Using Eddy Covariance Tower Clusters To Evaluate Biophysical Impacts Of Land Cover In The Community Land Model (CLM)

AGU Fall Meeting, 16 Dec 2016, B34A-04, Abstract ID 78558

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Biophysical Properties

- Albedo
- Surface roughness
- Bowen ratio

Not New Hampshire. Actually Switzerland. Thanks user Kamisan at DeviantArt.com

Winter Biophysical Properties

- Albedo
- Surface roughness
- Bowen ratio

Winter: Albedo

$$\text{Albedo} = SW_{up}/SW_{down}$$

Snow-Covered Field 0.85

Warmer forests

Cooler open lands

Winter: Surface roughness night

Surface roughness, or aerodynamic resistance to heat transfer

$$r_a = \rho C_p (T_s - T_a) / H$$

Warmer forests at night from enhanced mixing over rough canopies; cooler open land due to radiative cooling.

Winter: Surface roughness day

Surface roughness, or aerodynamic resistance to heat transfer

$$r_a = \rho C_p (T_s - T_a) / H$$

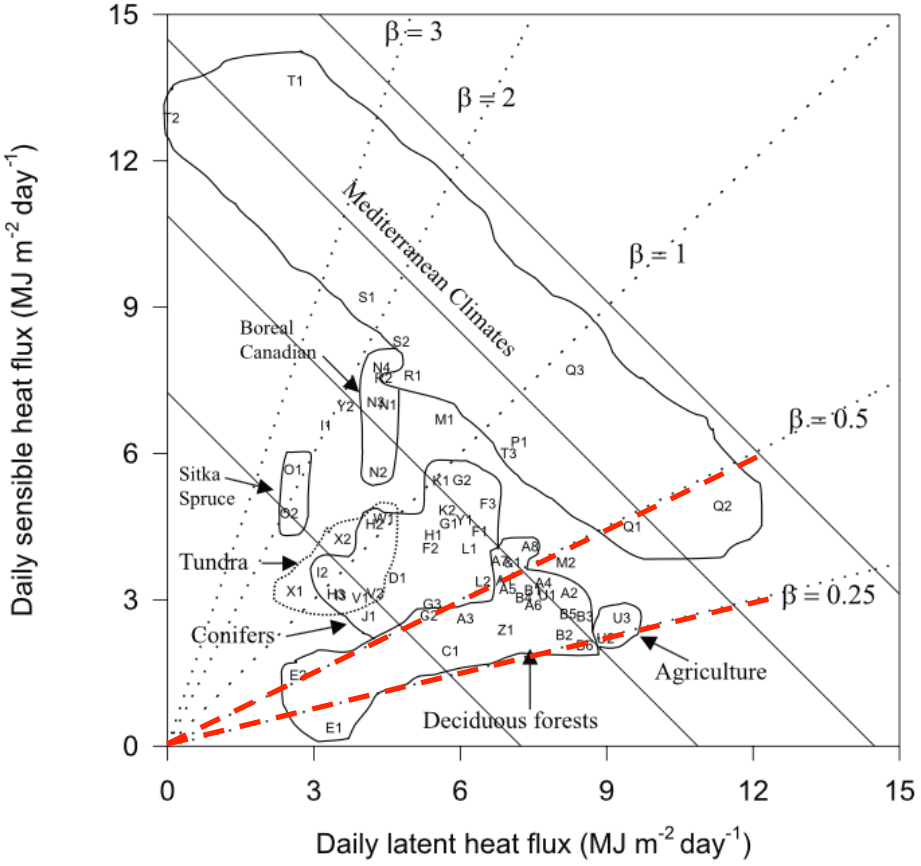
Warmer over open land during the day from suppressed mixing; cooler forest canopies that dissipate sensible heat more efficiently.

Summer Biophysical Properties

- Albedo
- Surface roughness
- Bowen ratio

Summer: Bowen ratio

$$\text{Bowen ratio } (\beta) = \frac{\text{Sensible Heat}}{\text{Latent Heat}}$$



Also depends on:

- Irrigation
- Rooting depth
- Soil moisture

Wilson et al., 2002

Which biophysical properties dominate temperature differences between forested and deforested lands on annual and seasonal time scales?

Intrinsic Biophysical Mechanism

$$\Delta T_s \approx \frac{\lambda_0}{1+f}\Delta S + \frac{-\lambda_0}{(1+f)^2} R_n \Delta f_1 + \frac{-\lambda_0}{(1+f)^2} R_n \Delta f_2$$

Radiative forcing due to changes in albedo

Energy Redistribution due to changes in surface roughness

Energy Redistribution due to changes in Bowen ratio

Lee et al. 2011

Approach: Eddy Covariance Towers

Eddy Covariance Tower Clusters

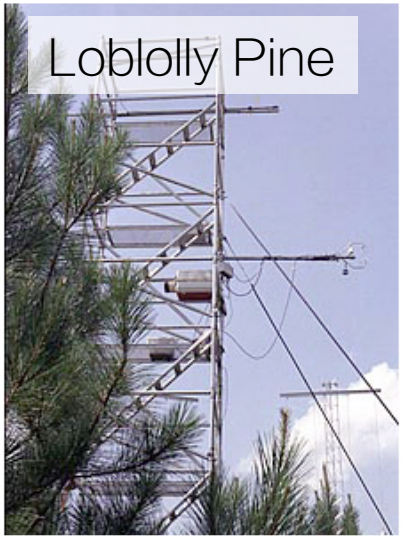
- Meteorological data (Air T, RH, wind speed, pressure, incoming and outgoing longwave & shortwave radiation, precip)
- Turbulent energy fluxes (latent, sensible)

