The role of planetary boundary layer height in coupled model benchmarking

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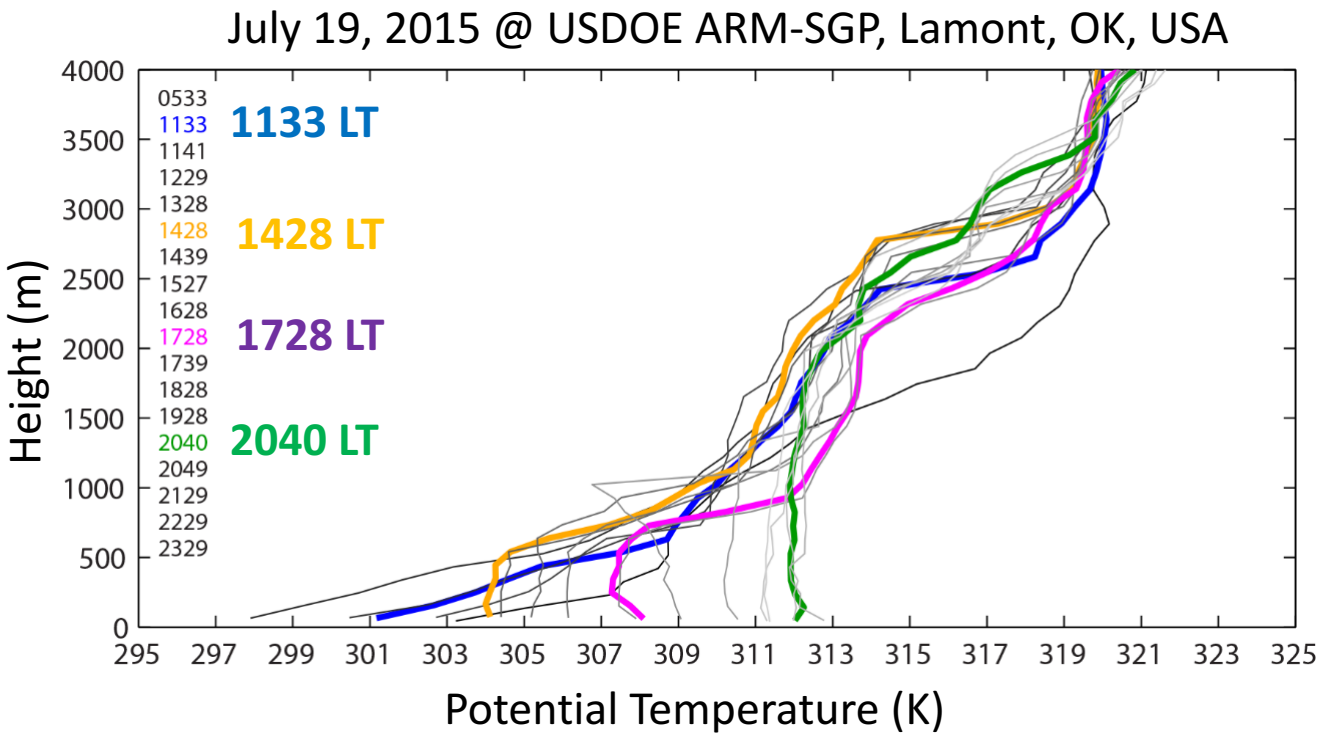


Motivations: Bottom Line First

PBLh evolution (and $PBLh_{max}$) is critical to representing the proper diurnal cycle over land, and the relative contribution of local vs. remote forcing.

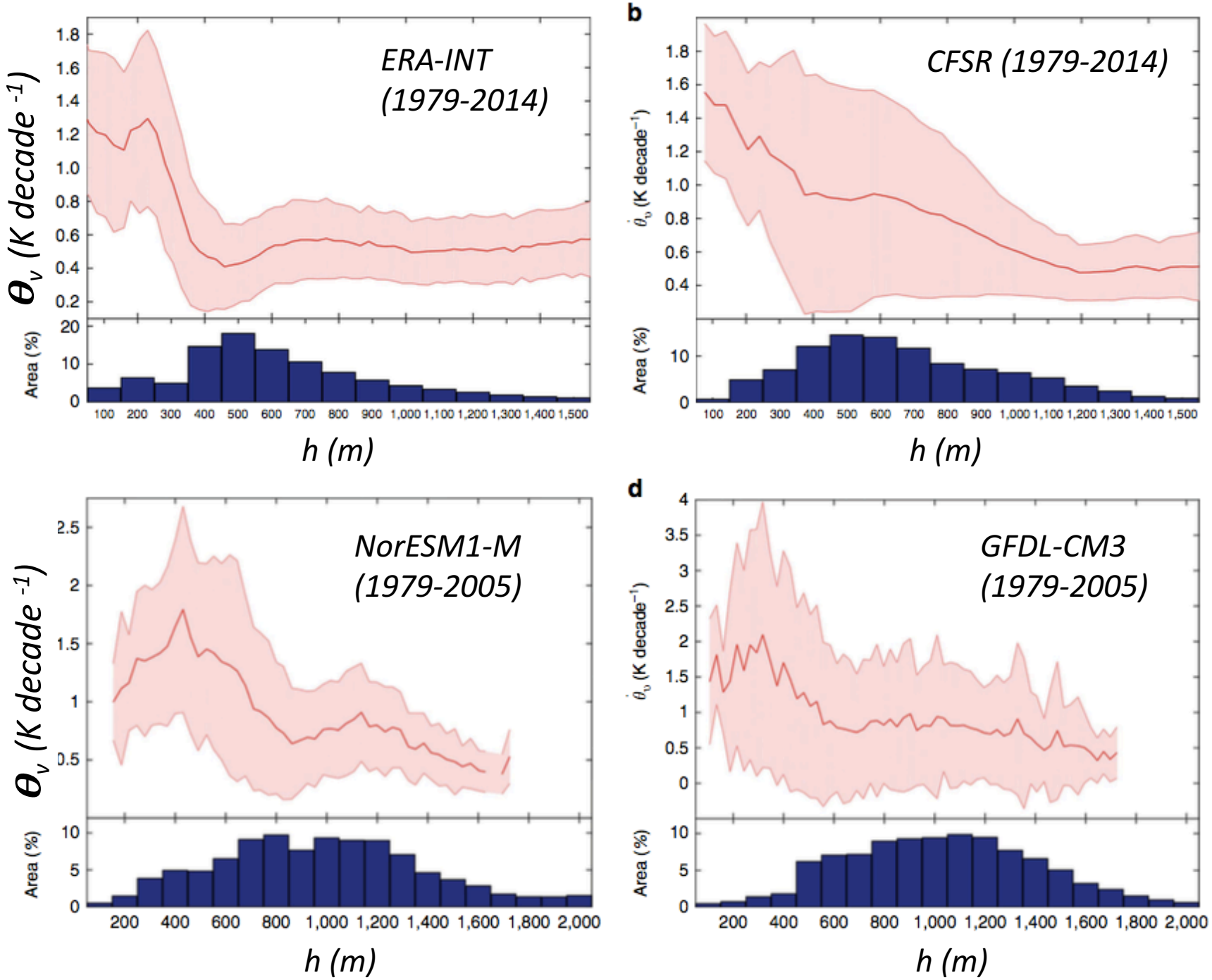
It is a prime candidate variable for ESM evaluation.

And it is designated as an “incubator” variable in the U.S. Natl. Academies Decadal Survey for Earth Science.

