Evaluating Biophysical Impacts of Land Cover in CLM and VR-CESM with Ameriflux Tower Clusters

CESM Land Model Working Group
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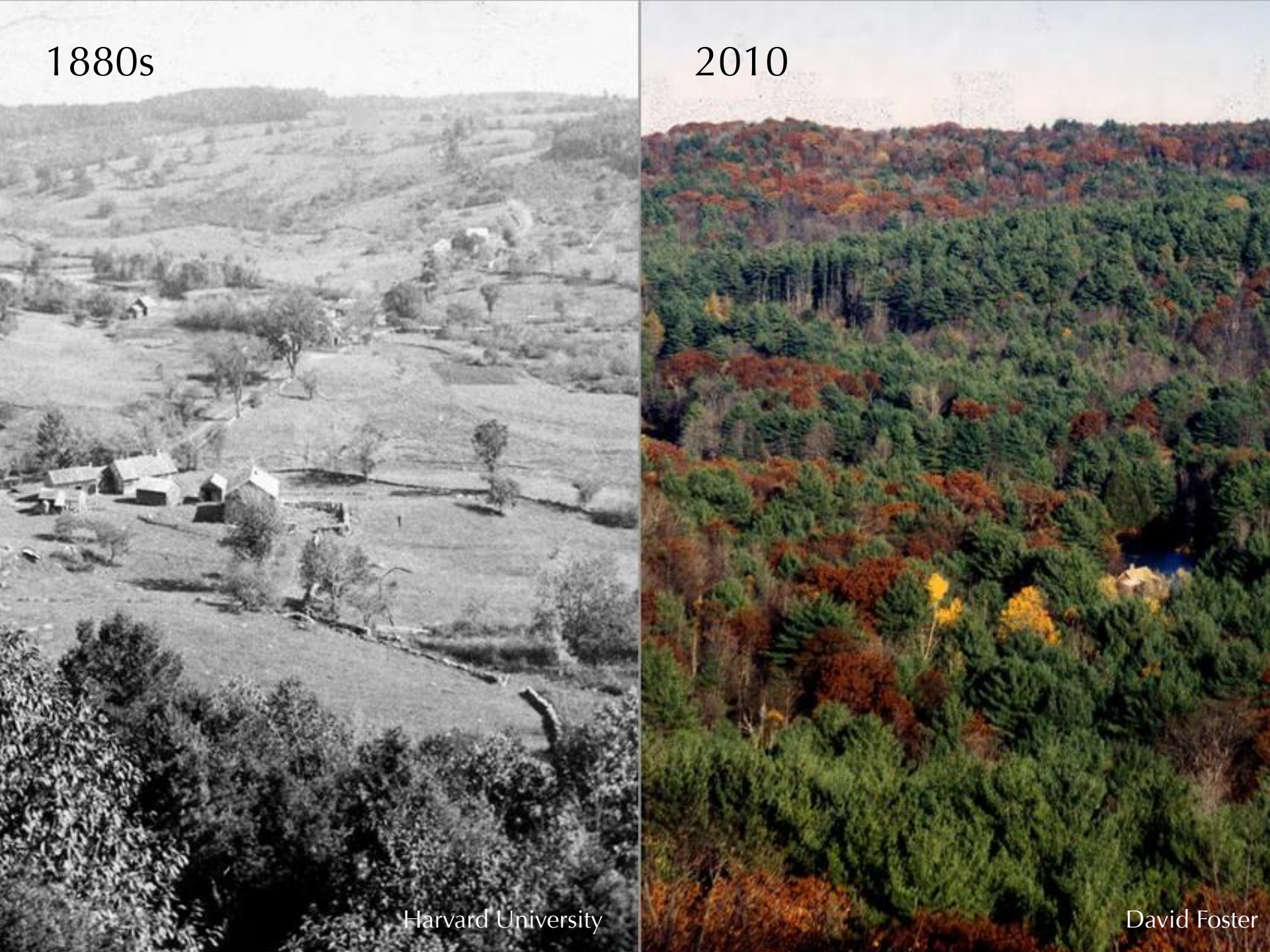
Elizabeth Burakowski, UNH & NCAR
Scott Ollinger, Andrew Ouimette, Lucie Lepine
Gordon Bonan, Ahmed Tawfik, Colin Zarzycki, NCAR
Kim Novick, Indiana University

Photo by David Lutz


1880s
2010
Harvard University
David Foster

Intrinsic Biophysical Factorization

Assume a forest and adjacent open field share same background climate:

$\Delta T_s \approx$ Difference in surface temperature (Open – Forest)

Lee et al. 2011

Intrinsic Biophysical Factorization

Assume a forest and adjacent open field share same background climate:

$$\Delta T_s \approx \frac{\lambda_0}{1+f}\Delta S$$

Radiative forcing due to changes in **ALBEDO**

Lee et al. 2011

Intrinsic Biophysical Factorization

Assume a forest and adjacent open field share same background climate:

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

Radiative forcing due to changes in **ALBEDO**

Energy Redistribution due to changes in **SURFACE ROUGHNESS**

Lee et al. 2011

Intrinsic Biophysical Factorization

Assume a forest and adjacent open field share same background climate:

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

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

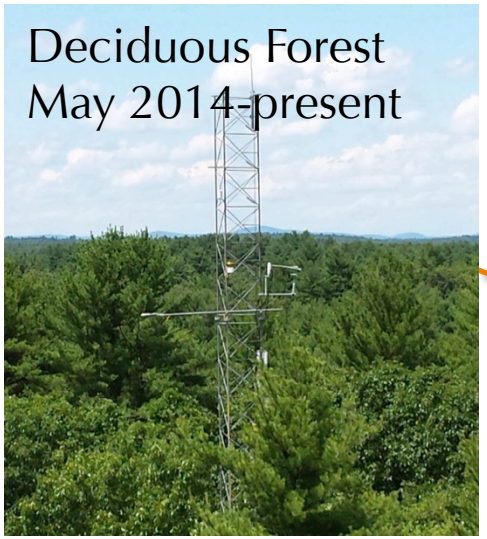
Approach: Eddy Covariance Towers

Eddy Covariance Tower Clusters

- Meteorological forcing
- Turbulent energy fluxes (latent, sensible)
- Radiative fluxes (incoming and outgoing shortwave and longwave)

