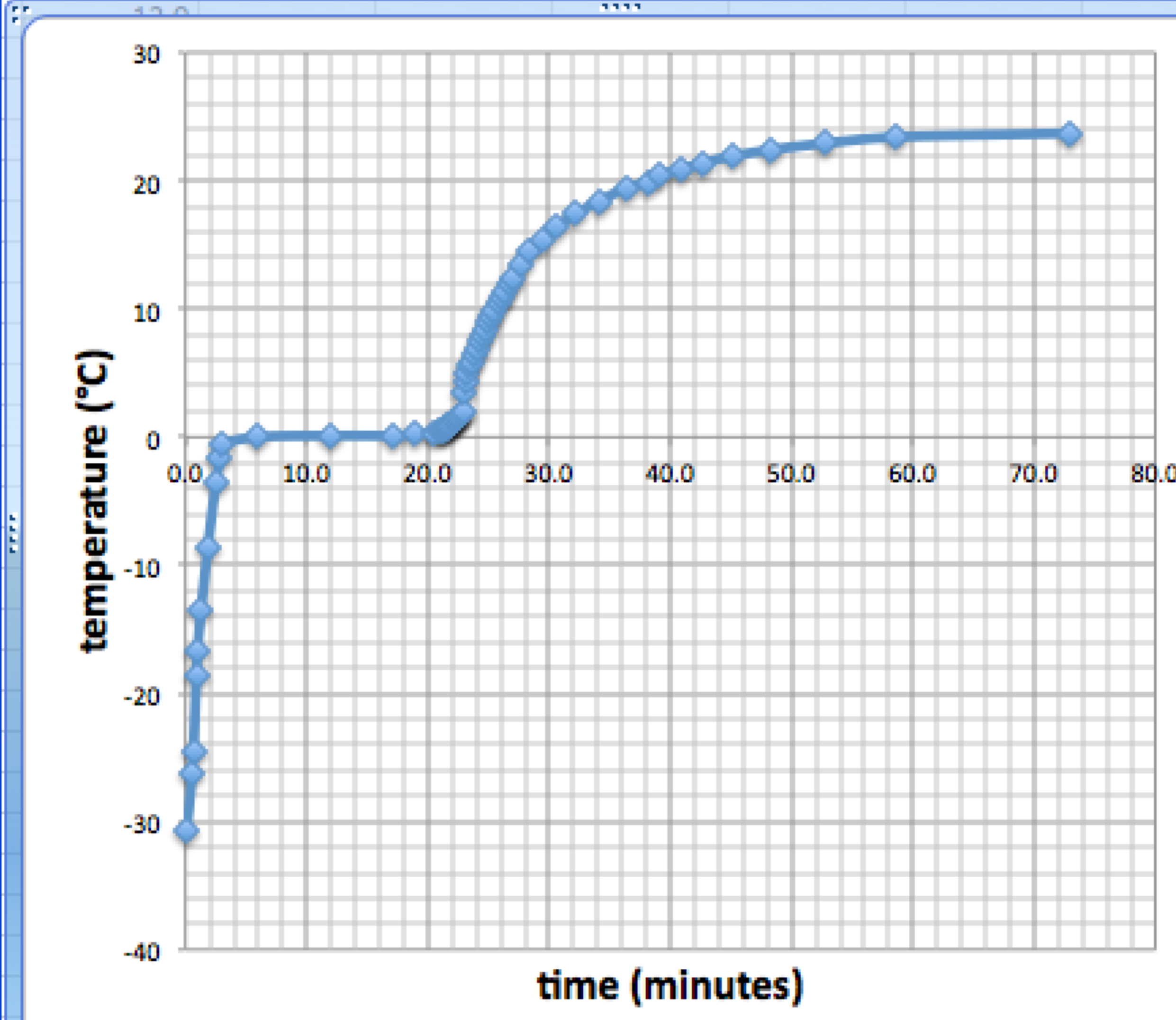
Students propose multiple hypotheses

Materials and Methods

- Thermocouple insulated e.g., with silicone; digital DMM/thermometer; test tube with internal shim to center TC; test tube rack; freezer or dry ice
- Discuss the experiment and student's hypotheses (while we're taking data)
- Students record the data (time from their iPhone)
- Plot data on board or in Excel
- Gotcha's
  - Freezing >~ 1ml may not equilibrate within a class period
  - Water can short out the thermocouple voltage