Motivations: Bottom Line First

Projected warming rates vary by PBLh

(*Davy and Esau,* 2016)



Motivations: Bottom Line First

Surprisingly,

(1) Community consensus/guidance on PBLh estimation is lacking

(2) Limited PBLh observational verification data exists (esp. outside of grasslands of Lamont, OK, USA, Cabauw, Netherlands, and 00/12UTC raobs)

(3) The spatio-temporal-accuracy requirements of a spaceborne PBLh sensor to improve weather/climate prediction are poorly defined

Accurate PBLh Evolution is Critical to WCRP/GEWEX

1.

WCRP World Climate Research Programme

Melting Ice and Consequences

Clouds, Circulation and Climate Sensitivity

Sea Level Rise

GEWEX

Water for the Food Baskets of the World

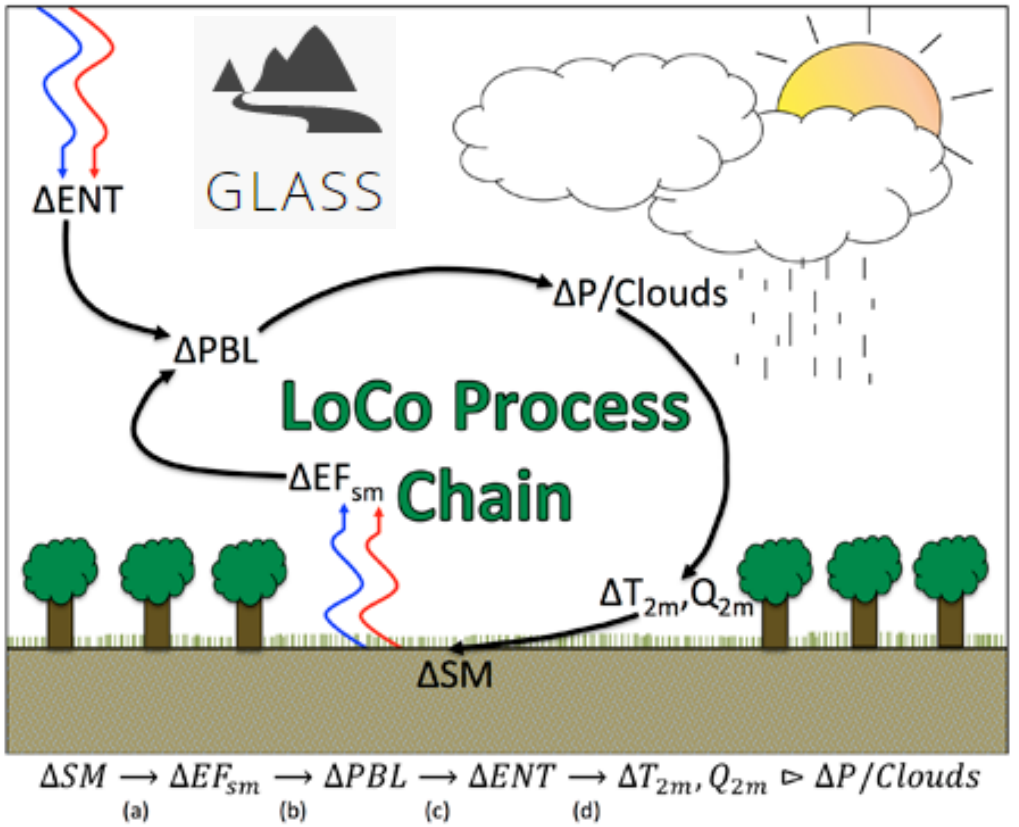
GHP

Weather and Extremes

Carbon Feedbacks

Near-Term Climate Prediction

2.

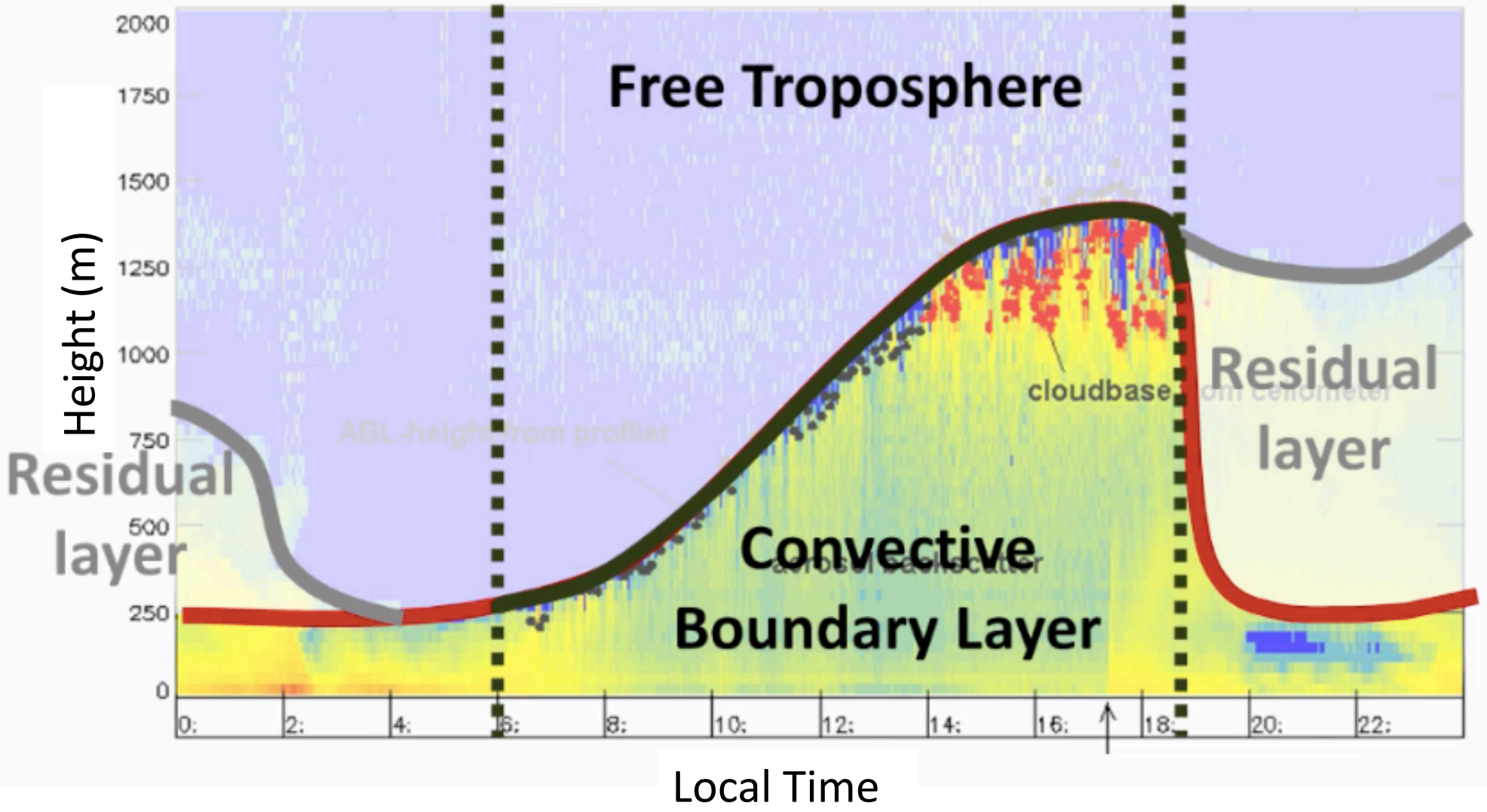


3.