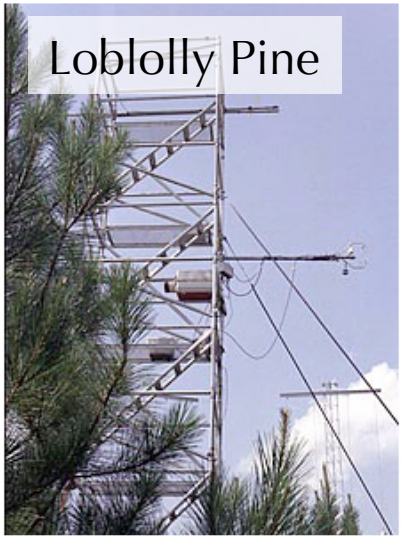
A tale of two Durhams

UNH Tower Cluster, Durham, NH



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

Duke Tower Cluster Durham, NC



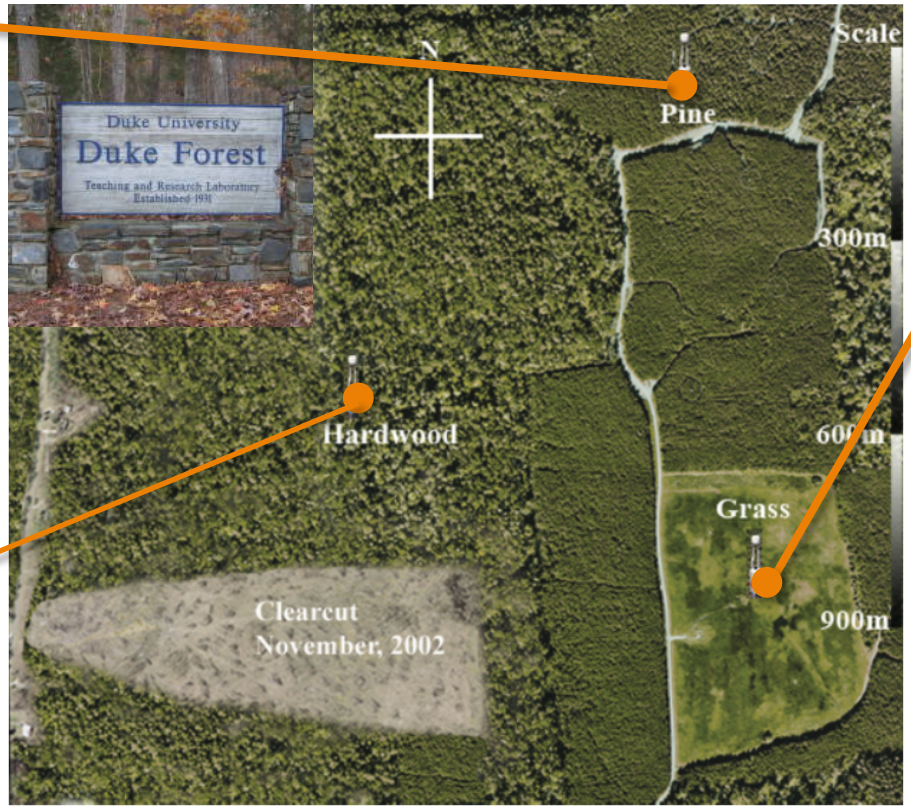
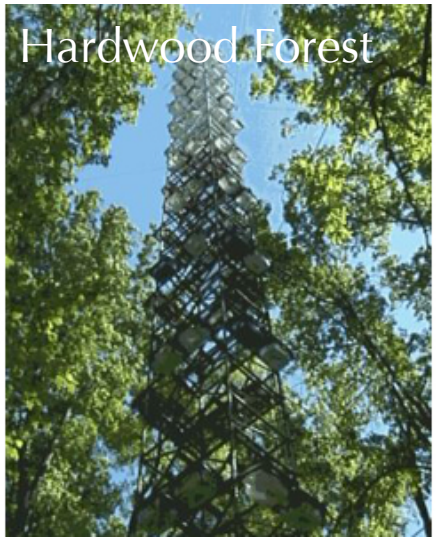


Image from Stoy et al. 2006



- Duke Eddy Covariance Towers

2004-2008 analysis period

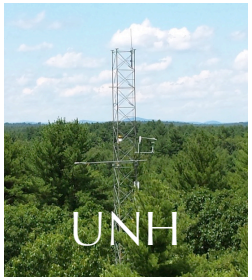
Novick et al., 2015; Juang et al. 2007

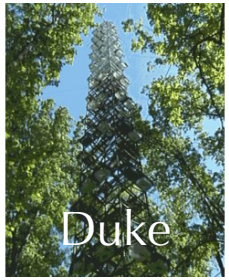
Approach: Point CLM4.5 Simulations

Eddy Covariance Tower Clusters → PTCLM4.5 Land only

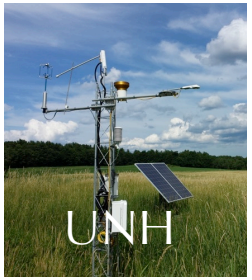
- Forced with tower meteorological data, not coupled to the atmosphere, 35 yr spin up
- Assigned plant functional type:

