Eddy Flux Data Analysis of Four Durham-Area Ecosystems

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Background

Understanding the dynamics of molecular exchange between variable land cover types and the atmosphere.

UNH Earth Systems Research Center
- Eddy Flux Network (January 2014-)

Land Management
- Atmospheric measurement system
- Climate impacts/response

Instrumentation
- Wind velocity, air temperature & molecular concentrations (10Hz)

Limitations
- Low turbulent periods
  - Land cover and weather determination
  - Losses via advection

Solution Implementation
  - Ustar (friction velocity) Filtering

New Hampshire Landscapes


Thompson Forest (mixed), Durham, NH


Kingman Hayfield, Madbury, NH


West Edge Parking (impervious), Durham, NH

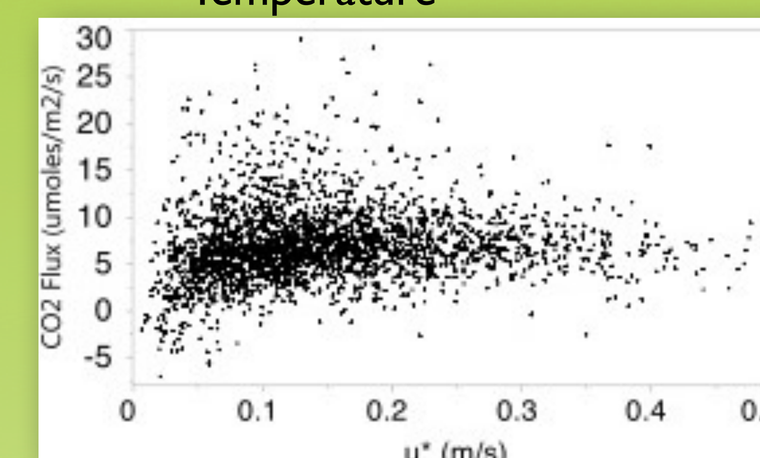

Moore Cornfield, Durham, NH

Methods

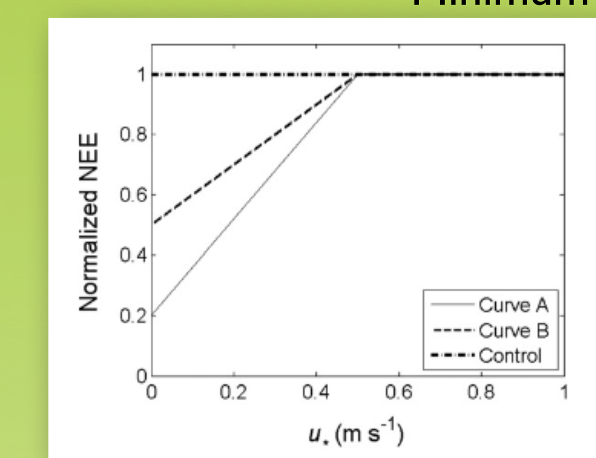
If eddy covariance requires turbulence to accurately measure fluxes within the boundary layer, then how can data collected over all time periods be filtered appropriately?

Preliminary
- Collected data (2014, 2015, 2016)
- Filtering
  - Quality value
  - Day/night
  - Growing/non-growing season
  - Temperature

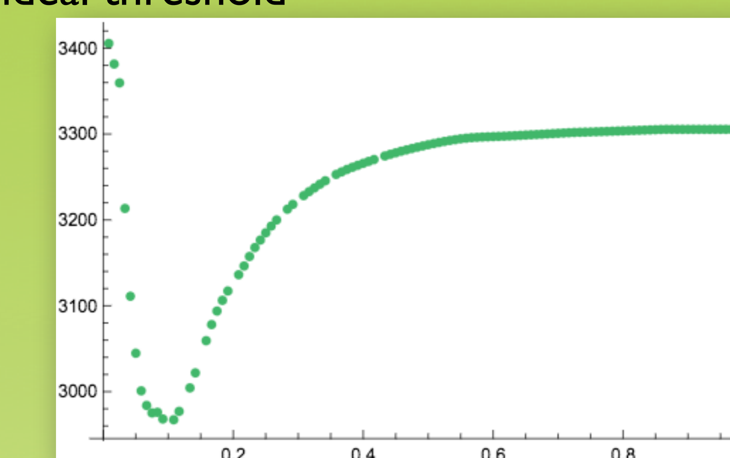
Objective
- Change-Point Detection
  - Piece-wise
  - Critical x_c (Ustar threshold)
- Mathematica Loop
  - Global solver
  - Minimum error: ideal threshold



