Using Eddy Covariance to assess terrestrial evapotranspiration

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NASA NEWS Meeting
June 13, 2011
Irvine, CA

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Overview

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1. **Introduction to Eddy Covariance (EC)**

2. **Network of flux towers and availability of data.**

3. **Ways EC has been used to constrain terrestrial ET**
   - -Validation of process-based LSMs
   - -Empirical/neural network approaches
   - -Tower Model Optimization

4. **Future status of networks**

5. **Concluding remarks**

Introduction to Eddy Covariance: Theory

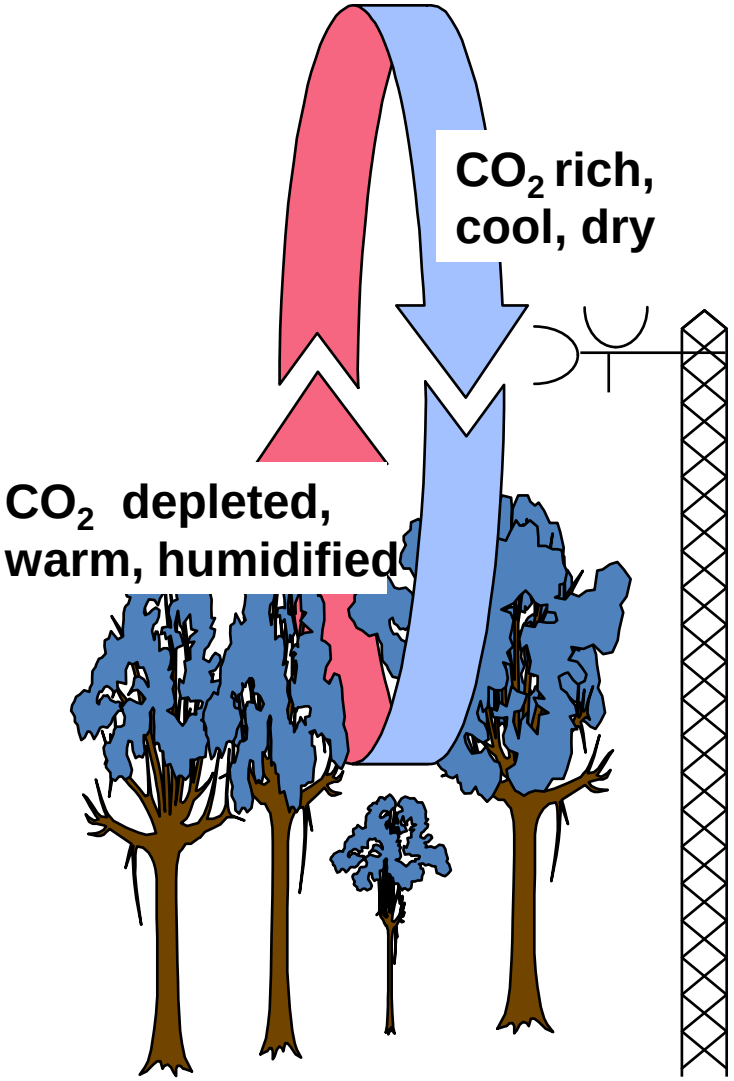
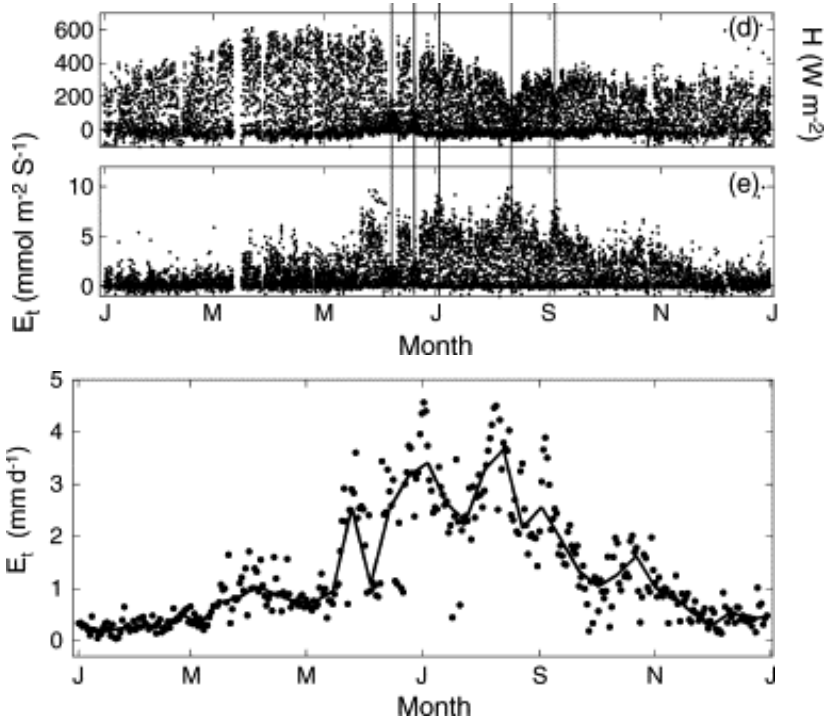


