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Wind, temperature and water vapor fields over the oasis – desert ecosystem: measurements and numerical simulations

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Deserts and oases generally act as the landscape matrix and mosaic within arid and semi-arid regions. Oases and deserts are two contradictions that are independent but interact. The interactions governing momentum, heat, and water vapor exchange between the deserts and oases have important and profound significance for the stable co-existence of oasis - desert ecosystem and water resource management in arid regions, which are important topics when studying the atmosphere, ecology, and hydrology of oases. The current study utilized an integrated approach, combining high-resolution ground-measurement data and the Computational Fluid Dynamics (CFD) method using the Reynolds-averaged Navier-Stokes (RANS) equations. In order to take into account the different landuse classes observed in the oasis (i.e. crops, shelterbelts and residential areas), Airborne Laser Scanning approach was used. The approach allowing to estimate height and porosity of each classes. The roughness elements of oasis were modelled by adding extra source/sink terms as function of porosity (plant density) distribution in equations for momentum, heat and moisture. The residential areas were treated as very dense vegetation. In addition for vegetation, a leaf energy balance model was used to determine the radiative heat fluxes between the leaf surfaces and ambient air. The developed model based on k - e turbulence closure was implemented in OpenFOAM to simulate the wind, air temperature and water vapor fields of oasis - desert ecosystem. The Weather Research and Forecast model (WRF) results (wind speed/directions, air temperature and relative humidity) were used as boundary conditions to initiate the CFD simulations. Simulated results were validated against data provided by dense observation networks (17 and 4 tower measurements in a kernel oasis experimental area and surrounded desert area, respectively). The interactions between deserts and oases were clearly revealed by simulation. The CFD-simulated wind fields successfully captured the wind dynamics and clearly showed the “wind shield effect” over the highly heterogeneous land surface, wherein the existence of shorter and longer wind-speed reduction areas at the windward and leeward sides of the shelterbelts contribute to protecting farmlands and orchards from desert wind erosion. Simulations have also showed that the air temperature and water vapor fields of desert-oasis system are clearly affected by wind dynamics. In the future, some experiments to investigate the “oasis effect” and “desert effect” will be performed, which are the phenomenon of thermal inversion, and negative sensible heat flux appear over oasis, and moisture inversion and negative (downward) water vapor flux near the surface layer over the desert during the daytime and vice versa at night, respectively.