Preliminary Filters



Change-Point


Error Plot (Kingman Hayfield)

Theory

Eddy Covariance: widely-used atmospheric technique for measuring and calculating vertical turbulent fluxes within atmospheric boundary layers (Carbon dioxide (CO_2), water vapor (H_2O), heat, latent heat)

- Must decompose as: $\zeta = \bar{\zeta} + \zeta'$ → Conservation equation: $\frac{\partial \rho_d \zeta}{\partial t} + \vec{\nabla}(\vec{u}\rho_d\zeta) + K_\zeta \Delta(\rho_d \zeta) = S_\zeta$

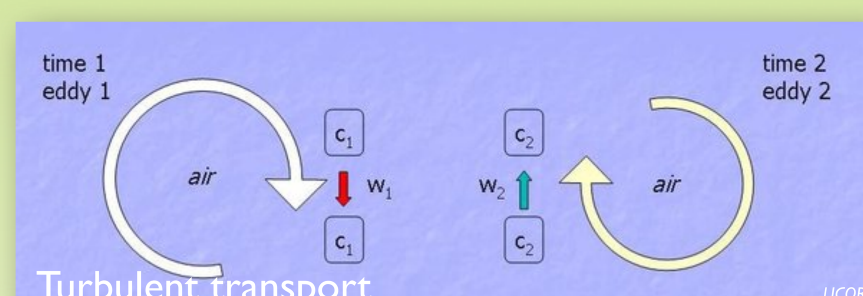
(I) (II) (III) (IV)

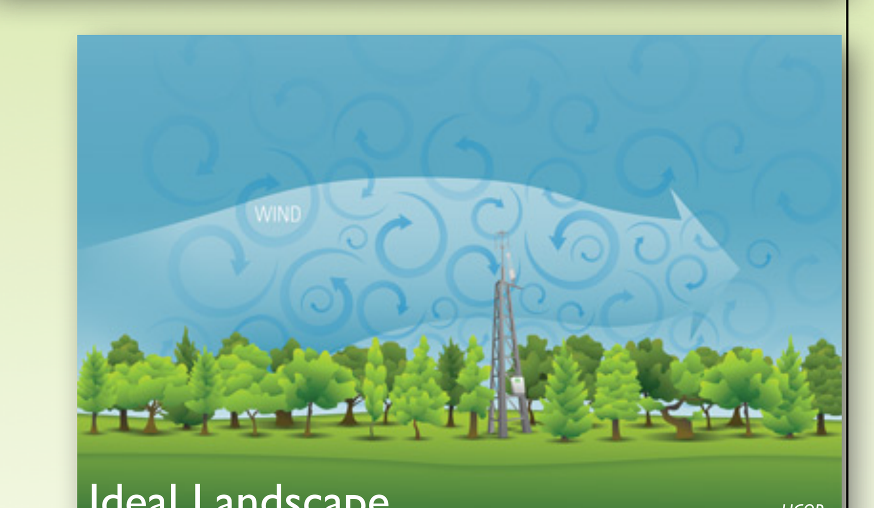
(I): time rate of change of quantity ζ (II): atmospheric transport (III): molecular diffusion (IV): Source/sink contributions to the system

