

Using 4-km WRF CONUS simulations to diagnose surface coupling strength

Liang Chen^{1,2}, Yanping Li¹, Fei Chen³, and Michael Barlage³

1. Global Institute for Water Security, University of Saskatchewan, Saskatoon, SK, Canada
2. Key Laboratory of Regional Climate Environment for Temperate East Asia, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China
3. National Center for Atmospheric Research, Boulder, Colorado, USA

Background and Goals

Uncertainties in representing land-atmosphere interactions can substantially influence regional climate simulations. Among these uncertainties, the surface exchange coefficient, Ch , is a critical parameter controlling the total energy transported from the land surface to the atmosphere and directly impacts the land-atmospheric coupling strength. Yet it has not been properly evaluated for regional climate models. This study assesses the representation of surface coupling strength in 4-km WRF simulations through comparing Ch values derived from WRF simulations with Ch values derived from offline Noah-MP simulations, and from data collected at 15 FluxNet sites of the Canadian Carbon Program (CPC) and AmeriFlux which represent four different eco-climate regions. Surface coupling strength in WRF are evaluated by the seasonal variations of Ch for different land-cover types in Canada. The impacts of uncertainties on Ch in coupled WRF simulations and in offline Noah-MP simulations are also evaluated.

FLUXNET sites used in this study

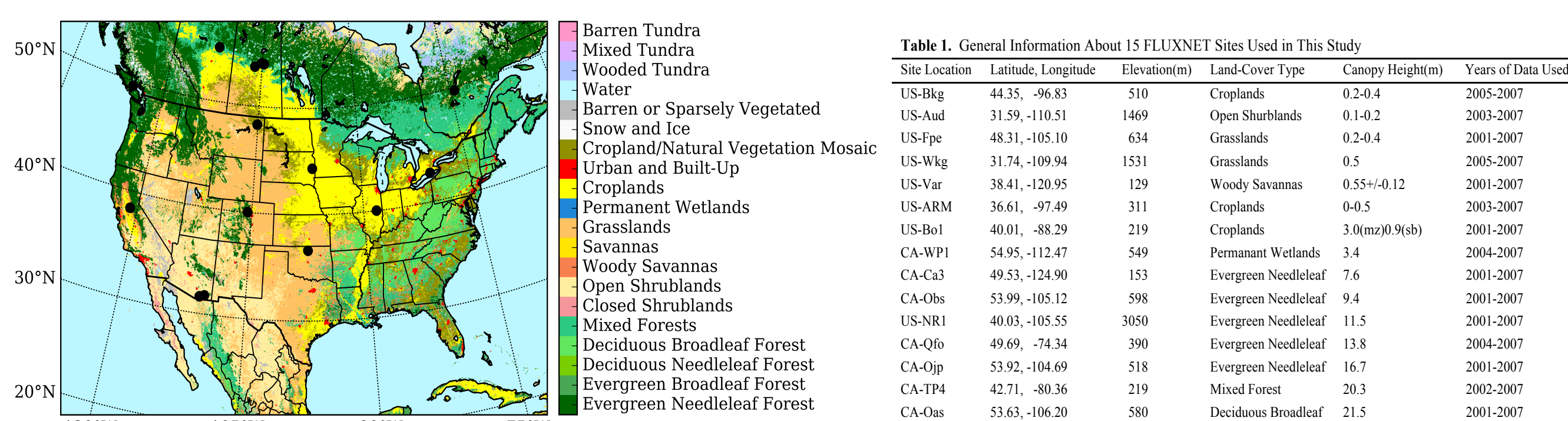


Fig. 1. Locations of 15 FLUXNET sites (in dark circles) selected for this study, with 7 sites from Canada and 8 sites from U.S.. The vegetation distribution based on the IGBP/MODIS land cover classification is shown in different colors.

