Uncertainty of Regional Carbon Fluxes and Boundary Layer Heights in Complex Terrain: The Airborne Carbon in the Mountains Experiment 2007

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and other AMCE 2007 Co-Authors

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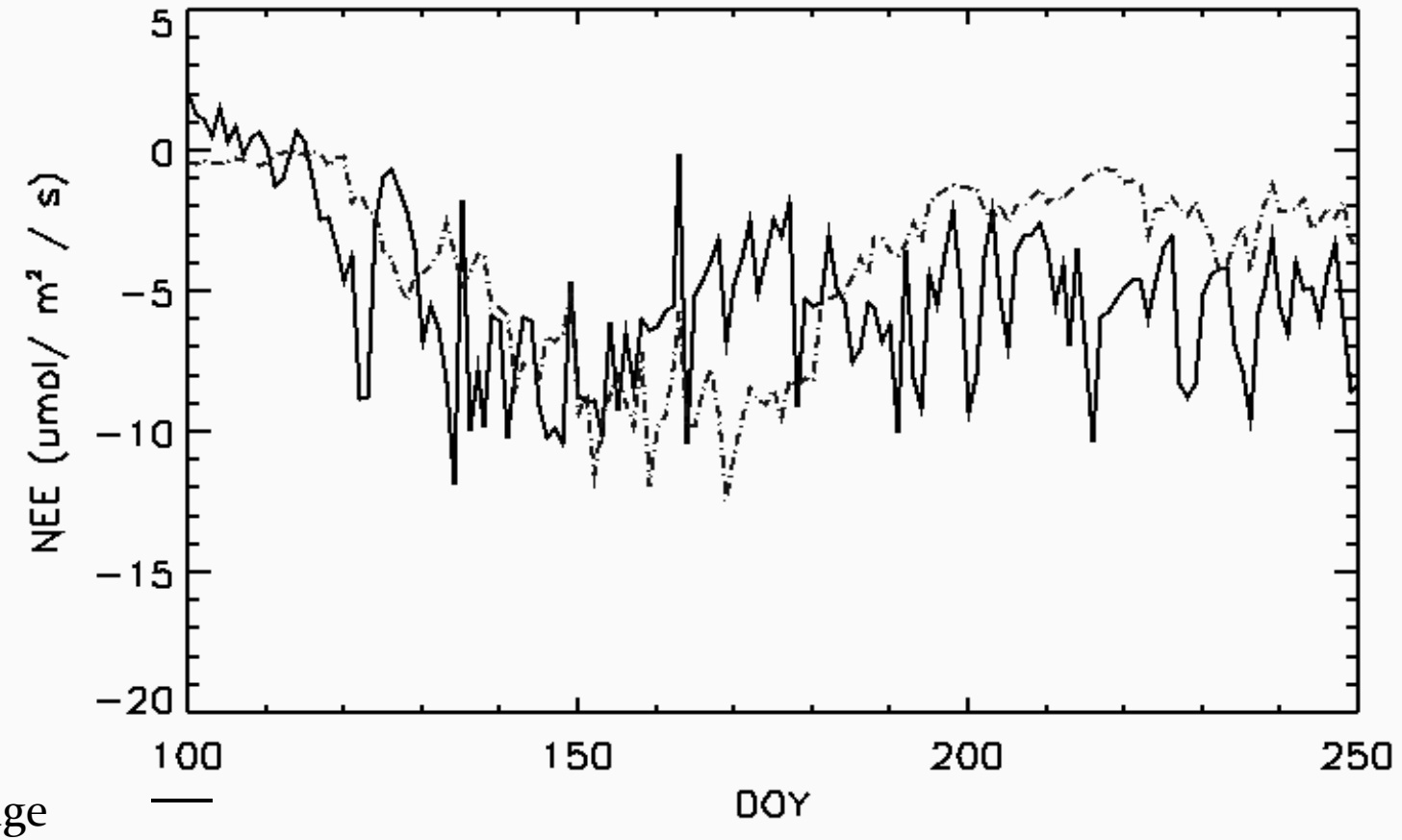
Motivation

- Abundant ecosystem in the Central Rocky Mountains is likely an important carbon sink
- Ongoing stresses have added to the uncertainty about future carbon uptake
- CO_2 land-atmosphere exchange is poorly constrained in global models

