Trinity College Dublin

Methodologies to measure land-atmosphere GHG exchange

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Objectives

At the end of this session, you should be able to:

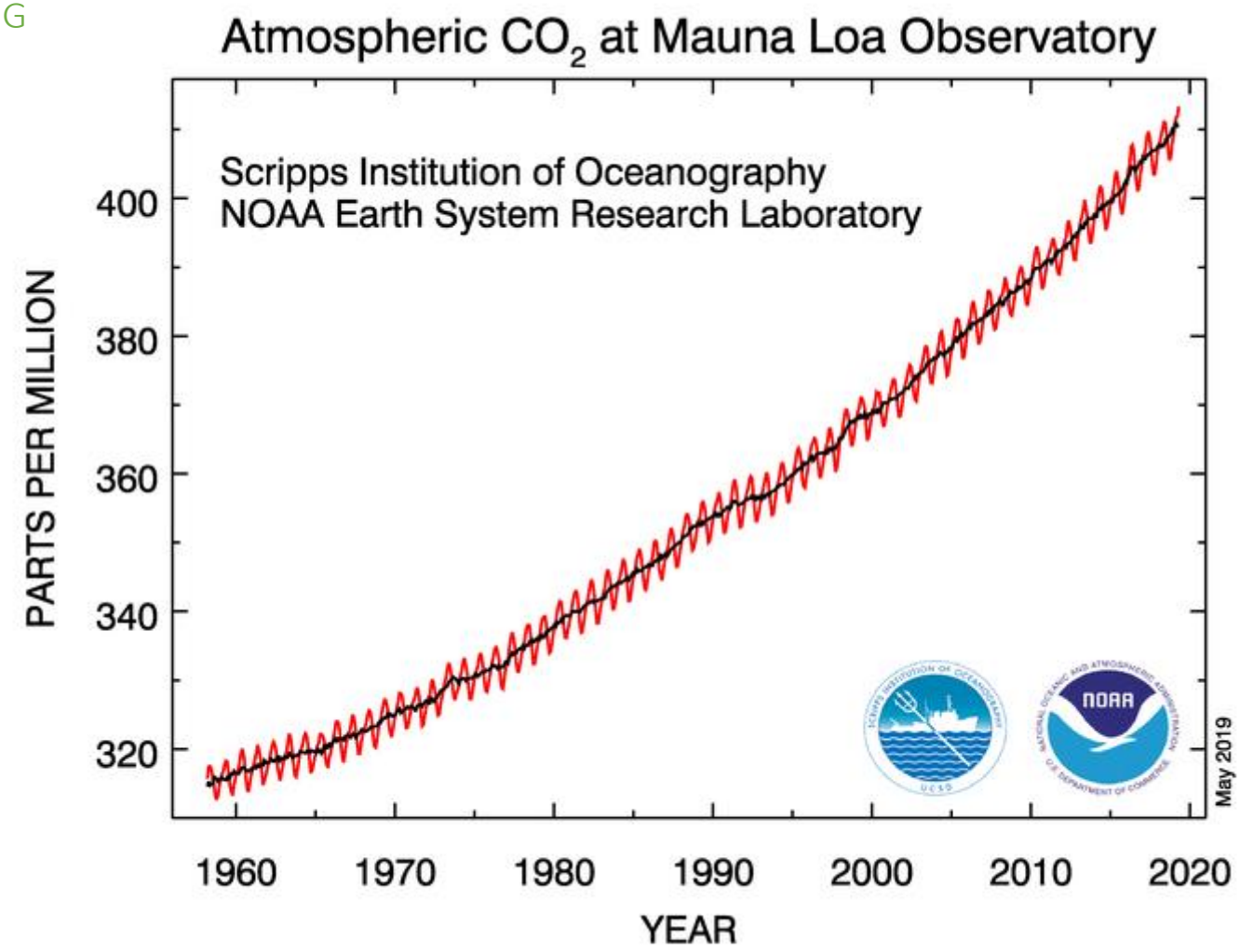
1. Classify the main techniques utilized to monitor C & GHG cycling
2. Identify the rationale behind main techniques used in natural and managed ecosystems
3. Justify why is important to measure these variables in a harmonized way
4. List some examples of methodological protocols

Atmospheric growth of GHGs

April 2019: 413.32 ppm
April 2018: 410.24 ppm
Last updated: May 6, 2019

Long-lived GHG

CO_2



https://www.esrl.noaa.gov/gmd

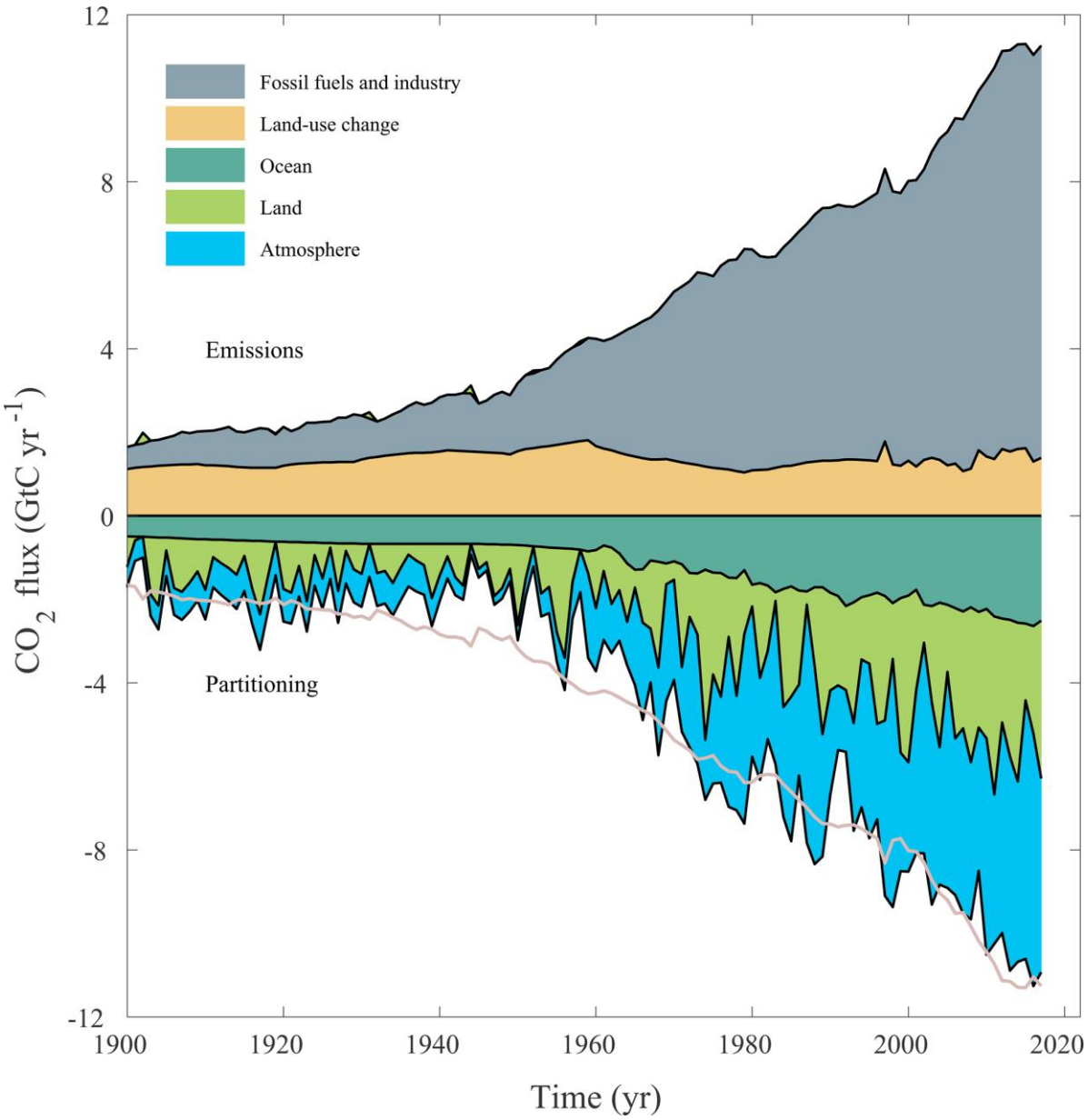
Sources: Use fossil fuels, fires, ecosystem respiration