Special Cases

1. $\zeta = 1$ → $\frac{\partial \rho_d}{\partial t} + \vec{\nabla}(\vec{u}\rho_d) = 0$
   [dry air mass continuity]
   1. Fully diffused, no source/sink
2. $\zeta = u_i$ (wind velocity component) → $\frac{\partial \overline{w'u'}}{\partial z} = 0$
   [momentum conservation]
   1. $w'u'$: eddy covariance term
3. $\zeta = \chi_s$ (molar mixing ratio) → $\frac{\partial \overline{\rho_d w'\chi'_s}}{\partial z} = \overline{S_s}$
   1. Active/passive tracer source term
   2. Active (ozone, VOCs, NOx): non-zero source
   3. Passive (water vapor, CO_2): zero source
4. $\zeta = c_p\theta$ (air enthalpy) → $\frac{\partial \overline{w'\theta'}}{\partial z} = \frac{1}{\rho c_p}\frac{\partial R}{\partial z}$
   1. Radiative flux divergence ≈ 0 if no fog, rain or smoke

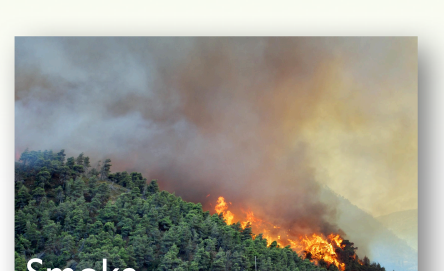
Aubinet et al., 2012

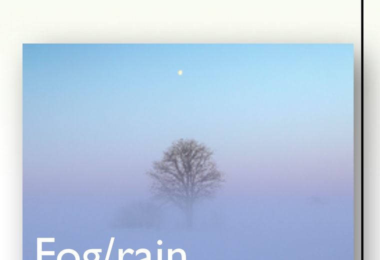


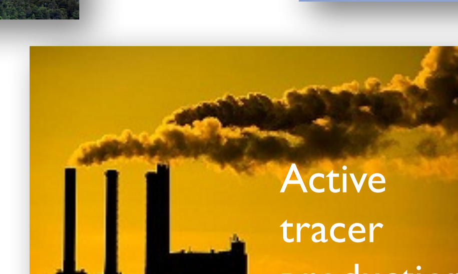


Collective Assumptions/Requirements
1. Boundary layer above land of interest *(few tens of meters)*
2. Turbulent flux: net vertical transfer via eddies
3. Horizontal/uniform terrain