RHPs: U.S. and HyMeX/LIAISE *(Land surface Interactions with the Atmosphere over the Iberian Semi-arid Environment)*

PBL realism dictates: (1) ability to model/forecast LULC modification (incl. deforestation and irrigation) impacts on weather, local climate, and the regional water cycle, (2) efficacy of land data assimilation , (3) heat wave forecast skill, etc.

Diurnal cycle: a simple case

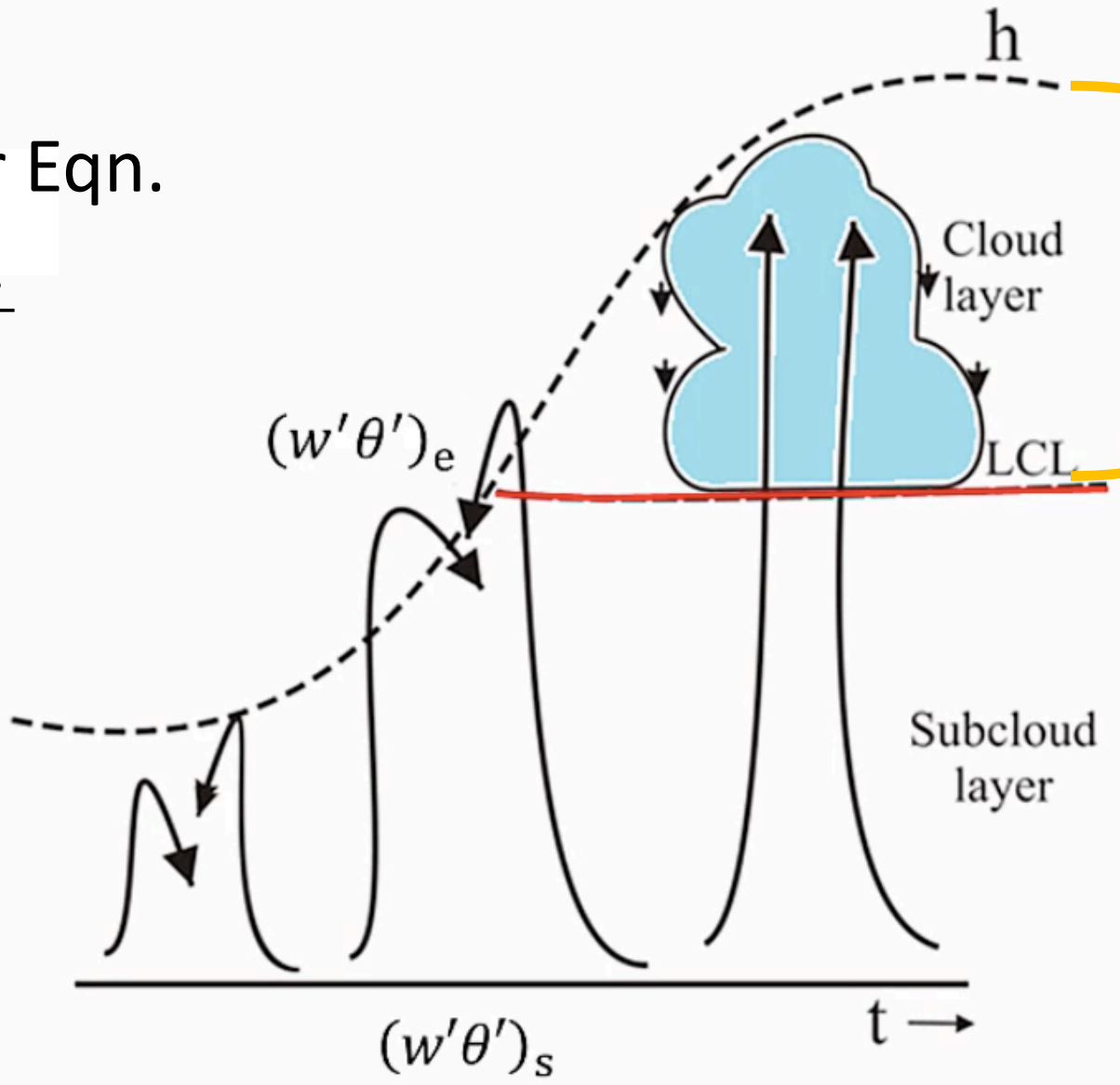


Courtesy: Jordi Vilà-Guerau de Arellano

Cloud Formation Process Schematic

Mixed-layer Eqn.

$$\frac{\partial \theta}{\partial t} = \frac{w'\theta'_s - w'\theta'_e}{h}$$



GLASS

Local Coupling (LoCo) metric: LCL Deficit (LCLh-PBLh)

Courtesy: Jordi Vilà-Guerau de Arellano

PBLh in the real world

2015 USDOE-ARM-SGP Enhanced Soundings for Local Coupling Studies Field Campaign (Oklahoma, USA)

On 12 IOP days:
daytime 1-hourly radiosondes with
10-minute 'trailer' radiosondes
every 3-h

Science Questions:

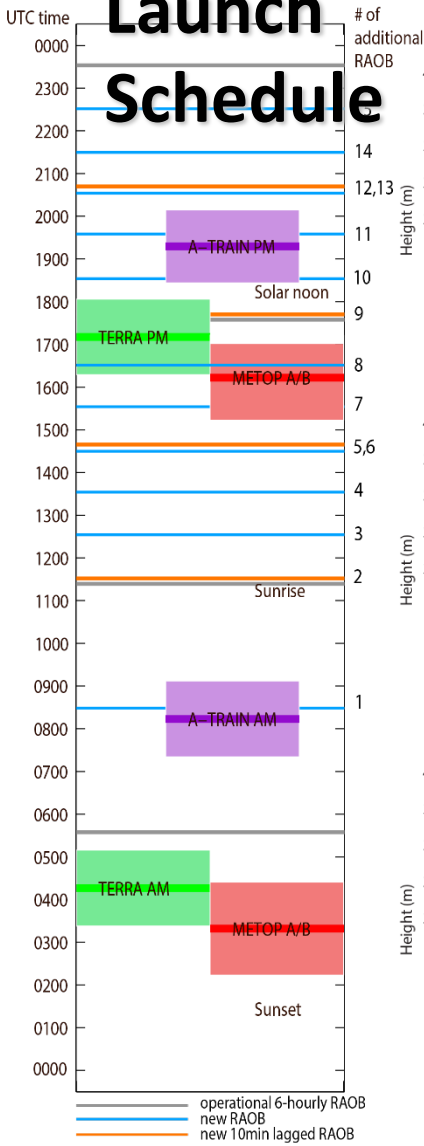
1. How well does the existing suite of instruments at ARM-SGP capture land-atmosphere interactions (in space and time)?(Gap Analysis)