Figure courtesy of Mike Goulden

- Directly measures exchange of heat (LE and H) and mass (CO_2, H_2O, other species) by high frequency measurements of atmospheric turbulence and concentration.
- Requires sufficiently large, homogeneous surface so no net advection of heat or mass.
- Requires sufficient turbulence and other atmospheric conditions, but less restrictive than Bowen ratio type approaches.
- Initial emphasis for most EC tower Pis was on CO_2 (terrestrial carbon sink)

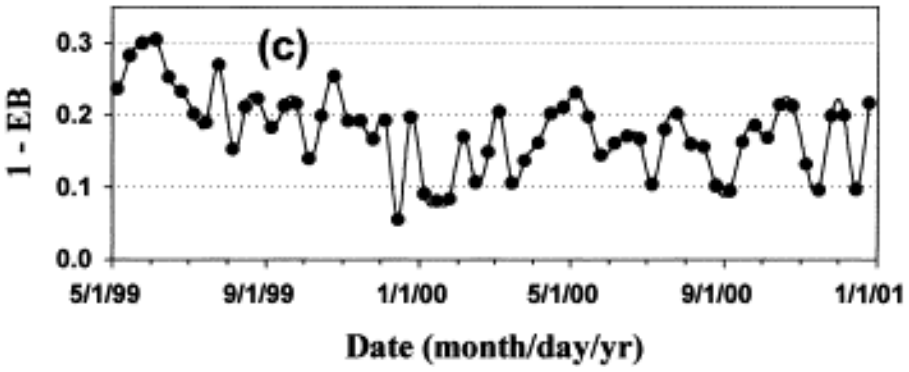
Introduction to Eddy Covariance: Advantages



H and ET at half-hourly (top) and daily ET at a Southern California marsh in 2003 [*Goulden et al.*, 2007].

- **Direct, independent measurement of ET at field scale (~10^4 m^2) at wide variety of temporal scales (30 minutes-years).**
- **Does not alter ecosystem or surface of measurement.**
- **Costs decreasing with more affordable sensors and computing, and better standardization of measurement and data processing protocols.**
- **Less restrictive atmospheric assumptions result in fewer data gaps than other micrometeorological methods.**

Introduction to Eddy Covariance: Disadvantages



10 day averages of Energy budget non-closure in Colorado conifer forest ([*Turnipseed et* al., 2007].

- **Need gap filling technique to deal with times when EC cannot measure fluxes.**
- **Direct EC measurements of LE + H are less than energy budget ($Rn-G>LE_{EC}+H_{EC}$). Energy budget gap usually 10-20%. Need to correct fluxes.**
- **Costs and technical expertise requirements still quite high.**
- **Fewer measurements in mountains and heterogeneous ecosystems because of methodology challenges.**

Networks and Data: Flux networks

Towers in the LaThuile-Fluxnet data synthesis (www.fluxdata.org).

