Eddy Covariance Experiment
Applications, Design, and Site Selection

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Topics will be covered

1. Eddy covariance applications，应用
2. Concept of flux footprint and fetch requirement，足迹和风浪区
3. Designing and implementation of EC experiment，设计
   - Tower height 塔高度
   - Location of the tower，位置

Questions scientists are trying to answer are

- What are the sources, sinks of CO_2, CH_4, N_2O (库和源)?
- What are the factors that regulate these source and sink strength (调控)?
- Atmospheric CO_2, CH_4, N_2O trend (变化趋势)?
- What kind of impact on climate and ecosystem, esp for the case of CO2 (影响)?
- Research approach (研究方法)
  - Atmospheric background, like Global Atmosphere Watch of WMO
  - Remote sensing, large scale modeling
  - Ecosystem level study
- Mitigation strategies (应对措施)

Applications，应用

- Climate change research 气候变化

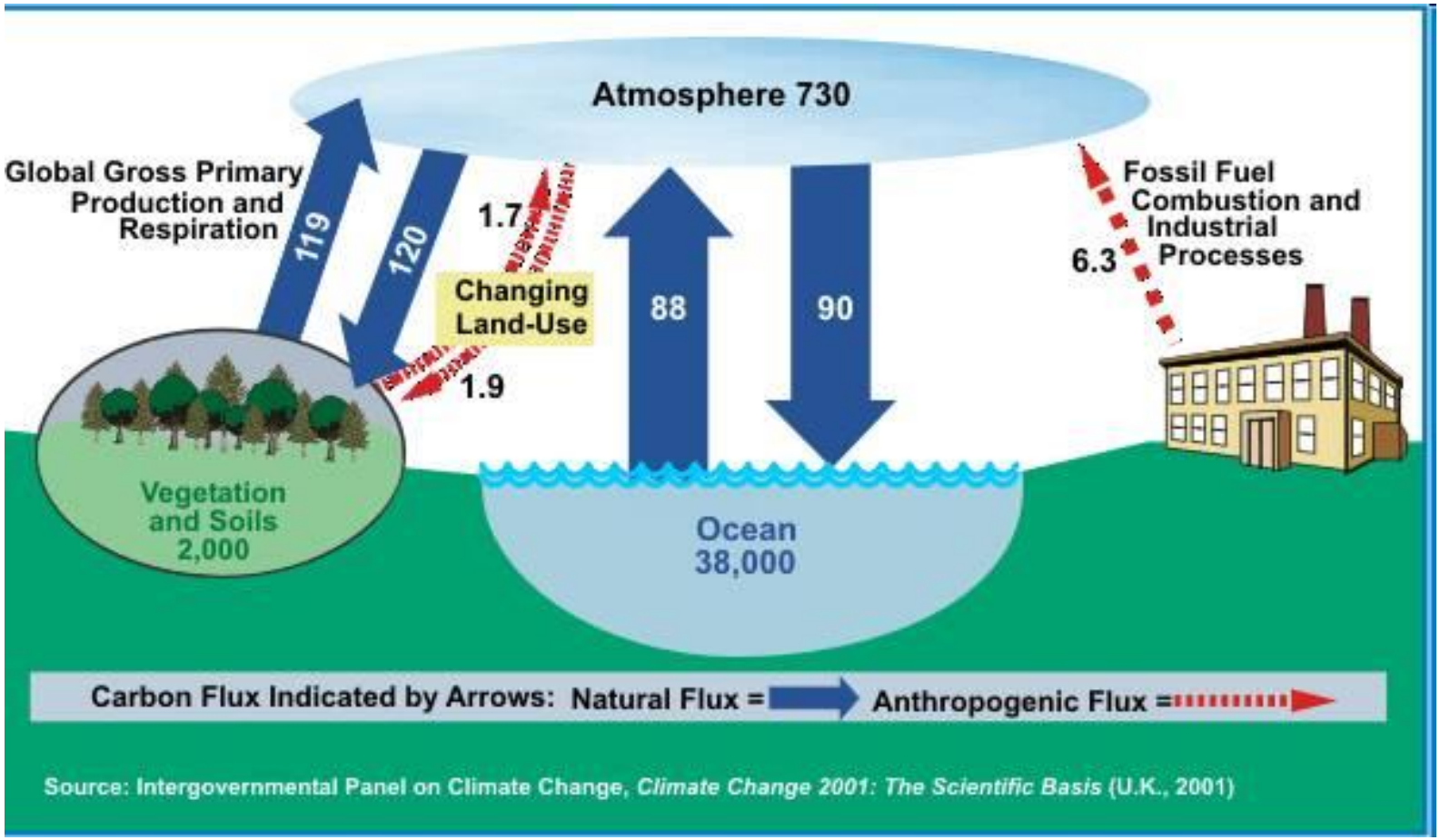
  Global Carbon Cycle

- Agricultural applications，农业

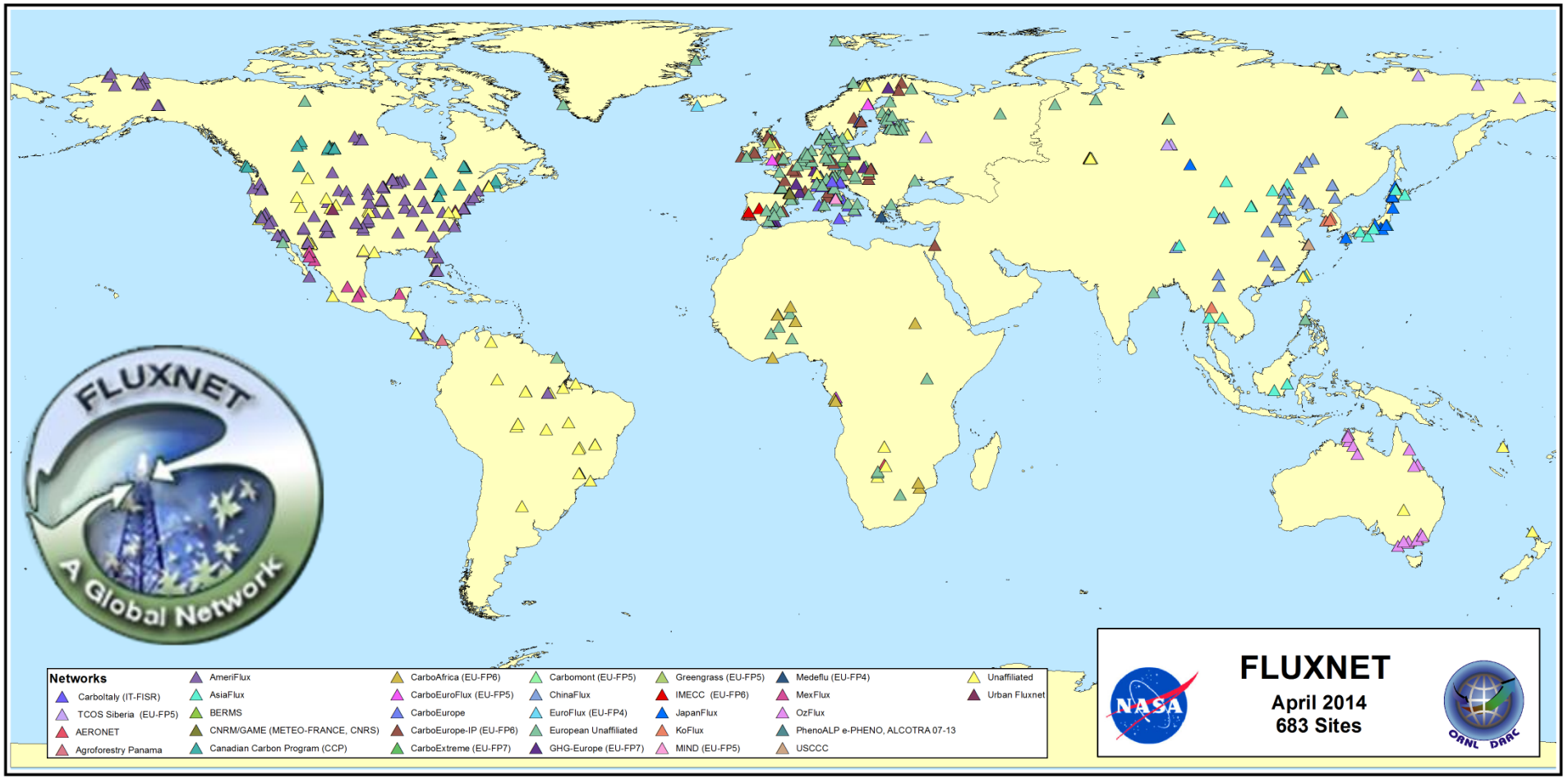
  Other GHG fluxes, N_2O, CH_4, $^{13}CO_2$ etc

