The Effect of Dynamic Root Water Uptake on the Land-Atmosphere Interactions of the Continental U.S.

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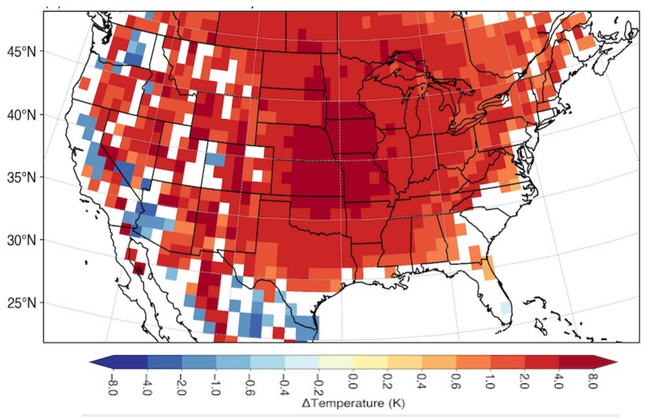
Background

- Most state-of-the-art land surface models underestimate ecosystem resiliency during drought conditions, resulting in evapotranspiration lower than observation under water stress conditions.
- Current LSMs lack an adaptation mechanism for plants to survive droughts due to prescribed, static, evenly-distributed root.
- Static root disconnects the interactions between changes in below ground water and nutrient resources and above ground plant carbon assimilation. (Niu et al. 2020)

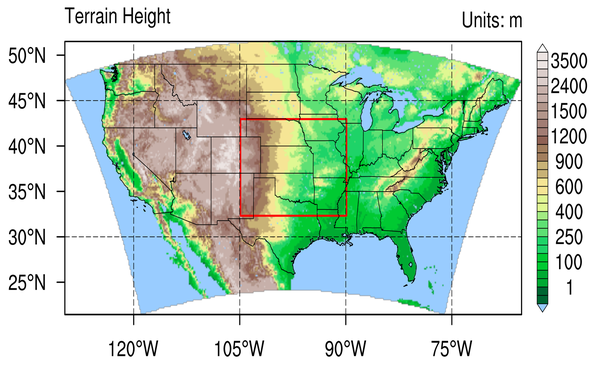
Hypothesis

- We hypothesize that the oversimplified root scheme in the model can also contribute to the warm-and-dry bias commonly seen in climate models.



CMIP5 ensemble model temperature warming bias. (Qian et al. 2020)

Experiment design



Version: WRF 4.4.1

Horizontal Grid Spacing: 4 km

Reanalysis data: NCEP FNL (Final) Operational Global Analysis data

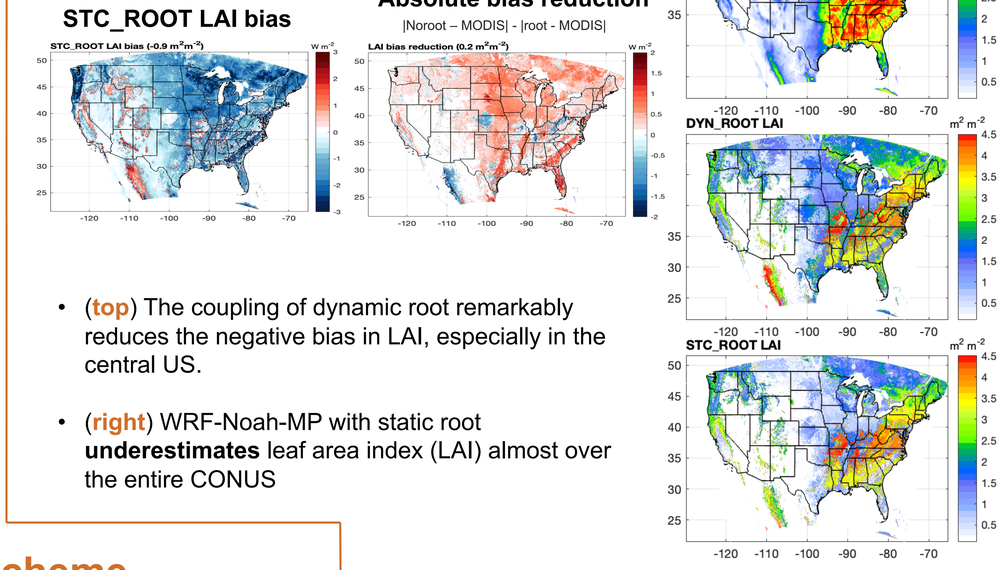
Simulation periods:

April 1 – August 31, 2012-2014

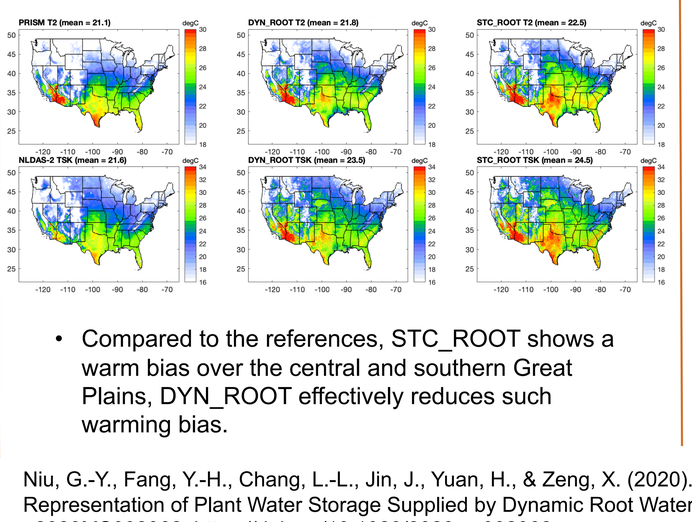
Noah-MP Land surface model:

