ChinaFlux 第十七次通量观测理论与技术培训			
Date (Beijing Time)		**Speaker**	**Topic**
2022-08-19	08:30-09:00	ChinaFlux Director	Openning ceremony
2022-08-19	09:00 - 09:50	Liukang Xu	Techniques commonly used for quantifying GHG (CO_2, CH_4 and N_2O) and energy fluxes at different spatial scale
	09:50 - 10:50	Liukang Xu	Ecosystem scale gas exchange measurement: the Eddy Covariance method
	10:50 - 11:00	Break	
	11:00 - 12:00	Jiahong LI	Eddy covariance application and experimental design
2022-18-20	09:00 - 09:50	Dave Johnson	The need of biomet information to intepret the EC flux
	09:50 - 10:50	Jiahong Li	EC data processing theory and steps
	10:50 - 11:00	Break	
	11:00 - 12:00	Dave Johnson	Supplementary measurements to EC; soil GHG flux, leaf-level photosynthesis, LAI etc.

Techniques Commonly Used in Ecology and Carbon Cycle Research for Quantifying GHG and Energy Fluxes

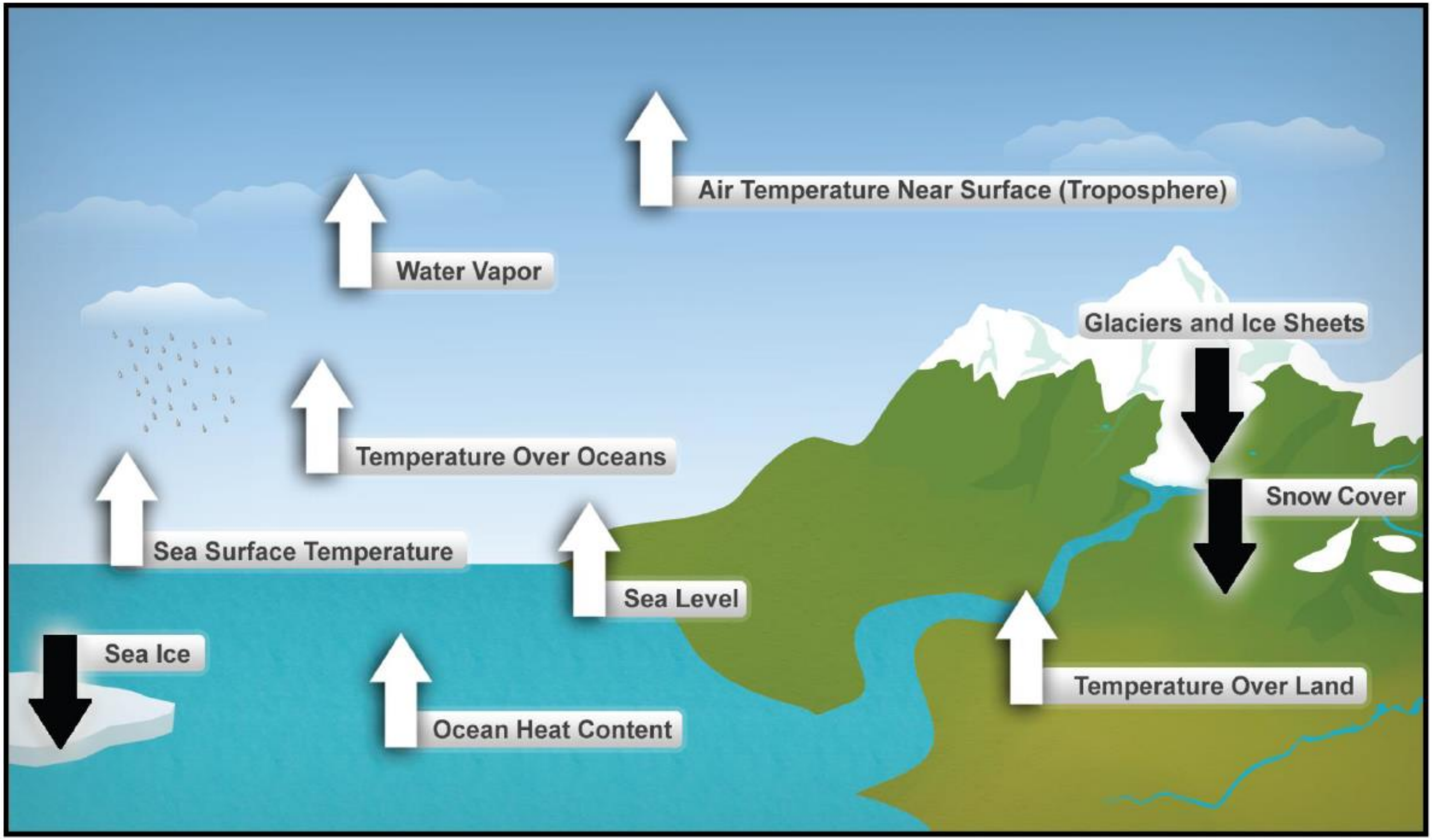
Liukang Xu, 2022 08 18

Discussion topics

1. Climate change & carbon cycle research

2. Techniques commonly used for studying GHG gas and energy fluxes and their theories
    a. Leaf level (stomatal conductance and gas exchange)
    b. Soil surface
    c. Canopy level

Evidences of global warming and climate change



Evidences of global warming: Glacier retreat

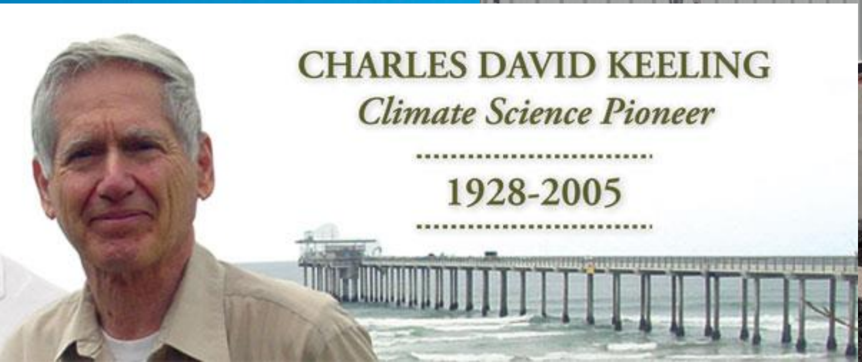
Muir and Riggs Glaciers, Alaska. August 13, 1941; August 4, 1950; and August 31, 2004.

Credits: 1941 and 1950 photographs by William O. Field, NSIDC and Glacier Bay National Park and Preserve Archive. 2004 photograph by Bruce F. Molnia, USGS.

