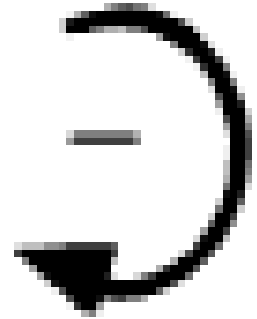


Amped Up

How feedback loops may amplify
climate change

What is a feedback loop?

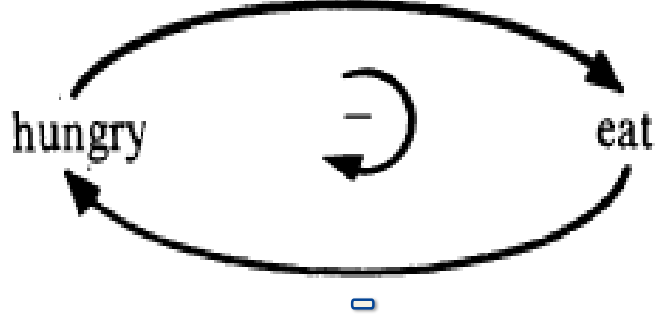
- The way a system reacts to a disturbance
- Negative feedback loop
 - the system acts to oppose the change from the input; the system tends to be stable (moving towards equilibrium)
- Positive feedback loop
 - The system continues to change in the same direction as the input (moving away from equilibrium)



- Roberts, Nancy. Teaching Dynamic Feedback Systems Thinking: An Elementary View. *Management Science*, Vol. 24, No.8 (Apr., 1978), p. 836 – 843.

