Cross-Scale Land-Atmosphere Experiment (CSLAEX)

PI: Pierre Gentine – Student: Yu Cheng

Columbia University

U.S. DEPARTMENT OF ENERGY | Office of Science

ASR Atmospheric System Research

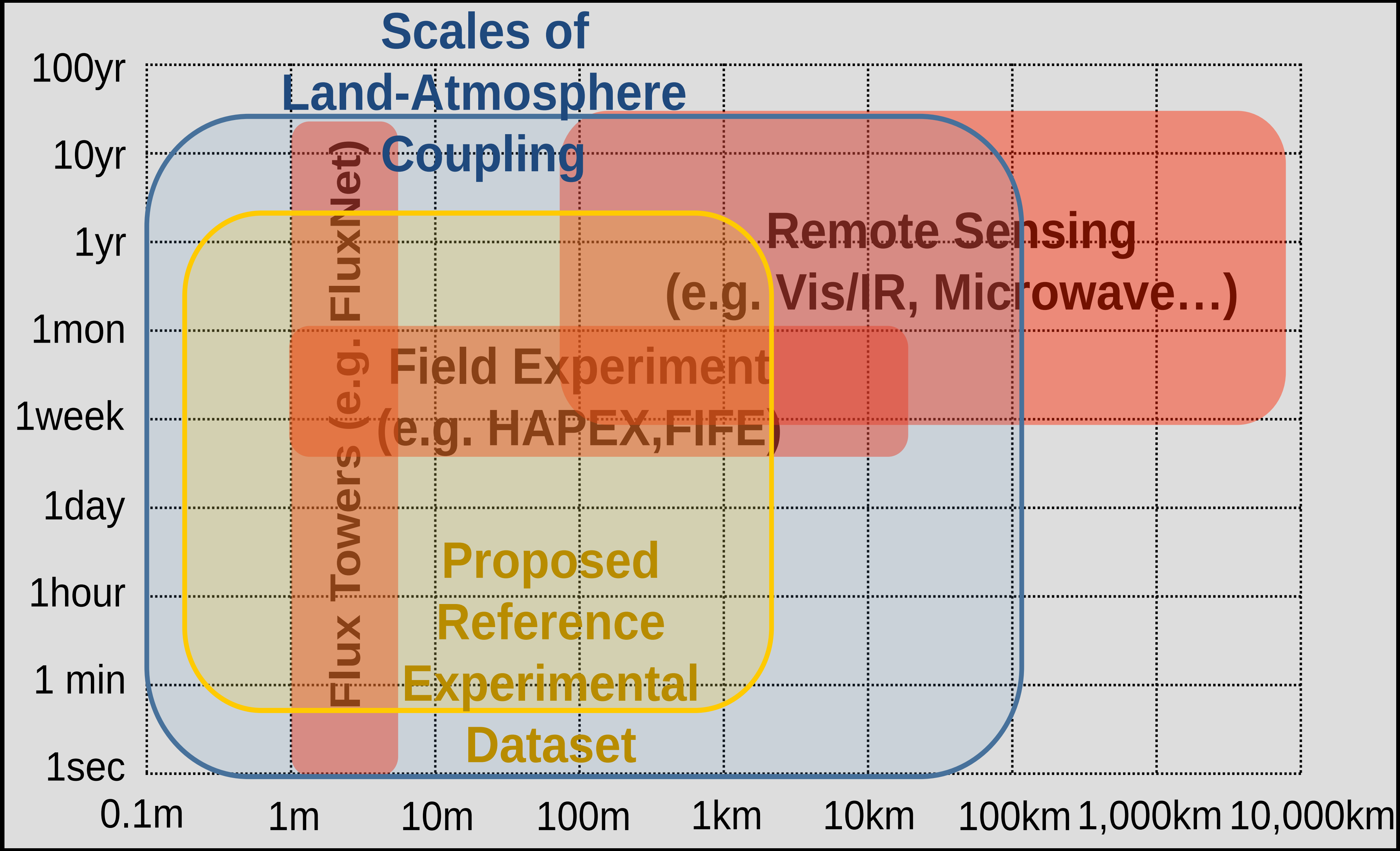
COLUMBIA | ENGINEERING
The Fu Foundation School of Engineering and Applied Science

Main objective:
Understanding the space-time nature of land-atmosphere interactions

Site: Department Of Energy
Southern Great Plains

Main strategy:
Using optical fibers and Distributed Temperature Sensing (DTS)
Span 1 mile transect

Why this setup?



First step
Initial smaller setup 200m – 2016 - MOISST site

Site in OK, near OSU
Similar landscape but smaller and with existing DTS for soil moisture measurements

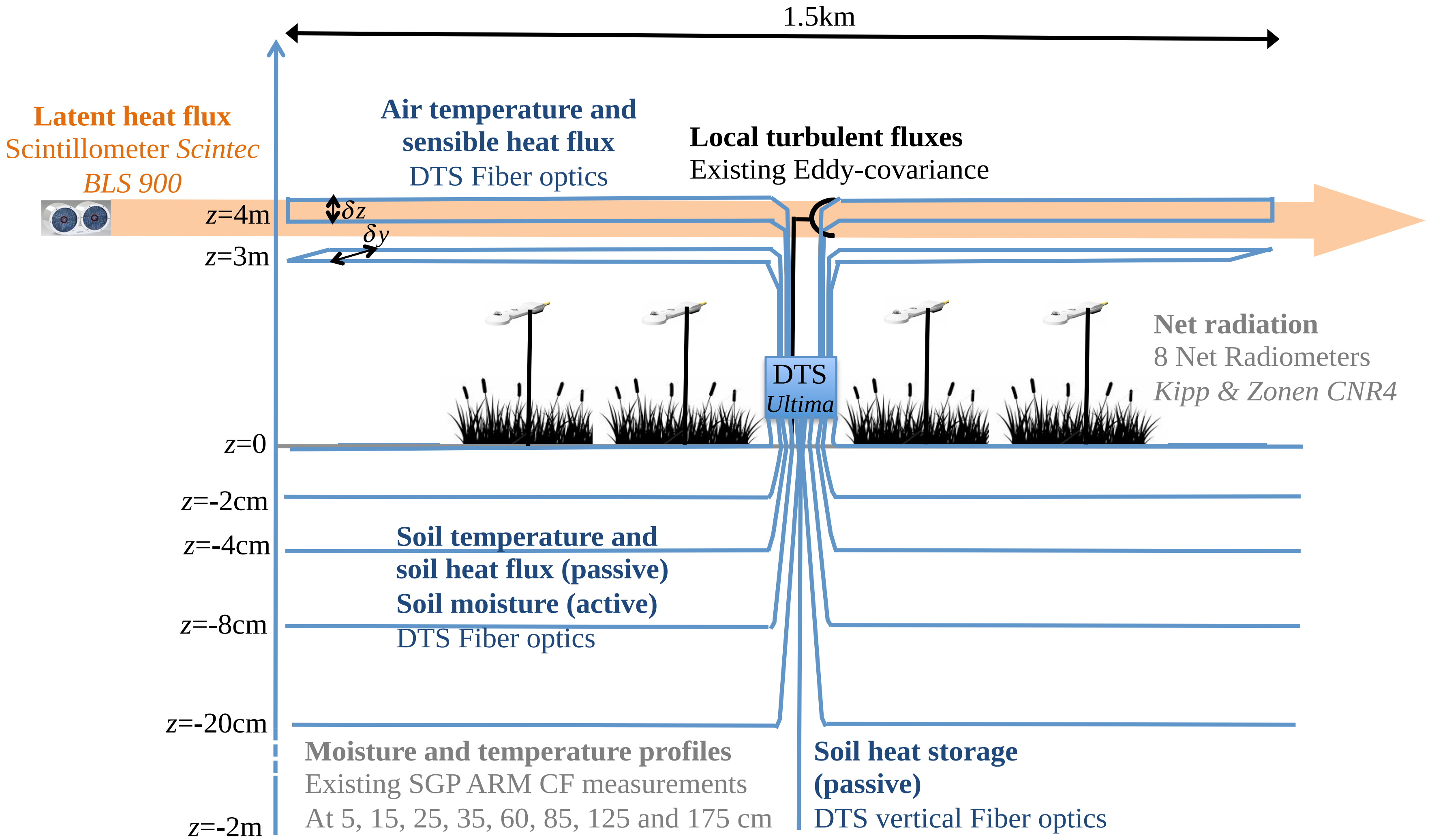
Campaign lasted for two weeks and installations stayed there over the summer (May to August)

