Roughness Sublayer Turbulence in the Community Land Model

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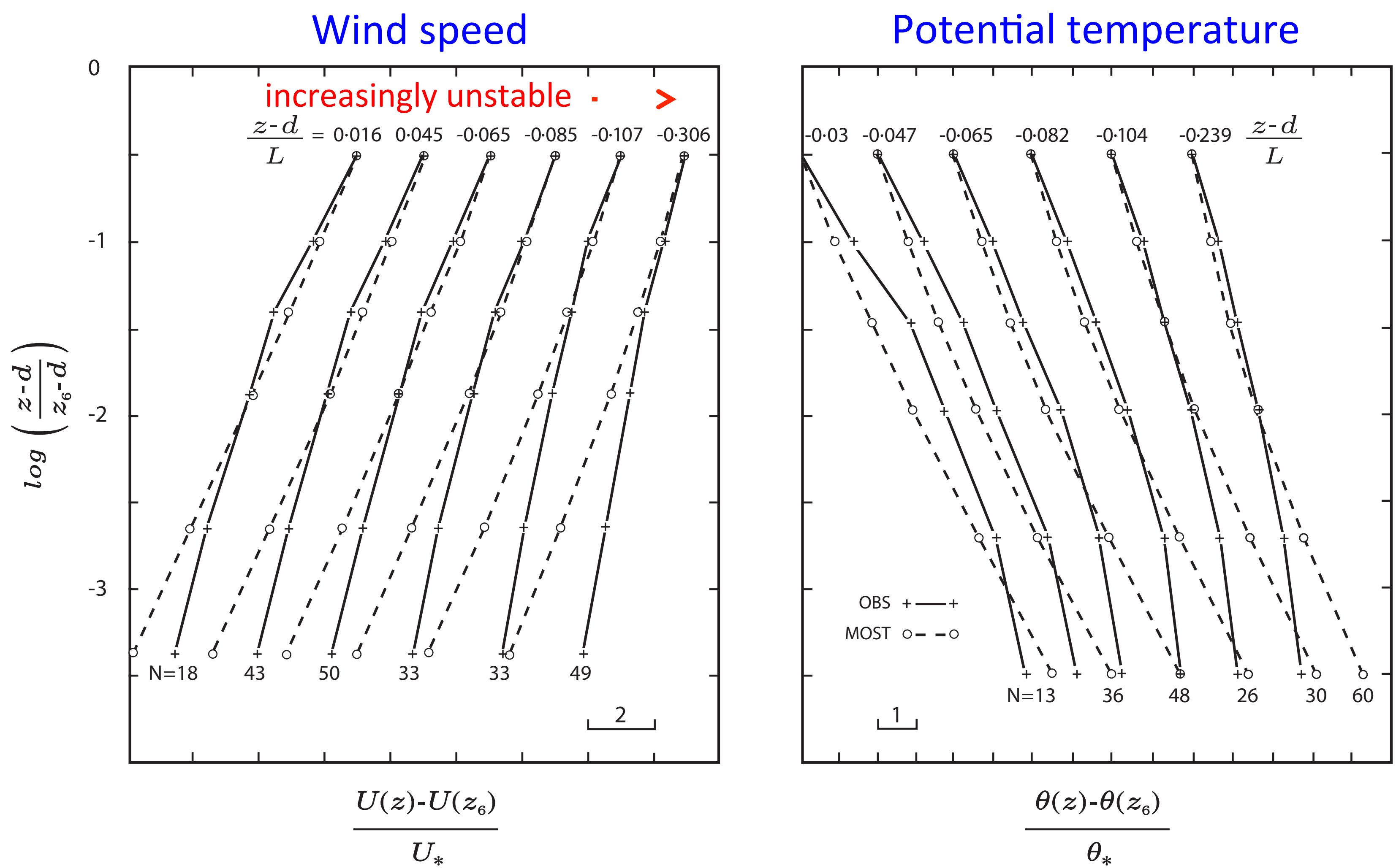
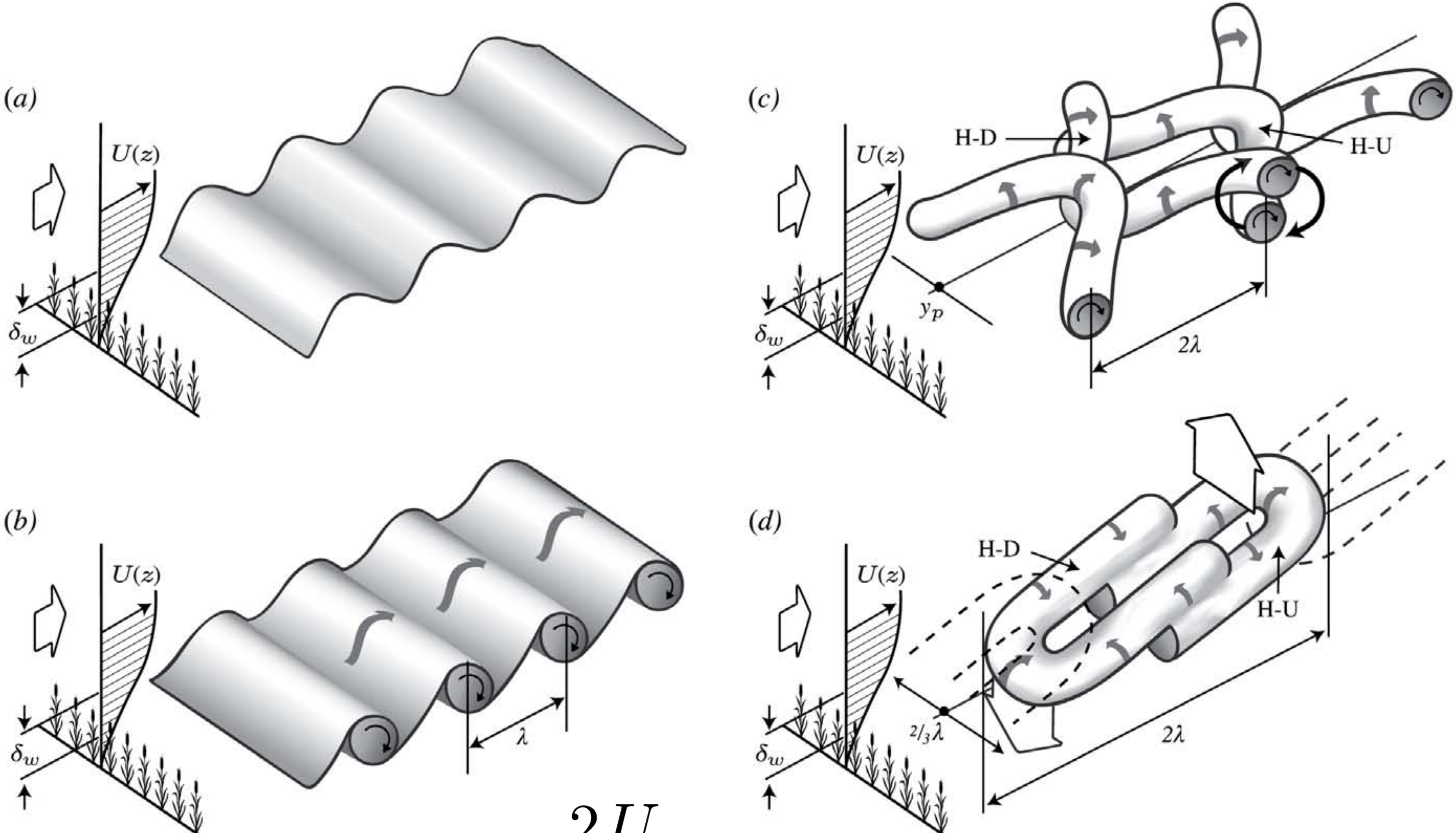
Canopy turbulence and the roughness sublayer