Broadleaf Deciduous Temperate Forest

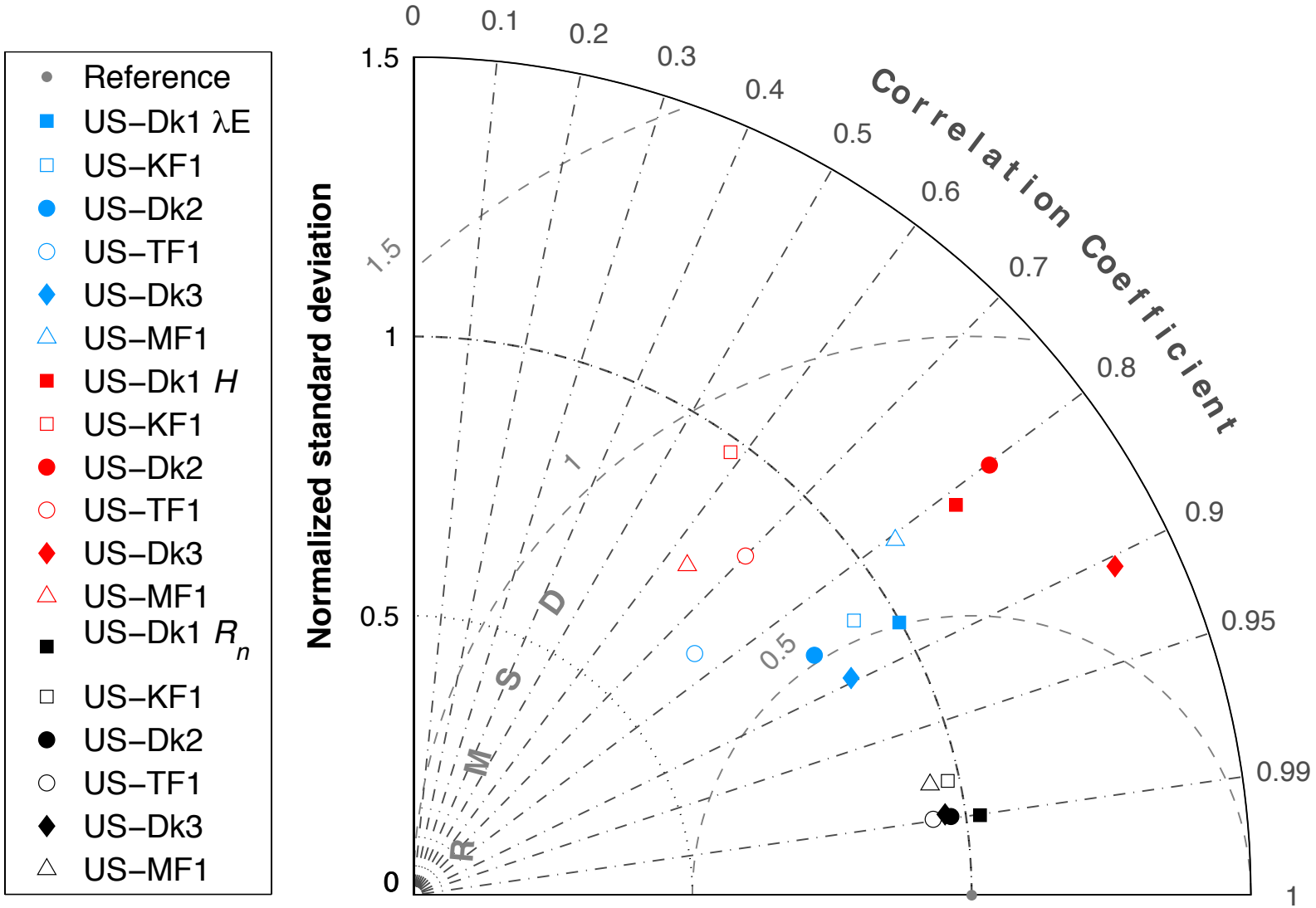




C3 Non-Arctic Grass



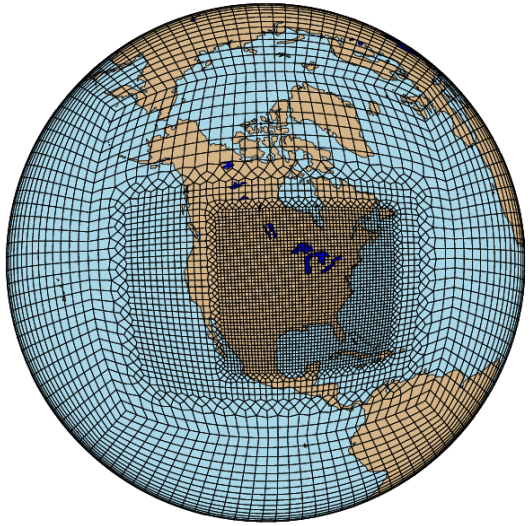
PTCLM4.5 Performance, Turbulent Fluxes and Net Radiation



Approach: Variable Resolution CESM

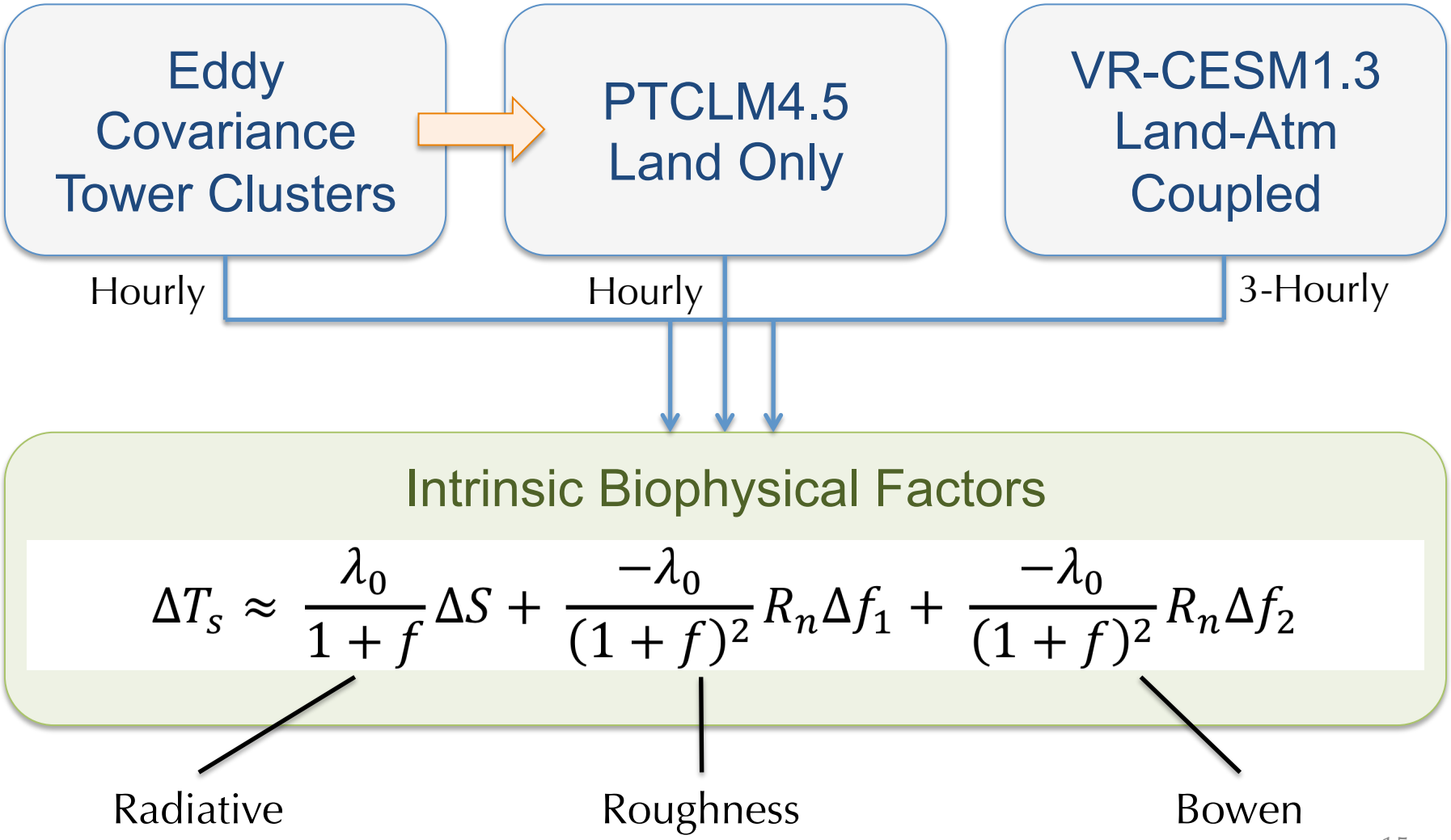
Eddy Covariance Tower Clusters → PTCLM4.5 Land only → VR-CESM1.3 Land-Atm Coupled

