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Transfer of Earth GCMs to other planets: viability of dynamical approximations

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Global Circulation Models (GCMs) reproduce the 3D evolution of planetary atmospheres, be they on Earth, Mars, Venus, or Titan. They have evolved from purely dynamical cores to far more complex codes, which may now also include microphysics, chemistry, and even plasma physics. But the dynamical core is by definition at the very heart of these models. From the complex reality to a discrete numerical description, many assumptions and hypotheses must be made.

Using our GCM model at the LMD-IPSL, we analysed the applicability of a few hypotheses broadly accepted in the dynamical modelling community. For example, taking into account the variation of the atmospheric heat capacity Cp with temperature (usually assumed to be constant although it varies by 38% between 0 and 100 km of altitude) can lead to significant changes in the vertical profiles of Venus.

We also focused on the "shallow atmosphere" hypothesis that induces large errors in the modelling of Titan's atmosphere. The Earth's mesopause is located 90 km above the surface, so its atmosphere is only 1.4% of the planets total radius. This justifies the term "shallow" and allows a few simplifications in the governing dynamical equations. However, Titan's 2,575 km radius is not significantly larger than the 615 km altitude of its mesopause, and hence its atmosphere must be described as "deep". This leads us to reflect from first principles on the approximations made in atmospheric modelling.