Flow within 2-3 canopy heights above/within tall (plant) canopies does not conform to Monin-Obukhov Similarity Theory (M-O); this region is called the roughness sublayer (RSL).

Raupach (1976), Chen and Schwerdtfeger (1989)

Theory for canopy-structure formation



$$\delta_\omega \approx \frac{2\,U}{\frac{\partial U}{\partial z}}(h)$$

Finnigan, Shaw and Patton (2009)

Simple roughness sublayer theory

- Extensive use of scaling arguments & 1st order turbulence closures

- Within canopy:
  - Mass / momentum balance for horizontally homogeneous canopy
  - Canopy characterised by adjustment length, L_c (Stanton number rc)

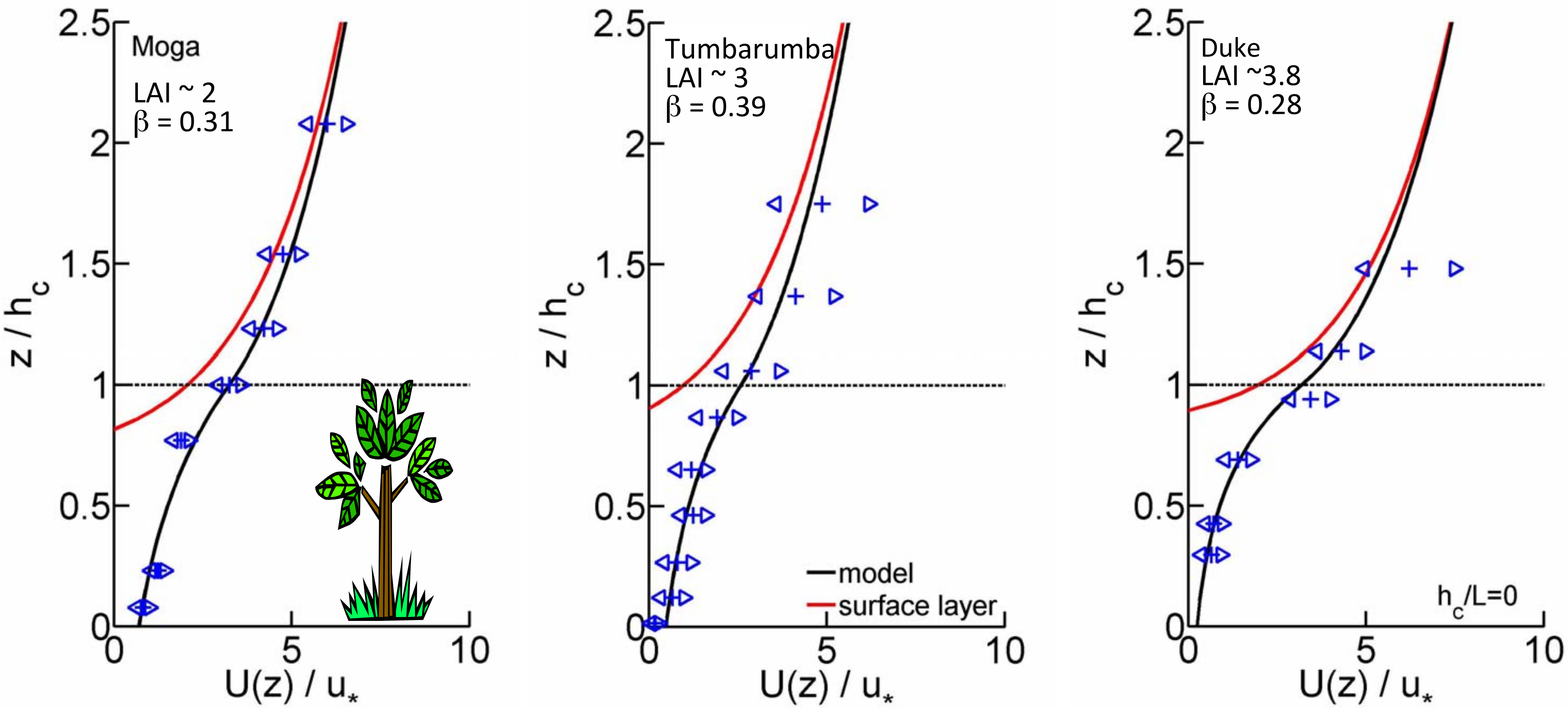
- Above Canopy:
  - Displacement height: Height of mean canopy drag momentum absorption
  - Modified M-O
  - Modification introduces an additional length scale – vorticity thickness from instability process (δ_ω)

- Couple two together
  - requires an observable value for $\beta = u_*(h) / U(h)$
  - remaining parameters in both profiles fixed by matching canopy-top means and fluxes

➢ roughness lengths and displacement height are functions of the flow

Harman and Finnigan (2007, 2008)

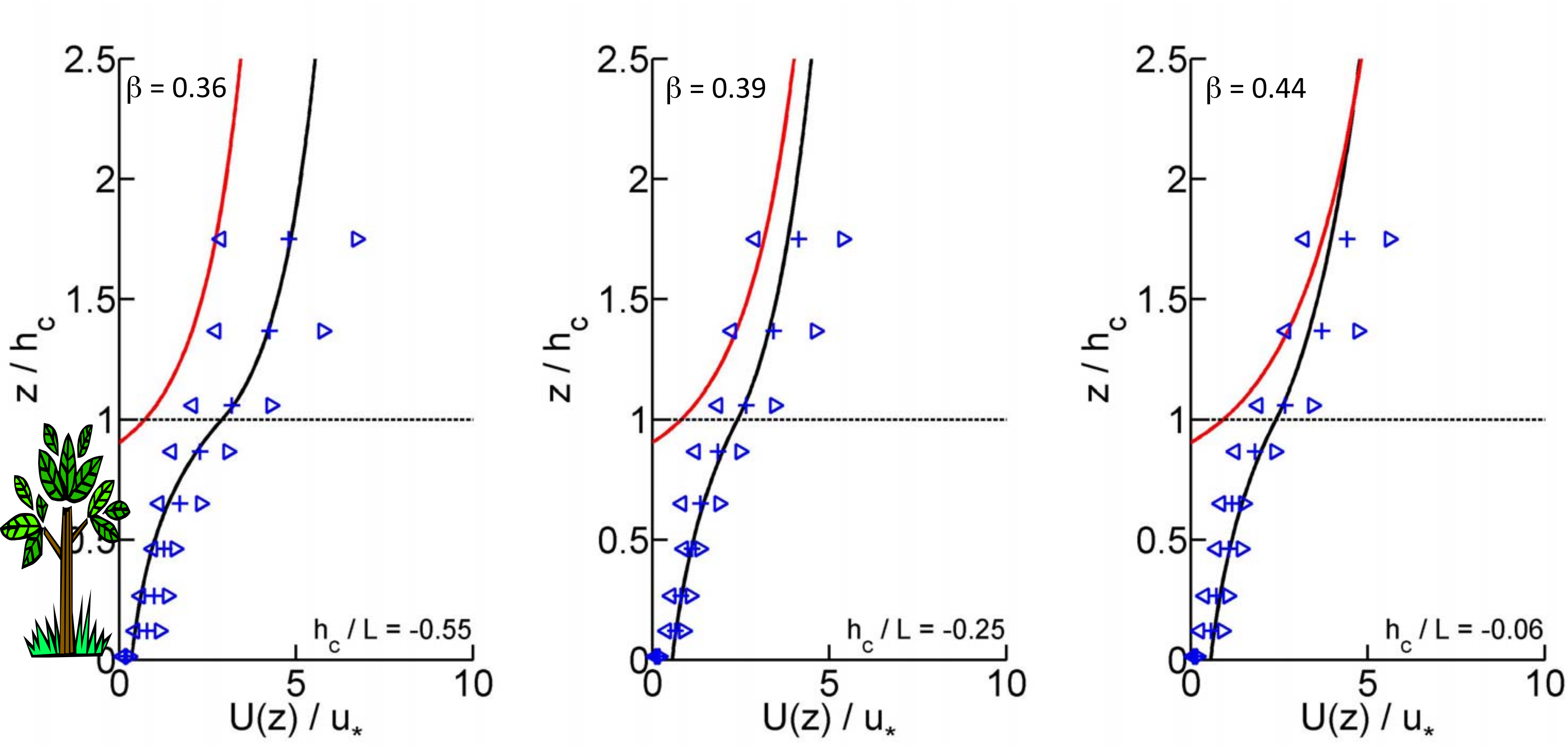
Comparison with observations – Neutral conditions



