Relating between the Counter-Propagating Rossby Wave and the Over-Reflection perspectives – toward a deeper understanding of shear instability

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Shear instability is a central mechanism in fluid dynamics in general, and in atmospheric dynamics in particular. Yet, a full mechanistic understanding, of the kind we have for the onset of buoyant convection, is still lacking. Some understanding has been gained using the framework of Counter–Propagating Rossby Waves (CRW), which describes the instability as an interaction between two Rossby waves which are phase locked in a reinforcing configuration. So far, this approach has only been used to explain the discrete spectrum set of solutions, including modal and non modal evolution, and has not been extended to the continuous spectrum. Hence, it can not fully explain optimal growth, which is thought to be central to cyclone growth in the atmosphere. In addition, the role of the critical surface, which is where the perturbations interact with the mean flow most strongly, is obscure.

A different approach to shear instability describes the perturbation growth as resulting from an overreflection of waves, which propagate across the shear and are then reflected back so that the reflected and overreflected waves interfere constructively to form a growing mode. The main limitation of this approach is the lack of a mechanistic understanding of the overreflection process itself, although the conditions necessary for it to happen are known. While both the overreflection and the CRW perspectives illuminate different fundamental aspects of shear instability they have not been unified into a coherent basic theory.

We propose to generalize the CRW approach to include also the continuous spectrum, using a Hamiltonian framework, and to apply this framework to understand overreflection and its role in shear instability as well as optimal growth in various physical norms. This will lead to a deeper, mechanistic understanding of shear instability and the necessary conditions for modal and non modal growth.