Stressors

Niwot Ridge AmeriFlux Tower vs. CarbonTracker



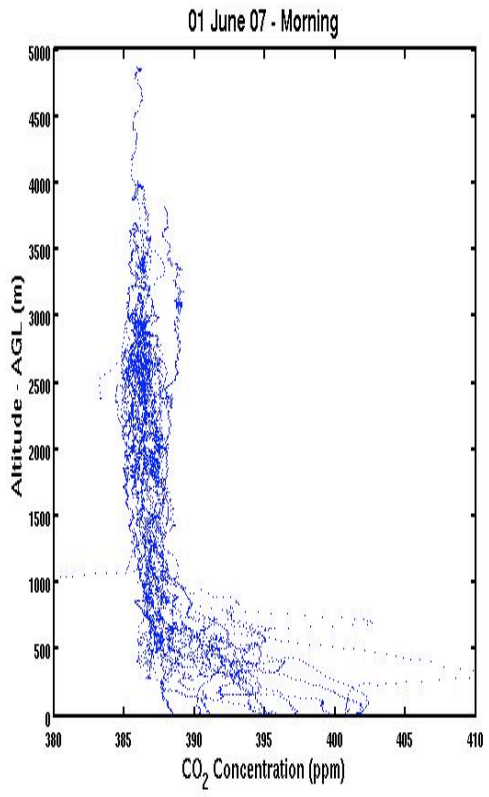
Niwot Ridge ——

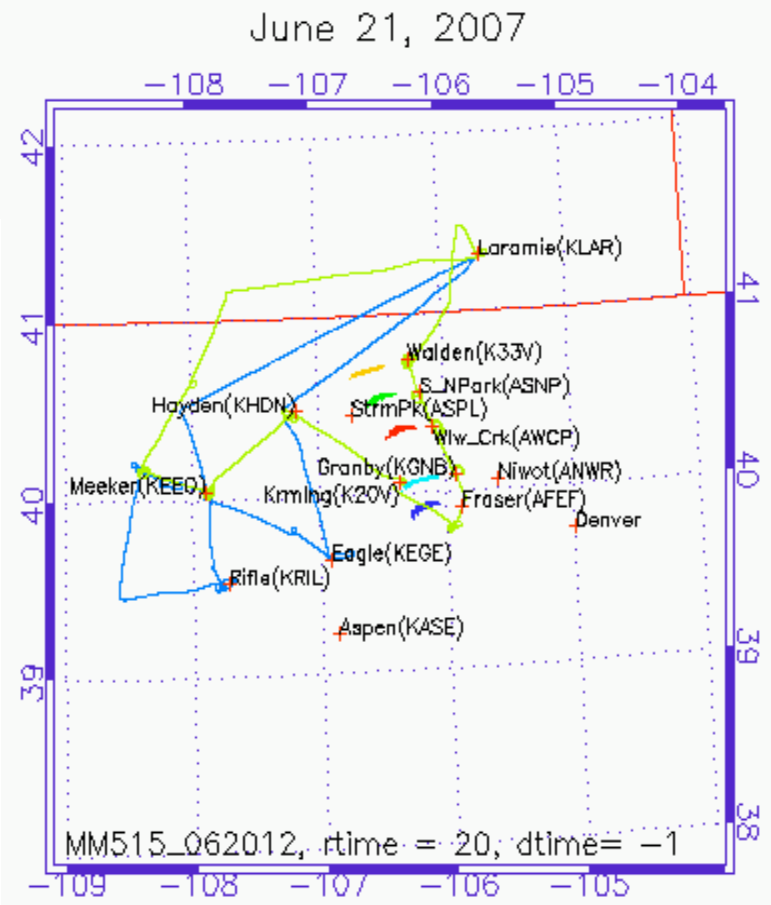
CarbonTracker - - -

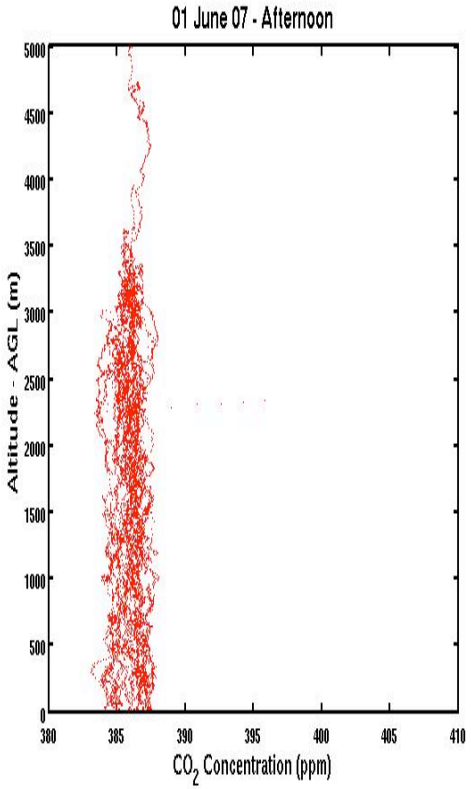
What is ACME?

- Field experiment that flew paired morning upwind and afternoon downwind profiles to measure carbon in the Central Rocky Mountains
- Collected airborne measurements of CO, CO_2, O_2 and H_2O as well as other atmospheric variables
- Over 60 hours of flight time from May to August
  - University of Wyoming's King Air Aircraft
- First conducted in 2004, then methods were improved for 2007

Particle Dispersion and Flight Profile







How is ACME Different from other Regional Carbon Studies?