increasingly dense

Harman and Finnigan (2007)

Comparison with observations – Unstable conditions

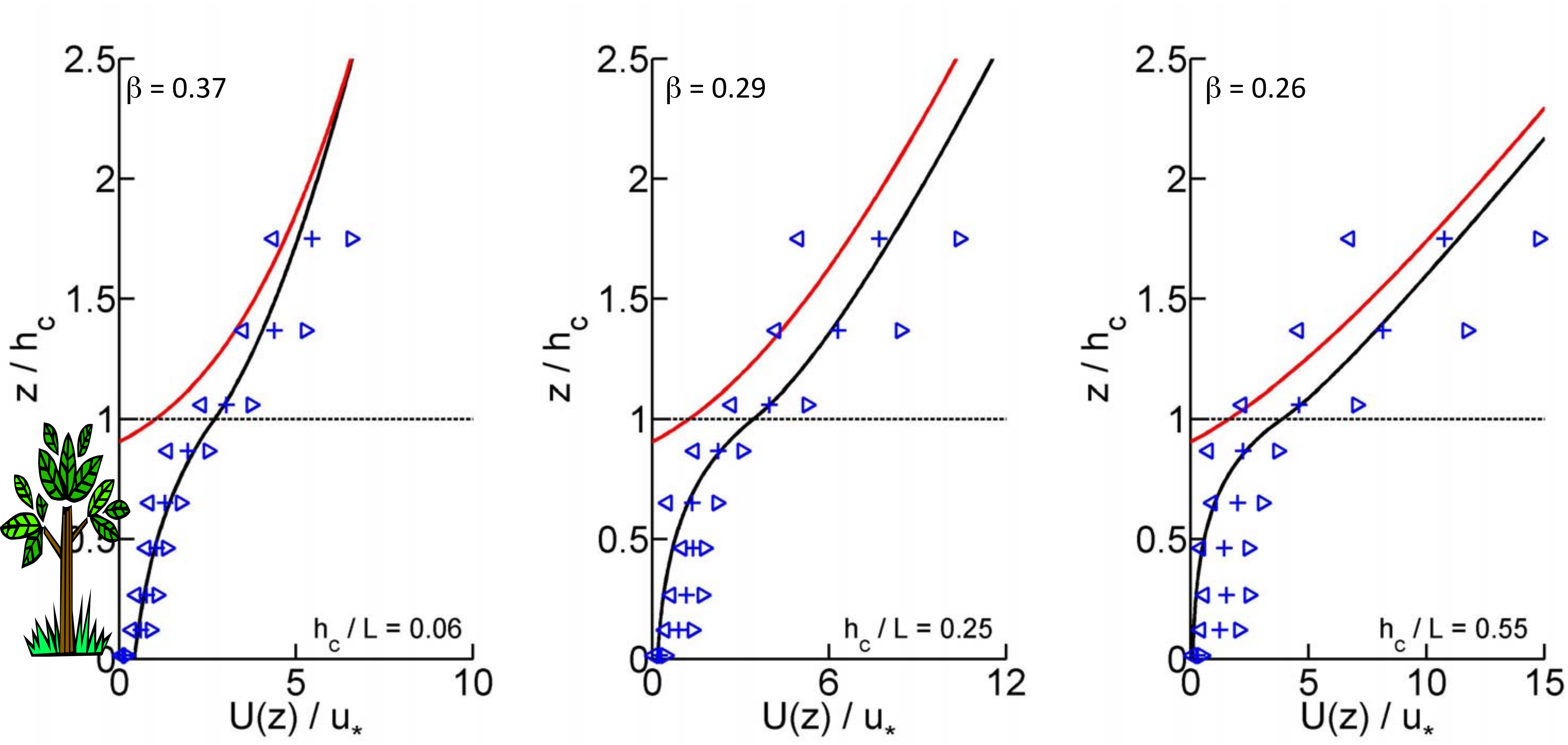


< increasingly unstable

Profiles from the CSIRO flux station near Tumbarumba

Harman and Finnigan (2007)