Atmospheric growth of GHGs

Le Queré *et al.* 2018 *Earth System Science Data*

Long-lived GHG

CO_2

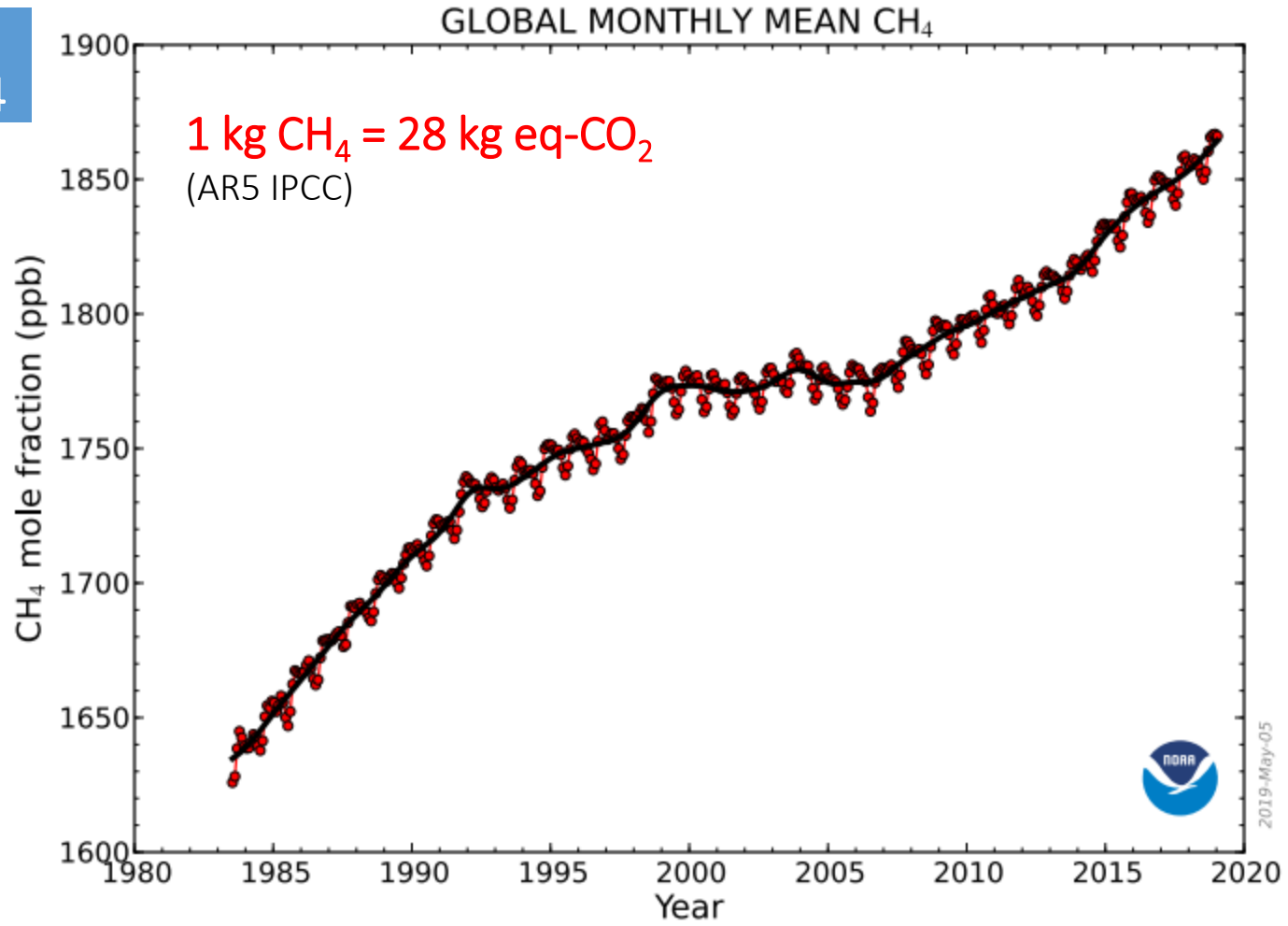


Atmospheric growth of GHGs

January 2019: 1866.1 ppb
January 2018: 1854.9 ppb
Last updated: May 05, 2019

Short-lived GHG

CH_4



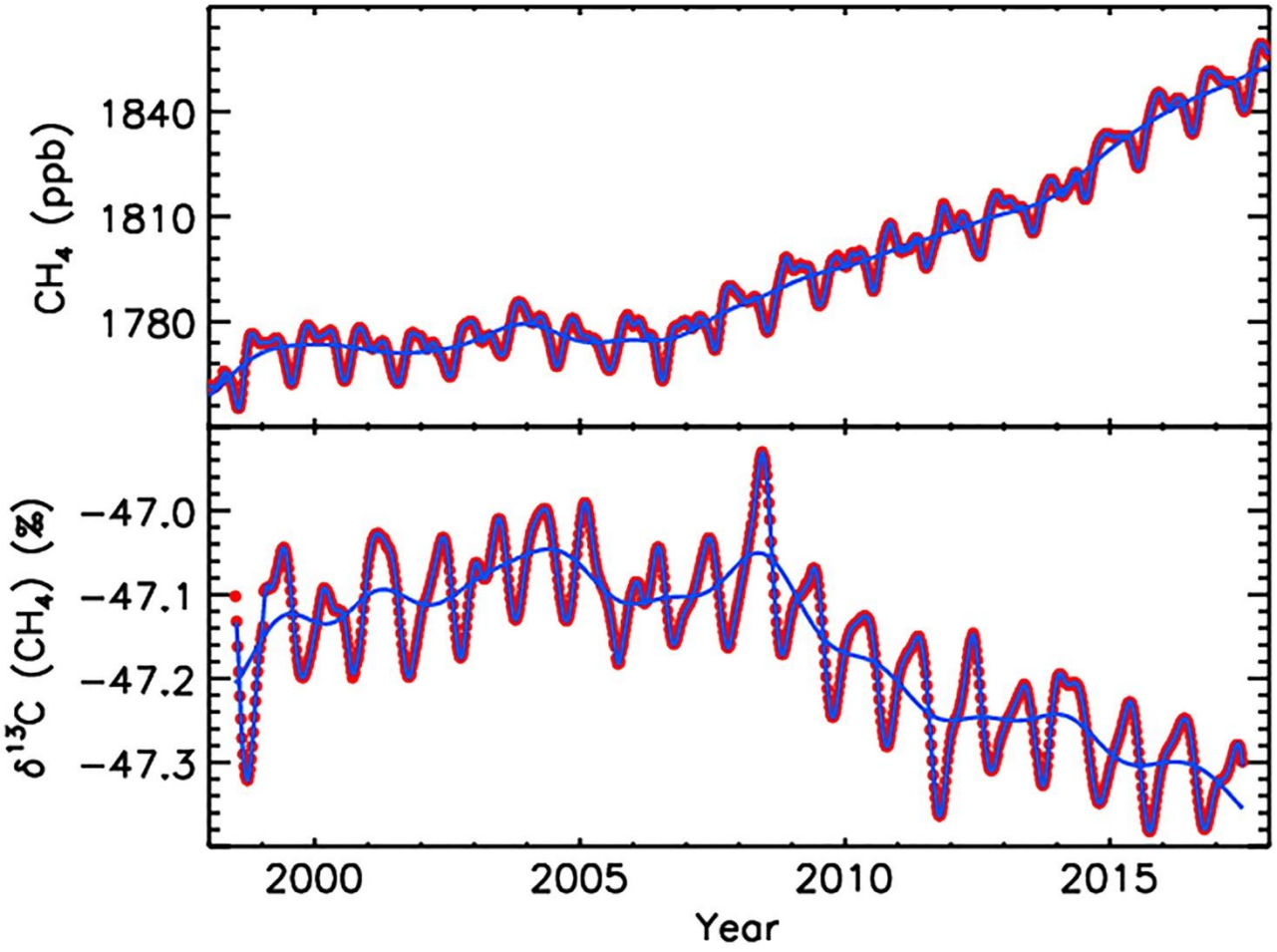
https://www.esrl.noaa.gov/gm

Sources: wetlands, fossil fuels, waste, ruminants, rice paddies.