Started acquiring and using data

Several issues:
Tensions, breaks, animals

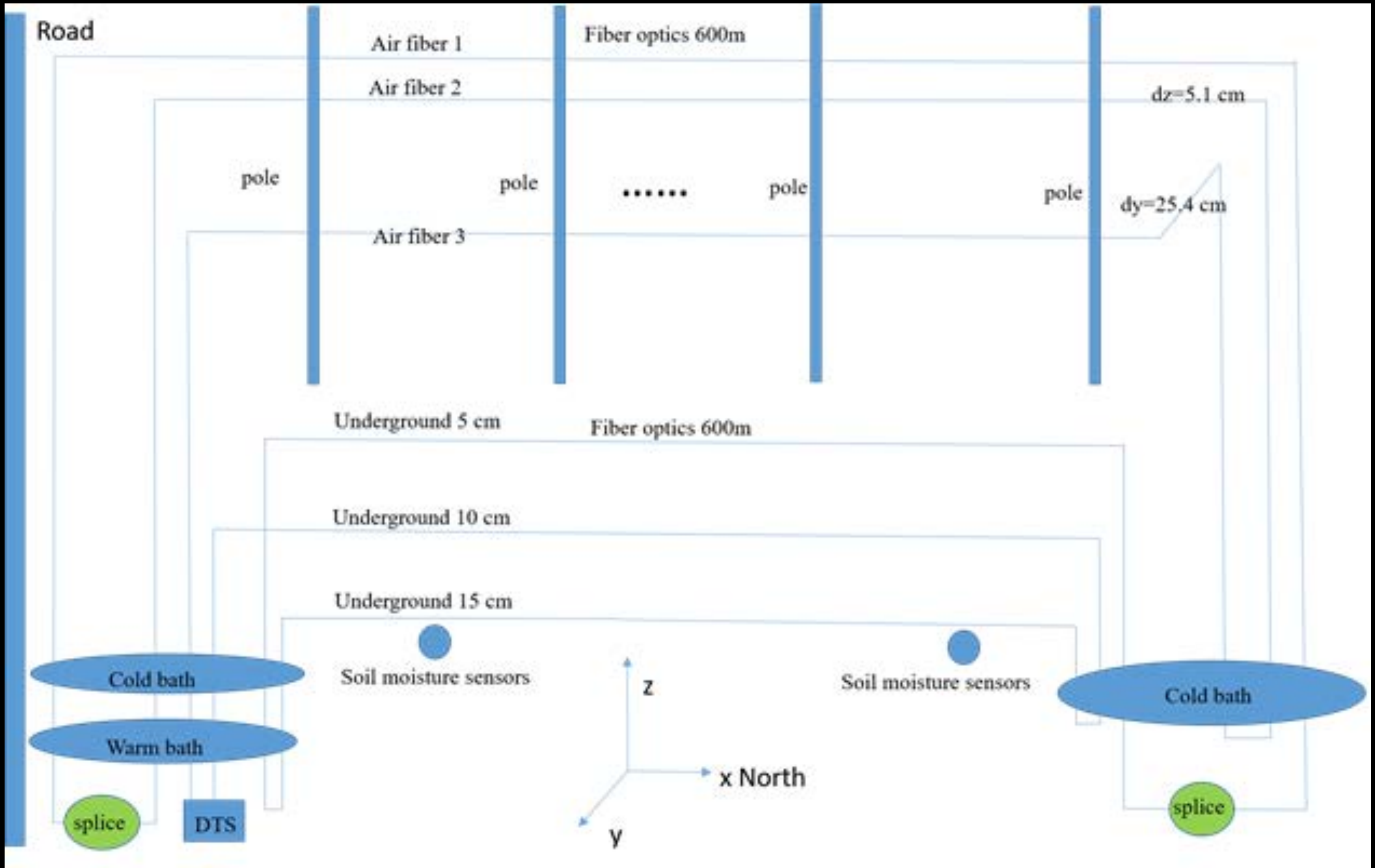
Second step
Full installation SGP site – Summer 2017

Initial envisioned setup



Second step
Full installation SGP site – Summer 2017

Final setup

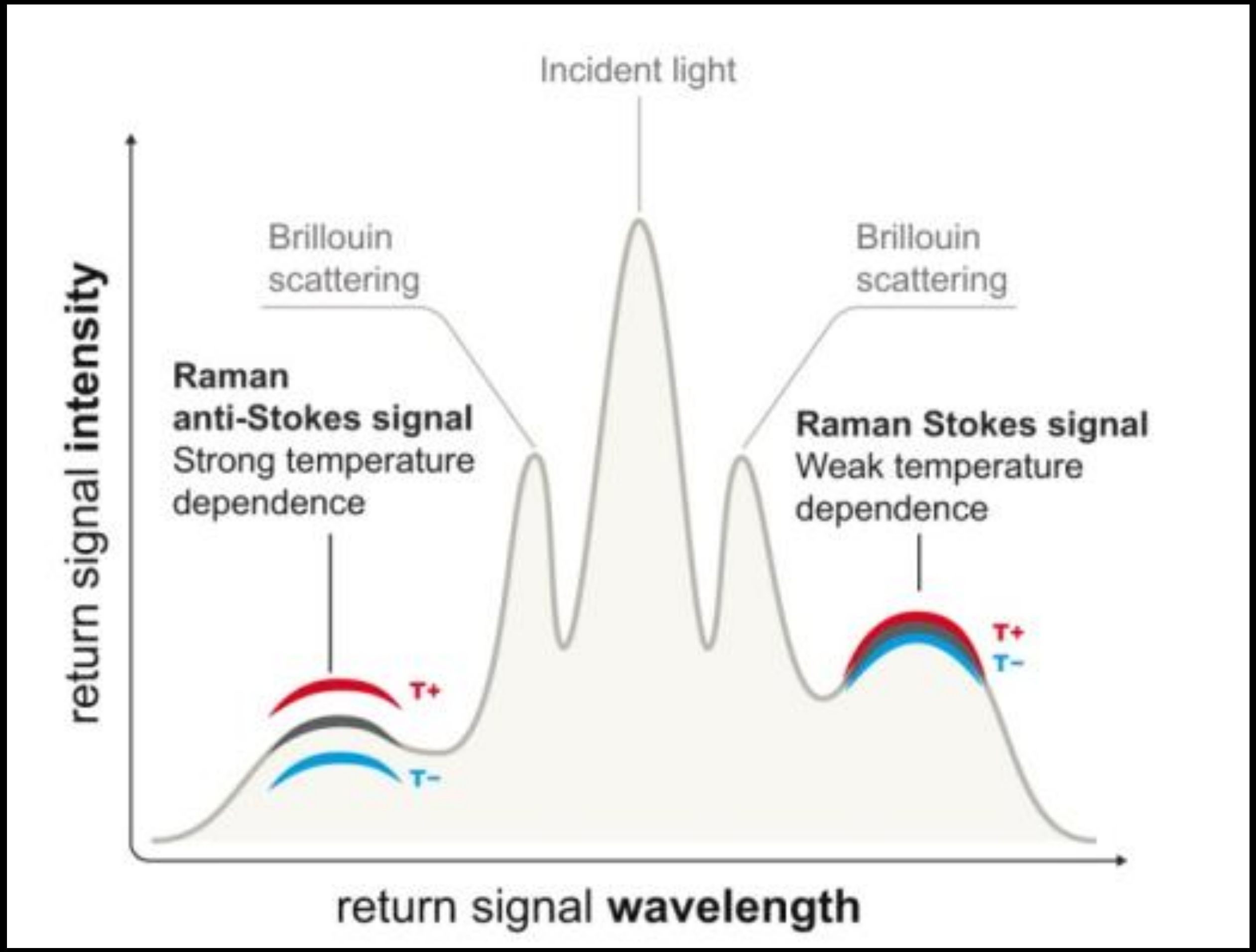


Second step
Full installation SGP site – Summer 2017

Depth and heights changed a bit
Also installation had to adjust
(no pulleys – too much tension – and a lot of issues…)

Second step
Full installation SGP site – Summer 2017
Spans two land cover types (alpha alpha and prairie)