Comparison with observations - stable conditions

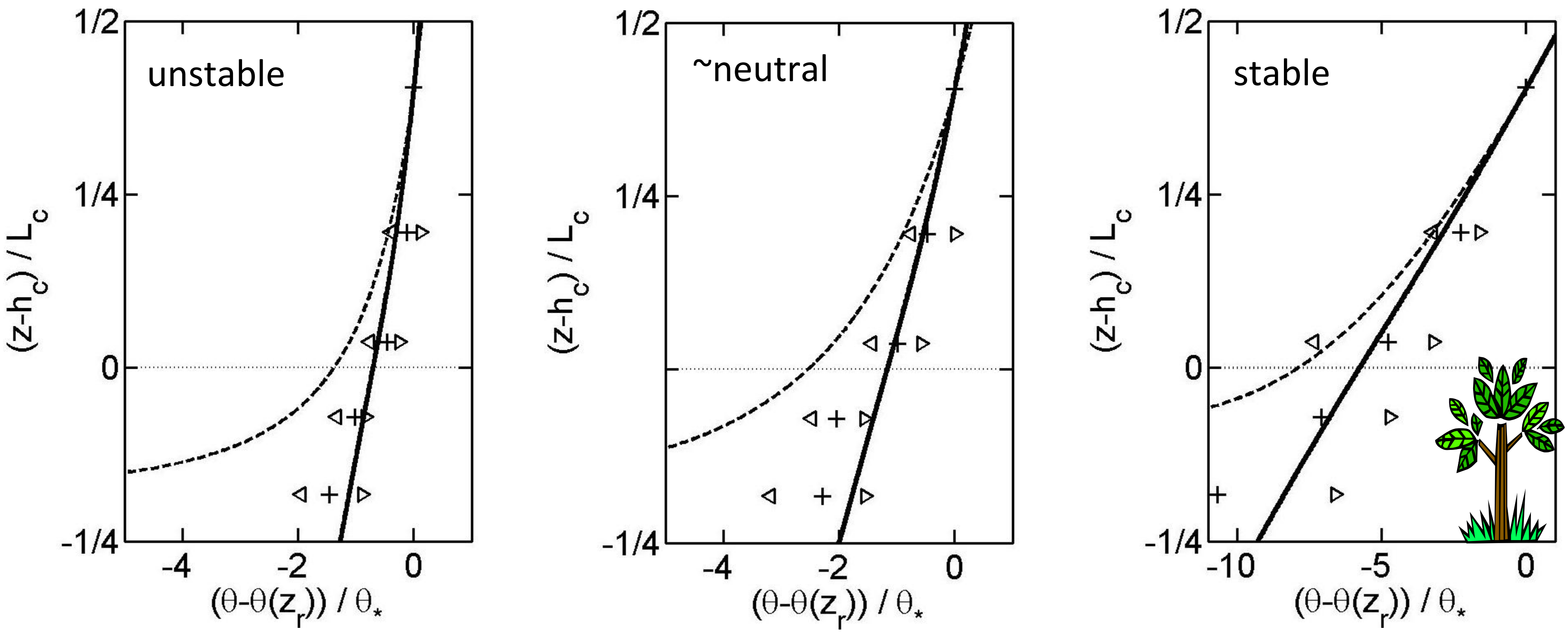


increasingly stable >

Profiles from the CSIRO flux station near Tumbarumba

Harman and Finnigan (2007)