A tale of two Durhams

UNH Tower Cluster, Durham, NH

- UNH Eddy Covariance Tower
- United States Climate Reference Network (USCRN)

Duke Tower Cluster Durham, NC



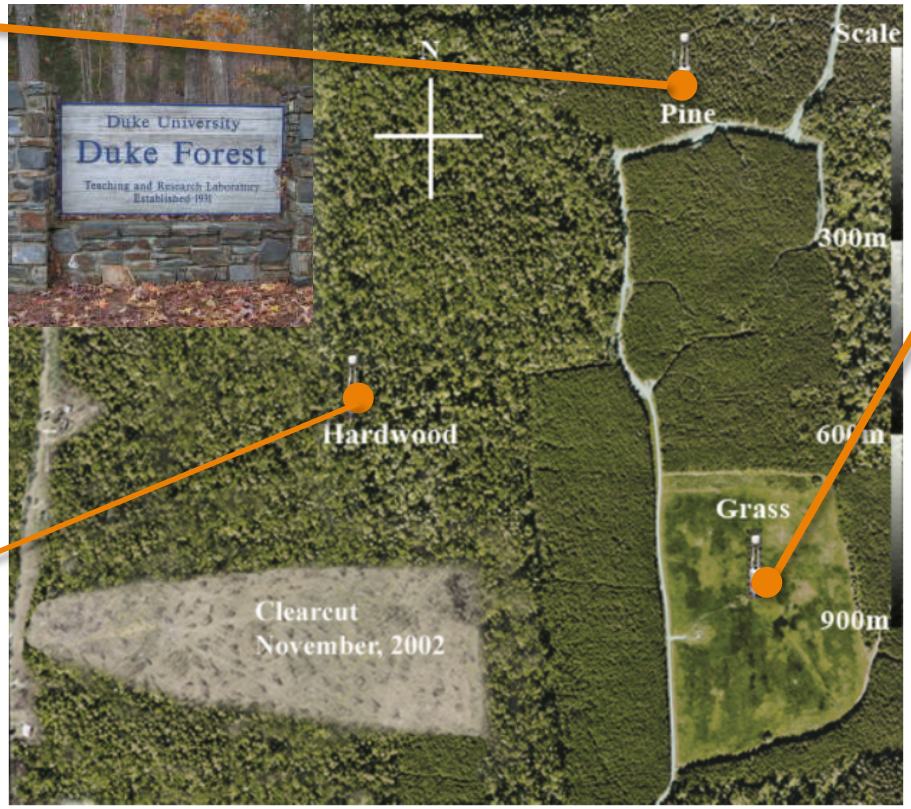
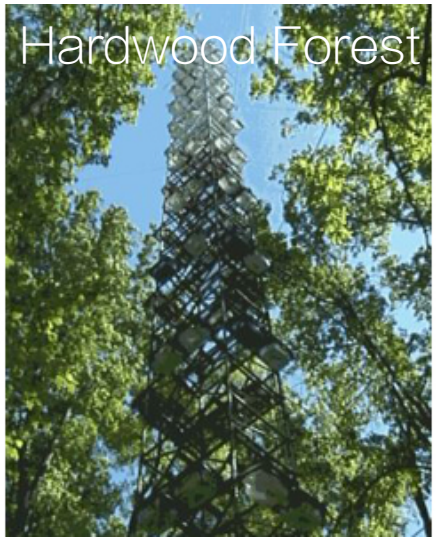


Image from Stoy et al. 2006



- Duke Eddy Covariance Towers

2004-2008 analysis period

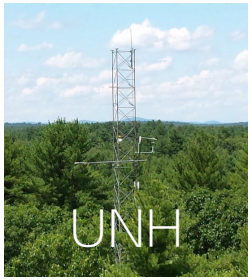
Novick et al., 2015; Juang et al. 2007

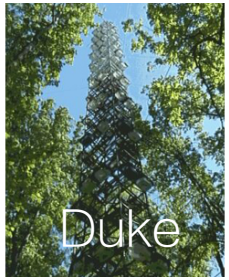
Approach: Point CLM4.5 Simulations

Eddy Covariance Tower Clusters → PTCLM4.5 Land only

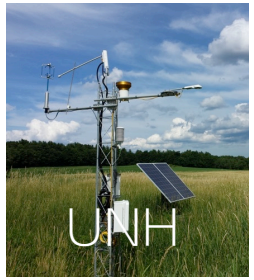
- Forced with tower meteorological data, not coupled to the atmosphere, 35 yr spin up
- Assigned plant functional type:

Broadleaf Deciduous Temperate Forest





C3 Non-Arctic Grass

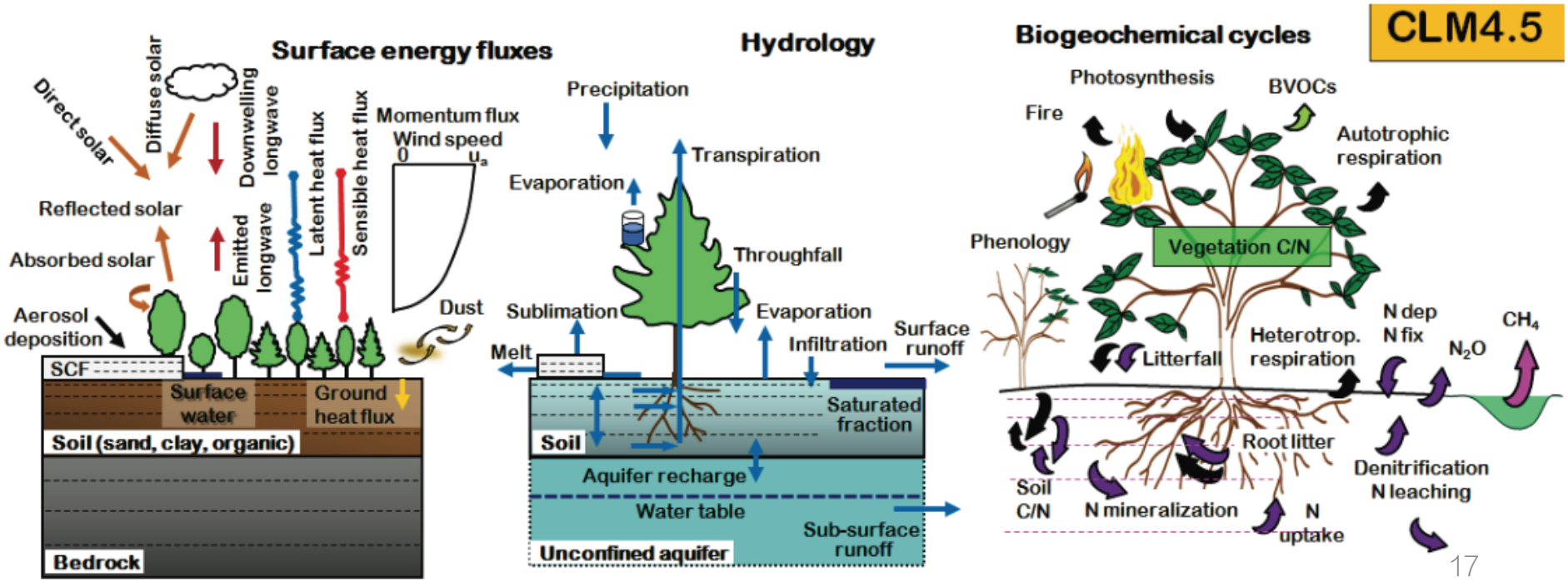


Approach: Point CLM4.5 Simulations

Eddy Covariance Tower Clusters

PTCLM4.5 Land only

Community Land Model



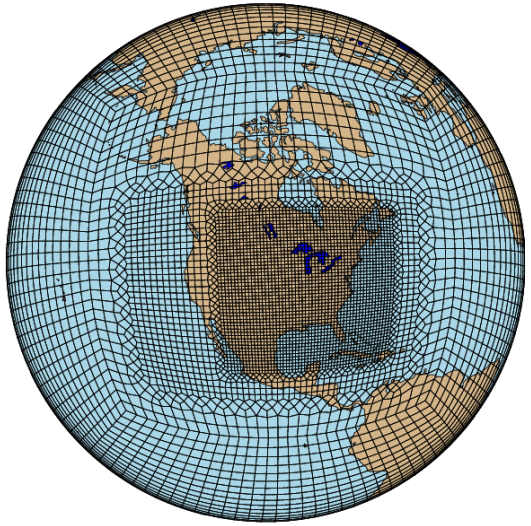
Oleson et al., 2010; Lawrence et al. 2011