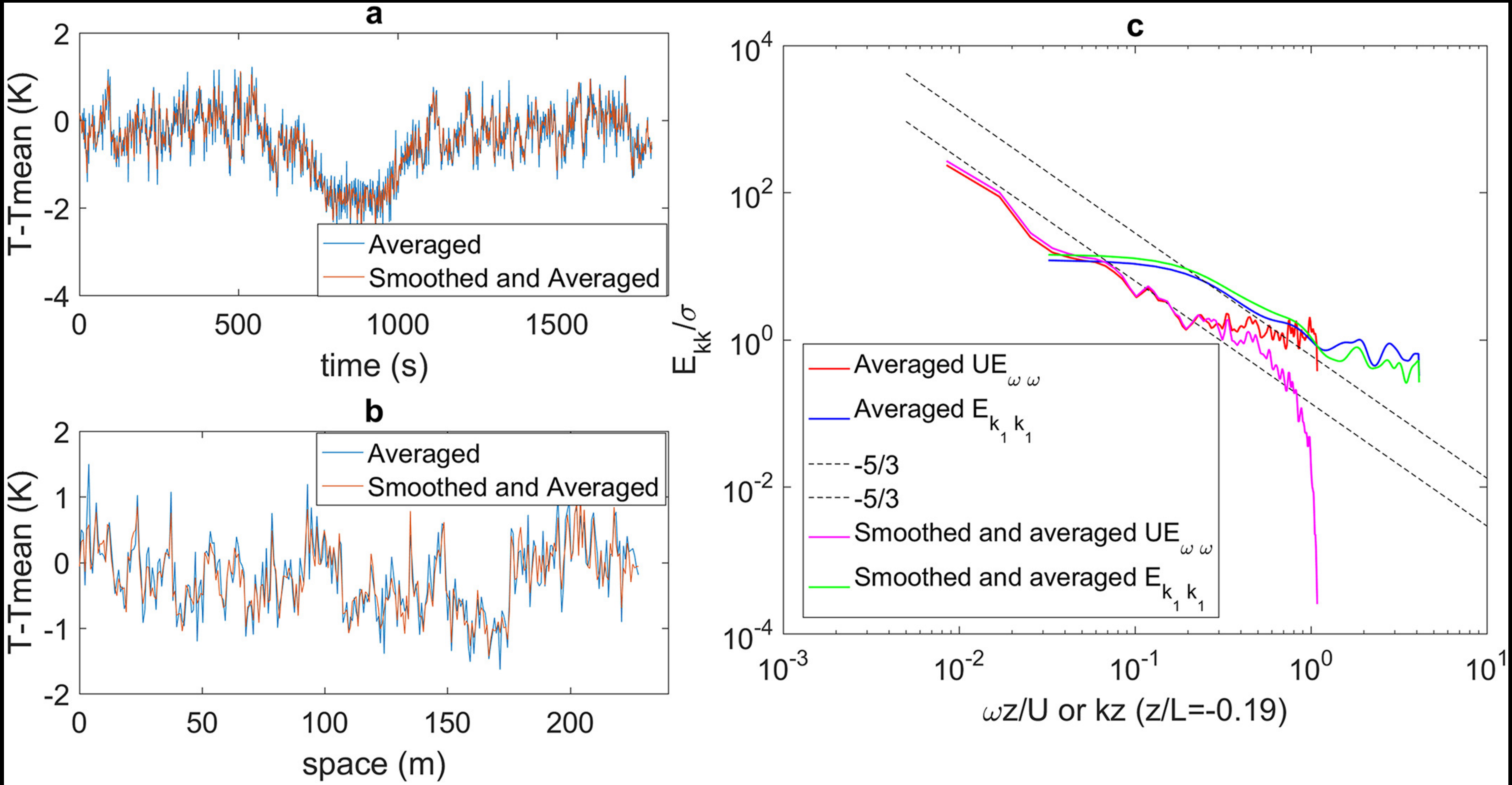
How does it work?
Span fiber linked to DTS (in a shelter), and need some reference temperature bath for gradient reconstruction
Based on Ramann scattering



Can know T(x,t)

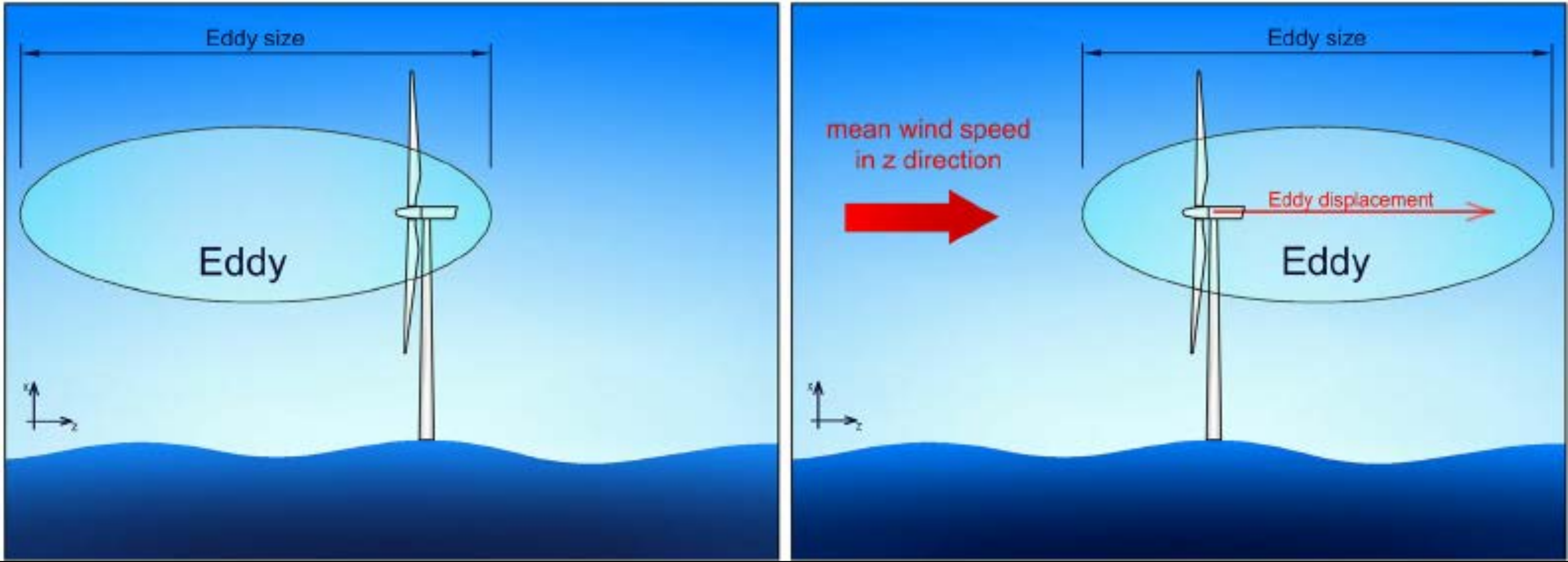
How does it work?

Example of response - 1Hz resolution, 0.25m resolution



What have we learnt?

1. Taylor frozen hypothesis



Can replace space with time (eddy-covariance)
Could be source of incorrect surface energy balance closure (~10 to 20%)

What have we learnt?

1. Taylor frozen hypothesis

Is turbulence really frozen, i.e. U does not depend on eddy size
Or is varying?

Use DTS to compute U(k) with k wavenumber, based on phase difference

$$U(k_1) = \frac{\Delta\varphi}{k_1 \times \Delta t},$$

Convective velocity (wavenumber dependent)

