Improvement of land-atmosphere exchange coefficient parameterization in regional numerical simulations

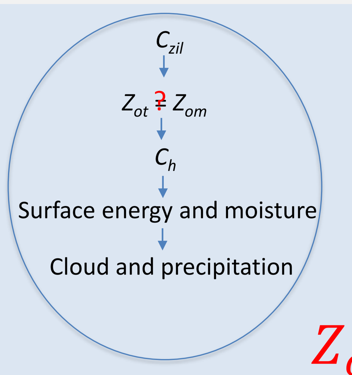
Xia Zhang[1,2,3] (xia.zhang@ntnu.no), Liang Chen[2], Zhuguo Ma[2,3]

[1]Industrial Ecology Programme, Department of Energy and Process Engineering, Norwegian University of Science and Technology (NTNU), Trondheim, Norway
[2]Key Laboratory of Regional Climate-Environment Research for Temperate East Asia, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, China
[3]University of Chinese Academy of Sciences, Beijing, China

Introduction

Land-atmosphere energy and moisture exchange can strongly influence local and regional climate changes. However, high uncertainties exist in the representation of land-atmosphere interactions in numerical models and the coupling strength between land and atmosphere is largely overestimated, in which the determination of surface exchange coefficient is one of the main problems. Here, we show the improvements from a dynamic vegetation-type-dependent exchange scheme in the offline Noah land surface model with multi-parameterization options and the Weather Research and Forecasting model when applied to China.

Land–atmosphere Coupling Method & Modeling Design



$$C_{zil} = 10^{(-0.4h)}$$

(Chen and Zhang, 2009)

$$Z_{ot} = Z_{om}\exp(-kC_{zil}\sqrt{R_e}),\ R_e = \frac{u_0^* z_{om}}{\upsilon}$$

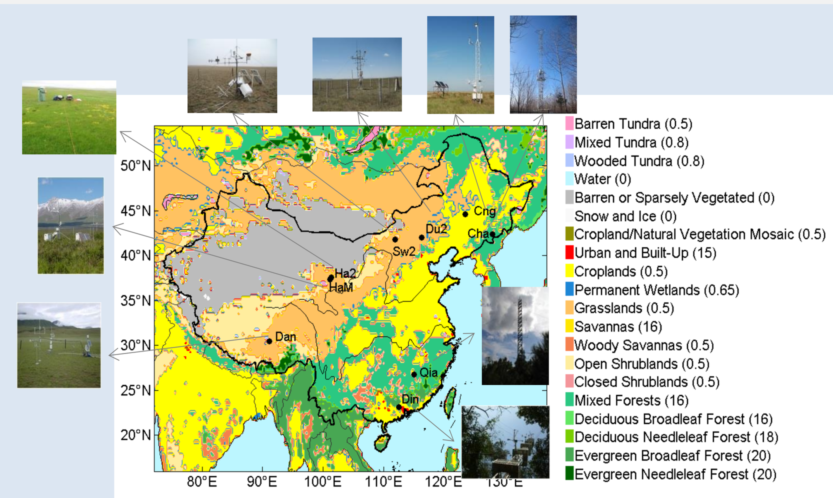
(Zilitinkevich, 1995)

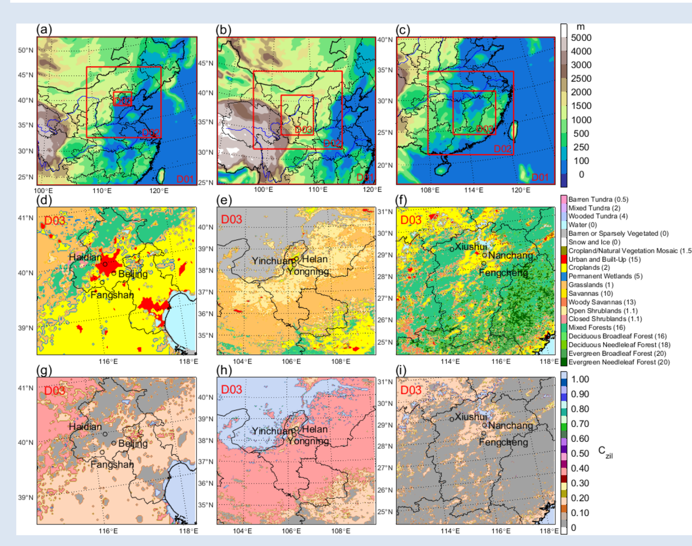
$$C_h = \frac{\kappa^2}{\left[\ln\left(\frac{z-d_0}{z_{om}}\right) - \psi_m\left(\frac{z-d_0}{L}\right)\right]\left[\ln\left(\frac{z-d_0}{z_{ot}}\right) - \psi_h\left(\frac{z-d_0}{L}\right)\right]}$$

