Carbon and energy fluxes in cropland ecosystems: a model-data comparison

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Objectives:

- Croplands are highly productive ecosystems that contribute significantly to land-atmosphere exchanges of carbon, energy, and water during their short but intense growing seasons.
- Current models of land-atmosphere interactions and carbon cycling are primarily based on natural ecosystems which have complex strategies for conserving scarce resources, while crop plants are bred for maximum productivity without the need to conserve resources; therefore, current models may not adequately estimate agricultural exchanges of carbon and energy.
- This study evaluated and compared net ecosystem exchange of CO_2 (NEE), latent heat flux (LE) and sensible heat flux (H) simulated by a suite of twenty ecosystem models at five agricultural eddy covariance flux tower sites in the central United States.
- One specific objective of this study was to evaluate the overall model performance against the observed carbon and energy fluxes at selected eddy covariance flux tower sites, each of which had been previously considered under the North American Carbon Program (NACP) site synthesis.
- Another objective was to assess the model performance for individual crops and sites based on the current parameterization and capabilities of the models.
- The authors also calculated mean absolute relative error (MARE), which increases as the absolute difference between the observations and model output increases.
- An overall objective of the study was to identify potential changes needed to improve model performance.

New Science:

- Most of the models overestimated H and underestimated NEE and LE during the growing season, leading to overall higher Bowen ratios compared to the observations.
- There was no single model that could perform equally well with regard to all three fluxes analyzed and the models showed significant variability in simulating both seasonal and diurnal cycles of the different fluxes.
- There was considerable variation in the model performance with regard to the inter-annual variability of net carbon uptake which is mostly driven by crop rotation.
- Certain crop-specific models that considered the high productivity and associated physiological changes in specific crops better predicted the NEE and LE at both rain-fed and irrigated sites.
- The problems in simulating drought stress were mostly observed in rain-fed sites, especially for maize, with the majority of models showing a bias for (i.e. overestimated) drought stress at rain-fed sites.
- For maize and soybean, the estimated MARE of H during peak growth was over 1.0 for all the models as well as the overall model mean, indicating that the difference between the observed and predicted H was more than twice the magnitude of observed H during the peak growth.
- Wheat showed comparatively lower relative error during the peak growth with the majority of models having MARE of less than 0.4 for H.
- There was no difference in model performance for NEE based on model grouping according to the gross primary productivity (GPP) calculation (i.e. enzyme kinetic, stomatal conductance, light use efficiency or statistical model).
- Unlike some previous studies, the model mean did not outperform the individual models, which was especially true for sites with maize and soybean crops, which had few models with crop specificity that had better skills compared to the ensemble mean.

Significance:

- The under-prediction of NEE and LE and over-prediction of H by most of the models suggests that models developed and parameterized for natural ecosystems cannot accurately predict the physiology of highly bred and intensively managed crop ecosystems.
- The analysis in this study reveals that having crop-specific parameterization within the models could help better simulation of the inter-annual variability of fluxes under crop rotation.
- Improving the simulation of drought stress would lead to more accurate and better predictions of carbon and energy fluxes from croplands.
- The systematic tendency toward excessive drought stress exhibited by these models is also likely to lead to overestimation of air temperature and atmospheric boundary layer depth and to underestimate atmospheric humidity, clouds, and CO2 seasonal uptake over agricultural regions when such models are coupled in Earth System Models.
- More realistic models of crop performance under any given climatic and environmental conditions are needed.

