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Helicity in dynamical processes in the atmosphere

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In modern geophysical fluid dynamics and dynamic meteorology, a notable interest is observed to the notion of helicity ("kinetic helicity" to be distinguished from "magnetic helicity" widely used in magnetohydrodynamics, astrophysics and Solar physics), which is defined by the scalar product of 3D vectors of velocity and vorticity. In this contribution, we bring together different, both known in the literature and novel formulations of the helicity balance equation, by also taking into account the effects of air compressibility and Earth rotation. Equations and relationships are presented that are valid under different approximations customarily made in the dynamic meteorology, e.g. Boussinesq approximation, quasi-static approximation, quasi-geostrophic approximation. An emphasis is placed on the helicity budget analysis in large-scale atmospheric motions. An explicit expression is presented for the rate of helicity injection from the free atmosphere into a non-linear Ekman boundary layer. This injection is shown to be exactly balanced by the helicity viscous destruction within the boundary layer. It is conjectured that this helicity injection may characterize the intensity of atmospheric circulation in extratropical latitudes of both terrestrial hemispheres. Examples are provided based on re-analyses data. Vertical distribution of helicity and superhelicity in different Ekman boundary layers is also discussed.