Not inclusive of all EC tower sites.

- **Flux networks are aggregations of PI-operated tower sites.**
- **Numerous national networks and Fluxnet.**
- **Significant gaps in coverage (Africa, Southwest, and South Asia).**
- **Towers funded for local research projects, not monitoring. Significant issues with tower continuity.**

Networks and Data: Data Availability

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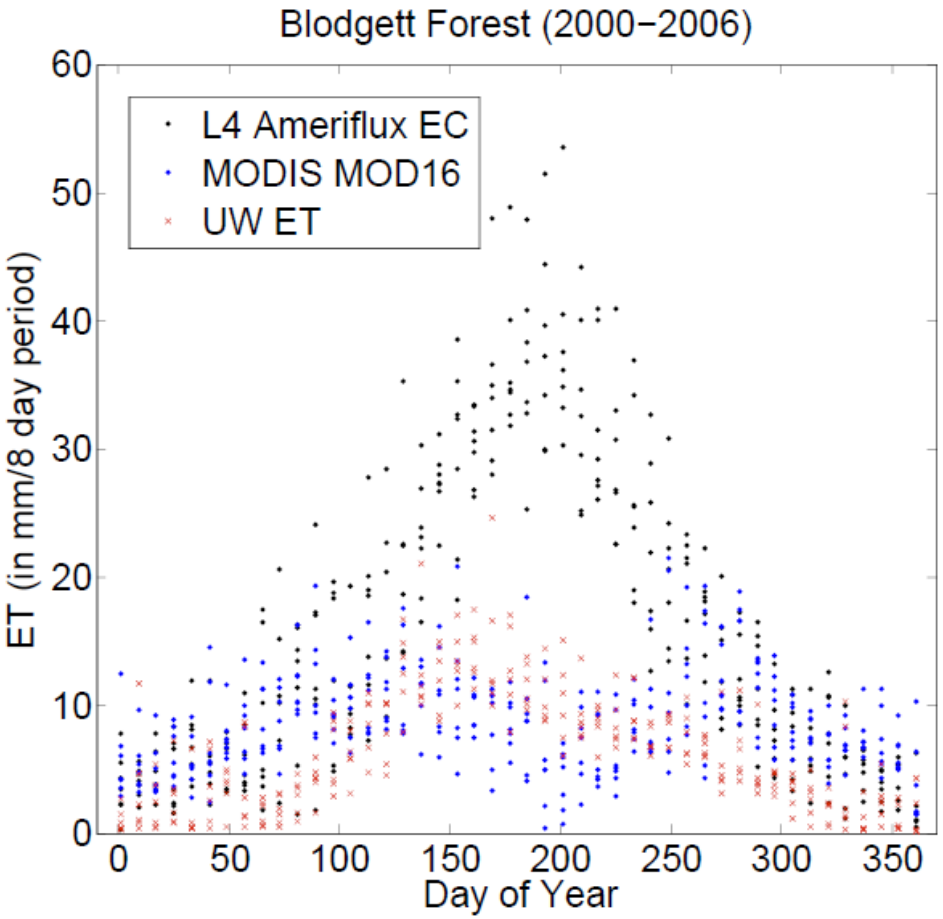
- Data access and use significantly complicated by operating structure of flux towers.
- Must check with PI of operating tower prior to using data in research products/publications.
- Using older/fair access data less likely to result in complications. Using for model validation is probably easier since analysis is less likely to conflict with tower PI's own research.
- Data/data policies can be found on network sites. www.fluxdata.org is most comprehensive, but only has data to 2007; currently major data update going on. Many tower PIs have more current data available on their own websites.

