Analysis of Flux Tower Data Combined with Single Point CLM Output: Lessons Learned

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with input from:
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Community Land Model (CLM/CTSM) Tutorial 2019
7 February 2019
Niwot Ridge AmeriFlux Tower (US-NR1)
Influence of Warm-Season Precipitation on Ecosystem Fluxes at Niwot Ridge Forest, based on years 1999-2014 (Burns, et al 2018, JAMES)

- Conditional sampling (of the diel cycle)
- Use CLM to look at processes which are difficult to measure
- Systematic variation of parameters/variables within CLM (e.g., Leaf Area Index (LAI) varied; here will show LAI= 2, 4, 6, US-NR1 forest has LAI approx 4).
- If possible--return to the physical processes
Warm-Season Precipitation, Conditional Sampling

**dDry**
- dDry: Dry Day, Dry Previous Day
- N = 931

**dWet**
- dWet: Wet Day, Dry Previous Day
- N = 145

**wWet**
- wWet: Wet Day, Wet Previous Day
- N = 73

**wDry**
- wDry: Dry Day, Wet Previous Day
- N = 147

![Graphs showing diurnal variations in rainfall, H, LE, and Precip for different conditions: dDry, dWet, wWet, wDry.](image-url)
Observations Summary

* Increase in nocturnal $\lambda E$ during wet periods

* Increase in mid-day $\lambda E$ during wDry days
CLM vs Observed Fluxes (Time Series Comparison)

- **Net Radiation [W/m²]**

- **Sensible Heat Flux [W/m²]**

- **Latent Heat Flux [W/m²]**

Day of Year 2010
CLM vs Observed Fluxes (I)

- **(a)**: Comparison of observed and CLM fluxes for dry (dDry) and wet conditions (dWet, wWet, wDry).
- **(b)**: Comparison of observed and CLM fluxes for humidity (H).
- **(c)**: Comparison of observed and CLM fluxes for latent heat (LE).
- **(d)**: Comparison of observed and CLM (CLM4.5) wind speed ($u_*$).

Local Hour of Day [MST]
CLM vs Observed Fluxes (II)

- **A1_soil_texture**
  - dDry: Red line, dWet: Black line, wWet: Green line, wDry: Gray line
  - Net Radiation ($R_{net}$) [W m$^{-2}$]
  - N: 931, 145, 73, 147

- **A1_default_180104**
  - dDry: Red line, dWet: Black line, wWet: Green line, wDry: Gray line
  - Net Radiation ($R_{net}$) [W m$^{-2}$]
  - N: 1148, 177, 97, 180

- **Observations vs CLM4.5**
  - LE: Black line (Observations), Red line (CLM4.5)
  - $\lambda E$ [W m$^{-2}$]

- **Wind Speed ($u_*$)**
  - Black line (Observations), Red line (CLM4.5)
  - [m s$^{-1}$]

Local Hour of Day [MST]
Aerodynamic resistances between the ground and subcanopy air for heat $r_{ah}'$ and water vapor $r_{aw}'$, 

$$r_{ah}' = r_{aw}' = \frac{1}{C_s U_{av}}$$

$U_{av} \equiv$ wind velocity on the vegetation  

$C_s \equiv$ turbulent transfer coefficient between ground and canopy airspace ($C_s \leq 0.004$)
Sensitivity of Latent Heat Flux Components to Cs

Daytime

Nighttime

CLM4.5 Subcanopy Turbulent Transfer Coefficient

Latent Heat Flux Diff [W m\(^{-2}\)]

Latent Heat Flux Diff [W m\(^{-2}\)]

CLM Total Latent Heat Flux (LE)
CLM Transpiration
CLM Canopy Evaporation
CLM Ground Evaporation

Observed LE
Latent Heat Flux Components of CLM4.5

Y-Axis Scale: -10 to 250 W/m²

LAI = 2

(a) LAI = 2

CLM4.5, Latent Heat Flux ($\lambda E$)

CLM4.5, Canopy Transpiration ($\lambda E_v$)

CLM4.5, Canopy Evaporation ($\lambda E_w$)

CLM4.5, Ground Evaporation ($\lambda E_g$)

(b) LAI = 4

at US-NR1, LAI = 4

CLM4.5, Latent Heat Flux ($\lambda E$)

CLM4.5, Canopy Transpiration ($\lambda E_v$)

CLM4.5, Canopy Evaporation ($\lambda E_w$)

CLM4.5, Ground Evaporation ($\lambda E_g$)

(c) LAI = 6

CLM4.5, Latent Heat Flux ($\lambda E$)

CLM4.5, Canopy Transpiration ($\lambda E_v$)

CLM4.5, Canopy Evaporation ($\lambda E_w$)

CLM4.5, Ground Evaporation ($\lambda E_g$)
2.6. Evaporation of a “wet” forest

CLM Maximum Leaf Wetted Fraction

Moors, E. J. (2012)

Figure 2.4: Picture on the left shows a thin layer of water covering the entire surface of the leaves during a light shower. Picture in the middle shows droplets of rain distributed on the leaf surface. Picture on the right shows needle leaves with droplets at their tips.

CLM Default Value = 1
(water covers entire leaf)
Latent Heat Flux Components of CLM4.5

(a) CLM4.5 B0 (LAI=4, $f_{\text{max}}^{\text{wet}} = 0.02$)

CLM4.5, Latent Heat Flux ($\lambda E$)

CLM4.5, Canopy Transpiration ($\lambda E_v$)

CLM4.5, Canopy Evaporation ($\lambda E_w$)

CLM4.5, Ground Evaporation ($\lambda E_g$)

(b) LAI= 4

CLM4.5, Latent Heat Flux ($\lambda E$)

CLM4.5, Canopy Transpiration ($\lambda E_v$)

CLM4.5, Canopy Evaporation ($\lambda E_w$)

CLM4.5, Ground Evaporation ($\lambda E_g$)

Relative Time [Days]

-10 to 250 W/m²

-5 to 85 W/m²

at US-NR1, LAI = 4
COMMENTS/QUESTIONS?

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A Comparison of the Diel Cycle of Modeled and Measured Latent Heat Flux During the Warm Season in a Colorado Subalpine Forest

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Abstract Precipitation changes the physiological characteristics of an ecosystem. Because land-surface models are often used to project changes in the hydrological cycle, modeling the effect of precipitation on the latent heat flux $\lambda E$ is an important aspect of land-surface models. Here we contrast conditionally sampled diel composites of the eddy-covariance fluxes from the Niwot Ridge Subalpine Forest AmeriFlux tower with the Community Land Model (CLM, version 4.5). With respect to measured $\lambda E$ during the warm season: for the day following above-average precipitation, $\lambda E$ was enhanced at midday by $\approx 40$ W m$^{-2}$ (relative to dry conditions), and nocturnal $\lambda E$ increased from $\approx 10$ W m$^{-2}$ in dry conditions to over 20 W m$^{-2}$ in wet
Sensitivity of Latent Heat Flux Components to Cs

Daytime

Nighttime

Latent Heat Fluxes [W m\(^{-2}\)]

dDry Conditions

Latent Heat Fluxes [W m\(^{-2}\)]

wDry – dDry

CLM4.5 Subcanopy Turbulent Transfer Coefficient

(a1)

(a2)

(b1)

(b2)