Atmospheric growth of GHGs

Short-lived GHG

CH_4

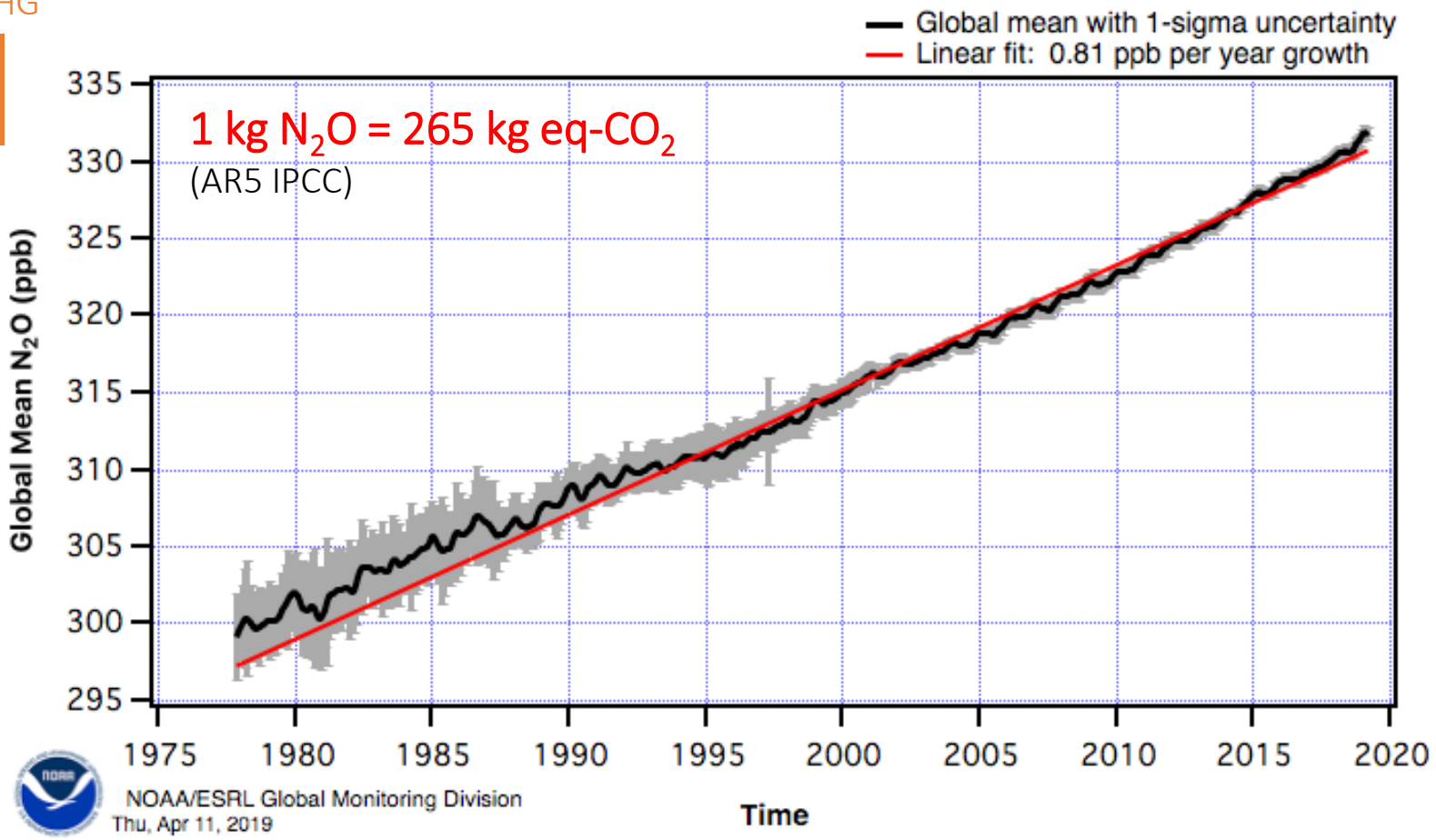


Nisbet *et al.* 2019 *Global Biogeochemical Cycles*

Atmospheric growth of GHGs

Long-lived GHG

N_2O



https://www.esrl.noaa.gov/gmd

Sources: use of fertilizers in agriculture, livestock manure

A lot of uncertainty still…

WE NEED TO ACQUIRE IN-SITU OBSERVATIONS OF LAND GHG SOURCES AND SINKS

Bottom-up methods

- GHG inventories (Tier 1 – 3) - sectors
- Based on Emission Factors (EF)
- GHG emission = activity * EF
- EF accuracy depends on:

ground-based in situ- data

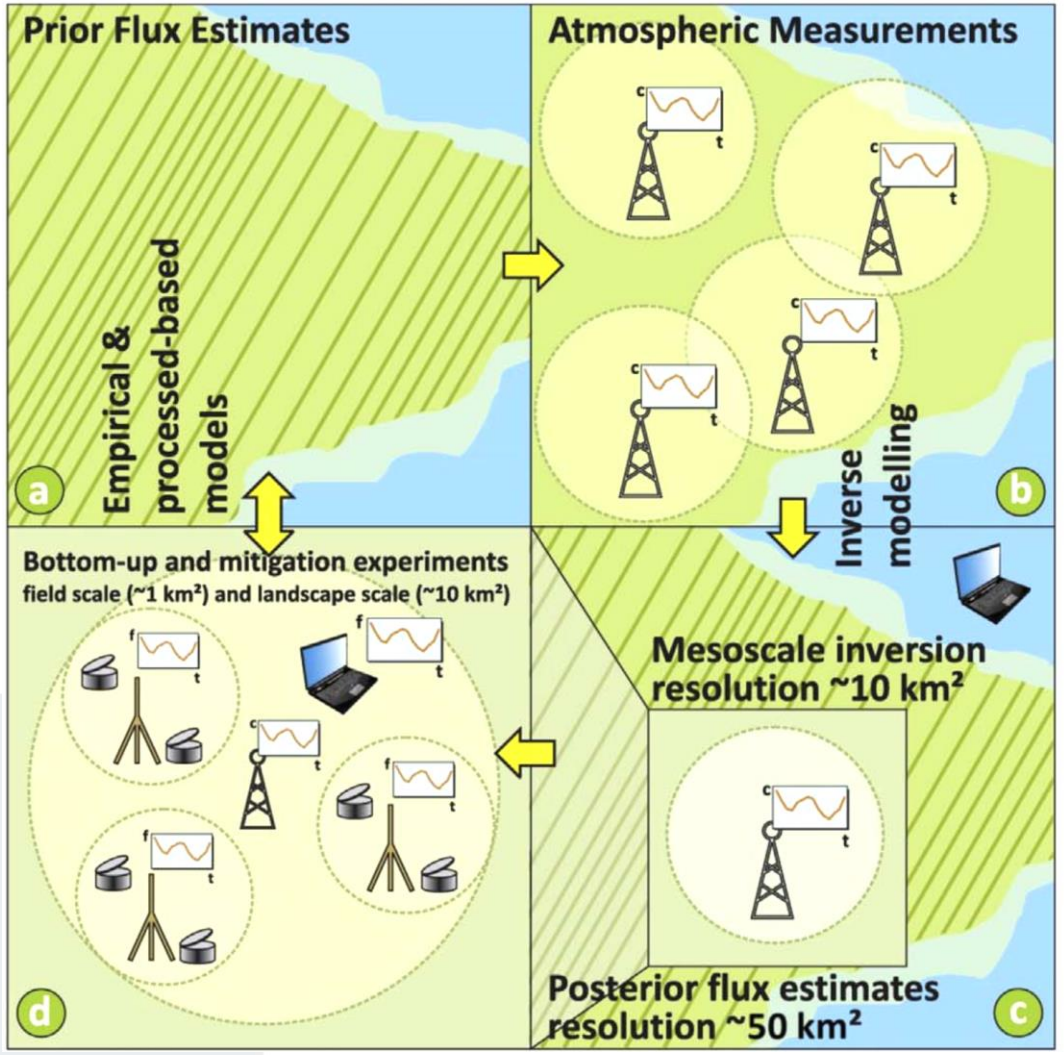
Top-down methods

- Atmospheric GHG concentration obs
  +
  Atmospheric transport models (inverse modelling)
  =
  sensitivity of change in atm GHG concentration to surface fluxes
  whose accuracy depends on:

in situ- data

An ideal GHG emission/sequestration assessment system

Leip *et al.* 2018
Atmospheric Environment

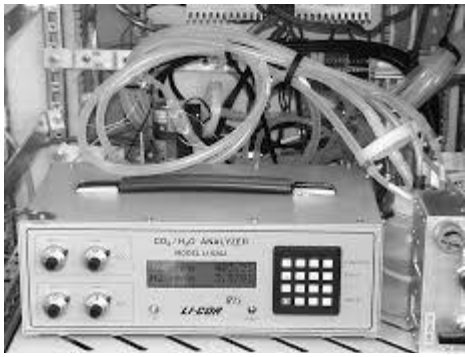


Key:

- Flux chamber
- Eddy covariance tower/site
- Atmospheric measurement site
- Flux
- Timeseries of observation: c = concentration; f = flux
- Flux sensitivity area

What to measure and how?