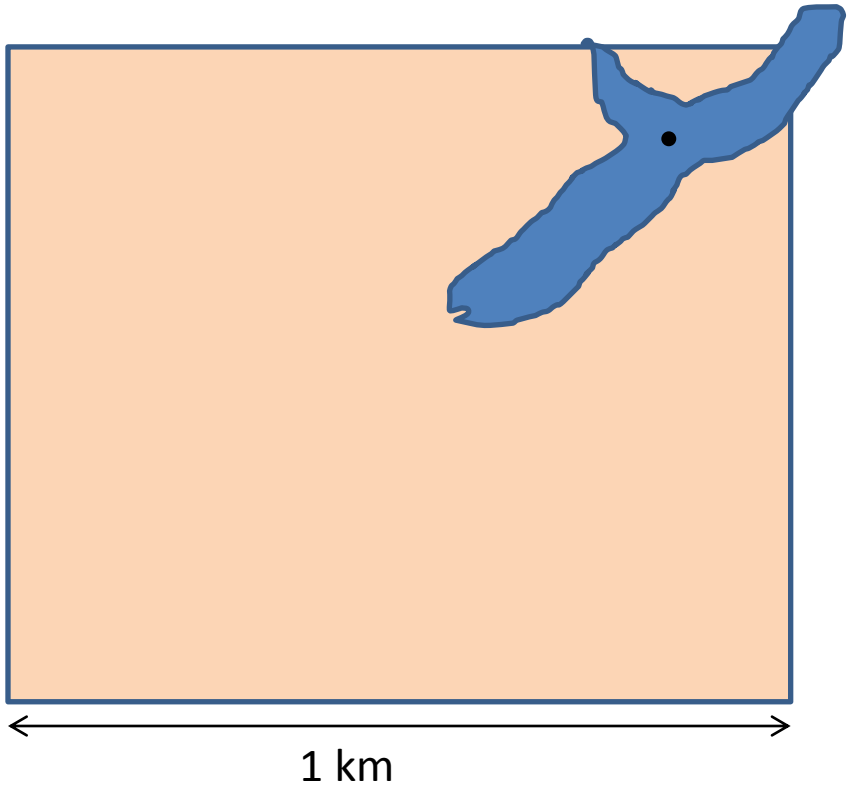
Using EC data: Model validation



Weekly ET from both an EC tower and two MODIS-based remote sensing approaches.

- **EC is desirable for model validation because of variety of temporal scale of measurements.**
- **Offers complimentary information to both small scale (e.g. lysimeters) and larger scale (catchments).**
- **Anciliary meteorological data collected at tower can be very useful for identifying causes of model-observation discrepancies.**