Results

	A	B	C	D	E	F	G
1							
2	temp	time, min	time sec	total time (min)	temp (°C)		slope
3	-32.2	0	10	0.2	-30.8		
4	-27.6	0	32	0.5	-26.2		12.5
5	-26	0	40	0.7	-24.6		
6	-20	0	54	0.9	-18.6		
7	-18	1	0	1.0	-16.6		
8	-15	1	17	1.3	-13.6		
9	-10	1	51	1.9	-8.6		
10	-5	2	30	2.5	-3.6		
11	-3	2	52	2.9	-1.6		
12	-2	3	4	3.1	-0.6		
13	-1.4	6	0	6.0	0		
14	-1.3	12	0	12.0	0.1		
15	-1.3	17	0	17.0	0.1		
16	-1.2	19	0	19.0	0.2		
17	-1.1	20	30	20.5	0.3		
18	-1	21	0	21.0	0.4		
19	-0.9	21	5	21.1	0.5		
20	-0.8	21	18	21.3	0.6		
21	-0.7	21	29	21.5	0.7		
22	-0.6	21	30	21.5	0.8		
23	-0.5	21	40	21.7	0.9		
24	-0.4	21	50	21.8	1		
25	-0.3	22	0	22.0	1.1		
26	-0.1	22	10	22.2	1.3		
27	0	22	20	22.3	1.4		
28	0.1	22	28	22.5	1.5		
29	0.2	22	36	22.6	1.6		



Discussion

- The students are (finally) engaged in asking/answering
  - Why the plateau?
  - When did the ice disappear?
  - Could we have made mistakes?
  - Meta-reflections
    - Why did our hypotheses fail?
    - What other prior notions of ours might be wrong??
    - What do scientists do when experiment and hypothesis disagree?
    - …
- We're really *doing* science now, vs. talking about it

Process, Content, & Inference

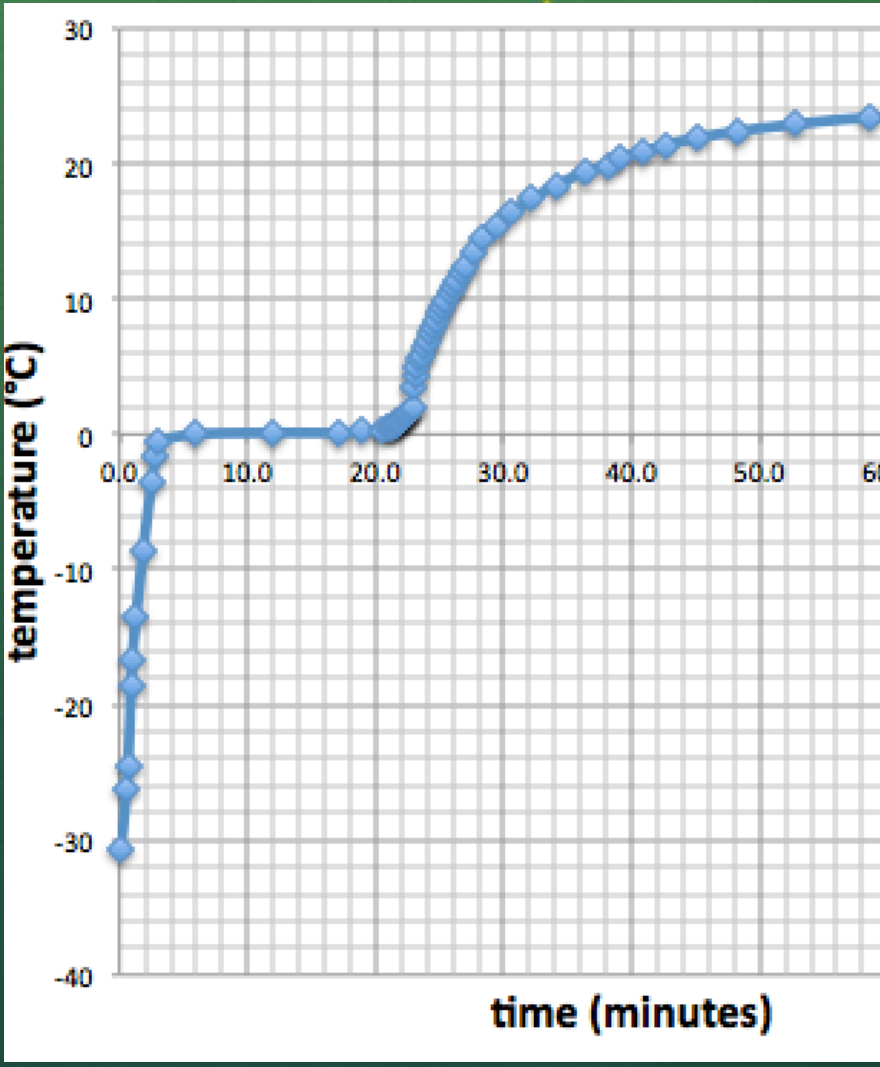
- Using thermal constants found online, we elucidate a more complicated, but accurate, theory of thermal dynamics of our system

