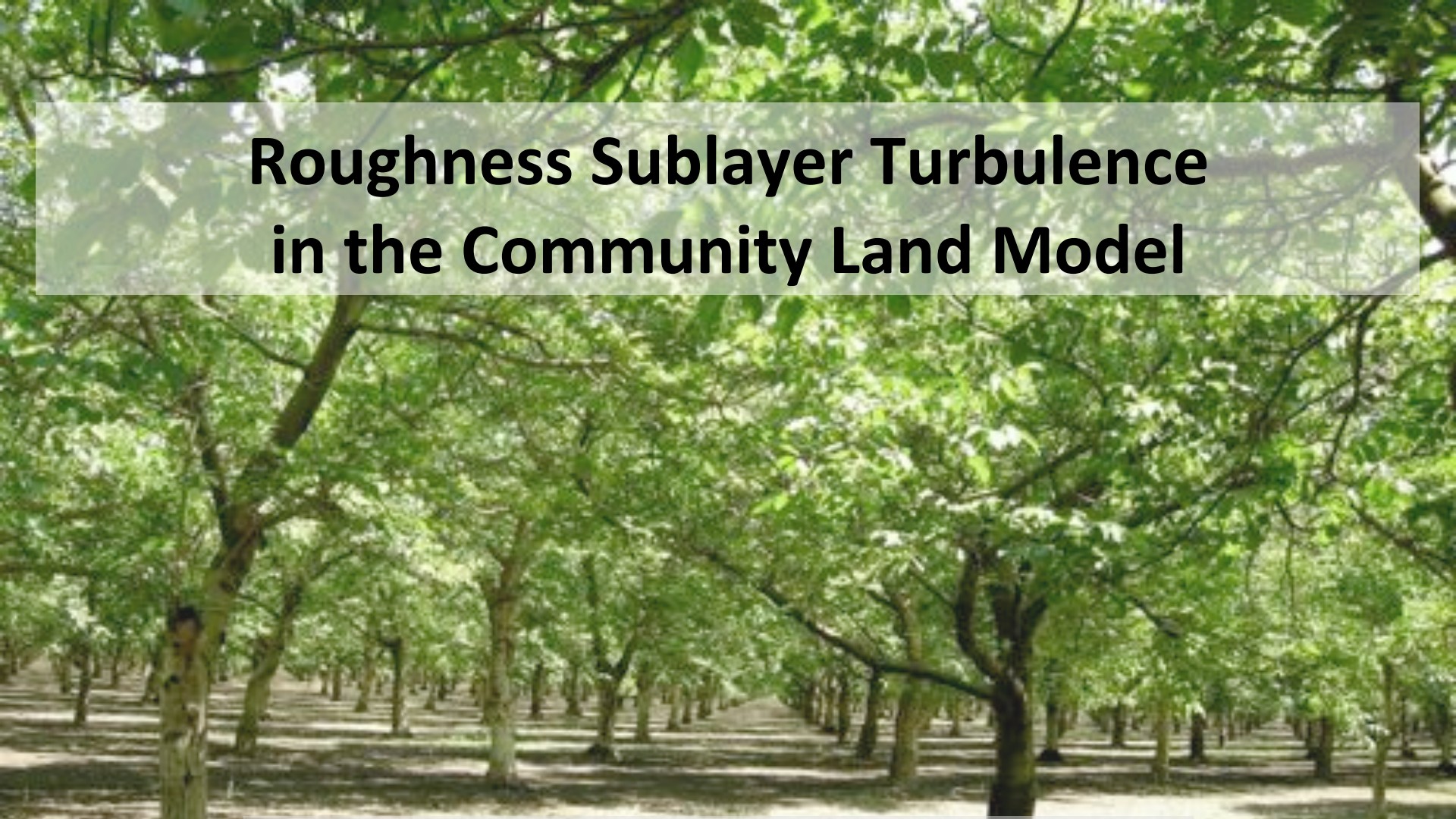
Roughness Sublayer Turbulence in the Community Land Model



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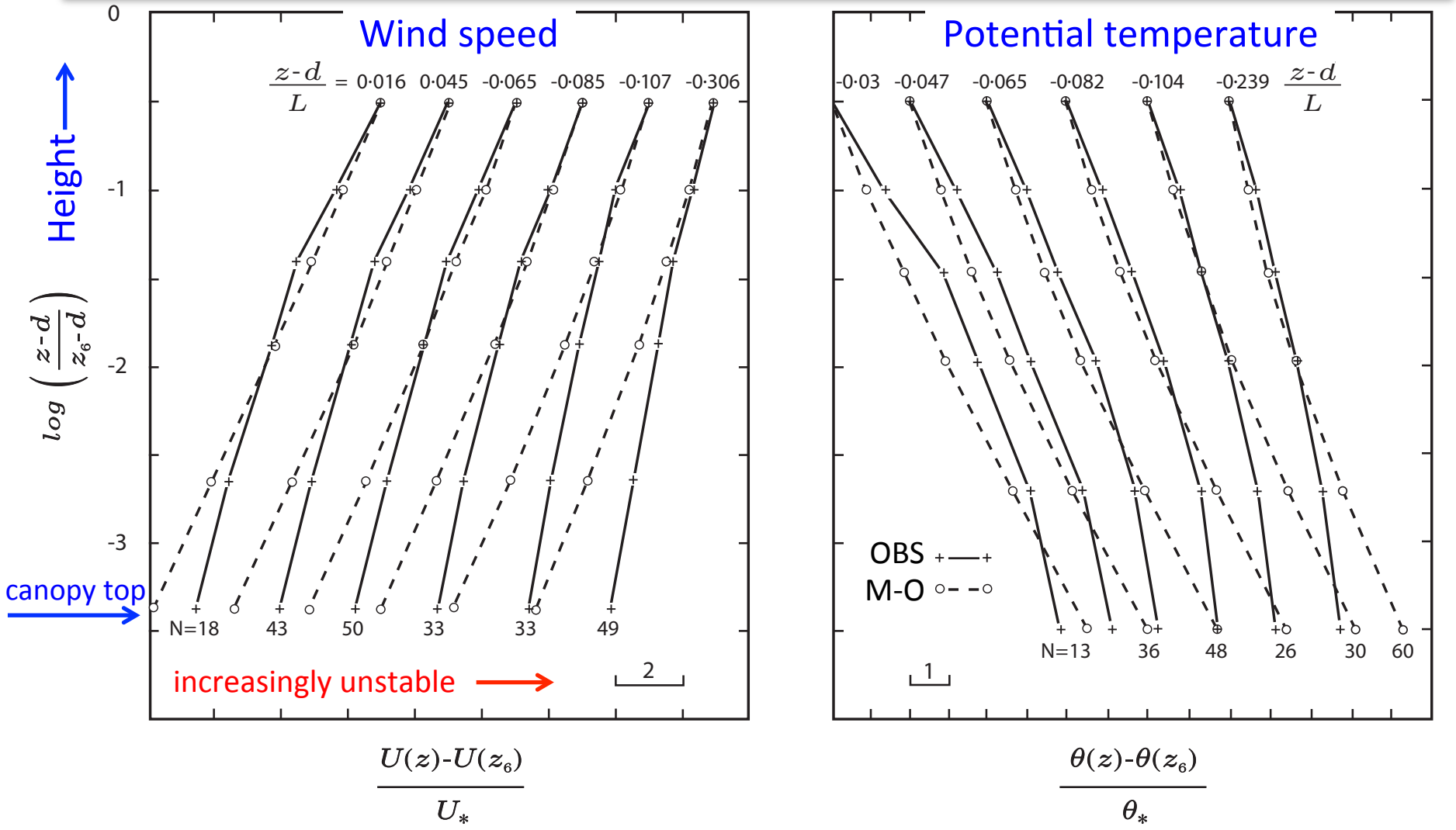
[2]CSIRO Marine and Atmospheric Research

