Limitations of WRF land surface model Noah-MP for simulating land-atmosphere variables in California

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Introduction

Background

- California (CA) has experienced severe drought in the past several years. Air quality could be exacerbated during drought periods. To accurately model air pollutant concentrations, it's essential to have an accurate meteorological simulation.
- Accurately representing land use and land cover by a land surface model (LSM) is important for atmospheric simulations. Noah is a LSM that has been widely used in Weather Research and Forecast (WRF) simulations.
- Noah with multiple-parameterization (Noah-MP) is an updated version of Noah, with advanced representation of some modules, especially in snow dominated areas. Noah-MP allows users to choose among different options for each land-atmosphere process.

Objectives

- Test the applicability of the Noah LSM and the default Noah-MP within the WRF model for the 2021 severe drought in California.
- Explore how different Noah-MP configurations affect the WRF model performance and identify a model configuration that most accurately simulates the complex meteorology during severe drought.

Methods

WRF Simulations

Domain	Resolution (km)	Time	Meteorology	LSM
CA	12-4	2021.4-6	ERA5	Noah
CA	12-4	2021.4-6	ERA5	Default Noah-MP

Model Evaluation

The AMET (Atmospheric Model Evaluation Tool) was used to evaluate the WRF model performance for near-surface meteorological variables, such as 2-m temperature and 2-m water mixing ratio.

Tested Noah-MP Configurations

Parameter	Default option	Test option
dveg (Dynamic vegetation)	4, Off (LAI from table; FVEG = maximum vegetation fraction)	2, On (LAI predicted; FVEG calculated)
		5, On (LAI predicted; FVEG = maximum vegetation fraction)
		9, Off (use input LAI; use maximum vegetation fraction)
crs (Stomatal resistance)	1, Ball-Berry	2, Jarvis

