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Jet stream wind power as a renewable energy resource: little power, big impacts

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Jet streams are regions of sustained high wind speeds in the upper atmosphere and are seen by some as a substantial renewable energy resource. However, jet streams are nearly geostrophic flow, that is, they result from the balance between the pressure gradient and Coriolis force in the near absence of friction. Therefore, jet stream motion is associated with very small generation rates of kinetic energy to maintain the high wind velocities, and it is this generation rate that will ultimately limit the potential use of jet streams as a renewable energy resource. Here we estimate the maximum limit of jet stream wind power by considering extraction of kinetic energy as a term in the free energy balance of kinetic energy that describes the generation, depletion, and extraction of kinetic energy. We use this balance as the basis to quantify the maximum limit of how much kinetic energy can be extracted sustainably from the jet streams of the global atmosphere as well as the potential climatic impacts of its use. We first use a simple thought experiment of geostrophic flow to demonstrate why the high wind velocities of the jet streams are not associated with a high potential for renewable energy generation. We then use an atmospheric general circulation model to estimate that the maximum sustainable extraction from jet streams of the global atmosphere is about 7.5 TW. This estimate is about 200-times less than previous estimates and is due to the fact that the common expression for instantaneous wind power $\frac{1}{2}\rho v^3$ merely characterizes the transport of kinetic energy by the flow, but not the generation rate of kinetic energy. We also find that when maximum wind power is extracted from the jet streams, it results in significant climatic impacts due to a substantial increase of heat transport across the jet streams in the upper atmosphere. This results in upper atmospheric temperature differences of $>20\,^{\circ}$C, greater atmospheric stability, substantial reduction in synoptic activity, and substantial differences in surface climate. We conclude that jet stream wind power does not have the potential to become a significant source of renewable energy.