Multi-scale Evapotranspiration in Arid Land

（課程博士・様式７）（Doctoral qualification by coursework,Form 7）

学 位 論 文 要 旨

Abstract of Doctoral Thesis

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論文要旨：
Abstract：

Knowledge on ET and its coupling with environmental factors in multi scales is critical for the scales issues in ecology and hydrology research. Current study focuses on the ET in arid land in plants scale, plot scale, and regional scale, and it is supposed to be the key step to clarify the scale transfer mechanism and how climate change will affect the arid land. The main study campaign locates in the southern edge of Gurbantünggüt desert.

The investigation on plant scale transpiration of a dominate species using sap flow technologies is introduced firstly in chapter 2. Plant scale transpiration is the most fundamental part of ET process. However, investigations on transpiration in arid land species under natural conditions have not been comprehensive. I present the long-term sap flow monitoring of a dominant desert species, *Haloxylon ammodendron*, at both tree and branch scales. Firstly, sap flows at tree scale and branch scale are compared. Daily sap flow at whole tree scale showed a good relationship with atmospheric evaporation demand ($P < 0.001$), while daily sap flow at branch scale showed good relationships with the variable of transpiration rate ($P < 0.01$). Hysteresis in hourly sap flow at both scales were observed as a function of micro-meteorological variables, in which the hysteresis between sap flow and VPD was clockwise rotation, suggesting the water use of *H. ammodendron* was not just related to the stomatal behavior, but also use of stored plant water. The hysteresis between sap flow and PPFD was counter-clockwise after precipitation, but turned to be clockwise under dry conditions, which was ever clearer at whole tree scale. Different responses of sap flows at branch and whole tree scale to climate factors were identified, which strongly indicated that *H. ammodendron* has some mechanisms to reduce whole tree water use at high transpiration demand, while maintaining part of canopy under relatively high water use, which resulted in canopy scale patchiness. Then, the transpiration of *H. ammodendron* is estimated from up-scaled tree scale sap flow monitoring. The stem sap flux density averaged at 1.86 $m^3\ m^{-2}\ d^{-1}$ during the measurement period for three years, while the transpiration per day based on ground area (E_C) ranged from 0.05 to 0.27 mm d^{-1}, and averaged at 0.14 mm d^{-1}, relatively lower than other species, mostly due to its extremely arid environment. The canopy stomatal conductance averaged at 0.30 mm s^{-1}, and maintained

a constant low value under high VPD, which is essential to keep such low transpiration compared with other species. E_C showed much less variability at annual scale because of the constant balance between evaporative demand of the atmosphere and plant factors. These results contribute to a better understanding of plant transpiration in arid land response and adaptation to climatic changes at annual and seasonal scales.

Chapter 3 investigates plot scale ET, which has been widely used to provide key data sets for evaluation of ET simulation and quality investigate the controlling factors of ET under different conditions. Total ET during the growing season was estimated about 135mm, much lower than other ecosystem in the relative wet region, even lower than most of arid and semi-arid land ecosystems. λET accounts for relative small part of net radiation according our energy balance measurement, and the Bowen ration was quit large (= 2.74 on the average). Meanwhile, the Priestley-Taylor parameter was always low, and showed good linear relationship with bulk surface conductance, suggesting the strong control of water availability on the ET of this desert ecosystem. Furthermore, a Jarvis-type surface conductance model was fitted to evaluate the controlling of surface conductance by meteorological factors. The selected factors totally accounts for about 30% of the variation of ET based on the 30min data through the growing season, which also highlights the controlling of water available and growing stages on the desert ecosystem.

Chapter 4 improves one remote sensing ET algorithms, the Surface Energy Balance Algorithms for Land (SEBAL), by coupling with a new radiation module based on Moderate Resolution Imaging Spectroradiometer (MODIS) data (hereafter referred to as $SEBAL_{coup}$) , to better estimate spatial variation of region ET, which is more useful in land and water resources management. The accuracies of $SEBAL_{coup}$ for estimating available energy and sensible heat (H) were improved significantly compared with the outputs from original SEBAL which was based on empirical equations. The $SEBAL_{coup}$ modeled instantaneous λET agreed much better with observations in the arid land of Central Asia than original SEBAL, with R^2 = 0.81, Bias = -2.86 W m^{-2}, RMSE = 9.75 W m^{-2}, NRMSE = 0.13, and MAPD = 0.14. The accuracy was blurred when scaling ET to a daily or monthly scale, mainly due to the uncertainties associated with temporal upscaling methods that were applied. Sensitivity analysis, which was conducted using numerical variance-based techniques, indicated that the estimated ET is sensitive to the available energy, suggesting the importance of obtaining accurate estimates of net radiation when applying $SEBAL_{coup}$ to estimate ET. In addition, the estimated ET was also found to be sensitive to the selection of anchor pixels. This study provides a simple and reliable way to utilize MODIS products and contains sensitivity analysis for helping correctly interpret the outputs, which are both important for large scale ET estimation. The relative low ET value in desert area can be easily distinguished in the ET map, and we foresee wide applications of the coupled model in larger areas.