Property	Value
Latent heat of melting	330 J/g
Specific heat of water	4.2 J/gK
Specific heat of ice	2.1 J/gK
Thermal conductivity of water	0.6W/mK
Thermal conductivity of ice	2.2W/mK

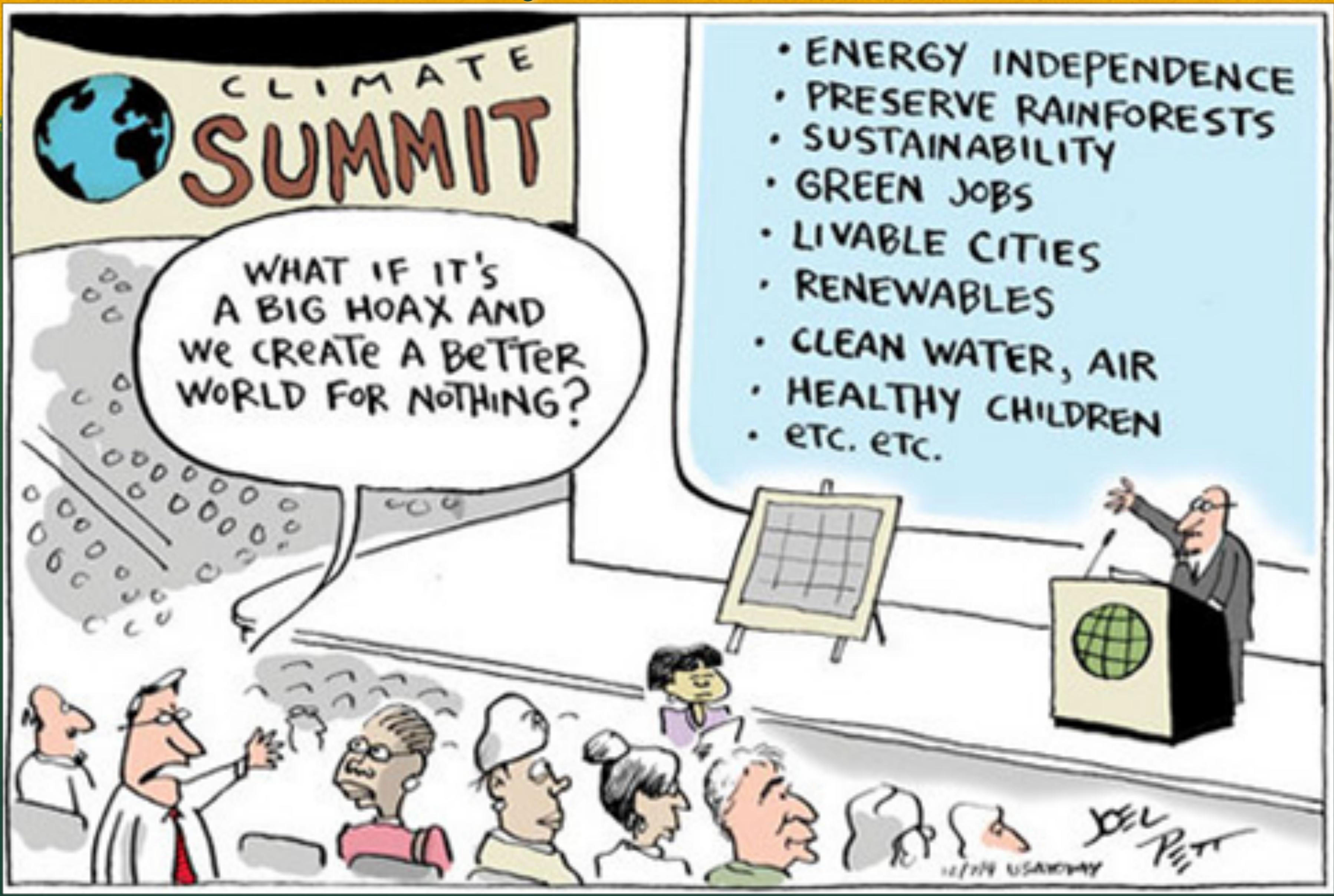
- Heat energy flows from the warm room to the ice, raising its temperature through its specific heat. At 0°C the inflowing energy melts the ice isothermally through its (large) latent heat. After all the ice has melted, the temperature takes off again via the specific heat of water.
- What might this model imply about global warming?