(Brutsaert, 1982)

$$SH = \rho C_p C_h |Ua| (\theta_s - \theta_a)$$

(Garratt, 1992)





Modeling domains

Key points in new scheme:

1. Monin-Obukhov (M-O) option
2. $Z_{ot} = Z_{om} \exp(-k\, C_{zil} \sqrt{R_e})$
3. $C_{zil} = 10^{(-0.4h)}$

Three cases

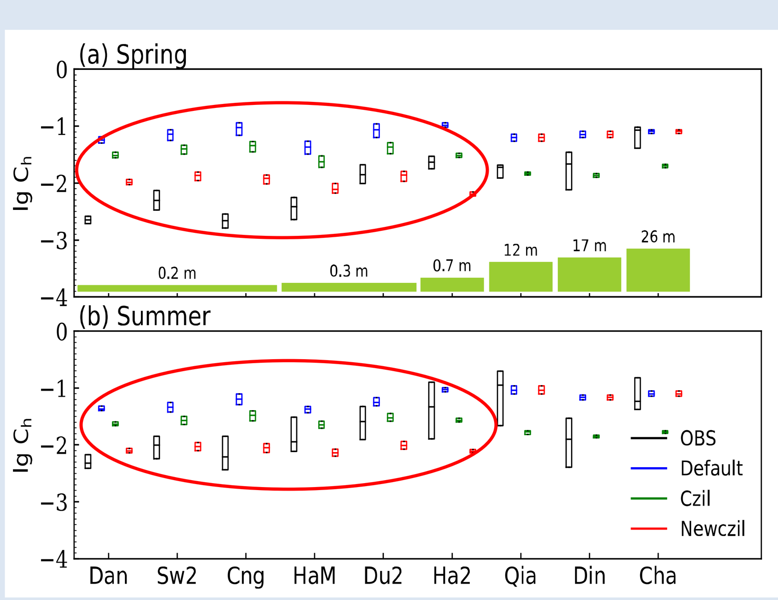
Default: default M-O option (No-C_{zil})
Constant C_{zil}: 0.01, 0.05, 0.1, 0.3, 0.5, 0.8
Newczil: $C_{zil} = 10^{(-0.4h)}$

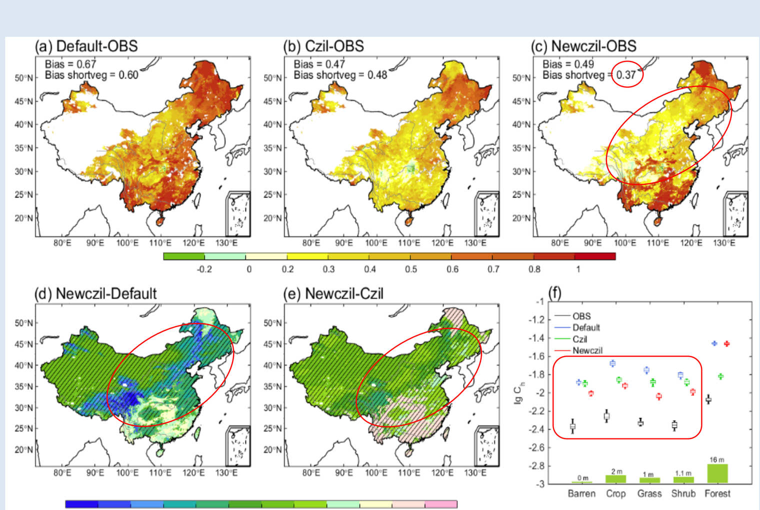
Offline Noah-MP land surface model
WRF/Noah-MP coupled atmospheric model

