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Dynamic equilibrium properties and regime transitions in the nocturnal boundary layer

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Numerous studies have shown that the nocturnal or stable boundary layer (SBL) tends to manifest itself in distinct regimes, namely a weakly stable and a strongly stable regime. In weak wind conditions, the shear forcing of turbulence may not be enough to sustain continuous turbulence and a transition can occur to a strongly stable boundary layer. The maximum sustainable heat flux (MSHF) framework provides a conceptual model in which the transition can be understood as a bifurcation in a simplified dynamical system. Near a bifurcation, the resilience of the system to perturbations around its equilibrium state changes and statistical indicators can be used to detect early signals of regime transitions.

We provide an experimental study of the dynamical stability (i.e. the resilience to perturbations) of the nocturnal boundary layer at different sites, based on a combination of dynamical systems techniques and statistical analyses. Near a regime transition, a turbulent observable is expected to have a slow recovery time to perturbations around its equilibrium state. Statistically, this translate into long memory effects in auto-regressive moving-average (ARMA) models. Our statistical indicator is based on ARMA processes and measures deviations from the behaviour expected by a turbulent observable near an equilibrium state, so as to detect nearing regime transitions. We use this indicator to calculate the temporal evolution of the dynamical stability of the near surface temperature inversion before and after sunset. We investigate the importance of ambient wind speed on the dynamic stability properties of the temperature inversion during the early development of the SBL, as well as when it is fully developed.