2. Can we forecast local land-induced convective triggering/ afternoon peak rainfall?

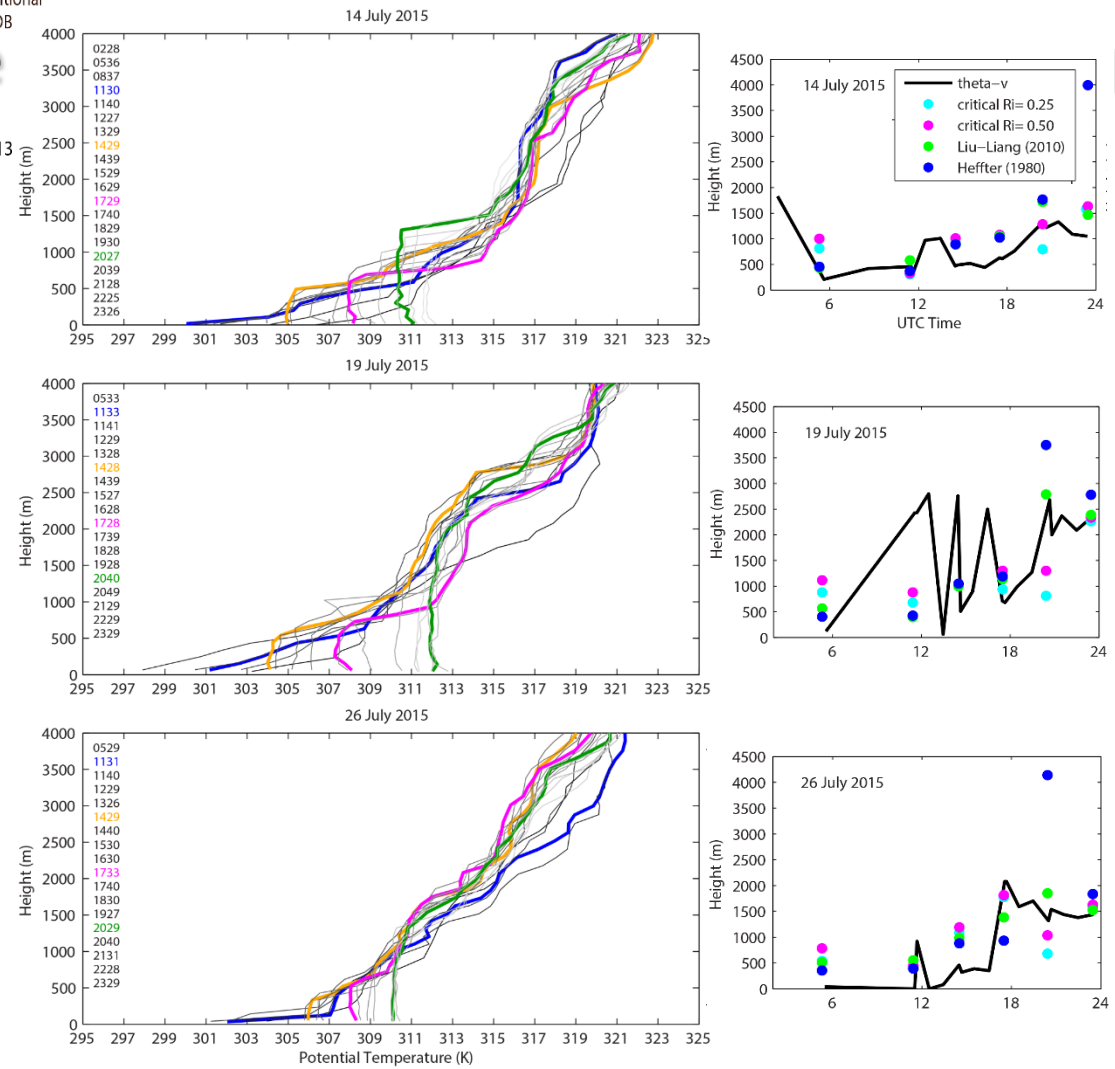
IOP Overview

Ferguson CR, JA Santanello, and P Gentine. 2016. Enhanced Soundings for Local Coupling Studies Field Campaign Report. Ed. by Robert Stafford, DOE ARM Climate Research Facility. *DOE/SC-ARM-16-023.*