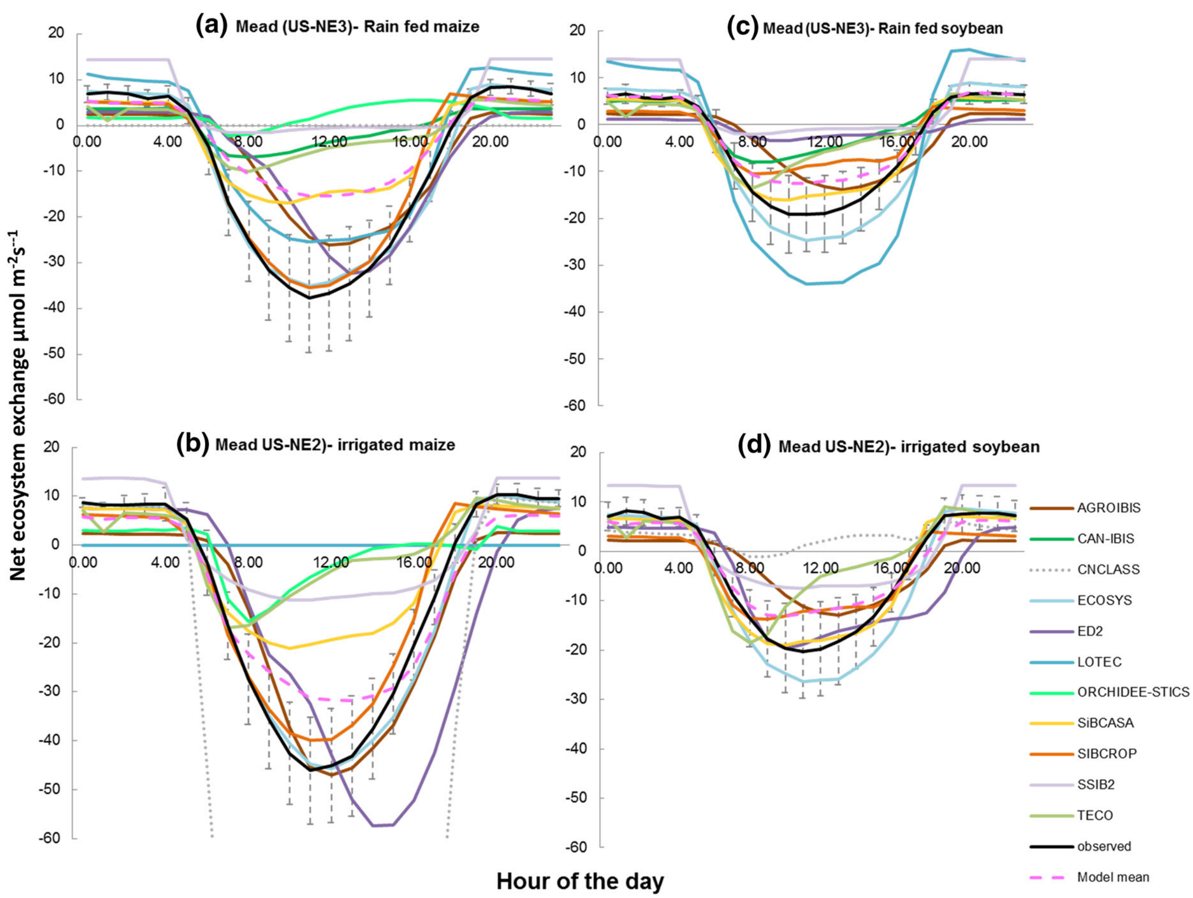

Figure 4 (page 66)
Diurnal cycles of NEE: Model performance against the site level observations at Mead rain-fed and irrigated sites during maize (left) and soybean (right) years, considering the average NEE over the growing season. The vertical error bars correspond to one standard deviation from the observed mean across the years that had observed data (i.e. 2001 and 2003 for maize and 2002 and 2004 for soybean).

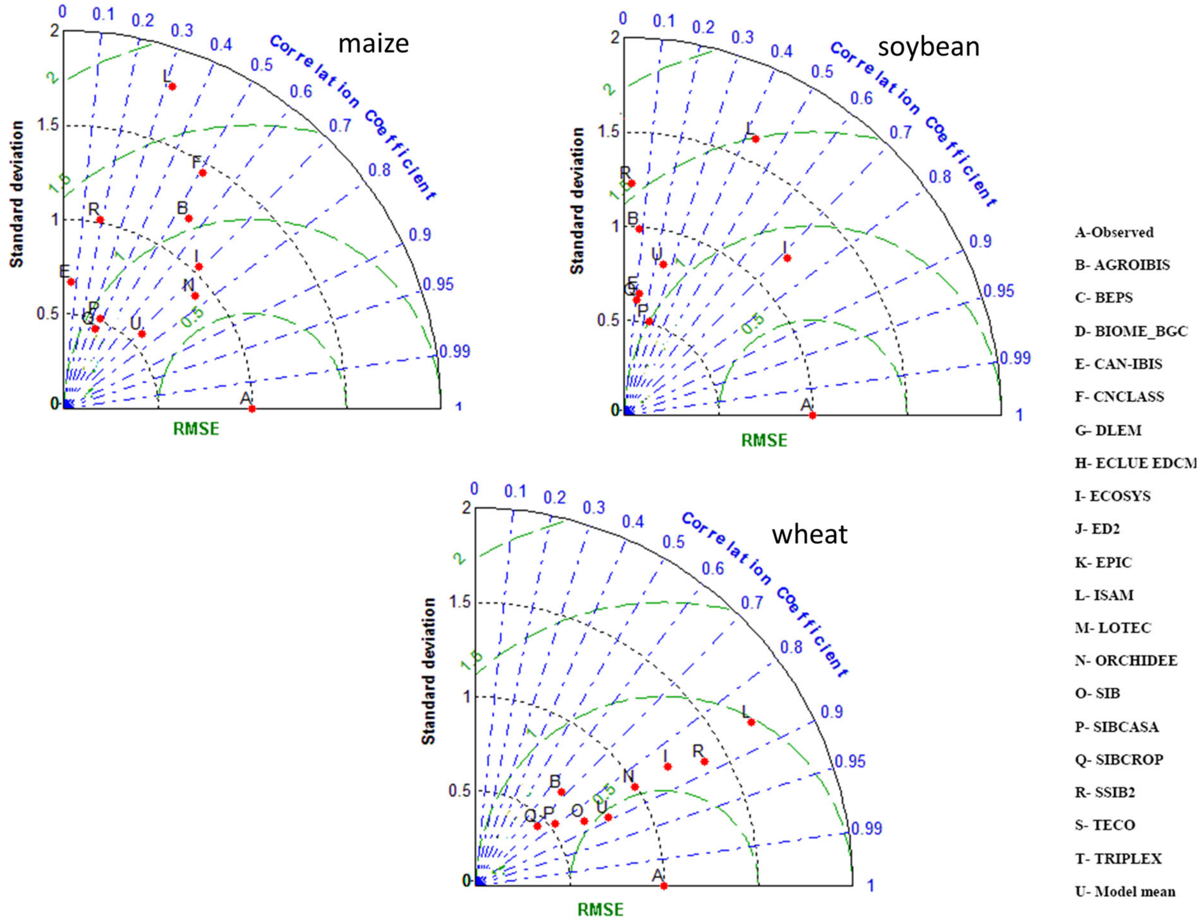

Figure 9 (page 71)
Taylor diagrams showing model performance by crop (i.e. combined sites) of sensible heat flux against the observations.