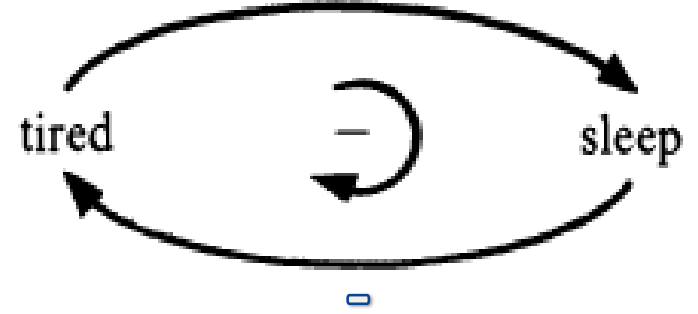
+

Causes me to

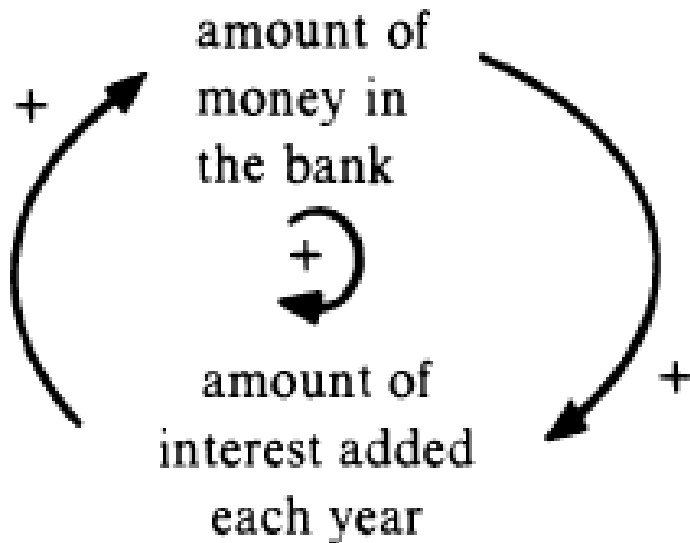


+

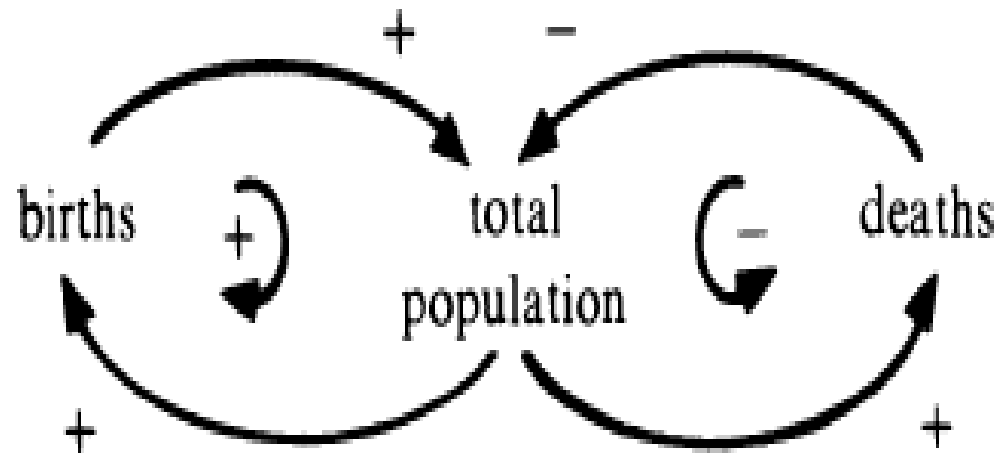
Causes me to



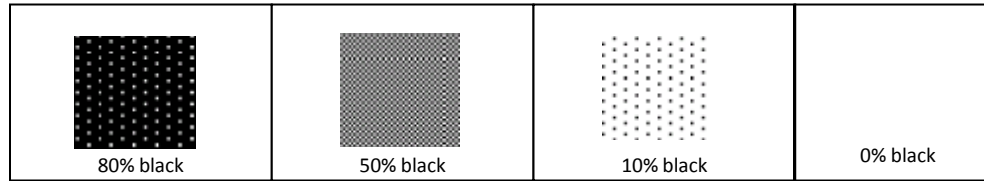
Causes me to



Causes me to



How does albedo affect heating & cooling?



Will the differently shaded pieces of paper heat up and cool down at the same rate?

Experiment set –up:

- Create a pocket out of each piece of paper
- Place a temperature probe in each pocket
- Arrange all four pockets under the lamp so they each receive the same amount of energy from the lamp
- ❖ Record the initial temperature of each pocket.
- ❖ Turn the lamp on and record the temperature from each thermometer every 2 minutes for 20 minutes
- ❖ Turn the lamp off, and continue to record the temperature for another 20 minutes
 - ❖ Fear not, we'll let the LabQuests record the data for us!

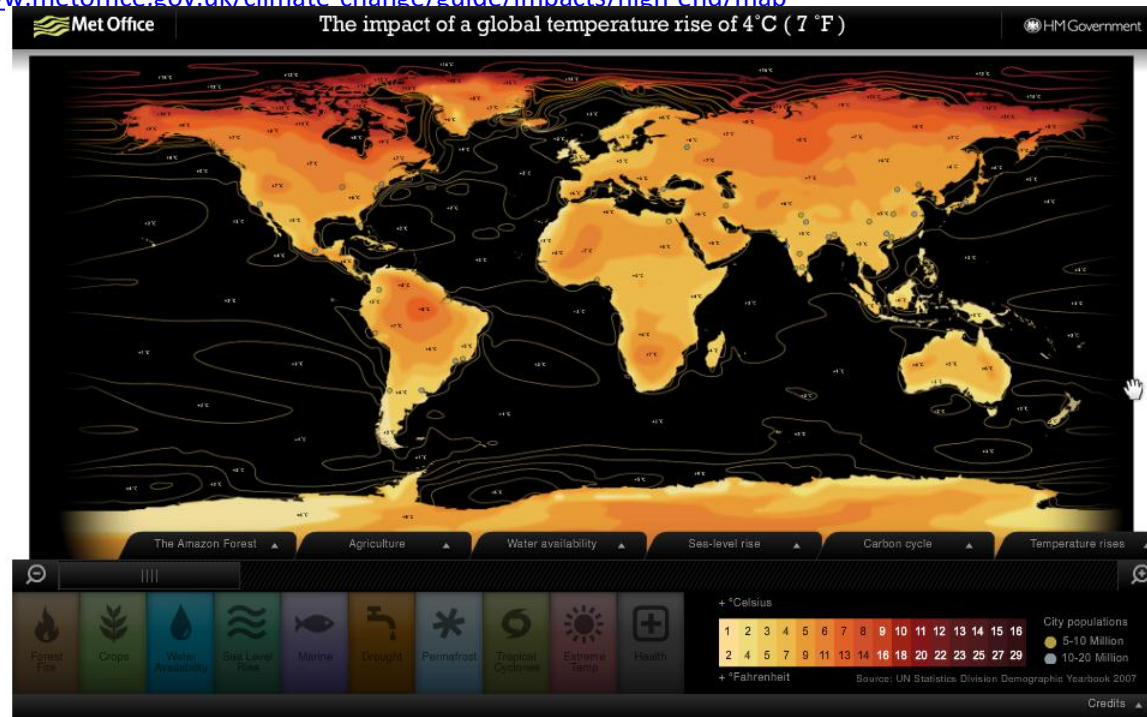
Lab Quest Directions

- Push the power button to turn on
- Check that all sensors display a reading
- All probes should be reading the same temp.
- Click on mode:
 - Set “length” to 40 minutes
 - Set rate to 0.5 samples/min
 - The interval should read “2 min/sample”
 - Hit “ok”
- When your experiment is set-up & ready, hit play

What is happening globally?