- Experiments was conducted in the Central Rocky Mountains
  - Complex terrain with various mesoscale flows
- Used multiple parallel profiles

Lessons Learned from ACME04

- Complex terrain imparted flux variations
  - Multiple parallel profile approach needed
- Vertical sheer was large
- Valley cold pools vented later than expected
  - Shifted times of flights

Research Questions

- What is the magnitude of carbon uptake in the Central Rocky Mountains?
- How do flux estimates from the boundary layer budget (BLB) method compare with CarbonTracker and Niwot Ridge and what is the uncertainty?
- What is the uncertainty of boundary layer heights in the region?

Issues with Inverse Modeling

- Why not use an inverse model??
  - It is HARD!!!
- Global inverse models provide too coarse a resolution
- Regional inverse models require good inflow fluxes and accurate assimilation methods

- Also have to account for spatial heterogeneity and local processes

Boundary Layer Budget Method

(Raupach et al., 1992)

$$F_c = PBL_{\max} \frac{dC_{avg}}{dt}$$

- Column averaged variations are not affected by variations in boundary layer height
- Issues with Method
  - Ability to track air masses from one region to another
  - Requires accurate estimates of boundary layer height

Why use PBL_{max}?

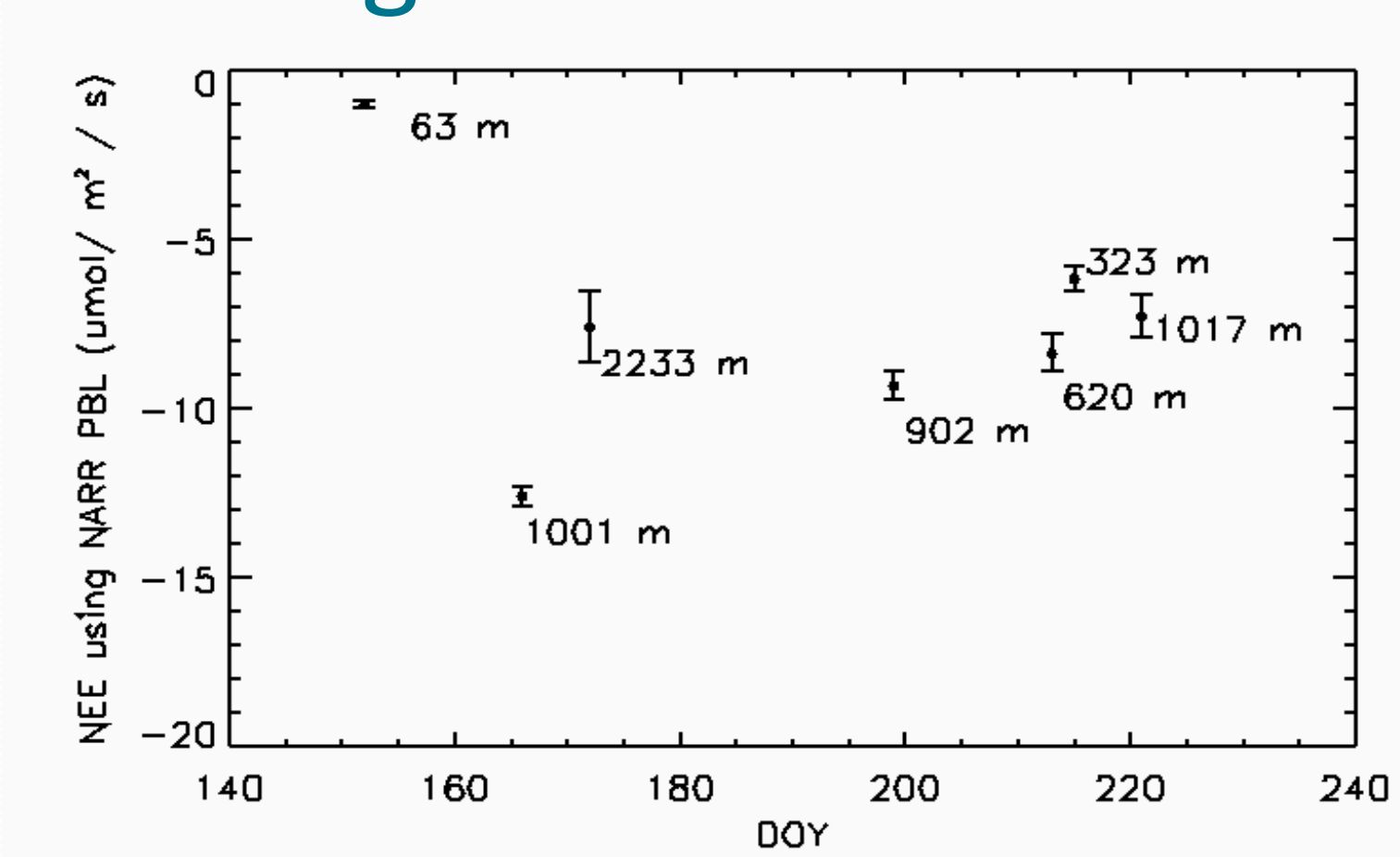
- The convective boundary layer is a vertically confined column of air (Stull, 1988; Garrat, 1990)
  - It incorporates overlaying air into it as it grows
    - Resolves issues with vertical entrainment
- Bulk properties of the column are independent of small scale heterogeneities (Stull, 1988; Garrat, 1990)
  - Natural integrator of surface fluxes over complex terrain
- Simulations with idealized initial conditions using RAMS show PBL_{max} to be a good proxy when compared with observations (DeWekker, in prep)