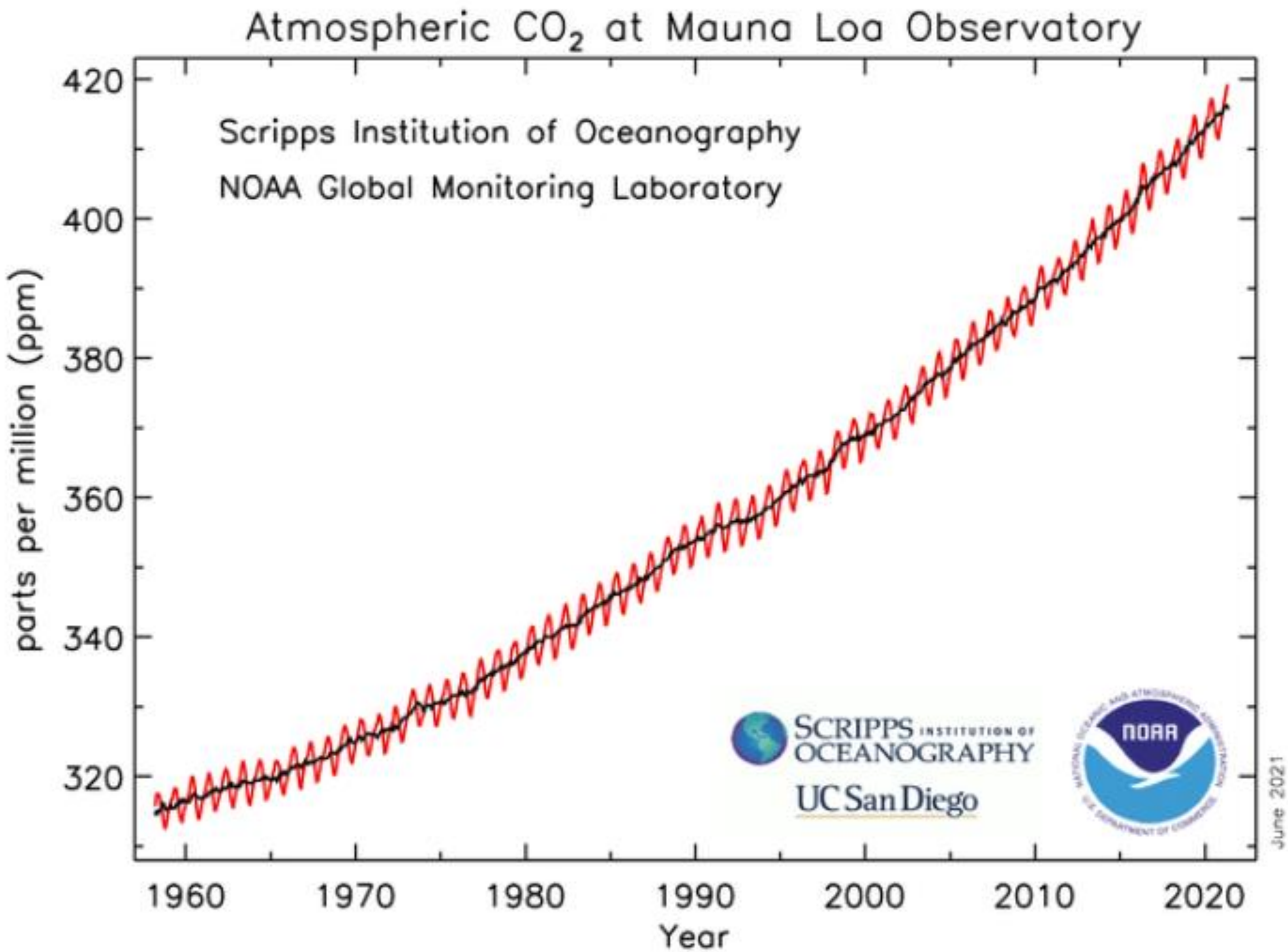

Mauna
Loa


Dedication June 28, 1956

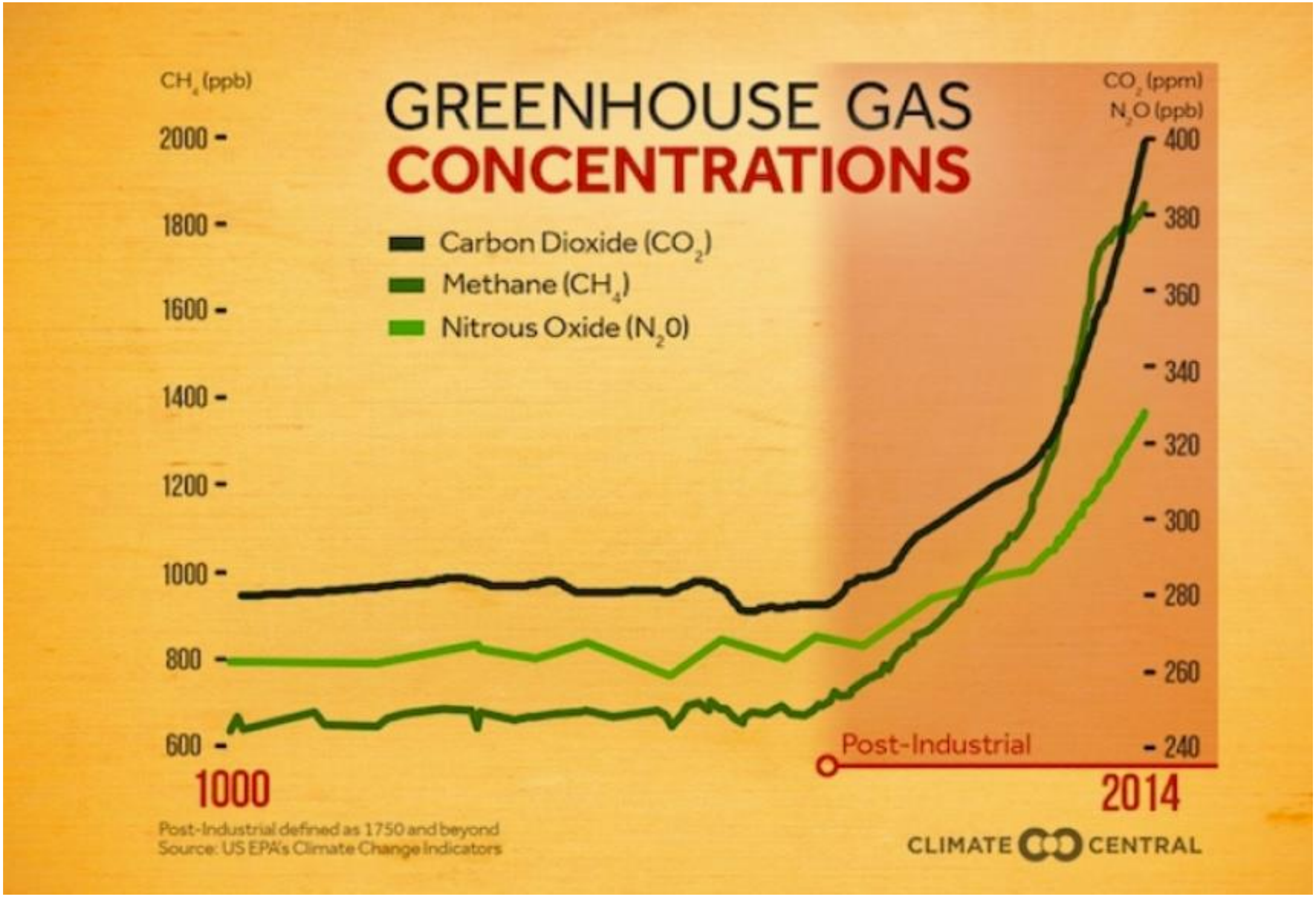

MAUNA LOA
OBSERVATORY


CHARLES DAVID KEELING
Climate Science Pioneer
1928-2005

Significance:



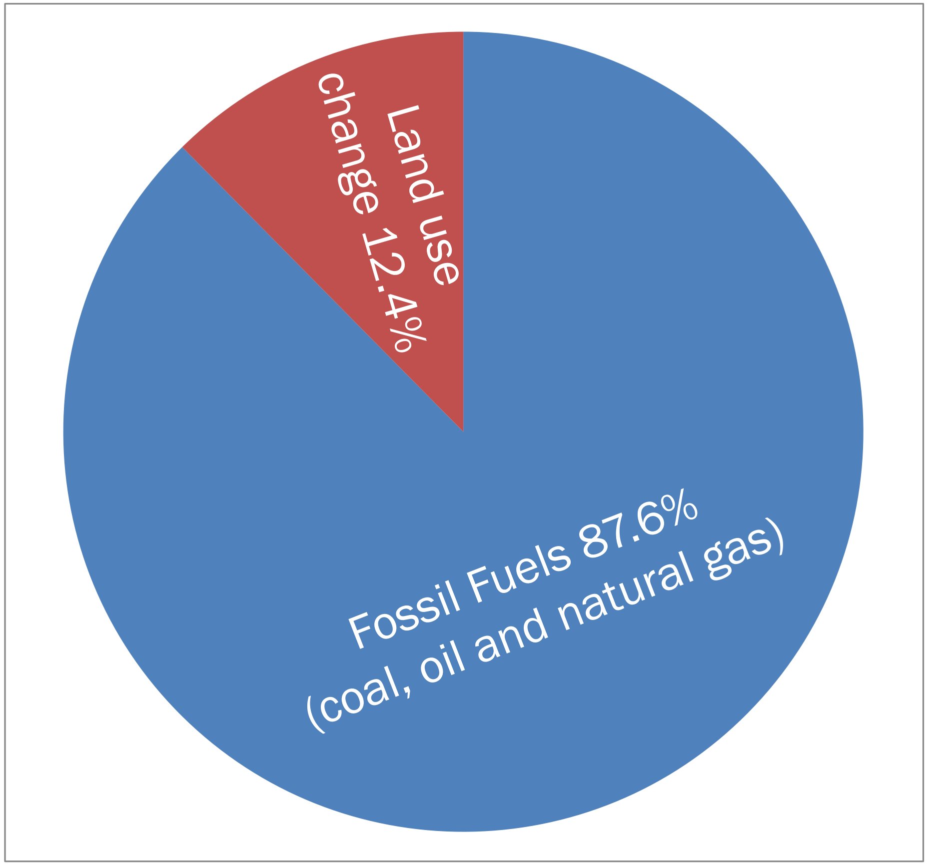
Significance:



