Eddy Covariance Applications and Experimental Design

Jiahong Li

Outline

- Applications of the eddy covariance method
- Flux footprint
- Experimental design

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Applications of the Eddy Covariance Method

- Carbon cycle
- Water cycle
- Energy flow

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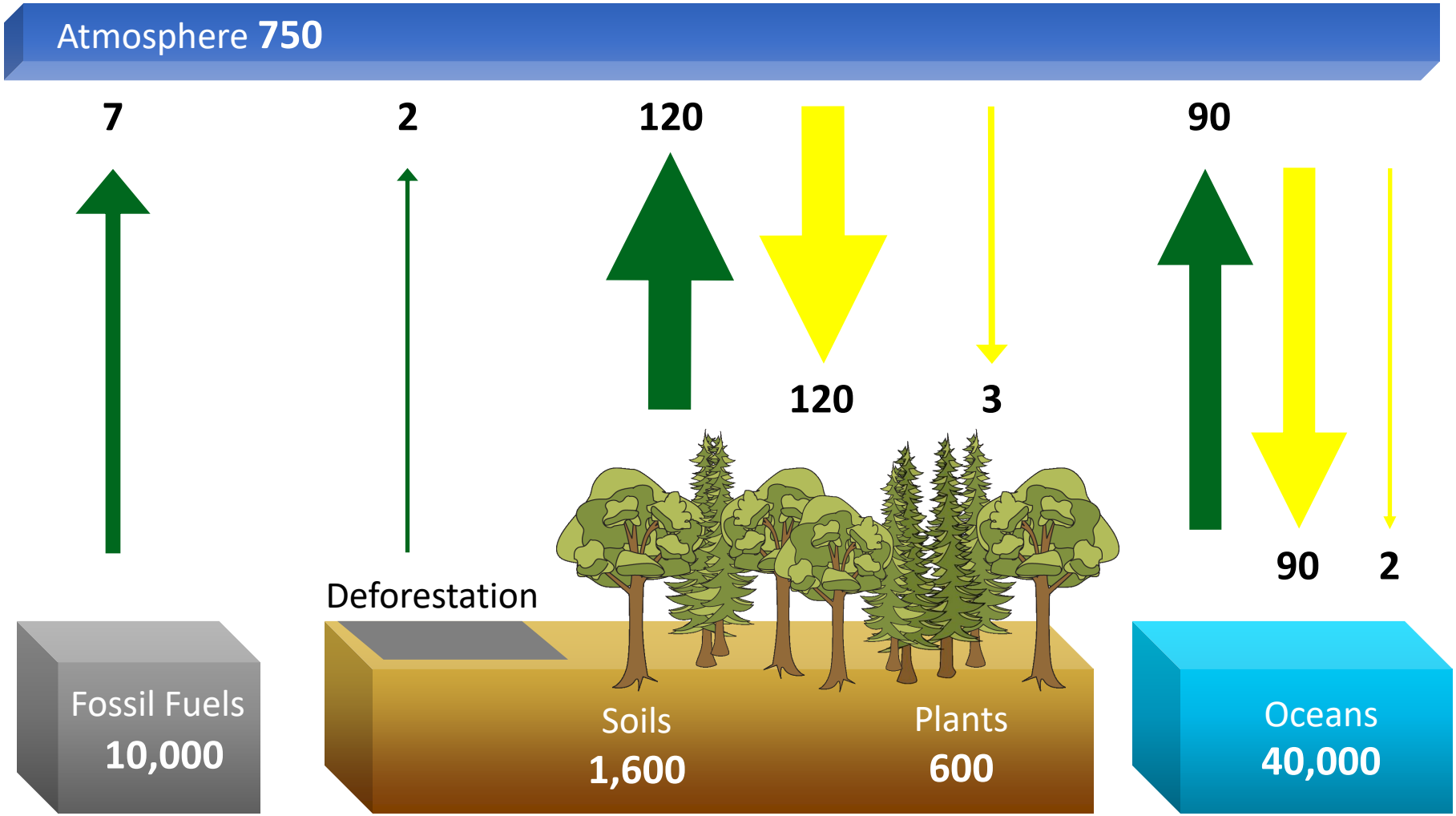
The Carbon Cycle

Global Carbon Flux (Gt/yr) and Storage (Gt)



Data sources: USGS, DOE, and IPCC

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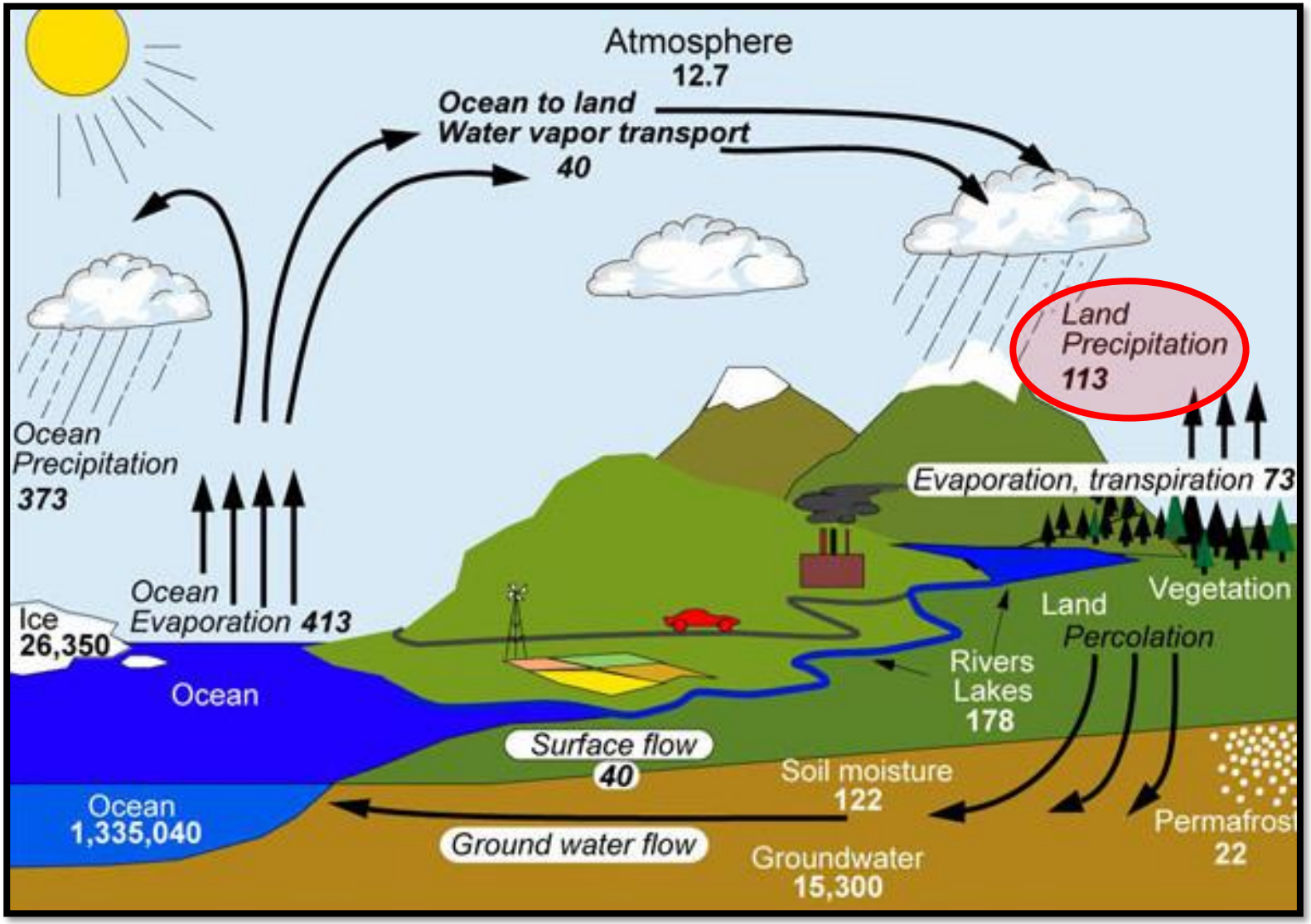
The Hydrological Cycle



Trenberth *et al*., 2007. *Journal of Hydrometeorology*, 8: 758-769.

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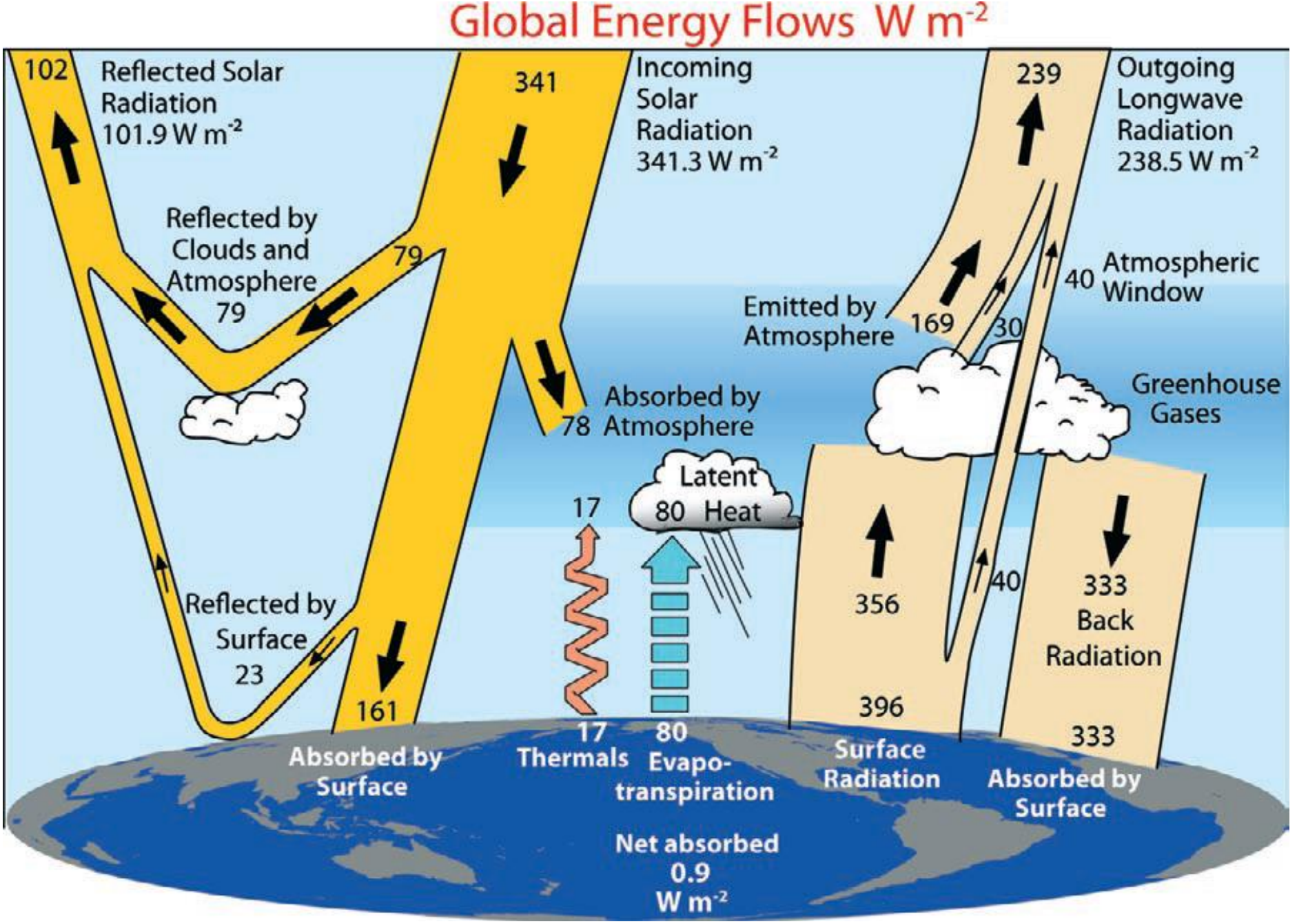
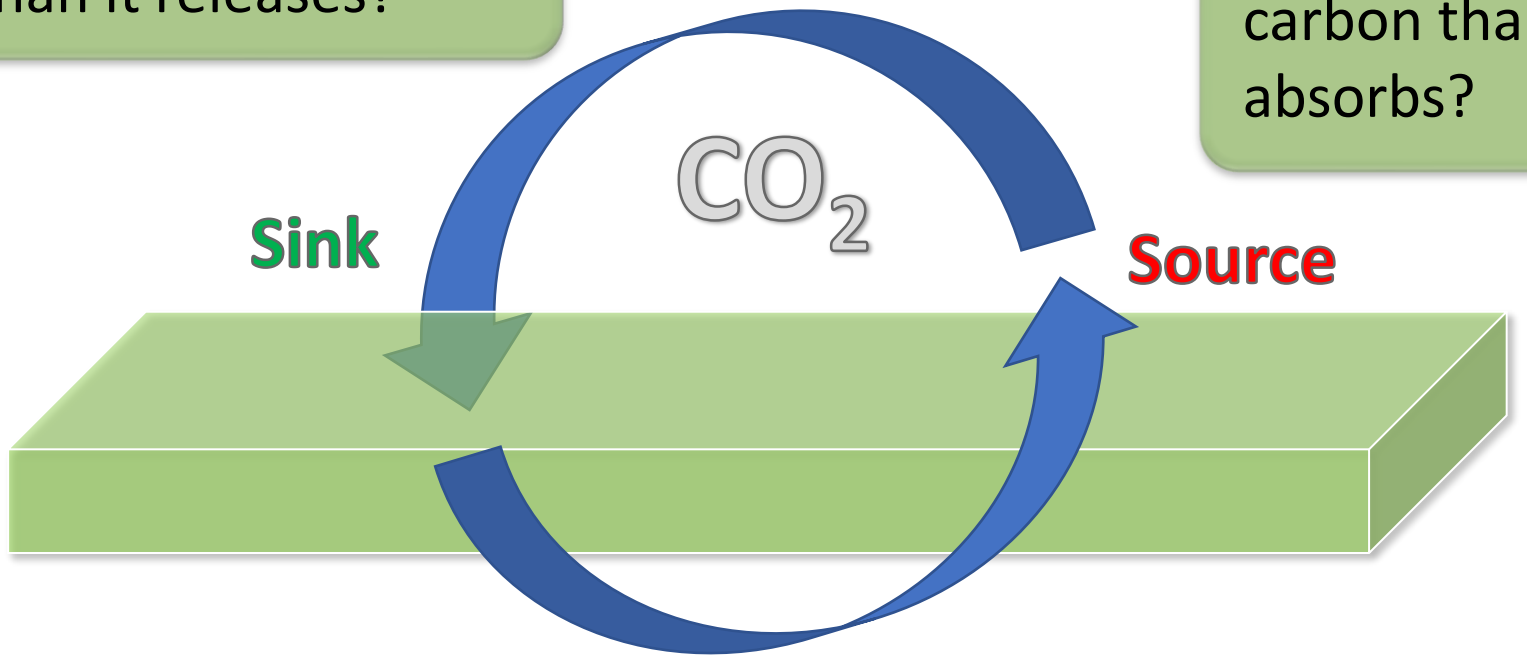


