University Students' Ideas about Climate Concepts Lack Systems Dynamics Thinking

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Goal: Effective teaching and learning of climate science

- Articulate climate science learning goals
- Find out what students think
- Design valid assessments that address student thinking
- Design learning activities that address student thinking
- Iterate to improve

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Think-Aloud Interviews

~13 questions, 45-60 mins

53 interviews, college/university students
5 campuses (North America & Hawaii)
62% female
61% year 3+
78% science majors

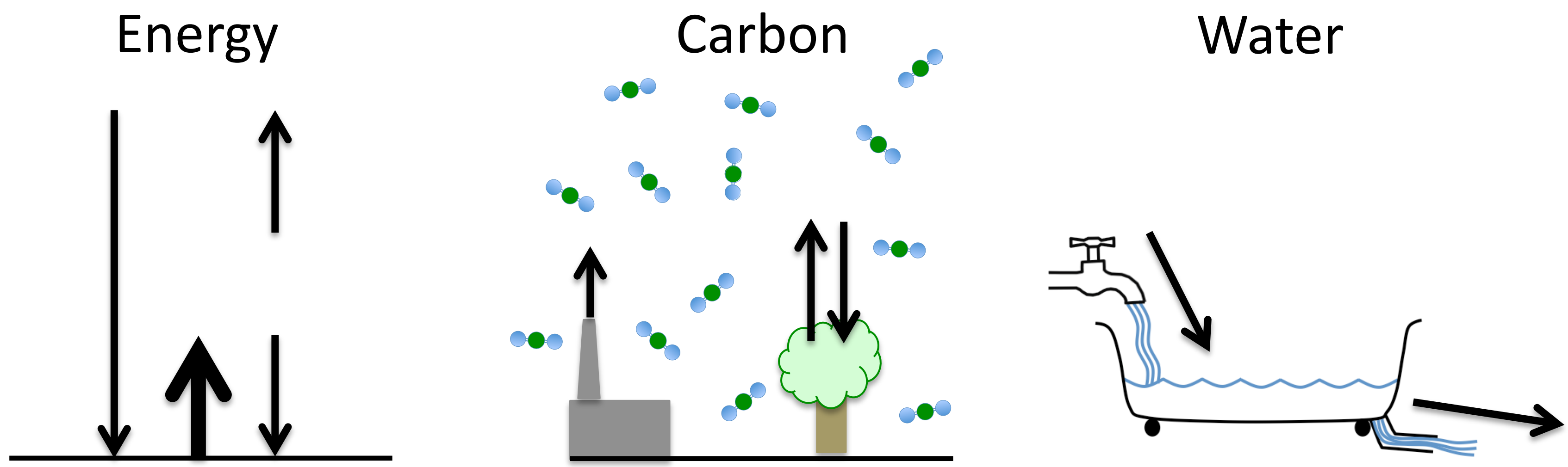
Livescribe SmartPen®

Interview Questions about Stock & Flow

Energy Stock and Flow: Greenhouse effect

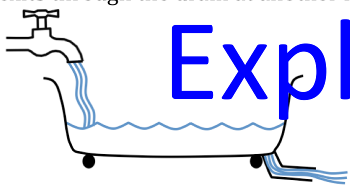
Carbon Stock and Flow: Keeling curve

Water Stock and Flow (explicit): Bathtub

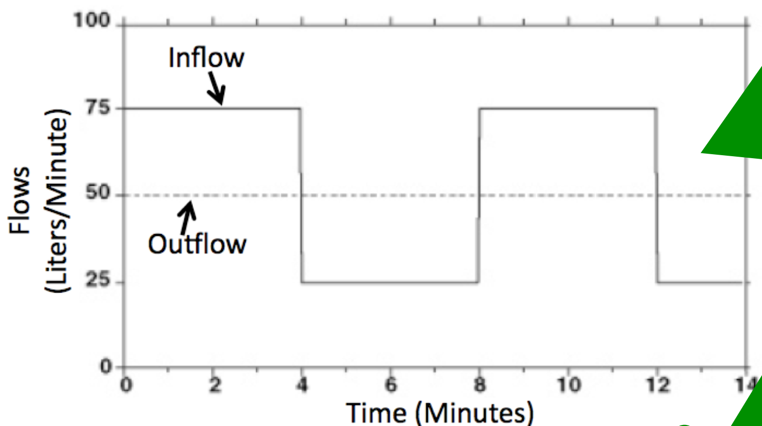


Explicit Stock & Flow: A bathtub

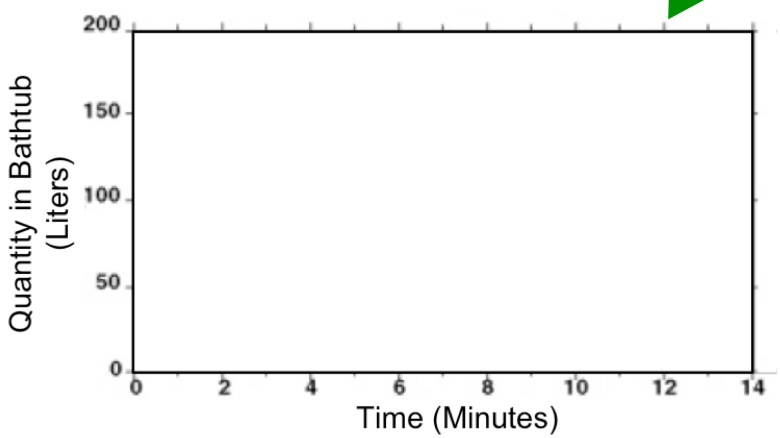