Climate modeling (2003-2012, 13 km, FLUXNET sites & China)
Convection-permitting modeling (3km, three rainstorms)

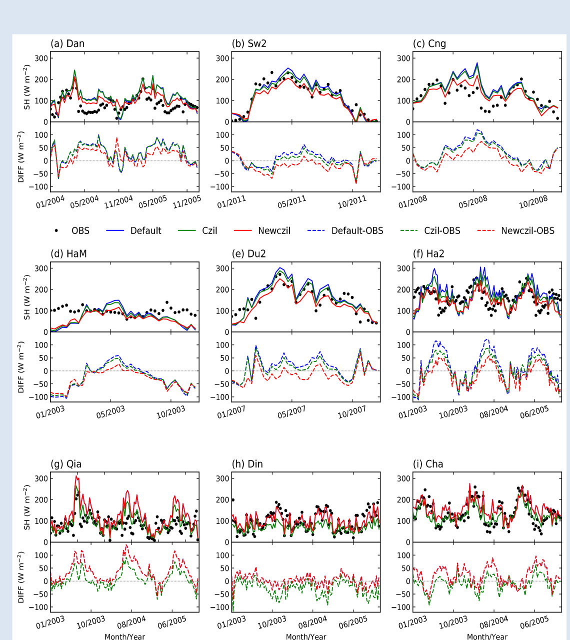
Results

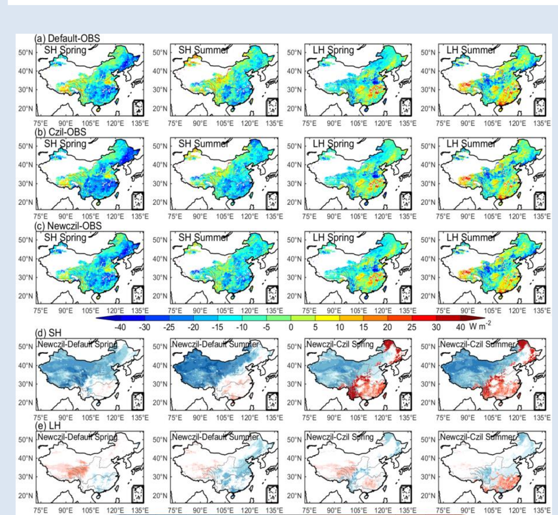
Reduced coupling strength overestimations