Trenberth *et al*., 2009, *Bulletin of the American Meteorological Society, 90, 311-324*

Ecological Research

Does this Ecosystem ***absorb*** more carbon than it releases?

Or ***release*** more carbon than it absorbs?



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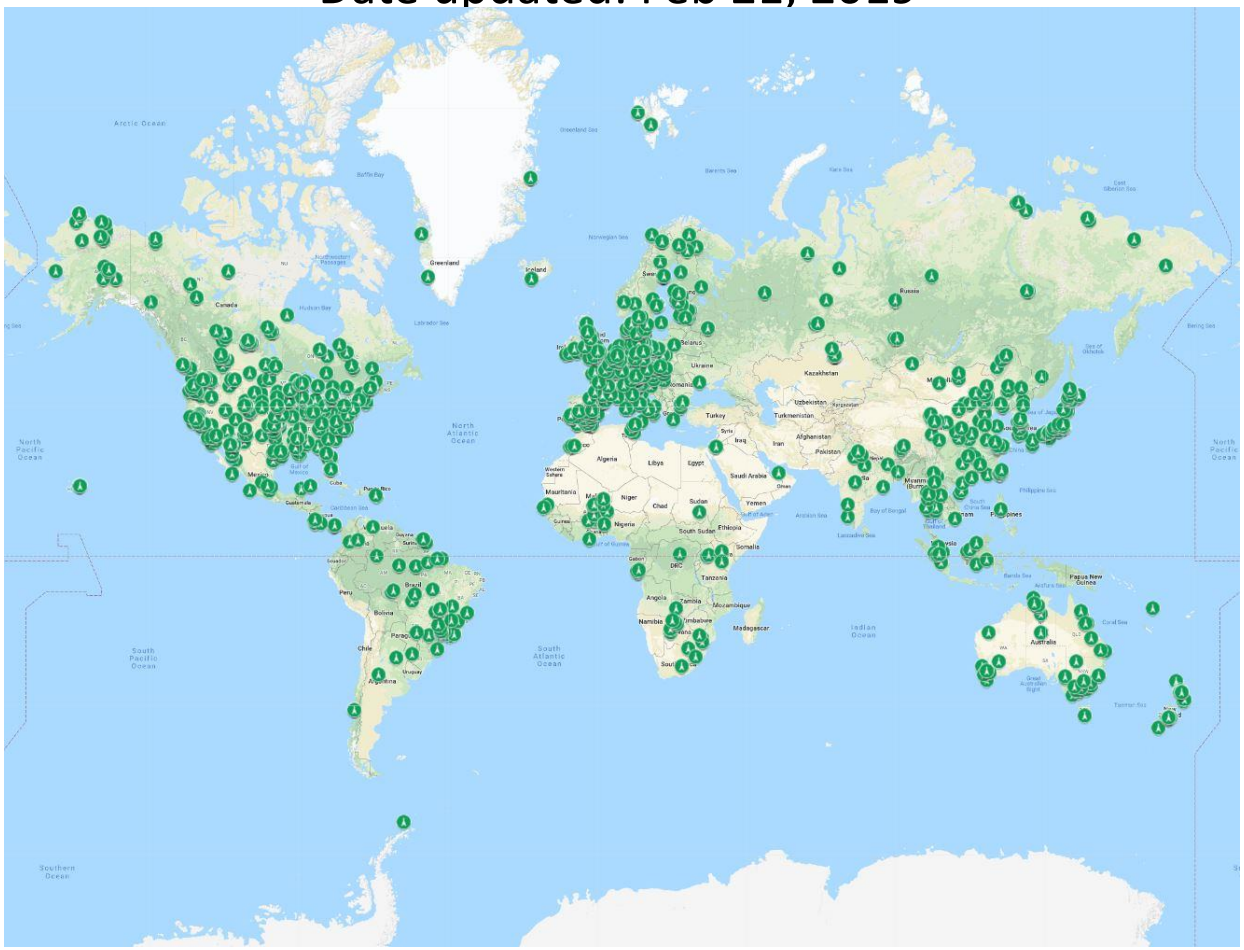
Ecological Research

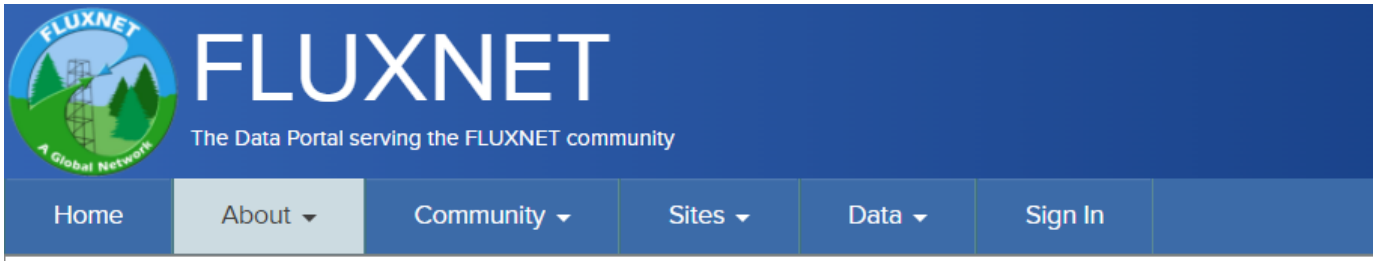
Past and present EC sites: 2029
Known discontinued EC sites: 608
Date updated: Feb 21, 2019



George Burba, 2019, Illustrative Maps of Past and Present Eddy Covariance Measurement Locations: I. Early Update. DOI - 10.13140/RG.2.2.25992.67844/1

Major Flux Network Links

http://fluxnet.org/about/regional-networks/



Home / About the FLUXNET Network / Regional Networks

Regional Networks

FLUXNET is a global activity collaborated and participated voluntarily by local **Tower Teams** and **Regional Networks**. The main contributors to FLUXNET are the local tower teams that collect and share their data (see site list). In addition, the regional network teams invest time and energy for the collection of site information, data harmonization, and data processing to support the FLUXNET (see network list below).

Regional networks supporting the FLUXNET have included, but are not limited to the following :

- AmeriFlux
- AsiaFlux
- BERMS (Boreal Ecosystem Research and Monitoring Sites) (Historical)
- Canadian Carbon Program (Historical)
- CarboAfrica
- CarboEurope (Historical)
- CarboItaly (Historical)
- Carbomont
- ChinaFlux

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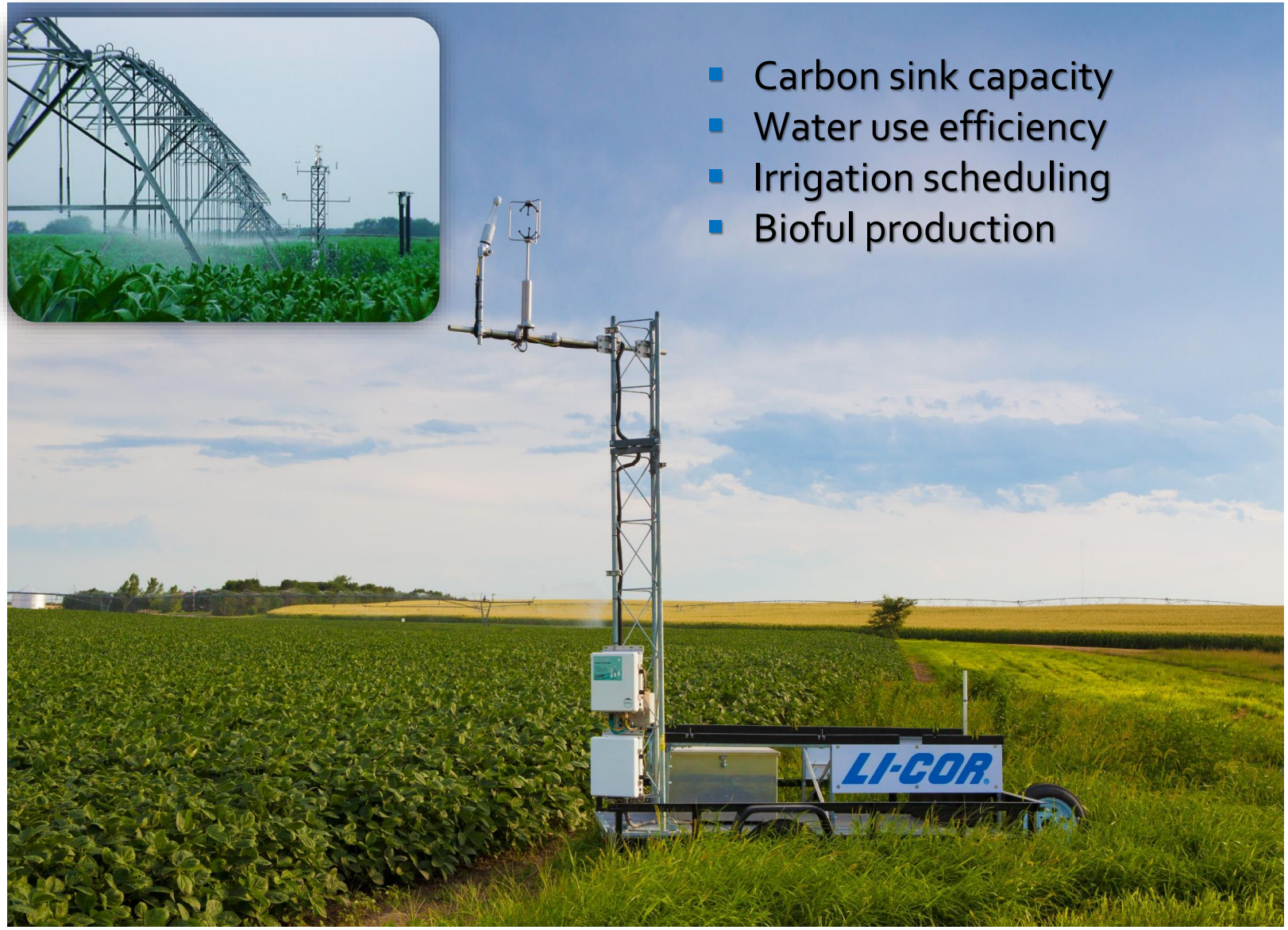
Agricultural Research



Wetland Research

Methane release?
Carbon balance?
Evapotranspiration?

