The conceptual basis of Regional Climate Modelling and Downscaling (invited)

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The purpose of Regional Climate Models (RCMs) is to infer details of the weather statistics (i.e., climate) in a limited area conditional upon the large-scale state.

Usually, RCMs simulations are cast as a boundary problem, i.e., the large-scale state is provided along lateral boundaries, usually within a “sponge zone”. This approach is, however, mathematically and conceptually not a well-posed problem. The dynamical state of the atmosphere is simply not determined by lateral boundary conditions; in practical terms an acceptable description is nevertheless obtained if the considered area is “flushed” within a sufficiently short time, i.e., if the information provided at the boundaries is advected through the integration area before the chaotic dynamics in the interior become significant. This is the case most of the time in mid latitudes; however, episodes of a decoupling of the internal dynamics and the large-scale driving state (“divergence in phase space”) emerge intermittently also in mid latitude applications.

An alternative approach is to consider the problem of regional detail not as a boundary value problem but as a problem of combining empirical knowledge about the large-scale state with theoretical knowledge about the regional atmospheric dynamics. Thus, the problem is framed as a data assimilation problem -- but differently from the standard weather forecast approach, this time not local observational data are assimilated but analyses of the large-scale state. In this concept, the RCM is not supposed to significantly change the large-scale state, which is already known from either a GCM simulation or from global analyses, but only to add regional detail in space and time. Thus, this concept consistently implements the downscaling approach.

A method of “large-scale” forcing of a RCM is introduced. Its merits in steering the RCM model consistently with the given large-scale states, including the suppression of intermittent divergence in the phase space, are demonstrated. Examples of significant improvements of local statistics (added value) in a long term reconstruction of European marine weather are shown.