Significance

Global CO_2 Sources

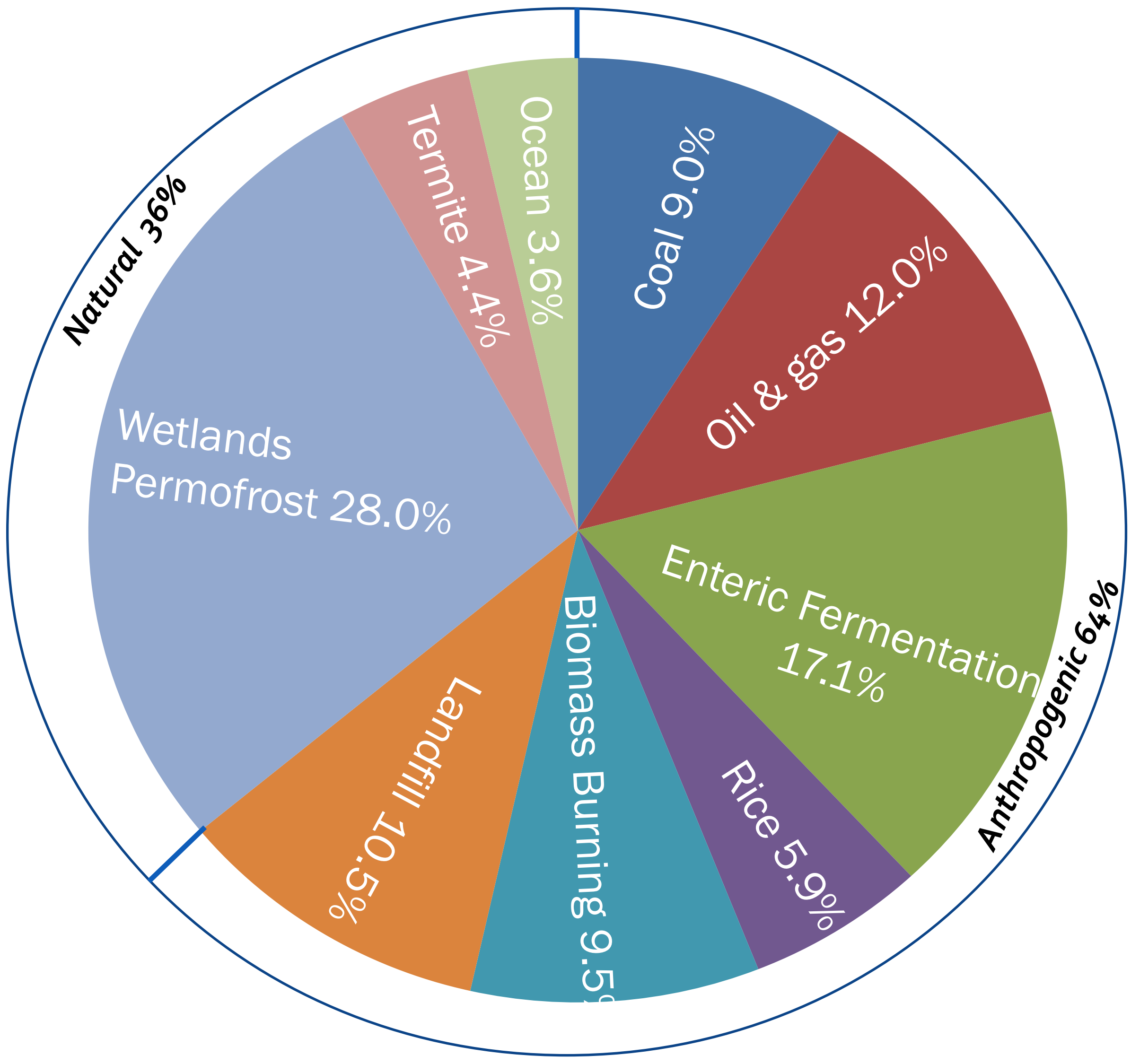
100% anthropogenic



Quere et al., 2014. Earth System Science Data Discussion

Significance

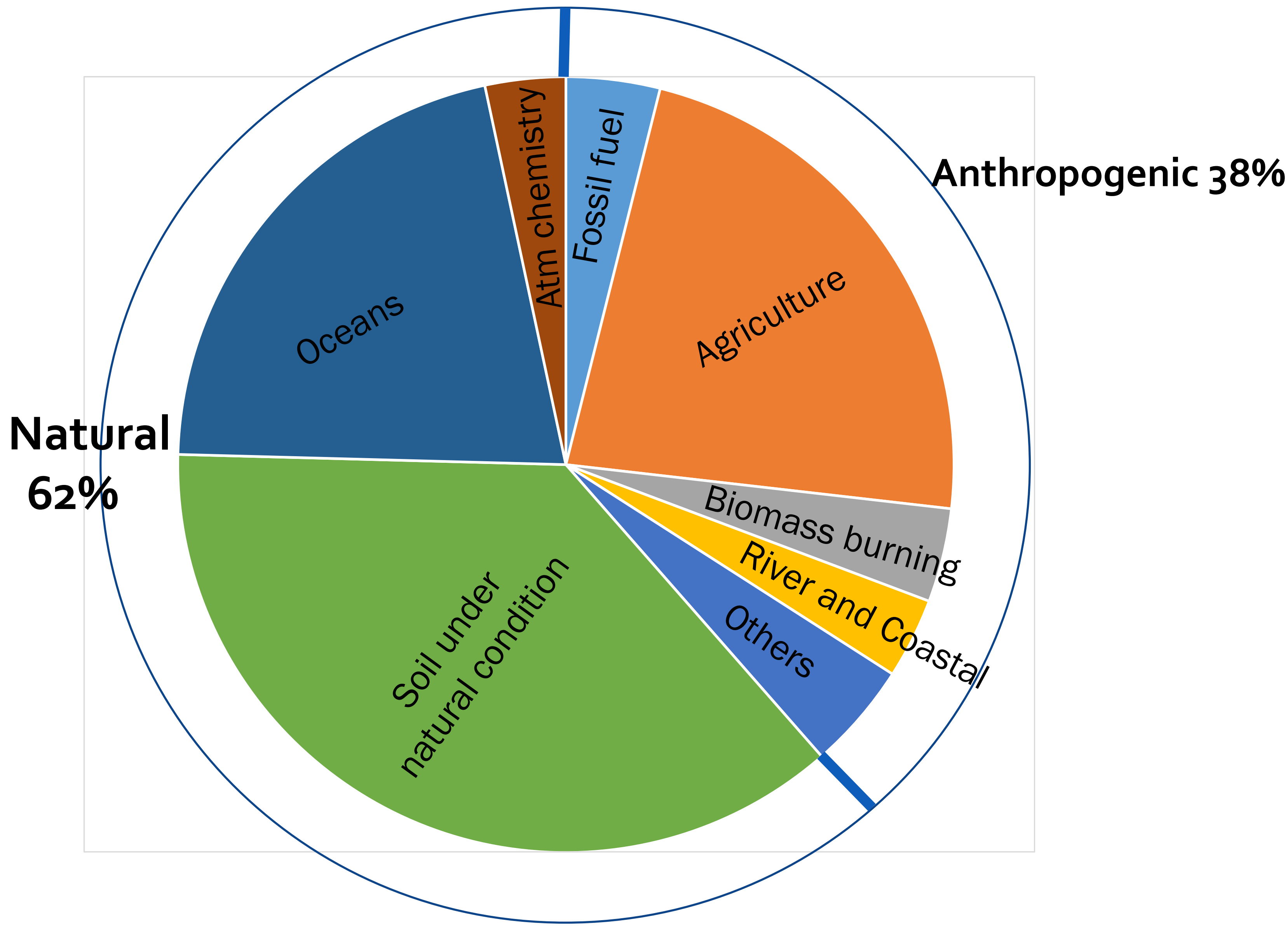
Global CH_4 Sources



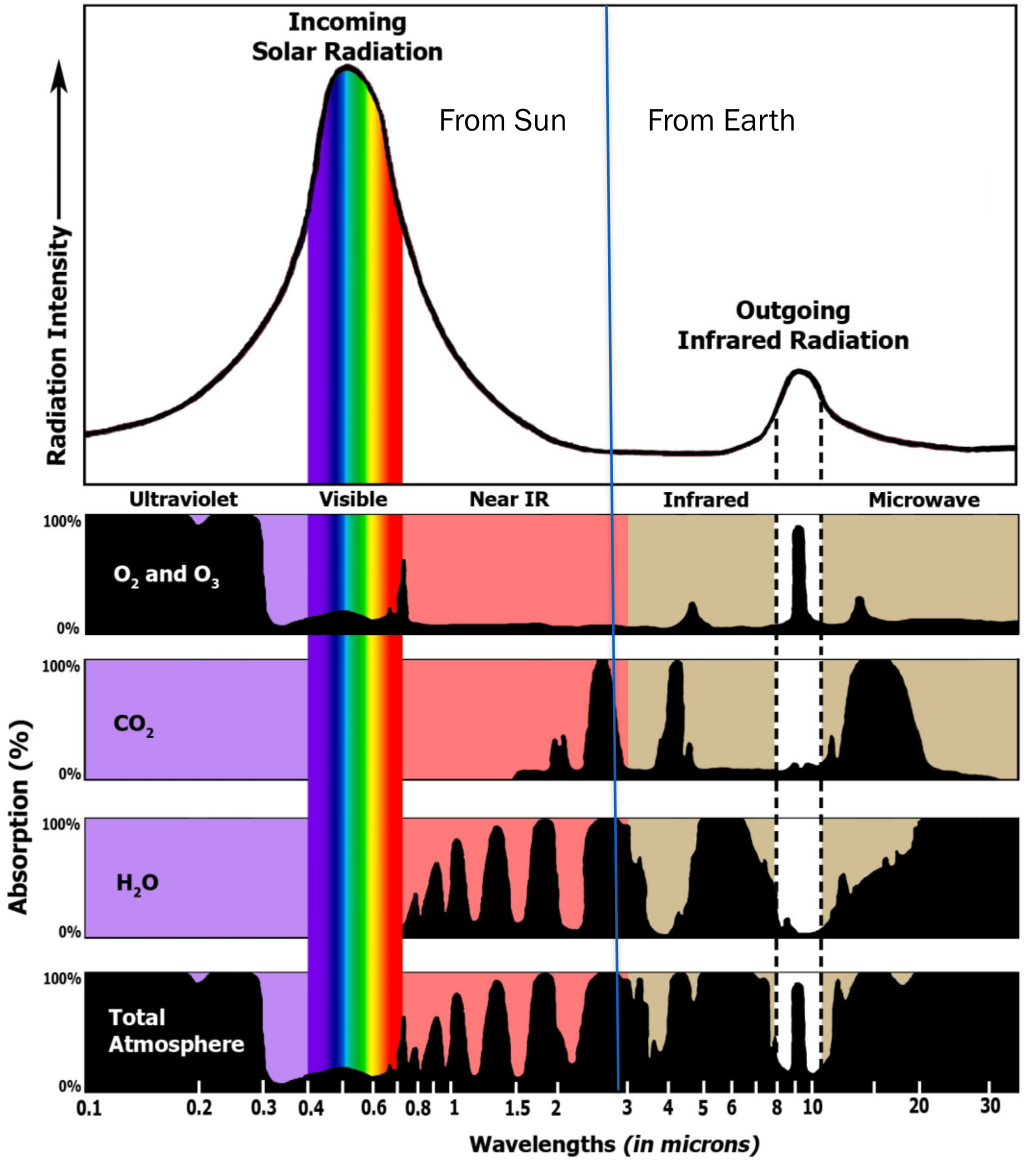
Dlugokencky et al., 2012. Philosophical Transactions of the Royal Society A

Significance

Global N_2O Sources



Global energy balance: Greenhouse effect

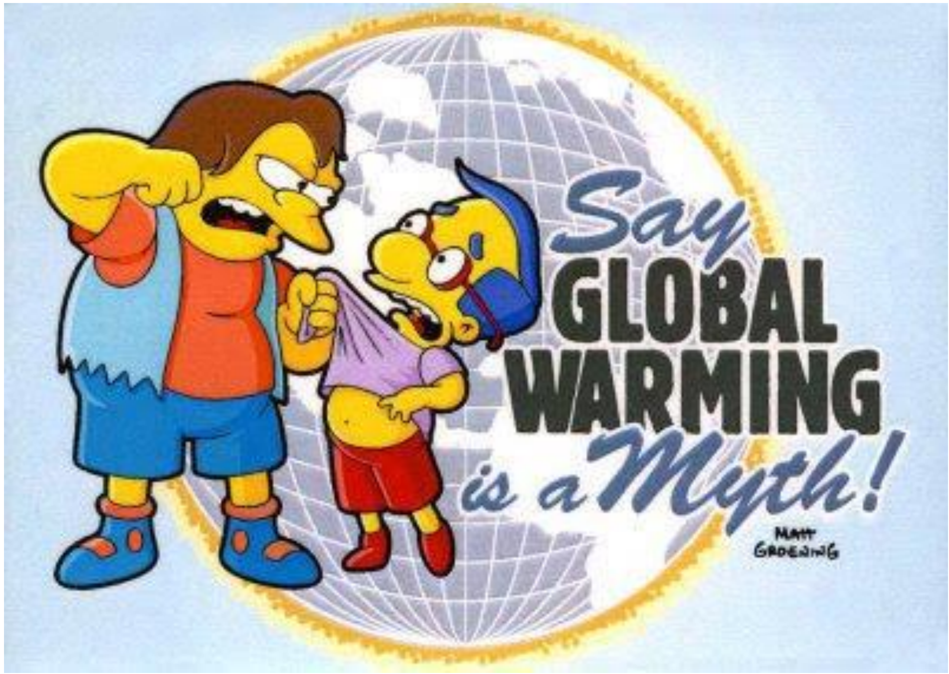


Major Greenhouse Gases

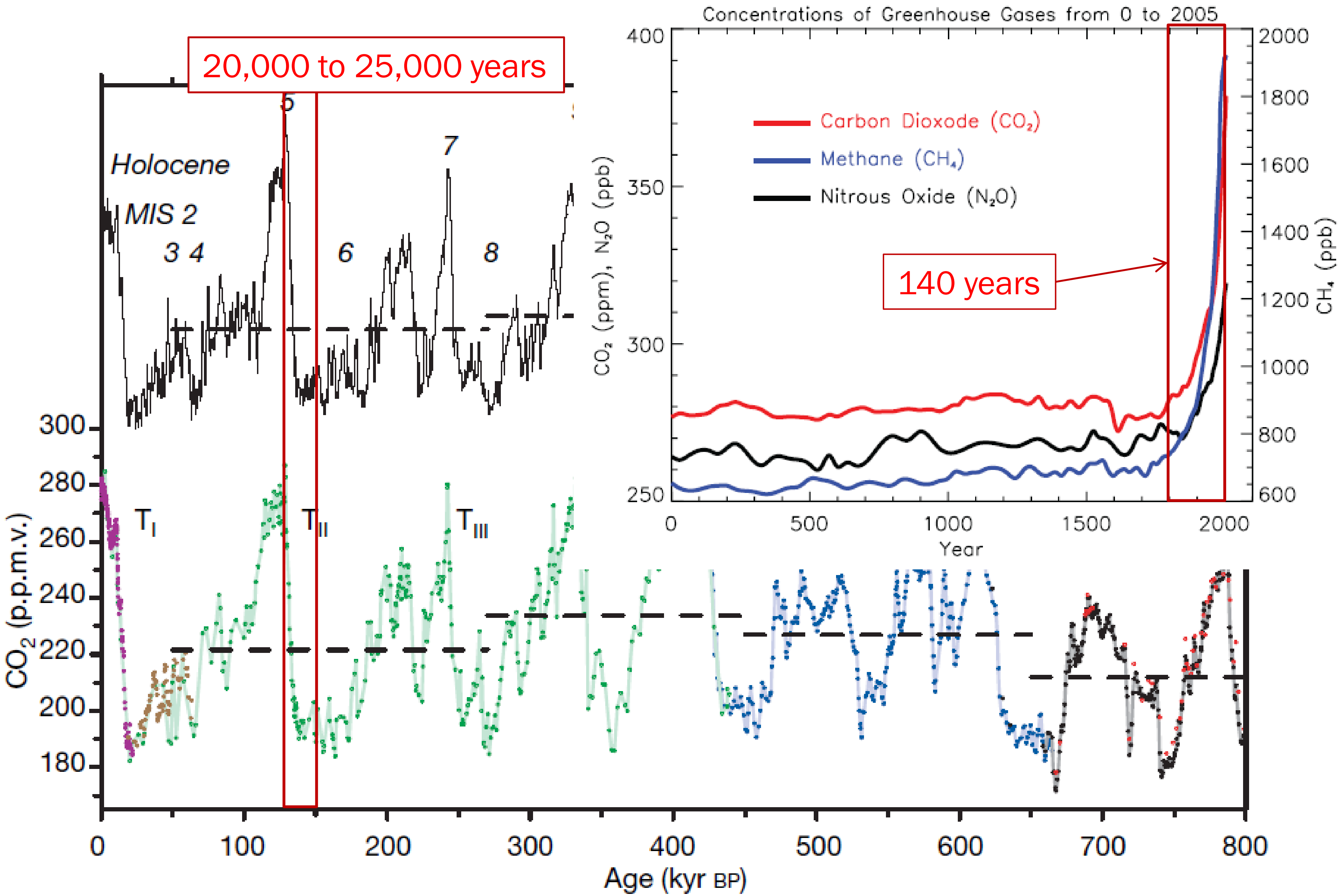
Greenhouse Gas	Current Atmospheric Concentration	Atmospheric Lifetime (year)	Global Warming Potential	Radiative Forcing ($W\ m^{-2}$)
CO_2	405 ppm	50-200	1	1.66
CH_4	1852 ppb	12±3	21	0.48
N_2O	328 ppb	120	310	0.16

At 2018 AGU

Is global warming a hoax ?