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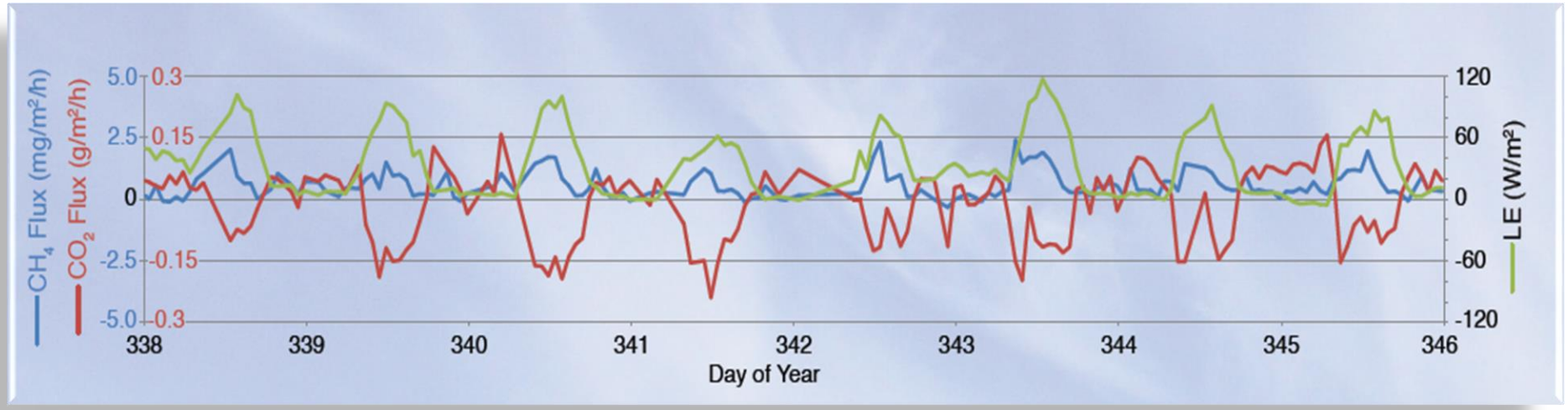
Wetland Research



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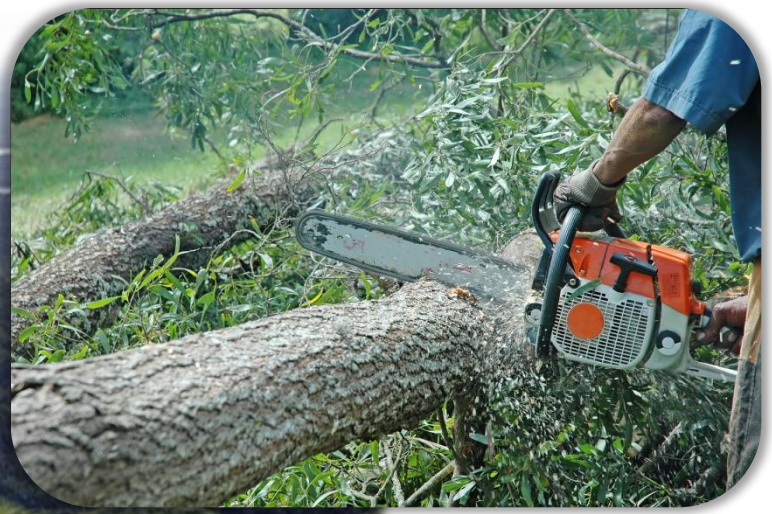
Land Managements

Deforestation and land clearing



Water Management

Water losses through **Evapotranspiration**?

- Agricultural Irrigation needs.
- Human demands for water.
- To protect endangered aquatic species.

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Urban Studies

Fluxes over Sea and Lake

Miller S. D. 2010. Ship-based measurement of air-sea CO_2 exchange by eddy-covariance. *J of Geophy. Res.* 115:D02304, doi: 10.1029/2009JD012193.

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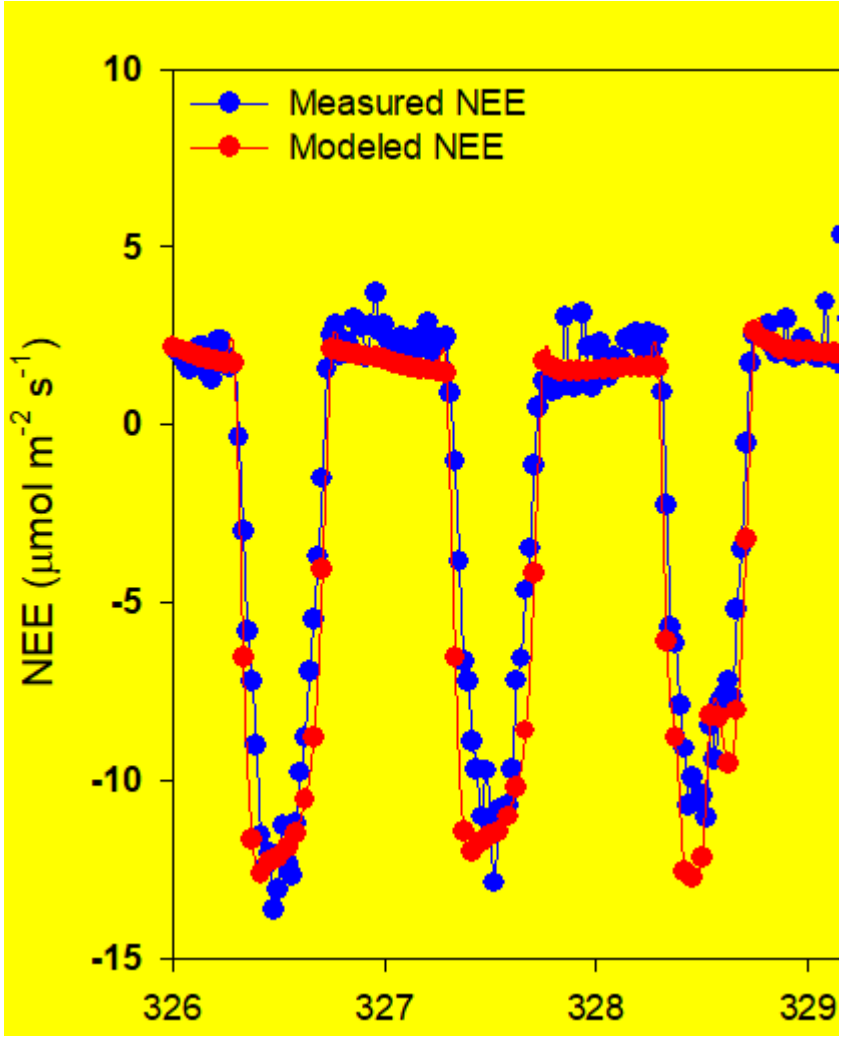
Modelling and Remote Sensing



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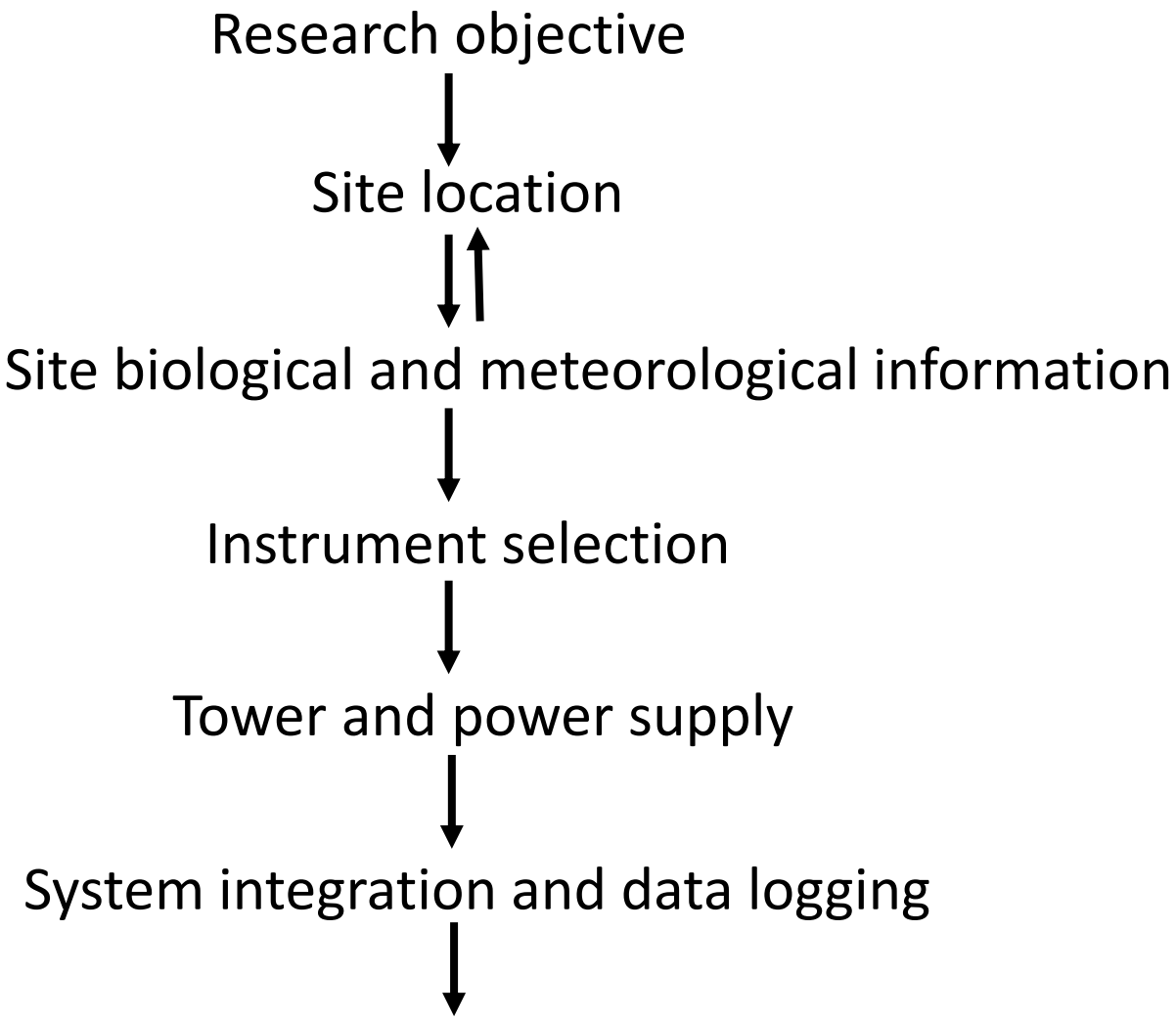
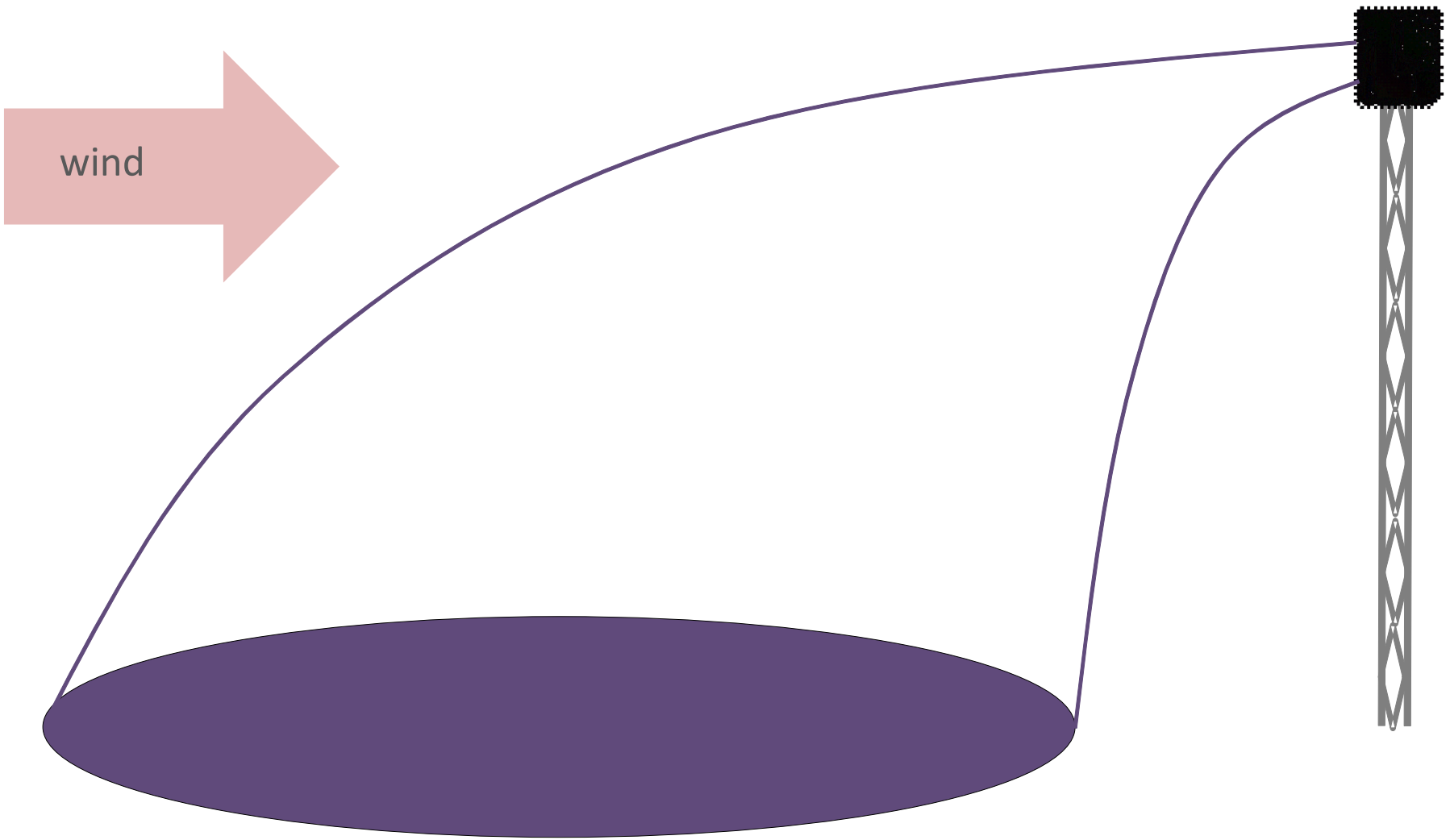
Experimental Design



