

Developing a quality assurance and quality control framework for NEON's eddy-covariance flux measurements

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Background

The National Ecological Observatory Network (NEON) is a continental-scale research platform with a projected operation of 30 years. NEON's purpose is to provide high quality data products that will facilitate discovering and understanding the impacts of climate change, land-use change, and invasive species on ecology. The eddy-covariance (EC) technique will be used to continuously monitor the exchange of sensible heat, water vapor, CO₂ and other scalars between ecosystems and the atmosphere at all 60 NEON research sites.



Map of 20 NEON domains with indicators for different sites.

Why flux QA/QC?

All data streams collected by NEON pass through an automated quality control (see [companion poster 80](#)). However, the EC method makes use of additional assumptions and simplifications, many of which are related to the mass balance equation;

$$F = \int_0^z \frac{\partial \bar{u} \bar{s}}{\partial x} + \int_0^z \frac{\partial \bar{v} \bar{s}}{\partial y} + \int_0^z \frac{\partial \bar{w} \bar{s}}{\partial z} + \int_0^z \frac{\partial \bar{w}' s'}{\partial z}$$

$$+ \int_0^z \frac{\partial \bar{u} \bar{s}}{\partial x} + \int_0^z \frac{\partial \bar{v} \bar{s}}{\partial y} + \int_0^z \frac{\partial \bar{w} \bar{s}}{\partial z}$$

with the total flux F into or out of an ecosystem, a scalar quantity s such as H₂O or CO₂ mixing ratios, along-, cross-, and vertical wind speeds u , v , and w with respect to the Cartesian coordinates x , y , and z ; t is time, and z is the measurement height.

Testing these assumptions and simplifications in addition to an automated quality control is indispensable to ensure high data quality as well as representativeness of the EC flux data products for the target ecosystems.

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The NEON flux QA/QC plan

Four stages of scalable tests, resulting in Quality metrics (QM)

Stage 1 "Temporally explicit flux QA/QC"

- Stationarity → QM_{STA}
- Developed turbulence → QM_{ITC}
- Comparison to reference spectrum → QM_{SPE}
- Comparison to reference cospectrum → QM_{COS}
- Random error → QM_{ERR}
- Systematic error → QM_{ERS}
- Energy balance residual → QM_{RES}

Stage 2 "Spatially explicit flux QA/QC"

- Footprint modeling considering 3D dispersion
- Superimpose footprints over high-resolution remote sensing data from NEON Airborne Observation Platform
- Evaluation of target land cover in footprint → QM_{SOU}

Criteria	Eq. Term	QM_{STA}	QM_{ITC}	QM_{SPE}	QM_{COS}	QM_{ERR}	QM_{ERS}	QM_{RES}	QM_{SOU}	QM_{PUR}
Storage	I									
Divergence	II–III	✓	✓							
Divergence	IV		✓							
Advection	V–VII	✓	✓							
Accuracy	-									
Random error	-					✓				
Flow distortion	-		✓	✓	✓					
Representativeness	-								✓	✓

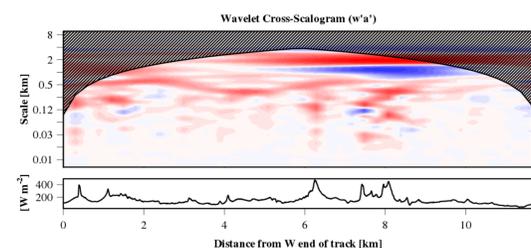
Stage 4 "Complex terrain"

- Detailed case studies for selected sites
- Analysis of Wavelet and Hilbert spectra for intermittent turbulence, coherent structures and gravity waves
- Large eddy simulation to study advection, drainage flow, non-propagating eddies, and more realistic footprints

Stage 3 "Flux un-mixing in heterogeneous terrain"

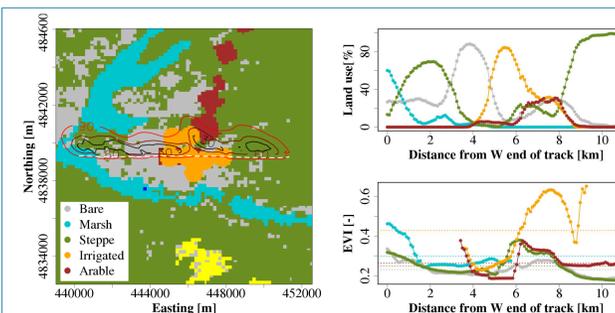
- High temporal resolution of fluxes from wavelet analysis, empirical mode decomposition or structure parameter
- Footprint weights for individual land covers
- Land cover specific fluxes from environmental response functions using boosted regression trees → QM_{PUR}

Example I – Wavelet analysis (aircraft data*)



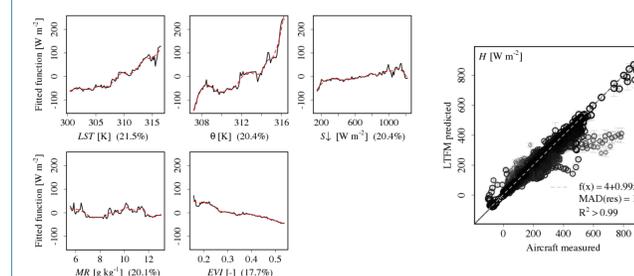
- Parseval's theorem: covariance of a signal can be studied equivalently in time- and frequency domain
- Integration over all turbulent scales for subsets of flux observations enables high temporal discretization

Example II – Footprint analysis (aircraft data*)



- Superimposing footprints over land cover maps
- Fractional land cover contribution to each individual flux measurement

Example III – Environmental response function



- Environmental response function (LTFM) relates sensible heat flux (response) to environmental drivers
- Excellent agreement between observations and LTFM

Objectives

- Enable the transition of EC measurements from principal-investigator-based into observatory-based operations
- Place QA/QC approaches into a production framework
- Ensure consistent quality rating over the range of climates and ecosystems across an entire continent
- Advance established tests and data flows (e.g., AmeriFlux, CarboEurope) to new state-of-the-art functionality
- Respond to requests from the research community
- Provide research community with open source algorithms