CO_2 Flux Measurement Uncertainty Estimates for NACP

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Outline

- **Background**
- **NEP (= -∫NEE) uncertainty associated with u_*^{Th} uncertainty**
- **NEP random uncertainty**
- **Summary**

Eddy-Covariance (EC) Measurement Uncertainties

Random uncertainty

- associated with measurement noise
- can be characterized using:
  - proximate paired towers
  - similar periods on consecutive days
  - comparison with gap-filling model
- *not* negligible at the annual time scale

Systematic uncertainty

- less well understood, less easily characterized
- caused by inadequate EC system design or violation of EC assumptions, as seen in under-measurement at low windspeeds (u_* or σ_w filtering), energy balance non-closure, cold-air drainage, and other 3D flow regimes

# Quantifying NEP Uncertainty Related to the Low-u_* NEE Exclusion Threshold u_*^{Th}
(adapted from Papale et al. 2006 with modifications)

- **Estimate u_*^{Th} and its uncertainty using change-point detection**
  - stratify each year into 4 seasons and each season into 3-7 temperature bins
  - for each stratum, plot binned NEE vs. u_* and evaluate the change-point
  - aggregate to one annual value
  - bootstrap 1,000 times per year and pool all years
- **Fill gaps in NEE (MDS and Fluxnet-Canada methods) for all values of u_*^{Th}**
- **Estimate NEP uncertainty as 95% confidence intervals from 2.5 and 97.5 percentiles**

Variation in u_*^{Th} by Land Cover

| Land Cover	Mean ± S.D. (n)
Permanent Wetland	0.12 ± 0.00 (2)
Cropland	0.19 ± 0.06 (5)
Shrubland & Savanna	0.20 ± 0.05 (3)
Grassland	0.21 ± 0.05 (5)
Juvenile Forest	0.20 ± 0.07 (6)
Mature Evergreen Needleleaf Forest	0.38 ± 0.13 (11)
Mature Deciduous Broadleaf Forest	0.40 ± 0.07 (6)
Mature Mixedwood Forest	0.41 ± 0.07 (3)

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95% Confidence Intervals in the $u_*{}^{Th}$ in Relation to the Median $u_*{}^{Th}$, by Site
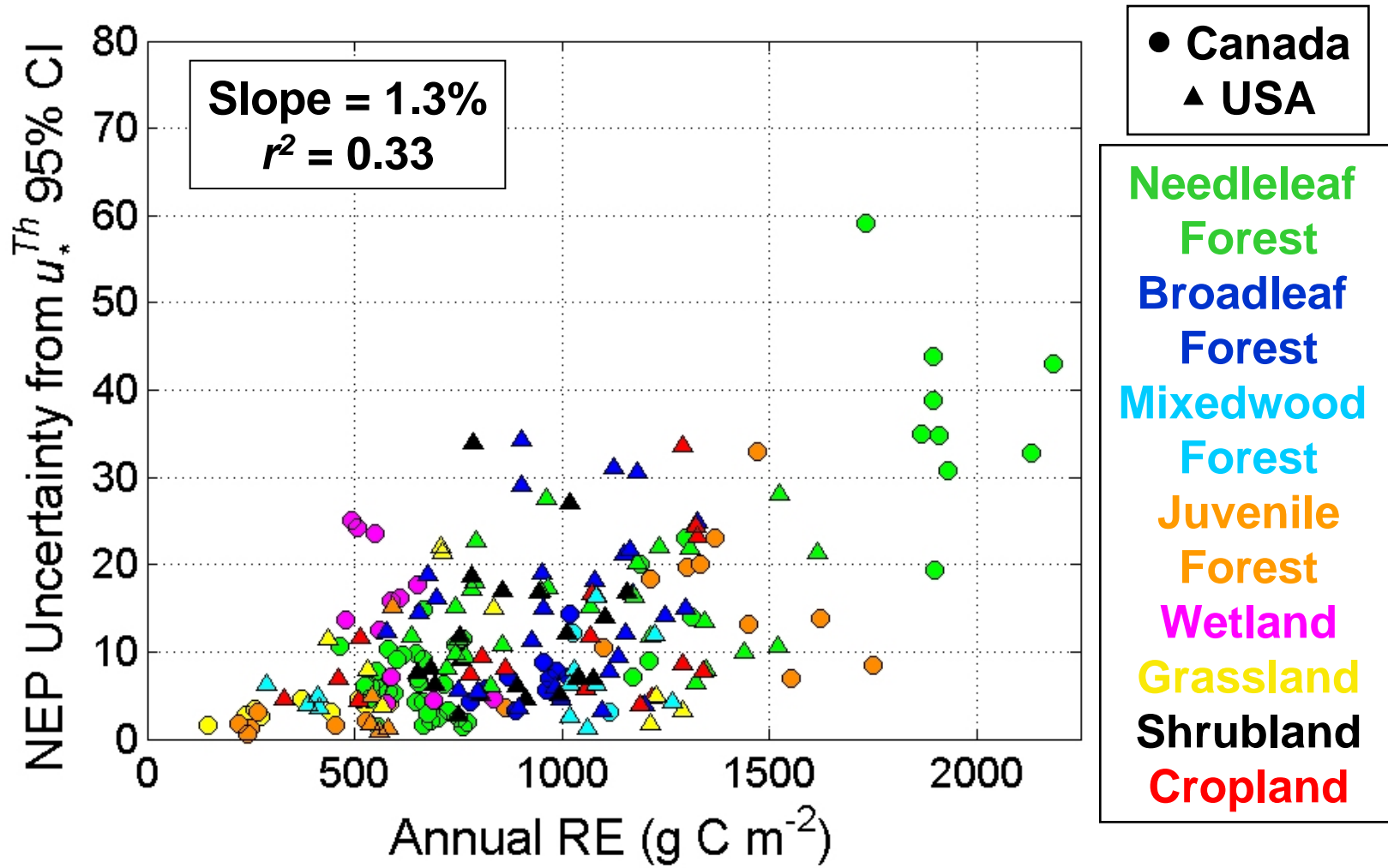