1. Consider the bathtub shown below. Water flows in from the faucet at a certain rate, and exits through the drain at another rate.



a. The first graph below shows the hypothetical behavior of the inflow and outflow rates for the bathtub for 14 minutes. Based on this first graph, describe in words what's happening with (1) the inflow rate and (2) the outflow rate over time.



b. Assume the initial quantity in the tub (at time zero) is 100 liters. From the information about inflow and outflow on the graph above, draw **what happens to the quantity of water in the tub over time**, on the graph below.



Modified from Booth Sweeney and Sterman (2000)

Basically, given inflow and outflow, draw the quantity of water in the tub over time

33% (17/51)

combine inflow and outflow correctly

20% (10/51)

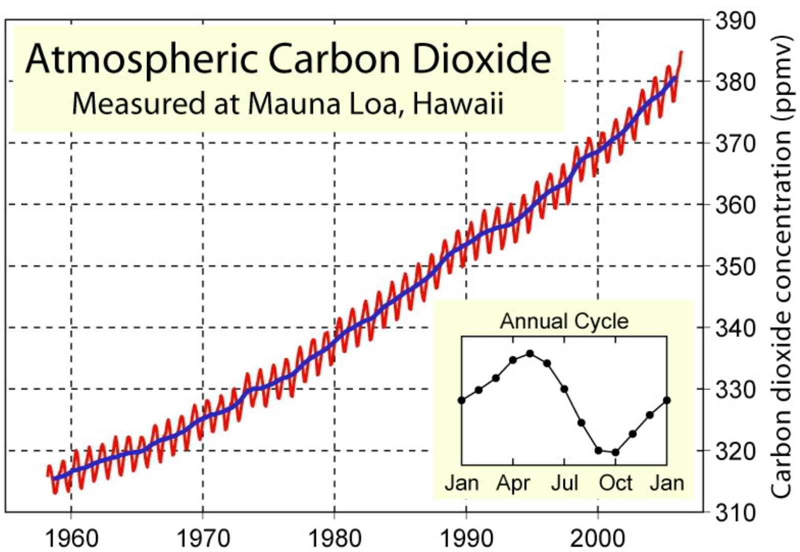
ignore outflow

Keeling Curve

(question is not explicit about stock & flow of carbon)

Below is a graph related to climate change.