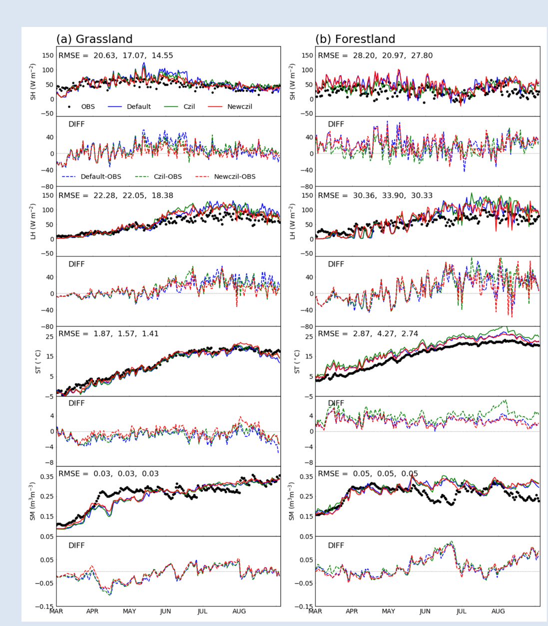


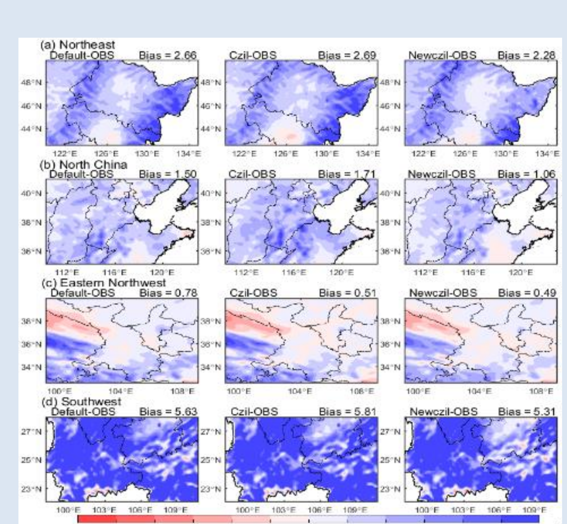
Reduced surface flux overestimations



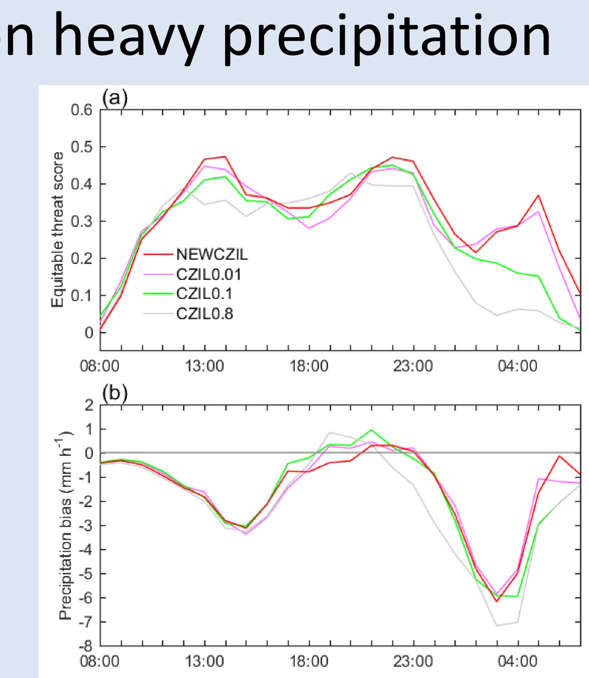


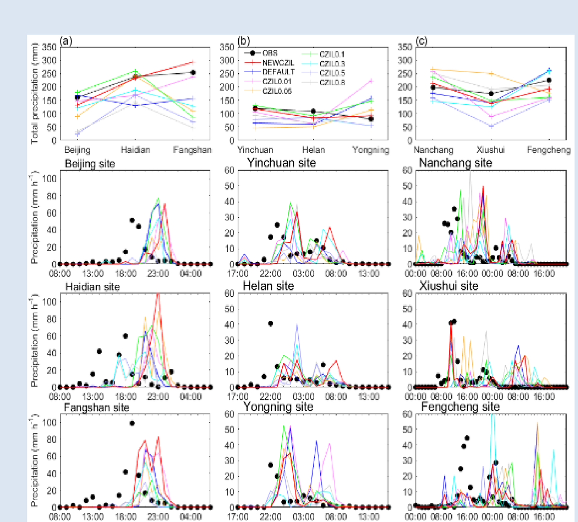
Climate simulations





Surface exchange impacts on heavy precipitation





Summary

✓A dynamic vegetation-type-dependent exchange scheme incorporated into the models brings improvements to the simulations.
✓Reduce land-atmosphere coupling strength overestimations and better reproduce observed surface energy and water variations.
✓Areas covered with short vegetation have the most remarkable improvements.
✓Better reproduce the intensity and location of the heaviest rainfall during the precipitation process.

Publications

1. Zhang, X., L. Chen, Z. Ma, and Y. Gao, 2021: Assessment of surface exchange coefficients in the Noah-MP land surface model for different land-cover types in China. *International Journal of Climatology*, 41, 2638-2659.
2. Zhang X., L. Chen, Z. Ma, J. Duan, D. Dai, and H. Zhang, 2022: Effects of surface coupling strength in WRF/Noah-MP model on regional climate simulations over China. *Climate Dynamics*.
3. Zhang X., L. Chen, Z. Ma, Z. Zheng, and Y. Meng, 2022: Sensitivity of Heavy Convective Precipitation Simulations to Changes in Land-Atmosphere Exchange Processes Over China. *JGR: Atmospheres*, 127 (22).