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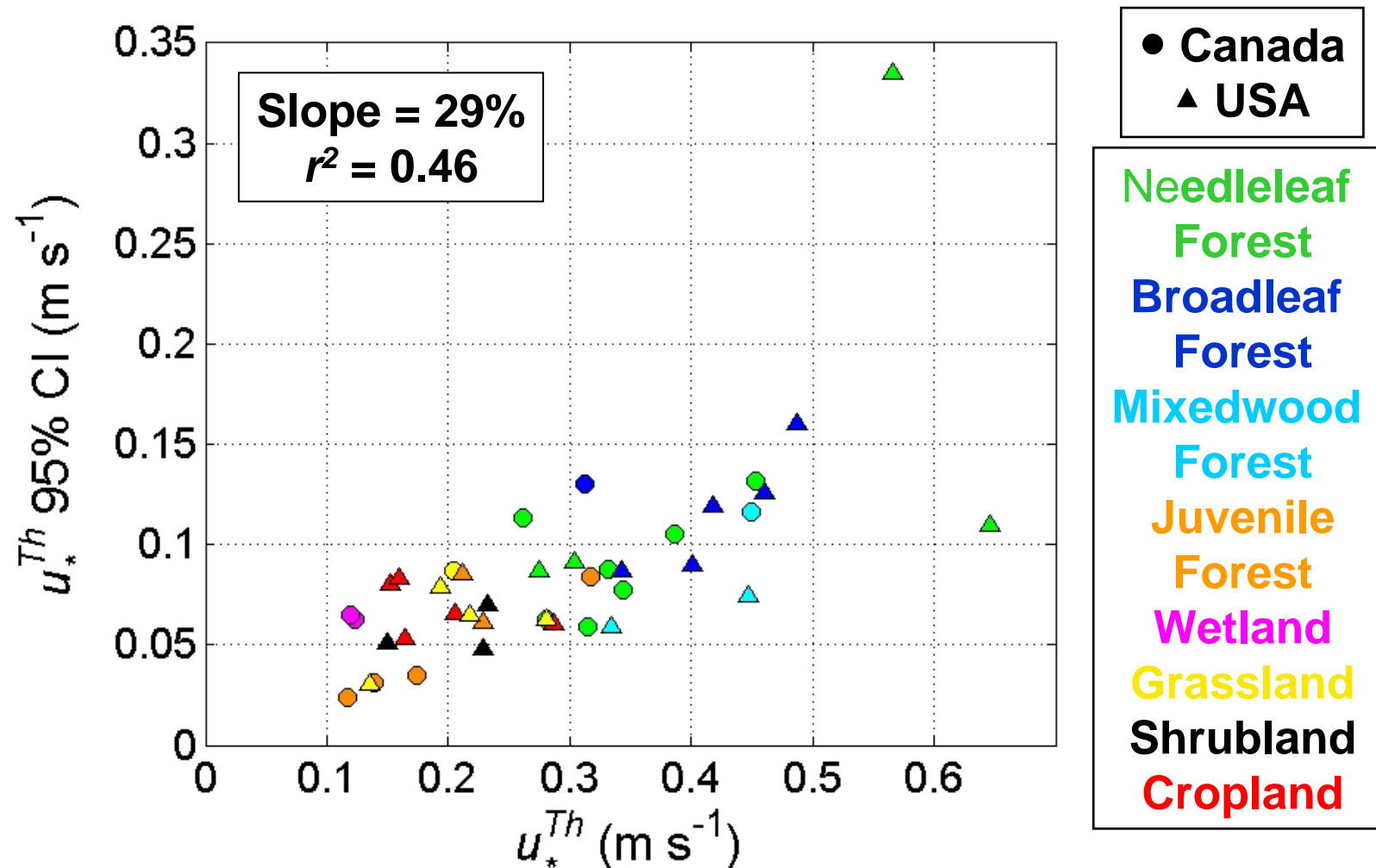
Percentage of Nighttime NEE Data Excluded by the Median u_*^{Th}
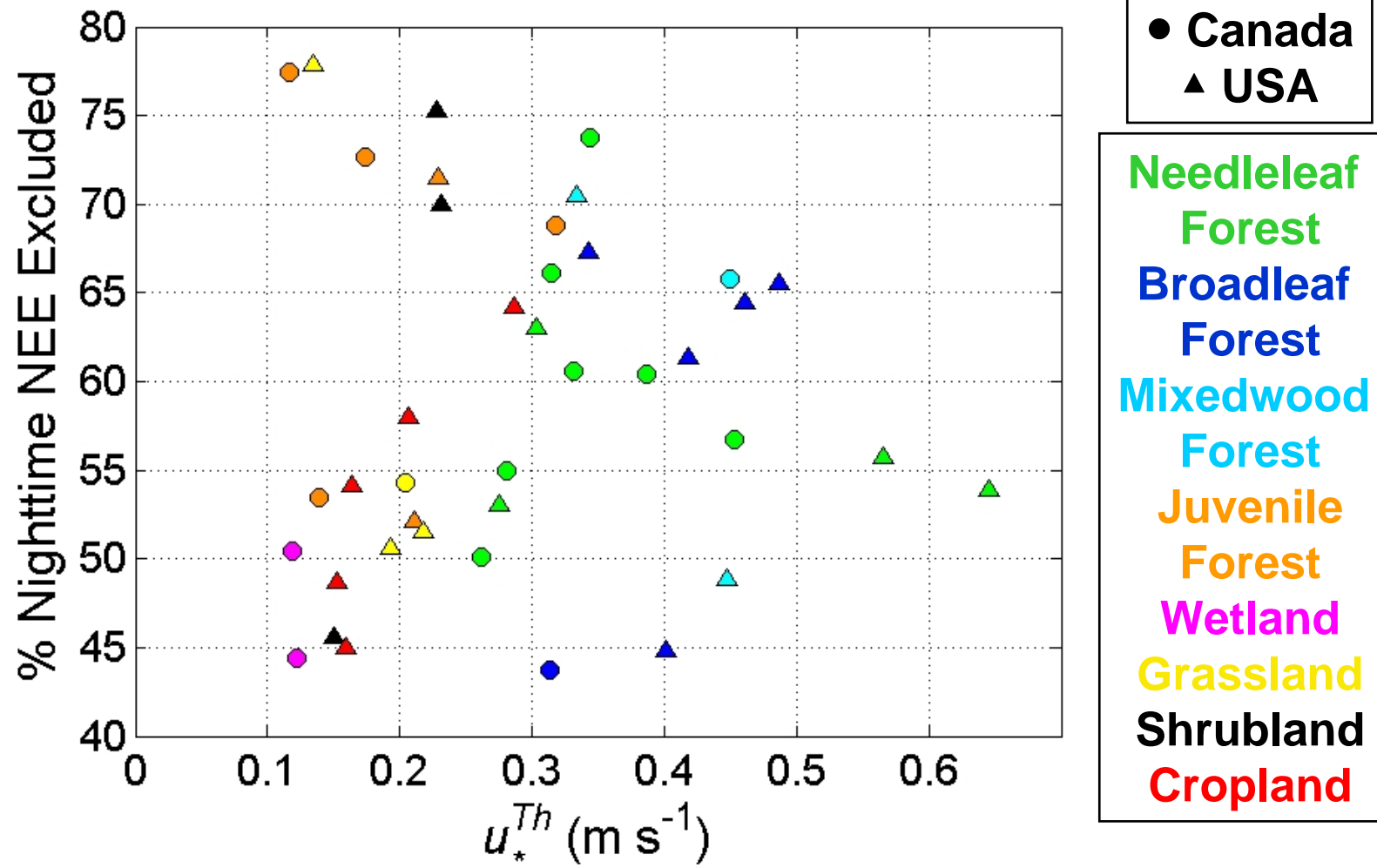