- 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



Zarzycki et al. 2015

Approach: Annual, Winter, Summer

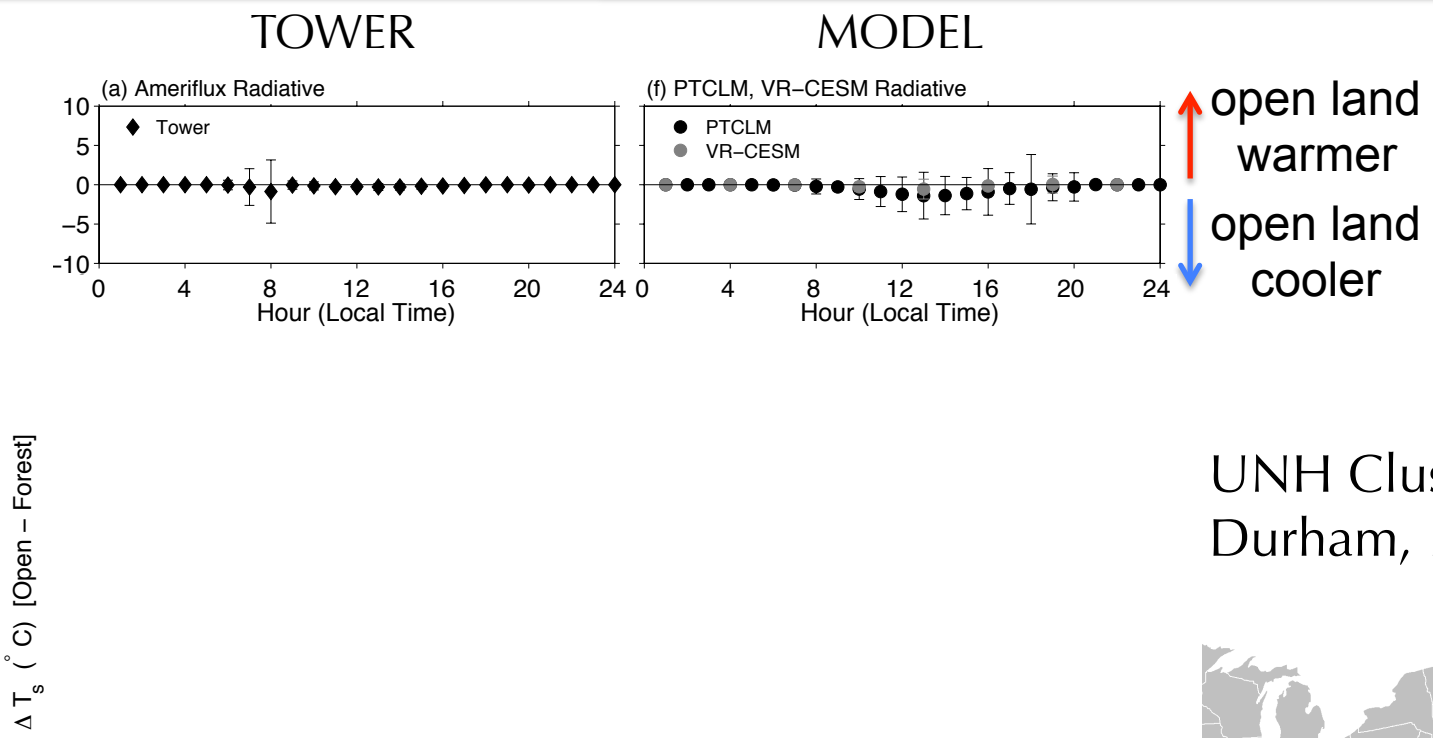


Lee et al. 2011

Intrinsic Biophysical Factors, Annual Open – Forest ΔT_s

Burakowski et al., *in prep*

RADIATIVE



UNH Cluster
Durham, NH

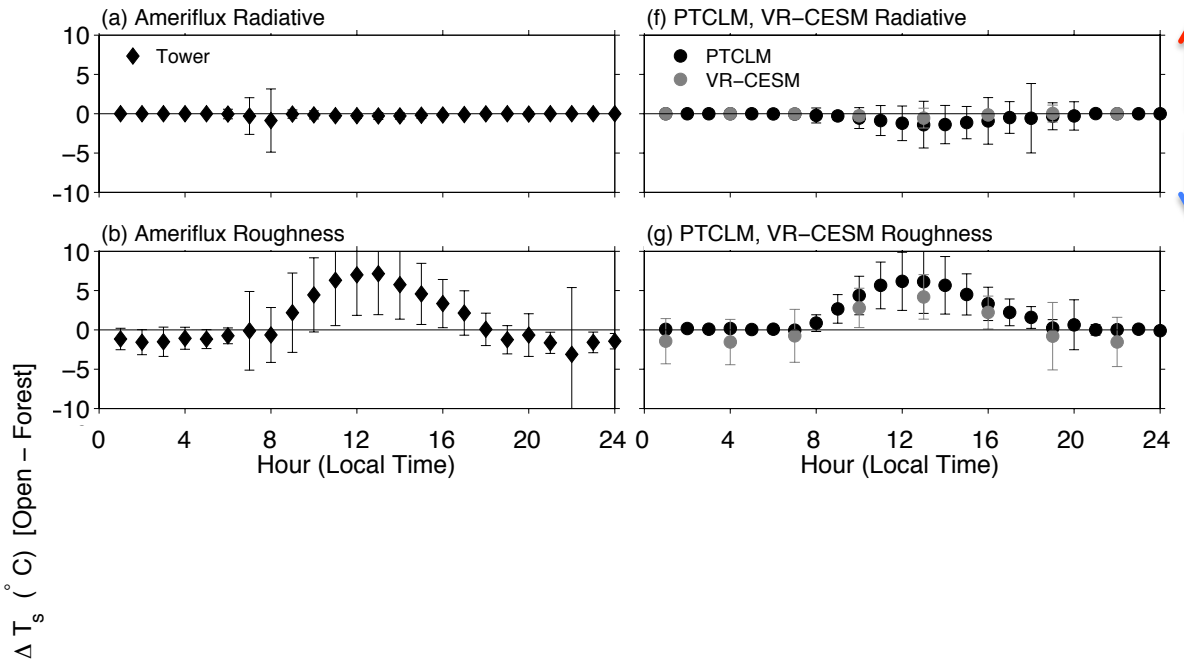
Intrinsic Biophysical Factors, Annual Open – Forest ΔT_s

