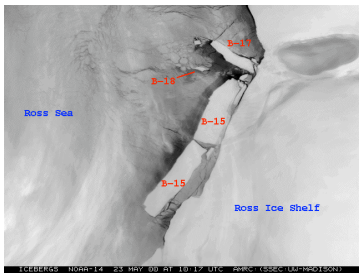
Unraveling the Mysteries of the Earth's Changing Ice Cover



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"So What if the Earth's climate changes a degree or two?!?! Why should anyone care about something so small?"

The Earth's climate is a very complicated system, with lots of intricately-interrelated components that interact with each other. Making a reliable mathematical model of the climate system has been the goal of meteorologists for decades, and our knowledge and technology are improving all the time.

One phenomenon that proves to be important in meteorology continuously is that of "feedback." It may be a cruel twist of linguistics and Nature, but "positive feedback" is something very much to be avoided in systems engineering, unlike in interpersonal relationships.

A good, commonly-known example of the "peril of positive feedback" is the loud squeal that occurs when a microphone gets too near a speaker to which it is connected (through an amplifier). Any minute electronic noise in the system produces a noise in the speaker, which is picked up by the microphone, amplified by the system, then fed out to the speaker as a much louder sound, where it is picked up by the microphone, amplified yet again by the system, and so forth, until the signal from the amp overloads the speaker, producing the excruciating squeal. (Circuitry designed to defeat feedback is why call-in radio shows are always reminding callers to "turn down their radios." Even with a built-in time delay in the broadcast, if the caller's phone is picking up background noise, then the radio broadcast and phone can produce a positive feedback loop, annoying all listeners even more than usual.)

It should be clear that a "positive feedback" in this context is synonymous with "vicious circle!"

Now, let's think about an ice-covered region in high latitudes, in the context of feedback in a climate system, not a sound amplification system. Let's say that, on average, the snow and ice on that surface on this surface will melt off completely for six months out of the year, revealing either dark earth or vegetation. The other six months, the much-more-reflective snow and ice covers the ground. That is our "system," at least for purposes of this thought experiment.

What would the expected system response to, say, a small local increase in the mean annual temperature for a few decades? The warmer temperatures would slightly delay the coverage of the area by snow and ice in the late Fall, and cause the snow and ice to melt off slightly earlier in the Spring. The darker soil would be exposed for a few more days than before the slight change in climate. Each day of additional solar exposure is an additional day the darker surface is warmed by sunlight that would have otherwise been almost totally reflected back into Space were the surface covered by the more-reflective snow and ice. That small amount of additional exposure causes additional warming, which in turn decreases the time period in which the surface is covered by snow and ice, which causes more solar heating of the surface, which in turn causes… a vicious circle, or "runaway" positive feedback. In most natural systems, other factors come into play to prevent a total collapse of the system. (Exactly what those factors are, exactly under what conditions they would come into play, and exactly what effect those

factors under those conditions would have on the changing system are questions of crucial importance to Humanity as our presence on the Earth becomes large enough to have a potential effect on the climate system.)

Negative feedback, on the other hand, provides a measure of system stability and control. An example of a system with negative control feedback is the thermostat and furnace system used to heat many homes. In this case, a thermometer in the thermostat monitors the temperature in the room, and turns on the furnace if the temperature falls below a certain level. The system response (the running of the furnace) changes the conditions of the system (heats the room) until the thermometer signals that a second pre-set temperature level is reached, when the furnace is turned off. The system response is always counter to the conditions the system is experiencing: too cold causes the system to add heat, too hot causes system to stop adding heat. Because the system acts to ***oppose*** any changes in system conditions, this kind of feedback is called "negative feedback."

If the controllers were supplying "positive feedback" to the system, it would (fail to) work something like this: When the room got cold enough to cause the thermostat trigger to activate, it would turn on the air conditioner instead of the furnace. The cooler the room got, the stronger the "supply more heat" signal from the thermostat, the more juice would be supplied to the A/C, the greater the cooling effect, etc. What would be the consequences of such a mis-connection if it were allowed to go on for very long? (Don't try this at home!)

Our Speaker

Dr. Waleed Abdalati is an expert on high-latitude glaciers and ice sheets, using remote sensing and field work in his studies. He obtained his Ph.D. from the University of Colorado in 1996, and then joined NASA's Goddard Spaceflight Center. He manages NASA's Cyrospheric Sciences Program, and has served as Program Scientist for NASA's ICESat mission. He received the Presidential Early Career Award for Scientists and Engineers in 1999, and the NASA Exceptional Service Medal in 2004, among many other honors.

References

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