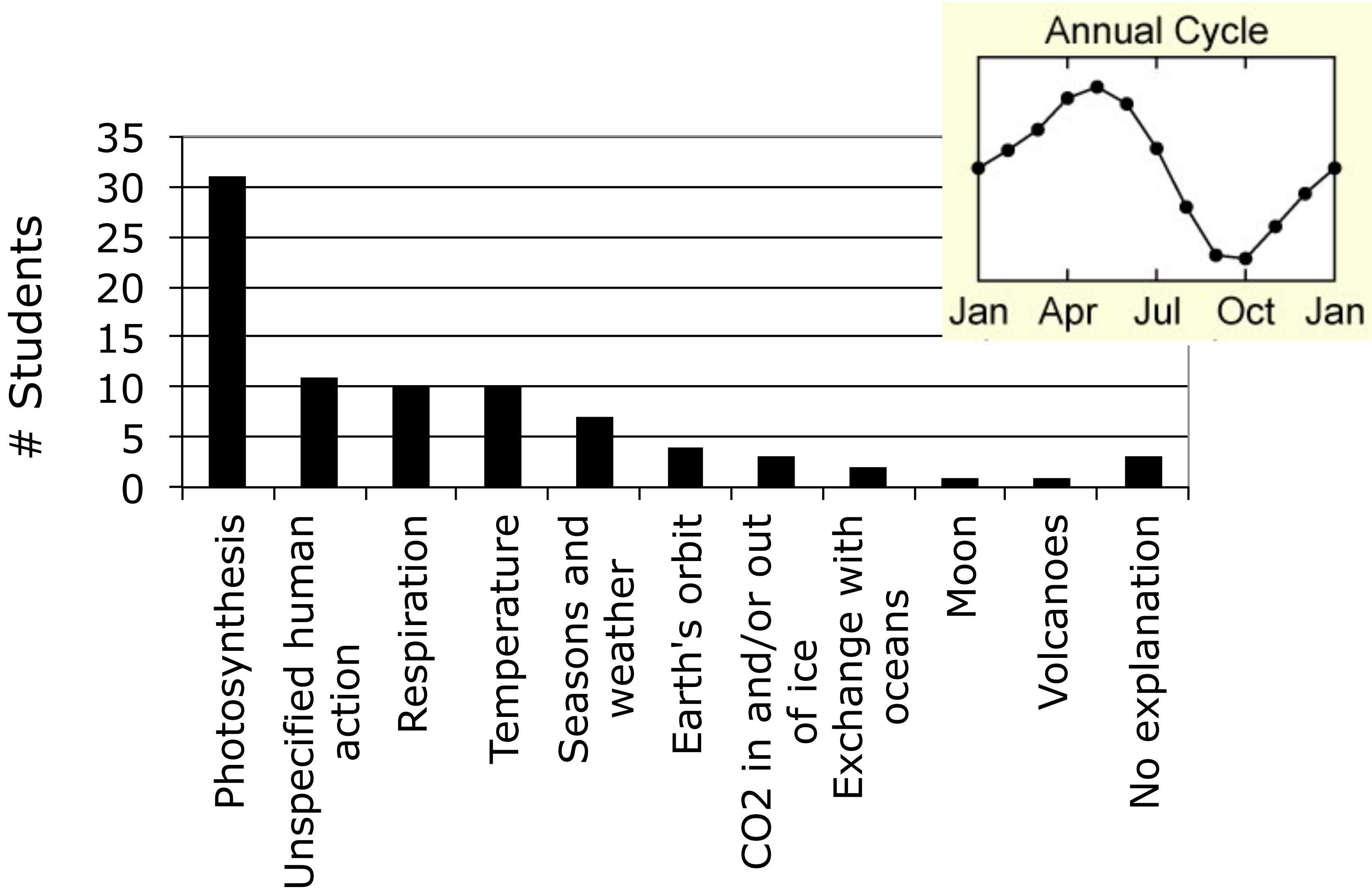
a. Describe the graph. Annotate the graph as needed.