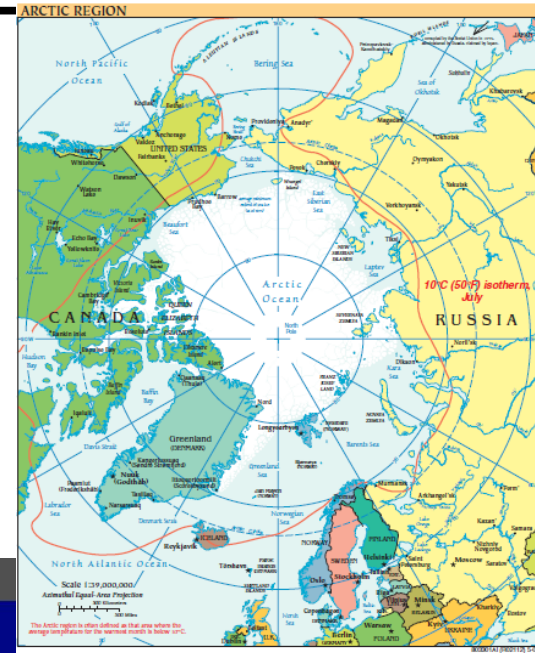
- Observations:
 - average global temperature has increased 0.74°C (1.3°F) over past century
- Projections:
 - global average temperatures projected to rise by up to 4°C (7.2°F) by the year 2100

• Met 4degrees map <http://www.metoffice.gov.uk/climate-change/guide/impacts/high-end/map>

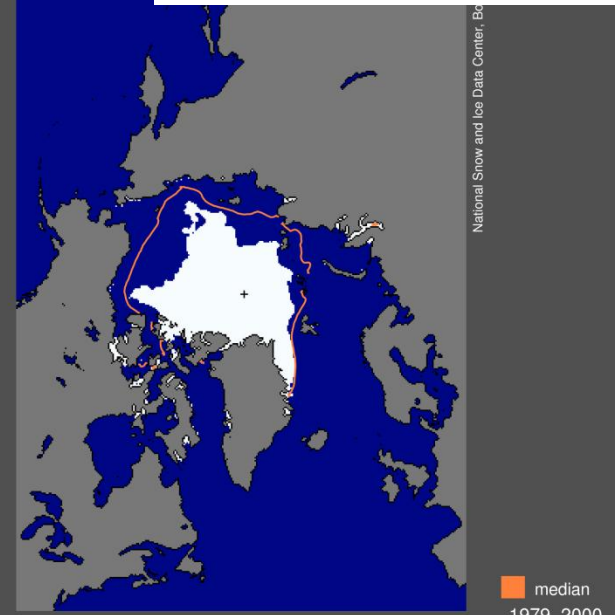


What is happening in the Arctic?

- Observations:
 - Arctic temperatures have risen 1.4°C (2.5°F) over the past century; that's twice as much as the rest of the planet
 - summer Arctic sea ice extent is approximately 40% lower than it was in 1979
- Projections:
 - by the year 2020, summer sea ice may be absent in the Arctic
 - by 2100 the Arctic may be ice free year round



Sea Ice Extent
09/09/2011



National Snow and Ice Data Center, Boulder, Colorado

median
1979-2000

Why is the Arctic warming so quickly?

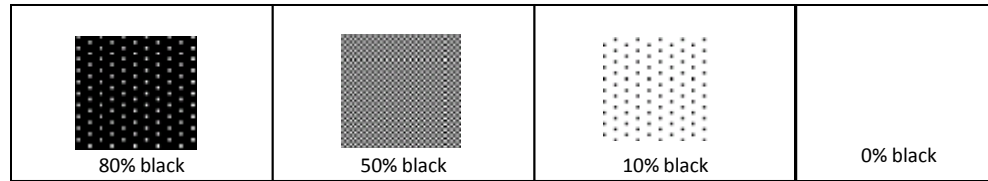
Feedback loops

- $\downarrow$ ice/snow $\rightarrow$ $\downarrow$ albedo $\rightarrow$ $\uparrow$ warming
- $\downarrow$ tundra $\rightarrow$
 - $\uparrow$ decomposition in soils $\rightarrow$ $\uparrow$ carbon dioxide $\rightarrow$ $\uparrow$ warming
 - $\uparrow$ methane producing microbes $\rightarrow$ $\uparrow$ methane $\rightarrow$ $\uparrow$ warming
- $\uparrow$ ocean temp. $\rightarrow$ $\uparrow$ methane $\rightarrow$ $\uparrow$ warming
(released from methane hydrates)
- $\downarrow$ sea ice $\rightarrow$ $\uparrow$ oil & gas reserves $\rightarrow$ $\rightarrow$ $\uparrow$ warming
- $\uparrow$ freshwater runoff $\rightarrow$ $\downarrow$ salinity & density $\rightarrow$ $\downarrow$ thermohaline circulation $\rightarrow$...cooling?