- Industrial applications，工业

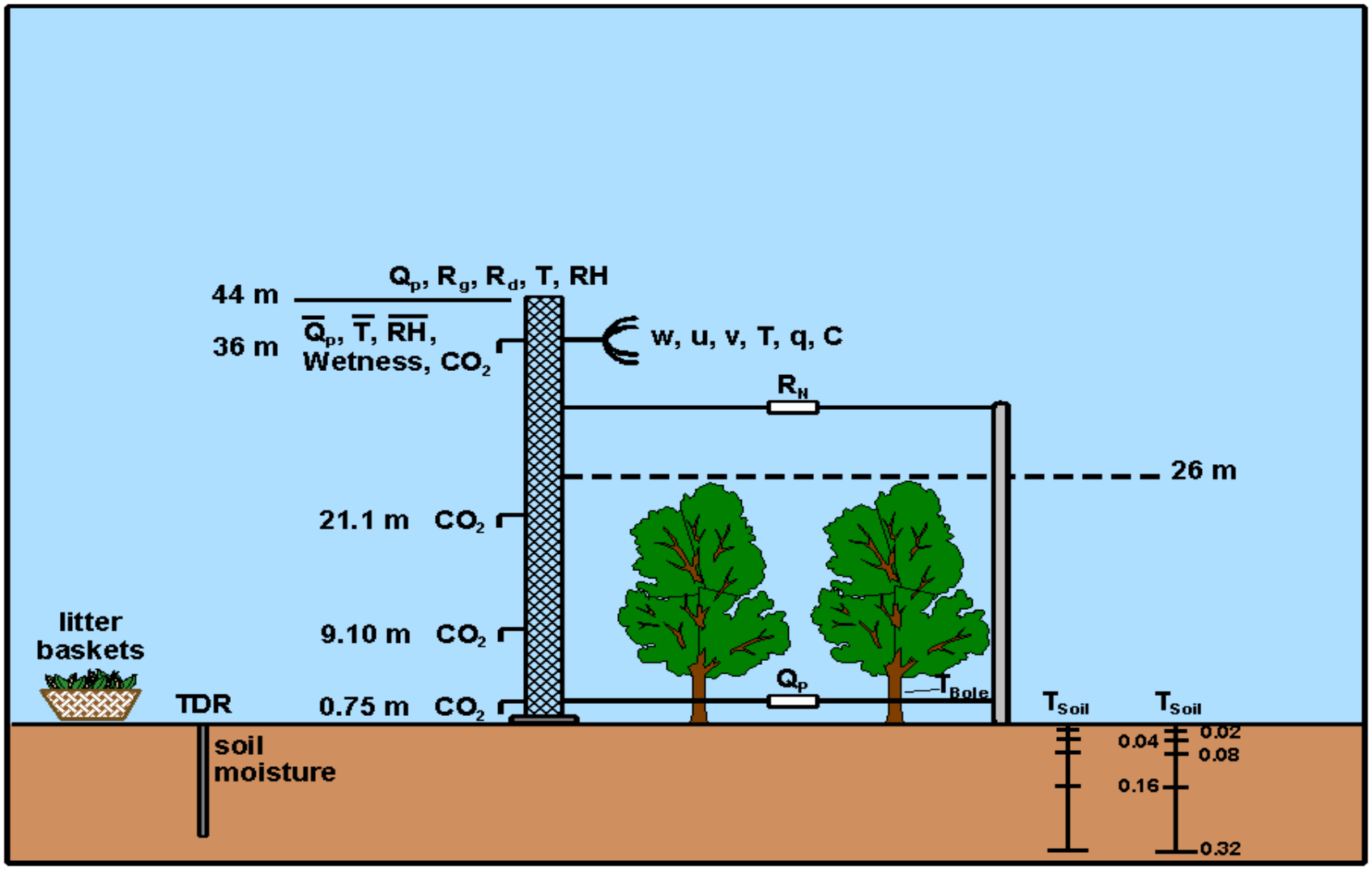
Global Carbon Cycle , 全球碳循环



Ecology, Carbon Cycle, 生态系统碳循环



Typical setting for a flux station

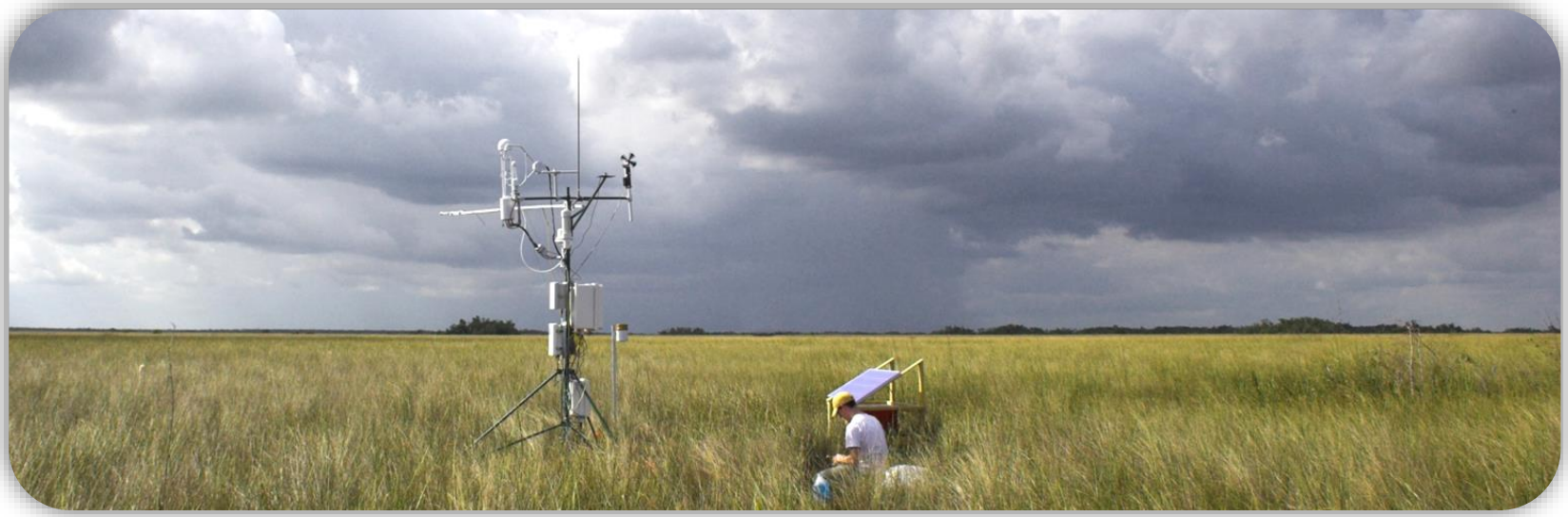


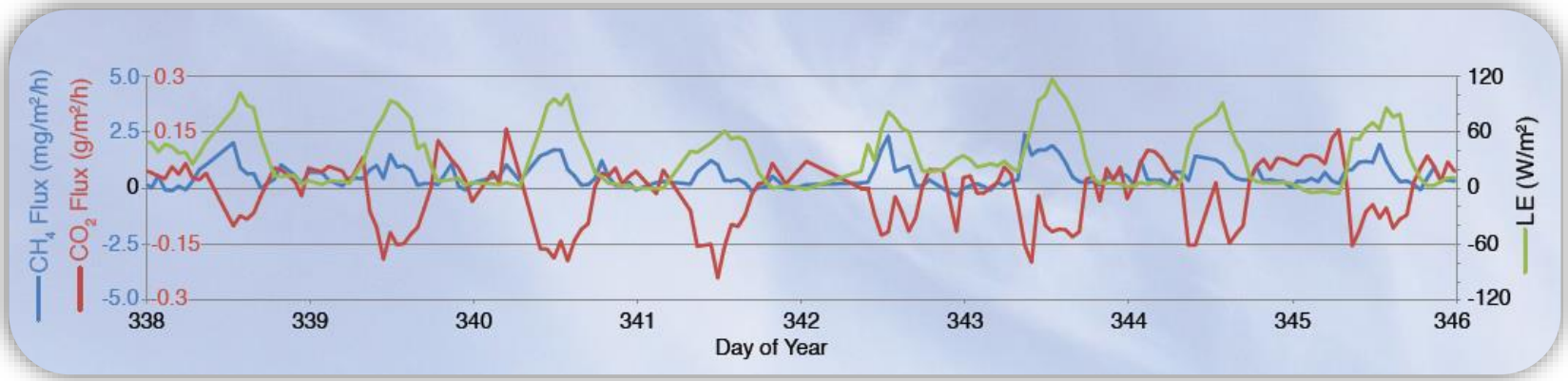
机理

ET or NEE = f (precipitation, temperature, soil moisture, VPD, radiation, diffuse radiation, LAI, vegetation type, etc.,)