Flux Footprint



Flux footprint is an upwind area "seen" by the instruments

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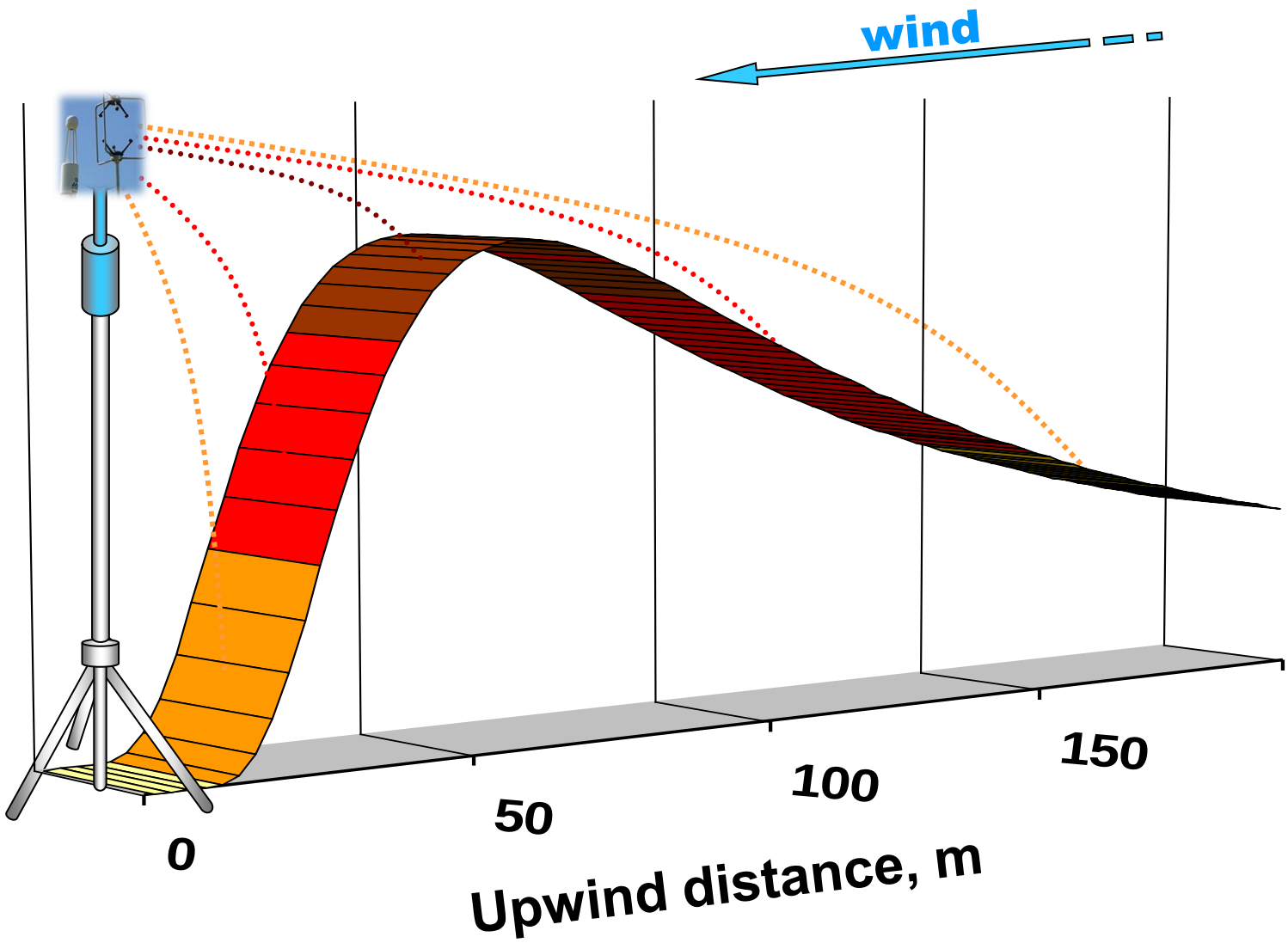

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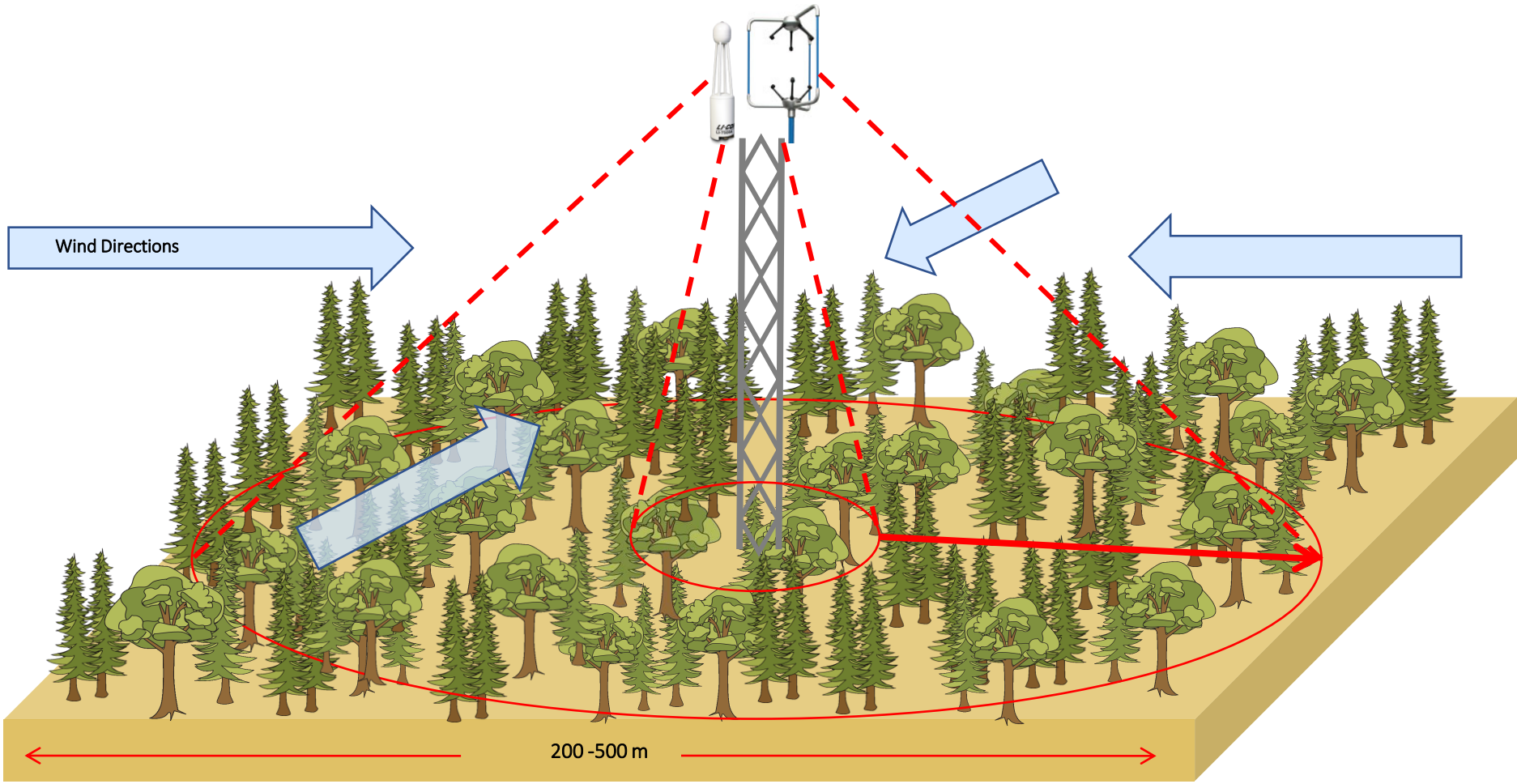
Flux Footprint



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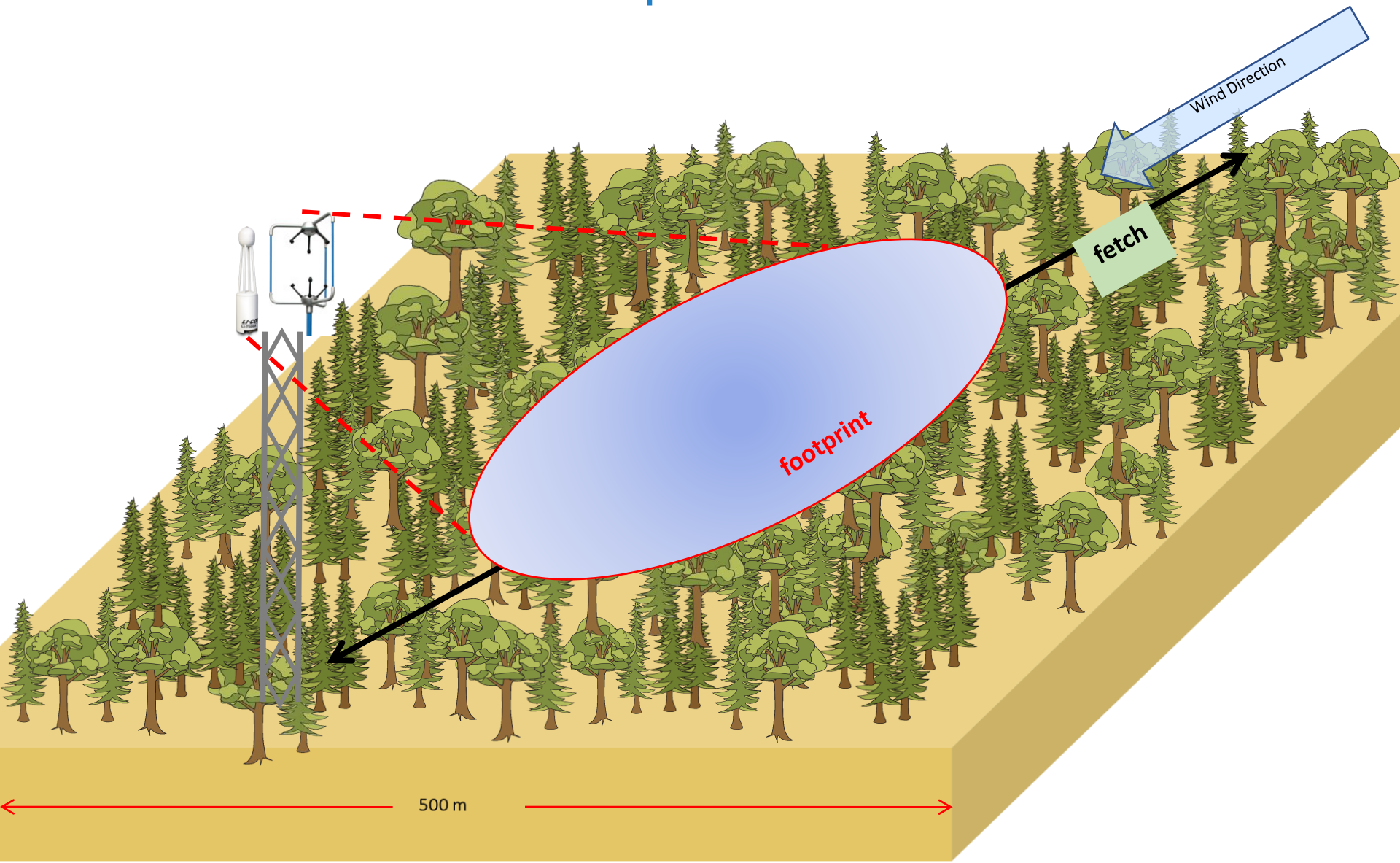
Flux Footprint vs. Fetch