Canopy turbulence and the roughness sublayer

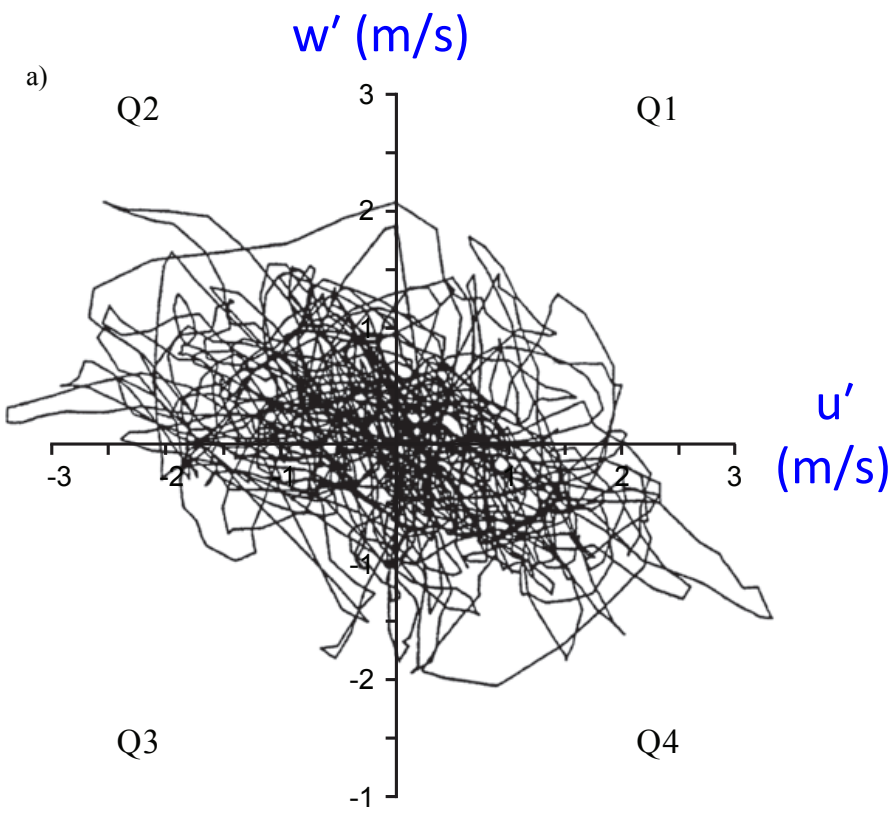


Flow within 2-3 canopy heights above/within tall (plant) canopies does not conform to Monin-Obukhov Similarity Theory (M-O); this region is called the roughness sublayer (RSL).

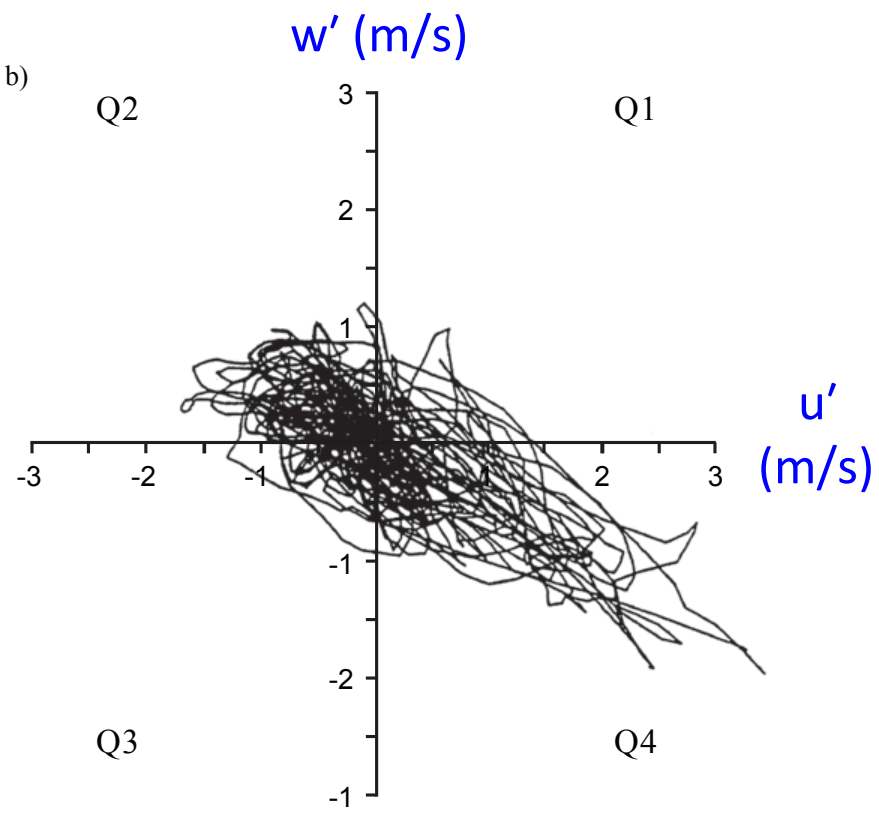
Raupach (1976), Chen and Schwerdtfeger (1989)