Approach: Variable Resolution CESM

Eddy Covariance Tower Clusters → PTCLM4.5 Land only → VR-CESM1.3 Land-Atm Coupled

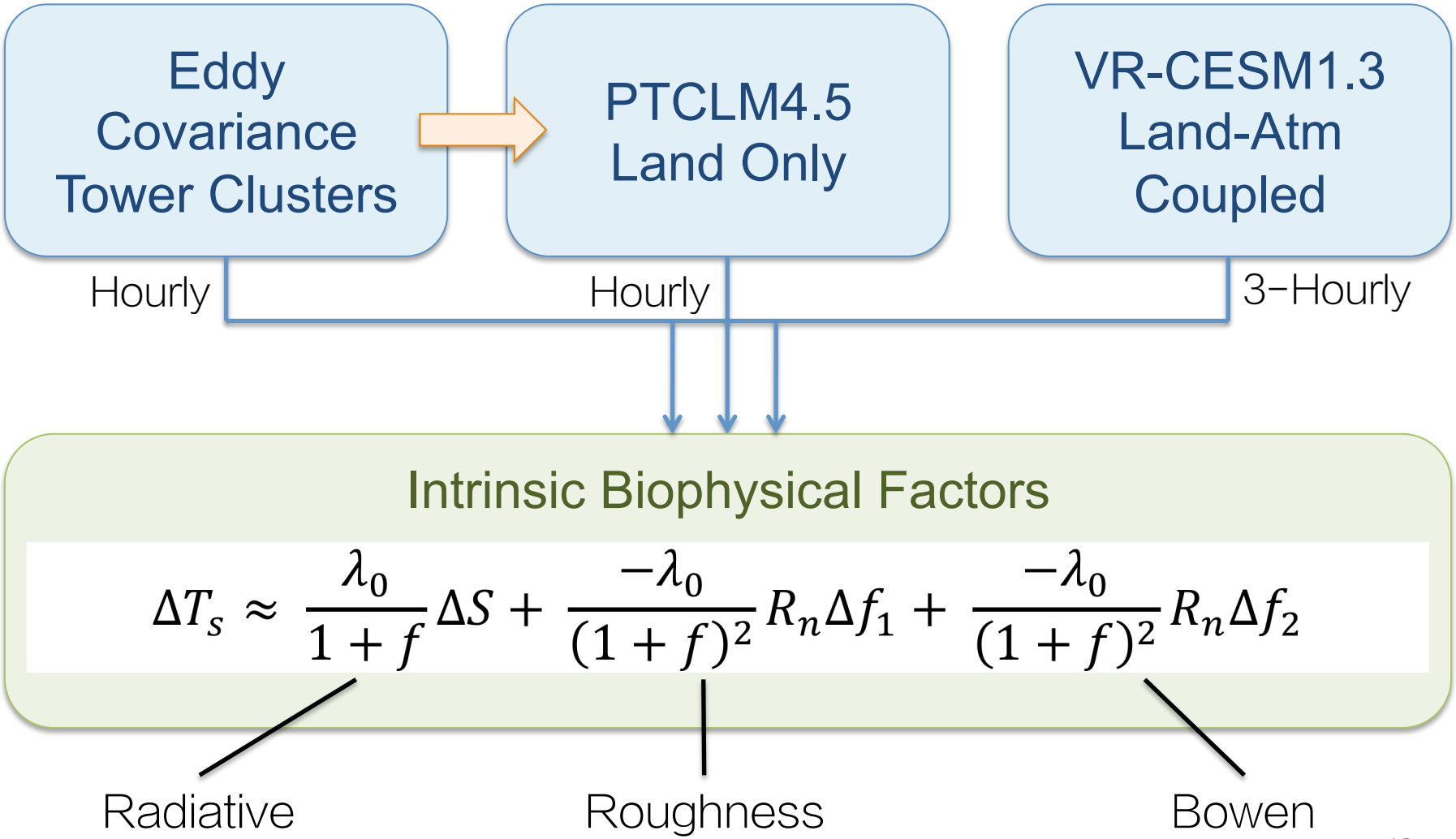
- Atmosphere-land coupled global simulation, 1979-2008
- Prescribed SSTs & sea ice
- CESM1.3 (CLM4.5, CAM5.3)
- 1 degree ➔ 0.25 degree
- Fractional land cover