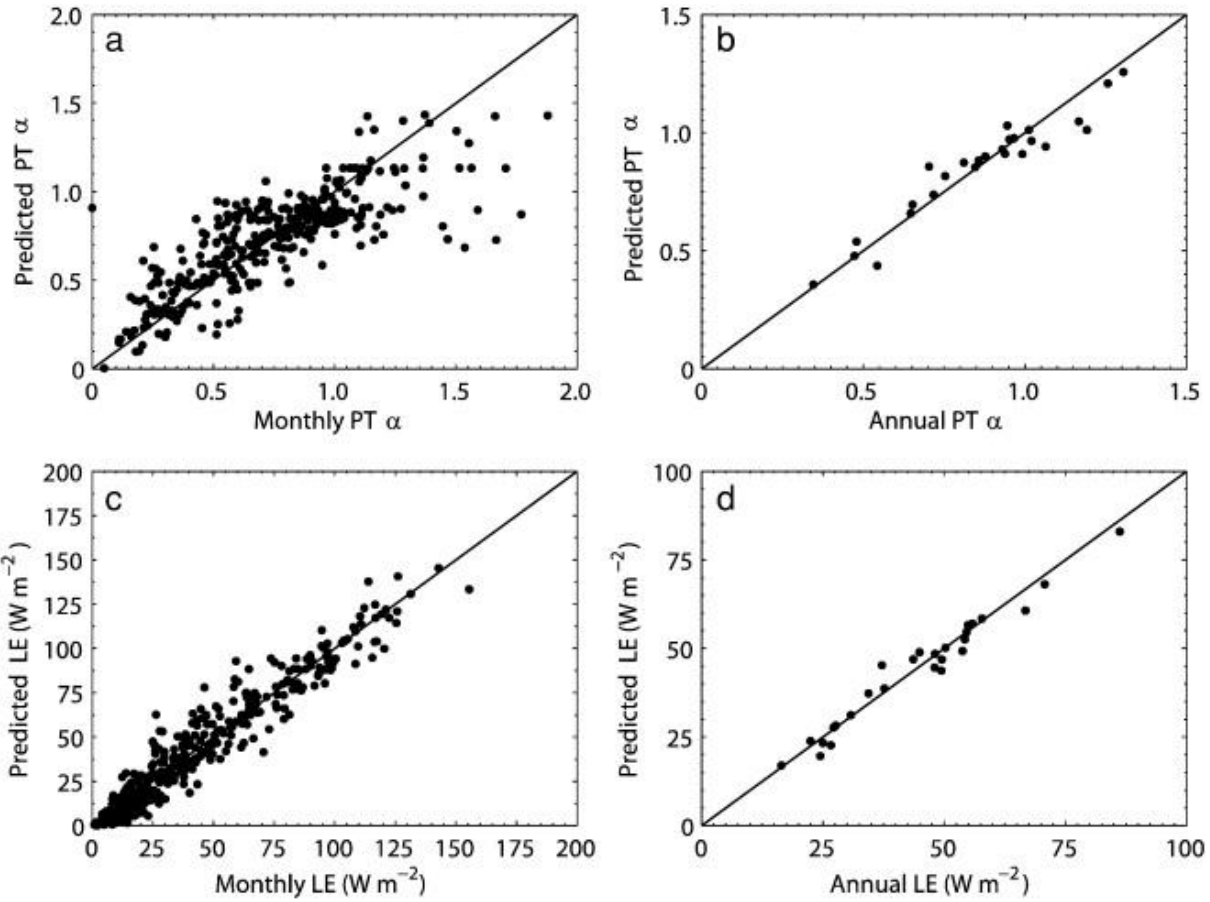
Using EC data: Model validation caveats



Conceptual diagram of the types of footprint issues that can occur when comparing EC and model or Remote sensing data.

- **Footprint mismatch is an issue: is the area measured by the tower the same as the model or remote sensing pixel?**
- **Need to correct fluxes for energy budget closure.**
- **Be careful comparing gap-filled data with model output. Gap filled data are really empirical model outputs.**