model validation, ground truth, and remote sensing

Wetland: CH_4/CO_2 and H_2O budgets





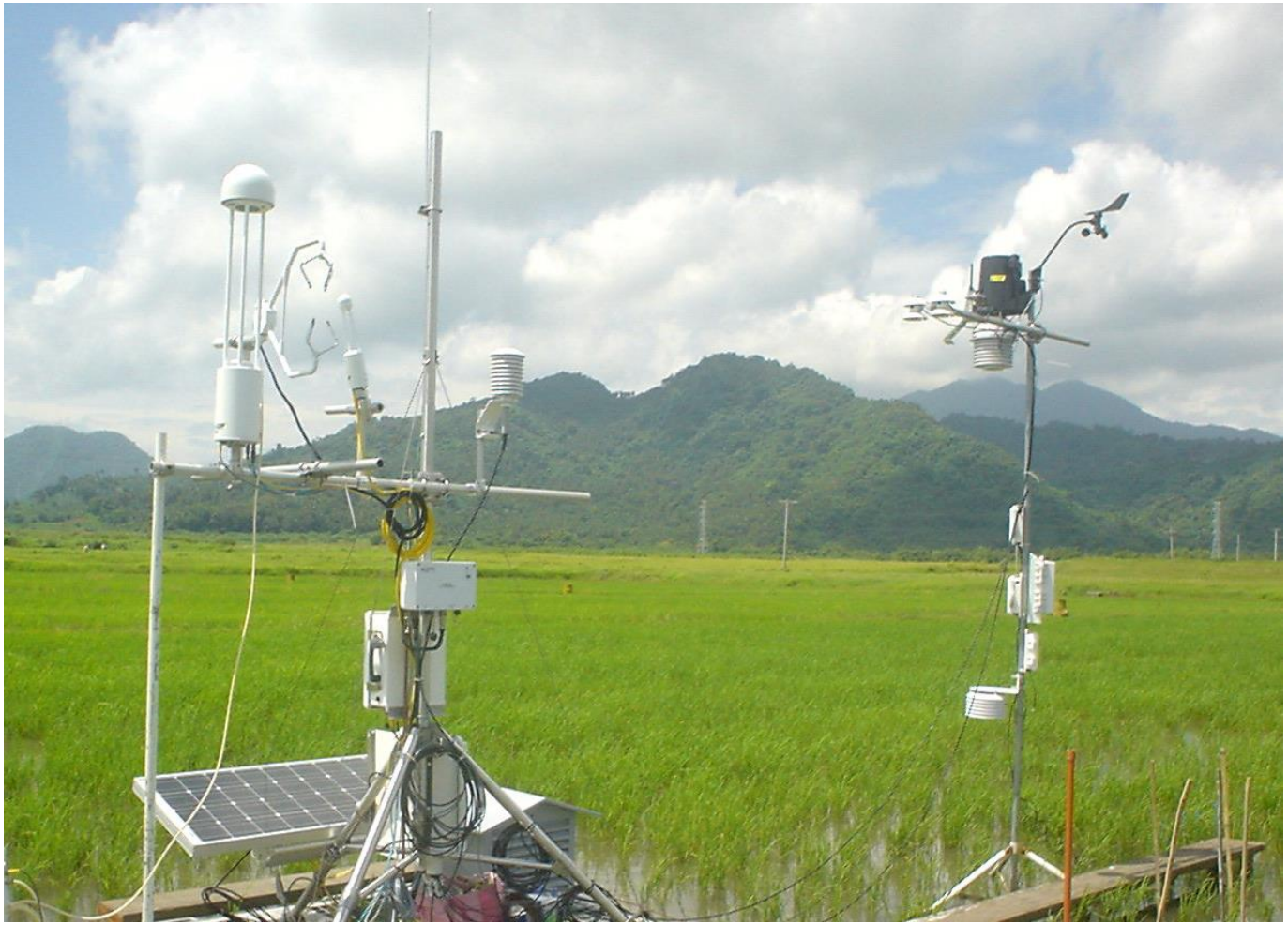
Laurila T. et al., 2012. Eddy covariance measurements over wetlands.

Agriculture

- Yield research
- Plant light and water use efficiencies
- Irrigation and water usage
- Agricultural carbon sequestration
- Bio-fuel investigations

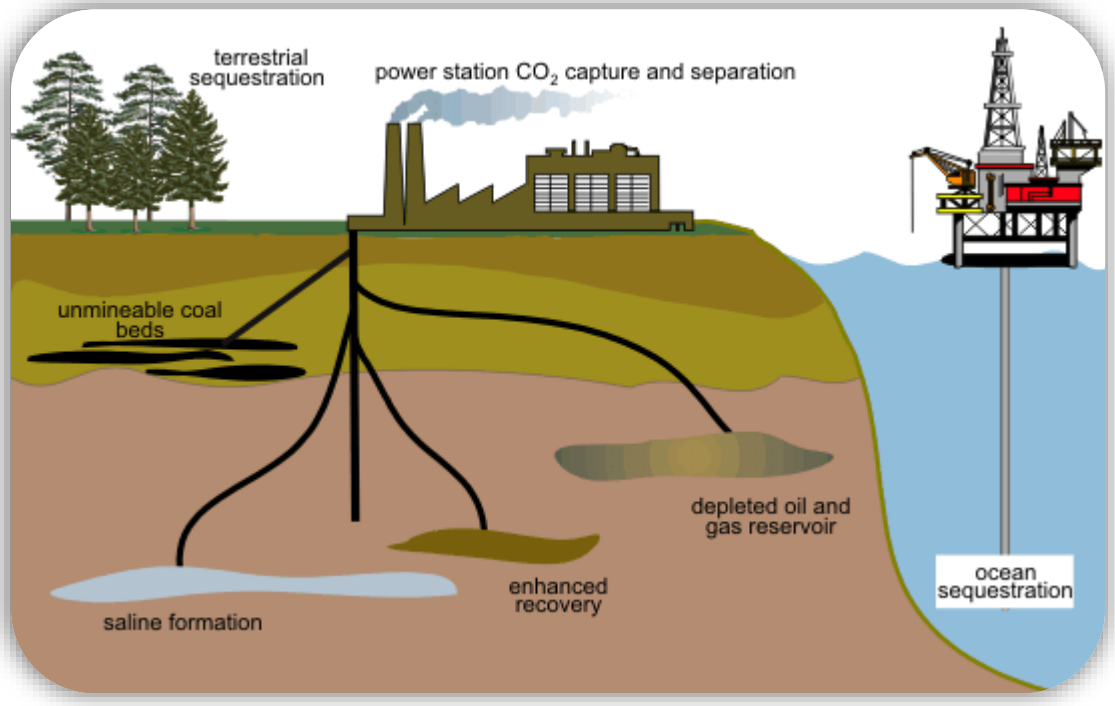
Verma et al., Agri For and Meteorol. 128:141-162.

Rice field, CO_2, ET, and CH_4 flux (IRRI)



Courtesy of Dr. M. Alberto

Is it safe to store CO_2 underground?



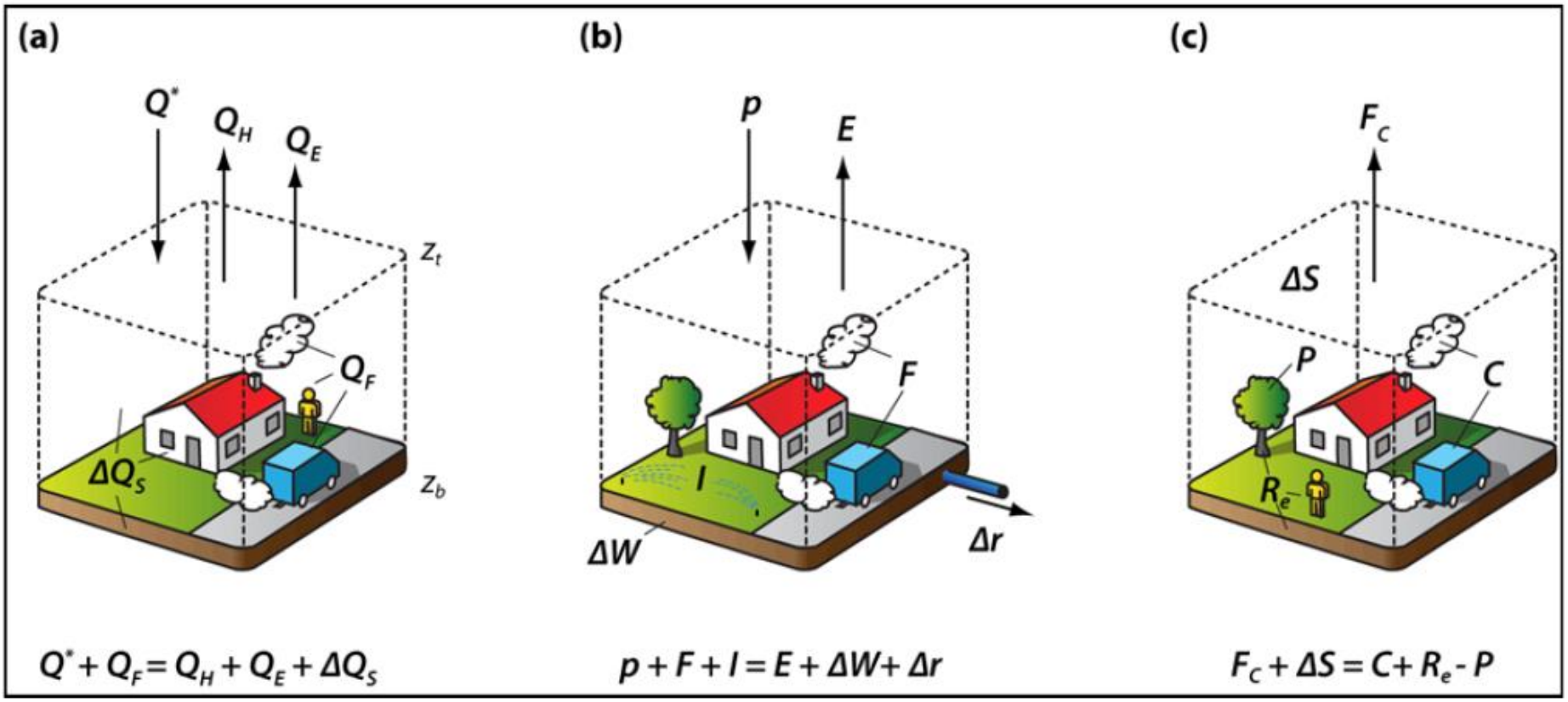
- Carbon capture & sequestration
- Carbon budget
- Leak detection

LI-COR Biosciences

Midwest Geological Sequestration Consortium Illinois Basin- Decatur Illinois Site. One million tons of CO_2 will be injected over a three year period at a rate of 1,000 ton/day. The pure CO_2 will be captured from a nearby ethanol plant, then injected into the 1,500 ft thick Sandstone, at a depth of 6,000 to 7,000 ft.