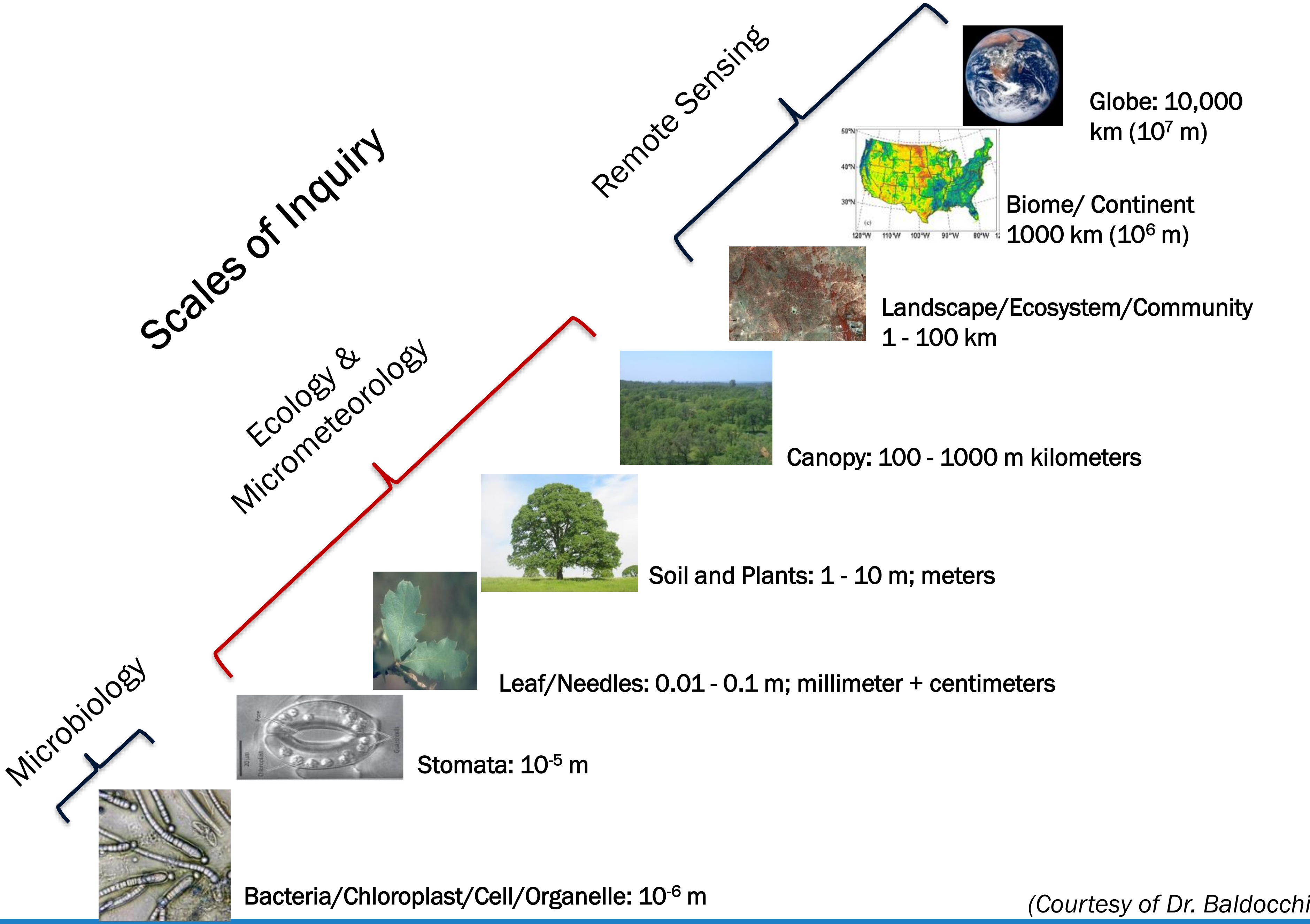


Is the global warming due to human influence or natural variation?



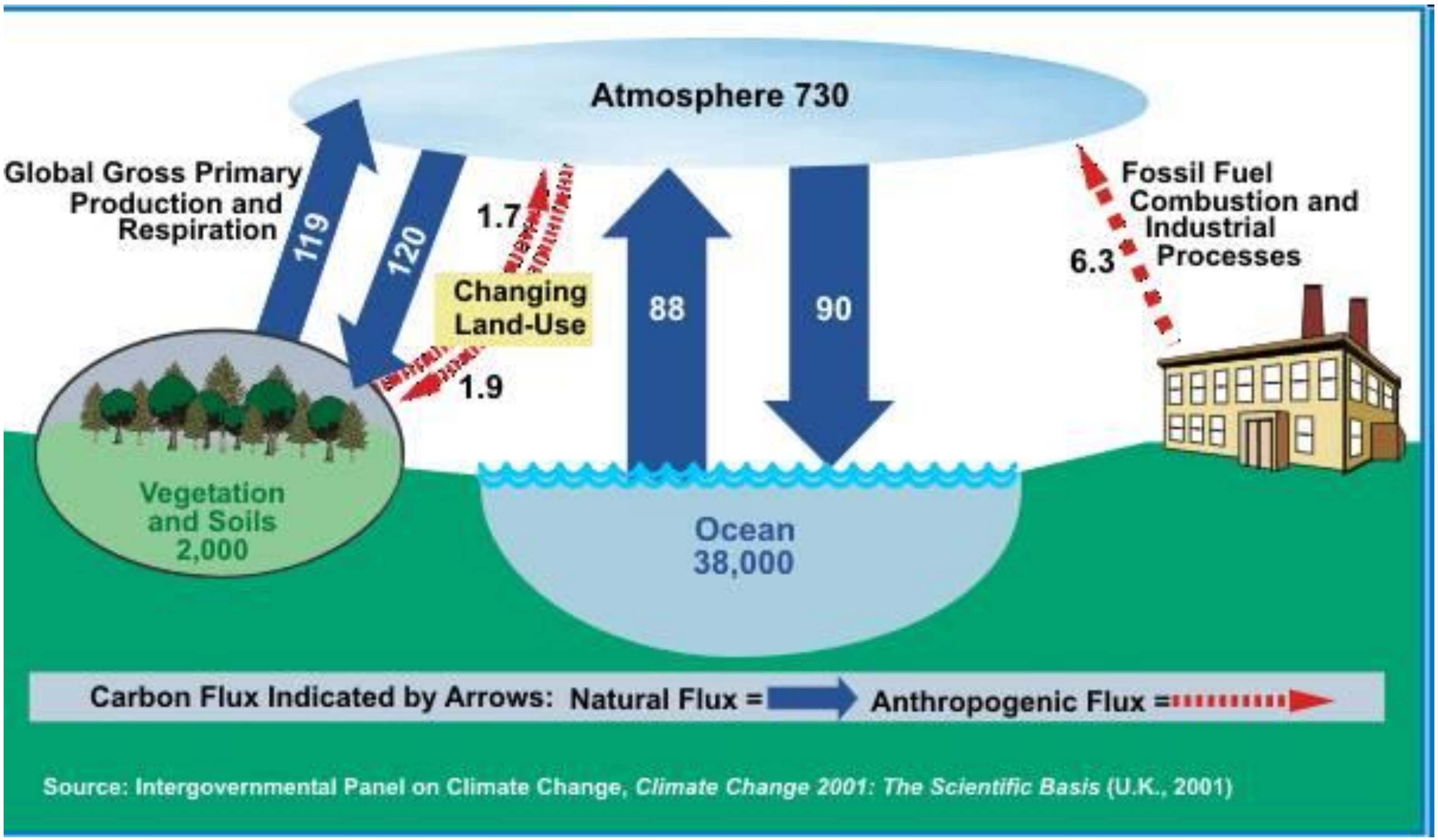
Lüthi et al., 2008. Nature. 453:379-382.

Scales of Inquiry



(Courtesy of Dr. Baldocchi)

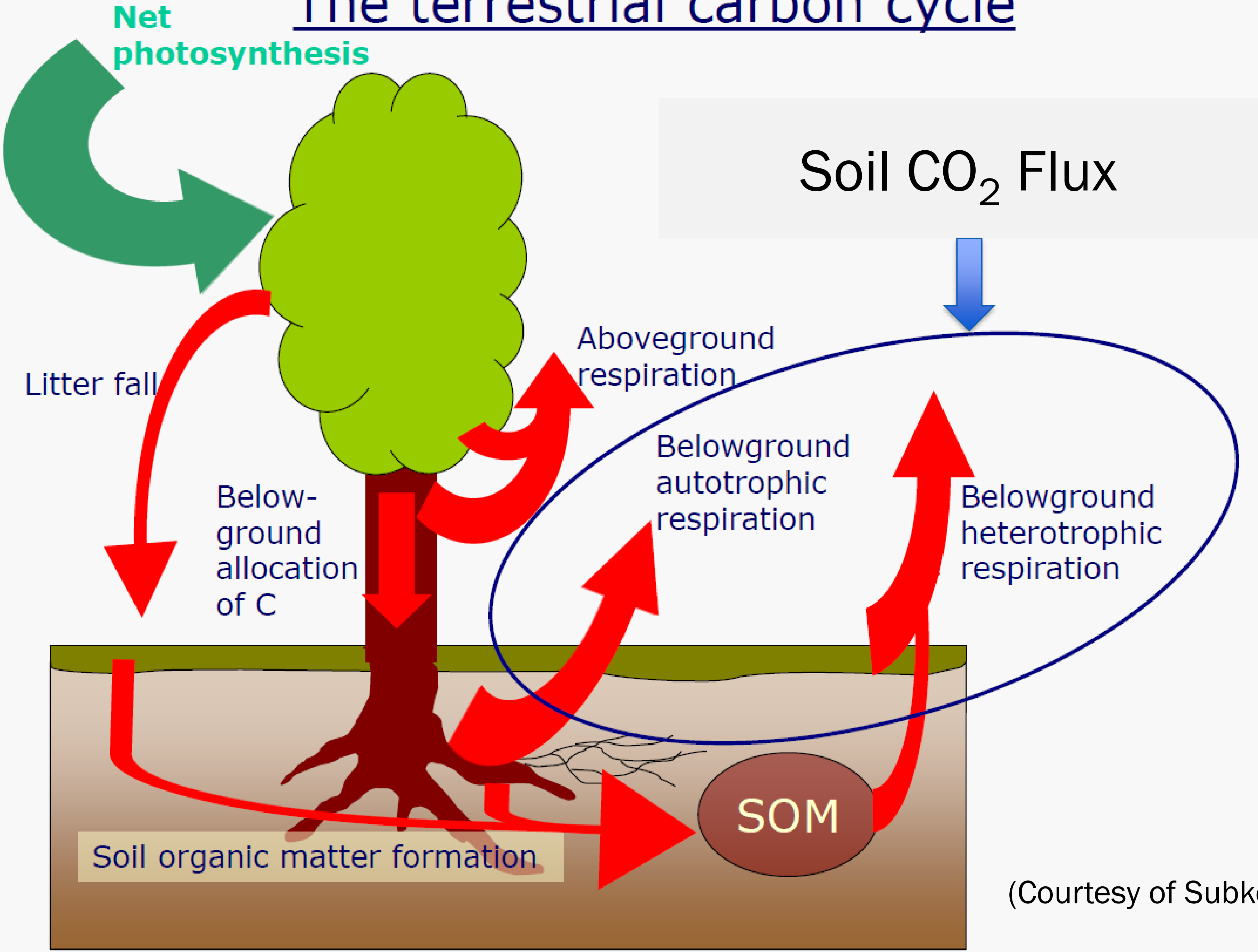
Global Carbon Cycle



Carbon cycle related research topics

1. What are the sources, sinks of CO_2, CH_4, N_2O?
2. Factors that regulate these source and sink strength
3. Atmospheric CO_2, CH_4, N_2O trend
4. What kind of impact on climate and ecosystem
5. Research approach
   - Atmospheric background, like Global Atmosphere Watch of WMO
   - Remote sensing, large scale modeling
   - Ecosystem level study
6. Mitigation strategies