Burakowski et al., *in prep*

TOWER MODEL

RADIATIVE

ROUGHNESS



open land warmer

open land cooler

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Intrinsic Biophysical Factors, Annual Open – Forest ΔT_s

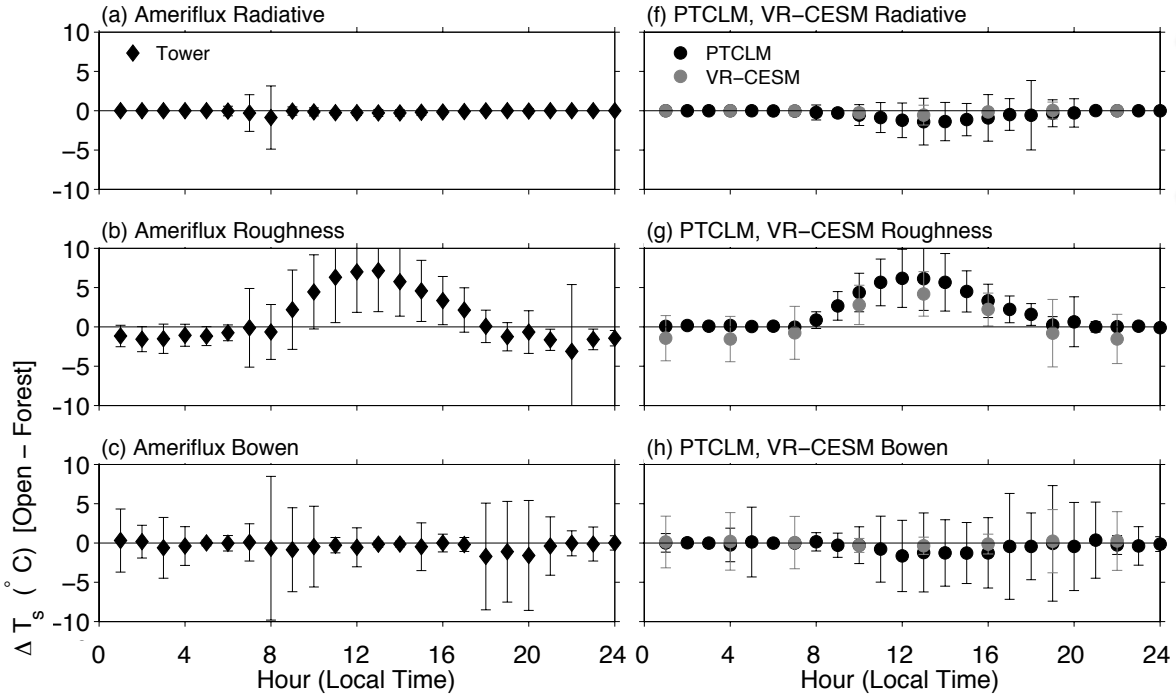
Burakowski et al., *in prep*

TOWER MODEL

RADIATIVE

ROUGHNESS

BOWEN



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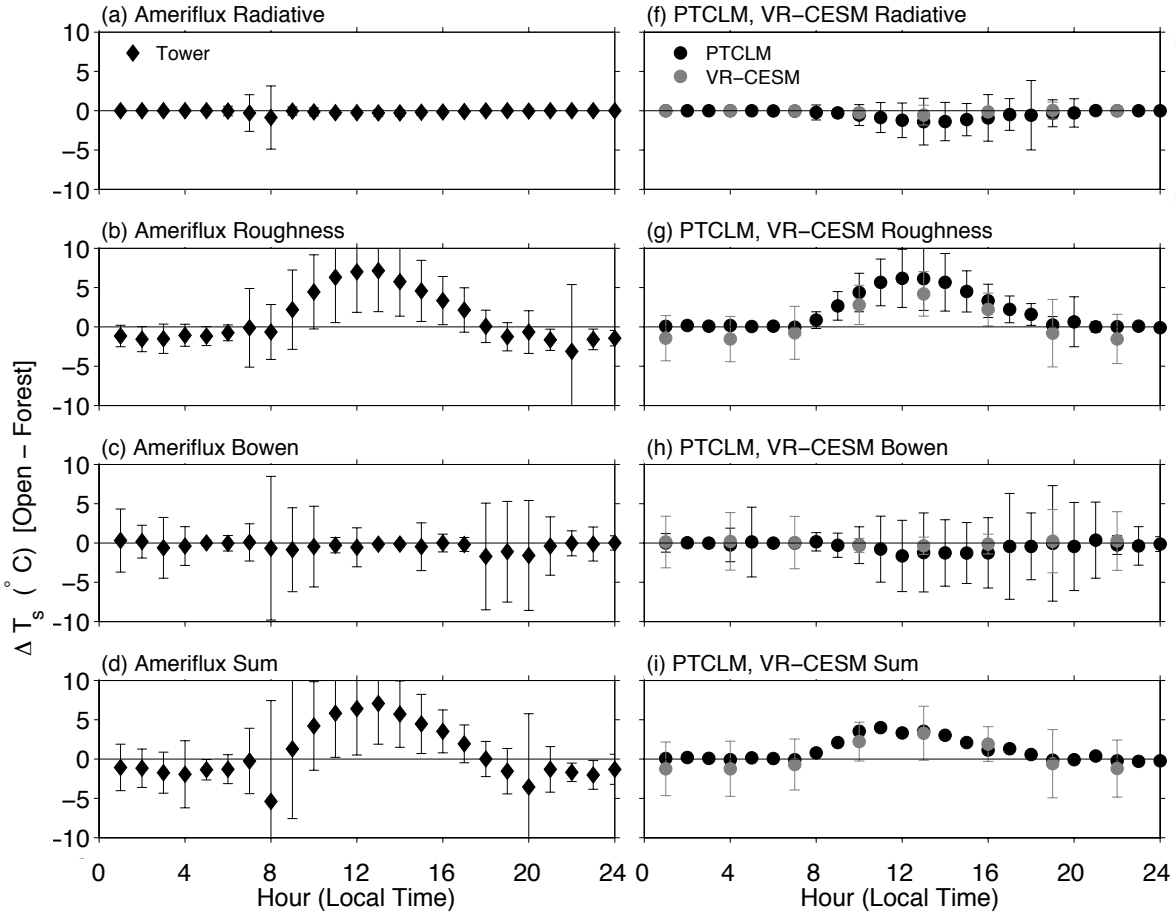
TOWER MODEL