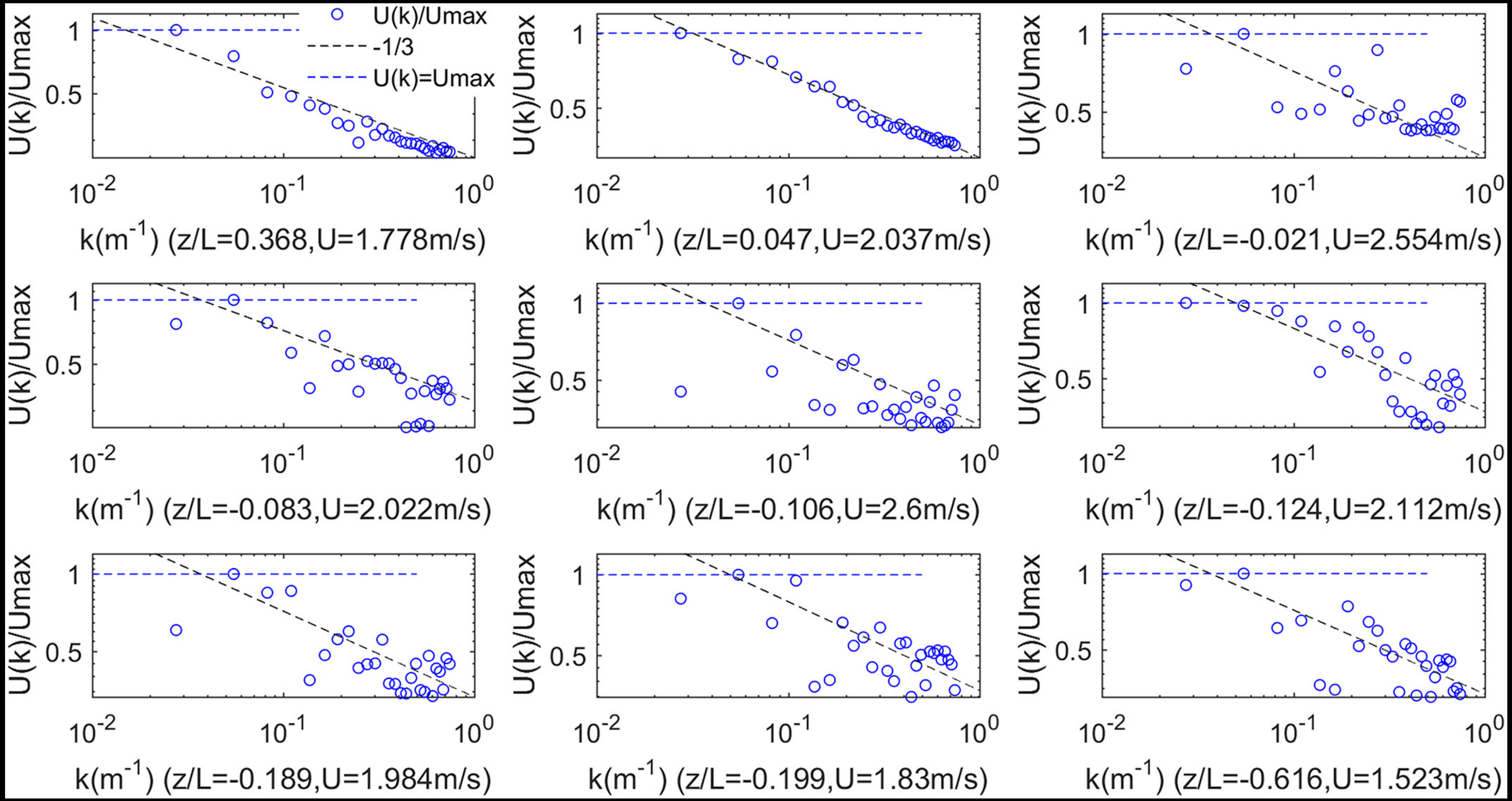
Usually assumed to be **constant**

Cheng et al. 2017 GRL

What have we learnt?

1. Taylor frozen hypothesis
   Results from DTS

$$U(k_1) = \frac{\Delta\varphi}{k_1 \times \Delta t},$$

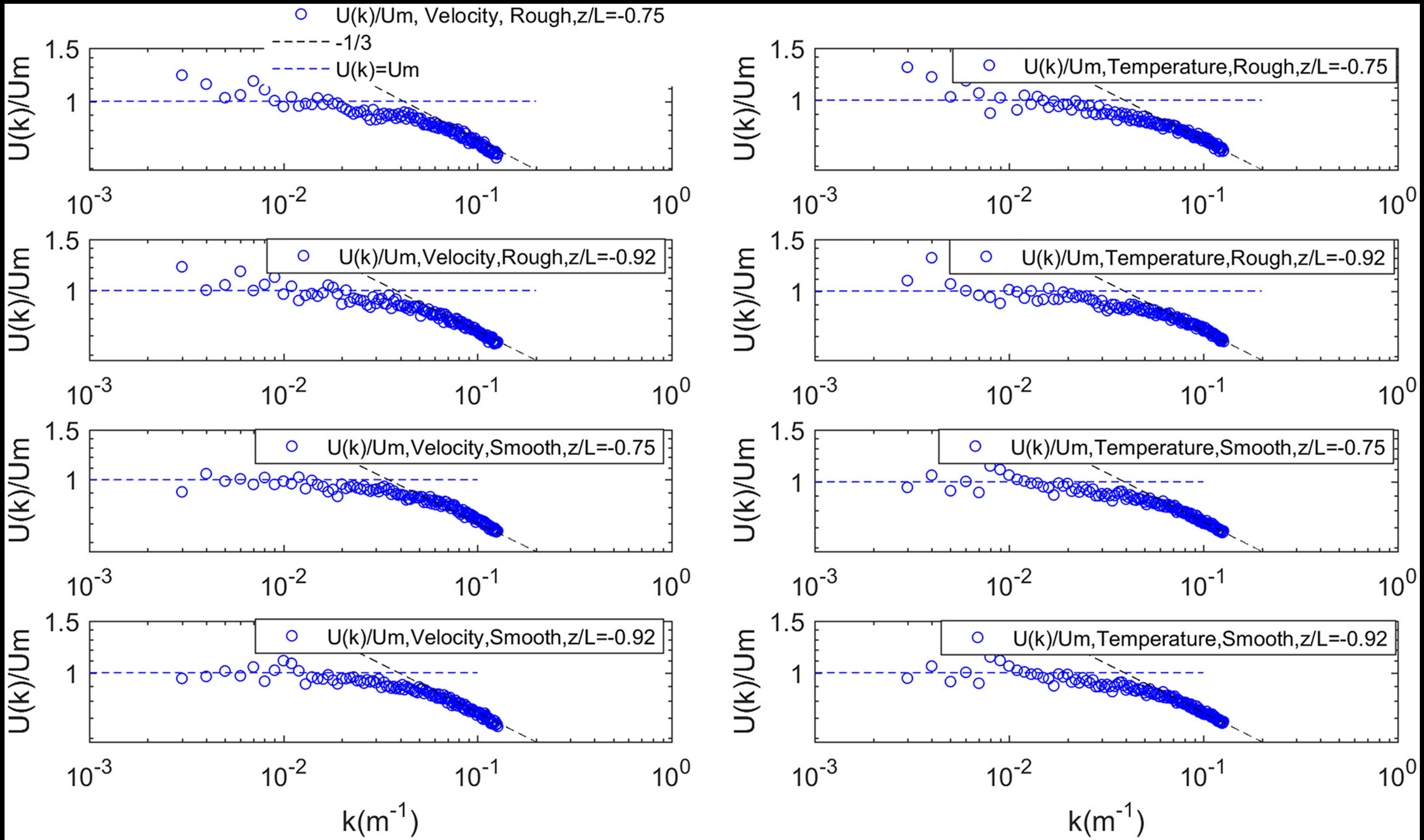


Across stability far from constant!

Cheng et al. 2017 GRL

What have we learnt?

1. Taylor frozen hypothesis
Could it be an artefact from sluggish DTS measurements



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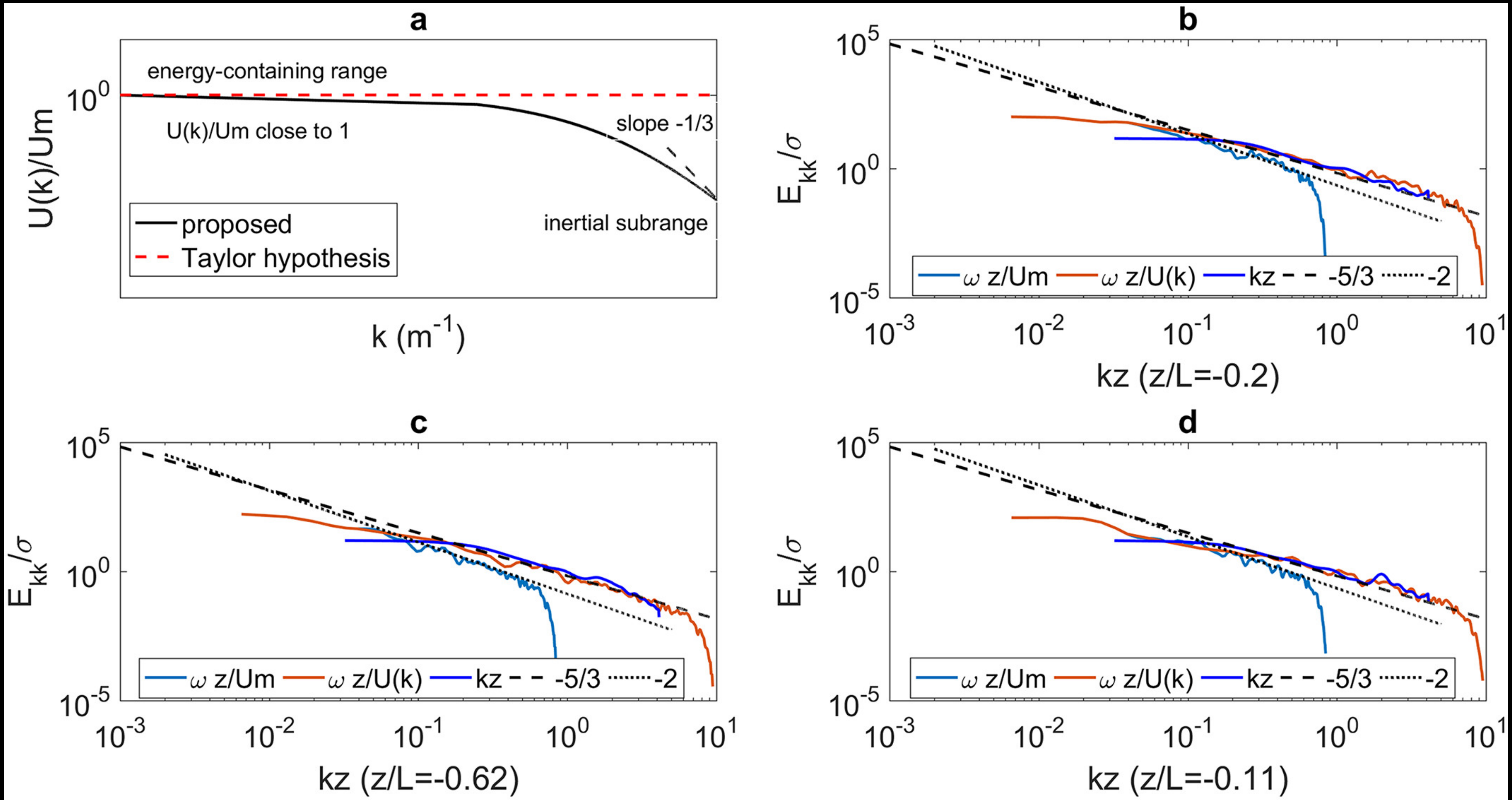
Checked with LES
A real signal