Analysis Results

OBS: FLUXNET observations

Default run: Offline Noah-MP simulated surface layer drag using M-O option ($Zot=Zom$)

czil0.1: Same as Default run but using $czil=Zot/Zom=0.1$ instead

new czil: Same as Default run but using $czil=10(-0.4h)$ instead

WRF: WRF 4-km CONUS run

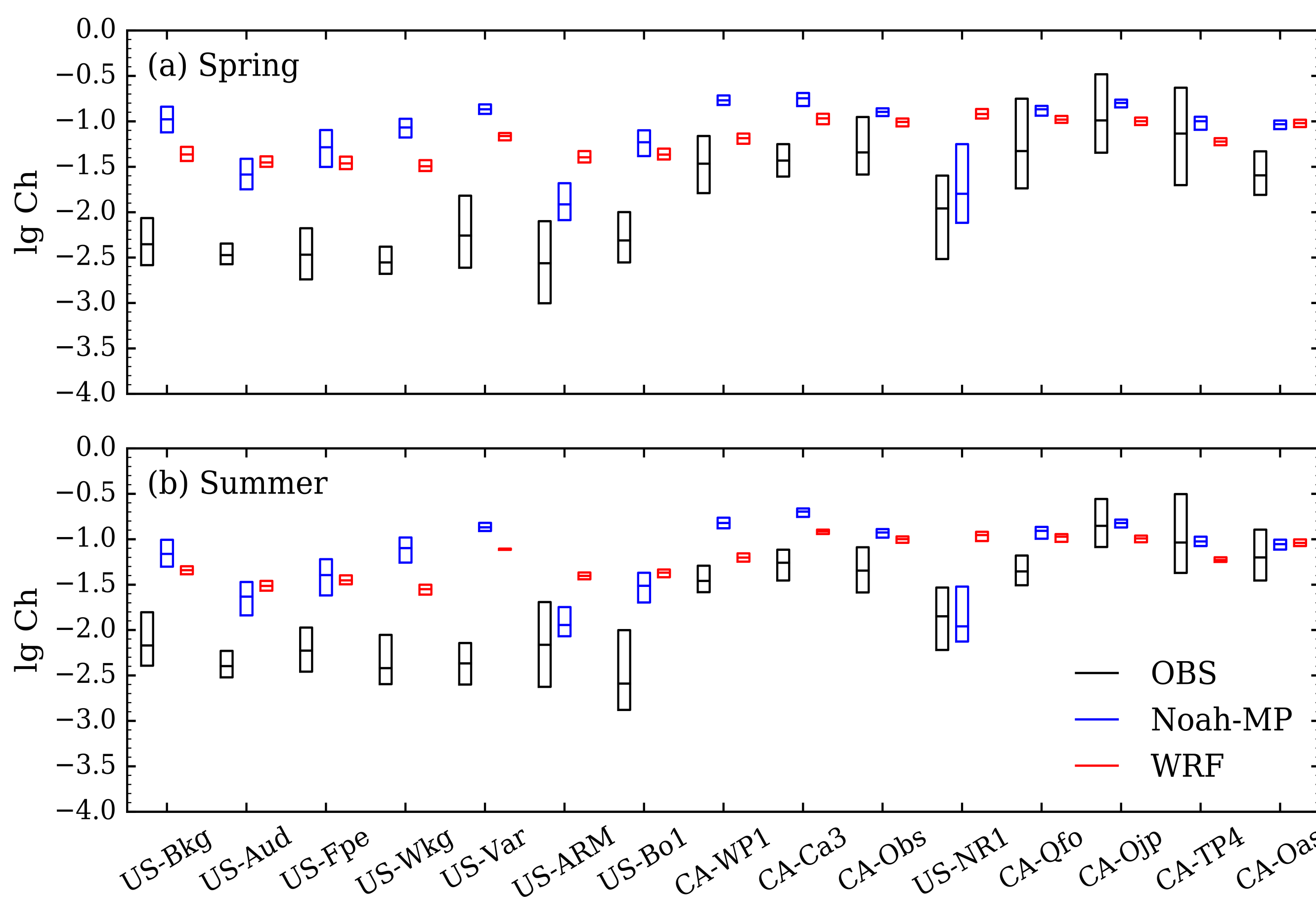


Fig. 2. Ch (plotted using log-10 scale) for different land-cover types derived from FLUXNET observations, from the offline Noah-MP LSM simulation (the Default run), and from the 4-KM WRF CONUS run. These are midday (1000–1500 LST) values averaged for spring (MAM) and summer (JJA). The median values for spring (summer) average Ch are shown in middle lines. The bars represent 75% of all midday values of Ch for spring (summer) at each site.