RADIATIVE

ROUGHNESS

BOWEN

Rad + Rough + Bowen SUM



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RADIATIVE

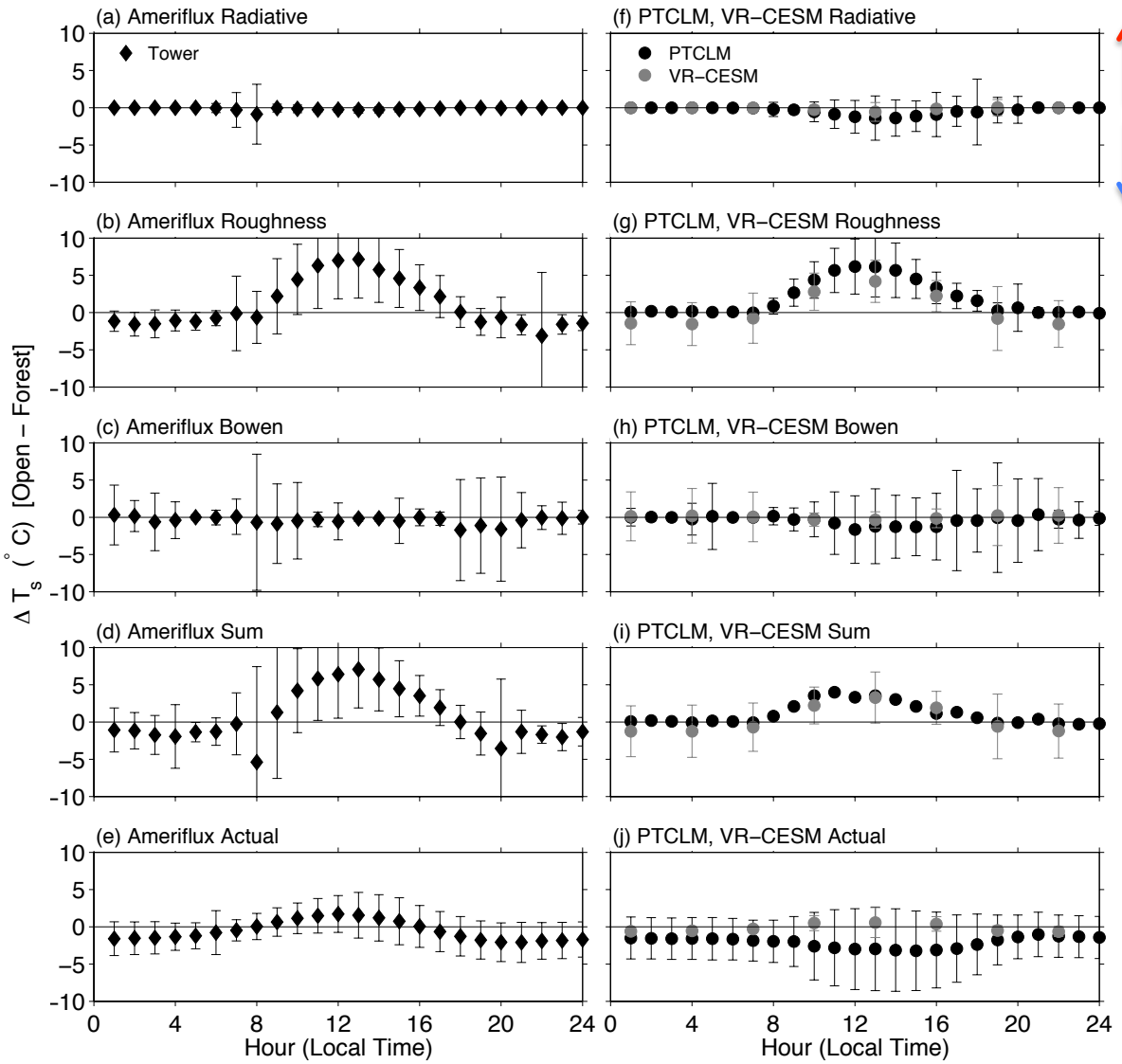
ROUGHNESS

BOWEN

Rad + Rough + Bowen SUM

ACTUAL

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



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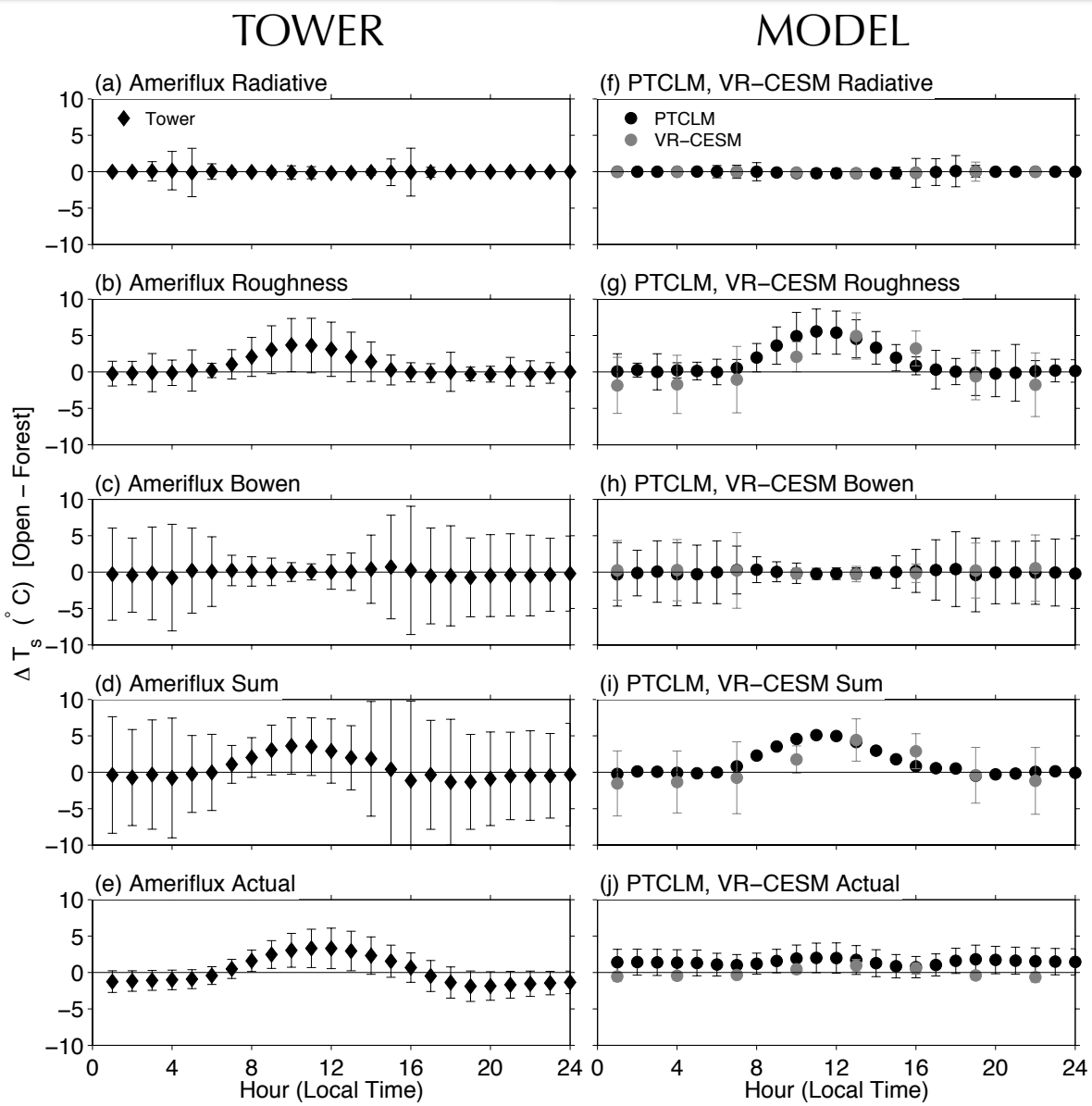