Factors Affecting Flux Footprint

FLUX FOOTPRINT DEPENDS ON:

Measurement height
Surface roughness
Atmospheric stability

SIZE OF FOOTPRINT INCREASES WITH:

Increased measurement height
Decreased surface roughness
Change in stability from unstable to stable

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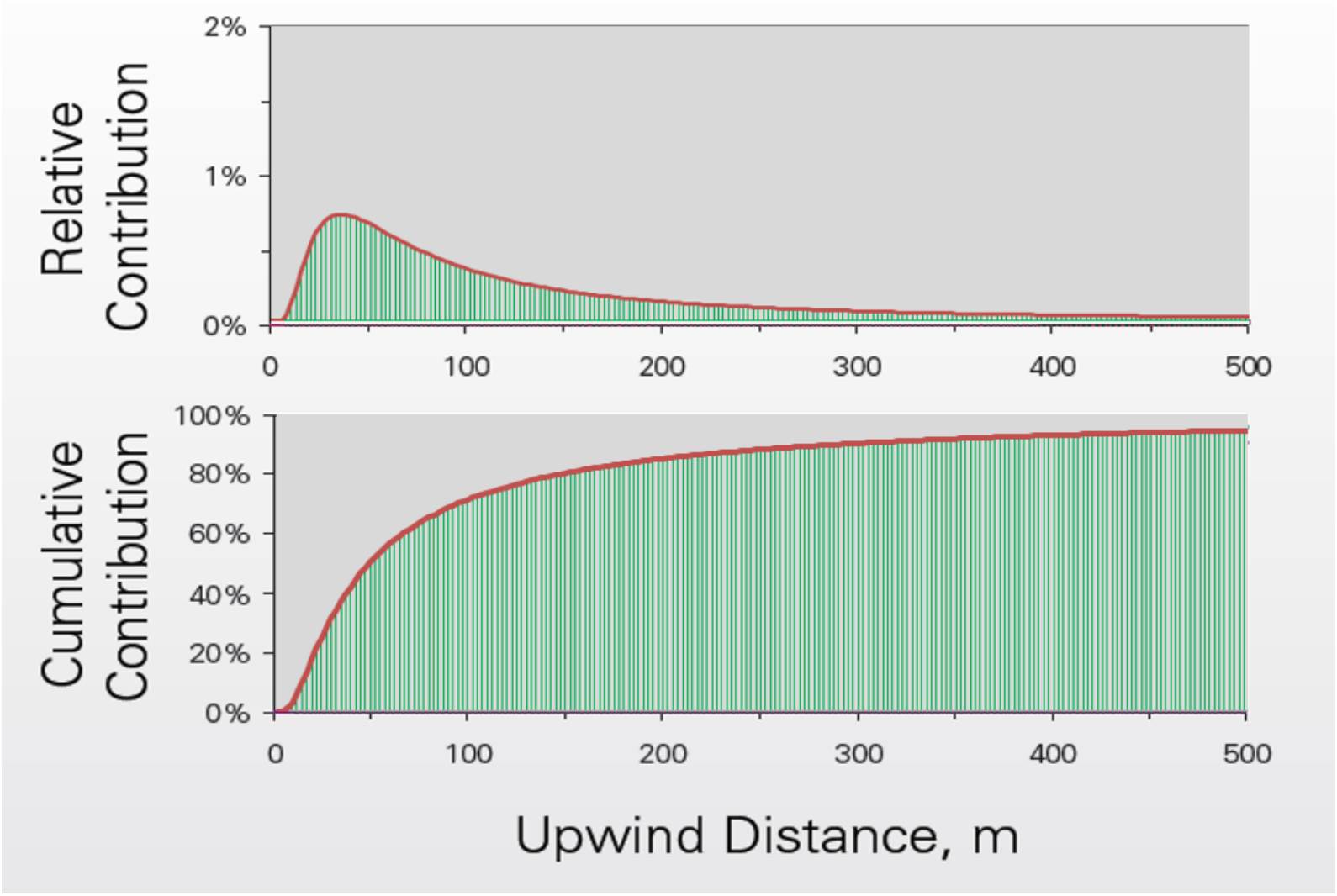
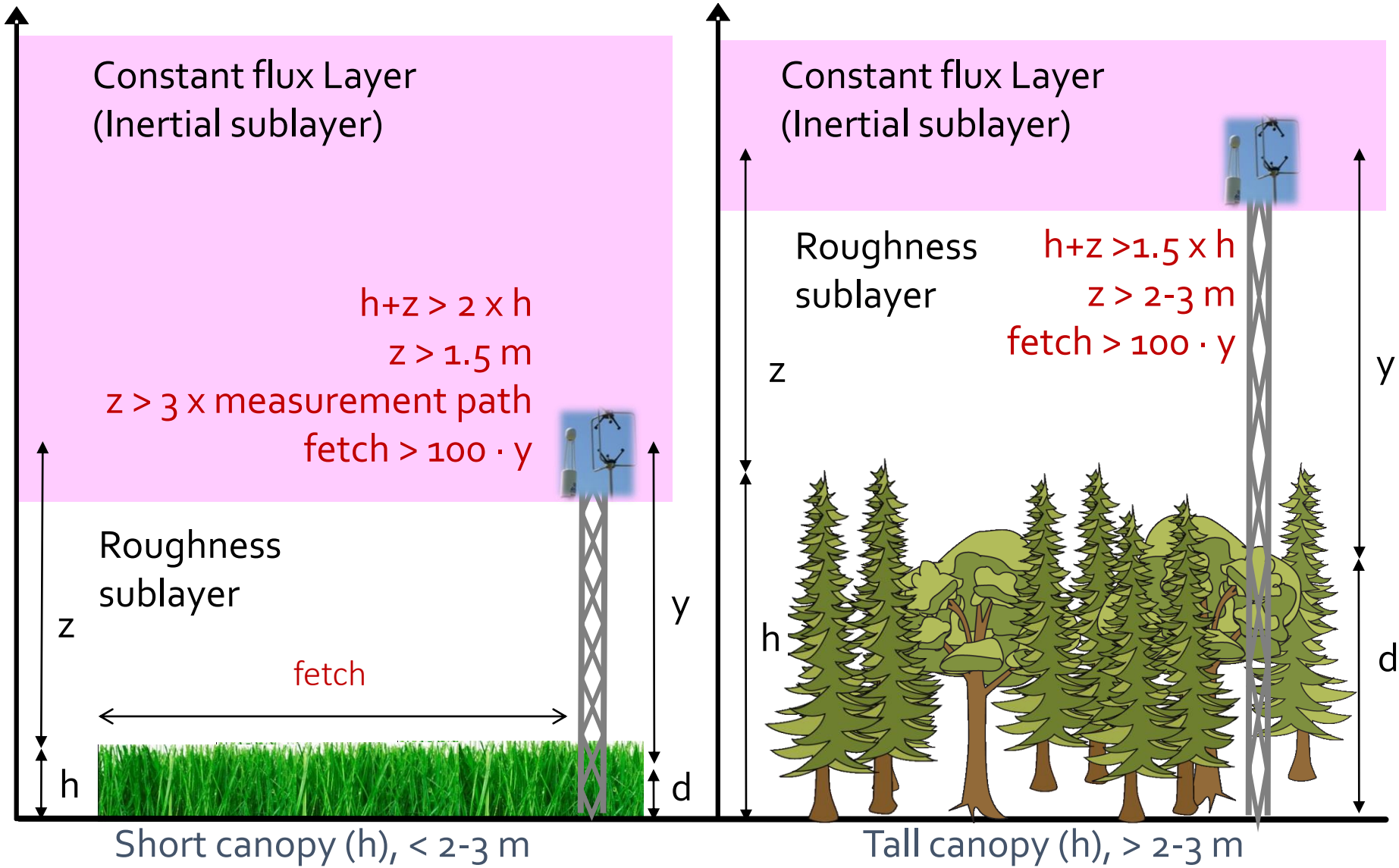
1D Flux Footprint