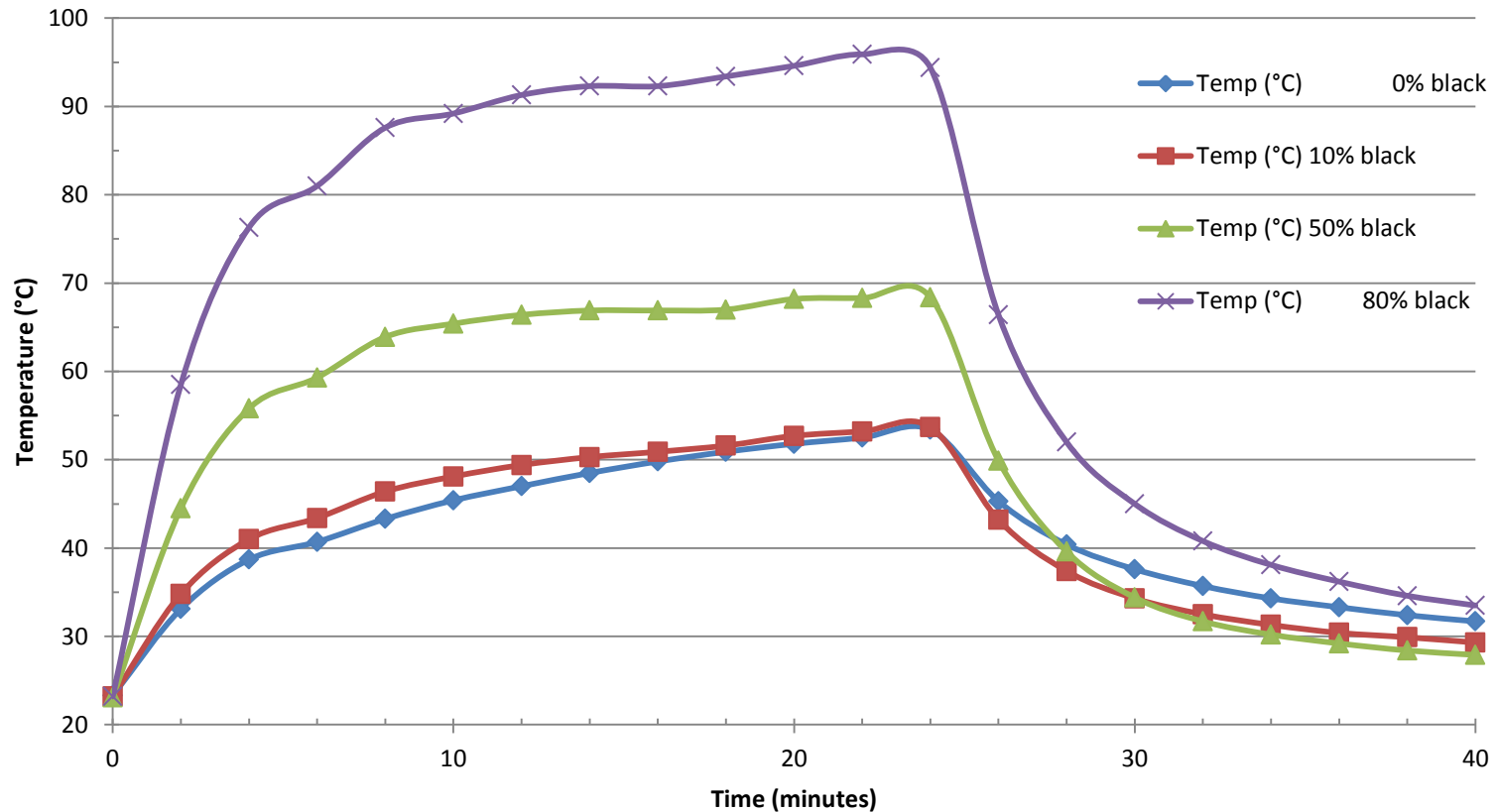
Exploration

- Station A - Black carbon
 - “*Changing Planet: Black Carbon*”
 - (6 minutes long - Link to video: http://icue.nbcunifiles.com/icue/files/nbclearn/site/video/widget/NBC_Learn_Video_Widget.swf?VIDEO_ID=1313605)
- Station B - Feedback loops
- Station C - Albedo
- Station D - Arctic sea ice extent

How does albedo affect heating & cooling?