Urban studies

Grimmond et al., 2002. *Env Pollution*, 116: S243-254



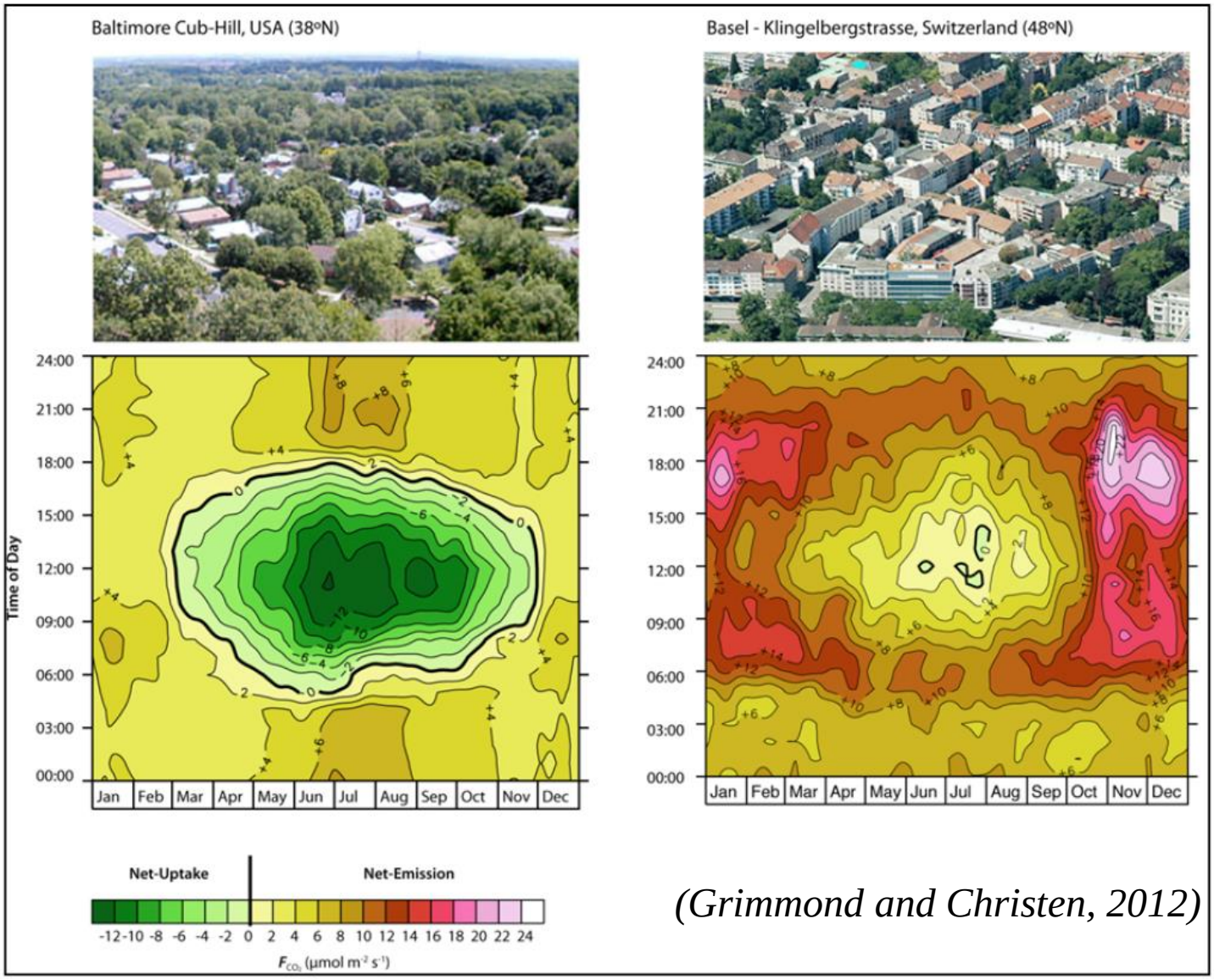
Q^*: net radiation
Q_F: heat from human activities
Q_H: sensible heat flux
Q_E: latent heat flux
ΔQ_s: storage term

P: precipitation
F: from combustion
I: irrigation
E: evaporation
ΔW: storage term
Δr: runoff

F_c: net CO_2 flux
Δs: storage term
C: combustion
R_e: respiration
P: photosynthesis

Feigenwinter et al., 2012

Urban CO_2 flux depends on vegetation cover



(Grimmond and Christen, 2012)

FLUX FOOTPRINT CONCEPT

FOR

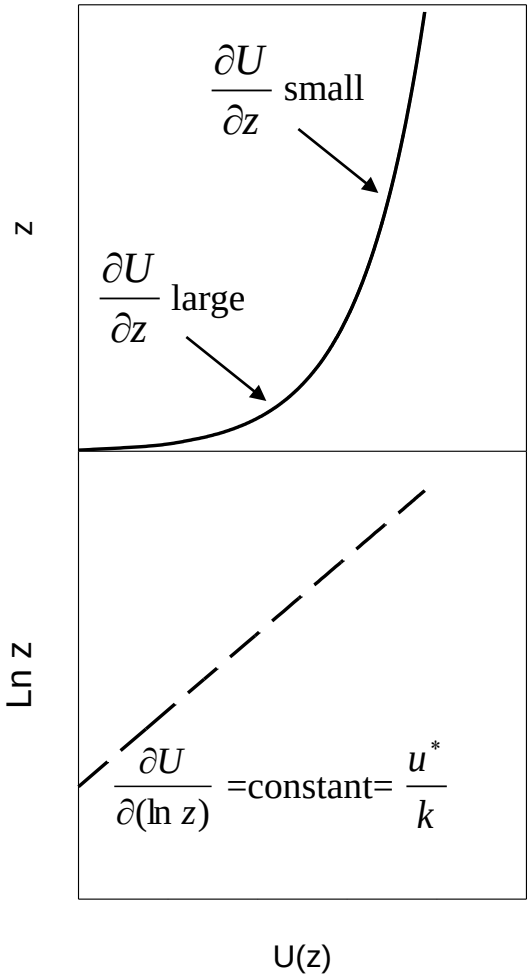
EC EXPERIMENT DESIGN

Fetch Requirement

Friction Velocity – *u**

Typical wind profile

Smooth surface and neutral stability



$$U_{(z)} = \frac{u^*}{k} \ln \frac{z}{z_0}$$

$U_{(z)}$ – horizontal wind speed at z

u* - friction velocity

k – von Karman constant (0.41)

z – height

z_o – roughness length

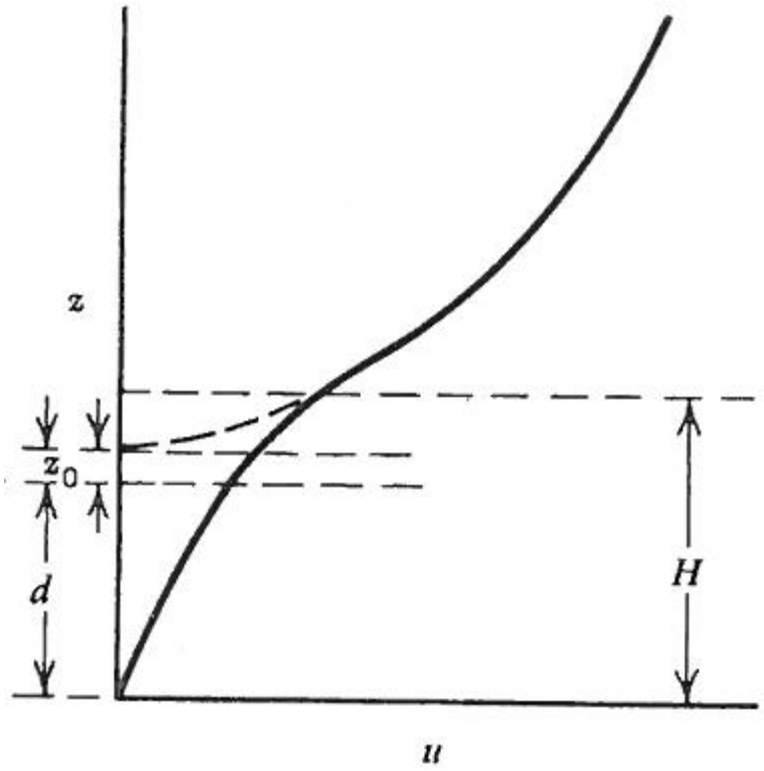
$$u_*^2 = [\overline{u'w'}^2 + \overline{v'w'}^2]^{1/2}$$

