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Bifurcation diagram for vegetation patterns model: old ways for new insight

Lilian Vanderveken and Michel Crucifix
Earth and Life Institute, Université catholique de Louvain, Ottignies-Louvain-le-Neuve, Belgium

Spatial organization is a well-known feature of vegetation in semi-arid regions. This phenomenon appears in various parts of the world where water is the limiting factor for plants growing. Those patterns can be reproduced by using reaction-diffusion equations. Rietkerk developed a vegetation patterns model where the joint effects of a local reaction and diffusion create heterogeneous solutions.

The existence of those solutions expands the range of precipitation conditions under which vegetation can prevail. The complete region in the bifurcation diagram where such stable patterns exist is called the Busse balloon.

To our knowledge, no full investigation of the Busse balloon in Rietkerk's model is available. Here we address this gap and dissect this Busse balloon by analysing the patterned solution branches of the bifurcation diagram.

For a given domain length, those branches can be computed starting from the different zero modes at the edge of the Turing zone around the branch of homogeneous solutions. Then, we use a Newton-Raphson method to track each branch for precipitation changes. Two types of branches appear. What we call the main branches have a roughly constant wavenumber along the branch. What we call the "mixed state branches" originate at the transition between stability and instability along one main branch. The corresponding solutions appear as mixing the solutions of two main branches, which is why we call them that way. However, we show that the latter plays a minor role in the dynamics of the system.

The awareness of the various patterned branch sheds new light on the dynamics of wavenumber switching or R-tipping for patterned systems. More generally, this work gives new insights into the behaviour of patterned systems under changing environment.