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u_*^{Th}-Related Uncertainty in Annual NEP
(95% Confidence Interval, g C m^{-2})
in Relation to Annual NEP (MDS)
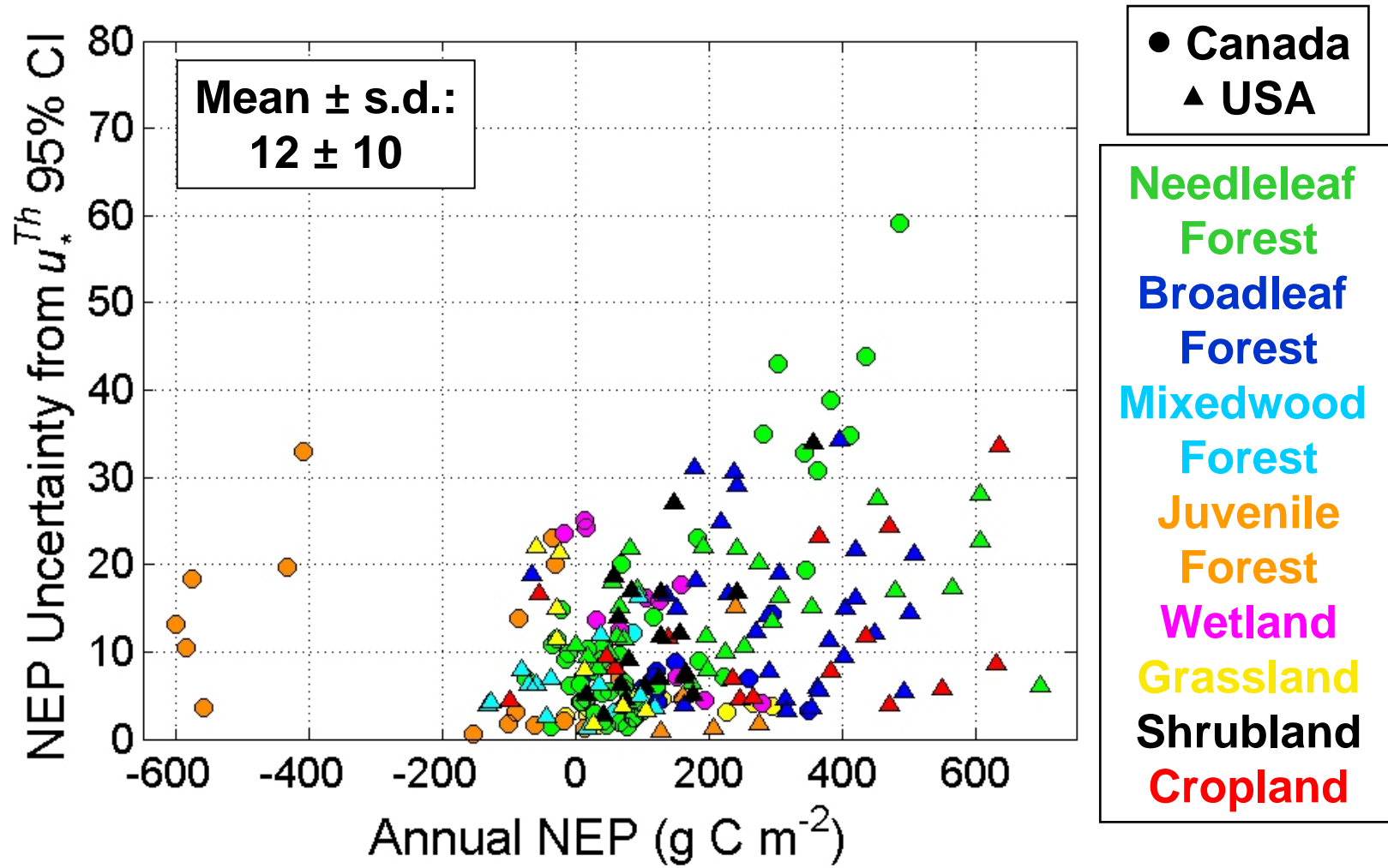
u_*^{Th}-Related Uncertainty in Annual NEP
(95% Confidence Interval, g C m^{-2})
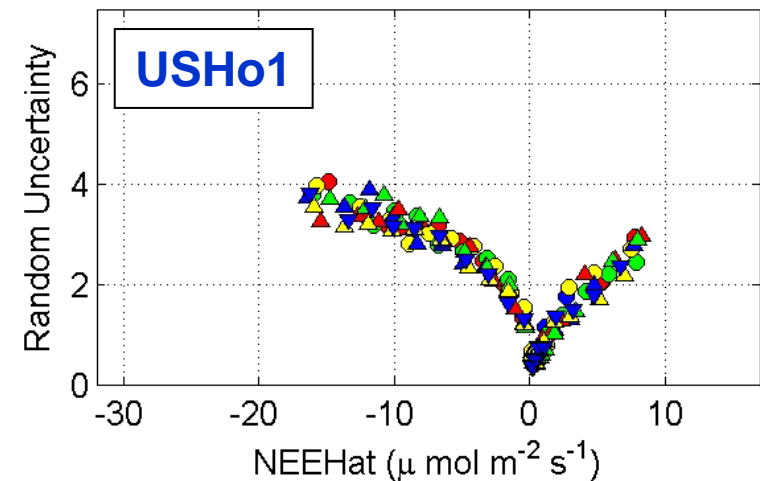## in Relation to Ecosystem Respiration RE