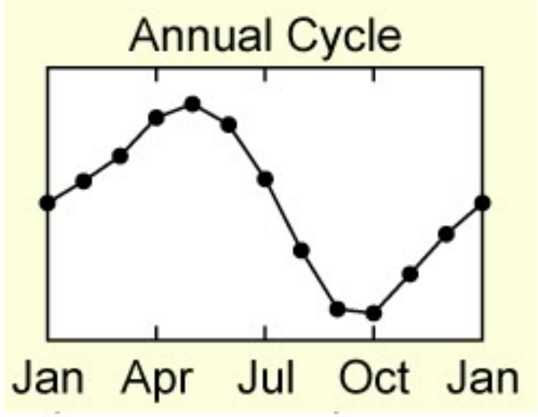
"You know, I've seen this graph, like, many times, I just never, like, had to answer any questions about it myself. Usually people show you the picture then tell you whatever their interpretations are"

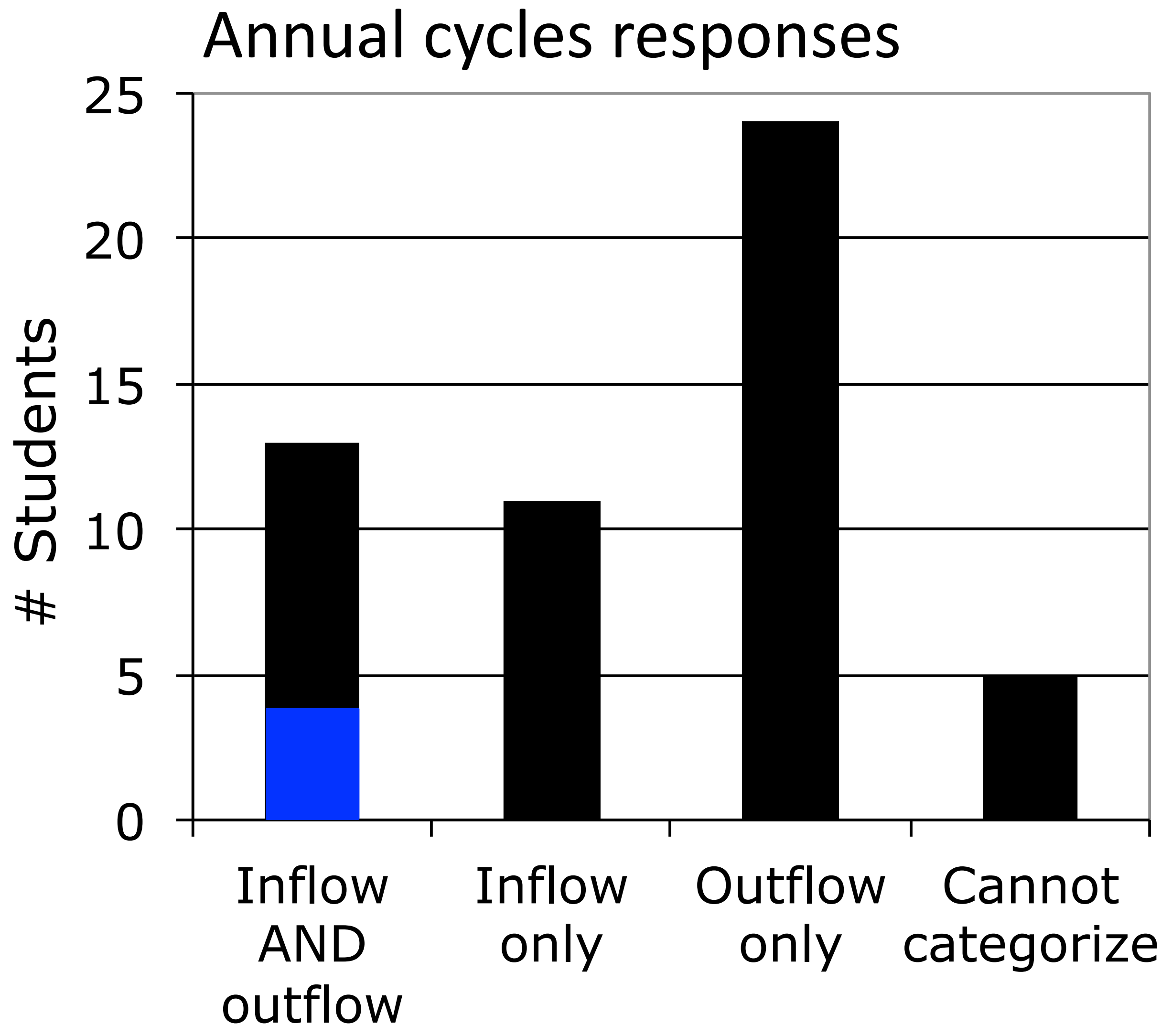
b. Explain what processes you think are related to the features you notice. Annotate the graph as needed.