Community Earth System Model



Zarzycki et al. 2015

Approach: Annual, Winter, Summer

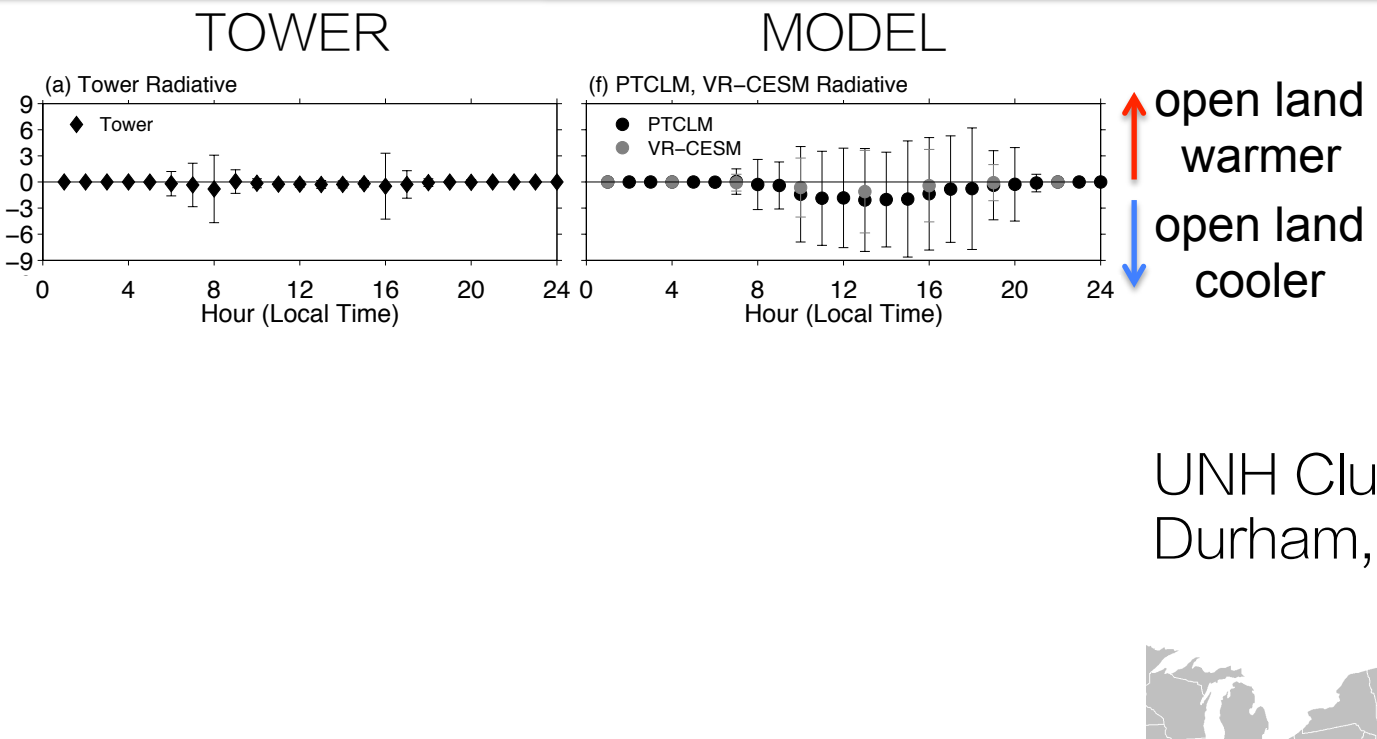


Lee et al. 2011

Intrinsic Biophysical Mechanism, Annual 2015: Open – Forest ΔT_s

Burakowski et al., *in prep*

RADIATIVE



UNH Cluster
Durham, NH

Intrinsic Biophysical Mechanism, Annual 2015: Open – Forest ΔT_s

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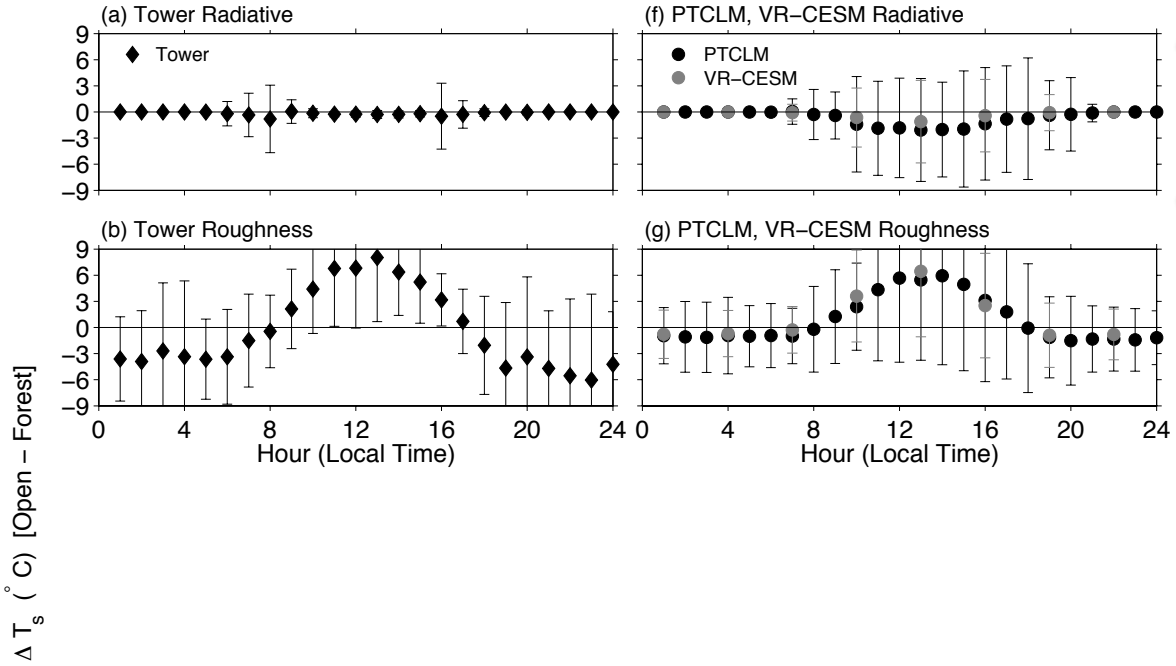
TOWER