What have we learnt?

1. Taylor frozen hypothesis
Then develop a theory based on eddy diffusion at small scale



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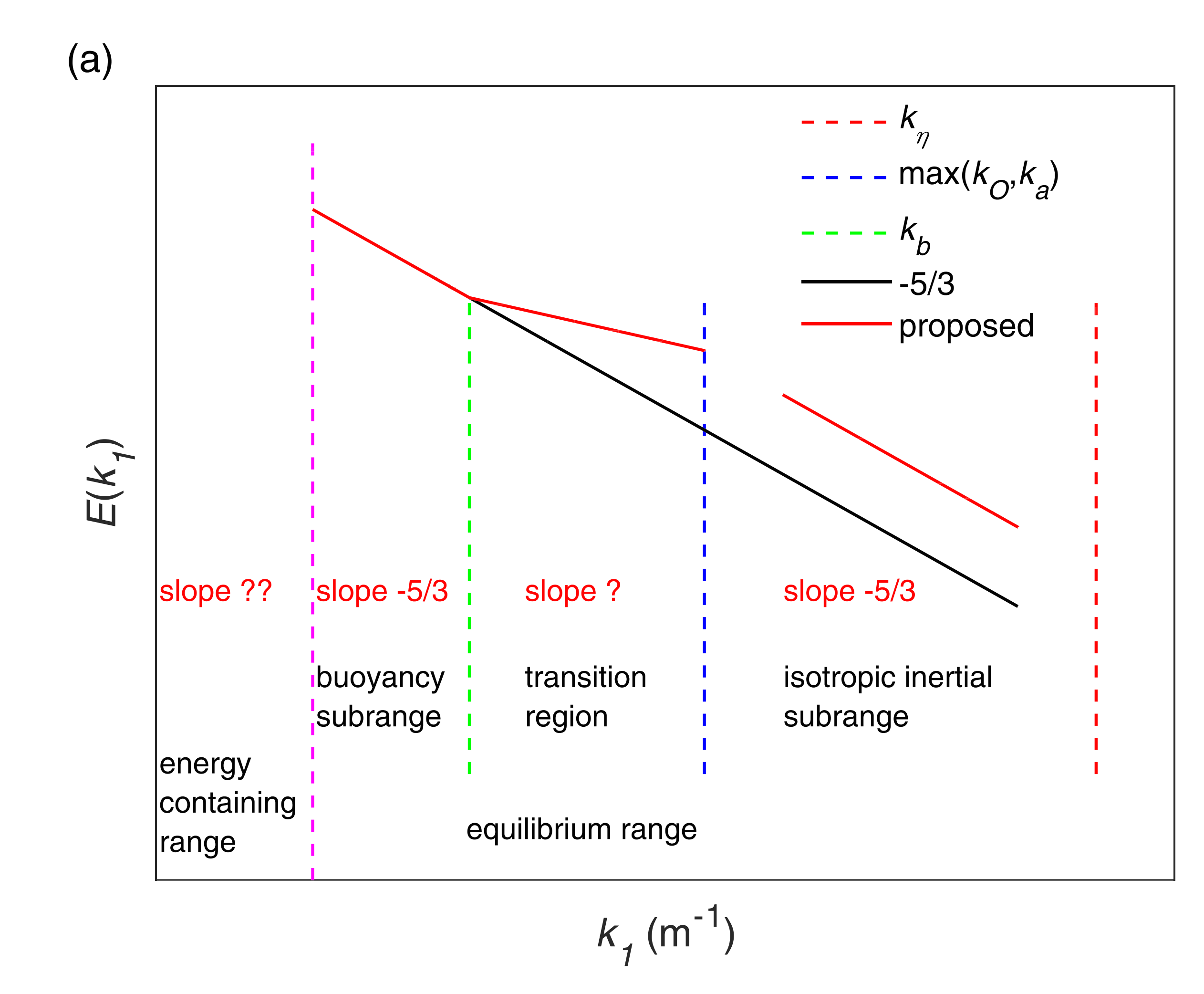
Departure is eddy size dependent.

Diffusion of coherence

What have we learnt?

