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Automatic remote sensing detection of the convective boundary layer structure over flat and complex terrain using the novel PathfinderTURB algorithm

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We have developed, applied and validated a novel algorithm called PathfinderTURB for the automatic and real-time detection of the vertical structure of the planetary boundary layer. The algorithm has been applied to a year of data measured by the automatic LIDAR CHM15K at two sites in Switzerland: the rural site of Payerne (MeteoSwiss station, 491 m, asl), and the alpine site of Kleine Scheidegg (KSE, 2061 m, asl). PathfinderTURB is a gradient-based layer detection algorithm, which in addition makes use of the atmospheric variability to detect the turbulent transition zone that separates two low-turbulence regions, one characterized by homogeneous mixing (convective layer) and one above characterized by free tropospheric conditions.

The PathfinderTURB retrieval of the vertical structure of the Local (5-10 km, horizontal scale) Convective Boundary Layer (LCBL) has been validated at Payerne using two established reference methods. The first reference consists of four independent human-expert manual detections of the LCBL height over the year 2014. The second reference consists of the values of LCBL height calculated using the bulk Richardson number method based on co-located radio sounding data for the same year 2014. Based on the excellent agreement with the two reference methods at Payerne, we decided to apply PathfinderTURB to the complex-terrain conditions at KSE during 2014. The LCBL height retrievals are obtained by tilting the CHM15K at an angle of 19 degrees with respect to the horizontal and aiming directly at the Sphinx Observatory (3580 m, asl) on the Jungfraujoch. This setup of the CHM15K and the processing of the data done by the PathfinderTURB allows to disentangle the long-transport from the local origin of gases and particles measured by the in-situ instrumentation at the Sphinx Observatory. The KSE measurements showed that the relation amongst the LCBL height, the aerosol layers above the LCBL top and the gas + particle concentration is all but trivial.

Retrieving the structure of the LCBL along the line of sight connecting KSE to the Sphinx Observatory allows to monitor when the LCBL top reaches the altitude of the in-situ instrumentation at the Sphinx and to relate the measured gas + particle concentration with the locally-produced aerosols. On the other hand, when the LCBL top is lower than the Sphinx altitude, the measured concentration of gas + particle at the Sphinx is either due to long transport of aerosols (>100 km) or to the residual aerosol layer reaching the Sphinx's height or to non-local (> 5 km and <100 km) CBL aerosols advected at the Sphinx's height. Except when the aerosol layer is decoupled from the LCBL underneath, for all the other cases the CHM15K sees the probed layer as a continuous (not necessarily well-mixed) aerosol layer starting at the KSE surface. The depth of this continuous layer has been retrieved by the PathfinderTURB and related with the black carbon absorption coefficient measured at Sphinx. The result of the comparison shows clearly that the depth of the layer is well correlated with the absorption coefficient measured at the Sphinx. This is an important result that allows not only to retrieve real-time CBL heights in an automatic and trustworthy way, but also to adapt the retrievals to complex-terrain and complex-atmospheric conditions with customized tilted instrument settings.