Data

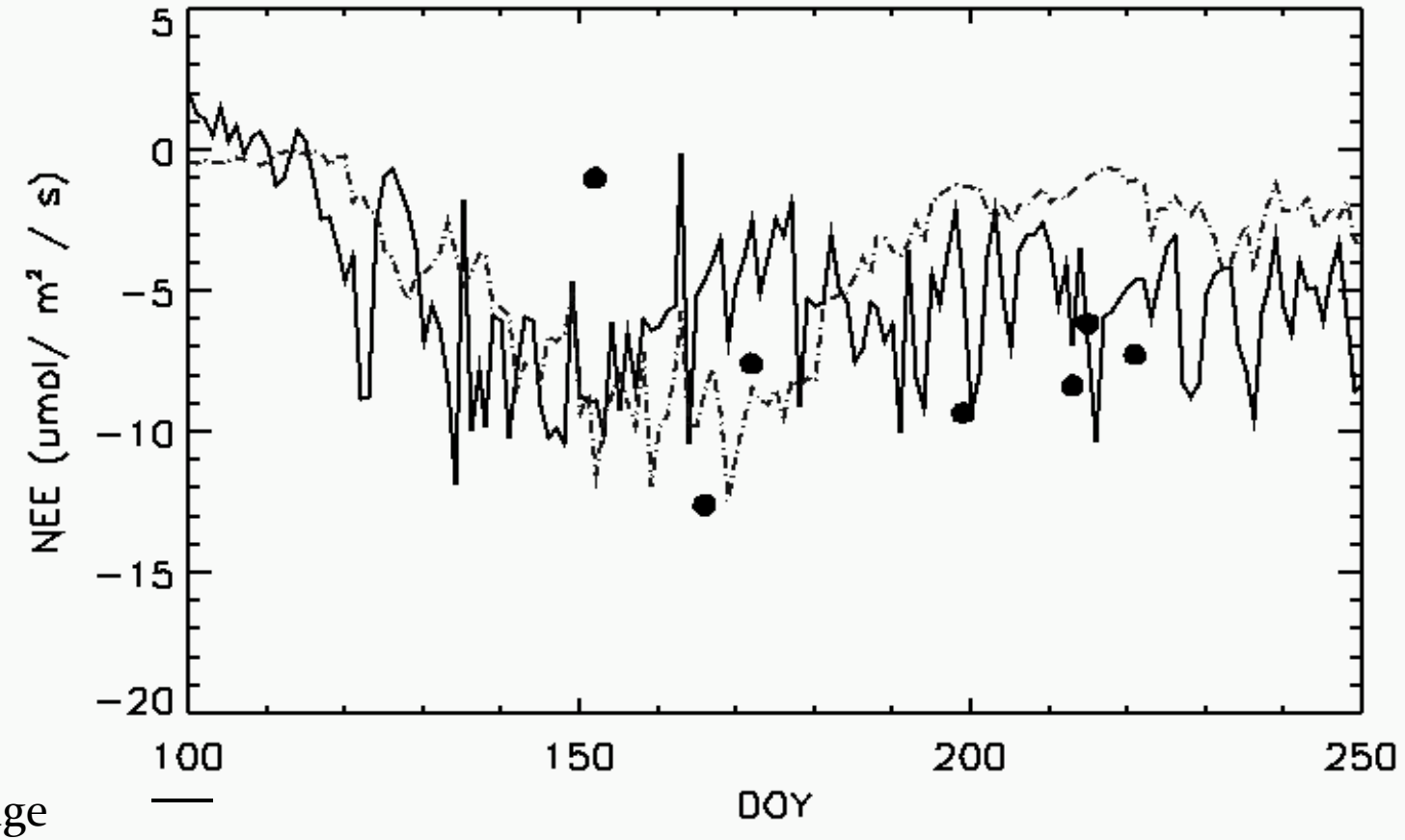
- NEE from Niwot Ridge AmeriFlux Tower
- NEE from 2008 release of CarbonTracker (NOAA ESRL)
- Airborne Observations from seven flight days
- North American Regional Reanalysis Boundary Layer Heights (NOAA NCEP)