InfraRed Gas Analyser (IRGA)



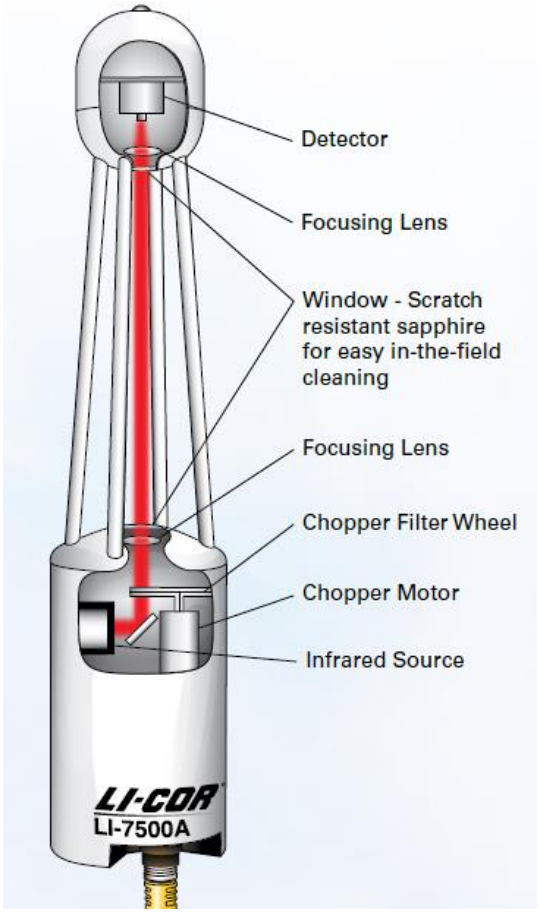
Beer-Lambert Law

$$\frac{I_1}{I_0} = e^{-\alpha l} = e^{-\frac{4\pi k_\lambda}{\lambda} l}$$

Molar density (mmol m^{-3})

$$\chi_i = \frac{n_{Mi} RT}{P}$$

Molar fraction (µmol mol^{-1})