The terrestrial carbon cycle



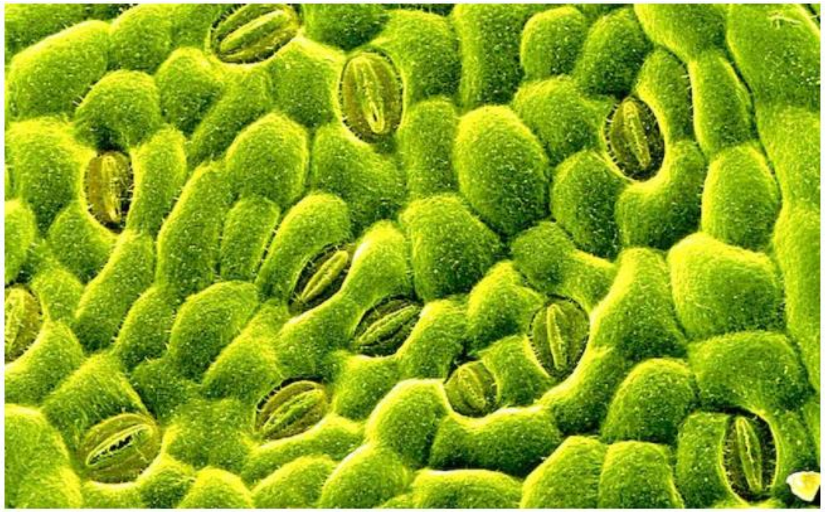
(Courtesy of Subke)

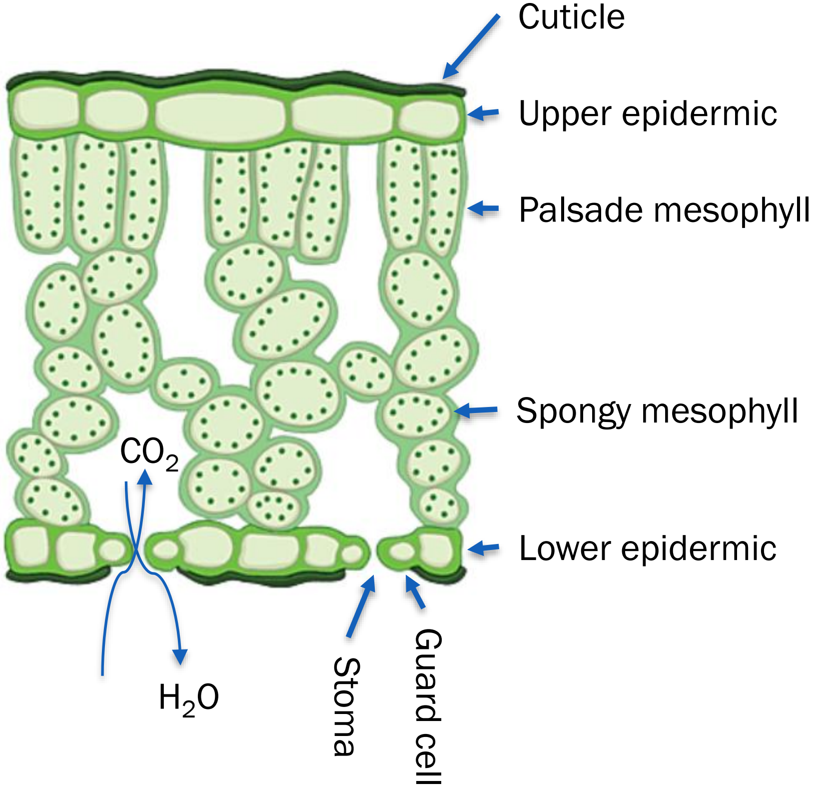
Technique to measure gas and energy flux at different spatial scale for ecological study

- Leaf level: Stomatal conductance and Photosynthesis measurement
- Soil surface; soil flux measurement
- Canopy scale: EC method for GHG and energy flux

Leaf level gas exchange instruments and theories

Stomatal conductance



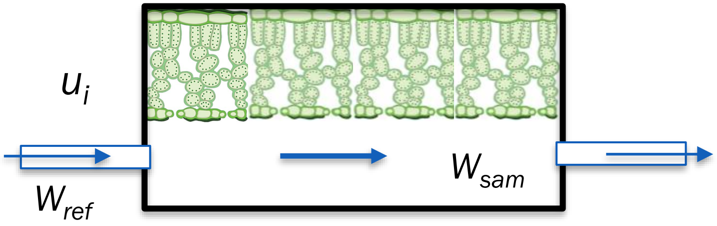


Size: 20-50 µm

Density: 10-80/mm^2 on upper surface
25-330/mm^2 on lower surface

Stomatal conductance

Only need 4-5 s to finish the g_{sw} measurement



$$E = \frac{u_i(W_{sam} - W_{ref})}{s(1 - W_{sam})}$$

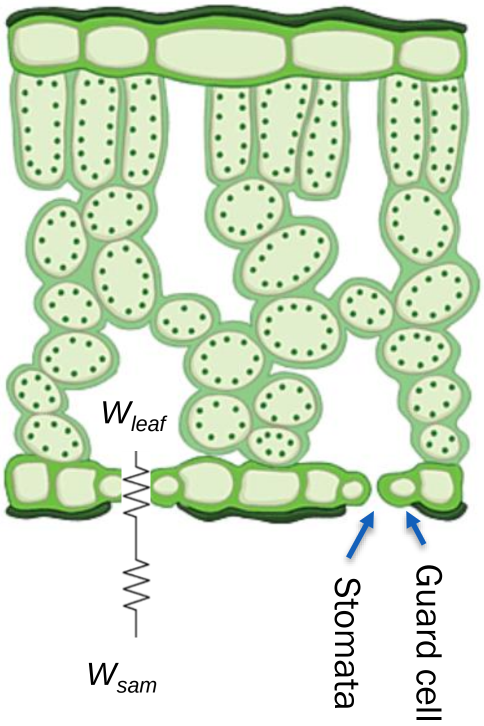
E	transpiration (mmol $m^{-2}s^{-1}$)
u	flow (mol s^{-1})
W	water mole fraction (mmol mol^{-1})
s	leaf area (m^2)

Total Conductance (g_{tw}) and stomatal conductance (g_{sw})

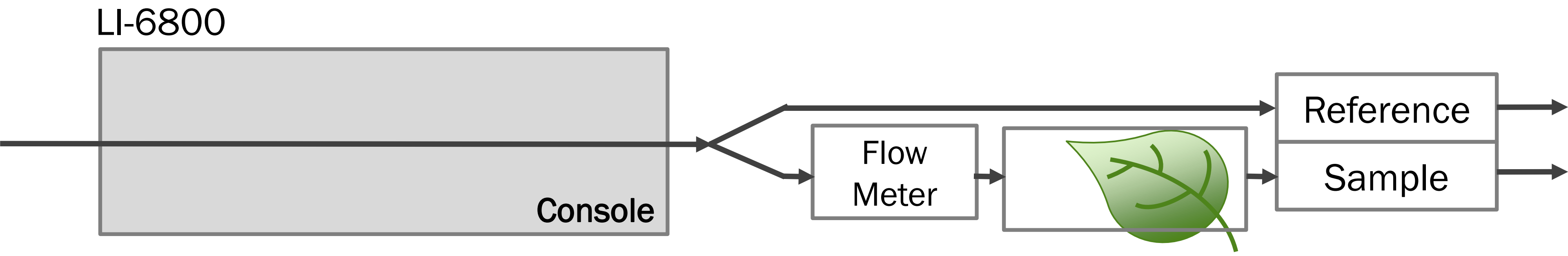
$$E = g_{tw}(W_{leaf} - W_{sam})$$

$$g_{tw} = \frac{E}{W_{leaf} - W_{sam}}$$

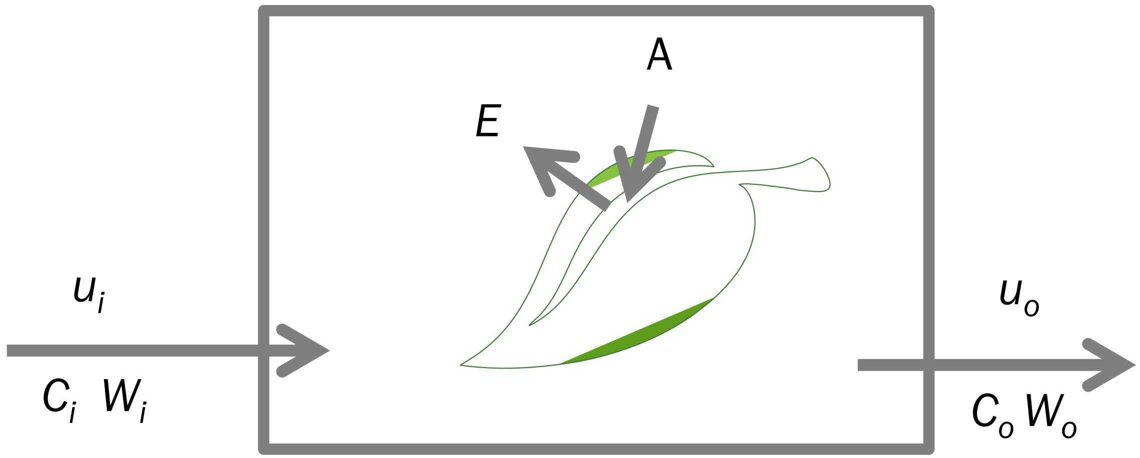
$$g_{sw} = \frac{1}{\frac{1}{g_{tw}} - \frac{1}{g_{bw}}}$$



Leaf gas exchange measurement



Mass balance in an open system



$$E = \frac{u_o W_o - u_i W_i}{s}$$

$$A = \frac{u_i C_i - u_o C_o}{s}$$

S: leaf area (m^2)
E: transpiration (mmol $m^{-2}s^{-1}$)
u: flow rate (mol s^{-1})
W: concentration of water vapor (mmol mol^{-1})
A: carbon assimilation (μmol $m^{-2}s^{-1}$)
C: concentration of CO_2 (μmol mol^{-1})