Photo Credit: Vanda Grubisic, DRI

NEE using PBL from NARR



Niwot Ridge AmeriFlux Tower vs. CarbonTracker with BLB



Niwot Ridge

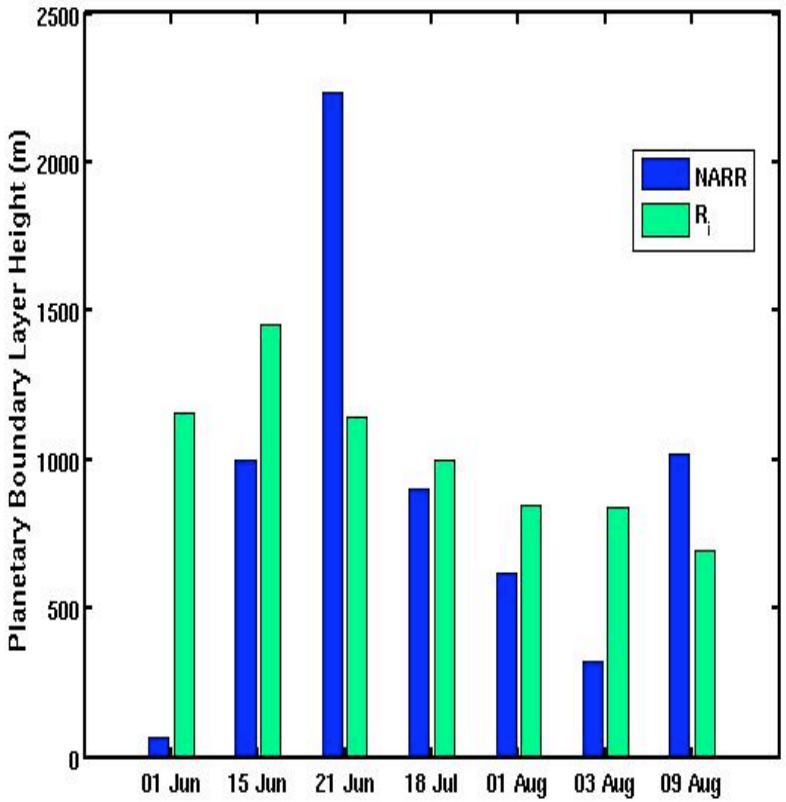
CarbonTracker

BLB

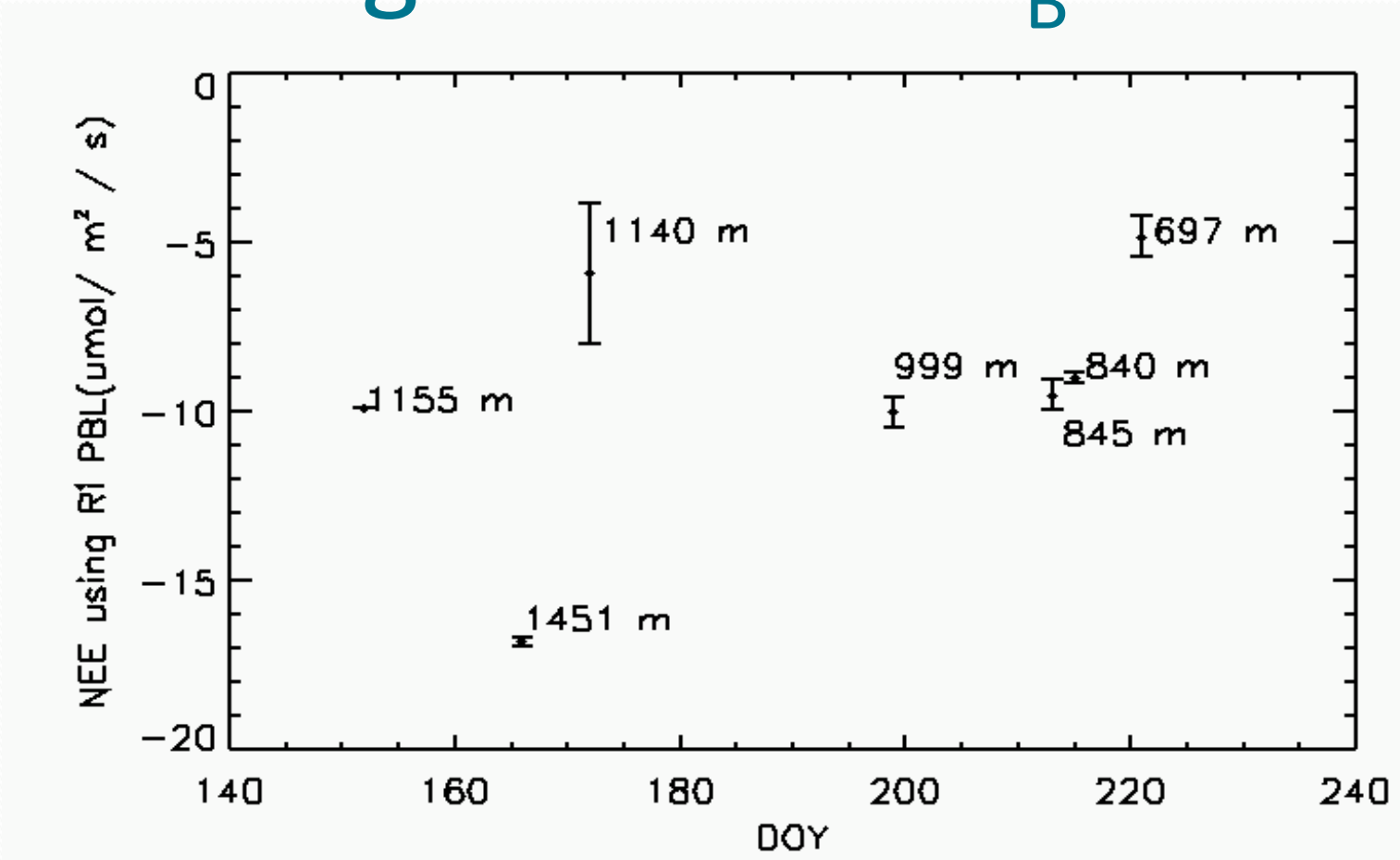
Bulk Gradient Richardson Number