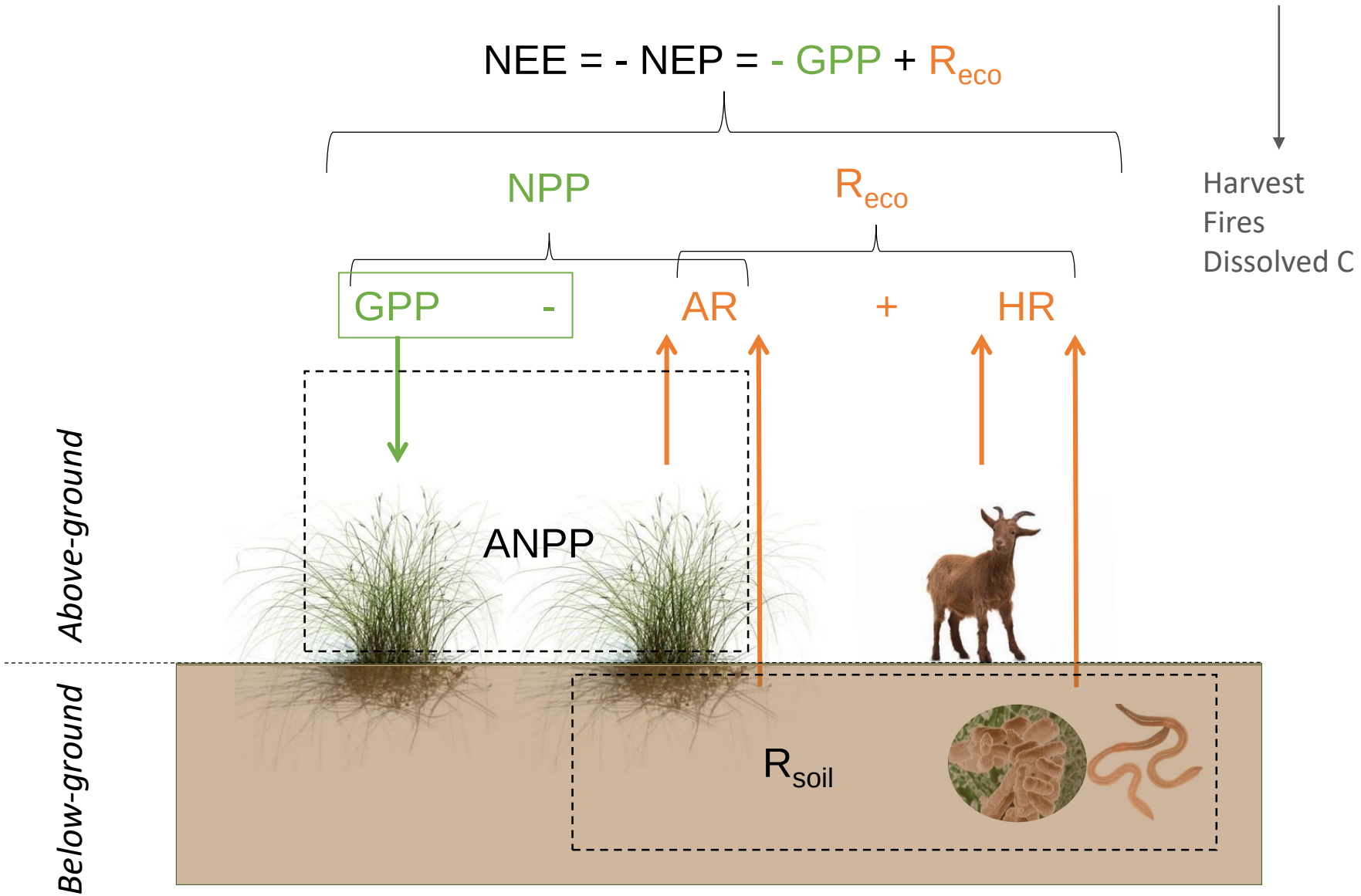


*Alternatively: Gas chromatography, quantum cascade lasers…

Relevant concepts C cycle

Net Biome Productivity

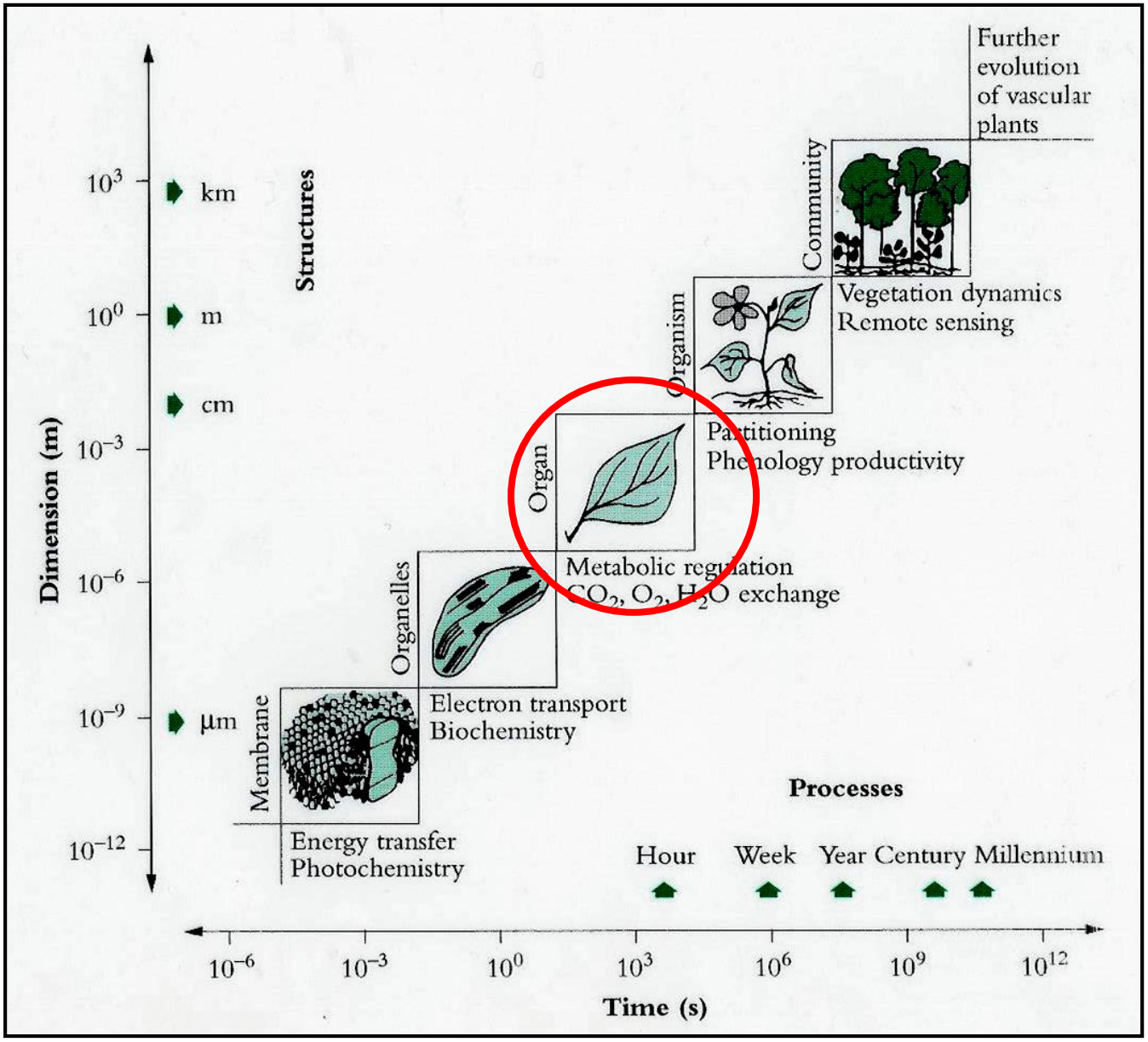
NBP = NEE + lateral C fluxes



Chapin *et al.* 2006 *Ecosystems*

Assessing temporal and spatial dynamics in gas exchange

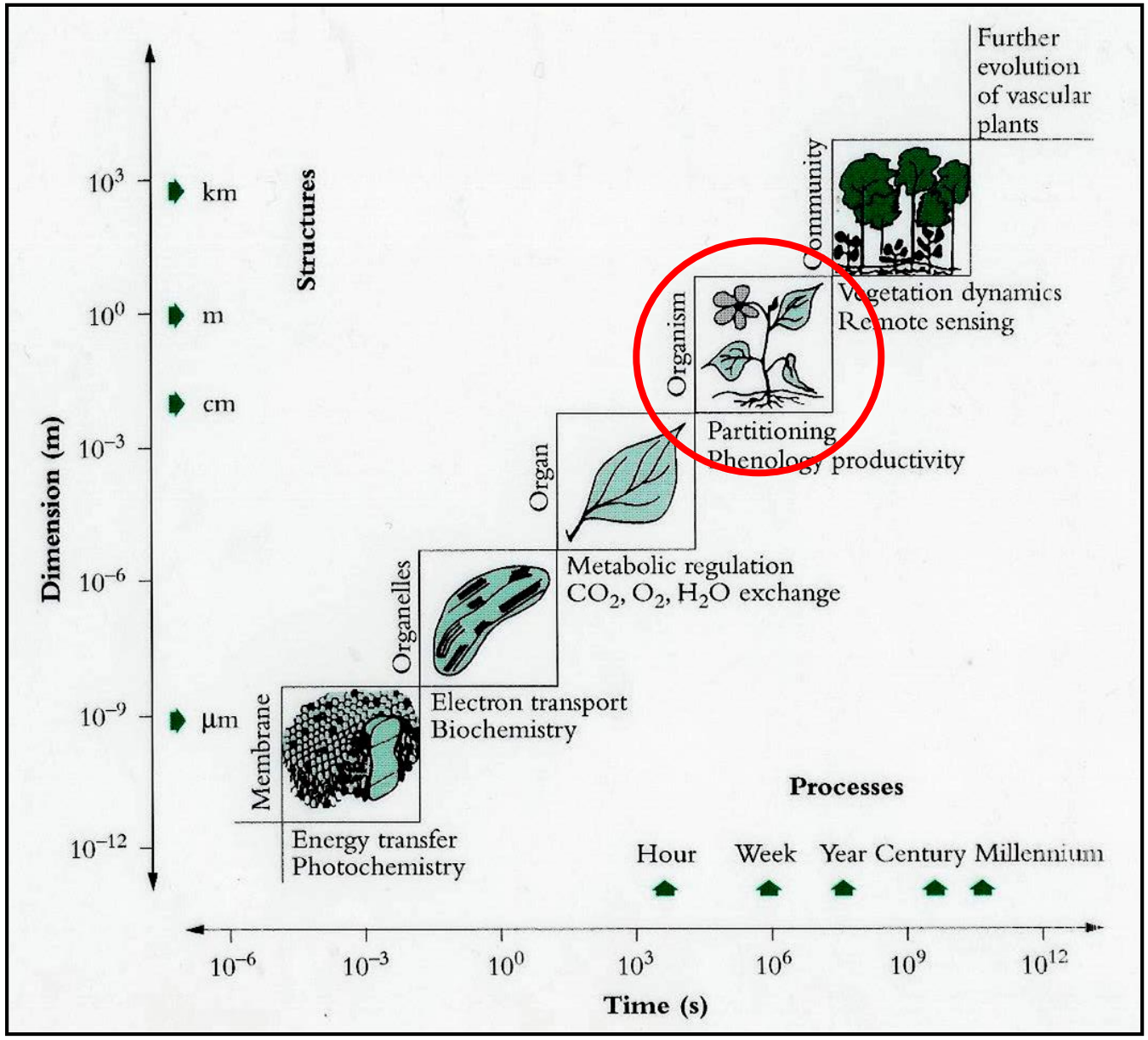
CO_2



Leaf gas exchange sensors (CO_2, H_2O – ANPP & T)

Porometers (H_2O – T)

Assessing temporal and spatial dynamics in gas exchange

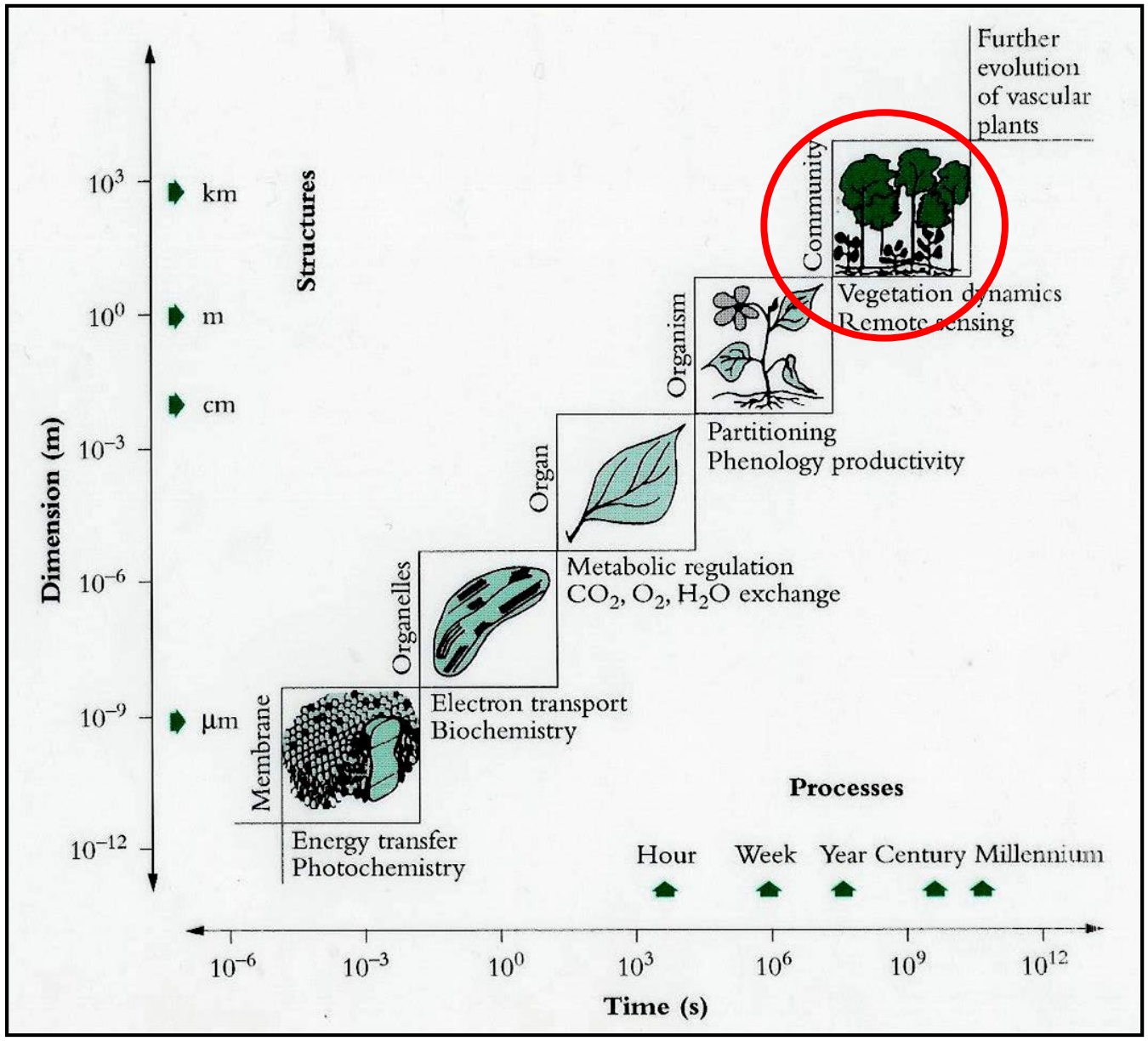


CO_2

Whole-Canopy gas exchange chamber

(CO_2, H_2O – ANPP & T)

Assessing temporal and spatial dynamics in gas exchange



EO - Spectral indices

Ecosystem-atmosphere gas exchange (CO_2, H_2O – NEE & ET)

Assessing temporal and spatial dynamics in gas exchange

Above-ground

Chamber method
(CO_2 , H_2O – NEE & ET plot scale)

Below-ground

R_{soil}

Soil respiration

Chamber method
(CO_2 , H_2O – R_{soil} & E, soil efflux)

Gradient method
(CO_2 , H_2O – R_{soil} & E, soil efflux)