Time-trace of velocity fluctuations

Surface layer

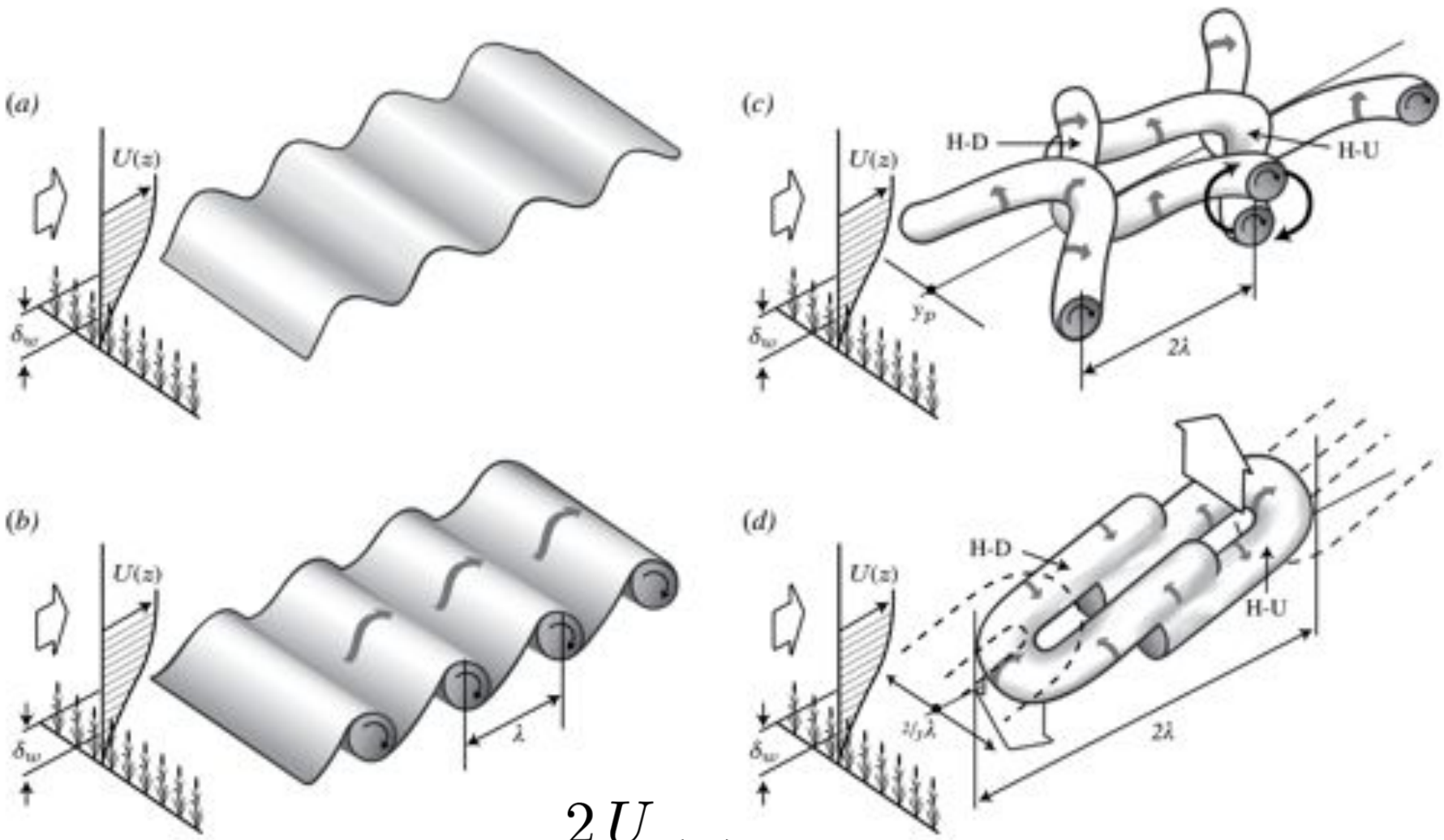


Roughness sublayer



Shaw and Patton (2003), Patton and Finnigan (2011)