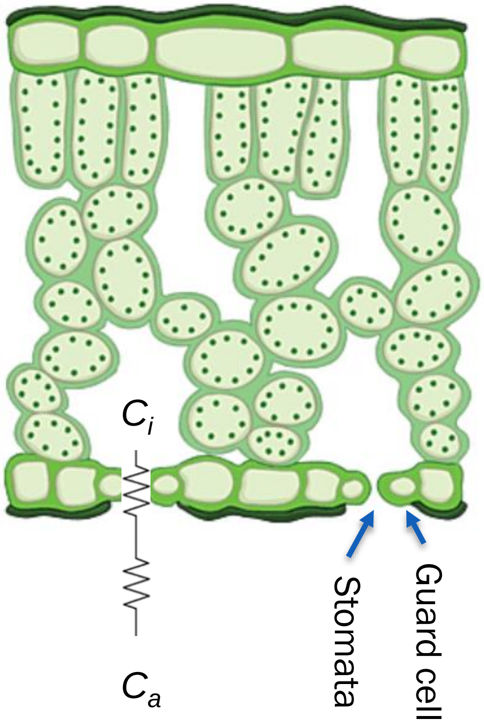
What else can we determine with gas exchange?

$$E = g_{total}^{H_2O}\left(w_i - w_a\right)$$

$$A = g_{total}^{CO_2}\left(c_a - c_i\right)$$

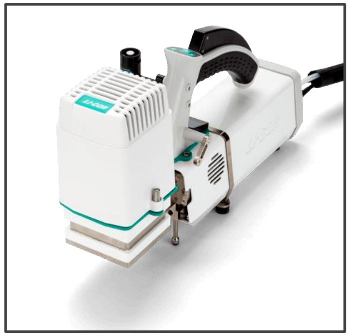
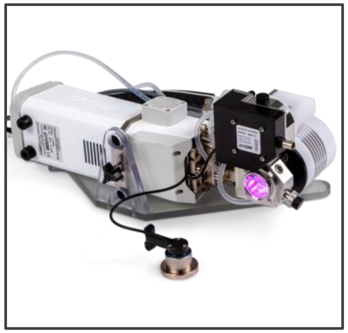
$$g_s = \frac{E}{(w_i - w_a)}$$

$$C_i = C_a - \frac{A}{g_{s\_CO2}}$$

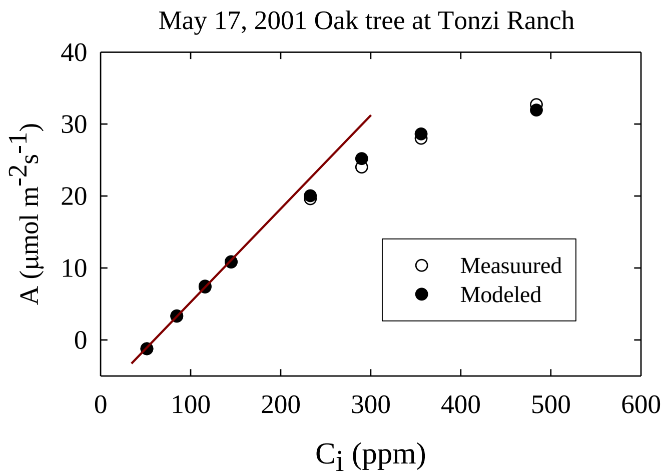


Other chamber options for the LI-6800



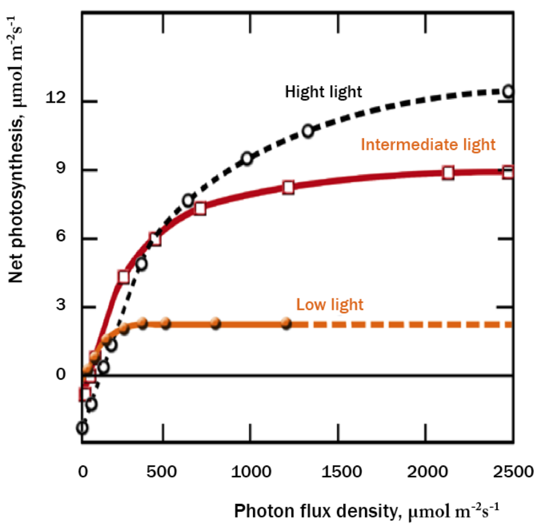

A-Ci and light response curve



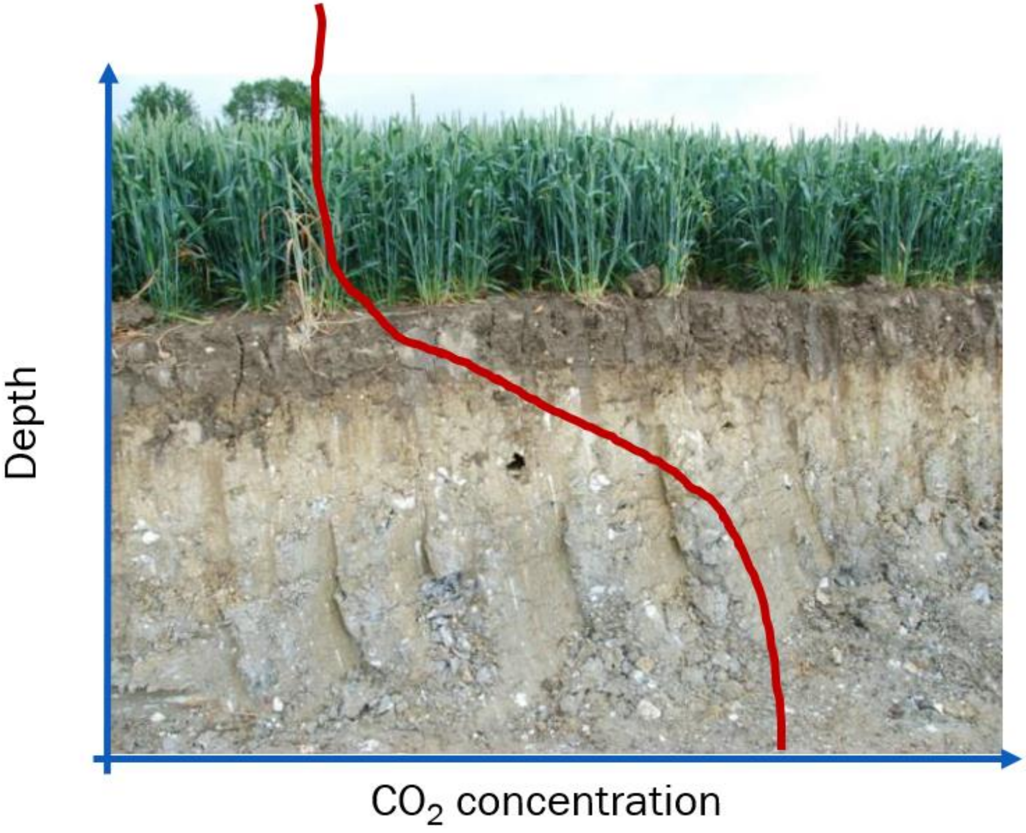
$$A = (1 - \frac{0.5O}{\tau C_i}) \min(W_c, W_j) - r_d$$

$$W_c = \frac{V_{c\max} C_i}{C_i + K_c (1 + O / K_o)}$$

$$W_j = \frac{\alpha J}{\left[1 + (\frac{\alpha I}{J_{\max}})^2\right]^{0.5}} \frac{C_i}{4(C_i + \frac{O}{\tau})}$$

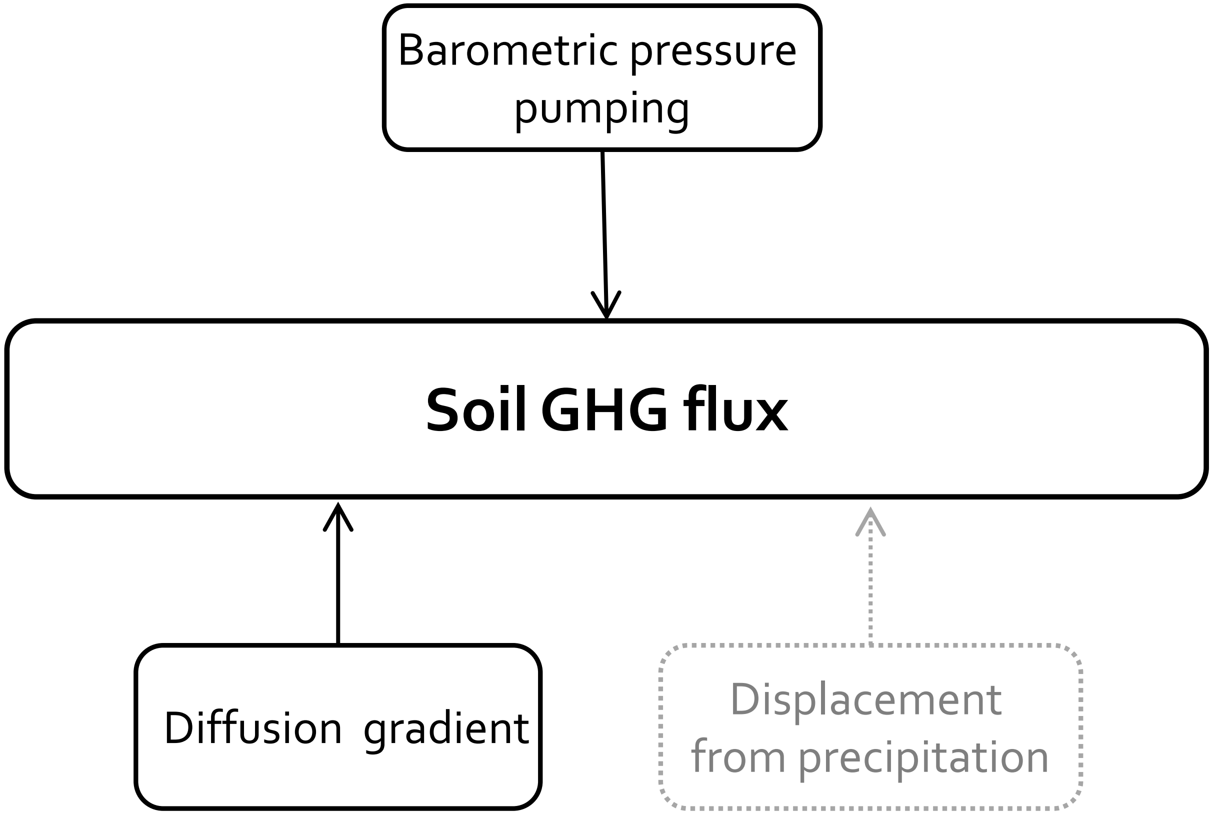


CO_2 profile in the soil

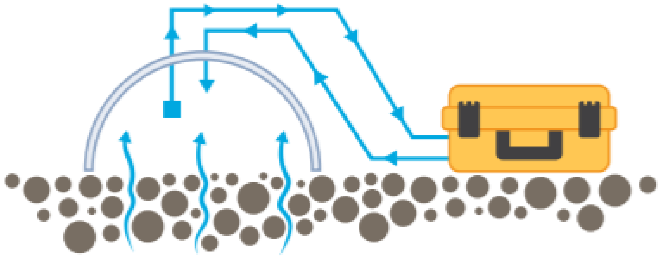


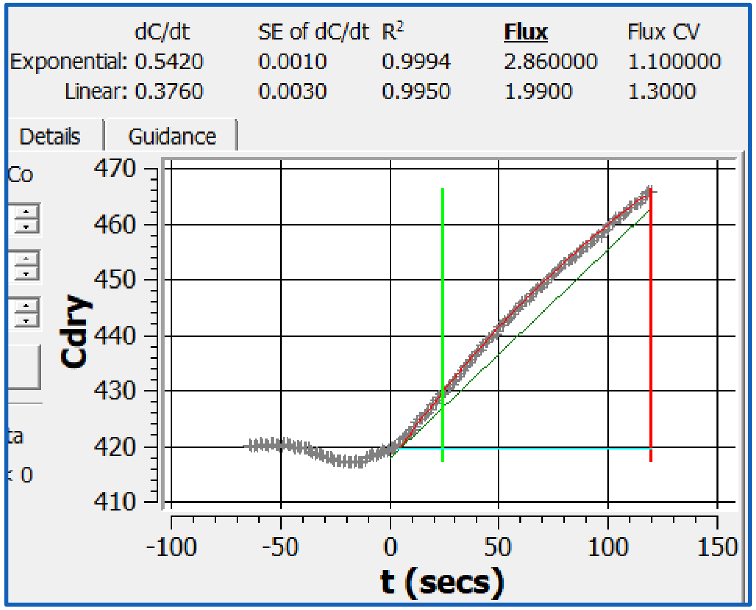
$$F_{CO_2} = g \times (CO_2^{soil} - CO_2^{chamber})$$