- dynamic root (DYN_ROOT)
- static root (STC_ROOT)

Results

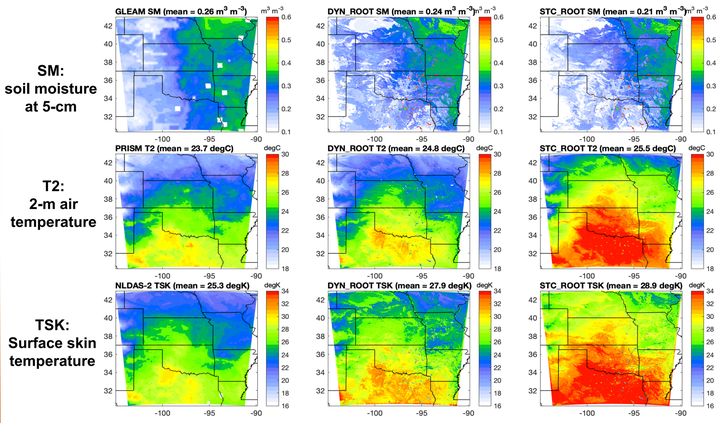


- (**top**) The coupling of dynamic root remarkably reduces the negative bias in LAI, especially in the central US.
- (**right**) WRF-Noah-MP with static root **underestimates** leaf area index (LAI) almost over the entire CONUS

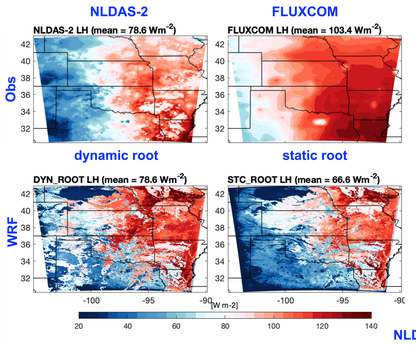


- Compared to the references, STC_ROOT shows a warm bias over the central and southern Great Plains, DYN_ROOT effectively reduces such warming bias.

Zoom-in to the central Great Plains

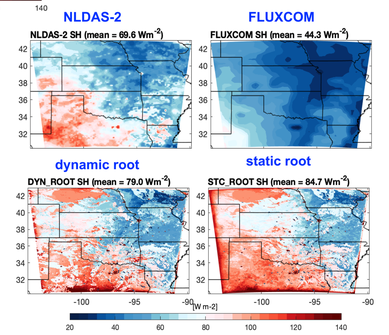


- Over the central Great Plains, the biases in surface air temperature and surface skin temperature is largely reduced by the incorporation of the dynamic root scheme.



Latent heat flux

LH mean bias is reduced by 12 W m^{-2}



Sensible heat flux

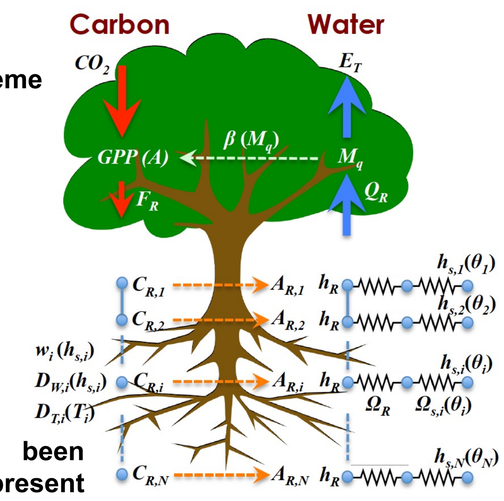
SH mean bias reduced by 5.7 W m^{-2}

Description of the dynamic root scheme

Characteristics of dynamic root scheme

- Subject to water and temperature stress
- Fraction (F_R) of *GPP* allocated to roots is greater in drought conditions
- More carbon to shallow layers and wetter layers

(Niu et al. 2020)



The dynamic root scheme has been coupled to the latest WRF4.4.1 to represent the root water uptake processes.

Conclusions

- ❖The dynamic root water uptake scheme has been successfully coupled to the latest WRF4.4.1.
- ❖At the CONUS scale, WRF-Noah-MP with static root underestimates LAI, resulting in underestimation of latent heat flux and overestimation of surface air (T2) and skin temperature (Tsk).
- ❖Compared to the static root, WRF with dynamic root performs better at simulating LAI, surface energy fluxes, soil moisture, and reduces biases in temperature over the central Great Plains.

Niu, G.-Y., Fang, Y.-H., Chang, L.-L., Jin, J., Yuan, H., & Zeng, X. (2020). Enhancing the Noah-MP Ecosystem Response to Droughts With an Explicit Representation of Plant Water Storage Supplied by Dynamic Root Water Uptake. *Journal of Advances in Modeling Earth Systems*, *12*(11), e2020MS002062. https://doi.org/10.1029/2020ms002062

Qian, Y., Yang, Z., Feng, Z., Liu, Y., Gustafson, W. I., Berg, L. K., et al. (2020). Neglecting irrigation contributes to the simulated summertime warm-and-dry bias in the central United States. *Npj Climate and Atmospheric Science*, *3*(1), 1–10. https://doi.org/10.1038/s41612-020-00135-w

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