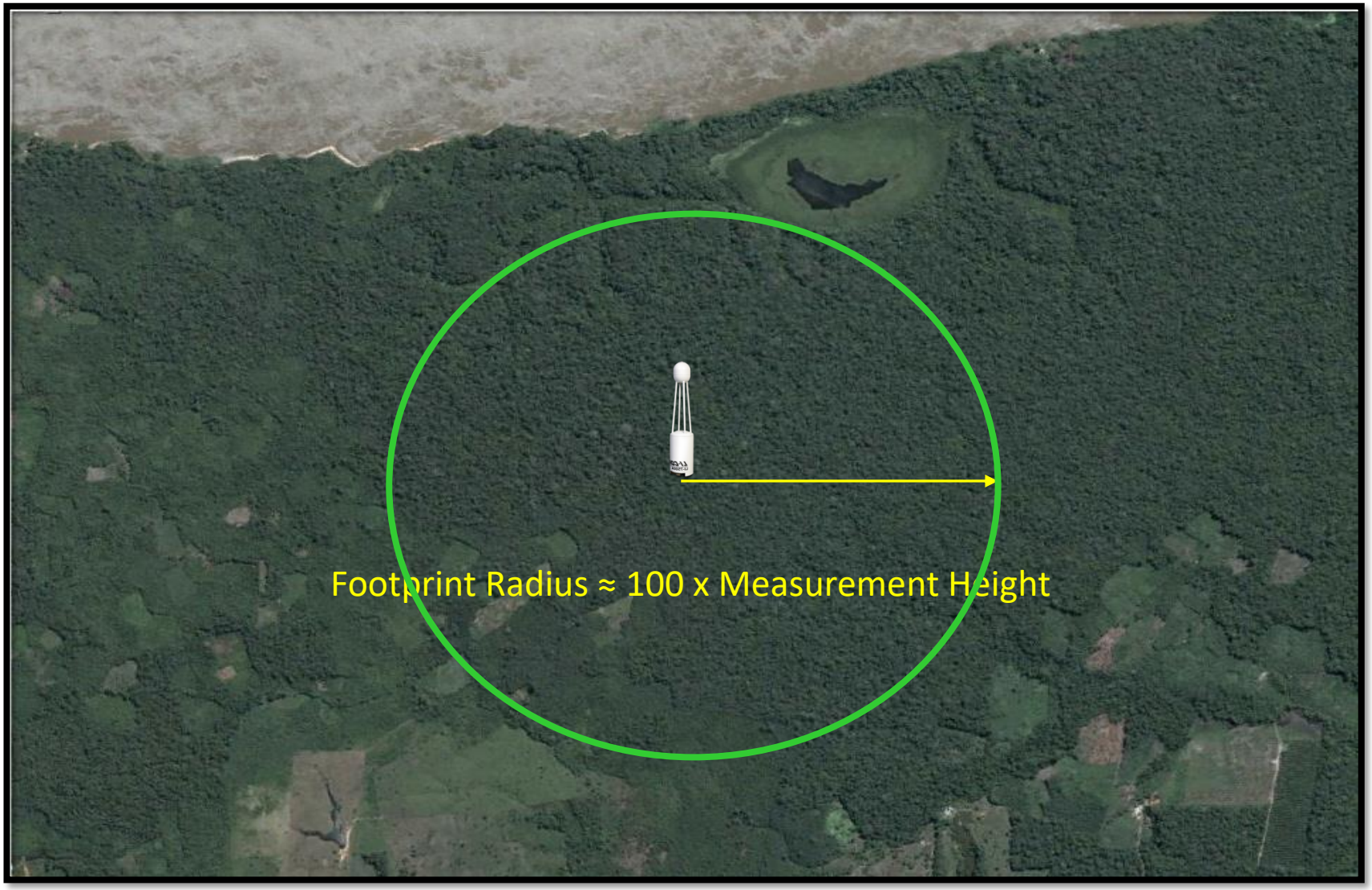


Canopy, Measurement Height and Required Fetch

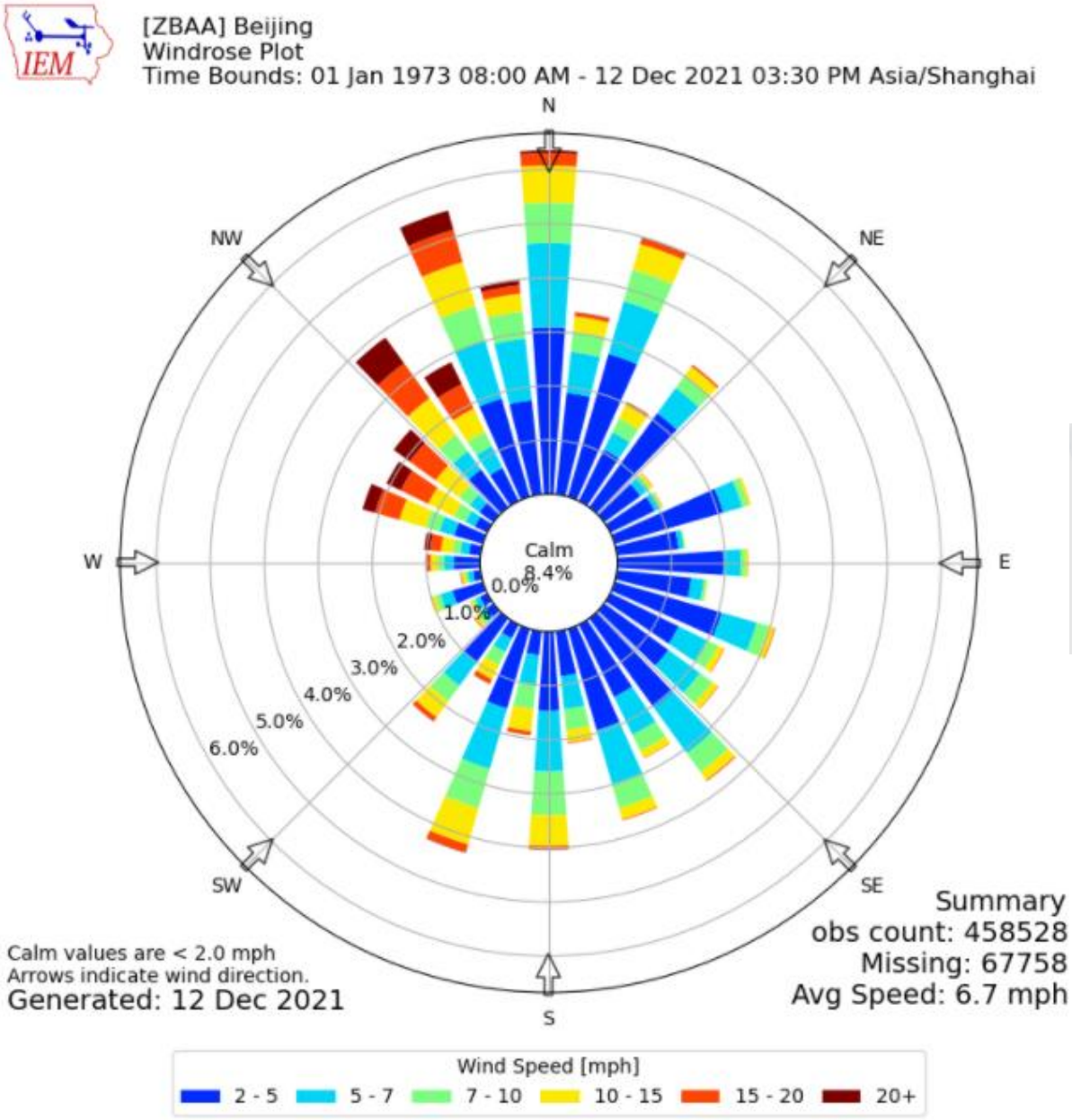


Fetch Requirement

Tower Location

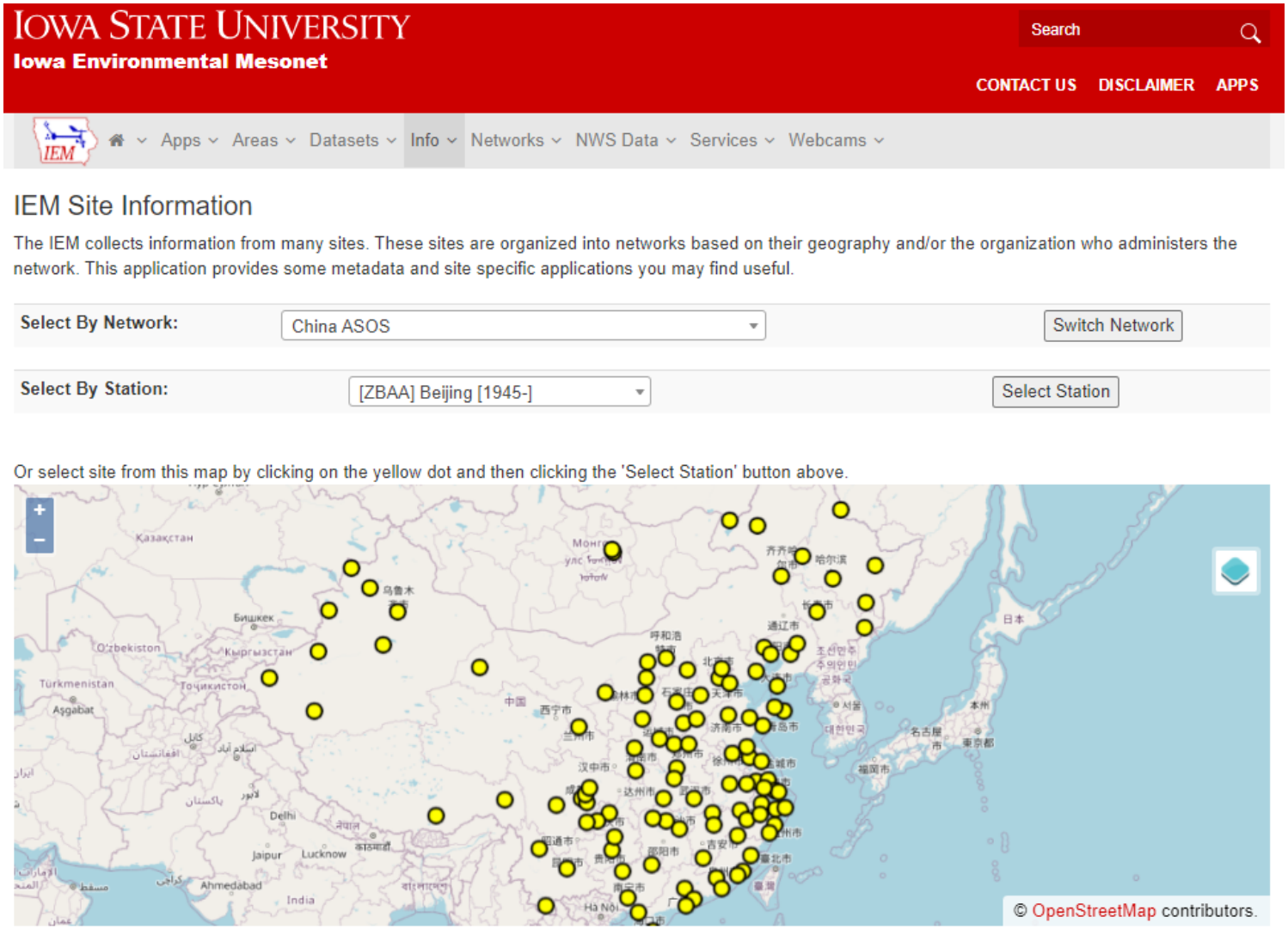


Prevailing Wind Direction and Wind Rose



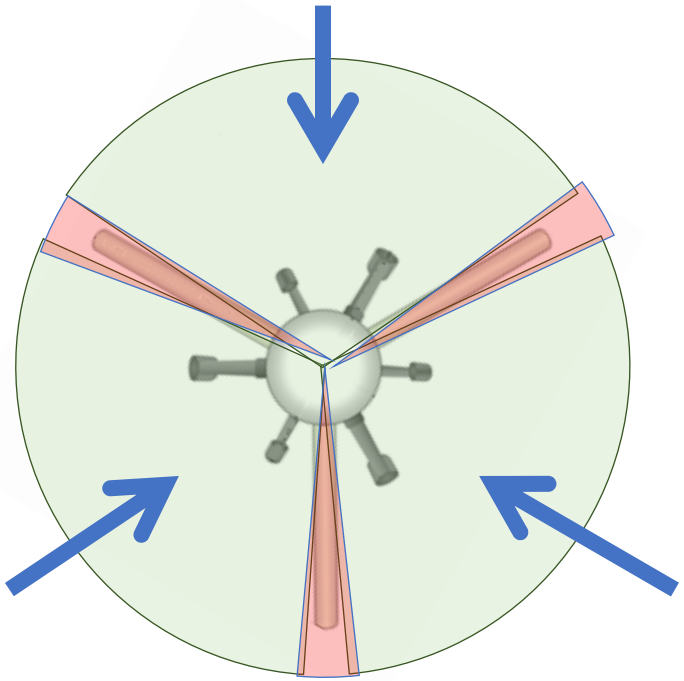
Useful Web Site for Wind Rose around the World

