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Estimating local instabilities from data with application to irregular annulus flows

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In stable flows, transient growth of 'non-normal' modes can lead to turbulence. A pipe flow is one example that follows this route to turbulence. Also for atmospheric flows, non-normal modes might be responsible for rapidly growing patterns that are hard to predict by numerical models. Usually, non-normal modes are computed from linearized model equations. However, for some problems the proper set of equations is unknown, or unhandy for the purpose of finding non-normal modes. Therefore it is proposed to estimate non-normal modes from data alone, without using the model equations. Crucial for such an estimation is a good guess of the linear system matrix for the flow under consideration. Such a guess can be obtained following an approach by Hasselmann discussed in the context of climate analysis.

Simple test cases will be presented that demonstrate the suitability of the approach to estimate non-normal modes from data. Subsequently, the method is applied to temperature data from a differentially heated rotating annulus, a laboratory model that covers features of the large-scale atmospheric circulation. It has been suggested that the irregular behavior of the flow in the differentially heated rotating annulus might be related to transient growth of non-normal modes. The method proposed might help to gain insight into the spatial structures of local instability in the annulus flow.