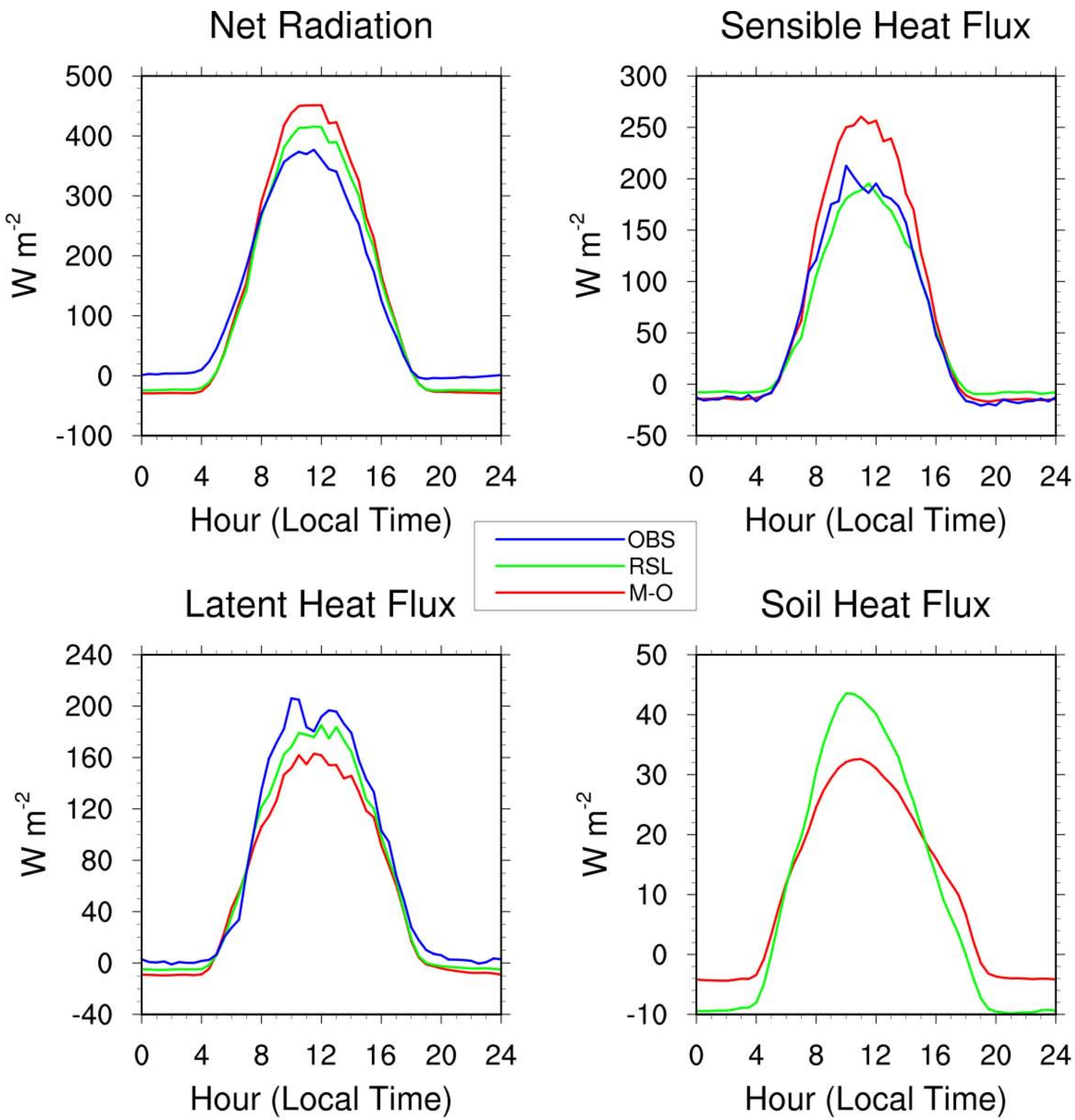
Comparison with observations - scalar profiles



Similar agreement for water vapor concentration but not for CO_2 concentration

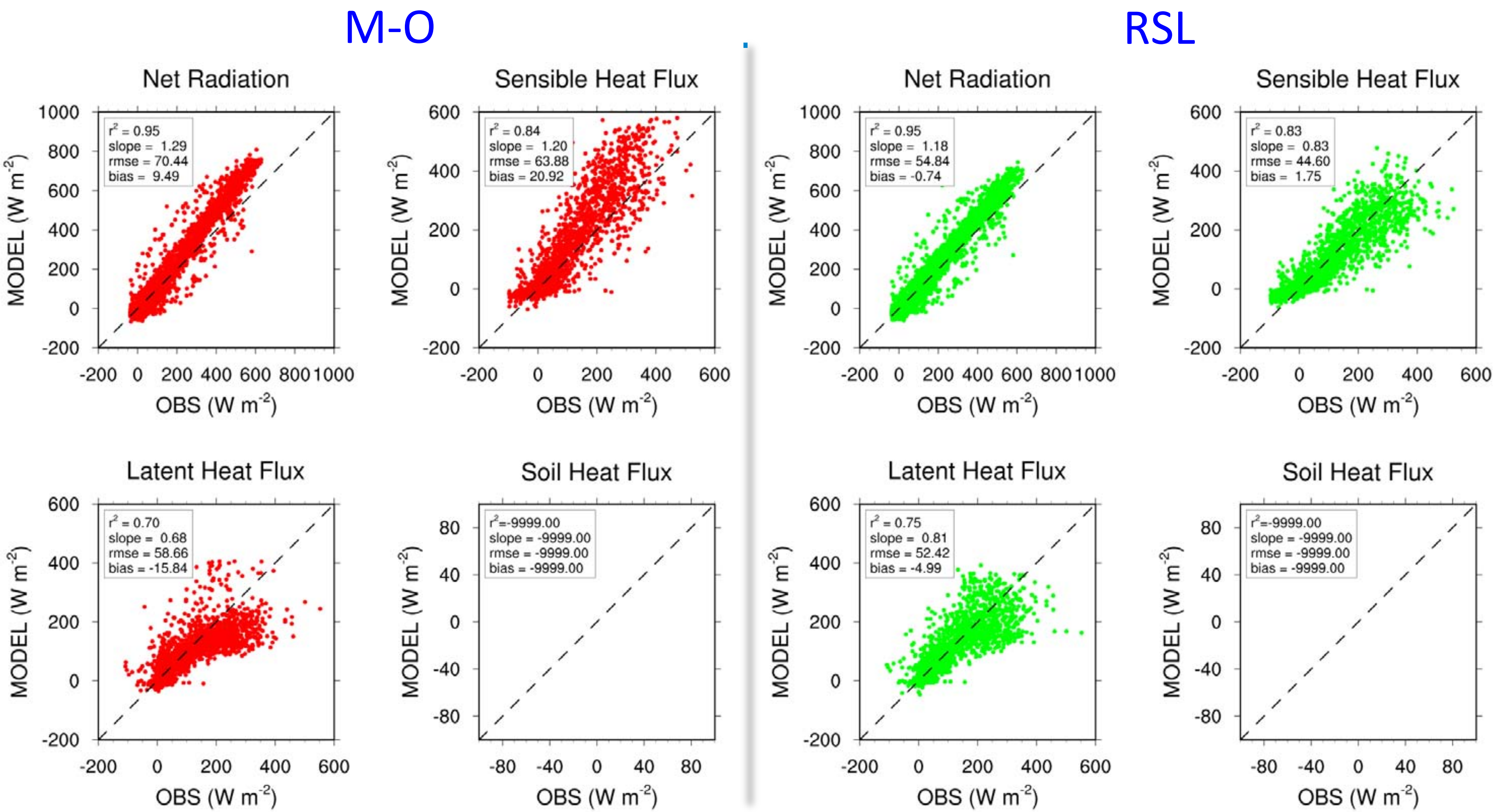
Harman and Finnigan (2008)