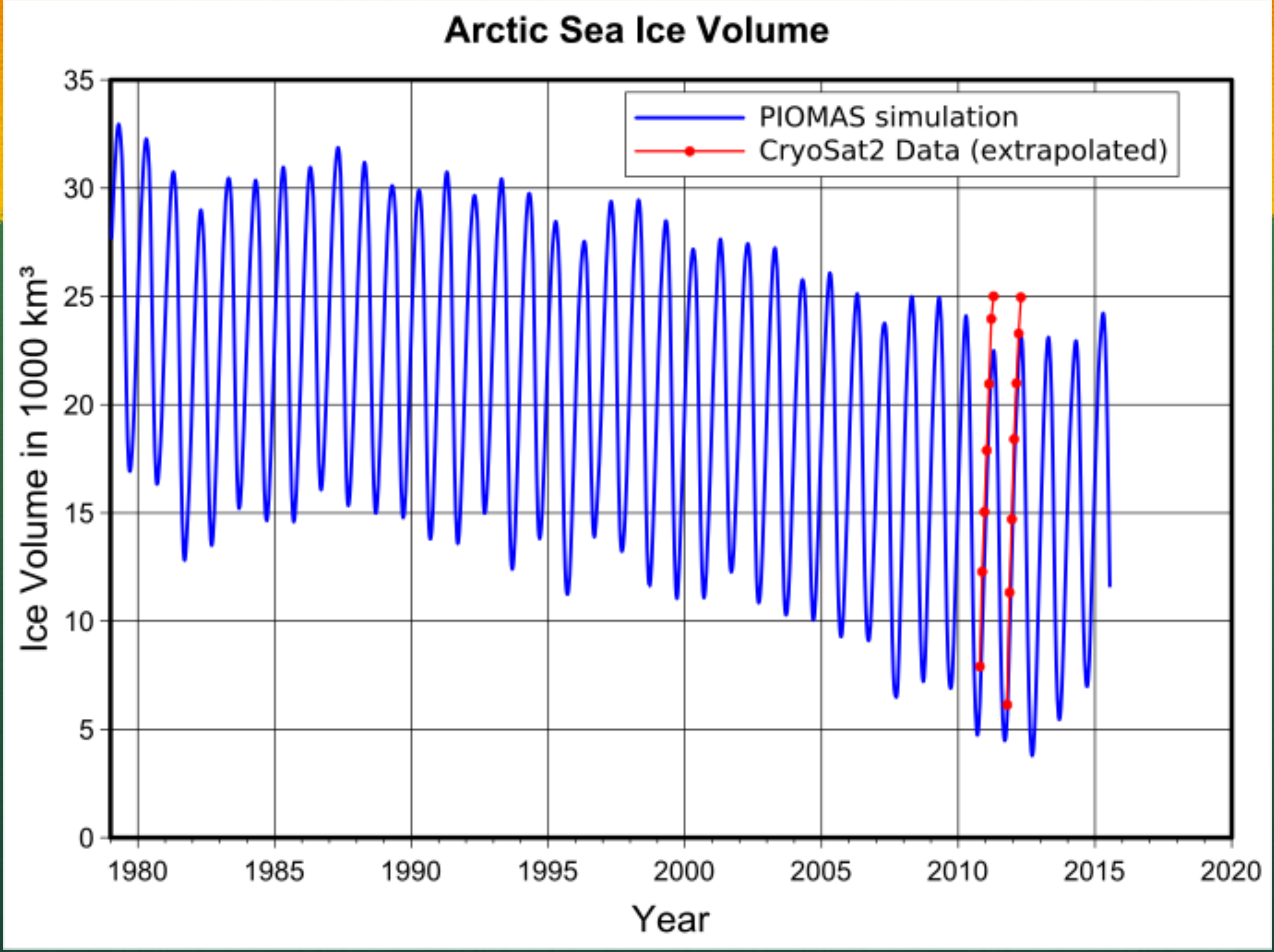
Why do I find this graph *frightening*??