http://mesonet.agron.iastate.edu/sites/locate.php

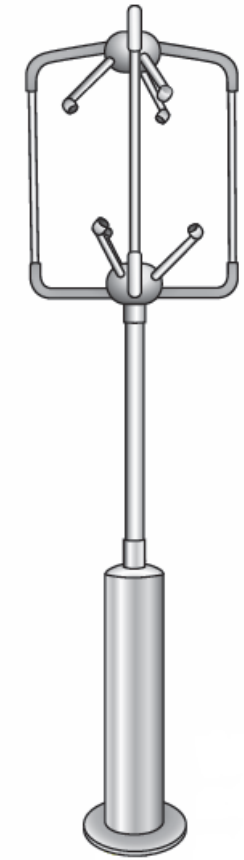


Omni-Directional Alignment

360 degrees



Prevailing Wind Directions



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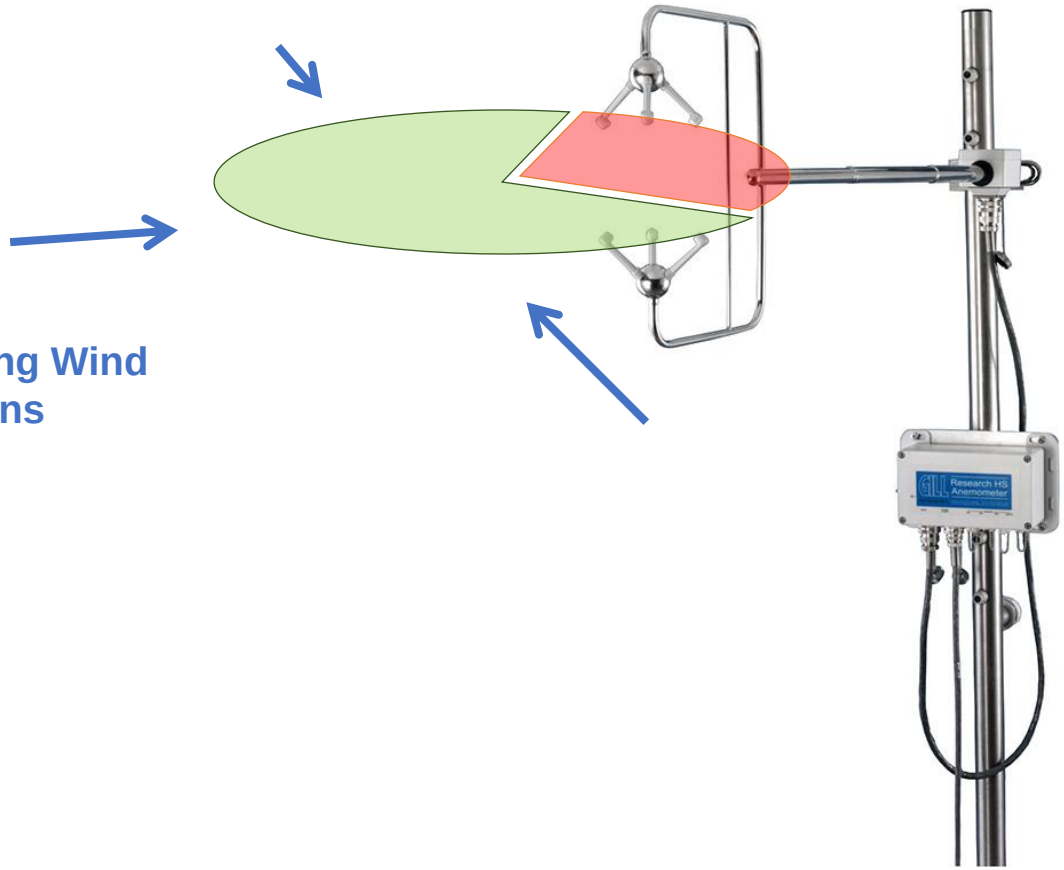
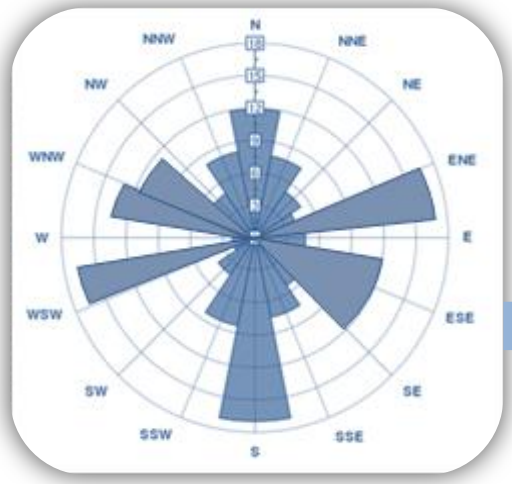
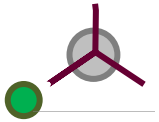
C-Clamp Alignment

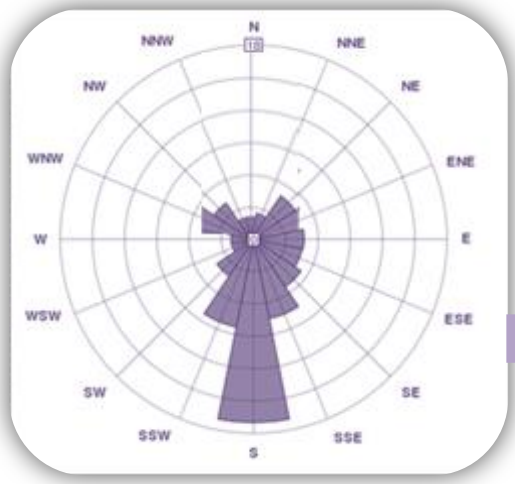




Variable winds:

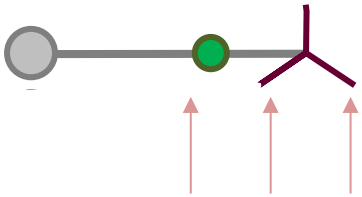
omni-directional setup is usually the best
non-omni-directional setup will provide less data





Prevailing winds:

omni-directional setup is still the best
but non-omni-directional setup is also acceptable



Instruments meet winds at the same time

Tower or pole

Sonic anemometer

Gas analyzer or intake

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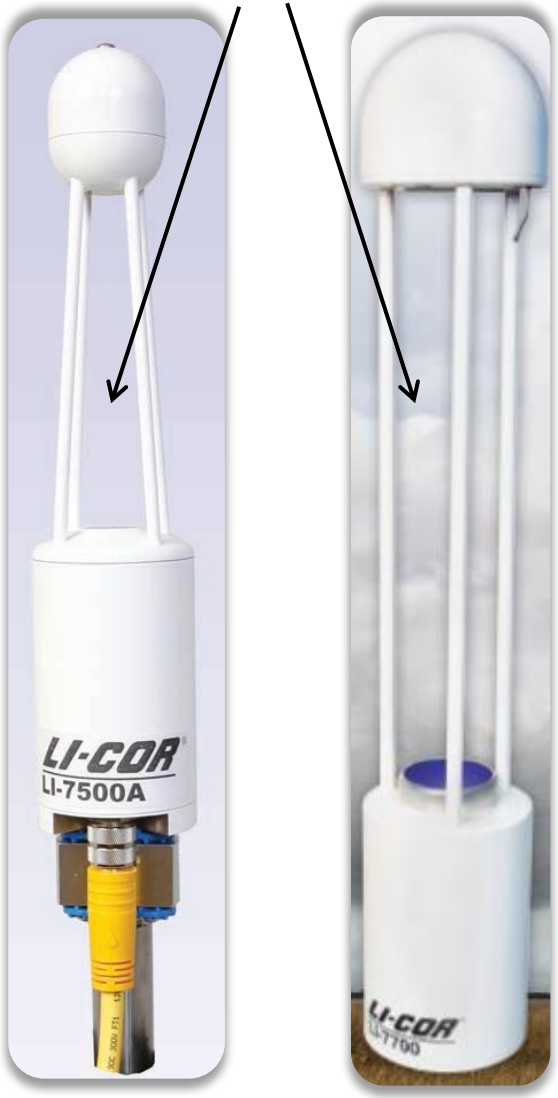
Open- and Closed- Path Systems

Open-path

Closed-path



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Open-Path vs. Closed-Path

	Open-path	Closed-path
Pump requirement	No	Yes
Power consumption	8 - 12 W	40 W
Data loss due to precipitation	Minor	Minimal

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Gas Analyzer Selection

- Ecosystem type and research objective
- Power supply
- Weather conditions

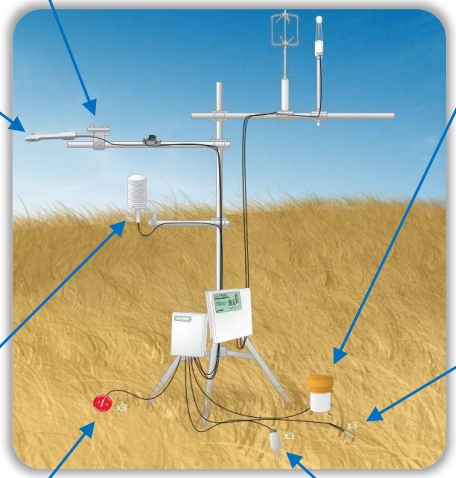
Biomet system for EC Data Quality Control, Interpretation and Gap-Fill

Solar Radiation and PAR

Net Radiation

Air Temperature and RH

Soil Heat Flux



Precipitation

Soil Temperature

Soil Moisture

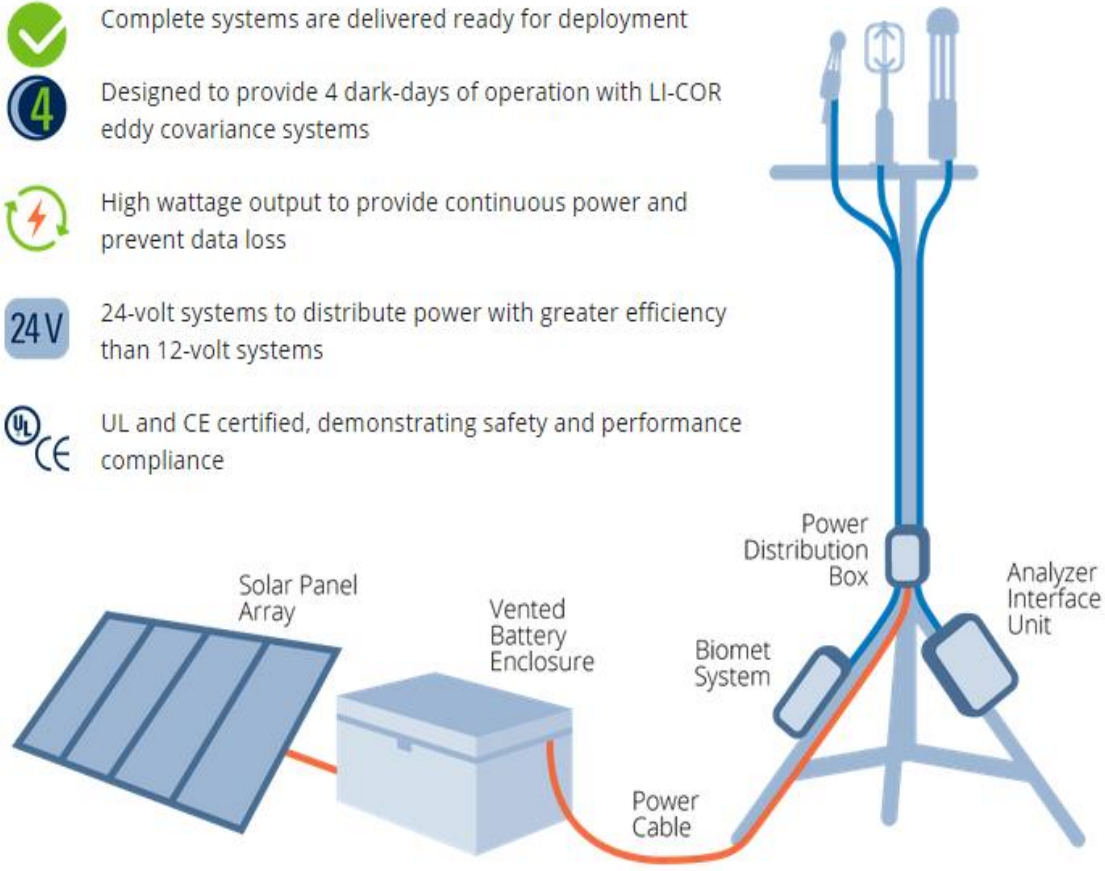
LI-COR Biosciences

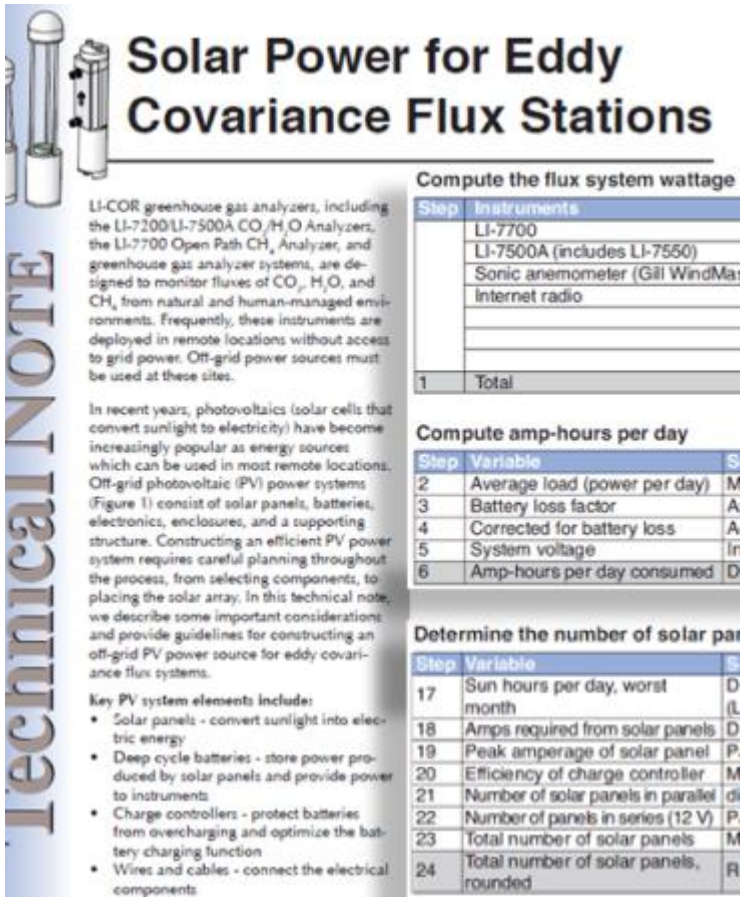
Measuring Change in a Changing World®

Solar Power System Design

Li-Cor solar power system

- Complete systems are delivered ready for deployment
- Designed to provide 4 dark-days of operation with LI-COR eddy covariance systems
- High wattage output to provide continuous power and prevent data loss
- 24-volt systems to distribute power with greater efficiency than 12-volt systems
- UL and CE certified, demonstrating safety and performance compliance





Technical NOTE

Solar Power for Eddy Covariance Flux Stations

LI-COR greenhouse gas analyzers, including the LI-7200/LI-7500A CO_2/H_2O Analyzers, the LI-7700 Open Path CH_4 Analyzer, and greenhouse gas analyzer systems, are designed to monitor fluxes of CO_2, H_2O, and CH_4 from natural and human-managed environments. Frequently, these instruments are deployed in remote locations without access to grid power. Off-grid power sources must be used at these sites.