RADIATIVE

ROUGHNESS

BOWEN

Rad + Rough + Bowen

SUM

ACTUAL

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

open land warmer

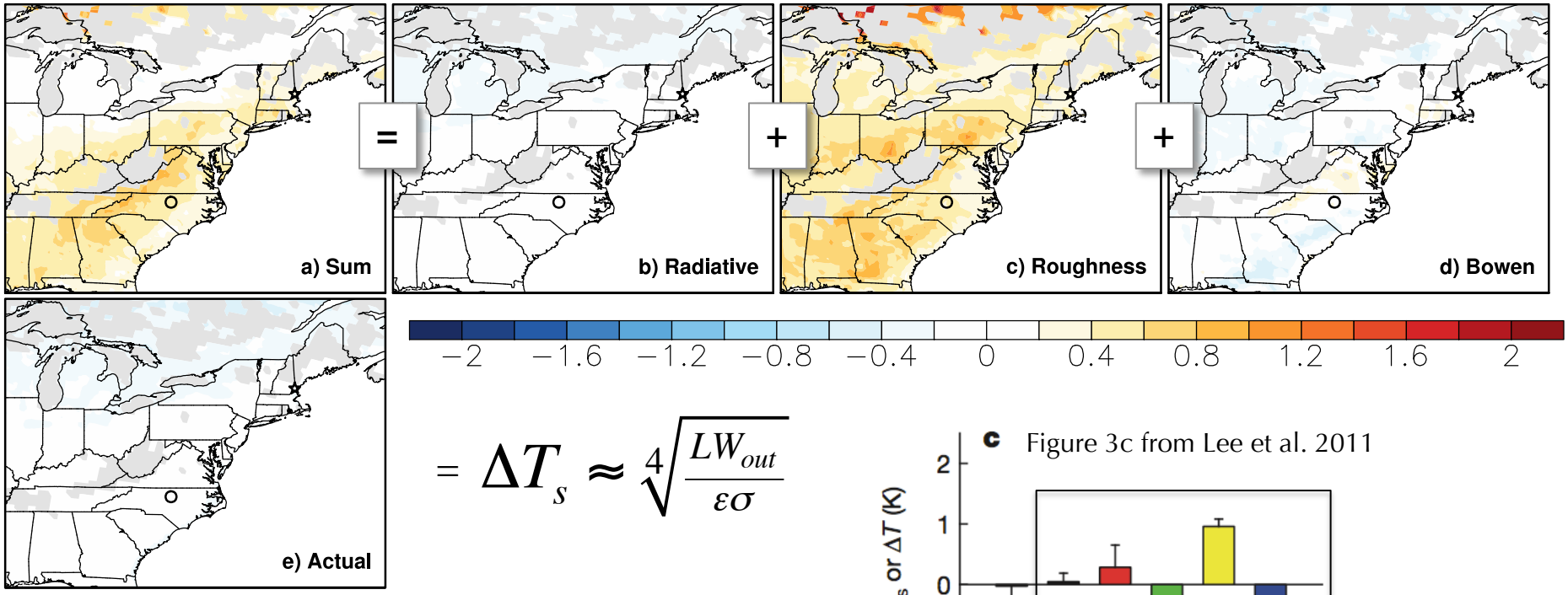
open land cooler

Duke Cluster
Durham, NC

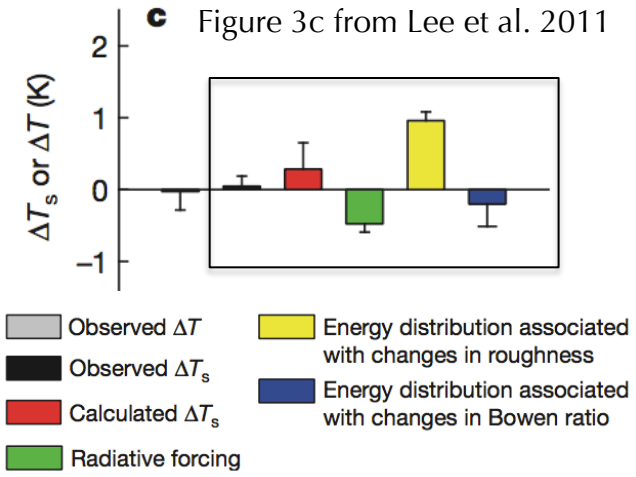
Annual Intrinsic Biophysical Factors VR-CESM1.3