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, $L_c = (C_d\, a)^{-1}$

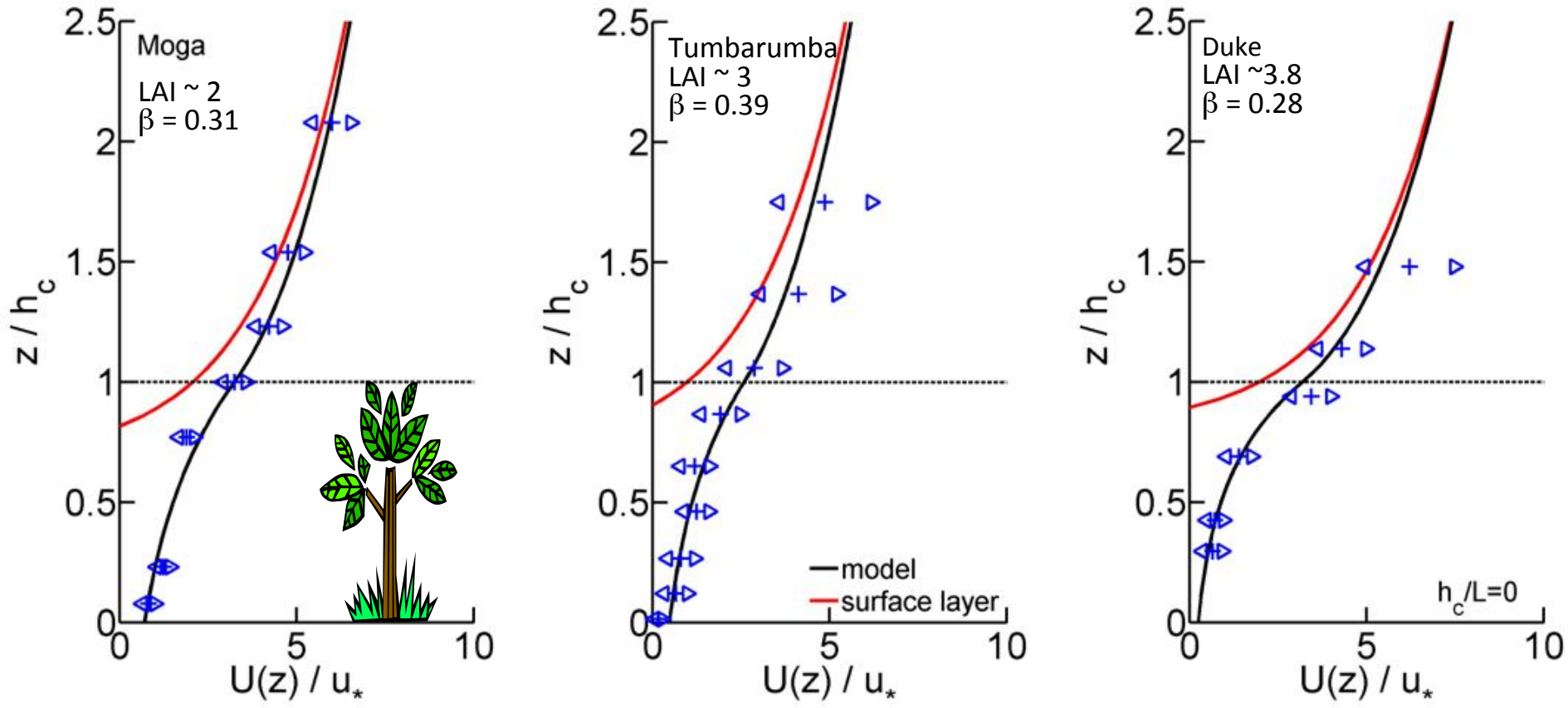
- Above Canopy:
  - Displacement height: Height of mean canopy drag momentum absorption
  - Modified M-O
  - Modification introduces an additional length scale – vorticity thickness associated with the instability process (δ_ω)

- Couple the 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

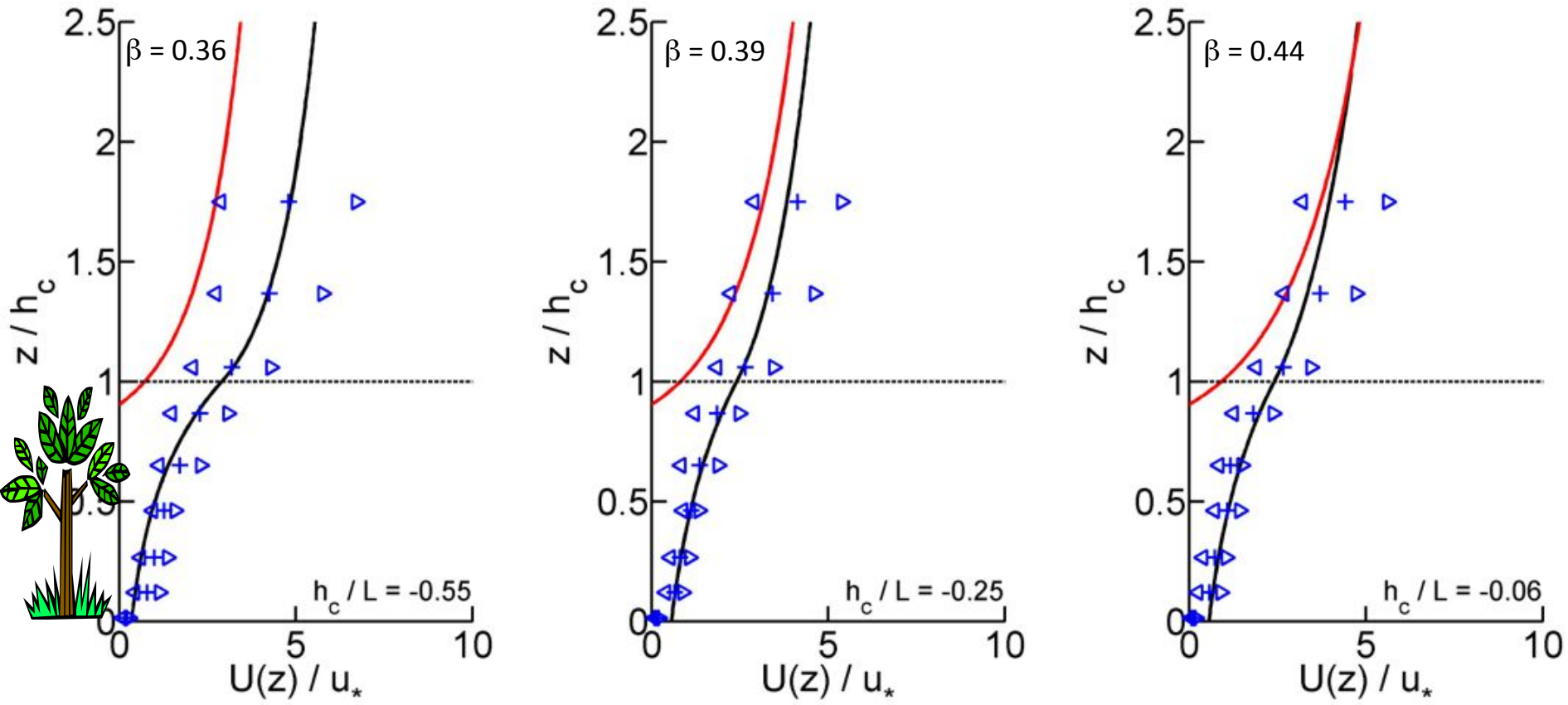
Harman and Finnigan (2007, 2008)