MODEL

RADIATIVE

ROUGHNESS



open land warmer

open land cooler

UNH Cluster
Durham, NH

Intrinsic Biophysical Mechanism, Annual 2015: Open – Forest ΔT_s

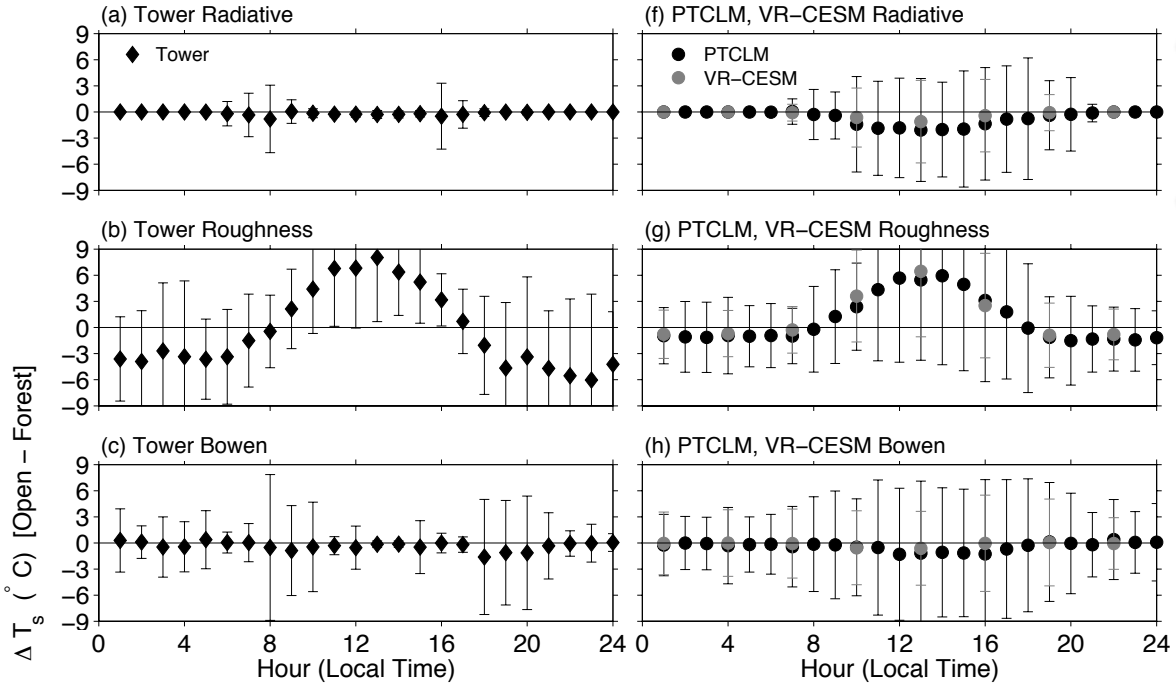
Burakowski et al., *in prep*

TOWER MODEL

RADIATIVE

ROUGHNESS

BOWEN



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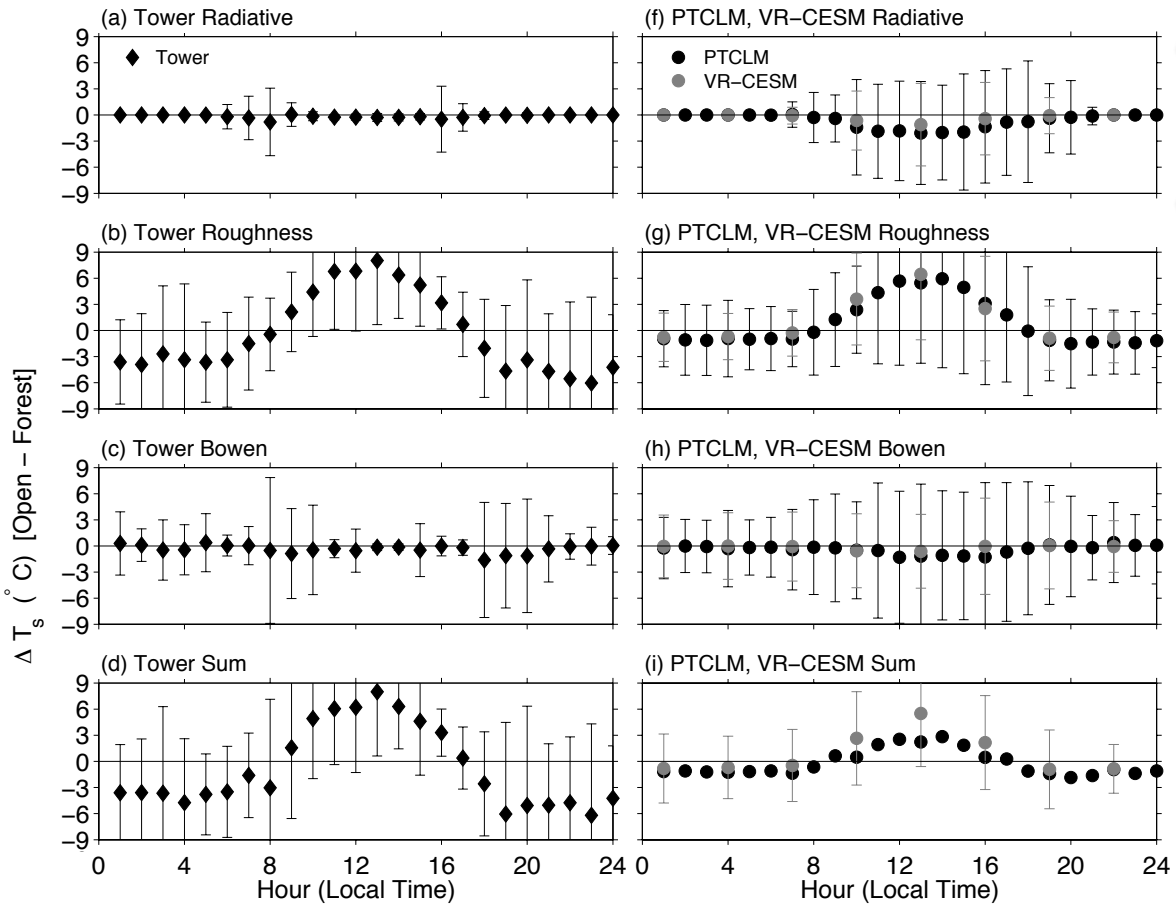
TOWER MODEL