LAI: Leaf Area Index; FVEG: Vegetation Fraction

Results

1. WRF with Noah performs better than with Noah-MP over the Central Valley

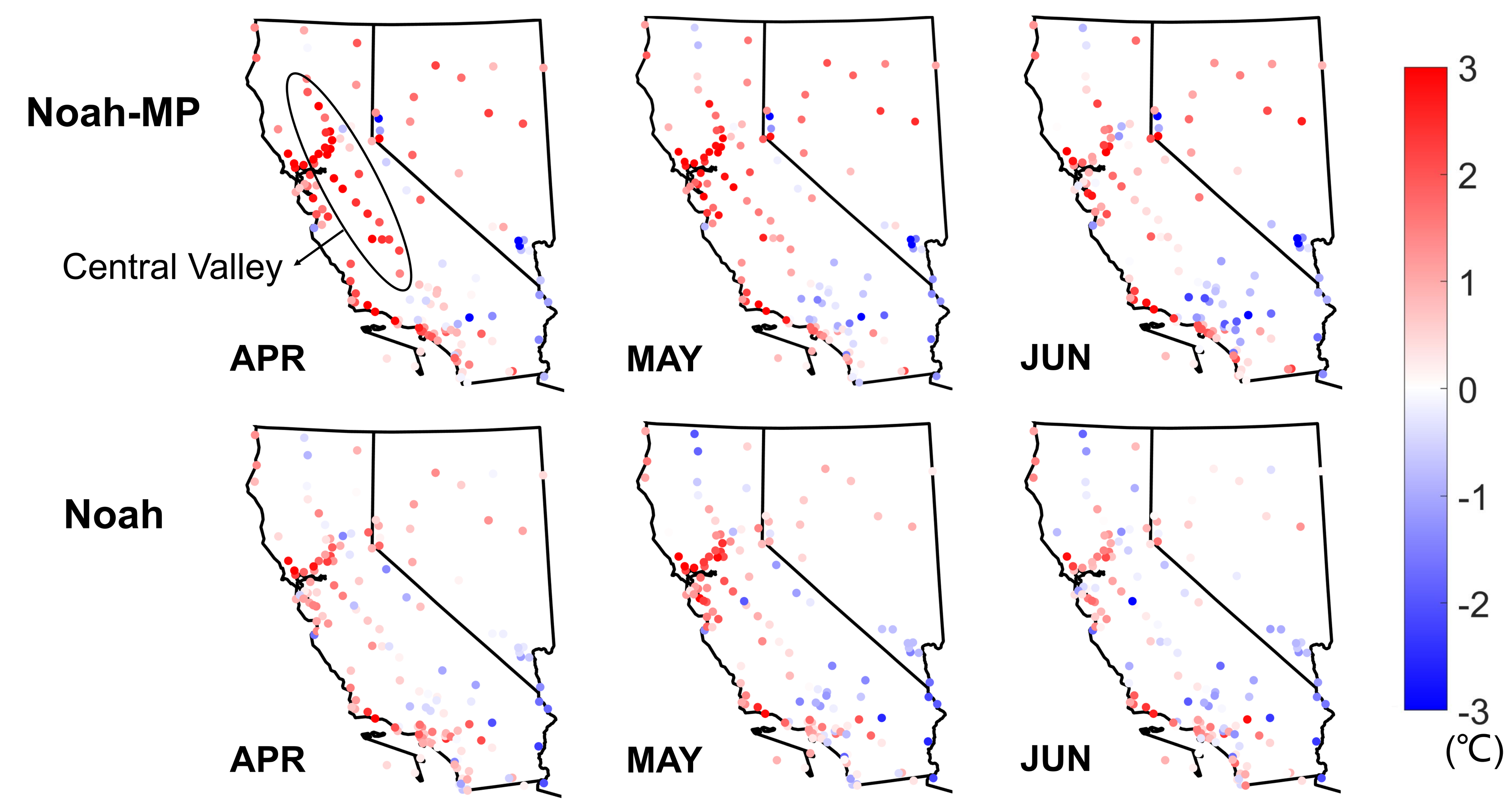

Figure 1. Mean bias of 2-m temperature (℃) in April to June in CA. With default Noah-MP, WRF overestimated the 2-m temperature by more than 1℃ over the Central Valley, San Francisco Bay, and some coastal areas. Noah performs better than Noah-MP, especially over the Central Valley. The differences between Noah and Noah-MP decrease from April to June. Both Noah-MP and Noah tend to present cooler bias over Southern CA.