Comparison with observations – neutral conditions



Harman and Finnigan (2007)

Comparison with observations – unstable conditions

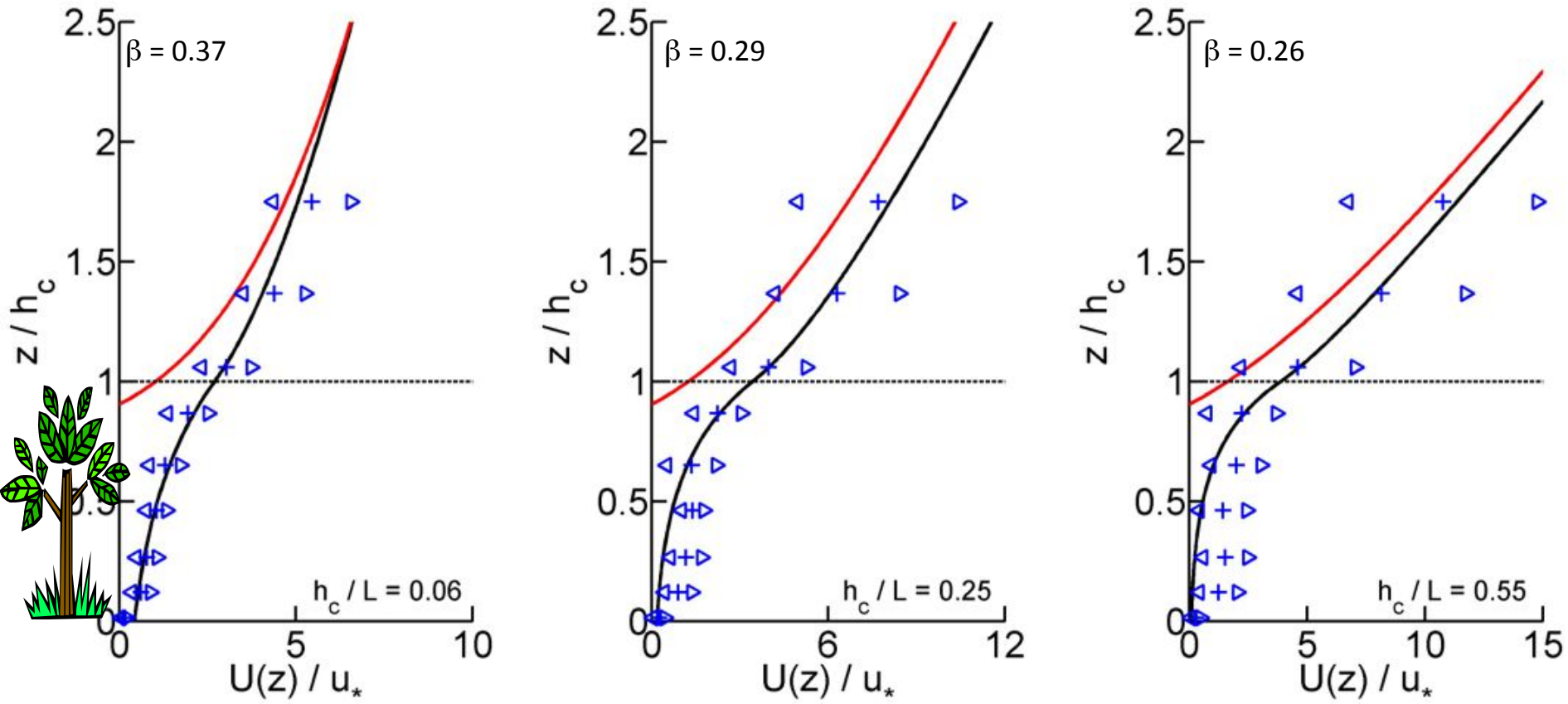


increasingly unstable

Profiles from the CSIRO flux station near Tumbarumba

Harman and Finnigan (2007)