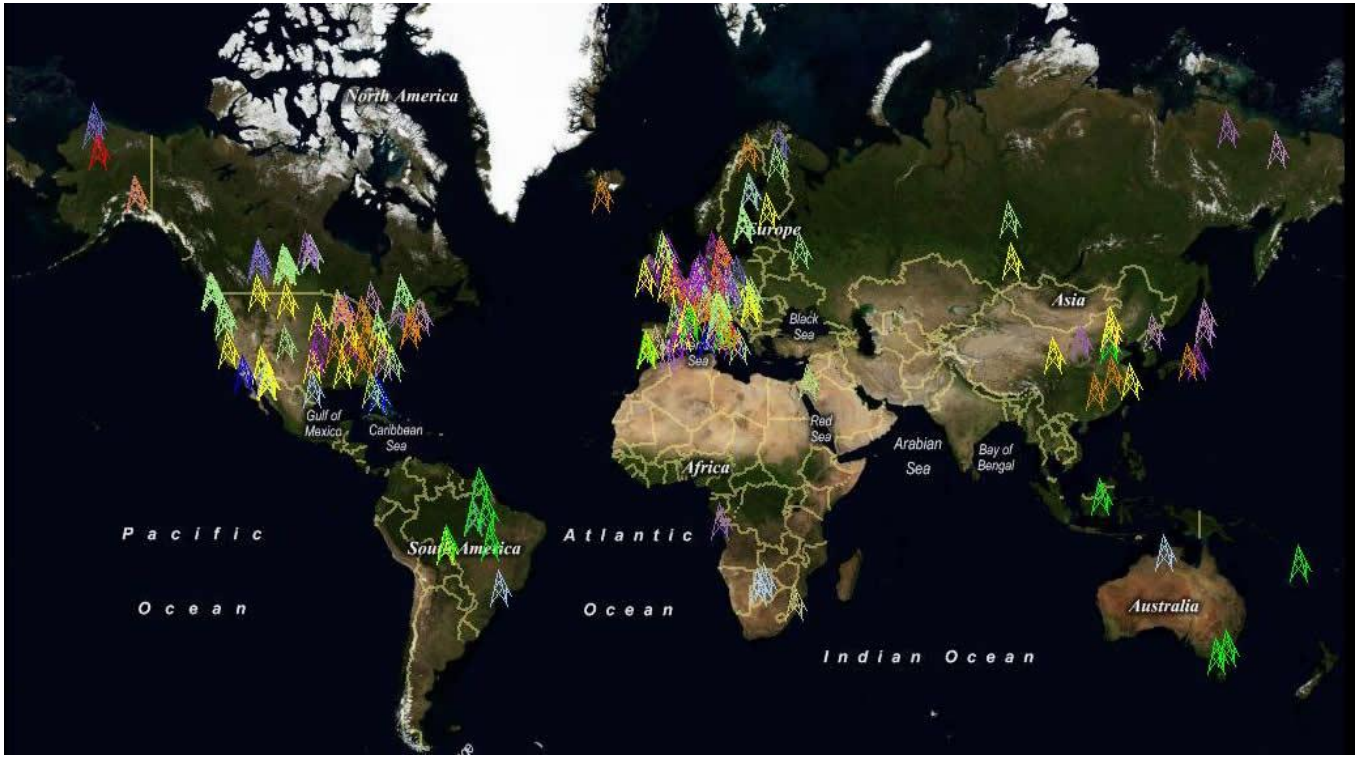
Using EC data: Optimizing model parameters using towers



Optimization of the α (emipircal parameter) in the Priestly-Taylor equation using MODIS LAI with tower ET and soil moisture data. PT equation then implemented in CASA model [*Jin et al.,* 2011 – in press].

