Synchronystic rowing for speed FREE

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LETTERS

Effect of seasons on greenhouse warming

Michael Gerver cites the planet Venus as a caution about runaway greenhouse warming (PHYSICS TODAY, September 2017, page 11). Apart from Venus's being much closer to the Sun and having a very dense carbon dioxide atmosphere, another critical difference between Earth and Venus is highly relevant to our greenhouse effect but rarely mentioned: Earth has seasons; Venus does not.

The importance of seasons struck me when I was puzzling how IR radiation can escape from the tropopause into outer space.

In the troposphere, heat is transported upward by convection. First-year undergraduates are taught how to calculate the lapse rate—the temperature drop with altitude—by considering gas thermodynamics alone. But at the tropopause, the temperature ceases to fall with altitude and begins to rise again. The cause is UV heating from above.

Above the tropopause, convection is no longer a viable mechanism for vertical heat transport, and that is why the stratosphere is stratified. If heat is to escape into space from the tropopause, it is going to be by IR radiation. But there is a problem: greenhouse gases, such as CO_2, which provide the IR. The CO_2 concentration makes the mean free path quite short for a photon at the center of the molecule's IR resonance. And with the temperature now rising, the net IR flux at that frequency is actually downward.

Nevertheless, IR radiation can cross the stratosphere at frequencies with a smaller CO_2 cross section. Raymond T. Pierrehumbert alluded to that in an excellent feature article he wrote for PHYSICS TODAY (January 2011, page 33). However, the restriction to off-resonance frequencies severely limits the amount of heat that can be shed into space.

In the case of Venus, the options essentially end there. Any extra heating at the surface will cause thermal runaway until some new mode of heat shedding is activated. For Venus, it would appear that the surface is hot enough for the temperature to fall monotonically with altitude all the way up.

Earth, however, has another savior: its shadow, which in winter shields the stratosphere near the poles and thus prevents UV heating from above. The temperature continues to fall with altitude, and IR radiation, even at the center of the CO_2 resonance, can cross the stratosphere.

What is surprising is that the seasonal heat shedding receives so little attention.

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Synchronystic rowing for speed

The Quick Study about rowing (PHYSICS TODAY, June 2017, page 82) by Jean-Philippe Boucher, Romain Labbé, and Christophe Clanet was interesting, but I think the authors missed the real answer to their question. To understand why rowing in sync is faster than rowing asynchronously, consider the authors' plot of velocity versus time. As the boat speed increases, the exertion of a given force by the rowers becomes increasingly difficult and the stroke time decreases; as a result, the per-stroke momentum imparted to the boat decreases. By reducing the boat speed during most of the stroke, synchronized rowing increases the effective power output of the rowers and thus raises the average speed.

I experienced the phenomenon during my brief time with the freshman crew at MIT in 1969: The faster the boat is going, the harder it is to pull effectively on the oar and the shorter the duration of the power stroke.

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▶ **Boucher, Labbé, and Clanet reply:** Eric Firing gives an interesting comment on our Quick Study. We reported the observation, with a model robotic rowing boat, that being synchronized goes faster than being asynchronized. Our explanation of the difference was that in the synchronized configuration, the motion of the rowers with respect to the boat during the recovery stroke had a propulsive effect, but that effect was canceled out in the asynchronous case.

With further experiments on our model boat, we confirmed that effect as