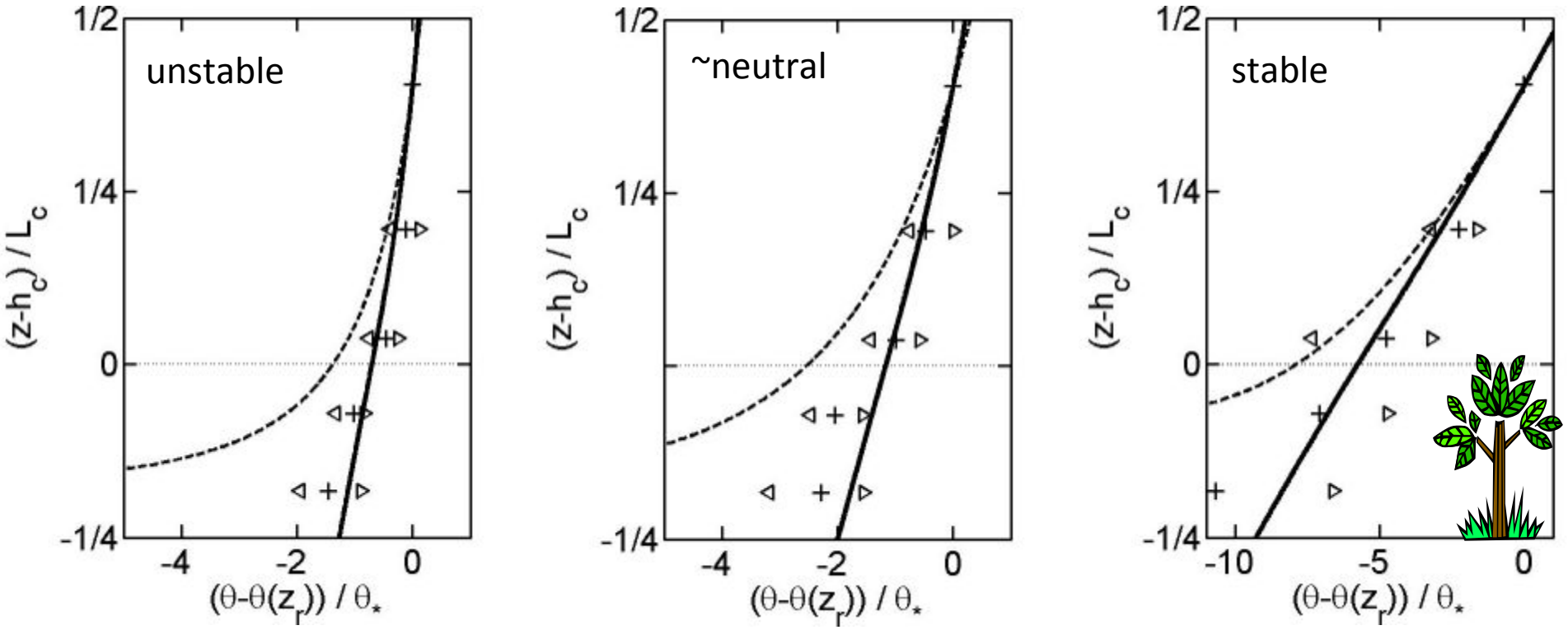
Comparison with observations - stable conditions



Profiles from the CSIRO flux station near Tumbarumba

Harman and Finnigan (2007)

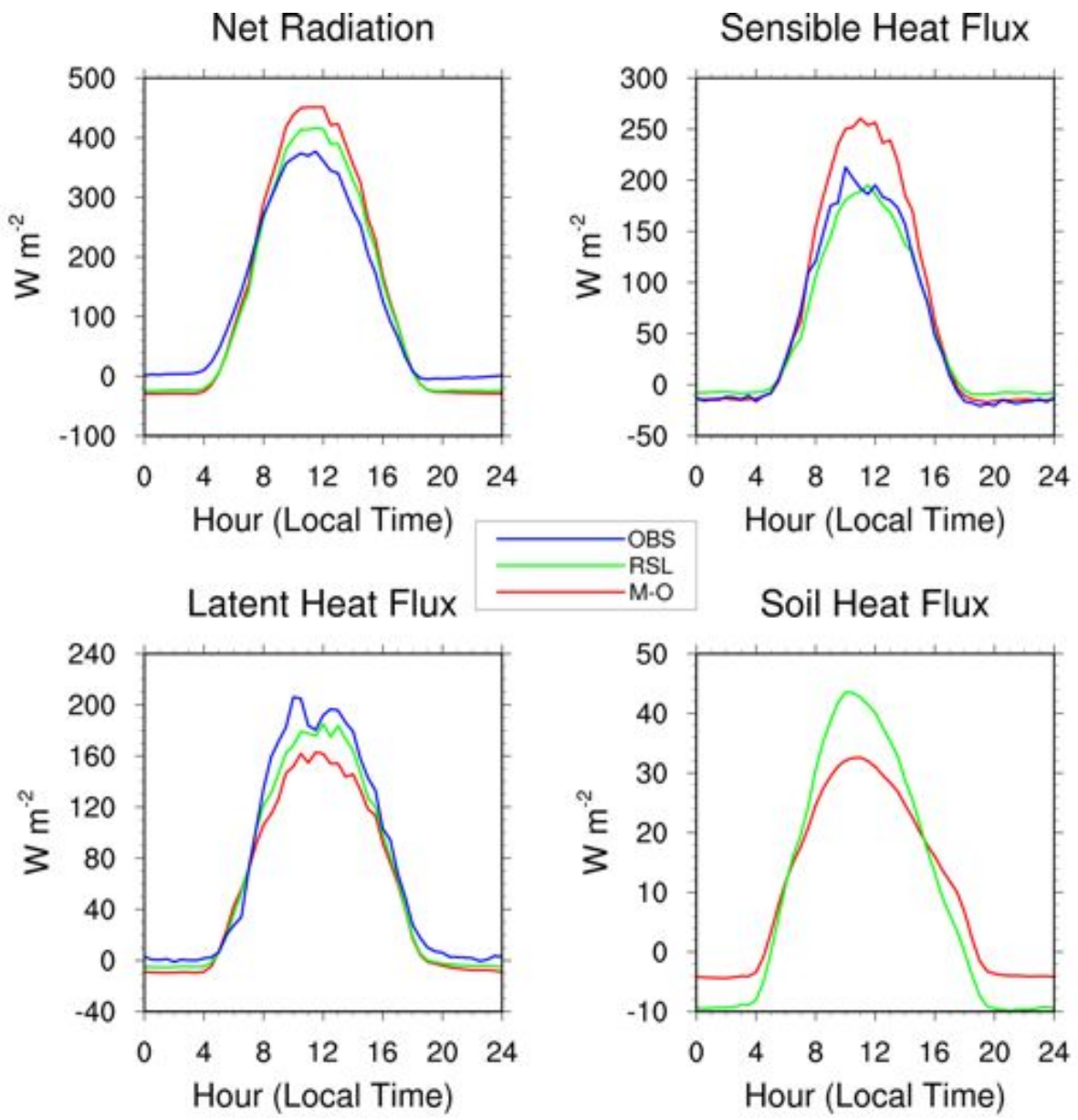
Comparison with observations - scalar profiles