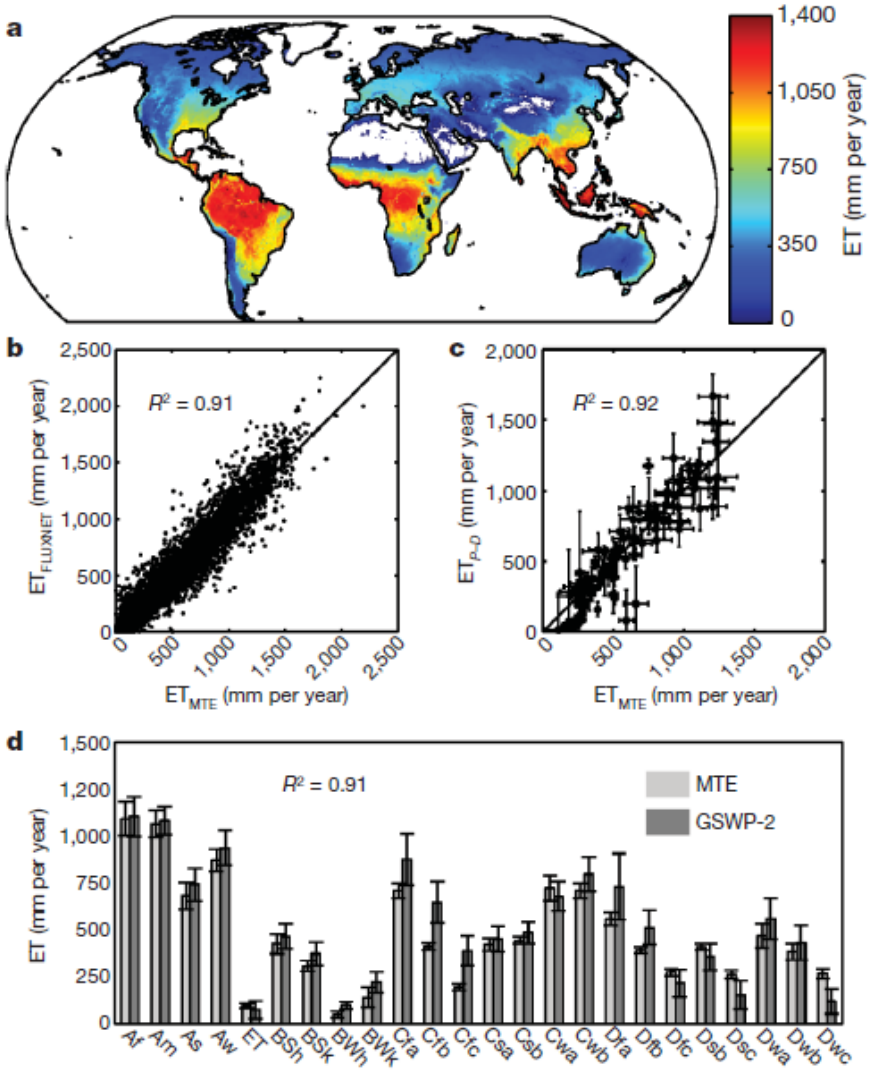
- **Towers can be used to tune empirical parameters for remote-sensing based approaches, enabling better use of simpler models (e.g. Priestley-Taylor).**
- **Useful for handling varied or unique ecosystems/regions that are poorly represented in model or remote sensing land-cover parameterizations.**

Using EC data: Optimizing model parameters - caveats



- **Approach less useful in regions with poor to no tower coverage.**
- **Footprint issues with relating tower measurements with satellite observations.**
- **Over-reliance on relatively few towers for tuning parameters.**

Using EC data: neural networks and empirical approaches



Jung et al. [2010] used a model tree ensemble to show a decline in terrestrial ET due to moisture supply limitations.

- **Neural networks can relate tower ET measurements to gridded climate and vegetation observations.**
- **Can be useful for estimating current and historical ET.**
- **Cross validation shows good agreement globally (and less uncertainty than process based models).**
- **Predictive capability for the future?**

Future status of networks: PI-driven towers

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- **Most funding for EC towers has come from research grant programs to answer site/region specific questions.**
- **This cycle has made it challenging to maintain long-term tower observations.**
- **More novel science in integrating multiple towers.**
- **Challenging funding environment.**
- **Strong operational/monitoring component to EC towers, but little specific funding.**

Future status of networks: Central networks

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- NSF is funding National Ecological Observatory Network (NEON).
- 20 ecological/climatological domains across U.S. with 3 towers/domain.
- 30+ year project. 5 year build phase depending upon Congress.
- Open data policy. Integration with many other land surface/ecology measurements.

Closing thoughts

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- Eddy Covariance is a powerful tool to assess terrestrial ET, but it is not the gold standard.

- Fills a unique observational niche.

- Has considerable short-term uncertainty (~20% uncertainty for possible for well run towers on a half hourly basis). Longer-term uncertainty less clear. In addition, site selection can result in a systematic bias in towers versus remote sensing or model pixels.

- Be aware of the processing steps in the data you are using so that you can use the appropriate product. Energy budget closure and gap-filled data are two biggest steps to check on with data. Also can be some difficulties if you use towers with vastly different instrumentation/processing protocols.

- Data use policies (and authorship expectations) are haphazard. Check with tower PI before using their data in a publication.

- NEON will be an option for those looking for U.S. data in medium term future or longer.

Questions?

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Thank you for listening. I would be happy to answer any questions.