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Towards a consistent treatment of cloudy air in ICON

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In ICON, the equation system describing the dynamics and thermodynamics of cloudy air is based on a consistent formulation proposed by Gassmann and Herzog (2008). They formulated an equation set for the mixture of a two-component system consisting of dry air and water, where water is allowed to occur in all three phases, including precipitating hydrometeors.

Of particular importance w.r.t. the treatment of cloudy air is the choice of the atmospheric reference velocity and the definition of the air density. Following Gassmann and Herzog (2008) the barycentric velocity $\mathbf{v}_{bc} = \sum_k \rho_k \mathbf{v}_k / \sum_k \rho_k$ is chosen as prognostic variable describing the atmospheric wind and the prognostic density ρ is interpreted as the total density of the mixture. I.e. it is the sum of all partial densities ρ_k, including those of dry air and all water constituents. By doing so, the prognostic equation for ρ is free from sources or sinks and reads

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}_{bc}) = 0\,. \qquad (1)$$

However, this does not mean that the atmospheric mass is necessarily conserved. Changes of atmospheric mass by precipitation and/or evaporation are automatically accounted for via the barycentric velocity, whose vertical component is generally non-zero at the lower boundary.

In the current implementation, however, changes of atmospheric mass due to precipitation and/or evaporation are neglected by setting $w_{bc} = 0$ at the lower boundary. Consequently, also the change in surface pressure due to precipitation/evaporation is neglected, which is a questionable approximation especially in heavily precipitating systems.

We will present first steps towards a more consistent treatment of cloudy air in ICON, by allowing $w_{bc} \neq 0$ at the surface and by taking into account the diffusive fluxes of non-precipitating constituents. The impact of the improved formulation will be investigated in the framework of an idealized tropical cyclone.