RADIATIVE

ROUGHNESS

BOWEN

Rad + Rough + Bowen SUM



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RADIATIVE

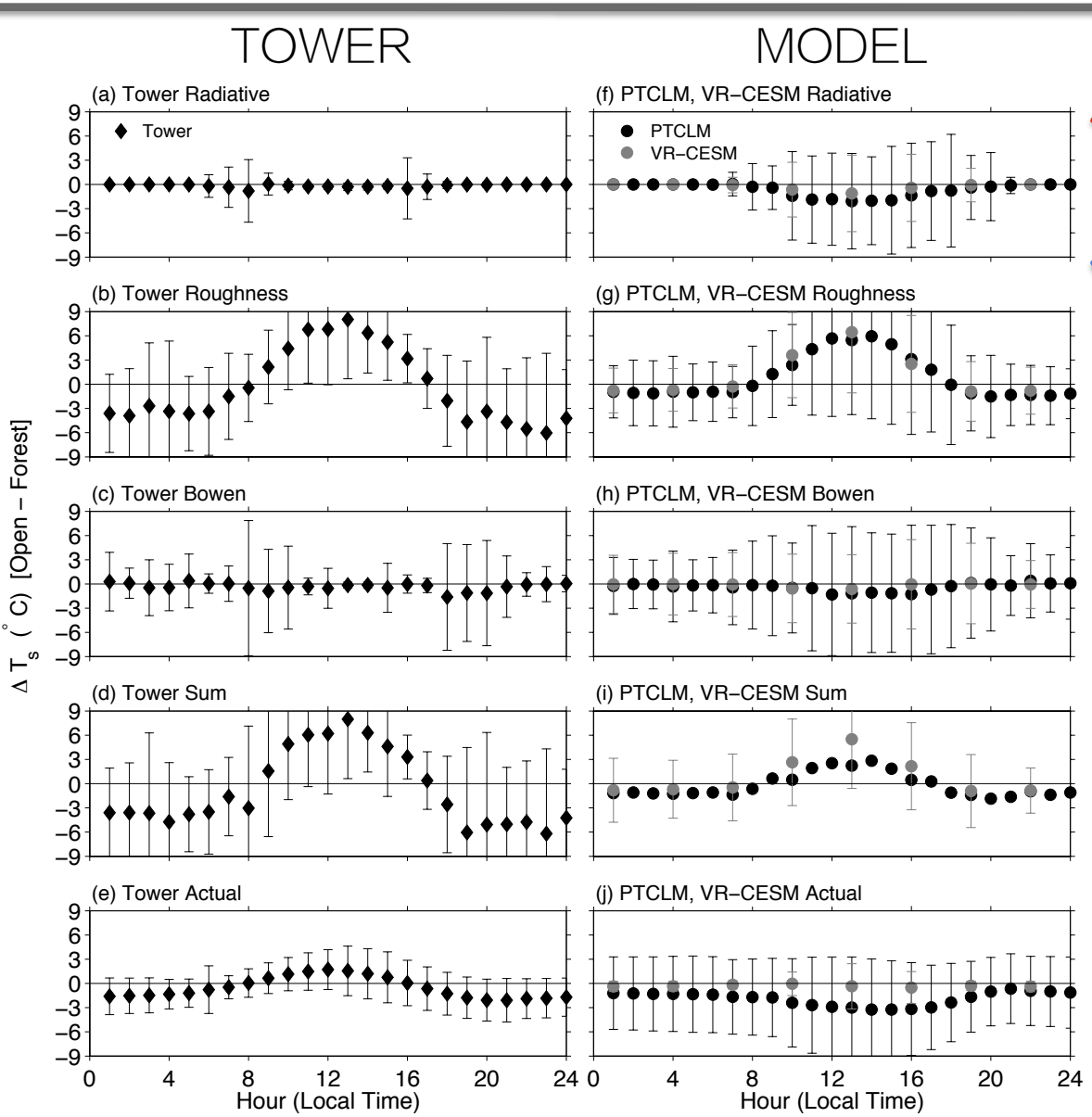
ROUGHNESS

BOWEN

Rad + Rough + Bowen SUM

ACTUAL

$$\Delta T_s \approx \sqrt[4]{\frac{LW_{out}}{\varepsilon\sigma}}$$



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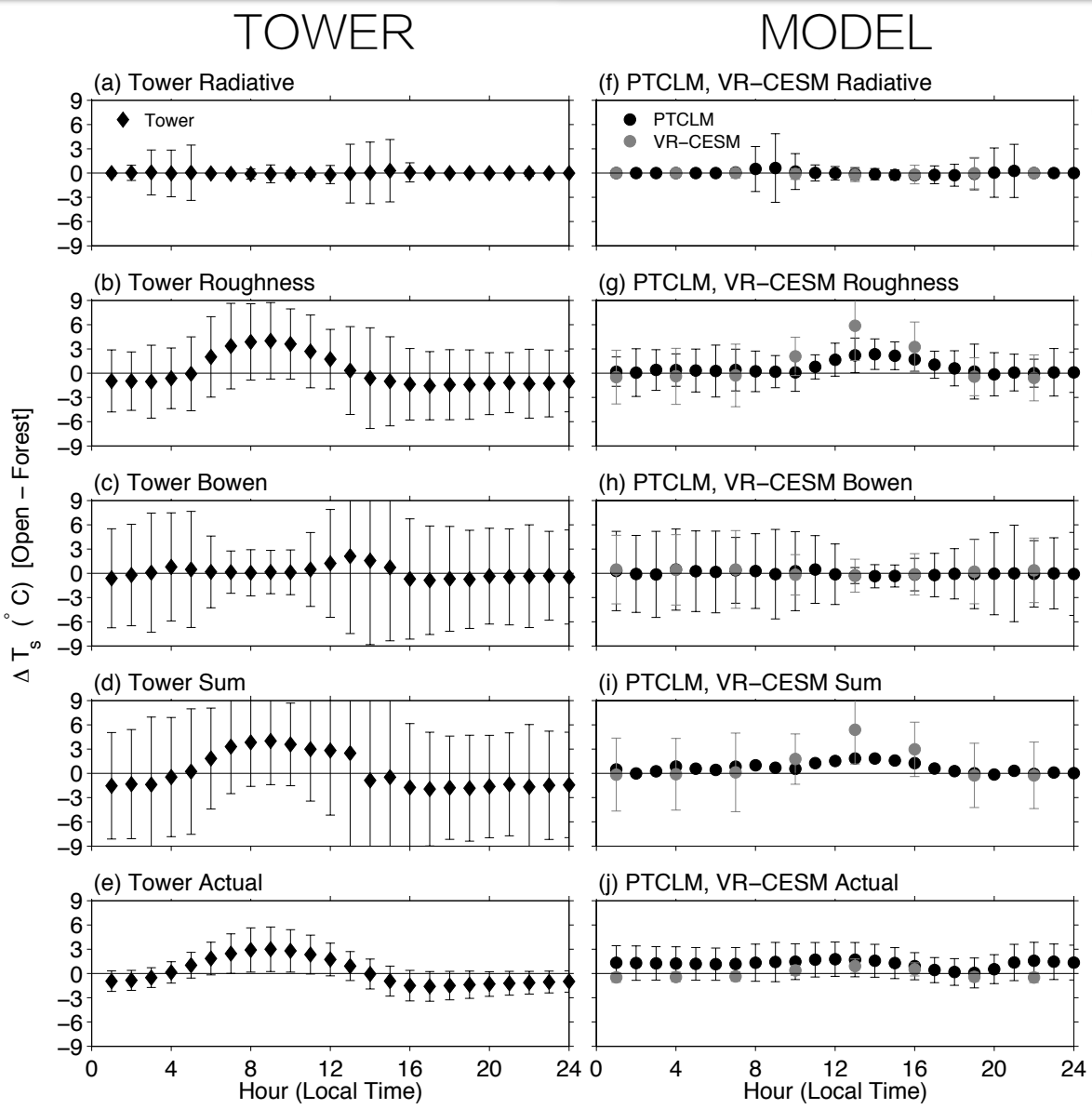