1979-2008

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



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



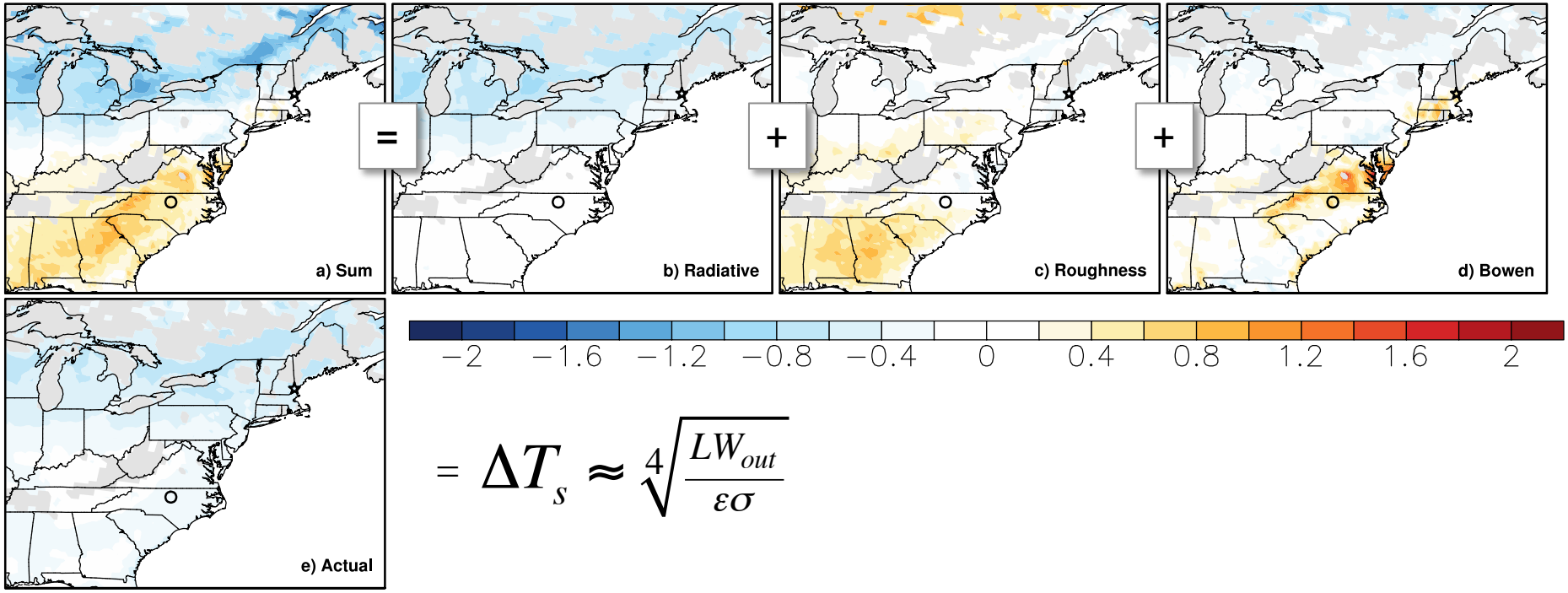
Burakowski et al. *in prep*

Winter Intrinsic Biophysical Factors VR-CESM1.3

1979-2008

Roughness is dominates in south

Albedo dominates in north.



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

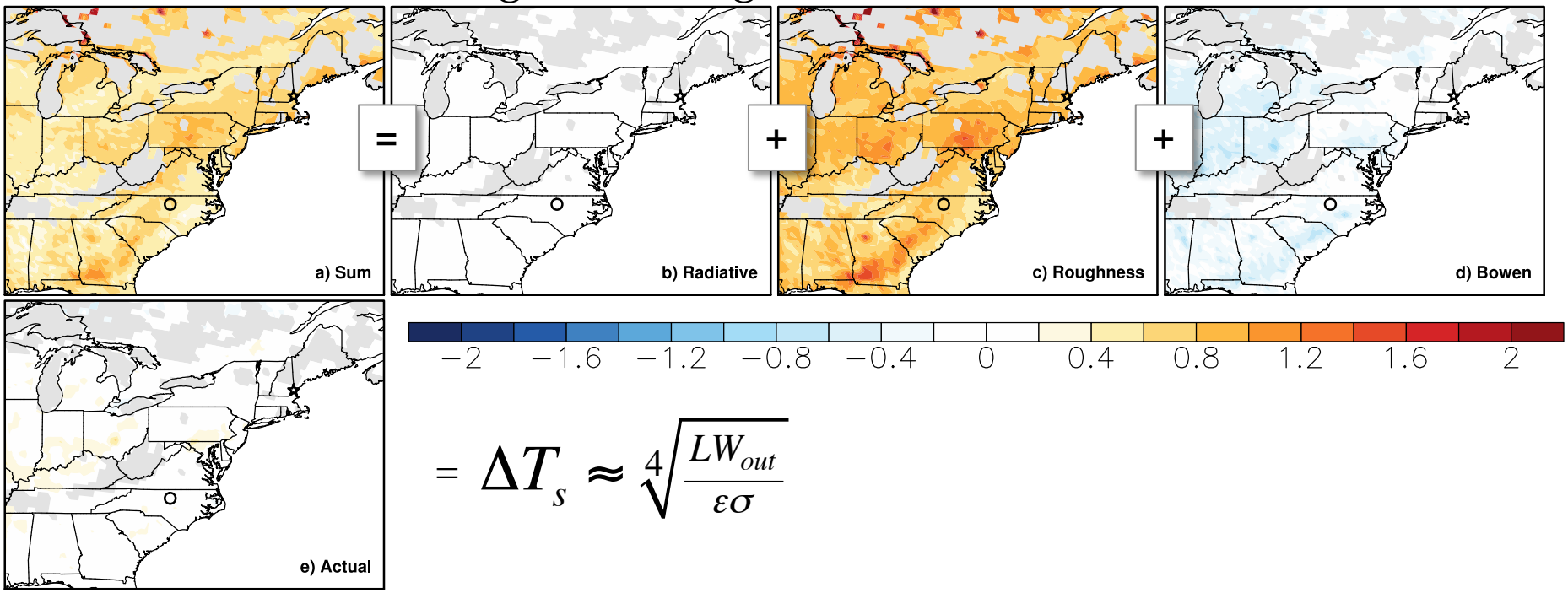
Burakowski et al. *in prep*

Summer Intrinsic Biophysical Factors VR-CESM1.3

1979-2008

Roughness dominates eastern US.

Bowen results in slight cooling.



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

Burakowski et al. *in prep*

Key Findings

- Open land generally cooler at night, warmer during day
- 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

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email: burakows@ucar.edu

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