2. Stable boundary layer
Challenging to model – too many scales
Plateau in energy spectrum



Cheng et al. 2020 JGR-Atmos/BLM

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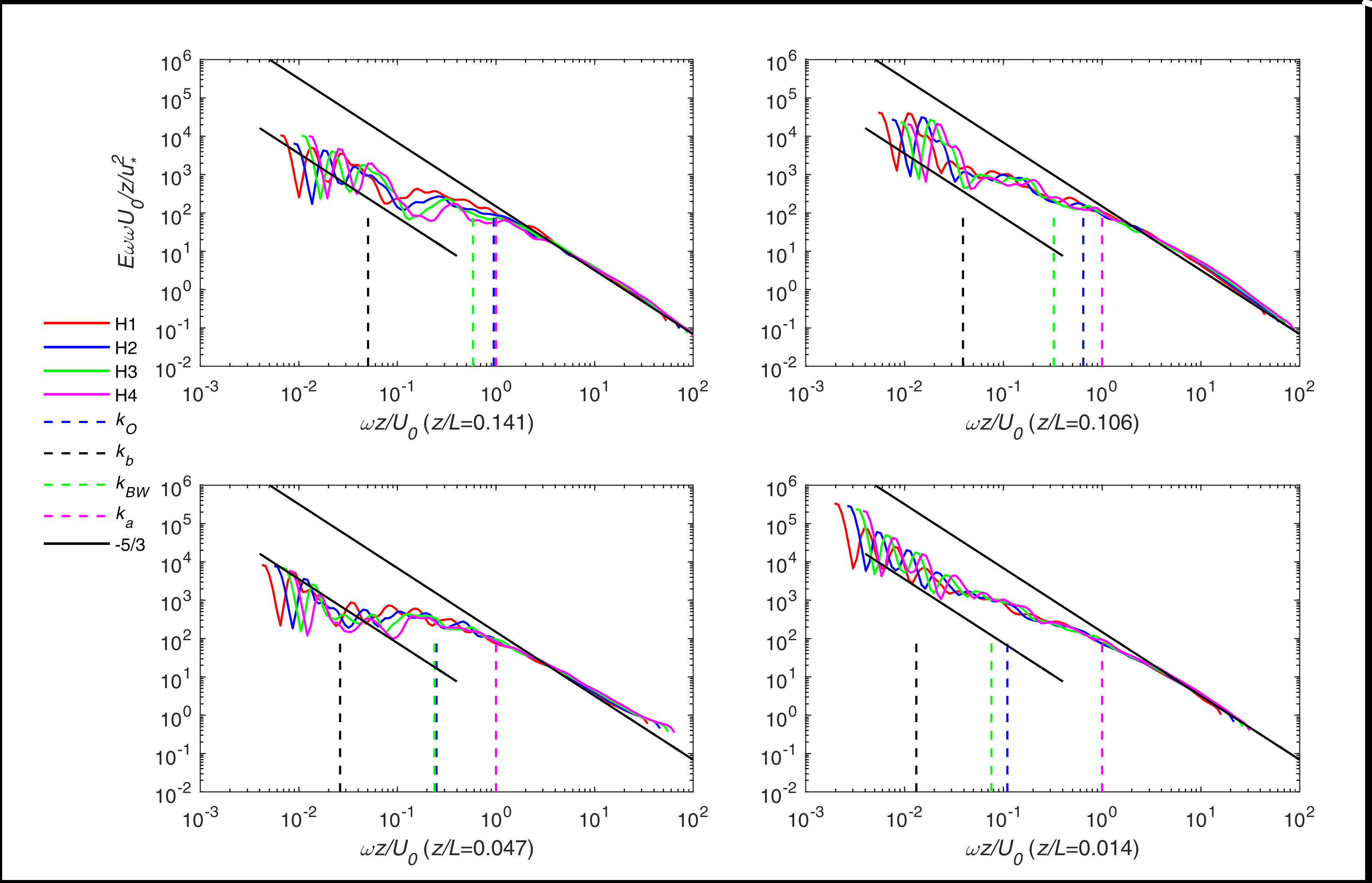
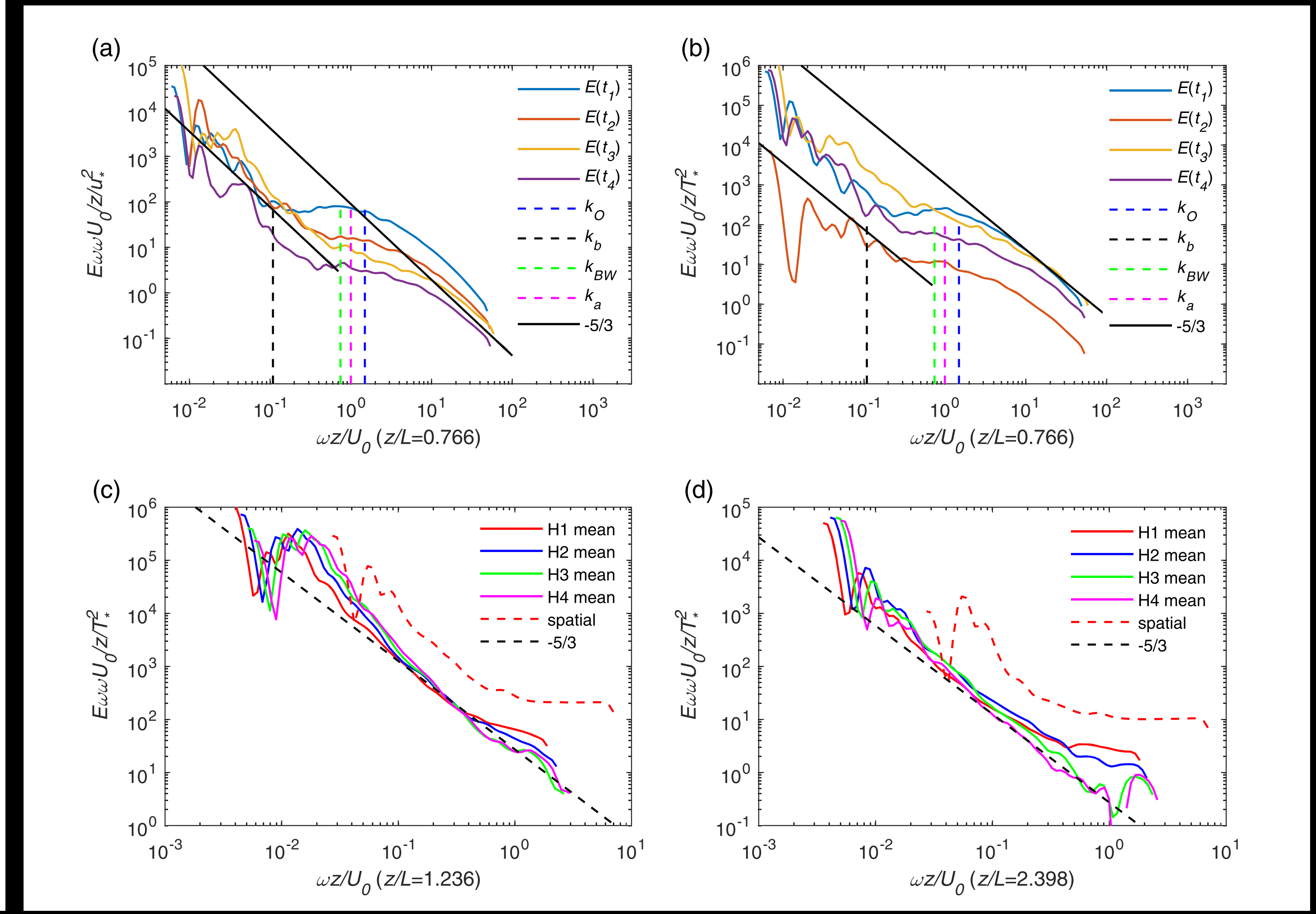


Eddy covariance (time using Taylor hypothesis)



Plateau confirmed by DTS

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What have we learnt?

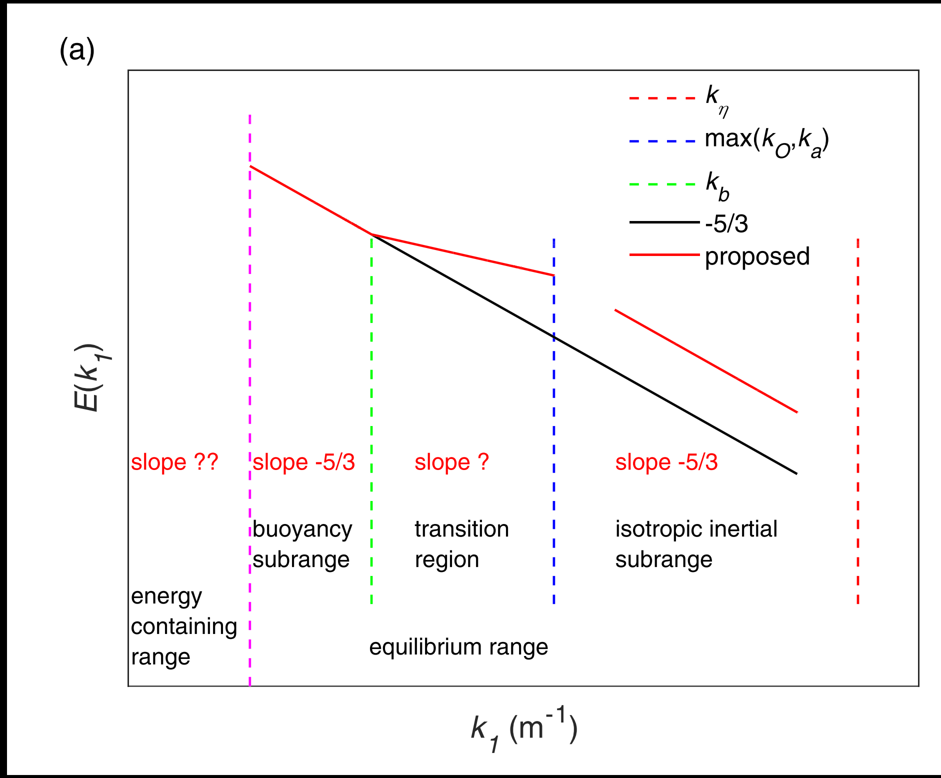
2. Stable boundary layer

Theory: two main time scales

Ozmidov scale (stratification and dissipation) L_O

Buoyancy scale (stratification and mean wind) L_B

Can develop a theory based on Weinstock (1978) explaining why we have this spectrum



