



## **Secondary circulations above a solitary forest surrounded by semi-arid shrubland**

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The dynamics of the heterogeneous atmospheric boundary layer are complex and still not fully understood. In particular, it is not known to what extent surface heterogeneities can induce secondary circulations. For this purpose, Doppler lidar and eddy-covariance measurements and large-eddy simulations were conducted at the Yatir forest in Israel, a pine forest that is surrounded by semi arid shrubland, in August and September 2013. Due to the low albedo of the forest and the increased turbulence intensity, the surface buoyancy flux was 220-290 W m<sup>-2</sup> higher at the forest site than in the surrounding desert during the measurement campaign. Moreover, the forest is about 6 x 10 km large which should be sufficient for affecting the whole atmospheric boundary layer. However, the large-eddy simulation suggested that under ambient background wind ( $\approx 6$  m s<sup>-1</sup>), the forest induces only a weak secondary circulation which should appear downwind of the forest. Nevertheless, persistent updrafts above the forest were detected with the Doppler lidar on 5 of the 16 measurement days. Such a circulation might have an impact on the validity of eddy-covariance fluxes, because its flux contribution cannot be reliably captured with a point measurement. We found that the energy balance closure was 80% at the desert site, but it was closed at the forest site, because the large eddies were broken up into smaller eddies there and those are captured by the eddy-covariance system.