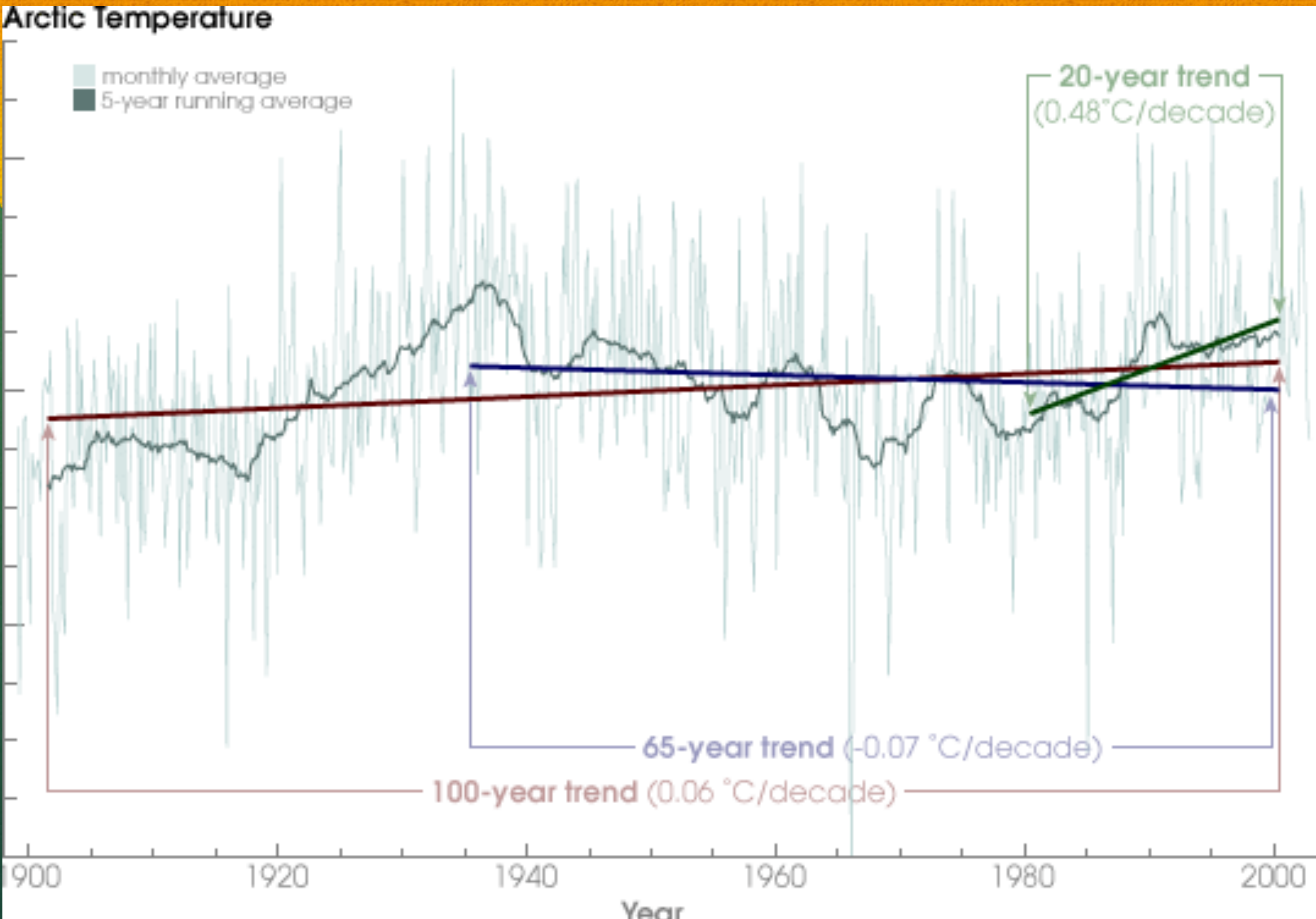
- Where *might you place* the Arctic on this graph?
- What can we *expect* will happen in the Arctic when its ice has all melted (within ~a decade)?
- What's wrong with this *climate model*?
- Why aren't people doing more about it?
- The class at this point is much more participatory and engaged



Thank you! Questions?




Arctic Sea Ice Volume
PIOMAS simulation
CryoSat2 Data (extrapolated)
Ice Volume in 1000 km³
0
5
10
15
20
25
30
35
1980
1985
1990
1995
2000
2005
2010
2015
2020
Year


Arctic Temperature
monthly average
5-year running average
20-year trend
(0.48°C/decade)
65-year trend (-0.07 °C/decade)
100-year trend (0.06 °C/decade)
1900
1920
1940
1960
1980
2000
Year