References:

1. Chen, L., Li, Y., Chen, F., Barr, A., Barlage, M., and Wan, B., (2016), The incorporation of an organic soil layer in the Noah-MP land surface model and its evaluation over a boreal aspen forest, *Atmos. Chem. Phys.*, 16, 8375–8387, doi:10.5194/acp-16-8375-2016.
2. Chen, F. and Zhang, Y., (2009), On the coupling strength between the land surface and the atmosphere: From viewpoint of surface exchange coefficients. *Geophysical Research Letters*, 36(10).
3. Liu, C., Ikeda, K., Rasmussen, R. et al. (2016), Continental-scale convection-permitting modeling of the current and future climate of North America, *Clim Dyn*, doi:10.1007/s00382-016-3327-9
4. Barlage, M., Chen, F., Tewari, M., Ikeda, K., Gochis, D., Dudhia, J., Rasmussen, R., Livneh, B., Ek, M. and Mitchell, K., (2010), Noah land surface model modifications to improve snowpack prediction in the Colorado Rocky Mountains. *Journal of Geophysical Research: Atmospheres*, 115(D22).

Analysis Results

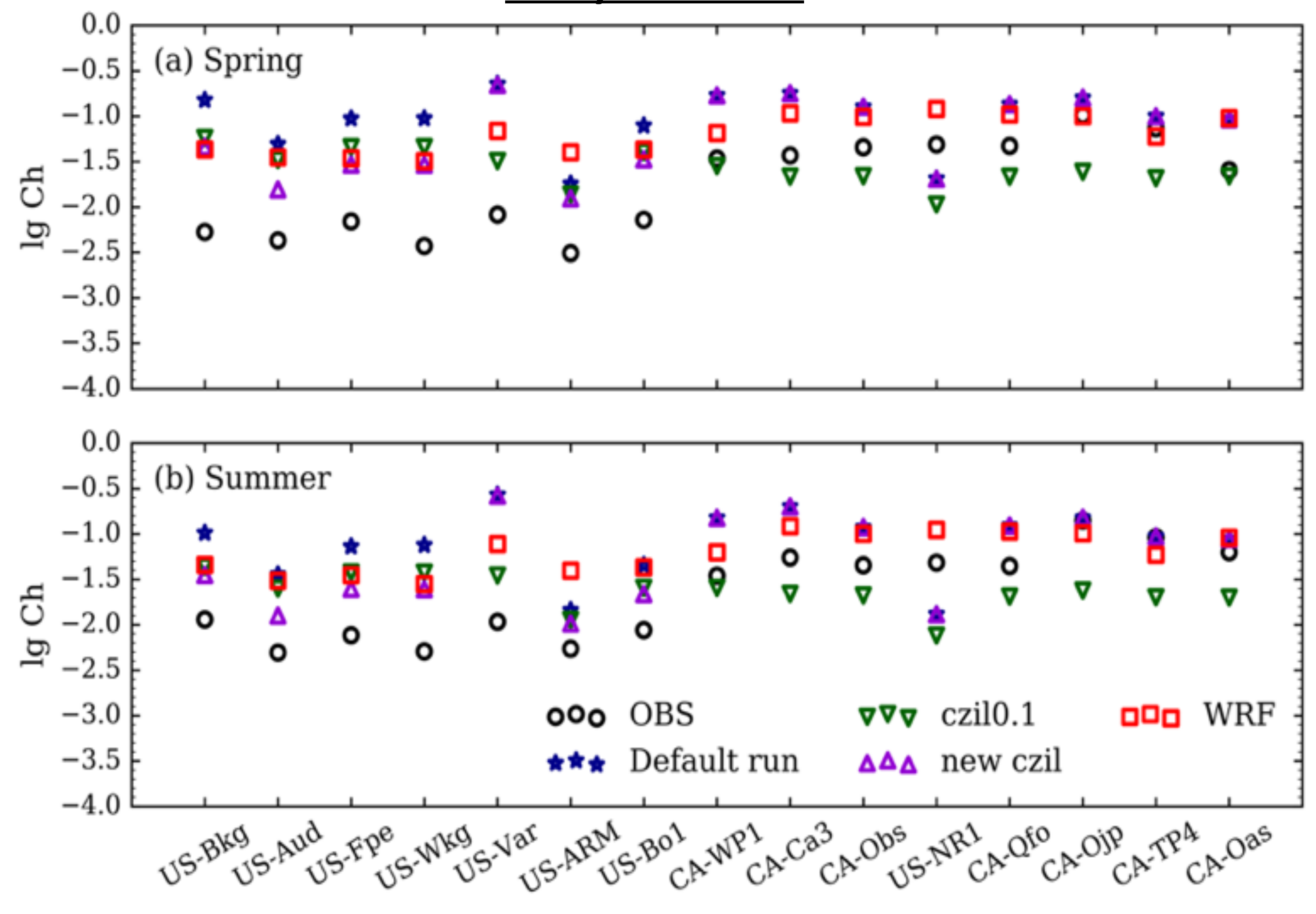


Fig. 3. Ch (plotted using log-10 scale) median values for different land-cover types derived from FLUXNET observations, from the offline Noah-MP LSM simulation (the Default run, $czil0.1$, and new $czil$), and from the 4-KM WRF CONUS run. These are midday (1000–1500 LST) values and averaged for spring (MAM) and summer (JJA).