Soil surface



Soil surface





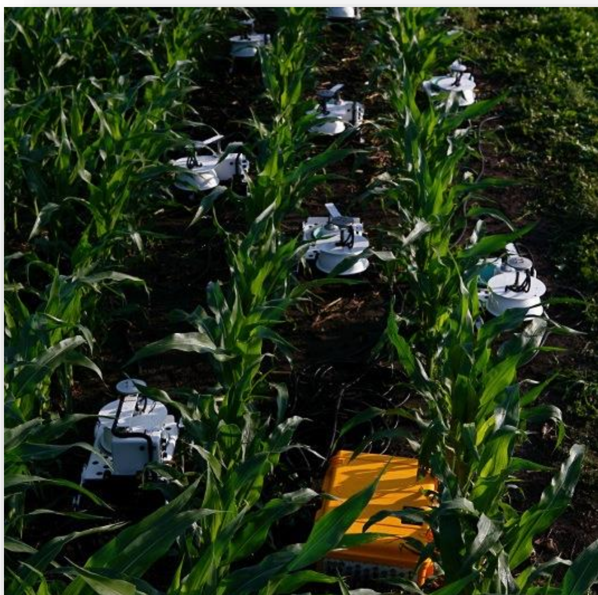
$$F_{CO2} = \frac{VP_o(1-W_o)}{RS(T_o+273.15)}\frac{dC'}{dt}$$

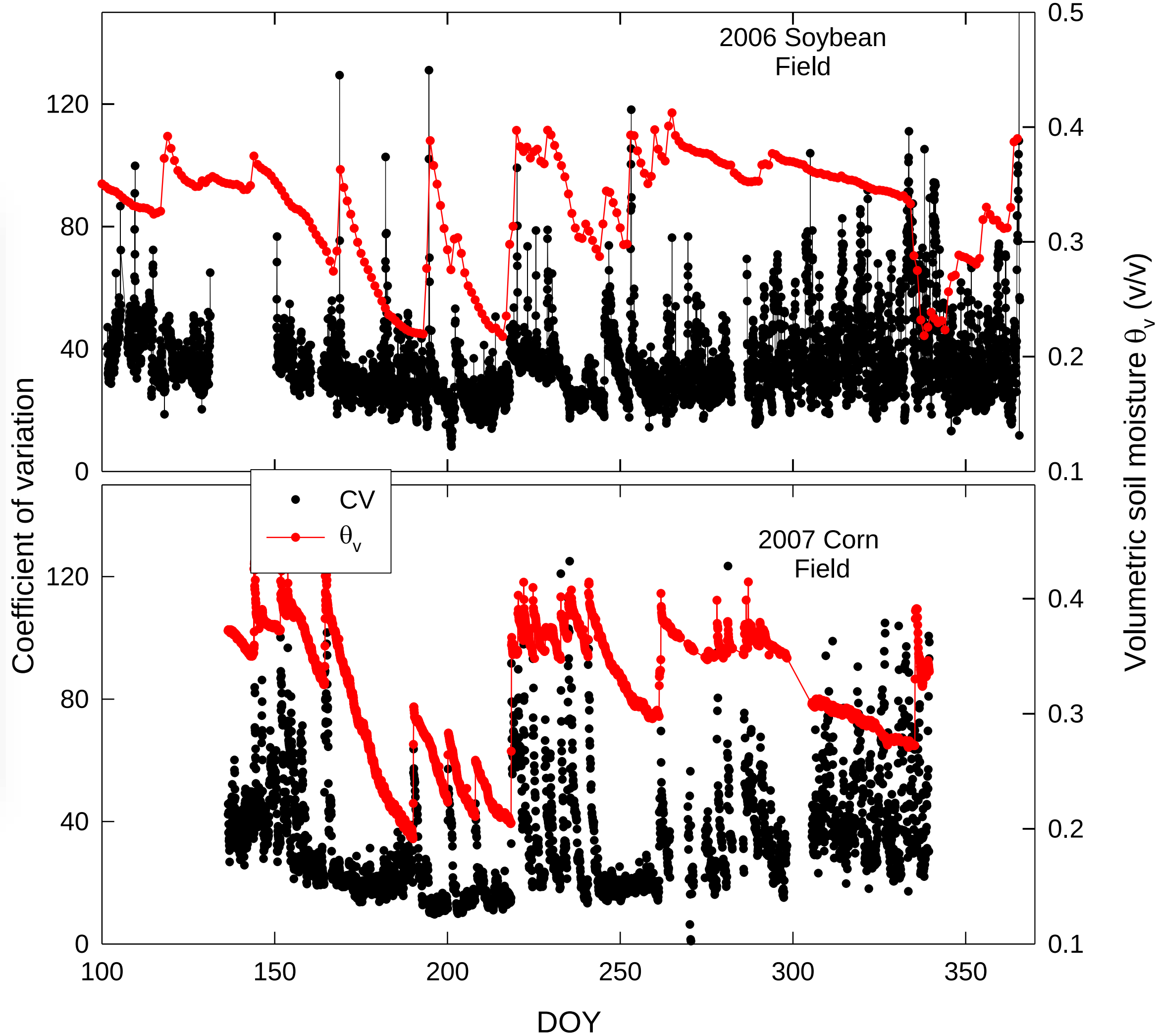
V:	Chamber volume,	m^3
P:	Pressure,	Pa
R:	Gas constant,	Pa m^3 $k^{-1}mol^{-1}$
S:	Soil area,	m^2
T:	Temperature,	K
$\frac{dC'}{dt}$	Slope,	µmol $mol^{-1}s^{-1}$
W_o	H_2O,	mol mol^{-1}
F_{CO2}:	Flux,	µmol $m^{-2}s^{-1}$

Requirements and considerations for chamber-based soil GHG flux measurement

1. Measure amount of GHG from the soil accurately
2. Minimize the influence on soil GHG “Transport”
3. Minimize the influence on soil GHG “Production”
4. Deal with temporal and spatial variation