RSL impact on CLM4 surface fluxes (diurnal cycle)



- Howland Forest, ME
- Average over the 1996 growing season - DOY 153 to 244
- Offline simulation - driven by observations
- Currently only modifying above-canopy flux-gradient relationships

Surface flux comparison - Obs vs. M-O or RSL



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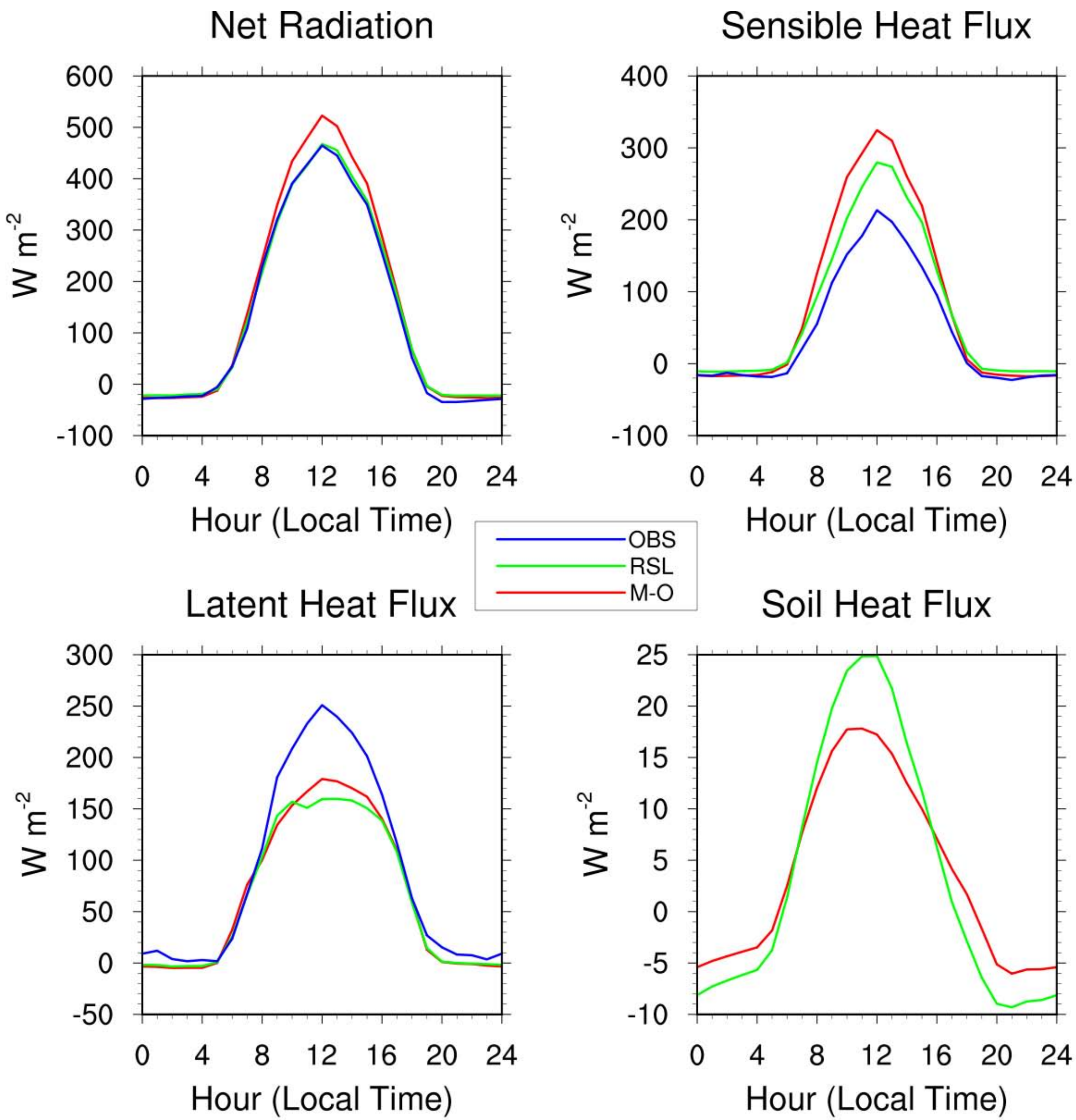

