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Why turbulence dominates the atmosphere and hydrosphere? (Alfred Wegener Medal Lecture)

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It is widely recognised that in very stable stratifications, at Richardson numbers (*Ri*) exceeding the critical value $Ri_c \sim 0.25$, turbulence inevitably decays and the flow becomes laminar. This is so, indeed, in the low-Reynolds-number (*Re*) flows, e.g., in some laboratory experiments; but this is by no means always the case. Air flows in the free atmosphere and water currents in deep ocean are almost always turbulent in spite of the strongly supercritical stratifications, with typical values of *Ri* varying in the interval $10 < Ri < 10^2$. Until recently, this paradox has remained unexplained. We demonstrate that the key mechanism of the seemingly paradoxical self-preservation of the very-high-*Re* geophysical turbulence as a loop including (i) conversion of the turbulent kinetic unto potential energy and (ii) self-control of the negative (down-gradient) turbulent heat flux through efficient generation of the positive (counter-gradient) heat transfer by the turbulent potential energy (Zilitinkevich et al., 2007, 2008, 2009, 2013). Thanks to this loop, turbulence is maintained in supercritical stratifications and, moreover, at $Ri > Ri_c$ the familiar "strong-mixing turbulence" regime, typical of boundary-layer flows and characterised by the practically invariable turbulent Prandtl number $Pr_T \sim 1$ (the so-called "Reynolds analogy"), gives way to a previously unknown "wave-like turbulence" regime, wherein Pr_T sharply increases with increasing *Ri* (rather than to the laminar regime as is often the case in lab experiments). It is precisely the wave-like turbulence that dominates the free flows in the atmosphere and ocean. Modellers have long been aware that the turbulent heat transfer in the free atmosphere/ocean is much weaker than the momentum transfer. Our theory gives authentic formulation for this heuristic rule and provides physically grounded method for modelling geophysical turbulence up to very stable startifications.