Rosenberg, et al., 1983, Microclimate: The Biological Environment

Friction Velocity – *u**

Typical wind profile

-Rough surface and neutral stability



$$U_{(z)} = \frac{u^*}{k} \ln \frac{z-d}{z_0}$$

$U_{(z)}$ – horizontal wind speed at z

***u** - friction velocity*

k – von Karman constant (0.41)

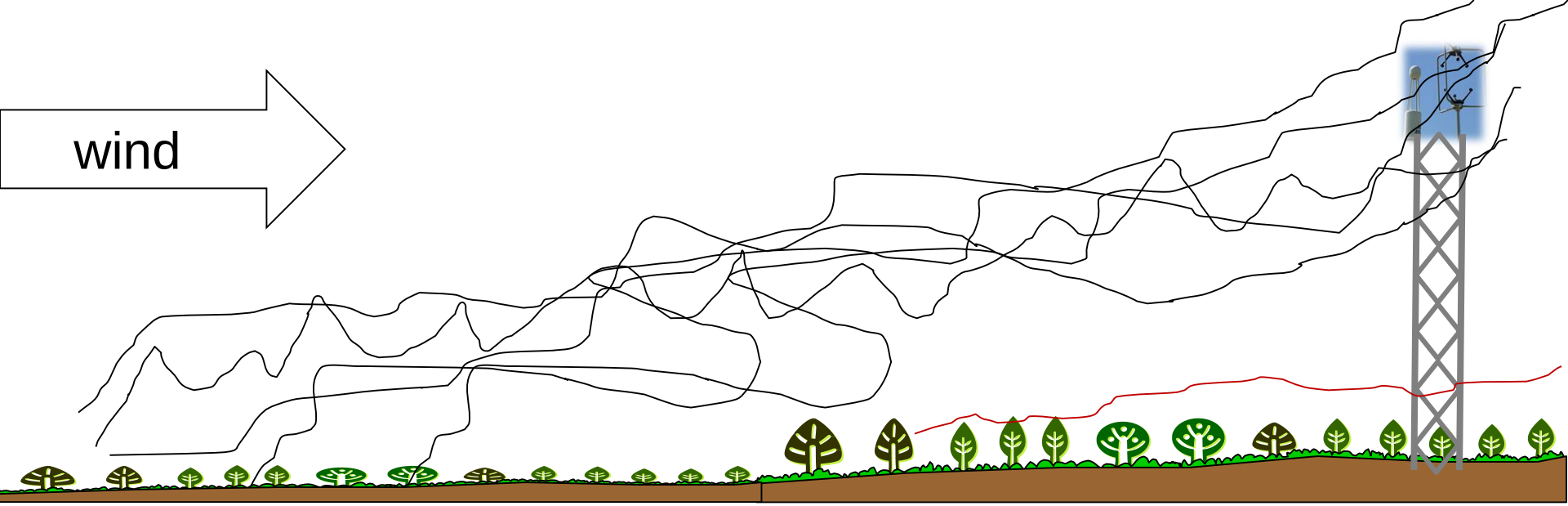
z – height

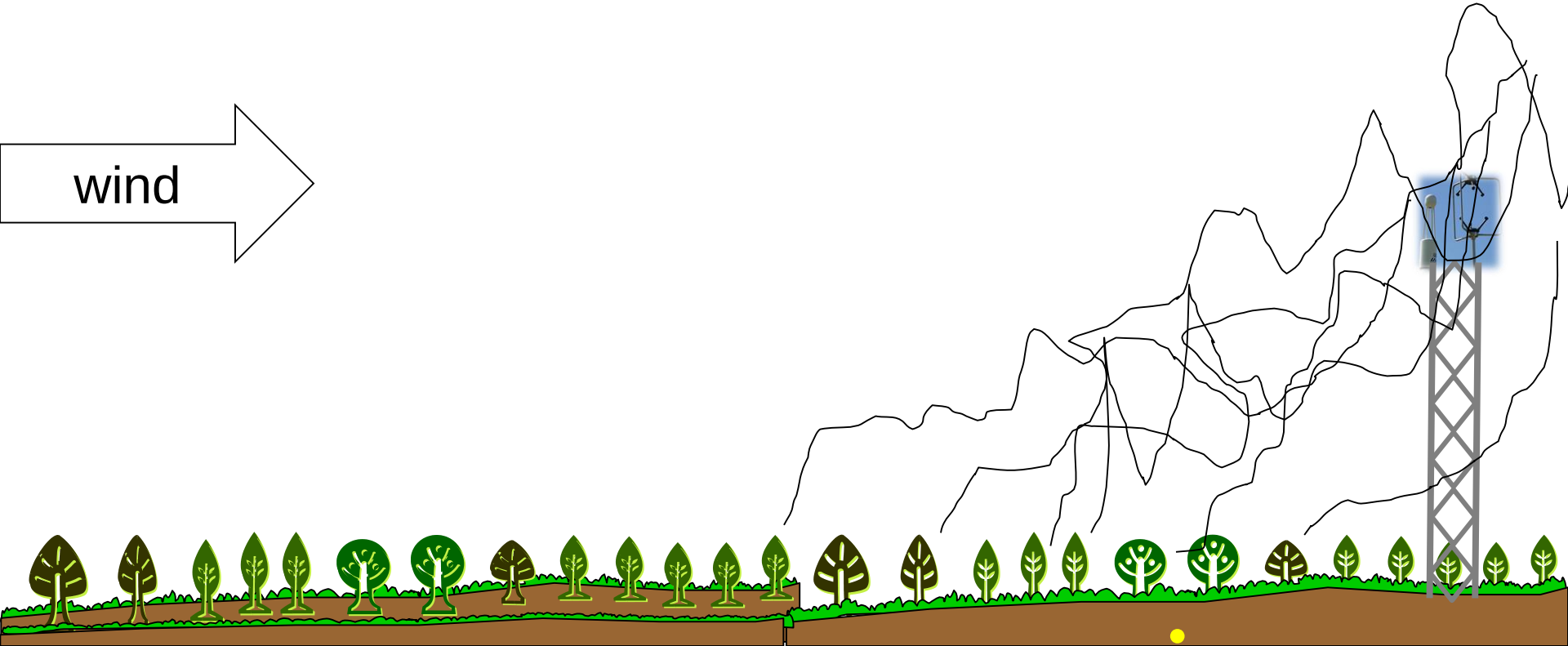
***z_o* – roughness length**

***d* – zero plane displacement, (d ≈ 0.66 h)**

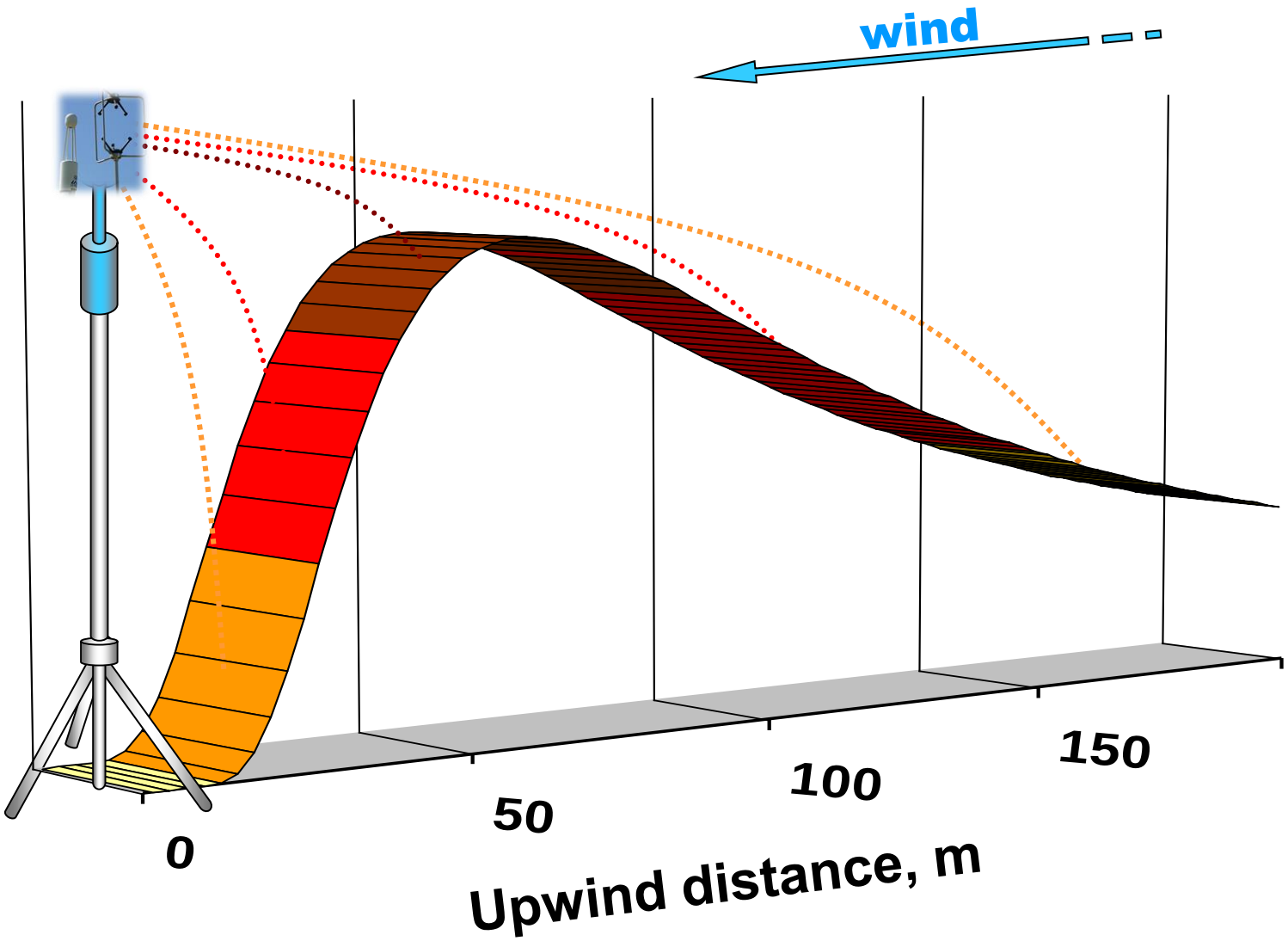
H– canopy height

Roseberg, et al., 1983, Microclimate: The Biological Environment

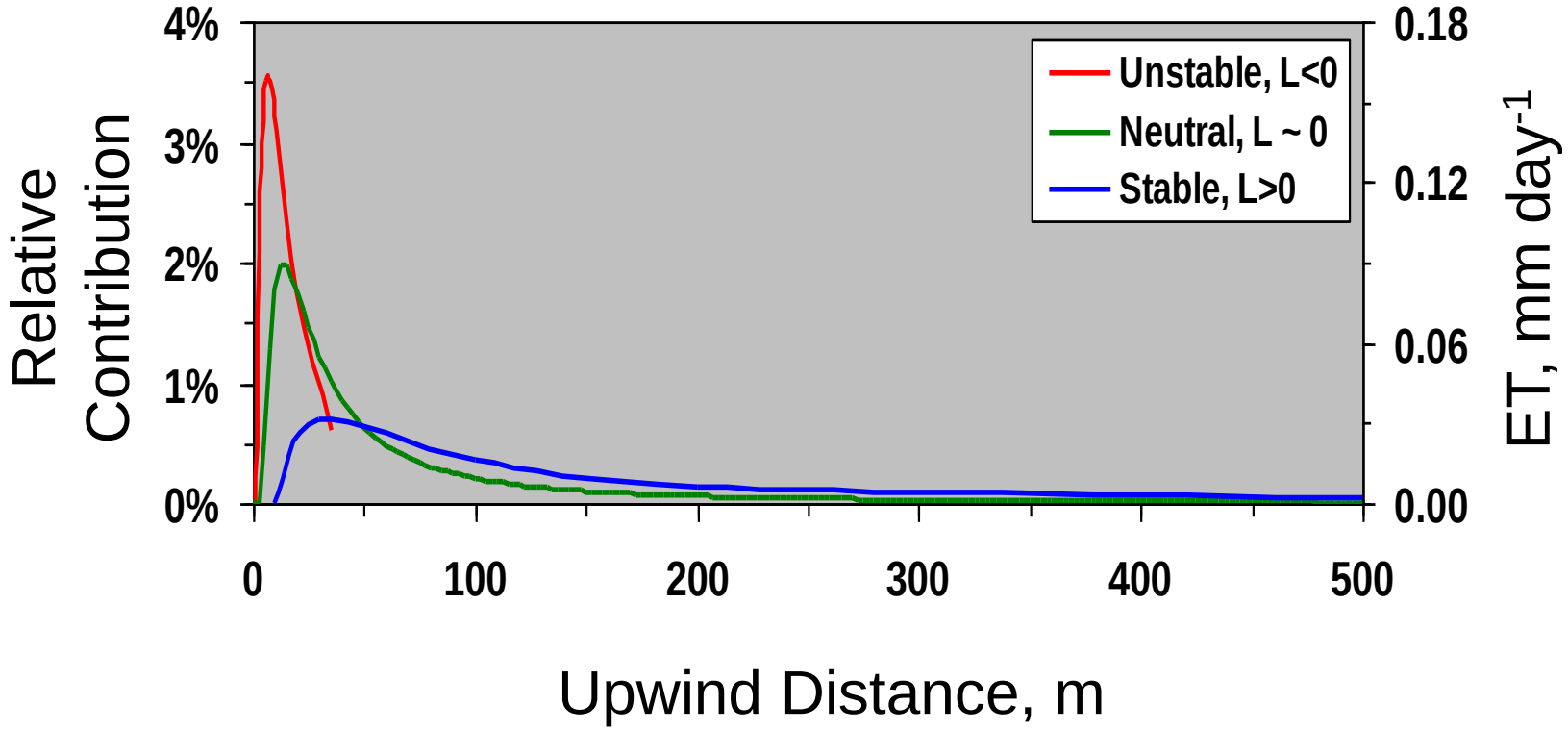