Similar agreement for water vapor — lesser agreement for CO_2

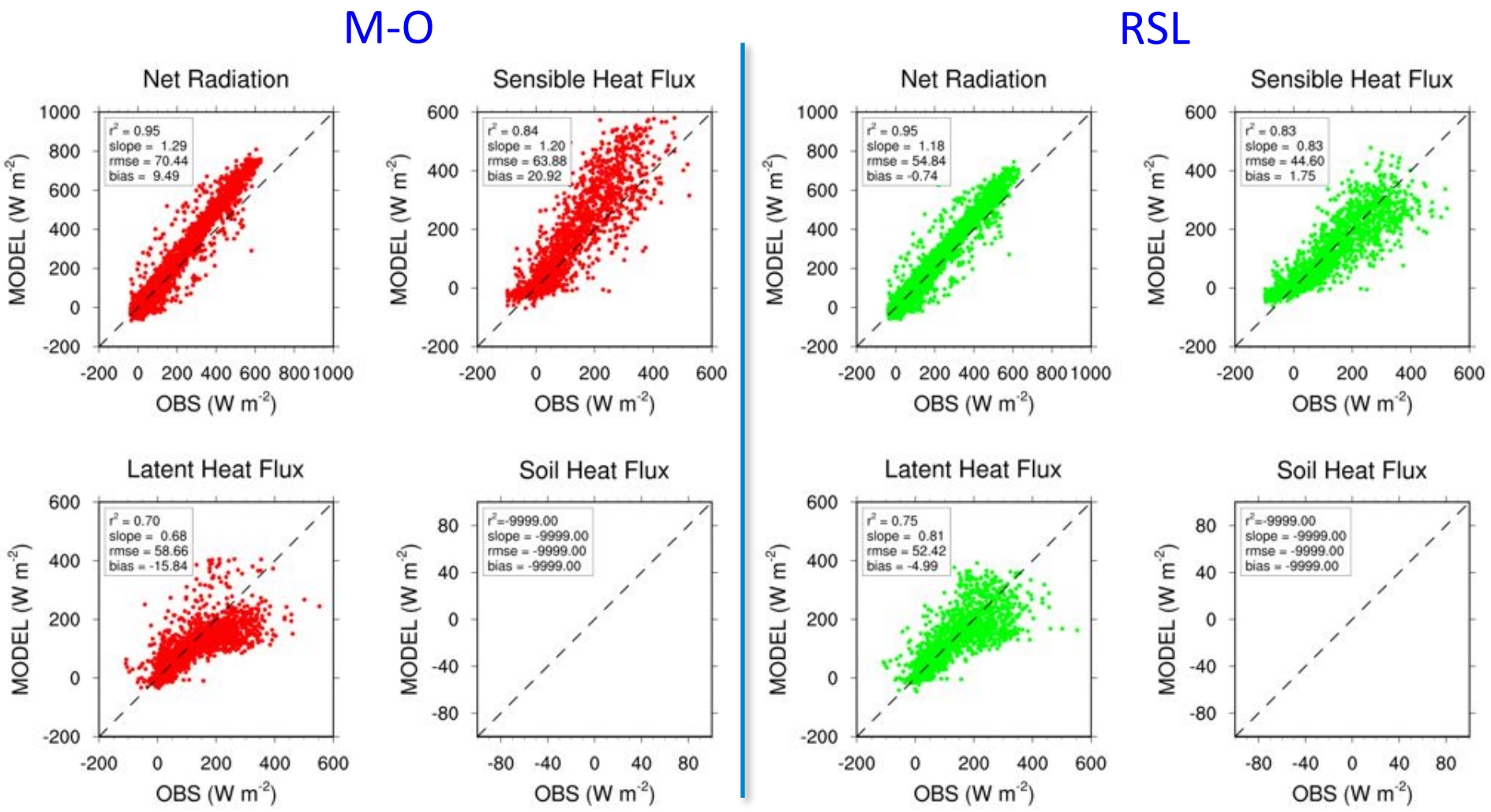
Harman and Finnigan (2008)

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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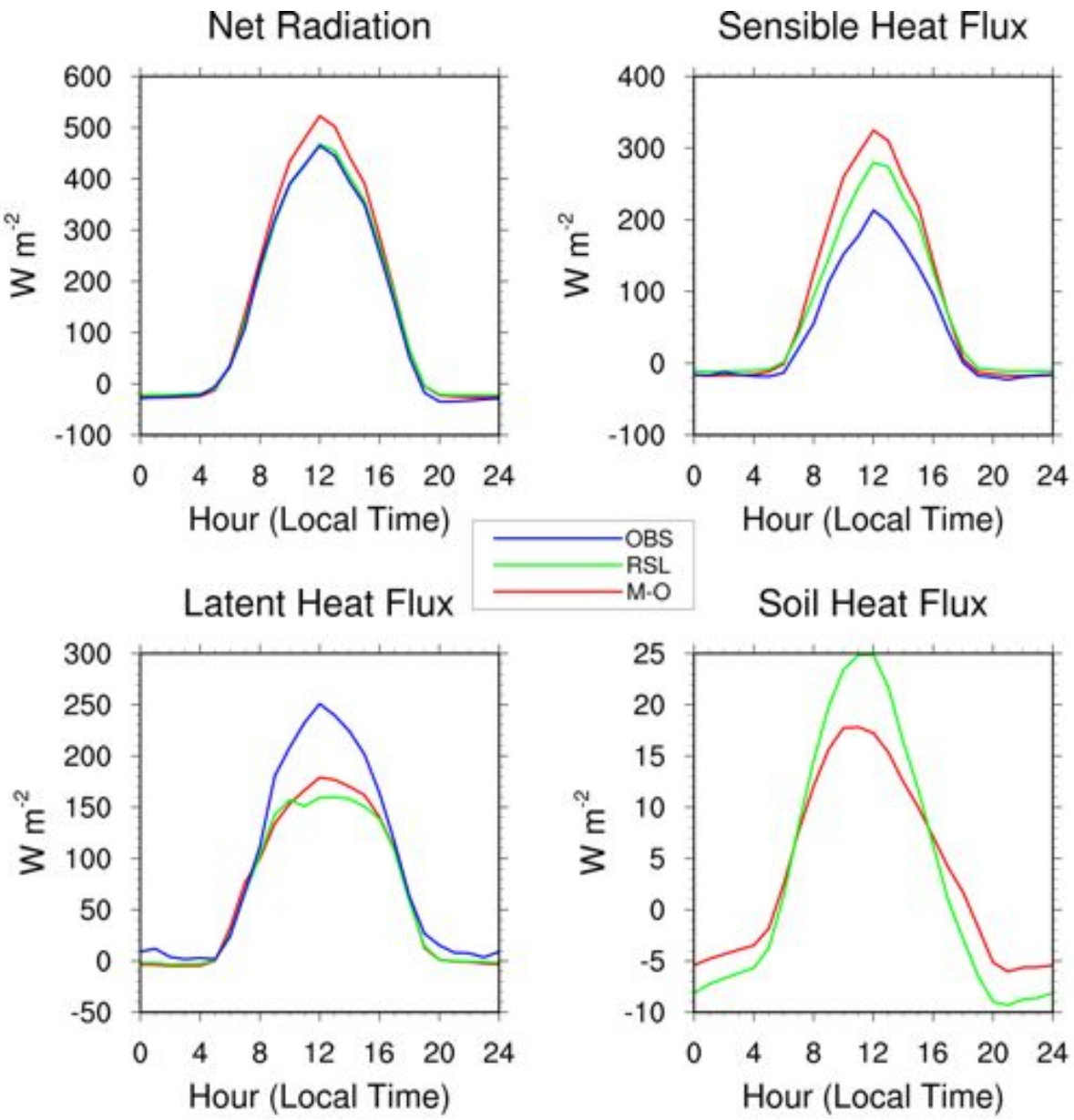