Quantifying Random Uncertainty
## (annual analysis following Richardson et al. 2006, 2007)

- **Quantify NEE random uncertainty curve**

- **Apply Monte-Carlo methods**

- Begin with gap-free synthetic data from gap-filling algorithm

- Add random noise

- Introduce and fill actual gaps

- Repeat 1,000 times

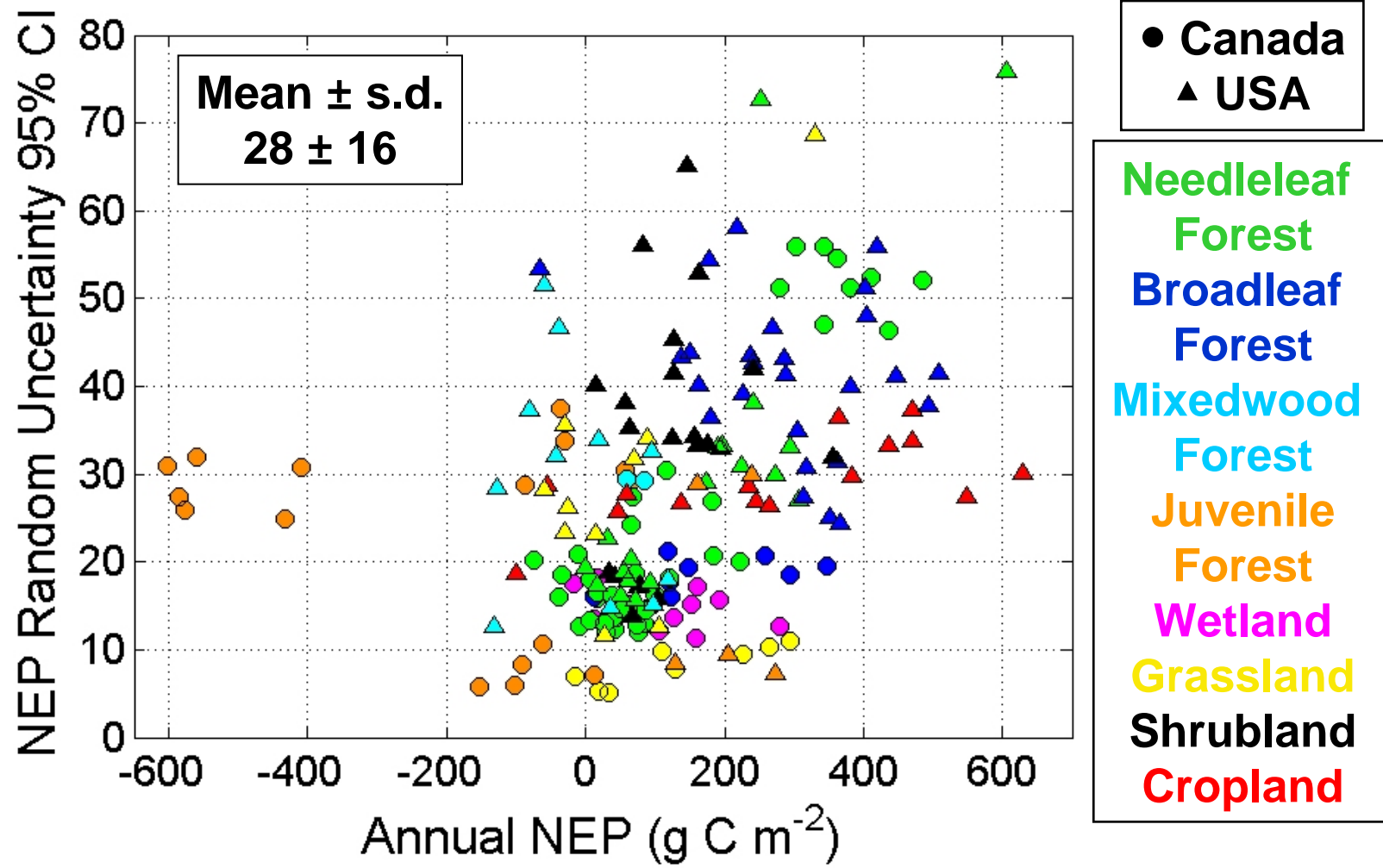- Calculate uncertainty at different time scales as 95% confidence intervals from 2.5 and 97.5 percentiles