wind


wind

足迹分布图 (Footprint) 是指在上风向不同地方对所测通量的相对贡献



Instrument height 1.5 m, and canopy height 0.6 m



Adopted from Leclerc and Thurtell (1990)

For near-neutral conditions:

$$CNF(x_L) = -\int_0^{x_L} \frac{U(z-d)}{u_* k x^2} e^{-\frac{U(z-d)}{u_* k x}} dx = e^{-\frac{U(z-d)}{u_* k x_L}}$$

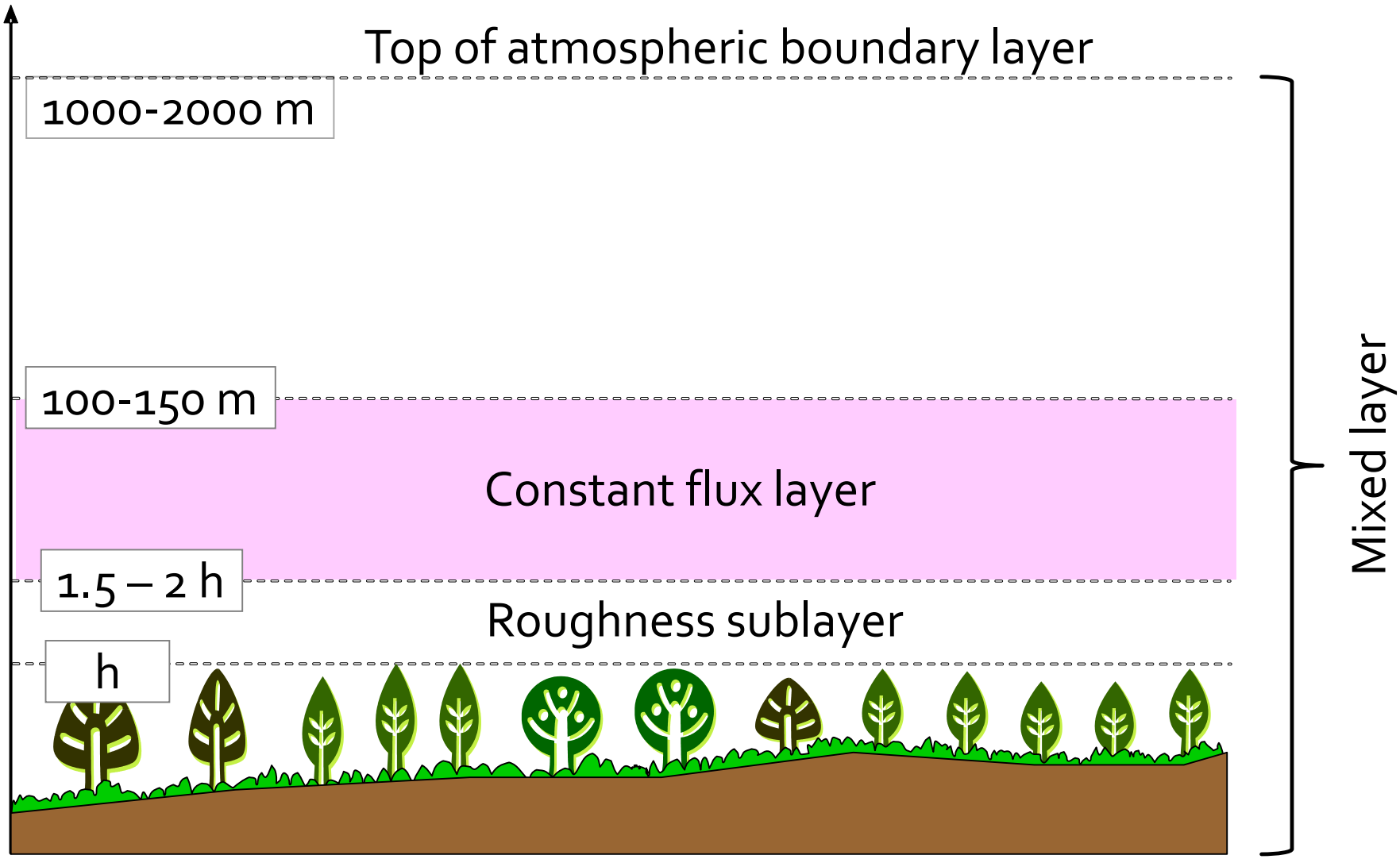
CNF is Cumulative Normalized contribution to Flux measurement, %
x_L is distance from the tower, m
U is mean integrated wind speed, m s^{-1}
z is measurement height, m
u_* is friction velocity, m s^{-1}
d is zero plain displacement, m
k is von Karman constant (0.4)

