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On the use of a stratospheric level of insignificant dynamics in the tendency equation for surface pressure

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Hydrostatic tendency equations of pressure and geopotential have been used in various forms since the beginning of the 20th century. Most approaches neglect effects of precipitation. In contrast to classical mass flux divergence formulations, all forms that involve vertical integrals of temperature tendencies contain an additional term related to geopotential tendency at the upper limit of the integral. In many previous studies it has been assumed that there exists a pressure level in the stratosphere (usually 100 hPa or 50 hPa) where these tendencies become negligible. This assumption implies a direct relation between net column heating and surface pressure fall.

Here we apply this concept to a case of unusually precipitation in tropical West Africa in January that was preceded by falling surface pressures over the Sahara and Sahel over several days, which in turn allowed moist southerlies to penetrate unusually far into the continent. Special attention was paid to testing the validity of the concept of a stratospheric level of insignificant dynamics on the basis of operational analyses from the ECMWF. In sharp contrast to the assumptions made in previous work, significant tendencies are found up to 10 hPa with considerable spatial and temporal variations. These results render a general neglect of the geopotential tendency on a fixed pressure level at the upper boundary problematic and call for a more detailed investigation of the dynamical causes, a re-evaluation of some previous work, and a more careful design of future studies on this subject.

For the West African precipitation case, a version of the pressure tendency equation will be presented that takes both geopotential tendencies at the upper limit of the integral and effects of precipitation and evaporation into account. The results are also compared to an extratropical storm case.

A more technical outcome from this study with some relevance for future application is that the usage of all available vertical levels is advisable to keep errors in the calculation of the vertical integral in the tendency equation at an acceptable level.