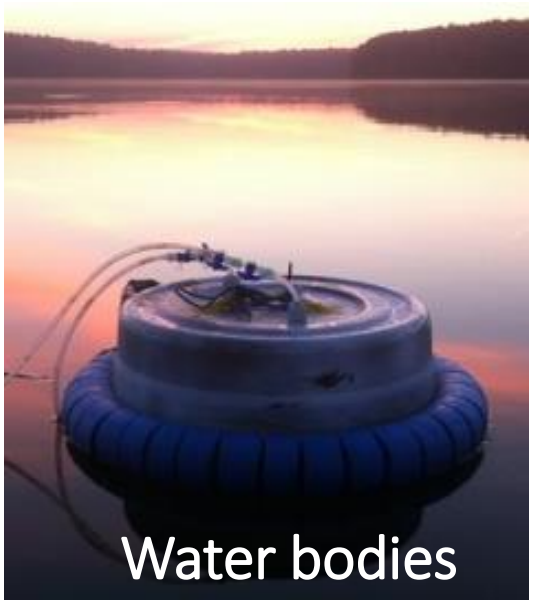
Assessing temporal and spatial dynamics in gas exchange

CH_4

https://eos.org/project-updates/a-new-data-set-to-keep-a-sharper-eye-on-land-air-exchanges

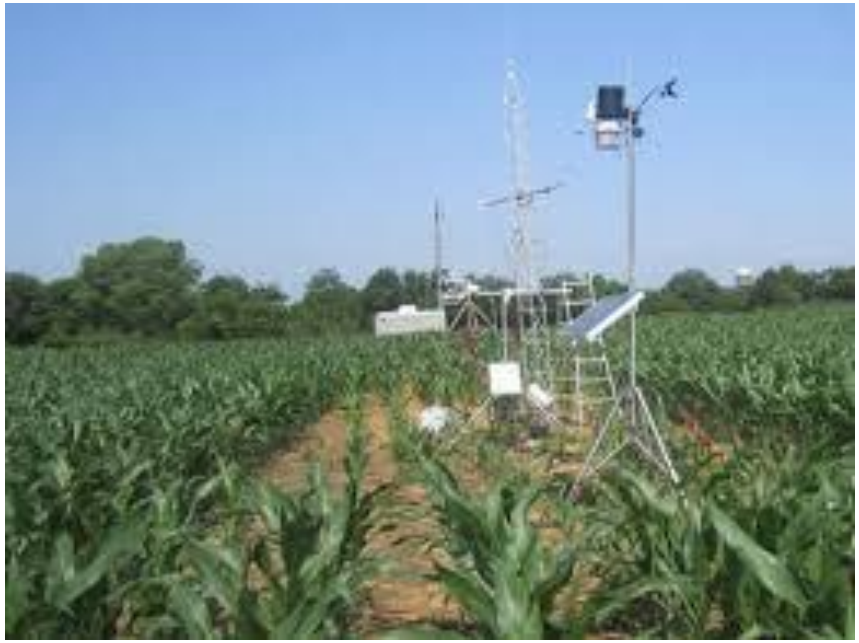
http://dels.nas.edu/resources/static-assets/basc/miscellaneous/basc-methane-mtg-2/9-adviento.pdf

https://www.fondriest.com/news/ultraportable-greenhouse-gas-detectors-enable-new-research-lake-methane-emissions.htm



Assessing temporal and spatial dynamics in gas exchange

N_2O



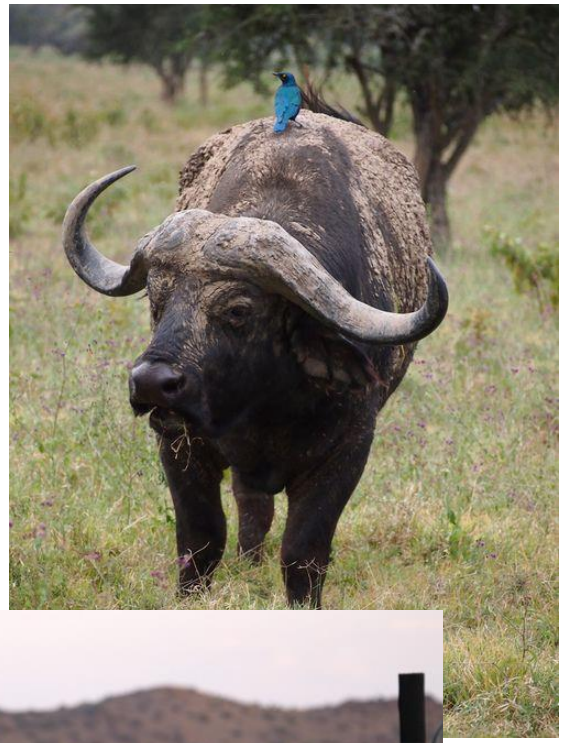
https://www.isws.illinois.edu/docs/default-source/atmospheric-science/eddy-covariance-chamber-measured-greenhouse-gas-emissions.pdf

https://phys.org/news/2014-04-nitrite-significant-role-nitrous-oxide.html

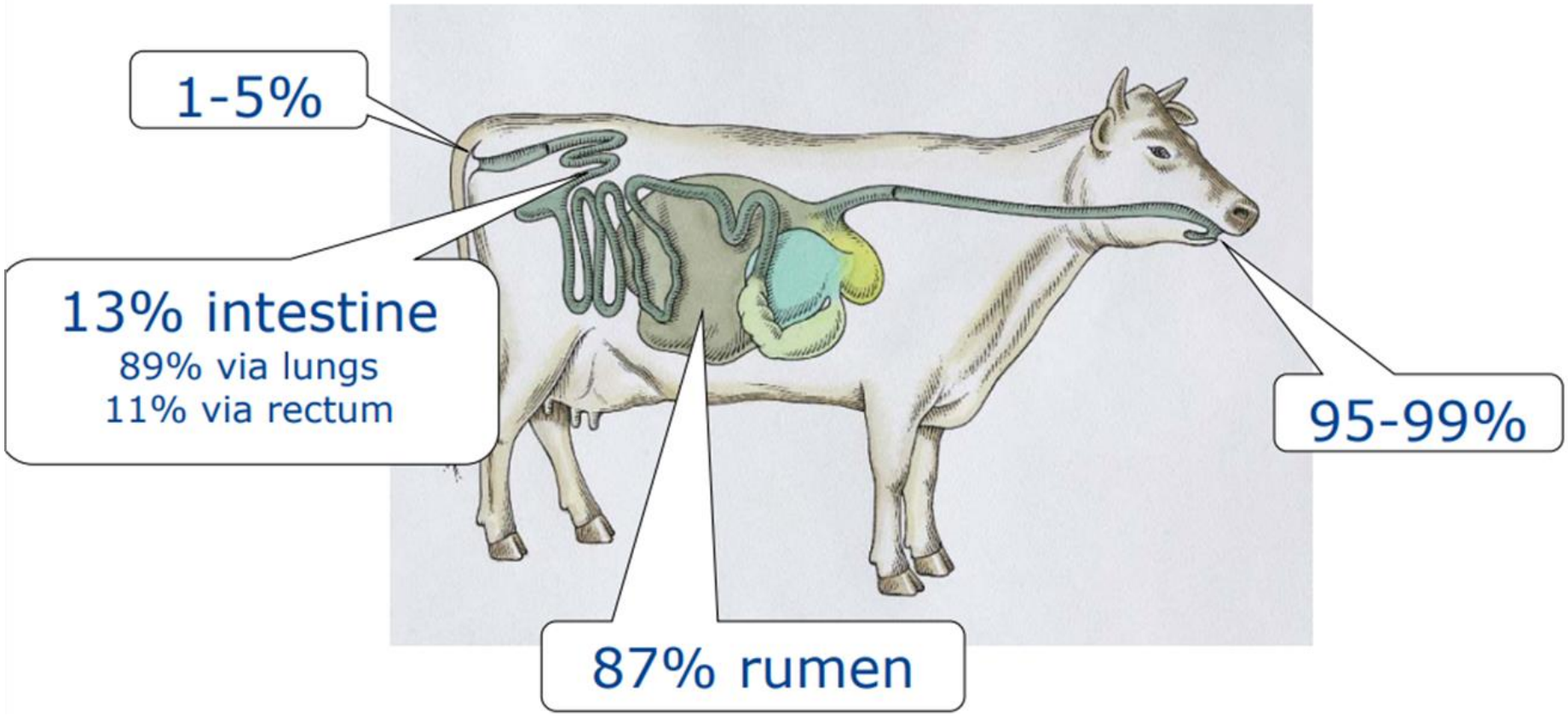
Methodologies used in livestock systems

Methane is produced by ruminants:

- Cattle
- Bovines
- Goats
- Sheep

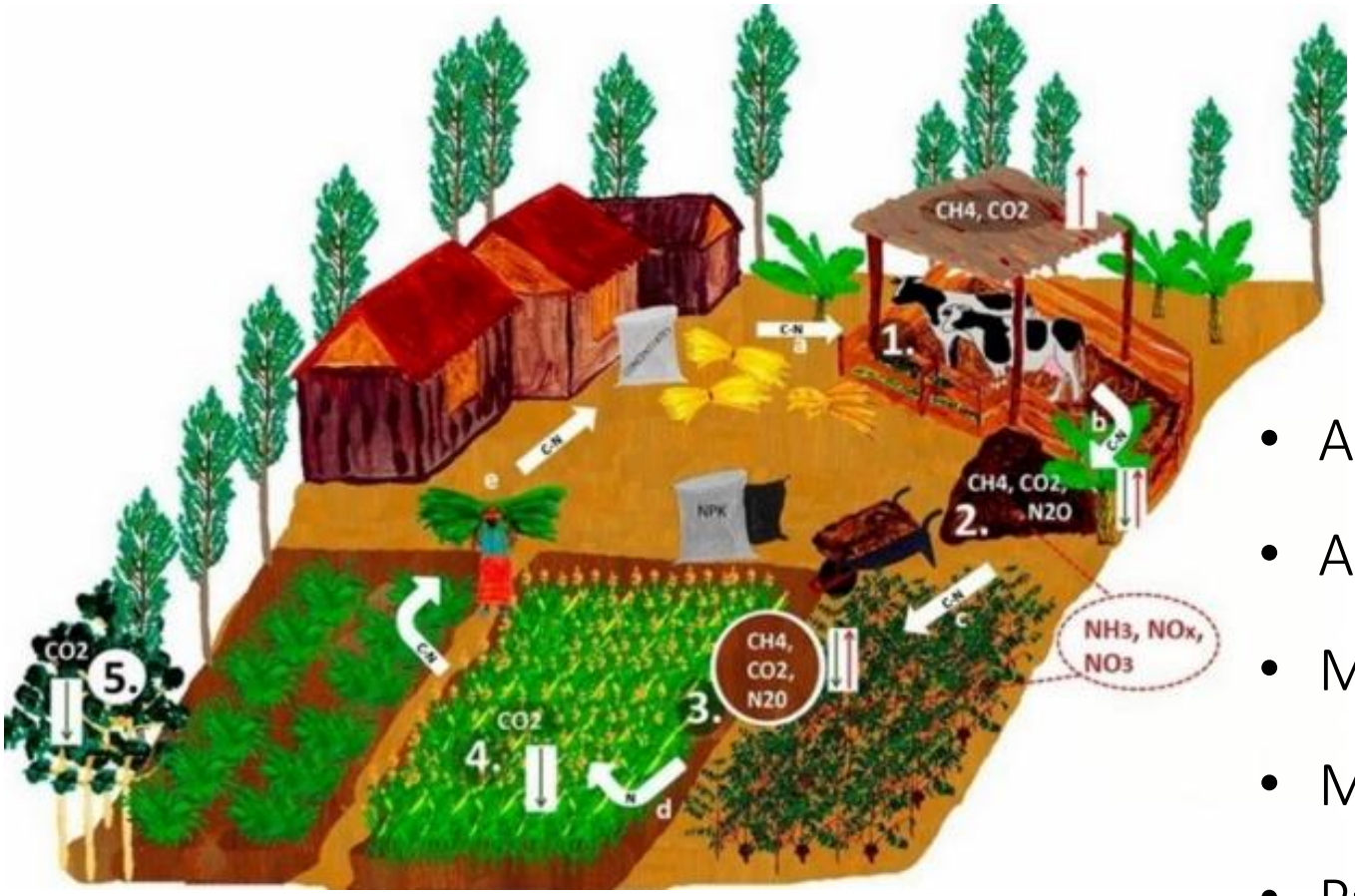


Methodologies used in livestock systems



http://anis.au.dk/fileadmin/DJF/Anis/DAWO_Lecture_methane_March_2017.pdf

Methodologies used in livestock systems



- Animal
- Animal house
- Manure storage
- Manure spreading
- Pasture/grazing

Ortiz-Gonzalo *et al.* 2017 *Agriculture, Ecosystems & Environment*

70% agricultural GHG emissions in Africa in 2010

(FAOSTAT, 2015)

Methodologies used in livestock systems

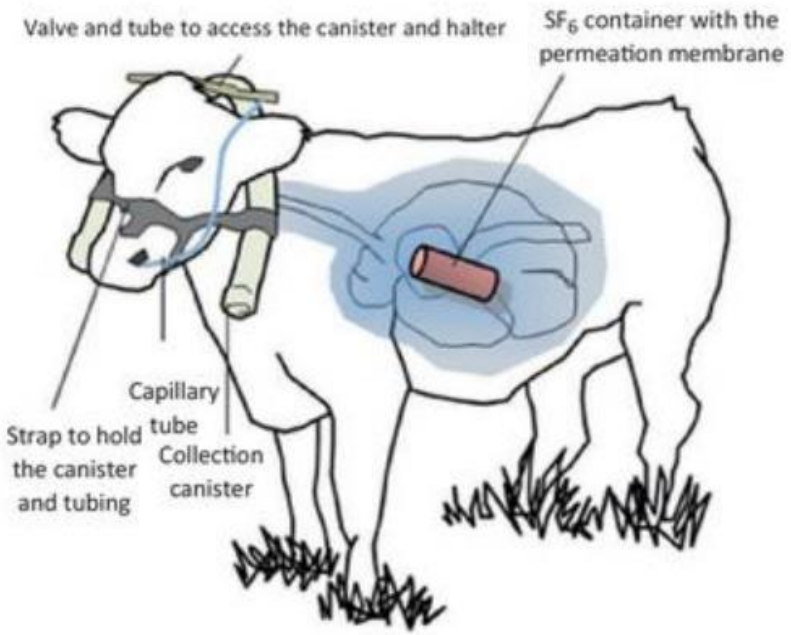
- Mass balance (animal, animal house, manure)
- Measuring emissions at the source (animal, animal house, manure storage, manure spreading, grazing)
- Micrometeorological methods (manure storage, manure spreading , grazing)

Methodologies used in livestock systems

- Mass balance (animal, animal house, manure)

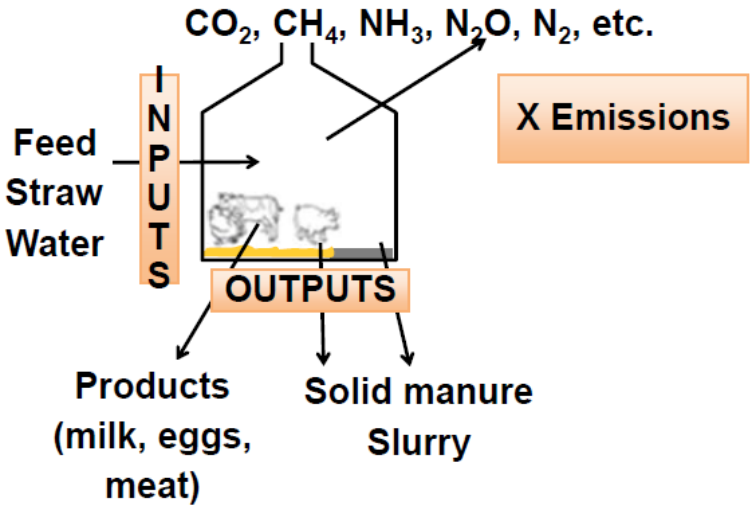
Tracer gas SF6

$$ER\ (_{SF6})/ER(_{CH4})=\Delta C_{SF6}/\ \Delta\ C_{CH4}$$



Hill *et al.* 2015 *Trends in Biotechnology*

N & C emissions = f(Δstocks)