Keeling Curve: Annual cycle explanations



Keeling Curve: Annual cycle





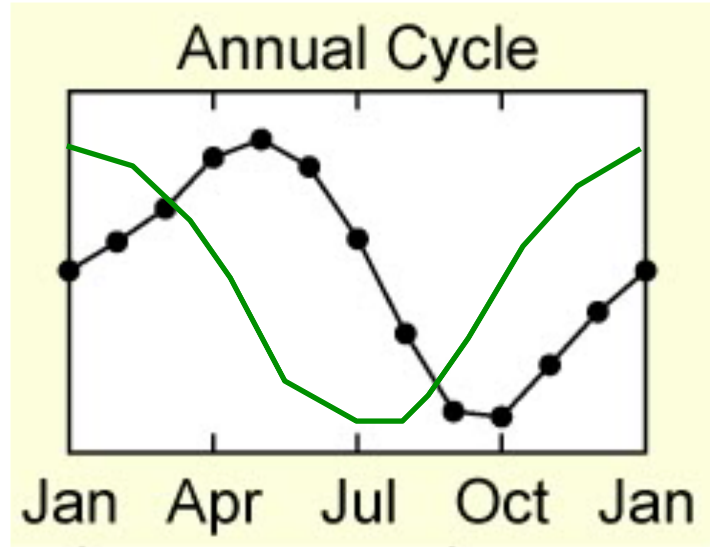
70% (35/53)

Carbon inflow OR outflow only

8% (4/53)