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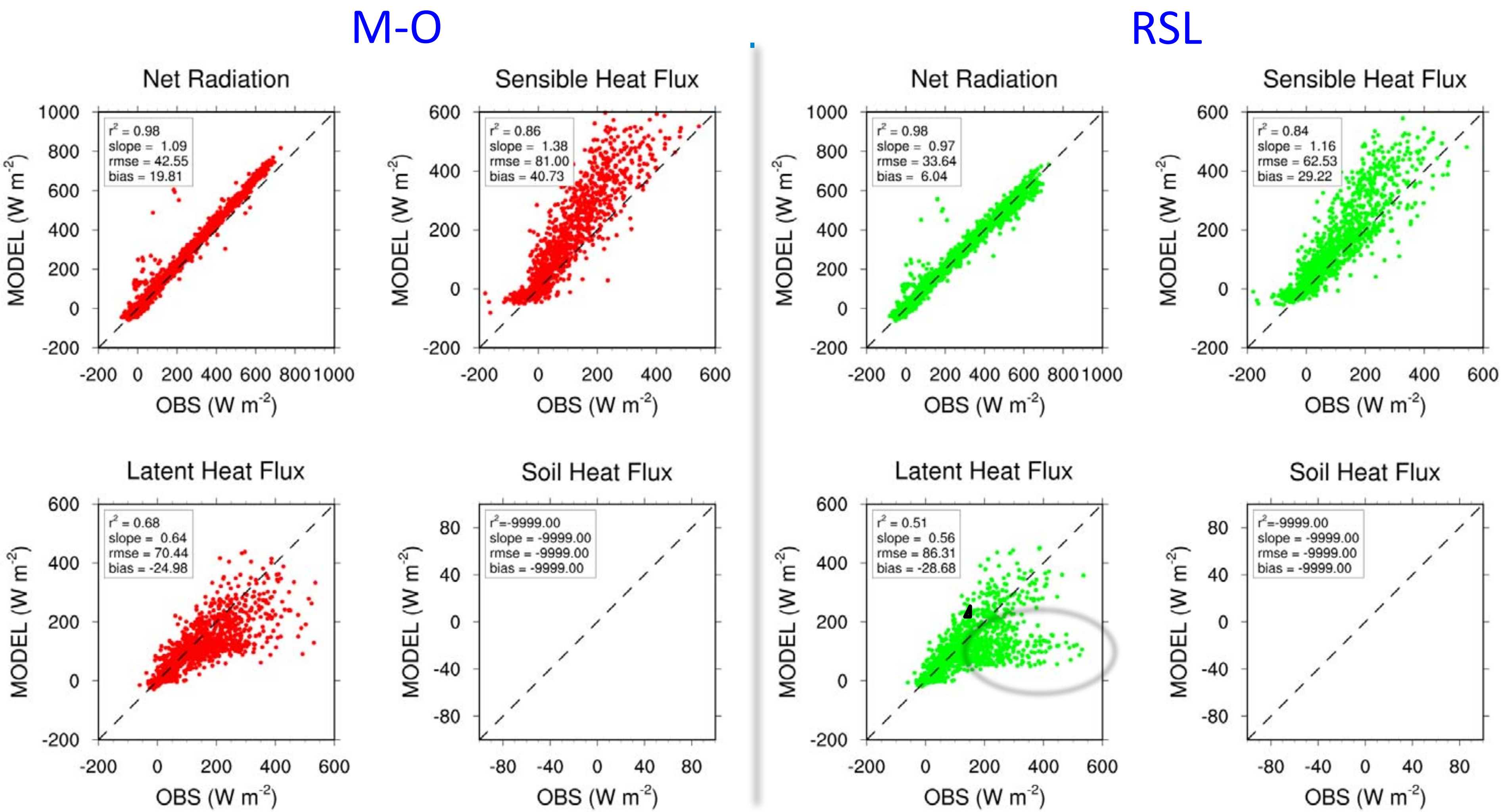

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Summary and Conclusions

- Introduced physically-based roughness sublayer parameterization into CLM
- Generally improves CLM's surface flux predictions when tested in offline mode
- Need to identify mechanisms responsible for stomatal shutdown (i.e., overly high leaf temperatures).

- Next steps:
  - Coupled mode
  - Within-canopy transport
  - Reactive chemistry (VOCs)

Questions?