$$Ri_B = \frac{gz\Delta\Theta_v}{\overline{\Theta_v}[u(z)^2 + v(z)^2]}$$

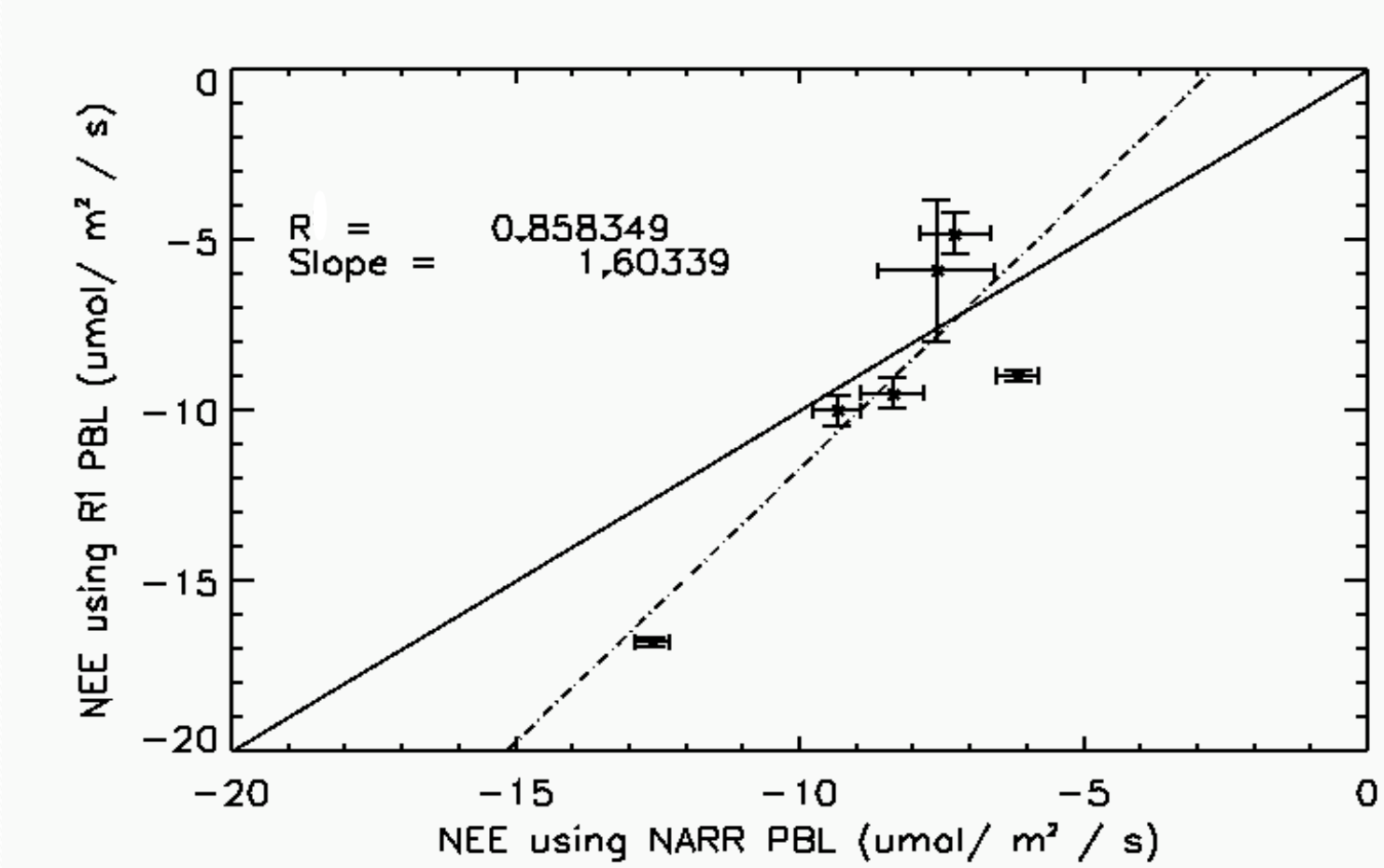
- Altitude at which Ri_B became greater than Ri_c was selected as the boundary layer height
- Ri_c = 0.25 (Pleim and Xiu, 1995)