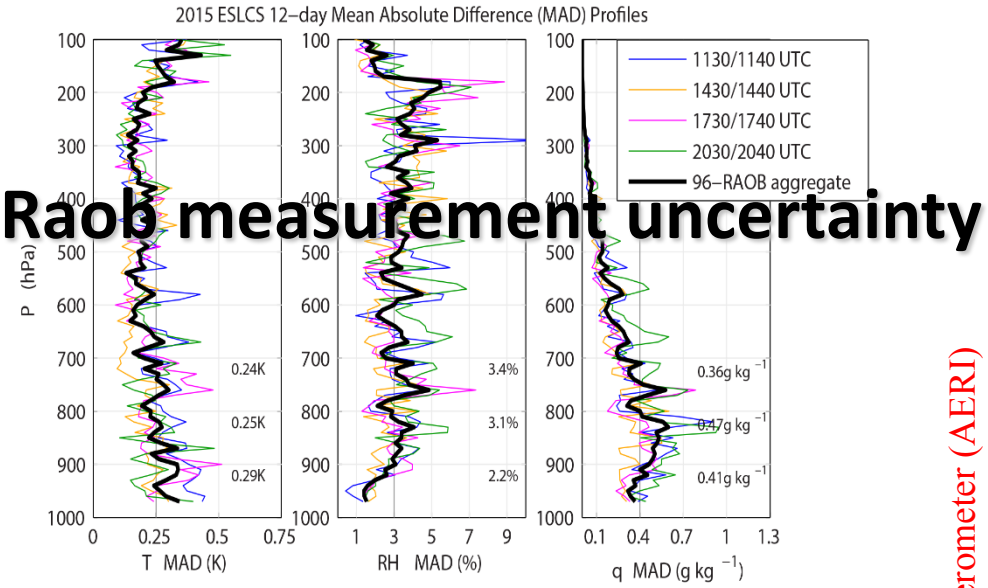
Launch Schedule



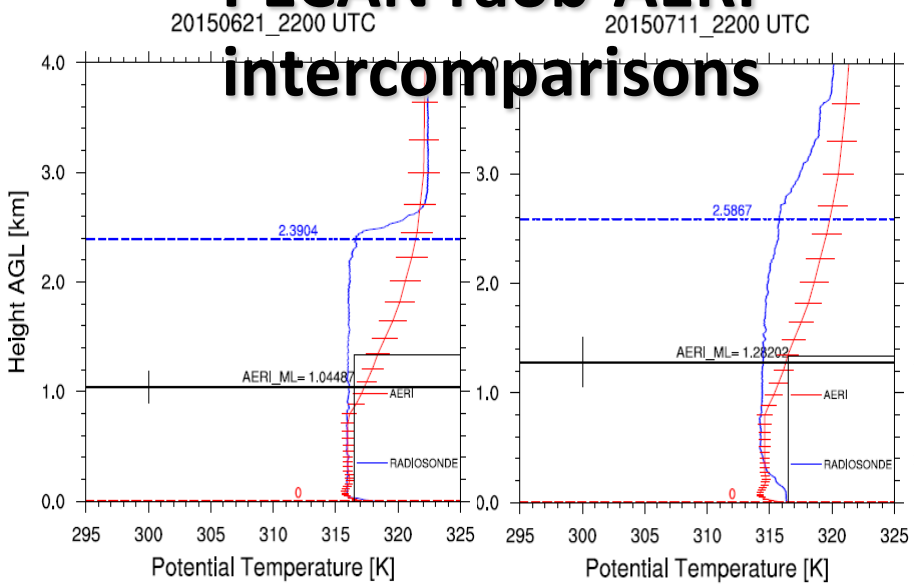
PBLh estimation uncertainty



Raob measurement uncertainty



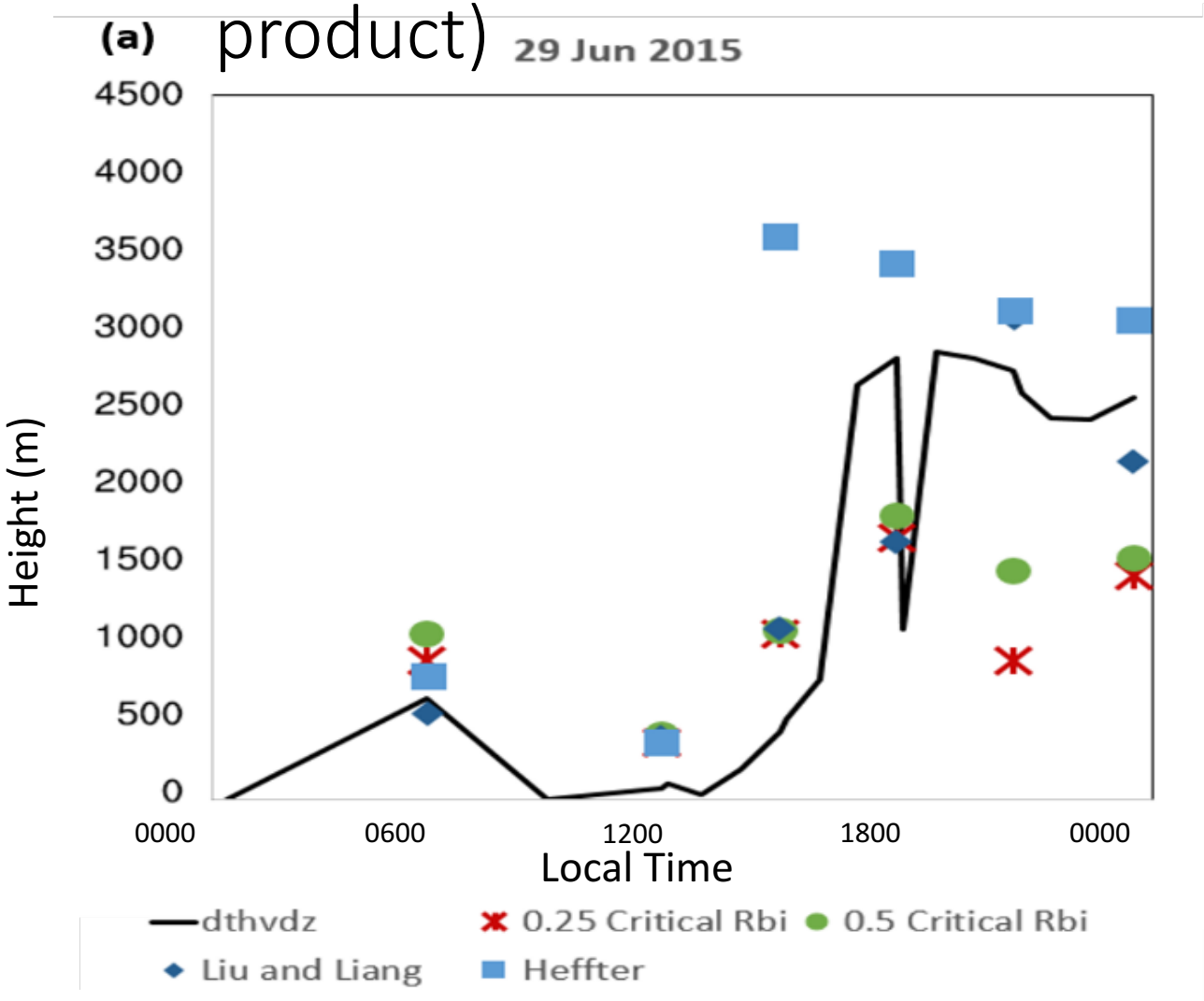
PECAN raob-AERI intercomparisons



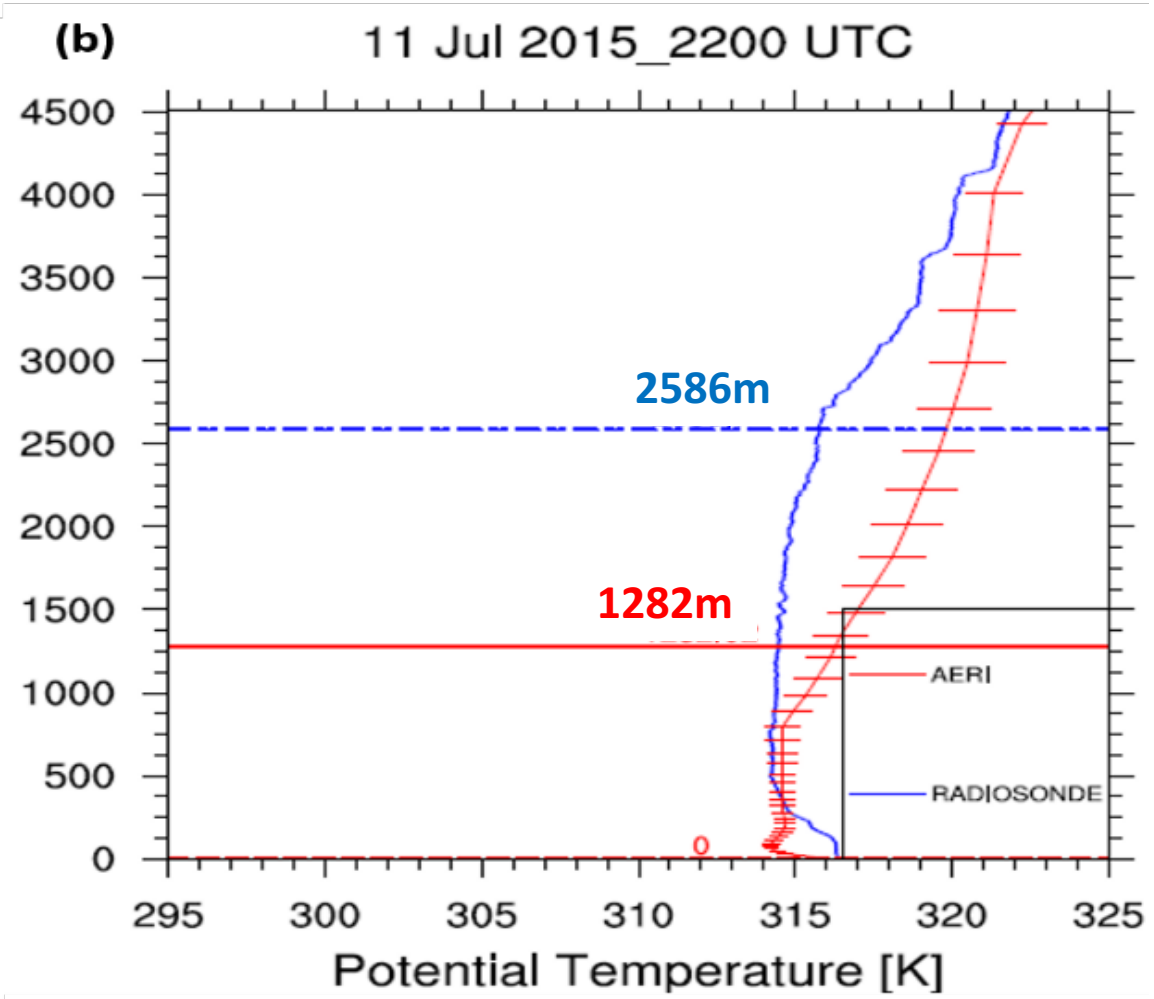
Radiosonde
Atmospheric Emitted Radiance Interferometer (AERI)

IOP Highlight: PBLh estimation

ARM PBLh VAP (value-added product)