In recent years, photovoltaics (solar cells that convert sunlight to electricity) have become increasingly popular as energy sources which can be used in most remote locations. Off-grid photovoltaic (PV) power systems (Figure 1) consist of solar panels, batteries, electronics, enclosures, and a supporting structure. Constructing an efficient PV power system requires careful planning throughout the process, from selecting components, to placing the solar array. In this technical note, we describe some important considerations and provide guidelines for constructing an off-grid PV power source for eddy covariance flux systems.

Key PV system elements include:

- Solar panels - convert sunlight into electric energy
- Deep cycle batteries - store power produced by solar panels and provide power to instruments
- Charge controllers - protect batteries from overcharging and optimize the battery charging function
- Wires and cables - connect the electrical components

Compute the flux system wattage

Step	Instruments
	LI-7700
	LI-7500A (includes LI-7550)
	Sonic anemometer (Gill WindMa
	Internet radio
1	Total

Compute amp-hours per day

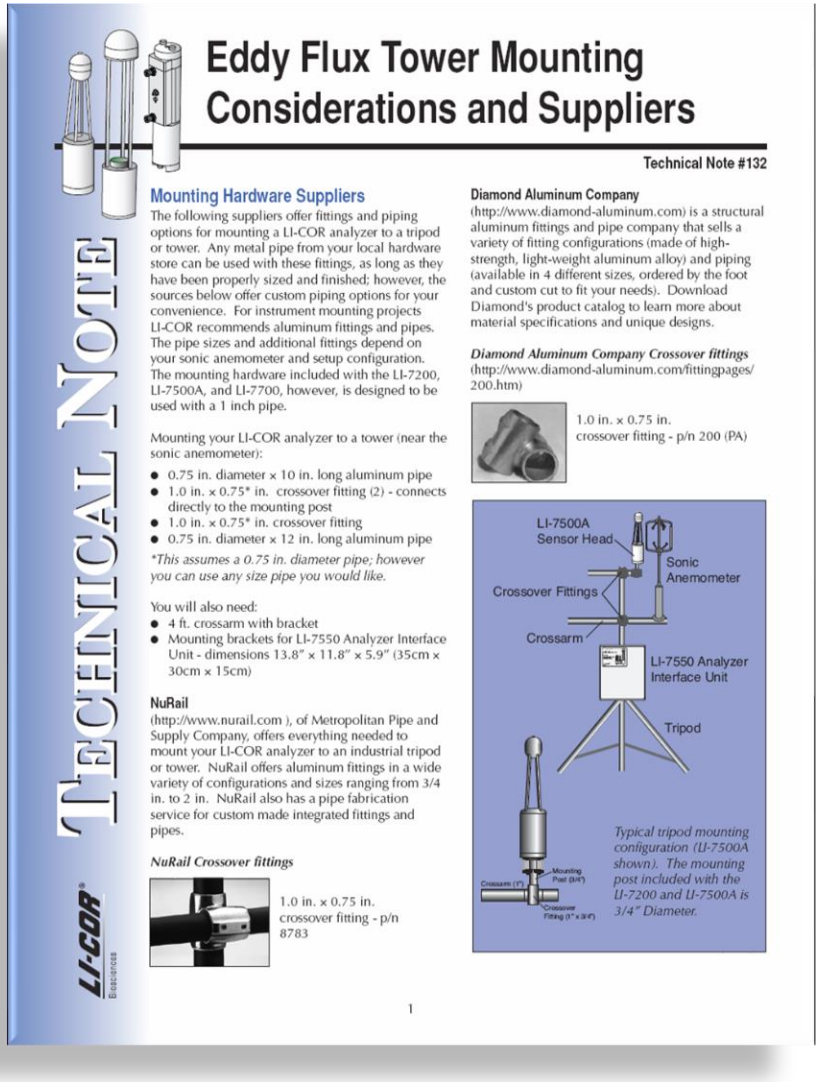
Step	Variable	S
2	Average load (power per day)	M
3	Battery loss factor	A
4	Corrected for battery loss	A
5	System voltage	In
6	Amp-hours per day consumed	D

Determine the number of solar pa

Step	Variable	S
17	Sun hours per day, worst month	D (L
18	Amps required from solar panels	D
19	Peak amperage of solar panel	P
20	Efficiency of charge controller	M
21	Number of solar panels in parallel	d
22	Number of panels in series (12 V)	P
23	Total number of solar panels	M
24	Total number of solar panels, rounded	R

Tower Setup and Instruments Mounting

Li-Cor Heavy Duty
Adjustable Tripod



TECHNICAL NOTE

LI-COR Biosciences

Eddy Flux Tower Mounting Considerations and Suppliers

Technical Note #132

Mounting Hardware Suppliers

The following suppliers offer fittings and piping options for mounting a LI-COR analyzer to a tripod or tower. Any metal pipe from your local hardware store can be used with these fittings, as long as they have been properly sized and finished; however, the sources below offer custom piping options for your convenience. For instrument mounting projects LI-COR recommends aluminum fittings and pipes. The pipe sizes and additional fittings depend on your sonic anemometer and setup configuration. The mounting hardware included with the LI-7200, LI-7500A, and LI-7700, however, is designed to be used with a 1 inch pipe.

Mounting your LI-COR analyzer to a tower (near the sonic anemometer):

- 0.75 in. diameter x 10 in. long aluminum pipe
- 1.0 in. x 0.75* in. crossover fitting (2) - connects directly to the mounting post
- 1.0 in. x 0.75* in. crossover fitting
- 0.75 in. diameter x 12 in. long aluminum pipe

**This assumes a 0.75 in. diameter pipe; however you can use any size pipe you would like.*

You will also need:

- 4 ft. crossarm with bracket
- Mounting brackets for LI-7550 Analyzer Interface Unit - dimensions 13.8" x 11.8" x 5.9" (35cm x 30cm x 15cm)

NuRail

(http://www.nurail.com), of Metropolitan Pipe and Supply Company, offers everything needed to mount your LI-COR analyzer to an industrial tripod or tower. NuRail offers aluminum fittings in a wide variety of configurations and sizes ranging from 3/4 in. to 2 in. NuRail also has a pipe fabrication service for custom made integrated fittings and pipes.

NuRail Crossover fittings

1.0 in. x 0.75 in. crossover fitting - p/n 8783

Diamond Aluminum Company

(http://www.diamond-aluminum.com) is a structural aluminum fittings and pipe company that sells a variety of fitting configurations (made of high-strength, light-weight aluminum alloy) and piping (available in 4 different sizes, ordered by the foot and custom cut to fit your needs). Download Diamond's product catalog to learn more about material specifications and unique designs.

Diamond Aluminum Company Crossover fittings

(http://www.diamond-aluminum.com/fittingpages/200.htm)

1.0 in. x 0.75 in. crossover fitting - p/n 200 (PA)

Typical tripod mounting configuration (LI-7500A shown). The mounting post included with the LI-7200 and LI-7500A is 3/4" Diameter.

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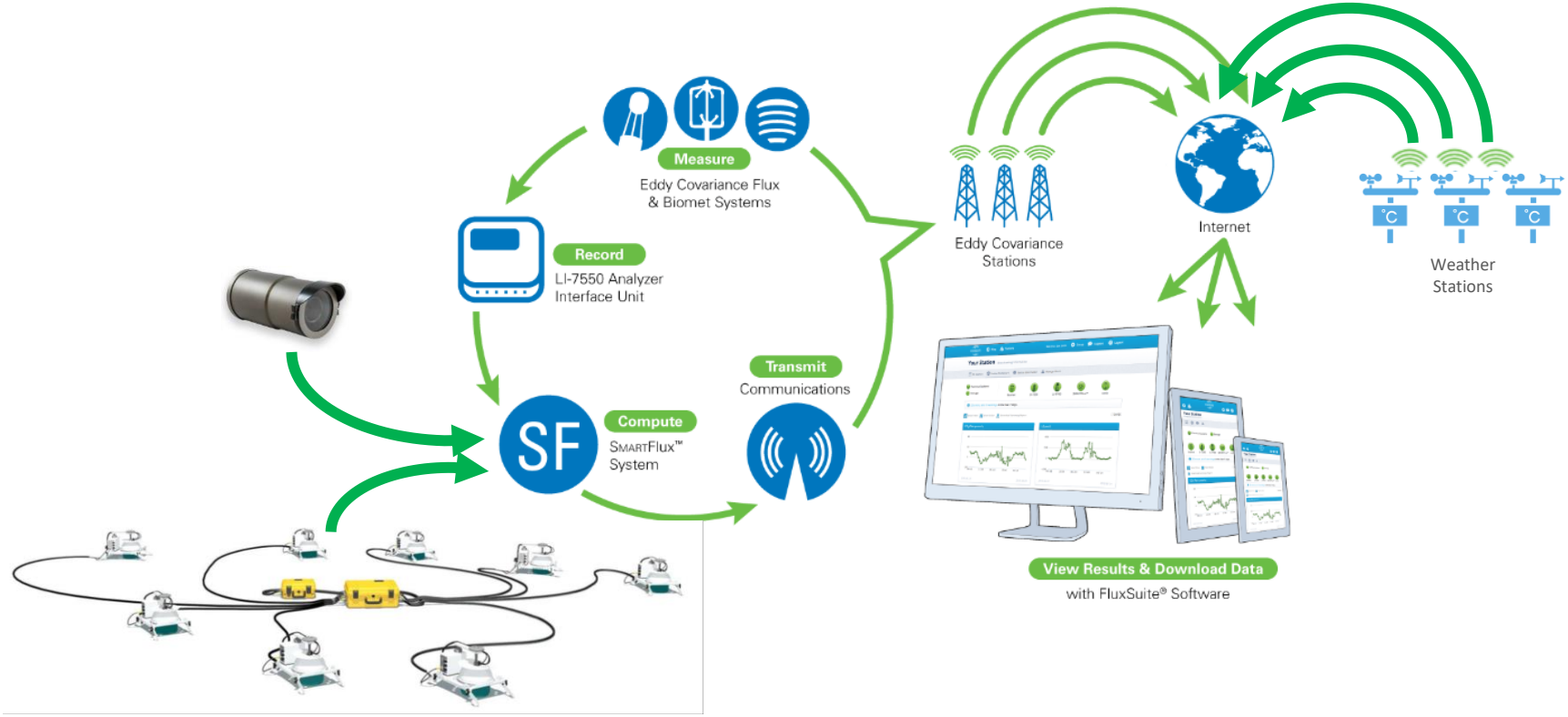
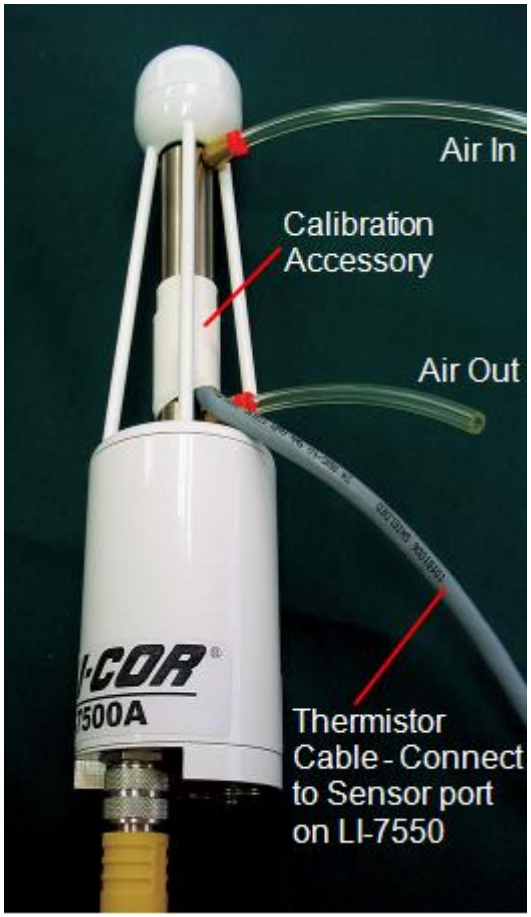
System Integration and Data Collection



System Operation and Maintenance

Changing internal chemicals

Calibrating



Thank You!

Questions?