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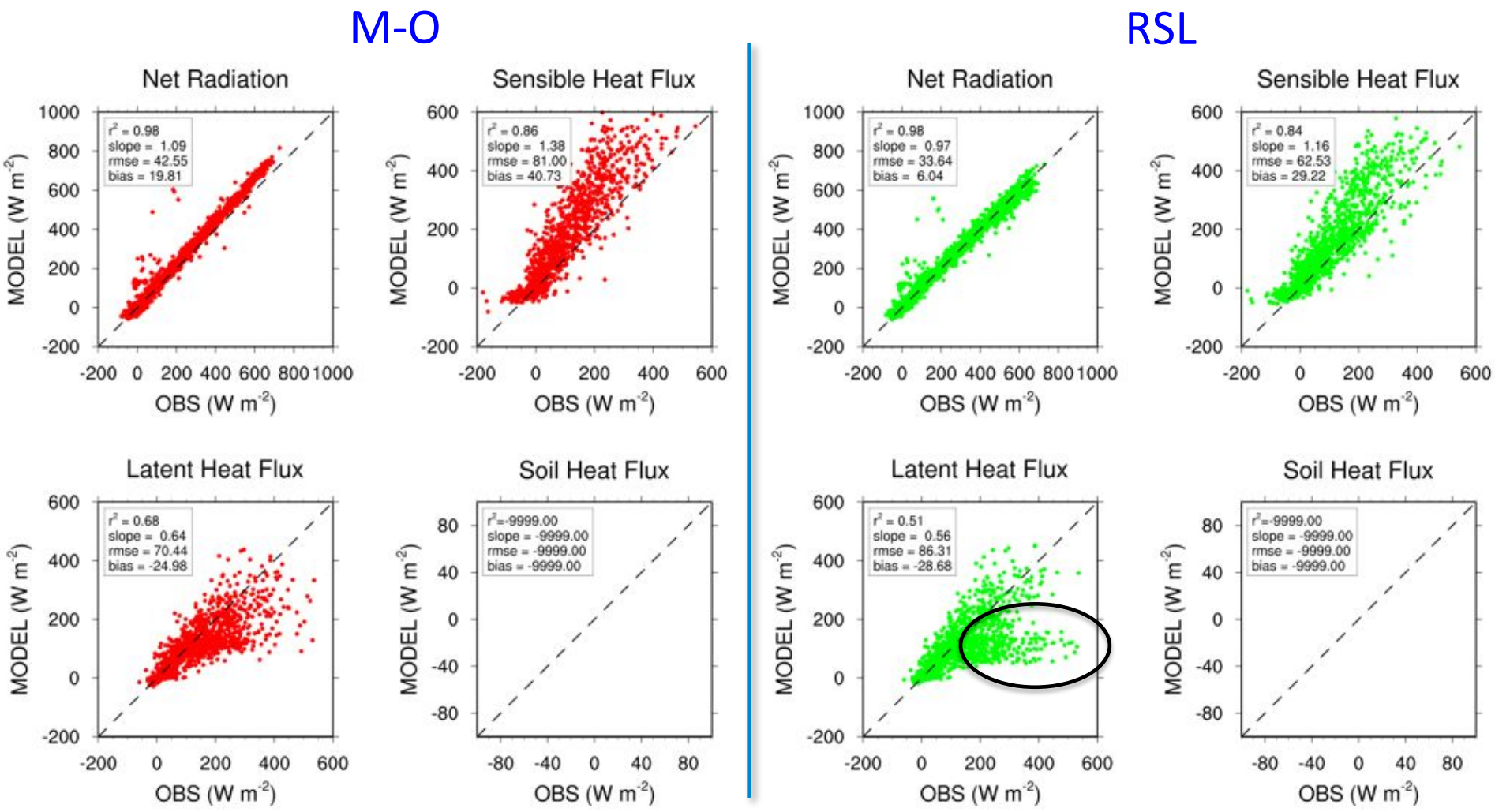

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Summary and Conclusions

- Introduced physically-based roughness sublayer parameterization into CLM4
- Generally improves CLM4's surface flux predictions when tested in offline mode
- Working to identify mechanisms responsible for stomatal shutdown (i.e., overly high leaf temperatures).

- Next steps:
  - Multi-level within-canopy transport
  - Reactive chemistry (VOCs)
  - Coupled mode

Within-canopy turbulence/chemistry data

CHATS and MFO datasets

Working to configure into AmeriFlux/FluxNet form for testing RSL-impacts on within-canopy CLM turbulence

Questions?