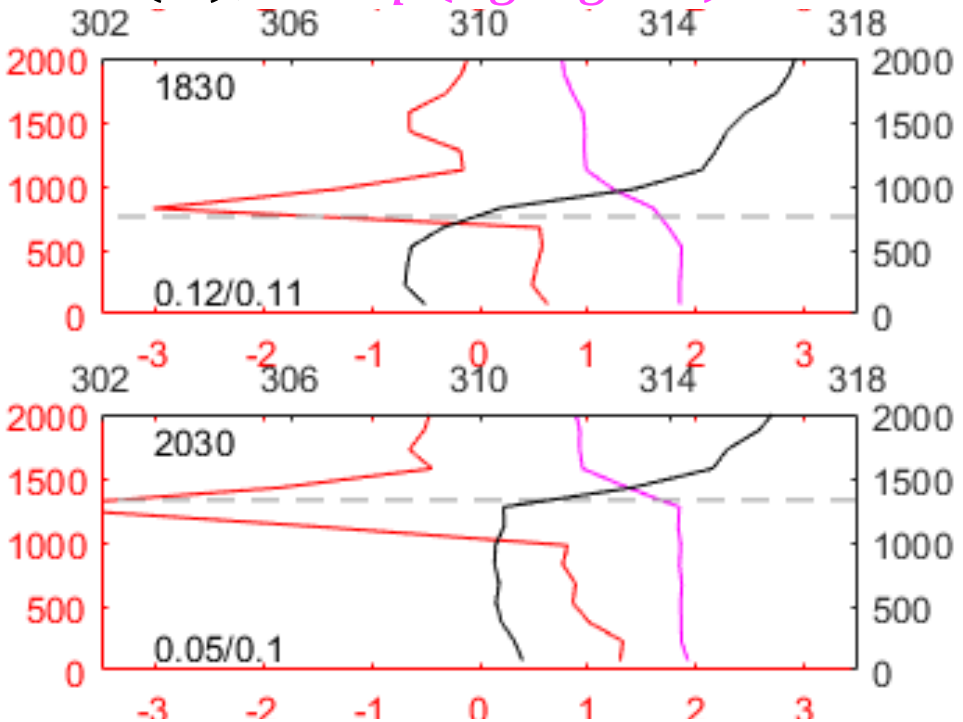


AERI vs. RAOB

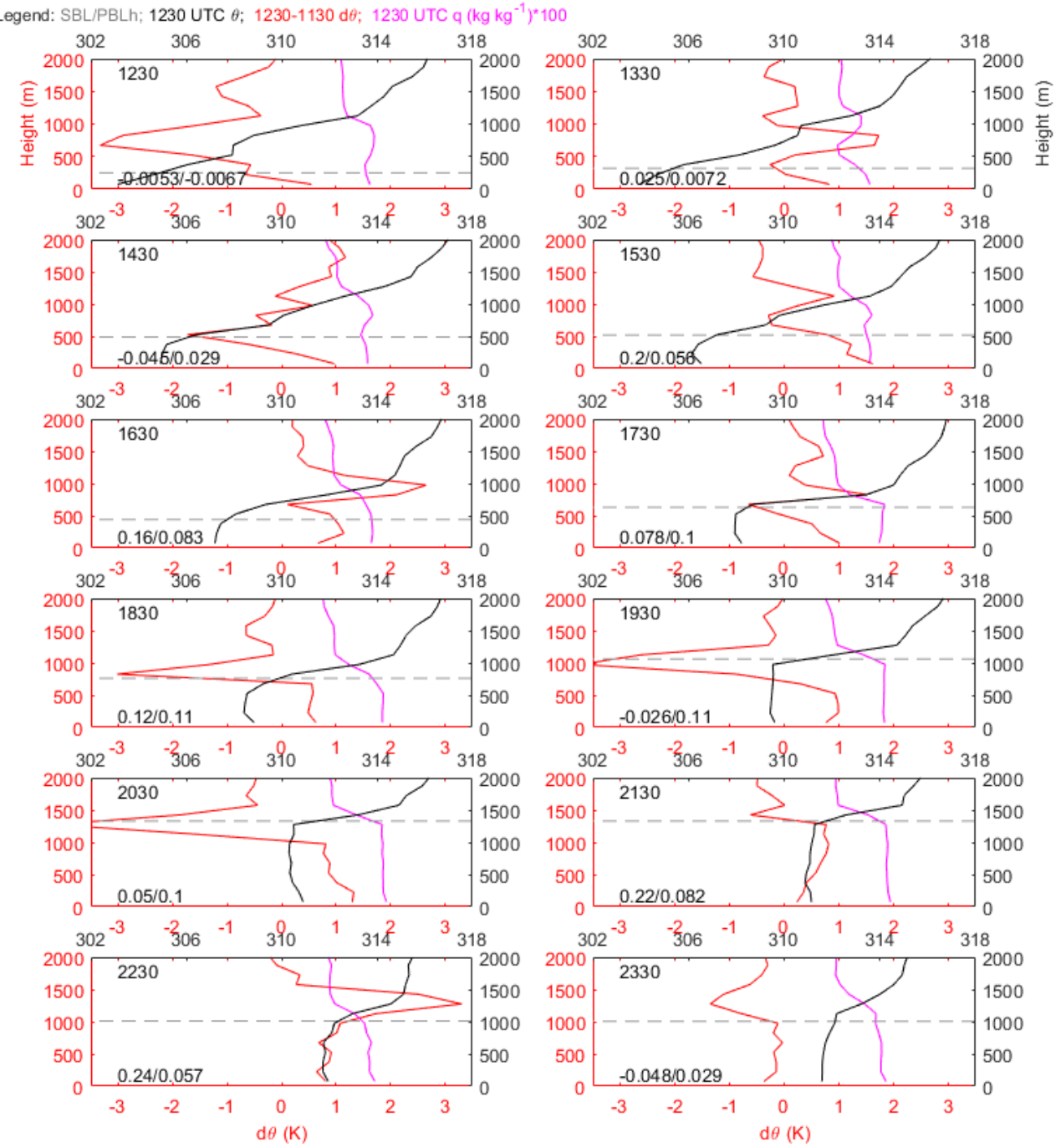


Entrainment Flux (PBLh) Estimation

$\theta\ (K)$, $q\ (kg\ kg^{-1}) * 100$

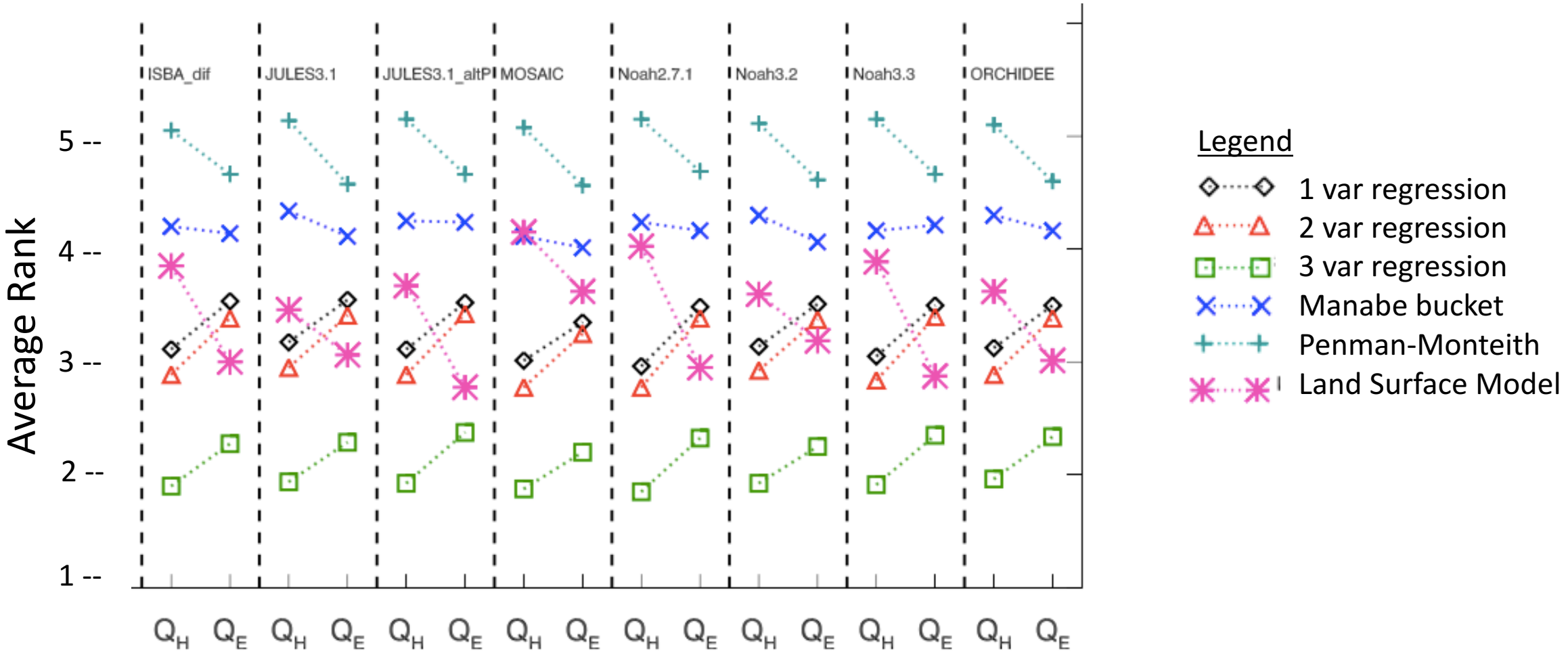


$1930 - 1830\ d\theta\ (K)(top)$;
$2130 - 2030\ d\theta\ (K)$

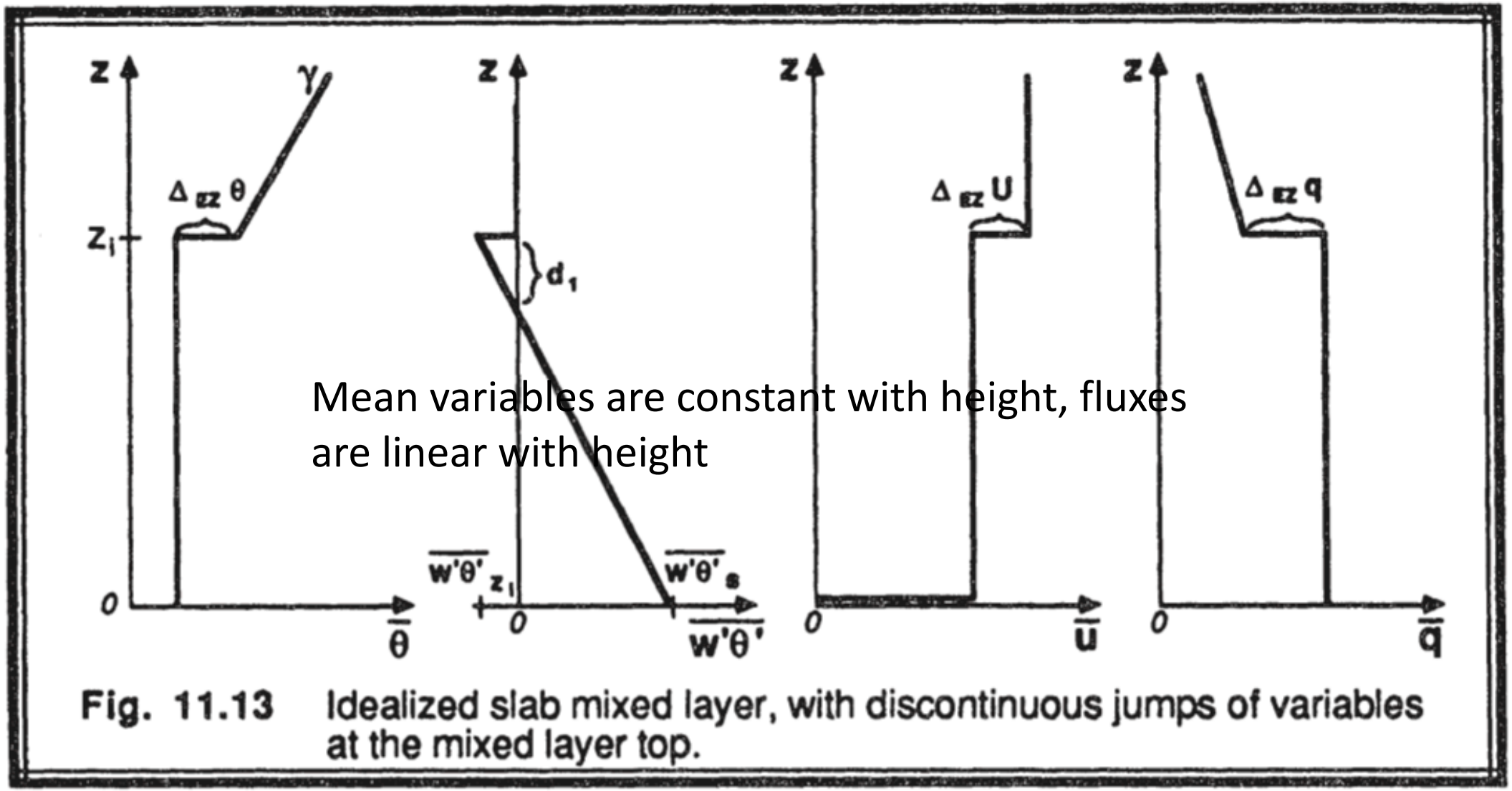


PBLh compliment to PLUMBER?

Protocol for the Analysis of Land Surface Models (PALS) Land Surface Model Benchmarking Evaluation Project (PLUMBER; *Best et al. 2015*)



Benchmark with a simple jump model



Mean variables are constant with height, fluxes are linear with height

Fig. 11.13 Idealized slab mixed layer, with discontinuous jumps of variables at the mixed layer top.