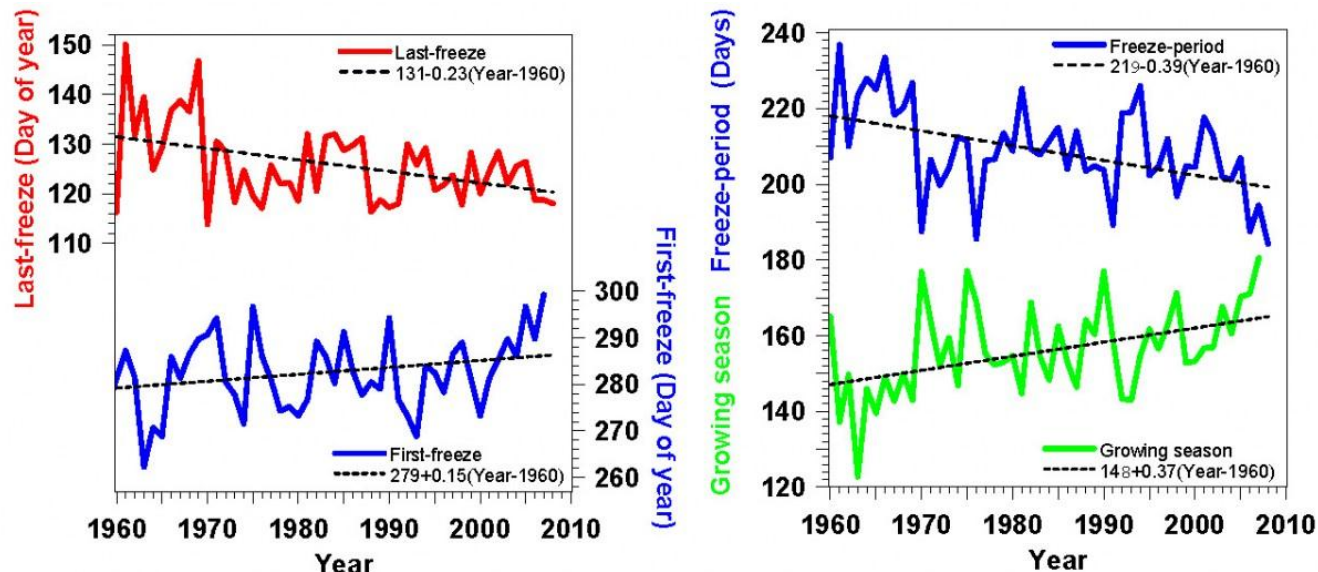


Temperature (°C) Change in Different Surfaces vs. Time (min)



How is this all connected to VT?

- stability of global climate system impacts VT
- VT is a source of black carbon
(emissions north of 40° most likely transported to Arctic) - Kitasei, S.
- VT is a ghg emitter
 - 8.1 MMT (million metric tons) CO₂ per year! - http://www.anr.state.vt.us/anr/climatechange/Vermont_Emissions.html
- Feedback loops influence VT winters
 - “This shrinking of the winter season is being driven by the same climate processes that are driving the rapid melt of the Arctic sea-ice in summer.” –Betts, A.K.



Betts, A. K. (2012), Climate change: Taking a Local Perspective to the Global Level. *Earthzine*. <http://www.earthzine.org/2012/02/27/climate-change-taking-a-local-perspective-to-the-global-level/>

Betts, A.K. images accessed on 3.7.12 from: <http://alanbetts.com/understanding-climate-change/topic/vermont-climate-change-indicators/>

Kitasei, Saya (2009). Arctic Amplification. *Climate Alert*. Vol. 19 No. 4.

Vermont Agency of Natural Resources. *Climate Change Team*. <http://www.anr.state.vt.us/anr/climatechange/Index.html>, accessed on 3.5.2012.

Being tired
causes me
to...

sleep

Sleeping
causes me
to...

be less tired

Being hungry
causes me
to...

eat

Eating
causes me
to...

be less

hungry

Increasing...

...the amount
of money in
the bank

Increases...

...the amount
of interest
added

Increasing...

...the total
population

Increases...

...the total
number of
births