Random Uncertainty in NEE

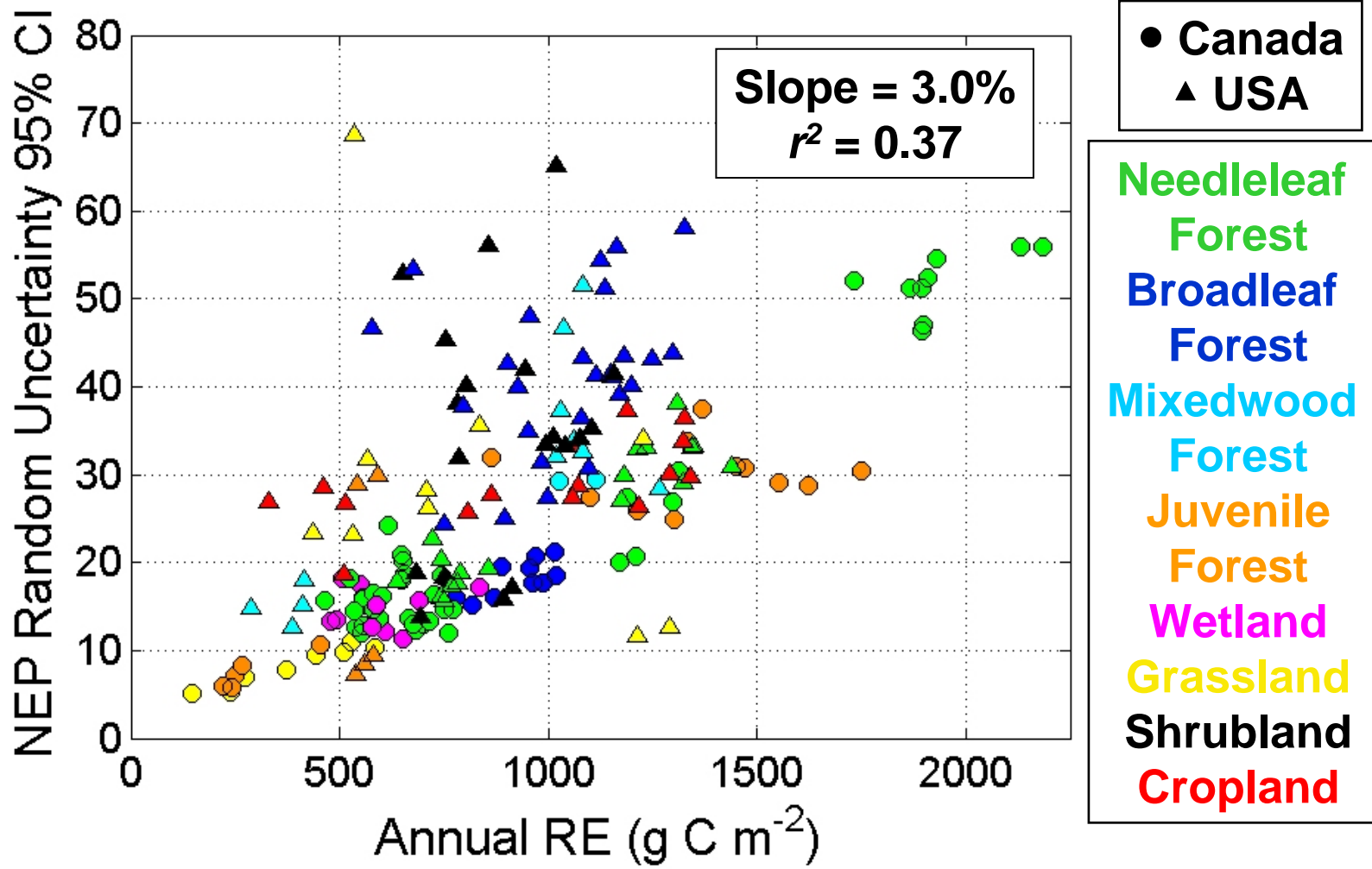## (showing μ (μmol m^{-2} s^{-1}) from a