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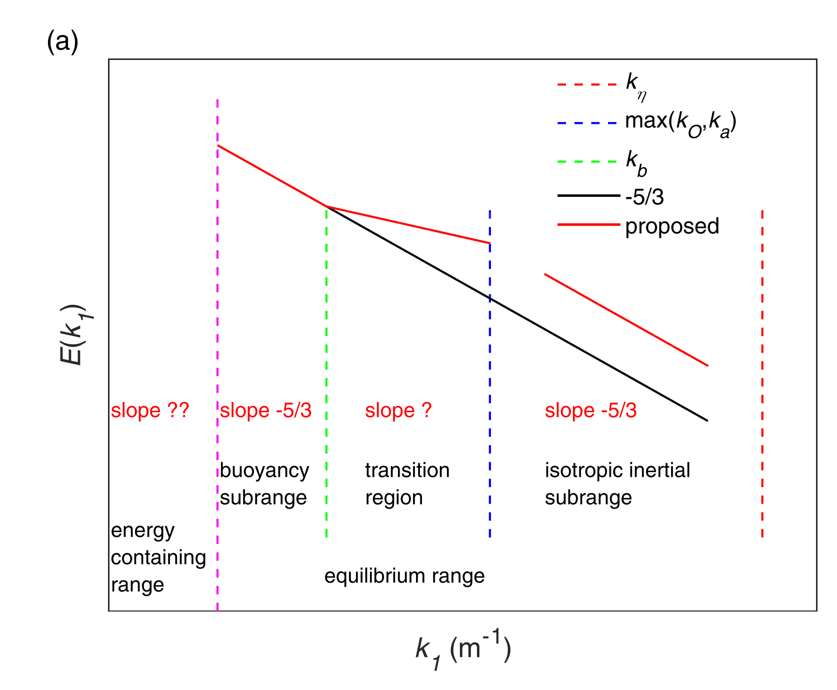
What have we learnt?

2. Stable boundary layer
Theory: two main time scales
Implication:
Failure of Monin-Obukhov Similarity theory for stable (and especially very stable boundary layers)



$$\frac{\partial X}{\partial z} = f\left(\frac{z}{L}\right)$$

With L the Obukhov length

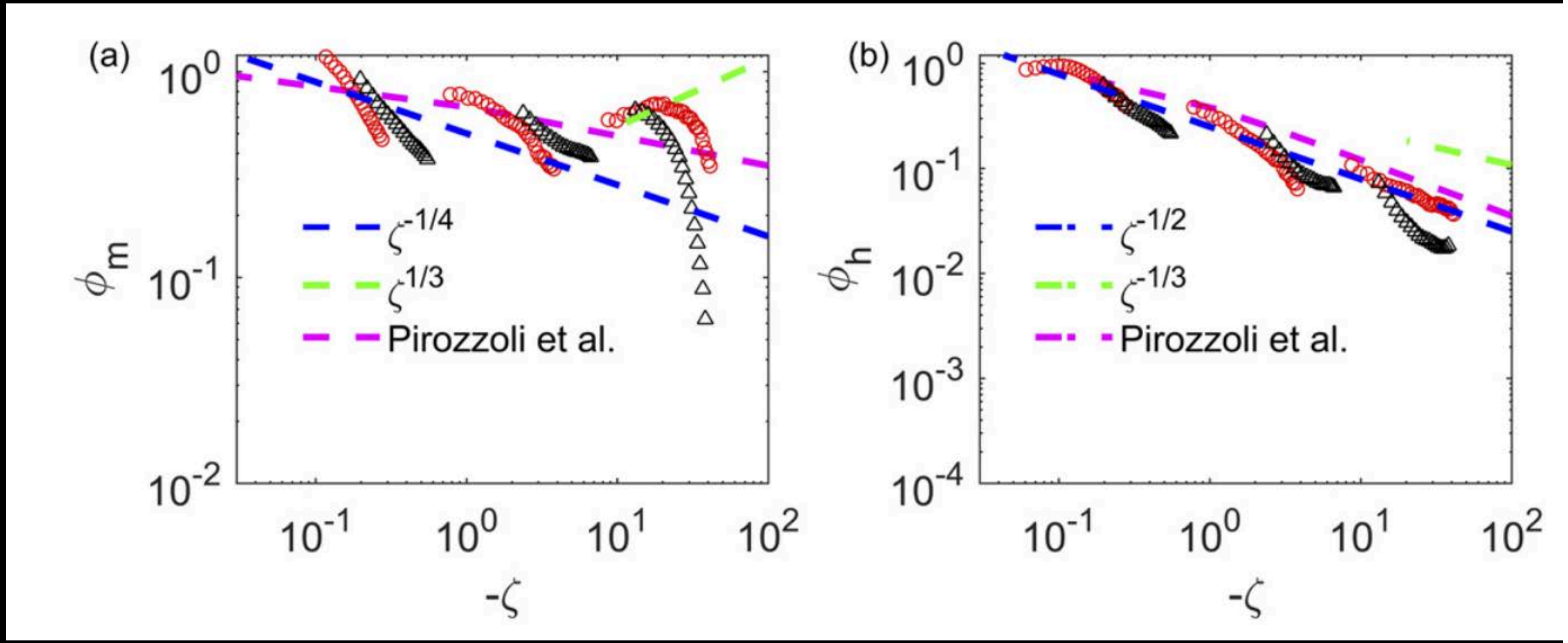
Missing an independent variable: L_B and slope of plateau (As L_O scales with L – see Li et al. 2016)

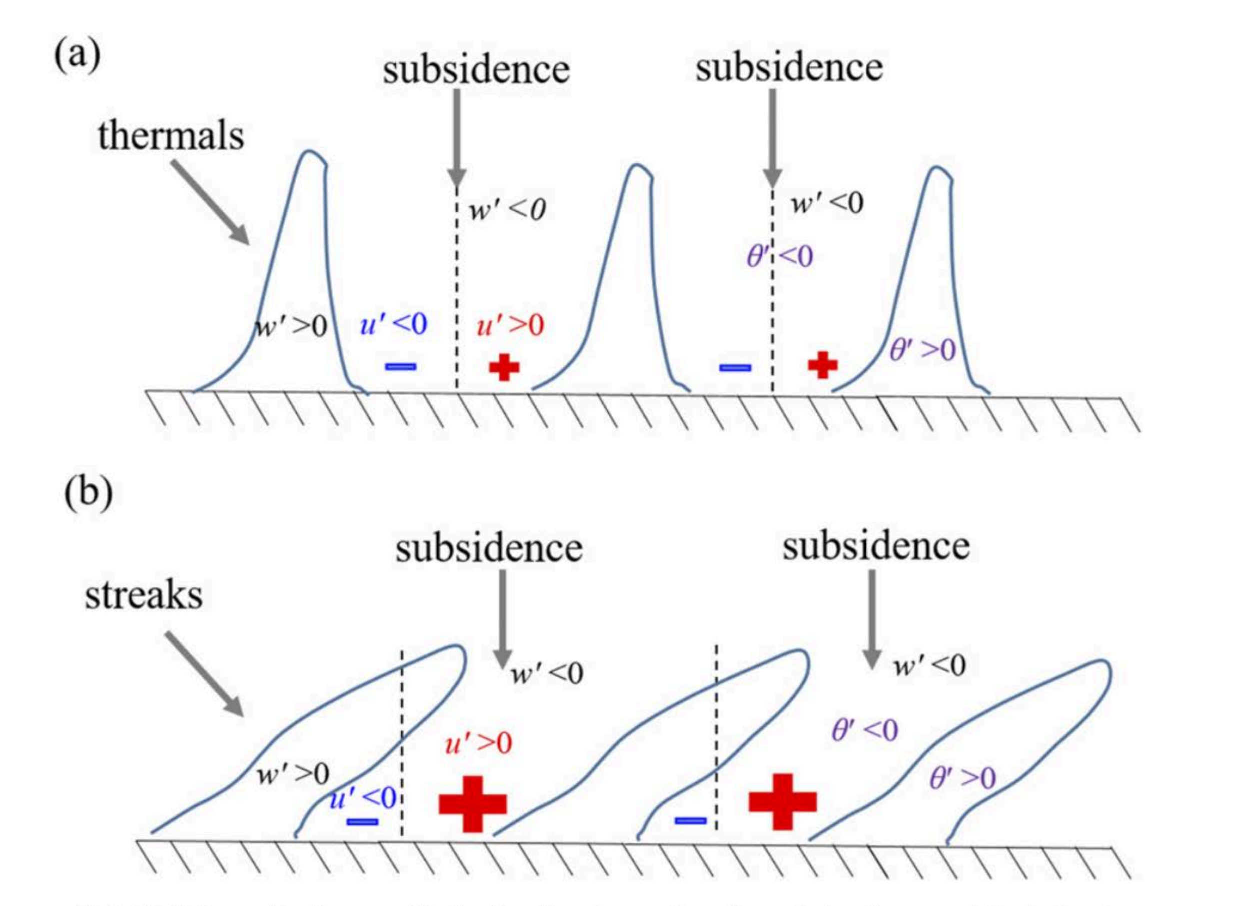
Cheng et al. 2020 JGR-Atmos/BLM

What have we learnt?