$$U^* = \sqrt{-\overline{u'w'}}$$

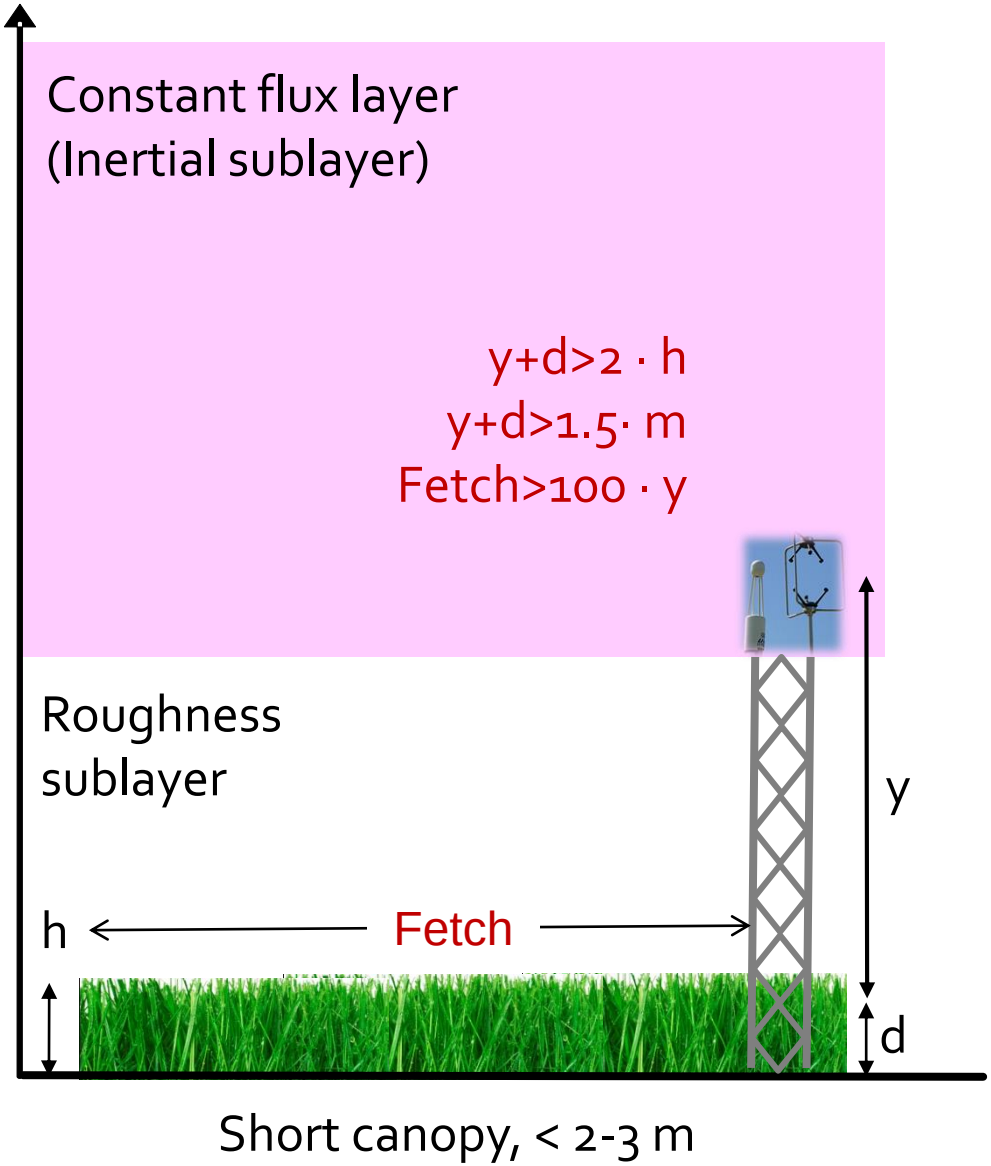
Schuepp, P.H., Leclerc, M.Y., Macpherson, J.I., and R.L. Desjardins (1990)
'Footprint prediction of scalar fluxes from analytical solution of the diffusion equation'

⇨ Flux Footprint Depends on:

Measurement height
Mechanic mixing (dU/dz)
Thermal stability ($d\theta/dz$)



(layers are based on Stull, 1988; Denmead *et al*., 1996; and Oke, 2007)



Short canopy, < 2-3 m

RULES OF THUMB

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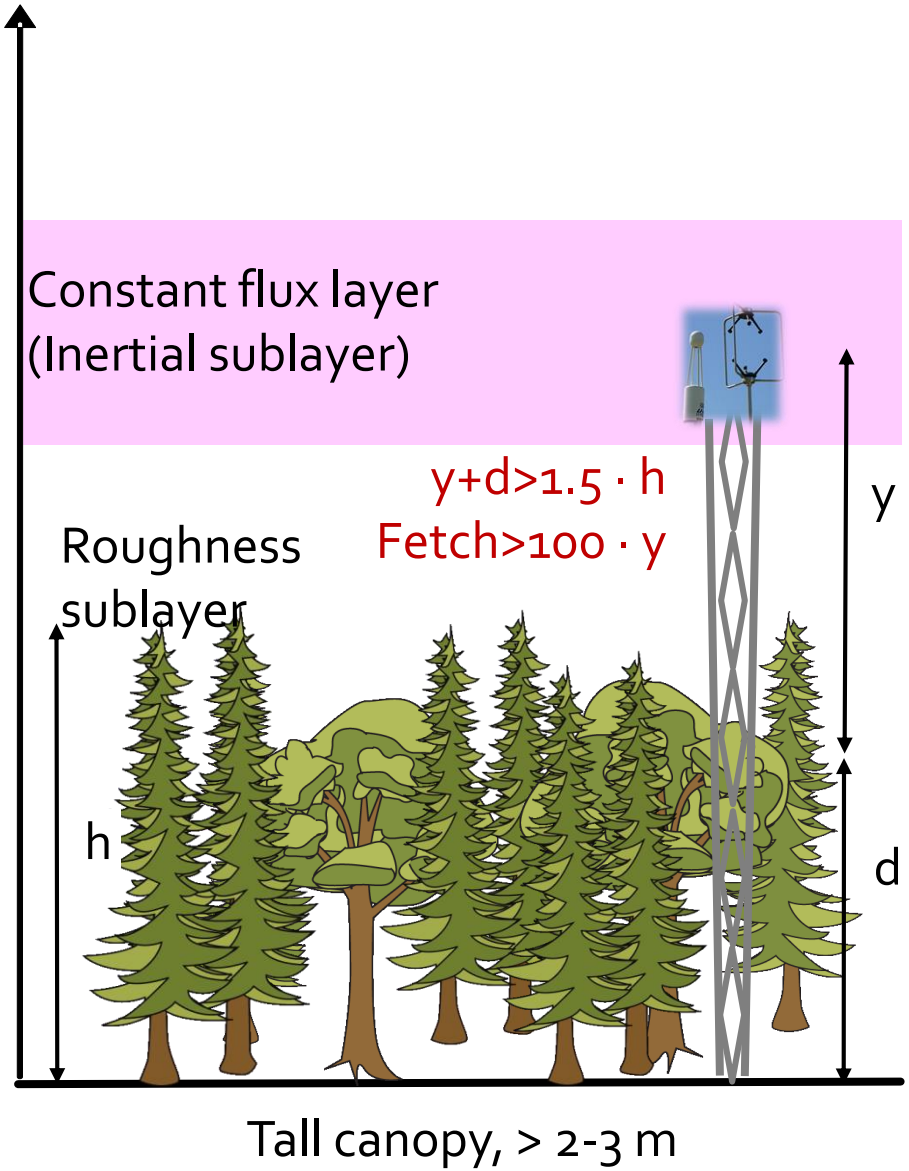
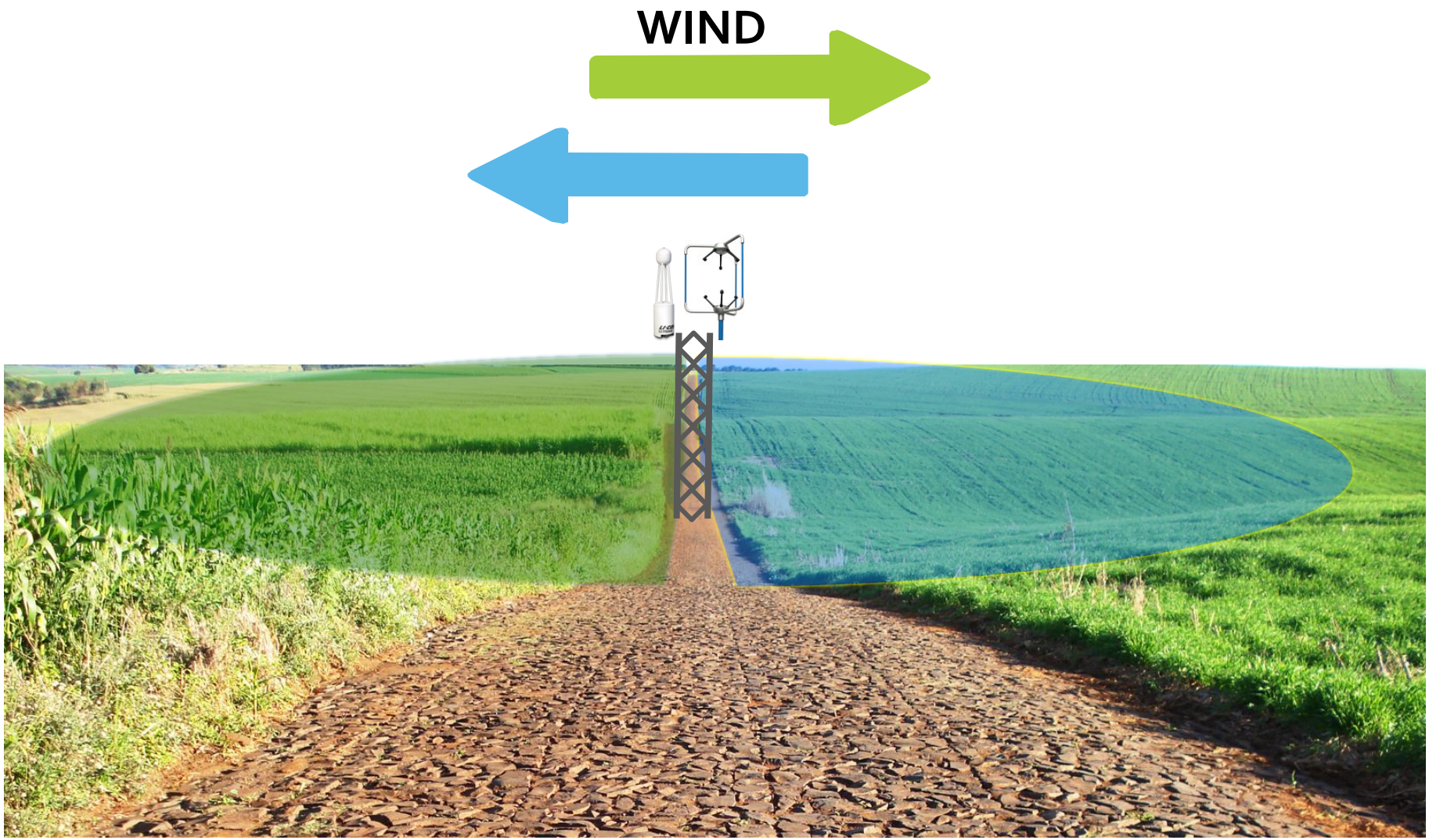