double exponential distribution in relation to gap-filling NEEHat)
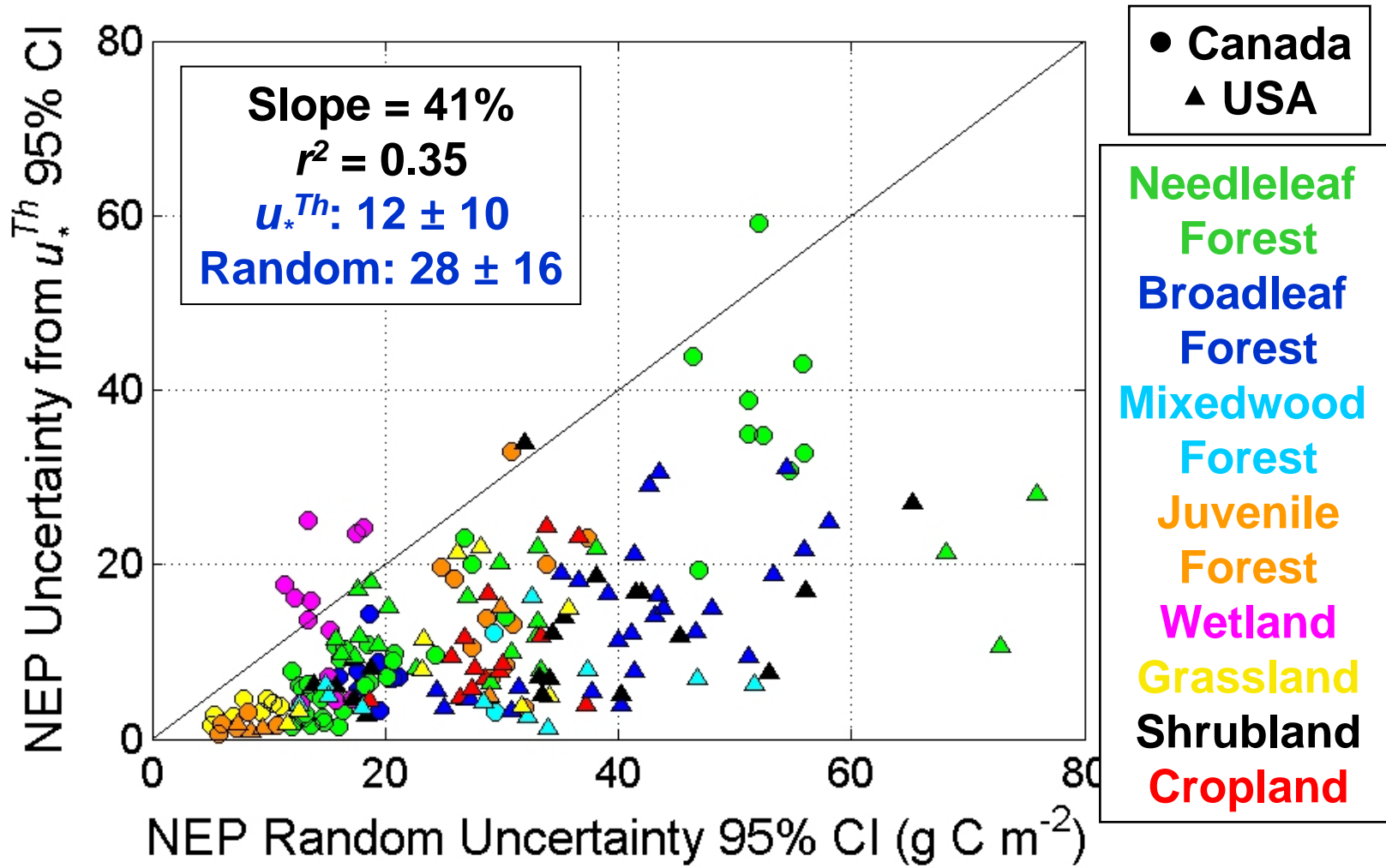