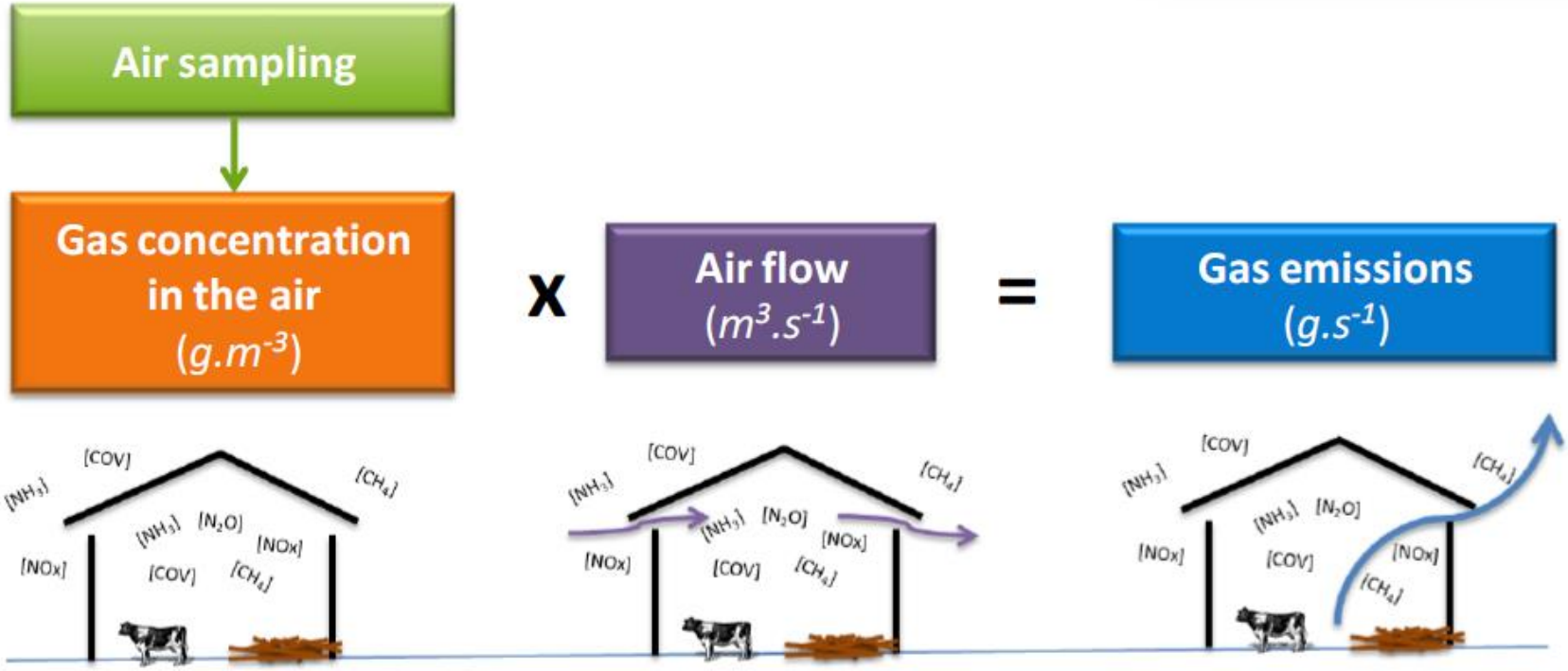


X_INPUTS-X_OUTPUTS=X_EMISSIONS
X is for N (Nitrogen) or C (Carbon) or W (Water)

Author: Melynda Hassouna

Methodologies used in livestock systems

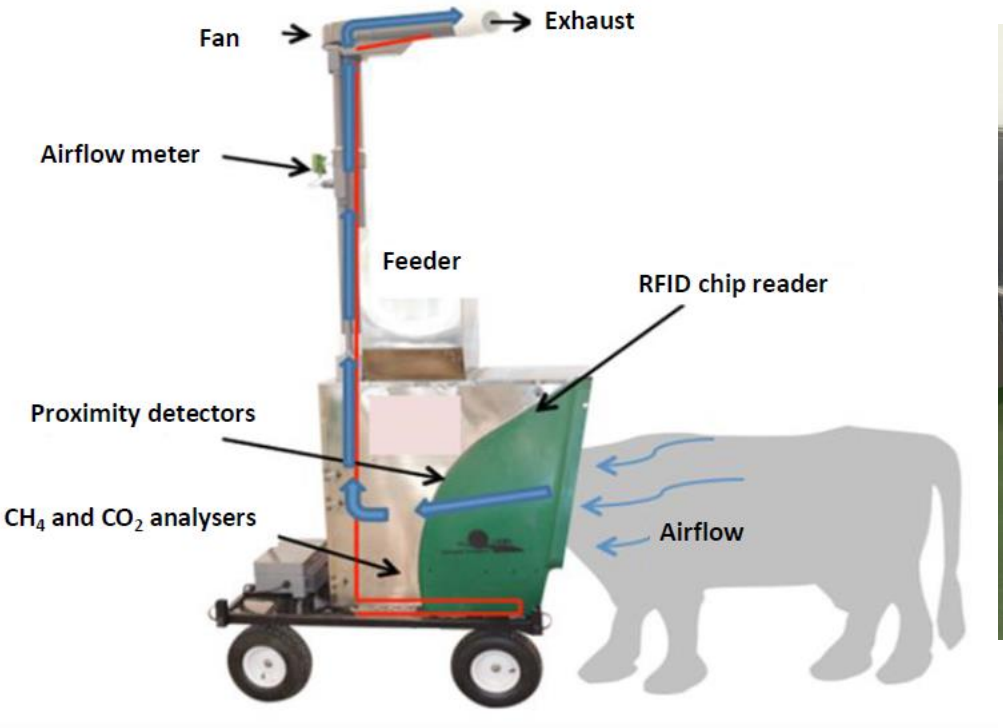
- Measuring emissions at the source (animal, animal house, manure storage, manure spreading, grazing)



Methodologies used in livestock systems

- Measuring emissions at the source (animal, animal house, manure storage, manure spreading, grazing)

Greenfeed system



Respirometry and CH_4 chambers

Partially open enclosures

Methodologies used in livestock systems

- Micrometeorological approaches (manure storage, manure spreading , grazing)

Sun et al. 2015 http://dx.doi.org/10.1016/j.agrformet.2015.06.007

Methodological harmonization within research networks

Research Network

- ✓ Group of researchers that perform common activities related to a specific research field
- ✓ Focused on answering one or more research questions
- ✓ Functioning depends on the individual budget of each network member

Research Infrastructure

- ✓ Facilities and resources with science or research in its core
- ✓ Its time horizon is longer than a research project
- ✓ Offers services to users outside the infrastructure
- ✓ Single-sited or distributed (organised network of resources)

General benefits

- The reduction of uncertainty in global & regional GHG budgets
- Better understanding of driving processes
- Validate satellite and modelling products

- Track anthropogenic GHG emissions
- Test mitigation and adaptation strategies

Standardization vs Harmonization

Standardization

a top-down approach where obligatory instructions related to specific aspects of observational methodologies (e.g. down to sensor model) and/or data processing approaches are set in order to assure interoperability within a given research network or RI

Very specific instructions are set beforehand and must be followed

Harmonization

a more flexible top-down approach that is result-oriented, hence, no fixed methodological instructions are set but quality requirements (e.g. temporal resolution) are enforced in order to reach an appropriate level of interoperability

Resulting data must accomplish some requirements

no matter the means to get it

Standardization vs Harmonization

Standardization

- Control of the whole process to produce the environmental data
- Low coordination effort once the instructions are defined
- Interoperability will be 100% assured

- High financial costs for equipment and human resources
- Requires long-term stability of financial support

Harmonization

- Lower financial and equipment costs
- More inclusive
- Allows higher uncertainty in regards of financial support

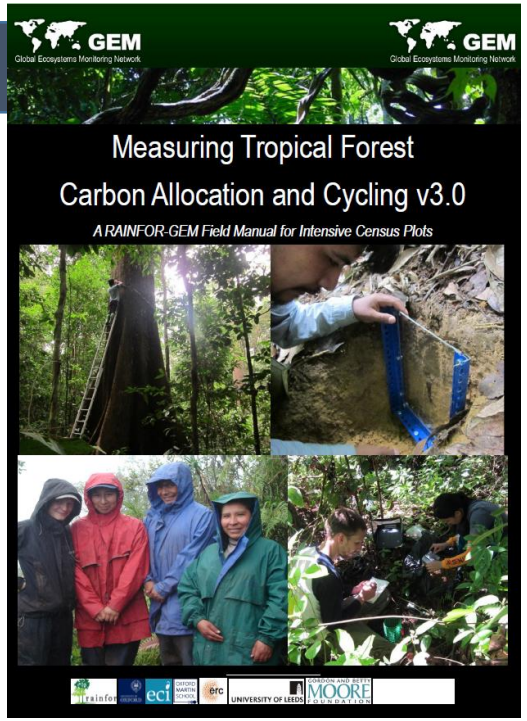
- Coordination effort is continuous and greater
- Community of practice is needed to assure interoperability
- Possible data gaps

Examples of methodological protocols

AfriTRON
African Tropical Rainforests Observation Network

Todd S. Rosenstock · Mariana C. Rufino
Klaus Butterbach-Bahl · Eva Wollenberg
Meryl Richards *Editors*

Methods for Measuring Greenhouse Gas Balances and Evaluating Mitigation Options in Smallholder Agriculture



RESEARCH PROGRAM ON
Climate Change, Agriculture and Food Security

GLOBAL RESEARCH ALLIANCE
ON AGRICULTURAL GREENHOUSE GASES

Guidelines for Measuring CH_4 and N_2O Emissions from Rice Paddies by a Manually Operated Closed Chamber Method

ICOS | Ecosystem Thematic Centre

INSTRUCTIONS FOR

ANCILLARY VEGETATION MEASUREMENTS
in
FOREST

GREEN AREA INDEX
ABOVEGROUND BIOMASS
LITTER BIOMASS

Vital Signs Protocol

Farm Field Soil Sampling and Processing

Version 1.0

March 2014

Take-home messages

- None measurement is useless, one measurement complement the other when studying a natural or managed ecosystem
- Method selection
  - ✓available financial and human resources
  - ✓targeted system
- It is important to produce data that is comparable to what others measure, usable for several purposes and publicly available
- Currently, there are many initiatives trying to harmonize or standardize environmental monitoring worldwide

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Questions?

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