open land warmer

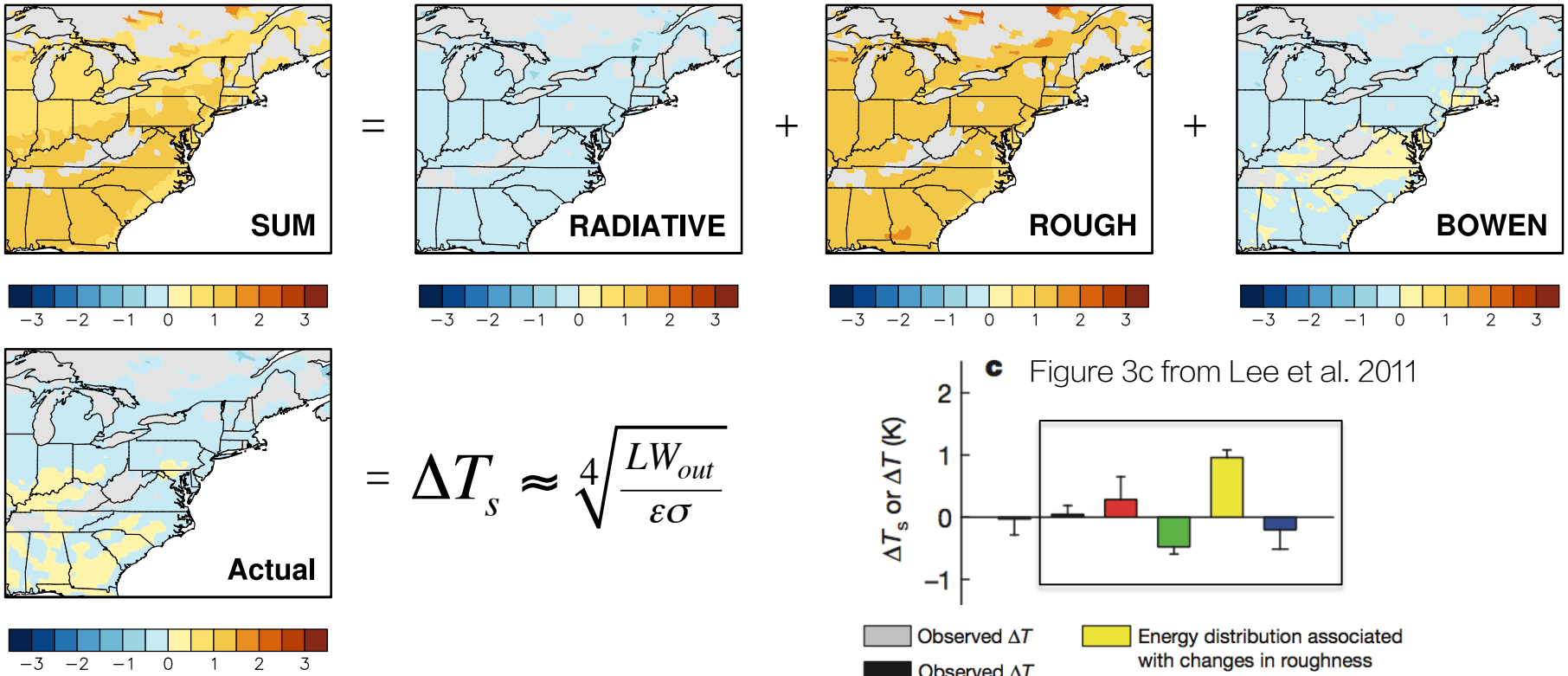
open land cooler

Duke Cluster
Durham, NC

Intrinsic Biophysical Mechanism, Annual: VR-CESM

1979-2008

Roughness is dominant biophysical factor influencing *annual* differences in surface skin temperature in coupled model.



Burakowski et al. *in prep*

Key Findings

- Open land is generally cooler at night, warmer during the day compared to adjacent forest based on tower observations at both sites.
- Modeled biophysical components (radiative, bowen, roughness) similar to tower observations.
- Actual differences in skin temperature not always consistent with sum of intrinsic biophysical factors.

Future Work

- Apply Intrinsic Biophysical Mechanism framework to other biome clusters (boreal, tropical) in PTCLM and VR-CESM
- Evaluate implications of surface roughness on land management
- Assess impacts of warmer climate, reduced snowpack on biophysical factors

Acknowledgements

email: burakows@ucar.edu

National Science Foundation Experimental Program to Stimulate Competitive Research (EPSCoR) Award #1101245

Computing, processing, and data storage provided by the NCAR Computational and Information Systems Laboratory (CISL)

National Aeronautics and Space Administration Terrestrial Ecology Program NNX12AK56G S01

USDA New Hampshire Agricultural Experiment Station