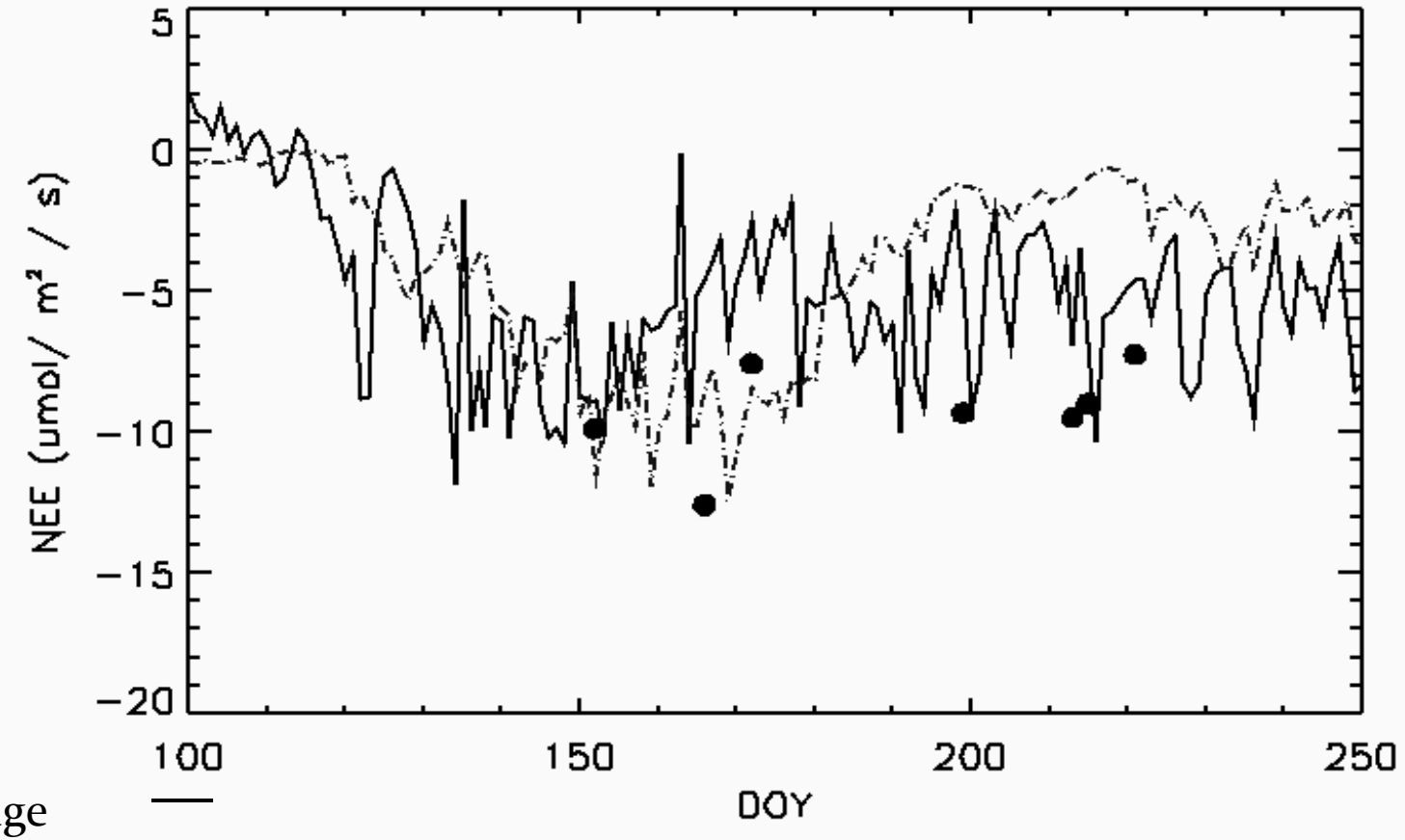
NEE using PBL from Ri_B



Comparison of NEE from different estimates of PBL



Niwot Ridge AmeriFlux Tower vs. CarbonTracker with Best Estimate from BLB

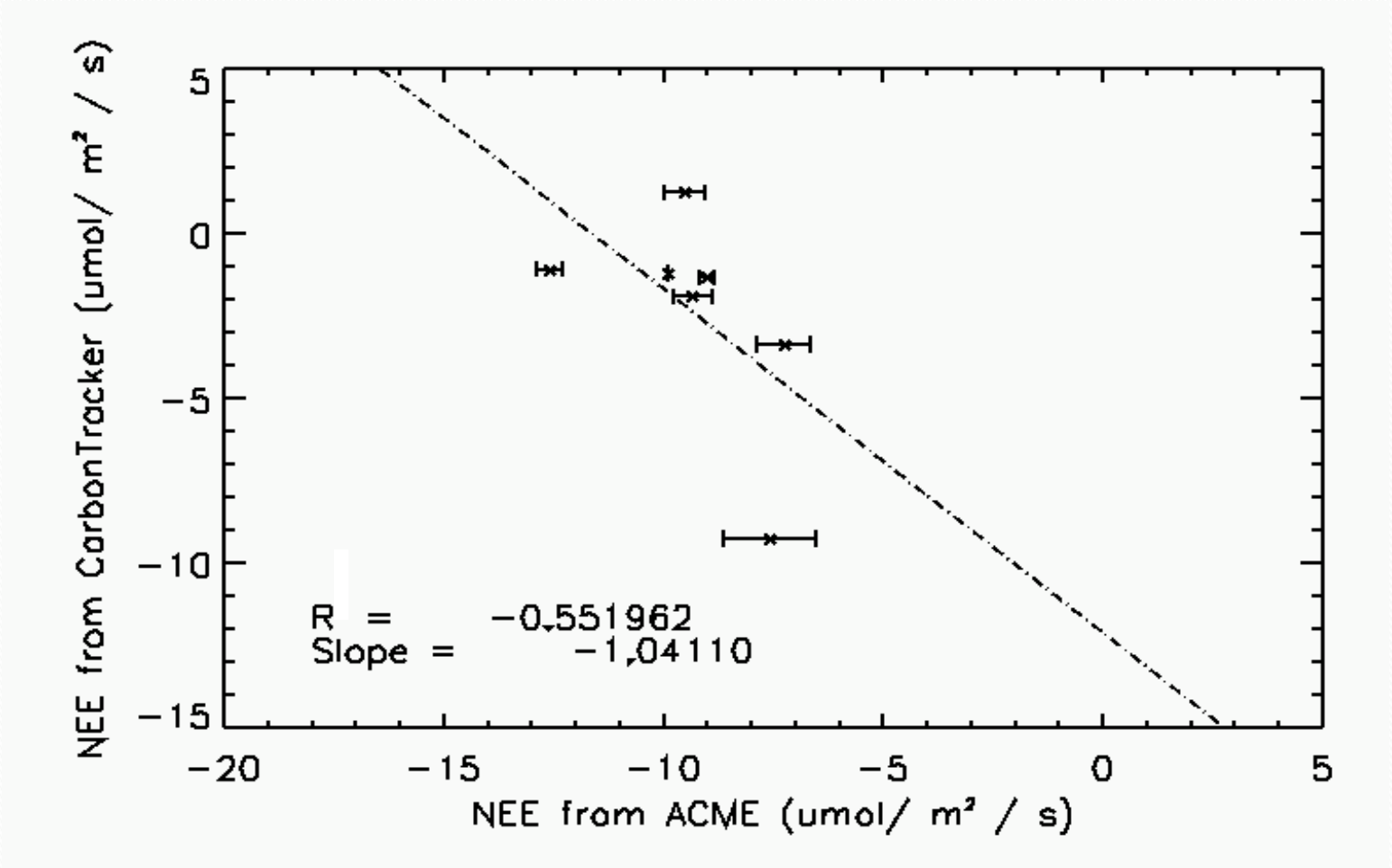


Niwot Ridge

CarbonTracker

BLB

BLB Flux vs. CarbonTracker



Summary

- Broad agreement among the three methods for mean daytime flux
- CarbonTracker shows less uptake in mid-summer when compared to Niwot Ridge and airborne observations
- Spatial and temporal averages of CarbonTracker fluxes over the domain show an inverse relationship when compared with airborne observations
- Accurate estimates of boundary layer growth required to further narrow the uncertainty of carbon fluxes in complex terrain

Questions?

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