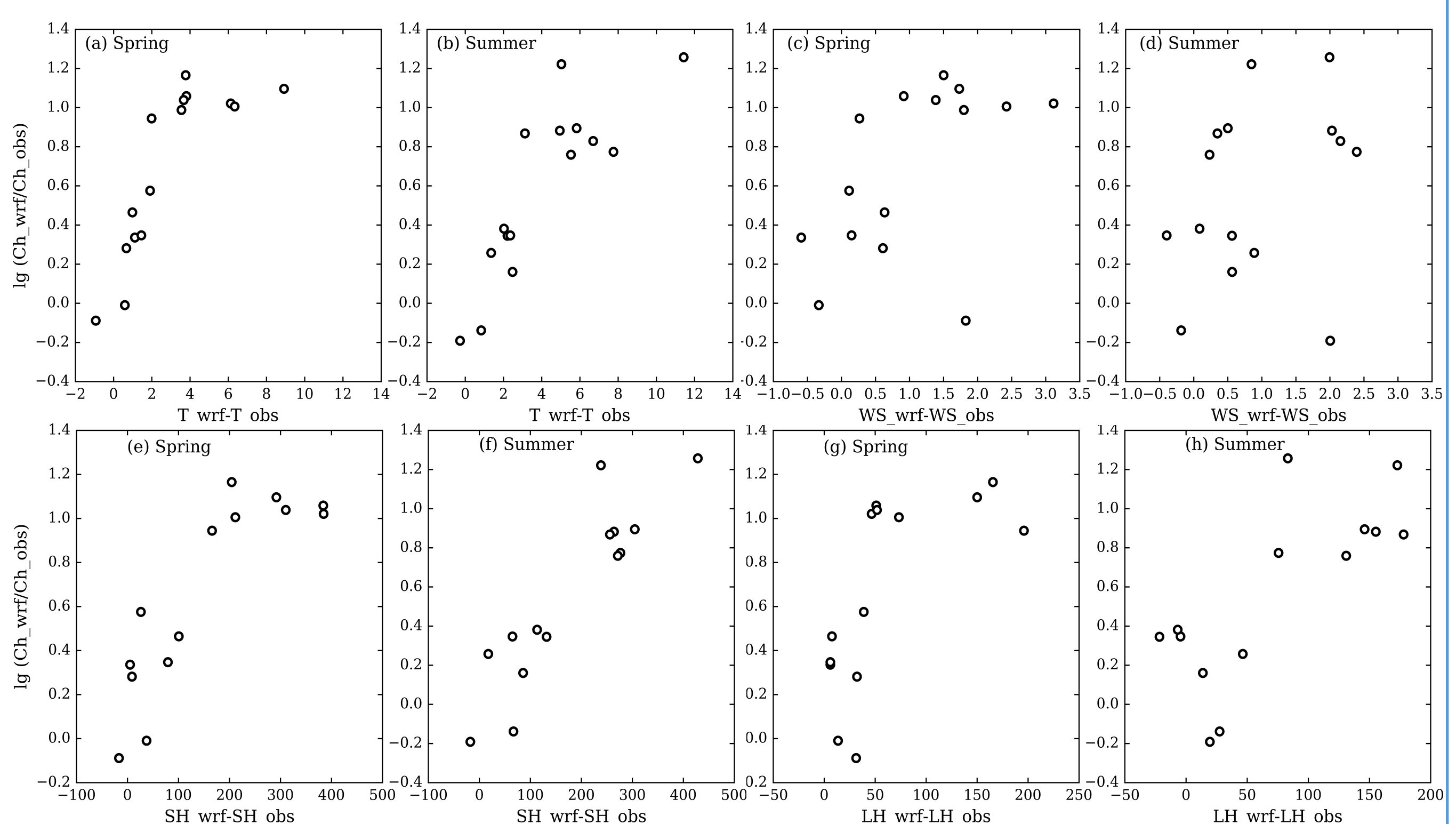


Fig. 4. Scatter plots of the biases between WRF 4-km CONUS simulations and observations for Ch ($\lg(Ch_{wrf}/Ch_{obs})$) versus Temperature ($T_{wrf}-T_{obs}$) in (a) spring and (b) summer, for Ch versus wind speed ($WS_{wrf}-WS_{obs}$) in (c) spring and (d) summer, for Ch versus sensible heat flux ($SH_{wrf}-SH_{obs}$) in (e) spring and (f) summer, for Ch versus latent heat flux ($LH_{wrf}-LH_{obs}$) in (g) spring and (h) summer. The biases between WRF-4km CONUS simulations and observations show that the biases of Ch increase with the increase of the temperature, wind speed, energy fluxes biases in low canopy height sites which have low Ch values. While the biases of Ch remain the same values as the increase of the temperature, wind speed, and energy fluxes biases in higher canopy height sites.

Concluding Remarks and Future Work

In this study, the land-atmospheric coupling strength was assessed using the offline Noah-MP and the high-resolution (4 km) coupled WRF-Noah-MP model simulation for different land-cover types and climate regimes. Multiple-year FLUXNET sites data were used to reconstitute the surface exchange coefficients Ch for spring and summer seasons. The observations have higher Ch for high canopy height vegetation than for low canopy height vegetation. Both the offline and coupled model tended to overestimate Ch for low canopy height vegetation such as grasslands, shrublands, and croplands. For the offline Noah-MP simulation, Chen's new definition of $czil$ (Chen and Zhang, 2009) was applied in M-O surface layer drag option. The results showed that both the $czil0.1$ (with $czil=0.1$) and the new $czil$ formulation improved the overestimation of Ch for low canopy height vegetation. However, for $czil=0.1$, the simulated Ch was underestimated for forests sites. While using new $czil$ formulation, the Ch results became more close to the observations. As to the biases between WRF 4-KM CONUS simulations and the observations, the Ch biases increased with the increases of the temperature, wind speed, and energy fluxes biases for low canopy height sites (low Ch values). Future work will be to evaluate the new $czil$ methods in the coupled WRF-Noah-MP model.