Current work:

1. Correcting Monin-Obukhov Similarity Theory (MOST) in unstable conditions, Large eddies are very important and need to be included AS they lead to departure from z/L scaling





Li et al. 2018 JAS

What have we learnt?

Current work:
2. Investigating heterogeneity in ground heat flux (G) and soil moisture at ~0.1m resolution and implication for surface energy balance

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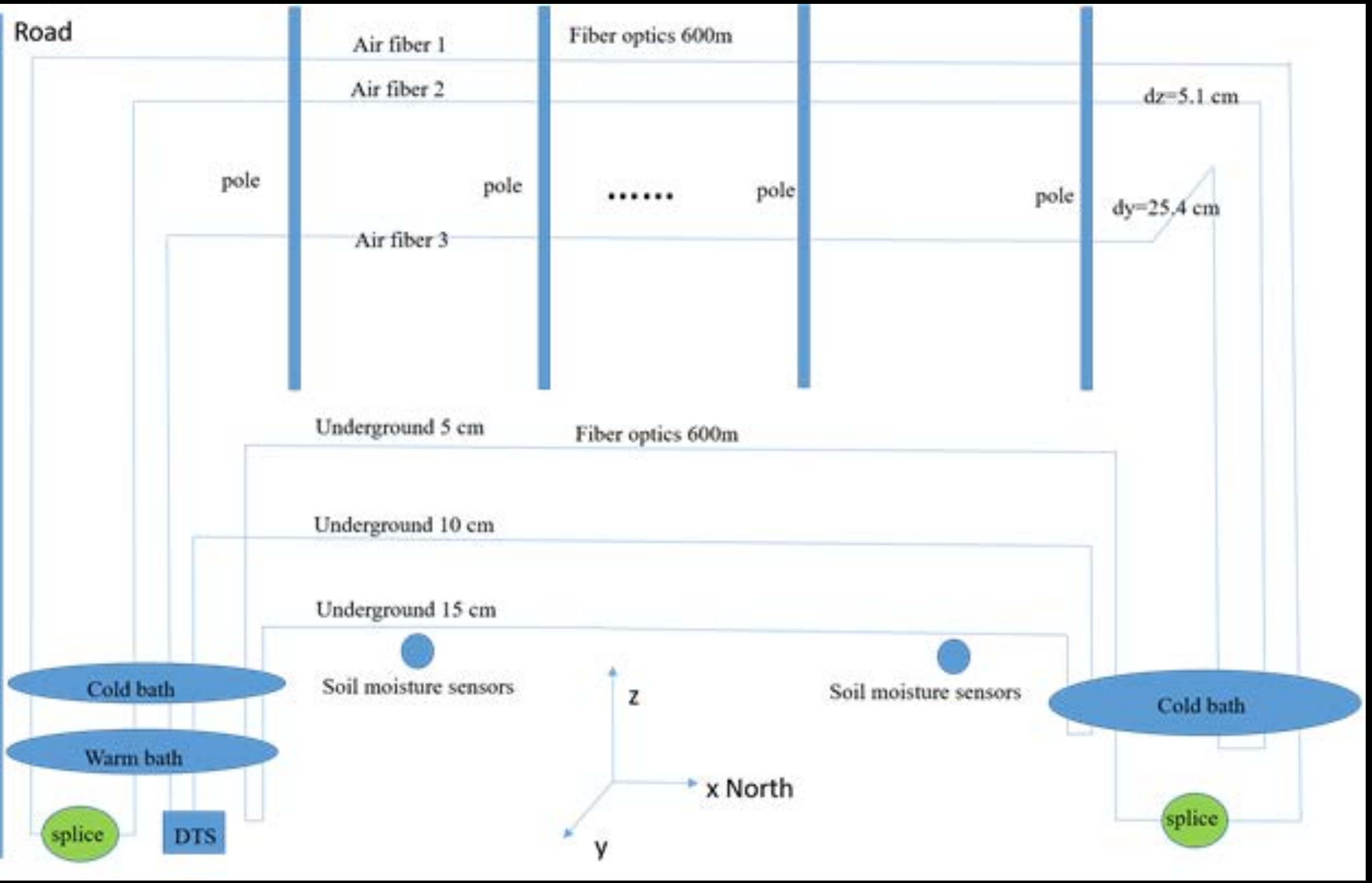

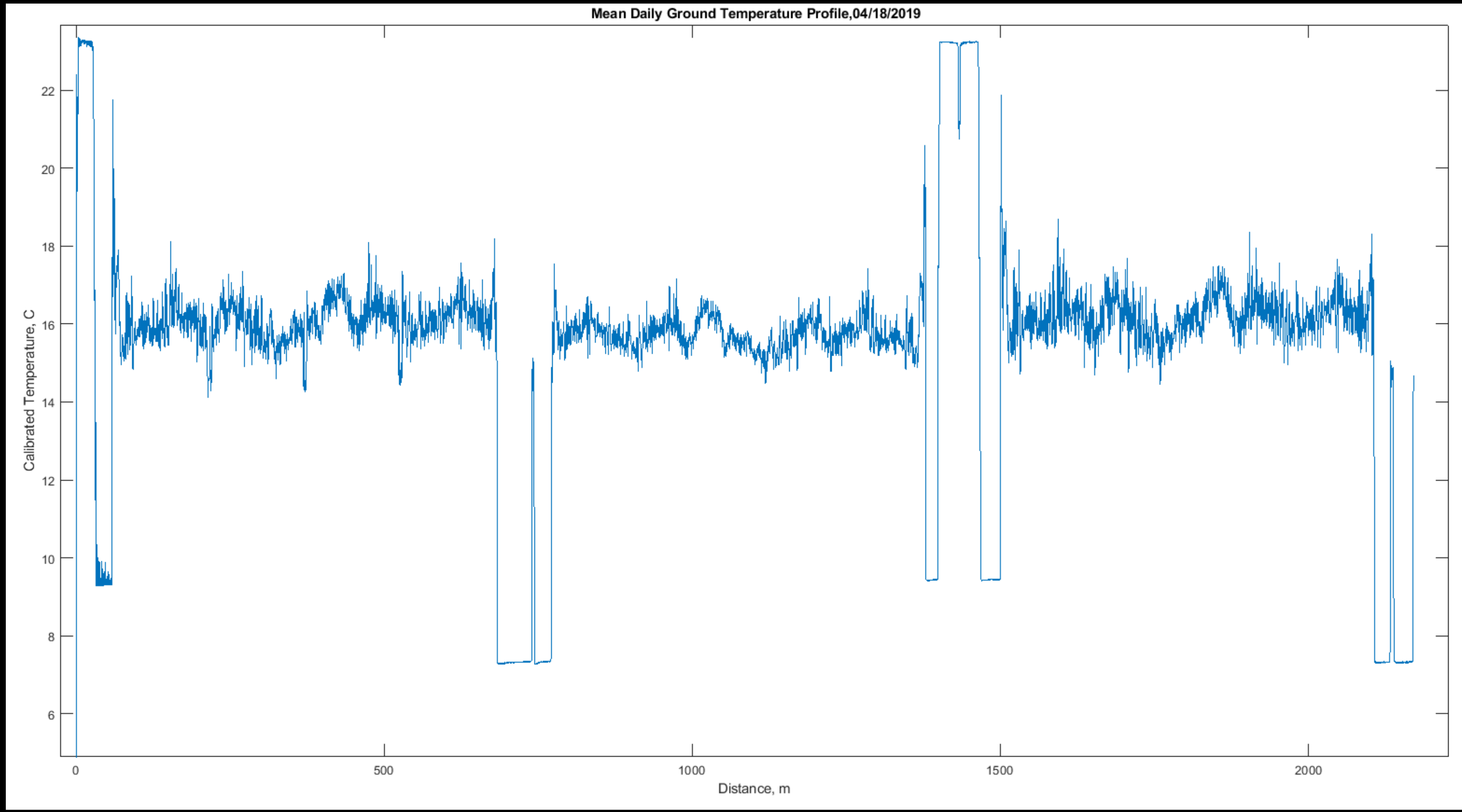

Acknowledgment

I would like to sincerely thank

- DOE ASR for the support

- The DOE SGP team – extremely reactive and creative, could not dream of a better team

- Chadi Sayde (NCSU) and student Mahmoud Shehata

Data is part of the DOE ARM SGP site

Publicly available
https://adc.arm.gov

Any question please contact me
pg2328@Columbia.edu

We hope people use the data