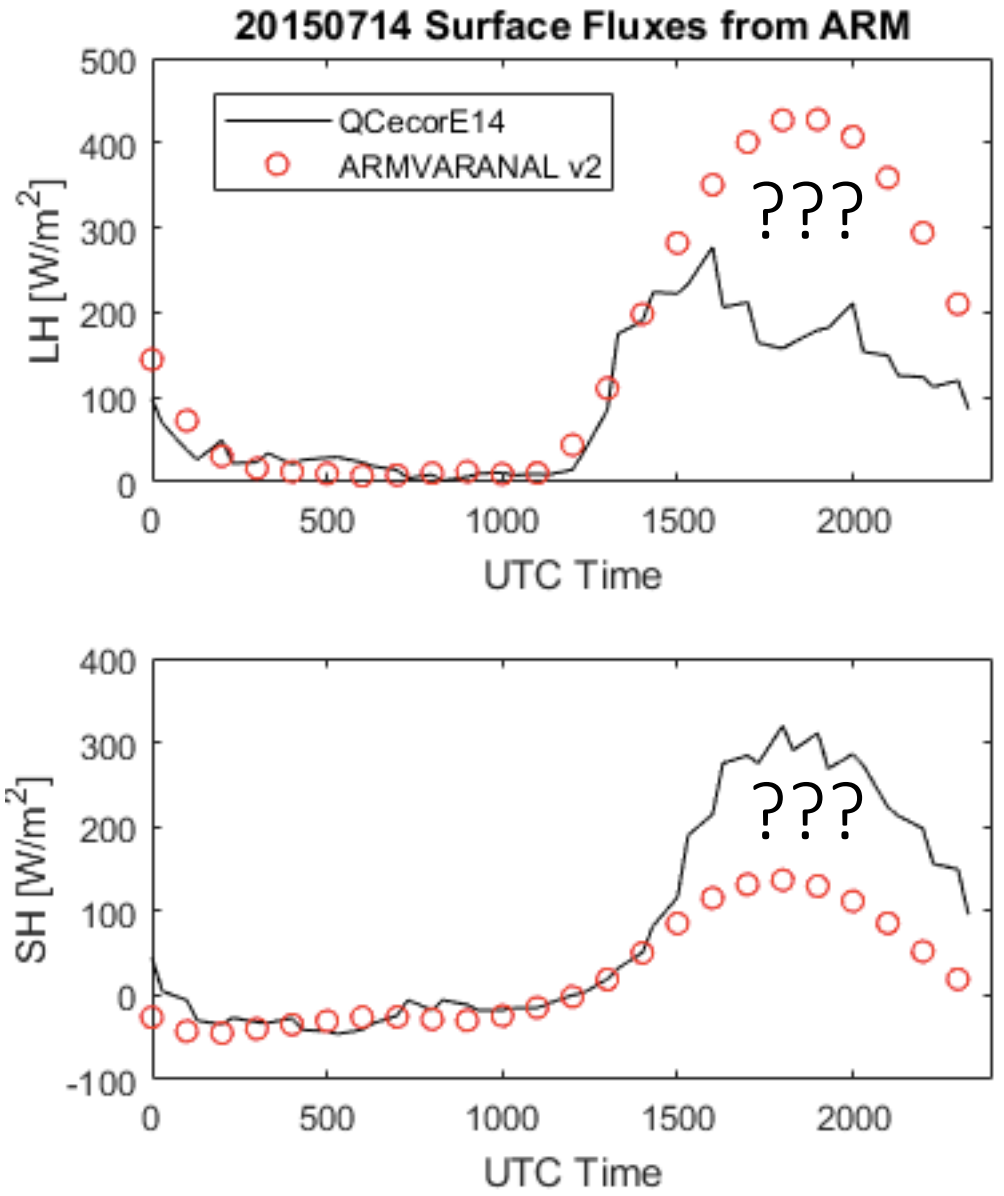
Courtesy: Stull (1988)

PBLh Benchmarking Approach

(1) Prescribe initial PBLh and states, θ lapse rate, and time-varying mean large scale divergence and surface heat fluxes from the USDOE-ARM Continuous Forcing Dataset (Zhang et al., 2001)

(2) Run a single column model using the same initial condition and boundary forcing in multiple PBL scheme configurations

(3) Interrogate model deviations from the jump model

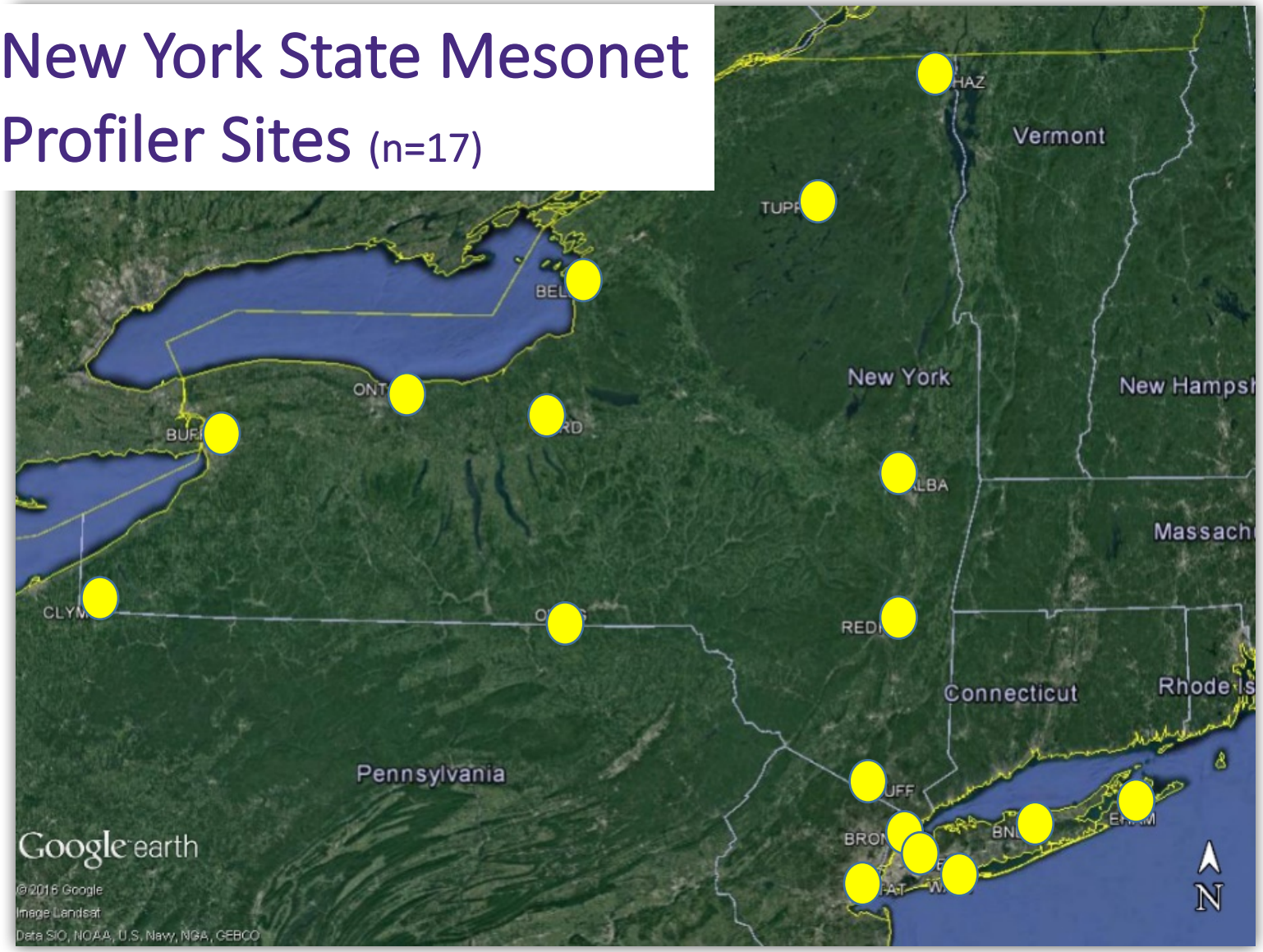


- ARM VARANAL v2 http://www.arm.gov/data/eval/29."

PBL Benchmarking Approach Extended

Repeat analyses over the NYS Mesonet, a temperate, forested landscape with strong vegetative controls on PBLh.

New York State Mesonet Profiler Sites (n=17)



Summary

- PBLh evolution (timing/growth) is a true land-atmosphere, multi-scale process that is critical to weather and climate prediction skill.
- Improved PBLh representation will be required to meet GEWEX GC for modeling and forecasting land-use/land cover modification (e.g., deforestation, irrigation) impacts on regional climate.