Characteristics: Large spatial variation

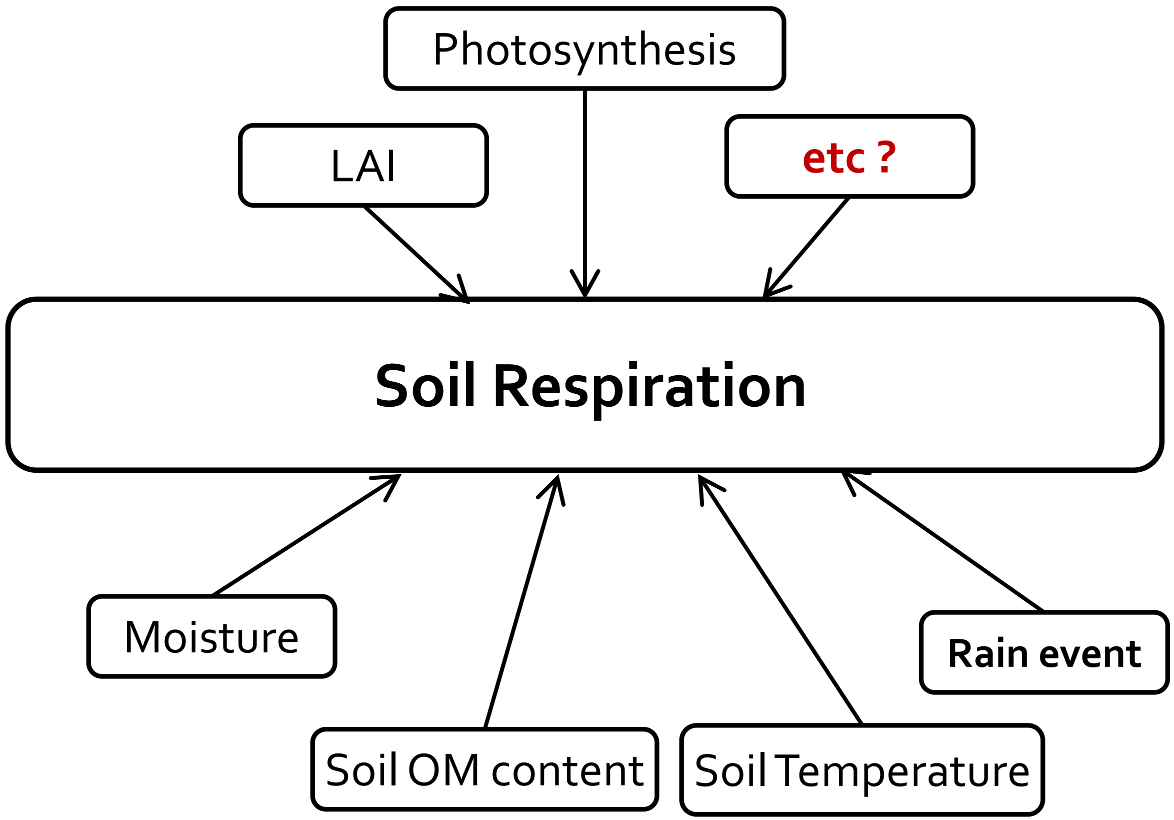




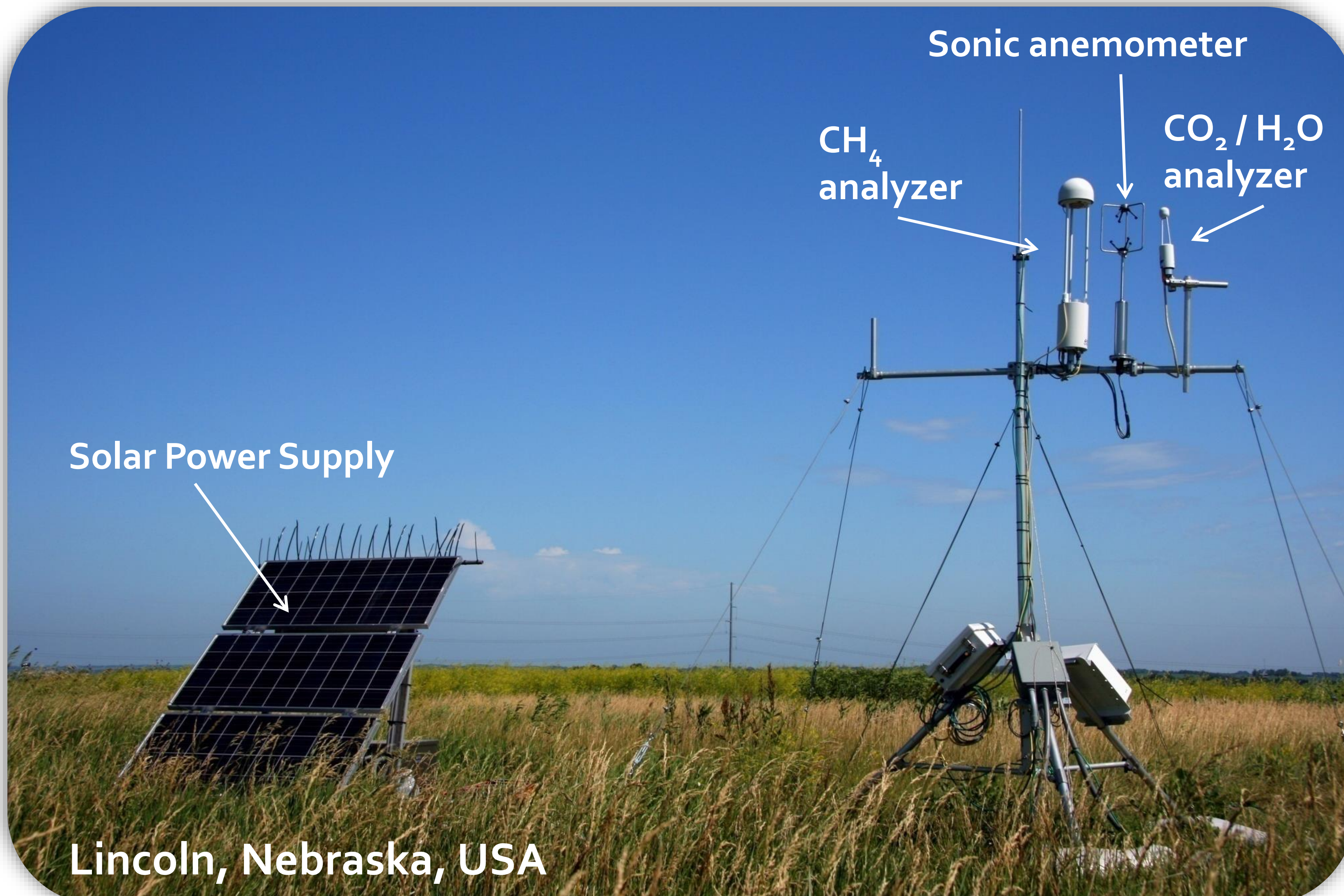
Survey Chamber

Long-term chamber system

Understanding control of soil respiration



Eddy covariance (EC) method



Eddy covariance:

$$F = \overline{wC}$$

Reynolds Decomposition

$$F = \overline{(\overline{w} + w')(\overline{C} + C')}$$

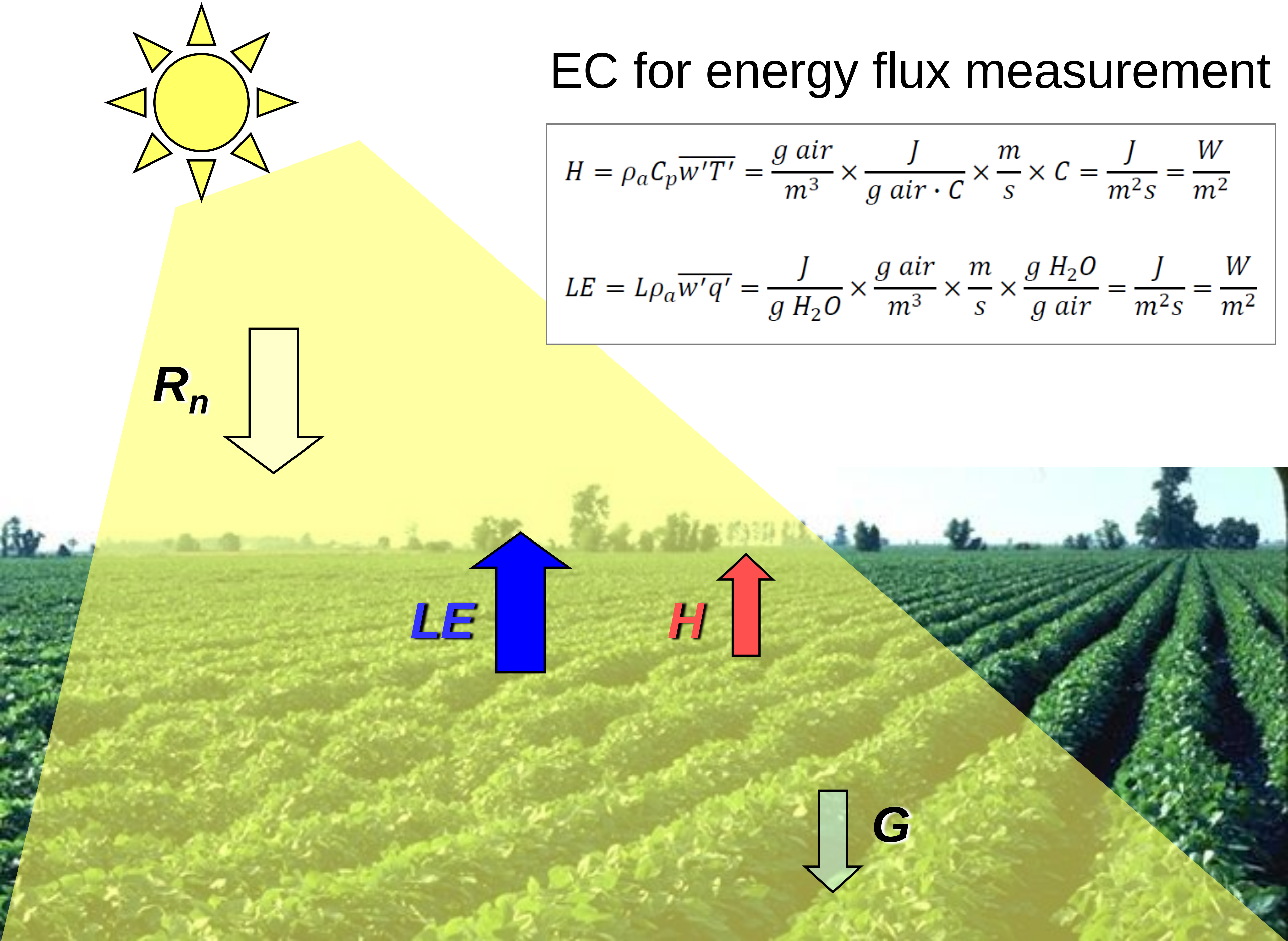
$$F = \overline{w'C'}$$

In statistics, $\overline{w'C'}$ is covariance between w, CO_2

EC for energy flux measurement

$$H = \rho_a C_p \overline{w'T'} = \frac{g\ air}{m^3} \times \frac{J}{g\ air \cdot C} \times \frac{m}{s} \times C = \frac{J}{m^2 s} = \frac{W}{m^2}$$

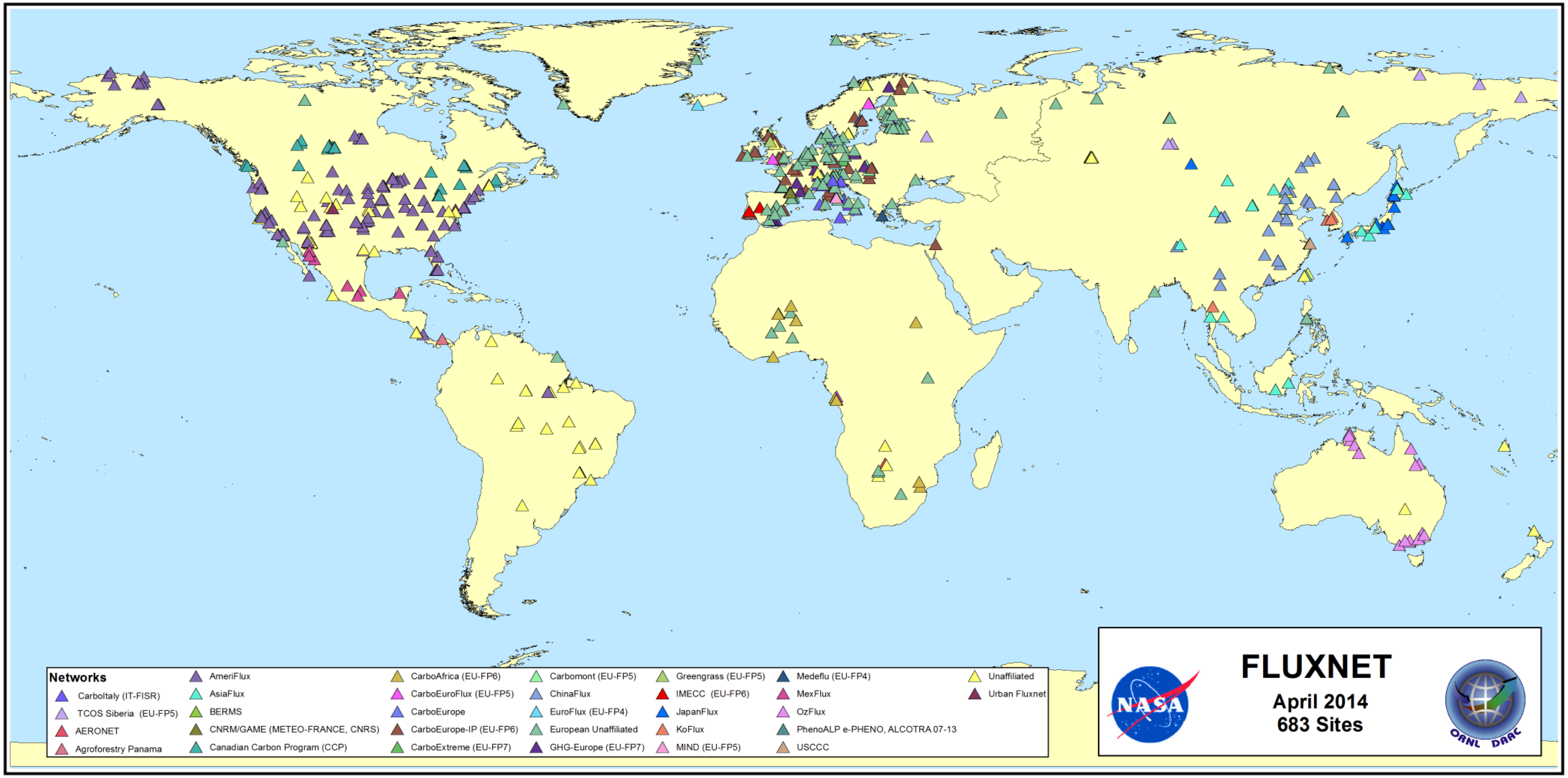
$$LE = L\rho_a \overline{w'q'} = \frac{J}{g\ H_2O} \times \frac{g\ air}{m^3} \times \frac{m}{s} \times \frac{g\ H_2O}{g\ air} = \frac{J}{m^2 s} = \frac{W}{m^2}$$



Canopy scale: eddy covariance (EC) method

Footprint for eddy covariance flux: > 10,000 m^2

Ecology, Carbon Cycle



Flux= *f*(precipitation, temperature, soil moisture, VPD, radiation, diffuse radiation, LAI, vegetation type, etc.,).

↓

model validation, upscaling, ground truth, and remote sensing

Summary

1. Relationship between climate change and rising of GHG in atmosphere
2. Theory of flux measurement at different spatial scale
    a. Stomatal conductance and leaf level gas exchange (porometer, photosynthesis system)
    b. Canopy scale (EC)
    c. Soil surface (Closed-chamber Based Method)

Two important advices

1. Understand the theory of the method you are using in your research will help you to get much better experimental data.

2. Look at your data as soon as you download from the instrument. If you see something wrong, try to fix the issue. Otherwise, you could lose more data.