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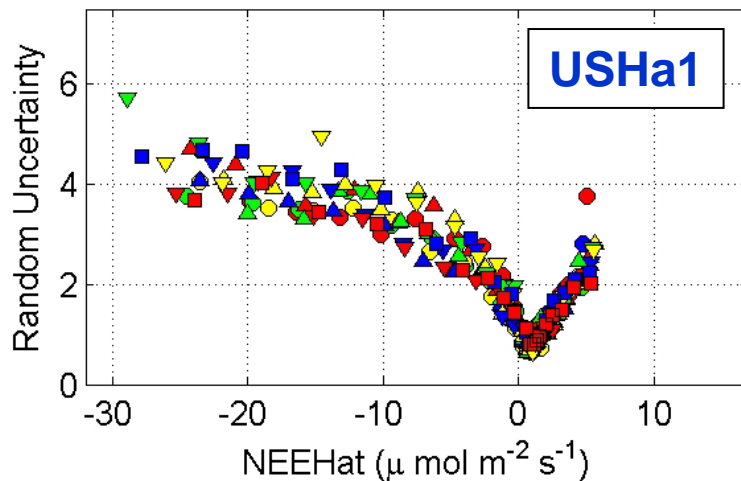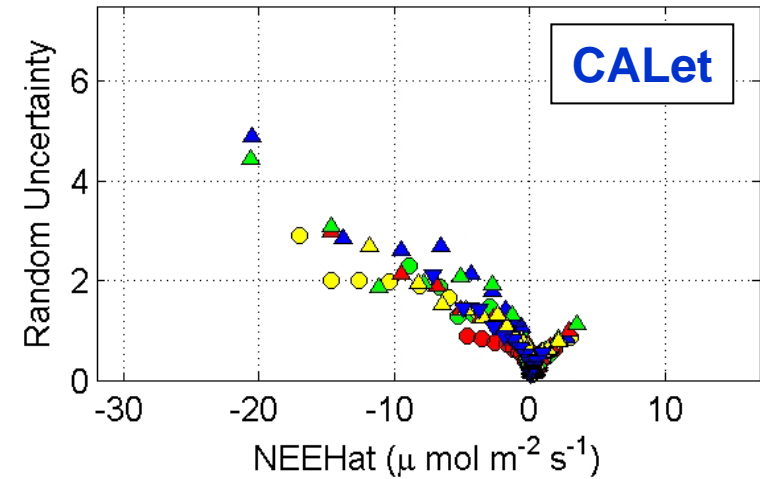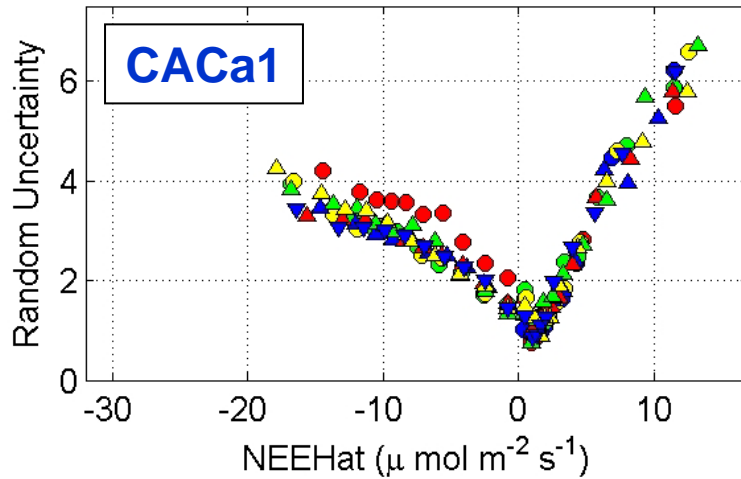
Random Uncertainty in Annual NEP
(95% Confidence Interval, g C m⁻²)
in Relation to Annual NEP

Random Uncertainty in Annual NEP
(95% Confidence Interval, g C m^{-2})
in Relation to Ecosystem Respiration RE

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Comparing u_*^{Th}-Related and Random Uncertainties in Annual NEP: All Sites

Slope = 41%
r^2 = 0.35
u_*^{Th}: 12 ± 10
Random: 28 ± 16

● Canada
▲ USA

Needleleaf Forest
Broadleaf Forest
Mixedwood Forest
Juvenile Forest
Wetland
Grassland
Shrubland
Cropland

NEP Uncertainty from u_*^{Th} 95% CI

NEP Random Uncertainty 95% CI (g C m^{-2})

Summary

- u_*^{Th} is well defined at most sites, excludes 44% to 78% of nighttime NEE

- Random uncertainties in NEP are larger than u_*^{Th} - related uncertainties

  - random: **28 ± 16**

  - u_*^{Th} - related: **12 ± 10 (g C m^{-2} y^{-1}, mean ± s.d.)**

- Both uncertainties increase with RE but with significant, unexplained differences among sites