Complex Situations for Traditional Methods







Practical Formula

$$F \approx \bar{\rho}_a \overline{w's'}$$

Results

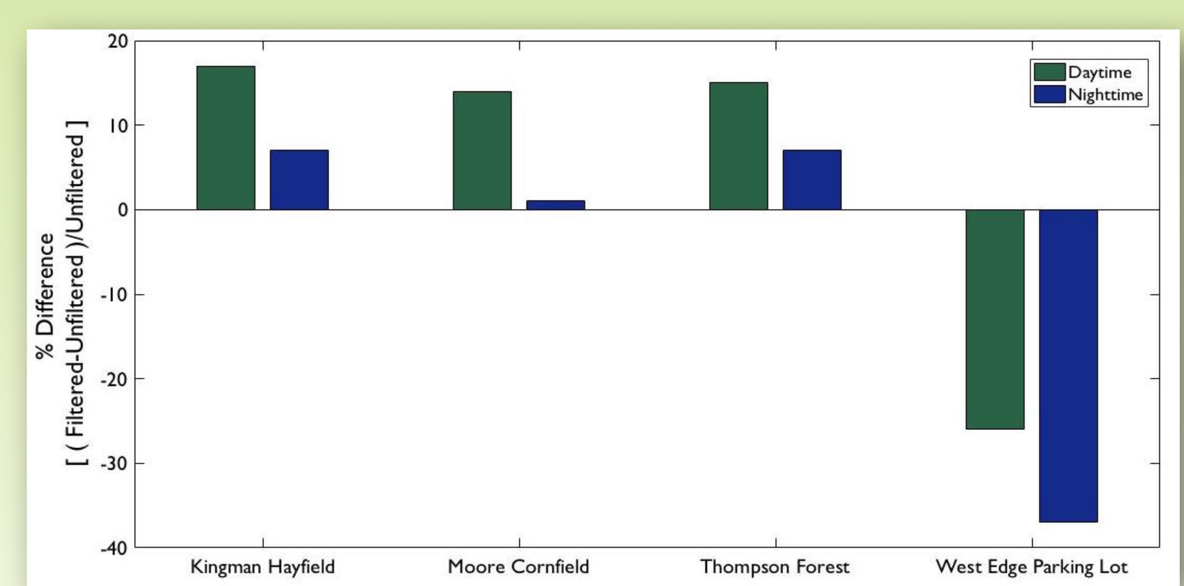
Ustar Threshold Values

Kingman Hayfield: 0.14 m/s
Moore Cornfield: 0.14 m/s
Thompson Forest: 0.3 m/s
West Edge Parking Lot: 0.14 m/s

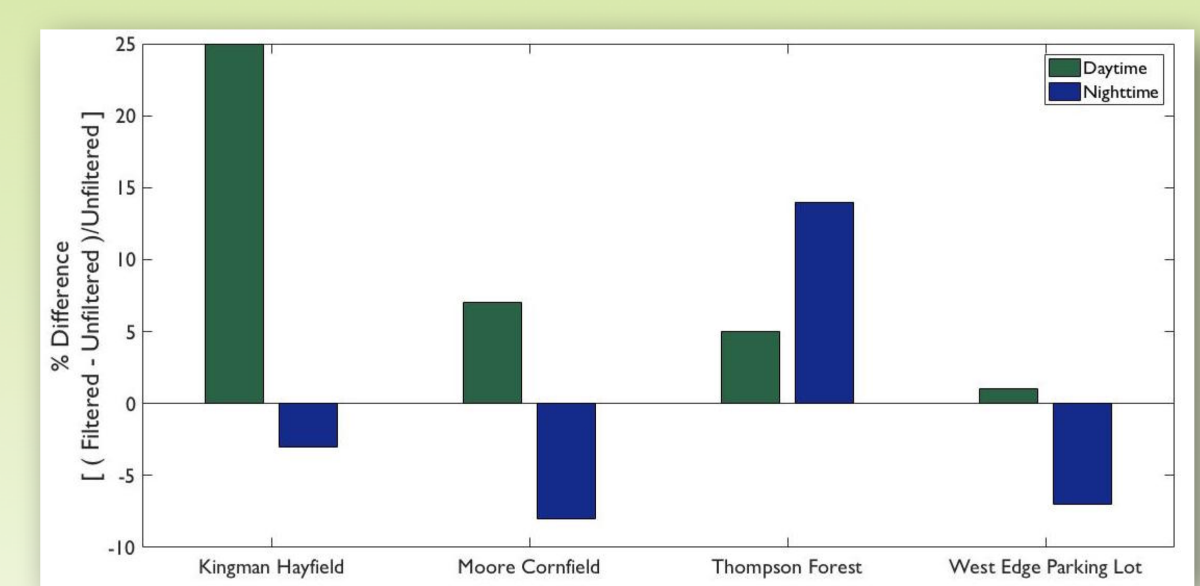
Absolute Carbon Flux Value Change

	[μmoles/m^{2}s]	Kingman	Moore	Thompson	West Edge
Growing	Day	0.03	0.02	0.02	0.07
	Night	0.01	0.00	0.01	0.12
Non-Growing	Day	0.03	0.00	0.01	0.00
	Night	0.00	0.00	0.02	0.01

Impact of Filtering on Average Carbon Flux Values (Percent Difference)



Growing Season



Non-Growing Season

Conclusion

1. Ustar filtering has the potential to drastically impact results
2. Errors are due to non-ideal conditions
   - Improvement via more robust filtering
   - Improvement via controls
3. Improved filtering techniques can enhance current mapping of ecosystem flux and climate predictions

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