Geophysical Research Abstracts
Vol. 15, EGU2013-3968, 2013
EGU General Assembly 2013

Thermodynamics of a dry atmosphere at different surface exchange rates and rotation speed

Salvatore Pascale (1), Francesco Ragone (1), Valerio Lucarini (1,2), Yixiong Wang (3), and Robert Boschi (1)

(1) University of Hamburg, Meteorologisches Institut, Hamburg, Germany (salvatore.pascale@zmaw.de), (2) Department of Mathematics and Statistics, University of Reading, UK, (3) University of Oxford, Clarendon Laboratory, Parks Road, Oxford, UK

We study the combined effect of the rotation speed Ω and of the surface exchange rate – quantified by a surface turbulent relaxation timescale τ – on the dissipative properties of an Earth-like dry atmosphere. The rotation speed Ω is varied between one tenth and eight times that of the Earth $\Omega_E \approx 7.29 \cdot 10^{-5}$ rad^{-1} and τ from 45 minutes to 500 days. We study the circulation regimes induced by such parametric variations through two key dimensionless parameters, the thermal Rossby number $\mathcal{R}o$ and the frictional dimensionless number $\mathcal{F}_f$. An extensive analysis is performed by using nonequilibrium thermodynamics diagnostic tools such as material entropy production, efficiency, meridional heat transport and kinetic energy dissipation. The thermal dissipation associated with the sensible heat flux is found to depend mainly on the surface properties and to be almost independent from the rotation rate, whereas the dissipation of kinetic energy depends in a nontrivial way on both. Slowly rotating, axisymmetric circulations ($\mathcal{R}o > 1$) have the highest mechanical dissipation when the surface drag is strong ($\mathcal{F}_f \approx 10^{-3}$), but the highest efficiency for $\mathcal{F}_f \approx 10$. For $0.01 < \mathcal{R}o < 1$ the peak is reached for $\mathcal{F}_f \approx 10^3$ ($\tau \sim 3$ d), corresponding to the maximum activity of the baroclinic eddies, the maximum meridional heat transport and the highest efficiency. At high rotation rates ($\mathcal{R}o < 10^{-2}$) there is a dramatic drop in the intensity of the atmospheric energy cycle and in the meridional heat transport as the atmosphere tends towards the radiative-convective equilibrium profile. When τ is interpreted as an internal parameter, our results also confirm the vagueness of the Maximum Entropy Production Principle, since its applicability seems to be dependent on both the dissipative functions and the dynamical regime. This study suggests the effectiveness of using fundamental nonequilibrium thermodynamics to investigate the properties of planetary atmospheres.