2. LAI is a key factor leading to the differences in WRF performance with Noah-MP and Noah

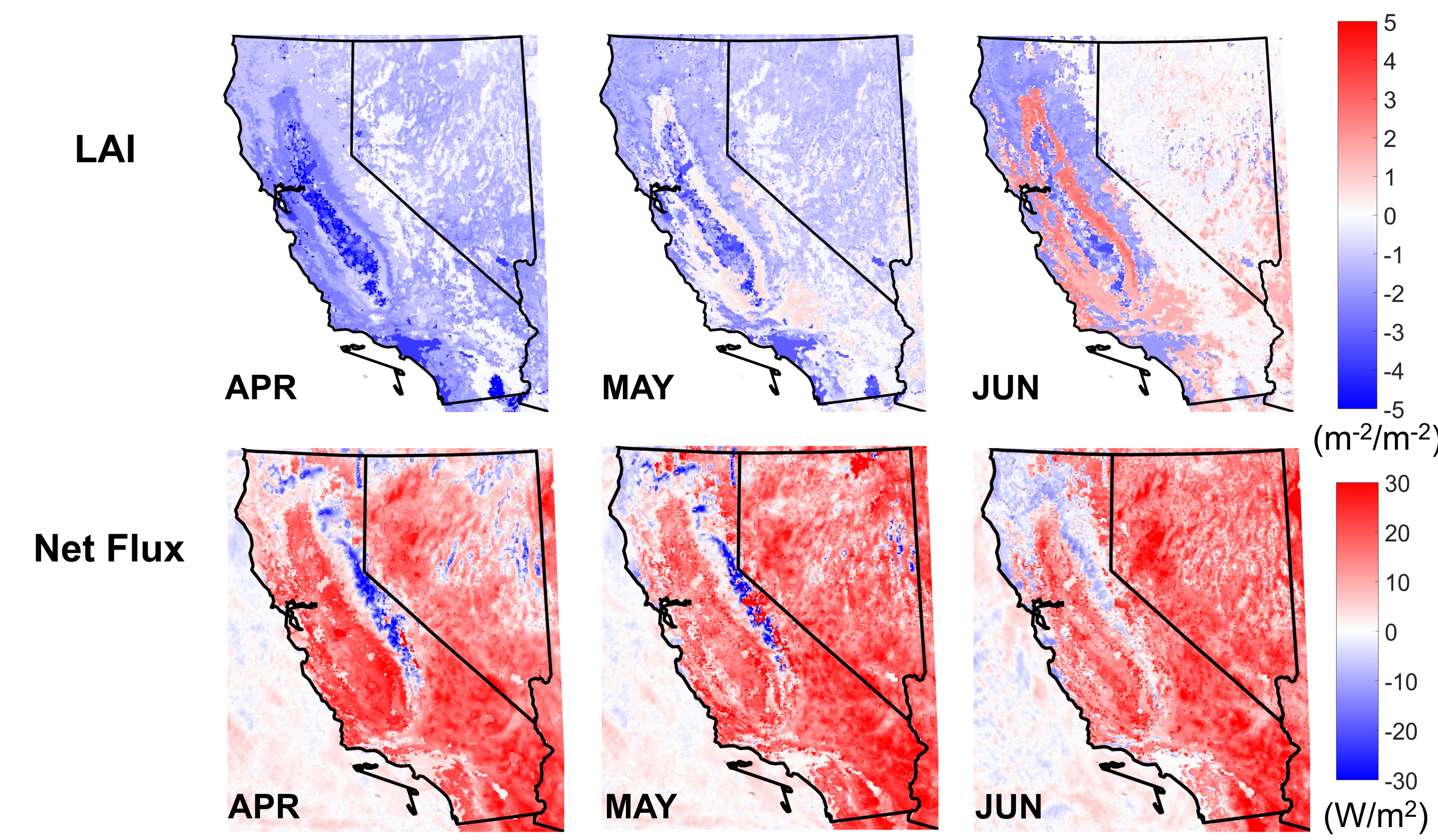

Figure 2. Differences in LAI and the net flux simulated by Noah-MP and Noah (Noah-MP minus Noah). LAI simulated by Noah-MP is lower than that simulated by Noah over the Central Valley, which is caused by an incorrect LAI profile for agricultural land. LAI differences decrease from April to June. Net flux is calculated using surface absorbed shortwave radiation minus the sum of sensible heat flux, latent heat flux and ground heat flux. The positive values represent energy flux differences tending to warm the surface; the negative values represent energy flux differences tending to cool the surface. The higher net flux simulated by Noah-MP corresponds to the warmer bias in Noah-MP than Noah.

3. WRF performance does not improve significantly with different Noah-MP configurations

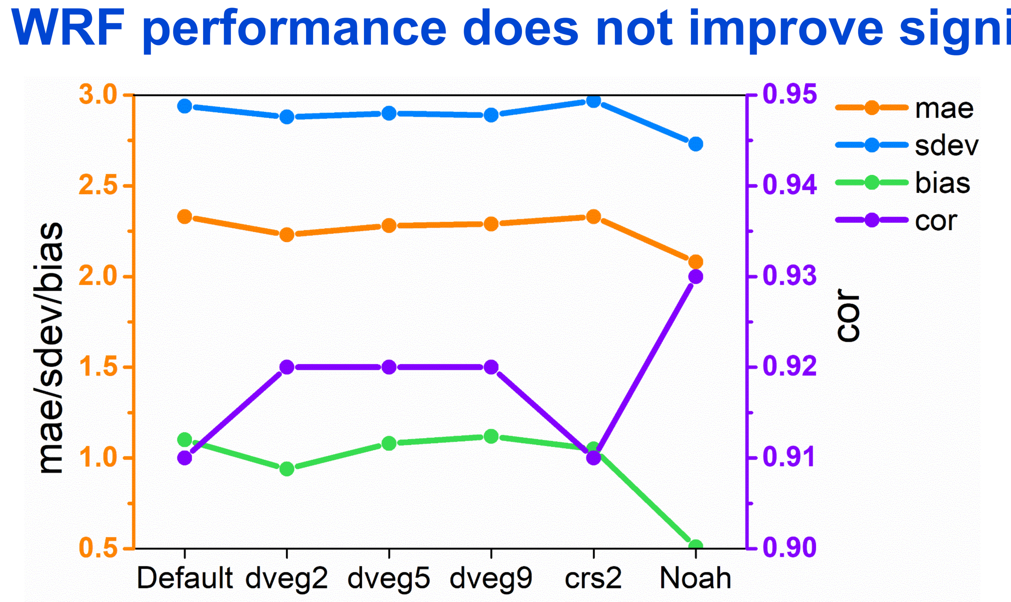

Figure 3. Performance of WRF with different Noah-MP configurations. The three dveg options tested slightly improved the WRF performance over the default Noah-MP, however, none of them performed as well as Noah. Compared to Noah-MP configurations, the bias when using Noah is decreased by nearly 50%.

(cor: correlation; mae: mean absolute error; sdev: standard deviation; bias: mean bias)

Conclusions

Summary

- With default Noah-MP, WRF overestimated the 2-m temperature by more than 1℃ over the Central Valley, San Francisco Bay, and some coastal areas.
- Noah performs better than Noah-MP, especially over the Central Valley. In this area, the Noah-MP simulated LAI is much lower due to an incorrect LAI profile for agricultural land. Both the differences in LAI and 2-m temperature between Noah and Noah-MP decrease from April to June. This suggests that a key factor to improve the Noah-MP performance over the Central Valley is to improve the LSM representation of vegetation.
- Over the most study areas, the net energy flux simulated by Noah-MP is higher than that simulated by Noah, with a warming effect on the surface.
- The tested several Noah-MP configurations didn't improve model performance beyond that of the Noah LSM simulation. This indicates that the application of Noah-MP during a drought year in California requires further development and/or additional testing before implementation, especially for air quality studies.

Future Work

- Predict air pollutant concentrations during drought and non-drought periods in CA using WRF-Chem with the Noah LSM to evaluate the effects of drought conditions on air quality.
- Continue to improve the WRF performance with Noah-MP in CA, such as improving the representation of LAI over the Central Valley, in order to take advantage of the advanced characteristics of Noah-MP, such as a more robust representation of groundwater.

Acknowledgement

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