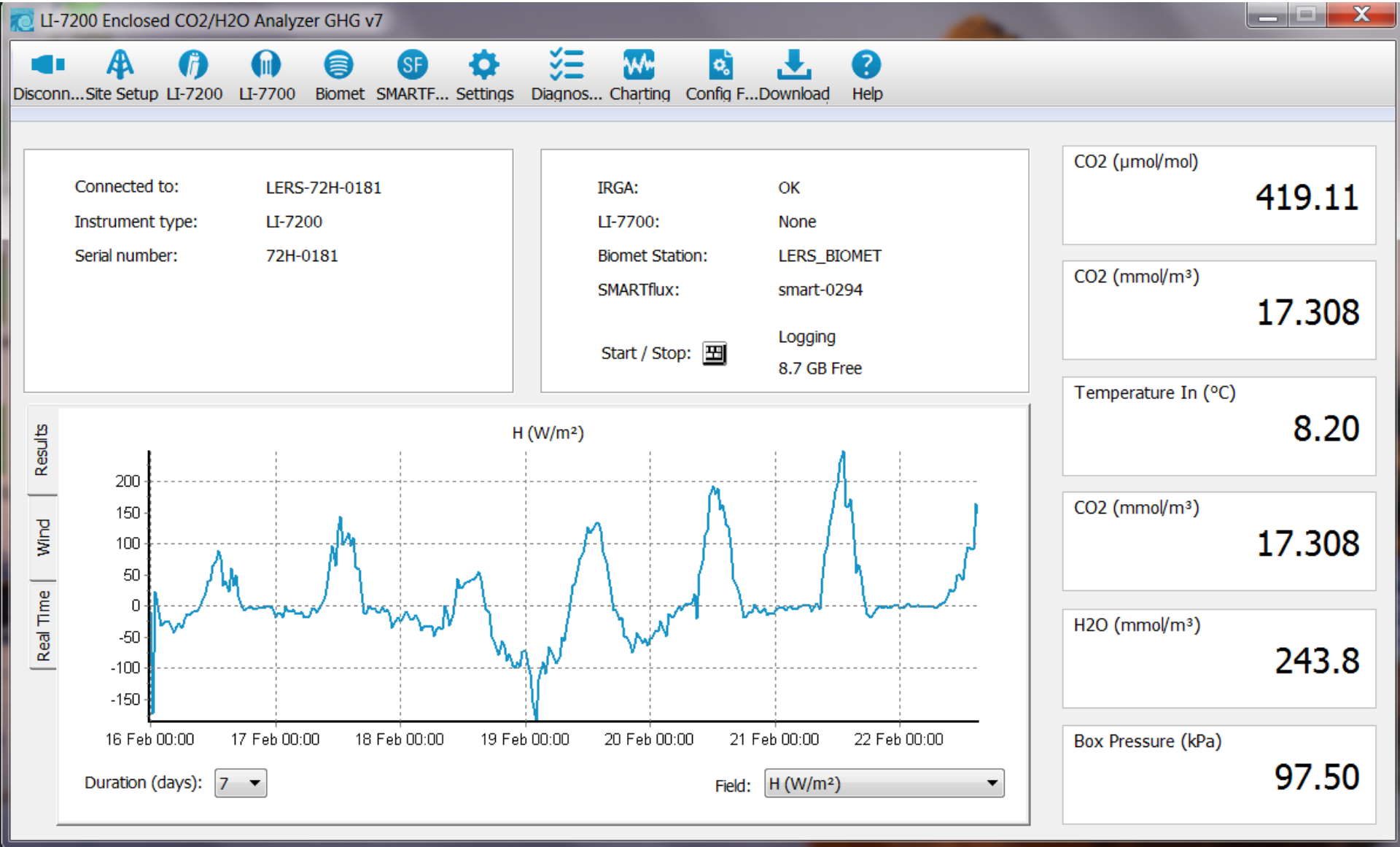
Tower Location

Tower Location?



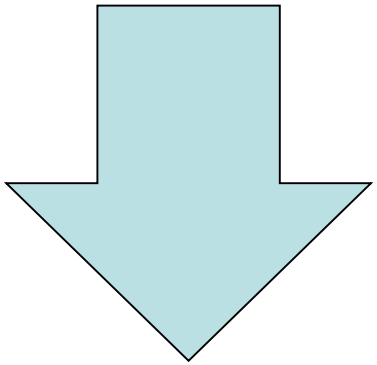

wind

Look through all channels to make sure output values in reasonable ranges?



Compute flux with EddyPro

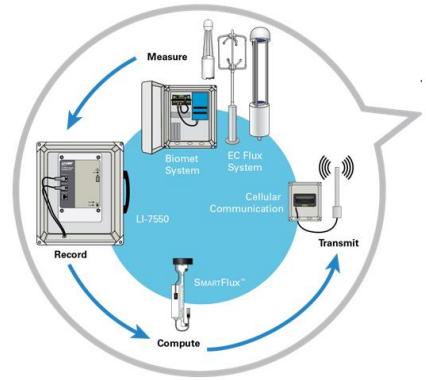
as soon as you get back from the field



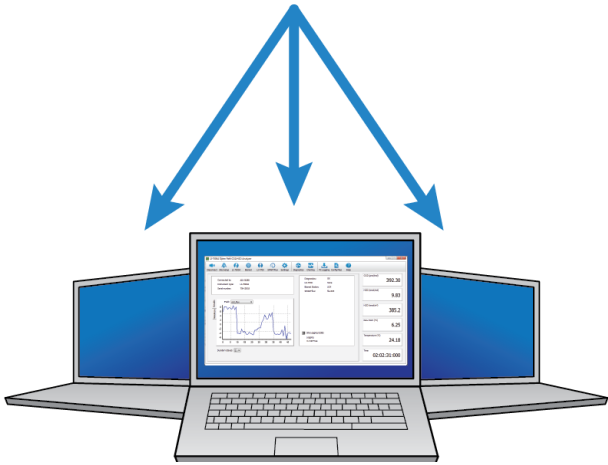
Do all the flux values make sense?

Do all the variables values make sense?

Instrumentation, data collecting, processing, transmit, monitoring, & managing



eddyPRO



View and download data

Analyze your data right away!

Summary

- Applications
- Footprint and fetch concept
- Tower location
- Some practical advices

Questions ?