Instability and abrupt changes in marine ice sheet behaviour

The West Antarctic ice sheet (WAIS), whose bedrock is to a large extent below sea level, has been identified as a tipping element in Earth's climate system because it could dramatically retreat and cause important sea-level rise. Different mechanisms underlying instabilities of such marine ice sheets have been proposed in the literature, but the risk that these mechanisms could trigger an accelerated retreat of the WAIS is still an open question.

In this work, which results from the literature study that I carried out during this ongoing first year of my PhD, I will review two main mechanisms that can cause marine ice sheet instability. The first mechanism is the marine ice sheet instability explained by Weertman who hypothesizes that marine ice sheets grounded on bedrocks which deepen inland can be inherently unstable. I will focus my attention on the stability of the steady states of this nonlinear dynamical system, as well as on the critical values of the external forcing parameters responsible for abrupt changes in the system behaviour (critical transitions). I will review how geological data suggest that rapid ice sheet retreats explained by Weertman's hypothesis occurred in Antarctica during the Pleistocene and the early Holocene. The recently observed accelerated ice loss of the Pine Island and Thwaites glaciers of the WAIS could also be considered as a consequence of this instability mechanism and could lead to an important contribution to sea-level rise in the future.

The second mechanism that I will review is the binge-purge oscillation mechanism which could have caused the disintegration of the Laurentide ice sheet during the last glacial period. These oscillations could also explain future behaviour of the WAIS. Binge-purge oscillations are short periods of enhanced ice flow (purge phase) followed by periods of much slower flow (binge phase). These oscillations are usually explained by a thermal-gravitational instability which takes place when basal conditions change. I will focus my attention on the mathematical and physical conditions which can trigger this instability process, as well as on examples of such oscillations in the WAIS in the past.

In the next few years in my PhD, I plan to focus my research on the quantification of uncertainties in the prediction of marine ice sheet instabilities. I am looking forward to my attendance at the summer school and the workshop allowing me to make new contacts and learn about the relevant mathematical theories and their applications.