Clear in & out explanations

Keeling Curve: Peak/valley timing

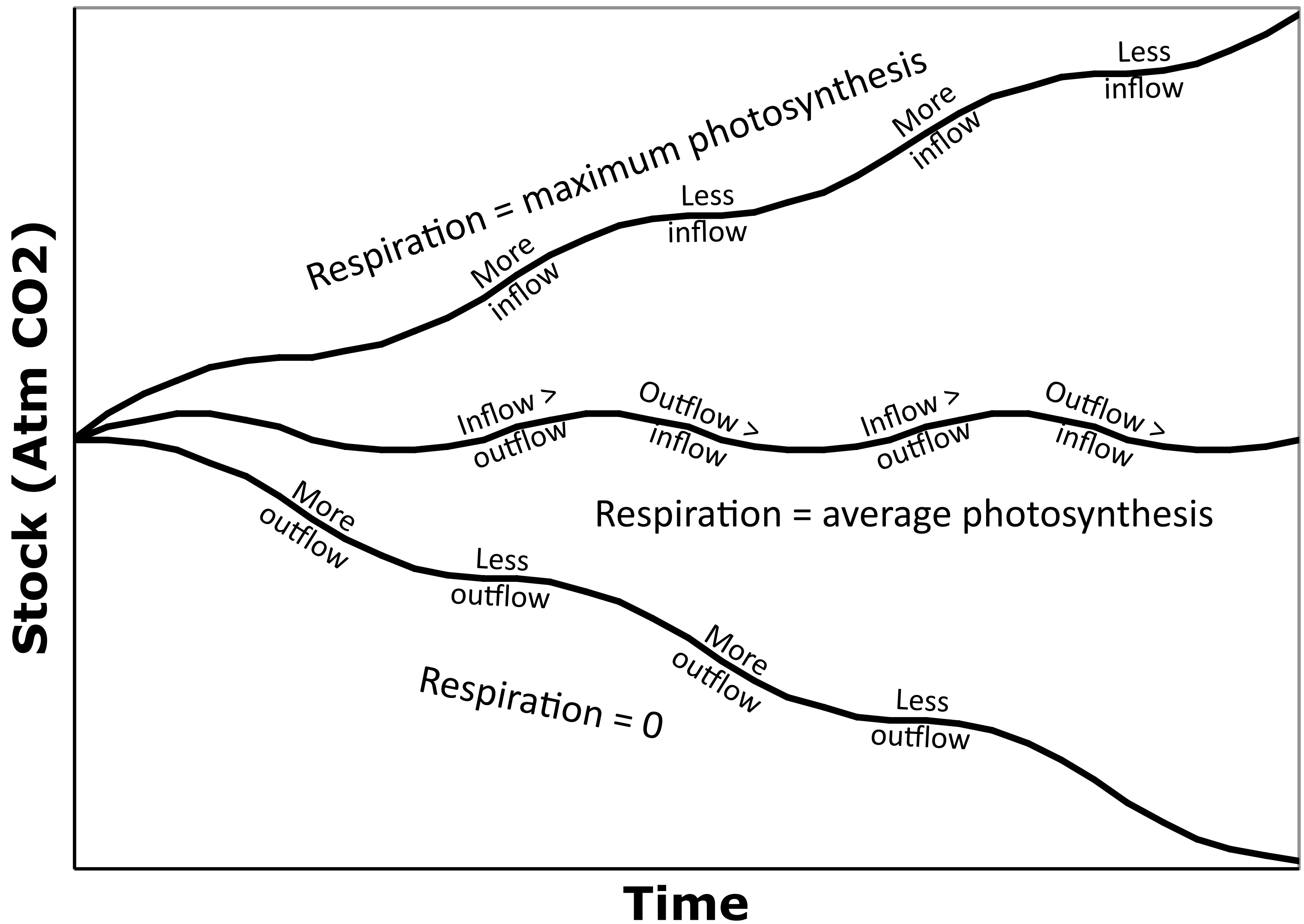


Valley in summer, peak in winter:

"as the plants die they can't take in as much carbon dioxide, so that would increase the amount in the air"

After explaining the annual cycle using only more/less photosynthesis*: "Ooops, was I backwards? Is this a zoomed-up square of one of these?.. Hmm. That's curious... the way I explained it before with the peak … corresponding to the boreal winter, and [the valley] being the boreal summer and it's, well, I guess it's sort of offset from where I'd assumed it to be…But that is just some lag time, due to something. Probably because energy absorption by plants in this area or in the beginning of spring is devoted to growth...um, I'm not sure. I may be talking myself in circles here"*

Keeling Curve: Illogical futures



Stock & flow thinking in Keeling scenario → better success at bathtub

55% (6/11) of those who generate inflow & outflow ideas also correctly answer bathtub question.

28% (11/40) of those who do NOT generate inflow & outflow ideas correctly answer the bathtub question

$\chi^2(1,n=51)=2.8$, $p=0.09$, but numbers are small

Conclusions

- Systems dynamics thinking is hard
- Most student explanations either don’t align with data, and/or are internally inconsistent, and/or would lead to wacky futures
- Incorporating **explicit practice in systems thinking** into climate education could help
- Climate change mitigation may take attention to both inflows and outflows